

**Environmental Health Concerns Related to Volcanic
Activity in Hawaii**

PHIP No. 43-01-0618

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General Medical: 500A

June 2018



(UNCLASSIFIED)

Environmental Health Concerns Related to Volcanic Activity in Hawaii June 2018

1 SUMMARY

Volcanic eruptions create solid, liquid, and gas releases that can present a threat to human health and well-being. In May 2018, the Kilauea Volcano on the island of Hawaii entered an active phase that is generating lava flows, gas emissions, and ash clouds that have persisted for weeks and are likely to continue in the short term. There are many resources available to Hawaiian residents to facilitate health and safety during these events. Personnel in proximity to the eruptions, or downwind of the releases, should heed municipal authority precautions and take protective measures to mitigate potential hazards.

2 BACKGROUND

2.1 Kilauea Volcano

Kilauea Volcano is one of the world's most active volcanoes. Situated on the southeast side of the island of Hawaii, it has been erupting continuously, with varying intensity, since 1983. The current eruption cycle began on May 3, 2018 following a magnitude 5.0 earthquake that struck the island. Kilauea is characterized by two major vents: the Halema'uma'u crater, which sits in the caldera at the summit of the volcano, and the Pu'u 'Ō'ō cone, which is 10 miles east of the caldera (see Figure 1). Twelve miles east of Pu'u 'Ō'ō there is a 4-mile stretch of about two dozen smaller fissures (or rifts) in an area known as the East Rift Zone (see Figure 2). These rifts developed subsequent to the earthquake on May 3, 2018.

2.2 Volcanic Activity in 2018

During May 2018, there have been multiple eruptions from the Kilauea summit and the East Rift Zone fissures. This volcanic activity has resulted in lava flows, volcanic smog (vog), sulfur dioxide (SO₂) gas emissions, ash clouds, and lava haze (laze) that have damaged land and property in the Puna District of the island and led to enhanced surveillance and intervention by state and Federal agencies to protect public safety and health. Scientists at the U. S. Geological Survey (USGS) are uncertain about the duration of Kilauea's current activity level but assert that past experience suggests it will continue for weeks and possibly months.¹

2.3 Army Presence

Army assets on the island of Hawaii include the Pohakuloa Training Area (PTA), and the Kilauea Military Camp (KMC) operated by the Army Family and Morale, Welfare, and Recreation services. The PTA occupies 133,000 acres on a high plateau (above 5,000 feet) in the center of the island. It is located 30 miles northwest of the Kilauea volcano. The KMC is situated in the Hawaii Volcanoes National Park (2 miles northeast of the Halema'uma'u crater) and has been closed indefinitely due to concerns about the ongoing eruptions from Kilauea.

¹ Finucane, Martin, "Expert says Hawaii volcano could erupt for a long time, though it probably won't explode." *Boston Globe*, May 22, 2018 [Internet] <https://www.bostonglobe.com/metro/2018/05/22/expert-says-hawaii-volcano-could-erupt-for-long-time-though-probably-won-explode/Xp74Tbad4zNJHyMEUjGXcM/story.html> (accessed June 1, 2018).

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2.4 Hawaiian Meteorology and Climatology

The Hawaiian Islands are situated in the tropics where the length of day and temperature are relatively uniform throughout the year. There are only two discernible seasons: summer from May to October and winter between October and April. Airflow in this region is dominated by the trade winds, which blow from the northeast and east-northeast throughout the year. In summer months, trade winds prevail 80–95% of the time; in winter they prevail 50–80% of the time with lowest frequency in September and October.² A less frequent meteorological phenomenon is known as Kona winds that reverse direction and blow from the southwest and south-southwest. Kona winds result from low-pressure systems forming northwest of the islands and often accompany rain storms.

3 ENVIRONMENTAL HAZARDS

3.1 Lava

Lava is the term for molten rock that breaks through the Earth's surface. Lava fountains and spatter are issuing from the East Rift Zone fissures in and near the Leilani Estates and Lanipuna subdivisions in the Puna District. Hundreds of buildings and homes have been destroyed by the advancing lava flows, and municipal authorities have evacuated affected areas. On May 20, lava streams crossed State Highway 137 (on the southeast perimeter of the island) and entered the Pacific Ocean. The color of molten rock can provide a crude estimate of its temperature: Yellow indicates a temperature of about 1,832–2,192 degrees Fahrenheit (°F). Orange indicates a slightly cooler temperature of about 1,472–1,832 °F. Red is even cooler, about 1,112–1,472 °F. The outer surface of erupting lava cools quickly when it is first exposed to air—hundreds of degrees per second.³

3.2 Volcanic Smog

The term “vog” is a hybrid of the words “volcanic smog”. Vog is a hazy mixture of SO₂ gas and aerosols (tiny particles or droplets), which are primarily sulfuric acid and sulfate compounds. Aerosols are created when SO₂ and other volcanic gases combine in the atmosphere and interact chemically with oxygen, moisture, dust, and sunlight over minutes to days. The exact composition of vog depends on how much time the volcanic plume has had to react in the atmosphere. In areas such as the Kona coast, far from Kilauea Volcano's active vents, aerosols are the main component of vog. Closer to the volcano, vog contains both aerosols and unreacted SO₂ gas.⁴

3.3 Sulfur Dioxide

SO₂ is present in gas bubbles dissolved in magma and is released from a volcano when magma is near the surface. If SO₂ is detected at a nonerupting volcano, it could be a sign that it will erupt soon. Kilauea emits between 550 and 11,000 tons of SO₂ each day during periods of continuous eruption.

² National Oceanic and Atmospheric Administration, National Climatic Data Center. *Climate of Hawaii* [Internet], https://www.ncdc.noaa.gov/climate_normals/clim60/states/Clim_HI_01.pdf (accessed May 25, 2018).

³ USGS, Hawaiian Volcano Observatory. *Frequently Asked Questions and Answers – Hawaiian Volcanoes and Hazards* [Internet] <https://volcanoes.usgs.gov/observatories/hvo/faqs.html> (accessed May 25, 2018).

⁴ USGS, Hawaiian Volcano Observatory. *Frequently Asked Questions about Volcanic Smog* [Internet] https://volcanoes.usgs.gov/observatories/hvo/faq_vog.html (accessed May 29, 2018).

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

Since 2008, Kilauea's summit vent in Halema'uma'u crater has been the dominant source of SO₂ emissions. In 2016, SO₂ emissions from Kilauea were about 992,000 tons.⁵ In contrast, 2016 SO₂ emissions from all U.S. anthropogenic sources were about 2.7 million tons.⁶ SO₂ is a colorless gas at ambient temperature and pressure. It can be detected by taste at concentrations of 0.35-1.05 parts per million (ppm) and has a pungent odor with an odor threshold of 0.67–4.75 ppm.⁷

3.4 Rock and Ash

"Tephra" is the term for volcanic rock fragments exploded or carried into the air during an eruption. The largest fragments, blocks and bombs (> 2.5 inches diameter), can be expelled with great force but are typically deposited near the eruptive vent. Volcanic ash (< 0.1-inch diameter) is not the product of combustion but is formed during eruptions when gases dissolved in magma expand and escape violently into the air, or when water is heated by magma and abruptly flashes into steam. The force of escaping gas shatters solid rocks. Expanding gas also shreds magma, blasting it into the air, where it solidifies into fragments of volcanic glass. Volcanic ash is hard and does not dissolve in water. It is also extremely abrasive, mildly corrosive, and conducts electricity when wet. Ash is easily carried by the wind and may be deposited hundreds of miles downwind. On May 15, 2018, the National Weather Service (NWS) issued the first ever ashfall advisory for Hawaii.

3.5 Laze

The term "laze" is a hybrid of the words "lava haze". Laze is formed when lava enters the ocean and triggers a series of chemical reactions resulting in a white cloud of steam, toxic gases, and tiny shards of volcanic glass. Water cools the lava, which forms a glass that shatters. Tiny pieces are picked up by the steam cloud, which contains hydrochloric (HCl) acid created by the interaction of lava and magnesium chloride salts present in the ocean water. Acid rain from a laze plume has a pH between 1.5 and 3.5 and has the corrosive properties of dilute battery acid. Laze forms continuously as new lava is exposed to sea water.

⁵ Elias, T., and Sutton, A.J., 2017. *Volcanic air pollution hazards in Hawaii: U.S. Geological Survey Fact Sheet 2017–3017*, 4 p., <https://doi.org/10.3133/fs20173017>.

⁶ USEPA, Air Emissions Inventories. *Air Pollutant Emissions Trends Data* [Internet] <https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data> (accessed May 29, 2018).

⁷ National Research Council. 2010. *Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/12770>.

4 HEALTH AND SAFETY ISSUES

4.1 Lava

The most immediate concern for lava is fire hazard for land and property, and burn hazard for human contact. Lava flows at temperatures upwards of 1,112 °F. Although a lava surface can form a crust thick enough to walk on within a few minutes, the interior flow can take days to months to cool due to the insulating properties of the crust. As a direct result, lava deltas comprising newly formed land at an ocean entry are extremely unstable. Delta collapses occur without warning, sometimes sending tens of acres of the delta plunging into the sea. When this happens, it can trigger explosions that hurl rocks hundreds of yards, both inland and seaward, and send huge waves of scalding water onto the coastline.⁸ Lava flow hazard zones on the island of Hawaii are shown in Figure 3.

4.2 Volcanic Smog

The primary constituents of vog are SO₂ (from direct gas emissions) and particulate matter (from aerosol formations and ash releases). The particulate matter in vog is known as PM_{2.5} because the particles are less than or equal to 2.5 micrometers in diameter (less than 1/10th the width of a human hair). In general, most of the vog, SO₂ and PM_{2.5} generated by Kilauea is dispersed over the southwest end of the island due to the flow of the trade winds. However, on the occasions when Kona winds prevail or the trade winds calm, pollutant levels created by volcanic releases can be elevated inland, and visibility can be impaired.

The Hawaii State Department of Health (HDOH) measures SO₂ and PM_{2.5} at a series of monitoring stations that ring the island (see Figure 4). These measurements are used to track compliance with state and Federal air quality standards and to report air quality hazards to the public. Between 2015 and 2017, there were more than 300 days/year when outdoor SO₂ levels exceeded the National Ambient Air Quality Standard (NAAQS) 1-hour standard for SO₂ (0.075 ppm) on the island of Hawaii (see Table 1). SO₂ concentrations above this level are considered unhealthy for some or all of the general public. Most of these excursions occurred at the Pahala and Ocean View stations (southwest end of the island) and Volcano National Park stations (near the Kilauea summit). This indicates that SO₂ levels on Hawaii are chronically elevated, even during periods when Kilauea is not in a heightened eruption cycle. Limited data available for January-May 2018 indicates that recent SO₂ levels are consistent with previous years.

Between 2015 and 2017, there were only 5 unique days (total) when outdoor PM_{2.5} levels exceeded the NAAQS 24-hour standard for PM_{2.5} (35 micrograms/cubic meter (µg/m³)) on the island of Hawaii (see Table 2). In contrast, there have already been 5 days between January-May 2018 when PM_{2.5} levels have been unhealthy for some or all of the general public. Locations of HDOH air quality monitoring stations on the islands of Hawaii and Oahu, and the air pollutants that they measure, are shown in Figures 4 and 5.

⁸ USGS Hawaiian Volcano Observatory. *Volcano Watch*, 2016-09-15 [Internet] https://volcanoes.usgs.gov/observatories/hvo/hvo_volcano_watch.html?vwid=455 (accessed May 30, 2018).

(UNCLASSIFIED)

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

Table 1. Days when the Outdoor SO₂ Concentration was Higher than the 1-Hour NAAQS for SO₂ on the Island of Hawaii, by Monitoring Station (days/year)^{9,10}

Site Name	2018 ^a	2017	2016	2015
Volcano National Park - Visitor Center	---	81	77	83
Volcano National Park - Observatory	---	96	106	112
Hilo	10	19	16	13
Kona	2	1	3	0
Puna E	---	0	0	0
Pahala	68	230	243	200
Ocean View	46	120	145	112
Mountain View	19	15	28	36
Unique Days When SO ₂ Concentration Was Higher Than 1-Hour NAAQS for SO ₂	98	301	310	304

^a Selected monitoring stations on island of Hawaii from January 1-May 31, 2018

Table 2. Days when the Outdoor PM_{2.5} Concentration was Higher than the 24-Hour NAAQS for PM_{2.5} on the Island of Hawaii, by Monitoring Station (days/year)^{9,11}

Site Name	2018 ^a	2017	2016	2015
Volcano National Park - Visitor Center	---	0	1	0
Volcano National Park - Observatory	---	0	1	0
Hilo	0	0	0	0
Kona	4	0	0	0
Puna E	---	0	0	0
Pahala	0	0	0	0
Ocean View	2	0	4	0
Mountain View	0	0	0	0
Unique Days When PM _{2.5} Concentration Was Higher Than 24-Hour NAAQS for PM _{2.5}	5	0	5	0

^a Selected monitoring stations on island of Hawaii from January 1-May 31, 2018

⁹ HDOH, Clean Air Branch, Notification of Exceedance of a National Ambient Air Quality Standard [Internet] https://health.hawaii.gov/cab/files/2018/03/exceedances_2018_06_08_11.pdf, (accessed June 8, 2018).

¹⁰ EPA, Outdoor Air Quality Data, Download Daily Data for SO₂, Hawaii, All Sites, 2015-2017 [Internet] <https://www.epa.gov/outdoor-air-quality-data/download-daily-data>, (accessed June 8, 2018).

¹¹ EPA, Outdoor Air Quality Data, Download Daily Data for PM_{2.5}, Hawaii, All Sites, 2015-2017 [Internet] <https://www.epa.gov/outdoor-air-quality-data/download-daily-data>, (accessed June 8, 2018).

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

There are additional air monitoring stations on the island of Hawaii operated by the U.S. Environmental Protection Agency (EPA), the National Park Service, and the USGS. In June 2018, EPA, HDOH and the Hawaii County Civil Defense Agency established a website that consolidates air monitoring data collected by these organizations and their partners. At the time of publication, the air data included SO₂ and hydrogen sulfide (H₂S) levels from approximately thirty locations on the island.¹²

Health concerns arising from exposure to vog constituents include—

4.2.1 SO₂ Inhalation

Short-term exposures to SO₂ can harm the human respiratory system and make breathing difficult. Children, the elderly, and those who suffer from asthma are particularly sensitive to effects of SO₂. Even short-term exposures can cause narrowing of the airways (bronchoconstriction), inducing asthma symptoms. Negative health effects can increase as SO₂ levels and/or breathing rates increase. At SO₂ levels considered unhealthy for the general population, even nonasthmatics may experience breathing difficulties. The HDOH and EPA levels of health concern for varying concentrations and durations of SO₂ exposure are shown in Table 3. Short-term SO₂ exposure can result in increased emergency department visits and hospital admissions for respiratory illnesses, particularly in the aforementioned 'sensitive groups'. Short-term health symptoms may include—¹³

- Eye, nose, throat, and/or skin irritation
- Coughing and/or phlegm
- Chest tightness and/or shortness of breath
- Headache
- Increased susceptibility to respiratory ailments
- Fatigue and/or dizziness

4.2.2 SO₂ Contamination of Water Supplies

Water from catchment systems in vog-prone areas can become acidic and leach harmful contaminants (such as lead, copper, and zinc) from roofing and plumbing materials, especially in older homes. Catchment water used for drinking or food preparation should be carefully monitored for ash infiltration. Based upon the magnitude or persistence of anticipated ashfall, it may be prudent to disconnect the water collection system until conditions improve or the catchment basin has been flushed. Alternatively, the pH of catchment water can be managed by adding baking soda to the tank or using an inline pH-adjusting filter.¹³

¹² EPA. Kilauea Eruption Air Monitoring [Internet] https://response.epa.gov/site/site_profile.aspx?site_id=12766 (accessed June 8, 2018).

¹³ USGS. *Frequently Asked Questions on Vog from Kilauea Volcano*, August 2016 [Internet] <https://vog.ivhnh.org/FAQ.pdf> (accessed May 31, 2018).

Table 3. Levels of Health Concern for Airborne SO₂ Exposure

HDOH 15-minute SO ₂ Concentration (ppm)	EPA Air Quality Index 1-Hour SO ₂ Concentration (ppm)	Air Quality Status	Color Code
0 – 0.10	0 - 0.035	Good	Green
0.11 – 0.20	0.036 - 0.075	Moderate	Yellow
0.21 – 1.00	0.076 – 0.185	Unhealthy for Sensitive Groups	Orange
1.01 – 3.00	0.186 – 0.304	Unhealthy	Red
3.01 – 5.00	0.305 – 0.604*	Very Unhealthy	Purple
> 5.01	0.605 – 1.004*	Hazardous	Maroon

* SO₂ thresholds reflect a 24-hour averaging interval.

4.2.3 PM_{2.5} Inhalation

Solid particles or liquid droplets in the form of PM_{2.5} can be inhaled and cause serious health problems. These particles can get deep into the lungs, and some may even get into the bloodstream. People with pre-existing heart or lung disease, older adults, and children are most at risk from PM_{2.5}. Even healthy individuals can be at greater risk during times of heightened PM_{2.5} when exercising or working strenuously since we breathe greater volumes of air, and more deeply, when physically active. The EPA levels of health concern for varying concentrations of PM_{2.5} are shown in Table 4. Both long- and short-term particle exposures have been linked to health concerns. High levels of particle pollution have been shown to result in increased hospital admissions, emergency room visits and even in premature death for some people with existing heart or lung disease. Low levels of PM_{2.5} are not considered as problematic for asthmatics as low levels of SO₂ gas. Particle pollution can cause temporary health symptoms such as—¹³

- Eyes, nose and/or throat irritation
- Coughing and/or phlegm
- Chest tightness and/or shortness of breath

Table 4. Levels of Health Concern for Airborne PM_{2.5} Exposure

EPA Air Quality Index 24-Hour PM _{2.5} Concentration (µg/m ³)	Air Quality Status	Color Code
0 – 12.0	Good	Green
12.1 – 35.4	Moderate	Yellow
35.5 – 55.4	Unhealthy for Sensitive Groups	Orange
55.5 – 150.4	Unhealthy	Red
150.5 – 250.4	Very Unhealthy	Purple
250.5 – 500.4	Hazardous	Maroon

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

4.3 Ashfall

Respiratory health concerns resulting from ashfall are the same as those discussed regarding PM_{2.5} in vog. However, ashfall has the potential to create additional physical hazards described below.

4.3.1 Roads

During an active ashfall, the resulting reduction in visibility can make driving conditions hazardous. This danger is compounded by ash covering roads, which could cover road markings. Thin layers of either wet or dry ash are very slippery, reducing traction. Thick deposits of ash may make roads impassable.

4.3.2 Water Supplies

Ashfall can cause contamination of water or clogging and damage of water supply equipment. Small, open-water supplies such as domestic water tanks with roof drainage (i.e., rainwater catchment) are especially vulnerable to volcanic ashfall, and even small quantities of ash may cause problems for potability. While the risk of toxicity is low, the pH may be reduced or chlorination inhibited. During and after ashfalls, there is also likely to be extra water demand for clean-up, resulting in water shortages.

4.3.3 Water and Wastewater Treatment

It is very difficult to exclude ash from sewers and stormwater collection networks. Systems with combined storm water/sewer lines are most at risk. Ash will enter sewer lines where there is inflow/infiltration by stormwater. Ash-laden sewage entering a treatment plant may cause blockage or failure of mechanical prescreening equipment such as step screens or rotating screens. Ash that penetrates further into the system will settle (due to gravity) and may reduce the capacity of biological reactors, increase the volume of sludge, and increase the proportion of inorganic material in the sludge which can alter digestion of decomposition characteristics.

4.4 Laze

The acidic nature of laze makes it a surface contact and inhalation hazard. Laze can cause skin and eye irritation, as well as breathing difficulties. Concentrations of HCl in a laze plume can reach 7.1 ppm within about 10 yards of the contact between lava and seawater. This is higher than the 5-ppm permissible exposure limit set by the Occupational Safety and Health Administration. However, within 100 yards of the source of the plume, the HCl concentration is likely to fall below 1 ppm.¹⁴

¹⁴ Hunter, Dana, "The Lowdown on LAZE: Kilauea's Most Recent Hazard." *Scientific American*, May 22, 2018 [Internet] <https://blogs.scientificamerican.com/rosetta-stones/the-lowdown-on-laze-kilaueas-most-recent-hazard/> (accessed June 1, 2018).

5 RECOMMENDATIONS

5.1 Situational Awareness (SA)

Maintain SA regarding volcanic activity and resulting emergency conditions by subscribing to public alert notifications. The County of Hawaii has established an [Emergency Notification System](#) to alert subscribers to emergency situations and directed actions on the island of Hawaii. The USGS has a [Volcano Notification Service](#) that provides notification email to subscribers about volcanic activity happening at U.S.-monitored volcanoes. The alert can be customized for certain volcanoes, as well as the type of notification.

5.2 Sulfur Dioxide

Maintain SA regarding outdoor SO₂ levels, at-risk populations, and associated behavior recommendations via the HDOH [Short Term SO₂ Advisory](#) website. Two-day forecasts of SO₂ concentration trajectories that can be used for planning purposes are available at the University of Hawaii at Manoa [Vog Model](#) website. When SO₂ levels are elevated, staying indoors, with doors and windows closed, can help reduce exposures over a short time period (hours), depending on how well the building is sealed from the outside environment. Air conditioning can provide comfort but will not filter SO₂ or PM_{2.5} from the air. Dust masks and other commercial masks sold to the public will not protect against inhalation of SO₂. Emergency response personnel or those expected to perform in elevated SO₂ environments should seek the guidance of qualified industrial hygiene specialists to determine the proper personal protective equipment.

5.3 PM_{2.5} Exposure

Maintain SA regarding outdoor PM_{2.5} levels, at-risk populations, and associated behavior recommendations via the EPA [AirNow](#) website. This tool shows both current PM_{2.5} conditions and 2-day forecasts for all of the Hawaiian Islands. Emergency response personnel or those expected to perform in elevated PM_{2.5} environments should seek the guidance of qualified industrial hygiene specialists to determine the proper personal protective equipment.

5.4 Ashfall

Maintain SA regarding ashfall events via the NWS [Hawaii Volcano Weather Products](#) website. Further, USGS requests that citizens report ashfall observations resulting from volcanic eruptions to aid the NWS advisories. Presence of ashfall may be reported at the USGS [Hawaiian Volcano Observatory](#) website.

5.4.1 Driving

Immediately after an ashfall, even a light one, driving conditions, visibility, and air quality can be dramatically affected, especially by the resuspension of ash by traffic. Rainfall has a sudden but temporary effect in improving air quality until the ash dries out again. Following an ashfall, refrain from driving and stay indoors if possible.

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

5.4.2 Indoor Environments

Keep all doors and windows closed whenever possible.

5.4.3 Respiratory Protection

Those undertaking clean-up operations should wear effective dust masks such as the N95 mask. The Hawaii Emergency Management Agency has [free dust masks](#) available for County residents. If no approved mask is available, a fabric mask improvised from cloth will filter out the larger ash particles (but will not protect against toxic gases like SO₂ or H₂S). Dampening the fabric with water will improve its effectiveness.

5.4.4 Eye Protection

In fine-ash environments, wear goggles. Wear corrective eyeglasses instead of contact lenses to protect eyes from irritation.

5.5 Laze

Avoid areas where lava flow intrudes into ocean water. Masks used for dust protection are not effective against acid vapors. Monitor wind direction as plume may be carried toward populated areas. Monitor active lava flows as laze will be generated whenever new lava is exposed to sea water.

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PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

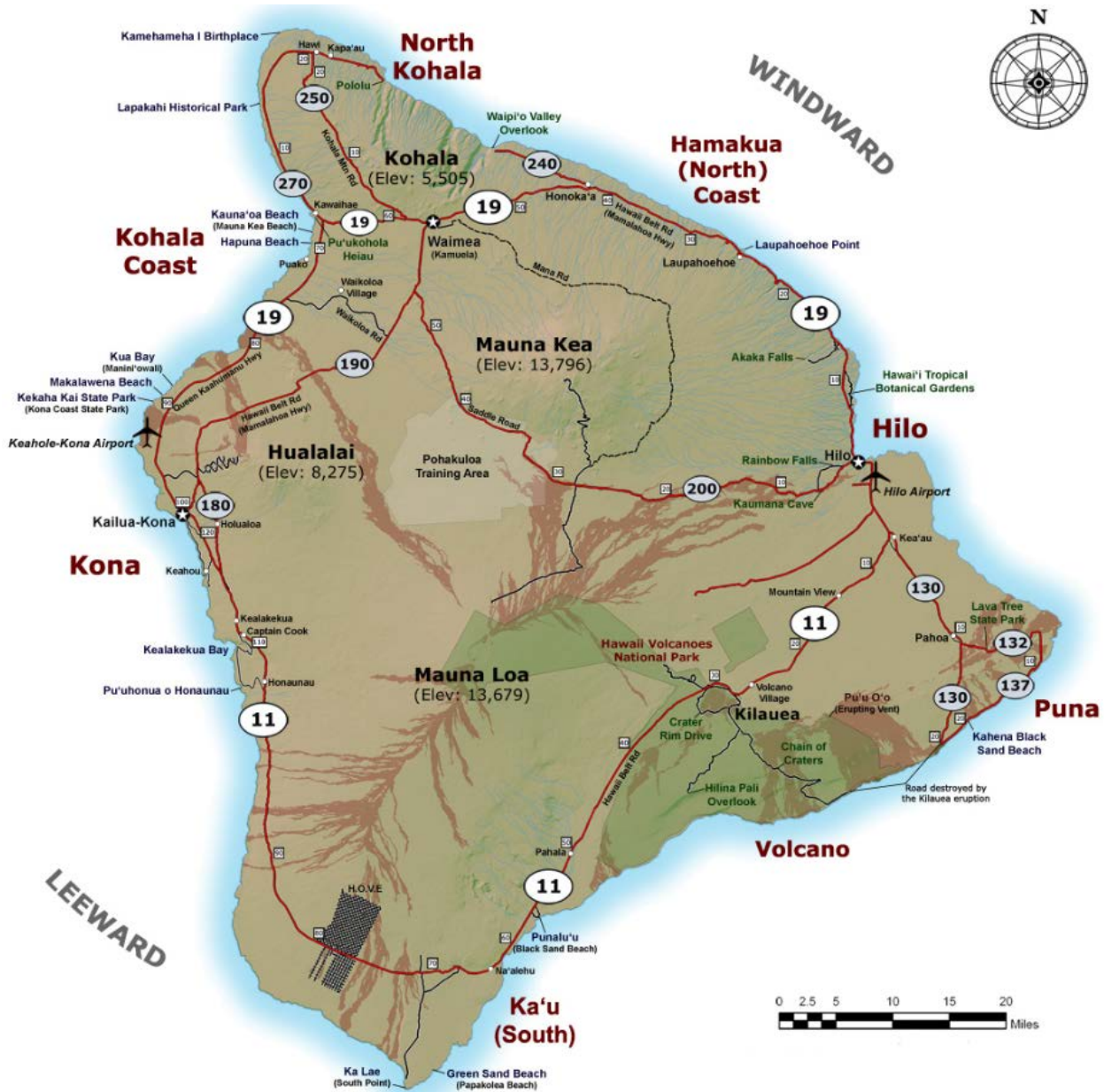


Figure 1. Map of the Island of Hawaii.¹⁵

¹⁵ Aloha Valley. *Hawaii's Largest Measured Earthquakes; to Date*, May 23, 2015 [Internet] <http://alohavalley.com/hawaiis-largest-measured-earthquakes-to-date/> (accessed May 25, 2018).

(UNCLASSIFIED)

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii

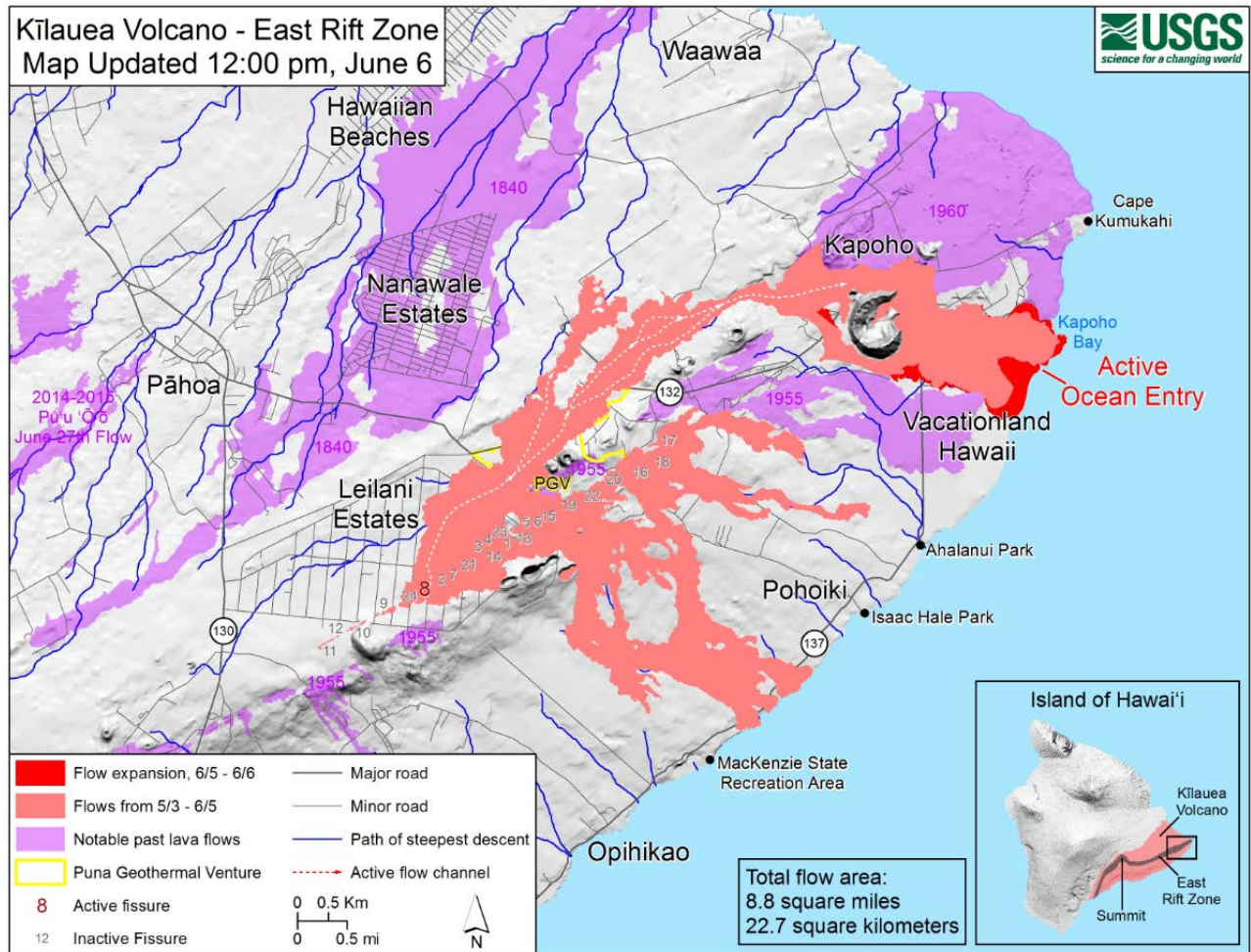


Figure 2. Map of East Rift Zone Fissures.¹⁶

¹⁶ USGS, Volcano Hazards Program. *Multimedia-Maps*. [Internet] https://volcanoes.usgs.gov/volcanoes/kilauea/multimedia_maps.html (accessed June 7, 2018).

(UNCLASSIFIED)

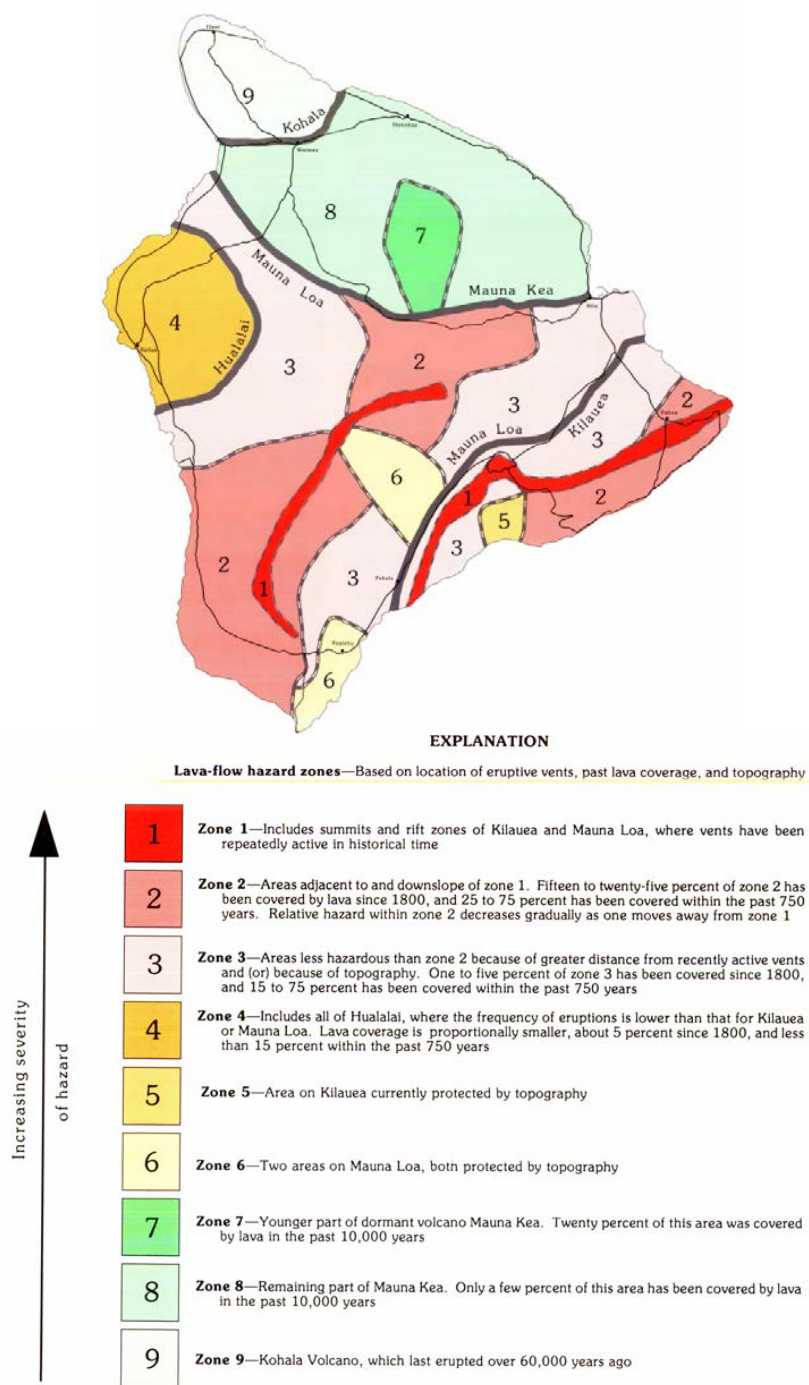
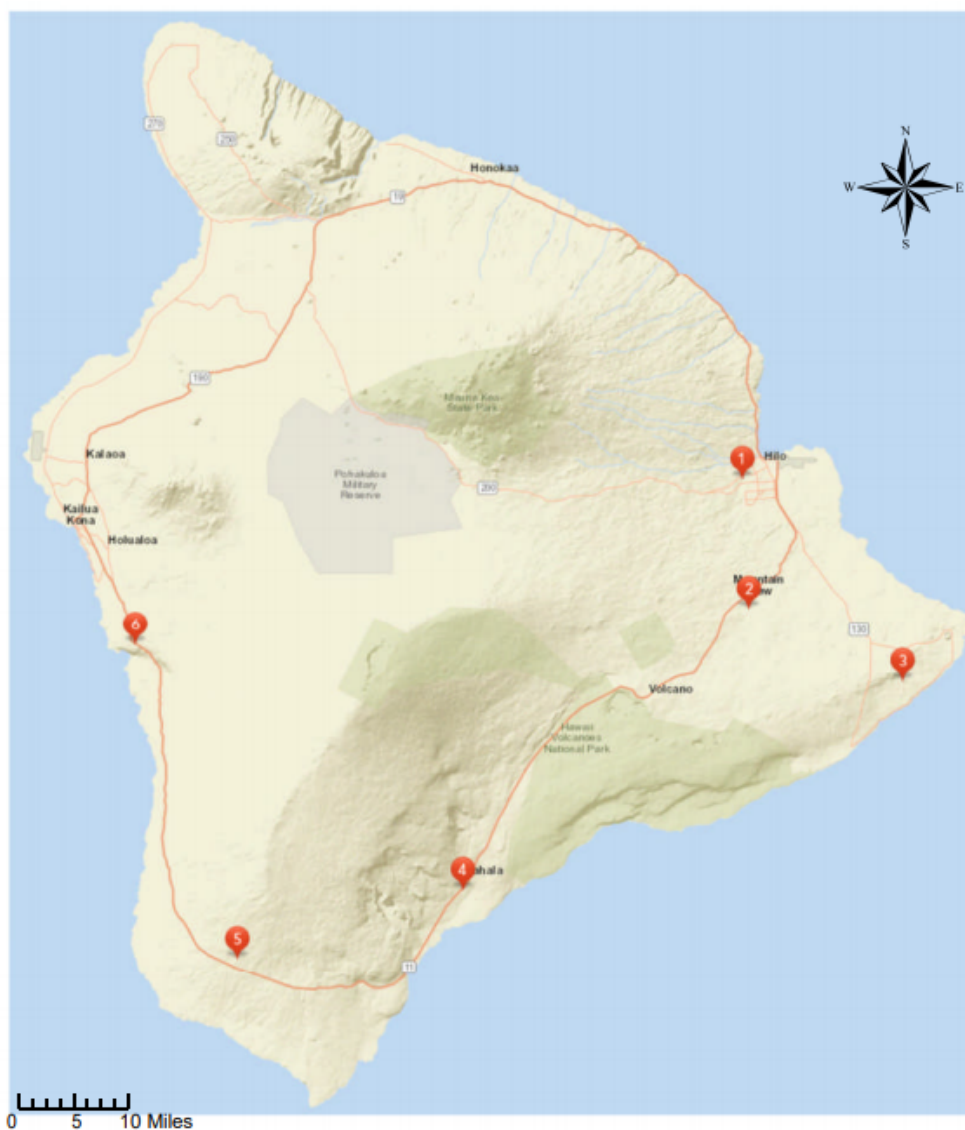


Figure 3. Lava Flow Hazard Map, Island of Hawaii.¹⁷

¹⁷ Wright, T.L., Chun, J.Y.F., Exposo, Jean, Heliker, Christina, Hodge, Jon, Lockwood, J.P., and Vogt, S.M., 1992, Map showing lava-flow hazard zones, Island of Hawaii: U.S. Geological Survey Miscellaneous Field Studies Map MF-2193, scale 1:250,000.

(UNCLASSIFIED)

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii



Station	Name	Location	Pollutants Monitored
1	Hilo	1099 Waianuenue Ave.	SO ₂ , PM _{2.5}
2	Mountain View	17-1235 Volcano Rd.	SO ₂ , PM _{2.5}
3	Puna E	TMK (3)-1-3-28-37 (Leilani)	H ₂ S, SO ₂
4	Pahala	96-3150 Pikake St.	SO ₂ , PM _{2.5}
5	Ocean View	92-6091 Orchid Mauka Circ.	SO ₂ , PM _{2.5}
6	Kona	81-1043 Konawaena School Rd.	SO ₂ , PM _{2.5}

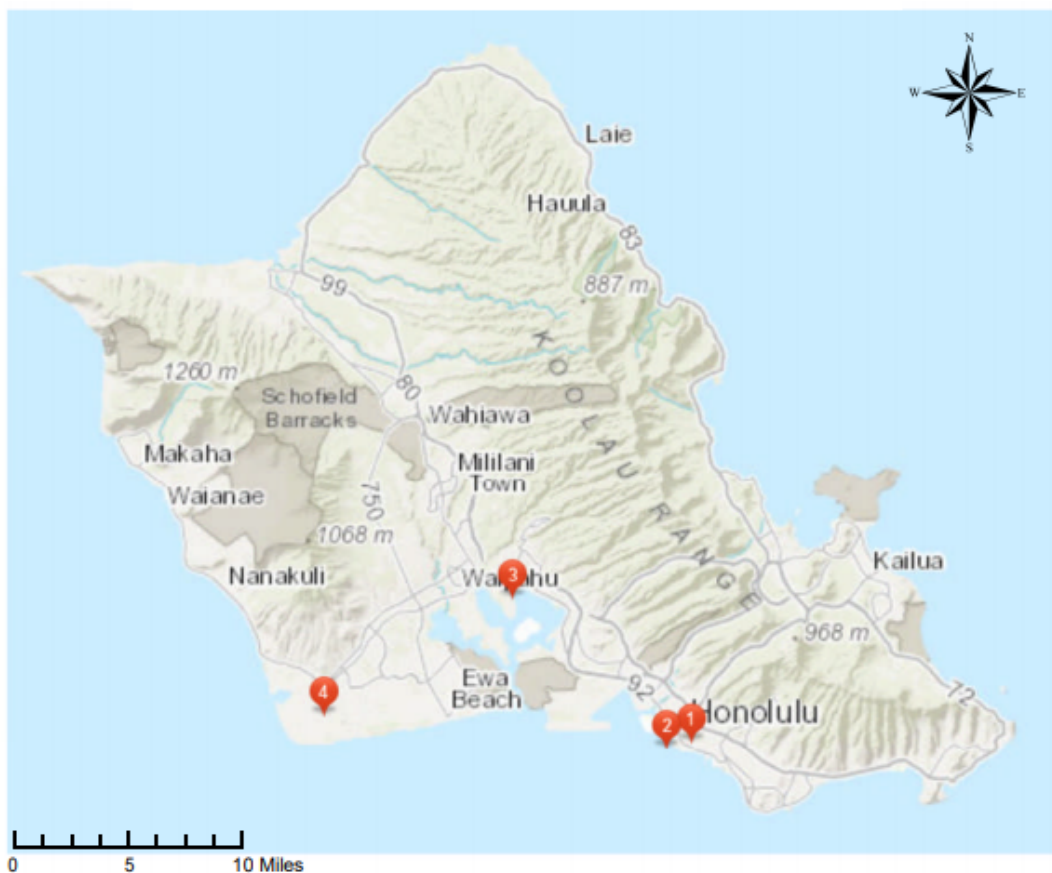
Figure 4. HDOH Air Monitoring Stations on the Island of Hawaii.¹⁸

¹⁸ HDOH. *State of Hawaii, Annual Summary 2015, Air Quality Data*. [Internet] https://health.hawaii.gov/cab/files/2016/12/aqbook_2015.pdf (accessed May 30, 2018)

(UNCLASSIFIED)

(UNCLASSIFIED)

PHIP No. 43-01-0618, Environmental Health Concerns Related to Volcanic Activity in Hawaii



Station	Name	Location	Pollutants/Parameters Monitored
1	Honolulu	1250 Punchbowl St.	CO, SO ₂ , PM _{2.5} , PM ₁₀
2	Sand Island	1039 Sand Island Pkwy.	O ₃ , PM _{2.5}
3	Pearl City	860 4th St.	PM _{2.5} , PM ₁₀
4	Kapolei	2052 Lauwiliwili St.	CO, SO ₂ , NO ₂
4	Kapolei NCore	2052 Lauwiliwili St.	CO trace, SO ₂ trace, NO/NO _y , Pb, O ₃ , PM _{2.5} , PM _{2.5} speciation, PM ₁₀ , PM _{10-2.5} , WS/WD

Figure 5. HDOH Air Monitoring Stations on the Island of Oahu.¹⁸

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