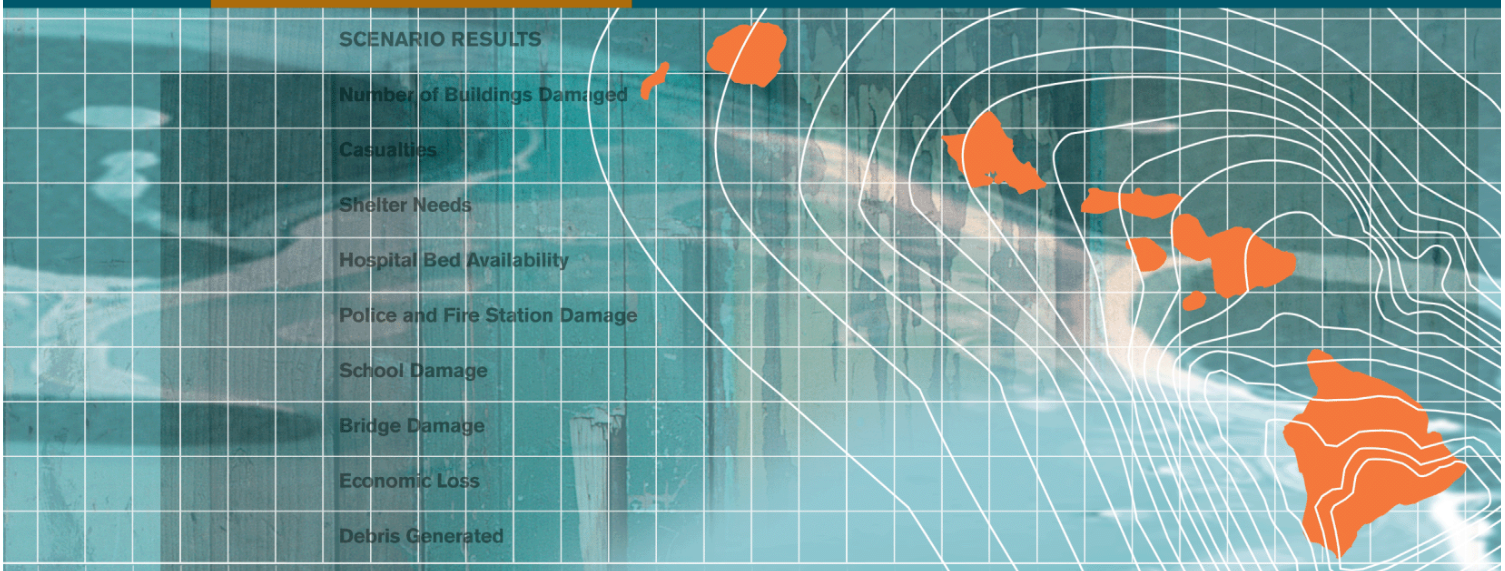
Earthquake Hazards and Estimated Losses



in the COUNTY OF HAWAII

State of Hawaii
Department of Defense

Hawaii State Department of Defense

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Hawaii State Earthquake Advisory Committee

The Hawaii State Earthquake Advisory Committee (HSEAC) was founded in 1990 by Hawaii State Civil Defense (SCD) to bring together seismic expertise from the Hawaii scientific, engineering, and emergency management communities. HSEAC serves as a technical advisory committee to SCD for identifying and implementing seismic hazards mitigation programs. Committee members are annually selected from the fields of seismology, geology, geotechnical engineering, structural engineering, earthquake engineering, planning, probability and risk analysis, and emergency management. HSEAC performed a critical role in adapting and customizing HAZUS to Hawaii.

Contributing Oversight Review by 2005 HSEAC Members

Glenn Bauer	2001-2005
Gary Chock	1990-2005
Stan Goosby	2000-2005
Laura Kong	1994-2005
John Marra	2004-2005
Charles McCreery	2003-2005
Brennon Morioka	2002-2005
Peter Nicholson	1993-2005
Ann Ogata-Deal	2004-2005
Paul Okubo	1990-2005
Ian Robertson	1995-2005
Paul Santo	2001-2005
Afaq Sarwar	2000-2005
Donald Thomas	1998-2005

Contributing Expertise by Former HSEAC Members

David Clague	1992-1996
Carl Johnson	1990-2002
Robert Koyanagi	1990-1994
Glenn Miyasato	1990-2004
John Parazette	1993-2000
Jiro Sumada	1995-1997; 1999-2000
Donald Swanson	1997-2002
Cecily Wolfe	2002-2003

Published February 2005, Honolulu, Hawaii

Estimated Future Annual Earthquake Losses in the County of Hawaii

The Top Ten Counties of Earthquake Risk in the United States

Ranked by estimated future Annual Earthquake Loss Ratio (AELR)
(Annual loss per million dollars of building value)

County	Annual losses per million dollars of building value
San Francisco, CA	**$3,200**
San Jose, CA	**$3,000**
County of Hawaii	**$2,900**
Oakland, CA	**$2,900**
Eureka, CA	**$2,900**
Ventura, CA	**$2,800**
Riverside, CA	**$2,700**
Santa Cruz, CA	**$2,600**
Los Angeles, CA	**$2,300**
Santa Rosa, CA	**$2,300**

"By presenting annualized losses in relation to the replacement value of the study area, the AELR provides a more accurate picture of seismic risk."

(FEMA 366, September, 2000)

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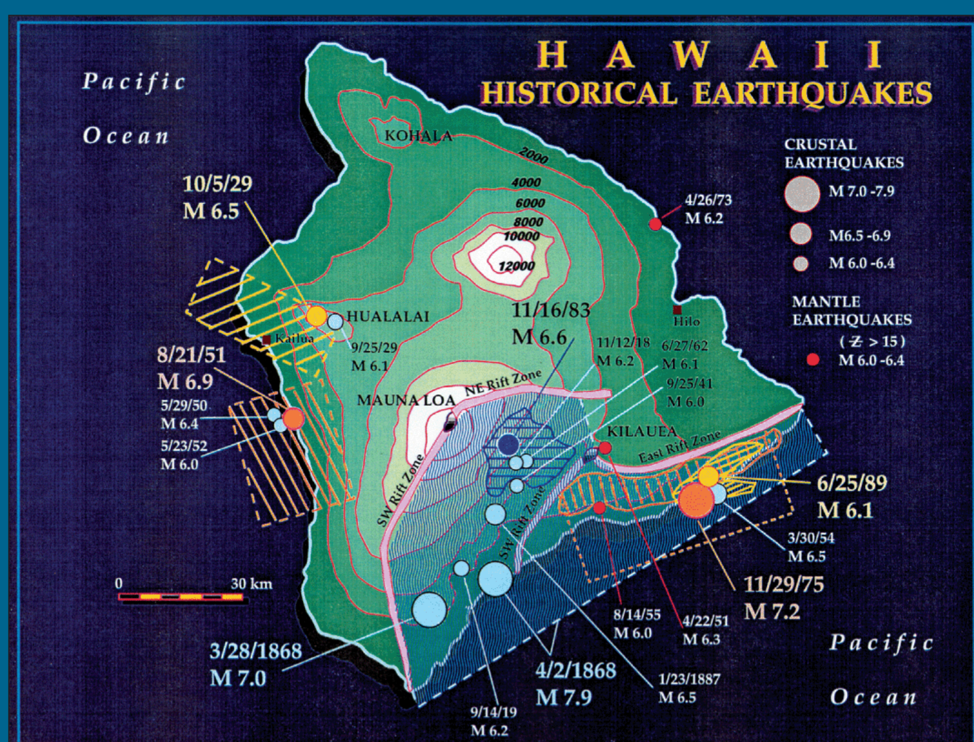
Historical Earthquakes in the County of Hawaii and Island Tectonics

Earthquake occurrence rates in the County of Hawaii are as high as that near the most hazardous fault areas on the mainland U.S. The largest earthquakes occur under the flanks of Kilauea, Mauna Loa and Hualalai. The flanks of these volcanoes respond to the intrusions of magma by storing compressive stresses and releasing it in crustal earthquake ruptures that can result in seaward slips of the flanks across near horizontal fault surfaces about 9 kilometers deep. Deeper mantle earthquakes result from flexure of the underlying lithosphere in long-term geologic response to the developing load of the island mass.

> "The largest Hawaiian earthquake in recorded history occurred in 1868 beneath the Ka'u district ... it had an estimated magnitude of 7.9."

The ground shaking hazard in Hawaii County ranks among the highest in the United States. In 1975, the south flank of Kilauea was the site of the magnitude 7.2 Kalapana earthquake. The Kalapana coast subsided as much as 11 feet, generating a huge tsunami that claimed two lives in Hawaii Volcanoes National Park, destroyed houses in Punaluu, sank fishing boats in Keauhou Bay, and damaged boats and piers in Hilo. The Kealakekua fault zone on Hawaii's Kona coast was the site of an earthquake of about magnitude 6.9 in 1951. The largest Hawaiian earthquake in recorded history occurred in 1868 beneath the Ka'u district on the southeast flank of Mauna Loa; it had an estimated magnitude of 7.9.

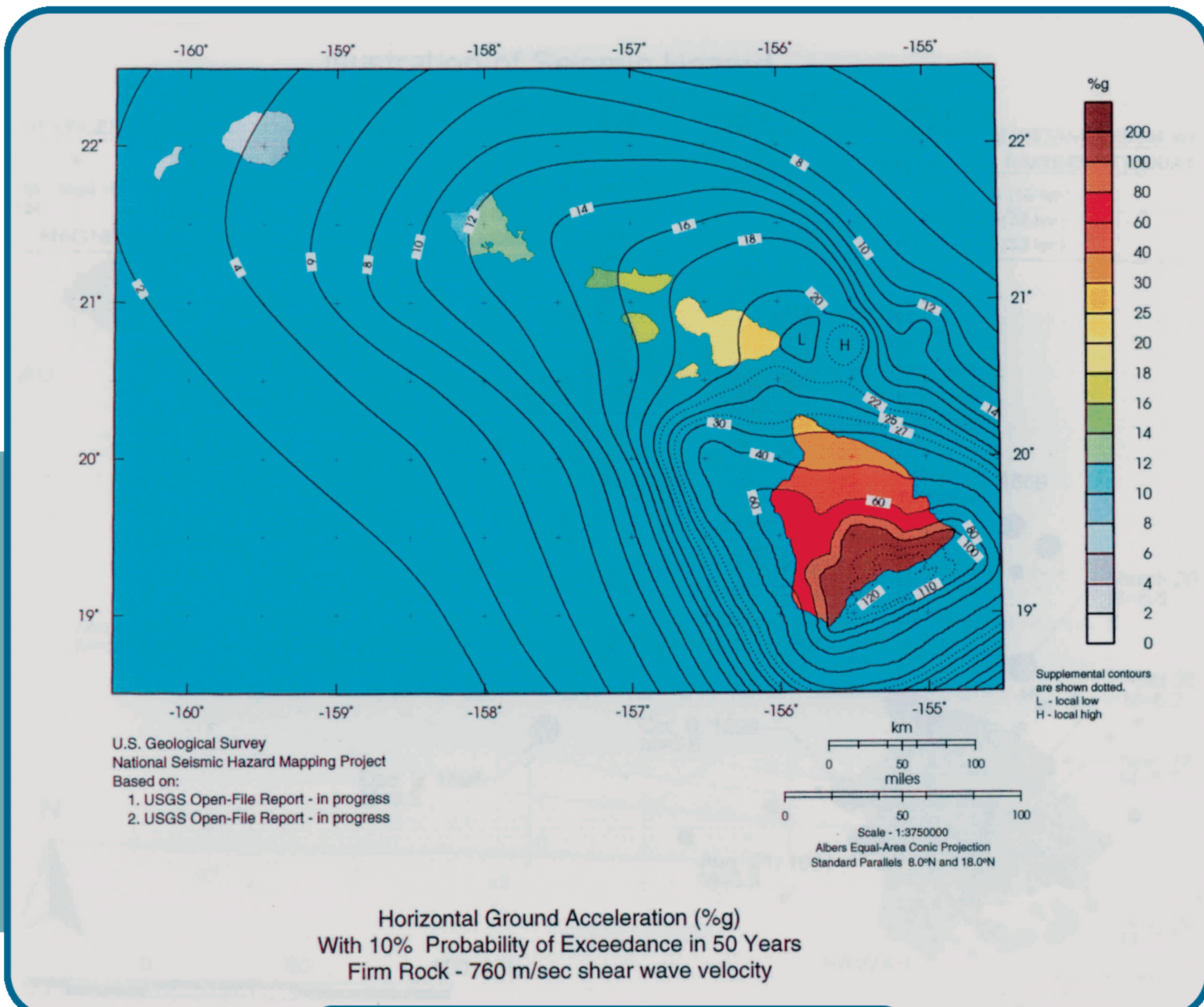


Large Hawaiian earthquakes and rupture zones. Circles are epicenters of the historical Hawaiian earthquakes. Outlined areas are rupture areas. (Klein, et. al., 2001)

Earthquake Ground Motion Hazard in Hawaii County

Earthquakes in Hawaii County

The island of Hawaii has been the site of numerous damaging earthquakes of Magnitude 6 or greater, and there was at least one event of nearly Magnitude 8 in historic time. Accordingly, the ground shaking hazard in Hawaii County ranks among the highest earthquake hazard locations in the United States.



USGS mapping of 500-year Peak Horizontal Acceleration

U.S. Geological Survey (1998)

House destroyed in the June 25, 1989 earthquake in Kalapana.

Spilled merchandise in Hilo supermarket.

Small landslide from spatter and cinder cone partially blocking Chain of Craters Road, Hawaii Volcanoes National Park.

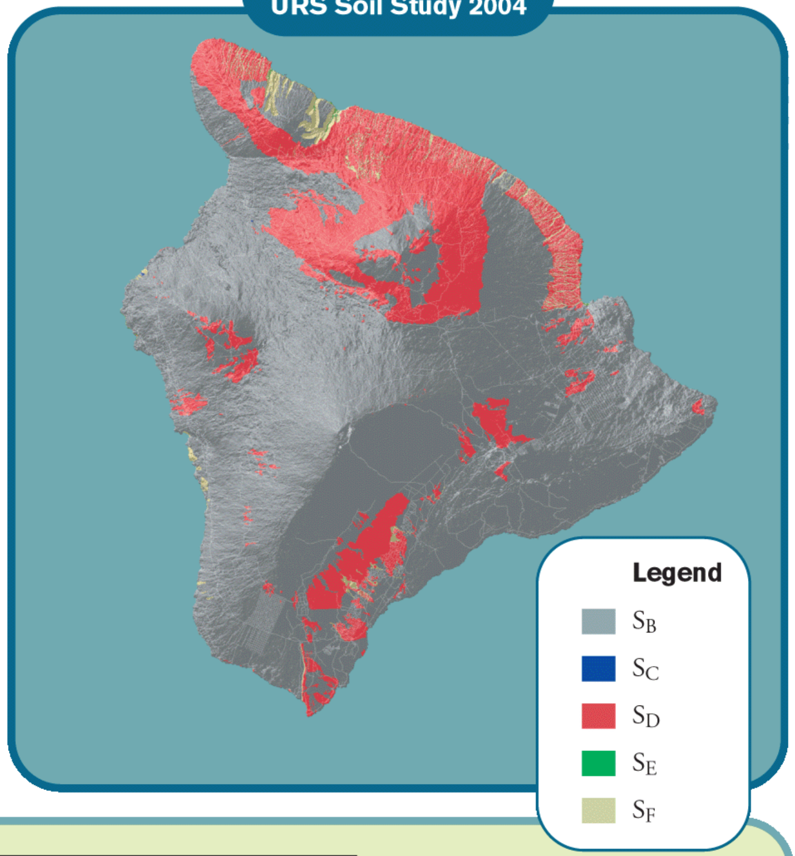
New Estimates of Potential Earthquake Losses Based on Computer Model Simulations

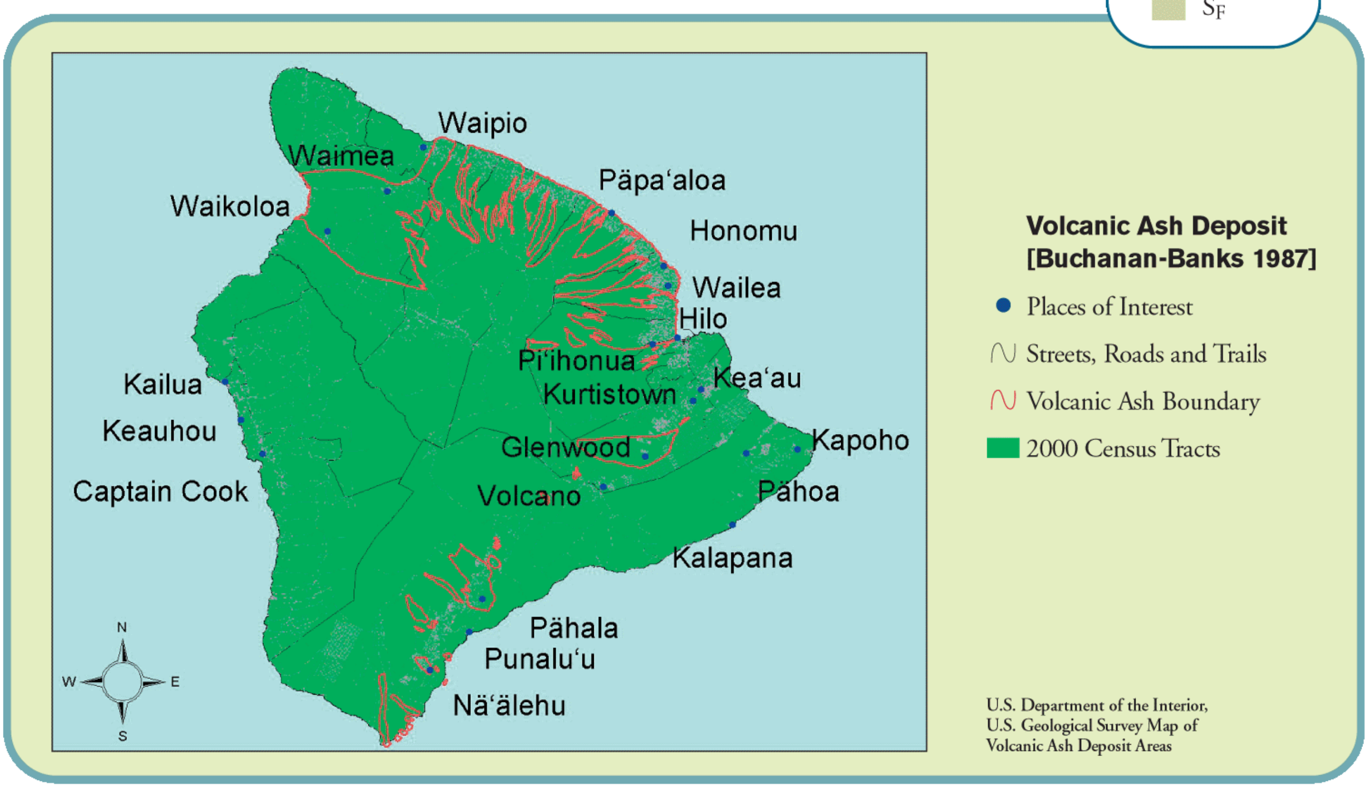
HAZUS

Hazards U.S. (HAZUS) is a computer program that estimates losses from earthquakes. It was developed by the Federal Emergency Management Agency (FEMA) in partnership with the National Institute of Building Sciences (NIBS). Characteristics of a hypothetical or actual earthquake are entered into HAZUS, and HAZUS then *estimates the intensity of ground shaking and calculates losses* based on the ground shaking results. Losses include the number and types of buildings damaged, number of casualties, damage to transportation systems, disruption to electrical and water utilities, damage to infrastructure, and estimated total economic losses.

State Civil Defense has developed customized HAZUS parameters to account for Hawaii seismicity and ground motion studies from past earthquakes, the spatial distribution of various soil types and volcanic ash deposits, Hawaii and Maui building construction types and their number and distribution, and local construction cost data. Ground acceleration during an earthquake can be significantly amplified by softer soil conditions.

Soil Types based on URS Soil Study 2004





Earthquake Loss Modeling Customizations for the County of Hawaii

HAZUS initially produced bias in its results because of the approximations and default parameters selected by FEMA. The accuracy of HAZUS has been increased by customizing these model parameters to be more region-specific. This customization has been done by State Civil Defense for Hawaii and Maui counties. The implementation and testing of these parameters were carried out under the technical supervision of the Hawaii State Earthquake Advisory Committee. In 2003 and 2004, this customized HAZUS model was utilized to produce loss estimates for the possible Maximum Considered Earthquake scenarios given in this publication.

For most regions of the nation, the Maximum Considered Earthquake ground motion is defined with a uniform probability of exceedance of 2 percent in 50 years. In regions of high seismicity such as the Mauna Loa South Flank and Kona, the seismic hazard can be controlled by large-magnitude events expected to occur on a limited number of characteristic fault rupture zones. For these regions, it is considered more appropriate to directly determine Maximum Considered Earthquake ground motions based on the characteristic earthquakes of these defined rupture zones.

Customizations of State Civil Defense's Version of HAZUS Specific to Hawaii County

Ground Motion

By studying data from past earthquakes, State Civil Defense has customized HAZUS to account for Hawaii seismicity and the distribution of ground motion. A ground motion attenuation function producing the closest fit to the ground motion acceleration data from past Hawaii County earthquakes was used (Munson & Thurber, 1997).

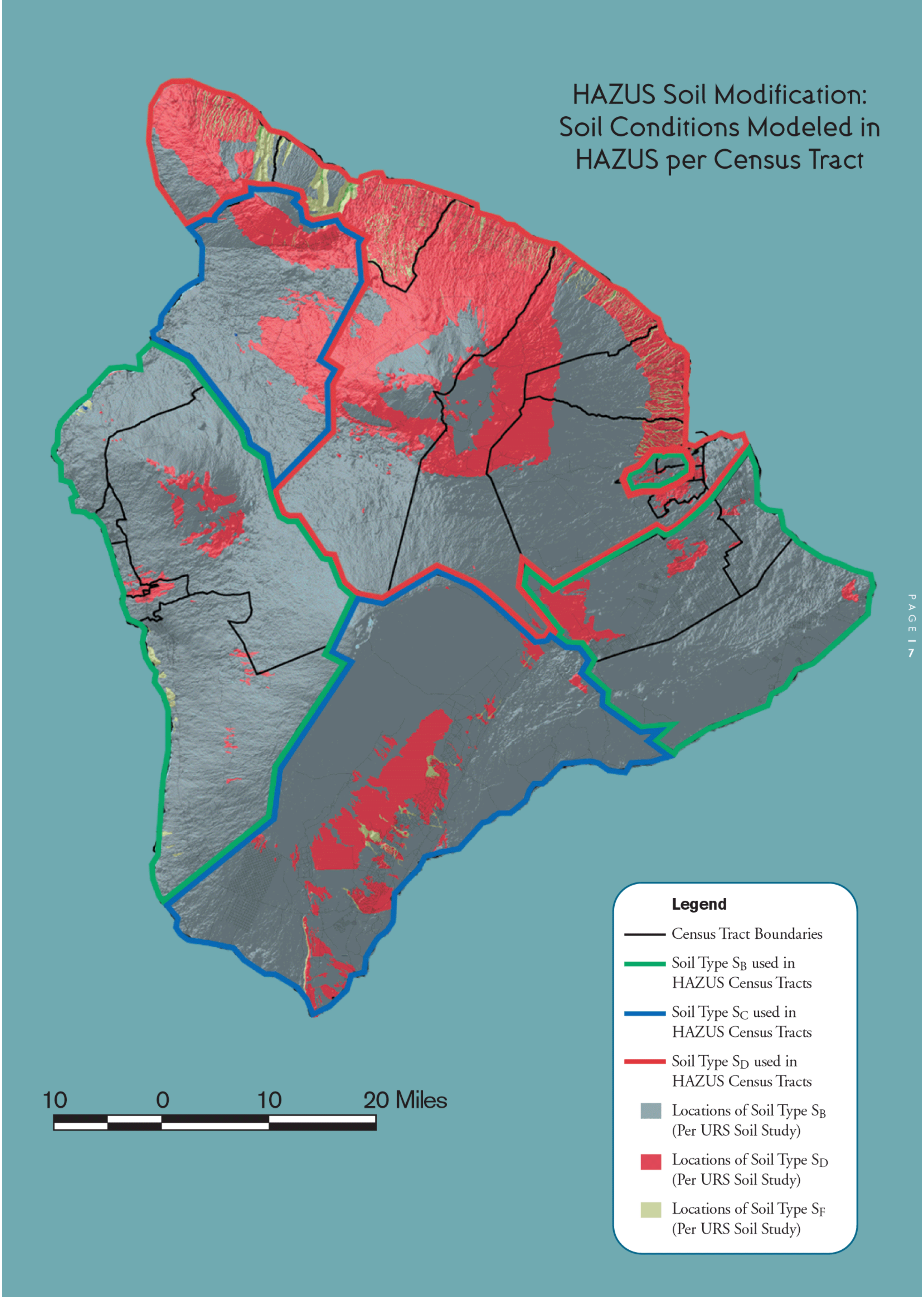
Building Inventory

State Civil Defense has revised the default HAZUS inventory to account for Hawaii building construction types, including single wall construction, the number and locations of specific building types, and Hawaii construction costs.

"State Civil Defense has customized HAZUS to account for Hawaii seismicity and the distribution of ground motion."

Soil

Ground motions during an earthquake can be significantly amplified by softer soil conditions. State Civil Defense has customized the HAZUS soil types to account for general locations of volcanic ash deposits by assigning Soil Type D values to Census Tracts that contained extensive ash deposits in populated areas. In addition, a comprehensive soil profile type survey of the island of Hawaii performed by URS Corporation in 2004 was accommodated in the Soil Type assignments for each Census Tract.


HAZUS Soil Modification: Soil Conditions Modeled in HAZUS per Census Tract
Legend
Census Tract Boundaries
Soil Type S_B used in HAZUS Census Tracts
Soil Type S_C used in HAZUS Census Tracts
Soil Type S_D used in HAZUS Census Tracts
Locations of Soil Type S_B (Per URS Soil Study)
Locations of Soil Type S_D (Per URS Soil Study)
Locations of Soil Type S_F (Per URS Soil Study)
10
0
10
20 Miles

Earthquake Vulnerability in Hawaii County

Hawaii County has a large inventory of bridges, communication sites, hospitals, and fire and police stations that need to remain functional after earthquakes or other catastrophic events. These types of structures are classified as Critical Facilities. Some schools are also designated as emergency shelters. The ground shaking hazard in south Hawaii County ranks among the highest earthquake hazards in the United States, and the Peak Ground Acceleration could be as high as 1g or more.

A "g" is a unit of acceleration equal to the acceleration due to gravity on the Earth's surface. Therefore, being accelerated upward by 1 g from the surface of the earth would result in a feeling of weightlessness. Accelerations due to earthquakes can occur in any direction. It is common to refer to it in percent (%) g. For example, one-half g = 50% g.

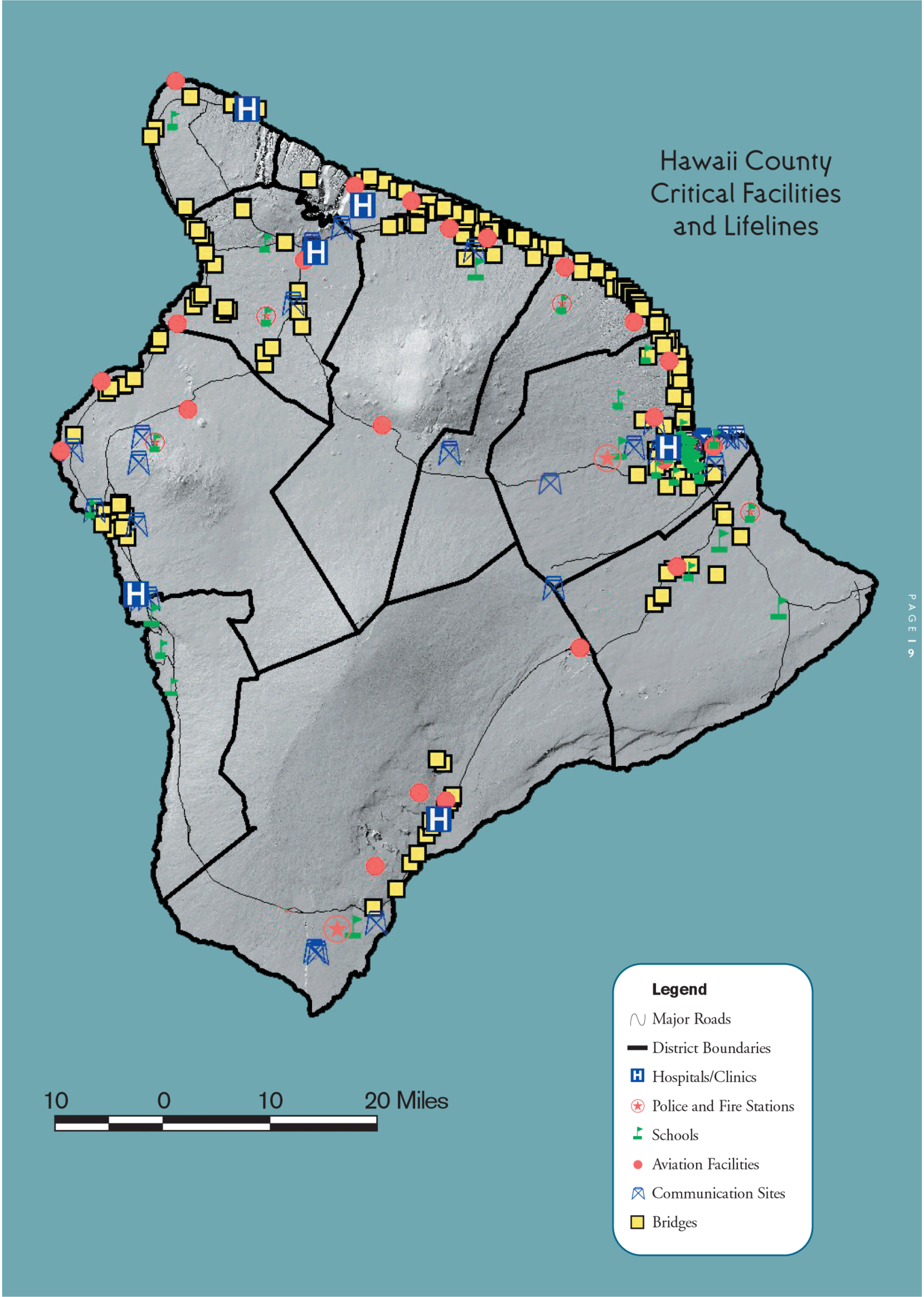
> "The ground shaking hazard in south Hawaii County ranks among the highest earthquake hazards in the United States..."

Damage to roadway due to the Kalapana earthquake M-7.2 1975.

Photo by: R. Holcomb, U.S. Department of the Interior, U.S. Geological Survey

Conversion of MMI to PGA (%g) Values Specific to Hawaii County (Based on Wyss & Koyanagi 1992)

Near-Source Modified Mercalli Intensity (MMI)	I	II-III	IV	V	VI	VII	VIII	IX	X
Maximum Peak Ground Acceleration (PGA) in %g	< 3.2	3.2 - 8.1	8.1 - 13	13 - 20	20 - 32	32 - 51	51 - 80	80 - 128	> 128
Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	None	None	None	Very Light	Light	Moderate	Moderate/ Heavy	Heavy	Very Heavy
Magnitude	–	–	–	< 5.5	5.5	6.0	6.5	7.0	7.5



Hawaii County
Critical Facilities
and Lifelines
Legend
Major Roads
District Boundaries
Hospitals/Clinics
Police and Fire Stations
Schools
Aviation Facilities
Communication Sites
Bridges
10
0
10
20 Miles

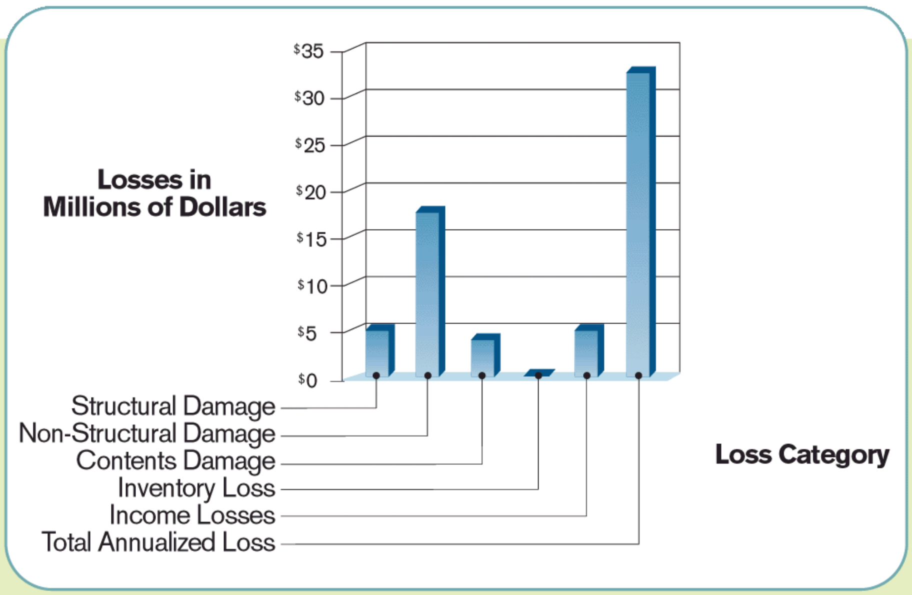
Expected Future Average Annualized Losses

AAL is Instrumental for Decision Making in Hazard Mitigation Planning

Average Annualized Loss (AAL) is an objective measure of expected future losses averaged on an annual basis. It is an unbiased economic measure of risk, and so AAL is instrumental for decision making in natural hazard mitigation planning. The Average Annualized Losses are developed by factoring in the estimated losses (L) caused by earthquakes by their probabilities of occurrence (P).

$$AAL = \sum_{i=1}^{n} L_i \times P_i$$

AAL considers all possible earthquakes throughout the County of Hawaii and their probabilities, and the resulting damage to buildings and infrastructure and business interruption losses.



HAZUS Estimate of Future Average Annualized Earthquake Losses for the County of Hawaii

Severity Ranking of County of Hawaii Greatest Hazards based on the Average Annualized Loss economic risk analysis

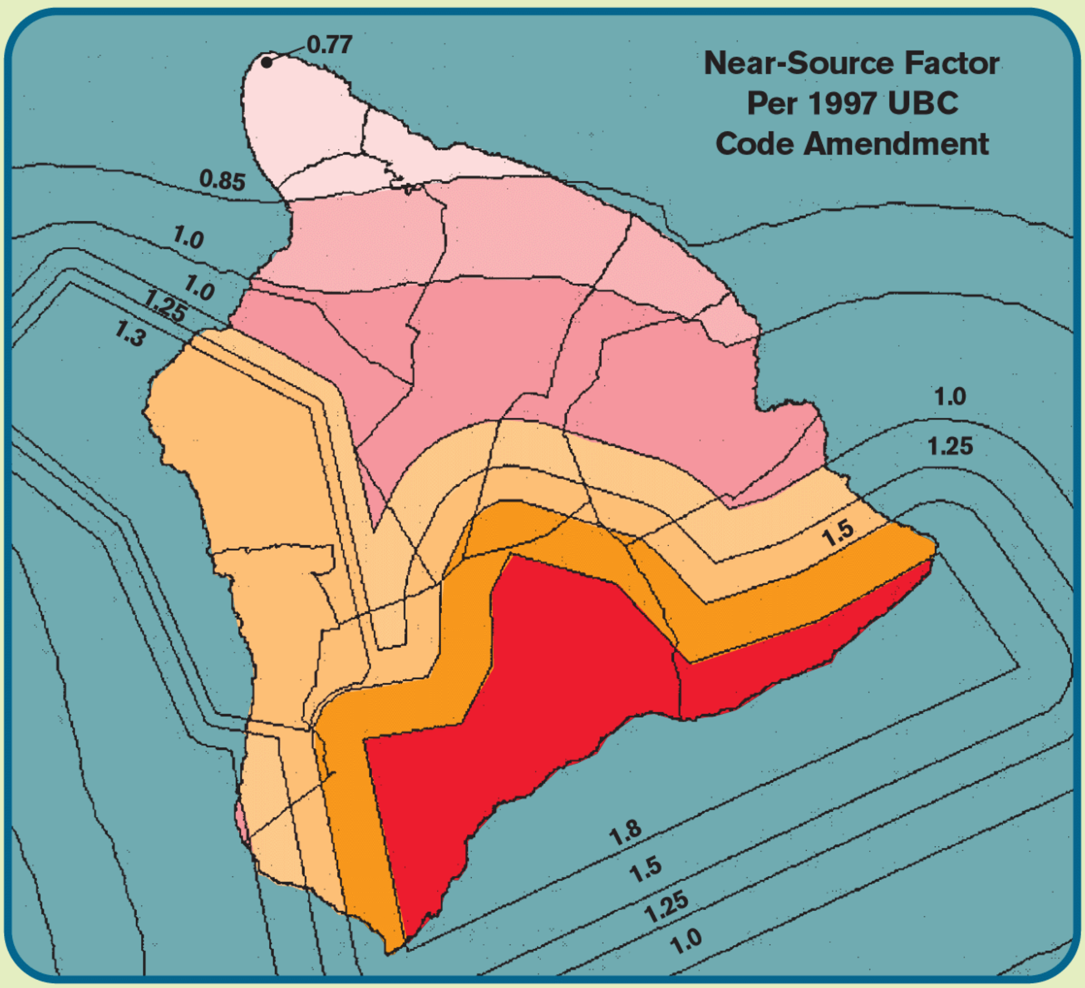
Earthquakes	**$32 Million / Year**
Hurricanes	$20 Million / Year
Lava Inundation	$9 Million / Year

Other severe hazards include frequent flooding and tsunamis resulting from local and distant earthquakes.

Designing to the Latest Code Mitigates Against Excessive Losses and Protects Public Safety

The most current seismic design provisions are contained in the International Building Code. These provisions incorporate a vastly improved seismic hazard mapping of Hawaii developed by the U.S. Geological Survey (USGS) and the Hawaii State Earthquake Advisory Committee. Hawaii State Civil Defense recommends that all counties adopt the seismic provisions of the International Building Code.

The County of Hawaii is considering adoption of near-source factor maps as an amendment to the 1997 Uniform Building Code. The maps developed by HSEAC approximate the intent of the International Building Code seismic load requirements.



The figure above indicates the short period spectral acceleration (in % of gravity) expected at a probability level consistent with the 1997 Uniform Building Code.

Definitions and Glossary

HAZUS
HAZUS is a software program that is used to estimate losses from earthquakes. Once the characteristics of an earthquake scenario are defined, HAZUS estimates the intensity of ground shaking, the number and types of buildings damaged, damage to infrastructure facilities, number of casualties, and the estimated total economic loss.

HAZUS 99 as adapted for use by Hawaii State Civil Defense
Through a series of studies beginning in 2000, the HAZUS 99 software Hawaii database was customized and validated to incorporate Hawaii and Maui County-specific building inventories, code adoption and enforcement policy histories of each county, geospatial and soil type information GIS layers, Hawaii-specific seismological and attenuation parameters, building damage functions including single wall construction, and local construction cost data parameters. The implementation and testing of these parameters was carried out under the technical supervision of the Hawaii State Earthquake Advisory Committee. Sensitivity and validation analyses were performed utilizing historical earthquake events of various magnitudes and seismic source regions, in order to compare results with recorded data and historical accounts. In 2003 and 2004, this customized HAZUS model was utilized to produce loss estimates for possible maximum credible earthquake scenarios. In 2004-2005, further studies were conducted to quantify loss reductions and the mitigation effectiveness of seismic retrofit, code adoption and enforcement policies, and to support the development of an electronic Earthquake Atlas providing loss estimates of other possible event scenarios.

Attenuation
The decrease in the amplitude of ground shaking with distance from the earthquake source.

Attenuation Relation
A mathematical expression used to quantify the estimated attenuation in ground shaking (peak ground acceleration or spectral acceleration) with distance from the earthquake source. The rate of decay can depend on the type of fault motion, the soil types existing between the source and where the effects are measured, the earthquake's depth and magnitude, and the path of the seismic waves.

Building Code
The building code sets minimum criteria for the design and construction of buildings. Buildings designed and built to modern U.S. codes, such as the 1997 Uniform Building Code and 2003 International Building Code, are anticipated to experience significant damage and extensive nonstructural damage during the severe ground shaking of a major earthquake that could pose some risk of casualties, but are not anticipated to collapse.

Crust
The outermost layer of the earth, ranging from about 10 to 65 kilometers in thickness worldwide.

Earthquake
The release of stored energy caused by sudden fracture and movement across a rupture zone. The energy released produces vibratory seismic waves that travel outward in all directions from the rupture.

Earthquake (Seismic) Hazard
The effects associated with an earthquake that can cause damage and loss. Earthquake hazards or seismic hazards include ground shaking, surface displacement, deformation, or ground faulting, landslides, lateral spreading, liquefaction, and tsunamis.

Earthquake Vulnerability
The loss or damage a constructed facility is likely to experience when it is subjected to seismic hazards of a specified intensity, such as ground shaking.

Epicenter
The epicenter is the point on the earth's surface vertically above the hypocenter (or focus) point in the crust where a seismic rupture begins.

Essential Facilities
Essential Facilities are those facilities providing services to the community that should be functional after a major earthquake. Essential facilities include hospitals, fire stations, police stations, emergency operations centers, and schools. (Note: Essential Facilities as utilized in HAZUS do not necessarily include all those that a community may consider to be Critical Facilities from the standpoint of Homeland Security, Continuity of Operations, and Continuity of Government.)

Focal Depth
The depth of an earthquake's hypocenter.

G
G is the force of gravitational acceleration. The forces caused by earthquake shaking can be measured as a percentage of the force of gravity, or percent g.

Lithosphere
The outer part of the Earth, including the crust and the uppermost mantle.

Magnitude
A quantitative measurement of the relative size of an earthquake. There are a number of different magnitude scales besides Richter's original magnitude scale. The idea of a logarithmic earthquake magnitude scale was first developed by Charles Richter in the 1930's for measuring the size of earthquakes occurring in southern California using relatively high-frequency data measured by nearby seismograph stations. This magnitude scale is referred to as ML, with the L standing for local, eventually become known as the Richter magnitude. The concept incorporated the distance of the seismograph from the epicenter so that, theoretically, the magnitude calculated from any seismograph station would be the same. As more seismograph stations were installed around the world, it became apparent that the method developed by Richter was strictly valid only for certain frequency and distance ranges. In order to take advantage of the growing number of globally distributed seismograph stations, new magnitude scales that are an extension of Richter's original idea were developed. These include body-wave magnitude, Mb, surface-wave magnitude, Ms, and moment magnitude, Mw. Each is valid for a particular frequency range and type of seismic signal.

Based on a logarithmic scale, an increase of one unit of magnitude corresponds to a ten times greater ground motion amplitude and approximately a 30-fold increase in the energy released.

Moment Magnitude
Because of the limitations of three of the magnitude scales, ML, Mb, and Ms, a new, more uniformly applicable extension of the magnitude scale, known as moment magnitude, or Mw, was developed. In particular, for very large earthquakes moment magnitude gives the most reliable estimate of earthquake size. New techniques that take advantage of modern telecommunications have recently been implemented, allowing reporting agencies to obtain rapid estimates of moment magnitude for significant earthquakes.

Since January 2002, the U.S. Geological Survey has been reporting moment magnitudes in reference to the size of earthquakes. The moment magnitude scale was developed to yield much the same results as the earlier magnitude scales such as ML (local magnitude), Ms(surface-wave magnitude), and Mb (body-wave magnitude). The two main features of the moment magnitude scale that make it superior to the earlier ones are: (1) moment magnitude measures a physical property of the earthquake source, and (2) moment magnitude accurately measures the size of large earthquakes relative to small earthquakes. In most cases, moment magnitude is measurable nearly immediately, thanks to the advent of modern seismometers, digital recording, and real-time communication links. For all future earthquakes, the USGS will report, if available and as soon as possible, moment magnitude as the earthquake magnitude.

Mantle

The rock layer in the Earth's interior between the crust and the metallic outer core that is about 2,900 kilometers thick.

Modified Mercalli Intensity Scale

The effect of an earthquake on the Earth's surface is called the intensity. Although numerous intensity scales have been developed over the last several hundred years to evaluate the effects of earthquakes, the one currently used in the United States is the Modified Mercalli Intensity (MMI) Scale. It was developed in 1931 by the American seismologists Harry Wood and Frank Neumann. It uses a qualitative ordinal intensity scale consisting of a categorized series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and finally – total destruction. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It does not have a mathematical basis; instead it is a ranking based on observed effects. The MMI value assigned to a specific site after an earthquake has a more meaningful measure of severity to the non-scientist than the magnitude because intensity refers to the effects actually experienced at that place.

The maximum observed intensity generally occurs near the epicenter. The lower numbers of the intensity scale generally deal with the manner in which the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above. The following is a description of the 12 levels of Modified Mercalli Intensity (USGS Hawaiian Volcano Observatory, http://hvo.wr.usgs.gov/earthquakes/felt/mercalli.html):

- I. Not felt. Marginal and long-period effects of large earthquakes.
- II. Felt by persons at rest, on upper floors, or favorably placed.
- III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
- IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frames creak.
- V. Felt outdoors; direction estimated. Sleepers awakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
- VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken visibly, or heard to rustle.
- VII. Difficult to stand. Noticed by drivers. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, also unbraced parapets and architectural ornaments. Some cracks in masonry C. Waves on ponds, water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
- VIII. Steering of cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
- IX. General panic. Masonry D destroyed; masonry C heavily damage, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas, sand and mud ejected, earthquake fountains, sand craters.
- X. Most masonry and frame structures destroyed with their foundations. Some well- built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
- XI. Rails bent greatly. Underground pipelines completely out of service.
- XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Munson & Thurber – Hawaii

Mathematical expression of attenuation published in 1997 derived from earthquake ground acceleration data in Hawaii to describe the expected variation in ground shaking (peak ground acceleration, or PGA) with earthquake magnitude, site soil type, and distance from the earthquake source.

Peak Ground Acceleration

Acceleration is the rate of change in velocity of the ground shaking, just as it is the rate of change in the speed of your car when you step on the accelerator or put on the brakes. The peak ground acceleration (PGA) is the largest acceleration recorded by a particular station during an earthquake.

Velocity is the measurement of the speed of the ground motion. Displacement is the measurement of the change from the initial position of the ground during an earthquake shaking. All three of the values can be measured continuously during an earthquake.

Rupture Length

The length of rupture along a fault segment or across a defined principal horizontal axis of a rupture zone.

Rupture Orientation

The angular orientation of the earthquake scenario ruptured segment when projected onto the ground surface, measured clockwise in degrees bearing from north.

Rupture Zone

The area of the Earth through which faulting occurred during an earthquake.

Seismic Risk

The probability of a certain level of loss or damage expected over a defined period of time. Equivalently, it is sometimes measured by an Average Annualized Loss (AAL), which is the expected future losses averaged on an annual basis The AAL is calculated by factoring in the estimated losses caused by earthquakes by their probabilities of occurrence.

Seismicity

The geographic and historical distribution of earthquakes and their magnitudes.

Seismograph

An instrument used to detect and record earthquake ground motion.

Soil Profile

The vertical arrangement and characteristics (such as strength and stiffness) of layers of soil down to the bedrock or down to some defined depth.

Soil Type

Soil Type S_B is defined as rock with a shear wave of velocity, 2,500 to 5,000 (feet/second) per UBC 97.

Soil Type S_C is defined as very dense soil and soft rock with a shear wave of velocity, 1,200 to 2,500 (feet/second) per UBC 97.

Soil Type S_D is defined as stiff soil profile with shear wave of velocity, 600 to 1,200 (feet/second) per UBC 97.

Spectral Acceleration

PGA (peak ground acceleration) is what is experienced by a particle on the ground. SA (spectral acceleration) is approximately what is experienced by a building, as calculated for a representative system comprised of a mass on a vertical rod having the same natural period of vibration as the building.

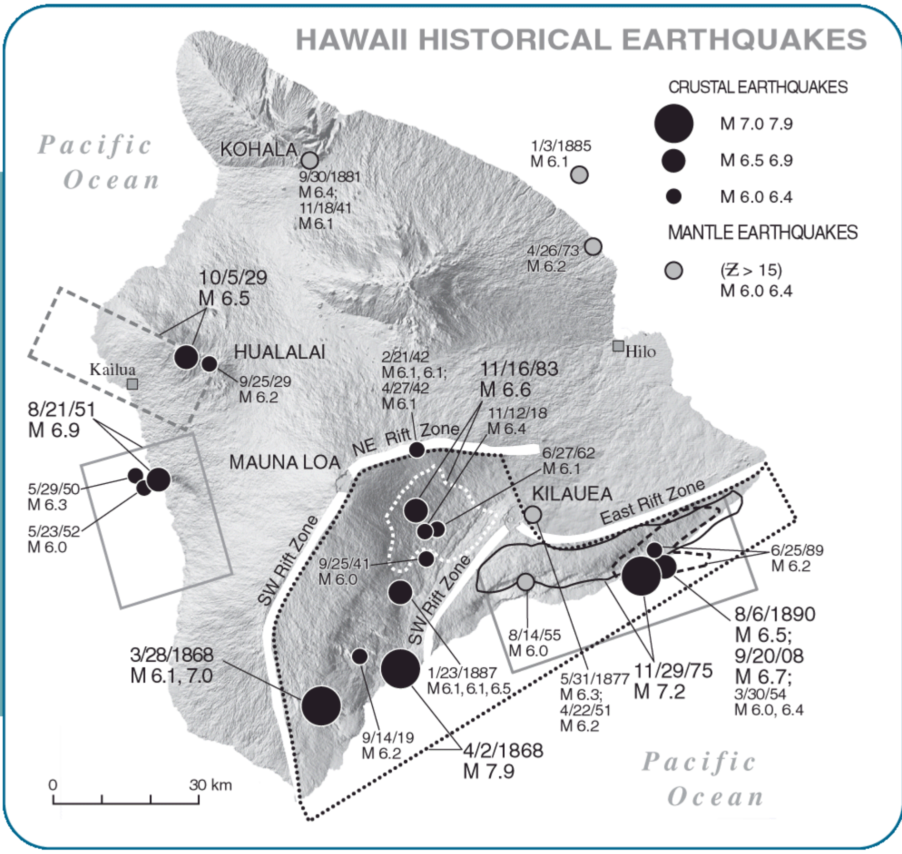
Maximum Considered South Flank Earthquake (Magnitude M_W = 8)

HAZUS Input and Peak Ground Accelerations

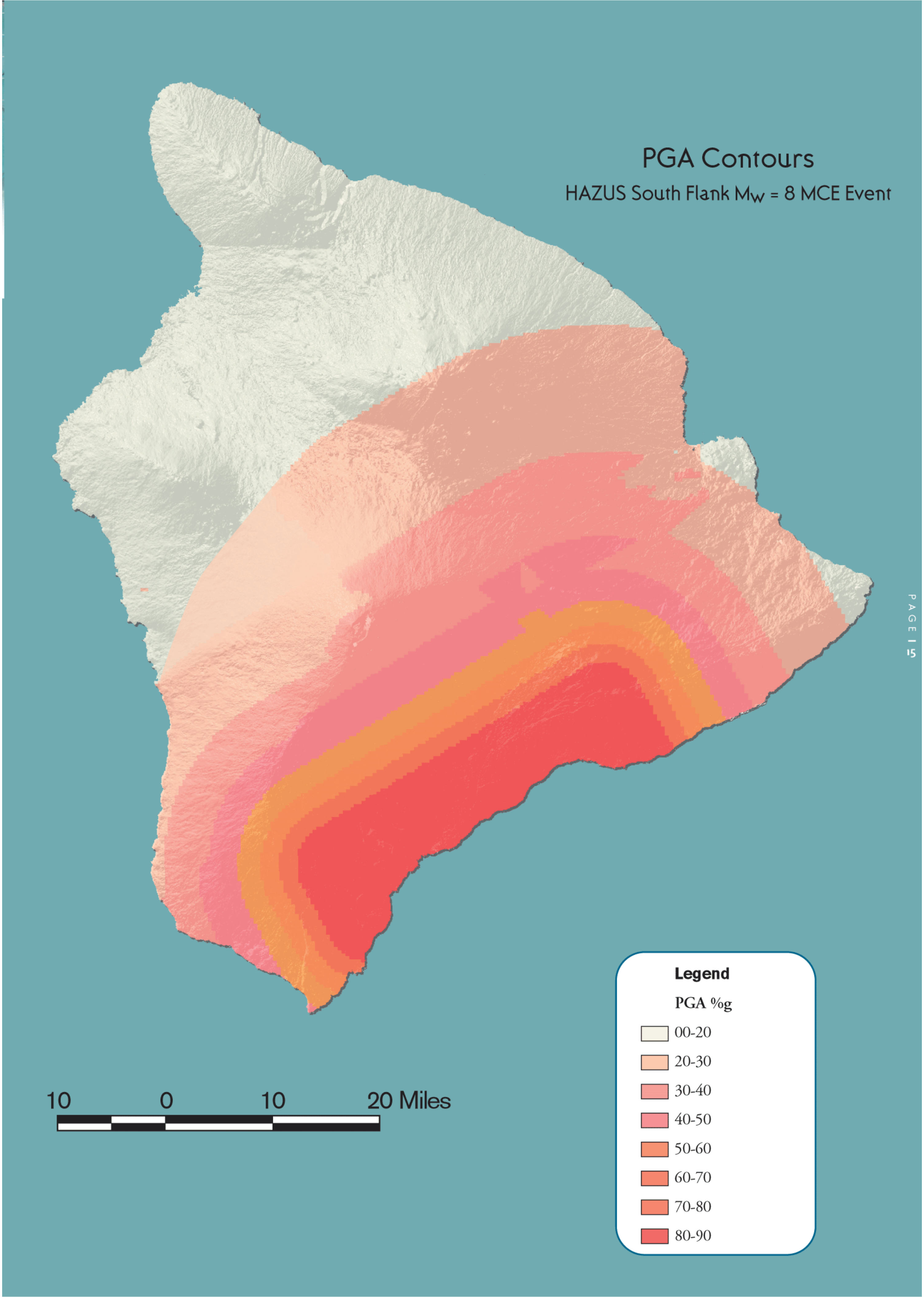
HAZUS South Flank Event PGA

The Peak Ground Acceleration (PGA) contours, from the South Flank Maximum Considered Event (MCE), are consistent with the horizontal fault location of the south flank and the behavior of the flank to slide away (seaward) from the rift zone after a large magnitude event.

HAZUS South Flank Event Input	
Magnitude	8.0
Latitude	19.2
Longitude	-155.4
Rupture (subsurface) Length	50 km
Depth	9 km
Orientation	60 Degrees
Attenuation Function	Munson & Thurber



Volcanic Rift Zones and South Flank Earthquake Rupture Zones (Klein, et. al., 2001)



PGA Contours
HAZUS South Flank Mw = 8 MCE Event
Legend
PGA %g
00-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
10 0 10 20 Miles

HAZUS Results from a South Flank Magnitude 8 Earthquake Event

INVENTORY AT RISK			
		Building Exposure	
Number of Buildings	48,000	Residential	**$10 BILLION**
Population	120,000	Total	**$11 BILLION**

SCENARIO RESULTS

Number of Buildings Damaged

Damage Level	(All Types)
Complete (more than 50% damage)	**1,900-2,600**
Extensive (10% - 50% damage)	**3,700-4,100**
Moderate (2% - 10% damage)	**6,800-6,900**
Slight (less than 2% damage)	**10,300-10,500**

Casualties

Fatalities	**41-56**
Life-Threatening Injuries	**24-34**

Shelter Needs

Displaced Households	**1,500-4,200**
People Needing Short Term Shelter	**1,200-3,300**

Hospital Bed Availability

Beds available after 1 day	**95-125 out of 496 total**
Beds available after 7 days	**133-169 out of 496 total**
Beds available after 30 days	**225-265 out of 496 total**

Police and Fire Station Damage

At Least Moderately Damaged	**5-7 out of 13 total**
Not Functional after 1 day	**6-8 out of 13 total**

School Damage

At Least Moderately Damaged	**51-60 out of 93 total**

Bridge Damage

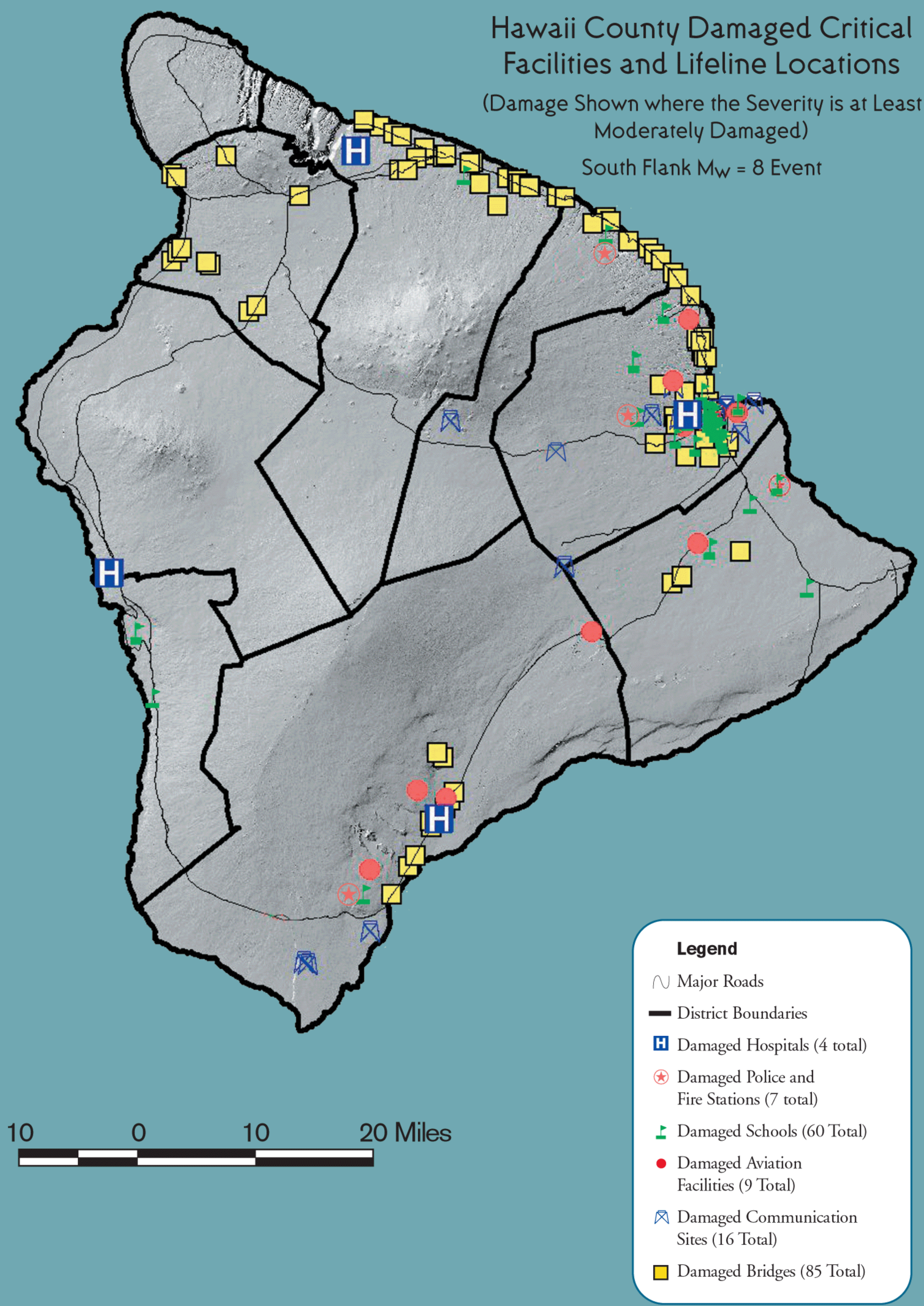
At Least Moderately Damaged	**67-85 out of 241 total**
Not Functional after 7 days	**41-60 out of 241 total**

Economic Loss

Property Damage Loss	**$0.80 - $1.0 Billion**
Business Income Loss	**$0.20- $0.23 Billion**
Total	**$1.0 - $1.2 Billion**

Debris Generated

Debris	**0.28 -0.79 Million Tons**
	11,000-31,000 Truckloads



Hawaii County Damaged Critical Facilities and Lifeline Locations
(Damage Shown where the Severity is at Least Moderately Damaged)
South Flank M_W = 8 Event
10
0
10
20 Miles
Legend
Major Roads
District Boundaries
Damaged Hospitals (4 total)
Damaged Police and Fire Stations (7 total)
Damaged Schools (60 Total)
Damaged Aviation Facilities (9 Total)
Damaged Communication Sites (16 Total)
Damaged Bridges (85 Total)

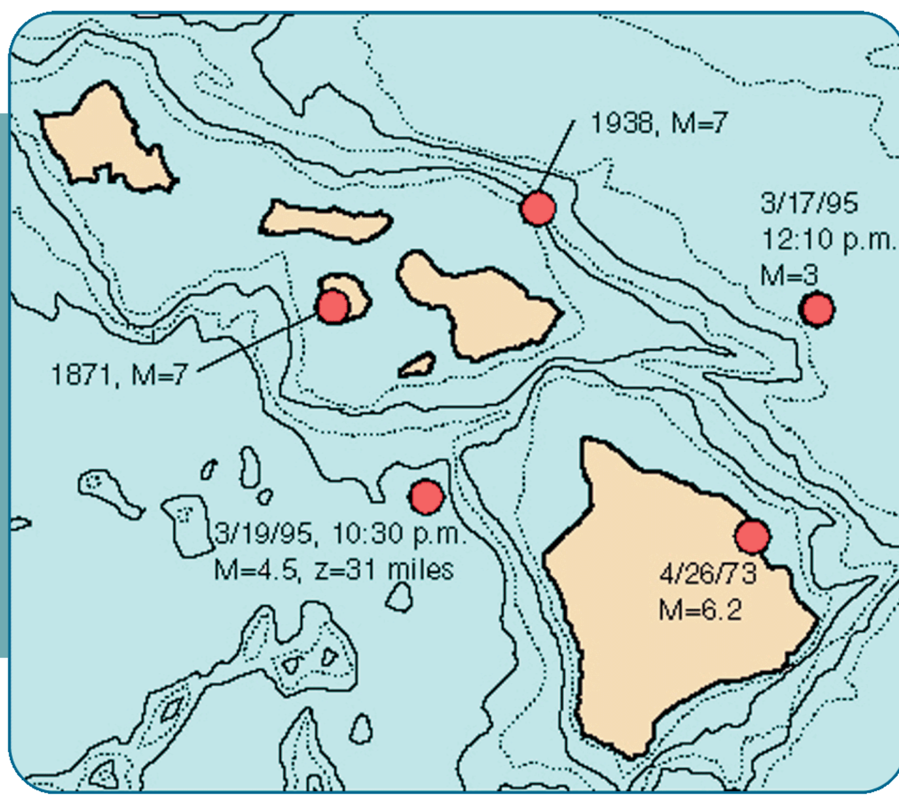
Maximum Considered Honomu Earthquake (Magnitude M_W = 7)

HAZUS Input and Peak Ground Accelerations

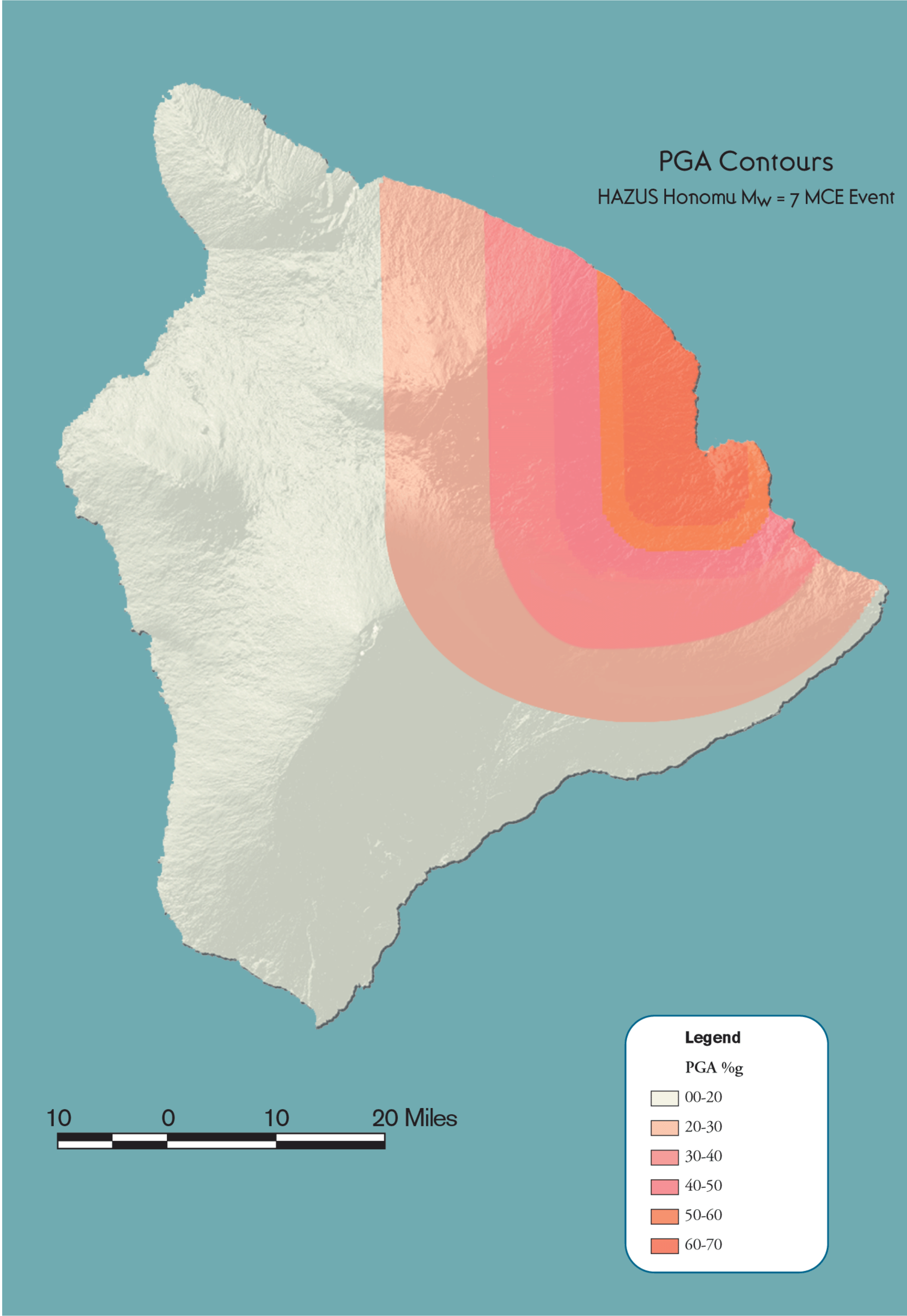
HAZUS Honomu Event PGA

The Peak Ground Acceleration (PGA) contours from the Honomu Magnitude 7 event shows the attenuation of the earthquake, i.e., the horizontal ground acceleration intensity diminishes with further distance from the epicenter. However, the lithospheric seismic source area encompasses all of Hawaii County, and the epicenter of a Magnitude 7 event could occur anywhere throughout the County.

HAZUS Honomu Event Input	
Magnitude	7.0
Latitude	19.87
Longitude	-155.15
Rupture (subsurface) Length	57 km
Depth	38.7 km
Orientation	0 Degrees
Attenuation Function	Munson & Thurber



U.S. Geological Survey, Hawaii Volcano Observatory


PGA Contours
HAZUS Honomu M_W = 7 MCE Event
10 0 10 20 Miles
Legend
PGA %g
00-20
20-30
30-40
40-50
50-60
60-70

HAZUS Results from a Honomu Magnitude 7 Earthquake Event

INVENTORY AT RISK

		Building Exposure	
Number of Buildings	48,000	Residential	**$10 BILLION**
Population	120,000	Total	**$11 BILLION**

SCENARIO RESULTS

Number of Buildings Damaged

Damage Level	(All Types)
Complete (more than 50% damage)	**1,700-2,800**
Extensive (10% - 50% damage)	**4,100-5,000**
Moderate (2% - 10% damage)	**7,300-8,200**
Slight (less than 2% damage)	**9,600-9,800**

Casualties

Fatalities	42-62
Life-Threatening Injuries	26-37

Shelter Needs

Displaced Households	**2,000-2,700**
People Needing Short Term Shelter	**1,500-2,200**

Hospital Bed Availability

Beds available after 1 day	**431-441 out of 496 total**
Beds available after 7 days	**450-454 out of 496 total**
Beds available after 30 days	**475-480 out of 496 total**

Police and Fire Station Damage

At Least Moderately Damaged	**2-3 out of 13 total**
Not Functional after 1 day	**5-6 out of 13 total**

School Damage

At Least Moderately Damaged	**15-24 out of 93 total**

Bridge Damage

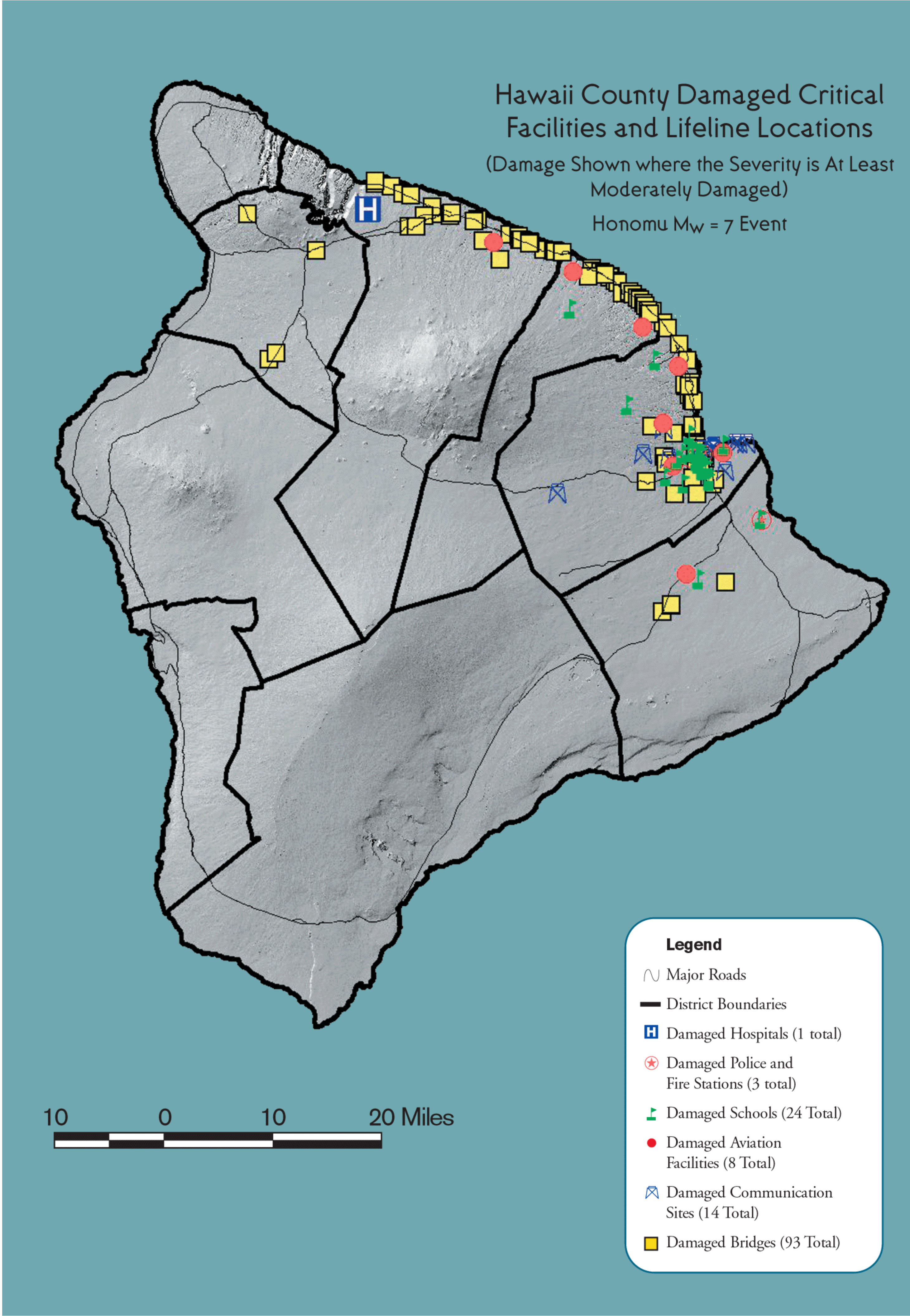
At Least Moderately Damaged	**84-93 out of 241 total**
Not Functional after 7 days	**50-65 out of 241 total**

Economic Loss

Property Damage Loss	**$1.0 - $1.3 Billion**
Business Income Loss	**$0.21- $0.27 Billion**
Total	**$1.2 - $1.6 Billion**

Debris Generated

Debris	**0.65-0.88 Million Tons**
	26,000-35,000 Truckloads


Hawaii County Damaged Critical Facilities and Lifeline Locations
(Damage Shown where the Severity is At Least Moderately Damaged)
Honomu M_W = 7 Event
Legend
Major Roads
District Boundaries
Damaged Hospitals (1 total)
Damaged Police and Fire Stations (3 total)
Damaged Schools (24 Total)
Damaged Aviation Facilities (8 Total)
Damaged Communication Sites (14 Total)
Damaged Bridges (93 Total)
10
0
10
20 Miles

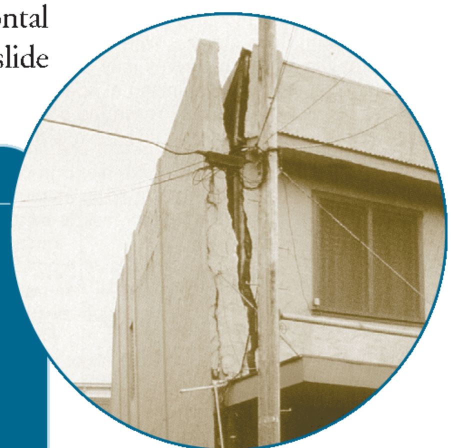
Maximum Considered Kaoiki Earthquake (Magnitude $M_W = 7$)

HAZUS Input and Peak Ground Accelerations

HAZUS Kaoiki Event PGA

The Peak Ground Acceleration (PGA) contours, from the Kaoiki Maximum Considered Event (MCE), are consistent with the horizontal fault location of the southeast flank and the behavior of the flank to slide away (seaward) from the rift zone after a large magnitude event.

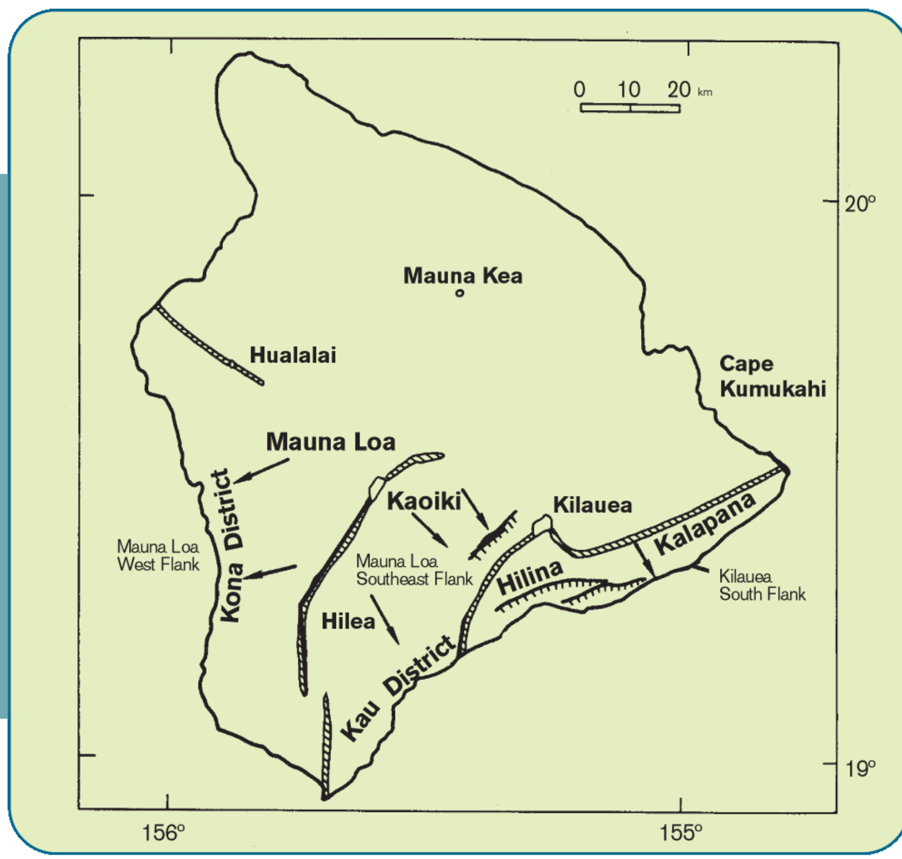
HAZUS Kaoiki Event Input	
Magnitude	7.0
Latitude	19.4
Longitude	-155.5
Rupture (subsurface) Length	30 km
Depth	11 km
Orientation	90 Degrees
Attenuation Function	Munson & Thurber

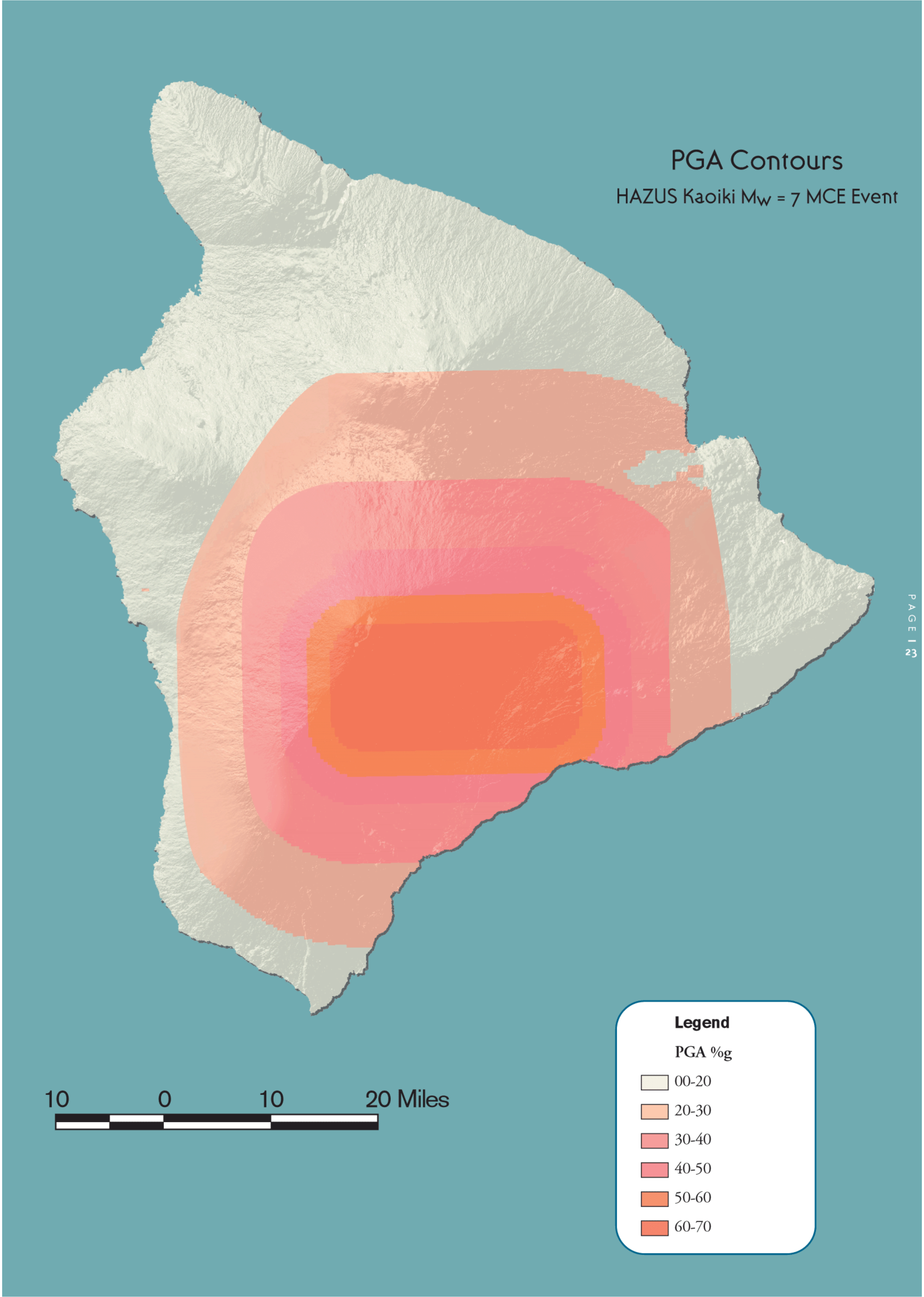


Hilo building damaged by the November 1983 Kaoiki earthquake.

Photo by: J.M. Buchanan-Banks, U.S. Department of the Interior, U.S. Geological Survey

Volcanic Rift Zones and Flank Displacement (after Wyss and Koyanagi 1992; modified with Flank Zones)




PGA Contours
HAZUS Kaoiki Mw = 7 MCE Event
Legend
PGA %g
00-20
20-30
30-40
40-50
50-60
60-70
10
0
10
20 Miles

HAZUS Results from a Kaoiki Magnitude 7 Earthquake Event

INVENTORY AT RISK

		Building Exposure	
Number of Buildings	48,000	Residential	**$10 BILLION**
Population	120,000	Total	**$11 BILLION**

SCENARIO RESULTS

Number of Buildings Damaged

Damage Level	(All Types)
Complete (more than 50% damage)	**90-210**
Extensive (10% - 50% damage)	**1,000-1,600**
Moderate (2% - 10% damage)	**4,700-5,800**
Slight (less than 2% damage)	**9,100-10,600**

Casualties

Fatalities	3-7
Life-Threatening Injuries	3-5

Shelter Needs

Displaced Households	**240-400**
People Needing Short Term Shelter	**190-310**

Hospital Bed Availability

Beds available after 1 day	**186-213 out of 496 total**
Beds available after 7 days	**251-378 out of 496 total**
Beds available after 30 days	**359-384 out of 496 total**

Police and Fire Station Damage

At Least Moderately Damaged	**1-3 out of 13 total**
Not Functional after 1 day	**3-4 out of 13 total**

School Damage

At Least Moderately Damaged	**12-34 out of 93 total**

Bridge Damage

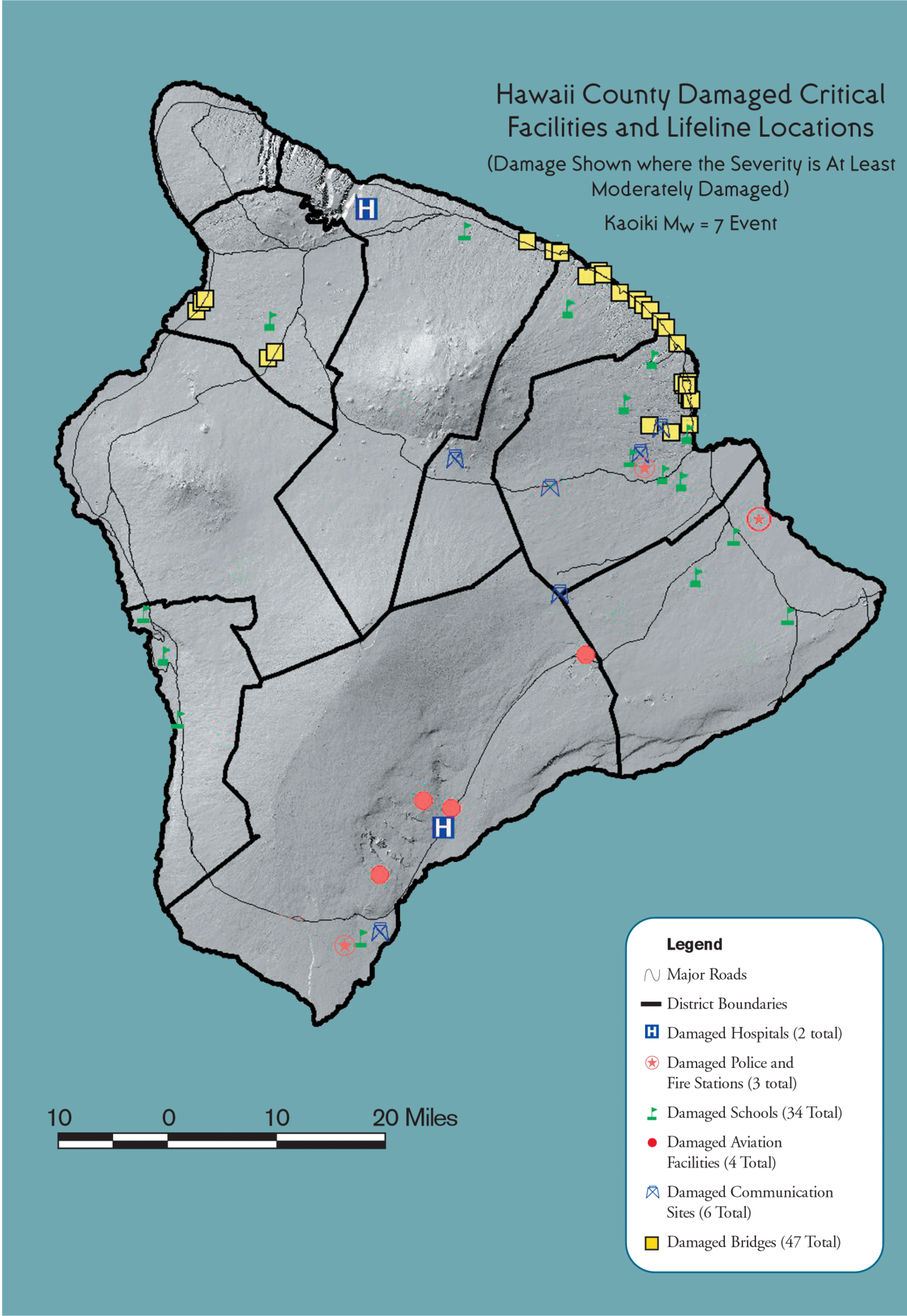
At Least Moderately Damaged	**38-47 out of 241 total**
Not Functional after 7 days	**11-14 out of 241 total**

Economic Loss

Property Damage Loss	**$0.23 - $0.34 Billion**
Business Income Loss	**$0.06- $0.09 Billion**
Total	**$0.30 - $0.40 Billion**

Debris Generated

Debris	**0.14-0.22 Million Tons**
	6,000-9,000 Truckloads


Hawaii County Damaged Critical Facilities and Lifeline Locations
(Damage Shown where the Severity is At Least Moderately Damaged)
Kaoiki M_W = 7 Event
10
0
10
20 Miles
Legend
Major Roads
District Boundaries
Damaged Hospitals (2 total)
Damaged Police and Fire Stations (3 total)
Damaged Schools (34 Total)
Damaged Aviation Facilities (4 Total)
Damaged Communication Sites (6 Total)
Damaged Bridges (47 Total)

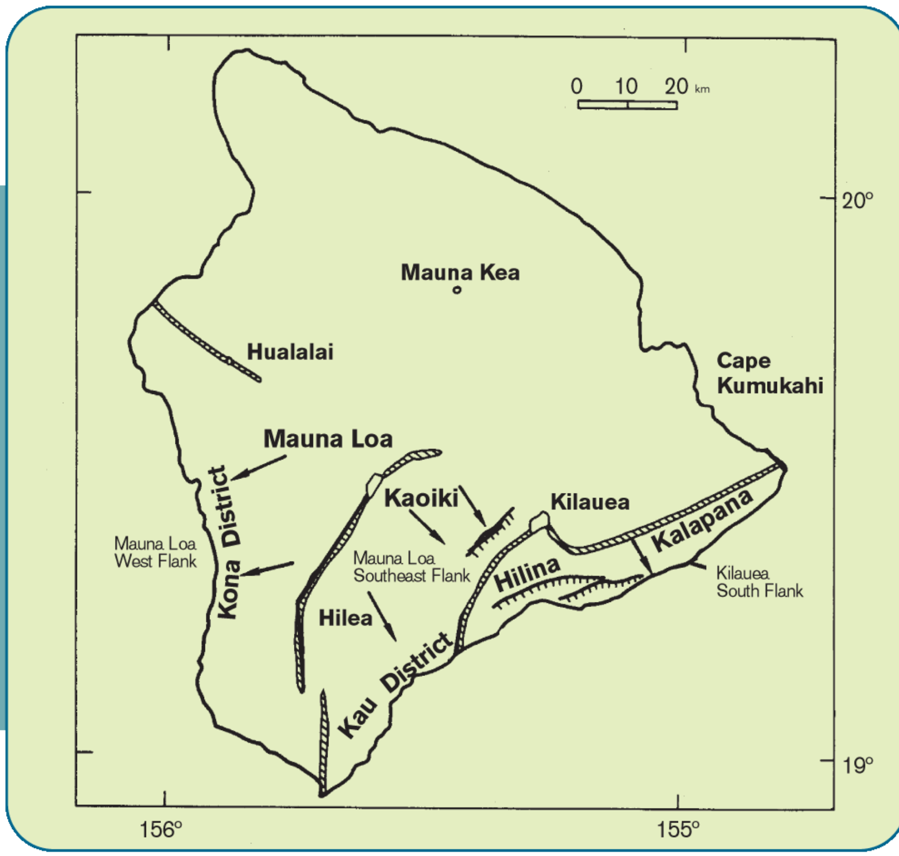
Maximum Considered Kona Earthquake (Magnitude M_W=7)

HAZUS Input and Peak Ground Accelerations

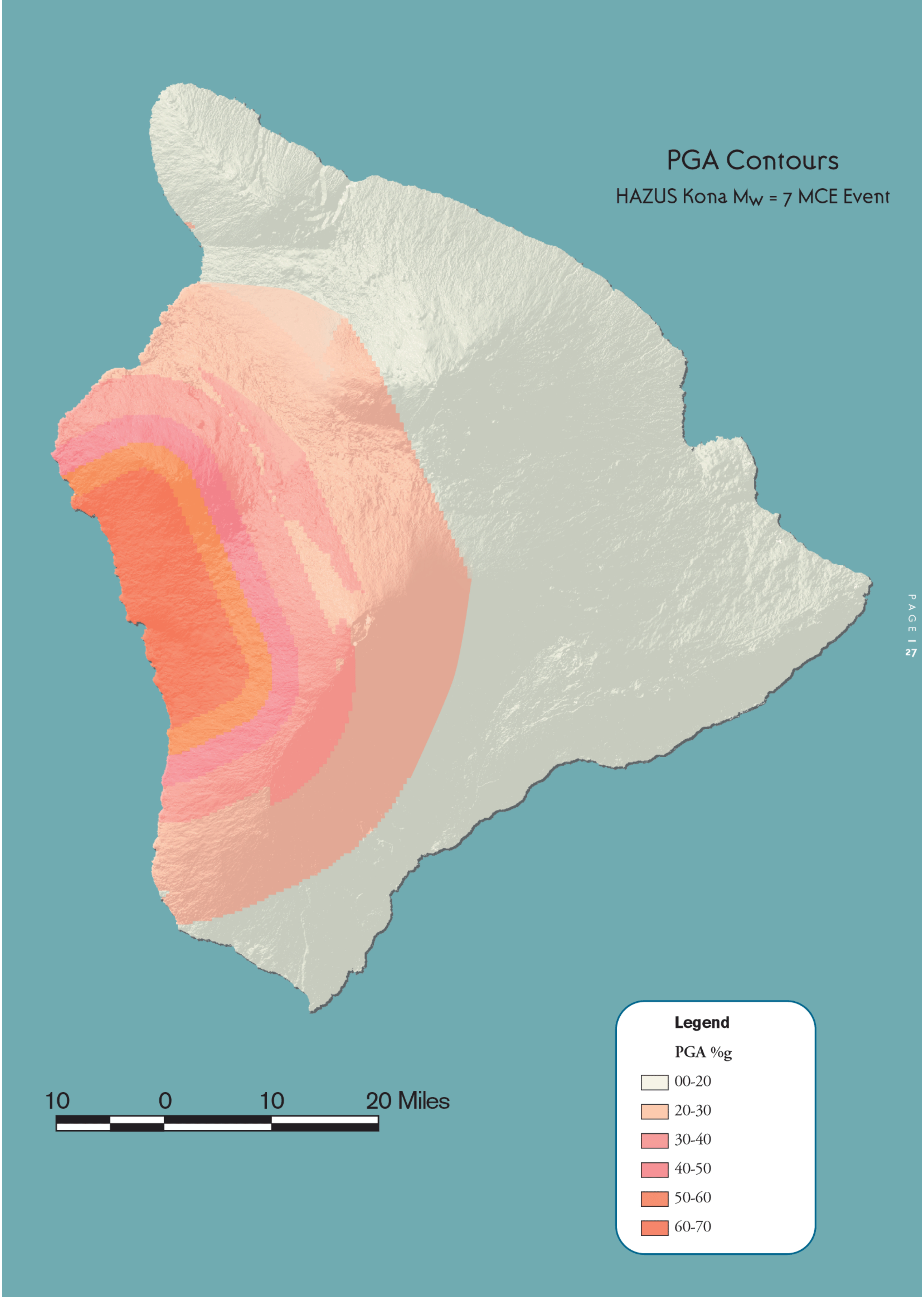
HAZUS Kona Event PGA

The Peak Ground Acceleration (PGA) contours, from the Kona Maximum Considered Event (MCE), are consistent with the horizontal fault location of the Mauna Loa west flank and the behavior of the flank to slide away (seaward) from the rift zone after a large magnitude event.

HAZUS Kona Event Input	
Magnitude	7.0
Latitude	19.5
Longitude	-155.95
Rupture (subsurface) Length	30 km
Depth	10 km
Orientation	140 Degrees
Attenuation Function	Munson & Thurber



Volcanic Rift Zones and Flank Displacement (after Wyss and Koyanagi 1992; modified with Flank Zones)


PGA Contours
HAZUS Kona Mw = 7 MCE Event
Legend
PGA %g
00-20
20-30
30-40
40-50
50-60
60-70
10
0
10
20 Miles

HAZUS Results from a Kona Magnitude 7 Earthquake Event

INVENTORY AT RISK

		Building Exposure	
Number of Buildings	48,000	Residential	**$10 BILLION**
Population	120,000	Total	**$11 BILLION**

SCENARIO RESULTS

Number of Buildings Damaged

Damage Level	(All Types)
Complete (more than 50% damage)	**300-400**
Extensive (10% - 50% damage)	**1,300-1,800**
Moderate (2% - 10% damage)	**5,000-5,700**
Slight (less than 2% damage)	**8,000-8,300**

Casualties

Fatalities	5-9
Life-Threatening Injuries	4-7

Shelter Needs

Displaced Households	**600-1,000**
People Needing Short Term Shelter	**400-700**

Hospital Bed Availability

Beds available after 1 day	**329-438 out of 496 total**
Beds available after 7 days	**378-460 out of 496 total**
Beds available after 30 days	**439-488 out of 496 total**

Police and Fire Station Damage

At Least Moderately Damaged	**0-4 out of 13 total**
Not Functional after 1 day	**5-6 out of 13 total**

School Damage

At Least Moderately Damaged	**17-18 out of 93 total**

Bridge Damage

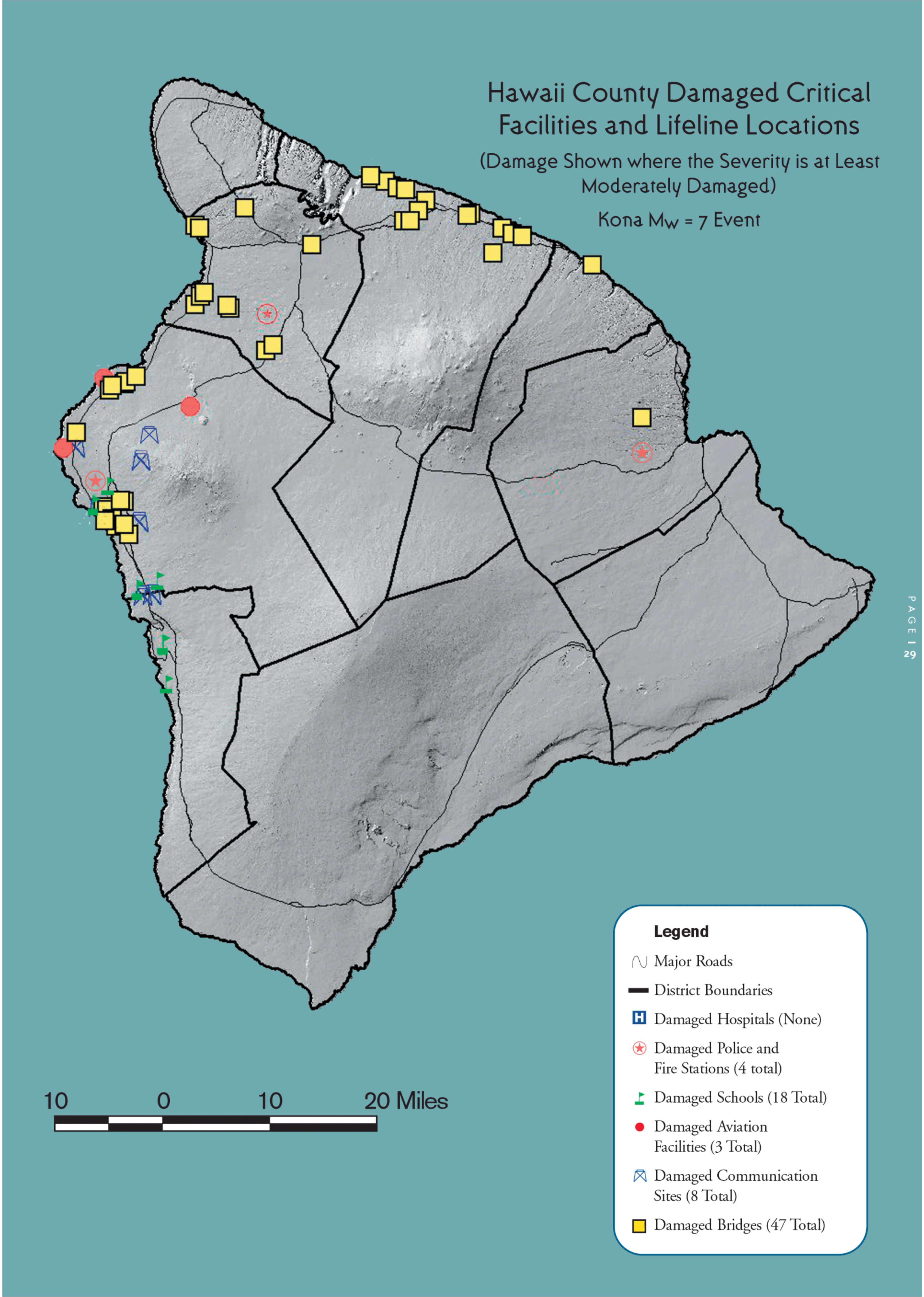
At Least Moderately Damaged	**38-47 out of 241 total**
Not Functional after 7 days	**11-13 out of 241 total**

Economic Loss

Property Damage Loss	**$0.58 - $0.77 Billion**
Business Income Loss	**$0.12- $0.15 Billion**
Total	**$0.7 - $0.9 Billion**

Debris Generated

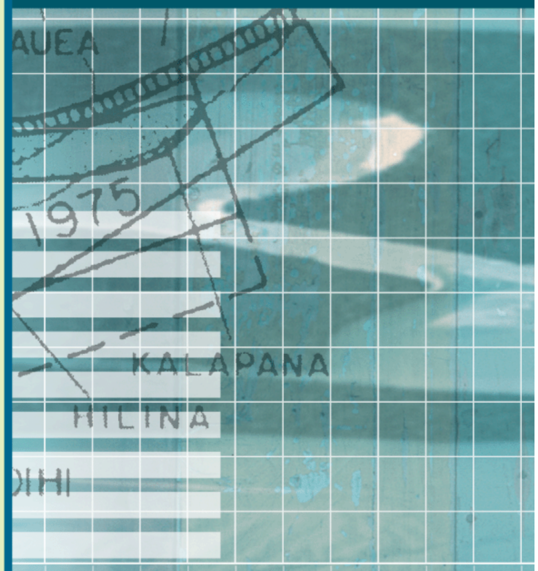
Debris	**0.24-0.35 Million Tons**
	9,000-14,00 Truckloads



Hawaii County Damaged Critical Facilities and Lifeline Locations
(Damage Shown where the Severity is at Least Moderately Damaged)
Kona Mw = 7 Event
Legend
Major Roads
District Boundaries
Damaged Hospitals (None)
Damaged Police and Fire Stations (4 total)
Damaged Schools (18 Total)
Damaged Aviation Facilities (3 Total)
Damaged Communication Sites (8 Total)
Damaged Bridges (47 Total)
10
0
10
20 Miles

How HAZUS can be used for Earthquake Hazard Mitigation

- Using HAZUS to predict losses due to earthquakes requires expert skills in seismology and earthquake engineering. Therefore, only qualified personnel should run HAZUS and interpret the output.
- State Civil Defense's version of HAZUS can produce risk-consistent comparisons of earthquake losses based on current knowledge of seismic hazards.
- The HAZUS methodology is accepted by FEMA.
- Emergency response planning and exercises can utilize the estimates of damage generated by HAZUS for specific scenarios.
- A Magnitude 8 event is possible within the Mauna Loa south flank region, and up to Magnitude 7 events are probable elsewhere.
- After an earthquake event, HAZUS can benefit government agencies by estimating damage to the most affected regions, and emergency aid can be concentrated in those areas.
- HAZUS can show which types of buildings, lifelines, and critical facilities are more susceptible to earthquakes. Approximate loss estimates can also be developed for an individual building's construction type, and structural evaluations and retrofits can be accordingly prioritized for a building owner.
- HAZUS comparisons of estimated losses to buildings illustrate the dependence of building performance on timely code adoption and enforcement.



Detailed statewide information on seismic hazards and loss mitigation is available from State Civil Defense and the Hawaii State Earthquake Advisory Committee's Program Manager:

Department of Defense
3949 Diamond Head Road
Honolulu, HI 96816

Phone (808) 733-4301
Fax (808) 733-4287

Sponsored by NOAA and the

Hawaii Coastal Zone Management Program

Office of Planning
Department of Business, Economic Development & Tourism
235 South Beretania Street
Honolulu, Hawaii 96813

MARTIN & CHOCK