# NOAA COASTAL MAPPING PROGRAM
# PROJECT COMPLETION REPORT

## *PROJECT WA1403-CM-N*

## *Puget Sound, Everett to Spring Beach, Washington*

### Introduction

NOAA Coastal Mapping Program (CMP) Project WA1403-CM-N provides highly accurate digital shoreline data for Puget Sound, from Everett to Spring Beach, in Washington. 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

The Requirements Branch (RB) of the Remote Sensing Division (RSD) formulated the photographic mission instructions for this project following the guidelines of the Photo Mission Standard Operating Procedures. The instructions discussed the project's purpose, geographic area of coverage, scope and priority; photographic 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's flight management system.

### Field Operations

The field operations consisted of the collection of static and kinematic Global Positioning System (GPS) data, Inertial Measurement Unit (IMU) data, and the acquisition of aerial imagery. The tide coordinated photographic mission operations were conducted on July 26 and 27, 2014 for Mean Lower Low Water (MLLW) imagery, and on August 8, 2014 for Mean High Water (MHW) imagery, using the NOAA King Air (N68RF) aircraft. Nine lines of color (RGB) and infrared (IR) digital images were acquired concurrently with an Applanix Digital Sensor System (DSS) 439 aerial camera at a nominal altitude of 10,000 feet, resulting in an approximate ground sample distance (GSD) of 0.35 meters.

Note that flight lines 7, 8, and 9, which cover the tidal sloughs and rivers of the Snohomish River Estuary, were acquired only once, without strict tide-coordination, since water level data was not available in this area. These lines, though, appear to have been collected close to low tide.

### GPS Data Reduction

GPS/IMU data was collected and processed by RSD personnel to yield precise positions and orientations of camera centers in order to provide a control network necessary for aerotriangulation. 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 kinematic GPS data was processed using Applanix POSPAC (ver. 6.2) software in August 2014 for MLLW imagery and in November 2014 for MHW imagery. For further information refer to the Airborne Positioning and Orientation Reports (APOR) on file with other project data within the Remote Sensing Division Electronic Data Library.

## Direct Georeferencing Data Processing

The processed GPS/IMU data were used to derive precise exterior orientation (EO) values of the 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 the Exterior Orientation Total Propagated Uncertainty (EO-TPU) tool developed by NGS. Using this tool, the predicted horizontal uncertainty at the 95% confidence level for all project imagery was calculated to be at most 1.4 meters. NGS third-order geodetic survey marks were measured in the acquired imagery using BAE Systems SOCET SET (v. 5.6.0) to verify the horizontal integrity of the directly georeferenced (DG) data. All stereo-models were examined and found to have acceptable levels of parallax for mapping purposes. Positional data is referenced to the North American Datum of 1983 (NAD 83).

## Aerotriangulation

Routine softcopy aerotriangulation methods were applied to establish a network of precise camera positions and other control for mapping, and to provide model parameters and orientation elements required for digital compilation. This work was performed by RSD Applications Branch (AB) personnel in May 2016 utilizing a softcopy photogrammetric workstation. A subset of the color and IR images covering the Port of Everett were measured and adjusted as a single block using the Multi-Sensor Triangulation (MST) module of SOCET SET (v 5.6.0) software. Upon successful completion of this process, the MST module provided the standard deviations for each aerotriangulated ground point, which were used to compute a predicted horizontal circular error of 0.4 meters based on a 95% confidence level. An Aerotriangulation Report was written and is on file with other project data within the RSD Electronic Data Library.

## Compilation

The data compilation phase of this project was accomplished by a member of AB in June 2016. The work was accomplished using a Digital Photogrammetric Workstation (DPW), which is a configuration of computer hardware, modular software components and other associated peripheral devices. The Feature Extraction module was used within SOCET SET (v 5.6.0) photogrammetric software. Feature identification and the assignment of cartographic codes were based on image analysis of the project digital images and information extracted from the appropriate NOAA Nautical Charts, 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.

Spatial data accuracies for project WA1403-CM-N were determined according to standard Federal Geographic Data Committee (FGDC) practices. Cartographic features compiled from the imagery that was photogrammetrically adjusted, as described above in the aerotriangulation

section of this report, were compiled to meet a horizontal accuracy of 0.8 meters at the 95% confidence level. This predicted accuracy of compiled well-defined points is derived by doubling the circular error calculated from the aerotriangulation statistics. The rest of the feature data within this project was compiled to meet a horizontal accuracy of 2.7 meters at the 95% confidence level, a predicted accuracy derived by doubling the horizontal uncertainty calculated from the EO-TPU tool.

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

| Date | Time (UTC) | Color Imagery | | Infrared Imagery | | Tide Level* |
|---|---|---|---|---|---|---|
| | | Roll | Images | Roll | Images | |
| 7-26-2014 | 19:36 – 19:38 | 14NC59 | 12957 – 12971 | 14NR50 | 9705 – 9719 | 0.0 m |
| 7-26-2014 | 19:43 – 19:45 | 14NC59 | 12972 – 12985 | 14NR50 | 9720 – 9733 | 0.1 m |
| 7-26-2014 | 19:52 – 19:54 | 14NC59 | 12986 – 13001 | 14NR50 | 9734 – 9749 | 0.1 m |
| 7-26-2014 | 19:58 – 20:00 | 14NC59 | 13002 – 13014 | 14NR50 | 9750 – 9762 | 0.1 m |
| 7-26-2014 | 20:05 – 20:07 | 14NC59 | 13015 – 13029 | 14NR50 | 9763 – 9777 | 0.2 m |
| 7-27-2014 | 17:26 – 17:28 | 14NC61 | 13351 – 13366 | 14NR52 | 10099 – 10114 | N/A |
| 7-27-2014 | 17:32 – 17:34 | 14NC61 | 13367 – 13384 | 14NR52 | 10115 – 10132 | N/A |
| 7-27-2014 | 17:39 – 17:42 | 14NC61 | 13385 – 13404 | 14NR52 | 10133 – 10152 | N/A |
| 7-27-2014 | 17:47 – 17:48 | 14NC61 | 13405 – 13412 | 14NR52 | 10153 – 10160 | 0.0 m |
| 8-09-2014 | 00:10 – 00:11 | 14NC67 | 15980 – 15987 | 14NR58 | 12728 – 12735 | 3.3 m |
| 8-09-2014 | 00:18 – 00:20 | 14NC67 | 15988 – 16002 | 14NR58 | 12736 – 12750 | 3.3 m |
| 8-09-2014 | 00:27 – 00:29 | 14NC67 | 16003 – 16015 | 14NR58 | 12751 – 12763 | 3.3 – 3.2 m |
| 8-09-2014 | 00:34 – 00:37 | 14NC67 | 16016 – 16031 | 14NR58 | 12764 – 12779 | 3.2 – 3.1 m |
| 8-09-2014 | 00:43 – 00:45 | 14NC67 | 16032 – 16045 | 14NR58 | 12780 – 12793 | 3.1 m |
| 8-09-2014 | 00:50 – 00:52 | 14NC67 | 16046 – 16060 | 14NR58 | 12794 – 12808 | 3.1 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 NOS gauges. Images with tide levels of N/A were collected without tide-coordination since water level data was not available in that area. The height of the MHW tidal datum, in the portion of the project area where tide data exists, varies between 3.00 – 3.12 meters above MLLW.

## Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by a senior member of AB. The final QC review was completed in July 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 10.1 software. All project data was evaluated for compliance to CMP requirements.

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

18441, Puget Sound, Northern Part, 1:80,000 scale, 47th Ed., Jun. 2011
18443, Approaches to Everett, 1:40,000 scale, 17th Ed., Jan. 2010
18444, Everett Harbor, 1:10,000 scale, 17th Ed., Nov. 2009
18446, Puget Sound, Apple Cove Point to Keyport, 1:25,000 scale, 18th Ed., Mar. 2011
18473, Puget Sound, Oak Bay to Shilshole Bay, 1:40,000 scale, 9th Ed., Apr. 2016

## End Products and Deliverables

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

**Remote Sensing Division Electronic Data Library**

- Project database
- Airborne Positioning and Orientation Report (APOR)
- Aerotriangulation Report
- GC11220 in shapefile format
- Project Completion Report (PCR)
- Chart Evaluation File in shapefile format

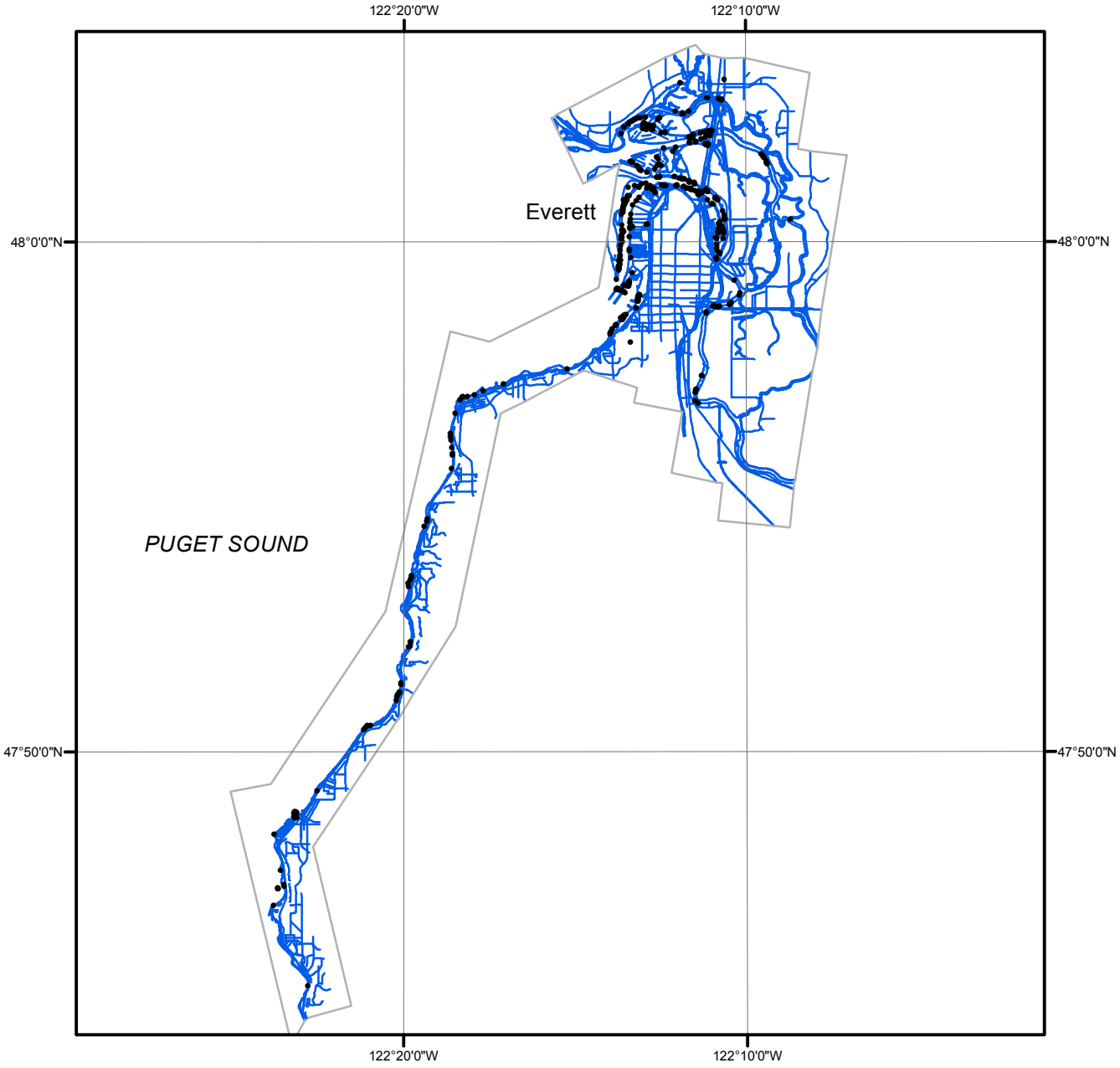
**NOAA Shoreline Data Explorer**

- GC11220 in shapefile format
- Metadata file for GC11220
- Digital copy of the PCR

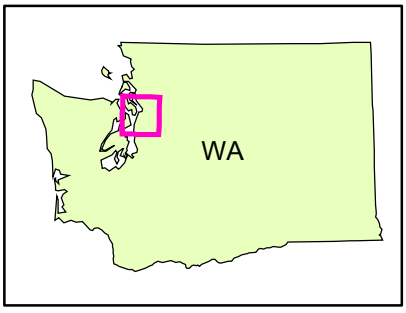
## End of Report

# PUGET SOUND, EVERETT TO SPRING BEACH

# WASHINGTON




Overview




WA1403-CM-N

GC11220