NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT FL1611-TB-N

Key West, Florida

Introduction

Coastal Mapping Program (CMP) Project FL1611-TB-N provides highly accurate digital shoreline data for the Key West area including Bay Keys, Lower Harbor Keys, and a portion of the Boca Chica Keys. 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

Project FL1611-TB-N was designed to support the application of the National Geodetic Survey's (NGS) ongoing research to support updated bathymetry data in the Florida Keys for NOAA's Hydrographic Surveys Division (HSD) and the Marine Charting Division (MCD). Operations of lidar Mean High Water (MHW) and Mean Lower Low Water (MLLW) elevation derived data will also support CMP GC production and the Continually Updated Shoreline Product (CUSP) program; a seamless database of high resolution shoreline data. The Requirements Branch (RB) of the Remote Sensing Division (RSD) formulated the mission instructions, which discussed the project's purpose, geographic area of coverage, scope and priority, imagery and lidar requirements, Global Positioning System (GPS) data collection procedures and guidelines, instructions for data recording and handling, and mission communication protocols. For further information, refer to the Project Instructions and Layout Diagrams, on file with other project data within the RSD Electronic Data Library.

Field Operations

The field operations 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

One hundred seventy-six lines of Topographic/Bathymetric (topobathy) lidar were acquired in April 2016 using a Riegl VQ880G lidar system on board the NOAA Twin Otter Aircraft (N57RF). The data was collected at a nominal altitude of 1,300 feet with a 50% swath overlap (planned single swath point density = 9 pt/m^2) The topobathy lidar data was collected within a +/- 2 hour time window of the MLLW tide stage.

Digital Aerial Imagery Acquisition

Eight lines of natural color digital aerial imagery (327 images) were collected on April 2016 using an Applanix Digital Sensor System DSS560/580 camera onboard the NOAA King Air

aircraft (N68RF). The imagery was collected within +/- 2 hours of the MHW tide stage and at a nominal altitude of 7,500 feet with a ground sample distance (GSD) of 0.24 m.

GPS/IMU Data Processing and Direct Georeferencing

GPS and IMU data were processed by RSD personnel to yield precise sensor positions and orientations for direct georeferencing (DG) of the imagery. A local GPS base station was established for use as a reference station for kinematic GPS processing operations. The position of the base station was determined using the NGS Online Processing User Service (OPUS), which computed fixed baseline solutions from nearby CORS stations. The airborne kinematic data was processed using Applanix POSPAC (ver. 7.1) software in January 2017. For further information refer to the Airborne Positioning and Orientation Reports (APOR) on file with other project data within the RSD Electronic Data Library.

The processed GPS/IMU data were used to derive precise exterior orientation (EO) values of the digital aerial imagery camera centers required for digital feature extraction. The predicted horizontal accuracy of the imagery was determined by propagating sensor EO and image measurement uncertainties through the photogrammetric collinearity equations using an Exterior Orientation Total Propagated Uncertainty (EO-TPU) tool developed by NGS. Using this tool, the predicted horizontal uncertainty at the 95% confidence level was calculated to be 0.7 meters.

Four NGS third-order geodetic control points were used to verify the horizontal integrity of the DG data. All stereo-models were examined and found to have acceptable levels of parallax for mapping purposes.

Lidar Data Processing

Lidar point cloud data were processed in February 2017 using the following RSD lidar data processing workflow. 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 RB 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.

> Accuracy Assessment: the LiDAR point cloud was compared to higher accuracy ground control points to understand vertical uncertainty, combined with the morphologic slope around the derived shoreline to understand corresponding horizontal uncertainties. Based on this assessment the MHW lidar derived shoreline vectors meet a horizontal accuracy of 2.3 meters at the 95% confidence level, and the MLLW lidar derived shoreline vectors meet a horizontal accuracy of 2.5 meters at the 95% confidence level.

Compilation

The data compilation phase of this project was completed in December 2017 by RSD personnel and accomplished in two phases: Automated extraction from TopoBathy lidar and manual extraction using digital stereo imagery.

1) Lidar Shoreline approach: MHW and MLLW shoreline vectors (in shapefile format) were delineated using the DEMs discussed above with a Raster-to-Vector (R2V) script implemented within ESRI ArcGIS 10.1 software. Subsequently, the April 2016 ortho imagery was used to review, edit, and attribute the lidar shoreline vectors. 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. The lidar-derived shoreline data were limited to terrain features at the land/water interface. As stated above, the lidar-derived MHW and MLLW features meet horizontal accuracies at the 95% confidence level of 2.3 meters and 2.5 meters respectively.

2) Manual Compilation approach: The MHW ("Shoreline") and MLLW ("Contour") lidar-extracted shape files were then reviewed and additional features significant to nautical charting, such as engineered, elevated features, bulkheads, piers, bridges, landmarks, etc., were compiled by RSD personnel using stereoscopic imagery using the Feature Extraction software module within SOCET SET (version 5.6.0). Selected features were further modified with additional descriptive information to refine general classification. All shapefiles were integrated into a single GC using ESRI ArcGIS 10.1 software. Cartographic features compiled from the stereo imagery meet a horizontal accuracy of 1.4 meters at the 95% confidence level – derived by doubling the horizontal uncertainty computed using the EO-TPU tool discussed above.

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

Date	Time (UTC)	Roll #	Strip / Photo #s	Tide Level*
4/14/2016	13:02 – 13:08	16VC39	45-001 / 9468 – 9507	0.3 – 0.5 m
4/14/2016	13:16 – 13:18	16VC39	45-002 / 9537 – 9547	0.3 m
4/14/2016	13:22 – 13:28	16VC39	45-003 / 9548 – 9588	0.3 – 0.4 m
4/14/2016	13:32 – 13:38	16VC39	45-003 / 9589 – 9629	0.4 – 0.3 m
4/14/2016	14:34 – 14:43	16VC39	45-008 / 9697 – 9712	0.2 – 0.3 m
4/14/2016	15:12 – 15:17	16VC39	45-006 / 9755 – 9796	0.3 m
4/14/2016	15:21 – 15:25	16VC39	45-008 / 9797 – 9852	0.3 – 0.2 m
4/14/2016	15:30 – 15:36	16VC39	45-007 / 9823 – 9864	0.3 m
4/14/2016	15:40 – 15:44	16VC39	45-002 / 9866 – 9893	0.3 – 0.4 m
4/18/2016	16:13 – 16:19	16VC40	45-005 / 9950 – 9990	0.4 – 0.6 m
4/18/2016	16:24 – 16:25	16VC40	45-004 / 9991 – 9999	0.6 – 0.5 m

4/18/2016	16:25 – 16:30	16VC40	45-004 / 10000 – 10031	0.5 – 0.3 m
4/18/2016	16:35 – 16:41	16VC40	45-003 / 10032 – 10072	0.3 – 0.6 m
4/18/2016	16:50 – 16:54	16VC40	45-004 / 10074 – 10108	0.5 – 0.3 m

* Tide levels are given in meters above MLLW and were calculated using the Pydro software tool with a TCARI grid referenced to verified water level observations at the time of photography from various NOS gauges in the vicinity of the project. The elevation of the MHW tidal datum in the project area varies from 0.31 – 0.66 m above MLLW.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by senior members of RSD. The final QC review was completed in March 2018. The review process included analysis of the DG 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 10.5 software. All project data was evaluated for compliance to CMP requirements.

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

- 11441, 42nd Ed., Feb. 2013
- 11446, 33rd Ed., Jan. 2013
- 11447, 38th Ed., Jan. 2013

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 Reports (APOR)
- Project database
- GC11308 in shapefile format
- Project Completion Report (PCR)
- CEF in shapefile format

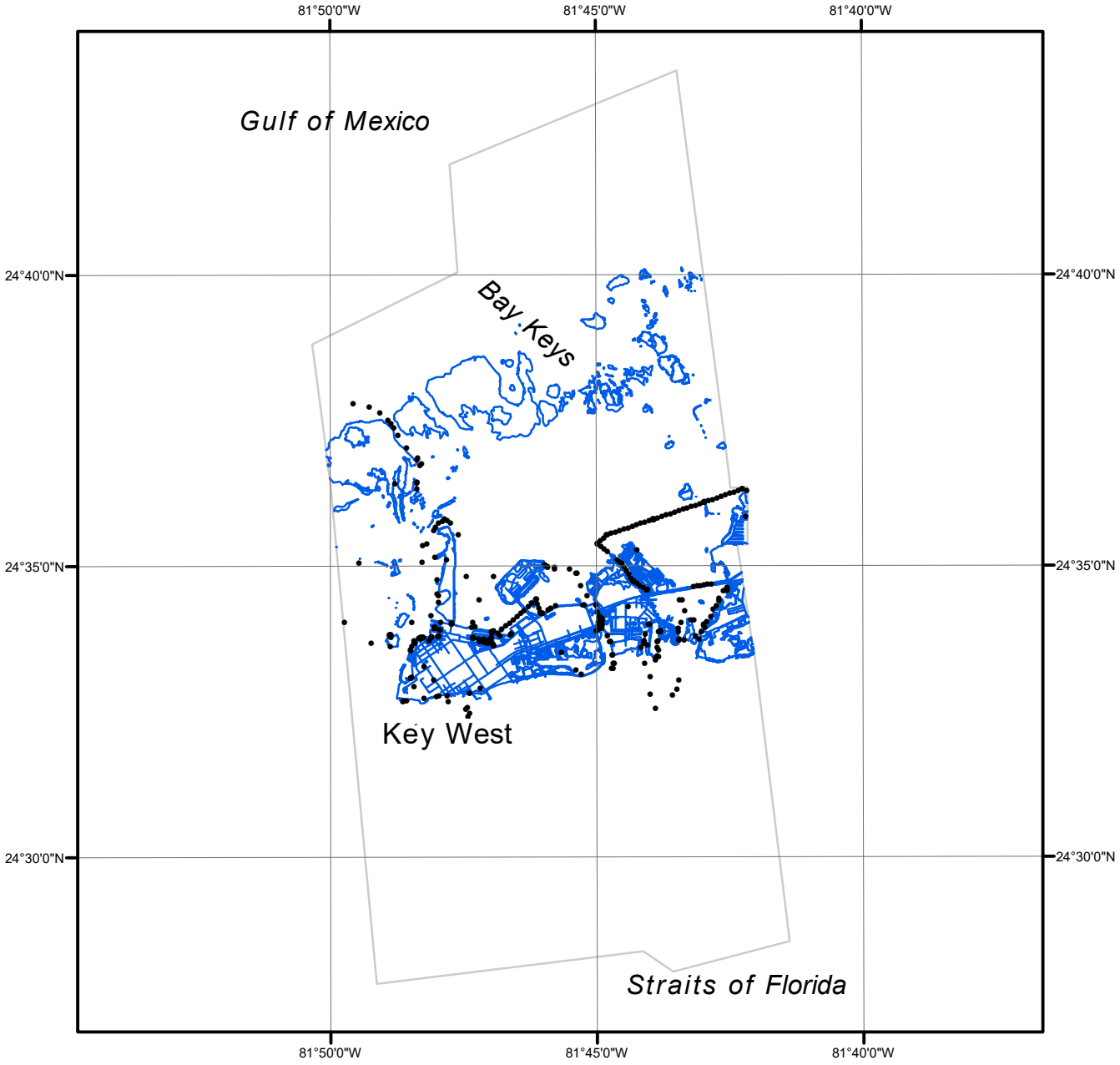
NOAA Shoreline Data Explorer

- GC11308 in shapefile format
- Metadata file for GC11308
- PCR in Adobe PDF format

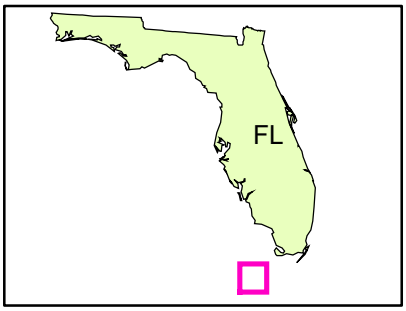
End of Report

KEY WEST

FLORIDA



Overview



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GC11308