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Regional Sediment Management (RSM) Program

Hawaii Regional Sediment Management (RSM): Regional Sediment Budget for the West Maui Region

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Lihwa Lin, and Linda S. Lillycrop

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Hawaii Regional Sediment Management (RSM): Regional Sediment Budget for the West Maui Region

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Final report

Abstract

This technical report provides a description of the Regional Sediment Management (RSM) investigations performed by the U.S. Army Corps of Engineers (USACE), Honolulu District (POH), along the West Maui coastal region of the Island of Maui, HI. The methodology for determining volume change rates as well as numerical modeling is discussed, including the particle tracking modeling, in support of identifying sediment pathways for the development of the regional sediment budget for the West Maui coast.

The West Maui Region incorporates a thin coastal margin backed by steep mountainous terrain that has been vastly altered by agricultural and urbanized development. Shoreline hardening is being proposed along portions of the region's coastline. Shoreline change for this area was quantified by the U.S. Geological Survey (USGS). All subregions were found to be erosional in the long and short term, based on average rates.

The dynamics of the area are complex with a wave climate affected by intricate bathymetry, wind, and island sheltering. Currents vary from nearshore to offshore and within the water column. Coastal morphology includes headlands and reefs with a very limited supply of sediment. Wave and current models indicate that large waves in the summer and winter drive the majority of sediment transport (northward-directed in summer and southward-directed in winter). Because of these seasonal patterns, the net transport of sediment is small. There is evidence of nearshore eddy formation that increases the complexity of sediment transport in the region with sediment pathways changing on short-term (hours) to longer-term (weeks to months) temporal scales. This is a very dynamic and seasonally affected shoreline, and the present RSM study is one tool that will help inform future shoreline management in the region.

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Preface

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQUSACE), Washington, DC, under the USACE Regional Sediment Management (RSM) Program, Project 454632, "Hawaii Regional Sediment Management (HRSM)" Project. The USACE RSM Program Manager was Linda S. Lillycrop, CEERD-HN-C. Jeffrey A. McKee was the HQUSACE Navigation Business Line Manager overseeing the RSM Program.

The work was performed by the U.S. Army Engineer District, Honolulu (POH), and by the Coastal Engineering Branch (CEERD-HN-C) and the Harbors, Entrances, and Structures Branch (CEERD-HN-H), of the Navigation Division (CEERD-HN), U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (ERDC-CHL). At the time of publication, Tanya M. Beck was Chief, CEERD-HN-C; James D. Gutshall was Chief, CEERD-HN-H; Jackie S. Pettway was Chief, CEERD-HN; and W. Jeff Lillycrop (CEERD-CHL) was the ERDC Technical Director for Civil Works and Navigation Research, Development, and Technology Transfer (RD&T) portfolio. The Director of ERDC-CHL was José E. Sánchez.

The cover photograph is reprinted with permission of the University of Hawaii, Coastal Geology Group.

The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. Jeffrey P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
cubic yards per year	0.76455	cubic meters per year
feet	0.3048	meters
feet per year	0.3048	meters per year
miles	1.60934	kilometers

1 Introduction

1.1 Purpose of the study

This technical report describes the development of the conceptual regional sediment budget for the West Maui Region, which is a component of the U.S. Army Corps of Engineers (USACE), Honolulu District (POH), Hawaii Regional Sediment Management (HRSM) Investigations. It describes the methodology used for determining volume change rates as well as numerical modeling completed, including the particle tracking modeling, in support of identifying sediment pathways in the region. The results of these investigations were used to create the present-day sediment budget for the West Maui Region using the Sediment Budget Analysis System (SBAS) software (Rosati and Kraus 1999; Dopsovic et al. 2002 [revised 2003]).

1.2 Background

The objective of the Regional Sediment Management (RSM) Program is to optimize the use of sediments and management of projects through a systems-based approach. RSM supports sustainable navigation and dredging, flood and storm damage reduction, and environmental restoration practices to increase overall benefits and reduce lifecycle costs. RSM strives to enhance the planning, construction, and operation and maintenance of projects where the exchange of sediments would occur naturally. RSM is also a means to involve stakeholders to leverage resources, share technology and data, identify needs and opportunities, and develop solutions to improve the utilization and management of sediments.

The main focus of RSM is to better understand the regional sediment transport processes through integration of regional data and application of tools that improve the knowledge of the regional processes. This also allows a better understanding and sharing of demands for sediment, and identification and implementation of adaptive management strategies to optimize use of sediments and streamline projects. Benefits of implementing the RSM approach are improved partnerships with stakeholders, improved sediment utilization and project management on a regional scale, improved environmental stewardship, and reduced overall lifecycle costs.

RSM was officially implemented at POH in February 2004. The POH overall RSM strategy is to investigate RSM opportunities along all regions in Hawaii. Conceptual regional sediment budgets have been developed in various regions throughout the islands to gain a general understanding of the control that morphology and coastal processes have on sediment pathways and transport volumes. The regional sediment budget for the West Maui Region was developed to help inform future sediment management planning and decision making and to aid in identification of potential RSM opportunities within the region.

The West Maui Region incorporates a thin coastal margin backed by steep mountainous terrain that has been vastly altered by agricultural and urbanized development. Increased siltation within nearshore waters associated with loss of forest land, historical agriculture practices, stream channelization, and rapid development has impacted coral reef health. Shoreline erosion threatens upland development consisting of large-scale resorts, hotels, condominiums, and single-family homes. Shoreline hardening is being proposed along portions of the region's coastline.

The State of Hawaii as the Hawaii RSM non-Federal sponsor, and the County of Maui, are looking for more natural solutions to the erosion problems in the West Maui Region. The Federally authorized West Maui Ridge to Reef (R2R) Initiative will engage various Federal, state, and county agencies in the implementation of a strategy to reduce the threats of land-based pollution to coral reefs in West Maui. Figure 1-1 shows the limits of the West Maui RSM Region which coincides with the limits of the POH West Maui Watershed Study and the West Maui R2R Initiative. More information about these studies is available from the West Maui R2R website (http://www.westmauir2r.com/).

Figure 1-2 shows 12 littoral cells that comprise the region. The cells from south to north are Hanakaoo (0.75 miles), South Kaanapali (0.70 miles), North Kaanapali (1.35 miles), Honokowai (0.95 miles), Kahana (1.35 miles), Kahana Sunset (0.25 miles), Napili Bay (0.25 miles), Kapalua Bay (0.15 miles), Oneloa Bay (0.45 miles), Honokahua Bay (0.35 miles), Mokuleia Bay (0.15 miles), and Honolua Bay (0.15 miles). There are no Federally authorized coastal flood risk management or navigation projects in the region. However, in September 2012, the Hawaii Department of Land and Natural Resources (DLNR) and POH signed a $3 million cost-share agreement to develop a watershed study to support the West Maui R2R

Initiative. It is one of the first efforts in the state to implement a comprehensive management strategy to address impacts to coral reefs across multiple watersheds. West Maui has some of the most severely impacted coral reefs in the state. Causes of coral reef decline are complex and not yet fully understood. However, land-based pollution is known to be a serious threat to coral reef ecosystems. Increased sedimentation associated with loss of forest land, historical agriculture practices, stream channelization, and rapid development has clearly impacted coral reef health. The West Maui R2R Initiative will engage various Federal and state agencies, and other organizations, in the implementation of a strategy to reduce the threats of land-based pollution to coral reefs in West Maui. RSM efforts in West Maui will inform the R2R Initiative and the watershed study as to sediment pathways in the nearshore environment.

Figure 1-1. Location map of the West Maui RSM Region.
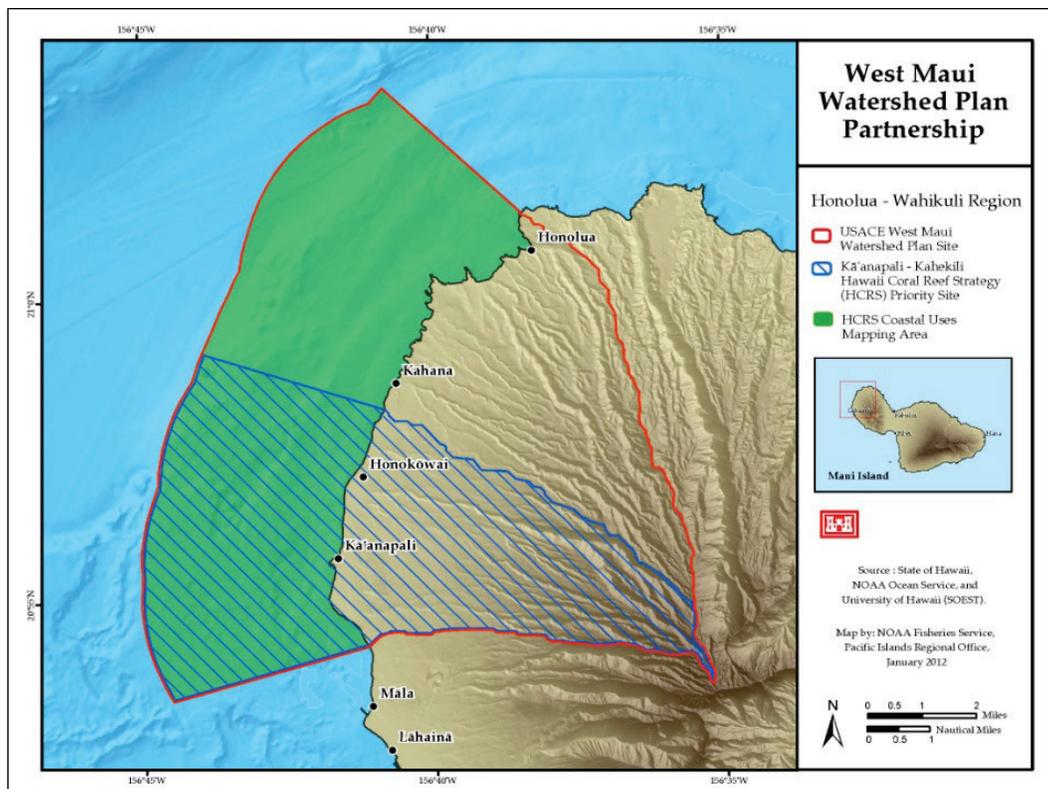
Figure 1-2. Littoral cells that comprise the West Maui Region.
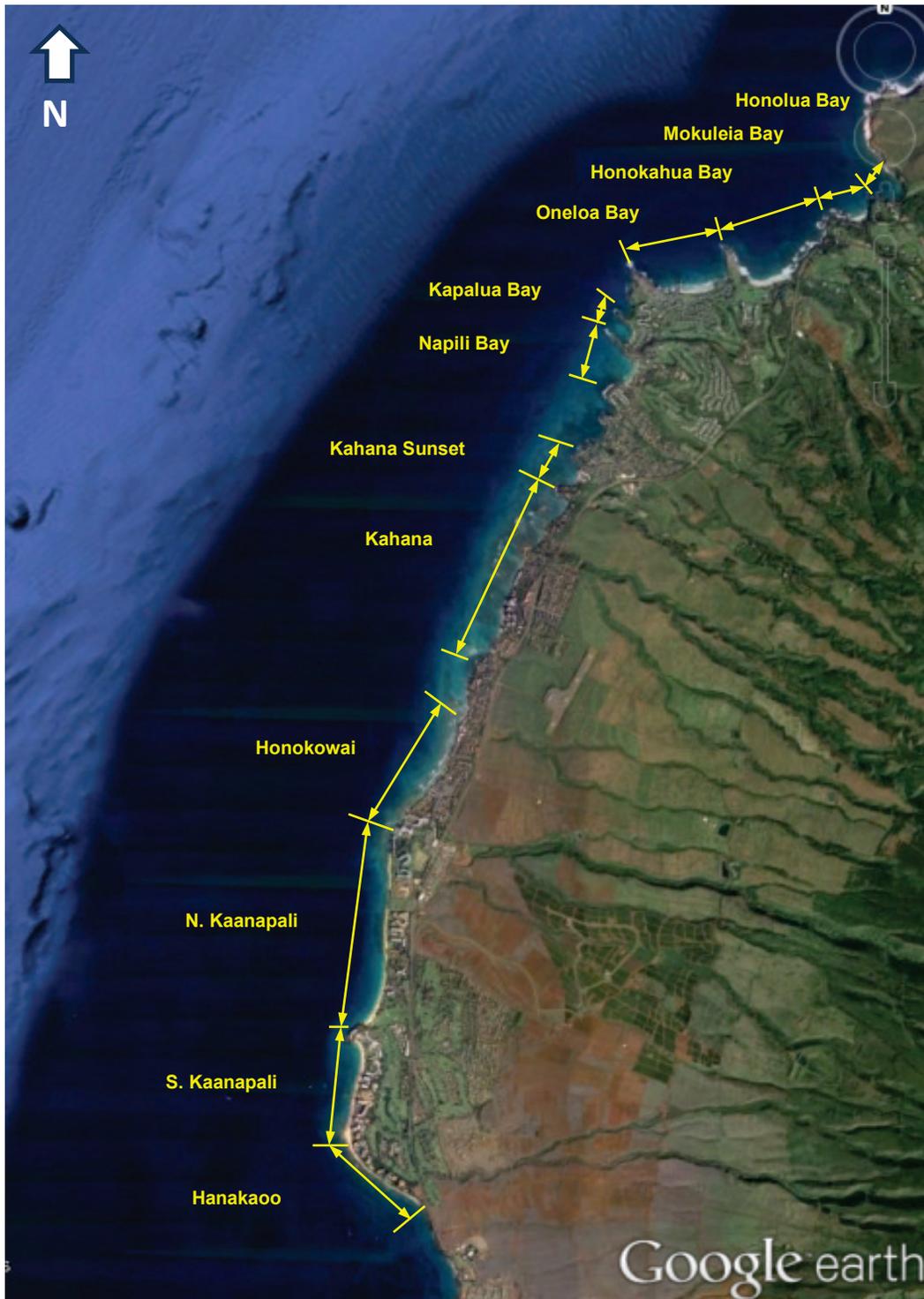
2   Shoreline and Volume Change Analyses

Shoreline change for the study area was quantified by the U.S. Geological Survey (USGS) and the University of Hawaii School of Ocean and Earth Science and Technology (UH/SOEST) (Fletcher et al. 2012) in the report *National Assessment of Shoreline Change: Historical Shoreline Change in the Hawaiian Islands.* Due to the presence of extensive reef and hard-bottom nearshore, this region has a limited sediment supply from the ocean side. Small amounts of freshwater and terrestrial sediments are brought into this region by streams.

POH estimated the shoreline change between 1997 and 2014 based on data obtained from use of Global Positioning System (GPS) along the shoreline. These two analyses are described in the following, along with the associated volume change estimates.

2.1   Shoreline change analysis

2.1.1   USGS/SOEST estimates

Shoreline change rates were calculated by the USGS/SOEST from *short-term* and *long-term* shoreline data. All available shorelines were used for long-term rate calculations. Post-World War II shorelines were used for short-term rate calculations. A minimum of three historical shoreline positions were required when calculating a shoreline change rate with the technique employed by the USGS (Fletcher et al. 2012).

All littoral cells (subregions) in West Maui are erosional based on the short- and long-term average shoreline change rates. The average erosion rate is slightly lower in the short-term than in the long-term. The average short-term rate is -0.43 ± 0.03 feet/year (ft/year) (-0.13 ± 0.01 meter/year [m/year]) with 77% of the region's shoreline being erosional. The average of all long-term rates for West Maui is -0.49 ± 0.03 ft/year (-0.15 ± 0.01 m/year), with 85% of the shoreline being erosional in the long term.

The maximum short-term erosion rate was found at Mokuleia Beach at -2.30 ± 5.58 ft/year (-0.70 ± 1.70 m/year). The Napili-Kapalua subregion has the highest average erosion rates at -0.62 ± 0.10 ft/year (-0.19 ± 0.03 m/year) in the short term and -0.72 ± 0.07 ft/year (-0.22 ±

0.02 m/year) in the long term. Other areas with significant long-term erosion include Honokowai (-1.64 ± 1.31 ft/year or -0.5 ± 0.4 m/year), Kahana (-1.31 ± 0.33 ft/year or -0.40 ± 0.10 m/year), and Napili Bay (-1.31 ± 0.64 ft/year or -0.40 ± 0.20 m/year).

2.1.2 Honolulu District estimates

Within the region's littoral cells, the 2014 shoreline position was acquired by POH through the use of GPS equipment. The USGS study tracked the movement of the beach toe (intersection of the beach profile and reef flat). POH adjusted the 2014 shoreline positions to account for the offset between the surveyed shoreline and the beach toe. Figures 2-1 and 2-2 display shoreline positions (from south to north) for 1997 (from USGS/SOEST) and 2014 in the Hanakaoo and South Kaanapali littoral cells, respectively.

Figure 2-1. Shoreline positions in Hanakaoo littoral cell for 1997 and 2014.
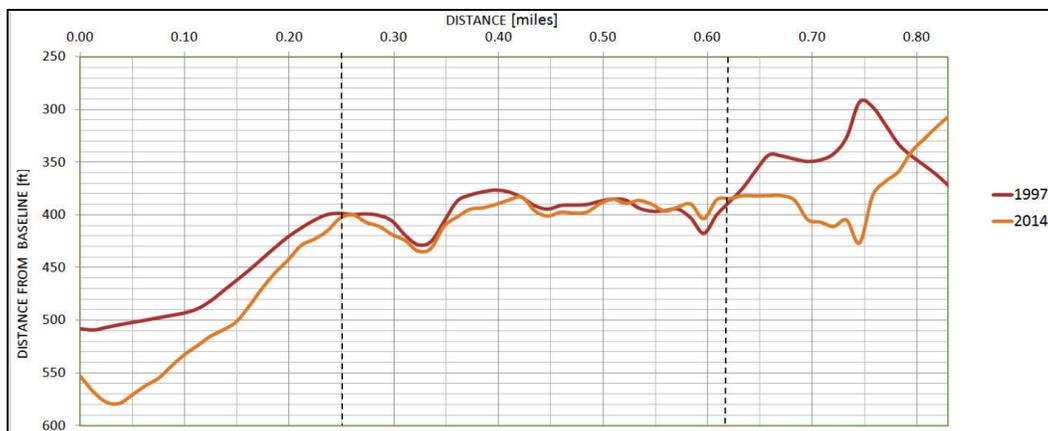
Figure 2-2. Shoreline positions in South Kaanapali littoral cell for 1997 and 2014.
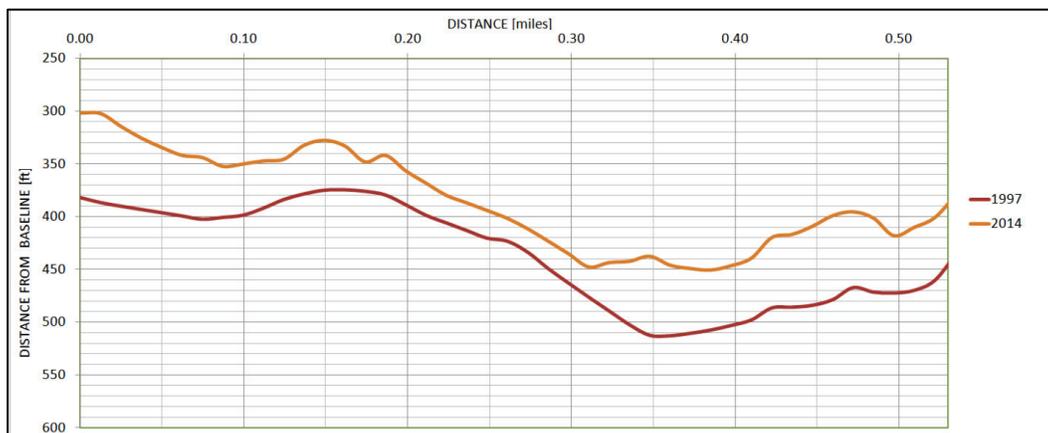
The shoreline along the southern 0.25 mile (0.40 kilometers [km]) and northern part from 0.62 to 0.8 (1.00 to 1.29 km) mile of the Hanakaoo littoral cell experienced erosion (receded). The central portion of the shore-line (from 0.25 to 0.62 mile [from 0.40 to 1.00 km])) was relatively stable over the period. In contrast, the shoreline advanced seaward along the entire half mile of the South Kaanapali littoral cell from 1997 to 2014 (Figure 2-2). Maximum shoreline advance (on the order of 60 ft or 20 m) occurs at the southern and northern limits of the cell while the central por-tion experienced uniform shoreline advance (on the order of 30 ft or 10 m).

2.2   Volume change rates

A conversion factor of 0.4 cubic yards (cy) (0.31 cubic meters [cm]) of sand per foot of shoreline change over each foot of shoreline length was used to estimate the volume change corresponding to the shoreline changes calculated by USGS/SOEST and Honolulu District. This conversion factor is based on the Bruun Rule (Bruun 1962) and experience with other Hawaii shorelines. For the study area, the active beach profile has a typical vertical extent of 10.8 ft (3.3 m), which included 3.0 ft (0.9 m) depth to the reef flat and 7.8 ft (2.4 m) elevation to the upper limit of the profile. This translates to 0.4 cy/ft/ft (3.3 cm/m/m) when the 10.8 ft (3.29 m) vertical extent is converted to volume per foot of shoreline change over each foot of shoreline length, when divided by 27 ft^3/cy.

Figures 2-3 and 2-4 show examples of sediment volume change rates for Hanakaoo and South Kaanapali cells, respectively. These volume change rates are in cubic yards per year (cy/year). The volume change rates are provided over various time periods available in the shoreline change data. A positive value indicates shoreline advancing and negative value for shoreline retreating. Results for calculated volume change estimates of all littoral cells are provided in Appendix A.

Results for these two littoral cells indicate the volume change rates are typically small for all time periods, remaining within (± 5,000 cy/year [3,822 cm/year]), and follow similar accretive/erosive trends. Extreme rates of erosion occurred in the Hanakaoo littoral cell during the periods of 1961–1963 (-24,000 cy/year [18,350 cm/year]) and 1988–1992 (-17,000 cy/year [13,000 cm/yr). Notable rates in the South Kaanapali littoral cell occurred from 1912–1932 (-7,000 cy/year [5,350 cm/year]) and 1988–1992 (with a rate of -8,000 cy/year [6,100 cm/yr], which includes the impacts of Hurricane Iniki). For the present time period (1997–2014), the volume

change rates in the Hanakaoo and South Kaanapali littoral cells were -2,148 cy/year (1,640 cm/yr) and 3,308 cy/year (2,530 cm/year), respectively.

Figure 2-3. Volume change rates through time (cy/year) for Hanakaoo littoral cell.
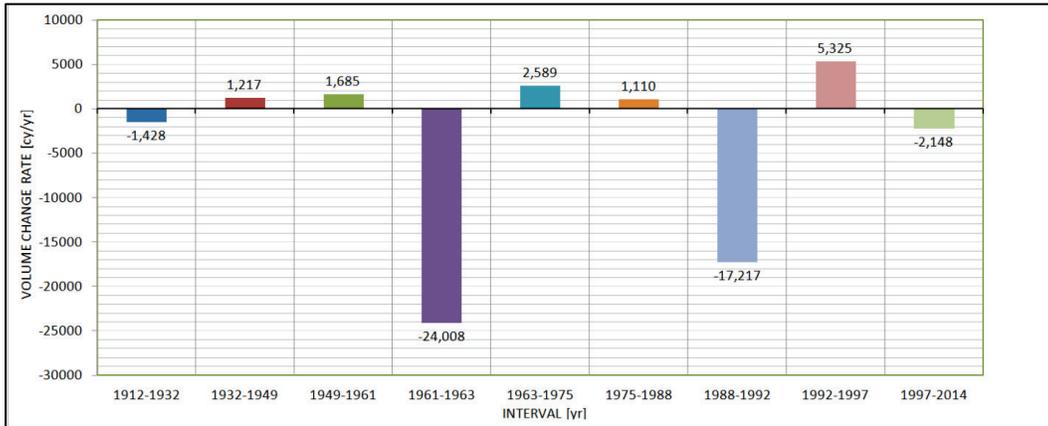
Figure 2-4. Volume change rates through time (cy/year) for South Kaanapali littoral cell.
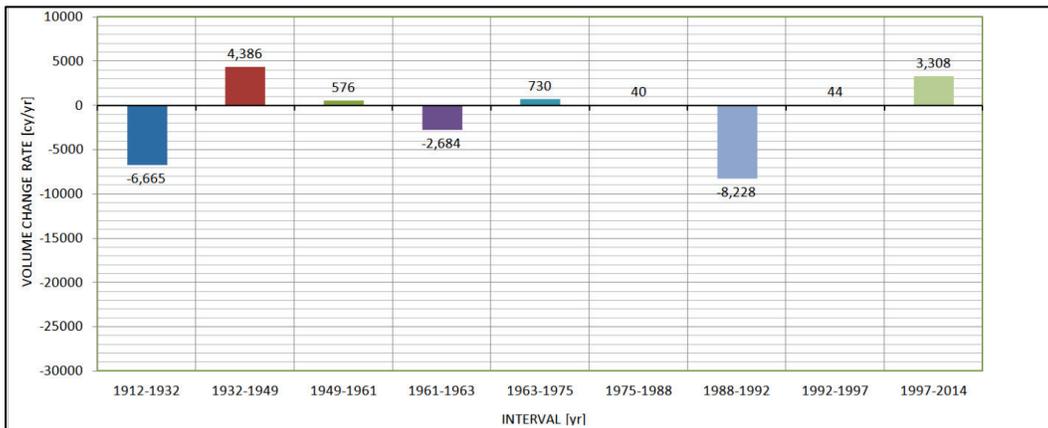
3   Numerical Modeling

A good understanding of the sediment transport processes for the West
Maui Region requires estimates of waves and circulation in the study area
including neighboring island effects. A wave and current modeling study
was implemented to infer regional sediment transport patterns and to
provide the basis for the development of a detailed regional sediment
budget. The regional processes that influence the West Maui shoreline
were considered in the numerical modeling. These include the following:

- a multidirectional wave climate with waves and swells arriving from
  north, south, and occasionally west
- wave sheltering from the islands of Lanai, Molokai, and Kahoolawe
- a propagating tide from south to north through Auau and Pailolo
  channels
- large internal tides in Hawaii
- complex nearshore bathymetry including coral reefs
- northeast trade winds occurring throughout the year, affecting the west
  Maui region strongly from April to November. The trade winds
  intensify by 50% in the channels between the islands of Maui, Molokai,
  and Lanai due to a funneling effect (Storlazzi and Field 2008).

3.1   Previous studies

Previous USGS field and numerical investigations (Storlazzi et al. 2006;
Vitousek et al. 2007; Storlazzi and Field 2008; Fletcher et al. 2012) have
reported the existence of two distinct circulation zones, inner and outer
zones, along the west Maui coast. Figure 3-1 shows a conceptualized
general pattern of the two circulation zones in this region. These earlier
investigations reported that along the shorelines north of Kanaapali, the
current was directed northward in the outer circulation zone at depths
greater than 8 m. In the inner circulation zone, the current flow was
directed southward. Both circulation zones were dominated by waves.
However, these two circulation gyres reversed directions south of
Kaanapali, which was attributed to changes in the turbidity and salinity
caused by local streams. Consequently, the alongshore current south of
Kaanapali is from south to north, opposite to the flow that dominates
north of this demarcation point on the west Maui coast.

Figure 3-1. Conceptual circulation and transport patterns along West Maui coast (after Storlazzi et al. 2006).
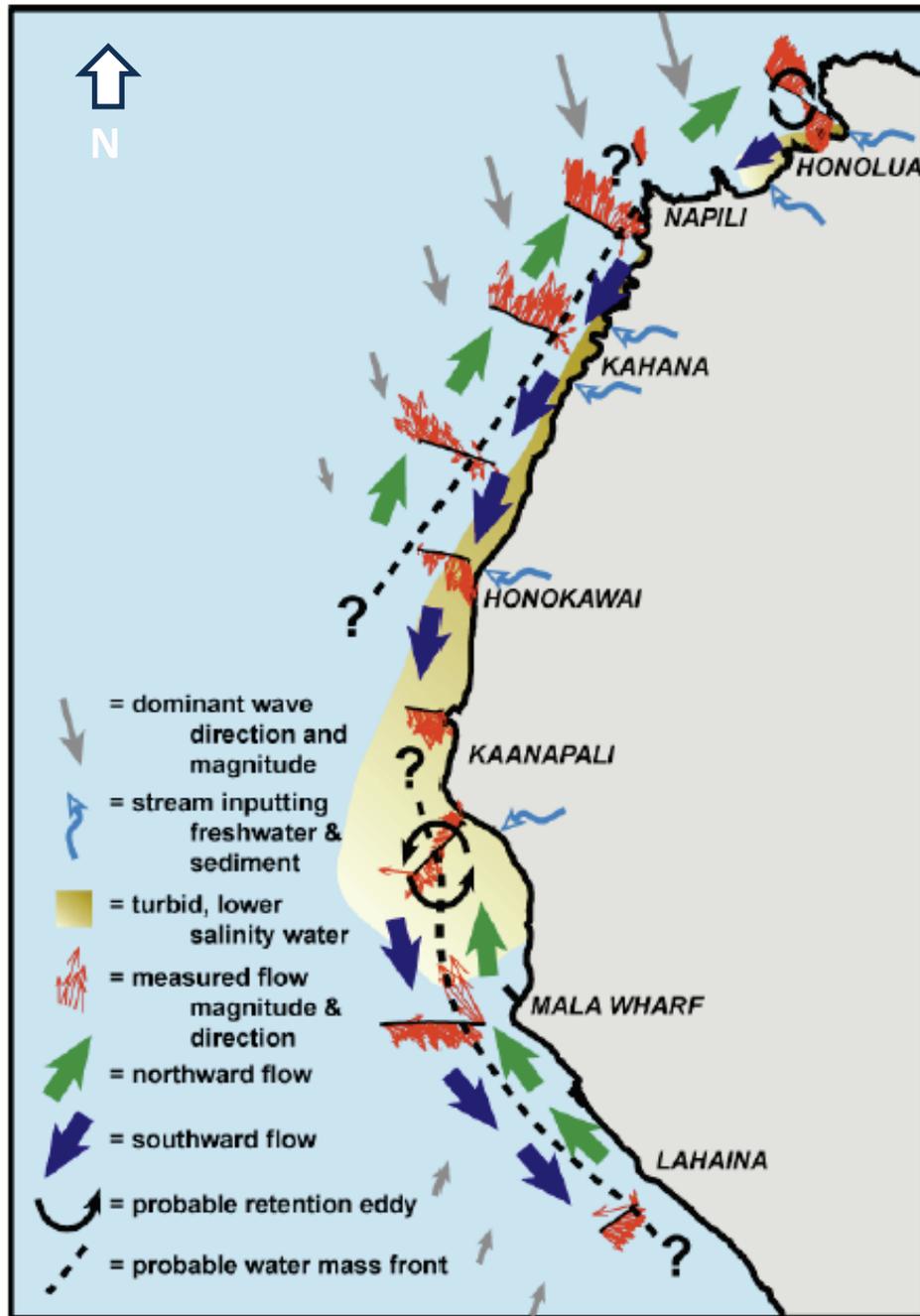
The nearshore hydrodynamics in this region are complex as they are dominated primarily by winds, waves, currents, and tides over the coastal reefs. Predominant waves and winds are from the north-northeast and northeast sector, and the largest waves are from the north-northwest sector, generated by distant storms in the north and northwest Pacific Ocean.

3.2 Modeling approach

A comprehensive understanding of sediment supply and movement in the West Maui Region requires the calculation of waves and circulation in and around the study area and also the neighboring regions and islands. In the present study, numerical models were used to calculate wave transformation and nearshore circulation. Model results were used to develop a sediment budget, which aids in optimizing and improving sediment management practices and strategies for the West Maui Region.

The Coastal Modeling System (CMS) (Demirbilek and Rosati 2011), numerical models CMS-Wave (Lin et al. 2011), and CMS-Flow (Sanchez et al. 2011) were implemented to simulate wave transformation and water circulation within the coastal region, respectively. Prevailing winds (trade wind) and predominant waves (northwest and south swell) were simulated by coupling of CMS-Wave and CMS-Flow to capture the interaction of waves and currents.

In addition to the CMS, the Particle Tracking Model (PTM) (Demirbilek et al. 2005a,b,c) was used to identify the dominant sediment pathways. The calculated waves and currents from the CMS were used as input to the PTM. The results from the shoreline change analysis and coastal processes modeling were utilized to develop the West Maui regional sediment budget estimates.

To better understand coastal dynamics in coral reef habitats, the USGS collected wave and current data at four locations (Figure 3-2) along the west coast of Maui. The field data collection included hourly observations of waves (wave heights and periods), currents (magnitude and directions), temperature, salinity, and turbidity off the West Maui coast from June to October 2003 (Storlazzi et al. 2004, 2006). All measurements were on the inner shelf in water depths between 29 and 40 ft (9 and 12 m). The wave and current data were used in the present study to calibrate and validate CMS models.

3.3 CMS grids

A nested grid system consisting of two grids was used in CMS-Wave and CMS-Flow simulations: (1) a parent grid with coarser resolution covering the regional area and (2) a child grid representing the key features in the coastal area such as reefs, irregular shorelines, headlands, coves, and bays.

Figure 3-2. Locations of USGS data collection (after Storlazzi et al. 2004).
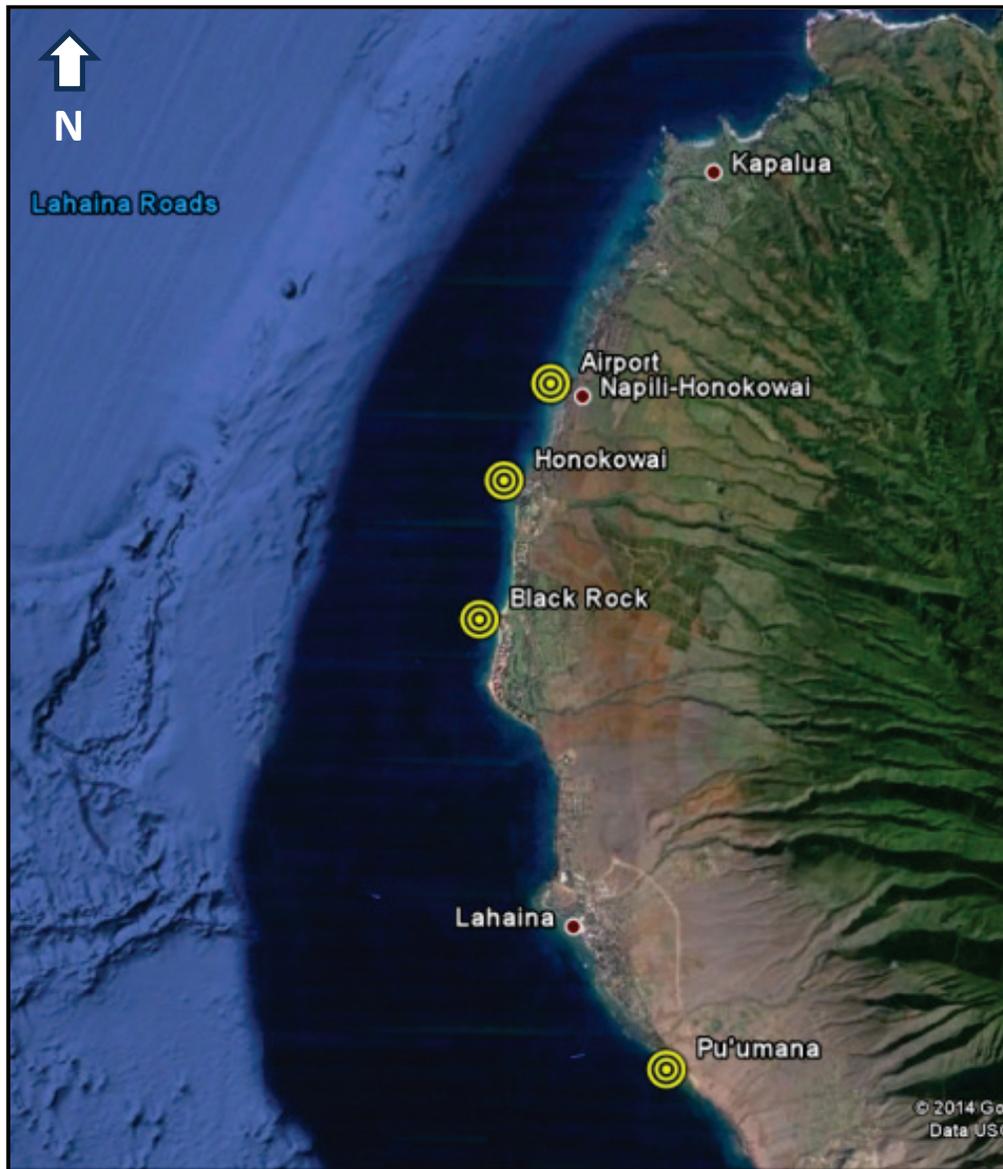
This nested grid system was necessary to properly estimate the wave, current, and sediment transport fields along the west coast of Maui. The model domain of the parent grid was 82.6 miles × 102.5 miles (130 km × 165 km), covering parts of eastern coast of Oahu and other four neighboring islands (Maui, Molokai, Lanai, and Kahoolawe). The parent grid used variable cell size ranged from 5,000 ft × 5,000 ft (1,524 m × 1,524 m) away from Maui to 820 ft × 1,640 ft (250 m × 500 m) near Maui. The child grid domain was approximately 6.2 miles × 12.4 miles (10 km × 20 km), covering a smaller area of the west coast of Maui. It had a variable cell size ranging from 820 ft × 820 ft (250 m × 250 m) offshore to 65 ft × 65 ft (20 m × 20 m) nearshore. Figure 3-3 shows the two nested grids.

Figure 3-3. Parent grid (red) and child grid (white) of study area.
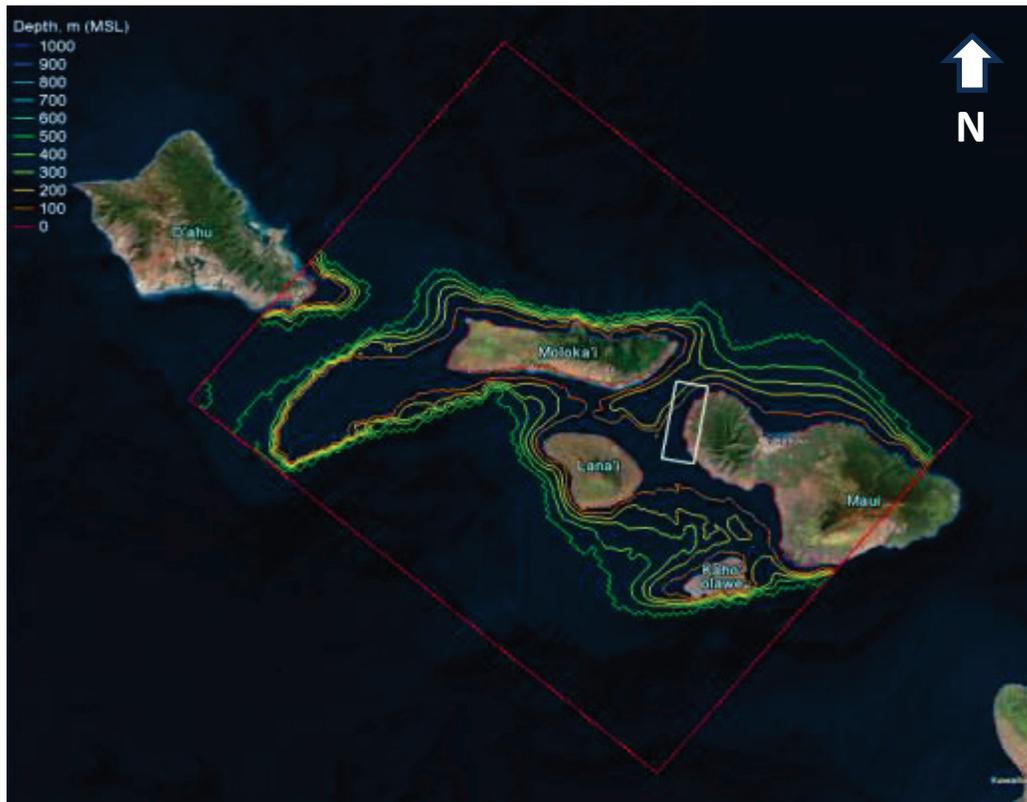
The CMS grid bathymetry for the wave and current models was created using the Hawaiian Islands dataset maintained by the UH/SOEST, Ocean and Resources Engineering Department (http://www.ore.hawaii.edu/). CMS-Wave was run on the parent grid in full-plane mode to allow waves to enter the domain from both the north and south directions. A spatially varying friction factor was applied to both CMS-Flow and CMS-Wave to incorporate the effects of increased friction over nearshore reefs on currents and wave breaking.

3.4   Metocean forcings

For open ocean wind and wave forcing, the USACE ERDC Wave Information Study (WIS) long-term hindcast data (http://wis.usace.army.mil/hindcasts.shtml) were available for wind and wave input to the CMS[1]. Figure 3-4 shows the WIS stations available surrounding the Hawaiian Islands. In the present study, wind and wave data from two WIS stations, Stations 82517 (north of Maui) and 82546 (south of Maui), were used as input to the CMS models. Figure 3-5 shows the location map of Stations 82517 and 82546.

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[1] Hesser, T., R. E. Jensen, and A. Cialone. In publication. Wave information studies: Pacific Ocean hindcasts. ERDC/CHL Technical Report. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 3-4. WIS wave hindcast stations available for the parent grid.
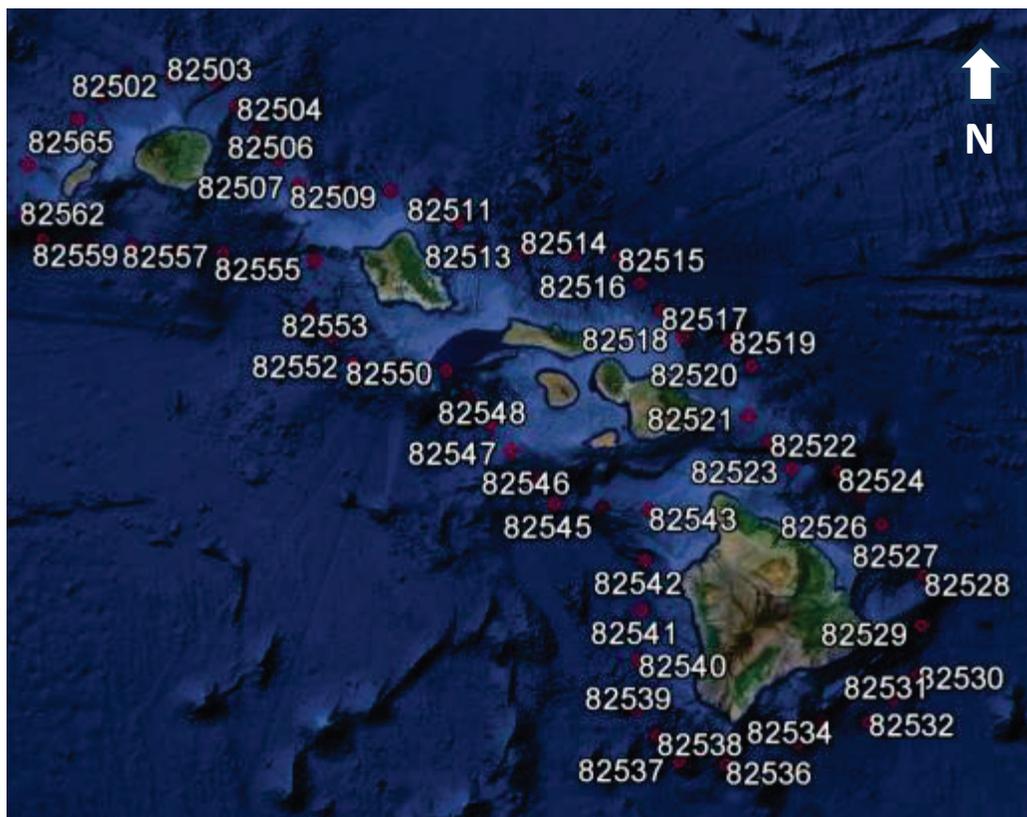
Tidal effects in the Hawaiian Islands are relatively small because the tidal range is less than 3.3 ft (1 m). Water level data were available from two nearby National Oceanographic and Atmospheric Administration (NOAA) tide gauges, Station 1615680 at Kahului Harbor and Station 1617433 at Kawaihae Harbor (Figure 3-5).

Figures 3-6 and 3-7 show examples of wind and wave roses, respectively, at Station 82517 and Station 82546 for the two different periods in 2003 and September 2009 to December 2010 that were used for model simulations. The wind roses clearly show the east trade winds are dominant at Station 82517 and Station 82546. The wind speeds at Station 82517 (north of Maui) are generally greater than those at Station 82546 (south of Maui). This is because the Station 82546 location is sheltered from the east trade winds by the Big Island and Maui.

Figure 3-5. WIS hindcast stations (red circles) and NOAA tide stations (yellow stars) for input data to CMS.
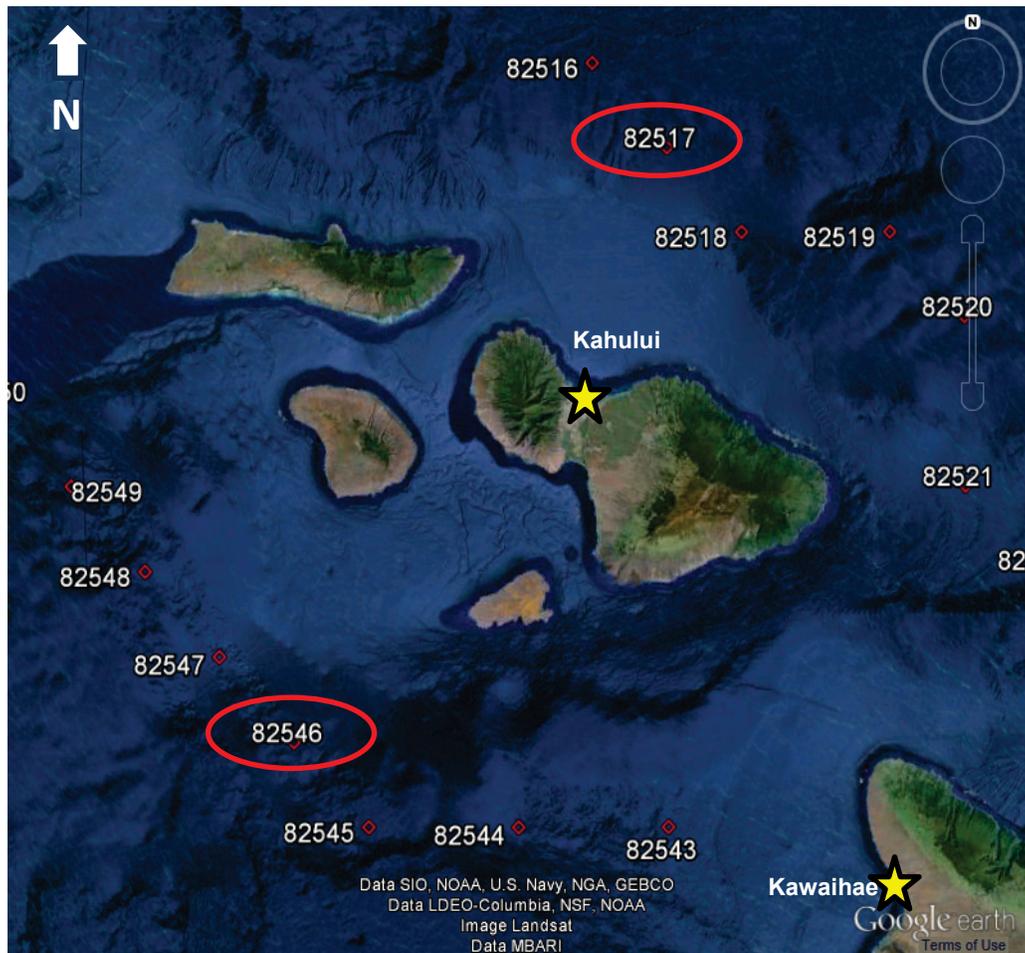
The wave roses show much larger wave heights at Station 82517 (north of Maui) than waves at Station 82546 (south of Maui). More than 30% of the wave population at Station 82517 is greater than 10 ft (3.1 m) as compared to less than 1% of waves greater than 10 ft (3.1 m) at Station 82546. At Station 82517, waves are mixed coming from the northeast (Gulf of Alaska), northwest (Japan Sea), and east direction (waves generated by the east trade winds). While more waves come from the east and east-northeast direction, larger waves come from north and north-northwest directions.

At Station 82546, waves are from northwest, south, and east directions. The northwest waves are the result of waves from the Japan Sea. The southerly and easterly waves are the results of southern hemisphere swell mixed with local wind waves generated by the trade wind.

Figure 3-6. Wind roses at WIS Stations 82517 and 82546 for 2003 and September 2009 to December 2010.
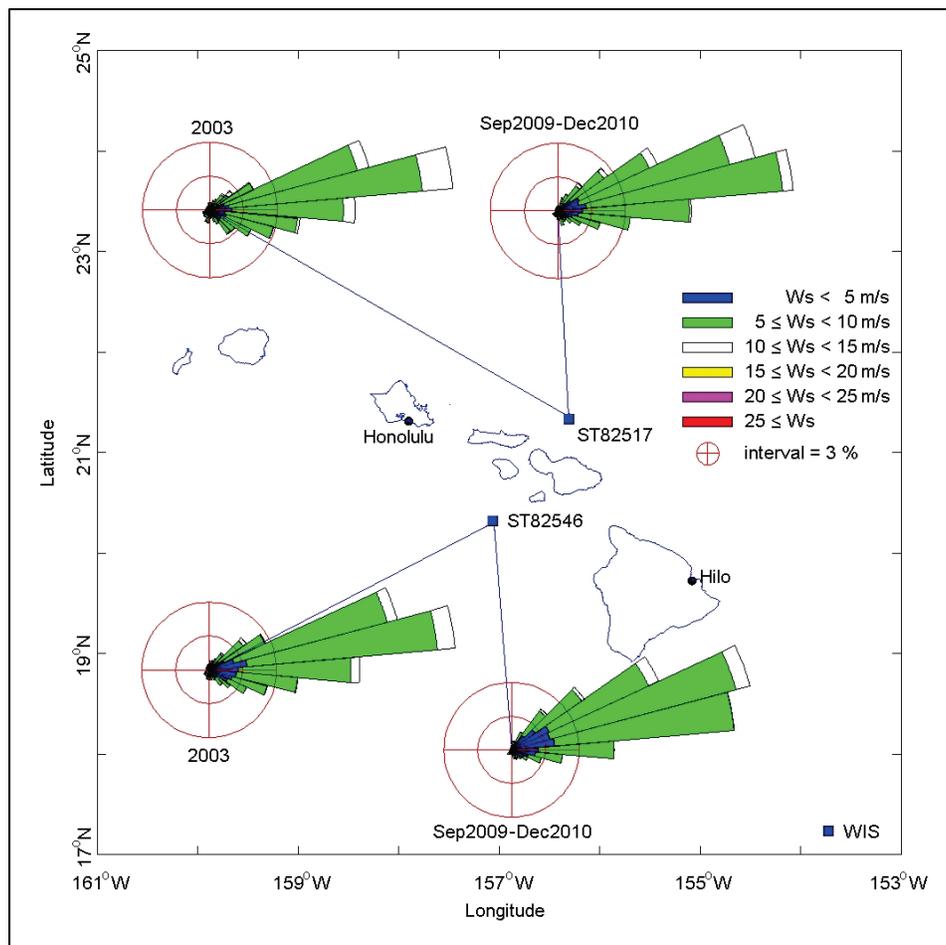
3.5   CMS calibration and validation

The calibration and validation of CMS models were conducted for July–October 2003. The parent grid for CMS-Wave was forced with incident waves and winds from WIS Stations 82517 and 82546 near the northern and southern boundaries, respectively (Figures 3-3 and 3-5). The parent grid for CMS-Flow was forced with measured water levels from NOAA tide stations at Kahului Harbor and Kawaihae Harbor along northern and southern boundaries, respectively. The parent grid simulations were made with coupled wave and flow models. Figure 3-8 shows the time series of hindcast wind and wave data from WIS Stations 82517 and 82546 for July–October 2003. Figure 3-9 shows the time series of measured water levels from NOAA coastal stations at Kahului Harbor (Station 1615680) and Kawailae Harbor (Station 1617433) for July-October 2003.

Figure 3-7. Wave roses at WIS Stations 82517 and 82546 for 2003 and September 2009 to December 2010.
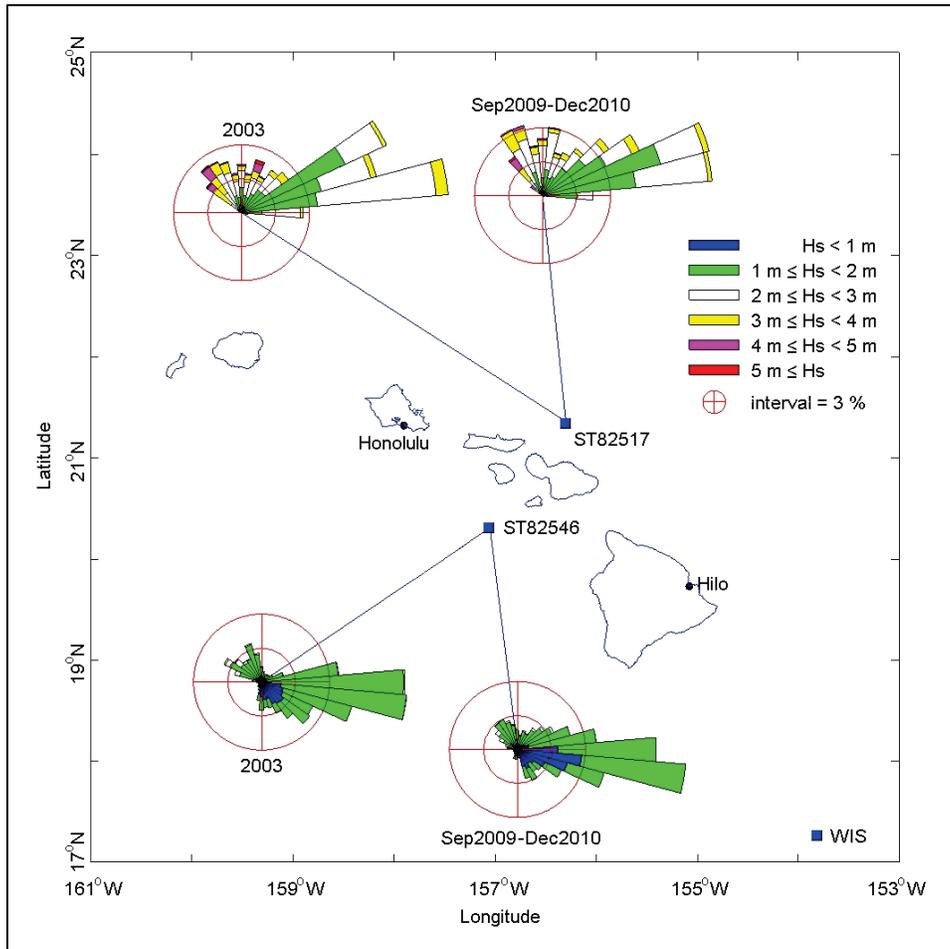
Figure 3-8. Hindcast wind and wave data at WIS Station 82517 and 82546 for July–October 2003.
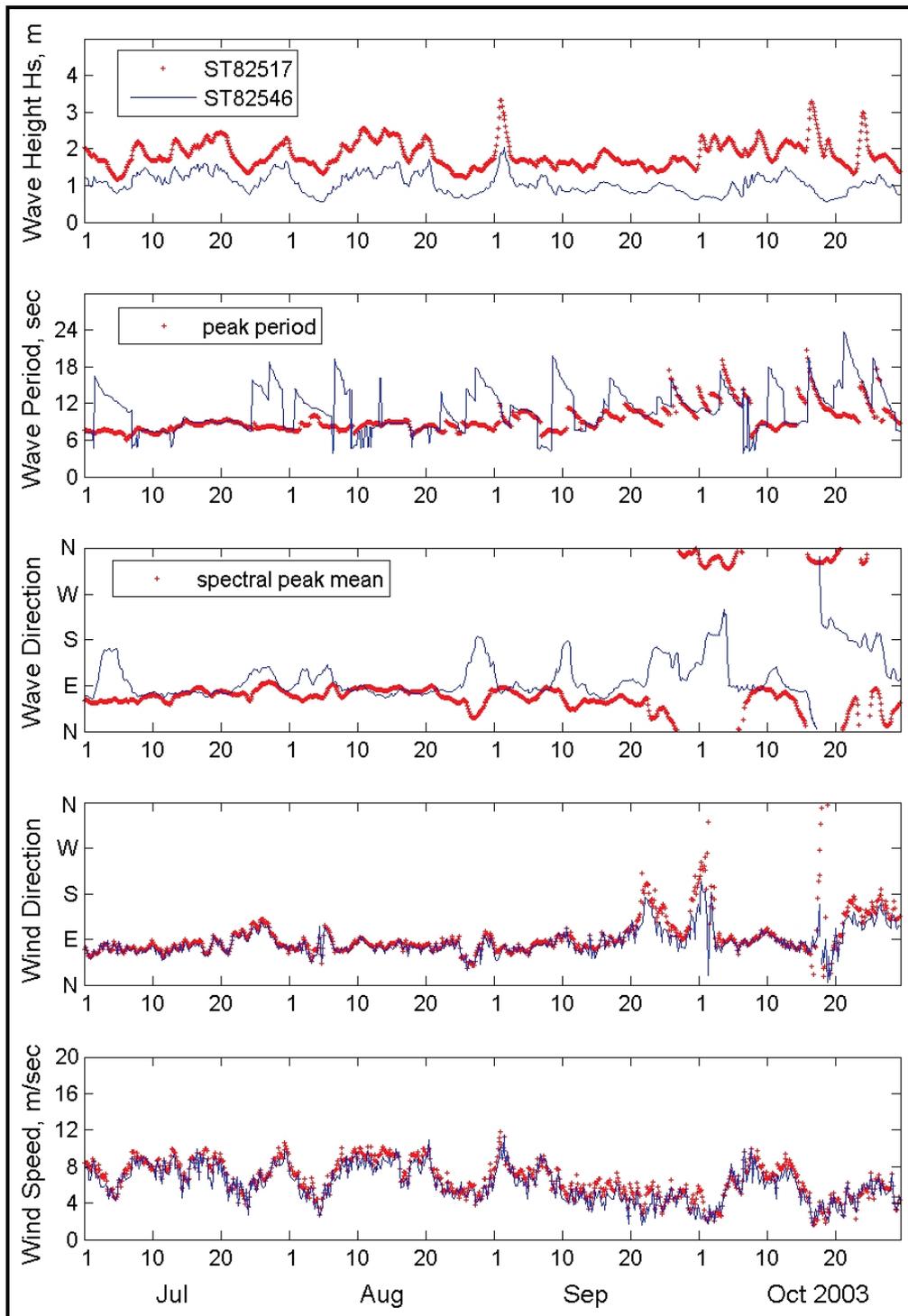
Figure 3-9. Water level data from NOAA Stations at Kahului Harbor and Kawailae Harbor for July–October 2003.
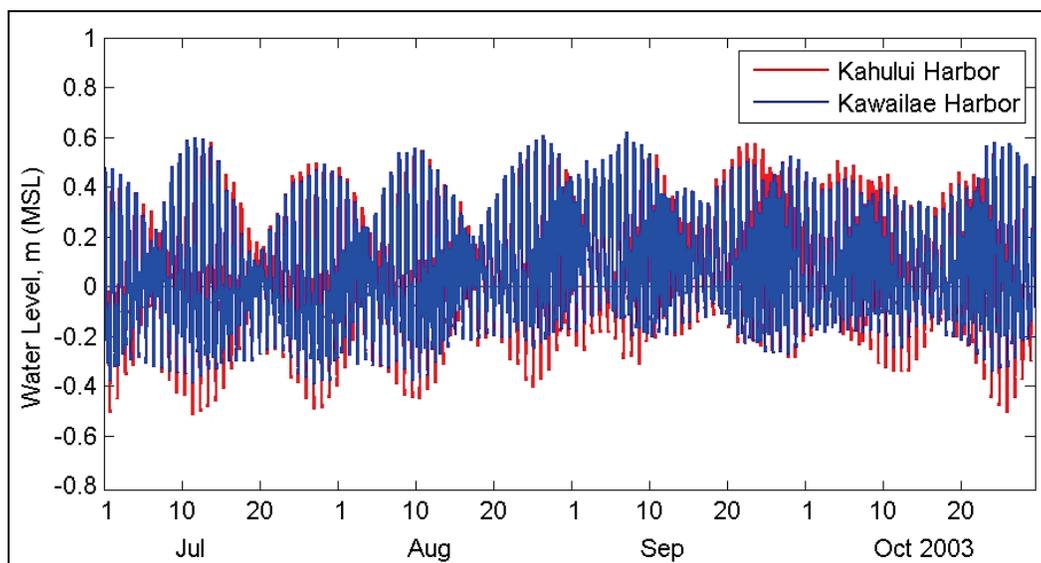
Figure 3-8 shows wave heights from WIS Station 82517 (north of Maui) are generally greater than waves at Station 82546 (south of Maui). This is expected as WIS Station 82517 is exposed to energetic waves from the northeast (Gulf of Alaska), northwest (Japan Sea), and east (waves generated by the east trade wind). The south side of Maui, conversely, is sheltered to these waves from the east, northeast, north, and northwest. Swells with moderate wave height and longer period from the distant southern hemisphere are often observed on the south side of Maui in the summer months. The wave periods at Station 82546 (south of Maui) are overall greater than waves at Station 82517 (north of Maui).

For the CMS calibration, the parent grid of the wave and flow models was forced by hindcast winds and directional wave spectra from WIS Station 82517 and 82546 and measured water level data from NOAA Stations 1615680 and 1617433 as boundary conditions. The input wind and incident wave spectra to the CMS as well as water level boundary conditions were updated on an hourly basis. The CMS-Wave and CMS-Flow models were coupled at a 1-hour (hr) interval. Model results from the parent grid were used to drive the child grid. Calibration tests indicated an adjustment to the friction coefficient was necessary to account for the effects of fringing reefs on wave breaking and resulting wave-induced currents in shallow depths. A spatially varying friction factor was used in both CMS-Flow and CMS-Wave simulations with an increased friction over nearshore reefs. For other modeling parameters, the default values were used.

Figure 3-10 shows the comparison of calculated water levels and data at APT (Kahana) and PUM (Puumana) for July 2003. Figure 3-11 compares calculated wave heights and period with data at BRK (Black Rock) and PUM for July 2003. Figure 3-12 shows the model current easting and northing components with data at HKW (Honokowai) for July 2003. Tables 3-1 and 3-2 present a basic statistics comparison (mean, bias, and root-mean-square-error [RMSE], and correlation coefficient) of the model wave results and data at BRK and PUM, respectively, for the period of July to September 2003. Table 3-3 presents a statistics comparison of model current results and data at HKW for July to October 2003.

Figure 3-10. Calculated and measured water levels at Kahana (APT) and Puamala (PUM) for July 2003.
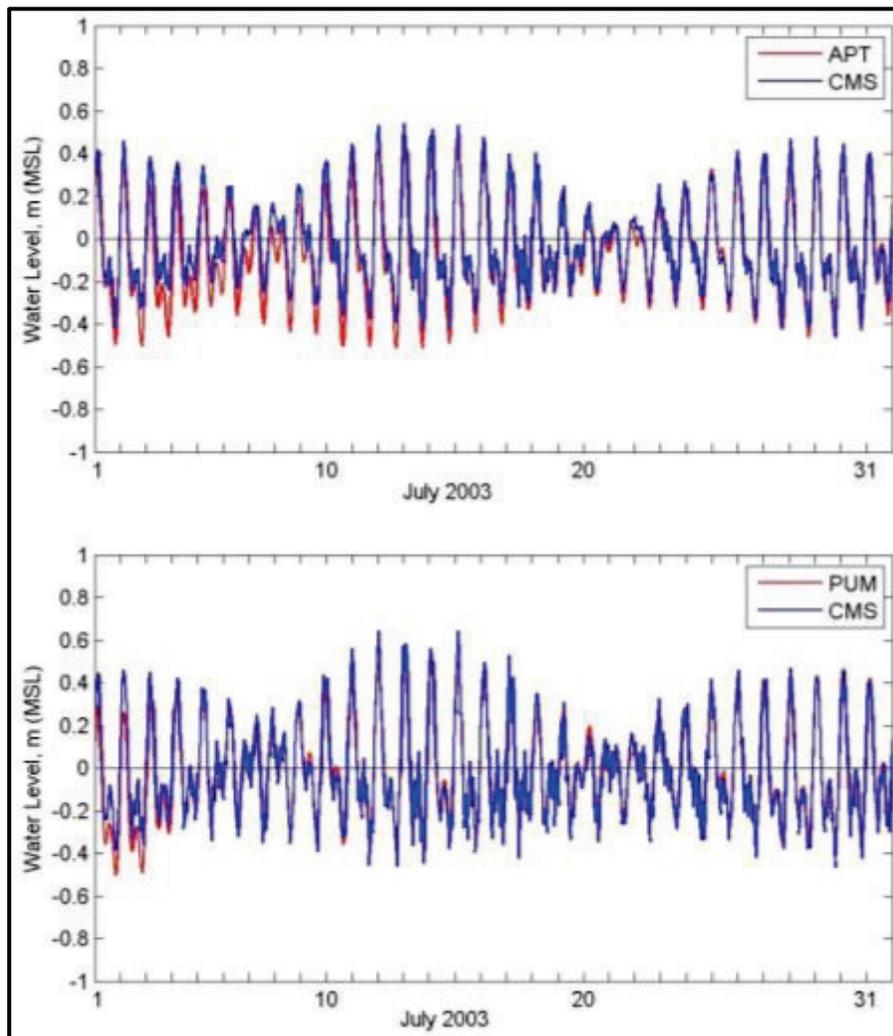
Figure 3-11. Calculated and measured wave heights at Black Rock (BRK) and Puamana (PUM) for July 2003.
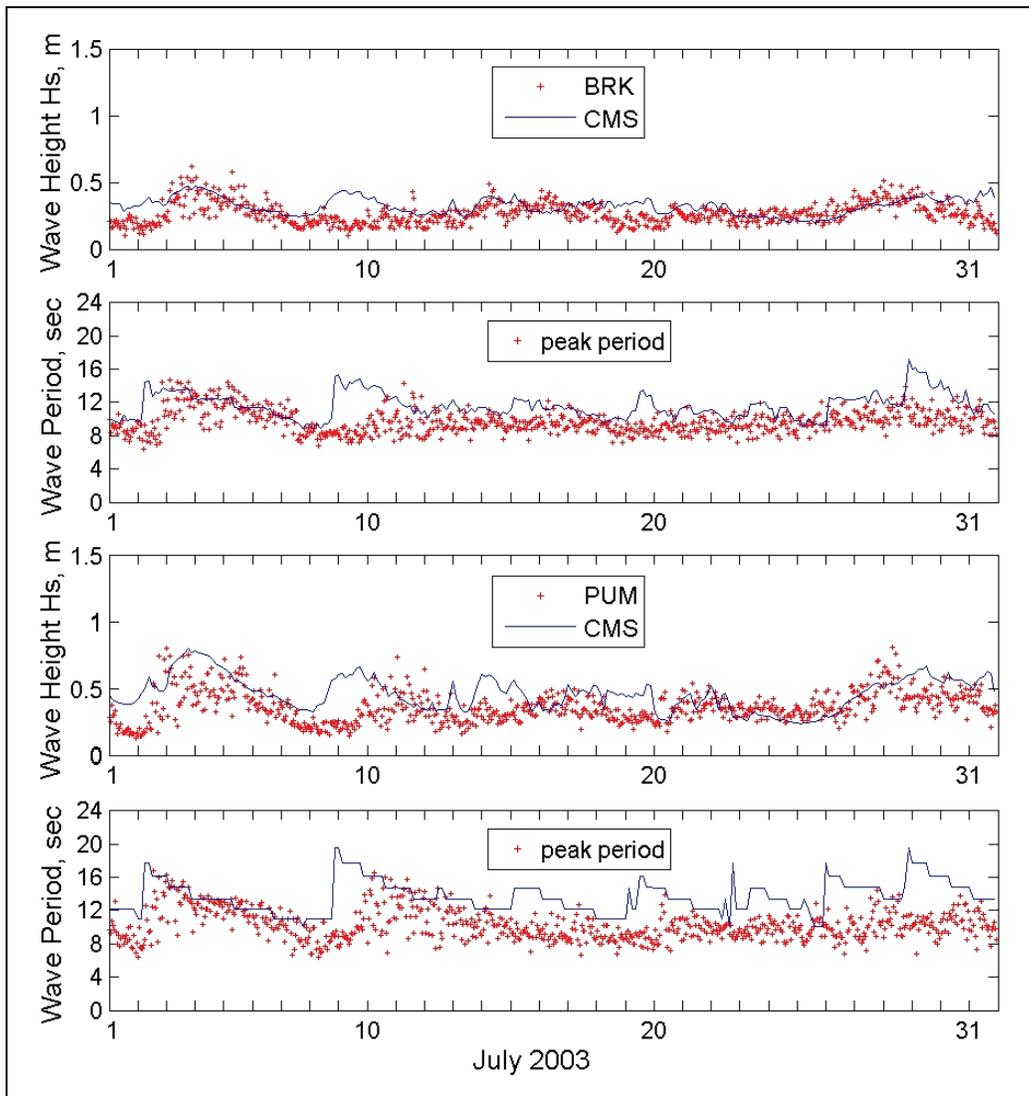
Figure 3-12. Calculated and measured current components at Honokowai (HKW) for July 2003.
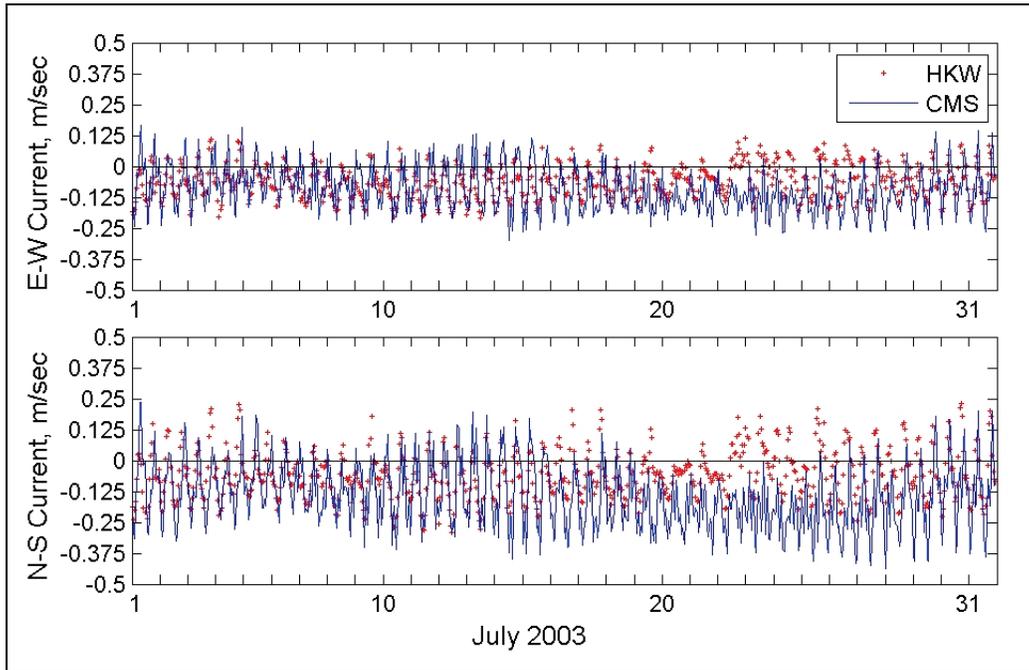
Table 3-1. Statistics of data and calculated wave heights and periods at BRK (Black Rock) for July–September 2003.

Parameter	CMS (Data)	
Statistics	H_s	T_p
Mean	0.23 m (0.30 m)	9.7 sec (11.1 sec)
Bias	-0.07 m	-1.4 sec
RMSE	0.07 m	1.7 sec
Correlation coefficient	0.5	0.35

Table 3-2. Statistics of data and calculated wave heights and periods at PUM (Puamana) for July–September 2003.

Parameter	CMS (Data)	
Statistics	H_s	T_p
Mean	0.31 m (0.40 m)	9.8 sec (13.1 sec)
Bias	-0.09 m	-3.3 sec
RMSE	0.10 m	2.3 sec
Correlation coefficient	0.6	0.33

Table 3-3. Statistics of data and calculated currents at HKW (Honokowai) for July–October 2003.

Parameter	CMS (Data)	
Statistics	Current speed easting component	Current speed northing component
Mean	-0.05 m/sec (-0.07 m/sec)	-0.06 m/sec (-0.10 m/sec)
Bias	0.02 m/sec	0.04 m/sec
RMSE	0.08 m/sec	0.13 m/sec
Correlation coefficient	0.61	0.59

3.6   Long-term simulations

The long-term time series simulations were completed for two selected time periods. The first time period included the entire year of 2003 and represented an extreme storm year. The second time period was the 15 months from September 2009 to December 2010, which represented a typical (average) year and included a full winter wave season.

Figures 3-13 and 3-14 show two sample snapshots of wave and current fields from the parent grid simulation for 3 July 2003 (at 0600 GMT), respectively. Offshore waves parameters at this time were Hs = 5.6 ft (1.7 m), T_p= 7.5 seconds (sec), and Dir = 57 degrees (deg) from WIS 82517 (north boundary), and Hs = 3.6 ft (1.1 m), T_p= 14.6 sec, and Dir = 127 deg from WIS 82546 (south boundary). The tide was at 0.67 ft (0.203 m) mean low low water (MLLW) and 1.21 ft (0.369 m) MLLW at the north and south boundaries, respectively, and on the way down from peak high tide. The figures indicate that the West Maui shoreline was dominated by south swell and, in turn, primarily north-directed currents during this summer swell.

Figures 3-15 and 3-16 shows two sample snapshots of wave and current fields from the parent grid simulation for 23 December 2009 (at 0300 GMT), respectively. Offshore waves parameters at this time were Hs = 10.2 ft (3.1 m), T_p= 17.7 sec, and Dir = 336 deg from WIS 82517 (north boundary), and Hs = 4.3 ft (1.3 m), T_p= 17.7 sec, and Dir = 1 deg from WIS 82546 (south boundary). The tide was at 0.95 ft (0.290 m) MLLW and 0.44 ft (0.134 m) MLLW at the north and south boundaries, respectively, and on the way up from lowest tide. The figures indicate that the West Maui shoreline was dominated by north swell and, in turn, primarily south-directed currents during this winter swell.

Figure 3-13. Calculated wave field at 06:00 GMT on 3 July 2003.
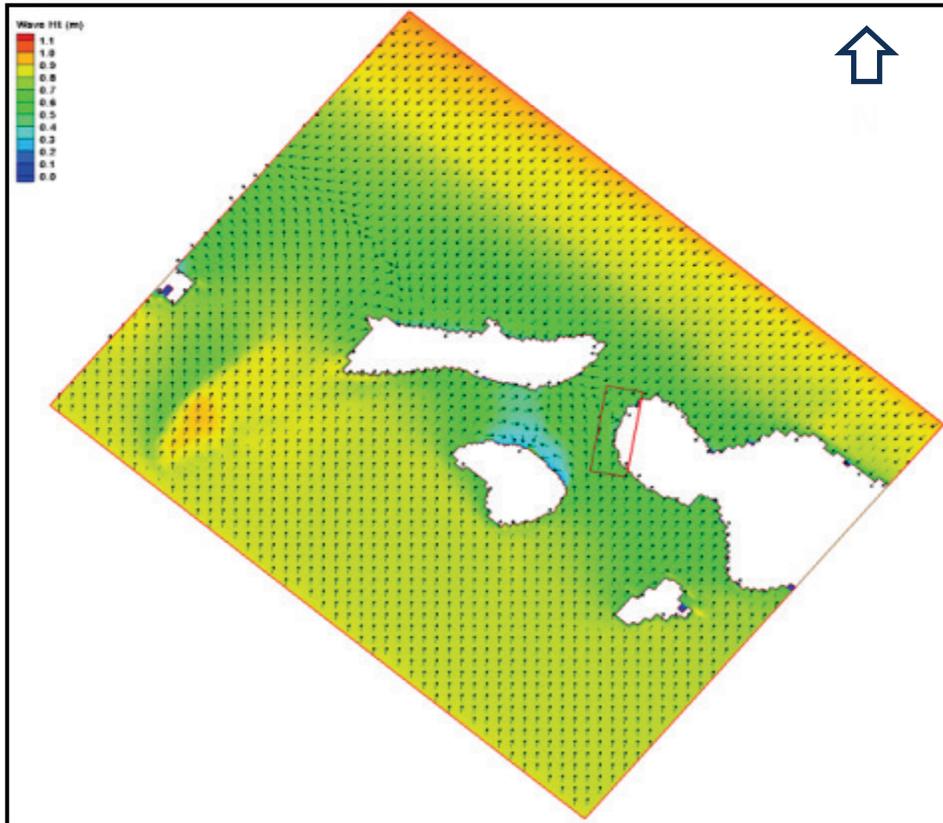
Figure 3-14. Calculated current field at 06:00 GMT on 3 July 2003.
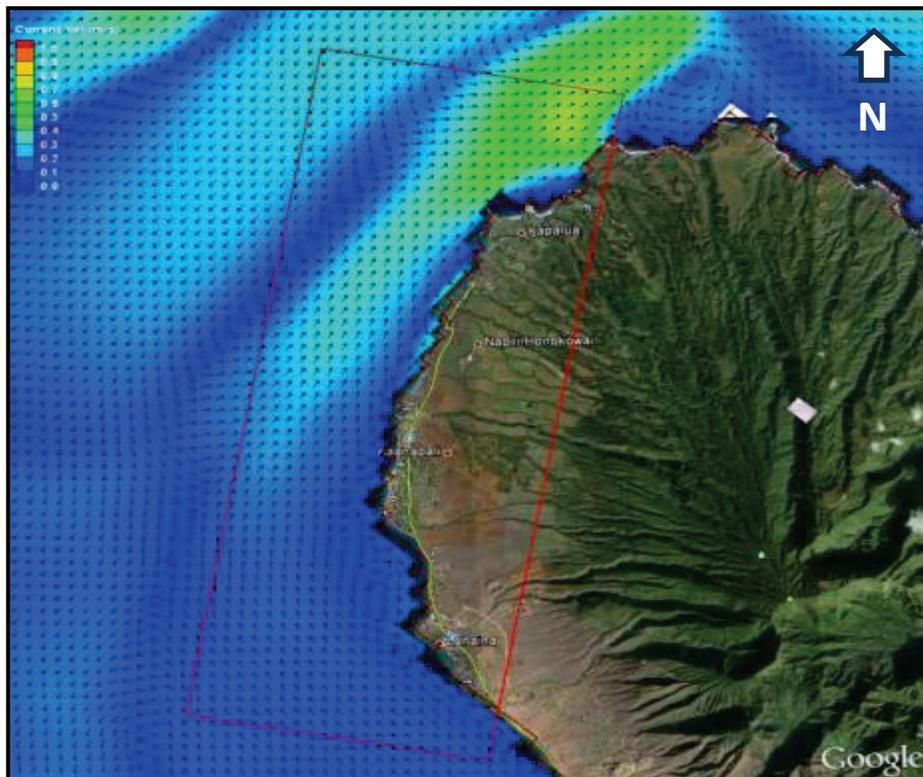
Figure 3-15. Calculated wave field at 03:00 GMT on 23 December 2009.
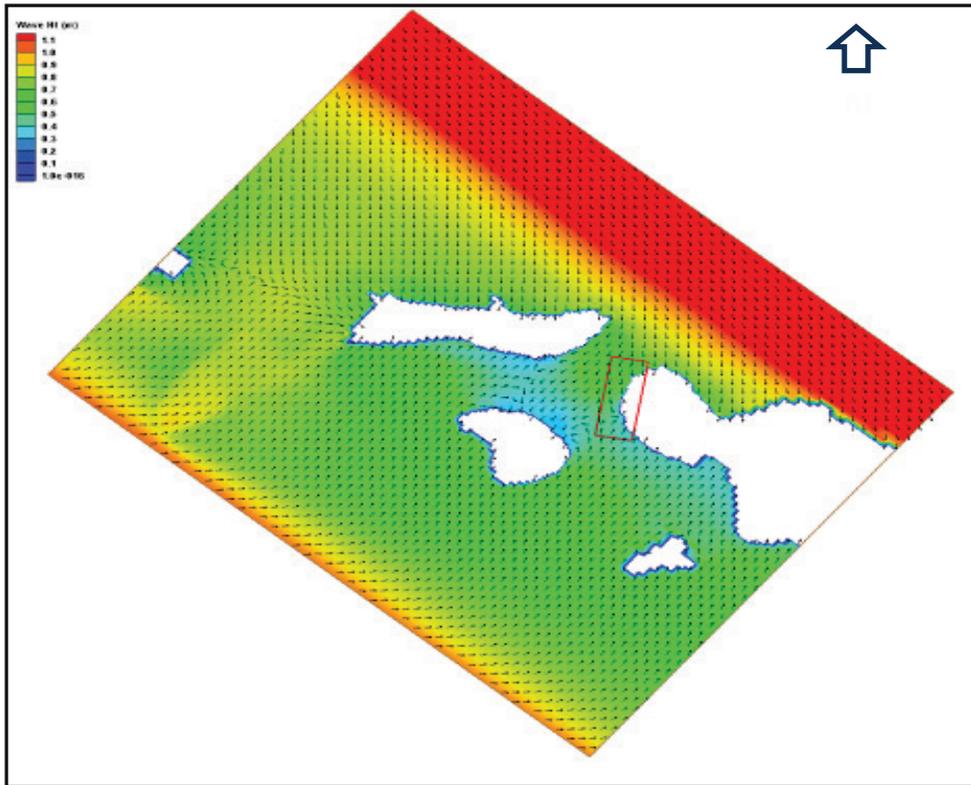
Figure 3-16. Calculated current field at 03:00 GMT on 23 December 2009.
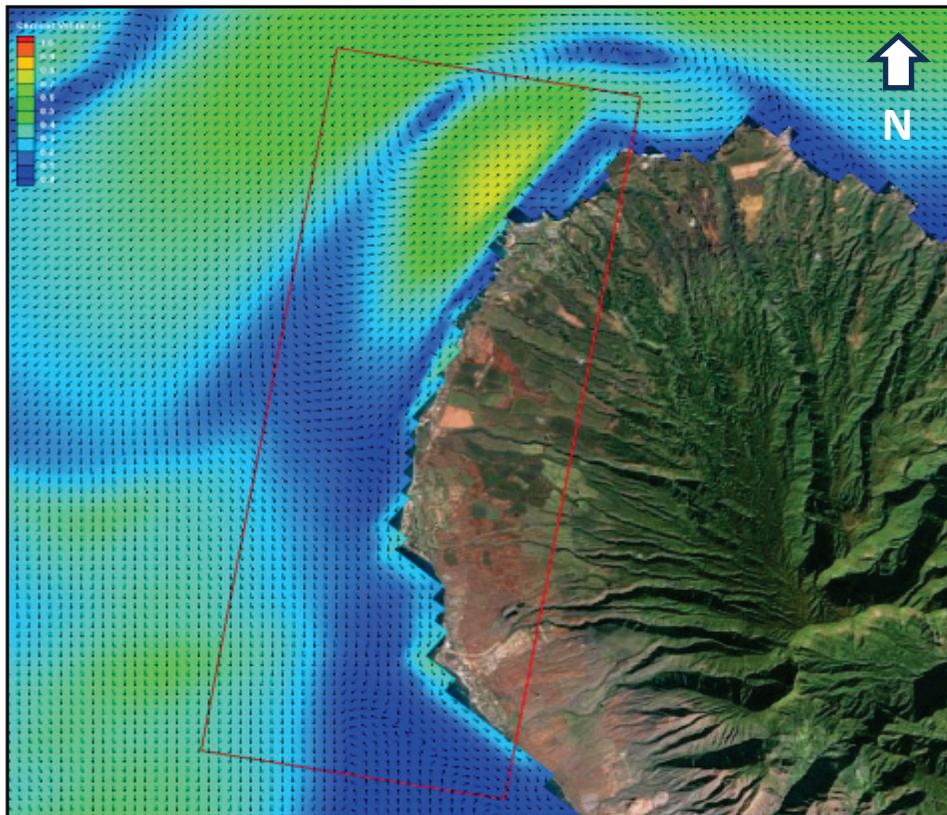
Results from these two long-term simulations were used in the PTM simulations to investigate seasonal pathways of sediment transport along the west Maui shoreline.

The PTM provides powerful visualizations of potential sediment transport utilizing the results from both CMS-Wave and CMS-Flow. Figure 3-17 shows the PTM results after 14 hr of run time during an August 2003 south swell event. An alongshore sediment source was placed in the highly eroded Kahana cell to simulate the fate of material from a hypothetical beach fill. The results show the north-directed transport during this summer south swell event. Figure 3-18 shows the PTM results after 14 hr of run time for a November 2003 north swell event, with sediment sources placed in (a) the North Kaanapali cell along the nearshore profile and (b) the South Kaanapali cell. The results show the south-directed transport during a north swell event along the Kaanapali shoreline.

Figure 3-17. A snapshot of sand particle locations at 14 hr PTM simulation time after initial release on 25 August 2003 (sources in yellow; particles in red).

Figure 3-18. A snapshot of sand particle locations at 14 hr PTM simulation time after initial release on 18 November 2003 (sources in yellow; particles in red).

4   Sediment Budget

Shoreline positions and annual volume change rates for each littoral cell were calculated as shown in Figures 2-3 and 2-4 (along with similar figures provided in Appendix A). Annual volume change rates are shown in Figure 4-1 and Figure 4-2 for the southern and northern portions of the West Maui Region, respectively. The results from the wave/circulation model runs and subsequent PTM visualizations, in combination with the shoreline change analysis, were intended to convey development of a conceptual regional sediment budget for the time period 1997 through 2014. The relatively low rates of annual volume change calculated for the period 1997 through 2014 indicate that the majority of littoral cells were stable to slightly accretionary. For this reason, and because the region is composed of many embayments without significant exchange of sediment, transport directions and quantities have not been assigned to the annual volume change rates in Figure 4-1 and Figure 4-2.

Figure 4-1. Annual sediment budget estimates for the southern portion of West Maui RSM Region (quantities in cy/year).

Figure 4-2. Annual sediment budget estimates for the northern portion of West Maui RSM Region (quantities in cy/year).

5   Conclusions

The analysis of shoreline change completed by USGS, University of Hawaii, and POH, as well as numerical modeling of waves, currents, and sediment pathways has aided in an increased understanding of the physical processes along the West Maui coast. Overall, the dynamics of the area are complex, with a wave climate affected by intricate bathymetry, wind, and island sheltering; currents that vary from nearshore to offshore and within the water column; varying coastal morphology including headlands; and a very limited supply of sediment. Wave and current, and particle tracking numerical modeling results, indicate that large wave events in the summer and winter drive the majority of sediment transport (northward-directed in summer and southward-directed in winter). This resulted in small values of net transport of sediment, though shorelines can be drastically affected by this seasonal pattern. There is also evidence of nearshore eddy formation due to coastal morphology which, in combination with quickly changing wave conditions, increases the complexity of sediment transport in the region with sediment pathways changing on hourly to weekly and monthly scales.

In summary, this is a very dynamic and seasonally affected shoreline, and the RSM investigations completed here will help inform future shoreline management about the dynamics and physical processes of the West Maui coast.

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Appendix A: West Maui Region

Shoreline Positions and Volume Change Rates of Littoral Cells

Figure A1. Shoreline positions within the North Kaanapali littoral cell for 1997 and 2014.
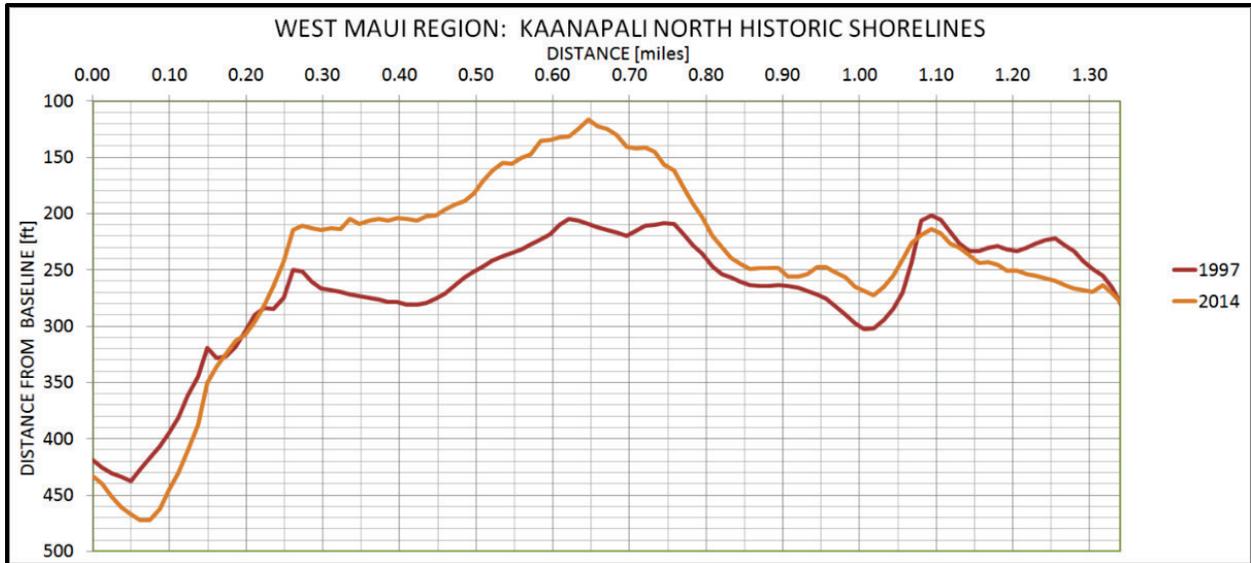
Figure A2. Volume change rates through time (cy/year) for the North Kaanapali littoral cell.
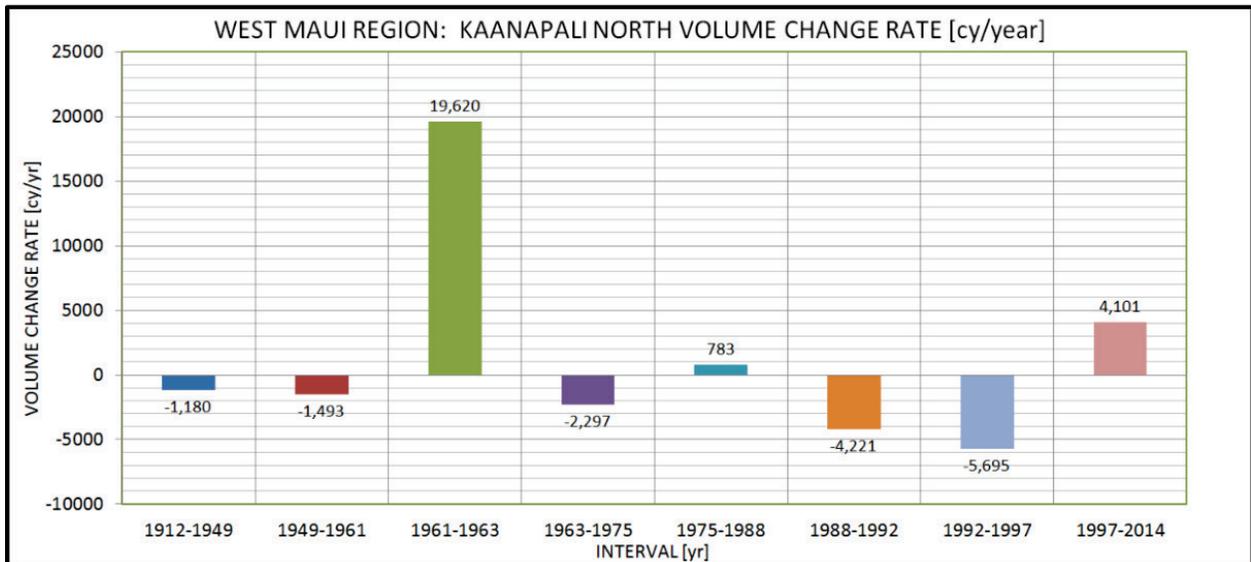
Figure A3. Shoreline positions within the Honokowai littoral cell for 1997 and 2014.
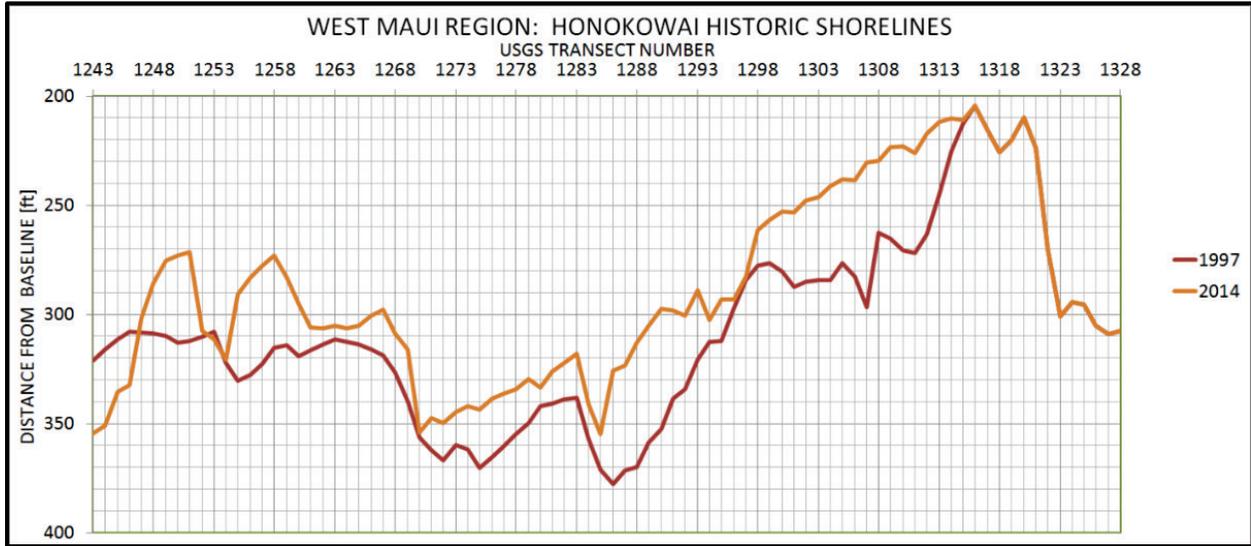
Figure A4. Volume change rates through time (cy/year) for the Honokowai littoral cell.
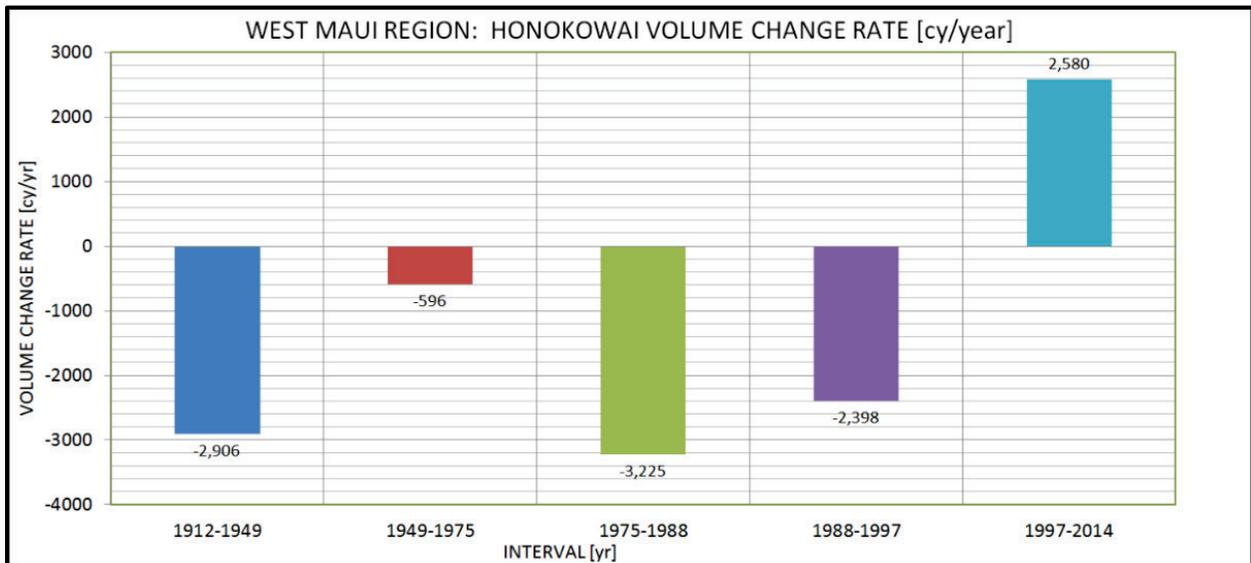
Figure A5. Shoreline positions within the Kahana littoral cell for 1997 and 2014.
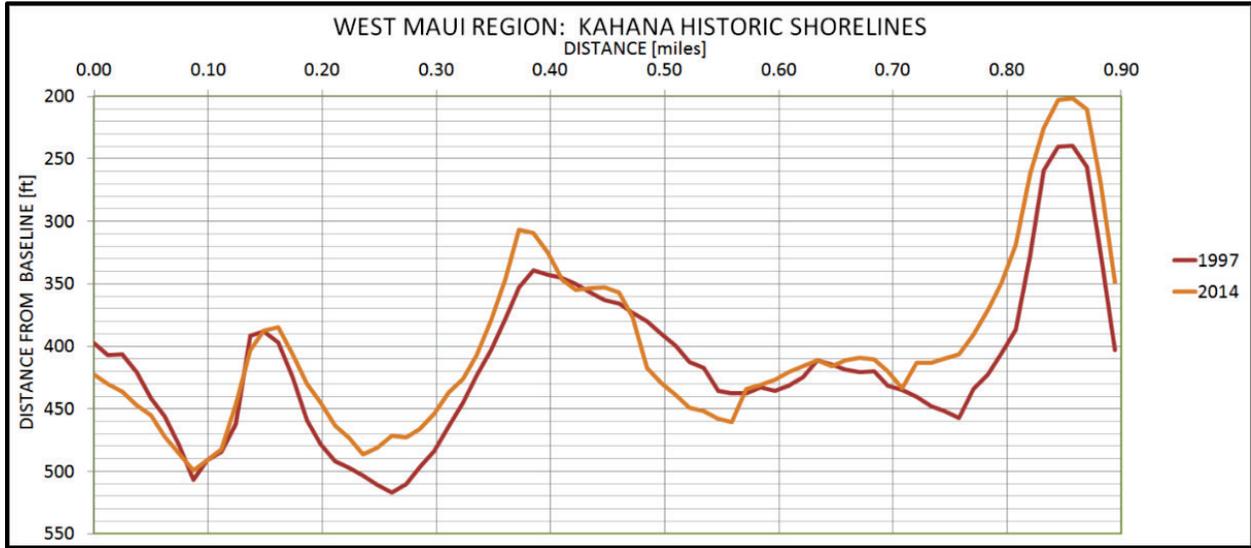
Figure A6. Volume change rates through time (cy/year) for the Kahana littoral cell.
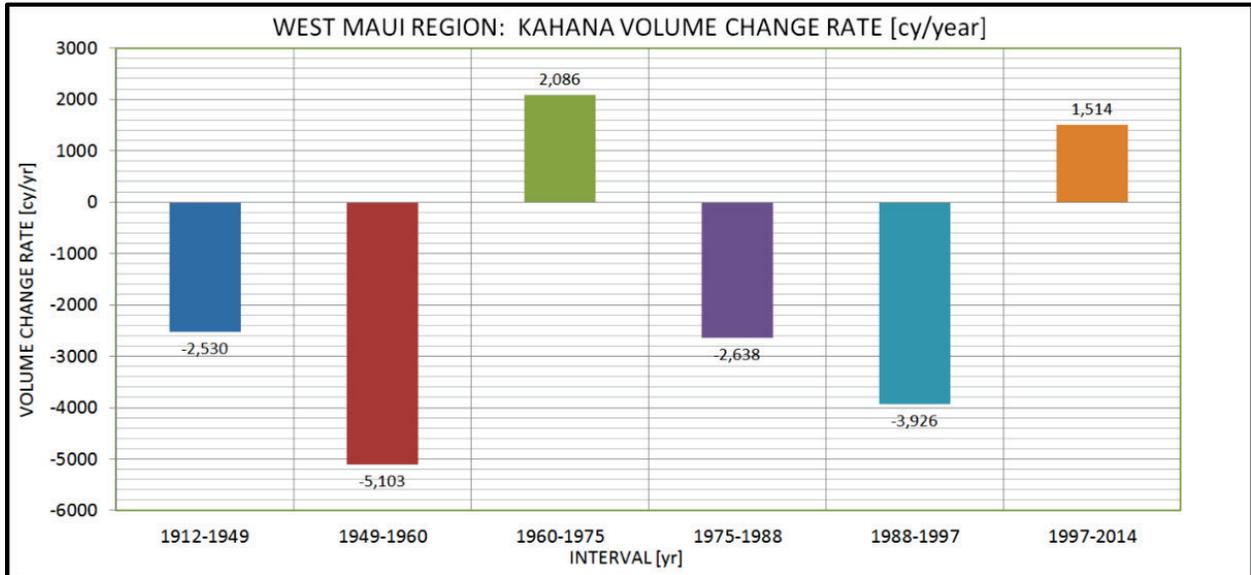
Figure A7. Shoreline positions within the Kahana Sunset littoral cell for 1997 and 2014.
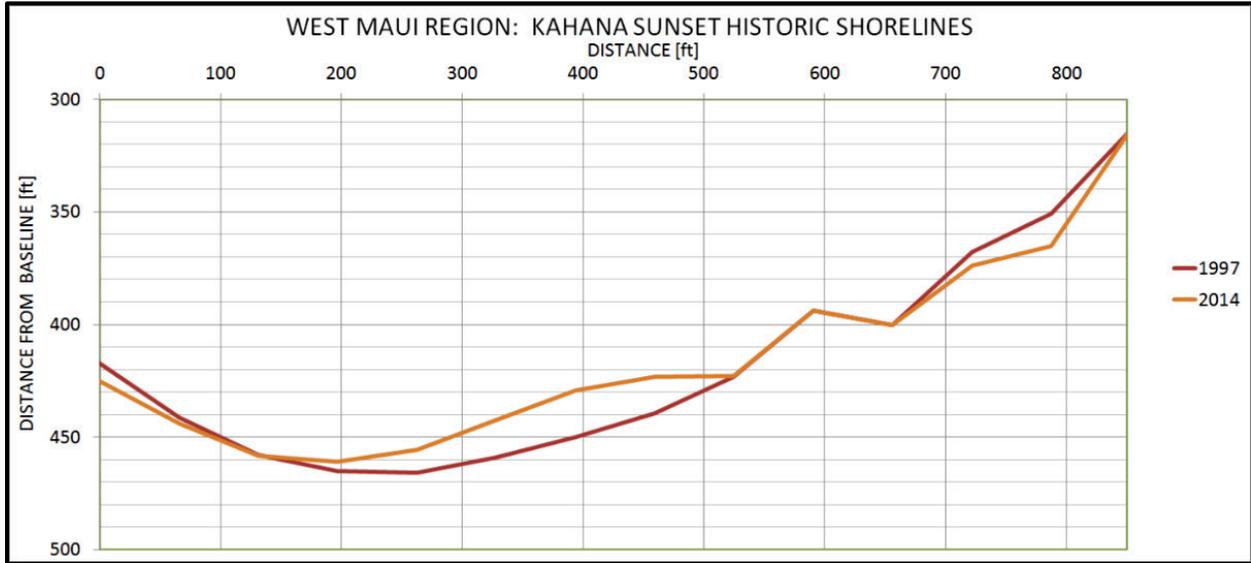
Figure A8. Volume change rates through time (cy/year) for the Kahana Sunset littoral cell.
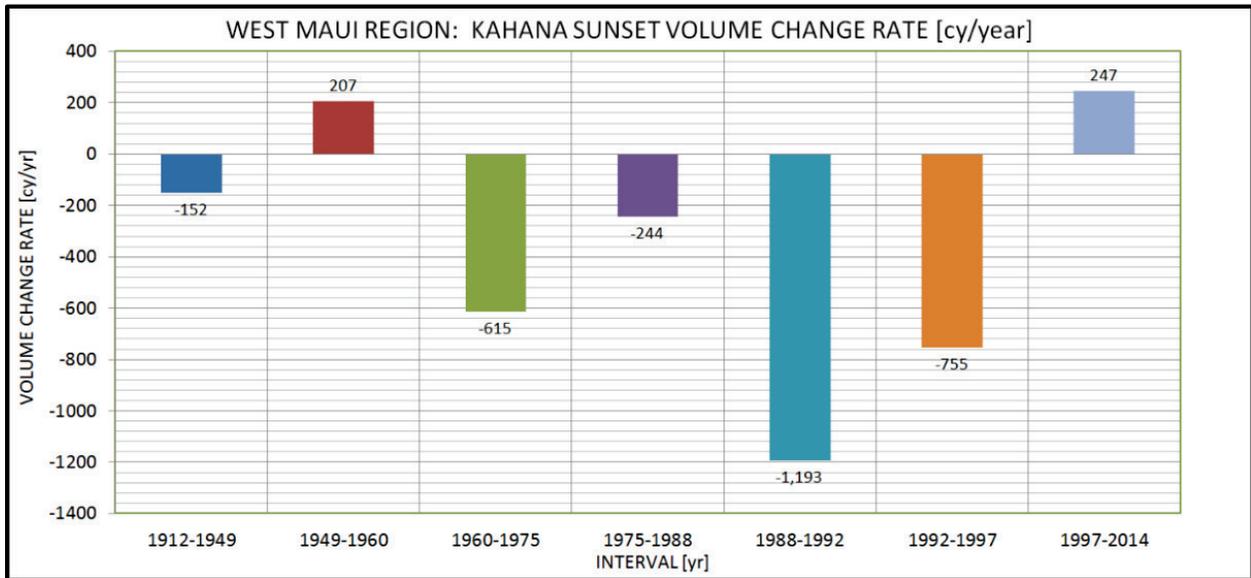
Figure A9. Shoreline positions within the Napili Bay littoral cell for 1997 and 2014.
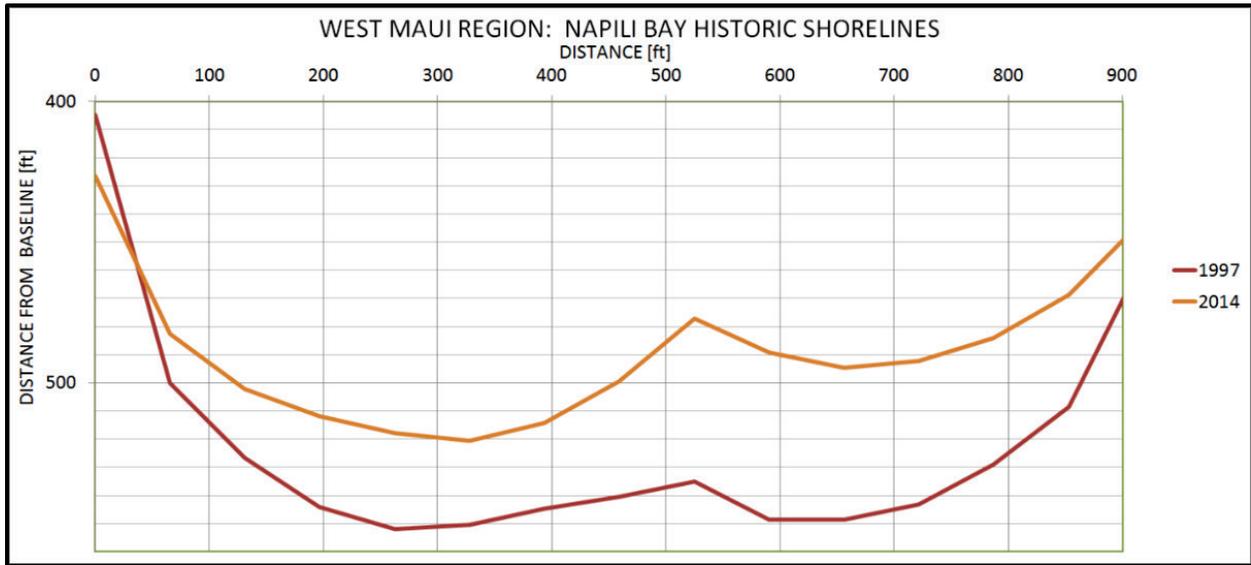
Figure A10. Volume change rates through time (cy/year) for the Napili Bay littoral cell.
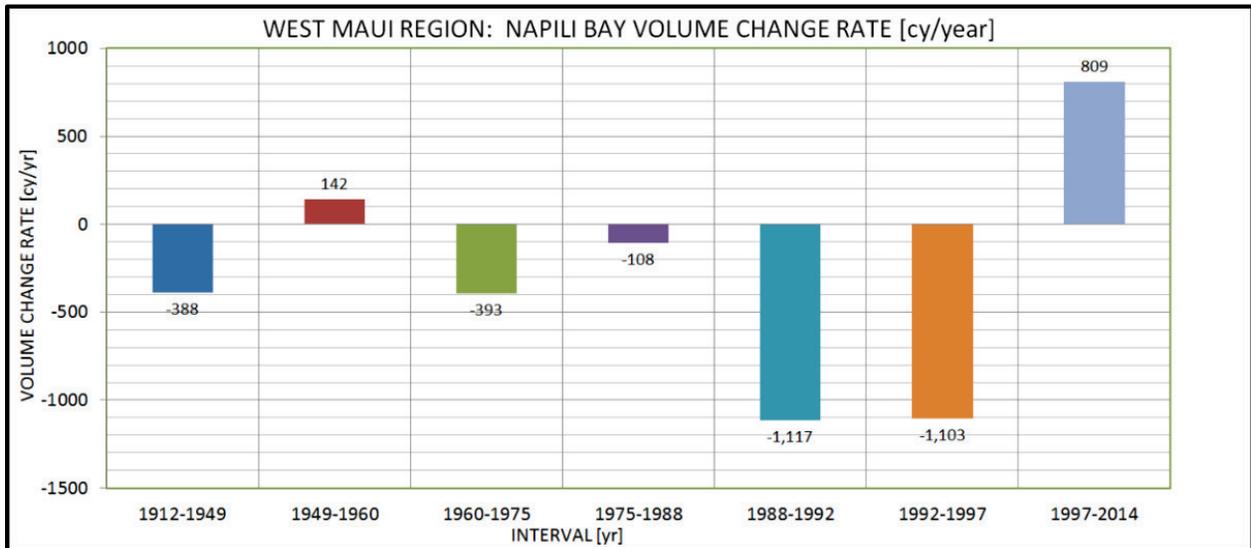
Figure A11. Shoreline positions within the Kapalua Bay littoral cell for 1997 and 2014.
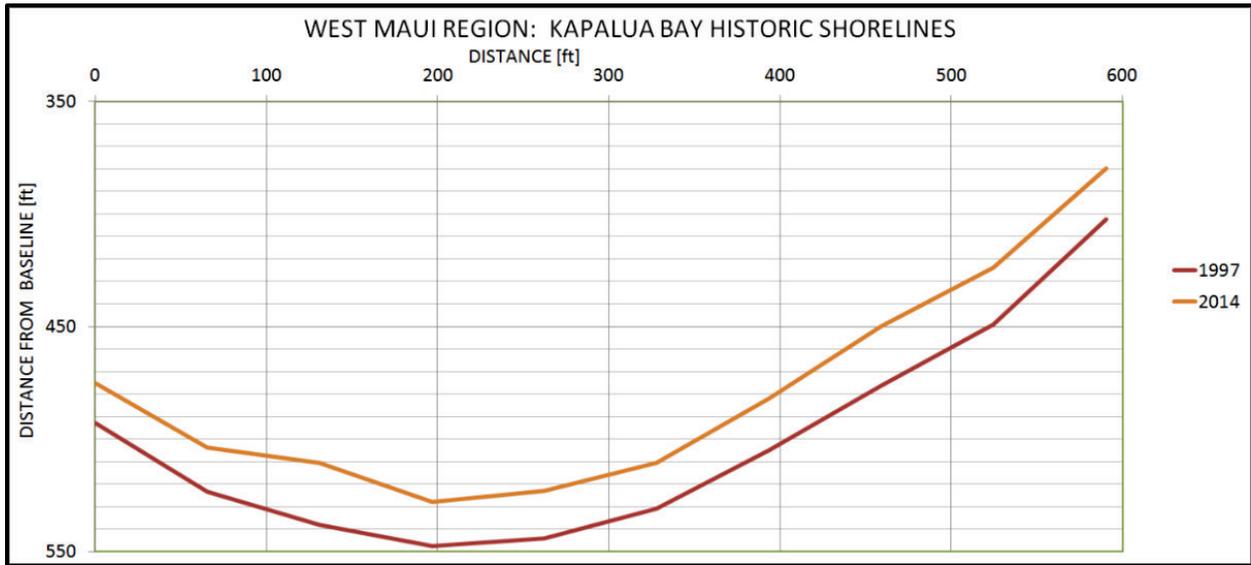
Figure A12. Volume change rates through time (cy/year) for the Kapalua Bay littoral cell.
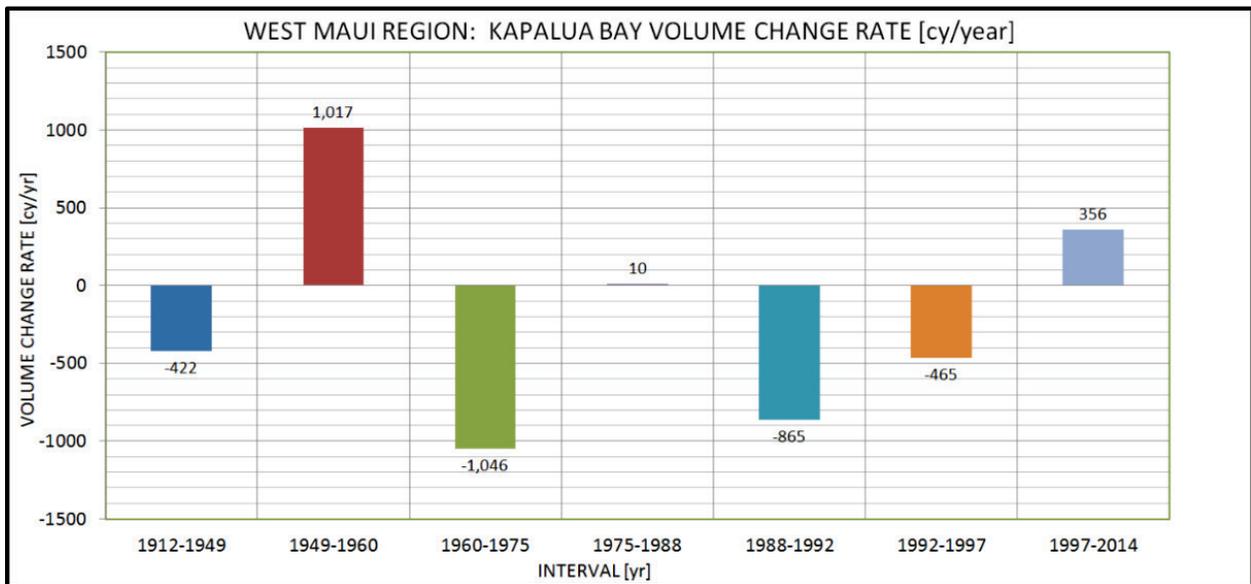
Figure A13. Shoreline positions within the Oneloa Bay littoral cell for 1997 and 2014.
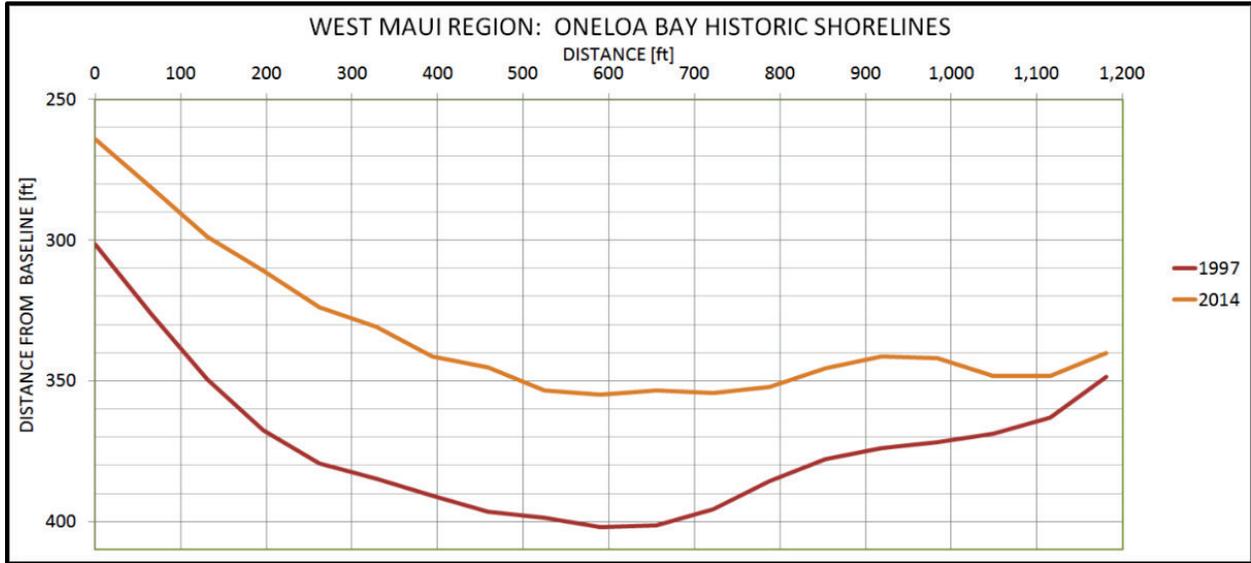
Figure A14. Volume change rates through time (cy/year) for the Oneloa Bay littoral cell.
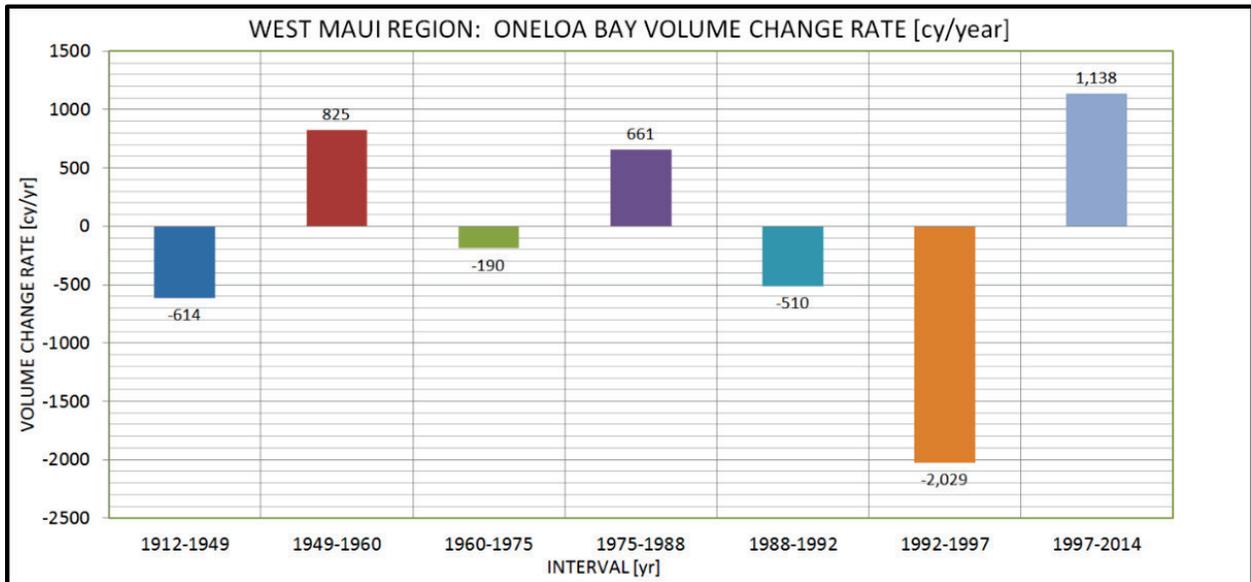
Figure A15. Shoreline positions within the Honokahua Bay littoral cell for 1997 and 2014.
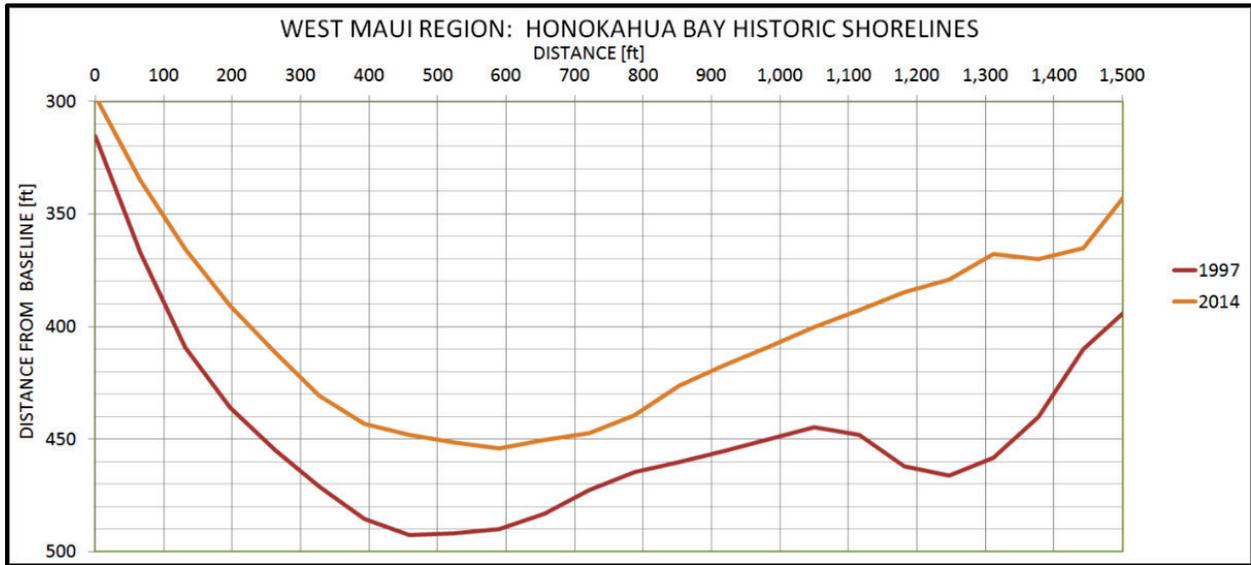
Figure A16. Volume change rates through time (cy/year) for the Honokahua Bay littoral cell.
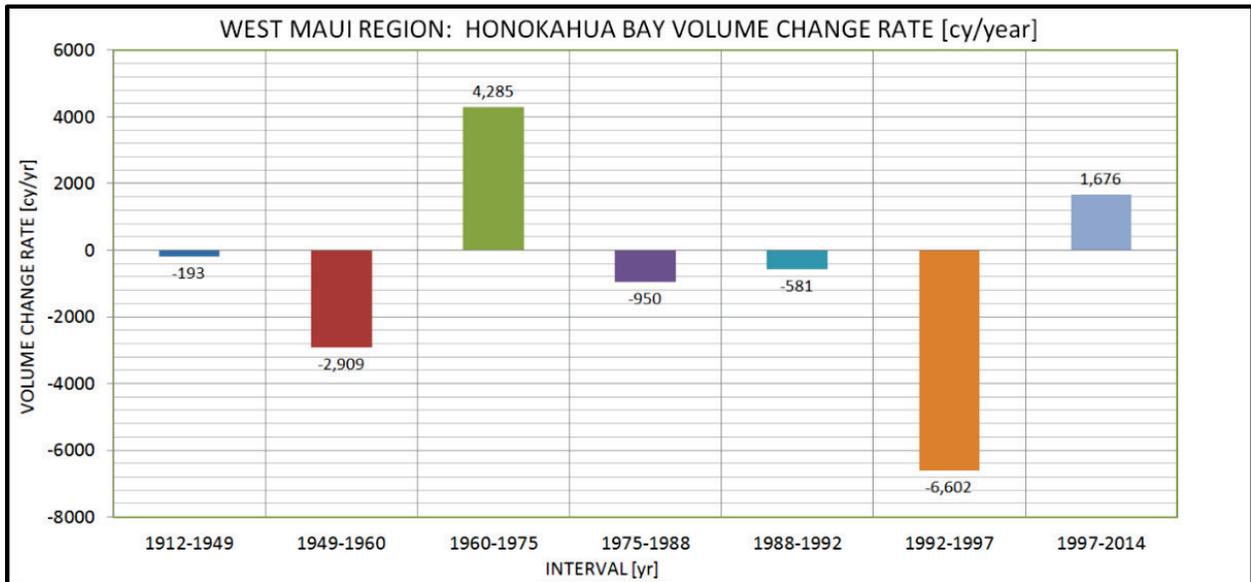
Figure A17. Shoreline positions within the Mokuleia Bay littoral cell for 1997 and 2014.
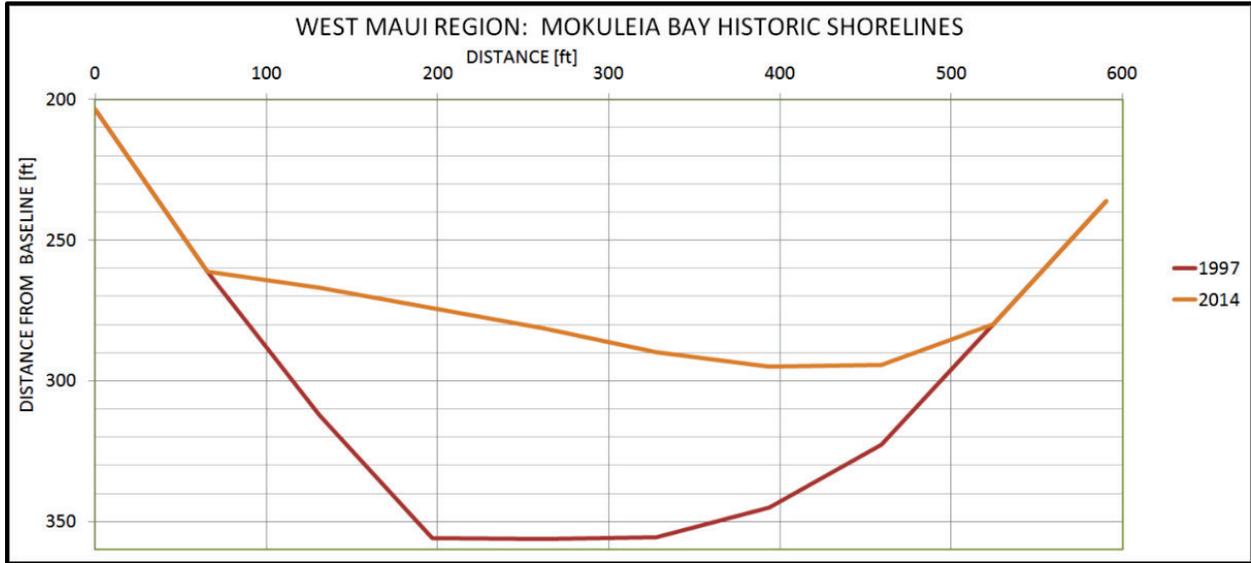
Figure A18. Volume change rates through time (cy/year) for the Mokuleia Bay littoral cell.
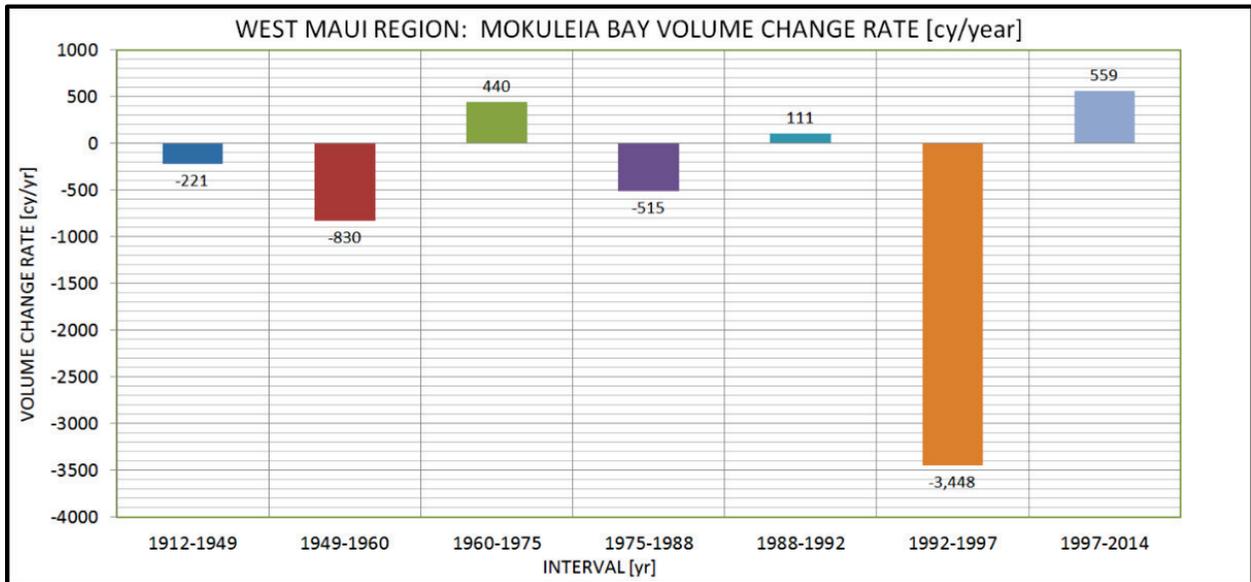
Figure A19. Shoreline positions within the Honolua Bay littoral cell for 1997 and 2014.
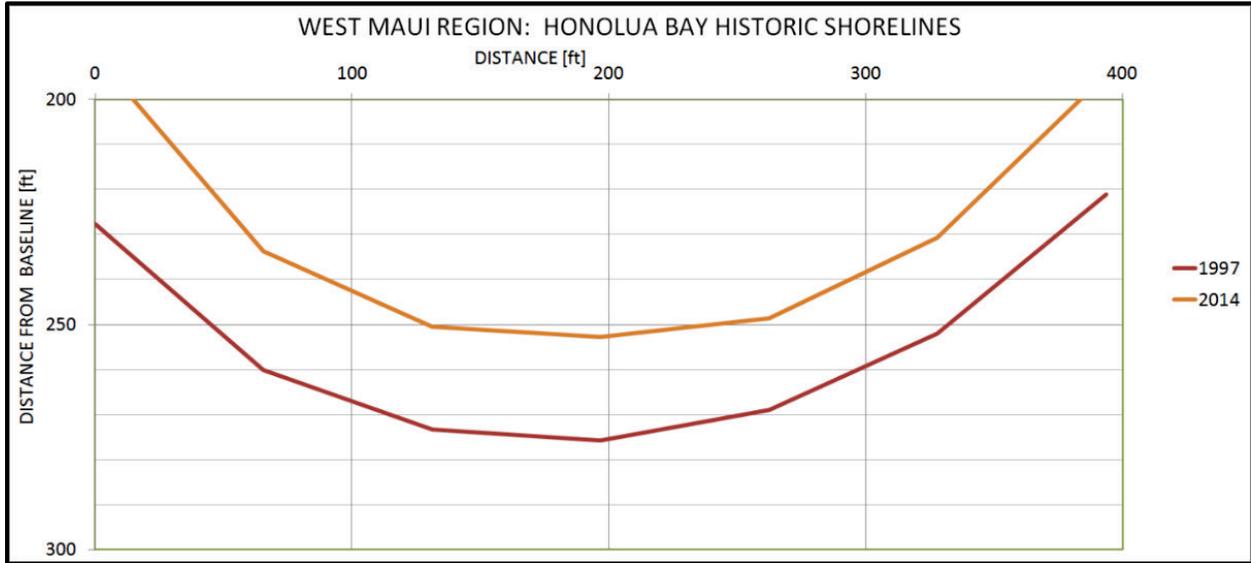
Figure A20. Volume change rates through time (cy/year) for the Honolua Bay littoral cell.
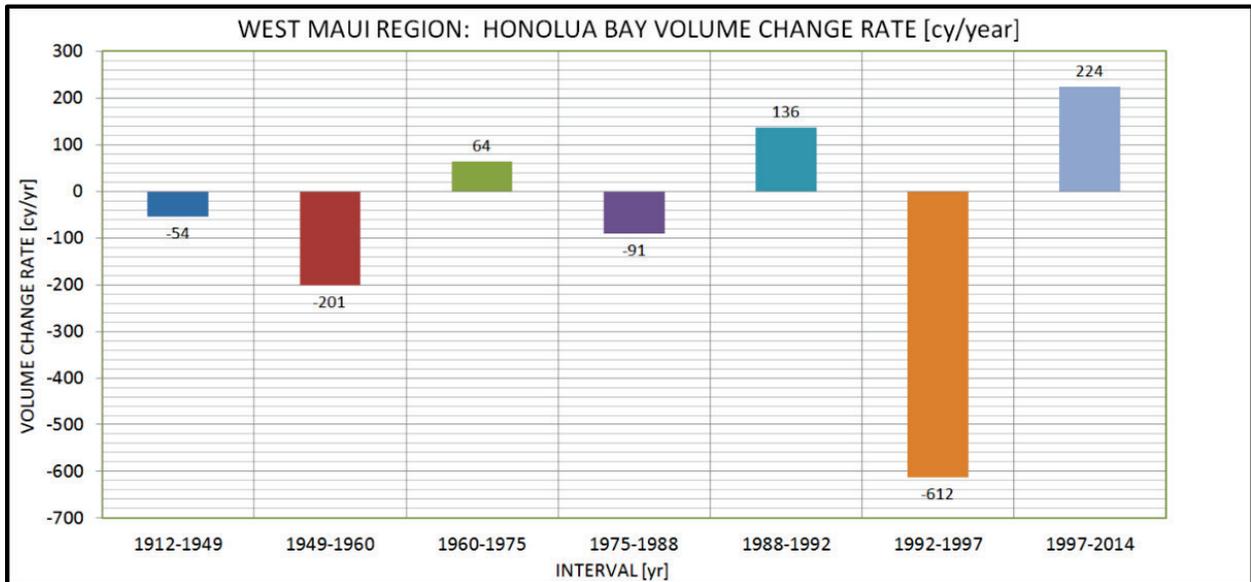
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13. SUPPLEMENTARY NOTES

14. ABSTRACT
This Technical Report provides a description of the Regional Sediment Management (RSM) investigations performed by the U.S. Army Corps of Engineers (USACE), Honolulu District (POH), along the West Maui coastal region of the Island of Maui, Hawaii. The methodology for determining volume change rates as well as numerical modeling is discussed, including the particle tracking modeling, in support of identifying sediment pathways for the development of the regional sediment budget for the West Maui coast. The West Maui Region incorporates a thin coastal margin backed by steep mountainous terrain that has been vastly altered by agricultural and urbanized development. Shoreline hardening is being proposed along portions of the region's coastline. Shoreline change for this area was quantified by the U.S. Geological Survey (USGS). All sub-regions were found to be erosional in the long and short-term, based on average rates. The dynamics of the area are complex with a wave climate affected by intricate bathymetry, wind, and island sheltering. Currents vary from nearshore to offshore and within the water column. Coastal morphology includes headlands and reefs with a very limited supply of sediment. Wave and current models indicate that large waves in the summer and winter drive the majority of sediment transport (northward-directed in summer and southward-directed in winter). Because of these seasonal patterns, the net transport of sediment is small. There is evidence of nearshore eddy formation that increases the complexity of sediment transport in the region with sediment pathways changing on short-term (hours) to longer term (weeks to months) temporal scales. This is a very dynamic and seasonally affected shoreline, and the present RSM study is one tool that will help inform future shoreline management in the region.

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Particle tracking model
Prevailing winds
Regional sediment budget
Regional sediment management
Sediment transport
Shoreline positions
Wave transformation