

Historical Shoreline Change and Cultural Sites Kawela-Kahuku, O‘ahu

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I certify that this thesis, in our opinion, is satisfactory in scope and quality as a thesis for the degree of Bachelor of Science in Global Environmental Science.

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Abstract

Hawaii's beaches are a focus of modern lifestyle as well as cultural tradition. Coastal erosion threatens areas that have served as burial grounds, home sites, and hold other forms of cultural significance. To improve understanding of the convergence of erosion patterns and historic uses, we mapped shoreline changes from Kawela Bay to Kahuku Point. Shoreline change rates are calculated from historical photographs using the single-transect (ST) and eigenbeaches (EX, EXT) methods to define the 50 and 100-year erosion hazard zones. To ensure that shoreline change rates reflect long-term trends, we include uncertainties due to short term shoreline position and other mapping errors. A hazard zone overlay was compared to cultural data provided by the State Historic Preservation Division and the Office of Hawaiian Affairs to identify threats to cultural features. Cultural features identified in the study include burials, artifacts, Pohaku Puo`o, and Punalua pond. A number of sites known to contain burials and cultural artifacts were found within the erosion hazard zones.

Keywords:

Coastal erosion, shoreline change, erosion rate, EX, EXT, ST, single-transect

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INTRODUCTION

Hawai‘i’s beaches are valuable because they are the focus of modern lifestyle as well as cultural tradition. In recent decades beaches on O‘ahu, Hawai‘i have narrowed or been lost due to erosion (Fletcher et al 1997). Coastal erosion is likely to expand and accelerate as sea level rises. Land vulnerable to erosion may contain cultural features such as burial sites, Hawaiian artifacts, former home sites, and others. Currently there is no management protocol to deal with erosion threats to cultural assets. This study evaluates chronic erosion threats to cultural assets on O‘ahu’s north coast in the area from Kawela Bay to Kahuku Point.

Iwi

Dunes have long been important burial sites (Markell 2009). Chronic erosion unearths iwi, or bones, thereby exposing them to potentially inappropriate treatment by an unknowing public. With continued and accelerated sea-level rise this problem will become more widespread. Hawaiians believe their existence is divided equally between their ‘uhane, or spirit, and their mana, or power. When a Hawaiian passes, the ‘uhane leaves the body for the afterlife, and the mana remains with the iwi. It is for this reason that Hawaiians place such high value on protocol with respect to the treatment of iwi. The word iwi is repeated throughout the Hawaiian language exemplifying its importance. For example kulāiwi literally means “plains of the bone” and is used in the Hawaiian language to refer to ones’ homeland.

It is not uncommon for shoreline change to expose iwi. For instance Markell (2009) reports that iwi are frequently “washed out” along roadways that hug the beaches in Ka‘a‘awa, Kualoa, Hā‘ula, and Waimānalo. At Kahala, near the Hunakai street beach

access, seawall construction and shifting sands are believed to be responsible for the exposure of iwi belonging to two individuals. At this site the iwi are incorporated into a calcareous grainstone (Markell pers comm, 2009). The iwi of approximately 70 individuals at Hāmākua Poko and Kūʻau on the north shore of Maui became exposed after a high wave event in the 1990's. Kahuku and Mōkapu, Oʻahu, Waiehu, Maui and Moʻomomi, Molokaʻi are some of the largest known coastal burial sites, and are believed to contain thousands of iwi. Coastal erosion is known to occur in these areas.

Iwi or other burial remains that are unearthed, including those resulting from coastal erosion, are considered an “inadvertent discovery”. The State Historic Preservation Division (SHPD) is given jurisdiction over all burial materials 50 years old or older. After consulting the appropriate ethnic organizations, the landowner, and any known lineal or cultural descendants, SHPD is responsible for determining whether human skeletal remains will be preserved *in situ* or relocated. In addition, the development of a preservation plan is a minimum requirement for permitted land disturbance. A preservation plan articulates the proper management and protection of all burial sites, including, but not limited to, buffers, landscaping, and access by known lineal or cultural descendants (DLNR, 2006). Although SHPD has yet to develop protocols specific to coastal erosion, the number of exposed iwi is likely to increase in the future and this is a concern.

Sea Level Rise

A 1m rise in global average sea level is projected by the year 2100 (Fletcher, 2009). As sea level rises, coastal environments including beaches will begin to migrate landward and upward. A 1m rise in sea-level may drive shoreline retreat as much as 100

m inland. Beaches may adjust to sea-level rise without much change in beach width as long as there continues to be a sufficient sand source located landward of the beach. However, much of Oahu's coastline is highly developed and sand dunes have been removed, thus backshore sand may be scarce. Homes, roads, iwi and other cultural sites will become increasingly threatened as the shoreline retreats due to sea-level rise. Current shoreline change rate models, including those used in this study have yet to account for the projected 1m rise in sea level, however it is important to understand how this process may affect coastal areas.

Previous Research

Shoreline change rates have been determined by the Coastal Geology Group at UH Mānoa for the islands of Kaua'i, O'ahu, and Maui. Based upon these rates, stricter shoreline setbacks have been established for Kaua'i and Maui.

Jurisdiction over Hawai'i's coast is split between the state and the counties, which can make proper management of shorelines difficult. Typically, the state has authority over the beach, while the counties govern the dunes. Despite the efforts being made by SHPD, the counties, and the state, there has yet to be a movement to couple data and management under a single process. The use of shoreline change rates to predict which cultural areas may be potentially threatened by coastal erosion can allow for better treatment of coastal cultural sites.

Physical Setting

The study area consists of Kawela Bay, Turtle Bay, and Kahuku Point, located on the north shore of O'ahu (Figure 2). Kawela Bay Beach lies between two limestone headlands, and is typically characterized by small waves due to protection by a shallow

reef at the mouth of the bay. The shoreline at Turtle Bay is largely composed of exposed limestone shelf with a ‘perched’ calcareous beach above the water line. Several small beaches are found between limestone headlands and beach rock is prevalent. Kahuku Point is the northern-most tip of the island of O‘ahu. Kaihalulu Beach extends from Turtle Bay resort to Kahuku Point. Kaihalulu Beach is similar to Turtle Bay. Shoreline position is highly variable at these beaches and limestone outcrops are intermittently exposed and buried by seasonal shifts in sand. The entire study area is exposed to north and west swells during winter months and trade wind waves year-round.

MATERIALS AND METHODS

Mapping Historical Shorelines

This study closely adheres to the methods of Fletcher et al. (2003) and Romine et al. (2009). Historical shorelines are digitized from 0.5 m orthorectified aerial photo mosaics and NOAA NOS topographic surveyor maps (T-sheets) from 1910-2007. PCI Geomatics’ Geomatica Orthoengine software (2007) is used to orthorectify and mosaic images. The orthorectification process geometrically corrects aerial photographs and T-sheets so that these images are uniformly scaled and can be measured as a map. The most recent aerial photographs acquired for the study area are from 2007. The orthorectified 2007 aerial photographs serve as the master images and are used to orthorectify all of the older images. The PCI program also reduces error that may result from lens distortion, Earth curvature, refraction, camera tilt, radial distortion, and terrain relief. The root mean square (RMS) positional errors that are produced from the orthorectification process are based upon how the orthorectification model for each year differs from the master image

(2007 image) and a digital elevation model (DEM). Only RMS values less than 2 m are accepted for the aerial photographs, and RMS values less than 4 m are accepted for T-sheets.

This study uses the low water mark (LWM) as a proxy for the shoreline. The LWM refers to the beach toe or the base of the foreshore. The vegetation line was also mapped in this study so that historical changes in beach width between the LWM and vegetation line may also be observed and calculated. The 1910 and 1932 T-sheets map the high water mark (HWM), as a shoreline proxy rather than the LWM. To correct this difference the HWM is migrated to the LWM using an offset calculated from measurements taken during beach profile surveys at Sunset Beach, O‘ahu (Romine et al., 2009). No beach profile surveys have been taken in the study area and Sunset Beach serves as the nearest beach with profile data. After mapping the historical shoreline for each time period, they are all displayed together on the master image (Figure 1).

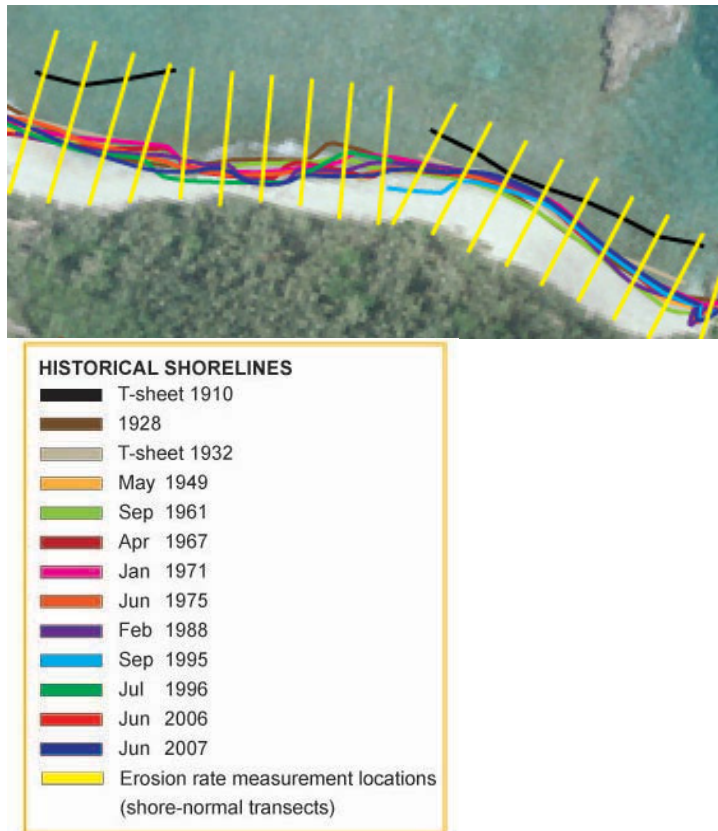


Figure 1. Historical Shorelines. LWMs from a portion of the study area are color coded by year. Yellow transects are points where shoreline change is measured.

Uncertainties in Shoreline Position

The methods of Romine et al. (2009) are used to calculate seven sources of uncertainty that are included in the shoreline change models. The seven sources of uncertainty account for the high variability of shoreline positions as well as any mapping errors. The seven sources of error include Digitizing Error (E_d), Pixel Error (E_p), Seasonal Error (E_s), Rectification Error (E_r), Tidal Error (E_{td}), T-sheet Plotting Error (E_{ts}), T-sheet Conversion Error (E_{tc}) (table 1.). The total positional uncertainty, E_t is the root sum of squares of individual errors: $E_t = (E_d^2 + E_p^2 + E_s^2 + E_r^2 + E_{td}^2 + E_{ts}^2 + E_{tc}^2)^{1/2}$.

Table 1. Uncertainties in Shoreline Position

Uncertainty Source
E_d , Digitizing Error
E_p , Pixel Error, aerial photos
E_p , Pixel Error, T-sheets
E_s , Seasonal Error
E_r , Rectification Error
E_{td} , Tidal Error
E_{ts} , T-sheet Plotting Error
E_{tc} , T-sheet Conversion Error
E_t, Total Positional Error

The Digitizing Error, E_d accounts for variability in interpreting shoreline position when measured by several experienced analysts at the Coastal Geology Group, UH Manoa. Pixel Error, E_p is a direct result of the resolution or the pixel size of the orthophotomosaics and T-sheets. The Seasonal Error, E_s is a measure of the variability between winter and summer shoreline positions (LWM) along a single transect used at the Sunset Beach profile. The Rectification Error, E_r is a measure of the variability between orthorectified aerial photographs, and t-sheets to the master orthorectified image and DEM. Tidal Fluctuation Error, E_{td} , accounts for possible fluctuations in shoreline position due to tides. T-Sheet Plotting Error, E_{ts} results from the use of the HWM as a proxy for shoreline position when mapping T-sheets. Conversion Error for T-sheets, E_{tc} accounts for uncertainty that may arise when migrating the T-sheet HWM to represent a contemporaneous LWM.

Calculating Shoreline Change Rates

Distances between shorelines are measured as transects spaced 20 m along the shore (Figure 1). Shoreline change rates are calculated from the time series of historical shoreline positions using the single-transect (ST) and eigenbeaches (EX, EXT) method. The ST method has been used in previous studies as well as coastal planning to calculate shoreline change rates for the islands of O‘ahu, Kaua‘i, and Maui. The ST method calculates a shoreline change rate and uncertainty at each shoreline transect using weighted least squares regression. Weighted least squares regression fits a trend line to the time series of historical shoreline positions by giving positions with higher uncertainty less of an influence on the trend line than shoreline positions with smaller uncertainty (Fletcher et al., 2003; Genz et al., 2007). The resulting slope of the trend line is the shoreline change rate. Recent work by Frazer et al. (2009) has identified three main shortcomings of the ST methods. The ST method is an unparsimonious model and tends to over-fit data by using more parameters than necessary. Secondly, the ST model only takes into consideration shoreline change data at a single transect and as a result ST shoreline change rates at each transect vary independently of the other transects along the shore. Thus ST shoreline change rates don’t account for the sharing of sand along the shore, which is an important characteristic of beaches. Finally the ST method tends to have high uncertainty as a result of modeling shoreline change independently at each transect.

Frazer et al. (2009) and Genz et al. (2009) have developed the EX and EXT models to model shoreline change rates in the alongshore as well as the cross shore direction. Like the ST method, the EX and EXT methods use linear regression to fit a

line with time and cross-shore shoreline change. The EX and EXT methods also take into consideration data from all transects along a beach, which accounts for the sharing of sand between transects. The EXT method identifies and calculates rate variations or acceleration of shoreline change rates in time. This is an important feature because shoreline change may not be constant. The uncertainties produced by the EX and EXT methods are lower than the uncertainties produced by the ST method.

Cultural Information

Cultural information was obtained from the Office of Hawaiian Affairs (OHA) and the State Historic Preservation Division (SHPD). Shape files provided by OHA are used to identify and locate ahupua'a or Hawaiian land divisions, burials, and cultural deposits found within the study area. All original shape files were orthorectified using the same UTM projection as this study. Kai Markell was interviewed on August 18, with regard to the significance of iwi to the Hawaiian culture. Kai has served as the head of Native Rights Land and Council at OHA, and he has also worked at SHPD. The Archaeological Mitigation Plan for the Turtle Bay Resort as well as SHPD burial reports are used to gather more information pertaining to the components of the identified cultural sites. These documents identify the number of burials found at each site, the types of artifacts found, and how Hawaiians have historically used the areas labeled cultural deposits.

Hazard Images

Erosion hazard zones are determined for the Kawela, Turtle Bay, and Kahuku Pt. study sites. Potentially threatened cultural features are identified as those that fall within the erosion hazard zones. Erosion hazard zones are constructed by projecting ST, EX, and

EXT shoreline erosion rates and uncertainties 50 and 100 years. In areas with no acceleration in shoreline erosion rates EX & EXT hazard zones are the same.

RESULTS

Kawela

Three cultural features are identified in the Kawela area. These cultural features include the Pahipahiālua Beach Park Burial 03765, Punaulua, and the Kawela Bay Subsurface Cultural Feature (Figures 3, 4). A fishing shrine is also known to exist along the Pahipahiālua Beach Park, however its exact location is unknown and as a result could not be labeled in this study (O’Hare and Hammat 2006). Further inland of Pahipahiālua Beach Park, along the western point of Kawela Bay is Punaulua pond. This brackish pond is fed by a freshwater spring and is believed to have once attracted Uluā or crevalle fish. Extending from the middle to the eastern portion of Kawela Bay is the Kawela Bay Subsurface Cultural Deposit 2899. PHRI was contracted by the Turtle Bay Resort to conduct an intense cultural survey on the Kawela Bay Subsurface Cultural Deposit 2899. PHRI identified midden, Hawaiian artifacts, and a total of 5 burials. The Kawela Bay Subsurface Cultural Deposit 2899 is divided into four main regions and labeled A, B, C, D (Figure 5). The highest density of artifacts and midden were found in area D, while area C contained the highest density of subsurface features. It is believed that areas C and D were once used to manufacture fishing gear. The shoreline that fronts areas C and D is referred to Wakiu and was once known for its large schools of moi and its fishpond (O’Hare and Hammat 2006).

The 50 and 100 year Kawela ST erosion hazard lines are projected from the 2007 vegetation line. The hazard zone extends landward of the Pahipahiālua Beach Park Burial (Figure 3, 4). The 50 and 100 year Kawela ST erosion hazard incorporate portions of the Kawela Bay Subsurface Cultural Deposit 2899 within the hazard zone. Due to the lack of acceleration in shoreline change rates, the EX and EXT models produce the same hazard projections. Due to the lower uncertainty associated with the EX and EXT hazard zones, a smaller portion of Cultural Deposit 2899 falls within the EX and EXT hazard zone in comparison to the ST hazard zone. Punaulua doesn't appear to fall within the ST, EX, or EXT hazard zones.

Turtle Bay

The Turtle Bay area contains a single culture feature, Burial 4488 (Figures 6, 7, 8). Burial 4488 consist of iwi from a total of 5 individuals. These iwi were found near the stables at the Turtle Bay resort during a sand mining project.

The Turtle Bay area is the only study site that showed acceleration of shoreline change in time, and thus produce different EX and EXT erosion hazard zones. All models project the erosion hazard line seaward of Burial 4488 (Figures 6, 7, 8). The ST erosion hazard zone has the highest uncertainty, and as a result is the only erosion hazard zone to include Burial 4488.

Construction of the Turtle Bay Resort was completed in May of 1972. Figure 9 is used to compare changes in shoreline before, during, and after the construction of the Turtle Bay Resort. In the 1967 photo the area that is now occupied by the Turtle Bay Resort was once covered in vegetation and also contained a stream. By 1971 construction in this area removed vegetation, the stream, and manipulated the sand dunes.

The 2007 aerial image gives a modern day perspective of the Turtle Bay Resort and the extent of construction that has taken place.

Kahuku Point

In March and April of 1986, PHRI conducted an intensive archaeological survey at the Kahuku Pt. Cultural Deposit 2911. The Kahuku Pt. Cultural Deposit is located makai or seaward of the Kahuku Pt. sand dunes (Figure 10 & 11). This cultural deposit contains 4 burials, Hawaiian artifacts, midden and is the site of a former Hawaiian settlement. Approximately 90 m inland of Kahuku Point is a brackish water pond known as Kukio Pond. This pond is believed to have been used to cultivate taro, and once served as a fishpond. Kukio Pond still remains today however it is believed to have formerly been much larger. According to long-time resident Mrs. John Kaleo the area between Kukio pond and the coast surrounding Kahuku point was used as a burial site. Her former family and relatives have all been buried in this area.

There is no acceleration in the shoreline change rates at Kahuku Pt and as a result EX and EXT erosion hazard projections are identical. Fifty year ST, EX and EXT erosion hazard zones all include the entire southwestern portion of Cultural Deposit 2911. The 100 year ST, EX, and EXT erosion hazard lines all fall landward of the southwestern portion of Cultural Deposit 2911.

Table 2. Kawela-Kahuku Cultural Features

Cultural Site	Location	Cultural Significance	Threatened?
Pahipahiālua Beach Park Burial 03765	Kawela	-Single Burial -Pahipahiālua -Fishing shrine	50 yr ST, EX, EXT
Punaulua 00258	Kawela	-Freshwater spring that attracted Ulua, or crevalle fish.	No
Kawela Bay Subsurface Cultural Deposit 2899	Kawela	-5 burials -Hawaiian artifacts -Former Hawaiian Settlement	50 yr ST, EX, EXT
Burial 4488	Turtle Bay	-5 burials	100 yr ST
Kahuku Pt. Cultural Deposit 2911	Kahuku Pt.	-4 burials -Hawaiian artifacts -Former Hawaiian Settlement -Kūki`o Pond	50 yr ST, EX, EXT

CONCLUSIONS

ST, EX, and EXT shoreline change rates and uncertainties may be used to project future erosion hazard zones. Potentially threatened cultural sites are identified as those that fall within the erosion hazard zones. The ST, EX and EXT models allow for potentially threatened cultural sites to be identified before erosion events occur. Pahipahiālua Beach Park Burial 03765, Kawela Bay Subsurface Cultural Deposit 2899, and Kahuku Pt. Subsurface Cultural Deposit 2911 are all found to be vulnerable to coastal erosion in the next 50 years. Burial 4488 may become vulnerable in 50 years based upon the ST model only. Punaulua 00258 is located further inland on a raised carbonate structure and is the only cultural feature that all models agree will not be threatened by erosion within the next 100 years.

The Turtle Bay area is the only study site that produced an EXT model, which indicates that the shoreline change rates in this area are accelerating in time. Acceleration in erosion rates at Turtle Bay may be due to the construction of the Turtle Bay Resort. Aerial photographs from 1971 show that construction in this area removed nearly all of the vegetation, covered a stream, and manipulated the sand dunes. According to the Archaeological Mitigation Plan for the Turtle Bay Resort (2006), a sand mining operation also took place near the area labeled Burial 4488. Present day Turtle Bay area is nearly entirely covered with Hotel structures, and cultivated vegetation. All of these factors may have negatively impacted sand sources and thus accelerated erosion rates in this area.

This study is the first to incorporate both shoreline change data and cultural data. Currently there is no protocol to deal with coastal erosion threats to cultural sites. The use of erosion hazard zones to identify vulnerable culture features can be a coastal management tool. Using the data provided in this study, managers can rank the vulnerability of the threatened cultural features based upon cultural significance and the time in which the feature may become threatened. Proper protocol may then be developed to appropriately manage the assets such as possible relocation and preservation of cultural features.

Currently SHPD is given jurisdiction over all iwi and burial goods 50 years and older. Any inadvertently discovered iwi that are found at the Turtle Bay Resort are relocated to a reinternment site located on the Turtle Bay Resort Property. If Hawaiian artifacts with no burial association are discovered on public land they also fall under the jurisdiction of DLNR, and usually SHPD. Hawaiian artifacts found on private land are

considered to be property of the landowner and may or may not be preserved based upon the discretion of the landowner. Thus it is important that the public as well as state and county agencies are aware of coastal erosion so that they may make informed decisions.

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