# Bathymetric Atlas of the Main Hawaiian Islands[1]

## *Information for Ecosystem Assessment and Monitoring*

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## PURPOSE OF THE ATLAS

The maps presented in this atlas show where bathymetric data have been collected during various shipboard and aero surveys around the Main Hawaiian Islands (MHI) as of 2004. Metadata for the bathymetric surveys, including the location information, were compiled by the Coral Reef Ecosystem Division (CRED) of the Pacific Islands Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA). These metadata are intended primarily as a planning tool for future ecosystem survey and assessment missions by NOAA and its partners. They also serve as a guide to the quality and usefulness of the bathymetric data for a variety of applications including benthic habitat analyses, reserves and sanctuaries designations, fisheries management, and charting.

The data are provisional because they come from a number of different sources and instrument types, and are of varying accuracy and resolution. They have been edited to remove obvious errors; however, data artifacts may still be present. All public bathymetric data known to the authors are included in this document, but other data may exist that are not presented here. This paper copy of the atlas is considered a static reference. The electronic version of the atlas will be a dynamic product, and will be updated as further bathymetric and benthic habitat mapping data become available in the MHI. The URL for the dynamic atlas is http://www.pifsc.noaa.gov/cred/himap/. Readers with knowledge of additional data for the atlas are urged to provide such information to the authors (send e-mail to Michael.Parke @noaa.gov).

These maps are not to be used for navigation.

## DATA SOURCES

The data described in this atlas originate from several sources and were collected using a variety of methods including sidescan sonar, airborne LIDAR, multibeam sonar, depth sounders, lead lines, and other methods.

**GLORIA** The original data were collected as part of the USGS EEZ-SCAN program, which was a cooperative mapping program between the US Geological Survey and the Institute of Oceanographic Sciences of the United Kingdom (UK). The survey areas included the entire US Exclusive Economic Zone (EEZ) of the East Coast, Gulf of Mexico, Puerto Rico, West Coast, Bering Sea, Aleutian Islands, Gulf of Alaska, Hawaiian Ridge, US Virgin Islands, Johnston Island, Kingman Reef and Palmyra Atoll. The GLORIA system is a long-range sidescan sonar system developed at the Institute of Oceanographic Sciences of the UK. The system was specifically designed to map the morphology and texture of seafloor features in the deep ocean. Acoustic images of the seafloor are formed by transmitting sound pulses toward the seafloor to either side of the towed vehicle and recording the backscattered sound waves. Two arrays of transducers mounted back to back are inside the towed vehicle. The arrays can emit pulses of energy at 20-, 30-, or 40-s intervals and, between transmissions, record the echoes from as far away as 30 km. The acoustic data are sequentially obtained from

narrow strips of seafloor, and thus successive transmissions over adjacent strips of seafloor are used to construct an image line-by-line. The maximum swath width largely depends on the prevailing acoustic propagation conditions. For GLORIA, the swath width can be as great as 30 km on each side of the track. Under normal conditions, however, it is usually somewhat less. If acoustic conditions are unfavorable and the water depth is less than about 1,500 m, then the range may be less than 10 km. The maximum range for the surveys is 22.5 km to either side of the ship's track.

Groome, M.G., C.E. Gutmacher, and A.J. Stevenson (1997). *Atlas of GLORIA sidescan-sonar imagery of the Exclusive Economic Zone of the United States: EEZ-View*. U.S. Geol. Surv. Open-File Rep. 97-540. http://pubs.usgs.gov/of/of97-540/

Gardner, J.V., M.E. Field, and D.C. Twichell, eds. (1996). *Geology of the United States Seafloor: The view from GLORIA*. Cambridge, UK: Cambridge Univ. Press.

**SHOALS** These data originated from the US Army Engineer Joint Airborne LIDAR Bathymetry Technical Center of Expertise (JALBCTX), and were collected by the SHOALS (Scanning Hydrographic Operational Airborne LIDAR Survey) system. The SHOALS system consists of an airborne laser transmitter/receiver capable of measuring 400 soundings per second. The system operates from a deHavilland DHC-6 Twin Otter flying at altitudes between 200 and 400 meters with a ground speed of about 100 knots. The SHOALS system also includes a ground-based data processing system for calculating accurate horizontal position and water depth. LIDAR is an acronym for Light Detection And Ranging. 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 backscattered 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 the radiance of bottom material, incident sun angle and intensity, and the type and quantity of organics or sediments in the water column. As a rule-of-thumb, the SHOALS system should be capable of sensing bottom to depths equal to two or three times the Secchi depth. SHOALS has demonstrated capabilities that meet US Army Corps of Engineers Hydrographic Survey accuracy requirements for Class 1 surveys and the International Hydrographic Organization nautical charting standards for Order 1.

The Kauai and Maui coastline survey was conducted from February to April 1999. The Oahu coastline survey was conducted from March to April 1999, and the Molokai and Lanai coastline survey was conducted in November 2000. The projection is geographic, the units are decimal degrees, and Datum is WGS84. The depth is in meters from Mean Lower Low Water. The horizontal positional accuracy is +/- 3 meters (1 sigma), and the vertical positional accuracy is +/- 15 cm (1 sigma).

**NOS SingleBeam** The original data sets were extracted from the National Ocean Survey (NOS) GEODAS database CD ROMs, available from the National Geophysical Data Center (NGDC).

Multiple source files were involved. NOS bathymetric soundings data sets collected before 1984 (as long ago as 1930) using a variety of methods, including depth finders, lead lines, etc., were consolidated into single file. The data within the Main Hawaiian Islands were in Old Hawaiian projections and NAD27 projections, and are transformed from the reference of NAD27 to NAD83 datum. The original soundings depths were recorded in fathoms, but are now in meters. The projection is geographic, the units are decimal degrees, and the horizontal positioning accuracy is unknown.

**NOS SeaBeam** The original data sets were extracted from the NOS GEODAS database CD ROMs, available from the National Geophysical Data Center (NGDC). The source file is a subset of SEABEAM files from the NOS bathymetric soundings. SEABEAM general instrument is 16 beams, 12 kHz. Five beams of actual data were extracted from each return. The sampling rate varies from 10 to 30 seconds along the track. A listing of the NOS reference numbers includes:

HYD9303022076, HYD9303022077, HYD9303022078, HYD9303022079, HYD9303022081, HYD9303022082, HYD9303022083, HYD9303022084, HYD9303022085, HYD9303022086, HYD9303022087, HYD9303022088, HYD9303022089, HYD9303022090, HYD9303022091, HYD9303022092, HYD9303022093, HYD9303022094, HYD9303022095, HYD9303032059, HYD9303032060, HYD9303032061, HYD9303032062.

The projection is geographic, the units are decimal degrees, and Datum is North American Datum 1983. The soundings are in meters from Mean Lower Low Water, and the horizontal positioning accuracy is variable, but assumed to be within 20 meters for GPS and within 50 meters for LoranC.

**JAMSTEC SeaBeam** The original data were collected from the two cruises to Hawaii with a *SeaBeam 2112* multibeam seafloor mapping sonar system during a collaborative research program between scientists from Japan and U.S. institutions that was funded by the Japan Marine Science and Technology Center (JAMSTEC) in 1998 and 1999. Because identical *SeaBeam 2112* sonar mapping systems are mounted on duplicate hulls of the sister ships *Kairei* and *Yokosuka*, merging their data is relatively simple and seamless. Approximately 115,000-km$^2$ was surveyed in the southeastern Hawaiian Islands.

SeaBeam 2112 is a multibeam survey system built by L-3 Communications Sea Beam Instruments, Inc. for producing wide-swath contour maps and acoustic backscatter images of the seafloor. The sonar beams, with a narrow 2° beam angle fore/aft, are projected as a swath and travel through the water column to the sea floor and are reflected off the bottom. The horizontal resolution of the bathymetry data depends on depth and ship speed. The accuracy of the depth measurement is specified as 0.5% of the depth or better. Data quality also depends greatly on the sea state. The typical swath width for this system around the Hawaiian Ridge (3000-5000 m water depth) is 10 km, or 2-3 times the depth.

Smith, J.R., K. Satake, K. Suyehiro (2002). Deepwater multibeam sonar surveys along the southeastern Hawaiian Ridge: guide to the CD-ROM, in Takahashi, E., P. Lipman, M. Garcia, J. Naka and S. Aramaki (eds.)

*Hawaiian Volcanoes: Deep Underwater Perspectives. Geophysical Monograph, 128*, 3-9.

**M/V Ocean Alert** In March 1998 the Monterey Bay Aquarium Research Institute (MBARI) and the United States Geological Survey (Dartnell and Gardner, 1999; MBARI 2000) completed surveys of selected areas offshore of the Hawaiian Islands using the same survey ship -- the *M/V Ocean Alert*, and the same sonar equipment -- Simrad EM300 multibeam system to collect bathymetry and backscatter data.

Dartnell, P. and J.V. Gardner (1999). *Sea-Floor Images and Data from Multibeam Surveys in San Francisco Bay, Southern California, Hawaii, the Gulf of Mexico, and Lake Tahoe, California-Nevada,* [CD-ROM]. Washington, D.C.: U.S. Geological Survey (Digital Data Series, DDS-55.Version 1.0).

MBARI (2000). *MBARI Hawaii Multibeam Survey, Version 1*. Digital Data Series No. 2 [CD-ROM]. Moss Landing, California: Monterey Bay Aquarium Research Institute.

**R/V *Ka'imikai-o-Kanaloa (K-O-K)*** The original data were from Dr. Christopher Kelley and Dr. John Smith of the Hawaii Undersea Research Laboratory (HURL) in 2001 and 2002 *Kaimikai-o-Kanaloa* surveys inside the Kahoolawe Island Reserve. A SeaBeam 210 multibeam sonar bathymetric mapping system is installed aboard K-O-K. SeaBeam is capable of acoustically charting the seafloor peaks and valleys with complete high resolution coverage to depths of 11,000 meters (nearly 7 miles). A near real-time contour plot for the current swath is produced, and the digital data are recorded for later post-processing on the shipboard Silicon Graphics UNIX workstations. Some applications of this technology are: hydrographic charting for hazards to navigation, search and recovery operations, submersible support, marine resource exploration, scientific research, and location of seamounts as natural fish aggregation devices.

**R/V KILO MOANA** The original data were from Dr. Bruce Appelgate and other researchers of the Hawaii Mapping Research Group (HMRG) in their test and research cruises of *R/V Kilo Moana*. The other data were from Dr. Christopher Kelley of HURL in his *CD-ROM product CREDITS AND MULTIBEAM DATA SOURCES FOR THE DLNR BOTTOMFISH GIS*, which collects

- 2002 *Kilo Moana* test cruise off Oahu and off Penguin Bank from Dr. Bruce Appelgate (HMRG), and Dr. Brian Taylor (UH).
- 2003 *Kilo Moana* survey in Maui County, off east Maui and off Penguin Bank and North Molokai from Dr. Christopher Kelley and Dr. John Smith (HURL).
- 2003 *Kilo Moana* survey off the Big Island of Hawaii from Dr. Michael Garcia of University of Hawaii (UH).
- 2003 *Kilo Moana* survey off south Maui from Dr. Eric Bergmanus (UH).
- Unreleased 2004 *Kilo Moana* student cruise survey data from Dr. Brian Taylor (UH).

R/V KILO MOANA has a large suite of modern mission electronic and sonar systems. Shipboard systems have been carefully designed to avoid interference with scientific sonar systems.

- Deep Water Multibeam Echo Sounder (Simrad EM120).
- Shallow Water Multibeam Echo Sounder (Simrad EM1002)

- Hydrographic Echo Sounder (Simrad EA 500)
- Acoustic Positioning System (Simrad HPR 418)

**R/V Thomas Thompson** The original data were from Dr. Christopher Kelley of HURL in his CD-ROM product *CREDITS AND MULTIBEAM DATA SOURCES FOR THE DLNR BOTTOMFISH GIS*, which includes data from the 2000 *R/V Thomas Thompson* survey in Maui County, off Kahoolawe, and off Niihau with a Kongsberg-Simrad EM300 Multibeam Echo Sounder system.

**SIO cruises** The following is a list of survey cruises within the Main Hawaiian Islands by three Scripps Institution of Oceanography (SIO) vessels equipped with multibeam sounding systems. The first six characters of the cruise ID indicate the abbreviated cruise name and leg number, and the last two characters are "WT" for the *R/V Thomas Washington* (16-beam SBClassic), "MV" for the *R/V Melville* ( 121-beam SB2000 system), and "RR" for the *R/V Roger Revelle* (151-beam SB2112 and now 191-beam EM120).

| CRUISE ID | CHIEF SCIENTIST | START DATE | START PORT | END DATE | END PORT |
|---|---|---|---|---|---|
| CRGN03WT | Cronan, David | 30-APR-87 | Papeete, Tahiti | 03-JUN-87 | Hilo, Hawaii |
| CRGN04WT | Lonsdale, Peter F. | 04-JUN-87 | Hilo, Hawaii | 07-JUN-87 | Honolulu, Hawaii |
| CRGN05WT | Hussong, Donald M. | 10-JUN-87 | Honolulu, Hawaii | 13-JUN-87 | Honolulu, Hawaii |
| MRTN01WT | Smith, Kenneth L | 24-MAR-84 | San Diego, Calif. | 27-APR-84 | Honolulu, Hawaii |
| MRTN04WT | Menard, Henry William (Deceased). | 14-JUL-84 | Kodiak, Alaska | 08-AUG-84 | Honolulu, Hawaii |
| RNDB01WT | Hildebrand, John A. | 29-APR-88 | San Diego, Calif. | 15-MAY-88 | Honolulu, Hawaii |
| RNDB02WT | Detrick, Rober S. Jr. | 18-MAY-88 | Honolulu, Hawaii | 10-JUN-88 | Honolulu, Hawaii |
| RNDB16WT | Guenther, Peter | 05-MAR-89 | Pago Pago, Samoa | 20-MAR-89 | Honolulu, Hawaii |
| RNDB18WT | Lonsdale, Peter F. | 03-MAY-89 | Honolulu, Hawaii | 30-MAY-89 | San Diego, Calif. |
| TUNE03WT | Talley, Lynne D. | 31-AUG-91 | Papeete, Tahiti | 01-OCT-91 | Honolulu, Hawaii |
| TUNE04WT | Constable, Steven | 06-OCT-91 | Honolulu, Hawaii | 16-OCT-91 | Honolulu, Hawaii |
| AVON05MV | Larson, Roger | 15-APR-99 | Apia, Western Samoa | 23-APR-99 | Honolulu, Hawaii |
| AVON06MV | Josep, Devorah | 28-APR-99 | Honolulu, Hawaii | 19-MAY-99 | Honolulu, Hawaii |
| AVON07MV | Drufffel, Ellen | 24-MAY-99 | Honolulu, Hawaii | 15-JUN-99 | Honolulu, Hawaii |
| AVON08MV | Colosi, John | 19-JUN-99 | Honolulu, Hawaii | 03-JUL-99 | Astoria, Oregon |
| COOK23MV | Measures, Christopher | 01-MAY-02 | Osaka, Japan | 06-JUN-02 | Honolulu, Hi |
| CNTL10RR | Luther, Douglas S | 10-JUN-03 | Honolulu, Hi | 15-JUN-03 | Honolulu, Hi |
| CNTL12RR | Porter, Michael B. | 24-JUN-03 | Honolulu, Hi | 09-JUL-03 | Honolulu, Hi |
| CNTL13RR | Michaels, Anthony F. | 14-JUL-03 | Honolulu, Hi | 22-AUG-03 | Honolulu, Hi |
| CNTL14RR | Miller, Stephen P. | 25-AUG-03 | Honolulu, Hi | 02-SEP-03 | Newport, Or |
| PANR06MV | Jeffrey Gee, Sio | 18-APR-98 | Papeete, Tahiti | 07-JUN-98 | Honolulu, Hawaii |
| PANR07MV | Ralph Stephen, Woods Hole | 12-JUN-98 | Honolulu, Hawaii | 20-JUN-98 | Honolulu, Hawaii |
| PANR08MV | Transit | 22-JUN-98 | Honolulu, Hawaii | 30-JUN-98 | San Diego, Ca |
| DRFT11RR | Transit | 08-MAR-02 | Pago Pago, American | 16-MAR-02 | Hilo, Honolulu |

| CRUISE ID | CHIEF SCIENTIST | START DATE | START PORT | END DATE | END PORT |
|---|---|---|---|---|---|
| | | | Samoa | | |
| DRFT12RR | Woody Sutherland | 18-MAR-02 | Hilo, Hawaii | 29-MAR-02 | Hilo, Hawaii |
| DRFT13RR | J. Hildebrand | 01-APR-02 | Hilo, Hawaii | 20-APR-02 | Honolulu, Hawaii |
| HNRO17RR | Smith, Stu (Retired), | 08-MAY-00 | Kaohsiung, Taiwan | 20-MAY-00 | Honolulu, Hawaii |
| KIWI02RR | Stephen, Ralph | 11-AUG-97 | San Francisco, California | 21-AUG-97 | Honolulu, Hawaii |
| KIWI03RR | Mcnutt, Marcia | 24-AUG-97 | Honolulu, Hawaii | 21-SEP-97 | Honolulu, Hawaii |
| KIWI04RR | Lukas, Roger | 24-SEP-97 | Honolulu, Hawaii | 26-SEP-97 | Honolulu, Hawaii |
| KIWI05RR | Miller, Stephen P. | 28-SEP-97 | Honolulu, Hawaii | 14-OCT-97 | Lyttleton, New Zealand |
| KIWI12RR | Luyendyk, Bruce | 09-MAY-98 | Pago Pago, Amer.Samoa | 29-MAY-98 | Honolulu, Hawaii |
| NECR02RR | Gee, Jeffrey | 13-AUG-00 | Astoria, Oregon | 25-AUG-00 | Honolulu, Hawaii |
| NECR04RR | Gregg, Michael | 05-OCT-00 | Honolulu, Hawaii | 06-NOV-00 | Honolulu, Hawaii |
| NECR05RR | Hildebrand, John | 12-NOV-00 | Honolulu, Hawaii | 07-DEC-00 | Hilo, Hawaii |
| NECR06RR | Peter Lonsdale, Scripps Inst. | 08-DEC-00 | Hilo, Hawaii | 16-DEC-00 | San Diego, California |
| SEAW02RR | Demoustier, Christian | 17-FEB-01 | San Diego, California | 25-FEB-01 | Honolulu, Hawaii |
| SEAW03RR | Demoustier, Christian | 25-FEB-01 | Hilo, Hawaii | 25-MAR-01 | Honolulu, Hawaii |

## EXPLANATION OF MAPS

The atlas consists of several sets of maps organized geographically:

- Entire Main Hawaiian Islands
- Kauai and Niihau
- Oahu
- Maui, Molokai, Lanai, and Kahoolawe
- Hawaii (Big Island)

Within each set, the first map is a bathymetry base map image without survey location metadata. This is followed by a map with a composite of survey locations (all data sources combined), then maps showing the survey locations for each data source.

## ACKNOWLEDGEMENTS

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Dr. Michael Parke and Haiying Wang of CRED processed and compiled the data using CRED and PIFSC resources. Dr. Rusty Brainard (CRED) provided critical oversight and support for the synthesis effort. Dr. Bruce Applegate of UH Hawaii Research Mapping Group (HRMG) provided R/V Kilo Moana images. Dr. John Smith of UH/NOAA Hawaii Undersea Research Laboratory (HURL) provided R/V K-O-K SeaBeam and JAMSTEC SeaBeam data. Dr. Christopher Kelley of UH/NOAA Hawaii Undersea Research Laboratory (HURL) provided Bottomfish GIS data from the Hawaii State Department of Land and Natural Resources (DLNR). Applegate, Smith, and Kelley all reviewed the draft document.

The base map image that underlies all of the data presented was produced by B.W. Eakins, J.E. Robinson, T. Kanamatsu, J. Naka, J.R. Smith, E. Takahashi and D.A. Clague from U.S. Geological Survey (USGS) Geologic Investigations Series I-2809. http://geopubs.wr.usgs.gov/i-map/i2809/.