NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT PR1801E-TB-C

West Coast of Puerto Rico, Punta Vaquero to Punta Puntilla

Introduction

NOAA Coastal Mapping Program (CMP) Project PR1801E-TB-C provides a highly accurate database of new digital shoreline data for the west coast of Puerto Rico, from Punta Vaquero to Punta Puntilla, including Isla Desecheo. Project PR1801E-TB-C is a subproject of a larger project, PR1801-TB-C, which covers Puerto Rico in its entirety. 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

NOAA's National Geodetic Survey (NGS) Remote Sensing Division (RSD) 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 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. NOAA also provided shapefiles depicting the shoreline to be mapped and the boundaries of the main project area.

Dewberry was responsible for the planning, acquisition, and processing of all imagery and lidar data in order to support feature compilation. This includes the establishment of ground control and the post-processing of airborne GPS data. In addition, Dewberry provided shapefiles of the flight lines and exposure centers of the imagery to be used for compilation.

Field Operations

Dewberry and their subcontractor Leading Edge Geomatics, LLC (LEG) performed field operations for Project PR1801-TB-C in conjunction with Project VI1801-TB-C consisting of the acquisition of aerial photographs and topographic-bathymetric (topobathy) lidar, as well as the surveying of ground control points (GCPs), accuracy assessment checkpoints (CPs), and the establishment of base stations to support aerial collection and real-time kinematic survey operations.

LEG surveyed 95 ground control points for PR1801-TB-C, to be used for the aerial triangulation of the aerial imagery using static and RTK GNSS/GPS surveying methods. Survey field work was performed from January to March 2019. Dewberry performed a separate survey of 40 ground control points and 292 check points, to be used to evaluate the vertical and horizontal accuracy of the PR1801-TB-C lidar data. Dewberry's survey field work was performed from March to May 2019. For further information see the Ground Survey Reports on file with other project data within the RSD Electronic Data Library.

The lidar acquisition for projects PR1801-TB-C and VI1801-TB-C was conducted by LEG from January through June 2019, and consisted of 992 parallel flight lines and 44 cross-flights with a combined nominal point density of 4.28 pulses per square meter. Topobathy lidar data was captured using a RIEGL VQ880-GII Topobathymetric lidar system on a Piper Aztec aircraft. For further information on lidar acquisition and processing see the Topobathy Final Report of Survey on file within the RSD Electronic Data Library.

Aerial photography acquisition for PR1801-TB-C was conducted by LEG between February and November 2019, using four aircraft outfitted with three aerial mapping cameras. Persistent cloud cover was an issue with this project. Portions of flight lines had to be recollected at various altitudes in an attempt to fly under the cloud cover. The ground sample distance (GSD) of the acquired imagery varied due to the different flying heights. Originally the imagery was required to be tide-coordinated within ±3 hours of the Mean Lower Low Water (MLLW) tide stage, but later the tidal restriction was relaxed to ±4 hours around low tide, in order to help mitigate the cloud problem. A total of 238 flight lines of digital RGB imagery were acquired, including many re-flights and patches due to clouds. Of these flight lines, a subset of all or part of 102 lines were used for the PR1801E-TB-C subproject. For further information see the Final Orthoimagery and Analytical Aerotriangulation Reports on file within the RSD Electronic Data Library.

GPS Data Processing

Airborne kinematic GPS/IMU data for PR1801-TB-C were processed using a variety of techniques to determine trajectory and exterior orientation data for aerotriangulation of the imagery and processing of the lidar data. A combination of static base stations and CORS stations were utilized as reference stations for the kinematic data processing. The data were processed using Applanix POSPac MMS (ver. 8.4) or Novatel Inertial Explorer (ver. 8.70.3114) software for each mission depending on which aircraft/camera system was used. The processing mode used for each trajectory varied between Singlebase, Multi-Singlebase, Applanix Smartbase, or Smoothed Tightly-Coupled Combined, depending on the software used and the number of viable reference stations available in the vicinity of the trajectory. For further information refer to the Airborne Positioning and Orientation Report (APOR) and the Topobathy Final Report of Survey on file within the RSD Electronic Data Library.

Lidar Data Processing

Lidar point cloud data for Project PR1801-TB-C were processed from February to December 2019. 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 lidar point cloud, and for classification of water surface, erroneous returns, bathymetric surface, and bare earth points. Refraction correction was performed with Dewberry's lidar processor. Additional quality control (QC), point classification, and formatting were performed with GeoCue, Terrasolid, and Global Mapper software. NOAA VDatum software was used to convert the vertical datum of the lidar points from NAD83 ellipsoid to local MHW and MLLW tidal datums. 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 numerous sample sites in the project area to determine the uncertainty of the vectors. Based on this assessment the MHW lidar-derived shoreline vectors meet horizontal accuracies of 1.3 – 1.5 meters at the 95% confidence level, and the MLLW lidar-derived shoreline vectors meet horizontal accuracies of 1.4 – 1.7 meters at the 95% confidence level. For further information refer to the Topobathy Final Report of Survey on file with other project data within the RSD Electronic Data Library.

Aerotriangulation

The aerotriangulation (AT) phase of PR1801-TB-C was performed by Dewberry subcontractor LEG using digital AT methods to establish the network of photogrammetric control required for the compilation phase. Inpho Match-AT software was used to perform automatic and interactive point measurements of tie points. The process included automatic point matching and least-squares-simultaneous-robust bundle-block adjustments consisting of three main blocks covering the mainland of Puerto Rico and the large islands of Culebra and Vieques. Additionally, there were 14 sub-blocks covering small islands off the coasts of the three main islands that could not be tied to the main blocks, and were adjusted separately using manually measured tie points and lidar-derived control points.

The PR1801E-TB-C subproject was covered by the Puerto Rico mainland block and four smaller sub-blocks (7 RI 4, 7 RI 5, 8 RI 1 & 9). 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. The predicted horizontal accuracies for the PR1801E-TB-C main blocks and sub-blocks are as follows:

- Mainland Block: 0.2 meters
- 7 RI 4 Sub-block: 0.2 meter
- 7 RI 5 Sub-block: 0.1 meter
- 8 RI 1 Sub-block: 1.1 meter
- 9 Sub-block: 0.4 meter

An AT Report is on file with other project data within the RSD Electronic Data Library. The project database consists of project parameters and options, camera calibration data, 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).

Compilation

Feature compilation for the project was initiated by Dewberry personnel in January 2021. NGS supplied the lidar-derived MHW and MLLW shapefiles to be edited, attributed and generalized. Additional features were then manually compiled using stereo imagery. Compilation was performed using the SOCET for ArcGIS module of BAE's SOCET SET (ver. 5.6) photogrammetric software suite, enabling compilation of features into an Esri Geodatabase where topological and attribution relationships could be enforced. Once compilation was

complete, the geodatabase features were exported to shapefile format. 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 subproject PR1801E-TB-C were determined according to standard Federal Geographic Data Committee (FGDC) practices. Horizontal accuracies at the 95% confidence level of cartographic features compiled from imagery for the PR1801E-TB-C main blocks and sub-blocks are listed below:

- Mainland Block: 0.4 meters
- 7 RI 4 Sub-block: 0.4 meter
- 7 RI 5 Sub-block: 0.2 meter
- 8 RI 1 Sub-block: 2.2 meter
- 9 Sub-block: 0.8 meter

These predicted accuracies of compiled, well-defined points are derived by doubling the circular error calculated from the AT statistics. The lidar-derived features had horizontal accuracies that varied from 1.3 meters to 1.7 meters as discussed above.

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

Date	Time (UTC)	Flight Line #	Photo IDs	Tide Level *
2/16/2019	14:30 – 14:31	37-801	1001 – 1007	0.2 m
2/16/2019	14:36 – 14:39	37-802	1001 – 1022	0.2 m
2/16/2019	14:44 – 14:47	37-805	1001 – 1020	0.2 m
2/16/2019	14:51 – 14:54	37-806	1002 – 1021	0.1 m
2/16/2019	14:57 – 14:59	37-807	1001 – 1020	0.1 m
2/16/2019	15:45 – 15:47	37-104	1080 – 1093	0.1 m
2/16/2019	15:54 – 15:57	37-101	1004 – 1024	0.1 m
2/16/2019	16:01 – 16:05	37-102	1001 – 1030	0.1 m
2/16/2019	16:09 – 16:13	37-103	1002 – 1033	0.1 m
2/16/2019	16:18 – 16:21	37-105	1001 – 1025	0.1 m
2/16/2019	16:43 – 16:45	37-106	1067 – 1084	0.1 m
2/27/2019	13:28 – 13:30	37-818	1003 – 1015	0.1 m
2/27/2019	13:49 – 13:55	37-819	1002 – 1043	0.1 m
2/27/2019	14:05 – 14:08	37-814	1005 – 1024	0.1 m
2/27/2019	14:15 – 14:19	37-815	1003 – 1030	0.1 m
2/27/2019	14:25 – 14:29	37-816	1001 – 1026	0.1 m
2/27/2019	14:35 – 14:38	37-817	1004 – 1023	0.1 m
3/2/2019	14:59 – 15:02	37-808	1029 – 1046	0.2 m

3/3/2019	16:21 – 16:24	37-835	1001 – 1025	0.2 m
3/3/2019	16:29 – 16:33	37-834	1002 – 1029	0.1 m
3/3/2019	16:40 – 16:48	37-833	1002 – 1055	0.1 m
3/3/2019	16:52 – 17:00	37-832	1001 – 1054	0.1 m
3/3/2019	17:14 – 17:15	37-829	1052 – 1064	0.1 m
3/3/2019	17:33 – 17:42	37-826	1002 – 1058	0.1 m
3/3/2019	17:47 – 17:54	37-823	1002 – 1054	0.1 m
3/3/2019	18:00 – 18:07	37-822	1002 – 1052	0.1 m
3/3/2019	18:12 – 18:19	37-821	1002 – 1051	0.1 m
3/14/2019	13:25 – 13:33	37-831	1006 – 1079	0.1 m
3/14/2019	13:36 – 13:46	37-830	1001 – 1082	0.1 m
3/14/2019	13:50 – 14:00	37-828	1006 – 1086	0.1 m
3/28/2019	13:32 – 13:35	28-812	1004 – 1029	0.2 m
3/28/2019	13:45 – 13:46	28-813	1019 – 1024	0.1 m
3/30/2019	14:58 – 14:59	28-193	2003 – 2008	0.1 m
3/30/2019	15:03 – 15:04	28-192	1003 – 1009	0.1 m
3/30/2019	15:08 – 15:08	28-191	1003 – 1008	0.1 m
4/9/2019	14:24 – 14:25	28-711	1007 – 1015	0.1 m
4/14/2019	17:43 – 17:46	28-710	2020 – 2040	0.1 m
4/19/2019	16:23 – 16:24	28-715	1003 – 1010	0.2 m
4/19/2019	16:45 – 16:49	28-716	1045 – 1071	0.1 m
4/20/2019	14:25 – 14:28	28-717	1045 – 1071	0.4 m
4/20/2019	14:37 – 14:42	28-718	1001 – 1030	0.4 m
4/20/2019	15:00 – 15:03	28-719	1044 – 1073	0.3 m
4/20/2019	15:21 – 15:22	28-722	1008 – 1018	0.1 m
4/20/2019	15:29 – 15:32	28-721	1001 – 1016	0.1 m
4/20/2019	15:37 – 15:40	28-720	3004 – 3021	0.1 m
5/6/2019	12:46 – 12:52	28-703	1001 – 1040	0.1 m
5/6/2019	12:57 – 13:03	28-704	1001 – 1044	0.1 m
5/6/2019	13:12 – 13:19	28-705	1001 – 1044	0.1 m
5/6/2019	13:24 – 13:30	28-706	1001 – 1044	0.1 m
5/6/2019	13:35 – 13:42	28-707	1001 – 1044	0.1 m
5/6/2019	13:46 – 13:49	28-708	1001 – 1023	0.1 m
5/6/2019	13:57 – 14:02	28-709	1007 – 1035	0.1 m
6/1/2019	14:57 – 15:03	28-809	2003 – 2051	0.1 m
6/1/2019	15:12 – 15:19	28-820	3002 – 3051	0.1 m
6/1/2019	15:26 – 15:34	28-824	2001 – 2060	0.1 m
6/2/2019	14:55 – 15:05	28-825	2004 – 2065	0.2 m

6/4/2019	16:06 – 16:16	28-827	3002 – 3066	0.2 m
6/4/2019	16:21 – 16:28	28-829	2002 – 2056	0.2 m
6/17/2019	15:06 – 15:08	28-803	2013 – 2026	0.2 m
6/17/2019	15:13 – 15:16	28-804	2001 – 2021	0.2 m
6/18/2019	14:39 – 14:45	28-810	3003 – 3047	0.3 m
6/18/2019	14:54 – 14:56	28-811	3015 – 3027	0.2 m
7/16/2019	13:02 – 13:03	11-842	2004 – 2015	0.4 m
7/16/2019	13:10 – 13:11	11-841	1013 – 1030	0.4 m
7/16/2019	13:16 – 13:17	11-840	1001 – 1020	0.3 m
7/16/2019	13:23 – 13:25	11-839	1011 – 1033	0.3 m
7/16/2019	13:29 – 13:30	11-838	1001 – 1019	0.3 m
7/16/2019	13:36 – 13:39	11-843	1001 – 1039	0.3 m
7/16/2019	13:43 – 13:45	11-844	1001 – 1039	0.3 m
7/16/2019	13:51 – 13:56	11-845	1001 – 1083	0.3 m
7/16/2019	14:03 – 14:08	11-846	1001 – 1077	0.3 m
7/16/2019	14:13 – 14:18	11-847	1001 – 1077	0.3 m
7/16/2019	14:27 – 14:29	11-851	1001 – 1021	0.1 m
7/16/2019	14:33 – 14:34	11-850	1001 – 1021	0.1 m
7/16/2019	14:41 – 14:41	11-852	1001 – 1007	0.1 m
7/16/2019	14:47 – 14:47	11-853	1001 – 1007	0.1 m
7/16/2019	14:56 – 14:58	11-854	1001 – 1025	0.1 m
7/16/2019	15:03 – 15:04	11-855	1001 – 1025	0.1 m
7/16/2019	15:09 – 15:11	11-856	1001 – 1027	0.1 m
7/16/2019	15:16 – 15:17	11-857	1001 – 1026	0.1 m
7/16/2019	15:24 – 15:25	11-858	1001 – 1026	0.1 m
7/16/2019	15:34 – 15:34	11-748	1001 – 1007	0.1 m
7/16/2019	15:39 – 15:40	11-747	1001 – 1020	0.1 m
7/16/2019	15:42 – 15:42	11-860	1001 – 1007	0.1 m
7/16/2019	15:51 – 15:51	11-859	1001 – 1007	0.1 m
7/16/2019	15:56 – 15:56	11-848	1001 – 1009	0.2 m
7/16/2019	16:01 – 16:02	11-849	1001 – 1009	0.2 m
7/17/2019	15:05 – 15:07	11-746	1001 – 1040	0.1 m
7/17/2019	15:13 – 15:16	11-745	1001 – 1041	0.1 m
7/17/2019	15:20 – 15:22	11-744	1001 – 1030	0.1 m
7/17/2019	15:29 – 15:31	11-743	1001 – 1031	0.1 m
7/17/2019	15:39 – 15:43	11-742	1001 – 1070	0.1 m
7/17/2019	15:52 – 15:57	11-741	1001 – 1067	0.1 m
7/17/2019	16:02 – 16:06	11-740	1001 – 1067	0.1 m

7/17/2019	16:18 – 16:19	11-739	1001 – 1012	0.1 m
7/17/2019	16:26 – 16:27	11-738	1001 – 1012	0.1 m
7/17/2019	16:35 – 16:35	11-737	1001 – 1006	0.1 m
11/22/2019	12:53 – 12:54	42-862	1001 – 1004	0.3 m
11/24/2019	12:28 – 12:30	42-752	1001 – 1007	0.4 m
11/24/2019	12:41 – 12:42	42-753	1001 – 1006	0.4 m
11/24/2019	12:44 – 12:45	42-754	1001 – 1005	0.4 m
11/24/2019	13:51 – 13:52	42-861	2001 – 2004	0.4 m

* Water levels are given in meters above MLLW and are based on verified observations recorded by the NOS tide gauges at: Mayaguez, PR - Station ID: 9759394; Magueyes Island, PR – Station ID: 9759110. The elevation of MHW above MLLW is 0.352 meters at Mayaguez and 0.201 meters at Magueyes Island.

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 May 2021. The review process included analysis of AT 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. 10.8.1) 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:

25671, West Coast of Puerto Rico, 19th Ed., Jul. 2011
25673, Bahia De Mayaguez and Approaches, 17th Ed., Sep. 2013
25675, Bahia De Boqueron, 10th Ed., Oct. 2011
25677, Guanica Light to Punta Tuna Light, 22nd Ed., Jul. 2013
25679, Bahia De Guanica, 11th Ed., Oct. 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
- Project database
- Ground Survey Reports
- Airborne Positioning and Orientation Report (APOR)
- Orthoimagery Final Report
- Topobathy Final Report of Survey
- Aerotriangulation Report
- Project Completion Report (PCR)
- GC11533 in shapefile format
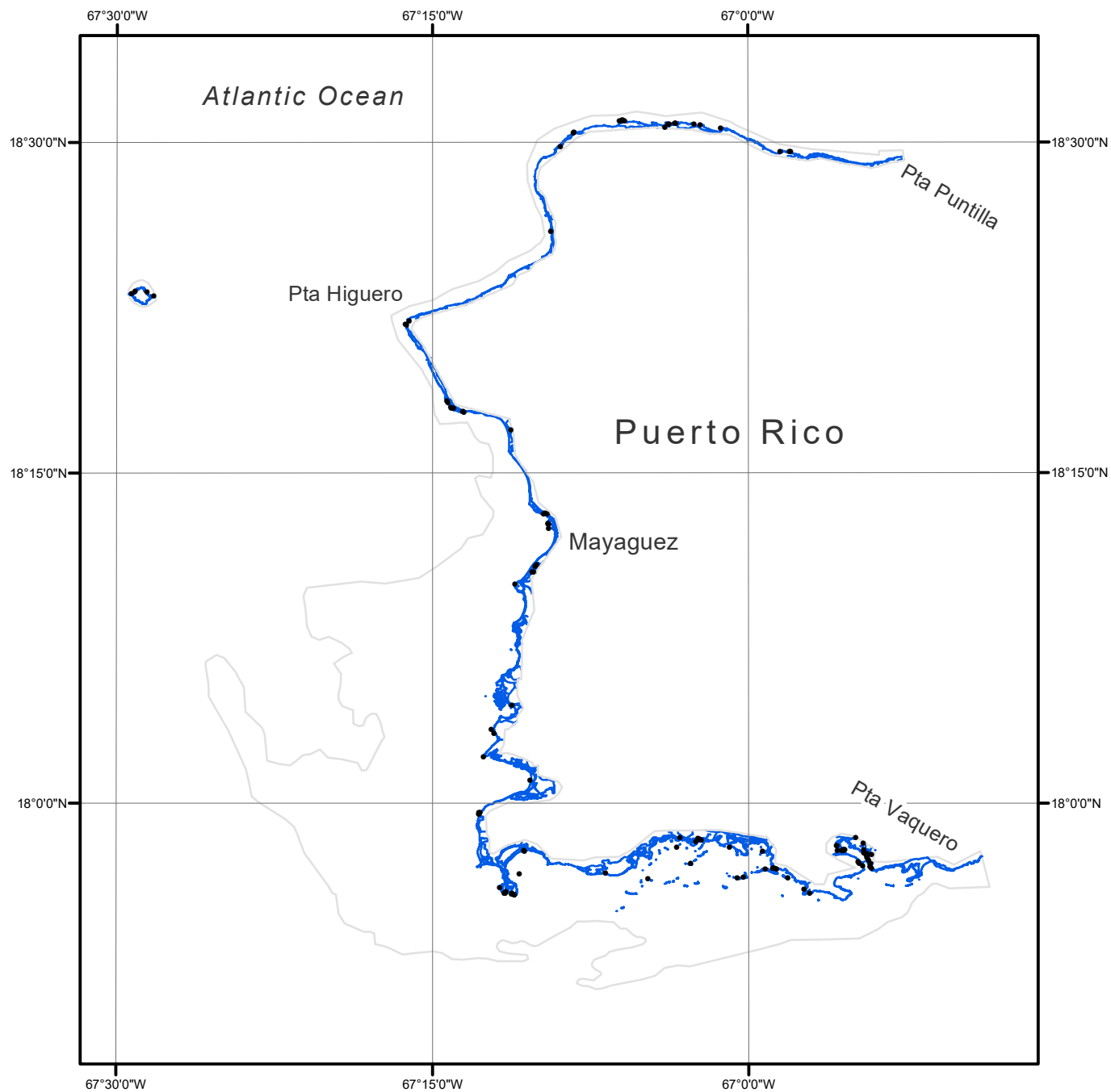- CEF in shapefile format

NOAA Shoreline Data Explorer
- GC11533 in shapefile format
- Metadata file for GC11533
- PCR in Adobe PDF format

End of Report

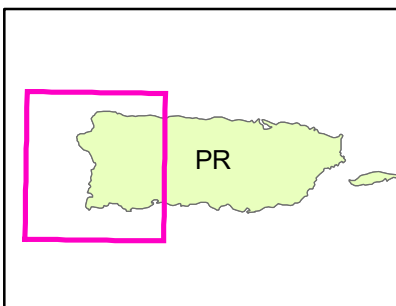# WEST COAST OF PUERTO RICO, PTA VAQUERO TO PTA PUNTILLA
PUERTO RICO

Atlantic Ocean

67°30'0"W 67°15'0"W 67°0'0"W

18°30'0"N

Pta Puntilla

Pta Higuero

Puerto Rico

18°15'0"N

Mayaguez

18°0'0"N

Pta Vaquero

67°30'0"W 67°15'0"W 67°0'0"W

Overview

PR

PR1801E-TB-C

GC11533