

Current Working Hypothesis for Palaeotsuanami
Inundation: Waihe'e Coastal Dunes and Wetlands
Refuge, Maui, Hawai'i

November, 2021



Waihe'e Coastal Dunes and Wetlands Refuge: 277-acres; 3 km of sandy/cobbly coast; 27-acres of palustrine discharge wetlands; 105-acres of late-pleistocene aeolian dunes.



Waihe'e Refuge Looking towards the southeast, Kahului Bay is visible in the background; the 27-acre wetlands are near the coast in the center of the photograph.



Palaeoecology and Palaeogeomorphology of Waihe'e, Maui

- The Palaeoecology and Palaeogeomorphology of Waihe'e are fairly well understood.
- Mid- to late- Pleistocene: formation of an alluvial plain (prior to the last major glacial period);
- Hypothesized, late-Pleistocene flank collapse along the Kahakuloa Coast, ~1-6 km distance from Waihe'e (photo below)
- This event seems to have generated a large tsunami and debris flow which contributed to the water-worn cobbles and boulders that form the shoreline;

Kahakuloa Coast (background): Possible Tsunamigenic Source of
Flank Collapse Tsunami that Impacted the Waihe'e Refuge
(foreground) in the mid- to late- Pleistocene;



Palaeoecology and Palaeogeomorphology (continued)

- Late Pleistocene glaciation lowered sea-levels around the Hawaiian Islands, contributing to the formation of the sand dunes which surround the Waihe'e Refuge;
- The mid-Holocene highstand likely caused the 27-acre wetlands to become a shallow marine embayment (likely similar to contemporary projections of late 21st Century sea level rise, portrayed below); this highstand lasted until approximately 3,800 BP
- Since the mid-Holocene, the wetlands appear to have been relatively stable; a closed canopy gallery forest of *Pritchardia* surrounded the wetlands, with a relatively diverse grouping of sedges (Cyperaceae) and Shrubs (esp. *Cheno-Ams* and likely *Scaevola*) and a few trees (e.g. *Colubrina*, *Polyscias*) .
- Anthropogenic modification of the landscape seems to have been quite early and dramatic.

Small Trench and Sediment Core from the Waihe'e Wetlands;
Trench: 50 m from coast;
Core: 120 m from coast;



Projection of future Sea Level Rise as a coarse proxy for Sea Level Inundation in the Mid-Holocene;



Anthropogenic modifications to the palaeocology and geomorphology of Waihe'e

- 950 CE: Polynesian arrival, dramatic ecological change (mainly due to the increased use of fire and the arrival of commensurate species, such as the *Rattus exulans*);
- Mid-15th century: construction of a ~2.5 hectare freshwater, dual-use fishpond (loko i`a kalo) in the mid-15th century (photo below).
- 1919-1970: construction of the Waihe'e dairy, wetlands drained in order to create and improve grazing land.
- 2003: Purchased by the Hawai'i Land Trust restore endangered species habitat, conduct research and education and protect cultural sites (see composite archaeological map).

Waihe'e Wetlands after Heavy Rains: Fishpond Wall is Visible in the Center; note proximity of wetlands to coast



Composite Archaeological Map of the Waihe'e Refuge



Waihe'e Refuge: history of known and hypothesized tsunami inundation, late pleistocene to present;

- A massive and catastrophic tsunamigenic flank collapse in the mid-to late pleistocene is suspected, although no definitive evidence for this event has been uncovered to date (discussed earlier);
- The April 1st, 1946 Aleutian Tsunami was the most destructive historic tsunami;
- 1957 and 1960 Aleutian and Valdivia, Chile tsunamis: no known reports of inundation;
- March 11th, 2011: Tohoku-oki tsunami caused (relatively minor) flooding, inundation and scouring along the coast, (photos below);
- Although storms are rare on Maui, they cannot be discounted as an agent of catastrophic saltwater inundation.

Tsunami Impacts at Waihe'e, April 1, 1946

- Numerous precise descriptions provided by witnesses have facilitated a relatively detailed understanding of the tsunami impacts at Waihe'e;
- Three homes at the Waihe'e Dairy were destroyed, though no lives were lost;
- Foundations of two homes remain on site;
- Most significant witness observation: a portion of a hau (*Hibiscus tiliaceus*) hedge was transported from east to west approximately 300 m (wave source was in the west, so impacts would be expected to travel from east to west; see photo)
- Significance: Suggests counter-directional impact from tsunami source, and significant refraction from nearby Kahului Bay;
- As discussed below this has important implications for green infrastructure/forested bioshield development for tsunami resilience.

Direction of Movement of Hau (*Hibiscus tiliaceus*) hedge during the 1946 tsunami: suggestive of wave impact from west to east.



Tsunami Impacts: March 11, 2011

- Several waves impacted the coast (self-observed), 1 meter estimated wave height;
- Wave appeared to have travelled perpendicular to the coast;
- In-spite of its relatively small size (a yoda tsunami), significant scouring was observed;
- Indigenous and endemic plant species (particularly *Scaevola* and *Vitex* spp.) seemed to reduce scouring compared to non-native spp.;









Tsunami and Catastrophic Saltwater Inundation Resilience at Waihe'e

- Waterbird habitat in the wetlands and the fishpond are the Land Trust's top protection and resilience priorities;
- Both are subject to catastrophic saltwater inundation and tsunamis because of their proximity to the coast;
- While a forested bioshield will afford some protection from wave energy, the fringing reef fronting the Waihe'e Refuge remains a critical element in attenuating wave energy (photo below);
- Resilience measures should focus on both establishing the forested bioshield and protecting reef health by reducing terrestrial sedimentation;

Establishment of forested bioshield around the wetlands, post- 2011 tsunami: Hala (*Pandanus tectorius*) is the preferred species





Fringing Reef in front of the Waihe'e Refuge



Summary of working hypotheses regarding tsunami and Palaeotsunami impacts at Waihe'e, Maui

- A flank collapse is hypothesized to have generated a tsunami that impacted Waihe'e in the mid- to late- Pleistocene; this event is not yet supported by evidence gathered through field investigations;
- Palaeotsunami (prior to 1778 CE) are suspected to have impacted the Waihe'e coast, but these have not been conclusively demonstrated to date;
- The 1946 Aleutian Islands tsunami was the most destructive recorded tsunami; a documented eye-witness account suggests that (at least one) wave may have refracted from west to east (counter-directional from tsunami-source);
- This has important implications for green infrastructure and forested bioshield development, especially the necessity of protecting the offshore-fringing reef;

Summary of what is known, or reasonably believed, about tsunami and Palaeotsunami impacts at Waihe'e, Maui, (part II)

- Green infrastructure and forested bioshields (particularly using indigenous and endemic species) has been demonstrated to attenuate wave energy in the 2011 Tohoku-oki tsunami (a relatively small, <1 m, yoda wave);
- It is possible that not enough data about palaeotsunami and catastrophic saltwater inundation can be gathered through field investigations. The following locations are propped alternative sites for field work (in descending order of ease of investigative access);

Alternative Sites for Palaeotsunami Investigation, Maui (in descending order of ease of access)

- 1. La‘īe Wetlands, South Maui; estuarine/intermittent riverine wetlands (request already made to the Maui County Council for \$25k for palaeotsunami investigation);
- 2. Ke‘ānae Peninsula, North Maui; traditional taro patch complex (lo‘i kalo);
- 3. Kanahā Wetlands, North Central Maui, palustrine/estuarine wetlands; State Wildlife Refuge;
- 4. Ke‘ālia Wetlands, South Central Maui, Estuarine Wetlands; National Wildlife Refuge;

Alternative Sites for Palaeotsunami Investigation (Waihe'e and Nu'u are marked in red)



Alternative Investigation Site 1: La‘īe Wetlands, South Coast of Maui



Alternative Investigation Site 2: Ke‘ānae Peninsula, North East Coast of Maui;



Alternative Investigation Site 3: Kanahā State Wildlife Refuge, North Central Maui



Alternative Investigation Site 4: Ke‘ālia National Wildlife Refuge: South Central Maui

