

Reef-top Sand Fields of Maui and Kauai

Kihei and Kahului, Maui; Poipu and Kekaha, Kauai



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Introduction

Beaches are critical to Hawai,,i lifestyle, culture, and economy. Coastal erosion threatens beaches but sediment management offers potential tools to mitigate the problem. Offshore sand fields have been used as a resource to replenish Hawai,,i's eroding beaches – specifically in Waikiki (DLNR, 2010).

The purpose of this research, sponsored by the U.S.Army Corps Regional Sediment Management program is to identify stable, shallow water (reef top) sand fields in four locations and determine their surface areas. The field sites are Kihei and the north shore of Maui (Fig. 1), Poipu and Kekaha on the south coast of Kauai (Fig. 2).

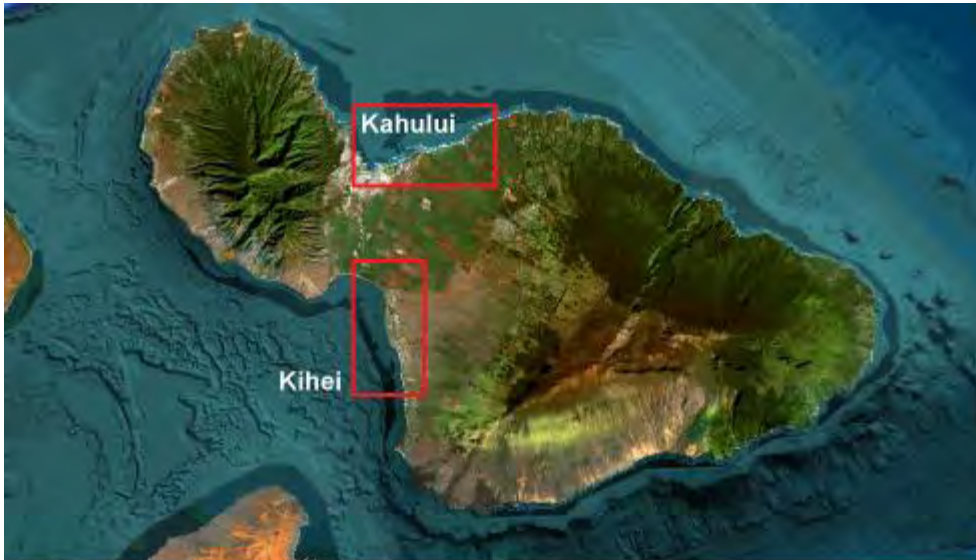


Figure 1. Maui study sites (red boxes indicate field areas).



Figure 2. Kauai study sites (red boxes indicate field areas).

Geologic Framework of Sand Bodies

Shallow, reef top sand fields are an accumulation of carbonate sediment in topographic depressions on shallow reefs (Bochicchio et al. 2009). These accumulations are typically thin and are classified as channels, fields, or patches (Conger et al. 2005). Biologic production, temporary and permanent storage, and loss (including offshore transport, bioerosion, dissolution, and abrasion) govern the accumulation of carbonate sands. The area and distribution of sand fields are determined by biologic productivity, water quality, wave energy, and storage space (Fletcher et al. 2008). Reef accretion due to rising sea level and dissolution (subaerial exposure) due to falling sea level also impact the area of storage available for sand.

Sand stored on reefs is mobile and may be transported seaward, landward, or captured by voids and interstices within the reef. Much of the sand within sand fields is stored temporarily; thus, the distribution and area of sand fields changes over time. Sand fields that undergo significant changes in surface area are more likely to consist of ephemeral, thin accumulations (and thus represent poor targets as borrow sites) compared to those that are stable over the same period. Stable sand fields are bodies of sand that have retained the same configuration over time, for example several decades. Ephemeral sand fields are bodies of sand that change configuration.

For this study, both stable and ephemeral sand fields were identified using historical and modern aerial photography with a clear view of the shallow seafloor. We assume that stable sand fields offer the best opportunities for characterization as resources, such as by jet probing, grain size analysis, or other methods.

Methodology

High-resolution orthophotomosaics of the field sites were produced to examine sand field extent. Aerial photos for this purpose were chosen based on their date, the area of coverage, the amount of surface glint and cloud cover, and water column clarity. Photomosaics from 1960 were used to provide historical coverage, and mosaics from 2002, 2006, and 2007 were used to provide modern coverage.

1. Kihei, Maui - Kamaole Beach Park to Kealia Pond. Mosaics from 1949 and 1975 were analyzed, but not used for historic coverage because of overall poor visibility of the seafloor. Therefore, photomosaics from 1960 and 1997 were used to provide historical coverage, and a 2007 mosaic was used to provide modern coverage.
2. Kahului, Maui - Kahului Harbor to Hookipa Park. For this field area, five mosaics (Kahului Harbor, Kanaha, Spreckelsville, Baldwin Park, and Kuau) provided coverage. Photomosaics from 1975 provided historical coverage, and mosaics from 2002 provided modern coverage.
3. Poipu, Kauai – Shipwreck Beach to Lawai Bay. Mosaics from 1999, 1992, 1988, 1982, 1960, 1950, and 1928 were analyzed; however these were not used because of incomplete coverage and/or poor visibility of the seafloor. A 1975 mosaic provided historical coverage, and a 2007 mosaic provided modern coverage.
4. Kekaha, Kauai – Waimea to Kekaha Beach Park. For this study area, two mosaics were used (one of

Waimea and one of Kekaha). Photomosaics from 1950 and 1987 provided historical coverage. Mosaics from 2006 provided modern coverage. Several other years of mosaics were available, but were not analyzed due to poor water conditions because of suspended sediment from Waimea River. The mosaics that were chosen for this study had the best seafloor viewing conditions.

ArcGIS 9 was used for this research. Each photomosaic was imported into ArcGIS as a TIFF image file and used as a base map. To increase the visual contrast of the photomosaics, a standard deviation stretch was applied to each image. This made the sand easier to distinguish from other material, such as coral reef, reef rubble, limestone pavement, or volcanic pavement. Any continuous sandy area consisting mainly of sand with very little to no alternate material present was classified as a sand field.

All visible sand fields were digitized manually for each mosaic using ArcMap. This was done by manually tracing each sand field using individual vectors. Once an entire sand field was traced, a polygon was created. With all of the sand fields digitized as polygons, ArcToolbox was used to determine the overlapping extent of historic and modern sand fields, which represents stable sand fields. Lastly, the surface areas of the ephemeral and non-ephemeral sand fields were calculated using ArcMap.

Errors and Uncertainties

Photomosaic resolution produces an uncertainty of 0.5 m (the pixel size) for all imagery. There are image quality and spatial uncertainties associated with ortho-rectification of the photographs.

Rectification errors are as follows:

- Kihei
 - 1960, ± 0.67 m
 - 1997, ± 0.73 m
 - 2007, ± 0.66 m
- Kahului
 - 1975, ± 0.96 m (avg.)
 - 2002, ± 0.10 m
- Poipu
 - 1975, ± 1.25 m
 - 2007, ± 0.73 m
- Kekaha (east)
 - 1950, ± 1.28 m
 - 1987, ± 0.75 m
 - 2006, ± 0.75 m
- Kekaha (west)
 - 1950, ± 1.99 m
 - 1987, ± 1.27 m
 - 2006, ± 0.78 m.

Uncertainty is also associated with digitizing the images. To determine the error in m^2 due to the digitization process, one large sand field and one small sand field from the 2007 Kihei base map were each manually digitized 30 times. The total area of each polygon was calculated, and standard

deviations were determined for the small and large sand fields. The error associated with the digitization of small sand fields is $\pm 25 \text{ m}^2$, and the error associated with the digitization of large sand fields is $\pm 137 \text{ m}^2$. Overall, digitization produces a Root Mean Square Error of $\pm 139 \text{ m}^2$. The RMS error represents 0.25% of the total area of stable sand identified.

Field Visits

Ground-truthing was performed in Poipu, Kauai to investigate possible sand resources. The areas of interest lay offshore of Brennecke Beach and Koloa Landing (Hanalei Bay). In the 2007 imagery, the depth of the water in both of the areas made it difficult to identify the composition of the seafloor. However, the color was slightly lighter, which suggested it was sand. Researchers swam about 250 m out from Koloa Landing to the presumed sand field. Some coarse sand was present in a channel leading out from shore; however this was an insignificant amount. From there, researchers swam west about 100 m. The sand field did not continue west as expected. The composition was mainly reef rubble and rock. It was concluded that the area off of Koloa Landing is not a viable resource for beach nourishment.

In addition, researchers swam out about 300 m from Brennecke Beach to the area of interest. The entire distance contained medium-grained sand. This sand field continued about 300 m west and ended before a tombolo where a rock shelf extends to the shore of Poipu Beach. This is a very large sand field that appears to be an excellent resource.

Visual assessment of Poipu Beach and Bay reveals that the mouth of the eastern bay is blocked by a shallow sill of less than 1 m depth. This prevents sand from entering the bay and renourishing losses due to currents carrying sand into the western bay. The offshore sand field immediately adjacent to the eastern bay appears to be a strong candidate for further investigation. Jet probing, the next likely step, should reveal whether the sand field has potential as a resource. It is recommended that the portion of the field closest to Poipu be targeted for use. This would likely eliminate any potential impacts to Brennecke Beach due to sand removal.

Results

Sandy area with no overlap between historic and modern coverage indicates that sand has been transported during the years of coverage. This sand is ephemeral, and it is not likely to be found in significant volume to be useful as a resource for beach nourishment. In contrast, any area of sand that is unchanging between historic and modern coverage represents non-ephemeral (stable) sand and is a potential target for further investigation as a resource for beach nourishment.

1. Kihei, Maui – A total of $521,034 \text{ m}^2$ of modern reef-top sand was identified along the Kihei coast (Fig. 3). Of this sand, $55,821 \text{ m}^2$ is stable reef-top sand. The largest non-ephemeral sand field has a surface area of $10,295 \text{ m}^2$, serving as a potential reservoir to replenish beaches. This sand field is located off of Kalama Beach Park. The next largest sand field is located off of

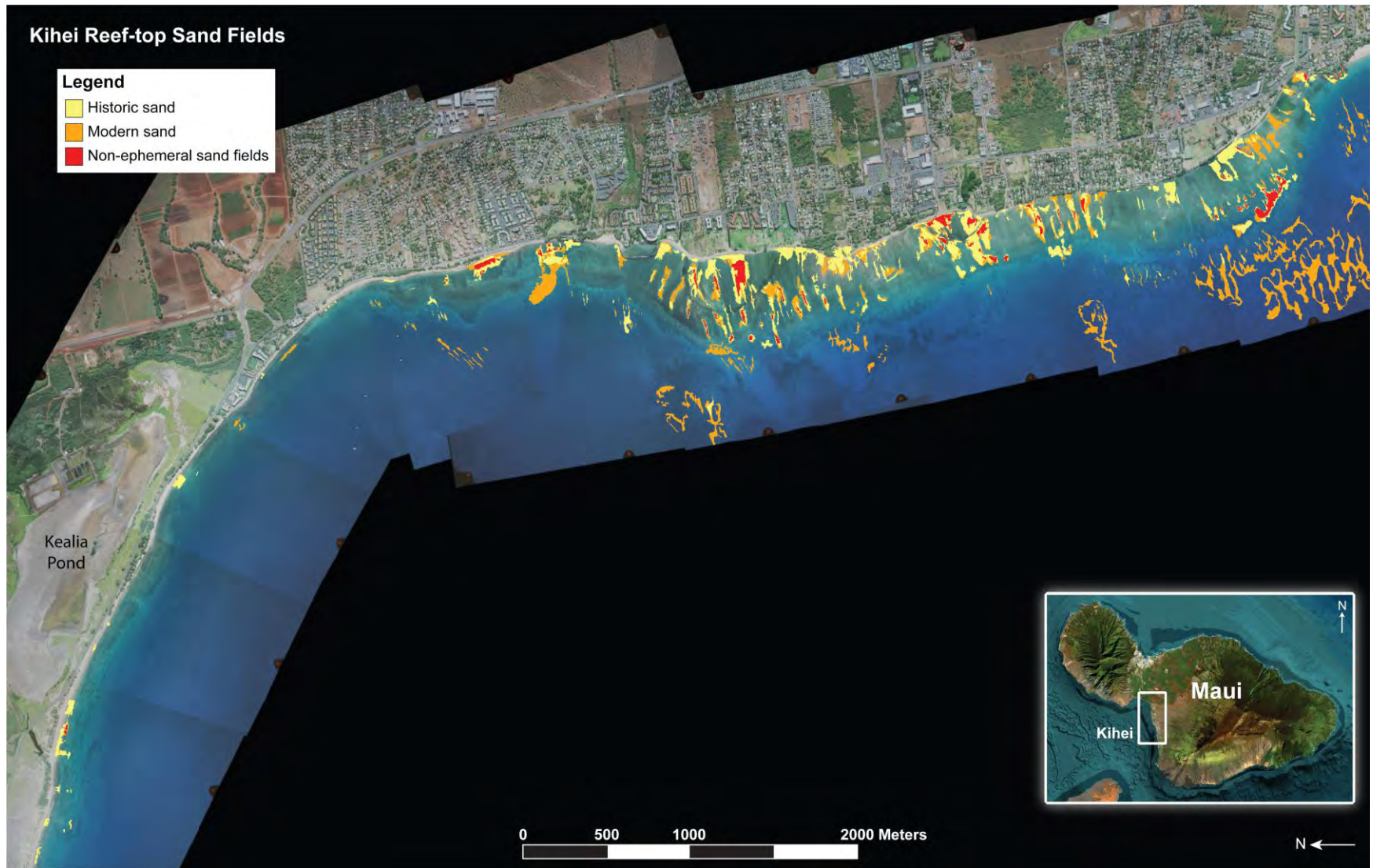


Figure 3. Reef-top sand fields located at Kihei, Maui.

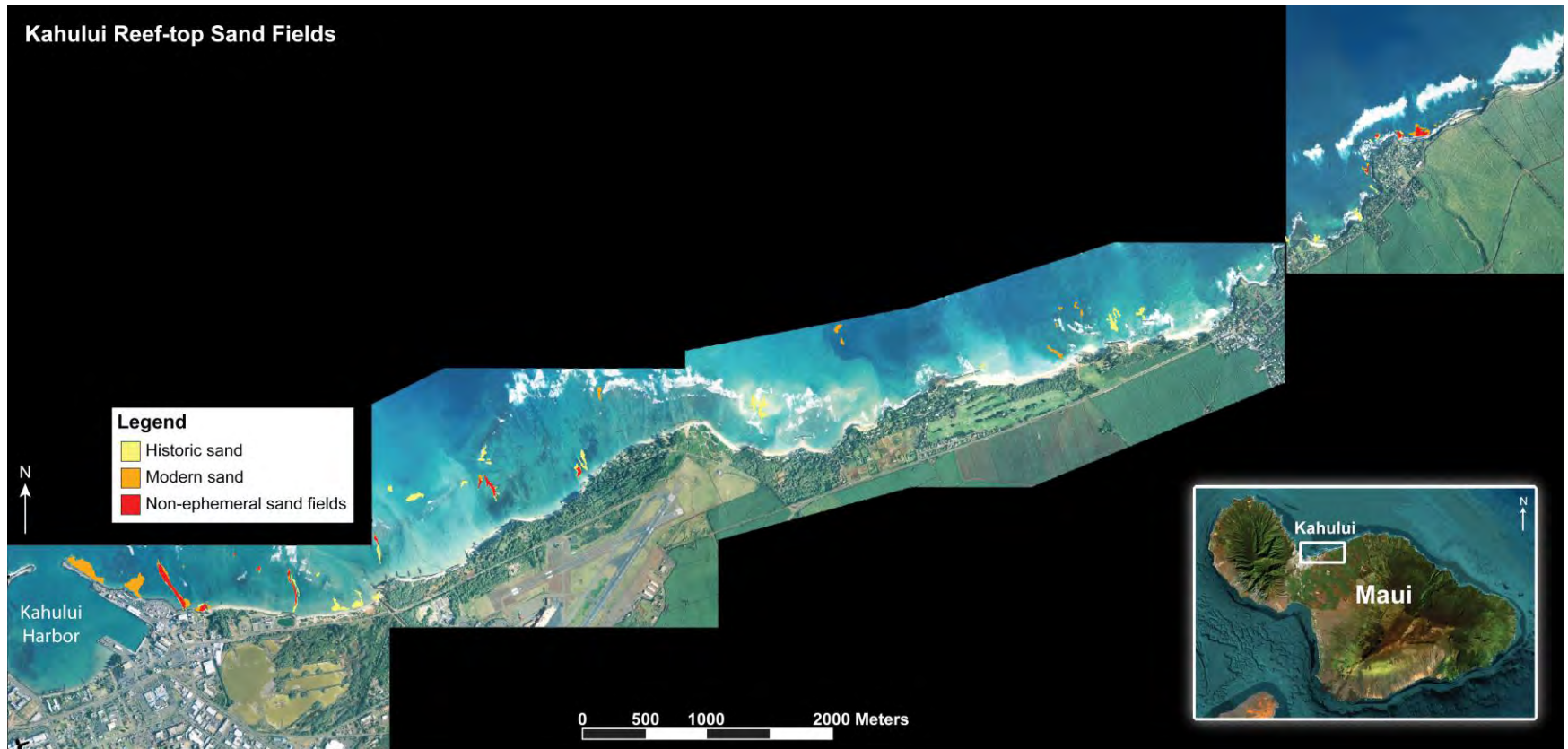


Figure 4. Reef-top sand fields located at Kahului, Maui.

- Waipuilani Park and consists of 9,115 m² of stable sand.
2. North Shore, Maui – A total of 93,927 m² of modern reef-top sand was identified along the north shore of Maui (Fig. 4). Of this sand, about a third (31,656 m²) is stable reef-top sand. The largest stable sand field has a surface area of 11,027 m² and is located just outside of Kahului Harbor (on the east side) in a channel leading out from the shore. In comparison to the other study areas, the north shore of Maui has the fewest number of stable sand fields and the smallest total area of stable sand. All of the stable sand fields identified are either small patches or channels, as opposed to large fields. However, it is possible that there is more stable sand along the north shore of Maui than estimated. This is because the imagery does not extend very far offshore. In some places, such as Kahului Harbor, the imagery only extends 600 m from the shore. In addition, there are several areas where turbidity of the water column obstructs the view of the seafloor.
 3. Poipu, Kauai – A total of 581,419 m² of modern reef-top sand was identified along the coast of Poipu (Fig. 5). Of this sand, about half (292,104 m²) is non-ephemeral, (stable) sand. The largest stable sand field is located off of Brennecke Beach and consists of 218,829 m². It is likely a significant resource for beach nourishment. The 2007 mosaic extends into deeper water than the 1975 mosaic. It is likely that the sand field off of Brennecke Beach extends further than the coverage of the 1975 mosaic. Thus, the sand field off Brennecke Beach may contain a greater area of sand than estimated.
 4. Kekaha, Kauai – A total of 850,592 m² of reef-top sand was identified along the coast of Kekaha (Fig. 6). The majority of this sand (766,461 m²) is non-ephemeral, stable sand. The largest sand field is located off of Kekaha Beach Park and consists of 638,448 m² of stable sand. It is a potential resource for beach nourishment, and should be further investigated. It is possible that this sand field has a greater surface area than estimated. The depth of the water in this area made it difficult to determine where the sand field ended. Therefore, the digitization performed was a conservative estimation of the size. The second largest sand field is also located off of Kekaha Beach Park and has a surface area of 76,952 m². No significant sand fields were found in the Waimea area. Suspended sediment from Waimea River caused poor water conditions and prevented the identification of sand in this area.

Discussion

Field visits for ground-truthing, to locations not yet visited, would be a beneficial next step in this research. This would help to decrease errors and uncertainties in the data. Surface glint, cloud cover, poor water quality, and depth were a major problem in the imagery. In particular, as the depth of water increased, visibility of the seafloor decreased. This resulted in many areas in the photomosaics where the composition of the seafloor was unclear. In many cases the seafloor may have been characterized by loose sand, however there was no way of determining this from the image. In these instances, no digitization was performed. Thus, it is possible that there are stable sand resources in the study areas that were overlooked. This can only be rectified by physically observing the composition in person.

In addition, jet probing, and sediment grain size analysis, targeting non-ephemeral (stable) sand fields as identified here, are recommended to determine the volume of sand available and its suitability as a beach resource. Surface area alone is not enough to determine if a sand field contains enough sand to be used as a resource. Jet-probing will determine the thickness, and therefore the volume of a sand

field. Grain size statistics will provide valuable information on the suitability of various sand fields as resources for beaches needing nourishment.

Conclusions

1. 55,821 m² of stable sand is stored on the reef flat off the coast of Kihei, Maui, serving as potential resource for beach replenishment.
2. 31,656 m² of stable sand is stored on the reef flat off of the north shore of Maui.
3. 292,104 m² of stable reef-top sand is stored off the coast of Poipu, Kauai. The majority of this sand is located in a large sand field off of Brennecke Beach.
4. 766,461 m² of stable reef-top sand is stored off the coast of Kekaha, Kauai. The majority of this sand is located in two large sand fields off of Kekaha Beach Park.
5. Crucial future directions include field visits and jet probing.

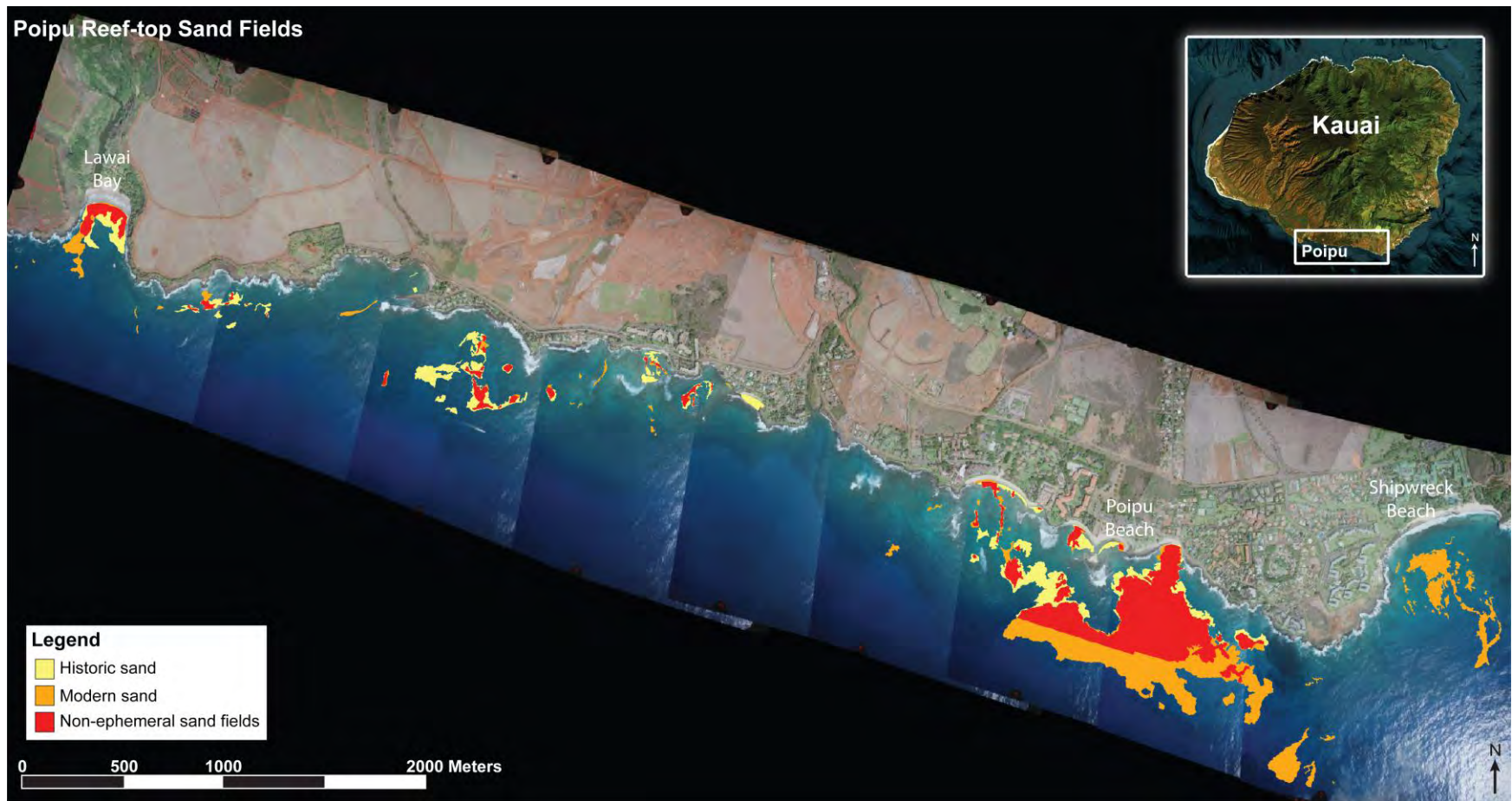


Figure 5. Reef-top sand fields located at Poipu, Kauai.

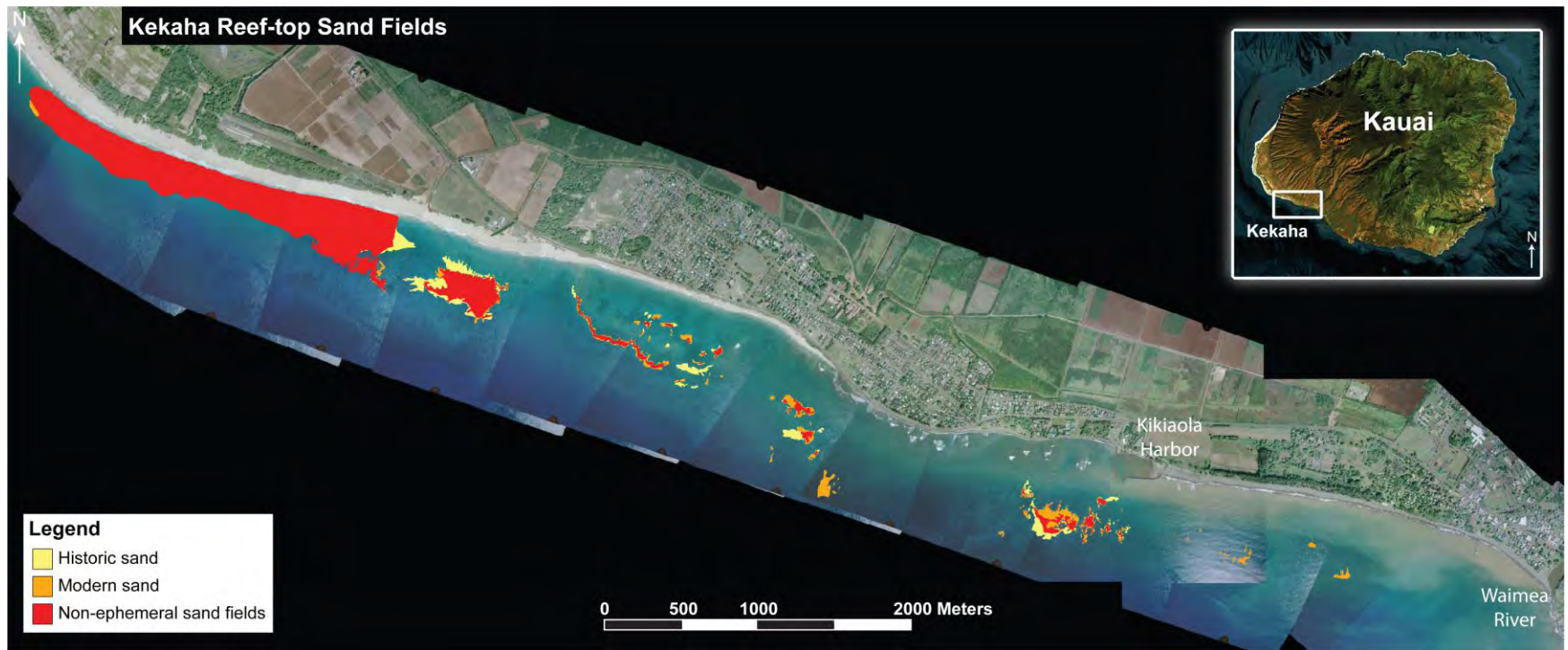


Figure 6. Reef-top sand fields located at Kekaha, Kauai.

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