W00071-W00078

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. W00071 - W00078

LOCALITY

State Hawaii

General Locality Oahu

Sublocality Northeast Coast of Oahu

2000

CHIEF OF PARTY

Maxim F. Van Norden

LIBRARY & ARCHIVES

DATE

(11-72)

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

HYDROGRAPHIC TITLE SHEET

REGISTER NO. W00071-W00078

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

FIELD NO.

State Hawaii

General Locali Northeast Coast of Oahu

Sublocality Kahuka Bay to Kaneohe Bay

Scale 1:10,000 Date of Survey August 1 - December 20, 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 sounder, hand lead, pole SHOALS 400 Lidar

Graphic record scaled by Fleet Survey Team

Graphic record checked by Fleet Survey Team

Evaluation by Bonnie Johnston Automated plo HP Designjet1050c

Verification by Physical Scientist: B. Johnston, Cartographer: Russ Davies

Soundings in meters at MLLW

REMARKS: Revisions and annotations appearing as endnotes were generated by the cartographer during office processing.

All depths listed in this report are referenced to mean lower low water unless otherwise noted.

UTM Zone 04

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

March 13, 2007

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

THROUGH: Commander Gerd G. Glang, NOAA
Chief, Hydrographic Surveys Division

FROM: Gary C. Nelson, NOAA *Gary C. Nelson*
Acting Chief, Pacific Hydrographic Branch

SUBJECT: Approval Memorandum for W00071-W00078

Pacific Hydrographic Branch has completed an evaluation and chart application of Outside Source Data from the Naval Oceanographic Office (W00071 – W00078). 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.

The northeast side of Oahu is currently listed as "Priority 4" in the NOAA Hydrographic Survey Priorities (NHSP). The LIDAR provided adequate depth information in the near shore areas. This area should remain classified as "Priority 4".

All of the survey data for the are was acquired by LIDAR and should be classified as Category of Zones of Confidence (CATZOC) "B" if used to update ENC's (Full seafloor coverage not achieved; uncharted features, hazardous to surface navigation are not expected but may exist. 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

December 22, 2006

MEMORANDUM TO: Commander Donald W. Haines, NOAA
Chief, Pacific Hydrographic Branch

FROM: Bonnie Johnston
Physical Scientist, Pacific Hydrographic Branch

SUBJECT: Review of Outside Source Data Survey W00071, W00072, W00073, W00074, W00075, W00076, W00077 and W00078
U.S. Naval Oceanographic Office/SHOALS 400 LiDAR
Northeast Oahu Island, HI

I have reviewed outside source hydrographic surveys W00071, W00072, W00073, W00074, W00075, W00076, W00077 and W00078 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 W00071 to W00078 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.[1] 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.
- Although the SHOALS 400 LIDAR system was used to collect data for the entire survey area, sections of the Northeast coast of Oahu were not surveyed to meet NOAA charting standards based on the needs of the agency requesting the survey. Data for surveys W00074 and W00075 were acquired for the US Army Corps of Engineers (USACE) to support coastal modeling and do not meet HSSDM data redundancy standards. Portions of surveys W00074 and W00075 do not have 200 % data coverage. [2]

Special attention should be given to:

- Lidar coverage is absent over a large portion of Kane'ohe Bay (Chart 19359), resulting in sparse and patchy coverage in the primary channel that traverses the bay. An overall shoaling trend and 8 dangers to navigation were noted in the small harbors and secondary channels surrounding the main Kane'ohe Bay channel. Despite the patchy coverage, the Lidar shoals were reviewed in Fledermaus and appear valid and should supersede the charted soundings. [3]
- Two data fliers were found in the NAVOCEANO smooth sheet for survey W00077 during a comparison with chart 19359. The depths were plotted as 1-foot and positioned at 21°27'31.5" N, 157°49'33.05" W and 21°27'24.49" N, 157°49'29.02" W. Charting the 1-foot Lidar depths would serve to close off the small harbor as a potential anchorage. The reviewer believes that these depths are fliers and should not be applied to the chart. [4]
- Refer to the Outside Source Data Quality Assurance Checklist for additional 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 19357 and 19359. [5]
- The data should not be used to supersede near shore features such as, charted shoals, wrecks, rocks, obstructions, foul areas or coral reefs. [6]
- The charted shoreline should be retained as charted. [7]
- Bottom samples were not acquired and should be retained as charted. [8]

Reviewed and approved: ______________________ Date: 22 Dec 06
Lieutenant(jg) Abigail Higgins, NOAA
Acting Hydrographic Team Leader, PHB

Revisions compiled during office processing by the cartographer

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[1] Concur
[2] In these areas, soundings and features should be retained as charted.
[3] Concur
[4] Concur
[5] Concur
[6] Except where there is evidence of shoaler features.
[7] It is recommended using the latest available RSD shoreline.
[8] Concur

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

January 29, 2007

MEMORANDUM TO: Commander Donald W. Haines
Chief, Pacific Hydrographic Branch

FROM: Russ Davies
Cartographer, Pacific Hydrographic Branch

SUBJECT: Application of Outside Source Data Surveys
W00071-W00078
U.S. Naval Oceanographic Office
SHOALS 400 LIDAR

I concur with all recommendations by the reviewer Bonnie Johnston except where noted in their reports.

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 W00071-W00078, supersede charted information within the common area and applied to charts 19357, 23rd Edition and 19359, 11th Edition.

Record of Application to Charts is attached.

Review and Approved

Gary Nelson, Cartographer Team Leader
Pacific Hydrographic Branch

Registry No: W00071, W00072, W00073, W00074, W00075, W00076, W00077, W00078

State: Hawaii

General Locality: Northeast Coast of Oahu

Sub Locality: Kahuka Bay to Kaneohe Bay

Dates of Survey: August 1 - December 20, 2000

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

OSD Project No:

Reviewer: Bonnie Johnston **Review Date:** 10/13/2006

I. DATA INVENTORY

A. Reports

Report Type	Format	Document Title	Date
Descriptive Report or equivalent	Microsoft Word	Hawaii LIDAR Report of Survey (ROS)	09/14/2004
Data Acquisition and Processing Report or equivalent	Microsoft Word	Hawaii LIDAR Report of Survey (ROS)	09/14/2004
Horizontal and Vertical Control Report or equivalent	NA	NA	
System Certification Report or Equivalent	NA	NA	
Other	PDF	Error Budget Analysis for US Naval Oceanographic Office (NAVOCEANO) Hydrographic Survey Systems	09/2001

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, 06x.dgn, 07x.dgn, 08x.dgn
XYZ ASCII Files	NA, Smooth Sheet Sounding Density	01x_101603.asc, 01x_101603.pfm.crs, 02x_101603.asc, 02x_101603.pfm.crs, 03x_101603.asc, 03x_101603.pfm.crs,
Multibeam	NA	NA
Side Scan Sonar	NA	NA
LIDAR	Fledermaus PFM, Full resolution Sounding Density	01x_101603.pfm, 02x_101603.pfm, 03x_101603.pfm, 04x_101603.pfm, 05x_101603.pfm, 06x_101603.pfm,
Single Beam	NA	Yes

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

____ Alignment bias and latency values provided

NA Draft measurements were conducted

____ Static Draft ____ Dynamic Draft ____ Loading

____ Draft values were provided

Yes 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

Yes 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

Note 3 Water level error estimate provided by CO-OPS

Water level / zoning error estimate: 0.179 meters (Tide Zone HAW213)

E. Survey Methodology

__Yes__ The surveyor has conducted adequate quality control of horizontal positioning data

__Note 4__ DTM, BASE surface, and/or mosaics indicate that seafloor coverage requirements (per NOAA HSSDM) were met and no significant coverage holidays exist.

__Note 5__ All least depths over shoals, wrecks, rocks, obstructions, and other features have been determined

__Note 6__ 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.

__Note 7__ 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.

Yes 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.

Note 7 **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.

Note 5 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, Note 8 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

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

- No, Note 9 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.

Yes, Note 10 Additional DTONs were noted during office evaluation and submitted

F. Aids to Navigation

Yes, Note 11 Aids to Navigation (ATONs) were positioned during this survey

- NA New ATONS were positioned during this survey
- Yes 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

Surveys W00071 through W00078 are composed of LIDAR data surveyed with the SHOALS 400 LIDAR System (Figure 1).

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 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:
A zoning error estimate was not provided by CO-OPS. However, NAVOCEANO obtained an accuracy estimate for tide zone HAW213 by comparing water levels measured at a tide gauge they installed at Waianae small boat harbor with the CO-OPS zone corrected reference tide station 161-2340 located in Honolulu. A standard deviation of 0.179 meters was calculated from the differences between observed tides at the installed station and the tide derived from the zoned station.

NOAA tide station161-2480 Mokuoloe located in Kane'ohe Bay served as the reference station for the tide zones (HAW201, HAW226, HAW227) applied to surveys W00071 - W00078.

Note 4:
W00074 and W00075 - Several large gaps in coverage were visible in the DTMs and Lidar data set. A majority of the gaps occur in the deep portions of channels and were most likely due to lower spot spacing density and insufficient sounding density due to lack of data redundancy (Figure 2).

W00076 to 77 - Lidar coverage is absent over a large portion of Kane'ohe Bay, resulting in sparse and patchy coverage in the primary channel that traverses the bay (Figure 3). This significant gap in coverage was attributed to poor water clarity in the NAVOCEANO Hawaii Lidar ROS. NAVOCEANO claims coverage was limited to 11 to 13m in the channel and inner bay due to clarity issues caused by high turbidity and an increase in chlorophyll numbers.

Also, a gap in coverage was found to the west of Mokapu Peninsula in the vicinity of 21°27'14.37" N, 157°46'42.96" W. The area is charted (19359) as dredged to 15 feet; however, the depths surrounding the gap were surveyed up to 25 feet. The gap coincides with the deepest part of the dredged area. It is believed by the reviewer that this region may have also been impacted by clarity issues.

Note 5:
Least depths over shoal areas and bathymetric features from the surveys were reviewed visually in Fledermaus and appear to be valid with a few exceptions found in survey W00077 (see V. Chart Comparison). 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.

Note 6:
Although the SHOALS 400 LIDAR system was used to collect data for the entire survey area, sections of the Northeast coast of Oahu were not surveyed to meet NOAA charting standards based on the needs of the agency requesting the survey. Data for surveys W00074 and W00075 were acquired for the US Army Corps of Engineers (USACE) to support coastal modeling and do not meet HSSDM data redundancy standards (Figure 4).

Surveys W00071-73 and W00076-78 were acquired for the US Navy and were completed with 4x4 meter spot density and 200% coverage, in compliance with IHO Order 1 standards for object detection and multiple coverage. However, the areas surveyed for the USACE were not required to meet IHO Order 1 standards, and were completed with 8x8 meter spot density and 100% coverage (Figure 5).

The high density Lidar data sets for W00074 and W00075 were reviewed in Fledermaus 3D Editor. Data subsets were selected at varying depths, with approximately 20 - 30 percent of the Lidar data reviewed. A large portion of the reviewed Lidar subsets appeared to have obtained 200 % coverage, despite having been collected for the USACE. However, there were a number of areas that only had 100 % coverage that often coincided with the deepest portions of the survey area.

Despite the lack of redundant data, the reviewer observed good depth agreement and continuity between Lidar data in areas with less than 200 percent coverage. Survey areas for W00074 and W00075 ranged approximately from La'ie to Kahana Bay. The reviewer believes that the Lidar data for these survey areas can be used to supersede charted depths.

Note 7:
Several fliers plotted on the NAVOCEANO smooth sheet were found in Survey W00077 during a chart comparison completed by the reviewer (See section V. Chart Comparison). Despite these fliers, in general the Fledermaus surfaces, DTMs and smooth sheet appeared free of noise.

Note 8:
Aside from exceptions in steeply sloped regions and over bathymetric features, a review of the standard deviation grids submitted with the Fledermaus PFM files did not reveal any areas with soundings exceeding the HSSDM accuracy requirements.

Note 9:
Four AWOIS items were located within the survey limits. None of the items were visible in the survey data; however, due to the unproven object detection capabilities of the Shoals 400 Lidar system, the items can not be sufficiently disproved.

The AWOIS items are located in section 16 of the database under record numbers 50465, 50796, 50458, and 50459.

Note 10:
Eight dangers to navigation were designated by the reviewer for survey W00077. See section V. Chart Comparison, Survey W00077 for more information.

Note 11:
NAVOCEANO confirmed the charted (19359) position of Buoy N "2" located along Crash Boat Channel, Survey W00077. The buoy's surveyed position was 21°27'8.139" N, 157°47'00.03" W. NAVOCEANO references the buoy in their Chart Review of 19359 (Appendix C, Hawaii Lidar ROS).

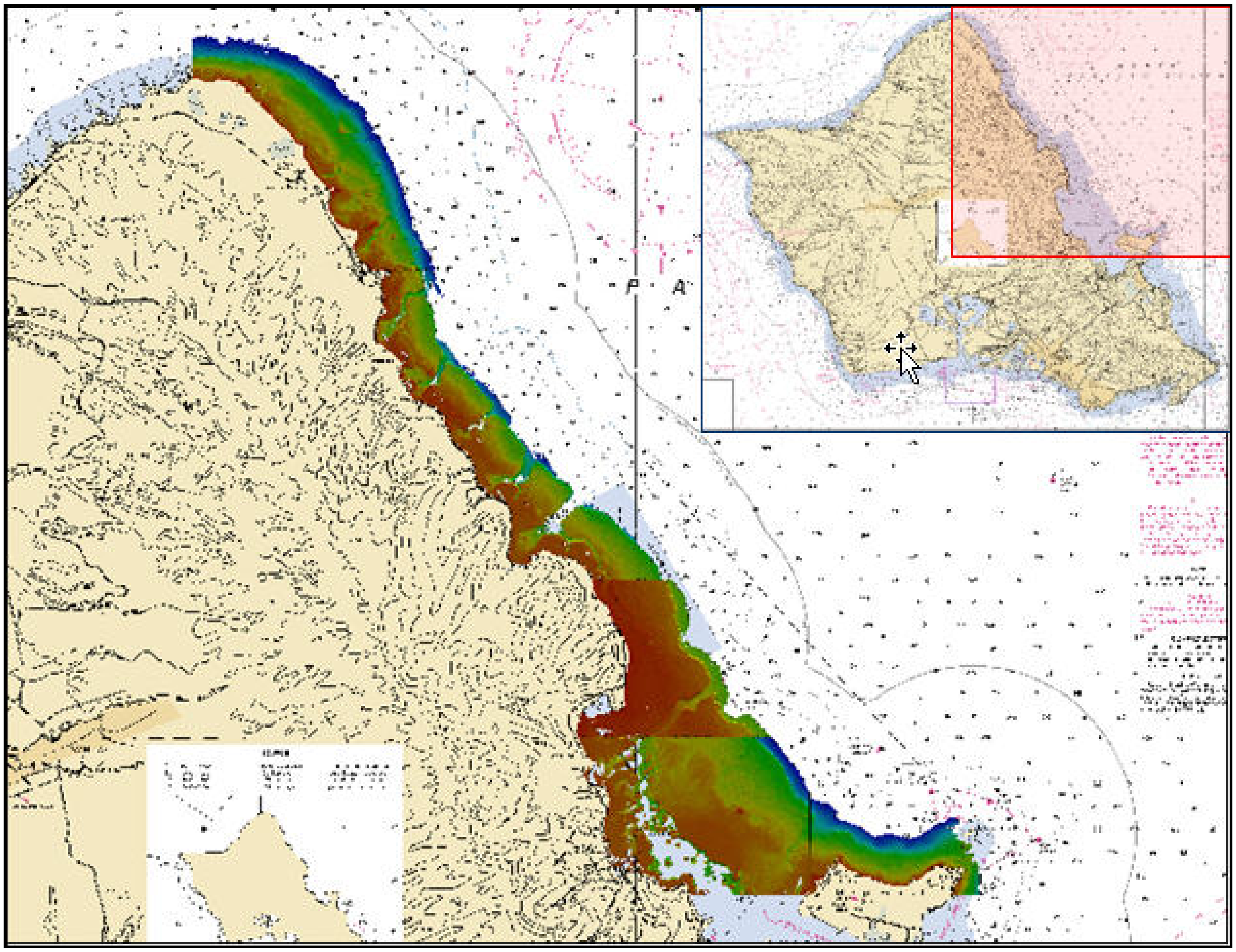

Figure 1. An overview of the area covered by NAVOCEANO Lidar surveys W00071 through W00078. The surveys cover the Northeast coast of Oahu, HI, spanning from Kahuku Point to Mokapu Peninsula. Digital terrain models (DTMs) from each survey area are overlain on NOAA chart 19357.

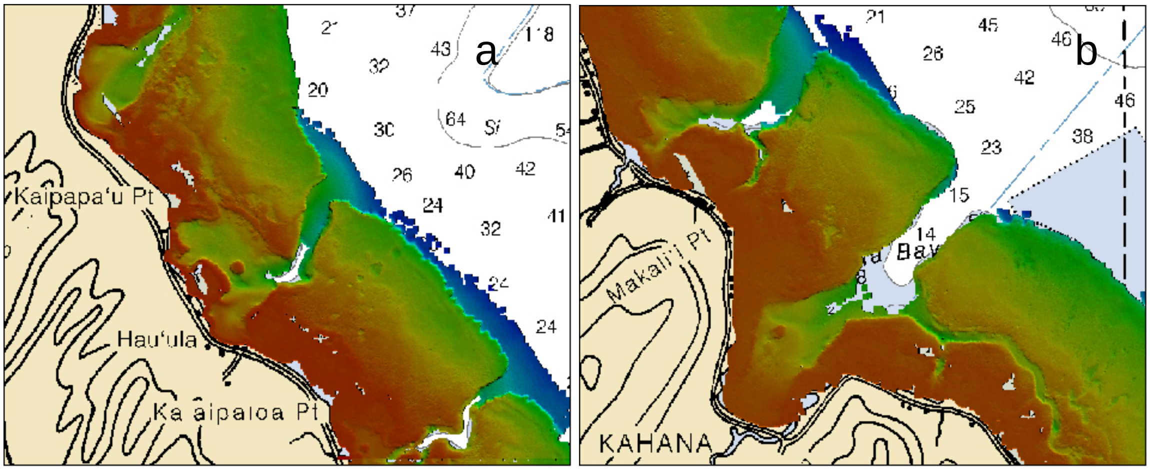

Figure 2. (a) A DTM from survey W00074 displaying gaps in data coverage. ***(b)*** A DTM from survey W00075 displaying gaps in data coverage. The large data gaps observed in surveys W00074 and 75 primarily correspond with the deepest portions of the survey area. This is most likely a product of the lower resolution spot density (8 x 8 m) that was used to acquire Lidar data for the US Army Corps of Engineer specific surveys. Both images feature chart 19357 in the background. DTMs were colored by depth. [1]

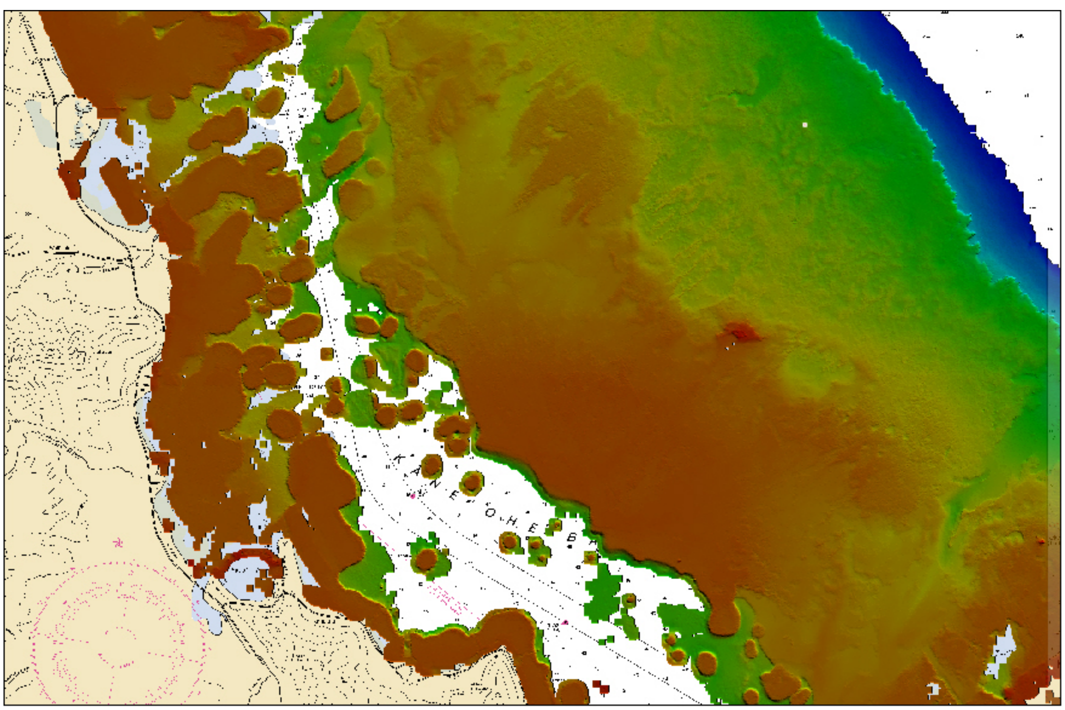

Figure 3. A DTM of survey W00077 colored by depth displaying the sparse coverage obtained over the majority of the main channel traversing Kane'ohe Bay. NAVOCEANO claimed coverage was limited in this area due to water clarity issues. NOAA chart 19359 is featured in the back ground.

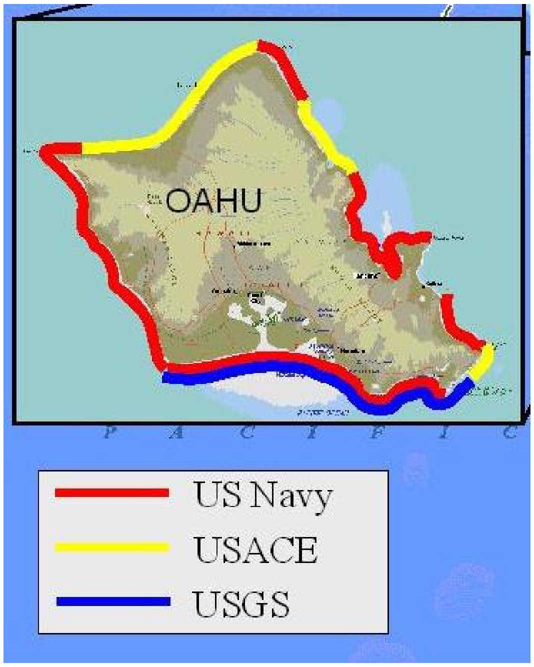

Figure 4. Image depicting Lidar coverage for Oahu. Areas surveyed by the US Navy and USGS were surveyed with 4x4 meter spot density and 200 % coverage. Areas surveyed by the USACE were surveyed with 8x8 meter spot density and 100 % coverage. The image was submitted in Appendix A of the Hawaii Lidar ROS. [2]

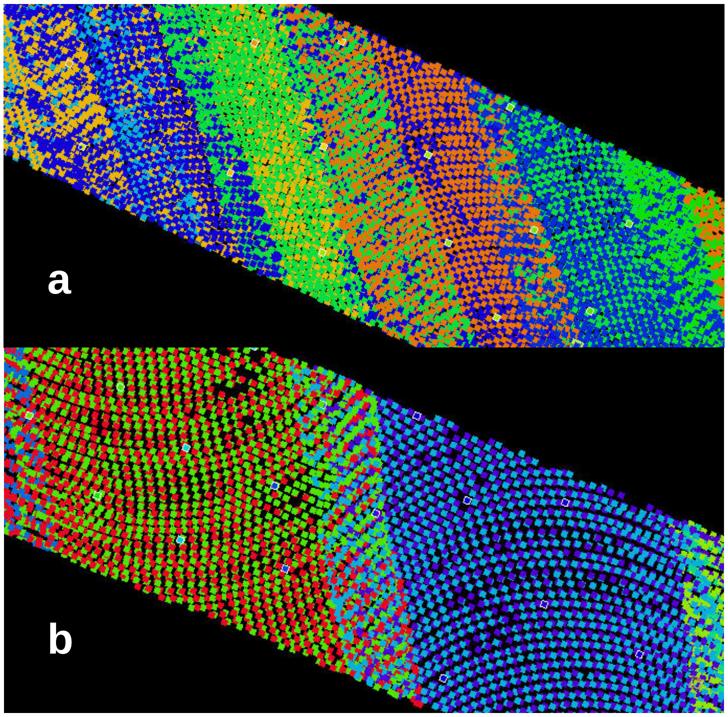

Figure 5. (a) Image of Lidar point data collected for survey W00073 flown at 4x4 meter spot density with a minimum of 200% data redundancy. ***(b)*** Image of Lidar point data collected for survey W00074 flown at 8x8 meter spot density with a minimum of 100% data redundancy. The data density observed in Image A is representative of the surveys flown for the US Navy, which is significantly higher than the data density of surveys W00074 and W00075 flown for the USACE. Data points were colored by line.

V. CHART COMPARISON

Chart comparisons were conducted for surveys W00071 through W00078. All surveys were compared to Chart 19357; surveys W00076, W00077 and W00078 were also compared to Chart 19359.[3]

In general, smooth sheet depths agree with the charted soundings within 1 to 2 fathoms, with the smooth sheet depths being shoaler than the charted soundings when slight discrepancies occurred. Numerous new shoals were detected with the LIDAR data. Shoaler surveyed depths should supersede deeper charted soundings, with exceptions noted below.

All charted wrecks, rocks, obstructions and shoals should be retained due to the absence of item investigations in the survey area and the unproven object detection capability of LIDAR systems for use in chart disprovals. [4]

A number of channels were visible in the sounding data for surveys W00073 through W00076. The channels are carved through a labyrinth of rocks and reefs; some are charted and some are not. NAVOCEANO noted the channels in their review of chart 19357 (Appendix C, Hawaii Lidar ROS) [5] and concluded that navigation would be hazardous to any vessel including shallow draft boats. The reviewer agrees with this assessment due to the numerous shoals, rocks and reefs in this area and the narrowness of the channels. The uncharted channels should remain uncharted and navigation left to local knowledge. [6]

The following sections highlight NAVOCEANO reported obstructions, new features and updates to charted features specific to individual surveys. Only the surveys with significant discrepancies or updates were included.

SURVEY W00073

Affected Charts

Chart	Scale	Edition	Date	Units
19357	1:80,000	23rd	Jul 1, 2006	Fathoms

Reported Obstructions

No obstructions were reported by NAVOCEANO for this survey.

Charted Features

A. A charted islet located east of Kalanai Pt at 21°39'48.26" N, 157°55'00.13" W was not visible in the smooth sheet depths or in the high-density Fledermaus data set. The surveyed depths do not rise above sea level (corrected to MLLW). However, a submerged rock or obstruction with a least depth of 4.36 meters (2.3 fathoms) was located in the vicinity of the charted islet (Figure 6). The submerged feature corresponds with a charted 1.75-fathom sounding (Figure 7). It is recommended that the islet be retained as charted and added to the AWOIS database for future investigation or disproval. [7]

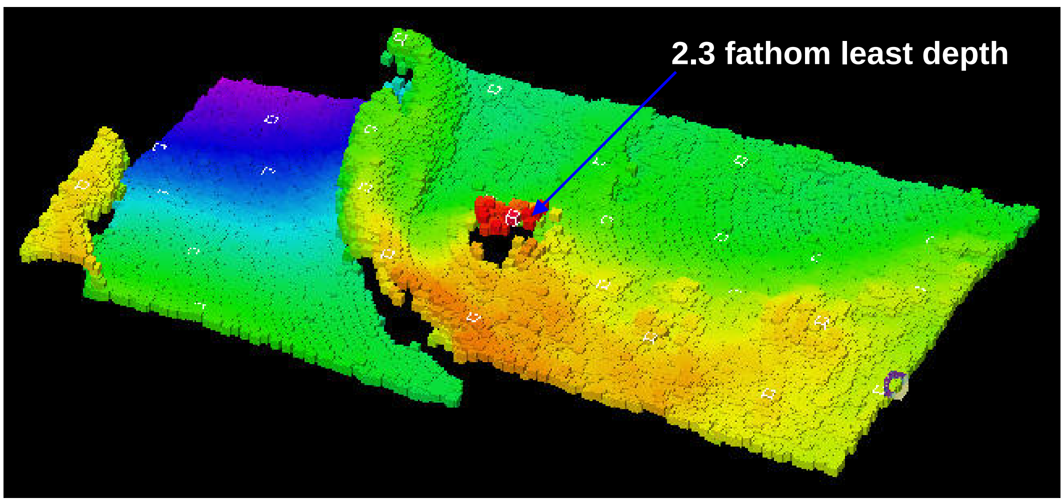

Figure 6. Lidar data points from survey W00073 colored by depth shown in Fledermaus 3D-Editor. A submerged feature with a least depth of 2.3 fathoms is displayed in red. The submerged feature is in the vicinity of a charted 1.75-fathom sounding. There is no evidence of an islet present in the Fledermaus data set.

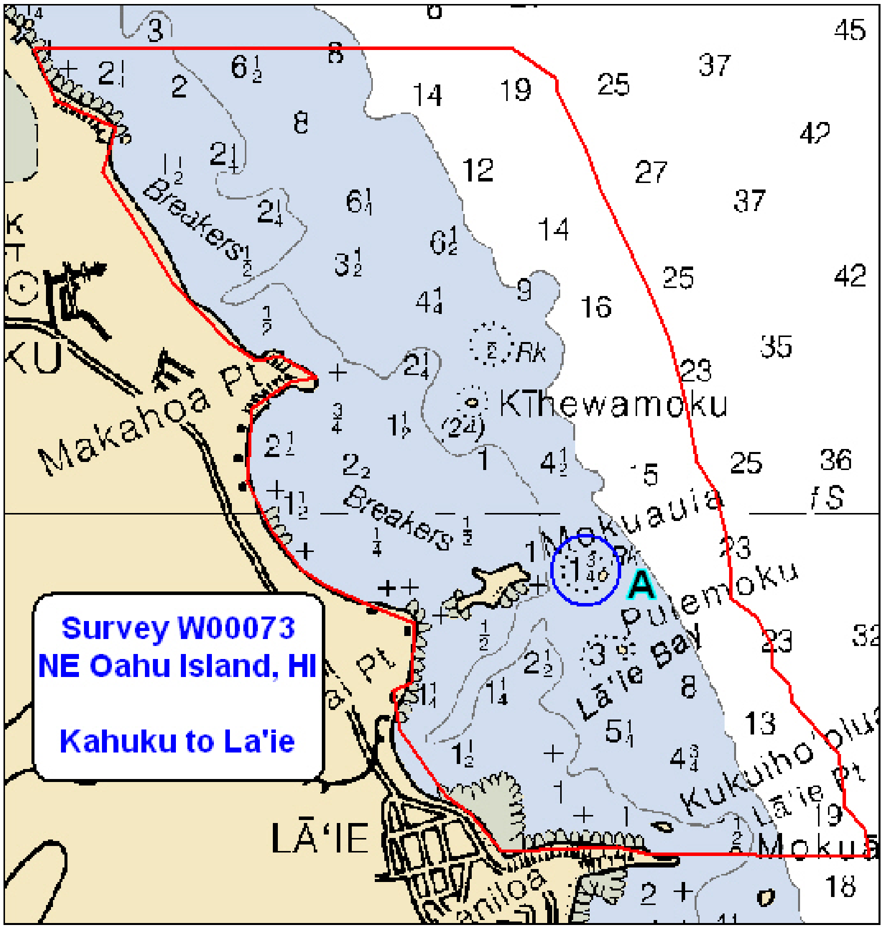

Figure7. Image depicting the survey outline and location of noted features for survey W00073; Chart 19357 is displayed in the background.

SURVEY W00074

Affected Charts

Chart	Scale	Edition	Date	Units
19357	1:80,000	23rd	Jul 1, 2006	Fathoms

Reported Obstructions

No obstructions were reported by NAVOCEANO for this survey. [8]

Charted Features

A. The entrance to a charted channel west of Kaipapa'u Point approximately located at 21°37'08" N, 157°55'53" W was surveyed deeper and wider than charted. A 10-fathom sounding was located in the vicinity of a charted 3.5-fathom sounding (Figure 8). Although there is not 200% data redundancy in this area, when viewed in Fledermaus 3D Editor, agreement and continuity between surrounding depths from multiple lines was good (Figure 9). It is recommended that charted soundings and contours be superseded by Lidar data. [9]

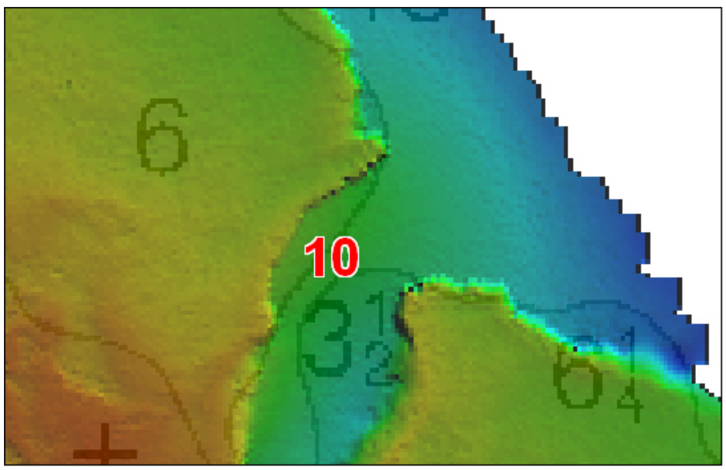

Figure 8. Image depicting the location of a 10-fm Lidar depth in the vicinity of a charted (19357) 3.5-fm sounding. A DTM from survey W00074 colored by depth was overlain on chart 19357.

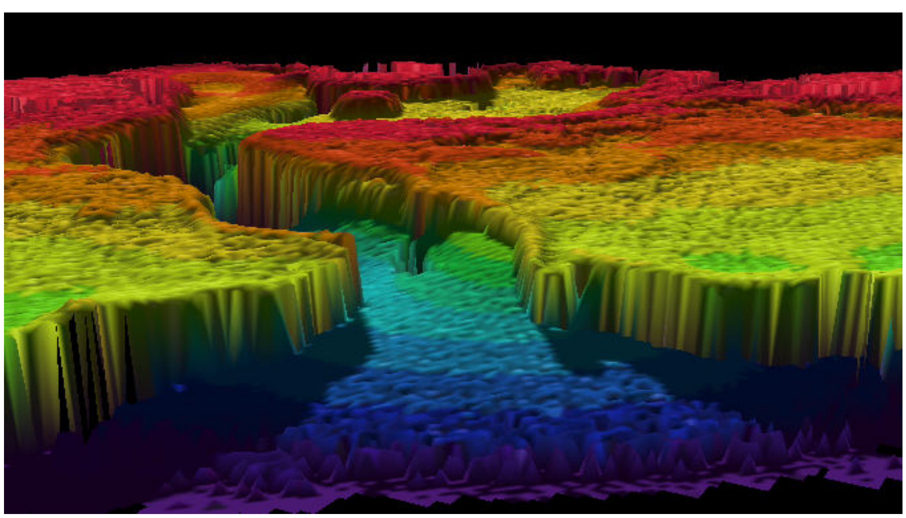

Figure 9. An image taken in Fledermaus of the channel entrance from survey W00074. Data are colored by depth and the image was taken facing west.

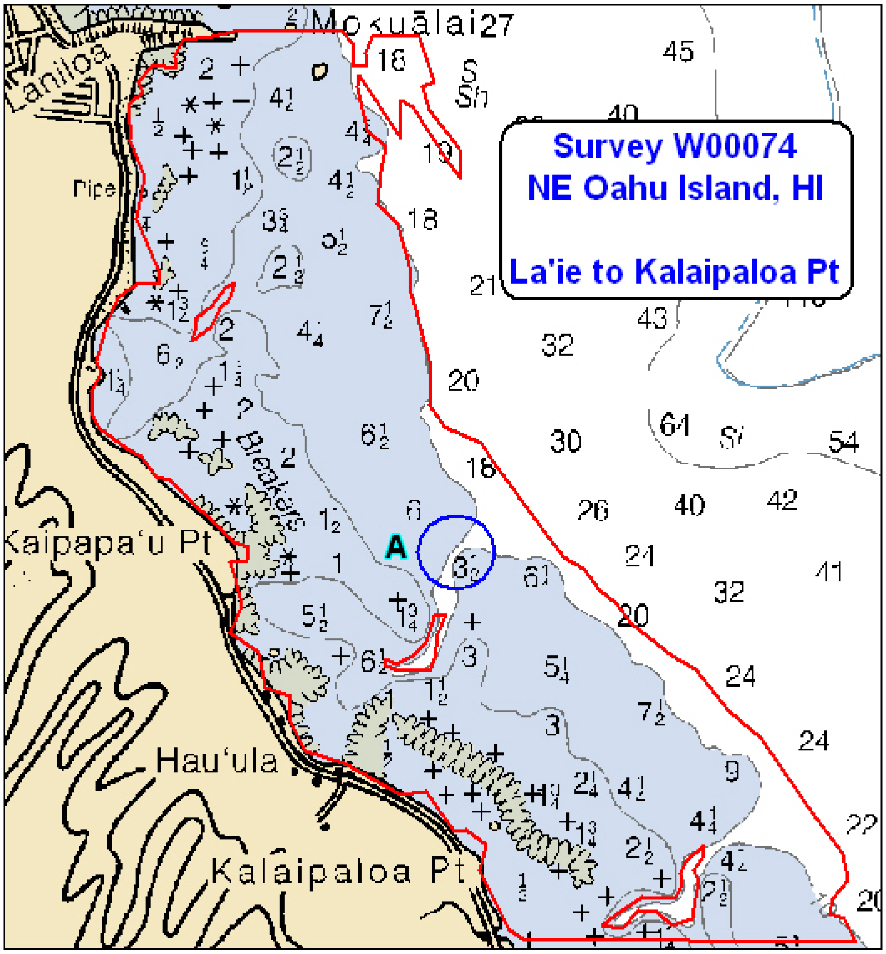

Figure 10. Image depicting the survey outline and location of noted features for survey W00074; Chart 19357 is displayed in the background.

SURVEY W00076

Affected Charts

Chart	Scale	Edition	Date	Units
19357	1:80,000	23rd	Jul 1, 2006	Fathoms
19359	1:15,000	11th	Oct 1, 2003	Feet

Reported Obstructions

No Obstructions were reported by NAVOCEANO for this survey. [10]

Charted Features

Chart 19357

A. A 17-fm depth was found in the vicinity of a charted 10-fm sounding. The charted sounding is located at 21°30'13.23" N, 157°47'40.3" W. The Lidar data was reviewed in Fledermaus 3DEditor and all surveyed depths in the vicinity were consistent with the 17 fathom depth. The surveyed depth appears valid and it is recommended that the charted depth be superseded.[11]

Chart 19359

A. A 103-foot depth was found in the vicinity of a charted 60-foot sounding. The charted (19359) depth corresponds with the charted (19357) 10-fm depth described in the above paragraph. It is recommended that the charted depth be superseded. [12]

New Features

Chart 19359

B. A19-ft Lidar depth positioned at 21°30'43.64" N, 157°49'4.752" W was located in the vicinity of a charted 30-ft contour. The surveyed depth was reviewed in Fledermaus 3DEditor and appears to be the least depth of a new shoal (Figure11). The shoal is located near the Northeast entrance to the main channel that traverses Kane'ohe Bay. It is recommended that the charted depths and contours be superseded by the Lidar data. [13]

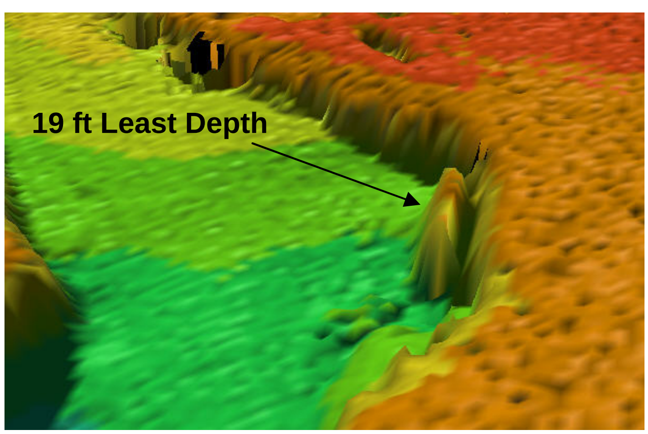

Figure 11. A new shoal from W00076 displayed in Fledermaus; data is colored by depth.

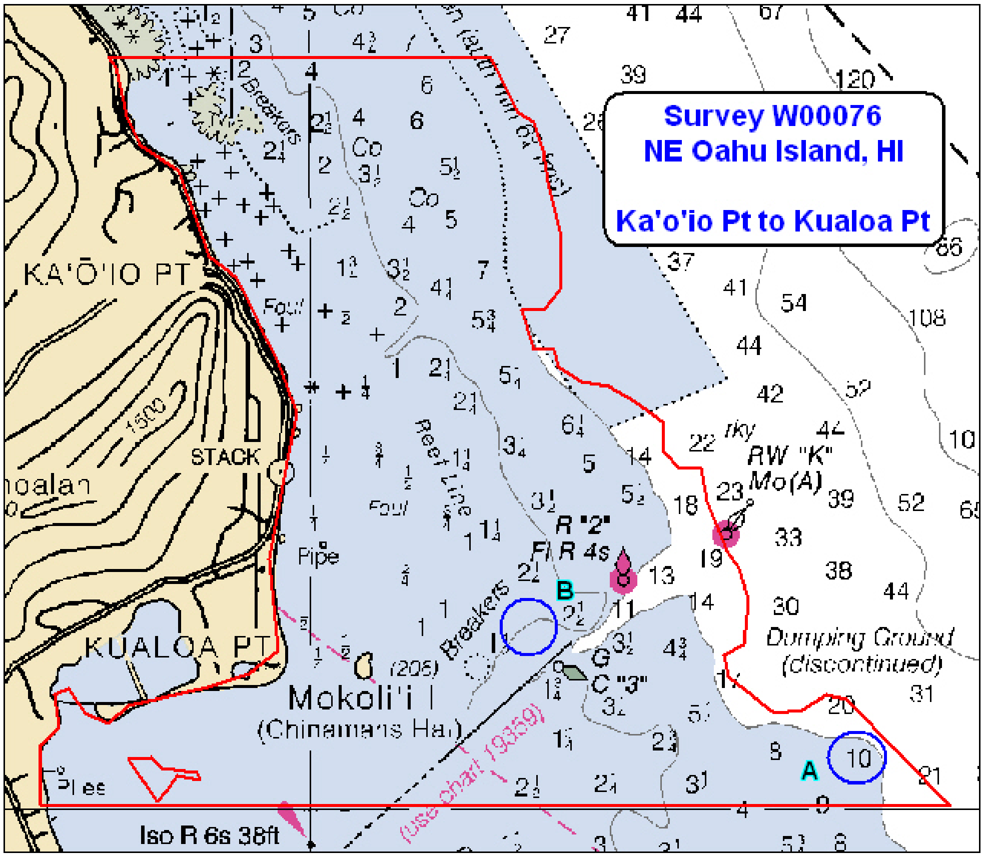

Figure 12. Image depicting the survey outline and location of noted features for survey W00076; Chart 19357 is displayed in the background.

SURVEY W00077

Affected Charts

Chart	Scale	Edition	Date	Units
19357	1:80,000	23rd	Jul 1, 2006	Fathoms
19359	1:15,000	11th	Oct 1, 2003	Feet

Smooth Sheet Soundings

A. Two 1-foot Lidar depths were plotted on the NAVOCEANO smooth sheet in the vicinity of a small harbor with charted depths of 36 -38 feet. The depths were positioned at 21°27'31.5" N, 157°49'33.05" W and 21°27'24.49" N, 157°49'29.02" W. Upon review in Fledermaus 3D-Editor, the 1-foot depths appear to be un-rejected data fliers that do not represent true features (Figure 13). The surrounding Lidar depths do not support these values and are consistent with the charted depths. The outliers are located in an area of patchy Lidar coverage caused by poor water clarity, increasing the likelihood of bad soundings to appear in the data set.

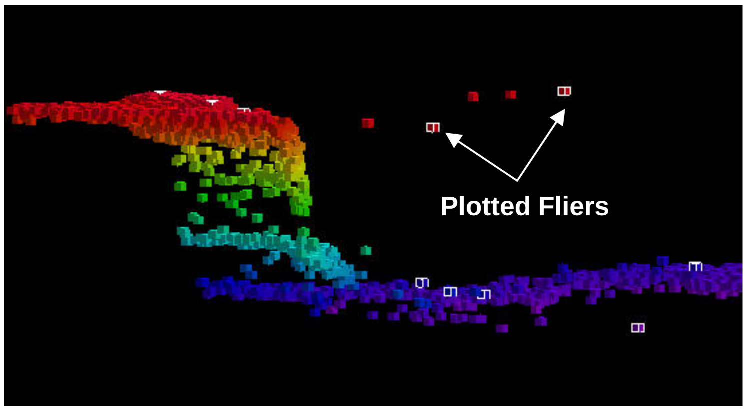

Figure 13. An image taken in Fledermaus 3D Editor displaying the position of the suspected fliers in relation to the surrounding Lidar depths. The depths outlined in white are plotted on the smooth sheet.

Surveyed depths were compared to singlebeam echosounder data from a NOAA survey conducted in 1976 (H09593). The singlebeam survey obtained good coverage in the vicinity of the questioned Lidar depths with what appears to be 50 meter survey line spacing (Figure 15). The singlebeam soundings agree with the charted depths and do not indicate the presence of any submerged features in the small harbor.

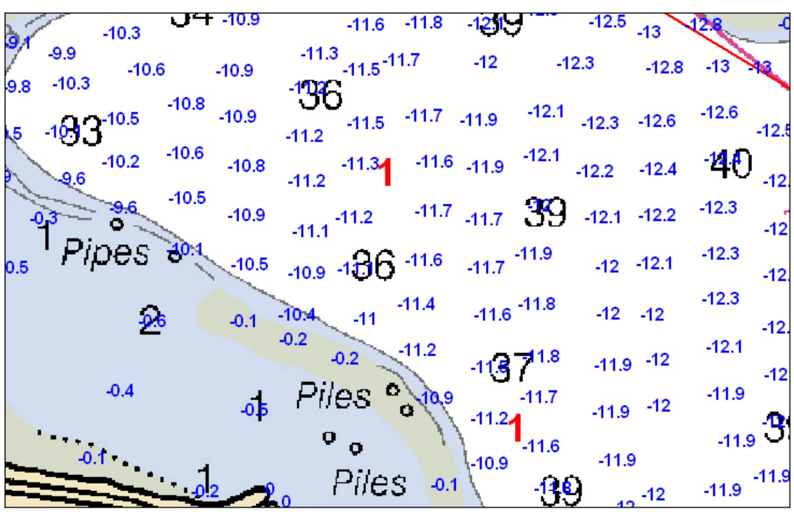

Figure 14. The location and depth (feet) of the suspect Lidar depths are shown in red, while the singlebeam echosounder depths (meters) from NOAA survey H09593 are shown in blue. Chart 19359 is displayed in the background.

NAVOCEANO did not include these depths in Appendix D: Targets, Obstructions, Wrecks of the Hawaii Lidar ROS, which implies that their inclusion in the smoothsheet was overlooked. Charting the 1-foot Lidar depths would serve to close off the small harbor as a potential anchorage. The reviewer believes that these depths are fliers and should not be applied to the chart.[14]

Reported Obstructions

No Obstructions were reported by NAVOCEANO for this survey. [15]

Charted Features

B. A 9 -foot sounding was found in the vicinity of a charted 21-foot sounding. The 9 foot sounding is located at 21°29'24.03" N, 157°50'18.25" W in the center of a narrow channel (100 m) connecting to the main channel of Kane'ohe bay. The 9 foot sounding is a least depth representing an overall shoaling trend in the channel. Due to the narrowness of the channel, it is unlikely that large draft vessels would enter; therefore, the difference in depth is not critical to navigation. The surveyed depths should supersede charted depths. [16]

C. An overall shoaling trend was observed in a small cove located in the vicinity of 21°28'30.23" N, 157°48'48.36" W. Surveyed depths ranged between 12 to 14 feet and were on average 15 to 20 feet shoaler than charted depths (Figure 15). The surveyed soundings should supersede the charted depths. [17]

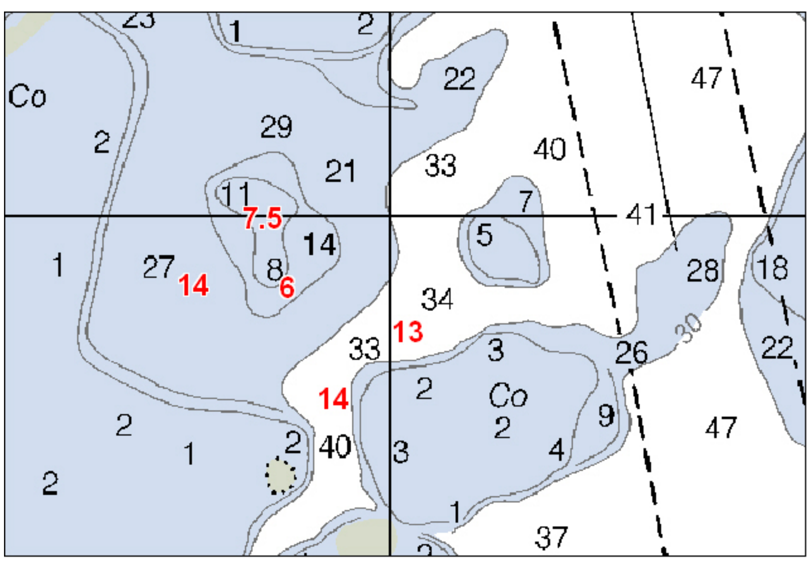

Figure 15. Several Lidar depths (feet) displayed in red were selected from the smooth sheet to show the large depth discrepancy between the charted (19359) and surveyed depths.

D. A 22-foot sounding was located at 21°28'23.30" N, 157°49'33.66" W in the vicinity of a charted 42-foot sounding. The surveyed depth was reviewed in Fledermaus 3D Editor, and despite the patchy coverage appears to be valid. The difference in depth does not pose a critical danger to navigation. The Lidar depth should supersede the charted soundings. [18]

E. A 2-foot sounding positioned at 21°27'7.452" N, 157°47'42.19" W was located in the vicinity of a charted (19359) 10-foot sounding located on a small reef. The Lidar depth was reviewed in Fledermaus, and appears valid. The charted depth should be superseded. [19]

Dangers to Navigation

Eight dangers to navigation (DTON) were found during the review of survey W00077. [20]

The DTONs are located in Kane'ohe Bay, along side the charted (19359) channel bounded by reefs and rocks to the east and west. The DTONs represent least depth soundings found in secondary channels and small harbors located to the west of the channel.

F. Surveyed depths of 19 and 20 feet were located in the vicinity of charted 34 and 37 foot soundings. The DTONs were located approximately 100 meters west of a charted (19359) shoal designated with a light (Q R 22ft) (Figure 16). The depths were reviewed in Fledermaus 3D-Editor and appear to be valid despite the low sounding density. There is good depth agreement within the sounding cluster from which the dtons were extracted and there were hits from multiple lines (Figure 17).

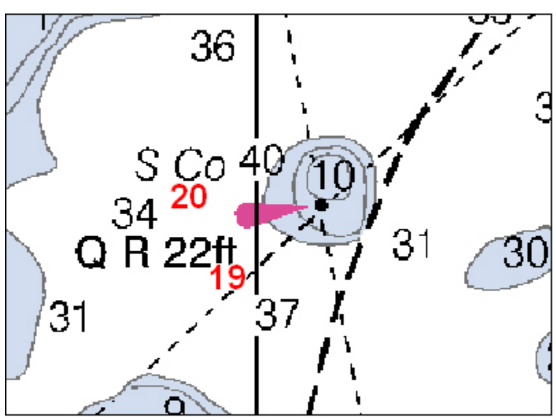

Figure 16. The positions and depths of the DTONs are shown in red with chart 19359 displayed in the background. All depths are in feet.

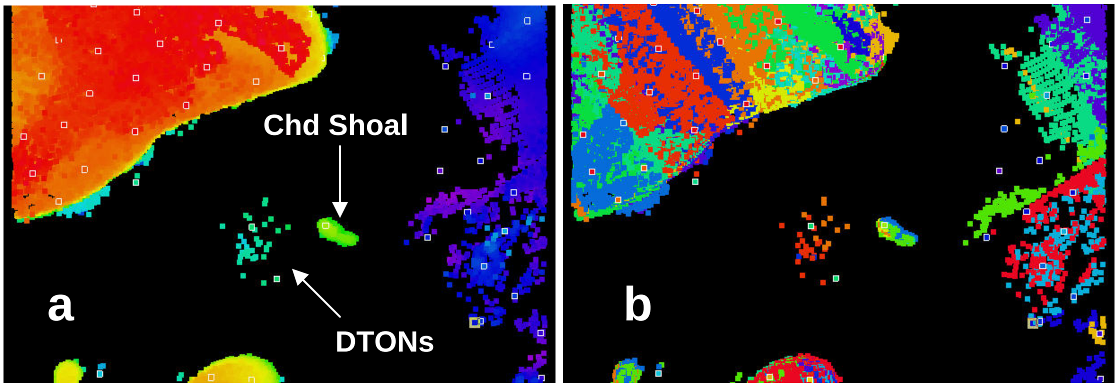

Figure 17. (a) This image was taken in Fledermaus 3D Editor with the Lidar data colored by depth. Two DTONs were selected from the cluster of Lidar depths to the west of the charted (19359) shoal. Note that there is good agreement between the surrounding depths. ***(b)*** The same subset of the Lidar data displayed in Fledermaus 3D Editor colored by survey line. This image shows that multiple Lidar passes obtained hits on the new shoal yielding similar depth values.

G. Three soundings of 17, 18 and 15 feet were selected to represent the shoaling trend evident in a small harbor located in the vicinity of 21°28'35.77" N, 157°50'05.71" W. Depths surveyed in the cove were up to 20 feet shoaler than the charted depths that ranged between 25 and 37 feet. A review of the surveyed soundings in Fledermaus 3D Editor confirmed the validity of the smooth sheet depths and revealed an overall shoaling of the harbor (Figure 18). The surveyed shoaling could pose a danger to vessels attempting to anchor in the cove.

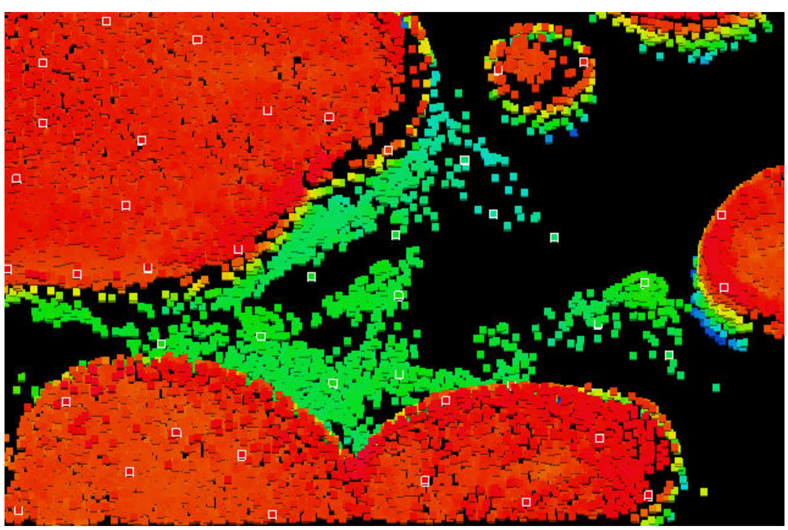

Figure 18. An image of the Lidar depths measured in the small cove displayed in Fledermaus 3D Editor. Lidar data is colored by depth. An overall shoaling trend was observed in the cove, which is surrounded by coral reefs, visible in red.

H. Several Lidar least depths were selected to represent a shoaling trend noted in a secondary channel located to the west of the primary channel transecting Kane'ohe Bay. A 5 and 11 foot sounding were found in the vicinity of a charted 35 foot sounding (21°28'13.97" N, 157°49'52.09" W). Also, a 16 foot sounding was located in the vicinity of a charted 36-foot sounding (21°28'20.16" N, 157°49'57.45" W). The sounding density for this region was very sparse; however, there was good agreement between sounding depths and there did not appear to be any fliers (Figure 19). Lidar data was reviewed in Fledermaus 3D Editor and the surveyed depths appear valid and should supersede the charted soundings. The large depth discrepancy between surveyed and charted depths and the close proximity of this region to the main channel poses a critical danger to navigation.

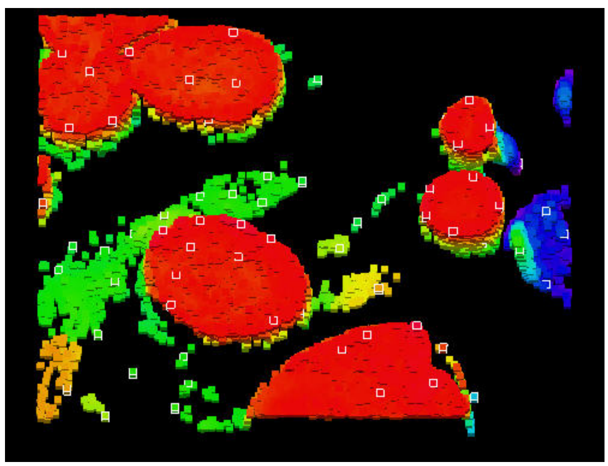

Figure 19. An image from Fledermaus 3D Editor with the Lidar data colored by depth. The depths outlined in white are plotted on the smooth sheet.

Feature	Depth (ft)	Latitude N (D/M/S)	Longitude W (D/M/S)
Sounding	**19** [21]	21/29/44.78	157/50/01.85
Sounding	**19**	21/29/42.56	157/50/00.77
Sounding	**17** [22]	21/28/34.45	157/50/2.088
Sounding	**18**	21/28/37.97	157/50/5.352
Sounding	**15**	21/28/36.20	157/50/9.852
Sounding	**5**	21/28/12.49	157/49/50.86
Sounding	**11**	21/28/15.27	157/49/53.16
Sounding	**15**	21/28/20.16	157/49/57.45

Table 1. Dangers to Navigation from NAVOCEANO Survey W00077.

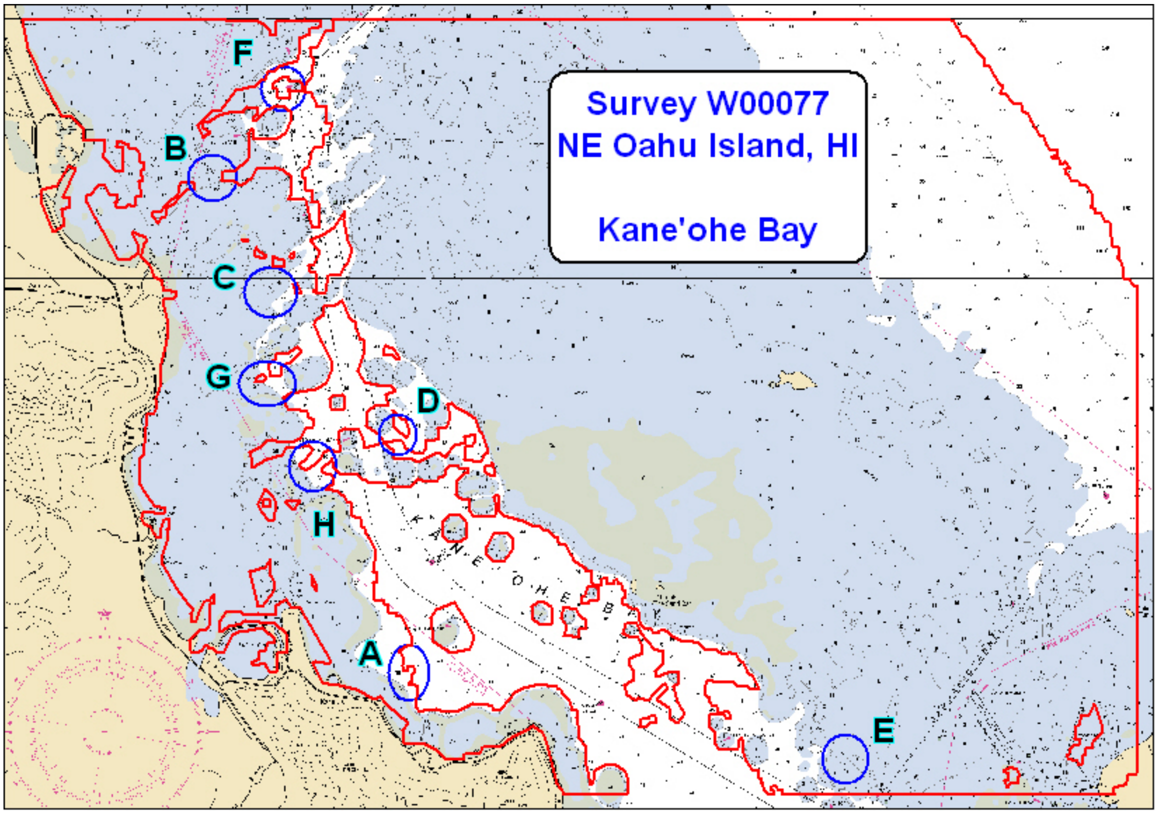

Figure 20. Image depicting the survey outline and location of noted features for survey W00077; Chart 19359 is displayed in the background.

SURVEY W00078

Affected Charts

Chart	Scale	Edition	Date	Units
19357	1:80,000	23rd	Jul 1, 2006	Fathoms
19359	1:15,000	11th	Oct 1, 2003	Feet

Reported Obstructions

No Obstructions were reported by NAVOCEANO for this survey. [23]

Charted Features

A. A PD charted wreck located approximately at 21°27'43" N, 157°45'38" W was reported as not seen in the data by NAVOCEANO. They report in the Chart Review (Appendix C, Hawaii Lidar ROS) that there is no local knowledge of the wreck and due to the surf and seas in the area, its existence is doubtful. It is recommended that the charted wreck be retained and added to the AWOIS database for future investigation or disproval. [24]

New Features

B. A new reef was visible in the surveyed data located southwest of Pyramid Rock on the north side of Mokapu Peninsula. The north and south extents of the reef are 21°27'42.19" N, 157°45'46.82" W and 21°27'27.04" N, 157°45'24.38" W. High points of the reef were surveyed at +/- 3 feet relative to MLLW (Figure 21). Charted (19359) depths in the vicinity of the new reef range between 7 and 16 feet. It is recommended by the reviewer that the surveyed reef be applied to the chart, superseding the charted depths.[25]

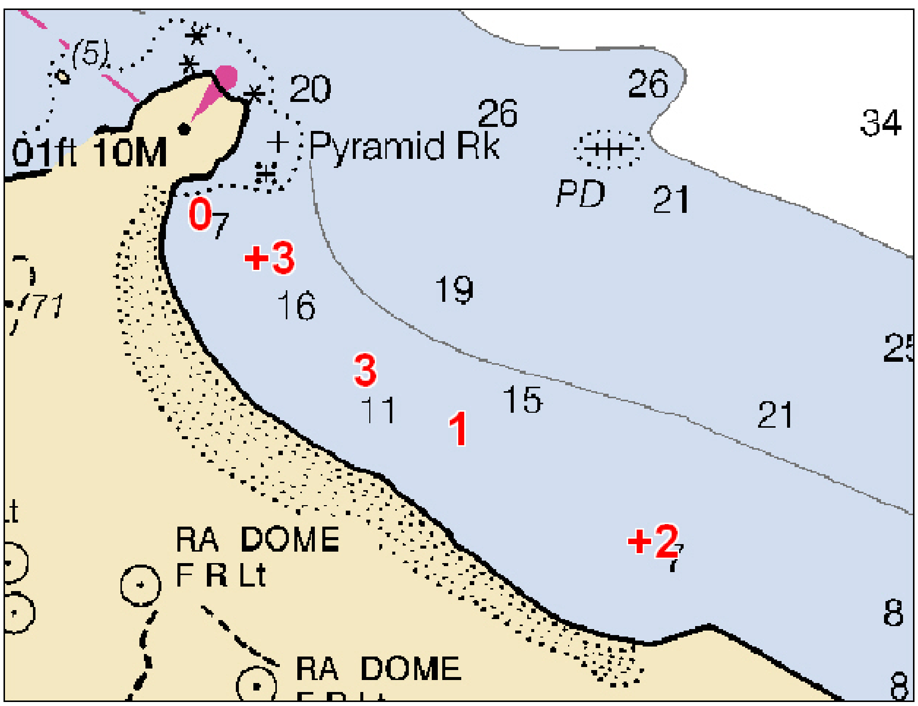

Figure 21. Lidar depths (feet) are shown in red to display the extents of the new reef. Depths preceded by a plus sign are above MLLW. Chart 19359 is displayed in the background.

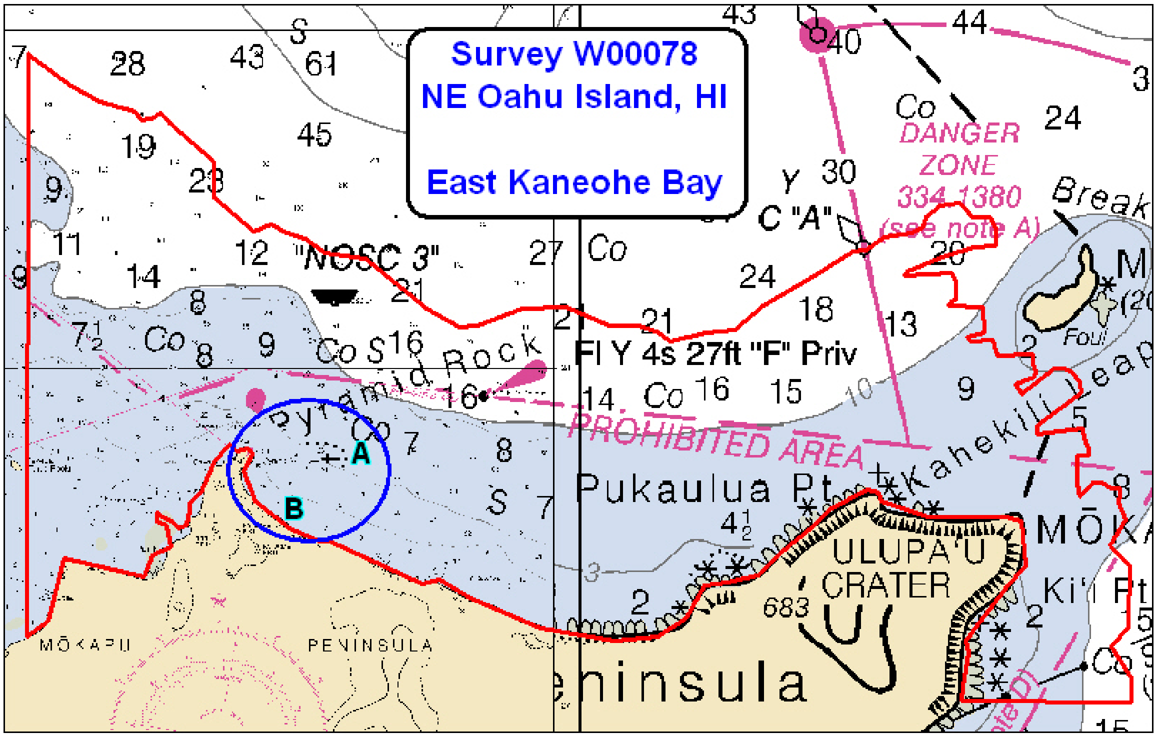

Figure 22. Image depicting the survey outline and location of noted features for survey W00078; Charts 19359 and 19357 are displayed in the background.

Revisions compiled during office processing by the cartographer

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[1] In the area of these gaps, sounding and features should be retained as charted.
[2] Attached to this report.
[3] Chart 19357, 23rd edition and chart 19359, 11th edition were used for comparison with the present surveys.
[4] Concur with clarification, LIDAR does not meet NOAA HSSDM object detection requirements. Charted shoal soundings have not been superseded by LIDAR data.
[5] Attached to this survey.
[6] Do not concur, chart according to these surveys. It is recommended that a caution note be charted in the vicinity of these surveys warning the mariner that local knowledge is advised when transiting these areas.
[7] Concur with clarification, retain islet and 1 3/4 Rk as charted
[8] Concur
[9] Do not concur, see endnote 4.
[10] Concur
[11] Do not concur, see endnote 4
[12] Do not concur, see end note 4
[13] Concur
[14] Concur, do not chart these features, these two soundings have been annotated in ink by hand on the smooth sheet..
[15] Concur
[16] Concur
[17] Concur
[18] Concur
[19] Concur
[20] The danger to navigation letter is attached to this report.
[21] Corrected depths for charting
[22] Picked 16 at latitude 21/28/35.4N, longitude 157/50/3.9W
[23] Concur
[24] Concur
[25] Concur

Subject: Re: DTONs for W00077
From: don haines <Don.Haines@noaa.gov>
Date: Fri, 08 Dec 2006 13:20:27 -0800
To: don haines <Don.Haines@noaa.gov>
CC: Russ Davies <Russ.Davies@noaa.gov>, Gary Nelson <Gary.Nelson@noaa.gov>, Bruce Olmstead <Bruce.Olmstead@noaa.gov>, "mcd.dton" <mcd.dton@noaa.gov>, Doug Baird <Doug.Baird@noaa.gov>, Brooke McMahon <brooke.mcmahon@noaa.gov>, abigail higgins <Abigail.Higgins@noaa.gov>, Chris Libeau <Chris.Libeau@noaa.gov>, Bonnie Johnston <Bonnie.Johnston@noaa.gov>

attachment added...

don haines wrote:

> Attached are 8 DTONs for W00077, a Navy LIDAR of Kaneohe Bay, Oahu, Hawaii. These DTONs were discovered during office review of the data and are approved for dissenimation.
>
> Attachment-W00077_DTON.doc

W00077_DTON.doc	**Content-Type:**	application/msword
	Content-Encoding:	base64

W00077 Danger to Navigation Report

Pacific Hydrographic Branch Danger to Navigation Report

Hydrographic Survey Registry Number: **W00077**

Survey Title: **State: Hawaii**
Locality: Northeast Oahu Island
Sub-locality: Kaneohe Bay

Survey Dates: LIDAR – August 1 – December 20, 2000

LIDAR depths are reduced to Mean Lower Low Water using verified tides.

Positions are based on the WGS84 horizontal datum.

CHARTS AFFECTED:

Chart	Scale	Edition	Date
19359	1:15,000	11th	Oct, 2003
19357	1:80,000	23rd	Jul, 2006

DANGERS:

Feature	Depth (ft)	Latitude N (D/M/S)	Longitude W (D/M/S)
Sounding	**20**	21/29/44.78	157/50/01.85
Sounding	**19**	21/29/42.56	157/50/00.77
Sounding	**17**	21/28/34.45	157/50/2.088
Sounding	**18**	21/28/37.97	157/50/5.352
Sounding	**15**	21/28/36.20	157/50/9.852
Sounding	**5**	21/28/12.49	157/49/50.86
Sounding	**11**	21/28/15.27	157/49/53.16
Sounding	**16**	21/28/20.16	157/49/57.45

COMMENTS:

Eight dangers to navigation (DTON) were found during review of survey W00077 submitted by the U.S. Naval Oceanographic Office.

W00077 Danger to Navigation Report

The DTONs are located in Kaneohe Bay, along side a charted (19359) channel that transects a coral reef. They represent least depth soundings found in secondary channels and small harbors located to the west of the channel.

Questions concerning this report should be directed to the Chief, Pacific Hydrographic Branch at *(206) 526-6835.*

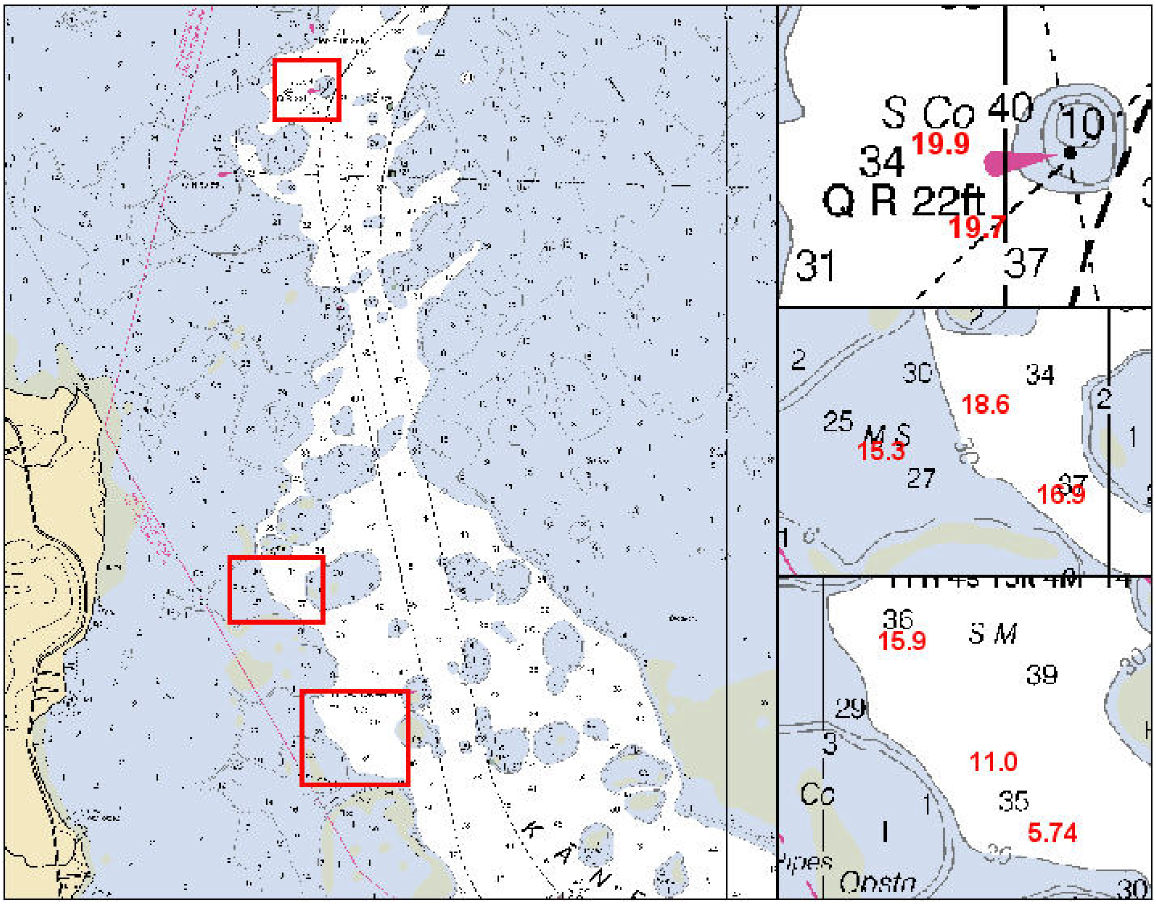

Figure 1. A chartlet depicting the location of the dangers to navigation reported for Survey W00077 with NOAA Chart 19359 as the background. Soundings are in feet.

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.

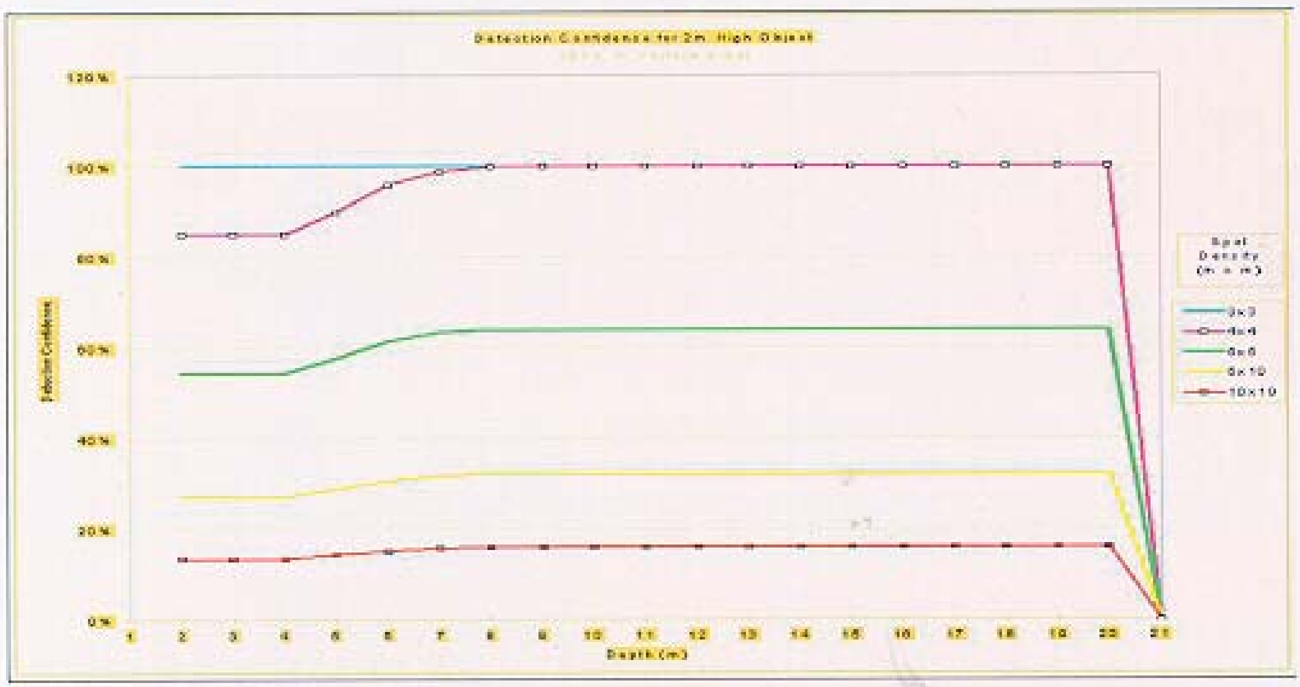
Subsequent testing of the follow-on CHARTS system, utilizing the same operating principles and algorithms and a lower power laser, at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths 5 – 30 meters. Based on these actual tests the LIDAR system meets IHO order 1 target detection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

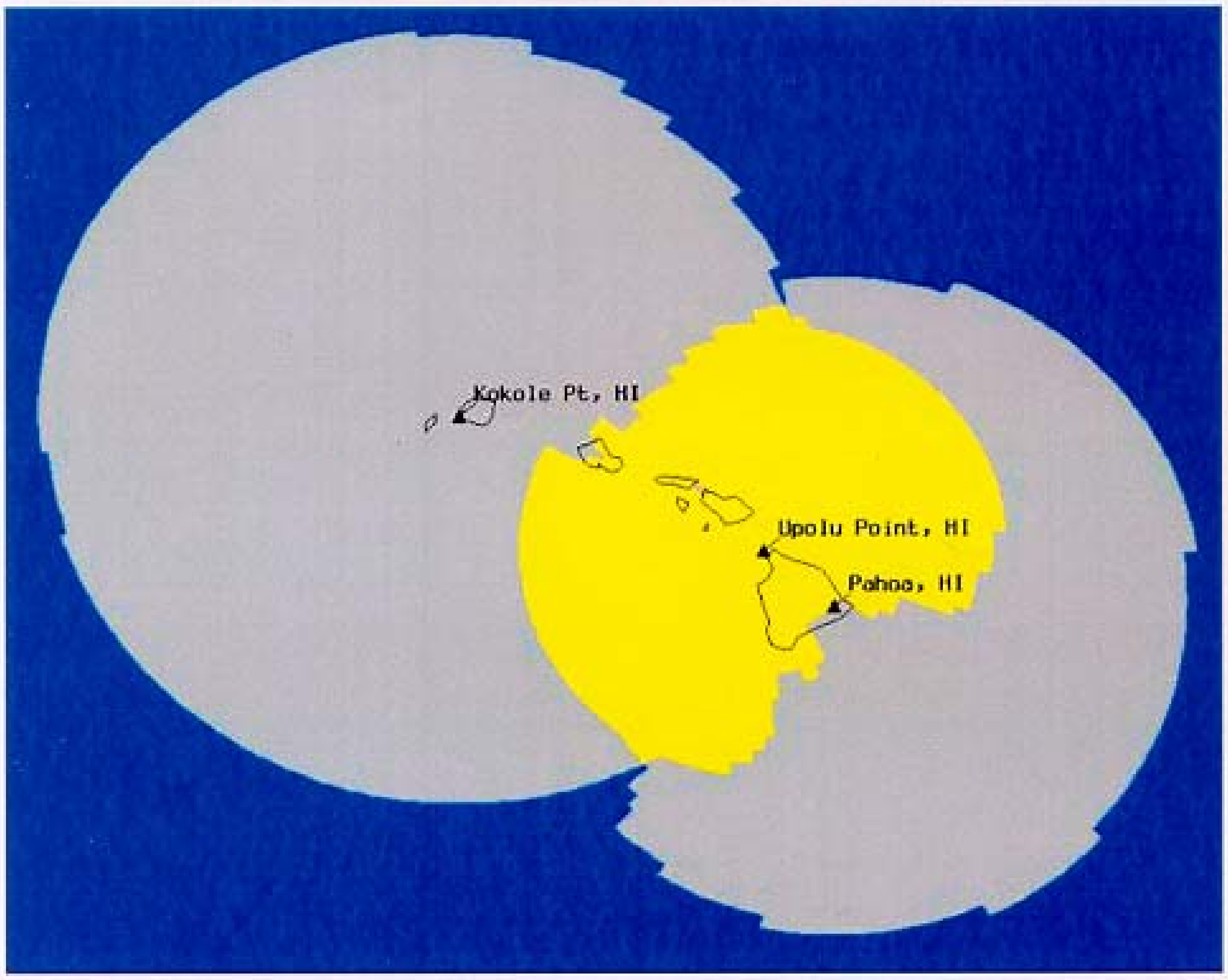
2.6 **Datum Shifts**. No datum shifts were applied.

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.

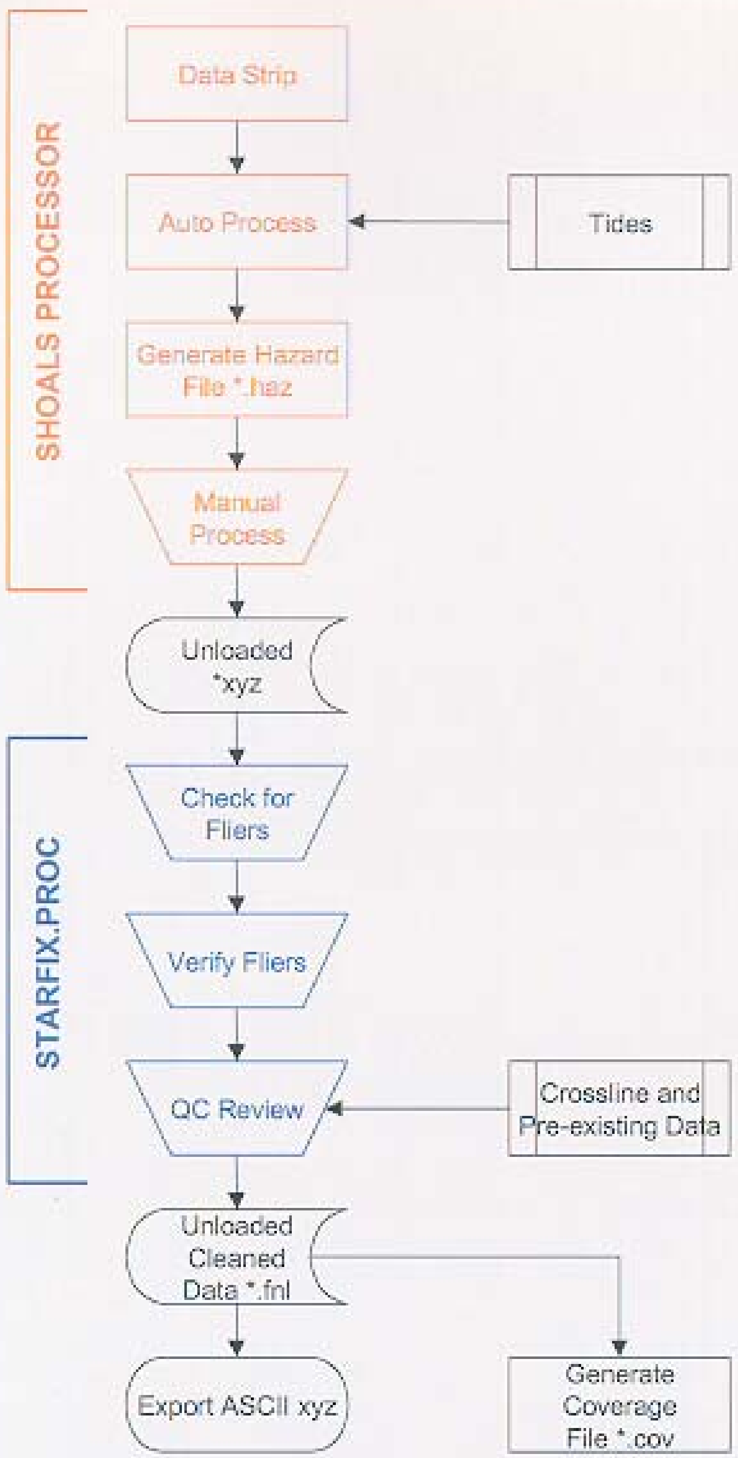


Figure 6: Data Processing Flow

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.

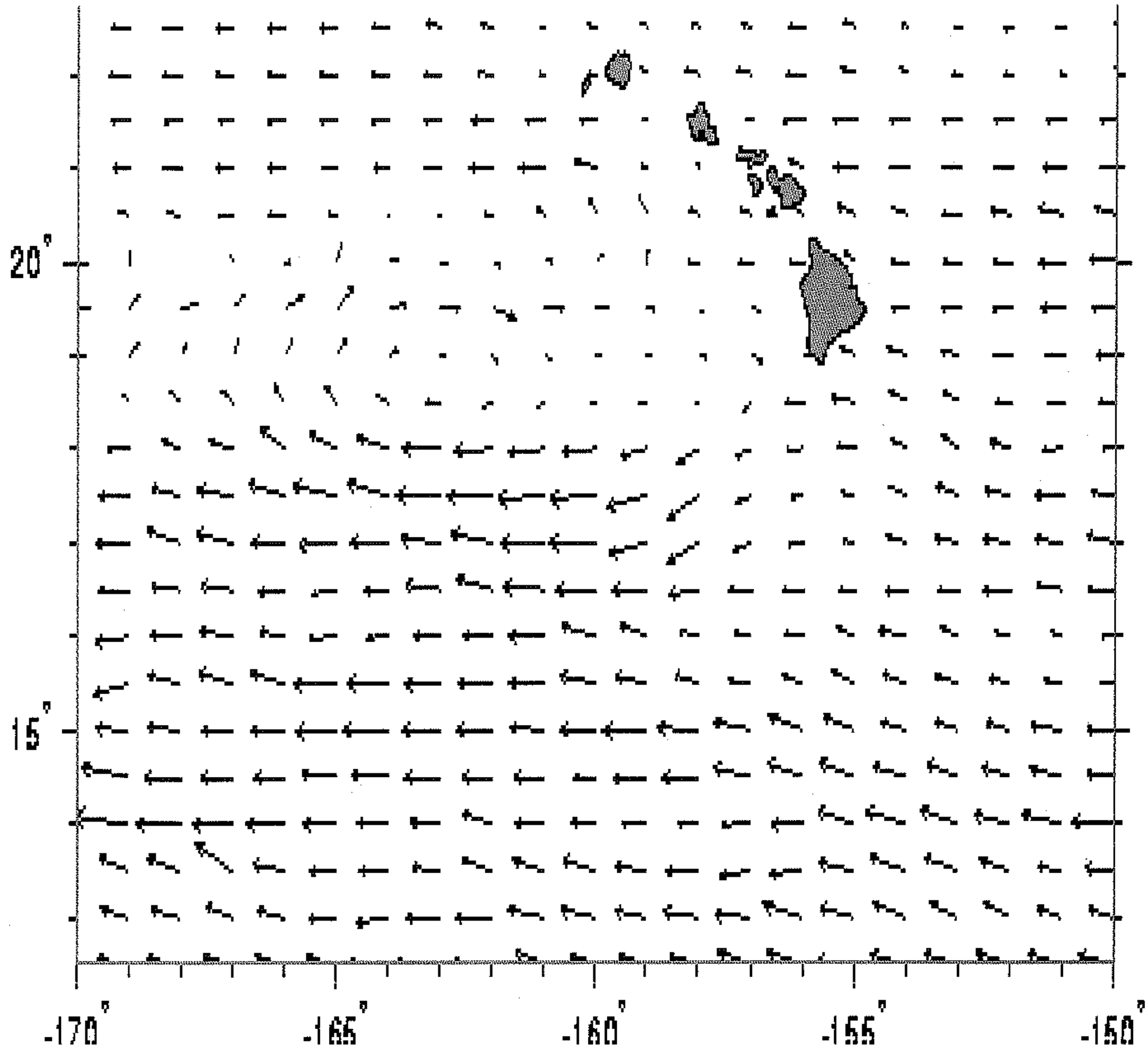


Figure 2. Large-scale ocean circulation around the Hawaiian Islands.

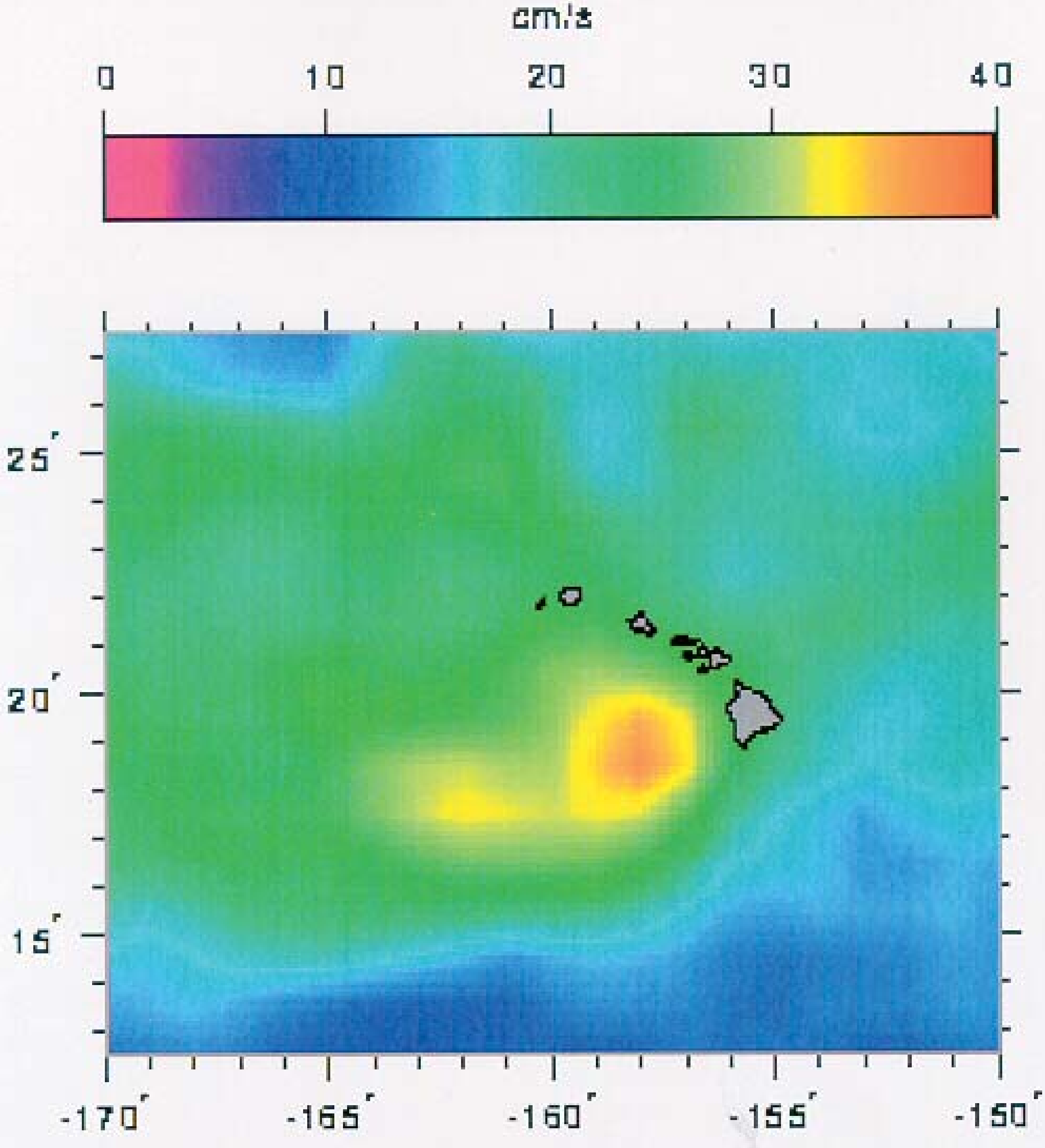


Figure 3. Large-scale ocean circulation variability around Hawaii indicates numerous eddies and swirls which obliterate slower average circulation.

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.

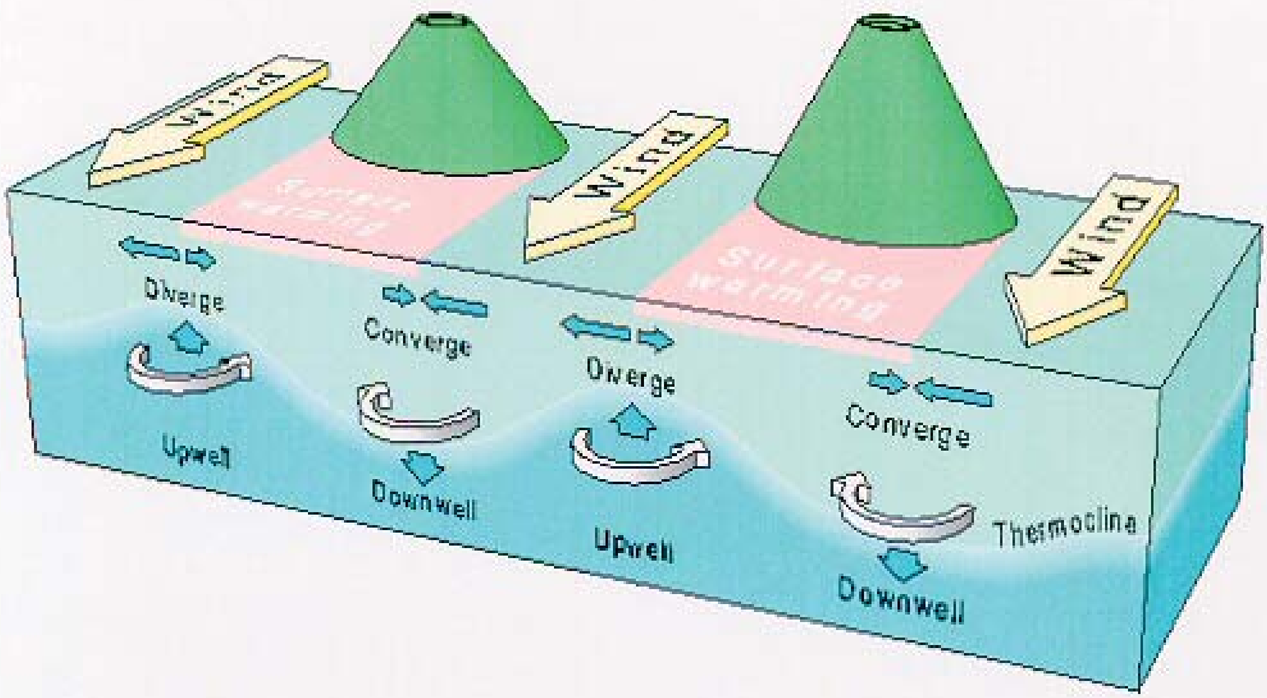


Figure 4. Regional current formation due to the modifying effect of land masses on large-scale circulation.

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.

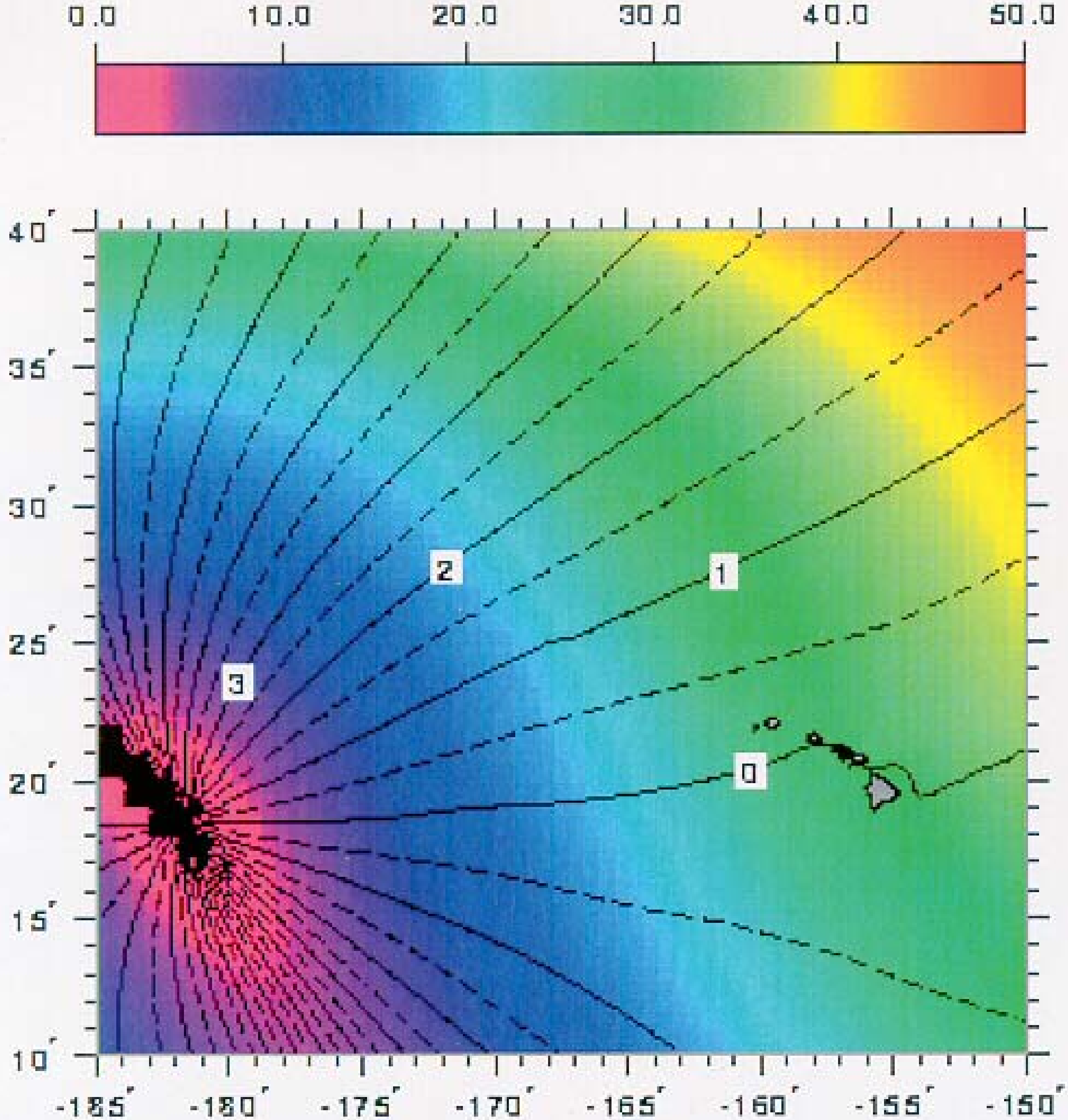


Figure 5. Response of the North Pacific to the longest duration tidal component (23h 56m) and the effect of the Hawaiian land mass.

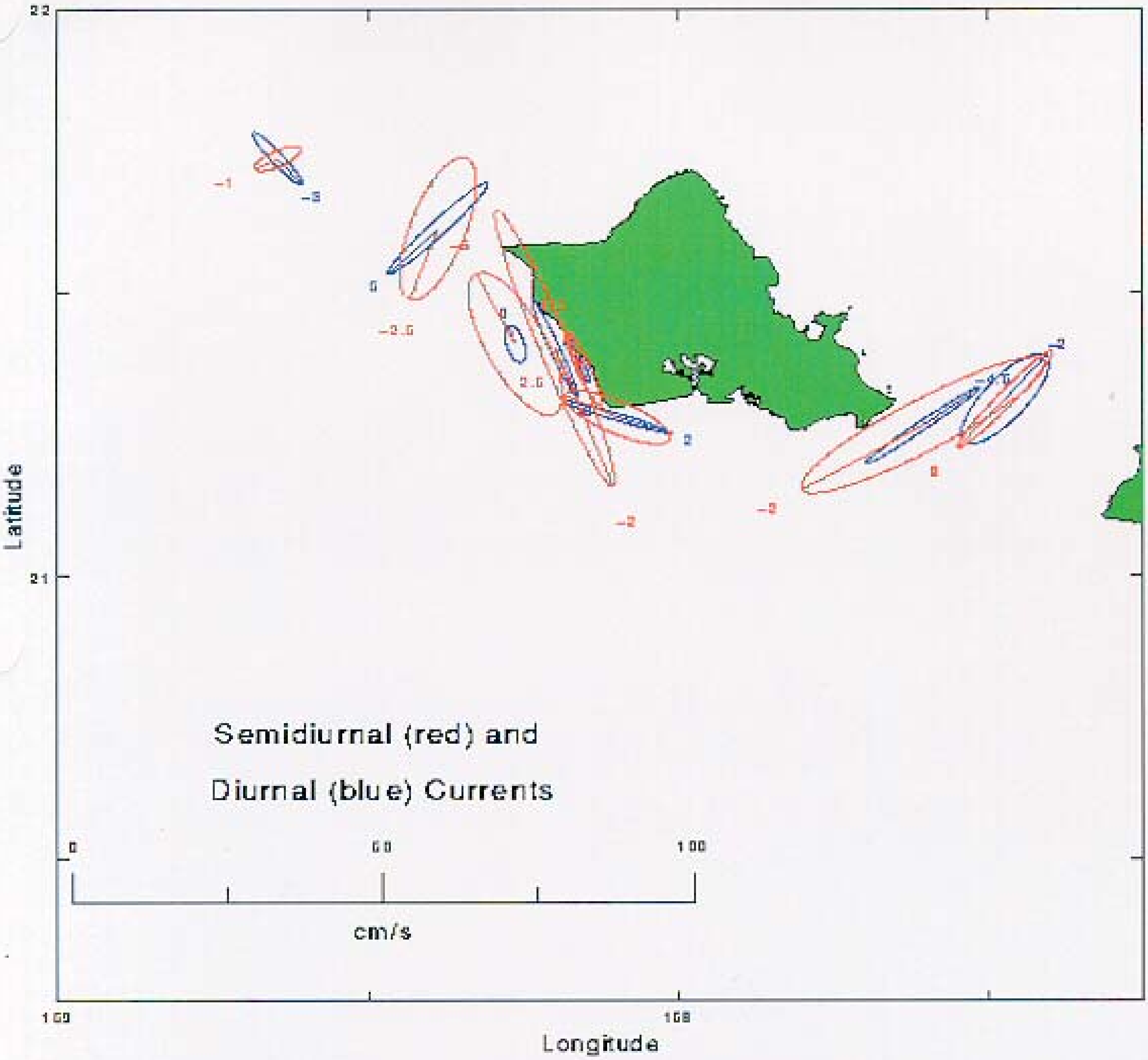


Figure 6a. Representative tidal current flow around the Hawaiian Islands. Diurnal and semi-diurnal tidal flows tend to be aligned with the shoreline. Strong eddies are often found around points and headlands.

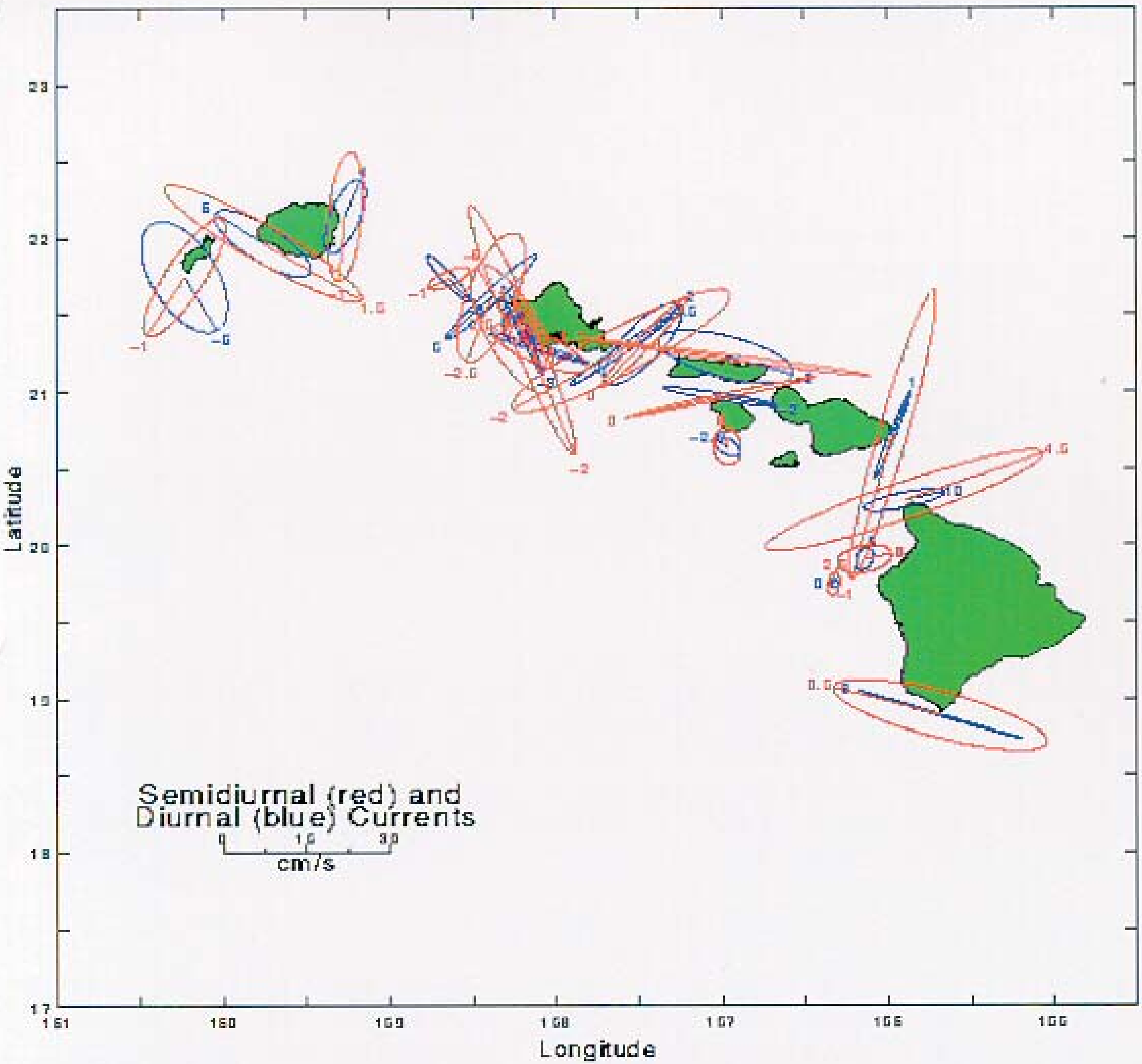


Figure 6b. Representative tidal current flow around the Hawaiian Islands. Diurnal and semi-diurnal tidal flows tend to be aligned with the shoreline. Strong eddies are often found around points and headlands.

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.

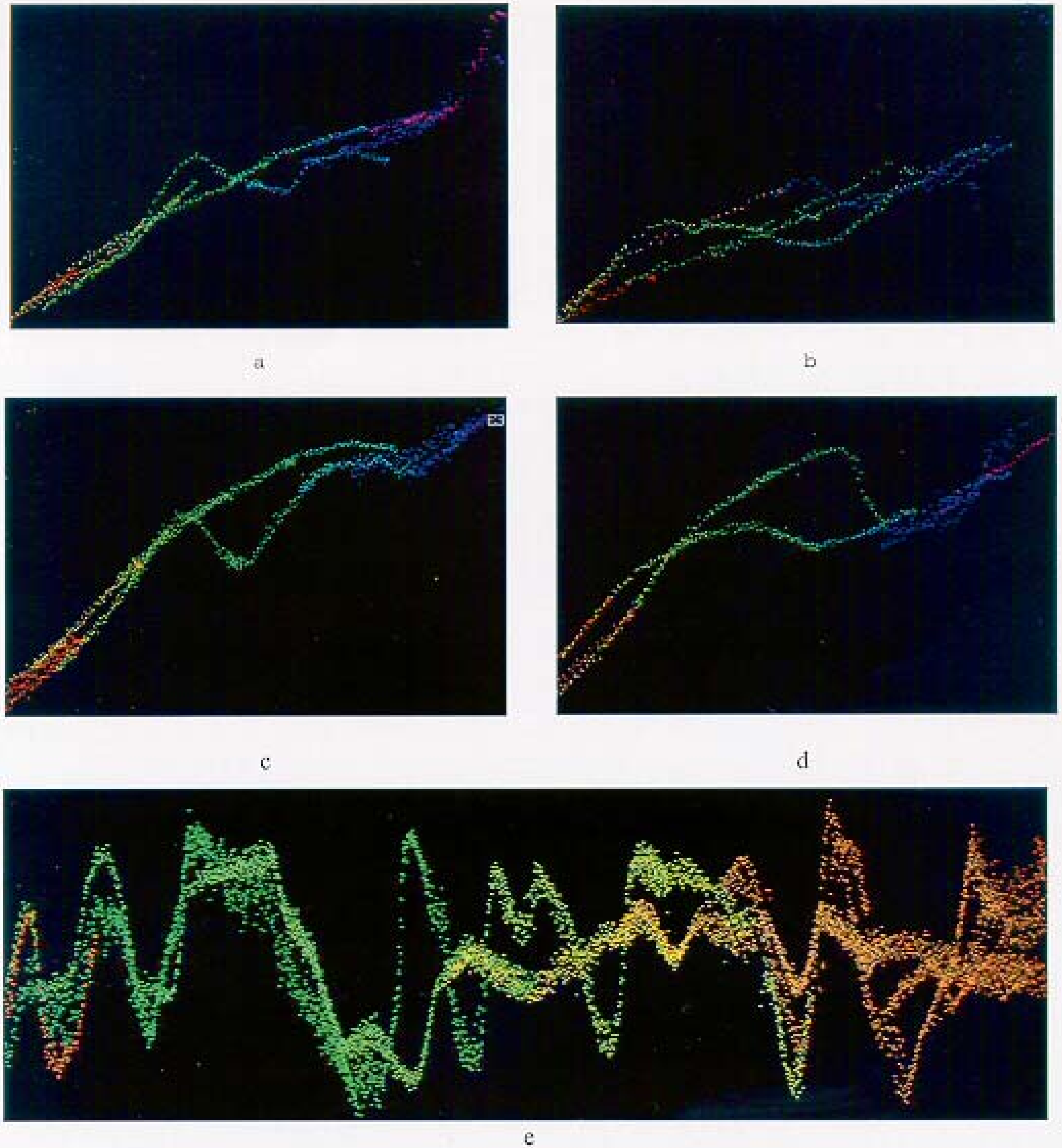


Figure 8. Series of near shore seabed to beach profiles from the area of Barking Sands, Kauai depicted in Figure 7. Insets a-d are west to east cross sections. Inset e is from the north east to southwest along the full length of the near shore.

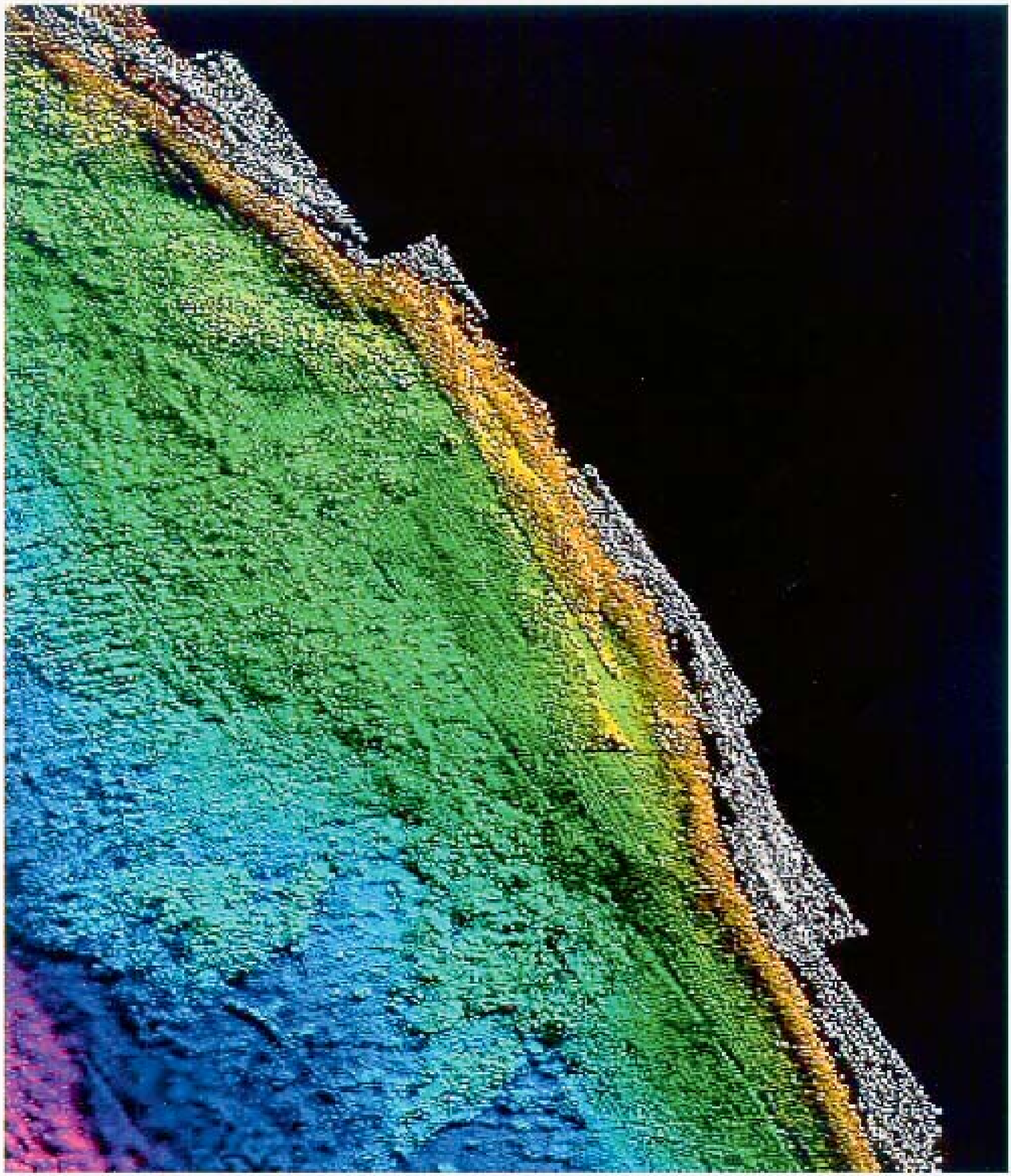
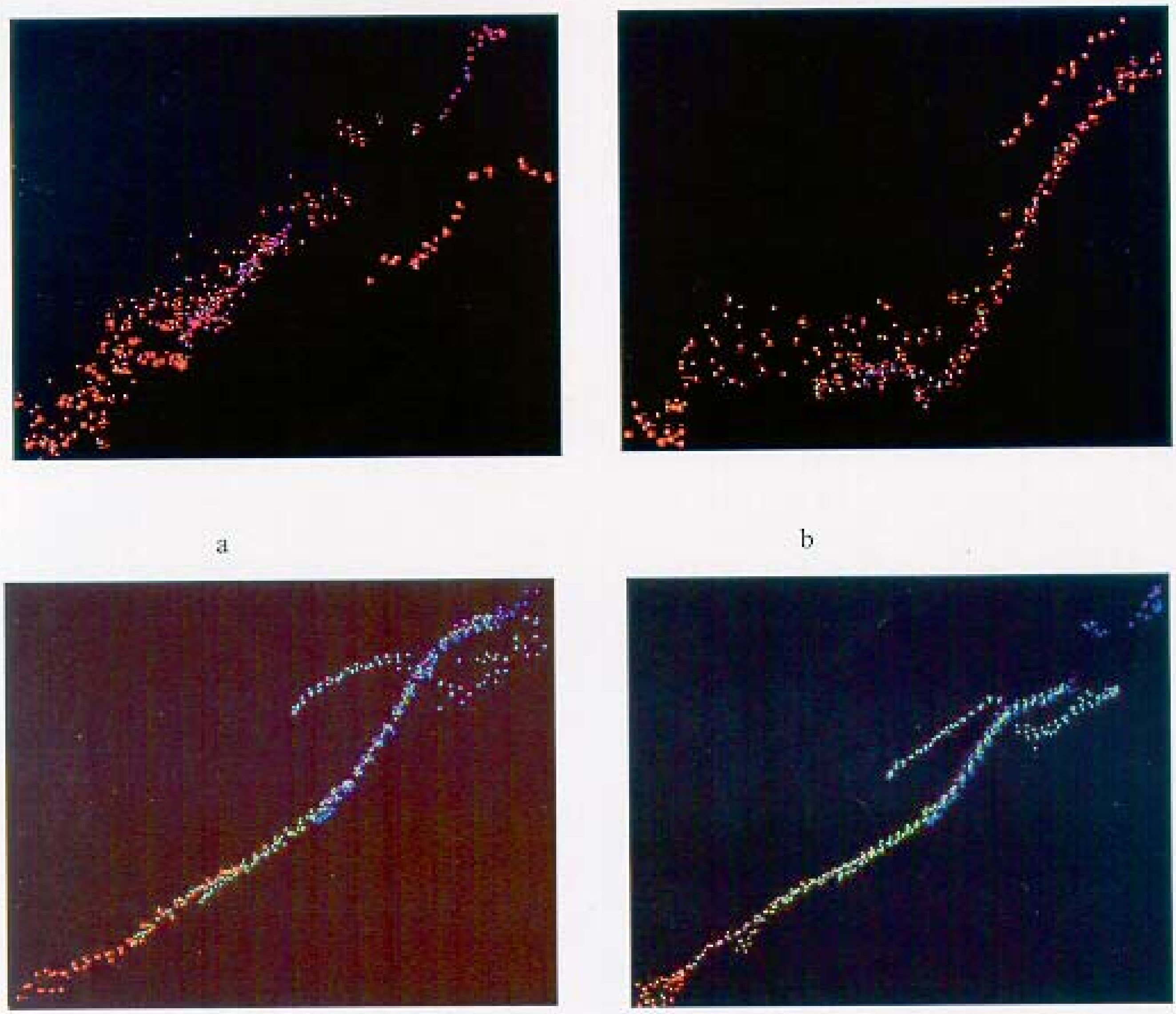


Figure 9. Majors Bay (Waiokapua Bay) Kauai showing near the shore seabed.



a b c d

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 $(\Sigma(a^2 + \ldots . l^2)^{1/2})$	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.

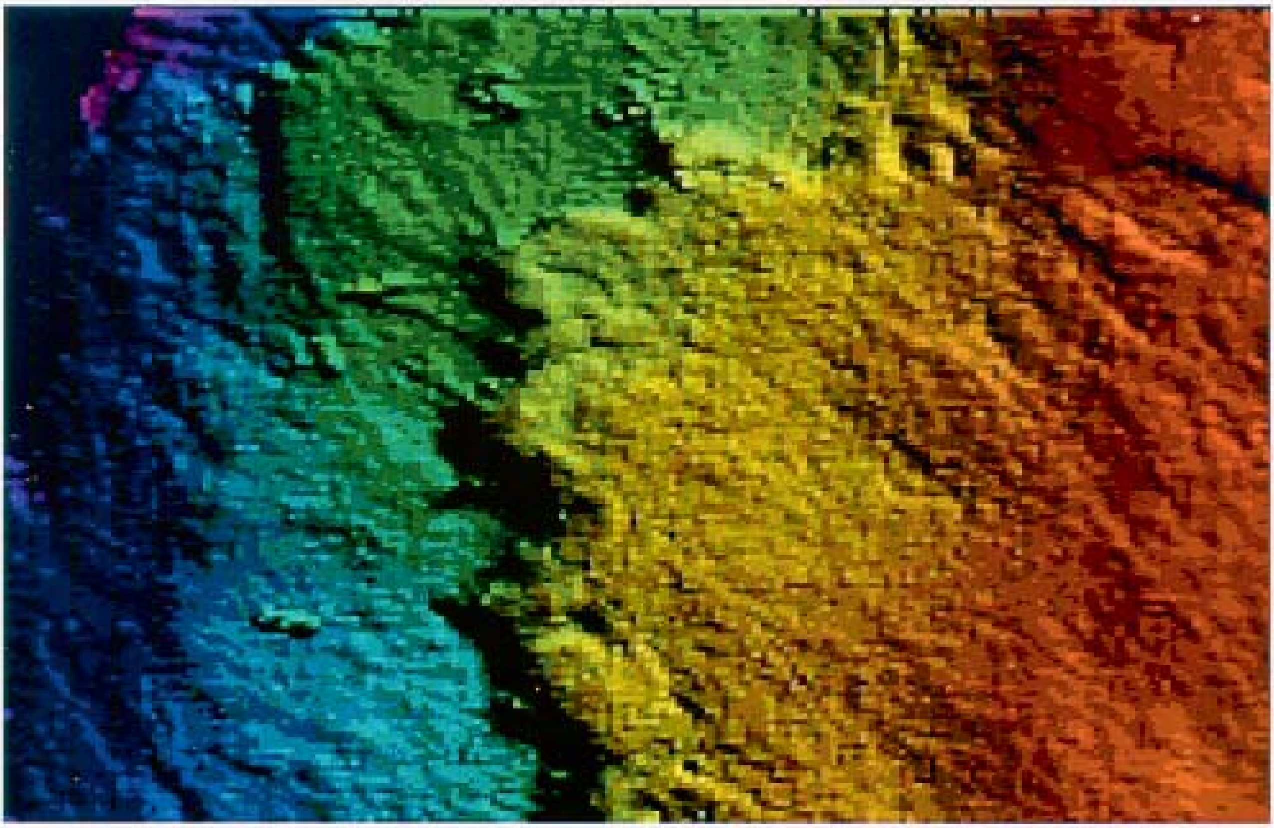


Figure 11. Wrecks and wreckage off Oahu's leeward west coast between Maili Pt. and Waianaae. Charted as fish haven and wrecks. One of these is believed to be the "Mali", a popular dive spot.

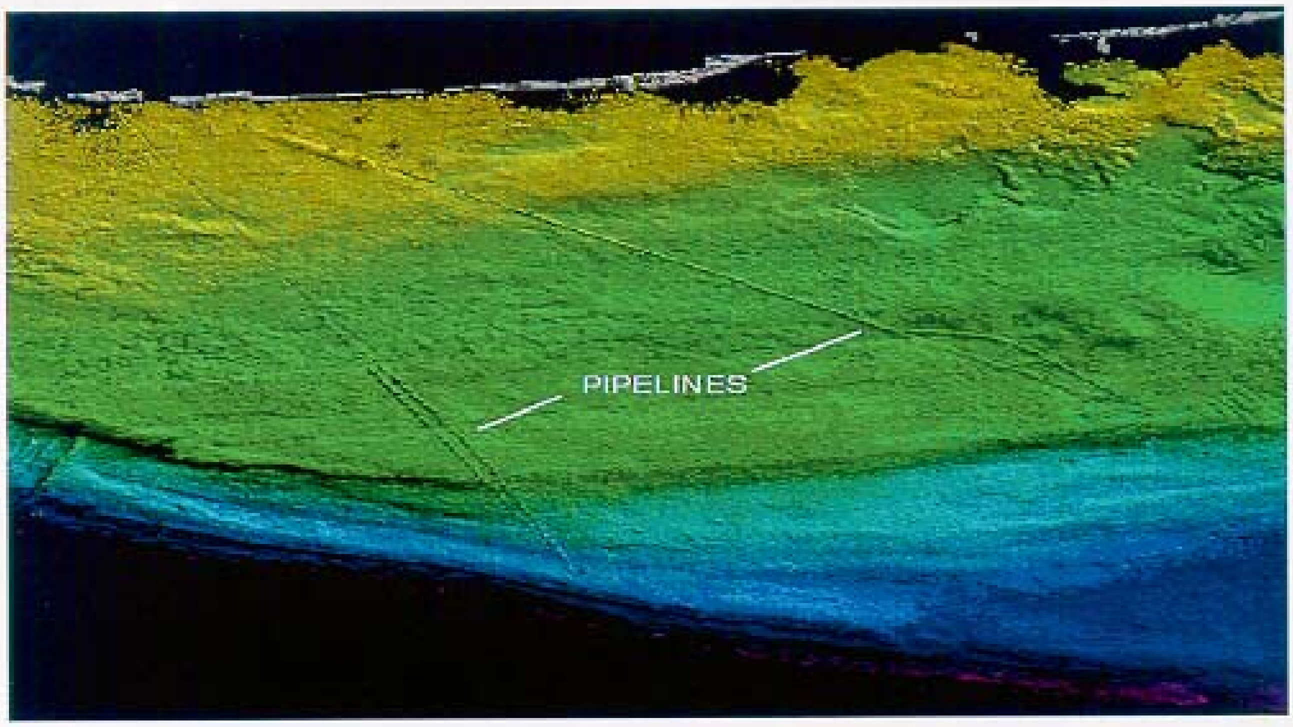


Figure 12. Offshore oil terminal pipelines off Barbers Pt. Oahu.

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

APPROVAL SHEET
W00071 – W00078

Evaluated by:

Bonnie Johnston
Physical Scientist (Hydrographer)
Pacific Hydrographic Branch

Review by:

LTJG Abigail Higgins
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:

Russ Davies
Cartographer
Pacific Hydrographic Branch

Reviewed by:

Bruce Olmstead
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.

Gary C. Nelson for
Donald W. Haines
CDR, NOAA
Chief, Pacific Hydrographic Branch

Digitally signed by Michael Riddle
Reason: AWOIS & SURF signed for Rachel Soraruf
Location: Operations Branch N/CS31
Date: 2007.04.20 15:02:59 -04'00'

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. W00071 - W00078

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
19357	1/18/07	Russ Davies	Full ~~Part~~ Before After Marine Center Approval Signed Via Full application
			Drawing No. of soundings, curves and features from
			the smooth sheet.
19359	1/9/07	Russ Davies	Full ~~Part~~ Before After Marine Center Approval Signed Via Full application
			Drawing No. of 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
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SUPERSEDES C&GS FORM 8352 WHICH MAY BE USED.