Section 4.16 Windstorm

Windstorm

The trade winds that blow across the Pacific are subject to intensification from high pressure cells north of the islands. Windstorms can damage infrastructure, disrupt electrical power due to damaged power lines, destroy buildings, create wind-borne debris missiles, and cause other damages statewide.

CHANGES SINCE 2018

+2
Declared Disasters

+44
Windstorm Events

COUNTIES MOST VULNERABLE

Kaua'i Honolulu Maui Hawai'i

SOCIALLY VULNERABLE POPULATION

22.3%
Of Total Population

316,257
Persons

HAZARD RANKING

Low Medium High

COMMUNITY LIFELINES

1,369
Total

CLIMATE PROJECTIONS

Change in prevailing winds may shift large-scale pressure and wind patterns

Muggy weather and vog are the result of fewer days of northeast trade winds

Average atmospheric and land surface temperatures may increase due to changing trade wind patterns

6,095
State Buildings

7,420
Environmental Resources
SQUARE MILES

337
Hawaiian Home Lands

975
Cultural Resources

1,104
Miles of State Road

CONTENTS

TABLES

FIGURES

[1] *Section Cover Photo: Wind-whipped palms on Kaua‘i’s east shore. Photo by Megan Brotherton*

SECTION 4. RISK ASSESSMENT

4.16 WINDSTORM

2023 SHMP Update Changes

- High windstorm events that occurred in Hawai'i from January 1, 2018, through December 31, 2022, were researched for this 2023 SHMP Update.
- This section now includes a discussion of how windstorms impact socially vulnerable populations and community lifelines.
- Six types of cultural resources (archaeology, burial sensitivity area, historic building, historic district, historic object, and historic structure) were added to the vulnerability assessment.

4.16.1 HAZARD PROFILE

Wind is defined as the horizontal component of natural air moving caused by horizontal pressure gradients close to the surface of the earth and at higher levels. This hazard profile and associated vulnerability assessment addresses high windstorms, in general, while Section 4.9 (Hurricane) addresses risk from tropical storms and hurricane-force winds in more detail.

HAZARD DESCRIPTION

Types of Winds

Winds in the State of Hawai'i originate from several different sources: trade winds, kona winds, midlatitude fronts and shear lines, and hurricanes/tropical storms. High winds from trade winds (which blow 70% of the time), kona winds, fast-moving cold fronts, and rare winds from hurricanes and tropical storms passing through Hawaiian waters all affect the state. The hazards from hurricanes and tropical storms are discussed in Section 4.9 (Hurricane). This section focuses on the other two wind patterns: trade and kona.

Trade Winds

The trade wind pattern over the Pacific Ocean is one of the largest and most consistent wind fields in the world, and these winds play a major role in defining the climatology of the region. The northeast trade winds prevail over the Hawaiian Islands throughout the year with an average speed of 15.7 mph, with speeds ranging between 10 and 25 mph. Occasional extreme events reach 40 to 50 mph when the subtropical high-pressure cell north of the Hawaiian Islands intensifies (Garza, et al. 2012).

Average wind speeds in the State of Hawai'i are the highest during the summer trade wind period (May through September) when trade winds are present 85% to 95% of the time, and wind speeds over the ocean exceed 12 miles per hour (mph) 50% of the time. During the winter (October through April), when trade winds are not as

prevalent (present 50% to 80% of the time), wind speeds are in excess of 12 mph about 40% of the time (Western Regional Climate Center 2018).

These persistent winds became known as trade winds long ago when clipper ships carrying cargo depended on the broad belt of easterly winds encircling the globe in the subtropics for fast passage; however, strong, gusty trade winds can cause problems for mariners. Strong trade winds, blowing from the northeast, funnel through the major channels between the islands—Kaua'i, Kaiwi, Pailolo, Kalohi, 'Au'au, and 'Alenuihāhā Channels—at speeds 5 to 20 knots (about 5.7 to 23.0 miles per hour) faster than the speeds over the open ocean. North Pacific high-pressure systems are responsible for the majority of the gusty trade wind episodes over Hawaiian waters, which commonly persist for several days before tapering off (Pacific Disaster Center 2011).

Kona Winds

Kona winds is a Hawaiian term for the stormy, rain-bearing winds that blow over the islands from the southwest or south-southwest in the opposite direction of trade winds. Kona is the Hawaiian word for leeward. When kona winds blow, the predominant wind pattern is reversed so that the western or leeward sides of the islands become windward. This type of wind is associated with a class of subtropical weather systems known as kona low-pressure systems or kona storms, which develop northwest of the State of Hawai'i and move slowly eastward. Kona storms can produce heavy rains, hail, floods, landslides, and other severe weather hazards in addition to the high winds discussed in this hazard profile (Hawai'i Life 2012). Strong kona winds can last for a day or for a week or more (Pacific Disaster Center 2011).

Midlatitude fronts and shear lines

Midlatitude cold fronts, which can usually be found to the north of Hawai'i in winter, can move very fast, shifting wind from southwesterly ahead of the front to northwesterly behind it. Because of the modification of the cold front by the underlying warm ocean, as it approaches Hawai'i, the temperature contrast across a frontal system may not be present. Often a frontal system is recognized as a wind shear line and is accompanied by clouds and/or precipitation (Businger 2013).

Wind Speed and Wind Load

There are several ways to measure the speed at which air is moving or "wind speed". The most commonly used methodologies for measuring wind speed are as follows:

- **The Fastest Mile Wind** – The Fastest Mile Wind speed is the average recorded speed during a time interval in which one mile of wind passes a fixed measuring point. The measurement is taken at an elevation of 33 feet in open terrain. The Fastest Mile Wind speed measurement was historically used in many older building codes and design standards such as the Uniform Building Code (all editions) and the American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures (until the 1993 edition) (Ghosh 2008).
- **Sustained Wind** – Sustained Wind is the wind speed averaged over 2 minutes. This is the measurement standard used by the National Weather Service (American Meteorological Society 2022).
- **Peak Gusts** – Peak Gusts are the maximum wind gust speeds averaged over a period of two to five seconds (American Meteorological Society 2012). This is the measurement standard used by modern Hawaiian building codes.

It is important to understand that it is wind load, and not wind speed, that causes wind damage. Wind load is the force or pressure that wind exerts on the outside of a structure. Wind exerts three types of forces on a structure:

- **Uplift load** – Wind flow pressures that create a strong lifting effect, much like the effect on airplane wings. Wind flow under a roof will push upward; wind flow over a roof will pull upward.
- **Shear load** – Horizontal wind pressure that could cause racking of walls, making a building tilt.
- Lateral load – Horizontal pushing and pulling pressure on walls that could make a structure slide off the foundation or overturn (Extension Disaster Education Network n.d.).

LOCATION

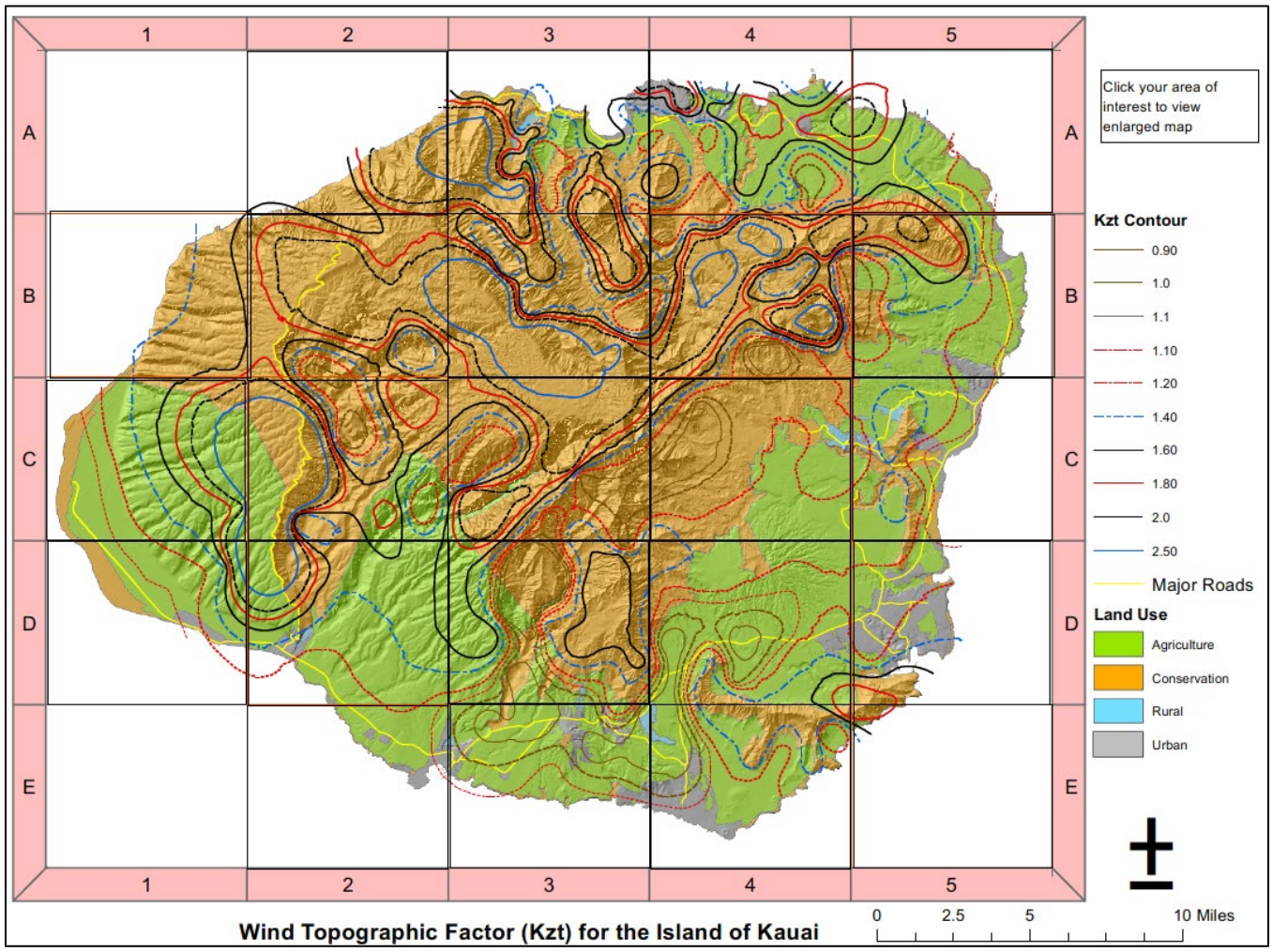
High windstorms can occur anywhere in the State of Hawai‘i; therefore, the entire state and all its counties are susceptible to the direct and indirect impacts of high windstorms; however, topography plays a significant role in where the impacts of high windstorms are most severe. For example, strong kona storms bring wind and rain and can cause extensive damage to south and southwest-facing shores (NOAA 2021). The Kāne‘ohe-Kahalu‘u area, on the windward coast of the Island of O‘ahu (City and County of Honolulu), has had extensive wind damage due to strong kona winds. In the case of the Island of Maui, trade winds appear to be stronger when passing through the isthmus between the West Maui Mountains and Haleakalā, so that wind speeds at locations such as Mā‘alaea and north Kīhei may be higher than locations along the island’s north shore due to wind channeling that often occurs when wind passes between two mountains or into a valley (USGS 2002). In general, wind speeds vary with height above ground—the higher the elevation, the stronger the wind. As a result, the mountainous areas of the State of Hawai‘i generally experience the highest wind speeds (Western Regional Climate Center 2018).

Topographic Effects on Windspeed

Wind speed increases over hills, ridges, and escarpments (steep slopes or long cliffs). This phenomenon is known as wind speed-up. Because wind speed is related to wind pressure, structures in wind speed-up areas will experience more severe damages than those located on flat, open terrain if building codes do not take the local topographic factor into consideration (Soleimanian, Kilanehei and Mehdi Memarpour 2019). In the past, the magnitude of wind speed-up caused by topography in the State of Hawai‘i has not been well understood, and it was not historically considered in any building code used in the state (State of Hawai‘i 2018).

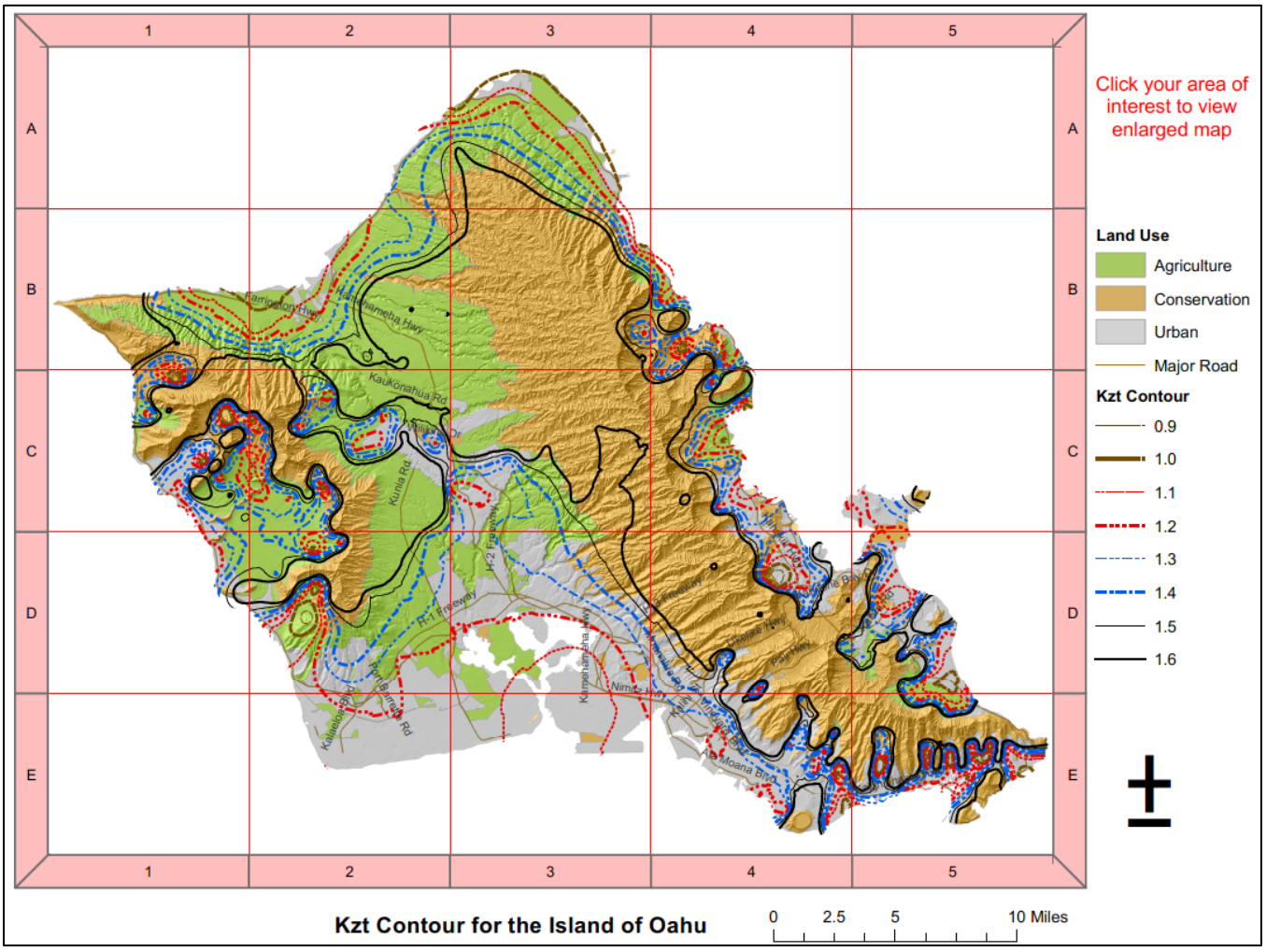
In the early 2000s, an assessment of wind speed-up in the State of Hawai‘i was conducted, and it was determined that existing mapping and standards were insufficient to adequately determine design wind pressures due to the complex topography in the state (Chock and Cochran 2002). In short, the topography has speed-up effects that cannot be adequately portrayed by a single statewide value of wind speed nor at the macro-scale of a national map. This factor, coupled with the designation of the State of Hawai‘i as a special wind region in American Society of Civil Engineers (ASCE) standards, resulted in the development of a procedure and associated mapping to determine design wind pressures in the state that could be incorporated into state and county building codes. The State of Hawai‘i wind design provisions for new construction are included in Appendix W of the Hawai‘i State Building Code (State of Hawai‘i 2021). The requirements are complex and include design provisions for windborne debris, ultimate design wind speeds, directionality factors, and exposure categories. Figure 4.16-1 through Figure 4.16-6 show the wind topographic factors for each island that are included in these design requirements.

Figure 4.16-1. Wind Topographic Factor (Kzt) for the Island of Kaua'i (County of Kaua'i)



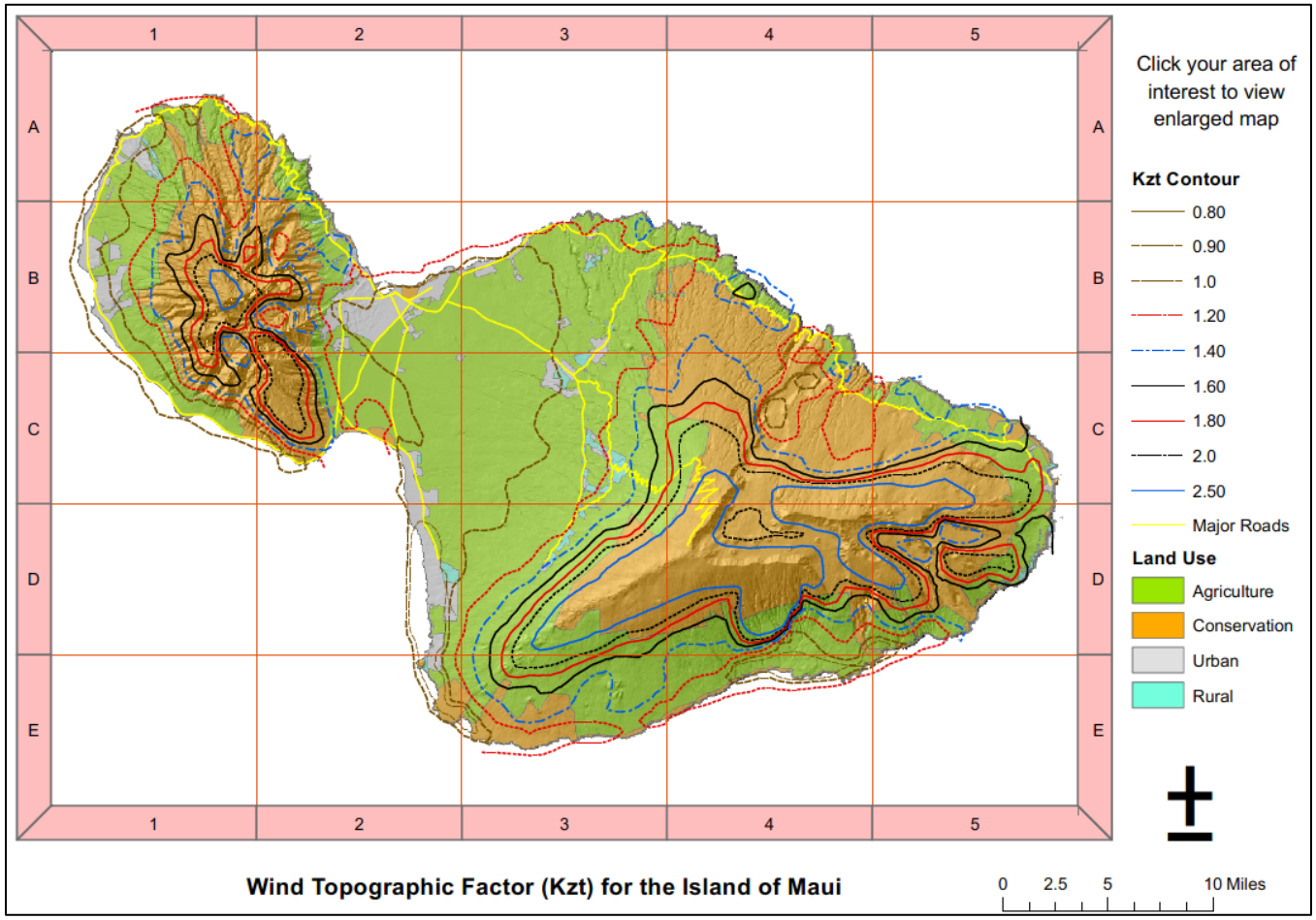
Source: State of Hawai'i Department of Accounting and General Services 2018

Figure 4.16-2. Wind Topographic Factor (Kzt) for the City and County of Honolulu



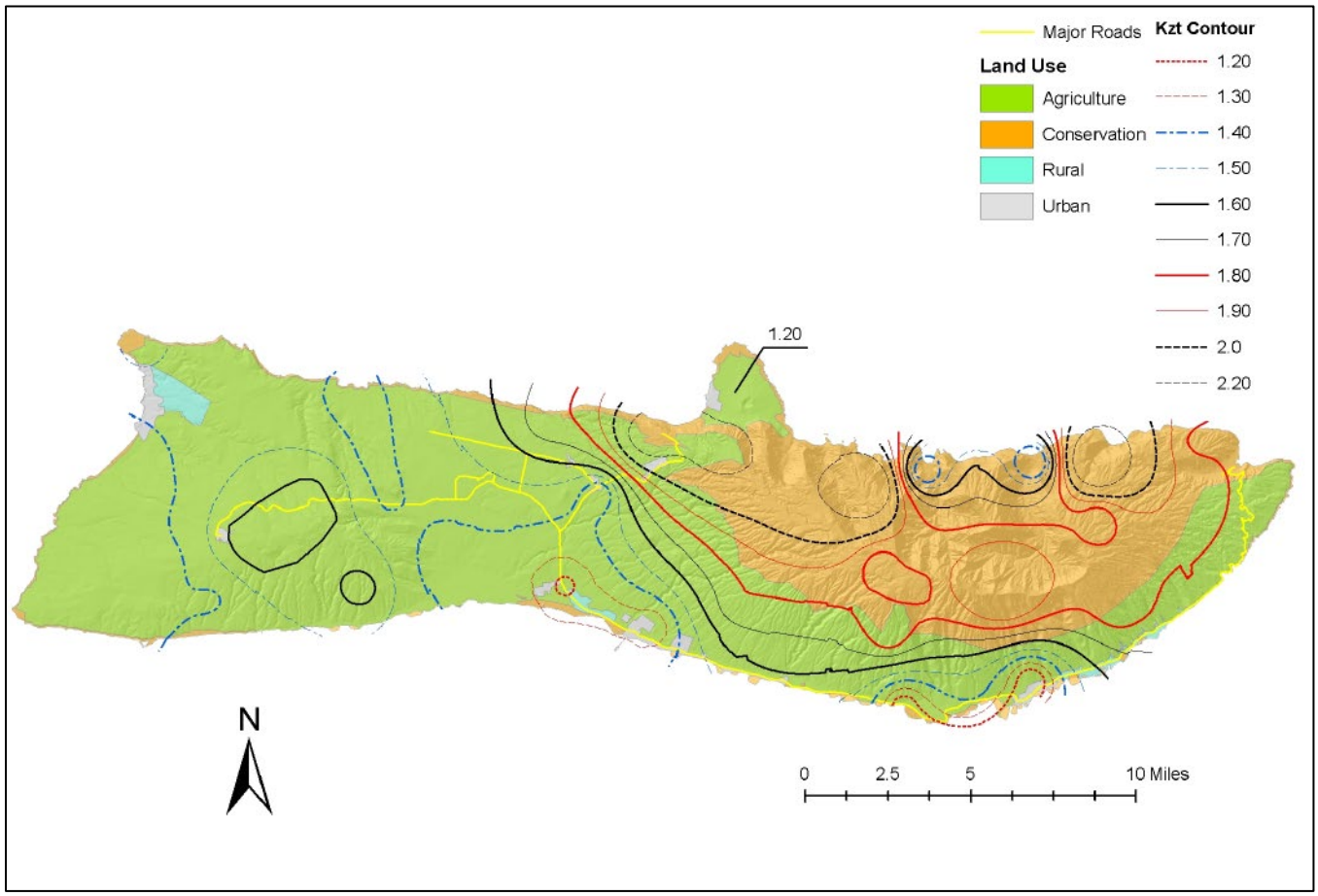
Source: State of Hawai'i Department of Accounting and General Services 2018

Figure 4.16-3. Wind Topographic Factor (Kzt) for the Island of Maui (County of Maui)



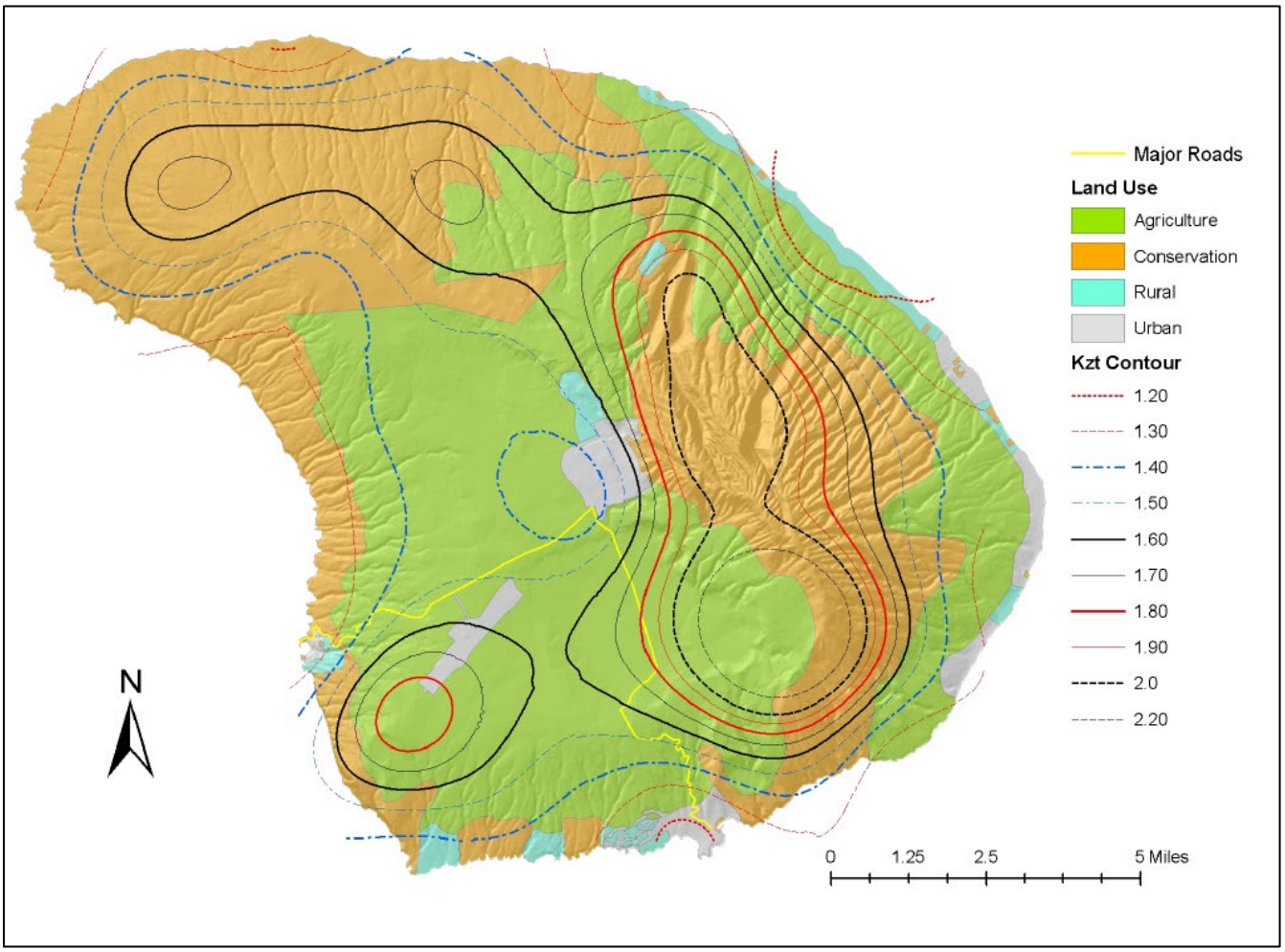
Source: State of Hawai'i Department of Accounting and General Services 2018

Figure 4.16-4. Wind Topographic Factor (Kzt) for the Island of Moloka'i (County of Maui)



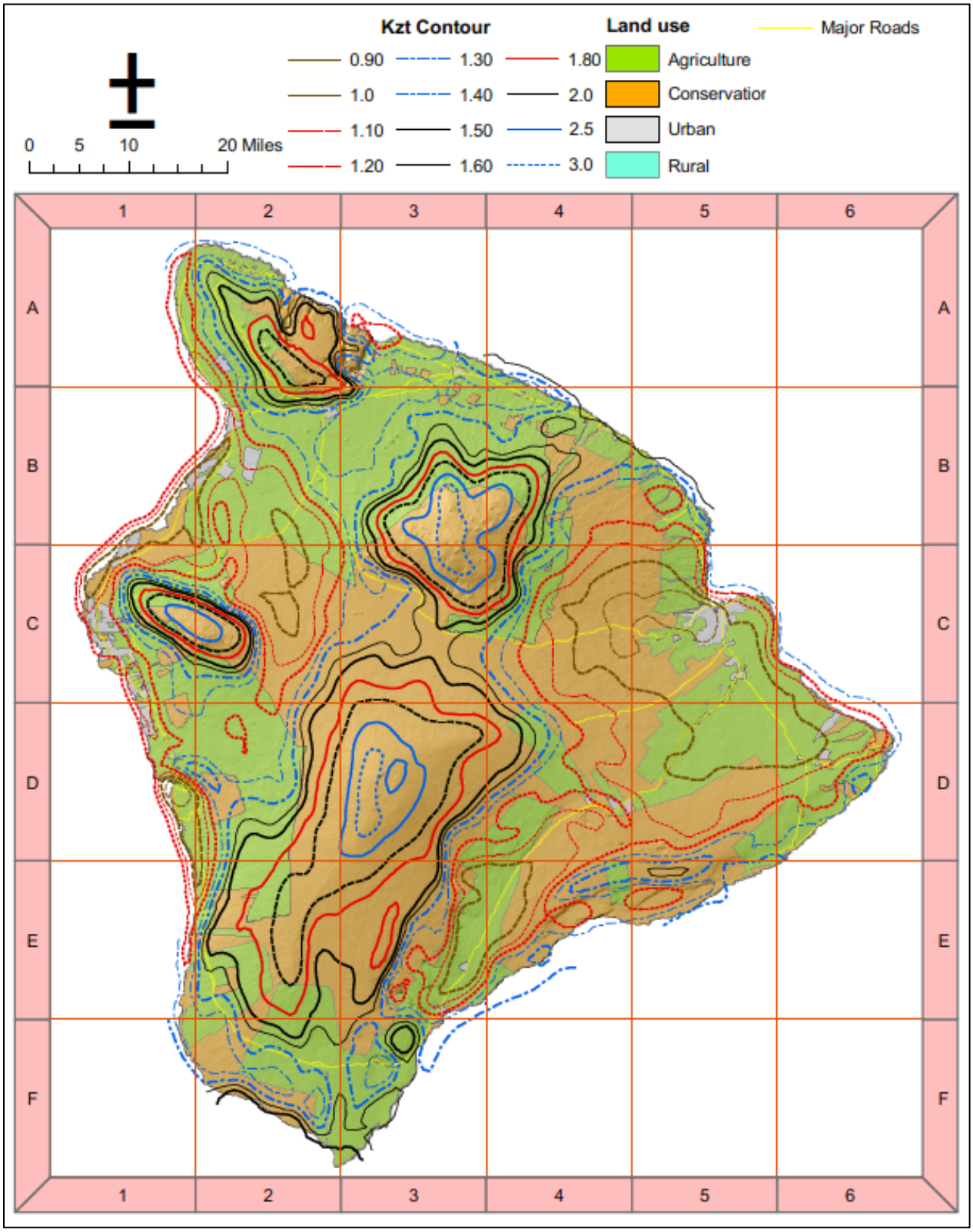
Source: State of Hawai'i Department of Accounting and General Services 2018

Figure 4.16-5. Wind Topographic Factor (Kzt) for the Island of Lānaʻi (County of Maui)



Source: State of Hawaiʻi Department of Accounting and General Services 2018

Figure 4.16-6. Wind Topographic Factor (Kzt) for the County of Hawai'i



Source: State of Hawai'i Department of Accounting and General Services 2018

The topographic factor (K_{zt}) acts as a multiplier in determining peak gusts relative to mild, flat terrain. As a result, buildings of all types constructed under this code are built to a uniform level of risk, that is, all occurrences of amplified wind are addressed in the design of that building so that no building has disproportionate risk (State of Hawai'i 2021, Chock and Cochran 2002).

EXTENT

The Beaufort wind scale, still in use today, was developed in 1805 to help sailors estimate the wind speed through visual observations. The scale includes a description of winds and specifications for use both at sea and on land (see Table 4.16-1) (National Weather Service 2016).

Table 4.16-1. Beaufort Wind Scale

Force	Speed mph (knots)	Description	Specifications for use at sea	Specifications for use on land
0	0 -1 (0 -1)	Calm	Sea like a mirror.	Calm; smoke rises vertically.
1	1 -3 (1 -3)	Light Air	Ripples with the appearance of scales are formed, but without foam crests.	Direction of wind shown by smoke drift, but not by wind vanes.
2	4 -7 (4 -6)	Light Breeze	Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break.	Wind felt on face; leaves rustle; ordinary vanes moved by wind.
3	8 -12 (7 -10)	Gentle Breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.	Leaves and small twigs in constant motion; wind extends light flag.
4	13 -18 (11 -16)	Moderate Breeze	Small waves, becoming larger; fairly frequent white horses.	Raises dust and loose paper; small branches are moved.
5	19 -24 (17 -21)	Fresh Breeze	Moderate waves, taking a more pronounced long form; many white horses are formed.	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	25 -31 (22 -27)	Strong Breeze	Large waves begin to form; the white foam crests are more extensive everywhere.	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	32 -38 (28 -33)	Near Gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	Whole trees in motion; inconvenience felt when walking against the wind.
8	39 -46 (34 -40)	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.	Breaks twigs off trees; generally impedes progress.
9	47 -54 (41 -47)	Severe Gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.	Slight structural damage occurs (chimney-pots and slates removed).
10	55 -63 (48 -55)	Storm	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole, the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected.	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	64 -72 (56 -63)	Violent Storm	Exceptionally high waves (small and medium sized ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	Very rarely experienced; accompanied by widespread damage.
12	72 -83 (64 -71)	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	Refer to Saffir-Simpson Hurricane Scale in Section 4.9 (Hurricane).

Source: National Weather Service 2016

The average speed of the Trade Winds (15.7 mph) is considered a moderate breeze using this scale. When passing through mountain gaps and over mountains, down-sloped kona wind gusts can reach over 100 mph, which are hurricane-force winds (Pacific Disaster Center 2011).

High windstorms can cause disruptions to power, uproot trees, damage boats, blow roofs off homes and have the potential to damage other structures in the state (National Weather Service 2015). Damage does not typically occur until wind speeds of 40 mph or greater are reached; however, large branches of the invasive Albizia *(Falcataria moluccana)* may break and fall with minor wind gusts of 35 mph. In recent years, utility companies have spent millions of dollars repairing infrastructure after high wind events caused Albizia trees and limbs to fall utility lines and poles (Big Island Invasive Species Committee 2023). The State of Hawai'i Building Codes references the ASCE 7 Standard for *Minimum Design Loads for Buildings and Other Structures*, which requires that new buildings in the state be designed to withstand a 120 mph sustained wind or wind gusts of 130 mph. This is equivalent to a Category 3 hurricane (see Section 4.9 Hurricane for more information). In addition, the State of Hawai'i building code imposes additional requirements for structures to be designed to account for the topographic factors discussed previously (State of Hawai'i 2021).

Warning Time

Meteorologists can often predict the likelihood of a high windstorm event. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time. The predicted wind speed given in wind warnings issued by the National Weather Service is for a one-minute average; gusts may be 25% to 30% higher.

The National Weather Service Honolulu Forecast Office issues specific watches, warnings, and advisories when weather threatens the state. For high windstorms, the following may be issued (NWS 2017):

- **High Wind Watch** is issued when sustained winds exceeding 40 mph and/or frequent gusts over 60 mph are likely to develop in the next 24 to 48 hours. For summit areas, high wind watches are issued when sustained winds are expected to exceed 56 mph and/or frequently gust over 66 mph. If you are in an area for which a High Wind Watch has been issued, you should prepare by securing loose objects outdoors that may blow about and avoiding outdoor activity that exposes you to high winds.
- **High Wind Warning** is issued when sustained winds exceeding 40 mph and/or frequent gusts over 60 mph are occurring or imminent. For summit areas, warnings are issued for winds exceeding 56 mph and/or frequently gusting over 66 mph. Wind warnings may be issued up to 24 hours ahead of the onset of high winds. If you are in an area where a high wind warning is in effect, you should avoid activities that expose you to high winds. Loose objects may be blown around. Tree limbs may break and fall. Power lines may be blown down.
- **Wind Advisory** is issued when sustained winds of 30 to 39 mph and/or frequent gusts to 50 mph or greater are occurring or imminent. For summit areas, the sustained wind range is 45 to 55 mph and/or frequent gusts of 55 to 65 mph. Wind advisories may be in effect for 6 to 12 hours. If you are in an area where a wind advisory is in effect, you should secure loose objects that may be blown about outdoors and limit activity that may expose you to high winds.

- **Small Craft Advisory** is issued for the coastal waters when winds of 28 to 37 mph and seas 10 feet or higher are occurring or forecast.
- A **Gale Warning** is issued for coastal, offshore, and high seas areas when winds of 39 to 54 mph not associated with a tropical cyclone are occurring or forecast.
- A **Storm Warning** is issued for coastal, offshore, and high seas areas when winds of 55 to 73 mph not associated with a tropical cyclone are occurring or forecast.

Previous Occurrences and Losses

High wind events, distinct from tropical cyclones, affect the State of Hawai'i on a relatively regular basis. It can be observed from more recent events that the major damage is typically: power outages due to fallen distribution poles; fallen trees, which create debris that often results in damage to structures or other property; and roof damage due to uplift of shingles, tiles, or other types of cladding. Occasionally there are deaths associated with the debris and structural collapses. The storms that produce these high winds often have associated flooding and other hazards that provide further damage and losses.

Many sources provided high windstorm events information regarding previous occurrences and losses throughout the State of Hawai'i. The 2018 SHMP discussed specific high windstorm events that occurred in Hawai'i through 2017. For this 2023 SHMP Update, high wind events were summarized between January 1, 2018, and December 31, 2022. Table 4.16-2 includes details of major high windstorm events that occurred in the state between 2018 and 2022. Not all events are captured in the table below. Only major events that resulted in injuries or fatalities, as reported by NOAA NCEI, events that resulted in the activation of the state and/or county EOC, and/or events that led to a FEMA disaster declaration are listed. For events prior to 2018, please refer to Appendix E (Hazard Profile Supplement).

Table 4.16-2. Windstorm Events in Hawai'i (2018 to 2022)

Date(s) of Event	Event Type	Counties Affected	Description
January 17, 2018	Strong Wind	Honolulu, Hawai'i	Strong trade winds caused power outages with downed lines and trees resulting in road closures. No significant injuries were reported. Crop damages totaled $5,000.00.
January 18, 2018	Strong Wind	Honolulu	Strong trade winds caused widespread power outages and traffic delays due to downed lines, utility poles and trees. No significant injuries were reported. Property damages amounted to $25,000.
January 30, 2018	High Wind	Hawai'i	Winds from the southwest exceeded 70 mph over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. No serious injuries or property damage were reported.
February 1, 2018	High Wind	Hawai'i	Southwest winds strengthened above high wind criteria as an upper air trough moved near the islands. No significant property damage or injuries were reported.
February 5, 2018	High Wind	Hawai'i	Middle- to upper-air flow strengthened over Mauna Kea and Mauna Loa on the Big Island of Hawai'i. No significant property damage or injuries were reported.
February 8, 2018	High Wind	Hawai'i	Middle- to upper-air flow strengthened over Mauna Kea and Mauna Loa on the Big Island of Hawai'i. No significant property damage or injuries were reported.
February 15, 2018	High Wind	Hawai'i	Southwest winds strengthened above high wind criteria over the summits of Mauna Kea and Mauna Loa on the Big Island. No serious property damage or injuries were reported.

Date(s) of Event	Event Type	Counties Affected	Description
February 19, 2018	High Wind	Hawai'i	Southwest winds increased to above high wind criteria over the summits of Mauna Kea and Mauna Loa. There were no reports of serious injuries or property damage.
February 23, 2018	Strong Wind	Hawai'i	Heavy showers, including thunderstorms, formed across the area. There were no reports of serious injuries. A roof in Hilo on the Big Island of Hawai'I was damaged. Winds gusts were recorded to be 39 knots or 45 mph. Property damages amounted to $10,000.00.
March 7, 2018	High Wind	Hawai'i	High winds from the southwest occurred over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. No serious injuries or property damage were reported.
March 12, 2018	High Wind	Hawai'i	Winds from the south to southwest increased across the summits of Mauna Kea and Mauna Loa on the Big Island. There were no reports of serious injuries or property damage.
March 20, 2018	High Wind	Hawai'i	South to southwest winds accelerated over the summits of Mauna Kea and Mauna Loa on the Big Island. There were no reports of serious injuries or property damage.
March 23, 2018	High Wind	Hawai'i	Southwest winds increased above high wind criteria over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. There were no reports of significant property damage or injuries.
April 2, 2018	High Wind	Hawai'i	Southwest winds over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i increased beyond the high wind threshold. No serious injuries or property damage were reported.
April 27, 2018	High Wind	Hawai'i	Winds from the southwest exceeded high wind criteria over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. There were no reports of serious property damage or injuries.
April 29, 2018	High Wind	Hawai'i	Southwest winds exceeded high wind criteria over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. No significant property damage or injuries were reported.
May 1, 2018	High Wind	Hawai'i	Southwest winds exceeded high wind criteria over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. No significant property damage or injuries were reported.
September 11, 2018 – September 12, 2018	Strong Wind	Honolulu, Maui	As Tropical Storm Olivia approached the islands from the east-northeast and then made a double landfall in Maui County on September 12th, it brought gusty winds and heavy precipitation. Most of its effects were concentrated over Maui, Molokai, and O'ahu. The system downed trees, closed roads, caused power outages and debris flows, and generated flash flooding. There were no reports of serious injuries. Crop damages totaled $18,000.00.
January 27, 2019	High Wind	Hawai'i	Southwest to west winds increased to more than 80 mph over the summits of Mauna Kea and Mauna Loa on the Big Island. No significant injuries or property damage were reported.
January 28, 2019 – January 30, 2019	Strong Wind	Hawai'i, Honolulu	A surface trough just east of the island chain, in combination with high pressure north of the state, induced strong north winds across the area. Damages from the winds occurred on the Big Island and O'ahu, with one individual injured on O'ahu as well. The tin roof of a building was blown off at the Kona Airport in the leeward part of the Big Island. Six trees were downed near Hilo. On O'ahu, a house lost its roof due to strong winds. An 89-year-old man was injured. Property damages amounted to $32,000.00.

Date(s) of Event	Event Type	Counties Affected	Description
February 7, 2019 – February 11, 2019	High Wind, Strong Wind	Kaua'i, Honolulu, Maui, Hawai'i	A powerful storm brought fierce winds to most areas of the state, with lower-level winds exceeding 50-knot gusts on Kaua'i at Port Allen and Barking Sands, and enhanced surf, especially along north- and west-facing shores. Surf heights in some locales reached above 50 feet for north-facing shores and above 30 feet for west-facing shores. The very strong winds at the summits of Mauna Kea and Mauna Loa on the Big Island and the summit of Haleakalā on Maui produced blizzard-type conditions as the feature affected the region. No significant injuries were reported. Winds gusted just over 50 knots at Barking Sands in leeward Kaua'i. Winds gusted over 55 knots at Port Allen in leeward Kaua'i. A rooftop was blown off and trees and power poles were downed on O'ahu, blocking roadways and causing power outages for nearly 10,000 customers. Mainly SW to W winds were sustained from 60 to 135 mph, with gusts as high as 161 mph, at the summits of Mauna Kea and Mauna Loa on the Big Island. Winds were somewhat less at the summit of Haleakalā on Maui. State highways on the Big Island of Hawai'i were closed by downed power poles and trees. A downed 100-foot tree crashed through a house, blocking a nearby road and taking down power lines near Honomu in windward Big Island. Property damages amounted to $185,000.00, crop damages totaled $44,000.00.
February 20, 2019	High Wind	Hawai'i	Winds from the south to southwest were sustained above 60 mph, with gusts as high as 77 mph. No serious injuries or property damage were reported.
February 27, 2019	High Wind	Hawai'i	Mainly south to southwest winds increased to over 60 mph, with gusts as high as 81 mph. No significant injuries or property damage were reported.
March 16, 2019	High Wind	Hawai'i	West winds on the summits of Mauna Kea and Mauna Loa on the Big Island gusted above 75 mph. There were no reports of serious injuries or property damage.
May 3, 2019	High Wind	Hawai'i	A late-season cold front and strong upper trough generated periods of heavy showers over parts of the state and high winds across the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. The precipitation caused ponding on roadways and small stream and drainage ditch flooding. There were no reports of serious injuries or property damage.
November 18, 2019	Strong Wind	Kaua'i, Honolulu, Hawai'i	Heavy showers and thunderstorms formed and rainfall affected most of the islands, with flash flooding occurring in Kaua'i and on the Big Island. However, no serious injuries were reported. Minor property damage occurred on O'ahu from trees falling on automobiles. There were minor power outages. Property damages amounted to $2,000.00.
December 20, 2019 – December 21, 2019	Strong Wind	Honolulu, Hawai'i	Trade winds became breezy to strong over most of the state. Trees and power poles were downed by the winds, especially on O'ahu. However, no serious injuries were reported. Several trees fell, and a roof was blown off. Strong winds toppled two power poles. Property damages amounted to $25,250.00; crop damages totaled $3,000.00.
December 24, 2019 – December 25, 2019	High Wind, Strong Wind	Kaua'i, Hawai'i, Honolulu	The weather system caused a flash flood and felled trees and power poles, especially on Kaua'i. No significant injuries were reported. Winds gusted to 63 mph on O'ahu in Honolulu County. Winds, mainly from the southwest, gusted over 80 mph for a time over the Big Island summits of Mauna Kea and Mauna Loa. Winds downed power lines and poles on Kaua'i. Roads were closed from downed trees. Property damages amounted to $10,000.00; crop damages totaled $2,000.00.
December 30, 2019	High Wind	Hawai'i	Winds from the northeast gusted around 70 to 80 mph over the summits of Mauna Kea and Mauna Loa on the Big Island. No significant injuries or property damage were reported.

Date(s) of Event	Event Type	Counties Affected	Description
January 5, 2020	High Wind	Hawai'i	Winds from the northeast gusted above 70 mph over the Big Island summits of Mauna Kea and Mauna Loa. There were no reports of serious property damage or injuries.
January 7, 2020	Strong Wind	Honolulu	Gusty trade winds caused by strong high pressure centered northeast of the islands downed a tree along the H-3 Freeway on O'ahu. For a time, the tree blocked the Kaneohe-bound lane of the roadway about five miles west of the town. Otherwise, there were no reports of serious property damage or injuries. Crop damages totaled $2,000.00.
January 12, 2020	High Wind	Hawai'i	Northeast winds gusted to over 100 mph over the Big Island summits of Mauna Kea and Mauna Loa. No significant injuries or property damage were reported.
February 6, 2020	High Wind	Kaua'i, Hawai'i	A front moving slowly from the northwest triggered showers and downpours across much of the state. The most significant rainfall was over Kaua'i, where flash flooding occurred over the northern part of the isle. High winds also accompanied the system, mainly over the summits of Mauna Kea and Mauna Loa on the Big Island. There were no significant injuries or property damage. Mainly southwest winds over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i were sustained, at times, over 100 mph, with gusts topping 140 mph.
February 13, 2020	Strong Wind	Hawai'i	Gusty winds felled several trees along the Old Saddle Road on the Big Island of Hawai'i, between the Daniel K. Inouye Highway and the Lower Waikii Ranch Gate. The trees on the roadway forced its closure for a time on the 13th. No serious injuries were reported. Crop damages totaled $20,000.00.
February 20, 2020	Strong Wind	Honolulu, Hawai'i	Strong winds caused several trees to on O'ahu, which closed roadways. Gusty winds brought down a power line on the Big Island, which closed the Old Mamalahoa Highway. There were no reports of serious injuries. Property damages amounted to $2,000.00; crop damages totaled $15,000.00.
February 29, 2020	Strong Wind	Honolulu	Blustery winds toppled a tree onto Waiahole Valley Road in windward O'ahu. The road was closed for a time due to the tree blocking both lanes of the roadway. No serious injuries were reported. Crop damages totaled $5,000.00.
March 11, 2020	High Wind	Hawai'i	An upper trough moving north of the islands produced southwest to west winds over the summits of Mauna Kea and Mauna Loa that gusted near 70 knots. No serious injuries or property damage were reported.
March 18, 2020	High Wind	Hawai'i	For a brief time, southwest winds gusted above 65 to 70 knots over the Mauna Kea and Mauna Loa summits on the Big Island. There were no reports of significant property damage or injuries.
March 25, 2020	Strong Wind	Honolulu, Hawai'i	Power lines and poles, and several trees, were felled by blustery trade winds on the Big Island and O'ahu. No serious injuries were reported. Downed tree and power lines blocked Highway 11 near Naalehu, on the Big Island. Kalihi Street was closed for a time in both directions near Umalu Place on O'ahu due to fallen power poles and trees on the roadway. Property damages amounted to $15,000.00; crop damages totaled $8,000.00.
April 10, 2020	High Wind	Hawai'i	Southwest winds briefly gusted above 60 mph over the summits of Mauna Kea and Mauna Loa on the Big Island. No serious injuries or property damage were reported.
November 22, 2020	Strong Wind	Hawai'i	Power lines were downed west of Naalehu in Hawaiian Ocean View Estates on the Big Island of Hawai'i. This caused a road closure. Property damages amounted to $5,000.00.
February 28, 2021 – March 1, 2021	Strong Wind	Honolulu, Hawai'i	Gusty winds toppled a tree near the Mililani Golf Course, injuring one person. Gusty trade winds helped keep showers moving as an upper trough induced downpours from the Big Island to O'ahu. The precipitation caused ponding on roadways, and small stream and drainage ditch flooding. Two individual hikers lost their lives. A large ironwood tree fell onto a vehicle on Kamehameha Highway near Kahana Bay. Two individuals were injured. Crop damages totaled $3,000.00.

Date(s) of Event	Event Type	Counties Affected	Description
December 4, 2021	High Wind	Honolulu, Hawai'i, Maui	A Kona low, produced heavy and sustained showers and thunderstorms as tropical moisture was pulled north over the dtate. The downpours also led to instances of flash flooding. High winds and wintry conditions affected the mountain summits on the Big Island and Haleakalā on Maui. No significant injuries were reported. The costs of any damages were not available. Winds from various directions gusted over 100 mph during a period that lasted more than one day over the summits of Mauna Kea and Mauna Loa on the Big Island of Hawai'i. Winds also gusted over 90 mph on the Haleakalā Summit on Maui.
May 18, 2022 – May 19, 2022	Strong Wind	Kaua'i	Strong winds associated with a front downed trees over portions of Kaua'i, blocking several roadways on the isle. No serious injuries or property damage were reported. Crop damages totaled $12,000.00.

Source: FEMA 2023; NOAA 2023
Note:
With high windstorm documentation for Hawai'i being so extensive, not all sources have been identified or researched. Additionally, loss and impact information for many events could vary depending on the source. Therefore, this table may not include all events that have occurred in the state and the accuracy of monetary figures discussed is based only on the available information identified during research for this 2023 SHMP update.

Disaster and Emergency Declarations

Known high wind events that have impacted the State of Hawai'i and were declared a FEMA disaster, between January 01, 2018, and December 31, 2022, are identified in Table 4.16-3. For events prior to 2018, please refer to Appendix E (Hazard Profile Supplement). It is recognized that FEMA declarations may not specify the event as a "high windstorm" and may refer to the event type as a severe storm, making it challenging to distinguish the declaration from hurricanes. For details regarding all declared disasters, refer to Section 4.1 (Overview) and Appendix D (Map Atlas).

Table 4.16-3. Windstorm-Related Federal Declarations (2018 to 2022)

Event Type	Date Declared	Federal Declaration Number	Counties Affected
Severe Storms and Flooding	July 9, 2020	DR-4549-HI	Kaua'i
Severe Storms, Flooding, and Landslides	February 15, 2022	DR-4639-HI	Honolulu, Maui

Source: FEMA 2023
Note:
Hurricane and Tropical Storm declarations are included in Section 4.9 Hurricane.

The following disaster declarations or emergency proclamations related to windstorm have been issued for Hawai'i:

- **Federal disaster (DR) or emergency (EM) declarations, 1955 – 2022**: 15 windstorm-related events, classified as severe storms, flooding, and landslides
- **Hawai'i state emergency proclamations, 2018 – 2022**: 2 windstorm-related events, classified as severe storm and flooding
- **USDA agricultural disaster declarations, 2018 – 2022**: 8 windstorm-related events

PROBABILITY OF FUTURE HAZARD EVENTS

Overall Probability

Overall, high wind events will occur regularly as part of severe weather events across the state. Based on historical record, the State of Hawai‘i has experienced 17 FEMA declarations associated with severe storms since 1954. The state can experience a major event that leads to a FEMA declaration once every five years.

Looking at all high wind events, there have been 611 events between 1954 and 2022. Based on this data, the State of Hawai‘i may experience between an estimated nine high wind events each year (NOAA 2023). The State of Hawai‘i can expect a 100% chance of high windstorms occurring annually.

Climate Change Impacts

Although the average atmospheric and land surface temperature are increasing in the State of Hawai‘i and are projected to continue rising, the rates will vary depending on land uses, topography, and trade wind and precipitation patterns. The effect of climate change on the trade winds, which bring a steady supply of rainfall to the Hawaiian Islands, is a source of uncertainty in local predictions. Winds are changing over the Hawaiian Islands. Changes detected in the prevailing wind over the Hawaiian Islands, the northeast trade wind, may shift large-scale pressure and wind patterns that impact the State of Hawai‘i in the future (Garza, et al. 2012).

There are fewer days with northeast trade winds than 40 years ago. Fewer days of northeast trade winds leads to more muggy weather and volcanic haze, resulting in longer-term effects for the state (Garza, et al. 2012).

Scientists from the University of Hawai‘i at Mānoa analyzed wind records from 1973 to 2009 at major airports in the State of Hawai‘i: Līhu‘e, Honolulu, Kahului, and Hilo. They also collected data from four weather buoys in waters around the islands. The study found for Honolulu, northeast trade winds dropped from 291 days per year to 210 days per year over the 40-year period. The two largest decreases occurred in 1981 and 1997. In 1981, a high-pressure system shut off northeast trade winds, causing a major drought in the state. In 1997, the strongest El Niño event ever recorded weakened the northeasterly trade winds (Garza, et al. 2012) (Live Science 2012).

The anticipated intensity, frequency, and duration of specific windstorm events resulting from climate change impacts is difficult to predict for a particular location in the state. The reduction of trade winds may increase drought conditions on windward sides of the islands, which may subsequently increase the likelihood of extreme heat events, wildfire risk, and air quality impacts from volcanic haze. The increase in kona winds on the leeward sides of the islands could subsequently increase the spread of wildfires exacerbated by drought conditions.

For details regarding climate change as a distinct hazard and its unique impacts to the State of Hawai‘i, refer to Section 4.2 (Climate Change and Sea Level Rise).

4.16.2 VULNERABILITY ASSESSMENT

High windstorms can occur anywhere in the State of Hawai‘i; however, as previously discussed, topography plays a significant role in where the impacts are most severe. Terrain-related amplification of wind speeds have led to significant losses in the state. Kona storm events not only bring high winds, but also large amounts of rain that

result in flash flooding, snow at high altitudes, hail, and severe thunderstorms. For further discussion on flooding and surge impacts, refer to Sections 4.6 (Flood) and Section 4.9 (Hurricane). This vulnerability assessment focuses on the high wind component to these storm events. No spatial data was available for the high windstorm vulnerability assessment. Therefore, a qualitative assessment was conducted and is presented below.

Assessment of State Vulnerability and Potential Losses

This section discusses statewide vulnerability of exposed state assets (state buildings and roads) and critical facilities to high windstorm events.

State Assets

As noted earlier, the Hawai'i State Building Code requires new structures to be built to withstand a Category 3 hurricane wind speed. Any state buildings that were built before the building code incorporated provisions for wind load and topographic factor are particularly vulnerable. Depending on the severity and duration of the storm, a high windstorm, as described earlier, can cause windows and doors to be blown out, roofs to be ripped off, and walls to collapse. Although it is unlikely that high winds would directly damage state roads, debris has blocked roads, isolating areas and putting already vulnerable populations at even greater risk.

Community Lifelines and Critical Facilities

All community lifelines and critical facilities in the state are vulnerable to high windstorms. Loss of utilities is the most common issue with high windstorms. High winds can severely impact power transmission lines as high winds are funneled through changes in terrain, causing widespread power outages. For example, on December 26, 2008, the entire electrical grid on the island of O'ahu (City and County of Honolulu) was blacked out for around 12 hours due to a kona storm (Bachmeiere 2008). The interruption of power, water, wastewater. as well as critical services such as hospitals and other emergency services has cascading impacts on residents, visitors, and all forms of economic activity.

As summarized in Section 4.2 (Climate Change and Sea Level Rise), the primary transportation arteries for the entry of people and goods to the state is the Daniel K. Inouye International Airport and Honolulu Harbor. In addition, each island has critical points of entry for people and goods located along the coast. Ports, harbors, and airports are especially vulnerable to the high windstorm hazard. Damages and closures to these critical facilities will likely be long-term and have cascading economic impacts statewide.

Kona wind events, such as the January 1980 storm, have caused the closure of airports. The 1980 storm produced sustained winds of 40 to 50 mph gusting over 100 mph in certain regions due to topographical features. According to the Hawai'i Department of Transportation, anchorage for deep-draft vessels exist outside the Honolulu Harbor in Mamala Bay off Sand Island and west of the Main Channel (also known as Fort Armstrong Channel). However, anchorage is not possible during kona wind conditions (World Port Source 2013).

In February 2017, the HI-EMA conducted a series of workshops to continue its ongoing efforts to address temporary emergency power planning requirements outlined in the 2015 *Hawai'i Catastrophic Hurricane Plan*. As a result, the state identified critical facilities within each county and developed a method to prioritize the allocation of limited generator resources. The critical facilities identified through this process were used in the risk

assessment for the 2018 SHMP Update and this 2023 SHMP Update. Exposure and potential impacts to these critical facilities resulting from natural hazard events are reported throughout Section 4 (Risk Assessment).

Economic (monetary) losses due to high windstorms on critical infrastructure such as airports, harbors, water, sewer, and power utilities were not calculated due to the variable cost of such infrastructure and the complexity and uncertainty involved based on design, siting, and construction. However, estimated costs for the resiliency and hardening of electric power systems are available through the efforts being made after Puerto Rico was struck by Hurricanes Irma and Maria in 2017. These two hurricanes resulted in catastrophic damage to the island and a complete failure of Puerto Rico's power grid. Similar to the State of Hawai'i, Puerto Rico also experiences wind speed-up due to the differences in terrain across the island. As reported in *Build Back Better: Reimagining and Strengthening the Power Grid of Puerto Rico*, the estimated cost per mile for hardening is $1.25 to $7 million, depending upon if low or high voltage lines are used (Puerto Rico Energy Resiliency Working Group and Navigant Consulting 2017).

Assessment of Local Vulnerability and Potential Losses

Overall, high windstorms can occur anywhere in the State of Hawai'i. In terms of vulnerability, the strong kona storms and associated wind, rain, and wave heights can cause extensive damage to the south- and west-facing shores of the islands. This section provides a summary of vulnerability and potential losses to population, general building stock, and environmental/cultural assets by county.

The local HMPs were reviewed to integrate risk assessment results into the 2023 SHMP Update; a summary of information available is below.

- **County of Kaua'i** –The County HMP includes windstorms as part of their Tropical Cyclone and Other High Winds hazard. The county includes an overview of wind types experienced in the plan area, including Trade Winds, Tropical Cyclones, and Kona Winds. The county performed a Level 2 Hazus analysis which found that 14,102 residents would be displaced by Category 4 hurricane wind; 288 critical facilities would be impacted by Category 4 hurricane wind (County of Kaua'i 2020).
- **City and County of Honolulu** – The City and County discusses Strong Winds in place of a Windstorm hazard. The HMP includes an overview of different types of wind pressure and wind types relevant for the county, including Trade Winds, Tropical Cyclones, and Kona Winds (Tropical Cyclones are explored as a separate hazard) (City and County of Honolulu 2020).
- **County of Maui** – The Maui County HMP provides a qualitative overview of windstorm risk within the county. Maui County is classified as a Zone II wind zone, capable of experiencing winds up to 160 miles per hour. Areas at greatest risk to wind events are south-facing shorelines and communities along the northern slopes of Haleakalā. Additionally, the HMP lists residents who are most vulnerable to flood risk, including single parent and dependent households, residents living below the poverty line, residents without adequate communication infrastructure and/or limited English proficiency, residents living in properties built prior to the 1950s, and residents with limited mobility (County of Maui 2020).
- **County of Hawai'i** – The HMP includes an overview of different types of wind pressure and wind types relevant for the county, including Trade Winds, Tropicaly Cyclones, and Kona Winds (Tropical Cyclones are explored as a separate hazard). Hawai'i County is located in FEMA's Wind Zone II, with speeds up to 160 miles per hour. The HMP discusses populations particularly at risk to windstorms, including the elderly,

low income or linguistically isolated populations, and people with life-threatening illnesses (County of Hawai‘i 2020).

Socially Vulnerable and Total Population

Because the entire population of the state is exposed and vulnerable to windstorms, the exposed population in socially vulnerable communities is equal to the total population. Vulnerable populations are the elderly, low income or linguistically isolated populations, people with life threatening illnesses, and residents living in areas that are isolated from major roads. Power outages from windstorms can be life-threatening to those dependent on electricity for life support and is a significant concern. These populations face isolation and exposure during windstorm events and could suffer more secondary effects of the hazard.

Certain areas are more vulnerable because of their geographic location and local weather patterns. For example, people living at higher elevations with large stands of trees or nearby powerlines may be more susceptible to wind damage and loss of power. Kona winds that accelerate down the slopes of mountains, hills, and escarpments, historically reaching up to 100 miles per hour, can be very destructive when they reach populated low-lying areas. It is common for trees to be uprooted, signs and utility poles to be overturned, debris to be carried by the winds and for residential roofs to be blown off. Damage can be inflicted on boats caught in the open ocean or anchored in the southwest-exposed anchorages (Pacific Disaster Center 2011).

Kona winds can also bring volcanic smog (vog) from Kīlauea in the County of Hawai‘i up the island chain reaching the County of Maui and City and County of Honolulu (Tofte, Chu and Barnes 2017). This makes visibility poor and causes eye and respiratory irritation. Refer to Section 4.14 (Volcanic Hazards) for a more detailed discussion of vog and human health impacts.

After high wind events, residents may be displaced or require temporary to long-term sheltering. Vulnerable populations, such as the elderly, low-income and linguistically isolated populations, are most susceptible to high windstorms. This vulnerability is based on several factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Other risk factors include that power outages can be life-threatening to people dependent on electricity for life support. Because these vulnerable populations face various forms of isolation, they are more at risk for secondary effects from the high wind hazard.

General Building Stock

As noted earlier, the Hawai‘i State Building Code requires new structures to be built to withstand a Category 3 hurricane wind speed. Any structures that were built before the building code incorporated provisions for wind load and topographic factor are particularly vulnerable. More vulnerable locations include those at higher elevations, on leeward sides of islands during Kona winds, on ridge lines, under or near powerlines, or near large trees. Depending on the severity and duration of the storm, a high windstorm can cause windows and doors to be blown out, roofs to be ripped off, and walls to collapse.

Spatial data was not available to conduct an exposure analysis based on wind speed zones. When estimating the potential impact to individual structures, the structural integrity, mitigation measures in place, building construction and date of construction should be considered. Because of differences in building construction,

residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. Refer to Section 4.9 (Hurricane) for further discussion on impacts resulting from high wind speeds associated with tropical cyclone events for all counties in the state.

Environmental Resources and Cultural Assets

Natural habitats such as forests and waterways are vulnerable to damage from high windstorms. Major damage can occur from downed or uprooted trees, other debris, as well as rivers and streams blocked by various types of debris. Agricultural losses have been reported due to historic kona wind events; for example, macadamia, coffee, foliage, and flower farms incurred losses as a result of the January 1980 event in the County of Hawai‘i. In general, forest trees on the leeward side of each island are sheltered from the prevalent trade winds, but strong kona winds blow from the opposite direction and can topple trees that are not accustomed to that wind direction and intensity.

A kona storm can bring large amounts of rain in a short period of time to the leeward side of the islands that tend to be drier. In addition, major kona storm events can bring large wave heights and resulting shoreline change which may impact environmental and cultural assets along the shore (Rooney and Fletcher III 2005).

Future Changes that May Impact State Vulnerability

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

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

All future development in each county and statewide is vulnerable to high wind hazards. However, the ability to withstand impacts from high winds is based in appropriate land use practices and consistent enforcement of codes and regulations for new construction. As older structures are replaced with new structures built to modern building codes, overall vulnerability to the high windstorm hazard will decrease.

It is possible to use global climate models and a regional high-resolution climate model to assess future high wind hazards and flooding events for the State of Hawai‘i. This approach, known as dynamical downscaling, promises to yield more detailed spatial distribution and temporal variability of meteorological hazards in the future. This approach is particularly amenable for Hawai‘i because of its complex terrain, high mountains, and rugged coastlines. Refer to the 2023 mitigation action plan in Section 6 (Mitigation Strategy) for new actions to further evaluate this hazard.

Windstorm Hazard Mitigation Success Story

Credit: HI-EMA

The Honolulu Board of Water Supply and the Hawai‘i County Department of Water Supply each received federal grant funding to protect the water supply of Honolulu and Hawai‘i Counties. Funding include the purchase of mobile generators and transfer switches to provide redundant power at key pumping facilities when the primary power supply is interrupted due to adverse weather conditions, including windstorms.