NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT MP1907C-TB-C

Saipan, Tinian, and Aguijan, Northern Mariana Islands

Introduction

NOAA Coastal Mapping Program (CMP) Project MP1907C-TB-C provides a highly accurate database of new digital shoreline data for Saipan, Tinian, and Aguijan, in the Commonwealth of the Northern Mariana Islands (CNMI). Project MP1907C-TB-C is a subproject of a larger project, MP1907-TB-C, which includes other areas affected by Typhoon Yutu within the Northern Marianas. 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 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 project instructions discuss 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.

Quantum Spatial (QSI or Quantum) was provided satellite imagery and lidar data to support photogrammetric processing and feature compilation. Maxar/DigitalGlobe Worldview satellite imagery was provided by NOAA NGS for aerotriangulation (AT) and feature compilation by Quantum. NOAA NGS supplied the lidar-derived MHW and MLLW shapefiles to be segmented, edited, and attributed by Quantum. NOAA NGS also provided shapefiles depicting the shoreline to be mapped and the boundaries of the main project area.

Field Operations

Woolpert was contracted to perform field operations in support of the contract with the NOAA Office of Coastal Management (OCM). These field operations consisted of the surveying of ground control and check points (GCPs), precise point positioning (PPP), and the acquisition and processing of topographic-bathymetric (topobathy) lidar data. See the Topographic and Bathymetric Lidar Survey Report (Commonwealth of the Northern Mariana Islands) on file in the RSD Electronic Data Library for full details on lidar planning, acquisition and processing for MP1907-TB-C.

Ground surveys were conducted in February and March of 2020. Due to the distance and remoteness of Rota, Aguijan, Farallon de Medinilla, and Pagan from the single base station on Saipan (SPN1), a precise point positioning (PPP) solution was used for them on ITRF2014. To establish a reliable coordinate for SPN1, data were uploaded to the NGS Online Positioning User Service (OPUS). For SPN2 and SPN3 Trimble CenterPoint RTX Post-Processing service was

used. To account for any potential trajectory shifts between each survey day for flights processed with PPP trajectories over Farallon de Medinilla, quality control (QC) data were acquired over single base survey data on Saipan Island across the acquisition period.

The lidar acquisition phase of the project was conducted by Woolpert with flights starting July 4, 2019 through July 14, 2020. A total of 61 missions were completed between two projects, MP1907-TB-C and GU1903-TB-C. Lidar data was acquired with a target pulse density ≥ 8 pulses/m^2 (topographic) and ≥ 2 pulses/m^2 (bathymetric) using a Leica Hawkeye 4X sensor.

The satellite imagery used by Quantum was supplied by NOAA. The multispectral satellite imagery was captured by DigitalGlobe Inc. The imagery was acquired at a nominal ground sample distance of 0.66 meters from WorldView Satellites. The imagery was captured on August 01, 2019 for Saipan; on October 16, 2019 and November 15, 2019 for Tinian; and on June 11, 2019 for Aguijan.

GPS Data Processing

For Saipan and Tinian, position and orientation data were acquired in the aircraft using a NovAtel SPAN GNSS with LCI-100C IMU. All data were post-processed using NovAtel Inertial Explorer software to provide a tightly coupled position and orientation solution. A single base station on Saipan was used to control trajectory processing providing final trajectories on NAD83 (MA11), Epoch 2010.

For Aguijan, position and orientation data were acquired using a PPP based on a single base station on Saipan. Data were uploaded to the NGS OPUS to establish a reliable coordinate for SPN1. All processing was done using Leica LSS, Microstation/Terrascan, and proprietary Woolpert Software.

Lidar Data Processing

The lidar processing phase of the project was performed by Woolpert. All processing was done using Leica LSS, Microstation/Terrascan, and proprietary Woolpert Software. Non-vegetated (NVA) and vegetated (VVA) points were collected by NOAA. NVA and VVA points were only collected on Saipan, Rota, and Tinian. Pagan, Aguijan, and Farallon de Medinilla were all controlled using PPP tied to the base station in Saipan.

Aerotriangulation

The AT phase of the project was performed by Quantum using digital AT methods to establish the network of photogrammetric control required for the compilation phase. The images were bridged in three bundle adjustments that included all 11, 12, and 2 multispectral satellite images for Saipan, Tinian, and Aguijan respectively. Measurements were made utilizing a digital photogrammetric workstation running the Windows 10 operating system. Socet GXP AT software was used to perform automatic point measurements and interactive point measurements of tie points. The final adjustment of each block was accomplished by using a rigorous simultaneous least squares bundle adjustment. Analysis tools within Socet GXP were used to refine the AT solutions and to evaluate the accuracies of the adjustments.

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 2.02, 1.99, and 2.78 meters for Saipan, Tinian, and Aguijan respectively. This accuracy refers to each overall block, but in the bundle adjustments the error was distributed such that the largest errors are associated with points around the edges of the project, as well as areas of vast water, where the strength of the solution is weakest. Points down the middle of each block located on areas of extensive land cover have the smallest errors, as those points are measured on a greater number of images.

As a final check, select strips of photography were examined in Socet Set to ensure horizontal and vertical integrity of the Socet GXP solution, and to verify the suitability of the database for use in compilation. Images were checked for proper parallax, and ground control tolerance.

The project database consists of project parameters and options, 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 is referenced to the Universal Transverse Mercator (UTM) Zone 55 coordinate system. An AT Report is on file with other project data within the RSD Electronic Data Library.

Compilation

The data compilation phase of the project was initiated by Quantum personnel on February 2, 2021. This work was accomplished using a Digital Photogrammetric Workstation (DPW), which consists of a stereo-enabled PC-based graphics workstation running the Windows 2010 operating system and DAT/EM Summit Evolution (ver. 7.6) digital photogrammetric software. NOAA supplied the lidar-derived MHW and MLLW shapefiles to be segmented, edited, and attributed by Quantum Spatial. The MHW lidar-derived shoreline vectors meet a horizontal accuracy of 2.0, 0.9, and 1.0 meters for Saipan, Tinian, and Aguijan respectively at the 95% confidence level. The MLLW lidar-derived shoreline vectors meet a horizontal accuracy of 6.9, 3.2, and 1.0 meters for Saipan, Tinian, and Aguijan respectively at the 95% confidence level. Feature identification, segmentation, and attribution were based on imagery analysis of the processed 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.

Spatial data accuracies for project MP1907C-TB-C were determined according to standard Federal Geographic Data Committee (FGDC) practices. Cartographic features were compiled to meet a horizontal accuracy of 4.0 meters for Saipan and Tinian and 5.6 meters for Aguijan, at the 95% confidence level. This predicted accuracy of compiled, well defined points is derived by doubling the circular error calculated from the AT statistics. Lidar-derived feature accuracies are indicated above. The table below provides information on the imagery used to complete this project:

Saipan			
Exposure Date	**Exposure Time (UTC)**	**Source File Name**	**Tide Level***
08/01/2019	00:57:30	19AUG01005730-M1BS_R1C1-010720713010_01_P001	0.2 m

08/01/2019	00:57:30	19AUG01005730-M1BS_R2C1-010720713010_01_P001	0.2 m
08/01/2019	00:57:30	19AUG01005730-M1BS_R3C1-010720713010_01_P001	0.2 m
08/01/2019	00:57:47	19AUG01005747-M1BS_R1C1-010720712010_01_P001	0.2 m
08/01/2019	00:57:47	19AUG01005747-M1BS_R2C1-010720712010_01_P001	0.2 m
08/01/2019	00:57:47	19AUG01005747-M1BS_R3C1-010720712010_01_P001	0.2 m
08/01/2019	00:58:42	19AUG01005842-M1BS_R1C1-010720713010_01_P001	0.2 m
08/01/2019	00:58:42	19AUG01005842-M1BS_R2C1-010720713010_01_P001	0.2 m
08/01/2019	00:58:59	19AUG01005859-M1BS_R1C1-010720712010_01_P001	0.2 m
08/01/2019	00:58:59	19AUG01005859-M1BS_R2C1-010720712010_01_P001	0.2 m
08/01/2019	00:58:59	19AUG01005859-M1BS_R3C1-010720712010_01_P001	0.2 m
Tinian			
Exposure Date	**Exposure Time (UTC)**	**Source File Name**	**Tide Level***
10/16/2019	00:59:00	19OCT16005900-M1BS_R2C1-011555451010_01_P001	0.7 m
10/16/2019	00:59:00	19OCT16005900-M1BS_R3C1-011555451010_01_P001	0.7 m
10/16/2019	00:59:00	19OCT16005900-M1BS_R4C1-011555451010_01_P001	0.7 m
10/16/2019	01:00:20	19OCT16010020-M1BS_R2C1-011555451010_01_P001	0.7 m
10/16/2019	01:00:20	19OCT16010020-M1BS_R3C1-011555451010_01_P001	0.7 m
10/16/2019	01:00:20	19OCT16010020-M1BS_R4C1-011555451010_01_P001	0.7 m
11/15/2019	00:54:38	19NOV15005438-M1BS_R2C1-011555453010_01_P001	0.7 m
11/15/2019	00:54:38	19NOV15005438-M1BS_R3C1-011555453010_01_P001	0.7 m
11/15/2019	00:54:38	19NOV15005438-M1BS_R4C1-011555453010_01_P001	0.7 m
11/15/2019	00:55:57	19NOV15005557-M1BS_R2C1-011555453010_01_P001	0.7 m
11/15/2019	00:55:57	19NOV15005557-M1BS_R3C1-011555453010_01_P001	0.7 m
11/15/2019	00:55:57	19NOV15005557-M1BS_R4C1-011555453010_01_P001	0.7 m
Aguijan			
Exposure Date	**Exposure Time (UTC)**	**Source File Name**	**Tide Level***
6/11/2019	01:20:55	19JUN11012055-M1BS-010822044010_01_P001	0.6 m
6/11/2019	01:21:58	19JUN11012158-M1BS-010822044010_01_P001	0.6 m

* Tide levels given in meters above MLLW and are based on verified observations recorded by the NOS tide gauge at Apra Harbor, Guam. The elevation of the MHW tidal datum at Apra Harbor is 0.678 meters above MLLW.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by a Quantum senior mapping professional. The final QC review was completed in June 2021. The review process included analysis of AT results and assessment of the identification and attribution of digital feature data within the subproject according to image analysis and criteria defined in C-COAST. The quality control process concluded with an inspection of topological connectivity within the project using ArcGIS (ver. 10.8.1) 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:

- 81067, CNMI, Saipan and Tinian, 9th Ed., Feb. 2009
- 81071, CNMI, Bahia Laolao, Saipan Island and Tinian Harbor, Tinian Island, 8th Ed., Feb. 2013
- 81076, CNMI, Saipan Harbor, 13th 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

- Project database
- Ground Survey Report
- Aerotriangulation Report
- Topographic and Bathymetric Lidar Survey Report
- GC11634 in shapefile format
- Project Completion Report (PCR)
- CEF in shapefile format

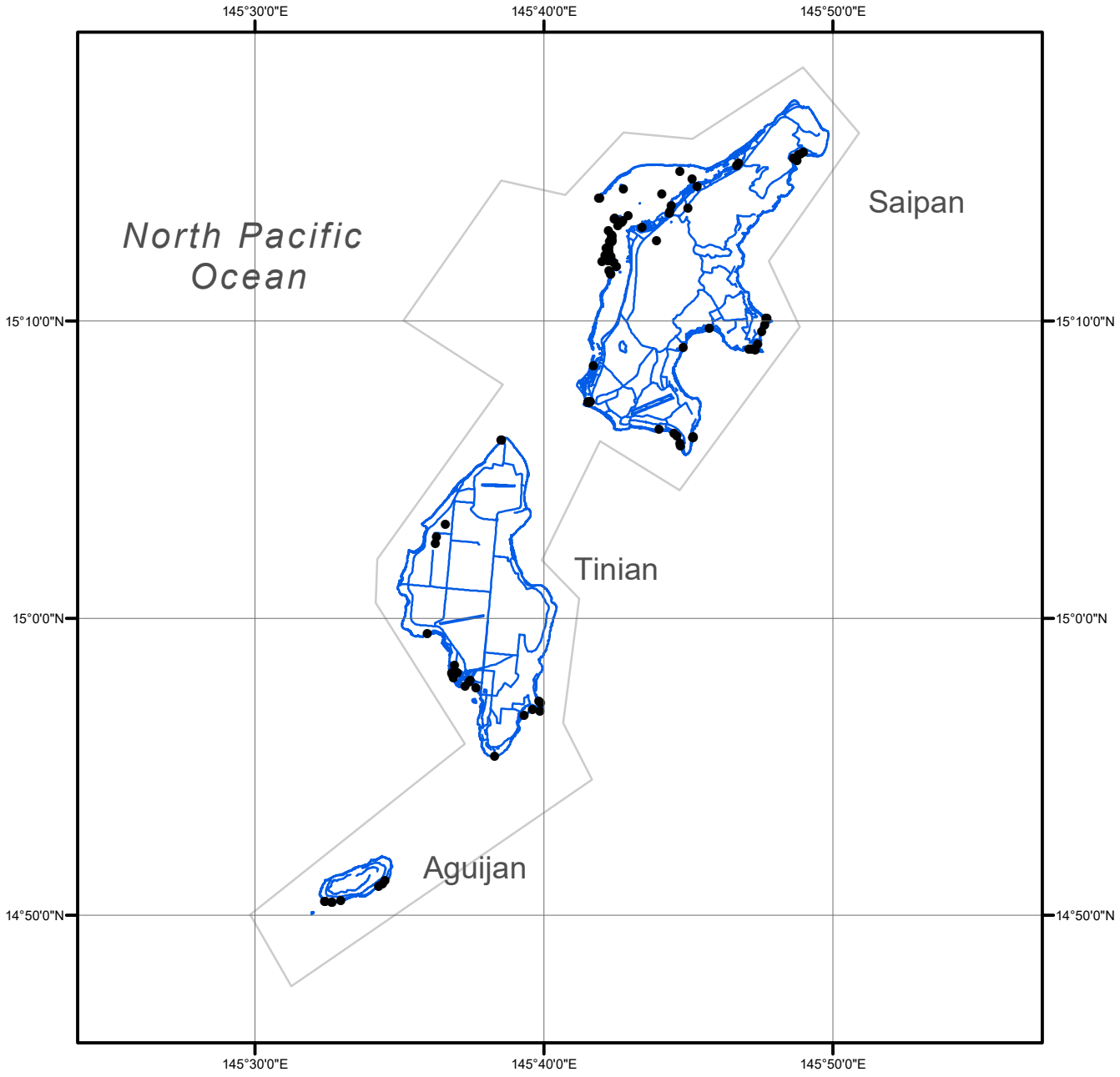
NOAA Shoreline Data Explorer

- GC11634 in shapefile format
- Metadata file for GC11634
- PCR in Adobe PDF format

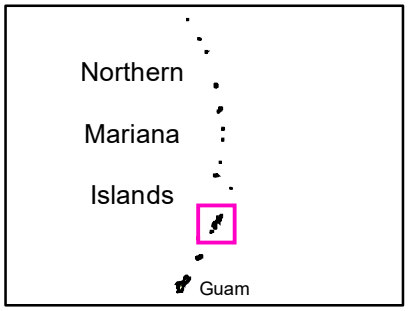
End of Report

SAIPAN, TINIAN, AND AGUIJAN

NORTHERN MARIANA ISLANDS



Overview



MP1907C-TB-C

GC11634