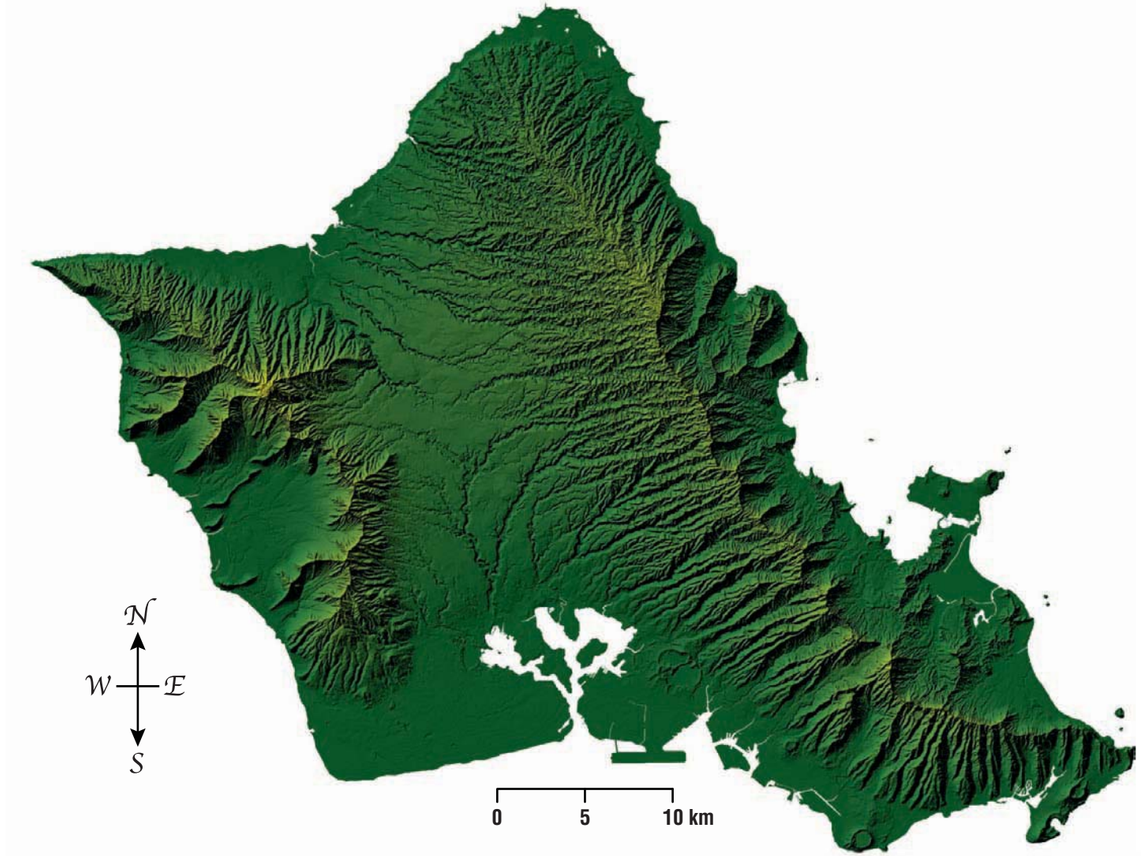
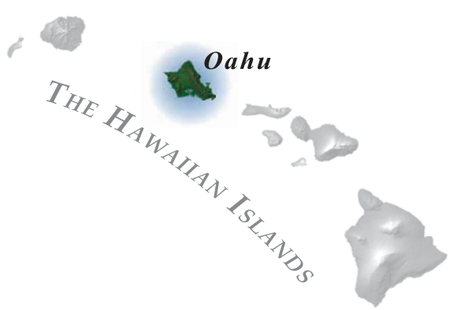
Oahu Coastal Stream Mouth Map Book





US Army Corps of Engineers

Department of Land and Natural Resources, State of Hawaii

School of Ocean and Earth Science and Technology, University of Hawai'i at Mānoa

United States Army Corps of Engineers, Honolulu Engineering District
Department of Land and Natural Resources, Office of Conservation and Coastal Lands
University of Hawaii at Manoa, School of Ocean and Earth Science and Technology
January 2010

THE FOLLOWING CONTRIBUTED TO THE PRODUCTION OF THIS MAP BOOK

The City and County of Honolulu (Department of Design and Construction, Facilities Division; Department of Facility Maintenance, Division of Road Maintenance; Department of Planning and Permitting), Hawaii Department of Land and Natural Resources (Division of Aquatic Resources, Office of Conservation and Coastal Lands), Hawaii Office of Planning, Hawaii Department of Transportation, Hawaii Department of Health, U.S. Army Corps of Engineers (Honolulu District), University of Hawaii Sea Grant Program, Troy Heitmann.

U. S. Army Corps of Engineers, 2010, Oahu Coastal Stream Mouth Map Book, prepared by the University of Hawaii Coastal Geology Group for Honolulu Engineering District, 70 p.

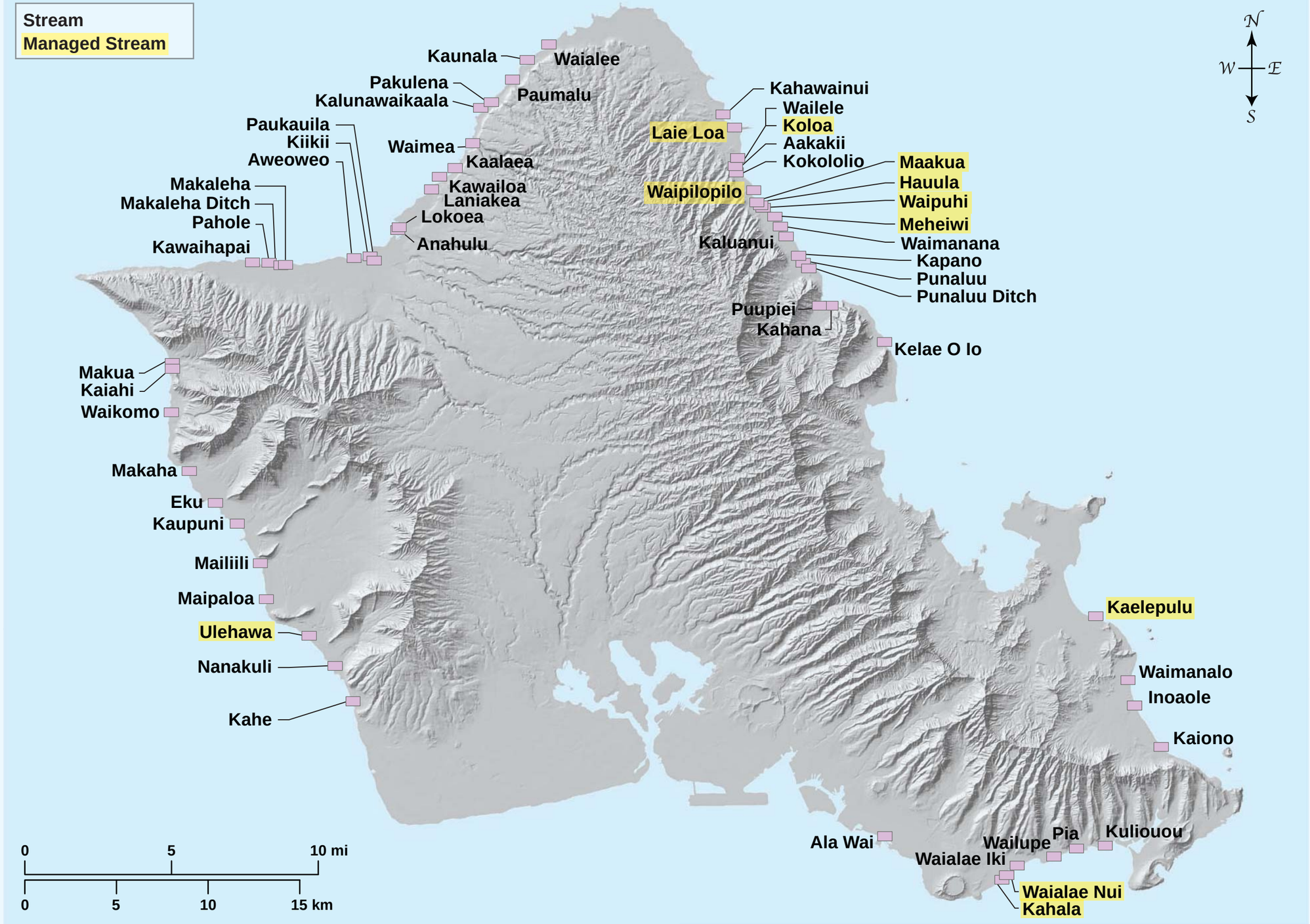


Figure 1 Oahu stream mouth locations included in this map book are indexed geographically beginning with Ala Wai and proceeding clockwise around the island. Yellow highlighted streams are managed.

Table of Contents

List of Figures:

Introduction and Coastal Characteristics

Introduction This map book was produced to assist in the development of appropriate sediment management practices at 59 stream mouths that empty into the ocean on Oahu. Streams are presented in clockwise order around the island beginning with the Ala Wai Canal. These have been identified largely through two sources: the Hawaii Geographic Information System (GIS) Office located in the Hawaii Department of Business and Economic Development (DBEDT); and the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* provided by the Division of Aquatic Resources (DAR) located in the Hawaii Department of Land and Natural Resources (DLNR). Most of these streams are intermittent and do not require regular sediment management. However, at least 11 streams do require regular maintenance.

This map book devotes one page to each stream mouth including a description of the littoral setting, an orthophoto map is included showing location as well as ground level photographs. Superimposed on the orthophoto map are symbols indicating wind and wave approach that may impact sediment transport.

Stream Names The majority of stream names around the island of Oahu were collected from the state inventory of streams geographic information system layer for the island of Oahu. There are several instances where these names are different from signage at the stream location and the common name used by the local community. In these instances care was taken to include alternative names and their source.

Climate Managing stream mouths requires an awareness of coastal littoral sediment transport as well as discharge and sediment delivery from the adjacent watershed; Hence, island climatology is important. Island-wide, the climate is sub-tropical oceanic. Honolulu has a mean monthly temperature of 21.7°C (71.1°F) in January, rising to 25.6°C (78.2°F) in July, and an average annual rainfall of 802 mm (31.6 in). However, due to wind and rain shadowing and orographic effects there is significant climate diversity across the island. Specific localized rainfall, wind, and wave conditions govern sediment behavior, accumulation, and composition at the shoreline.

Stream Mouth Setting The island of Oahu has four primary coastal segments: north shore, windward, south shore, and leeward (Figure 2).

Rain Oahu Island lies in the zone of northeasterly tradewinds, which bring rainfall to the windward mountain slopes while the leeward coasts are in rain shadow (Figure 3). Oahu's preeminent example of this orographic rain is the difference in rainfall between the windward shoreline (1524-2032 mm/yr; 60-80 in/yr) and the more arid west shore (508-762 mm/yr; 20 to 30 in/yr).

Streams drain watersheds that experience variable rainfall along their length. Streams draining windward slopes are fed by watersheds with rainfall ranging from 2032 to 6604 mm/yr (80 to 260 in/yr). West shore watersheds are semi-arid, with annual rainfall of 762 to 1524 mm (30 to 60 in) throughout their watersheds. South shore watersheds drain lands receiving 762 to 5080 mm/yr (30 to 200 in/yr) and north shore watersheds receive 1016 to 5080 mm/yr (40 to 200 in/yr).

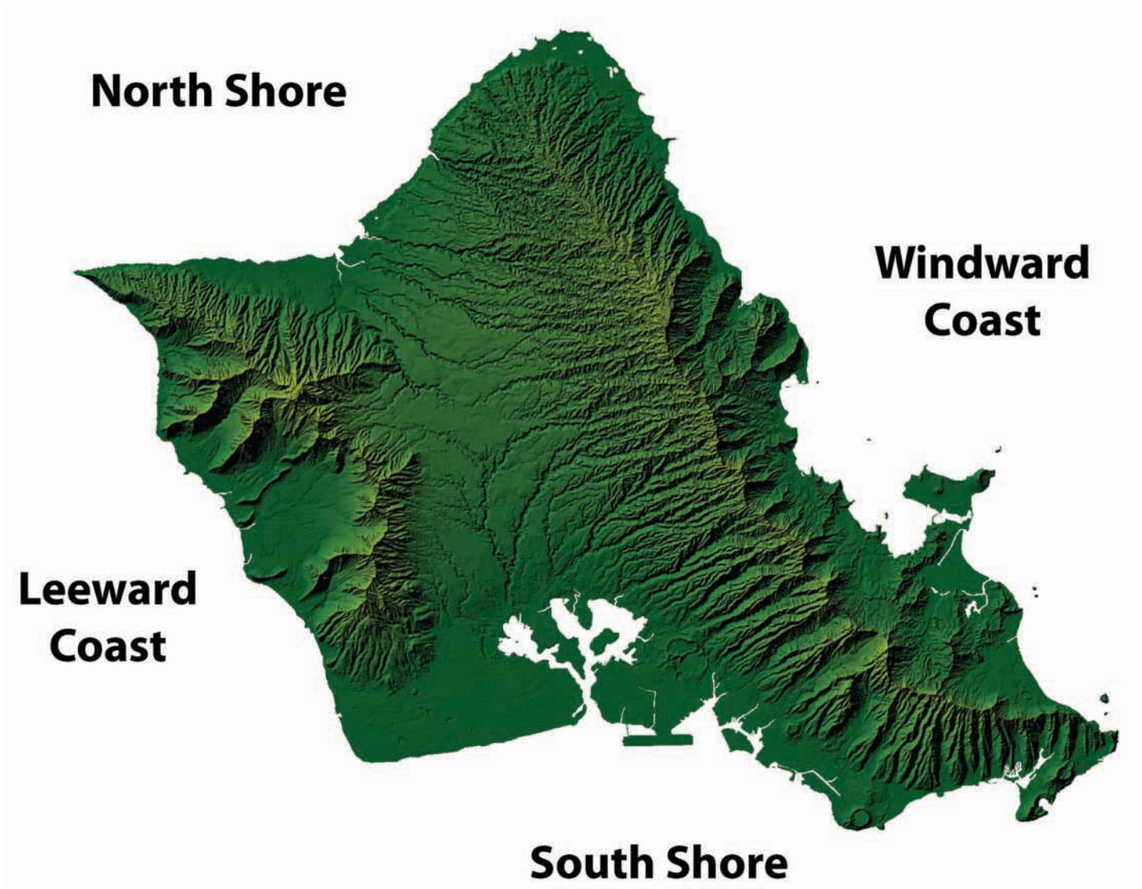


Figure 2 The four coastal segments of Oahu.

Floods Flashfloods pose significant management challenges at stream mouths (Fletcher et al. 2002). Capable of experiencing over 254 mm (10 in) of rainfall in an hour, Oahu watersheds on all sides of the island may evolve from dry stream beds to raging flood waters in less than one hour. Under these conditions, stream mouths that are clogged with sediment pose a potential flood problem for steam bank communities located on low coastal lands. During high tide or periods of high waves when the sea level is high, stream mouths may not drain effectively. As a result flood waters flow over the bank and accumulate on the coastal plain. These may cause damage to low lying communities such as Laie, Hauula, and portions of Kailua, Waimanalo, and others.

Sea Level Tide range on Oahu is small. Honolulu has a mean spring tide range of 0.6-0.8 m (2.0-2.6 ft). The Honolulu tide gauge records a long-term mean sea level rise of approximately 1.5 mm/yr (0.6 in/decade). However, submerged wave cut notches and raised coral reef can be found at various elevations and locations around Oahu indicating past oscillations of land and sea level (Fletcher et al., 2008). On most shores, a high sea level about 3000 years ago deposited sand on which we have since built roads and communities.

Because of global warming, sea level rise has accelerated globally (Church and White, 2006). In a study of Hawaii tide gauges, Firing and Merrifield (2004) found that superimposed on the long

term rate of rise are punctuated short term periods of accelerated rise that are increasing in frequency and magnitude. As sea level continues to rise, the ability of stream mouths to effectively drain into the ocean is reduced. With marine inundation, stream mouths will deepen and widen into estuaries rimmed by tidal wetlands. This trend will be marked by increasingly frequent and damaging flooding events especially where runoff and high tide coincide. With a rise of 0.75 - 1.9 m projected by the end of the 21st century (Vermeer and Rahmstorf, 2009), many Oahu stream mouths will broaden into significant estuarine ecosystems with new management challenges. Flooding will increase in frequency and magnitude and the effects of high tide and high wave periods will be felt by an increasingly large portion of the community and ecosystem.

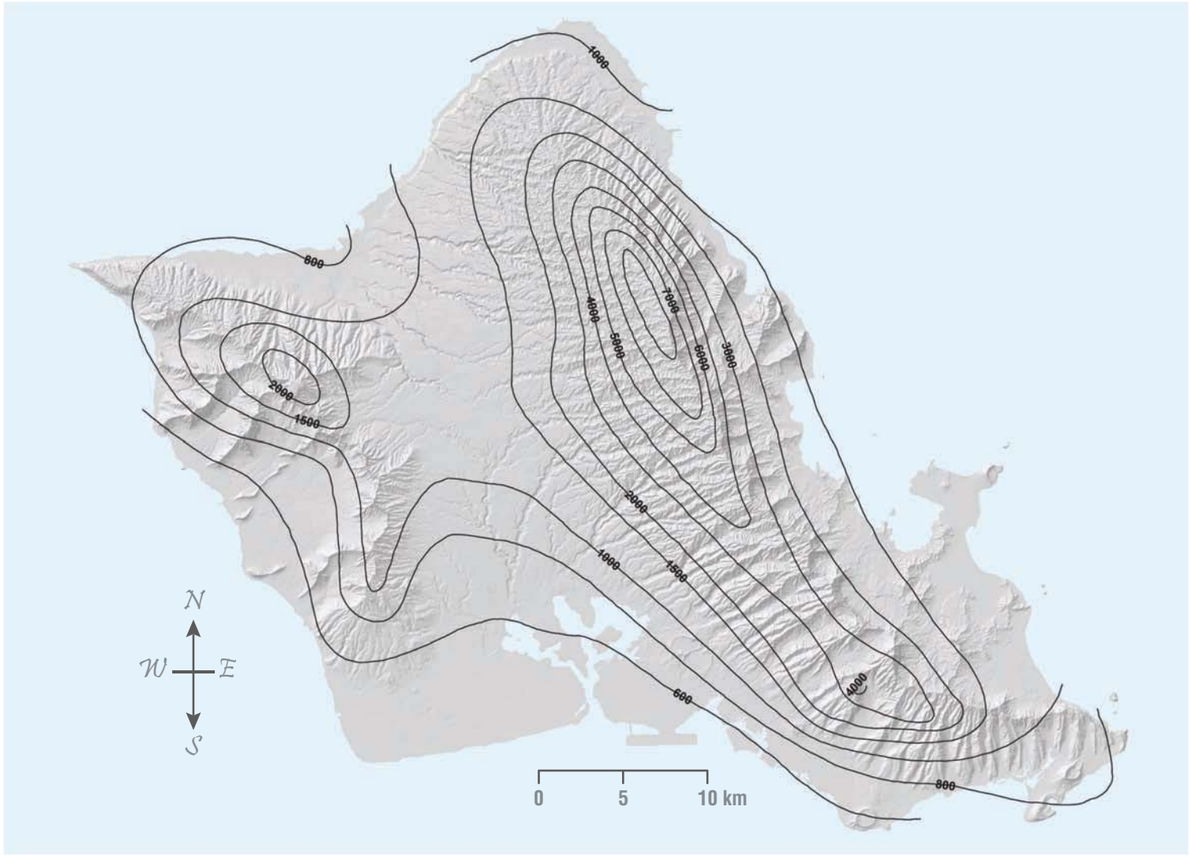


Figure 3 Oahu rainfall; contours in millimeters of median annual rainfall (500 mm interval).

Sand Many streams on Oahu are intermittent, only flowing during times of direct rainfall; hence the stream mouth is often clogged with coastal sand (Figure 4) as that is the only sediment in active transport most times of the year. A critical issue for stream mouth management is the disposal of beach quality sands that are periodically removed as part of maintenance. Year after year beaches are deprived of sand that is hauled away from coastal stream mouths. This may contribute to chronic coastal erosion. Proper disposal of beach quality sands on the adjoining shoreline should be a matter of establishing best management practices wherein both beaches and the stream mouth are co-managed with equal consideration under the same plan.

Beaches include creamy white calcareous ($CaCO_3$) sand, derived from the tests of microorganisms, weathered coral, calcareous marine algae, lithic fragments (typically of Pleistocene skeletal limestone), mollusk and echinoderm fragments (Harney et al. 2000) , and black and green sand derived from volcanic material. Ferromagnesian olivine and other basaltic minerals are relatively unstable in the tropical climate of Hawaii, and are reduced by weathering. Calcareous beaches are dominant on Oahu where significant coral reef communities have been able to develop.

Most of the Oahu shoreline is fronted by fringing reefs (Figure 5). These are home to organisms that produce much of the coastal sand that tends to fill stream mouths. Other sources of sand include erosion of the adjacent coastal plain which releases sand deposited there by wind and past higher sea levels, and landward transport of sand through channels incised into fringing reefs. Most Oahu beaches are dominated by longshore transport so that managing sand requires knowledge of sediment movement along the adjacent shore.

Two organisms serve as principal architects of Hawaiian reefs: scleractinian (stony or hard) corals, and coralline and calcareous algae. There are over fifty species of coral found in the Hawaiian Islands but only a few are common. The more abundant Hawaiian genera include rice corals (Montipora species), lobe and finger corals (Porites species), cauliflower or moosehorn corals (Pocillopora species), and false brain corals (Pavona species). These may be bioeroded and/or abraded and battered by high waves to yield coral sand.

Coralline algae and calcareous algae are members of a marine plant group on the reef that deposits calcium carbonate in its tissue. When the algae die, it leaves a fossil skeleton that is hard and whitish. A few species of calcareous algae, such as the Halimeda, are especially abundant in Hawaii and important reef components. Hard plant debris builds up as piles of sediment in reef environments and is an important source of beach sand, making up over half the grains on many Hawaiian beaches. The coralline algae look like coral and grow in a binding and encrusting form on the reef, competing for space with corals. Most coralline algae are red, but there are some exceptions. A visit to any intertidal rocky coast in Hawaii will reveal the encrusting coralline community coloring the rocks a brilliant hue in between the rise and fall of the waves. However, their sand products are whitish.

The coastal plains of most Hawaiian Islands hold major calcareous eolian (wind), littoral (intertidal), and marine sand deposits formed during and following high sea levels about 3,000 years ago (Fletcher and Jones 1996; Grossman and Fletcher 1998) and persistent recent deposition under seasonal winds. Sand is also stored on the reef flat in shore-normal reef channels and shallow Pleistocene karst depressions (Fletcher et al. 2008). Longshore transport dominates sediment movement on the coast in distinct littoral cells.

Clasts Stream mouths are also the site of basalt clast deposition. Clasts are gravel and boulders typically brought from the watershed during flashfloods. Clasts are usually composed of basalt and derived from the volcanic outcrops that line the streambed and banks in steeper sections of the watershed. Clasts and basaltic sand, as well as red mud produced by chemical weathering of basalt, mix with carbonate sand and gravel on the shoreline to form small delta deposits in some stream mouths. These control the sedimentology and the morphology of the shoreline in the

Figure 4 Photo of Kaelepulu stream mouth, Kailua Beach Park. White carbonate sand dominates most Oahu beaches and collects in many stream mouths.

immediate area.

Waves In addition to northeasterly waves generated by the tradewinds there are ocean swells from the north in the winter and the south in the summer months. The central Pacific location of Oahu exposes it to wind and ocean swells from all directions. Portions of coastline may have rain, wind, and wave shadows, and are either protected from, or vulnerable to, wind and wave impact. The four dominant regimes responsible for large waves in Hawaii are: north Pacific swell, tradewind swell, south swell, and Kona storms. The regions of influence of these regimes, outlined by Moberly & Chamberlain (1964), are shown in Figure 6; a wave rose depicting annual swell heights and directions has been added to their original graphic (Vitousek and Fletcher, 2008).

Inter-annual and decadal cycles including El Niño Southern Oscillation (ENSO) occurring approximately every three to four years, and Pacific Decadal Oscillation (PDO) occurring around 20–30 years, influence the variability of the wave climate. These large-scale oceanic and atmospheric phenomena are thought to control the magnitude and frequency of extreme swell events. For example, times of strong ENSO may result in larger and more frequent swell. Understanding the magnitude and frequency of extreme wave events is important as they may control processes such as sediment transport, beach morphology, and sea level position that modulates stream mouth flooding.

In the winter, Hawaii receives large ocean swell from extra-tropical storms that track predominantly eastward from origins in the northwest Pacific. These storms produce waves that travel for thousands of kilometers until reaching the shores of Hawaii. North swell have annually recurring maximum deep-water significant wave heights of 7.7 m (25.2 ft) with peak periods of 14-18 s. However, the size and number of swell events each year is highly variable – varying by a factor of 2. The annual maximum wave height ranges from about 6.8 m (22.3 ft; in 1994, 1997, 2001) to 12.3 m (40.3 ft; 1988).

Occurring about 75% of the year, the tradewinds arrive from the east and northeast with an average speed of 25 km/hr (15 miles/hr) and direction 73°. In winter months, the north Pacific high generating these winds flattens and moves closer to the islands decreasing tradewind persistence. Although the number of windy days in summer months increases, the mean tradewind speed in summer and winter months remains similar. The trades generate choppy seas with average wave heights of 2 m (6.6 ft; 1σ = 0.5 m; 1.6 ft) and peak periods of 9 s (1σ = 2.5 s) from the northeast. Although these represent nominal conditions, tradewind swell can exceed 5 m (16.4 ft) in height and have periods of 15–20 s.

Figure 5 Aukai Beach Park, Hauula. Fringing reefs line much of the Oahu shoreline.

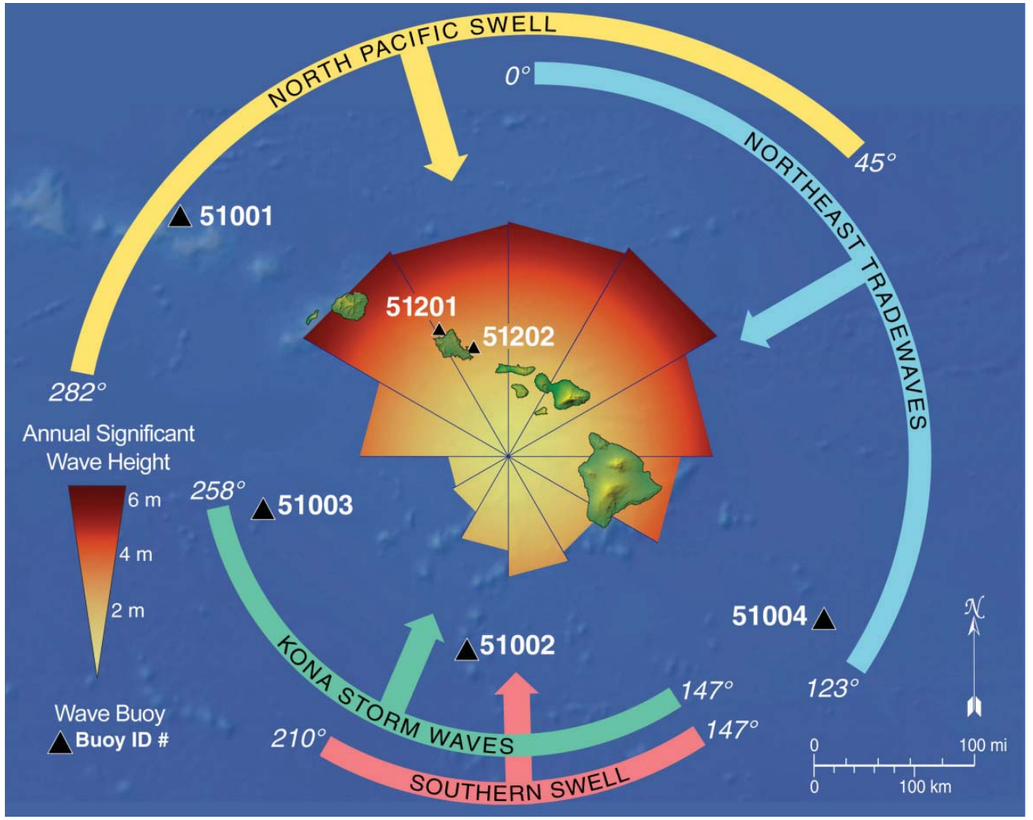


Figure 6 Hawaii dominant swell regimes after Moberly & Chamberlain (1964), and wave monitoring buoy locations; from Vitousek & Fletcher (2008).

Southern swell arriving in Hawaii is typically generated farther away than north Pacific swell. These are usually produced by storms south of the equator near Australia, New Zealand and as far as the Southern Ocean and propagate to Hawaii with little attenuation outside the storm-generated region. South swells occur in summer months (southern hemisphere winter) and reach Hawaii with an annual significant wave height of 2.5–3 m (8.2-9.8 ft) and peak periods of 14–22 s, which are slightly longer than north Pacific swell.

Kona storms are low-pressure areas (cyclones) of subtropical origin that usually develop northwest of Hawaii in winter and move slowly eastward, accompanied by southerly winds from whose direction the storm derives its name, and by the clouds and rain that have made these storms synonymous with bad weather in Hawaii. Strong Kona storms generate wave heights of 3–4 m (9.8-13.1 ft) and periods of 8–11 s, along with wind and rain, and can cause extensive damage to south and west facing shores. While minor Kona storms occur practically every year in Hawaii, major Kona storms producing strong winds, large wave heights and resulting shoreline change tend to occur every 5–10 years during the 20–30 year negative PDO cycle. Consequently, positive (warm) PDO, and El Niño phases tend to suppress Kona storm activity.

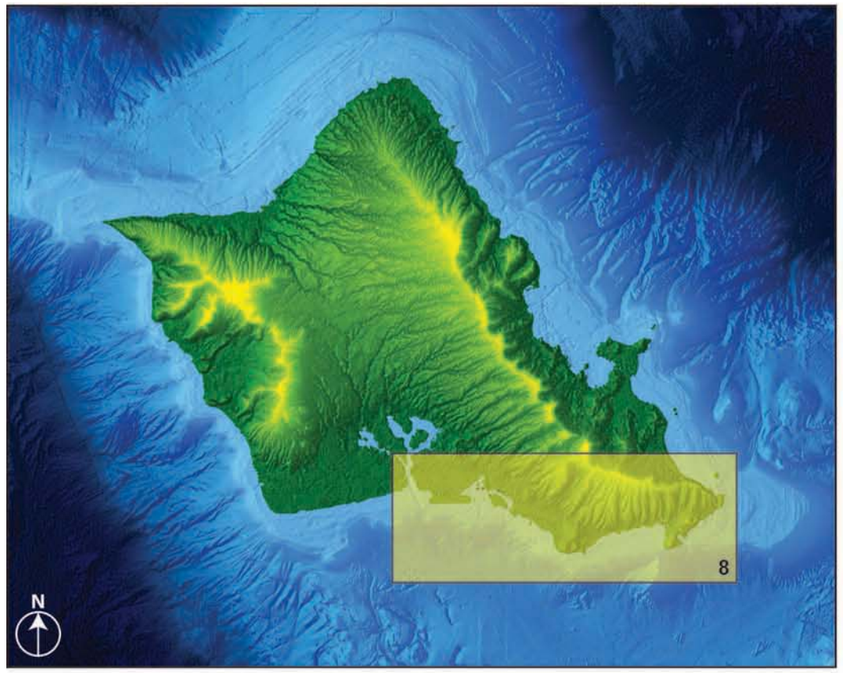


Figure 7 Locations for SWAN model results showing wave direction on the south shore. Wave conditions acquired from the National Data Buoy Center (NOAA-NDBC).

It is notable that the worst flash flooding has happened in association with Kona activity that either settles in over the islands for a prolonged stay, or a passing storm of such intensity that it overwhelms the discharge capacity of a watershed within hours and produces damaging flooding usually at the stream mouth where it enters the ocean.

Coastal Erosion There is widespread but variable coastal erosion in Hawaii in response to human interference with sand availability, waves and currents, and the inferred influence of sea level rise. For instance, researchers at the University of Hawaii measured the historical rate of shoreline change on every beach on the island of Kauai. Their data reveal that 72 percent of the beaches on Kauai are eroding and the average rate of erosion is 0.3 m/yr (1 ft/yr). On 22 percent of the eroding beaches, the rate of erosion is accelerating.

In pristine coastal areas calcareous sand stored on the low-lying coastal plain is released to the beach as sea level rises, allowing a wide sandy shore to be maintained even as the shoreline recedes. However, the threat to coastal property has led to extensive armoring of the coastline. Artificial hardening to protect coastal land may occur at the expense of the beach, preventing waves from accessing the sandy reservoirs impounded behind the seawalls and revetments. Thus, efforts to mitigate coastal erosion have created a serious sand deficiency on armored

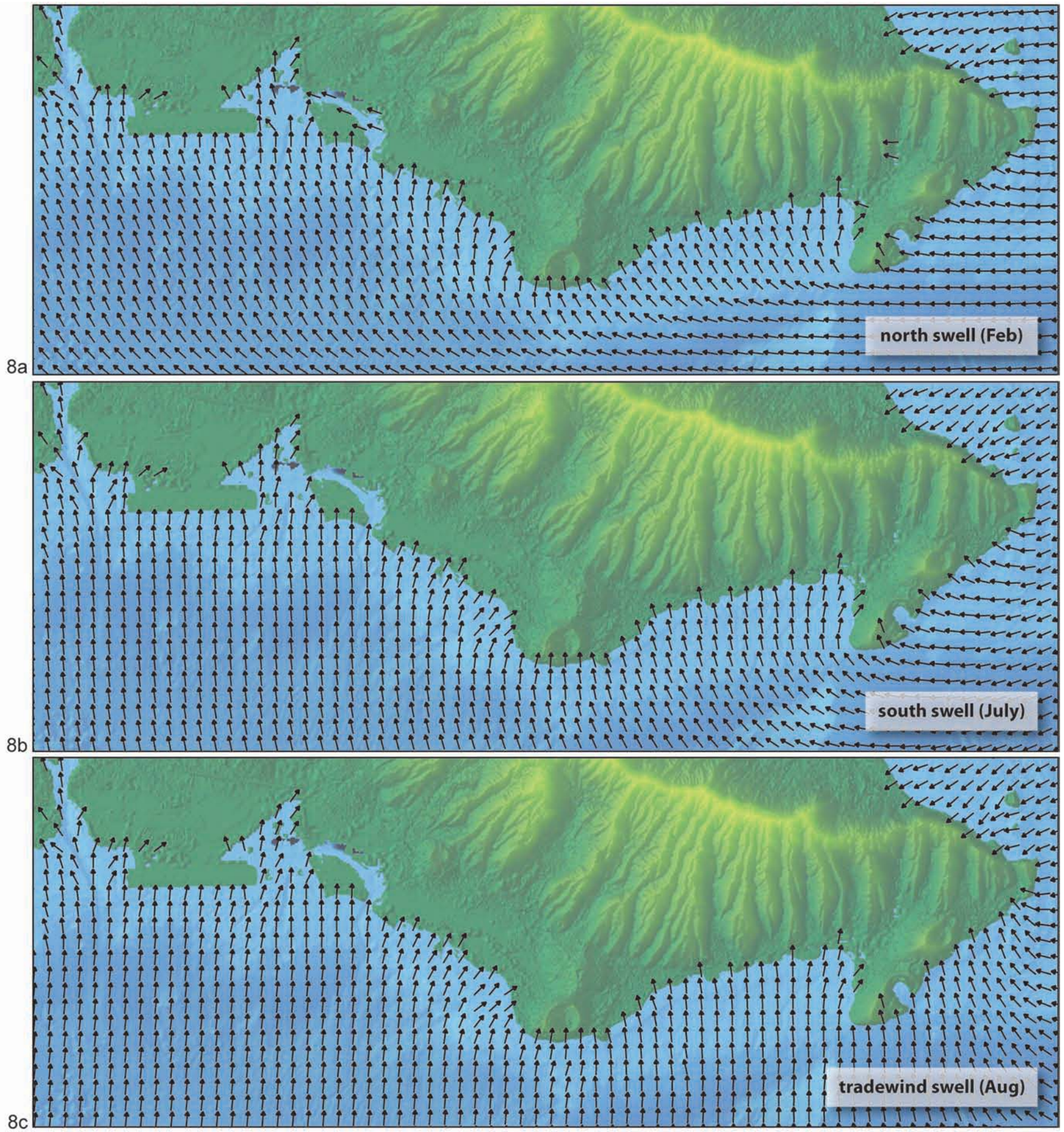


Figure 8 Modeled swell directions south shore: 8a - north swell (top); 8b - south swell (middle); 8c - tradewind swell (bottom)

beaches leading to widespread beach loss, particularly on Oahu where nearly one-quarter of the length of beaches at World War II had been lost by the late 1990's (Fletcher et al., 1997). The need to address this issue is acknowledged by the state and local communities. A broadly scoped management plan would keep a balance between the natural coastal morphology and human resource demands. Appropriate management of stream mouth sediment is one very important step in improving beach management.

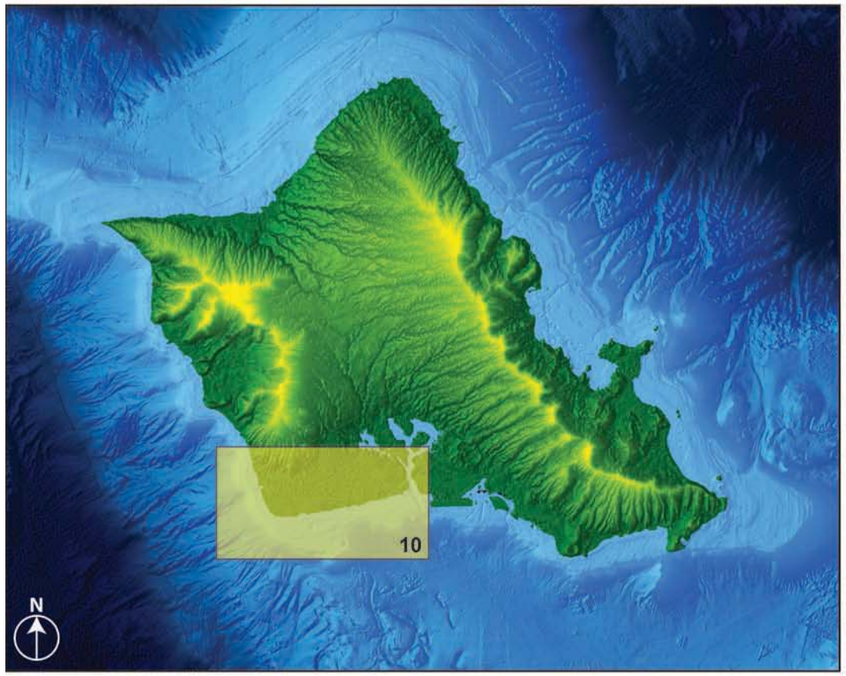
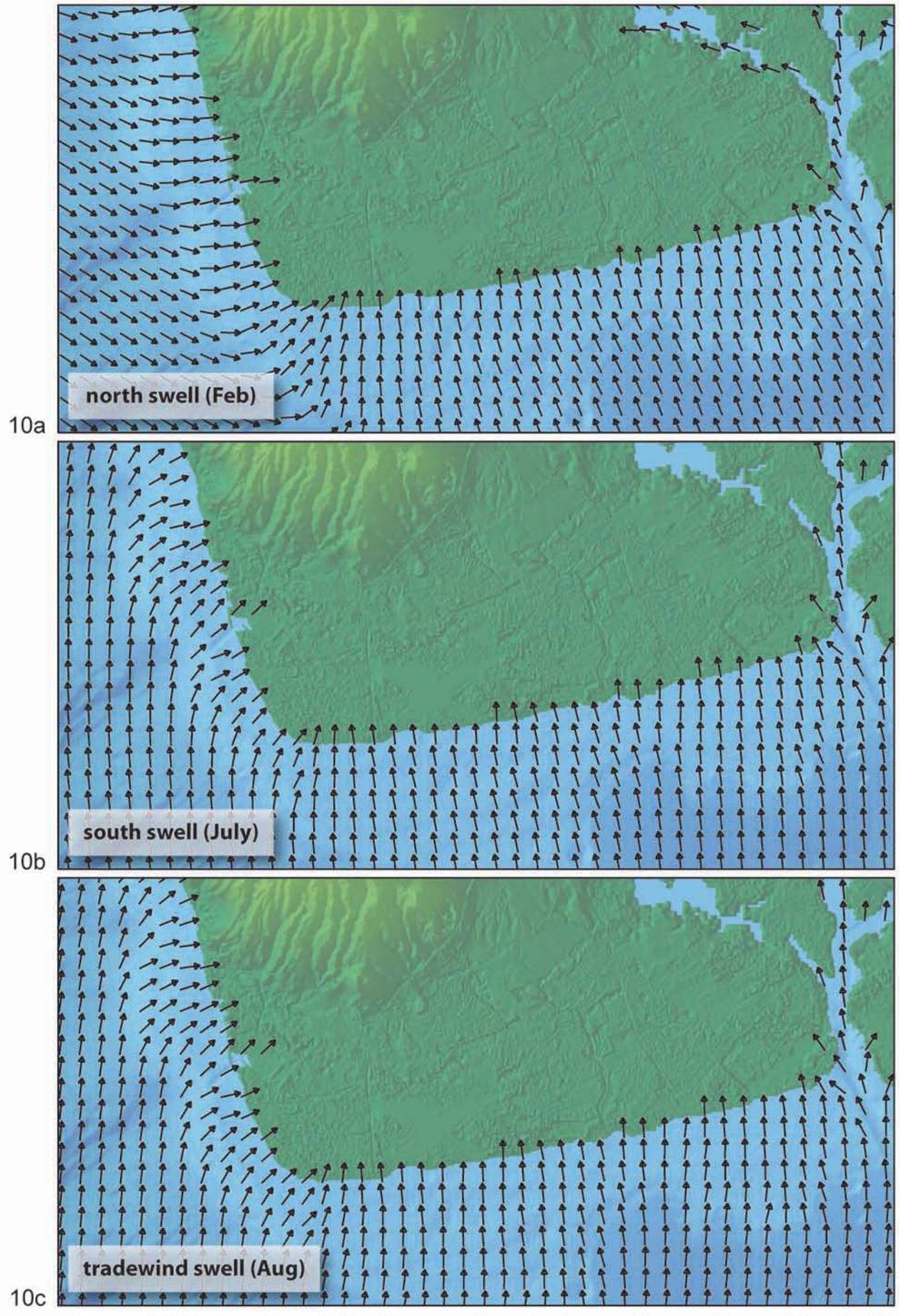


Figure 9 Locations for SWAN model results showing wave direction on the southwest shore.

Longshore Wave Approach The SWAN model simulates wave approach across deep and shallow bathymetry. SWAN results have been used to depict swell directions for coastal segments along the Oahu coast. Figures 7 - 18 shows results for Oahu. These provide background information to assist in decision-making for stream mouth management. Arrow diagrams can be interpreted in light of additional information of a more specific nature to assess longshore sand movement.

Hardened Structures At many locations around Oahu, stream mouth locations and nearby shorelines are stabilized using groins, channels, and seawalls. Where shore-normal structures exist at sediment rich locations, these may impede the longshore transportation of sand and lead to sand accumulation on the up-drift side and erosion on the down-drift side of the structure. If sand builds up in stream mouths because of this tendency, it may lead to obstruction of stream flow and flooding on the adjacent coastal plain. Sand trapping such as this will require maintenance to clear the sediment. In the case of shore-parallel structures such as sea walls and revetments, sediment is impounded landward of the structure. This may result in a net sediment deficiency in the littoral cell and overall migration of sand out of the active sandy beach system. In summary, sandy coastlines can be viewed as a "sand-sharing system" wherein it is appropriate for management practices to be evaluated in light of their potential to negatively impact adjacent environments.

Managing Oahu's Stream Mouth Sediment There is a large burden on federal, state and local government to effectively balance the myriad interests involved in accessing, moving and placing stream mouth sediment. Intense development along the Oahu coastline immediately surrounding stream mouths brings scrutiny to any sediment management activities. A general lack of beach quality sand coupled with water quality concerns have resulted in *ad hoc*



10a
10b
10c

Figure 10 Modeled swell directions southwest shore: 10a - north swell (top); 10b - south swell (middle); 10c - tradewind swell (bottom)

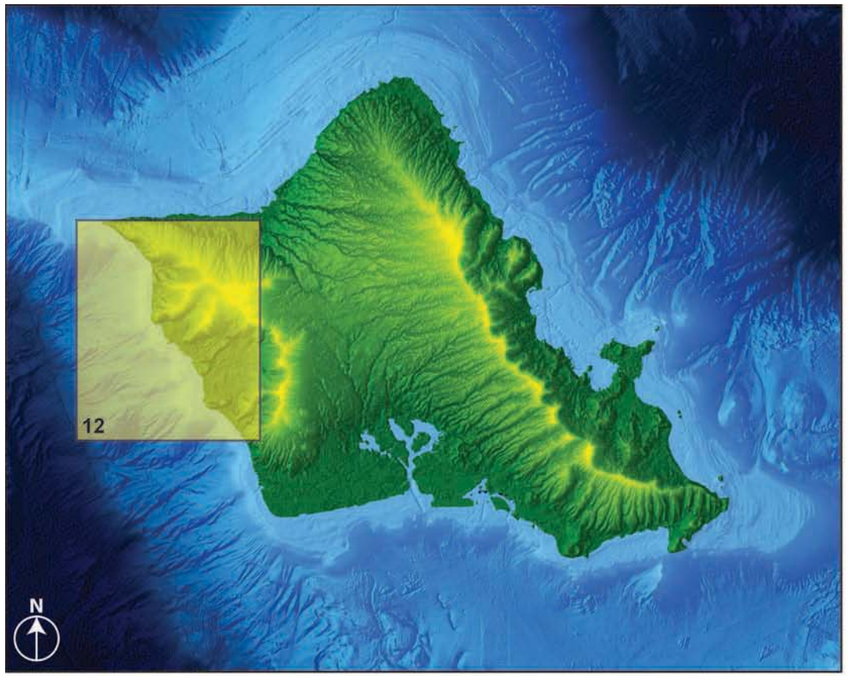


Figure 11 Locations for SWAN model results showing wave direction on the west shore.

management rather than integrated planning that balances all issues.
At the time of this publication, the City and County of Honolulu (C&C) Department of Facilities and Maintenance (DFM) provides maintenance responsibility to stream mouths around Oahu to protect the public and public infrastructure from flood hazards. They hold a general permit for sand moving that requires notification of the State Department of Health and Army Corps of Engineers before maintenance work. Notification takes the form of a schedule of works to be performed at specified locations, on specified dates.

Mandated sediment management responsibility lays with the Department of Land and Natural Resources (DLNR). However, required permitting on a case-by-case basis, limits their ability to provide regular coordinated management. In the interest of public safety and the protection of private property, the DFM routinely clears 12 stream mouths of upland debris and sediment on a scheduled monthly basis. Of these 12, 11 are described in this book (the 12th, Ewa canal contains no beach sediment and is not included in this study). Additional stream mouths are cleared as needed or requested by concerned communities and other C & C or state agencies with responsibilities near stream mouths (ie. State Department of Transportation). The works are carried out by DFM district depots that use available equipment. The type of equipment used largely dictates the type of sediment clearing and flexibility of placement.

(Continued on p. 8)

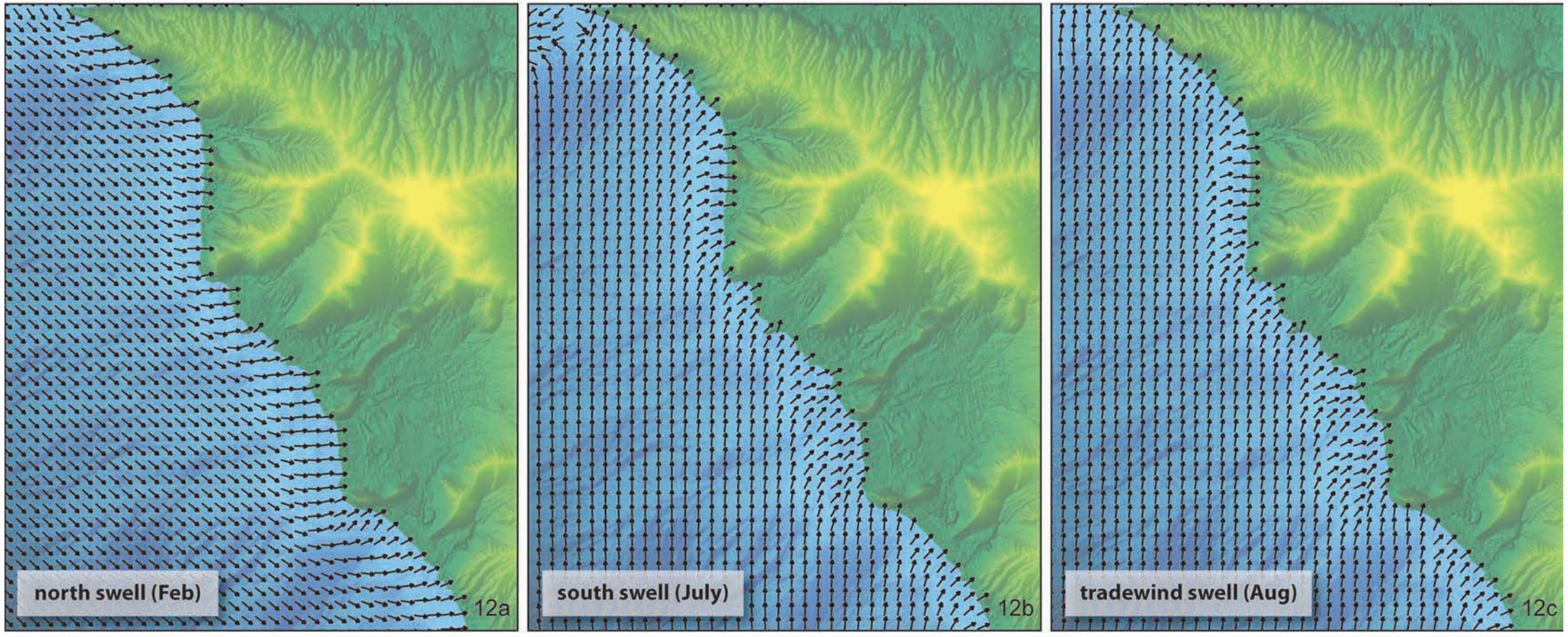


Figure 12 Modeled swell directions west shore: 12a - north swell (left); 12b - south swell (middle); 12c - tradewind swell (right)

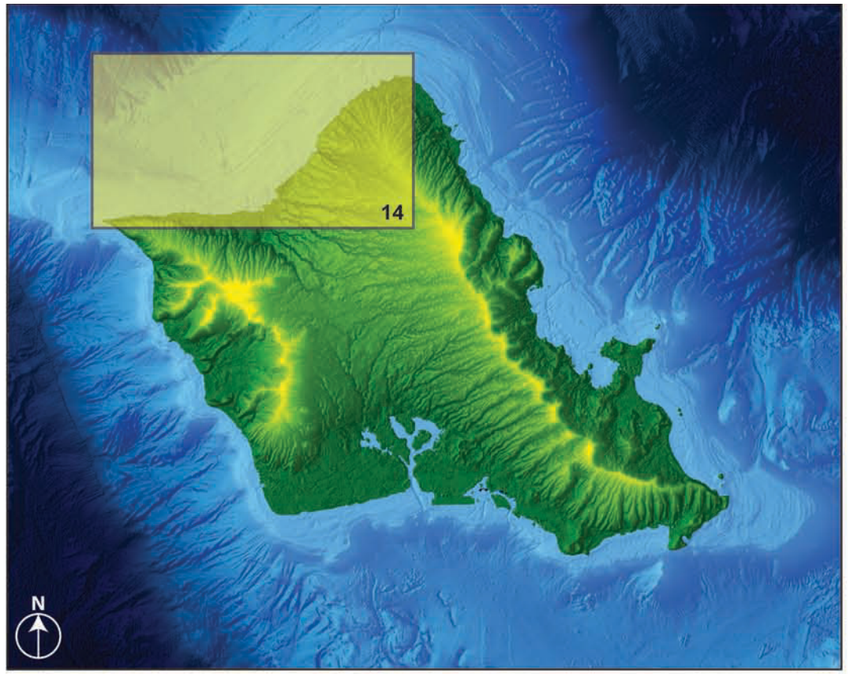


Figure 13 Locations for SWAN model results showing wave direction on the north shore.

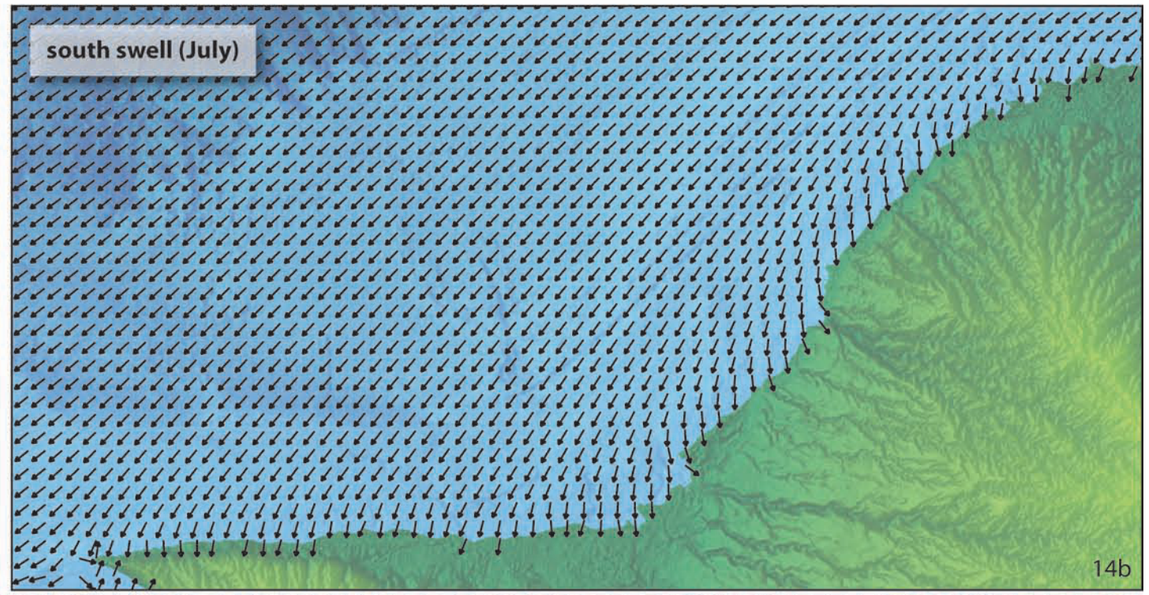
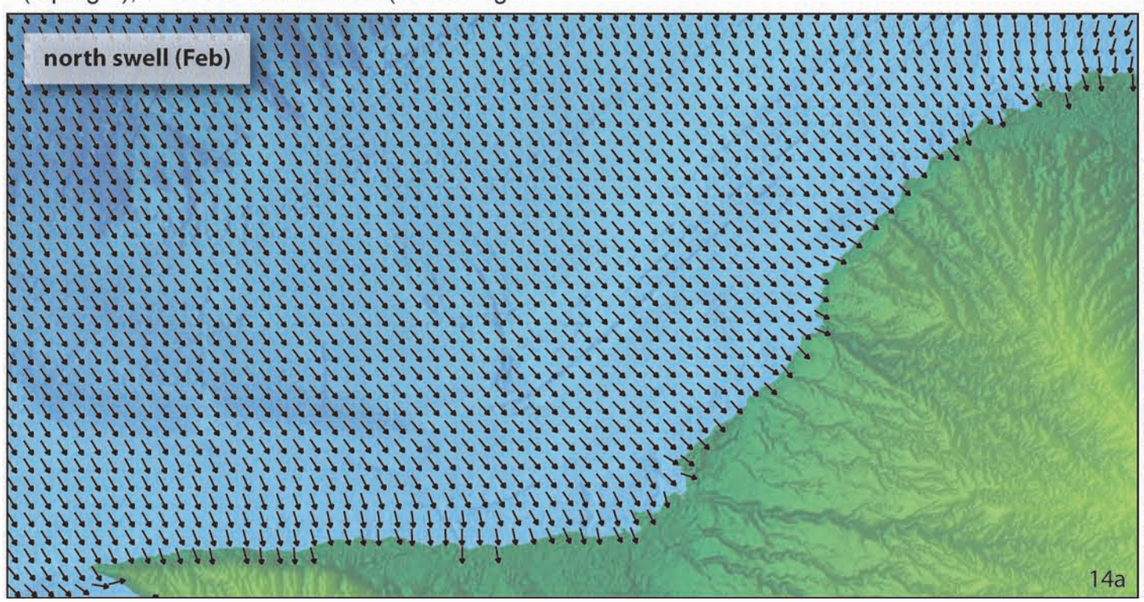
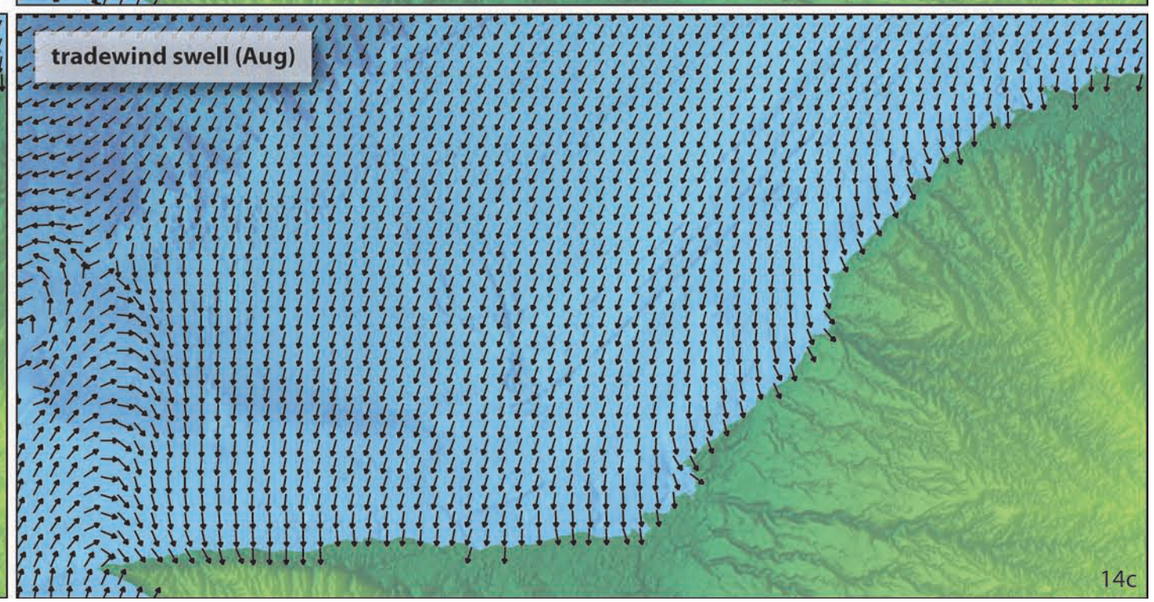


Figure 14 Modeled swell directions north shore: 14a - north swell (below left); 14b - south swell (top right); 14c - tradewind swell (bottom right





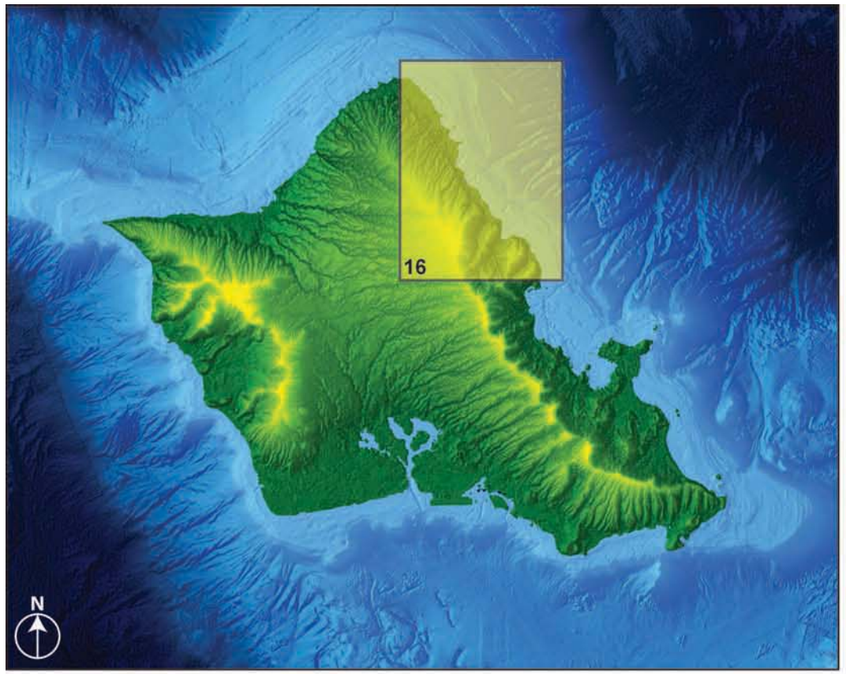


Figure 15 Locations for SWAN model results showing wave direction on the northeast shore.

Managed Stream Mouths Eleven stream mouths are recognized as actively managed by the C&C, DFM.

Scheduled clearing removes sediment from the mouth to allow stream water access to the ocean. Work is scheduled and completed on Monday, Tuesday or Wednesday to allow settling of suspended sediment related to the work prior to weekend public use. Removed sediment is required to be placed above the high water line (hwl) adjacent to the stream mouth at the discretion of the clearing crew. Clearing is contingent on the weather and available equipment. Generally sand is placed on the adjacent beach, and silty sand is disposed at Waimanalo Gulch landfill

(Continued on p. 10)

Figure 16 Modeled swell directions northeast shore: 16a - north swell (right); 16b - south swell (right center); 16c - tradewind swell (far right)

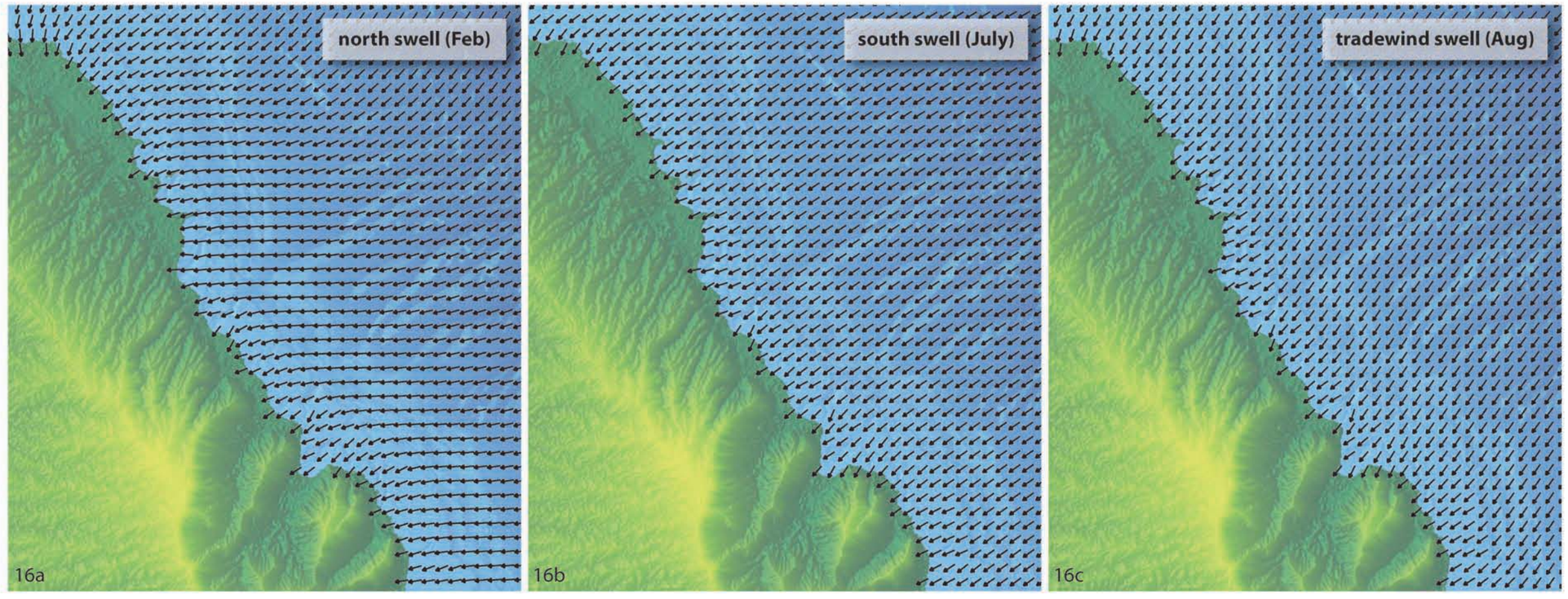
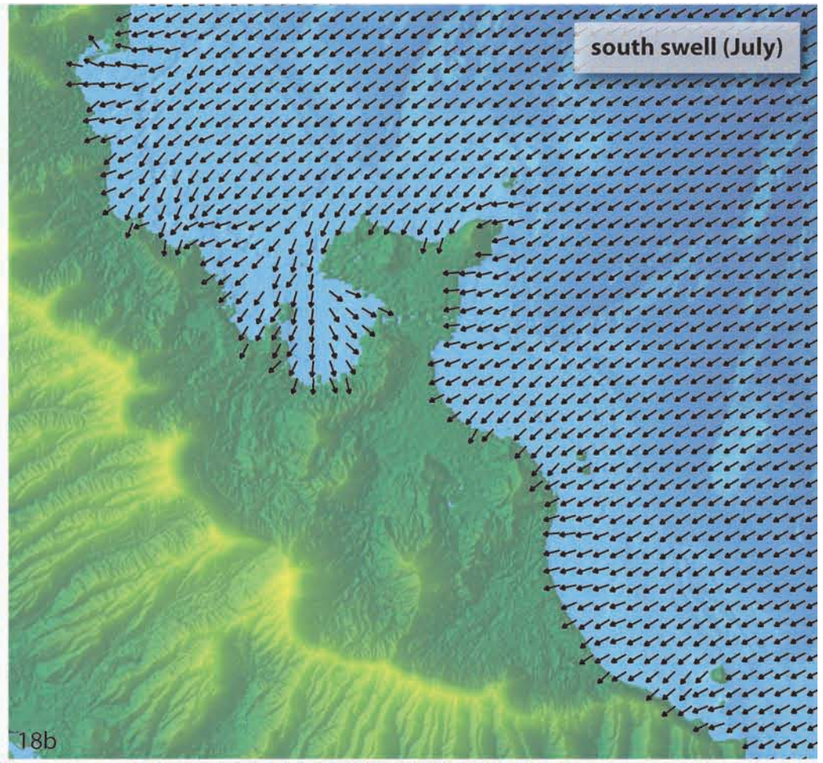


Figure 17 Locations for SWAN model results showing wave direction on the east shore.



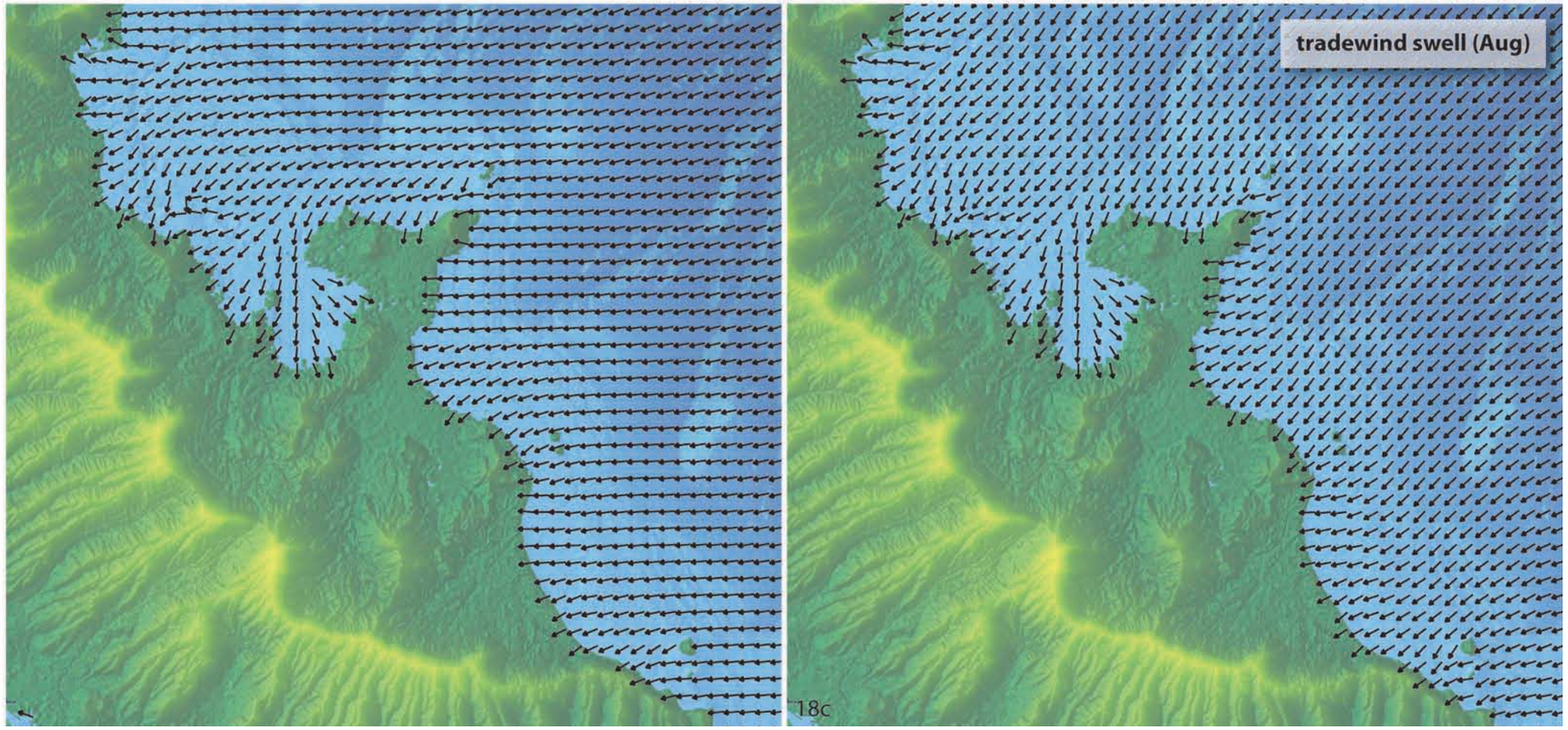


Figure 18 Modeled swell directions east shore: 18a - north swell (right); 18b - south swell (top right); 18c - tradewind swell (bottom right)

Recommended Management This map book provides baseline data and information on stream mouths around the island of Oahu. Some of these locations possess significant sand resources. The effective management of this sand is likely to benefit the adjacent beach and dune environment, perhaps even neighboring roads and buildings that are vulnerable to coastal erosion. Approximately 30 stream mouths receive routine or requested maintenance throughout the year. In some cases, stream mouths will clear naturally when sufficient rainfall in the watershed supplies the stream with the discharge necessary to mobilize and transport sediment out of the mouth. This is the preferred method of stream clearing and ideally every stream would clear itself by this means on a regular basis, returning sand to the adjacent littoral system. However, when the surface relief of the deposited sediment at the mouth is higher in elevation than surrounding stream banks, flooding becomes a concern and management of the stream mouth sediment is needed. Additionally, during flooding, a blocked stream mouth may lead to avulsion, a channel jumping process by which a stream finds a new path to the sea. Current management practices demonstrate a need for a coordinated interagency effort to routinely monitor and move sediment at stream mouth locations that pose a significant danger to public health and safety and infrastructure. A solution which reintroduces beach sand into the source littoral cell at locations of identified need (such as erosion hotspots) may introduce additional stakeholders, both public and private, into the management process who might otherwise regard stream maintenance solely as the government's province.

Any public/private endeavor to effectively manage stream mouth sediments requires permits from appropriate agencies. At the time of publication, discussions between the US Army Corps of Engineers, State of Hawaii DLNR, and City and County of Honolulu indicate a willingness to establish a framework of needs and priorities that include establishment of a best management practices (BMP) guide for work to ensure effective results. The role of government in this setting would advise contractors and agencies through the permit process, supplying expertise and knowledge to effectively address the myriad public health, environmental, and legal concerns accompanying BMP development. Interagency teams, working with local communities and stakeholders, could identify public infrastructure designs and practices that might aid in mitigating the volume of sediments in stream mouths. Final permit authority will require Hawaii State Department of Health approval.

Stakeholder Meeting Notes The following notes are from a meeting of stakeholders involved in the Oahu Regional Sediment Management Study, Oahu Stream Management Study. The meeting was held on 15 December, 2009 at the State of Hawaii, Department of Land and Natural Resources. In attendence were: Tom Smith, Peter Galloway, Justin Goo, Sam Lemmo, Dolan Eversole, Terry Hildebrand, Clifford Lau, Thomas Takeuchi, Charles Fletcher, Matt Dyer and Matthew Barbee.

The meeting was held to discuss draft versions of this map book, stream mouth management around the island of Oahu, relevant policy and procedures to effectively manage the sediment moved during stream mouth clearing, and possible solutions within the framework of existing policy to appropriately make use of cleared sediment resources.

1) Sunset Beach
- a) Stream plugged from recent swell. Need to identify an area to backpass the material to.
- b) Staff inquired as to whether they can put it at along the bike path in the area that was recently impacted by high surf run-up.
- c) Subsequent DLNR/C&C Parks meetings discussed backpassing 500 cy of sand from stream mouth to eroded bank.

2) Stream Names: There are multiple names for some of the streams on Oahu. The names come from various sources. Need to determine which name to use for each stream. Beaches of Oahu reference book and state GIS system used for stream naming.

3) Wave Modeling: UH used the SWAN wave transformation numerical model to determine general sediment transport directions for the Stream Mouth Map Book

4) C&C of Honolulu Currently Managed Stream Mouths
- a) C&C Stream Clearing Maps: UH requested copies of C&C maps that provide current management practices at the streams that are actively maintained. C&C to determine whether or not they can provide the maps for public release. These streams are cleared monthly.
- b) Big Rain/Runoff Events: C&C has pre-event stream mouth clearing protocol.
- c) Stream Clearing: Current C&C practice is to side cast materials onto stream slopes.
  - • Request was made to add current clearing practice to map book for each stream.
- d) Water Placement: DOH has issues with placing stream sediment in the water (fines/contaminants).
- e) General Notes:
  - • Stream mouths are plugged by natural processes.
  - • Natural processes are rarely enough to clear out sediment plugs. In many cases there is not enough discharge to naturally flush the system.
  - • May want to try creating small opening in a stream mouth plug and allow the initial flow to open up the stream and discharge material into the nearshore.
- f) Stream maintenance currently conducted on a site specific basis but done on a scheduled rotation.

5) Regulatory Issues
- a) Notice of stream clearing sent out by the C&C. Notices currently sent to USACE (Honolulu District- POC is George Young: Chief, Regulatory Branch).
- b) Current problem with the placement of cleared sand on the beach due to 401 constraints with placement of material into state waters. This has led to a practice of placing cleared sediment on stream banks rather than the beach system and may result in a sediment sink for the system.
- c) Need to pursue a state-wide Programmatic Authority for stream clearing. Also need to develop a state-wide stream mouth clearing program. This would be preferable to doing permits on a stream-by-stream basis. Think in terms of Regional General Permit (RGP).
- d) Section 10 & Section 404 Permits: Section 404 dependent upon extent of tidal influence within each stream. Federal Authority dependent upon extent of tidal waters upstream. Section 404 not necessary above high tide line provided that there is no return flow.
- e) General Permits are for 5 Years. Can be extended while active.
- f) Right of Way Entry: May need blanket Right of Entry for access through state lands.
- g) BMP's: Need to adhere to the latest BMP's. Specific Federal requirements based on extent of tidal waters.
- h) Stream Discharge is DOH's jurisdiction.

6) Pilot Stream Mouth Sediment Projects
- a) Kaaawa
  - • Current Federal Project

- Southern transport clogging stream
- Good candidate for backpassing material to the updrift shoreline.
- City currently has Sea Engineering assessing all beach parks on Oahu.

b) Kailua Beach Park Kaelepulu, and Kaaawa are highest priority areas for the C&C of Honolulu Design and Construction Office.

References

Church, J. A. and White, N.J. (2006) 20th century acceleration in global sea-level rise, Geophysical Research. Letters, 33(1), L01602.

Clark, John R. K. (2002) Hawaii Place Names: shores, beaches and surf sites. University of Hawaii Press, Honolulu, USA.

Clark, John R. K. (2005) Beaches of Oahu, revised edition. University of Hawaii Press, Honolulu, USA.

Firing, Y. and Merrifield, M.A. (2004) Extreme sea level events at Hawaii: influence of mesoscale eddies. Geophysical Research Letters, 31, L24306, doi:10.1029/2004GL021539.

Fletcher, C.H., Jones, A.T. (1996) Sea-level high stand recorded in Holocene shoreline deposits on Oahu, Hawaii. Journal of Sedimentary Research. 66.3, p. 632-641.

Fletcher, C.H., Mullane, R.A., and Richmond, B.M. (1997) Beach loss along armored shorelines on Oahu, Hawaiian islands. Journal of Coastal Research, v. 13, p. 209-215.

Fletcher, C.H., Grossman, E.E., Richmond, B.M., Gibbs, A.E. (2002) Atlas of natural hazards in the Hawaiian coastal zone. U.S. Geological Survey, Denver, CO, Geologic Investigations Series I-2761, 182p. http://geopubs.wr.usgs.gov/i-map/i2761/

Fletcher, C.H., Bochicchio, C., Conger, C.L., Engels, M., Feirstein, E.J., Grossman, Grigg, R., E.E., Harney, J.N., Rooney, J.J., Sherman, C.E., Vitousek, S., Rubin, K., Murray-Wallace, C.V. (2008) Geology of Hawaii Reefs. Chapter 11 in “Coral Reefs of the U.S.A.”, Springer, p. 435-488.

Grossman, E.E., and Fletcher, C.H., (1998) Sea level 3500 years ago on the Northern Main Hawaiian Islands. Geology, April, v. 26, no. 4, p. 363-366

Harney, J.N., Grossman, E.E., Richmond, B.M., and Fletcher, C.H. (2000) Age and composition of carbonate shoreface sediments, Kailua Bay, Oahu, Hawaii: Coral Reefs, v. 19, pg. 141-154.

Moberly, R., and Chamberlain, T. (1964). Hawaiian beach systems. Hawai‘i Institute of Geophysics Report 64-2, University of Hawai‘i at Manoa, Honolulu.

Vermeer, M. and Rahmstorf, S. (2009) Global sea level linked to global temperature. Proceedings of the National Academy of Sciences Early Edition, found on Dec 15, 2009 at www.pnas.org/cgi/doi/10.1073/pnas.0907765106.

Vitousek, S. and Fletcher, C.H. (2008) Maximum annually recurring wave heights in Hawai‘i. Pacific Science, vol. 62, no. 4: 541-553.

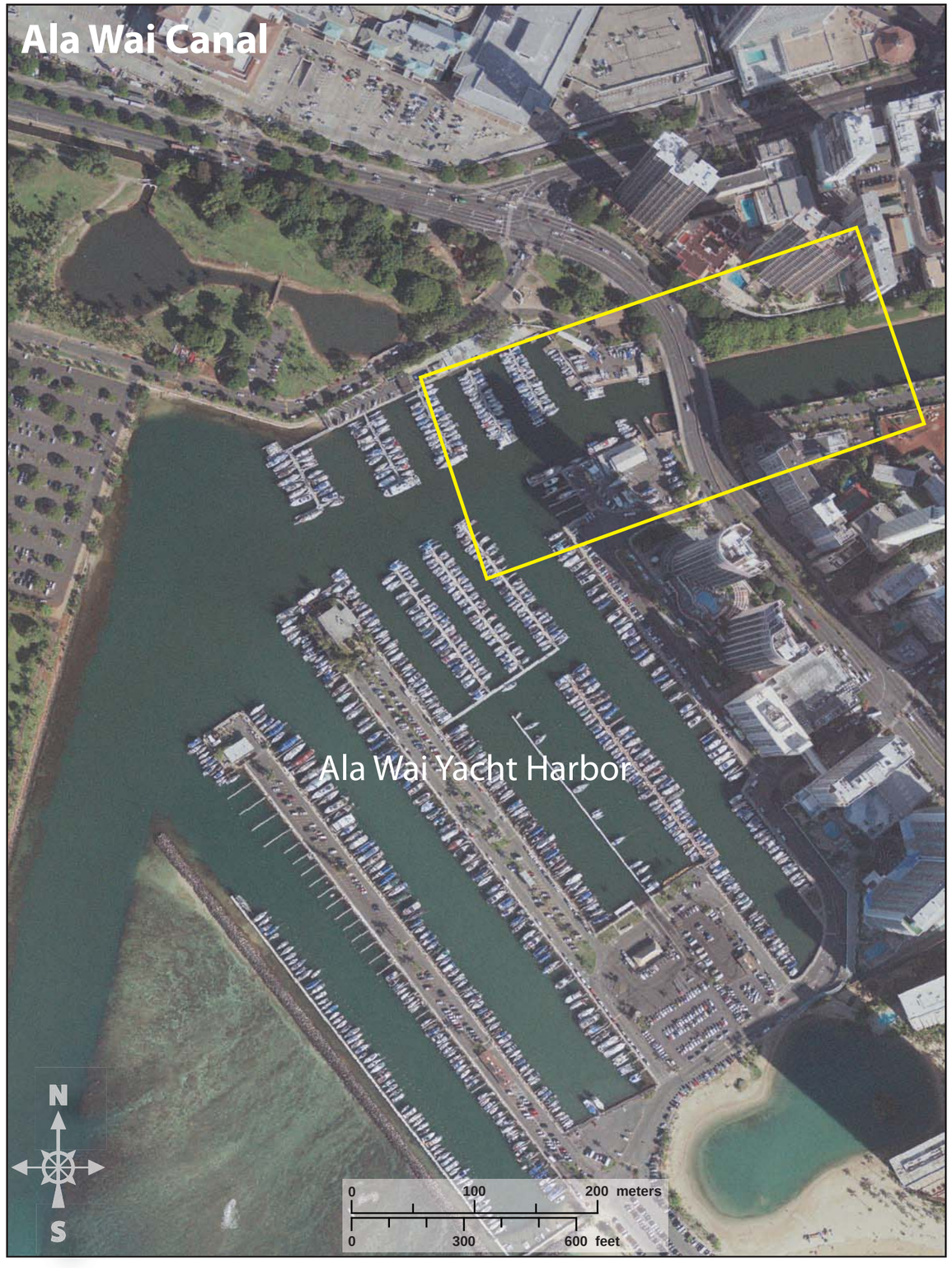


Photo 1. October 24, 2009 looking landward across the harbor.

Photo 2. October 24, 2009 looking toward the ocean.

Ala Wai Canal (non-perennial, NDAR_CODE 33007001)
Lat. 21.288
Long. -157.841 (stream mouth)

Coastal Processes:
Ala Wai Canal is an artificialwater way that was completed in 1929 in order to divert water from Manoa, Palolo, and Makiki streams in order to drain the Waikiki area. The canal empties into the ocean in the Ala Wai boat harbor at the western end of Waikiki on Oahu's south shore. The mouth of the Ala Wai is well protected from winds and waves but does experience tides and tidal currents. Flow rates for the Ala Wai are generally very low and are not sufficient to flush the canal; hence fine sediment and debris tends to accumulate over time.

Ala Wai

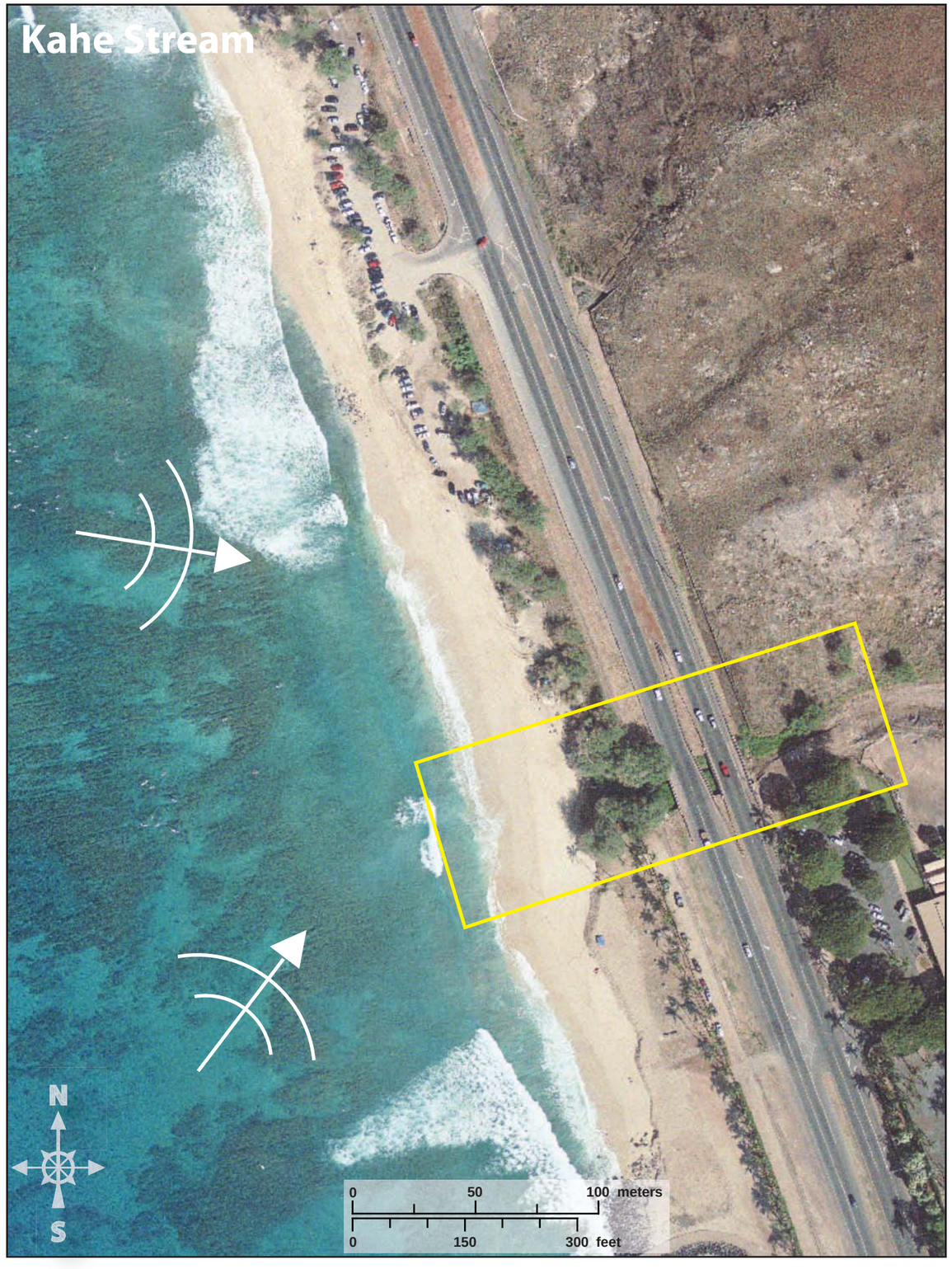


Photo 1. November 30, 2009 looking landward toward the Kahe Stream Bridge.

Photo 2. November 30, 2009 looking north toward Waianae.

Kahe Stream (non-perennial, NDAR_CODE 34027001)
Lat. 21.358
Long. -158.131 (stream mouth)

Coastal Processes

Kahe Stream mouth is located on the west shore of Oahu just north of Koolina Beach and south of Nanakuli. Kahe Beach is approximately 60 ft wide and is bounded by a rock jetty to the south and a rocky headland to the north. The overall length of the beach is about 0.5 mi. Tradewinds blow offshore at this location and wave energy is seasonally variable; from the south in the summer and from the north in the winter.

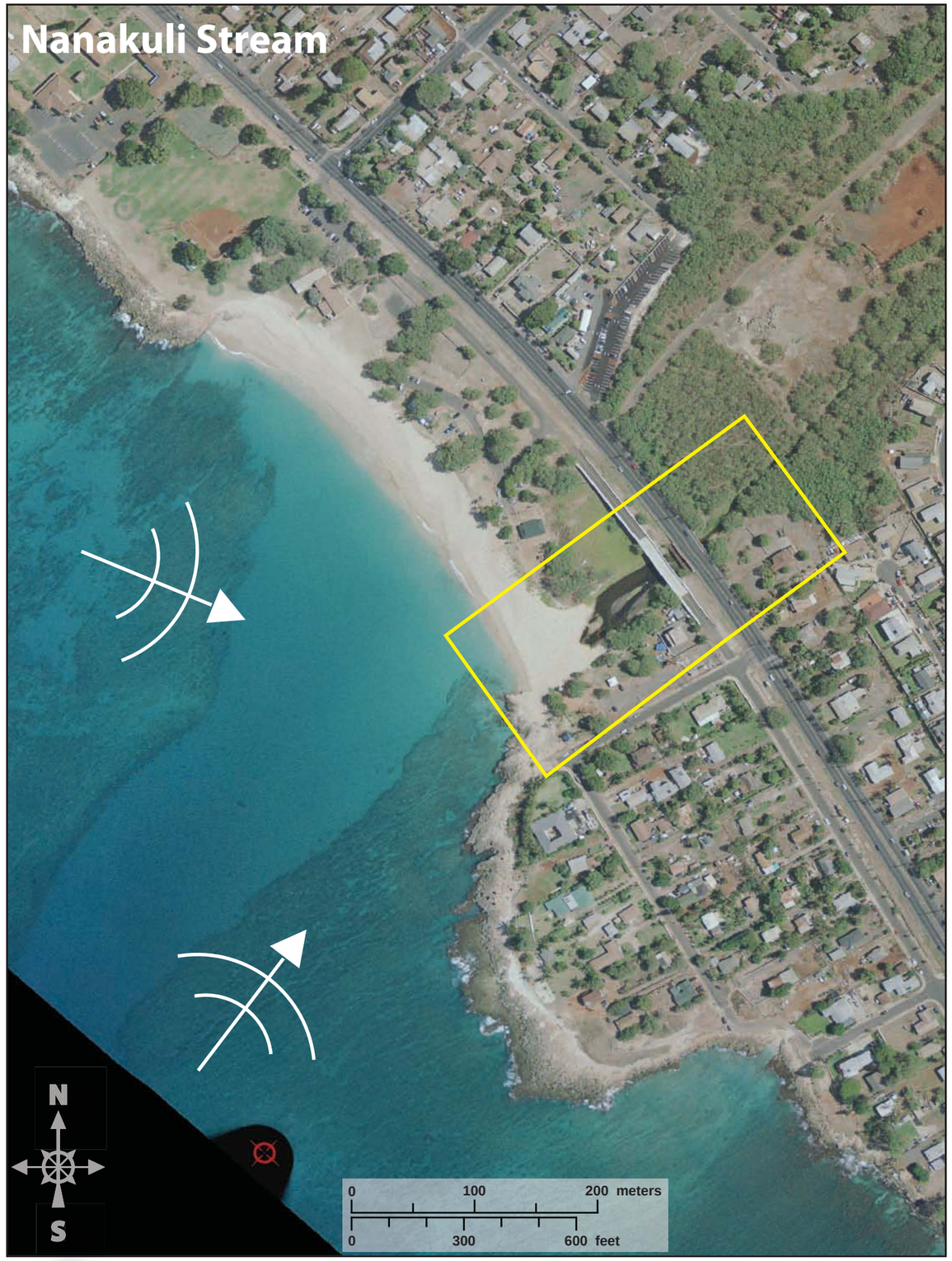


Photo 1. November 29, 2009 looking south along the beach from stream mouth.

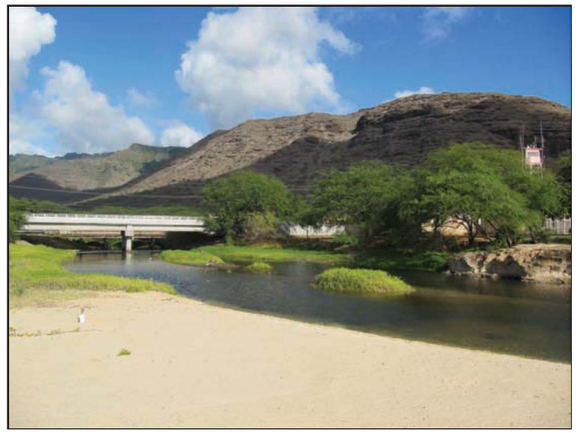
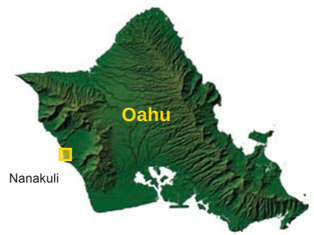


Photo 2. November 29, 2009 looking landward up the stream from the mouth.

Nanakuli Stream (perennial, NDAR_CODE 35001001)
Lat. 21.375
Long. -158.141 (stream mouth)

Coastal Processes

Nanakuli Stream mouth is located on the west shore of Oahu in Nanakuli at the south end of Nanakuli Beach Park. The stream mouth is approximately 140 ft wide and is typically blocked by beach sand. The beach at Nanakuli is primarily fine calcareous sand. This small bay is bounded to the north and south by carbonate rock headlands. Tradewinds blow offshore at this location. Nanakuli beach is exposed to swells from the north (winter) and summer (south). The beach is steep and slopes into deep water offshore where a sand-filled channel cuts through the fringing reef. This beach is characterized by heavy shore-break.



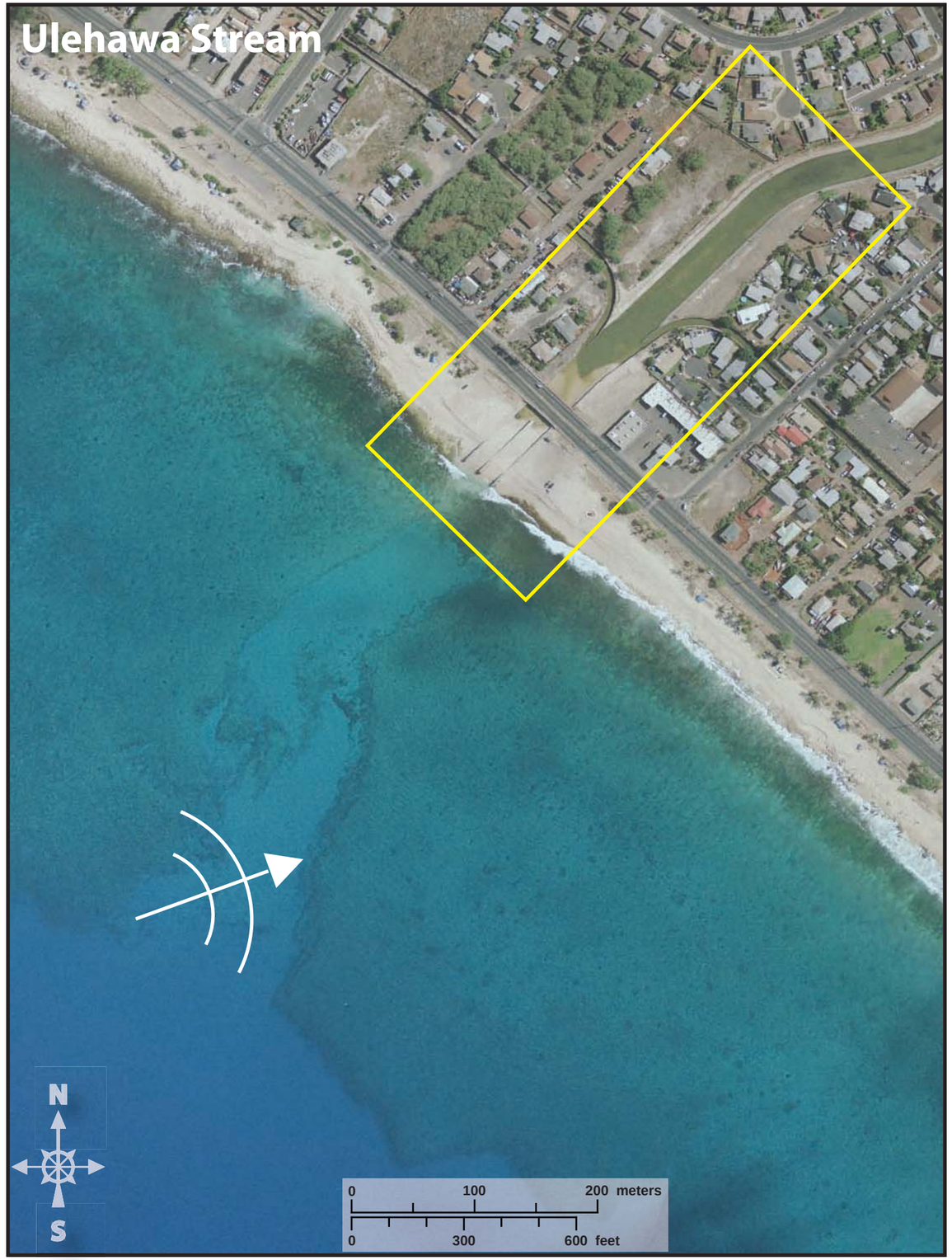


Photo 1. November 29, 2009 looking toward the ocean from the bridge.

Photo 2. November 29, 2009 looking south from the north side of stream.

Ulehawa Stream (perennial, NDAR_CODE 35002001)
Lat. 21.611
Long. -157.909 (stream mouth)

Coastal Processes:
Ulehawa Stream is located on the west shore of Oahu to the north of Nanakuli. The beach consists of fine to medium carbonate sand overlying carbonate rock. Ulehawa Stream has been hardened and is approximately 90 ft wide. It is typically blocked by beach sand. The absence of a fringing reef exposes the shoreline to variable wave conditions from the north (winter) and south (summer). The shifting wave climate alternately buries and exposes the rock platform with beach sand.

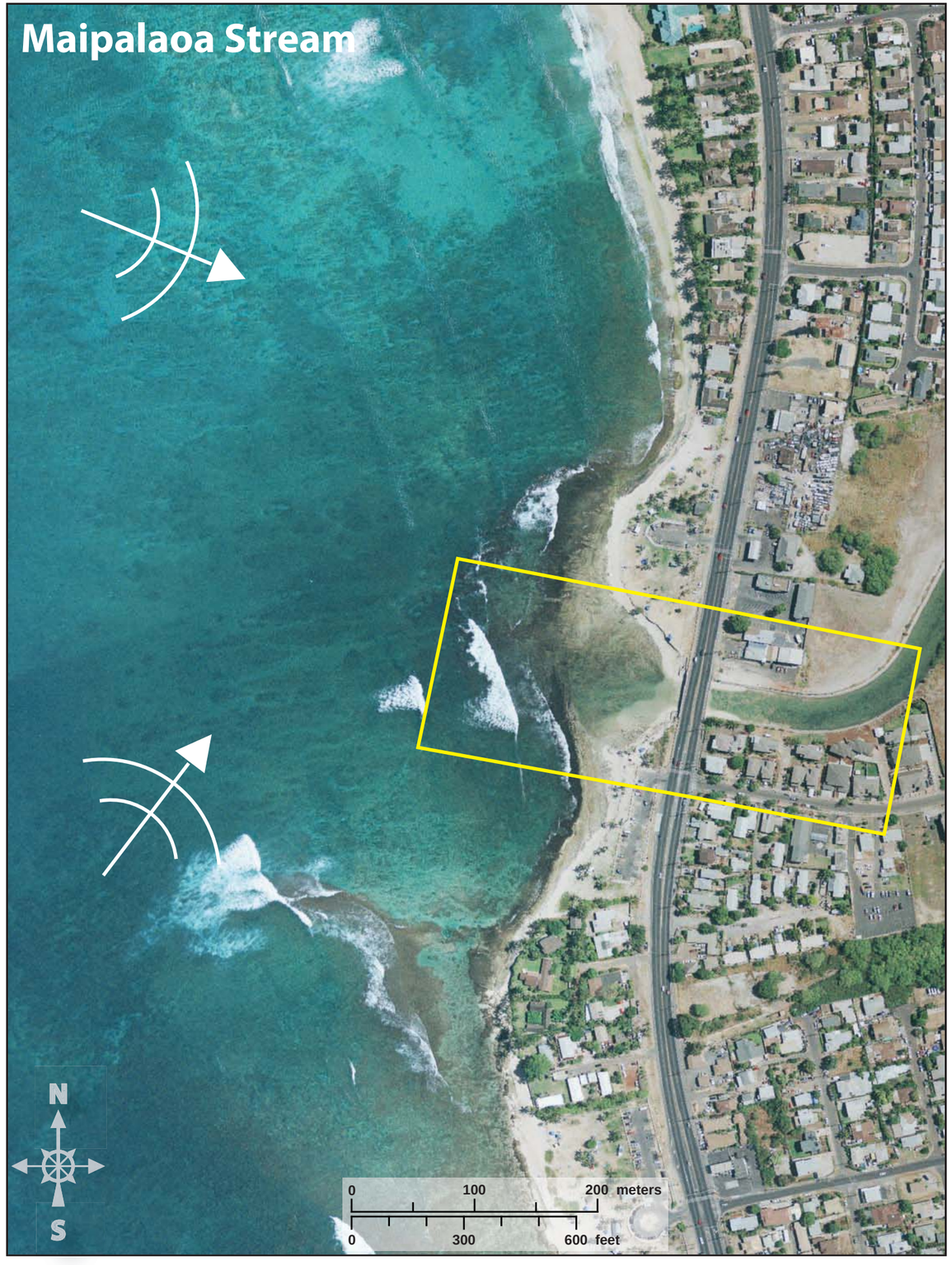


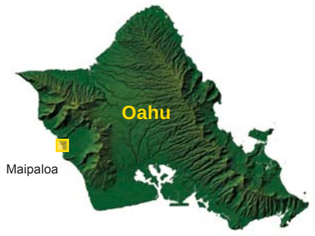
Photo 1. November 30, 2009 looking northwest down the south side of the stream mouth.

Photo 2. November 30, 2009 looking north from the south side of the stream mouth.

Maipalaoa Stream (NDAR_CODE N/A)
Lat. 21.409
Long. -158.178 (stream mouth)

Coastal Processes

Maipalaoa Stream is a channelized system that flows into the ocean at Maili on the west coast of Oahu. The stream is about 90 ft wide at the bridge. North and south of the channel are carbonate rock headlands with perched beaches sitting above the tidal zone. There is significant reef structure seaward of the stream mouth which provides some protection from the onshore energy of seasonally variable north (winter) and south (summer) swells.



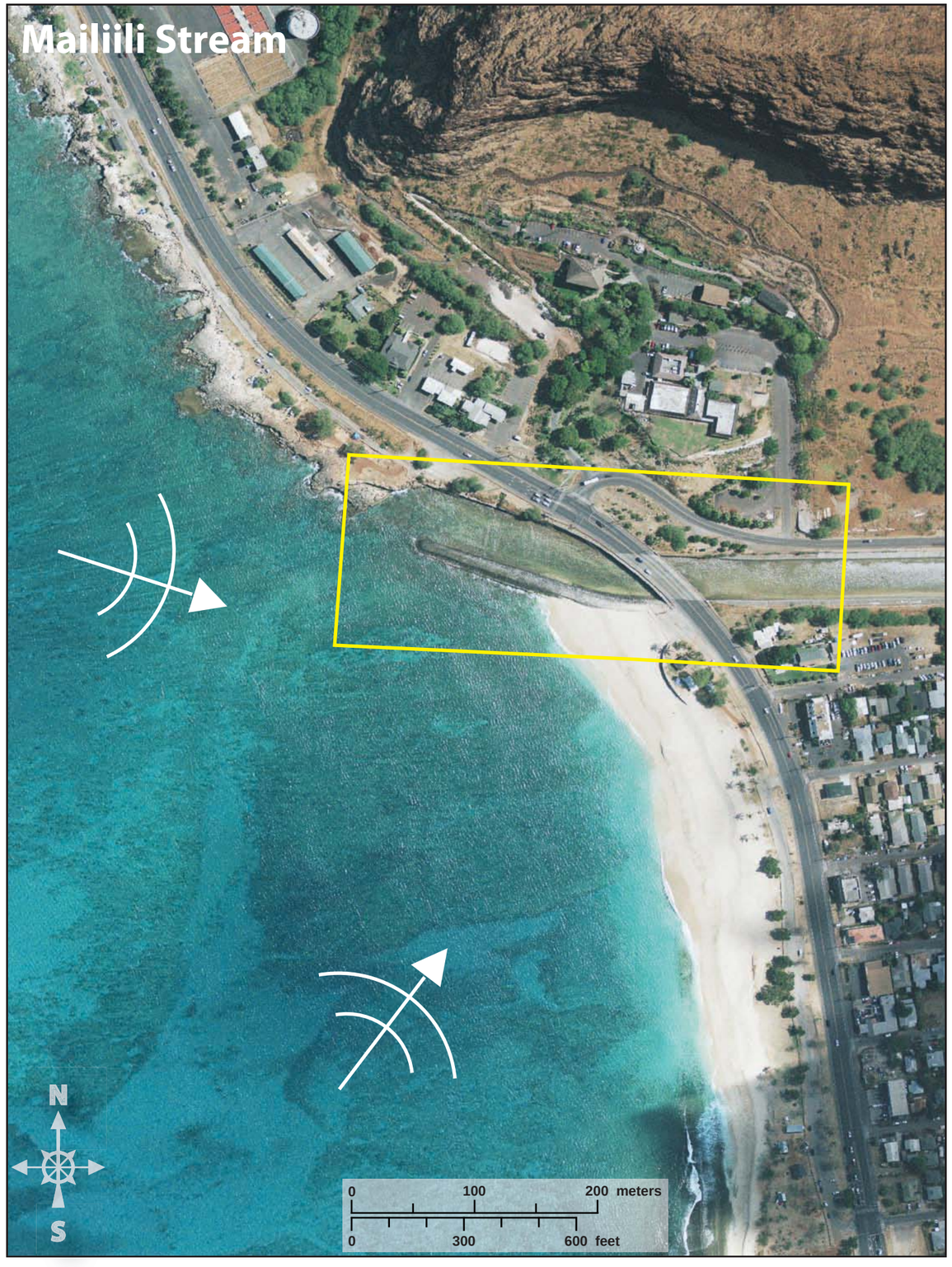


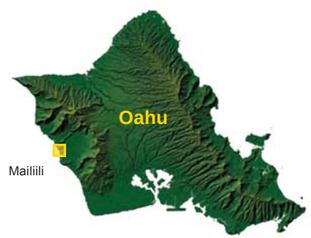
Photo 1. November 30, 2009 looking south from the south bank of the stream.

Photo 2. November 30, 2009 looking toward the ocean.

Mailiili Stream (non-perennial, NDAR_CODE 35004001)
Lat. 21.429
Long. -158.181 (stream mouth)

Coastal Processes

Mailiili Stream is located on the west shore of Oahu in Maili. The channelized stream is approximately 150 ft wide at the mouth. Both the north and the south banks have been hardened. Directly to the north is a carbonate rock headland. Directly to the south is the wide carbonate sand beach at Maili Beach park. Tradewinds blow offshore at this location. This shoreline is exposed to seasonally variable swell arriving from the north (winter) and south (summer).



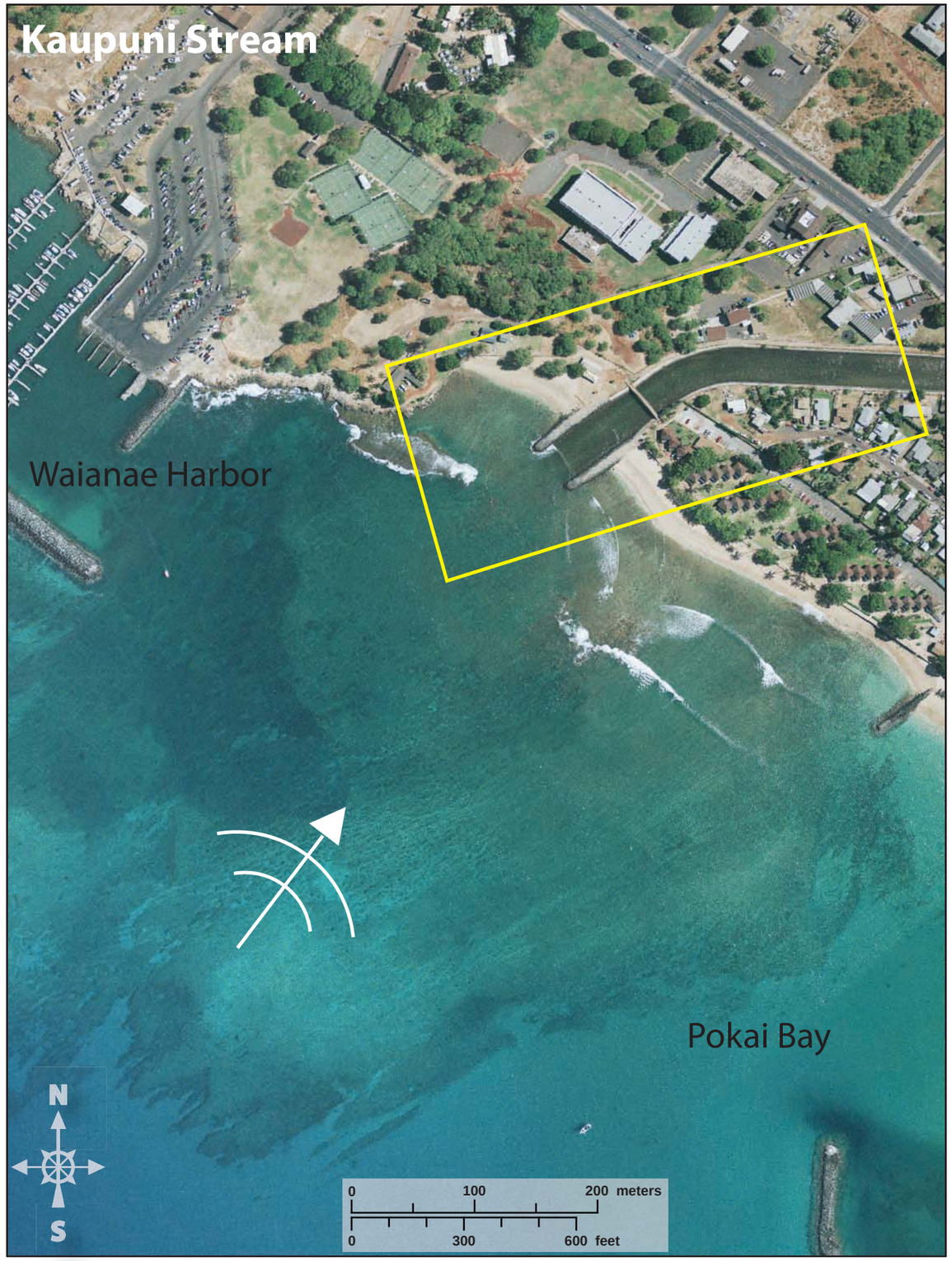
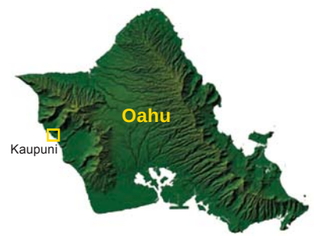


Photo 1. November 29, 2009 looking south across the stream mouth.

Photo 2. November 29, 2009 looking at the beach and seawall directly north of the stream mouth.

Kaupuni Stream (non-perennial, NDAR_CODE 35005001)
Lat. 21.448
Long. -158.193 (stream mouth)

Coastal Processes:
Kaupuni Stream mouth is located on the west shore of Oahu directly south of Waianae Boat Harbor in the northern corner of Pokai Bay. The stream mouth, approximately 100 ft wide, is hardened (channelized) on both banks. Tradewinds blow offshore and swell energy approaches from directly offshore.



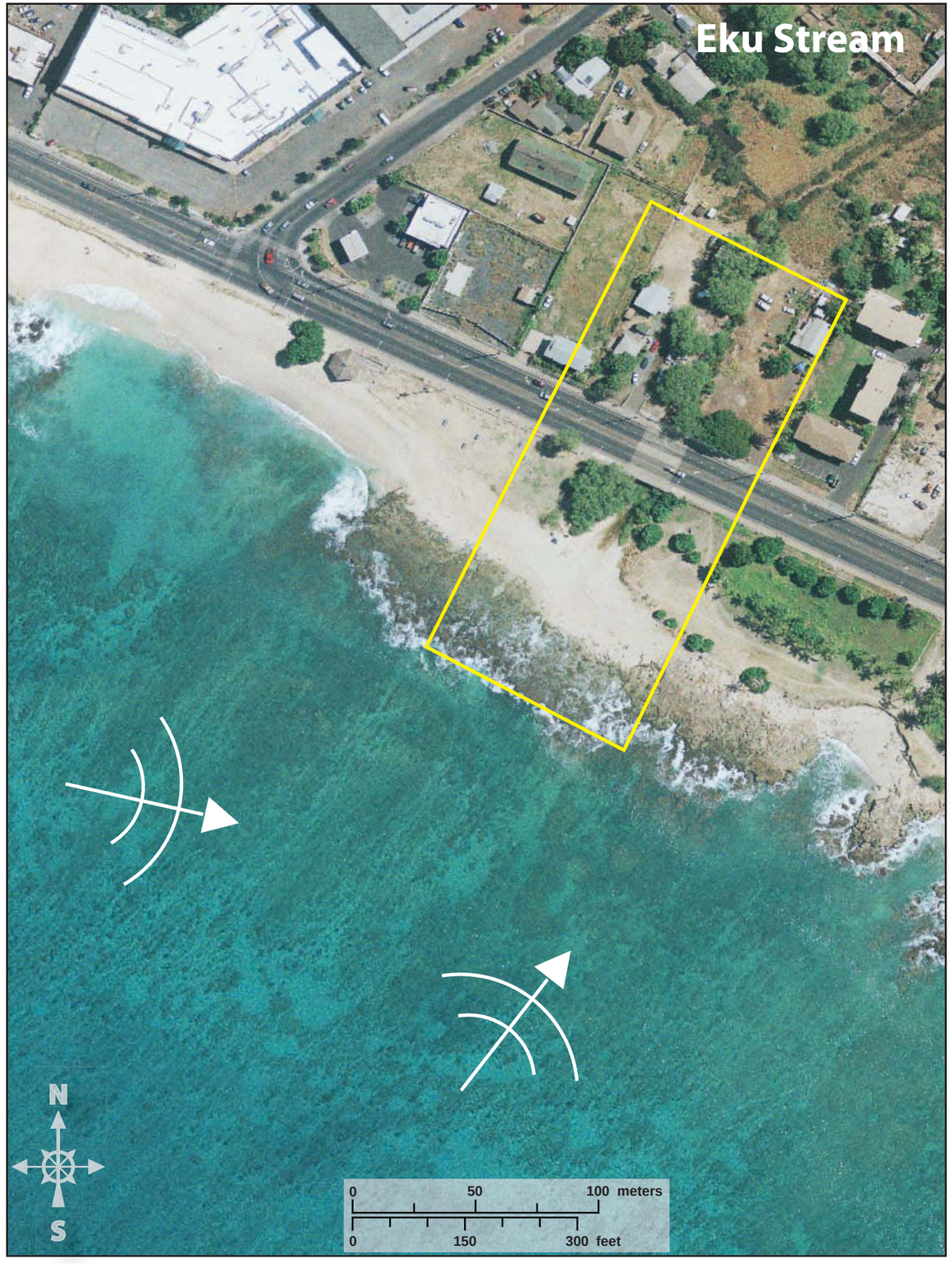
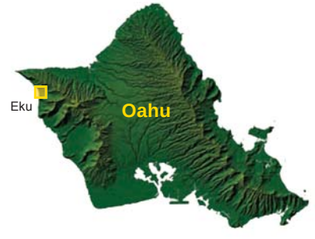


Photo 1. November 29, 2009 looking seaward down the stream bed from the side of the road.

Photo 2. November 29, 2009 looking seaward and north across the beach and exposed carbonate platform.

Eku Stream (non-perennial, NDAR_CODE 35009001)
Lat. 21.459
Long. -158.205 (stream mouth)

Coastal Processes:
Eku Stream is located on the west side of Oahu, south of Makaha and is typically blocked by beach sand. The beach at Eku is approximately 0.5 mi long and consists of fine to medium carbonate sand overlying a rock platform. Wave and current energy at this location is seasonally variable from the north (winter) and south (summer).



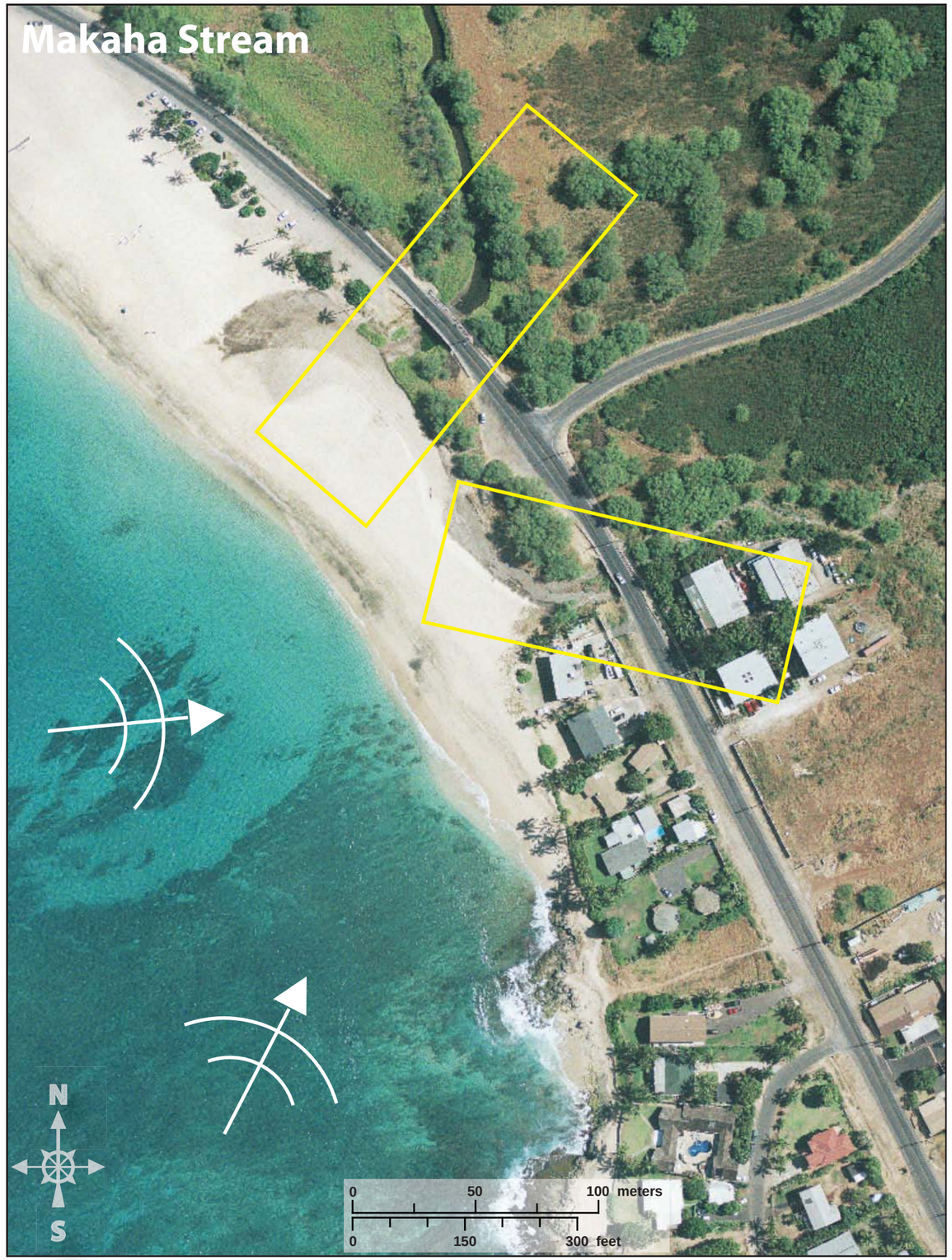


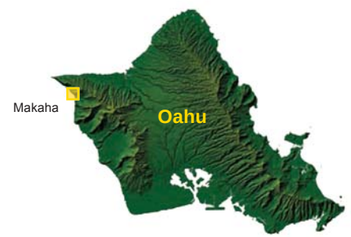
Photo 1. November 29, 2009 looking west across Makaha Beach.

Photo 2. November 29, 2009 looking downstream.

Makaha Stream (intermittent (south), perennial (north)), NDAR_CODE 35007001)
Lat. 21.477
Long. -158.220 (north stream mouth)

Coastal Processes

Makaha Stream mouth is located in Makaha on the west shore of Oahu where two streams discharge to the ocean within a short distance. Both stream mouths are typically blocked by sand. The beach is primarily fine carbonate sand. Tradewinds trend offshore at this location. Makaha Beach is exposed to seasonally variable waves, refracting into the bay from the north in the winter and the south in the summer.



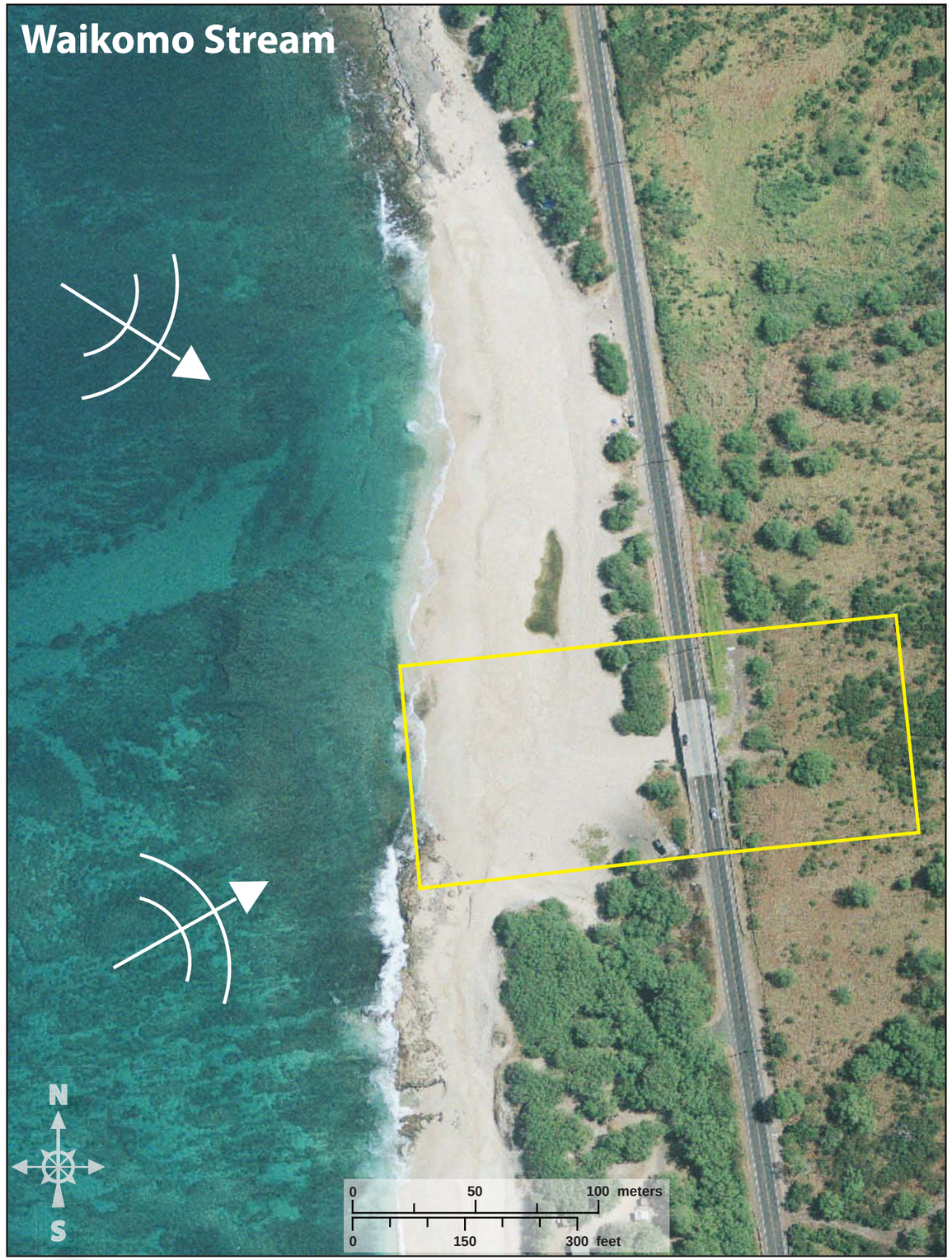


Photo 1. October 24, 2009 looking seaward from the road.

Photo 2. October 24, 2009 looking northwest from the north side of the stream.

Waikomo Stream (Non-Perennial), NDAR_CODE 35010001) This stream is labeled Waikomo Stream on the bridge but labeled Keaau Stream in the Hawaii Statewide GIS data.
Lat. 21.496
Long. -158.229 (stream mouth)

Coastal Processes:
Waikomo Stream is located on the west shore of Oahu. The beach is primarily fine carbonate sand which typically blocks the stream mouth. Tradewinds blow offshore at this location. This stretch of coastline is exposed to seasonally variable swell events from the north and south. As a result, longshore sediment transport is variable depending on the seasons and blocking from local headlands. Directly to the south carbonate rock outcrops at the water line.

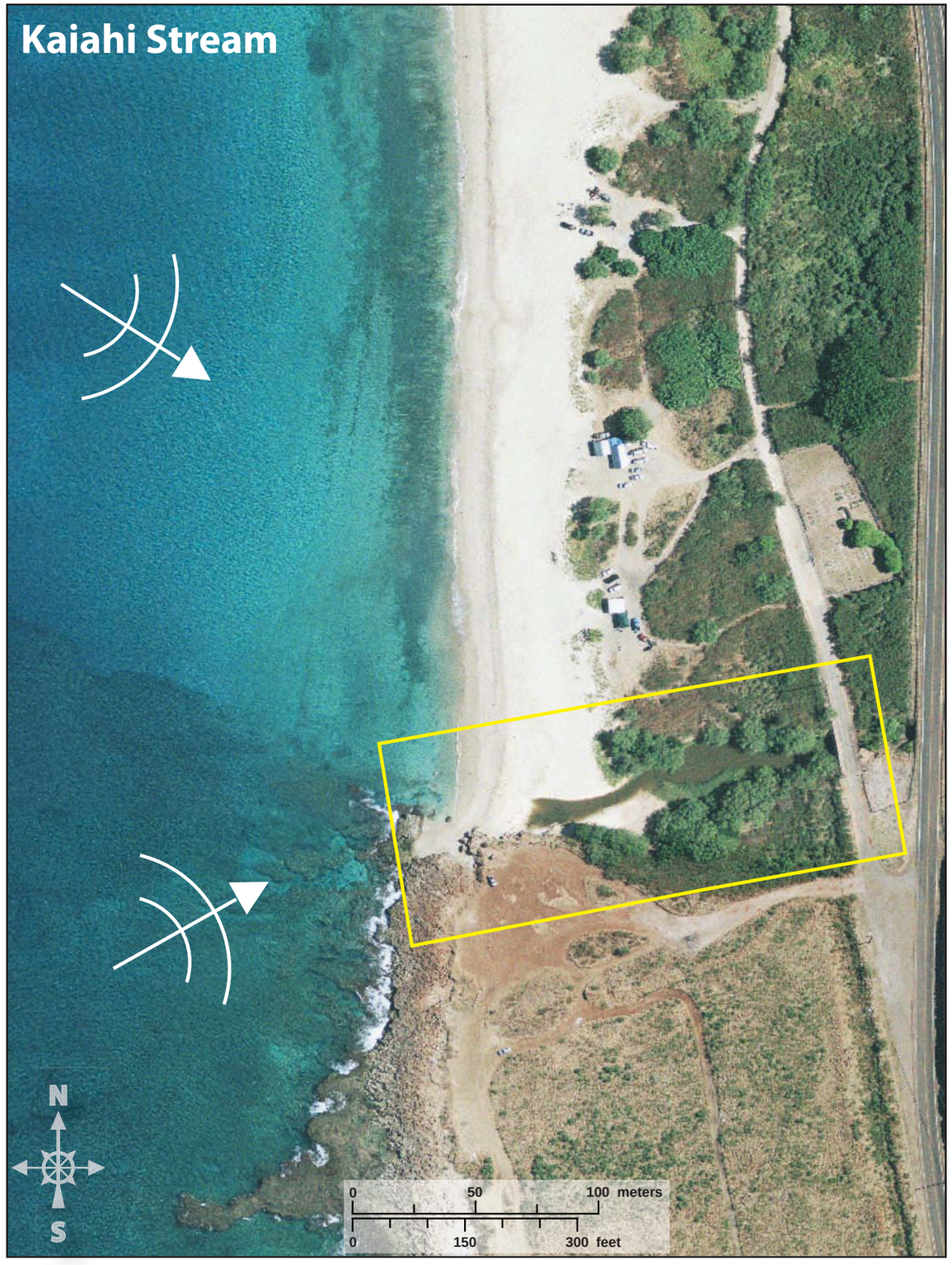


Photo 1. November 30, 2009 looking landward toward Makua Valley.

Photo 2. November 30, 2009 looking North toward Yokohama Bay and Kaena Point.

Kaiahi Stream (non-perennial, NDAR_CODE 350012001)
Lat. 21.527
Long. -158.229 (stream mouth)

Coastal Processes:
Kaiahi Stream mouth is located on Oahu's leeward coastline at the south end of Makua Beach and is typically blocked by beach sand. Makua Beach ranges in width from 50 to 200 ft and sand is fine to medium grained. Tradewinds blow offshore here and the site is exposed to seasonally variable swell energy from the south and north. The beach is bounded by rocky headlands to the north and south.

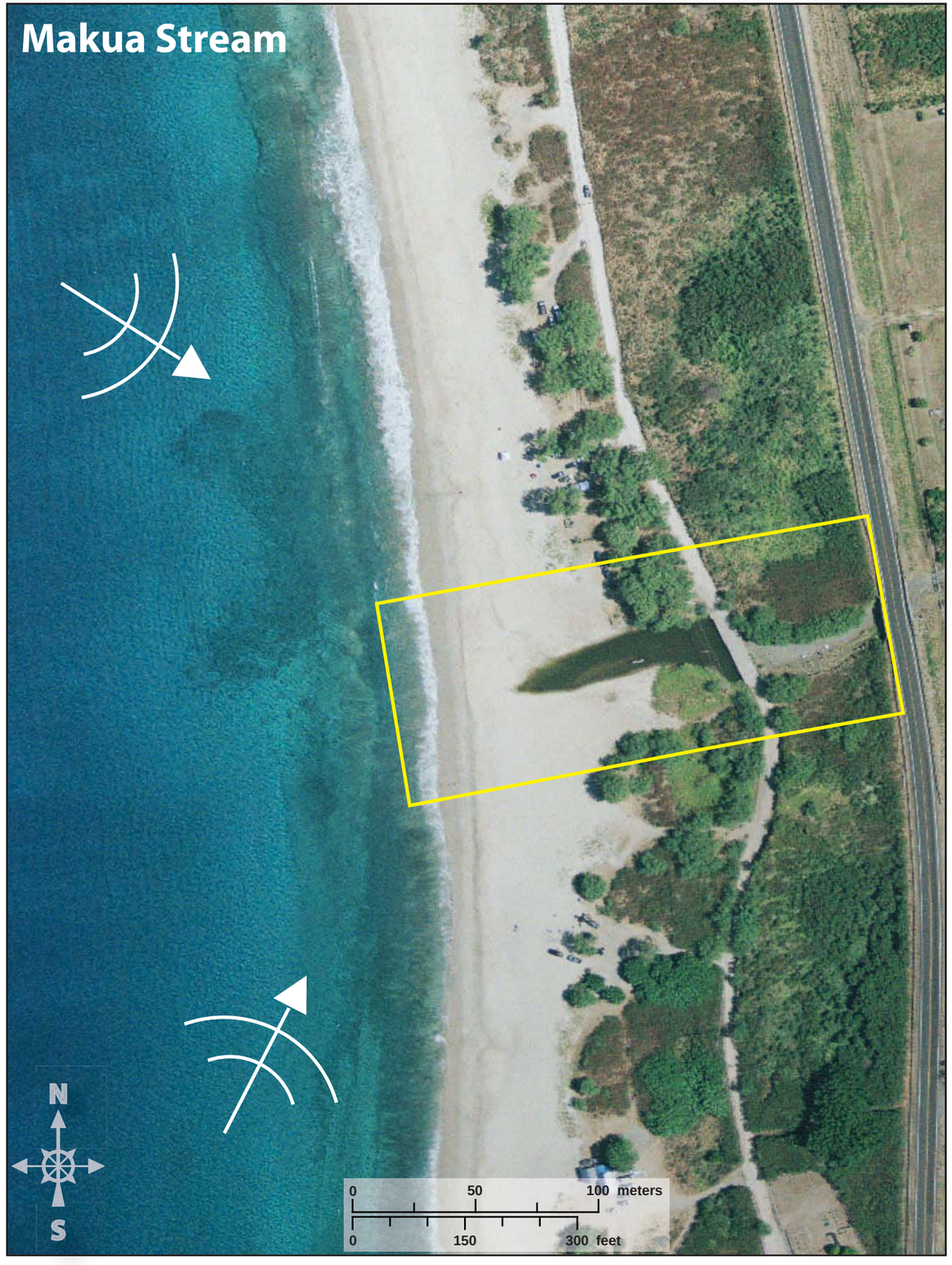


Photo 1. November 29, 2009 looking south across the stream mouth and beach.

Photo 2. November 29, 2009 looking west down the stream and across beach.

Makua Stream (intermittent, NDAR_CODE 35008001)
Lat. 21.530
Long. -158.229(stream mouth)

Coastal Processes

Makua Stream mouth is located on the west shore of Oahu. The stream mouth is approximately 60 ft wide and typically blocked by beach sand. The beach is primarily fine carbonate sand that changes morphology in response to seasonally variable wave conditions. Tradewinds blow offshore. North waves in the winter and south waves in the summer drive sand movement along the shoreline.

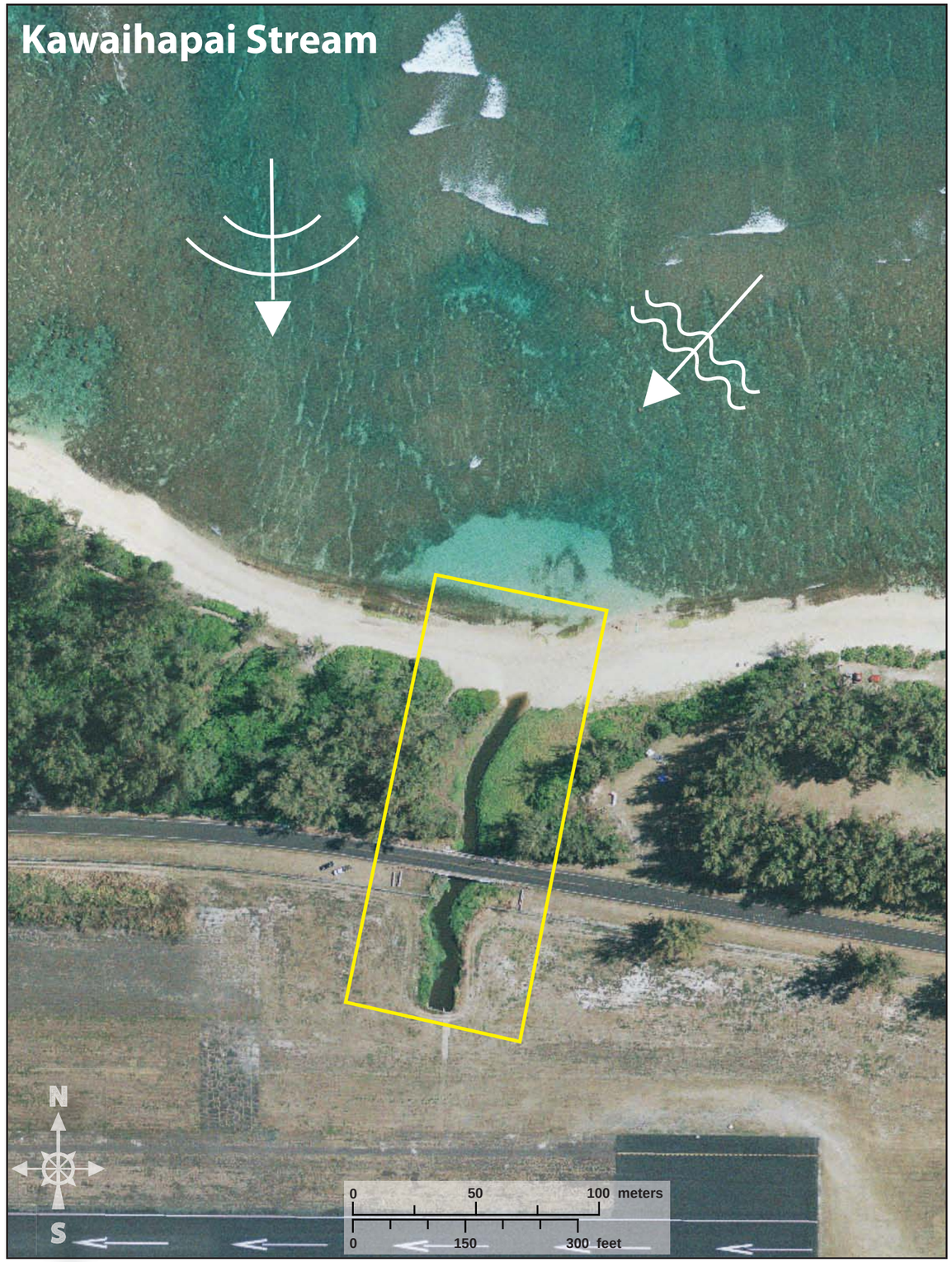


Photo 1. December 13, 2009 looking seaward toward the stream mouth and the beach.

Photo 2. Decmber 13, 2009 looking landward and east from the west side of the stream mouth.

Kawaihapai Stream (perennial, NDAR_CODE 36001001)
Lat. 21.577
Long. -158.261 (stream mouth)

Coastal Processes:
Kawaihapai Stream mouth is located on the Mokuleia shoreline on the north coast of Oahu. Kawaihapai is narrow (<50 ft in width), and typically blocked by beach sand. The beach is primarily composed of carbonate sand and beachrock outcrops characterize the foreshore and shallow surf zone of the beach. Trade winds approach from the east and seasonal swell from the north and northwest. A shallow fringing reef dissipates much of the wave energy before it arrives at the beach.

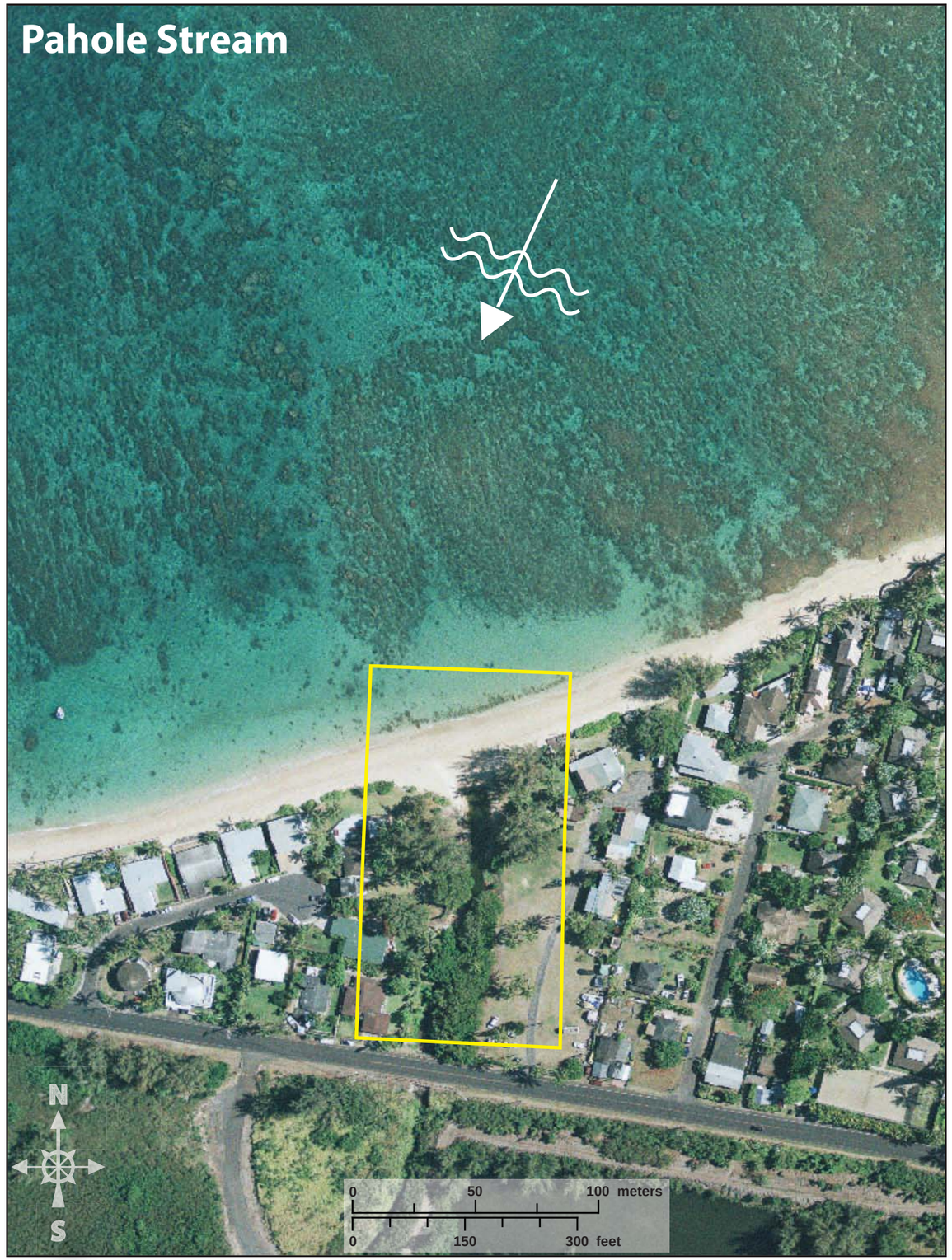


Photo 1.December 13, 2009 looking seaward from the stream bank.

Photo 2. December 13, 2009 looking from beach to the stream mouth.

Pahole Stream (perennial, NDAR_CODE 36002001)
Lat. 21.580
Long. -158.177 (stream mouth)

Coastal Processes

Pahole Stream mouth is located on the Mokuleia side of the north shore on Oahu. The stream cuts across a fine carbonate sand beach and is typically blocked by beach sand. This area of coastline is exposed to tradewind waves and large swell in the winter. There is a shallow fringing reef directly offshore so that much of the wave energy is dissipated. Sediment transport is typically at high tide and driven by tradewind waves.

Makaleha Ditch

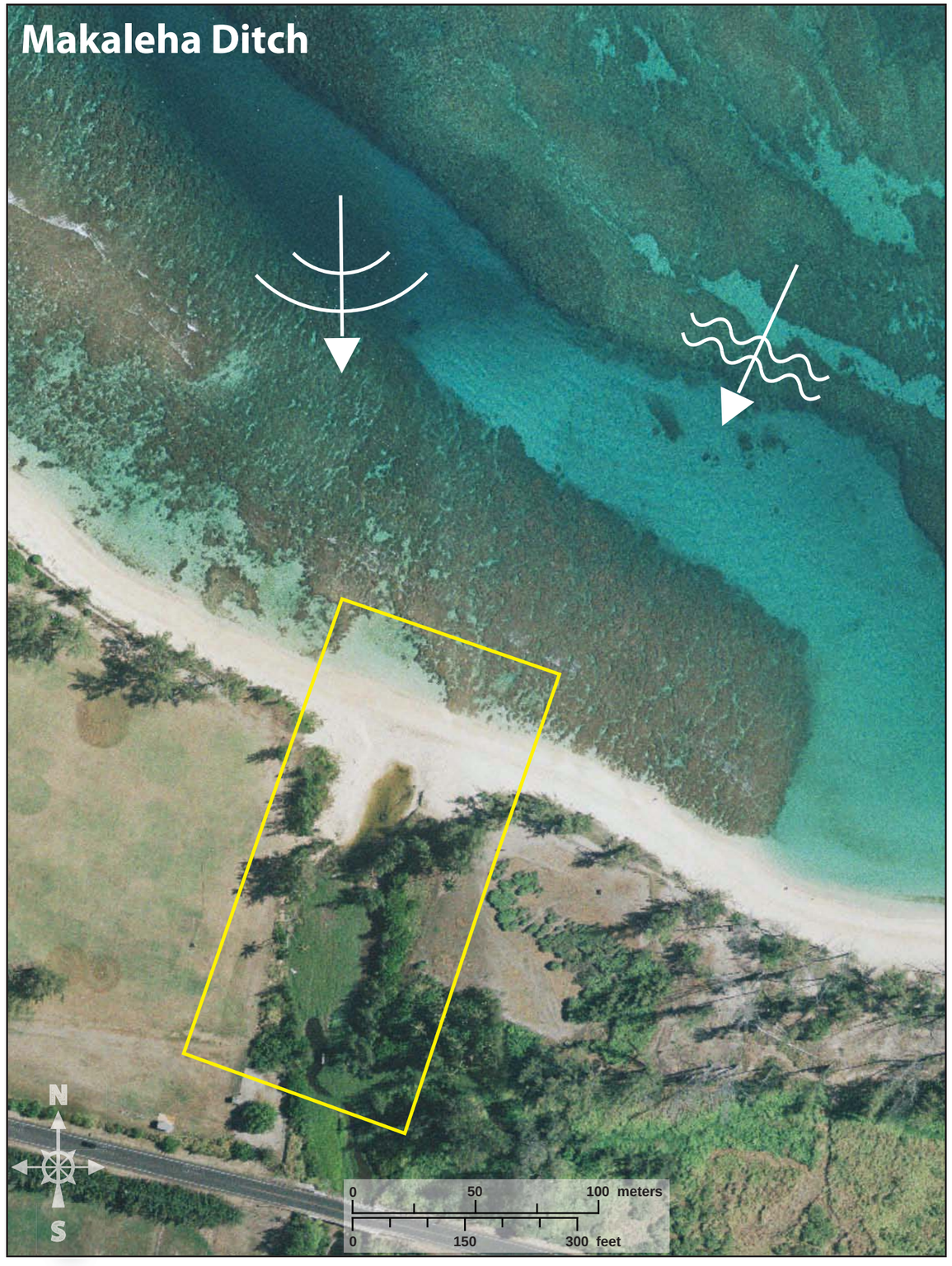


Photo 1. December 14, 2009 looking west down the beach at the stream mouth.

Photo 2. December 14, 2009 looking down stream from the road toward the beach.

Makaleha Ditch (ditch, NDAR_CODE N/A)
Lat. 21.580
Long. -158.170 (ditch mouth)

Coastal Processes:
Makaleha Ditch is located on the Mokuleia side of the north shore of Oahu. It is typically blocked by beach sand. The stream is approximately 100 ft in width. The beach is primarily fine carbonate sand with carbonate rock outcropping at the base of the foreshore. The north shore of Oahu is exposed to large swell energy in the winter from the northeast to the west. The majority of large swell events occur between the months of October and March. Tradewinds approach this coastline from the east, producing longshore sediment transport.

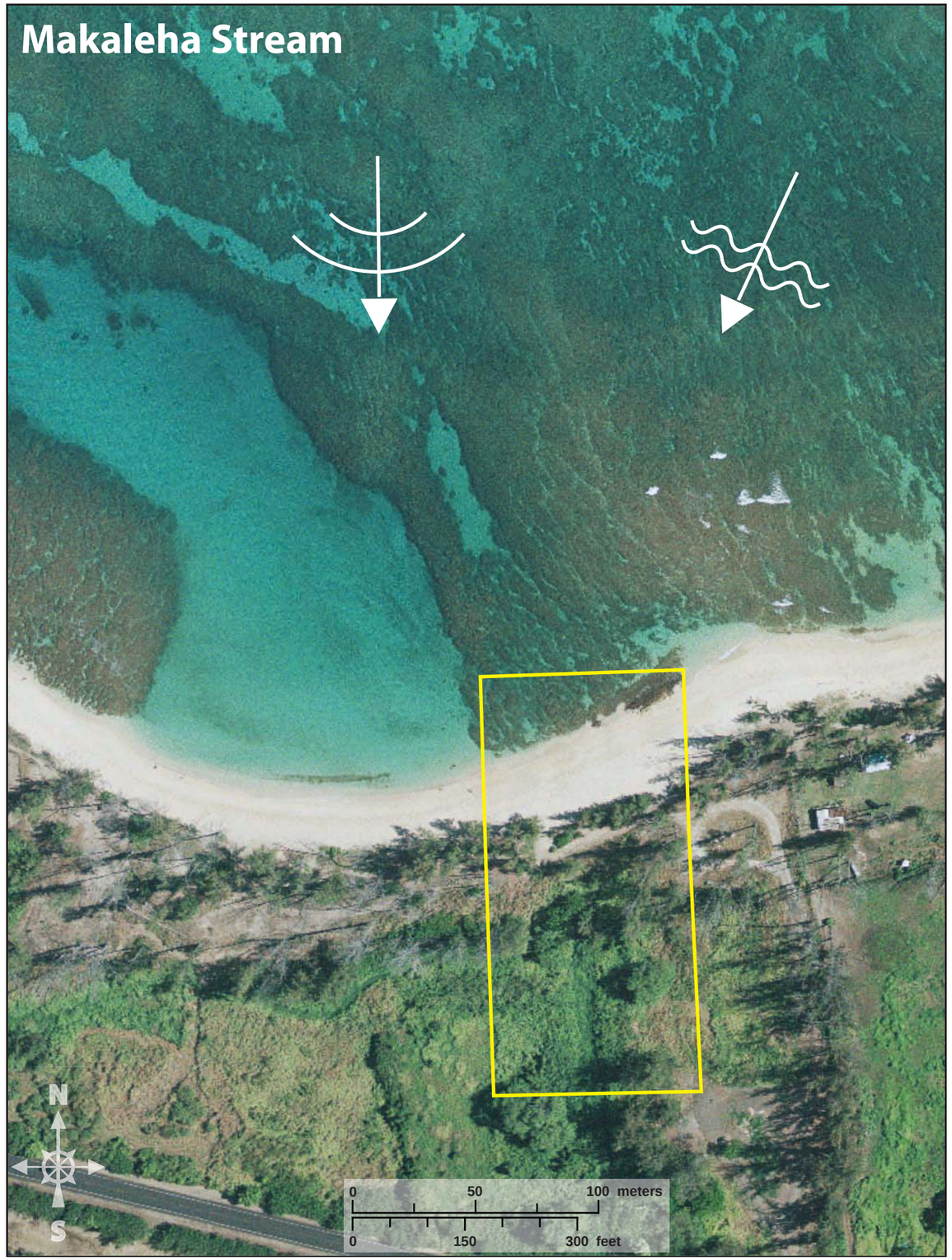


Photo 1. December 14, 2009 looking west down the beach and across the stream mouth.

Photo 2. December 14, 2009 looking down the stream mouth from mid-beach.

Makaleha Stream (perennial, NDAR_CODE 36004001)
Lat. 21.579
Long. -158.167 (stream mouth)

Coastal Processes

Makaleha Stream is located on the Mokuleia side of the north shore of Oahu. The stream is less than 50 ft in width and it typically blocked by beach sand. The beach is primarily fine carbonate sand with carbonate rock outcropping at the base of the foreshore. The north shore of Oahu is exposed to large swell energy in the winter from the northeast to the west. The majority of large swell events occur between the months of October and March. Tradewinds approach this coastline from the east, producing longshore sediment transport.

Aweoweo Stream

Photo 1. December 13, 2009 looking up stream from the beach.

Photo 2. December 13, 2009 looking east across the stream mouth.

Aweweo Stream (non-perennial, NDAR_CODE 36019001)
Lat. 21.582
Long. -158.130 (stream mouth)

Coastal Processes:
Aweoweo stream mouth is located on east Mokuleia Beach just west of Kaiaka Bay on the north shore of Oahu. The beach in this area is composed of medium carbonate sand and ranges in width from approximately 40 to 70 ft. The reef at this location is wide so the majority of long period wave energy is dissipated. However, tradewinds and currents moving across the reef surface deliver substantial energy to the beach and determine sediment transport. Tradewinds arrive from the east, hence transport at the stream mouth is predominantly from east to west.

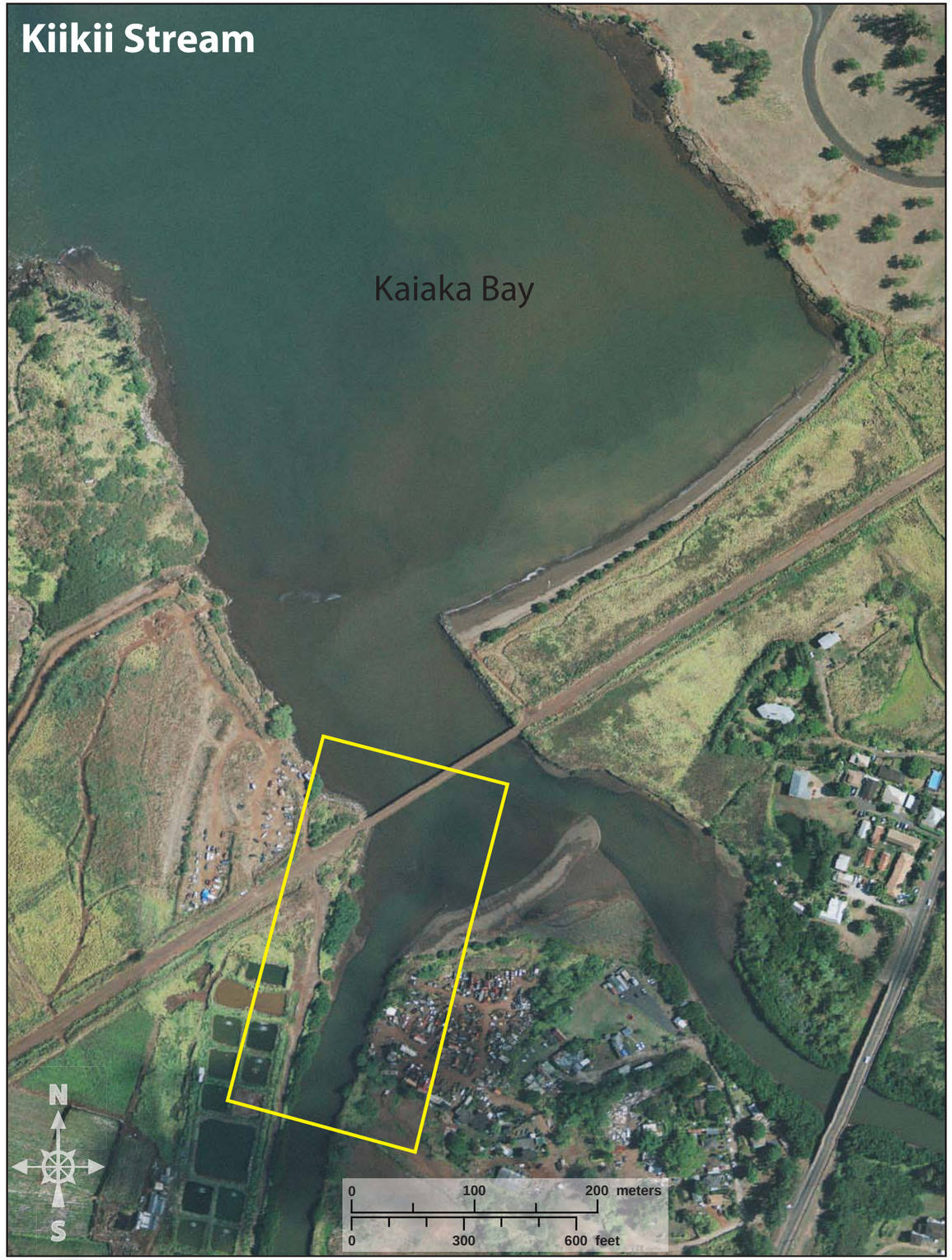


Photo 1. Decmber 13, 2009 looking east and seaward.

Photo 2. December 13, 2009 looking landward at stream mouth.

Kiikii Stream (Perennial, NDAR_CODE 36007001 Paukauila, 36006001 KiiKii)
Lat. 21.577
Long. -158.261 (stream mouth)

Coastal Processes:
Kaiaka Bay is a small bay on the north shore of Oahu. Kiikii stream and Paukauila Stream converge here and form one stream mouth. There is no beach to the west. The beach to the east is a mix of carbonate sand and terriginous sediment.

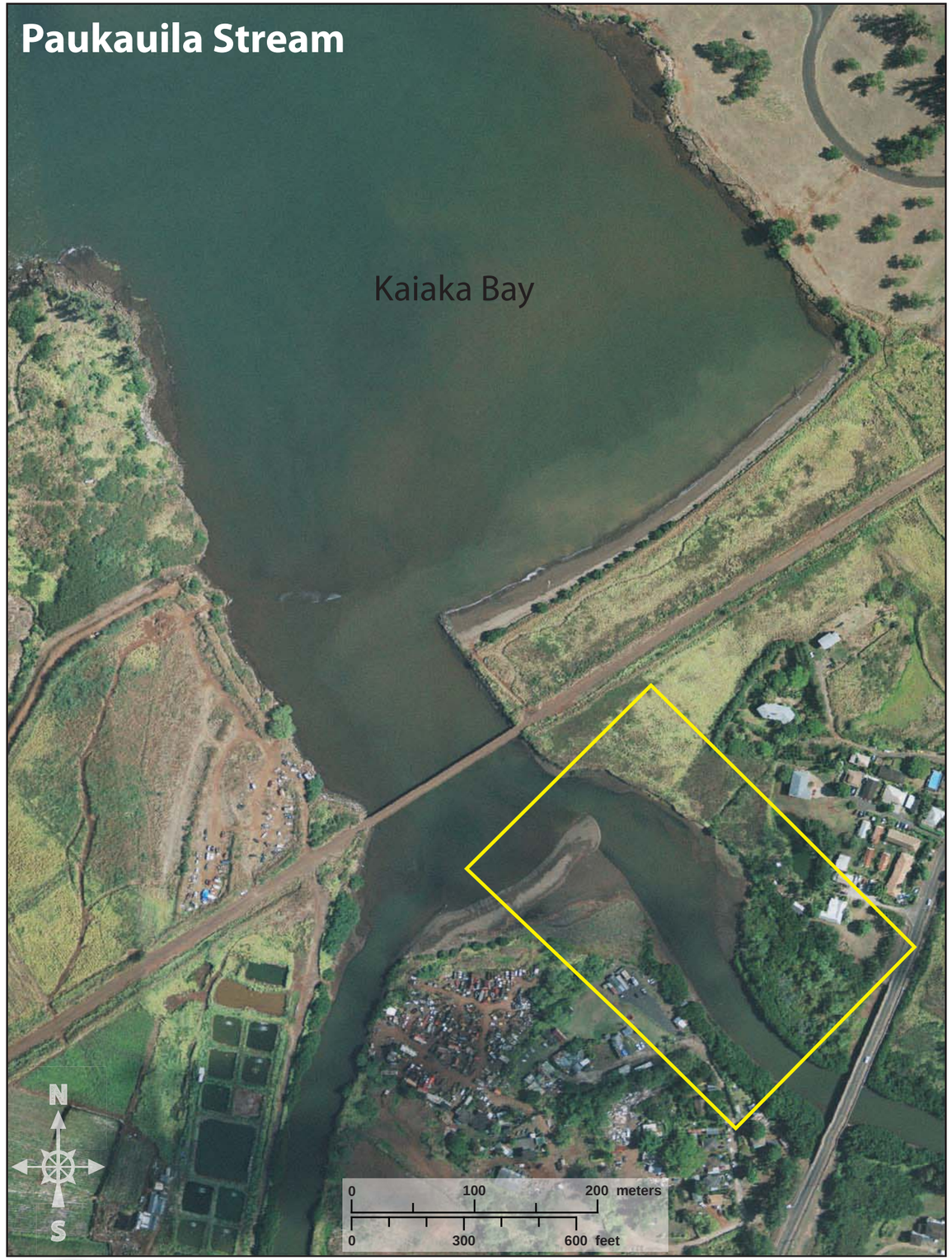


Photo 1. Decmber 13, 2009 looking down stream from the bridge.

Photo 2. December 13, 2009 looking landward and at the bridge in Kaiaka Bay.

Paukauila Stream (perennial, NDAR_CODE 36007001 Paukauila, 36006001 KiiKii)
Lat. 21.577
Long. -158.261 (stream mouth)

Coastal Processes:
Paukauila Stream enters Kaiaka Bay at Haleiwa on the north shore of Oahu. The stream is open throughout the year and largely protected from ocean waves. Sedimentation in the area is dominated by terrigenous mud and little carbonate sand is found. The stream mouth is estuarine and tidal.

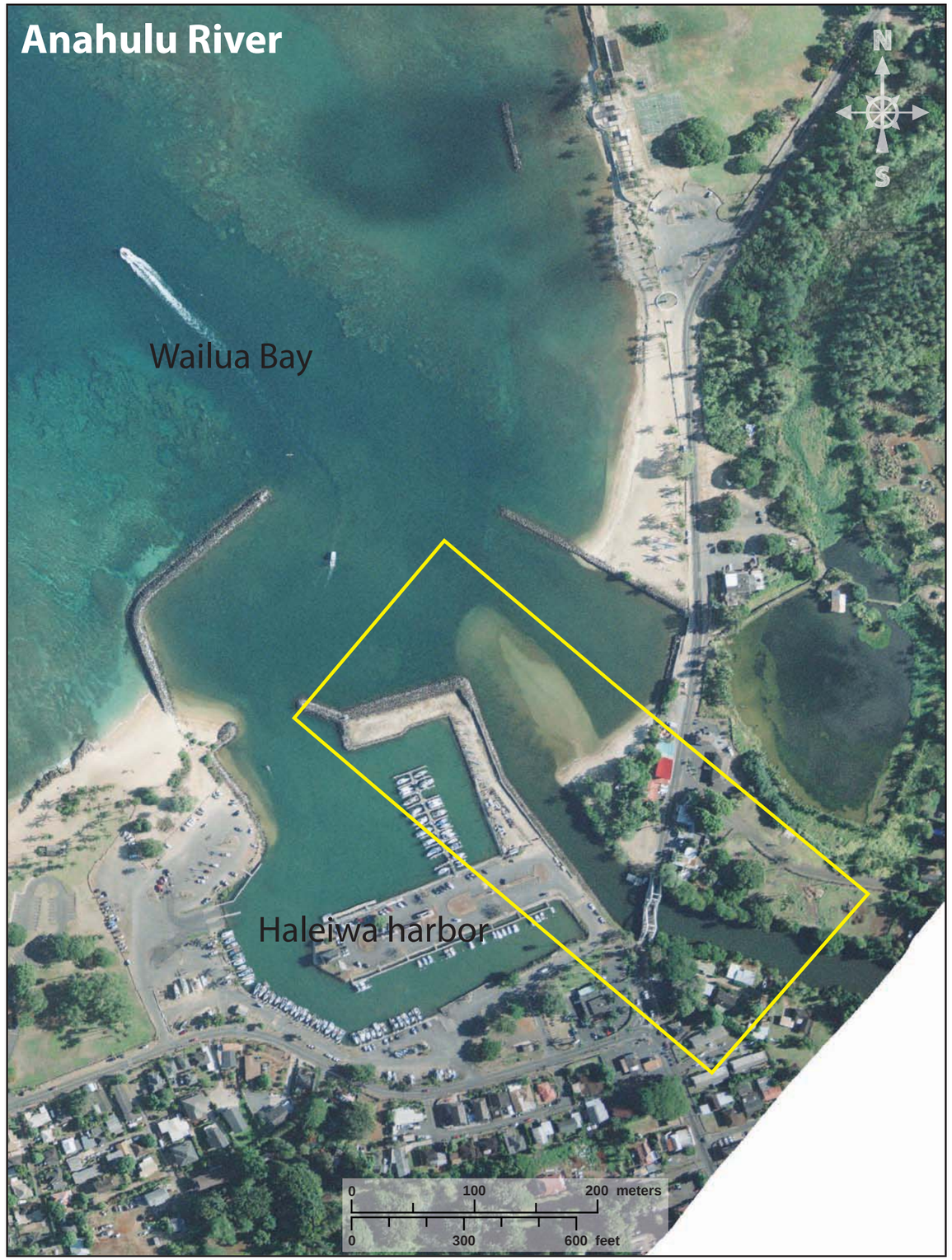


Photo 1. December 14, 2009 looking west toward Haleiwa Harbor.

Photo 2. December 14, 2009 looking upstream toward the bridge and Haleiwa.

Anahulu Stream (perennial, NDAR_CODE36008001)
Lat. 21.594
Long. -158.104 (stream mouth)

Coastal Processes:
Anahulu River mouth is located in Waialua Bay in Haleiwa Harbor on the north shore of Oahu. The stream is approximately 60 ft wide where it enters the ocean The west bank is hardened and acts as the eastern boundary of the harbor. The east bank is also hardened but does not extend offshore. The sand in this area is calcareous ranging from carbonate silt to coarse gravel sized clasts. There is a sand bar at the mouth of Anahulu River that changes position and shape reflecting waves and current conditions.

Photo 1. December 14, 2009 looking behind the bridge at the stream mouth.

Photo 2. December 14, 2009 looking at the stream mouth from the east side of the bridge.

Loko Ea Stream (Perennial, NDAR_CODE 36009001)
Lat. 21.577
Long. -158.261 (stream mouth)

Coastal Processes:
Loko Ea Stream is located on the north side of Haleiwa on the north shore of Oahu. The stream mouth is inside Haleiwa Harbor and as a result is sheltered from most wave energy. The waters are estuarine and tidal.

Photo 1. December 5, 2009 looking across the stream on the landward side of the bridge.

Photo 2. December 5, 2009 looking landward at the bridge from Laniakea Beach.

Laniakea Stream(perennial, NDAR_CODE 36020001)
Lat. 21.577
Long. -158.261 (stream mouth)

Coastal Processes:
Laniakea Stream mouth is located on the north shore of Oahu on Laniakea Beach. This stream is typically blocked by sand. Immediately to the north, fossil reef outcrops at the beach toe and continues to the north end of the beach. South of the stream mouth is a long and sandy beach. The position of the beach toe in this area can vary depending swell intensity and direction. During north swell in the winter months the longshore current generally runs from the north. Tradewinds approach from the east; hence longshore transport tends to be to the west.

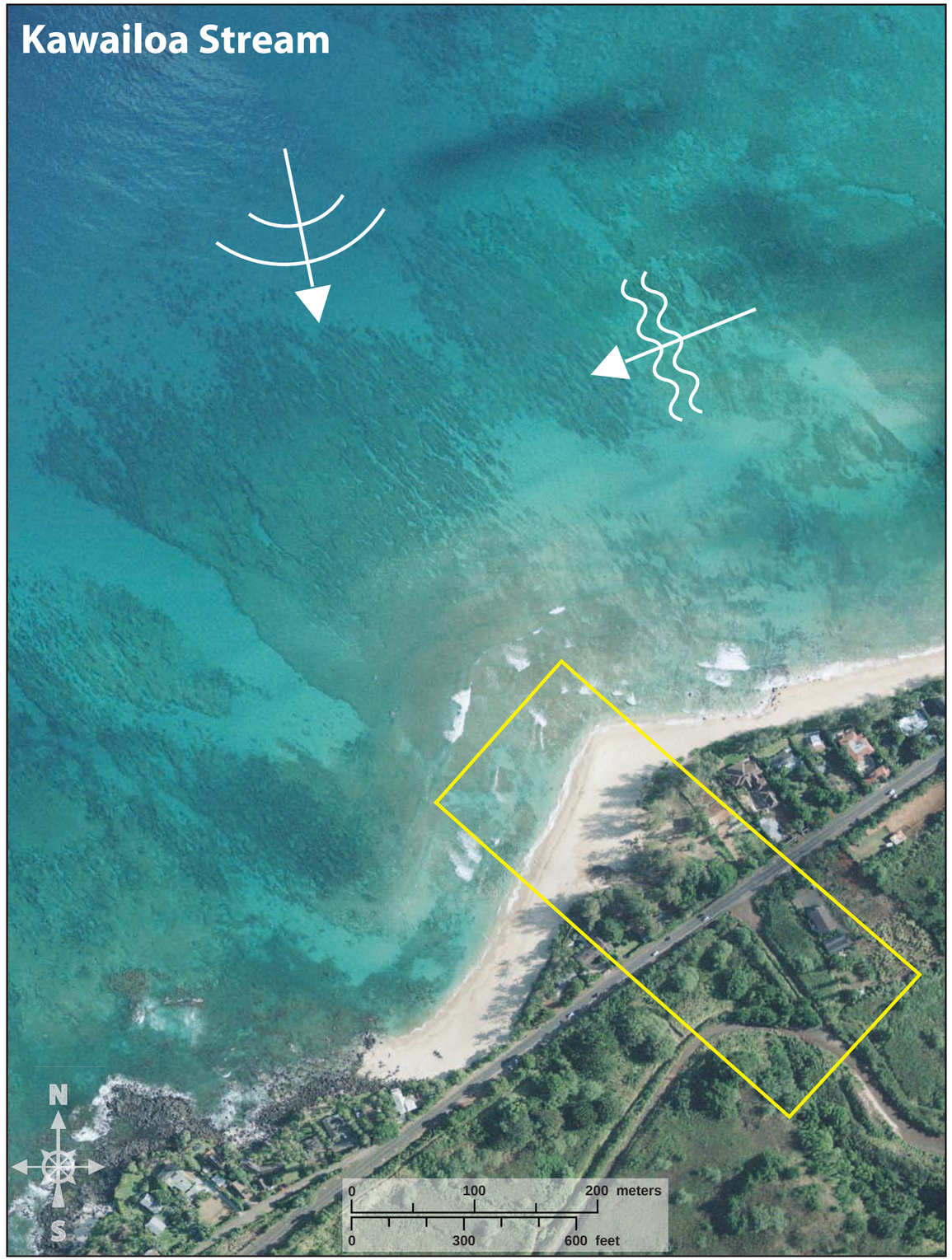


Photo 1. October 19, 2009 looking seaward down the stream bed.

Photo 2. October 19, 2009 looking lanward down stream bed.

Kawailoa Sream (non_perennial, NDAR_CODE 36021001)
Lat. 21.623
Long. -158.081 (stream mouth)

Coastal Processes:
Kawailoa Stream mouth is located on the north shore of Oahu on Kawailoa Beach. It is typically blocked by beach sand. Approximately 600 ft to south there a basalt rock headland marks the end of the littoral cell. The stream mouth is approximately 30 to 50 ft in width. This region is exposed to large seasonal swell energy from the north and west. Trade winds approach from along the shoreline from the east. The beach is primarily fine to medium grained carbonate sand.

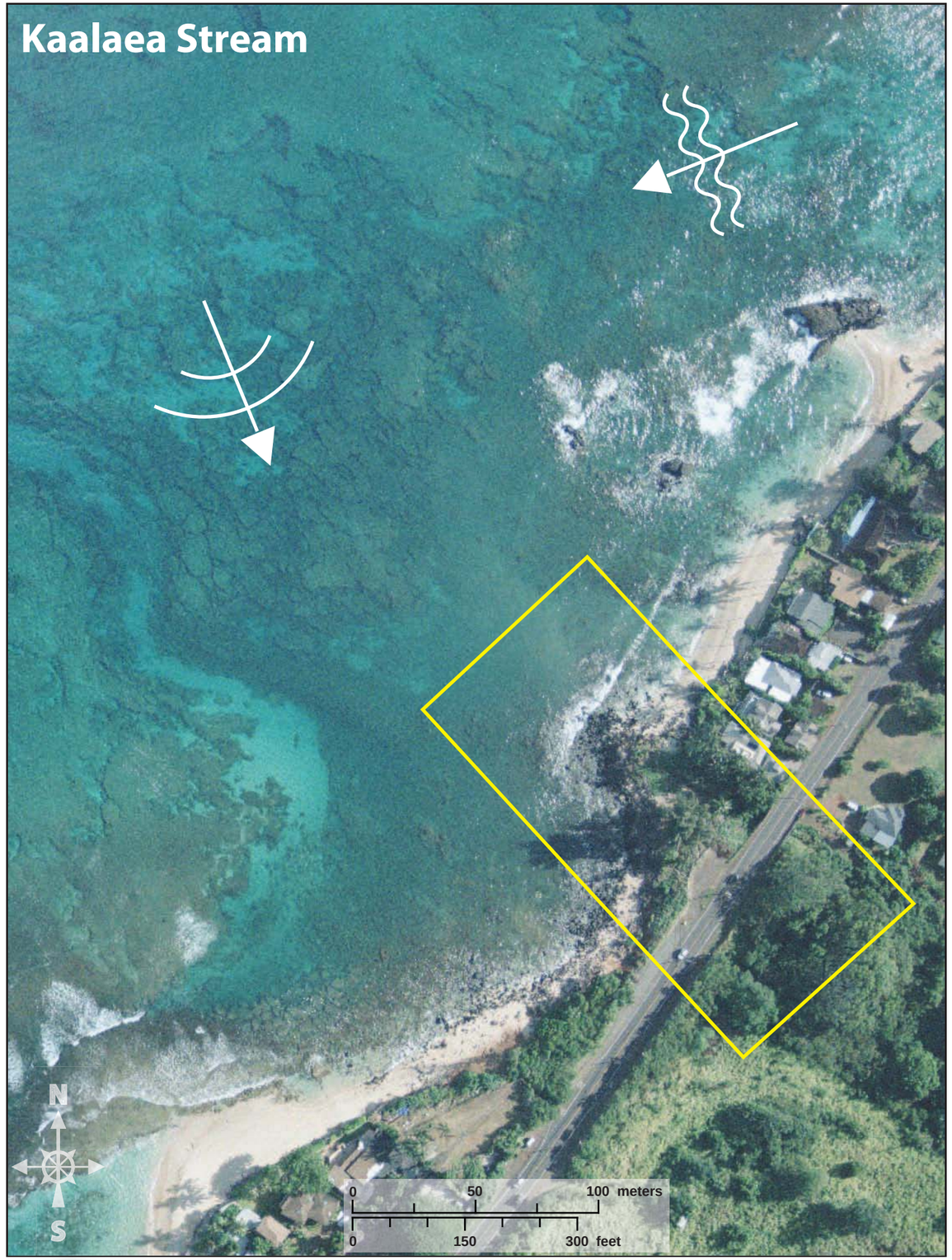


Photo 1. November 30, 2009 looking east from the stream bed.

Photo 2. November 30, 2009 looking north from the stream bed.

Kaalaea Sream (non-perennial, NDAR_CODE 36022001)
Lat. 21.628
Long. -158.074 (stream mouth)

Coastal Processes:
Kaalaea Stream mouth is located at the north end of Kawailoa Beach on the north shore of Oahu. The beach at this location tends to be sand-depleted and is a mixture of coarse carbonate sand and basalt boulders. The stream is narrow (~10 ft). This location is exposed to strong, but seasonal swell from the north and west in winter, and lies in the lee of tradewinds that blow throughout the year.

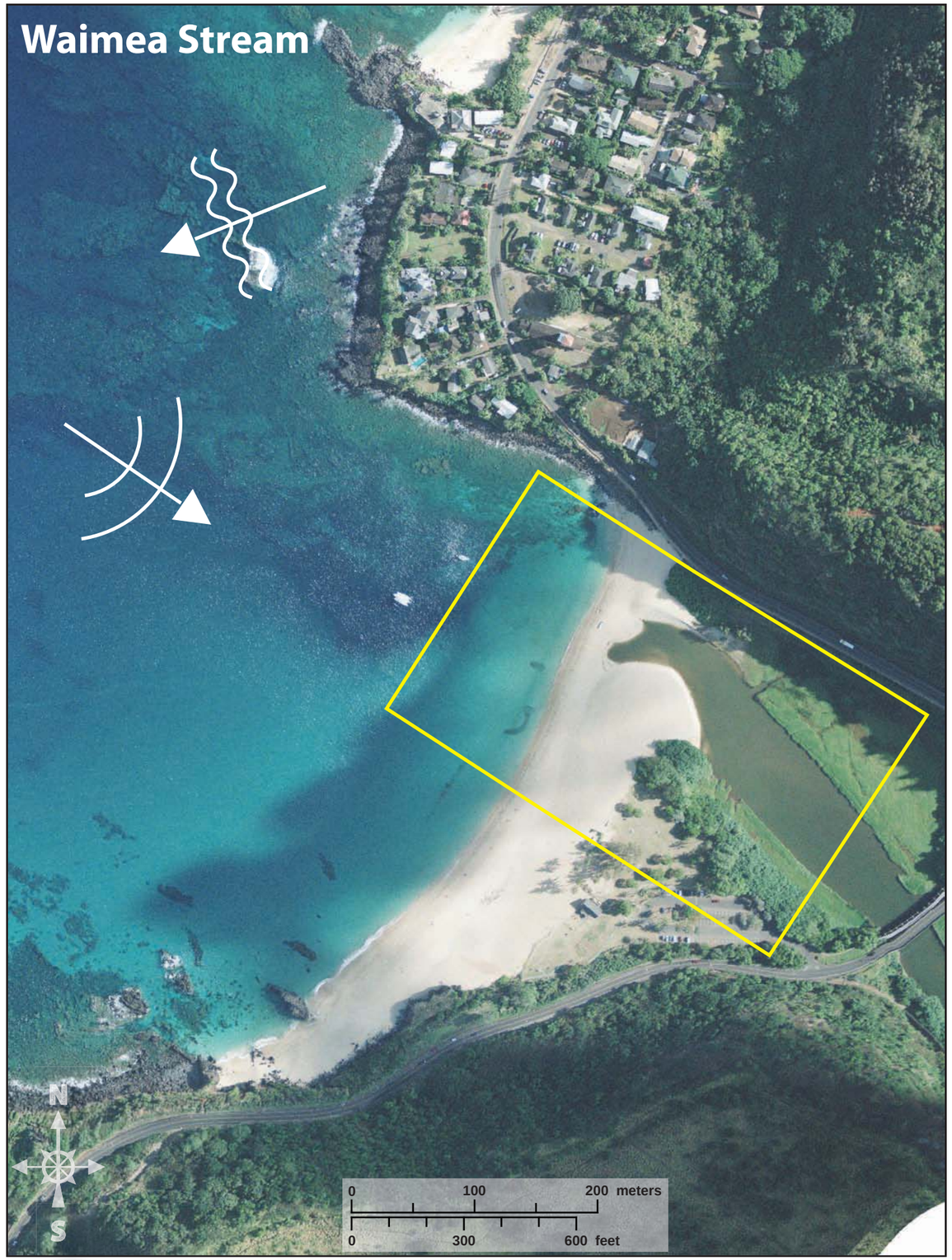


Photo 1. December 14 2009 from Waimea Beach up toward the stream mouth.

Photo 2. December 14, 2009 looking toward Waimea Bay with stream in back ground.

Waimea Stream (NDAR_CODE 36010001)
Lat. 21.641
Long. -158.063 (stream mouth)

Coastal Processes

Waimea Stream mouth is located in Waimea Bay on the north shore of Oahu. This beach is a pocket beach and bound in the north and south by basaltic headlands. The stream mouth is typically blocked by beach sand. The beach is primarily fine to medium grained calcareous sand. Tradewinds blow offshore at this location. The beach has a steep cross-section with deep offshore waters; hence wave energy can be extremely variable but is strong in the winter. This stream mouth is exposed to winter swell from the west through northeast.

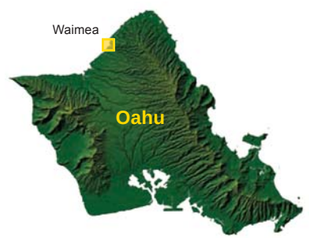


Photo 1. October 24, 2009 looking landward toward from the stream mouth.

Photo 2. October 24, 2009 looking looking landward and north from the south side of the stream mouth.

Kalunawaikaala Stream (intermittent, NDAR_CODE 31001001)
Lat. 21.658
Long. -158.058 (stream mouth)

Coastal Processes:
Kalunawaikaala Stream mouth is located on Ke Iki beach on the northern shoreline of Oahu. The stream mouth is approximately 30 to 50 ft across and is typically blocked by beach sand. Ke Iki Beach is primarily composed of fine to coarse carbonate sand and ranges in width from 100 to 200 ft. The beach terminates to the south into a large carbonate headland. The north shore of Oahu is exposed to high winter swell energy from the northeast through the west, and yearlong energy from the northeast tradewinds.

Photo 1. November 29, 2009 looking seaward from the road, down the stream bed.

Photo 2. November 29, 2009 looking northeast and across the stream bed.

Pakulena Stream (intermittent, NDAR_CODE 31002001)
Lat. 21.661
Long. -158.058 (stream mouth)

Coastal Processes

Pakulena Stream is located on the north shore of Oahu. It is typically blocked by beach sand. This area is exposed to large swell energy in the winter and tradewind waves throughout much of the year. The beach is primarily fine to medium carbonate sand and is transported largely from east to west along the shoreline.

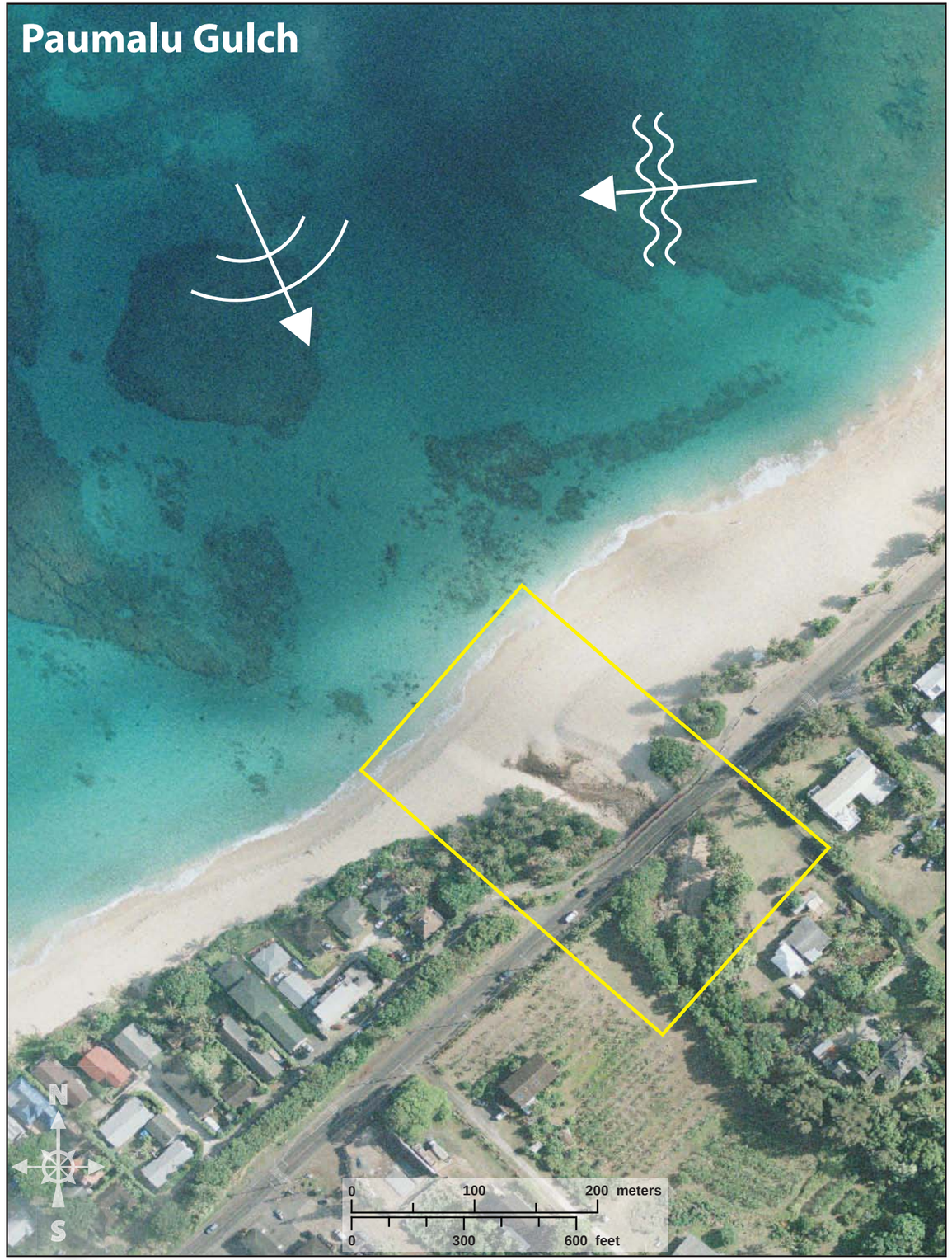


Photo 1. October 24, 2009 looking landward at the stream mouth and the bike bridge at Sunset Beach.

Photo 2. October 24, 2009 looking north west at the stream mouth.

Paumalu Gultch (intermittent, NDAR_CODE 31003001)
Lat. 21.673
Long. -158.042 (stream mouth)

Coastal Processes

Paumalu Gulch is located at the southwest end of Sunset Beach on the north shore of Oahu. The north shore of Oahu is exposed to large swell energy in the winter season and tradewinds throughout the year. The beach is primarily fine to medium grained carbonate sand and the stream is typically blocked by beach sand.

Kaunala Stream

Photo 1. December 14, 2009 looking landward from the west side of the stream mouth.

Photo 2. December 14, 2009 looking landward and west from the east side of the stream mouth.

Kaunala Stream (non-perennial, NDAR_CODE 31023001)
Lat. 21.681
Long. -158.034 (stream mouth)

Coastal Processes

Kaunala Stream mouth is located on the north shore of Oahu. The beach at this location ranges between 50 and 150 ft wide and is typically blocked by calcareous beach sand. Tradewinds at this location blow alongshore from east to west. Energy from large northerly swell impinges on the beach and shapes morphologic changes.

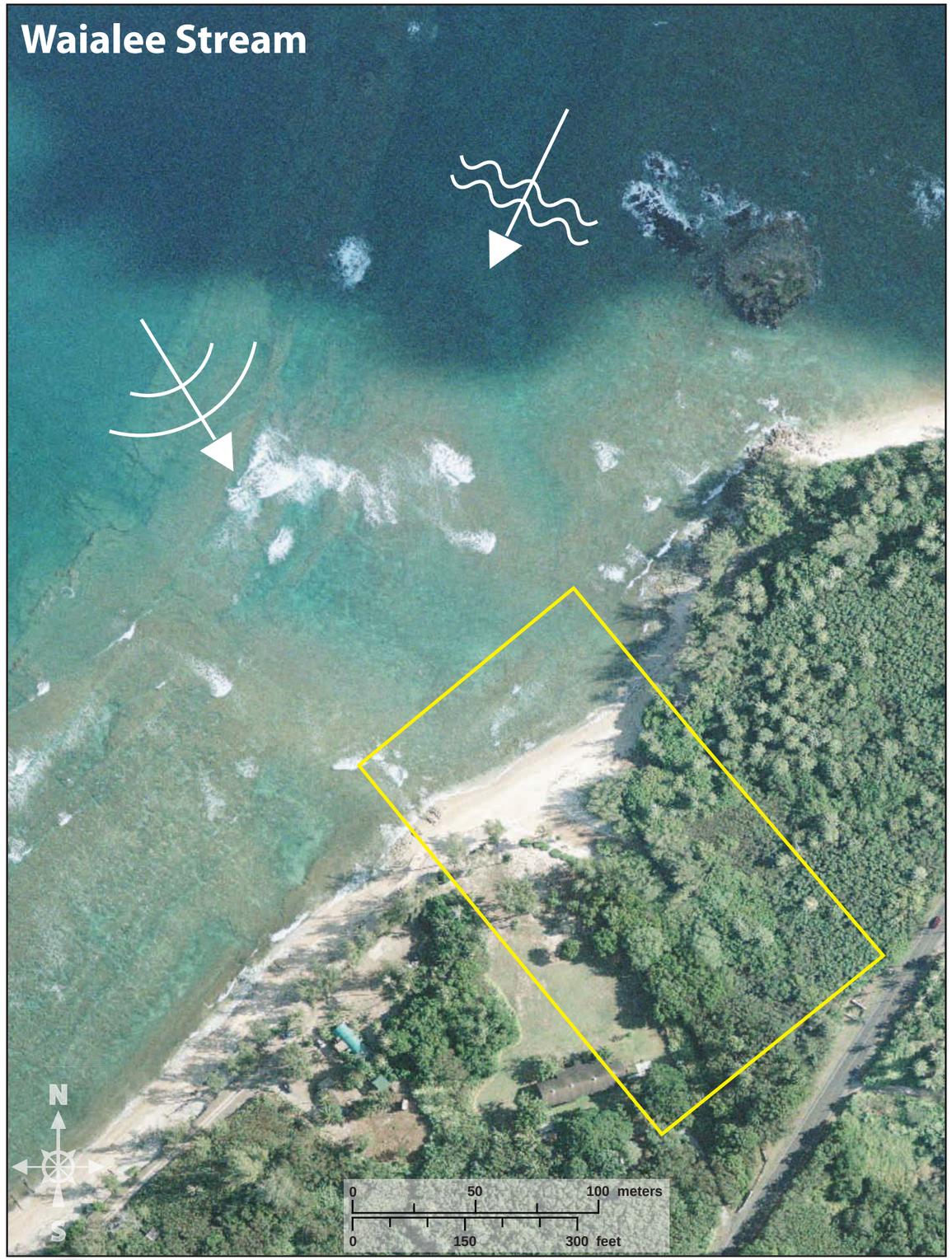


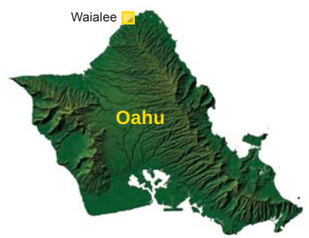
Photo 1. October 24, 2009 looking landward from the west side of the stream mouth.

Photo 2. October 24, 2009 looking west along the beach from the south side of the stream mouth.

Waialee Stream (Non-Perennial, NDAR_CODE, 31025002)
Lat. 21.691
Long. -158.022 (stream mouth)

Coastal Processes

Waialee Stream mouth is located on the North shore of Oahu just SE of Kawela Bay. This area of coast is exposed to side onshore trade winds and trade wind generated swell. This area is also exposed to larger swell ot of the directions ranging fro NE through W.



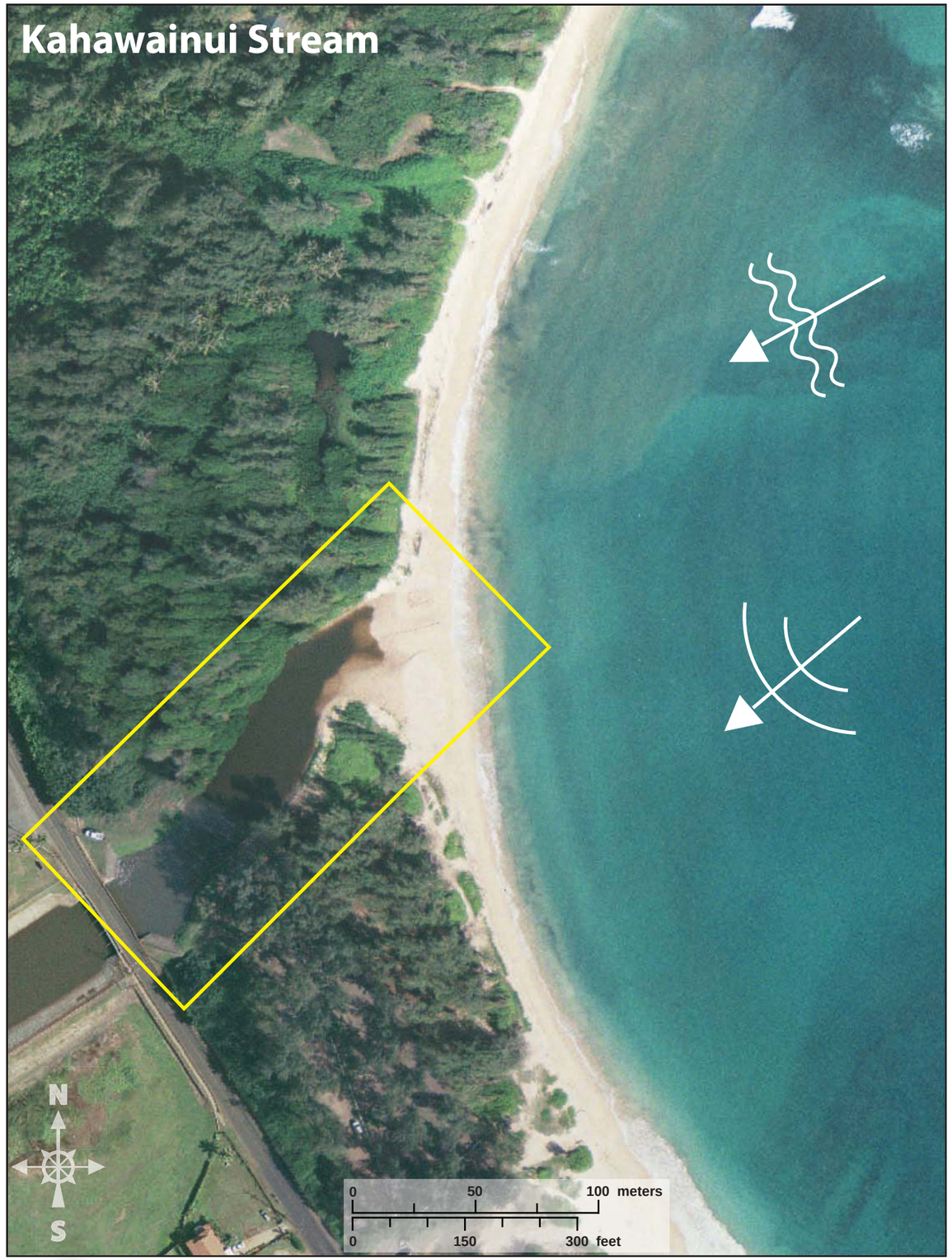


Photo 1. November 30, 2009 looking northeast from the bridge.

Photo 2. November 30, 2009 looking down stream from the bridge toward the ocean.

Kahawainui (NDAR_CODE 31007001)
Lat. 21.633
Long. -157.921 (stream mouth)

Coastal Processes:
Kahawainui Stream mouth is located in Laie on the northeast shore of Oahu. The stream is channelized landward of the bridge and its mouth is typically blocked by beach sand. Seaward of the bridge the stream remains wide but it is in a natural state. Tradewinds blow onshore on this location. Large waves are generally blocked due to the presence of Goat Island and a fringing reef.

Photo 1. November 30, 2009 looking landward at the bridge from the beach.

Photo 2. November 30, 2009 looking seaward, down stream from the bridge.

Laie Loa Stream (NDAR_CODE 31007001) This stream is labeled Laie Loa on the bridge but named Kahawainui in the Hawaii Statewide GIS database.
Lat. 21.633
Long. -157.921 (stream mouth)

Coastal Processes:
Laie Loa Stream mouth is located in Laie on the northeast shore of Oahu just north of Laie Point. The stream mouth is typically blocked by beach sand. Tradewinds blow onshore on this location. Large waves are generally blocked due to the presence of Goat Island, Laie Point and a fringing reef.

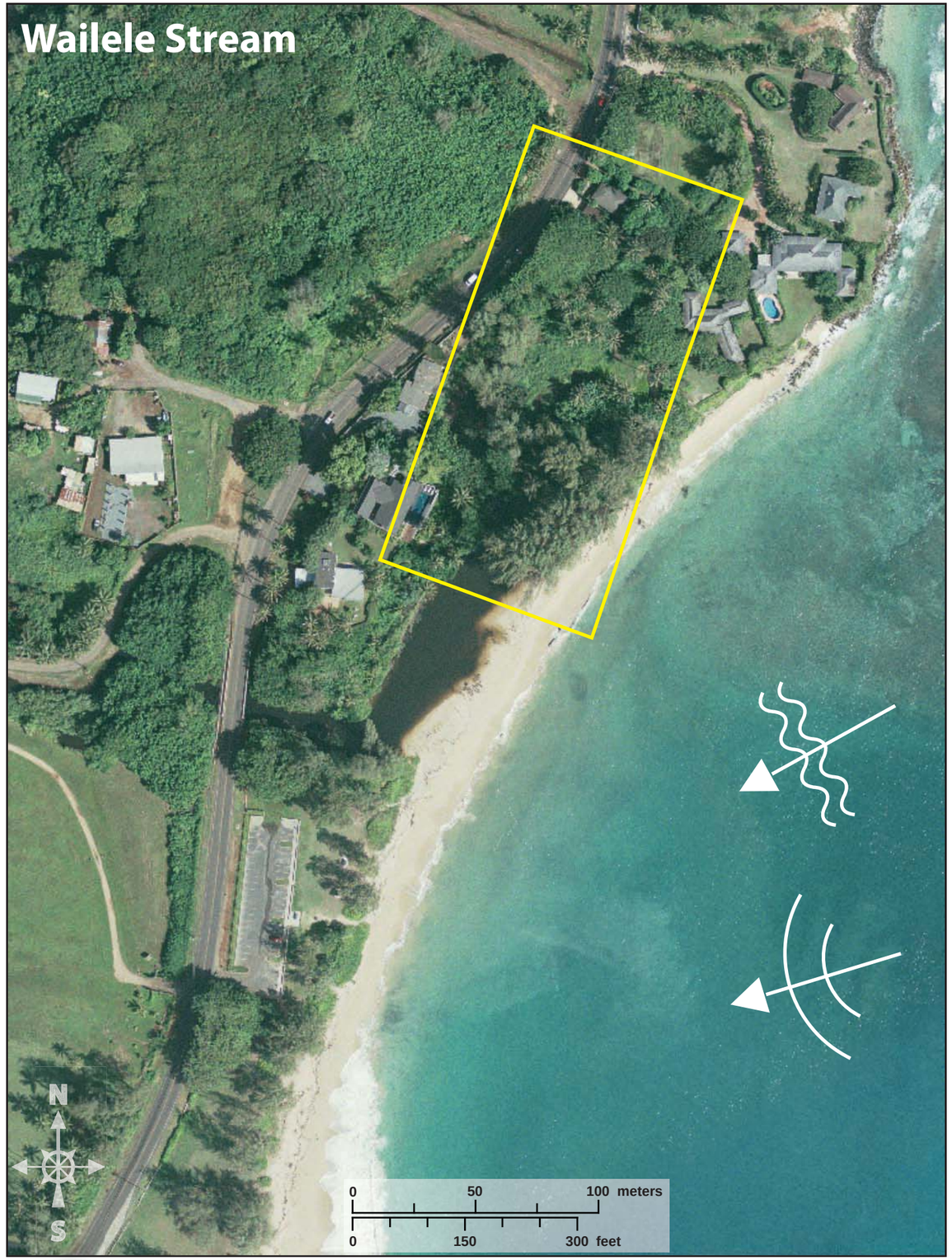


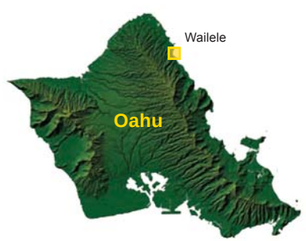
Photo 1. November 30, 2009 looking north from the south bank.

Photo 2. November 30, 2009 looking south and seaward.

Wailele Stream (Perennial NDAR_CODE 31009001 Koloa, Perennial, NDAR_CODE 31008001 Wailele)
Lat. 21.633
Long. -157.921 (stream mouth)

Coastal Processes

Wailele Stream mouth is located on the northeast shore of Oahu in Laie at the north end of Laie Beach Park. At this location two streams come together where they empty into the ocean. This stream mouth is typically plugged by sand. The beach is primarily fine to medium carbonate sand. This beach is bound by a carbonate rock headland to the south and a hardened stretch of shoreline to the north. Tradewinds blow onshore in this location the majority of the year. There is a narrow entrance to this bay through fringing reef so most northeast swell energy is dissipated before reaching the shoreline.



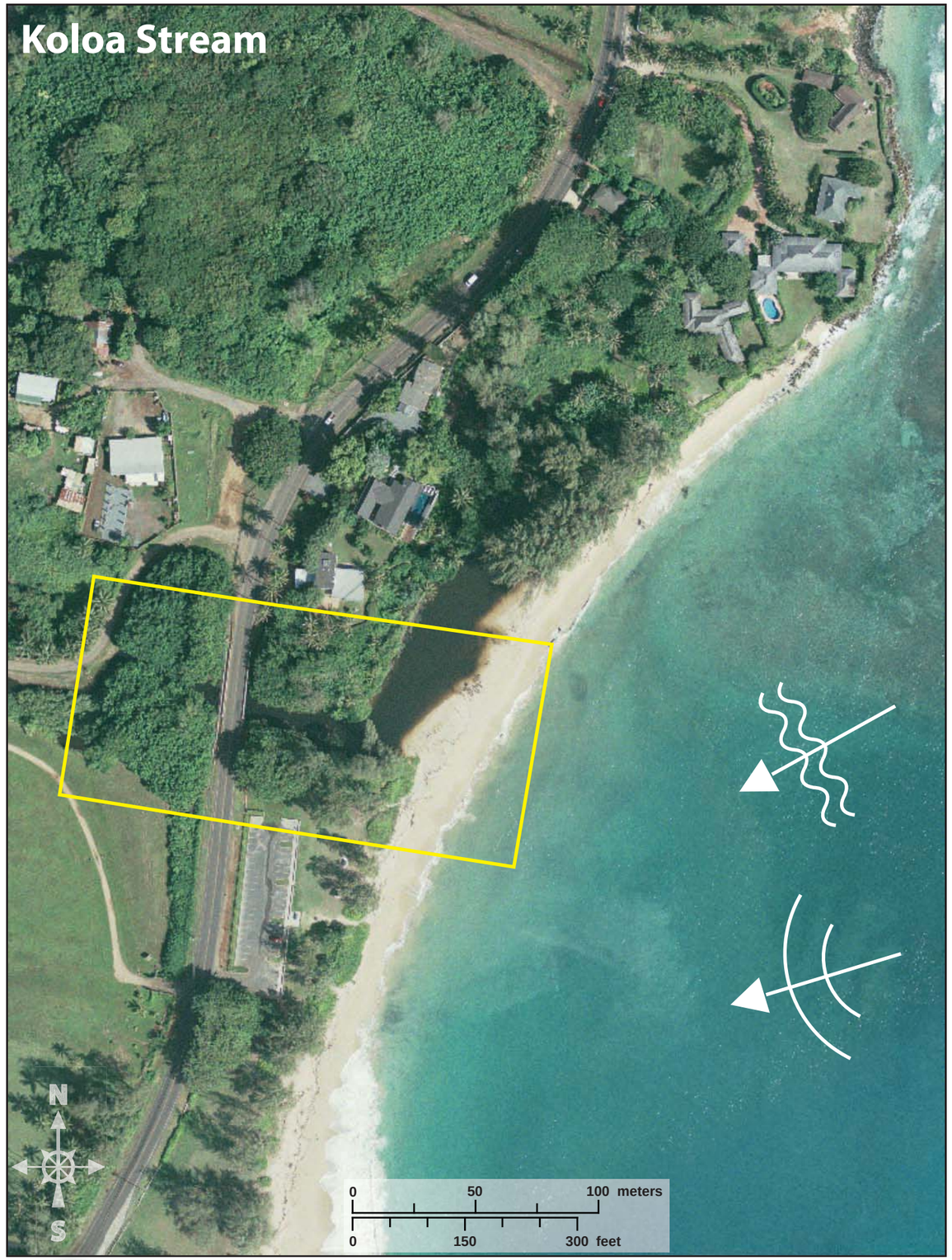


Photo 1. November 30, 2009 looking North from south bank

Photo 2. November 30, 2009 looking South from south bank

Koloa Stream (Perennial NDAR_CODE 31009001 Koloa, Perennial, NDAR_CODE 31008001 Wailele)
Hawaii Statewide GIS labels the south most stream here Koloa, Department of Facility Maintanance Division of Road Maintanance refers to this stream as Laie Wai.
Lat. 21.633
Long. -157.921 (stream mouth)

Coastal Processes:
Koloa Stream mouth is located on the northeast shore of Oahu in Laie at the north end of Laie Beach Park. At this location two streams come together where they empty into the ocean. This stream mouth is typically plugged by sand. The beach is primarily fine to medium carbonate sand. This beach is bound by a carbonate rock headland to the south and a hardened stretch of shoreline to the north. Tradewinds blow onshore in this location the majority of the year. There is a narrow entrance to this bay through fringing reef so most northeast swell energy is dissipated before reaching the shoreline.

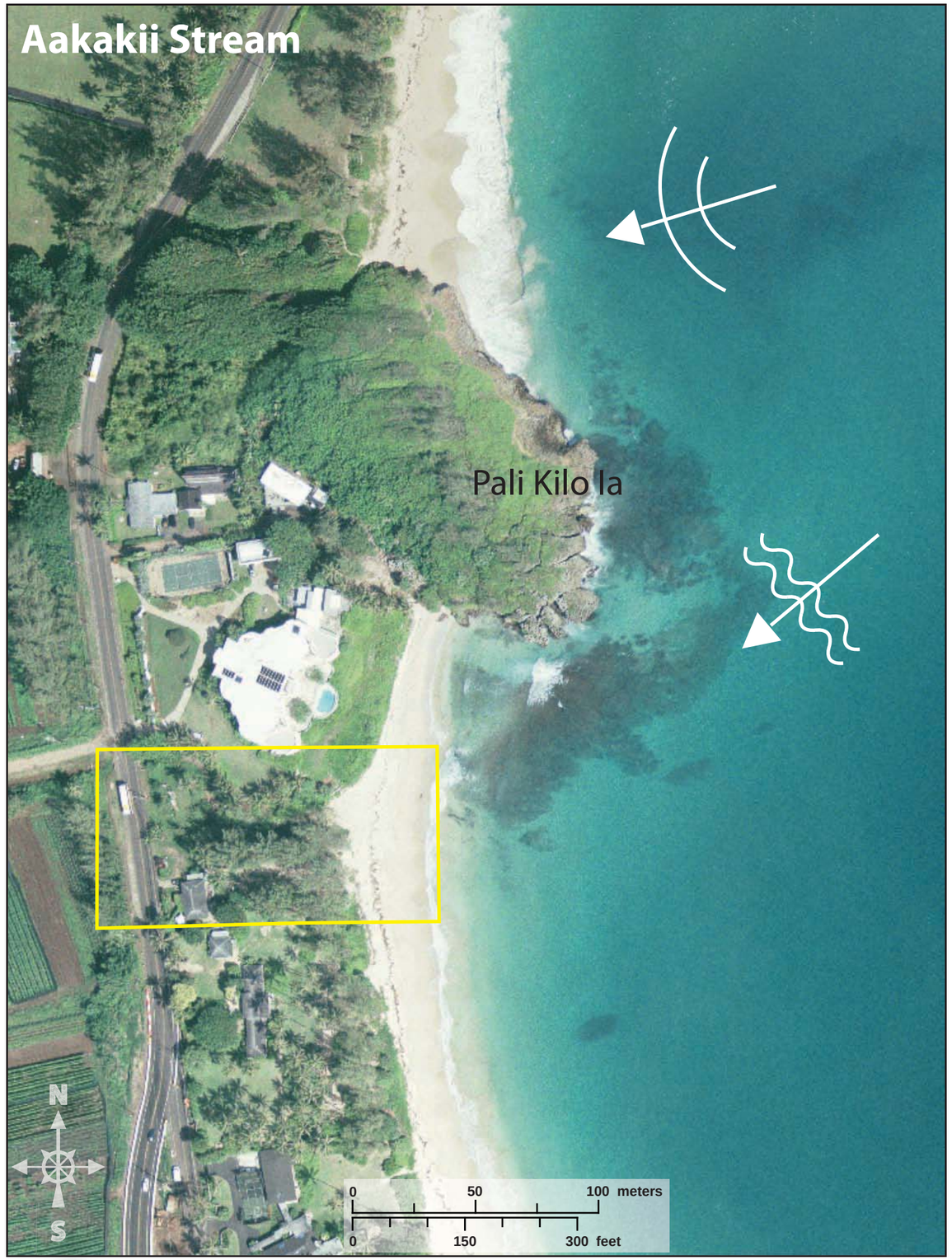


Photo 1. November 30, 2009 looking south along Kokololio Beach.

Photo 2. November 30, 2009 looking north along Kokololio Beach.

Aakakii Stream (non-perennial, NDAR_CODE 31031001)
Lat. 21.627
Long. -157.921 (stream mouth)

Coastal Processes:
Aakakii Stream mouth is located at the northern end of Kokololio Beach Park on Oahu's northeast coastline. The beach in this area is primarily fine calcareous sand and generally ranges between 50 and 200 ft in width. This area is bounded by rocky Pali Kilo Ia to the north. Tradewinds blow onshore and slightly to the south at this location hence longshore transport is predominately north to south.

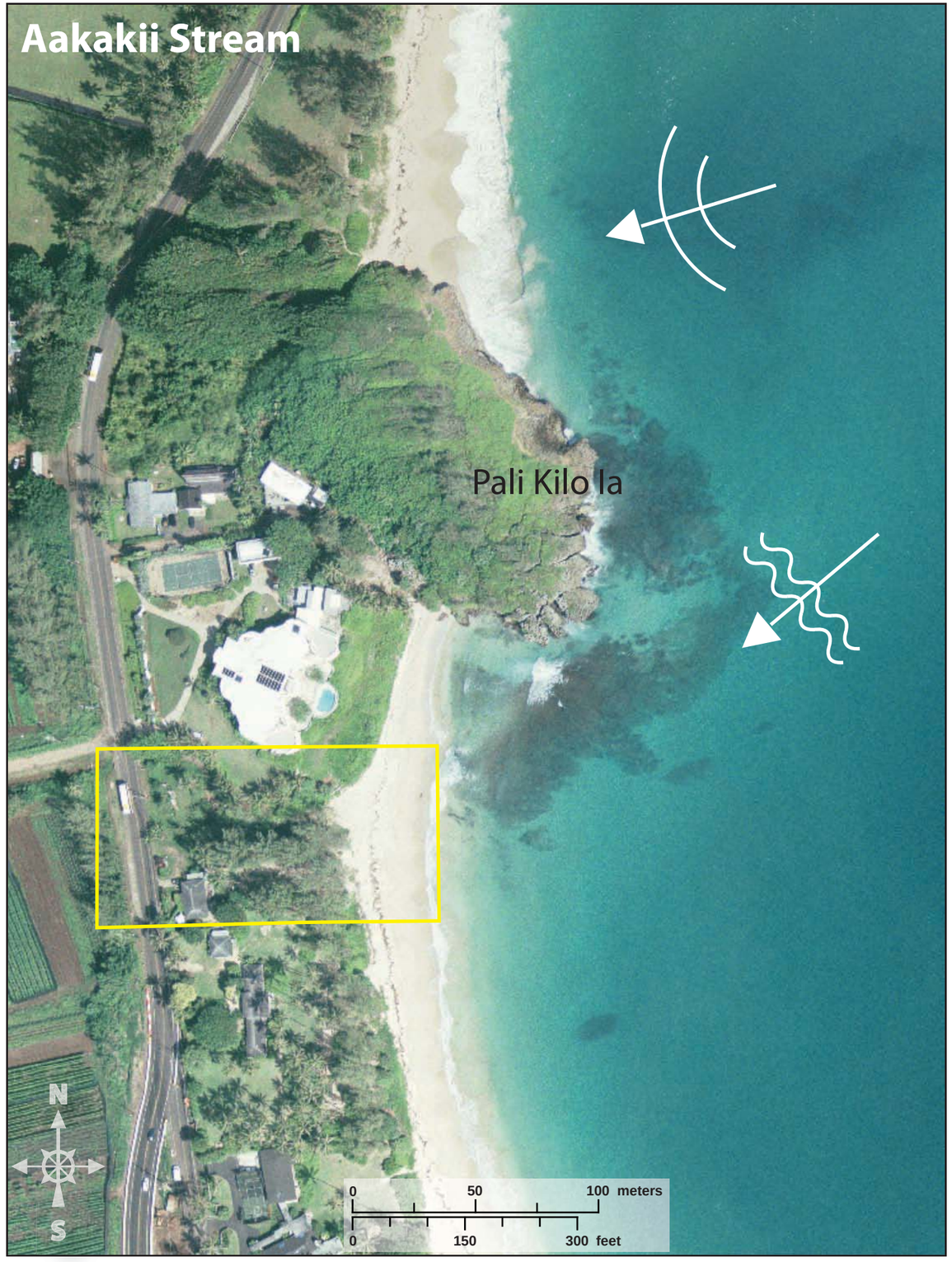


Photo 1. November 30, 2009 looking South along Kokololio Beach

Photo 2. November 30, 2009 looking North along Kokololio Beach

Kokololio Stream (Non-Perennial, NDAR_CODE 31031001)
Lat. 21.627
Long. -157.921 (stream mouth)

Coastal Processes:
Aakakii Stream mouth is located at the northern end of Kokololio Beach Park on Oahu's northeast coastline. The stream mouth is approximately 25 ft across. The beach in this area is primarily fin calcareous sand and general ranges between 50 and 200ft in width. This area is bounded by Pali Kilo Ia in the north and shallow reef off the point at the south end of Kokololio Beach park. Trade winds blow onshore at this location. Trade wind generated swell at this location is onshore however some of the energy is blocked from offshore reefs and the angle of the channel.

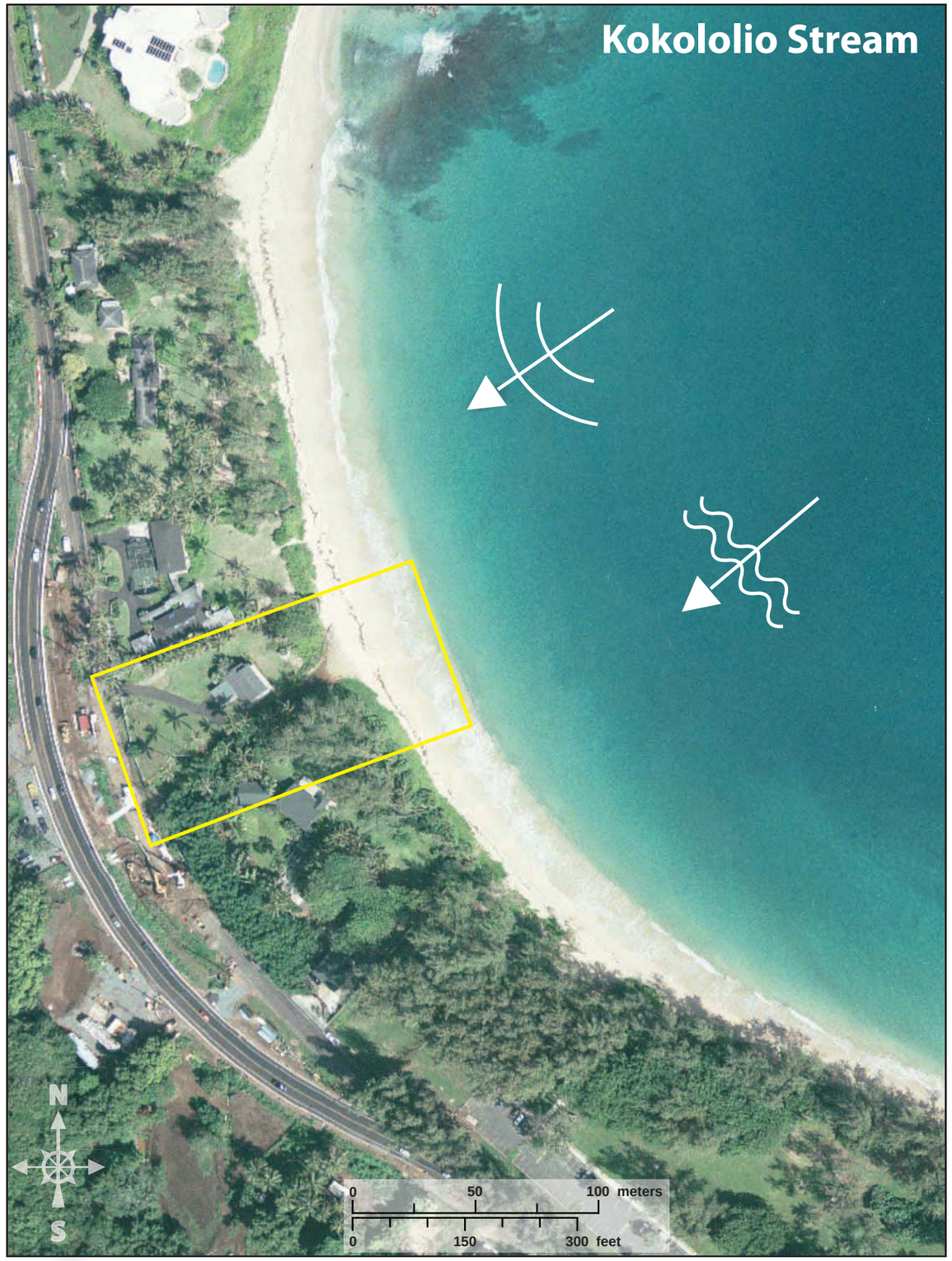


Photo 1. November 30, 2009 looking landward down the stream bed.

Photo 2. November 30, 2009 looking down the stream bed at the southen bank.

Kokololio Stream (non-perennial, NDAR_CODE 31031001)
Lat. 21.627
Long. -157.921 (stream mouth)

Coastal Processes:
Kokololio Stream mouth is located at Kokoloio Beach on the east shore of Oahu. The beach at this location is composed of carbonate sand and ranges in width from 15 to 50 ft. Fringing reef to the north and south dissipate much wave energy, but large events do impact the shoreline each winter season. The stream mouth is typically blocked with beach sand.

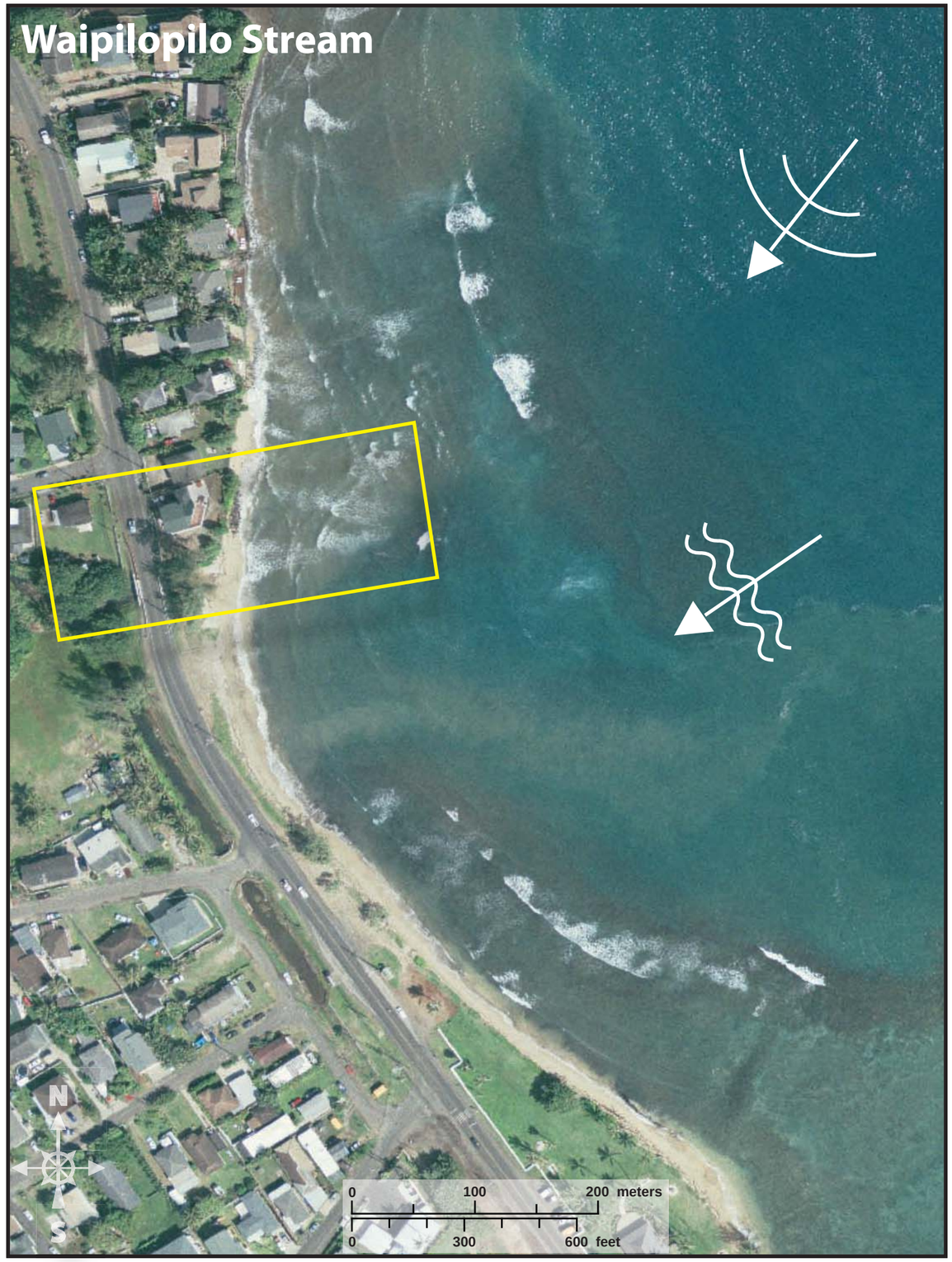


Photo 1. November 30, 2009 looking South from south bank.

Photo 2. November 30, 2009 lookingNorth from south bank.

Waipilopilo Stream (Perennial, NDAR_CODE 310010004)
Lat. 21.615
Long. -157.913 (stream mouth)

Coastal Processes:

Waipilopilo stream mouth is located in Hauula on Oahu's northeast coastline. Waipilopilo stream empties onto a fine carbonate sand beach that extends to Kaipapau stream approximately 200m to the north and to Kapalaoa Beach park in the south. To the north this beach becomes increasingly more narrow as the shoreline transitions from a dominant carbonate sand beach to a hard shoreline composed of cobble, silt and carbonate rock and sea wall. To the south the beach remains characterized by fine carbonate sand.

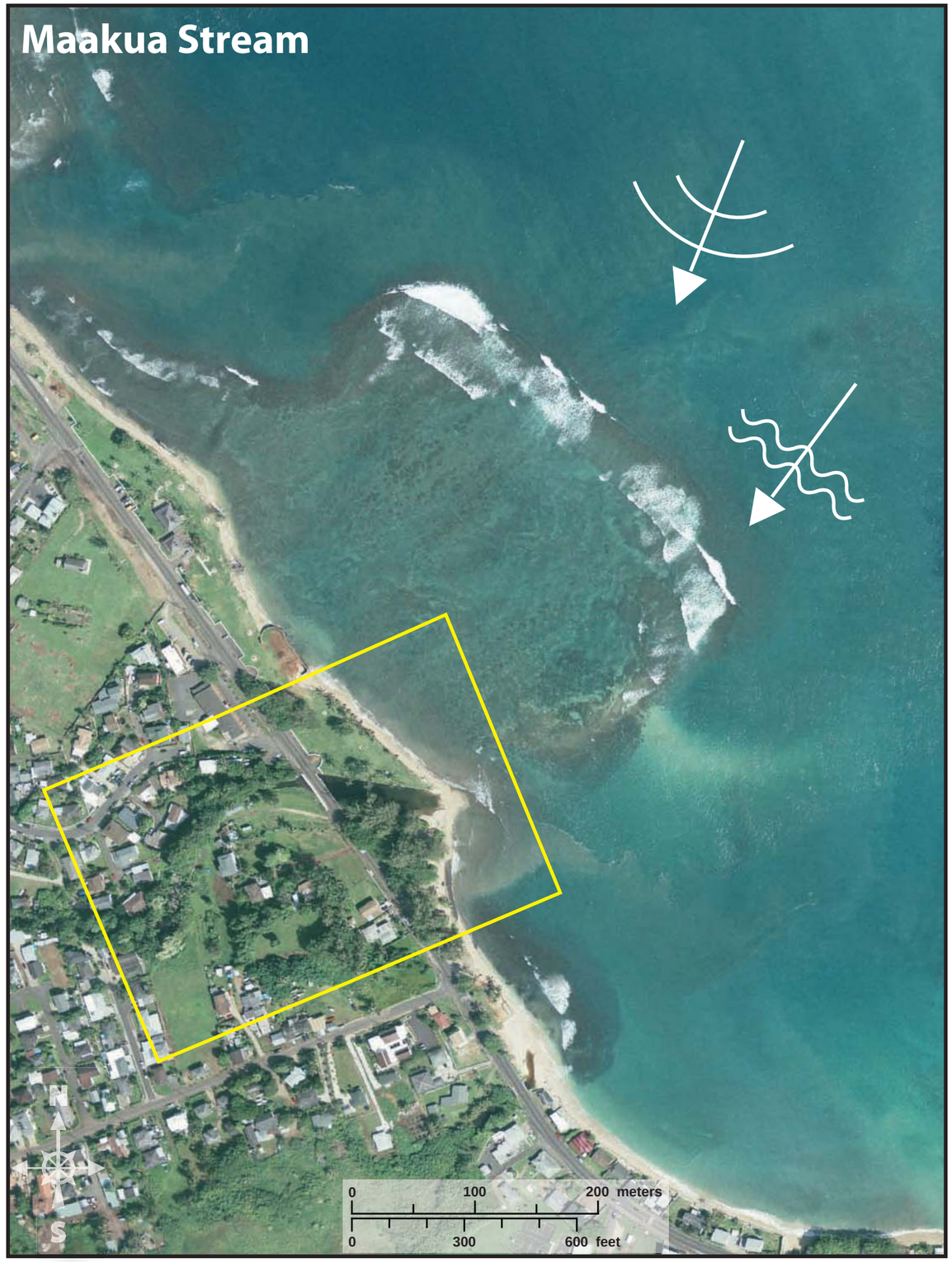


Photo 1. November 30, 2009 looking south down the beach from the southern side of the stream mouth.

Photo 2. November 30, 2009 looking east down the stream bed.

Maakua Stream (intermittent, NDAR_CODE31011001)
Lat. 21.611
Long. -157.909 (stream mouth)

Coastal Processes:

Located at Kapalaoa Beach park in Hauula, Maakua Stream mouth empties into the ocean on a primarily carbonate sand beach. Typically the stream mouth is partially or wholly blocked by beach sand. The stream is located at the southern boundary of a shallow fringing reef system and the northern boundary of a small sandy bay. The reef provides some protection to Maakua Stream mouth from seasonal north to north east swell and tradewind energy. The shoreline directly to the north is characterized by a narrow sand and cobble beach with a significant erosional scarp at the high waterline indicating an area of chronic erosion.

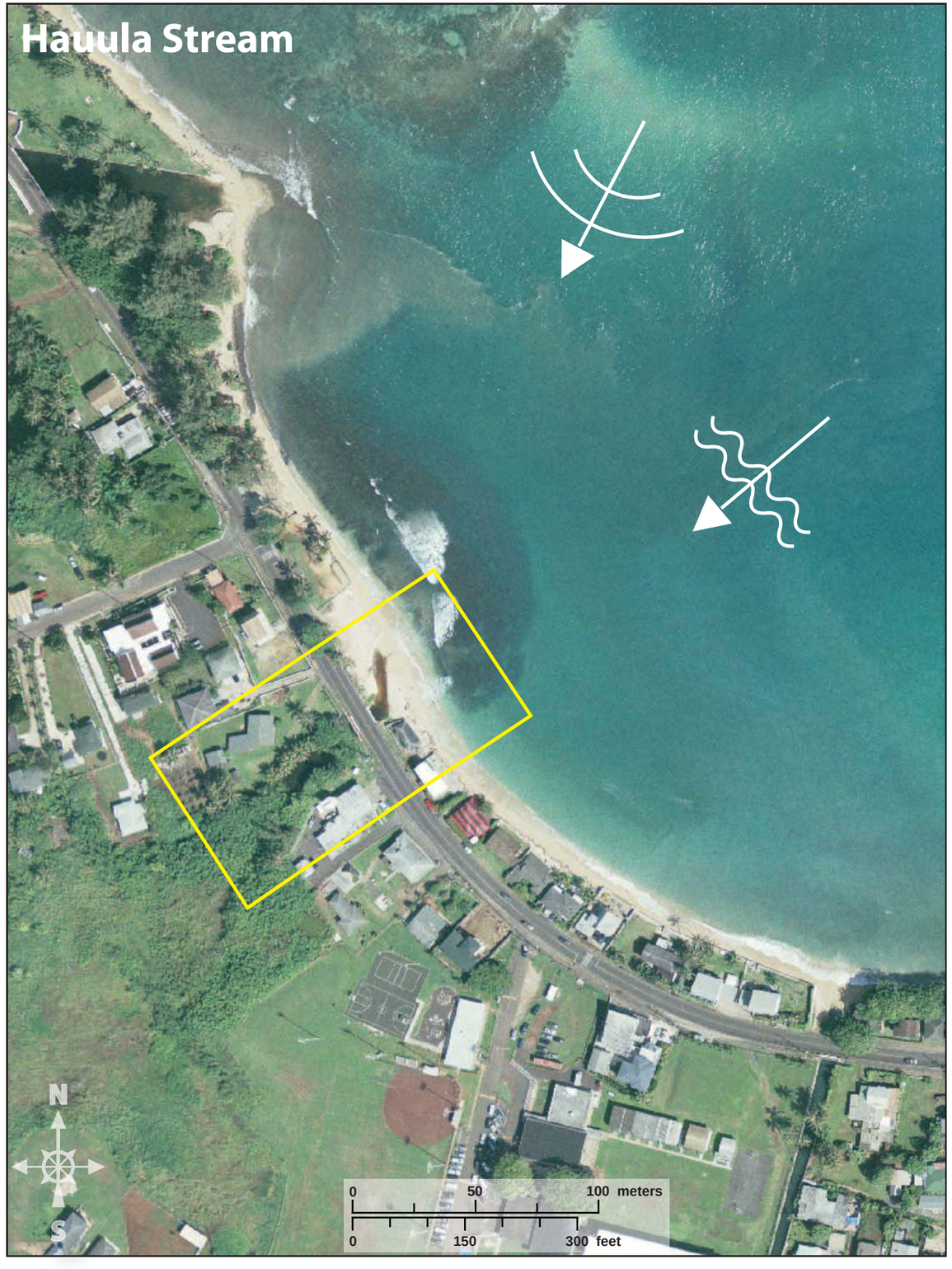


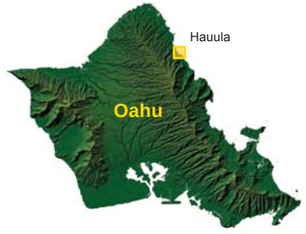
Photo 1. November 30, 2009 looking south from the north side of the stream mouth

Photo 2. November 30, 2009 looking seaward from the bridge.

Hauula Stream (NDAR_CODE NA) This stream is not labeled on the Hawaii Statewide GIS database but is called Hauula Stream by the Department of facilities and Maintenance.
Lat. 21.607
Long. -157.907 (stream mouth)

Coastal Processes

Waipuhi Stream mouth is located in Hauula on the east shore of Oahu. It is a channelized stream approximately 30 ft wide at the bridge, and typically blocked by beach sand. Hauula stream mouth empties into the ocean on a primarily fine carbonate sand beach. The stream is located at the head of a sand channel that cuts through the fringing reef. Tradewind waves approach from offshore and refracted north swell is seasonally prevalent. Discharge from the adjacent watershed governs the hydrology of the channel.



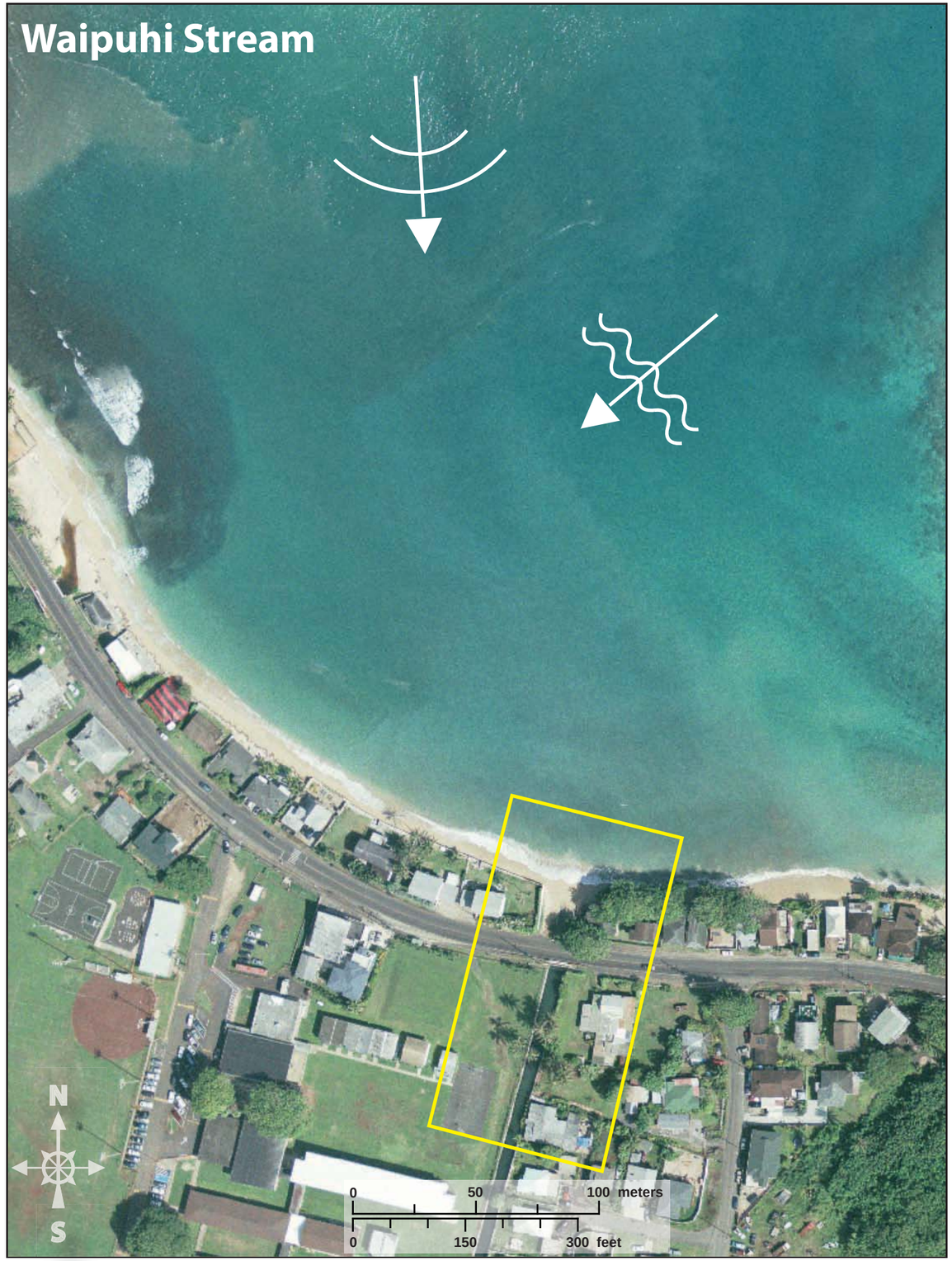


Photo 1. November 30, 2009 looking seaward toward the stream mouth from the side of the road.

Photo 2. November 30, 2009 looking landward from stream mouh.

Waipuhi Stream (non-perennial, NDAR_CODE 31032001) This stream is labelled Hauula on the Hawaii Statewide GIS database but is called Wipuhi by the Department of facilities and Maintenance.
Lat. 21.607
Long. -157.907 (stream mouth)

Coastal Processes

Waipuhi Stream mouth is located in Hauula on the east shore of Oahu. It is a channelized stream approximately 30 ft wide at the bridge, and typically blocked by beach sand. Waipuhi stream mouth empties into the ocean on a primarily fine carbonate sand beach. The stream is located at the head of a sand channel that cuts through the fringing reef. Tradewind waves approach from offshore and refracted north swell is seasonally prevalent. Discharge from the adjacent watershed governs the hydrology of the channel.

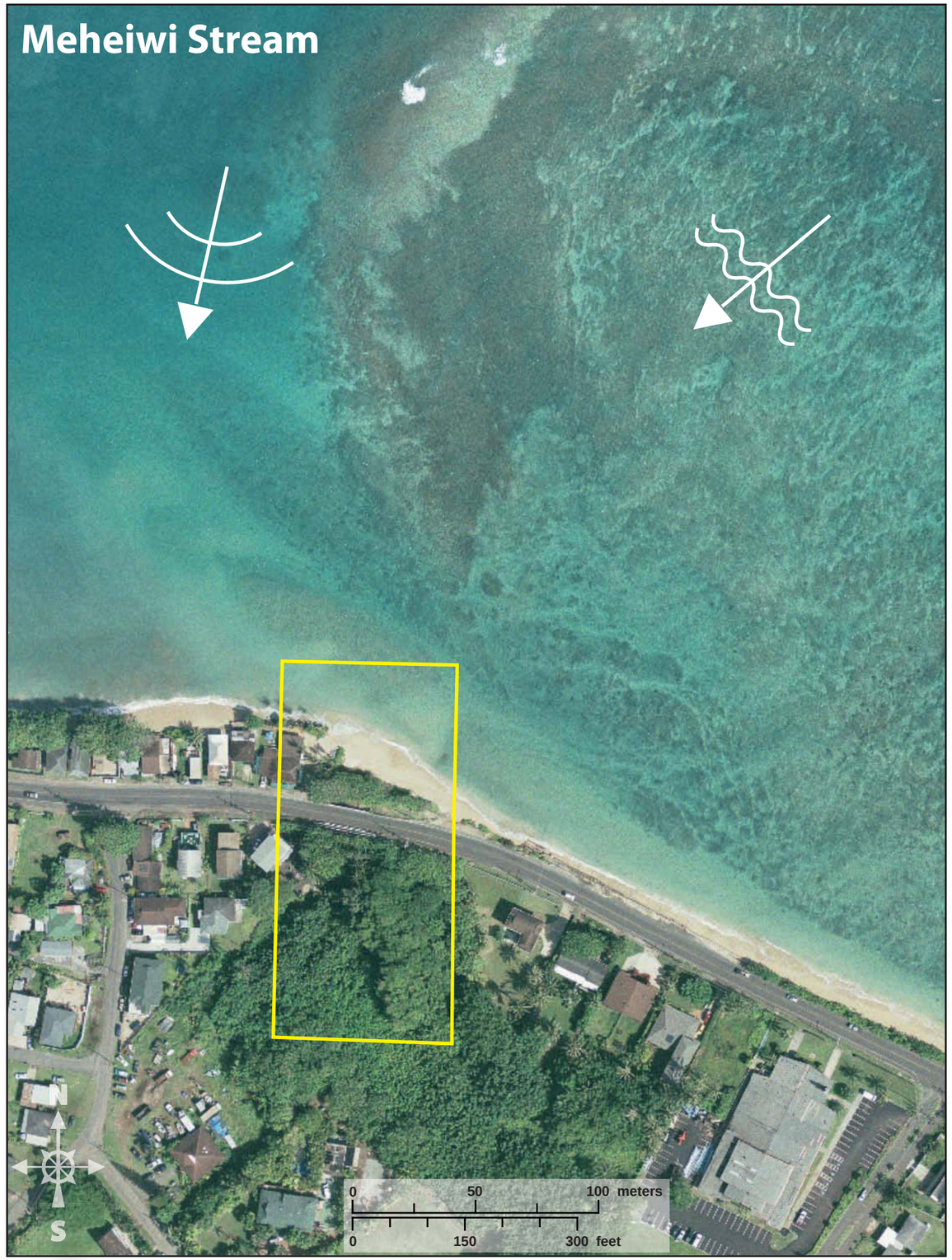


Photo 1. November 30, 2009 looking south from the southern side of the stream mouth.

Photo 2. November 30, 2009 looking north across the stream mouth.

Meheiwi Stream (non-perennial, NDAR_CODE 31033001) This stream is labelled Meheiwi on the bridge but named Makao on the Hawaii Statewide GIS database
Lat. 21.607
Long. -157.906 (stream mouth)

Coastal Processes

Meheiwi Stream mouth is located in Hauula on the east shore of Oahu. The stream empties into the ocean on a primarily fine carbonate sand beach and it is typically blocked by sand. Offshore of the stream mouth is a shallow fringing reef and a deep, sand-filled channel that cuts into the reef. Refracted north swell in the winter, and tradewind-generated waves throughout the year, govern sediment transport along the shoreline.

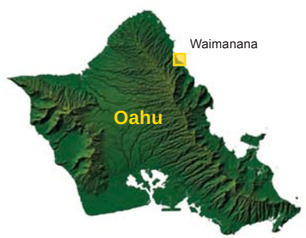
Photo 1. November 30, 2009 looking landward from the bridge.

Photo 2. November 30, 2009 looking North from the Waimanana stream mouth

Waimanana Stream (non-perennial, NDAR_CODE 31034001) This stream mouth is labelled Waimanana Stream on the Bridge but Kapaka Stream on the Hawaii Statewide GIS database
Lat. 21.603
Long. -157.900 (stream mouth)

Coastal Processes

Waimana Stream is located in Hauula on the east shore of Oahu. The stream mouth, approximately 50 to 100 ft wide, is typically blocked by a small accumulation of beach sand. The immediate coastal segment is severely depleted with respect to sand and is characterized by seawalls and revetments protecting homes and the coastal highway. Adjacent to the stream mouth is a CRM and rubble mound jetty located to the north.



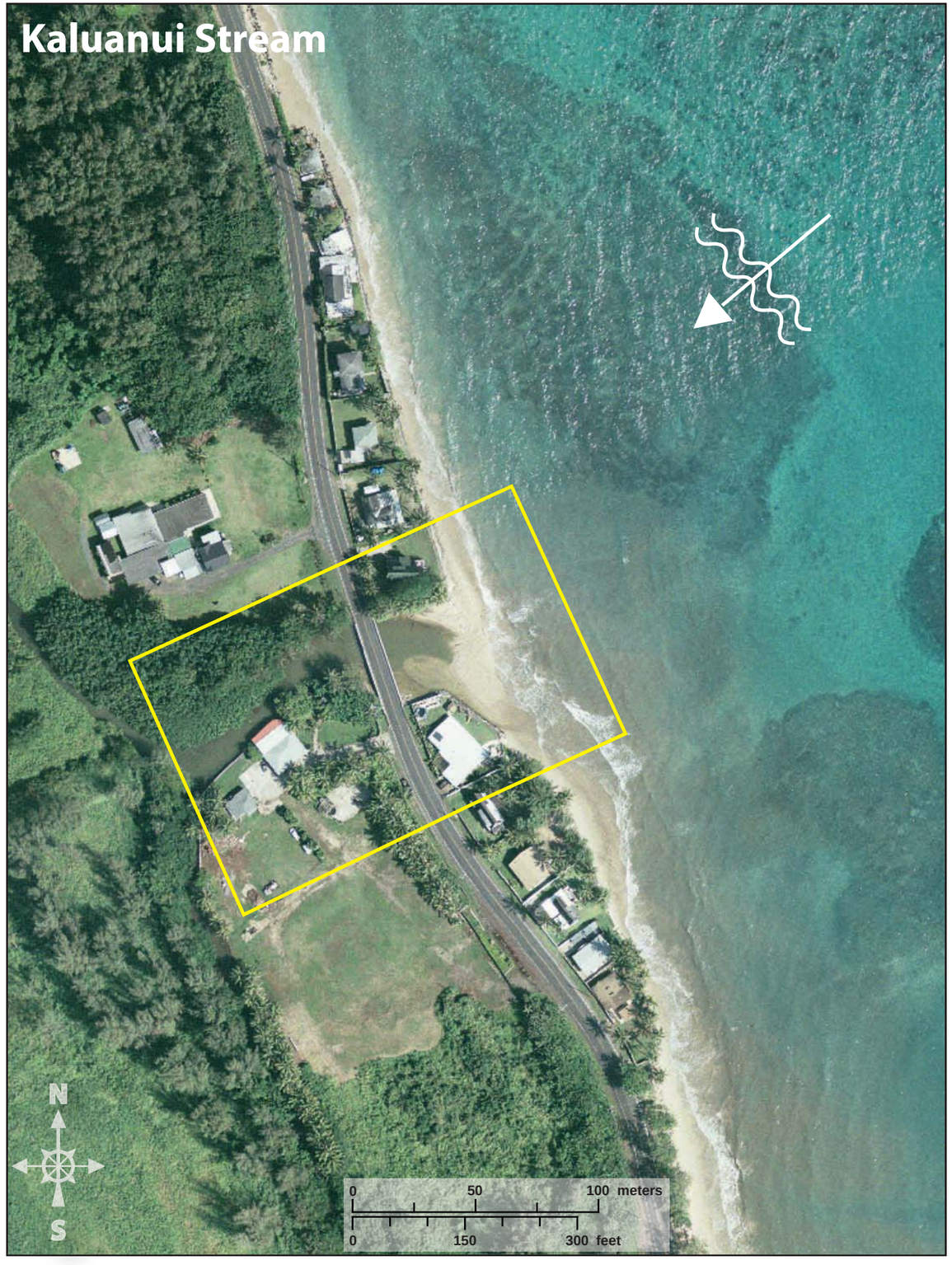


Photo 1. November 30, 2009 looking south from the north side of the bridge.

Photo 2. November 30 2009 looking north across the stream bed.

Kaluanui Stream (non-perennial, NDAR_CODE 31013001)
Lat. 21.598
Long. -157.897 (stream mouth)

Coastal Processes:
Kaluanui Stream mouth is located on the east shore of Oahu in Hauula. The beach in this location is primarily fine to medium carbonate sand with small amounts of terrigenous sediment and gravel sized carbonate debris. The stream mouth is typically blocked by beach sand. Conditions are typical of the windward shoreline of Oahu with consistent onshore winds and generate small short period swell across the reef flat. The stream mouth is approximately 50 to 100 ft wide and the flow fluctuates depending on rainfall in the adjacent watershed.

Photo 1. November 30, 2009 looking north from the stream bed.

Photo 2. November 30, 2009 looking south from stream bed.

Kapano Stream (non-perennial, NDAR_CODE 31037001)
Lat. 21.583
Long. -157.887 (stream mouth)

Coastal Processes

Kapano Stream is located on the east shore of Oahu north of Kahana Bay. The stream is approximately 30 to 75 ft across and is typically blocked by beach sand. Tradewinds regularly blow onshore and from the north at this location. Tradewind swell and refracted seasonal north swell tend to be effectively dissipated by the shallow fringing reef, however at high tide additional energy does impinge onto the beach and transport sand. Small and short period waves are generated by the tradewinds across the fringing reef surface.

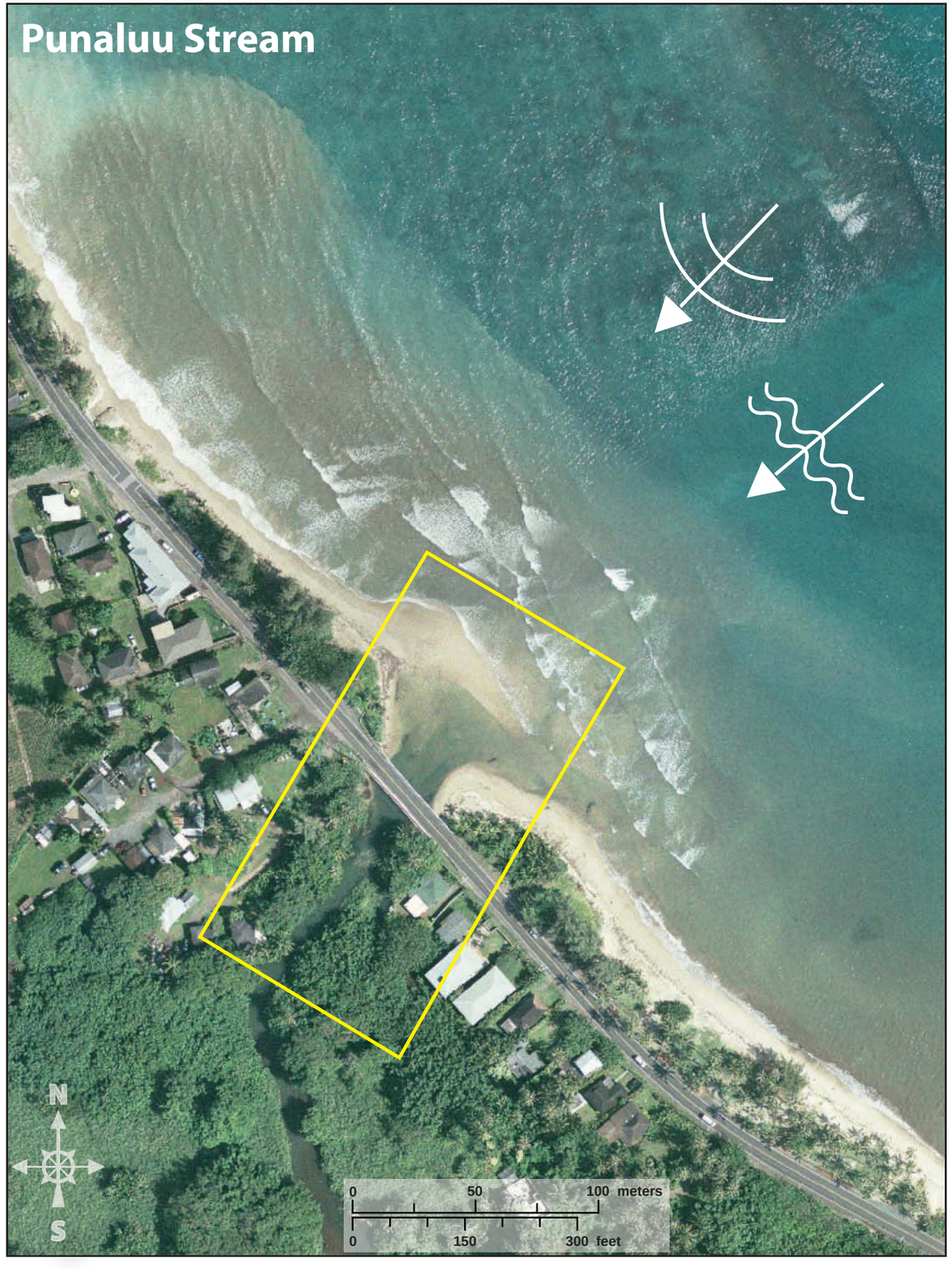


Photo 1. November 30, 2009 looking landward from the bridge.

Photo 2. November 30, 2009 looking east and seaward from bridge.

Punaluu Stream (non-perennial, NDAR_CODE 31016001)
Lat. 21.579
Long. -157.885 (stream mouth)

Coastal Processes

Punaluu Stream mouth is located on the east shore of Oahu. The northern bank extends across the stream mouth as a sandy spit. This will close the channel on occasion depending on discharge from the adjacent watershed. Tradewinds and seasonal refracted north swell approach from directly offshore. The presence of the spit indicates that sediment transport is alongshore from the north.

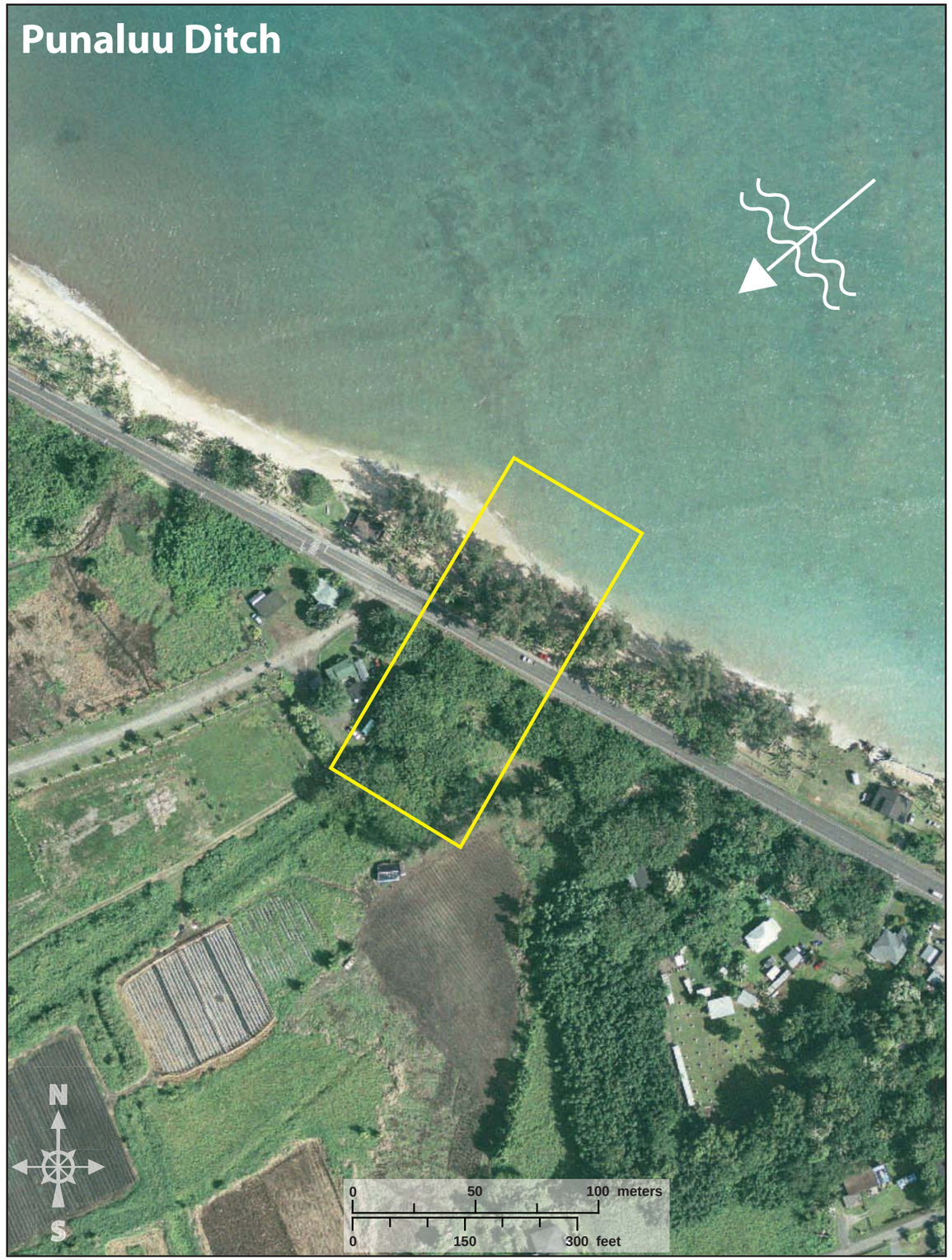


Photo 1. November 30, 2009 looking seaward from the ide of the road.

Photo 2. November 30, 2009 looking seaward and south from the side of the road.

Punaluu Stream (non-perennial, NDAR_CODE 31016047)
Lat. 21.577
Long. -157.881 (stream mouth)

Coastal Processes

Punaluu Ditch is located on the east shore of Oahu. The channel is narrow and flow is intermittent depending on discharge from the adjacent watershed. Typically the channel is blocked by beach sand. Tradewinds and seasonal refracted north swell approach from directly offshore.

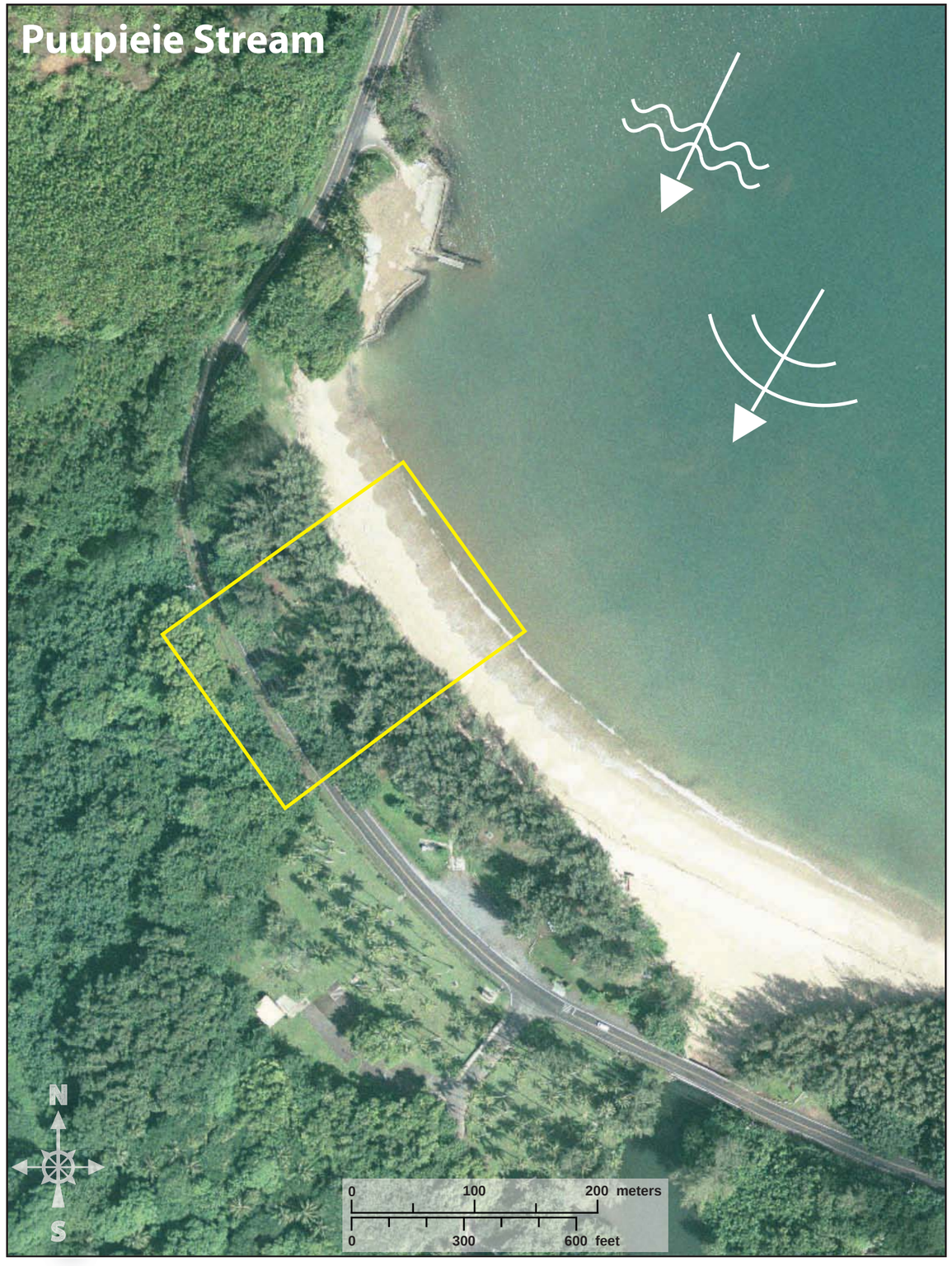


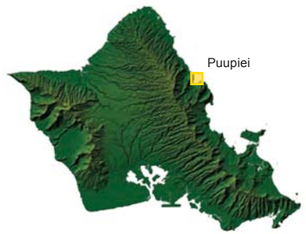
Photo 1. November 30, 2009 Photo of western mouth looking seaward and north out of Kahana Bay

Photo 2. November 30, 2009 looking seaward and down stream

Puupiei Stream (non-perennial, NDAR_CODE 31018004 west mouth)
Lat. 21.557
Long. -157.876 (stream mouth)

Coastal Processes

Puupiei Stream is located in Kahana Bay on the East, windward shoreline of Oahu. The beach in Kahana Bay is primarily medium to fine grained carbonate sand. The beach ranges in width from 35ft to 120ft. Trade winds blow directly onshore at this location and trade wind swell is directly onshore. Offshore in Kahana Bay the bottom is sandy, shallow and gently sloping, dissipating onshore energy as it approaches the beach.



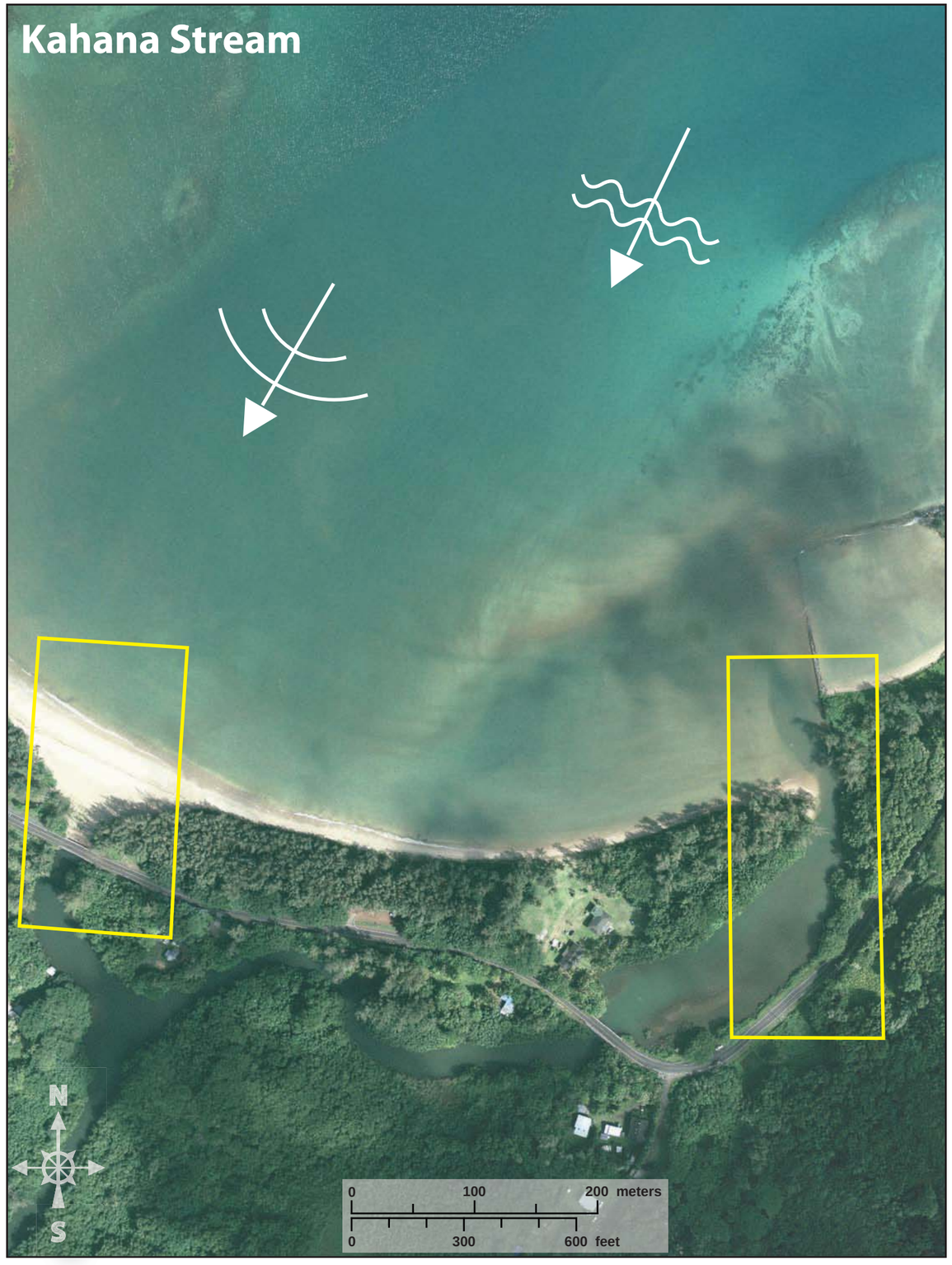


Photo 1. November 30, 2009 photo of the western mouth looking seaward and north out of Kahana Bay.

Photo 2. November 30, 2009 looking Landward under the bridge of the western most outflow of Kahana Stream.

Kahana Stream (non-perennial, NDAR_CODE 31018004 west mouth)
Lat. 21.556
Long. -157.875 (west stream mouth)

Coastal Processes

Kahana Stream is located in Kahana Bay on the east, windward shoreline of Oahu. Kahana Stream divides into two outflows at the shoreline which empty into the bay at central and eastern portions of the shoreline. The central outflow is typically blocked by beach sand, whereas the outflow to the east is often open. The beach in Kahana Bay is primarily medium to fine-grained carbonate sand and ranges in width from 35 to 120 ft. Tradewinds tend to blow onshore or from the northeast at this location. Tradewind and north swell refract into the bay so that they approach from directly offshore. The bottom is sandy, shallow and gently sloping, and tends to dissipate wave energy as it approaches the beach. The bay accretes sand from fringing reefs to the north thus contributing to stream mouth blockage.

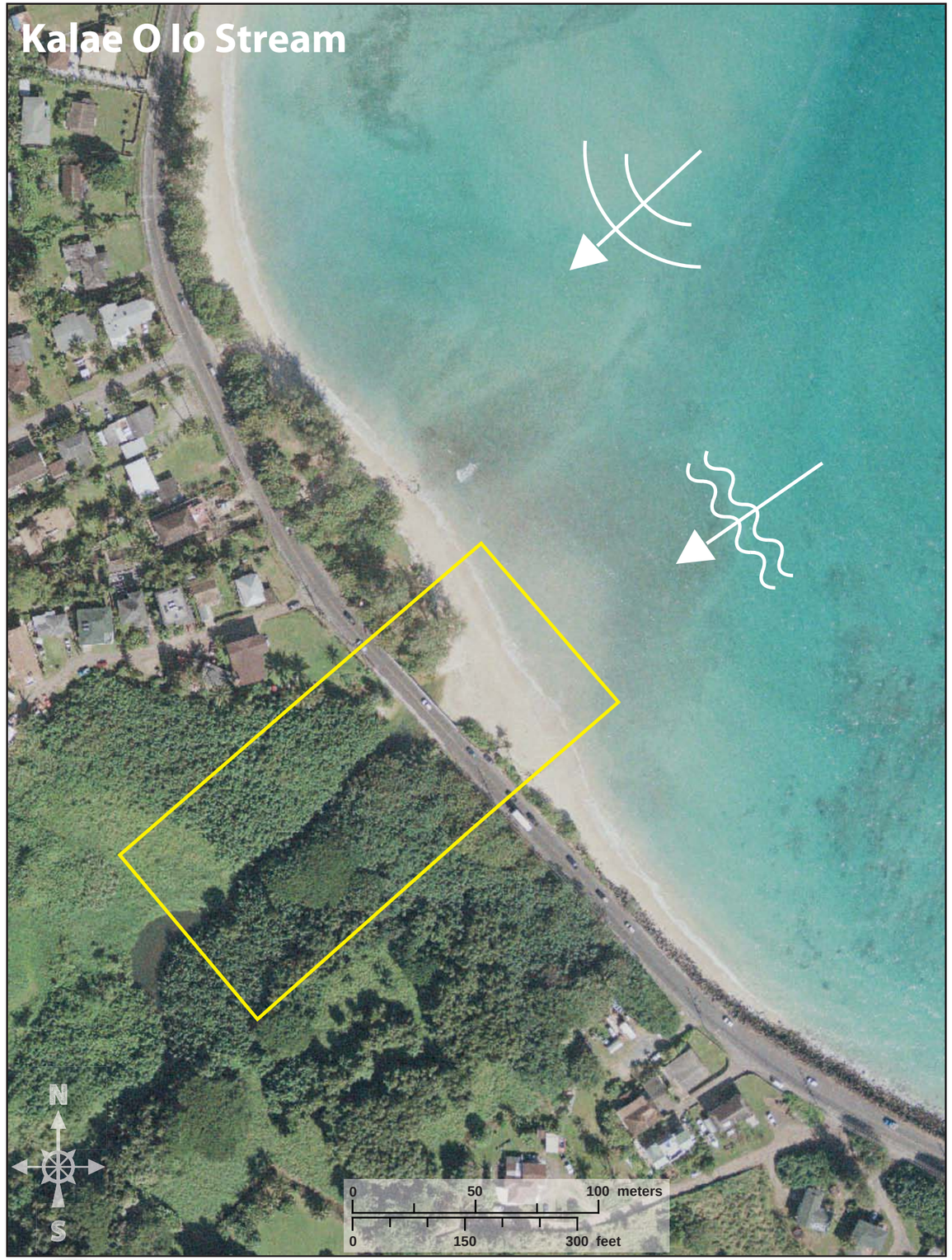


Photo 1. November 30, 2009 looking seaward and south from the north side of the stream mouth.

Photo 2. November 30, 2009 looking landward and south back under the bridge.

Kaaawa Stream (perennial, NDAR_CODE 31019001) This Stream is labelled as Kalae O Io on the bridge and as Kaaawa on the Hawaii Statewide GIS database .
Lat. 21.545
Long. -157.845 (south stream mouth)

Coastal Processes:
Kalae O Io Stream mouth is located on the east shore of Oahu in Kaaawa at Kalae O io Beach Park and is typically blocked by beach sand. The beach at this location is primarily medium-grained carbonate sand with small amounts of terrigenous sediment. Consistent onshore tradewinds and small short period waves are the dominant influence on the coastline. Longshore transport is weakly to the north. Kaaawa Stream mouth is approximately 80 ft wide and the flow fluctuates depending on rainfall in the immediate watershed of Kaaawa Valley.

Photo 1. October 19, 2009 looking down stream from the bridge to the stream mouth.

Photo 2. October 19, 2009 sand from stream mouth clearing.

Kaelepulu Stream: (perennial, NDAR_CODE32014001)
Lat. 21.397
Long. -157.726 (stream mouth)

Coastal Processes:
Kaelepulu Stream mouth is located at the southern end of Kailua Beach on Oahu's windward coast. It is typically blocked by beach sand. This location is characterized by east to northeast tradewinds that blow onshore the majority of the year. Kailua Bay has a broad but relatively deep carbonate reef system characterized by a major sand channel, sand fields, and encrusting coral and carbonate and calcareous algae. This reef system and blocking by Mokapu Peninsula immediately to the north are responsible for dissipating portions of seasonal north swell energy. However, the bay is open to tradewind energy. The stream mouth is also protected by Popoio Island located ~¼ mi offshore. Breaking wave height is typically <2 ft on the shoreline here. Near the stream mouth, Kailua Beach is composed primarily of fine carbonate sand that has undergone severe erosion in recent years. Dominant alongshore transport at the stream mouth is to the north.

Photo 1. October 24, 2009 looking north toward the Waimanalo Stream mouth.

Photo 2. October 24, 2009 aerial image of Waimanalo Stream and Waimanalo Bay.

Waimanalo Stream (non-perennial, NDAR_CODE 32015001)
Lat. 21.365
Long. -157.710 (stream mouth)

Coastal Processes

Waimanalo Stream is located in Waimanalo Bay on the south East shore of Oahu. This beach is composed of fine calcareous sand with no exposed rock except for the engineered jetties on the north and south sides of the stream mouth. This area of coast experiences onshore trade winds and trade wind generated swell. This area is exposed to large NE through E swell events but onshore energy is greatly reduced due to an extensive offshore reef crest.

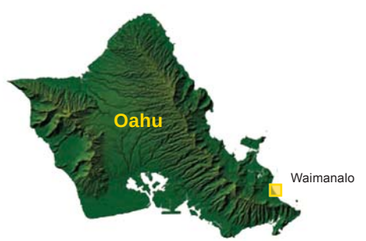


Photo 1. October 24, 2009 aerial image looking at Kahewai stream and Waimanalo Beach.

Photo 2. October 24, 2009 looking down Waimanalo Beach toward Kahewai Stream mouth.

Inoaole Stream (non-perennial, NDAR_CODE 31018004)
Lat. 21.351
Long. -157.706 (stream mouth)

Coastal Processes:
Inoaole Stream mouth is located in the middle of Waimanalo Beach on the eastern shoreline of Oahu. It is typically blocked by beach sand. Waimanalo Beach is composed primarily of fine calcareous sand. The beach ranges in width from 50 to 150 ft. Waimanalo Beach is curved; hence tradewinds blow both alongshore and directly onshore depending on location. At Kahe wai predominate tradewind energy approaches from offshore. Waimanalo Bay ranges in depth from 10 to 25 ft across a wide fringing reef. Thus the energy from large swell events is effectively dissipated and breaking wave heights at the shoreline are rarely more than 3-4 ft.

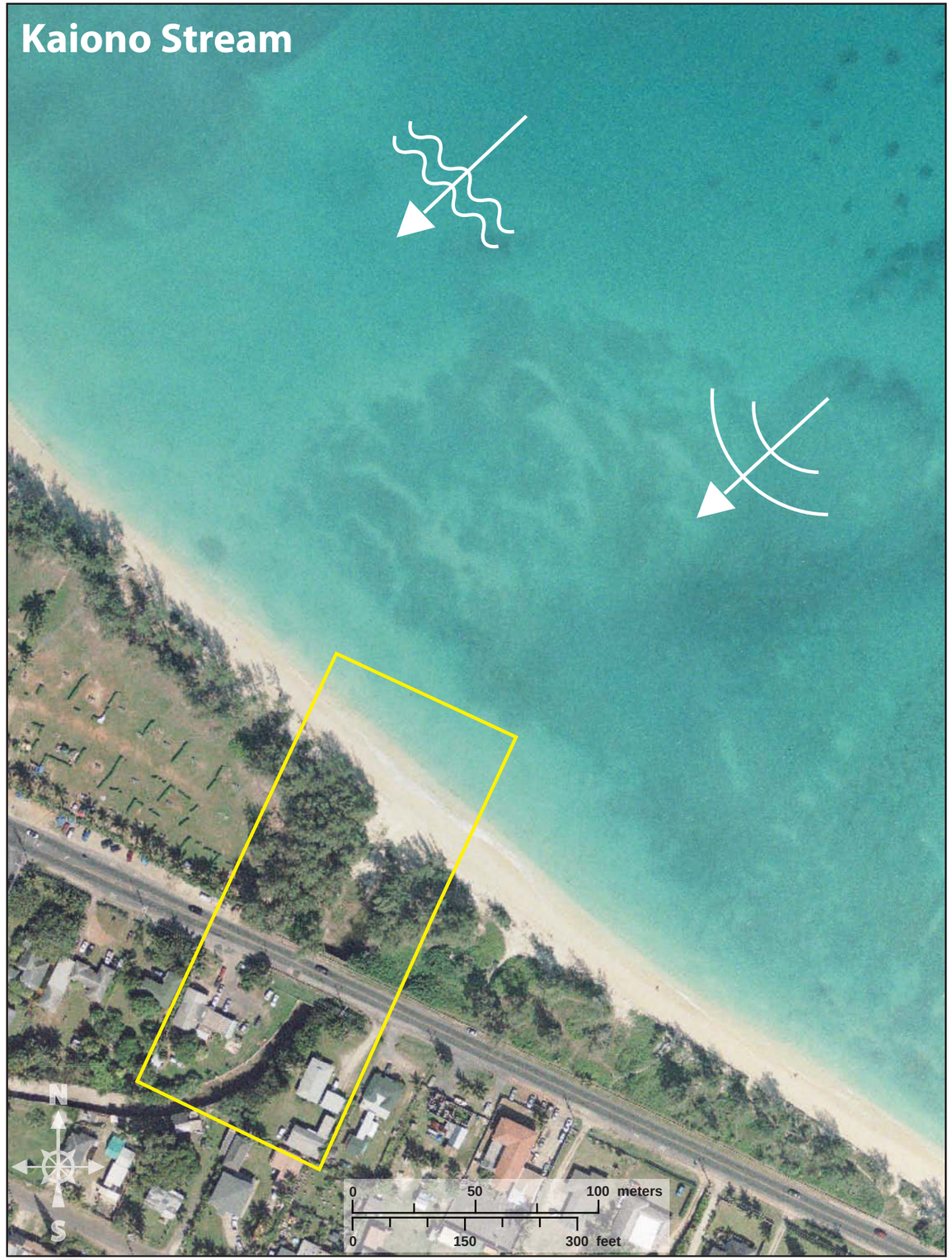


Photo 1. November 30, 2009 looking east toward Waimanalo Beach from the bridge.

Photo 2. November 30, 2009 looking north toward Belows Beach and Lanikai.

Kaiono Stream (non-perennial, NDAR_CODE 32021001)
Lat. 21.330
Long. -157.691 (stream mouth)

Coastal Processes:
Kaiono Stream mouth is located at the southern end of Waimanalo Beach on the eastern shoreline of Oahu and is typically blocked by beach sand. The beach is composed primarily of fine calcareous sand and ranges in width from 50 to 200 ft. Waimanalo Beach is curved; hence tradewinds blow both alongshore and directly onshore depending on location. At Kaiono predominate tradewind energy approaches from offshore. Waimanalo Bay ranges in depth from 10 to 25 ft across a wide fringing reef. Thus the energy from large swell events is effectively dissipated and breaking wave heights at the shoreline are rarely more than 3-4 ft.

Photo 1. October 24, 2009 looking landward toward Kalanianiole Hwy.

Photo 2. October 24, 2009 looking Southwest towards Hawaii Kai back reef.

Kuliouou Stream (perennial, NDAR_CODE 33003001)
Lat. 21.284
Long. -157.722 (stream mouth)

Coastal Processes:
Located in Hawaii Kai at Kuliouou Beach park, Kuliouou stream empties into Maunalua Bay through a channelized segment of the watershed. This area is typically calm as it is sheltered by the Koko Head headland. Tradewinds blow from east to west along the shoreline, though the stream mouth lies largely beyond their reach. A wide and shallow fringing reef creates calm conditions at the stream mouth and sediments are characterized by some carbonate sand mixed with fine terrigenous much from the watershed.

Photo 1. October 24, 2009 looking south out of Pia Stream.

Photo 2. October 24, 2009 looking inland from Pia stream mouth.

Pia Stream (perennial, NDAR_CODE 33004001
Lat. 21.280
Long. -157.738 (stream mouth)

Coastal Processes:
Pia Stream mouth is located between Wailupe Peninsula and Hawaii Kai boat ramp on the southern shoreline of Oahu. The beach is narrow, typically less than 30 ft wide and is often absent at high tide. The beach is primarily carbonate sand with varying amounts of terrigenous sediment. This area of coast is heavily armored with seawalls. A broad fringing reef blocks the majority of swell energy and waters are typically shallow, <4 ft. The stream is channelized and typically blocked with a mixture of sand and mud.

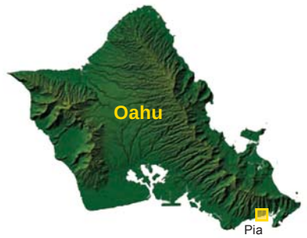


Photo 1. October 24, 2009 looking down stream at the mouth from the bridge.

Photo 2. October 24, 2009 looking at the stream mouth.

Wailupe Stream (Perennial, NDAR_CODE 33005001
Lat. 21.277
Long. -157.750 (stream mouth)

Coastal Processes:
Wailupe Stream mouth is located on the eastern side of Wailupe peninsula on the southern shoreline of Oahu. The beach in this area is narrow, typically less than 30 ft wide and often on absent on high tide. The beach is primarily carbonate sand but also has a varying amount of terrigenous sediment mixed in. This area of coast line also has a large proportionate amount of sea walls. The back reef in Wailupe is extensive, located approximately 900 ft offshore. Backwaters are typically less than 1m in depth. Typical conditions for this area are consistent trade winds and trade wind swell as well as southerly ground swell. The presence of the reef crest protect the shoreline from the majority of the onshore energy. Wailupe stream mouth has hardened banks and is less than 60 ft wide.

Photo 1. October 24, 2009 looking east toward Portlock.

Photo 2. October 24, 2009 looking landward from the Waialae golf course bridge.

Waialae Iki Stream (Non-Perennial, NDAR_CODE 330160001
Lat. 21.272
Long. -157.771 (stream mouth)

Coastal Processes

Waialae Iki Stream mouth is located in Kahala between Black Point and Wailupe Penninsula. This area of coastline is exposed to side onshore trade winds and swell ranging in direction from SE to SW. There is a shallow back reef (<6ft deep) and an extensive and shallow fringing reef that provide the shoreline with protection against onshore energy.

Waialae Iki

Photo 1. October 24, 2009 looking landward toward Kahala Ave.

Photo 2. October 24, 2009 looking southwest toward the Kahala back reef.

Waialae Nui Stream (perennial, NDAR_CODE 33060011) This stream is named Waialae Nui in the Hawaii Statewide GIS database but called Kapakahi Stream by the Department of Facilities and Maintenance
Lat. 21.269
Long. -157.777 (stream mouth)

Coastal Processes:
Waialae Nui Stream mouth is located in Kahala between Black Point and Wailupe Peninsula. This area of coastline is exposed to tradewinds from the east and refracted south swell that is largest in summer months. A shallow fringing reef (<6 ft deep) provides the shoreline with protection against onshore energy although at high tide currents may develop.

Photo 1. October 15, 2009 looking landward down the stream bed from the beach toe.

Photo 2. October 15, 2009 looking West towards Diamond Head from the east side of the stream mouth

Kahala Stream (non-perennial, NDAR_CODE 33017001) This stream is named Kahala in the Hawaii Statwide GIS database but called Waialae stream by the Department of Facilities and Maintenance
Lat. 21.267
Long. -157.779 (stream mouth)

Coastal Processes

Kahala Stream mouth is located several hundred feet west of Waialae Beach Park in Kahala on Oahu's southern shoreline. Kahala Stream empties onto a shallow reef flat in water typically <4 ft deep. Southern swell and tradewind swell are common at this location, but due to the fringing reef much of the energy is dissipated offshore at low tide. However, along-shore currents can be strong during southern swell at high tide. Tradewinds in this area typically blow onshore or from the northeast.

Journal of Coastal Research, v. 19.4, p. 1026-1043.

41. Moberly, R. (1963) Coastal Geology of Hawaii. Hawaii Institute of Geophysics Report No. 41. Prepared for Department of Planning and Development, State of Hawaii, under Contract No. 6031.

42. Moberly, R., and Chamberlain, T. (1964) Hawaiian Beach Systems. Hawaii Institute of Geophysics Report HIG-64-2. Prepared for Harbors Division, Department of Transportation, State of Hawaii.

43. Moberley, R. (1968) Loss of Hawaiian littoral sand. Journal of Sedimentary Petrology, v. 38, no. 1, p. 17-34.

44. Moberly, R., Campbell, J.F., and Coulbourn, W.T. (1975) Offshore and other sand resources for Hawaii. Sea Grant Technical Paper, UNIHI-SEAGRANT-TR-75-03. The University of Hawaii Sea Grant Program, Honolulu, HI.

45. Noda, Edward K. (1991) Sand Source Investigations for Waikiki Beach Fill, Waikiki Beach Improvement Project. Prepared for State of Hawaii Department of Transportation Harbors Division. Report No. EKN-1201-R-4-1. Honolulu HI.

46. Norcross, Z.M., Fletcher, C.H., and Merrifield, M. (2002) Annual and interannual changes on a reef-fringed pocket beach: Kailua Bay, Hawaii. Marine Geology 190, p. 553-580.

47. Norcross, Z., Fletcher, C.H., Rooney, J.J.R., Eversole, D., and Miller, T.L. (2003) Hawaiian beaches dominated by longshore transport. Proceedings, Coastal Sediments '03, Clearwater, Florida, May 18-23, 2003.

48. Sea Engineering, Inc. (1993) Beach Nourishment Viability Study. Prepared for Office of State Planning Coastal Zone Management Program. SEI Report 92-26.

49. Sea Engineering, Inc. (2008) Lanikai Beach Restoration Study Conceptual Design Report. Prepared for the U.S. Army Corps of Engineers, Honolulu District.

50. Sea Engineering, Inc. (2008) Waikiki Beach War Memorial Natatorium Honolulu, Hawaii: Shoreline restoration study conceptual design review report. Prepared for the U.S. Army Corps of Engineers, Honolulu District.

51. Sea Engineering, Inc. and Precision Signal Inc. (1995) Development of a broadband FM subbottom profiler for seafloor imaging and sediment classification. Prepared for the National Defense Center of Excellence for Research in Ocean Science (CEROS).

52. Stahl, M.S. (1976) Hawaiian sand resources recommendation memo. University of Hawaii Pacific Urban Studies and Planning Program, Coastal Zone Management Program.

53. Stearns, H.T. (1935) Pleistocene shorelines on the islands of Oahu and Maui, Hawaii. Geological Society of America Bulletin, v. 46, p. 1927-1956.

54. Wiegel, R.L. (2008) Waikiki Beach, Oahu, Hawaii: History of its transformation from a natural to an urban shore. Shore & Beach, Vol. 76, No. 2.

v. 17, p. 215-234.

15. Coulbourn, W.T., Campbell, J.F., Anderson, P.N., Daugherty, P.M., Greenberg, V.A., Izuka, S.K., Lauritzen, R.A., Tsutsui, B.O., and Yan, C. (1988) Sand deposits offshore Oahu. Hawaii. Pacific Science, v. 42, p. 267-299.

16. Cox, D. C. (1978) Hawaii Coastal Zone Management Program technical supplement 12: Notes on Hawaiian sand beach management. Prepared for the State of Hawaii Department of Planning and Economic Development by the University of Hawaii Pacific Urban Studies and Planning Program.

17. Cruickshank, Michael J. (1991). Analysis of Options and Recommendations for the Recovery, Beneficiation and Transportation of Sand from Selected Offshore Deposits for Replenishment of Waikiki Beach. Consultants Report. Honolulu HI.

18. Dollar, S.J. (1979) Sand mining in Hawaii: research, restrictions, and choices for the future. Sea Grant Technical Paper, UNIHI-SEAGRANT-TP-79-01, The University of Hawaii Sea Grant Program, Honolulu, HI, 106 p.

19. Engels, M.S., Fletcher, C.H., Field, M., Conger, C.L., Bochicchio, C. (2008) Demise of reef-flat carbonate accumulation with late Holocene sea-level fall: evidence from Molokai, Hawaii. Coral Reefs.

20. Ericksen, M.C., Barry, J.H., and Schock, S.G. (1997) Sub-bottom imaging of the Hawaiian shelf. Sea Technology, June 1997, p. 89-92.

21. Eversole, D. and Fletcher, C.H. (2003) Longshore sediment transport rates on a reef-fronted beach: Field data and empirical models, Kaanapali Beach, Hawaii: Journal of Coastal Research, v. 19, p. 649-663.

22. Eversole, D. 2004. Results from Current Study Research (September 2004) Nearshore Kuhio Beach, Oahu. State of Hawaii, Department of Land and Natural Resources. http://www6.hawaii.gov/dlnr/occl/files/waikiki/results.pdf

23. Fletcher, C.H. and Sherman, C. (1995) Submerged shorelines on Oahu, Hawaii: Archive of episodic transgression during the deglaciation? Journal Coastal Research, Special Issue 17 Holocene Cycles: Climate, Sea Level, and Sediment, p. 141-152.

24. Fletcher, C.H., Murray-Wallace, C., Glenn, C., Popp, B., Sherman, C. (2005) Age and origin of late quaternary eolianite, Kaiehu Point (Moomomi), Molokai, Hawaii. Journal of Coastal Research, SI 42, p. 97-112.

25. Fletcher, C.H., Grossman, E.E., Richmond, B.M., Gibbs, A.E. (2002) Atlas of natural hazards in the Hawaiian coastal zone. U.S. Geological Survey, Denver, CO, Geologic Investigations Series I-2761, 182p. http://geopubs.wr.usgs.gov/i-map/i2761/

26. Fletcher, C.H., Bochicchio, C., Conger, C.L., Engels, M., Feirstein, E.J., Grossman, Grigg, R., E.E., Harney, J.N., Rooney, J.J., Sherman, C.E., Vitousek, S., Rubin, K., Murray-Wallace, C.V. (2008) Geology of Hawaii Reefs. Chapter 11 in “Coral Reefs of the U.S.A.”, Springer, p. 435-488.

27. Fletcher, C.H. and E.J. Feirstein (2009) Hawaii. Chapter 1.16 in The World's Coastal Landforms, Bird, E.C.F. (Ed.), Springer-Verlag, Heidelberg.

28. Fletcher, C.H. (2009) Sea level by the end of the 21st century: A review. Shore and Beach, v. 77, no. 4, pp. 1-9.

29. Gerritsen, F. (1978) Beach and surf parameters in Hawaii. University of Hawaii Sea Grant College Program Technical Report UNIHI-SEAGRANT-TR-78-02.

30. Gibbs, A.E., Richmond, B.M., Fletcher, C.H., and Hillman, K.P., 2001, Hawaii beach monitoring program: beach profile data. U.S. Geological Survey Open-File Report 01-308, CD. (See also: http://geopubs.wr.usgs.gov/open-file/of01-308)

31. Hampton, M.A., Fletcher, C.H., Barry, J.H., and Lemmo, S.J. (2002) The Halekulani sand channel and Makua shelf sediment deposits: Are they a sand resource for replenishing Waikiki's beaches? In: Robbins, L.L., Magoon, O.T., and Ewing, L. (eds.), Carbonate Beaches 2000: First International symposium on Carbonate Sand Beaches, Reston, VA, American Society of Civil Engineers, p. 67-81.

32. Hampton, M.A., Blay, C.T., Murray, C., Torresan, L.Z., Frazee, C.S., Richmond, B.M., Fletcher, C.H. (2003) DATA REPORT: Geology of Reef-Front Carbonate Sediment Deposits around Oahu, Hawaii, OFR 03-441, U.S. Geological Survey Open File Report. See at: http://walrus.wr.usgs.gov/reports/ofr03-441.html

33. Harney, J.N., Hallock-Muller, P., Fletcher, C.H., Resig, J.M., and Richmond, B.M. (1999) Standing crop and sediment production of reef-dwelling foraminifera on Oahu, Hawaii. Pacific Science, v. 53, no. 1, p. 61-73.

34. Harney, J.N., and Fletcher, C.H. (2003) A budget of carbonate framework and sediment production, Kailua Bay, Oahu, Hawaii. Journal of Sedimentary Research, v. 73, no. 6, p. 856-868.

35. Harney, J.N. and Fletcher, C.H. (2003) Modeling biogenic sediment production on carbonate coasts. Coastal Sediments ’03.

36. Harney, J.N., Grossman, E.E., Richmond, B.M., and Fletcher, C.H. (2000) Age and composition of carbonate shoreface sediments, Kailua Bay, Oahu, Hawaii: Coral Reefs, v. 19, pg. 141-154.

37. Hwang, D.J. and Fletcher, C.H. (June 1992). Beach management plan with beach management districts. Report prepared for Hawaii Coastal Zone Management Program, Office of State Planning, and Office of the Governor.

38. Isoun, E., Fletcher, C.H., Frazer, N., and Gradie, J. (2003) Multi-spectral mapping of reef bathymetry and coral cover; Kailua Bay, Hawaii. Coral Reefs, v. 22, p. 68-82.

39. Marine Advisors, Inc. (1968) Sand survey at Waikiki and the Honolulu Harbor entrance, Oahu. Prepared for the State of Hawaii Department of Transportation, Harbors Division.

40. Miller, T.L. and Fletcher, C.H. (2003) Waikiki: Historical analysis of an engineered shoreline.

Monty Hampton with the U.S. Geological Survey conducted offshore sand body research for several years in the late 1990's and early 2000's. His Open File Report No. 03-441 (Hampton et al., 2003) provides original research on sand fields using sub bottom geophysical data and vibra-cores. The report includes photographs of cores and places emphasis on the need for sand resources to maintain Waikiki Beach – this is a valuable reference that can be accessed here: http://walrus.wr.usgs.gov/reports/ofr03-441.html; last viewed 12/17/09. This research provides seismic data and cores from fields around the entire island of Oahu.

Since Hampton et al, remote sensing and jet-probing have been employed to assess reef-top sand fields. An analysis of reef-top sand field resources at Waikiki, performed for the Hawaii State Department of Land and Natural Resources, was conducted by the University of Hawaii Coastal Geology Group. The data are provided in map form in this report. This data informed the decision-making with regard to the Kuhio Beach renourishment project (Eversole, 2004). Similar (though more extensive) work was published by Bochicchio et al (2009) for the windward region of Kailua, Lanikai, and Waimanalo. They probed over 200 sand fields to assemble a comprehensive database of reef-top sand resources. Another unpublished probing effort was performed on Maui where a dozen fields were probed along the West Maui coast between Napili Bay and Kaanapali.

This report builds on the work of Conger et al (in press) by extending the remote sensing identifi-cation of reef-top sand fields on the Oahu south shore between Ewa and Black Point. The map of these sand resources is provided herein. Additional work has been performed under commercial contract, largely with the Waimanalo company Sea Engineering, Inc. but this information is not publically available.

In general, offshore sand resources are found to be thin and generally unsuitable for large-scale nourishment projects. However, there are exceptions: a large field of thick coarse carbonate sand in 40 ft of water offshore of West Maui has been identified; a large field of carbonate sand in 60-110 ft of water offshore of the Honolulu Airport is described in Barry (1995); Barry also reports that the Penguin Bank plateau holds viable deposits (though Whale Sanctuary status and heavy fishing use likely prevent mining this area); and a moderate field of thick carbonate sand in 40 ft of water between Lanikai and Waimanalo is described in Bochicchio et al (2009). Additionally, it has been reported that Sea Engineering is using the Halekulani sand channel in Waikiki as a resource for nourishing Greys Beach, Waikiki with approximately 15,000 yd^3 of sand.

Future Needs

Several recommendations emerge from this review:

1. Given the continued need to nourish Waikiki, research to identify sand resources in waters fronting the fringing reef there (in depths of 15 to 80 ft) would be justified.
2. The "Reef Runway" sand field fronting the Honolulu airport has been identified as a potential resource. Further work assessing this location and sand quality is justified.
3. Offshore sand assessment for fields on the leeward coast (pending the analysis in Hampton et al), and Maunalua Bay are justified as these locations are proximal to Waikiki.
4. Sand needs on Maui are significant. Further assessment is justified at West Maui and the north shore.
5. Sand fields deemed viable as a beach resource using preliminary tactics (i.e., diver surface samples, jet probing) will need vibracore analysis to confirm the character of the deposit.

Sand Reports

1. Barry, J.H., Jr. (1995) Characterization of sand deposits on the insular shelf of southern Oahu, off western Molokai, and on Penguin Bank. SOEST Technical Report 95-02, Hawaii Natural Energy Institute, Marine Minerals Technology Center, Honolulu, HI, 128 p.

2. Bochicchio, C., Fletcher, C.H., Dyer, M., Smith, T. (2009) Reef-top sediment bodies: Windward Oahu, Hawaii. Pacific Science, vol. 63, no. 1:61-82.

3. Bodge, K. (2003) Design Aspects of Groins and Jetties. Advances in Coastal Structure Design, ASCE, p. 181-199.

4. Bodge, K. (2000) Independent Evaluation Study of the Proposed Kuhio Beach Improvements. Olsen Associates, Inc., Jacksonville, FL.

5. Bodge, K. (1998) Beach Fill Stabilization with Tuned Structures: Experience in the Southeastern U.S.A. and Caribbean. Proc. Coastlines, Structures, and Breakwaters '98. Thomas Telford Publishing, London, p. 82-93.

6. Calhoun, R.S., Fletcher, C.H., and Harney, J.N. (2002) A budget of marine and terrigenous sediments, Hanalei Bay, Kauai, Hawaiian Islands. Sedimentary Geology, 150, 1-2, 61-87.

7. Calhoun, R.S., and Fletcher, C.H. (1999) Measured and predicted sediment yield from a subtropical, heavy rainfall, steep-sided river basin: Hanalei, Kauai. Geomorphology, v. 30, p. 213-226.

8. Calhoun, R.S., Fletcher, C.H. (1996) Late Holocene coastal-plain stratigraphy and sea level history at Hanalei, Kauai, Hawaiian Islands. Quaternary Research. 45, p. 47-58.

9. Chamberlain, T. (1968) The littoral sand budget, Hawaiian Islands. Pacific Science, v. 22, no. 2, p. 161-183.

10. Chave, K.E., Tait, R.J. , Stimson, J.S., and Chave, E.H. (1973). Waikiki Beach Erosion Project: Marine Environment Study. Hawaii Institute of Geophysics, University of Hawaii, Report No. HIG-73-12. Prepared for the U.S. Army Corps of Engineers.

11. Conger, C.L., Fletcher, C.H., Hochberg, E.J., Frazer, N., Rooney, J.J., (in press). Remote sensing of sand distribution patterns across an insular shelf: Oahu, Hawaii. Marine Geology.

12. Conger, Christopher L., Eric J. Hochberg, Charles H. Fletcher, III, and Marlin J. Atkinson (2006) A new method of decorrelating remote sensing color bands from bathymetry in optically shallow waters. IEEE Transactions on Geoscience and Remote Sensing. 44(6): 1655-1660

13. Conger, C.L., Fletcher, C.H., Barbee, M., (2005) Artificial neural network classification of sand in all visible submarine and subaerial regions of a digital image. Journal of Coastal Research, 21.6, p. 1173-1177.

14. Coulbourn, W.T., Campbell, J.F., and Moberly, R., Jr., 1974, Hawaiian submarine terraces, canyons, and Quaternary history evaluated by seismic-reflection profiling. Marine Geology,

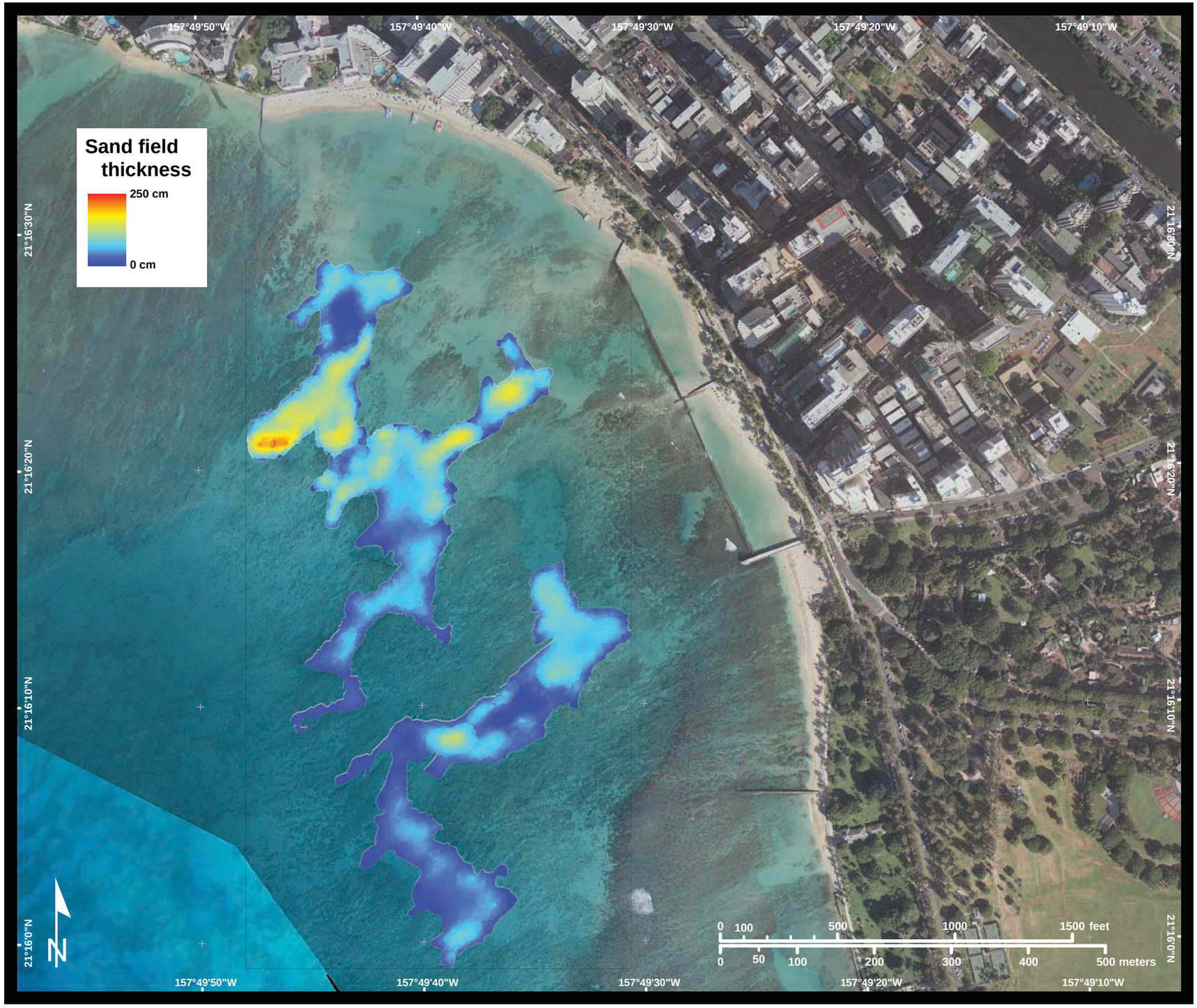


Figure 6 Jet probing of sand bodies in Waikiki reveals sand thickness from which sand body volumes may be calculated.

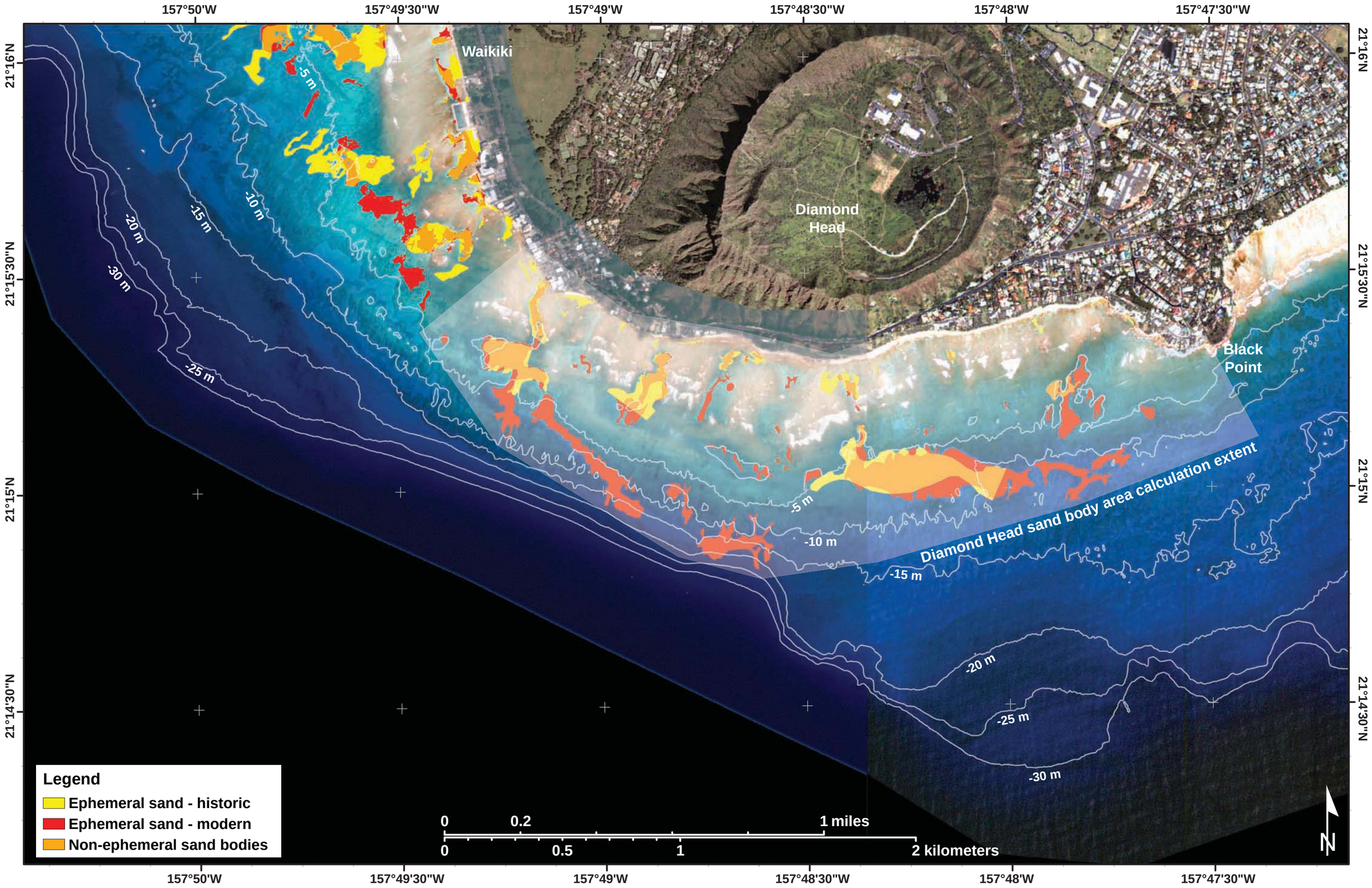


Figure 5 Diamond Head reeftop sand resources. Results indicate approximately 87,000 m^2 of non-ephemeral sand within the Diamond Head sand body area calculation extent (light shaded area).

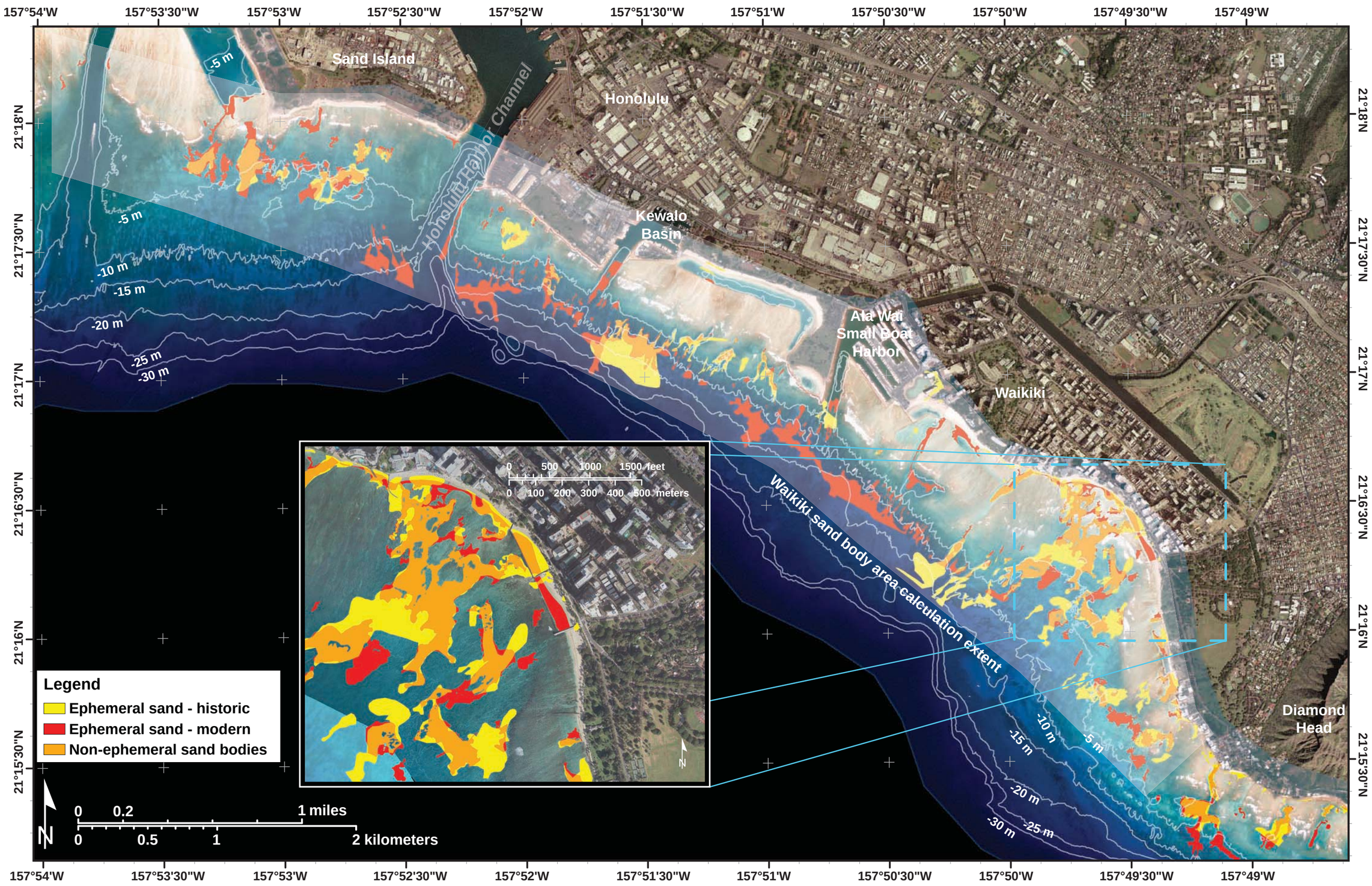


Figure 4 Waikiki reeftop sand resources. Results indicate approximately 490,000 m^2 of non-ephemeral sand within the Waikiki sand body area calculation extent (light shaded area).

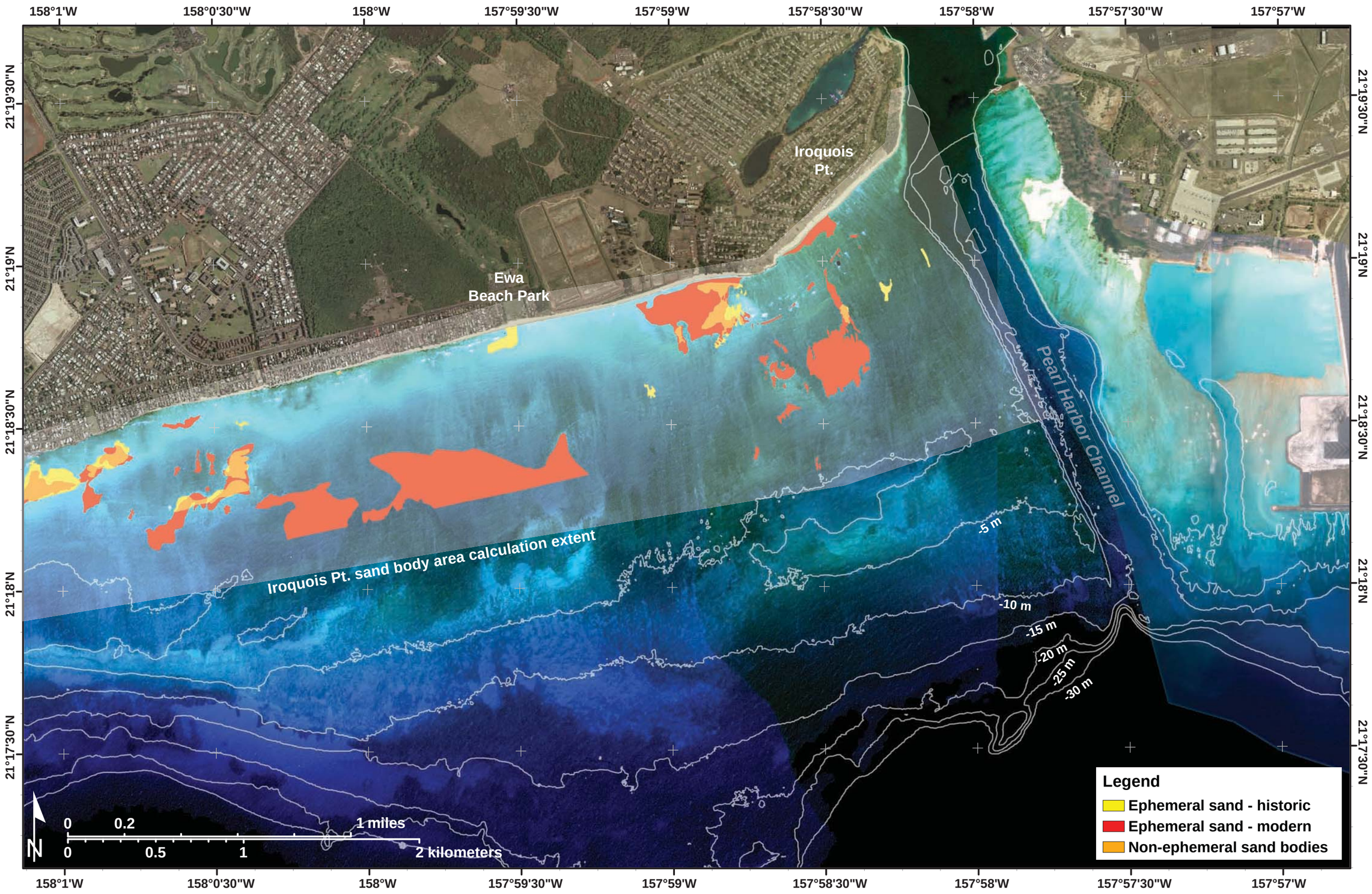


Figure 3 Iroquois Pt. reeftop sand resources. Results indicate approximately 100,000 m^2 of non-ephemeral sand within the Iroquois Pt. sand body area calculation extent (light shaded area).

Reeftop Sand Body Analysis

Coastal high-resolution (0.5 m) ortho-photomosaics were selected as base maps to examine nearshore submarine sand fields. Changes in the extent of these sand bodies over time help differentiate ephemeral and non-ephemeral sand volumes that may indicate potential sand resources. A selection criterion for mosaic use was based on the date of the mosaicked photo base maps, and the quality of the water surface and water column properties for imaging the seafloor. Five years of orthophotomosaic coverage were identified for this study; four of these years constitute “historic” coverage while one year is used to delineate modern sand extent. Changes in sand surface area between historic and modern images are used to represent “ephemeral” vs “non-ephemeral” sand bodies.

Mosaics from 1949, 1950, 1967, and 1970 were selected as base maps to quantify historical sand body extent. Mosaic coverage from 2005 was chosen for the modern base map. All imagery was processed to map quality with Root Mean Square Error of < 2 m. Continuous sand bodies visible in each mosaic were manually digitized using ArcMap. ArcToolbox was used to extract the overlapping spatial extent of modern and historical sand body data; these provide sand body surface areas. The extent of mosaic coverage varies both within historical mosaic years and between historical and modern coverage. Historic coverage is compiled to approximate modern coverage bounds.

Sandy area that is unchanging between historical and modern datasets is inferred to represent relatively stable, ‘non-ephemeral’ areas of sand that may be of potentially significant volume. Sandy area with no spatial overlap indicates sand that has been transported within the past 50 years (the temporal extent of map coverage) and is not likely to be of sufficient thickness for use as a resource because it is ephemeral.

Water column clarity in portions of the historical mosaics varies significantly. Visual analysis of image data and bathymetry yielded a good correlation between depth and clarity (i.e. light attenuation through water increases with depth) except where surface glint (water surface reflectance) and suspended sediments in shallower water (< -5 m depth) obscure potential sandy substrate identification. These two sources of uncertainty affected sand body identification offshore of Ewa Beach Park to the west of Pearl Harbor Channel (see Figure 2). Modern coverage in these areas indicates significant sand (~350,000 m^2). However, no apparent bottom is visible in historic imagery due to large amounts of suspended sediment.

Sand body analysis of the south shore of Oahu between Ewa Beach and Black Point indicates approximately 680,000 m^2 of non-ephemeral sand. The Iroquois Pt. portion of the study area (Figure 3) between Pearl Harbor Channel and Ewa Beach contains approximately 100,000 m^2 of stable sand. The near-shore area is characterized by shallow (< -5 m) reef flat within the extents of available base map data. The water in this area is turbid with suspended sediments obscuring positive bottom identification in many of the historical base maps. Stable sand bodies are located within ~600 m of shore towards the east and west sections of the area near hard shoreline structures.

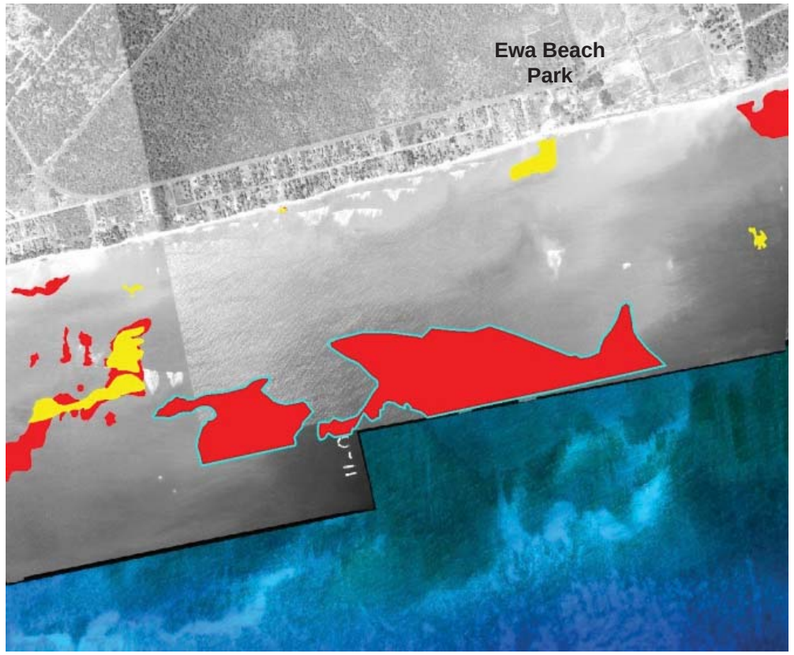


Figure 2 Modern sand bodies (red) and historic sand bodies (yellow); two modern sand bodies (red outlined with blue) are not visible in historic imagery (used as the base photo here). This is likely due to significant suspended sediment in the shallow water.

The central portion of the study area between the airport runway and Diamond Head (Figure 4) contains approximately 490,000 m^2 of apparently stable sand. The nearshore area is characterized by reef and hard bottom interspersed with sand pockets and fields in 0 - 15 m water depth. The remaining section of the study area between Black Point and Diamond Head (Figure 5) contains approximately 87,000 m^2 of apparently stable sand. The majority of this sand (75,000 m^2) is a single sand body between 5 and 10 m water depth.

Jet Probing

Reef-top sand resources at Waikiki were investigated using a “jet probe.” Sediment thickness measurements (Figure 6) were obtained with a jet probe deployed from a small boat and operated by a researcher using SCUBA. The jet probe is built from a small diameter pipe connected to a shipboard water pump via fire hose. High-pressure water is pumped out of the pipe to displace sediment as the diver pushes it into sandy substrate. A volume of sediment is washed out of the hole by water pressure (called ‘‘outwash’’) affording observations of buried sediment texture, composition, and color. The probe stops penetrating when it contacts a boundary with bedrock or an impenetrable layer of consolidated sediment. Depth of penetration provides a measure of unconsolidated sediment thickness. The probe length is 3.0 m; if sand body thickness exceeds 3.0 m, a value of 3.1 m is recorded. Among reef-top sand bodies, few fields exceed the 3.0 m length of the probe. These sand bodies could be considerably thicker; hence all thickness interpolation labeled as 3.0 m and should be considered a minimum estimate. At each sample location three thickness measurements were taken within a 20 m radius of the anchored boat and the average is reported as the thickness at the site (see Bochicchio et al., 2009 for volume calculation methods).

Sand Body Research

The State of Hawaii and the island of Oahu (in particular), have a long history of offshore sand research. The primary references describing this work are Dollar (1979), who summarizes the early work, and Barry (1995) and Sea Engineering (1993) who update the summary to 1995. Sea Engineering (1993) also includes an analysis of sand samples from certain offshore sand fields.

(Continued on p. 6)

South Oahu Reeftop Sand Bodies

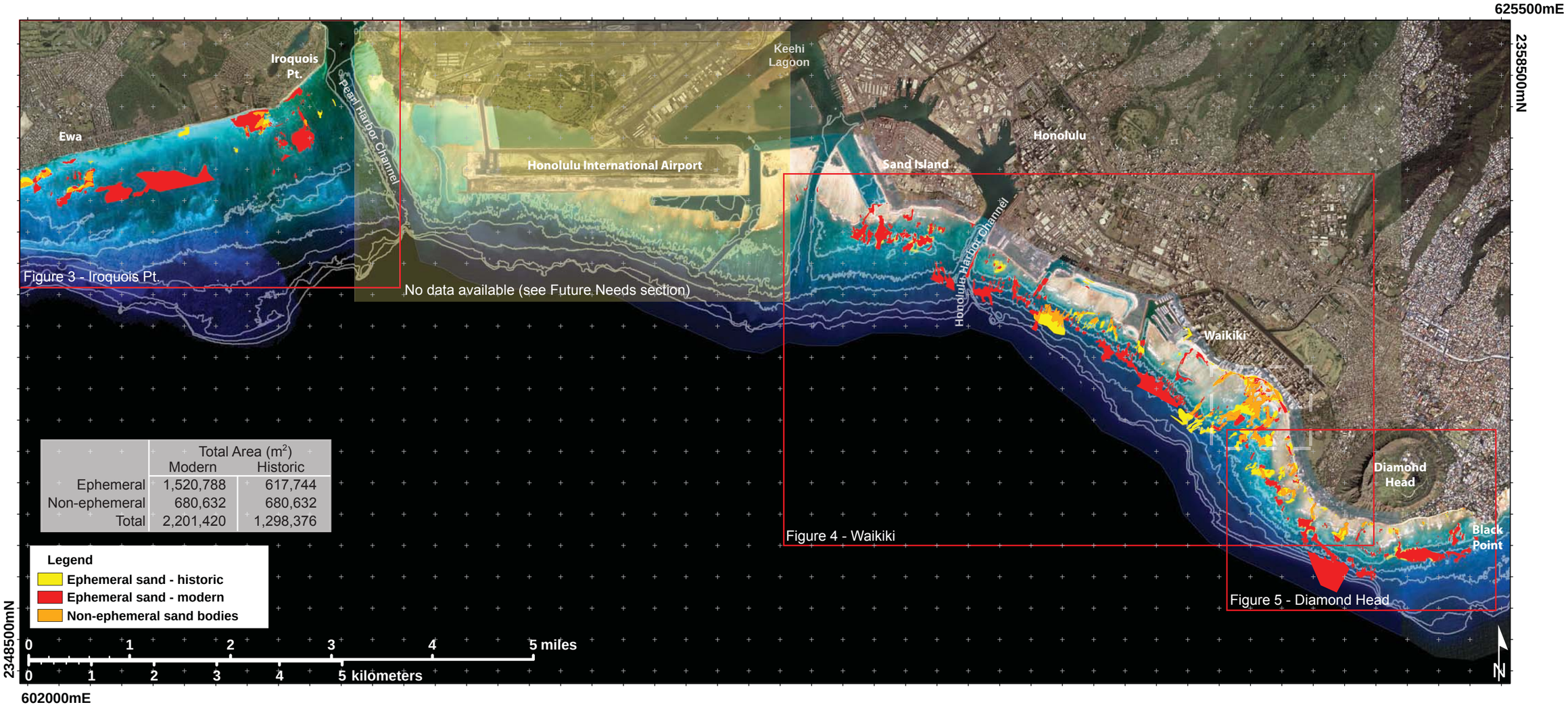


Figure 1 Digitized modern sand bodies (red) and historic (yellow) with intersecting (presumed non-ephemeral) bodies in orange. Base map is a 2005 Quickbird satellite image mosaic.

US Army Corps of Engineers ®

United States Army Corps of Engineers, Honolulu Engineering District
Department of Land and Natural Resources, Office of Conservation and Coastal Lands
University of Hawaii at Manoa, School of Ocean and Earth Science and Technology

January 2010