NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT VA1408-TB-C

Cape Charles, Virginia to Delaware Bay, Delaware

Introduction

NOAA Coastal Mapping Program (CMP) Project VA1408-TB-C provides a highly accurate database of new digital shoreline data for a portion of the Eastern Coastline of the United States extending from Cape Charles, Virginia northward to the Delaware Bay, in Delaware. The approximate bounding coordinates of the project are 37°04' to 38°58' north latitude, and 75°00' to 76°00' west longitude. VA1408-TB-C is part of a larger topographic/bathymetric lidar mapping initiative to provide updated shoreline data from Winyah Bay, South Carolina to Montauk, New York, in the wake of Hurricane Sandy.

Successful completion of this project resulted in a densification of the National Spatial Reference System, a set of controlled metric-quality aerial photographs, lidar point cloud data, and digital feature data of the coastal zone which complements the Nautical Charting Program as well as geographic information systems (GIS) for a variety of coastal zone management applications.

The project database consists of information measured and extracted from aerial lidar data and digital imagery, and metadata related to shoreline extraction and derivation. Base mapping was conducted within both digital GIS and stereo softcopy photogrammetric environments using associated cartographic practices supplemented with lidar derived Mean High Water (MHW) and Mean Lower Low Water (MLLW) contour data.

Project Design

VA1408-TB-C was designed to support:

1) Application of topographic/bathymetric (topobathy) data acquired under the Sandy Supplemental Topo-Bathy project at the National Geodetic Survey (NGS),
2) Chart update activity of the Marine Chart Division (MCD),
3) Bathymetric data assessment by the Hydrographic Surveys Division (HSD).

The NOAA National Geodetic Survey (NGS) formulated the Project Instructions for this project following the guidelines of the "Scope of Work, Shoreline Mapping for the Coastal Mapping Program" (SOW), Version 14A, dated October 24, 2012. The instructions discussed the project's purpose, geographic area of coverage, scope and priority; data acquisition, processing, accuracy, and compilation requirements; product delivery and reporting instructions; and contact and communication information.

Field Operations

The field operations for VA1408-TB-C consisted of acquisition of topobathy lidar data, digital aerial imagery, static and kinematic GPS data, and Inertial Measurement Unit (IMU) data. Static

GPS data were collected to support aerial data acquisition and processing operations, as well as to assess the accuracy of post-processed lidar data.

Lidar Data Acquisition
The topobathy lidar acquisition was conducted from November 11, 2013 through July 27, 2014 and consisted of a total of 262 lidar acquisition missions for airborne laser point cloud data. Lidar was captured with an approximate nominal point density of ≥ 4 pulses per square meter through the use of the Riegl VQ-820G sensor. The data were collected within a +/- 2 hour time window of the Mean Lower Low Water (MLLW) tide stage at a nominal altitude of 1,000 feet with a 50% swath overlap.

Digital Aerial Imagery Acquisition
The digital imagery acquisition for VA1408-TB-C was conducted from January 1, 2014 through April 20, 2014 and consisted of a total of eighteen (18) flight lines of natural color imagery, tide coordinated within 25% of the mean range. Imagery was captured at a nominal altitude of 10,000 feet with a ground sample distance (GSD) of 0.30 meters through the use of three large-format Intergraph *Z/I Imaging* Digital Mapping Cameras (DMC) with focal lengths of 120 mm.

Ground Control
A total of fifty-three (53) ground control points were established in the VA1408-TB-C project area using a combination of traditional static, fast-static, rapid-static, real-time kinematic, and post processed kinematic GPS techniques. Survey field work was performed between November 23, 2013 and June 03, 2014. A Ground Survey Report is on file with other project data within the NGS Remote Sensing Division (RSD) Electronic Data Library.

GPS Data Processing

Acquisition aircraft were equipped with either an Applanix POSAV Model 510 IMU and/or a dual-frequency Trimble BD960 to collect the ABGPS and IMU data. NGS CORS, and several Cooperative CORS stations, were used for base stations on the project, with at least two of these CORS stations being used to process each POSAV dataset to achieve the final photo center locations. For further information refer to the Airborne Positioning and Orientation Report (APOR) on file with other project data within the RSD Electronic Data Library.

Lidar Data Processing

LIDAR point cloud data for all of the areas acquired under the Sandy Supplemental Topo-Bathy project were processed from January 2014 to September 2015 using the following steps:

1) Riegl RiProcess software was utilized to transform the lidar point cloud into a mapping projection and check the calibration stability.
2) Terrasolid software was utilized for assessing relative and absolute accuracies between overlapping lifts and relative with each lift, initial point cloud classification, editing of the lidar point cloud, and for classification of water surface, erroneous returns, bathymetric surface and bare earth points.
3) Refraction correction was performed through Dewberry's Lidar Processor
4) Additional QC, point classification, and formatting were performed with GeoCue, Terrasolid, and Global Mapper Software.

5) NOAA VDatum software was used to convert the vertical datum of the lidar points from NAD83 ellipsoid to local MHW and MLLW tidal datums.
6) QTModeler and custom ArcGIS Scripts were used to produce bare earth MHW and MLLW digital elevation models (DEMs) at a 1 meter grid resolution and the extraction and formatting of MHW and MLLW Shoreline Shapefiles
7) Accuracy Assessment: the lidar point cloud was compared to higher accuracy ground control points to determine vertical uncertainties of the data set, and then compared to the morphologic slope around the derived shoreline at 91,460 sample sites in the project area (63,748 MHW and 27,712 MLLW sites) to determine the uncertainty of the vectors. Based on this assessment:
    a. MHW lidar derived shoreline vectors meet a horizontal accuracy ranging from 1.06 to 2.77 meters at 95% CE,
    b. MLLW lidar derived shoreline vectors meet a horizontal accuracy ranging from 1.28 to 4.20 meters at 95% CE.

The journal article "Lidar-Derived National Shoreline: Empirical and Stochastic Uncertainty Analyses" (2010), published in the Journal of Coastal Research, contains more detailed information, and is on file in the RSD Electronic Data Library.

Aerotriangulation

The aerotriangulation (AT) phase of the project was performed using digital AT methods to establish the network of photogrammetric control required for the compilation phase. The Intergraph ImageStation Automatic Triangulation (ISAT) software (ver. 6.1) was used to perform automatic point measurements and interactive point measurements of tie points. The imagery for the overall Sandy Supplemental Topo-Bathy project was aerotriangulated in three separate blocks. All the imagery for project VA1408-TB-C was included in Block 2.

The Root Mean Square (RMS) of the standard deviations in both X and Y directions were calculated and used to determine a predicted horizontal circular error at the 95% confidence level of 0.30 meters. An AT Report is on file with other project data within the RSD Electronic Data Library. The project database consists of project parameters and options, camera calibration data, interior orientation parameters, ground control parameters, adjusted exterior orientation parameters, and positional listing of all measured points. Positional data is referenced to the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD88).

Compilation

The data compilation phase of this project was completed in August 2015 and accomplished in two phases: 1) Automated extraction from topo-bathy lidar, and 2) manual extraction using digital stereo imagery.

1) Lidar Shoreline approach: MHW and MLLW shoreline vectors (in shapefile format) for the outer coastline were delineated using the DEMs discussed above (LiDAR processing section) along with a Raster-to-Vector (R2V) script implemented within ESRI ArcGIS 10.2 software. Subsequently, digital orthoimagery and/or stereoscopic imagery were used to review, edit, and attribute the lidar shoreline vectors. The lidar derived shoreline data were limited to terrain features at the land/water interface and did not include

engineered, elevated features such as bulkheads, piers, bridges, landmarks, etc. The MHW ("Shoreline") and MLLW ("Contour") shape files were then imported into BAE Systems SOCET SET (SS) software (version 5.6.0), and a Feature Database (FDB) was created.

2) Manual Compilation approach: The manual data compilation phase was accomplished using a Digital Photogrammetric Workstation (DPW), which consists of a stereo-enabled PC-based graphics workstation running the Windows 2007 operating system and SOCET SET suite of digital photogrammetric software (version 5.6.0). The FDB, created above, was populated with additional features compiled using the SS Feature Extraction software module based on imagery analysis of the processed digital images and information extracted from the appropriate NOAA Nautical Charts, the U.S. Coast Guard Light List and other ancillary sources. Feature attribution was assigned in compliance with the Coastal Cartographic Object Attribute Source Table (C-COAST), which provides the definition and attribution scheme for the full range of cartographic features pertinent to the CMP. Selected features were further modified with additional descriptive information to refine general classification. Features compiled using this method meet a horizontal accuracy of 0.6 meters at the 95% confidence level. This accuracy is derived by doubling the 95% CE computed from the AT.

The following table provides information on the imagery used to complete this project:

Date	Time (UTC)	Flight Line	Photo #s	GSD (Nominal)	Tide Level*
01/01/2014	16:57:51 – 17:00:23	30207	0001 – 0016	0.30 m	-0.1 m
01/01/2014	17:08:40 – 17:19:22	30208	0001 – 0059	0.30 m	-0.1 m
01/01/2014	17:24:04 – 17:35:09	30209	0001 – 0055	0.30 m	-0.1 m
01/01/2014	17:46:32 – 17:52:59	30205	0072 – 0113	0.30 m	0.0 m
01/12/2014	15:05:57 – 15:12:38	30200	0001 – 0035	0.30 m	0.2 m
01/12/2014	15:18:07 – 15:30:51	30201	0001 – 0069	0.30 m	0.2 m
01/12/2014	15:36:40 – 15:51:06	30203	0001 – 0075	0.30 m	0.1 m
01/12/2014	16:05:25 – 16:12:46	30206	0001 – 0040	0.30 m	0.1 m
02/27/2014	17:20:04 – 17:30:45	30205	0001 – 0071	0.30 m	-0.1 m
04/09/2014	15:41:44 – 15:43:10	30217	0001 – 0011	0.30 m	0.3 m
04/09/2014	15:46:57 – 15:48:28	30216	0001 – 0014	0.30 m	0.3 m
04/09/2014	15:53:29 – 15:57:10	30215	0001 – 0031	0.30 m	0.3 m
04/09/2014	16:00:46 – 16:04:58	30214	0001 – 0031	0.30 m	0.4 m
04/09/2014	16:09:48 – 16:12:23	30213	0001 – 0023	0.30 m	0.4 m
04/09/2014	16:15:54 – 16:18:07	30212	0001 – 0017	0.30 m	0.4 m
04/09/2014	16:22:18 – 16:25:26	30211	0001 – 0028	0.30 m	0.4 m
04/09/2014	16:29:07 – 16:32:22	30210	0001 – 0024	0.30 m	0.4 m

04/20/2014	20:43:01 – 20:50:11	30204	0001 – 0056	0.30 m	0.6 m
04/20/2014	20:53:34 – 20:59:13	30202	0001 – 0042	0.30 m	0.6 m

* Water levels are given in meters above MLLW and are based on verified observations recorded by the NOS tide gauges at: Kiptopeke (Station ID: 8632200) and Wachapreague (Station ID: 8631044) in Virginia; Ocean City Inlet (Station ID: 8570283) in Maryland; and Lewes (Station ID: 8557380) in Delaware. The elevation of the MHW tidal datum along the outer coast in the project area varies between 0.8 – 1.3 m. above MLLW.

Quality Control / Final Review

Quality control tasks were conducted by RSD personnel and the final QC review was completed in January, 2016. The review process included analysis of AT results and assessment of the identification and attribution of digital feature data within the GC according to image analysis, using Stereo and Ortho-image data, and criteria defined in C-COAST. The quality control process concluded with an inspection of topological connectivity within the GC using ArcGIS 10.2 software. All project data was evaluated for compliance to CMP requirements.

Comparisons of the largest scale NOAA nautical charts with orthomosaics, natural color photographs and compiled project data resulted in creation of the Chart Evaluation File (CEF). The following nautical charts were used in the comparison process:

- 12210, Chincoteague Inlet to Great Machipongo Inlet, 1:80,000 scale, 40th Ed., Aug./15
- 12211, Fenwick Island to Chincoteague Inlet, 1:80,000 scale, 45th Ed., May/13
- 12214, Cape May to Fenwick Island, 1:80,000 scale, 49th Ed., Nov./10
- 12216, Cape Henlopen to Indian River Inlet, 1:40,000 scale, 29th Ed., Jun./12
- 12222, Chesapeake Bay, Cape Charles to Norfolk Harbor, 1:40,000 scale, 55th Ed., Feb./15
- 12224, Chesapeake Bay, Cape Charles to Wolf Trap, 1:40,000 scale, 26th Ed., Aug./14
- 12304, Delaware Bay, 1:80,000 scale, 47th Ed., Oct./14

End Products and Deliverables

The following specifies the location and identification of the products generated during the completion of this project:

Remote Sensing Division Electronic Data Library

- Ground Control Report
- Airborne Positioning and Orientation Reports (APOR)
- Aerotriangulation Report
- Project Completion Report (PCR)
- Project database
- GC11174 in shapefile format
- Chart Evaluation File (CEF) in shapefile format

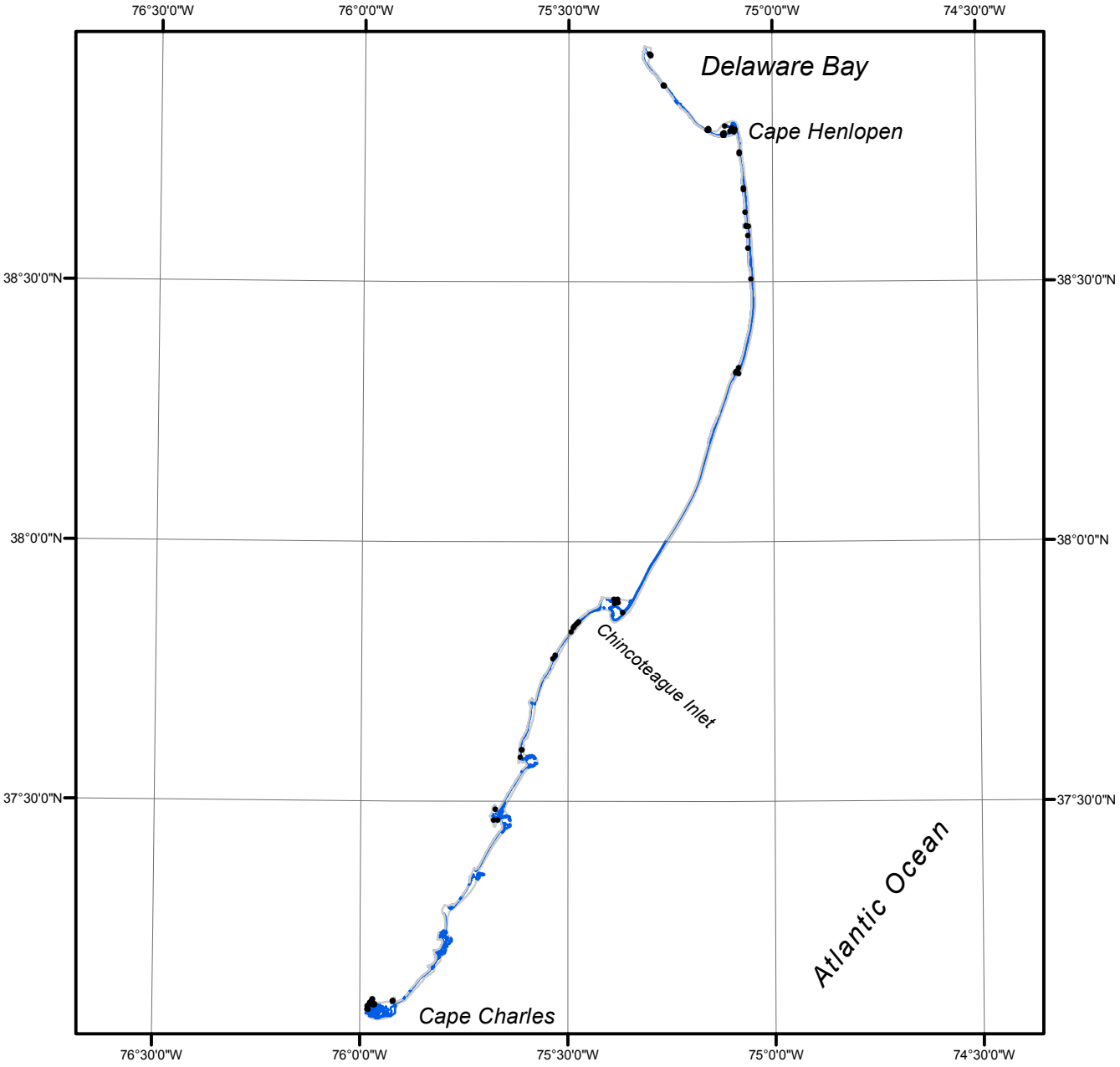
NOAA Shoreline Data Explorer

- GC11174 in shapefile format
- Metadata file for GC11174
- Digital copy of the PCR in Adobe PDF format

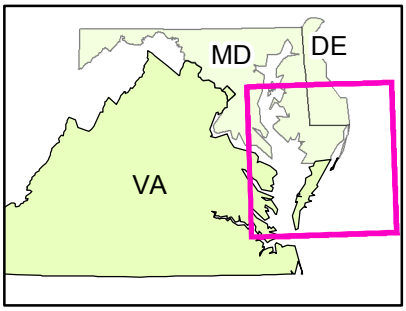
End of Report

CAPE CHARLES TO DELAWARE BAY

VIRGINIA, MARYLAND, AND DELAWARE



Overview



VA1408-TB-C

GC11174