NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT NH0801

Portsmouth Harbor, New Hampshire and Maine

Introduction

Coastal Mapping Program (CMP) Project NH0801 encompasses Portsmouth Harbor in New Hampshire and Maine, including the approaches to the Harbor and the Piscataqua River to Dover Point and the confluence with the Oyster River. The approximate bounding coordinates are 43°01' to 43°08' latitude, and 70°39' to 70°50' longitude.

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

Project Design

The Requirements Branch (RB) of the Remote Sensing Division (RSD) formulated the photographic mission instructions for this project supplementary to the Photo Mission Standard Operating Procedure Version II (7/1/1993), the GPS Controlled Photogrammetry Field Operations Manual (1/2/1996), and the Light Detection And Ranging (LIDAR) Requirements Version 5 (7/3/2003). The instructions discussed the project's purpose, geographic area of coverage, scope and priority; photographic and LIDAR requirements; flight line priority; Global Positioning System (GPS) data collection procedures and guidelines for both kinematic and static surveys; data recording and handling instructions; and contact and communication information. RB created a Project Layout Diagram, flight maps and input files for the aircraft flight management system.

Field Operations

The field operations consisted of acquisition of aerial LIDAR data, digital aerial imagery, static and kinematic Global Positioning System (GPS) data, and Inertial Measurement Unit (IMU) data. Static GPS data were collected to support aerial data collection and processing operations as well as to assess the accuracy of post-processed imagery and LIDAR products.

The airborne survey operations were conducted June 8-9, 2008 with the NOAA Cessna Citation (N52RF) aircraft. Twelve strips of tandem tide-coordinated imagery, in both natural color and black & white infrared (IR), were acquired at both the Mean High Water (MHW) and Mean Lower Low Water (MLLW) tide stages. All imagery was acquired at a flying height of 1,500 meters, for a nominal ground sample distance (GSD) of 0.17 meters, using an Applanix Digital Sensor System (DSS-439) with dual camera heads (DualCam). Additionally, topographic

LIDAR data were collected, in tandem with the MLLW imagery, using an Optech ALTM 3100 Topographic LIDAR sensor. LIDAR postings were collected at a nominal density of 1 posting per square meter.

Airborne GPS/IMU Data Processing

GPS and IMU data were processed by RSD personnel to yield precise camera positions and orientations in order to provide a control network necessary for aerotriangulation. A local temporary base station, set up over a PK Nail at Portsmouth International Airport (KPSM), was used as base data for the GPS/IMU post-processing. The airborne kinematic data was processed using Applanix POSPAC (ver. 4.4) software in July 2008. An Airborne Positioning and Orientation Report was written and is on file with other project data within the RSD Applications Branch (AB) Project Archive.

Ortho-image Processing

Ortho-images were created in July 2008 from the DSS-439 imagery and associated image Exterior Orientation (EO) data using Applanix RapidOrtho software. The United States Geological Survey (USGS) National Elevation Dataset (NED) was utilized to rectify the data.

LIDAR Data Processing

LIDAR point cloud data were processed in April 2009 using the following steps:

1) Optech's *Project Dashboard* pre-processing software to place the LIDAR point cloud into a mapping projection,
2) Terrasolid's suite of LIDAR calibration and editing software to correct alignment, remove erroneous returns, and classify bare earth points,
3) NOAA's VDatum software to convert the vertical datum of the bare earth points from NAVD88 to local MHW, and
4) GeoCue LIDAR processing software to produce MHW digital elevation models (DEM) at 1 m. pixel resolution.

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 Project Archive.

Aerotriangulation

The aerotriangulation (AT) task was initiated by RSD personnel in April of 2011 utilizing a Digital Photogrammetric Workstation (DPW). Image measurements and block adjustments were performed using BAE Systems' SOCET SET (SS, version 5.5) photogrammetric software. AT procedures were accomplished using the Multi-Sensor Triangulation (MST) module of SS. The Automatic Point Measurement (APM) algorithm, within MST, was used to collect tie points, and a simultaneous solve adjustment was then performed. The predicted horizontal circular error, using all measured image points, was computed to be 0.27 meters at the 95% confidence level (CE95). Positional data for this project is referenced to the North American Datum of 1983 (NAD 83). An Aerotriangulation Report was written and is on file with other project data within the RSD Project Archive.

Compilation

The data compilation phase of this project was performed between April 2009 and July 2011 and consisted of the following three distinct technical approaches:

1) *LIDAR MHW Shoreline approach* – A MHW shoreline vector (in shapefile format) was delineated using the MHW DEM discussed above and a Raster-to-Vector (R2V) script implemented within ESRI's ArcGIS 9.3 software. The shapefile table was then edited to create attribute fields compatible with the RSD interim shapefile format. Subsequently, the ortho-images were used to review, edit, and attribute the LIDAR shoreline vector. The LIDAR shoreline was limited to MHW shoreline features and was not utilized to delineate engineered features such as bulkheads, piers, bridges, etc that lie above the MHW level.

   Based on the study referenced in the LIDAR processing section, above, the LIDAR derived shoreline vectors were compiled to meet a horizontal accuracy of 4.5 meters at the 95% confidence level.

2) *Semi-Automated Feature Extraction (AFE) approach* – For compilation of MLLW Depth Contour features and certain Danger features (Ledges, Reefs), an AFE method was performed using the ortho-images discussed above in combination with an object-based image analysis approach from within the ENVI Feature Extraction (Fx) software. ENVI Fx allows the user to interactively create and classify objects, based on image rules that meet in-situ criteria, and then run a R2V algorithm to convert the classified objects to an ArcGIS polygon shapefile. Upon completion of the AFE process, the polygon shapefile was imported into ArcGIS and 1) *aggregated* to merge polygons separated by less than the standard minimum distance, 2) *converted* to a polyline format, 3) *smoothed* and *simplified*, and 4) *edited* to create attribute fields (within the table) compatible with the RSD interim shapefile format. Subsequently, the ortho-images were used to review, edit, and attribute the AFE shoreline vectors.

   Based on the expected accuracy of the ortho-image production process, the AFE derived features were compiled to meet a horizontal accuracy of 2.0 meters at the 95% confidence level. This estimated accuracy was later verified during the manual part of the compilation phase by comparing features extracted from the ortho-images to the higher-accuracy aerotriangulated stereo imagery.

Note: The shape files, created in phases 1 and 2 above, were imported into SOCET SET (SS) and a Feature Database (FDB), consisting of the extracted Shoreline, Contour, and Danger class features, was created.

3) *Stereo-Models and Manual Compilation approach* – The FDB, created above, was reviewed and edited within the SS Feature Extraction module, by the original compiler, and populated with additional features compiled using the stereo-models derived from the AT solution. This served to integrate all coastal features within a single FDB. This manual data compilation phase utilized the *traditional* RSD digital mapping approach of

stereoscopic interpretation integrated with “heads-up” digitizing.

Features that were compiled and/or edited manually from the stereo models were compiled to meet a horizontal accuracy of 0.5 meters at the 95% confidence level (CE95), calculated by doubling the circular error derived from AT statistics.

Feature attribution, for all three phases above, 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.

The following table provides information on aerial photographs used in the project completion.

Type	Date	Time (UTC)	Roll #	Photo #s	GSD	Tide Level*
Color MLLW	6-8-2008	12:10 – 12:11	08NC29	5400 – 5408	0.17	0.2
	6-8-2008	12:17 – 12:18	08NC29	5409 – 5431	0.17	0.2 – 0.1
	6-8-2008	12:23 – 12:25	08NC29	5432 – 5454	0.17	0.1
	6-8-2008	12:30 – 12:32	08NC29	5455 – 5477	0.17	0.1
	6-8-2008	12:38 – 12:39	08NC29	5478 – 5500	0.17	0.1 – 0.0
	6-8-2008	12:44 – 12:46	08NC29	5501 – 5529	0.17	0.0 – 0.1
	6-8-2008	12:52 – 12:53	08NC29	5530 – 5549	0.17	0.0
	6-8-2008	12:58 – 13:00	08NC29	5550 – 5565	0.17	(-0.1)
	6-8-2008	13:04 – 13:06	08NC29	5566 – 5582	0.17	(-0.1)
	6-8-2008	13:11 – 13:14	08NC29	5583 – 5621	0.17	(-0.1) – 0.0
	6-8-2008	13:24 – 13:27	08NC29	5622 – 5658	0.17	(-0.15) – 0.0
	6-8-2008	13:32 – 13:35	08NC29	5659 – 5698	0.17	0.0 – (-0.2)
IR MLLW	6-8-2008	12:10 – 12:11	08NR09	2076 – 2084	0.17	0.2
	6-8-2008	12:17 – 12:18	08NR09	2085 – 2107	0.17	0.2 – 0.1
	6-8-2008	12:23 – 12:25	08NR09	2108 – 2130	0.17	0.1
	6-8-2008	12:30 – 12:32	08NR09	2131 – 2153	0.17	0.1
	6-8-2008	12:38 – 12:39	08NR09	2154 – 2176	0.17	0.1 – 0.0
	6-8-2008	12:44 – 12:46	08NR09	2177 – 2205	0.17	0.0 – 0.1
	6-8-2008	12:52 – 12:53	08NR09	2206 – 2225	0.17	0.0
	6-8-2008	12:58 – 13:00	08NR09	2226 – 2241	0.17	(-0.1)
	6-8-2008	13:04 – 13:06	08NR09	2242 – 2258	0.17	(-0.1)
	6-8-2008	13:11 – 13:14	08NR09	2259 – 2297	0.17	(-0.1) – 0.0
	6-8-2008	13:24 – 13:27	08NR09	2298 – 2334	0.17	(-0.15) – 0.0
	6-8-2008	13:32 – 13:35	08NR09	2335 – 2374	0.17	0.0 – (-0.2)

Type	Date	Time (UTC)	Roll #	Photo #s	GSD	Tide Level*
IR MHW	6-9-2008	19:43 – 19:44	08NR16	3099 – 3107	0.17	2.6
	6-9-2008	19:49 – 19:51	08NR16	3108 – 3130	0.17	2.7
	6-9-2008	19:56 – 19:58	08NR16	3131 – 3153	0.17	2.7
	6-9-2008	20:02 – 20:04	08NR16	3154 – 3176	0.17	2.7
	6-9-2008	20:09 – 20:11	08NR16	3177 – 3199	0.17	2.7 – 2.5
	6-9-2008	20:16 – 20:17	08NR16	3200 – 3228	0.17	2.5 – 2.7
	6-9-2008	20:21 – 20:23	08NR16	3229 – 3245	0.17	2.7 – 2.8
	6-9-2008	20:26 – 20:27	08NR16	3246 – 3261	0.17	2.8 – 2.7
	6-9-2008	20:31 – 20:33	08NR16	3262 – 3281	0.17	2.8 – 2.6
	6-9-2008	20:37 – 20:40	08NR16	3282 – 3320	0.17	2.5 – 2.8
	6-9-2008	20:48 – 20:50	08NR16	3321 – 3357	0.17	2.5 – 2.8
	6-9-2008	20:55 – 20:58	08NR16	3358 – 3397	0.17	2.8 – 2.5

* Tide levels given in meters above MLLW and were calculated using the Pydro software tool with a TCARI grid referenced to verified water level observations at NOS gauges. The height of the MHW tidal datum in the project area varies between 2.51 – 2.74 meters above MLLW.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by a senior member of AB. Final QC review was completed in August 2011, including analysis of aerotriangulation results, assessment of the spatial placement of the LIDAR and AFE derived shorelines from within the stereo viewing environment, 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 9.3 software. All project data were 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:

13283, Cape Neddick Harbor to Isles of Shoals, 20th Ed. Oct. /07, Scale 1:20,000
13285, Portsmouth to Dover and Exeter, 11th Ed. Jul. /05, Scale 1:20,000
13286, Cape Elizabeth to Portsmouth, NH, 31st Ed. Jun./11, Scale 1:80,000

End Products and Deliverables

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

RSD Applications Branch Archive

- Hardcopy of Airborne Positioning and Orientation Report (APOR)
- Hardcopy of Aerotriangulation Report

- Hardcopy of the Project Completion Report (PCR)
- Page-size graphic plot of GC10887 file contents, attached to PCR
- Hardcopy of the journal article, “Lidar-Derived National Shoreline: Empirical and Stochastic Uncertainty Analyses” by White et al

Remote Sensing Division Electronic Data Library

- Project database
- GC10887 in shapefile format
- Digital copy of the PCR in Adobe PDF format
- CEF in shapefile format

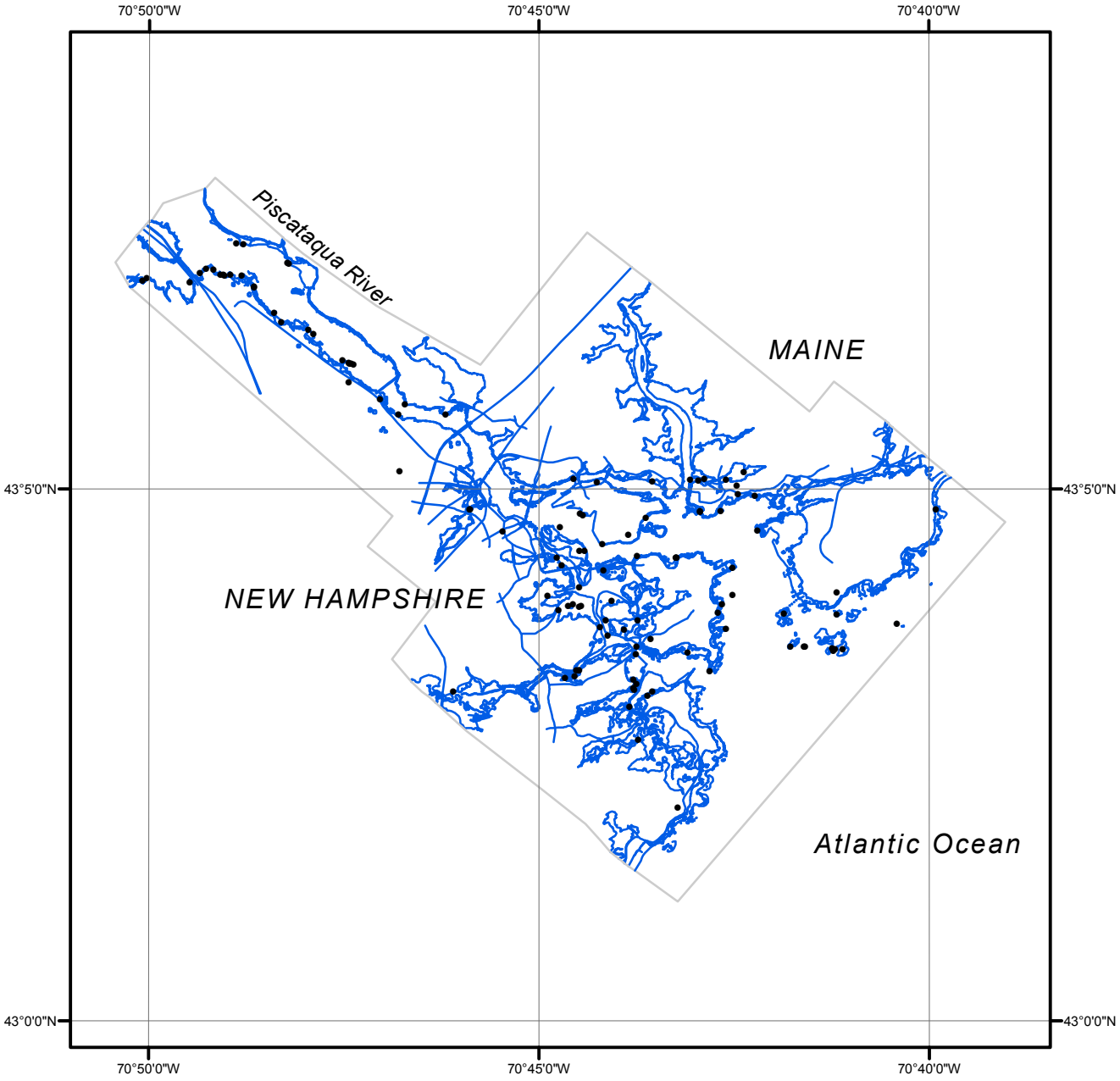
NOAA Shoreline Data Explorer

- GC10887 in shapefile format
- Metadata file for GC10887
- Digital copy of the PCR in Adobe PDF format

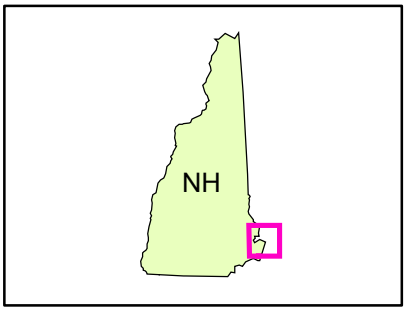
End of Report

PORTSMOUTH HARBOR

NEW HAMPSHIRE AND MAINE



Overview



NH0801

GC10887