NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT DE1401A-TB-C

Back Bays, Sinepuxent Bay to Cape Henlopen, Maryland and Delaware

Introduction

NOAA Coastal Mapping Program (CMP) Project DE1401A-TB-C provides a highly accurate database of new digital shoreline data for the back-bay side of coastline along the Eastern Shore of Maryland and Delaware, extending from Sinepuxent Bay to Cape Henlopen. Project DE1401A-TB-C is a subproject of a larger project, DE1401-TB-C, which includes portions of the back-bays and marshes, and some areas of outer coastline and harbors from Sinepuxent Bay, Maryland to Smyrna River, Delaware. The Geographic Cell (GC) may be used in support of the NOAA Nautical Charting Program (NCP) as well as geographic information systems (GIS) for a variety of coastal zone management applications.

Project Design

DE1401A-TB-C was designed to support the application of topographic and bathymetric (topo-bathy) data acquired under the Sandy Supplemental Topo-Bathy Project. The Remote Sensing Division (RSD) of 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, as well as the guidelines of the "Scope of Work for Shoreline Mapping In Support of Public Law No: 113-002, Disaster Relief Appropriations Act 2013, Light Detection and Ranging (LIDAR) and Digital Camera Imagery Requirements." 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 data for DE1401-TB-C were conducted as part of the Sandy Supplemental Topo-Bathy Project VA1408-TB-C, in which Quantum Spatial Inc. (QSI) was a subcontractor to Dewberry Consultants, LLC. For that project QSI was responsible for the planning, acquisition and post-processing of aerial imagery and LIDAR data to support photogrammetric processing and feature compilation. This included the establishment of ground control, the post-processing of airborne GPS data and calibration of the LIDAR data.

A total of twenty-four (24) ground control points were established in the DE1401A-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 2013 and June 2014. A Ground Survey Report is on file with other project data within the NGS Remote Sensing Division (RSD) Electronic Data Library.

The digital imagery acquisition for DE1401A-TB-C was conducted between January and June 2014 and consisted of two independent imagery collections: 1) the Sandy Supplemental collect, and 2) the State of Delaware collect.

For the Sandy Supplemental data, a total of five (5) flight lines of natural color imagery were collected and used in this project. This 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. The Sandy Supplemental imagery were acquired within a tolerance of 25% of the mean range of tide around the Mean Lower Low Water (MLLW) tide stage.

For the State of Delaware data, twenty-one (21) flight lines of natural color imagery were collected and used in this project. This imagery was captured at a nominal altitude of 3,000 feet with a GSD of 0.10 meters using the Intergraph Z/I DMC described above. The Delaware imagery was not acquired in coordination with any particular tide level.

The LIDAR acquisition was conducted between November 2013 and July 2014 and consisted of a total of 262 LIDAR acquisition missions for airborne laser point cloud data covering the entire Sandy project area with an average point density of ≥ 4 pulses per square meter and a 50% swath overlap, though only a subset of these flights collected data over the DE1401A-TB-C project area. Topo-bathy Green LIDAR and topographic Near-Infrared (NIR) LIDAR were captured in tandem through the use of three Riegl VQ-820G sensors (topo-bathy), and a Riegl 480 or two Leica ALS50-II (topographic) sensors. The topo-bathy data was used to derive the Mean High Water (MHW) and MLLW shorelines, while the NIR data was used as an aid to developing the water surface model necessary for applying refraction corrections to the topo-bathy data.

The flight lines on the ocean side were required to be collected twice, once within 20% of the mean range of tide around MLLW, and once within 30% of the mean range of tide around Mean High Water (MHW), but the flight lines on the estuarine side of the shoreline had no tide-coordination requirement. The contractor's plan for the project, however, called for all lines to be collected at both MLLW and Higher Water (HW – defined as everything not collected at MLLW) tide levels, with near-shore lines flown at a height of 600 meters above ground level (AGL) and lines over ocean waters at 300 m. AGL. For further information about all field operations see the Final Report of Survey on file within the 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 for the Sandy Supplemental Topo-Bathy Project were processed from January 2014 to September 2015. Riegl RiProcess software was utilized to transform the LIDAR point cloud into a mapping projection and to check the calibration stability. Terrasolid software was used 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. Refraction correction was performed through Dewberry's LIDAR Processor. Additional quality control (QC), point classification, and formatting were performed with GeoCue, Terrasolid, and Global Mapper software packages. NOAA VDatum software was used to convert the vertical datum of the LIDAR points from NAD83 ellipsoid to local MHW and MLLW tidal datums. 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 to create and format the MHW and MLLW vectors into shapefile format.

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 points for MHW and 27,712 points for MLLW sites) to determine the uncertainty of the vectors. Based on this assessment the MHW LIDAR derived shoreline vectors meet a horizontal accuracy ranging from 1.1 to 2.8 meters at the 95% confidence level and the MLLW LIDAR derived shoreline vectors meet a horizontal accuracy ranging from 1.3 to 4.2 meters at 95% confidence level.

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 DE1401A-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 (CE95) for both imagery collections. The CE95 for the Sandy Supplemental collection was determined to be 0.30 meters, and the CE95 for the State of Delaware collection was determined to be 0.09 meters. AT Reports are on file, for both imagery collections, within the RSD Electronic Data Library.

The project database consists of project parameters and options, camera calibration data, airborne GPS control 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 project DE1401A-TB-C was completed by Dewberry personnel in December 2016. NGS supplied the LIDAR derived MHW and MLLW shapefiles to be edited, attributed and generalized by Dewberry. Additional features were then manually compiled using stereo imagery. This work was accomplished using a Digital Photogrammetric Workstation (DPW) with the SOCET SET suite of digital photogrammetric software (ver. 5.6). Feature identification, segmentation, and attribution was accomplished using the SOCET SET 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.

Subsequent to completion of compilation, a single WorldView-3 orthorectified pan-sharpened commercial satellite image from DigitalGlobe was obtained in order to add a new pier, at the request of the Marine Chart Division (MCD) of NOAA's Office of Coast Survey. This image was adjusted to match the positioning of existing features in the GC using the Georeferencing tool within Esri's ArcGIS (ver. 10.7.1) desktop GIS software.

Spatial data accuracies for project DE1401A-TB-C were determined according to standard Federal Geographic Data Committee (FGDC) practices. Cartographic features derived from the stereo imagery were compiled to meet horizontal accuracies of either 0.6 meters (Sandy Supplemental) or 0.2 meters (State of Delaware) at the 95% confidence level. This predicted accuracy of compiled, well defined points is derived by doubling the circular errors calculated from the aerotriangulation statistics. The LIDAR derived features had horizontal accuracies that varied depending on location and shoreline type ranging from 1.1 meters to 2.6 meters.

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

Aerial Imagery					
Date	**Time (UTC)**	**Roll #**	**AT Frame #s**	**Index Frame #s**	**Tide Level***
1/1/2014	16:57:51 – 17:00:23	1436M01	0001 – 0016	30-207 / 0001 – 0016	0.0 m
1/1/2014	17:09:02 – 17:18:27	1436M01	0003 – 0054	30-208 / 0019 – 0070	0.0 – 0.2 m
1/1/2014	17:25:06 – 17:33:42	1436M01	0050 – 0008	30-209 / 0081 – 0123	0.1 – (-0.1) m
1/1/2014	17:43:59 – 17:48:08	1436M01	0111 – 0093	30-205 / 0133 – 0151	-0.1 m
4/9/2014	16:24:58 – 16:25:26	1436M12	0005 – 0001	30-211 / 3237 – 3241	0.4 m
6/23/2014	14:01:00 – 14:02:14	1436M20	0019 – 0002	08-005 / 5407 – 5424	0.3 m
6/23/2014	14:05:51 – 14:06:53	1436M20	0004 – 0019	08-006 / 5429 – 5444	0.3 m
6/23/2014	14:10:34 – 14:11:35	1436M20	0020 – 0006	08-007 / 5448 – 5462	0.3 m
6/23/2014	14:15:41 – 14:16:34	1436M20	0013 – 0025	08-008 / 5480 – 5492	0.2 m
6/23/2014	14:19:45 – 14:21:25	1436M20	0032 – 0010	08-009 / 5493 – 5515	0.2 m
6/23/2014	14:25:47 – 14:27:27	1436M20	0010 – 0034	08-010 / 5534 – 5558	0.2 m
6/23/2014	14:30:32 – 14:32:11	1436M20	0036 – 0013	08-011 / 5560 – 5583	0.2 m
6/23/2014	14:36:32 – 14:38:30	1436M20	0007 – 0035	08-012 / 5602 – 5630	0.2 m
6/23/2014	14:41:57 – 14:43:58	1436M20	0035 – 0007	08-013 / 5637 – 5665	0.2 m
6/23/2014	14:48:29 – 14:50:07	1436M20	0014 – 0037	08-014 / 5685 – 5708	0.2 m
6/23/2014	14:56:53 – 15:01:37	1436M20	0077 – 0012	08-015 / 5761 – 5826	0.2 m
6/23/2014	15:06:13 – 15:10:48	1436M20	0010 – 0076	08-016 / 5847 – 5913	0.2 m
6/23/2014	15:14:29 – 15:19:20	1436M20	0073 – 0006	08-017 / 5926 – 5993	0.2 m
6/23/2014	15:24:03 – 15:27:57	1436M20	0011 – 0067	08-018 / 6009 – 6065	0.2 m

6/23/2014	15:31:44 – 15:35:36	1436M20	0066 – 0013	08-019 / 6076 – 6129	0.2 m
6/23/2014	15:40:27 – 15:45:00	1436M20	0007 – 0073	08-020 / 6148 – 6214	0.2 m
6/23/2014	15:49:26 – 15:54:15	1436M20	0074 – 0008	08-021 / 6223 – 6289	0.2 m
6/24/2014	15:19:30 – 15:24:27	1436M22	0075 – 0007	08-022 / 7566 – 7634	0.2 m
6/24/2014	15:33:55 – 15:36:57	1436M22	0063 – 0110	08-023 / 7703 – 7750	0.2 – 0.3 m
6/28/2014	19:30:57 – 19:31:17	1436M24	0015 – 0010	08-003 / 9372 – 9377	0.2 m
6/28/2014	19:35:29 – 19:36:24	1436M24	0005 – 0018	08-004 / 9391 – 9404	0.2 m

Satellite Imagery				
Date	**Time (UTC)**	**Source Type**	**File**	**Tide Level**
1/7/2020	6:22:02	WV03_VNIR	20200107_WV03_ORI_R1C1.jp2	n/a

* Water levels are given in meters above MLLW and are based on verified observations recorded by the NOS tide gauges at: Ocean City Inlet in Maryland (Station ID: 8570283), and Lewes in Delaware (Station ID: 8557380). The elevation of the MHW tidal datum in the project area ranges between 0.5 – 1.3 meters above MLLW.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by a senior member of Dewberry. The final QC review was completed in December 2016. The review process included analysis of aerotriangulation results and assessment of the identification and attribution of digital feature data within the GC according to image analysis and criteria defined in C-COAST. The quality control process concluded with an inspection of topological connectivity within the GC using ArcGIS (ver. 10.5.1) software. All project data was evaluated for compliance to CMP requirements.

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

- 12211, Fenwick Island to Chincoteague Inlet, 47th Ed., Feb. 2017
- 12214, Cape May to Fenwick Island, 49th Ed., Nov. 2010
- 12216, Cape Henlopen to Indian River Inlet, 30th Ed., Feb. 2018

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

- Airborne Positioning and Orientation Report (APOR)
- Ground Survey Report
- Aerotriangulation Report
- Final Report of Survey
- Project Completion Report (PCR)
- Project database
- GC11238 in shapefile format
- CEF in shapefile format

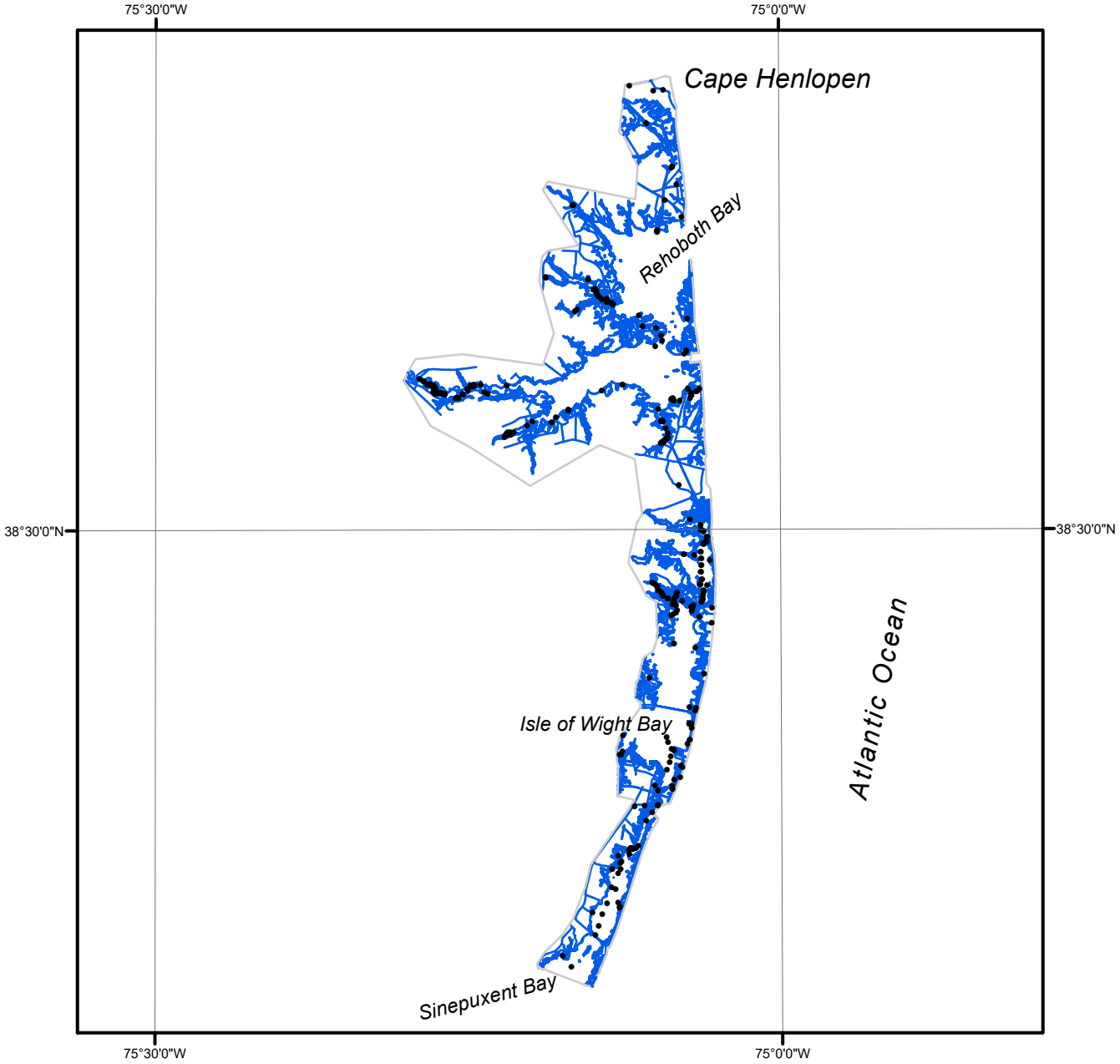
NOAA Shoreline Data Explorer

- GC11238 in shapefile format
- Metadata file for GC11238
- PCR in Adobe PDF format

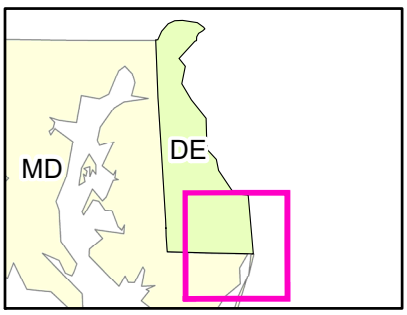
End of Report

BACK BAYS, SINEPUXENT BAY TO CAPE HENLOPEN

MARYLAND AND DELAWARE



Overview



DE1401A-TB-C

GC11238