NOAA Technical Memorandum NESDIS NGDC-4

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UNITED STATES DEPARTMENT OF COMMERCE

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Also available from the National Technical Information Service (NTIS)
(http://www.ntis.gov)

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Digital Elevation Model of Dutch Harbor, Alaska: Procedures, Data Sources and Analysis

1. Introduction

In August 2006, the National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), developed a bathymetric/topographic digital elevation model (DEM) of Dutch Harbor, Alaska (Fig. 1) for the Pacific Marine Environmental Laboratory (PMEL), NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov/). The 1 arc-second (~30 meter) elevation grid was generated from several, diverse digital datasets in the region (grid boundary and sources shown in Fig. 4). The DEM will be used as input for the Method of Splitting Tsunami (MOST) model (http://www.pmel.noaa.gov/pubs/PDF/tito1927/tito1927.pdf) developed by PMEL to simulate tsunami generation, propagation and inundation. This report provides a summary of the data sources and methodology used in developing the Dutch Harbor DEM.

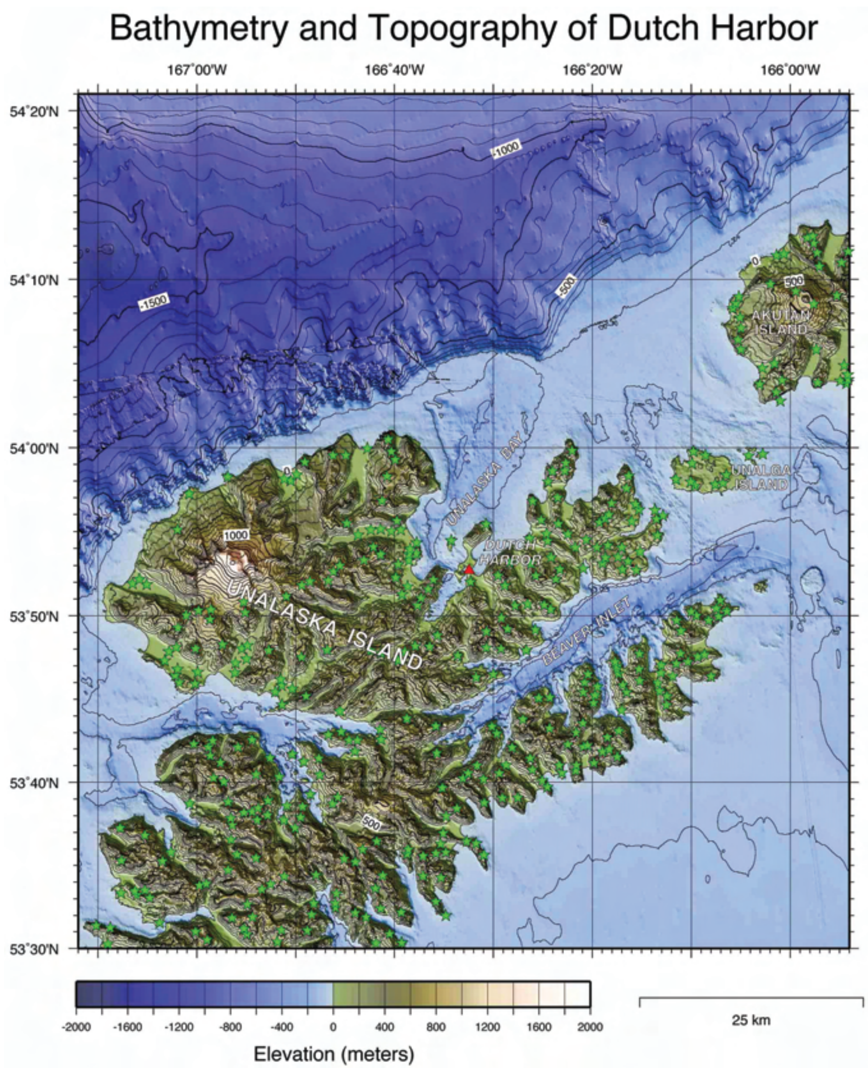

Figure 1. *Shaded-relief image, derived from the DEM, of the Dutch Harbor, Alaska area. Red triangle locates tidal station listed in Table 12; green stars locate USGS bench marks listed in Table 13. Contour interval (referenced to MHW): 100 meters, bold every 500 meters.*

2. Study Area

Dutch Harbor is the official name of the port of the city of Unalaska, the 11th largest settlement in Alaska. The city and harbor are located on Unalaska Island, one of the largest islands in the Aleutian chain, which forms a rugged, volcanic island arc curving from the tip of the Alaska Peninsula and approaching Russia. The Aleutians lie along the edge of the North American plate, where the Pacific plate is subducting underneath it. The great majority of the islands bear evident marks of volcanic origin, and there are numerous volcanic cones on the north side of the chain, some of them active. Many of the islands, however, are not wholly volcanic, but contain crystalline or sedimentary rocks, as well as amber and beds of lignite. The coasts are rocky and surf-worn, and the approaches are exceedingly dangerous, the land rising immediately from the coasts to steep, bold mountains.

In the 2000 census, there was a population of 8,162 on the islands, of whom 4,283 were living in the main settlement of Unalaska. According to the U.S. Census Bureau, the city has a total area of 549.9 km^2 (212.3 mi^2): 287.5 km^2 (111.0 mi^2) of it is land and 262.4 km^2 (101.3 mi^2) of it (47.71%) is water. Its economy is based on commercial fishing and shipping/transportation.

The large April 1st (April Fool's Day), 1946 earthquake just south of Unalaska Island provided the impetus to establish the tsunami warning network in the Pacific. An earthquake-generated tsunami greater than 100 feet high obliterated the nearby Scotch Cap lighthouse (Fig. 2), on Unimak Island, though Dutch Harbor was protected. The tsunami also traveled across the Pacific, drowning 159 people in Hilo, Hawaii.

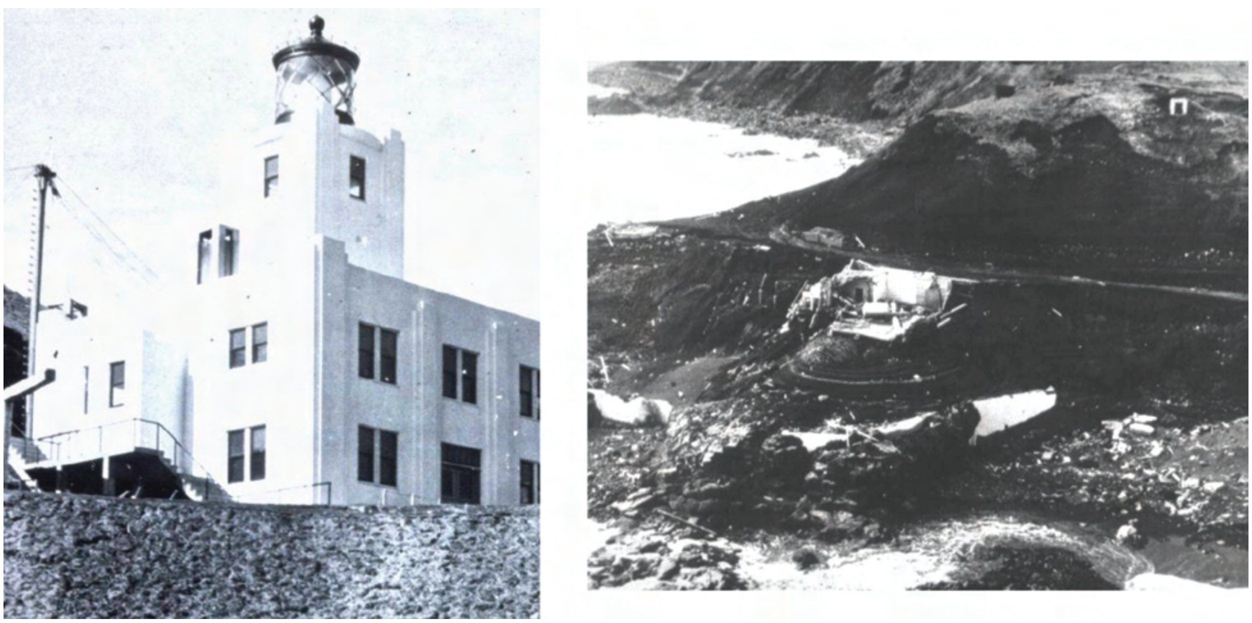

Figure 2. *Photographs of the Scotch Cap Lighthouse, 40 feet above sea level, before and after the April Fool's Day earthquake and tsunami of 1946. [Taken from* *http://www.usalights.com/alaska/scotchcap.htm]*

Just recently, NOAA Fisheries Service formally established the Aleutian Islands Habitat Conservation Area in Alaska, creating 279,114 square nautical miles of protected habitat to the southwest of Dutch Harbor (Fig. 3). The Fisheries Service worked with partners to develop a plan to restrict fishing activities that can destroy sensitive habitats on the ocean floor. Designating the area as a habitat conservation area makes the plan a reality. Resulting from a February 2005 recommendation by the North Pacific Fishery Management Council, the Aleutian Islands Conservation Area establishes a network of fishing closures in the Aleutian Islands and Gulf of Alaska. The area protects habitat for deepwater corals and other sensitive features that are slow to recover once disturbed by fishing gear or other activities. While certain sites that have been trawled repeatedly in the past will remain open, fragile coral gardens discovered by NOAA scientists in 2002 will now be protected. NOAA worked closely with environmental groups, the commercial fishing industry, the fishery management council, and other partners to develop unprecedented protections over this huge area (http://www.fakr.noaa.gov/).

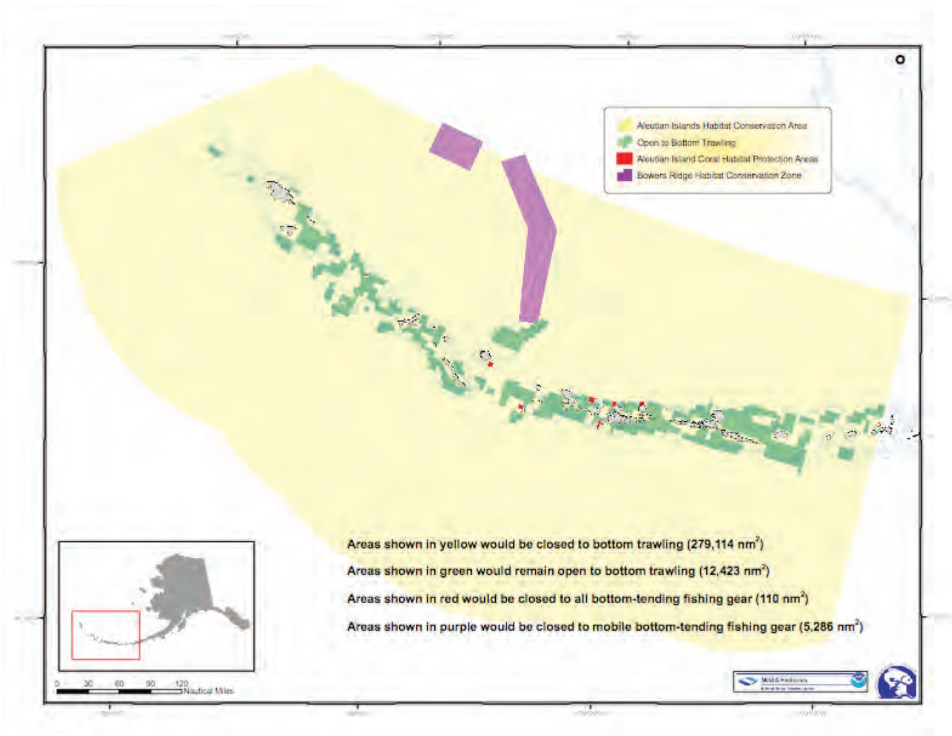

Figure 3. *Aleutian Islands Habitat Conservation Area southwest of Dutch Harbor.*

3. METHODOLOGY

The Dutch Harbor DEM was developed to meet PMEL required specifications (Table 1), based on input requirements for the MOST inundation model. The best available data were obtained by NGDC and used to produce the DEM. Data processing, grid assembly, and quality assessment are described in the following subsections.

Table 1: PMEL specifications for the Dutch Harbor, Alaska DEM.

Grid Area	Dutch Harbor, Alaska
Coverage Area	167.2 º to 165.9º W; 53.5º to 54.35º N
Coordinate System	Geographic decimal degrees
Horizontal Datum	World Geodetic System (WGS84)
Vertical Datum	Mean High Water
Vertical Units	Meters
Grid Spacing	1 arc-second
Grid Format	ASCII raster grid

3.1 Data Sources and Processing

Shoreline, bathymetric, and topographic data (Fig. 4) were obtained from several federal and state government agencies, including: NOAA's National Ocean Service (NOS), Office of Coast Survey (OCS), and NGDC; the Alaska Department of Natural Resources; the U.S. Fish and Wildlife Service; and the U.S. Geological Survey (USGS). Safe Software's (http://www.safe.com/) FME data translation tool package was used to convert datasets into ESRI (http://www.esri.com/) ArcGIS shape files. The shape files were then displayed to assess data quality and manually edit datasets. Vertical datum transformations to Mean High Water (MHW) were achieved using FME and data from the Dutch Harbor tide station, as no VDatum model software (http://nauticalcharts.noaa.gov/csdl/vdatum.htm) was available for this area.

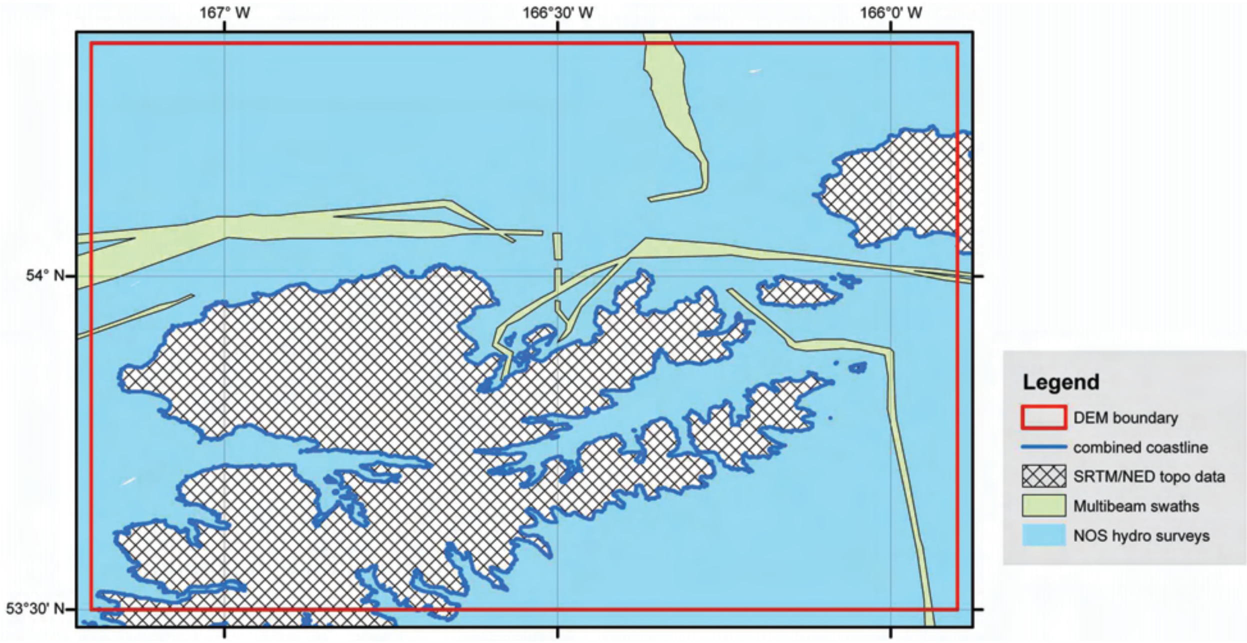

Figure 4. *Coverage of data sources used to compile the Dutch Harbor, Alaska DEM.*

3.1.1 Shoreline

Five digital coastline datasets of the Dutch Harbor region were available for analysis: NGA Global Shoreline, OSC electronic navigational charts and one chart with vector MHW shoreline, U.S. Fish and Wildlife Service statewide Alaska digital coastline, and Alaska Department of Natural Resources statewide digital coastline.

Table 2. Shoreline data sources used in gridding.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum/Coordinate System*	*Original Vertical Datum*	*URL*
OCS Electronic Navigational Charts	1989 to 1991	inferred MHW coastline	Digitized from 1:20,000 and 1:80,000 scale charts	WGS84 geographic	Inferred MHW	http://chartmaker.ncd.noaa.gov/
OCS MHW vector shoreline of Chart #16522	2003	MHW coastline	Digitized from 1:40,000 and 1:80,000 scale charts	NAD83 geographic	MHW	http://chartmaker.ncd.noaa.gov/
U.S. FWS	2006	compiled coastline	Various	WGS84 geographic	unknown	http://chartmaker.ncd.noaa.gov/

1) NGA global shoreline

The National Geospatial-Intelligence Agency (NGA; http://www.nga.mil/) has developed a 'Prototype Global Shoreline Data' digital shoreline. The NGA Global Shoreline Data is an unclassified vector dataset generated by Earth Satellite Corporation (http://www.earthsat.com/) of Rockville, Maryland for NGA, under contract to Boeing in 2004. The shoreline is an approximation to the High Water Line and constructed from consistently orthorectified Landsat TM satellite imagery (GeoCover Ortho), acquired between 1998-2002 for NASA under the Global Land Mapping Program (GLMP). NDVI and SWIR models were used to define the landward extent of inundation (i.e., MHW). Independently verified positional accuracy for the source product (GeoCover Ortho) is consistently better than 50 meter root mean square (RMS) error.

The NGA coastline matches the topographic data along island edges but without the detail of other coastline datasets, due principally to its lower resolution. This dataset was not used in the gridding process.

2) OCS electronic navigational charts

Eight electronic navigational charts (ENCs) are available for the Dutch Harbor region (Fig. 5; Table 3), which were downloaded from NOAA's Office of Coast Survey (OSC) website (http://chartmaker.ncd.noaa.gov/); the ENCs are digital versions of NOAA's published nautical charts. The NOAA Coastal Services Center's 'Electronic Navigational Chart Data Handler for ArcView' extension was used to import the data into ArcGIS (http://www.csc.noaa.gov/products/enc/). The chart data include coastline data files (inferred MHW, though not clearly specified), which were compared with the other coastline datasets, topographic data, and NOS hydrographic soundings. They also include soundings (extracted from NOS hydrographic surveys) and land elevations (see Section 3.1.3).

The ENC coastlines for the 6 charts at 1:40,000 to 1:80,000 (Table 3) generally correspond well with NOS soundings and topographic data: the exception being occasional piers, docks, bridges and even ships that were erroneously included and had to be deleted manually. The two ENCs at 1:300,000 scale, however, exhibit significant offset in their coastline data (up to 200 meters to the west-northwest) compared with the topographic data, NOS soundings and the larger-scale ENCs, and are also of lower resolution (e.g., Fig. 6). For this reason they were deemed unreliable and were not used in the gridding process. The 6 larger-scale ENCs did not, however, provide complete coastline coverage for the Dutch Harbor region and were therefore combined with other datasets to build a 'combined' coastline (Fig. 8).

Several NOAA nautical charts do not exist in digital form (Table 4), but were nevertheless useful in evaluating the completeness of the coastline datasets. For example, several small islands (rocky knolls) are identified on Chart #16528 and on the small-scale ENC/Chart #16520. Such features from the small-scale ENCs were included in the combined coastline.

Table 3. Electronic navigational charts in the Dutch Harbor, Alaska region.

Nautical Chart #	*ENC ref.#*	*Region*	*Scale*	*Pub. Date*
16500	US3AK60M	Unalaska I. to Amukta I.	1:300,000	8-1990
16514	US5AK65M	Kuliliak Bay to Surveyor Bay	1:40,000	7-1990
16515	US5AK66M	Chernofski Harbor to Skan Bay	1:40,000	7-1990
16517	US5AK68M	Makushin Bay	1:40,000	12-1991
16518	US5AK69M	Cape Kovrizhka to Cape Cheerful	1:40,000	9-1989
16520	US3AK61M	Unimak and Akutan Pass	1:300,000	4-1989
16521	US5AK6AM	Protection Bay to Eagle Bay	1:40,000	12-1990
16531	US4AL6FM	Krenitzin I.	1:80,000	12-1990

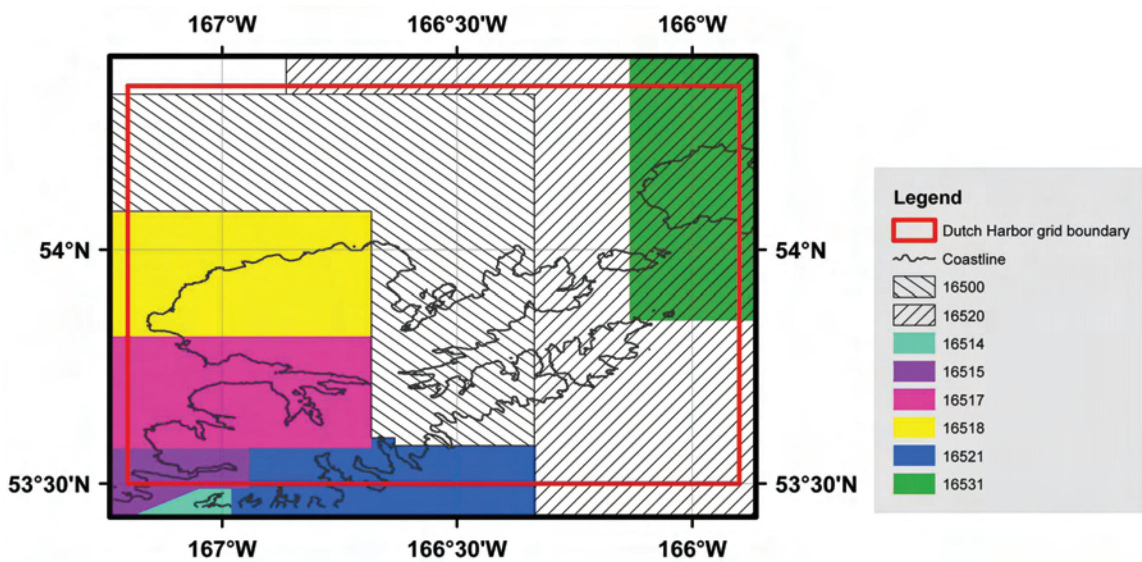

Figure 5. *Spatial coverage of digital ENCs in the Dutch Harbor region. Small-scale charts are hachured, large-scale colored.*

Table 4. Non-digitized NOAA nautical charts in the Dutch Harbor, Alaska region.

Nautical Chart #	*Region*	*Scale*	*Pub. Date*
16522	Beaver Inlet	1:40,000	05-1992
16528	Unalaska Bay & Akutan Pass	1:40,000	05-1992
16529	Dutch Harbor	1:10,000	08-1994
16530	Captains Bay	1:10,000	04-1996

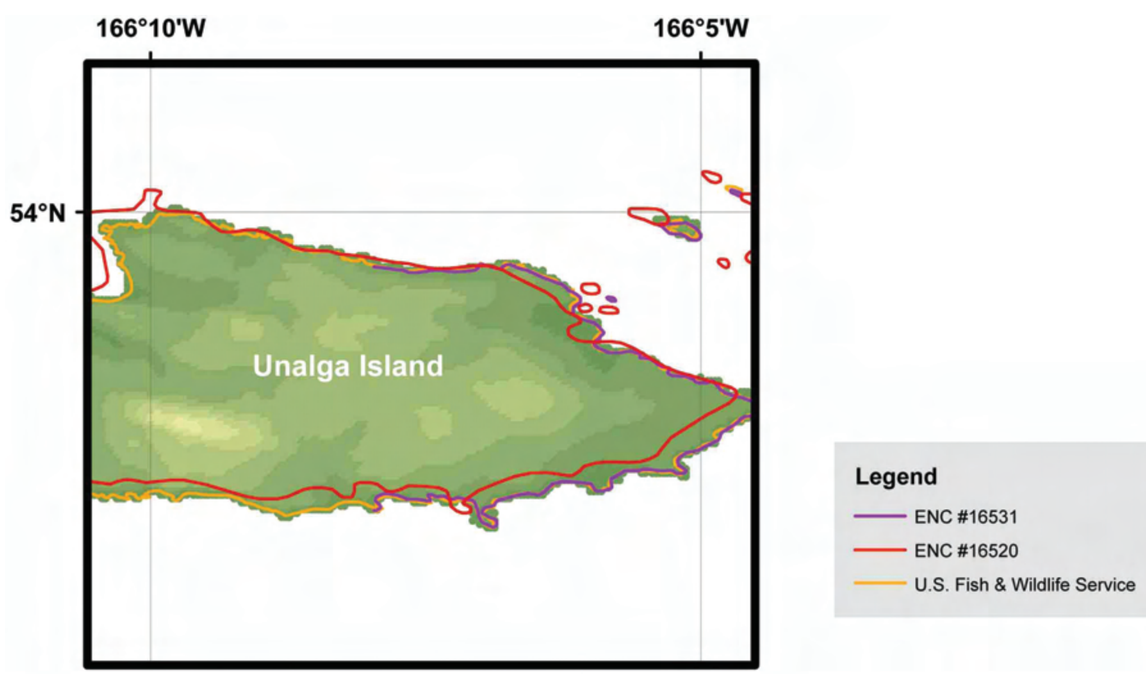

Figure 6. *Offset between small-scale, #16520, and large-scale, #16531, ENCs along part of Unalga Island's coast. Note WNW offset (~200 meters) of the small-scale, #16520, ENC coastline. Color image derived from USGS 2 arc-second NED topography.*

3) OCS mean high water vector shoreline

OCS has also developed a MHW vector shoreline for the U.S., which was digitized from NOAA nautical charts (http://chartmaker.ncd.noaa.gov/): in the Dutch Harbor gridding region the data is from Nautical Chart #16522 ('Unalaska Island—Beaver Inlet', 1:40,000). Digital chart data are in NAD83 horizontal datum.

This shoreline dataset is consistent with the topographic data, NOS hydrographic soundings and the large-scale ENC coastlines, and was used in developing the combined coastline (Fig. 8), though it also contained manmade features (piers, ships, rivers, etc.) that had to be deleted before gridding (e.g., Fig. 7).

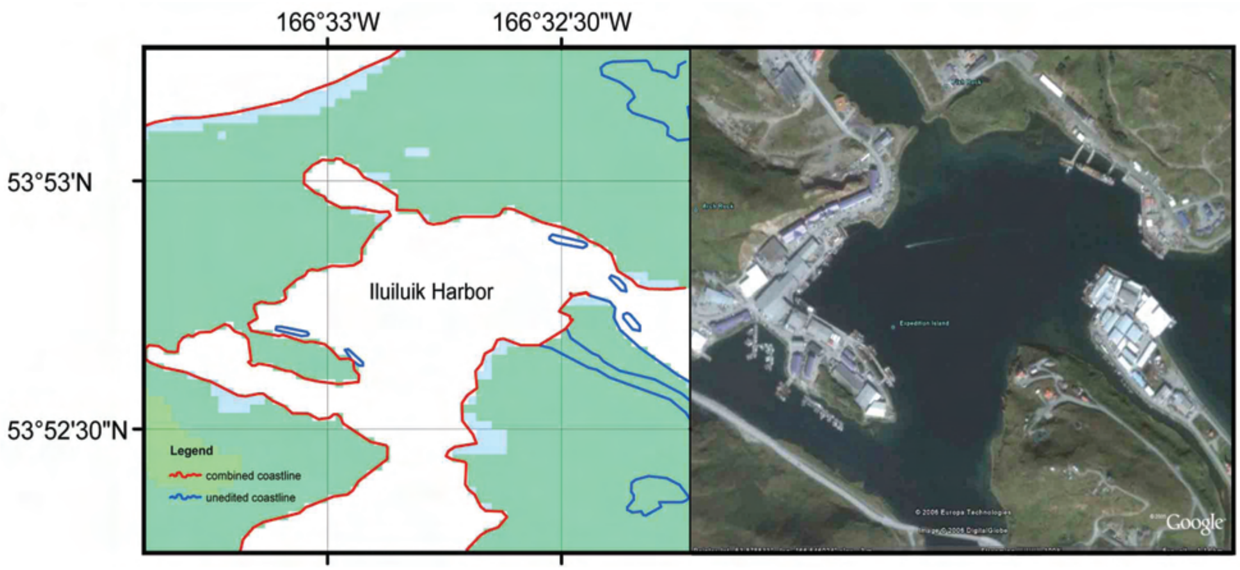

Figure 7. Manmade features present in coastline datasets. Left panel shows original, unedited coastline extracted from OSC MHW vector shoreline (Chart #16522), and the edited version used in building the combined coastline. Google Earth satellite image in right panel permitted identification of piers, ships, docks, rivers, etc. that had to be deleted from the combined coastline.

4) U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) has compiled a seamless digital coastline of the State of Alaska from a variety of existing sources, including: the National Hydrography Dataset, NOAA nautical charts, U.S. Fish and Wildlife Service, National Geographic Topo Software, U.S. Army Corps of Engineers, and Alaska Department of Natural Resources. Though efforts were made to obtain the highest resolution coastlines available, their vertical datums were apparently not determined nor controlled in any way in compiling the FWS coastline; horizontal datum of the compiled FWS coastline is WGS84. This coastline is consistent with the topographic data and NOS hydrographic soundings, and the large-scale ENC coastlines and was used in developing the combined coastline (Fig. 8).

5) Alaska Department of Natural Resources

The Alaska Department of Natural Resources has also made a "first cut" at building a statewide digital coastline for Alaska, nominally at 1:63,360 scale, though not in entirety (some areas at 1:250,000 scale). The primary dataset appears to be USGS topographic quadrangles. Horizontal datum is WGS84, vertical datum is undefined. The coastline exhibits good resolution, however, it is shifted roughly 150 meters to the northeast relative to NOS soundings, topographic data, and the other, reliable coastline datasets. It was not used in the combined coastline.

To obtain the best digital MHW coastline, NGDC combined the OSC large-scale ENC and MHW shorelines with the FWS coastline. Where overlap occurred, the FWS coastline was excised, as the OSC coastlines were determined to more reliably define the MHW line and were more consistent with the topographic data. This 'combined coastline' (Fig. 8) was subsampled to 30-meter spacing and converted to point data for use in the gridding process. The combined coastline was also used as a coastal buffer for the NOS pre-surfacing algorithm (see Section 3.3.2) to ensure that interpolated bathymetric values reached "zero" at the coast.

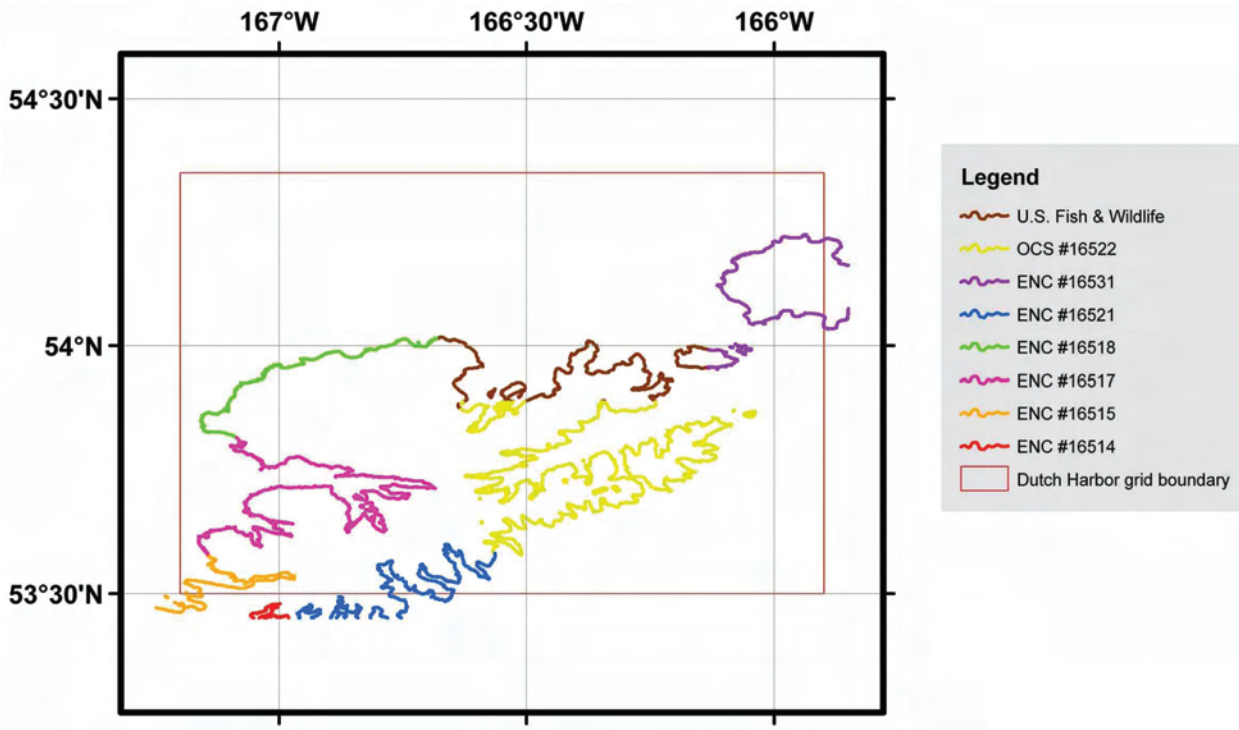

Figure 8. *Digital coastline segments combined for use in the Dutch Harbor DEM. Most segments are derived from digitized versions of large-scale NOAA nautical charts.*

3.1.2 Bathymetry

Bathymetric datasets used in the compilation of the Dutch Harbor DEM include 42 NOS hydrographic surveys, and multibeam swath sonar data archived at NGDC and the Marine Geoscience Data System.

Table 5. Bathymetric data sources used in gridding.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum/ Coordinate System*	*Original Vertical Datum*	*URL*
NOS	1934 to 1991	Hydrographic survey soundings	Ranges from 20 meters to 5 kilometers (varies with scale of survey, depth, traffic and probability of obstructions)	NAD27, NAD83, Unalaska	MLLW (meters)	http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html
NGDC, MGDS	1988 to 2004	Multibeam swath sonar	Ranges from 10 to 150 meters (varies with water depth)	WGS84 geographic	MSL (meters)	http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html; http://www.marine-geo.org

1) NOS hydrographic survey data

A total of 42 NOS hydrographic surveys conducted between 1934 and 1991 were included in the Dutch Harbor DEM compilation (Fig. 9; Table 6); two very sparse surveys from 1910 and 1913 were excluded (H03194 and H03579). The survey data were originally vertically referenced to Mean Lower Low Water (MLLW) and horizontally referenced to either Unalaska, NAD27, or NAD83 datums. Many smooth sheets contain registration marks for both Unalaska and NAD27 datums (e.g., Fig. 15), which necessitated careful assessment to determine the datum to which each of these surveys were referenced to when digitized in the 1990s. Dave Doyle, National Geodetic Survey, computed the shift necessary to convert from Unalaska to NAD83 (see Appendix A).

Data point spacing for the surveys ranged from about 20 meters in shallow water to 5 kilometers in deep water. All surveys were extracted from NGDC's online database (http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html) in their original datums (Table 6). The data were then converted to WGS84 using FME software, an integrated collection of spatial extract, transform, and load tools for data transformation (http://www.safe.com). The surveys were subsequently clipped to a polygon 0.05 degrees (~5%) larger than the final gridding area to support data interpolation along grid edges.

After converting all NOS survey data to MHW (see Section 3.2.1), the data were displayed in ESRI ArcMap and reviewed for digitizing errors against scanned original survey smooth sheets and compared to current NED topographic data, the combined coastline, and *Google Earth* satellite imagery.

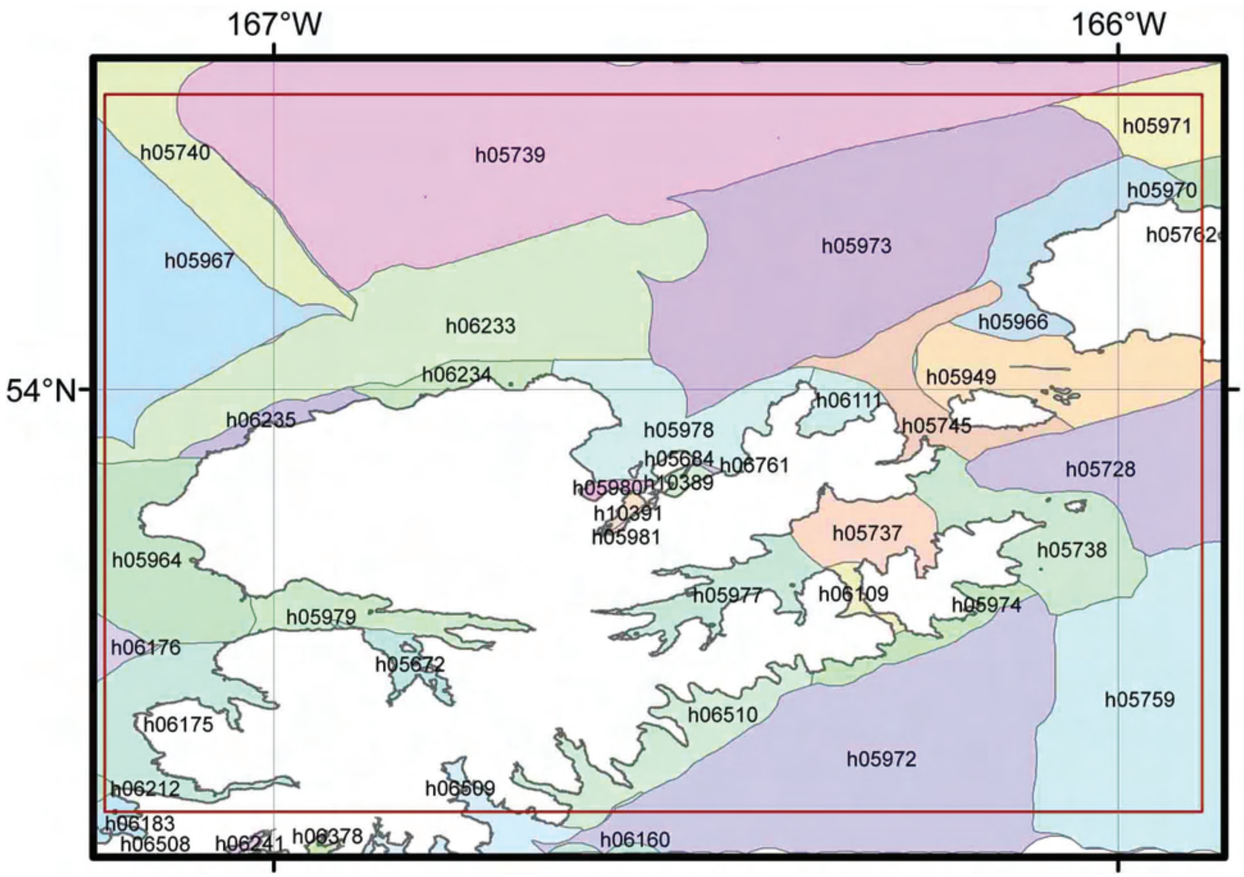

Figure 9. *Digital NOS hydrographic survey coverage in the Dutch Harbor region. Red line denotes DEM boundary; combined coastline in gray.*

Table 6. Digital NOS hydrographic surveys used to build the Dutch Harbor, Alaska DEM.

Survey ID	*Year*	*Survey Scale*	*Original Horizontal Datums*	*Digitized Horizontal Datum*	*Original Vertical Datum*
H05672	1934	20,000	Unalaska	Unalaska	MLLW
H05684	1934	5,000	*smooth sheet is not available*	Unalaska	MLLW
H05728	1934	40,000	Unalaska	Unalaska	MLLW
H05737	1934/35	20,000	Unalaska	Unalaska	MLLW
H05738	1934/35	20,000	Unalaska	Unalaska	MLLW
H05739	1934	80,000	Unalaska	Unalaska	MLLW
H05740	1934	160,000	Unalaska	Unalaska	MLLW
H05745	1934	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H05759	1934	80,000	Unalaska, NAD 1927	NAD 1927	MLLW
H05762	1934	20,000	Unalaska, NAD 1927	Unalaska	MLLW
H05949	1935	20,000	Unalaska, NAD 1927	Unalaska	MLLW
H05964	1935	20,000	Unalaska	Unalaska	MLLW
H05966	1935	20,000	Unalaska, NAD 1927	Unalaska	MLLW
H05967	1935	160,000	Unalaska	Unalaska	MLLW
H05970	1935	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H05971	1935	40,000	Unalaska	Unalaska	MLLW
H05972	1935	80,000	Unalaska	Unalaska	MLLW
H05973	1935	40,000	Unalaska	Unalaska	MLLW
H05974	1935	20,000	Unalaska	Unalaska	MLLW
H05977	1935	20,000	Unalaska	Unalaska	MLLW
H05978	1935	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H05979	1935	20,000	Unalaska	Unalaska	MLLW
H05980	1935	5,000	Unalaska	Unalaska	MLLW
H05981	1935	5,000	Unalaska	Unalaska	MLLW
H06109	1935	10,000	Unalaska	Unalaska	MLLW
H06111	1935	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06160	1936	80,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06175	1936	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06176	1936	40,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06183	1936	10,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06212	1937	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06233	1937	40,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06234	1937	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06235	1937	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06241	1937	10,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06378	1938	20,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06508	1939	10,000	Unalaska, NAD 1927	NAD 1927	MLLW
H06509	1939	20,000	Unalaska, NAD 1927	Unalaska	MLLW
H06510	1939	20,000	Unalaska, NAD 1927	Unalaska	MLLW
H06761	1941	2,000	Unalaska	Unalaska	MLLW
H10389	1991	5,000	NAD 1983, Polyconic projection	NAD 1983	MLLW
H10391	1991	5,000	NAD 1983, Polyconic projection	NAD 1983	MLLW

2) Multibeam swath sonar data

The websites of NGDC (http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html) and the Marine Geoscience Data System (MGDS; http://www.marine-geo.org) were queried for multibeam swath sonar bathymetric data in the vicinity of Dutch Harbor (Fig. 10). Non-proprietary data from 8 cruises were downloaded (Table 7) and utilized in the Dutch Harbor DEM. Cruise 'FOCI93' required manual editing to remove anomalous soundings along the northwest flank of Unalaska Island; cruise 'RNDB06WT' was not included due to significant mismatch with other multibeam cruise data. All multibeam data were originally in WGS84 geographic coordinates and inferred mean sea level (MSL) vertical datum.

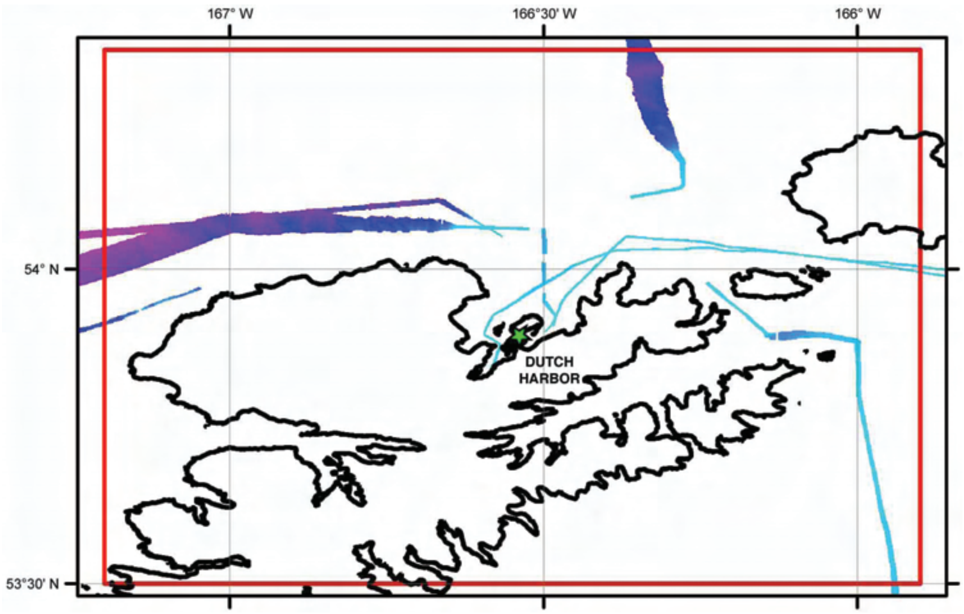

Figure 10. *Spatial coverage of multibeam swath sonar surveys into and out from Dutch Harbor that were utilized in DEM development.*

Table 7. Cruises with multibeam swath sonar data that were utilized in the Dutch Harbor DEM.

Cruise	*Ship*	*Year*	*Sonar*	*Source*
EW0204	Ewing	2002	Simrad EM-120	MGDS
EW9408	Ewing	1994	Atlas Hydrosweep	MGDS
EW9411	Ewing	1994	Atlas Hydrosweep	MGDS
FOCI93	Surveyor	1993	SeaBeam "Classic"	NGDC
FOCI95	Surveyor	1995	SeaBeam "Classic"	NGDC
HLY-04-Ta	Healy	2004	SeaBeam 2112	MGDS
NBP0304B	Palmer	2003	Simrad EM120	MGDS
RNDB09WT	Thomas Washington	1988	SeaBeam "Classic"	NGDC

3.1.3 Topography

Topographic data were obtained from several sources: USGS National Elevation Dataset (NED) 2 arc-second (~60 meter) gridded topographic DEMs; NASA shuttle radar topographic DEMs (1 arc-second), and NOAA OCS electronic navigational charts (Table 8).

Table 8. Topographic data sources used in gridding.

Source	*Year*	*Data Type*	*Spatial Resolution*	*Original Horizontal Datum/Coordinate System*	*Original Vertical Datum*	*URL*
USGS NED	2006	Topographic DEM	2 arc-second grid	NAD27 geographic	NGVD29 (meters)	http://ned.usgs.gov/
NASA SRTM	2000	Topographic DEM	1 arc-second grid	WGS84 geographic	WGS84/EGM96 Geoid (meters)	http://srtm.usgs.gov/
OCS ENCs	1989 to 1991	Surveyed land elevations	Digitized from 1:20,000 to 1:80,000 scale charts	WGS84 geographic	MHW (feet)	http://chartmaker.ncd.noaa.gov/

1) USGS NED topography

The U.S. Geological Survey's (USGS) National Elevation Dataset (NED; http://ned.usgs.gov/) provides 2 arc-second coverage of Alaska[1]. Data are in NAD27 Alaska geographic coordinates and NGVD29 vertical datum (meters). The extracted bare-earth elevations have a vertical accuracy of +/- 7 to 15 meters depending on source data resolution. See the USGS Seamless web site for specific source information (http://seamless.usgs.gov/). The dataset was derived from USGS quad maps and aerial photos based on surveys conducted in the 1970s and 1980s.

The NED data included "zero" values over the open ocean (see Fig. 11), which were removed from the dataset before gridding. Some anomalous values still remained over the open ocean, which were visually inspected and compared with NOAA nautical charts, the combined coastline, and *Google Earth* satellite imagery. These points were removed in ArcCatalog by clipping to the combined coastline.

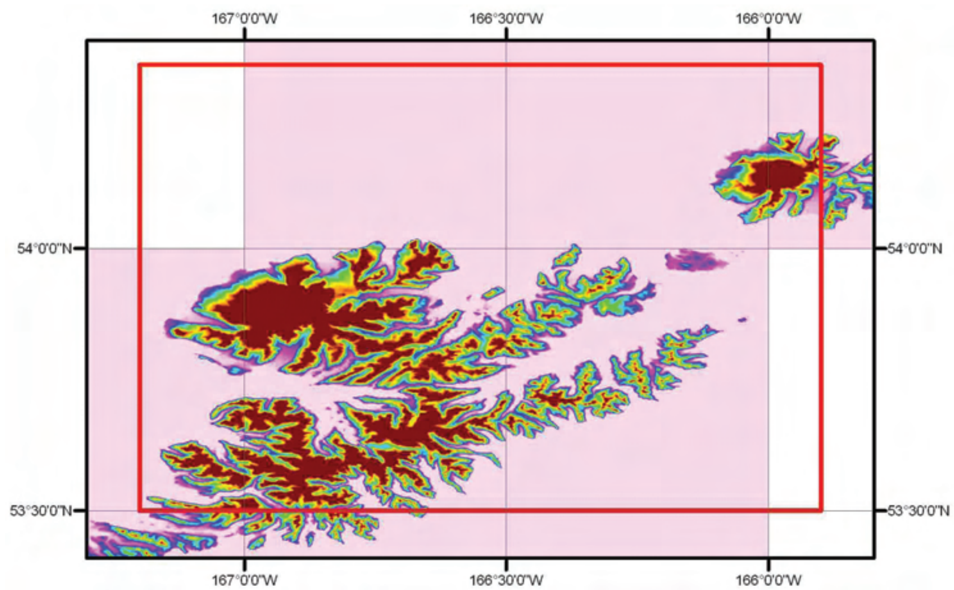

Figure 11. *Color image of the NED DEM extracted from the USGS web site. Note data values over the open ocean (light pink) that had to be excised prior to gridding.*

1. The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous U.S. and 1:63,360-scale DEM data for Alaska. The dataset provides seamless coverage of the United States, HI, AK, and the island territories. NED has a consistent projection (Geographic), resolution (1 arc second), and elevation units (meters). The horizontal datum is NAD83, except for AK, which is NAD27. The vertical datum is NAVD88, except for AK, which is NGVD29. NED is a living dataset that is updated bimonthly to incorporate the "best available" DEM data. As more 1/3 arc second (10 m) data covers the U.S., then this will also be a seamless dataset. [Extracted from USGS NED website]

2) NASA space shuttle radar topography

The NASA Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth[2]. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. Data from this mission have been processed into 1 degree × 1 degree tiles that have been edited to define the coastline, and are available from the USGS Seamless web site (http://seamless.usgs.gov/). The data have not been processed to bare earth, but meet the absolute horizontal and vertical accuracies of 20 and 16 meters, respectively.

For U.S. regions, the data have a 1 arc-second spacing and are referenced to the WGS84/EGM96 Geoid. While providing mostly complete coverage of the Aleutian Islands in the vicinity of Dutch Harbor, there are numerous small areas with "no data" values (e.g., Fig. 12) that were filled with NED topographic data (see Table 11). The SRTM DEMs also contain "zero" values over the open ocean, which had to be excised prior to gridding.

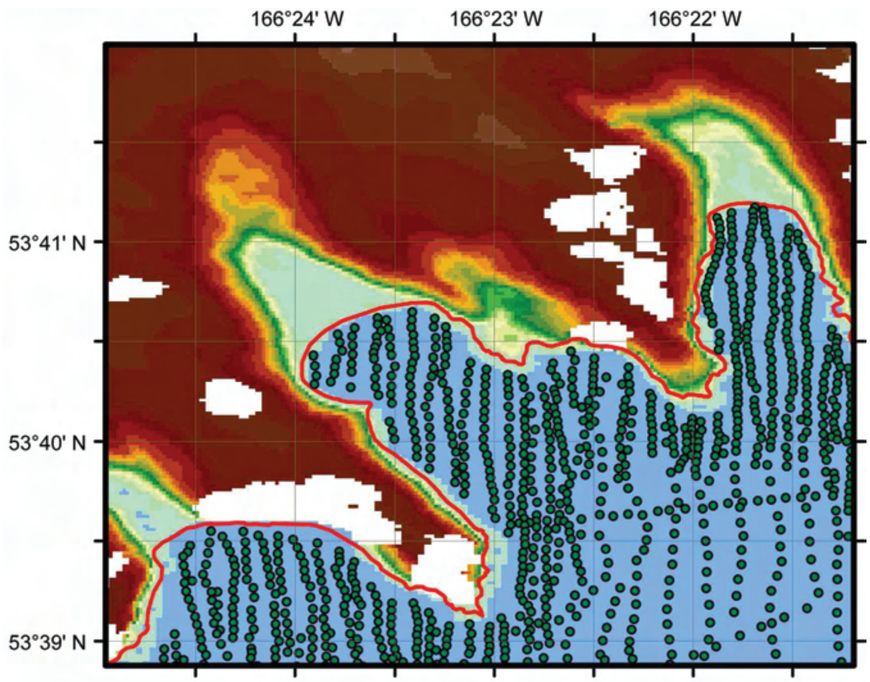

Figure 12. *Example of gaps in SRTM data coverage. Numerous gaps (white areas) exist over land areas in the SRTM DEMs, which also include "zero" values (blue) over water that had to be excised. Gaps were filled with data from the NED DEM. Combined coastline in red; NOS soundings (green dots) from survey H06510.*

2. The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA – previously known as the National Imagery and Mapping Agency, or NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry. The SRTM instrument consisted of the Spaceborne Imaging Radar-C (SIR-C) hardware set modified with a Space Station-derived mast and additional antennae to form an interferometer with a 60 meter long baseline. A description of the SRTM mission can be found in Farr and Kobrick (2000). Synthetic aperture radars are side-looking instruments and acquire data along continuous swaths. The SRTM swaths extended from about 30 degrees off-nadir to about 58 degrees off-nadir from an altitude of 233 km, and thus were about 225 km wide. During the data flight the instrument was operated at all times the orbiter was over land and about 1000 individual swaths were acquired over the ten days of mapping operations. Length of the acquired swaths range from a few hundred to several thousand km. Each individual data acquisition is referred to as a "data take." SRTM was the primary (and pretty much only) payload on the STS-99 mission of the Space Shuttle Endeavour, which launched February 11, 2000 and flew for 11 days. Following several hours for instrument deployment, activation and checkout, systematic interferometric data were collected for 222.4 consecutive hours. The instrument operated almost flawlessly and imaged 99.96% of the targeted landmass at least one time, 94.59% at least twice and about 50% at least three or more times. The goal was to image each terrain segment at least twice from different angles (on ascending, or north-going, and descending orbit passes) to fill in areas shadowed from the radar beam by terrain. This 'targeted landmass' consisted of all land between 56 degrees south and 60 degrees north latitude, which comprises almost exactly 80% of Earth's total landmass. [Extracted from SRTM online documentation]

3) OCS electronic navigational charts

Electronic navigational charts (ENCs; Table 3) were downloaded from NOAA's Office of Coast Survey (OSC) website (http://chartmaker.ncd.noaa.gov/). The chart data includes land elevations for local topographic highs (in MHW vertical datum, feet; Fig. 13), which were compared with the other topographic datasets and *Google Earth* satellite imagery. As these points represent surveyed values taken from USGS topographic quadrangles, they are considered to have greater accuracy than the NED and SRTM data (see Table 11). Numerous coastal rocks and small islands on the non-digital NOAA nautical charts (Table 4) that also have land elevations were digitized by NGDC for inclusion in the Dutch Harbor DEM (Table 9; Fig. 13).

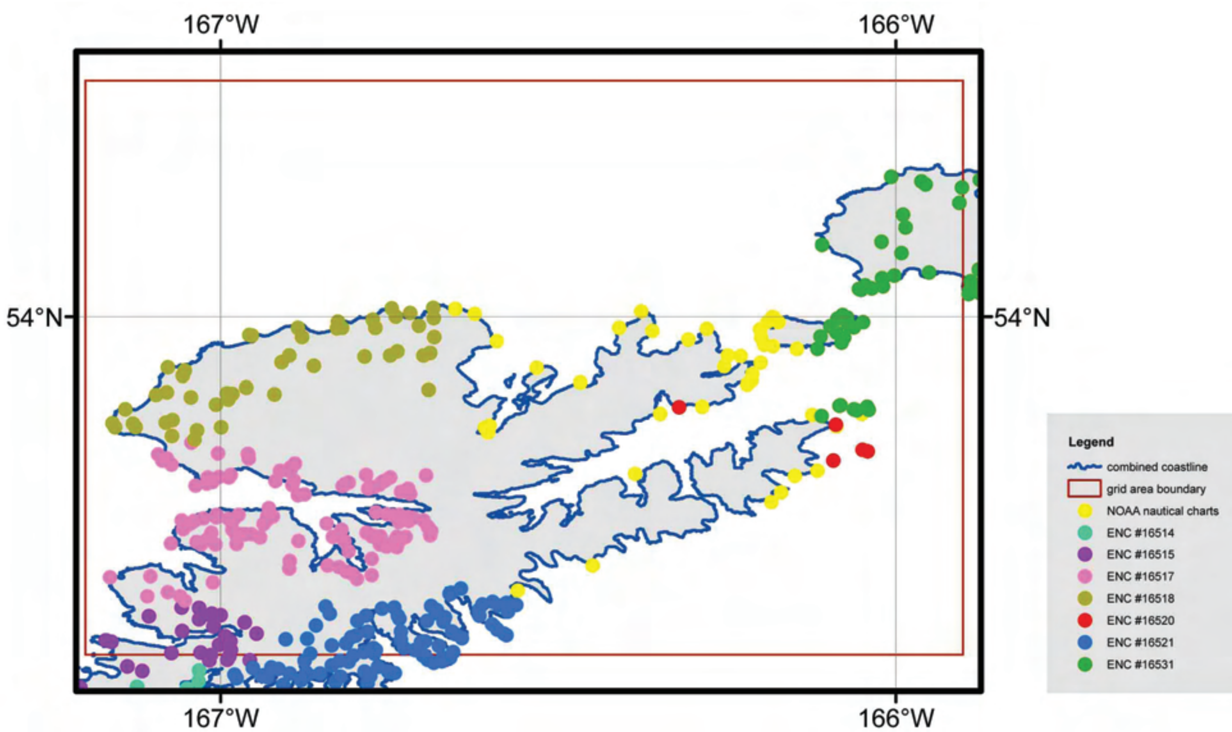

Figure 13. *Land elevation points extracted from ENCs and digitized from NOAA nautical charts. Points manually digitized by NGDC (yellow) are listed in Table 9.*

Table 9. Topographic features digitized from published NOAA nautical charts in the Dutch Harbor, Alaska region.

Nautical Chart #	*Feature*	*Longitude*	*Latitude*	*Elevation (m above MHW)*
16521	unnamed	-166.56	53.60	1.219200
16522	unnamed	-166.45	53.63	4.572000
16522	unnamed	-166.18	53.73	2.133600
16522	unnamed	-166.17	53.74	13.71600
16522	unnamed	-166.15	53.77	8.839200
16522	unnamed	-166.12	53.77	1.828800
16522	Inner Signal	-166.09	53.79	38.4
16522	Outer Signal	-166.05	53.80	9.1
16522	Outer Signal	-166.04	53.80	3
16522	unnamed	-166.09	53.84	23.77440
16522	unnamed	-166.05	53.86	47.853600
16522	unnamed	-166.12	53.86	38.100000
16522	Round Island	-166.39	53.77	41.452800
16522	unnamed	-166.35	53.86	1.8288000
16528	unnamed	-166.29	53.87	12.192000
16528	unnamed	-166.22	53.90	15.849600
16528	unnamed	-166.21	53.91	15.240000
16528	unnamed	-166.21	53.92	25.908000
16528	unnamed	-166.20	53.90	6.7056000
16528	unnamed	-166.23	53.94	4.572000
16528	unnamed	-166.15	53.95	3.962400
16528	unnamed	-166.18	53.96	30.48000
16528	unnamed	-166.19	53.96	1.219200
16528	unnamed	-166.20	53.97	2.438400
16528	unnamed	-166.20	53.98	7.924800
16528	unnamed	-166.19	53.99	5.181600
16528	unnamed	-166.17	53.99	5.486400
16528	unnamed	-166.18	54.00	12.192000
16528	unnamed	-166.18	54.00	32.308800
16528	unnamed	-166.25	53.93	2.133600
16528	unnamed	-166.25	53.94	0.609600
16528	unnamed	-166.28	53.98	20.421600
16528	unnamed	-166.31	53.97	31.089600
16528	unnamed	-166.36	53.98	13.716000
16528	Priest Rock	-166.38	54.01	62.179200
16528	Princess Head	-166.41	53.98	65.227200
16528	Second Priest Rock	-166.47	53.90	22.860000
16528	Needle Rock	-166.53	53.92	20.421600
16528	unnamed	-166.59	53.96	27.432000
16528	unnamed	-166.62	54.00	6.096000
16528	unnamed	-166.65	54.01	16.764000
16530	unnamed	-166.60	53.83	6.096
16530	unnamed	-166.60	53.83	7.62
16530	unnamed	-166.61	53.84	35.3568
16530	unnamed	-166.60	53.84	20.726400
16530	unnamed	-166.60	53.84	19.202400

3.2 Establishing Common Datums

3.2.1 Vertical datum transformations

Datasets used in the compilation and evaluation of the Dutch Harbor DEM were originally referenced to a number of vertical datums including: Mean Lower Low Water (MLLW), Mean Sea Level (MSL), WGS84/EGM96 Geoid, and North American Vertical Datum of 1929 (NGVD29). All datasets were transformed to MHW to provide the worst case scenario for inundation modeling.

1) **Bathymetric data**

   The NOS survey data were transformed from MLLW to MHW (see Table 10) using FME. Multibeam data were inferred to be relative to MSL and were also transformed using FME (see Section 3.3.3).

2) **Topographic data**

   The NED and SRTM DEMs were originally in NGVD29 and WGS84/EGM96 Geoid vertical datums, respectively. There are no survey markers anywhere in the vicinity of Dutch Harbor that relate these two geodetic datums to the local tidal datums. Thus, it was assumed out of necessity that both datums are essentially equivalent to MSL in this area (Table 10). Conversion to MHW, using FME software, was accomplished by adding a constant value of -0.376 meters. Land elevations taken from the ENCs and NOAA nautical charts were already referenced to MHW.

Table 10. Relationship between Mean High Water and other vertical datums in the Dutch Harbor region.*[3]

Vertical datum	*Difference to MHW*
MTL	-0.364
MSL	-0.376
NGVD29+	-0.376
WGS84 Geoid+	-0.376
MLW	-0.728
MLLW	-1.011

* Datum relationships determined by tidal station at Dutch Harbor, Alaska.
+ Assumed to be equivalent to MSL.

3.2.2 Horizontal datum transformations

Datasets used to compile the Dutch Harbor DEM were originally referenced to Unalaska, NAD27, NAD83, and WGS84 horizontal datums. The relationships and transformational equations between these horizontal datums are well established, with the exception of the Unalaska datum. The transformation from the early Unalaska datum to NAD83 was computed by Dave Doyle, National Geodetic Survey (see Appendix A). All data were converted to a horizontal datum of WGS84 using FME software.

3. The Dutch Harbor, Aleutian Islands region of Alaska has anomalous relative sea-level trends compared to most other geographic regions in the United States. This is due to a general uplift of the land in the area, which has been occurring at a rapid rate. Because of the magnitude of the sea level trends in these areas, NOAA has adopted a procedure for computing accepted tidal datums for the National Water Observation Network (NWLON) using the last several years of sea level data rather than the 19-year tidal epoch. The tide ranges are still based on the 1983–2001. National Tidal Datum Epoch (NTDE) and are applied to the five year (1997–2001) Mean Tide Level (MTL) to compute other tidal datums. The adoption of this procedure was necessary to ensure that these tidal datums accurately represent the existing stand of sea level. [Extracted from NGS bench mark sheet #9462620]

3.3 Digital Elevation Model Development

3.3.1 Verifying consistency between datasets

After horizontal and vertical transformations were applied, the resulting ESRI shape files were checked in ESRI ArcMap for inter-dataset consistency. Problems and errors were identified and resolved before proceeding with subsequent gridding steps; the quality-assessed ESRI shape files were then converted to xyz files in preparation for gridding. Problems included:

- Data values over the open ocean in the NED and SRTM topographic DEMs. Each dataset required automated clipping of the erroneous values and visual inspection and comparison of remaining offshore values with the combined coastline, NOAA nautical charts and *Google Earth* satellite imagery to determine their reliability.
- Offsets between various incomplete coastline datasets. Data from multiple sources were required to build the most accurate coastline.
- Multiple near-shore rocks and islands did not exist in any dataset and had to be manually digitized for inclusion in the DEM.

3.3.2 Smoothing of sparse NOS data

The NOS hydrographic surveys are generally sparse at the resolution of the 1 arc-second (30 meter) grid: in deep water, the NOS survey data had point spacings up to 5 kilometers apart. In order to reduce the effect of artifacts in the form of lines of "pimples" in the DEM due to this low resolution dataset, and to provide effective interpolation into the coastal zone, a 3 arc-second-spacing (~90 meter) 'pre-surface' or grid was generated using GMT, an NSF-funded share-ware software application designed to manipulate data for mapping purposes (http://gmt.soest.hawaii.edu/).

The NOS point data were first combined into a single file, along with points extracted every 90 meters from the combined coastline—to provide a "zero" buffer along the entire coastline. These point data were then smoothed using the GMT tool 'blockmedian' onto a 3 arc-second grid 0.05 degrees (~5%) larger than the Dutch Harbor grid region. The GMT tool 'surface' then applied a tight spline tension to interpolate cells without data values; 'surface' does not support a data hierarchy (see Section 3.3.4). The GMT grid created by 'surface' was converted into an Arc ASCII grid file using the MB-System tool 'mbm_grd2arc'. Conversion of this Arc ASCII grid file into an Arc raster permitted clipping of the grid by the combined-coastline polygon (to eliminate data interpolation into land areas). The resulting surface was compared with the original soundings to ensure grid accuracy (e.g., Fig. 14), converted to a shape file, and then exported as an xyz file for use in the final gridding process.

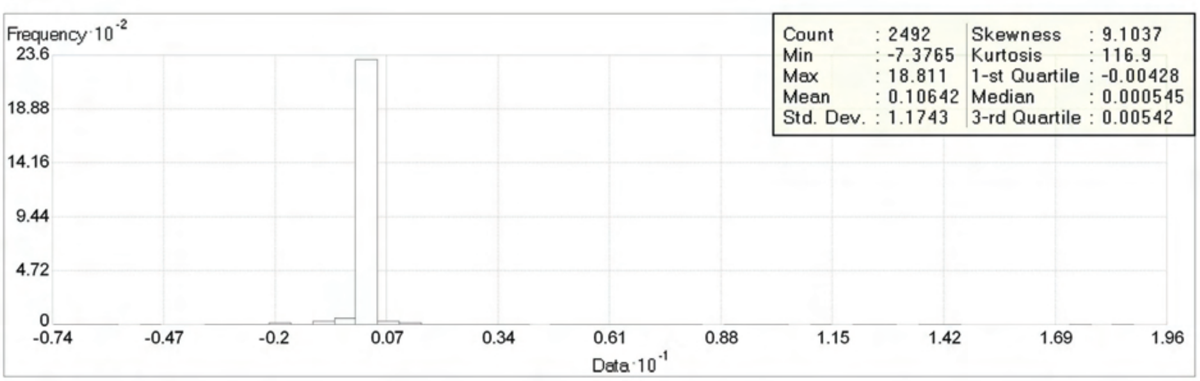

Figure 14. *Histogram of the difference between NOS soundings for survey H06234 (relatively dense survey on northwest flank of Unalaska Island) and the NOS pre-surface grid. The greatest differences derive from the averaging of multiple, closely-spaced soundings in shallow areas with highly variable relief.*

One interesting type of anomaly in the pre-surfaced NOS grid is isolated pits and peaks along the flanks of the islands. The NOS grid is consistent with the original soundings taken from the NOS hydrographic surveys, however, the surveys simply do not have enough resolution to capture detailed submarine relief. The coastal zone of the Aleutian Chain is known to have rugged topography that is hazardous to navigation, and it is expected that such relief continues into the deeper water. Figure 15 illustrates how the sparseness of the NOS soundings fails to define what is probably a submarine canyon on the northwest flank of Unalaska Island—as the movement of sediment at the coast would rapidly fill any near-shore pits. It is doubtful that any computerized gridding algorithm could faithfully represent linear features such as submarine canyons from sparse point data. Thus, the pre-surfaced NOS grid, and the resulting Dutch Harbor DEM contain assorted pits and peaks (1-dimensional features) that are more likely parts of poorly resolved two-dimensional features, but nevertheless are consistent with available bathymetric data. Higher-resolution near-shore bathymetric surveys are necessary to accurately characterize these 2-D features and ensure their representation in future DEMs.

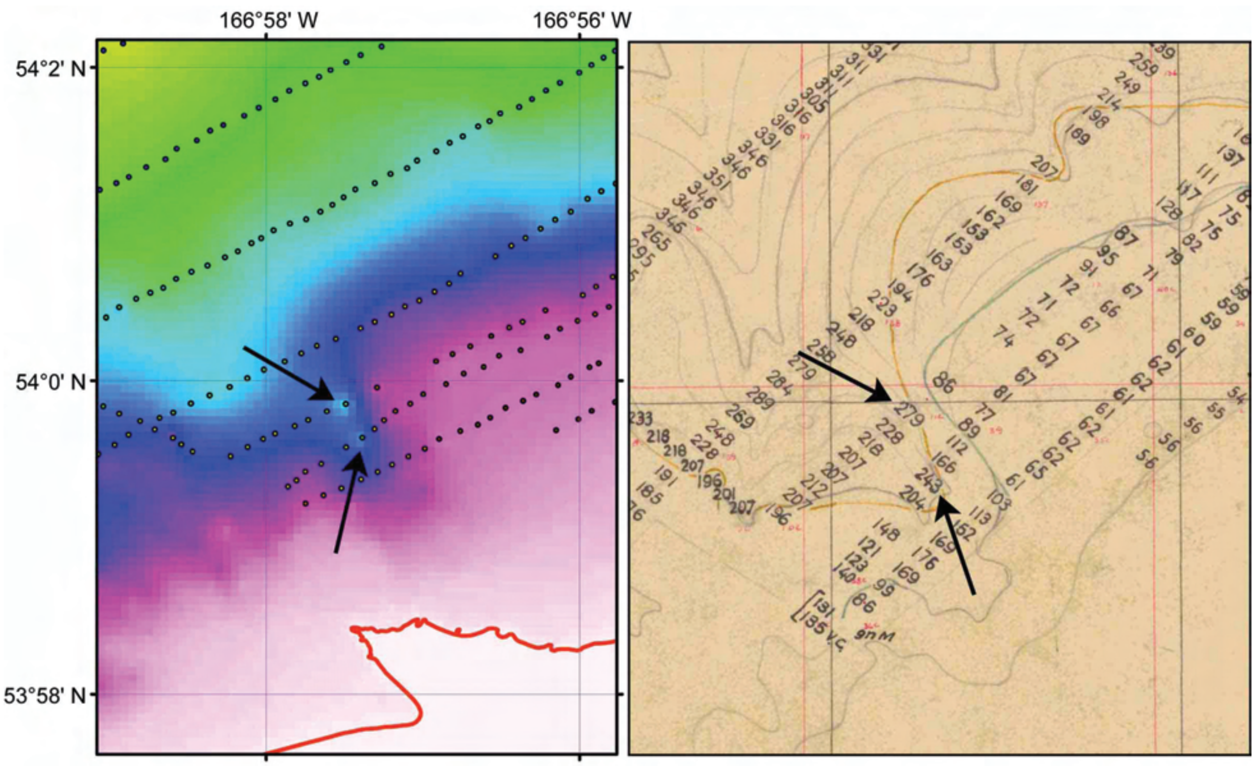

Figure 15. Failure of sparse NOS hydrographic soundings to capture rugged seafloor relief. Left panel shows pits (light blue, arrows) in the pre-surfaced NOS grid along what is likely a submarine canyon on the northwest flank of Unalaksa Island. Right panel is corresponding image taken from NOS smooth sheet for survey H06233. A hint of the canyon is identifiable in the corresponding soundings (arrows), and in the hand-drawn bathymetric contours, however, GMT is incapable of accurately representing this feature with the sparse NOS soundings available. Soundings in right panel are in fathoms referenced to MLLW. Note registration marks for both Unalaska (black lines) and NAD27 (red lines).

3.3.3 Pre-gridding of multibeam swath sonar data

The multibeam swath sonar data, inferred to be in MSL vertical datum, were pre-gridded using the MB-System tool ‘mbgrid’. MB-System (http://www.ldeo.columbia.edu/res/pi/MB-System/) is an NSF-funded share-ware software application specifically designed to manipulate submarine multibeam sonar data, though it can utilize a wide variety of data types, including generic xyz data. This pre-gridding was necessary to permit vertical datum shift to MHW, a function that is not supported in MB-System. Data were pre-gridded to 1 arc-second cell-size (~30 meters) then exported to ArcGIS using the MB-System tool ‘mbm_grd2arc’. The resulting Arc ASCII file was converted to an Arc raster in ArcCatalog, then converted again to an ESRI shape file and shifted to MHW using FME. The resulting point data were consistent with overlapping NOS hydrographic soundings, though providing significantly greater seafloor resolution.

3.3.4 Gridding the data with MB-System

All processed xyz files were gridded using MB-System (http://www.ldeo.columbia.edu/res/pi/MB-System/). The MB-System tool 'mbgrid' was used to create the Dutch Harbor DEM—a modeled surface draping the point data—of weighted sounding and topographic point data, using a tight spline tension to interpolate cells without data values. The data hierarchy used in the 'mbgrid' gridding algorithm as relative gridding weights is listed in Table 11. Greatest weight was given to the surveyed land elevation points extracted from the ENCs and digitized by NGDC from NOAA nautical charts. Least weight was given to the pre-surfaced NOS grid.

Table 11. Data hierarchy used to assign gridding weight in MB-System.

Dataset	*Relative Gridding Weight*
ENC land elevation points	100
NASA SRTM topographic DEM	10
USGS NED topographic DEM	1
Combined coastline	10
Multibeam swath sonar bathymetry grid	10
NOS hydrographic surveys: soundings	1
NOS hydrographic surveys: gridded	0.01

3.4 Quality Assessment of the DEM

3.4.1. Horizontal accuracy

The digital elevation model has an estimated horizontal accuracy of no better than 30 meters for topographic features. Bathymetric features are resolved only to within a few tens to a few hundred meters in deep-water areas; shallow, near-coastal regions have an accuracy approaching the subaerial topographic features. Bathymetric positional accuracy is limited by the sparseness of deep-water soundings, and potentially large positional accuracy of pre-satellite navigated (GPS) hydrographic surveys.

3.4.2 Vertical accuracy

The Dutch Harbor DEM has an estimated vertical accuracy of between 10 and 15 meters for topographic areas, and 0.3 meters to 5% of water depth for bathymetric areas, depending upon source dataset. Topographic values are derived from the USGS NED DEM, which have an estimated vertical accuracy between 7 and 15 meters, and the SRTM DEM, which have a vertical accuracy better than 16 meters but are typically about 10 meters. Bathymetric values are derived from a wide range of input data, consisting of single and multibeam sounding measurements from the early 20^{th} centuries to recent: modern NOS standards are 0.3 m in 0–20 m of water, 1.0 m in 20–100 m of water, and 1% of the water depth in 100 m of water. Gridding interpolation to determine bathymetric values between sparse, poorly located NOS soundings degrades the vertical accuracy of elevations in deep water.

3.4.3 Slope maps and 3-D perspectives

ESRI ArcCatalog was used to generate a slope grid from the Dutch Harbor DEM to allow for visual inspection and identification of artificial slopes along boundaries between datasets (Fig. 16). The DEM was transformed to UTM Zone 3 coordinates (horizontal units in meters) in ArcCatalog for derivation of the slope grid; equivalent horizontal and vertical units are required for effective slope analysis. Three-dimensional viewing of the UTM-transformed DEM (e.g., Fig. 17) was accomplished using ESRI ArcScene. Analysis of preliminary grids revealed suspect data points, which were corrected before regridding the data. Edge effects are visible along the margins of the multibeam swath sonar data, where they abut the sparse NOS hydrographic data: this is due to the pre-surfacing of each dataset, but is not a significant submarine DEM feature.

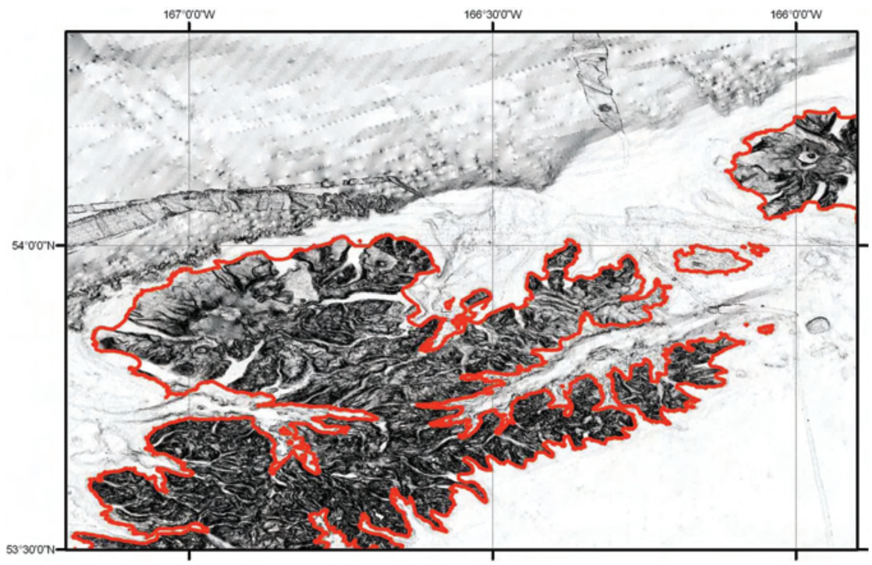

Figure 16. *Slope map of the 1 arc-second Dutch Harbor DEM. Flat-lying slopes are white; dark shading denotes steep slopes; combined coastline in red.*

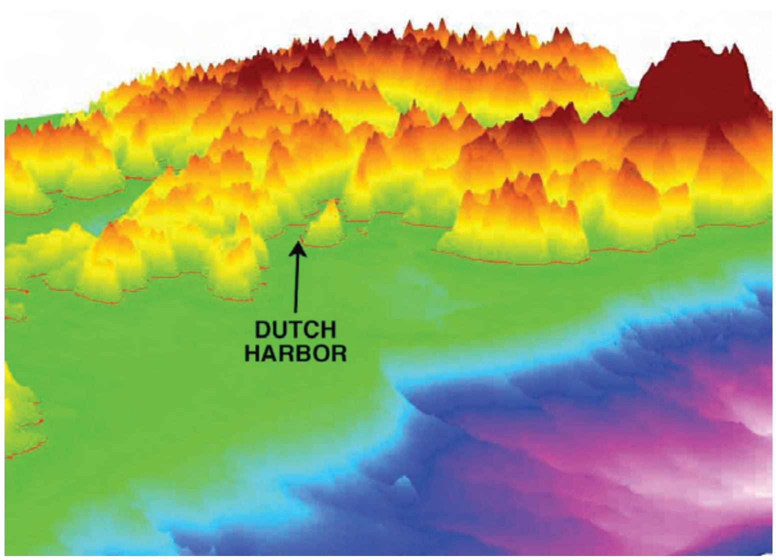

Figure 17. *Perspective view from the northeast of the Dutch Harbor DEM. Combined coastline in red; vertical exaggeration–times 5.*

3.4.4 Comparison with source data files

To ensure grid accuracy, the Dutch Harbor DEM was compared to select source data files. Files were chosen on the basis of their contribution to the grid-cell values in their coverage areas, i.e., had the greatest weight and did not overlap other data files with comparable weight. A histogram of the comparison of the multibeam swath bathymetry data with the Dutch Harbor DEM is shown in Fig. 18.

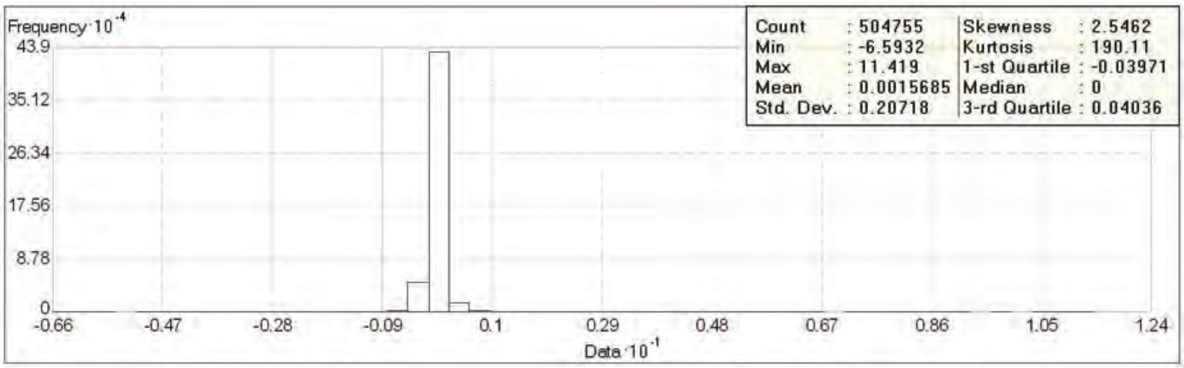

Figure 18. *Histogram of the difference between the multibeam swath bathymetry data and the Dutch Harbor DEM.*

3.4.5 Comparison with NOAA tidal stations

The National Geodetic Survey (NGS) data sheets for U.S. tidal stations (http://tidesandcurrents.noaa.gov/) document benchmark elevations, in meters above MHW, allowing for direct comparison with DEM values at those locations. There is only one tidal station lying within the Dutch Harbor study area, which was compared with the value taken at the same locale from the 1 arc-second (~30 meter) Dutch Harbor DEM (see Fig. 1 and Table 12 for station location). The station has multiple benchmark stampings, all of which have the same geographic position, recorded to within 6 arc-seconds (~180 meters). The description of the location of one of its benchmark stampings, however, places it along the fence on the northeast side of the Holy Ascension Russian Orthodox Church in Unalaska. That location (53°52′35″ N, 166°32′14″ W, taken from the USGS topographic quadrangle: http://www.topozone.com) has a DEM value of 1.484 meters, which compares favorably with the bench mark's elevation of 2.333 meters (Table 12).

Table 12. Comparison of NOAA tidal benchmark elevation, in meters above MHW, with the Dutch Harbor DEM.

Station number	*Station name*	*Year*	*Longitude*	*Latitude*	*Bench mark*	*DEM*	*Difference*
9462620	DUTCH HARBOR	1982	166°32′14″ W	53°52′35″ N	2.333	1.484	-0.849

3.4.6 Comparison with USGS topographic elevations

USGS topographic elevations were extracted from online digital USGS topographic quadrangles (http://www.topozone.com), which give position and elevation in WGS84 and NGVD29 vertical datum (in feet). Elevations were converted to meters and shifted to MHW vertical datum (see Table 10) for comparison with the Dutch Harbor DEM (see Fig. 1 for station locations). Positional accuracy is to within .0002 degrees (~22 meters). Significant differences exist between the Dutch Harbor DEM and the USGS topo elevations: from -101 to 19 meters, with a negative value indicating that the DEM is less than the topo elevation (Fig. 19). Much of the difference results from horizontal offsets between the positional information taken from the online quadrangles, and the corresponding feature in the DEM. Such offsets range up to 75 meters, though not in any consistent direction. The values of the topo elevations and the corresponding DEM feature, typically local highs, are often within about 10 meters. These differences may be attributable to the fact that the SRTM and NED topographic data represent averages of land elevations over 30 × 30 meter, and 60 × 60 meter square areas, respectively, while the topo elevations represent maximum heights.

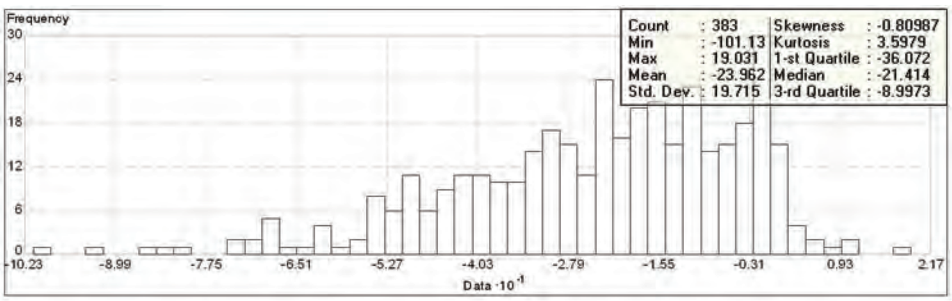

Figure 19. *Histogram of the difference between the USGS topo elevations and the Dutch Harbor DEM. The pronounced negative values (DEM less than topo elevations) results partly from horizontal offsets of features, typically local highs, but may also result from comparing average elevation over an area with a local maximum.*

4. SUMMARY AND CONCLUSIONS

A topographic/bathymetric digital elevation model with cell spacing of 1 arc-second (~30 meters) of the Dutch Harbor, Alaska area was developed for the Pacific Marine Environmental Laboratory (PMEL), NOAA Center for Tsunami Research. The best available data from U.S. federal and state agencies were obtained for grid compilation. The data were quality checked, processed and gridded using ESRI ArcGIS, FME, GMT, and MB-System software.

Recommendations to improve the DEM based on NGDC's research and analysis are listed below:

- Conduct bathymetric LiDAR surveys of the near-shore areas within the Dutch Harbor region to accurately incorporate tsunami-influencing offshore rocks and shoals.
- Obtain digital versions of several NOAA nautical charts (#16522, 16528, 16529, 16530) that have not yet been digitized.
- Establishment, via survey, of the relationships between tidal and geodetic datums in the Dutch Harbor region.

5. ACKNOWLEDGMENTS

The creation of these grids was funded by the NOAA, Pacific Marine Environmental Laboratory. The authors thank Chris Chamberlin, Angie Venturato, and Hal Mofjeld (PMEL), Dave Doyle (National Geodetic Survey), Bret Christensen (U.S. Fish and Wildlife Service), and David Scharff (NOS).

6. References

Nautical Chart #16522, 5th Edition, 1992. Unalaska Island—Beaver Inlet. Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #16528, 15th Edition, 1992. Unalaska Bay and Akutan Pass. Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #16529, 14th Edition, 1994. Unalaska Island—Dutch Harbor. Scale 1:10,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #16530, 6th Edition, 1996. Unalaska Island—Captains Bay. Scale 1:10,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

S.M. Carbotte, R. Arko, D.N. Chayes, W. Haxby, K. Lehnert, S. O'Hara, W.B.F. Ryan, and R.A. Weissel, Lamont-Doherty Earth Observatory, Palisades,N.Y.; T. Shipley, L.Gahagan, and K. Johnson, University of Texas Institute for Geophysics,Austin; and T. Shank, Woods Hole Oceanographic Institution, Mass. New Integrated Data Management System for Ridge2000 and MARGINS Research, Eos, Vol. 85, No. 51, 21 December 2004, http://www.marine-geo.org

U.S. Geological Survey, Alaska topographic quadrangles. Scale 1:63,360. TopoZone, http://www.topozone.com

7. Data Processing Software

ArcGIS v. 9.1, developed and licensed by ESRI, Redlands, California, http://www.esri.com/

Electronic Navigational Chart Data Handler for ArcView, developed by NOAA Coastal Services Center, http://www.csc.noaa.gov/products/enc/

FME 2006 GB – Feature Manipulation Engine, developed and licensed by Safe Software, Vancouver, BC, Canada, http://www.safe.com/

GMT v. 4.1.1 – Generic Mapping Tools, shareware developed and maintained by Paul Wessel and Walter Smith, funded by the National Science Foundation, http://gmt.soest.hawaii.edu/

MB-System v. 5.0.9, shareware developed and maintained by David W. Caress and Dale N. Chayes, funded by the National Science Foundation, http://www.ldeo.columbia.edu/res/pi/MB-System/

APPENDIX A. COMPUTATION OF UNALASKA TO NAD83 HORIZONTAL DATUM SHIFT

Computation of the shift from Unalaska horizontal datum to the North American Datum of 1983 (NAD83) was performed by Dave Doyle, National Geodetic Survey (NGS). The National Geophysical Data Center (NGDC) supplied NGS with the Unalaska datum position of survey control points taken from multiple National Ocean Service (NOS) smooth sheets in the Dutch Harbor region. NGS confirmed the contemporary NAD 83 values for these points by searching the data maintained in the National Spatial Reference System and extracting the NAD 83 position information for 10 of these control points. The average shift over the survey region was determined by subtracting the NAD 83 latitudes and longitudes from the Unalaska positions, which yielded a change of -2.191 arc-seconds of longitude, and -6.081 arc-seconds of latitude (Table A-1). This average shift was then applied to all NOS hydrographic surveys that had been digitized in the Unalaska datum.

Table A-1. Computation of Unalaska to NAD83 horizontal datum shift.

DUTCH HARBOR, AK UNALASKA DATUM TO NORTH AMERICAN DATUM OF 1983 (1986)					
Computation by: David Doyle, National Geodetic Survey (July, 2006)					
Source Data: Unalaska Datum -- NGS Archive #370-96-0291, Box 6					
Source Data: NAD 83 -- National Spatial Reference System					
Latitude Shift, UNALASKA DATUM to NAD 83 (1986) (seconds)				-6.081	
Latitude Shift, UNALASKA DATUM to NAD 83 (1986) (meters)				-188.05	
Latitude Shift, Standard Deviation (seconds)				0.088	
Latitude Shift, Standard Deviation (meters)				2.73	
Longitude Shift, UNALASKA DATUM to NAD 83 (1986) (seconds)				-2.191	
Longitude Shift, UNALASKA DATUM to NAD 83 (1996) (meters)				-38.75	
Longitude Shift, Standard Deviation (seconds)				0.037	
Longitude Shift, Standard Deviation (meters)				0.65	
PID	**STATION**	**NAD 83 D/M**	**NAD 83 S**	**UNAK S**	**Diff S**
UV9341	BOLD 1896	53 52	43.15389	49.164	-6.010
		166 34	36.03659	38.235	-2.198
UV9132	BRIDGE 1901	53 59	33.31155	39.487	-6.175
		166 02	52.61265	54.744	-2.131
UW0110	CEMENT 1901	54 07	18.45465	24.630	-6.175
		166 07	2.74326	5.005	-2.262
UV9362	GRASS 1896	53 49	49.95154	55.942	-5.990
		166 35	39.22776	41.436	-2.208
UW0117	KALEKLITA 1901	54 00	16.45973	22.540	-6.080
		166 22	33.77588	35.954	-2.178
UV9343	OBER 1896	53 51	21.98633	27.987	-6.001
		166 33	48.19981	50.393	-2.193
UW0115	TRIPLET 1901	54 02	25.44180	31.638	-6.196
		166 03	1.96702	4.150	-2.183
UV9308	UNALASKA SOUTH BASE	53 53	51.53100	57.550	-6.019
		166 30	53.30916	55.480	-2.171