APPENDIX A

LITERATURE SEARCH / ANNOTATED BIBLIOGRAPHY

Documents Reviewed in Support of this RSM Plan

Winds, Waves, Tides, and Currents

Hearn, C.J. 1999. Wave-breaking hydrodynamics within coral reef systems and the effect of changing relative sea level. Journal of Geophysical Research, 104 No.C12, pp. 30,007-30,019.

Develops a model to describe the hydrodynamics of wave-driven flow across a coral reef and the resultant flushing of its lagoon. The model requires a current depth coefficient that is sensitive to the form of the frictional law on the reef flat.

Houston, J.R. 1978. Interaction of Tsunamis with the Hawaiian Islands Calculated by a Finite-Element Numerical Model. Journal of Physical Oceanography 8, pp. 93-102.

Describes a finite-element numerical model that determines the interaction of tsunamis with the Hawaiian Islands, and shows good agreement with tide gauge recordings of the 1964 Alaskan tsunami and the 1960 Chilean Tsunami.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press. Also available online at <http://www.ipcc.ch/>.

A very detailed synthesis of accepted science with predictions of possible future climate change, including sea level rise. Provides projections for sea level rise out to 2100.

National Oceanic and Atmospheric Administration (NOAA). 2010a. Datums for Kahului Harbor, HI, 1615680. Also available online at <http://co-ops.nos.noaa.gov/data_menu.shtml?stn=1615680 Kahului, Kahului Harbor, HI&type=Datums>

Provides tidal elevations and other information for the Kahului Harbor tide gauge station.

National Oceanic and Atmospheric Administration (NOAA). 2010b. Mean Sea Level Trend: 1615680, Kahului Harbor, Hawaii. Also available online at < http://co-ops.nos.noaa.gov/sltrends/sltrends_station.shtml?stnid=1615680 Kahului, Kahului Harbor, HI>

Plots the monthly mean sea level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval.

Smith, E.R., B.A. Ebersole, and Ping Wang, 2004. Dependence of Total Longshore Sediment Transport Rates on Incident Wave Parameters and Breaker Type. United States Army Corps of Engineers ERDC/CHL CHETN-IV-62.

Tested the CERC formula for longshore transport, in particular the coefficient K, against laboratory experiments. The CERC formula, which is not sensitive to breaker types, overestimated measurements by a factor of 7 to 8 for spilling breakers, and more than a factor of 3 for plunging breakers. Swash zone transport accounts for a third of total transport for the higher energy cases, and 40 to 60 percent for the lower energy cases.

Storlazzi, C.D. and B.E. Jaffe. 2008. The relative contribution of processes driving variability in flow, shear, and turbidity over a fringing coral reef: West Maui, Hawai'i. Estuarine, Coastal and Shelf Science 77, pp.549-564.

High-frequency measurements of waves, currents and water column properties were made on a fringing coral reef off northwest Maui, Hawai'i, for 15 months between 2001 and 2003 to aid in understanding the processes governing flow and turbidity over a range of time scales and their contributions to annual budgets.

U.S. Army Corps of Engineers (USACE). 2009. Water Resource Policies and Authorities: Incorporating Sea-Level Change Considerations in Civil Works Programs. Engineering Circular EC 1165-2-211, dated July 1 2009.

Gives guidance for incorporating future sea level change into Civil Works projects. The general approach is to consider a low future rate (based on present day trends), and medium and high rates based on defined curves. The high rate corresponds to an increase of approximately 1.5 meters over 100 years.

Vitousek, S. and C.H. Fletcher. 2008. Maximum annually recurring wave heights in Hawai'i. Pacific Science 62, No. 4, pp. 541-553. <http://www.soest.hawaii.edu/coasts/publications/Vitousek_SCD08.pdf>

The goal of this study was to determine the maximum annually recurring wave height approaching Hawai'i. The annual recurring significant wave height was found to be (25 ft± 0.9 ft) for open north Pacific swell. Directional annual wave heights were obtained by applying hindcast swell direction to observed nondirectional buoy data.

Reef Ecology

Edinger, E.N., Jompa, J., Limmon, G.V., Widjatmoko, W. and M. J. Risk. 1998. Reef degradation and coral biodiversity in Indonesia: Effects of land-based pollution, destructive fishing practices and changes over time. Marine Pollution Bulletin 36, pp. 617-630.

Uses transect surveys on 15 reefs in three regions of Indonesia to estimate the relative decrease in within-habitat coral species diversity associated with different types of reef degradation. Reefs subject to land-based pollution (sewage, sedimentation, and/or industrial pollution) show 30% to 60% reduced diversity. Bombed or anchor damaged reefs are approximately 50% less diverse in shallow water (3 m depth) than are undamaged reefs, but at 10 m depth the relative decrease is only 10%. The results found a 25% decrease in generic diversity of corals on two reefs re-sampled after 15 years.

Halley, R.B. 2000. 11 things a geologist thinks an engineer should know about carbonate beaches. In L.L. Robbins, O.T. Magoon, and L. Ewing (eds.), Carbonate Beaches 2000, American Society of Civil Engineers.

This conference paper provides a general overview of carbonate beach sand characteristics and reef production.

Rogers, C.S. 1990. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series, 62, No. 1-2, pp.185-202.

Unprecedented development along tropical shorelines is causing severe degradation of coral reefs primarily from increases in sedimentation. Sediment particles smother reef organisms and reduce light available for photosynthesis. Heavy sedimentation is associated with fewer coral species, decreased net productivity of corals, and slower rates of reef accretion. Sedimentation can also alter the complex interactions between fish and their reef habitat. Long-term data sets describing these reef responses are critically needed.

Tomascik, T. and F. Sander, F. 1985. Effects of eutrophication on reef-building corals. 1. Growth rate of the reef-building coral Montastrea annularis. Marine Biology 87, pp.143-155.

Fourteen environmental variables were monitored at seven locations along the west coast of Barbados on a weekly basis over a one-year period, 1981 to 1982. The physicochemical and biological data indicate that an environmental gradient exists because of increased eutrophication of coastal waters. Growth rates measured of Montastrea annularis along the environmental gradient exhibit high correlation with a number of water quality variables. Concentration of suspended particulate matter is the best univariate estimator of skeletal extension rates, suggesting such matter may be an energy source for reef corals, increasing growth up to a certain maximum concentration. After this, reduction of growth occurs due to smothering and reduced light levels.

Coastal Geomorphology of the Hawaiian Islands

Dickinson, W.R. 2001. Paleoshoreline record of relative Holocene sea levels on Pacific islands. Earth-Science Reviews 55, pp.191-234.

Gives a history of Holocene sea levels throughout the tropical Pacific Ocean, with particular emphasis on the mid-Holocene highstand that affected the development of shoreline morphology throughout the tropical Pacific Ocean.

Feirstein, E.J., and C.H. Fletcher. 2004. Hawai‘i’s Coastline. In: The World’s Coastline, Bird, E. (Ed.). <http://www.soest.hawaii.edu/coasts/publications/hawaiiCoastline/HawaiisCoastline.pdf>

Gives a very general introduction to the geology of Hawai‘i, and then discusses each island in turn.

Fletcher, C.H., and others. 2008. Geology of Hawaii Reefs. Chapter 11 in B.M. Riegl and R.E. Dodge (eds.), Coral Reefs of the USA. Springer Science+Business Media. <http://www.soest.hawaii.edu/coasts/publications/GeologyofHawaiiReefs.pdf>

This chapter contains a detailed geological description of Hawai‘i, with particular emphasis on its reefs.

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. <http://www.soest.hawaii.edu/coasts/publications/FletcherFiersten_Hawaiichaptercoasts.pdf>

Gives a broad introduction to the geology and coastal processes in Hawai‘i.

Moberly, R. 1963. Coastal Geology of Hawaii. Hawaii Institute of Geophysics Report No. 41. Prepared for Department of Planning and Economic Development, State of Hawaii.

The bulk of this report is an inventory of 90 beaches in Hawaii, including several beaches within the Kahului and Kihei regions . The report also provides a general geological and coastal process description of the beaches.

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

Provides a general geomorphic description of the Hawaiian beaches; seasonal rates of erosion and accretion of beach sand reservoirs; and grain size parameters. Gives a basic overview of coastal processes, including different wind and wave conditions. Discussions conditions and seasonal beach variations at 112 beaches in Hawai‘i, including two in the Kihei study regions.

Rooney, J., C. Fletcher, E. Grossman, M. Engels, and M. Field. 2004. El Niño influence on Holocene reef accretion in Hawai'i. Pacific Science 58, No. 2, pp. 305-324.

In Hawai'i, accretion occurred during early to middle Holocene time in areas where today it is precluded by the wave regime, suggesting an increase in wave energy. This may be associated with changes in strength of the El Nino Southern Oscillation (ENSO) during the Holocene period.

Coastal Erosion in the Hawaiian Islands

Fletcher, C.H., et al. 2008. On the Shores of Paradise. Chapter 9: Coastal Erosion and Beach Loss. <http://www.soest.hawaii.edu/coasts/publications/shores/index.html>.

Gives a general description of coastal erosion; the tension between preserving coasts and preserving upland infrastructure; and of specific regulatory issues in Hawai'i.

Fletcher, C.H., E.E. Grossman, B.M. Richmond, and A.E. Gibbs. 2002. Atlas of Natural Hazards in the Hawaiian Coastal Zone. United States Geological Survey Geological Investigations Series I-2761. <http://pubs.usgs.gov/imap/i2761/>

Provides maps of coastal hazard levels along the shoreline of each island. The documented and ranked hazards include: coastal erosion, sea-level rise, major storms, volcanic and seismic activity, tsunami inundation, coastal stream flooding, and extreme seasonal high wave events.

Fletcher, C.H., J.J.B. Rooney, M. Barbee, S.-C. Lim and B.M. Richmond. 2003. Mapping Shoreline Change using Digital Orthophotogrammetry on Maui, Hawaii. Journal of Coastal Research, Special Issue 38: 106-124.

Describes the basis for the shoreline change rates prepared by the University of Hawai'i. Digital, aerial orthophotomosaics, used with NOAA topographic maps (T-sheets), document past shoreline positions on Maui Island, Hawai'i. A least squares linear regression (outliers excluded and weighted by intrinsic errors) is used to determine a shoreline trend termed the reweighted linear squares (RLS). To determine the annual erosion hazard rate (AEHR) for use by shoreline managers the RLS data is smoothed in the longshore direction using a weighted moving average five transects wide with the smoothed rate applied to the center transect. The paper discusses specific areas in Maui.

Hawai'i Coastal Geology Group. 2010. Maui Shoreline Study Erosion Maps. <http://www.soest.hawaii.edu/asp/coasts/maui/index.asp>.

Provides rectified aerial photography, draft erosion hazard maps, and a description of methods used in developing shoreline retreat rates for the sandy shorelines of Maui. Note that numerical data were provided directly to Moffatt & Nichol by Matt Dyer and Bradley Romine, Coastal Geology Group.

Makai Ocean Engineering, Inc and Sea Engineering, Inc. Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. Prepared for the State of Hawaii Office of State Planning and Coastal Zone Management. June 1991.

Vertical aerial photographs were analyzed to determine historical changes in the shoreline position. Aerials generally dated from 1950 to present and were taken at approximately 10 to 15 year intervals. The study also includes 22.2 miles of sandy shoreline in Kauai and 27.3 miles on Maui. RSM regions covered in Kauai consist of Kekaha to Waimea and Makahuena Point to Haula Beach. RSM regions covered in Maui consist of Maalea Harbor to Kalama Beach Park, Kamaole to Makena and Kahului Harbor to Hamakua Poko Point. Information from each section of coast includes: general coast/beach characteristics, land use and development, wave climate, shoreline processes, beach usage, and shoreline history. Regional erosion / accretion rate summary tables are given for each section of coast.

Richmond, B.M., C.H.Fletcher, E.E.Grossman, and A.E. Gibbs. 2001. Islands at risk: Coastal hazard assessment and mapping in the Hawaiian Islands. Environmental Geosciences 8, No.1, pp. 21-37.

Describes the development of the coastal hazard database and atlas, *Atlas of Natural Hazards in the Hawaiian Coastal Zone*.

Maui – General

University of Hawaii Sea Grant Extension Service and County of Maui Planning Department. 1997. Beach Management Plan for Maui.

This report makes recommendations on how Maui County can better address beach management issues. It is intended to be a guiding policy document, rather than be adopted in its entirety as formal law. Issues include: Where and why coastal erosion and beach loss have occurred; Recommendations for more effective management of shoreline areas; and the development of increased options for resource conservation and erosion mitigation.

Maui - Kahului Region

Moffatt & Nichol. 2008. Wailuku Kahului WWRF Preliminary Engineering Report, Shoreline Erosion Control (Draft). Prepared for the County of Maui, Wastewater Reclamation Division, Department of Environmental Management. June.

Objectives were to quantify shoreline erosion trends, assess potential causes for erosion, and develop preliminary shoreline protection alternatives for the WWRF site. Findings included:

- The largest contributor to long-term erosion of the north shore beaches is historical sand mining;

- Typical seasonal variations for the WWRF beach area are 20 to 30 feet; maximum seasonal variations are 50 to 60 feet;
- Typical long-term erosion rates for the WWRF beach area are 2.4 feet per year; maximum long-term erosion rates are 2.4 feet per year;
- Net rate of sediment transport at the shoreline adjacent to the WWRF is currently between 1,300 and 4,000 cubic yards per year.
- The revetment in front of the WWRF is now acting as a groin.

U.S. Army Engineer Division, Pacific Ocean. 1973. Detailed Project Report Prevention and Mitigation of Shore Damages for the Kahului Harbor, Maui, Hawaii. August.

Study investigated two miles of coastline in the vicinity of Kahului Harbor for shoreline erosion. Study includes detailed analysis of 5,200 feet of shoreline extending from Pier 2 to the coral fill area to the west within the harbor. The report includes detailed oceanographic information for the Kahului Harbor including: waves, tides, observed littoral currents in the harbor. Wave conditions entering the harbor are modeled under varying swell conditions. Chronology of harbor, shoreline protection and beach nourishment activities along this reach are described.

USACE. Miscellaneous Correspondence Related to the Construction of the Kahului Harbor. Various Years.

Miscellaneous correspondence from the USACE regarding the construction schedule, costs, bid advertisement, etc. of Kahului Harbor.

Maui - Kihei Region

U.S. Army Corps of Engineers, Honolulu District. 1967. Report on Survey of Shores of the Island of Maui, Hawaii in the Vicinity of Kihei for Beach Erosion Control. February.

Study purpose was to investigate coastal erosion and littoral processes in the vicinity of Kihei and develop an engineering solution to reduce erosion in this region. Report presents volumetric shoreline change rates based on surveys conducted over an approximately 60 year period (i.e. 1900 - 1964). Based on this data, annual erosion rate in the area was estimated at 6,400 cy. Additionally, the report provides general geologic and oceanographic setting, shoreline armoring inventory for the region, and beach sediment composition and sediment origins. The recommended plan entailed the placement of a protective revetment and beach fill (6,800 cy) along the entire Kalama Park front (approximately 3,000 feet). Plans were provided in the report.

U.S. Army Corps of Engineers, Honolulu District, Hawaii Department of Land and Natural Resources and the Division of Boating and Ocean Resources. 1998. Draft Supplement II Environmental Impact Statement Ma'alaea Harbor for Light-Draft Vessels, Maui, Hawaii. April.

Report addresses proposed navigation improvements to Ma'alaea Harbor for the purposes of reducing the surge and navigation hazards within the harbor. Improvements entail the re-alignment of the entrance channel and modifying the existing breakwater to protect the new entrance channel. The supplement EIS discusses environmental impacts of the proposed improvements. Sedimentation of the harbor was discussed briefly (from land sources). Plans for each of the proposed improvements are provided. Marine resources and surfing impacts in the project vicinity are discussed in detail.

Department of the Army, Honolulu District, Corps of Engineers. 1966. Report on Survey of the Shores of the Island of Maui, Hawaii in the Vicinity of Kihei for Beach Erosion Control. May.

The study investigates coastal erosion of a seven mile reach of shoreline in Kihei. Justification for a federal assistance project was only granted to Kalama Beach Park. The proposed project at this site consisted of a 75-foot wide beach berm and the placement of a stone revetment for a distance of 3,000 feet. Geomorphology, littoral materials, littoral forces, and shore history of this study area are described in this report.

Rooney, John and Charles Fletcher III. University of Hawaii. 2001. Shoreface Sediment Dynamics along the West Maui and Kihei Coasts of Maui, Hawaii. Prepared for the State of Hawaii Department of Land and Natural Resources, Division of Aquatic Resources. November.

Study created historical shoreline positions from orthorectified aerial photomosiacs and U.S. Coast and Geodetic Survey topographic surveys. The overall long-term (1900 to 1997) erosion rate was calculated for the west coast of Maui to be -0.15 m/yr (-0.49 ft/yr), with rates for the Kihei coast slightly higher. The report provides high resolution shoreline change rates (short and long term), projected shoreline change rates, and sediment production (i.e. sources). Shoreline change in relation to climatic fluctuations (e.g. PDO) is also discussed.

Oceanit Laboratories, Inc. 2004. Ma'alaea Harbor Supplemental Studies – Shoreline Erosion, Investigation of Wastewater Discharges, Confirmation of Coral Reef Resources, and Investigation of Surf Shoal Construction Methods. Prepared for the U.S. Army Corps of Engineer Division, Pacific Ocean. April.

Includes a number of studies prepared in support of the third Supplemental EIS for improvement to Ma'alaea Harbor. Historical shoreline behavior adjacent to the harbor was investigated as part of this effort. Shoreline behavior was characterized through review of historical aerial photographs and interviews conducted by researchers. The study determined that sand migration was from the northwest to southeast along the beach (away from the harbor). Volumetric estimates were provided for the area immediately east of the harbor and were on the order of 400 -1000 cy/yr. Wave climate and sediment transport patterns were described to address probable causes for shoreline erosion and beach loss in the vicinity. The Surf Shoal Construction Methods report summarizes technological developments of artificial surfing reefs and examples constructed to date.

Environmental Consultants, Inc. 1997. A Reconnaissance Survey of Nearshore Marine Environments at Kihei, Maui. Prepared for the U.S. Army Engineer Division, Pacific Ocean. September.

The report presents the results of a marine reconnaissance survey conducted for the USACE to provide baseline data on the nature of the inshore marine environment in the proximity of four channel mouths or their proposed channel alignments. The report was geared toward assessing the potential impacts of proposed stream channel modifications. Water quality (salinity, turbidity nutrients), sediment sampling and biological surveys (benthic infauna and reef fish) were conducted under this study. Sites included the Kihei/Waiakoa Gulch, Kalepolepo and Waipiolani Gulc, Kalama Park and the Keawakapu Beach Park / Inoale Gulch. Twenty sediment samples were collected at the shoreline for grain size distribution.

Munekiyo & Hiraga, Inc. 2005. Draft Environmental Assessment for the Proposed Ma’alaea Small Boat Harbor Improvements. Prepared for the State of Hawaii, Department of Land and Natural Resources. February.

Report discusses the potential environmental impacts of proposed improvements to the Ma’alaea Small Boat Harbor related to its proposed use as a second inter-island ferry port. The document provides a description of the existing environment and marine resources. Contains information about a shoreline setback variance and provides a certified shoreline survey conducted in 1973 (Appendix G).

Hadley, L., Thompson, E., and D. Wilson. U.S. Army Engineer Waterways Experiment Station Coastal Hydraulics Laboratory. 1997. Updated Wave Response of Proposed Improvements to the Small Boat Harbor At Maalaea, Maui, Hawaii. Prepared for the U.S. Army Division, Pacific Ocean. December.

Study presents results of an updated numerical model wave response study of the proposed improvements to Maalaea small boat harbor. All proposed alternatives were analyzed with the goal of selecting an optimal design. Wave environment for the region were discussed.

Moffatt & Nichol. 2000. Kihei Flood Control System Analysis and Shoreline Impact Study. Prepared for the County of Maui, Department of Public Works and Waste Management. August.

Study objective was to evaluate the impact of County flood control practices on sand loss in the Kihei area. Findings were that breaching the dunes to drain streams is detrimental to the Kihei shoreline. Report provides information about the shoreline processes and history of the Kihei area. Recommends long term measures to reduce shoreline impacts from flood control actions and to provide shoreline enhancement.

Rooney, John J.B. and Fletcher, Charles H. 2000. A High Resolution, Digital, Aerial Photogrammetric Analysis of Historical Shoreline Change and Net Sediment Transport Along the Kihei Coast of Maui.

Examined historic shoreline change along the Kihei coast based on aerial photographs from 1949 to 1997, and NOAA T-sheet shorelines from 1900 and 1912. Using the historic shoreline data, recent and long-term erosion rates were estimated. General results were:

- South Kihei, from Kamaole 1 Park to the southern portion of Halama Street, has experienced persistent long-term erosion for the entire century;
- North Kihei was generally accretional from 1900 through the mid-1960s, but has exhibited net erosion since 1975.
- Areas of significant localized accretion include North Halama Street just south of St. Theresa's groin, Kawililipoa, and northern Waipulani Kalama.
- Approximately 80,000 cubic yards eroded from the southern end of the study area, and 98,000 cubic yards accreted to the north, resulting in a net sediment gain to the region of about 30 percent;
- The location of the most severe erosion has gradually moved north from Kalama Park in the early 1900s to Halama Street by 1997.

Makai Ocean Engineering, Inc. and Sea Engineering, Inc. 1991. Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui, and Hawaii. Prepared for the State of Hawaii, Office of State Planning.

Historic aerial photographs were digitized and used to track shoreline behavior from 1949 to 1988. The study included the sector from Maalaea Harbor to Kalama Beach Park. Findings were comparable to those reported by Rooney and Fletcher, 2000.

U.S. Army Engineer District, Honolulu. 1992. Draft Supplemental Environmental Impact Statement for Maalaea Harbor for Light-Draft Vessels, Maui, Hawaii. Sponsored by the State of Hawaii, Department of Transportation. November.

Supporting document for the improvements to Maalaea Harbor. Improvements include the realignment of the entrance channel, modification to the existing breakwater and expansion of berthing facilities by the State of Hawaii. Document addresses significant but mitigable impacts to the endangered humback whale as recognized in the Biological Opinion prepared by the National Marine Fisheries Service. The document also addresses impacts to five surf breaks adjacent to the harbor.

United States Army Corps of Engineers, Honolulu District. General Design Memorandum and Final Environmental Impact Statement for the Maalaea Harbor for Light-Draft Vessels, Maui, Hawaii. 1980. July.

Describes the feasibility and the impacts of navigation improvements for Maalaea Harbor. Three alternative plans are presented and one is selected as the recommended plan. The recommended plan provides for the dredging of a 610-foot long, 150 to 180 foot wide, 15 to 12-foot deep entrance channel, a 1.7 acre, 12-foot deep turning basin, and a 720-foot long, 80-foot wide, 8-foot deep access channel; and provides for the construction of a 620-foot long, 13-foot high extension to the existing south breakwater, including a 400-foot long exterior revetted mole. Local sponsor (State of Hawaii) improvements to harbor facilities are also included in the project description.

United States Army Corps of Engineers, Honolulu District. General Design Memorandum and Final Environmental Impact Statement for the Maalaea Harbor for Light-Draft Vessels, Appendix C through J. 1980. July.

Appendix C discusses recreational (parks and beaches) and natural resources (terrestrial, marine, water quality, and endangered species) in the project vicinity. Appendix D is a U.S. Fish and Wildlife Report. Appendix E social and cultural resources. Appendix F Environmental Impact Statement. Appendix G is a Section 404 Evaluation. Appendix H is an Executive Order 11988 Compliance Statement. Appendix I is a Coastal Zone Management Consistency Determination. Appendix J is a list of reviewers and pertinent correspondence.

Other Islands and Other Areas of Maui

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

Develops a sediment budget for Hanalei Bay on the north shore of Kauai. There are significant terrigenous (siliciclastic) sediment components from the Hanalei River watershed, in addition to the carbonate components. Excess carbonate sediment is estimated based on published production rates for different.

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 19 No. 3, pp. 649-663.

Longshore sediment transport (LST) measured at monthly beach profiles on Kaanapali Beach, on the leeward coast of Maui, is compared to three predictive models. The presence of fringing reef significantly affects the ability of LST models to accurately predict sediment transport: the functional beach profile area available for sediment transport is assumed much larger than actually exists in Kaanapali; wave parameters are also important.

Storlazzi, C.D., A.S. Ogston, M.H. Bothner, M.E. Field, and M.K. Presto. 2004. Wave- and tidally-driven flow and sediment flux across a fringing coral reef: Southern Molokai, Hawaii. Continental Shelf Research 24, pp. 1397-1419.

Deployed instrumentation across the fringing coral reef off the south coast of Moloka‘i to understand the processes governing fine-grained terrestrial sediment suspension on the shallow reef flat and its advection across the reef crest and onto the deeper fore reef. Relatively clear water flows up onto the reef flat during flooding tides. At high tide, more wave energy is able to propagate onto the reef flat and sediment suspension is increased. During ebb tide, the water and associated suspended sediment drains off the reef flat and is advected offshore and to the west by trade wind and tidally driven currents. There is relatively high turbidity on the fore reef during ebb tide.

Offshore Sand Sources

Sea Engineering, Inc. November 2008. Kahului Bay Sub-Bottom Survey.

In May, 2008, Sea Engineering, Inc. conducted a sub-bottom survey, using geophysical methods, of Kahului Bay on the north shore of the island of Maui. The survey was designed to investigate the nature of sand deposits in the bay. Previous benthic surficial mapping by NOAA had indicated the broad presence of sand deposits within the bay, however there were no data available to determine the thickness of the sand deposits. The presence of sand deposits 10 to 20 feet in thickness over much of Kahului Bay was confirmed by the Sea Engineering sub-bottom survey.

Regional Sediment Management – General

Hawaii Department of Land and Natural Resources. November 2006. Report to the Twenty-Fourth Legislature Regular Session of 2007 – 3-year plan for beach restoration studies and projects.

Provides an overview of the Department’s efforts to implement beach restoration projects and studies to support such efforts. Includes a discussion of the Department’s efforts to create a comprehensive management plan

(Hawai‘i Beach Management Plan) to conserve and restore Hawai‘i’s important beaches; and a discussion of existing and proposed studies and beach restoration projects being conducted by the Department.

Rosati, J.D., B.D. Carlson, J.E. Davis, and T.D. Smith. 2001. The Corps of Engineers National Regional Sediment Management Demonstration Program. CHETN-XIV-1, U.S. Army Engineer Research and Development Center ERDC/CHL, Vicksburg, MS. <http://chl.erdc.usace.army.mil/library/publications/chetn/pdf/chetn-xiv-1.pdf>.

Gives a general introduction to Regional Sediment Management and discusses ongoing demonstrations by the U.S. Army Corps of Engineers.

United States Army Corps of Engineers, 2005. Army Corps, State DLNR announce implementation of programmatic general permit for beach nourishment, restoration and enhancement for Hawaii. Public Affairs Office, Honolulu Engineer District, and DLNR Public Information Office.

The USACE and the State DLNR announce the issuance of a State Programmatic General Permit (SPGP) for Beach Nourishment and Restoration in the State of Hawai‘i. This is an expedited permit for beach nourishment, allowing replenishment of up to 10,000 cubic yards of sand as an alternative to shoreline hardening and beach loss.

APPENDIX B

WAVE TRANSFORMATION MODELING – KAHULUI REGION (USACE 2011)

Kahului, Maui, RSM Waves

Kahului is on the north shore of the Maui with exposure to waves arriving from approximately 300 to 90 deg. The closest Wave Information Studies (WIS) save point is Station 102 located at 21.5 deg North and 156 deg West in a depth of 4974 m. Station 102 is shown in Figure B-1 with a yellow circle. WIS Station 101 is also near the site of interest. Stations 101 and 102 have very similar wave height, period, and direction distributions, but Station 101 has slightly higher peak wave heights due to more exposure to the northwest. Station 102 was selected because it is closer to the site of interest and the exposure is more representative. A wave rose for Station 102 for 1981-2004 is given in Figure B-2. The wave rose shows distribution of wave height with wave direction. Large wave heights are prevalent out of all directions from northwest to east.

Three representative years were chosen for further study and nearshore wave transformation. The three years include a low wave condition year (1984), a medium wave condition year (1992) and a high wave condition year (1994). Figures B-3, B-4, and B-5 show compressed time series of the years 1984, 1992 and 1994 at Station 102.

Since the WIS save points are in deep water and away from Maui, the wave heights include energy from both waves moving toward and away from the island. To eliminate energy moving away from Kahului, the WIS spectra for these three years were truncated to include only energy from 272.5 to 87.5 deg (0 deg +/-87.5 deg). Then, the truncated spectra were used to recalculate wave height, peak wave period, and mean wave direction. These wave parameters were then transformed to the 100 m depth (approximate nearshore grid boundary) with linear shoaling and refraction (assuming bottom contours are approximately aligned east to west). These transformed wave parameters from the truncated spectra were then analyzed using the Coastal Engineering Design and Analysis System (CDAS) to quantify the distributions of wave height period and direction. ASCII files with the hourly date, wave height, peak wave period, and mean wave direction were imported to CDAS Beach model under STWAVE using the WWWL Data utility. The units of meters were set under the “waves” tab and the time history was saved in a NetCDF format. Then this file was opened using the WSAV utility under STWAVE. The data were then binned and plotted.

Percent and number of occurrence plots are shown in Figures B-6-12 for 1984, in Figures B-13-19 for 1992, and Figures B-20-26 for 1994. The directions on these plots are relative to the normal of the local wave grid (0 deg in the relative system is a wave from north, +45 deg is 315 deg, and -45 deg is 45 deg). The plots are useful is assessing wave height, period, and direction combinations to be run for the nearshore wave transformation analysis.

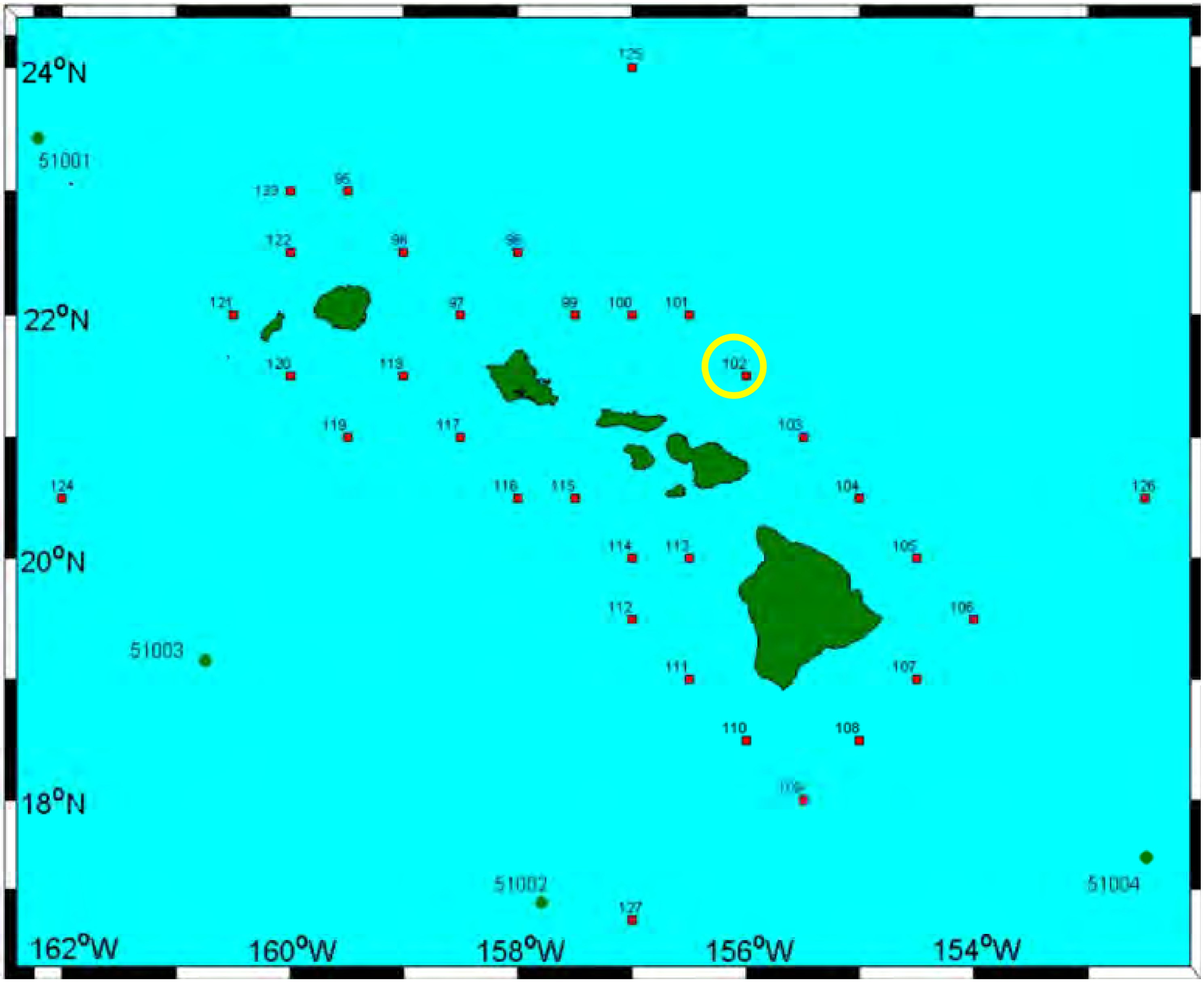


Figure B-1. WIS Station Map – Kahului Region

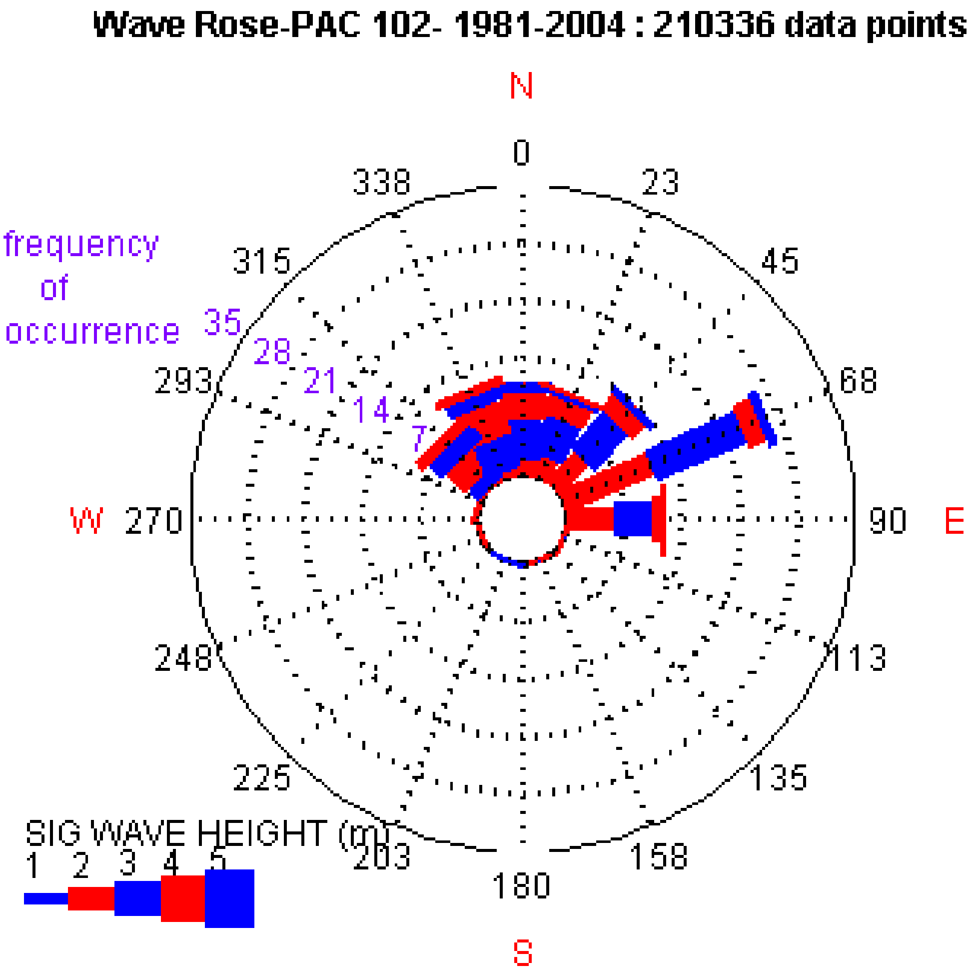


Figure B-2. Wave Rose for 1981-2004 for WIS Station 102.

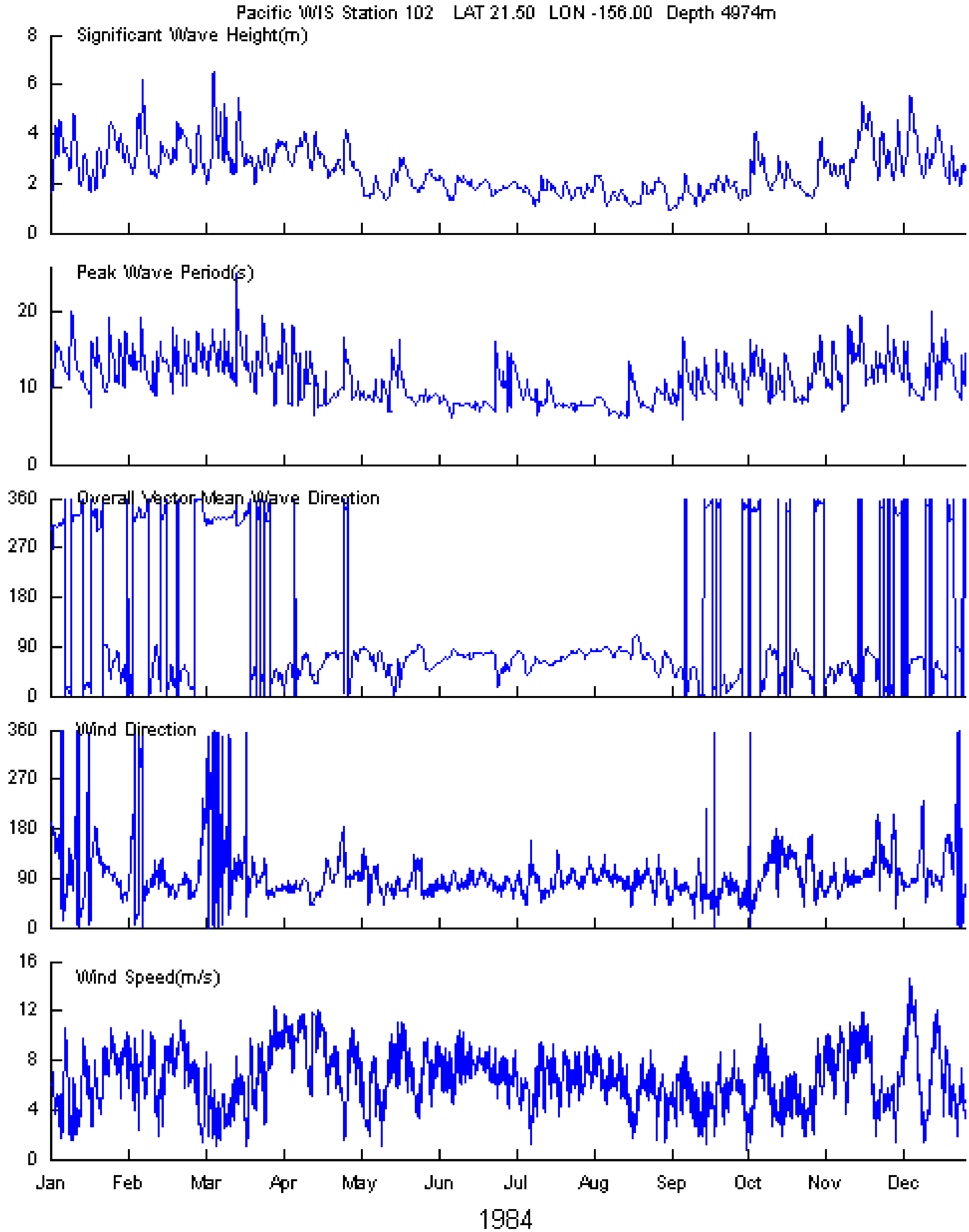


Figure B-3. 1984 wave and wind time histories for WIS Station 102.

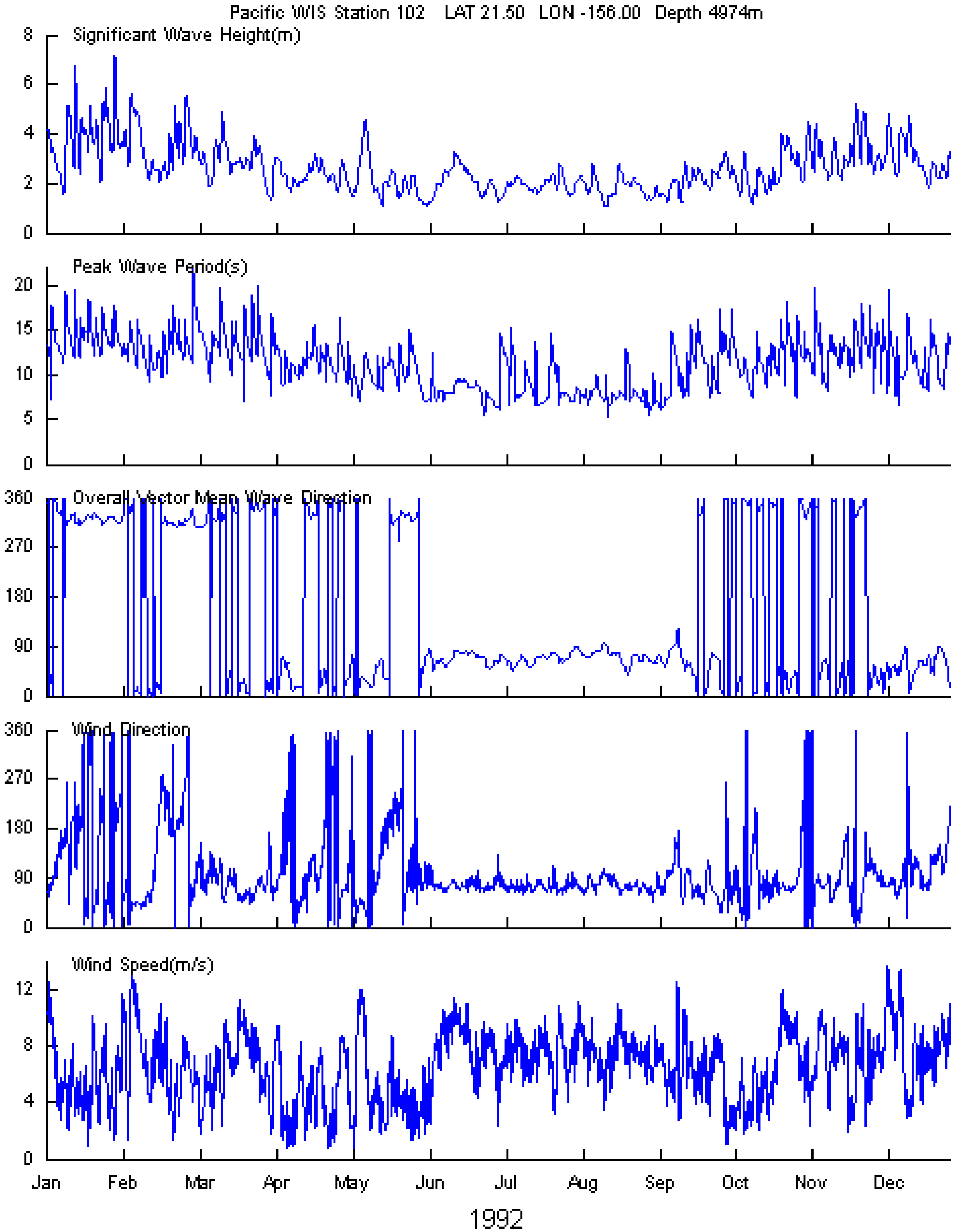


Figure B-4. 1992 wave and wind time histories for WIS Station 102.

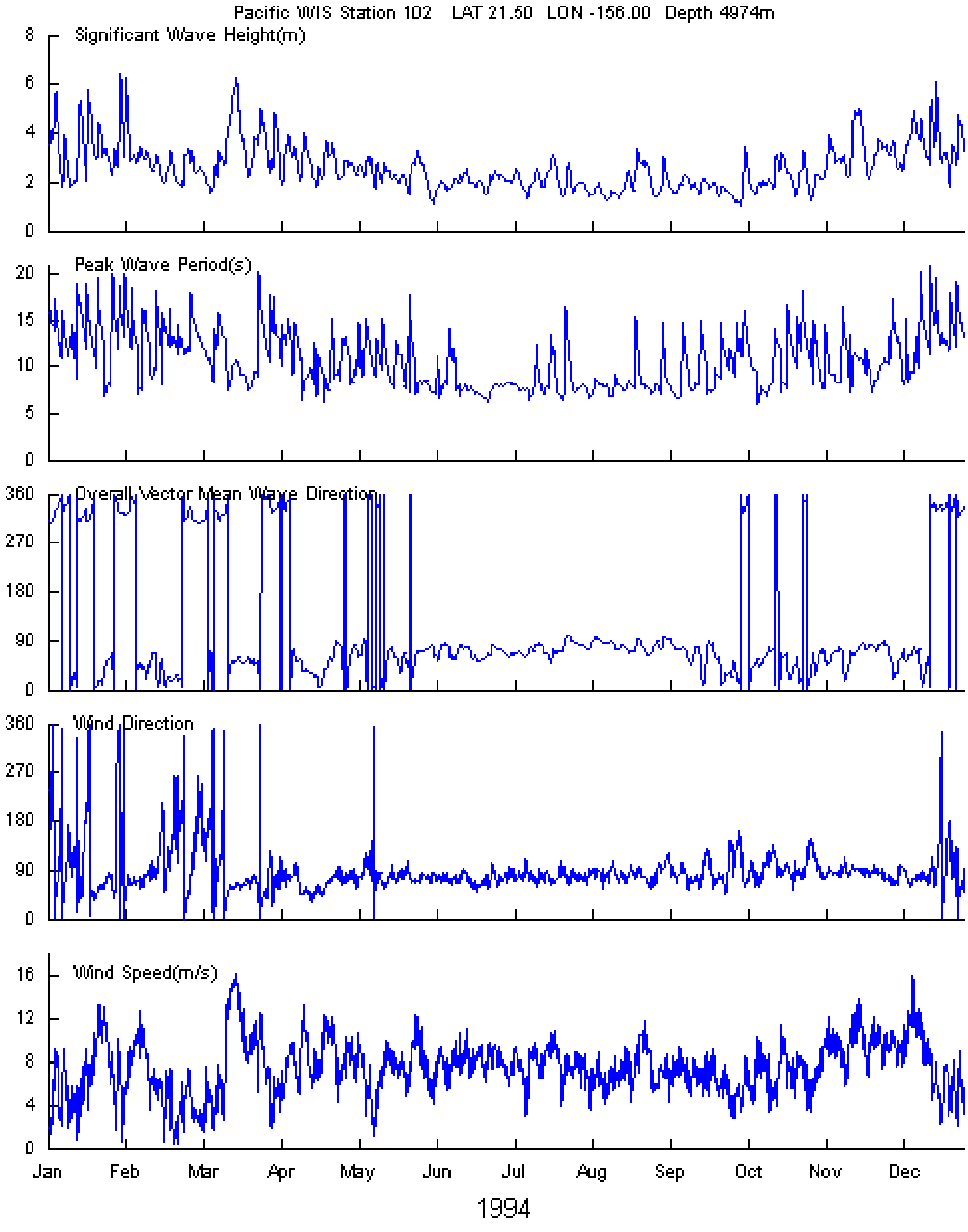


Figure B-5. 1994 wave and wind time histories for WIS Station 102.

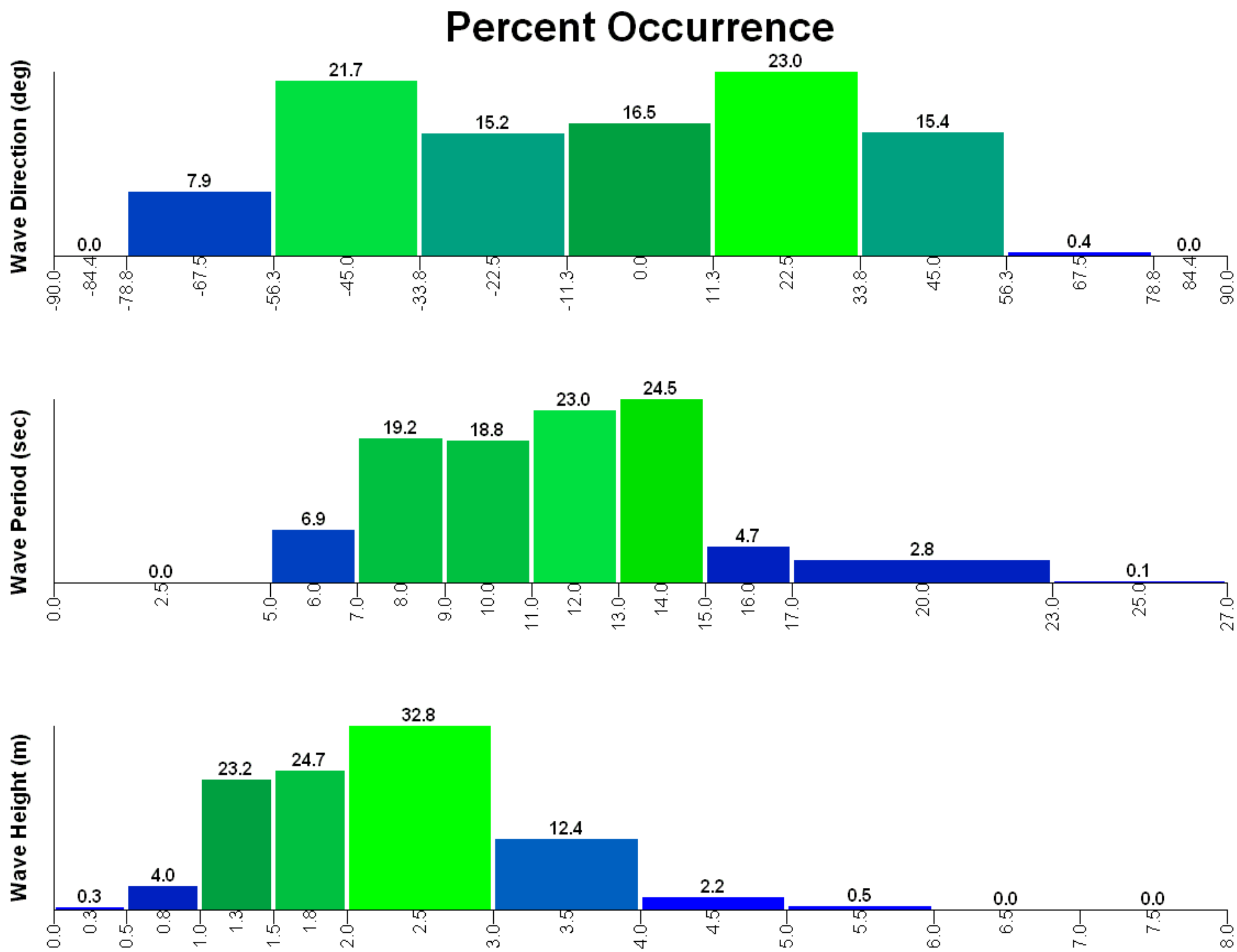


Figure B-6. 1984 percent occurrences for wave height, peak period, and mean direction for WIS Station 102.

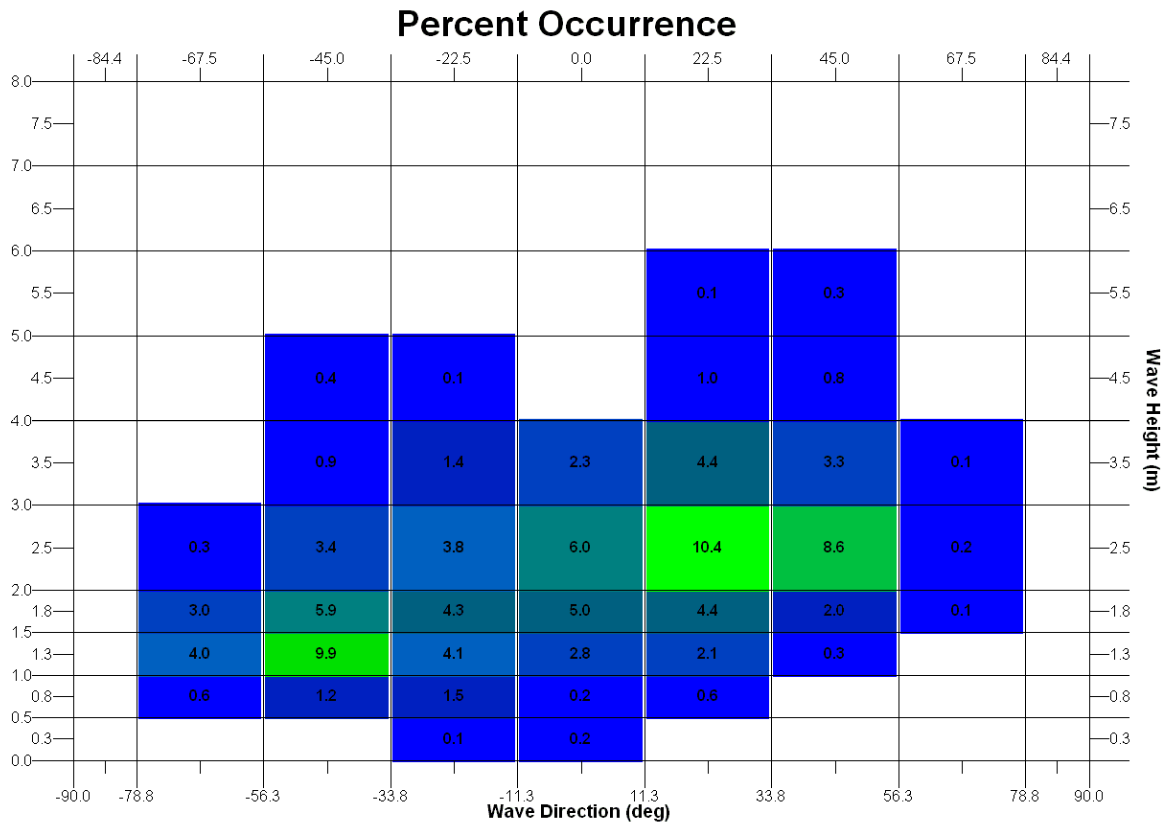


Figure B-7.1984 percent occurrences for wave height and mean direction for WIS Station 102

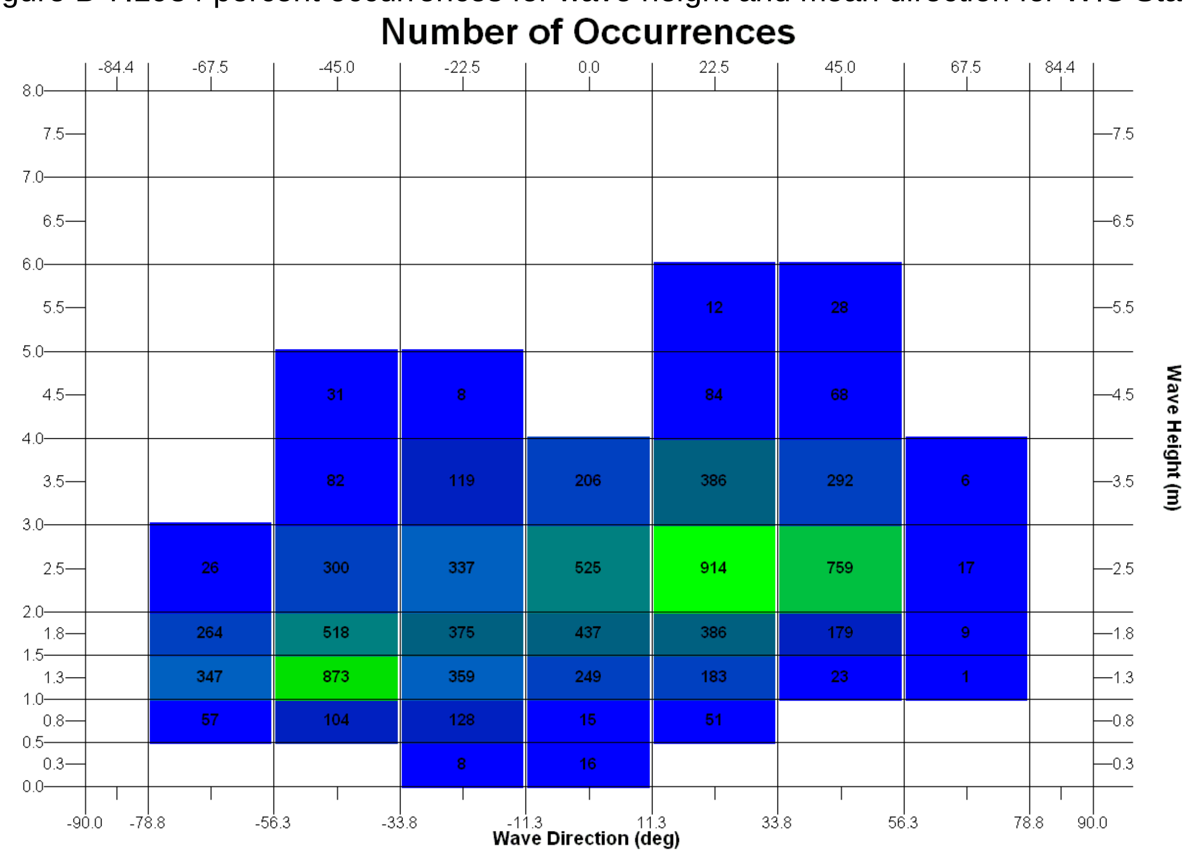


Figure B-8. 1984 number of occurrences for wave height and mean direction for WIS Station 102

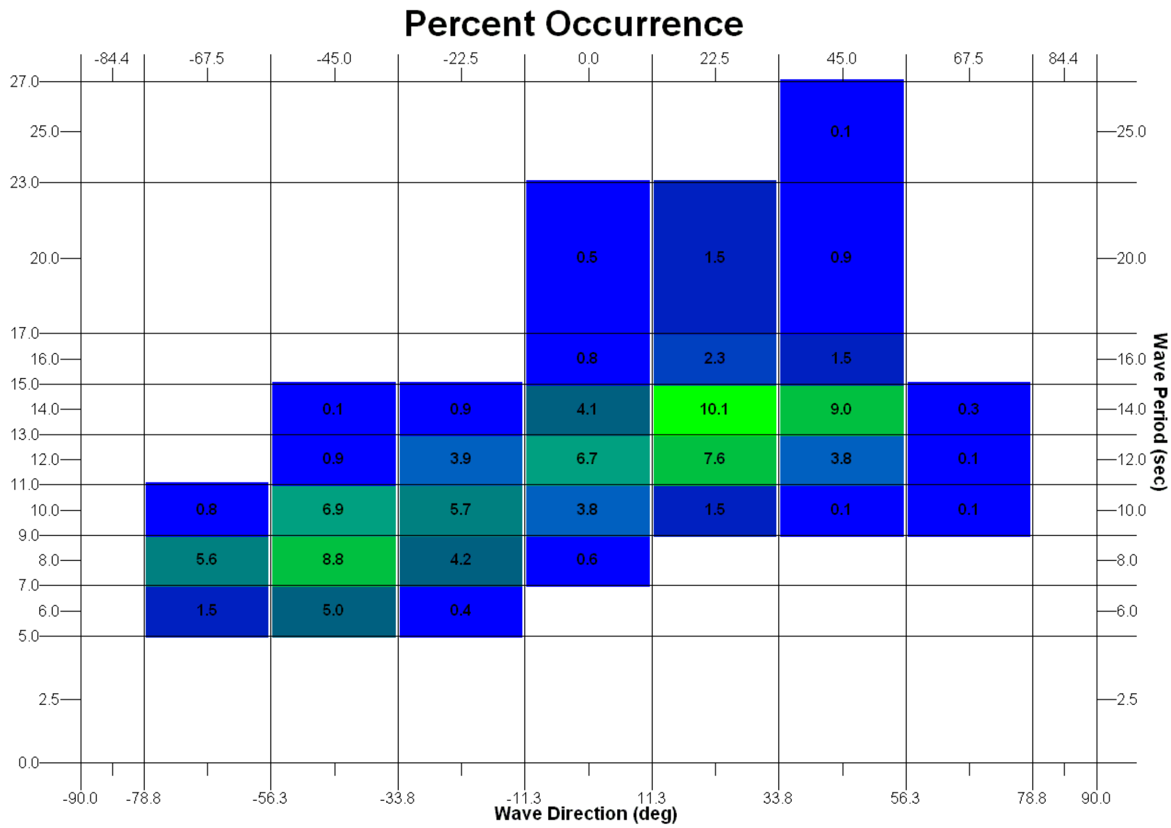


Figure B-9. 1984 percent occurrences for peak period and mean direction for WIS Station 102

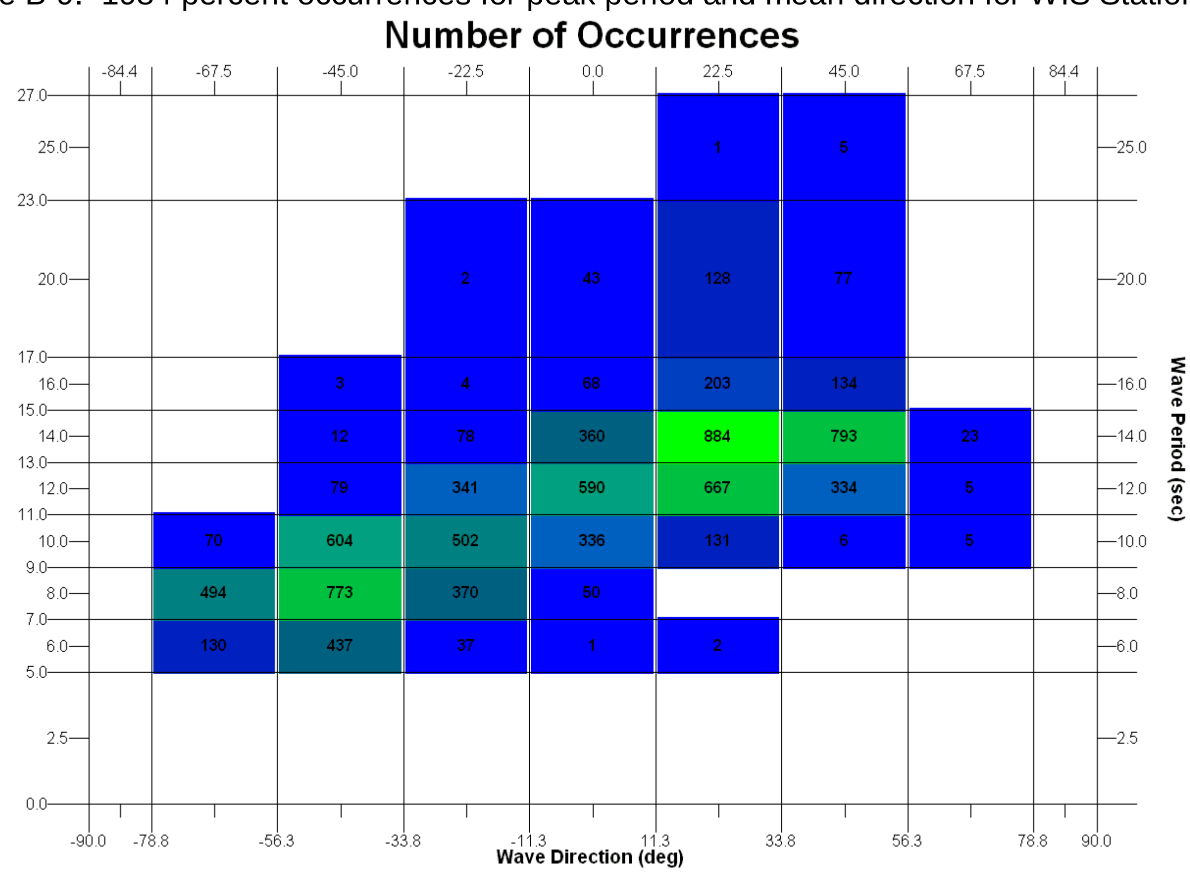


Figure B-10. 1984 number of occurrences for peak period and mean direction for WIS Station 102

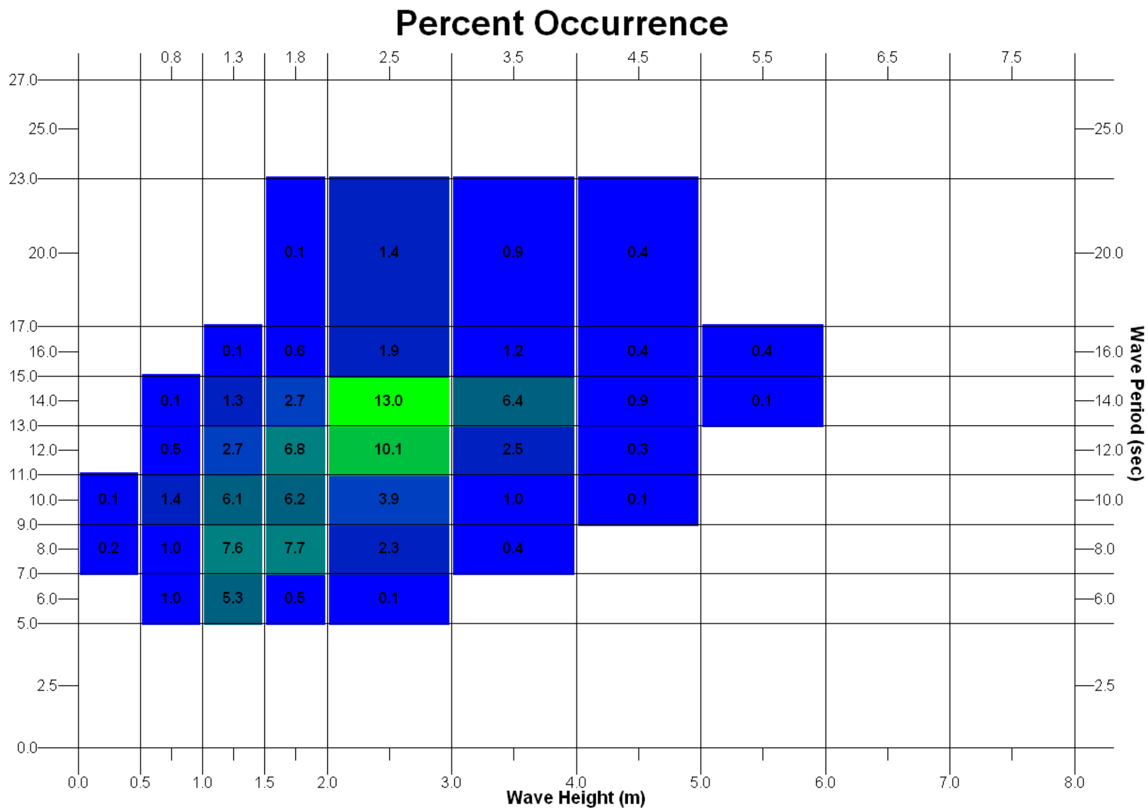


Figure B-11. 1984 percent occurrences for peak period and wave height for WIS Station 102

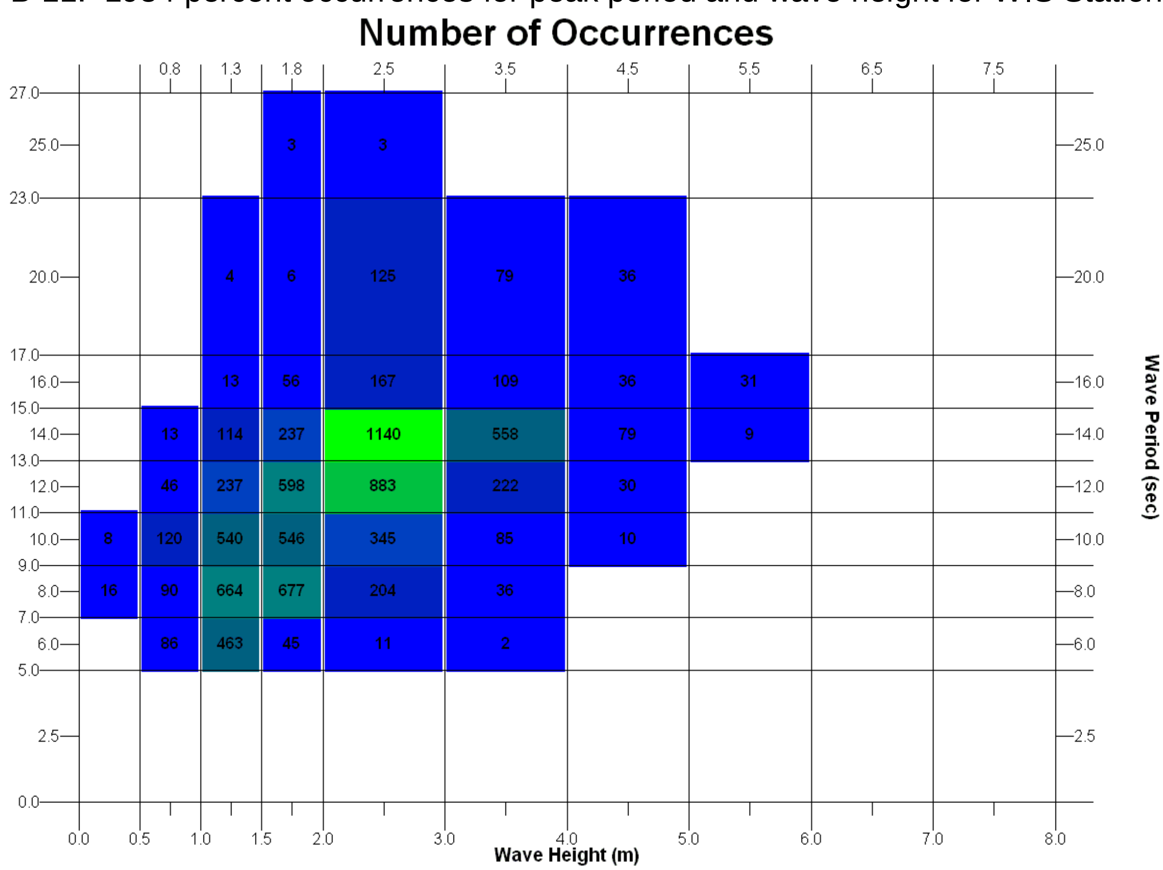


Figure B-12. 1984 number of occurrences for peak period and wave height for WIS Station 102

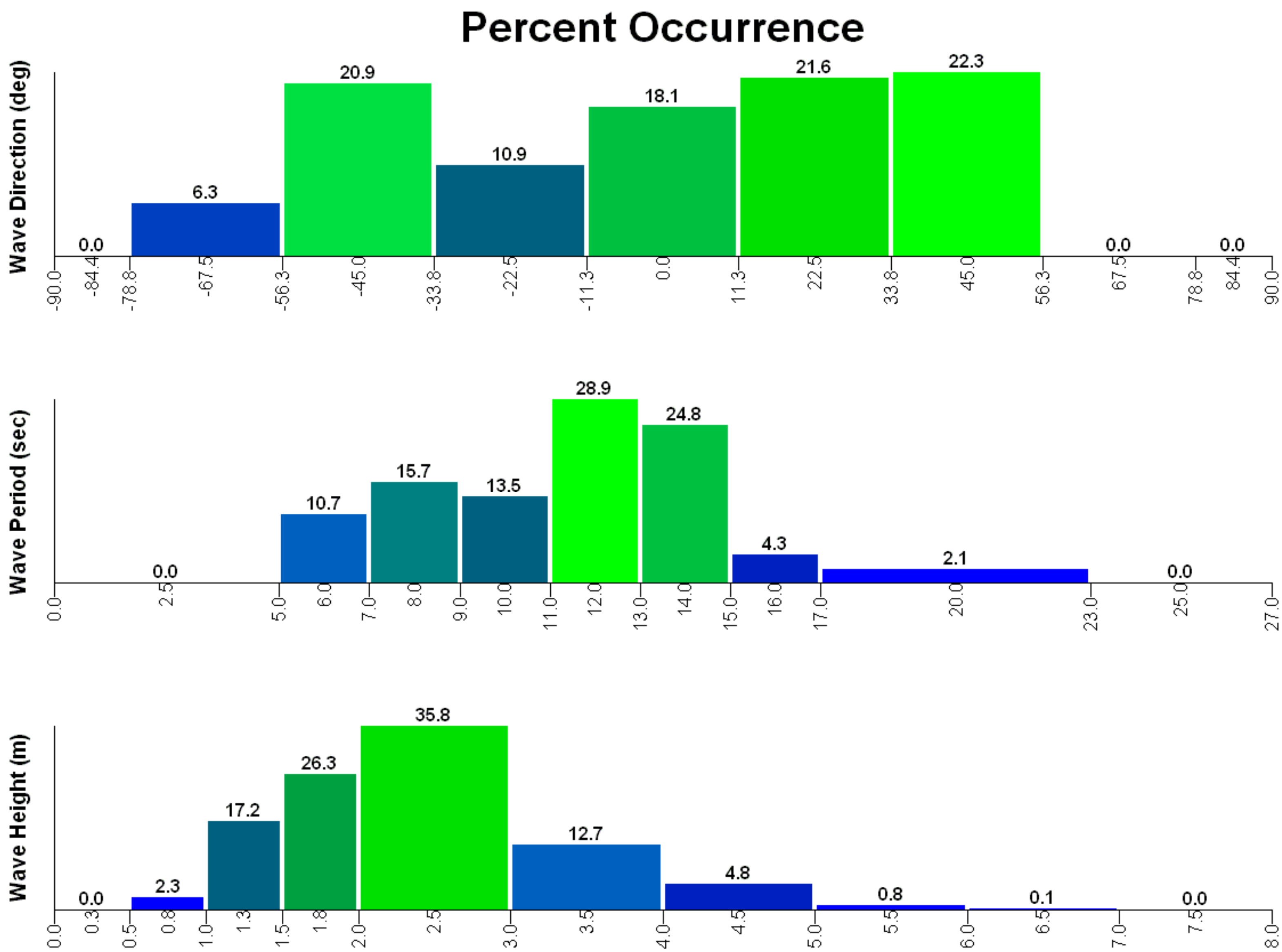


Figure B-13. 1992 percent occurrences for wave height, peak period, and mean direction for WIS Station 102.

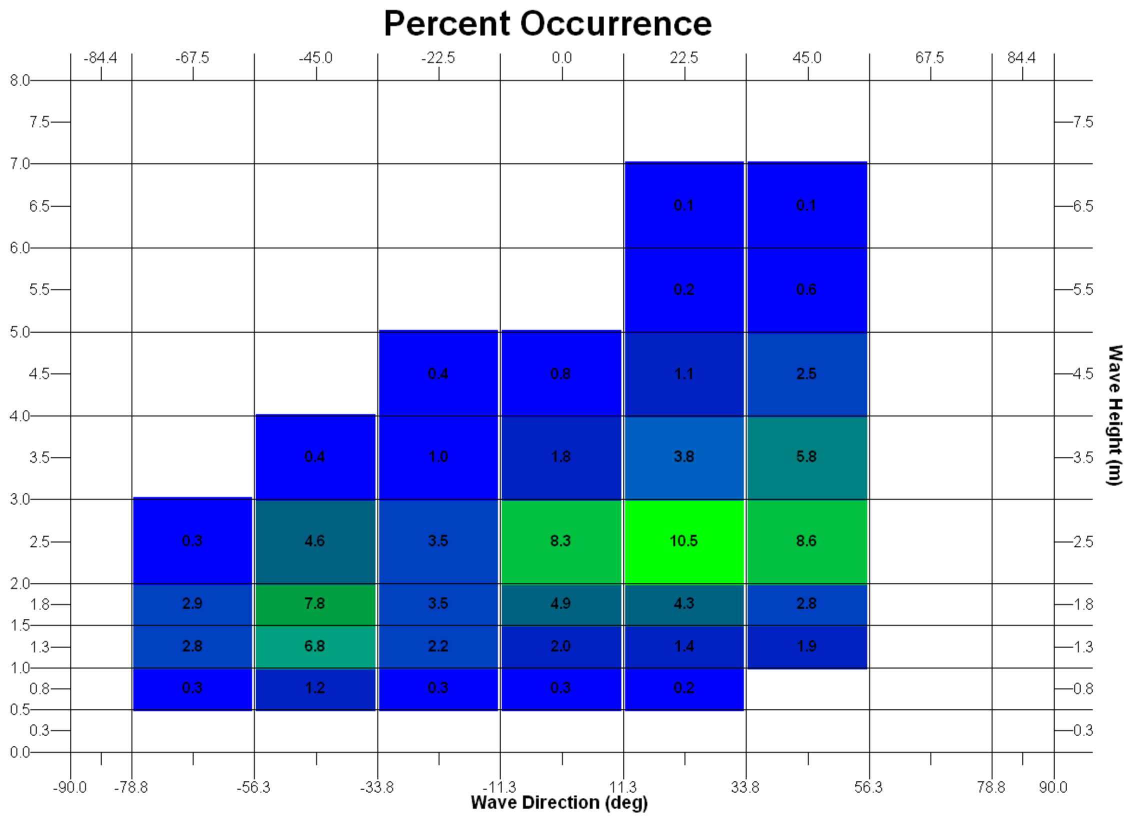


Figure B-14. 1992 percent occurrences for wave height and mean direction for WIS Station 102

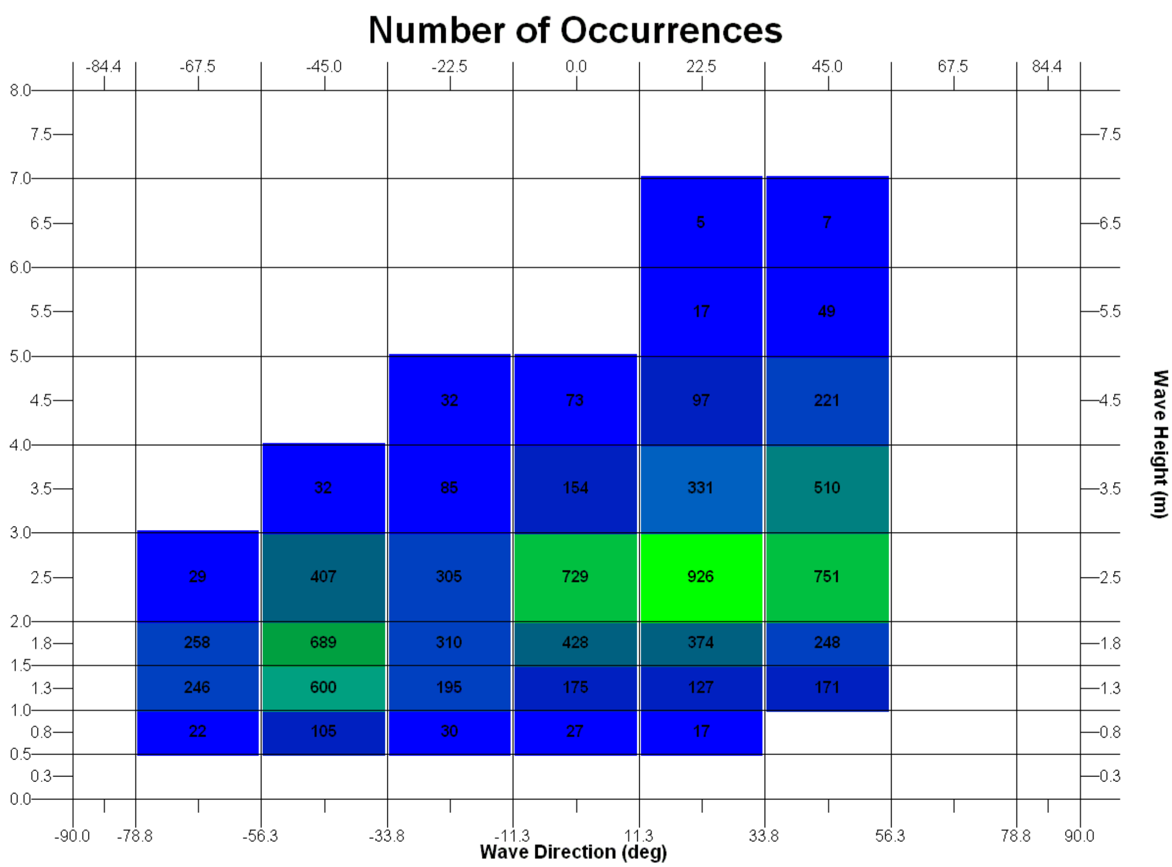


Figure B-15. 1992 number of occurrences for wave height and mean direction for WIS Station 102

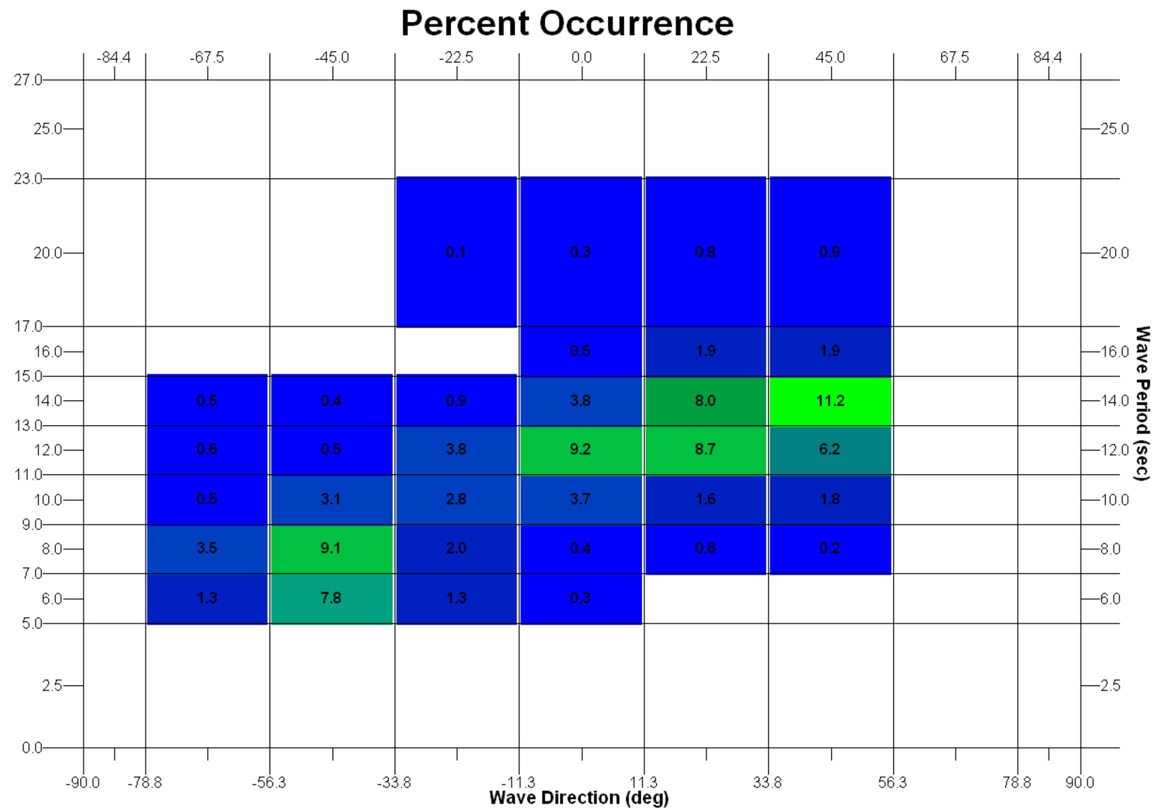


Figure B-16. 1992 percent occurrences for peak period and mean direction for WIS Station 102

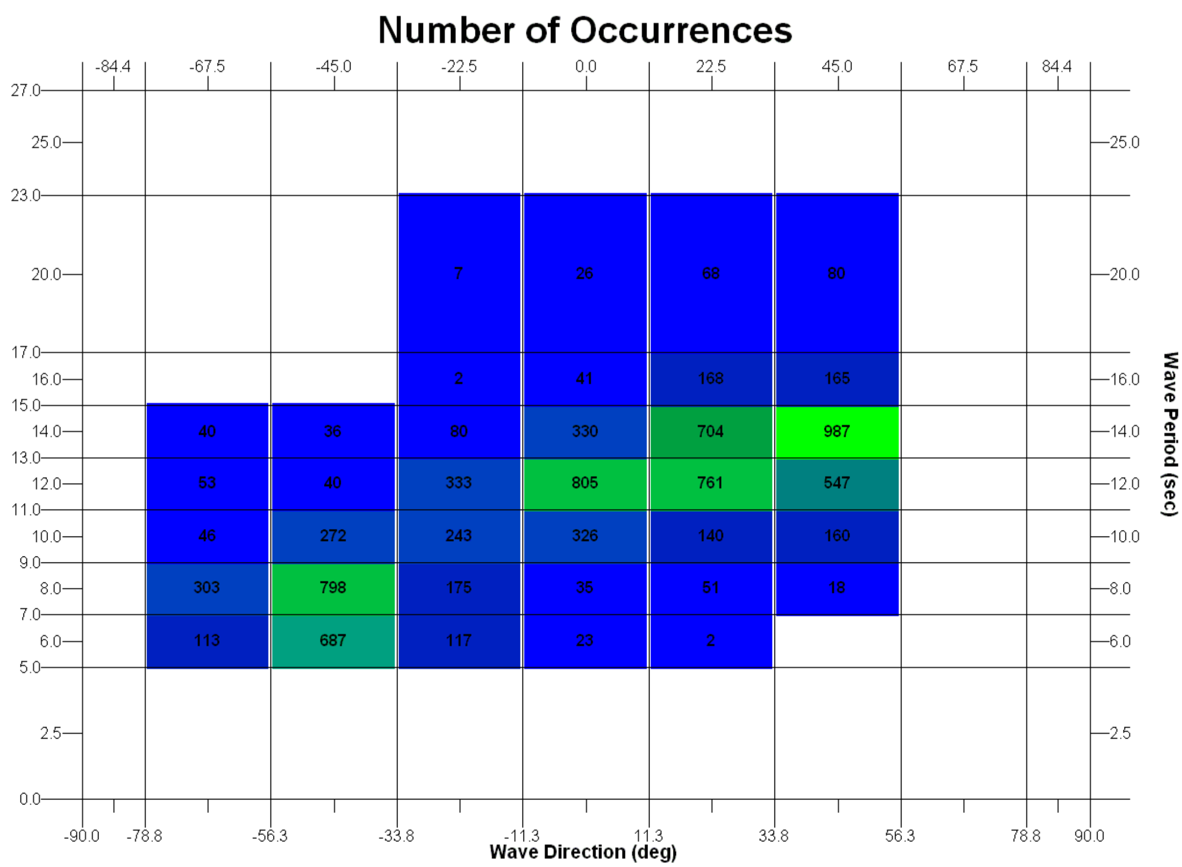


Figure B-17. 1992 number of occurrences for peak period and mean direction for WIS Station 102

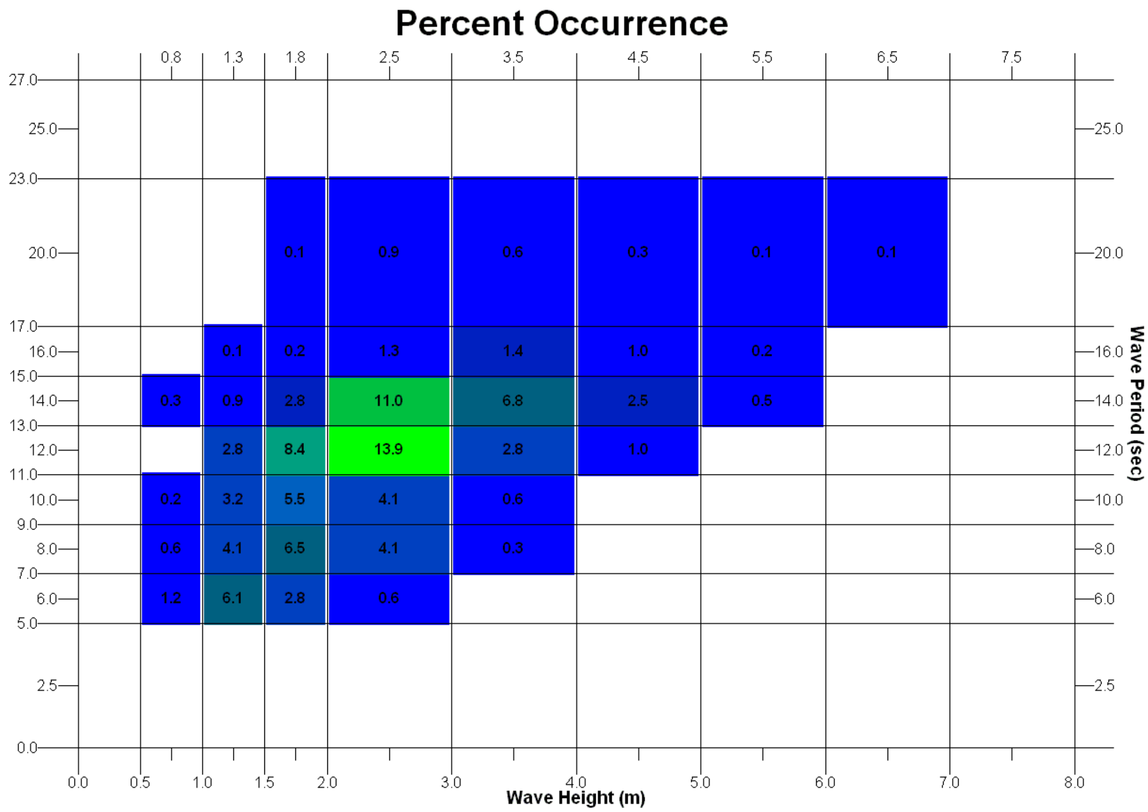


Figure B-18. 1992 percent occurrences for peak period and wave height for WIS Station 102.

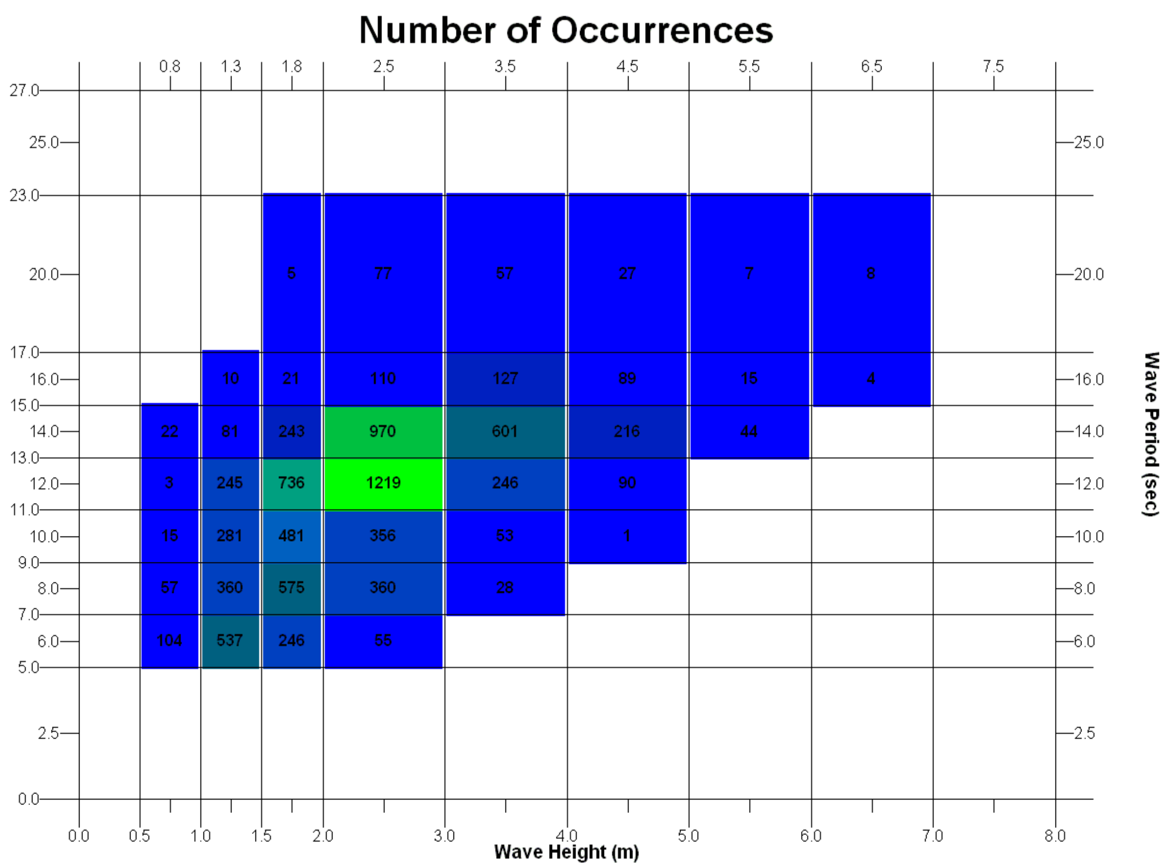


Figure B-19. 1992 number of occurrences for peak period and wave height for WIS Station 102

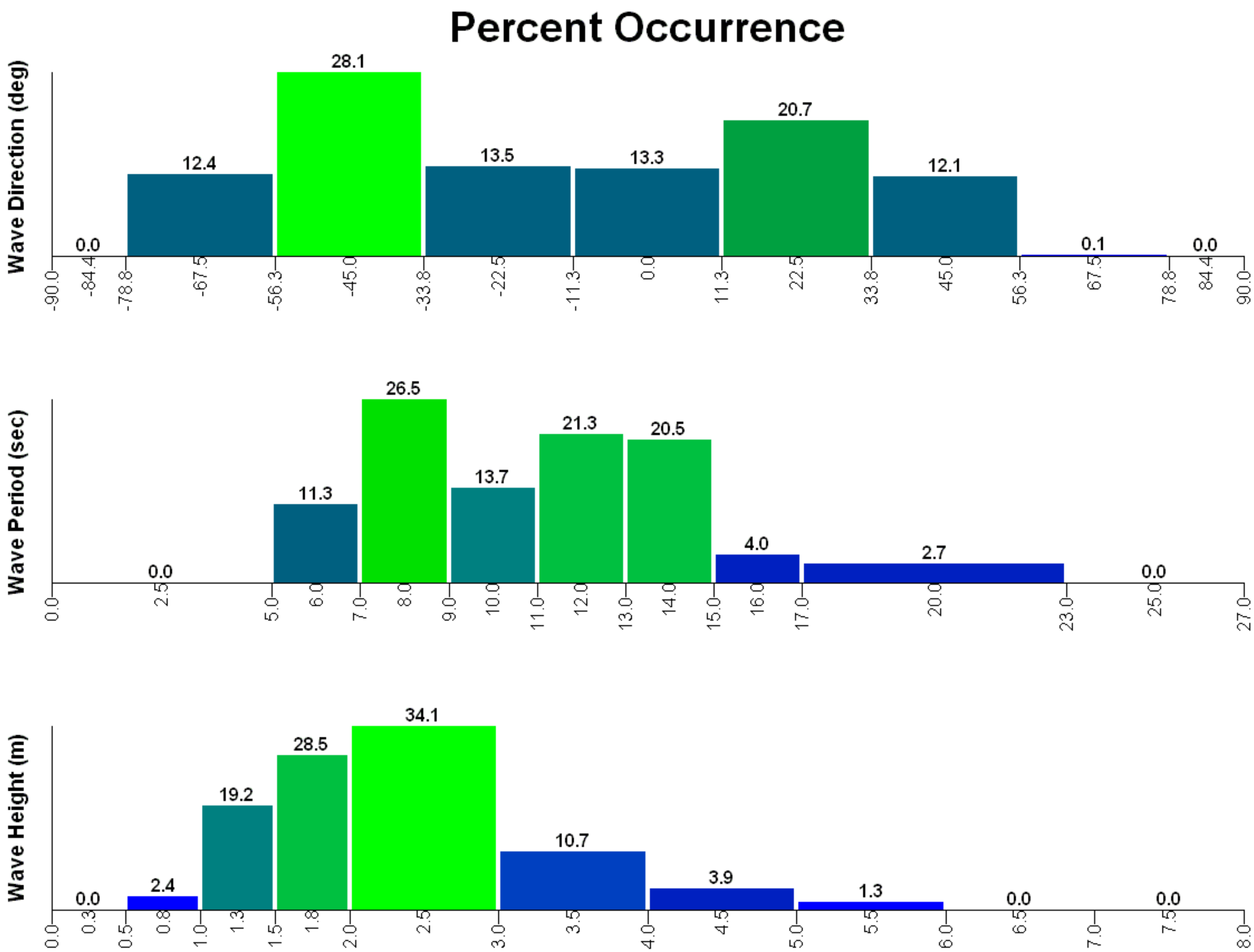


Figure B-20. 1994 percent occurrences for wave height, peak period, and mean direction for WIS Station 102.

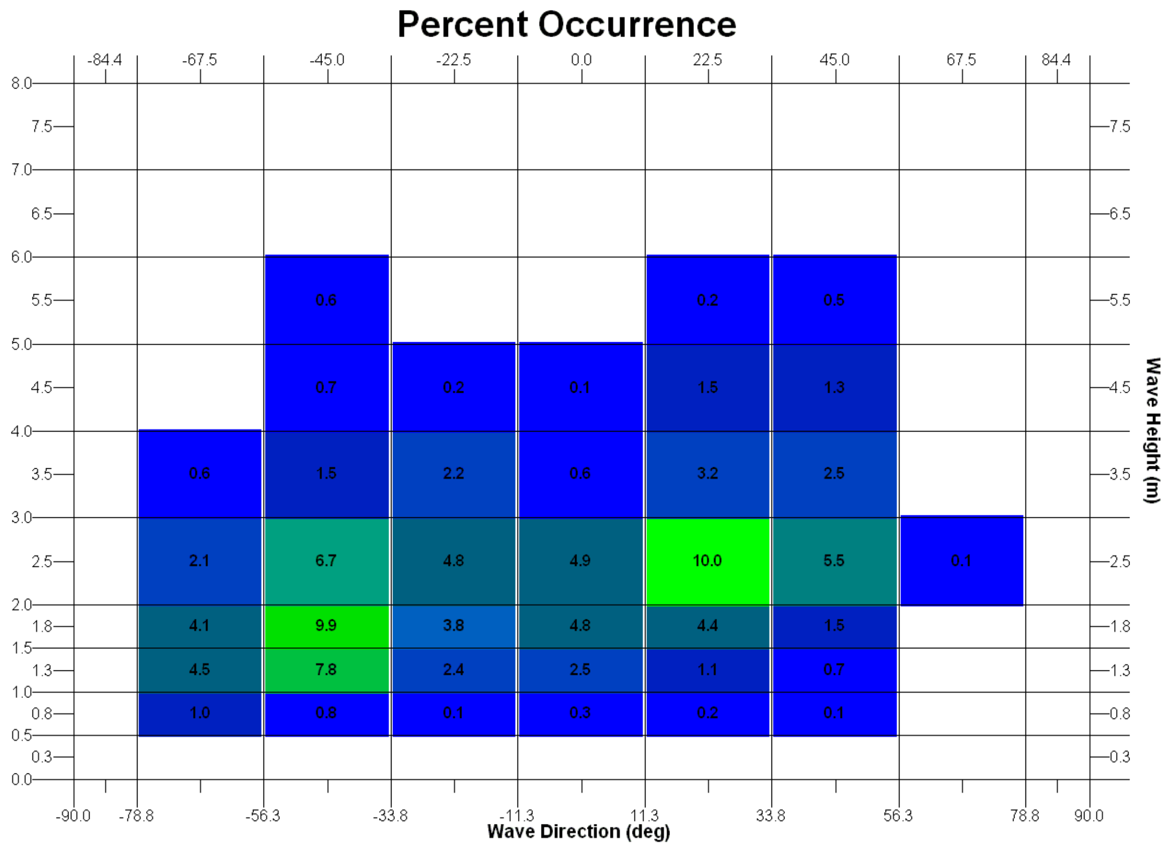


Figure B-21. 1994 percent occurrences for wave height and mean direction for WIS Station 102

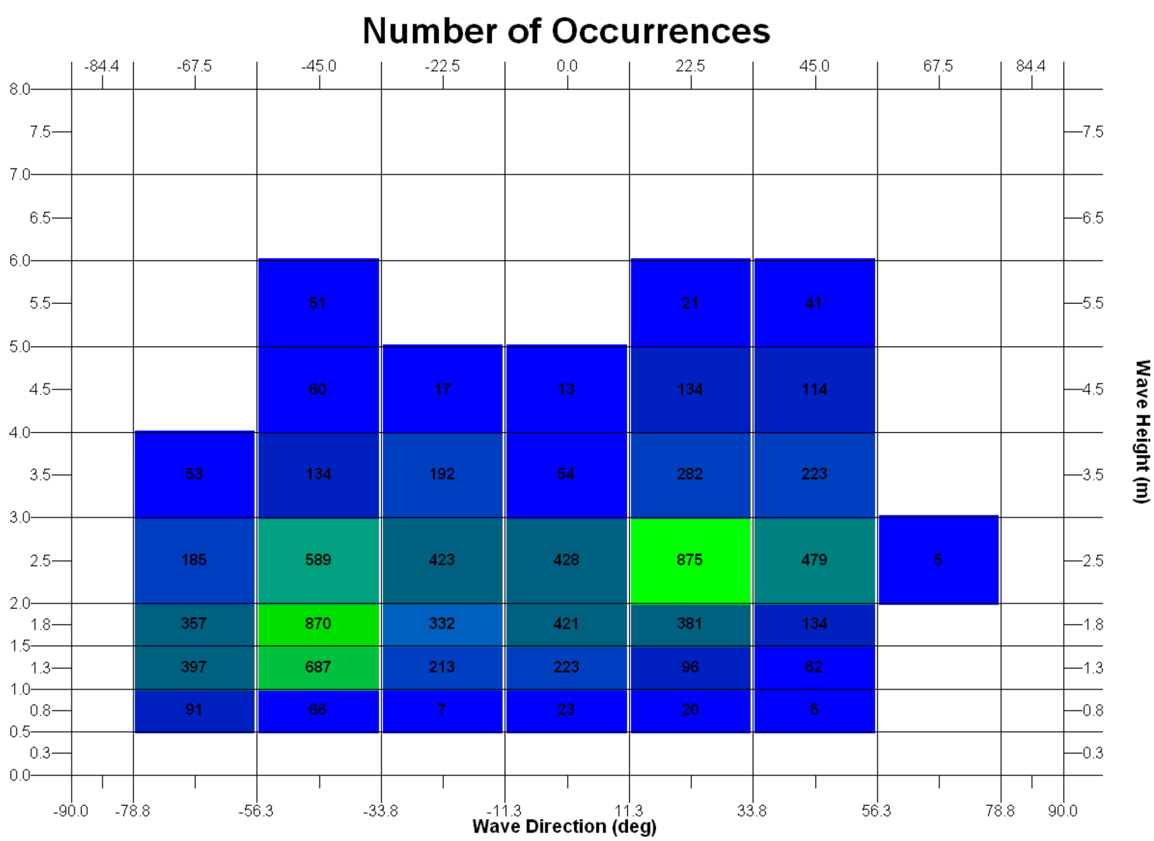


Figure B-22. 1994 number of occurrences for wave height and mean direction for WIS Station 102

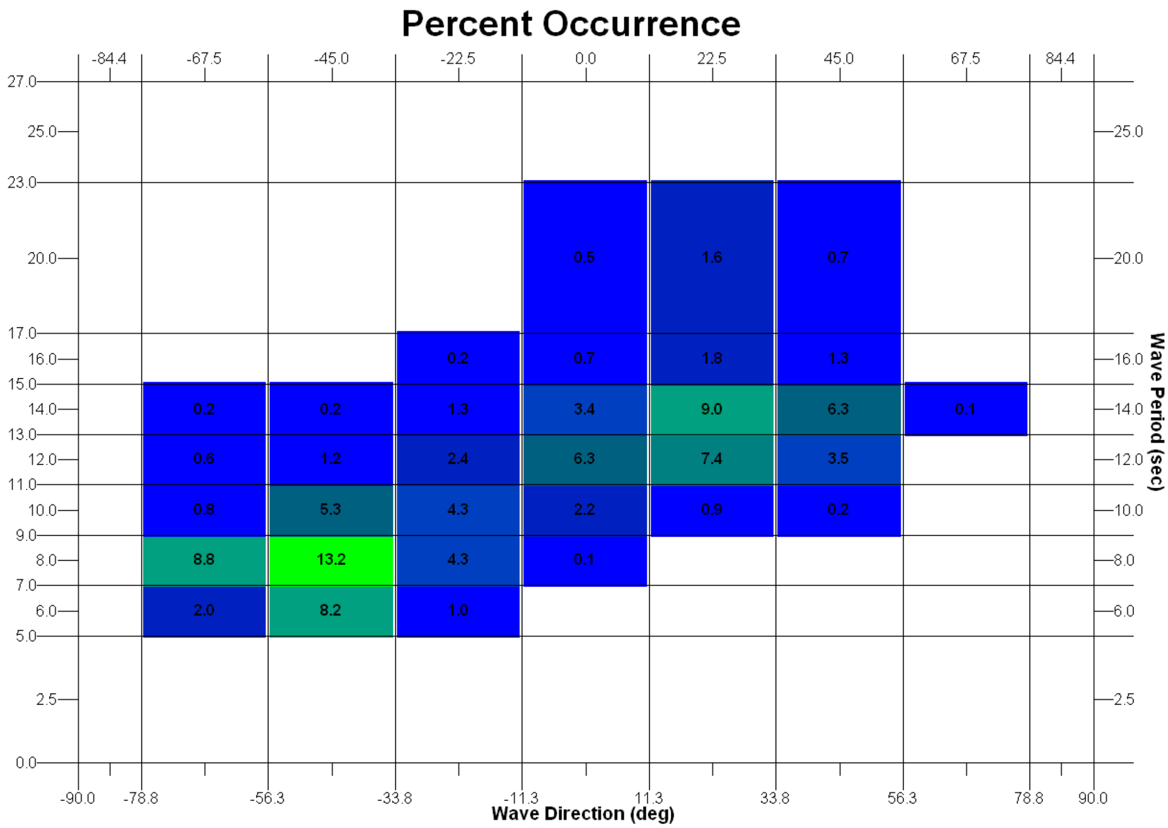


Figure B-23. 1994 percent occurrences for peak period and mean direction for WIS Station 102.

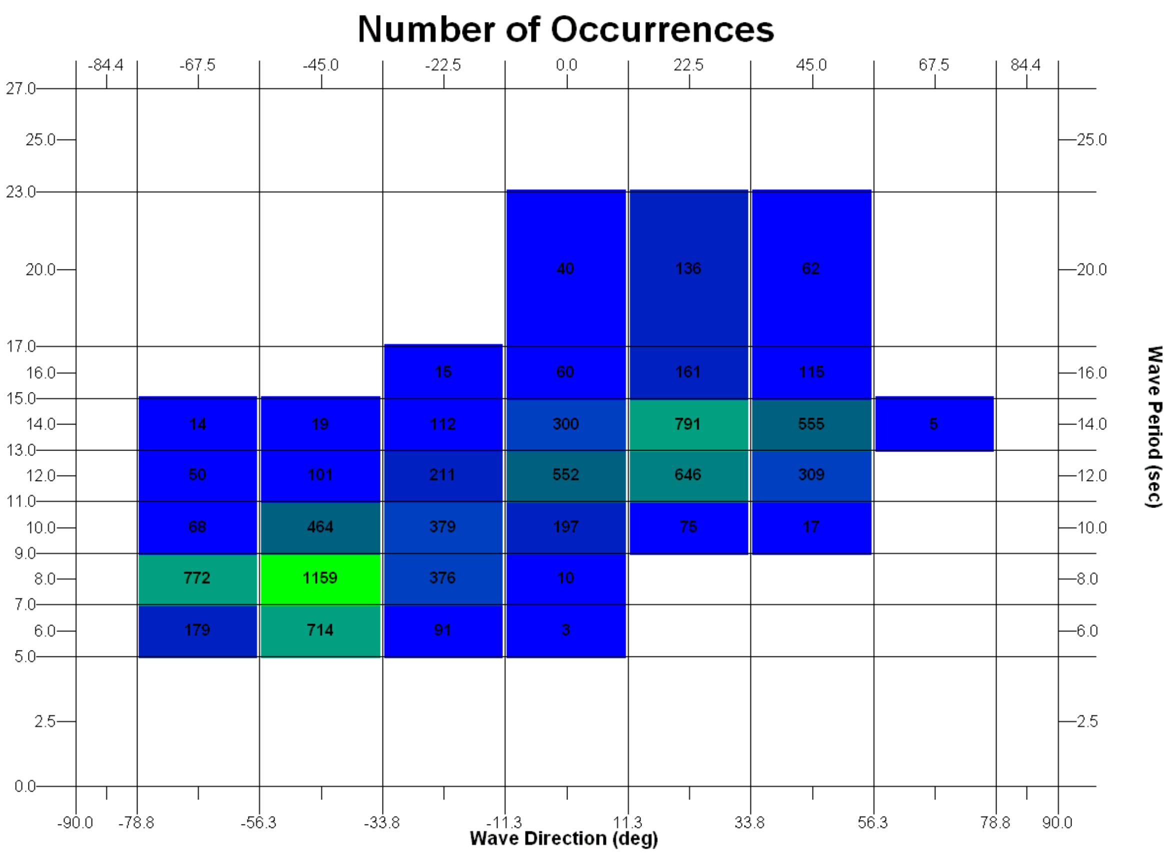


Figure B-24. 1994 number of occurrences for peak period and mean direction for WIS Station 102

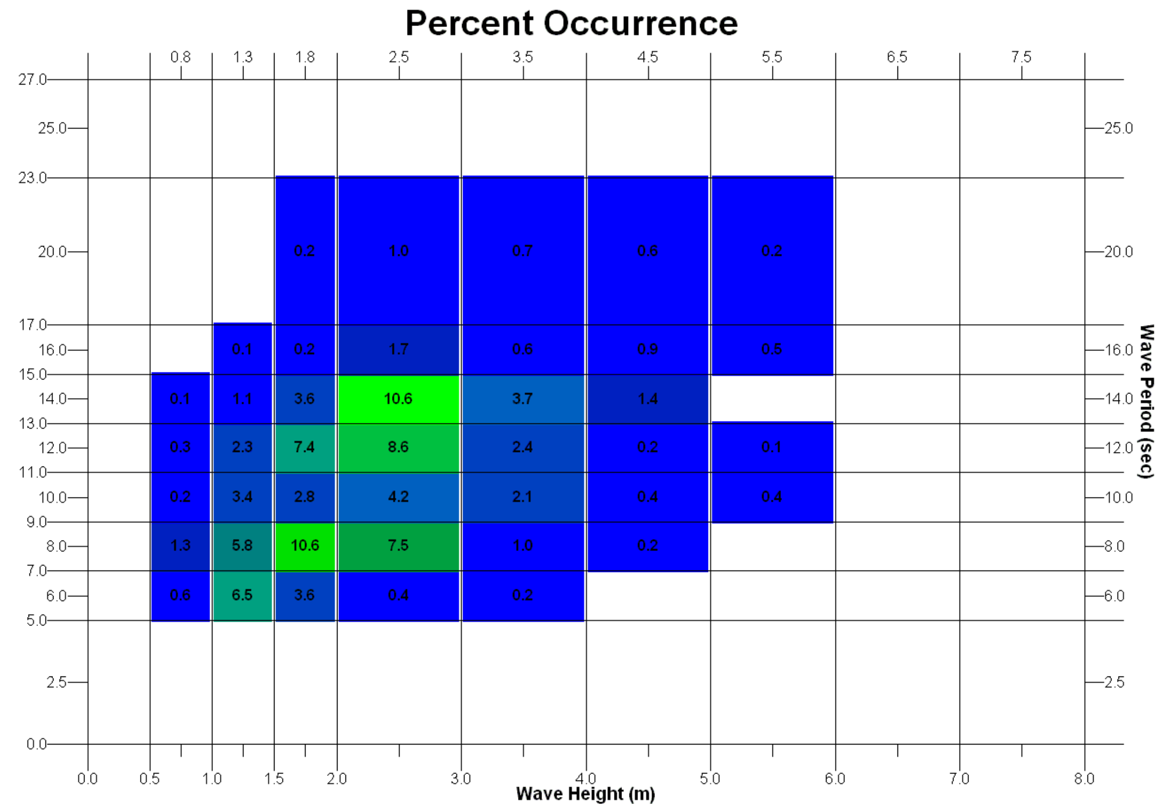


Figure B-25. 1994 percent occurrences for peak period and wave height for WIS Station 102.

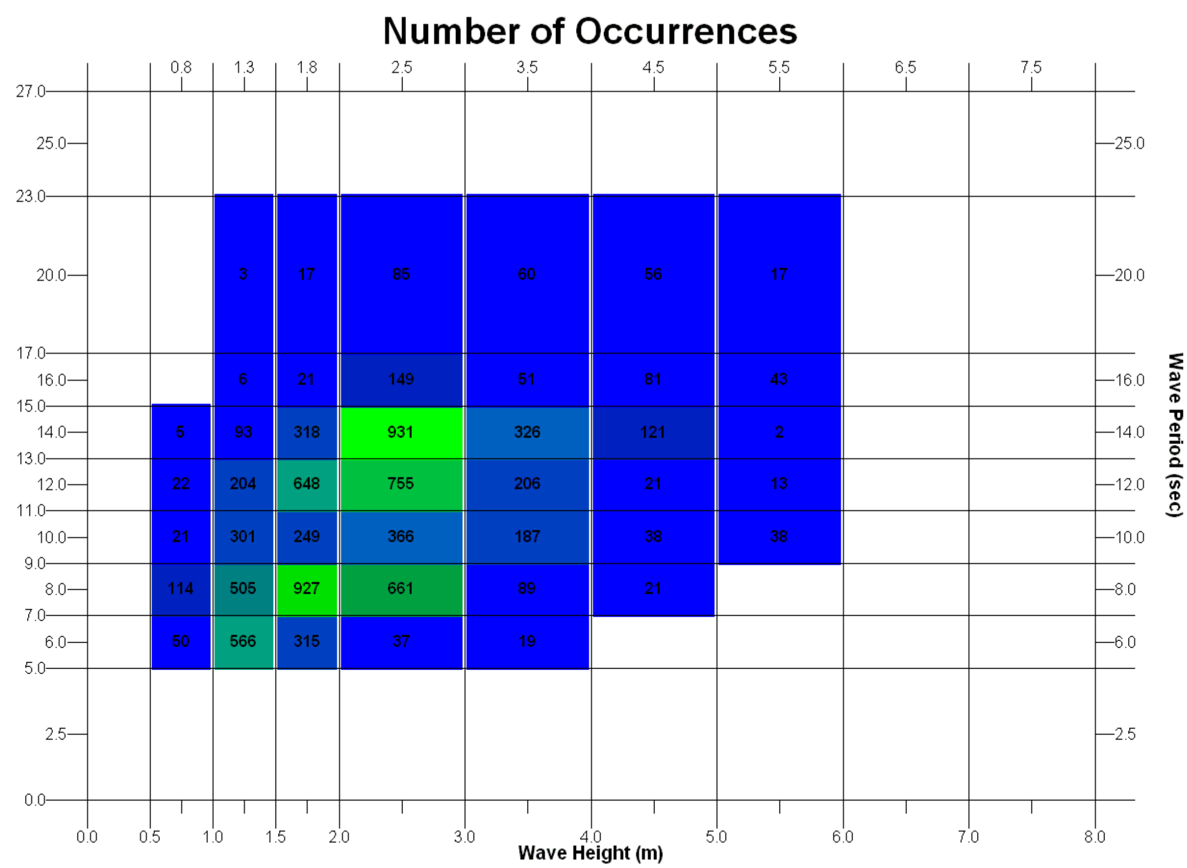


Figure B-26. 1994 number of occurrences for peak period and wave height for WIS Station 102

Table B-1 provides a summary of the mean and maximum wave statistics for the years 1984, 1992, and 1994. Tables B-2 and B-3 provide wave parameters used to complete nearshore wave model runs and to build a lookup table to be used in simulating nearshore wave climatology.

Table B-1. Mean and Maximum Statistics

	1984	1992	1994
Mean Wave Height (m)	2.1	2.3	2.2
Mean Peak Period (s)	11.3	11.3	10.8
Largest Wave Height (m)	5.8	6.4	5.9
Peak of Largest Height (s)	16.3	16.3	11.2
Direction Bin of Largest Height (deg)	337.5	315	45

Table B-2. Typical Conditions (392 conditions)

Significant Wave height, m	Wave period, sec	Wave Direction, deg from grid x-axis	Wave Direction, deg meteorological convention
0.5 (1)	6 (1)	-67.5 (1)	from 67.5 deg
1.0 (2)	8 (2)	-45 (2)	from 45 deg
1.5 (3)	10 (3)	-22.5 (3)	from 22.5 deg
2.0 (4)	12 (4)	0 (4)	from 0 deg
2.5 (5)	14 (5)	22.5 (5)	from 337.5 deg
3.0 (6)	16 (6)	45 (6)	From 315 deg
4.0 (7)	20 (7)	67.5 (7)	from 292.5 deg (sheltered)
5.0 (8)			

Table B-3. Extreme Conditions (30 conditions)

Significant Wave height, m	Wave Period, sec	Wave Direction, deg from STWAVE axis	Wave Direction, deg met convention
6 (9)	10 (3)	-45 (2)	from 45 deg
7 (10)	12 (4)	-22.5 (3)	from 337.5 deg
	14 (5)	45 (6)	from 315 deg
	16 (6)		
	20 (7)		

Nearshore STWAVE grids were generated for the Kahului and Kihei regions using the island-wide bathymetry data developed for the Surge and Wave Island Modeling Studies (SWIMS) being conducted by the US Army Corps of Engineers, the University of Hawaii, and Notre Dame University, in combination with high-resolution Light Detection and Ranging (LiDAR) data in the nearshore (from USACE Joint Airborne LiDAR Bathymetry Technical Center of Expertise). The SWIMS dataset incorporates various sources of data and was used for areas of deep water (> 30m), because it has relatively low resolution (~300 meters). The LiDAR data was used to augment shallow, nearshore areas, and has resolution as fine as 1 meter. The STWAVE grid encompasses the entire Kahului RSM region, as shown in Figure B-27 below, with a grid resolution of 50m.

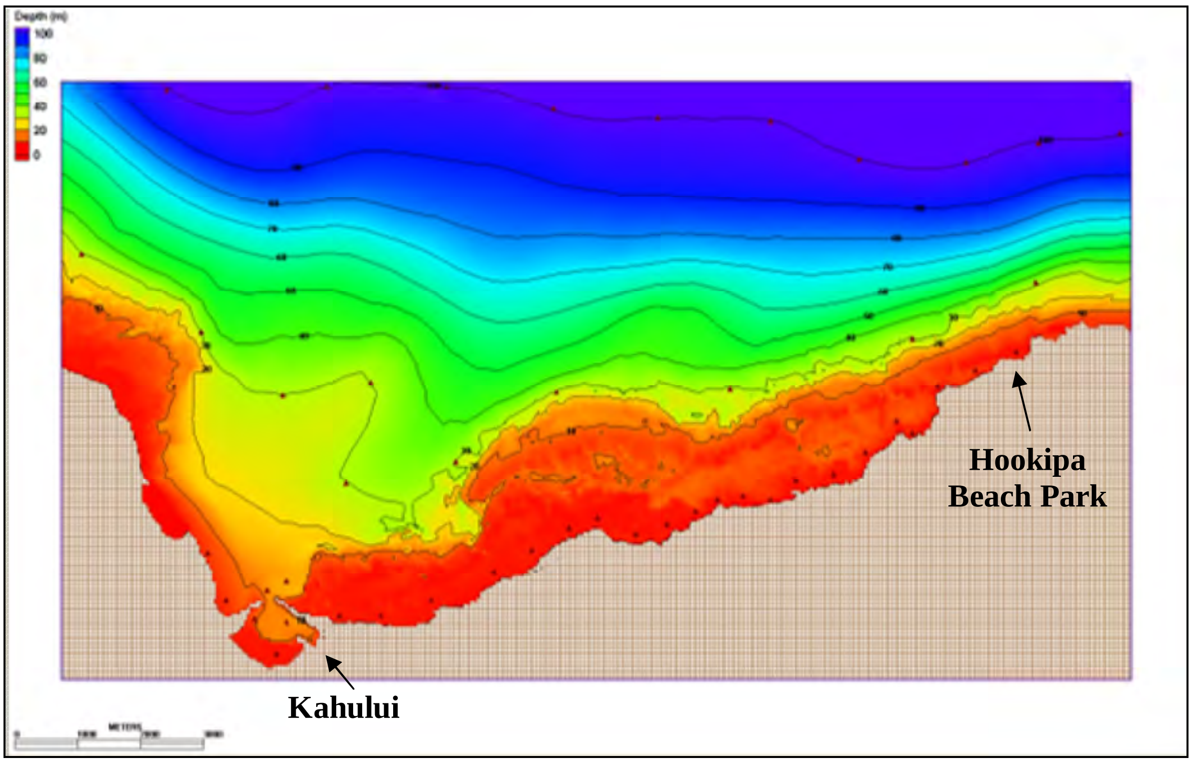


Figure B-27. STWAVE Grid Extents for Kahului Region (10-meter contours shown)

The Kahului region grid is oriented such that its offshore boundary (at approximately 100m depth) faces directly north at 0 degrees True North (TN). The bathymetry along the nearshore areas includes the well-resolved features of the reef and other features such as channels and headlands. Figure B-27 shows the features of Kahului Bay including Waihee Reef to the northwest of the harbor. A detailed view of the STWAVE grids in the nearshore areas adjacent to Kahului Harbor is shown in Figure B-28.

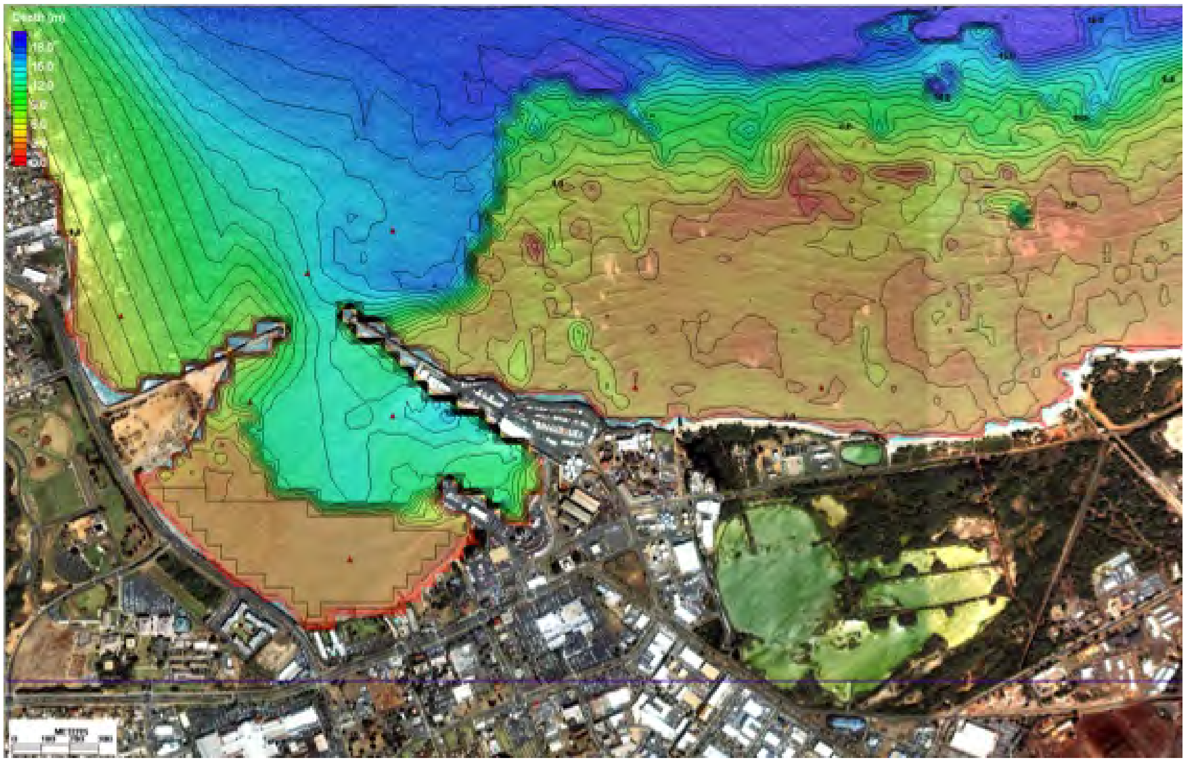


Figure B-28. STWAVE grid adjacent to Kahului Harbor in Kahului Region (1-meter contours shown)

Wave parameters from Tables B-2 and B-3 were used to generate wave input spectra for the Kahului grid. The parameters were entered into the Surfacewater Modeling System (SMS) and wave spectra files were generated for each case using the TMA (named for TEXEL, MARSEN and ARSLOE storm data sets) shallow water spectra option and the recommended values of n (directional peak spreading factor) and gamma (spectral peak spreading factor). These wave spectra were used to force the offshore boundary of each grid, and the wave transformation was carried out by STWAVE. Wave height (meters), wave period (seconds) and wave direction (degrees) were saved for each wave case at all ocean cells within the grid. An example of the resulting wave height information (in color) and wave direction (arrows) for the Kahului grid is shown in Figure B-29. In addition, observation points were placed along the nearshore at approximately 1 to 3 meters depth, and along the 30 m and 100 m contours (also visible in Figure B-29 as black squares). Wave parameters for these selected locations were saved in a separate file for use in the next step of the process.

A database (or "lookup table") of wave parameters that correlates the most frequent offshore wave conditions at the WIS station (from Tables B-2 and B-3) to the resulting nearshore wave conditions at the selected observation points has been developed from the application of STWAVE for several hundred wave transformations for each region.

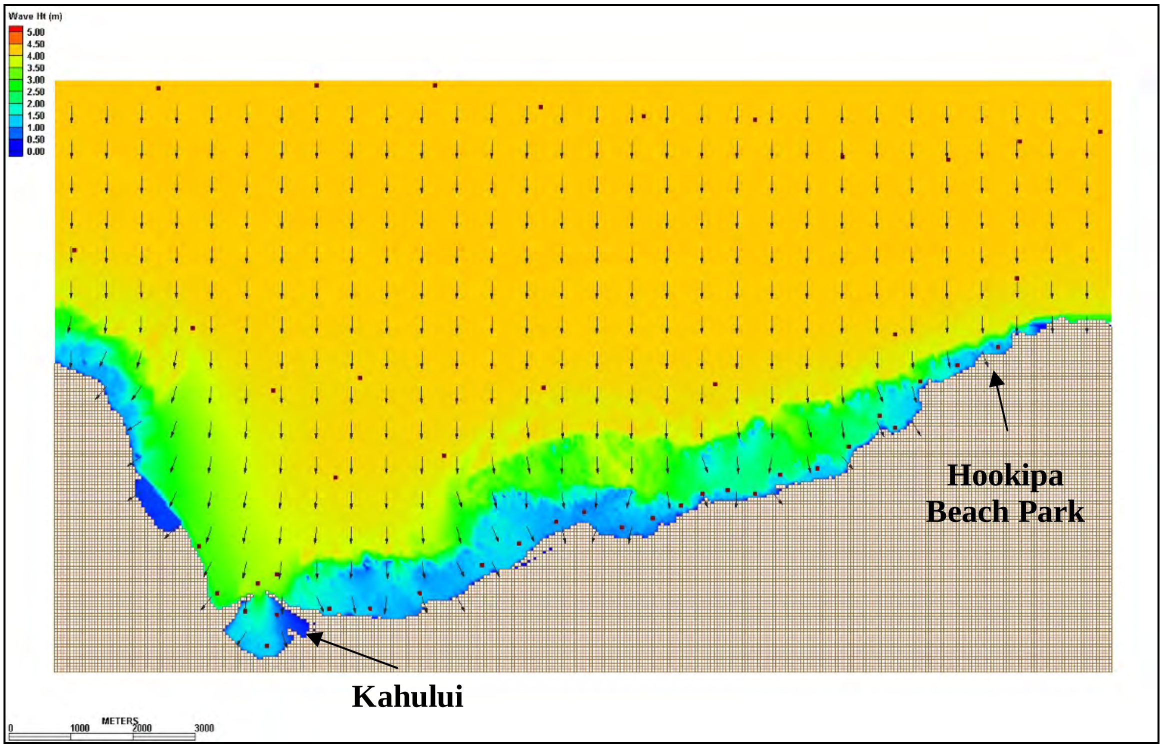


Figure B-29. Resulting wave height (color scale) and Wave Direction (arrows) in Kahului Region for Case 724 (Ho = 4m, T= 8s, Dir=0 TN) and Location of Observation Points (black squares)

The next step carried out was to develop a FORTRAN program to automate the "lookup table" process, so that the hourly time series of wave data from the three representative years (1984, 1992, and 1994) of WIS data could be converted to nearshore wave parameters at each observation point. This program required inputs of the WIS time series data, the output wave parameter file from the STWAVE runs, as well as a file denoting the angle of the "onshore" direction (relative to TN) at each nearshore observation point so that a relative wave angle could be determined. Since it was not possible to model each specific wave case that occurs in the WIS time series, the hourly parameter data was binned to find the closest matching wave case that was defined in the model runs. If no such case existed, the program returned a result of 0.0 and the nearshore wave parameters were not calculated for that time step. Since the most frequent wave occurrences were determined as described previously, it is assumed that this condition does not represent a significant quantity of the WIS time series, and therefore the nearshore wave climate. A cursory examination of output files suggests this condition occurred < 5% of the time. An output nearshore time series including all three years of WIS data was calculated for each nearshore observation point, in the Kahului grid. A portion of an output file resulting from the application of the FORTRAN program is shown in Figure B-30 for reference. Output parameters are date/ time, wave height, wave period, wave direction (relative to shoreline) and wave direction (relative to TN).

26322		1	0		1	0
1984010100	0.942	10.0	-10.0	346.0		
1984010101	0.948	10.0	0.0	336.0		
1984010102	0.959	10.0	0.0	336.0		
1984010103	0.974	10.0	0.0	336.0		
1984010104	0.996	10.0	0.0	336.0		
1984010105	1.024	10.0	0.0	336.0		
1984010106	1.061	12.5	-3.0	339.0		
1984010107	1.106	12.5	-3.0	339.0		
1984010108	0.868	12.5	-2.0	338.0		
1984010109	0.911	12.5	-2.0	338.0		
1984010110	0.957	12.5	-2.0	338.0		
1984010111	0.985	12.5	-10.0	346.0		
1984010112	1.030	12.5	-10.0	346.0		
1984010113	1.075	12.5	-10.0	346.0		
1984010114	0.898	12.5	-9.0	345.0		
1984010115	0.934	12.5	-9.0	345.0		
1984010116	0.966	12.5	-9.0	345.0		
1984010117	0.997	12.5	-9.0	345.0		
1984010118	1.025	12.5	-9.0	345.0		
1984010119	1.050	12.5	-9.0	345.0		
1984010120	0.894	12.5	-9.0	345.0		
1984010121	0.910	12.5	-9.0	345.0		
1984010122	0.924	12.5	-9.0	345.0		
1984010123	0.937	12.5	-9.0	345.0		
1984010200	0.950	12.5	-9.0	345.0		
1984010201	0.941	14.3	-11.0	347.0		
1984010202	0.959	14.3	-11.0	347.0		
1984010203	0.982	14.3	-11.0	347.0		
1984010204	1.009	14.3	-11.0	347.0		
1984010205	1.041	14.3	-11.0	347.0		
1984010206	1.042	14.3	-11.0	347.0		
1984010207	1.079	14.3	-11.0	347.0		
1984010208	0.840	14.3	-11.0	347.0		
1984010209	0.842	16.7	-12.0	348.0		
1984010210	0.870	16.7	-12.0	348.0		
1984010211	0.896	16.7	-12.0	348.0		

Figure B-30. Sample Nearshore Observation Point Time Series Output File from FORTRAN Program (Date/time, Wave Height (m), Wave Period (s), Wave Direction (relative degrees), Wave Direction (relative TN))

Finally, the time series for each observation point was used to develop a histogram for that location indicating the percent occurrence of wave approach direction (separated into 10 degree direction bins) as well as the frequency of significant wave height within each wave bin (separated into 0.5m wave height bins). An example histogram for an observation point near the Kahului Wastewater Plant is shown in Figure B-31. This figure shows that 21% of waves during the 3 selected years approached from 350-360 degrees TN, and that the wave heights at this location were in the 0.5 to 1.0m and 1.0 to 1.5 m ranges. Similarly, 64% of waves approached from 0 – 10 degrees TN, also within the 0.5 to 1.0m and 1.0 to 1.5 m ranges. Finally, 15% of waves approached from 10-20 degrees TN, however the wave heights from this direction were lower in the 0 to 0.5m and 0.5 to 1.0m ranges. Another histogram of an observation point outside the entrance to Kahului Harbor is shown in Figure B-32, and indicates a larger variability in significant wave height and direction. This would be expected due to the greater depth and exposure of the observation point outside the harbor.

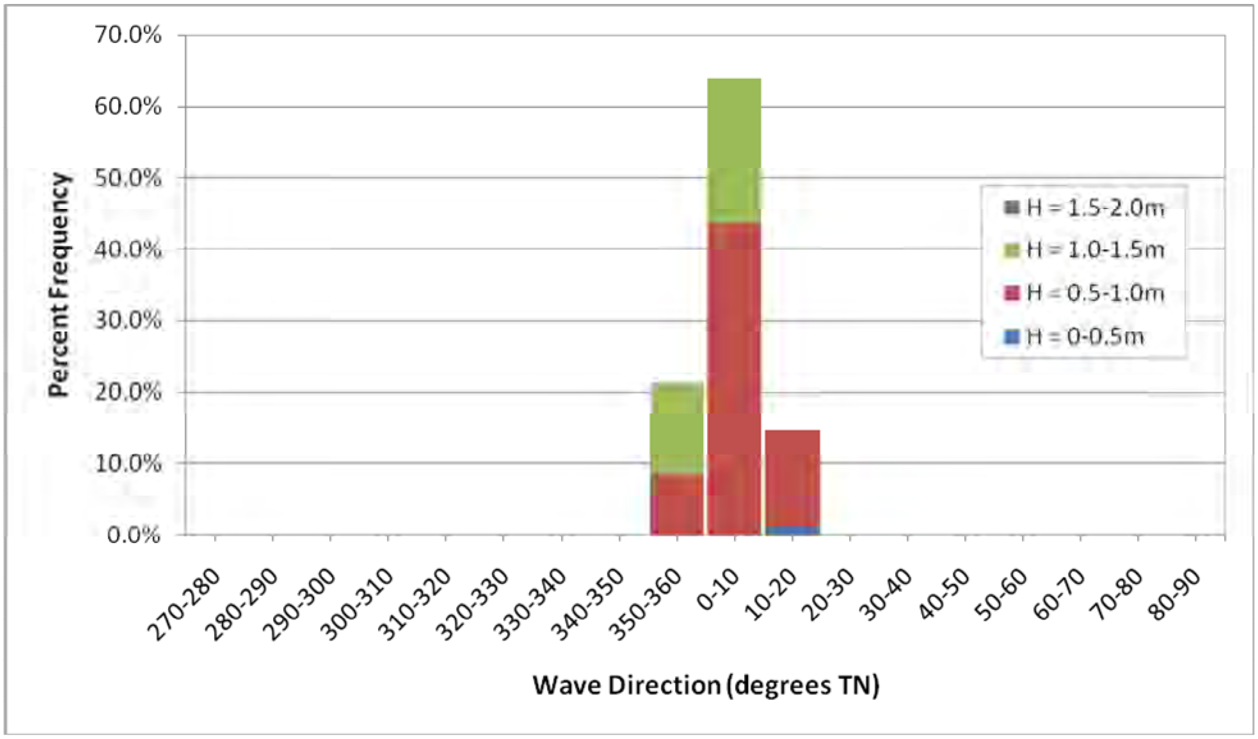


Figure B-31. Histogram of Wave Height and Direction at Nearshore Observation Point Close to Kahului Wastewater Plant (Shore normal = 7 degrees TN)

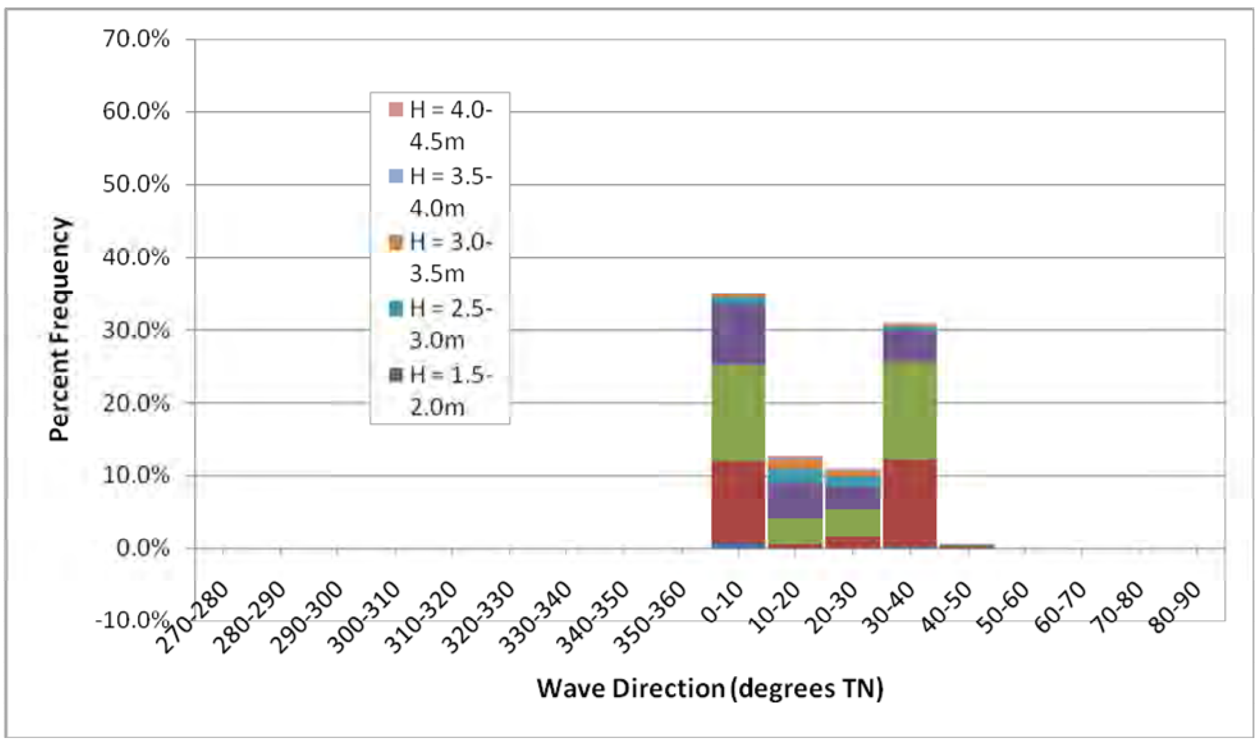


Figure B-32. Histogram of Wave Height and Direction at Nearshore Observation Point at Entrance to Kahului Harbor (Shore normal = 55 degrees TN)

APPENDIX C

WAVE TRANSFORMATION MODELING – KIHEI REGION (USACE 2011)

Kihei, Maui, RSM Waves

Kihei is on the south shore of the Maui with exposure to waves arriving from approximately 160 to 270 deg. The closest Wave Information Studies (WIS) save point is Station 113 located at 20 deg North and 156.5 deg West in a depth of 3659 m. Station 113 is shown in Figure C-1 with a yellow circle. Station 113 was selected because it is the closest to the site of interest and has a similar wave exposure. A wave rose for Station 113 for 1981-2004 is given in Figure C-2. The wave rose shows distribution of wave height with wave direction. Large wave heights are prevalent from northwest and northeast at this WIS station, but the waves are sheltered by southern part of Maui, Kahoolawe, Lanai and Molokai for the Kihei region.

Three representative years were chosen for further study and nearshore wave transformation. The three years include a low wave condition year (1984), a medium wave condition year (1992) and a high wave condition year (1994). Figures C-3, C-4, and C-5 show compressed time series of the years 1984, 1992 and 1994 at Station 113.

Percent and number of occurrence plots are shown in Figures C-6 through C-12 for 1984, in Figures C-13 through C-19 for 1992, and Figures C-20 through C-26 for 1994. The directions on these plots are relative to the normal of the local wave grid (0 deg in the relative system is a wave from south, +45 deg is 135 deg, and -45 deg is 225 deg). The plots are useful in assessing wave height, period, and direction combinations to be run for the nearshore wave transformation analysis.

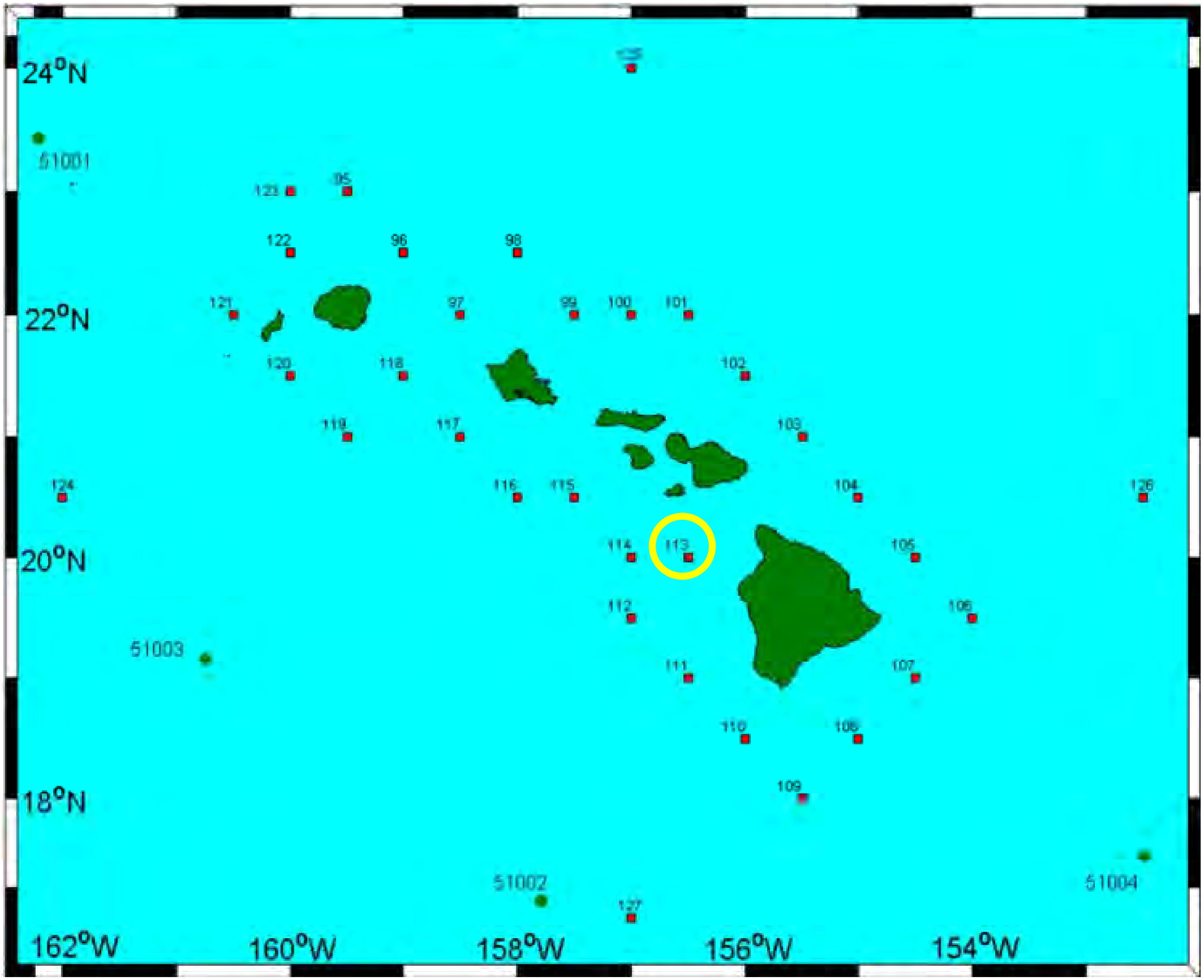


Figure C-1. WIS Station Map – Kihei Region

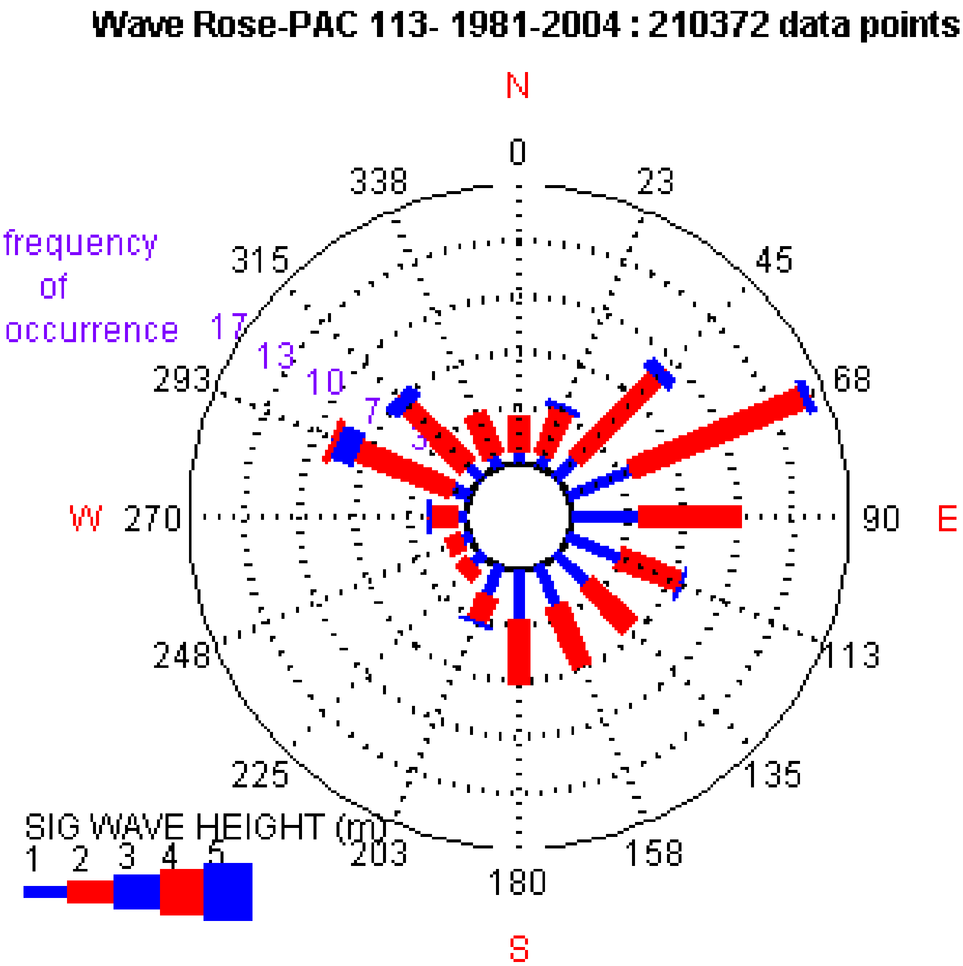


Figure C-2. Wave Rose for 1981-2004 for WIS Station 113.

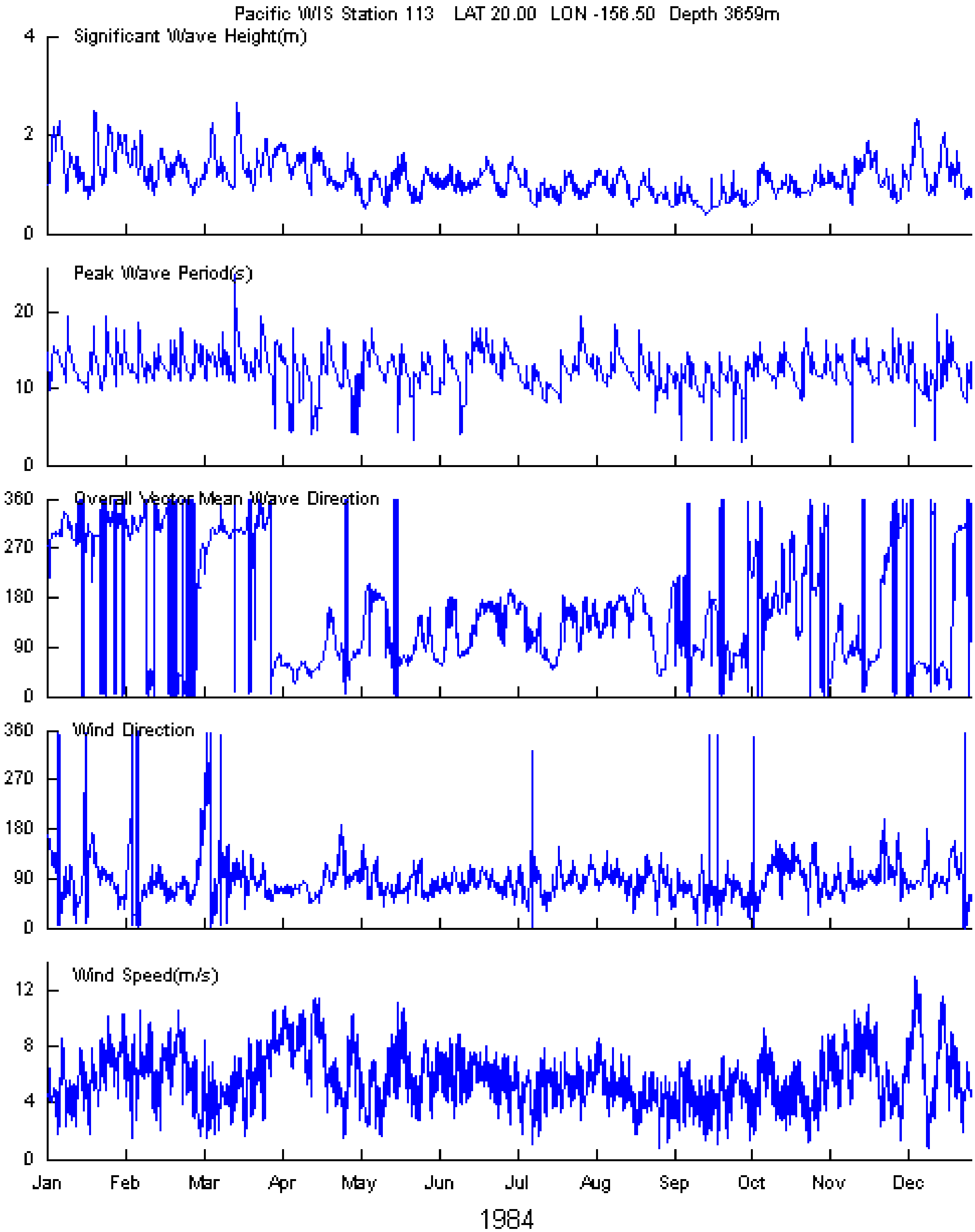


Figure C-3. 1984 wave and wind time histories for WIS Station 113.

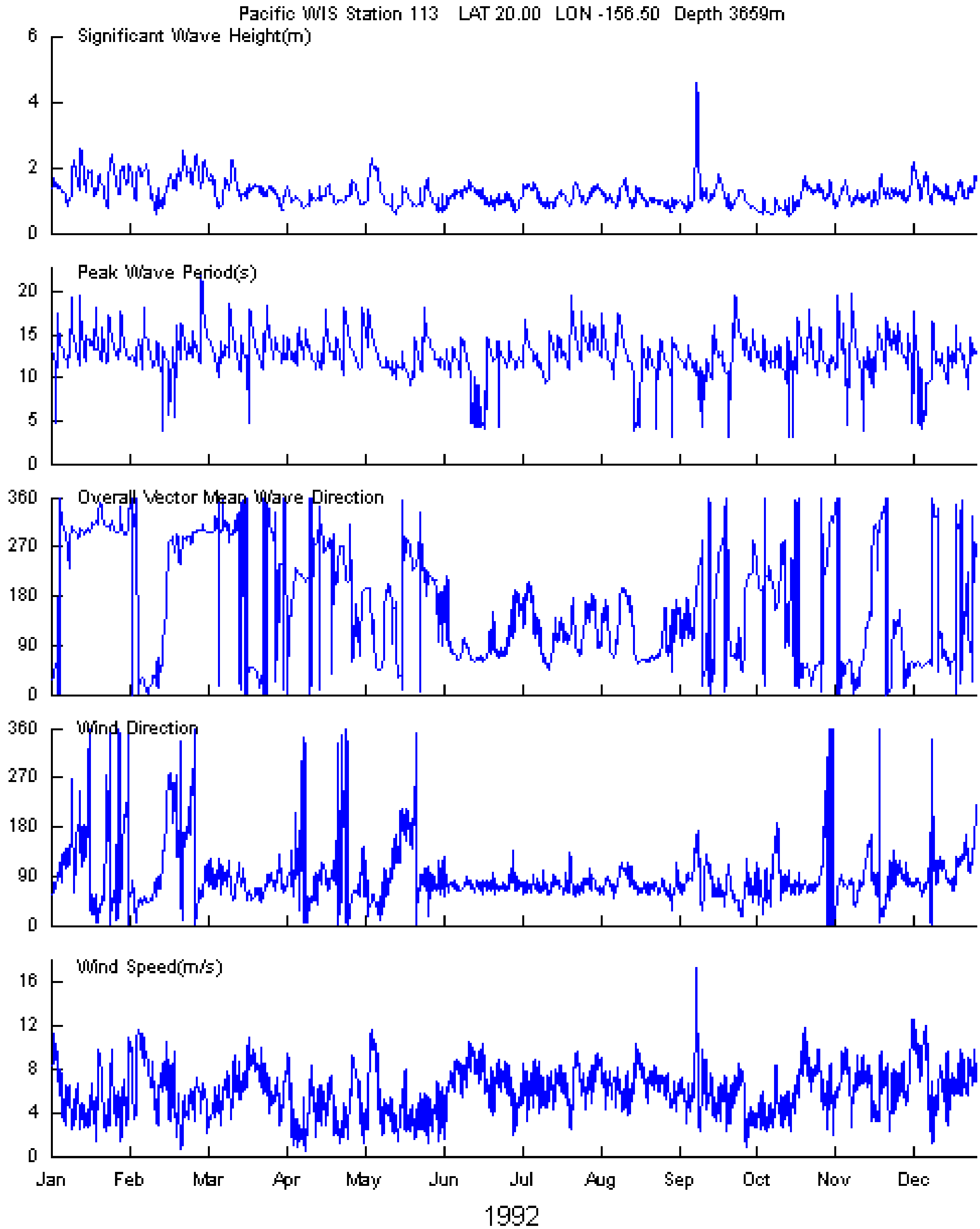


Figure C-4. 1992 wave and wind time histories for WIS Station 113.

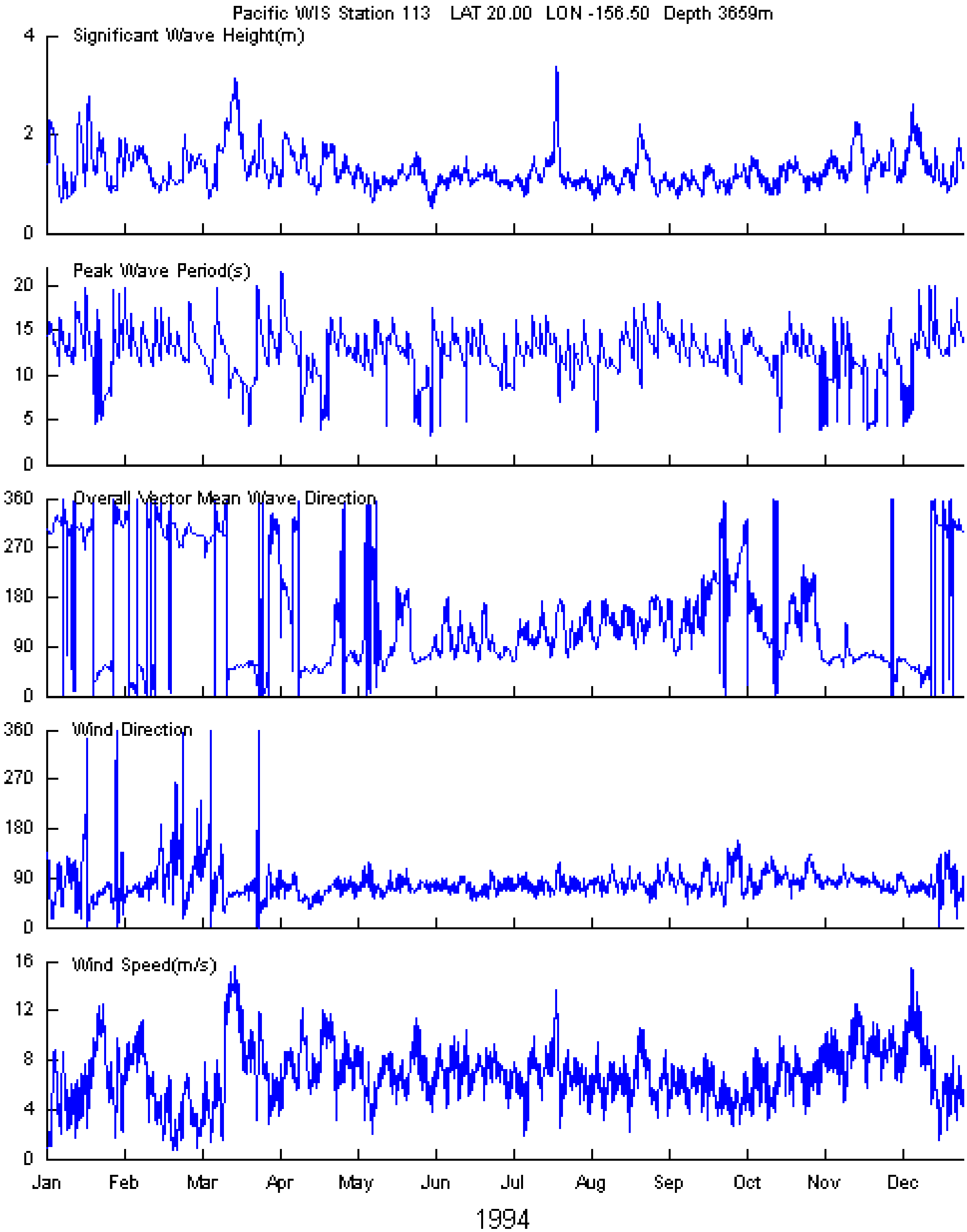


Figure C-5. 1994 wave and wind time histories for WIS Station 113.

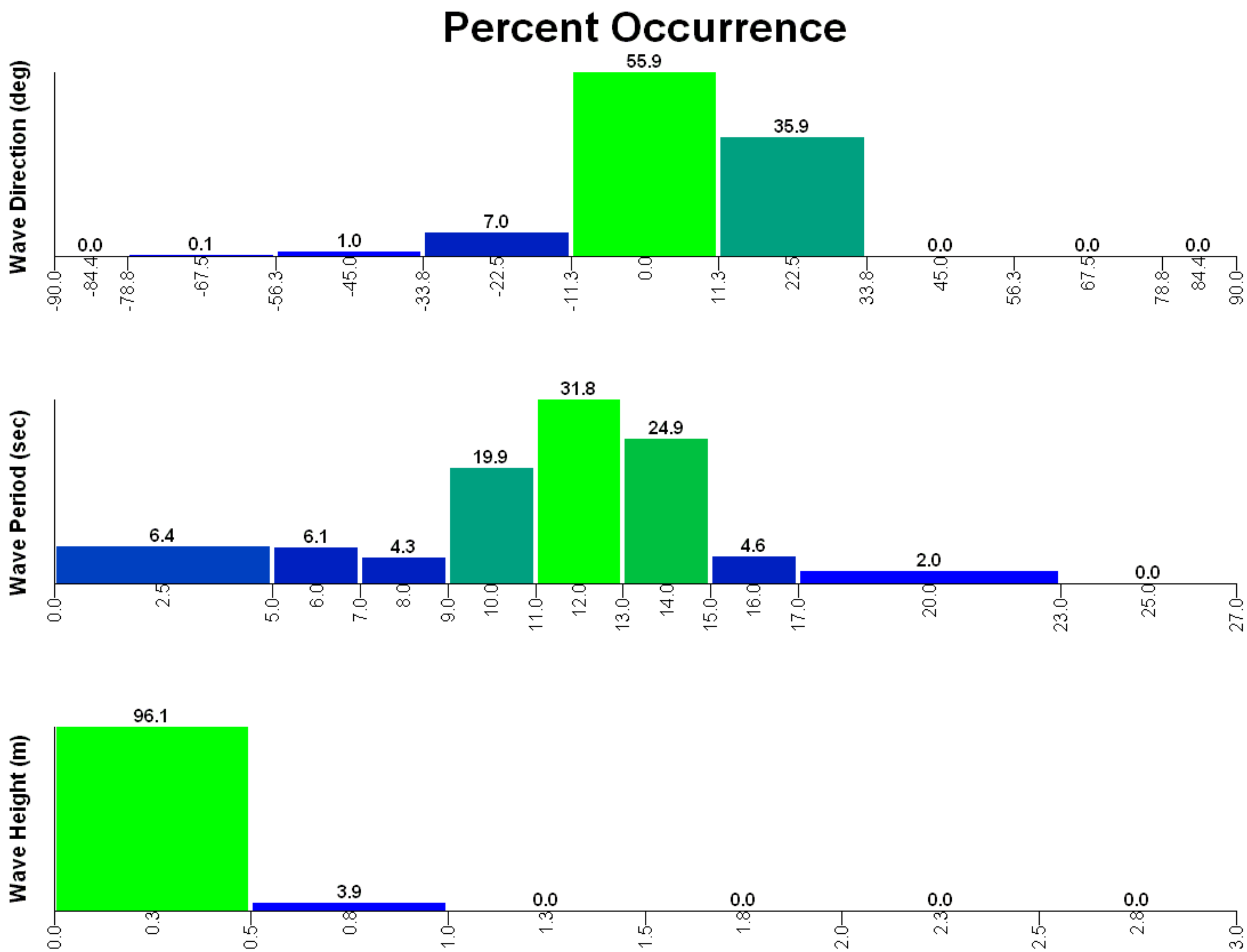


Figure C-6. 1984 percent occurrences for wave height, peak period, and mean direction for WIS Station 113.

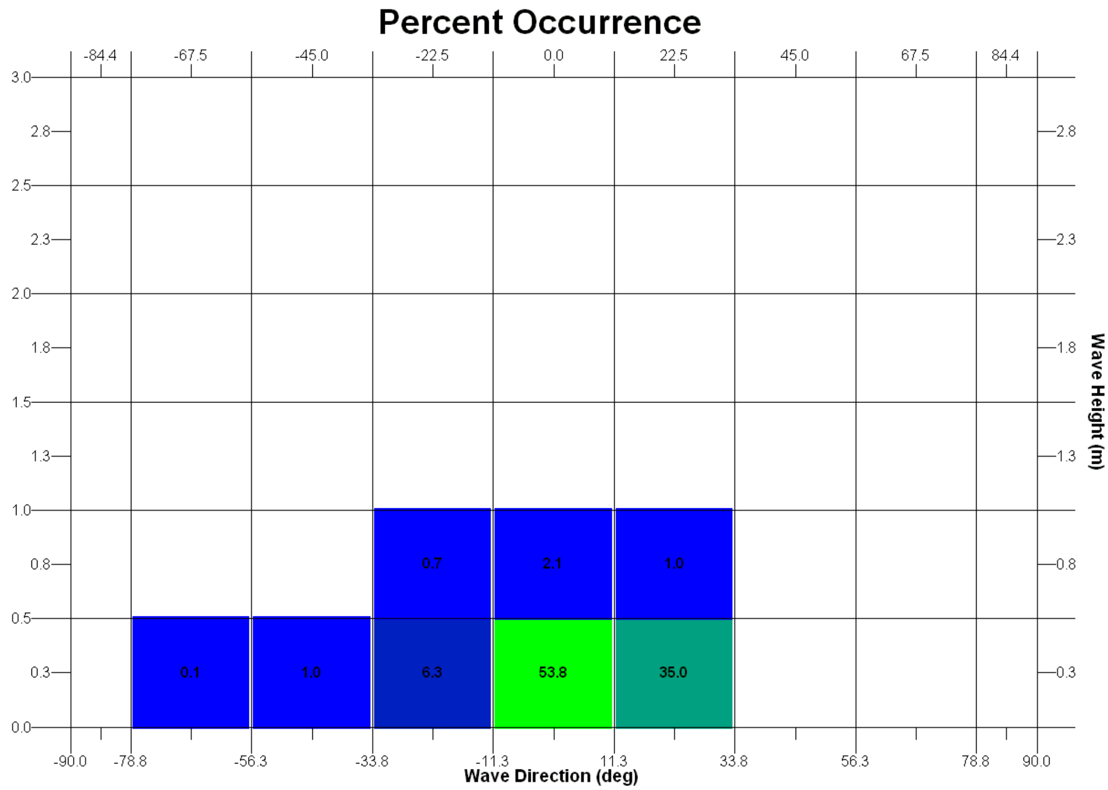


Figure C-7. 1984 percent occurrences for wave height and mean direction for WIS Stn 113

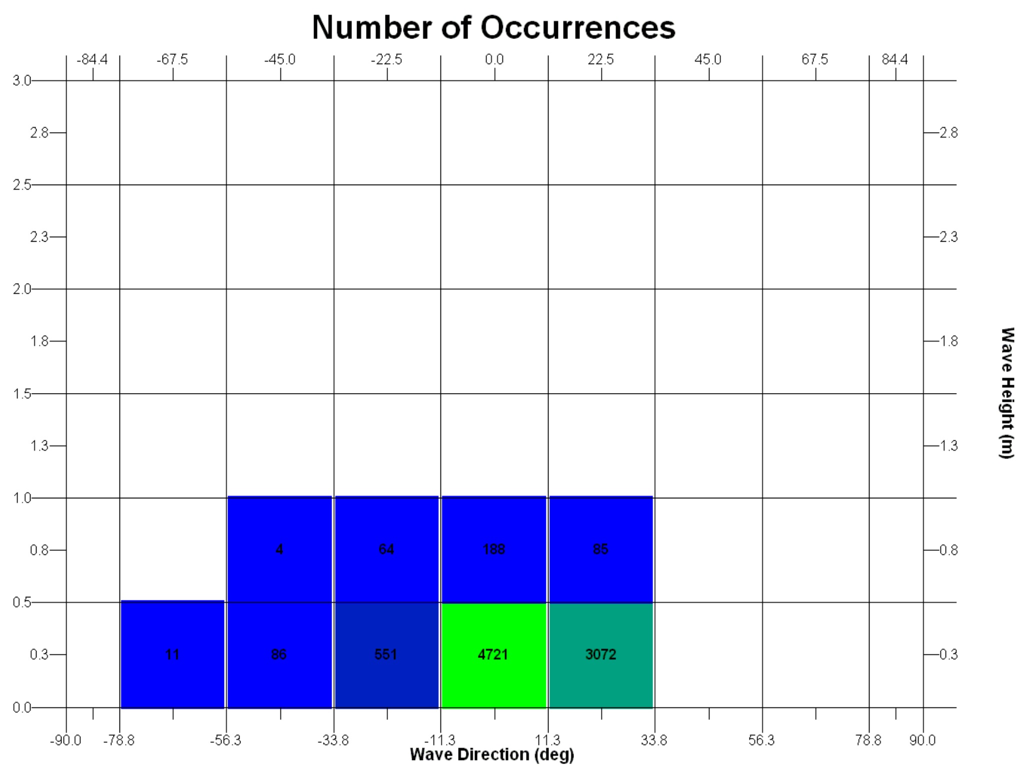


Figure C-8. 1984 number of occurrences for wave height and mean direction for WIS Station 113.

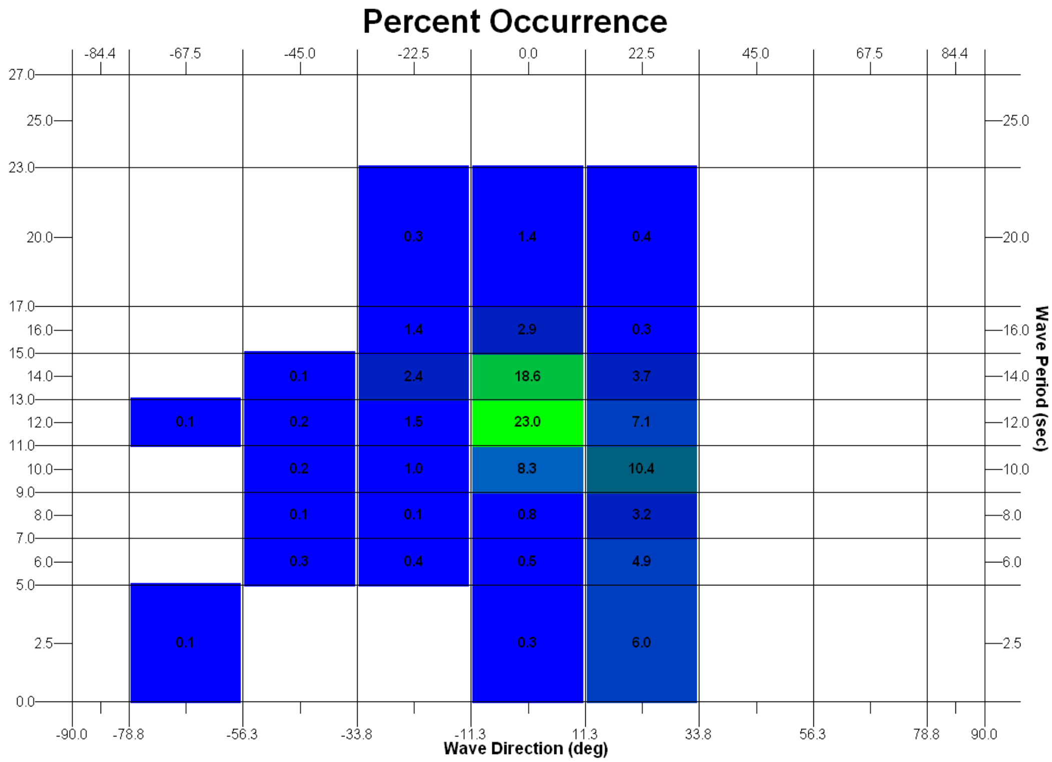


Figure C-9. 1984 percent occurrences for peak period and mean direction for WIS Station 113.

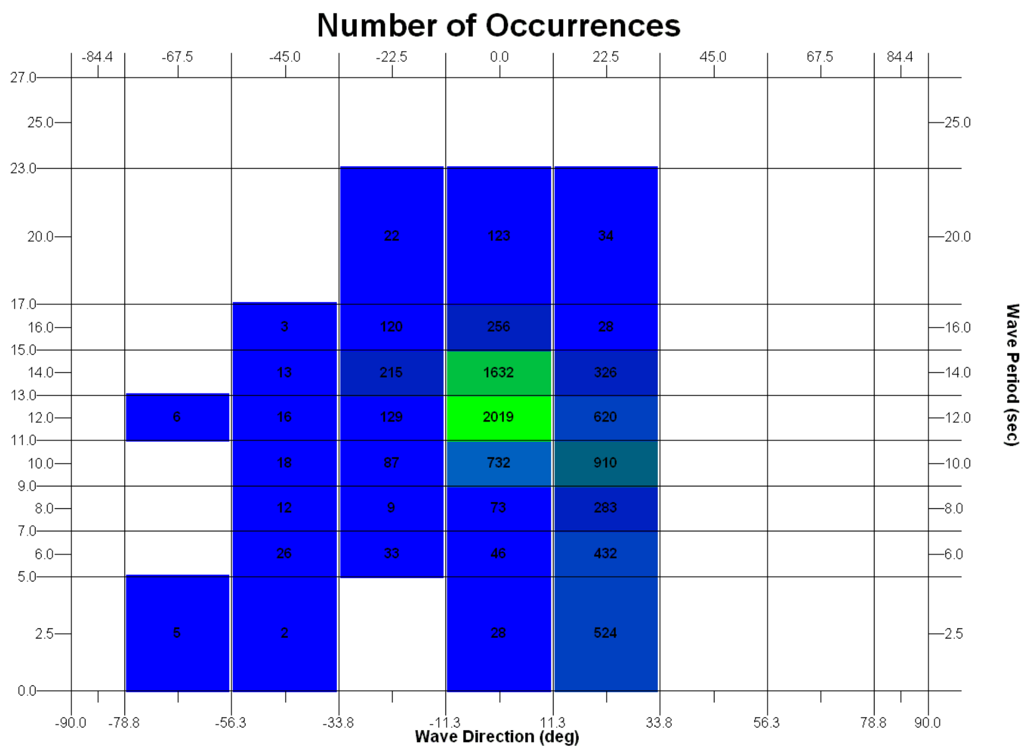


Figure C-10. 1984 number of occurrences for peak period and mean direction for WIS Station 113.

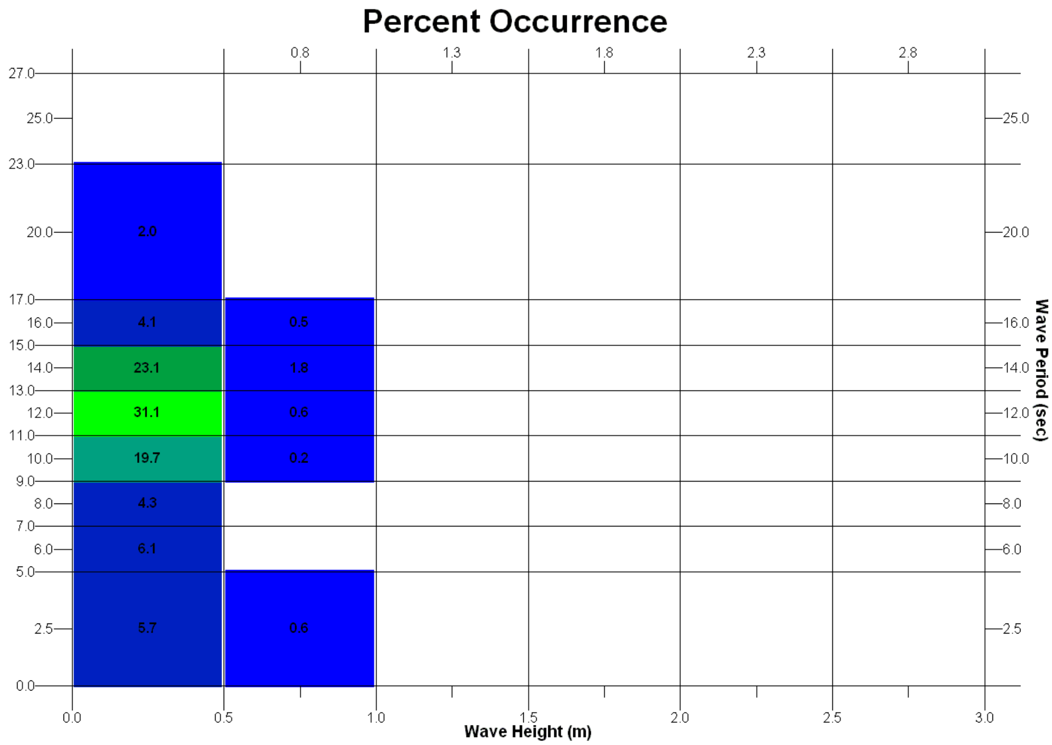


Figure C-11. 1984 percent occurrences for peak period and wave height for WIS Station 113.

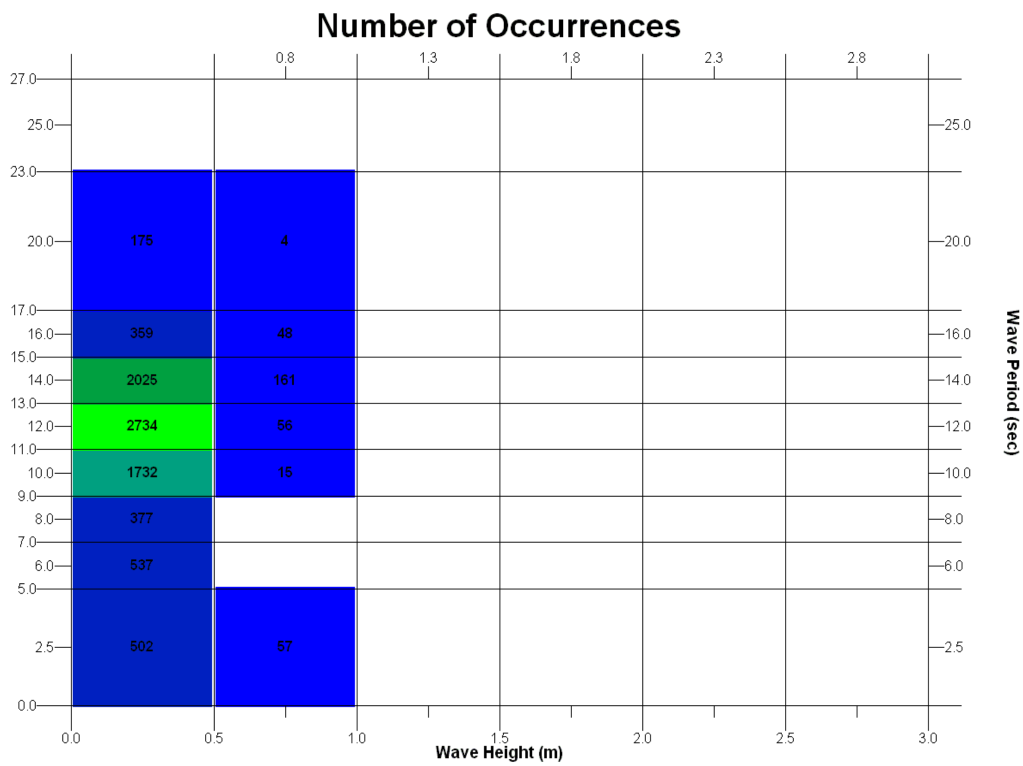


Figure C-12. 1984 number of occurrences for peak period and wave height for WIS Station 113.

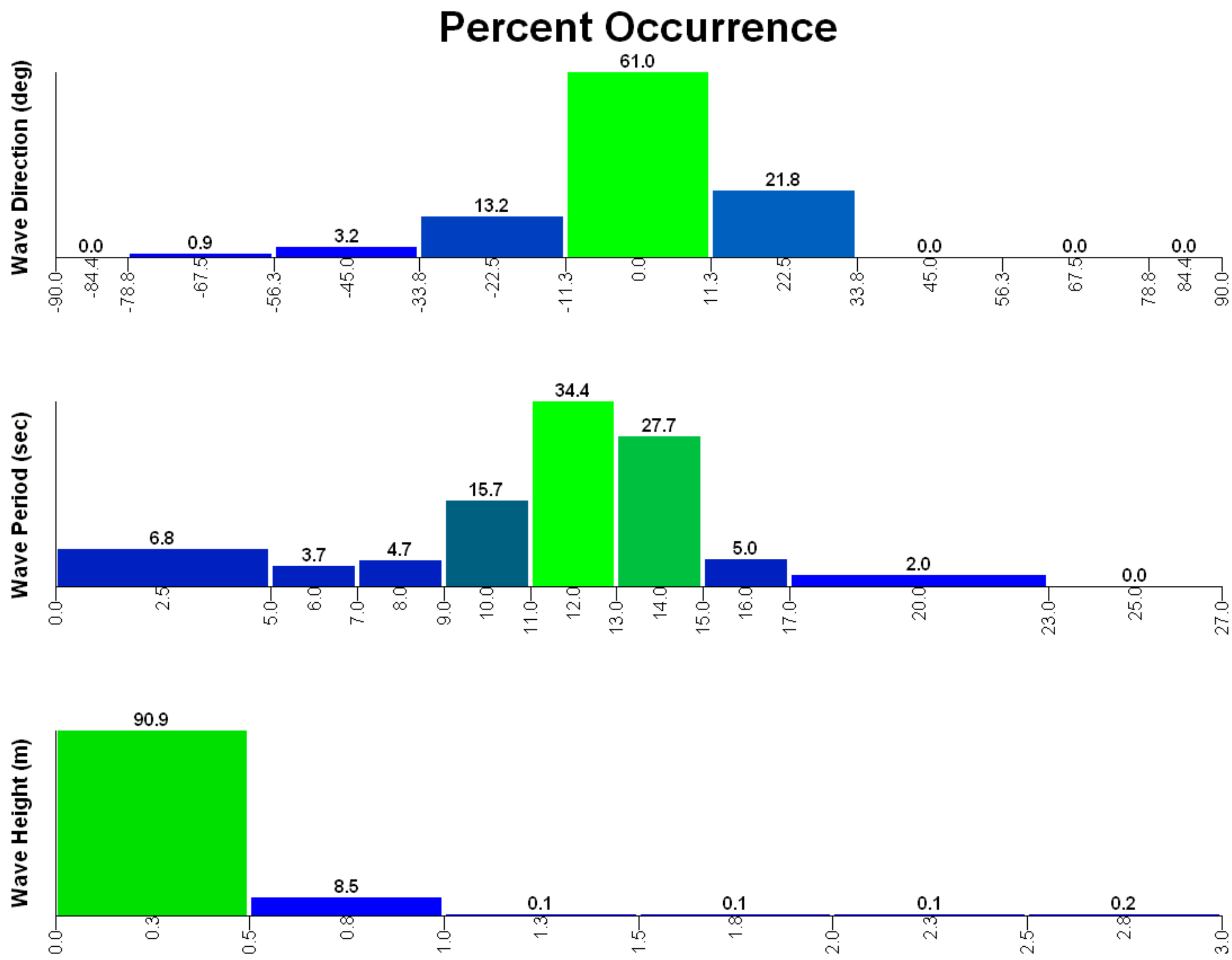


Figure C-13. 1992 percent occurrences for wave height, peak period, and mean direction for WIS Station 113.

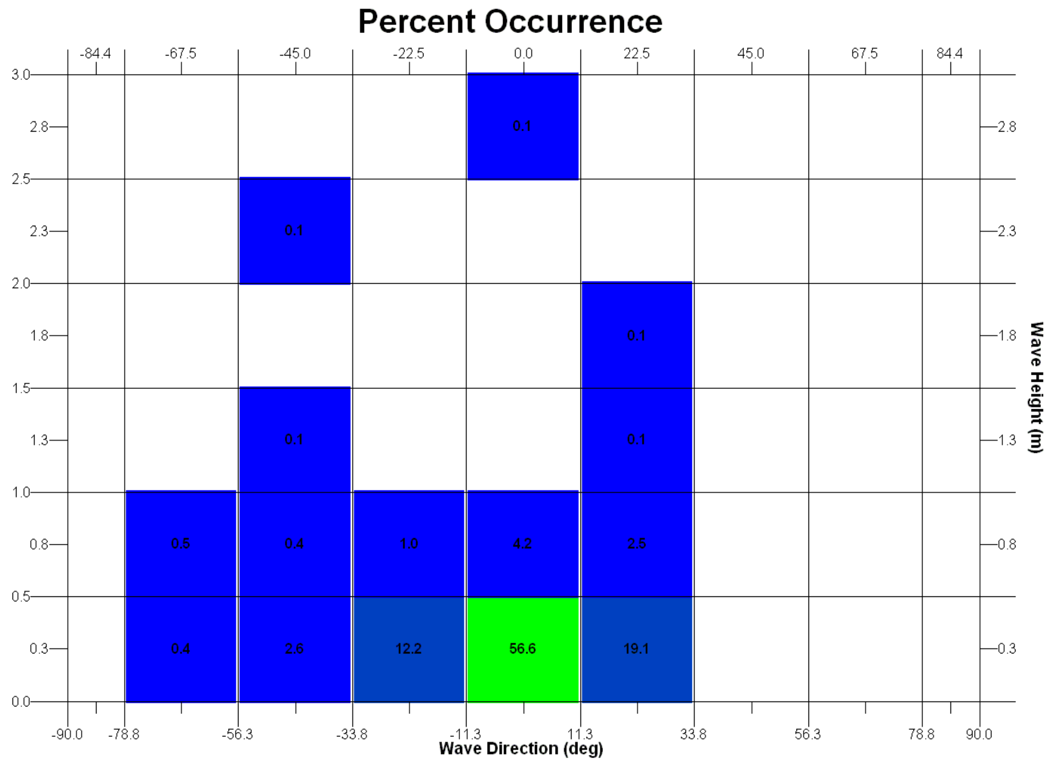


Figure C-14. 1992 percent occurrences for wave height and mean direction for WIS Station 113.

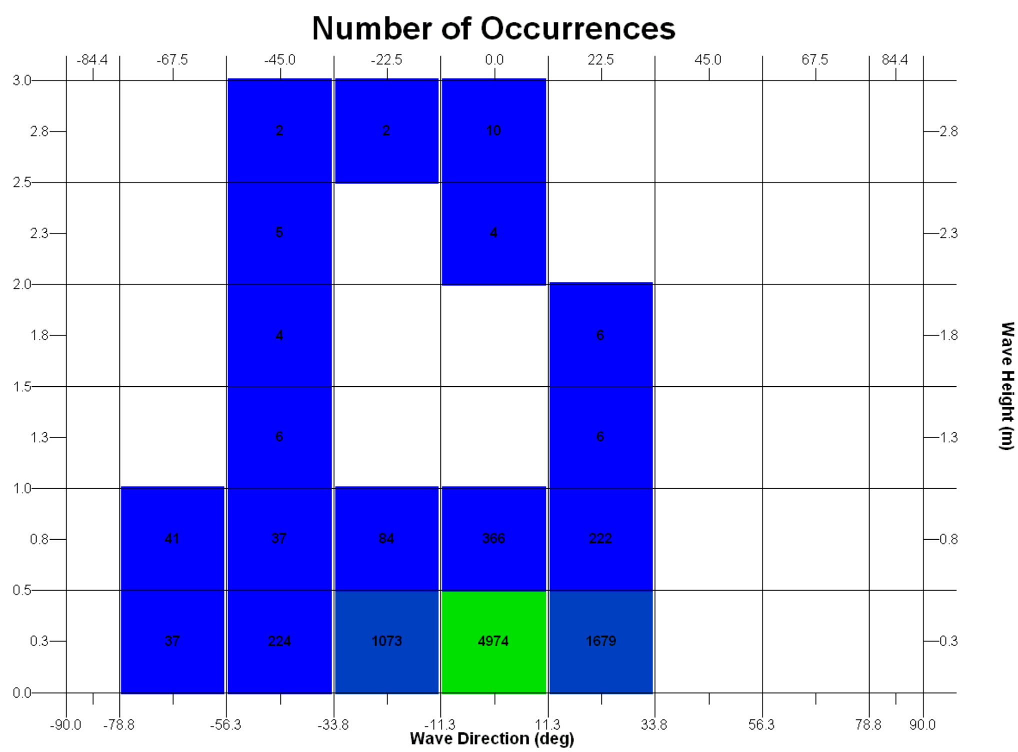


Figure C-15. 1992 number of occurrences for wave height and mean direction for WIS Station 113.

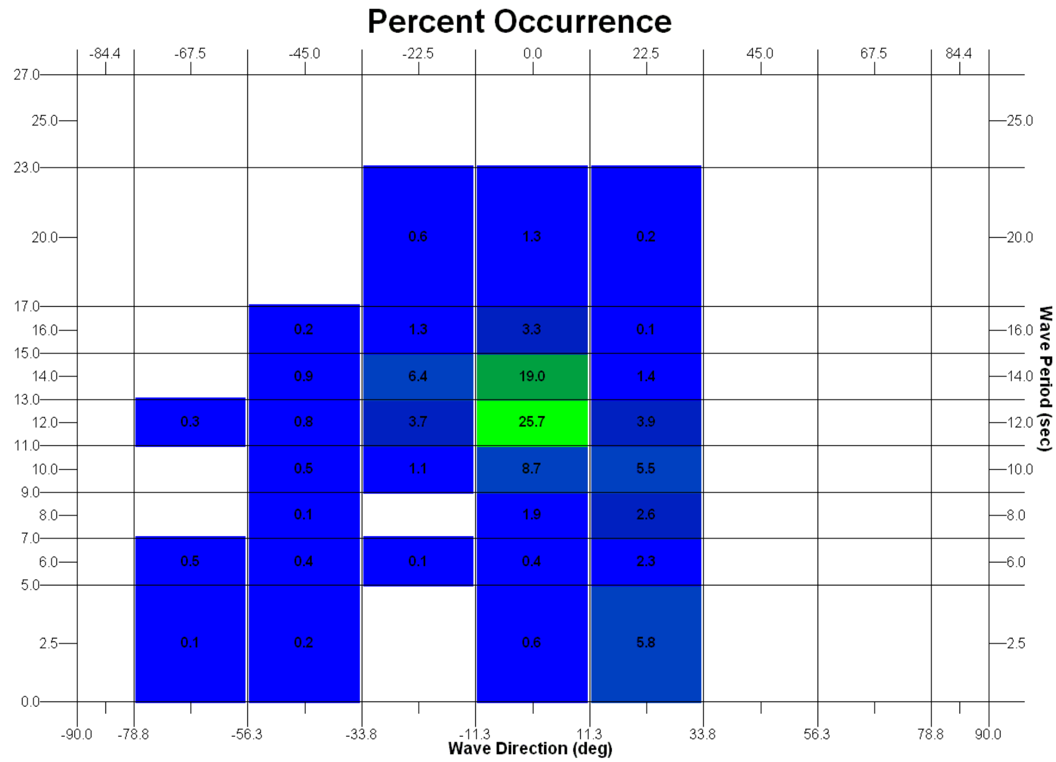


Figure C-16. 1992 percent occurrences for peak period and mean direction for WIS Station 113.

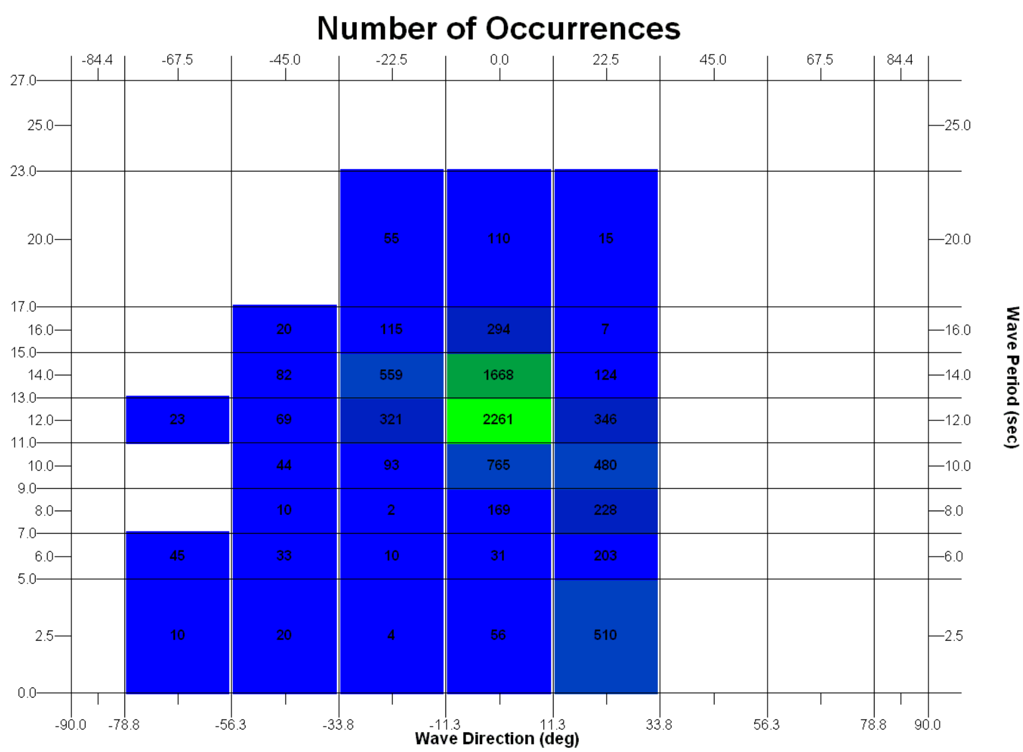


Figure C-17. 1992 number of occurrences for peak period and mean direction for WIS Station 113.

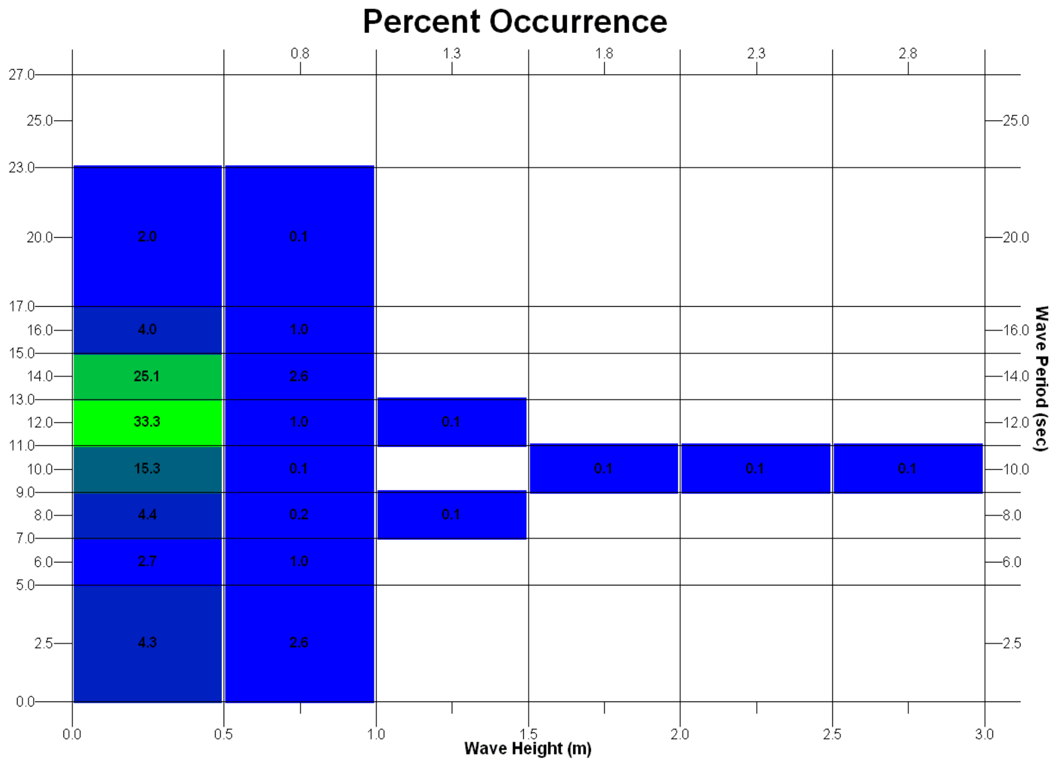


Figure C-18. 1992 percent occurrences for peak period and wave height for WIS Station 113.

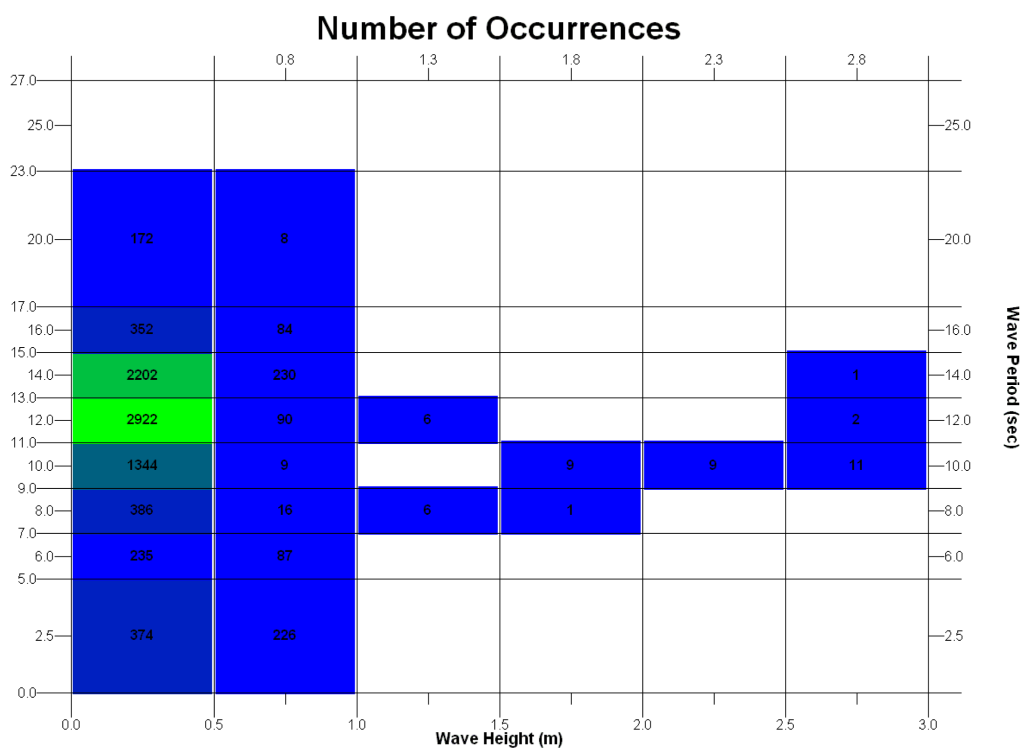


Figure C-19. 1992 number of occurrences for peak period and wave height for WIS Station 113

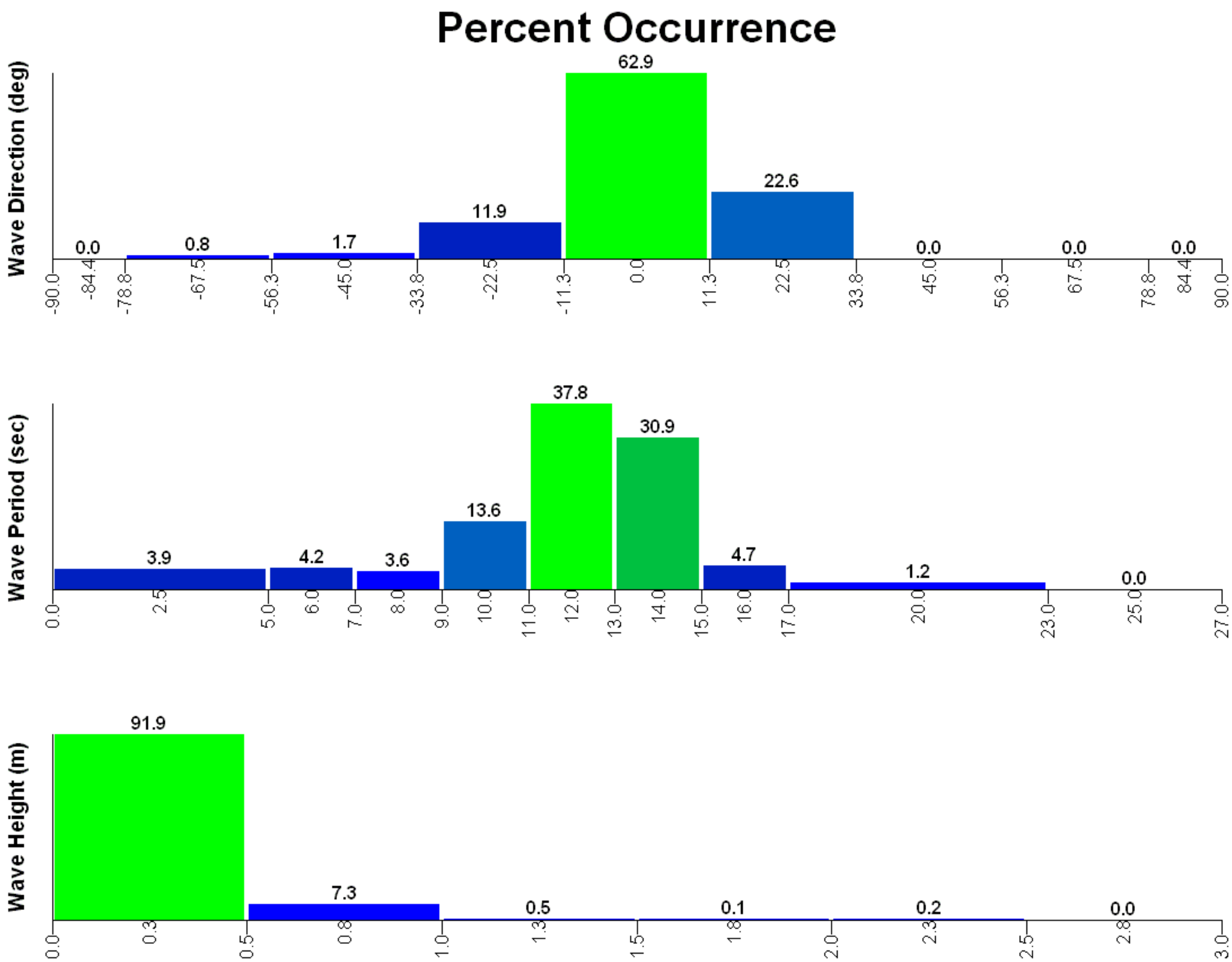


Figure C-20. 1994 percent occurrences for wave height, peak period, and mean direction for WIS Station 113.

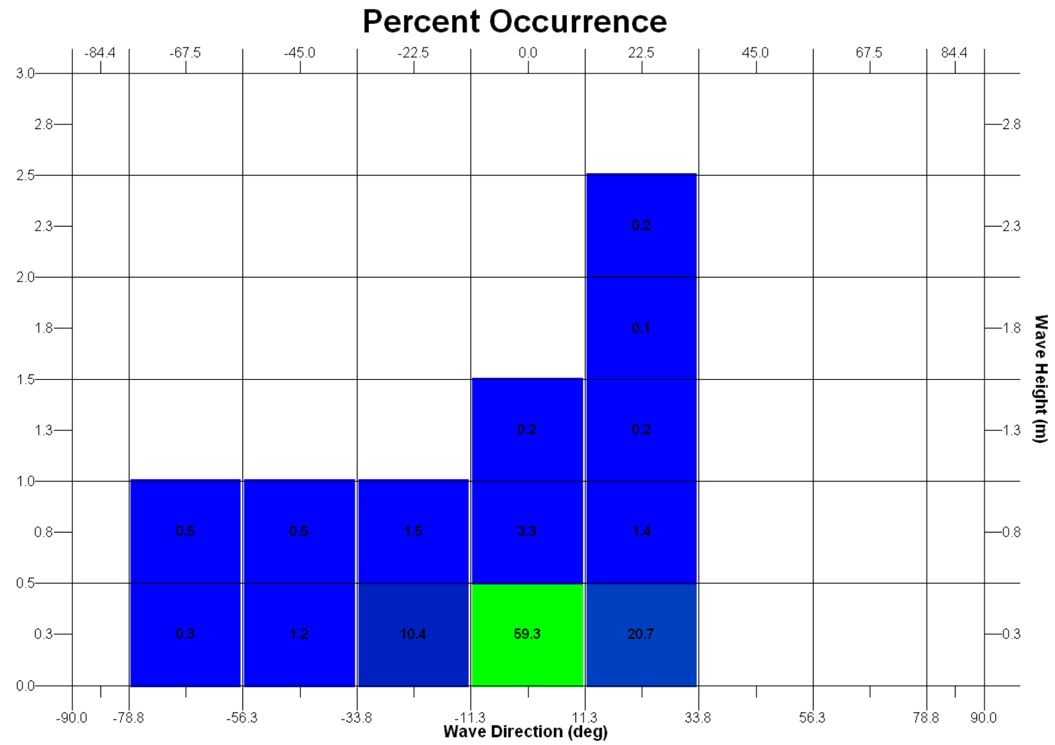


Figure C-21. 1994 percent occurrences for wave height and mean direction for WIS Station 113.

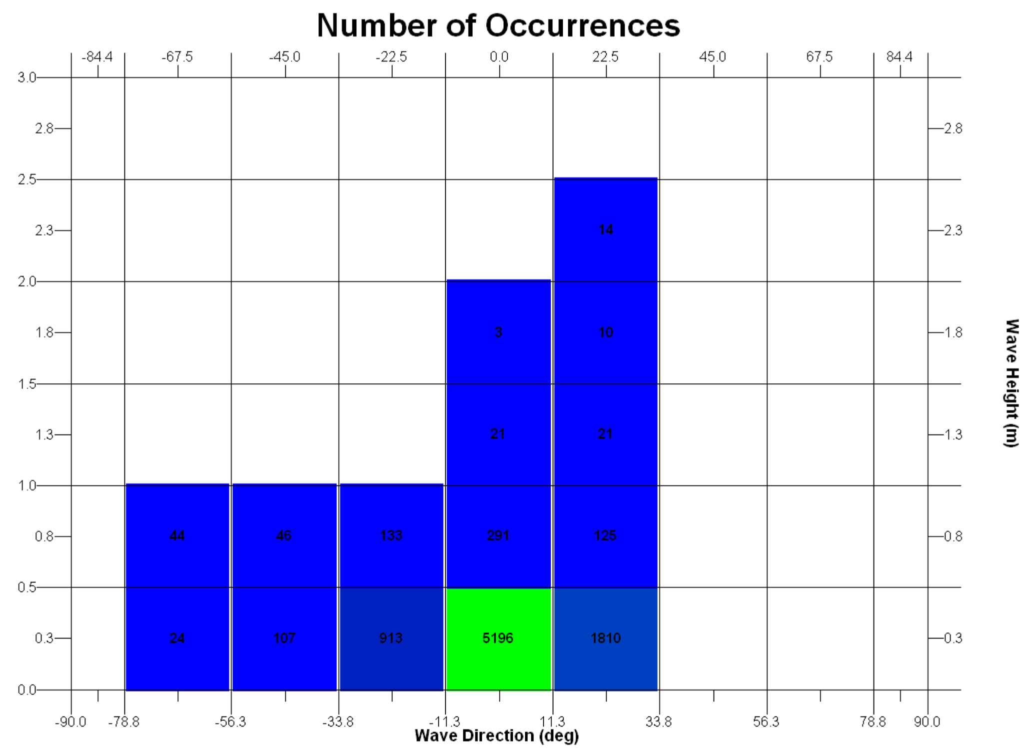


Figure C-22. 1994 number of occurrences for wave height and mean direction for WIS Station 113.

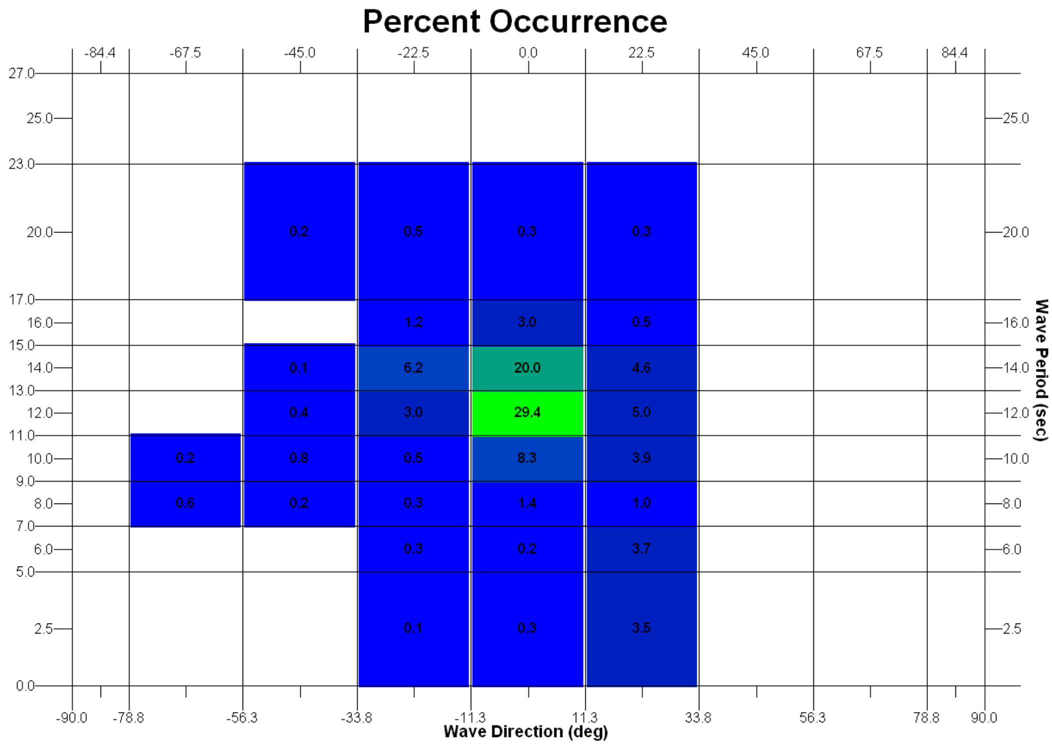


Figure C-23. 1994 percent occurrences for peak period and mean direction for WIS Station 113.

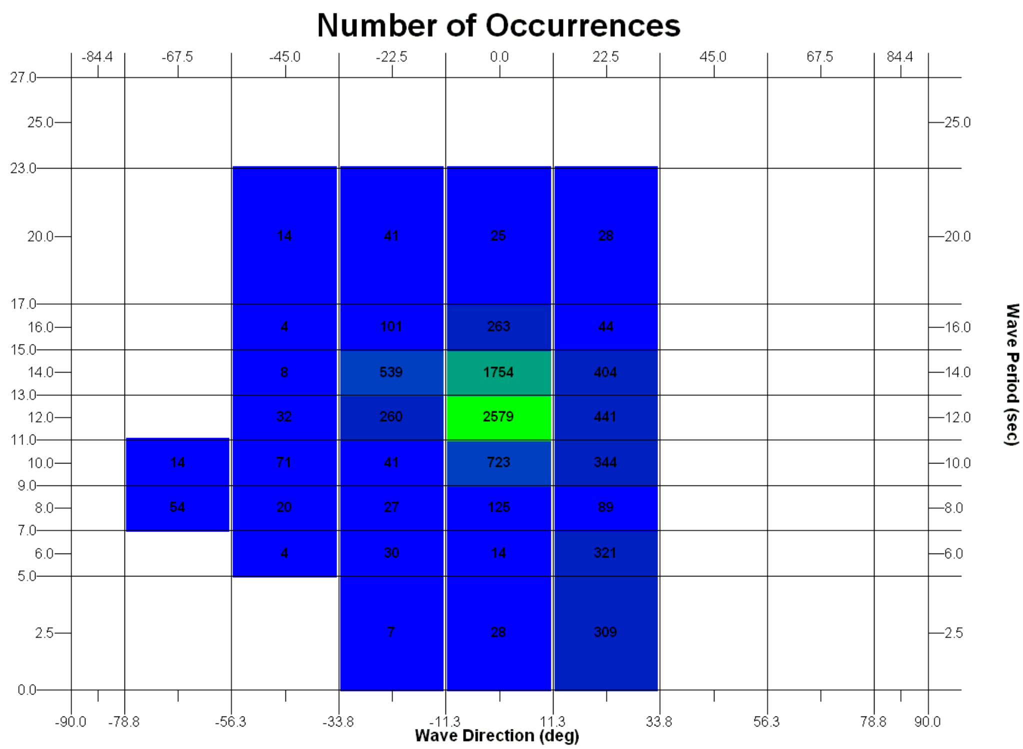


Figure C-24. 1994 number of occurrences for peak period and mean direction for WIS Station 113.

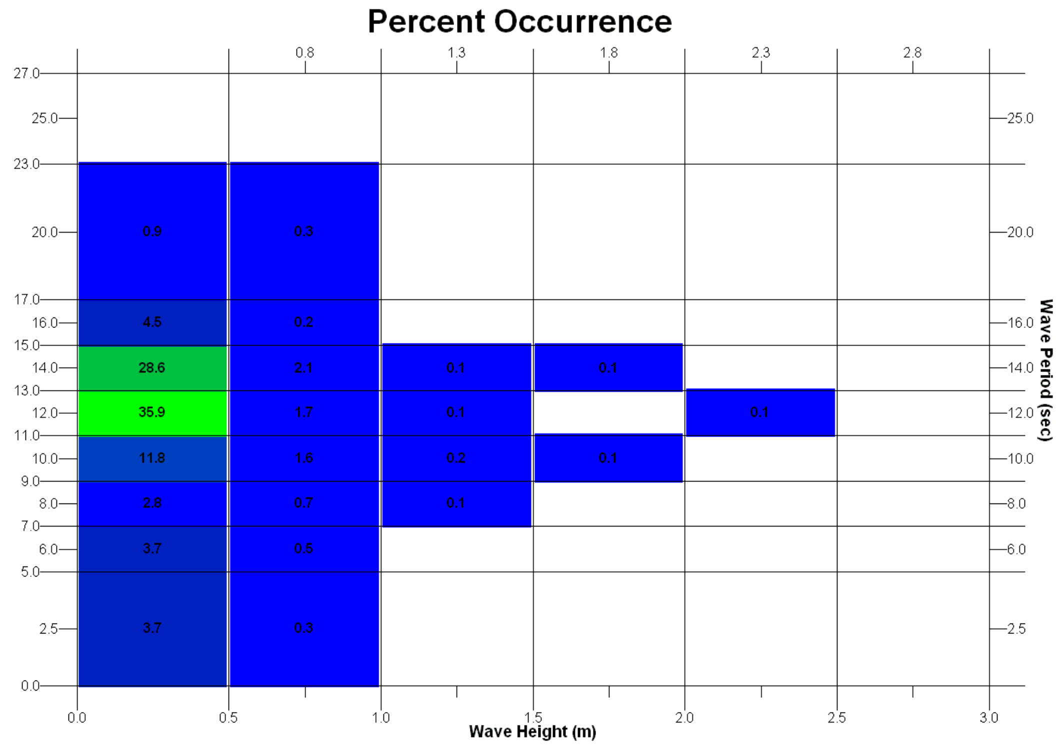


Figure C-25. 1994 percent occurrences for peak period and wave height for WIS Station 113.

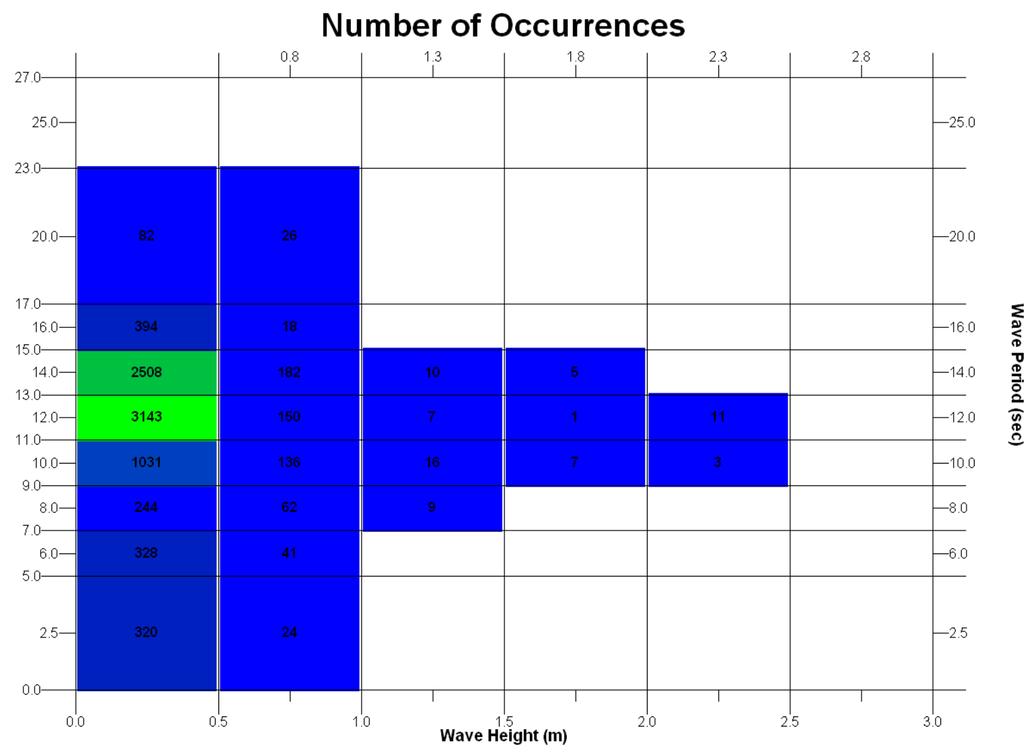


Figure C-26. 1994 number of occurrences for peak period and wave height for WIS Station 113.

Table C-1 provides a summary of the mean and maximum wave statistics for the years 1984, 1992, and 1994. Tables C-2 and C-3 provide wave parameters used to complete nearshore wave model runs and to build a lookup table to be used in simulating nearshore wave climatology. There are a total of 118 runs in the two tables. Wave conditions at this site cover a much smaller range of wave heights than other sites due to sheltering and transformation to 100-m depth.

Table C-1. Mean and Maximum Statistics			
	1984	1992	1994
Mean Wave Height (m)	0.3	0.3	0.3
Mean Peak Period (s)	11.3	11.6	11.9
Largest Wave Height (m)	0.8	2.9	2.4
Peak of Largest Height (s)	4.7	10.2	11.2
Direction Bin of Largest Height (deg)	157.5	180	157.5

Table C-2. Typical Conditions (70 conditions)			
Significant Wave height, m	Wave period, sec	Wave Direction, deg from grid x-axis	Wave Direction, deg meteorological convention
0.5 (1)	6 (1)	-67.5 (1)	from 247.5 deg
1.0 (2)	8 (2)	-45 (2)	from 225 deg
	10 (3)	-22.5 (3)	from 202.5 deg
	12 (4)	0 (4)	from 180 deg
	14 (5)	22.5 (5)	from 157.5 deg
	16 (6)		
	20 (7)		

Table C-3. Extreme Conditions (48 conditions)			
Significant Wave height, m	Wave Period, sec	Wave Direction, deg from STWAVE axis	Wave Direction, deg met convention
1.5 (3)	8 (2)	-45 (2)	from 225 deg
2 (4)	10 (3)	-22.5 (3)	from 202.5 deg
3 (5)	12 (4)	0 (4)	from 180 deg
	14 (5)	22.5 (5)	from 157.5 deg

The STWAVE grid encompasses the entire Kihei RSM region, as shown in Figure C-27 below, with a grid resolution of 50m. The Kihei grid is oriented such that its offshore boundary (at approximately 100 m depth) faces southwest at 225 degrees TN. The bathymetry along the nearshore areas includes the well-resolved features of the reef and other features such as channels and headlands. Figure C-27 shows the shallow contours of the Maalaea Bay area. A detailed view of the STWAVE grids in the nearshore areas adjacent to Maalaea Harbor is shown in Figure C-28.

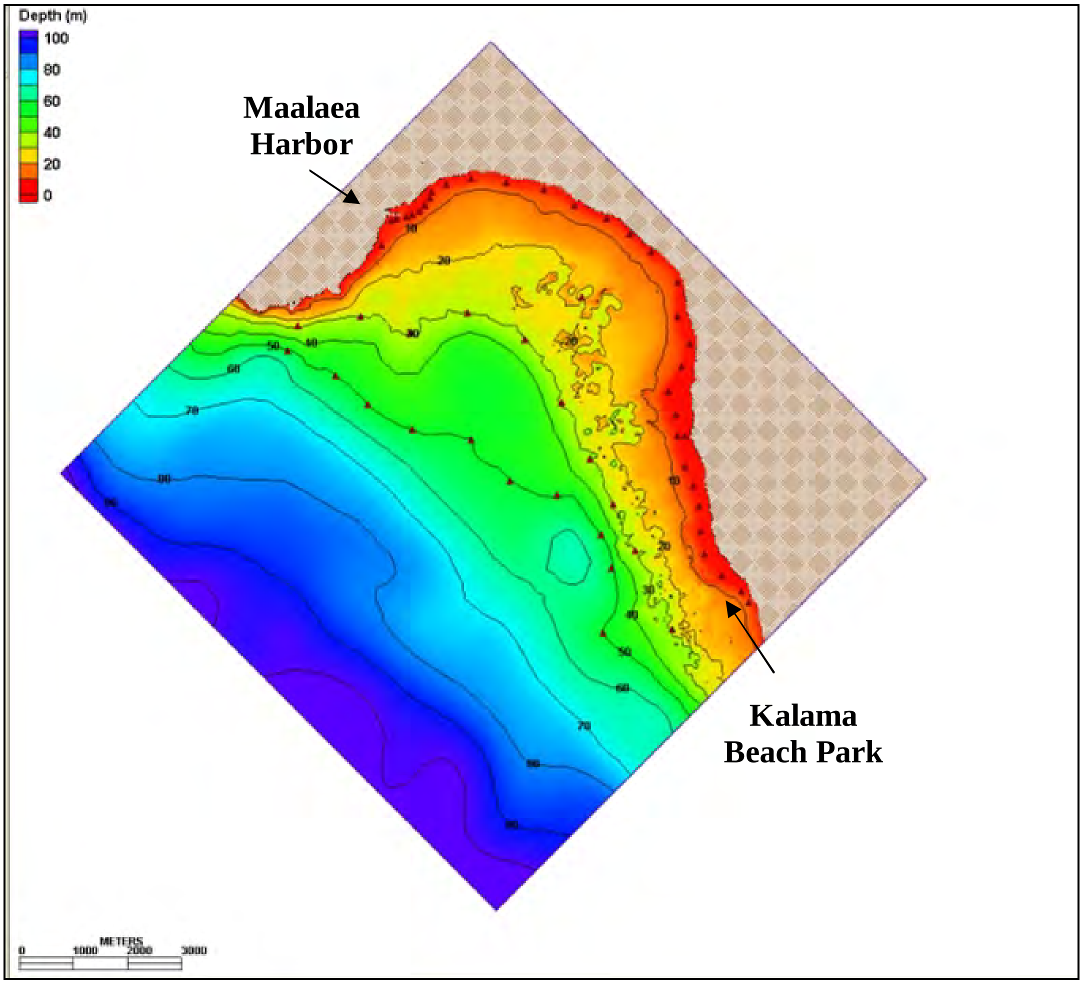


Figure C-27. STWAVE Grid Extents for Kihei Region (10-meter contours shown)

Wave parameters from Tables C-2 and C-3 were used to generate wave input spectra for the Kihei grid. An example of the resulting wave height information (in color) and wave direction (arrows) for the Kihei grid is shown in Figure C-29. In addition, observation points were placed along the nearshore at approximately 1 to 3 meters depth, and along the 30 m and 100 m contours (also visible in Figure C-29 as black squares). Wave parameters for these selected locations were saved in a separate file for use in the next step of the process.

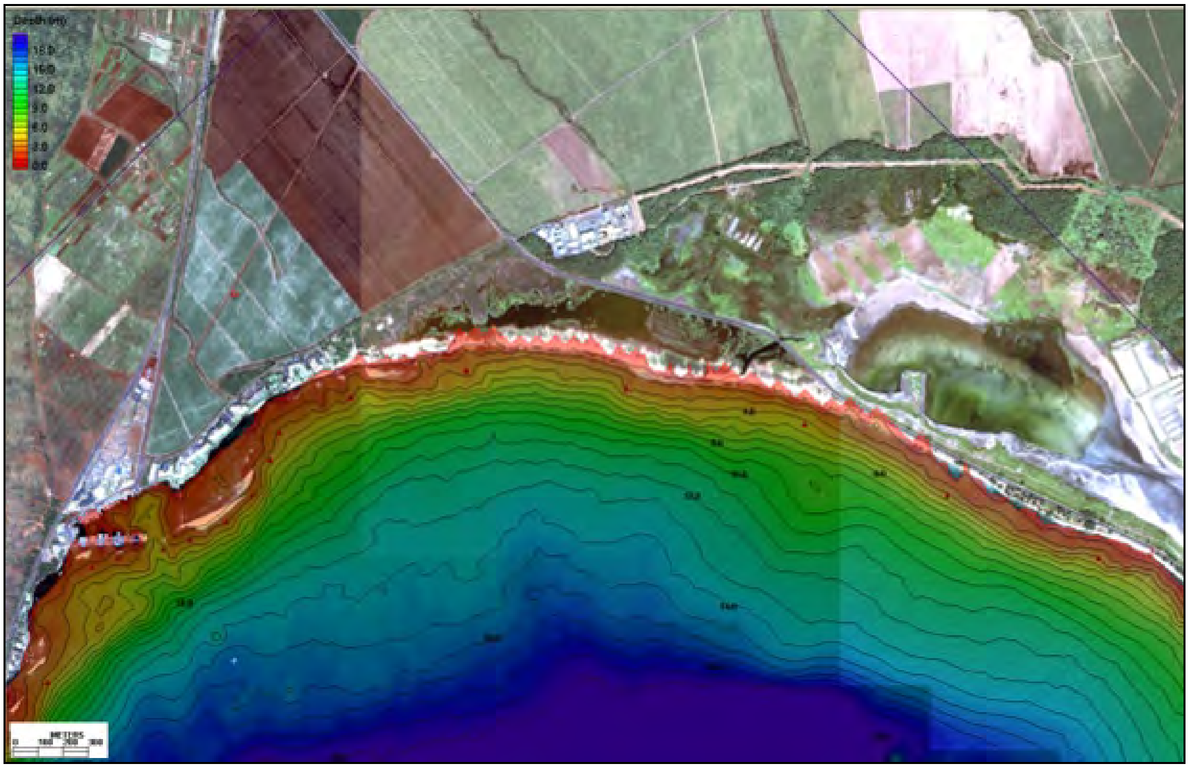


Figure C-28. STWAVE Grid Adjacent to Maalaea Harbor in Kihei Region
(1-meter contours shown)

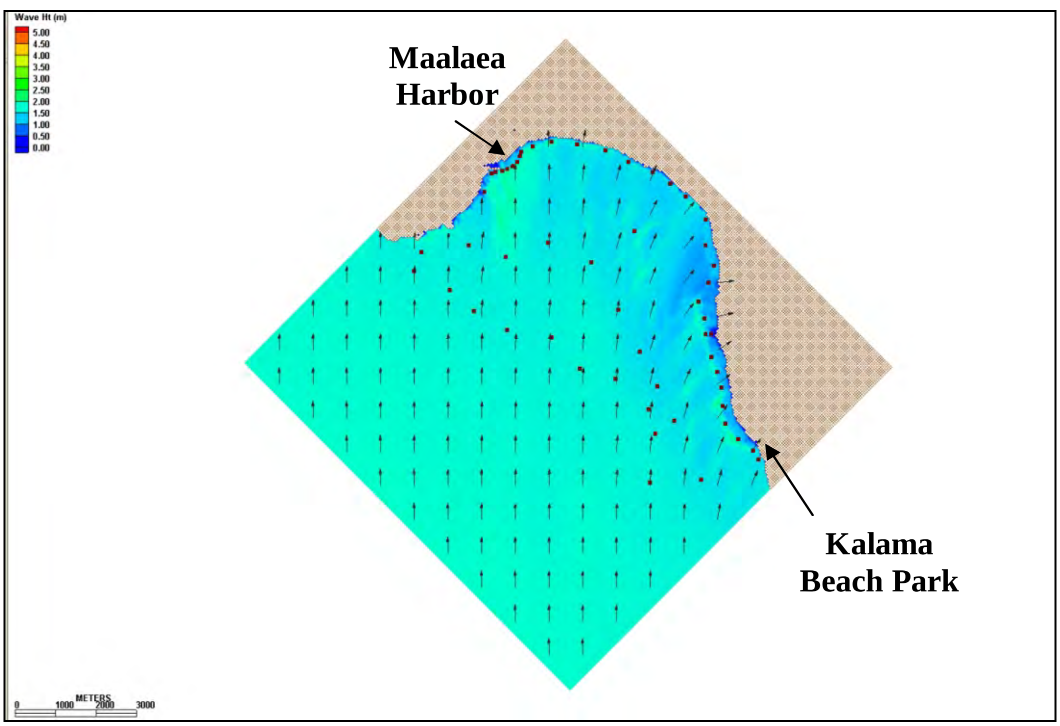


Figure C-29. Resulting Wave Height (color scale) and Wave Direction (arrows) in Kihei Region for Case 356 (Ho = 1.5m, To= 14s, Dir=180) and Location of Observation Points

A database (or "lookup table") of wave parameters that correlates the most frequent offshore wave conditions at the WIS station (from Tables C-2 and C-3 for Kihei) to the resulting nearshore wave conditions at the selected observation points has been developed from the application of STWAVE for several hundred wave transformations for each region.

The next step carried out was to develop a FORTRAN program to automate the "lookup table" process, so that the hourly time series of wave data from the three representative years (1984, 1992, and 1994) of WIS data could be converted to nearshore wave parameters at each observation point. An output nearshore time series including all three years of WIS data was calculated for each nearshore observation point in the Kihei grid.

Finally, the time series for each observation point was used to develop a histogram for that location indicating the percent occurrence of wave approach direction (separated into 10 degree direction bins) as well as the frequency of significant wave height within each wave bin (separated into 0.5m wave height bins). Histograms of two locations in the Kihei region, near Maalaea Harbor and Kalama Beach Park, are shown in Figures C-30 and C-31, respectively.

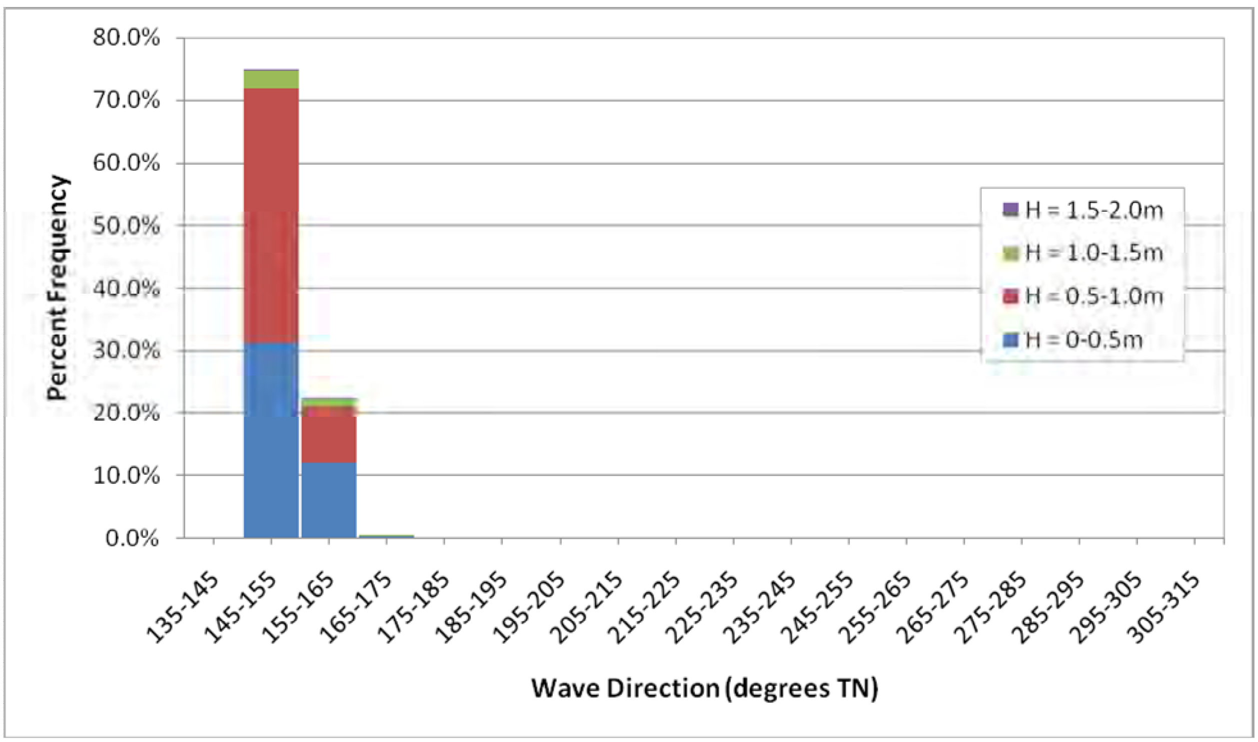


Figure C-30. Histogram of Wave Height and Direction at Nearshore Observation Point Near Entrance to Maalaea Harbor (Shore normal = 130 degrees TN)

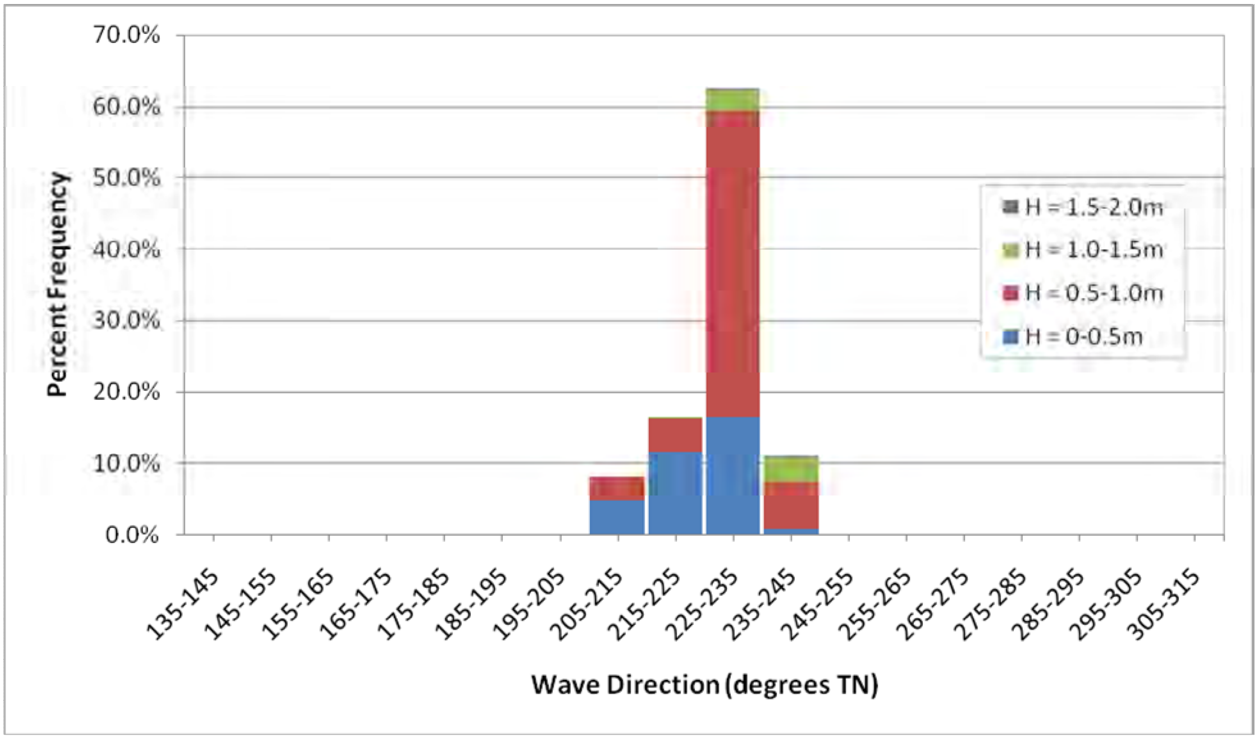


Figure C-31. Histogram of Wave Height and Direction at Nearshore Observation Point Near Kalama Beach Park (Shore normal = 252 degrees TN)

APPENDIX D

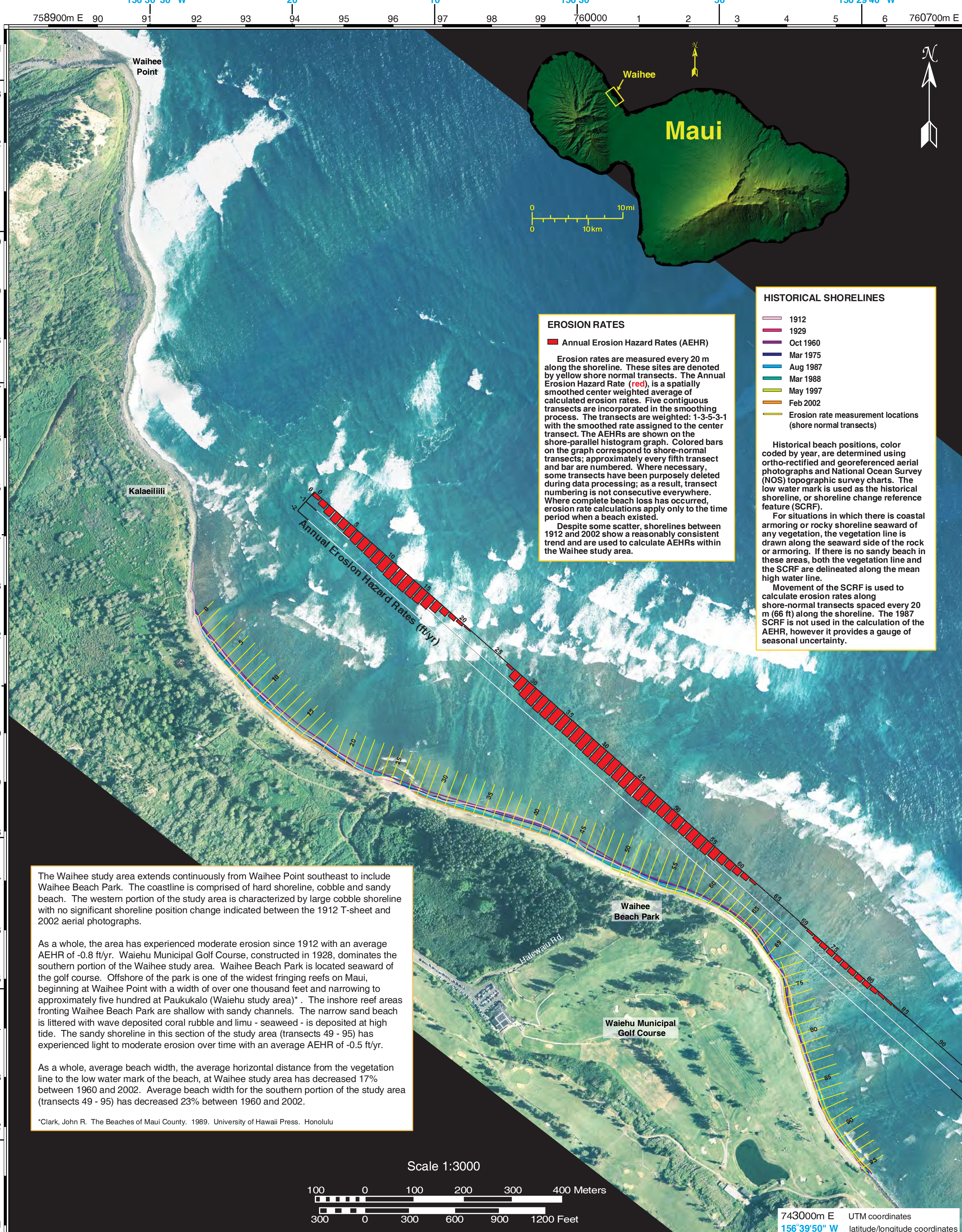
EROSION HAZARD MAPS – KAHULUI REGION (UH 2010)

Waihee, Maui, Hawaii

Smoothed Erosion Rates

Published under
Contract No. G0605.

Produced for the County of Maui by:
Coastal Geology Group
Department of Geology and Geophysics
School of Ocean and Earth Science and Technology
University of Hawaii at Manoa
1680 East - West Road
Honolulu, Hawaii 96822



EROSION RATES

Annual Erosion Hazard Rates (AEHR)

Erosion rates are measured every 20 m along the shoreline. These sites are denoted by yellow shore normal transects. The Annual Erosion Hazard Rate (red), is a spatially smoothed center weighted average of calculated erosion rates. Five contiguous transects are incorporated in the smoothing process. The transects are weighted: 1-3-5-3-1 with the smoothed rate assigned to the center transect. The AEHRs are shown on the shore-parallel histogram graph. Colored bars on the graph correspond to shore-normal transects; approximately every fifth transect and bar are numbered. Where necessary, some transects have been purposely deleted during data processing; as a result, transect numbering is not consecutive everywhere. Where complete beach loss has occurred, erosion rate calculations apply only to the time period when a beach existed.

Despite some scatter, shorelines between 1912 and 2002 show a reasonably consistent trend and are used to calculate AEHRs within the Waihee study area.

HISTORICAL SHORELINES

- 1912
- 1929
- Oct 1960
- Mar 1975
- Aug 1987
- Mar 1988
- May 1997
- Feb 2002
- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

The Waihee study area extends continuously from Waihee Point southeast to include Waihee Beach Park. The coastline is comprised of hard shoreline, cobble and sandy beach. The western portion of the study area is characterized by large cobble shoreline with no significant shoreline position change indicated between the 1912 T-sheet and 2002 aerial photographs.

As a whole, the area has experienced moderate erosion since 1912 with an average AEHR of -0.8 ft/yr. Waiehu Municipal Golf Course, constructed in 1928, dominates the southern portion of the Waihee study area. Waihee Beach Park is located seaward of the golf course. Offshore of the park is one of the widest fringing reefs on Maui, beginning at Waihee Point with a width of over one thousand feet and narrowing to approximately five hundred at Paukukalo (Waiehu study area)* . The inshore reef areas fronting Waihee Beach Park are shallow with sandy channels. The narrow sand beach is littered with wave deposited coral rubble and limu - seaweed - is deposited at high tide. The sandy shoreline in this section of the study area (transects 49 - 95) has experienced light to moderate erosion over time with an average AEHR of -0.5 ft/yr.

As a whole, average beach width, the average horizontal distance from the vegetation line to the low water mark of the beach, at Waihee study area has decreased 17% between 1960 and 2002. Average beach width for the southern portion of the study area (transects 49 - 95) has decreased 23% between 1960 and 2002.

*Clark, John R. The Beaches of Maui County. 1969. University of Hawaii Press. Honolulu

Kahului Harbor, Maui, Hawaii

Smoothed Erosion Rates

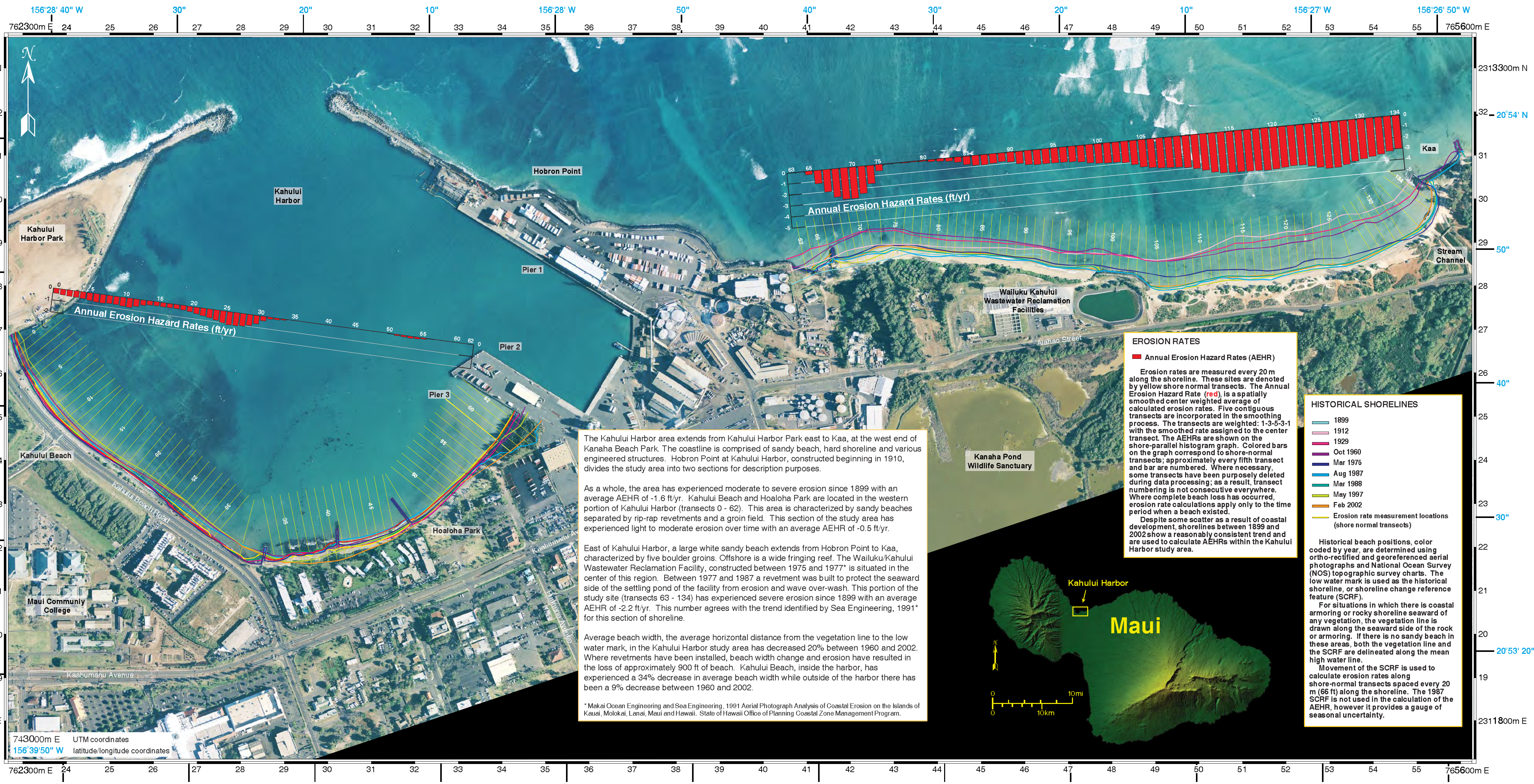
Scale 1:3000

100 0 100 200 300 400 Meters

300 0 300 600 900 1200 Feet

Published under Contract No. G0605.

Produced for the County of Maui by:
Coastal Geology Group
Department of Geology and Geophysics
School of Ocean and Earth Science and Technology
University of Hawaii at Manoa
1680 East - West Road
Honolulu, Hawaii 96822



The Kahului Harbor area extends from Kahului Harbor Park east to Kaa, at the west end of Kanaha Beach Park. The coastline is comprised of sandy beach, hard shoreline and various engineered structures. Hobron Point at Kahului Harbor, constructed beginning in 1910, divides the study area into two sections for description purposes.

As a whole, the area has experienced moderate to severe erosion since 1899 with an average AEHR of -1.6 ft/yr. Kahului Beach and Hoaloha Park are located in the western portion of Kahului Harbor (transects 0 - 62). This area is characterized by sandy beaches separated by rip-rap revetments and a groin field. This section of the study area has experienced light to moderate erosion over time with an average AEHR of -0.5 ft/yr.

East of Kahului Harbor, a large white sandy beach extends from Hobron Point to Kaa, characterized by five boulder groins. Offshore is a wide fringing reef. The Wailuku/Kahului Wastewater Reclamation Facility, constructed between 1975 and 1977* is situated in the center of this region. Between 1977 and 1987 a revetment was built to protect the seaward side of the settling pond of the facility from erosion and wave over-wash. This portion of the study site (transects 63 - 134) has experienced severe erosion since 1899 with an average AEHR of -2.2 ft/yr. This number agrees with the trend identified by Sea Engineering, 1991* for this section of shoreline.

Average beach width, the average horizontal distance from the vegetation line to the low water mark, in the Kahului Harbor study area has decreased 20% between 1960 and 2002. Where revetments have been installed, beach width change and erosion have resulted in the loss of approximately 900 ft of beach. Kahului Beach, inside the harbor, has experienced a 34% decrease in average beach width while outside of the harbor there has been a 9% decrease between 1960 and 2002.

* Makai Ocean Engineering and Sea Engineering, 1991 Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. State of Hawaii Office of Planning Coastal Zone Management Program.

EROSION RATES

Annual Erosion Hazard Rates (AEHR)

Erosion rates are measured every 20 m along the shoreline. These sites are denoted by yellow shore normal transects. The Annual Erosion Hazard Rate (red), is a spatially smoothed center weighted average of calculated erosion rates. Five contiguous transects are incorporated in the smoothing process. The transects are weighted: 1-3-5-3-1 with the smoothed rate assigned to the center transect. The AEHRs are shown on the shore-parallel histogram graph. Colored bars on the graph correspond to shore-normal transects; approximately every fifth transect and bar are numbered. Where necessary, some transects have been purposely deleted during data processing; as a result, transect numbering is not consecutive everywhere. Where complete beach loss has occurred, erosion rate calculations apply only to the time period when a beach existed.

Despite some scatter as a result of coastal development, shorelines between 1899 and 2002 show a reasonably consistent trend and are used to calculate AEHRs within the Kahului Harbor study area.

HISTORICAL SHORELINES

- 1899
- 1912
- 1929
- Oct 1960
- Mar 1975
- Aug 1987
- Mar 1988
- May 1997
- Feb 2002
- Erosion rate measurement locations (shore normal transects)

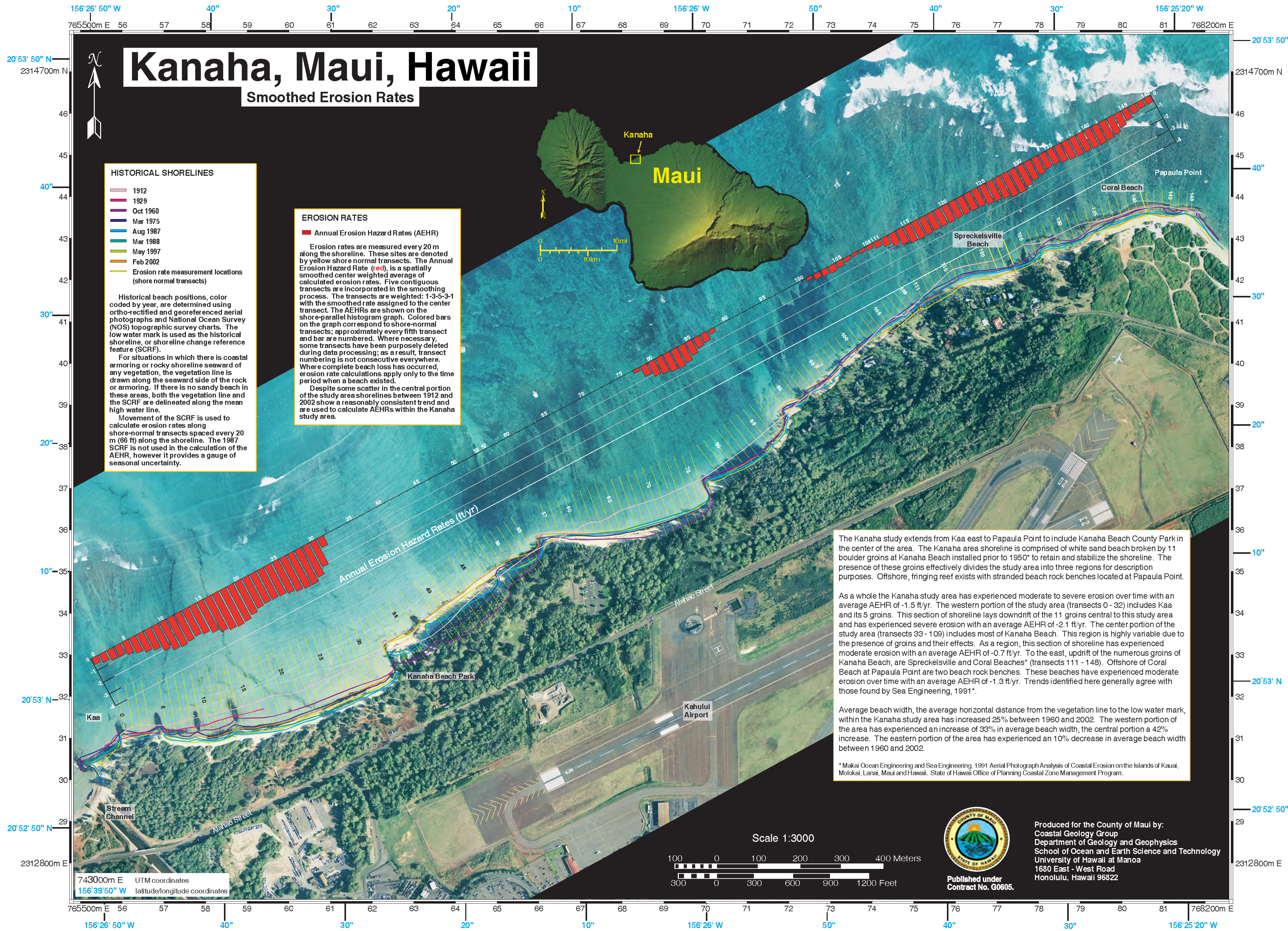
Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

Kanaha, Maui, Hawaii

Smoothed Erosion Rates



HISTORICAL SHORELINES

- 1912
- 1929
- Oct 1960
- Mar 1975
- Aug 1987
- Mar 1988
- May 1997
- Feb 2002
- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

EROSION RATES

- Annual Erosion Hazard Rates (AEHR)

Erosion rates are measured every 20 m along the shoreline. These sites are denoted by yellow shore normal transects. The Annual Erosion Hazard Rate (red), is a spatially smoothed center weighted average of calculated erosion rates. Five contiguous transects are incorporated in the smoothing process. The transects are weighted: 1-3-5-3-1 with the smoothed rate assigned to the center transect. The AEHRs are shown on the shore-parallel histogram graph. Colored bars on the graph correspond to shore-normal transects; approximately every fifth transect and bar are numbered. Where necessary, some transects have been purposely deleted during data processing; as a result, transect numbering is not consecutive everywhere. Where complete beach loss has occurred, erosion rate calculations apply only to the time period when a beach existed.

Despite some scatter in the central portion of the study area shorelines between 1912 and 2002 show a reasonably consistent trend and are used to calculate AEHRs within the Kanaha study area.

The Kanaha study extends from Kaa east to Papaula Point to include Kanaha Beach County Park in the center of the area. The Kanaha area shoreline is comprised of white sand beach broken by 11 boulder groins at Kanaha Beach installed prior to 1950* to retain and stabilize the shoreline. The presence of these groins effectively divides the study area into three regions for description purposes. Offshore, fringing reef exists with stranded beach rock benches located at Papaula Point.

As a whole the Kanaha study area has experienced moderate to severe erosion over time with an average AEHR of -1.5 ft/yr. The western portion of the study area (transects 0 - 32) includes Kaa and its 5 groins. This section of shoreline lays downdrift of the 11 groins central to this study area and has experienced severe erosion with an average AEHR of -2.1 ft/yr. The center portion of the study area (transects 33 - 109) includes most of Kanaha Beach. This region is highly variable due to the presence of groins and their effects. As a region, this section of shoreline has experienced moderate erosion with an average AEHR of -0.7 ft/yr. To the east, updrift of the numerous groins of Kanaha Beach, are Spreckelsville and Coral Beaches* (transects 111 - 148). Offshore of Coral Beach at Papaula Point are two beach rock benches. These beaches have experienced moderate erosion over time with an average AEHR of -1.3 ft/yr. Trends identified here generally agree with those found by Sea Engineering, 1991*.

Average beach width, the average horizontal distance from the vegetation line to the low water mark, within the Kanaha study area has increased 25% between 1960 and 2002. The western portion of the area has experienced an increase of 33% in average beach width, the central portion a 42% increase. The eastern portion of the area has experienced an 10% decrease in average beach width between 1960 and 2002.

* Makai Ocean Engineering and Sea Engineering, 1991 Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. State of Hawaii Office of Planning Coastal Zone Management Program.

Published under Contract No. G0605.

Produced for the County of Maui by:
Coastal Geology Group
Department of Geology and Geophysics
School of Ocean and Earth Science and Technology
University of Hawaii at Manoa
1680 East - West Road
Honolulu, Hawaii 96822

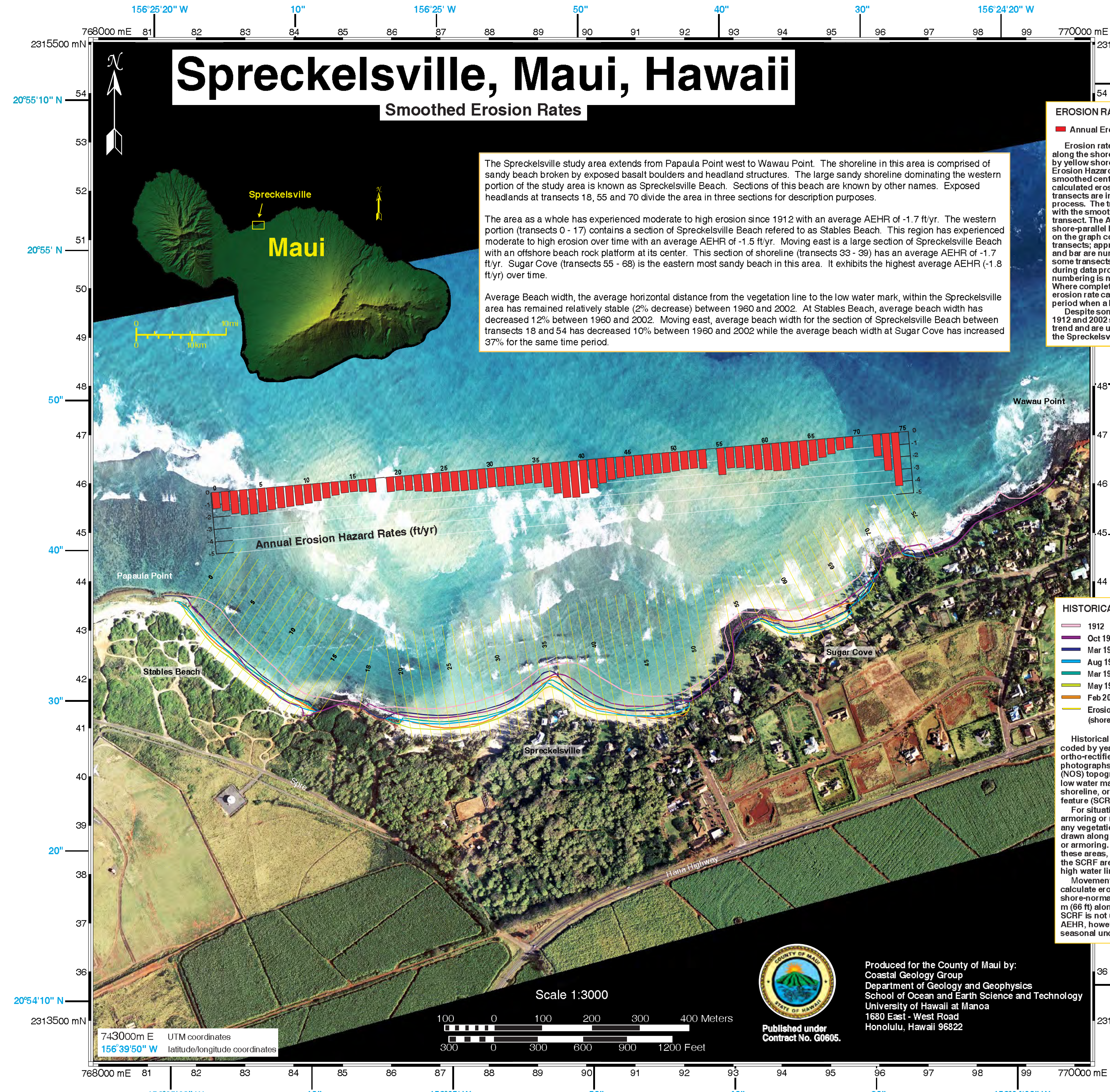
Spreckelsville, Maui, Hawaii

Smoothed Erosion Rates

The Spreckelsville study area extends from Papaula Point west to Wawau Point. The shoreline in this area is comprised of sandy beach broken by exposed basalt boulders and headland structures. The large sandy shoreline dominating the western portion of the study area is known as Spreckelsville Beach. Sections of this beach are known by other names. Exposed headlands at transects 18, 55 and 70 divide the area in three sections for description purposes.

The area as a whole has experienced moderate to high erosion since 1912 with an average AEHR of -1.7 ft/yr. The western portion (transects 0 - 17) contains a section of Spreckelsville Beach refered to as Stables Beach. This region has experienced moderate to high erosion over time with an average AEHR of -1.5 ft/yr. Moving east is a large section of Spreckelsville Beach with an offshore beach rock platform at its center. This section of shoreline (transects 33 - 39) has an average AEHR of -1.7 ft/yr. Sugar Cove (transects 55 - 68) is the eastern most sandy beach in this area. It exhibits the highest average AEHR (-1.8 ft/yr) over time.

Average Beach width, the average horizontal distance from the vegetation line to the low water mark, within the Spreckelsville area has remained relatively stable (2% decrease) between 1960 and 2002. At Stables Beach, average beach width has decreased 12% between 1960 and 2002. Moving east, average beach width for the section of Spreckelsville Beach between transects 18 and 54 has decreased 10% between 1960 and 2002 while the average beach width at Sugar Cove has increased 37% for the same time period.



EROSION RATES

Annual Erosion Hazard Rates (AEHR)

Erosion rates are measured every 20 m along the shoreline. These sites are denoted by yellow shore normal transects. The Annual Erosion Hazard Rate (red), is a spatially smoothed center weighted average of calculated erosion rates. Five contiguous transects are incorporated in the smoothing process. The transects are weighted: 1-3-5-3-1 with the smoothed rate assigned to the center transect. The AEHRs are shown on the shore-parallel histogram graph. Colored bars on the graph correspond to shore-normal transects; approximately every fifth transect and bar are numbered. Where necessary, some transects have been purposely deleted during data processing; as a result, transect numbering is not consecutive everywhere. Where complete beach loss has occurred, erosion rate calculations apply only to the time period when a beach existed.

Despite some scatter, shorelines between 1912 and 2002 show a reasonably consistent trend and are used to calculate AEHRs within the Spreckelsville study area.

HISTORICAL SHORELINES

- 1912
- Oct 1960
- Mar 1975
- Aug 1987
- Mar 1988
- May 1997
- Feb 2002
- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

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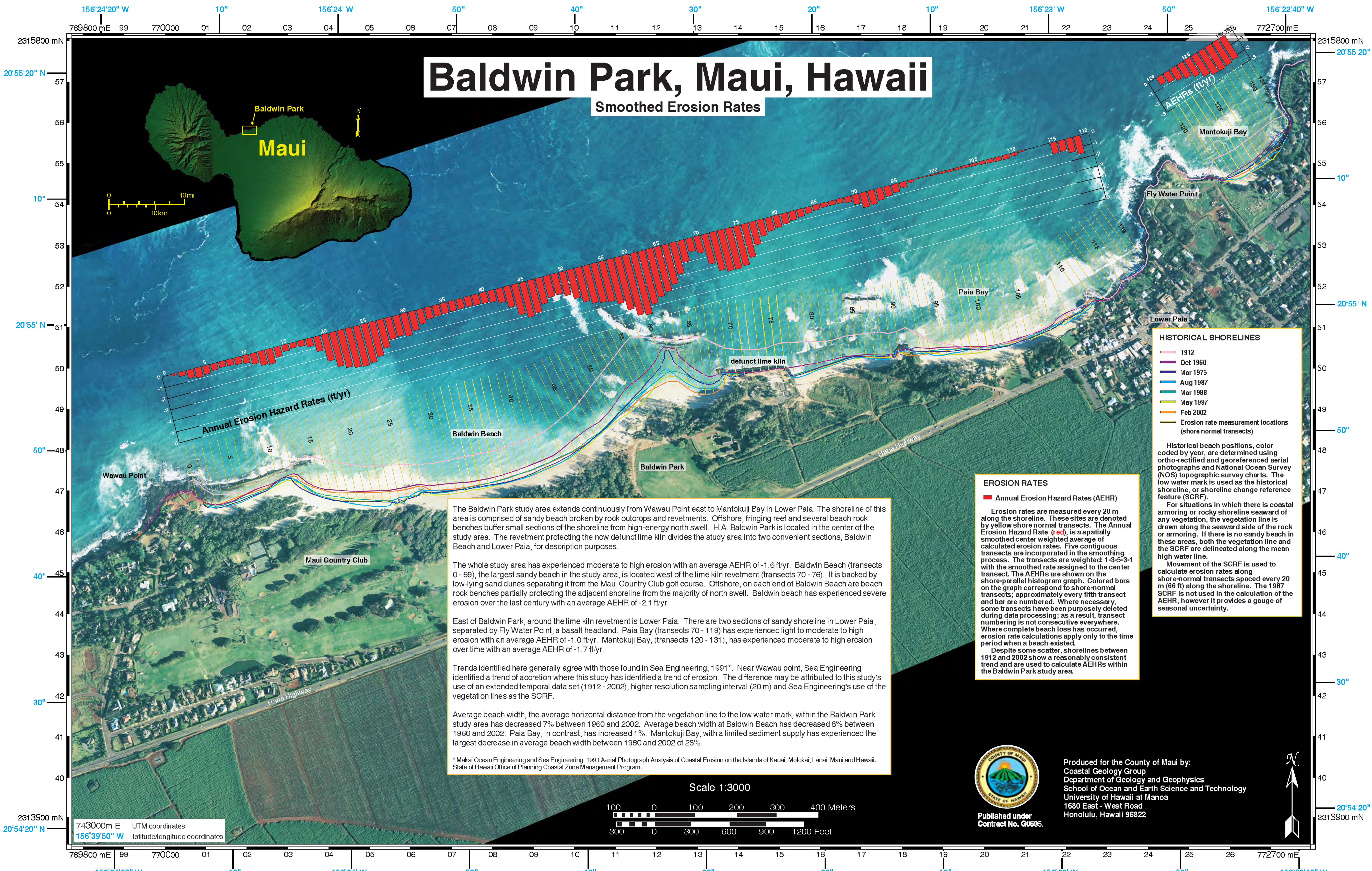
Baldwin Park, Maui, Hawaii

Smoothed Erosion Rates



The Baldwin Park study area extends continuously from Wawau Point east to Mantokuji Bay in Lower Paia. The shoreline of this area is comprised of sandy beach broken by rock outcrops and revetments. Offshore, fringing reef and several beach rock benches buffer small sections of the shoreline from high-energy north swell. H.A. Baldwin Park is located in the center of the study area. The revetment protecting the now defunct lime kiln divides the study area into two convenient sections, Baldwin Beach and Lower Paia, for description purposes.

The whole study area has experienced moderate to high erosion with an average AEHR of -1.6 ft/yr. Baldwin Beach (transects 0 - 69), the largest sandy beach in the study area, is located west of the lime kiln revetment (transects 70 - 76). It is backed by low-lying sand dunes separating it from the Maui Country Club golf course. Offshore, on each end of Baldwin Beach are beach rock benches partially protecting the adjacent shoreline from the majority of north swell. Baldwin beach has experienced severe erosion over the last century with an average AEHR of -2.1 ft/yr.

East of Baldwin Park, around the lime kiln revetment is Lower Paia. There are two sections of sandy shoreline in Lower Paia, separated by Fly Water Point, a basalt headland. Paia Bay (transects 70 - 119) has experienced light to moderate to high erosion with an average AEHR of -1.0 ft/yr. Mantokuji Bay, (transects 120 - 131), has experienced moderate to high erosion over time with an average AEHR of -1.7 ft/yr.

Trends identified here generally agree with those found in Sea Engineering, 1991*. Near Wawau point, Sea Engineering identified a trend of accretion where this study has identified a trend of erosion. The difference may be attributed to this study's use of an extended temporal data set (1912 - 2002), higher resolution sampling interval (20 m) and Sea Engineering's use of the vegetation lines as the SCRF.

Average beach width, the average horizontal distance from the vegetation line to the low water mark, within the Baldwin Park study area has decreased 7% between 1960 and 2002. Average beach width at Baldwin Beach has decreased 8% between 1960 and 2002. Paia Bay, in contrast, has increased 1%. Mantokuji Bay, with a limited sediment supply has experienced the largest decrease in average beach width between 1960 and 2002 of 28%.

* Makai Ocean Engineering and Sea Engineering, 1991 Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. State of Hawaii Office of Planning Coastal Zone Management Program.

EROSION RATES

Annual Erosion Hazard Rates (AEHR)

Erosion rates are measured every 20 m along the shoreline. These sites are denoted by yellow shore normal transects. The Annual Erosion Hazard Rate (red), is a spatially smoothed center weighted average of calculated erosion rates. Five contiguous transects are incorporated in the smoothing process. The transects are weighted: 1-3-5-3-1 with the smoothed rate assigned to the center transect. The AEHRs are shown on the shore-parallel histogram graph. Colored bars on the graph correspond to shore-normal transects; approximately every fifth transect and bar are numbered. Where necessary, some transects have been purposely deleted during data processing; as a result, transect numbering is not consecutive everywhere. Where complete beach loss has occurred, erosion rate calculations apply only to the time period when a beach existed.

Despite some scatter, shorelines between 1912 and 2002 show a reasonably consistent trend and are used to calculate AEHRs within the Baldwin Park study area.

HISTORICAL SHORELINES

- 1912
- Oct 1960
- Mar 1975
- Aug 1987
- Mar 1988
- May 1997
- Feb 2002
- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

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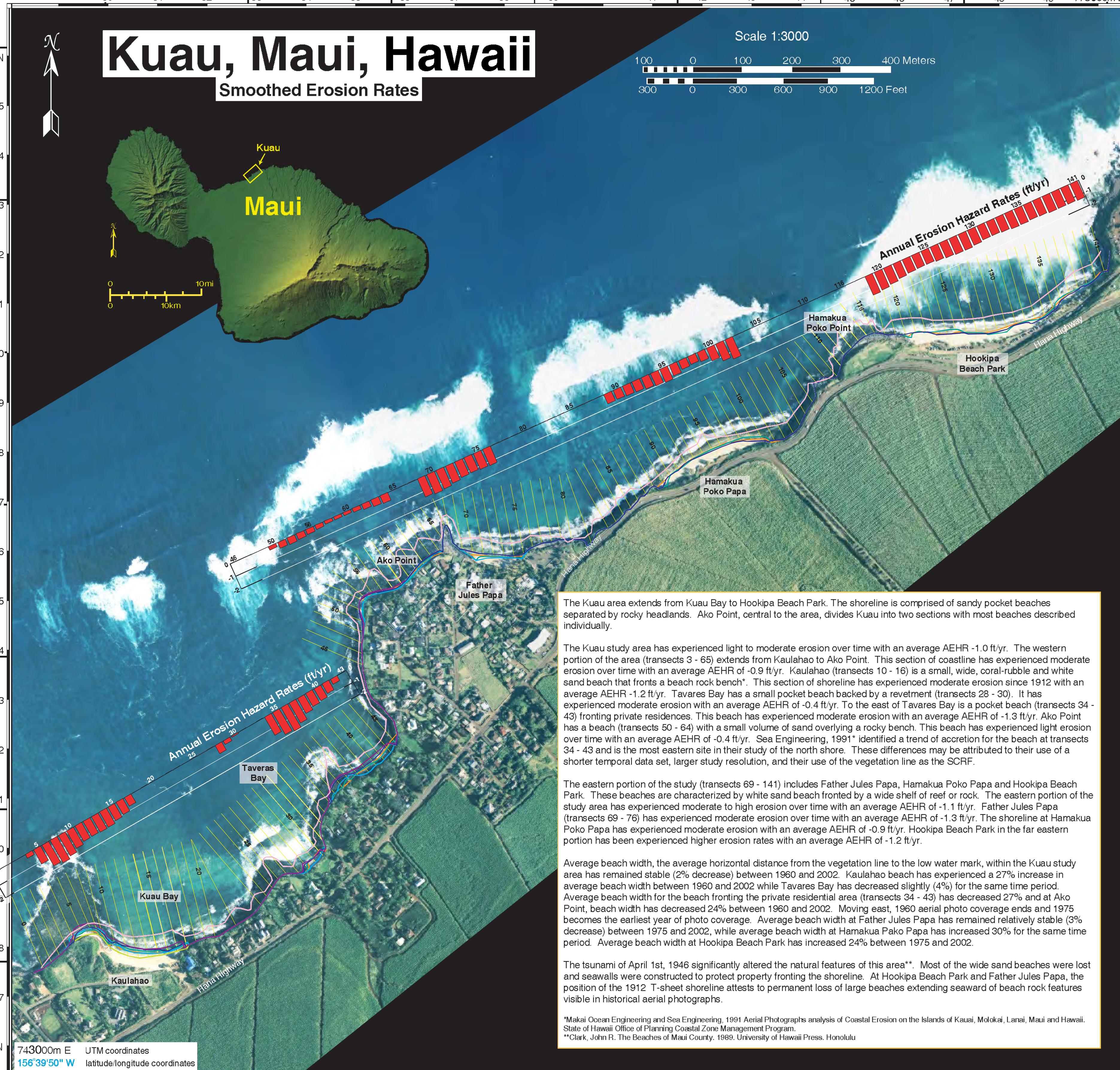

The Kuau area extends from Kuau Bay to Hookipa Beach Park. The shoreline is comprised of sandy pocket beaches separated by rocky headlands. Ako Point, central to the area, divides Kuau into two sections with most beaches described individually.

The Kuau study area has experienced light to moderate erosion over time with an average AEHR -1.0 ft/yr. The western portion of the area (transects 3 - 65) extends from Kaulahao to Ako Point. This section of coastline has experienced moderate erosion over time with an average AEHR of -0.9 ft/yr. Kaulahao (transects 10 - 16) is a small, wide, coral-rubble and white sand beach that fronts a beach rock bench*. This section of shoreline has experienced moderate erosion since 1912 with an average AEHR -1.2 ft/yr. Tavares Bay has a small pocket beach backed by a revetment (transects 28 - 30). It has experienced moderate erosion with an average AEHR of -0.4 ft/yr. To the east of Tavares Bay is a pocket beach (transects 34 - 43) fronting private residences. This beach has experienced moderate erosion with an average AEHR of -1.3 ft/yr. Ako Point has a beach (transects 50 - 64) with a small volume of sand overlying a rocky bench. This beach has experienced light erosion over time with an average AEHR of -0.4 ft/yr. Sea Engineering, 1991* identified a trend of accretion for the beach at transects 34 - 43 and is the most eastern site in their study of the north shore. These differences may be attributed to their use of a shorter temporal data set, larger study resolution, and their use of the vegetation line as the SCRF.

The eastern portion of the study (transects 69 - 141) includes Father Jules Papa, Hamakua Poko Papa and Hookipa Beach Park. These beaches are characterized by white sand beach fronted by a wide shelf of reef or rock. The eastern portion of the study area has experienced moderate to high erosion over time with an average AEHR of -1.1 ft/yr. Father Jules Papa (transects 69 - 76) has experienced moderate erosion over time with an average AEHR of -1.3 ft/yr. The shoreline at Hamakua Poko Papa has experienced moderate erosion with an average AEHR of -0.9 ft/yr. Hookipa Beach Park in the far eastern portion has been experienced higher erosion rates with an average AEHR of -1.2 ft/yr.

Average beach width, the average horizontal distance from the vegetation line to the low water mark, within the Kuau study area has remained stable (2% decrease) between 1960 and 2002. Kaulahao beach has experienced a 27% increase in average beach width between 1960 and 2002 while Tavares Bay has decreased slightly (4%) for the same time period. Average beach width for the beach fronting the private residential area (transects 34 - 43) has decreased 27% and at Ako Point, beach width has decreased 24% between 1960 and 2002. Moving east, 1960 aerial photo coverage ends and 1975 becomes the earliest year of photo coverage. Average beach width at Father Jules Papa has remained relatively stable (3% decrease) between 1975 and 2002, while average beach width at Hamakua Pako Papa has increased 30% for the same time period. Average beach width at Hookipa Beach Park has increased 24% between 1975 and 2002.

The tsunami of April 1st, 1946 significantly altered the natural features of this area**. Most of the wide sand beaches were lost and seawalls were constructed to protect property fronting the shoreline. At Hookipa Beach Park and Father Jules Papa, the position of the 1912 T-sheet shoreline attests to permanent loss of large beaches extending seaward of beach rock features visible in historical aerial photographs.

*Makai Ocean Engineering and Sea Engineering, 1991 Aerial Photographs analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. State of Hawaii Office of Planning Coastal Zone Management Program.
**Clark, John R. The Beaches of Maui County. 1989. University of Hawaii Press. Honolulu

HISTORICAL SHORELINES

- 1912
- Oct 1960
- Mar 1975
- Aug 1987
- Mar 1988
- May 1997
- Feb 2002
- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

EROSION RATES

- Annual Erosion Hazard Rates (AEHR)

Erosion rates are measured every 20 m along the shoreline. These sites are denoted by yellow shore normal transects. The Annual Erosion Hazard Rate (red), is a spatially smoothed center weighted average of calculated erosion rates. Five contiguous transects are incorporated in the smoothing process. The transects are weighted: 1-3-5-3-1 with the smoothed rate assigned to the center transect. The AEHRs are shown on the shore-parallel histogram graph. Colored bars on the graph correspond to shore-normal transects; approximately every fifth transect and bar are numbered. Where necessary, some transects have been purposely deleted during data processing; as a result, transect numbering is not consecutive everywhere. Where complete beach loss has occurred, erosion rate calculations apply only to the time period when a beach existed.

For most of the Kuau study area, the 1912 T-sheet is included in erosion rate calculations. The T-sheet in the section of shoreline at Ako Point (transects 50 through 64) is unclear as to whether the indicated shoreline feature is sand or headland. The T-sheet shoreline is not used in erosion rate calculations for this portion.

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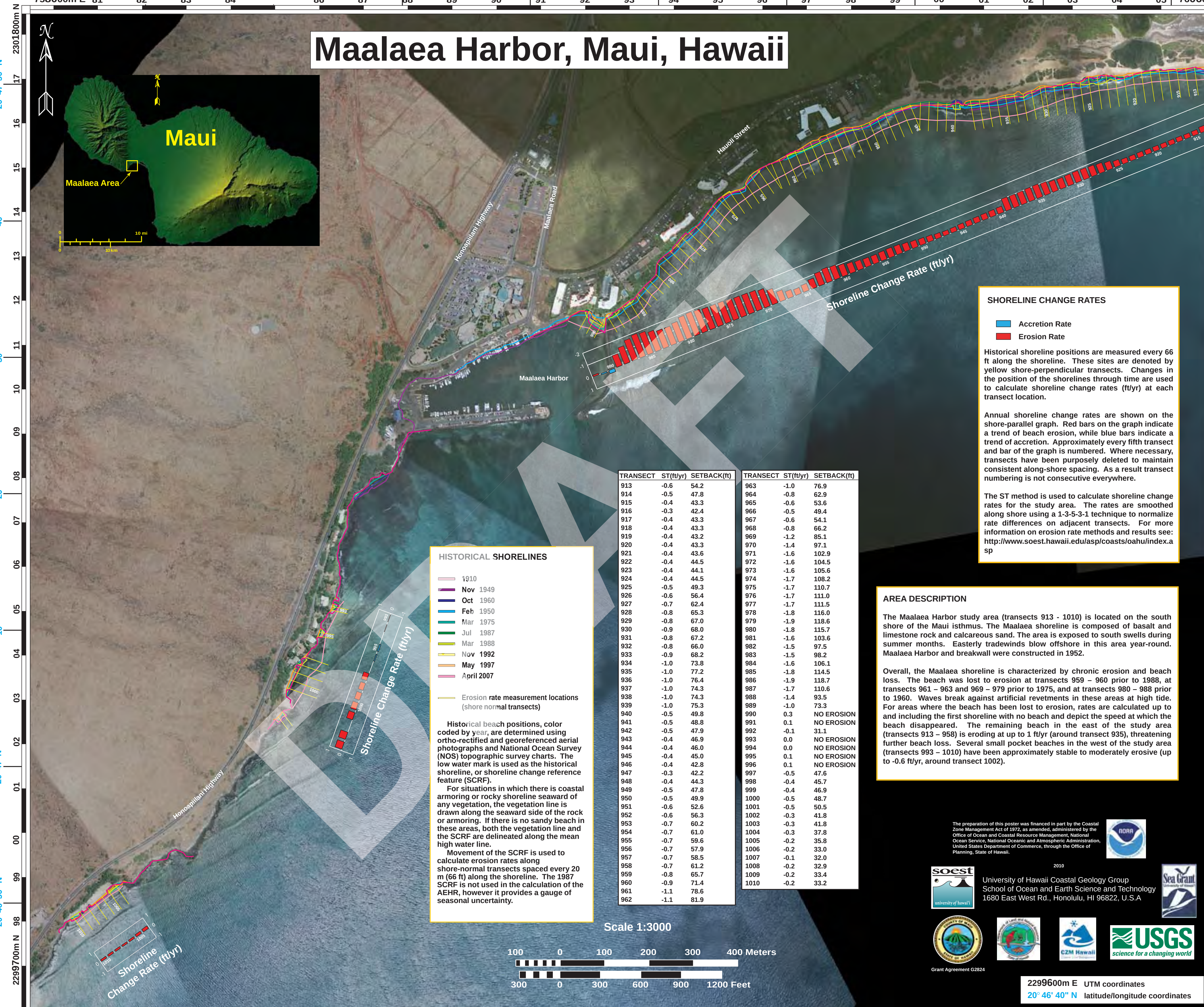
APPENDIX E

EROSION HAZARD MAPS (DRAFT) – KIHEI REGION (UH 2010)

Maalaea Harbor, Maui, Hawaii



SHORELINE CHANGE RATES

Accretion Rate
Erosion Rate

Historical shoreline positions are measured every 66 ft along the shoreline. These sites are denoted by yellow shore-perpendicular transects. Changes in the position of the shorelines through time are used to calculate shoreline change rates (ft/yr) at each transect location.

Annual shoreline change rates are shown on the shore-parallel graph. Red bars on the graph indicate a trend of beach erosion, while blue bars indicate a trend of accretion. Approximately every fifth transect and bar of the graph is numbered. Where necessary, transects have been purposely deleted to maintain consistent along-shore spacing. As a result transect numbering is not consecutive everywhere.

The ST method is used to calculate shoreline change rates for the study area. The rates are smoothed along shore using a 1-3-5-3-1 technique to normalize rate differences on adjacent transects. For more information on erosion rate methods and results see: http://www.soest.hawaii.edu/asp/coasts/oahu/index.asp

AREA DESCRIPTION

The Maalaea Harbor study area (transects 913 - 1010) is located on the south shore of the Maui isthmus. The Maalaea shoreline is composed of basalt and limestone rock and calcareous sand. The area is exposed to south swells during summer months. Easterly tradewinds blow offshore in this area year-round. Maalaea Harbor and breakwall were constructed in 1952.

Overall, the Maalaea shoreline is characterized by chronic erosion and beach loss. The beach was lost to erosion at transects 959 – 960 prior to 1988, at transects 961 – 963 and 969 – 979 prior to 1975, and at transects 980 – 988 prior to 1960. Waves break against artificial revetments in these areas at high tide. For areas where the beach has been lost to erosion, rates are calculated up to and including the first shoreline with no beach and depict the speed at which the beach disappeared. The remaining beach in the east of the study area (transects 913 – 958) is eroding at up to 1 ft/yr (around transect 935), threatening further beach loss. Several small pocket beaches in the west of the study area (transects 993 – 1010) have been approximately stable to moderately erosive (up to -0.6 ft/yr, around transect 1002).

HISTORICAL SHORELINES

1910
Nov 1949
Oct 1960
Feb 1950
Mar 1975
Jul 1987
Mar 1988
Nov 1992
May 1997
April 2007

Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

TRANSECT	ST(ft/yr)	SETBACK(ft)
913	-0.6	54.2
914	-0.5	47.8
915	-0.4	43.3
916	-0.3	42.4
917	-0.4	43.3
918	-0.4	43.3
919	-0.4	43.2
920	-0.4	43.3
921	-0.4	43.6
922	-0.4	44.5
923	-0.4	44.1
924	-0.4	44.5
925	-0.5	49.3
926	-0.6	56.4
927	-0.7	62.4
928	-0.8	65.3
929	-0.8	67.0
930	-0.9	68.0
931	-0.8	67.2
932	-0.8	66.0
933	-0.9	68.2
934	-1.0	73.8
935	-1.0	77.2
936	-1.0	76.4
937	-1.0	74.3
938	-1.0	74.3
939	-1.0	75.3
940	-0.5	49.8
941	-0.5	48.8
942	-0.5	47.9
943	-0.4	46.9
944	-0.4	46.0
945	-0.4	45.0
946	-0.4	42.8
947	-0.3	42.2
948	-0.4	44.3
949	-0.5	47.8
950	-0.5	49.9
951	-0.6	52.6
952	-0.6	56.3
953	-0.7	60.2
954	-0.7	61.0
955	-0.7	59.6
956	-0.7	57.9
957	-0.7	58.5
958	-0.7	61.2
959	-0.8	65.7
960	-0.9	71.4
961	-1.1	78.6
962	-1.1	81.9

TRANSECT	ST(ft/yr)	SETBACK(ft)
963	-1.0	76.9
964	-0.8	62.9
965	-0.6	53.6
966	-0.5	49.4
967	-0.6	54.1
968	-0.8	66.2
969	-1.2	85.1
970	-1.4	97.1
971	-1.6	102.9
972	-1.6	104.5
973	-1.6	105.6
974	-1.7	108.2
975	-1.7	110.7
976	-1.7	111.0
977	-1.7	111.5
978	-1.8	116.0
979	-1.9	118.6
980	-1.8	115.7
981	-1.6	103.6
982	-1.5	97.5
983	-1.5	98.2
984	-1.6	106.1
985	-1.8	114.5
986	-1.9	118.7
987	-1.7	110.6
988	-1.4	93.5
989	-1.0	73.3
990	0.3	NO EROSION
991	0.1	NO EROSION
992	-0.1	31.1
993	0.0	NO EROSION
994	0.0	NO EROSION
995	0.1	NO EROSION
996	0.1	NO EROSION
997	-0.5	47.6
998	-0.4	45.7
999	-0.4	46.9
1000	-0.5	48.7
1001	-0.5	50.5
1002	-0.3	41.8
1003	-0.3	41.8
1004	-0.3	37.8
1005	-0.2	35.8
1006	-0.2	33.0
1007	-0.1	32.0
1008	-0.2	32.9
1009	-0.2	33.4
1010	-0.2	33.2

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2010

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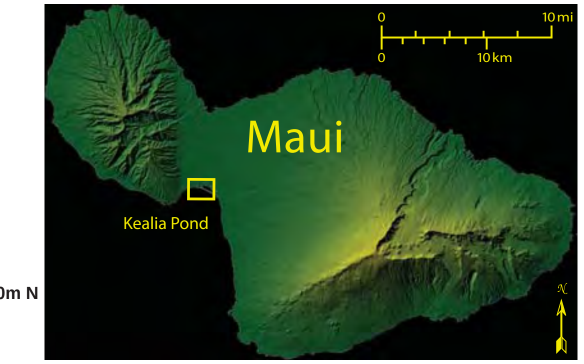
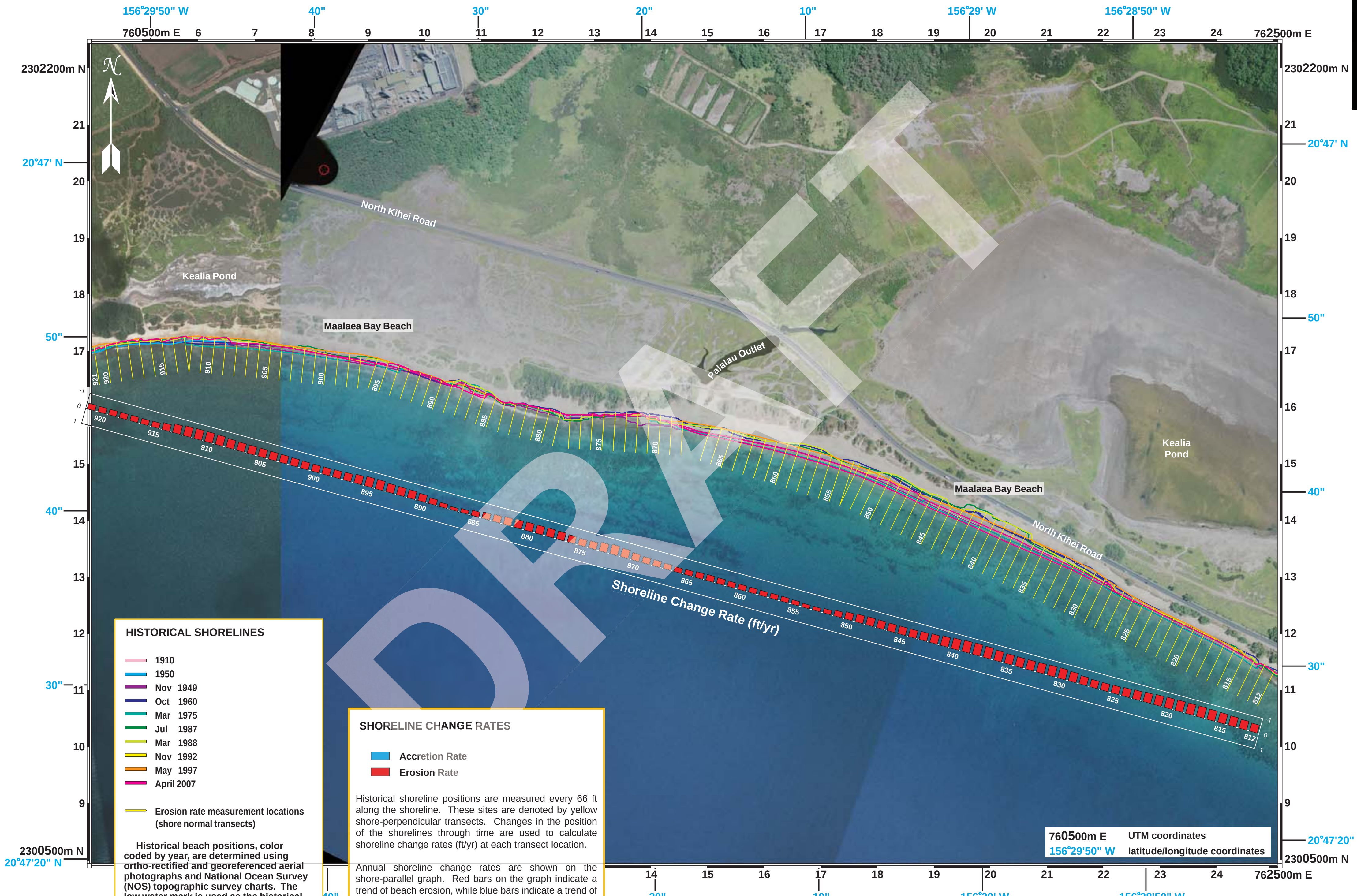
2299600m E UTM coordinates
20° 46' 40" N latitude/longitude coordinates

Kealia Pond, Maui, Hawaii





TRANSECT	ST(ft/yr)	SETBACK(ft)
812	-0.5	51.8
813	-0.6	54.4
814	-0.6	56.3
815	-0.7	57.8
816	-0.7	59.0
817	-0.7	59.8
818	-0.7	60.1
819	-0.7	60.1
820	-0.7	59.6
821	-0.7	58.4
822	-0.6	56.5
823	-0.6	54.5
824	-0.5	52.2
825	-0.5	50.6
826	-0.5	49.5
827	-0.5	49.8
828	-0.5	52.2
829	-0.6	56.3
830	-0.7	58.6
831	-0.7	58.3
832	-0.6	57.0
833	-0.6	56.3
834	-0.6	56.2
835	-0.6	56.8
836	-0.7	58.6
837	-0.7	61.4
838	-0.8	62.7
839	-0.7	61.9
840	-0.7	59.9
841	-0.6	57.0
842	-0.6	53.9
843	-0.5	51.9
844	-0.5	50.6
845	-0.5	50.4
846	-0.5	50.2
847	-0.5	51.0
848	-0.5	51.6
849	-0.5	50.9
850	-0.5	48.4
851	-0.4	43.9
852	-0.3	39.4
853	-0.2	37.1
854	-0.2	37.4
855	-0.3	39.4
856	-0.3	40.9
857	-0.3	41.1
858	-0.3	41.1
859	-0.3	41.7
860	-0.3	42.3
861	-0.4	42.7
862	-0.4	43.6
863	-0.4	44.4
864	-0.4	43.9
865	-0.3	41.7
866	-0.3	41.0
867	-0.4	42.8

TRANSECT	ST(ft/yr)	SETBACK(ft)
868	-0.4	44.7
869	-0.4	45.2
870	-0.5	48.0
871	-0.6	52.9
872	-0.6	56.2
873	-0.6	53.2
874	-0.5	48.6
875	-0.4	47.1
876	-0.5	48.7
877	-0.5	51.5
878	-0.5	52.3
879	-0.5	52.1
880	-0.5	52.1
881	-0.5	51.6
882	-0.5	50.2
883	-0.5	47.9
884	-0.4	45.5
885	-0.3	42.0
886	-0.2	37.4
887	-0.2	35.1
888	-0.3	38.6
889	-0.4	43.8
890	-0.5	48.8
891	-0.5	51.4
892	-0.5	52.1
893	-0.6	53.1
894	-0.6	55.8
895	-0.6	56.0
896	-0.6	53.5
897	-0.5	50.5
898	-0.5	49.1
899	-0.5	48.5
900	-0.5	48.2
901	-0.5	48.7
902	-0.5	49.8
903	-0.5	50.7
904	-0.5	51.3
905	-0.5	52.0
906	-0.5	52.3
907	-0.6	52.8
908	-0.6	54.2
909	-0.6	57.1
910	-0.7	57.8
911	-0.7	58.0
912	-0.6	57.0
913	-0.6	54.2
914	-0.5	47.8
915	-0.4	43.3
916	-0.3	42.4
917	-0.4	43.3
918	-0.4	43.3
919	-0.4	43.2
920	-0.4	43.3
921	-0.4	43.6

HISTORICAL SHORELINES

- 1910
- 1950
- Nov 1949
- Oct 1960
- Mar 1975
- Jul 1987
- Mar 1988
- Nov 1992
- May 1997
- April 2007

- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

SHORELINE CHANGE RATES

- Accretion Rate
- Erosion Rate

Historical shoreline positions are measured every 66 ft along the shoreline. These sites are denoted by yellow shore-perpendicular transects. Changes in the position of the shorelines through time are used to calculate shoreline change rates (ft/yr) at each transect location.

Annual shoreline change rates are shown on the shore-parallel graph. Red bars on the graph indicate a trend of beach erosion, while blue bars indicate a trend of accretion. Approximately every fifth transect and bar of the graph is numbered. Where necessary, transects have been purposely deleted to maintain consistent along-shore spacing. As a result transect numbering is not consecutive everywhere.

The ST method is used to calculate shoreline change rates for the study area. The rates are smoothed along shore using a 1-3-5-3-1 technique to normalize rate differences on adjacent transects. For more information on erosion rate methods and results see: *http://www.soest.hawaii.edu/asp/coasts/oahu/index.asp*

Scale 1:3000

100 0 100 200 300 400 Meters

300 0 300 600 900 1200 Feet

AREA DESCRIPTION

The Kealia Pond study area (transects 812 – 921) encompasses the west half of Maalaea Bay Beach fronting Kealia Pond and North Kihei Road. The area is exposed to south swells in summer months. Easterly tradewinds blow offshore in this area year-round. The Kealia study area has experienced low to moderate erosion rates since 1910, with an average rate of all transects of -0.5 ft/yr.

The preparation of this poster was financed in part by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Ocean Service, National Oceanic and Atmospheric Administration, United States Department of Commerce, through the Office of Planning, State of Hawaii.

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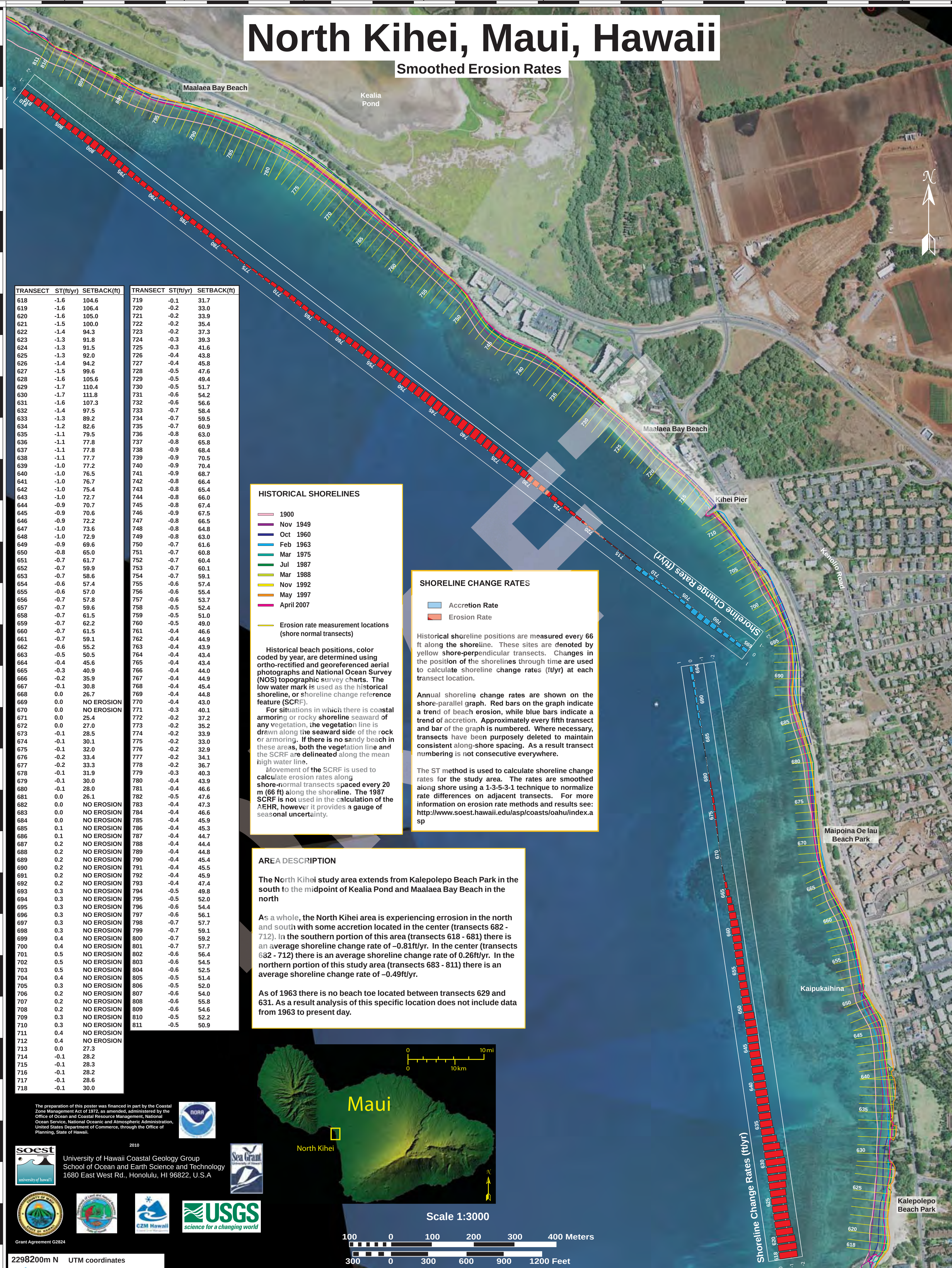
North Kihei, Maui, Hawaii

Smoothed Erosion Rates



TRANSECT	ST(ft/yr)	SETBACK(ft)
618	-1.6	104.6
619	-1.6	106.4
620	-1.6	105.0
621	-1.5	100.0
622	-1.4	94.3
623	-1.3	91.8
624	-1.3	91.5
625	-1.3	92.0
626	-1.4	94.2
627	-1.5	99.6
628	-1.6	105.6
629	-1.7	110.4
630	-1.7	111.8
631	-1.6	107.3
632	-1.4	97.5
633	-1.3	89.2
634	-1.2	82.6
635	-1.1	79.5
636	-1.1	77.8
637	-1.1	77.8
638	-1.1	77.7
639	-1.0	77.2
640	-1.0	76.5
641	-1.0	76.7
642	-1.0	75.4
643	-1.0	72.7
644	-0.9	70.7
645	-0.9	70.6
646	-0.9	72.2
647	-1.0	73.6
648	-1.0	72.9
649	-0.9	69.6
650	-0.8	65.0
651	-0.7	61.7
652	-0.7	59.9
653	-0.7	58.6
654	-0.6	57.4
655	-0.6	57.0
656	-0.7	57.8
657	-0.7	59.6
658	-0.7	61.5
659	-0.7	62.2
660	-0.7	61.5
661	-0.7	59.1
662	-0.6	55.2
663	-0.5	50.5
664	-0.4	45.6
665	-0.3	40.9
666	-0.2	35.9
667	-0.1	30.8
668	0.0	26.7
669	0.0	NO EROSION
670	0.0	NO EROSION
671	0.0	25.4
672	0.0	27.0
673	-0.1	28.5
674	-0.1	30.1
675	-0.1	32.0
676	-0.2	33.4
677	-0.2	33.3
678	-0.1	31.9
679	-0.1	30.0
680	-0.1	28.0
681	0.0	26.1
682	0.0	NO EROSION
683	0.0	NO EROSION
684	0.0	NO EROSION
685	0.1	NO EROSION
686	0.1	NO EROSION
687	0.2	NO EROSION
688	0.2	NO EROSION
689	0.2	NO EROSION
690	0.2	NO EROSION
691	0.2	NO EROSION
692	0.2	NO EROSION
693	0.3	NO EROSION
694	0.3	NO EROSION
695	0.3	NO EROSION
696	0.3	NO EROSION
697	0.3	NO EROSION
698	0.3	NO EROSION
699	0.4	NO EROSION
700	0.4	NO EROSION
701	0.5	NO EROSION
702	0.5	NO EROSION
703	0.5	NO EROSION
704	0.4	NO EROSION
705	0.3	NO EROSION
706	0.2	NO EROSION
707	0.2	NO EROSION
708	0.2	NO EROSION
709	0.3	NO EROSION
710	0.3	NO EROSION
711	0.4	NO EROSION
712	0.4	NO EROSION
713	0.0	27.3
714	-0.1	28.2
715	-0.1	28.3
716	-0.1	28.2
717	-0.1	28.6
718	-0.1	30.0

TRANSECT	ST(ft/yr)	SETBACK(ft)
719	-0.1	31.7
720	-0.2	33.0
721	-0.2	33.9
722	-0.2	35.4
723	-0.2	37.3
724	-0.3	39.3
725	-0.3	41.6
726	-0.4	43.8
727	-0.4	45.8
728	-0.5	47.6
729	-0.5	49.4
730	-0.5	51.7
731	-0.6	54.2
732	-0.6	56.6
733	-0.7	58.4
734	-0.7	59.5
735	-0.7	60.9
736	-0.8	63.0
737	-0.8	65.8
738	-0.9	68.4
739	-0.9	70.5
740	-0.9	70.4
741	-0.9	68.7
742	-0.8	66.4
743	-0.8	65.4
744	-0.8	66.0
745	-0.8	67.4
746	-0.9	67.5
747	-0.8	66.5
748	-0.8	64.8
749	-0.8	63.0
750	-0.7	61.6
751	-0.7	60.8
752	-0.7	60.4
753	-0.7	60.1
754	-0.7	59.1
755	-0.6	57.4
756	-0.6	55.4
757	-0.6	53.7
758	-0.5	52.4
759	-0.5	51.0
760	-0.5	49.0
761	-0.4	46.6
762	-0.4	44.9
763	-0.4	43.9
764	-0.4	43.4
765	-0.4	43.4
766	-0.4	44.0
767	-0.4	44.9
768	-0.4	45.4
769	-0.4	44.8
770	-0.4	43.0
771	-0.3	40.1
772	-0.2	37.2
773	-0.2	35.2
774	-0.2	33.9
775	-0.2	33.0
776	-0.2	32.9
777	-0.2	34.1
778	-0.2	36.7
779	-0.3	40.3
780	-0.4	43.9
781	-0.4	46.6
782	-0.5	47.6
783	-0.4	47.3
784	-0.4	46.6
785	-0.4	45.9
786	-0.4	45.3
787	-0.4	44.7
788	-0.4	44.4
789	-0.4	44.8
790	-0.4	45.4
791	-0.4	45.5
792	-0.4	45.9
793	-0.4	47.4
794	-0.5	49.8
795	-0.5	52.0
796	-0.6	54.4
797	-0.6	56.1
798	-0.7	57.7
799	-0.7	59.1
800	-0.7	59.2
801	-0.7	57.7
802	-0.6	56.4
803	-0.6	54.5
804	-0.6	52.5
805	-0.5	51.4
806	-0.5	52.0
807	-0.6	54.0
808	-0.6	55.8
809	-0.6	54.6
810	-0.5	52.2
811	-0.5	50.9

HISTORICAL SHORELINES

- 1900
- Nov 1949
- Oct 1960
- Feb 1963
- Mar 1975
- Jul 1987
- Mar 1988
- Nov 1992
- May 1997
- April 2007

- Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

Movement of the SCRF is used to calculate erosion rates along shore-normal transects spaced every 20 m (66 ft) along the shoreline. The 1987 SCRF is not used in the calculation of the AEHR, however it provides a gauge of seasonal uncertainty.

SHORELINE CHANGE RATES

- Accretion Rate
- Erosion Rate

Historical shoreline positions are measured every 66 ft along the shoreline. These sites are denoted by yellow shore-perpendicular transects. Changes in the position of the shorelines through time are used to calculate shoreline change rates (ft/yr) at each transect location.

Annual shoreline change rates are shown on the shore-parallel graph. Red bars on the graph indicate a trend of beach erosion, while blue bars indicate a trend of accretion. Approximately every fifth transect and bar of the graph is numbered. Where necessary, transects have been purposely deleted to maintain consistent along-shore spacing. As a result transect numbering is not consecutive everywhere.

The ST method is used to calculate shoreline change rates for the study area. The rates are smoothed along shore using a 1-3-5-3-1 technique to normalize rate differences on adjacent transects. For more information on erosion rate methods and results see: http://www.soest.hawaii.edu/asp/coasts/oahu/index.asp

AREA DESCRIPTION

The North Kihei study area extends from Kalepolepo Beach Park in the south to the midpoint of Kealia Pond and Maalaea Bay Beach in the north

As a whole, the North Kihei area is experiencing errosion in the north and south with some accretion located in the center (transects 682 - 712). In the southern portion of this area (transects 618 - 681) there is an average shoreline change rate of –0.81ft/yr. In the center (transects 682 - 712) there is an average shoreline change rate of 0.26ft/yr. In the northern portion of this study area (transects 683 - 811) there is an average shoreline change rate of –0.49ft/yr.

As of 1963 there is no beach toe located between transects 629 and 631. As a result analysis of this specific location does not include data from 1963 to present day.

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Grant Agreement G2824

2298200m N UTM coordinates
156°28'40" W latitude/longitude coordinates

Kawililipoa, Maui, Hawaii

HISTORICAL SHORELINES

- 1900
- 1912
- Nov 1949
- Oct 1960
- Feb 1963
- Mar 1975
- Jul 1987
- Mar 1988
- Nov 1992
- May 1997
- Apr 2007

Erosion rate measurement locations (shore normal transects)

Historical beach positions, color coded by year, are determined using ortho-rectified and georeferenced aerial photographs and National Ocean Survey (NOS) topographic survey charts. The low water mark is used as the historical shoreline, or shoreline change reference feature (SCRF).

For situations in which there is coastal armoring or rocky shoreline seaward of any vegetation, the vegetation line is drawn along the seaward side of the rock or armoring. If there is no sandy beach in these areas, both the vegetation line and the SCRF are delineated along the mean high water line.

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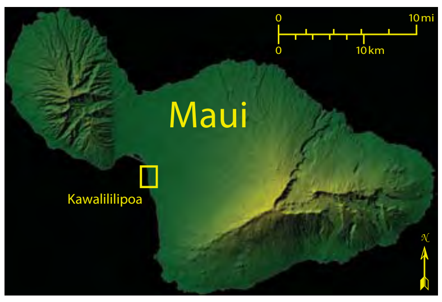

AREA DESCRIPTION

The Kawililipoa study area (transects 513 – 617) is located on the south coast of Maui between a groin in the south and Koieie Fishpond in the north. The shoreline is composed of calcareous sand beach and artificial revetments. The coast is exposed to south swell in summer months and Kona storm waves. A shallow fringing reef protects the shoreline from the full energy of open-ocean waves. In addition to Koieie Fishpond, remains of three other fishponds are found just offshore and may be a factor in the pattern of shoreline change in the area.

The Kawililipoa shoreline is characterized by alternating cells of erosion and accretion along the shore. The south end of the study area (transects 513 – 526) has been approximately stable to slightly erosive with rates under -0.3 ft/yr. An accreted cusp of sand has formed at Kawililipoa (transects 527 – 560) since 1900 or earlier with annual accretion rates as high as 4.8 ft/yr around transect 552. A small area of erosion at transects 561 – 576, with rates up to -0.8 ft/yr, separates Kawililipoa from another accreted cusp at transects 579 – 608 with rates as high as 2.1 ft/yr. The beach inside Koieie Fishpond (transects 609 – 617) has eroded at up to -3.1 ft/yr resulting in loss of the beach at transects 609 – 612 and 616 – 617 and construction of stone revetments to protect shorefront properties.

SHORELINE CHANGE RATES

- Accretion Rate
- Erosion Rate

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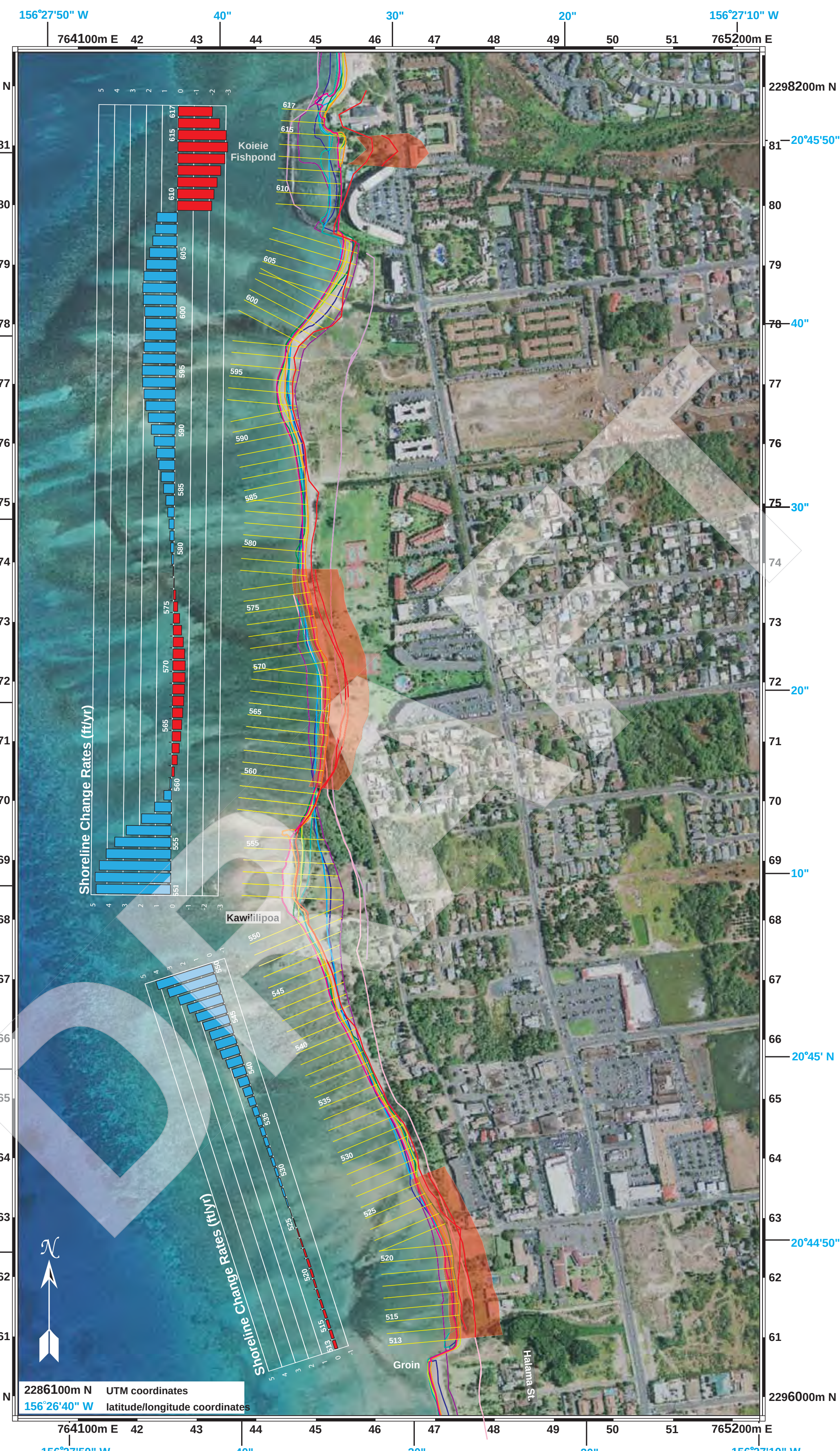
EROSION HAZARD FORECAST LINE

Erosion Hazard Forecast Line
50 years + 20 feet
with 95% confidence interval

The Erosion Hazard Line is a 50 year forecast of the vegetation line position based on the historical rate of erosion at each transect plus a 20 foot buffer. The thick red band shows the uncertainty of the hazard forecast line at the 95% confidence interval. Erosion hazard forecast lines are shown along the shoreline where historical shorelines indicate erosion. Erosion hazard lines are not shown where the beach has been lost and is now hardened (e.g., seawalls).

TRANSECT	ST(ft/yr)	SETBACK(ft)
513	-0.2	36.5
514	-0.2	35.5
515	-0.2	34.8
516	-0.2	34.4
517	-0.2	33.0
518	-0.1	31.6
519	-0.1	31.6
520	-0.2	33.6
521	-0.2	34.0
522	-0.1	31.9
523	-0.1	30.0
524	-0.1	28.9
525	0.0	27.0
526	0.0	NO EROSION
527	0.1	NO EROSION
528	0.2	NO EROSION
529	0.2	NO EROSION
530	0.2	NO EROSION
531	0.2	NO EROSION
532	0.3	NO EROSION
533	0.3	NO EROSION
534	0.3	NO EROSION
535	0.3	NO EROSION
536	0.4	NO EROSION
537	0.5	NO EROSION
538	0.6	NO EROSION
539	0.8	NO EROSION
540	0.9	NO EROSION
541	1.2	NO EROSION
542	1.3	NO EROSION
543	1.5	NO EROSION
544	1.7	NO EROSION
545	1.9	NO EROSION
546	2.2	NO EROSION
547	2.6	NO EROSION
548	3.0	NO EROSION
549	3.6	NO EROSION
550	4.2	NO EROSION
551	4.7	NO EROSION
552	4.8	NO EROSION
553	4.5	NO EROSION
554	4.1	NO EROSION
555	3.5	NO EROSION
556	2.8	NO EROSION
557	1.9	NO EROSION
558	1.1	NO EROSION
559	0.5	NO EROSION
560	0.1	NO EROSION
561	-0.2	33.4
562	-0.3	42.1

TRANSECT	ST(ft/yr)	SETBACK(ft)
563	-0.5	47.9
564	-0.5	52.4
565	-0.6	54.9
566	-0.7	57.7
567	-0.7	60.6
568	-0.8	62.7
569	-0.8	63.8
570	-0.8	63.9
571	-0.7	61.8
572	-0.6	57.4
573	-0.5	51.6
574	-0.4	45.1
575	-0.3	38.8
576	-0.2	32.5
577	0.0	27.2
578	0.0	NO EROSION
579	0.1	NO EROSION
580	0.2	NO EROSION
581	0.3	NO EROSION
582	0.3	NO EROSION
583	0.4	NO EROSION
584	0.5	NO EROSION
585	0.7	NO EROSION
586	0.8	NO EROSION
587	1.0	NO EROSION
588	1.2	NO EROSION
589	1.3	NO EROSION
590	1.5	NO EROSION
591	1.7	NO EROSION
592	1.9	NO EROSION
593	2.0	NO EROSION
594	2.1	NO EROSION
595	2.1	NO EROSION
596	2.1	NO EROSION
597	2.0	NO EROSION
598	2.0	NO EROSION
599	1.9	NO EROSION
600	2.0	NO EROSION
601	2.1	NO EROSION
602	2.1	NO EROSION
603	2.1	NO EROSION
604	1.9	NO EROSION
605	1.7	NO EROSION
606	1.5	NO EROSION
607	1.4	NO EROSION
608	1.3	NO EROSION
609	-2.2	133.0
610	-2.3	139.7
611	-2.5	149.3
612	-2.7	160.3
613	-3.0	173.2
614	-3.1	181.5
615	-3.0	176.5
616	-2.6	155.3
617	-2.1	132.2



Scale 1:3000

100 0 100 200 300 400 Meters

300 0 300 600 900 1200 Feet

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Grant Agreement G2824

Halama Street, Maui, Hawaii

TRANSECT	ST(ft/yr)	SETBACK(ft)
402	-1.1	79.0
403	-1.0	77.3
404	-1.0	72.6
405	-0.8	64.2
406	-0.7	58.6
407	-0.7	59.4
408	-0.8	66.7
409	-0.9	71.0
410	-0.9	72.1
411	-0.9	70.5
412	-0.8	67.3
413	-0.7	62.4
414	-0.7	58.9
415	-0.7	60.3
416	-0.8	66.5
417	-0.9	72.3
418	-1.0	75.8
419	-1.0	76.9
420	-1.0	77.0
421	-1.1	78.8
422	-1.1	81.9
423	-1.2	85.5
424	-1.3	89.3
425	-1.3	90.4
426	-1.3	88.1
427	-1.2	87.0
428	-1.3	89.2
429	-1.5	97.6
430	-1.8	116.3
431	-2.3	141.2
432	-2.6	156.8
433	-2.7	162.4
434	-2.7	161.7
435	-2.7	158.4
436	-2.6	156.9
437	-2.6	157.4
438	-2.7	159.3
439	-2.7	160.7
440	-2.7	160.0
441	-2.6	156.4
442	-2.5	151.0
443	-2.4	143.4
444	-2.2	137.0
445	-2.2	135.3
446	-2.3	139.7
447	-2.3	141.0
448	-2.3	138.9
449	-2.2	136.1
450	-2.2	133.2
451	-2.1	132.0

TRANSECT	ST(ft/yr)	SETBACK(ft)
452	-2.0	127.1
453	-1.9	119.2
454	-1.7	109.9
455	-1.5	97.9
456	-1.2	82.7
457	-1.1	77.6
458	-1.2	85.9
459	-1.5	100.0
460	-1.6	103.8
461	-1.4	97.4
462	-1.4	93.0
463	-1.4	93.7
464	-1.4	96.3
465	-1.5	100.1
466	-1.6	105.5
467	-1.7	112.2
468	-1.8	114.0
469	-1.7	110.7
470	-1.6	105.6
471	-1.6	102.6
472	-1.6	102.5
473	-1.5	101.8
474	-1.5	98.5
475	-1.4	92.9
476	-1.2	86.6
477	-1.2	83.1
478	-1.1	81.4
479	-1.1	79.3
480	-1.1	78.7
481	-1.1	81.2
482	-1.2	83.3
483	-1.1	82.0
484	-1.0	75.8
485	-0.8	66.1
486	-0.7	59.4
487	-0.8	65.0
488	-1.1	79.9
489	-1.2	86.2
490	-1.2	82.8
491	-1.0	74.5
492	-0.8	63.9
493	-0.5	51.8
494	-0.3	39.9
495	-0.1	28.0
496	0.2	NO EROSION
497	0.5	NO EROSION
498	0.7	NO EROSION
499	0.9	NO EROSION
500	1.1	NO EROSION
501	1.2	NO EROSION

TRANSECT	ST(ft/yr)	SETBACK(ft)
502	1.3	NO EROSION
503	1.4	NO EROSION
504	1.5	NO EROSION
505	1.5	NO EROSION
506	1.5	NO EROSION
507	1.5	NO EROSION
508	1.5	NO EROSION
509	1.6	NO EROSION
510	1.6	NO EROSION
511	1.7	NO EROSION
512	1.8	NO EROSION

SHORELINE CHANGE RATES

Accretion Rate

Erosion Rate

Historical shoreline positions are measured every 66 ft along the shoreline. These sites are denoted by yellow shore-perpendicular transects. Changes in the position of the shorelines through time are used to calculate shoreline change rates (ft/yr) at each transect location.

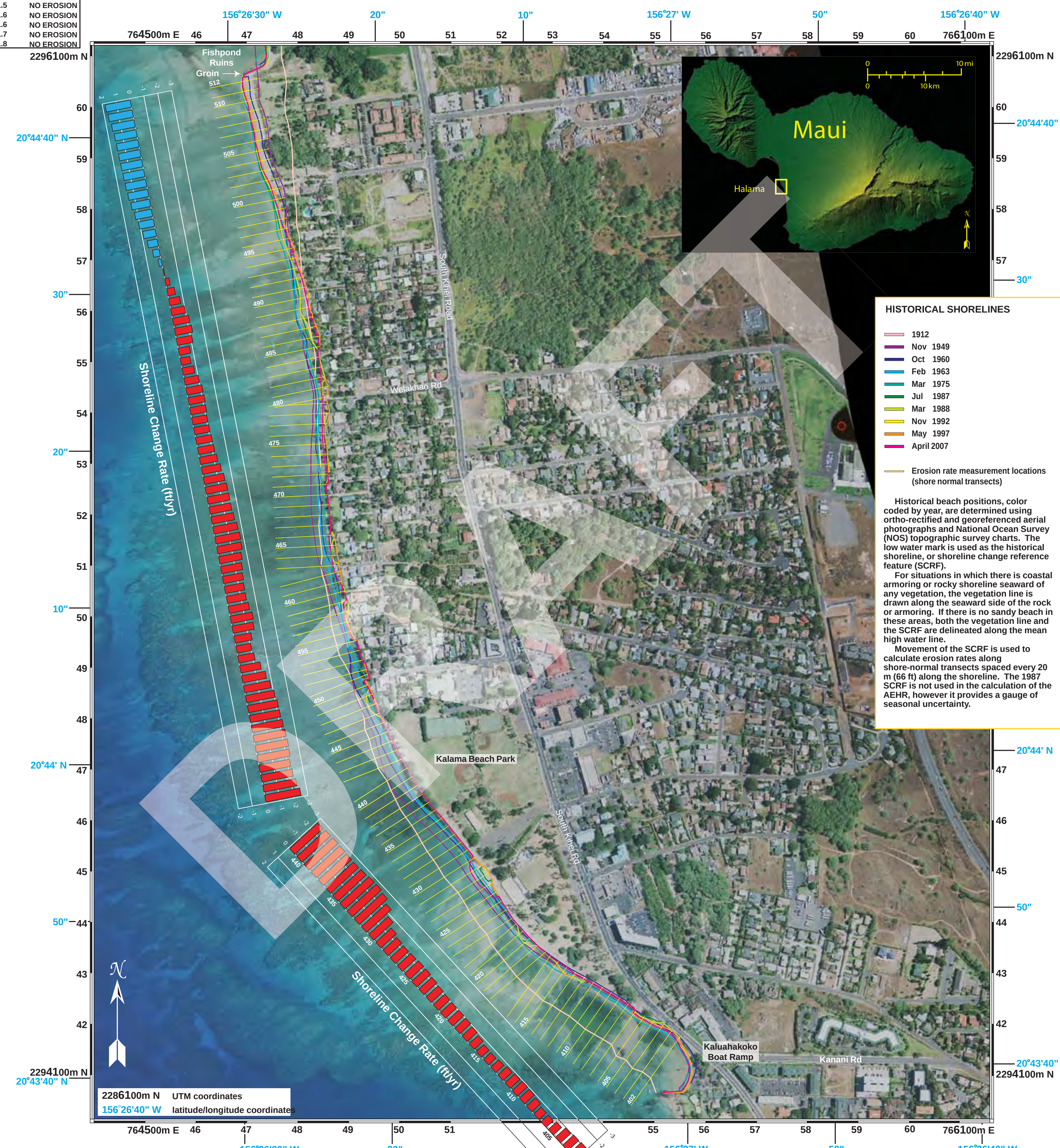
Annual shoreline change rates are shown on the shore-parallel graph. Red bars on the graph indicate a trend of beach erosion, while blue bars indicate a trend of accretion. Approximately every fifth transect and bar of the graph is numbered. Where necessary, transects have been purposely deleted to maintain consistent along-shore spacing. As a result transect numbering is not consecutive everywhere.

The ST method is used to calculate shoreline change rates for the study area. The rates are smoothed along shore using a 1-3-5-3-1 technique to normalize rate differences on adjacent transects. For more information on erosion rate methods and results see: *http://www.soest.hawaii.edu/asp/coasts/oahu/index.asp*

AREA DESCRIPTION

The Halama Street study area (transects 402 -512) is located on the south shore of Maui between the ruins of a Hawaiian fishpond and a groin in the north and Kaluahakoko Boat Ramp in the south. The shoreline is exposed to southerly swell in summer and Kona storm waves. A shallow fringing reef protects the shoreline from the full energy of open-ocean waves.

The central and southern portions of the Halama Street study area (transects 402 - 495) are characterized by chronic erosion and beach loss. Little or no beach has existed between transects 402 - 450 since the 1970's, transects 451 - 484 since the 1980's, and transects 485 - 495 since the 1990's. Waves break against revetments in this area at high tide. Only intermittent pockets of sand are found in small openings and at the base of revetments in this area in the 2007 air photos. For areas where the beach has been lost to erosion, shoreline change rates are calculated up to and including the first shoreline with no beach and show the rate at which the beach disappeared. The beach in the north of the study area (transects 496 - 512) has accreted against the south side of a groin. Expanding beach loss toward the north and accretion against the south side of the groin suggests that predominant sediment transport is to the north and that there is a threat of continued expansion of the extent of erosion and beach loss toward the north.



Scale 1:3000

100 0 100 200 300 400 Meters

300 0 300 600 900 1200 Feet

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APPENDIX F

SEDIMENT TRANSPORT BUDGETS – KAHULUI REGION

I. Sediment Budget Methodology

A. Overview

The sediment budgets are based on available information regarding shoreline accretion and erosion. The significant uncertainties in the different elements of the budget, and the fact that the losses offshore and into the deep channels have not been quantified, mean that the actual numbers should only be considered a guide. However, the values are adequate for planning and evaluating potential sediment management and beach nourishment projects in the region.

Section B below describes an approach commonly used in sediment budget analyses, but which was proven to be not useful from the Oahu D2P Sediment Budget Report (M&N 2009). Conventional sediment transport rates are actually potential rates, based on the assumption that a sandy bottom is present throughout the study reach: a more sophisticated sediment transport analysis would be needed to provide insight into the Maui regions because of the presence of the reef bottom.

Since this sediment transport rate analysis was found not to be useful, the sediment budget was developed based on volumetric changes over the past few decades, or after all significant structures were constructed in each region. The timeframe for the analysis varies by littoral cell, based on the extent of recent human modifications. The general approach to budget development was as follows.

- The historical volumes of sediment on the beaches were estimated from the historical shoreline positions developed by the University of Hawai‘i (Hawai‘i Coastal Geology Group 2009; see Section IX.B) and using a conversion factor of 0.40 cubic yards per square foot of beach, based roughly on the results of analysis performed in the D2P study. The total beach volume in these graphs is defined as the volume of beach between the shoreward toe (moves over time) and a stable back beach vegetation line (does not move over time).
- The beach volume graphs were studied, relative to historical events and erosional versus accretional trends, to calculate representative average erosion or accretion rates for appropriate time periods for each littoral cell. This rate was based on a linear fit of the beach volume data using a weighted least squares approach.
- The rates take into account historical beach nourishment which would be included in the historical beach volumes of the graphs below. There has been some historical beach nourishment on Maui. The most significant ongoing beach nourishment within the Kahului region has been at Sugar Cove in the Sprecklesville area (M&N 2008). Sand was also placed within Kahului Harbor in 1969 (USACE 1973) and a small beach nourishment project occurred near Mama’s Fish House in 2006 (DLNR 2010). In the Kihei region, nourishment projects occurred on beaches fronting the Maui Lu hotel and a private residence within the North Kihei cell (DLNR 2010) and on beaches fronting condominiums just east of Maalaea Harbor (USACE 2004).

- The rates take into account seasonal fluctuation to some extent by use of the least squared regression analysis, which includes a seasonal variation uncertainty error.

These steps are described further below. The resulting preliminary sediment budgets for the different littoral cells are provided in Section II of this appendix.

With the volume changes established, the sediment transport pathways could be developed based on coastal processes, particularly current modeling, and on general morphological considerations. This may be done in future studies and/or future revisions of this document.

B. Potential Sediment Transport Rates

The rate of longshore sediment transport is often modeled as a function of such inputs as breaker wave height, period, approach direction, and sediment parameters. A typical model – far from the only one of its type – is known as the CERC Equation, which is based on the assumption that the longshore sediment transport rate is proportional to the longshore energy flux. It is expressed by Smith, Ebersole, and Wang 2004 as follows:

$$Q = \frac{K}{16\sqrt{g}} r_w g^{3/2} H_{sb}^{\ 5/2} \sin 2a$$

where Q is the longshore sediment transport rate expressed as an immersed weight, K is an empirical coefficient, r_w is the density of water, g is the acceleration due to gravity, H_{sb} is the significant wave height at breaking, γ is the breaker index, and α is the angle between the breaking wave crests and the shoreline. The calibration coefficient K has been obtained for different conditions based on field measurements.

Models of this type produce potential transport rates – that is, the rate of sediment transport under the assumption that plentiful sediment is available throughout the breaker zone. This is not the case in the presence of a fringing reef, which introduces a hard bottom over much of the breaker zone (e.g., Eversole and Fletcher 2003). In addition, breaker dynamics are affected by the large bottom friction that results from the very rough reef surface (Hearn 1999). Therefore, it is likely that the straightforward application of standard potential transport rate equations region will vastly overpredict the actual transport rates. This was proven out in the Oahu D2P Sediment Budget Report (M&N 2009) and is assumed to be the case for Maui.

C. Beach Erosion and Accretion

Volumetric erosion and accretion rates were based on the shoreline erosion mapping work prepared by the University of Hawai‘i (University of Hawai‘i Coastal Geology Group 2010; methods are described in Fletcher et al. 2003). Measured shoreline positions along each transect (spaced at 20 meters) were provided to M&N. M&N performed a beach area analysis, calculating the changes in total beach area for individual littoral cells and some subcells (in contrast to the work by UH, which focused on retreat distances along the shoreline). The result of this work was an estimate of total beach area, relative to the latest vegetation line, for each cell. The area was converted to beach volume using a factor of 0.40 cubic yards per square foot of beach.

D. Structures, Storms, and Historical Sand Placement

Table F-1 provides an overview of the known sand placement activities, along with a chronology of other significant coastline activities, in the Kahului region. There has been some historical beach nourishment on Maui. The most significant ongoing beach nourishment within the Kahului region has been at Sugar Cove in the Sprecklesville area (M&N 2008). Sand was also placed within Kahului Harbor in 1969 (USACE 1973) and in 1976. A small beach nourishment project occurred near Mama's Fish House in 2006 (DLNR 2010).

Table F-1. Kahului Region Structures, Storms, Historical Sand Placement

Date	Activity	Volume (cy) where relevant	Cell	Comments
1900 - 1975	Sand mining in region			
1904	Initial construction of Kahului Harbor by the Kahului RR Company.		Kahului Harbor	Improvements consisted of a 1,800-foot east breakwater and a turning basin.
1910	Kahului Harbor adopted as a Federal project.		Kahului Harbor	
1913	Completed construction of a 400-foot extension of the east breakwater of Kahului Harbor.		Kahului Harbor	
1919	Completed donstruction of a 1,950 foot long west breakwater of Kahului Harbor and dredging of the basin.		Kahului Harbor	Dredging of the basin to an to an average width of 900 feet and a minimum depth of 35 feet.
1929	Start of construction of Kahana Beach Park west groins		Kanaha Beach	
1931	Kahului Harbor: Extension of east and west breakwaters to 2,850 and 2,390 feet in length, respectively; enlargement of the harbor basin and dredging of the entrance channel.		Kahului Harbor	Enlargement of the harbor basin to 2,000 feet in length with a maximum width 1,450 feet and dredging of the entrance channel 600 feet wide between the breakwaters, all to a depth of 35 feet.
Dec. 1957	Hurricane Nina			
Aug.1959	Hurricane Dot			
pre-1960	Construction of Kanaha Beach Park central and east groins		Kanaha Beach	
pre-1960	Construction of groins east of Kahana Beach groins		Kanaha Beach	
1962	Kahului Harbor constructed to current configuration. Dredge material from this project was placed in the northwest corner (near the west breakwater).		Kahului Harbor	Current configuration: 2,050 feet by 2,400 feet with a depth of 35 feet.
1960-1975	Conclusion of historic sand mining in region			
1969	Groins and revetment constructed within Kahului Harbor, on north-facing shoreline		Kahului Harbor	
3/24/1964	Alaska tsunami			
Mar.1977	Kahului Harbor dredged	24,300	Kahului Harbor	
1977-78	WWRF revetment built		Kanaha Beach	
11/23/1982	Hurricane Iwa			
Mar.1990	Kahului Harbor dredged	73,700	Kahului Harbor	
9/11/1992	Hurricane Iniki			
Feb.1999	Kahului Harbor dredged	91,000	Kahului Harbor	
2005	Kahului Light Draft Harbor dredged	8,700	Kahului Harbor	
Beach Nourishments:				
1969	Beach nourishment within Kahului Harbor, in groin field on north-facing shoreline	4,000	Kahului Harbor	
1976	Beach nourishment as part of Kahului Bay Mitig. Project	6,550	Kahului Harbor	
1996-2002	Sugar Cove beach nourishment	17,000	Sprecklesville	
2002 - 2007	Sugar Cove beach nourishment	6,000	Sprecklesville	
Oct. 2006	Mama's Fish House Beach Nourishment	500	Hookipa	

E. Seasonal Trends

Seasonal trends in beach characteristics are common worldwide. Seasonal changes in wave energy can bring about onshore-offshore transport, with beaches typically becoming narrower during periods of high wave energy and recovering when the wave energy decreases. Seasonal changes in wave direction can bring about longshore transport, with different areas accreting and eroding at different seasons.

Beach profiles for areas within both regions of Maui have been developed by the University of Hawaii (2010) and USGS (2010b). Following are the beach profiles within the Kahului region ("north shore Maui"). The profile locations are shown on the map (Figure F-1) below. The profiles are ordered from west to east.

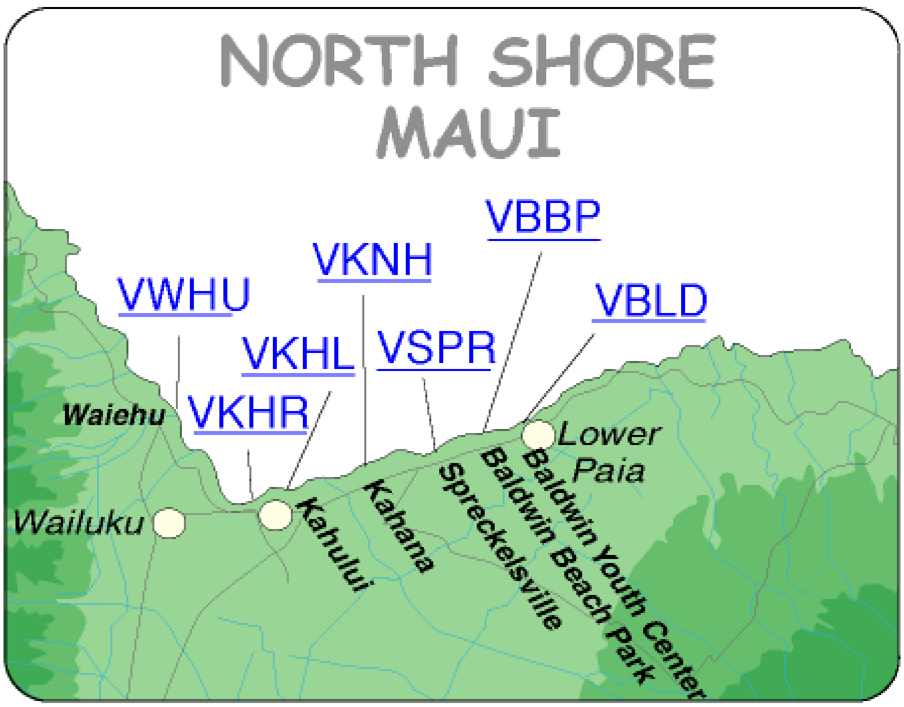
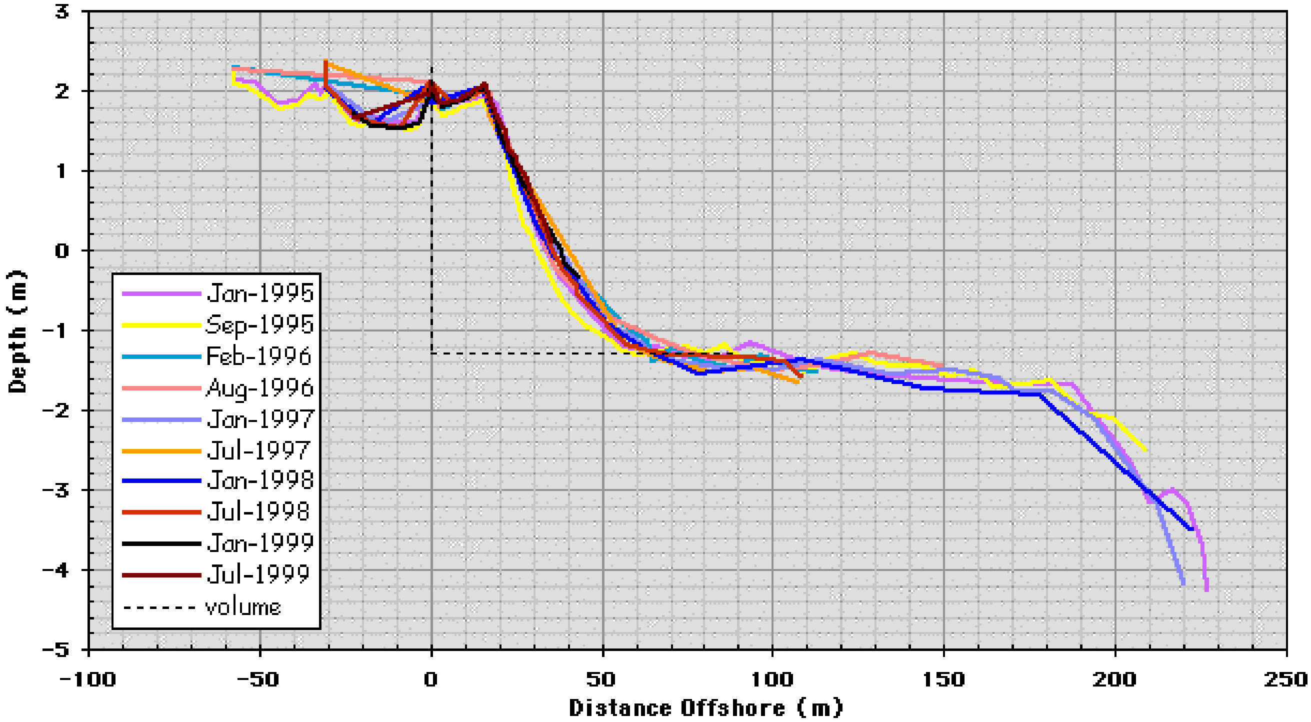
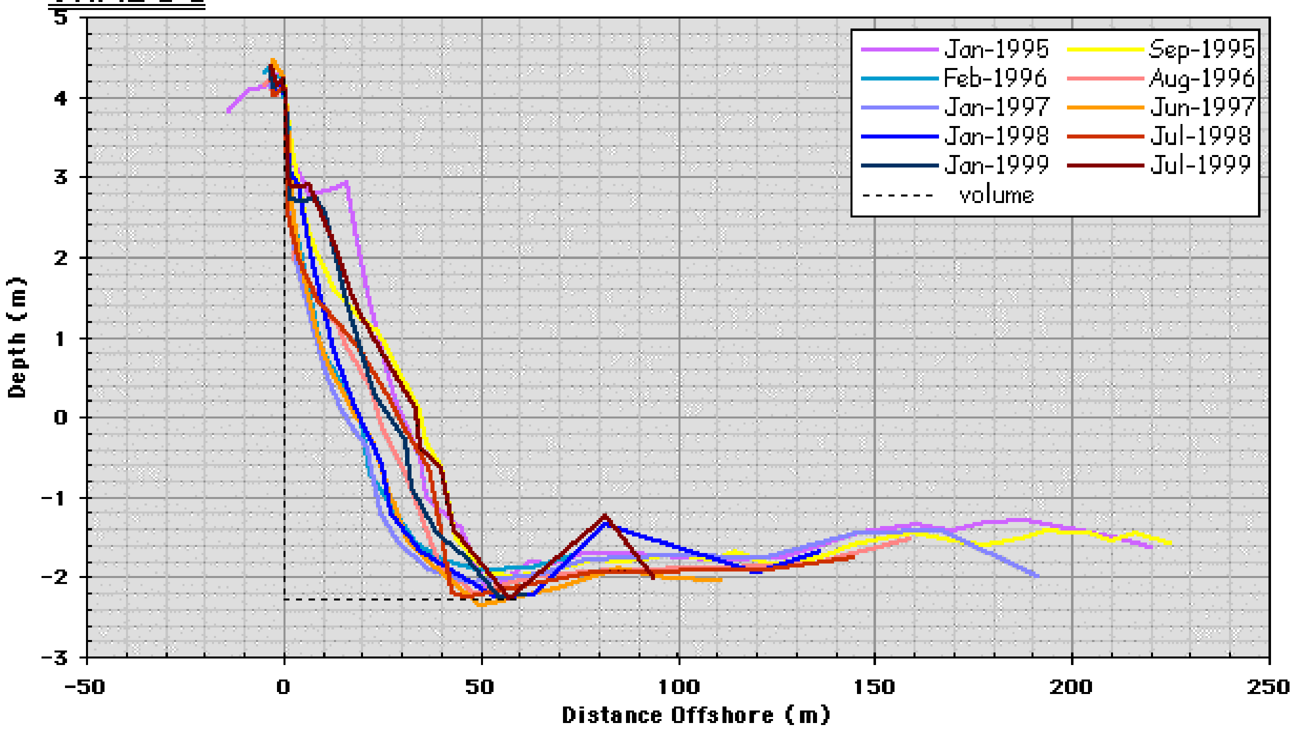


Figure F-1. Locations of Kahului Region Beach Profiles

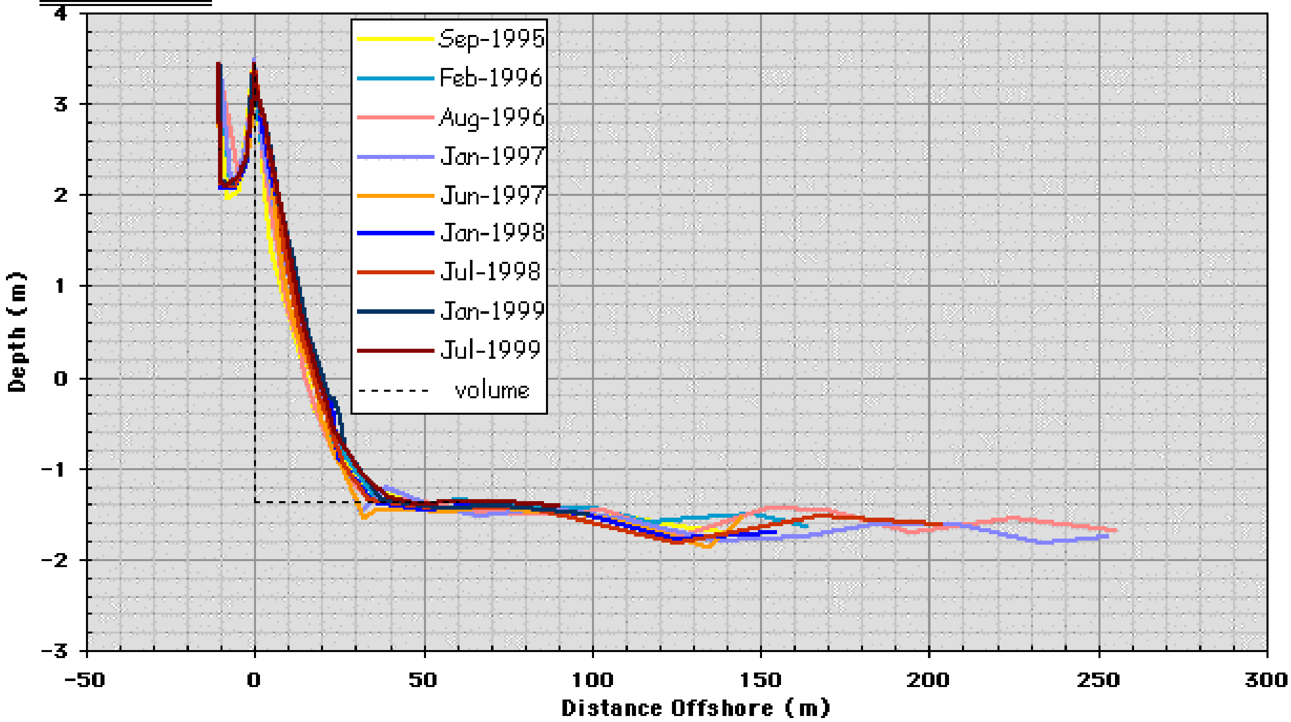
VKHR 1-1



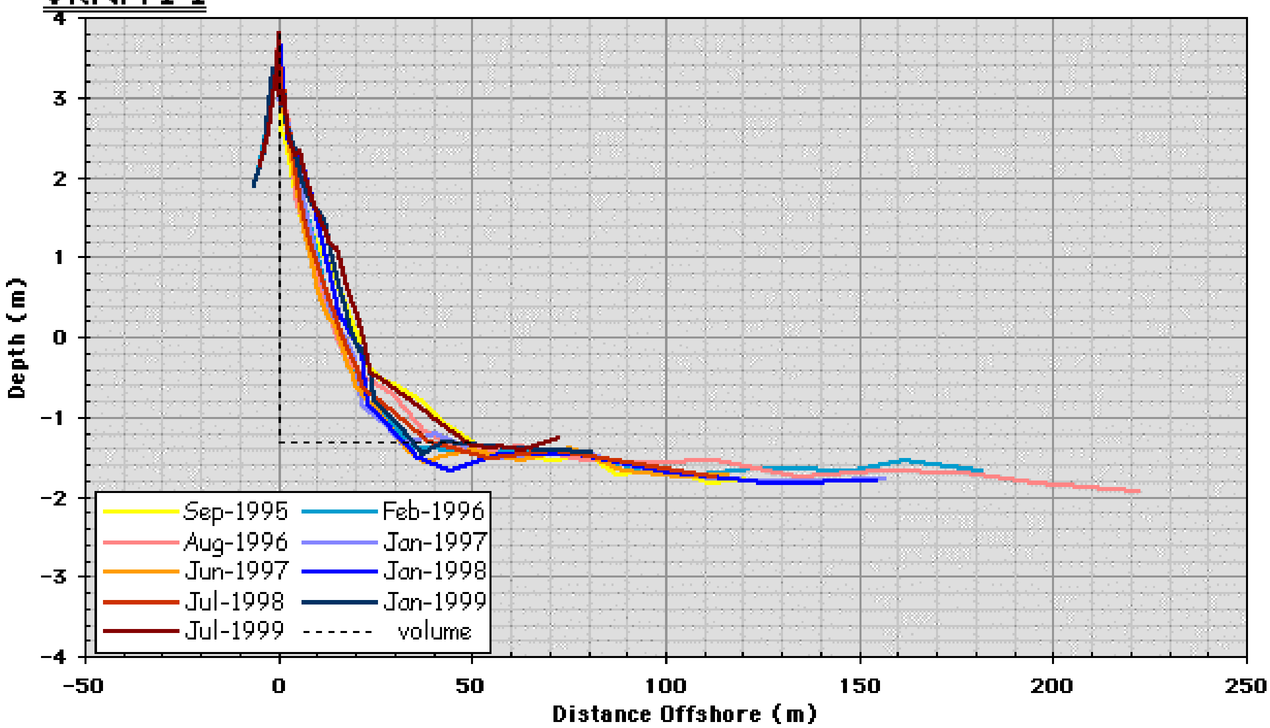
VKHL 1-1

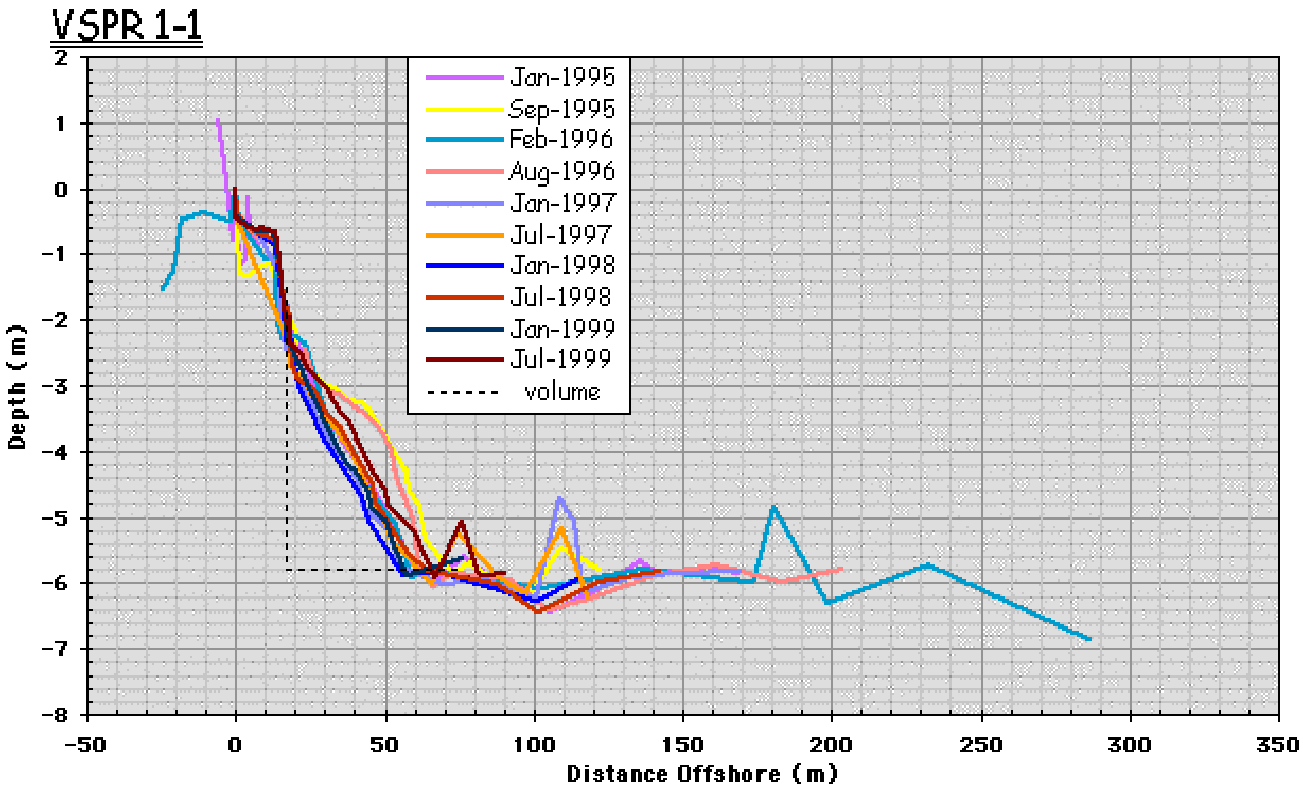


VKNH 1-2

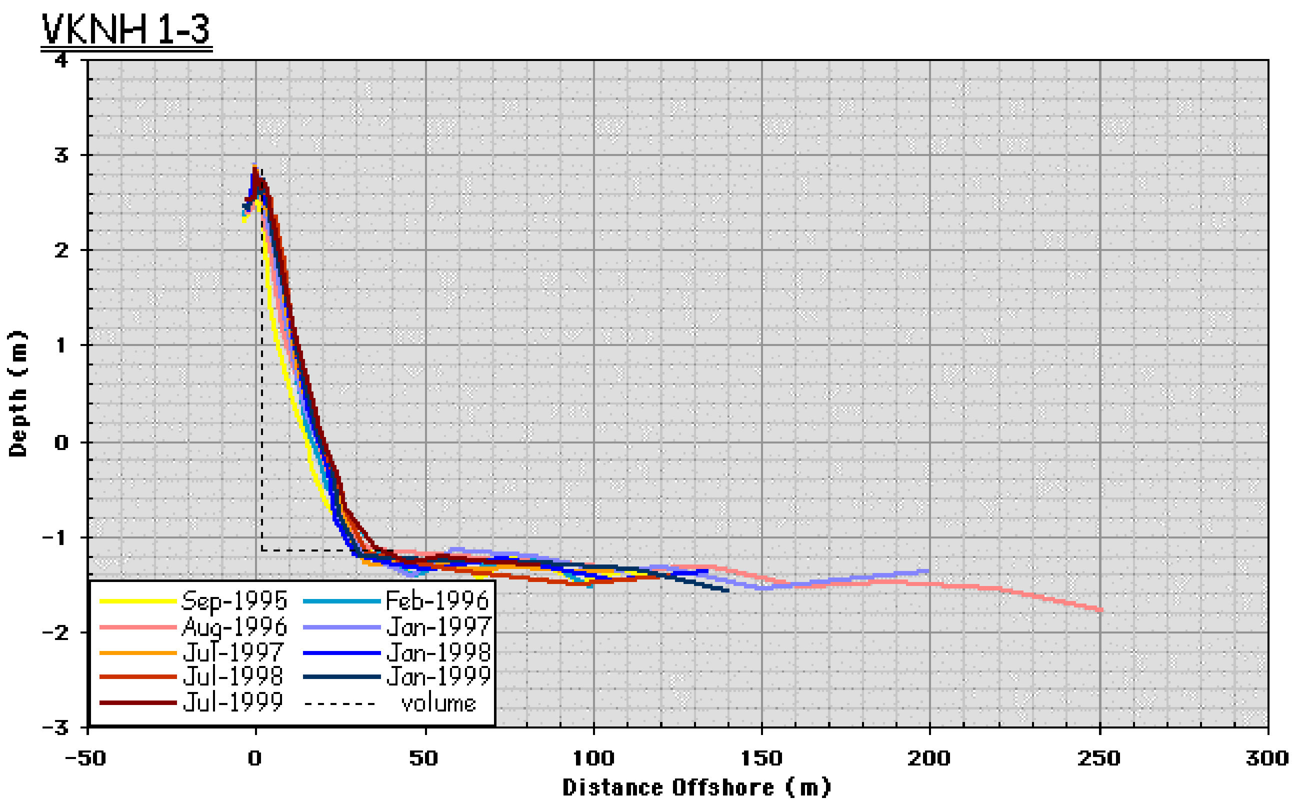


VKNH 1-1



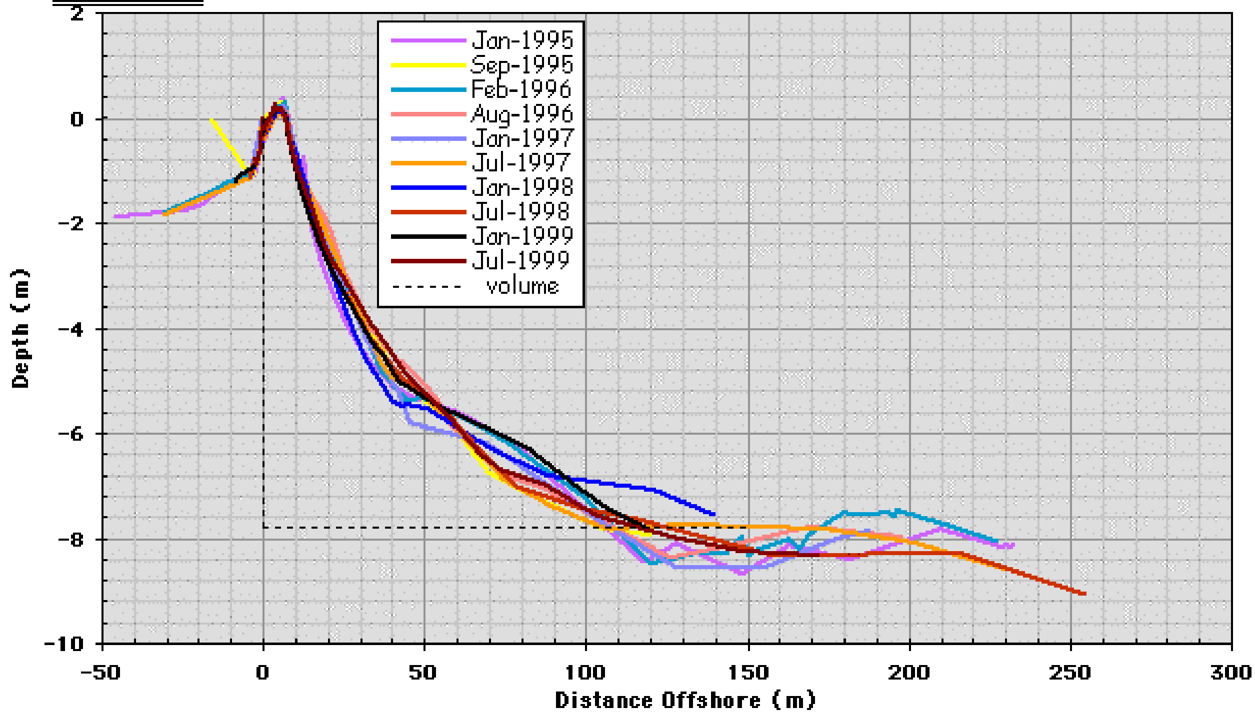


VSPR 1-1
Jan-1995
Sep-1995
Feb-1996
Aug-1996
Jan-1997
Jul-1997
Jan-1998
Jul-1998
Jan-1999
Jul-1999
volume
Depth (m)
Distance Offshore (m)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-50
0
50
100
150
200
250
300
350

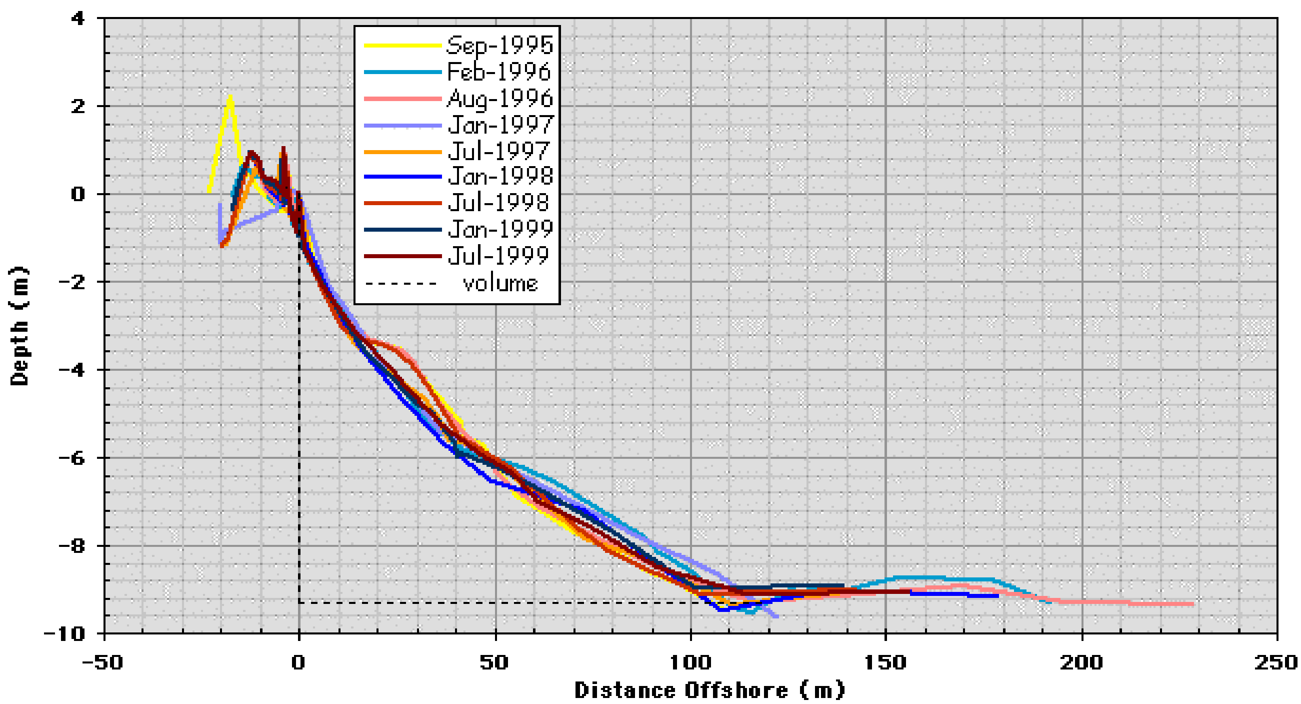


VKNH 1-3
Sep-1995
Feb-1996
Aug-1996
Jan-1997
Jul-1997
Jan-1998
Jul-1998
Jan-1999
Jul-1999
volume
Depth (m)
Distance Offshore (m)
4
3
2
1
0
-1
-2
-3
-50
0
50
100
150
200
250
300

VBLD 1-1



VBBP 1-1



Figures F-2 through F-10. Beach Profiles within the Kahului Region

For the calculated volumetric erosion/accretion rates, seasonal variation is addressed by the linear regression / weighted least squares analysis of the volumes. The analysis is based on the total position uncertainty error provided by UH for each of the erosion maps, and the total position uncertainty error includes a factor for the seasonal fluctuation. This calculated seasonal fluctuation error varies in the Kahului region from approximately 15 feet (Kahului Harbor, Kanaha cells) to approximately 30 feet in the Baldwin Park, Sprecklesville, and Paukukulo cells.

The estimated potential error band associated with seasonal variation, and other uncertainty errors, is shown on each line graph as an error bar. This bar is an attempt to bound the potential range of beach volume within a given year and thus account for seasonal variation when comparing the limited shoreline data points.

A separate analysis of the seasonal variations in the Kanaha Beach area within the Kahului area, specifically the beach fronting the wastewater reclamation facility, was previously completed by Moffatt & Nichol (2008). A summary of the analysis is provided below, including a discussion of both the long-term/annual changes and seasonal changes.

M&N (2008)

USGS Profile Data

Profile data measured by the USGS from 1995 to 1999 measured by were obtained from the USGS website (<http://geopubs.wr.usgs.gov/open-file/of01-308/HTML1/Mnorth.html>). The nearest profile location to the study site is called VKHL and it is located near the western property line of the WWRF, close to Station 72 in the County Erosion Maps. The data from these profiles were reviewed to evaluate short-term – annual and seasonal – changes in trends in shoreline position west of the WWRF.

Annual Changes

For the annual shoreline change rates, it is important to compare data from the same seasons to obtain an accurate picture of the shoreline trends without the seasonal fluctuations.

At VKHL, the winter profile data (Figure F-11) show that from January 1995 (black line with crosses) to February 1996 (dark blue/squares), the MLLW contour receded approximately 42 feet. The shoreline position remained similar at the January 1997 measurement, but recovered somewhat by 1998 (light blue/triangles). The January 1999 (gray/ circles) data indicate the shoreline had advanced again and had almost reached the original January 1995 position.

The summer profiles show a similar trend (Figure F-12). The shoreline receded approximately 30 feet between September 1995 (dark red/squares) and August 1996 (light red/diamonds). By June 1997 (yellow/triangle), the shoreline receded an additional 12 feet. The shoreline advanced over the following two years, such that by July 1999 (mauve/crosses) the shoreline position was almost at the same position as the 1995 shoreline.

These data indicate the shoreline at this location has varied in recent years around a mean rather than displaying a consistent erosional or accretional trend. The maximum variation from year to year is 40 to 45 feet.

Seasonal Changes

The shoreline also moves between summer and winter profiles every year. The direction of movement is the opposite of that suggested by the analysis of plan view changes and general observations regarding the generally erosional effects of waves generated by northeast trade winds. As is shown below, the winter profiles, measured before the northeast trade season (January/February), are consistently landward of the summer profiles, measured in the middle and end of the season (June through September). The likely reasons for this are discussed below, after the data have been presented.

Figure F-13 and Figure F-14 present the seasonal changes for each year of the shoreline profile data. The winter profiles are consistently landward of the previous summer profiles. From Figure F-19, the largest recession is on the order of 42 feet, observed between September 1995 and February 1996. The 1997-1998 and 1998-1999 profiles show little or no erosion (a maximum of 6 feet) between the summer and subsequent winter locations.

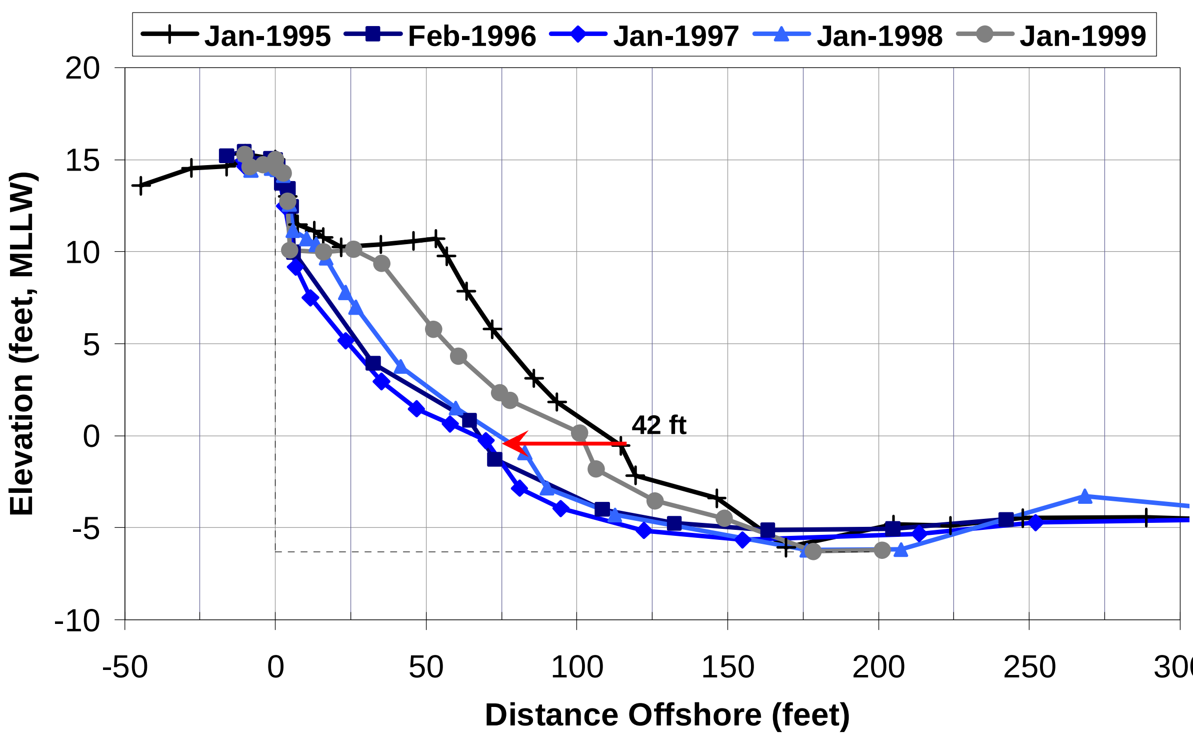


Figure F-11. Winter Profiles at VKHL from 1995 to 1999.

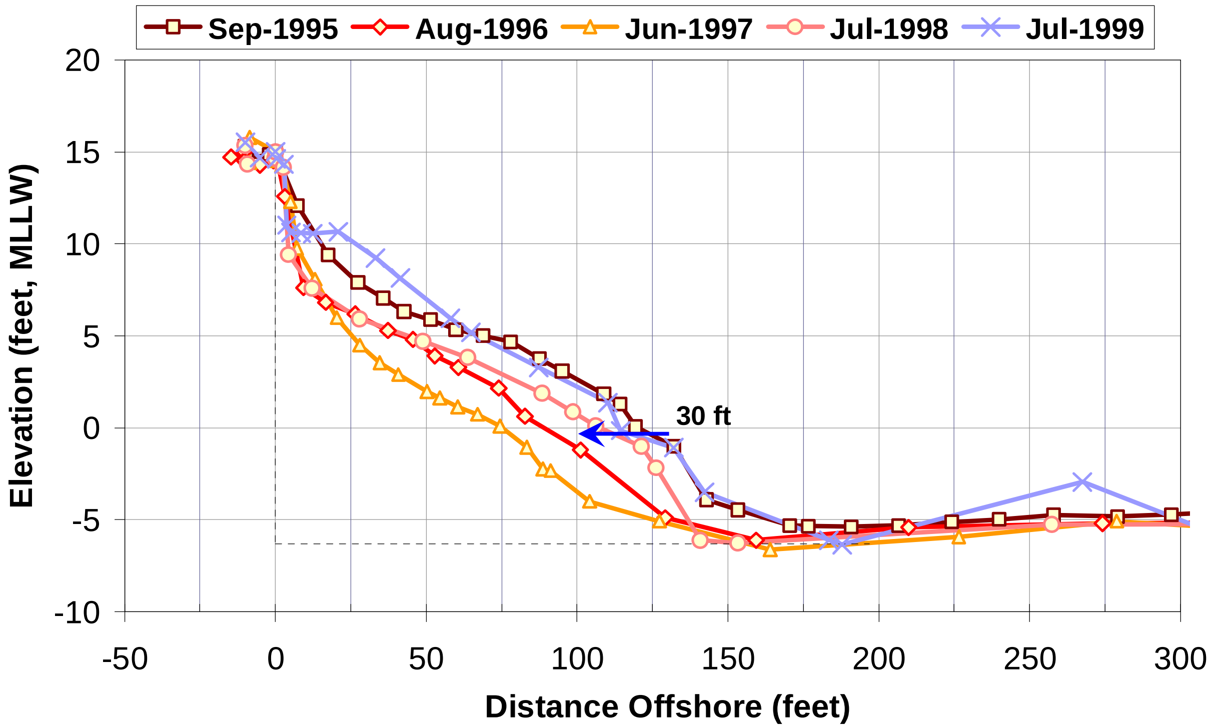


Figure F-12. Summer Profiles at VKHL from 1995 to 1999.

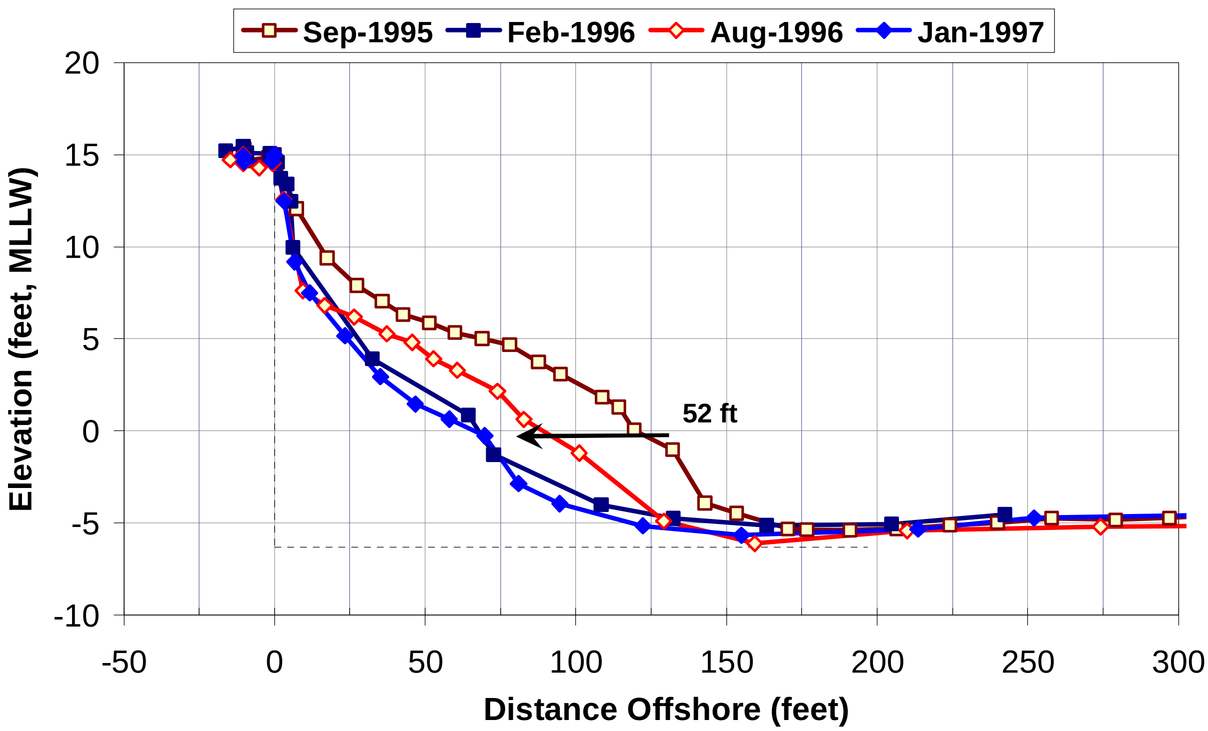


Figure F-13. Seasonal Changes in Profiles at VHKL, 1995-1996 and 1996-1997

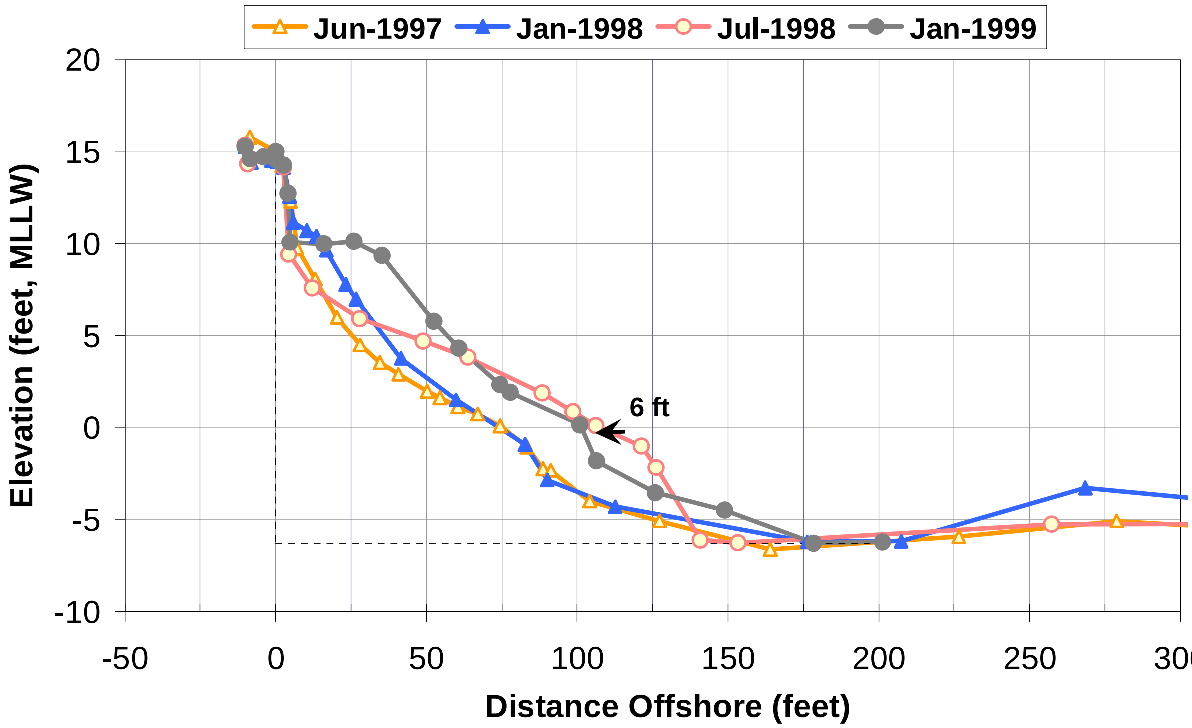


Figure F-14. Seasonal Changes in Profiles at VHKL, 1997-1998 and 1998-1999

The reason for this contrary behavior of the shoreline at VHKL – with the shoreline accreting rather than receding during the northeast trade season – is that the profile is located close to the western limit of the WWRF beach. During the northeast trade season, the WWRF beach and Kite Beach both generally experience erosion. However, since the waves generated by the northeast trade winds are directed towards the southwest, there is also a tendency for the sediment within the two, largely isolated, beaches to move towards the west. The movement of sediment towards VHKL near the western limit of the WWRF beach apparently outweighs the general narrowing of the WWRF beach during this season.

Recent decadal changes in the beach at VHKL, at approximately Station 72, are directed contrary to the decadal changes in the WWRF beach as a whole. Repeating the analysis for the western, middle, and eastern thirds of the WWRF beach, show the expected seasonal changes (narrowing during the northeast trade season) are by far the most consistent in the middle of this littoral subcell. The typical seasonal variation in this middle portion of the beach is about 30 feet.

F. Sand Loss Mechanisms

Although directional sediment budgets were not prepared for this study, it is assumed that any loss of sand is offshore; into offshore channels or into the dredged areas of the harbors. In general, these losses are used to balance the budget – they are not estimated independently. Additional modeling and analysis work would be valuable to confirm these general rates.

Sand loss mechanisms that are considered small, and therefore not usually included explicitly in sediment budgets, are as follows.

- **Sea level rise**. This is not strictly a sand loss mechanism. However, it must be considered in a sediment budget analysis, because the shoreline will retreat as the sea level rises unless additional sand is available to build the beach up.

  The nearshore profile for Hawaiian beaches is often stated to have a typical slope of 1 percent (e.g., Fletcher *et al.* 2008). This means that a sea level rise of 1 inch would cause the shoreline to retreat by 100 inches, or about 8 feet in a century. However, this is not typical of the shorelines in the study regions. The Kahului region shorelines have active profiles that range approximately from 5 and 10 percent slope. Sea level rise in the study region has been historically 0.06 inches per year (NOAA 2010b), which corresponds to a horizontal retreat rate of up to 1.2 inches or 0.1 feet per year. This is very small compared with the typical rates of shoreline retreat in the study regions. Therefore, the effects of sea level rise upon the near-term sediment budget are very small.

- **Beachrock**. Beachrock is formed by cementation of beach sand in the intertidal zone. Beachrock can consist of sand or gravel cemented by calcium carbonate – which in turn is formed from, and impounds, calcareous sediments. There is beachrock found in the Maui regions, but any beachrock would remain on the beach – and would not be removed from the beach volume. Therefore, its formation is not believed to be a significant component in coastal erosion in the area, and it may actually help to stabilize the beach in certain instances.

- **Abrasion and dissolution of calcareous sand grains**. This is believed to be important for calcareous beaches over the long-term (millennial scale). However, it has not been adequately quantified for use in a short-term sediment budget. Any uncertainties in this loss mechanism can be incorporated into the uncertainties in reef sediment production.

- **Sand mining** is an obvious mechanism for beach erosion. In the early 1900s, large quantities of sand were removed from Kahului region beaches. Large-scale sand mining is now prohibited: the few exceptions include clearing sand from stream mouths.

G. Climate Change

Over the longer term – possibly over a timescale as short as 50 years – the sediment budget could be affected by climate change. There are a number of contributing factors:

- The potential for increased sea level rise, possibly as much as 4 to 5 feet over the next century;
- The potential for changes in the wave climate;
- The potential for degradation to the reef structure (e.g., bleaching);
- The potential for increased dissolution of calcareous grains as the seas acidify.

These potential changes are not incorporated into the preliminary sediment budget given here, which describes the littoral system as in a steady state apart from changes in the rate of beach nourishment. The potential for these effects to change the sediment budget presented here should be addressed as this RSM Plan progresses and the science presents quantifiable changes.

II. Sediment Budget Results – Kahului Region

A. Descriptions of Littoral Cells

The Kahului study region is approximately nine miles on the windward side of Maui and includes the towns of Kahului and Paia. The study region was divided into the following seven littoral cells, as shown in Figure F-15:

1. Paukukalo
2. Kahului Harbor
3. Kanaha Beach
4. Spreckelsville
5. Baldwin Park
6. Paia East
7. Hookipa

These cells are described below and shown in the following figures. Each of the littoral cell figures includes the shoreline features which possibly affect the shoreline sediment transport.

Paukukalo Littoral Cell

Paukukalo Littoral Cell is approximately 4,000 feet and extends from the Nehe Point (just northwest of the Iao Stream) to the Kahului Harbor Park. The shoreline is comprised of sand and cobble beach interspersed with hardened shoreline. A fringing reef system exists offshore, which acts to buffer the shoreline from the large seasonal north swells. The Iao Stream discharges into this cell.

Kahului Harbor Littoral Cell

The Kahului Habor Littoral Cell includes the region of the harbor between the east and west breakwaters, which includes both the deep draft and light draft channels. The breakwaters and groin (located on the shoreline immediately east of the harbor) were constructed in 1900 and improved in 1913. A sandy beach and protected shoreline exists within the bay and extends from Kahului Harbor Park east to Kaa, at the west end of Kanaha Beach Park. The Kahului Harbor is maintained periodically by the USACE and was last dredged in 2005. At that time, 8,700 cy of sediment was dredged from the channels. Previous dredging was performed in 1999 (91,000 cy), 1990 (73,700 cy) and 1977 (24,300 cy).

Kanaha Beach Littoral Cell

The Kanaha Beach Littoral Cell spans approximately three miles from Hobron Point to Papaula Point. Moderate width sandy beaches exist in this cell with a number of areas with shoreline protection in place. Shoreline features in the cell include:

- A shoreline-protruding outfall structure just east of Hobron Point;

- Five boulder groins exist in the region of Kaa;
- Eleven boulder groins at Kanaha Beach constructed in phases beginning around 1929; and
- A 450-foot rock revetment constructed in 1979, fronting the Wailuku / Kahului Wastewater Reclamation Facility retention pond.

A wide fringing reef exists offshore with stranded beach rock benches located at Papaula Point. The Kalialinui Gulch is a non-perennial stream that discharges to the cell.

M&N (2008) concluded that there is significant seasonal variation in the area, up to 52 feet at one location. However, there is a typical pattern of seasonal shoreline erosion followed by recovery.

Spreckelsville Littoral Cell

The Spreckelsville Littoral Cell is approximately one mile in length and extends from Papaula Point west to Wawau Point. The shoreline is comprised of sandy beach broken by exposed basalt boulders and headland structures. Revetment fronting residential homes exists in Spreckelsville. Beach nourishment has taken place over multiple years on the beach fronting the Sugar Cove Apartments. Approximately 17,000 cy of sand was placed in this location between 1996 and 2002 and approximately 6,000 cy was placed between 2002 and 2007.

Baldwin Park Littoral Cell

The Baldwin Park Littoral Cell extends 1.5 miles from Wawau Point east to Flywater Point. The shoreline in this reach is comprised of sandy beach broken by rock outcrops and revetments. Fringing reef and several beach rock benches buffer small sections of the coastline from seasonal north swells. A revetment exists protecting the now defunct lime kiln (a former location of sand mining). The Kailu Gulch is a non-perenial stream that discharges to the cell.

Paia East Littoral Cell

The Paia East Littoral Cell is approximately one mile in length and extends from Fly Water Point to Ako Point. The cell consists of sandy, pocket beaches separated by rocky headlands. The tsunami of 1946 significantly altered the natural features of this area. Most of the sand beaches were lost and seawalls were constructed to protect the property fronting the shoreline.

Hookipa Littoral Cell

The Hookipa Littoral Cell is approximately one mile in length and is comprised of sandy pocket beach separated by rocky headlands. The Kuau Stream is a non-perenial stream that discharges into the littoral cell. The Hamakuapoko Stream is located just east of the limits of the Hookipa Littoral Cell. The beaches are fronted by a wide shelf of nearshore bedrock and offshore reef. The tsunami of 1946 significantly altered the natural features of this area. Most of the sand beaches were lost and seawalls were constructed to protect the property fronting the shoreline.

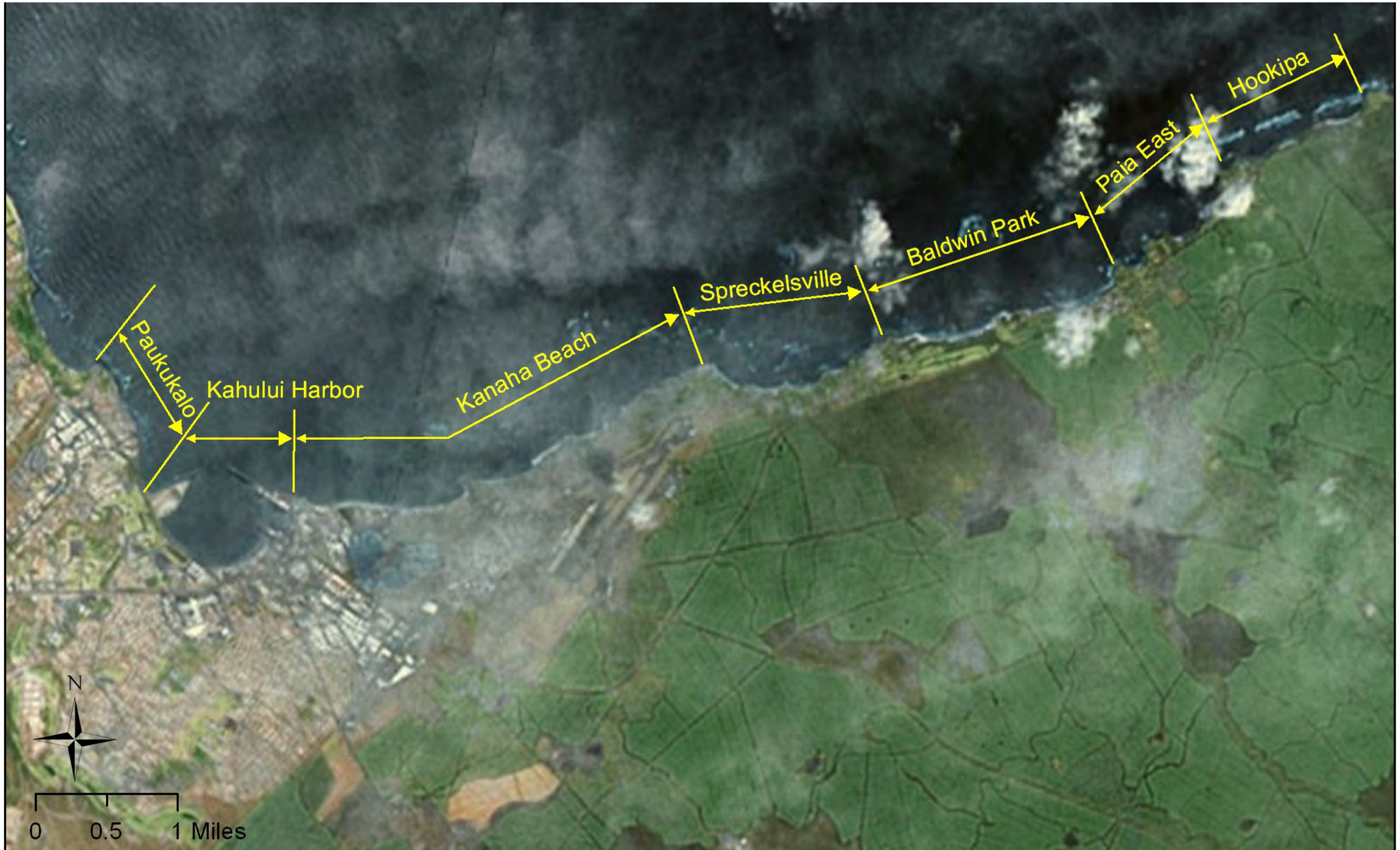
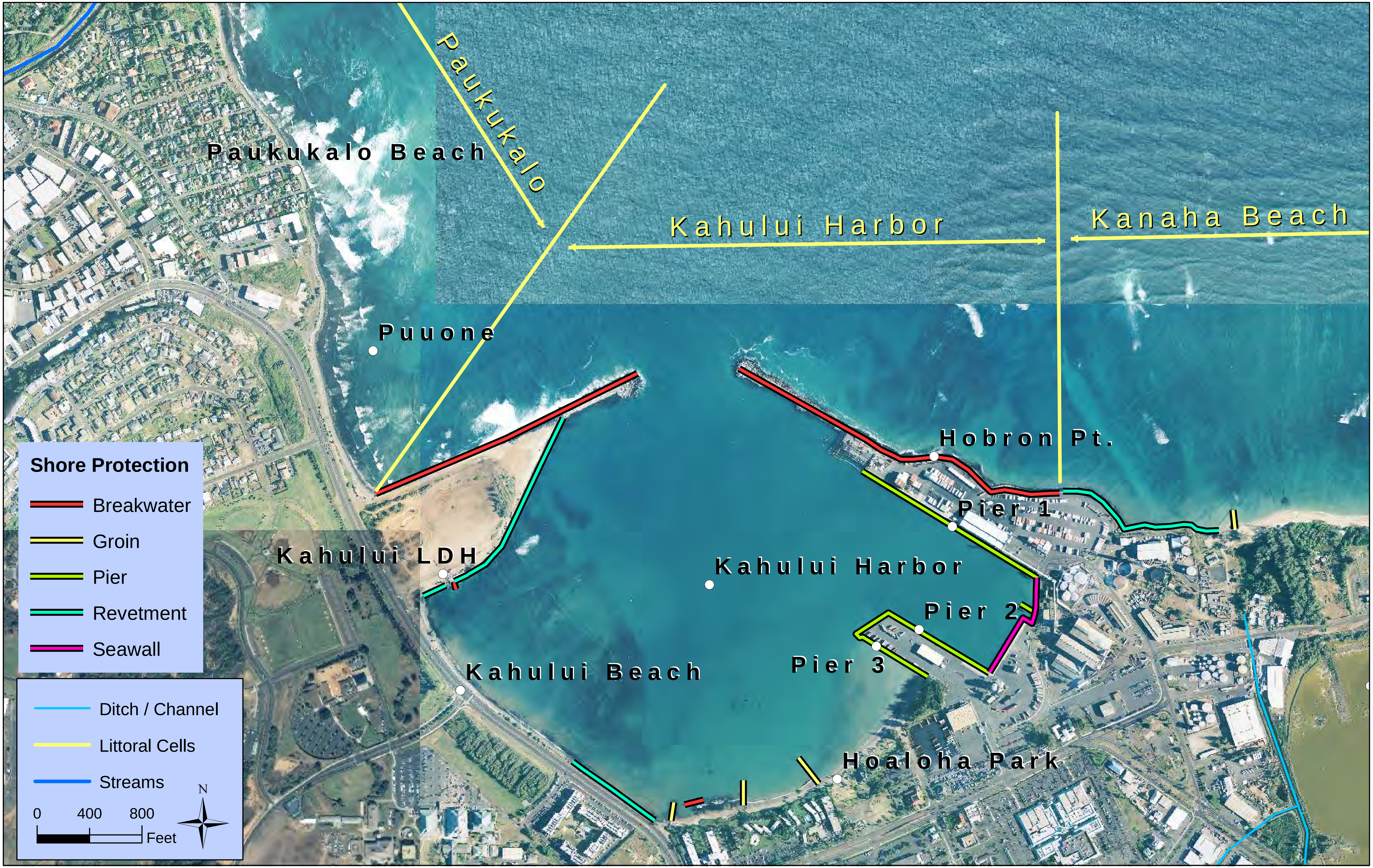
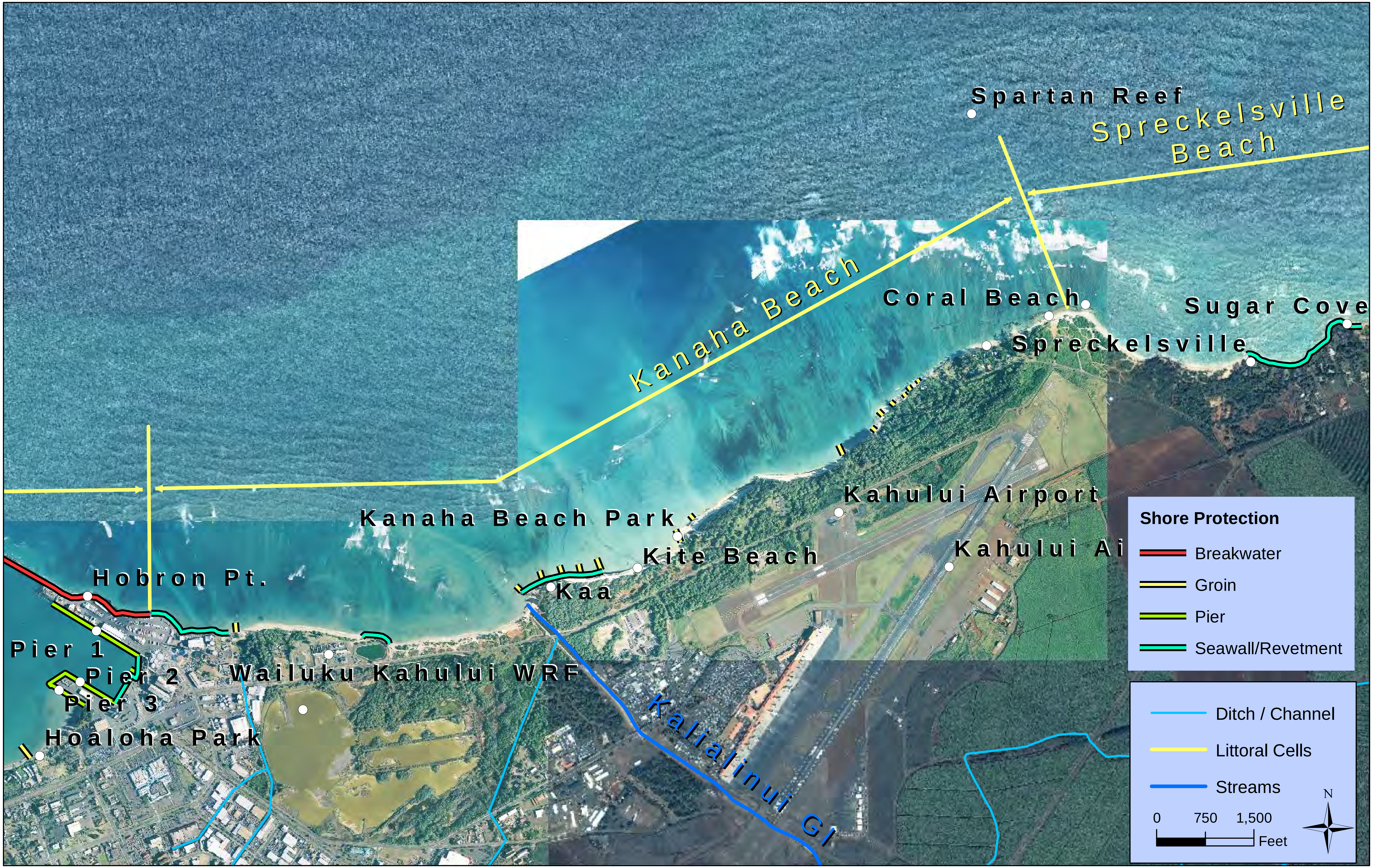


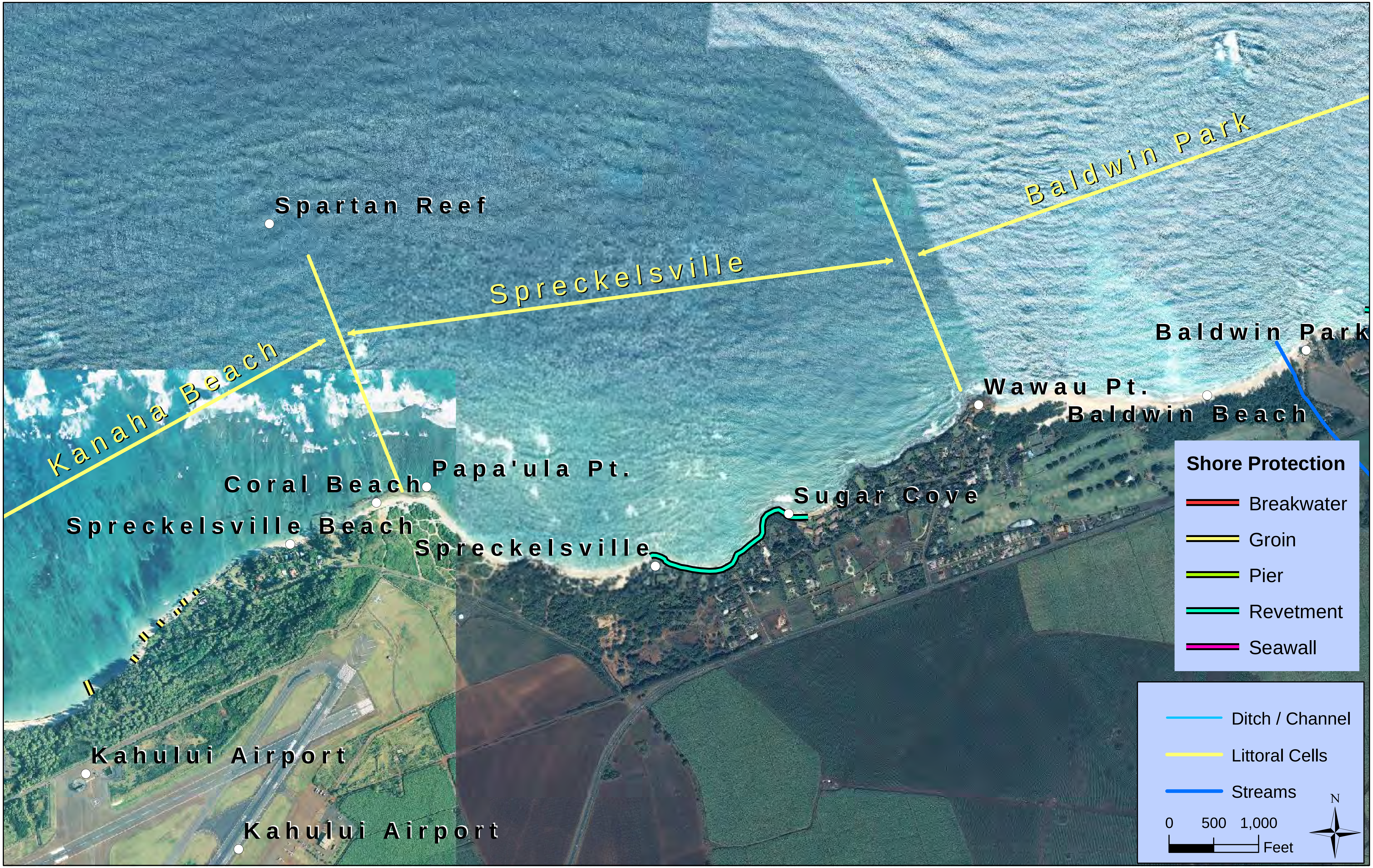
Figure F-15. Kahului Region Littoral Cells

Nehe Point
Paukukalo
Paukukalo Beach
Kahului Harbor
Puuone
Hobron Pt.
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0 300 600
Feet
N



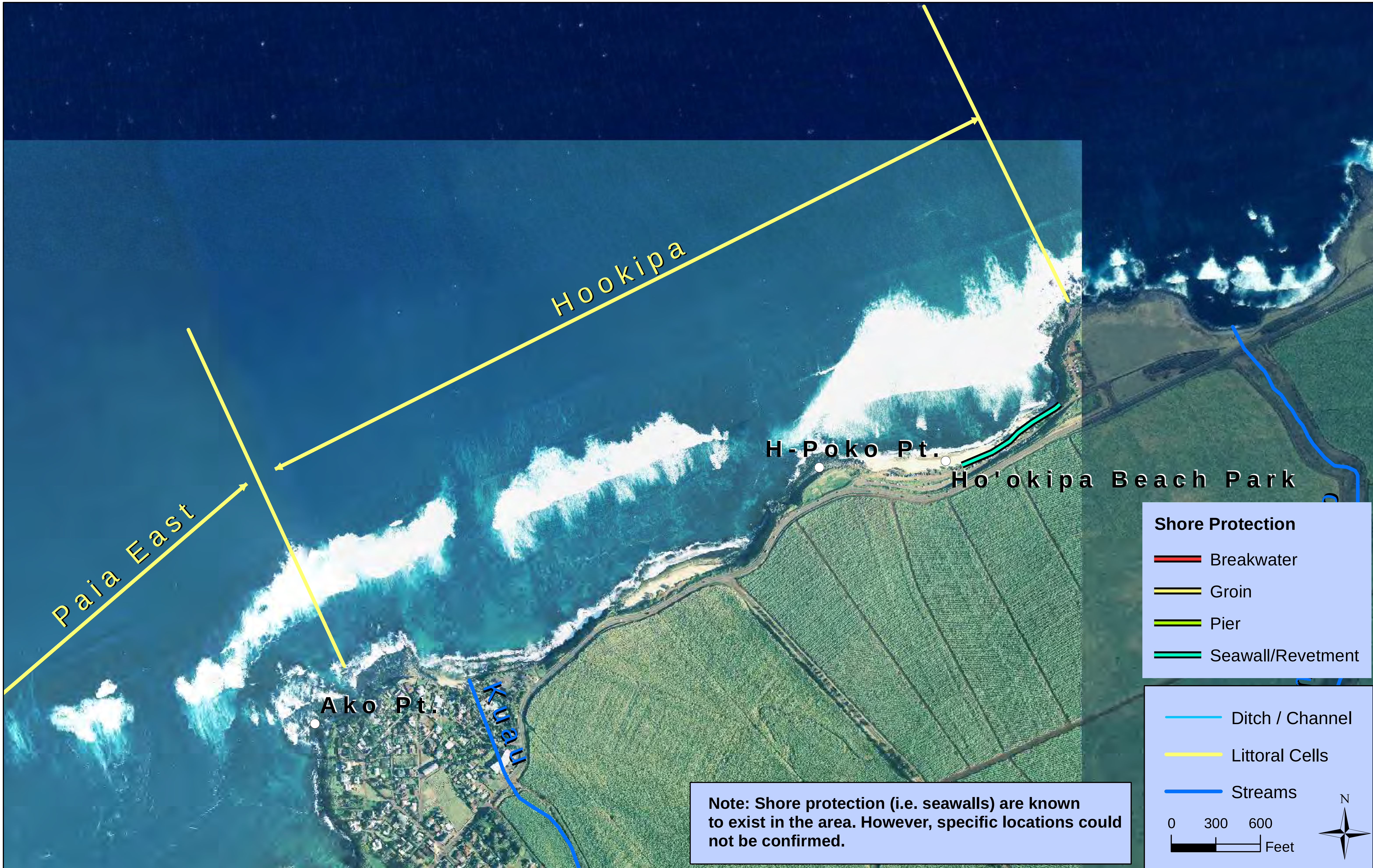
Paukukalo
Paukukalo Beach
Kahului Harbor
Kanaha Beach
Puuone
Hobron Pt.
Pier 1
Kahului LDH
Kahului Harbor
Pier 2
Pier 3
Kahului Beach
Hoaloha Park
Shore Protection
Breakwater
Groin
Pier
Revetment
Seawall
Ditch / Channel
Littoral Cells
Streams
0
400
800
Feet
N


Spartan Reef
Sprecklesville Beach
Kanaha Beach
Coral Beach
Sugar Cove
Spreckelsville
Kahului Airport
Kanaha Beach Park
Kite Beach
Kahului Ai
Hobron Pt.
Kaa
Pier 1
Pier 2
Pier 3
Wailuku Kahului WRF
Hoaloha Park
Kalialinui Gl
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0
750
1,500
Feet
N


Spartan Reef
Sprecklesville
Baldwin Park
Kanaha Beach
Baldwin Park
Wawau Pt.
Baldwin Beach
Papa'ula Pt.
Coral Beach
Sugar Cove
Spreckelsville Beach
Spreckelsville
Kahului Airport
Kahului Airport
Shore Protection
Breakwater
Groin
Pier
Revetment
Seawall
Ditch / Channel
Littoral Cells
Streams
N
0
500
1,000
Feet

Paia East
Taveras Bay
Kuau Bay
Baldwin Park
Mantokuji Bay
Fly Water Point
Spreckelsville
Pa'ia Bay
defunct lime kiln
Baldwin Park
Wawau Pt.
Baldwin Beach
Kailua Gl
Sugar Cove
Spreckelsville
Shore Protection
Breakwater
Groin
Pier
Revetment
Seawall
Ditch / Channel
Littoral Cells
Streams
N
0 500 1,000
Feet


Hookipa
Paia East
Baldwin Park
Ako Pt.
Kuau
Taveras Bay
Kuau Bay
Fly Water Point
Mantokuji Bay
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0
375
750
Feet
N
Note: Shore protection (i.e. seawalls) are known to exist in the area. However, specific locations could not be confirmed.



Hookipa
Paia East
H-Poko Pt.
Ho'okipa Beach Park
Ako Pt.
Kuau
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0
300
600
Feet
N
Note: Shore protection (i.e. seawalls) are known to exist in the area. However, specific locations could not be confirmed.

B. Beach Volumes

For each littoral cell, a graph of beach volume versus time was developed based on historical shorelines provided by the University of Hawaii and using a conversion factor of 0.40 cubic yards per square foot of beach.

It should be noted that the number of available historical shorelines is limited and the curves were interpolated between available data points. Accordingly, the following should be understood:

- The points do not necessarily bound the minimum and maximum beach volumes.
- It is probably that the chronological transitions from erosional to accretional conditions (and vice versa) are not at the exact date shown by the line in the graph.

Following are graphs of each of the cells within the Kahului region (Figures F-17 to F-24), as well as a summary graph which includes all cells in the region (Figure F-16). The line graphs show the estimated historical beach volumes over the time period of shoreline data records and the bar graphs show the change rates over different time periods of interest. Potentially significant events are shown on the line graphs. Table F-2 summarizes the associated erosion and accretion rates over the time period of record and over the most recent time period for each of the littoral cells. Figures F-25 through F-31 show the most recent change rate (sediment budget) for each of the littoral cells.

Table F-2. Kahului Region Beach Sand Volume Change Rates

Littoral Cell	**Accretion(+) / Erosion(-) Rate Over Entire Time Period of Record, cubic yards per year**	**Accretion(+) / Erosion(-) Rate Over Recent Period, cubic yards per year**
Paukukalo	**-1,200**	**0**
Kahului Harbor	**-1,100**	**-800**
Kanaha Beach - Total	**-6,500**	**-10,550**
Spreckelsville	**-2,300**	**-2,400**
Baldwin Park	**-4,800**	**-400**
Paia East	**-500**	**-500**
Hookipa	**0**	**0**

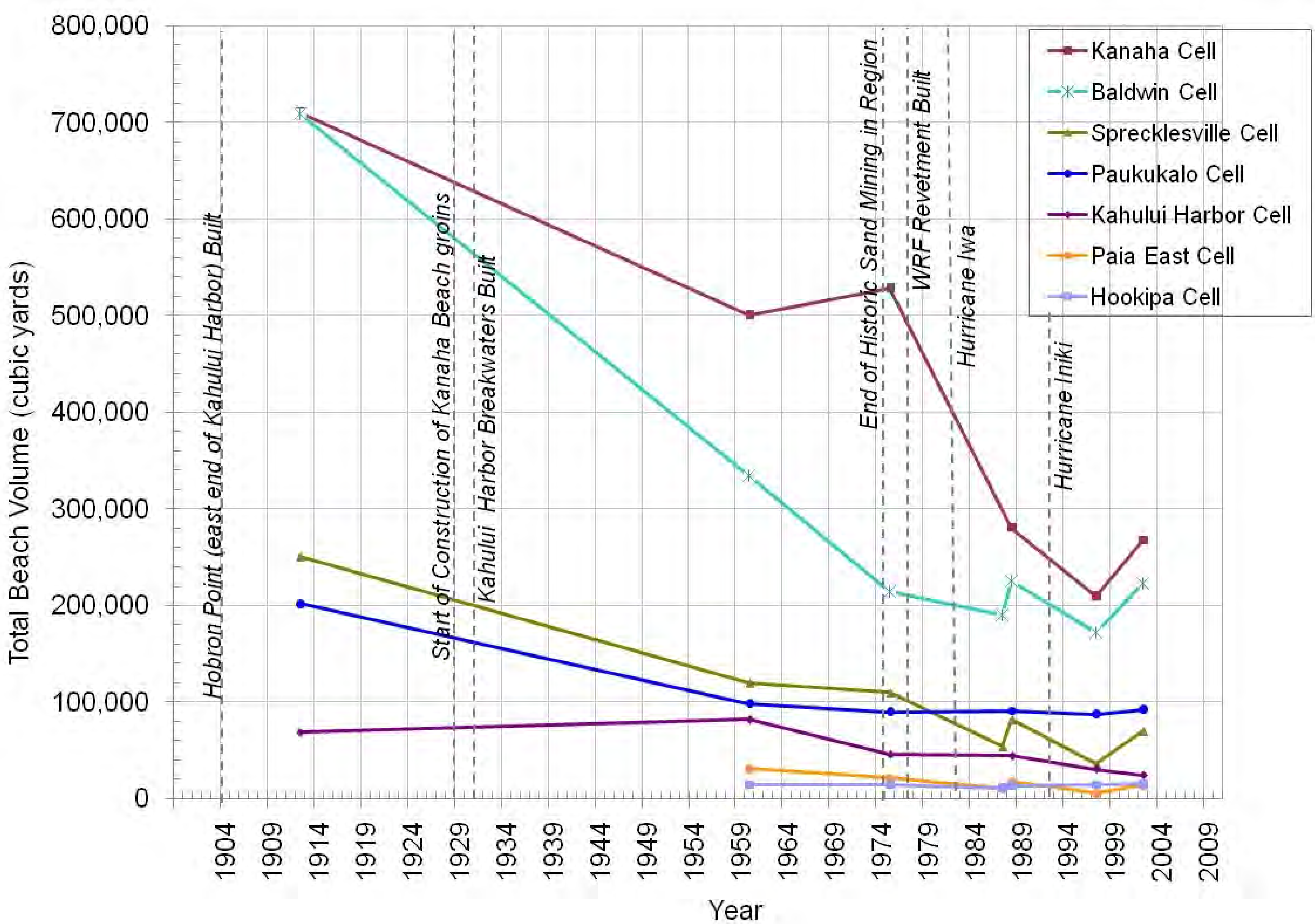


Figure F-16. Historical Beach Volumes of Kahului Region Littoral Cells

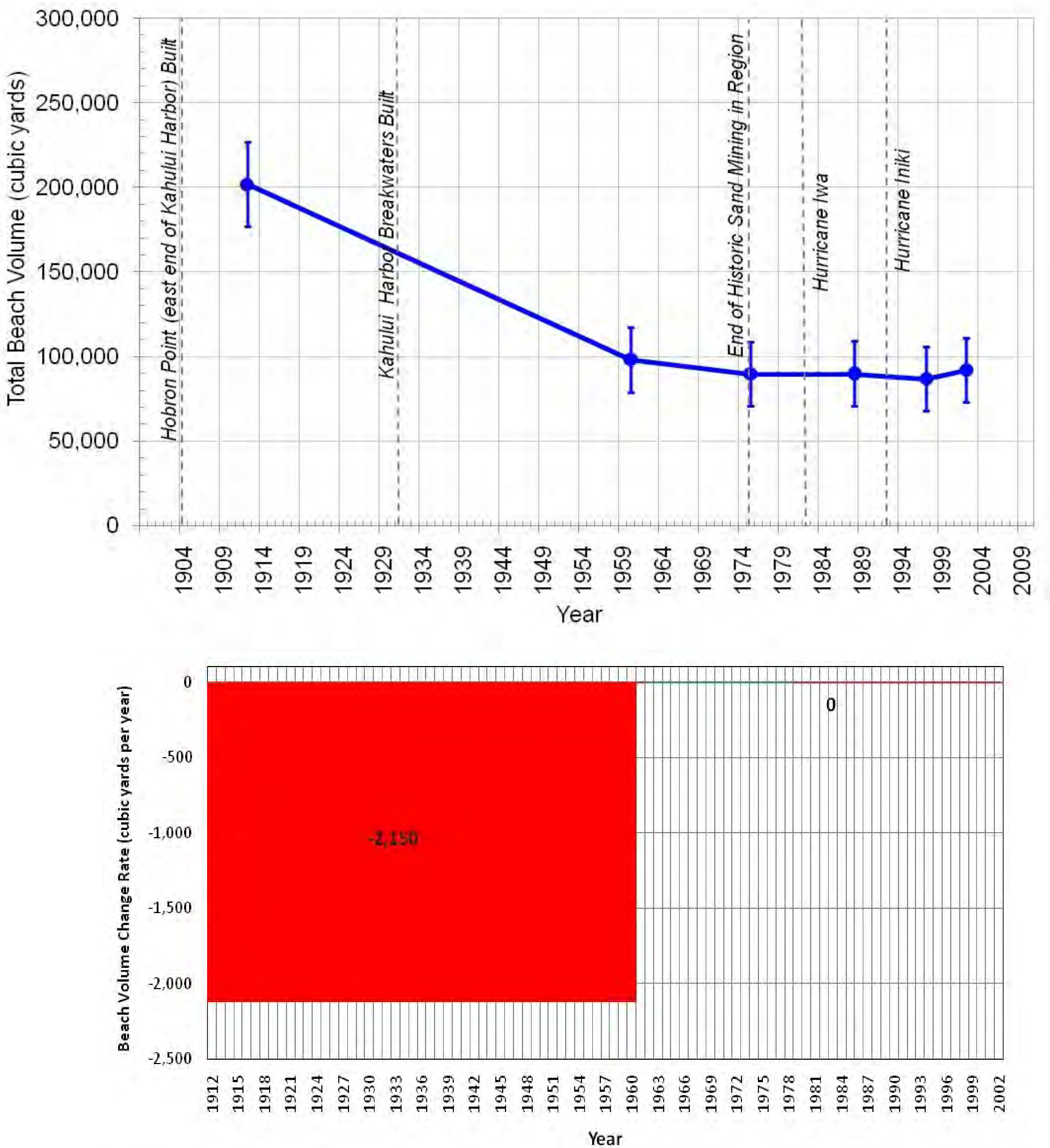


Figure F-17. Historical Beach Volumes / Change Rates for Paukukalo Littoral Cell

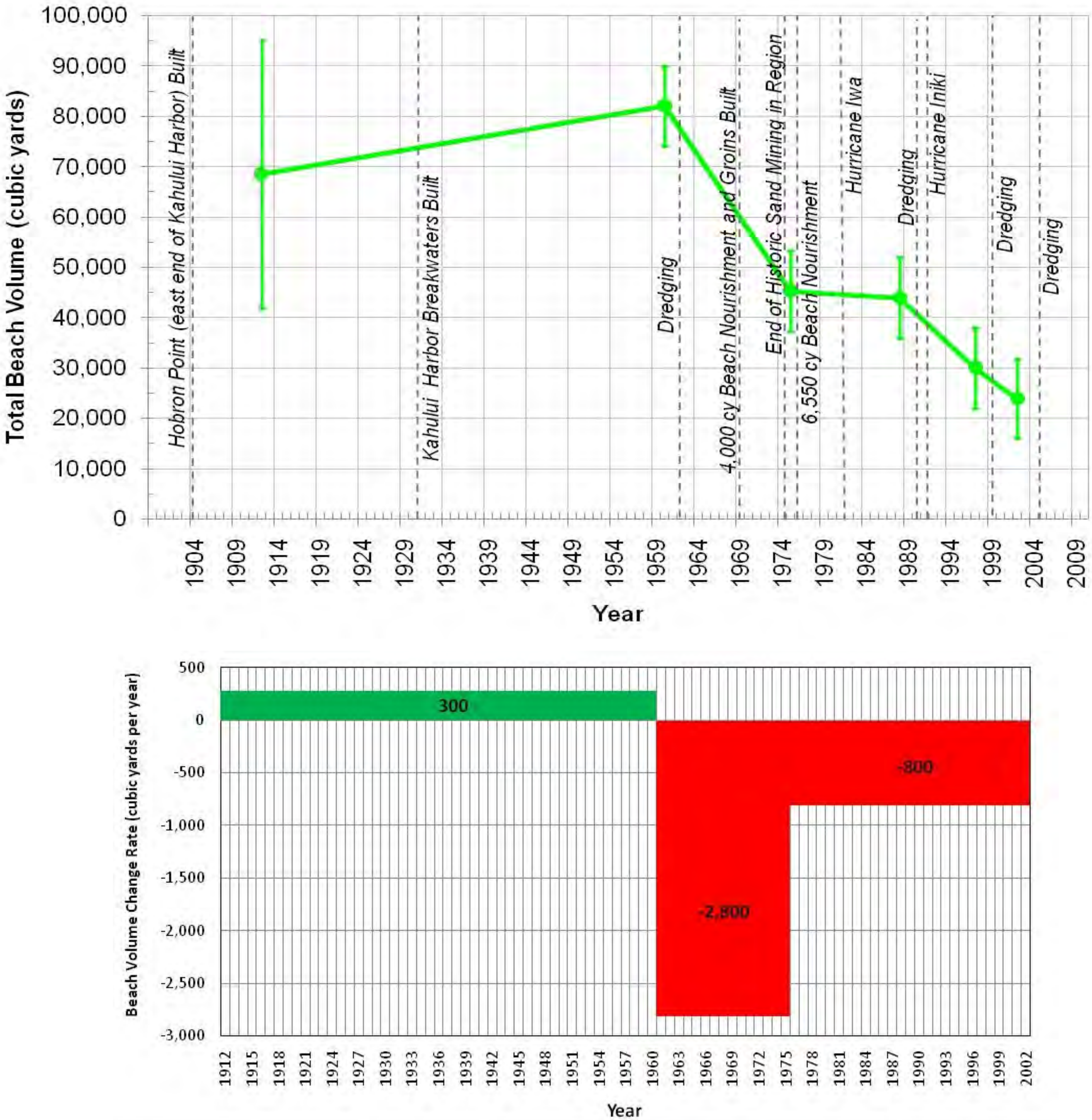


Figure F-18. Historical Beach Volumes / Change Rates for Kahului Harbor Littoral Cell

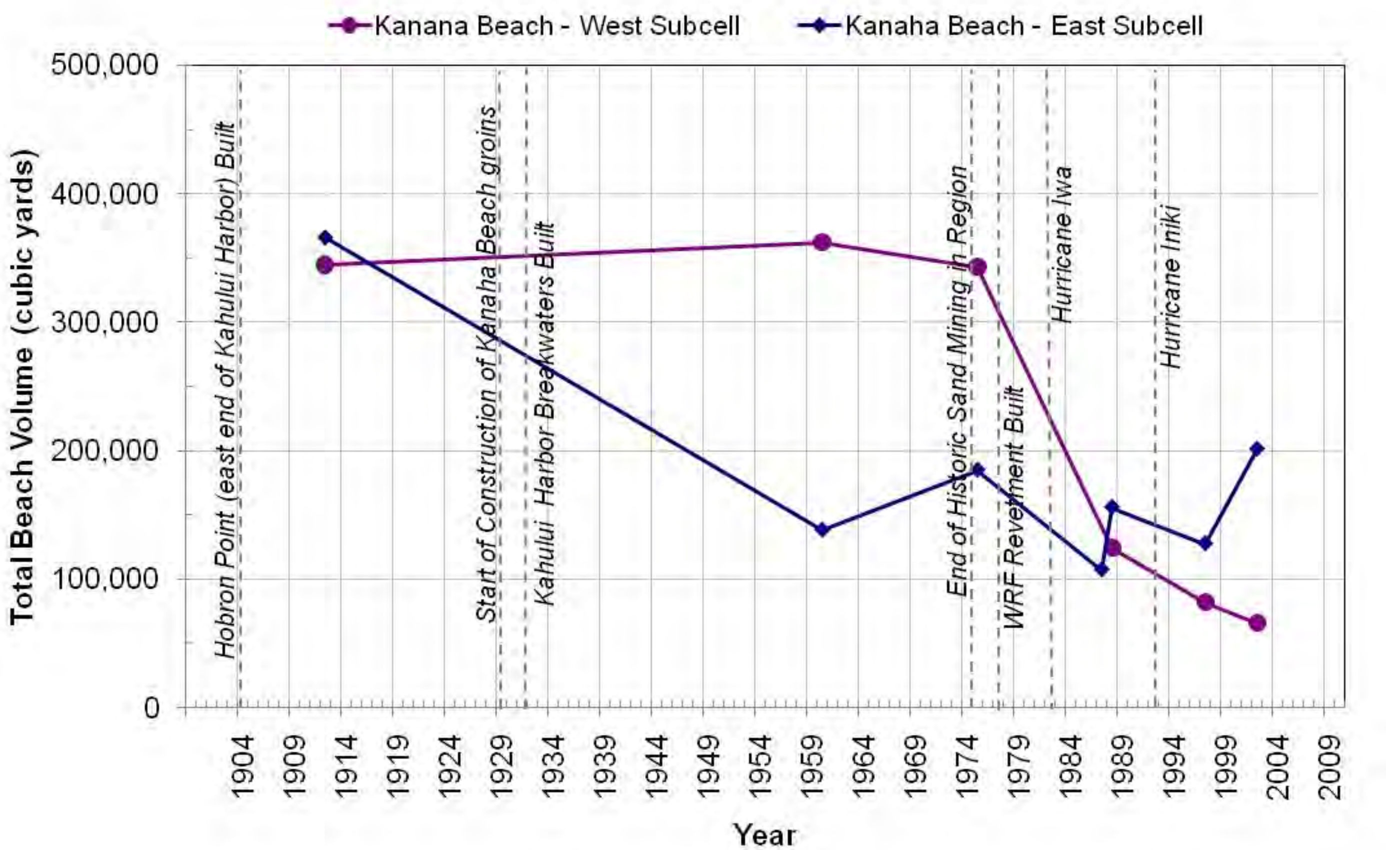


Figure F-19. Historical Beach Volumes for West and East Sections of Kanaha Littoral Cell

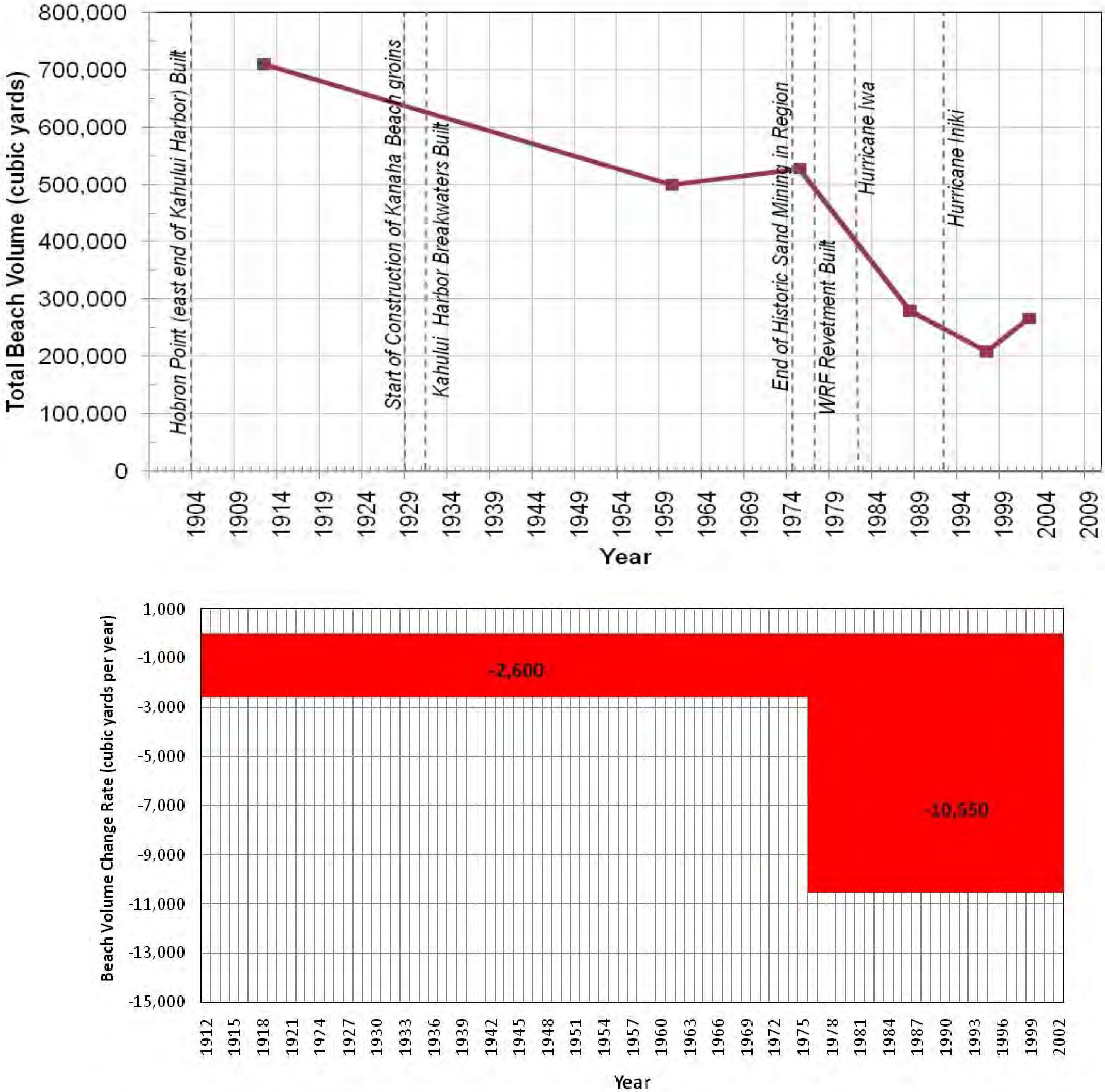


Figure F-20. Historical Beach Volumes / Change Rates for Kanaha Littoral Cell

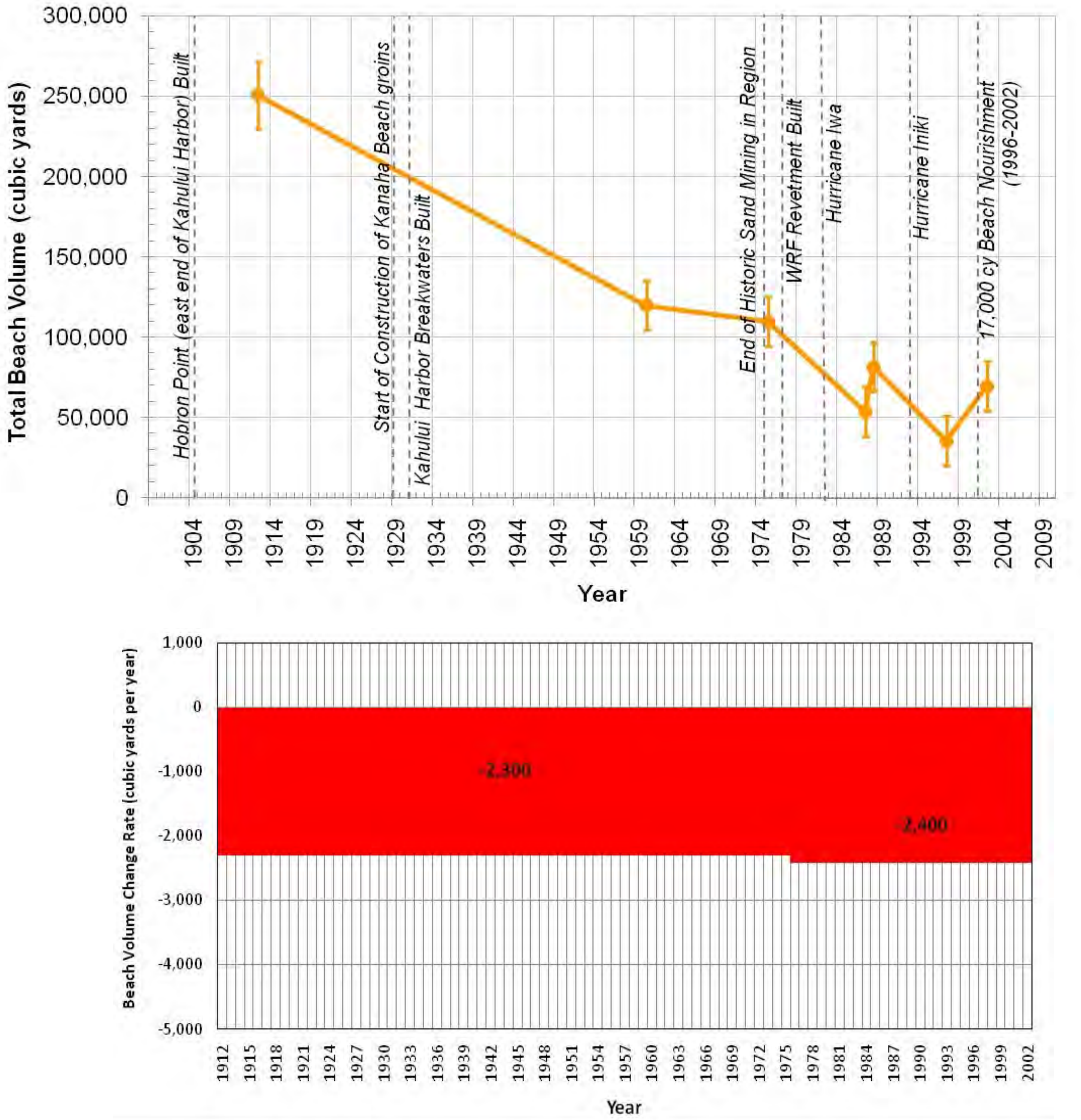


Figure F-21. Historical Beach Volumes / Change Rates for Sprecklesville Littoral Cell

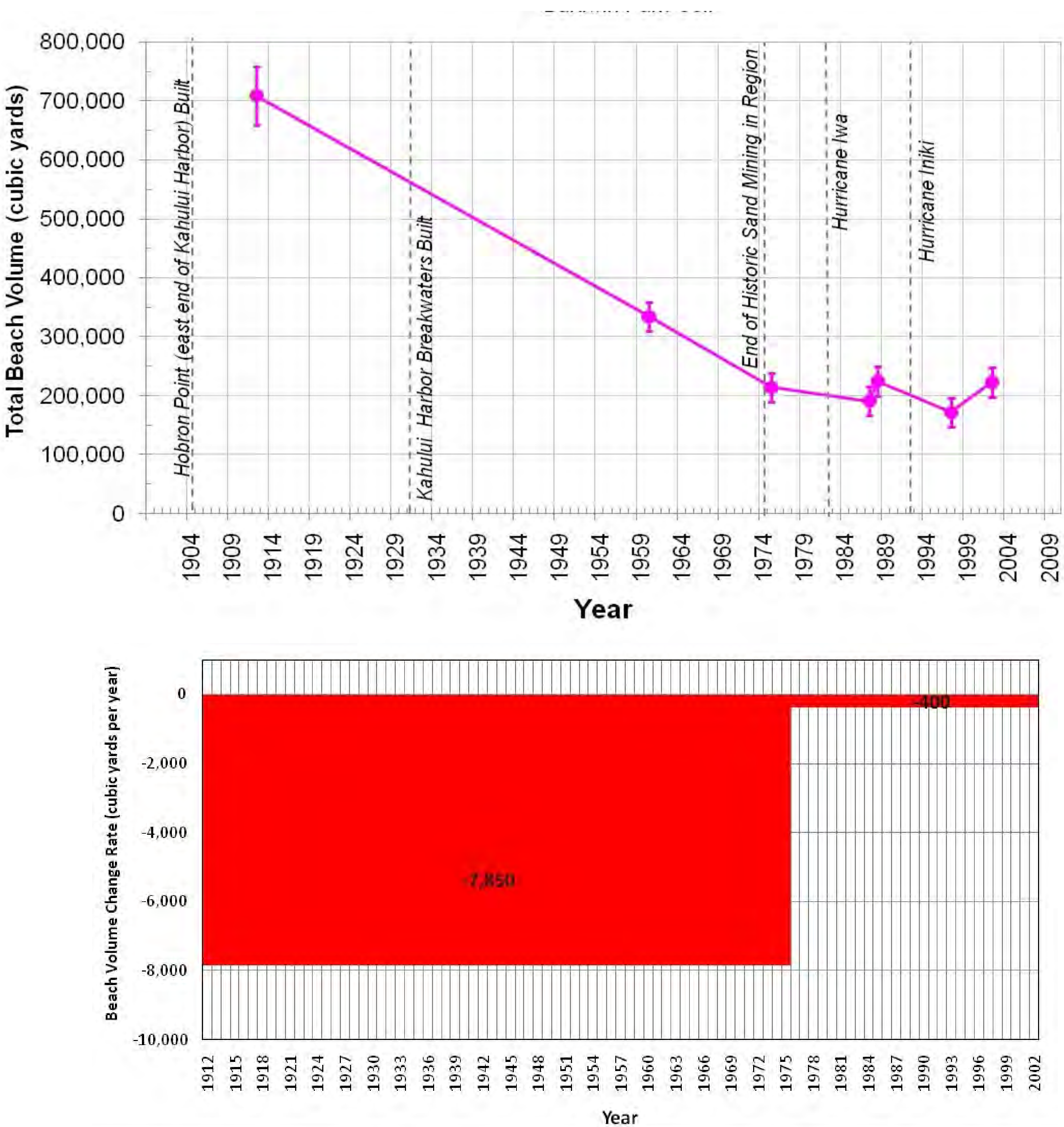


Figure F-22. Historical Beach Volumes / Change Rates for Baldwin Park Littoral Cell

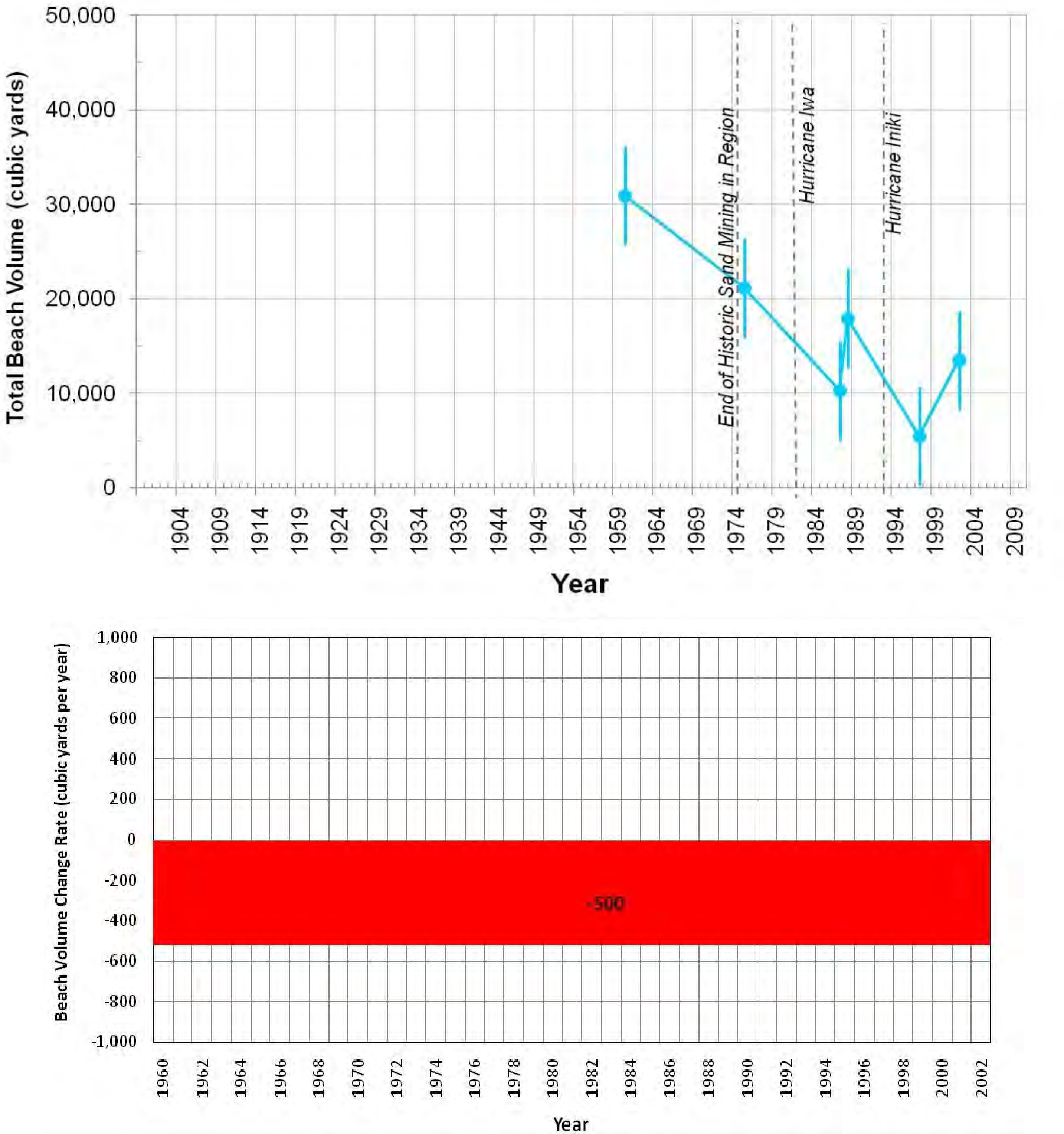


Figure F-23. Historical Beach Volumes / Change Rates for Paia East Littoral Cell

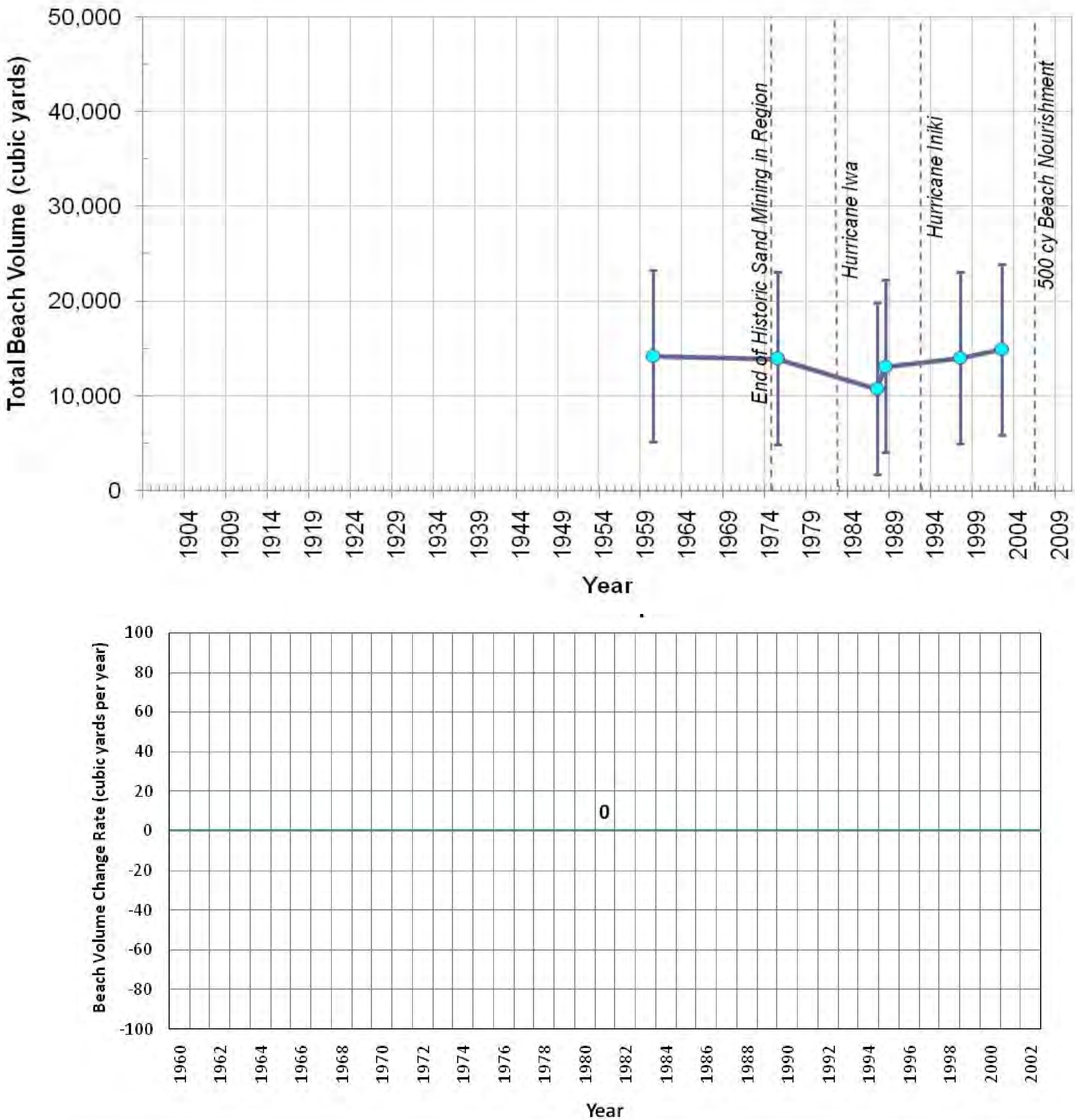


Figure F-24. Historical Beach Volumes / Change Rates for Hookipa Littoral Cell

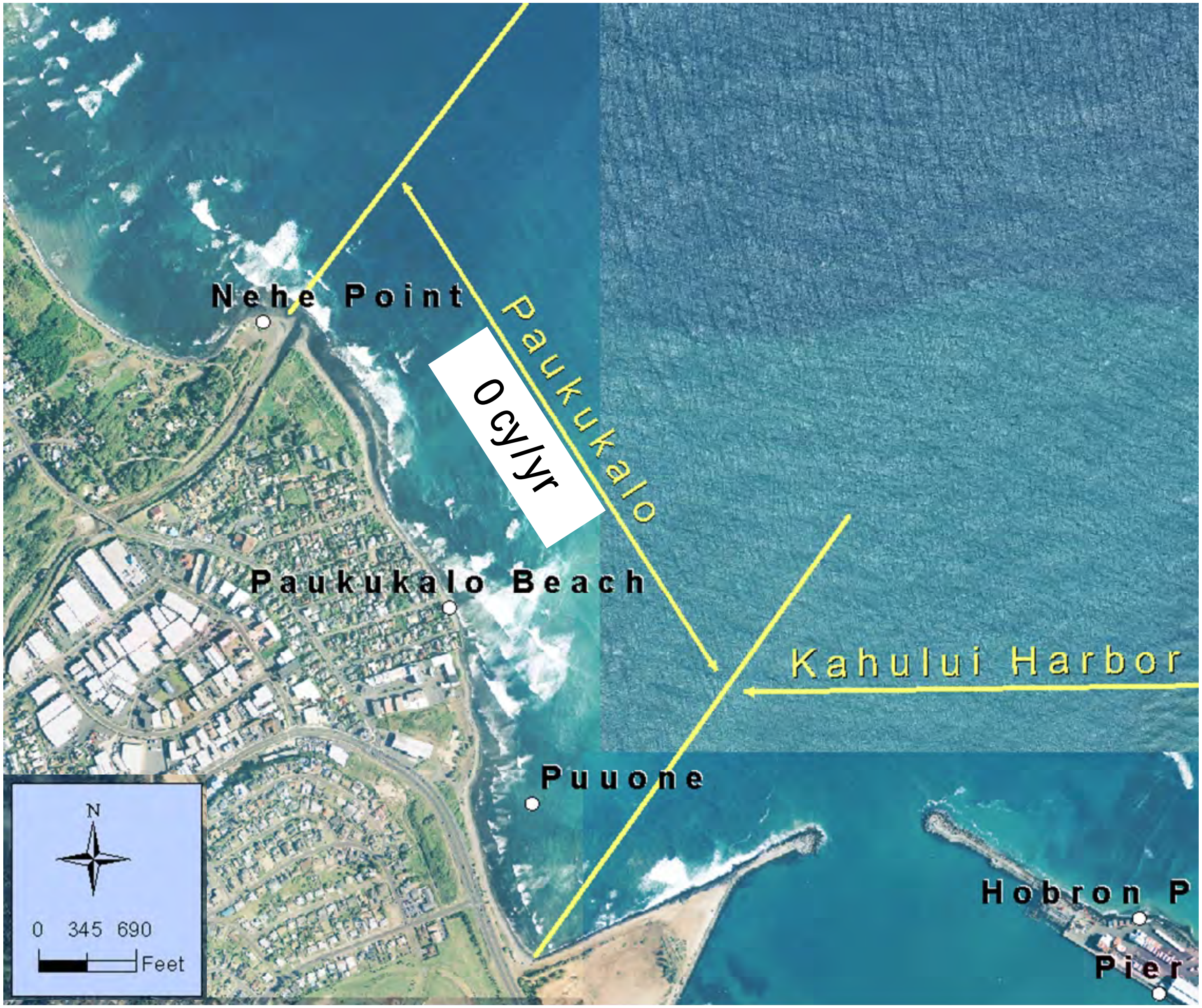


Figure F-25. Beach Volume Change Rate for Paukukalo Littoral Cell

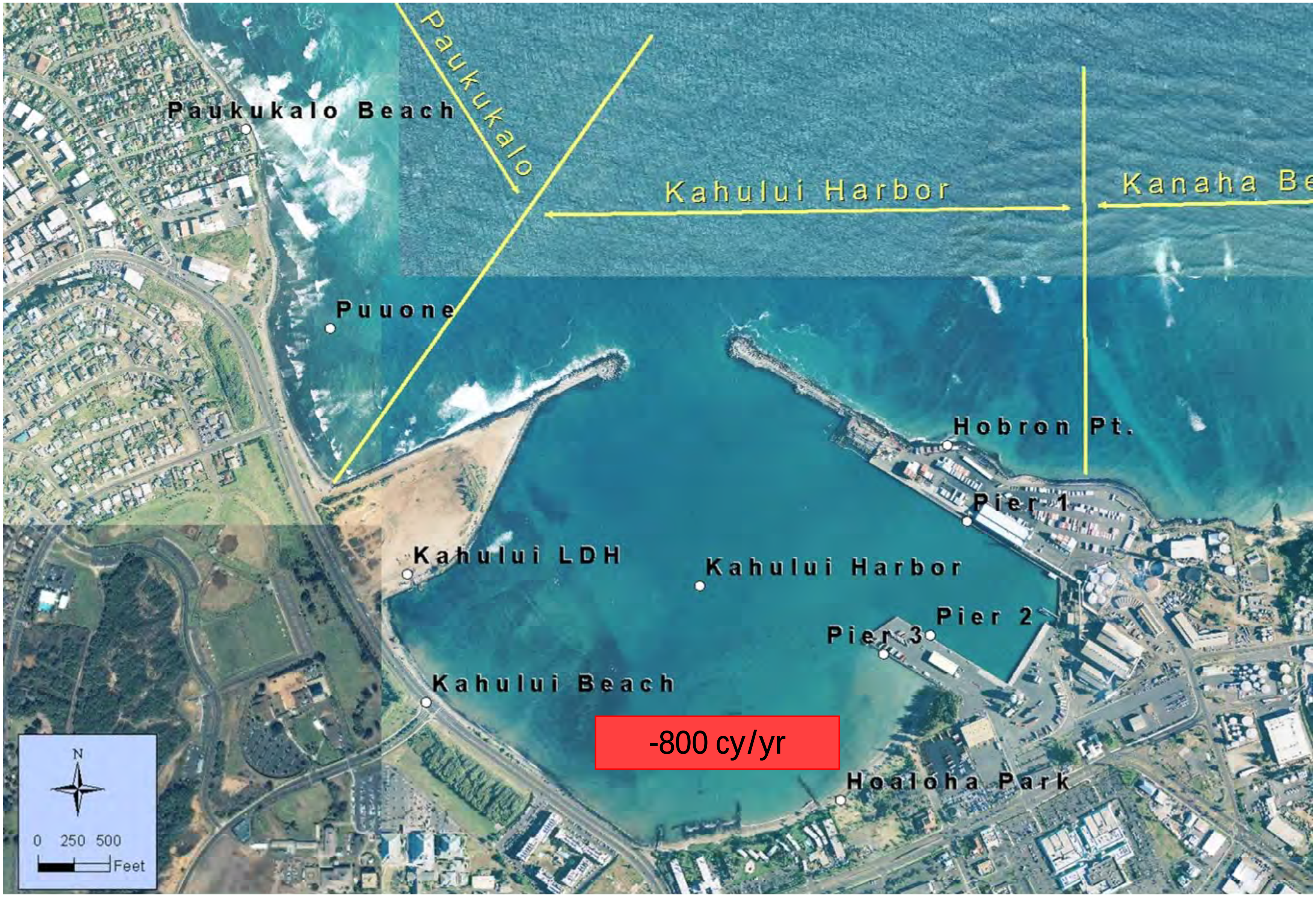


Figure F-26. Beach Volume Change Rate for Kahului Harbor Littoral Cell

Figure F-27. Beach Volume Change Rate for Kanaha Littoral Cell

Figure F-28. Beach Volume Change Rate for Spreckelsville Littoral Cell

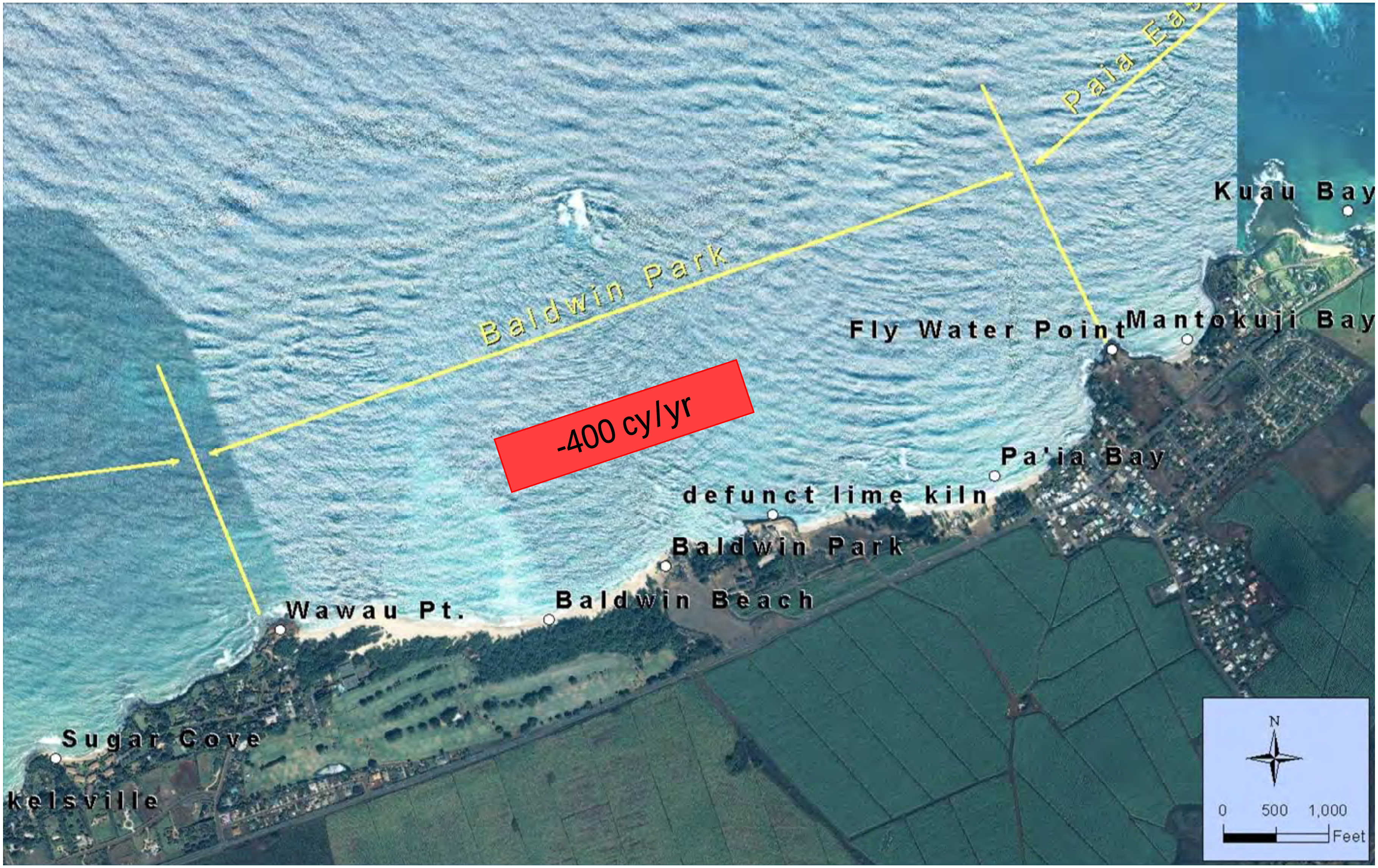


Figure F-29. Beach Volume Change Rate for Baldwin Park Littoral Cell

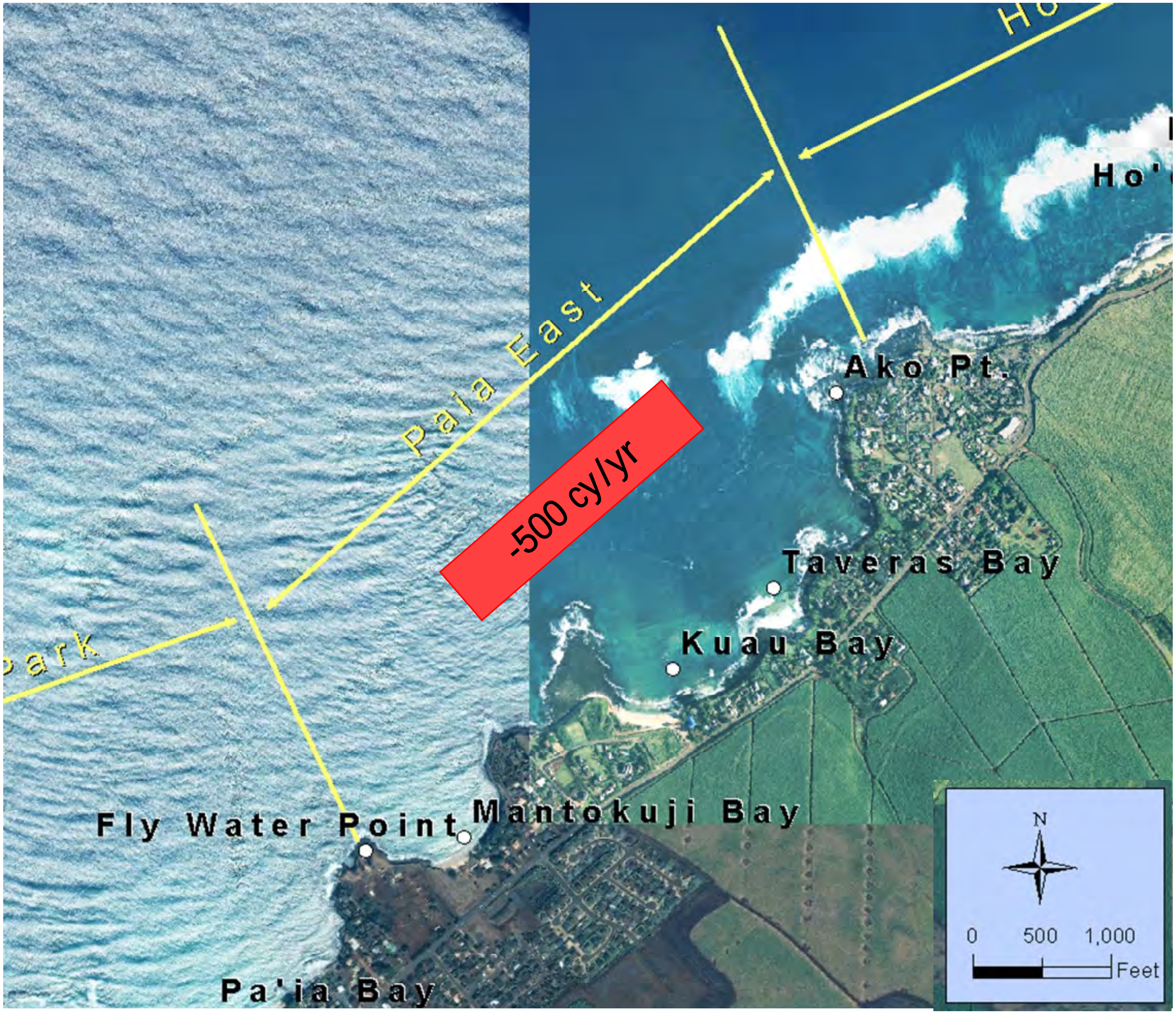


Figure F-30. Beach Volume Change Rate for Paia East Littoral Cell

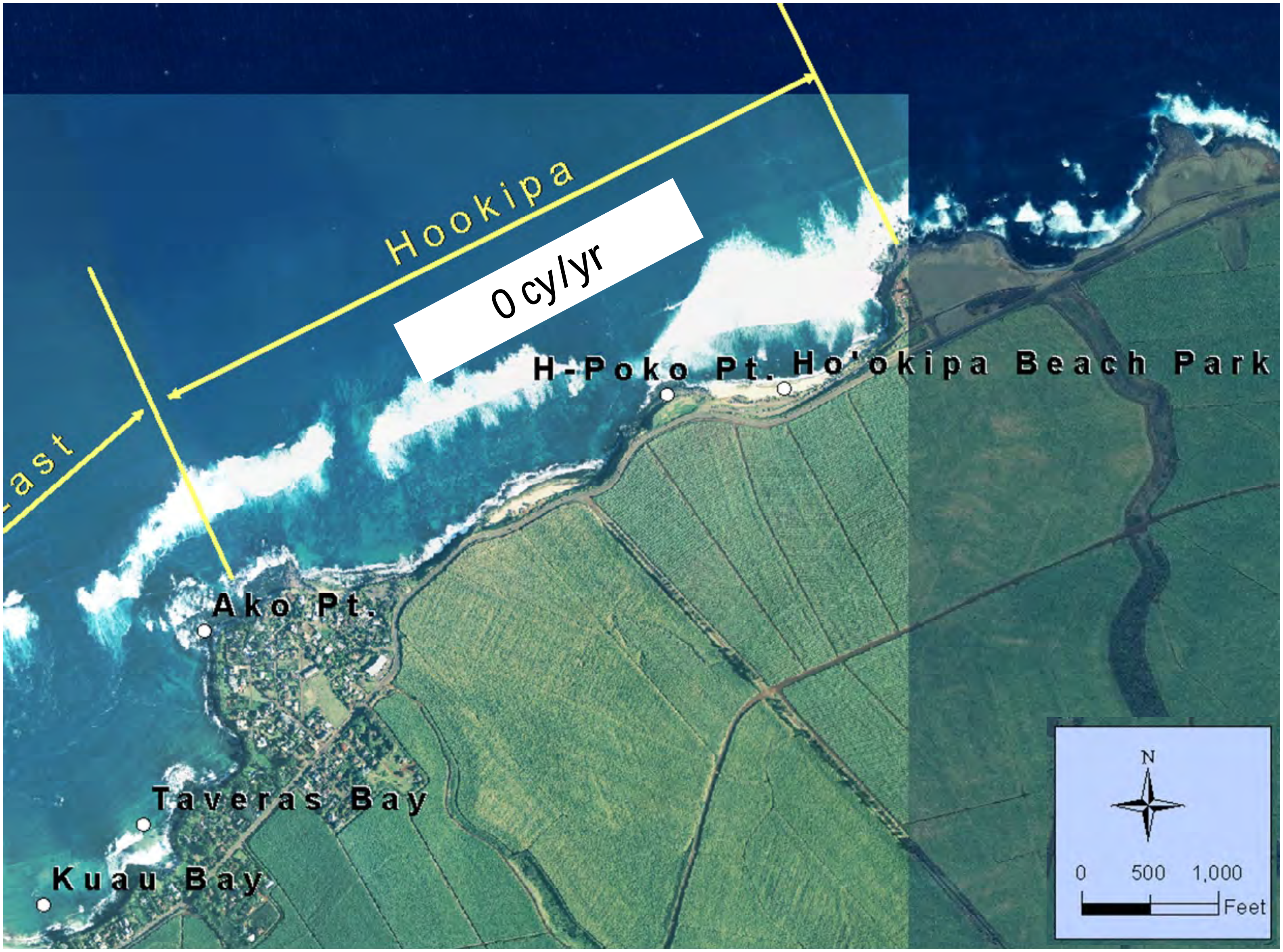


Figure F-31. Beach Volume Change Rate for Hookipa Littoral Cell

Results for the Kahului Region littoral cells indicate the following:

- The **Paukukalo** cell, to the west of Kahului Harbor, experienced erosion from 1912 to 1960, similar to the other cells in the region, and then was relatively stable, but not accreting, after that time. The slowing of the erosion rate, but lack of accretion is possibly related to construction of Kahului Harbor coupled with a decreased input of sediment from Iao Stream (from channelization of the stream banks). Development of sediment transport direction (potential future task) would provide further insight into this.
- Following construction of the present-day configuration of **Kahului Harbor**, this cell has a clear erosional trend probably due to the effects of winter storm waves pushing sediment into the harbor basin and then that material being dredged and then the shoreline further eroding from over-steep (non-equilibrium) slopes caused by the dredge cuts. As noted previously, several dredge cycles have occurred in Kahului Harbor and the dredge material is disposed offshore at an EPA designated ocean disposal site, i.e. disposed beyond the littoral zone.
- The most significant historic beach volume losses were in the **Kanaha** littoral cell, specifically the western section near the Wastewater Reclamation Facility, and in the **Baldwin Park** littoral cell. Whereas the most recent Baldwin Park erosion rate has decreased significantly since approximately 1975, the Kanaha cell erosion rate has increased significantly. The Kanaha loss in the period from 1975 to 1987 was possibly associated with Hurricane Iwa or the construction of the revetment fronting the WWRF. Figure F-19 indicates the Kanaha cell erosion since 1975 is primarily in the shoreline reach west of Kaa (“west subcell”), which is the beach area fronting the WWRF.
- The **Sprecklesville** and **Baldwin Park** cells (adjacent to each other) experience very similar patterns. It is interesting to note the accretion of sand in these cells from August 1987 to March 1988. This accretion from a summer profile to winter profile is not typical for this area.
- Almost all of the cells within the Kahului region experienced relatively significant erosion during the time period prior to approximately 1987. This is consistent with impacts from the historic sand mining in the area, which concluded in the 1960-1975 timeframe. It has been hypothesized that the removal of this sand resulted in an erosional wave that proceeded down coast from the lime kiln site (Baldwin Park littoral cell) towards Kahului Harbor. The Kanaha littoral cell seems to still be experiencing this erosional wave. Since 1987, some of the other beaches have been relatively stable (lower erosion rates), but this could be simply from a lower volume of sand now on the beaches.

APPENDIX G

SEDIMENT TRANSPORT BUDGETS – KIHEI REGION

I. Sediment Budget Methodology

Sections A, B, C, F, G - See description provided in previous appendix.

D. Structures, Storms, and Historical Sand Placement

Table G-1 provides an overview of the known sand placement activities, along with a chronology of other significant coastline activities, in the Kihei region. In the Kihei region, nourishment projects occurred on beaches fronting the Maui Lu hotel and a private residence within the North Kihei cell (DLNR 2010) and on beaches fronting condominiums just east of Maalaea Harbor (USACE 2004).

E. Seasonal Trends

Seasonal trends in beach characteristics are common worldwide. Seasonal changes in wave energy can bring about onshore-offshore transport, with beaches typically becoming narrower during periods of high wave energy and recovering when the wave energy decreases. Seasonal changes in wave direction can bring about longshore transport, with different areas accreting and eroding at different seasons.

Beach profiles for areas within both regions of Maui have been developed by the University of Hawaii (2010) and USGS (2010b). Following are the beach profiles within the Kihei region ("South west Maui"). The profile locations are shown on the map (Figure G-1) below. The profiles are ordered from west to east/south.

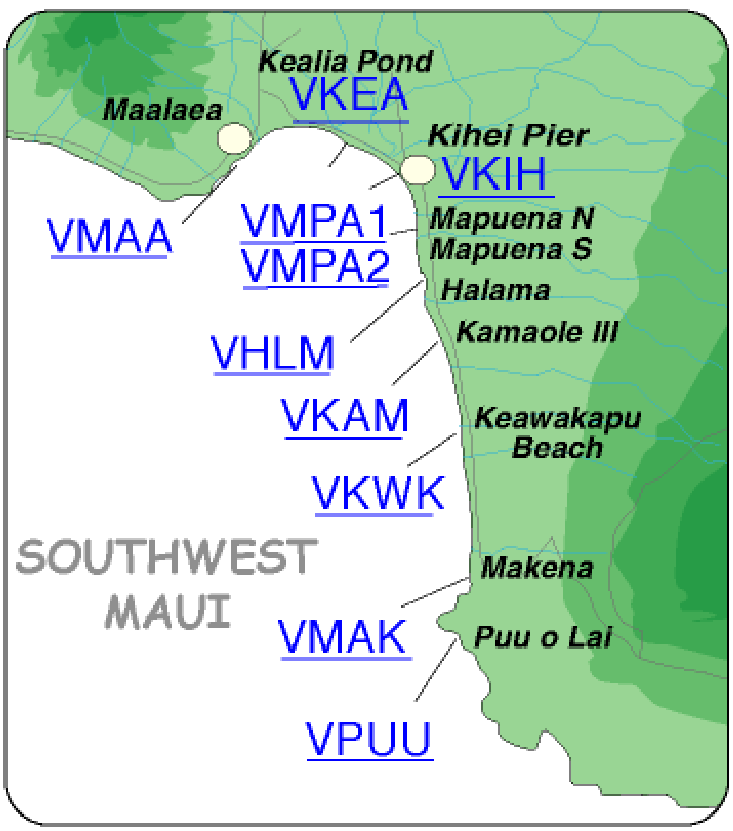
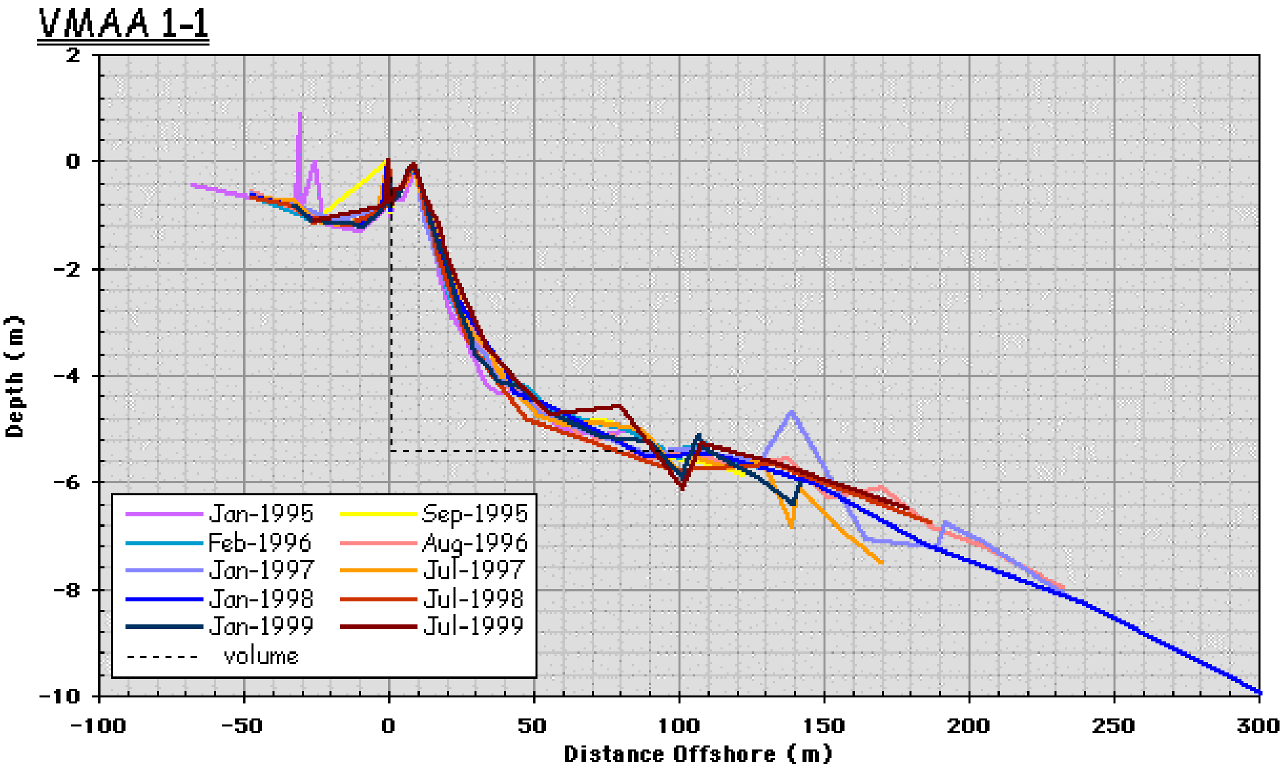
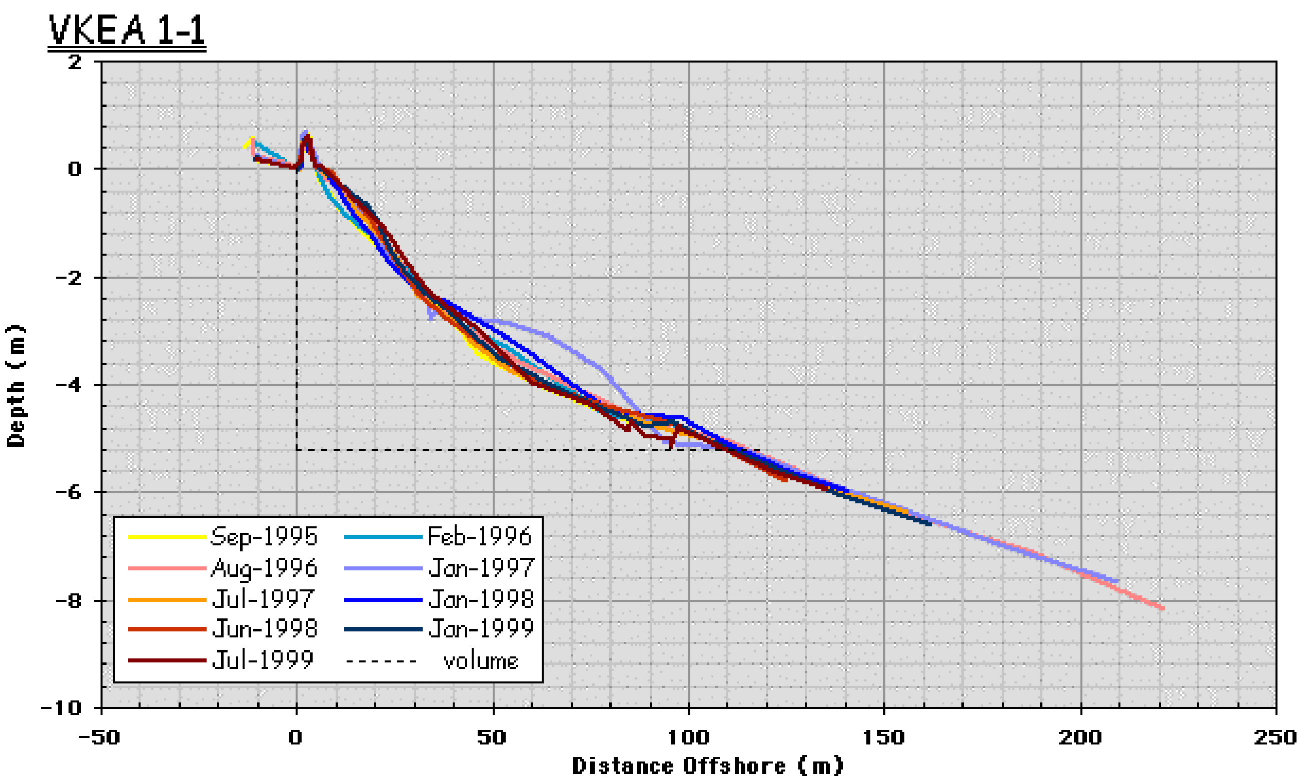


Figure G-1. Locations of Kihei Region Beach Profiles

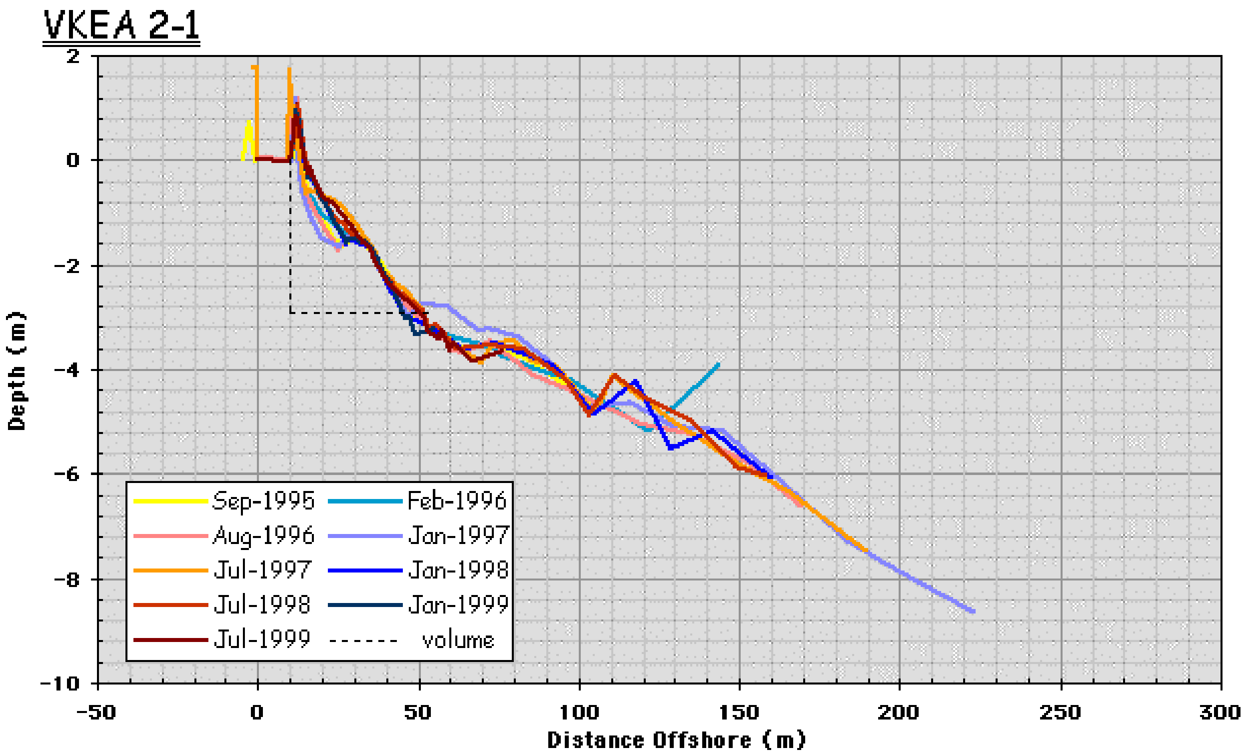
Table G-1. Kihei Region Structures, Storms, Historical Sand Placement

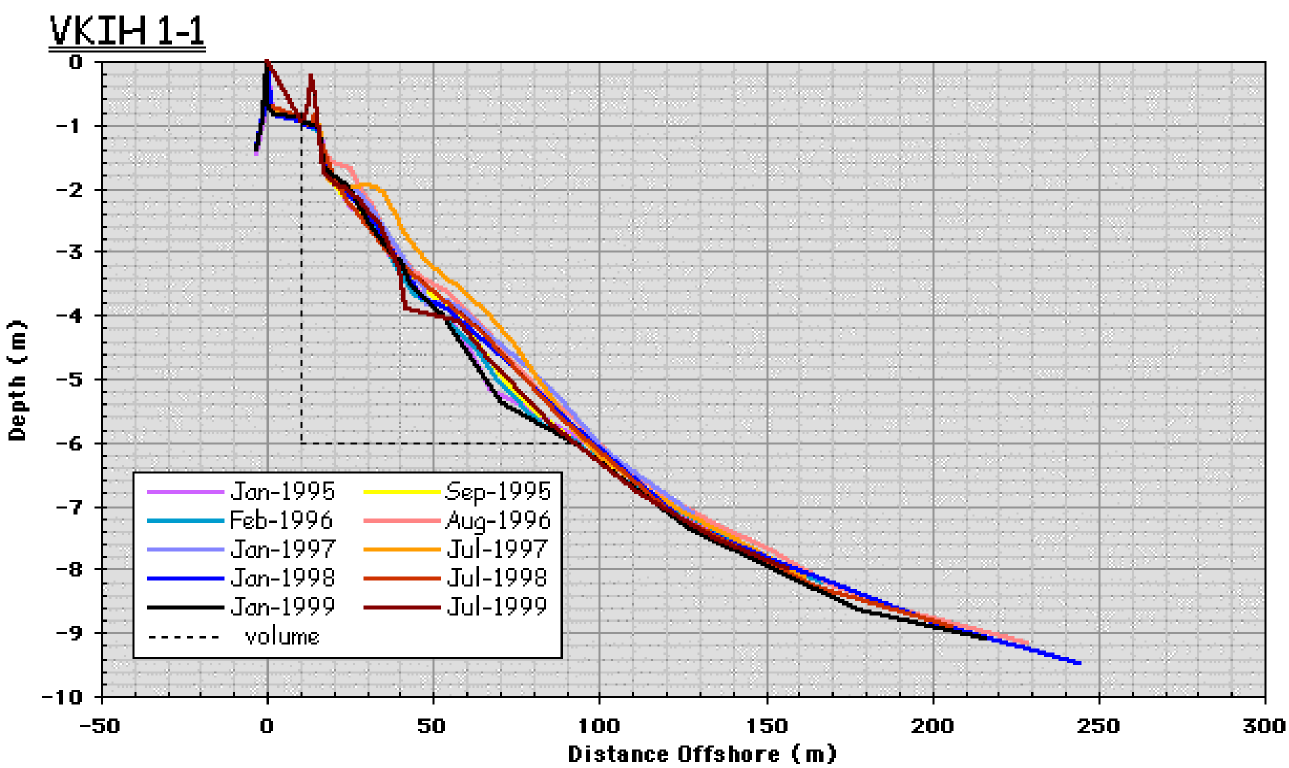
Date	Activity	Volume (cy) where relevant	Cell	Comments
500+ years ago	Hawaiian fishponds built along Kihei shoreline			remnants of fishponds remain
1899	Kihei Pier (Kihei Wharf) built		Kihei - Kealia	
1912-1961	Kalama Beach Park shoreline receeded 300 ft		Kalama	
1943-45	South Kalama Park - direct destruction of reef by Navy		Kalama	
1952	Malaaea Harbor - south breakwater built		Maalaea Harbor	
Dec. 1957	Hurricane Nina			
1958	Maalaaea Harbor - east breakwater built		Maalaea Harbor	
Aug.1959	Hurricane Dot			
Mar. 24, 1964	Alaska tsunami			
1964	St. Theresa's/Lipoa Street/Halama Street groin built		Kalama	
1964	Kaluaehakoko Boat Ramp built		Kalama	
	Historic mining of coral rubble deposits at flood control stream ends			
1971	Kalama Beach Park revetment built		Kalama	
1971-81	East of Maalaea Harbor - condos and revetment built		Maalaea Bay Beach	
1975	Halama Street coral rubble reef present (now gone)		Kalama	
Nov. 23, 1982	Hurricane Iwa			
1983	Kihei Boat Ramp built			
Dec. 11-19, 1987	Kona Storm Event			*
Nov. 4-5, 1988	Kona Storm Event (high surf)			*
Dec. 18-21, 1988	Kona Storm Event			*
Sept. 11, 1992	Hurricane Iniki			
Feb. 24-28, 1997	Kona Storm Event (high surf)			*
Oct. 5, 1999	Big swell hits Kihei - causes major flooding			
1999	Dredging of Kihei Boat Ramp			
Jan. 28– Feb. 2, 2002	Kona Storm Event			*
2007(?)	Dredging of Kihei Boat Ramp	4,000-5,000		
Beach Nourishments:				
1997	Beach Nourishment - Kanaia Nalu condos	1,500	Maalaea Bay Beach	
1998	Beach Nourishment - Kanaia Nalu condos	3,000	Maalaea Bay Beach	
2003	Beach Nourishment - Kanaia Nalu condos	3,000	Maalaea Bay Beach	
May.2007	Beach Nourishment - Maui Lu	6,400	Kihei	
August.2007	Beach Nourishment - Altman Residence	500	Kihei	not sure if ever completed
Ongoing	Beach seaweed removal (sand also gets removed) - between Koieie Fishpond and Veterans of Foreign Wars property	1,000-1,500 cy per year		
** reference: Caruso and Businger (2006, Weather and Forecasting, AMS)*				





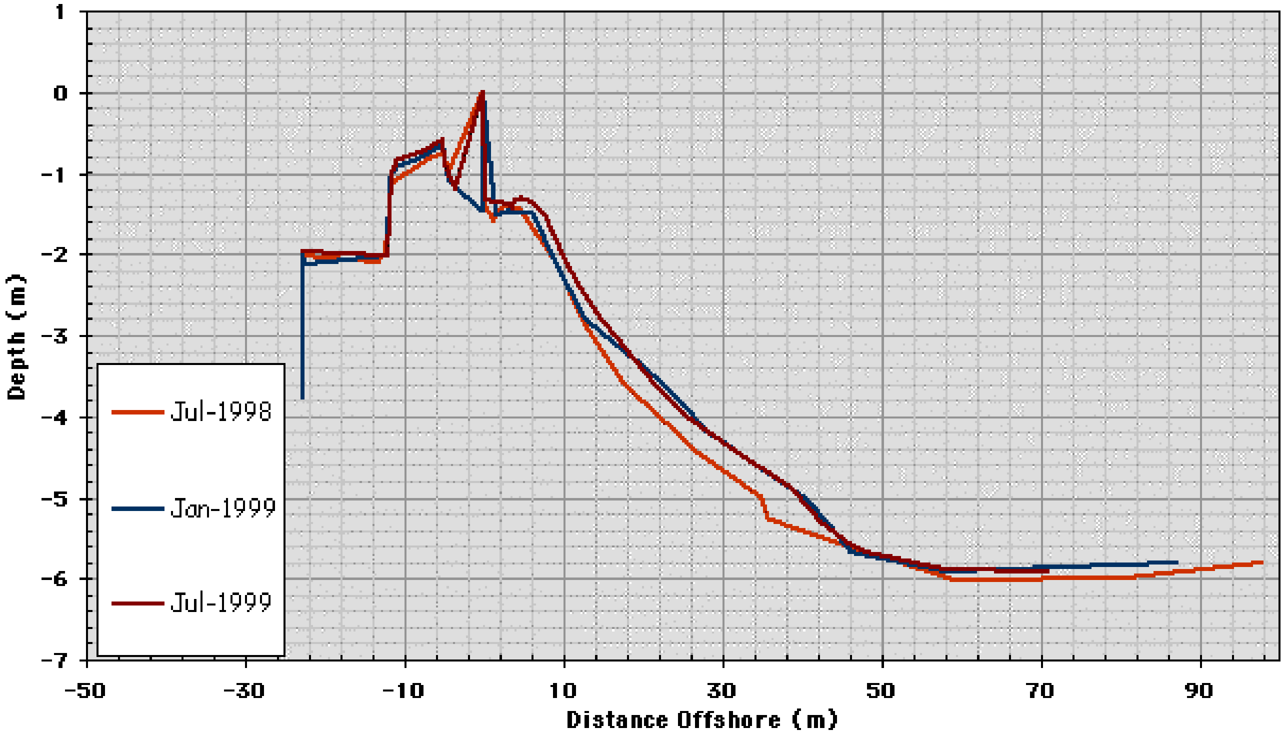
Figures G-2 and G-3. Kihei Region Beach Profiles



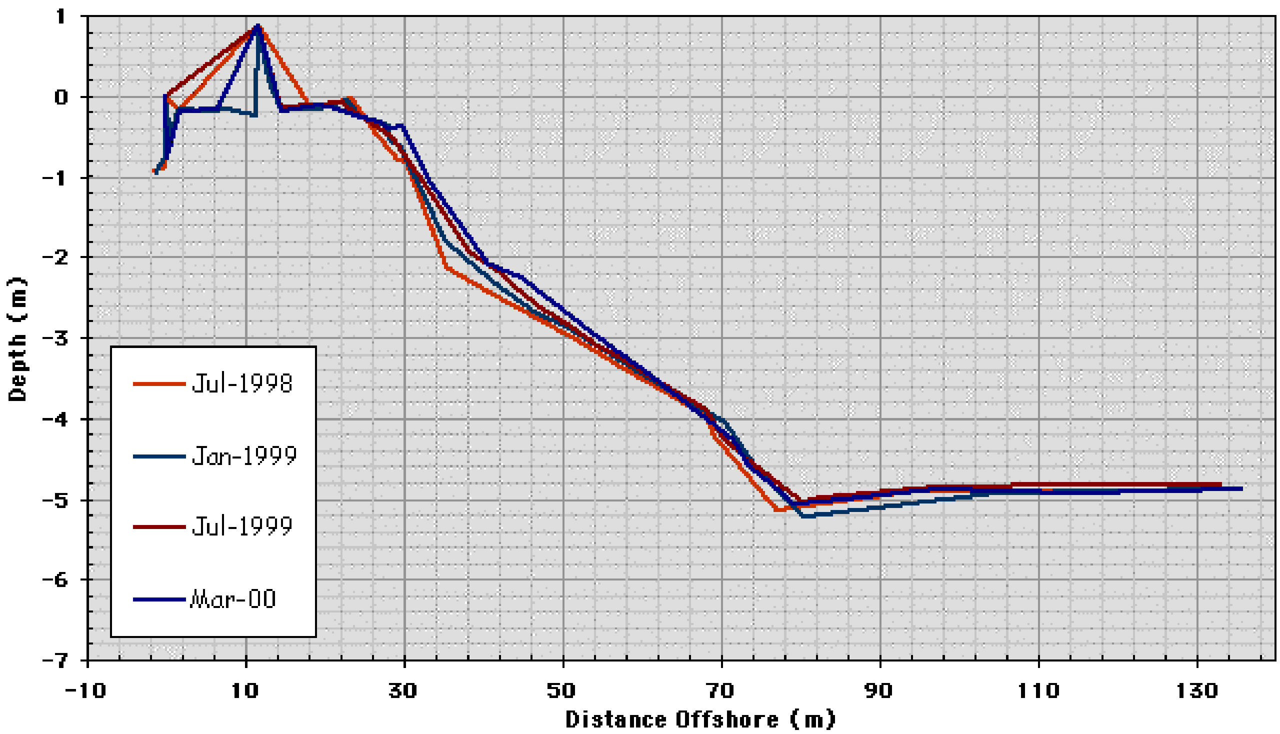


Figures G-4 and G-5. Kihei Region Beach Profiles (cont.)

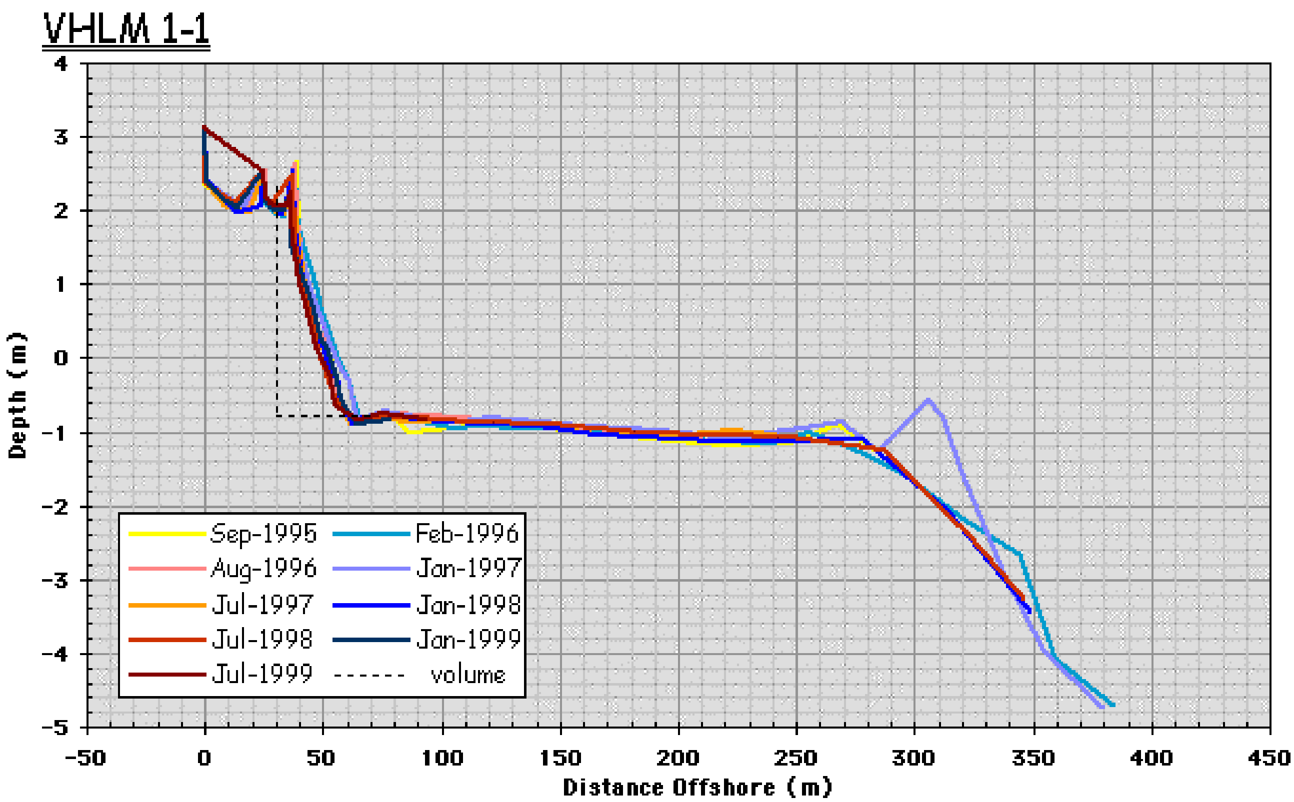
VMPA 1-1

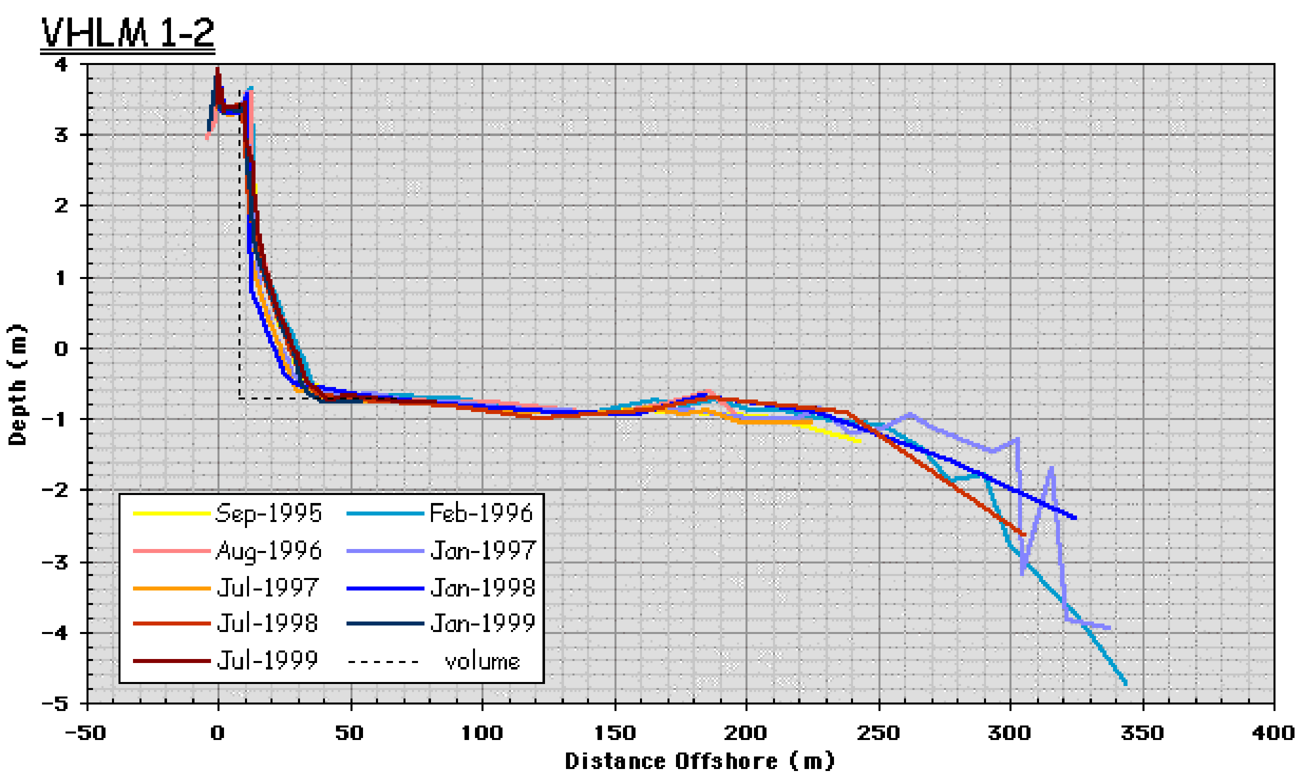


VMPA 2-1



Figures G-6 and G-7. Kihei Region Beach Profiles (cont.)





Figures G-8 and G-9. Kihei Region Beach Profiles (cont.)

For the calculated volumetric erosion/accretion rates, seasonal variation is addressed by the linear regression / weighted least squares analysis of the volumes. The analysis is based on the total position uncertainty error provided by UH for each of the erosion maps, and the total position uncertainty error includes a factor for the seasonal fluctuation. This calculated seasonal fluctuation error is on the order of 20 feet for the Kihei region.

The estimated potential error band associated with seasonal variation, and other uncertainty errors, is shown on each line graph as an error bar. This bar is an attempt to bound the potential range of beach volume within a given year and thus account for seasonal variation when comparing the limited shoreline data points.

II. Sediment Budget Results – Kihei Region

A. Descriptions of Littoral Cells

The Kihei Study Region comprises of approximately 7.5 miles of shoreline on the leeward side of Maui and includes the towns of Maalaea and Kihei. The shoreline within this reach faces both due south in the vicinity of Maalaea and west in the Kihei area. The study region was divided into seven littoral cells, as shown in Figure G-10 and listed from west to east (south) below:

1. West Maalaea
2. Maalaea Harbor
3. Maalaea Bay Beach
4. Kealia
5. North Kihei
6. Kawililipoa Beach
7. Kalama

These cells are described below and shown in the following figures. Each of the littoral cell figures includes the shoreline features which possibly affect the shoreline sediment transport.

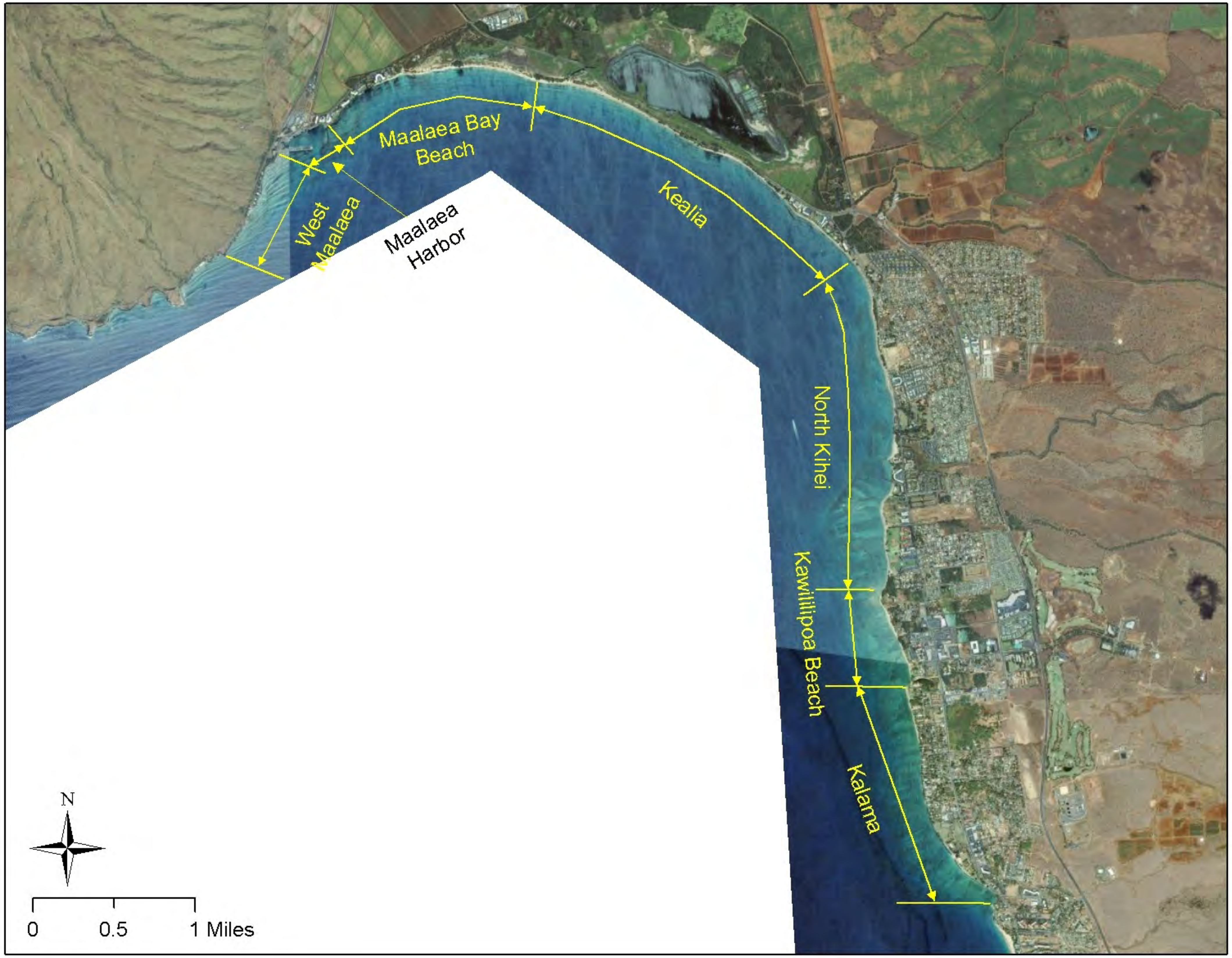


Figure G-10. Kihei Region Littoral Cells

West Maalaea Littoral Cell

The West Maalaea Littoral Cell is approximately one-half mile in length and extends from just north and east of McGregor Point to the west breakwater of the Maalaea Harbor. The shoreline faces southwesterly within this cell and consists of small pocket beaches interspersed among hard shoreline and basaltic headlands. The Malalowaiaole Gulch is a non-perennial stream located to the south and west of the littoral cell.

Maalaea Harbor Littoral Cell

The Maalaea Harbor Littoral Cell is approximately 1,600 feet and consists of the area between the east and west harbor breakwaters. The south breakwater was constructed in 1952 and the east breakwater was constructed in 1958. Maalaea Harbor improvements were constructed in 1979 and additional improvements are currently proposed. A breakwater exists within the harbor, which acts to attenuate surge within the harbor. The Maalaea Stream is non-perennial and flows into the northeastern shore of the harbor.

Maalaea Bay Beach Littoral Cell

The Maalaea Bay Beach Littoral Cell is approximately 6,500 linear feet in length and faces generally southerly. The Kanaio Stream discharges to the western end of the cell and is non-perennial. There is no fringing reef in this cell.

The western approximately 2,500 feet of coastline within the cell was developed with beach front condos between 1971 and 1981. Shoreline protection in the form of seawalls and rock revetments front these structures. Mined sand from inland dunes has been placed in front of the Kanai'a Nalu Condo's for the purposes of beach nourishment. In 1997, the property owners placed 1,500 cy of sand, followed by 3,000 cy in 1998, and 3,000 cy in 2003. At the 2011 Maui RSM workshop, it was stated that this beach nourishment had a secondary beneficial effect of covering the exposed red clay and thus decreasing the turbidity effects to Maalaea Bay caused by erosion of the clay.

Kealia Littoral Cell

The Kealia Littoral Cell is approximately two miles long and extends from just west of the Waikapu Stream outlet to the Kihea Pier to the east. Both the Waikapu Stream and the Waiakoa Gulch provide non-perennial discharges to the cell. The beaches are backed by vegetated dunes, and there are occasional outcrops of beach rock.

Notable shoreline features in the aera include stub jetties at the Waikapu Stream outlet and the Kihei Pier at the easternmost limit of the cell. The majority of the shoreline is undeveloped, aside from an approximately 2,600 foot stretch in the vicinity of the Kihei Pier.

North Kihei Littoral Cell

The North Kihei Littoral Cell is approximately two miles long and extends from the Kihei Pier to the north to the Kawililipoa Sand Spit in the south. The cell faces westerly. The

Kawililipoa Sand Spit is a sand deposit formed from natural, coral rubble mounds that act as groins. Non-perennial discharges to the cell include the Kulanihakoi Gulch and the Waipuilani Gulch. The fringing reef along the west-facing coastline extends to the northern limit of this cell. Most of the beaches are backed by vegetated dunes of varying heights.

The shoreline is relatively developed and shoreline protection in the form of revetments exists in the vicinity of Ka Ipu Kai Hina and the Kalepolepo Beach. Windblown sand is deposited upland on the north side of the Koieie Fishpond in the vicinity of Kalepolepo Beach due the revetment structure.

Kawililipoa Beach Littoral Cell

The Kawililipoa Beach Littoral Cell is approximately 3,000 feet long and extends from Kawililipoa Sand Spit to the Halama Street Groin to the south. The cell faces westerly.

Notable shoreline features in this reach include an offshore fringing reef, the sand spit features in the vicinity of La'ie and the Halama Street Groin to the south. The sand spit is where unique coral rubble formations protrude a few inches above mean sea level (M&N 2000).The Halama Street Groin was constructed prior to 1964. Beach-front homes in the vicinity of Halama Street are protected with vertical seawalls or with stone or geobag revetments. Development is generally set back from the shoreline along this reach.

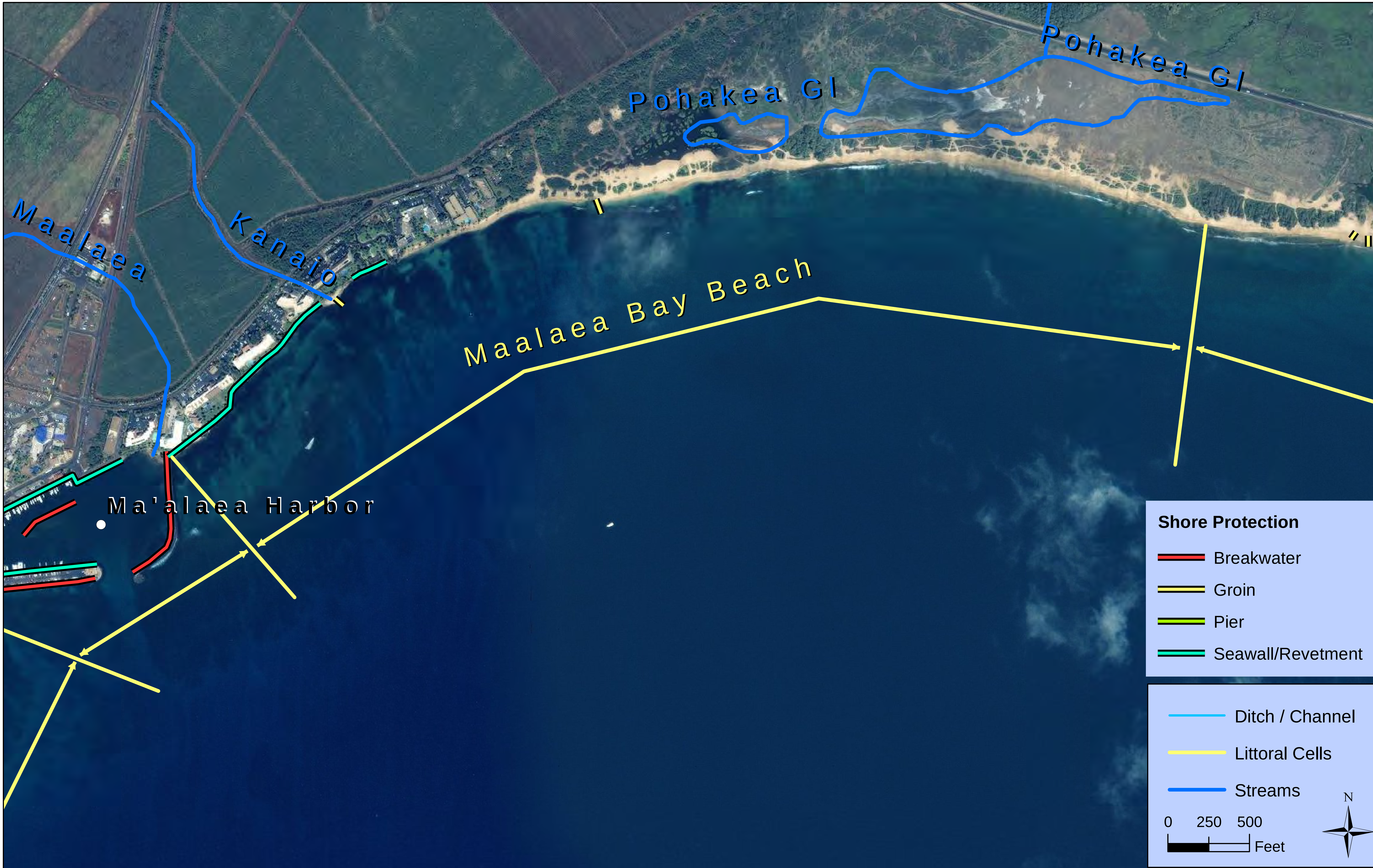
Kalama Littoral Cell

The Kalama Littoral Cell is approximately 1.5 miles long and extends from the Halama Street Groin on the north end to the Kaluahakoko Boat Ramp on the south end. The shoreline in this cell consists of mostly narrow beach, with a groin at the north end, a variety of sea wall types fronting residential properties, and rock revetment along Kalama Beach Park. The Kaluahakoko Boat Ramp was constructed in 1964 and sand shoaling is common in this area. The Kalama Beach Park Revetment is 3,000 foot revetment and was built in the early 1970's.

The offshore bottom is very shallow and rocky, marking the beginning of the coral fringing reef. The reef is about 1,200 feet wide and extends offshore (M&N 2000). Its surface near the shoreline is mantled by a thin veneer of sand that, in some areas, becomes large sand pockets. The reef partially buffers the shoreline from south swell and Kona storm activity.

West Maalaea
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0 200 400
Feet
N

Maalaea
Ma'alaea Harbor
Maalaea Bay Beach
Maalaea Harbor
West Maalaea
Shore Protection
Breakwater
Groin
Pier
Revetment
Seawall
Ditch / Channel
Littoral Cells
Streams
0
200
400
Feet
N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Pohakea Gl
Maalaea
Kanaio
Maalaea Bay Beach
Ma'alaea Harbor
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0 250 500
Feet
N

Pohakea Gl
Palalau Outlet
Kealia Pond
Ma'alaea Bay Beach
Waikapu
Kealia
Waiakoa Gl
Kihei Pier
Shore Protection
Breakwater
Groin
Pier
Revetment
Seawall
Ditch / Channel
Littoral Cells
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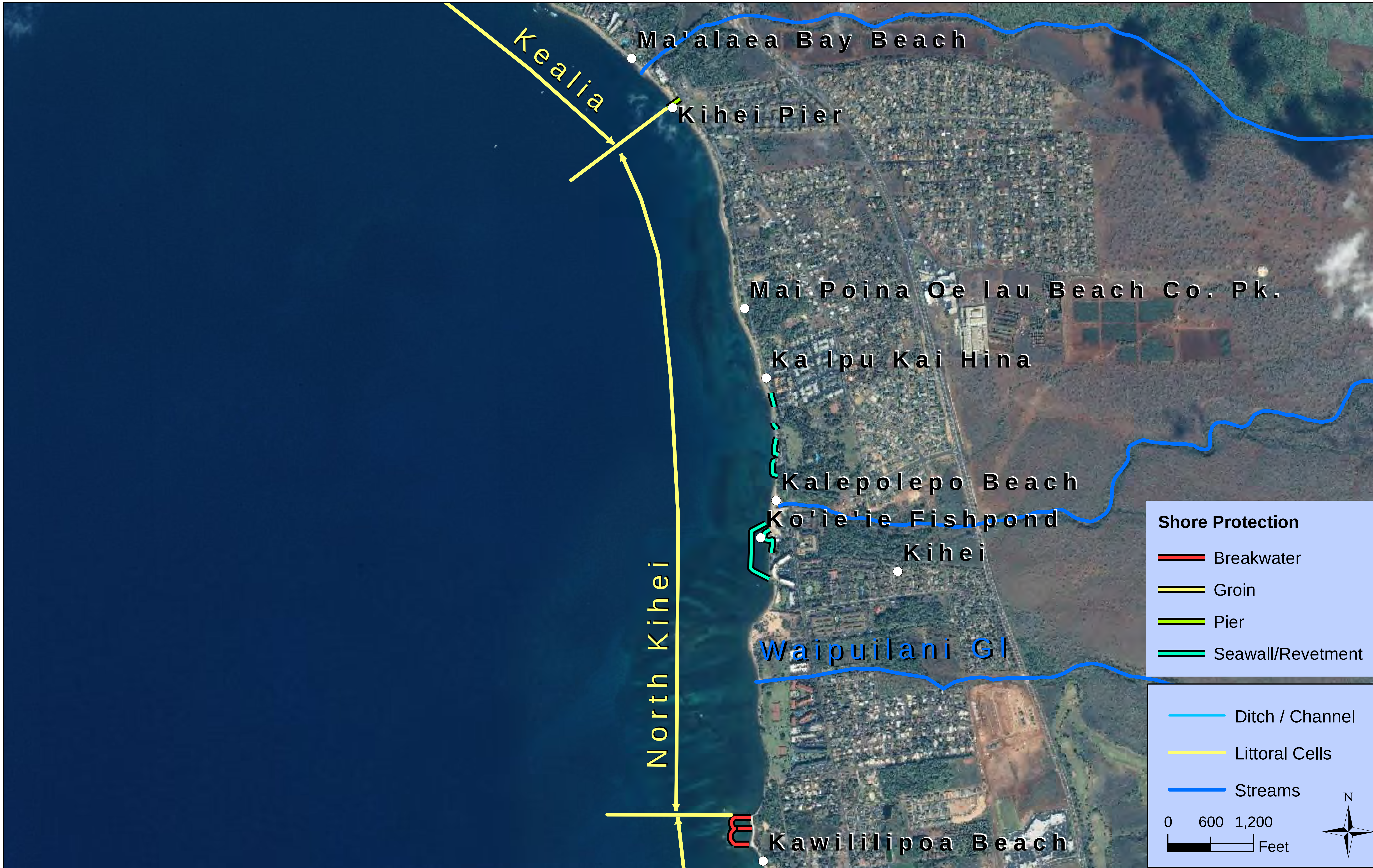
500
1,000
Feet
N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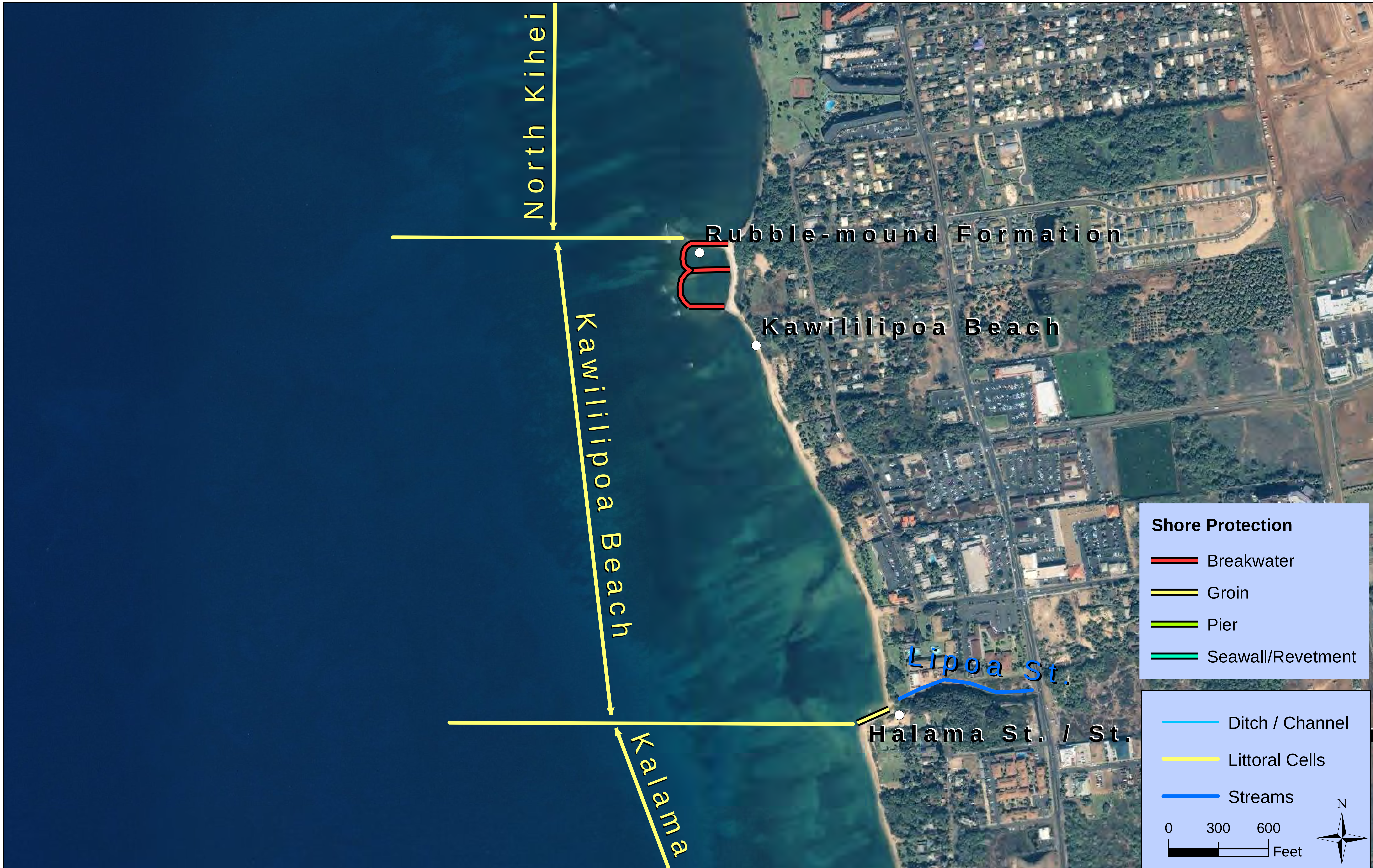
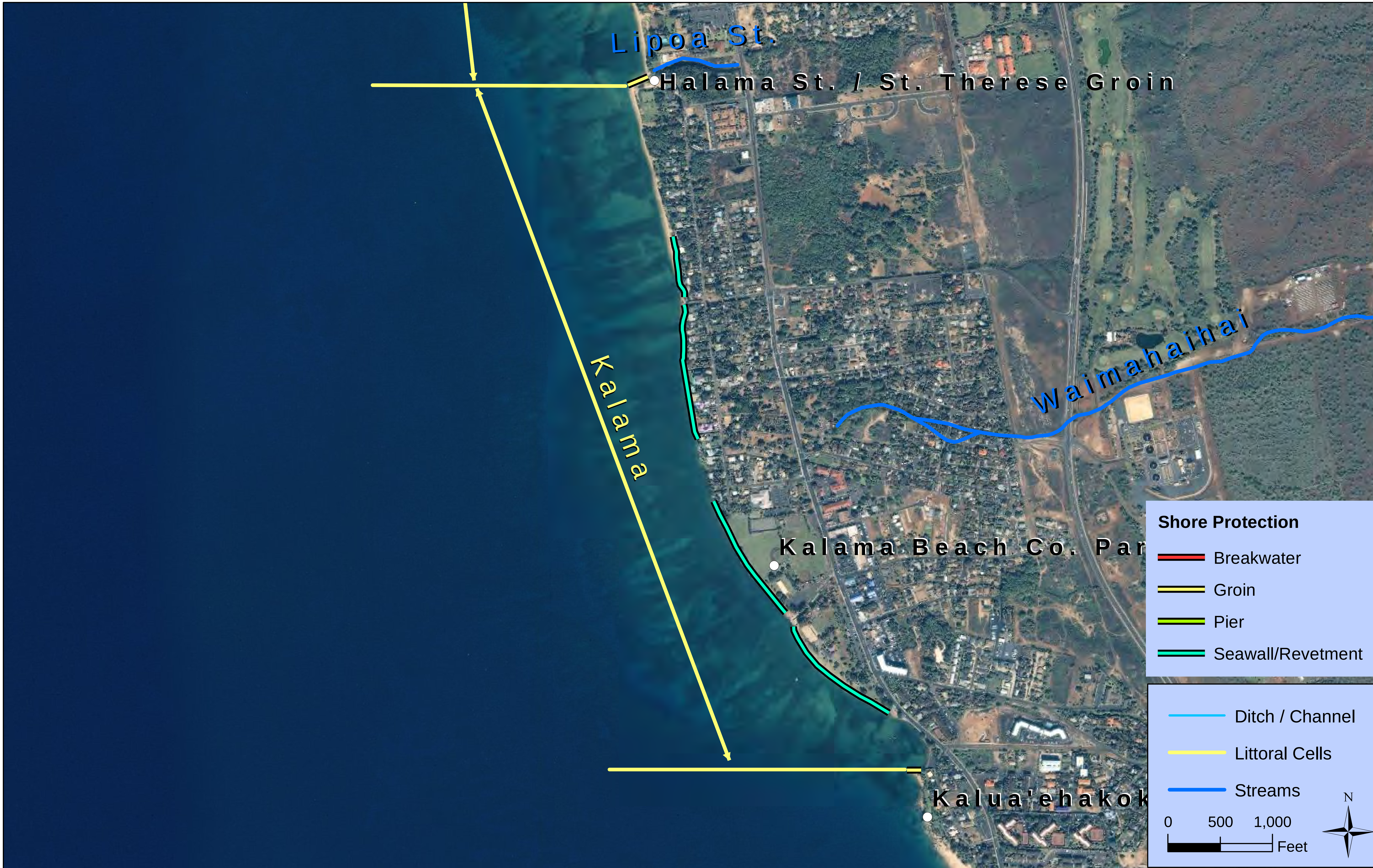
Kealia
Kihei Pier
Mai Poina Oe Iau Beach Co. Pk.
Ka Ipu Kai Hina
Kalepolepo Beach
Ko'ie'ie Fishpond
Kihei
North Kihei
Waipuilani Gl
Kawililipoa Beach
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0 600 1,200
Feet
N


North Kihei
Rubble-mound Formation
Kawililipoa Beach
Kawililipoa Beach
Lipoa St.
Halama St. / St.
Kalama
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0
300
600
Feet
N


Lipoa St.
Halama St. / St. Therese Groin
Kalama
Waimahaihai
Kalama Beach Co. Par
Kalua'ehakok
Shore Protection
Breakwater
Groin
Pier
Seawall/Revetment
Ditch / Channel
Littoral Cells
Streams
0 500 1,000
Feet
N

B. Beach Volumes

For each littoral cell, a graph of beach volume versus time was developed based on historical shorelines provided by the University of Hawaii and using a conversion factor of 0.40 cubic yards per square foot of beach.

It should be noted that the number of available historical shorelines is limited and the curves were interpolated between available shoreline data points. Accordingly, the following should be understood:

- The points do not necessarily bound the minimum and maximum beach volumes.
- It is probable that the chronological transitions from erosional to accretional conditions (and vice versa) are not at the exact date shown by the breaks in the lines in the graphs.

Following are graphs of each of the cells within the Kihei region (Figures G-12 to G-17), as well as a summary graph which includes all cells in the region (Figure G-11). The line graphs show the estimated historical beach volumes over the time period of shoreline data records and the bar graphs show the change rates over different time periods of interest. Potentially significant events are shown on the line graphs. Table G-2 summarizes the associated erosion and accretion rates over the time period of record and over the most recent time period for each of the littoral cells. Figures G-18 through G-24 show the most recent change rate (sediment budget) for each of the littoral cells.

Table G-2. Kihei Region Beach Sand Volume Change Rates

Littoral Cell	**Accretion(+) / Erosion(-) Rate Over Entire Time Period of Record, cubic yards per year**	**Accretion(+) / Erosion(-) Rate Over Recent Period, cubic yards per year**
West Maalaea	**-100**	**+50**
Maalaea Harbor	**0**	**0**
Maalaea Bay Beach	**-1,300**	**-800**
Kealia	**-2,300**	**-2,800**
North Kihei	**-800**	**+8,800**
Kawililipoa Beach	**+1,400**	**+1,200**
Kalama	**-1,400**	**-1,600**

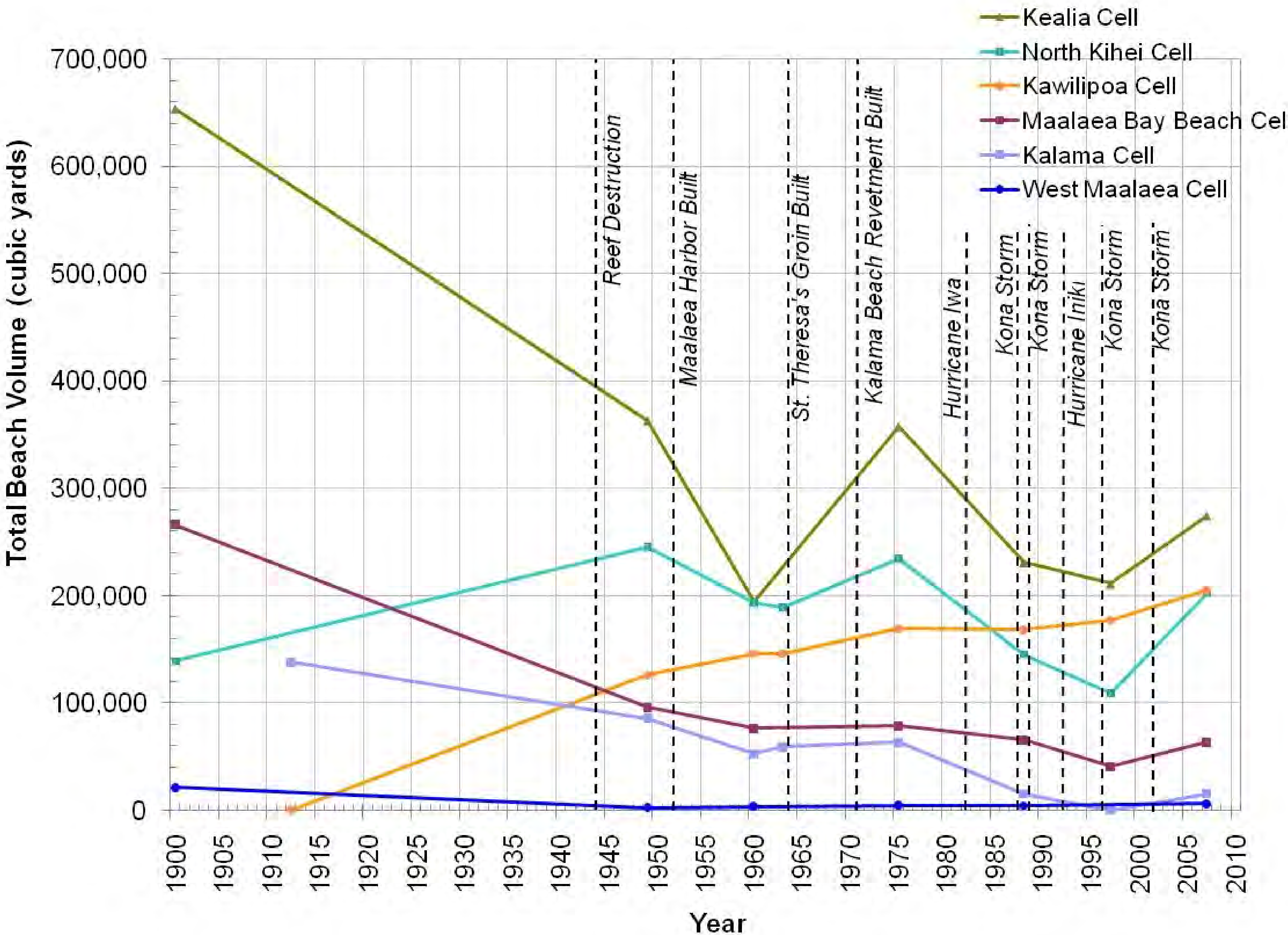
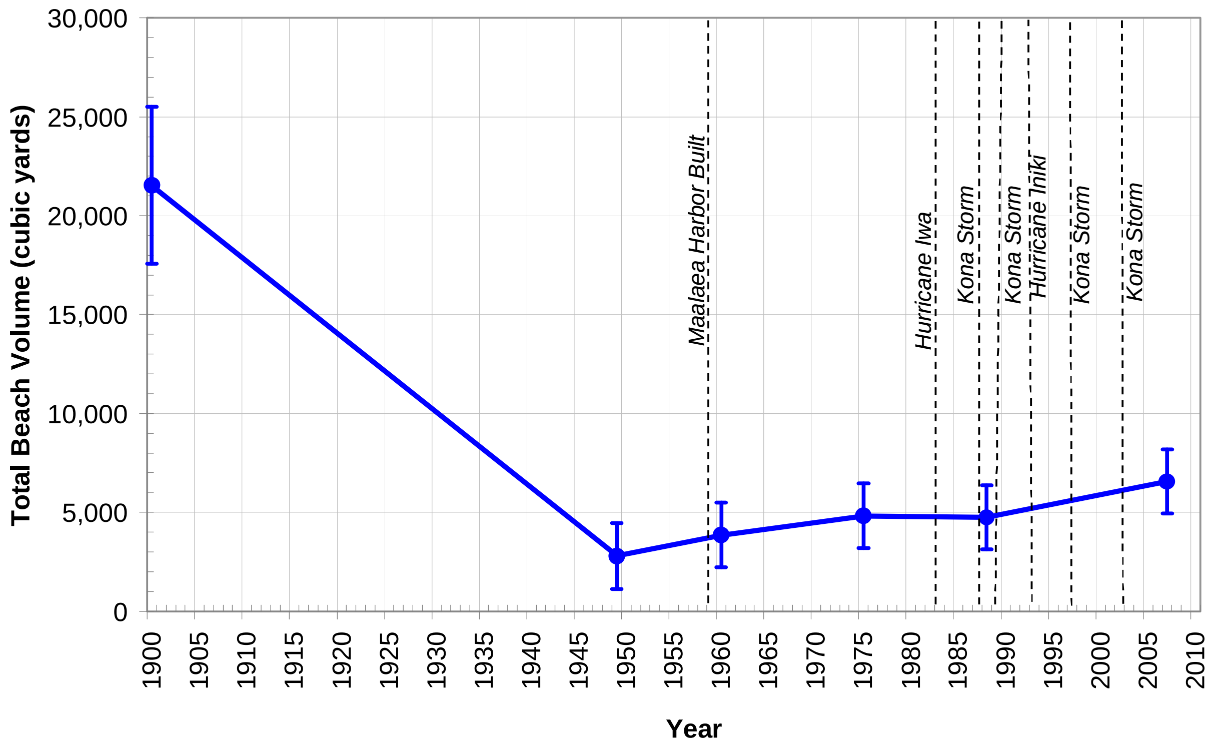


Figure G-11. Historical Beach Volumes of Kihei Region Littoral Cells



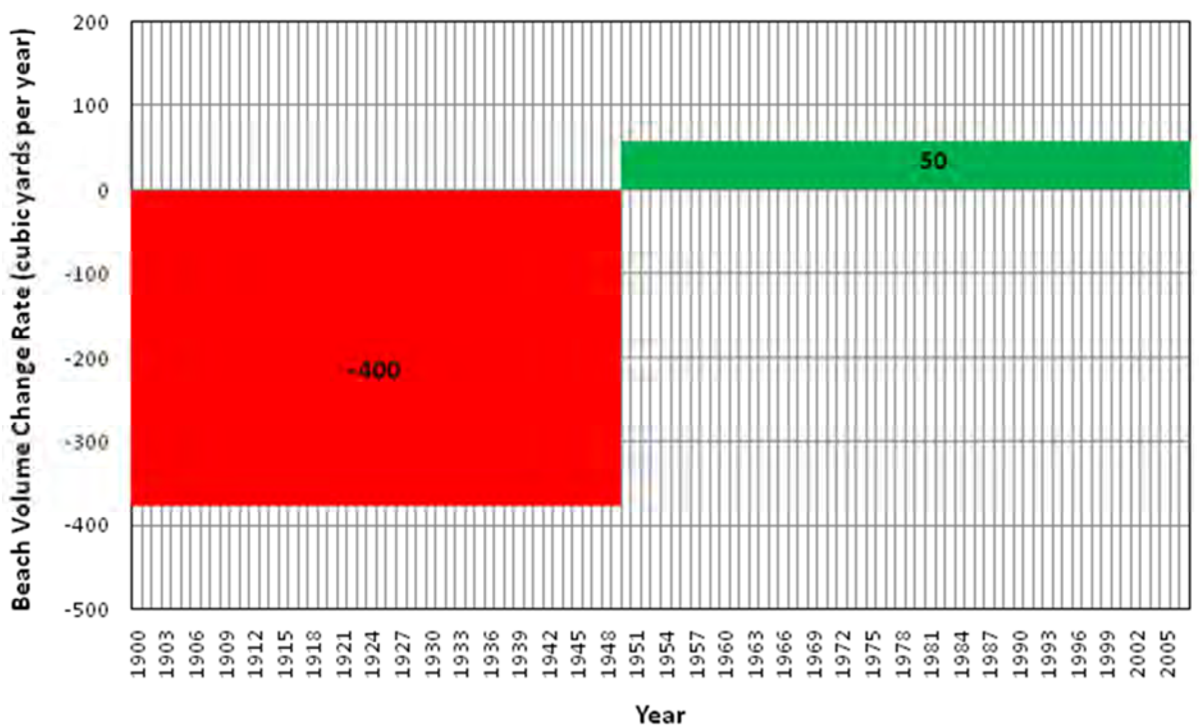


Figure G-12. Historical Beach Volumes / Change Rates for West Maalaea Littoral Cell

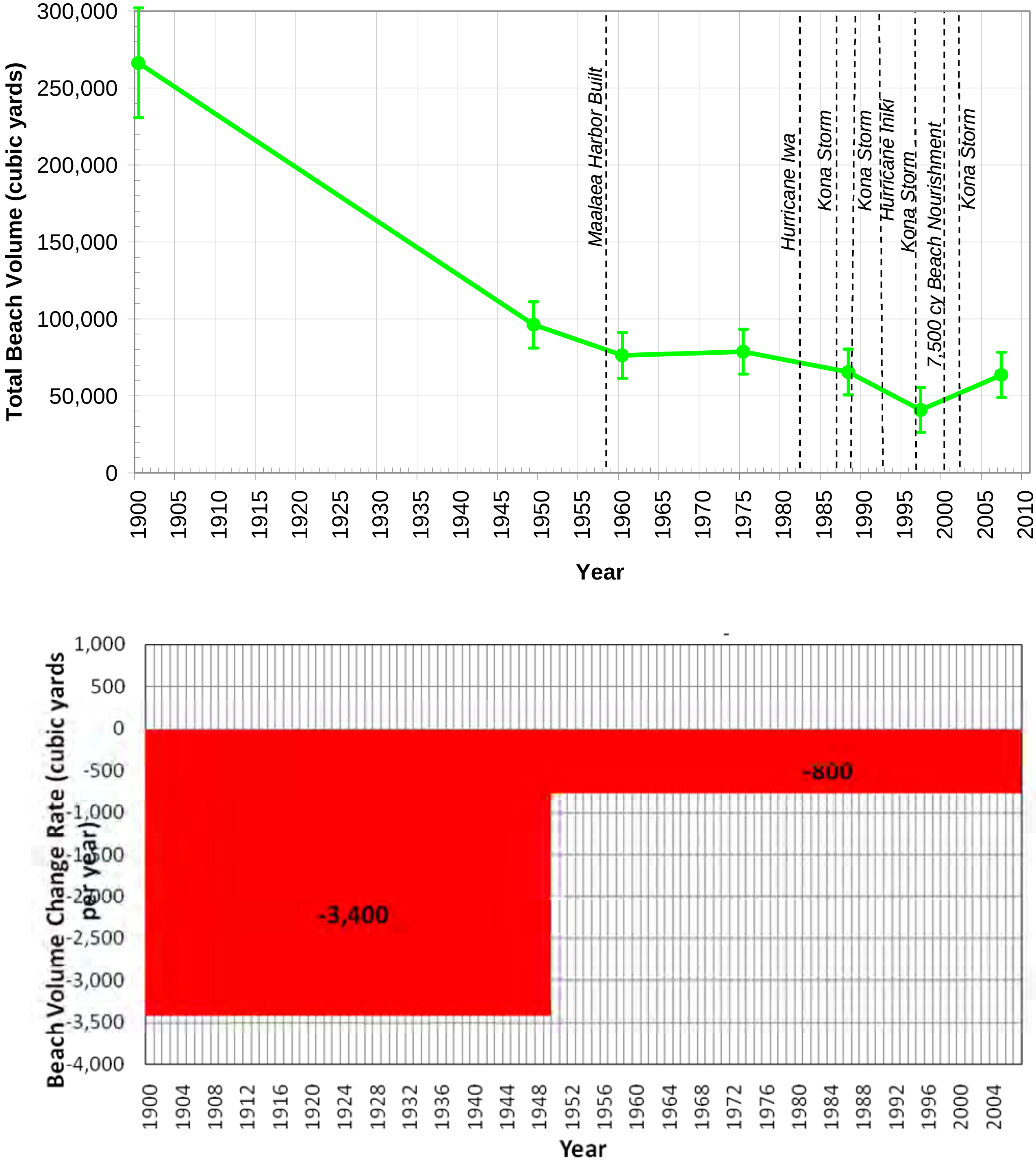


Figure G-13. Historical Beach Volumes / Change Rates for Maalaea Bay Beach Littoral Cell

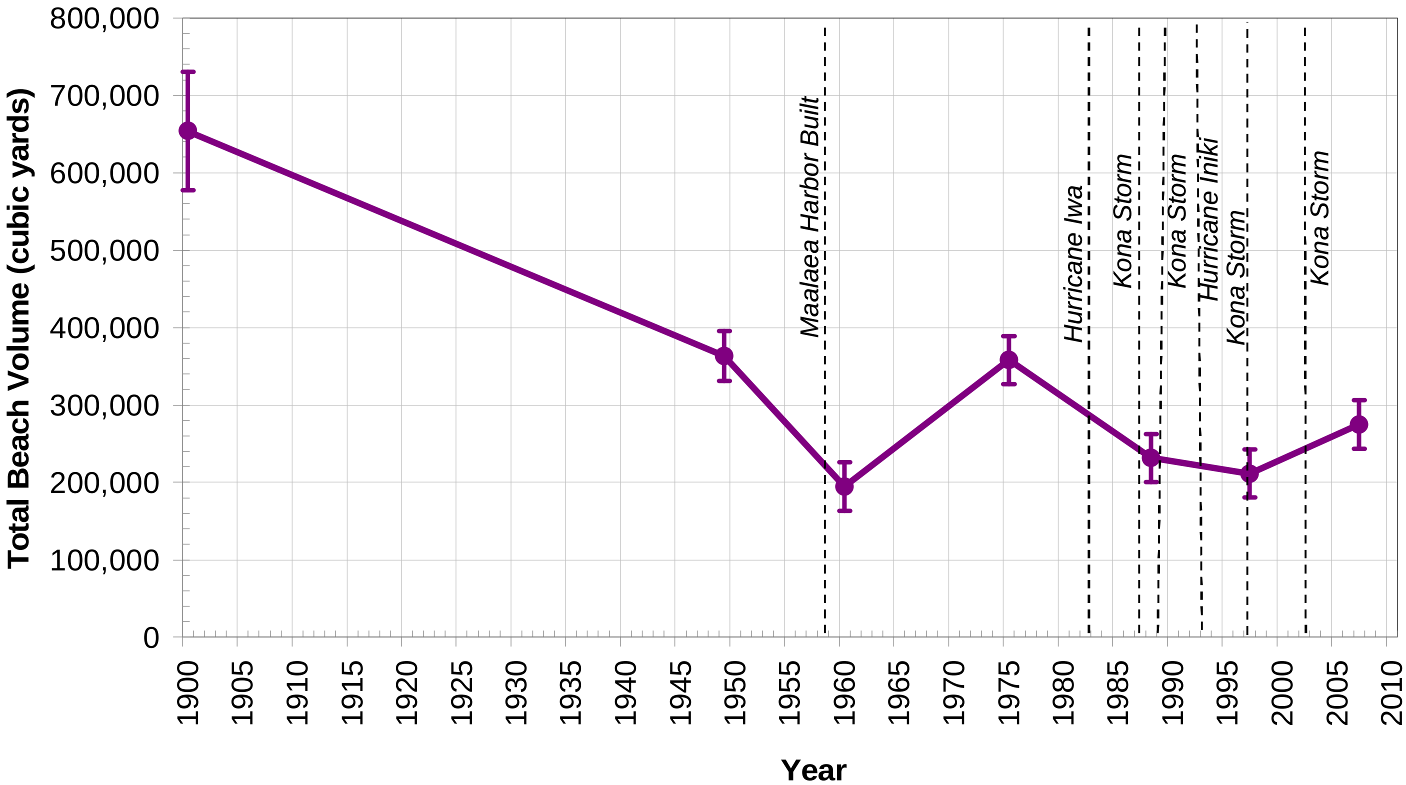


Figure G-14. Historical Beach Volumes / Change Rates for Kealia Littoral Cell

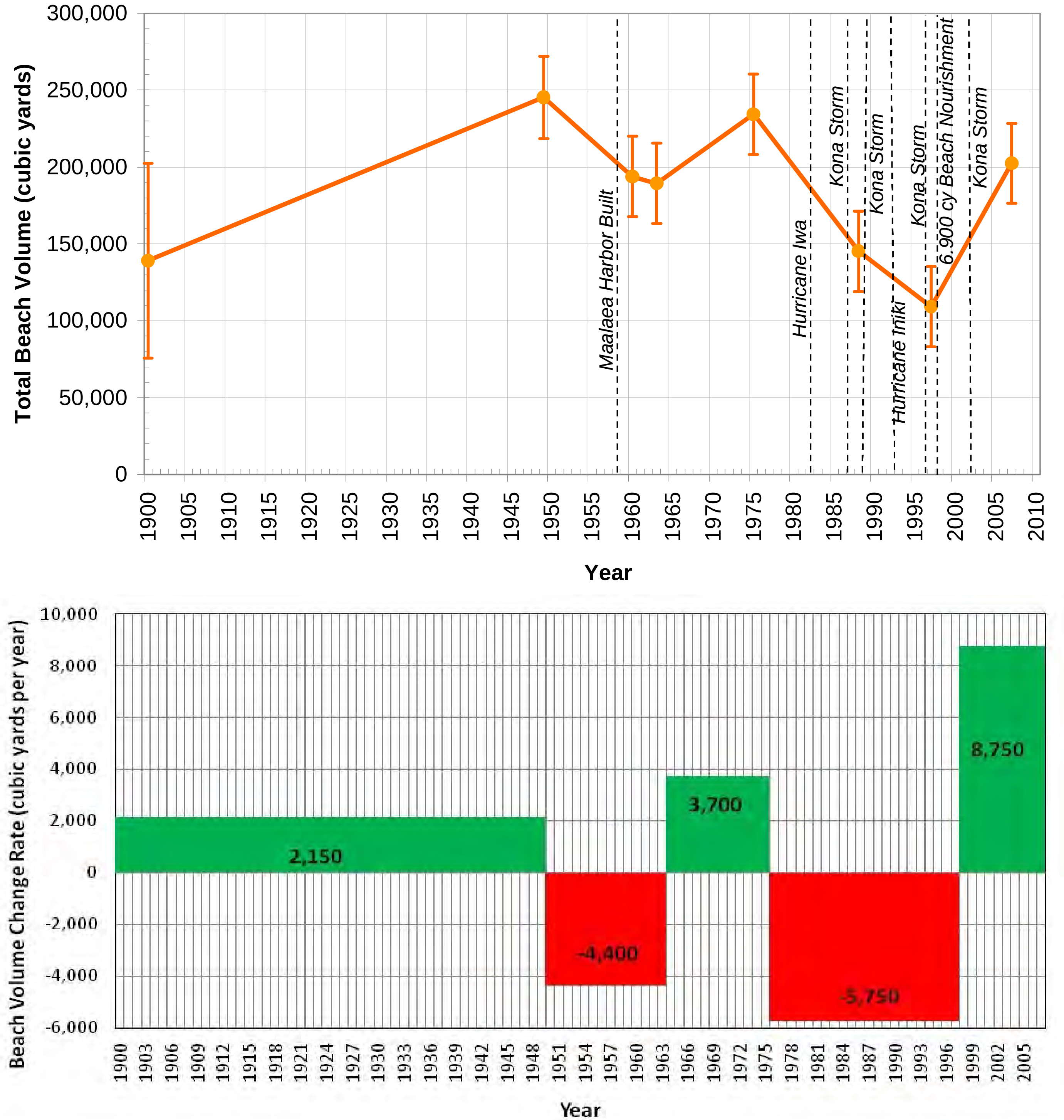


Figure G-15. Historical Beach Volumes / Change Rates for North Kihei Littoral Cell

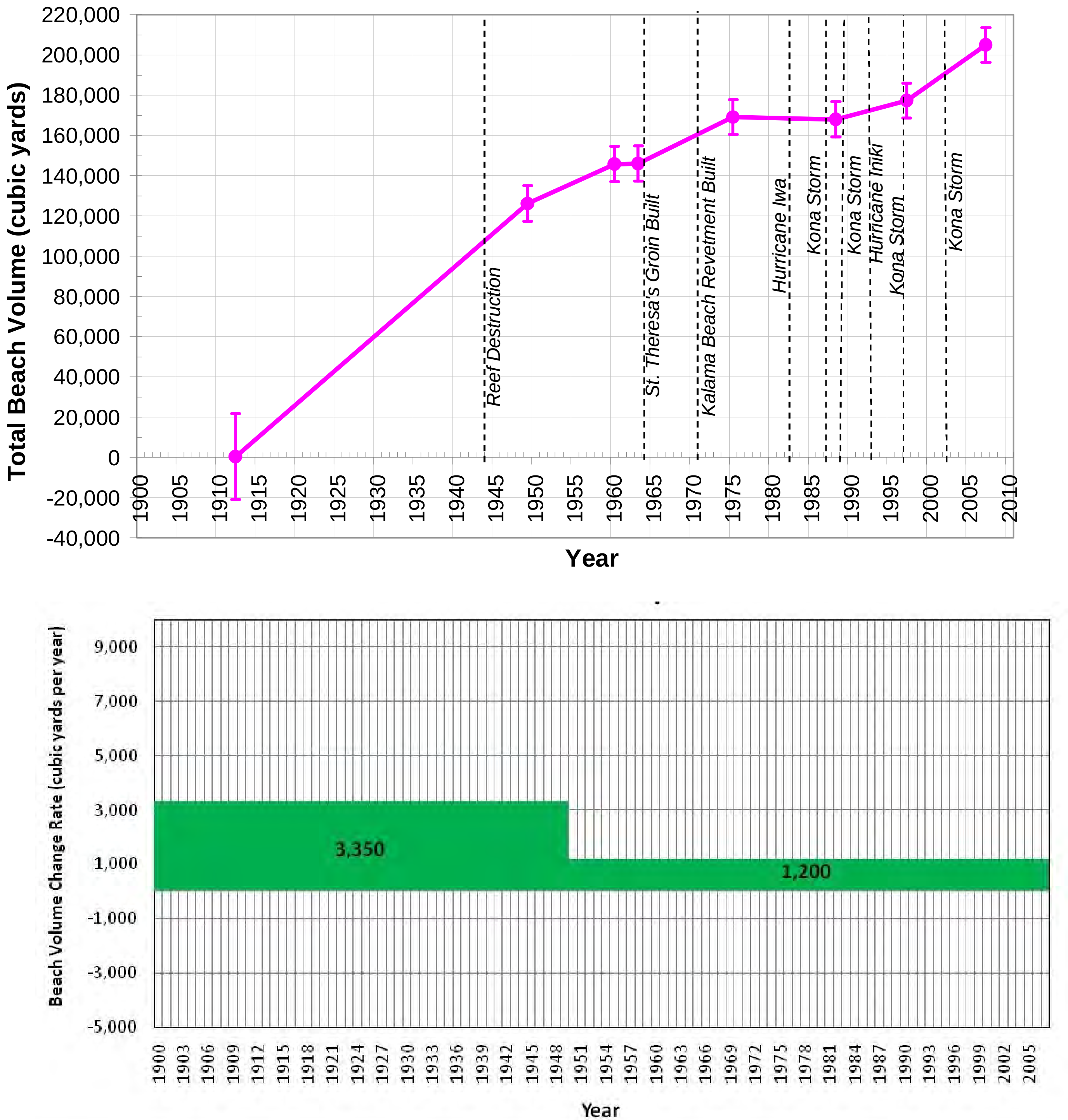
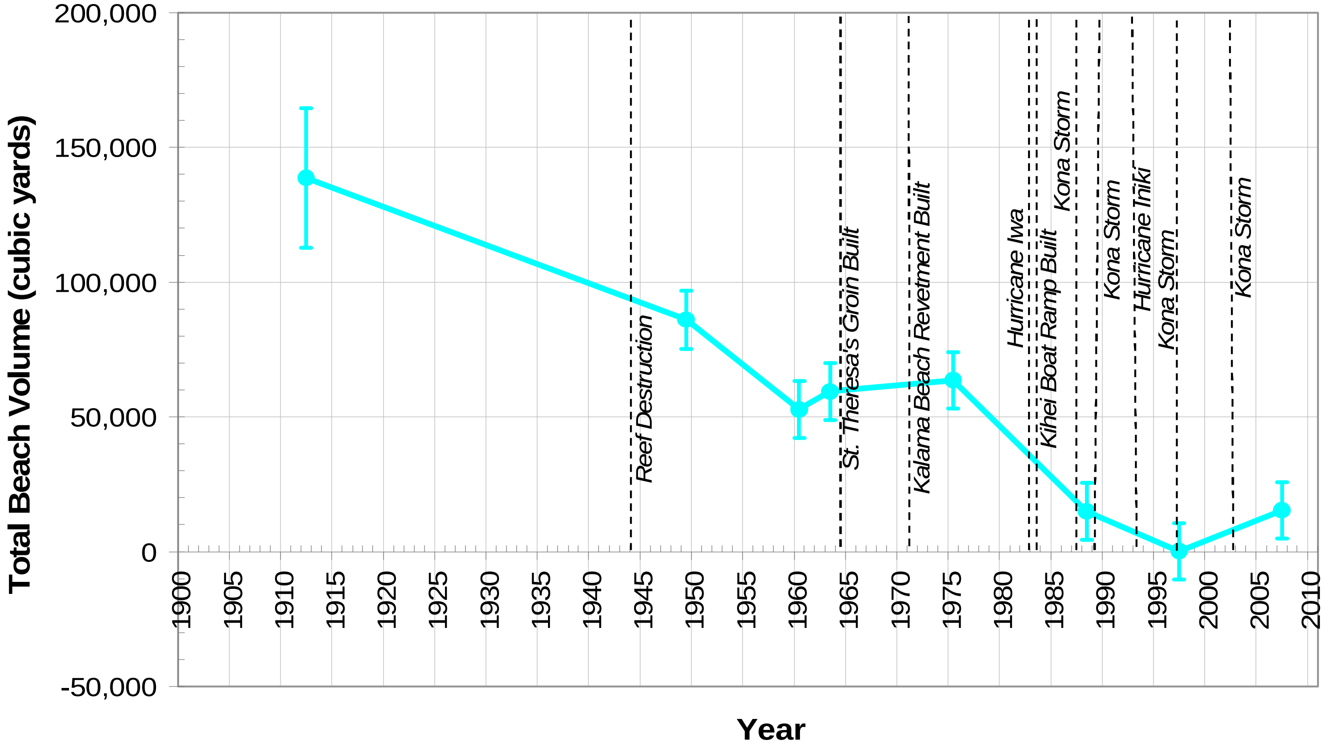


Figure G-16. Historical Beach Volumes / Change Rates for Kawililipoa Littoral Cell



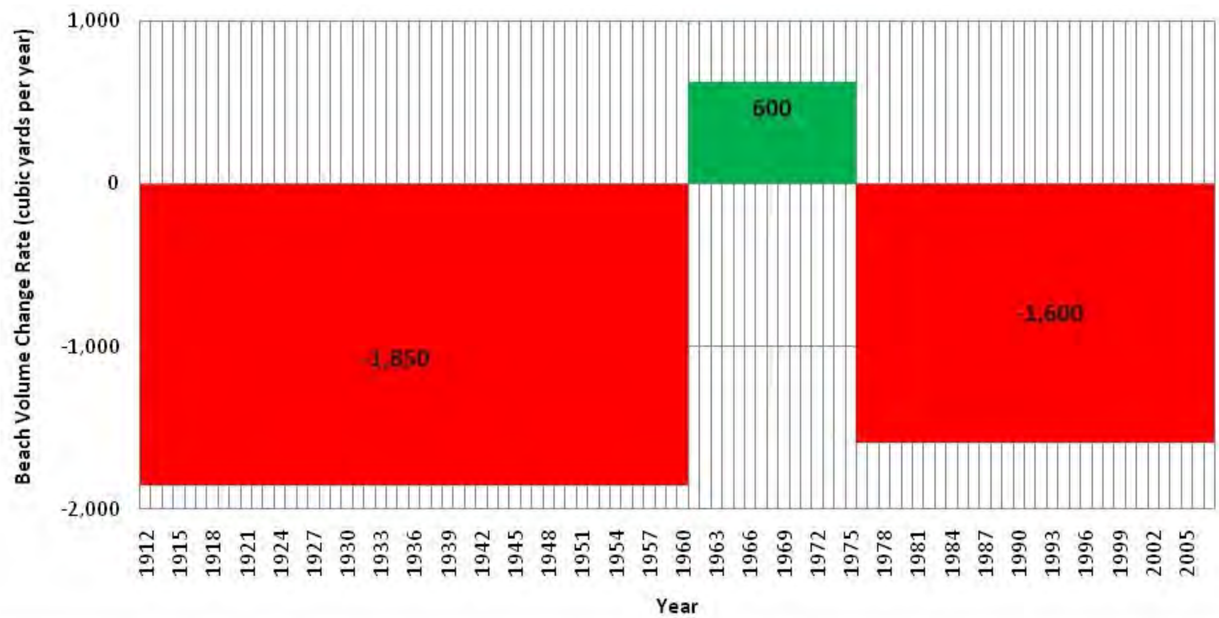


Figure G-17. Historical Beach Volumes / Change Rates for Kalama Littoral Cell

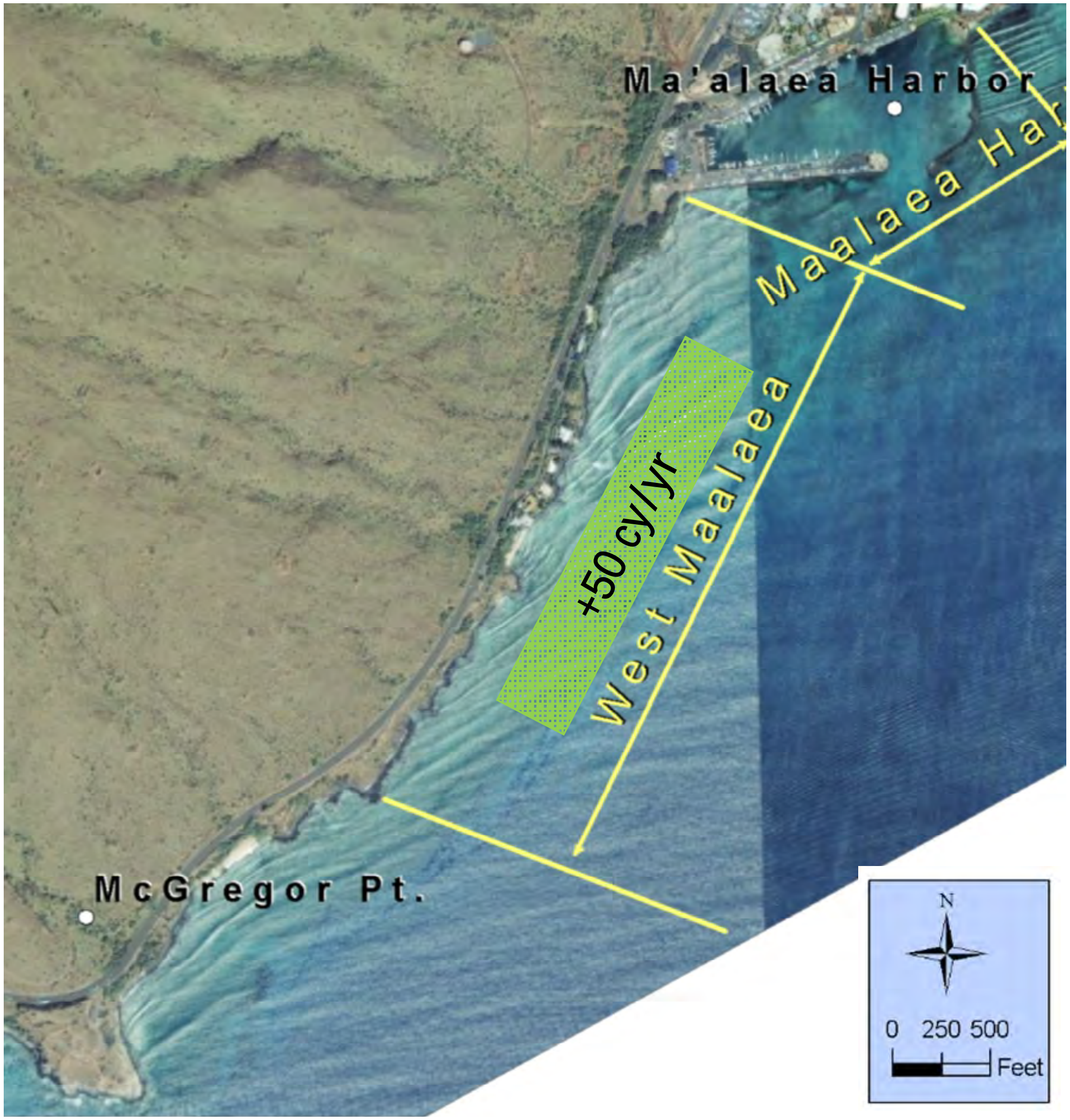


Figure G-18. Beach Volume Change Rate for West Maalaea Littoral Cell

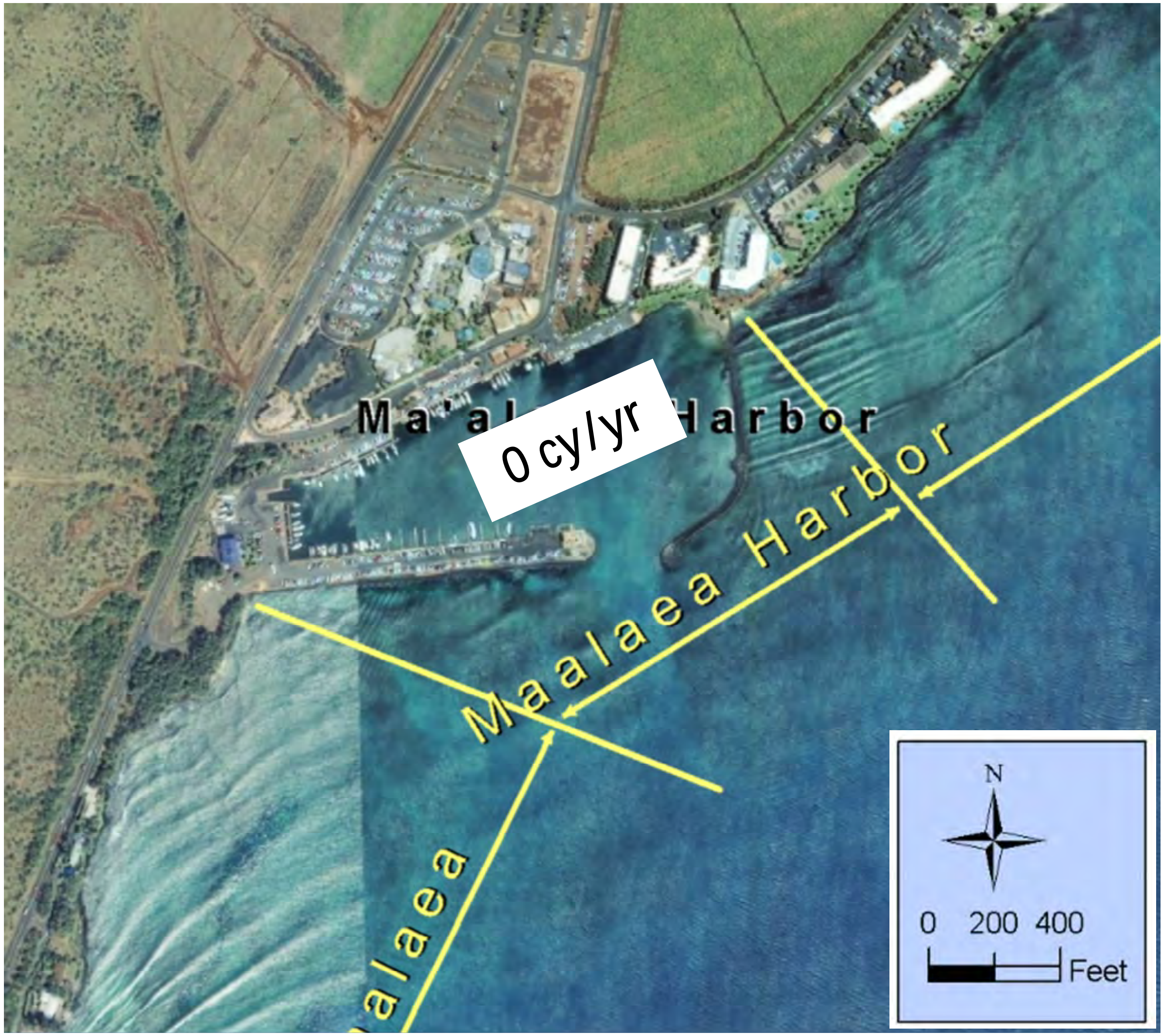


Figure G-19. Beach Volume Change Rate for Maalaea Harbor Littoral Cell

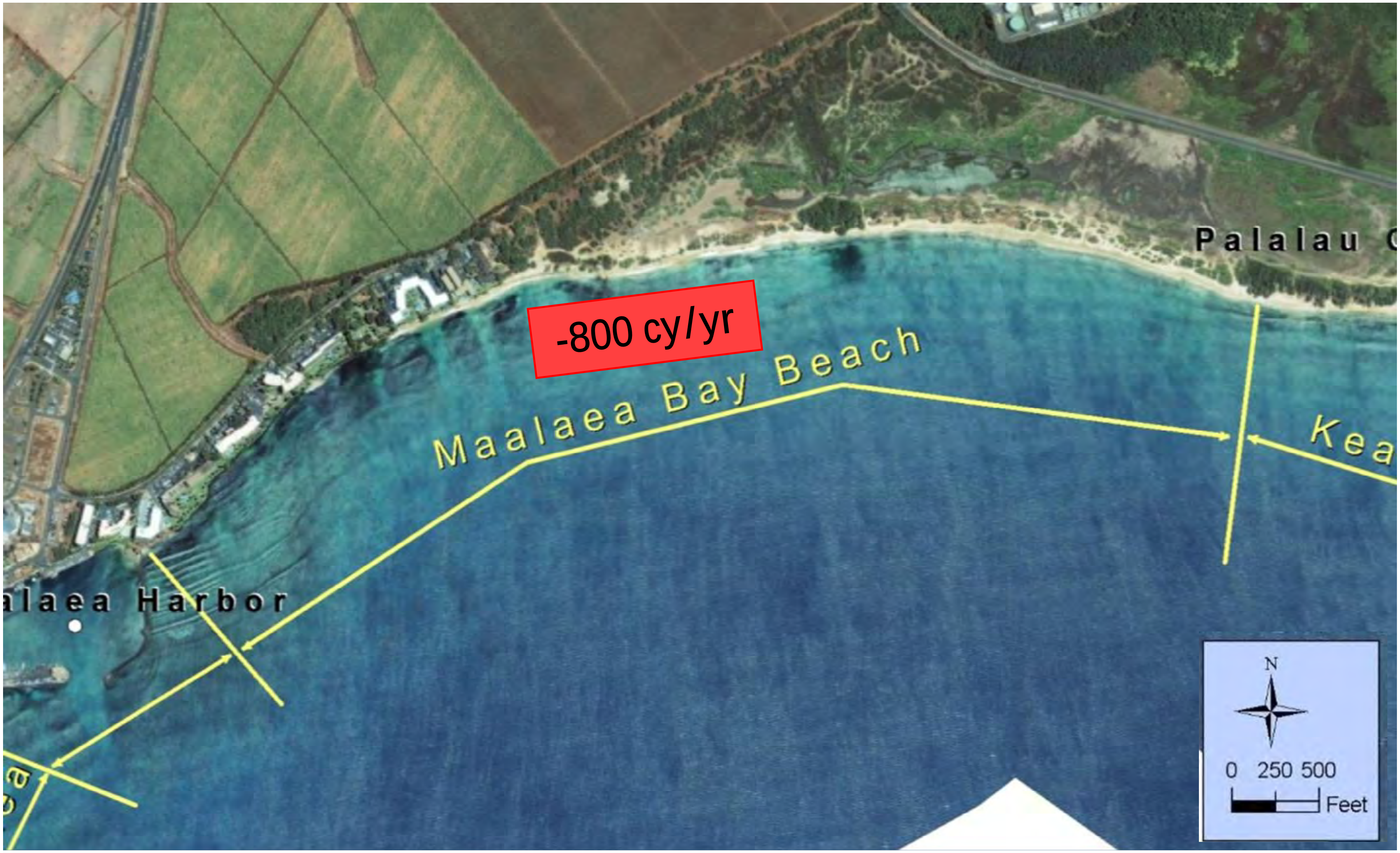


Figure G-20. Beach Volume Change Rate for Maalaea Bay Beach Littoral Cell

Figure G-21. Beach Volume Change Rate for Kealia Littoral Cell

Figure G-22. Beach Volume Change Rate for North Kihei Littoral Cell

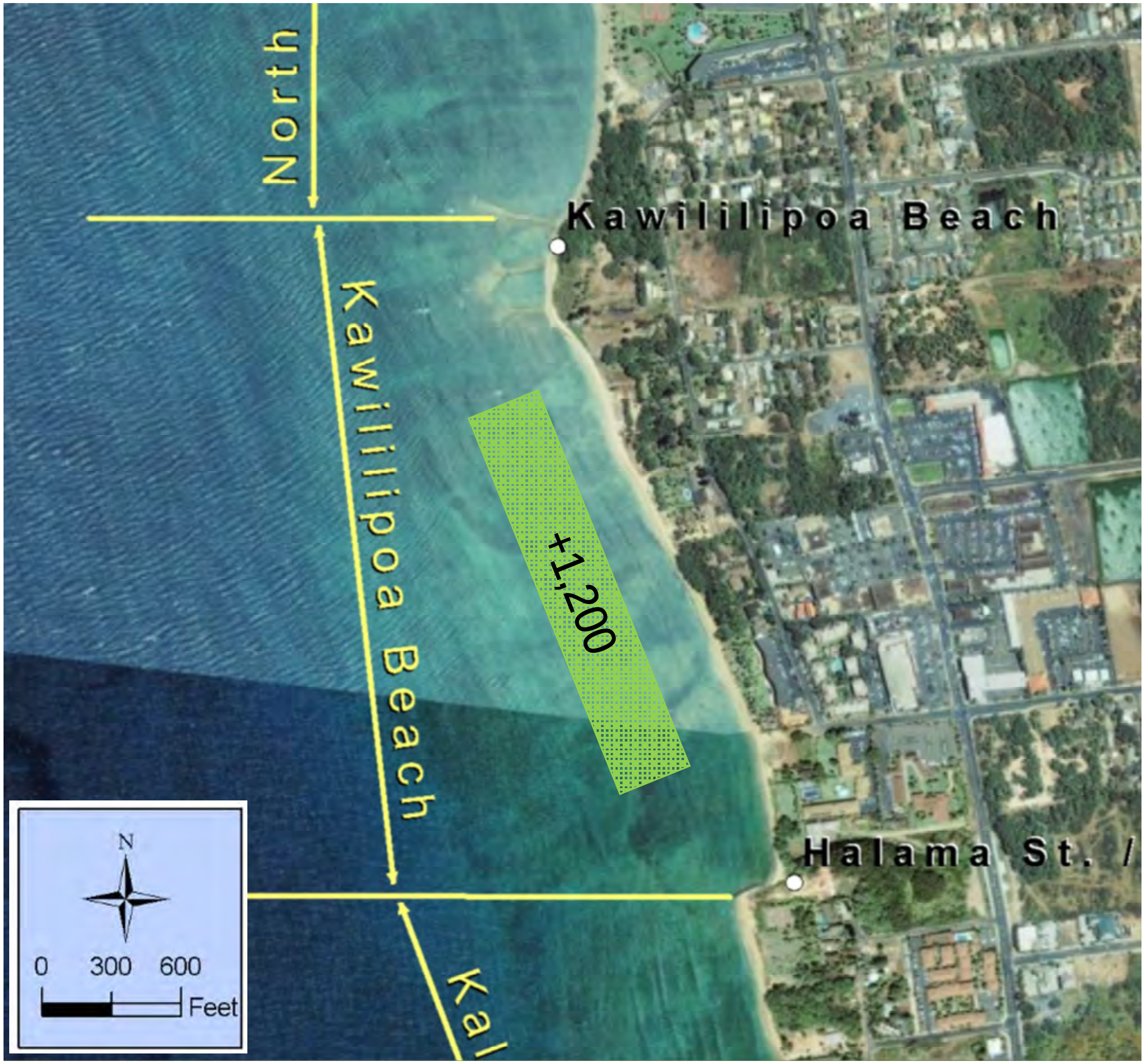


Figure G-23. Beach Volume Change Rate for Kawililipoa Littoral Cell

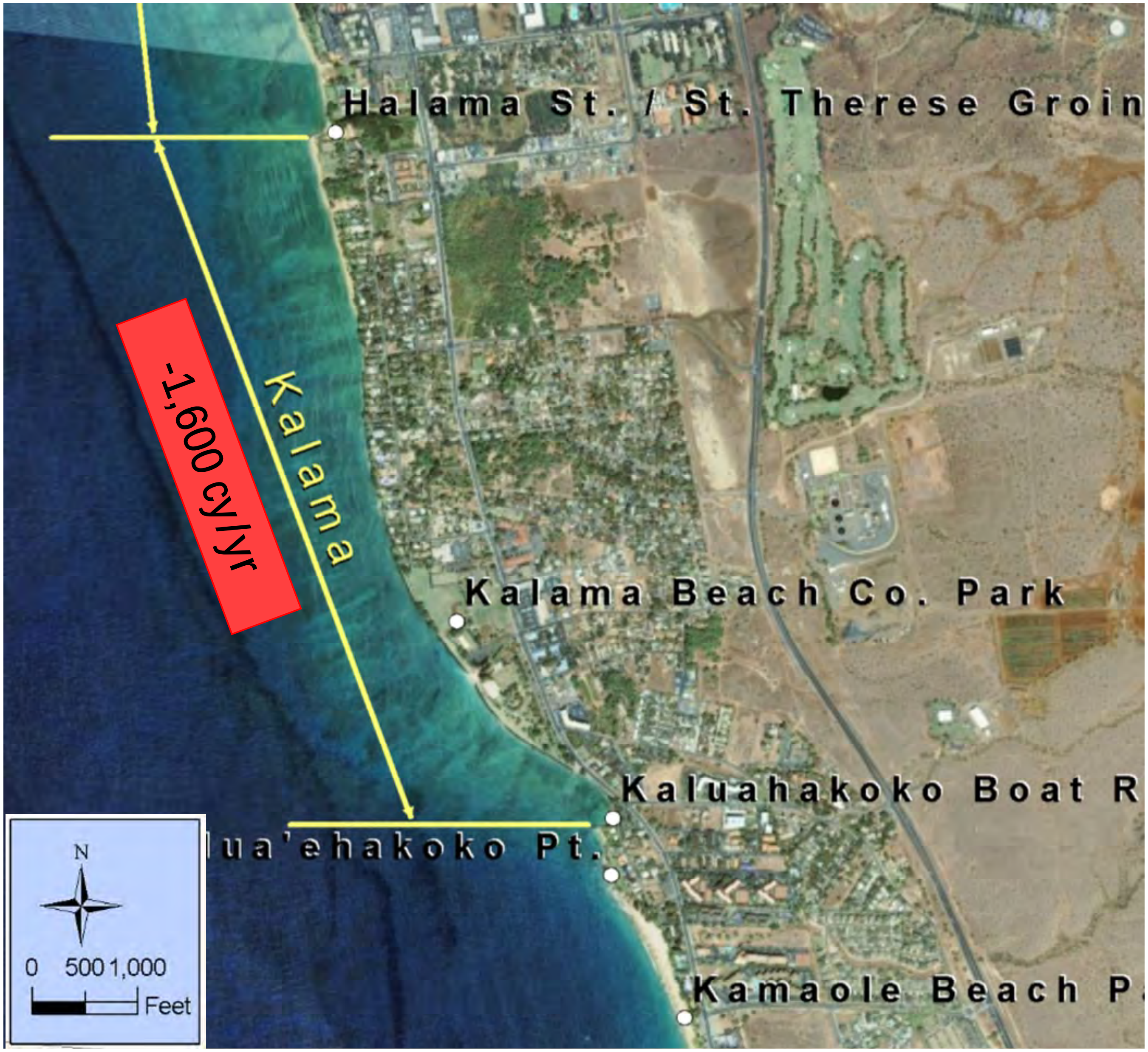


Figure G-24. Beach Volume Change Rate for Kalama Littoral Cell

Results for the Kihei Region littoral cells indicate the following:

- The **West Maalaea** cell has experienced erosion of its already small sandy beach.
- The **Maalaea Bay Beach** cell had a significant erosion period in the first half of the 1900s, and has continued to erode, but at a much lower rate. Development of sediment transport direction (potential future task) would provide further insight into this.
- Since construction of Maalaea Harbor, the **Maalaea Bay Beach**, **Kealia, and North Kihei** cells have experienced very similar long-term cyclical erosional/accretion pattern as seen in Figure G-25.
- It is interesting to note that the **Kawililipoa** cell accreted when the **Kalama** cell (to the south) was eroding. This is possibly an indication of a dominant sand transport direction from south to north, and a loss of source to the Kalama area.
  - The unique reef rubble formation (most likely an ancient Hawaiian fish pond) in the nearshore at the north end of the Kawililipoa Beach littoral cell may act as a groin and interrupt sand transport to the north, causing accretion on its downcoast side.
  - The upcoast littoral sand source to the Kalama littoral cell is likely interrupted by the old boat ramp cove area near Kaluahakoko Point, just south of Kalama Beach Park.

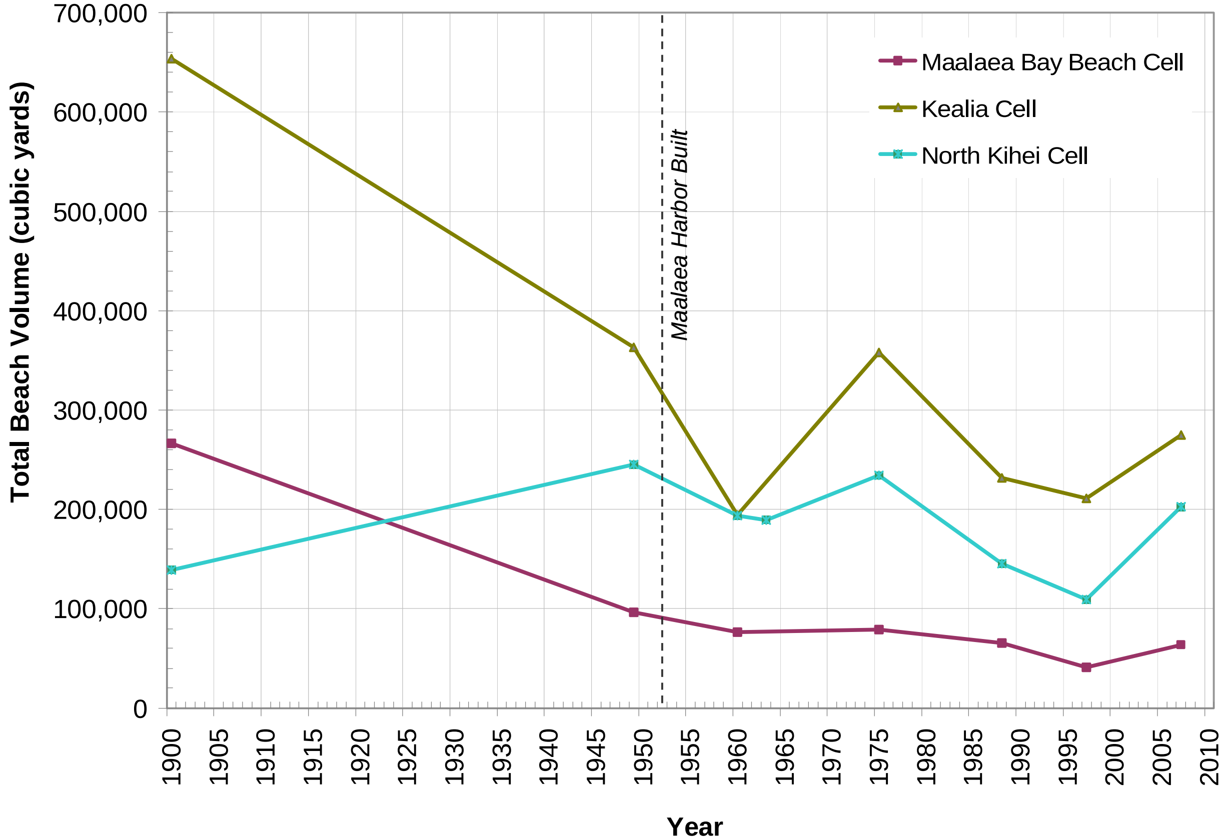


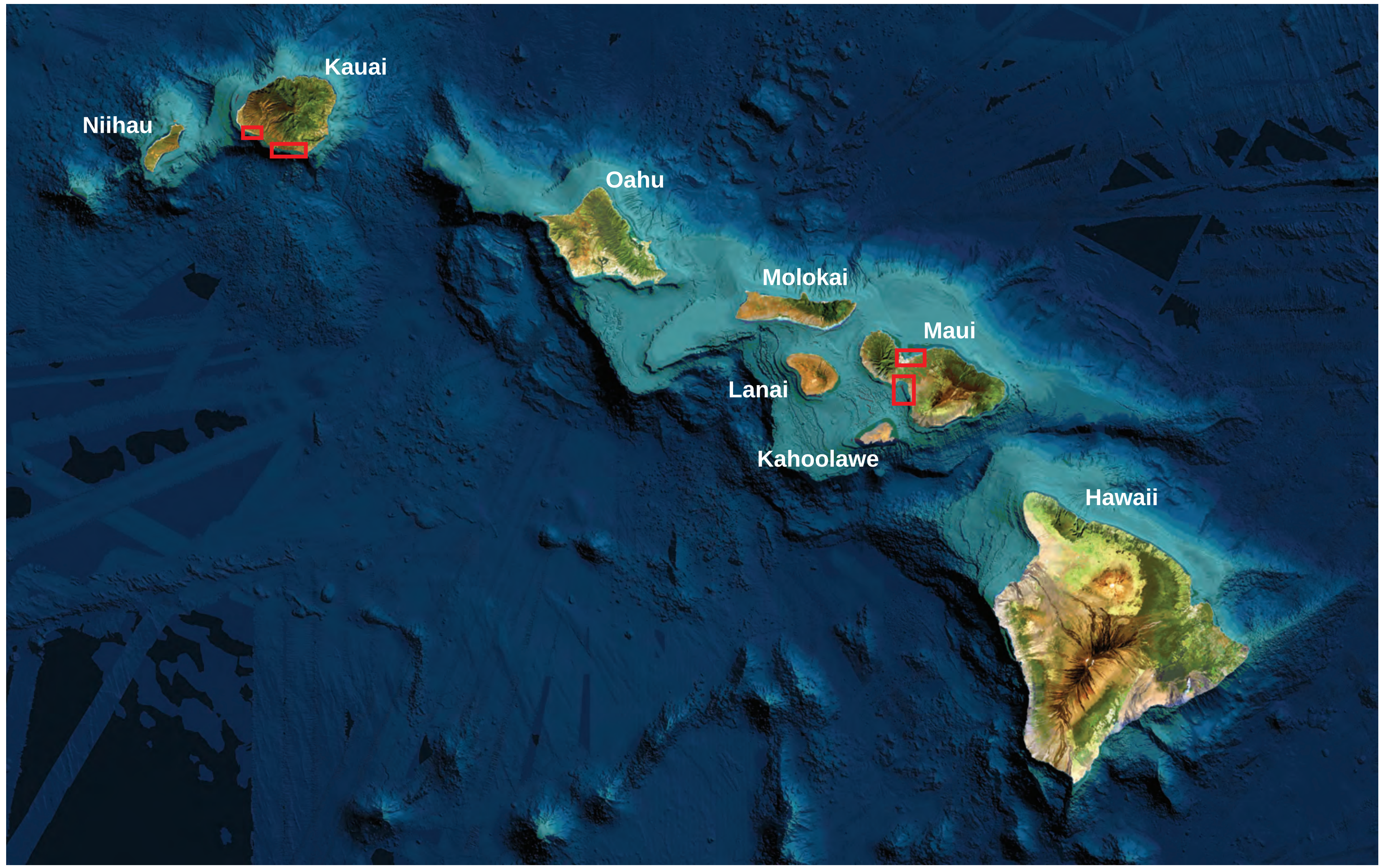
Figure G-25. Beach Volume Change Rate History for Littoral Cells Along North Tip of Maalaea Bay.

APPENDIX H

OFFSHORE SAND SOURCE INVENTORY (UNIVERSITY OF HAWAII 2011)

Reef-top Sand Fields of Maui and Kauai

Kihei and Kahului, Maui: Poipu and Kekaha, Kauai



US Army Corps of Engineers

United States Army Corps of Engineers, Honolulu Engineering District
University of Hawaii at Manoa, School of Ocean and Earth Science and Technology
EA/HHF Joint Venture

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Figures

Introduction

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

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

Geologic Framework of Sand Bodies

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

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

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

Methodology

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

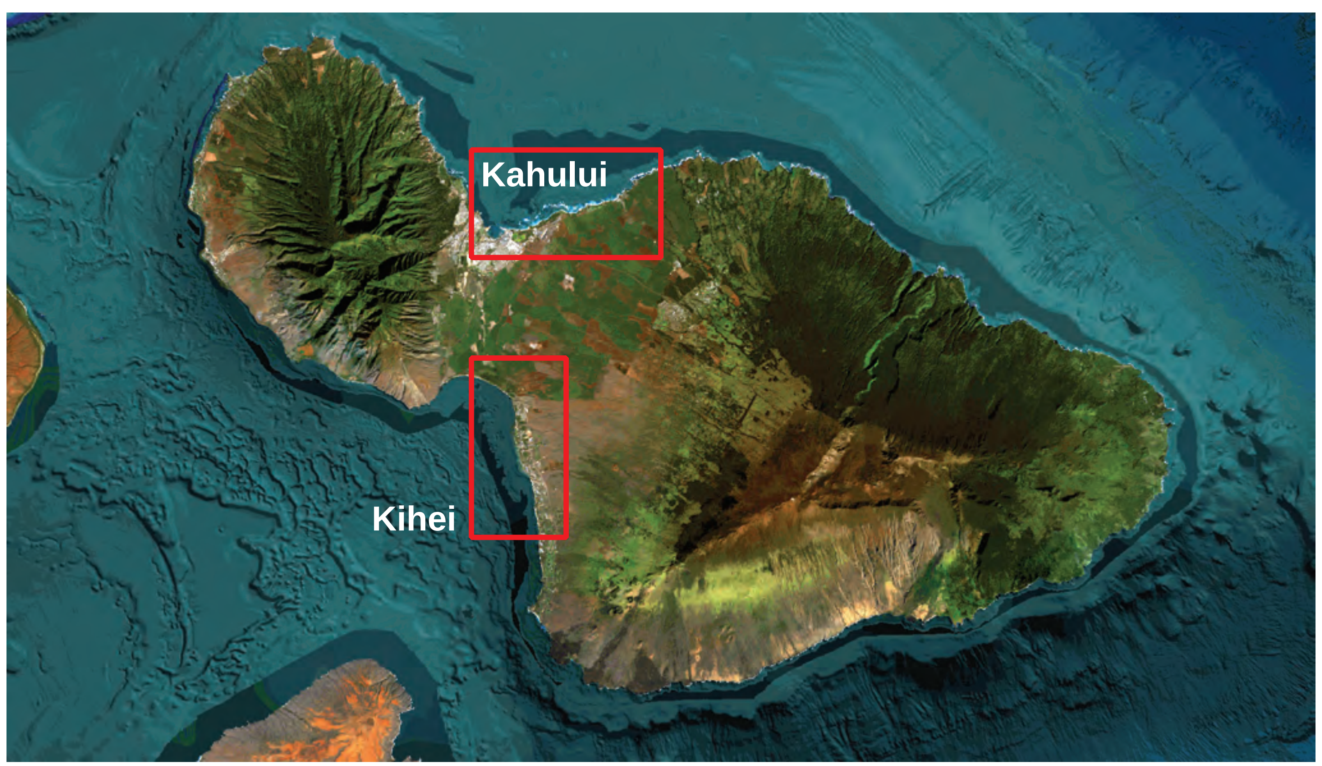

Figure 1. The red boxes indicate the two study sites on Maui: Kihei and Kahului

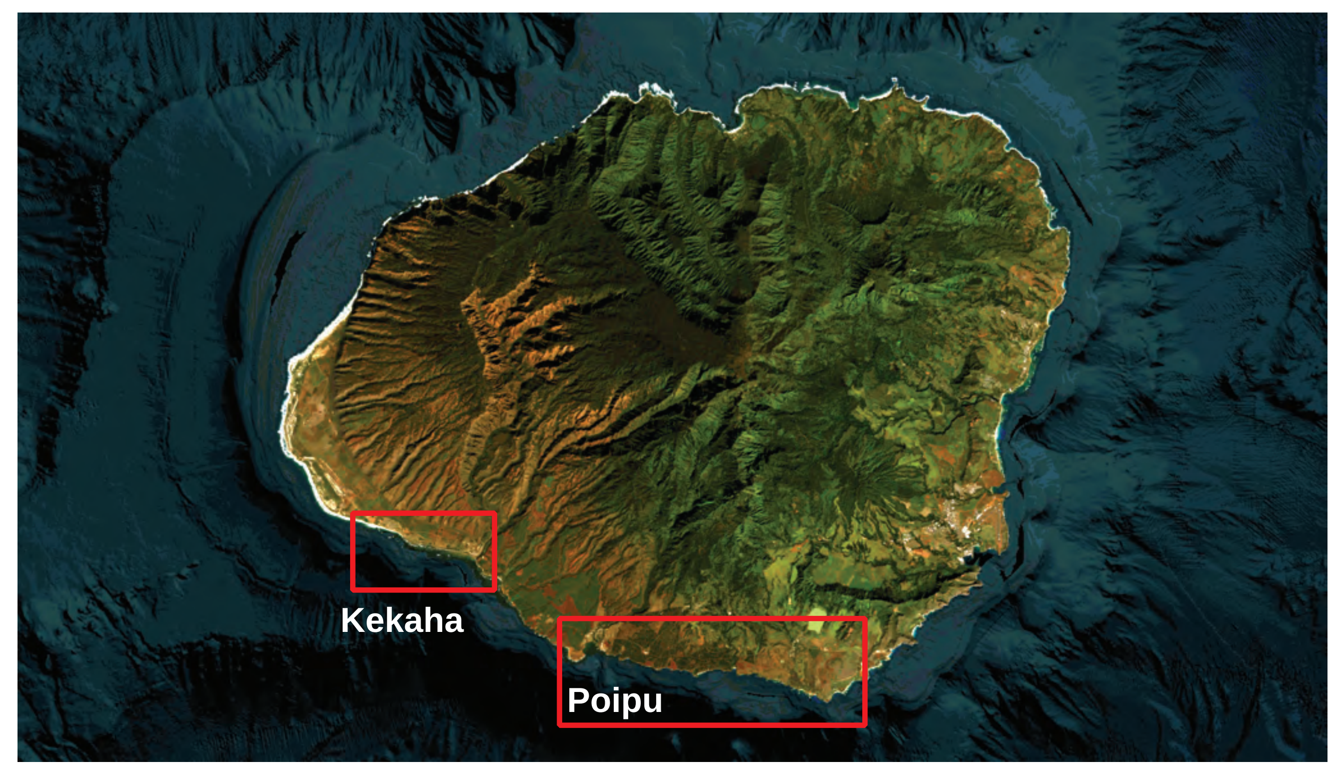

Figure 2. The red boxes indicate the two study sites on Kauai: Poipu and Kekaha

were used to provide historical coverage, and mosaics from 2002, 2006, and 2007 were used to provide modern coverage.

1. Kihei, Maui - Kamaole Beach Park to Kealia Pond. Mosaics from 1949 and 1975 were analyzed, but not used for historic coverage because of overall poor visibility of the seafloor. Therefore, photomosaics from 1960 and 1997 were used to provide historical coverage, and a 2007 mosaic was used to provide modern coverage.

2. Kahului, Maui - Kahului Harbor to Hookipa Park. For this field area, five mosaics (Kahului Harbor, Kanaha, Spreckelsville, Baldwin Park, and Kuau) provided coverage. Photomosaics from 1975 provided historical coverage, and mosaics from 2002 provided modern coverage.

3. Poipu, Kauai – Shipwreck Beach to Lawai Bay. Mosaics from 1999, 1992, 1988, 1982, 1960, 1950, and 1928 were analyzed; however these were not used because of incomplete coverage and/or poor visibility of the seafloor. A 1975 mosaic provided historical coverage, and a 2007 mosaic provided modern coverage.

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

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

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

Errors and Uncertainties

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

- Kihei
  - 1960, ±0.67 m
  - 1997, ±0.73 m
  - 2007, ±0.66 m
- Kahului
  - 1975, ± 0. 96 m (avg.)
  - 2002, ± 0.10 m
- Poipu
  - 1975, ±1.25 m
  - 2007, ±0.73 m
- Kekaha (east)
  - 1950, ±1.28 m
  - 1987, ±0.75 m
  - 2006, ±0.75 m
- Kekaha (west)
  - 1950, ±1.99 m
  - 1987, ±1.27 m
  - 2006, ±0.78 m.

Uncertainty is also associated with digitizing the images. To determine the error in m^2 due to the digitization process, one large sand field and one small sand field from the 2007 Kihei base map were each manually digitized 30 times. The total area of each polygon was calculated, and standard deviations were determined for the small and large sand fields. The error associated with the digitization of small sand fields is ±25 m^2, and the error associated with the digitization of large sand fields is ±137 m^2. Overall, digitization produces a Root Mean Square Error of ±139 m^2. The RMS error represents 0.25% of the total area of stable sand identified.

Field Visits

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

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

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

Results

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

1. Kihei, Maui – A total of 521,034 m^2 of modern reef-top sand was identified along the Kihei coast (Fig. 3). Of this sand, 55,821 m^2 is stable reef-top sand. The largest non-ephemeral sand field has a surface area of 10,295 m^2, serving as a potential reservoir to replenish beaches. This sand field is located off of Kalama Beach Park. The next largest sand field is located off of Waipuilani Park and consists of 9,115 m^2 of stable sand.

2. North Shore, Maui – A total of 93,927 m^2 of modern reef-top sand was identified along the north shore of Maui (Fig. 4). Of this sand, about a third (31,656 m^2) is stable reef-top sand. The largest stable sand field has a surface area of 11,027 m^2 and is located just outside of Kahului Harbor (on the east side) in a channel leading out from the shore. In comparison to the other study areas, the north shore of Maui has the fewest number of stable sand fields and the smallest total area of stable sand. All of the stable sand fields identified are either small patches or channels, as opposed to large fields. However, it is possible that there is more stable sand along the north shore of Maui than estimated. This is because the imagery does not extend very far offshore. In some places, such as Kahului Harbor, the imagery only extends 600 m from the shore. In addition, there are several areas where turbidity of the water column obstructs the view of the seafloor.

3. Poipu, Kauai – A total of 581,419 m^2 of modern reef-top sand was identified along the coast of Poipu (Fig. 5). Of this sand, about half (292,104 m^2) is non-ephemeral, (stable) sand. The largest stable sand field is located off of Brennecke Beach and consists of 218,829 m^2. It is likely a significant resource for beach nourishment. The 2007 mosaic extends into deeper water than the 1975 mosaic. It is likely that the sand field off of Brennecke Beach extends further than the coverage of the 1975 mosaic. Thus, the sand field off Brennecke Beach may contain a greater area of sand than estimated.

4. Kekaha, Kauai – A total of 850,592 m^2 of reef-top sand was identified along the coast of Kekaha (Fig. 6). The majority of this sand (766,461 m^2) is non-ephemeral, stable sand. The largest sand field is located off of Kekaha Beach Park and consists of 638,448 m^2 of stable sand. It is a potential resource for beach nourishment, and should be further investigated. It is possible that this sand field has a greater surface area than estimated. The depth of the water in this area made it difficult to determine where the sand field ended. Therefore, the digitization performed was a conservative estimation of the size. The second largest sand field is also located off of Kekaha Beach Park and has a surface area of 76,952 m^2. No significant sand fields were found in the Waimea area. Suspended sediment from Waimea River caused poor water conditions and prevented the identification of sand in this area.

Discussion

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

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

Conclusions

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

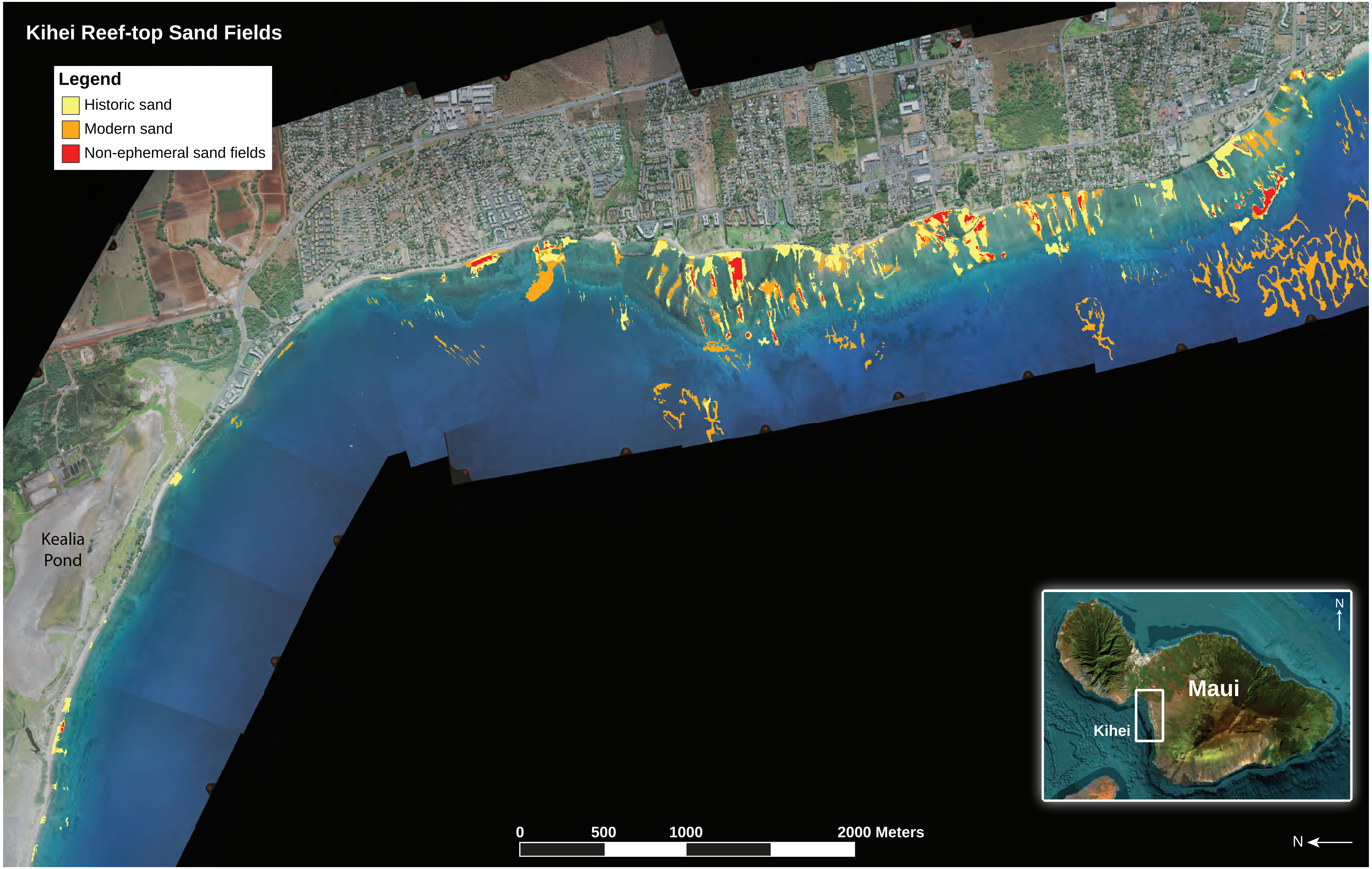

Figure 3. Reef-top sand fields located at Kihei, Maui.

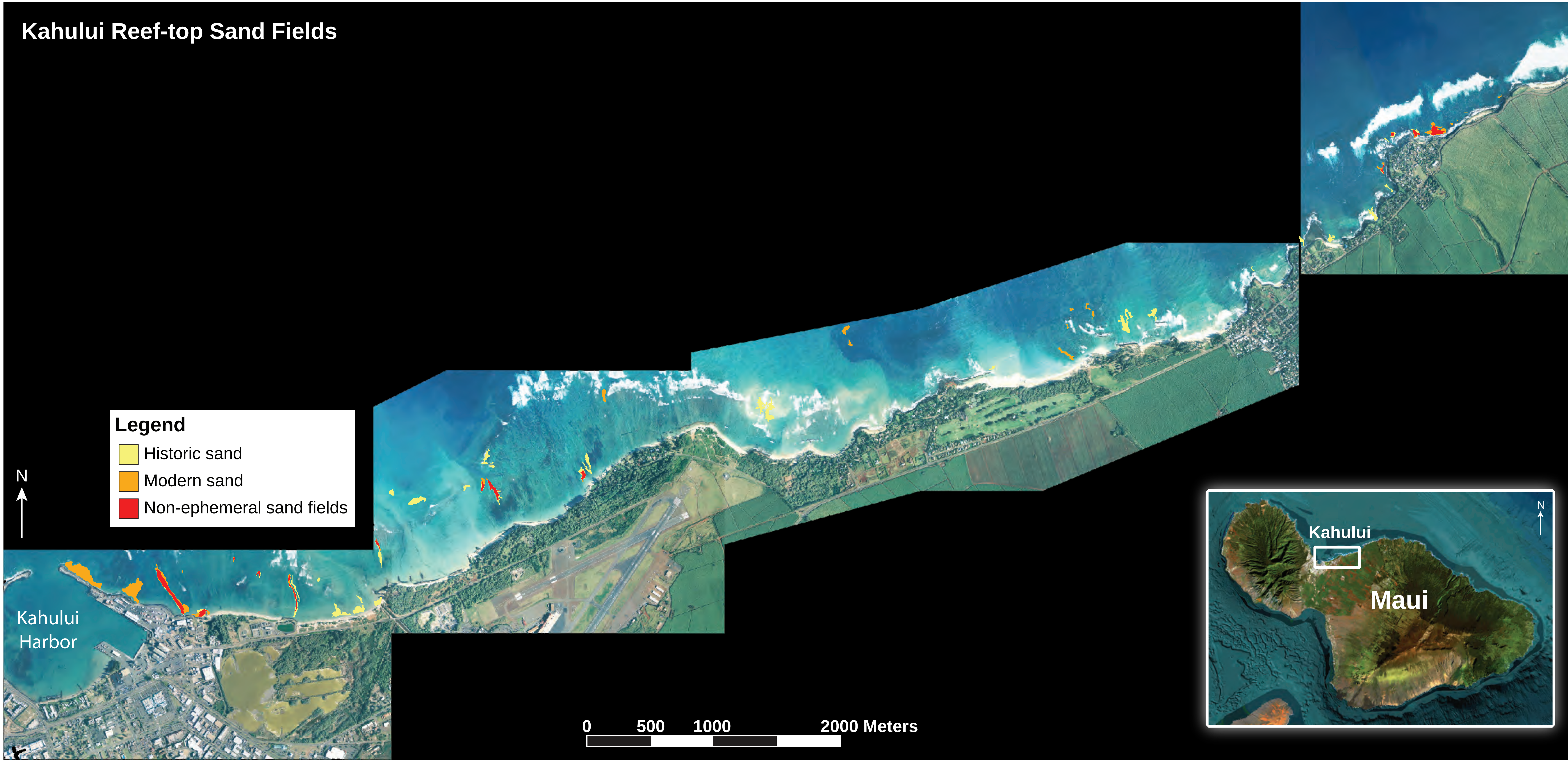

Figure 4. Reef-top sand fields located at Kahului, Maui

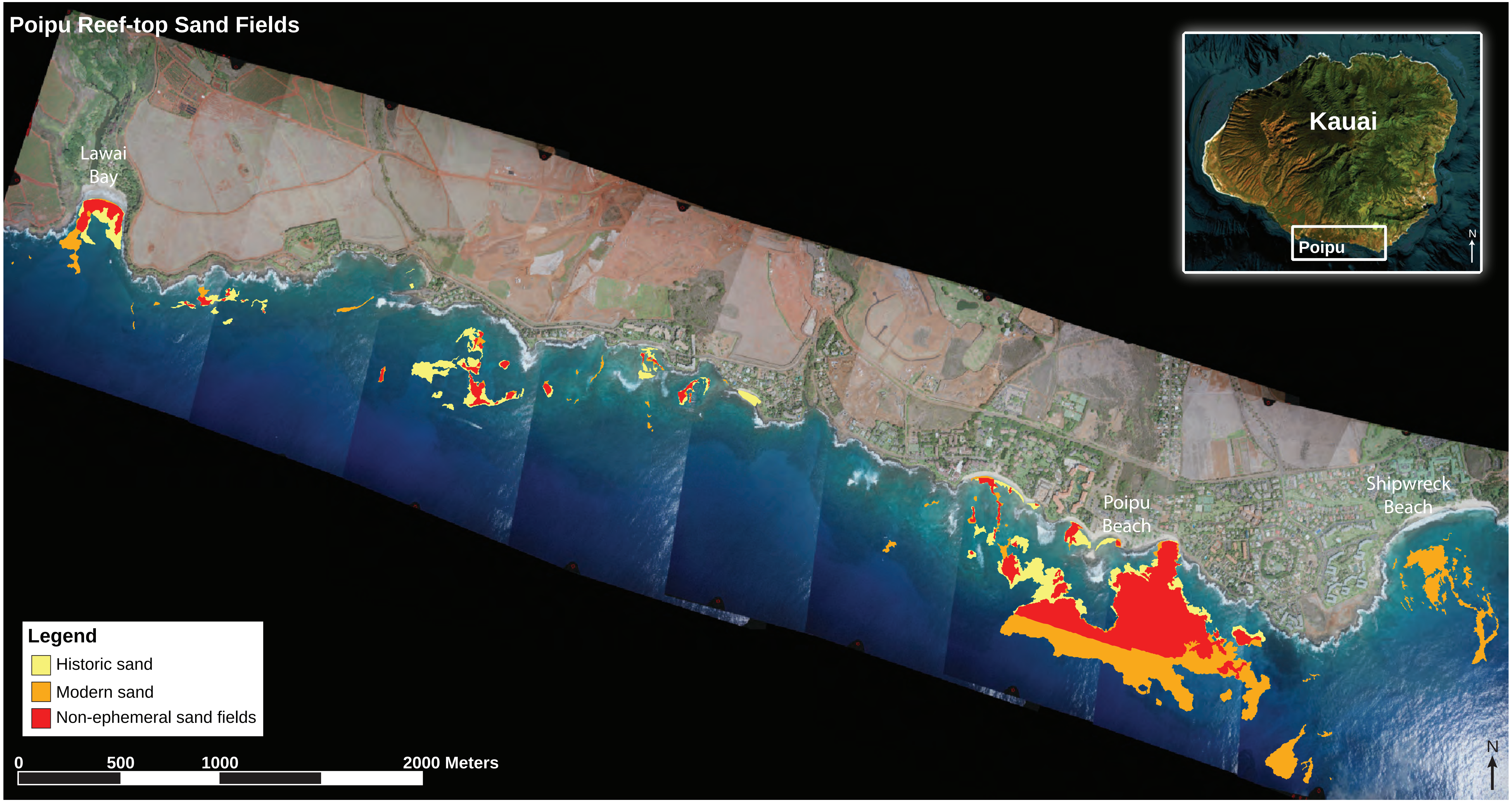

Figure 5. Reef-top sand fields located at Poipu, Kauai.

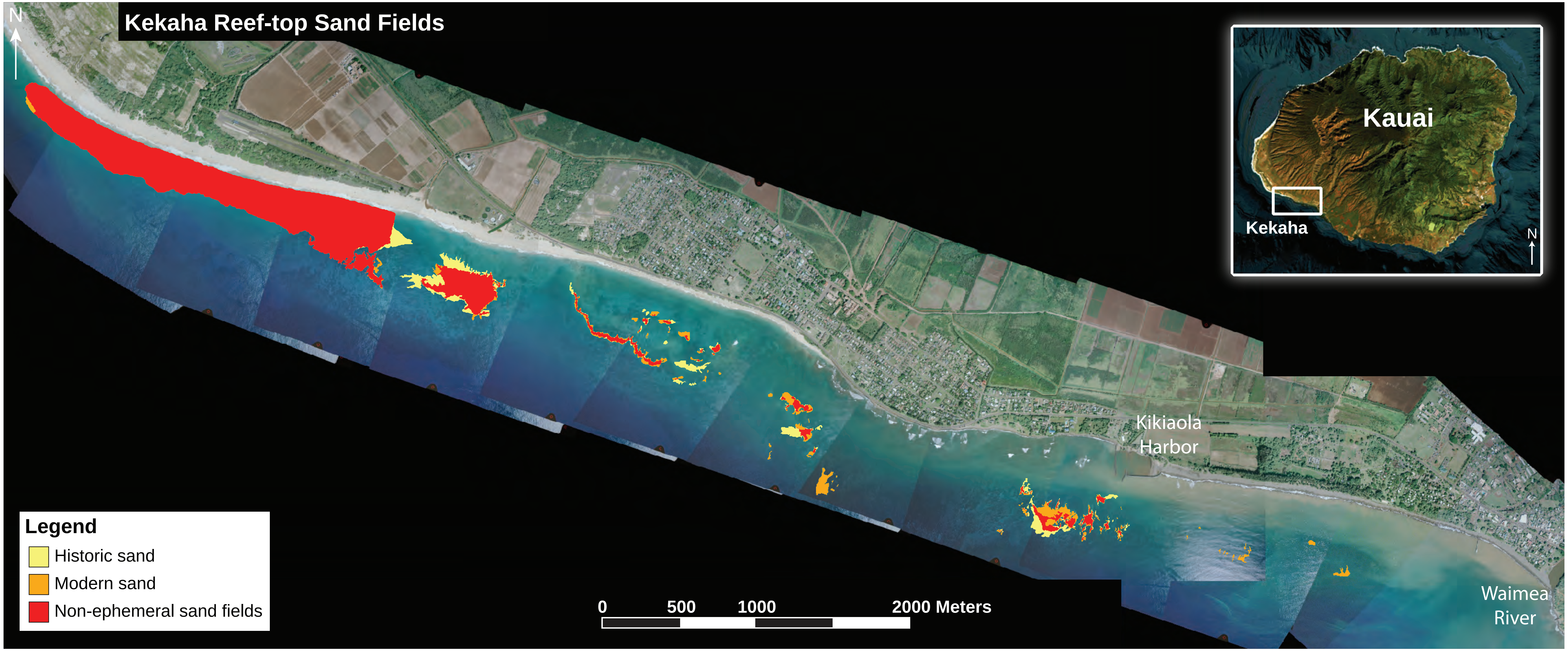

Figure 6. Reef-top sand fields located at Kekaha, Kauai.

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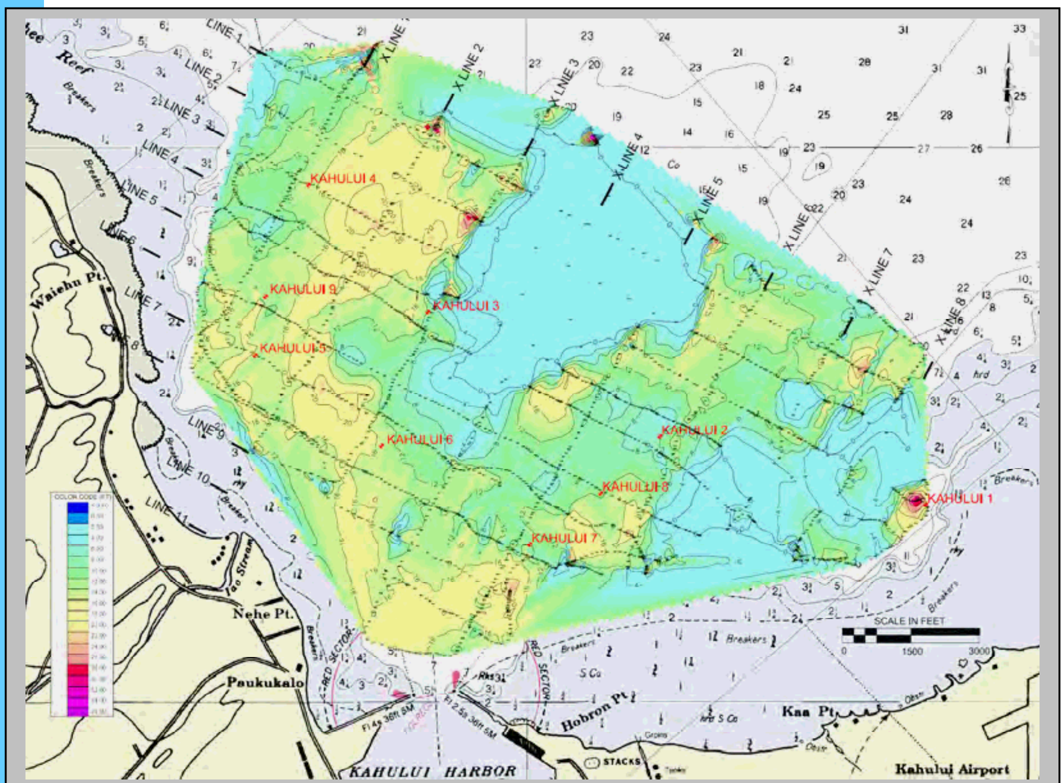
APPENDIX I

MAUI SAND SOURCE INVENTORY – REFERENCE DOCUMENT

(Sea Engineering 2008)

KAHULUI BAY SUB-BOTTOM SURVEY

November 2008



Prepared for:
Moffatt & Nichol
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Long Beach, CA 98060

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Sea Engineering, Inc.
Makai Research Pier
Waimanalo, Hawaii 96795

SEI Job No.25117

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1. INTRODUCTION

In May, 2008, Sea Engineering, Inc. (SEI) was retained by Moffatt & Nichol to conduct a sub-bottom survey using geophysical methods of Kahului Bay on the north shore of the island of Maui. The survey was designed to investigate the nature of sand deposits in the bay. Previous benthic surficial mapping by NOAA (National Oceanographic and Atmospheric Administration) had indicated the broad presence of sand deposits within the bay, however there were no data available to determine the thickness of the sand deposits.

The survey covered an area of approximately 5.5 square miles. Primary survey lines were run at 1,000-ft intervals, and survey cross-lines were run at 2,000-ft intervals. The project location and survey line plan is shown in Figure 1-1.

The geophysical work was conducted over the course of two days, May 13 and 14, 2008. In addition, a series of nine surficial sediment samples were collected using a Ponar grab sampler.

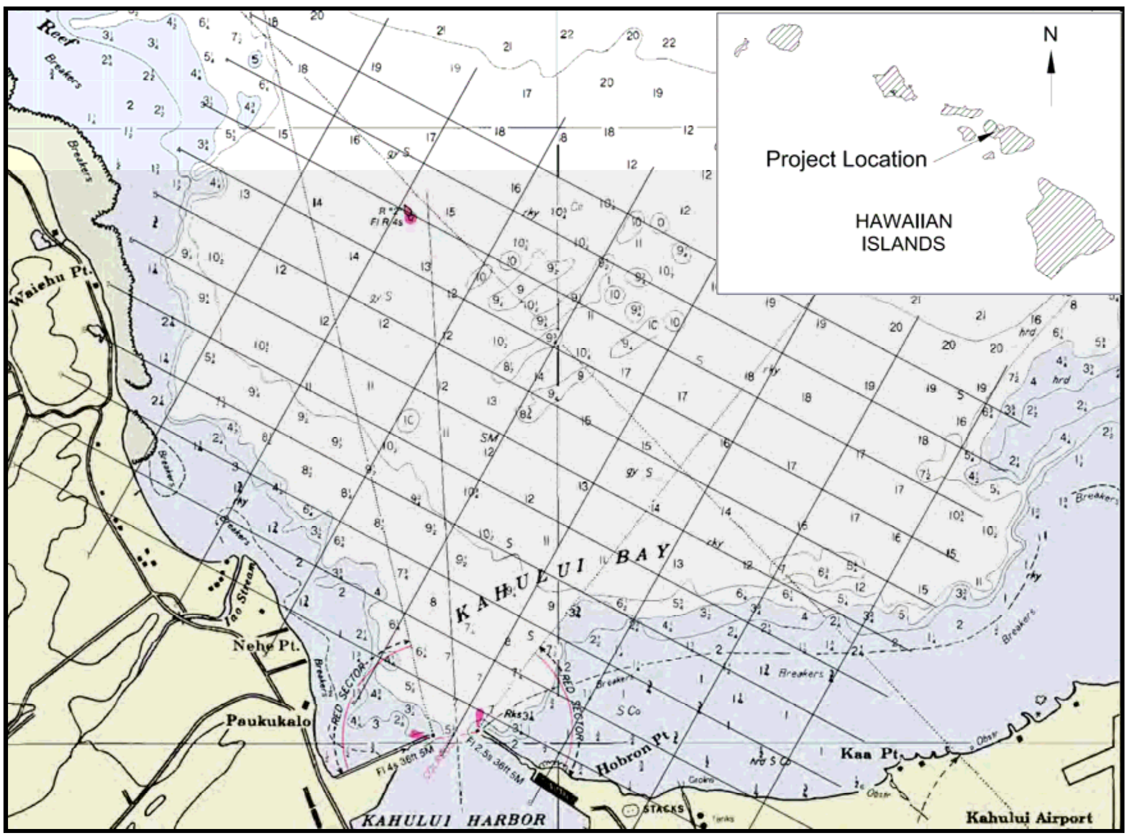

Figure 1-1 Survey Location and Plan

2. METHODOLOGY

2.1 Sub-Bottom Profiling Methods

Geophysical sub-bottom profiling systems are essentially echo-sounders that use lower acoustic frequencies to penetrate into the substrate. Where common echo-sounders may use an acoustic frequency in the vicinity of 200 kHz, sub-bottom system frequencies are typically between 500 Hz and 20 kHz. The term sub-bottom refers to a generally hard layer of sediment or rock that underlies recent soft sediment deposition. The lower the acoustic frequency, the deeper into the bottom the system can penetrate

For this survey, an EdgeTech 0512i "chirp" sub-bottom profiler was used with an EdgeTech 3200XS processing system. The chirp processors use signal processing to shape the acoustic wavelets used to image the substrate. They provide significantly greater image resolution than traditional impulsive systems such as boomers and sparkers. Different wavelets are available with the system for use in different terrains. After on-site system deployment, trial survey lines were conducted using various pulse configurations. The optimal pulse for the substrate in Kahului Bay was found to be a 20 ms pulse with a frequency range of 500 Hz to 7kHz. This is a relatively low frequency range, but necessary for penetration into the coralline limestone sands and gravels found in Hawaii. The EdgeTech 0512i system is in fact a specialty system for use in coarse sand environments.

2.2 Sub-Bottom Data Processing and Interpretation

The sub-bottom data were reviewed with EdgeTech software and sub-bottom horizons were digitized for processing. Sand thickness data were contoured using Digital Terrain Model (DTM) software, and final charts created using AutoCAD.

The offshore substrate around the Hawaiian Islands is complex, and can consist of different combinations of carbonate sand, coral gravels and cobbles, lithified or indurated sediment horizons, hard coralline limestone and some areas with volcanic rock features and terrigenous sediment. The sub-bottom horizons are therefore often difficult to interpret. As a generalized model, Kahului Bay appears to have a hard reef layer that is overlain by sediment layers 20 to 60 feet in thickness, and sometimes greater. The reef emerges from the bottom and outcrops in bathymetric high areas scattered throughout the survey area. However, the thick sediment overlying the reef has numerous acoustic reflectors that are indicative of hard layers. A conservative approach was taken for this study, and sand thickness was mapped to the first indication of a hard layer. Sand thickness in mapped areas is typically 10 to 20 feet. Sand deposits less than about 6 feet in thickness were difficult to map.

Figure 2-1 is a typical sub-bottom image showing the basal reef layer (acoustic basement – the limit of acoustic imaging) and overlying sediments, including about 15 to 20 ft of sand. The basal layer is approximately 40 to 60 feet below the seafloor. The intermediate sediments are likely to be an assortment of indurated sand, gravel, cobble and possibly even thin layers of coralline reef limestone. Figure 2-2 is a section showing the emergence of reef limestone into a bathymetric high.

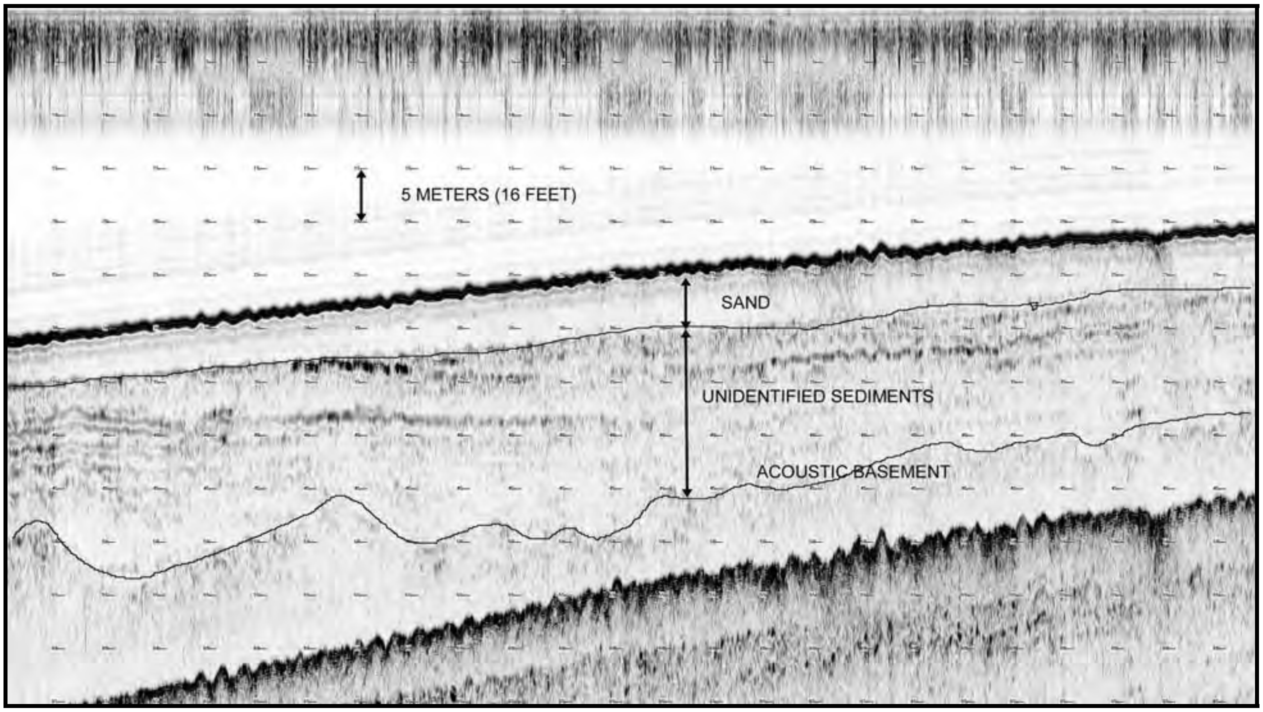

Figure 2-1 Typical sub-bottom imagery in Kahului Bay

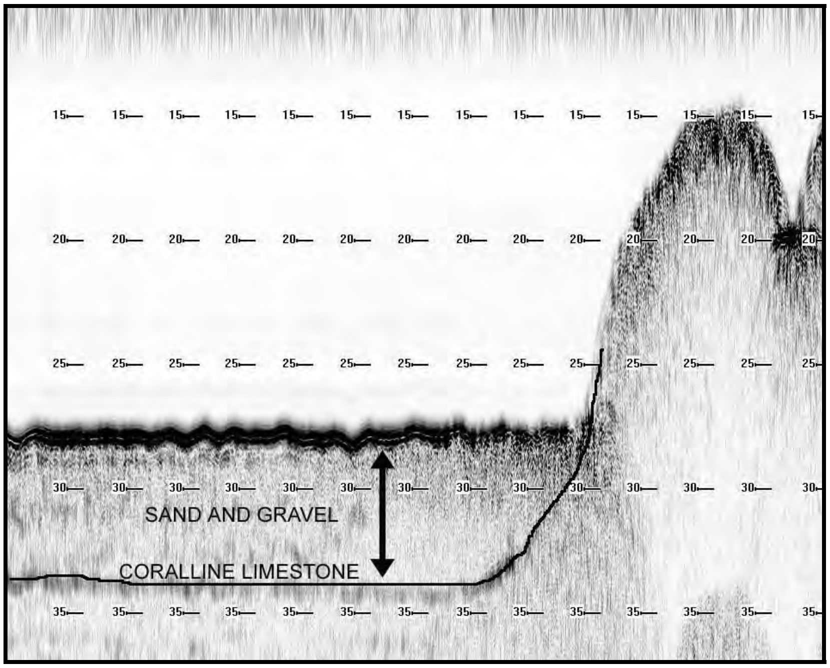

Figure 2-2 Sub-bottom imagery showing emergence of reef substrate

2.3 Bottom Sediment Samples

A total of nine bottom surface samples were retrieved using a Ponar sampler. Eight of the samples were analyzed for grain size by AECOS, Inc (note: sample Kahului 1 was not analyzed as it consisted of coral gravel and cobbles). Sediment descriptions and photographs are included as an appendix; size distribution results are shown in Table 2-1 and Figure 2-3.

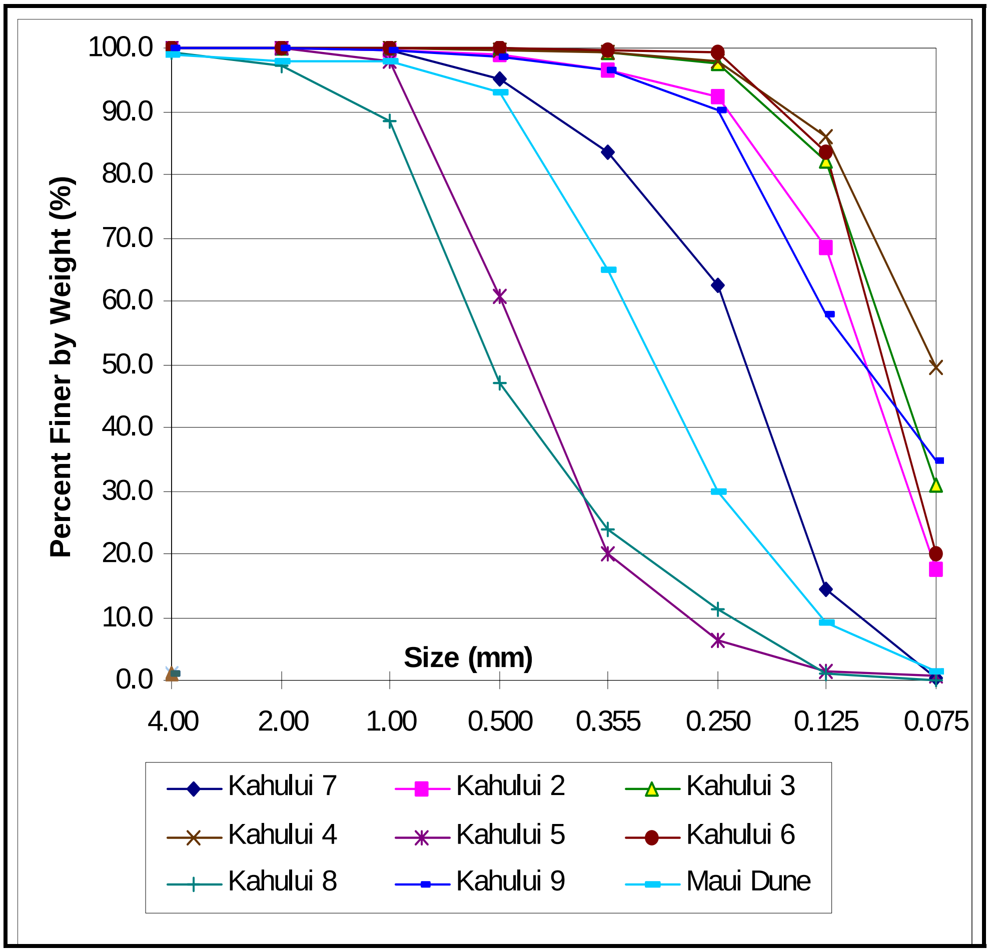

Figure 2-3 Graph of sample grain size distribution

Table 2-1 Sample grain size distribution

Percent Finer by Weight (%)								
size (mm)	**4.00**	**2.00**	**1.00**	**0.500**	**0.355**	**0.250**	**0.125**	**0.075**
Kahului 2	100.0	100.0	99.8	99.1	96.7	92.2	68.4	17.5
Kahului 3	100.0	100.0	100.0	100.0	99.2	97.4	82.1	30.8
Kahului 4	100.0	100.0	100.0	99.8	99.4	98.0	86.1	49.4
Kahului 5	100.0	99.8	97.8	60.6	19.8	6.4	1.6	0.8
Kahului 6	100.0	100.0	100.0	100.0	99.8	99.1	83.4	19.9
Kahului 7	100.0	100.0	99.8	95.0	83.7	62.4	14.3	0.4
Kahului 8	99.4	97.4	88.3	47.2	23.9	11.1	1.0	0.0
Kahului 9	100.0	100.0	99.6	98.4	96.5	90.2	58.1	34.7

3. RESULTS

3.1 Sub-bottom survey results

The presence of sand deposits 10 to 20 feet in thickness over much of Kahului Bay was confirmed by the sub-bottom survey. Figure 3-1 shows the results of the survey, with thickness contours highlighted in color. The bottom morphology of the bay is dominated by a broad central area with bathymetrically high reef areas (see Figure 2-2). With the exception of these emergent reef areas, it appears that most of the bay has at least 6 feet of sand substrate. As a conservative approach was taken during the interpretation process, it is possible that some areas have thicker sand deposits. As a general observation, the western portion of the bay appears to have somewhat thicker sand deposits. Differentiation between sand and gravel is difficult in sub-bottom images, and gravel areas were not mapped for that reason. However, what appear to be gravel deposits were more prevalent in the eastern portion of the bay.

The surface sand layers are commonly underlain by unknown sediment deposits that are stratified by acoustically reflective horizons. These sediments are likely to be inter-bedded layers of sand, gravel, indurated sand – in fact, any kind of coralline limestone reef derived deposits. It is also possible that viable sand deposits could be found underneath some of the hard reflectors that have been mapped as the base of the surficial deposits.

3.2 Sand sample results

Sand sample locations and photographs are contained in Appendix 1. Locations are also shown on the survey drawing, Figure 3-1 labeled as Kahului 1 through Kahului 9. Grain size distributions are shown in Figure 2-3 and Table 2-1. For comparison, Figure 2-3 also shows the distribution for Maui Dune Sand. The dune sand has been one of the major sources of sand for small-scale beach nourishment projects and sand bag protection projects on Maui. It is fine sand and barely meets grain size criteria for most beach projects, and is not really suitable for beach nourishment in energetic wave conditions.

Offshore sand deposits in Hawaii typically have two major limitations with respect to use for beach nourishment:

- Deposits are typically too fine-grained and,
- Deposits are often stained gray in color and therefore aesthetically un-pleasing.

Of the nine samples collected, two (Samples 5 and 8) had both good color and grain size characteristics. Sample 8 was coarse sand with a buff color that is attractive for beach sand. Sample 5 is exceptional in both color and grain size characteristics. It has a “salt and pepper” appearance due to a high percentage of terrigenous basalt fragments so it may not be suitable for all applications. Most of the samples (Samples 2, 3, 4, 6, 9) were both too fine and poorly colored. Sample 7 was too fine, although nicely colored, and Sample 1 consisted of large coral pieces.

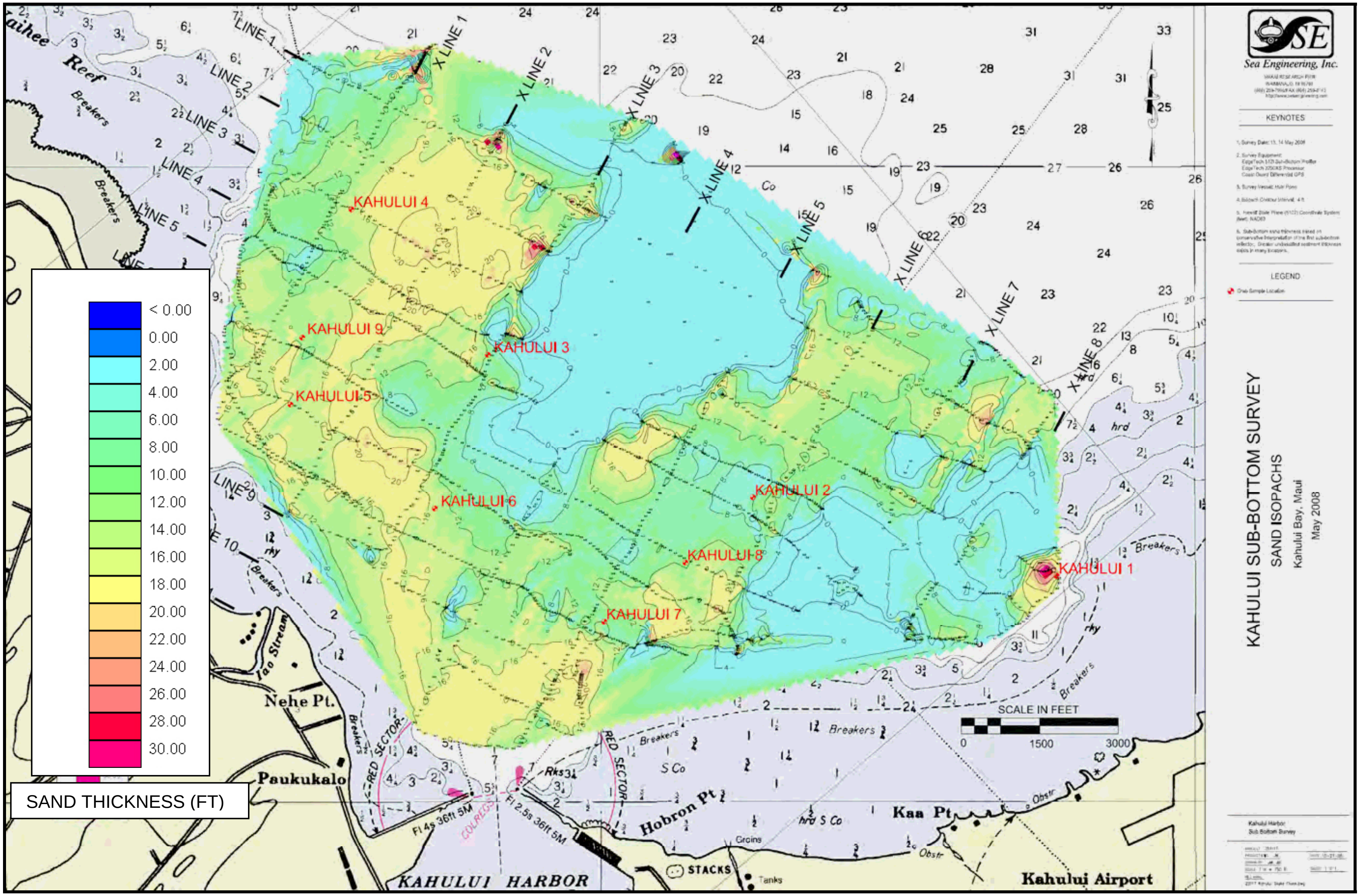

Figure 3-1 Kahului Bay sand thickness and sample locations

4. DISCUSSION

The survey results show the presence of widespread sand deposits in Kahului Bay. Most of the sand in the bay is probably too fine and poor in color for beach projects. However, two out of nine bottom samples indicated sand that would be suitable for beach nourishment, and in fact have excellent color and grain size characteristics. The extent of the suitable sand is not known and will require follow up investigations in order to characterize the areal extent of the deposits, and grain size and color characteristics below the surface.

Follow on work may include survey work in the form of side scan sonar and drop camera surveys for acoustic and visual imaging of the bottom surface, a more intensive bottom sampling effort, and vibracore sampling to collect deposits below the bottom surface. SEI recently completed a comprehensive study of this type off West Maui for the Kaanapali Operators Association.

Kahului Bay is on the exposed windward side of the island, and conditions are generally poor for ocean work. Much of the fieldwork mentioned above will require calm weather windows, such as light and variable or Kona wind conditions, in order to produce good quality field data.

APPENDIX 1. SAMPLE PHOTOGRAPHS AND DESCRIPTIONS

Ponar Surface Sample Vessel: Huki Pono		**Kahului Bay, Maui Date: 14 May, 2008**
Sample: Kahului 1		
Position (NAD83 State Plane, ft)		**Description**
1,717,194 E / 210,174 N		Coral gravel and cobble, 0.5 to 3 inch fragments

Ponar Surface Sample Vessel: Huki Pono		**Kahului Bay, Maui Date: 14 May, 2008**
Sample: Kahului 2		
Position (NAD83 State Plane, ft)		**Description**
1,7115,79 E / 211,654 N		Well sorted light gray fine sand

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 3		
Position **(NAD83 State Plane, ft)**		**Description**
1,706,510 E / 214,379 N		Well sorted gray fine sand

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 4		
Position **(NAD83 State Plane, ft)**		**Description**
1,703,902 E / 217,150 N		Well sorted gray fine sand

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 5		
Position **(NAD83 State Plane, ft)**		**Description**
1,702,734 E / 213,427 N		Well sorted coarse sand, “salt and pepper” mix of coralline components and approx. 30% basalt components.

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 6		
Position **(NAD83 State Plane, ft)**		**Description**
1,705,498 E / 211,443 N		Well sorted light gray fine sand.

Ponar Surface Sample Vessel: Huki Pono		**Kahului Bay, Maui Date: 14 May, 2008**
Sample: Kahului 7		
Position (NAD83 State Plane, ft)		**Description**
1,708,736 E / 209,290 N		Moderately sorted fine-grained buff colored coralline sand.

Ponar Surface Sample Vessel: Huki Pono		**Kahului Bay, Maui Date: 14 May, 2008**
Sample: Kahului 8		
Position (NAD83 State Plane, ft)		**Description**
1,710,287 E / 210,415 N		Moderately sorted coarse-grained buff colored coralline sand.

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 9		
Position **(NAD83 State Plane, ft)**		**Description**
1,702,960 E / 214,707 N		Well sorted gray fine sand.

APPENDIX J

MAUI RSM WORKSHOP MEETING MINUTES

Hawaii Regional Sediment Management Program
Maui Workshop Meeting Minutes
19 January 2011

I. Purpose

A workshop was held on 19 January 2011 to present the findings of the Hawaii Regional Sediment Management (RSM) Program, focusing on Maui in the Kihei and Kahului regions. The meeting started at approximately 1:00 PM in the Sanctuary Learning Center, 726 South Kihei Road, Kihei, HI 96753. Sections IV through XIII below summarize the technical presentations and group discussions that took place at the workshop. These presentations are available on the U.S. Army Corps of Engineers Honolulu District public website at the following location:

http://gis.poh.usace.army.mil/rsm/index.htm

The workshop agenda is presented in Attachment A.

II. Attendees

The list of attendees is presented in Attachment B.

III. Introductions

Tom Smith, U.S. Army Corps of Engineers (USACE), Honolulu District, Technical Lead, presented introductory remarks to welcome everyone to the workshop. Representing the non-federal sponsor for the RSM Program was Chris Conger, University of Hawaii, Sea Grant Extension agent and technical advisor for the State of Hawaii Department of Land and Natural Resources, Office of Conservation and Coastal Lands (OCCL). Mr. Conger, who was standing in for Sam Lemmo, administrator of the OCCL, briefly thanked the USACE, University of Hawaii, governmental agencies (local state and county), and private consulting firms for their support of this project, Jackie Conant, USACE Project Manager, then gave a brief introduction for the technical experts who gave the technical presentations discussed below.

IV. Regional Sediment Management Overview (Presented by Tom Smith, U.S. Army Corps of Engineers, Honolulu District POH Technical Lead)

The remarks made by Tom Smith have been summarized below.

The U.S. Army Corps of Engineers' nationwide RSM Program has an integrated approach to sediment management taking a holistic view of coastal, estuary, and river sediments on a regional scale in the planning and maintenance of water resource projects to achieve balanced and sustainable systems. The program started in 2000 in the U.S. southern region – USACE, Mobile District, and over the past 10 years has spread throughout the east, west, and gulf coasts as well as in southeast Lake Michigan. Although there is not as much sedimentation in Hawaii and therefore not as much opportunity for RSM, the Honolulu District has gained funding for this initiative in Hawaii. For the Southeast Oahu (SEO) RSM study, there were about 30 miles of coast covered on the island of Oahu: the first spanning from Mokapu Point to Makapuu Point and the second RSM study spanning from Diamond Head to Pearl Harbor (D2P), which includes Ewa Beach. Regional sediment budgets, historical shoreline change, modeling results, and GIS platforms have been compiled and have led to a RSM plan and identification of potential RSM projects.

The purpose of the SEO/RSM study was to optimize the use of sediment resources by gaining an understanding of complex sediment transport pathways; studying large portion of critically eroded shorelines; investigating armored shorelines; and discovering economical sand sources yet to be identified. Ultimately the goal of the study was to increase understanding of littoral processes with intentions of preserving and restoring beaches in the region with potential applications elsewhere.

It was discovered that in this region, the shoreline is highly variable due to seasonal changes causing sand loss. The University of Hawaii Manoa, School of Ocean and Earth Science and Technology (SOEST) is conducting various research efforts to support the Hawaii RSM Program. To identify offshore sand sources, graduate students have analyzed jet probe data (up to 10 feet in depth) to determine how thick the sand is in areas of Kailua Bay, Lanikai Beach, and Bellows Beach at Bellows Air Force Station. It was discovered that the sand in the Kailua stream channel is a major component of why the beach is so stable in this region. There are a number of isolated patches of sand that may be available for beach nourishment. Investigations further offshore are recommended for future study.

Wailea Point sediment sand transport analysis: This analysis was conducted by using the basic concept that sediment becomes better sorted in the direction of the transport. UH took grab samples and using various methods of analysis, such as the Gao-Collins (1992) and Roux method (1994), it was demonstrated that sand has historically been transported south to north around Wailea Point, with reversals in the southern portion of Lanikai beach. By combining the two analytical methods, it is understood that there is a northward transport and that Lanikai has historically received sand from the Bellows Beach area. Using historical analysis, modeling, and sediment trend analysis, the results indicate the following:

- In the 1950s, Bellows acted as a source for accretion in South Lanikai.
- In the 1970s, revetments stabilized Bellows and South Lanikai eroded.
- From 1970 to the present, Lanikai has a northern sediment transport without replenishment.

By studying volume and direction of sediment transport, the ultimate goal is to produce a regional sediment budget. Using the Mokapu Point to Makapuu Point offshore wave gauge data collected over the past seven years, nearshore conditions at ten points have provided input for analyzing gross and net sediment transport directions. Using the results of this information, maps have been created for each stretch of beach illustrating sediment erosion and accretion along the shoreline.

Potential RSM Projects (PRPs): PRPs identified in the region included Kaelepulu Stream, Bellows Air Force Station, Kaupo and Kaiona Beaches, and Lanikai Beach. Although the funds to perform these projects have not been secured, it is important to identify the projects with the highest potential for improving regional sediment issues. For example, Kaelepulu Stream is plugged with sand and there is shoreline erosion downdrift. At Bellows Air Force Station, the beach is wide to the south and narrows to a hardened shoreline in the north. Sea Engineering worked with the USACE on a pilot beach restoration project involving the construction of two geotextile fabric groins along with up to 10,000 cubic yards of beach fill adjacent to the Pokole Way beach access in Lanikai.

This work has been summarized in the RSM document for this region, along with interactive mapping capabilities, available on the following website:

http://gis.poh.usace.army.mil/rsm/index.htm

V. Maui Wave Climate Overview (Presented by Jessica Podoski, U.S. Army Corps of Engineers, Honolulu District Coastal Engineer)

Jessica Podoski, has been working with wave information study (WIS) hindcast database to generate nearshore wave information for the Kihei and Kahului study regions.

There are WIS savepoints located throughout the Hawaiian Islands that provide hourly wave hindcast parameters for the 24-years from 1981 – 2004.

Wave modeling has been generated using computer models and observed wave fields, it has been compared to actual wave gage data for accuracy and provides a much longer term data set that is useful for establishing wave climate. Station 102 Kahului deepwater WIS Station was selected for comparison.

Wave roses show waves from 90 degrees to 300 degrees (shown from WNW clockwise through the East) and large waves (5-6 m) from most directions. The wave roses also capture tradewind seas (ENE directions) and long-period swells (N&NW) directions. Data were truncated to capture only energy moving toward the island (270 degrees through 90 degrees). Three representative years (1984, 1992, and 1994) were transformed to the 100 meter contour using linear shoaling and diffraction, which were then analyzed in order to select most common wave cases.

For the Kahului region, 422 discrete wave cases were transformed to the nearshore using the numerical model STWAVE. Wave data were saved at specific nearshore “savepoints” along coastline at areas of interest. Results were used to develop histograms of the nearshore wave parameters in order to identify potential sediment transport directions.

For the Kihei region, data from deepwater WIS Station 113 were extracted for the same three years in the WIS hindcast database. However, the WIS station is much less exposed than for the WIS station used for the Kahului region.

Wave roses show waves from all directions and mid-range wave heights (2-3 m) from most directions. The wave roses capture both tradewind seas (ENE direction) and long-period swells (N&NW directions and South). Data were truncated to capture only energy moving toward the region (90 degrees through 270 degrees). Again, WIS data was used for three representative years (1984, 1992, and 1994) and transformed to 100-meter contour using STWAVE. The analysis was able to capture the influence of sheltering by Kahoolawe as waves propagate into the waters offshore of the Kihei region.

For Kihei, 118 discrete WIS cases were transformed onto the reefs within the study region. Wave data were saved at specific nearshore “savepoints” along the coastline at areas of interest and results were used to indicate relationship between nearshore wave conditions and sediment transport.

For both study regions, wave roses developed for nearshore locations will help to identify the dominant wave directions. From this information, the direction of longshore sediment transport can be determined along the study area and this will provide valuable information for development of the regional sediment budgets.

Questions:

Q1: Why were the three years 1984, 1992, and 1994 chosen as representative years from the WIS hindcast database?

A1: These dates were chosen because they represent low, medium, and high wave energy years. It may be possible in the future to analyze all of the available WIS data; however there was not sufficient time or funds in the FY10 budget to do so in this

Q2: Have you been able to select any nearshore data?

A2: Instrument data is needed to verify nearshore trends and it was not included as part of this study.

VI. <u>Kihei and North Shore Shoreline Change Studies (Presented by Tara Miller-Owens of UH Sea Grant as a representative of Chip Fletcher, University of Hawaii, SOEST)</u>

Maui was one of the first islands to map shoreline changes and Maui is currently working on updating those maps. This is a 10-year effort and there are numerous stakeholders that have supported this project including USACE, DLNR, Maui County, USGS, the Castle Foundation, FEMA, Hawaii CMZ, and Sea Grant. Information gained through these studies will aid coastal managers in identifying coastal areas facing an increased risk of future beach erosion.

UH has been investigating long-term shoreline changes that have occurred over the past few decades, and has been measuring change using historical shoreline positions mapped from aerial photographs and coast charts from as far back as the 1920s. Data are used to orthorectify and map historical shoreline positions. Transects are generated at 20 meter intervals and combined with the historical shorelines shows movement over time. Uncertainties are determined based on season variation of shoreline and other variables. These uncertainties are taken into account when running the shoreline linear regression analysis, in which the slope of the line (m/yr or ft/yr) with a positive or negative uncertainty indicates either advance or recession of the shoreline.

Sea level rise and vulnerability maps are also being created for the Maui Planning Department in every area where shoreline change is being mapped. To be consistent with NOAA Coastal Services Center, 1-foot contour intervals are being used and the previous 25-centimeter increments are being revised. These maps will show lowlands where the water table is likely to produce flooding and areas where inflow from the ocean through tidal ditches will expand tidal wetlands.

For Kihei, 1,011 transects (about 20 kilometer) were used for the study area, which shows a beach loss of 2.1 km (about 11%). The long-term average rate was about -0.13 ± 0.01 m/yr with 83% erosional and 16% stable shoreline. Short term (1940-present) shows an average rate or -0.12 ± 0.02 m/yr with 77% erosional and 20% stable shoreline.

Maps have been created to show beach accretion and erosion starting north from Maalaea Harbor and moving south along the Kihei coast. In most cases, there is overall beach erosion from the south to the north except in the case of a manmade structure, such as a groin or a fish pond, which obstructs the transport of sediments and causes localized accretion/erosion patterns.

Based on new data for the north shore shoreline, 903 transects were analyzed (about 18 km) showing beach loss to be about 0.9 km (about 6%). The long -term average rate is about -0.26 ± 0.02 m/yr with 87% erosional and 12% stable shorelines. The short term (since 1940's) average rate is -0.22 ± 0.03 m/yr with 74% erosional and 16% stable shorelines.

Maps have also been created for the north shore of Maui; however, the data are currently being updated. In general the region is erosional with the exception of obstructions to sediment transport which cause localized accretion. Kihei area has lots of erosion except where manmade structures have inhibited longshore transport. Historically erosion is Kona storm related when winds and storm waves arrive from the southeast through the southwest.

Project information is also used to create flood inundation zones.

Questions:

Q1: For the linear regression plots, how does the construction of a revetment effect the calculations?

A1: These features are accounted for when interpreting the data: is rate change due to a newly constructed structure impeding sediment transport or is it due to lack of sediment available for transport.

Q2: In general, what are the erosion maps being used for?

A2: The erosion maps are being used to determine setbacks on all shoreline properties. Depth of setback is based on erosion rate with a little added for uncertainty of the future.

Q3: Are you evaluating the vegetation zone?

A3: Not currently, but selected regions have been evaluated previously, but are not being used by Maui County.

Q4: Have other nonlinear approaches been used?

A4: Yes, but results show that there is not sufficient data for nonlinear approaches.

Q5: What does County use to determine to develop setback?

A5: County uses shoreline change maps to develop setback amount based upon erosional rate.

VII. <u>Maui Reef-top Sand Field Studies (Presented by Terra Miller-Owens as a representative for the work of Chip Fletcher, University of Hawaii, SOEST)</u>

The purpose of this study was to identify the areas of offshore sand sources for potential use in future beach nourishment projects. This section of the presentation uses Waikiki to demonstrate the methodology of comparing old aerial photographs with modern aerial photographs to identify “stable” sand fields that are potential targets for further testing.

Once sand sources are identified in modern imagery, they are compared with historical imagery to determine where the sand has been stable over time. A final map is created to depict three classes of sand – modern, historic, and stable sand. The process of mapping these sand sources is dependent on water clarity and photo quality and therefore, the lack of sand source mapping offshore may not be due to lack of sand but it is due to poor photograph and/or water quality. Stable areas indicate extent of potential borrow areas; however more studies would be needed to determine available sand volumes and characteristics.

The methodology used in Oahu was also applied to the Kahului and Kihei regions. The Kahului conditions (water quality, turbidity and large waves) caused issues with the mapping process and the study area lacks historical imagery offshore. In the Kahului region, the results of this cursory analysis indicate that there is not a lot of sand available. However, due to the lack of waters clarity in these image sets, the results for this region are inconclusive. While these images are the best available at this time, many of the areas need to be field checked to distinguish between sand, gravel, and hard bottom. For example, in the Kahului region, it is known that there is a large sand field off the entrance of the harbor, but UH was unable to find photographs to support the methodology. However, there are other studies that exist, such as work done by Sea Engineering, that define the large sand field.

Questions:

Q1: Is it better to take from the ephemeral or non-ephemeral (stable or unstable) sands?

A1: There is no definitive answer to this question; however, it may be better to take from the ephemeral sand sources to reduce environmental impacts. On the other hand, the stable sand source areas may be the only viable locations due to the high cost of dredging.

Q2: Have these data been compared to the NOAA data circa 2002?

A2: No this information has not been correlated.

Q3: Who controls the offshore sediment?

A3: The State has jurisdiction over the offshore resources, but any activities offshore are subject to federal regulation and permitting. The sand up to three miles off the shore falls under jurisdiction of the Office of Conservation and Coastal Lands but is considered a public resource. These resources can be used for activities such as dredging, as long as it is not used for private economic benefit. As a caveat, a private entity can use the offshore sediment resources; however, the use has to ultimately benefit the public (answer from Chris Conger).

Q4: Is there a streamlined process for beach nourishment permits? Sometimes there is an urgent need to address public safety or other pressing concerns that may require immediate response.

A4: State tried to consolidate permitting under a small scale nourishment permit for small projects. Beach nourishment permits originally involved ten separate permits that were later combined into one permit. However, now this permit has been broken up into three separate permits that involve a somewhat streamlined process in which the same submittal package can be used for all three permits. The process for getting permits approved can take up to three years but in some cases can take as little as one year (answer from Chris Conger).

Q5: Have you considered using coastal charts or ocean depth maps to identify potential area of sand offshore?

A5: Not at this time.

Q6: Should stable or nonstable sand be used for beach nourishments?

A6: Stable, as it is more likely to be thicker and not a veneer.

VIII. Maui Preliminary Regional Sediment Budget (Presented by Rob Sloop, Moffat and Nichol [M&N])

The study areas were separated into different cells that are interrupted by some sort of barrier to sediment transport between the cells. For the Maui regions, the littoral cells are broken into fairly large areas of study. The RSM project is regional in scope and not small scale.

Beach volume is defined as the beach between the stable back beach line and the mobile shoreward toe line. First, sand sources were identified using UH erosion hazard maps that depict sand released by beach erosion, USGS beach profiles, historical records of beach nourishment, and reef production (the process and volume are poorly understood and estimated from reef area). These data were used to calculate beach widths for available historic shorelines and then beach area was calculated by multiplying the average beach width by the cell shoreline length. Volume changes were calculated by multiplying the local shoreline change rate by a factor of 0.40 and multiplying the resultant by the length of shoreline under consideration. The results were then depicted on graphs showing beach volume changes over time.

Beach volume change rate is determined by selecting time periods of interest based on line graphs and historical events within each littoral cell. Change rates are calculated for each time period and over complete period of the record. Rates are calculated using regression analysis and least squares fit, and factors in seasonal variations and other uncertainties. Rate is corrected for any historical beach nourishment. For sand pathways, some sand sources and sinks have been identified but sediment transport directions have not been defined or quantified.

For each cell, the study first aims to identify each of the shoreline features using GIS. Next, each cell is analyzed for beach volume history. Then plots are compiled on the maps to show the beach loss and direction per year. Seasonal changes, in some cases, are greater than the overall change over the past 100 years.

The Kanaha Beach WWRF area and Baldwin Park beaches have historically high erosion rates. However, since around 1976, Baldwin Park erosion rate is relatively low and the Kanaha Beach erosion rate has continued to worsen. For Baldwin Park there was a large sand deficit that has been affecting each of the proceeding cells downshore as well.

Sprecklesville and Paia East have relatively constant erosion rates over the period of record. The Paukukalo cell beach volume has been stable since around 1960. The Hookipa area is affected mainly by seasonal changes due to strong reef and strong headlands. For Kanului Harbor, there has been about 800 cy/yr sediment loss.

The North Kihei and Kawililipoa cells are currently accretional, although this conclusion is based on limited data points. In Kihei in general most sand is lost to longshore movement. In the North Kihei region there are a lot of streams that are helping bring sediment to the beaches although they are not helping with ocean water quality. North Kihei cell is going back and forth between accretion and erosion. One theory for the oscillation in sand around the mean is that sand is probably moving back and forth due to wave changes. Therefore, there have been 9,400 cy/yr net gains in sediment most likely due to the construction of groins in this area.

Kawilipioa has had a steady accretion but has had a steady decline in accretion over time. Kealia and Kalama have the highest erosion rates within the Kihei region with sediment in Kalama continuing to steadily decline. This indicates that the transport is moving south to north from Kalama to Kawilipio. In Maalaea Harbor there is no record of channel shoaling. But in the Maalaea Bay Beach cell the erosion rate has slowed since around 1950 but recently this area was affected by a major blow out in the storm drain that is currently being fixed.

Recommendations for further study:

- Complete wave transformation and circulation modeling to define sediment transport directions.
- Develop data on sediment yields (inputs) from streams and rivers.
- Quantify losses associated with winds and dune breaching.
- Analyze grain size compatibility of beaches versus potential sand sources.
- Perform jet probing of preliminarily identified sand sources.

Questions:

Q1: Do you evaluate the inland geology during study (rock vs. sand, etc)?

A1: No, as only available data are be used and this information was not available.

Q2: Will the recommendations listed above for further study be performed?

A2: Further studies depend on federal funding and the simple answer is that currently there is no funding for further studies such as these.

Q3: Will reef production be evaluated in the RSM budget in a manner similar to the D2P report?

A3: The available data are limited, and with large error margins.

Q4: One big question/issue is whether there is a prioritized list of how to determine where to put sediment as it comes available, i.e. should a small amount of sand be put on a small beach where it would make a big difference or on a big beach where it wouldn't be as big an impact?

A4: Review of projects falls to State.

Q5: To what extent are beach nourishment projects hampered by the Clean Water Act (CWA) requirements?

A5: The CWA does potentially block projects. The locale of a project might affect its ability to meet standards at all. Motivation is needed for the State of Hawaii Department of Health to change the permit process.

Q6: Are the cells that are defined in this report the same cells that would be used for Small Scale Beach nourishment (SSBN) permit?

A6: This would be one of the main references for the SSBN permits along with the UH erosion maps.

Q7: Is there any speculation on the overall transport of the north shore sediment transport?

A7: In general, the majority of sediment transport is east to west as long as the sediment can get past the headlands. However, in some regions, for example Baldwin, there has been transport across cells, but there has also been some reversals in this cell as well.

Comments:

Comment 1: Overall volume loss is based on the shoreline change data. One thing the shoreline analysis does not account for are shorelines with large dunes. Rob believes that the losses are actually underestimated.

Comment 2*:* People walking and driving on the dunes and displacing the sediment is having a significant effect on the beaches. Another issue is that much of the sand is produced offshore and the fish that aid this process are decreasing and subsequently the sand sources are depleting. One idea for investigate this is to radio-carbon-date the sand in the different location to see if new sand is no longer being produced.

Response (Comment 2): In the D2P report, reef reproduction of sand sources was quantified, but these data were not available for the Maui report. While the effects of reef production and sediment creation do have implications for sediment budgets and such, they have not been quantified and will not be included in this report.

Comment 3: In the case of the revetments, it seems that they do not affect the shoreline if they are not too steeply sloped. Need to design a structure that can be put in the beach that would lead to accretion?

IX. Maui Regional Sediment Management Plan (Presented by Rob Sloop, M&N)

As part of the RSM Plan for each of the regions in Maui, existing federal projects have been taken into consideration. In the Kahului region, existing federal projects include the Iao Stream flood control project, the Kahului Deep Draft Harbor project, the Kahului Light Draft Harbor project, the Kahului Bay mitigation project, the Kahului wastewater plant shore protection project, and the Kanaha pond sanctuary ecosystem restoration project.

In the Kihei region there is the Maalaea Harbor project, the Kihei Area Erosion study, and the Kihei Beach shore protection (Kalama Park Revetment) project.

Currently the Kealia and Lalama cells have the highest erosion rates. North Kihei accreted from 1997 to 2007 (but this information is based on only two data points); and previous to 1997, this cell had erosion rates of -2,400 cy/yr. Since the 1950's, erosion rates for West Maalaea and Maalaea Bay Beach cells have improved. The UH sand investigation results show that the Kahului region offshore sand sources are about 7.8 acres, not including additional areas offshore from Kahului Harbor and about 1.3 acres of offshore sand sources in the Kihei region.

Beach nourishment projects involve a number of different laws and regulations, including federal (Clean Water Act and Harbors Act under the USACE, and USFWS, and NMFS); State (Coastal Zone Management Act, work offshore of certified shorelines under DLNR, the Department of Health Clean Water Act, Historic Preservation Office, Office of Hawaiian Affairs, Department of Transportation, Highways and Harbors Divisions; and local (including County of Maui, Public Works, Planning Department and Planning Commission). Inter-agency coordination is critical to efficient permitting. However, there are a variety of regulatory and coordination issues that arise in regards to beach nourishment projects.

In 2005, DLNR and USACE issued a State Programmatic General Permit (SPGP) to streamline small-scale beach nourishment (<10,000 cubic yards) in the State of Hawaii. However, the State Department of Health Section 401 Water Quality Certification component has lapsed. Therefore, there is now a consolidated permit within the DLNR which includes the Department of the Army, SPGP; the State Department of Health, Section 401 Water Quality Certification; the State CZM Federal Consistency Review; and DLNR Conservation District Use Permit.

In Maui there has been some local coordination, such as the Sprecklesville Beach Restoration Foundation completion of beach nourishment project. The County of Maui Wastewater Reclamation Division at WWRF has been coordination on projects as well.

The intent of the RSM Plan is to give federal, state, and local agencies and groups more information to pursue sediment management projects. The Maui RSM Plan contains the following information for each region that can be easily accessed in the reports online at the USACE website:

- Existing federal projects
- Coastal processes
- Wave climate
- UH Shoreline erosion maps
- Beach profiles

- Shoreline features (maps and descriptions)
- Beach volume graphs
- Beach volume change rates
- Historical events chronology
- Ocean sand sources
- Potential RSM projects

In summary, beach nourishment may be viable and the RSM projects that have been identified through these studies do have the potential to be implemented in the future, but require more study and analysis. For example, Sea Engineering investigated the Kahului Harbor and found around two acres of potential sand sources; however, the quality of the sand in unknown. For sediment management on a statewide level, since the Hawaiian Islands are so remote but relatively close to each other, there is the possibility for sand sources to be used in areas other than the region where it came from; however, the impacts must be well understood before we enter into projects such as these.

Potential RSM project in the Kihei region may include Kihei Beach hurricane and storm damage reduction/beach nourishment. This area has a high potential for hurricane and storm damage reduction benefits. Beach nourishment may consist of 358,000 cy over approximately five miles of shoreline. There is federal interest in pursuing a shore protection project in Kihei, but a cost-sharing non-federal sponsor has yet to be identified that has the financial capability of providing the required items of cooperation.

Federal Input:

The is an authorized project for Maalaea Harbor which has not been constructed due to multiple issues that include impacts to surf spots and environmental concerns.

The Kihei Area Erosion Study looked at storm damage reduction. In the 2004-2005 time frame, federal interest in the project was demonstrated but there was no local support and therefore it never moved passed the study phase.

State Input:

While projects to take sand from one location and use it in a separate county, or another island could be presented to the DLNR, they would also be examined by the public and other regulating agencies.

In the Maalaea area, the UH Sea Grant studied water quality before, during and after beach nourishment. The sand sources covered up a clay basin on this portion of the coast and it reduced turbidity and improved overall water quality.

Questions:

Q1: Could RSM actually help with quantifying the sediment loads in streams?

A1: EPA and the USACE have similar projects going on in South Maui with watershed planning projects and maybe these efforts will work together to generate findings for sediment loads to streams.

Q2: To what extent are efforts to take some of the material that has been modified and discussed today and put it on shoreline area and to what degree has that been limited by DOH water quality limitations in different regions?

A2: A monitoring standard was developed for DOH and the county complies with their pre- and post-construction standards; however, it may be challenging for other counties to comply with these standards. From the conservation district perspective, the first thing to evaluate is the sand source through sediment sampling. Analysis of sand sources should follow USACE standards, which are justifiably stringent.

Q3: Can you explain why gain size analysis is important?

A3: Grain sizes and energy in the environment have to be matched so that when the new sediment responds naturally to the energy of the environment it stays in equilibrium. Edging to courser grain is better and more likely to get accepted for permitting than finer grained sediment. There are also areas in the rest of the world that have mixed (silica and carbonate) sediments but it has never been attempted in Hawaii and it would be a very hard sell. There is a need to evaluate the grain size of the borrow material against the native material at a beach. This is important because if it's not matched well, the sand will not stay in place. If matched, there will be a longer residence time. It is recommended to error on the larger size for borrow

Q4: Is there natural turtle nesting in some of the different beaches in the study area and is this factor taken into account in the report, as it may indicate some stability in the beach?

A4: ESA protects the historic nesting beaches, which may affect beach nourishment. There may be instances where you cannot do nourishment because there are historic nesting locations, but in many cases where there are manmade structures, if they are affecting the beach so that it will become completely eroded, then the structure may have to be taken out to protect the turtles. Turtle nesting areas should be of special concern because turtles may adapt to current sand where they were hatched, and not lay eggs in sand that is different. Rob Sloop commented that the lack of maintenance of sand areas could be a problem with endangered animals.

Q5: Would removing the road through Kealia pond in north Kihei help to rebuild the beach and improve the environment in this area?

A5: If you could prove that this area could be built up with dunes so that it was a protection system for the pond then you may be able to protect the ecosystem there.

Q6: What happens if there is a large hurricane or tsunami that takes out some of the beaches?

A6: Right now there are no rules or regulations that guide the redevelopment. It may be a two part solution in which you are allowed to place a revetment at a public beachfront for double protection.

Comment: One idea is to have the community move forward in obtaining a blanket permit for a large area or large cell so that there are guidelines for the nourishment and then individual entities can obtain specialized permission for small projects within the blanket permitted region.

A potential RSM project in the Kahului region may include a Wailuku Kahului Wastewater Reclamation Facility (WWRF) Beach nourishment project. It has been decided that the facility will not be relocated; therefore, it is mandated that it must be protected. For the Environmental Impact Statement for this facility, it is the government's preferred alternative that the revetment will be extended without having to extend the beach. However, there are two beach replenishment alternatives with may include (1) a 3,800 ft reach, 40 ft wide berm with about 105,000 cy initial amount of sediment, with 21,000 cy per eight years of maintenance or (2) 2,400 ft reach with 40 ft wide berm and about 65,000 cy initial sediment and 16,000 cy per eight years of maintenance. Coordination would have to occur between federal and State government and the County of Maui including the County of Maui Wastewater Reclamation Division. Potential funding may provide the opportunity to characterize specific sediment sources and permitting of the work.

Federal Input:

The USACE is in charge of keeping the Kahului Harbor navigable and performing maintenance dredging. The last time that it was dredged was 1998, and the USACE has to go through all of the permitting and approval processes that anyone else would have to go through. However, as a result of the project, the USACE is responsible to potentially utilizing the dredged material elsewhere.

Comment: In the permitting process at the Kealia Pond, there is a medical center that wants to go in next to the pond. They went through the permitting process with DOT (who owns the land) and they wanted to do a restoration of the marsh and take out invasive species, but DOT revoked the project because they didn't want more birds in the area since it would increase the treat of bird strikes associated with airport traffic.

State Input:

Long term the state would like to see beach nourishment instead of hard structures. The state is evolving their monitoring programs. Waikiki beach nourishment has a $2M budget that will include significant monitoring. There needs to be more monitoring upfront, during, and after. Also, DLNR is constantly reaching out to other agencies to assist in helping to improve their monitoring activities. A lot of the monitoring reports are developed by criteria from other agencies such as Department of Health and the National Marine Fisheries Service and as long as they are meeting the determine criteria, the monitoring reports are considered adequate.

It is important to include all of the stakeholders in all of these projects, because in some cases, there can be a dichotomy in beliefs about the importance and success of a project. Beach nourishment should also consider water quality and encourage agencies working on water quality issues to work hand in hand.

Chris Conger provided closing remarks and gave his thanks to all that participated.

Meeting was adjourned at 5:25pm

Attachment A: Meeting Agenda

Attachment B: List of Attendees

Attachment A – Meeting Agenda

HAWAII REGIONAL SEDIMENT MANAGEMENT

MAUI RSM WORKSHOP

Sanctuary Learning Center
726 South Kihei Rd, Kihei, HI 96753

January 19, 2011

1300 - 1310	Welcome and Introductions	Conger Conant
1310 - 1330	Regional Sediment Management Overview	Smith
1330 - 1500	Maui RSM	
	Waves Climate	Podoski
	Shoreline Change	Miller-Owens
	Offshore Sand Sources	Miller-Owens
	Region Sediment Budget	Sloop
	Regional Sediment Management Plan	Sloop
1500 - 1515	Break	
1515 - 1615	Kihei Region: Potential RSM Projects	Sloop
	Federal Perspective	Smith
	State Perspective	Conger
	General Discussion	All
1615 - 1630	Break	
1630 - 1725	Kahului Region: Potential RSM Projects	Sloop
	Federal Perspective	Podoski
	State Perspective	Conger
	General Discussion	All
1725 - 1730	Wrap-up and Adjourn	Conger Conant

HAWAII RSM WEB SITE: http://gis.poh.usace.army.mil/rsm/index.htm