Modeling the 1%-Annual-Chance Coastal Flood Zone (1%CFZ) with Sea Level Rise in Hawai‘i

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Introduction

Tropical storms, hurricanes, and tsunamis create waves that flood low-lying coastal areas. The National Flood Insurance Program (NFIP) produces flood insurance rate maps (FIRMs) that depict flood risk zones referred to as Special Flood Hazard Areas (SFHA) based modeling 1%-annual-chance flood event also referred to as a 100-year flood. The purpose of the FIRM is twofold: (1) to provide the basis for application of regulatory standards and (2) to provide the basis for insurance rating.

SFHAs identify areas at risk from infrequent but severe storm-induced wave events and riverine flood events that are based upon historical record. By law (44 Code of Federal Regulations [CFR] 60.3), FEMA can only map flood risk that will be utilized for land use regulation or insurance rating based on historical data, therefore, future conditions with sea level rise and other impacts of climate change are not considered in FIRMs. It is important to note that FEMA can produce Flood Insurance Rate Maps that include future condition floodplains, but these would be considered “awareness” zones and not to be used for regulatory of insurance rating purposes.

The State of Hawaiʻi 2018 Hazard Mitigation Plan incorporated the results of modeling and an assessment of vulnerability to coastal flooding from storm-induced wave events with sea level rise (Tetra Tech Inc., 2018). The 1% annual-chance-coastal flood zone with sea level rise (1%CFZ) was modeled to estimate coastal flood extents and wave heights for wave-generating events with sea level rise. Modeling was conducted by Sobis Inc. under State of Hawaiʻi Department of Land and Natural Resources Contract No: 64064. The 1%CFZ with 3.2 feet of sea level rise was utilized to assess vulnerability to coastal event-based flooding in mid to - late century.

The 1%CFZ with sea level rise would greatly expand the impacts from a 100-year flood event meaning that more coastal land area will be exposed to damaging waves. For example, over 120 critical infrastructure facilities in the City and County of Honolulu, including water, waste, and wastewater systems and communication and energy facilities would be impacted in the 1%CFZ with 3.2 feet of sea level rise (Tetra Tech Inc., 2018). This is double the number of facilities in the SFHA which includes the impacts of riverine flooding.

Modeling Approach

A simplified version of the Wave Height Analysis for Flood Insurance Studies (WHAFIS) extension (FEMA, 2019b) included in Hazus-MH, was used to create the 1% annual chance coastal floodplain. Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, tsunamis, and hurricanes (FEMA, 2019a). A schematic of key inputs and outputs of modeling the 1%CFZ with sea level rise is shown in Figure 1.

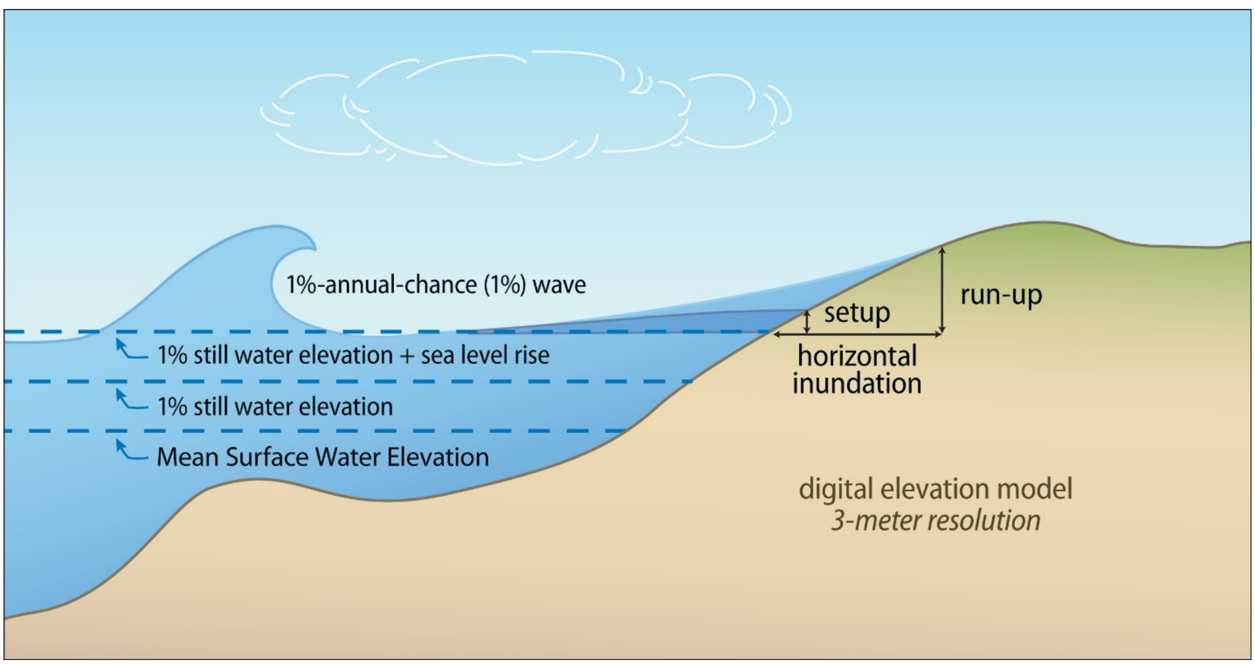

Figure 1. Schematic diagram of showing key inputs and outputs of modeling the 1%-annual-chance coastal flood zone (1%CFZ)

The current 1%-annual-chance stillwater elevations were collected using the most current flood insurance studies (FIS) for each island conducted by FEMA (FEMA, 2004, 2010, 2014, 2015). The FIS calculates the 1%-annual-chance stillwater elevation, wave setup, and wave run-up (called maximum wave crest) at regularly-spaced transects around the islands based on historical data. Modeling for the 1%CFZ used the NOAA 3-meter digital elevation model (DEM) which incorporates LiDAR data sets collected between 2003 and 2007 from NOAA, FEMA, the State of Hawaiʻi Emergency Management Agency, and the USACE (NOAA National Centers for Environmental Information, 2017).

Before Hazus was run for future conditions, it was run for the current conditions and compared to the FEMA regulatory floodplain to determine model accuracy. This also helped determine the stillwater elevation for the large gaps between some transects in the FIS. Hazus was run at 0.5-foot stillwater level intervals and the results were compared to the existing Flood Insurance Rate Map (FIRM). The interval of 0.5-feet was chosen as a small enough step to result in a near approximation of the FIRM while not being too impractically narrow to require the testing of dozens of input elevations. The elevation which matched up best was used as the current base flood elevation.

Key steps in modeling the projected 1%CFZ with sea level rise include: (1) generating a contiguous (no gaps along the shoreline) and present-day 1%-annual-chance stillwater elevation based on the most recent FIS, (2) elevating the present-day 1%-annual-chance stillwater elevation by adding projected sea level rise heights, and (3) modeling the projected 1%-annual-chance coastal flood with sea level rise in HAZUS using the 1%-annual-chance wave setup and run-up from the FIS. The 1%CFZ extent and depth was generated using the HAZUS 3.2 coastal flood risk assessment model, 3-meter DEM, the FIS for each island, and the IPCC AR5 upper sea level projection for RCP 8.5 scenario for 0.6 feet, 1.0 feet, 2.0 feet, and 3.2 feet of sea level rise above MHHW (IPCC, 2014). The HAZUS output includes the estimated spatial extent of coastal flooding as well as an estimated flood depth map grid for the four sea level rise projections.

Using the current floodplain generated with Hazus, the projected 1%-annual-chance stillwater elevation was generated using the four sea level rise projections. This stillwater elevation with sea level rise was used as a basis for modeling. The projected 1%-annual coastal flood with sea level rise was modeled in Hazus using the current 1%-annual-chance wave setup and run-up from the FIS and the projected 1%-annual-chance stillwater elevation with sea level rise. Example maps showing the extent of the 1%CFZ with 1 foot and 3.2 feet of sea level rise in Honolulu are shown in Figure 2 and 3, respectively.

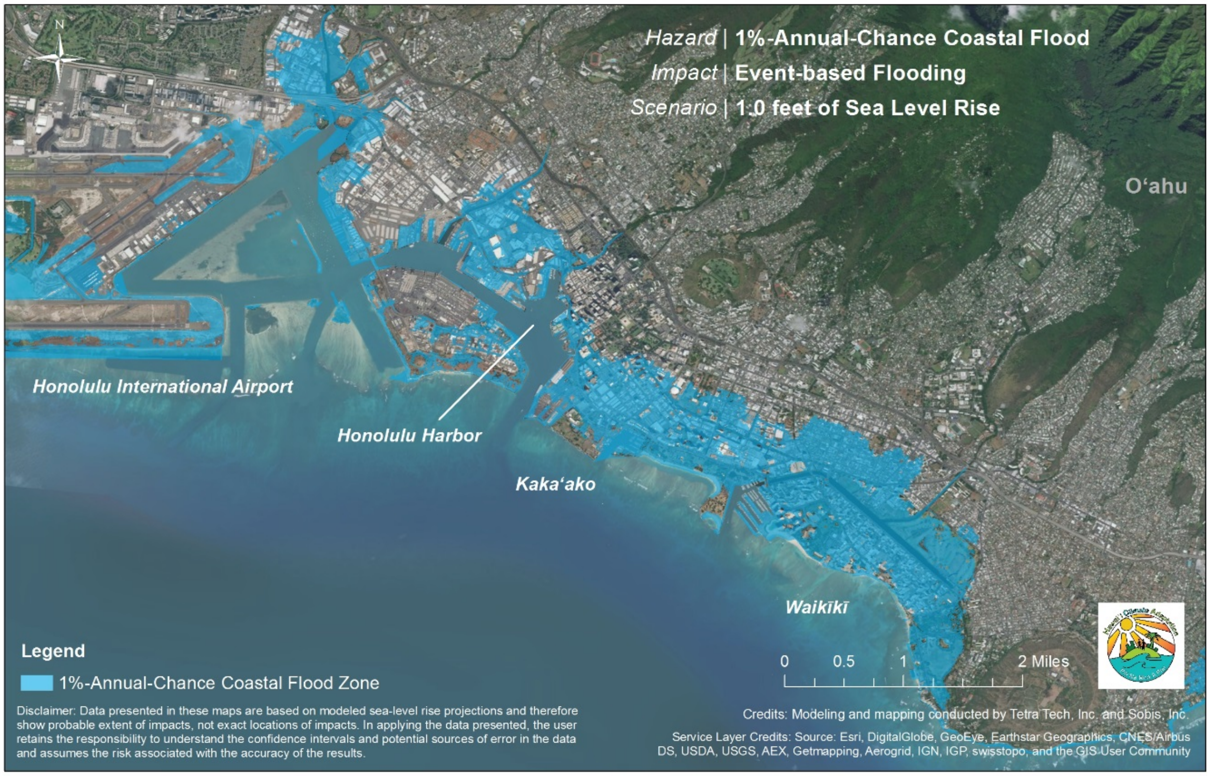

Figure 2. Example map showing results of 1%-annual-chance coastal flood modeling with 1.0 of sea level rise for Honolulu, O‘ahu

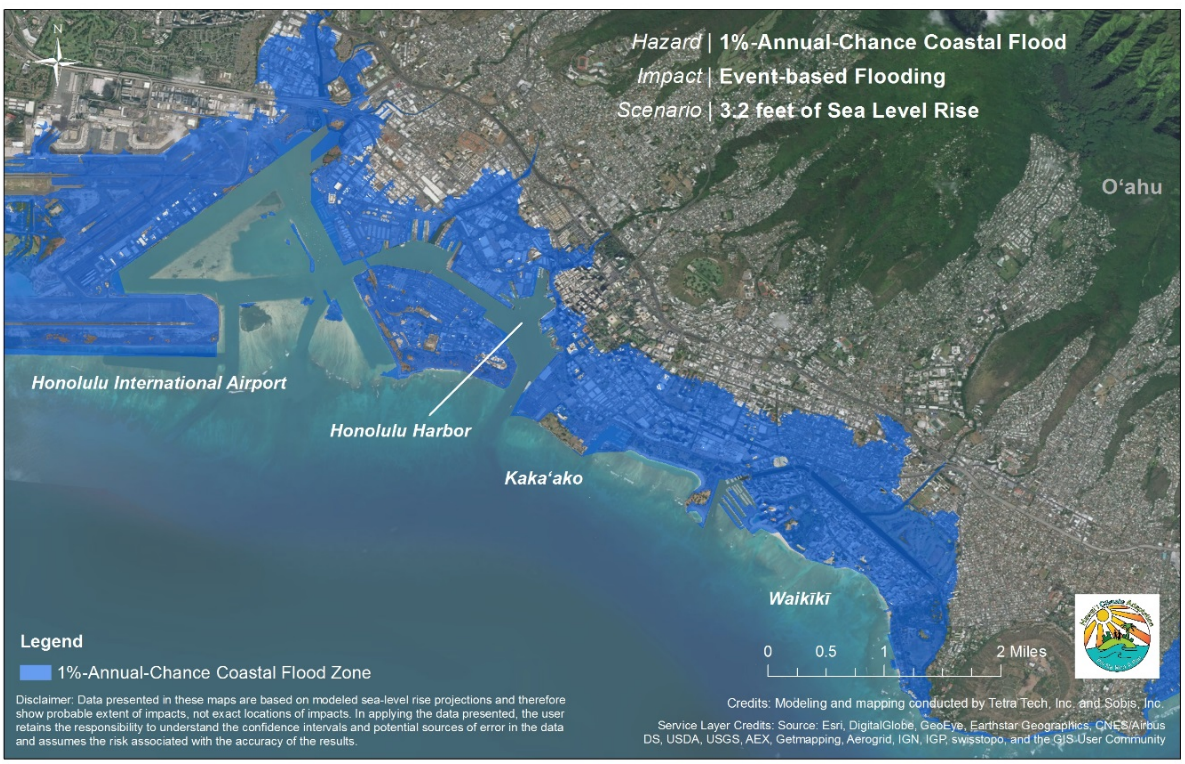

Figure 3. Example map showing results of 1%-annual-chance coastal flood modeling with 3.2 feet (bottom) of sea level rise for Honolulu, O‘ahu

Assumptions and Limitations

Historical records of severe wave events used to model the 1%CFZ with sea level rise do not consider potential changes in tropical cyclone activity related to climate change. Historical data used to model the 1%CFZ were based on the current FIS for each island conducted by the NFIP. The FISs use historic severe wave events from hurricanes, tsunamis, and other significant events to develop the FIRMs.

The 1%CFZ with sea level rise is modeled as a static rise of the base flood elevation using a fixed shoreline. As such, it does not consider changes in the location of the shoreline resulting from coastal erosion. While the current FIS for each island was used for modeling; these studies are based on historical records of hurricanes, tsunamis, and other coastal wave events and do not include projected changes in waves due to changes in storm frequency or intensity as a result of climate change. Also, riverine flooding is not included in the modeling.

Opportunities

The NFIP depicts two coastal flood hazard zones on its FIRMs: (1) V Zone, where the flood elevation includes wave heights greater than 3 feet and (2) Coastal A Zone, where the flood elevation includes wave heights less than 3.0 feet but greater than 1.5 feet (Figure 4). Post-storm field visits and laboratory tests throughout coastal flood hazard areas have consistently confirmed that wave heights as low as 1.5 feet can cause significant damage to structures that are constructed without considering coastal hazards.

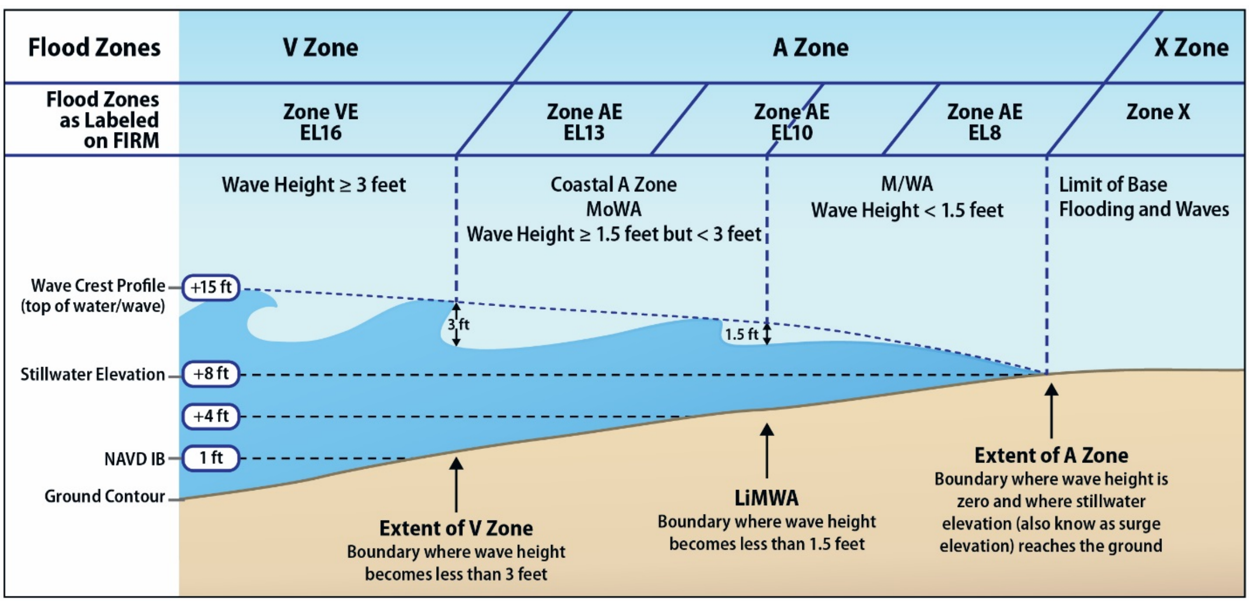

Figure 4. Schematic of coastal flood zones defined under the National Flood Insurance Program

The 1%CFZ with sea level can be used to depict estimates of future coastal flood zones (Figure 5). Wave heights produced from this modeling can highlight areas of greater risk of being damaged by storm surge, inform land use planning and the development of hazard mitigation projects to address event-based coastal flooding.

A county may also request that FEMA include the 1%CFZ with 3.2 feet of sea level rise on its FIRM as an "X Zone" In 2001, FEMA reviewed and revised their regulations to allow communities to request that future-conditions floodplains are displayed on the FIRM (FEMA, 2001). A community may request that FEMA show the future-conditions 1-percent-annual-chance (100-year) floodplain on the printed FIRM and be designated as Zone X with no base (1-percent-annual-chance) flood elevations (BFEs) shown. Showing the future-conditions floodplains on the FIRM could help reduce confusion between federal and county floodplain maps and increase awareness of the public that flood hazards may increase in the future. As such, counties in Hawai'i may wish to request that FEMA include the 1%CFZ with 3.2 feet of sea level rise to depict future-conditions floodplains.

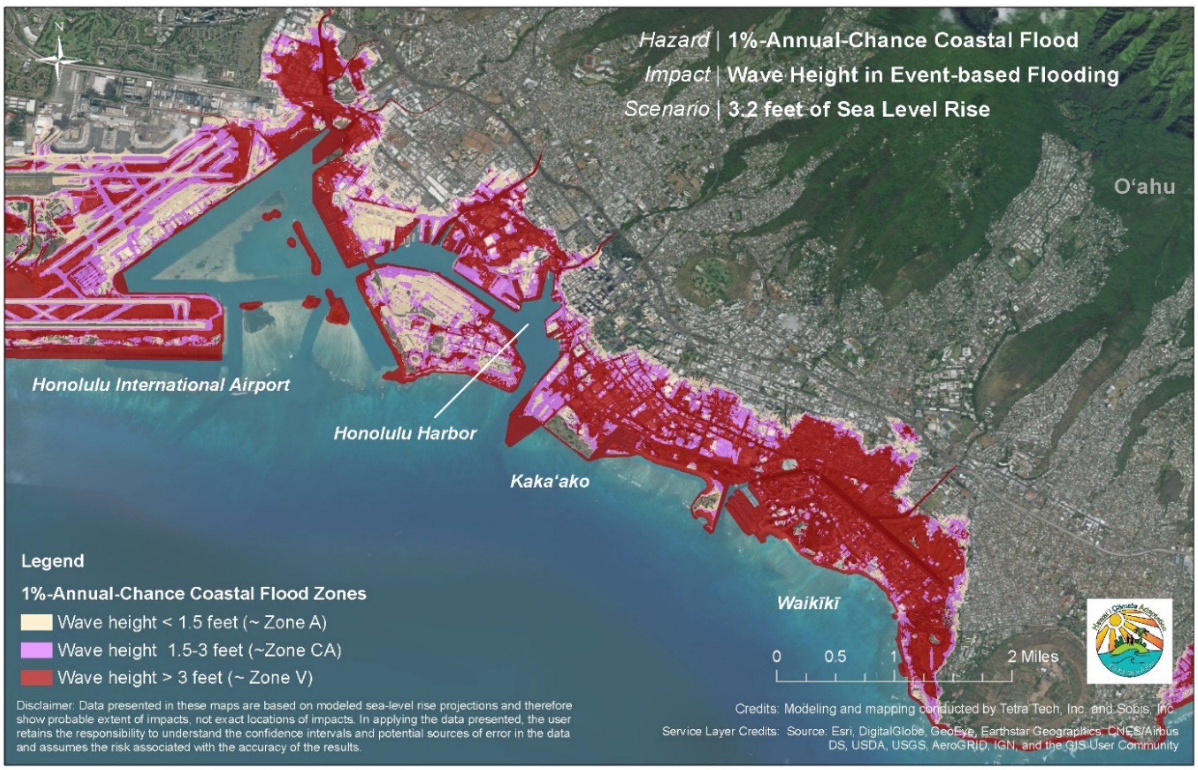

Figure 5. Example map showing three wave height zones in the 1%CFZ with 3.2 feet of sea level rise for Honolulu, O'ahu

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