Summary and preliminary interpretations of USGS cruise A202HW: Underwater video surveys collected off of Oahu, Molokai, and Maui, Hawaii June- July 2002

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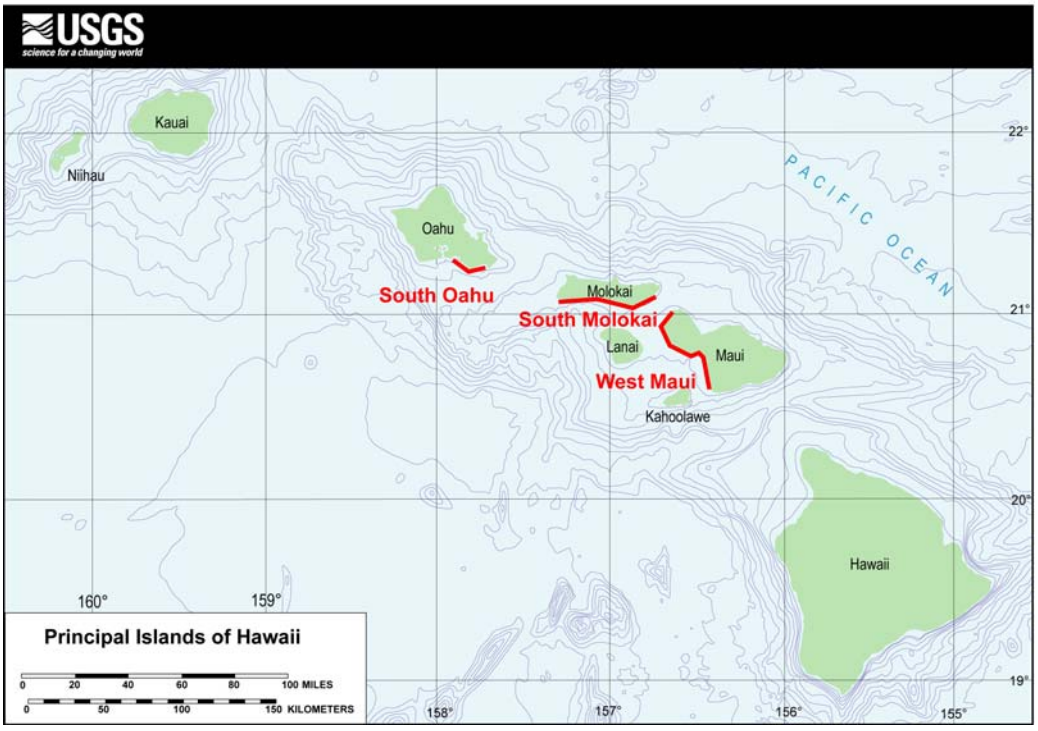

Summary and Preliminary Interpretations of USGS Cruise A-2-02-HW: Underwater Video Surveys Collected Off Of Oahu, Molokai, and Maui, Hawaii June- July 2002

By Ann Gibbs[1], Eric Grossman[1], *and* Bruce Richmond[1]

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ADDITIONAL DIGITAL INFORMATION

For additional information regarding USGS activity A-2-02-HW, please see:
http://walrus.wr.usgs.gov/infobank/a/a202hw/html/a-2-02-hw.meta.html

For an online PDF version of this report, please see:
http://pubs.usgs.gov/of/2005/1244/

For more information on the U.S. Geological Survey Western Region's Coastal and Marine Geology Team, please see:
http://walrus.wr.usgs.gov

For more information on the U.S. Geological Survey's Coral Reef Project, please see:
http://coralreefs.wr.usgs.gov

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The insular shelves of the southern coasts of the islands of Oahu and Molokai, and the western coast of Maui in the Hawaiian Archipelago were surveyed using ship-towed video between June 26 and July 11, 2002 as part of USGS-CMG cruise A-2-02-HW (Figure 1.1). The goals of the survey were to collect underwater video of the sea floor to: (1) Characterize substrate type and benthic habitat distribution; and (2) Ground-truth recently-acquired data including bathymetric (SHOALS) lidar, side-scan sonar, seismic reflection, and surface texture and grain size. The underwater video also aids in the interpretation and evaluation of Hawaii's benthic habitat maps produced by NOAA (Coyne *et al.* 2003) and coral reef distribution monitored by the State of Hawaii (Coral Reef Assessment and Monitoring Program – CRAMP; http://cramp.wcc.hawaii.edu/). Additional metadata for this cruise is available at: http://walrus.wr.usgs.gov/infobank/a/a202hw/html/a-2-02-hw.meta.html.

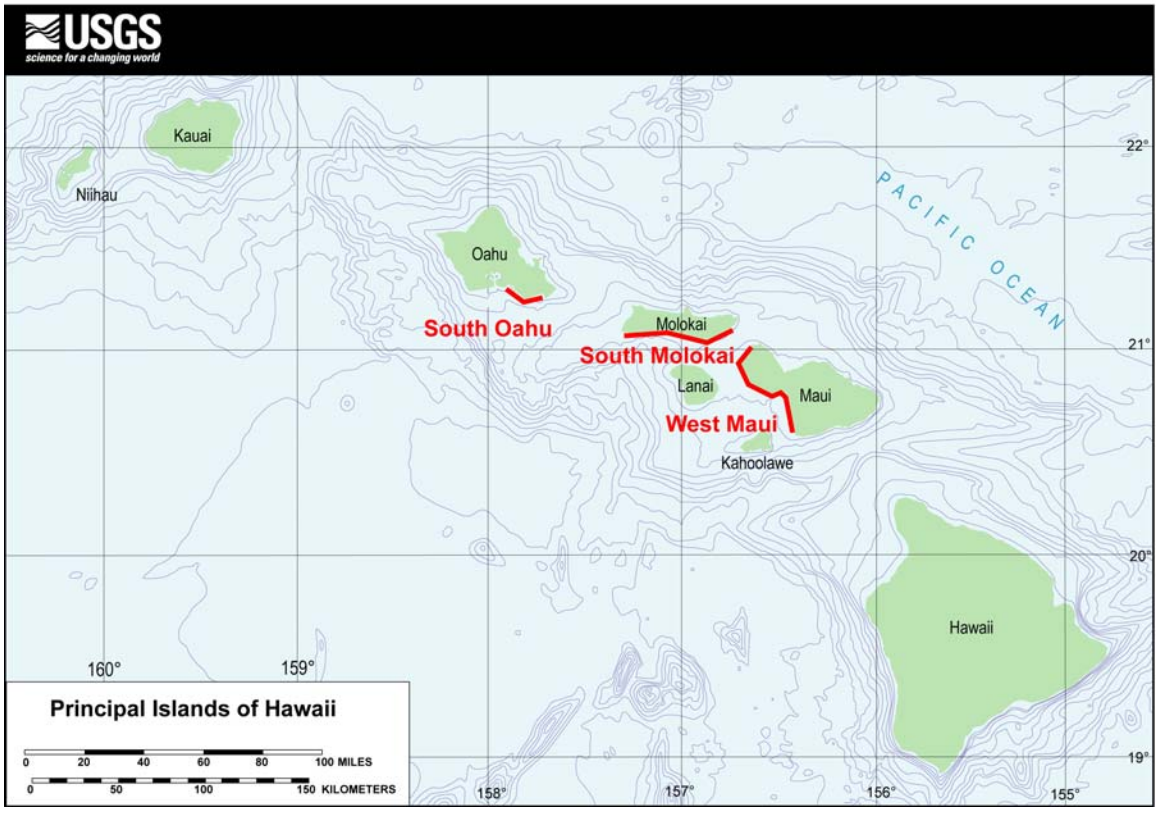

Figure 1.1 Map showing areas surveyed during USGS video mapping cruise A-2-02-HW

Equipment and Methods

Underwater video was collected with two different video camera systems towed behind the *AlyceC*, a 32-ft vessel operated by Cpt. Joe Reich of Molokai (Figure 1.2). The first camera system ("SLED") was fabricated by Hank Chezar (USGS) and included two video cameras – one looking down at nadir, the other slightly ahead along track, HID lights, two lasers, a depth transducer, and a conductivity/temperature (CT) sensor mounted in a robust sled requiring the use of a winch and block (Figure 1.3).

Figure 1.2 Photograph of the research vessel, *AlyceC* heading out of the Maalaea Harbor, Maui.

The second camera system ("SEAVIEWER") was constructed by Eric Grossman, Gerry Hatcher, and Kevin O'Toole of the USGS by integrating a SeaViewer Camera, LED lights, and battery-powered lasers into a small, hand-held frame (Figure 1.4). Weighing only 12 lbs, the SeaViewer was manually deployed and either 'towed' behind the boat or 'dropped' over the side. Live video from both systems was viewed topside on a standard CRT monitor and recorded directly to Digital-8 tape and DVD. Time, date, location, and ship speed were overlain on the video using the Sea-Trak™ GPS overlay system developed by SeaViewer Cameras.

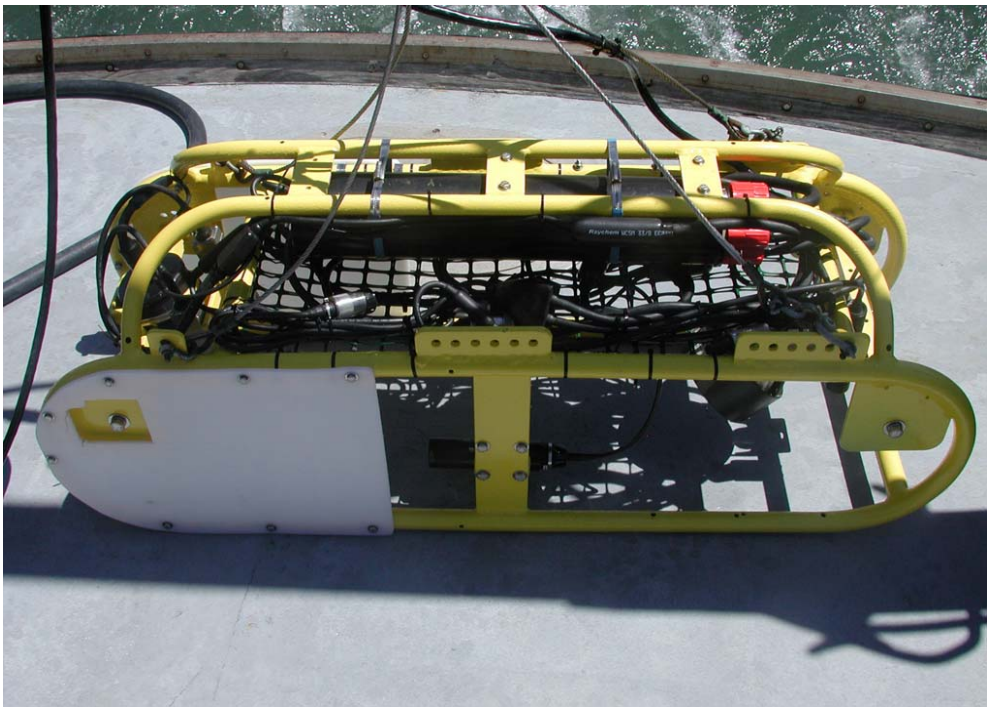

Figure 1.3 Photograph of the USGS video "SLED" camera system

Towed video transects were typically collected from the shallowest depth accessible by the *AlyceC* onshore to offshore, ending where the benthic environment was either 1) coral free; 2) the seafloor was an unchanging vegetated or non-vegetated sand sheet; 3) where the limit of visibility was reached; or 4) we had deployed maximum cable out (200 feet; ~61 m). Transects typically started in water depths of about 10 m but extended into water depths as great as 40 m. At some locations, shore parallel transects were collected to obtain more detailed information on alongshore variations and to better define transitions in bottom type and/or coral reef environments.

Simultaneous navigation, recording of ship position, and feature annotation was conducted in real-time using Red Hen Systems VMS200 hardware and MediaMapper software on a PC laptop (Figure 1.5). Location data was recorded using a handheld, WAAS-enabled, Garmin GPS76 receiver. The stated horizontal accuracy of the Garmin GSP76 is less than 3 m when receiving WAAS corrections. The VMS200 transmitted NMEA formatted GPS data at two second intervals to the 1st audio channel of the video tape. A database was simultaneously created by MediaMapper to cross-reference the GPS locations and video time codes. This technique allowed for navigation

and video to be viewed real-time and the location of features of interest and comments (e.g. Start/End of Lines, substrate types) to be added to the database during data collection. Back in the lab, this technique allowed rapid random access to the original video by selecting locations along the navigation trackline within the MediaMapper software package. Video could be interactively queried and geographically referenced feature annotations added to the data base.

High resolution 1999 and 2000 SHOALS bathymetry (courtesy Jim Gardner, USGS) and geo-rectified 1997 aerial photography (courtesy Chip Fletcher *et al.,* Univ. of Hawaii.; http://www.soest.hawaii.edu/coasts/data/index.html) were used as base map layers in the MediaMapper software. Survey and transect information, starting and ending line positions, environmental conditions, and pertinent features observed on the video were marked and logged real time during the surveys. Eric Grossman provided a running commentary of seafloor substrate type, coral and algal genera/species identifications, coral colony morphologies, and other bottom characteristics. This information was recorded on the primary audio track of the DVD.

It should be noted that all navigation information, including the location of the camera and any features referenced along the video, is the position of the GPS antenna on board the ship and not the real location of the camera in the water. A reasonable estimate of the camera's position behind the ship's GPS (the "layback") was determined during this cruise by manually measuring the distance of the camera behind the GPS over the range of operational ship velocities and depths. Resulting curves of layback distance are shown in Figure 1.6. Positional data in this report were not corrected for layback and thus represent only approximate locations. The layback curves are included here so future users can refer to them in order to determine more accurate positions.

Figure 1.4 Photograph of the SEAVIEWER camera system rigged to collect towed video.

Figure 1.5 Data acquisition for the camera SLED included a DVD recorder, monitor, and text overlay unit housed in ocean-going black case (left). Video from the SEAVIEWER system was recorded on a Digital-8 tape deck (in yellow waterproof box, center) after the. GPS data was burned onto the video image and written to the audio track. A PC Laptop (right) displayed track lines for navigation, recorded incoming GPS position data, and output display topside for captain's navigation.

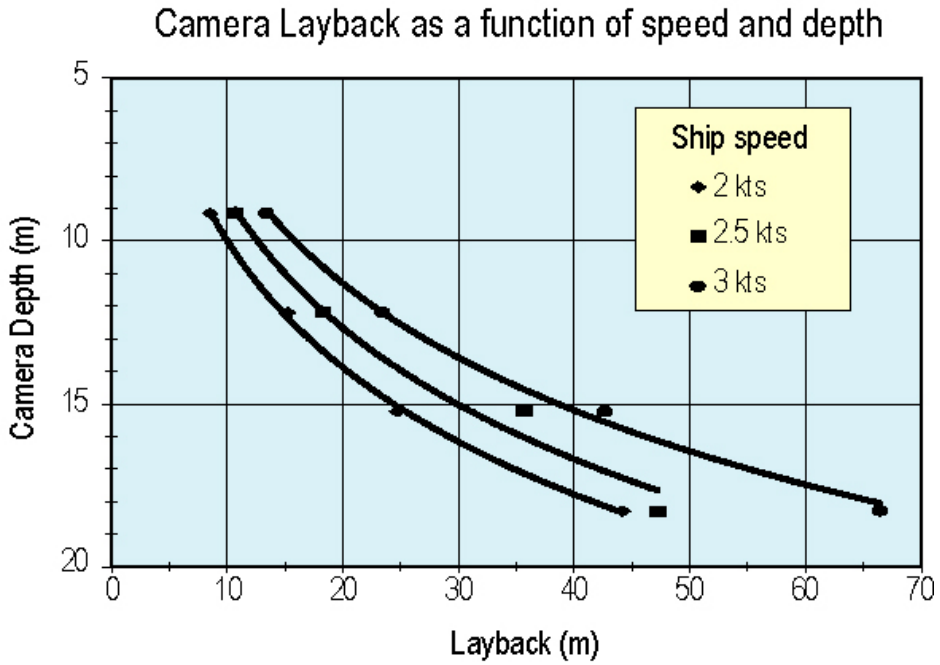

Figure 1.6 Plot of layback distance as a function of ship speed and camera depth.

Substrate Type and Benthic Habitat Descriptions

Descriptions of substrate and bottom types included in this report are loosely based on the Habitat Classification Scheme developed by NOAA for the Main 8 Hawaiian Islands (Coyne *et al.,* 2003). Our descriptions differ from the NOAA scheme in that only general habitats are described and percent cover within the different categories are not determined. Definitions of the habitats (from Coyne *et al.,* 2003) and representative photos acquired from the video are presented below.

Unconsolidated sediment-Sand: Coarse sediment typically found in areas exposed to currents or wave energy.

Uncolonized Pavement: Flat, low relief, solid carbonate rock that is often covered by a thin sand veneer. The pavement's surface often has sparse coverage of macroalgae, hard coral, zoanthids, and other sessile invertebrates that does not obscure the underlying surface.

Colonized Pavement: Flat, low-relief, solid carbonate rock with coverage of macroalgae, hard coral, zoanthids, and other sessile invertebrates that are dense enough to begin to obscure the underlying surface.

Colonized Volcanic Rock/Boulder: Solid volcanic rock that has coverage of macroalgae, hard coral, zoanthids, and other sessile invertebrates that begins to obscure the underlying surface.

Aggregated Coral: Coral-dominated formations with high relief and structural complexity. Often serve the same role as linear reef in fringing reef systems where the reef crest is relatively unorganized.

Spur and Groove: Habitat having alternating sand and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment. The coral formations (spurs) of this feature typically have a high vertical relief relative to pavement with sand channels and are separated from each other by 1-5 meters of sand or bare hardbottom (grooves), although the height and width of these elements may vary considerably. This habitat type typically occurs in the fore reef or bank/shelf escarpment zone.

Continuous Macroalgae: Macroalgae covering 90 percent or more of the substrate. May include blowouts of less than 10 percent of the total area that are too small to be mapped independently (less than the MMU). This includes continuous beds of any shoot density (may be a continuous sparse or dense bed). **Representative Species:** *Caulerpa spp., Dictyota spp., Halimeda spp., Lobophora variegata , Laurencia spp.*

The remainder of this cruise report includes three stand-alone chapters that summarize the surveys and observations for each individual island. Preliminary interpretations of bottom characteristics and transition zones are described. A more comprehensive data set, including water depth, spatial extent of benthic habitats, percent cover, species identification, etc. may be released for each island after more extensive review of the data. Descriptions of the four lines at Maui Nui and the 365 'drops' collected on Molokai are not included in the report. A cruise summary and list of data (tapes) collected can be found in Appendix I and II, respectively.

2. Substrate and Benthic Habitat Mapping of the Southern Oahu, Hawaii Insular Shelf

Eric Grossman

General Mapping Results

Twenty kilometers of bottom video data were collected along 17 transects between Kewalo Basin and Koko Head Crater between June 26 and 28, 2002 (Figures 2.1 and 2.2, TABLES 2.1 and 2.2). Fourteen of the 17 transects were oriented perpendicular to the coast, while three were oriented parallel to the coast to tie several cross-shore lines together. Transect locations and orientations were selected to ground truth recent USGS side-scan sonar, seismic reflection, and substrate texture (grain size) surveys and provide large spatial characterization of coral coverage toward NOAA efforts to assess and monitor coral health.

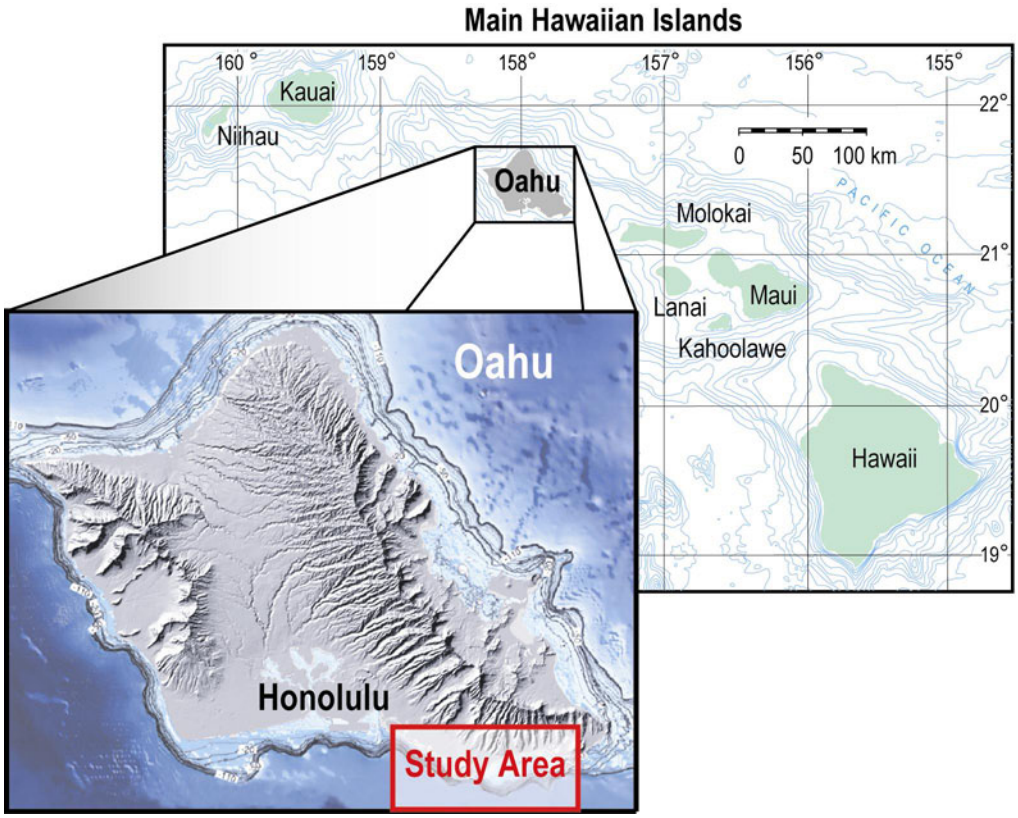

Figure 2.1 Study area for the benthic habitat mapping conducted off the south shore of the Island of Oahu, Hawaii.

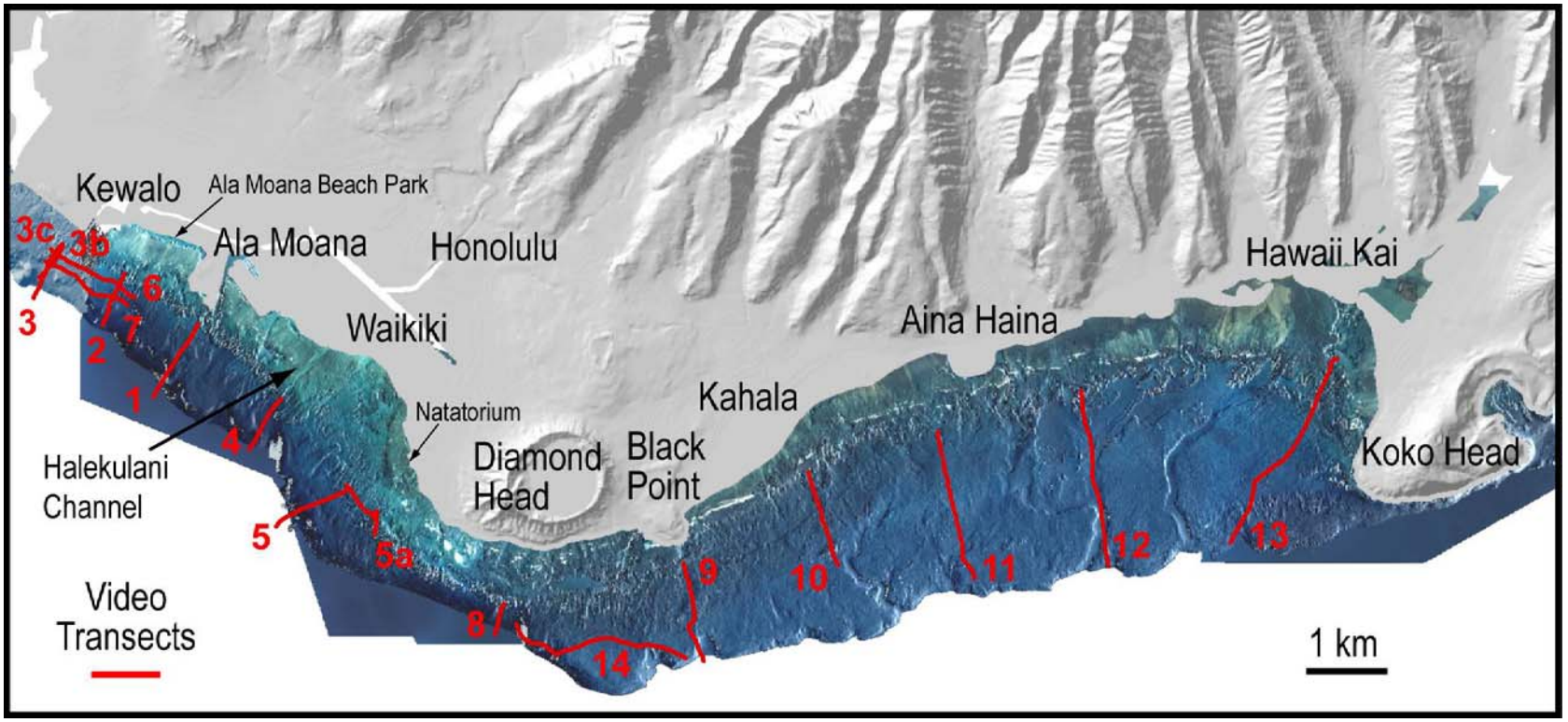

Figure 2.2 Location map of bottom video transects along the South Oahu shelf.

Results of the bottom characterization of substrate and benthic habitat are presented below for the three general areas, Kewalo to Ala Moana, Diamond Head to Black Point, and Black Point to Koko Head.

Kewalo to Ala Moana

The Kewalo – Ala Moana region bordering the greatest concentration of urban development on Oahu shows a gradient in coral cover from relatively high cover near Kewalo to very low cover in the center of Waikiki. The topography has high relief near Kewalo and is much flatter and smoother offshore of Ala Moana. The landward portions of Transects 3, 3b, and 3c (water depths of - 4 to -11 m) are characterized by large patch reefs and aggregated coral, where local cover of *Porites lobata* and *Porites compressa* ranges between 50% and 80%. Patch reefs are separated by active sand channels where sand movement under moderate wave energy scours the base and walls of patch reefs. Along the base and walls, coral cover is low and consists of encrusting coral and coralline algae. The substrate offshore of Kewalo is characterized by steadily decreasing coral cover seaward of the 15 m contour where fossil reef with thin sand cover dips into a large sand field at approximately 18 m depth. Coral cover declines rapidly immediately east of the Kewalo Basin channel. Transects 6 and 7 that parallel the Ala Moana Beach Park shoreline show a decrease in coral cover eastward and a general increase in fleshy algae. The substrate along transects 6 and 7 are characterized as uncolonized pavement. Narrow sand channels are common between coral spurs along transect 6 along the west end of Ala Moana Beach Park, while toward the east end, they coalesce into fewer but larger sand fields. Transect 7 is largely composed of uncolonized pavement and sand fields. The reef offshore of Ala Moana (Transect 1), transitions seaward from a sparsely colonized pavement to an uncolonized pavement at the ~10 m contour. Within the center of Waikiki near the Halekulani Channel (Transect 4) the substrate is low-sloping and largely an uncolonized pavement. Sparse and small head corals occur near the channel, while evidence of sand abrasion is extensive on the higher surfaces of the fossil reef terrace.

Diamond Head to Black Point

The shelf offshore of Diamond Head and Black Point is narrow and steep. A narrow shallow reef flat that is exposed at low tide fringes the coast between the Natatorium and Diamond Head Beach and is likely fossil. Coralline algae are common on this feature and coral colonies that exist are

generally sparse and small typically comprised of *Porites lobata* and *Pocillopora meandrina*. Transects 5 and 5a are characterized by uncolonized pavement that exhibits occasional small 0.5 m to 1.0 m scarps running shore-parallel. Sand fields are common near the seaward extent of these two transects and coral cover is sparse. Transects 8 and 14 range between water depths of 15 m and 25 m and are dominated by fossil reef pavement and sand fields. Isolated coral communities occur along transect 14, ranging from several meters to 10 m in diameter, are composed of lobate and encrusting *Porites lobata* and *Montipora capitata* and stout branching *Pocillopora meandrina* and *Pocillopora eydouxi* corals. Isolated gardens of *Halimeda sp.* are present in the deeper sand fields in water depths of 15 m to 20 m. The largely basalt boulder substrate along the landward portion of Transect 9 directly offshore of Black Point is partly colonized by stout-branching *Pocillopora meandrina* and encrusting *Porites lobata corals*. Coral cover quickly decreased offshore in water depths >10 m where the substrate is primarily uncolonized pavement.

Black Point to Koko Head

Between Black Point and Koko Head the south coast of Oahu is arcuate with a broad fringing reef that reaches up to 1.5 km wide between Aina Haina and Hawaii Kai. The reef crest is exposed at low tide and the fore reef drops off steeply in places, especially near Kahala. Coral cover along the majority of the fringing reef is low and composed of small lobate, stout branching and encrusting coral colonies. Offshore of approximately the 10 m isobath, the fringing reef pinches out onto a wave-abraded pavement composed of volcanic tuff. Several mounds with relief of 2-4 m exist on the flat and low-sloping volcanic terrace and support a healthy community of coral and coralline algae, presumably because they are well removed from sand abrasion below. These mounds are volcanic remnants capped by thin veneers of recent coral and coralline algae growth. Robust, stout-branching *Pocillopora meandrina, Porolithon gardineri*, and encrusting *Porites lobata* corals are common seaward of the reef crest of Kahala (Transect 10). At the base of the fore reef along Transect 10 (-12 m), the substrate transitions from partly colonized pavement to uncolonized pavement. A large sand channel emanating from a drowned paleostream crosses the transect between –12 and –14 m. Seaward of the 14 m isobath, the Kahala shelf is characterized by uncolonized pavement with sparse volcanic remnants topped by modest coral cover. A similar trend of low coral and coralline algal cover within the reef crest and fore reef that pinches out onto uncolonized pavement and volcanic tuff characterizes Transects 11-13. The only significant difference among these three areas occurs along Transect 13 offshore of Hawaii Kai. Here an

extensive sand field has formed within the deep embayment immediately west of Koko Head and has filled much of the paleostream channel emanating from Hawaii Kai. Several small reef outcrops occur within the landward portion of the embayment but most of these are uncolonized or only partly colonized by sparse coralline algae and encrusting *Porites lobata* corals.

TABLE 2.1 Underwater video transect summary for S. Oahu.

Line*	Camera	Location	Length (km)
OHVM_1	Sled	E. Ala Moana	1.05
OHVM_2	Sled	W. Ala Moana	0.69
OHVM_3	Sled	Kewalo	0.75
OHVM_3b	Seaviewer	Kewalo	0.3
OHVM_3c	Seaviewer	Kewalo	0.28
OHVM_4	Sled	Halekulani Channel	0.75
OHVM_5	Sled	Natatorium	0.98
OHVM_5a	Sled	50 ft isobath (15.2 m) b/w lines 5 and 8	1
OHVM_6	Sled	40 ft isobath (12.2 m) b/w lines 2 and 3	1.23
OHVM_7	Sled	60 ft isobath (18.3 m) b/w lines 2 and 3	1.18
OHVM_8	Sled	Central Diamond Head	0.43
OHVM_9	Sled	Black Point	1.3
OHVM_10	Seaviewer	Kahala	1.23
OHVM_11	Sled	Aina Haina	1.9
OHVM_12	Sled	Kawai kui Beach Park	2.21
OHVM_13	Sled	Hawaii Kai	2.7
OHVM_14	Sled	50 ft isobath (15.2 m) b/w Black Pt. and Central Diamond Head	2.36
		Total length surveyed (km)	20.34

*Video data of transect lines OVHM 1-14 are archived on Tapes 1-9 (9).

TABLE 2.2 UTC, start (SOL) and end (EOL) locations of survey transects.

Line	UTC	Latitude*	Longitude*
1_SOL	20021781814100	21.279578	-157.847683
1_EOL	20021781827540	21.271567	-157.852973
2_SOL	20021772253480	21.285180	-157.856295
2_EOL	20021772308180	21.279467	-157.858887
3_SOL	20021772044080	21.288418	-157.863568
3_EOL	20021772052420	21.282517	-157.866968
3b_SOL	20021772158380	21.288210	-157.863510
3b_EOL	20021772202220	21.286008	-157.864822
3c_SOL	20021772235020	21.286585	-157.864533
3c_EOL	20021772252120	21.284793	-157.866277
4_SOL	20021782052000	21.271253	-157.837937
4_EOL	20021782101040	21.265725	-157.841787
5_SOL	20021782014220	21.261127	-157.830477
5_EOL	20021782028040	21.257228	-157.838655
5a_SOL	20021781949260	21.256243	-157.827082
5a_EOL	20021782006100	21.261702	-157.830348
6_SOL	20021772320120	21.287905	-157.864905
6_EOL	20021772336000	21.282490	-157.855035
7_SOL	20021772343360	21.281642	-157.855987
7_EOL	20021772357140	21.286523	-157.865530
8_SOL	20021792154580	21.248512	-157.811957
8_EOL	20021792201060	21.245163	-157.813057
9_SOL	20021792234460	21.252843	-157.790883
9_EOL	20021792253280	21.242093	-157.788567
10_SOL	20021790452400	21.262762	-157.776022
10_EOL	20021790508420	21.252520	-157.772693
11_SOL	20021790408360	21.250938	-157.756743
11_EOL	20021790436400	21.267033	-157.760760
12_SOL	20021790314260	21.271420	-157.743948
12_EOL	20021790349380	21.252193	-157.740847
13_SOL	20021790214240	21.274853	-157.713845
13_EOL	20021790254120	21.254625	-157.726578
14_SOL	20021792259080	21.242437	-157.790627
14_EOL	20021792336020	21.246328	-157.810595

UTC time format is YYYYDDDHHMMSST (year, Julian_day, hour, minute, seconds, tenths)
Coordinates are decimal degrees, WGS84

3. Substrate and Benthic Habitat Mapping of the Southern Molokai, Hawaii Insular Shelf

Bruce M. Richmond

Fifteen transects (Figure 3.1, Tables 3.1 and 3.2) were collected off the southern coast of Molokai between June 30 and July 2, 2002. Both the SLED and SEAVIEWER camera systems were used to characterize the seabed in support of coral community studies (e.g. Jokiel *et al.,* 2004), reef history and development (e.g. Engels *et al.*, 2004), reef morphology (e.g. Storlazzi *et al.,* 2003), and benthic habitat mapping (e.g. Brown *et al.,* 2004). Both reef-parallel and reef-normal video transects were collected and extended from where it was navigably safe in the shallow areas (~4-6 m water depths) offshore to beyond the depth where significant coral colonies occurred, generally 25-30 m.

The south coast of Molokai encompasses the best developed fringing reef of the main 8 Hawaiian Islands. An extensive reef flat, up to 1,500 m wide, is fronted by a reef crest and well-developed fore reef zones. The fringing reef extends for about 50 km along the semi-protected southern coast. Variations in reef morphology and habitat composition appear to be controlled by a combination of oceanographic influences (primarily wave energy), terrigenous input, and antecedant reef structure (Storlazzi *et al.,* 2003; 2005; Barnhardt *et al.,* 2003).

Individual Transect Descriptions

The following are brief descriptions of the general orientation, coverage, and bottom type observed for each video transect collected along southern Molokai. Table 3.1 summarizes the camera system used, general location, and line length for each transect. The line numbering follows the original field designation.

MVM1 is a reef normal transect. The line traverses a deep "blue hole" (no visible bottom on the video) and extends over the reef crest and through the fore reef, to water depths greater than 35 m. The reef section consists mostly of aggregated coral with scattered sand pockets and channels, locally comprising up to 50% of the overall bottom type. The deeper fore reef portion of the line is composed of sand, colonized by up to 50% macroalgae (*Halimeda sp.*?) with localized coverage approaching 100%.

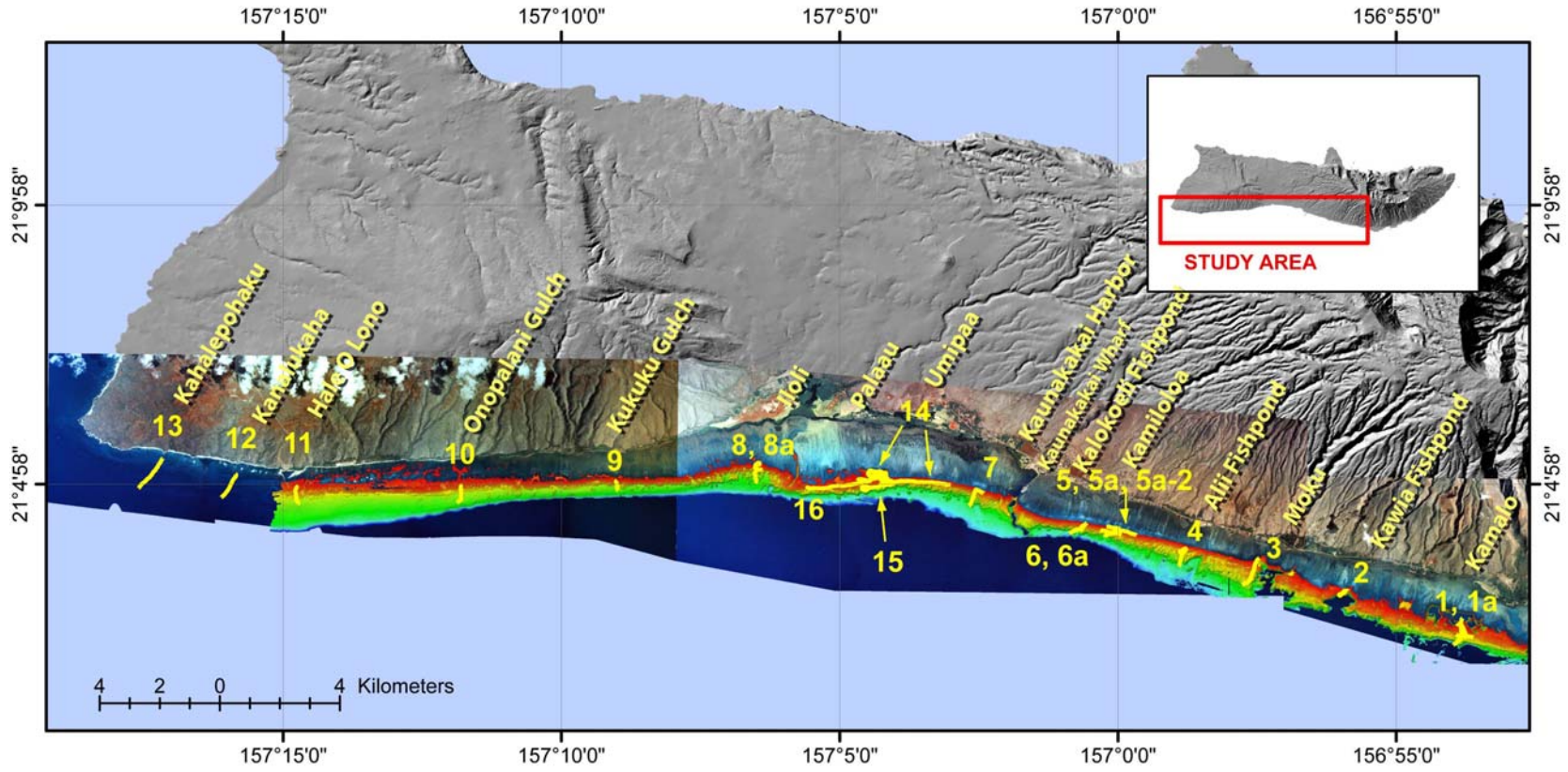

Figure 3.1. Underwater video trackline locations overlain on a composite image (color vertical aerial photography, SHOALS lidar, and DEM shaded-relief) of the Molokai study area.

MVM1a is an east to west, reef parallel transect along the ~10 m depth contour. Aggregated coral is the dominant bottom type for most of the line with scattered sand pockets and a few small sand channels (grooves).

MVM2 begins as a reef parallel line running east to west near the reef crest (and back reef areas) then veers obliquely offshore towards the southwest and the deeper fore reef. A loop is made at the fore reef and the track heads towards the northeast and reef crest where a final turn to the west is made. The transect is comprised primarily of 3 bottom types: shallow sand of the back reef area; aggregated coral on the reef crest and reef front, and sand and macroalgae of the deeper fore reef. Video quality is poor over the fore reef area and generally good over the reef front and in shallower areas.

MVM3 begins as a north to south, reef-normal transect that gradually bends to the west because of the wind-induced westerly directed currents pushing the vessel to the west. The line starts in very rugged aggregated coral terrain with spur-and-groove morphology with abundant encrusting coral morphotypes. Bottom relief is 2-4 m in average water depths of ~5 m. The channels (grooves) have limited sand and rubble deposits. In general, overall rugosity becomes lower and the number of branching corals increases downslope. A large sediment-rich depression is encountered between 10 and 15 m water depths. Video quality is generally good over the entire line.

MVM4 is predominantly a southwest directed reef-normal transect, however, there is a loop over shallow (5-15 m) reef near the start of the line. During the loop the bottom is a mixture of mostly sand with macroalgae (10-30%) and patches of aggregated coral. After the loop the line begins a reef normal transect to the southwest. Shallow areas (<10 m) are mostly sand with macroalgae (10-40%) interspersed with areas of pavement and encrusting coral and macroalgae. Video image quality is not good in this shallow area but improves in deeper water (20–30 m). At about 20 m water depth aggregated coral becomes predominant with 80-100% coral coverage, mostly branching and platy types, and isolated sand pockets. Visibility decreases again at ~30 m where there is a combination of aggregated coral and sand with macroalgae.

MVM5 is a west-northwest oriented, reef parallel line, near the reef crest, in less than 5 m of water. The seafloor alternates between colonized pavement and rippled sand sheets with scattered rubble layers and encrusting coralline algae.

MVM5a is an oblique, reef-normal line directed to the southwest. The transect starts in very shallow water (<5 m) near the reef crest and extends to about 25 m water depth. Colonized pavement with scattered rippled sand bodies comprise the <10 m shallow segment, with a gradual transition to aggregated coral (although some colonized pavement is still present). At ~20 m water depth, sediment with macroalgae (*Halimeda sp.*+?) becomes the dominant bottom type. Sediment, where present, appears to be poorly sorted with some granule/coarse sand particles.

MVM6 is a south-southwest, reef-normal transect starting in about 5 m of water and ending in approximately 30 m of water. The shallow water section begins on a pavement surface with encrusting coralline algae and isolated small corals. At ~10 m the seafloor descends into a sand rich reef front terrace with 10-30% macroalgae cover (line ends at ~30 m water depth).

MVM6a is an oblique, reef-normal line oriented towards the southwest. The line starts near the reef crest in < 5 m water depth. Colonized pavement is prominent to ~10 m depth and includes isolated compact corals, scattered macroalgae, and patchy veneers of sand and/or rubble. From ~10 m to 20 m depths the seafloor is mostly sand, often rippled, with 10-30% macroalgae coverage, pavement, and/or algal mat patches (80-100% coverage). There is a broad transition zone from the sandy seafloor to aggregated coral (~25 m) that occurs as the line traverses a sediment-filled channel to a coral-covered ridge. Scattered pockets of macroalgae-covered sand occur within the aggregated coral zone. A transition to a dominantly sand bottom with 20-50% macroalgae cover occurs at ~30 m depth.

MVM7 is a reef-parallel line oriented towards the west, just seaward of the reef crest in shallow water (5-10 m). The seafloor is composed of a spur-and-groove zone with mostly aggregated coral ridges separated by narrow channels (grooves). The vertical relief of the seabed is on the order of ~1-2 m and branching and encrusting corals comprise 80-100% of the bottom.

MVM7a is a reef-normal line, starting at about 5 m water depth. Along this line the seafloor alternates between aggregated coral and rippled sand channels. The aggregated coral covers 80-100% of the hardground surface. There are occasional broad expanses of rippled sand (several to 5+ m wide). Aggregated coral continues on the fore reef to ~ 25 m depth. A sand terrace and/or channel, with patches of aggregated coral, occurs beyond the reef front. At around 30 m depth it is difficult to discern if the bottom is aggregated coral, colonized pavement, or sand covered with macroalgae because of poor video quality.

MVM8 is a reef-normal line with a loop near the start of line. The shallow portion (<10 m depth) consists mostly of aggregated coral with 90-100% coverage of the seafloor. The aggregated coral is interrupted by isolated channels filled with sand and rubble. Over the very shallow portions of the line the seafloor consists of aggregated coral and scattered patches of reef rubble. The fore reef is bordered by a sand terrace (~20 m depth) with occasional blocks of aggregated coral. Bottom variations along the terrace include: sand with rubble, sand with macroalgae (10-30%), and smooth sand with bioturbation structures (mounds). The line crosses over a deeper patch reef covered with rubble and aggregated coral, beyond which the seafloor is predominantly sand with prolific *Halimeda sp.* (40-80% coverage).

MVM8a is a west to east reef-parallel line that approximately follows the -5 m contour. The seafloor is mostly aggregated coral interrupted by some rubble veneers and isolated sand pockets and small sand channels. The bottom relief is on the order of 1-2 m. Compact branching corals and crevices are common.

MVM9 is a reef-normal line extending from about 5 to 26 m water depth. The shallow section is characterized by aggregated coral with isolated sand channels. The fore reef sand terrace includes: rippled sand (somewhat degraded ripples); undifferentiated macroalgae 10-40%; and *Halimeda sp.* meadows with 20-50% bottom coverage. In general, ripple size and spacing decreases with increasing depth.

MVM10 is a reef-normal line oriented toward the south. The line begins in about 7 m of water and ends in around 25 m of water. The reef crest and shallow fore reef consist mostly of aggregated coral broken by occasional sand channels filled with rippled sediment. Relief of the coral surface

is on the order of ~ 1-2 m and consists predominantly of compact branching and encrusting corals. The transect follows the edge of a larger channel which is floored mostly by rippled sand. The larger channel begins at ~10 m depth where the track line follows the channel flanked by a ridge of aggregated coral. Within the channel itself there are aggregated coral ridges and pinnacles which are surrounded by areas of rippled sand (~15 m depth). Most of the channel floor consists of clean rippled sand that merges into the sand terrace fronting the reef. The sand terrace has abundant macroalgae (*Halimeda sp.*~ 10-30%).

MVM11 is a reef-normal line beginning at about 5 m water depth where the seafloor is dominated by aggregated coral (1-2 m relief) and occasional sand channels as part of incipient spur-and-groove development zone. In about 10 m of water there is a large sand flat embedded within the reef complex. The sand flat is part of a reef-parallel arrangement of alternating coral ridges and low-lying sand flats. Further seaward the sand flat is replaced by a coral covered ridge dominated by compact branching and encrusting corals and occasional sand channels. There is a gradual transition from the coral-dominated reef front to the sediment-dominated reef front terrace. The base of reef front contains rubble and patches of aggregated coral and colonized pavement. The terrace is characterized by low-relief rippled sand and patches of macroalgae (mostly *Halimeda sp.*). The transect ends in rippled sand at ~22 m depth.

MVM12 is a reef-normal line in an area of alternating reef ridges and intervening sand flats. The line starts in shallow water where the seafloor is a combination of aggregated coral and colonized pavement with a predominance of coral heads. Occasional shallow sand channels are present. The hard bottom abruptly changes to a reef-parallel sand flat with mostly large-scale ripples that are long-crested and reef-parallel which grade into degraded bioturbated ripples. The sand flat abruptly gives way to an east-west oriented linear reef of aggregated coral mixed with coral colonized pavement. Coral coverage varies from 70-100% and consists of low branching and encrusting corals. Further seaward is another reef-parallel, elongated sand flat covered with rippled sand. The ripples grade from long-crested large ripples at the landward edge of the flat to smaller ripples, and finally to a macroalgae (10-40%) covered sand flat. A third hard bottom is encountered and consists of colonized pavement with scattered corals, isolated sand veneers, rubble pockets, and patches of macroalgae. Some areas have dense coral coverage (>80%) and there are also occasional linear sand bodies. Towards end of line the seafloor appears to be more aggregated

coral than colonized pavement. The end of the line is marked by a reef parallel sand body of long-crested degraded ripples with debris-filled troughs.

MVM13, the westernmost reef-normal line, begins in shallow water where the seafloor consists of uncolonized pavement of spur-and-groove morphology. Approximately 60-70% of the seafloor is colonized pavement while 30-40% consists of small sand channels. The sand areas are characterized by long-crested shore-parallel ripples and occasional rubble deposits. The colonized pavement areas contain scattered coral heads and rubble on pavement surface with occasional sand ribbons. Encrusting coralline algae and macroalgae are also present. Sand areas increase down slope with a concomitant increase in macroalgae coverage (*Halimeda sp.* mostly). Interspersed with the sand flats are colonized pavement. The pavement is generally sparsely colonized with scattered corals, macroalgae, and coralline algae. Scattered sand pockets and ribbons (veneers) are also present. Further seaward the hard bottom is replaced by a low relief, reef-parallel sand body with 10-30% macroalgae coverage (mostly *Halimeda sp.*). Within the sand body there are scattered coral heads.
MVM5a-2 is a long reef-parallel transect running east to west and roughly following the 10 m contour. The line begins east of Kaunakakai Wharf and heads towards the west. The seafloor alternates between three primary bottom types: aggregated coral, colonized pavement, and sand.

MVM14 is a shallow (~5-7 m), reef-parallel line from east to west beginning west of Kaunakakai Wharf. The line includes a loop through a reef-enclosed blue hole. Except for the blue hole, which is sediment filled, the line is dominated by aggregated coral with typically 80-100% coral coverage with substantial thickets of branching corals. The aggregated coral is broken by occasional sand channels filled with clean, rippled sand. The blue hole is sand-floored with ripples that appear to be active in places and degraded in others.

MVM15 is a west to east reef-parallel line in 5-15 m water depth (the line contains several loops). Throughout the transect the seafloor is mostly aggregated coral with numerous small, and several large, sand channels. The aggregated coral is predominantly branching corals with 80-100% coverage. Sand areas are typically clean rippled sand.

Southern Molokai Video Survey Summary

The fringing reef of southern Molokai is the best-developed reef in the main Hawaiian Islands. It extends for about 50 km along the coast with reef flat widths greater than 1500 m in the central reef area. The reef is narrower and less well developed on the eastern and western margins where wave and current activity is higher. The reef flat is generally shallow, well defined, and covered with a veneer of mixed carbonate-terrigenous sediment and patches of macroalgae (Calhoun and Field, 2000). Incorporated into the fringing reef are numerous blue holes. These are deep, steep-sided depressions that are characterized by aggregated corals around the rim and sediment filled interiors. Isolated coral heads, colonized pavement, and reef rubble occur landward of the reef crest.

The reef crest is usually defined by a zone of breaking waves and is marked by high cover of encrusting coralline algae over pavement, patches of rubble, and coral. Active reef accretion extends from near the reef crest down to about 27 m water depth (Logan *et al.,* in press).

Areas of prolific coral growth are marked by a highly rugose seafloor with up to 2 m of vertical relief. Spur-and-grooves are well developed along much of the fore reef zone and vary morphologically (size and spacing) with wave exposure (Storlazzi *et al.*, 2003). The spurs (ridges) are primarily composed of aggregated coral while the intervening grooves (channels) are typically smooth, U-shaped, and partially filled with sand and/or coral rubble. Areas of aggregated coral are often interspersed with scattered sand pockets. Coral species distribution and coverage is related to wave energy with more species, but lower coverage, in the higher energy zones at the east and west margins (Storlazzi et. al., 2005). Fore reef areas often abruptly merge into a reef front terrace that is predominantly covered by sediment derived from either the adjacent reef, the land, or in-situ production. Macroalgae cover is typically high along the fore reef sand bodies.

TABLE 3.1. Underwater video transect summary for southern Molokai.

Line*	Camera	Location	Length (km)
MVM_1	Sled	Kamalo W	0.97
MVM_1a	Seaviewer	Kamalo W	0.55
MVM_2	Seaviewer	Kawia Fishpond	0.79
MVM_3	Seaviewer	Moku	1.09
MVM_4	Seaviewer	Alii Fishpond	1.18
MVM_5	Seaviewer	Kamiloloa	0.99
MVM_5a	Seaviewer	Kamiloloa	0.55
MVM_5a-2	Sled	Kamiloloa	0.66
MVM_6	Seaviewer	Kalokoeli Fishpond	0.30
MVM_6a	Seaviewer	Kalokoeli Fishpond	0.64
MVM_7	Seaviewer	Kaunakakai Harbor W	0.83
MVM_7a	Seaviewer	Kaunakakai Harbor W	??
MVM_8	Seaviewer	Iloli	1.09
MVM_8a	Seaviewer	Iloli	0.20
MVM_9	Seaviewer	Kukuku Gulch	0.33
MVM_10	Seaviewer	Onopalani Gulch	0.63
MVM_11	Seaviewer	Hale O Lono	0.63
MVM_12	Seaviewer	Kanalukaha	0.90
MVM_13	Seaviewer	Kahalepohaku	1.23
MVM_14	Sled	Umipaa	4.51
MVM_15	Sled	Palaau	3.37
		Total length surveyed (km)	21.44

*Video data of transect lines MVM 1-15 are archived on tapes 10-16 (7).

TABLE 3.2 UTC, start (SOL) and end (EOL) locations of survey transects.

Line	UTC	Latitude	Longitude
1_SOL	20021811838400	21.042805	-156.897072
1_EOL	20021811853100	21.035090	-156.899580
1a_SOL	20021811943400	21.037237	-156.893670
1a_EOL	20021811951100	21.037975	-156.898763
2_SOL	20021812027100	21.051045	-156.931343
2_EOL	20021812037500	21.050120	-156.933185
3_SOL	20021812056200	21.060695	-156.957888
3_EOL	20021812111500	21.052940	-156.962840
4_SOL	20021812129000	21.063760	-156.979432
4_EOL	20021812145200	21.058658	-156.981830
5_SOL	20021812156000	21.067738	-156.994662
5_EOL	20021812207100	21.070290	-157.003517
5a_SOL	20021812214200	21.069707	-156.999440
5a_EOL	20021812221500	21.067622	-157.004083
6_SOL	20021821754500	21.071148	-157.009595
6_EOL	20021821758100	21.068983	-157.011305
6a_SOL	20021821802500	21.071175	-157.009558
6a_EOL	20021821811300	21.068333	-157.014628
7_SOL	20021821828300	21.080318	-157.040480
7_EOL	20021821832200	21.076528	-157.044473
7a_SOL	20021821832300	21.081230	-157.042710
7a_EOL	20021821841200	21.076407	-157.044477
8_SOL	20021821911000	21.087403	-157.108350
8_EOL	20021821927500	21.083405	-157.108473
8a_SOL	20021821934400	21.088543	-157.109517
8a_EOL	20021821943400	21.087260	-157.108616
9_SOL	20021822002600	21.083910	-157.150292
9_EOL	20021822008100	21.081102	-157.149850
10_SOL	20021822033300	21.082573	-157.197007
10_EOL	20021822041200	21.077515	-157.197850
11_SOL	20021822102300	21.082167	-157.246170
11_EOL	20021822111200	21.077128	-157.245580
12_SOL	20021822122500	21.085837	-157.264243
12_EOL	20021822133600	21.079105	-157.268487
13_SOL	20021822146600	21.090390	-157.285995
13_EOL	20021822201000	21.081723	-157.293005
5a-2_SOL	20021831847300	21.067922	-156.999192
5a-2_EOL	20021831858200	21.069192	-157.005237
14_SOL	20021831956100	21.082718	-157.050270
14_EOL	20021832052400	21.084012	-157.077922
15_SOL	20021832055500	21.082567	-157.076882
15_EOL	20021832150000	21.084377	-157.071267

UTC time format is YYYYDDDHHMMSST (year, Julian_day, hour, minute, seconds, tenths)
Coordinates are decimal degrees, WGS84

4. Substrate and Benthic Habitat Mapping of the Western Maui, Hawaii Insular Shelf

Ann E. Gibbs

Over 32 kilometers of underwater video was collected along 30 transects between Kahana and the Ahihi-Kinau Natural Area Preserve between July 3 and 6, 2002 (Figure 4.1, Tables 4.1 and 4.2). The field excursion was reconnaissance in nature, with the objectives of characterizing overall bottom type and identifying regional transitions in reef morphology, coral cover, and coral health. Seven fundamentally distinct regions, based on bottom type and reef morphology, were delineated along the west coast of Maui (Figure 4.1). From north to south they are: Kahana, Honokowai, Kaanapali, Lahaina, Olowalu, Kihei, Wailea, and the Ahihi-Kinau Preserve. Preliminary observations, interpretations, and maps of the seven regions are presented below.

Prior to this fieldwork, published references to the location of coral reefs on the island of Maui were limited to NOS (National Ocean Service) navigation charts, the REEFBASE web site (http://www.reefbase.org), Coral Reefs of the World (Wells and Jenkins, 1988), recreational dive books, miscellaneous gray literature, communication with knowledgeable locals, and personal experience. At the time of this survey, the NOAA benthic habitat classification map for the island of Maui was complete, but not publicly available. The maps are now available online from the NOAA Biogeography Program at: http://biogeo.nos.noaa.gov/products/hawaii_cd/. The NOAA benthic habitat mapping was based primarily on the interpretation of the 2000 aerial photography collected from Poelua Bay on Maui's north shore, west and south to Keawa Bay on the south/southeast shore of Maui, near the town of Hana. A gap in coverage exists between Mahinahina Point and Hanakaoo Point. Figure 4.2 shows the distribution of coral reef and colonized hardbottom as mapped on the original NOS charts and the recently published NOAA benthic habitat maps.

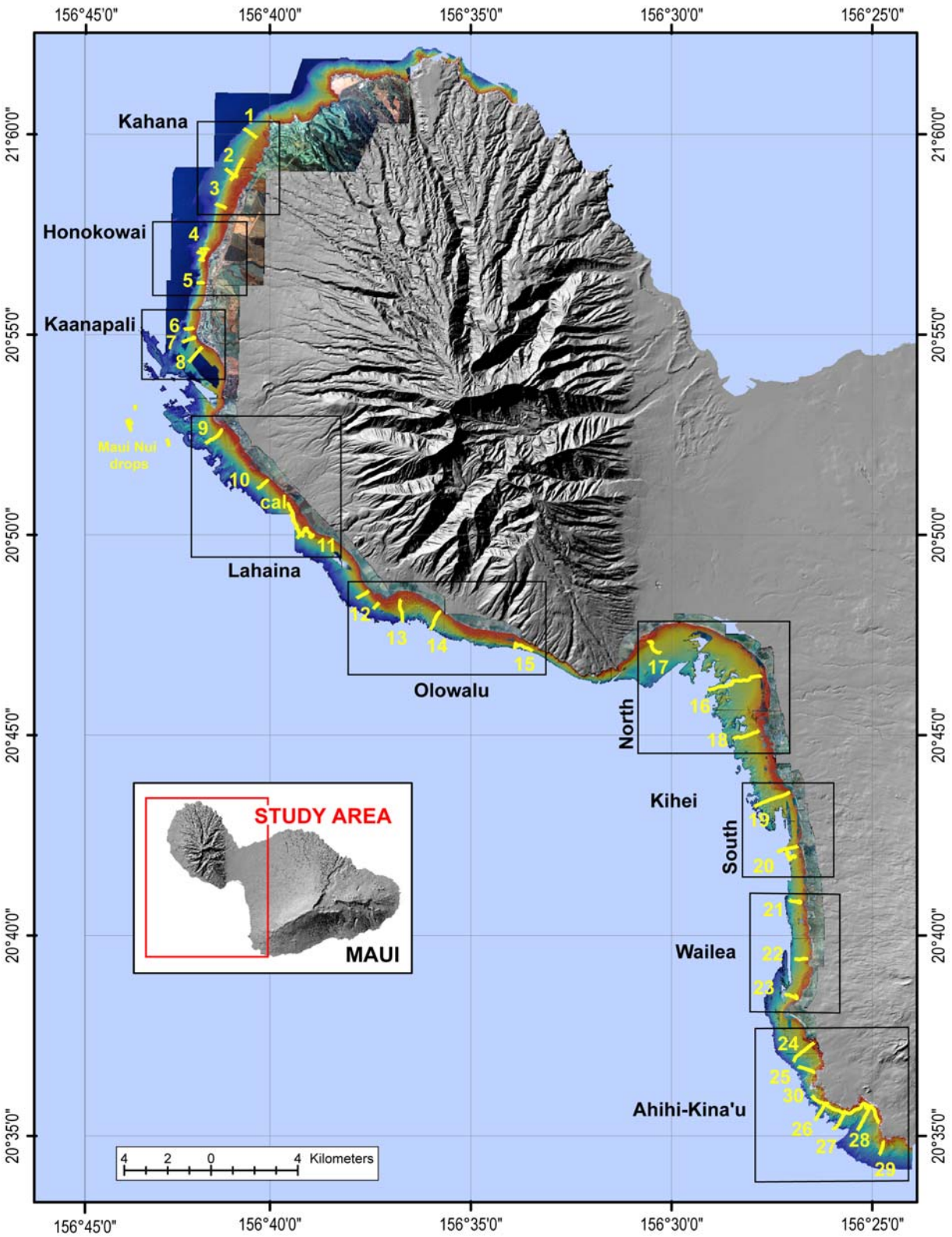

Figure 4.1. Underwater video trackline locations overlain on a composite image (color vertical aerial photography, SHOALS lidar, and DEM shaded-relief) of the Maui study area.

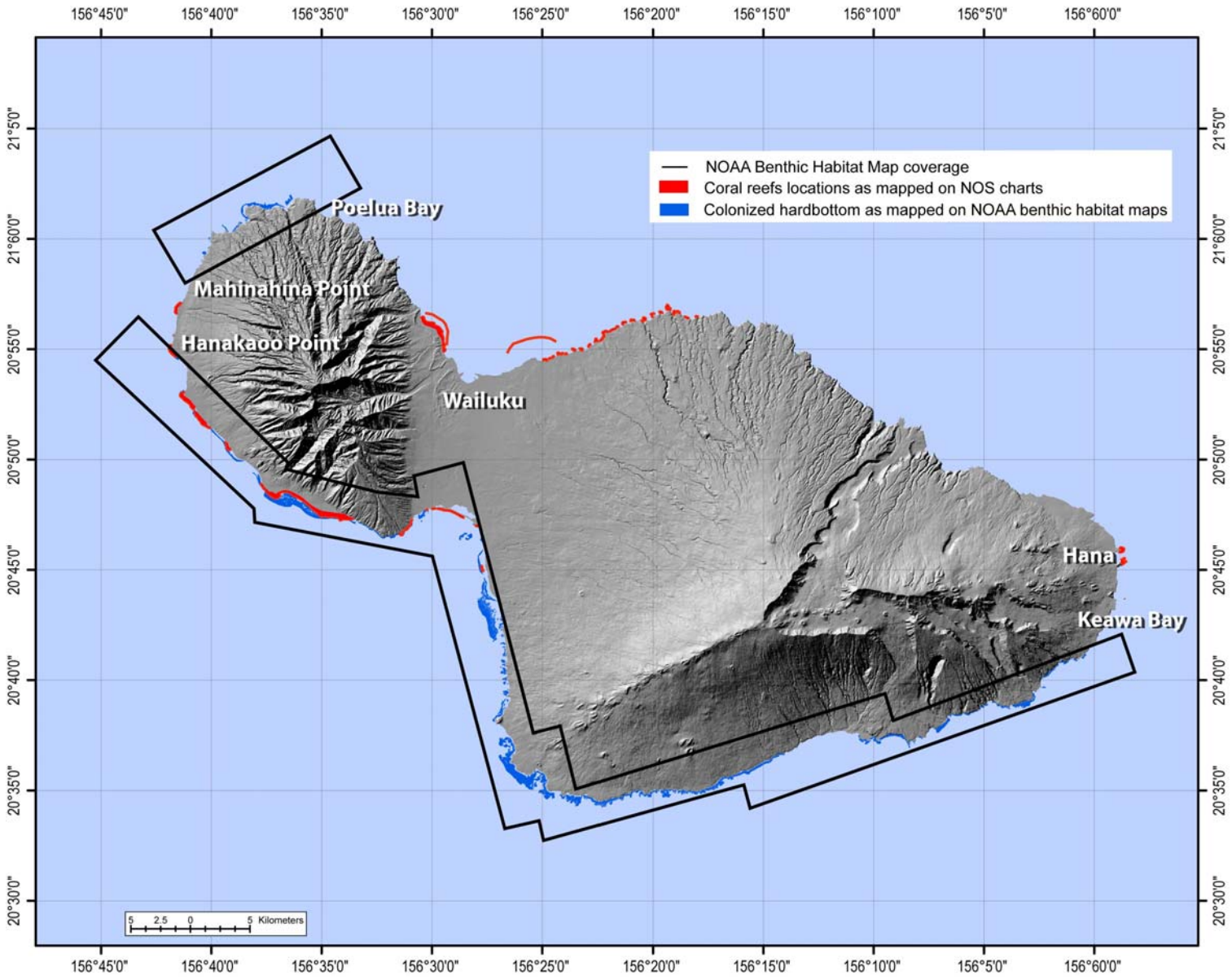

Figure 4.2. Location of coral reefs and colonized hardbottom on the island of Maui as mapped on NOS charts (red) and NOAA benthic habitat maps (blue).

General Mapping Results

Kahana

One shore parallel and three shore normal transects were collected in the Kahana region, between Napili Bay and Kapua (Figure 4.3). The Kahana region is characterized by uncolonized sand fields and uncolonized pavement. Some *Halimeda sp.*, turf algae, and few encrusting corals were observed offshore. Lines VVM2 and VVM2a were collected over the location of the USGS instrument tripod (Storlazzi and Jaffe, 2003).

Honokowai

One shore parallel and four shore normal transects were collected in the Honokowai region (Figure 4.4). This area is characterized by an extensive, colonized reef platform and associated spur-and-groove structure. It is the most northern continuous reef complex on West Maui. North of this area, coral assemblages are typically confined to areas close to shore, within the rocky embayments.

The Honokowai transects (VVM4) show high coral cover inshore (~8 m water depth) transitioning to sand with fairly dense beds of *Halimeda sp.* in deeper water. The reef appeared to be relatively healthy. At the Kahikili CRAMP site (VVM5), our line started in a water depth deeper than the deepest CRAMP site. The transect showed high coral coverage and transitions similar to those at VVM4.

Kaanapali

A cluster of three transects were collected around Hanakaoo Point in Kaanapali in order to evaluate potential transitions in reef morphology around a headland (Figure 4.5). Beach profile data collected in the area show large seasonal variations in beach volume at this location, reflecting the strong seasonal changes in wave energy and direction along this coast (Gibbs *et al.,* 2002; Eversole and Fletcher, 2003).

Off the north side of Hanakaoo Point (VVM6), good coral cover was observed close to shore, while sparse coral cover in water deeper than 10 m transitioned rapidly to sand colonized with thick beds of *Halimeda sp.* offshore.

Off the middle of Hanakaoo Point (VVM7), high cover, healthy coral close to shore transitioned quickly to somewhat degraded, sparsely colonized pavement and an uncolonized sand field about 600 m offshore. This transect, where the first occurrence of significant pavement was observed, showed very different bottom character than anything observed to north. This may also reflect, or have implications for determining differences in sediment transport pathways and sand availability to beaches. For example, do the large seasonal changes in wave energy drive north-south/south-north transport of offshore sediment, similar to what is observed on the adjacent beaches? (See Gibbs *et al.*, 2002, and Eversole and Fletcher, 2003).

Line VVM8, off the south side of Hanakaoo Point, was located in a broad reentrant in the carbonate platform, perhaps indicating a site of an old stream channel and potential fresh water influx. Severe beach erosion is also apparent at this location in 1997 aerial photography. Nearshore coral cover appeared more degraded and fundamentally different than coral to the north. Offshore, colonized pavement alternated with algae (*Halimeda sp.?*) covered sand flats.

An interesting note, the offshore bathymetry in this area, continuing south of Lahaina, is quite unusual and may represent a fossil reef and/or some type of ravinement surface. Unfortunately, there are many gaps in the SHOALS data in this area. This should be an interesting and important area for future work because of both the transitions in benthic environments, as well as possible anthropogenic pressures of coastal development in the region.

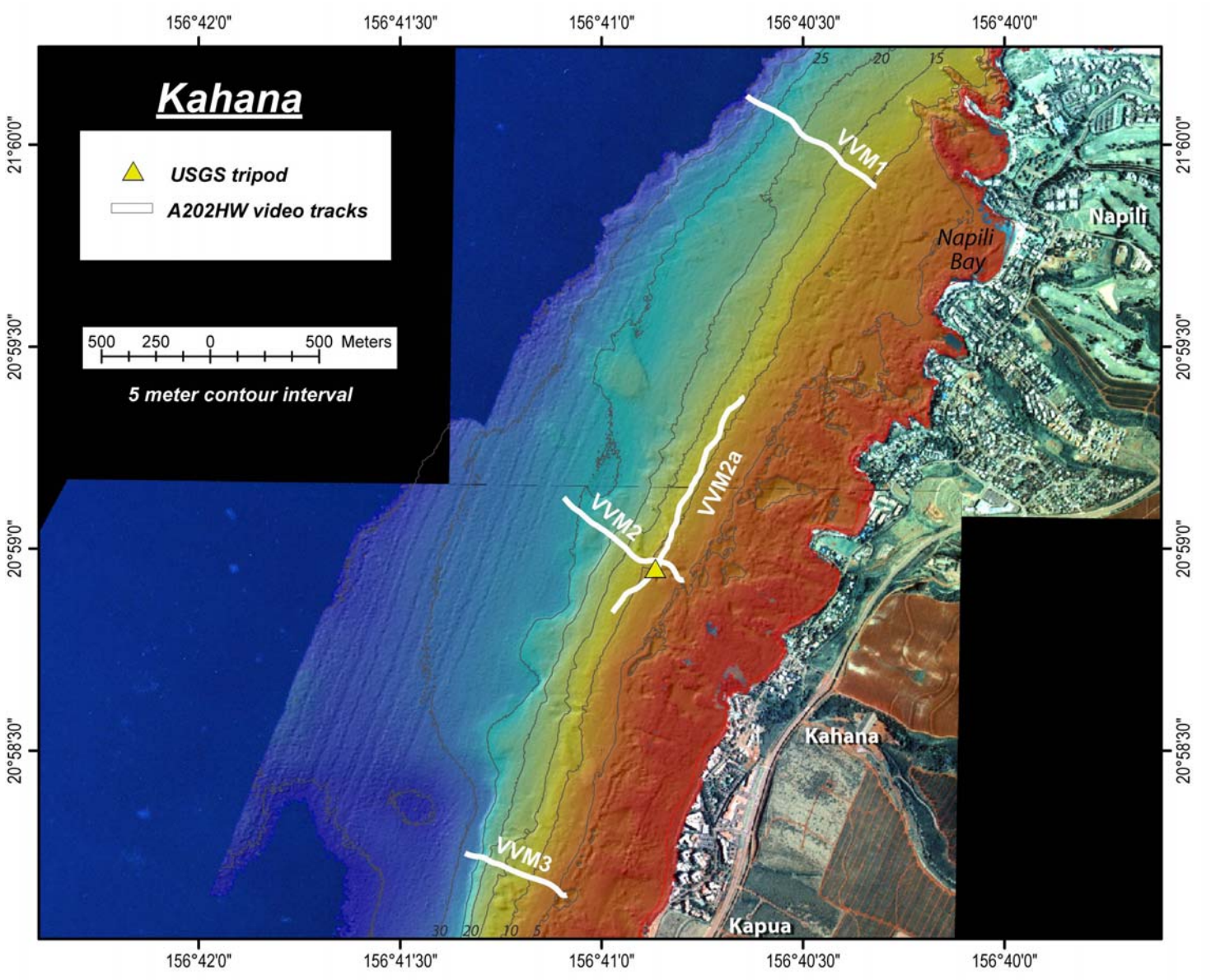

Figure 4.3 Underwater video trackline locations and the location of the USGS instrument tripod overlain on a composite image (color vertical aerial photography and SHOALS lidar bathymetry) within the Kahana region off the west coast of Maui.

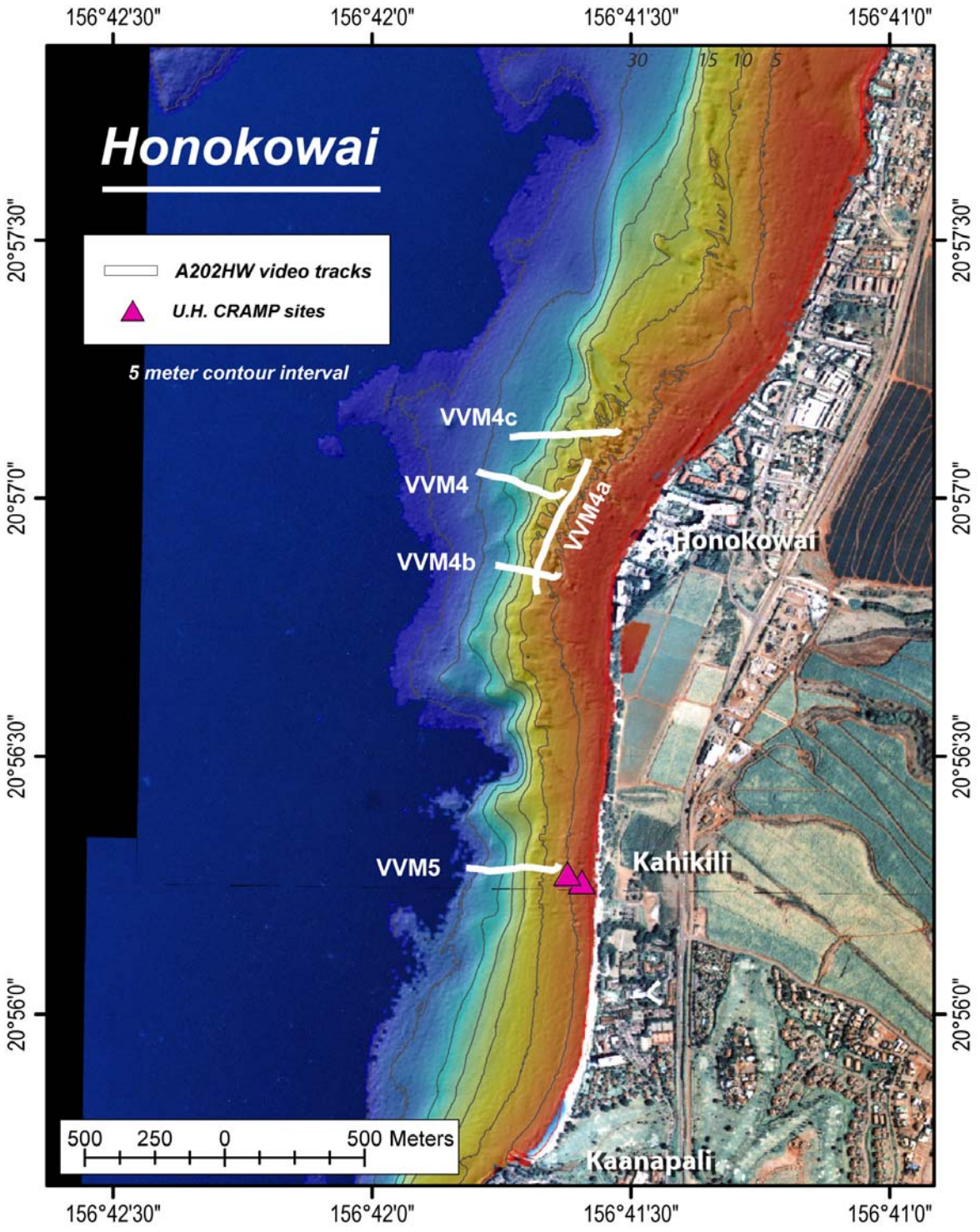

Figure 4.4 U.H. CRAMP sites and underwater video trackline locations overlain on a composite image (color vertical aerial photography and SHOALS lidar bathymetry) within the Honokowai region off the west coast of Maui.

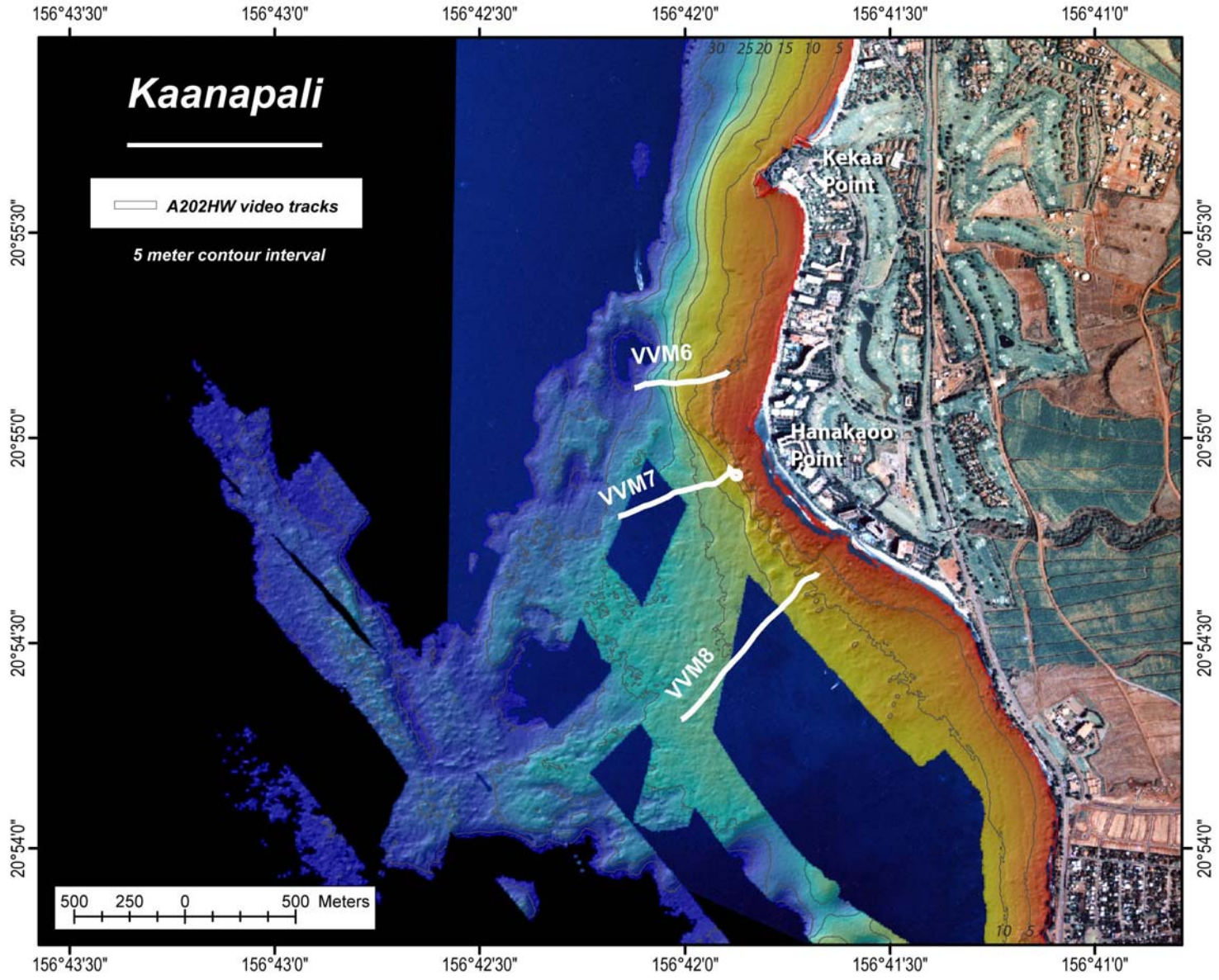

Figure 4.5 Underwater video trackline locations overlain on a composite image (color vertical aerial photography and SHOALS lidar bathymetry) within the Kaanapali region off the west coast of Maui.

Lahaina

Two shore parallel and three shore normal transects were collected in the Lahaina region, between Lahaina and Launiupoko Point (Figure 4.6). Between Lahaina and Launiupoko, several extensive (1-2 km alongshore), shallow (< 10 m) reef complexes are mapped on the NOS charts. Very little coral reef was observed in the area, however, transects typically started in water depths greater than 10 m. High boat traffic in the area prevented surveying this area in greater detail and the individual transect may not be representative of the area. More work is probably warranted in this region, especially around Lahaina, because of the large reef tract and the potential anthropogenic pressures on the reef.

Line VVM9 off the north side of Lahaina showed large amounts of turf algae, degraded coral, and many urchins. There was no good coral coverage in either type or quality. Video cover started in more than 10 m of water and the nearshore, shallow reef platform was missed. This transect may not be representative of the area.

Line VVM10, near the Puamana CRAMP site, was primarily a sand flat covered with algae (*Halimeda sp.?*) and poor coral cover offshore. The CRAMP site was too shallow to image, and was located about 20 m north of the start of the line.

Line VVM11, off Launiupoko Pt. showed a benthic environment not observed to the north. In the video, it appeared to be a muddy substrate colonized with turf algae and sparse *Pocillopora meandrina* transitioning first to uncolonized, rippled sand and then to *Halimeda sp.* populated sand flats. There is a muddy, 2-3 m high, eroding cliff exposed on the shoreline adjacent to this site. An attempt was made to two days later to re-occupy the site and collect a sample. Some discussion ensued whether or not the sample collected was of the substrate observed previously and described above. In any event, it was fossil reef covered with turf algae – no mud was present.

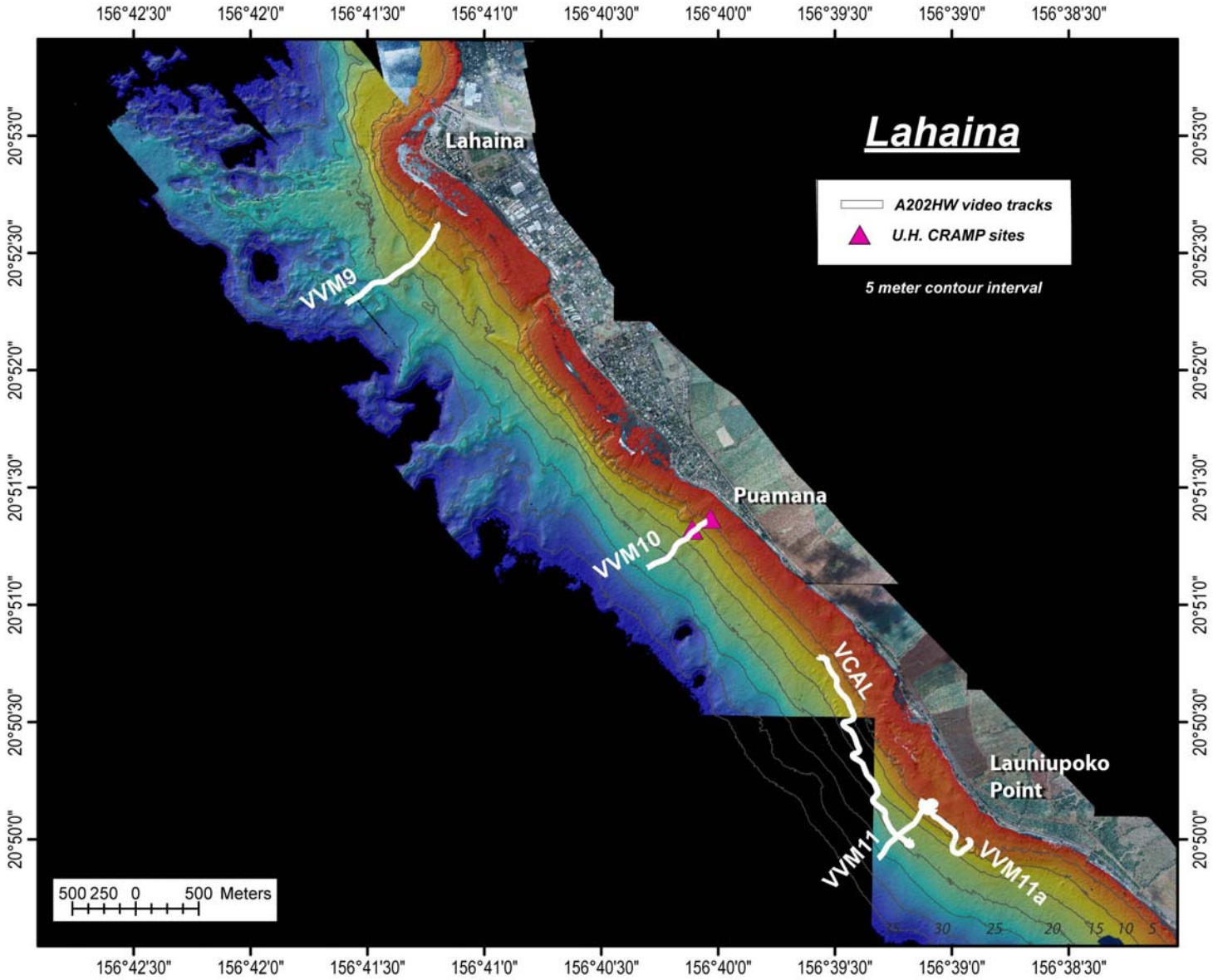

Figure 4.6 U.H. CRAMP sites and underwater video trackline locations overlain on a composite image (color vertical aerial photography and SHOALS lidar bathymetry) within the Lahaina region off the west coast of Maui.

Olowalu

One shore parallel and five shore normal transects were collected in the Olowalu region, between Olowalu and Papawai Point (Figure 4.7). Olowalu sits atop an alluvial fan and numerous steep gulches incise the upland mountains and reach the coastal terrace in this region. The island's largest and most well-developed fringing reef is also found in this area. Typically a very low energy environment, the day it was surveyed was fairly windy and choppy causing the water to be quite turbid.

Limited coral reef was observed off the north side of the pier at Olowalu and Hekili Point (VVM12). The reef quickly transitioned to thick *Halimeda sp.* beds offshore. Line 12a was added just south of pier to better define the coral communities on the northwest-southeast trending portion of reef flat surrounding Hekili Point (compared to the southwest-northeast trending reef southeast of the point). Video along line VVM12a showed an extensive fringing reef characterized by high coral cover and a sharp transition to sand and rubble with *Halimeda sp.* offshore.

Off the south side of Hekili Pt. the reef tract changes orientation from northwest-southeast to southwest-northeast trending reef front. Here an extensive reef flat with 90-100% coral cover was observed, extending past the SHOALS bathymetry and the end of the cable. SHOALS data show this to be an area of very irregular bathymetry, with spur-and-groove and "blue hole" morphology.

Line VVM14, is located about 2 km southeast of VVM13 in an area where the sea floor bathymetry is much smoother. The bottom was similar to VVM13 with highly colonized spur-and-groove morphology and coral cover out to at least 40 m water depth.

Line VVM15 is located just south of Papawai Point. Here good coral cover was observed inshore, but, because of turbid water and a steep offshore gradient, it was difficult to observe much offshore. An attempt was made to cross a series of topographic highs to the east of VVM15 (VVM15a). High seas, turbid water, and boat traffic prevented ideal coverage, however, it appeared that there was potentially 100% coral cover along the entire transect, even in the deep water between the mounds. Thorne (2001) maps coral coverage in pinnacles and coves throughout the area between here and Maalaea Harbor to the east.

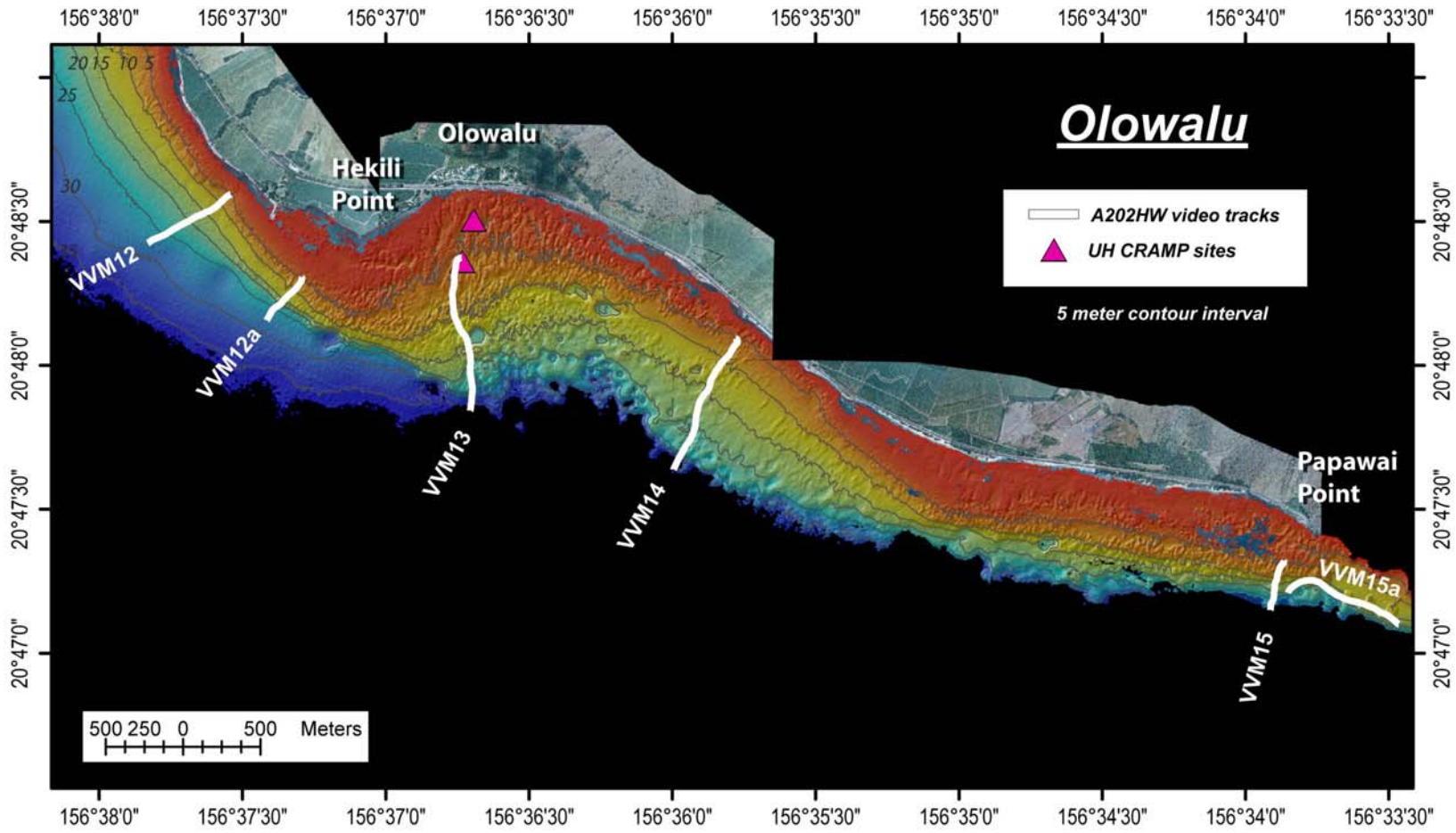

Figure 4.7 U.H. CRAMP sites and underwater video trackline locations overlain on a composite image (color vertical aerial photography and SHOALS lidar bathymetry) within the Olowalu region off the west coast of Maui.

Kihei

One shore parallel and five shore normal transects were collected in the Kihei region, between Maalaea Harbor and Keawakapu (Figures 4.8 and 4.9). The area between Maalaea Bay to just south of Keawakapu is characterized by discontinuous shallow reef flat close to shore, transitioning to sand flats, sometimes with algae, and then to coral covered, shore sub-parallel ridges offshore. The ridges show very high, very healthy coral cover. Little, if any, coral reef has been mapped previously in this offshore area and no published information describing this area was found by the author. The NOAA benthic habitat maps do not identify coral reef in this area. SHOALS bathymetry shows well the fairly high relief bathymetry offshore, with ridges and platforms in depths greater than about 15 m. This morphology continues south to about 400 m south of Keawakapu (see description below for VVM20a). The bathymetric highs offshore are likely entirely covered with healthy dense coral. The presence of near shore reef may not have been detected due to the inability to collect video in water depths less than about 10 m.

The water directly off the breakwater at Maalaea Harbor (VVM17), one of the CRAMP sites, was too murky to determine bottom type. However, three pinnacles located between 0.5 and 1 km offshore, between about 12 and 15 m water depths, were covered with nearly 100% live coral.

Continuing around the Maalaea embayment to site VVM16, just south of the Kihei pier, the water continued to be murky. Close to shore the bottom type was predominantly sand. In water depths greater than about 15 m and about 1.5 km offshore, dense coral cover was observed on numerous mounds and pinnacles.

NOS navigation charts show a fairly extensive shallow reef platform offshore of central Kihei, between Kalepolepo and Kalama Park. A transect across the northern end of this platform, was collected (VVM18). The transect started along seaward edge of the platform and showed a nearshore colonized reef platform transitioning to aggregate coral/spur-and-groove, *Halimeda sp.* in sand, and finally poorly (?) colonized pavement offshore.

Line VVM19, at the southern boundary of the same reef complex, showed mostly sand close to shore, however, several hundreds of meters of 90-100% coral cover on the offshore ridges were

found, transitioning to coral rubble and algae about 32 m and the seaward end of SHOALS coverage.

Transect VVM20, off the north side of Keawakapu, showed transitions similar to VVM19, with sand inshore transitioning to 90-100% coral cover on the offshore ridges.

At the next site south (VVM21), off Wailea Point, the benthic environment changes dramatically (as described in the next section), indicating a fundamental transition in bottom type and coral cover somewhere between Keawakapu and Wailea. Unfortunately, the SHOALS bathymetry in this transition zone is sparse. Bathymetric contours on NOS charts show that the offshore slope steepens dramatically south of Keawakapu. Line VVM20a was collected to define this boundary and suggests the transition is about 400 m south of VVM20. Preliminary NOAA Benthic Habitat maps located this transition about 700 m to the south.

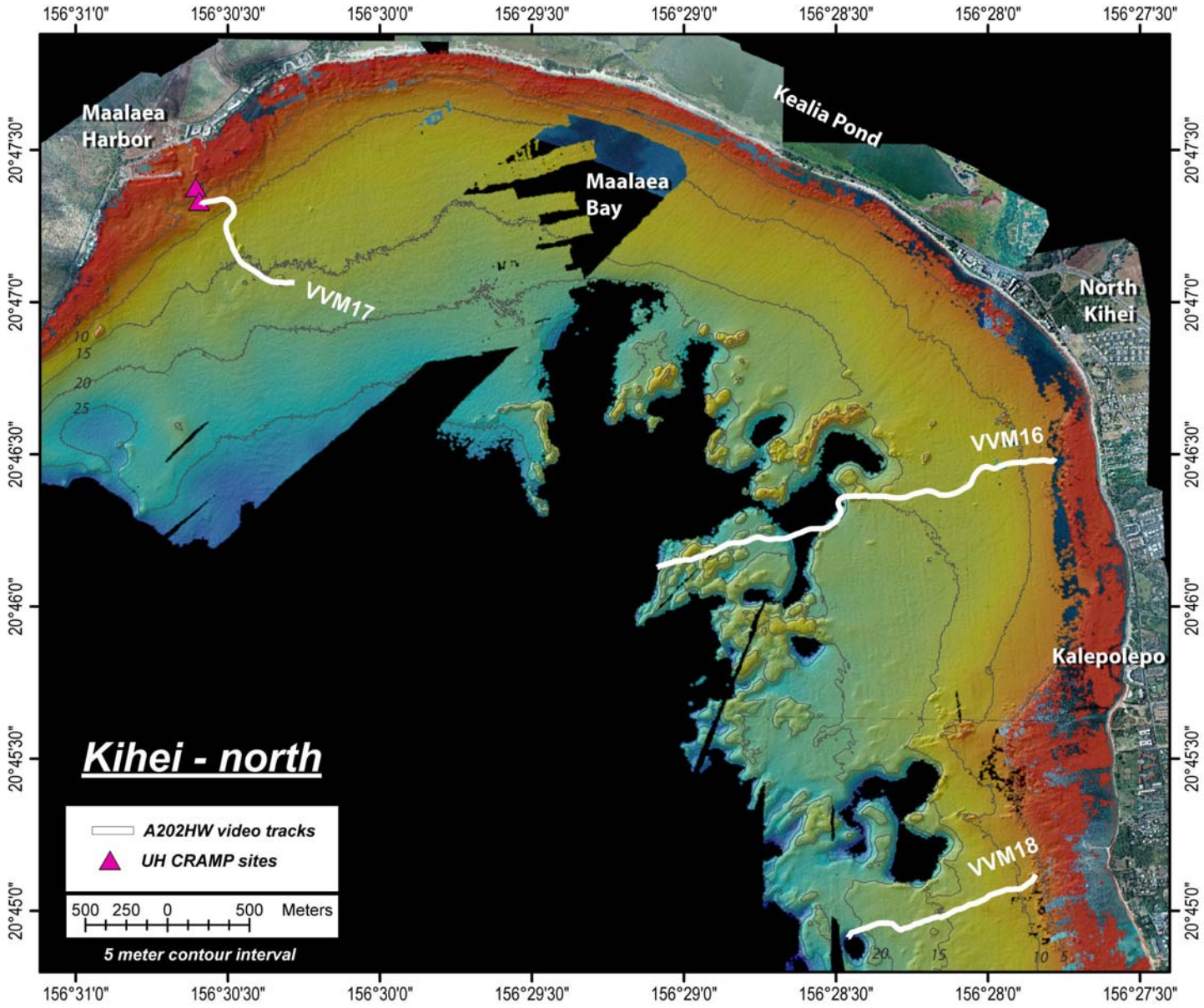

Figure 4.8 Map showing SHOALS lidar bathymetry, aerial photography, and the locations of the U.H. CRAMP sites and video transects collected in the north Kihei region off the west coast of Maui.

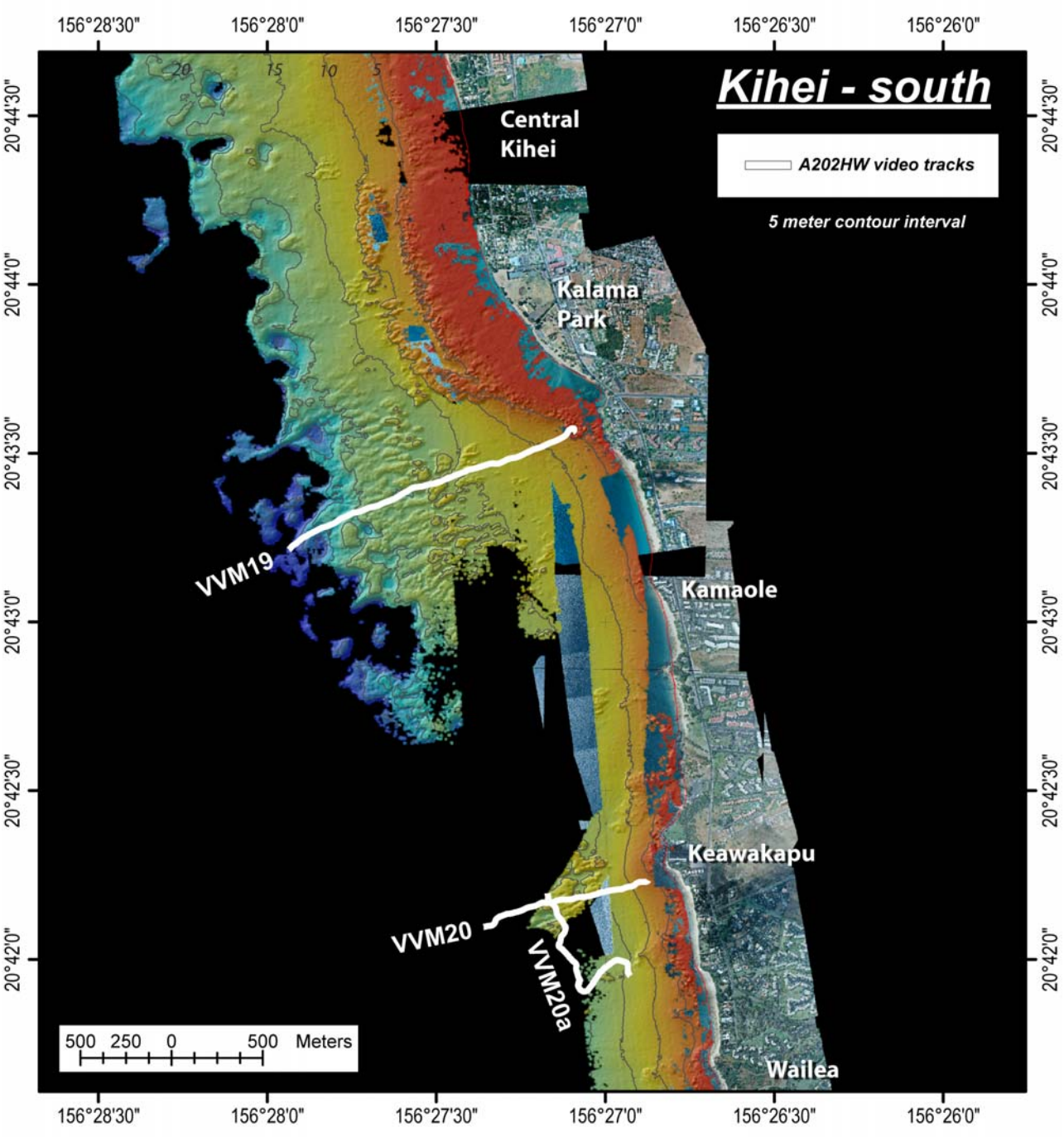

Figure 4.9 Map showing SHOALS lidar bathymetry, aerial photography, and video transects collected in the south Kihei region off the west coast of Maui.

Wailea

Three shore normal transects were collected in the Wailea Region, between Wailea Point and Puu Olai (Figure 4.10). A distinct transition in offshore morphology and bottom type was observed between the Kihei and Wailea regions, as discussed above. The Wailea area is characterized by dense coral cover in embayments close to shore, transitioning to macroalgae-covered sand flats offshore.

The transect off Wailea Point (VVM21), a rocky volcanic headland, showed high coral cover in the nearshore, transitioning quickly to extensive beds of thick green and brown macroalgae-covered sands offshore. This algae was 'thick' and of a different type than observed to the north (*Clodophora sp.??*).

Line VVM22, off Nuhuna Point, the volcanic headland just north of Makena showed a similar, fairly abrupt transition from healthy, dense coral nearshore to algae covered sand flats and possible uncolonized pavement offshore. Similarly, along the northern base of Puu Olai (VVM23), beautiful dense coral inshore transitioned to pavement then macroalgae-covered sands in deeper water.

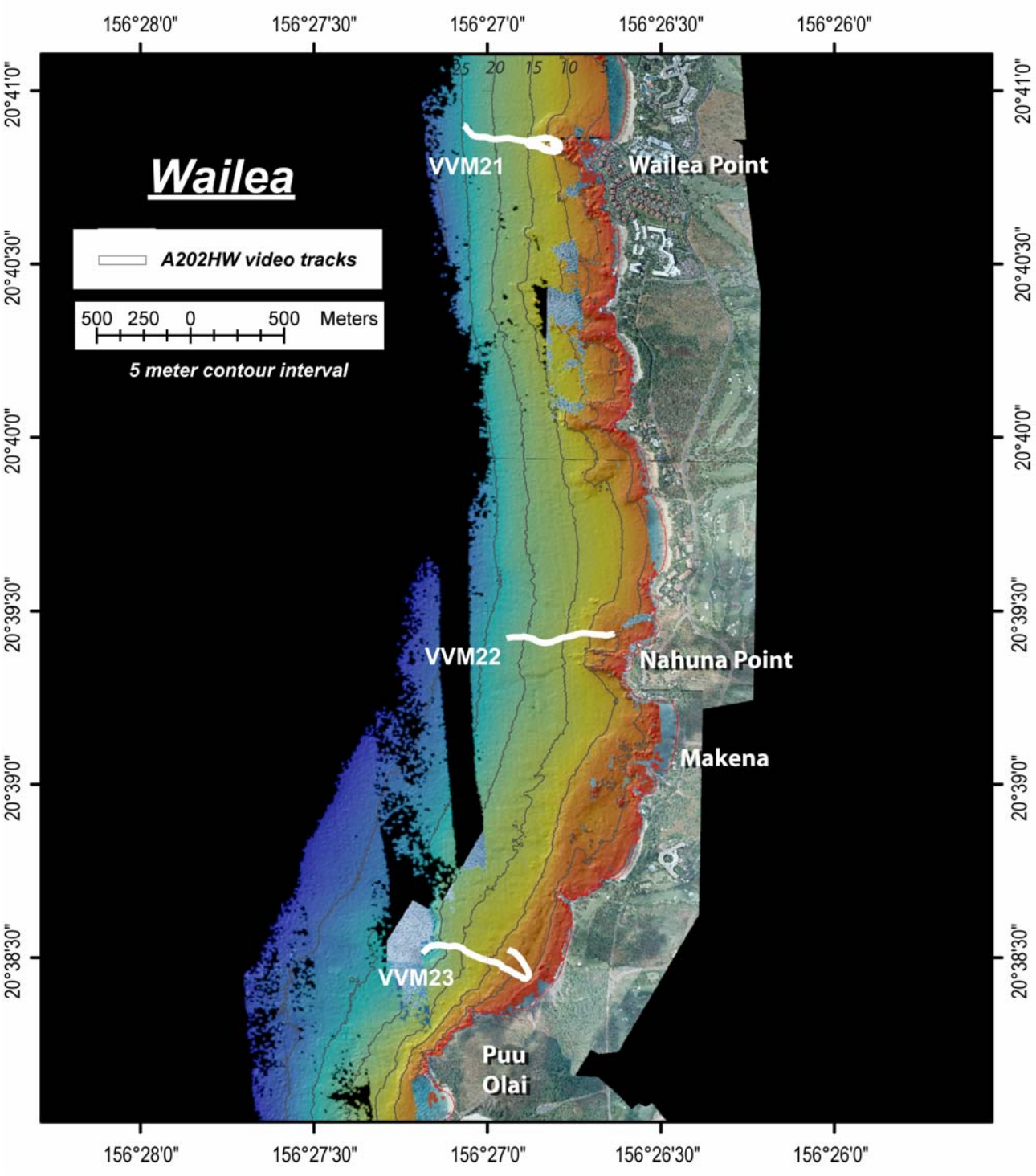

Figure 4.10 Map showing SHOALS lidar bathymetry, aerial photography, and video transects collected in the Wailea region off the west coast of Maui.

Ahihi-Kinau Preserve

One shore parallel and six shore normal transects were collected in the Ahihi-Kinau Preserve, between Ahihi Bay and Cape Hanamanioa (Figure 4.11). This area is characterized by very high coral cover in water depths less than 10 m, transitioning to partially colonized volcanic pavement with rubble and sand flats, with or without *Halimeda sp.*, in deeper water. The area is geologically young, with the coral colonizing volcanic flows presumed to have erupted from Haleakala between A.D. 1490 and 1600 (U.S. Geological Survey, 1999). This area is one of the few areas outside the Northwest Hawaiian Islands where 'naïve fish behavior' has been observed (Besty Gagne, Department of Land and Natural Resources (DLNR), personal communication 2002). During this survey, little coral reef habitat or fish were observed.

Line VVM24 on the north side of Ahihi Bay showed some live coral cover close to shore transitioning to sparse, isolated coral seaward of the first ledge, alternating with fields of rippled, uncolonized sand and beds of *Halimeda sp.*.

Line VVM25, off the north end of Cape Kinau showed both live and dead coral reef continuing offshore to a sharp transition with sand and *Halimeda sp.* over a ledge/sharp drop.

Line VVM26, off of Kanahena Point showed coral covered basalt with very high rugosity and high coral cover.

Line VVM27, off of Kalaeloa showed high coral cover close to shore, decreasing offshore to *Halimeda sp.* beds in deeper water (similar to VVM26).

Line VVM28, within La Peruse Bay showed mostly sand and rubble with a coral covered linear ridge in middle of bay.

Line VVM29, off the southern end of Cape Hanamanioa showed a wide, shallow reef flat with good coral cover.

Line VVM30, was a shore parallel line from Cape Hanamanioa to just north of Kanahena Point. Some good coral cover was observed in less than 10 m of water. The video imagery acquired along this transect is less than ideal because of high seas and turbid water during data collection.

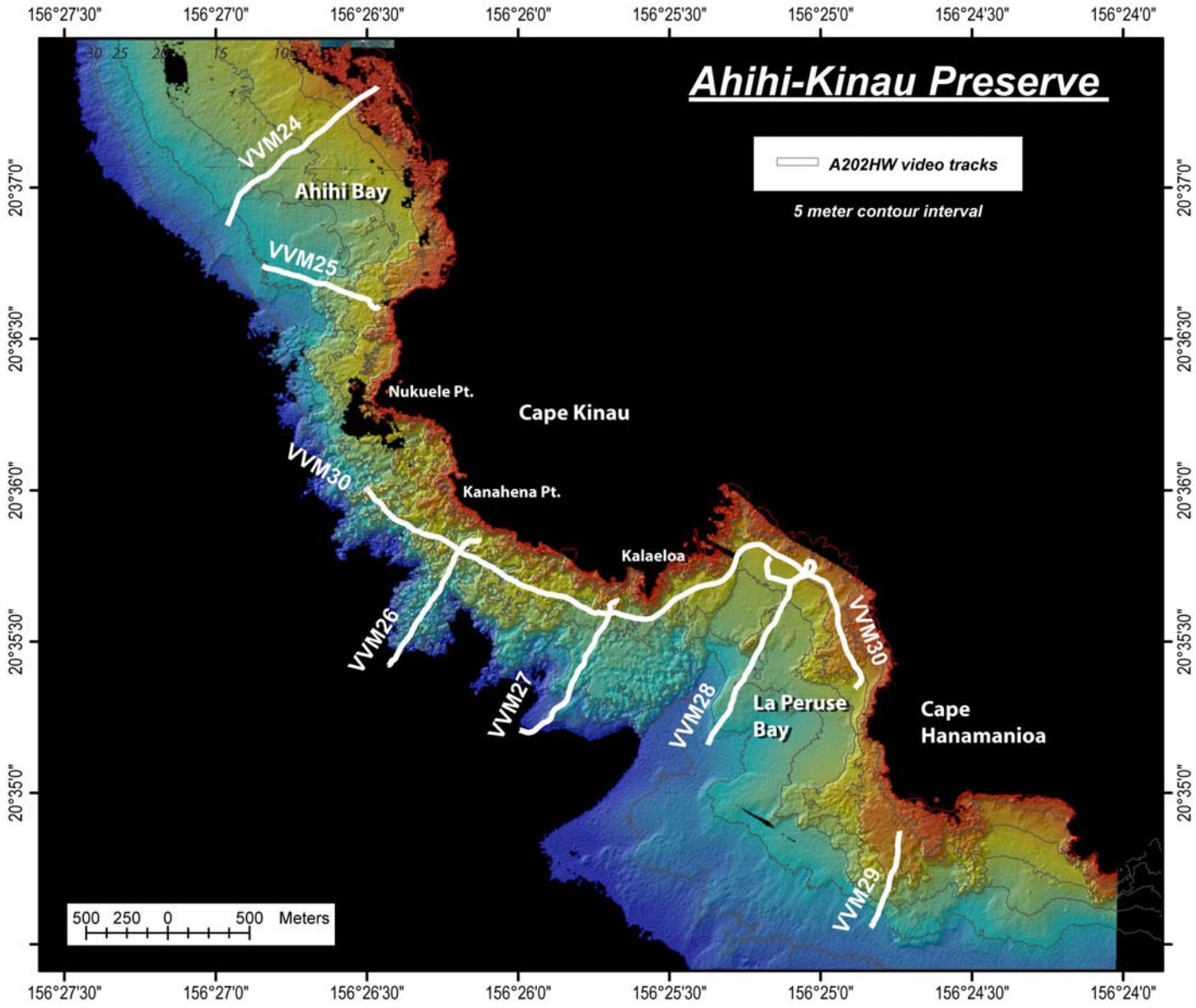

Figure 4.11 Map showing SHOALS lidar bathymetry and location of video transects collected in the Ahihi-Kinau region off the west coast of Maui.

Table 4.1. Underwater video transect summary for western Maui.

Line*	Description	Length (km)
VVM 1	Shore normal transect off the south end of Napili Bay	0.71
VVM2	Shore normal transect off the south end of Kaia Pt. across Kahana tripod site	0.67
VVM2a	Shore parallel transect along the 10m contour, across Kahana tripod site	1.18
VVM3	Shore normal transect near Kapua	0.49
VVM4	Shore normal transect off Honokowai Point	0.32
VVM4a	Shore parallel transect across VVM4, along ~10 m contour	0.52
VVM4b	Shore normal transect about 300 m south of VVM4	0.22
VVM4c	Shore normal transect about 500 m north of VVM4	0.38
VVM5	Shore normal transect offshore Kahikili CRAMP site	0.33
VVM6	Shore normal transect off the north side of Hanakaoo Point	0.41
VVM7	Shore normal transect off the middle of Hanakaoo Point	0.67
VVM8	Shore normal transect off the south side of Hanakaoo Point	0.89
VVM9	Shore normal transect off Lahaina, between Puunoa and the harbor	0.97
VVM10	Shore normal transect south of Lahaina at the Puamana CRAMP site	0.59
VVM11	Shore normal transect off Launiupoko Point	0.58
VVM11a	Shore parallel transect across VVM11	0.74
VVM12a	Shore normal transect off Hekili Point; NW-SE trending reef platform	0.36
VVM13	Shore normal transect south of Hekili Point; NE-SW trending reef platform	1.03
VVM14	Shore normal transect off Ukumehame	0.95
VVM15	Shore normal transect off Manawaipueo Gulch	0.33
VVM15a	Shore parallel transect across pinnacles just southeast of VVM15	0.78
VVM16	Shore normal transect between Kihei Pier and Mapoina Park	2.58
VVM17	Shore normal transect off Maalaea Harbor CRAMP site	0.92
VVM18	Shore normal transect off the Maui Sunset	1.22
VVM19	Shore normal transect off the north end of Kamaole I Beach Park	1.66
VVM20	Shore normal transect off Keawakapu	0.92
VVM20a	Shore parallel transect crossing VVM20 to define morphological transition	1.02
VVM21	Shore normal transect off Wailea	0.93
VVM22	Shore normal transect off Makena	0.56
VVM23	Shore normal transect at the base of the northern side of Puu Olai	0.79
VVM24	Shore normal transect through northern part of Ahihi Bay	1.24
VVM25	Shore normal transect off north side of Cape Kinau, near Ka Lae Mamane	0.75
VVM26	Shore normal transect off Cape Kinau, between Kanahena Pt. and Pohaku Paea	0.99
VVM27	Shore normal transect off southern side of Cape Kinau, near Kalaeloa	1.07
VVM28	Shore normal transect through center of La Peruse Bay	1.78
VVM29	Shore normal transect off Cape Hanamanioa	0.62
VVM30	Shore parallel transect, approx. 30-40' water depth, between Cape Hanamanioa and Kanahena Point	1.95
	Total length surveyed (km)	32.12

*Video data of transect lines VVM 1-30 are archived on tapes 17-22 and 25-27 (9).

TABLE 4.2 UTC, Start (SOL) and End (EOL) locations of survey transects.

Line	UTC Time	Latitude	Longitude	Line	UTC Time	Latitude	Longitude
1_SOL	20021842206600	20.998270	-156.671972	20_SOL	20021852012600	20.703905	-156.447890
1_EOL	20021842214300	21.002013	-156.677328	20_EOL	20021852025100	20.701598	-156.456001
2_SOL	20021842228100	20.982053	-156.679935	21_SOL	20021852039100	20.680860	-156.446858
2_EOL	20021842235200	20.985443	-156.684895	21_EOL	20021852051600	20.681663	-156.451135
2a_SOL	20021842245100	20.989618	-156.677567	22_SOL	20021852107600	20.657241	-156.443968
2a_EOL	20021842301300	20.980708	-156.682887	22_EOL	20021852115300	20.657026	-156.449076
3_SOL	20021842312500	20.969042	-156.684788	23_SOL	20021852123500	20.642048	-156.449008
3_EOL	20021842318100	20.970763	-156.688980	23_EOL	20021852134000	20.641863	-156.453120
4_SOL	20021842332200	20.950276	-156.693816	20a_SOL	20021852209300	20.699181	-156.448774
4_EOL	20021842336200	20.950868	-156.696615	20a_EOL	20021852225000	20.703256	-156.452855
4a_SOL	20021842341400	20.951258	-156.693033	18_SOL	20021852305500	20.751992	-156.464058
4a_EOL	20021842346300	20.946903	-156.694667	18_EOL	20021852322500	20.748563	-156.474318
4b_SOL	20021842352500	20.947581	-156.693996	12_SOL	20021862221100	20.807147	-156.630415
4b_EOL	20021842355300	20.947827	-156.696028	12_EOL	20021862221200	20.807097	-156.630513
4c_SOL	20021850002100	20.952220	-156.692036	12a_SOL	20021862231600	20.805100	-156.621545
4c_EOL	20021850007300	20.951970	-156.695571	12a_EOL	20021862236400	20.802612	-156.623583
5_SOL	20021850018400	20.938186	-156.693988	13_SOL	20021862248400	20.806244	-156.612260
5_EOL	20021850023400	20.938062	-156.696962	13_EOL	20021862301400	20.797388	-156.611751
6_SOL	20021850036400	20.919380	-156.698252	14_SOL	20021862313200	20.801547	-156.596310
6_EOL	20021850042100	20.918688	-156.702055	14_EOL	20021862324100	20.793983	-156.599928
7_SOL	20021850048100	20.915520	-156.698153	15_SOL	20021862345000	20.788690	-156.564445
7_EOL	20021850100000	20.913467	-156.702712	15_EOL	20021862349100	20.785838	-156.565223
8_SOL	20021850108500	20.911191	-156.694613	15a_SOL	20021870000200	20.785011	-156.557763
8_EOL	20021850120500	20.905228	-156.700151	15a_EOL	20021870007400	20.786826	-156.564194
9_SOL	20021850137600	20.877090	-156.686713	24_SOL	20021871703000	20.622222	-156.441088
9_EOL	20021850153200	20.871383	-156.693107	24_EOL	20021871715200	20.614585	-156.449360
10_SOL	20021850212400	20.856016	-156.667686	25_SOL	20021871724300	20.610148	-156.441000
10_EOL	20021850220200	20.852648	-156.671697	25_EOL	20021871733200	20.612373	-156.447430
11_SOL	20021850233500	20.835900	-156.651925	26_SOL	20021871745400	20.597385	-156.435497
11_EOL	20021850240400	20.831980	-156.655252	26_EOL	20021871758000	20.590392	-156.440453
11a_SOL	20021850247100	20.833273	-156.648906	27_SOL	20021871807300	20.594025	-156.427922
11a_EOL	20021850254400	20.836103	-156.652295	27_EOL	20021871821500	20.586788	-156.433238
17_SOL	20021851712400	20.788665	-156.509768	28_SOL	20021871836400	20.596285	-156.419397
17_EOL	20021851724500	20.784393	-156.504690	28_EOL	20021871855100	20.585980	-156.422888
16_SOL	20021851747300	20.774787	-156.462995	29_SOL	20021871907500	20.581235	-156.412347
16_EOL	20021851817100	20.768803	-156.484783	29_EOL	20021871914200	20.575935	-156.413915
19_SOL	20021851909300	20.726040	-156.451606	30_SOL	20021871928200	20.589097	-156.414780
19_EOL	20021851929200	20.720241	-156.465598	30_EOL	20021872002200	20.600150	-156.441740

UTC time format is YYYYDDDHHMMSST (year, Julian_day, hour, minute, seconds, tenths)
Coordinates are decimal degrees, WGS84

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Appendix I

A-2-02-HW: Cruise summary
Vessel: *AlyceC*, Joe Reich Captain
Dates: 25-Jun-02 to 11-Jul-02

Oahu
Chief: Grossman
Crew: Hank Chezar, Eric Grossman, Gerry Hatcher
Dates: 25-Jun-02 to 28-Jun-02
Tapes: 1 – 9 (9)
Lines: OVHM 1 – 14

Molokai
Chief: Richmond
Crew: Hank Chezar, Ann Gibbs, Eric Grossman, Gerry Hatcher
Dates: 30-Jun-02 to 02-Jul-02
Tapes: 10 – 16 (7)
Lines: MVM 1-16

Maui
Chief: Gibbs
Crew: Eric Grossman, Bruce Richmond
Dates: 03-Jul-02 to 06-Jul-02
Tapes: 17 – 27 (11)
Lines VVM 1-30

Molokai (pc_Molokai)
Chief: Pat Chavez
Crew: Ann Gibbs, Will Smith
Dates 08-Jul-02 to 11-Jul-02
Tapes: 28 – 37 (10)
Points: 1 – 365

Appendix II

Summary of Digital 8 video tapes, location, dates, and lines collected

Island	Chief	Date	Index	Tape	Lines
Oahu	Grossman	26-Jun-02	A202HW_TAPE1_26Jun02	1	OHVM 2, 3, 3a, 3b
		26-Jun-02	A202HW_TAPE2_26Jun02	2	OHVM 6,7
		27-Jun-02	A202HW_TAPE3_27Jun02	3	OHVM 1,5,5a
		27-Jun-02	A202HW_TAPE4_27Jun02	4	OHVM 4
		27-Jun-02	A202HW_TAPE5_27Jun02	5	OHVM 13
		27-Jun-02	A202HW_TAPE6_27Jun02	6	OHVM 12, 11
		27-Jun-02	A202HW_TAPE7_27Jun02	7	OHVM 11(cont.),10
		28-Jun-02	A202HW_TAPE8_28Jun02	8	OHVM 8,9
		28-Jun-02	A202HW_TAPE9_28Jun02	9	OHVM 14
Molokai	Richmond	30-Jun-02	A202HW_TAPE10_30Jun02	10	MVM 1,1a,1b,2,3
		30-Jun-02	A202HW_TAPE11_30Jun02	11	MVM 4,5,5a
		1-Jul-02	A202HW_TAPE12_01Jul02	12	MVM 6,6a,7,7a,8,8a
		1-Jul-02	A202HW_TAPE13_01Jul02	13	MVM 9,10,11,12,13
		2-Jul-02	A202HW_TAPE14_02Jul02	14	MVM 5a-2,14
		2-Jul-02	A202HW_TAPE15_02Jul02	15	MVM 14
		2-Jul-02	A202HW_TAPE16_02Jul02	16	MVM 15,16
Maui	Gibbs	3-Jul-02	A202HW_TAPE17_03Jul02	17	VVM 1,2,2a,3
		3-Jul-02	A202HW_TAPE18_03Jul02	18	VVM 4,4a,4b,4c,5,6,7,8
		3-Jul-02	A202HW_TAPE19_03Jul02	19	VVM 9,10,11,11a
		4-Jul-02	A202HW_TAPE20_04Jul02	20	VVM 17,16
		4-Jul-02	A202HW_TAPE21_04Jul02	21	VVM 19,20,21
		4-Jul-02	A202HW_TAPE22_04Jul02	22	VVM 22,23,20a, 18
Maui Nui	Grossman	5-Jul-02	A202HW_TAPE23_05Jul02	23	VMN 1,2,3,4
Maui	Gibbs	5-Jul-02	A202HW_TAPE24_05Jul02	24	VCAL1
		5-Jul-02	A202HW_TAPE25_05Jul02	25	VVM 12,12a,13,14,15,15a
		6-Jul-02	A202HW_TAPE26_06Jul02	26	VVM 24,25,26,27
		6-Jul-02	A202HW_TAPE27_06Jul02	27	VVM 28,29,30
Molokai	Chavez	8-Jul-02	A202HW_TAPE28_08Jul02	28	Points 1-46
		8-Jul-02	A202HW_TAPE29_08Jul02	29	Points 47-78
		8-Jul-02	A202HW_TAPE30_08Jul02	30	Points 79-105
		9-Jul-02	A202HW_TAPE31_09Jul02	31	Points 107-162
		9-Jul-02	A202HW_TAPE32_09Jul02	32	Points 163-205
		10-Jul-02	A202HW_TAPE33_10Jul02	33	Points 206-248
		10-Jul-02	A202HW_TAPE34_10Jul02	34	Points 249-295
		10-Jul-02	A202HW_TAPE35_10Jul02	35	Points 296-301
		11-Jul-02	A202HW_TAPE36_11Jul02	36	Points 302-340
		11-Jul-02	A202HW_TAPE37_11Jul02	37	Points 341-365