SECTION 4. RISK ASSESSMENT

4.6 Earthquake

2018 HMP Update Changes

- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, and probability of future occurrence (including climate change).
- Earthquake events that occurred in Hawaiʻi from January 1, 2012, through December 31, 2017, were researched for this 2018 HMP Update. Due to the severity of recent events, the May 2018 event is discussed; however, details regarding monetized impacts are not available at the time of this plan update.
- New and updated figures from federal and state agencies are incorporated.
- The probability of future occurrences was calculated based on the total number of earthquakes with epicenters in the State.
- Hazus was used to determine potential losses for the 100-year Probabilistic Event and four historic earthquake scenarios.

4.6.1 Hazard Profile

Thousands of earthquakes occur every year in the State of Hawaiʻi. Earthquakes in Hawaiʻi are caused by eruptive processes within the active volcanoes or by deep structural adjustments due to the weight of the islands on Earth's underlying crust (U.S. Geological Survey Hawaiian Volcano Observatory [USGS HVO] 2017). Most of these earthquakes are closely related to volcanic processes and are so small they can only be detected by seismometers. Some are strong enough to be felt on one or more of the islands. A few earthquakes are large enough to cause significant damage and impact residents across the State (USGS HVO 2017). Additionally, local or distant earthquakes can lead to tsunamis in the State of Hawaiʻi. For details regarding the volcano hazard in Hawaiʻi, refer to Section 4.13. For details regarding the tsunami hazard in the State of Hawaiʻi, refer to Section 4.12.

Hazard Description

Hawaiian earthquakes fall into three main categories: volcanic, tectonic, and mantle:

- Volcanic – magma movement within, and eruptions from, the presently active volcanoes in the state (Kīlauea, Mauna Loa, Hualālai, Haleakalā, and Lōʻihi) are usually accompanied by hundreds to thousands of small earthquakes that rarely cause significant damage. The small earthquakes are caused by the movement of magma and often occur in shallow swarms, especially after an eruption. These volcanic earthquakes are important for volcano monitoring (Wong et al. 2011; USGS HVO 2017).
- Tectonic – earthquakes occur when the large, thin plates of the earth's crust and upper mantle become stuck as they move past one another. They lock together, pressures build up, and when released, earthquakes occur (Gillespie 2018). Tectonic earthquakes are the most common type of less damaging earthquakes (up to magnitude 5) in the State of Hawaiʻi (USGS HVO 2017).

- Mantle – this type of earthquake reflects the flexing/bending of the earth's crust and upper mantle, known as the lithosphere, due to the weight of the islands above. This is the most common source of damaging earthquakes north of the Island of Hawaiʻi. This type of earthquake generally occurs more than 12 miles below sea level (USGS HVO 2017).

Location

The majority of earthquakes in the State of Hawaiʻi occur on and around the County of Hawaiʻi, especially in the southern districts of the island where Kīlauea, Mauna Loa, and Lōʻihi volcanoes are located. These three volcanoes are the most active in the state (USGS HVO 2017). Most earthquakes are caused by ruptures along geological faults. The County of Hawaiʻi has 10 fault systems: Hilina fault system, Ka'oiki-Honu'apo fault system, Ka'oiki seismic zone, Kahuku fault system, Kealakekua fault system, Kilauea Volcano, Koa'e fault system, Kohala Volcano, Lo'ihi Seamount, and Mauna Loa Volcano (see Figure 4.6-2). Shaking from large scale events could potentially be felt anywhere in the State, but are most likely to be felt close to the earthquake's epicenter. Where shaking can be felt is discussed in more detail in the Extent Section below.

NEHRP Soil Classifications

Ground shaking is the primary cause of earthquake damage to buildings and infrastructure. Softer soils amplify ground shaking. One contributor to shaking amplification is the velocity at which the rock or soils transmits shear waves (S-waves). The National Earthquake Hazard Reduction Program (NEHRP) defined five soil types based on their shear-wave velocity (Vs.) that aid in identifying locations that will be significantly impacted by an earthquake. The NEHRP soil classification system ranges from A to E, as noted in Table 4.6-1, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses.

Table 4.6-1. NEHRP Soil Classifications

Soil Classification	Description
A	Hard Rock
B	Rock
C	Very dense soil and soft rock
D	Stiff soils
E	Soft soils

Source: FEMA 2013

The NEHRP soil classifications have only been determined and spatially delineated for the Counties of Maui and Hawaiʻi (Table 4.5-2). Approximately 112 square miles (or 9.5%) of the County of Maui is underlain by NEHRP soil classes D and E, mainly class D; the County of Hawaiʻi has a similar size area underlain by D and E soil classes (130.1 square miles). Figure 4.6-1 and Figure 4.6-2 show the NEHRP soil classifications for these two counties.

Table 4.6-2. Area of NEHRP Class D and E Soils

County	Area (in square miles)		
	Total Area	Area of NEHRP Class D and E Soils	Area as % of Total Area
County of Kauaʻi	620.0	-	-
City and County of Honolulu	600.7	-	-
County of Maui	1,173.5	111.9	9.5%
County of Hawaiʻi	4,028.4	130.1	3.2%
Total	**6,422.6**	**242.1**	**3.8%**

Source: AECOM; Tetra Tech
Notes: NEHRP National Earthquake Hazard Reduction Program
The area of NEHRP soil classifications for the Counties of Kauaʻi and City and County of Honolulu are unknown at this time.
NEHRP soil classifications for the County of Maui are approximate and are appropriate for planning purposes only. Please see Section 4.0 Risk Assessment Overview for additional information.

Liquefaction Susceptibility

Liquefaction can be defined as a process by which sediments below the water table temporarily lose strength and behave as a liquid, usually in areas of loosely packed soil. Roads might buckle, bridges and overpasses might crash down, low-rise buildings might sink, but high-rise buildings which are anchored in the underlying rock should be able to survive without collapsing (Hawaiʻi State HMP 2013; Honolulu Magazine 2013). Areas underlain by NEHRP class D and E soils are more susceptible to liquefaction. Refer to the figures above for the location of these types of soils in the County of Maui and the County of Hawaiʻi.

In addition, NOAA Coastal Service Center sponsored a project in 2005 to identify areas with the potential for soil liquefaction in the Counties of Maui and Hawaiʻi. The results of the study showed small areas of high liquefaction susceptibility in Maui: the west Maui region (from Lahaina to Nāpili), the south Maui area (from Kīhei to Mākena), and the central Maui region (Kahului and Wailuku) (Hawaiʻi State HMP 2013).

Figure 4.6-1. NEHRP Soil Classification for the County of Maui

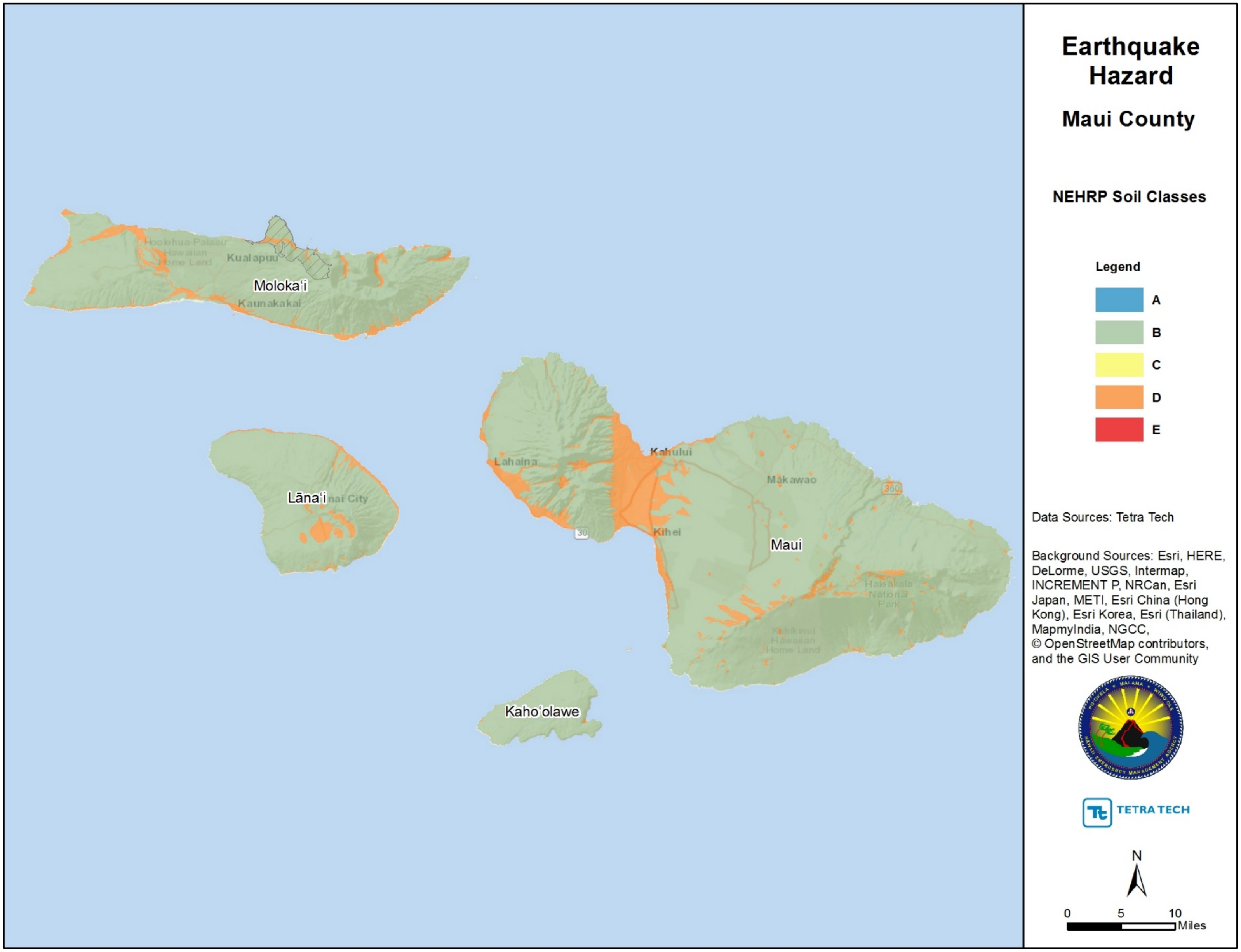
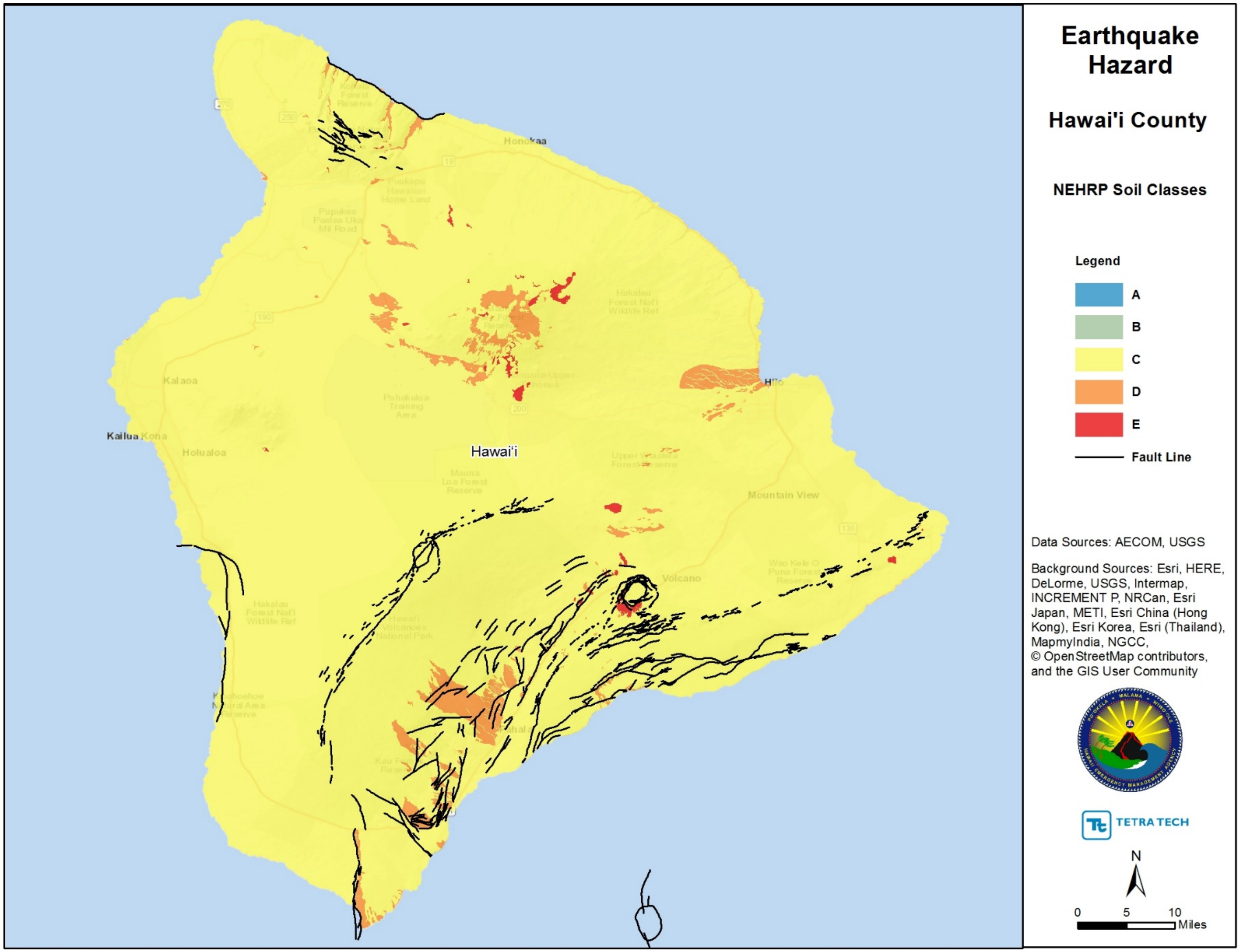


Figure 4.6-2. NEHRP Soil Classification for the County of Hawaiʻi



Extent

The severity of an earthquake is classified by magnitude and intensity. Magnitude is the amount of energy released at the epicenter of an earthquake. Intensity measures the effects of an earthquake on people and structures.

Ground Motion

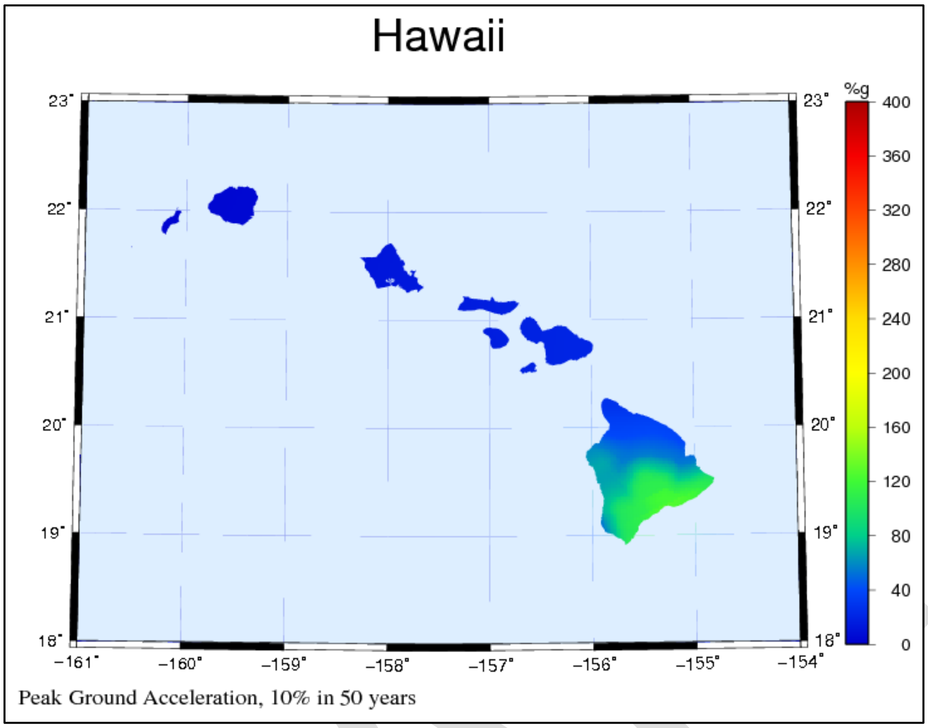
One way to express an earthquake's severity is to compare its acceleration to the normal acceleration due to gravity. Peak ground acceleration (PGA) measures the rate of change in motion to the earth's surface and expresses it as a percent of the established rate of acceleration due to gravity (9.8 meters per second squared [m/sec^2]). PGA is expressed as a percent acceleration force of gravity (%g). For example, 100%g PGA in an earthquake (an extremely strong ground motion) means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10%g PGA means that the ground acceleration is 10 percent that of gravity.

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. The following generalized observations provide qualitative statements about the likely extent of damages for earthquakes with various levels of ground shaking (PGA) at a given site:

- Ground motions of 1 to 2%g are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
- Ground motions below 10%g usually cause only slight damage, except in unusually vulnerable facilities.
- Ground motions of 20 to 50%g may cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
- Ground motions greater than 50%g may cause higher levels of damage in many buildings, even those designed to resist seismic forces.

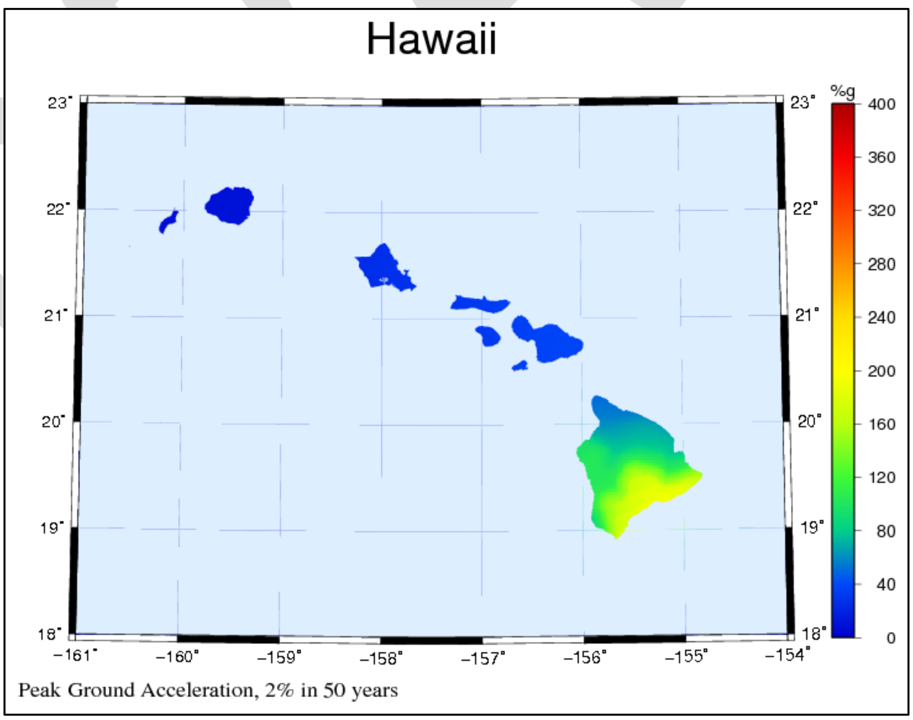
According to USGS Earthquake Hazards Program, PGA maps (also known as earthquake hazard maps) are used as planning tools when designing buildings, bridges, highways, and utilities so that they can withstand shaking associated with earthquake events. These maps are also used as planning tools for the development of building codes that establish construction requirements appropriate to preserve public safety. Figure 4.6-3 and Figure 4.6-4 show contours of PGA with 10% and 2% chances of occurring over the next 50 years. These maps are created with data from the USGS to produce uniform probabilistic seismic hazard maps for the United States. The 10% of a 50-year PGA value means that over the next 50 years, there is a 10% probability of this level of ground shaking or higher. This also represents a likely earthquake while the 2% of a 50-year PGA represents a level of ground shaking close to but not the absolute worst-case scenario. Both figures show a majority of the State have low levels of seismic hazard with the Island of Hawaiʻi having intermediate levels of seismic hazard.

Figure 4.6-3. 1998 Seismic Hazard Map, PGA with 10% Probability of Exceedance in 50 Years



Source: USGS 1998

Figure 4.6-4. 1998 Seismic Hazard Map, PGA with 2% Probability of Exceedance in 50 Years



Source: USGS 1998

Magnitude

An earthquake's magnitude is a measure of the energy released at the source of the earthquake. Magnitude is commonly expressed by ratings on the moment magnitude scale (Mw), the most common scale used today (USGS 2017). This scale is based on the total moment release of the earthquake (the product of the distance a fault moved and the force required to move it). The scale is as follows:

- Great—Mw > 8
- Major—Mw = 7.0 – 7.9
- Strong—Mw = 6.0 – 6.9
- Moderate—Mw = 5.0 – 5.9
- Light—Mw = 4.0 – 4.9
- Minor—Mw = 3.0 – 3.9
- Micro—Mw < 3.

Intensity

The intensity of an earthquake is based on the observed effects of ground shaking on people, buildings, and natural features, and varies with location. The Modified Mercalli scale expresses intensity of an earthquake; the scale is a subjective measure that describes how strong a shock was felt at a particular location. The Modified Mercalli scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. Table 4.6-3 summarizes earthquake intensity as expressed by the Modified Mercalli scale and lists damage potential and perceived shaking by PGA factors, compared to the Mercalli scale.

Table 4.6-3. Modified Mercalli Intensity and Peak Ground Acceleration Equivalents

Modified Mercalli Scale	Perceived Shaking	Potential Structure Damage		Estimated PGA (%g)
		Resistant Buildings	Vulnerable Buildings	
I	Not Felt	None	None	<0.17%
II-III	Weak	None	None	0.17% – 1.4%
IV	Light	None	None	1.4% – 3.9%
V	Moderate	Very Light	Light	3.9% – 9.2%
VI	Strong	Light	Moderate	9.2% – 18%
VII	Very Strong	Moderate	Moderate/Heavy	18% – 34%
VIII	Severe	Moderate/Heavy	Heavy	34% – 65%
IX	Violent	Heavy	Very Heavy	65% – 124%
X – XII	Extreme	Very Heavy	Very Heavy	>124%

Sources: USGS, 2008; USGS, 2010
Notes: Peak ground acceleration (PGA) measured in percent of g, where g is the acceleration of gravity
< = Less than
> = More than
USGS U.S. Geological Society

ShakeMap

The ShakeMap was developed by the U.S. Geological Survey (USGS) and facilitates communication of earthquake information beyond just the magnitude and location. A ShakeMap shows the extent and variation of ground shaking in a region immediately following significant earthquakes.

Three types of ShakeMaps are typically generated:

- Probabilistic—A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain ground motion, such as the 10 percent probability of exceedance in 50 years. This level of ground shaking has been used for designing buildings in high seismic areas.
- Figure 4.6-5 shows the estimated ground motion for the 100-year probabilistic seismic hazard in the State of Hawaiʻi generated by Hazus v4.2.
- Scenario Maps—Earthquake scenario maps describe the expected ground motions and effects of hypothetical large earthquakes for a region. Maps of these scenarios can be used to support all phases of emergency management.
- Historic/Current Scenario Events—ShakeMaps are generated for historic earthquake events or earthquake events that have recently occurred. Recent events help emergency managers and the public understand where damages are likely and also provide insight to what types of damages would be likely if the event were to occur with today's level of development. Four historic scenarios were chosen for analysis in the 2018 HMP Update (see Figure 4.6-6 through Figure 4.6-9):
    - Kalapana M7.2 earthquake on November 29, 1975 (Kalapana M7.7 ShakeMap data represents this event)
    - Kaʻū District M7.9 earthquake on April 3, 1868 (Kaʻū M8.0 ShakeMap data represents this event)
    - Lānaʻi M6.8 earthquake on February 20, 1871 (Lānaʻi M7.0 ShakeMap data represents this event)
    - Northeast (NE) Maui M6.5 earthquake on January 23, 1938 (NE Maui 7.0 ShakeMap data represents this event).

Warning Time

Under the Disaster Relief Act of 1974, the USGS has the federal responsibility to issue alerts for earthquakes, enhance public safety, and reduce losses through effective forecasts and warnings. USGS currently issues rapid, automatic earthquake information via the Internet, e-mail messages, text messages, and social media (USGS 2012). However, this is no current reliable way to predict the day or month that an earthquake will occur at any given location. Research is being done with warning systems that use the low energy waves that precede major earthquakes. These potential warning systems give approximately 40 seconds notice that a major earthquake is about to occur. The warning time is very short but it could allow for someone to get under a desk, step away from a hazardous material they are working with, or shut down a computer system.

Figure 4.6-5. PGA for the 100-Year Probabilistic Statewide Scenario

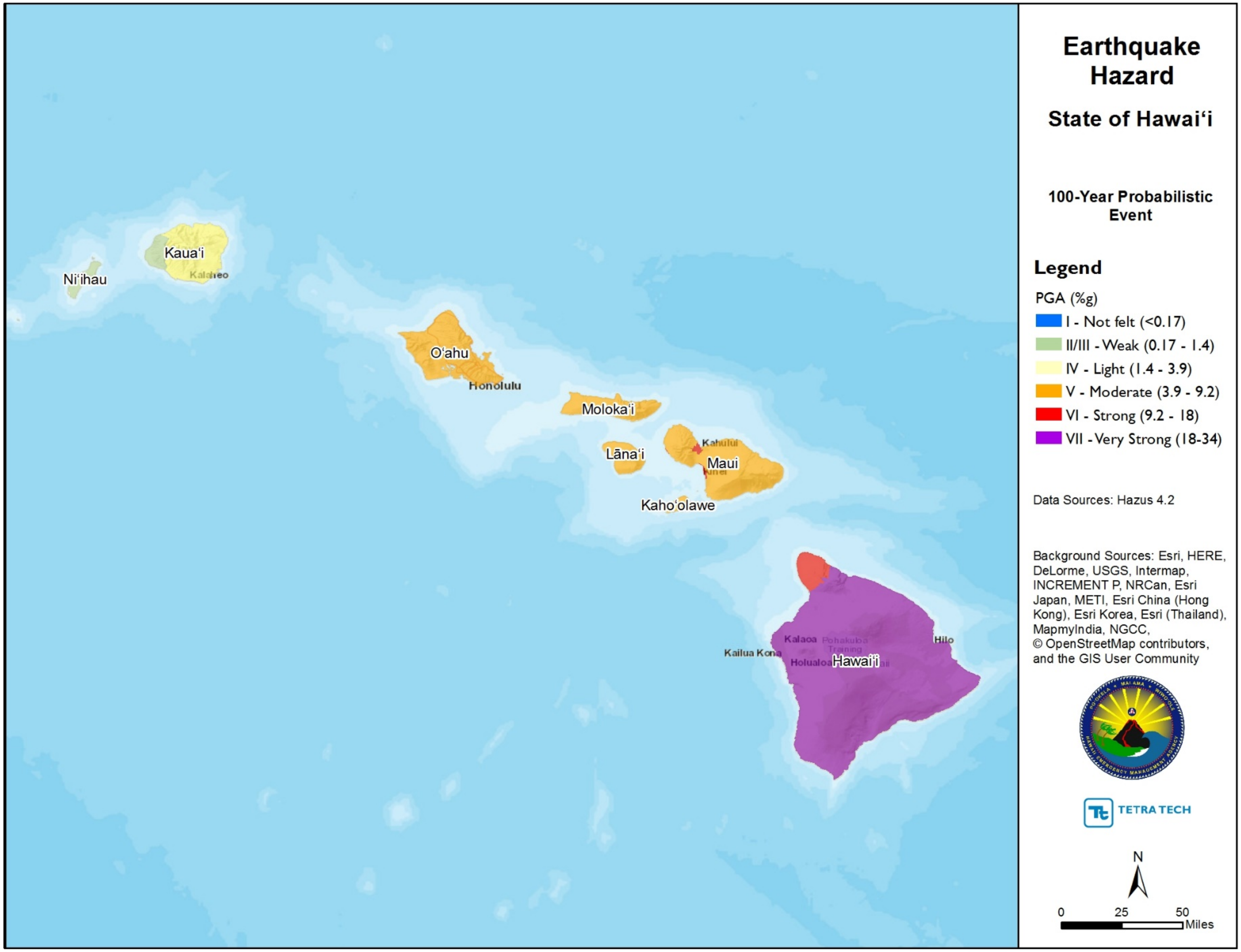
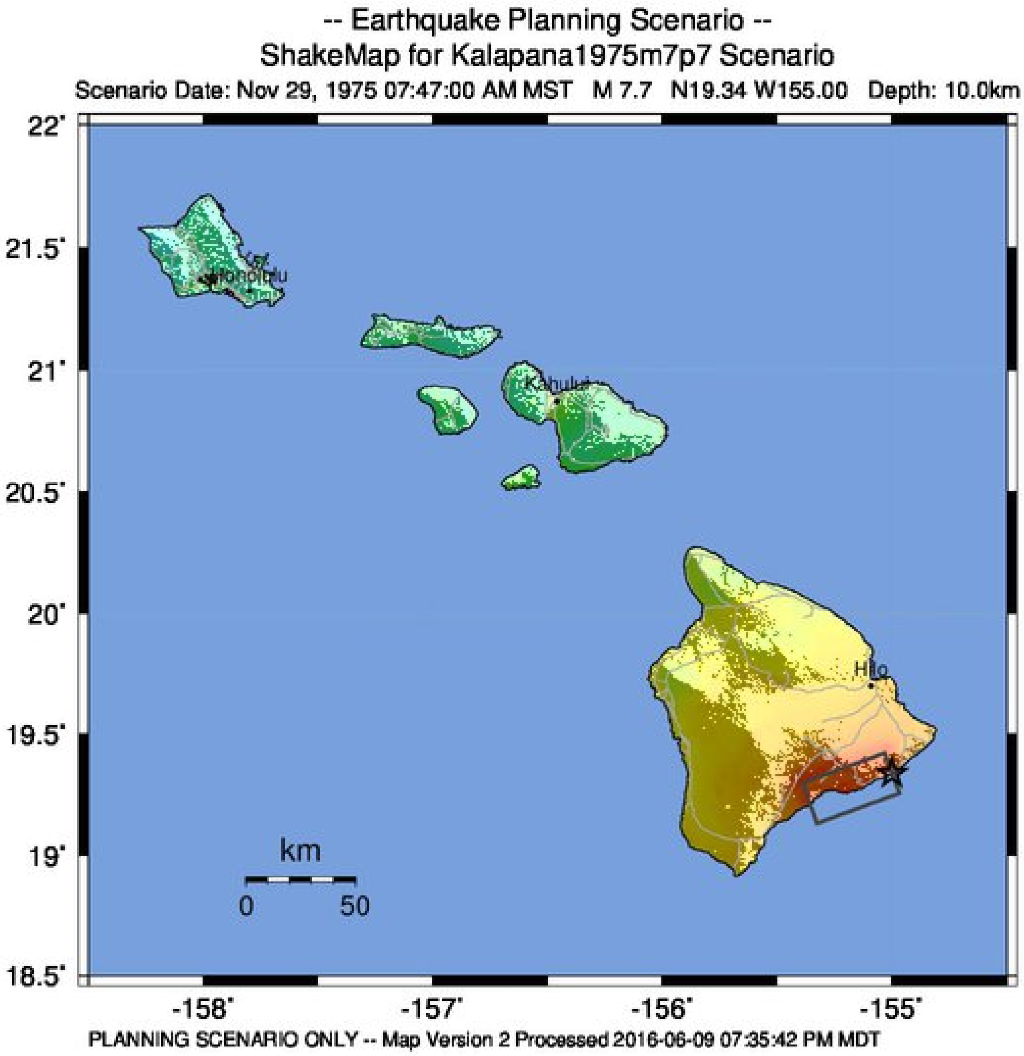


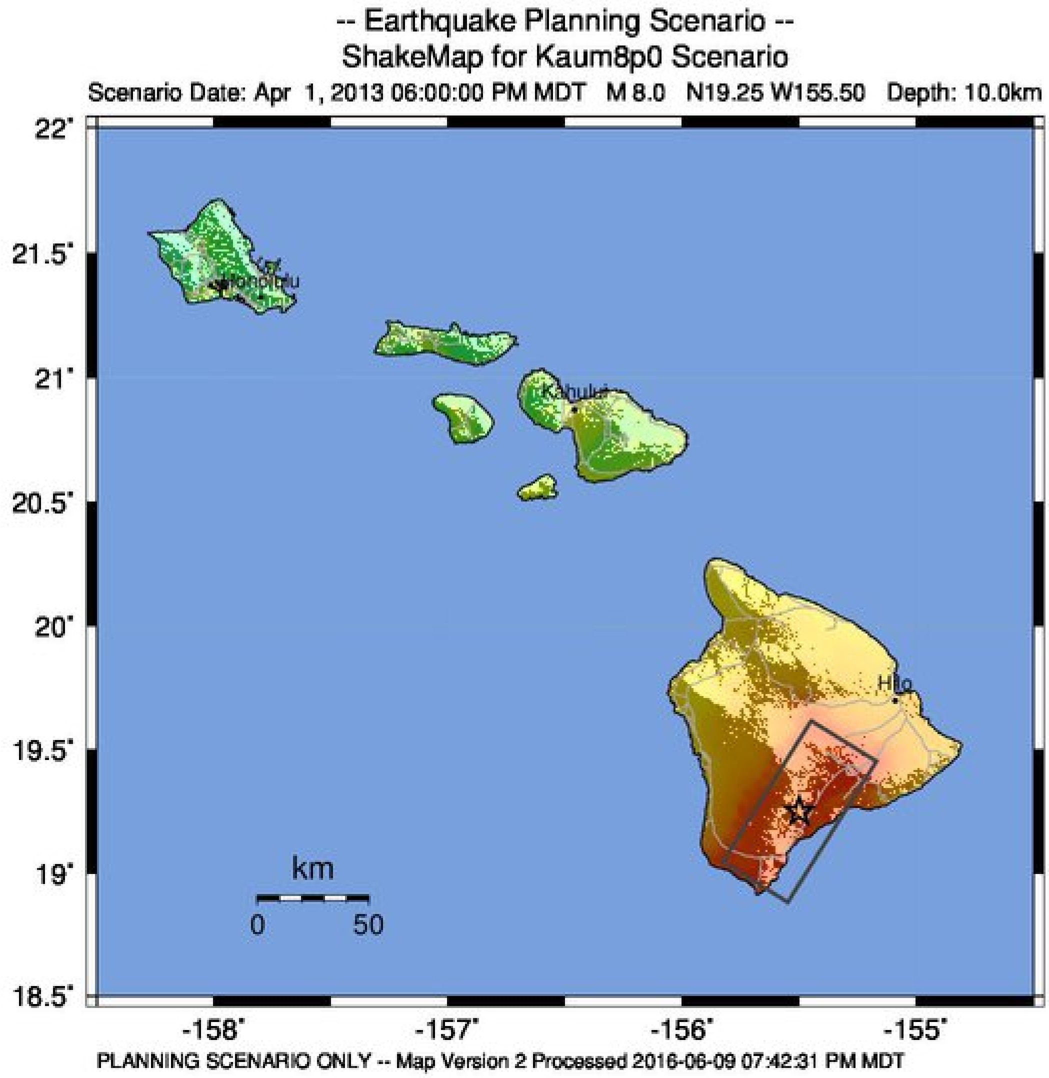
Figure 4.6-6. Kalapana M7.2 Earthquake Scenario



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

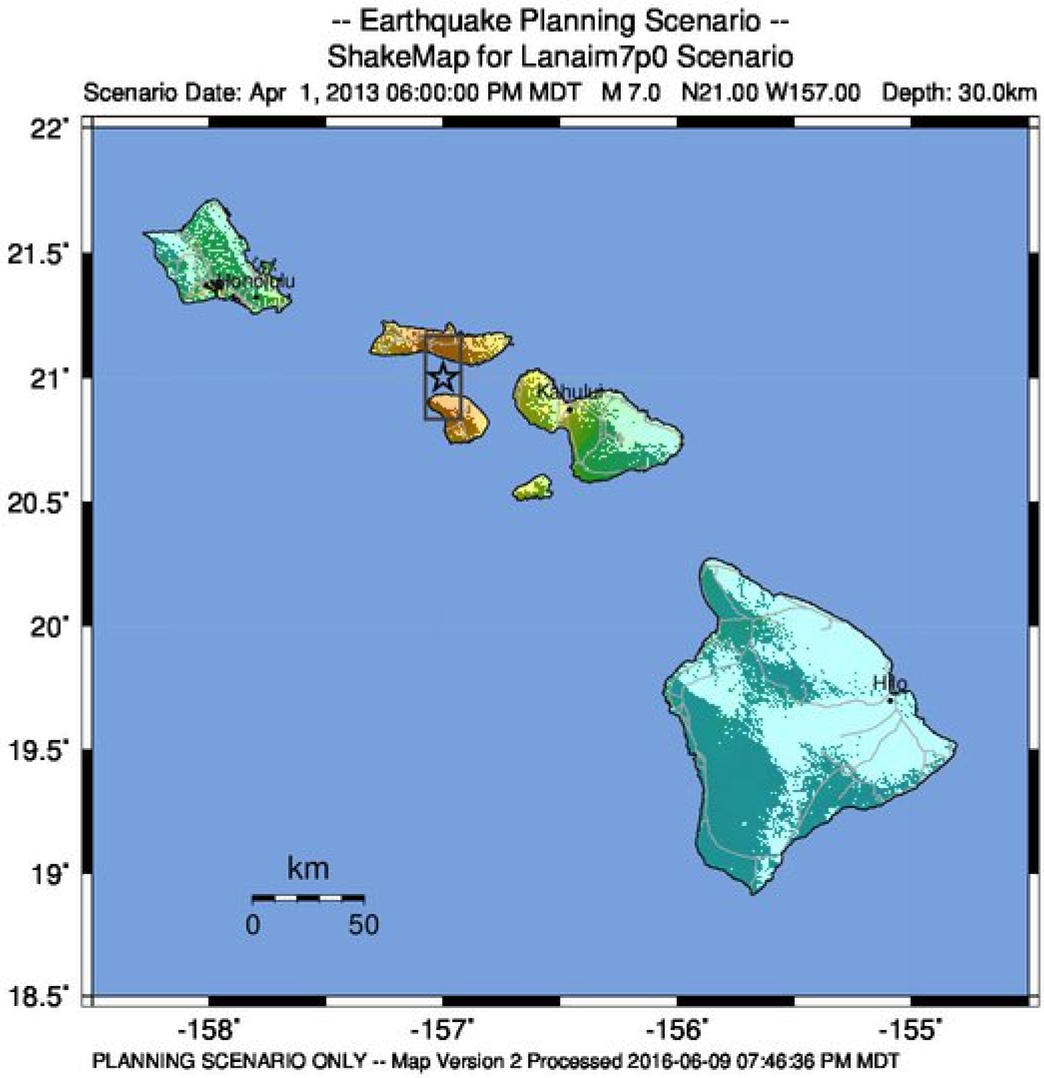
Figure 4.6-7. Kaʻū District M7.9 Earthquake Scenario



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

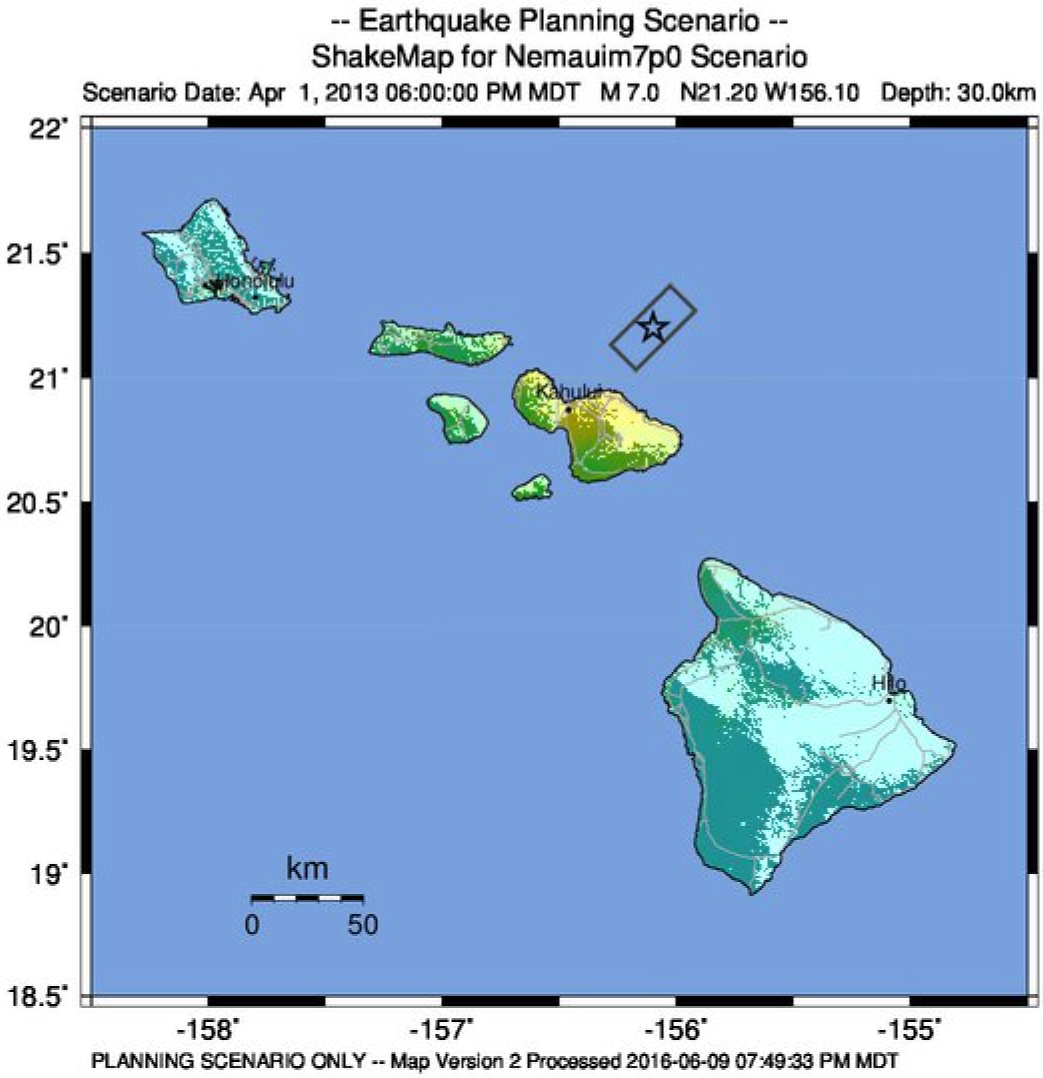
Figure 4.6-8. Lānaʻi M6.8 Earthquake Scenario



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Figure 4.6-9. Northeast (NE) Maui M6.5 Earthquake Scenario



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Previous Occurrences and Losses

During the planning process for this plan update, many sources were researched that provided earthquake information regarding previous occurrences and losses associated with earthquake events throughout the State of Hawaiʻi. The 2013 Plan discussed specific earthquake events that occurred in the State of Hawaiʻi through 2012. For this 2018 HMP Update, earthquake events were summarized between January 1, 2012, and December 31,

2017. According to the USGS, over 11,000 earthquakes have been recorded in the state between 2012 and 2018. The magnitudes of these events range from 1.0 to 6.9 (USGS 2018).

Table 4.6-5 includes details regarding earthquake events that occurred in the State between 2012 and 2017 that had a magnitude 4 or higher. For events prior to 2012, please refer to Appendix X.

FEMA Disaster Declarations

Between 1954 and 2017, FEMA included the State of Hawaiʻi in five earthquake-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: earthquake, volcanic disruptions, or seismic waves. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations as determined by FEMA (FEMA 2017).

Tale 4.6-4 lists the earthquake events that have affected the State of Hawaiʻi and were declared a FEMA disaster, between 2012 and 2018. This table provides information on the disaster declarations for earthquake events, including date of declaration, federal disaster declaration and disaster number, and counties affected. For details regarding all declared disasters to date, refer to Section 4 (Risk Assessment Overview). Refer to Appendix X which illustrates the number of earthquake-related FEMA-declared disasters by county since 1954.

Table 4.6-4. Earthquake-Related Federal Declarations (2012 to 2018)

Year	Event Type	Date Declared	Federal	Counties Affected
2012	Severe Storms, Flooding and Landslides	April 18, 2012	DR-4062	Kauaʻi, Maui

Source: FEMA 2018

Table 4.6-5. Earthquake Events in Hawaiʻi with a Magnitude of 4 or Greater, 2012 to 2017

Date(s) of Event	Magnitude*	Location (recorded epicenter)	Counties Affected	Description
January 23, 2012	4.8	Hawaiʻi region, Hawaiʻi	Maui and Hawaiʻi	USGS reported that over 600 people on the islands of Hawaiʻi and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
February 24, 2012	4.1	Hawaiʻi region, Hawaiʻi	Maui and Hawaiʻi	USGS reported that over 70 people on the Islands of Hawaiʻi and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
February 24, 2012	4.5	Hawaiʻi region, Hawaiʻi	Hawaiʻi	USGS reported that over 90 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating moderate shaking.
March 24, 2012	4.6	Hawaiʻi region, Hawaiʻi	Maui and Hawaiʻi	USGS reported that 800 people on the Islands of Hawaiʻi and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking. However, according to the ShakeMap for this event, the maximum intensity of shaking was VI, indicating strong shaking.
November 25, 2012	4.3	Hawaiʻi region, Hawaiʻi	Hawaiʻi	USGS reported that over 90 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
January 5, 2013	4.3	Hawaiʻi region, Hawaiʻi	Hawaiʻi	USGS reported that over 300 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
April 13, 2013	4.3	50 km northeast of Honokaʻa, Hawaiʻi	Maui and Hawaiʻi	USGS reported that over 90 people on the Islands of Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
June 5, 2013	5.3	54 km southeast of Pāhala, Hawaiʻi	Oʻahu, Kalawao, Maui and Hawaiʻi	USGS reported that over 400 people on the Islands of Oʻahu, Molokaʻi, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
June 21, 2013	4.5	48 km north of Kualapuʻu, Hawaiʻi	Honolulu, Kalawao, and Maui	USGS reported that over 60 people on the Islands of Oʻahu, Molokaʻi, and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.

Date(s) of Event	Magnitude*	Location (recorded epicenter)	Counties Affected	Description
August 11, 2013	4.9	10 km south-southwest of Volcano, Hawaiʻi	Maui and Hawaiʻi	USGS reported over 600 people on the Islands of Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
June 7, 2014	4.1	34 km southwest of Kaunakakai, Hawaiʻi	Honolulu, Maui and Kalawao	USGS reported that over 100 people on the Islands of Oʻahu, Molokaʻi and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
August 7, 2014	4.5	14 km west-northwest of Waimea, Hawaiʻi	Maui and Hawaiʻi	USGS reported over 600 people on the Islands of Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
August 12, 2014	4	30 km east-northeast of Honokaʻa, Hawaiʻi	Hawaiʻi	USGS reported that 70 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
August 22, 2014	4.2	74 km west-northwest of Lānaʻi City, Hawaiʻi	Honolulu and Maui	USGS reported that over 100 people on the Islands of Oʻahu and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was III on the Modified Mercalli Intensity Scale, indicating weak shaking.
August 22, 2014	4.2	61 km south of Waimānalo Beach, Hawaiʻi	Hawaiʻi	USGS reported that 70 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
October 13, 2014	4	13 km west-southwest of Pāhala, Hawaiʻi	Honolulu and Maui	USGS reported that over 100 people on the Islands of Oʻahu and Maui said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was III on the Modified Mercalli Intensity Scale, indicating weak shaking.
October 13, 2014	4	13 km west-southwest of Pāhala, Hawaiʻi	Hawaiʻi	No reference and/or no damage reported.
December 13, 2014	4.2	53 km west-northwest of Kalaoa, Hawaiʻi	Hawaiʻi	USGS reported that over 100 people on the Islands of Oʻahu, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
February 9, 2015	4.25	12 km west-southwest of Volcano, Hawaiʻi	Hawaiʻi	USGS reported that over 100 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
April 5, 2015	4.5	12 km west of Kalaoa, Hawaiʻi	Hawaiʻi	USGS reported that over 250 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking. However,

Date(s) of Event	Magnitude*	Location (recorded epicenter)	Counties Affected	Description
				according to the ShakeMap for this event, the maximum intensity of shaking was V, indicating moderate shaking.
May 9, 2015	4.46	13 km west-southwest of Pāhala, Hawaiʻi	Hawaiʻi	USGS reported that over 140 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
June 28, 2015	5.2	11 km south-southeast of Volcano, Hawaiʻi	Honolulu, Maui and Hawaiʻi	USGS reported that over 950 people on the Islands of Oʻahu, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking. However, according to the ShakeMap for this event, the maximum intensity of shaking was VI, indicating strong shaking.
February 12, 2016	4.1	18 km south of Fern Acres, Hawaiʻi	Hawaiʻi	USGS reported that over 200 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
March 20, 2016	4.59	14 km southeast of Waikoloa, Hawaiʻi	Honolulu, Kalawao, Maui and Hawaiʻi	USGS reported that over 800 people on the Islands of Oʻahu, Molokaʻi, Lānaʻi, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking. However, according to the ShakeMap for this event, the maximum intensity of shaking was VI, indicating strong shaking.
April 1, 2016	4.2	72 km north-northeast of Honokaʻa, Hawaiʻi	Honolulu, Kalawao, Maui and Hawaiʻi	USGS reported that 76 people on the Islands of Oʻahu, Molokaʻi, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
July 23, 2016	4.32	3 km west-southwest of Honalo, Hawaiʻi	Kalawao, Maui, and Hawaiʻi	USGS reported that over 400 people on the Islands of Molokaʻi, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
September 6, 2016	4.05	28 km east of Hōnaunau-Nāpoʻopoʻo, Hawaiʻi	Hawaiʻi	USGS reported that 3 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported was III on the Modified Mercalli Intensity Scale, indicating weak shaking. However, according to the ShakeMap for this event, the maximum intensity of shaking was VI, indicating strong shaking.
December 18, 2016	4.5	77 km south-southeast of Hawaiian Ocean View, Hawaiʻi	Hawaiʻi	USGS reported that 75 people on the Island of Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was III on the Modified Mercalli Intensity Scale, indicating weak shaking.

Date(s) of Event	Magnitude*	Location (recorded epicenter)	Counties Affected	Description
February 17, 2017	4.66	28 km west-northwest of Waikoloa Village, Hawaiʻi	Honolulu, Kalawao, Maui and Hawaiʻi	USGS reported that over 1,500 people on the Islands of Oʻahu, Molokaʻi, Lānaʻi, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
March 9, 2017	4.71	75 km north-northeast of Kualapuʻu, Hawaiʻi	Honolulu, Kalawao, Maui and Hawaiʻi	USGS reported that over 500 people on the Islands of Oʻahu, Molokaʻi, Lānaʻi, Maui and Hawaiʻi said they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
March 23, 2017	4.49	17 km south-southeast of Volcano, Hawaiʻi	Hawaiʻi	USGS reported that over 200 people on the Island of Hawaiʻi reported having the felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was V on the Modified Mercalli Intensity Scale, indicating moderate shaking.
June 8, 2017	5.28	16 km southeast of Volcano, Hawaiʻi	Honolulu, Maui, and Hawaiʻi	USGS reported that nearly 1,000 people on the Islands of Oʻahu, Maui and Hawaiʻi reported having felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was between V and VI on the Modified Mercalli Intensity Scale, indicating moderate to strong shaking. This was the largest earthquake to strike Hawaiʻi in over 10 years.
June 21, 2017	4.51	28 km east-southeast of Hawaiian Ocean View, Hawaiʻi	Maui and Hawaiʻi	USGS reported that over 200 people on the Islands of Maui and Hawaiʻi reported they felt the earthquake. The maximum intensity of shaking reported and computed by the USGS was IV on the Modified Mercalli Intensity Scale, indicating light shaking.
July 30, 2017	4.21	33 km west-northwest of Hawi, Hawaiʻi	Hawaiʻi, Maui, Molokaʻi, and Oʻahu	The maximum intensity of shaking reported by residents on the Islands of Hawaiʻi, Maui, Molokaʻi, and Oʻahu and computed by the USGS ShakeMap was III on the Modified Mercalli Intensity Scale, indicating light shaking. According to HVO Seismic Network Manager Brian Shiro, the earthquake was likely due to bending of the oceanic plate from the weight of the island and poses no significant hazard.
August 19, 2017	4.1	107 km east-northeast of Hawaiian Beaches, Hawaiʻi	Hawaiʻi, Maui, Molokaʻi, and Oʻahu	USGS reported that approximately 100 people on the Islands of Hawaiʻi, Maui, Molokaʻi, and Oʻahu said they felt the earthquake. USGS stated that the earthquake was likely caused by the bending of the oceanic plate from the weight of the island.
May – June 2018	0.5 to 6.9	Kīlauea Volcanic Eruption and Earthquakes (DR-4366)	Hawaiʻi	Between May 1 and June 7, there have been over 6,000 recorded earthquakes, ranging in magnitude 0.5 to magnitude 6.9. On May 1, the USGS HVO issued a report that a migration of seismicity and deformation downrift (east) of Puʻu ʻŌʻō indicated that a large area along the East Rift Zone was potentially at risk of new outbreak, possibly in the Lower Puna area. On May 3, Kīlauea began erupting and has been erupting since then with numerous earthquakes occurring each day. On May 11,

Date(s) of Event	Magnitude*	Location (recorded epicenter)	Counties Affected	Description
				FEMA issued a major disaster declaration for the State of Hawaiʻi due to the eruption of Kīlauea. The County of Hawaiʻi was included in this declaration. As of the date of this plan update, this is an ongoing event and not all information regarding this event has been captured. For details regarding the volcanic eruption, please refer to Section 4.13 (Volcanic Hazards).

Sources: FEMA 2018; USGS 2018; Okubo 2017
** Magnitudes with decimals are approximate*
Note (1): For events that occurred between 2012 and 2017, only those with magnitude 4 are shown in the above table
Note (2): With earthquake documentation for Hawaiʻi being so extensive, not all sources have been identified or researched. Additionally, loss and impact information for many events could vary depending on the source. Therefore, Table 4.5 4 may not include all events that have occurred in the State (in that time period and magnitude level) and the accuracy of monetary figures discussed is based only on the available information identified during research for this 2018 HMP Update.
FEMA Federal Emergency Management Agency
Km Kilometers
USGS U.S. Geological Survey

PROBABILITY OF FUTURE HAZARD EVENTS

For the purpose of this 2018 HMP Update, the probability of future occurrences is defined by the number of events over a specified period of time. Between 1950 and 2017, there have been 1,247 earthquakes, magnitude 3 (often felt but causes minor damage) and greater (refer to Table 4.5-3 earlier in this section for a description of magnitude and intensity), with epicenters in or near the State of Hawaiʻi. Based on this historic data, the state may experience an average of 18 earthquakes, magnitude 3 or greater, each year. As for earthquakes categorized as strong to severe, between 1950 and 2017, there have been 8 earthquakes, magnitude 6 and greater, with epicenters in or near the State of Hawaiʻi. Based on this historic data, the state has an estimated 11% annual chance of a strong or greater strength earthquake occurring.

Impacts of Climate Change on Future Probability

The potential impacts of global climate change on earthquake probability are unknown. Some scientists feel that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the Earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity according to research into prehistoric earthquakes and volcanic activity. National Aeronautics and Space Administration (NASA) and USGS scientists found that retreating glaciers in southern Alaska might be opening the way for future earthquakes. A University College London scientist reported that over the past 40 years, El Niño cycles in the Pacific Ocean have triggered a regular seismic response as the pressure of water has changed with short-term sea level fluctuations. There are more earthquakes in the eastern Pacific in the months after the cycle lowers sea levels in the area by a few centimeters, which flexes the plates beneath (Pearce 2012).

Secondary impacts of earthquakes could be magnified by climate change. Earthquakes can cause large and sometimes disastrous landslides. Any steep slope is vulnerable to slope failure. Rising air temperatures can facilitate soil breakdown, allowing more water to penetrate soils and affect the rates of erosion, sediment control, and the likelihood of landslides. Climate change may also increase the probability of more frequent, intense rain storms. This can result in greater erosion, higher sediment transport in rivers and streams, and a higher probability of landslides, primarily as a result of higher soil content (University of Washington 2014). Refer to Section 4.11 (Landslides and Rock Falls) for details regarding climate change impacts on landslides.

Another secondary impact of an earthquake is dam failure. Earthen dams are highly susceptible to seismic events. The most common type of earthquake-induced dam failure is slumping or settlement of earth-fill dams where the fill has not been properly compacted. If the slumping occurs when the dam is full, then overtopping of the dam, with rapid erosion leading to dam failure is possible. Changes in weather patterns and increase in rainfall can lead to dams being full more often, increasing the risk of a failure during an earthquake. Refer to Section 4.3 (Dam Failure) for details regarding climate change impacts on dam failure.

4.6.2 Vulnerability Assessment

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 events 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.

Assessment of State Vulnerability and Potential Losses

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

State Assets

The total replacement cost value of state buildings is an estimated $24 billion; all of which are exposed to an earthquake event. Table 4.6-6 summarizes these values by county. The potential damage estimated to state buildings associated within the 100-year probabilistic earthquake event is approximately $754 million which represents approximately 3% of the inventory's total replacement cost value. The County of Hawaiʻi has the greatest estimated potential loss (12.2%) to state buildings.

Table 4.6-6. State Buildings Exposure and Potential Losses to the 100-year Probabilistic Earthquake Event

County	Total Value	Estimated Potential Loss	
		Value	Percent of Total
County of Kauaʻi	$957,679,537	$408,327	<1%
City and County of Honolulu	$16,750,785,426	$200,226,950	1.2%
County of Maui	$2,862,316,819	$38,663,498	1.4%
County of Hawaiʻi	$4,209,774,236	$515,166,625	12.2%
Total	**$24,780,556,017**	**$754,465,400**	**3.0%**

Source: Hawaiʻi State Risk Management Office 2017; Hazus v4.2

The estimated potential state building loss to the Kaʻū M8.0 and the Lānaʻi M7.0 scenarios are summarized in Table 4.6-7; and results for the Kalapana M7.7 and the NE Maui M7.0 scenarios are summarized in Table 4.6-8 by county. The results by state agency for the 100-year Probabilistic Earthquake Event and the four historic scenario events are included in Appendix X.

Of the four historic scenarios evaluated, the Kaʻū M8.0 scenario has the greatest potential state building loss at approximately $191 million (see Table 4.6-7). The County of Hawaiʻi has the greatest estimated potential state building loss equating to $189.8 million (3.7%) of the four counties.

Table 4.6-7. State Buildings Exposure and Potential Losses to the Ka'ū M8.0 and Lāna'i M7.0 Earthquake Events

County	Total Value	Estimated Potential Loss			
		Ka'ū M8.0		Lāna'i M7.0	
		Value	Percent of Total	Value	Percent of Total
County of Kaua'i	$1,067,278,062	$7,990	<1%	$7,990	<1%
City and County of Honolulu	$18,548,040,469	$979,185	<1%	$1,330,246	<1%
County of Maui	$2,983,348,758	$138,204	<1%	$74,132,065	2.5%
County of Hawai'i	$5,095,297,885	$189,822,827	3.7%	$4,425	<1%
Total	**$27,693,965,174**	**$190,948,206**	**0.7%**	**$75,474,725**	**0.3%**

Source: Hazus v4.2
Notes: M Magnitude

Table 4.6-8. State Buildings Exposure and Potential Losses to the Kalapana M7.7 and NE Maui M7.0 Earthquake Events

County	Total Value	Estimated Potential Loss			
		Kalapana M7.7		NE Maui M7.0	
		Value	Percent of Total	Value	Percent of Total
County of Kaua'i	$1,067,278,062	$7,990	<1%	$7,990	<1%
City and County of Honolulu	$18,548,040,469	$467,367	<1%	$270,490	<1%
County of Maui	$2,983,348,758	$52,197	<1%	$2,651,332	<1%
County of Hawai'i	$5,095,297,885	$136,781,301	2.7%	$7,217	<1%
Total	**$27,693,965,174**	**$137,308,854**	**0.5%**	**$2,937,029**	**0.01%**

Source: Hazus v4.2.
Notes: M Magnitude

State roads can be damaged by moderate to significant earthquake shaking. Roads that are on soft ground or on embankments can experience extensive cracking, ripped apart, settlement and sloughing. This can result in a disruption of transportation systems, which limits post-disaster emergency response.

Table 4.6-9 shows the length of State roads located on the vulnerable NEHRP Class D and E soils for the Counties of Hawai'i and Maui. The County of Maui has the greatest number of miles (80.4 miles) located on NEHRP Class D and E soils. The County of Hawai'i has a total of 12.8 miles on Class D and E soils. A complete list of state roads exposed is included in Appendix X.

Table 4.6-9. State Road Exposure to NEHRP Class D and E Soils by County

County	Length (in miles)						
	Total Length of State Roads	NEHRP Class D Area	Exposed Length as % of Total	NEHRP Class E Area	Exposed Length as % of Total	NEHRP Class D and E Area	Exposed Length as % of Total
County of Kaua'i	104.0	-	-	-	-	-	-
City and County of Honolulu	375.3	-	-	-	-	-	-
County of Maui	238.6	80.4	33.7%	0.0	0.0%	80.4	33.7%

County	Length (in miles)						
	Total Length of State Roads	NEHRP Class D Area	Exposed Length as % of Total	NEHRP Class E Area	Exposed Length as % of Total	NEHRP Class D and E Area	Exposed Length as % of Total
County of Hawaiʻi	378.7	12.6	3.3%	0.2	0.0%	12.8	3.4%
Total	**1,096.5**	**93.0**	**8.5%**	**0.2**	**0.0%**	**93.2**	**8.5%**

Source: State of Hawaiʻi SDOT State Routes GIS layer 2017
Notes: GIS Geographic Information System
NEHRP National Earthquake Hazard Reduction Program
SDOT State Department of Transportation
The County of Kauaʻi and the City and County of Honolulu do not have spatially-delineated NEHRP soils available for this analysis.

Critical Facilities

All critical facilities in the State of Hawaiʻi are exposed to the earthquake hazard. Critical facilities need to remain in operation during and after a disaster event to provide essential services. To remain in operation, these facilities may depend on electrical power. Maintaining electrical power generation and distribution is essential; however, substations and switchyards are vulnerable to strong ground shaking. As part of the *Makani Pahili 2017 Temporary Emergency Power County Workshop Report*, the HI-EMA and county emergency managers developed a list of county and state critical facilities and essential services that require emergency power during response operations; and a methodology to prioritize temporary emergency power in each county. These critical facilities are included in the Hazus analysis for the 2018 HMP Update.

Table 4.6-10 summarizes the estimated potential losses to critical facilities as a result of the 100-year probabilistic earthquake event by county. The County of Hawaiʻi has the greatest estimated loss ($404 million or 8.1% of the total value of critical facilities in the county). The greatest loss is to the Mass Care Support Services core category ($217 million), followed by water, waste and wastewater systems ($144 million).

Refer to Appendix X which lists the estimate potential loss to critical facilities for the four historic earthquake scenarios evaluated.

Table 4.6-10. Estimated Potential Losses to Critical Facilities to the 100-year Probabilistic Earthquake Event

County	Total Replacement Cost Value	Estimated Potential Loss	
		Replacement Cost Value	Percent (%) of Total
County of Kauaʻi	$2,859,152,410	$216,373	0.0%
City and County of Honolulu	$19,235,387,455	$78,367,504	0.4%
County of Maui	$6,286,051,833	$33,919,568	0.5%
County of Hawaiʻi	$4,966,896,651	$404,613,545	8.1%
Total	**$33,347,488,348**	**$517,116,990**	**1.6%**

Source: Makani Pahili 2017 Emergency Power Prioritization Workshop Series final report; Hazus v4.2

Table 4.6-11. Critical Facilities Potential Losses by Core Category to the 100-year Probabilistic Earthquake Event

Core Category	Total Number of Critical Facilities	Total Replacement Cost Value	Estimated Potential Loss	
			Replacement Cost Value	Percent (%) of Total
Commercial Facilities	60	$206,894,206	$2,668,319	1.3%
Communications	130	$523,848,060	$7,134,239	1.3%
Emergency Services	149	$1,017,628,710	$15,566,716	1.5%
Energy	90	$2,591,975,628	$20,242,145	0.8%
Food & Agriculture	39	$829,869,410	$47,906,425	5.8%
Government Facilities	100	$399,781,575	$5,641,081	1.4%
Healthcare & Public Health	193	$3,399,521,375	$36,091,347	1.1%
Mass Care Support Services	353	$11,497,547,155	$217,342,622	1.9%
Transportation Services	56	$1,739,256,960	$20,052,619	1.1%
Water, Waste, & Wastewater Systems	305	$9,481,445,760	$144,471,477	1.3%
Total	**1,475**	**$31,687,768,838**	**$517,116,990**	**1.6%**

Source: Makani Pahili 2017 Emergency Power Prioritization Workshop Series final report; Hazus v4.2

Fires may also follow earthquakes, often occurring in developed areas. They may be caused by broken power lines or leaking combustibles that find a source of ignition. Response may be affected due to losses incurred to critical facilities and services including communication service, isolated or damaged equipment, water supply access and other competing emergency demands on available facilities and resources.

Assessment of Local Vulnerability and Potential Losses

This section provides a summary of vulnerability and potential losses to population, general building stock, and environmental resources and cultural assets by county.

Population

The entire population is potentially exposed to the direct and indirect impacts from earthquakes. The degree of exposure is dependent on many factors including the age and type of construction people live in, the soil types their homes are located on, the intensity of the earthquake etc. Whether directly or indirectly impacted, residents may be faced with business closures, road closures that could isolate population and loss of function of critical facilities and utilities.

Overall, the County of Kauaʻi lies in an area of reduced seismic risk. However, if a severe earthquake affects the City and County of Honolulu) the County of Kauaʻi, as well as the Counties of Hawaiʻi and Maui would be impacted severely in the receipt of goods, services, and finances since many systems rely on the ports and harbors or institutions on the island of Oʻahu.

Table 4.6-12 displays the estimated population located on the NEHRP Class D and E soils. Greater than 50% of the population in the County of Maui are located on Class D and E soils. As noted earlier, NEHRP soils are only delineated for the Counties of Maui and Hawaiʻi. This analysis does not include the number of tourists and visitors in the State whose lodgings may be located on NEHRP Class D and E soils. Therefore, this estimate may be underestimating exposure and vulnerability.

While all people located in the NEHRP Class D and E Soils areas are considered exposed and potentially vulnerable, populations considered most vulnerable include the elderly (persons over the age of 65) and individuals living below the U.S. Census poverty threshold. These socially vulnerable populations are most susceptible based on many factors including their physical and financial ability to react or respond during a hazard, the location and construction quality of their housing, and the ability to be self-sustaining for prolonged periods of time after an incident because of limited ability to stockpile supplies. In the County of Maui, 7% of the population on Class D and E soils is over the age of 65 years and greater than 12% have an annual income less than $30,000 per year.

Table 4.6-12. 2010 U.S. Census Population Located on the NEHRP Class D and E Soils by County

County	Population						
	Total Population	Population on Class D and E Soils	Population Exposed as Percent (%) of Total	Population Over 65 in Hazard Area	Population Over 65 Exposed as Percent (%) of Total	Income <$30K/yr in Hazard Area	Income <$30K/yr Exposed as Percent (%) of Total
County of Kauaʻi	67,091	-	-	-	-	-	-
City and County of Honolulu	953,207	-	-	-	-	-	-
County of Maui	154,924	82,293	53.1%	11,052	7.1%	18,936	12.2%
County of Hawaiʻi	185,079	7,069	3.8%	1,085	0.6%	3,783	2.0%
Total	**1,360,301**	**89,362**	**6.6%**	**12,137**	**0.9%**	**22,719**	**1.7%**

Source: U.S. Census 2010
Notes: NEHRP National Earthquake Hazard Reduction Program
The County of Kauaʻi and the City and County of Honolulu do not have spatially-delineated NEHRP soils available for this analysis.
The poverty threshold for the State is $24,000/year (Federal Register 2017). Utilizing the demographic layer in Hazus, the total households with an income of $30,000 or less was calculated. Per the U.S. Census Bureau QuickFacts, the average number of persons per household (2012-2016) is 3.03 for the State of Hawaiʻi. To convert households to residents, three people per household was used.

Residents may be displaced or require temporary to long-term sheltering because of an earthquake event. The number of people requiring shelter is generally less than the number displaced, as some displaced persons use hotels or stay with family or friends following a disaster event. Estimated shelter requirements as a result of the 100-year probabilistic event and the four historic scenario events were calculated using Hazus; results of these analyses are summarized in Table 4.6-13 and Table 4.6-14.

Table 4.6-13. Estimated Shelter Requirements for the 100-year Probabilistic Event

County	100-year Probabilistic Event	
	Displaced Households	Short-Term Sheltering Needs
County of Kauaʻi	0	0
City and County of Honolulu	104	65
County of Maui	84	49
County of Hawaiʻi	1,549	1,044
Total	**1,737**	**1,158**

Table 4.6-14. Estimated Shelter Requirements for the for Ka‘ū, Lāna‘i Kalapana and NE Maui Scenarios

County	Ka‘ū M8.0		Lāna‘i M7.0		Kalapana 1975 M7.7		NE Maui M7.0	
	Displaced Households	Short-Term Sheltering Needs	Displaced Households	Short-Term Sheltering Needs	Displaced Households	Short-Term Sheltering Needs	Displaced Households	Short-Term Sheltering Needs
County of Kaua‘i	0	0	0	0	0	0	0	0
City and County of Honolulu	0	0	0	0	0	0	0	0
County of Maui	0	0	6	5	0	0	0	0
County of Hawai‘i	76	53	0	0	45	31	0	0
Total	**76**	**53**	**6**	**5**	**45**	**31**	**0**	**0**

Source: Hazus v4.2
Notes: M Magnitude
NE Northeast

Hazus 4.2 estimates the number of people that may be potentially be injured and/or killed by an earthquake depending on the time of day the event occurs. These estimates are provided for three times of day (2:00 a.m., 2:00 p.m. and 5:00 p.m.), representing the periods of the day that different sectors of the community are at their peak. The 2:00 am estimate considers the residential occupancy at its maximum; the 2:00 p.m. estimate considers the educational, commercial, and industrial sector at their maximum; and the 5:00 p.m. estimate represents peak commuter time. Table 4.6-15 and Table 4.6-16 summarize the injuries and casualties estimated for the 100-year probabilistic event and the four earthquake scenarios.

Table 4.6-15. Estimated Injuries and Casualties for 100-year Probabilistic Event

Level of Severity	100-year Probabilistic Event		
	2AM	2PM	5PM
Injuries	377	708	501
Hospitalization	71	178	118
Casualties	10	38	23

Source: Hazus v4.2

Table 4.6-16. Estimated Injuries and Casualties for Ka‘ū, Lāna‘i Kalapana and NE Maui Scenarios

Level of Severity	Ka‘ū M8.0			Lāna‘i M7.0			Kalapana 1975 M7.7			NE Maui M7.0		
	2AM	2PM	5PM	2AM	2PM	5PM	2AM	2PM	5PM	2AM	2PM	5PM
Injuries	37	93	65	7	13	9	25	62	40	2	4	3
Hospitalization	4	19	12	1	2	1	3	10	6	0	0	0
Casualties	1	3	2	0	0	0	0	1	1	0	0	0

Source: Hazus v4.2

Notes: M Magnitude
NE Northeast

Land Use Districts

Table 4.6-17 shows the square miles of NEHRP Class D and E soils in the combined State Land Use District in the County of Maui and the County of Hawaiʻi; refer to Appendix X for results by County. Agricultural District lands have the most square miles of Class D and E soils, as these soil types frequently overlap with floodplain areas, which are commonly highly productive agricultural lands. Approximately 16.2% of the Urban District Land in these two counties have Class D or E soils. Urban Districts are those areas that are most likely to be developed. The majority of this area of intersect is in Maui County with 44% of Urban District land on these soil types. NEHRP soils are used in the International Building Code (IBC) to classify sites, with Class A and E corresponding to the best and poorest soil conditions, respectively) (Hawaiʻi State HMP 2013). The State of Hawaiʻi adopted the 2010 IBC on April 16, 2010 and include seismic designs required for buildings in the state based on NEHRP soil classifications (Hawaiʻi State Building Code 2010). Counties in the State have adopted or are in the process of adopting the 2012 IBC (see Section 5 for more information).

Table 4.6-17. State Land Use Districts with on NEHRP Class D and E Soils

Land Use District	Total (square miles)	Square Miles NEHRP Class D and E Soils	Percent (%) of Total Area
Agricultural	2,454.5	118.1	4.8%
Conservation	2,602.1	98.7	3.8%
Rural	14.0	3.1	22.5%
Urban	133.1	21.6	16.2%
Total	**5,203.7**	**241.5**	**4.6%**

Source: AECOM; Tetra Tech; State Land Use Commission, 2016
Notes:
Total area calculated from the State of Hawaiʻi State Land Use District GIS layer
The County of Kauaʻi and the City and County of Honolulu do not have spatially-delineated NEHRP soils available for this analysis.
Hazard area clipped to coastline downloaded from State of Hawaiʻi GIS Program Geospatial Data Portal
Total area may differ slightly between this and other calculations due to slight differences in the shoreline geography.

General Building Stock and Economy

Similar to the analyses presented earlier, the general building stock data was overlaid with the earthquake hazard area to assess vulnerability. The total replacement cost value of general building stock is an estimated $242 billion; all of which are exposed to an earthquake event. Table 4.6-18 summarizes these values by county. The potential damage estimated to general building stock as a result of a 100-year probabilistic earthquake event is approximately $2.1 billion statewide. The County of Hawaiʻi may experience the greatest damages ($1.7 billion or 5.4% of their total general building stock inventory replacement cost).

Table 4.6-18. General Building Stock Exposure and Potential Losses to the 100-year Probabilistic Earthquake Event

County	Total Replacement Cost Value	Estimated Potential Loss	
		Replacement Cost Value	Percent (%) of Total
County of Kauaʻi	$13,287,882,000	$156,787	0.0%
City and County of Honolulu	$164,787,212,000	$216,109,266	0.1%
County of Maui	$31,320,693,000	$137,500,628	0.4%

County	Total Replacement Cost Value	Estimated Potential Loss	
		Replacement Cost Value	Percent (%) of Total
County of Hawaiʻi	$33,326,392,000	$1,783,530,908	5.4%
Total	**$242,722,179,000**	**$2,137,297,589**	**0.9%**

Source: Hazus v4.2

Of the four historic scenarios evaluated, the Kaʻū M8.0 scenario would result in the greatest estimated potential building loss; approximately $372 million in damages statewide (see Table 4.6-19). The County of Hawaiʻi is estimated to experience the greatest loss at more than $347 million in building damages, followed by the City and County of Honolulu and County of Maui, respectively. The estimated potential building losses resulting from all four historic scenarios are summarized in Table 4.6-19 and Table 4.6-20 by county.

Table 4.6-19. General Building Stock Exposure and Potential Losses to the Kaʻū M8.0 and Lānaʻi M7.0 Earthquake Events

County	Total Replacement Cost Value	Estimated Potential Loss			
		Kaʻū M8.0		Lānaʻi M7.0	
		Value	Percent of Total	Value	Percent of Total
County of Kauaʻi	$13,287,882,000	$503,490	<1%	$0	<1%
City and County of Honolulu	$164,787,212,000	$13,354,539	<1%	$8,806,737	<1%
County of Maui	$31,320,693,000	$10,525,454	<1%	$87,185,308	0.3%
County of Hawaiʻi	$33,326,392,000	$347,847,705	1.0%	$90,888	<1%
Total	**$242,722,179,000**	**$372,231,186**	**0.2%**	**$96,082,933**	**<1%**

Source: Hazus v4.2
Notes: M Magnitude

Table 4.6-20. General Building Stock Exposure and Potential Losses to the Kalapana M7.7 and NE Maui M7.0 Earthquake Events

County	Total Replacement Cost Value	Estimated Potential Loss			
		Kalapana M7.7		NE Maui M7.0	
		Value	Percent of Total	Value	Percent of Total
County of Kauaʻi	$13,287,882,000	$503,490	<1%	$0	<1%
City and County of Honolulu	$164,787,212,000	$9,131,224	<1%	$2,370,220	<1%
County of Maui	$31,320,693,000	$4,363,416	<1%	$53,376,422	0.2%
County of Hawaiʻi	$33,326,392,000	$218,870,428	0.7%	$318,104	<1%
Total	**$242,722,179,000**	**$232,868,558**	**0.1%**	**$56,064,746**	**<1%**

Source: Hazus v4.2.
Notes: M Magnitude
NE Northeast

Earthquakes have the potential to impact economies at both the local and regional scale. Losses can include structural and non-structural damage to buildings, loss of business function, damage to inventory, relocation costs, wage loss, and rental loss caused by the repair and replacement of buildings. Table 4.5-21 summarizes the estimated potential economic loss as calculated by Hazus for the four historic earthquake scenarios evaluated.

Roads that cross earthquake-prone soils have the potential to be significantly damaged during an earthquake event, potentially impacting commodity flows. Access to major roads is crucial to life and safety after a disaster event, as well as to response and recovery operations. Further, water and sewer infrastructure would likely suffer considerable damage in the event of an earthquake.

Table 4.6-21. Estimated Potential Economic Losses for the State of Hawaiʻi (Millions of Dollars) for the Kaʻū, Lānaʻi Kalapana and NE Maui Scenarios

	Kalapana 1975 M7.7	Kaʻū M8.0	Lānaʻi M7.0	NE Maui M7.0
Income Losses				
Wage	$5.4	$9.9	$2.9	$0.4
Capital-Related	$3.6	$6.4	$2.1	$0.3
Rental	$6.5	$11.0	$2.9	$0.7
Relocation	$14.4	$23.3	$4.9	$0.9
Subtotal	**$29.8**	**$50.6**	**$12.8**	**$2.3**
Capital Stock Losses				
Structural	$28.1	$50.1	$9.2	$3.0
Non-Structural	$146.9	$232.1	$59.3	$33.8
Content	$57.9	$90.1	$27.6	$19.2
Inventory	$0.9	$1.7	$0.2	$0.2
Subtotal	**$233.8**	**$374.0**	**$96.3**	**$56.3**
Total	**$263.6**	**$424.5**	**$109.1**	**$58.6**

Source: Hazus v4.2

Due to its geographic location and isolation, the state faces unique challenges in addressing disaster debris. With limited landfill capacity, advanced planning for large amounts of debris is critical. The Hazus earthquake model also estimates volume of debris that may be generated as a result of an earthquake event to enable the State to prepare and rapidly and efficiently manage debris removal and disposal. Debris estimates are divided into two categories: (1) reinforced concrete and steel that require special equipment to break up before transport, and (2) brick, wood, and other debris that can be loaded directly onto trucks with bulldozers (FEMA 2015). Table 4.6-22 summarizes the estimated debris generated by the 100-year probabilistic event and the four earthquake scenarios in Hazus 4.2.

Table 4.6-22. Estimated Debris Generated for each Earthquake Scenario

Scenario	Debris Type	
	Brick/Wood (tons)	Concrete/ Steel (tons)
100-year Probabilistic Event	224,819	282,275
Kalapana 1975 M7.7	20,217	18,110
Kaʻū M8.0	32,596	38,248
Lānaʻi M7.0	7,094	4,829
NE Maui M7.0	3,533	707

Source: Hazus 4.2
Notes: M Magnitude
NE Northeast

Environmental Resources

Earthquakes can lead to numerous, widespread, and devastating environmental impacts. Hazardous materials releases can occur during an earthquake from fixed facilities or transportation-related incidents. During an earthquake, structures storing these materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment. Facilities holding hazardous materials are of concern because of possible isolation of neighborhoods surrounding them. Transportation corridors can be disrupted during an earthquake, leading to the release of materials to the surrounding environment.

Additional environmental impacts may include but are not limited to:

- Induced flooding or landslides
- Poor water quality
- Damage to vegetation
- Breakage in sewage or toxic material containments

Cultural Assets

Consistent with Native Hawaiian culture, Hawaiian Home Lands include areas from mauka to makai (from the mountain to the sea). The population and structures located on Hawaiian Home Lands are more vulnerable to earthquake events if located on NEHRP Class D and E soils (see Table 4.6-23). The County of Maui has 7.5% of its Hawaiian Home Lands on this type of soil.

Table 4.6-23. Hawaiian Home Lands on NEHRP Class D and E Soils

	Area (in square miles)						
County	Total Area of Hawaiian Home Lands	NEHRP Class D Area	Percent (%) of Total	NEHRP Class E Area	Percent (%) of Total	Total NEHRP Class D and E Area	Percent (%) of Total
County of Kauaʻi	32.0	-	-	-	-	-	-
City and County of Honolulu	10.9	-	-	-	-	-	-
County of Maui	92.6	7.0	5.2%	0.0	0%	7.0	7.5%
County of Hawaiʻi	190.3	5.2	2.7%	2.5	1.3%	7.7	4.1%
Total	**325.8**	**12.2**	**4.3%**	**2.5**	**0.9**	**14.7**	**5.2%**

Source: State of Hawaiʻi GIS layer Trust Land, State of Hawaiʻi GIS Program Geospatial Data Portal
Notes: GIS Geographic Information System
NEHRP National Earthquake Hazard Reduction Program
The County of Kauaʻi and the City and County of Honolulu do not have spatially-delineated NEHRP soils available for this analysis.

Future Changes that May Impact State Vulnerability

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

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

NEHRP Class D and E soil areas were overlain on areas that may experience significant changes in development or redevelopment in future years (see Table 4.6-24 below; refer to Section 3 for more information on projected development areas). Because only the County of Hawaiʻi and the County of Maui have this data available, the analysis was only conducted using Maui Development Project Areas and Enterprise Zones in these counties. About 22% of the area in the Maui Development Projects are and 6% of Enterprise Zone areas have Cass D or E soils. Generally, new development will be more resistant to damage from earthquake events than older construction as building code seismic design standards have improved over time and modern codes, such as the International Building Code, include provisions for classifying soils.

Table 4.6-24. Maui Development Projects and Enterprise Zones Located in NEHRP Class D or E Soils

County	Area (square miles)					
	Maui Development Projects (Total Area)	Total Area Exposed to Hazard	Hazard Area as % of Total Area	Enterprise Zones (Total Area)	Total Area Exposed to Hazard	Hazard Area as % of Total Area
County of Maui	27.6	6.0	21.9%	1,016.7	93.8	9.2%
County of Hawaiʻi	-	-		1,286.6	45.6	3.5%
Total	**27.6**	**6.0**	**21.9%**	**2,303.4**	**139.4**	**6.1%**

Notes: *NEHRP soil classification has not been conducted in the County of Kaua'i or in the City and County of Honolulu*
Total area calculated from: (1) Maui Development Projects GIS layer from Maui County Planning Department (2) Enterprise Zones from Community Economic Development Program, DBEDT
Hazard area clipped to coastline downloaded from State of Hawaiʻi GIS Program Geospatial Data Portal
NEHRP National Earthquake Hazard Reduction Program