9. EARTHQUAKE

9.1 HAZARD PROFILE

9.1.1 HAZARD DESCRIPTION

This section provides a description of the hazard, including causes, hazard or incident characteristics, and potential impacts.

Overview

An earthquake is a shaking of the earth’s surface by energy waves emitted when slow-moving tectonic plates move against one another underneath the earth’s surface, or when volcanic eruptions occur (FEMA 2023). Hawaii experiences thousands of earthquakes every year, mostly caused by eruptive processes in active volcanoes on the Island of Hawaiʻi or by deep structural adjustments due to the weight of the islands on the earth’s underlying crust. Most of these earthquakes are so small they are not felt by the public and can only be detected by seismometers. Some are strong enough to be felt on one or more islands. Though rare, earthquakes large enough to cause significant damage across the state have occurred (USGS 2023).

Earthquake Causes

Earthquakes in Hawaiʻi are classified into three main types:

- **Volcanic**—These earthquakes are caused by magma moving within or erupting from active volcanoes such as Kīlauea on Hawaiʻi Island. They often occur in swarms of hundreds to thousands of small shallow quakes, particularly after an eruption, that rarely cause significant damage (USGS 2023).
- **Tectonic**—These earthquakes involve slippage along tectonic faults beneath or within volcanoes. There are two main types:
  - Minor to moderate earthquakes occur on upper crustal faults beneath and within the volcanoes. These are the most numerous types of earthquakes in Hawaiʻi.
  - Large flank earthquakes occur along the décollement fault, which separates the ancient oceanic crust from the volcanic island mass at depths of 5 to 6 miles. Tectonic events at these deep faults are the most dangerous type of earthquake in Hawaiʻi since they can result in both large earthquakes and local tsunamis. A large tectonic earthquake can trigger a volcanic eruption by causing stress changes in the earth’s crust that destabilize magma chambers within the volcano (USGS 2023).
- **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 Hawai’i. This type of earthquake generally occurs more than 12 miles below sea level (USGS 2023).

Potential Impacts

Ground shaking is the vibration of the ground during an earthquake and is the primary cause of earthquake damage. Buildings vibrate as a consequence of the ground shaking; damage takes place if the building cannot withstand these vibrations (USGS n.d.). Usually, the severity of ground shaking increases as with the strength of the initial seismic event and decreases with distance from the epicenter of that event.

The ground shaking caused by an earthquake has the potential to trigger other hazards that lead to additional impacts. Whether these impacts occur depends on various factors, including the severity of ground shaking, characteristics of the environment where the shaking was most severe, and the type of earthquake.

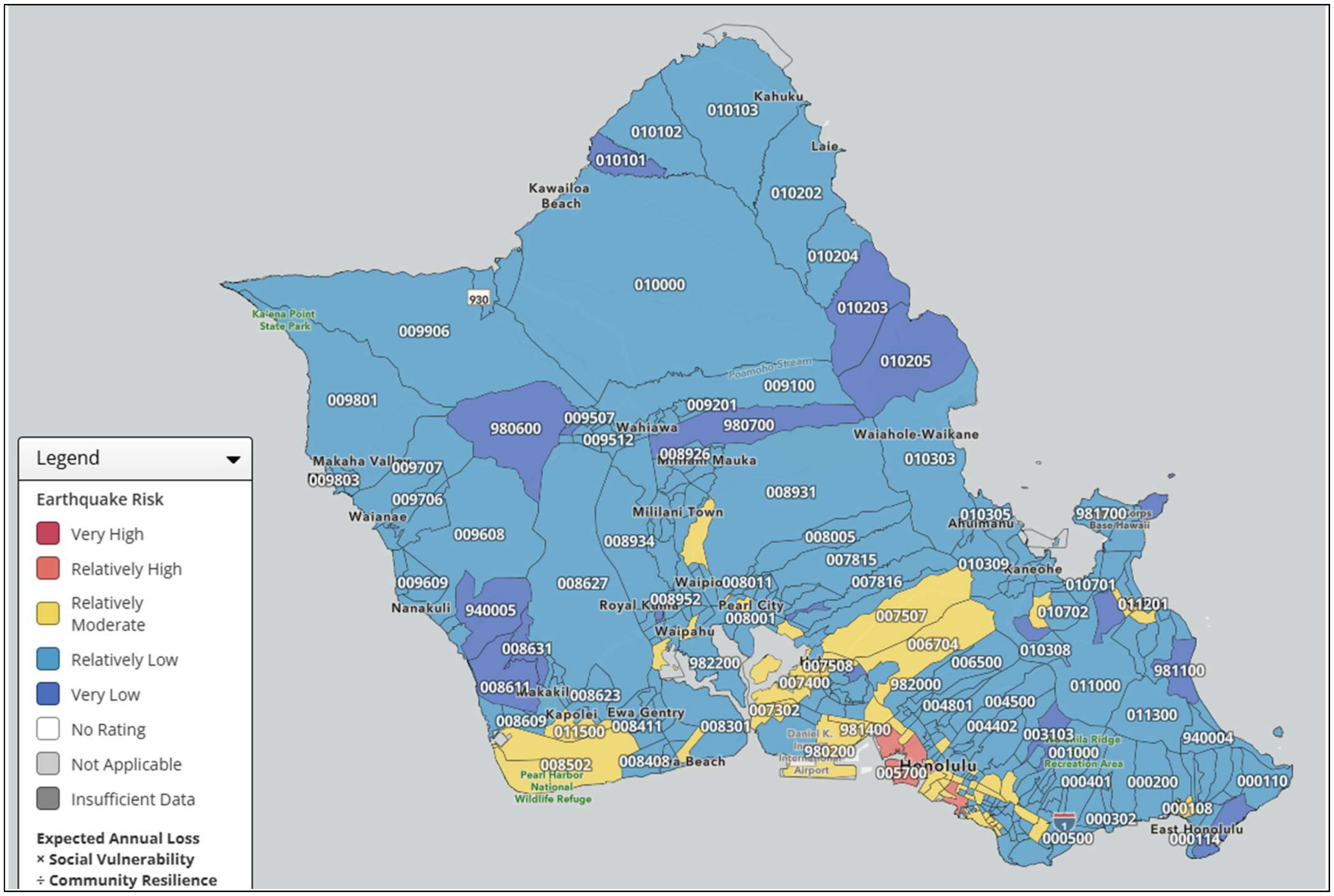
- **Ground liquefaction**—Liquefaction can be defined as a process by which sediments below the water table temporarily lose strength and behave as a liquid, usually in areas of loosely packed soil. This process can cause impacts such as roads buckling, bridge and overpass failure, and sinking of low-rise buildings. High-rise buildings anchored in the underlying rock should survive without collapsing (U.S. Geological Survey n.d.).
- **Fire**—Fires in developed areas may follow earthquakes. They may be caused by broken power lines or leaking combustibles that find a source of ignition.
- **Landslide—**The most abundant types of earthquake-induced landslides are rock falls and slides of rock fragments that form on steep slopes, such as the Koʻolau Mountains. The size of the area affected by earthquake-induced landslides depends on the magnitude of the earthquake, the topography and geologic conditions near the fault, and the amplitude, frequency composition, and duration of ground shaking (USGS n.d.). Landslides are discussed in greater depth in Chapter 16.
- **Tsunami**—An earthquake that is big enough and close enough to cause a sudden vertical movement of the sea floor can generate a tsunami. Tsunamis are discussed in greater depth in Chapter 17.

9.1.2 LOCATION

As noted above, earthquakes occur frequently in the state. Most of them are volcanic earthquakes that occur on and around Hawaii County, particularly in the southern districts where the state’s three most active volcanoes are located. While few of these earthquakes are felt by the public, earthquakes can occur that cause damage and impacts statewide.

Though Oʻahu can be impacted by damaging earthquakes, most of the island’s earthquake risk is classified as ‘relatively low’ according to the FEMA National Risk Index (NRI), as shown in Figure 9-1. The southern half of Oʻahu has the only areas classified above ‘relatively low’ or ‘very low risk.’ There is one ‘relatively high’ risk area in part of Urban Honolulu, and a few areas at ‘relatively moderate’ risk. (FEMA, 2023).

Figure 9-1. Earthquake Risk in the City



Source: (NRI n.d.)

9.1.3 EXTENT

Hazard extent refers to the potential severity or magnitude of hazard events in a given area. This section describes measurements used to indicate the extent of this hazard and the systems in place for monitoring severity and providing warnings as necessary.

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 (32 feet per second per second). PGA is expressed as

> **Key Terms Simplified**
>
> - **PGA—**Peak ground acceleration is motion experienced by a person on the ground during an earthquake.
> - **SA—**Spectral acceleration is motion experienced by a building during an earthquake

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.

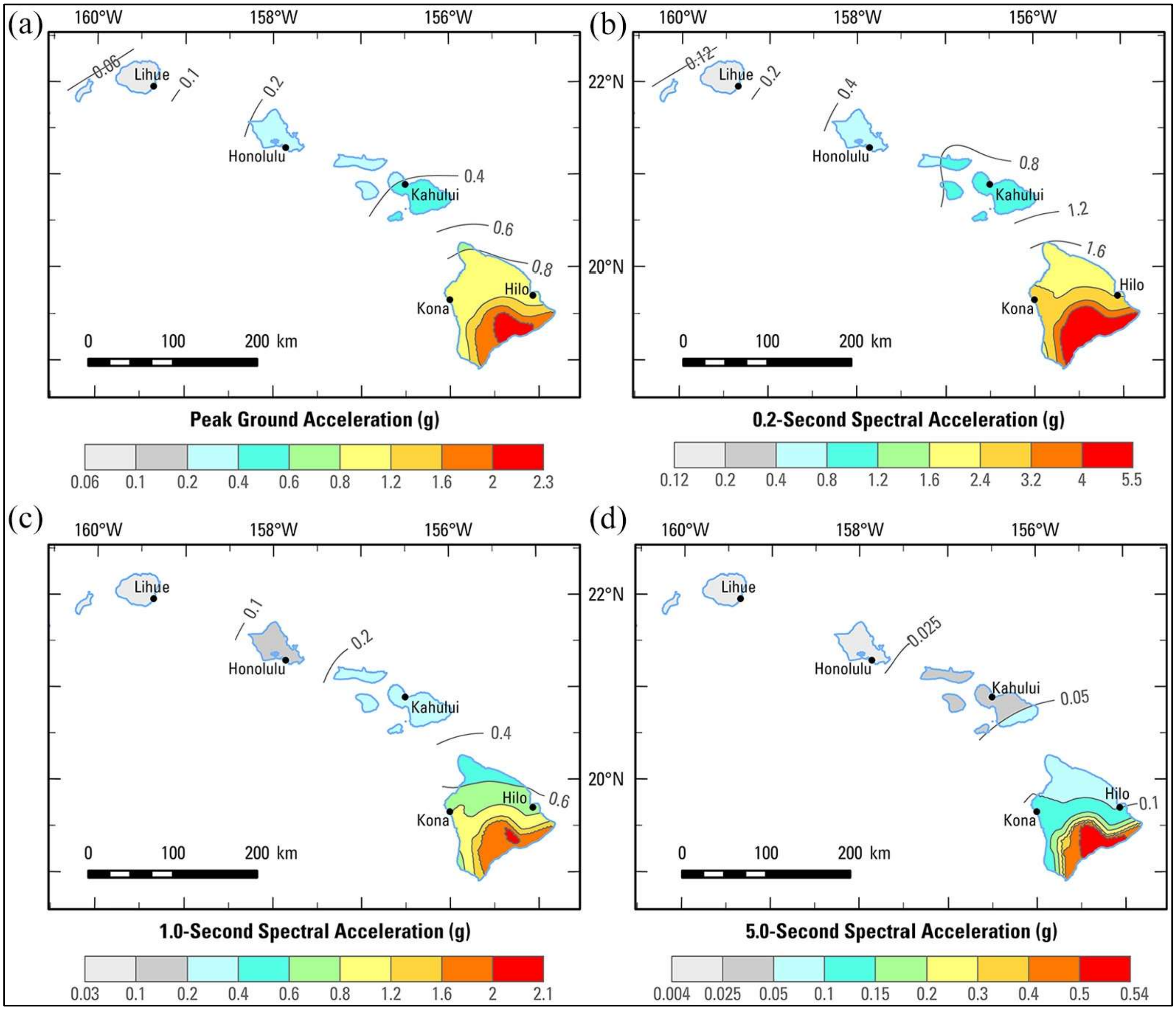
Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. The following generalized observations provide qualitative statements about the likely extent of damages for earthquakes with various levels of ground shaking (PGA) at a given 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. Similar maps are created for expected spectral acceleration (SA) during an earthquake, which is the acceleration experienced by buildings.

Figure 9-2 shows contours of PGA and 0.2-second, 1-second, and 5-second SA with 2 percent chance of occurring over the next 50 years. These maps were created with data from the USGS to produce uniform probabilistic seismic hazard maps for the United States. The 2 percent in 50-years acceleration values mean that over the next 50 years, there is a 2 percent probability that ground shaking or building shaking will reach this level or higher. The 2 percent in 50 years PGA represents a level of ground shaking close to but not the worst-case scenario. The figures show the majority of the state has low levels of seismic hazard.

Figure 9-2. 2021 Seismic Hazard Map, PGA, 0.2, 1, and 5 SA with



Source: (Petersen, Shumway and Shiro 2021)

Magnitude

An earthquake's magnitude is a measure of the energy released at the source, or epicenter, of the earthquake.

Magnitude is commonly expressed by ratings on the moment magnitude scale (Mw). 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) (U.S. Geological Survey n.d.). Table 9-1 lists magnitudes, their effects, and the estimated number that occur globally each year.

Table 9-1. USGS Global Earthquake Magnitude Scale

Magnitude	Earthquake Effects	Estimated Number Each Year Worldwide
2.5 or less	Usually not felt, but can be recorded by seismograph.	Millions
2.5 to 5.4	Often felt, but only causes minor damage.	500,000
5.5 to 6.0	Slight damage to buildings and other structures.	350
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	10-15
8.0 or greater	Great earthquake. Can destroy communities near the epicenter.	One every year or two

Source: (MT n.d.)

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 most commonly used intensity scale is the Modified Mercalli Intensity scale, which rates intensity from I (weakest shaking) to XII (catastrophic destruction). The Modified Mercalli Intensity scale, along with PGA values associated with the steps, is shown in Table 9-2.

Table 9-2. 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	Less than 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	More than124%

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

Seismic Design Categories

Seismic design maps can also help illustrate the extent of the earthquake risk in specific locations. Seismic design maps are developed under the National Earthquake Hazards Reduction Program (NEHRP) and published in the International Residential Code (IRC) and International Building Code (IBC).

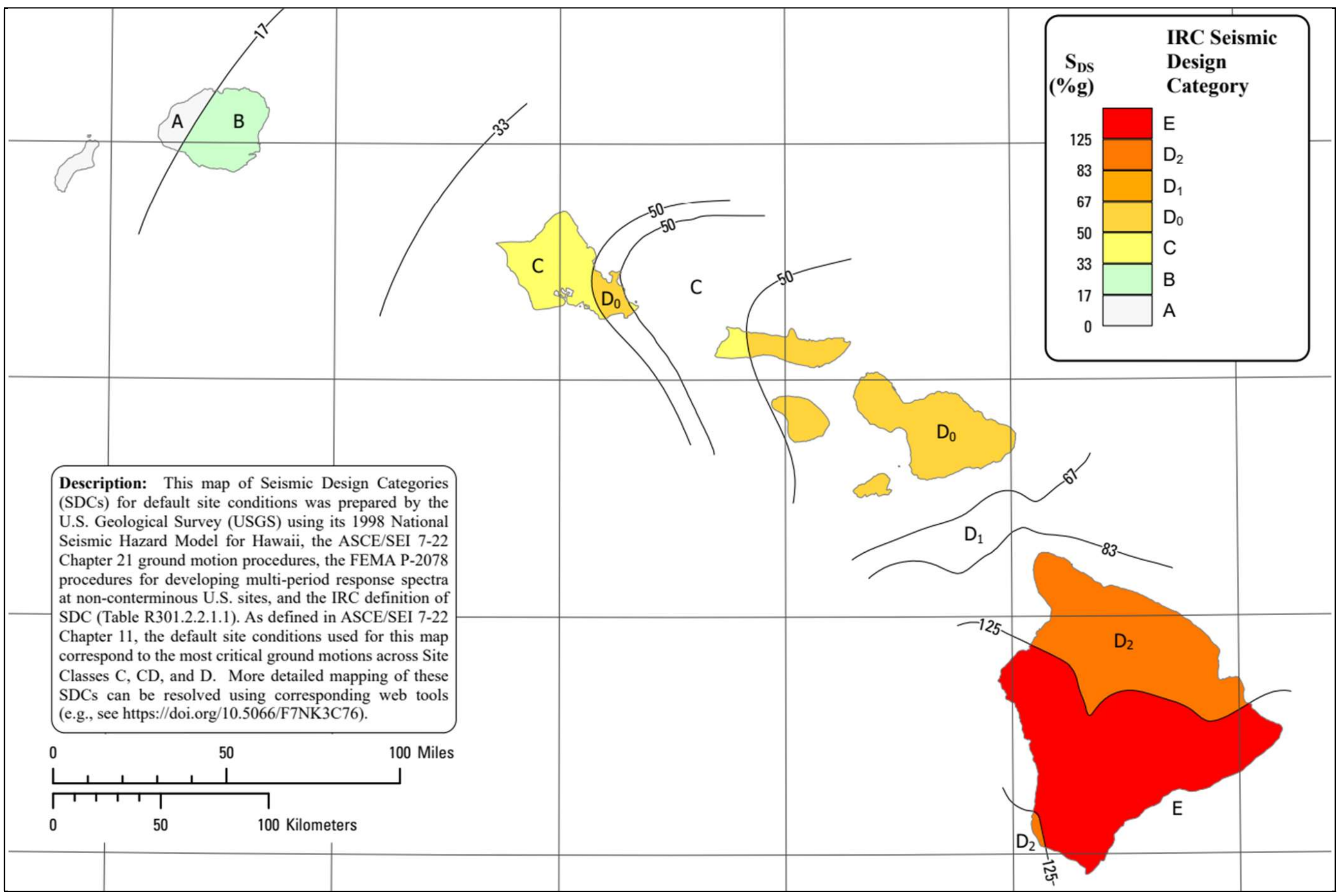
These maps show seismic design categories (SDCs), which are used in building codes to determine the level of earthquake resistance required based on a location's potential for earthquake ground motion, site soil amplification, structure size, configuration, occupancy and uses. The updated seismic design maps shown below were adopted in the 2024 editions of the IBC and the IRC, which have not yet been adopted by the City.

SDCs vary from SDC A, representing the lowest hazard with little to no anticipated damage due to earthquakes, to SDC E and F, representing very high hazard and the possibility of significant earthquake damage, even to robust structures.

SEISMIC DESIGN MAP USED IN THE IRC

The IRC maps SDCs directly for low-rise residential construction, which includes one- and two-family detached dwellings and townhouses up to three stories in height. As noted on Figure 9-3, there are two SDCs on Oʻahu: D0 and C.

Figure 9-3. Seismic Design Category Map for 2024 IRC

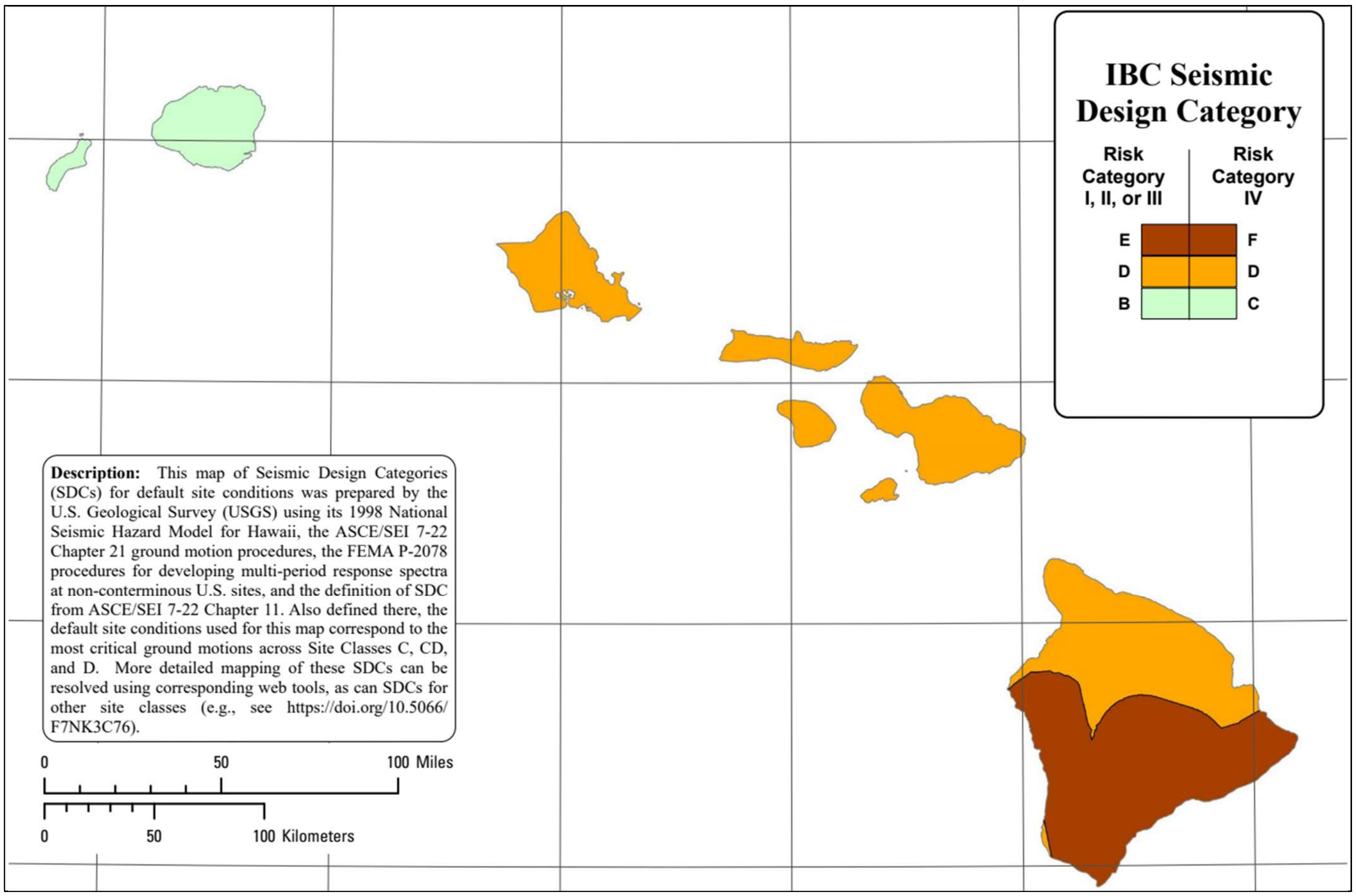


Source: (FEMA 2023)

SEISMIC DESIGN MAPS USED IN THE IBC

The IBC is a national model code for the design of buildings and other structures with a much broader range of occupancies and uses than those addressed in the IRC. Categories in the IBC range from A to F, where F represents an emergency response or similar facility located in regions of very high seismic hazard and is the most critical category for design. In some cases, the SDC depends on the nature of the structure as defined by the structure's risk category. The SDC for Risk Category IV structures may be higher than the SDC at the same location for structures with Risk Category I, II, or III. Risk Category IV structures are generally essential facilities that must remain operational during a hazard event, such as hospitals or emergency utilities. As shown in Figure 9-4, all of Oʻahu is in Category D (Cobeen and Westcott 2024).

Figure 9-4. Seismic Design Category Map for 2024 IBC



Source: (FEMA 2023)

Earthquake Monitoring and Warning

Unlike weather events, earthquakes cannot be predicted. USGS scientists can only calculate the probability that a significant earthquake will occur in a specific area within a certain number of years, which is different from a prediction, which would require a specific 1) the date and time, 2) the location, and 3) the magnitude.

The USGS Hawaiʻi Volcano Observatory (HVO) monitors earthquakes and active volcanoes in Hawaiʻi, assesses their hazards, and issues warnings. HVO is unique among USGS volcano observatories in that it is responsible for earthquake monitoring as it relates to both volcanic and seismic hazards. HVO operates a regional seismic network that is part of the USGS Advanced National Seismic System. The seismic monitoring network in Hawaiʻi includes various types of ground-shaking sensors at about 100 sites. These are operated by different partners as one statewide virtual network known as the Hawaiʻi Integrated Seismic Network (USGS 2017).

After HVO detects seismic signals with its monitoring network and analyzes those signals with computer tools, it disseminates the information. The system automatically locates earthquakes and posts them to the internet in real-time. Within hours to days, HVO seismic analysts review, re-compute, and update earthquake locations and magnitudes. Earthquakes above magnitude 4.0 are usually widely felt and may be damaging. These trigger a rapid response by HVO and others, who manually review the earthquake and issue an information statement within 2 hours.

9.1.4 PREVIOUS OCCURRENCES

This section provides an overview of earthquakes since the publication of the previous LHMP, covering the period between January 2020 and February 2025. It identifies events that resulted in federal disaster declarations and/or state or local emergency proclamations. For events prior to 2020, refer to the 2020 LHMP.

Recent Events

Table 9-3 shows recent earthquake events for Oʻahu. Events included on this table were limited to earthquakes that occurred on or near Oʻahu with a magnitude of 2.5 or above, or regional earthquakes resulted in population or property impacts. During this period, there have been occasional smaller tremors, none have reached a magnitude that would result in damage or impact to the island's infrastructure (USGS, 2021).

Table 9-3. Earthquake Events in Honolulu (2019 to 2024)

Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
12/03/24	N/A	N/A	N/A	Magnitude 3.5 WNW of Maunaloa – No impacts
09/24/23	N/A	N/A	N/A	Magnitude 3.0 - ESE of East Honolulu – No impacts
5/6/23	N/A	N/A	N/A	Magnitude 3.0 ENE of Waimanalo Beach – No Impacts

Source: (USGS n.d.)

Federal Disaster Declarations

Under the Stafford Act, the President of the United States may issue an Emergency Declaration (EM) or Major Disaster Declaration (DR) for health related events and activate certain federal assistance programs based on factors related to the magnitude of the hazard threat or impacts. No Stafford Act declarations for this hazard type that included the City occurred during this period.

State and Local Emergency Proclamations

State law authorizes the Governor to issue emergency proclamations if an emergency or disaster has occurred, or there is imminent danger or threat of an emergency or disaster in any portion of the state. County Mayors have the authority to issue local emergency proclamations when such conditions exist within any part of their respective counties. No state or local emergency proclamations related to this hazard were issued for the City during this period.

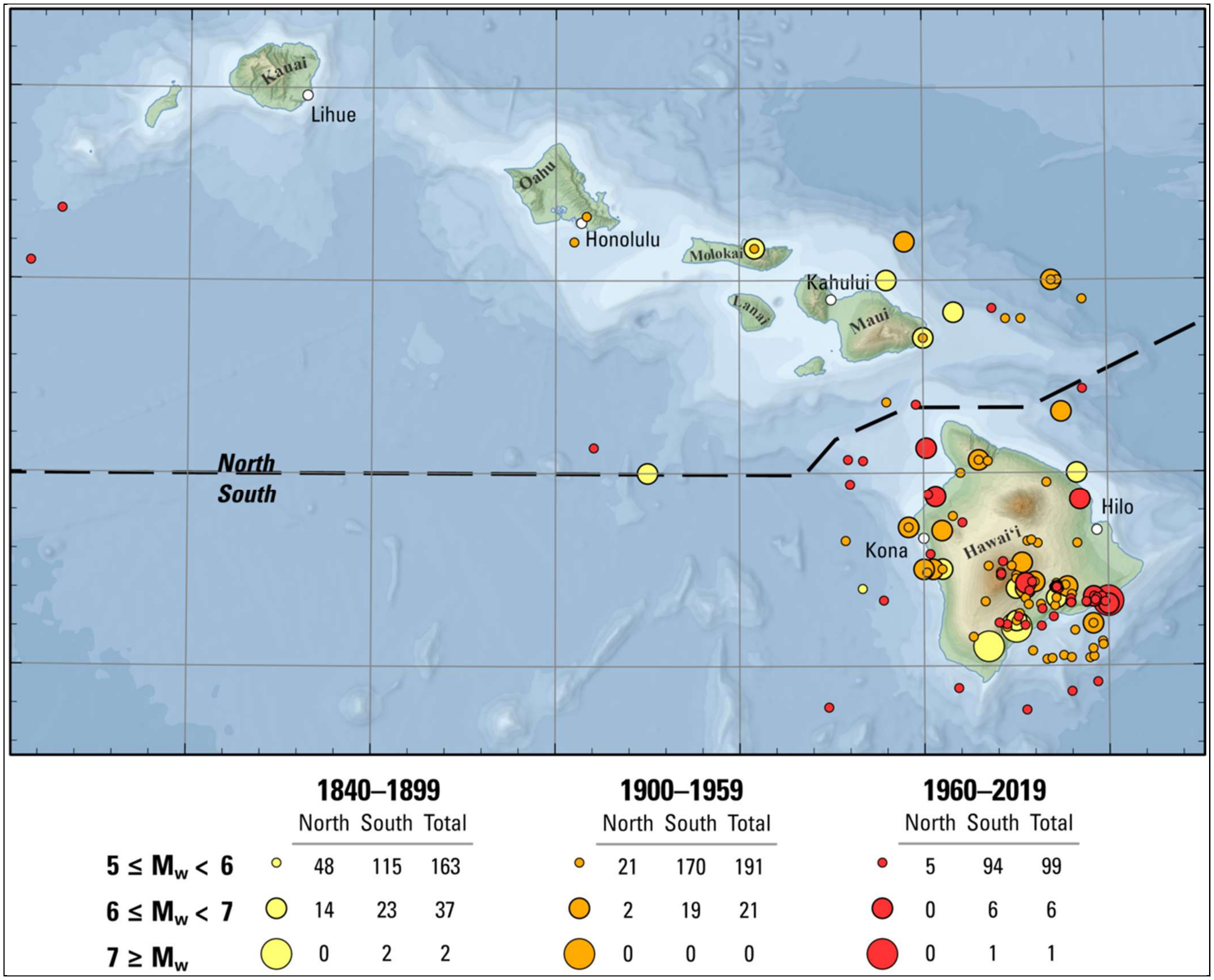
9.1.5 PROBABILITY OF FUTURE OCCURRENCES

While earthquake activity in Hawaiʻi has decreased over the past 60 years, potentially due to reduced volcanic activity at Mauna Loa, the history of frequent earthquakes is a strong indicator of future risk. Table 9-4 summarizes the number and magnitude of earthquakes experienced in the State of Hawaiʻi from 1823 through the present and the average days between earthquakes. Most of these earthquakes occurred on or around the active volcanoes on the Island of Hawaii. Figure 9-5 shows the locations where earthquakes greater than magnitude 5 have occurred since 1840.

Table 9-4. Average Earthquake Incidence in the State of Hawaiʻi since 1823

Magnitude	Average Earthquakes per Year	Average Days Between Earthquakes
3.0 - 3.9	102	3.5
4.0 - 4.9	11	32
5.0 - 5.9	0.7	533 (1.5 years)
6.0 - 6.9	0.1	2,818 (7.7 years)
7+	0.02	20,378 (55.8 years)

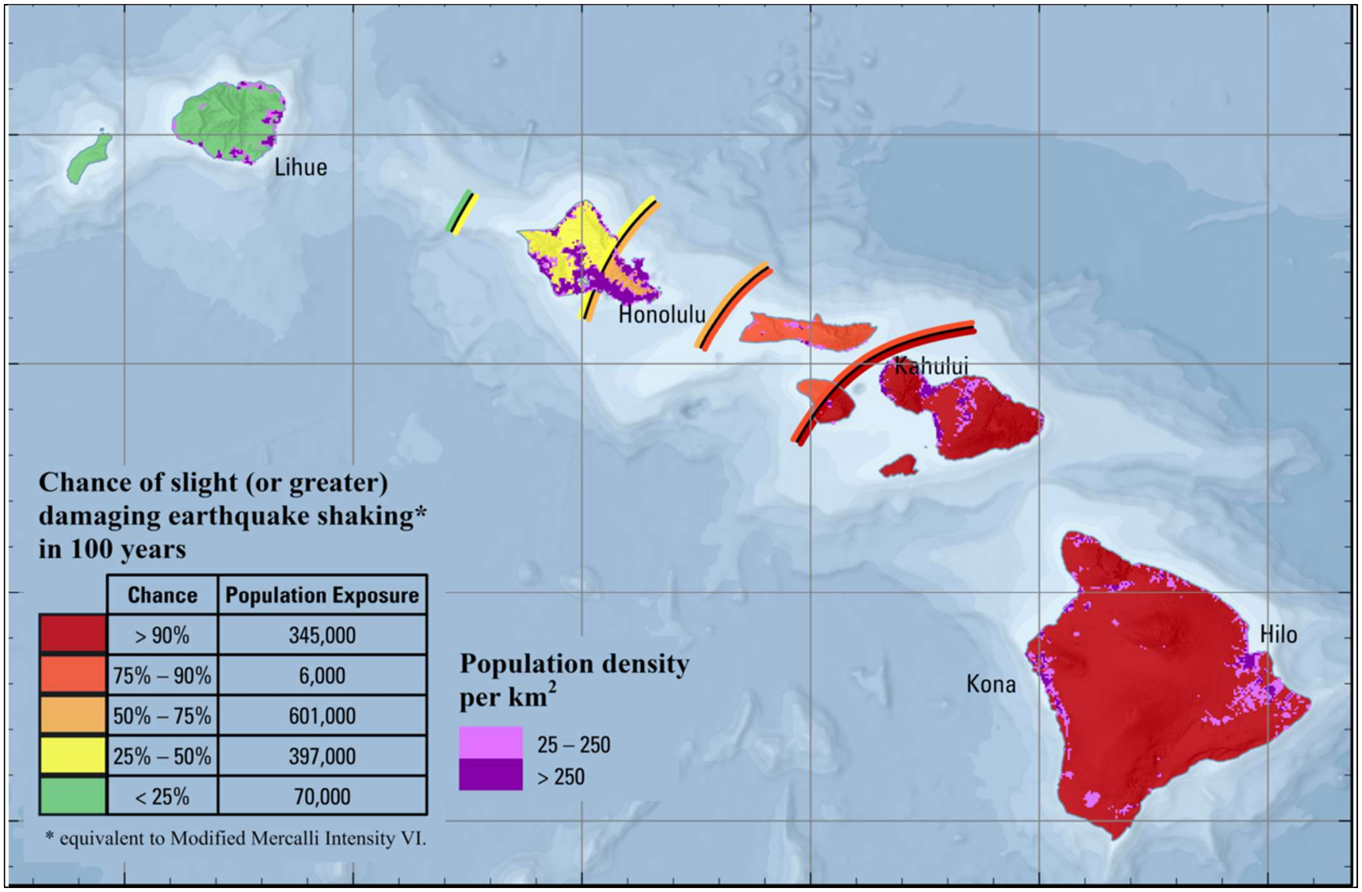
Figure 9-5. Hawai‘i Earthquakes M>5 from the 1840-1899, 1900-1959, and 1960-2019 Catalogs



Source: (USGS 2021)

As shown on Figure 9-6, a ground-shaking model published in Earthquake Spectra indicates a 50 to 75 percent chance of damaging shaking occurring in the southeastern portion of the island near Honolulu over the next 100 years (USGS 2021).

Figure 9-6. Chance of Damaging Earthquake Shaking in Hawai‘i



On an annual basis, the probability of experiencing a damaging earthquake in O‘ahu is about 2.6 percent (see Table 9-5). Based on these records, the probability of occurrence for earthquakes in Honolulu is considered "rare," but the cumulative risk over time underscores the importance of continued preparedness efforts for potential seismic events.

Table 9-5. Probability of Future Earthquake Events in the City

Hazard Type	Number of Occurrences, 1960 – 2024	% Chance of Occurring in Any Given Year
Earthquake	2	2.6%

Source: (FEMA 2024) (USGS n.d.)

Note: The time period presented in this table is the most complete period of record for the various data sources reviewed. The number of occurrences includes magnitude 4.5 and higher earthquakes.

9.2 Vulnerability and Impact Assessment

To understand risk, a community must evaluate what assets are vulnerable to the identified hazard area and the potential impacts on those assets. This section evaluates the potential impact of the earthquake hazard in Honolulu. Potential impacts were estimated using the Hazus model, as described in Section 4.2.9. The analysis assessed the 500-year mean return period (MRP) scenario and the 2,500-year MRP scenario, whose estimated intensities across the City are shown in Figure 9-7 and Figure 9-8.

Figure 9-7. 500-Year MRP Earthquake

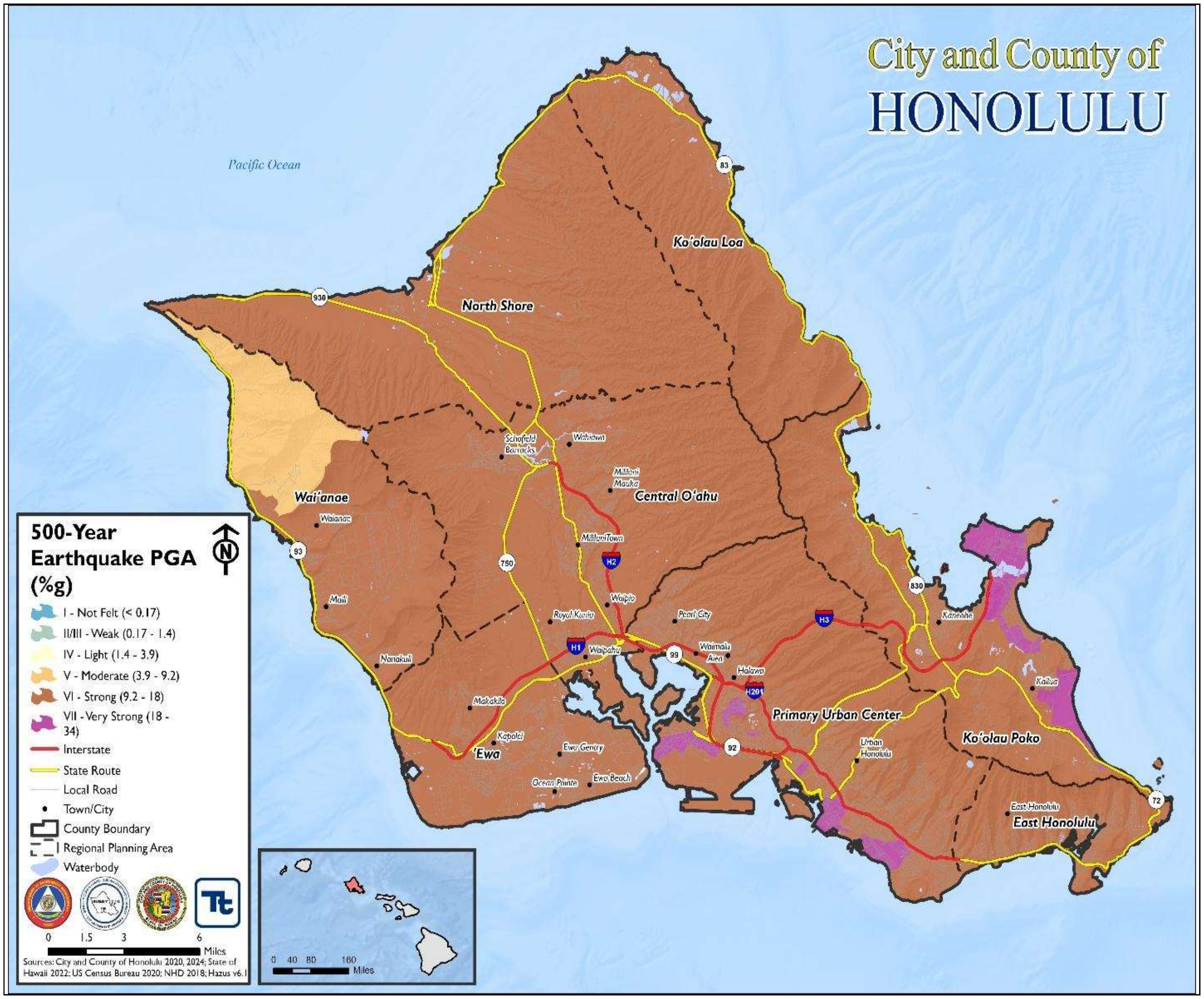
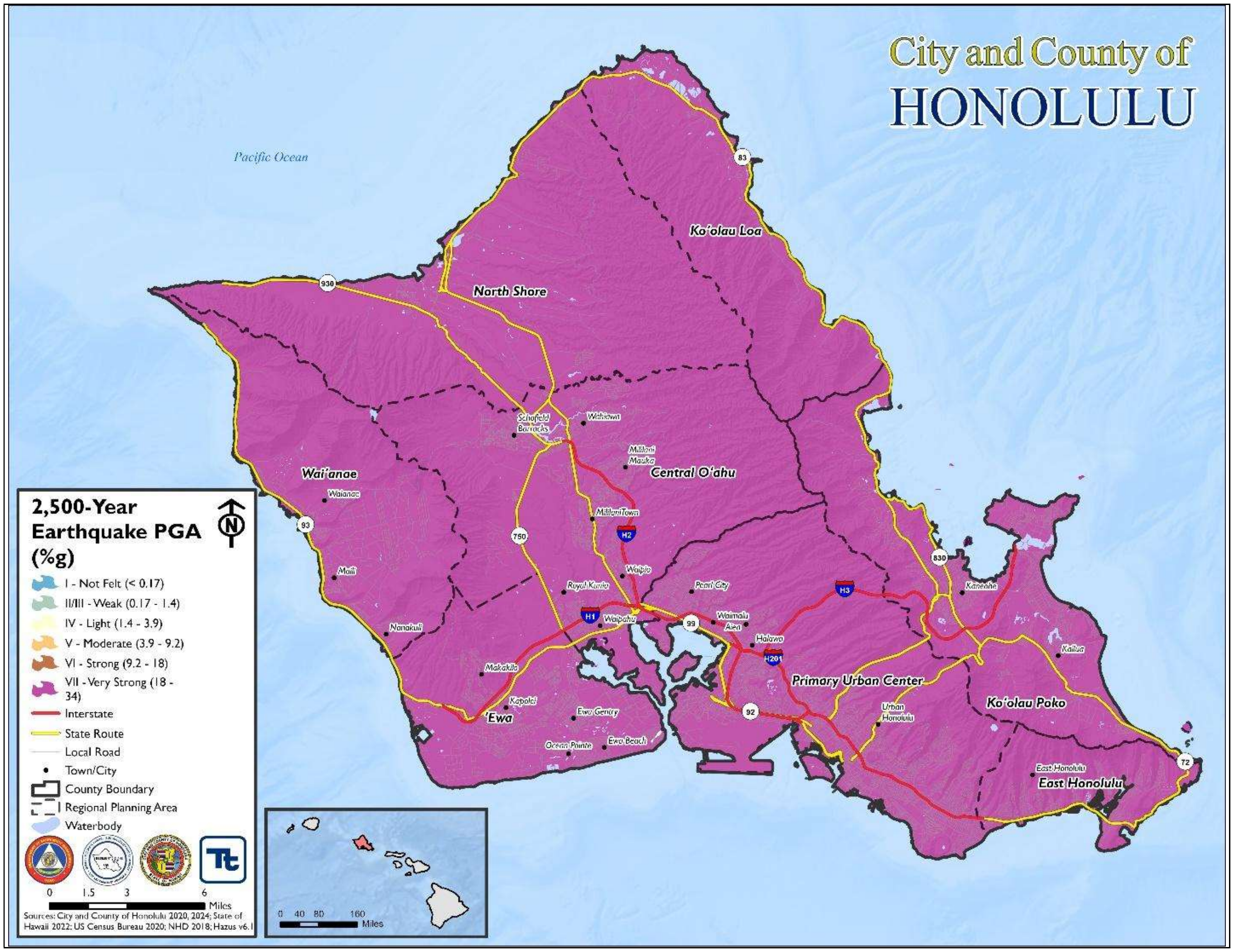


Figure 9-8. 2,500-Year MRP Earthquake



9.2.1 LIFE, HEALTH, AND SAFETY

The City is home to more than 1 million people and they are all at risk from earthquakes. The earthquake intensity experienced will vary, depending on soil type, distance from fault, and magnitude.

Table 9-6 lists the estimated number of people that would be injured or killed by the evaluated earthquake scenarios. The estimates are provided for three times of day representing the periods when different sectors of the community are at their peak. The 2:00 AM estimate is assumed to be the maximum residential occupancy period, the 2:00 PM estimate is assumed to be the maximum educational, commercial, and industrial occupancy period, and 5:00 PM represents peak commute time.

Table 9-6. Injury and Fatality Estimates for the Evaluated Earthquake Scenarios

Level of Severity	500-Year MRP Earthquake Scenario			2,500-Year MRP Earthquake Scenario		
	2:00 AM	2:00 PM	5:00 PM	2:00 AM	2:00 PM	5:00 PM
Injuries Without Hospitalization	334	377	273	2,065	2,548	1,793
Hospitalizations	52	60	44	479	611	435
Fatalities	8	9	7	101	132	93

Source: Hazus v6.1

9.2.2 ECONOMY AND GENERAL BUILDING STOCK

Hazus estimated the potential impact of the earthquake scenarios on the island's building stock. Table 9-7 and Table 9-8 display the building stock losses that could occur during a 500- and 2,500-year MRP earthquake. A 2,500-year MRP earthquake could cause more than $11 billion in damage to the general building stock.

Table 9-7. Estimated Damage to City Building Stock, 500-Year Earthquake

Regional Planning Area	Total Replacement Cost Value (RCV)	Estimated Losses				
		Total Damage	Damage as % of Total RCV	Residential Damage	Commercial Damage	Damage, All Other Occupancies
Central Oʻahu	$31,358,898,963	$262,264,366	0.8%	$178,116,611	$46,465,983	$37,681,771
East Honolulu	$12,765,314,977	$104,098,112	0.8%	$79,091,698	$15,520,899	$9,485,515
ʻEwa	$23,523,097,571	$261,980,868	1.1%	$158,470,628	$50,373,807	$53,136,434
Koʻolau Loa	$3,703,783,129	$15,354,010	0.4%	$9,245,626	$2,079,335	$4,029,049
Koʻolau Poko	$24,614,804,769	$246,256,370	1.0%	$158,145,865	$55,067,262	$33,043,243
North Shore	$3,819,600,126	$19,622,649	0.5%	$12,388,404	$4,630,889	$2,603,355
Primary Urban Center	$137,698,243,063	$1,483,935,237	1.1%	$683,463,387	$558,920,702	$241,551,148
Waiʻanae	$7,730,241,840	$31,400,287	0.4%	$19,593,451	$7,313,059	$4,493,777
City and County of Honolulu (Total)	**$245,213,984,438**	**$2,424,911,899**	**1.0%**	**$1,298,515,670**	**$740,371,937**	**$386,024,293**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

Table 9-8. Estimated Damage to the City Building Stock, 2,500-Year Earthquake

Regional Planning Area	Total Replacement Cost Value (RCV)	Estimated Losses				
		Total Damage	Damage as % of Total RCV	Residential Damage	Commercial Damage	Damage, All Other Occupancies
Central Oʻahu	$31,358,898,963	$1,339,551,101	4.3%	$930,235,961	$222,621,643	$186,693,498
East Honolulu	$12,765,314,977	$506,326,166	4.0%	$390,070,449	$71,535,870	$44,719,847
ʻEwa	$23,523,097,571	$1,238,443,925	5.3%	$764,269,431	$234,325,835	$239,848,660
Koʻolau Loa	$3,703,783,129	$93,549,546	2.5%	$57,332,694	$11,862,611	$24,354,241
Koʻolau Poko	$24,614,804,769	$1,129,701,505	4.6%	$735,772,687	$246,186,941	$147,741,877
North Shore	$3,819,600,126	$112,610,095	2.9%	$73,811,928	$24,715,053	$14,083,114
Primary Urban Center	$137,698,243,063	$6,772,174,476	4.9%	$3,165,450,782	$2,537,730,516	$1,068,993,178
Waiʻanae	$7,730,241,840	$189,908,915	2.5%	$121,222,284	$41,421,434	$27,265,197
City and County of Honolulu (Total)	**$245,213,984,438**	**$11,382,265,728**	**4.6%**	**$6,238,166,214**	**$3,390,399,902**	**$1,753,699,612**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

Another planning consideration for major earthquakes is the amount of debris that could be created and require clean-up by recovery crews. Table 9-9 displays the debris amounts and types that could be created during 500- and 2,500-year MRP earthquakes. A 2,500-year MRP earthquake could generate almost 2 million tons of debris, a serious concern for an island with limited waste disposal resources.

Table 9-9. Debris Generated by Earthquakes in the City

Regional Planning Area	Debris Generated by 500-Year MRP Event		Debris Generated by 2,500-Year MRP Event	
	Brick/Wood (tons)	Concrete/Steel (tons)	Brick/Wood (tons)	Concrete/Steel (tons)
Central Oʻahu	34,234	19,526	149,197	133,424
East Honolulu	10,136	6,839	42,761	43,365
ʻEwa	30,090	19,800	124,853	129,201
Koʻolau Loa	1,479	912	6,919	6,553
Koʻolau Poko	19,642	15,548	82,172	98,550
North Shore	1,734	1,168	8,457	8,499
Primary Urban Center	76,440	128,390	330,580	786,075
Waiʻanae	3,468	2,486	16,536	18,105
City and County of Honolulu (Total)	**177,223**	**194,670**	**761,475**	**1,223,771**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; Hazus v6.1

9.2.3 COMMUNITY LIFELINES AND OTHER CRITICAL FACILITIES

The Hazus analysis estimated potential impact of earthquakes on the island's community lifeline facilities. Table 9-10 and Table 9-11 display the loss of days and damage that could occur to the community lifelines during a 500- and 2,500-year earthquake.

Strong earthquakes have the potential to damage the transportation routes and ship-to-shore cranes in the Honolulu Harbor that are essential to moving cargo around the state. This coastal infrastructure presents a vulnerability for Oʻahu and the entire state. (NOAA 2024).

Table 9-10. Community Lifeline Damage in the City, 500-Year MRP Earthquake

Community Lifeline	Average Percent Probability of Sustaining Damage					Average Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communications	68.1%	17.7%	10.9%	2.8%	0.4%	68.1%	85.7%	96.7%	99.5%
Energy	65.9%	18.7%	11.8%	3.1%	0.5%	65.8%	84.5%	96.4%	99.4%
Food, Hydration, Shelter	62.3%	20.0%	13.3%	3.7%	0.6%	62.3%	82.3%	95.7%	99.3%
Hazardous Materials	65.5%	18.9%	12.0%	3.1%	0.5%	65.4%	84.3%	96.3%	99.4%
Health and Medical	80.8%	16.2%	2.9%	0.1%	<0.1%	80.7%	96.6%	99.9%	99.9%
Safety and Security	72.9%	13.0%	10.9%	3.0%	0.2%	72.8%	85.7%	96.8%	98.7%
Transportation	83.8%	9.2%	5.5%	1.3%	0.2%	83.8%	92.9%	98.4%	99.7%
Water Systems	68.5%	17.7%	10.7%	2.7%	0.4%	68.5%	86.1%	96.9%	99.5%

Source: City and County of Honolulu 2023, 2024; State of Hawaiʻi 2017,2021,2022,2023,2024; US Energy Atlas 2024; Hazus v6.1

Table 9-11. Community Lifeline Damage in the City, 2,500-Year MRP Earthquake

Community Lifeline	Average Percent Probability of Sustaining Damage					Average Percent Functionality			
	None	Slight	Moderate	Extensive	Complete	Day 1	Day 7	Day 30	Day 90
Communications	27.2%	23.5%	28.3%	15.0%	6.1%	27.1%	50.5%	78.9%	93.9%
Energy	23.6%	23.2%	29.6%	16.5%	7.1%	23.5%	46.7%	76.4%	92.9%
Food, Hydration, Shelter	20.8%	22.4%	30.5%	18.0%	8.2%	20.7%	43.1%	73.7%	91.7%
Hazardous Materials	23.2%	23.1%	29.8%	16.7%	7.2%	23.2%	46.2%	76.0%	92.7%
Health and Medical	40.2%	34.8%	22.1%	2.3%	0.5%	40.2%	74.2%	97.1%	98.2%
Safety and Security	33.3%	17.7%	28.3%	17.3%	3.3%	33.2%	50.6%	79.3%	89.9%
Transportation	60.7%	13.7%	15.1%	7.7%	2.9%	61.5%	74.6%	89.4%	97.0%
Water Systems	27.0%	24.1%	28.5%	14.7%	5.7%	26.9%	51.0%	79.6%	94.2%

Source: City and County of Honolulu 2023, 2024; State of Hawai'i 2017,2021,2022,2023,2024; US Energy Atlas 2024; Hazus v6.1

9.2.4 NATURAL, HISTORIC, AND CULTURAL RESOURCES

Natural Resources

Earthquakes can lead to widespread and devastating environmental impacts. During an earthquake, structures storing hazardous materials could rupture and leak into the surrounding area or an adjacent waterway, having a disastrous effect on the environment. Additional environmental impacts may include damage to trees and other vegetation and disruption of natural water courses.

Historic and Cultural Resources

All cultural and historic sites on Oʻahu are at risk from earthquakes. Table 9-12 lists the number of sites on the State and National Registers of Historic Places by regional planning area. The Primary Urban Center contains the highest number of historically significant places on the island.

Table 9-12. Historic Sites in the City

Regional Planning Area	Historic Sites Count
Central Oʻahu	9
East Honolulu	8
ʻEwa	2
Koʻolau Loa	2
Koʻolau Poko	27
North Shore	8
Primary Urban Center	449
Waiʻanae	3
City and County of Honolulu (Total)	**508**

Source: City and County of Honolulu 2024

9.2.5 FUTURE CHANGES THAT MAY AFFECT RISK

Potential or Planned Development

On Oʻahu, the directed growth policy of the City encourages growth to occur beyond the primary urban center (Honolulu 2021). As noted in the IRC map above (Figure 9-3), the eastern tip of the island is at a higher risk of seismic damage than the rest of the island. As noted in Chapter 3, new and potential developments on Oʻahu, particularly on the leeward and central sides of the island, are mainly occurring outside of this hazard area.

Projected Changes in Population

Honolulu's population is expected to moderately increase over the coming decades, as shown in Table 9-13. While population increases are unlikely to have an impact on the incidence of earthquakes, a major earthquake could displace a larger portion of the population.

Table 9-13. City Population Projections

Year	2020	2030	2040	2050
Population	1,012,305	1,033,600	1,054,670	1,060,110

Source: (DBEDT 2023)

Climate Change

Climate change impacts are not projected to change the location, intensity, frequency, or duration of earthquakes. However, 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 affecting rates of erosion, sediment control, and the likelihood of landslides. Climate change may also increase the probability of more frequent, intense rainstorms, which can result in greater erosion, higher sediment transport in rivers and streams, and a higher probability of earthquake-caused landslides (HI-EMA 2022).