W00058-W00062

NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DESCRIPTIVE REPORT

Type of Survey HYDROGRAPHIC

Field No.

Registry No. W00058-W00062

LOCALITY

State Hawaii

General Locality Kauai

Sublocality Alongshore Port Allen to Oomano Point

2000

CHIEF OF PARTY
Maxim F. Van Norden

LIBRARY & ARCHIVES

DATE

NOAA FORM 77-28
(11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTER NO.

W00058-62

HYDROGRAPHIC TITLE SHEET

FIELD NO.

INSTRUCTIONS - The hydrographic sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the office.

State: Hawaii

General Locality: Kauai

Sublocality: Alongshore Port Allen to Oomano Point

Scale: 1:10,000

Date of Survey 1 August-20 December, 2000

Instructions Dated:

Project No.

Vessel: LIDAR (SHOALS)

Chief of Party: Maxim F. Van Norden

Surveyed by: U.S. Naval Hydrographic Office

Soundings taken by echo sounders: SHOALS 400 Lidar

Graphic record scaled by: Fleet Survey Team

Graphic record checked by: Fleet Survey Team

Evaluation by: B. Olmstead, Russ Davies

Automated plot b HP Designjet 1050c

Verification by: Bonnie Johnston

Soundings in: Meters at MLLW

REMARKS: Time in UTC. UTM Projection Zone 4

Revisions and annotations appearing as endnotes were
generated during office processing.
As a result, page numbering may be interrupted or non-sequential
All separates are filed with the hydrographic data.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
OFFICE OF COAST SURVEY
Pacific Hydrographic Branch
Seattle, Washington 98115-6349

June 19, 2008

MEMORANDUM TO: Captain John E. Lowell, NOAA
Chief, Marine Chart Division

THROUGH: Jeffrey Ferguson
Chief, Hydrographic Surveys Division

FROM: Commander David O. Neander, NOAA
Chief, Pacific Hydrographic Branch

David Neander
2008.06.19
08:23:14 -07'00'

SUBJECT: Approval Memorandum for W00058-W00062

The Pacific Hydrographic Branch has completed an evaluation and chart application of Outside Source LIDAR Data from the Naval Oceanographic Office (W00058 – W00062). I have reviewed the data, reports and compilation to the chart. Data are suitable for nautical charting except where specifically recommended in the Evaluation and Quality Assurance Memorandum and Chart Application Memorandum.

Within the 2007 NOAA Hydrographic Survey Priorities (NHSP), the southwest coast of Kauai is listed as "Priority 2" and Hanapepe Bay/Port Allen are listed as "Critical Area". Except as noted in the Evaluation and Quality Assurance Memorandum and Chart Application Memorandum, LIDAR provided adequate depth information in the near shore areas where it was utilized. However, due to the object detection limitations of LIDAR, it cannot be stated definitely that least depths on all new and charted features were obtained. Additional fieldwork including side-scan and/or multibeam surveys of AWOIS items, approaches to harbors and anchorage areas is recommended as resources allow in order to complete bottom search and object detection requirements. Hanapepe Bay and Port Allen should remain classified as "Critical Area" and all other areas within the survey limits should remain classified as "Priority 2".

Survey data acquired by LIDAR should be classified as Category of Zones of Confidence (CATZOC) "B" if used to update ENC's (Seafloor Coverage: Full seafloor coverage not achieved; uncharted features, hazardous to surface navigation are not expected but may exist. Typical Survey Characteristics: Controlled, systematic survey to standard accuracy.).

cc: Chief, HSD Operations Branch N/CS31

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE OFFICE OF COAST SURVEY
Pacific Hydrographic Branch Seattle, Washington
98115-6349

June 11, 2008

David Neander
2008.06.19 08:24:33
-07'00'

MEMORANDUM TO: Commander David Neander, NOAA
Chief, Pacific Hydrographic Branch

Kurt Brown
For Bonnie Johnston
2008.06.17 13:37:19 -07'00'

FROM: Bonnie Johnston
Physical Scientist

SUBJECT: Review of Outside Source Data Surveys W00058 to W00062
U.S. Naval Oceanographic Office (NAVOCEANO)
Kauai Island, Hanapepe Bay to Oomano Point

I have reviewed outside source hydrographic surveys W00058 to W00062 with regard to data integrity and completeness of the data submission package, survey field procedures, data processing and quality assurance methods, and overall data accuracy and data quality. Surveys W00058 to W00062 comply with specifications and requirements set forth in the NOS Hydrographic Surveys Specifications and Deliverables Manual, with the following exceptions:

- SHOALS 400 LIDAR data acquired in this survey does not meet NOAA HSSDM requirements (equivalent to IHO Order 1) for object detection. The capability of LIDAR to meet NOAA object detection requirement is still unproven and questionable, and item investigations to either disprove charted features or acquire definitive least depths were not conducted. These data do meet NOAA HSSDM requirements for depth and position accuracy.

Refer to the Outside Source Data Quality Assurance Checklist for specific charting recommendations.

Final Recommendations:

- The data should be used to chart soundings and depth curves representing general bathymetric trends, and new shoals and features that are not currently depicted on NOAA charts 19381, 19382 and 19386.
- The data should not be used to supersede near shore features such as wrecks, rocks, obstructions, foul areas or coral reefs.
- The charted shoreline should be retained as charted.
- Bottom samples were not acquired and should be retained as charted.

Kurt Brown
2008.06.17 13:37:32 -07'00'

Reviewed and approved: ________________________________

PS Kurt Brown, NOAA
Acting Hydrographic Team Leader, PHB

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
OFFICE OF COAST SURVEY
Pacific Hydrographic Branch
Seattle, Washington 98115-6349

June 16, 2008

David Neander
2008.06.19
08:24:56 -07'00'

MEMORANDUM TO: Commander Dave O. Neander
Chief, Pacific Hydrographic Branch

FROM: Charles R Davies
Cartographer, Pacific Hydrographic Branch

SUBJECT: Application of Outside Source Data Surveys
W00058-W00062
U.S. Naval Oceanographic Office
SHOALS 400 LIDAR

I concur with all recommendations by the reviewer Bonnie Johnston except where noted in this report.

Summary of compilation:

- -soundings, curves and features applied
- -no rocks, shoals were superseded
- -shoreline was retained as charted
- -bottom characteristics were retained
- -recommend aids to navigation be updated with the latest information
- -no additional Dangers to Navigation were found during compilation

It is recommended that OSD surveys W00058-W00062 supersede charted information within the common area and applied to charts 19381, 19382, and 19386.

Record of Application to Charts is attached.

Review and Approved Gary C. Nelson

Digitally signed by Gary C. Nelson
DN: cn=Gary C. Nelson, c=US, o=NOAA, ou=Pacific Hydrographic Branch, email=gary.nelson@noaa.gov
Date: 2008.06.17 13:33:12 -07'00'

Gary Nelson, Cartographer Team Leader
Pacific Hydrographic Branch

David Scharff
AWOIS and Surf Check
2008.07.13 21:48:32 -04'00'

Registry No: W00058, W00059, W00060, W00061, W00062

State: Hawaii

General Locality: Southwest Coast of Kauai

Sub Locality: Hanapepe Bay to Oomano Point

Dates of Survey: August 1 - December 20, 2000 (Lidar)

OSD Supplier: U.S. Naval Oceanographic Office (NAVOCEANO)

OSD Project No: 00US/16/02US27 Surveys 00601/00602/00603/00604/00605

Reviewer: Bonnie Johnston **Review Date:** May/June 2008

I. DATA INVENTORY

A. Reports

Report Type	Format	Document Title	Date
Descriptive Report or equivalent	Microsoft Word	HAWAII LIDAR ROS, Lidar Report of Survey	01/31/2002
Data Acquisition and Processing Report or equivalent	Microsoft Word	HAWAII LIDAR ROS, Lidar Report of Survey	01/31/2002
Horizontal and Vertical Control Report or equivalent	NA	NA	
System Certification Report or Equivalent	NA	NA	
Other	PDF		

B. Data

Data Type	Format	Description (Raw, Processed)
Smooth Sheet Sounding Plots	Microstation, 1:10,000	File Names: 01x.dgn, 02x.dgn, 03x.dgn, 04x.dgn, 05x.dgn
XYZ ASCII Files	NA, Smooth Sheet Sounding Density	01x_102303.asc, 01x_102303.pfm.crs, 02x_102303.asc, 02x_102303.pfm.crs, 03x_102303.asc, 03x_102303.pfm.crs,
Multibeam	Fledermaus PFM, Full Resolution	01x.pfm, 02x.pfm, 03x.pfm, 04x.pfm, 05x.pfm
Side Scan Sonar	NA	NA
LIDAR	Fledermaus PFM, Full resolution Sounding Density	01x.pfm, 02x.pfm, 03x.pfm, 04x.pfm, 05x.pfm
Single Beam	NA	NA

Data Type	Format	Description (Raw, Processed)
Detached Position Point Feature	NA	Data not provided, no positions were taken
Kinematic / Static GPS	NA	Data not provided
Sound Velocity	NA	Data not provided
Water Levels	NA	Data not provided
AWOIS	NA	None were investigated by the Hydrographer
DtoN	NA	None were identified by the Hydrographer
Shoreline	NA	Data not provided. Source shoreline was digitized from vector data used in the DNC of the area.
Bottom Sample	NA	No Bottom Samples were taken.

Yes ______ All data open correctly and without error (MBES lines, SSS lines, VBES, Crosslines, Fieldsheets, Smooth Sheets, Sessions, DTM's, BASE grids, Mosaics, and DP's).

C. Sensors

List all sensor(s) that were used to acquire data.

Sensor	Manufacturer	System	Model	Vessel / Platform
Position	Ashtech	Z-12		SHOALS
LIDAR	Optech	SHOALS	400	SHOALS
Motion	APASS			SHOALS

Note 1 ______ Are all sensors listed above capable of meeting NOAA HSSDM accuracy and object detection requirements? Provide information in the comments section.

II. DATA ACQUISITION AND PROCESSING

A. System Calibrations and/or Certifications

Note 2 A sensor offset and alignment survey was conducted to NOAA HSSDM requirements

No Offset values provided

NA Patch tests were conducted for shallow-water multibeam systems

NA Alignment bias and latency values provided

NA Draft measurements were conducted

____ Static Draft ____ Dynamic Draft ____ Loading

____ Draft values were provided

Note 3 Sensors were calibrated in accordance with manufacturer requirements and NOAA specifications

No Calibration reports were provided.

B. Sound Velocity Corrections

NA Sound velocity sampling regimen is in accordance with NOAA HSSDM requirements

NA Sound velocity profiles were supplied

NA All profiles appear valid

C. Water Levels

Note 4 Water level measuring equipment and methods are consistent with NOAA equipment and methods and are capable of meeting specifications

Equipment / method used: NOAA tide gauges and zoning

No Tide corrector files were supplied

NA All tide correctors appear valid

Yes Water level correctors applied to sounding data

✔ Verified ___ Observed ___ Predicted ✔ NOAA Zoning ___ Other zoning

No Water level error estimate provided by CO-OPS

Water level / zoning error estimate: ________________

E. Survey Methodology

Yes — The surveyor has conducted adequate quality control of horizontal positioning data

Note 5 — DTM, BASE surface, and/or mosaics indicate that seafloor coverage requirements (per NOAA HSSDM) were met and no significant coverage holidays exist.

Note 6 — All least depths over shoals, wrecks, rocks, obstructions, and other features have been determined

Yes — The Hydrographer has conducted the required quantity of cross lines, or acquired sufficient redundant data, in accordance with the HSSDM, to assess internal data consistency.

F. Data Processing and Quality Control

Yes — An adequate description of data processing and quality control methods is provided in documentation.

Processing software used: NAVOCEANO Area Based Editor in LINUX; Fledermaus

Yes — Data processing methodology is robust enough and adequate to provide a dataset suitable for charting.

Yes — Data have been reviewed and are cleaned appropriately with no noise, fliers, or systematic errors noted.

Yes — Crossline agreement or redundant data overlap has been visually inspected by the hydrographer

No — Disagreements have been noted

Yes — A Chart comparison was conducted by the hydrographer

Yes — Disagreements have been noted.

See Section V

III. DATA QUALITY AND RESULTS

A. Internal Data Consistency

Yes, PFMs Full resolution data was provided in order to gauge the adequacy of cleaning and/or processing of the data.

NA A review of the data reveals no positioning errors exceeding NOAA specifications

Yes Crossline agreement or redundant data overlap shows no disagreements exceeding NOAA HSSDM tolerances.

No **A**nomalous data (fliers, noise, etc) were apparent in the BASE surface, DTM, and/or selected sounding set.

No Are there any tide errors exceeding NOAA HSSDM requirements observable in the data

NA Are there any observable SV errors exceeding NOAA HSSDM accuracy standards.

Yes All shoals are valid (no fliers) and the proper least depth has been retained.

NA Where multiple systems, platforms, and/or sensors were used, junctioning or overlapping data agree within NOAA HSSDM tolerance between platforms.

Yes Any statistical assessment of the data (e.g. BASE standard deviation, QC reports, etc) indicate that data agree within NOAA HSSDM tolerances.

B. Error Budget Analysis

Yes An error budget analysis was provided by the surveyor

- Yes The error budget analysis indicates that data are capable of meeting NOAA HSSDM standards
- Yes The evaluator concurs with the provided error budget analysis

No The evaluator has conducted an error budget analysis

- NA The error budget analysis indicates that data are capable of meeting NOAA HSSDM standards

D. Automated Wreck and Obstruction Information System (AWOIS) Items

0 AWOIS Items are located within the limits of the survey.

- NA AWOIS Items can be sufficiently confirmed or disproved using data from this survey (Attach AWOIS pages to the certification memorandum.).

E. Dangers to Navigation

___NA___ Dangers to Navigation (DTONs) were selected and submitted by the surveyor / data provider

__NA__ DTONs have been verified by the office evaluator.

___No___ Additional DTONs were noted during office evaluation and submitted

F. Aids to Navigation

___No___ Aids to Navigation (ATONs) were positioned during this survey

__NA__ New ATONS were positioned during this survey

__NA__ Survey positions match charted positions

__NA__ The surveyor / data provider issued DTONs or notified the USCG for any ATON discrepancies

__NA__ ATON discrepancies were noted during office evaluation and submitted as DTONs.

G. Shoreline and Bottom Samples

___NA___ The shoreline (MHW and/or MLLW lines) were included as part of this survey

__NA__ Surveyed shoreline matches charted shoreline

__NA__ Surveyed shoreline compares with NGS/RSD source data

__NA__ Surveyed shoreline should be used to revise nautical charts

___NA___ Shoreline features were positioned during this survey

__NA__ Surveyed features match charted shoreline

__NA__ Surveyed features compares with NGS/RSD source data

__NA__ Surveyed features should be used to revise nautical charts

___NA___ Bottom samples were acquired during this survey

__NA__ Bottom sample spacing was in accordance with NOAA HSSDM requirements

__NA__ Bottom samples should be used to update NOAA charts

IV. COMMENTS

Data for surveys W00058 through W00062 were acquired solely with the SHOALS 400 LIDAR System (Figure 1). The Kauai surveys were conducted due to a request by the Pacific Missile Range Facility (PMRF) for detailed inshore bathymetric data to meet the increasing interest in very shallow water operations.

Note 1:
At this time NOAA does not have sufficient experience or empirical test results confirming that the SHOALS 400 system is capable of meeting NOAA HSSDM object detection requirements. These data should not be considered to meet object detection requirements. According to the Report of Survey (ROS), the system is theoretically capable of meeting IHO Order 1 object detection requirements in depths of 5 to 30 meters at a 4 x 4 meter spot density; however, more empirical testing is needed to confirm this.

The SHOALS 400 system is capable of meeting NOAA HSSDM standards for depth and positioning accuracy.

Note 2:
The LIDAR ROS states that "The laser system and motion sensors are optically aligned and the offsets measured with respect to the phase center of the GPS antenna. This is done at every system or component installation. The measured offsets were entered into a "STATIC" file and are applied to the data during post processing. The STATIC file was not submitted with the bathymetric data.

It is not known if the system alignment survey method meets HSSDM standards.

Note 3:
According to the HAWAII LIDAR Report of Survey (ROS), the SHOALS system was calibrated prior to survey operations and whenever major system components were changed or modified.

Note 4:
Tide corrector values were obtained from a NOAA-maintained gauge located at Nawiliwili, Kauai. NAVOCEANO installed an additional gauge in a small craft harbor on Kauai located south of the PMRF between Kekaha and Waimea Bay. The installed gauge was used as a backup to the NOAA gauge on Kauai and was also used to confirm the NOAA tide-zoning scheme (See Lidar ROS Appendix B).

Note 5:
All surveys off the Southwest coast of Kauai were acquired for the US Navy and were reported to be completed with 4x4 meter spot density and 200 percent coverage. According to the NAVOCEANO ROS, this coverage would meet IHO Order 1 standards for object detection and multiple coverage. A review of the Lidar data in Fledermaus, showed that most areas obtained the reported 200 percent coverage.

Note 6:
Least depths over shoal areas and bathymetric features obtained during the NAVOCEANO Lidar surveys were reviewed visually in Fledermaus and appear to be valid. Due to the object detection limitations of LIDAR, it can not be said definitively that the least depths on all new and charted features were obtained.

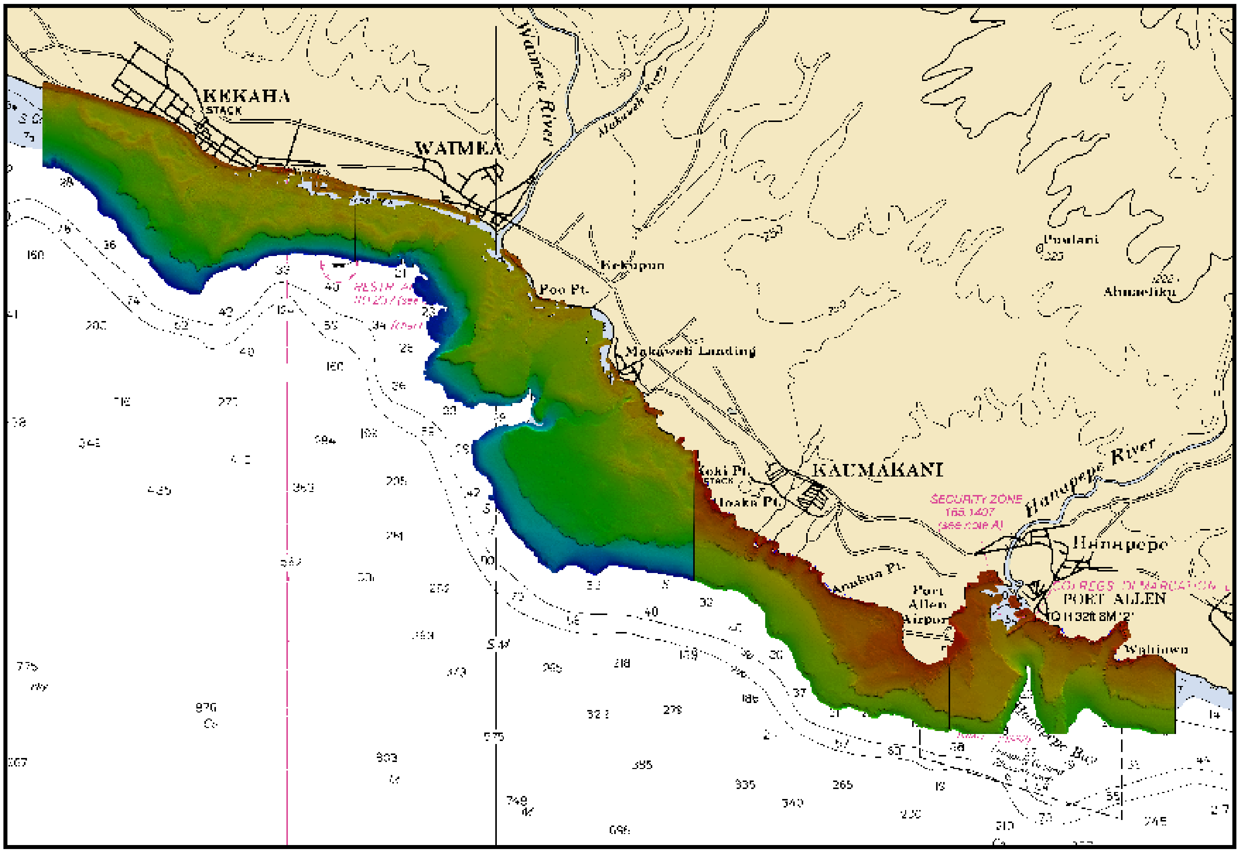
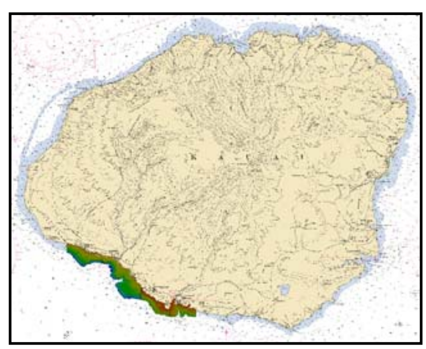


Figure 1. An overview of the area covered by NAVOCEANO surveys W00058 through W00062. The surveys cover a portion of the Southwest coast of Kauai, HI, spanning from Hanapepe Bay to Oomano Point. Digital terrain models (DTMs) from each survey area are overlain on chart 19381.



V. CHART COMPARISON

Chart comparisons were conducted by the Reviewer for Surveys W00058 through W00062 using the largest scale charts that were available for the survey areas. The following charts were compared with the surveyed smooth sheet soundings:

Chart	Scale	Edition	Date	Units
19382	1:5,000	15th	July 1993	Ft
19386	1:10,000	11th	July 2005	Fm
19381	1:80,000	8th	July 1993	Fm

In general, smooth sheet depths agreed with the charted soundings within 1 fathom.[1] A significant difference in depths was observed along a large section of the charted 10-fathom contour, where it appears that the shape of the shelf has either changed or was never properly positioned. Additional shoaling and deepening trends were noted along the 10-fm contour; these discrepancies and additional significant changes noted during the chart comparison will be noted below on a survey specific basis. [2]

Shoaler surveyed depths should supersede deeper charted soundings and charted contours should be updated. All charted wrecks, rocks, obstructions and shoals should be retained due to the absence of feature investigations in the survey area and the unproven object detection capability of Lidar systems for use in disprovals of charted features. [3]

SURVEY W00058

Chart 19382

Several areas of significant shoaling were noted over a submerged ledge located around Weli Point (Figure 2). A new seaward extent of the submerged ledge with a depth of 21 feet was positioned at 21-53-31.7 N, 159-34-37.4 W in between charted depths of 43 and 33 feet. [4]

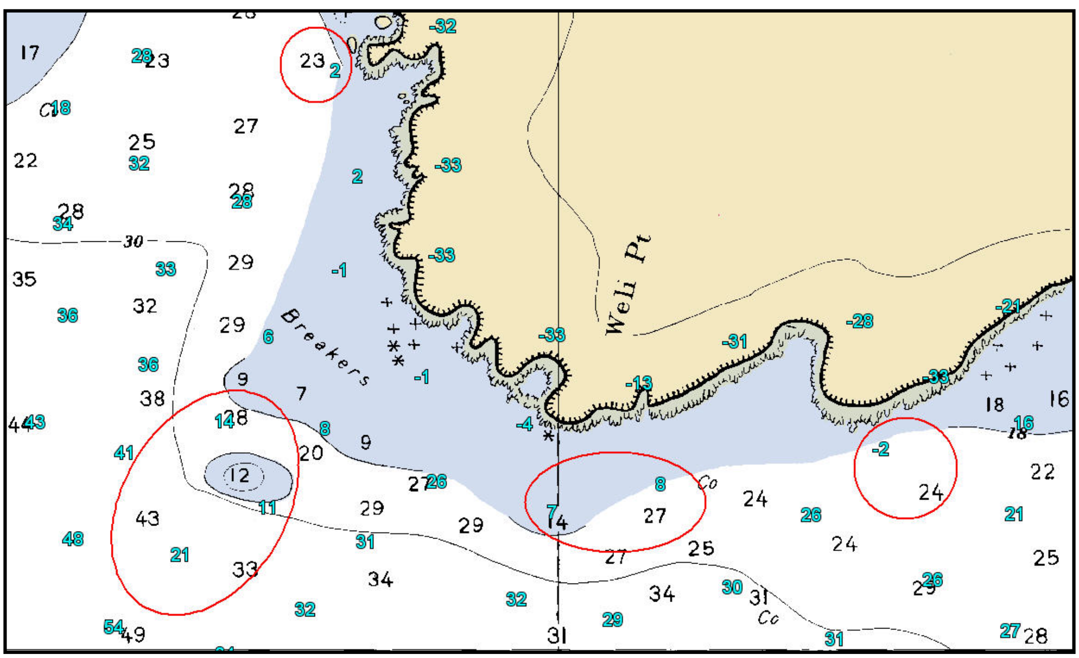


Figure 2. In this image, smooth sheet depths from survey W00058 are colored in blue and overlain on Chart 19382. The red circles highlight locations where the smooth sheet depths were significantly shallower than charted depths surrounding Weli Point. All depths are in feet.

A new shoal was surveyed approximately 300 meters west of Weli Point. A 25 foot depth located at 21-53-34.9 N, 159-34-41.7 W was surveyed seaward of a charted 40 foot depth. [5]

A 9-foot depth located at 21-53-43.27 N, 159-34-54.9 W [6] was surveyed seaward of a charted 22-foot sounding (Figure 3). The 9-foot depth is a new extent of a submerged ledge located west of Port Allen. [7]

Two charted shoals with depths of 8 feet located south of Port Allen were not found in the surveyed data (Figure 4). One of the charted 8-foot shoals located at 21-53-50.5 N, 159-35-09 W, was surveyed with a depth of 16 feet, and was not visible in the high density sounding data set when viewed in Fledermaus 3D Editor. [8]

A review of the data in Fledermaus also revealed that the second 8-foot shoal was surveyed approximately 30 meters to the northwest of its charted position. [9] The charted shoal should be moved to the new surveyed position located at 21-53-49.7 N, 159-35-09.3 W. This feature may also represent the true location of the reported wreck charted nearby (Figure 4). [10]

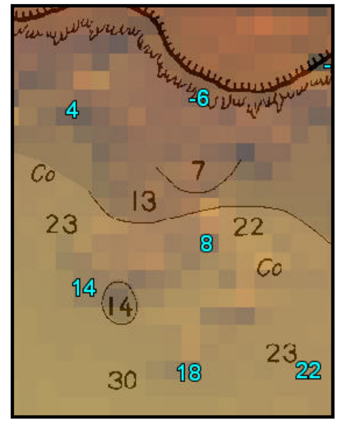


Figure 3. An 8-ft depth was surveyed seaward of a charted 22-ft depth. A DTM is overlaid on chart 19382, with surveyed depths in blue.

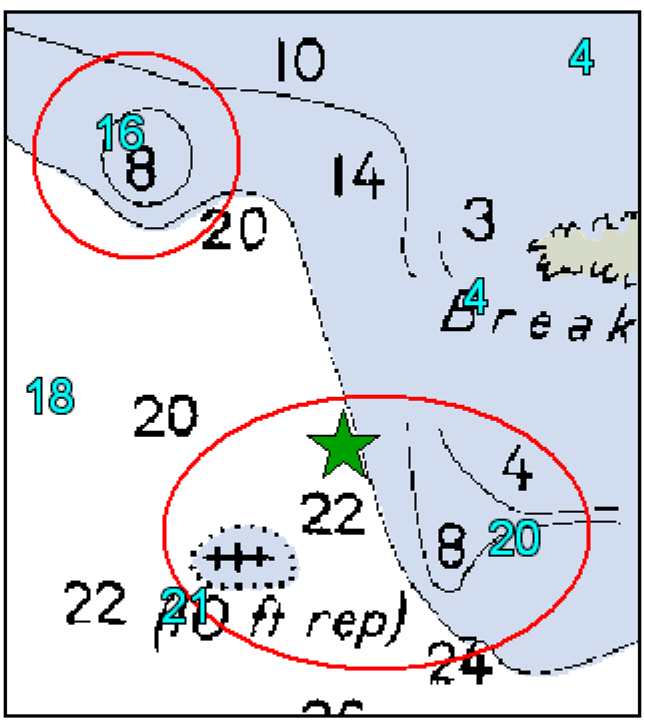


Figure 4. The red circles highlight the locations of two charted 8-ft shoals located south of Port Allen. The northern 8-ft shoal was not found and was surveyed as 16 feet. The southern 8-ft shoal was repositioned 30 meters to the northwest, with the new surveyed position represented by the green star. The Reviewer believes that the surveyed feature is the true location of the reported 10-ft wreck located 30 meters to the south. Chart 19382 is displayed in the background.

Near the western bound of Survey W00058, a new least depth of 15 feet located at 21-53-31.2 N, 159-35-46.8 W was surveyed over a charted submerged ledge. At the seaward most extent of the same submerged ledge, a 28-foot depth located at 21-53-22.4 N, 159-35-47.9 W was surveyed over a charted 38 foot depth. It is recommended that the charted 30-foot contour be updated to follow the new southern extent of the submerged ledge. [11]

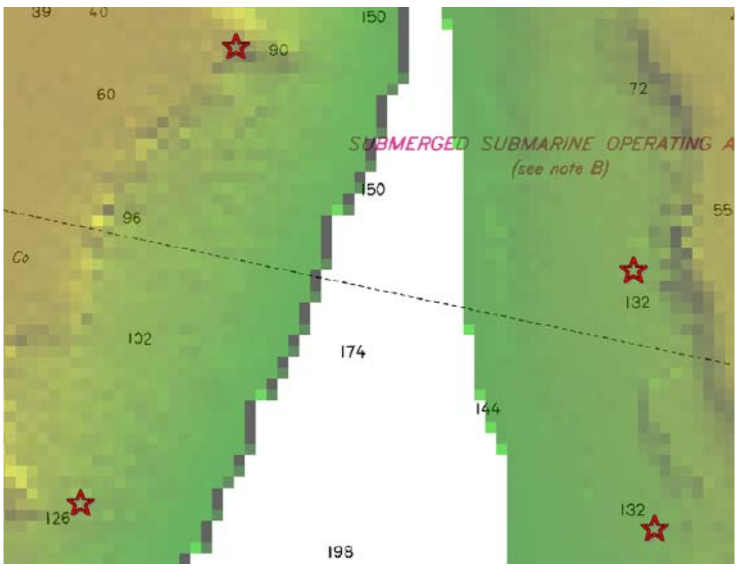


Figure 5. The red stars represent the locations where significant shoaling was noted along the channel leading into Port Allen, Kauai. A DTM was overlain on Chart 19382, with soundings displayed in feet.

Some significant changes were noted on the east and west sides of the channel heading into Port Allen (Figure 5). On the west side of the channel, a 54-foot depth located at 21-53-28.7 N, 159-35-21.5 W was surveyed 20 meters to the west of a charted 90-foot depth and a 99-ft depth located at 21-53-17.8 N, 159-35-25.4 W was surveyed seaward of a charted 126-foot depth. [12] On the east side of the channel, a 103-foot depth located at 21-53-23.4 N, 159-35-11.3 W was surveyed 20 meters north of a charted 132-foot depth and a 111-foot depth located at 21-53-17.24 N, 159-35-10.76 W was located in the vicinity of a charted 132-ft depth. [13]

Finally, there were three more instances noted where surveyed depths were over 10 feet shallower than charted depths. A 55-foot depth located at 21-53-19.02 N, 159-35-6.07 W was surveyed in the vicinity of a charted 66-foot depth. In deeper water, a charted 144-foot depth located at 21-53-15.24 N, 159-34-49.7 W was surveyed as 126 feet and a 126-foot charted depth located at 21-53-19 N, 159-34-50 W was surveyed as 111 feet. [14]

SURVEY W00059

<u>Chart 19382</u>

A new extent of a submerged ledge was surveyed to the south of Puolo Point. A 24-foot depth located at 21-53-23.33 N, 159-36-12.57 W was surveyed seaward of a 30-foot contour and a 17-foot depth located at 21-53-25.11 N, 159-36-12.57 W surveyed in the vicinity of a charted 24-foot depth.

SURVEY W00060

New Features

Two potential new wrecks were surveyed west of Hoanuanu Bay (Figure 6). These obstructions do not pose a danger to navigation.

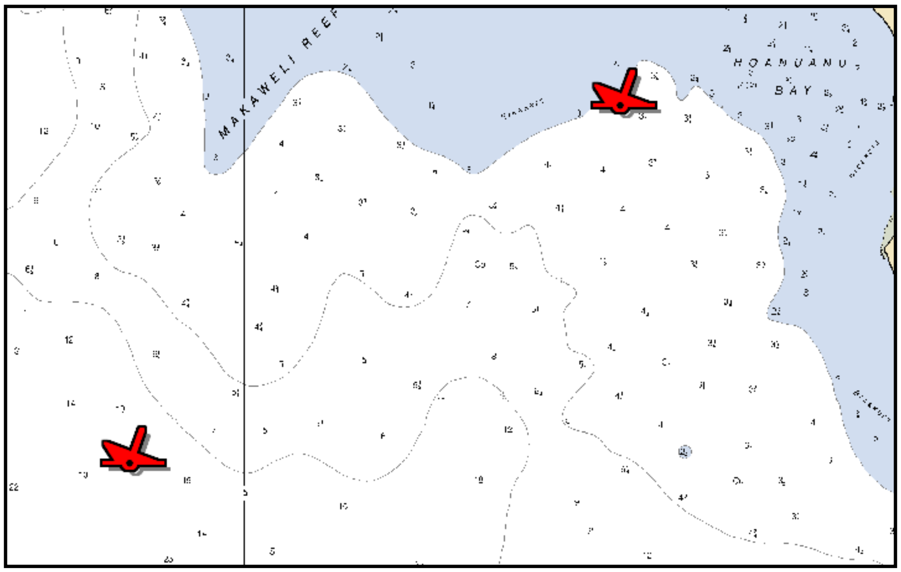


Figure 6. The locations of two potential new wrecks are highlighted in red, to the west of Hoanuanu Bay, with Chart 19386 in the background.

The first obstruction is located at 21-56-17.47 N, 159-39-25.3 W approximately 300 meters to the west of Hoanuanu Bay and has a least depth of 2.4 fm (Figure 7). The second obstruction is located at 21-55-46.8 N, 159-40-10.4 W approximately 700 meters south of Makaweli Reef and has a least depth of 12.4 fm (Figure 8). It is not possible to state from the available soundings whether the features are indeed wrecks; additional investigations would be required with either a shallow water multibeam sonar or sidescan sonar to make that determination. [15]

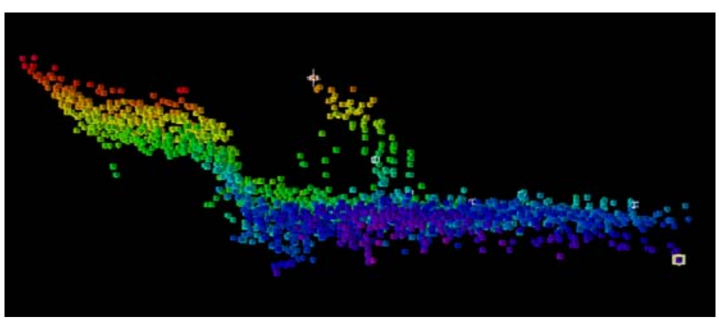


Figure 7. Potential wreck located on the western approach to Huanuanu Bay shown in Fledermaus 3D Editor. Soundings are colored by depth.

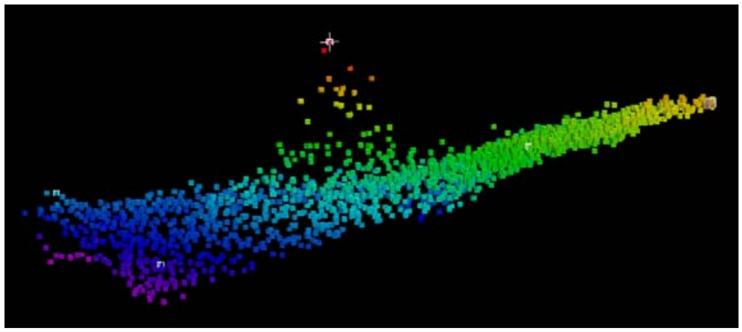


Figure 8. Potential wreck located seaward of the Makaweli Reef shown in Fledermaus 3D Editor. Soundings are colored by depth.

<u>Chart 19386</u>

A shoal located to the west of Koki Point has expanded to cover a larger region than what is actually charted (Figure 9). The shoal is located in the vicinity of 21-55-10.8 N, 159-38-47.5 W and surveyed depths in this area are between 0.2 to 1 fathom shallower than charted. It is recommended that the charted 3-fathom contour be updated to reflect the true size and location of the shoal. [16]

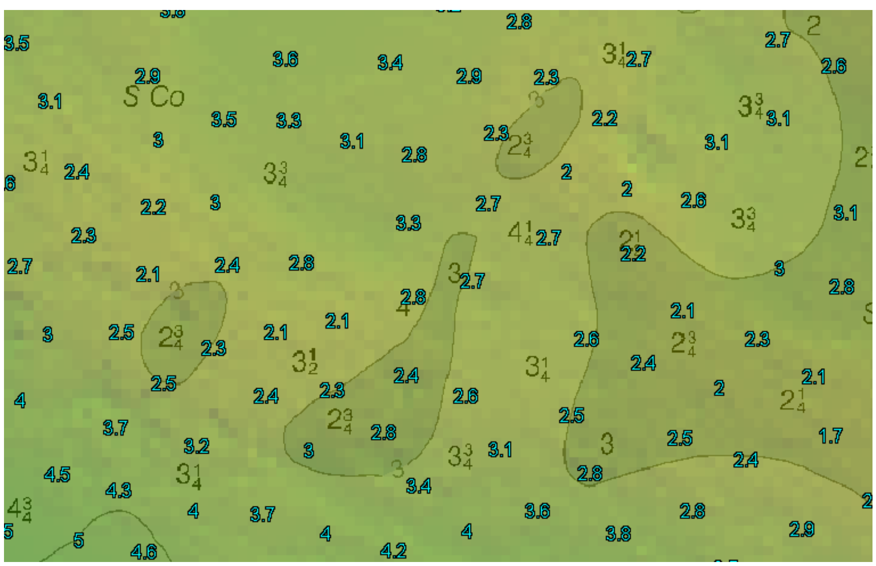


Figure 9. Many soundings shoaler than 3 fathoms were surveyed outside the 3-fm contours surrounding the charted shoal to the west of Koki Point. The surveyed depths should be used to update the 3-fm contour to better represent the shape of the shoal. Smooth sheet depths from Survey W00060 are colored in blue with a partially transparent DTM overlain over Chart 19386. All depths are in fathoms.

A new reef was surveyed near the coastline between Koki Point and Pakala Point, extending between 21-55-24.3 N, 159-38-28.15 W and 21-55-26.2 N, 159-38-31.2 W. The depths on the high points of the reef were surveyed as -0.1 and -0.3 fathoms (Figure 10). [17]

An uncharted narrow channel was surveyed leading to Robinson Landing (Figure 11). The channel is bounded by the reef on both sides and has a controlling depth of 0.9 fm located at 21-55-47.15 N, 159-38-45.1 W. Due to the narrowness of the channel and uncertainty regarding whether the least depths were obtained, it is recommended that the channel remain uncharted and navigation left to local knowledge. [18]

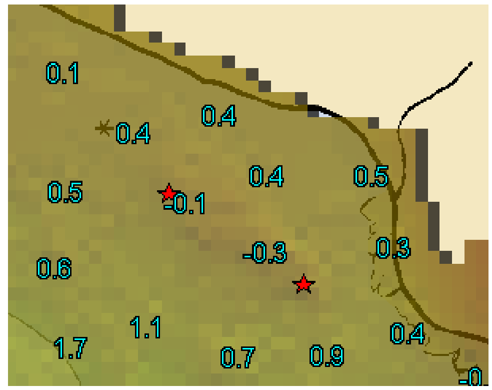


Figure 10. The red stars represent the extents of the new reef and the smooth sheet depths are shown in blue over Chart 19386. All depths are in fathoms.

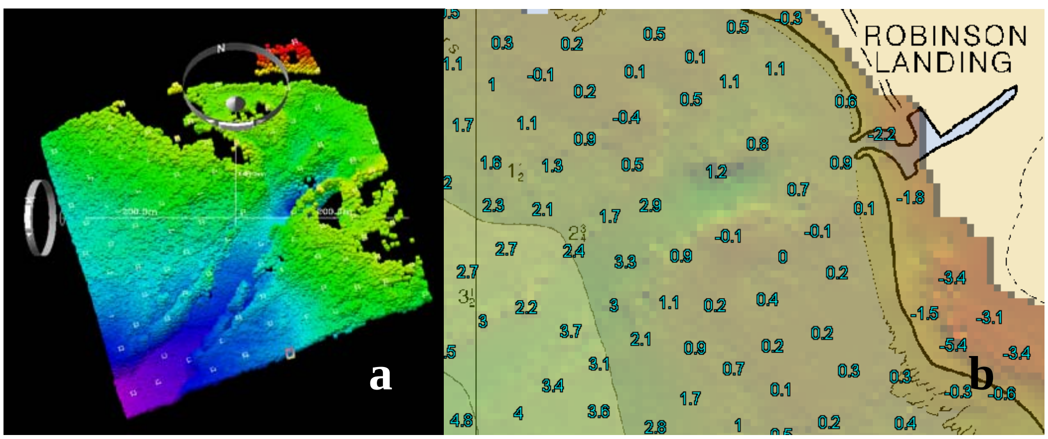


Figure 11. (a) The Robinson Landing end of the uncharted channel as seen in Fledermaus 3D Editor. Data points were colored by depth. **(b)** Smooth sheet depths (in blue) are displayed with a partially transparent DTM overlaid on Chart 19386. Depths are in fathoms.

A new least depth was surveyed over a charted shoal on the west side of Makaweli Reef. A 2-fm depth was surveyed at 21-56-20.54 N, 159-40-5.56 W in the vicinity of a charted 3.5-fathom sounding. [19]

New depths of 1.8 and 2 fathoms were surveyed in Hoanuanu Bay. The 2-fm depth was located at 21-56-17.76 N, 159-39-13.64 W and the 1.7-fm depth was located 100 meters inshore at 21-56-18.57 N, 159-39-9.4 W. [20]

Although shoaling between 0.5 and 1 fathom was noted along the charted 5-fathom contour, more significant discrepancies were noted between surveyed depths and the charted 10-fathom contour extending through Survey W00060 into Survey W00061. The 10-fathom contour appears to follow the shape of the seaward edge of the submerged shelf that is visible in the NAVOCEANO submitted DTMs. In many instances, the charted 10-fathom contour is not accurate and surveyed depths range between being 3 to 5 fathoms deeper than charted (Figure 12) or up to 2.5 fathoms shoaler than charted (Figure 13). It is recommended that the charted 5 and 10 fathom contours be modified using the surveyed depths. [21]

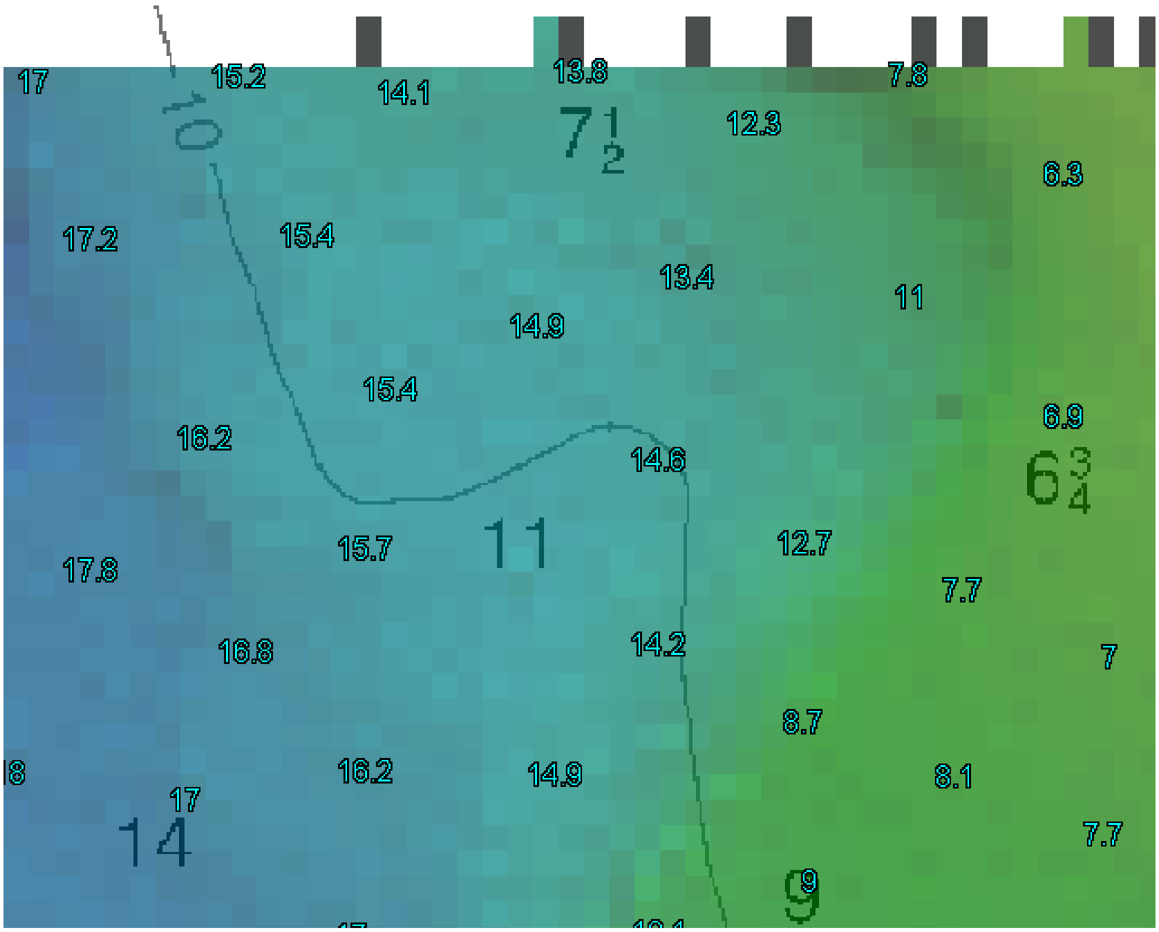


Figure 12. In the northwest corner of Survey W00060 (~21-56-26.36 N, 159-40-19.1 W), a large discrepancy was found between the charted 10-fm contour and the surveyed depths. Smooth sheet depths are shown in blue and were over 5 fathoms deeper than charted depths. Also, a partially transparent DTM colored by depth was overlain on Chart 19386.

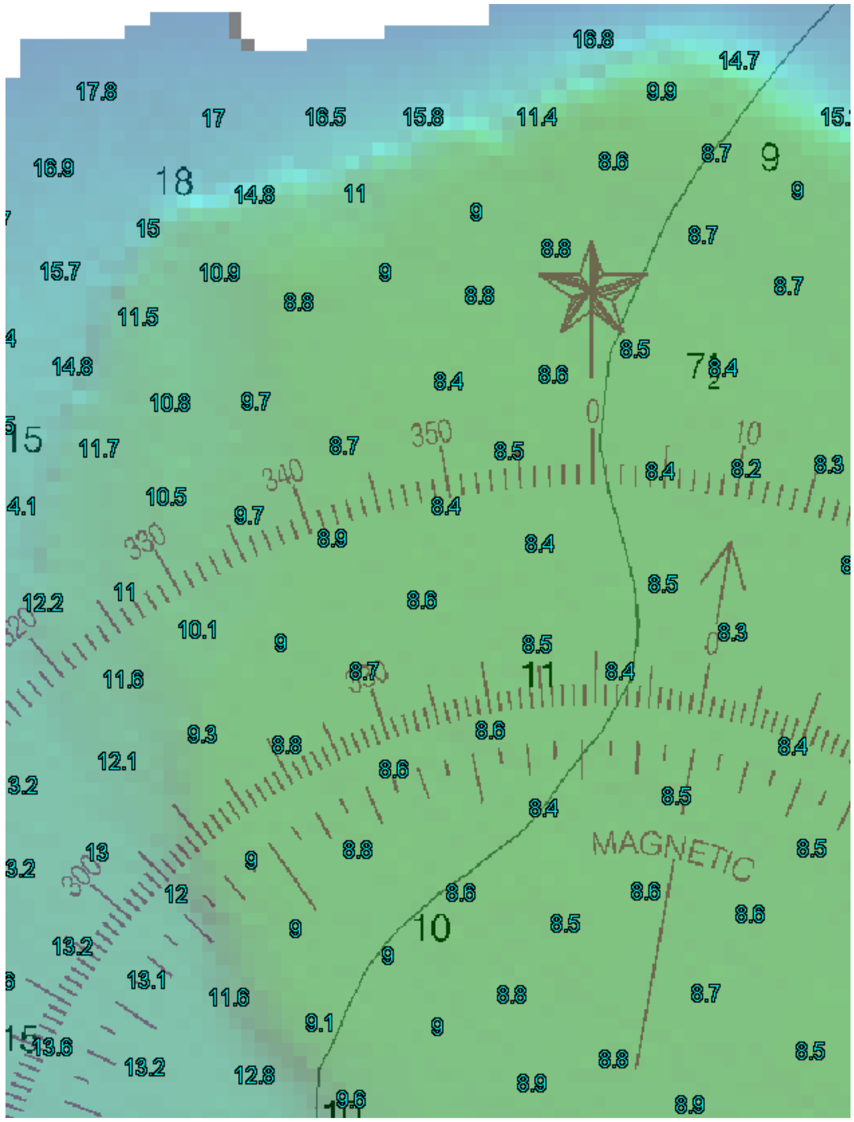


Figure 13. An example of shoaling noted along the charted 10-fm contour in survey W00060 (~21-55-21.9 N, 159-39-48.8 W). Smooth sheet depths are shown in blue, with the 10-fm contour represented by the grey line running diagonally across the center of the image. Surveyed depths in this situation are up to 1.6 fathoms shallower than charted. A partially transparent DTM colored by depth was overlaid on Chart 19386.

SURVEY W00061

<u>Chart 19386</u>

There was a particularly pronounced deepening trend noted along the charted 10-fathom contour for the majority of Survey W00061. Surveyed depths were 2.5 to 5 fathoms deeper than the charted 10-fm contour starting at 21-56-30.26 N, 159-40-22.22 W and ending approximately at 21-56-56.33 N, 159-40-53.69 W. It is recommended that the charted contours be updated using the surveyed depths. [22]

Two new seaward extensions of the submerged reef were surveyed in the western approach to Waimea Bay (Figure 14). A least depth of 3 fathoms located at 21-56-59.9 N, 159-40-31.4 W was surveyed over the eastern extension of the reef, located seaward of the charted 5-fm contour. The least depth over the western extension of the reef was surveyed as 4.2 fathoms located at 21-57-1.3 N, 159-40-43.9 W situated in between two charted depths of 6.25 fathoms. [23]

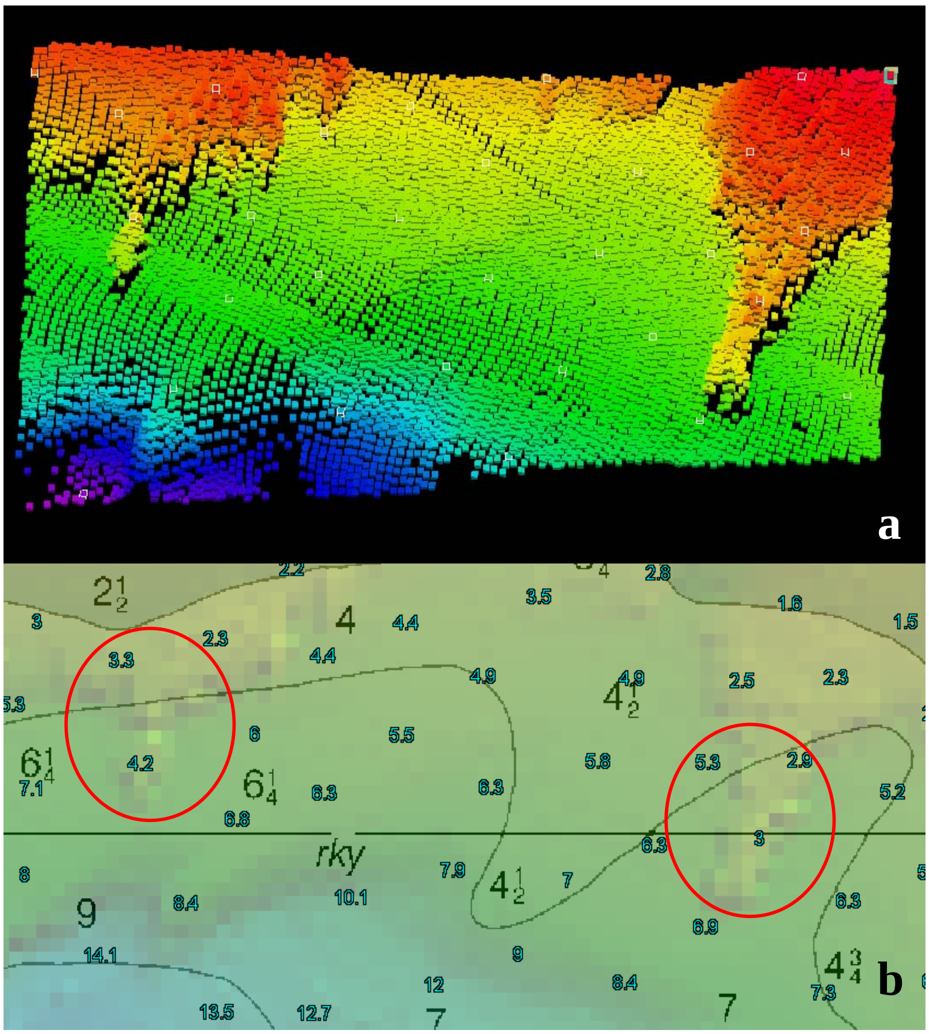


Figure 14. (a) Two new extensions of the reef shown in Fledermaus 3D Editor with data points colored by depth. **(b)** The new reef extensions are highlighted by the red circles, with smooth sheet depths shown in blue and a DTM overlain on Chart 19386. All depths are in fathoms.

SURVEY W00062

Chart 19386

A 16.4-fathom depth located at 21-56-57.7 N, 159-41-16.8 W was surveyed in the vicinity of a charted 26-fathom sounding. [24]

There were several instances of significant shoaling along the 10-fathom contour. A 6-fathom depth was surveyed over the 10-fathom contour at 21-57-6.7 N, 159-41-59.7 W. Depths of 6.8 and 7.4 fathoms were surveyed in the vicinity of the 10-fm contour at 21-57-0.7 N, 159-41-8.6 W. Discrepancies of up to 1.5 fathoms, shallower and deeper, were noted along the 5-fathom contour. Contours should be modified using surveyed data. [25]

A deepening trend was observed between the 5 and 10 fathom contours for a large section of Survey W00062, ranging from 21-56-30.65 N, 159-40-16.3 W to 21-56-58.7 N, 159-40-42.1 W. Depths were up to 5 fathoms deeper than charted, one case in particular was when a depth of 12 fathoms was surveyed over a charted 7 fathom sounding at 21-56-55.53 N, 159-40-37.15 W. [26]

A charted shoal to the south of Oomano Point has expanded (Figure 15). Depths surrounding the shoal located in the vicinity of 21-57-12.96 N, 159-42-02.7 W were 0.5 to 2 fathoms shoaler than charted. It is recommended that the 3-fathom contour be updated to better define the true extents of the shoal. [27]

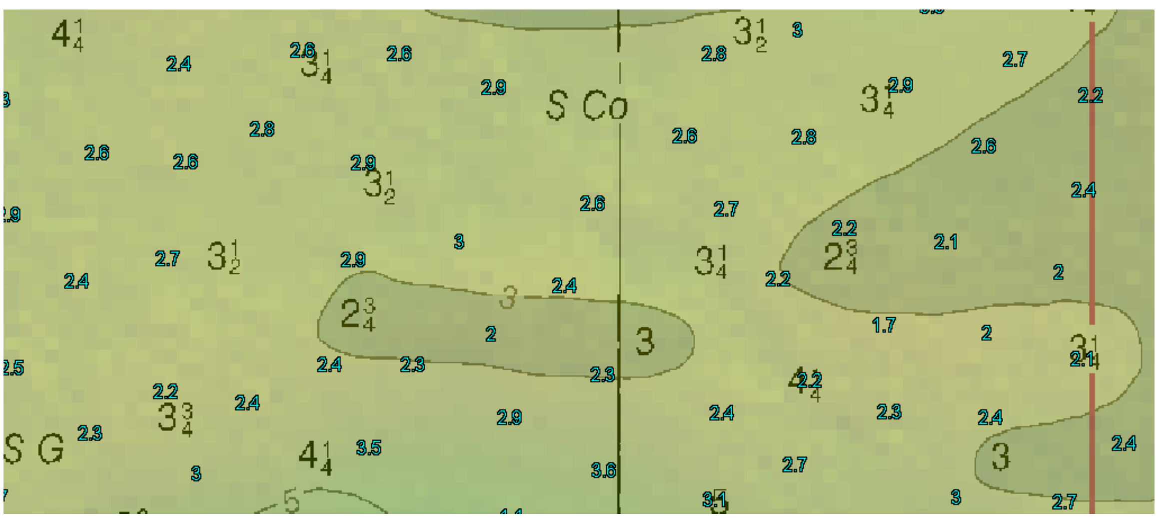


Figure 15. Many soundings shoaler than 3 fathoms were surveyed outside the 3-fm contours surrounding the charted shoal to the south of Oomano Point. The surveyed depths should be used to update the 3-fm contour to better represent the shape of the shoal. Smooth sheet depths from Survey W00062 are colored in blue with a partially transparent DTM overlain over Chart 19386. All depths are in fathoms.

Revisions Compiled During Office processing and Certification

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[1] Concur
[2] Chart area as shown on the Hdrawing.
[3] Concur
[4] Chart area according to this survey.
[5] Chart area according to this survey.
[6] Concur
[7] Chart according to the Hdrawing
[8] Due to the object detection limitations of LIDAR, it can not be said definitively that the least depths on all new and charted features were obtained. Retain soundings as charted.
[9] This sounding was pulled through to the Hdrawing from the Fledermaus position; it was not on the smooth sheet. The 8 foot sounding should be charted as shown on the HDrawing.
[10] Due to the object detection limitations of LIDAR, the charted eight foot depth should be retained as charted and the new eight foot should be charted at the Fledermaus position with an added note *Obstn.* This item should be added to the AWOIS database for further investigation.
[11] Concur
[12] A shoaler depth (56 feet) was found nearby, chart area according to the Hdrawing and smooth sheet.
[13] There were shoaler sounding nearby, chart according to the smooth and Hdrawing.
[14] Chart area as shown on the smooth sheet and Hdrawing.
[15] Chart 12 fathom and 2 fathom 2 foot obstructions at the survey positions. It is recommended that these features be added to the AWOIS database for further investigation.
[16] Concur
[17] Chart according to the smooth sheet and Hdrawing.
[18] Concur
[19] Chart area according to the smooth sheet and Hdrawing.
[20] Chart area according to the smooth sheet and Hdrawing.
[21] Concur
[22] Concur
[23] Chart area according to the smooth sheet and Hdrawing.
[24] Chart area according to the smooth sheet and Hdrawing.
[25] Concur
[26] There is a consistent deepening trend in this region, chart according to the smooth sheet and Hdrawing.
[27] Concur

APPROVAL SHEET
W00058 – W00062

Kurt Brown
For Bonnie Johnston
2008.06.17 13:38:27
-07'00'

Evaluated by:

Bonnie Johnston
Physical Scientist (Hydrographer)
Pacific Hydrographic Branch

Kurt Brown
2008.06.17 13:38:36
-07'00'

Review by:

Kurt Brown
Hydrographic Team Leader

Cartography

The evaluated survey has been inspected with regard to delineation of the depth curves, development of critical depths, cartographic symbolization, and verification or disproval of charted data

Compiled by:

for Bruce Olmstead
Cartographer
Pacific Hydrographic Branch

Reviewed by:

Charles Davies
Cartographer
Pacific Hydrographic Branch

Approval

I have reviewed the data, and reports. Data are suitable for nautical charting except where specifically recommended in this report.

David Neander
2008.06.19 08:25:40
-07'00'

David O. Neander
CDR, NOAA
Chief, Pacific Hydrographic Branch

FILE: HAWAII LIDAR ROS.DOC
UPDATED: 14 Sept 2004
BY: Scott Ebrite SNR

NAVAL OCEANOGRAPHIC OFFICE

Stennis Space Center, Mississippi

REPORT OF SURVEY

LIDAR

HAWAII

Vessel: SHOALS AIRCRAFT

Detachment: SHOALS PROJECT

Country: U. S.

Dates of Survey: 01 AUGUST - 20 DECEMBER 2000

Archive Number: 00US16

Areas: Hawaiian Islands
Oahu
- Makua Training Area, Pokai Bay, leeward coast; Kaena Pt. to Barbers Pt.
- Kaneohe Bay
- MCBH Kaneohe
- Bellows AFS - Waimanalo Bay and Bellows Beach
- Kahuku
- Pearl Harbor/Approach
- Waialua Bay

Kauai
- PMRF - Barking Sands, Majors Bay, Waimea Bay
- Port Allen

Molokai
- Kaunakakai area and south coast, other areas

Hawaii
- Kawaihae Harbor and approach, other areas

Maui
Lanai

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REPORT OF SURVEY CONTENTS

1.0 Introduction

1.1 Purpose of Survey

The Hydrographic Survey Specification for the aforementioned areas was generated at the request of the primary Functional Customer (CINCPACFLT) in response to a DoD/US Navy initiative. This initiative is to support present and future increased naval activity and usage in WESTPAC as follows.

1.1.1 Seal Delivery Team One (SDVT-1) has requested SHOALS surveys of several training areas within Hawaii and the WESTPAC areas of Guam, Saipan, Tinian and Farallon de Medinilla (FDM). The requirement is not simply to update existing nautical charts, but to create unique high-density digital bathymetric datasets that can be used by SDVT-1 to improve the safety of their SDV training operations. SDVT-1 uses commercial GIS packages (ESRI ArcView with Spatial Analyst) to produce tailored products for their operations, including 3D perspectives of their target and training areas. Additionally, SDVT-1 has, or will be, requesting STOIC's (Special Tactical Operational Information Charts) for their training areas.

1.1.2 Pearl Harbor and Approaches. Pearl Harbor and its approaches are a safe haven for major surface and sub-surface Fleet units. The survey is required for updating charts 19AHA19366, 19AHA19362, 19AHA19369 and 19AHA19364. CINCPACFLT recently removed Limited Distribution restrictions on hydrographic data in Pearl Harbor and the approach. This effectively transfers the responsibility of charts for Pearl Harbor from NIMA to NOAA NOS. CINCPACFLT also intends to cancel chart 19AHA19369 following NOS publication of new editions of 19AHA19362 and 19AHA19369 with necessary approach data for Pearl Harbor. CINCPACFLT would like to create a complete baseline dataset of unclassified hydrographic and topographic data for use by NOAA NOS in updating Pearl Harbor charts. These data will provide a complete bathymetric model of Pearl Harbor that will be suitable for a variety of uses, including SDVT-1 training, geospatial product prototyping, high- resolution DNC, environmental impact modeling, and harbor defenses. USACOE has recently completed a standard survey of Pearl Harbor in support of normal dredging operations and these data have been forwarded to NIMA and NOAA NOS.

1.1.3 Pacific Missile Range Facility (PMRF) Kauai. PMRF desires detailed bathymetric data inshore of the Silas Bent survey of 1995. Their test and evaluation clientele are increasingly interested in very shallow water operations. Barking Sands, the PMRF beach north of the airfield, is also used for various amphibious training operations, including major exercises (RIMPAC). Majors Bay, south of the airfield, is a major amphibious and SOF training area. SDVT-1 also requires data in Waimea Bay, between PMRF and Port Allen, and Port Allen to support training operations. Data will be used for updating NOAA NOS charts 19ACO19381, 19BHA19382 and 19XHA19386 and NIMA charts COMBT808528 and COMBT801253.

1.1.4 Bellows Air Force Station - Waimanalo Bay Bellows Beach is one of the three primary beaches in the Hawaiian Islands used for amphibious exercises including RIMPAC. Lack of high-density data for the approach to the beach presents problems for both safety and environmental protection. High-density data will improve the margin of safety in using this beach for future exercises. Data will be used to update NIMA chart COMBT800744 and NOAA NOS chart 19AHA19358. Data will also be used for future STOIC production.

1.1.5 Makua Training Area including Pokai Bay and leeward coast from Kaena Pt. to Barbers Pt.
Makua Military Reservation is a live fire facility. Data are required to support SDVT-1 and ASDS and amphibious landing exercises at Makua Beach. Data will be used to update NIMA chart COMBT805647 and NOAA NOS chart 19ACO19357.

1.1.6 Kahuku
Data are required to support SDVT-1 training operations. Data will be used to update NOAA NOS chart 19ACO19357.

1.1.7 Kawaihae Harbor, Hawaii
This area on the leeward coast of the Big Island is used for SDVT-1 training. Kawaihae Harbor is the Sea Port of Debarkation (SPOD) for USMC units deploying to Hawaii for training at the US Army training facility on Hawaii.

1.1.8 Kaunakakai, Molokai
The area is to be used for SDVT-1 training operations. Data will be used to update NOAA NOS chart 19XHA19353.

1.1.9 Honolulu/SE Oahu
This area is to be used for SDVT-1 training operations. Data will be used to update NIMA chart COMBT800744 and NOAA NOS chart19AHA19364.

1.1.10 Kaneohe Bay, MCBH Kaneohe
This area is to be used for SDVT-1 training operations. Data will be used to update NIMA chart COMBT800744 and NOAA NOS chart 19BHA19359.

1.1.11 The Hawaiian Islands datasets consist of LIDAR data collected in support of the above requirements, and data collected in support of USACOE and USGS requirements. The delineating factor separating these data and requirements are:

1.2 General Survey Specifications:

All Navy LIDAR operations are planned and executed to meet IHO Order 1 as a matter of policy. No specific survey specifications exist for areas originally outside the Navy areas. However, some of these areas were developed to meet IHO Order 1, as discussed in section 1.4.

1.3 Tasking

1.3.1 The scope of the LIDAR survey was depth measurement only from the shoreline out to the laser extinction depth, with shoreline delineation, limited beach topography and hazard detection within the capabilities of the system. LIDAR did not perform, nor was one intended, a comprehensive hydrographic survey and no comprehensive survey was done in areas worked solely by LIDAR. The survey specification required an IHO order 1 survey with 100% target/obstruction detection in all Navy areas of interest. USCOE and USGS requirements were not to charting specification, but were to support coastal modeling requirements.

1.4 IHO Standards and Coverage

1.4.1 All Navy areas meet IHO Order 1 specifications for positional and depth measurement accuracy. Theoretically, all Navy areas meet IHO Order 1target/object detection requirements at the 95% confidence level for depths from 7m to 20m with single flight coverage. At depths deeper than 20m signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects (Figure 1). Multiple flight coverage will theoretically improve the confidence of target detection capability in the depth range of 2m to 7m, and possibly down to 20m.

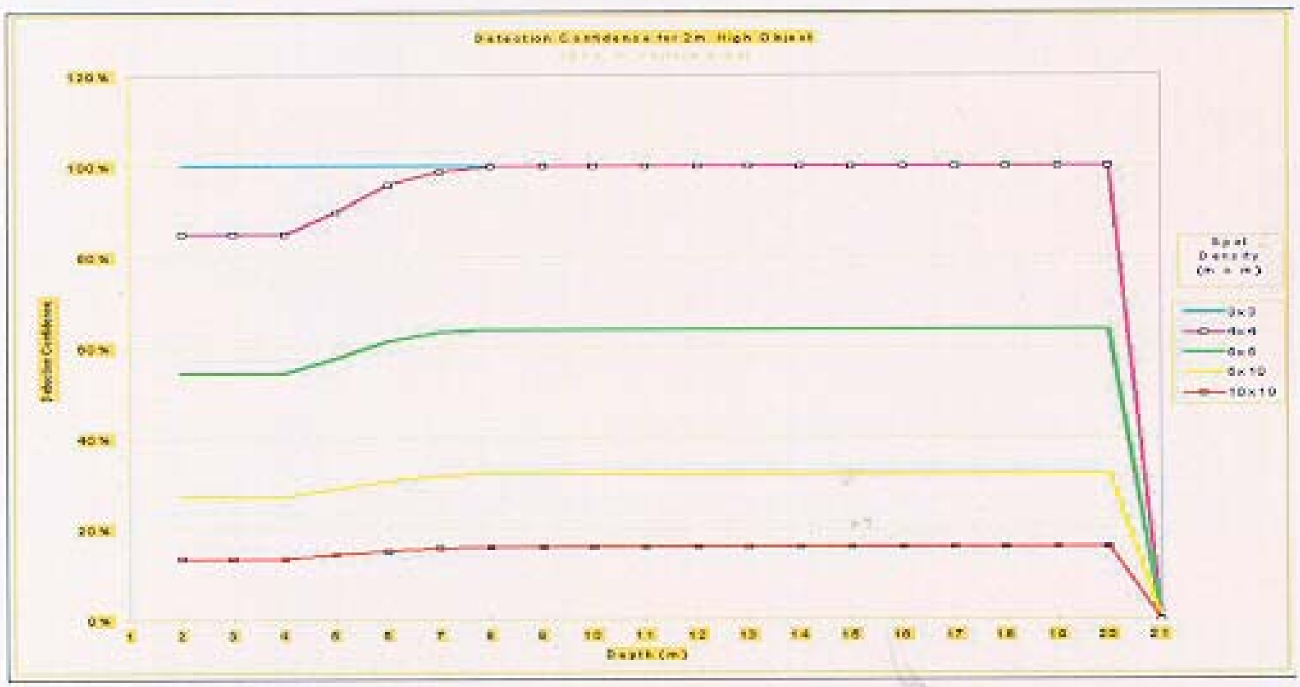
Subsequent testing of the follow-on CHARTS system, utilizing the same operating principles and algorithms and a lower power laser, at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths 5 – 30 meters. Based on these actual tests the LIDAR system meets IHO order 1 target detection requirements. Multiple coverage provides a degree of redundancy for this capability.

1.4.2 The Navy areas were surveyed at 4x4-meter spot density and with greater than 200% coverage to ensure a very high confidence of target detection. USGS areas were also flown at 4x4-meter spot density and 100% coverage. USACE areas were flown at 8x8-meter spot density and 100% coverage. USACE and USGS areas were not typically surveyed to meet charting standards, and therefore do not require IHO accuracy and may not meet Order 1 standards for target/object detection. These areas were surveyed to support coastal modeling, storm surge, coral reef and environmental studies. There are, however, exceptions to this procedure, described below.

1.4.3 Where the USACE and USGS areas were small and adjacent to and interleaved with Navy areas, the USGS and USACE areas were typically flown as part of the Navy area for operational efficiency. In such cases, these USGS and USACOE areas will have multiple coverage and also will meet Navy requirements. Regardless of spot density and coverage, all areas meet IHO Order 1 positional and depth accuracy. These specific areas are described in the graphics of Appendix A.

1.4.4 Theoretically, based on target detection probability curves produced by NOAA, Guenther, et al, all Navy areas meet IHO Order 1 target/object detection requirements at the 95% confidence level for depths from 7m to 20m with single-flight coverage. At depths deeper than 20m, signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects less than 2 meters (Figure 1). Multiple-flight coverage will theoretically improve the confidence of target detection capability in the depth range of 2m to 7m, and possibly down to 20m.

1.4.5 Subsequent testing of the follow-on CHARTS system, utilizing the same operating principles and algorithms and a lower power laser at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths of 5 to 30 meters. Based on these actual tests the LIDAR system meets IHO Order 1 target detection requirements. Multiple coverage provides a degree of redundancy for this capability.



Theoretical detection confidence vs. depth for a 2m target at different laser spot densities.

Figure 1. Target detection confidence

1.5 **Survey Sheet and Survey Area Details.**

1.5.1 Oahu
IHO Order 1 sheets consist of sheets 01 - 03, 06 - 28, and sheet 30. Portions of USACOE area sheets 29, 31, 32, 33, 34 and 35 will meet Order 1 due to multiple coverage. Sheets 04 and 05 do not meet Order 1 due to lack of multiple coverage.

1.5.2 Kauai
All west coast sheets, 01 - 13, from Port Allen north to Barking Sands and the Na Pali coast meet IHO Order 1 requirements. Sheet 14 at Nawiliwili meets Order requirements due to lack of hazard/object detection.

1.5.3 Molokai
Sheets 01 - 10 along the south coast meet IHO Order 1 requirements. Sheets 11 - 18 meet Order 2 requirements due to lack of hazard/object detection.

1.5.4 Maui
All Maui sheets meet IHO Order 2 requirements. Maui sheets do not meet Order 1 requirements. NO TIDE CORRECTIONS APPLIED. Lack of double coverage to ensure target detection.

1.5.5 Lanai
All Lanai sheets meet IHO Order 2 requirements. Lanai sheets do not meet Order 1 requirements. NO TIDE CORRECTIONS APPLIED. Lack of double coverage to ensure target detection.

1.5.6 Hawaii (Big Island)
Kawaihae Harbor meets IHO Order 1 requirements. All other Hawaii areas meet Order 2 requirements due to lack of hazard/object detection. NO TIDE CORRECTIONS APPLIED other than Kawaihae Harbor and Bay.

1.5.7 Coverage. LIDAR coverage is 100% or better from above the shoreline to approximately 35m depth in all areas. Exceptions are:

1.5.8 Oahu - Pearl Harbor, west and north to Kaena Pt. coverage is to 50m depth. Oahu - Kaneohe Bay, coverage limited to 11m - 13m in the channel and inner bay due to water clarity issues. Turbidity and to some extent chlorophyll increases at 8m - 10m depth with a rapid falloff of transmissivity in the 532 nm optical band. See Appendix F for Kaneohe optics data demonstrating optical properties in the bay.

Oahu - Barbers Pt. harbor, coverage very limited due to water clarity.
Oahu - Pearl Harbor, no coverage due to water clarity.
Kauai - Port Allen, harbor coverage very limited due to water clarity.

1.6 **Hydrographic Survey Specifications**:

Hydrographic Survey Specifications for Hawaii, Archive No. 00US16

1.7 **Weather**.

The survey was conducted from late summer into winter. The only weather that affected operations were the winds, occasional rain showers and seas on the windward coasts. The Hawaiian Islands fall within the North east trade winds. The winds were a continuous 15 - 25 kts. Winds flowing over the mountain ranges and funneling down through the valleys made for difficult flying in many areas, with line keeping and altitude holding nearly impossible. Many holidays resulted that required numerous re-fly's. Surf on Oahu's north and east coasts, and the Big Islands windward north and east coasts made getting complete coverage in one or two flights difficult, if not impossible.

1.8 **Extraneous Activities Affecting the Survey**

1.8.1 Honolulu International Airport operations. This is reported to be the 15th busiest airport in the US. Initial discussions with the FAA indicated no flights would be possible within five miles of the airport, the area within the Terminal Control Area (TCA). After NAVO suggestions to the FAA to fly the survey flights during off-peak hours, we worked the survey flights into the midnight to 0500L time slot. Even at this time of day there were an average of 60 arrival/departures that required the SHOALS aircraft to vacate the area for short, though numerous, periods of time. Additionally, transitioning the flight crew from daytime to nighttime operations required a 24-hour rest period prior to and after night ops. As holidays became apparent in processing, usually after swapping back to daytime operations, we had to break flight operations for 24 hours to switch to night ops. This affected productivity and efficiency. Toward the end of the survey as time became a serious constraint, it became apparent there would be areas that did not get the required double flight coverage. This is because we couldn't continue to suffer the loss of 24 hours of survey time to swap the flight crews from days back to nights, and still meet other survey requirements within the allotted time frame. This was deemed not aserious issue in the area affected due to the relatively uniform bottom and no "surprises". The only area affected was within five miles of the VOR tower at Honolulu airport. This is an area of mixed Navy, USACoE and USGS requirements where Navy coverage requirements are not always met.

1.8.2 Political concerns. Prior to survey operations we were informed of numerous possible political concerns and sensitivities of the island residents. These were primarily noise abatement, environmental and governmental intrusion issues. We were informed by the FAA that residents are particularly sensitive to noise with respect to aircraft over-flight, and to expect many complaints concerning our low flying aircraft. During the course of five months of surveying only one noise complaint was received. Local officials informed us of native Hawaiian sensitivities and suspicions with regard to anything government or militarily related, mostly in reference to politically charged land use issues. No problems were encountered.

1.5.1 Surfers and Boogie boarders. Due to the popularity of Hawaii's beaches and surf, some lines had to be rescheduled to avoid "lighting up" the beach goers and wave riders.

2.0 Geodetic Control

2.1	**Horizontal Datum**:	WGS-84
	Projection:	Transverse Mercator
	Spheroid:	World Geodetic System of 1984
	Grid:	Universal Transverse Mercator
	Vertical Datum:	MLLW for LIDAR derived topography
	Sounding Datum:	MLLW

A vertical datum of MLLW for LIDAR-derived topography is contrary to the standard MSL datum for vertical elevations. All LIDAR data is referenced to the sea surface, thus LIDAR topography is referenced to the sea surface which is referenced to MLLW. The only exception to this is with kinematic GPS surveys utilizing On-The-Fly (OTF) processing techniques where the data are referenced to the ellipsoid. The Hawaii survey DID NOT USE OTF techniques.

Sounding Datum: Mean Lower Low Water. The NOAA-maintained automatic tide gauge, located at Honolulu Harbor, Oahu, Mokuoloe, Oahu (northern Kaneohe Bay), Nawilili, Kauai and Kawaihae, Hawaii were all referenced to MLLW.

2.4 **Time.** The time standard is UTC (GMT).

2.5 **Existing and New Control.** None used or established.

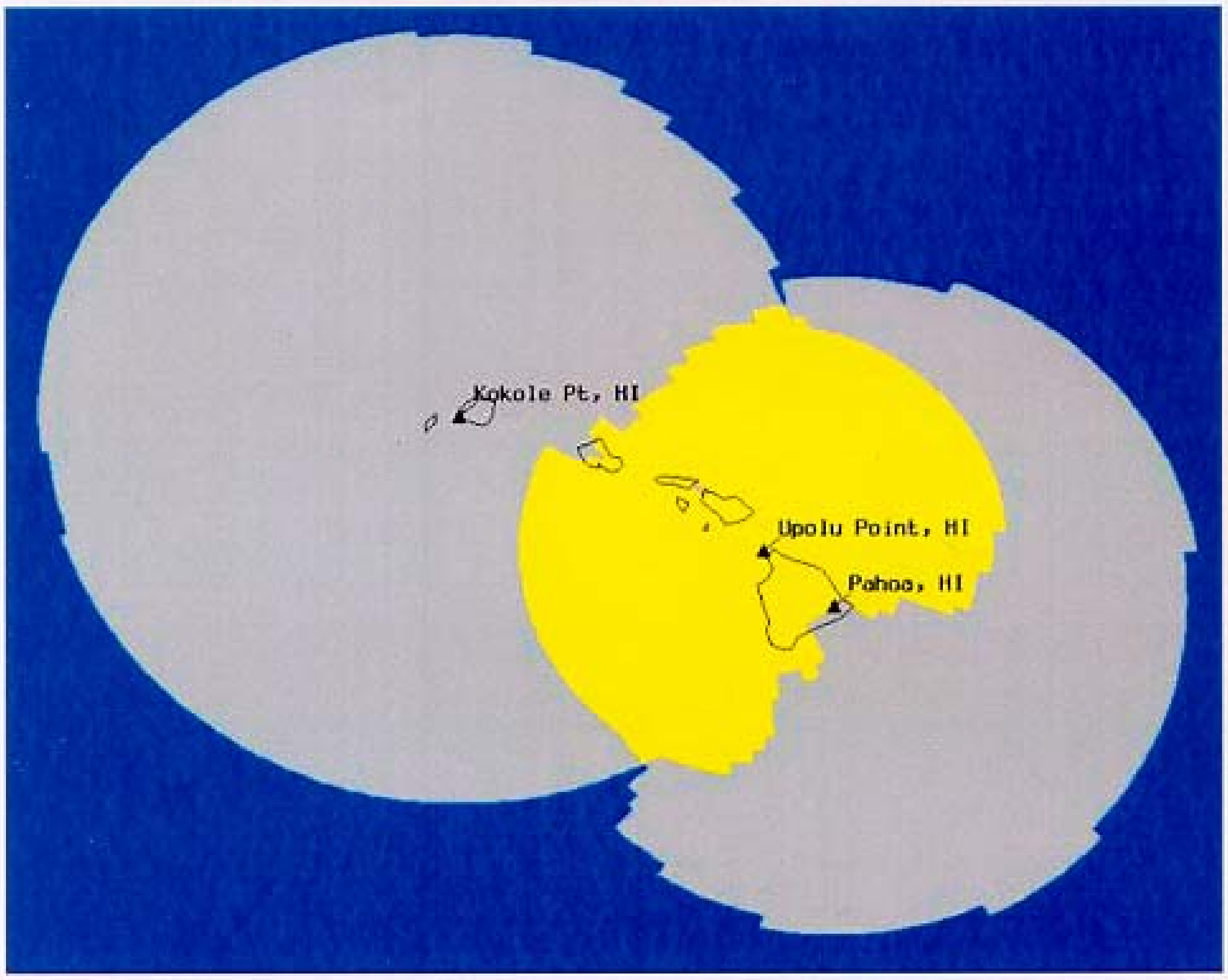
2.6 **Datum Shifts**. No datum shifts were applied.

2.7 **Horizontal Control Reports.** No horizontal control reports were generated.

2.8 **Station Descriptions/Recovery Forms**. No station descriptions/recovery forms were completed or issued.

3.0 Digital Survey System

3.1 **SHOALS GPS Positioning Systems**. ASHTECH Z-12 L1/L2 GPS receivers were used during the survey to provide navigational control in the survey platform in the DGPS. USCG DGPS stations located at Kokole Point Kauai, Upolu Point Hawaii (Big Island) and Pahoa Hawaii (Big Island) were utilized continuously to provide DGPS corrections to the aircraft Ashtech Z-12 receiver.



USCG DGPS beacon coverage for Hawaii.

Kokole Point was used for Kauai, and Oahu. Upolu Point was used for Molokai, Maui, Lanai and all but the south shore of Hawaii. Pahoa was used for the south shore of Hawaii.

3.2 **SHOALS Lidar data acquisition system.** The SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system consists of an airborne laser transmitter/receiver capable of measuring 400 soundings per second. Lidar is an acronym for LIght Detection And Ranging. The system operates from a deHavilland DHC-6 Twin Otter flying at altitudes between 300 and 400 meters with a ground speed of about 104 knots. The SHOALS system also includes a ground-based data processing system for calculating accurate horizontal position and water depth. The system operates by emitting a pulse of light that travels from an airborne platform to the water surface where a small portion of the laser energy is reflected back to the airborne receiver. The remaining energy at the water's surface propagates through the water column and reflects off the sea bottom and back to the airborne detector. The time difference between the surface return and the bottom return corresponds to water depth. The maximum depth the system is able to sense is related to the complex interaction of radiance of bottom material, incident sun angle and intensity, and the type and quantity of organic material or sediments in the water column. As a rule-of-thumb, the SHOALS system is capable of sensing bottom to depths equal to two or three times the Secchi depth.

3.2.1 The airborne system conducts all the data collection and is divided into three subsystems:

1) Acquisition, control and display,
2) Transceiver, and
3) Positioning and auxiliary sensors.

3.2.2 **Acquisition, Control and Display Sub-System (ACDS).** The ACDS is the primary component through which all data are collected and recorded, system integrity and self-checks conducted, and operator monitoring of key real-time system and survey information. All airborne data are recorded on Exabyte 8-mm dual tape drives at a rate of approximately 300 Kbytes per second. These tape drives were selected over other possible data storage media because of their proven performance and reliability in aircraft. The data tape is the only link between the airborne data collection system and the data processing system. It also provides the ability to load survey flight information for each survey mission into the airborne system prior to each flight.

3.2.3 The survey operator's interface with the system is through the ACDS. Real-time information is provided so that the operator can accomplish two tasks, first as the surveyor to ensure that the planned mission is successfully implemented and completed and second, as the Lidar system operator to monitor system status during the mission to ensure that the system operates within expected parameters. The main indicator of survey status and progress is from real-time depths provided to the operator at 100 Hz. These real-time depths are not corrected for tides or water surface waves, but they do provide an estimate of project depths to within approximately +/- 1 m.

3.2.4 The ACDS also provides survey navigation information to the pilot such as the required altitude, speed, and position along a selected survey line, necessary to conduct the planned mission and produce the desired sounding density. The operator selects the flight line and the ACDS converts its position and other flight parameters to navigation information and presents this to the pilot on a small video monitor mounted in the cockpit.

3.2.5 The Transceiver is mounted over a window in the belly of the aircraft. The main component is the laser, which operates at 400 Hz. There are four receiver channels, two for detecting the water surface and two for detecting the sea bottom. The two water surface channels include the IR return from which the surface location is determined. The second channel is to ensure a water surface return by detecting the Raman scattering. The two bottom channels are used to detect returns from shallow and deep depths.

3.2.6 Included is a gyro-stabilized scanner, which directs each laser pulse to a predetermined location on the sea surface. An inertial reference system provides aircraft attitude information allowing the scanner to compensate for aircraft motion and measures accelerations necessary for accurately resolving the sea surface location during post-flight data processing. The width of the scan is nominally equal to half the altitude of the aircraft. At a speed of 120 knots and an altitude of 200 m, this yields a uniform sounding spacing of 4 m x 4 m. the sounding density can be altered by flying higher/lower and faster/slower and also by selecting a different scan width.
Aircraft Positioning And Auxiliary Sensors Sub-System (APASS).

3.2.7 The APASS consist of DGPS and a video camera. DGPS is used for horizontal positioning of the aircraft and the differential correction is available through Fugro's Omnistar system. The other function of the APASS is to record a video image of the area being scanned by the laser. This provides a visual and audio record of each survey mission and a record for the data processor/hydrographer conducting the data processing to check or evaluate any anomalies that may be encountered during data processing, such as algae on the water surface or over-flight of an island.

3.3 SHOALS System Calibration

3.3.1 To ensure accuracy of the system, SHOALS requires both a hard target test and a calibration flight for calibration of the system. The hard target test is accomplished through firing the laser against a known baseline distance. The test is performed for each receiver of the surface and bottom channels. Any observed error is nulled out through adjustment of appropriate parameters.

3.3.2 The SHOALS system undergoes an in-flight calibration for the determination of the small offsets of the scanner mirror frame relative to the optical axes of the system, in the roll, pitch and heading directions as defined by the Inertial Navigation System. Critical to this calibration is locating and flying a calm, flat area in the field. To calculate the angular offsets an average of the water surface is derived by the system, then a special calibration program developed by the National Ocean Service derives these small angular offsets assuming that the sea surface is flat. The offsets are folded back into the collected standard data and the successful plotting of a flat-water surface shows that the angles were correctly derived.

3.3.3 In the first six years of SHOALS operation, a standard survey line was used to derive these small angular offsets. In early 2000 is was thought that a wider excursion of the scanner forward angles would result in better calibration values and a raster scanner pattern became the standard operational procedure. Either procedure raster or standard pattern is acceptable as long as the resulting angular corrections produce a flat-water surface. (Carswell; Optech, Inc. 2002)

3.4 **SHOALS Positioning Quality Control.** The operator continuously monitors position quality in the air. Flight lines are re-flown if any of the following specifications are exceeded:

PDOP exceeds 4. The PDOP is recorded as a field within the data.

The semi-major axis of the positional error ellipse exceeds 3.5m at the 95% confidence level.

The DGPS correction age exceeds 10 seconds.

The minimum number of satellites being tracked for continued sounding is less than 4 healthy SV's.

The minimum elevation for SV is less than 10°angle from the horizontal.

3.5 **SHOALS Lidar data processing system.** Hydrographic Data Processing utilized the SHOALS data processing suite; data tapes from the aircraft are read in and the depth derived from the processed laser pulse. The algorithms utilized in the SHOALS processing suite were developed at NOAA by Gary Guenther, et al. Time tagged position and depth, the *.out file and laser waveform files were then transferred to the NAVOCEANO system. Data quality control, additional editing and validation were carried out using the NAVOCEANO Area Based Editor running under LINUX. Upon return to NAVOCEANO, the data underwent further analysis and refinement using 3D visualization tools (Fledermaus) and application of NOAA verified tides.

3.5.1 **Ground Processing Environment** All processing, cleaning and product generation is carried out on off-the-shelf NT workstations using software developed by Optech, Inc. specifically for SHOALS.

3.5.2 **Processing Of Data, General Principles.** All survey data collected are field processed, verified and validated concurrent with survey operations. Verification methods include comparison of collected data to existing charts and prior surveys. Discrepancies discovered in field processing are resolved immediately. Discrepancies requiring significant additional operational time and effort to resolve are brought to the attention of the Operations Manager, for decision.

3.5.3 **Post Processing Lidar Data.** SHOALS Lidar data is processed by an NT-based automated processing software package that includes automated post-flight depth extraction procedures, various calculation and utility programs, and a manual processor operator interface that provides access to individual waveforms for display and editing. The suite maximizes throughput by recognizing and handling most problems routinely, minimizing the amount of human interaction with the raw data.

3.5.4 After the data is extracted from the flight tape and input into the database, it is processed by an automated routine consisting of a lidar waveform processor and sounding position determination algorithm. The main function of the automated processor is to obtain inputs from the raw data; calculate depths, positions, and other products; correct for tides and waves; and write the outputs back to file database. It runs at a 1:0.1 time ratio with data collection and data processing.

3.5.5 All data is then manually edited for obvious anomalies. Where such anomalies are clearly due to fish, or similar causes, they will be flagged as invalid returns; any other anomalies resembling bottom hazards will require investigation of the waveform in order to determine whether the feature is real and should be retained in the data set. In cases of doubt, such features will be marked for further investigation through re-flight of the area in question.
The processed data is then output as an ASCII (*.xyz) file which can either be input directly into Hypack, or converted to Fugro Binary Format (*.fbf) for input into Starfix.Proc for review, QC and ultimately subsequent mapping and product generation. This process is outlined in Figure 6.

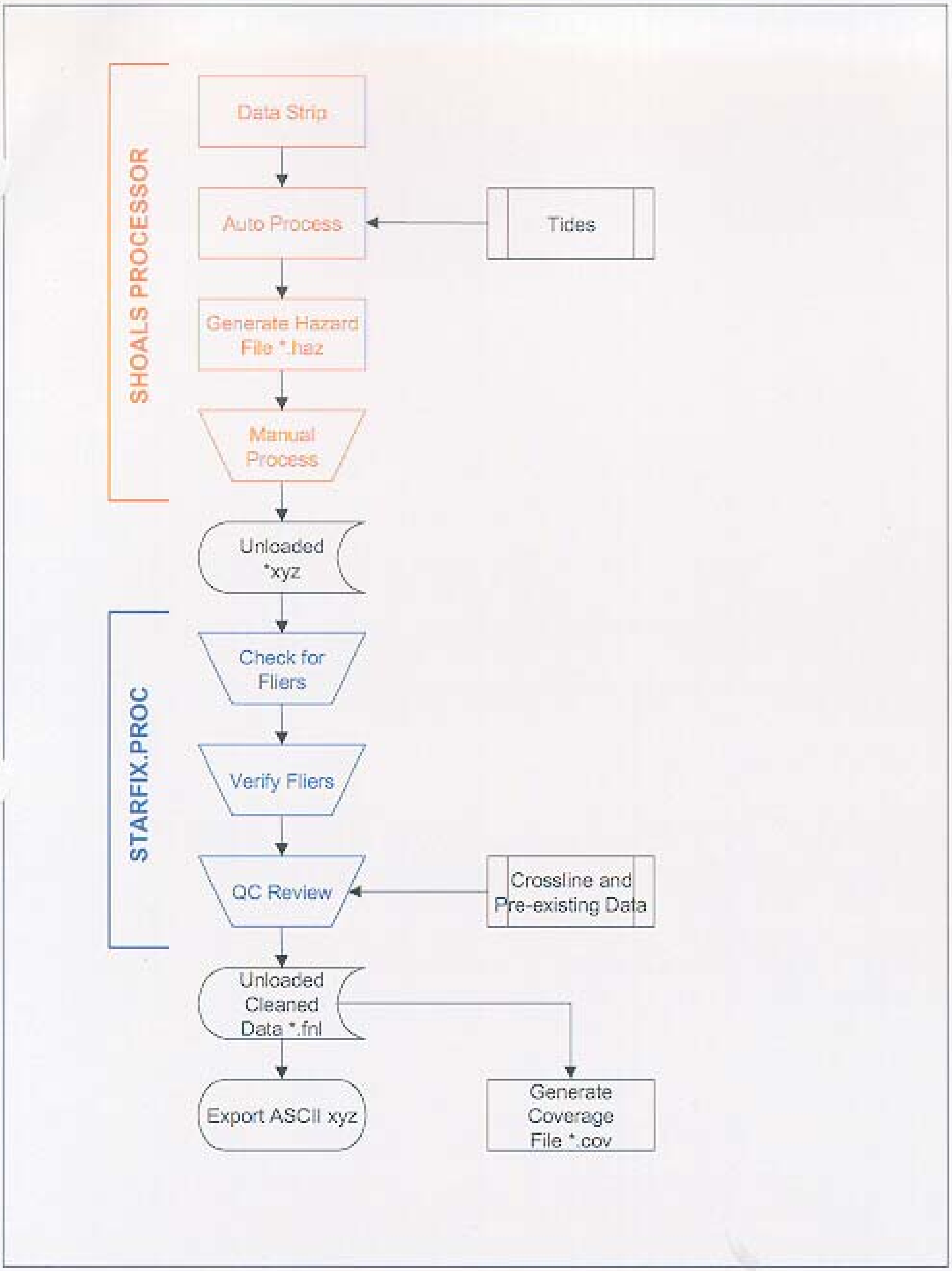


Figure 6: Data Processing Flow

3.5.6 **Data Review and Inspection.** Output xyz data from the processor is transformed to the appropriate projection using Corpscon or GeoCoordinator and then input into Starfix.Proc where the process of spatial review and comparing each data set to expected values is performed. Each dataset is compared with any available pre-existing charts, maps or other information data; overlapping datasets are also compared to each other to make sure each falls within the systems limitations. The data is then plotted out on paper with a contour interval 1 or 2 m in order to identify any further anomalies that may not have been apparent from inspection of individual flightlines and only become evident in a broader spatial context. Any such anomalies will then be resolved through reference back to the waveforms.

3.5.7 **Second Depth Description and Methodology.** The laser waveform from the bottom return is capable of having two valid returns (second depths) for a single sounding. Multiple returns can be from any object suspended in the water column, sharp drops in the bottom topography, or objects rising above the bottom. The initial processing of the data picks the more shallow depth for that particular sounding. The post processing software allows for viewing of all soundings with multiple returns and evaluation by the hydrographer to determine the validity of the return. The hydrographer is allowed to keep, swap or kill the return based on the waveform analysis and review of the surrounding and overlapping data. The keep option will keep the sounding as it was initially calculated by the post processing algorithm. The swap option allows the hydrographer to change the sounding to the second of the valid returns calculated by the software. The kill option allows the hydrographer to kill the sounding so that the sounding is not reported in the final cleaned xyz data. A report of this process is output from the post processing software and details the status of each second depth return as either keep, swap, or kill. See appendix "F" for second depth report for this project. Soundings reviewed here are kept unless there is valid evidence to support change.

3.5.8 **Flier Description and Methodology.** Possible fliers are listed within Starfix.Proc and output to a log file. The timestamps listed in this log file are then reviewed in the post processing software by the hydrographer to determine the validity of the return. The analysis is similar to that of the second depths in that adjacent and overlapping data are reviewed in conjunction with the waveform. A report of these fliers is then compiled with the action taken (either keep or kill) for each sounding. See appendix "G" for the flier report. As with the second depths all soundings are kept unless valid evidence exist to support killing of the sounding.

3.5.9 **Area Investigation and Review.** In areas where soundings are killed due insufficient energy return, or areas where the second depth and / or flier review produce questions to the validity of the sounding, re-flights are performed. The field hydrographer is responsible for determining which areas are to be re-flown based on the client's maximum gap in coverage requirements.

3.5.10 **Data Mapping**. The final cleaned xyz files are then binned using a 4m by 4m bin size to help reduce the size of the files. This file is the final delivered xyz file. The final mapping is performed using MicroStation and Inroads. These programs produce maps in DGN format. The contour files produced by Inroads where derived from a reduced data set of xyz files. The reduced data set was produced by HyPack's point reduction program. After mapping in the DGN format the files were exported to a DXF format for the final deliverable.

4.0 Calibrations

4.1 **Positioning Systems**. No formal calibrations of the Ashtech Z-12 receivers operating in the DGPS mode were conducted in the field. However, internal accuracy (precision) of the system was monitored by the SHOALS system utilizing standard positional QC (HDOP, PDOP, SNR data) techniques. Overall accuracy was not checked against independent (terrestrial) navaids, but crossline, swath overlap and multiple flights over features such as pier ends/corners and NAVAIDS and comparison checks on the sounding data did allow a high degree of trust in positional integrity to be reached. Fugro/Chance personnel received daily solar storm forecasts and activity reports. Data collection during periods of high solar activity was avoided. During processing, graphical analysis of LOP data indicated no problems with the positioning system. With the vast majority of cross-checks and overlapping swaths showing good agreement however, both sounding reduction and navigational accuracy were assessed as adequate for the survey.

4.2 **SHOALS System Calibration.** To ensure accuracy of the system, SHOALS requires both a hard target test and a calibration flight for calibration of the system. The hard target test is accomplished through firing the laser against a known baseline distance. The test is performed for each receiver of the surface and bottom channels. Any observed error is nulled out through adjustment of appropriate parameters.

4.2.1 The SHOALS system undergoes an in-flight calibration for the determination of the small offsets of the scanner mirror frame relative to the optical axes of the system, in the roll, pitch and heading directions as defined by the Inertial Navigation System. Critical to this calibration is locating and flying a calm, flat area in the field. To calculate the angular offsets an average of the water surface is derived by the system, then a special calibration program developed by the National Ocean Service derives these small angular offsets assuming that the sea surface is flat. The offsets are folded back into the collected standard data and the successful plotting of a flat-water surface shows that the angles were correctly derived.

4.2.2 In the first six years of SHOALS operation, a standard survey line was used to derive these small angular offsets. In early 2000 is was thought that a wider excursion of the scanner forward angles would result in better calibration values and a raster scanner pattern became the standard operational procedure. Either procedure raster or standard pattern is acceptable as long as the resulting angular corrections produce a flat-water surface. (Carswell; Optech, Inc. 2002)

4.3 **Survey System Offsets/Alignment**. The laser system and motion sensors are optically aligned and the offsets measured with respect to the phase center of the GPS antenna. This is done at every system or component installation. The measured offsets are contained in what is called the "STATIC" file. This file is written to the survey plan and, during initialization of the data collection system, written to the daily data tape. During processing the offset values are stripped from tape along with the data applied during post processing (SHOALS NT processor). During processing tide corrections are applied. In the event of a kinematic survey the KGPS derived positions and ellipsoid to MSL offset is also applied. For surveys covered in this report no kinematic data collection was conducted.

4.4 **Deep Bias Offset Correction**

4.4.1 There has been a suspected deep bias present in SHOALS 400 data. This bias has never been quantifiable due to a lack of suitable ground truth data. The SHOALS-400 algorithm applied a constant bias to make the SHOALS derived depths shallower by 12 cm. This was based on the original Sarasota data and also the later Tampa Bay data. Recent testing of the follow-on Lidar system, SHOALS 1000, or CHARTS, the NAVOCEANO term for the system, at the South Florida Test Facility (SFTF) operated by the Naval Surface Weapons Center off Dania Beach Florida has allowed for the quantifying of this deep bias error. True, the deep bias error has been quantified with the SHOALS 1000 system, it is applicable to the SHOALS 400 system because the physics involved is the same as are the algorithms utilized to derive depth from the laser shots.

4.4.2 All of the SHOALS 400 data has been corrected for a depth bias that was discovered during the ground truth tests for the CHARTS system at the South Florida Test Facility. The equation used is as follows:

```
if (out.au.reported_depth > 7.0)
{
   correction = 0.17235 - 0.02485 * out.au.reported_depth;

   out.au.tide_cor_depth -= correction;
   out.au.reported_depth += correction;
   out.au.result_depth += correction;
   out.au.sec_depth += correction;
}
```

4.4.3 The equation represents the difference between the historical depth bias corrector (SHOALS-400) that was applied to the data and the new depth bias corrector taken from the SFTF data. The equation was derived by Grant Cunningham of Optech. This information came in an email (10/10/03) from Paul LaRocque of Optech. Note that the 12cm bias mentioned in the email was not depth dependent and was not removed from the data.

0 cm effect at 7 m

8 cm effect at 10 m
20 cm effect at 15 m
32 cm effect at 20 m
57 cm effect at 30 m
82 cm effect at 40 m.

The SHOALS-400 algorithm applied a constant bias to make the SHOALS derived depths shallower by 12 cm. This was based on the original Sarasota data and also the later Tampa Bay data. The following new recipe will make the SHOALS-400 data even shallower by the amounts stated in table above.

To apply the newest depth bias corrector to older (i.e., SHOALS-400) data, the following equation should be used:

delta_depth = 0.0 m, for reported_depths < 7 meters
delta_depth = [0.17235 - (0.02485 * reported_depth)] m, for
reported_depths >= 7 meters

This delta_depth should be ADDED to the older values of the reported_depth, as below:
new_reported_depth = (old_reported_depth + delta_depth)

Therefore, at 40 meters old_reported_depth this will make the new_reported_depth shallower by about 82 cm.

This bias offset was proven and quantified after the first data delivery to NOAA. Subsequently, the above described procedure was applied to ALL Hawaii data and the data was re-submitted to NOAA. All Hawaii data currently held by NOAA Pacific Hydrographic Branch has been corrected for this bias.

5.0 Side Scan Sonar

5.1 **Requirements.** No side scan sonar requirement was defined for Hawaii.

5.2 **Equipment.** N/A

5.3 **Coverage.** N/A

6.0 **Tides and Water Levels.**

6.1 **General Requirements**. Tidal zoning shall be constructed and tidal data observed and recorded such that derived tidal corrections to the sounding data meet 0.5 meter accuracy standards. The survey area shall be sufficiently zoned and tide gauges strategically located to ensure tidal corrections meet accuracy requirements.

6.2 **Tidal Data Collection, Scope of Work.**

6.2.1 The primary NOAA tide Gauges. Also NOAA CO-OPS was responsible for posting preliminary unverified tidal data on the CO-OPS web site, tidal data processing and verification, posting of verified data to the web site and tidal zoning.

6.3 **Tide Gauges**

NOAA-maintained automatic tide gauges are at the following locations:

Honolulu Harbor, Oahu
Mokuoloe, Oahu (northern Kaneohe Bay)
Nawilili, Kauai
Kawaihae, Hawaii

6.2.3 **Additional Gauges**. NAVOCEANO installed backup gauges on Oahu at the Barbers Pt. Harbor and the Waianae small craft harbor. On Kauai NAVOCEANO installed a tide gauge at a small craft harbor just south of PMRF between Kekaha and Waimea. NOAA gauges supporting the zoning were located on the windward side of the islands, well away from much of the survey area. The NAVOCEANO installed gauges were installed as a backup to the NOAA gauges. Furthermore, the data from the NAVOCEANO installed gauges were used to confirm the NOAA tide-zoning scheme.

6.4 **Preliminary Tidal Zoning.**

6.4.1 Tide zones were developed by NOAA CO-OPS based on historical data from the above mentioned gauges.

6.5 **Tide Zone Accuracy**

6.5.1 Results of comparing zone HAW213 (Oahu west coast from Barbers Pt. harbor to Kepuhi Pt. and including Waianae) referenced to NOAA's Honolulu gauge and the installed Waianae gauge are as follows:

Maximum difference:	0.35 meters
Mean difference:	0.15 meters
Standard Deviation:	0.179 meters

6.6 **Final Tidal Zoning.**

6.6.1 Tidal No adjustment was made to the NOAA CO-OPS zone scheme. Tidal time series from the NAVOCEANO gauges and tidal time series for the appropriate NOAA tide zone agreed very well. No adjustment to the NOAA zones was necessary.

6.7 **Application of Tides.**

6.7.1 The NAVOCEANO processing system does not utilize "tide correctors", per se. The NOAA CO-OPS zoning scheme partitioned the survey areas into zones referenced to a reference tide gauge. For each zone there is a phase and amplitude correction, also referenced to the reference tide gauge. NAVOCEANO's processing system handles tide correction by creating a tide file for each zone by applying zonal corrections to the reference gauge tides. The processing software identifies in which zone a sounding falls and applies that zone's tide to the sounding. Tide correctors are applied during post processing, just prior to data editing and validation.

6.8 **Currents and Tidal Streams**

See Appendix E for a summary of Hawaiian currents from published literature. *Informational for Tactical Products.*

6.8.1 **Large-scale Currents**

Source: www.atftp.soest.hawaii.edu.

The average currents around the Hawaiian Islands form a large Gyre centered at about 32N. The geostrophic basin scale clockwise circulation sweeps the islands roughly east to west and intensifies southward. At and near the surface, currents driven by the wind combined with the geostrophic currents result in more complicated flow patterns.

South of Hawaii, the surface North Equatorial Current (NEC) reaches an average westward speed 0.35 knot at 13 N, and gradually decreases towards the islands. Between 18 N and 22 N, the currents are strongly influenced by the islands. The NEC forks at Hawaii; the northern branch becomes the North Hawaiian Ridge Current (NHRC), and intensifies near the islands with a typical speed of 0.5 knots. West of the islands, two elongated circulations appear. A clockwise circulation is centered at 19 N, merging to the south with the southern branch of the NEC. A counter-clockwise circulation is centered at 20-30 N. Between them is the narrow Hawaiian Lee Counter

Current(HLCC). Surface currents over the western islands and north east of the NHRC are variable. Current variability shown below indicates numerous eddies or swirls in the lee of the islands.

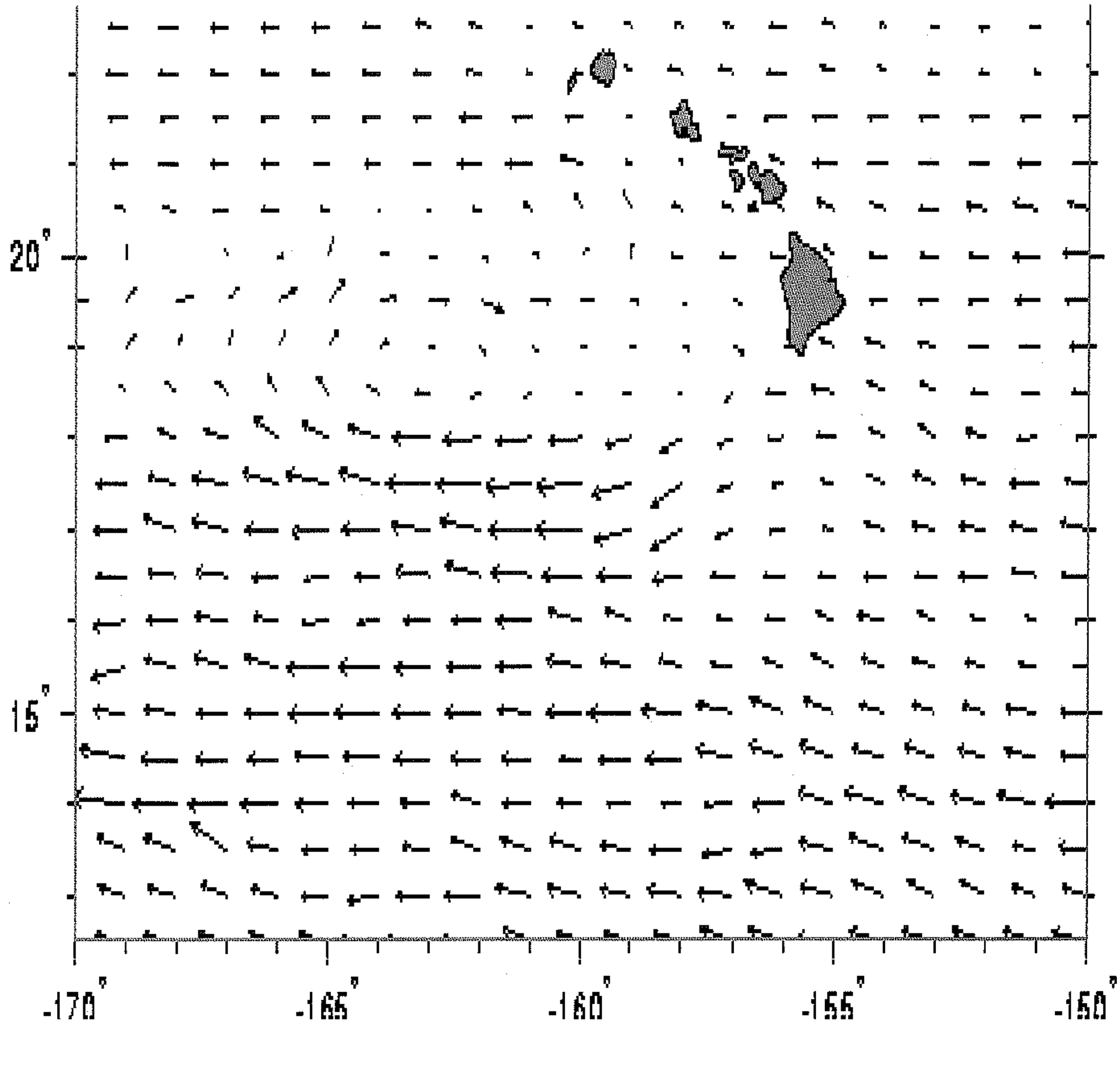


Figure 2. Large-scale ocean circulation around the Hawaiian Islands.

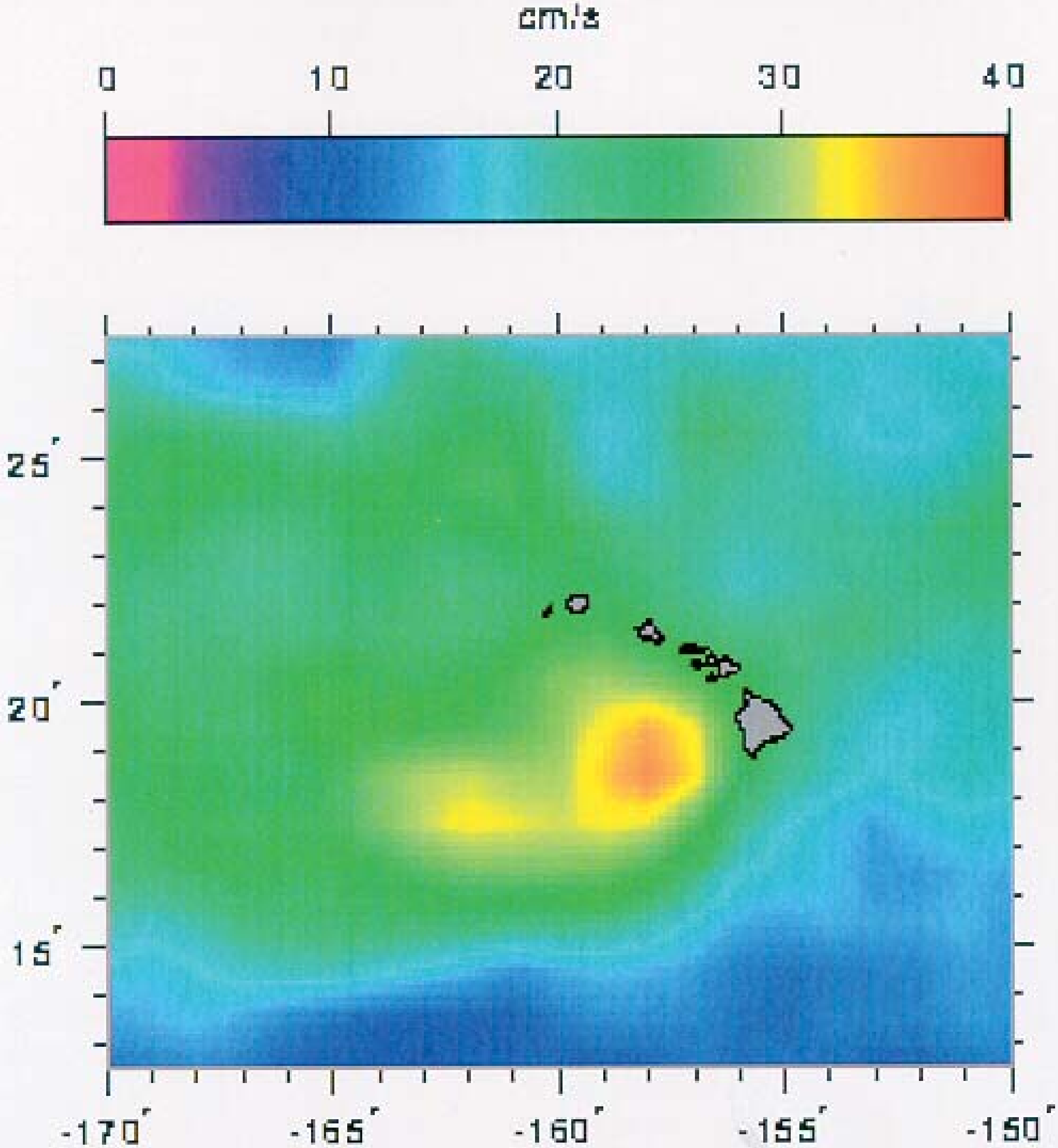


Figure 3. Large-scale ocean circulation variability around Hawaii indicates numerous eddies and swirls which obliterate slower average circulation.

6.8.2 Regional currents

The island chain affects the ocean by two important mechanisms:

interactions of the islands with the large scale ocean currents, and wind speed variations in the lee of the islands.

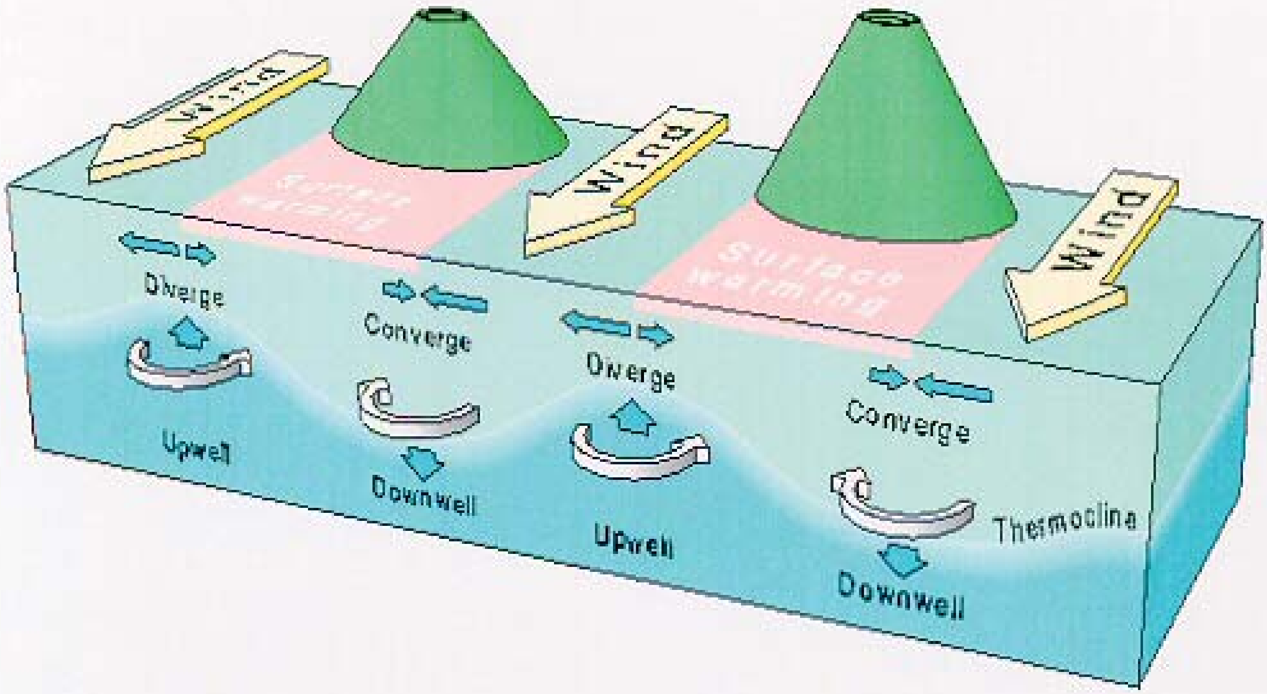


Figure 4. Regional current formation due to the modifying effect of land masses on large-scale circulation.

At the northern and southern boundaries of each island, the trade winds with speeds of 22-44 mph are separated from the calmer lee by narrow wind shear lines. Locally, the depth of the surface mixed layer depends on wind speed: in the channels, deep mixed layers are observed; in the lee, stirring by the wind is not sufficient to mix down solar heating and intense daytime warming of the ocean surface results. Sharp surface temperature fronts, sometimes reaching a difference of 4 C, are often associated with these wind shear lines.

Variations of wind have subtle effects on current patterns. When wind blows for many days over a surface mixed layer, the water moves to the right of the wind in the Northern Hemisphere due to the earth's rotation. Water therefore moves away from the northern shear line. To compensate for this divergent surface motion, water upwells from greater depths, appearing as a cold spot at the surface. Similarly, water moves towards the southern shear line, resulting in a deepening of the thermocline there.

Geostrophic currents result from these variations of thermocline depth, in the form of intense counter-clockwise eddies under northern shear lines, and somewhat less intense clockwise eddies under southern shear lines. This process is quite dramatic -- the depth of the mixed layer in the lee of the island of Hawaii can vary from less than 20 m in the counter-clockwise eddy, to more than 120 m in the clockwise eddy. The large counter-clockwise average circulation is believed to result from the repeated occurrence of eddies spun up by the shear lines of the islands of Maui and Hawaii.

Eddies can also be generated when intense currents such as the NEC impinges on the islands. The large clockwise circulation south west of the island of Hawaii appears to be caused by many such clockwise eddies repeatedly formed near South Point.

6.8.3 **Tidal Currents and other Oscillations**

On scales of oceanic basins, tides exist as very long waves propagating in patterns determined by their period and the geometry of the basin. The figure below shows the response of the North Pacific to the tidal period of 23 h 56 min, the largest diurnal component. Phase lines along which high tide occurs at the same time converge to an amphidrome point west of Hawaii where the tidal range is zero. Phase lines rotate counter-clockwise around this amphidrome, so that the offshore diurnal tide reaches the Hawaii island first, then sweeps across Maui, Oahu and finally Kauai.

Local bathymetry affects the ranges and phases of the tides along the shore, as the tidal waves wrap around the islands. For example, high tide at Haleiwa on the north shore of Oahu occurs over an hour before high tide at Honolulu Harbor.

Tidal currents result from tidal variations of sea level, and near shore are often stronger than the large scale circulation. Current meter records collected off Oahu, Maui and Hawaii (below) show that semi- diurnal and diurnal tidal currents tend to be aligned with the shoreline.

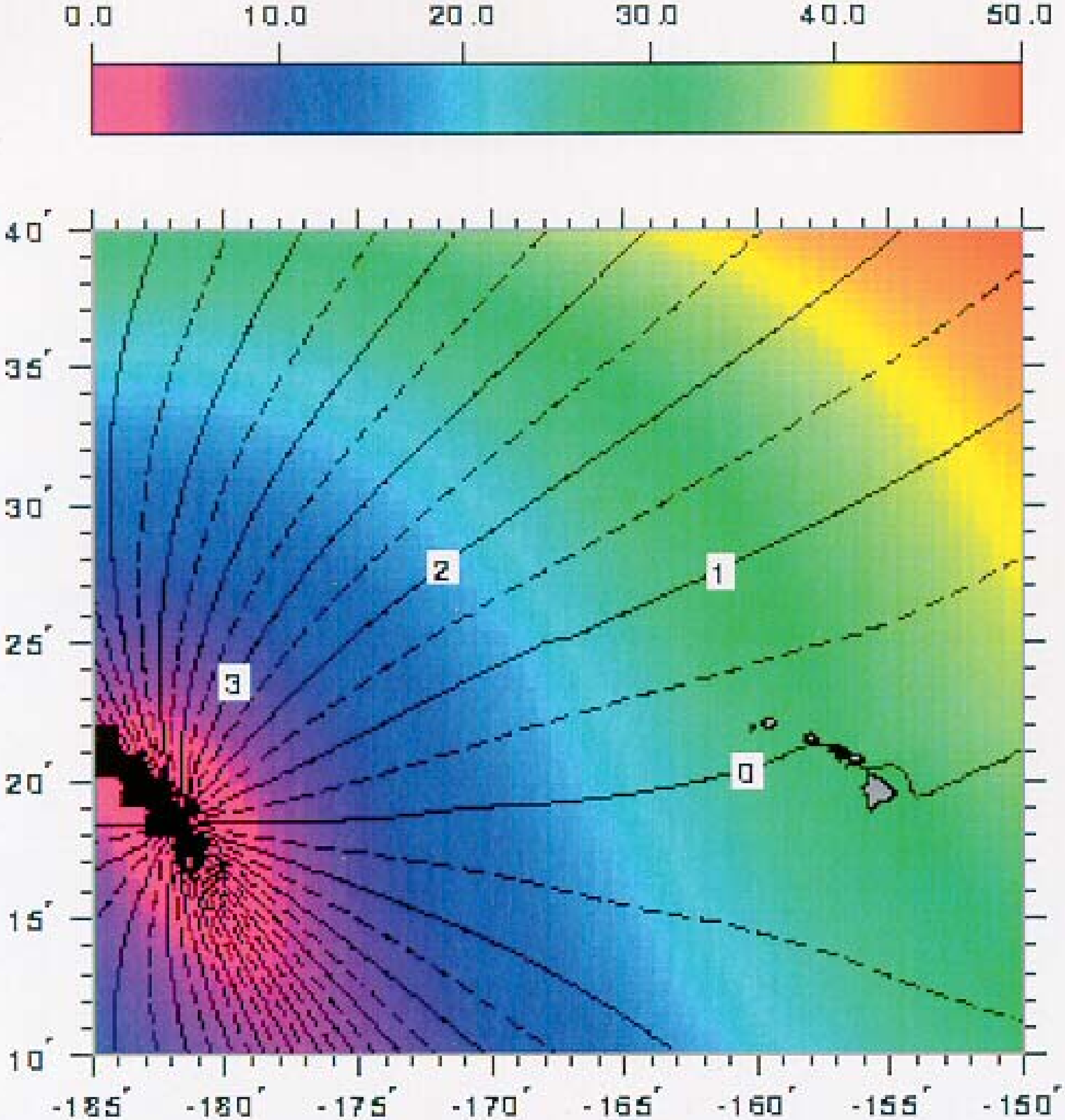


Figure 5. Response of the North Pacific to the longest duration tidal component (23h 56m) and the effect of the Hawaiian land mass.

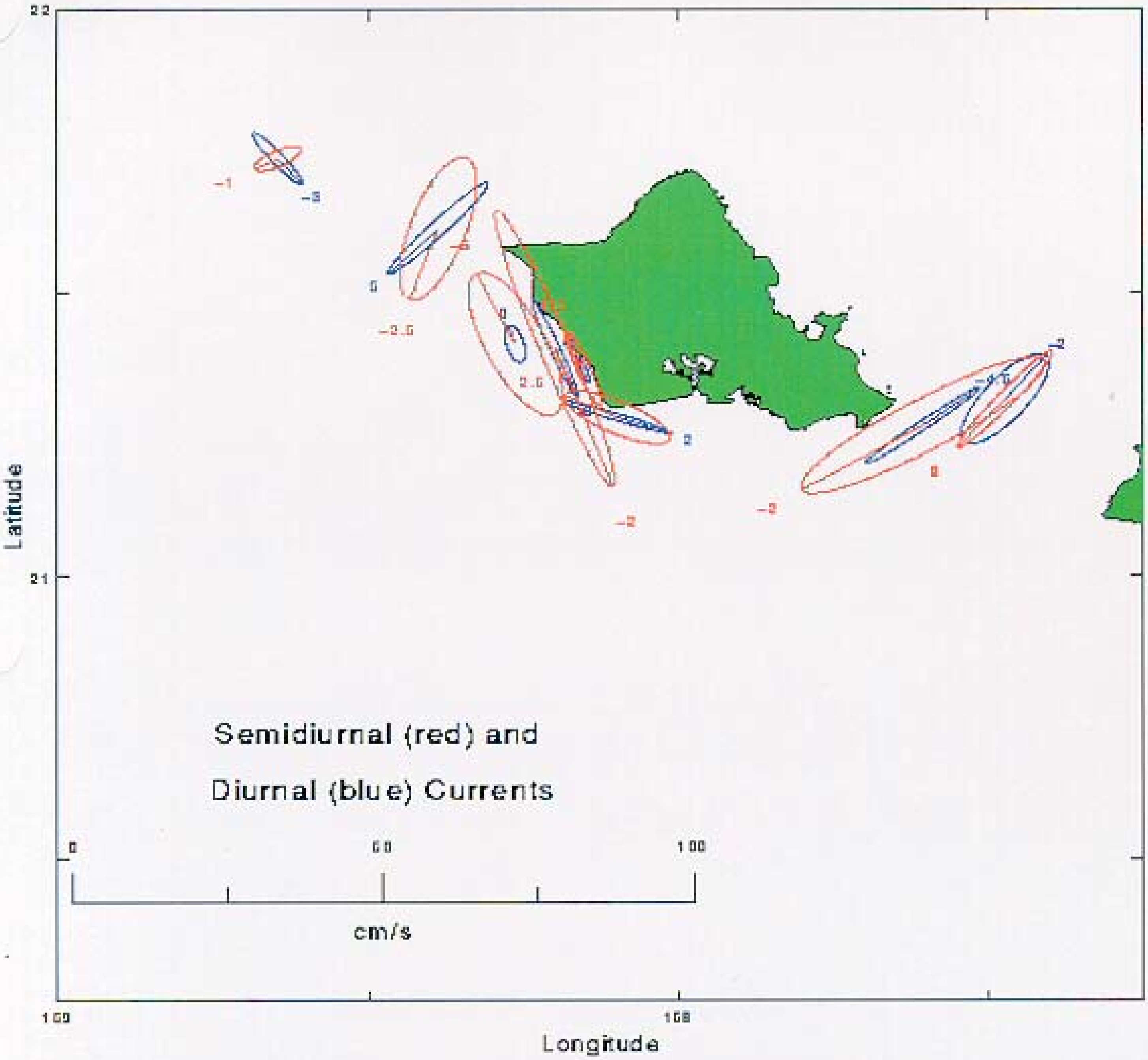


Figure 6a. Representative tidal current flow around the Hawaiian Islands. Diurnal and semi-diurnal tidal flows tend to be aligned with the shoreline. Strong eddies are often found around points and headlands.

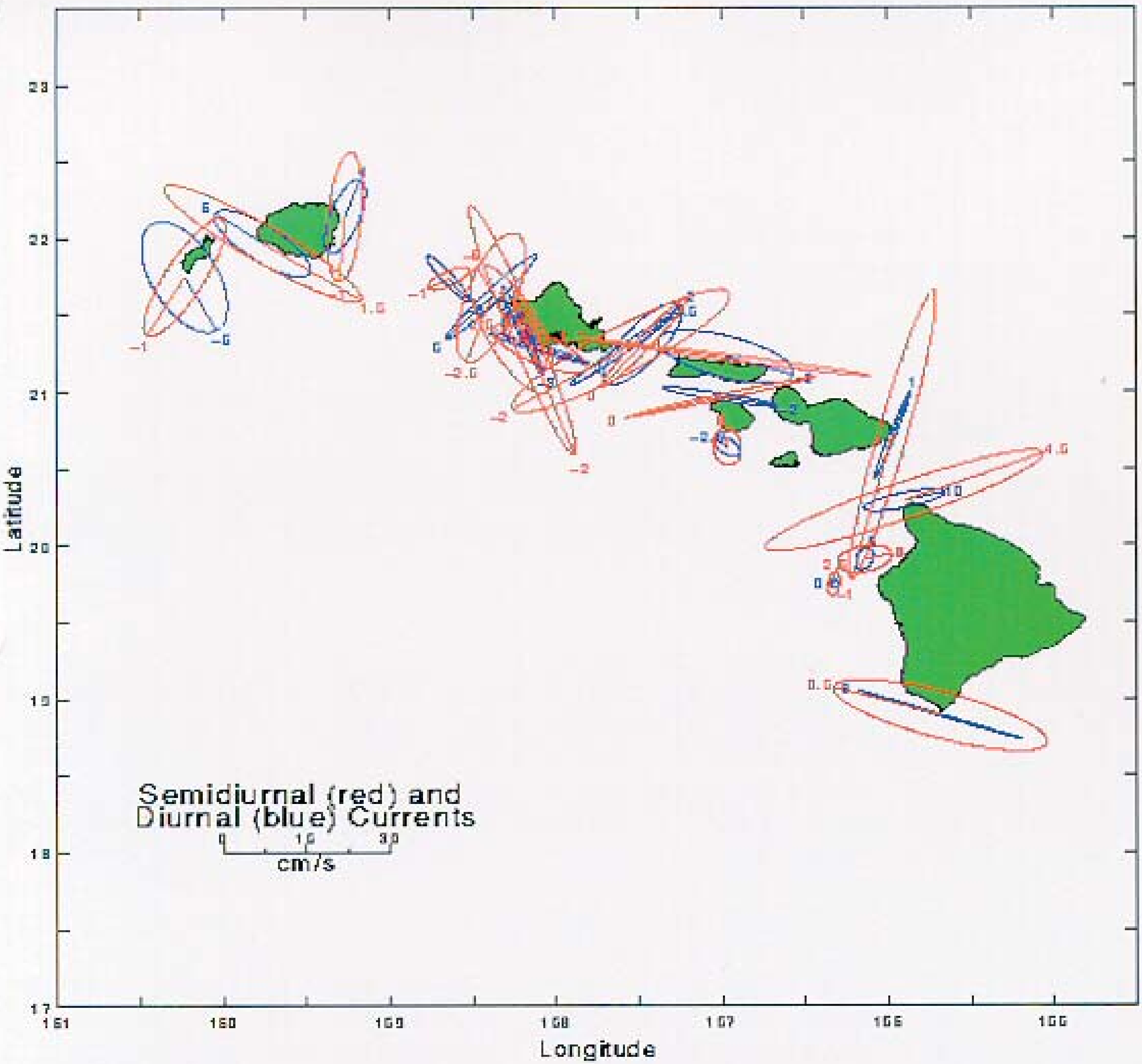


Figure 6b. Representative tidal current flow around the Hawaiian Islands. Diurnal and semi-diurnal tidal flows tend to be aligned with the shoreline. Strong eddies are often found around points and headlands.

Due to high variability of tidal currents around the islands, however, this statistical representation may not correspond to the flow at a particular time -- tidal currents cannot be predicted as precisely as sea level. Strong swirls often result from tidal currents flowing around points and headlands, and present hazards to divers.

Variations of sea level and currents at periods of 1.5 to 3 days are also observed around the Hawaiian islands. Although they manifest themselves as oscillations just like tides, they are not forced by gravitation, but by time-varying winds and possibly swells. They displace the sea surface by only a few centimeters, but the depth of isotherms by tens of meters. Such oscillations, usually occurring during the winter, may be associated with currents up to 1 knot, and horizontal water displacements of 8 km (5 miles).

7.0 Data Collection and Field Work

7.1 **Units**. All soundings are in meters.

7.2 **Corrections to Soundings**. Alignments, offsets and verified tides were applied during appropriate stages of data collection and processing.

7.3 Hydrography

7.3.1 **Source of Shorelines**. The shoreline source was initially generated from the vector shoreline used in the DNC of the area; this should be revised using high resolution shoreline derived from the zero contour obtained from the LIDAR datasets as the charted shoreline accuracy could use some improvement.

7.4 Sounding Development and Coverage

120-meter swath at 4x4 meter spot density. Greater than 200% coverage in Navy areas separated by a time span of several hours. USGS areas werecovered at 4x4-meter spot density at 100% coverage. USGS areas along Oahu's south coast were covered at 200% because of their small size and proximity to Navy areas. USACOE areas were covered at 8x8-meter spot density and 100% coverage. This is also discussed in 1.1.13.1 and 1.1.13.2.

7.5 **Sounding Selection**. NAVOCEANO area-based, shoal-biased sounding selection algorithm.

7.6 Seabed Topography and Texture

Seabed topography is derived from the LIDAR data. No bottom samples were collected.

7.7 Near Shore Seabed Topography.

Numerous coastal areas in the Hawaiian Islands are exposed to a Predominatel northerly Swell for most of the year. During the winter months the swell becomes quite significant. As a result the beaches and near shore areas are quite dynamic. Oahu north shore beaches undergo re-sculpting during the winter months. The same occurs along the leeward west coast where the beaches and near shore of Makua and Makaha are significantly altered. Along Kauai's northwest Na Pali coast the beaches completely erode in winter, then reappear in the spring. Along Barking Sands, and Majors Bay (Waiokapua Bay) Kauai, north and south of PMRF, beaches and near shore are quite dynamic during any time of high swell and rough surf.

Figure 7. Barking Sands, Kauai. Near shore seabed topography.

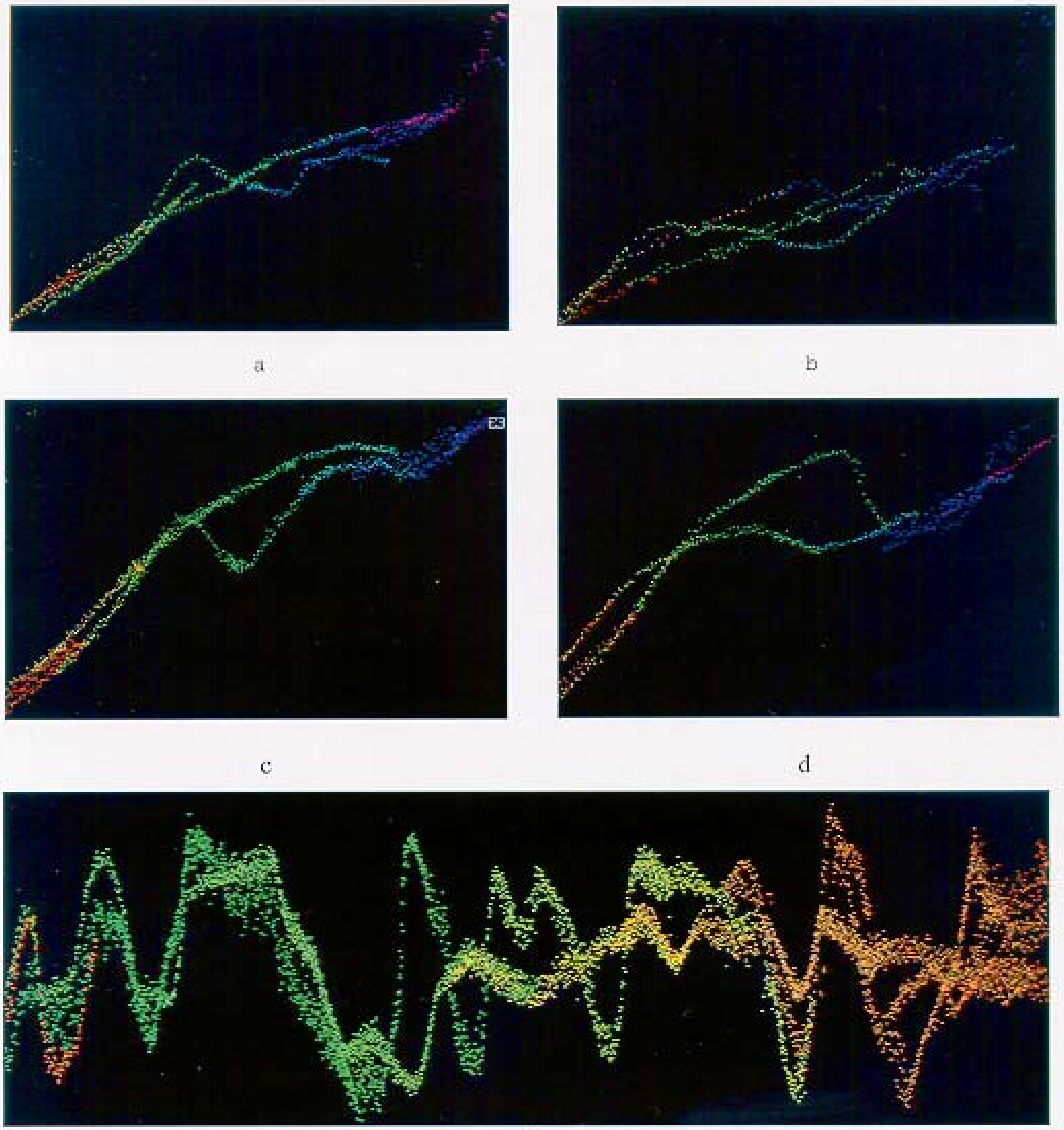


Figure 8. Series of near shore seabed to beach profiles from the area of Barking Sands, Kauai depicted in Figure 7. Insets a-d are west to east cross sections. Inset e is from the north east to southwest along the full length of the near shore.

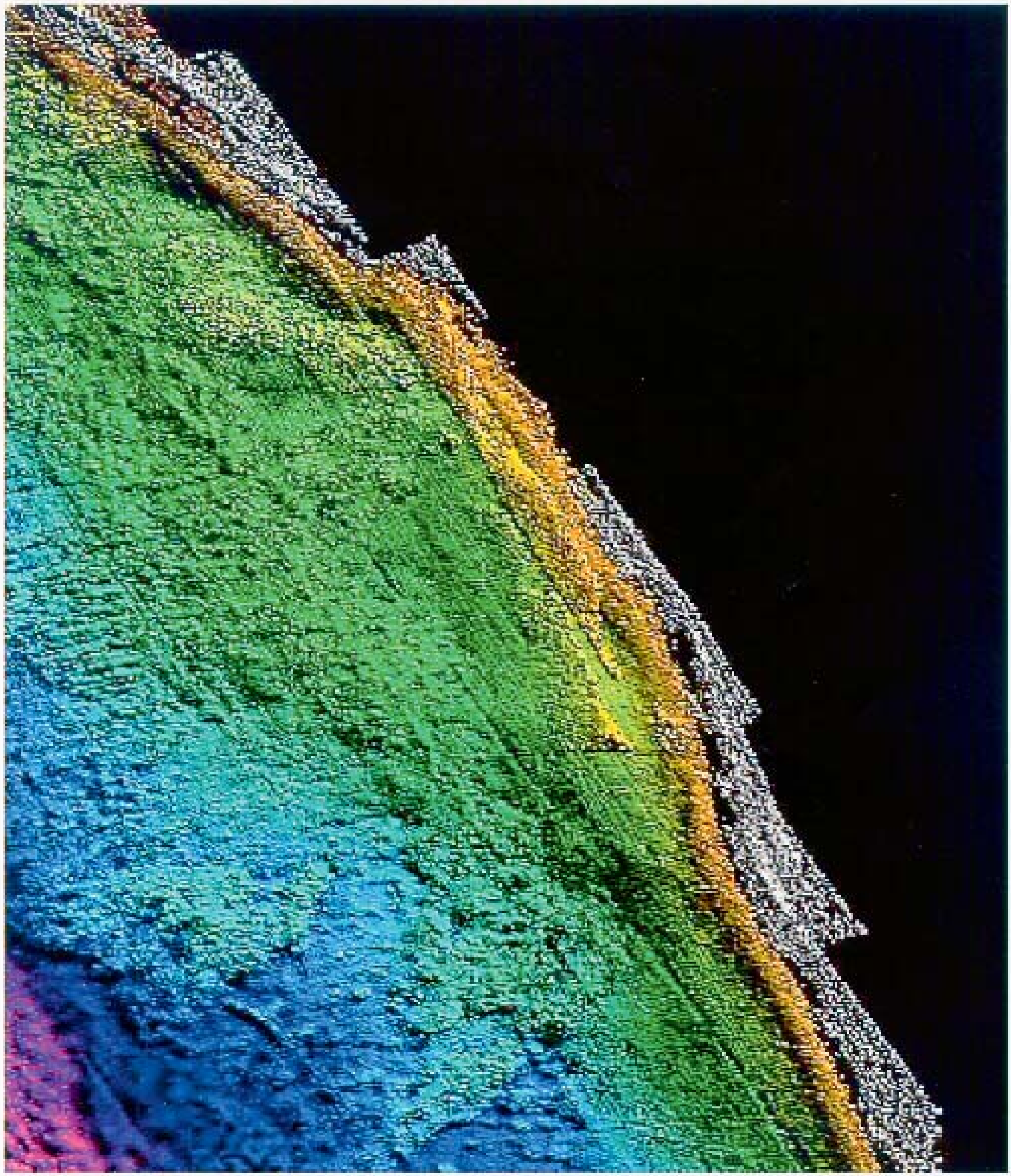


Figure 9. Majors Bay (Waiokapua Bay) Kauai showing near the shore seabed.

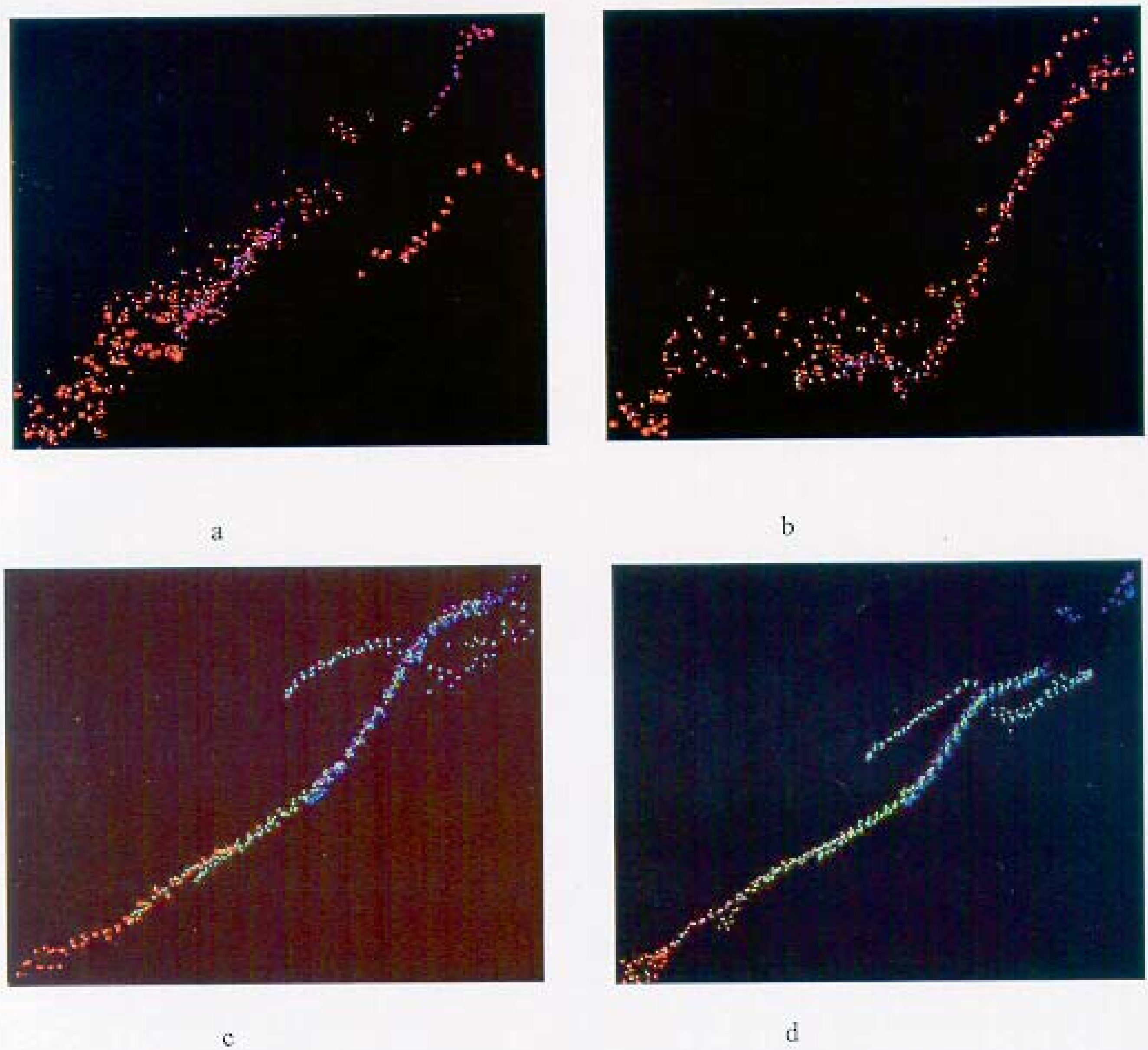


Figure 10. Series of near shore seabed to beach profiles from the area of Majors Bay (Waiokapua Bay) Kauai depicted in Figure 9. Insets a-d are west to east cross sections. Colors represent datasets from different days. These cross sections cover a time span of 6 weeks.

7.8 Data Quality Control

7.8.1 **Processing Methodology**. Graphical examination/evaluation of LOP time series data and deletion of bad data. Graphical examination/evaluation of roll, heading, vertical acceleration time series. 3D visualization of data as a sun-shaded surface colored by depth, line or file. Visualization of data with color and gray scale palette. Visualization of data from any view angle, elevation or lighting position. Visualization of the sun shaded statistical, minimum, average and maximum surfaces. Area based editing of data. Data can be rotated. Multiple and overlying data can be compared. Complete 3D editing capability through the Area Based Editors. Overlay of GeoTif chart images with sounding sheets.

7.8.2 Cross check/swath overlap agreements

Standard crosscheck lines were not run. All Navy areas required two- flight coverage, with the second flights flown some time after the first flights (4 hours to several days). This survey development technique and adjacent line overlap proved more than sufficient to identify any positional or tide correction problems.

Tide correction problems were identified early in the survey. The problem was not with the tides themselves, but with application of the tide correctors. There were three primary problems. (1) Extraneous and unprintable (viewable) ASCII characters contaminated some tide corrector files such that the tide would not apply when APPLY_TIDES was run, and no error message issued. These were identified early and resolved. (2) A data file time stamp problem was identified in the OPTEK airborne software. When the day changed over at midnight GMT a bit is supposed to be set in the *.fl file. This didn't always happen. However, the time stamp was not reset to zero, just continued. As ping time is derived from the ping counter, the tide correctors were being applied from the wrong day. (3) Four data file format changes occurred of which NAVO was never informed. Three of these affected data time. Addition to these main three problems, a couple of errors were discovered in the tide zone polygon definition files. One polygon was not closed and another had an extraneous point that caused the polygon to cross several others. These errors were all corrected and tides re-applied at NAVOCEANO. Currently, there are no discrepancies in the tide corrections and all soundings are properly corrected.

7.9 Agreement with Existing Charts

See Appendix C for a synopsis of chart and data comparison. The highly detailed LIDAR data show more features. Numerous wrecks indicated along Oahu's south coast were not detected in the LIDAR data. Status and/or existence of these wrecks is unknown.

7.10 **Agreement with Prior Surveys**

Due to the short-notice nature of the tasking and rapid generation of the definitive report, previous survey data were not made available and therefore neither a critical nor favorable comparison can be made.

7.11 **Navigational Aids**

Navaids were not positioned during the course of this survey. No tasking for this was designated and no suitable equipment was available. Discussions, however, with the Honolulu Harbor Master, Hawaii Ports and Harbors Commission, Harbor pilots and the USCG district revealed no discrepancies with charted navaids and the Notice to Mariners.

The only navaids positioned were a Navy-maintained buoy off PMRF Kauai and the observation tower at the Makua Training Area, Oahu.

Buoy designated "TANGO"	Position:	N 22 00.330'	W 159 47.557'
Tower, Makua	Position:	N 21 31' 43.56"	W 158 13' 37.81"

7.12 **Shoreline**

The shoreline source was initially generated from the vector shoreline used in the DNC of the area. This should be revised where possible using high-resolution shoreline derived from the zero contour obtained from theLIDAR datasets.

8.0 **Accuracy and Resolution of Soundings**

8.1 **LIDAR Positional Accuracy**

8.1.1 The error budget discussed below pertains to the positioning system operating in differential mode.

Based on the following:

System measurement circular error:	1.0 m
Slope error (variable, 1.0 m flat bottom)	1.0 m
Navigational System accuracy:	4.0 m
Heading error	0.5 m
Roll/Pitch error (beam pointing error) (less than 0.05 degrees, less than 26 cm @ 300 meters altitude)	0.26 m

8.1.2 The cumulative effects of the above errors (RMS) would be: +/- 4.16 meters: allowing for the navigational accuracy of +/- 5 meters, the total RMS value for sounding positional accuracy is +/- 5.13 meters.

8.1.3 IHO Positional Accuracy (Order 1) requires +5m +5% of depth, which equates to an allowable error of:

5.25 m	in 5 m depth
5.50 m	in 10 m depth
5.75 m	in 15 m depth
6.00 m	in 20 m depth

IHO 1st order positional accuracy is therefore considered to have been met in all areas throughout the survey. In areas of steeply sloping or high bottom variability deeper than 15 m IHO 1st order positional accuracy is considered to have been met.

8.2 Accuracy of Soundings - Assessment and Evaluation

8.2.1 **LIDAR**. Assessment of the accuracy of LIDAR soundings entails an evaluation of the following:

a. LIDAR zero mark (water surface)	+/- 0.10 m
b. Depth measurement (system accuracy)	+/- 0.10 m
c. Laser propagation velocity error	+/- 0.05 m
d. Roll, pitch, heading	+/- 0.00 m
e. Vertical motion (heave)	+/- 0.00 m
f. Tidal Measurement	+/- 0.02 m
g. Co-tidal corrections	+/- 0.10 m
h. seabed slope	+/- 0.0 – 0.25 m

8.2.2 **LIDAR zero mark** (a) The zero or reference mark for Lidar data is not the platform or sensor, it is the water surface while operating in DGPS mode or the GPS antenna while operating KGPS mode. The accuracy of the zero reference is very dependent on the surface model utilized to compensate for wave and swell. The accuracy of the surface reference is considered to be 0.1 meters on a normal ocean surface. The surface reference accuracy improves over calm seas and in protected waters. A nominal value of 0.10 meters has therefore been accepted as typical.

8.2.3 **Depth Measurement error** (b) (Instrument Accuracy/Error). System accuracy (depth resolution) for the LIDAR is 0.1 meters RMS. A nominal value of 0.10 meters has therefore been accepted as typical, given the relatively shallow water nature of this survey.

8.2.4 **Speed of Light Correction.** (c) In any medium light travels more slowly than it does in a vacuum. The velocity of light in a medium is equal to the velocity of light in a vacuum divided by the refractive index of the medium. The refractive index of light in air is 1.00028 and, for our purposes, is not significantly different from that in a vacuum, 1.00 by definition. The refractive index of water, though it varies slightly with temperature, salt concentration and wavelength, may be regarded as 1.33 for all natural waters. Assuming a velocity of light in a vacuum of 300,000,000 m/s, the velocity in water is about 225,000,000 m/s. The refractive index variability in natural waters is negligible, as is the speed. Therefore variation in light speed is not a limiting factor for LIDAR data and errors attributed to velocity of light variability can be considered non-existent.

8.2.5 **Roll, Pitch, Heading** (d) Roll, Pitch and Heading are sensed by an onboard POS/AV. Roll, pitch and heading are fully compensated for in real time through direct interfacing to the laser/scanner servo control system. Servo compensation within the limits of +/- 20 degrees of motion ensures the scanning mirror is referenced to nadir at all times. All out-of-tolerance motion results in system warnings and discarded Lidar pulses. Roll, pitch and heading errors are considered negligible.

8.2.6 **Vertical Motion Corrections.** (e) Not applicable for LIDAR data because the zero reference is not the platform or sensor, it is the water surface (when operating in DGPS mode) or the GPS antenna (when operating in KGPS mode). However, aircraft platform motion is compensated for by an aircraft mounted inertial motion system (POS/AV). This resolves undulations in the flight path. Aircraft movement outside of normal parameters result in "jerk" flags and rejected data.

8.2.7 **Tide corrections.** (f), (g) Tide correction errors consist of the actual observation errors at the tide gauge and any errors resulting from a tidal zoning schema or cotidal analysis. Observation errors from the NOAA tide gauges are known to be very low. The estimated error for observed tides is 0.025 meters (1 SIGMA). A similarly small margin of error for co-tidal corrections (0.35 meters) was calculated from comparison of a gauge installed on the leeward sides of Oahu and Kauai and the zone corrected reference tide station data. The standard deviation between the observed tide at these locations and the tide derived from the zoning was 0.179 meters. A similarly small margin of error for co-tidal corrections is based on the range and extent of the survey area in relation to the reference tidal stations and minimal shallow water effects due to the deep surrounding ocean water.

8.2.7.1 Incidentally, the three-day period when there was 0.35 meter difference between the observed tide and the NOOA COOPs cotidal zoned tide on the west coast of Oahu, no data was being collected in the area at this time. This error was strictly an observation and part of the tidal zone validation.

8.2.8 **Sea bed slope** (h) Slope error is normally related to footprint size at the sea floor. Directly related to beam spreading, the Lidar footprint is approximately 0.5 times the water depth. In 25 meters of water the footprint size is about 8 meters across. Normally, this would induce significant error on a sloping bottom due to the shallower part of the footprint reflecting back before the deeper edge of the footprint. This error is significantly reduced with the use of a narrow field-of-view (FOV) receiver telescope. The Lidar receiver telescope FOV is approximately 1.0 meters in diameter. Regardless of the actual beam spreading, only the 1 meter diameter area in the center of the beam is actually received. The leading edge of the return pulse, that which would be received from the shallowest part of the footprint, is not where the depth is computed. Depth determination utilizes a centroid of mass method within the 1 meter receiver FOV. Induced error estimates due to seafloor slope are based on the narrow receiver FOV footprint size.

8.3 **SHOALS Lidar Sounding Error Budget**

The resultant theoretical error budget is tabulated below representing typical shallow, mid-water and deepest values in the survey area

Source of Error	At 10m	At 25m	At 50m
a LIDAR zero reference (surface mark)	0.10	0.10	0.10
b system measurement accuracy	0.10	0.10	0.10
c laser propagation velocity error	0.05	0.05	0.05
e roll, pitch (this is positional error)	0.0	0.0	0.0
f tidal measurements	0.025	0.025	0.025
g co-tidal corrections (maximum 0.35m, STDEV 0.179m)	0.179	0.179	0.179
h seafloor slope 0	0.0	0.0	0.0
seafloor slope 1:4	0.0625	0.0625	0.0625
seafloor slope 1:2	0.125	0.125	0.125
seafloor slope 1:1	0.25	0.25	0.25
Combined total $(\Sigma(a^2 +.....l^2)^{1/2})$ flat bottom 1:4 bottom slope 1:2 bottom slope 1:1 bottom slope	0.235 0.25 0.354 0.500	0.235 0.25 0.354 0.500	0.235 0.25 0.354 0.500
IHO Cat 1 Requirement $[+/-(a^2 + (b*d)^2)^{1/2}]$	0.502m	0.509m	0.542m
Standard Met?	YES	YES	YES

8.3.1 As an adjunct to the standard calibration procedures approximately 200 tide corrected lead line observations were collected over a flat sand bottom and flat seas. Comparison of the lead line data to LIDAR data indicated agreement within a maximum of 0.06 meters with a mean agreement of 0.04 meters. Very close agreement with the lead line observations allows a very high confidence in the accuracy of LIDAR soundings.

8.3.2 **IHO Standards**. The accuracy for Order 1 allowable error (95% or 2 SIGMA) for depths from 0 to 50 meters is +/- 0.5 meters to +/- 0.542 meters. The calculated error for the motion-corrected LIDAR data and observed tides (see comments above) for this survey has a maximum value of approximately 0.354 meters and is therefore within the IHO accuracy limits for Order 1 surveys. As has been discussed, it is considered that the accuracy's estimated are both realistic and pragmatic; in no way do they negate the quality of the survey data so rendered nor do they serve to provide critical comment on the methods and equipment used in the survey. Indeed, the error could probably be reduced a bit with tide gauges installed on all sides of the islands.

8.4 **SHOALS LidarTarget Detection** Theoretically, based on target detection probability curves produced by NOAA, all Navy areas meet IHO Order 1 target/object detection requirements at the 95% confidence level for depths from 7m to 20m with single-flight coverage. At depths deeper than 20m signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects less than 2 meters (Figure 1). Multiple-flight coverage will theoretically improve the confidence of target detection capability in the depth range of 2m to 7m, and possibly down to 20m. Subsequent testing of the follow-on CHARTS system utilizing the same operating principles and algorithms, targets of 2 meters and larger were detected 100% of the time in depths of 5 to 30 meters. Based on actual tests the LIDAR system meets IHO Order 1 target detection requirements. Multiple coverage greatly improves this capability.

8.4.1 Subsequent testing of the follow-on CHARTS system, utilizing the same operating principles and algorithms and a lower power laser, at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths of 5 to 30 meters. Based on these actual tests the LIDAR system meets IHO Order 1-target detection requirements. Multiple coverage provides a degree of redundancy for this capability. The results of these tests have not yet been formally documented.

9.0 N/A

10.0 Navigational Aids

10.1 Navigational aids were not positioned during this survey due to a lack of available equipment during the survey period.

11.0 Sailing Directions

11.1 **General**. Not verified due to the nature of the survey.

11.2 Coastal Pollution

None noted although water quality in the harbors is somewhat degraded in comparison to that of the open ocean, primarily as a result of increased turbidity due to vessel activity and reduced circulation. Local environmental awareness, however, results in minimal pollution.

11.3 **Anchorage and Moorings**. N/A\

11.4 **Photography**. Photographs of selected areas of shoreline were taken in support of future STOIC production in Navy exercise areas. Areas that were photographed are the Makua Training Area, Pokai Bay, Waimanalo Bay (Bellows AFS), Kahuku, MCBH Hawaii at Kaneohe (east of Pyramid Rock), PMRF and Majors Bay, Kauai.

12.0 **Charted and Uncharted Wrecks and Obstructions**. Targets are listed in Appendix D. Other than what is listed, no other wrecks, objects or targets, charted or uncharted, were detected or observed with the LIDAR system.

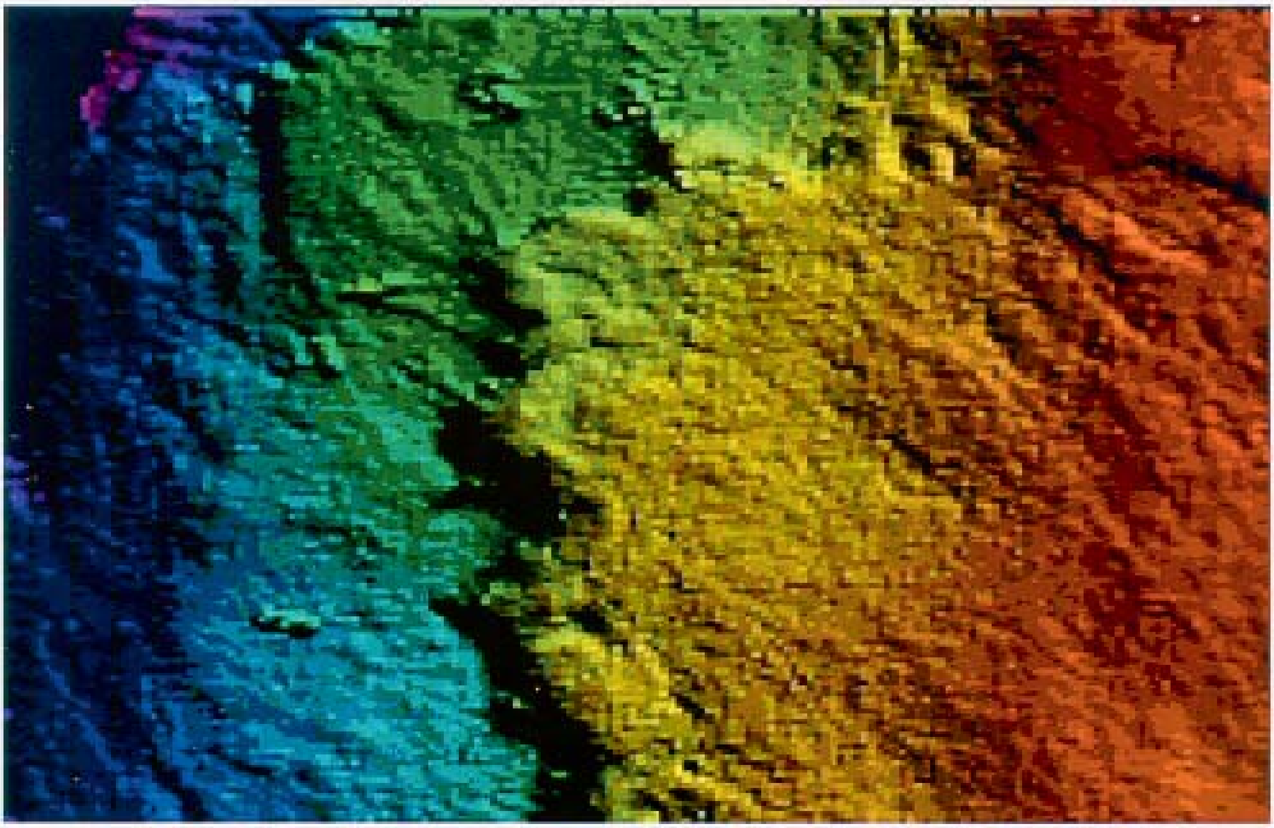


Figure 11. Wrecks and wreckage off Oahu's leeward west coast between Maili Pt. and Waianaae. Charted as fish haven and wrecks. One of these is believed to be the "Mali", a popular dive spot.

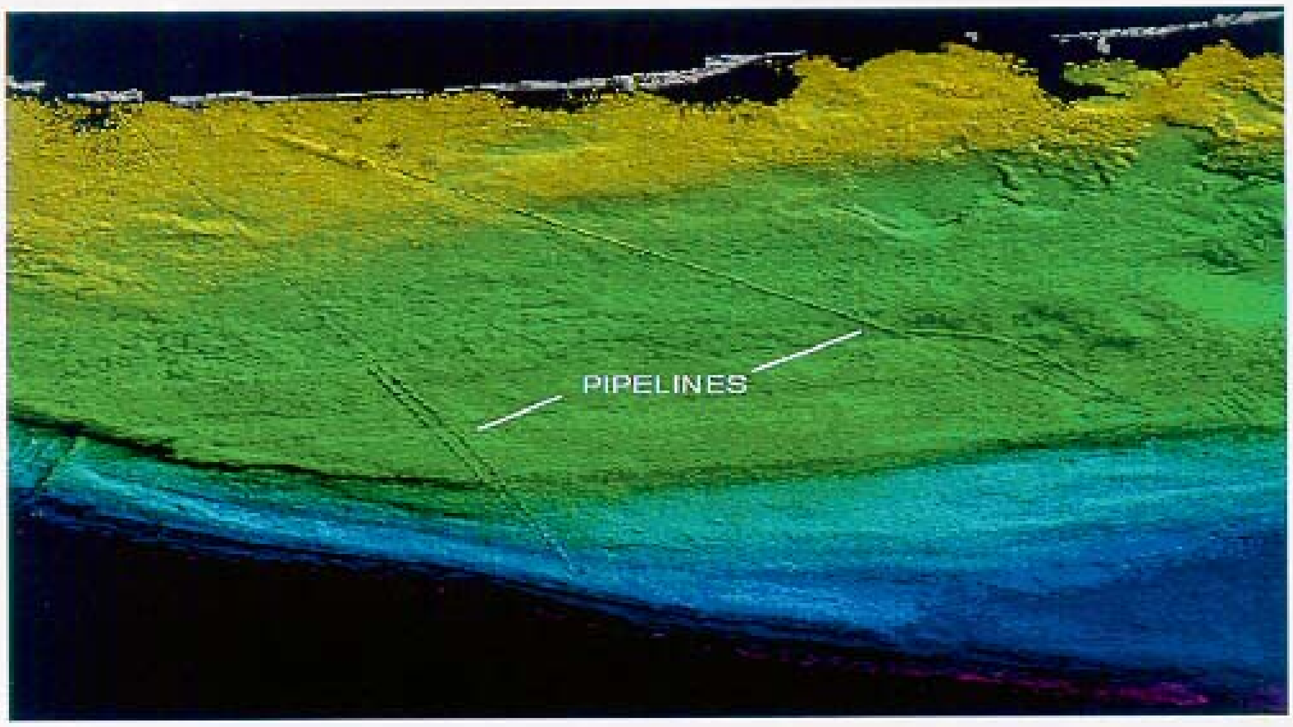


Figure 12. Offshore oil terminal pipelines off Barbers Pt. Oahu.

Figure 13. Barbers Pt. Oahu. Offshore oil terminal

13.0 Ancillary Observations

13.1 Water Clarity Observations

See Appendix F

13.2 Meteorological Observations

N/A

13.3 Biological Observations

N/A

Station ID: **1611400** PUBLICATION DATE: 08/23/2000
Name: **NAWILIWILI, NAWILIWILI HARBOR, KAUAI, HAWAII**
NOAA Chart: 19383 Latitude: 21ø 57.4' N
USGS Quad: LIHUE Longitude: 159ø 21.6' W

T I D A L   D A T U M S

Tidal datums at NAWILIWILI, NAWILIWILI HARBOR, KAUAI based on:

LENGTH OF SERIES: 10 YEARS
TIME PERIOD: January 1960 - December 1980
TIDAL EPOCH: 1960-1978
CONTROL TIDE STATION: 1612340 HONOLULU, HONOLULU HARBOR, OAHU ISLAND

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

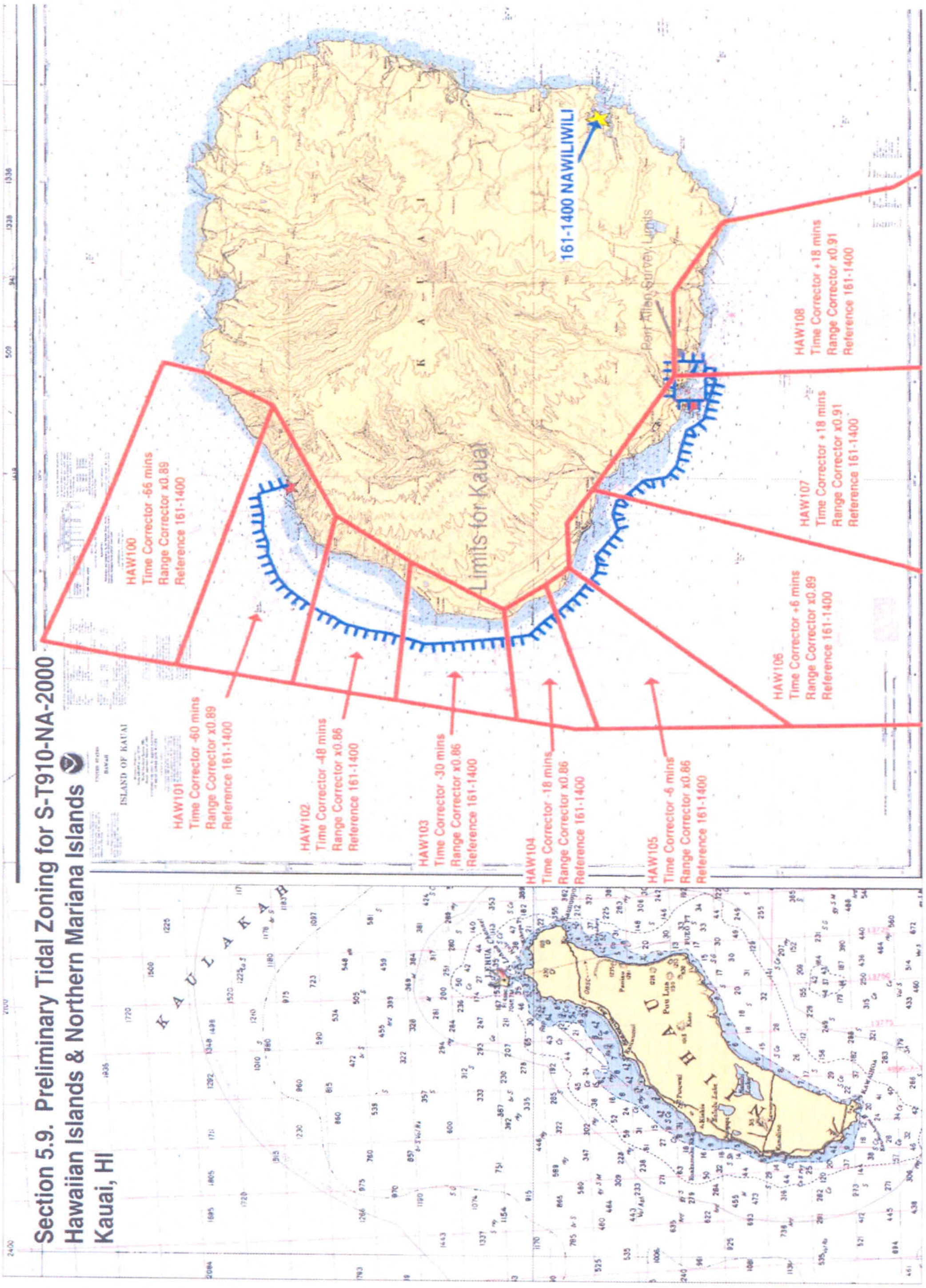
HIGHEST OBSERVED WATER LEVEL (09/11/1992)	= 1.552
MEAN HIGHER HIGH WATER (MHHW)	= 0.567
MEAN HIGH WATER (MHW)	= 0.427
MEAN SEA LEVEL (MSL)	= 0.260
MEAN TIDE LEVEL (MTL)	= 0.247
MEAN LOW WATER (MLW)	= 0.068
MEAN LOWER LOW WATER (MLLW)	= 0.000
LOWEST OBSERVED WATER LEVEL (05/24/1967)	= -0.298

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
NO 14 1974	2.491	2.064
NO 5 1954	1.590	1.163
1400 A 1980	2.444	2.017
1400 B 1980	2.392	1.965
1400 C 1983	1.947	1.520
1400 F 1991	2.596	2.169
WALL	1.889	1.462
1400 G 1997	2.620	2.193
1400 H 1997	2.546	2.119

APPENDIX B2
HAWAII TIDE ZONES

KAUAI



NOAA FORM 75-96
(10-83)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

MARINE CHART BRANCH

RECORD OF APPLICATION TO CHARTS

FILE WITH DESCRIPTIVE REPORT OF SURVEY NO. W00058-W00062

INSTRUCTIONS

A basic hydrographic or topographic survey supersedes all information of like nature on the uncorrected chart.
1. Letter all information.
2. In "Remarks" column cross out words that do not apply.
3. Give reasons for deviations, if any, from recommendations made under "Comparison with Charts" in the Review.

CHART	DATE	CARTOGRAPHER	REMARKS
19386	3/19/08	Bruce Olmstead	Full ~~Part~~ ~~Before~~ After Marine Center Approval Signed Via Full application of
			Drawing No. soundings, curves and features from the
			smooth sheet.
19381	3/19/08	Bruce Olmstead	Full ~~Part~~ ~~Before~~ After Marine Center Approval Signed Via Full application of
			Drawing No. soundings, curves and features from the
			smooth sheet.
19382	3/19/08	Bruce Olmstead	Full ~~Part~~ ~~Before~~ After Marine Center Approval Signed Via Full application of
			Drawing No. soundings, curves and features from the smooth
			sheet.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
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			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.

SUPERSEDES C&GS FORM 8352 WHICH MAY BE USED.