Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Ibajay River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Cebu

APRIL 2017

Published by UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of Grant-in-Aid Program and is to be cited as:

E.C. Paringit and J.R. Sinogaya (eds.) (2017), LiDAR Surveys and Flood Mapping of Ibajay River, Quezon City: University of the Philippines Training Center on Applied Geodesy and Photogrammetry-180pp.

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National Library of the Philippines
ISBN: 978-621-430-106-5

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAM-RIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND IBAJAY RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer R. Sinogaya, PhD.

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Cebu (UPC). UPC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 22 river basins in the Western Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Ibajay River Basin

Ibajay River Basin is located in the Province of Aklan located at the north of Panay Island and covers portions of the barangays of Poblacion, Colongcolong, Polo, Tul-Ang, Laguinbanua, Bagacay, Rizal, Unat, Naligusan, Agdugayan, and Naile in Ibajay, Aklan. The DENR River Basin Control Office identified the basin to have a drainage area of 246 km^2 and an estimated annual run-off of 386 million cubic meter (MCM) (RBCO, 2015).

The floodplain and drainage area of 69 km^2 and 57.189 km^2 respectively covers the municipalities of Ibajay, Pandan, Tangalan, Makato and Malinao. The floodplain is 100% covered with LiDAR data which compromises 7 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of 0.09 and then bathy burned. The bathy survey conducted reached a total length of 9.57 km starting from Agdugayan, Ibajay up to the river mouth with 1543 points surveyed. There are 9320 buildings, 78.85 km roads, 275 waterbodies and 17 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 8858 of them are Residential, 212 are schools and 23 are Medical Institutions.

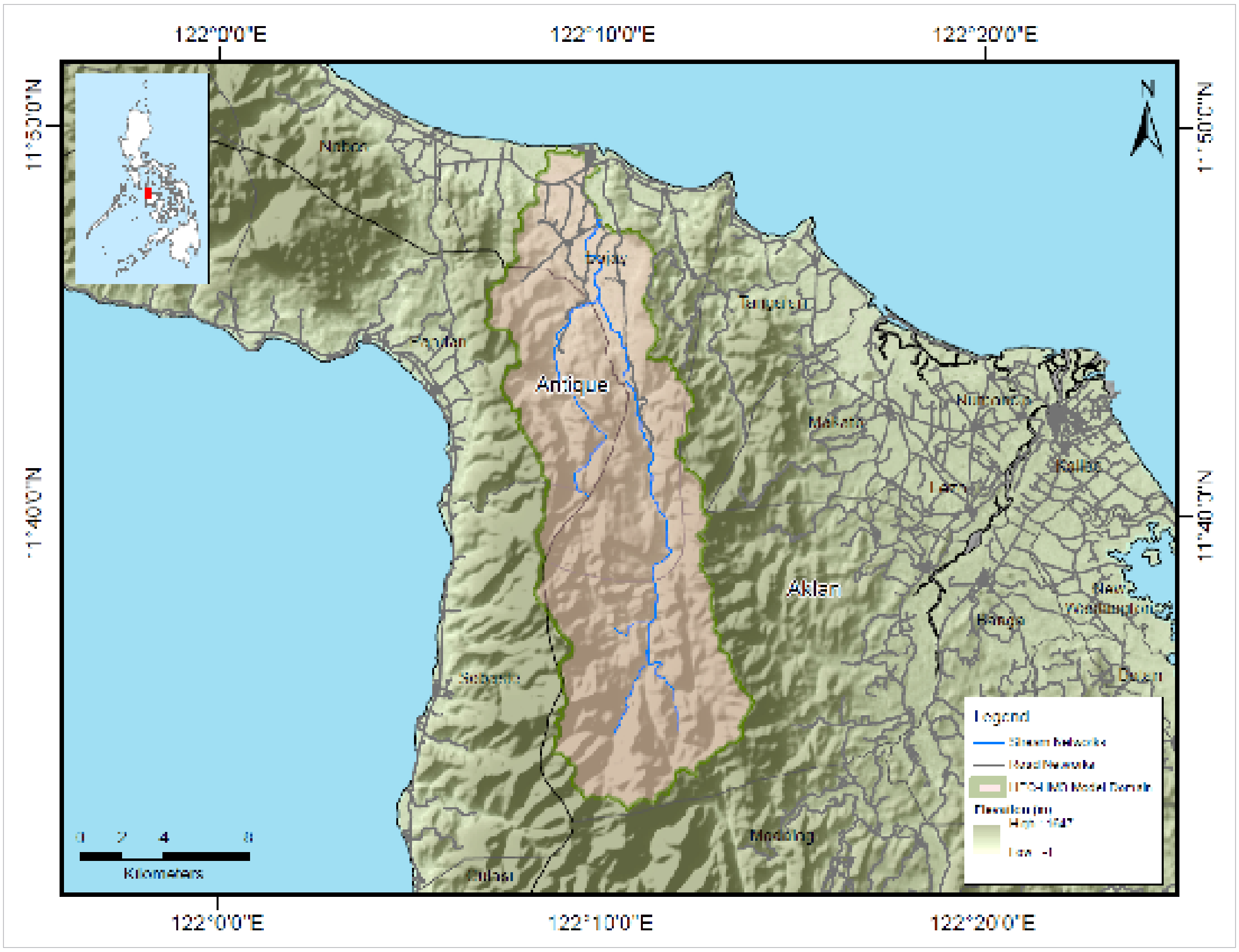

Figure 1. Map of Ibajay River Basin (in brown)

Its main stem, Ibajay River, is among the twenty-two (22) river system in Visayas Region. According to the 2015 national census of NSO, a total of 17,006 persons are residing within the immediate vicinity of the river which is distributed among eleven (11) barangays in the municipality of Ibajay (NSO, 2015). Aside from the municipality's rich in agricultural resources, handicrafts, pottery and tourism largely play on their economic development. Their local products includes handicrafts made from Nito fern, bricks, vases and jars.Some of the tourist spots in the municipality are Campo Verde, Katunggan It Ibajay Mangrove Park and Ibajay Falls and Ibajay River (http://aklan.gov.ph/tourism/ibajay/, 2017). Last December 30, 2012, province of Aklan has been placed under a state of calamity due to flooding brought by Tropical Storm "Quinta". Eight of the Aklan's 17 towns were affected by flooding which includes Ibajay River (http://newsinfo.inquirer.net/332007/aklan-placed-under-state-of-calamity, 2017).

The flood hazard map produced covers the 16.17 km^2, 20.64 km^2, 23.22 km^2 for the 5-year, 25-year, and 100 year rainfall return period in Ibajay which affects 27 barangays as well as in Nabas which affects 2 barangays and in Pandan which affects 4 barangays. A flood depth validation was conducted using 210 randomly generated points which is spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded a 0.966 m RMSE.

A rating curve was developed at San Jose Flow Site, Ibajay, Aklan, which shows the relationship between the observed water levels at San Jose Flow Site and outflow of the watershed at this location. This rating curve equation, expressed as Q = 66.291e0.5476x, was used to compute the river outflow at San Jose Flow Site for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE IBAJAY FLOODPLAIN

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The methods applied in this chapter were based on the DREAM methods manual (Ang, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Ibajay floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Ibajay Floodplain in Aklan. These flight missions were planned for an average of 21 lines and ran for at most four and a half hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1 and Table 2. Figure 2 shows the flight plan for Ibajay floodplain survey.

Table 1. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 38G	600	30	36	50	40	130	5
BLK 38I	600	30	36	50	40	130	5
BLK 38D	600	30	36	50	40	130	5
BLK 38F	600	30	36	50	40	130	5
BLK 38C	600	30	36	50	40	130	5
BLK 38J	600	30	36	70	40	130	5
BLK 38H	600	30	36	50	40	130	5

Table 2. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 38A	800	25	50	125	40	130	5
BLK 38B	800	25	50	125	40	130	5
BLK 38C	1000	30	50	142	40	130	5
BLK 38D	1000	30	40	125	50	130	5
BLK 38E	1200	30	30	100	50	130	5

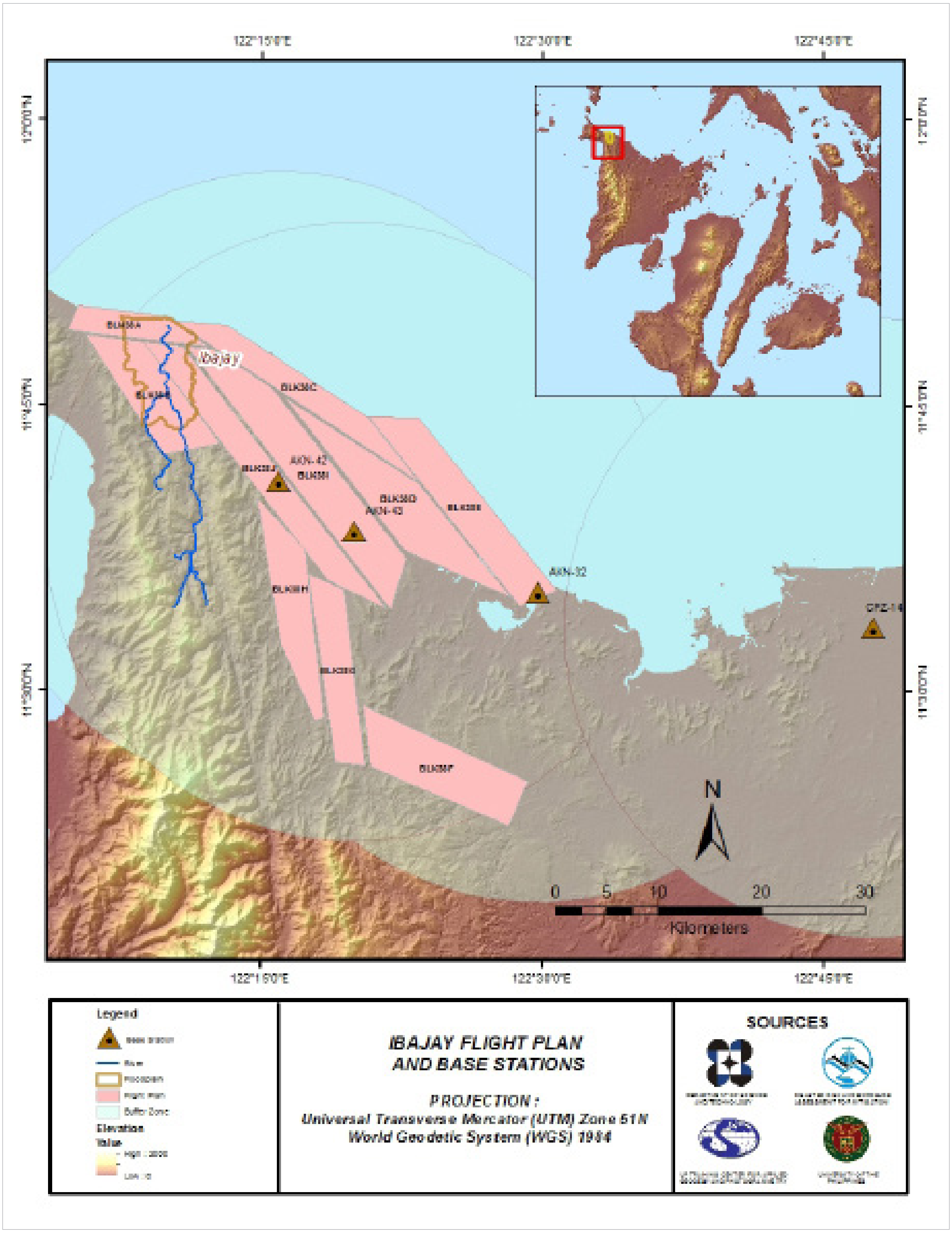

Figure 2. Flight Plan and base stations used for the Ibajay Floodplain survey using Aquarius and Gemini sensors.

2.2 Ground Base Stations

The field team was able to recover four (4) NAMRIA ground control points: AKN-43, AKN-42, AKN-32, and CPZ-14, which are all of second (2nd) order accuracy.

The certifications for the base stations are found in ANNEX 2 while the baseline processing reports for the established control points are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey from March 15 to 22, 2014 and September 18 to 30, 2015. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985 and TOPCON GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ibajay floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Ibajay Floodplain LiDAR Survey. Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area of the floodplain, while Table 3 to Table 6 show the details about the following NAMRIA control stations and established points. Table 7, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3. GPS set-up over AKN-43 located on the concrete sidewalk and recovered in front of the municipal hall of Banga, Aklan and NAMRIA reference point AKN-43 as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point AKN-43 used as base station for the LiDAR acquisition.

Station Name	AKN-43	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 38' 27.12194" North 122° 19' 53.01891" East 17.74900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	427093.296 meters 1287298.051 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 38' 22.52687" North 122o 19' 58.16083" East 72.44500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	427118.81 meters 1286847.47 meters

Figure 4. GPS set-up over AKN-42 at the open court in Barangay Libang, Makato, Aklan (a) and NAMRIA reference point AKN-42 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point AKN-42 used as base station for the LiDAR acquisition.

Station Name	AKN-42	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 41' 4.84235" North 122° 15' 49.78166" East 17.77900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	419737.946 meters 1292162.5 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 41' 0.23066" North 122° 15' 54.92018" East 72.20000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	419766.04 meters 1291710.22 meters

Figure 5. GPS set-up over AKN-32 located at the centerpoint of Batan Multi-purpose Sports Center, (a) and NAMRIA reference point AKN-32 as recovered by the field team.

Table 5. Details of the recovered NAMRIA benchmark AKN-32 used as base station for the LiDAR acquisition.

Station Name	**AKN-32**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 35' 14.35956" North 122° 29' 42.04171" East 3.89400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	444924.599 meters 1281338.493 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 35' 9.79172" North 122° 29' 47.18726" East 59.12600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	444943.88 meters 1280890.00 meters

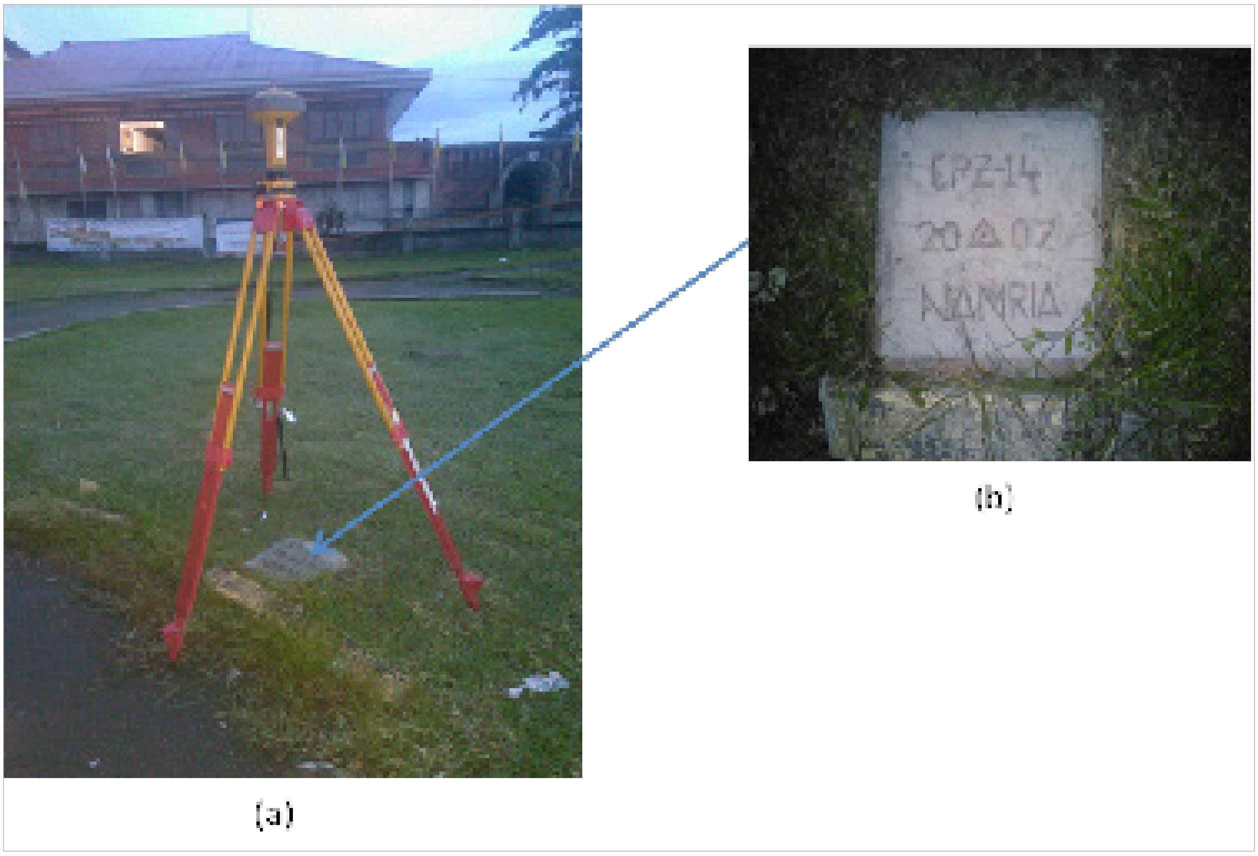

Figure 6. GPS set-up over CPZ-14 located at the centerpoint of Batan Multi-purpose Sports Center (a), and NAMRIA reference point CPZ-14 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontall control point CPZ-14 used as base station for the LiDAR acquisition.

Station Name	**CPZ-14**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°33’24.51899” North 122° 47’34.41876” East 4.91900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	477410.249 meters 1277923.165 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11°33’ 19.98412” North 122° 47’ 39.56494” East 60.96000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	477418.16 meters 1277475.87 meters

Table 7. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 15, 2014	1214A	3BLK38G074A	AKN-43, AKN 42
March 19, 2014	1232A	3BLK38G078B	AKN-43, AKN 42
March 12, 2014	1238A	3BLK38GS080A	AKN-43, AKN 42
March 21, 2014	1240A	3BLK38HS080B	AKN-43, AKN 42
March 22, 2014	1242A	3BLK38V081A	AKN-43, AKN 42
September 18, 2015	2742G	2BLK38D261A	AKN-43, AKN 42
September 19, 2015	2746G	2BLK38ADSE262A	AKN-43, AKN 42
September 24, 2015	2766G	2BLK38C267A	AKN-43, AKN 42
September 25, 2015	2770G	2BLK38BDVES268A	AKN-43, AKN 42, AKN-32
September 30, 2015	2790G	2BLK38BSF273A	AKN-43, AKN 42, AKN-32, CPZ-14

2.3 Flight Missions

A total of ten (10) missions were conducted to complete the LiDAR data acquisition in Ibajay floodplain, for a total of thirty-six hours and twenty-one minutes (36+21) of flying time for RP-C9322 and RP-C9022 (See ANNEX 6). All missions were acquired using the Gemini and Aquarius LiDAR systems. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 8, while the actual parameters used during the LiDAR data acquisition are presented in Table 9.

Table 8. Flight missions for the LiDAR data acquisition of the Ibajay Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within the Floodplain (km²)	Area Surveyed outside the Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
15-Mar-14	1214A	139.3	198.29	1.14	197.15	-	2	29
19-Mar-14	1232A	83.78	75.45	0	75.45	-	3	5
12-Mar-14	1238A	112.01	84.75	15.34	69.41	-	4	47
21-Mar-14	1240A	114.34	70.09	3.93	66.16	-	2	41
22-Mar-14	1242A	85.02	18.21	7.26	10.95	-	2	29
18-Sep-15	2742G	138.91	121.57	1.16	120.41	-	3	53
19-Sep-15	2746G	142.57	170.8	18.14	152.66	1056	4	6
24-Sep-15	2766G	112.3	162.23	0	162.23	-	4	5
25-Sep-15	2770G	230.37	198.77	18.55	180.22	898	4	23
30-Sep-15	2790G	140.57	157.9	46.52	111.38	953	4	23
TOTAL		**703.53**	**797.35**	**57.19**	**740.16**	**2907**	**32**	**261**

Table 9. Actual parameters used during the LiDAR data acquisition of the Ibajay Floodplain.

Date Surveyed	Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (kHz)	Scan Frequency (Hz)	Speed of Plane (Kts)
March 15, 2014	1214A	600	30	36	50	40	130
March 19, 2014	1232A	600	30	36	50	40	130
March 12, 2014	1238A	600	30	36	50	40	130
March 21, 2014	1240A	600	30	36	50	40	130
March 22, 2014	1242A	600	30	36	70	40	130
September 18, 2015	2742G	800/1000	30	40/30	125	50/40	130
September 19, 2015	2746G	800	30	40	125	50	130
September 24, 2015	2766G	1000	30	40	125	40	130
September 25, 2015	2770G	800	30	40	125	50	130
September 30, 2015	2790G	1000/800/600	30	40/30	125/100	50	130

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Ibajay floodplain (See ANNEX 7). It is located in the province of Aklan with majority of the floodplain situated within the municipalities of Lezo, Numancia, New Washington, Kalibo, and Banga. The list of municipalities surveyed with at least one (1) square kilometer coverage is shown in Table 10. Figure 7, on the other hand, shows the actual coverage of the LiDAR acquisition for the Ibajay floodplain.

Table 10. The list of municipalities and cities surveyed of the Ibajay Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Aklan	Lezo	20.24	20.06	99.11%
	Numancia	23.62	22.72	96.19%
	New Washington	48.08	43.67	90.82%
	Kalibo	34.09	30.52	89.53%
	Banga	66.1	58.69	88.79%
	Tangalan	63.43	48.75	76.85%
	Makato	63.68	46.73	73.39%
	Ibajay	132.35	94.48	71.38%
	Batan	80.55	32	39.73%
	Malinao	220.46	78.05	35.40%
	Nabas	83.38	20.99	25.17%
	Balete	108.4	21.12	19.48%
	Libacao	173.15	29.25	16.89%
	Madalag	291.29	32.13	11.03%
Capiz	Jamindan	500.16	37.99	7.56%
Antique	Pandan	153.32	35.3	23.02%
TOTAL		**2062.3**	**652.45**	**31.64%**

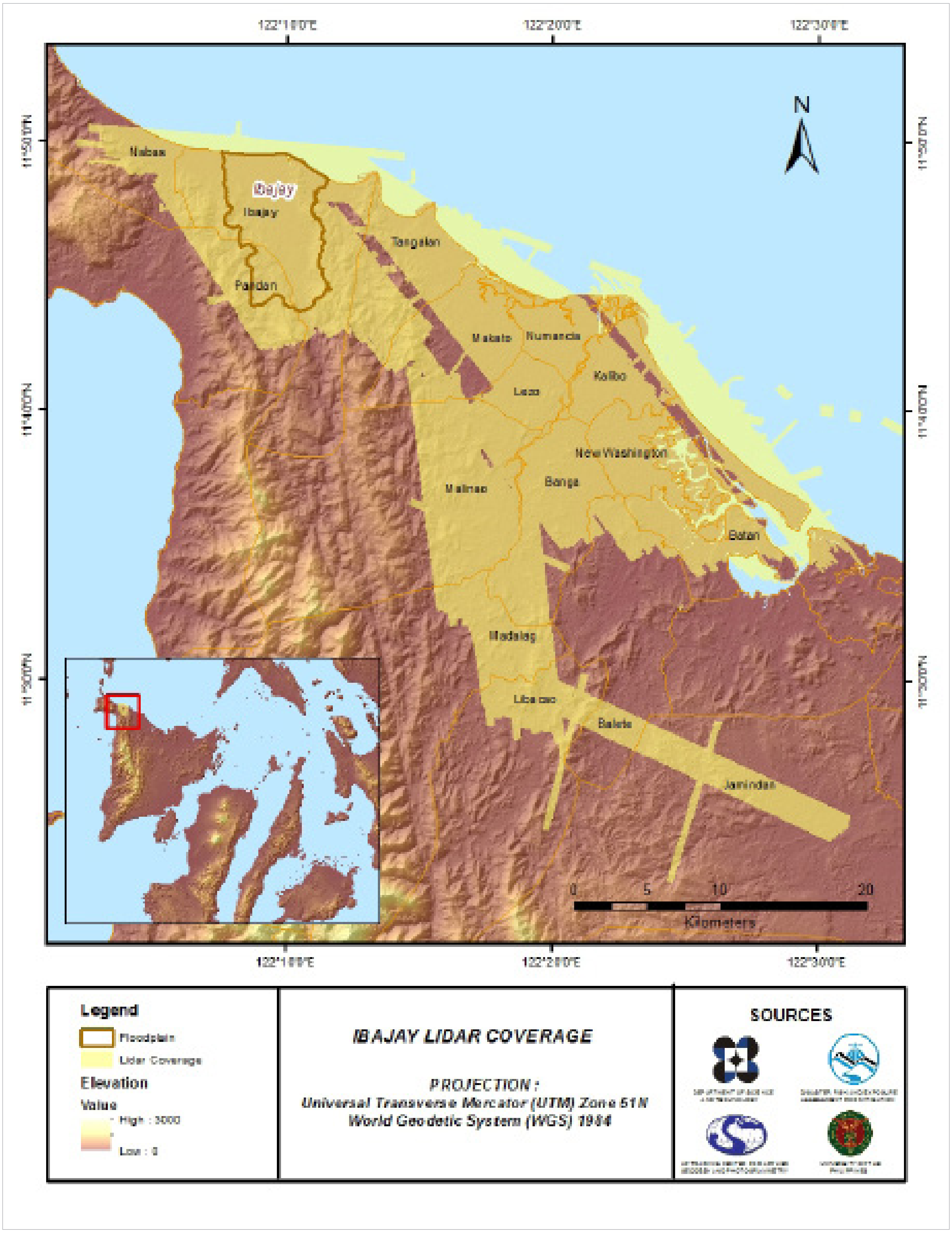

Figure 7. Actual LiDAR survey coverage of the Ibajay Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE IBAJAY FLOODPLAIN

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The methods applied in this chapter were based on the DREAM methods manual (Ang, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 8.

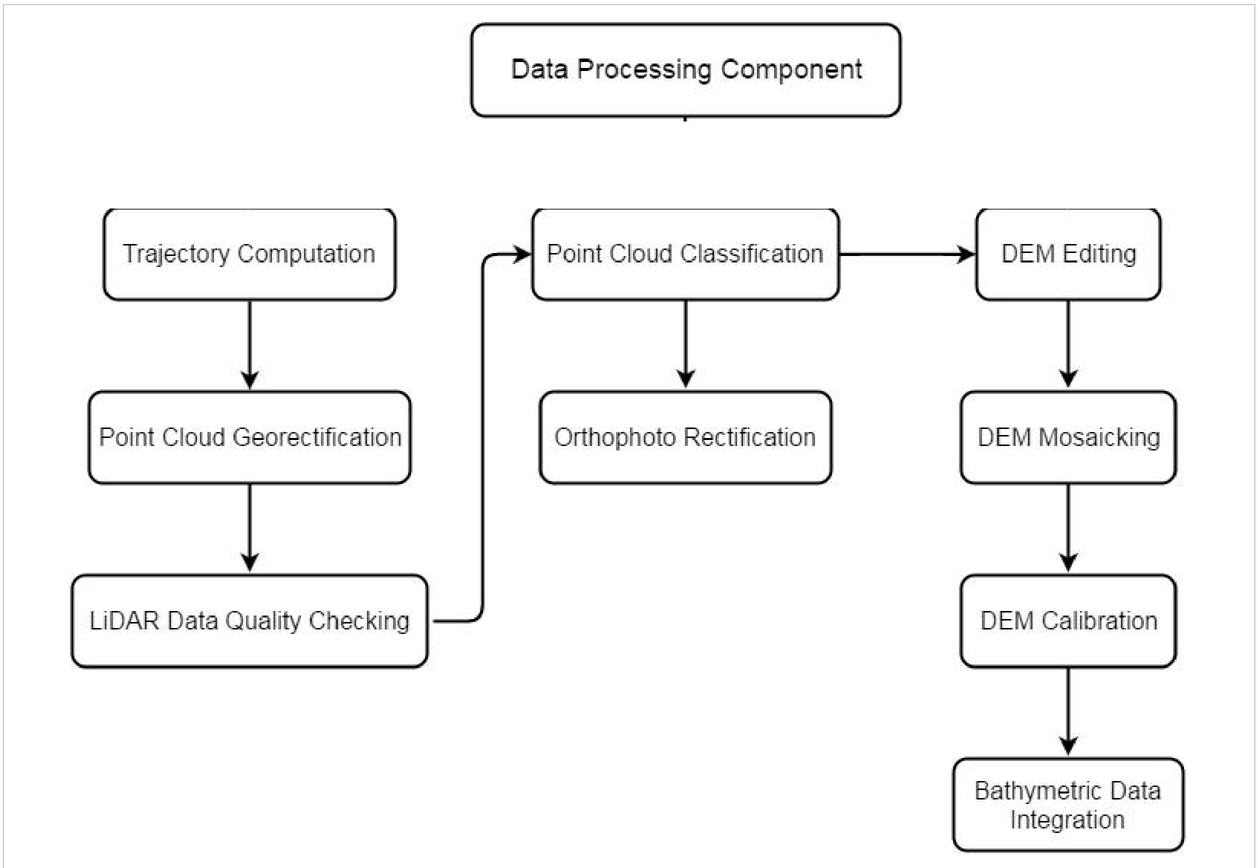

Figure 8. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Ibajay Floodplain can be found in ANNEX 5. The missions flown during the conduct of the first survey in March 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the last survey in September 2015 were flown using the Gemini system over Western Visayas.

The Data Acquisition Component (DAC) transferred a total of 174.65 Gigabytes of Range data, 2.06 Gigabytes of POS data, 525 Megabytes of GPS base station data, and 366.70 Gigabytes of raw image data to the data server on March 15, 2014 for the first survey and September 30, 2015 for the last survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Ibajay Floodplain was fully transferred on October 9, 2015, as indicated on the Data Transfer Sheets for Ibajay floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 1238A, one of the Ibajay flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of March 21, 2014, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

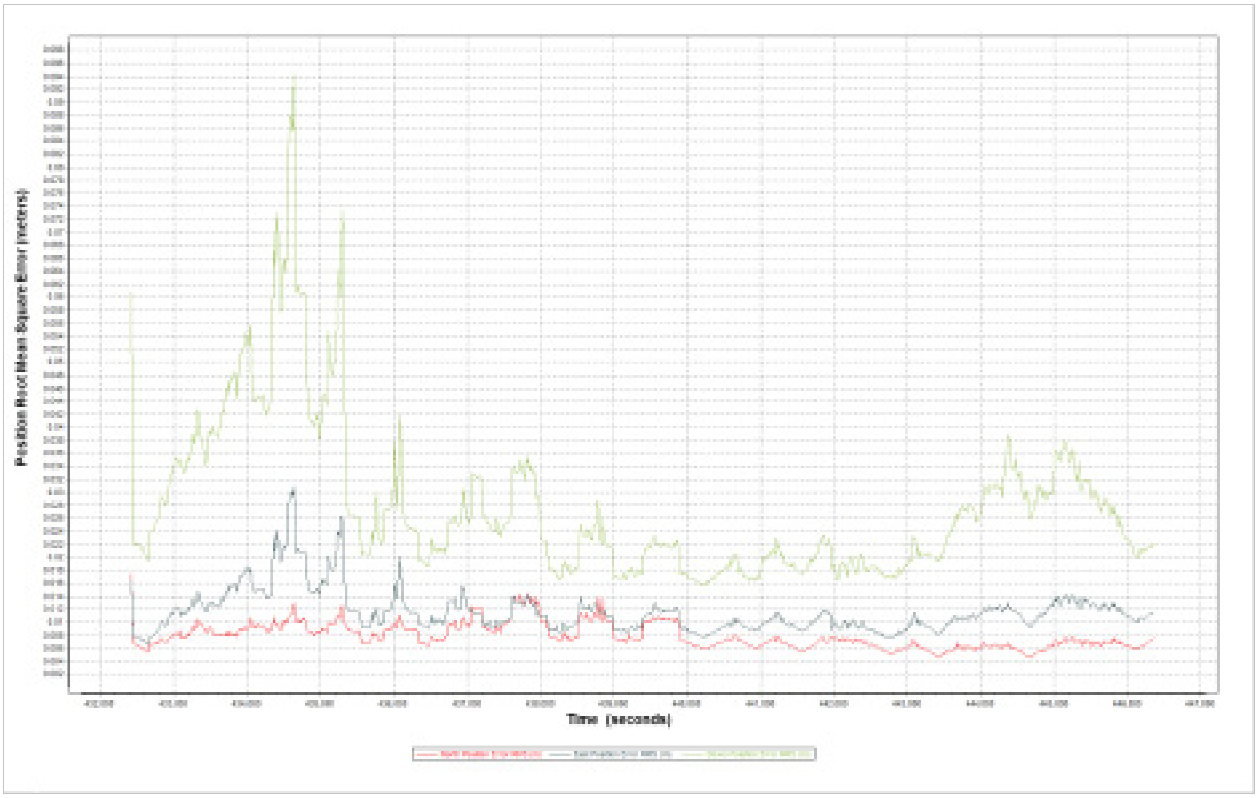

Figure 9. Smoothed Performance Metrics of Ibajay Flight 1238A.

The time of flight was from 432000 seconds to 447000 seconds, which corresponds to morning of March 21, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.60 centimeters, the East position RMSE peaks at 3.20 centimeters, and the Down position RMSE peaks at 9.60 centimeters, which are within the prescribed accuracies described in the methodology.

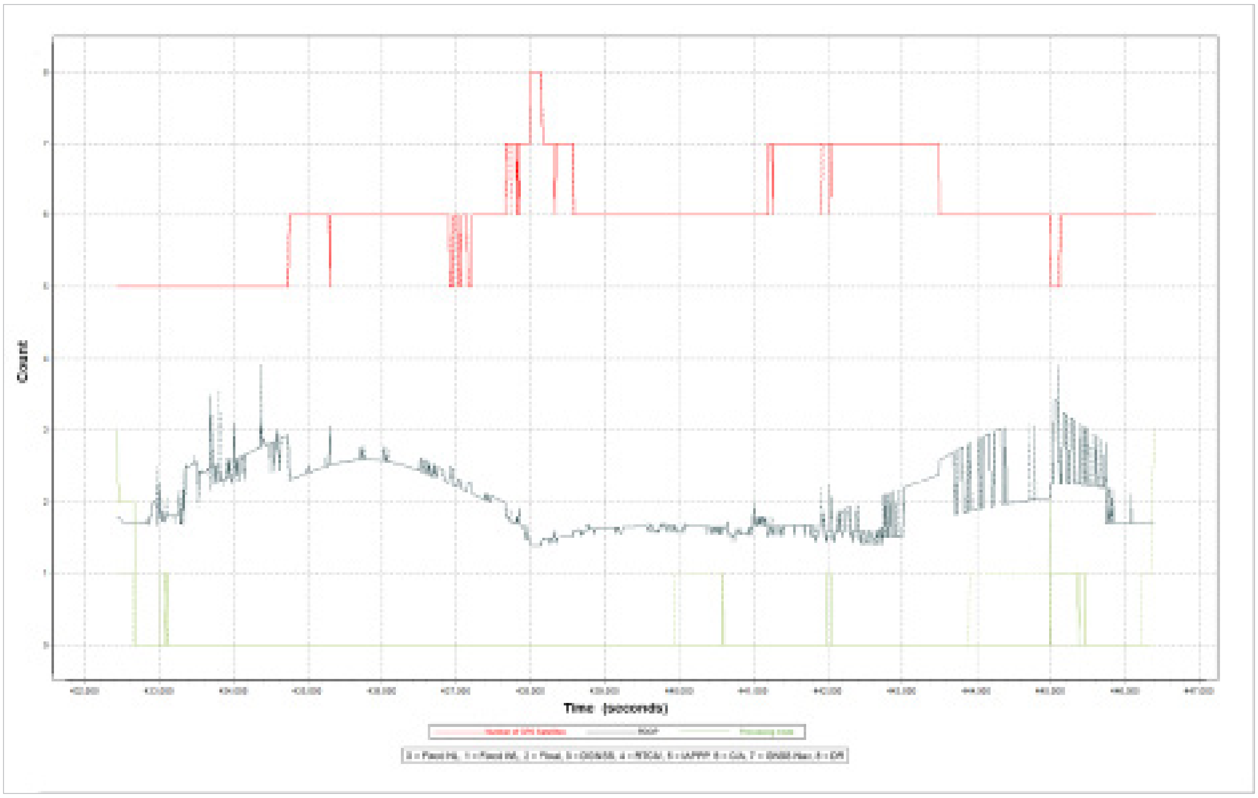

Figure 10. Solution Status Parameters of Ibajay Flight 1238A.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Ibajay Flight 1238A are shown in Figure 10. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 6 and 8, not going lower than 6. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also remained at 0 for the majority of the survey stayed at the value of 0. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for the POSPAC MMS. Fundamentally, all of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Ibajay flights is shown in Figure 11.

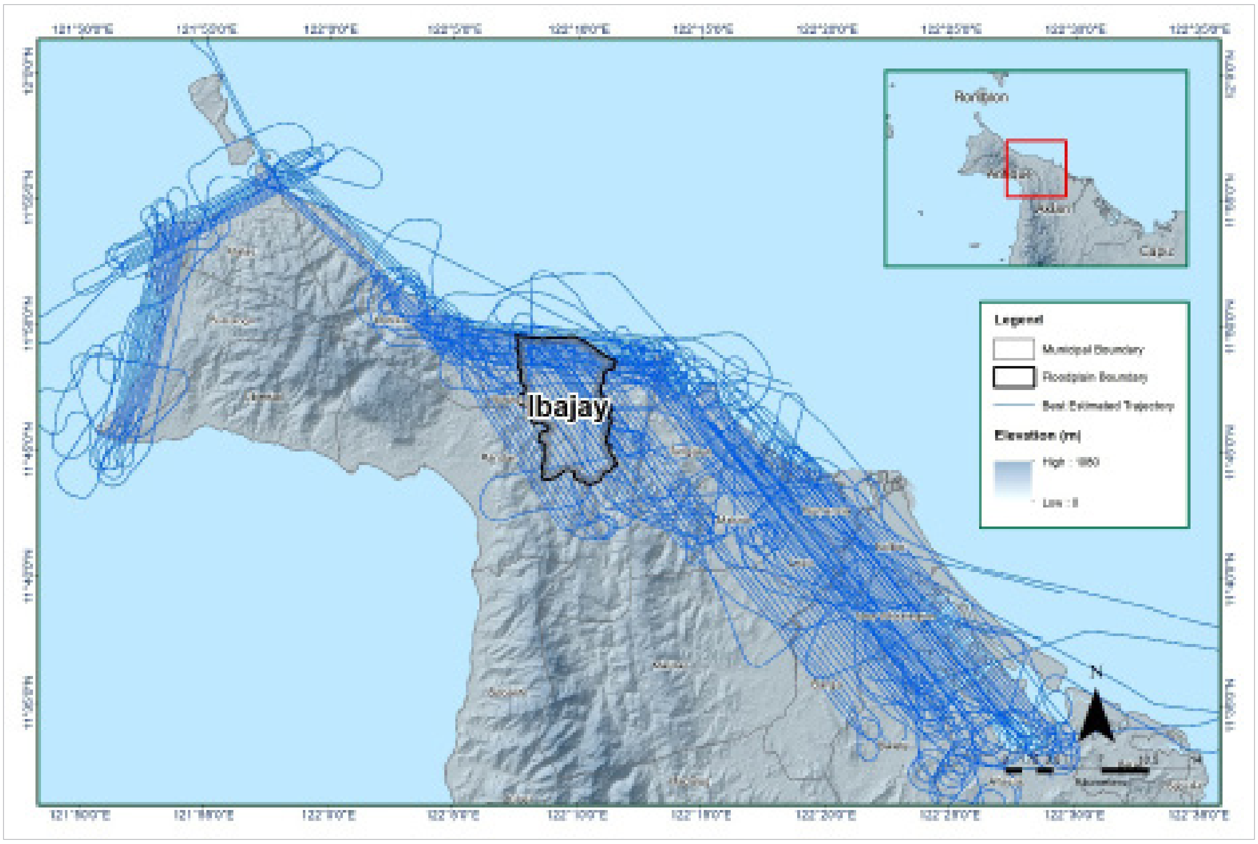

Figure 11. Best estimated trajectory of the LiDAR missions conducted over the Ibajay Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 12 flight lines, with each flight line containing one channel, since the Gemini and Aquarius system both contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Ibajay floodplain are given in Table 11.

Table 11. Self-calibration Results values for Ibajay flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000527
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000902
GPS Position Z-correction stdev (<0.01meters)	0.0024

The optimum accuracy values for all Ibajay flights were also calculated which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (ANNEX 8).

3.5 LiDAR Quality Checking

The boundaries of the processed LiDAR data are shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

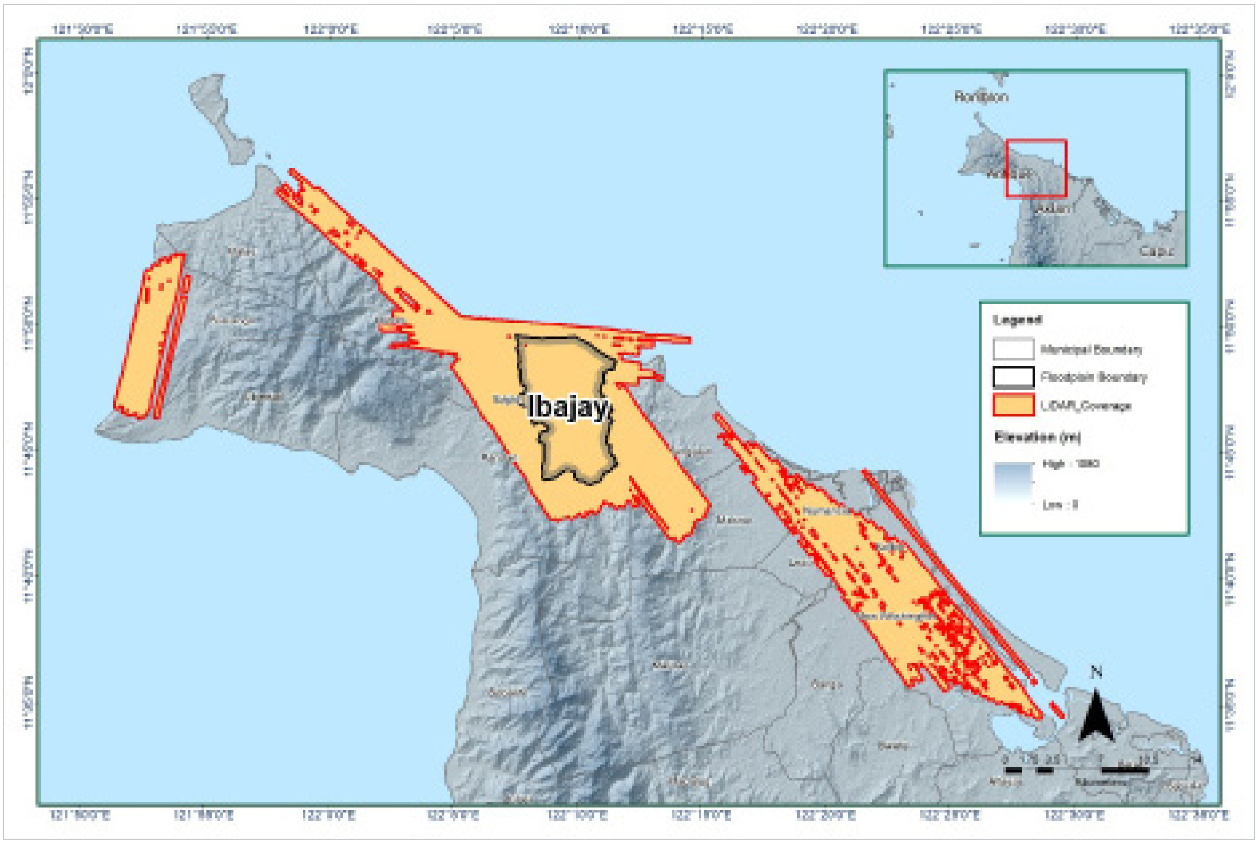

Figure 12. Boundaries of the processed LiDAR data on top of the SAR Elevation Data over the Ibajay Floodplain..

A total area of 422.23 square kilometers (sq. kms.) were covered by the Ibajay flight missions as a result of ten (10) flight acquisitions, which were grouped and merged into seven (7) blocks accordingly, as portrayed in Table 12.

Table 12. List of LiDAR blocks for the Ibajay floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Aklan Blk38G	1232A	141.61
	1238A	
	1214A	
Aklan Blk38Voids	1242A	15.66
Aklan Blk38I_additional	1240A	5.80
Aklan Blk38D	2742G	35.95
	2746G	
	2770G	
Aklan Blk38C	2766G	31.37
Capiz-Aklan Blk38A	2746G	57.19
Capiz-Aklan Blk38B	2770G	134.65
	2790G	
TOTAL		**422.23 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Gemini and Aquarius system both employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

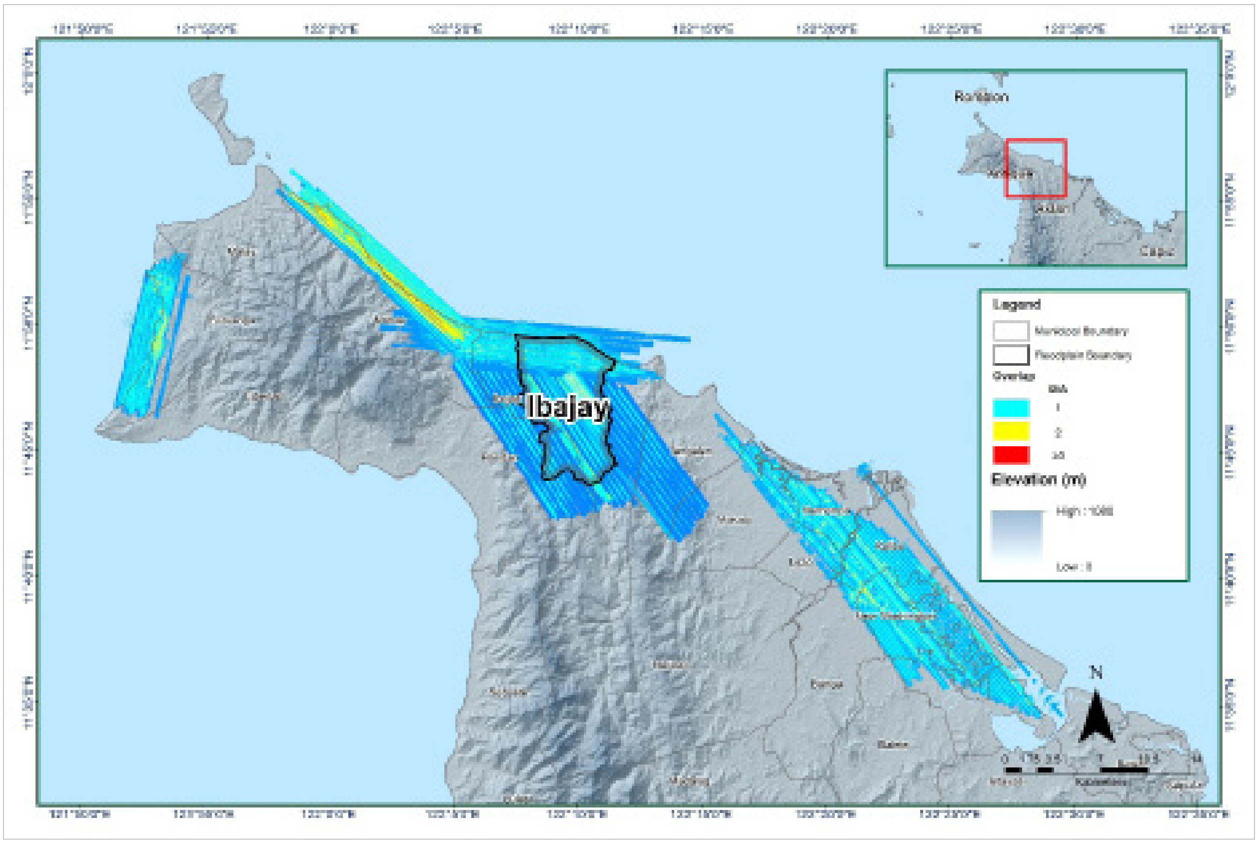

Figure 13. Image of data overlap for Ibajay floodplain.

The overlap statistics per block for the Ibajay floodplain can be found in the Mission Summary Reports (ANNEX 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 29.60% and 50.46% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 14. As seen in the figure below, it was determined that all LiDAR data for the Ibajay Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 4.12 points per square meter.

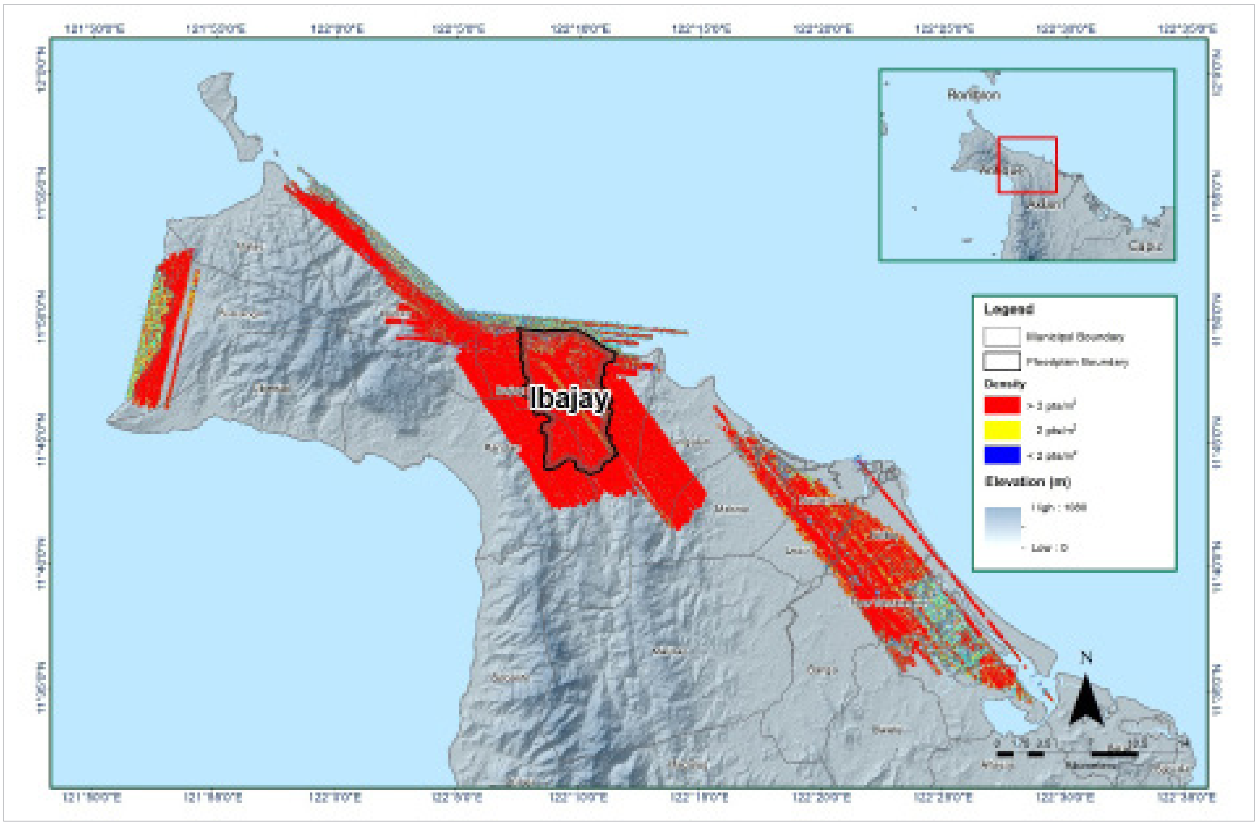

Figure 14. Pulse density map of the merged LiDAR data for Ibajay floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

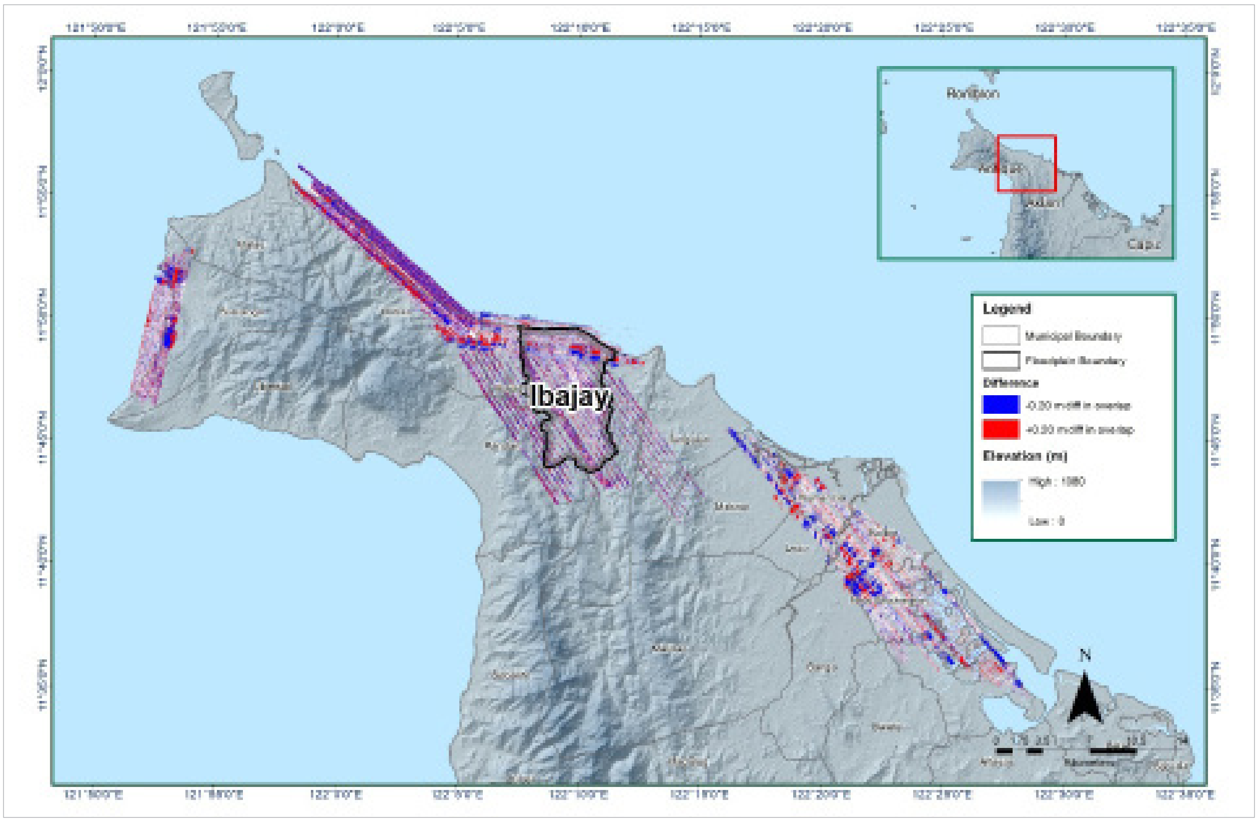

Figure 15. Elevation difference Map between flight lines for the Ibajay Floodplain Survey.

A screen-capture of the processed LAS data from Ibajay flight 1238A loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

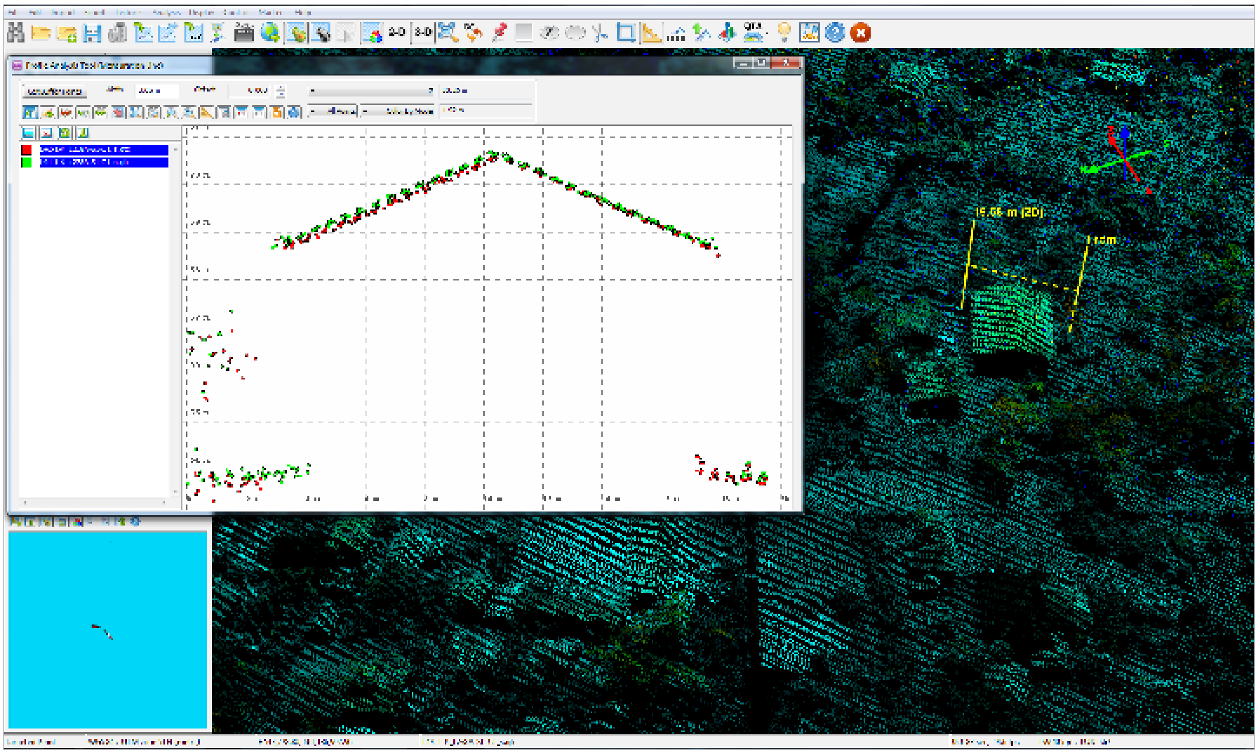

Figure 16. Quality checking for Ibajay flight 1238A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Ibajay classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	175,497,281
Low Vegetation	195,609,176
Medium Vegetation	505,537,454
High Vegetation	643,811,711
Building	15,501,211

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Ibajay floodplain is shown in Figure 17. A total of 747 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 13 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 803.61 meters and 37.07 meters respectively.

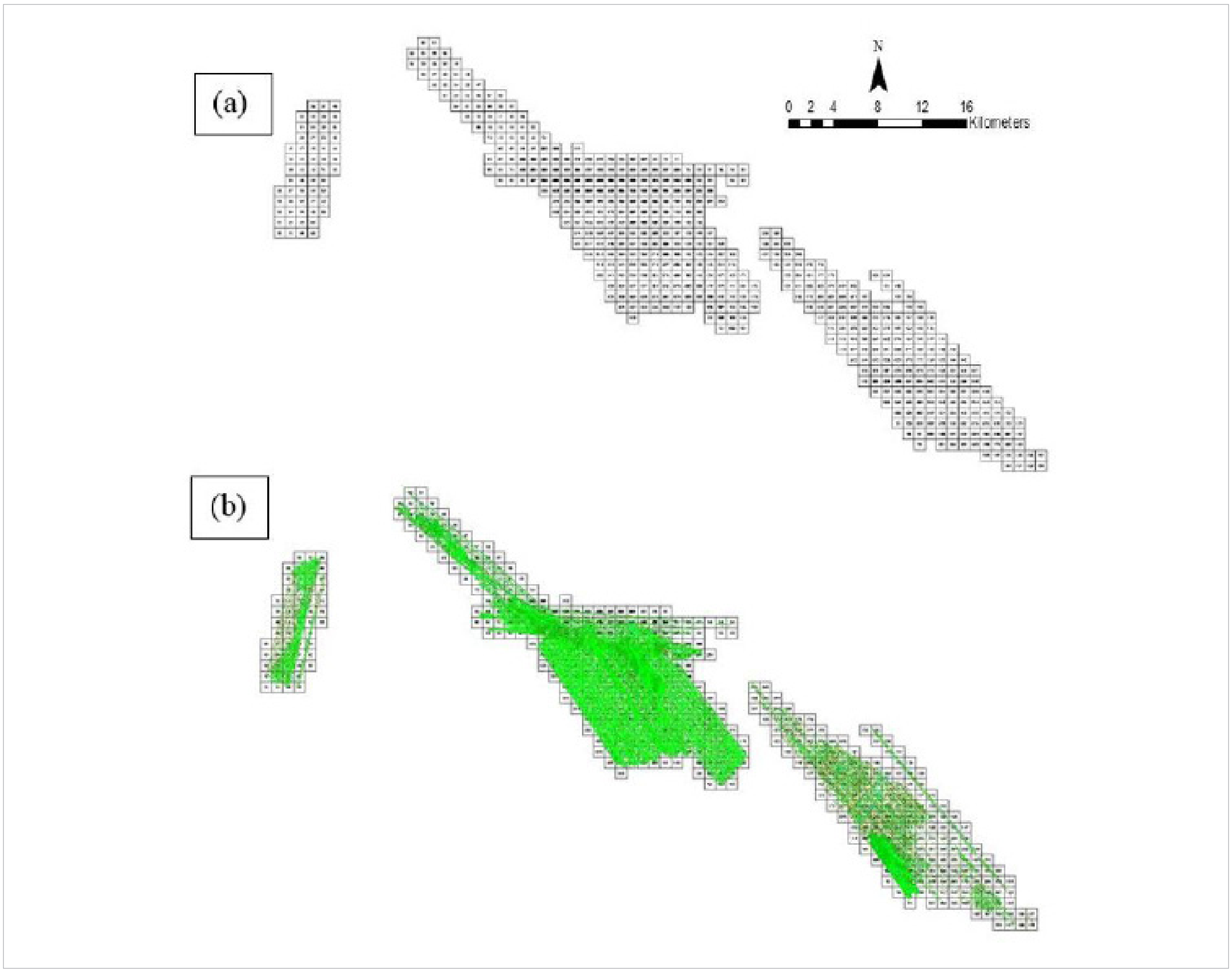

Figure 17. Tiles for Ibajay floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are highlighted in orange, while the vegetation are in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

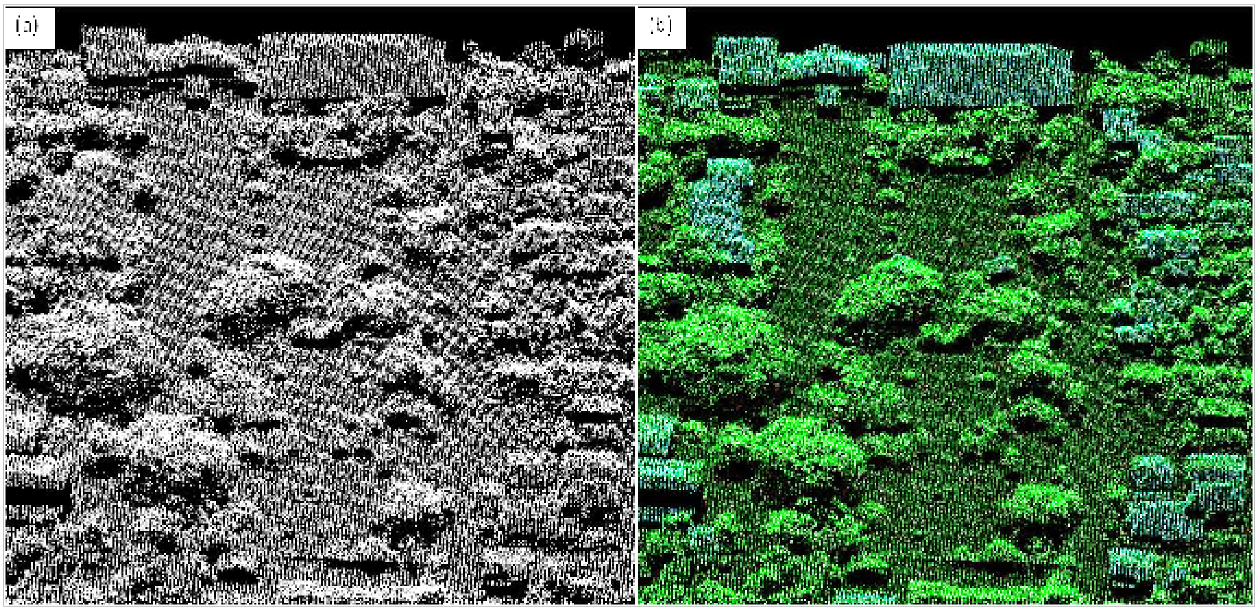

Figure 18. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present such as buildings and vegetation.

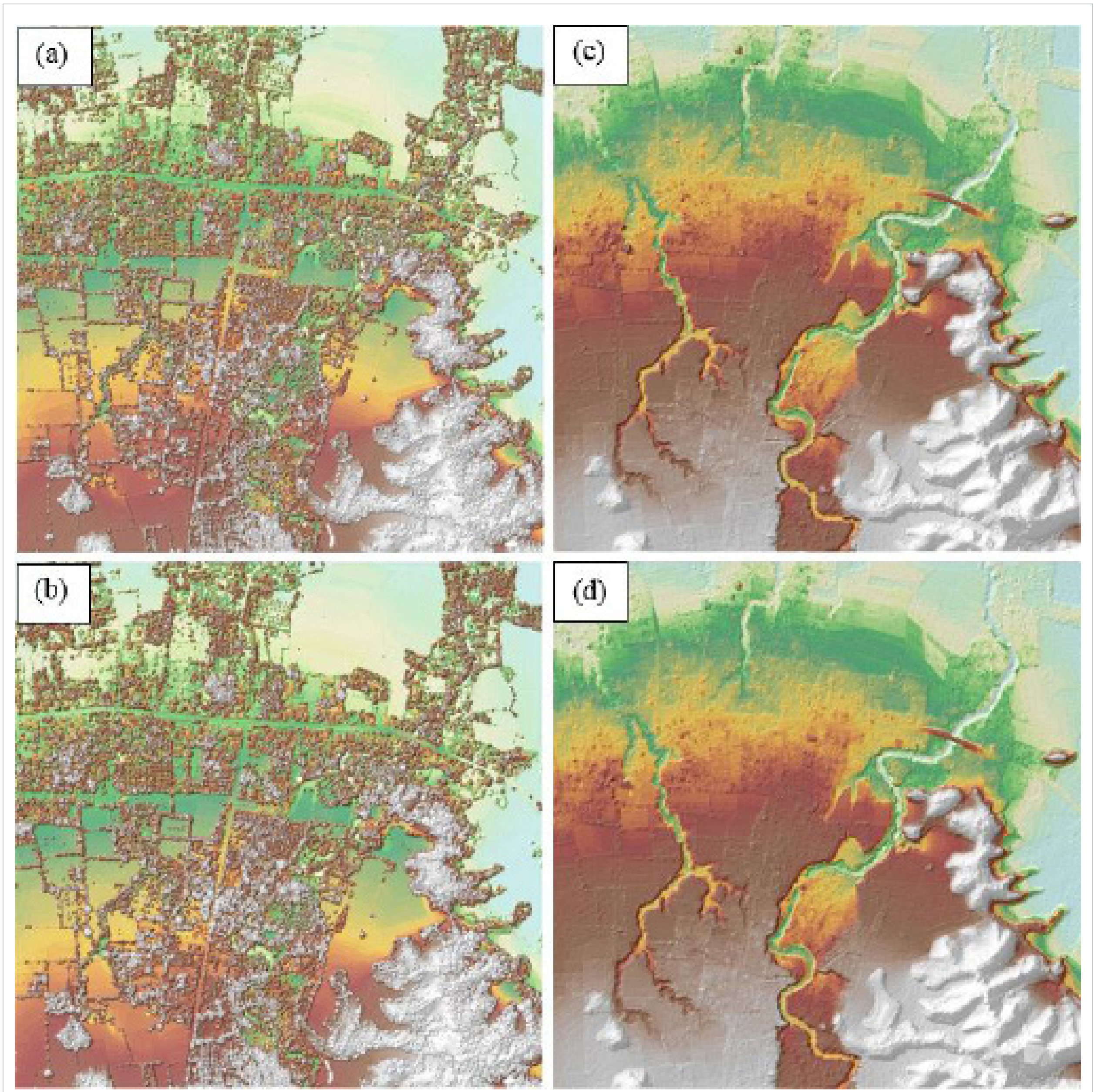

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ibajay floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 386 1km by 1km tiles area covered by the Ibajay floodplain is shown in Figure 20. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Ibajay floodplain attained a total of 365.17 sq. kms. in orthophotograph coverage comprised of 3,326 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

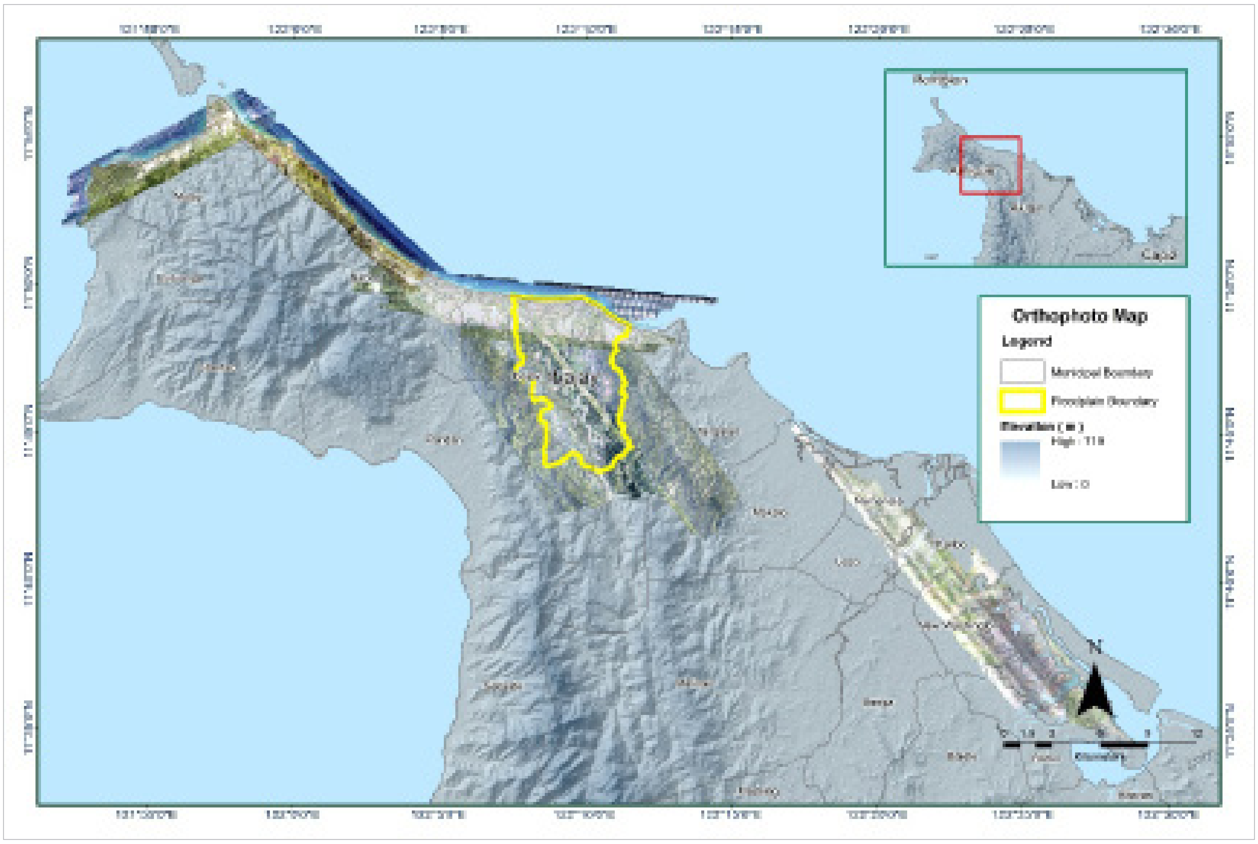

Figure 20. Ibajay Floodplain with the available orthophotographs.

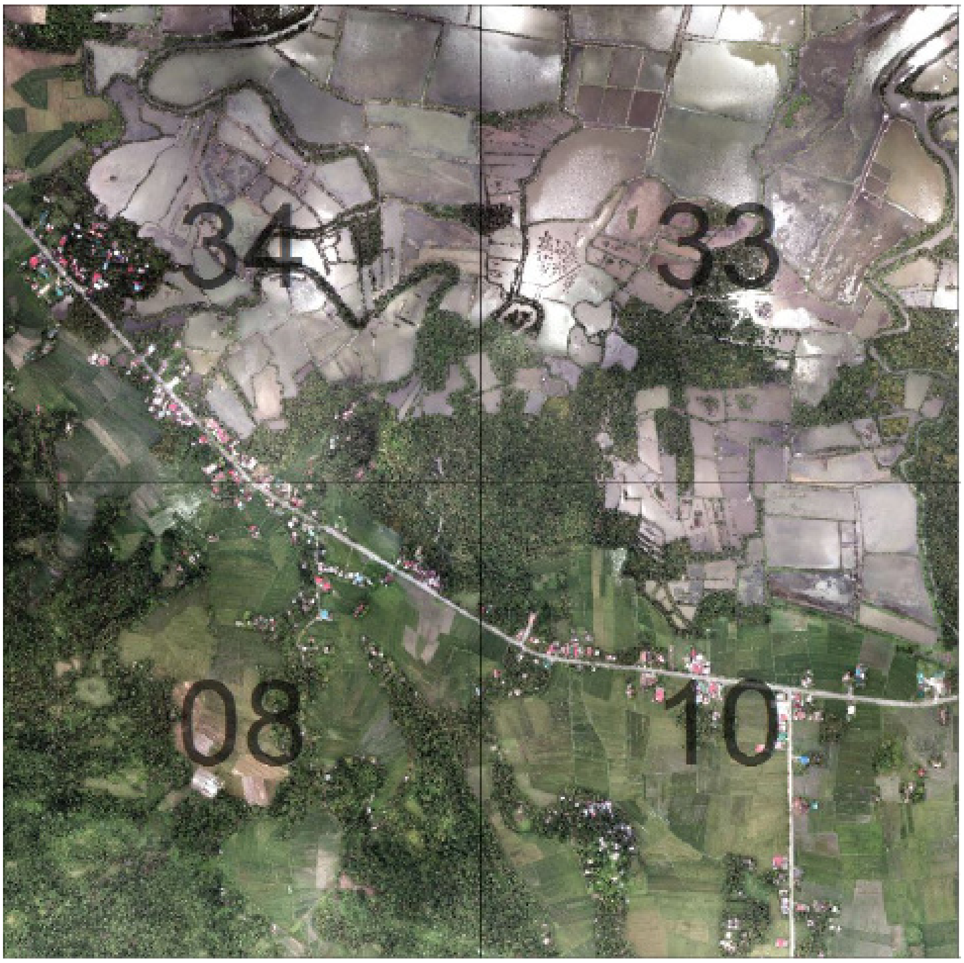

Figure 21. Sample orthophotograph tiles for the Ibajay Floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for the Ibajay Floodplain Survey. These blocks are composed of Aklan and Capiz_Aklan blocks with a total area of 422.23 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Aklan_Blk38C	31.37
Aklan_Blk38D	35.95
Aklan_Blk38G	141.61
Aklan_Blk38I_additional	5.80
Aklan_Blk38Voids	15.66
Capiz_Aklan_Blk38A	57.19
Capiz_Aklan_Blk38B	134.65
TOTAL	422.23 sq.km

Figure 22 shows portions of a DTM before and after manual editing. As evident in the figure, the fish pond (Figure 22a) was misclassified and removed during the classification process. To complete the surface, the fish pond (Figure 22b) was retrieved and reclassified through data retrieval to allow the correct water flow. Likewise, the bridge (Figure 22c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 22d). Another example is a mountain that is interpolated in the DTM after classification (Figure 22e) and has to be retrieved through manual editing (Figure 22f).

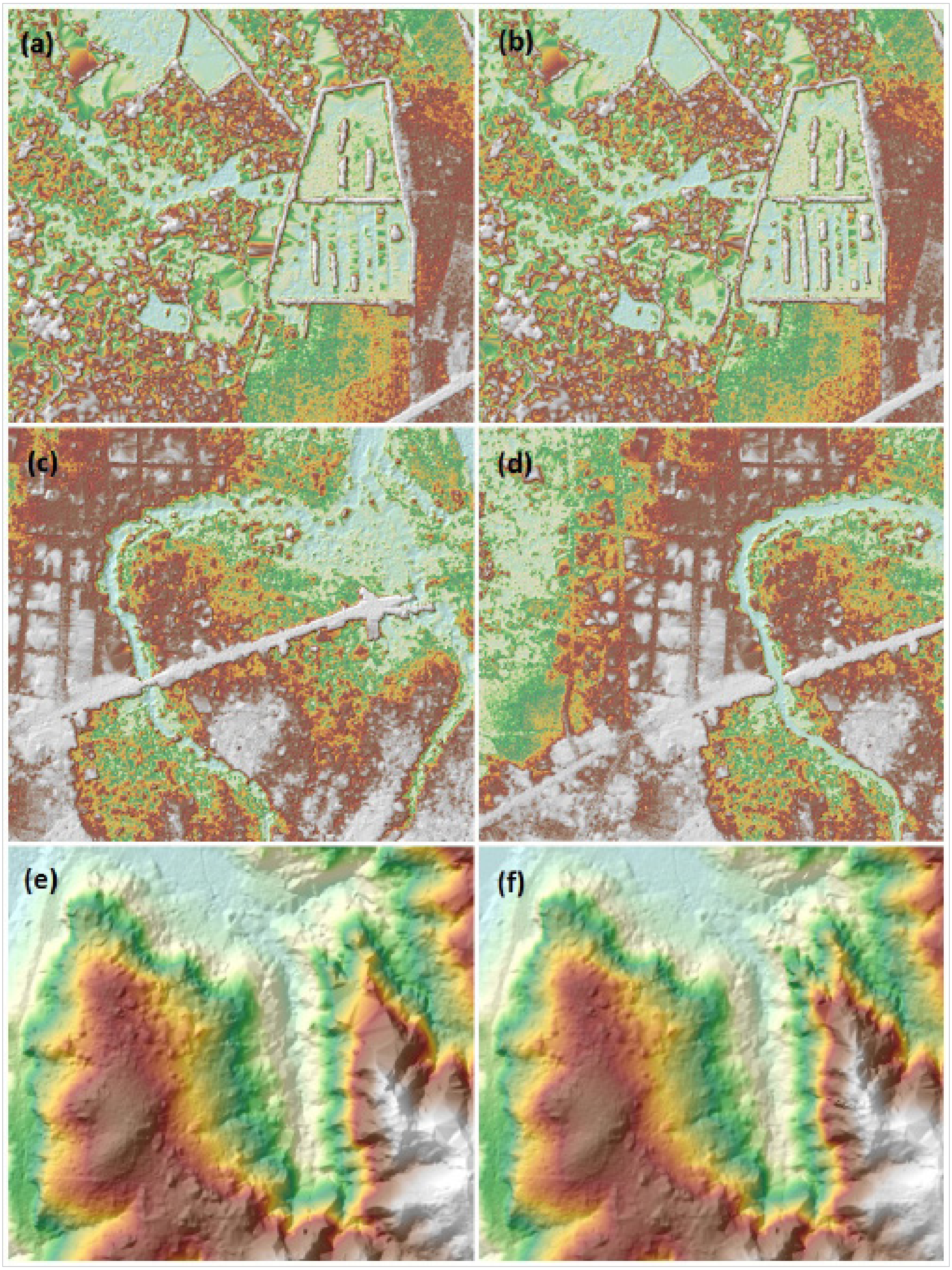

Figure 22. Portions in the DTM of the Ibajay Floodplain – fish pond before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing, and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

CapizAklan_Blk38D was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Ibajay Floodplain is shown in Figure 23. It can be seen that the entire Ibajay floodplain is 100% covered by LiDAR data.

Table 15. Shift values of each LiDAR block of Ibajay Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Aklan_Blk38C	NA	NA	NA
Aklan_Blk38D	-0.48	0.22	0.13
Aklan_Blk38G	-0.48	0.22	-0.06
Aklan_Blk38I_additional	-0.53	0.22	0.07
Aklan_Blk38Voids	-0.48	0.22	0.08
Capiz_Aklan_Blk38A	-0.48	0.22	-1.01
Capiz_Aklan_Blk38B	-0.48	0.22	-0.56

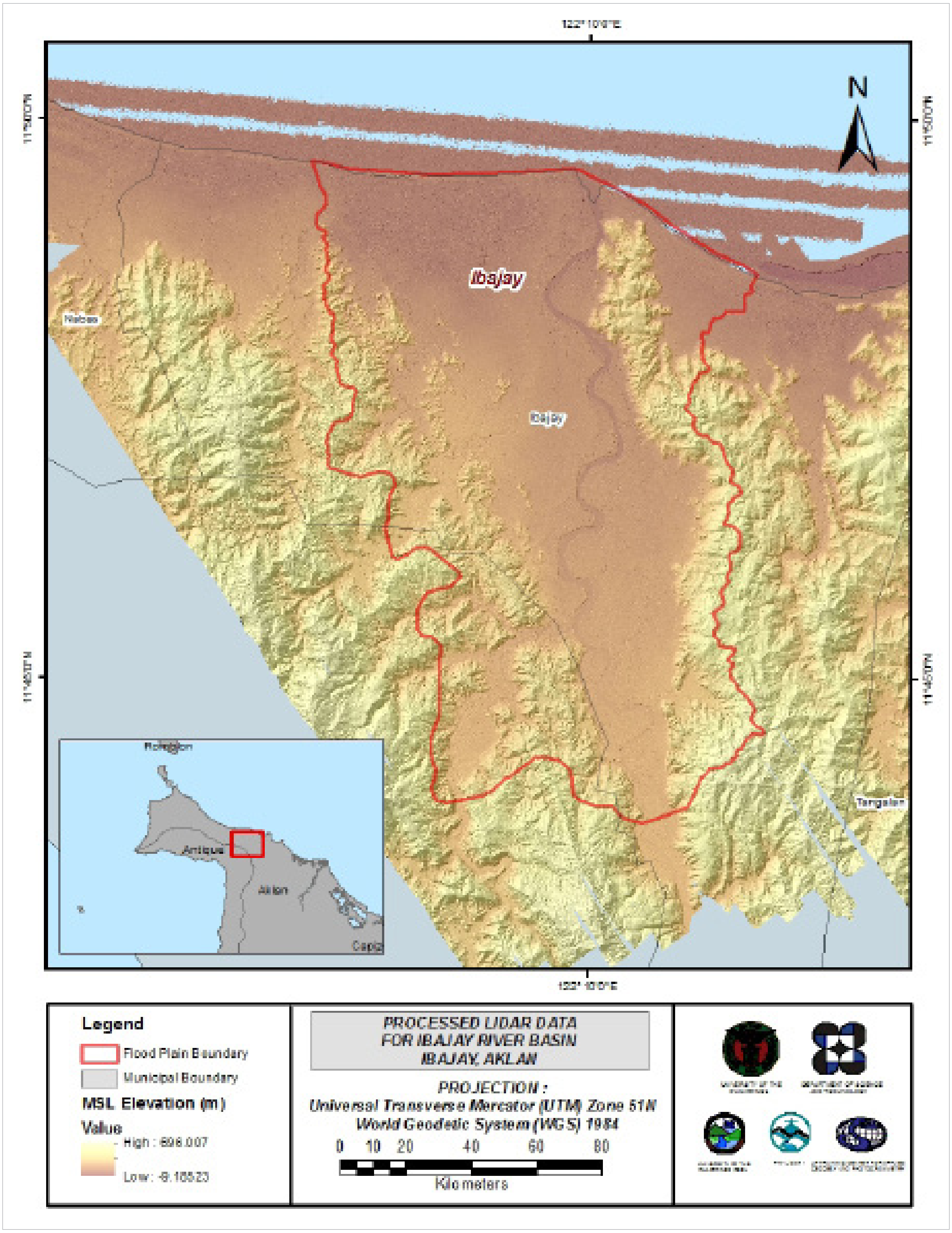

Figure 23. Map of processed LiDAR data for the Ibajay Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ibajay to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 3,836 points were gathered for the Ibajay floodplain. However, the point dataset was not used for the calibration of the LiDAR data for Ibajay because during the mosaicking process, each LiDAR block was referred to the calibrated Jalaur DEM. Therefore, the mosaicked DEM of Ibajay can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Jalaur LiDAR DTM and ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 1.71 meters with a standard deviation of 0.17 meters. Calibration of Jalaur LiDAR data was done by subtracting the height difference value, 1.71 meters, to Jalaur mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between Jalaur LiDAR data and calibration data. These values were also applicable to the Ibajay DEM.

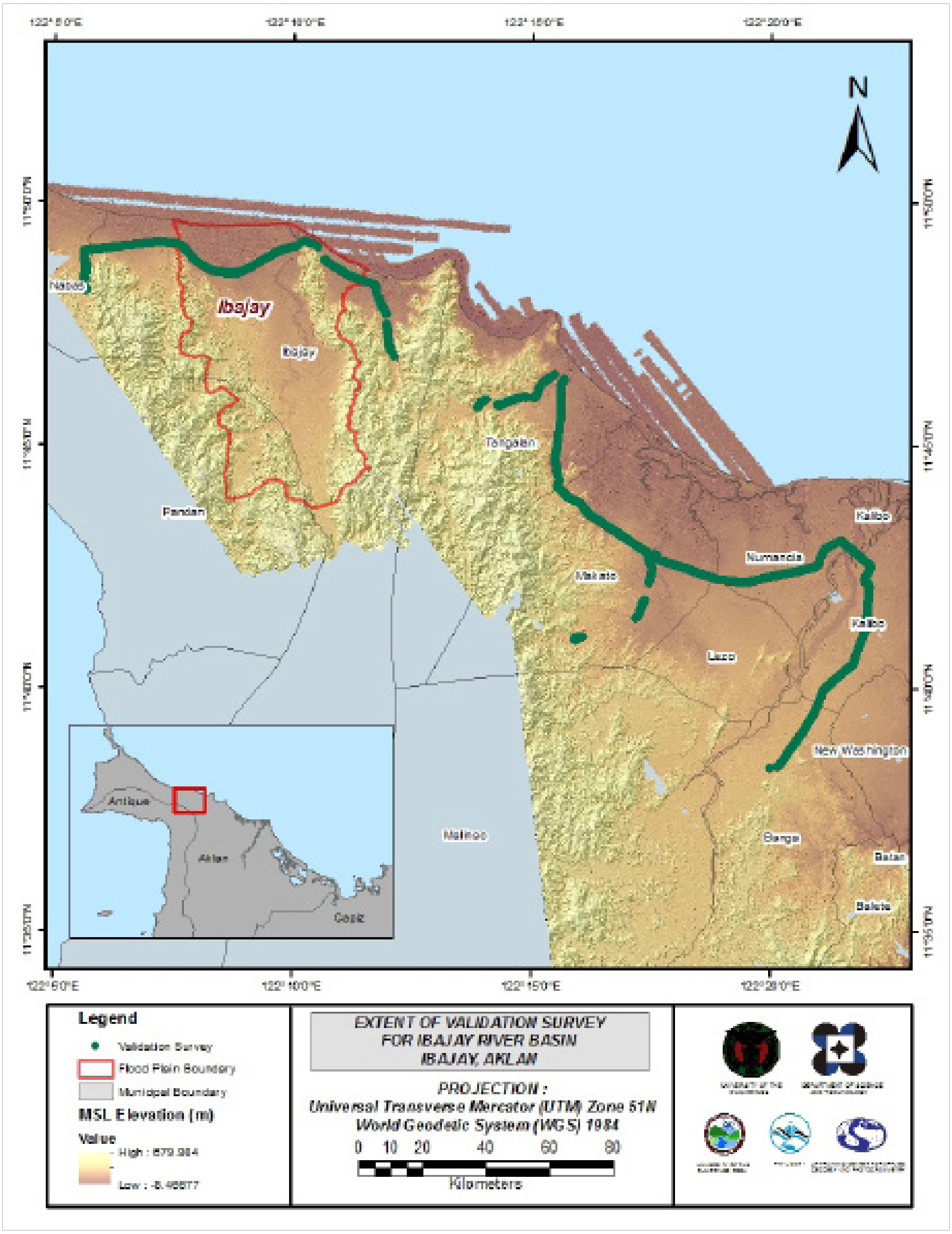

Figure 24. Map of Ibajay Floodplain with validation survey points in green

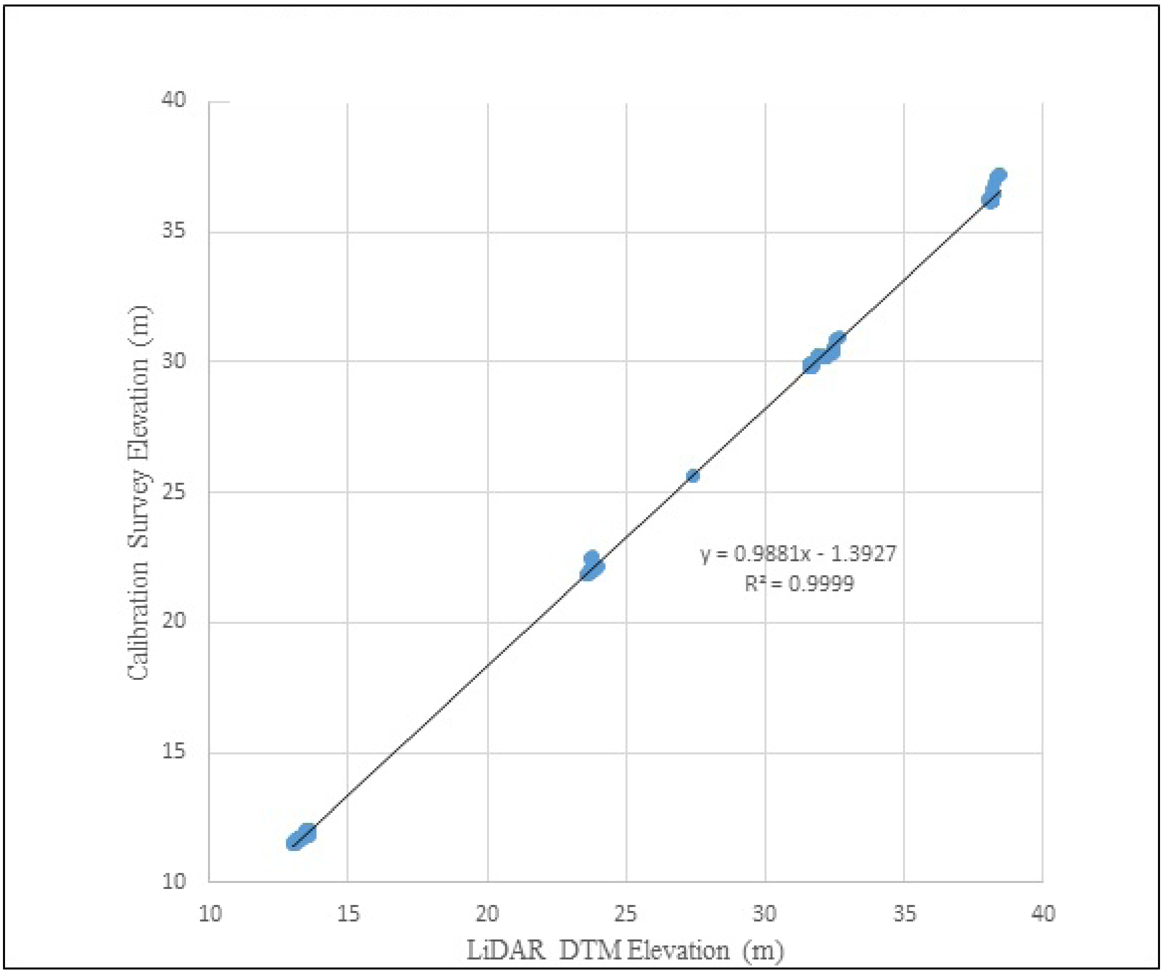

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	1.71
Standard Deviation	0.17
Average	-1.70
Minimum	-2.13
Maximum	-1.16

A total of 5,421 survey points that are near and within the Ibajay flood plain were used for the validation of the calibrated Ibajay DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.15 meters, as shown in Table 17.

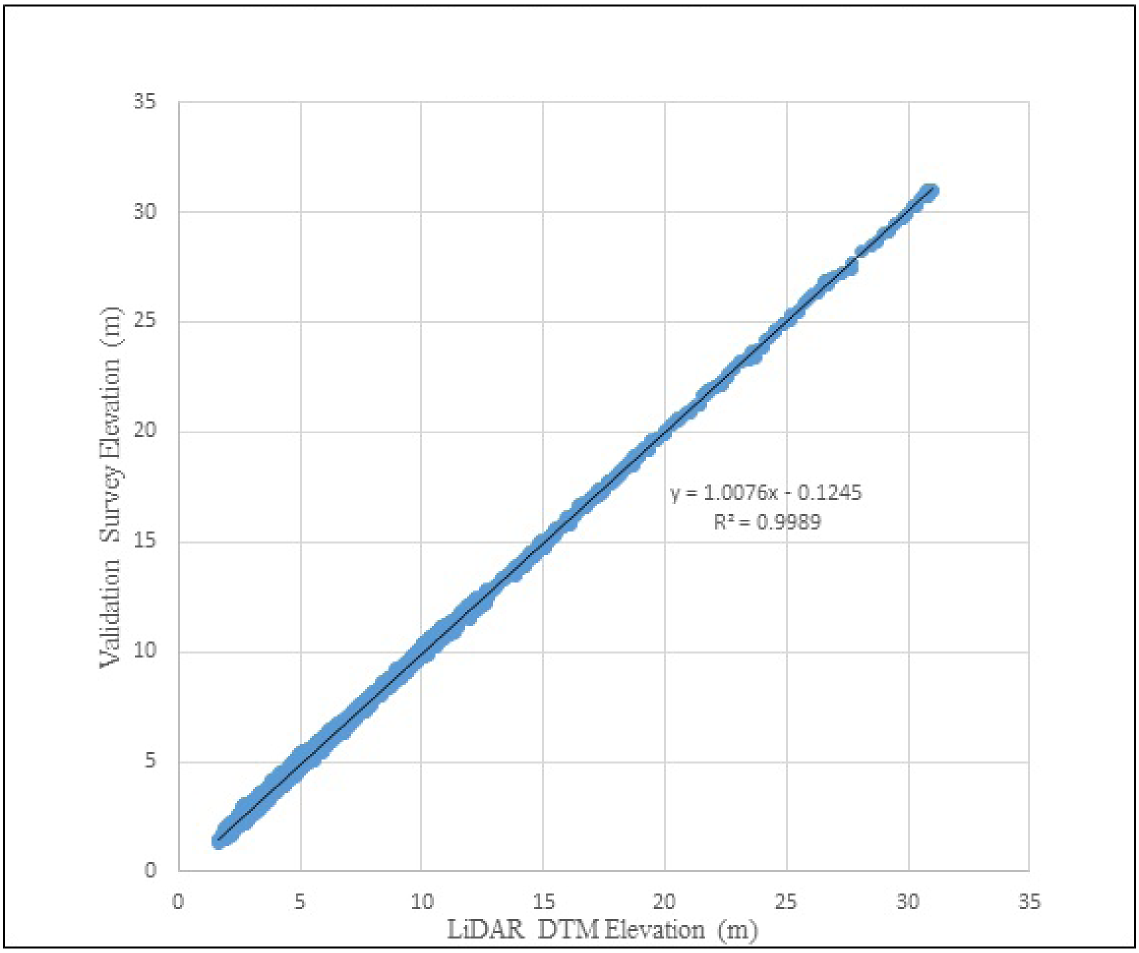

Figure 26. Correlation plot between the validation survey points and the LiDAR data.

Table 17. Validation Statistical Measures

Calibration Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.15
Average	0.08
Minimum	-0.41
Maximum	0.50

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Ibajay with a total of 1,542 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.35 meters. The extent of the bathymetric survey done by the CSU's Field Survey Team (FST) in coordination with Data Validation and Bathymetry Component (DVBC) in Ibajay integrated with the processed LiDAR DEM is shown in Figure 27.

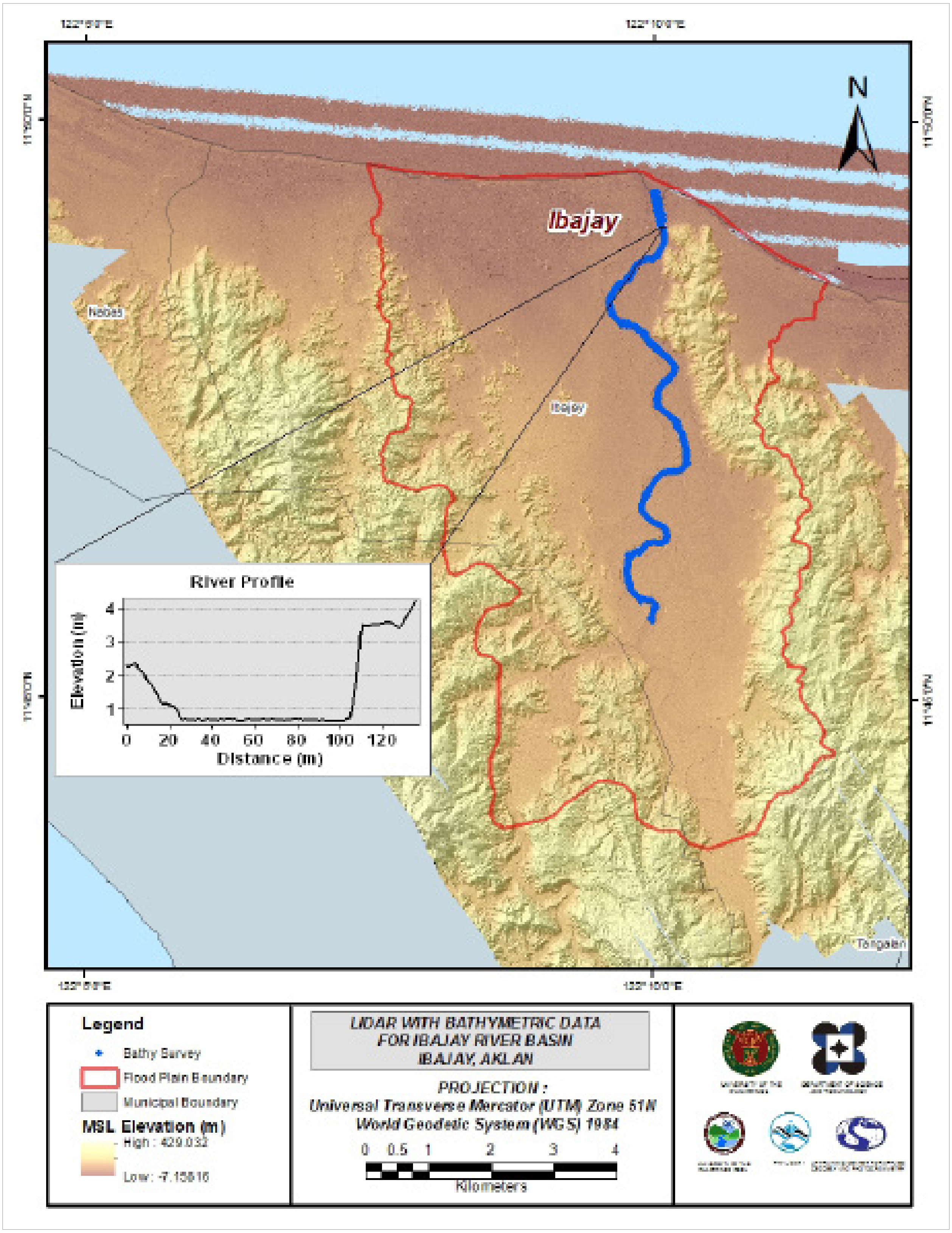

Figure 27. Map of Ibajay floodplain with bathymetric survey points in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks comprise of main thoroughfares such as highways and municipal and barangay roads essential for the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Ibajay floodplain, including its 200-m buffer, has a total area of 65.06 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 1,410 building features, were considered for QC. Figure 28 shows the QC blocks for the Ibajay floodplain.

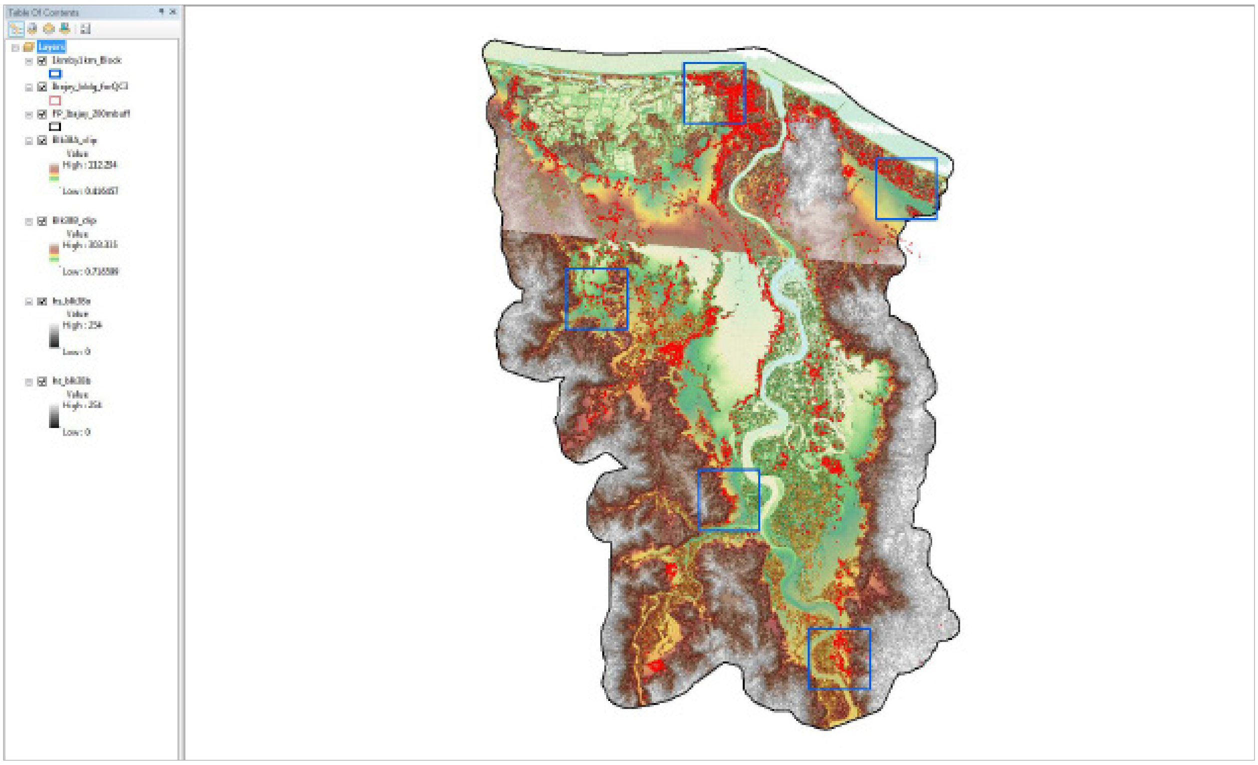

Figure 28. Blocks (in blue) of Ibajay building features that were subjected to QC.

Quality checking of Ibajay building features resulted in the ratings shown in Table 18.

Table 18. Details of the quality checking ratings for the building features extracted for the Ibajay River Basin

Floodplain	Completeness	Correctness	Quality	Remarks
Ibajay	100.00	99.86	99.72	PASSED

3.12.2 Height Extraction

Height extraction was done for 9,389 building features in Ibajay floodplain. Of these building features, 69 buildings were filtered out after height extraction, resulting to 9,320 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 17.72 meters.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed local key personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map includes the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the flood plain of the river basin.

Table 19 summarizes the number of building features per type, while Table 20 shows the total length of each road type. Table 21, on the other hand, shows the number of water features extracted per type.

Table 19. Building features extracted for Ibajay Floodplain.

Facility Type	No. of Features
Residential	8858
School	212
Market	15
Agricultural/Agro-Industrial Facilities	3
Medical Institutions	23
Barangay Hall	24
Military Institution	2
Sports Center/Gymnasium/Covered Court	12
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	4
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	1
Religious Institutions	43
Bank	6
Factory	0
Gas Station	7
Fire Station	0
Other Government Offices	19
Other Commercial Establishments	61
Others	29
Total	**9320**

Table 20. Total length of extracted roads for Ibajay Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Ibajay	24.00	14.97	30.02	9.12	0.74	**78.85**

Table 21. Number of extracted water bodies for Ibajay Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Lipadas	36	0	0	237	2	**275**

A total of 7 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 29 shows the completed Digital Surface Model (DSM) of the Ibajay floodplain overlaid with its ground features.

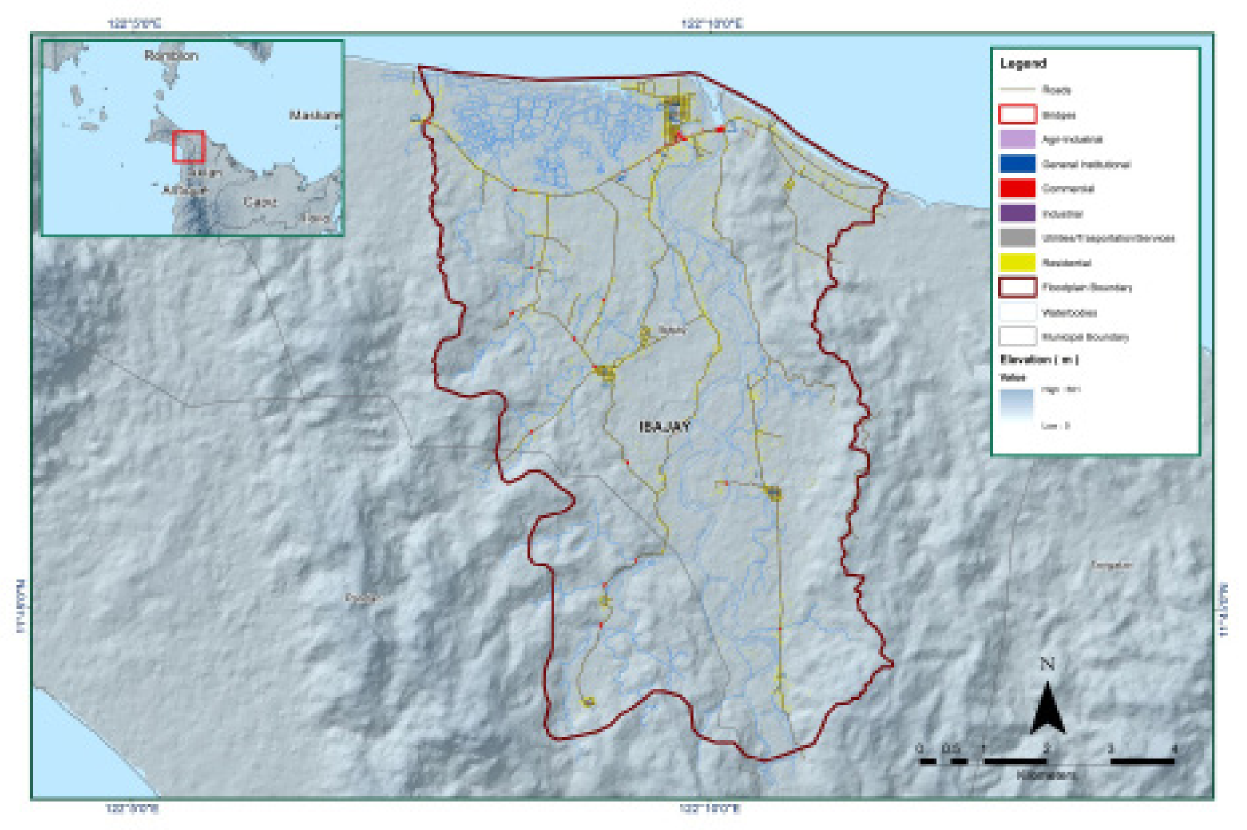

Figure 29. Extracted features of the Ibajay Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE IBAJAY RIVER BASIN

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The methods applied in this chapter were based on the DREAM methods manual (Ang, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Ibajay River on October 29 to November 7, 2015 with the following scope of work: reconnaissance; bathymetric survey, cross-section, bridge as-built and water level marking of Ibajay Bridge abutment in Brgy. Polo, Ibajay; validation point acquisition of about 38.6 km; and bathymetric survey from Brgy. Agdugayan down to the mouth of the river in Brgy. Polo, Ibajay, Aklan, with an approximate length of 8.69 km using GNSS PPK survey technique (Figure 30).

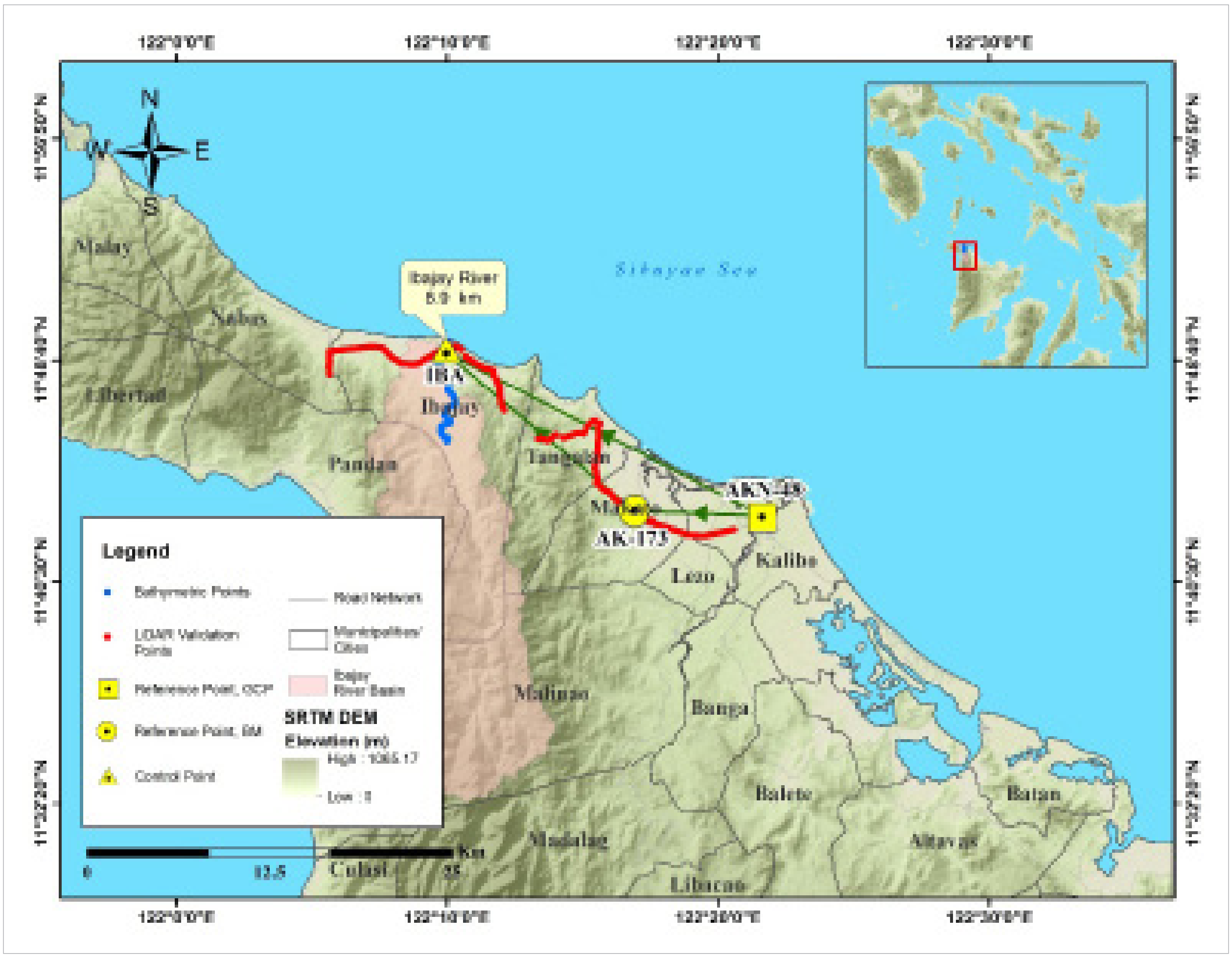


Figure 30. Extent of the bathymetric survey (in blue line) in Ibajay River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Ibajay River survey is composed of a single loop established on October 1, 2014 occupying the following reference points: SRS-53, a second order GCP in Brgy. Poblacion, Municipality of San Agustin, Surigao Del Sur; and SS-202, a first order BM in Brgy. Otieza, Municipality of San Agustin, Surigao Del Sur.

A control point was established along approach of Ibajay Bridge namely, UP-IBA in Brgy. Polo, Ibajay, Aklan.

Table 22 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Ibajay River Survey.

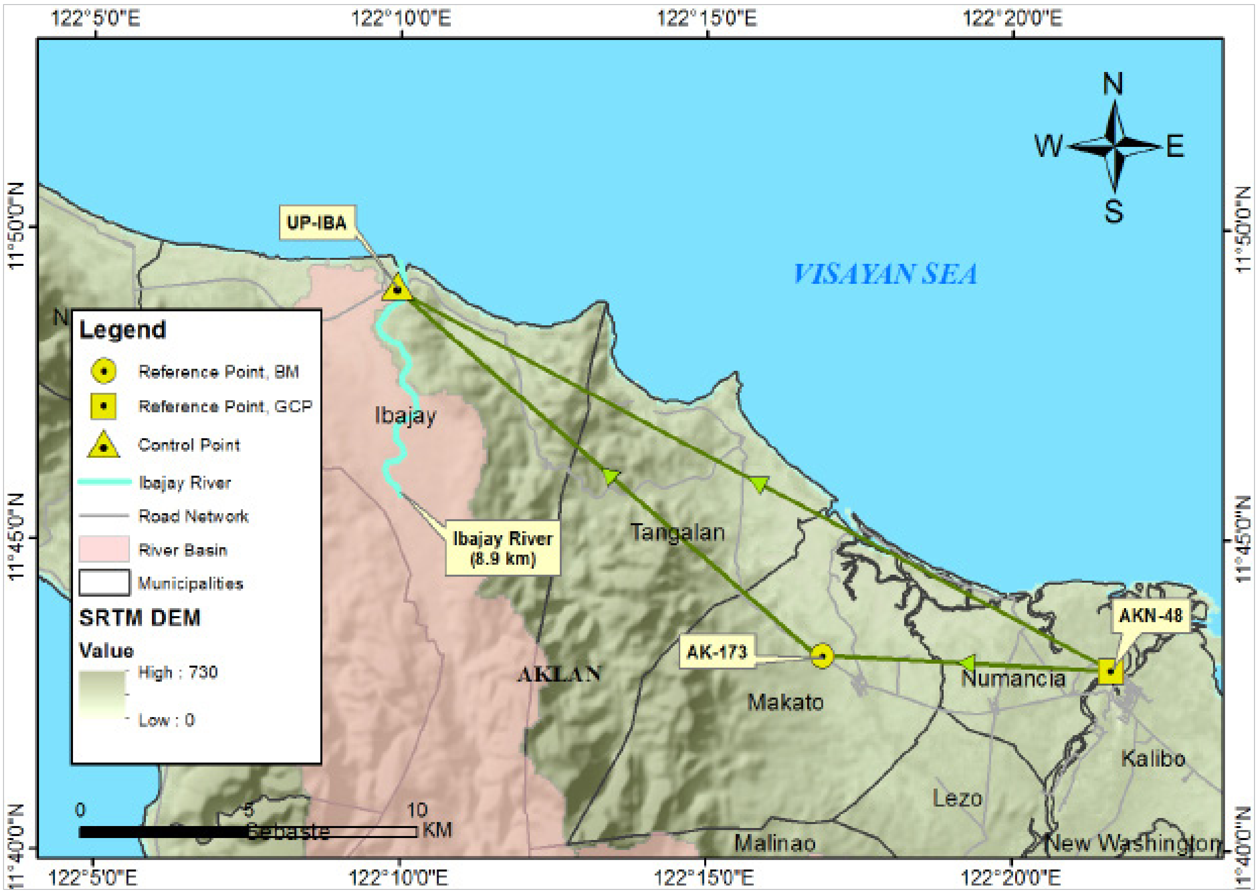


Figure 31. The GNSS Network established in the Ibajay River Survey.

Table 22. References used and control points established in the Ibajay River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
AK-173	1st Order, BM	-	-	66.243	10.515	2007
AKN-48	2nd Order, GCP	11°42'53.76901"	122°21'38.37193"	62.745	-	2007
UP-IBA	UP Established	-	-	-	-	2014

Figure 32 to Figure 34 depict the setup of the GNSS on recovered reference points and established control points in the Ibajay River.

Figure 32. The GNSS base receiver setup, Trimble® SPS 882 at AK-173, Dumga Bridge in Brgy. Dumga, Makato Municipality, Aklan

Figure 33. GNSS base receiver setup, Trimble® SPS 852, at AKN-48 on the east approach of Kalibo Bridge in Brgy. Bulwang, Kalibo City, Aklan

Figure 34. GNSS base receiver setup, Trimble® SPS 852 at UP-IBA, Ibajay Bridge in Brgy. Polo, Ibajay Municipality, Aklan

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 23 presents the baseline processing results of control points in the Ibajay River Basin, as generated by the TBC software.

Table 23. The Baseline processing report for the Ibajay River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
AKN 48 --- AK173	10-1-2014	Fixed	0.003	0.011	272°44'45"	8610.026	3.34
AK173 --- UP-IBA	10-1-2014	Fixed	0.007	0.032	311°03'45"	16723.38	-5.928
AKN 48 --- UP-IBA	10-1-2014	Fixed	0.007	0.028	298°15'50"	24076.97	-2.588

As shown in Table 23, a total of three (3) baselines were processed with the coordinates of AKN-48, and the elevation value of reference point AK-173 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. Looking at the Adjusted Grid Coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm for each control point; or in equation form:

$$\sqrt{(x_e)^2 + (y_e)^2} < 20\,cm \text{ and } z_e < 10\,cm$$

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

For complete details, see the Network Adjustment Report shown in Table 23 to Table 26.

The three (3) control points: AK-173, AKN-48 and UP-IBA were occupied and observed simultaneously to form a GNSS loop. Coordinates of AKN-48; and elevation value of AK-173 were held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Constraints applied to the adjustment of the control points.

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
AK-173	Grid				Fixed
AKN-48	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. The fixed control points AKN-48 and AK-173 have no values for grid and elevation errors, respectively.

Table 25. Adjusted grid coordinates for the control points used in the Ibajay River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
AK-173	421731.971	0.005	1295542.850	0.003	10.516	?	e
AKN-48	430328.297	?	1295111.046	?	7.102	0.020	LL
UP-IBA	409154.704	0.007	1306556.921	0.005	5.526	0.040	

The results of the computation for accuracy are as follows:

a. AKN-48

horizontal accuracy = Fixed
Vertical accuracy = 2.0 cm < 10 cm

b. AK-173

horizontal accuracy = $\sqrt{(0.5)^2 + (0.3)^2}$
= $\sqrt{0.25 + 0.90}$
= 1.1 cm < 20 cm
Vertical accuracy = Fixed

c. UP-IBA

horizontal accuracy = $\sqrt{(0.7)^2 + (0.5)^2}$
= $\sqrt{0.49 + 0.25}$
= 0.9 cm < 20 cm
Vertical accuracy = 4.0 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the three occupied control points are within the required precision.

Table 26. Adjusted geodetic coordinates for control points used in the Ibajay River Flood Plain validation.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
AK-173	N11°43'07.15289"	E122°16'54.36782"	66.084	?	e
AKN-48	N11°42'53.76901"	E122°21'38.37193"	62.745	0.020	LL
UP-IBA	N11°49'04.57051"	E122°09'57.81862"	60.152	0.040	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Ibajay River GNSS Static Survey are seen in Table 27.

Table 27. The reference and control points utilized in the Ibajay River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
AK-173	1st Order, BM	11°43'07.15289"	122°16'54.36782"	66.084	1295542.85	421731.971	10.516
AKN-48	2nd Order, GCP	11°42'53.76901"	122°21'38.37193"	62.745	1295111.046	430328.297	7.102
UP-IBA	UP Established	11°49'04.57051"	122°09'57.81862"	60.152	1306556.921	409154.704	5.526

4.5 Cross-section and Bridge As-Built survey and Water Level Marking

The bridge cross-section and as-built surveys were conducted on November 5, 2015 along the downstream portion of Ibajay Bridge in Brgy. Polo, Ibajay, Aklan using the GNSS receiver Trimble® SPS 985 utilizing GNSS PPK survey technique.

The cross-sectional line of Ibajay Bridge is about 244 meters with fifty-three (53) points acquired using UP-IBA as GNSS base station. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 35, Figure 36 and Figure 37.

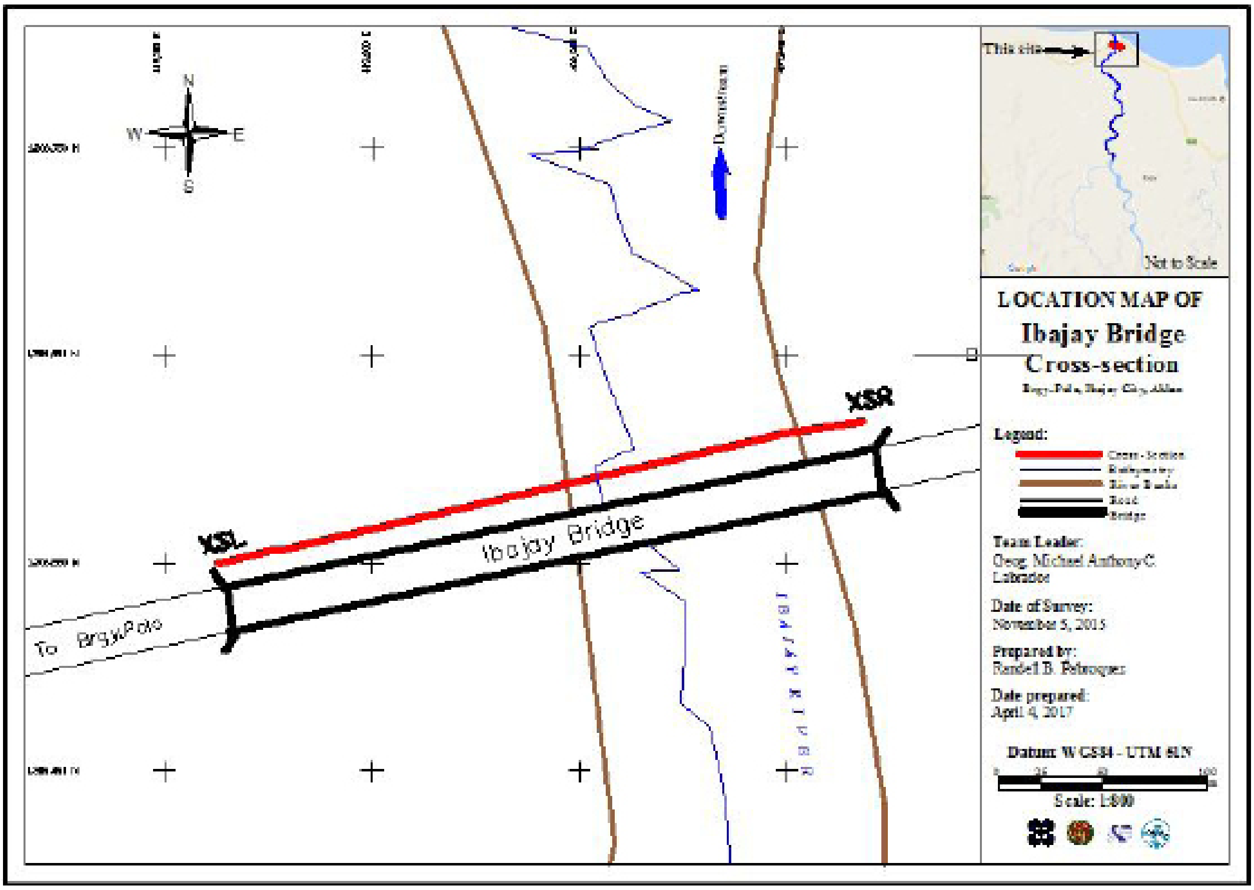


Figure 35. Location map of the Ibajay Bridge cross-section survey.

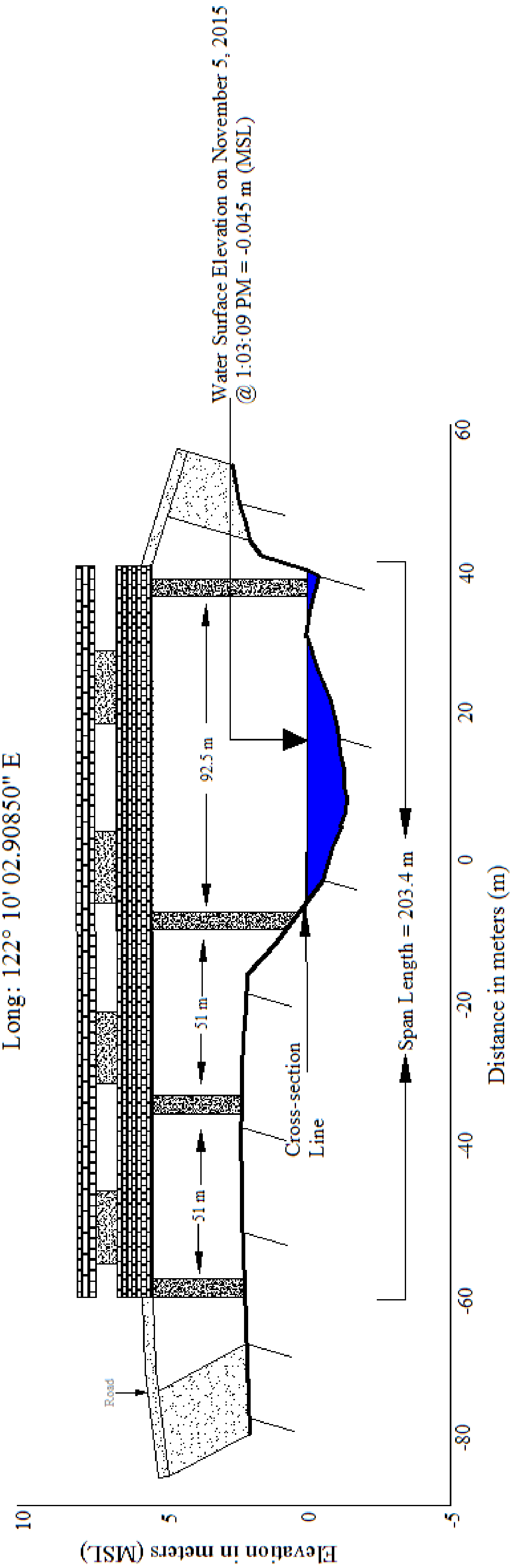
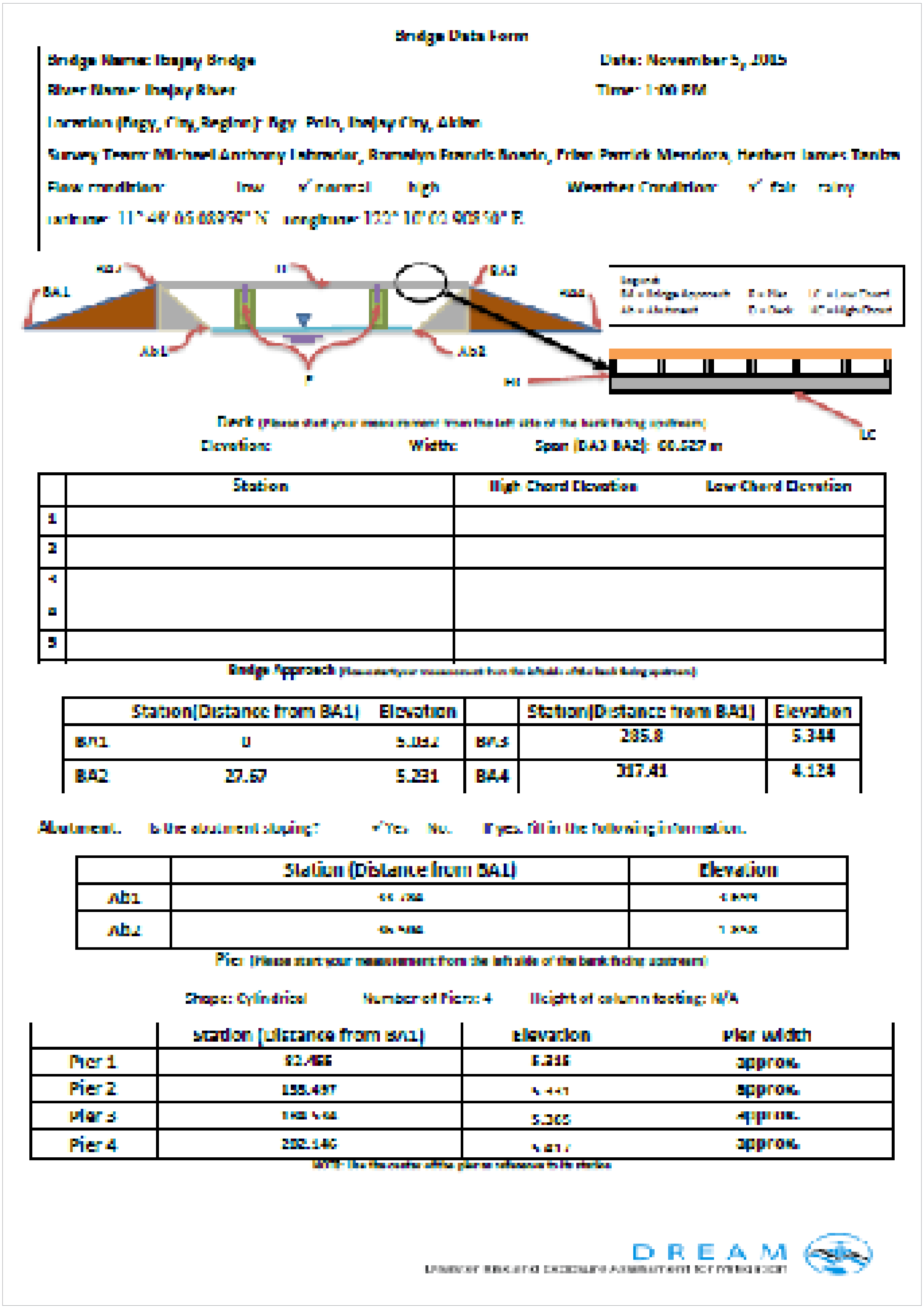


Figure 36. The Ibajay Bridge cross-section survey drawn to scale.



Bridge Data Form

Bridge Name: Ibajay Bridge
Date: November 5, 2015
River Name: Ibajay River
Time: 1:00 PM
Location (Brgy, City, Region): Brgy. [illegible], Ibajay City, Aklan
Survey Team: Michael Anthony Labrador, [illegible]
Flow condition: low ✓ normal high
Weather Condition: ✓ fair rainy
Latitude: [illegible] N Longitude: [illegible] E

Deck (Please start your measurement from the left side of the bank facing upstream)
Elevation: Width: Span (BA3-BA2): [illegible] m

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			
5			

Bridge Approach (Please start your measurement from the left side of the bank facing upstream)

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	[illegible]	BA3	285.8	5.344
BA2	27.57	5.231	BA4	317.41	4.124

Abutment: Is the abutment sloping? ✓ Yes No; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	[illegible]	[illegible]
Ab2	[illegible]	[illegible]

Pier (Please start your measurement from the left side of the bank facing upstream)

Shape: Cylindrical Number of Piers: 4 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	[illegible]	[illegible]	approx.
Pier 2	[illegible]	[illegible]	approx.
Pier 3	[illegible]	5.365	approx.
Pier 4	[illegible]	[illegible]	approx.

Figure 37. The Ibajay Bridge as-built survey data.

The water surface elevation of Ibajay Bridge was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on November 5, 2015 at 1:03:09 PM with a value of -0.045 m (MSL) as shown in Figure 46. This was translated into marking on the bridge's abutment using the same technique as shown in Figure 38. It now serves as the reference for flow data gathering and depth gauge deployment of the University of the Philippines-Cebu (UPC), the partner SUC responsible for the monitoring of Ibajay River.

Figure 38. Painting of water level markings on Ibajay Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 31, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached at the front of the vehicle as shown in Figure 39. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.532m measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-IBA occupied as the GNSS base station. Gathered data were processed using Trimble® Business Center Software.

Figure 39. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey

The survey acquired 5,559 ground validation points with an approximate length of 38.64km that covered major roads running along Aklan West Road and Iloilo-Antique Road from Brgy. Solido, Municipality of Nagas Municipality to Brgy. Aliputos, Municiapality of Numancia, Aklan as illustrated in the map in Figure 40.

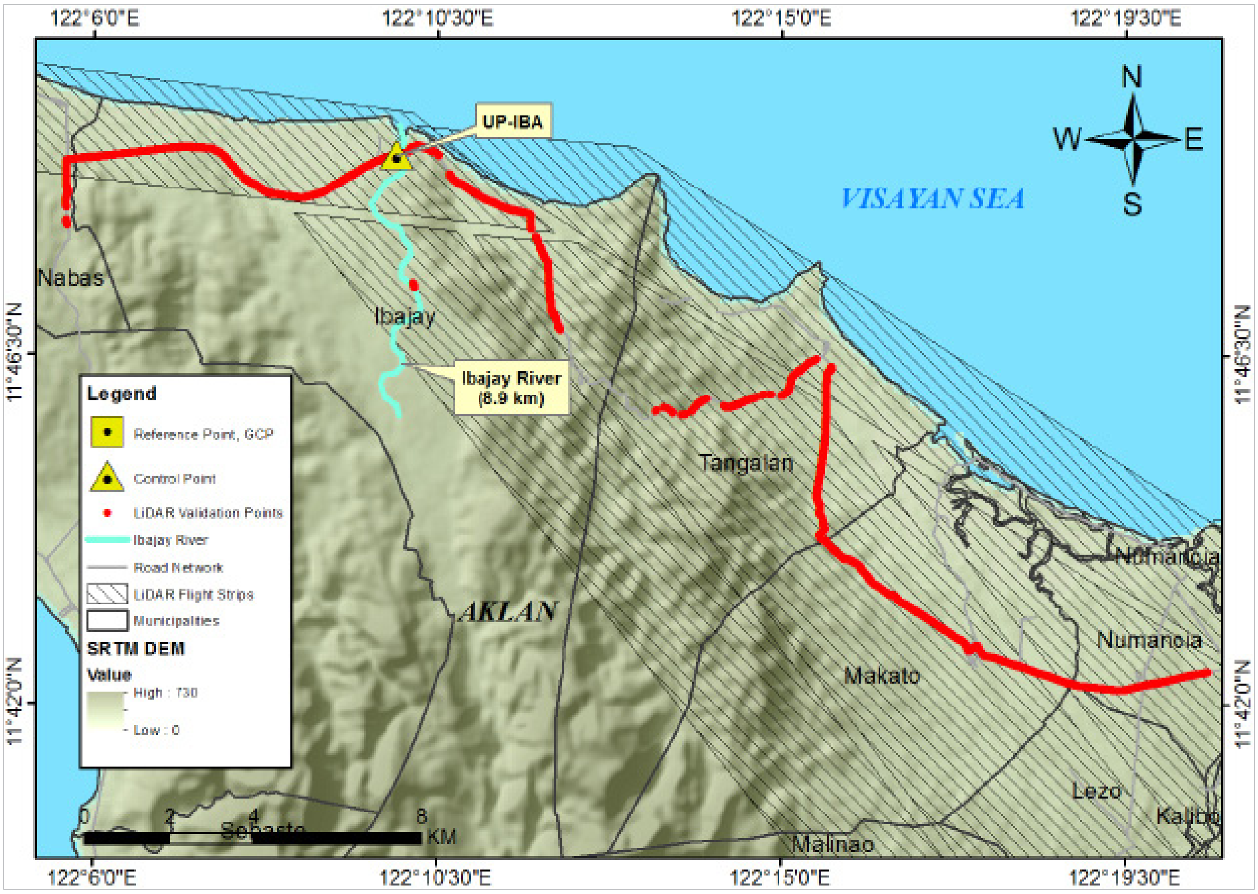


Figure 40. Extent of the LiDAR ground validation survey (in red) along Aklan West Road and Iloilo-Antique Road

4.7 River Bathymetric Survey

A manual bathymetric survey was performed on October 30 to 31 and November 5, 2015 by traversing the entire length of the river by foot with a Trimble SPS 882® and SPS 985® rover receivers as shown in Figure 41. The survey began in the upstream part of the river in Brgy. Agdugayan, municipality of Ibajay with coordinates 11°45'41.34558"N, 122°09'59.18782"E and ended at the mouth of the River in 11°49'23.11511"N, 122°09'59.08247"E in Brgy. Colongcolong, Ibajay, Aklan. The control UP-IBA was used as GNSS base station all throughout the entire survey.

Figure 41. Photos showing setup for the Bathymetric Survey in Ibajay River - Trimble® SPS 882 Rover in Brgy. Bagcay and Trimble® SPS 985 Rover in Brgy. Polo.

The entire bathymetric data coverage for Ibajay River is illustrated in the map in Figure 42. The bathymetric line is approximately 8.69 km in length with 1,637 bathymetric points acquired covering Brgy. Agdugayan, Ibajay downstream to Brgy. Colongcong, Municipality of Ibajay. A CAD diagram was also produced to illustrate the Ibajay riverbed profile as shown in Figure 43. The lowest elevation was recorded at 0.74 m (below MSL), while 8.964 meters change in elevation was observed from the Brgy. Agdugayan to Brgy. Polo and an elevation of 0.07 below MSL on Ibajay Bridge.

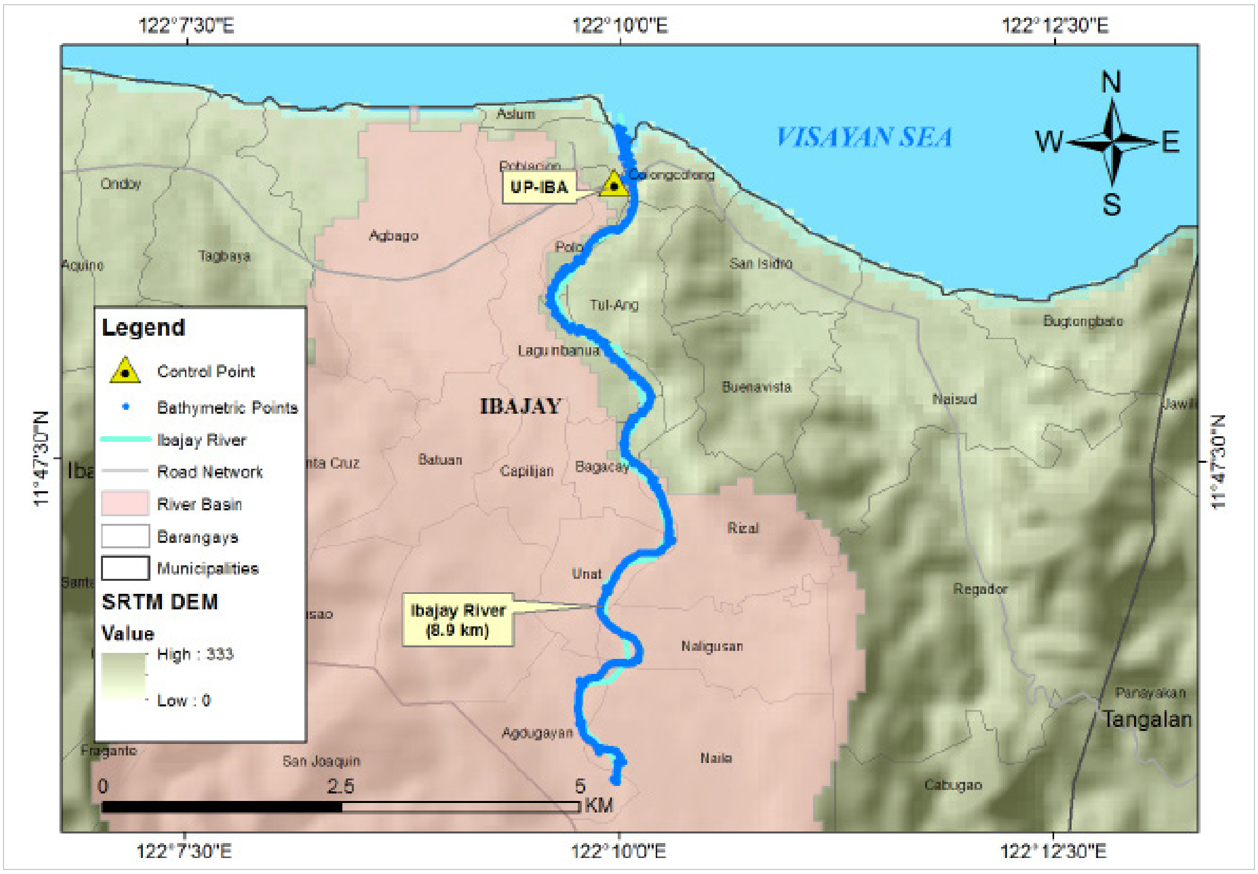


Figure 42. The extent of the Ibajay River Bathymetry Survey.

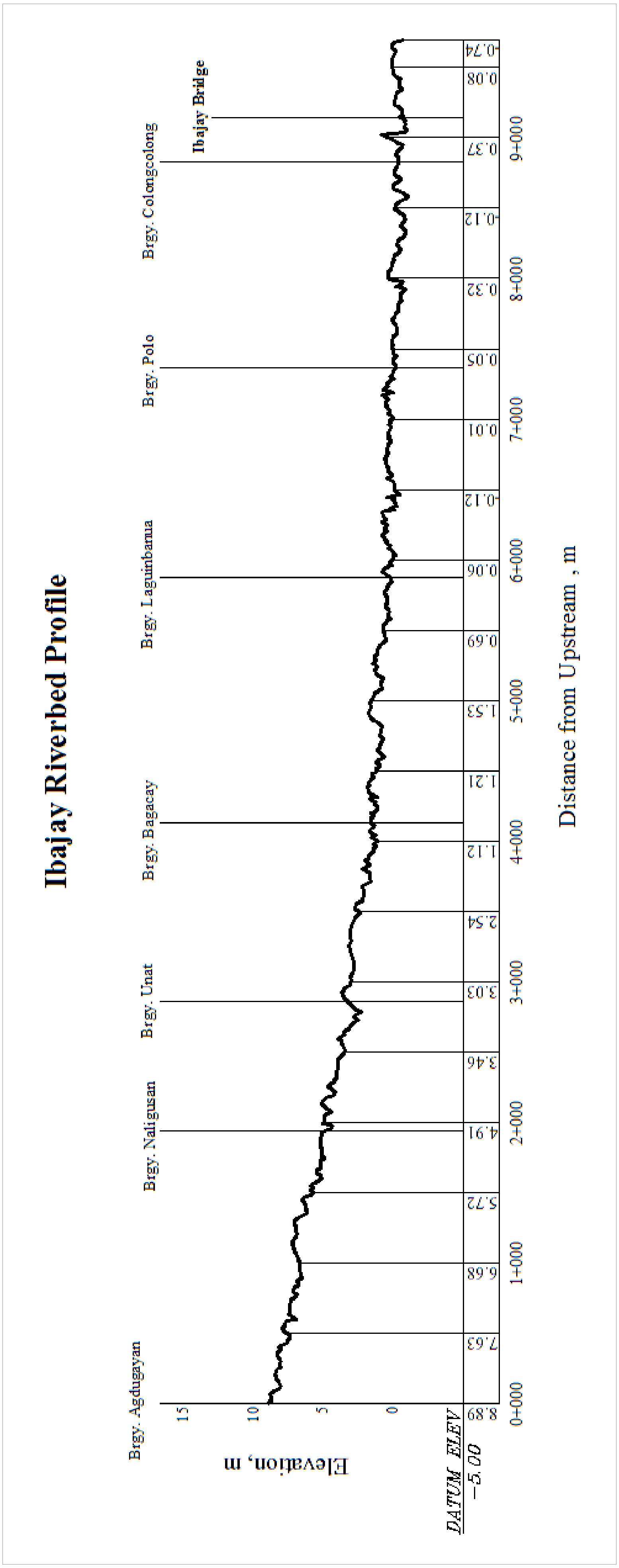


Figure 43. The Ibajay River Bed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Narvin Clyd Tan, and Marvin Arias

The methods applied in this chapter were based on the DREAM methods manual (Ang, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Ibajay River Basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Ibajay River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the University of the Philippines Cebu (UPC) Flood Modelling Component (FMC) Team. The ARG was installed at Brgy. San Jose, Ibajay, Aklan, as illustrated in Figure 44. The precipitation data collection started from August 24, 2016 at 11:15 AM to 2:50 PM with a recording interval of 5 minutes.

The total precipitation for this event in Brgy San Jose ARG was 7.1 mm. It has a peak rainfall of 1.40 mm. on August 24, 2016 at 2:50 in the afternoon. The lag time between the peak rainfall and discharge at Ibajay Bridge is 7 hours and 30 minutes.

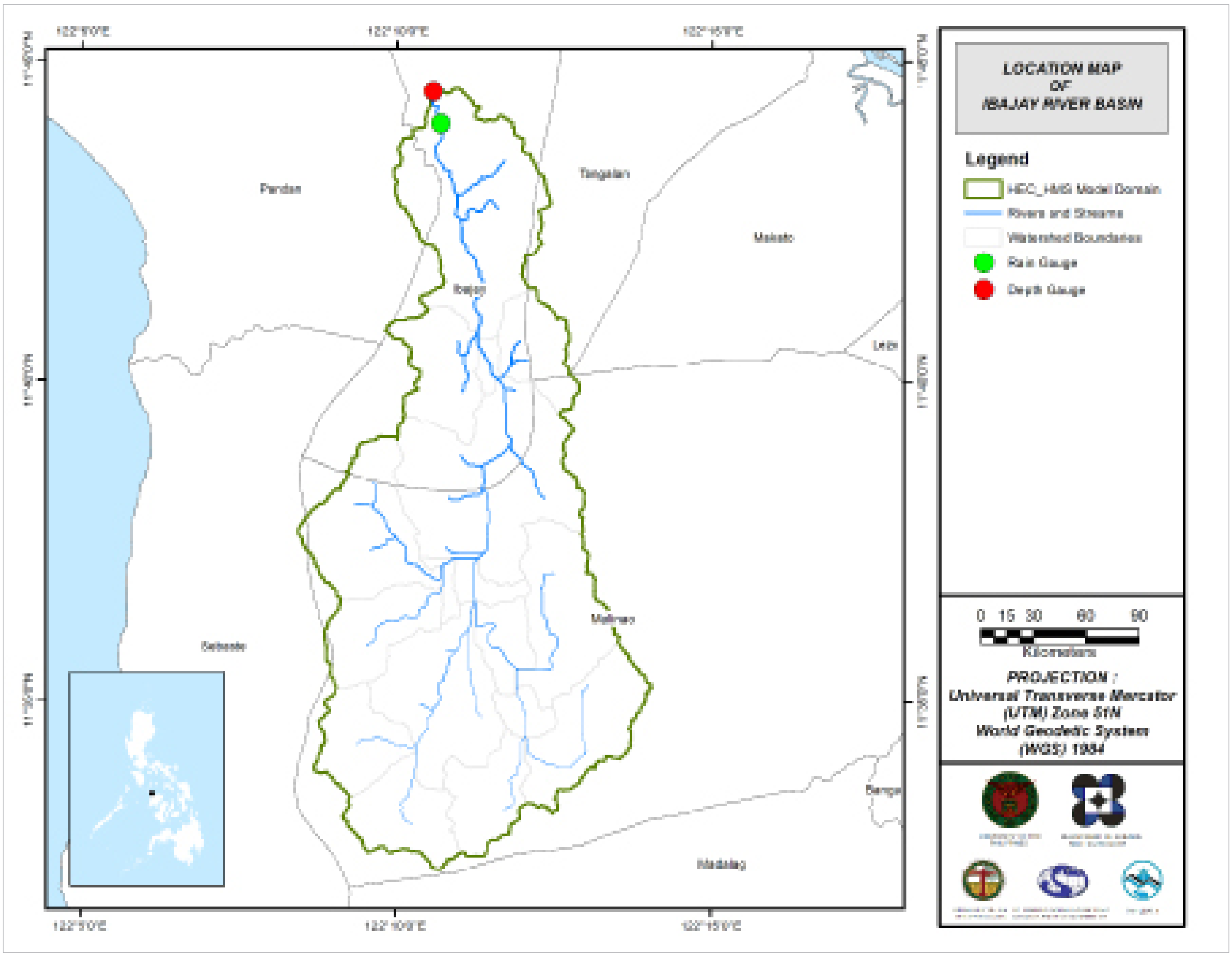


Figure 44. Location Map of the Ibajay HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Ibajay Bridge, San Agustin, San Jose Flow Site, Ibajay, Aklan (11°44'32.58"N, 122°10'34.96"E) to establish the relationship between the observed water levels (H) at Ibajay Bridge and outflow (Q) of the watershed at this location.

For San Jose Flow Site, the rating curve is expressed as Q = 66.291e0.5476x as shown in Figure 46.

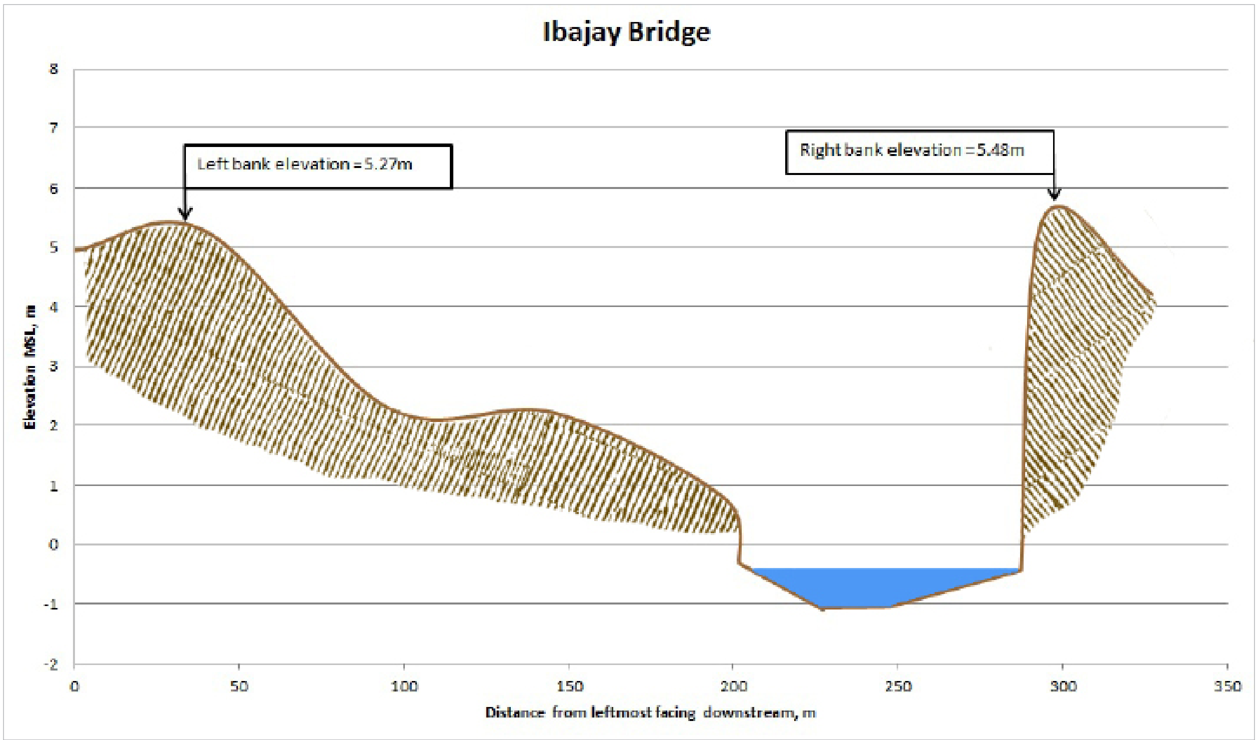


Figure 45. The cross-section plot of the Ibajay Bridge.

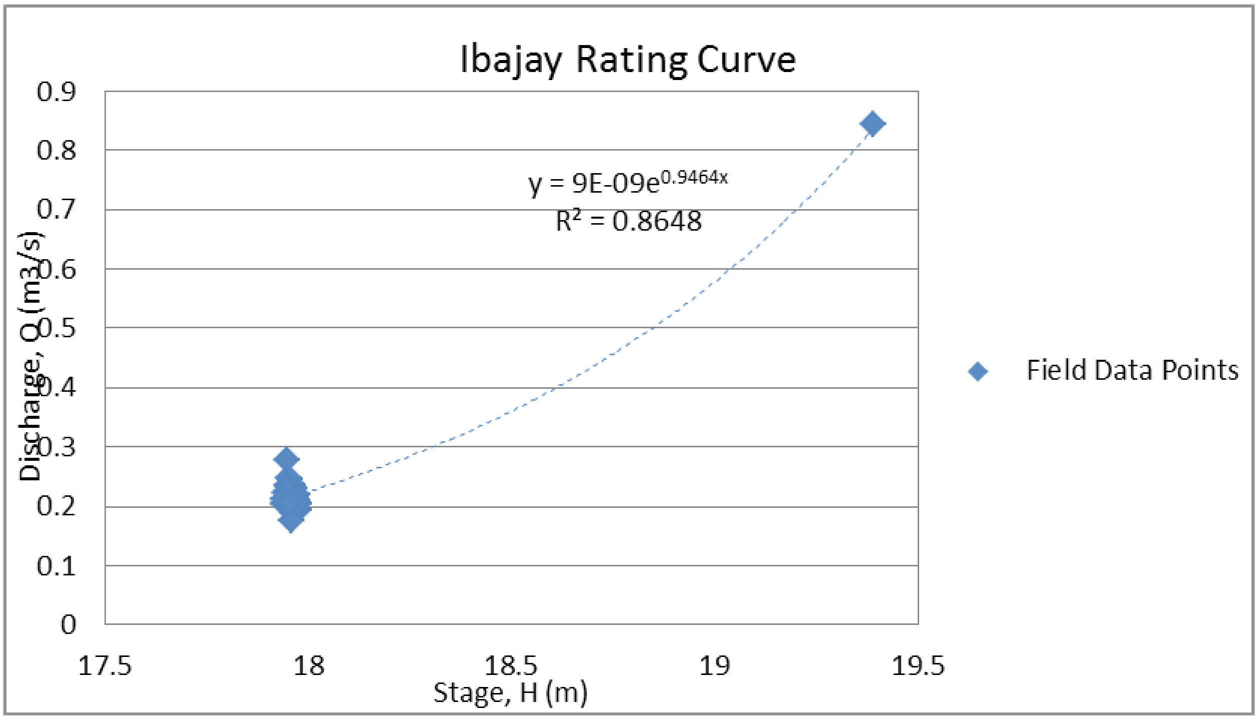


Figure 46. The rating curve at San Jose Flow Site, Ibajay, Aklan.

This rating curve equation was used to compute the river outflow at San Jose Flow Site for the calibration of the HEC-HMS model shown in Figure 46. The total rainfall for this event is 7.1 mm and the peak discharge is 22.665 m^3 at 9:20 PM, August 24, 2016.

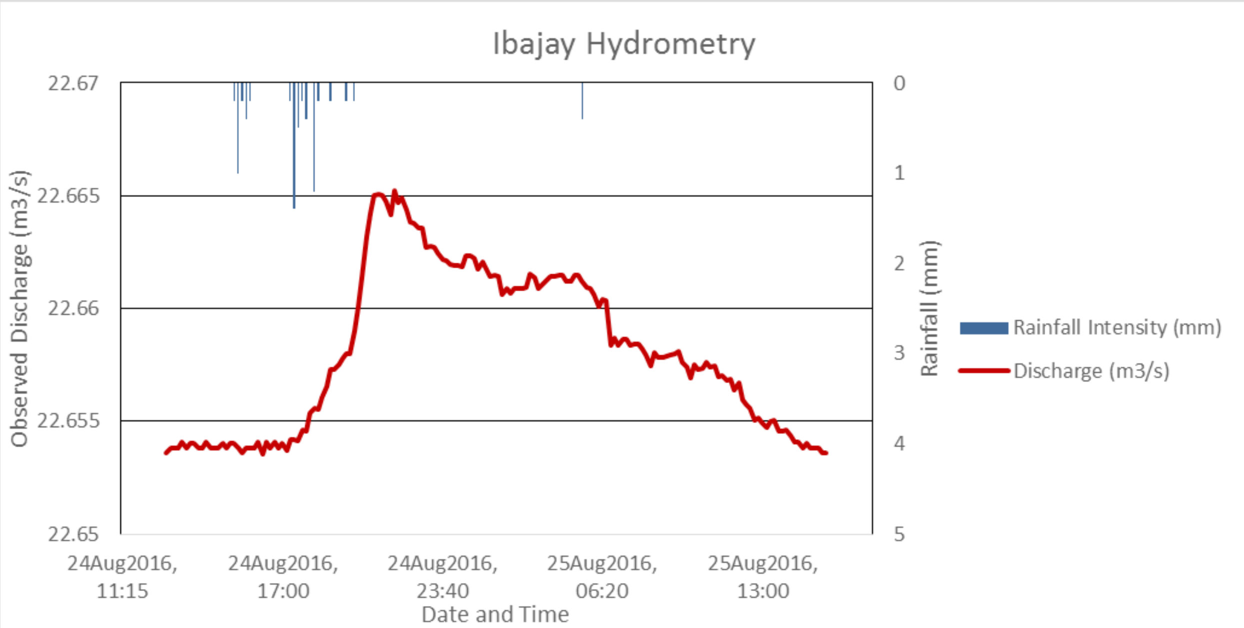


Figure 47. Rainfall and outflow data at the Ibajay River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Roxas Rain Gauge (Table 28). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 48). This station was selected based on its proximity to the Ibajay watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 28. RIDF values for the Roxas Rain Gauge, as computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
5	26.6	40.5	51.3	72.1	98	115.5	142.8	165.9	186.2
10	31.3	47.8	60.7	86.2	118	139.4	172.3	200.1	224.6
25	37.4	57	72.5	104	143.1	169.6	209.7	243.4	273
50	41.8	63.8	81.3	117.2	161.8	192	237.4	275.4	308.9
100	46.2	70.5	90	130.2	180.3	214.2	264.9	307.2	344.6

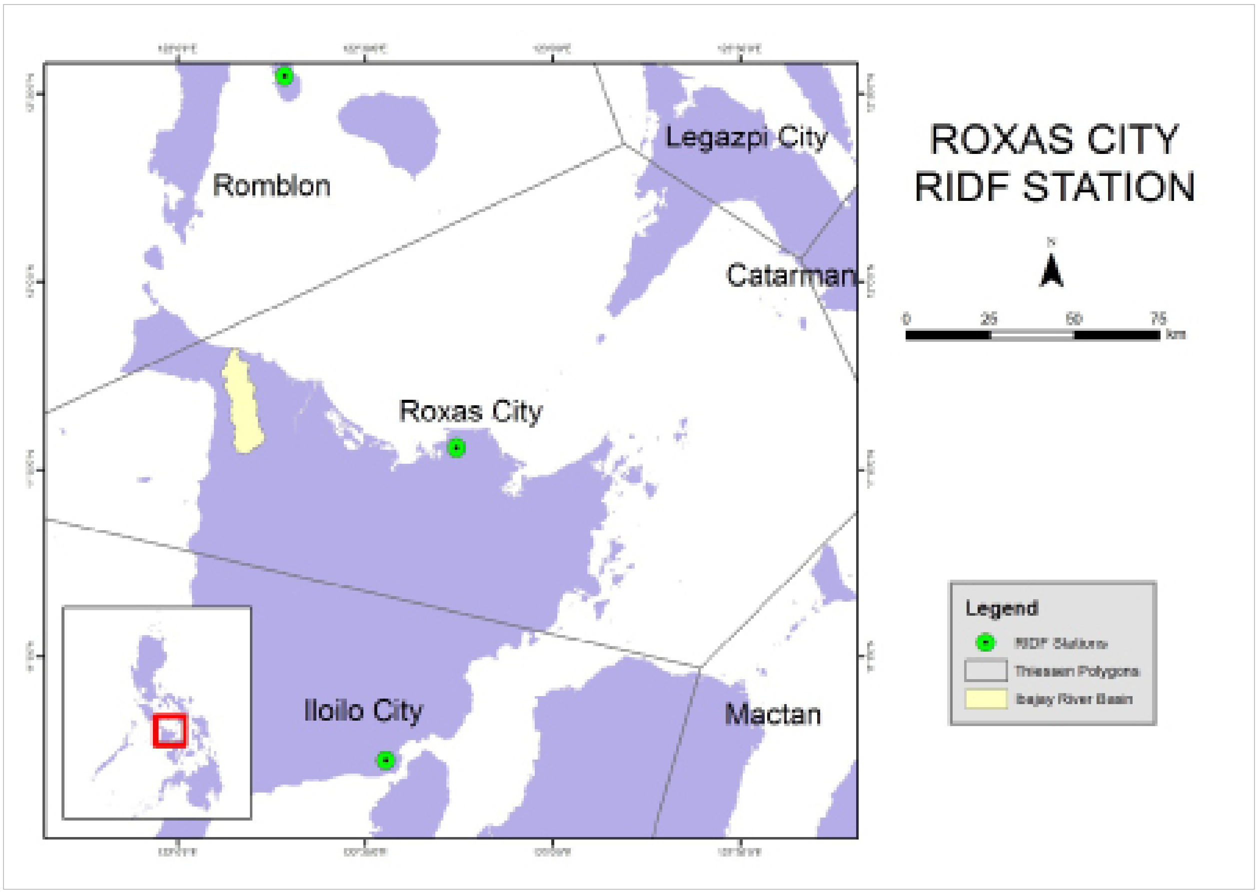


Figure 48. The location of the Roxas RIDF station relative to the Ibajay River Basin.

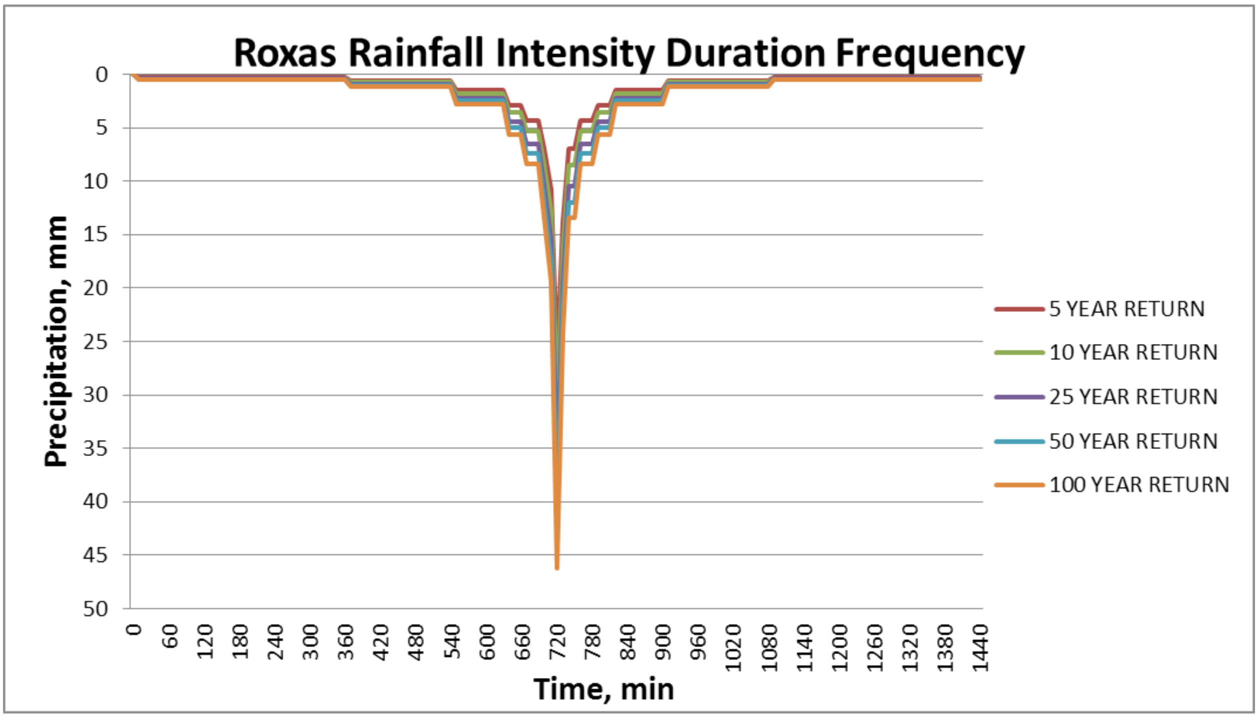


Figure 49. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Ibajay River Basin are shown in Figure 50 and Figure 51 respectively.

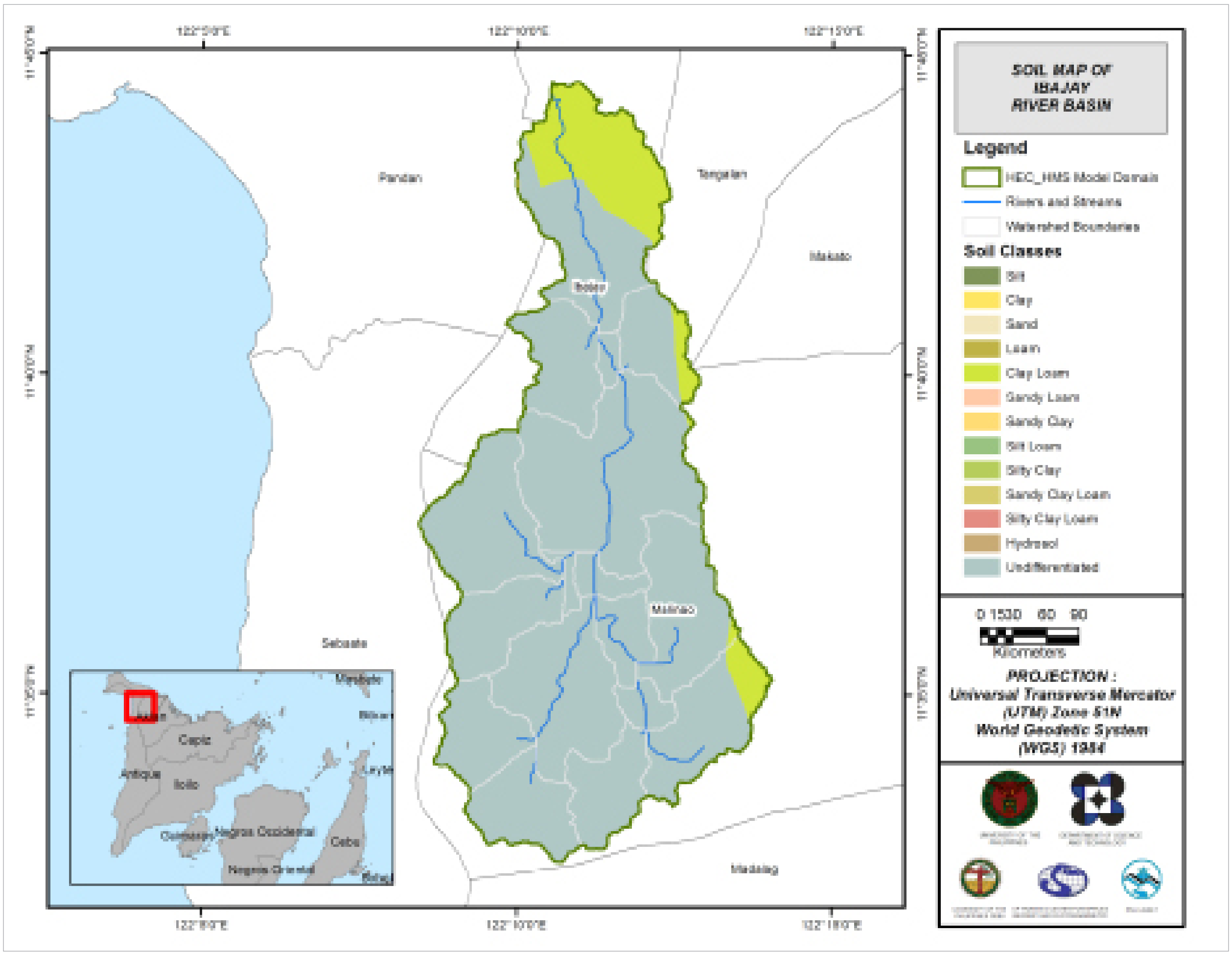


Figure 50. Soil Map of Ibajay River Basin.

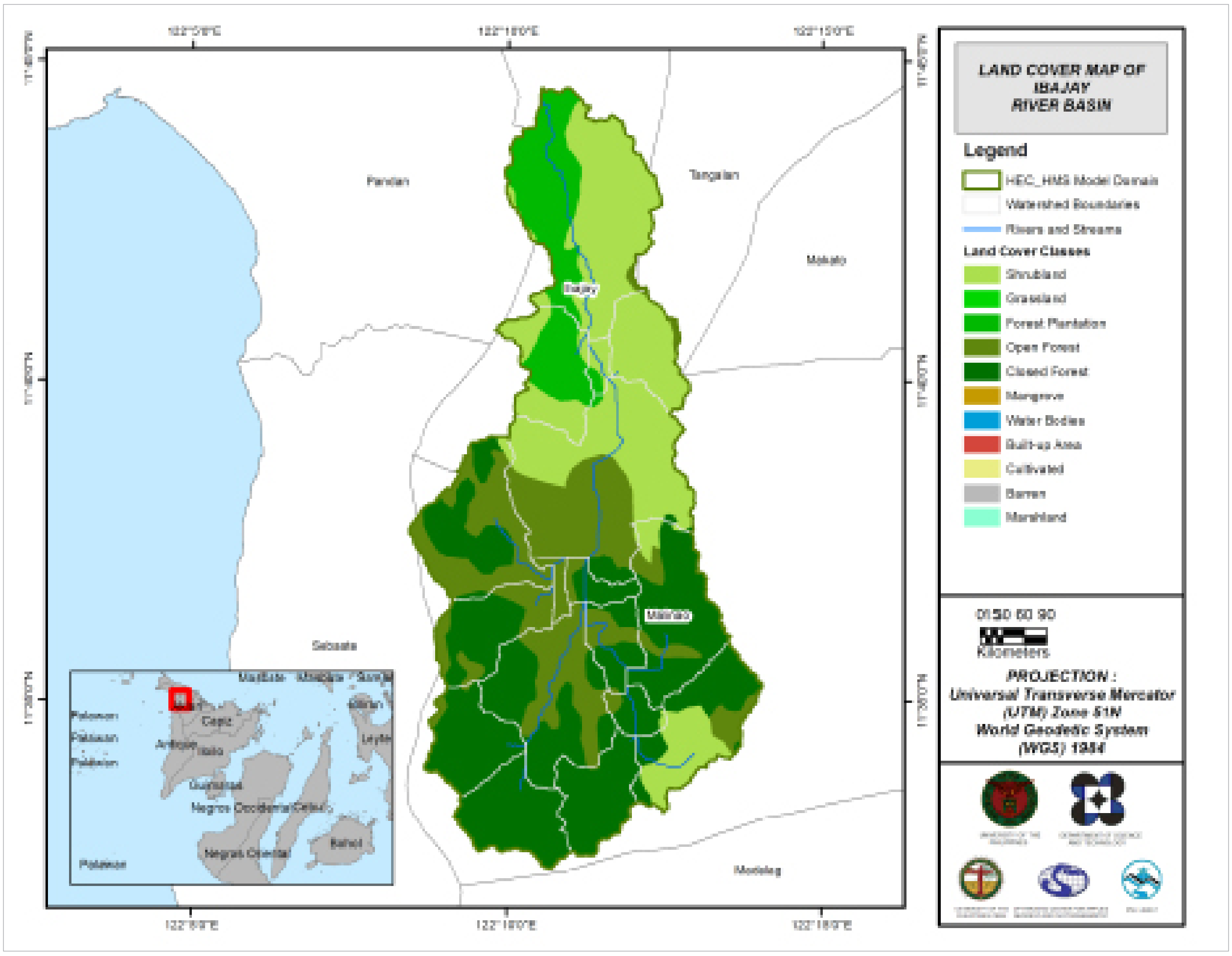


Figure 51. Land Cover Map of Ibajay River Basin.

For Ibajay, two soil classes were identified. These are clay loam, and undifferentiated soil. Moreover, four land cover classes were identified. These are closed and open forest, shrubland, and forest plantation.

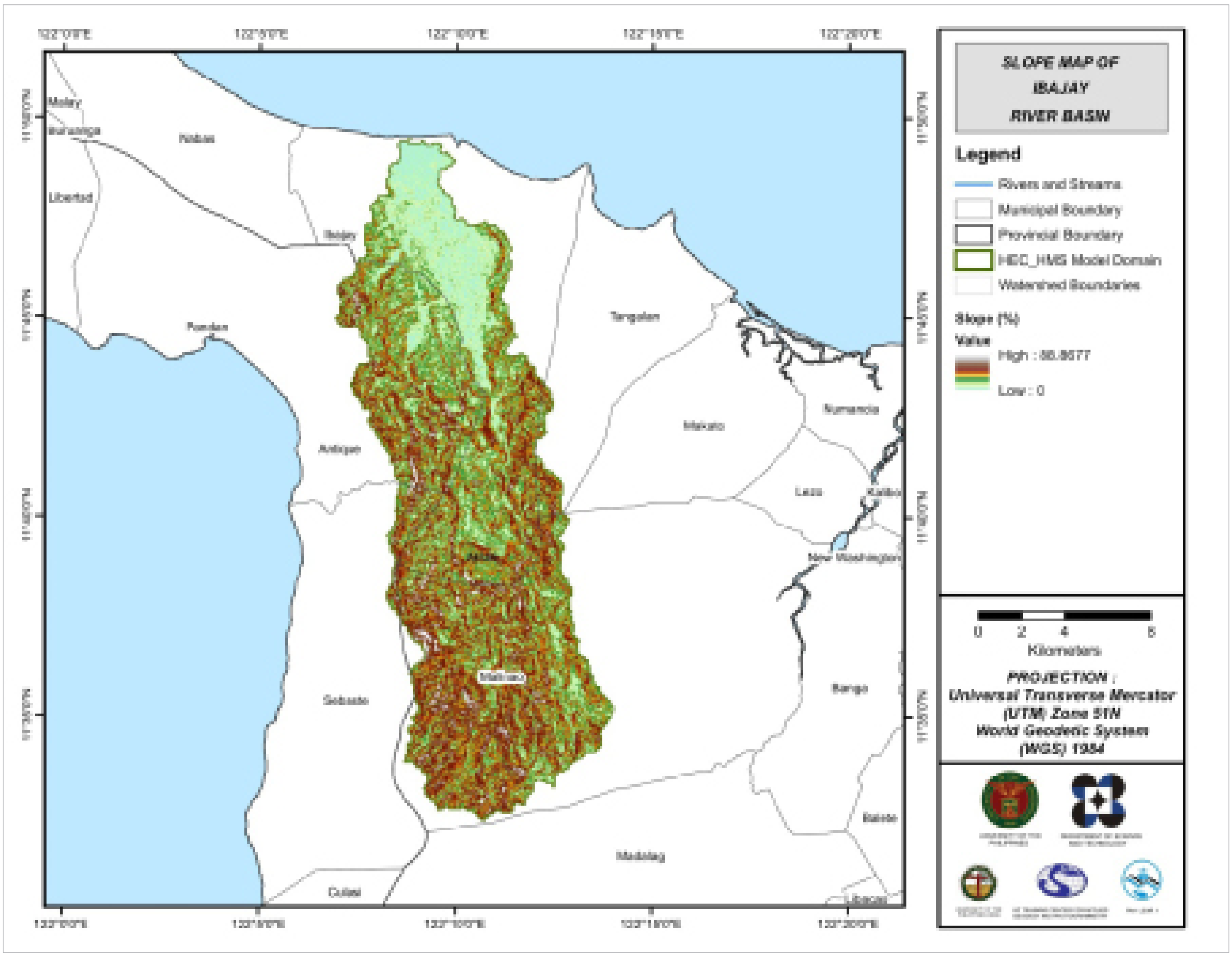


Figure 52. Slope Map of the Ibajay River Basin.

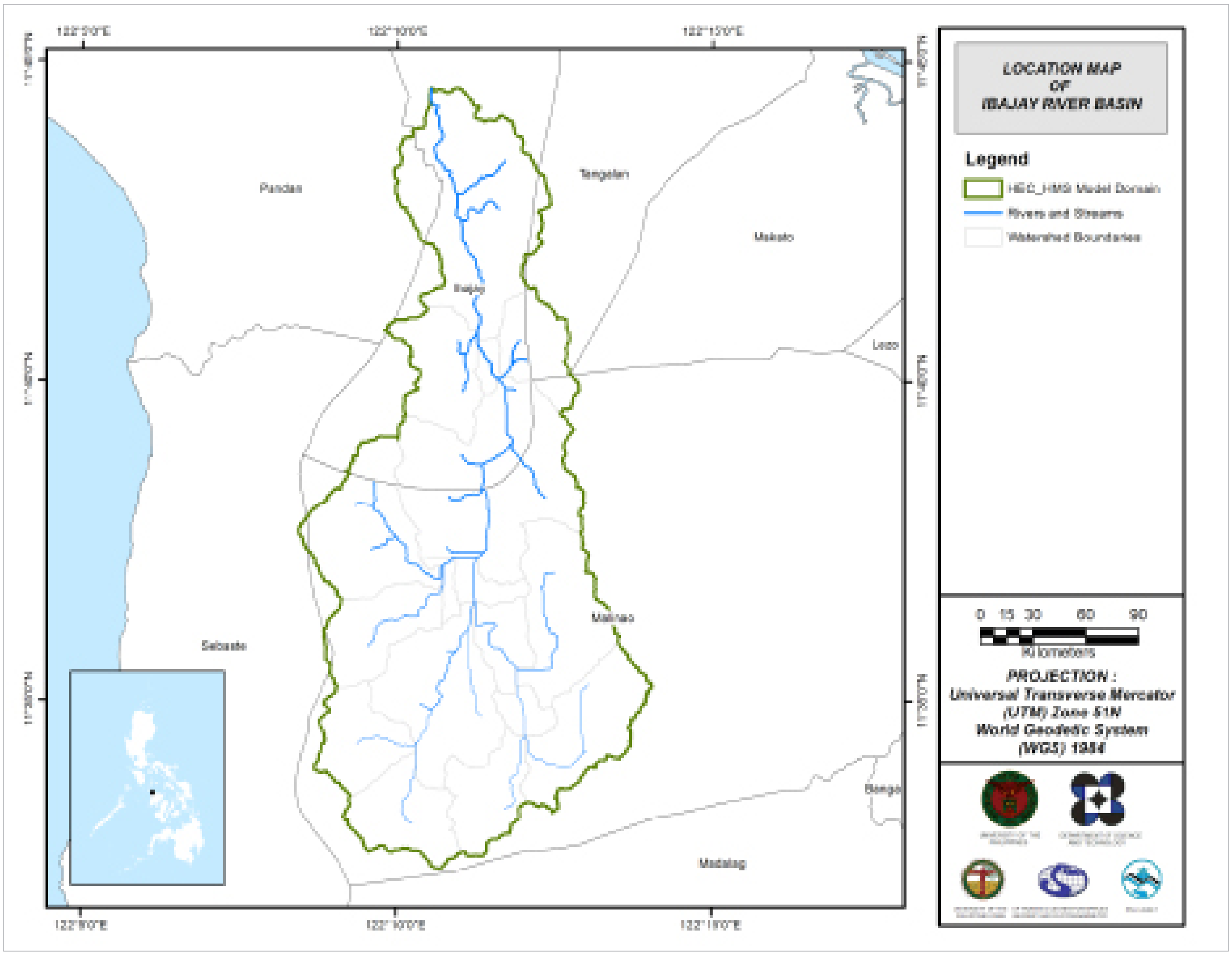


Figure 53. Stream Delineation Map of Ibajay River Basin

Using the SAR-based DEM, the Ibajay basin was delineated and further subdivided into subbasins. The model consists of 17 sub basins, 8 reaches, and 8 junctions, as shown in Figure 54. The main outlet is at San Jose Flow Site.

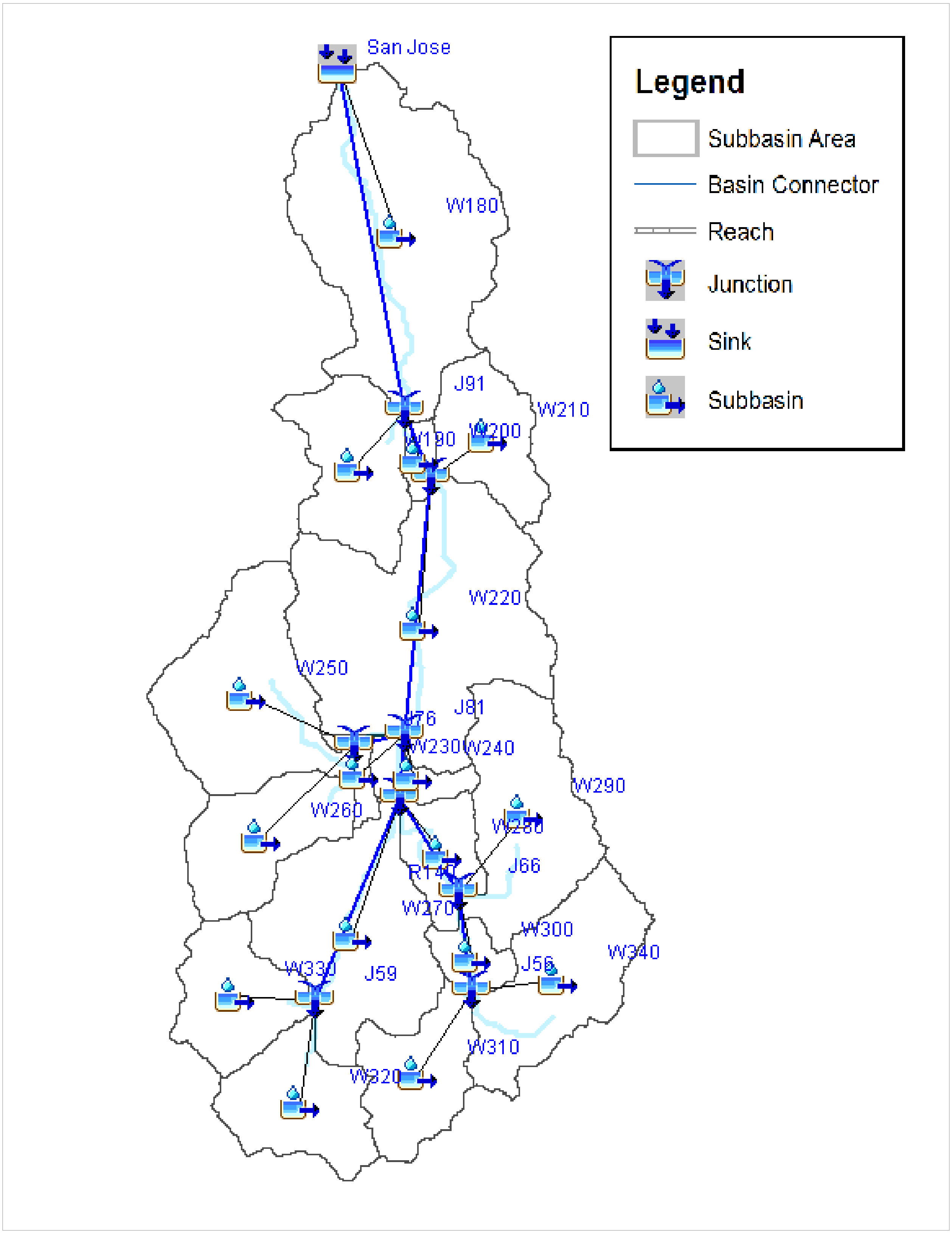


Figure 54. Ibajay river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 55).

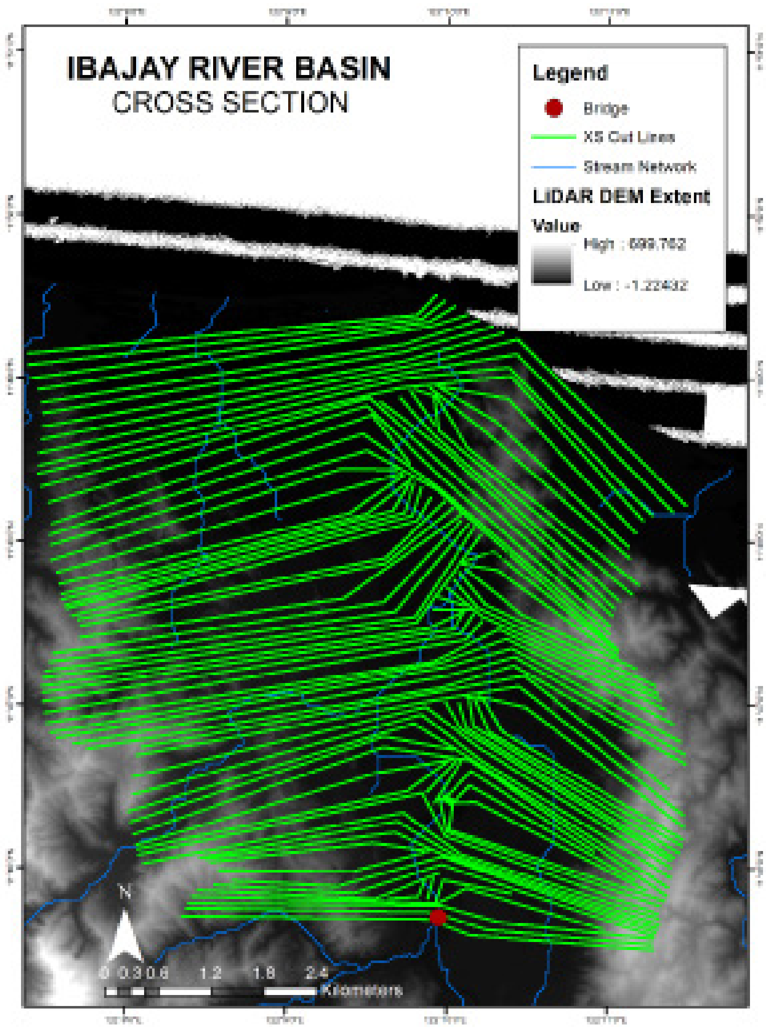


Figure 55. River cross-section of the Ibajay River through the ArcMap HEC GeoRas tool

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the south of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

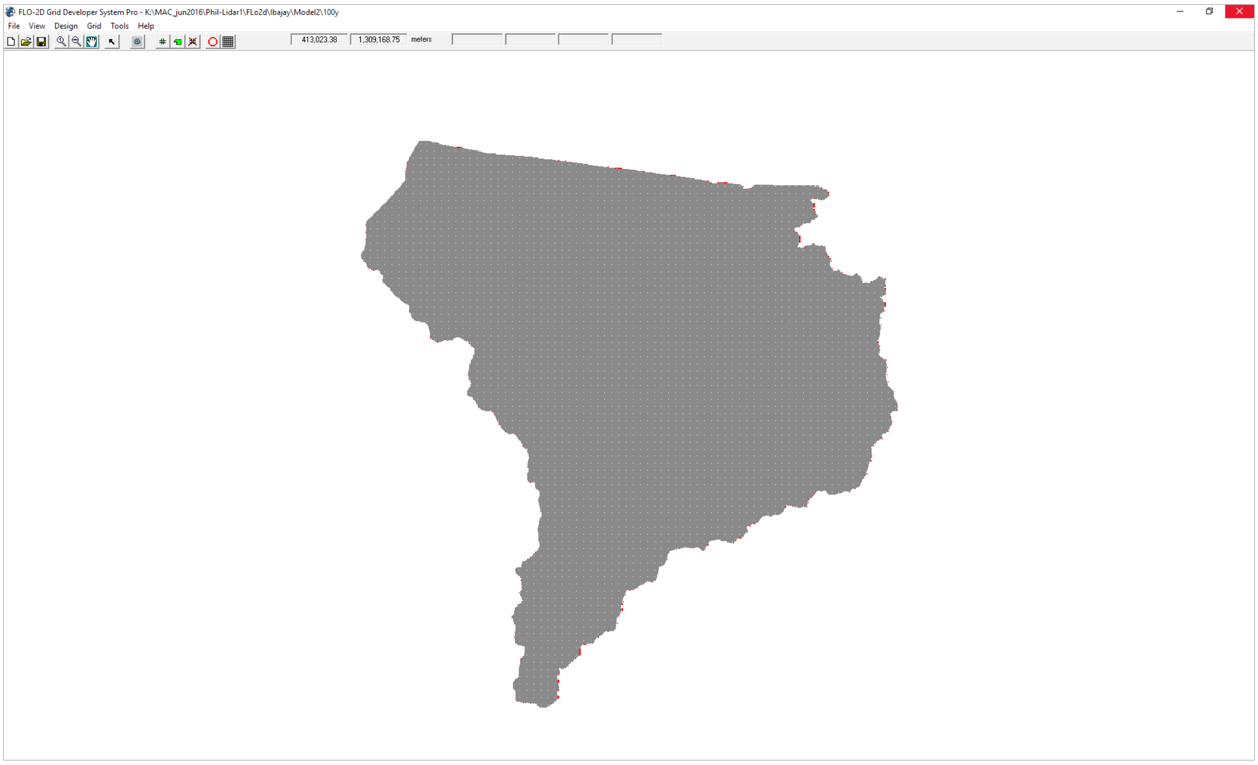


Figure 56. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 19.16083 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s. The generated hazard maps for Ibajay are in Figure 60, 62, 64.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 31450300.00m^2. The generated flood depth maps for Ibajay are in Figure 61, 63, 65.

There is a total of 10784659.06 m^3 of water entering the model. Of this amount, 10784659.06 m^3 is due to rainfall while 0.00 m^3 is inflow from other areas outside the model. 3368651.00 m^3 of this water is lost to infiltration and interception, while 3289933.82 m^3 is stored by the flood plain. The rest, amounting up to 4126070.49 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Ibajay HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

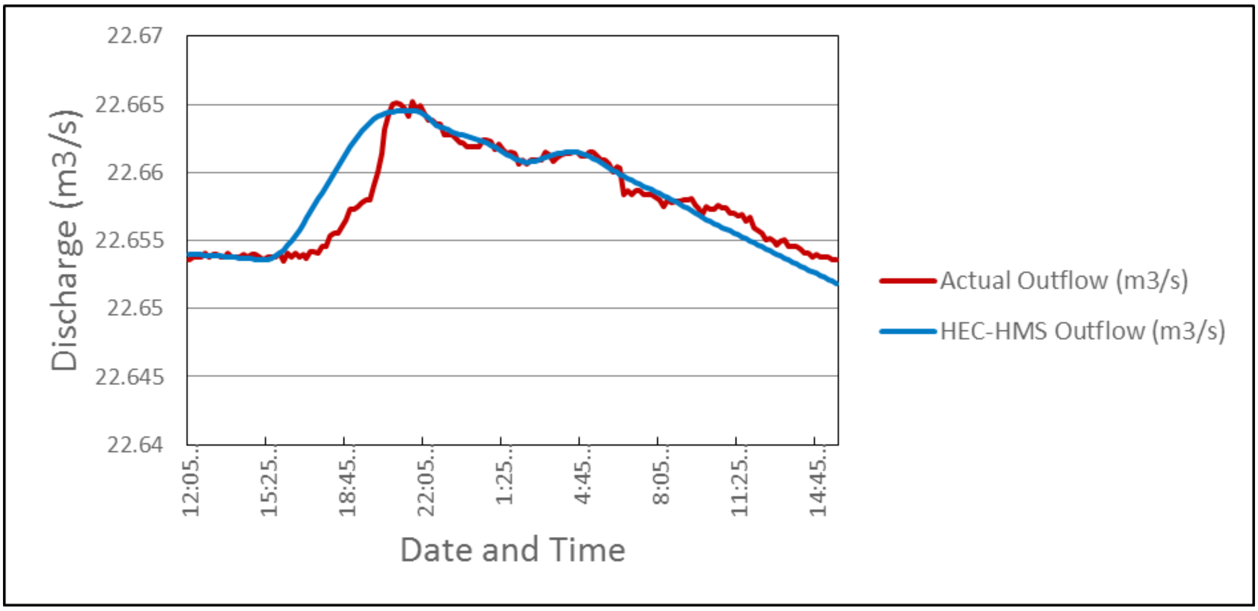


Figure 57. Outflow Hydrograph of Ibajay Bridge produced by the HEC-HMS model compared with observed outflow

Table 29 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of calibrated values for the Ibajay River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	4.15-7.53
			Curve Number	44.9-48.4
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1.3-6.9
			Storage Coefficient (hr)	0.95-4.9
	Baseflow	Recession	Recession Constant	0.9991
			Ratio to Peak	0.9998
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.09

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 4.15 mm to 7.53 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 44.9 to 48.4 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Ibajay, the basin mostly consists of closed and open forests, shrublands, and grasslands, and the soil consists of clay loam, and undifferentiated soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.95 hours to 6.9 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9991 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.9998 indicates a gentler receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.09 corresponds to the common roughness in the Ibajay watershed, which is determined to be cultivated with medium to dense brush, shrubland (Brunner, 2010).

Table 30. Summary of the Efficiency Test of the Ibajay HMS Model

Accuracy measure	Value
RMSE	0.00171
r^2	0.90228
NSE	0.77124
PBIAS	-0.00150
RSR	0.47829

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.0017 (m^3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.90228.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.77124.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.0015.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.47.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 58) shows the Ibajay outflow using the Roxas Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 196.2m³ in a 5-year return period to 344.6m³ for a 100-year return period.

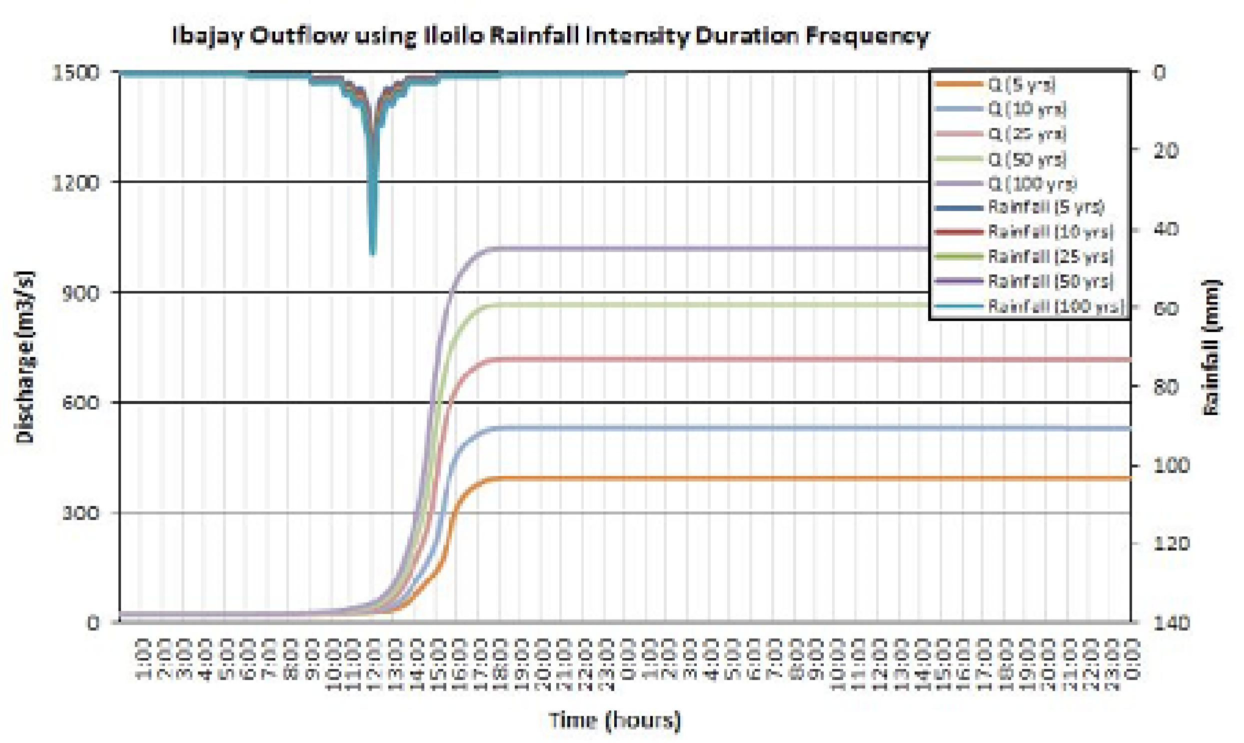


Figure 58. The Outflow hydrograph at the Ibajay Station, generated using the Roxas RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Ibajay discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. The peak values of the Ibajay HEC-HMS Model outflow at Ibajay Bridge using the Iloilo RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	186.2	26.6	394.29	7 hours
10-Year	224.6	31.3	530.76	6 hours, 50 minutes
25-Year	273	37.4	718.27	6 hours, 20 minutes
50-Year	308.9	41.8	866.18	6 hours, 20 minutes
100-Year	344.6	46.2	1018.9	6 hours, 20 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 59 shows a generated sample map of the Ibajay River using the calibrated HMS event flow.

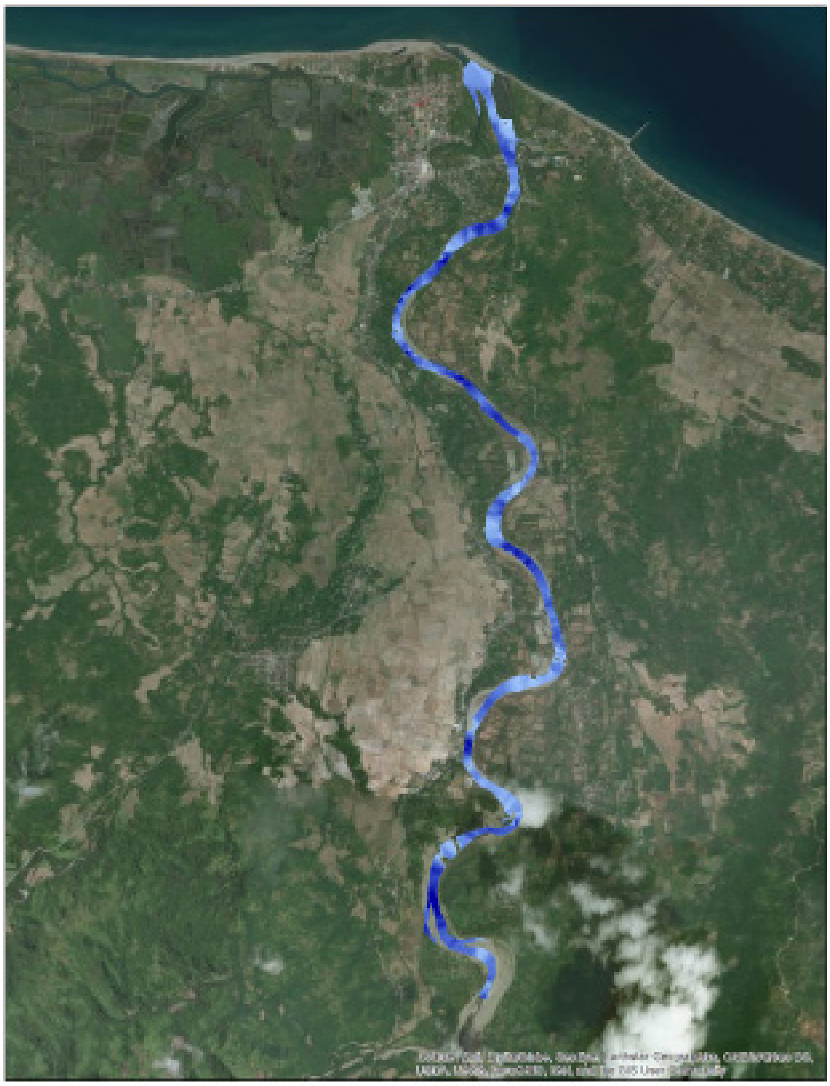


Figure 59. Sample output map of the Ibajay RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 60 to Figure 65 shows the 5-, 25-, and 100-year rain return scenarios of the Ibajay floodplain. The floodplain, with an area of 56.37 sq. km., covers three municipalities namely Ibajay, Nabas, and Pandan. Table 32 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Ibajay floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Ibajay	148.5	52.644	35.445	1.50%
Nabas	87.01	0.8885	1.0211	0.13%
Pandan	146.9	2.694393	1.83468	

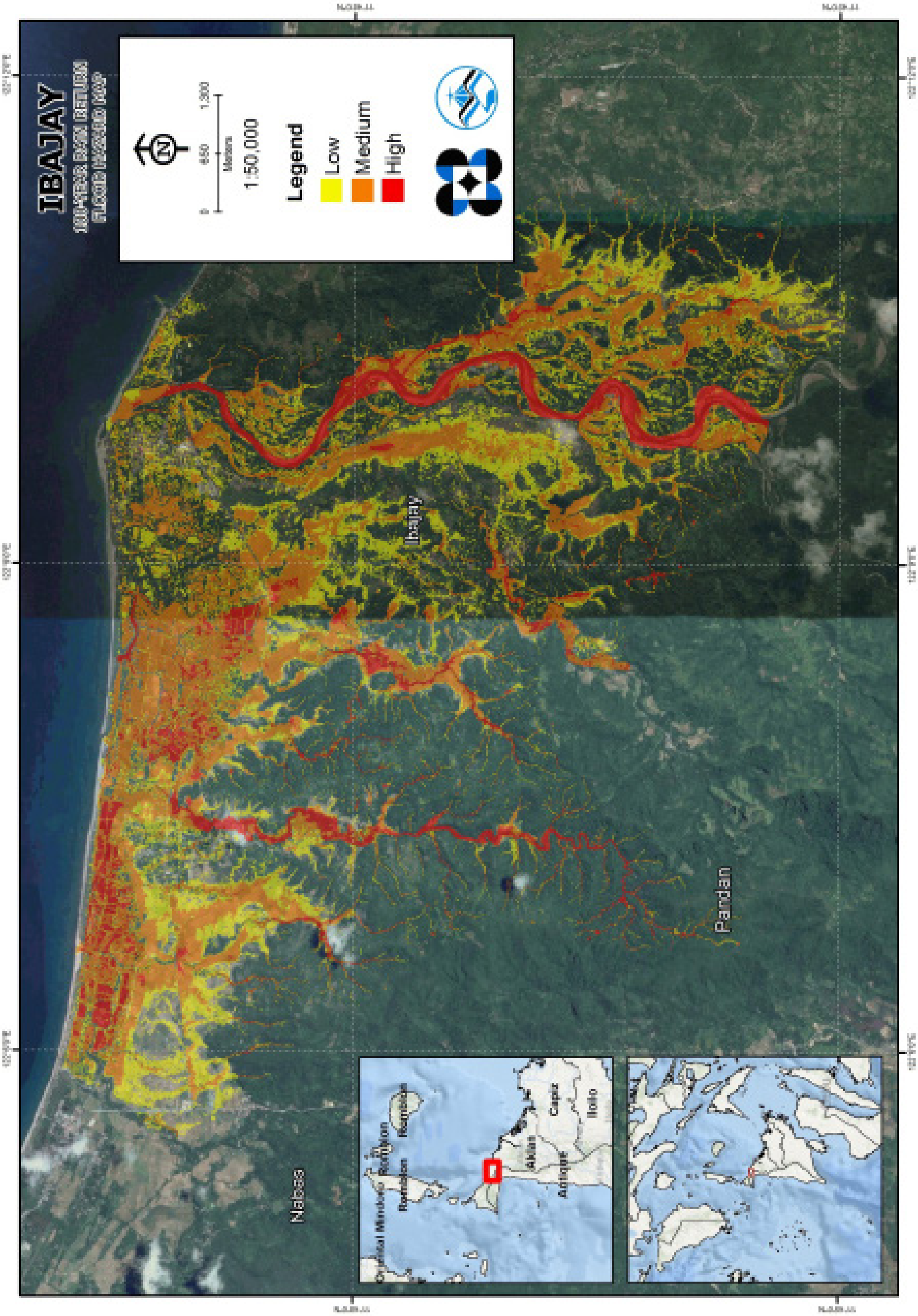


Figure 60. A 100-year Flood Hazard Map for Ibajay Floodplain overlaid on Google Earth imagery.

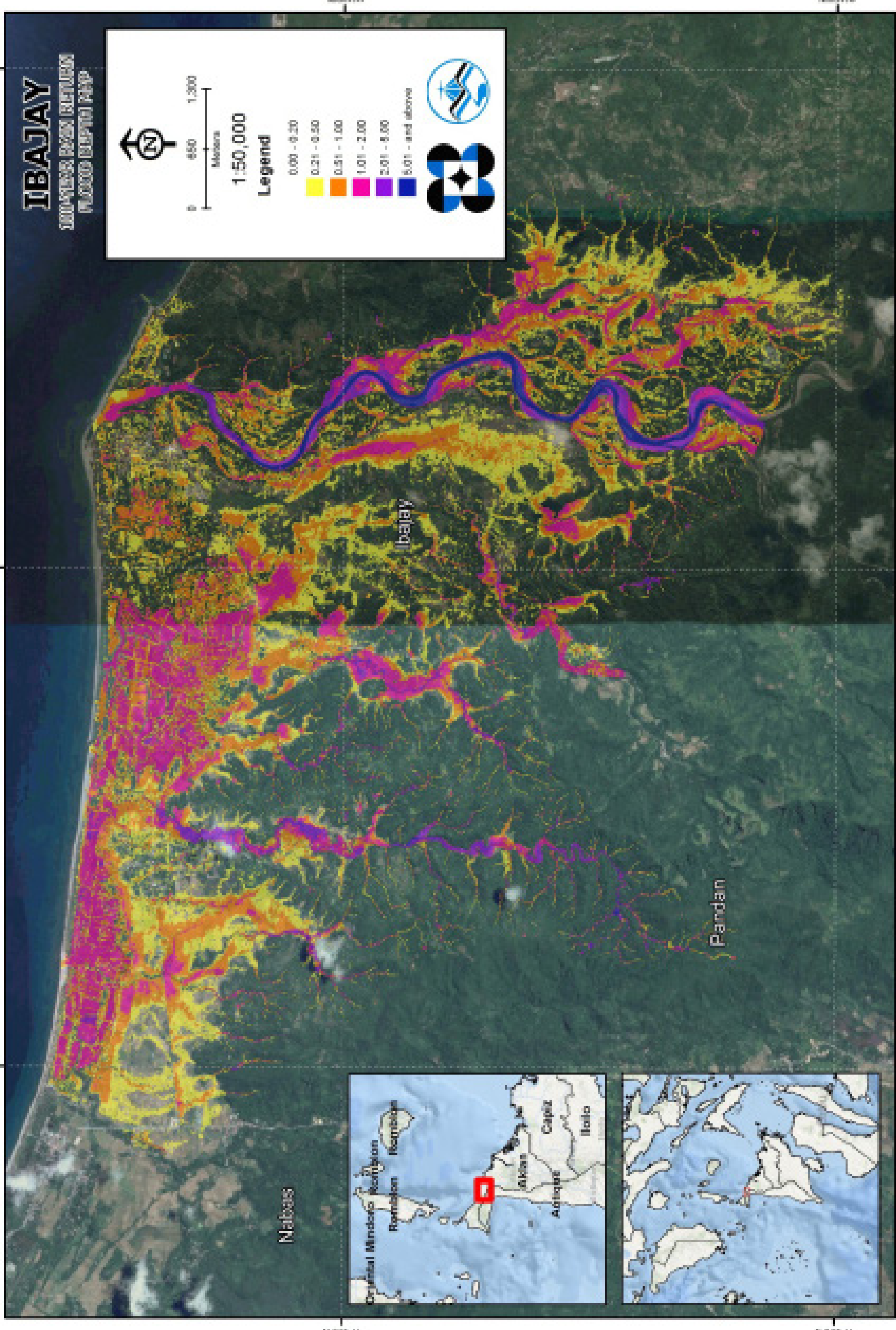


Figure 61. A 100-year Flow Depth Map for Ibajay Floodplain overlaid on Google Earth imagery.

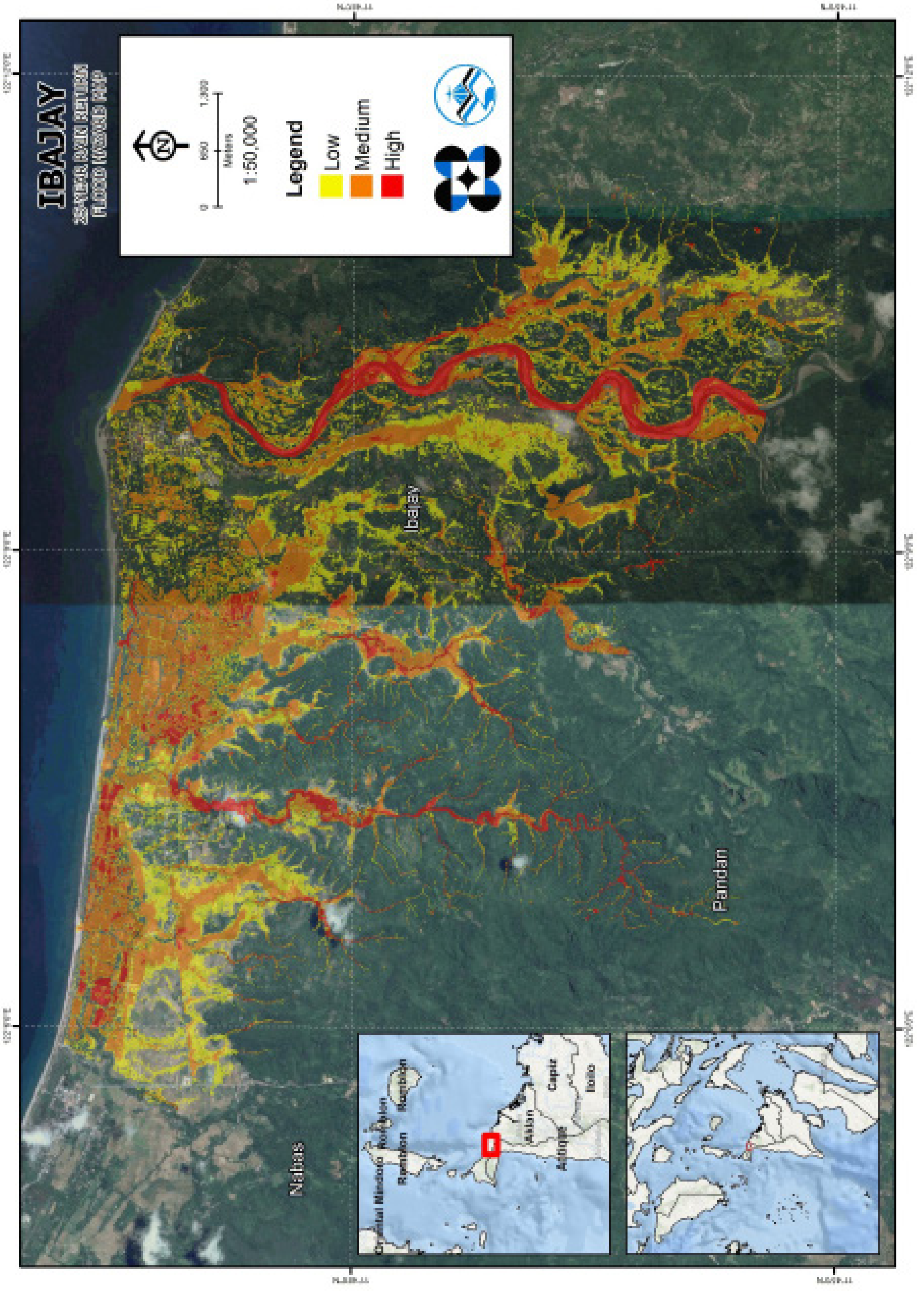


Figure 62. A 25-year Flood Hazard Map for Ibajay Floodplain overlaid on Google Earth imagery.

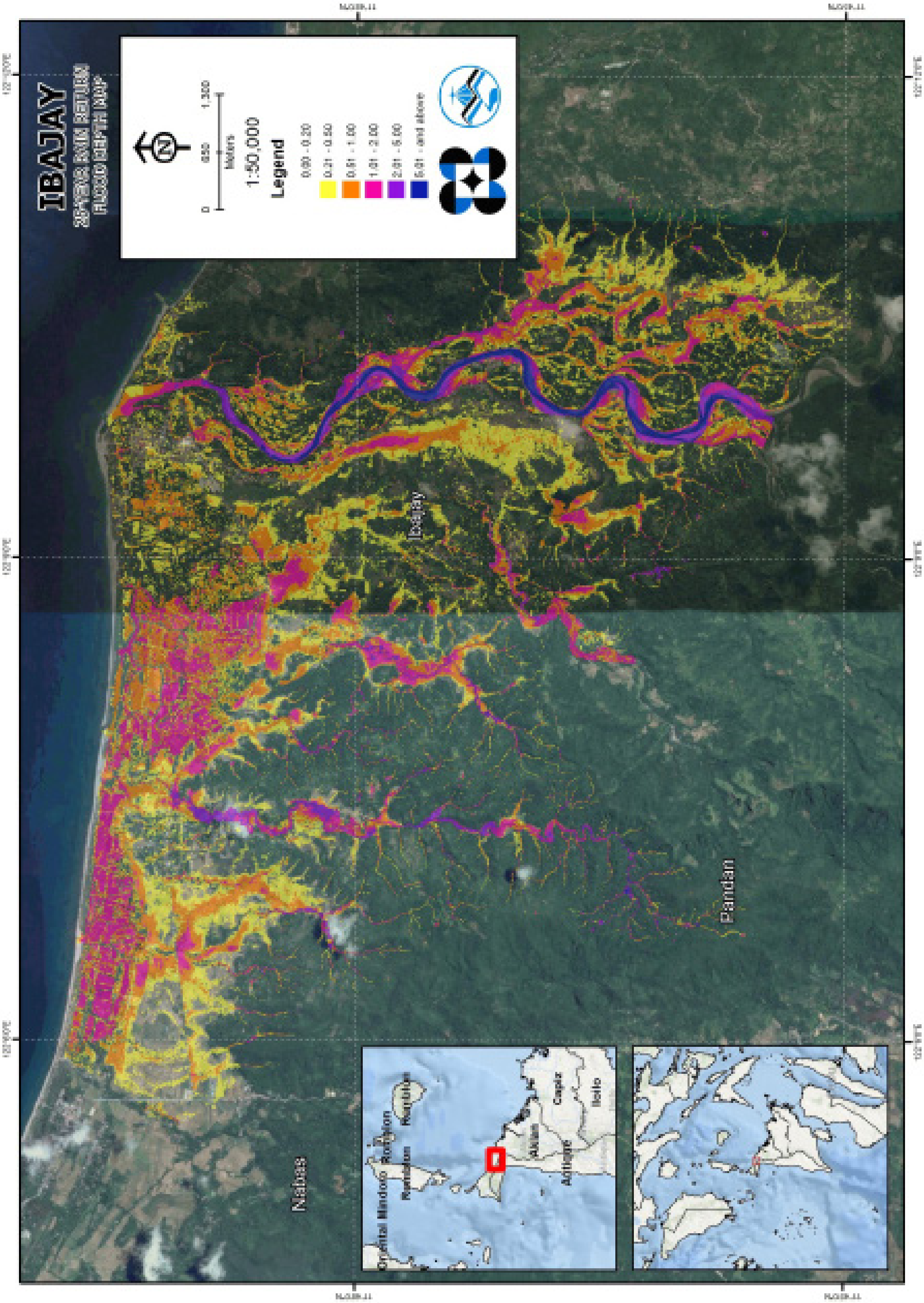


Figure 63. A 25-year Flow Depth Map for Ibajay Floodplain overlaid on Google Earth imagery.

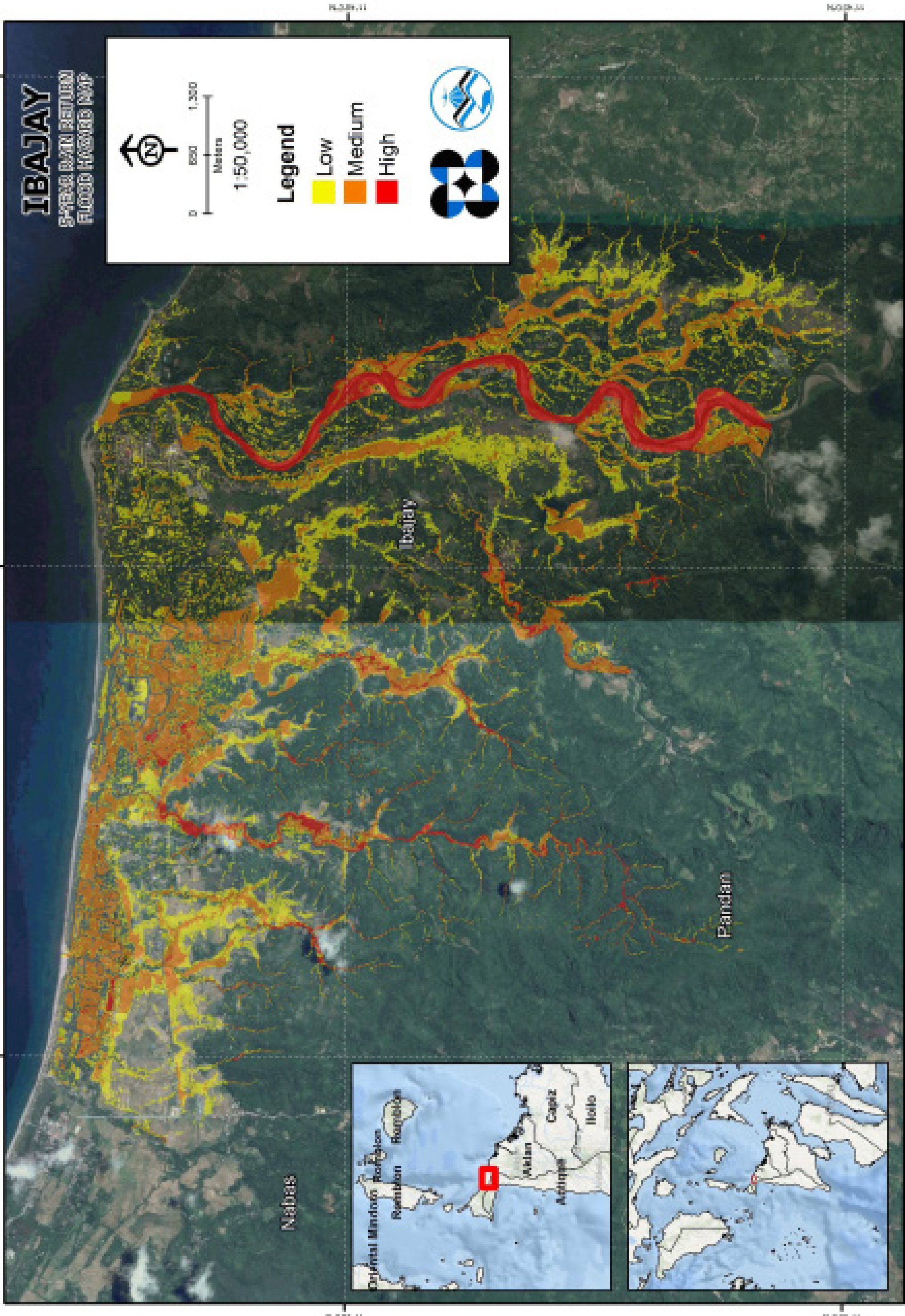


Figure 64. A 5-year Flood Hazard Map for Ibajay Floodplain overlaid on Google Earth imagery.

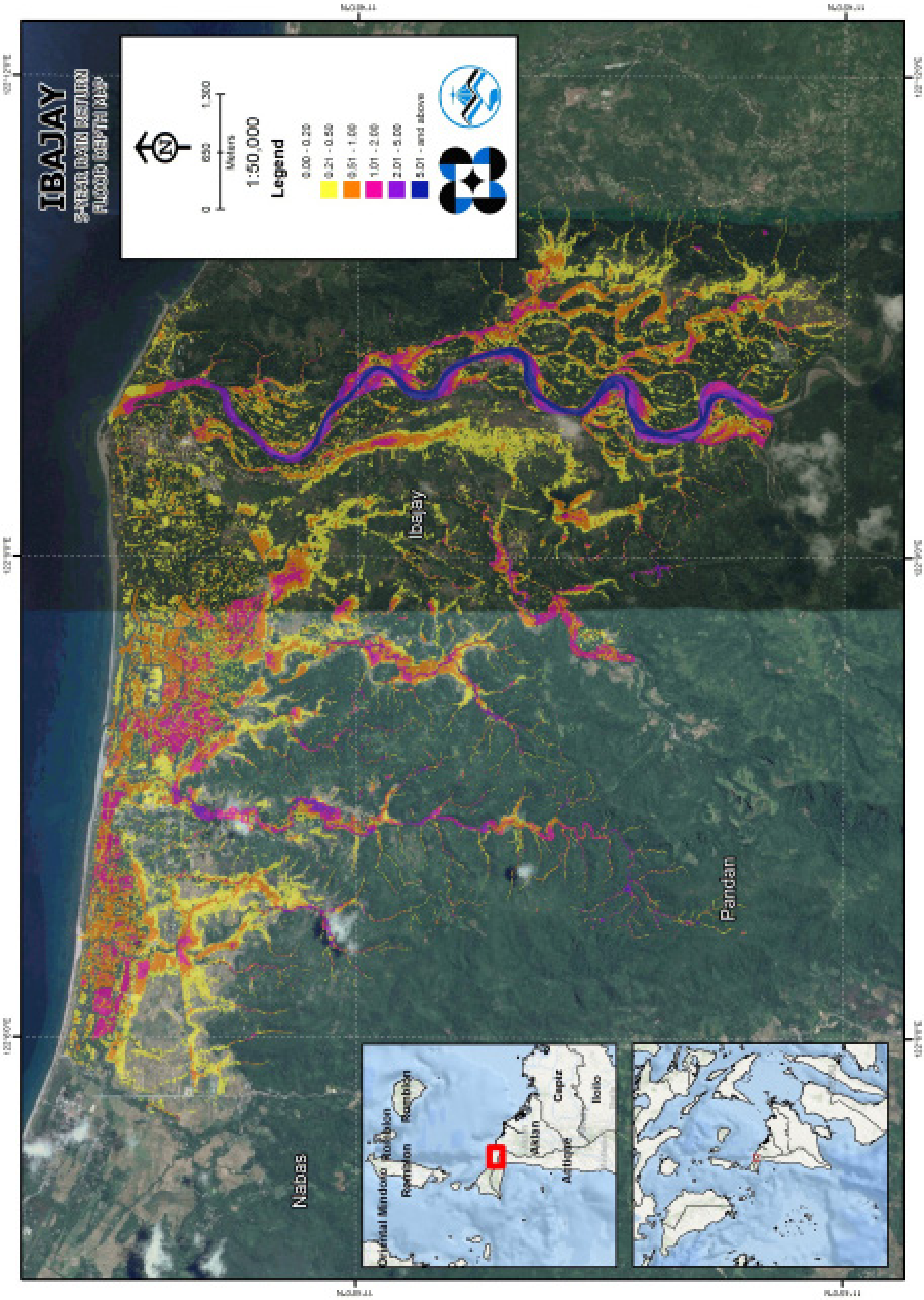


Figure 65. A 5-year Flood Depth Map for Ibajay Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Ibajay River Basin, grouped accordingly by municipality. For the said basin three (3) municipalities consisting of 33 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the municipality of Ibajay with an area of 148.52 sq. km., 25.08% will experience flood levels of less 0.20 meters. 4.97% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 1.44%, 0.5%, and 0.32% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33are the affected areas in Ibajay in square kilometers by flood depth per barangay. ANNEX 12 and ANNEX 13 shows the educational and health institutions exposed to flooding, respectively.

Table 33. Affected Areas in Ibajay, Aklan during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Ibajay (in sq. km.)									
	Agbago	Agdugayan	Antipolo	Aquino	Aslum	Bagacay	Batuan	Buenavista	Cabugao	Capilijan
0.03-0.20	3.11	1.04	5.63	3.91	0.21	0.46	1.45	0.063	0.00011	0.84
0.21-0.50	1.28	0.19	0.26	1.06	0.04	0.18	0.21	0.0013	0	0.17
0.51-1.00	0.96	0.15	0.21	0.7	0.019	0.11	0.052	0.00081	0.000093	0.015
1.01-2.00	0.31	0.096	0.16	0.24	0.0043	0.07	0.016	0.00065	0	0.0028
2.01-5.00	0.00059	0.12	0.079	0.024	0	0.046	0.003	0.0017	0	0
> 5.00	0	0.071	0.00043	0.0001	0	0.088	0	0	0	0
Affected Area (sq. km.) by flood depth (in m.)										
	Colongcolong	Laguinbanua	Mabusao	Maloco	Naile	Naisud	Naligusan	Ondoy	Poblacion	Polo
0.03-0.20	0.54	1.26	0.68	2.22	3.5	0.05	1.3	1.47	0.82	0.33
0.21-0.50	0.082	0.28	0.048	0.29	0.7	0.0002	0.4	0.38	0.25	0.082
0.51-1.00	0.031	0.19	0.077	0.18	0.32	0.0001	0.2	0.22	0.048	0.038
1.01-2.00	0.036	0.1	0.1	0.076	0.12	0	0.04	0.13	0.025	0.014
2.01-5.00	0.0011	0.087	0.013	0.024	0.081	0.00034	0.024	0.0008	0	0.066
> 5.00	0	0.063	0	0.001	0.055	0	0.059	0	0	0.0066

Affected Area (sq. km.) by flood depth (in m.)	Regador	Rizal	San Isidro	Santa Cruz	Tagbaya	Tul-Ang	Unat			
0.03-0.20	0.3	1.63	0.27	1.76	2.44	1.23	0.74			
0.21-0.50	0.0053	0.3	0.0044	0.22	0.5	0.15	0.27			
0.51-1.00	0.0023	0.26	0.0018	0.22	0.45	0.12	0.059			
1.01-2.00	0.0015	0.12	0.001	0.083	0.3	0.045	0.023			
2.01-5.00	0.0007	0.026	0.0004	0.03	0.061	0.035	0.037			
> 5.00	0	0.034	0	0.0003	0.00017	0.0086	0.09			

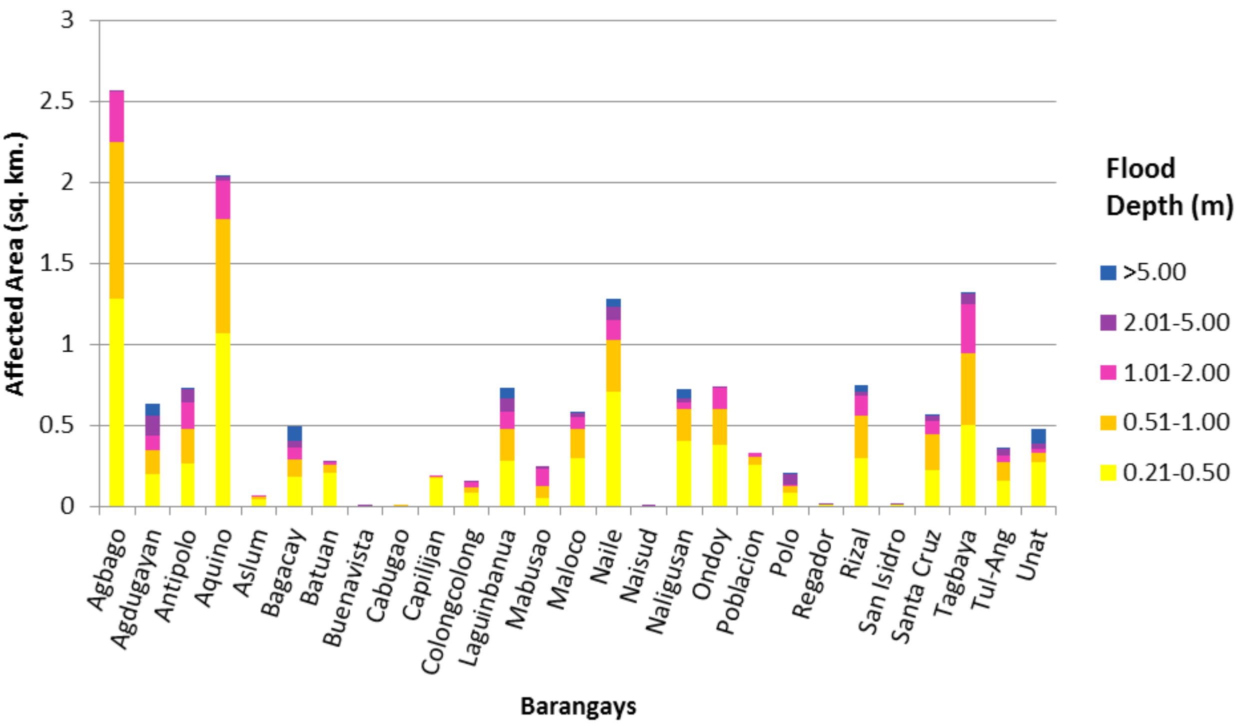


Figure 66. Affected Areas in Ibajay, Aklan during 5-Year Rainfall Return Period.

For the municipality of Nabas with an area of 87.01 sq. km., 0.81% will experience flood levels of less 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.01%, and 0.0002%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 34 are the affected areas in Nabas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Nabas, Aklan during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nabas (in sq. km.)	
	Alimbo-Baybay	Solido
0.03-0.20	0.42	0.29
0.21-0.50	0.11	0.03
0.51-1.00	0.03	0.0042
1.01-2.00	0.0071	0.001
2.01-5.00	0	0.0002
> 5.00	0	0

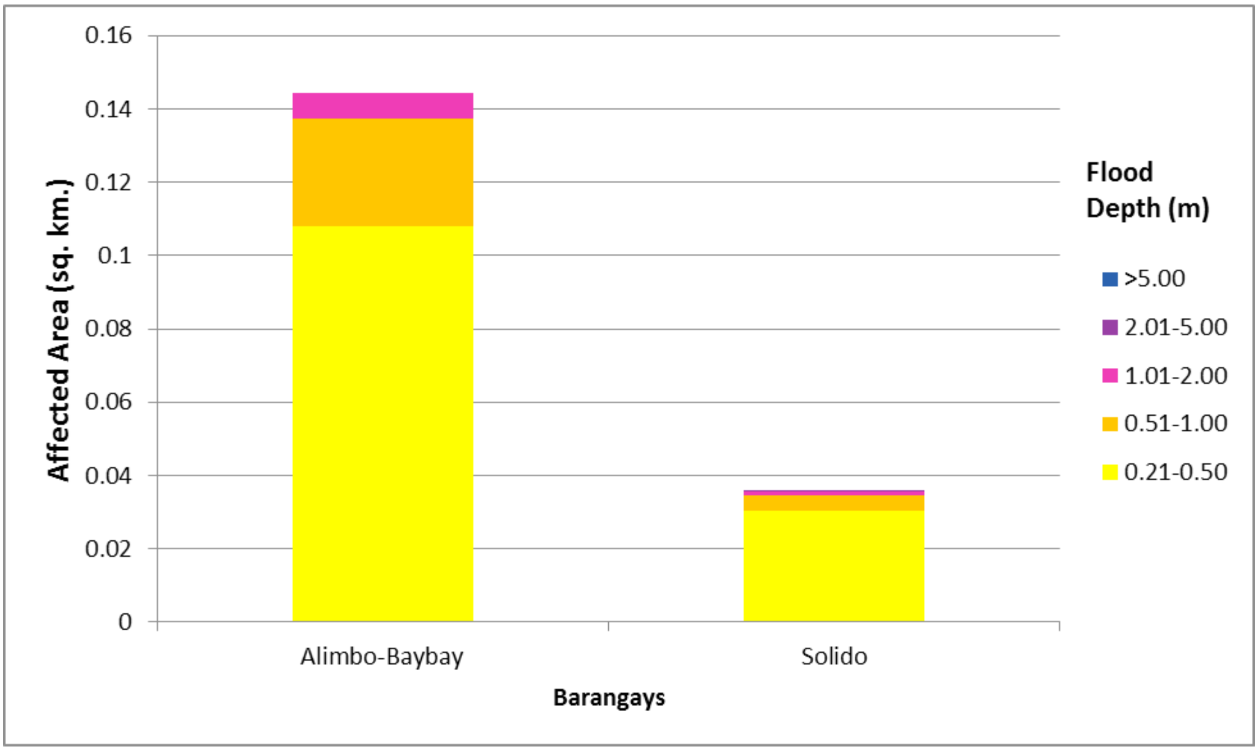


Figure 67. Affected Areas in Nabas, Aklan during 5-Year Rainfall Return Period.

For the municipality of Pandan with an area of 146.86 sq. km., 1.7% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.032%, 0.037%, 0.02%, and 0.002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in Pandan in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Pandan, Antique during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pandan (in sq. km.)			
	Buang	Fragante	San Joaquin	Santa Cruz
0.03-0.20	1.67	0.46	0.35	0.023
0.21-0.50	0.044	0.011	0.0071	0.00026
0.51-1.00	0.039	0.0042	0.0042	0.00026
1.01-2.00	0.042	0.0021	0.0096	0
2.01-5.00	0.027	0.0002	0.0039	0
> 5.00	0.0022	0	0	0

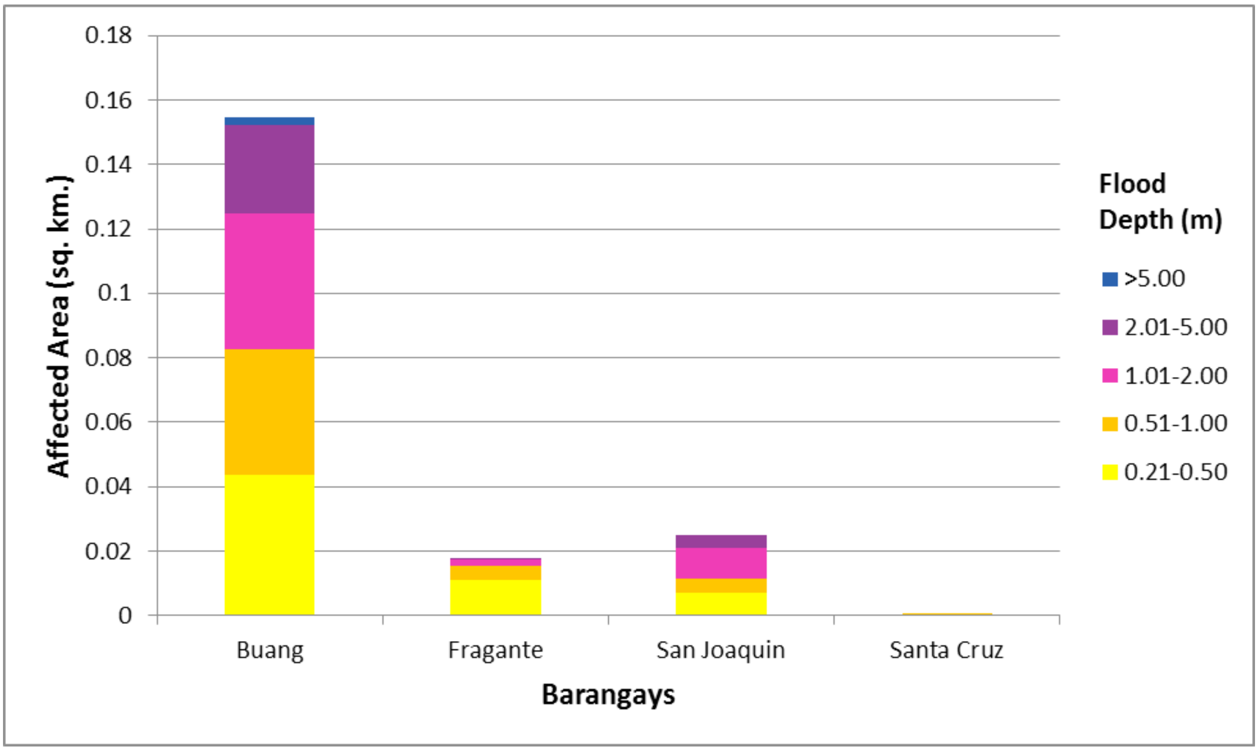


Figure 68. Affected Areas in Pandan, Antique during 5-Year Rainfall Return Period.

For the 25-year return period, for the municipality of Ibajay with an area of 148.52 sq. km., 22.15% will experience flood levels of less 0.20 meters. 5.62% of the area will experience flood levels of 0.21 to 0.50 meters while 4.13%, 2.58%, 0.64%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Ibajay, Aklan during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Ibajay (in sq. km.)									
	Agbago	Agdugayan	Antipolo	Aquino	Aslum	Bagacay	Batuan	Buenavista	Cabugao	Capilijan
0.03-0.20	2.2	0.97	5.47	3.28	0.2	0.35	1.31	0.062	0.00011	0.74
0.21-0.50	1.21	0.23	0.3	1.19	0.05	0.2	0.32	0.0014	0	0.23
0.51-1.00	1.42	0.17	0.21	0.83	0.024	0.17	0.076	0.00072	0	0.049
1.01-2.00	0.85	0.11	0.22	0.61	0.0074	0.095	0.022	0.0011	0.000093	0.0039
2.01-5.00	0.0045	0.12	0.14	0.033	0	0.05	0.0038	0.0024	0	0.000002
> 5.00	0	0.072	0.0023	0.0001	0	0.089	0	0	0	0
Affected Area (sq. km.) by flood depth (in m.)										
	Colongcolong	Laguinbanua	Mabusao	Maloco	Naile	Naisud	Naligusan	Ondoy	Poblacion	Polo
0.03-0.20	0.5	1.1	0.66	2.07	3.14	0.05	1.1	1.13	0.69	0.28
0.21-0.50	0.11	0.33	0.057	0.34	0.88	0	0.47	0.52	0.26	0.097
0.51-1.00	0.041	0.24	0.076	0.24	0.42	0.0003	0.28	0.31	0.16	0.062
1.01-2.00	0.038	0.15	0.11	0.12	0.2	0.0001	0.083	0.24	0.033	0.018
2.01-5.00	0.0026	0.094	0.015	0.027	0.083	0.00034	0.024	0.0035	0	0.062
> 5.00	0	0.067	0	0.0015	0.056	0	0.06	0	0	0.012

Affected Area (sq. km.) by flood depth (in m.)	Regador	Rizal	San Isidro	Santa Cruz	Tagbaya	Tul-Ang	Unat			
0.03-0.20	0.3	1.48	0.26	1.65	2.15	1.15	0.61			
0.21-0.50	0.0072	0.31	0.0046	0.21	0.49	0.18	0.35			
0.51-1.00	0.0023	0.31	0.0022	0.22	0.56	0.15	0.1			
1.01-2.00	0.0024	0.2	0.0016	0.19	0.43	0.066	0.028			
2.01-5.00	0.001	0.035	0.0005	0.046	0.12	0.039	0.038			
> 5.00	0	0.035	0	0.0007	0.00027	0.0089	0.091			

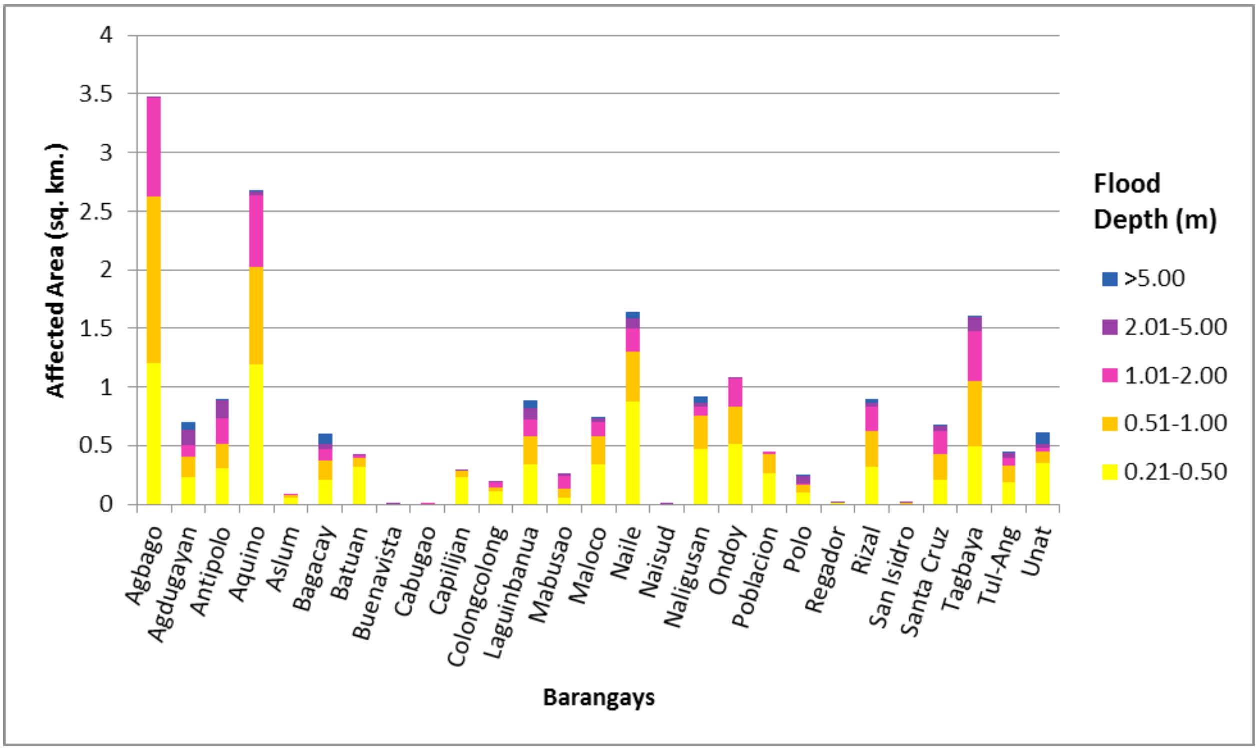


Figure 69. Affected Areas in Ibajay, Aklan during 25-Year Rainfall Return Period.

For the municipality of Nabas with an area of 87.01 sq. km., 0.72% will experience flood levels of less 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.085%, 0.02%, and 0.0002%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Nabas, Aklan during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nabas (in sq. km.)	
	Alimbo-Baybay	Solido
0.03-0.20	0.36	0.27
0.21-0.50	0.12	0.043
0.51-1.00	0.067	0.0074
1.01-2.00	0.016	0.0012
2.01-5.00	0	0.0002
> 5.00	0	0

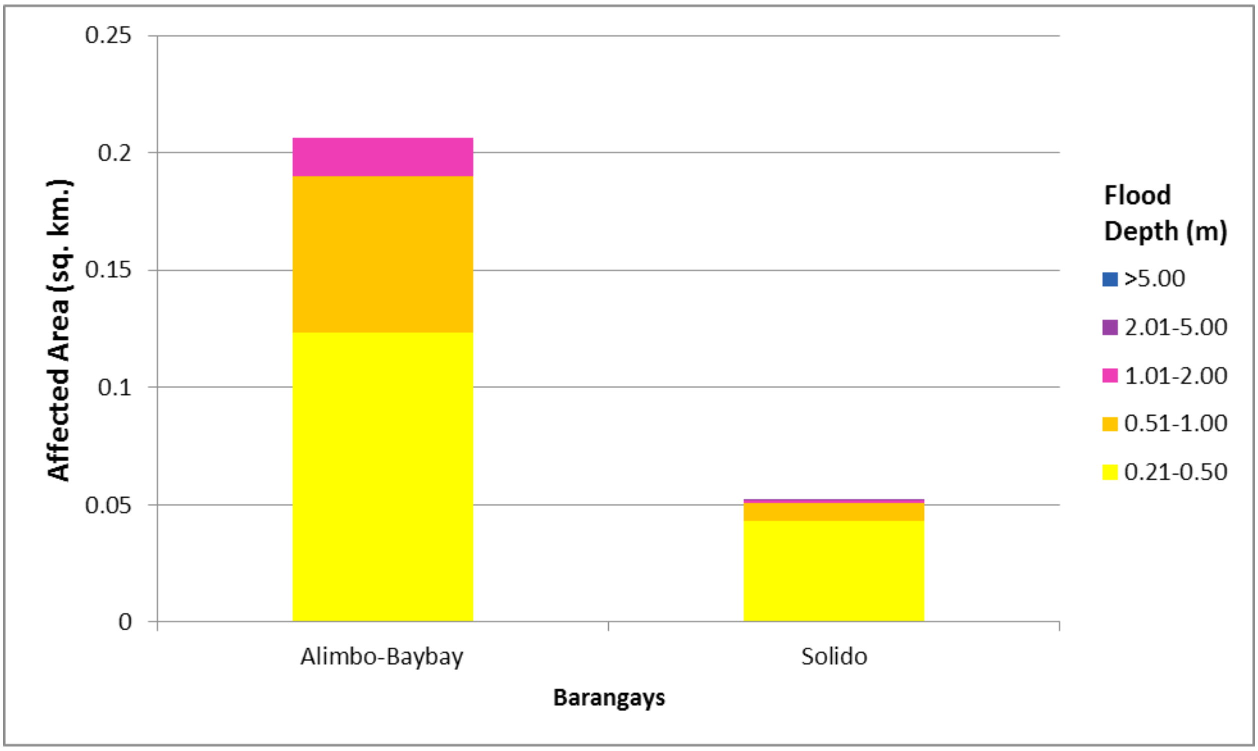


Figure 70. Affected Areas in Nabas, Aklan during 25-Year Rainfall Return Period.

For the municipality of Pandan with an area of 146.86 sq. km., 1.67% will experience flood levels of less 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.035%, 0.04%, 0.03%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Pandan, Antique during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pandan (in sq. km.)			
	Buang	Fragante	San Joaquin	Santa Cruz
0.03-0.20	1.64	0.45	0.35	0.022
0.21-0.50	0.047	0.012	0.0085	0.00033
0.51-1.00	0.04	0.0065	0.005	0.00026
1.01-2.00	0.046	0.003	0.0096	0
2.01-5.00	0.042	0.00039	0.005	0
> 5.00	0.0054	0	0.00024	0

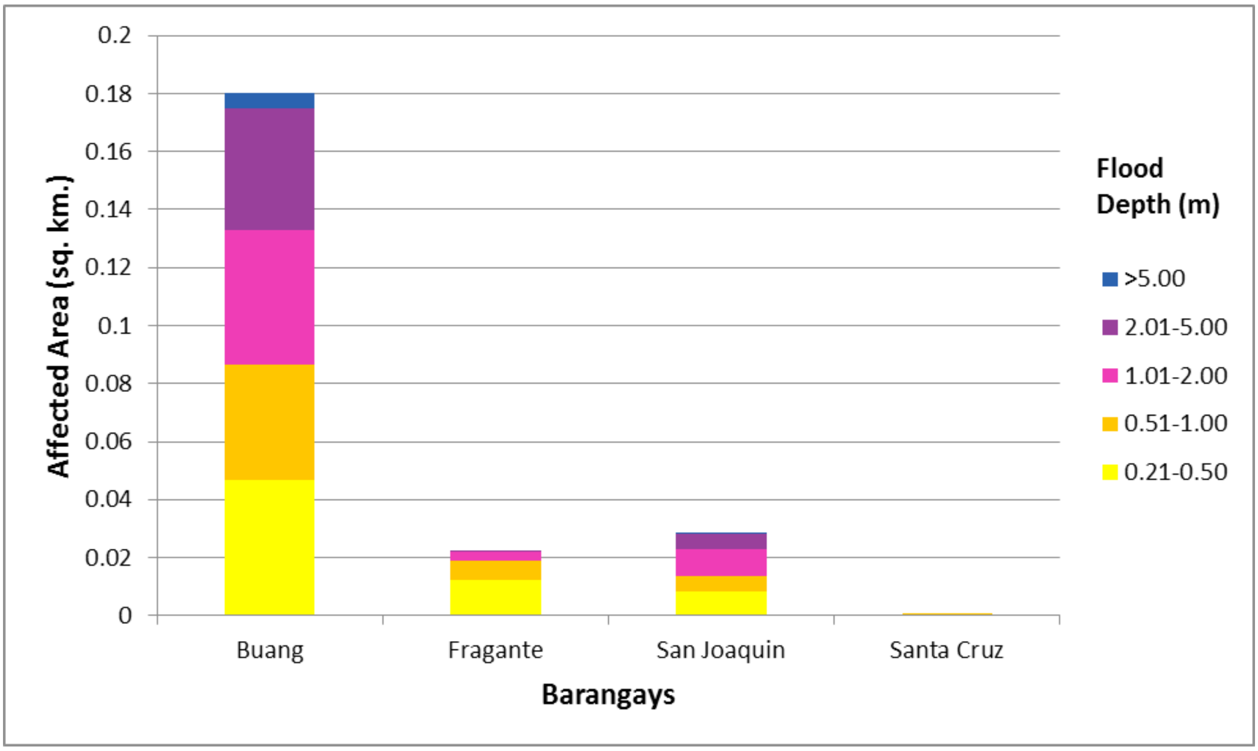


Figure 71. Affected Areas in Pandan, Antique during 25-Year Rainfall Return Period.

For the 100-year return period, for the municipality of Ibajay with an area of 148.52 sq. km., 20.9% will experience flood levels of less 0.20 meters. 5.75% of the area will experience flood levels of 0.21 to 0.50 meters while 4.68%, 3.36%, 0.76%, and 0.29% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Ibajay, Aklan during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Ibajay (in sq. km.)									
	Agbago	Agdugayan	Antipolo	Aquino	Aslum	Bagacay	Batuan	Buenavista	Cabugao	Capilijan
0.03-0.20	1.78	0.92	5.39	2.94	0.18	0.28	1.19	0.061	0.00011	0.68
0.21-0.50	1.15	0.25	0.32	1.23	0.054	0.2	0.41	0.0017	0	0.25
0.51-1.00	1.45	0.19	0.23	0.95	0.029	0.2	0.096	0.00098	0	0.092
1.01-2.00	1.27	0.12	0.23	0.76	0.0093	0.13	0.027	0.0012	0.000093	0.0079
2.01-5.00	0.017	0.12	0.19	0.057	0	0.054	0.0043	0.0024	0	0.000002
> 5.00	0	0.073	0.0059	0.0002	0	0.09	0	0.0003	0	0
Affected Area (sq. km.) by flood depth (in m.)										
	Colongcolong	Laguinbanua	Mabusao	Maloco	Naile	Naisud	Naligusan	Ondoy	Poblacion	Polo
0.03-0.20	0.48	1	0.65	1.95	2.89	0.05	0.95	0.95	0.62	0.26
0.21-0.50	0.12	0.36	0.063	0.39	0.97	0.0002	0.5	0.55	0.26	0.1
0.51-1.00	0.047	0.27	0.072	0.27	0.51	0.0002	0.35	0.41	0.2	0.079
1.01-2.00	0.038	0.18	0.12	0.16	0.26	0.0002	0.13	0.27	0.061	0.021
2.01-5.00	0.0057	0.1	0.017	0.03	0.087	0.00034	0.024	0.026	0	0.056
> 5.00	0	0.07	0	0.002	0.057	0	0.06	0	0	0.019

Affected Area (sq. km.) by flood depth (in m.)	Regador	Rizal	San Isidro	Santa Cruz	Tagbaya	Tul-Ang	Unat			
0.03-0.20	0.3	1.38	0.26	1.59	2.04	1.09	1.09			
0.21-0.50	0.0077	0.31	0.0051	0.2	0.45	0.19	0.19			
0.51-1.00	0.0034	0.34	0.0025	0.2	0.61	0.18	0.18			
1.01-2.00	0.0024	0.27	0.0017	0.26	0.5	0.087	0.087			
2.01-5.00	0.0011	0.041	0.0005	0.064	0.14	0.041	0.041			
> 5.00	0	0.035	0	0.0009	0.00057	0.0099	0.0099			

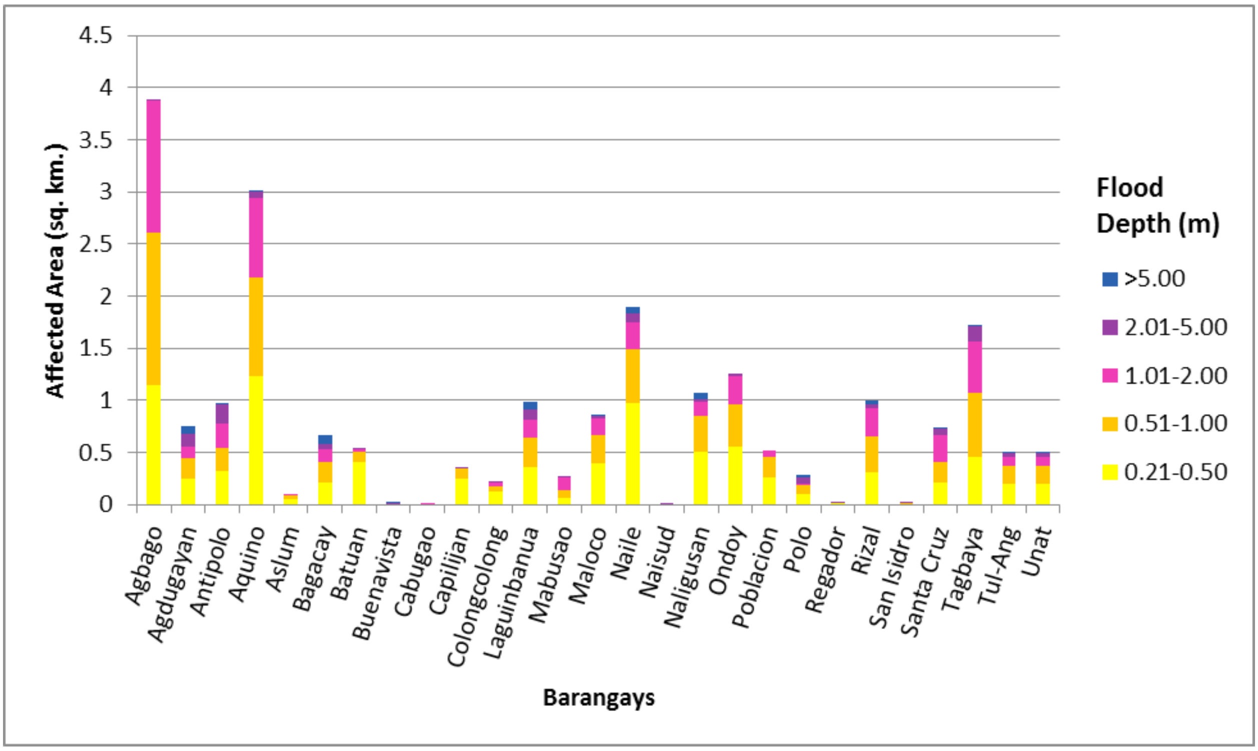


Figure 72. Affected Areas in Ibajay, Aklan during 100-Year Rainfall Return Period.

For the municipality of Nabas with an area of 87.01 sq. km., 0.68% will experience flood levels of less 0.20 meters. 0.24% of the area will experience flood levels of 0.21 to 0.50 meters while 0.065%, 0.037%, and 0.0002%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Nabas, Aklan during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Nabas (in sq. km.)	
	Alimbo-Baybay	Solido
0.03-0.20	0.31	0.26
0.21-0.50	0.15	0.056
0.51-1.00	0.076	0.0086
1.01-2.00	0.031	0.0013
2.01-5.00	0	0.0002
> 5.00	0	0

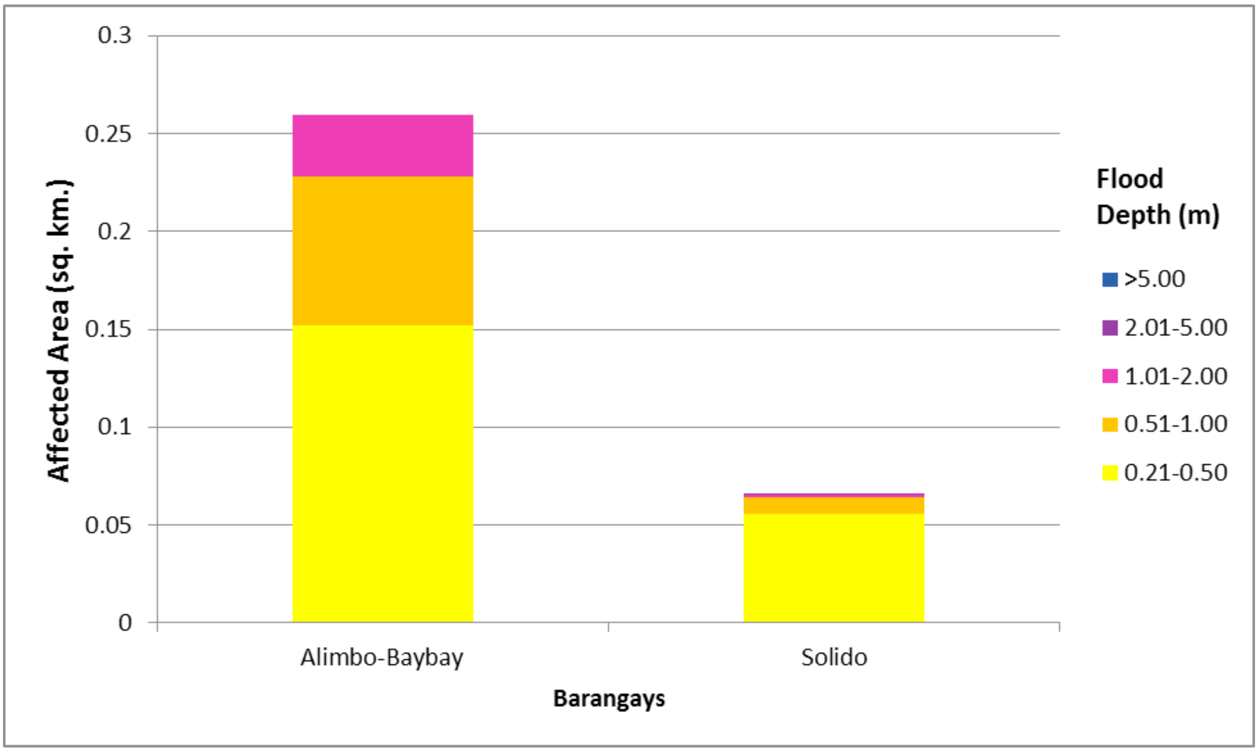


Figure 73. Affected Areas in Nabas, Aklan during 100-Year Rainfall Return Period.

For the municipality of Pandan with an area of 146.86 sq. km., 1.67% will experience flood levels of less 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.037%, 0.04%, 0.04%, and 0.006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Pandan, Antique during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pandan (in sq. km.)			
	Buang	Fragante	San Joaquin	Santa Cruz
0.03-0.20	1.63	0.45	0.34	0.022
0.21-0.50	0.046	0.014	0.009	0.00033
0.51-1.00	0.041	0.0075	0.006	0.00016
1.01-2.00	0.045	0.0035	0.0099	0.0001
2.01-5.00	0.055	0.0005	0.0057	0
> 5.00	0.0081	0	0.00024	0

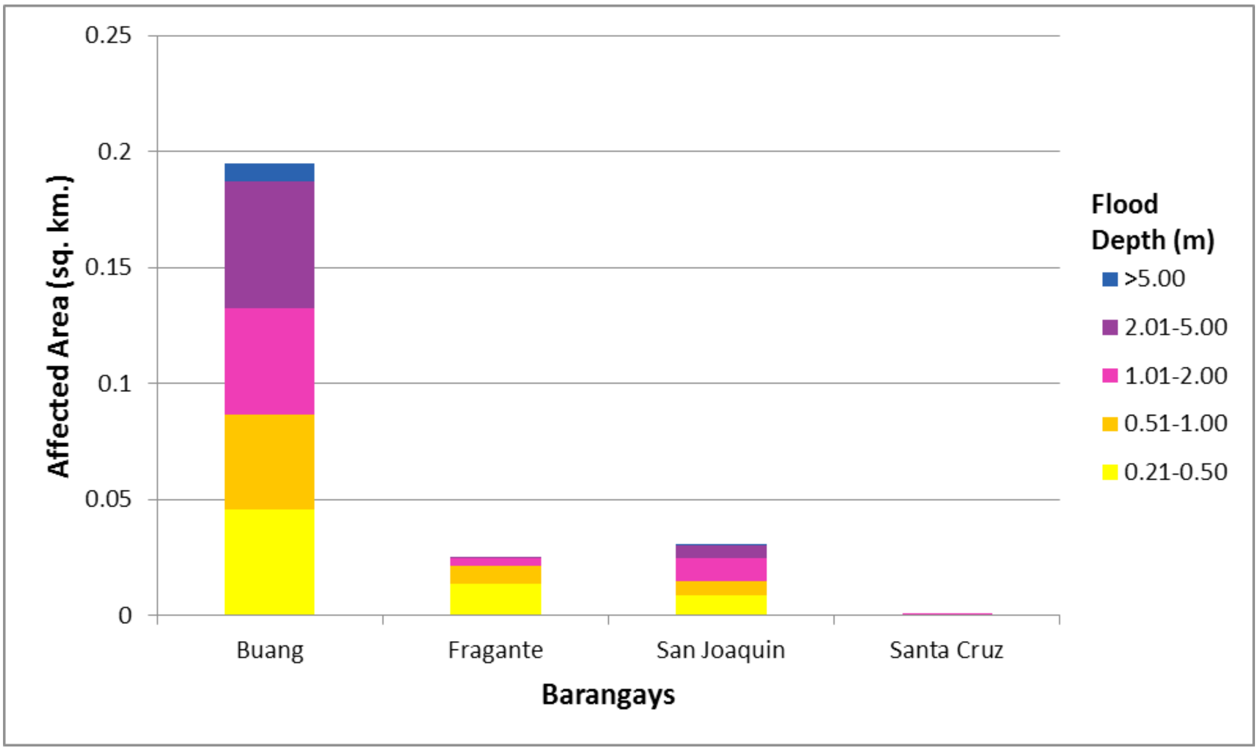


Figure 74. Affected Areas in Pandan, Antique during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Ibajay, Antipolo is projected to have the highest percentage of area that will experience flood levels at 4.28%. Meanwhile, Aquino posted the second highest percentage of area that may be affected by flood depths at 4%.

Among the barangays in the municipality of Nabas, Alimbo-Baybay is projected to have the highest percentage of area that will experience flood levels at 0.57%. Meanwhile, Solido posted the second highest percentage of area that may be affected by flood depths at 0.32%.

Among the barangays in the municipality of Pandan, Buang is projected to have the highest percentage of area that will experience flood levels at 1.24%. Meanwhile, Fragante posted the second.

Moreover, the generated flood hazard maps for the Ibajay Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-year, 25-year, and 100-year).

Table 42. Area covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km		
	5 year	25 year	100 year
Low	7.83	8.80	9.19
Medium	6.56	9.25	10.73
High	1.84	2.66	3.37
Total	**16.23**	**20.71**	**23.29**

Of the 40 identified Education Institutions in Ibajay flood plain, six (6) schools were discovered exposed Low-level flooding during a 5-year scenario, while four (4) schools were found exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, twelve (12) schools were found exposed to the Low-level flooding, while five (5) schools were exposed to Medium-level flooding.

For the 100-year scenario, 13 schools were discovered exposed Low-level flooding, while six (6) schools were exposed to Medium-level flooding.

Apart from this, seven (7) Medical Institutions were identified in the Ibajay Floodplain, yet only one (1) was discovered exposed to Low-level flooding in the two (2) different scenarios (25-year and 100-year).

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gathered secondary data regarding flood occurrence in the area within the major river system in the Philippines.

From the flood depth maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios were identified for validation.

The validation personnel went to the specified points identified in a river basin and will gather data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview of some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 75.

The flood validation consists of 213 points randomly selected all over the Ibajay flood plain Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.97 m. Table 43 shows a contingency matrix of the comparison. The validation points are found in ANNEX 11.

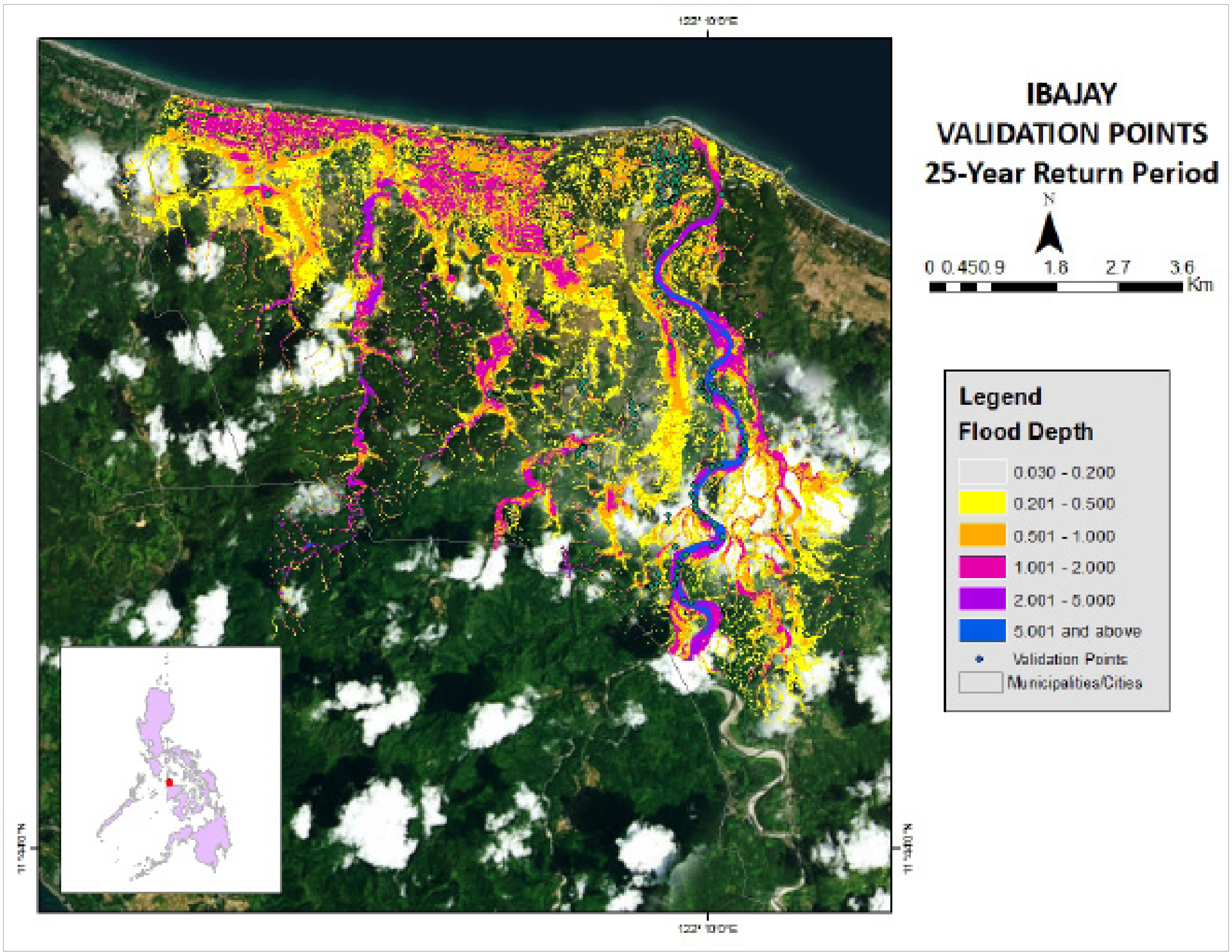


Figure 75. Validation Points for a 25-year Flood Depth Map of the Ibajay Floodplain.

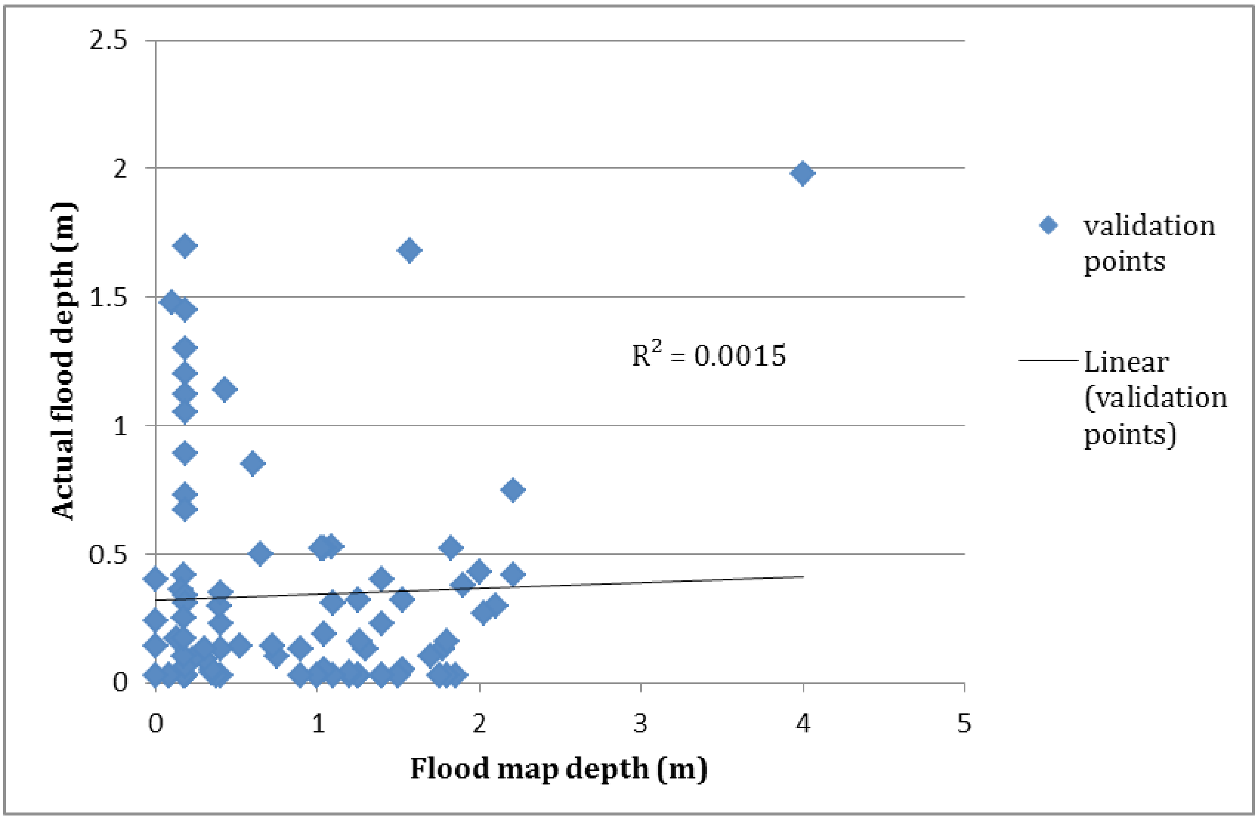


Figure 76. Flood map depth versus actual flood depth.

Table 43. Actual Flood Depth versus Simulated Flood Depth at different levels in the Ibajay River Basin.

Actual Flood Depth (m)	MODELED FLOOD DEPTH (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	35	7	3	7	0	3	55
0.21-0.50	11	3	0	1	1	3	19
0.51-1.00	20	1	1	0	3	5	30
1.01-2.00	30	7	4	1	2	10	54
2.01-5.00	28	6	1	1	0	2	38
> 5.00	17	0	0	0	0	0	17
Total	141	24	9	10	6	23	213

On the whole, the overall accuracy generated by the flood model is estimated at 18.78%, with 40 points correctly matching the actual flood depths. In addition, there were 28 points estimated one level above and below the correct flood depths while there were 42 points and 100 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 47 points were overestimated while a total of 126 points were underestimated in the modelled flood depths of Ibajay. Table 44 depicts the summary of the Accuracy Assessment in the Ibajay River Basin Flood Depth Map.

Table 44. Summary of the Accuracy Assessment in the Ibajay River Basin Survey.

	No. of Points	%
Correct	40	18.78
Overestimated	47	22.07
Underestimated	126	59.15
Total	**213**	**100.00**

REFERENCES

Ang M.O., Paringit E.C., et al. 2014. *DREAM Data Processing Component Manual.* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Balicanta L.P., Paringit E.C., et al. 2014. *DREAM Data Validation Component Manual.* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Brunner, G. H. 2010a. HEC-RAS River Analysis System Hydraulic Reference Manual. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.

Lagmay A.F., Paringit E.C., et al. 2014. *DREAM Flood Modeling Component Manual.* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. *Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods.* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Sarmiento C., Paringit E.C., et al. 2014. *DREAM Data Acquisition Component Manual.* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

UP TCAGP 2016, *Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM) and Ground Control Points (GCP).* Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

ANNEX

ANNEX 1. Technical Specifications of the LiDAR Sensors used in the Ibajay Floodplain Survey

Table A-1.1. Technical Specifications of the LiDAR Sensors used in the Ibajay Floodplain Survey

1. AQUARIUS SENSOR

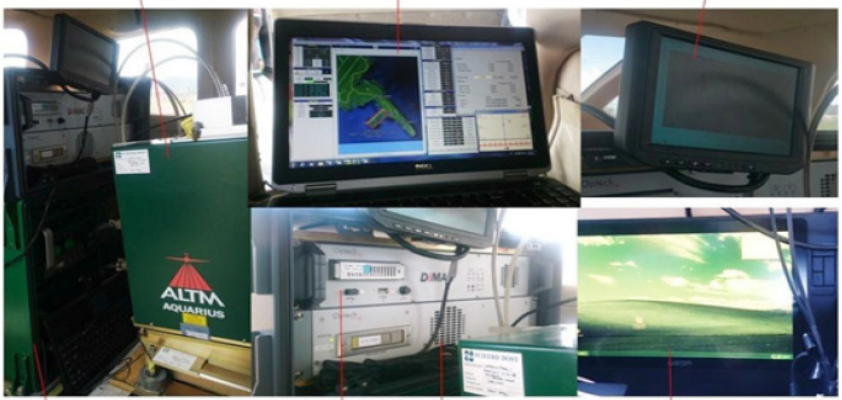


Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specifications of Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitiude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

2. GEMINI SENSOR

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specifications of Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/ Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

ANNEX 2. NAMRIA Certification of Reference Points Used in the LiDAR Survey

1. AKN-43 Table A-2.1. NAMRIA Certification of Reference Points used in the LiDAR Survey

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

March 25, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **AKLAN**
Station Name: **AKN-43**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BANGA**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude:	11° 38' 27.12194"	Longitude:	122° 19' 53.01891"	Ellipsoidal Hgt:	17.74900 m.

WGS84 Coordinates

Latitude:	11° 38' 22.52687"	Longitude:	122° 19' 58.16083"	Ellipsoidal Hgt:	72.44500 m.

PTM Coordinates

Northing:	1287298.051 m.	Easting:	427093.296 m.	Zone:	4

UTM Coordinates

Northing:	1,286,847.47	Easting:	427,118.81	Zone:	51

Location Description

AKN-43
From Kalibo, travel S to the Mun. of Banga. Station is located on the concrete sidewalk in front of the mun. hall in line with the flagpole, about 20 m. SW of Rosal St. and 7 m. from Sampaguita St. Mark is the head of a 4 in. copper nail centered on a 25 cm. x 25 cm. cement putty, with inscriptions "AKN-43 2007 NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795529 A**
T.N.:	**2014-654**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

NAMRIA OFFICES:
Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch: 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. AKN-43

2. AKN-42

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

March 25, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **AKLAN**
Station Name: **AKN-42**
Order: **2nd**

Island: **VISAYAS**
Municipality: **MAKATO**
Barangay: **LIBANG**

PRS92 Coordinates

Latitude:	11° 41' 4.84235"	Longitude:	122° 15' 49.78166"	Ellipsoidal Hgt:	17.77900 m.

WGS84 Coordinates

Latitude:	11° 41' 0.23066"	Longitude:	122° 15' 54.92018"	Ellipsoidal Hgt:	72.20000 m.

PTM Coordinates

Northing:	1292162.5 m.	Easting:	419737.946 m.	Zone:	4

UTM Coordinates

Northing:	1,291,710.22	Easting:	419,766.04	Zone:	51

Location Description

AKN-42

From Kalibo, travel NW to the Mun. of Makato. From the town proper, travel for about 5.6 km. to Brgy. Libang. Station is located at Brgy. Libang Multi-Purpose Center, beside the basketball court about 14 m. and 5 m. from the road, respectively.

Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty, with inscriptions "AKN-42 2007 NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796829 A**
T.N.: **2014-650**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. AKN-42

3. AKN-32

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

March 25, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **AKLAN**
Station Name: **AKN-46 (AKN-32)**
Order: **2nd**

Island: **VISAYAS** Municipality: **BATAN**		Barangay: **POBLACION**
	PRS92 Coordinates	
Latitude: **11° 35' 14.35956"**	Longitude: **122° 29' 42.04171"**	Ellipsoidal Hgt: **3.89400 m.**
	WGS84 Coordinates	
Latitude: **11° 35' 9.79172"**	Longitude: **122° 29' 47.18726"**	Ellipsoidal Hgt: **59.12600 m.**
	PTM Coordinates	
Northing: **1281338.493 m.**	Easting: **444924.589 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,280,890.00**	Easting: **444,943.88**	Zone: **51**

Location Description

AKN-46 (AKN-32, 2000)

Is located at the Mun. of Batan, at the center point of Batan Multi-Purpose Sports Center, SW portion of the tennis court.

Mark is the head of a 4 in. copper nail centered on a 7 in. x 7 in. cement putty, with inscriptions "AKN-32 2000 NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795829 A**
T.N.:	**2014-658**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

9 9 0 3 2 5 2 0 1 4 1 1 4 7 3 2

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. AKN-32

4. CPZ-14

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

April 26, 2013

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: CAPIZ
Station Name: CPZ-14
Order: 2nd

Island:	VISAYAS			Barangay:	POBLACION ILAWOD
Municipality:	PANAY				
		PRS92 Coordinates			
Latitude:	11° 33' 24.61899"	Longitude:	122° 47' 34.41876"	Ellipsoidal Hgt:	4.81800 m.
		WGS84 Coordinates			
Latitude:	11° 33' 19.98412"	Longitude:	122° 47' 39.66494"	Ellipsoidal Hgt:	60.98000 m.
		PTM Coordinates			
Northing:	1277923.166 m.	Easting:	477410.249 m.	Zone:	4
		UTM Coordinates			
Northing:	1,277,476.87	Easting:	477,418.16	Zone:	51

Location Description

CPZ-14
From Roxas City, travel E to the Mun. of Panay. Then proceed directly to the town plaza, where the station is located. Station is located at Panay Park, about 30 m. from the church and about 30 m. from the nat'l road. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground with inscriptions "CPZ-14 2007 NAMRIA".

Requesting Party: UP-TCAGP
Purpose: Reference
OR Number: 3943584 B
T.N.: 2013-0364

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

NAMRIA OFFICES:

Figure A-2.4. CPZ-14

ANNEX 3. Baseline Processing Reports of Control Points used in the LiDAR Survey

ANNEX 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	ENGR. LOVELYN ASUNCION	UP-TCAGP
		LOVELY GRACIA ACUNA	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
		PAULINE JOANNE ARCEO	
	Research Associate (RA)	JONATHAN ALMALVEZ	
		PATRICIA ALCANTARA	
		DAN CHRISTOFFER ALDOVINO	
		MARY CATHERINE ELIZABETH BALIGUAS	
Ground Survey	Research Associate (RA)	JERIEL PAUL ALAMBAN	UP-TCAGP
		REGINA AEDRIENNE FELISMINO	
LiDAR Operation	Airborne Security	SSG. DAVE GUMBAN	Philippine Air Force (PAF)
		SSG. JAYCO MANZANO	
	Pilot	CAPT. ALBERT LIM	Asian Aerospace Corporation (AAC)
		CAPT. JERICO JECIEL	AAC
		CAPT. JEPH ALAJAR	AAC
		CAPT. JACKSON JAVIER	AAC

ANNEX 5. Data Transfer Sheet for Ibajay Floodplain

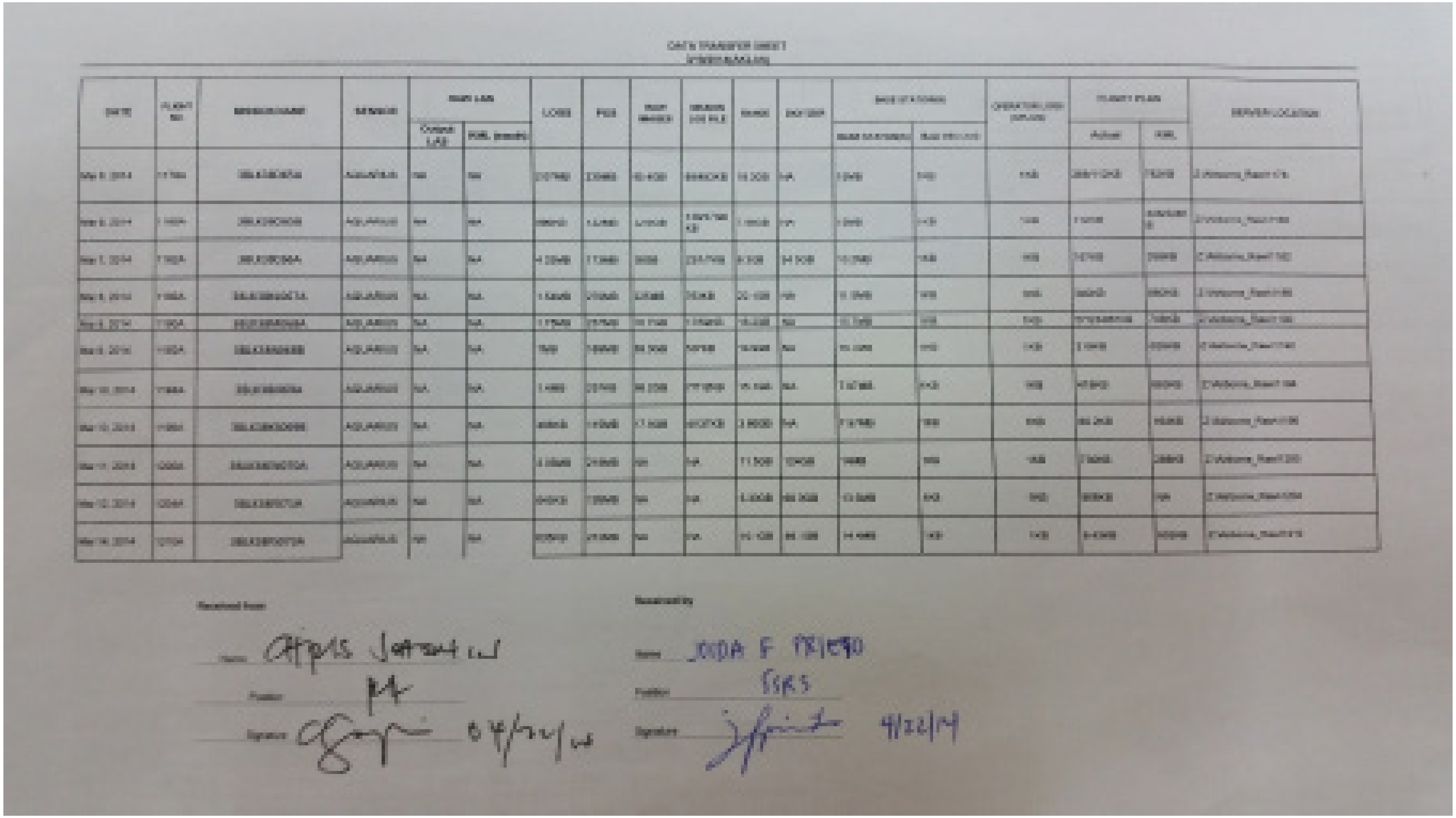


Figure A-5.1. Transfer Sheet for Ibajay Floodplain - A

DATA TRANSFER SHEET
Capiz - Aklan 9/22/15

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
18-Sep-15	2742G	2BLK38D261A	gemini	na	409	711	215	33.1	276	18.3	na	73.1	1KB	1KB	12	27	Z:\DAC\RAW DATA
19-Sep-15	2746G	2BLK38ADSE262A	gemini	na	698	1.28	242	67.6	527	29.3	na	111	1KB	1KB	25	na	Z:\DAC\RAW DATA

Received from

Name C. SOLOMON
Position PD
Signature

Received by

Name AC Bongat
Position CSRS
Signature 10/5/15

Figure A-5.2. Transfer Sheet for Ibajay Floodplain - B

DATA TRANSFER SHEET
[illegible]

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
23-Sep	2762G	2CALIBBLK58C266A	gemini	na	230	580	243	40.4	311	17.8	na	70.4	1KB	1KB	45	na	Z:\DAC\RAW DATA
24-Sep	2766G	2BLK58C267A	gemini	na	1010	1.18	243	34.9	234	20.8	na	82.8	1KB	1KB	27	na	Z:\DAC\RAW DATA
24-Sep	2768G	2BLK58G267B	gemini	na	483	780	185	34.8/4.93	204/37	17.3	na	82.8	1KB	1KB	29	na	Z:\DAC\RAW DATA
25-Sep	2770G	2BLK58BDVS268A	gemini	na	830	1	243	66.7	401	20.8	na	80.1	1KB	1KB	29	na	Z:\DAC\RAW DATA
25-Sep	2772G	2BLK58GS268B	gemini	na	883	940	186	40.9	316	20.8	na	80.1	1KB	1KB	28	na	Z:\DAC\RAW DATA
26-Sep	2774G	2BLK58ES269A	gemini	na	60/593	0.99	330	21.7/80.6	208/180	30.3	na	74.3	1KB	1KB	8	na	Z:\DAC\RAW DATA
26-Sep	2776G	2BLK58J269B	gemini	na	8770	661	64.2	7.74	59	5.18	na	74.3	1KB	1KB	18	na	Z:\DAC\RAW DATA
30-Sep	2790G	2BLK58BSF273A	gemini	na	1318	1.5	258	67.4	272	20.1	na	90.5	1KB	1KB	30	na	Z:\DAC\RAW DATA
30-Sep	2792G	2BLK37U273B	Pegasus	712 GB	590	781	190	11.4/22.7	90/215	21.8	na	90.5	1KB	1KB	21	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name Iriish R. Cortez 10/19/15
Position RA
Signature

Figure A-5.3. Transfer Sheet for Ibajay Floodplain - C

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 1214A Missio

DREAM Data Acquisition Flight Log Flight Log No.: 1214

1 LIDAR Operator: JM Mantara	2 ALTM Model: Aquarius	3 Mission Name: 3BLK26G074A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: Javier	8 Co-Pilot: Menor	9 Route:			
10 Date: Mar 15	12 Airport of Departure (Airport, City/Province): Roxas		12 Airport of Arrival (Airport, City/Province): Roxas		
13 Engine On: 2148	14 Engine Off: 1050 1017	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Rainy, low clouds					

20 Remarks:

Mission aborted, full of data voids, changed area 3x
Bad weather – low clouds, rain

21 Problems and Solutions:

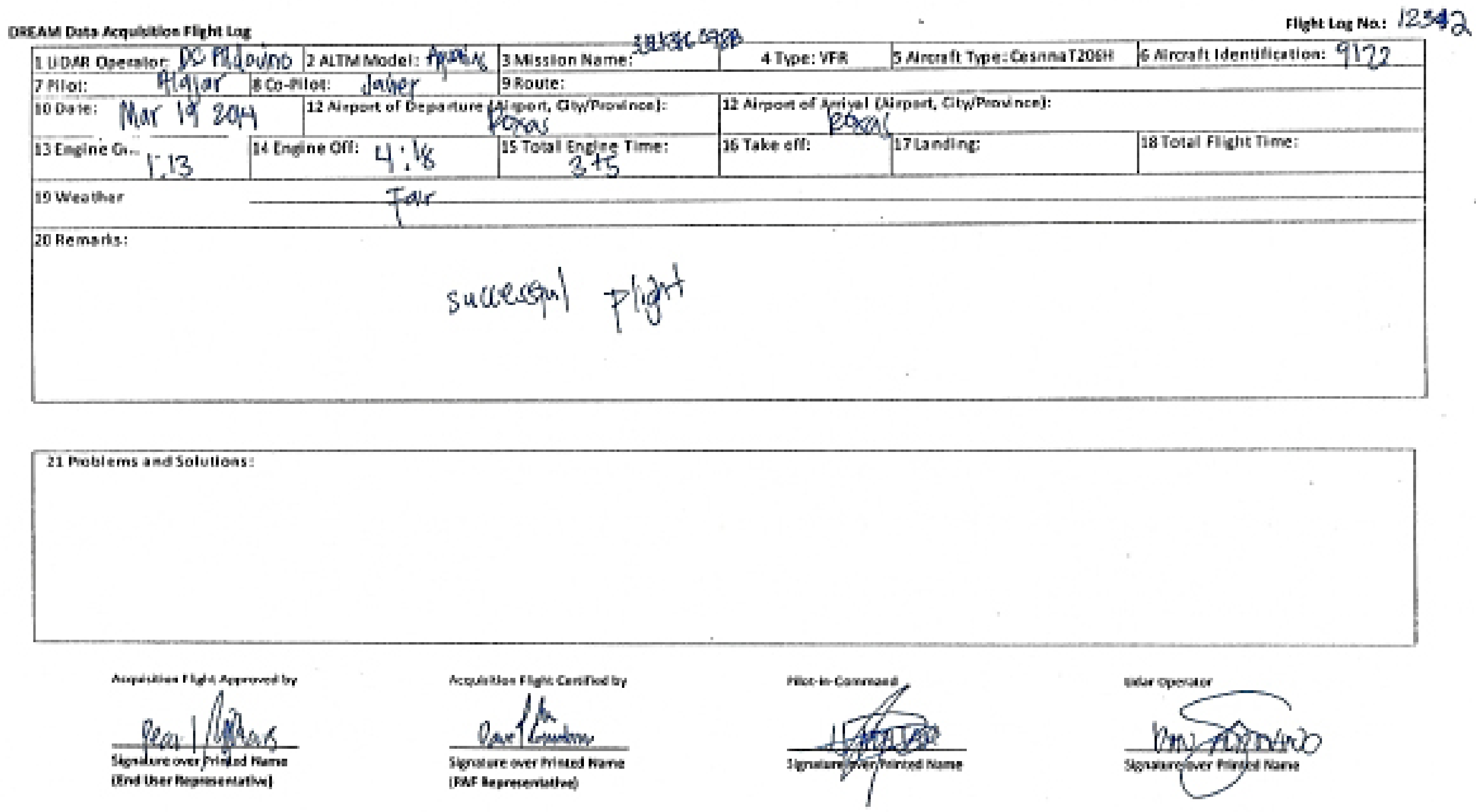
Camera empty status, no photos; restart camera

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk Exposure and Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1214A

2. Flight Log for 1232A Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 12342

1 LIDAR Operator: DC Maldonado	2 ALTM Model: Aquarius	3 Mission Name: 3BLK36C078B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: Alajar	8 Co-Pilot: Jaber	9 Route:			
10 Date: Mar 19 2014	12 Airport of Departure (Airport, City/Province): Roxas		12 Airport of Arrival (Airport, City/Province): Roxas		
13 Engine On: 1:13	14 Engine Off: 4:18	15 Total Engine Time: 3+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: successful flight					

21 Problems and Solutions:

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1232A

3. Flight Log for 1238A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1238

1 LIDAR Operator: P. Moros	2 ALTM Model: Aquarius	3 Mission Name: 2014BG080A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: Major	8 Co-Pilot: Lavier	9 Route:			
10 Date: 21 Mar 2014	12 Airport of Departure (Airport, City/Province): Roxas		12 Airport of Arrival (Airport, City/Province): Roxas		
13 Engine On: 7:40	14 Engine Off: 12:27	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: successful flight					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Dave Gamboa Signature over Printed Name (PAF Representative)	V. V. Major Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1238A

4. Flight Log for 1240A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1240

1 LIDAR Operator: DC ALDOVINO	2 ALTM Model: AQUA	3 Mission Name: 3BLK38B084A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: [illegible]
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route: ANILAO			
10 Date: MAR. 24, 2014	12 Airport of Departure (Airport, City/Province): ANILAO		12 Airport of Arrival (Airport, City/Province): ANILAO		
13 Engine On: 1342	14 Engine Off: 1543	15 Total Engine Time: 2+01	16 Take off:	17 Landing:	18 Total Flight Time: 2+33
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1240A

5. Flight log for 1242A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1242A

1 LiDAR Operator: P. Maca	2 ALTM Model: Aquarius	3 Mission Name: 3BLK36V081A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: Aligar	8 Co-Pilot: Jayer	9 Route:			
10 Date: Mar 22 2014	12 Airport of Departure (Airport, City/Province): Roxas		12 Airport of Arrival (Airport, City/Province): Roxas		
13 Engine On: 1:46	14 Engine Off: 4:15	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks: successful flight					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Dave Gamboa Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1242A

6. Flight Log for 2742G Mission

Data Acquisition Flight Log

Flight Log No.: 2742G

1 LIDAR Operator:	2 ALTM Model: Gemini	3 Mission Name: 2BLK34D261A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Gabuco	9 Route:			
10 Date: Sept. 18, 2015	12 Airport of Departure (Airport, City/Province): Roxas		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0717	14 Engine Off: 1003	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Flight Classification

20.a Billable
- Acquisition Flight
- Ferry Flight
- System Test Flight
- Calibration Flight

20.b Non Billable
- Aircraft Test Flight
- AAC Admin Flight
- Others:

20.c Others
- LIDAR System Maintenance
- Aircraft Maintenance
- Phil-LIDAR Admin Activities

21 Remarks

Surveyed BLK34D

22 Problems and Solutions
- Weather Problem
- System Problem
- Aircraft Problem
- Pilot Problem
- Others:

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Aircraft Mechanic/ Technician — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 2742G

7. Flight log for 2746G Mission

7 Pilot: A. Lim
8 Co-Pilot: P. Cabudol
9 Route:
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9122
10 Date: Sept. 19, 2015
12 Airport of Departure (Airport, City/Province): Roxas
12 Airport of Arrival (Airport, City/Province):
13 Engine On: 1129
14 Engine Off: 1535
15 Total Engine Time: 04+06
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather: Cloudy
20 Flight Classification
20.a Billable
Acquisition Flight
Ferry Flight
System Test Flight
Calibration Flight
20.b Non Billable
Aircraft Test Flight
AAC Admin Flight
Others: ______
20.c Others
LIDAR System Maintenance
Aircraft Maintenance
Phil-LIDAR Admin Activities
21 Remarks
Surveyed BLK53A & BLK53E and voids over BLK19D
22 Problems and Solutions
Weather Problem
System Problem
Aircraft Problem
Pilot Problem
Others: ______
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)
Pilot-in-Command
Signature over Printed Name
Lidar Operator
Signature over Printed Name
Aircraft Mechanic/ Technician
Signature over Printed Name

Figure A-6.7. Flight Log for Mission 2746G

8. Flight log for 2766G Mission

Data Acquisition Flight Log

Flight Log No.: 2766G

1 LIDAR Operator: MCE BALIGUAT	2 ALTM Model: GEM	3 Mission Name: 3BLK19C267A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 24 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0550	14 Engine Off: 0955	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ___________

20.c Others
- o LIDAR System Maintenance
- o Aircraft Maintenance
- o Phil-LIDAR Admin Activities

21 Remarks

Completed BLK 19C

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ___________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	MCE BALIGUAT Signature over Printed Name	Signature over Printed Name

Figure A-6.8. Flight Log for Mission 2766G

9. Flight log for 2770G Mission

Data Acquisition Flight Log

Flight Log No.: 2770G

1 LIDAR Operator: PAL PELUSMINA	2 ALTM Model: GEM	3 Mission Name: 2BLK38DVFS 268A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 25 SEPT 15	12 Airport of Departure (Airport, City/Province): ROXAS		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0535	14 Engine Off: 1018	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: ______

20.c Others
- ○ LIDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LIDAR Admin Activities

21 Remarks

Covered voids over BLK38D & 4 lines over BLK38E

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ______

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	A. LIM Signature over Printed Name	PENINA PELUSMINA Signature over Printed Name	Signature over Printed Name

Figure A-6.9. Flight Log for Mission 2770G

10. Flight log for 2790G Mission

Data Acquisition Flight Log

Flight Log No.: 2790G

1 LIDAR Operator:	2 ALTM Model: GEM	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 15 SEPT 15	12 Airport of Departure (Airport, City/Province): ROXAS		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0935	14 Engine Off: 1358	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: ___________

20.c Others
- ○ LIDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LIDAR Admin Activities

21 Remarks

Covered voids over BLK38B 1 & lines over BLK38E

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ___________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	A. LIM Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.10. Flight Log for Mission 2790G

ANNEX 7. Flight status reports

Aklan and Capiz-Aklan Reflights

July 3 to August 1, 2014

Table A-7.1. Flight Status Report

Flight No	Area	Mission	Operator	Date Flown	Remarks
1214A	BLK 38G, 38H, 38I	3BLK38G074A	PAT ALCANTARA	15 MAR 14	Strips of BLK 38G, H, I. Mission aborted duet to low cloud ceiling and precipitation in the survey area
1232A	BLK 38G	3BLK38G078B	DC ALDOVINO	19 MAR 14	Completed 15 lines of BLK 38G
1238A	BLK 38G	3BLK38GS080A	PEARL MARS	21 MAR 14	Completed BLK 38R and completed BLK 38G. Experienced heavy air traffic in Kalibo airport
1240A	BLK 38H	3BLK38HS080B	DC ALDOVINO	21 MAR 14	Supplementary to BLK 38H
1242A	Voids area	3BLK38V081A	PEARL MARS	22 MAR 14	Mission completed
2742G	BLK38D	2BLK38D261A	MCE BALIGUAS & PJ ARCEO	SEPT. 18, 2015	Covered several lines of BLK38D. 3 lines wherein the beam divergence became wide and roll compensation was off. Presence of data gap. No digitizer. Partly cloudy and strong winds.
2746G	BLKs38 A, D, & E	2BLK38ADSE262A	MCE BALIGUAS & PJ ARCEO	SEPT. 19, 2015	Continuation of BLK38D, covered BLK38A and few lines from BLK38E. 2 lines wherein beam divergence became wide and roll compensation was off. No digitizer. Partly cloudy
2766G	BLK38C	2BLK38C267A	MCE BALIGUAS	SEPT. 24, 2015	Completed BLK38C. Cloudy in high terrain, hazy and strong gust of winds. Getting dark images from the camera. No digitizer
2770G	BLKs38 B, D & E	2BLK38BDVES268A	RA FELISMINO	SEPT. 25, 2015	Completed BLK38 A, covered voids on D and 3 lines of E. No digitizer
2790G	BLKs38 B & F	2BLK38BSF273A	RA FELISMINO	SEPT. 30, 2015	Completed BLK38B and few lines of BLK38F. Changed of altitudes because of clouds and high terrain

SWATH PER FLIGHT MISSION

Flight No. : 1214A
Area: BLK 38G, H, I
Mission Name: 3BLK38G074A
Parameters: Alt: 600m; Scan Fz: 40; Scan angle: 18; Overlap: 30%

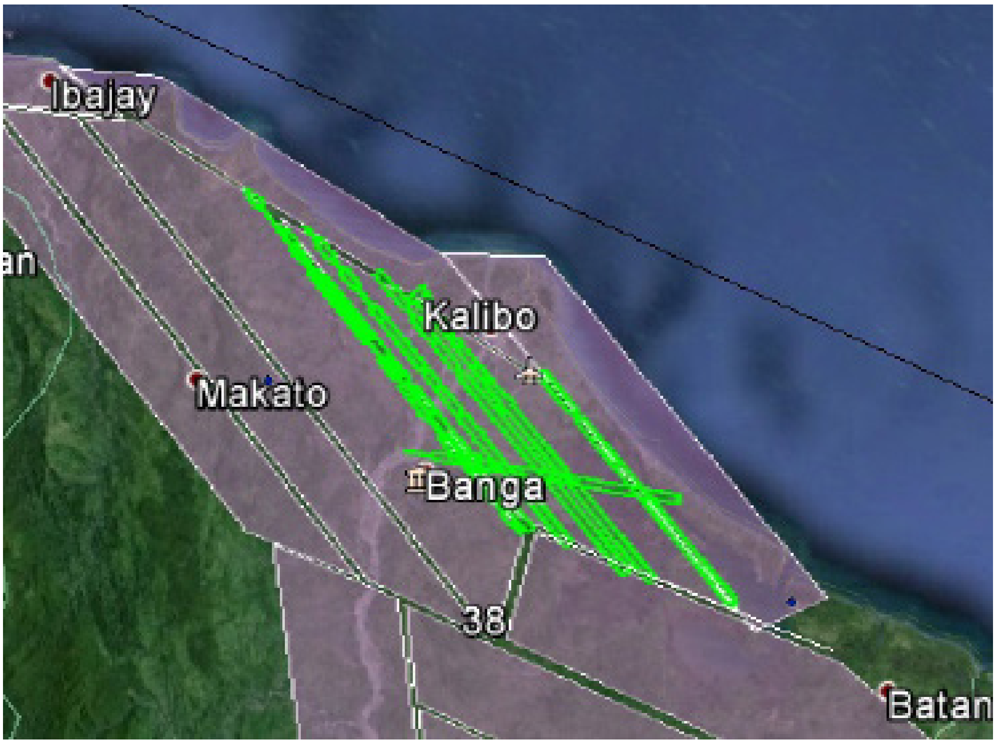


Figure A-7.1. Swath for Flight No. 1214A

Flight No. : 1232A
Area: BLK 38G
Mission Name: 3BLK38G078B
Parameters: Alt: 600m; Scan Fz: 40; Scan ange: 18; Overlap: 30%

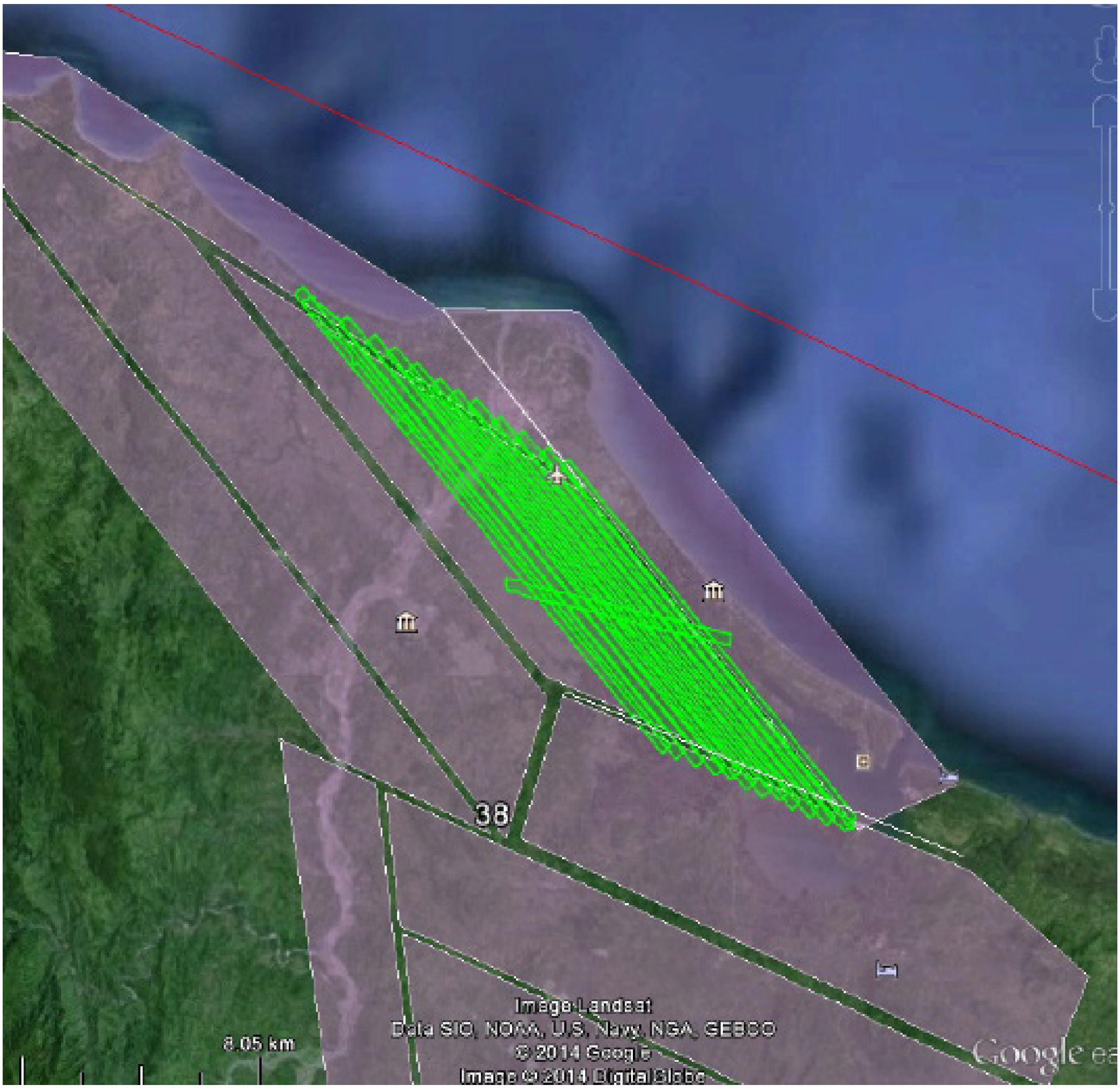


Figure A-7.2. Swath for Flight No. 1232A

Flight No. : 1238A
Area: BLK 38G
Mission Name: 3BLK38GS080A
Parameters: Alt: 600m; Scan Fz: 40; Scan ange: 18; Overlap: 30%

Figure A-7.3. Swath for Flight No. 1238A

Flight No. : 1240A
Area: BLK 38F
Mission Name: 3BLK38HS080B
Parameters: Alt: 600m; Scan Fz: 40; Scan ange: 18; Overlap: 30%

Figure A-7.4. Swath for Flight No. 1240A

Flight No. : 1242A
Area: VOIDS AREA
Mission Name: 3BLK38V081A
Parameters: Alt: 600m; Scan Fz: 40; Scan ange: 18; Overlap: 30%

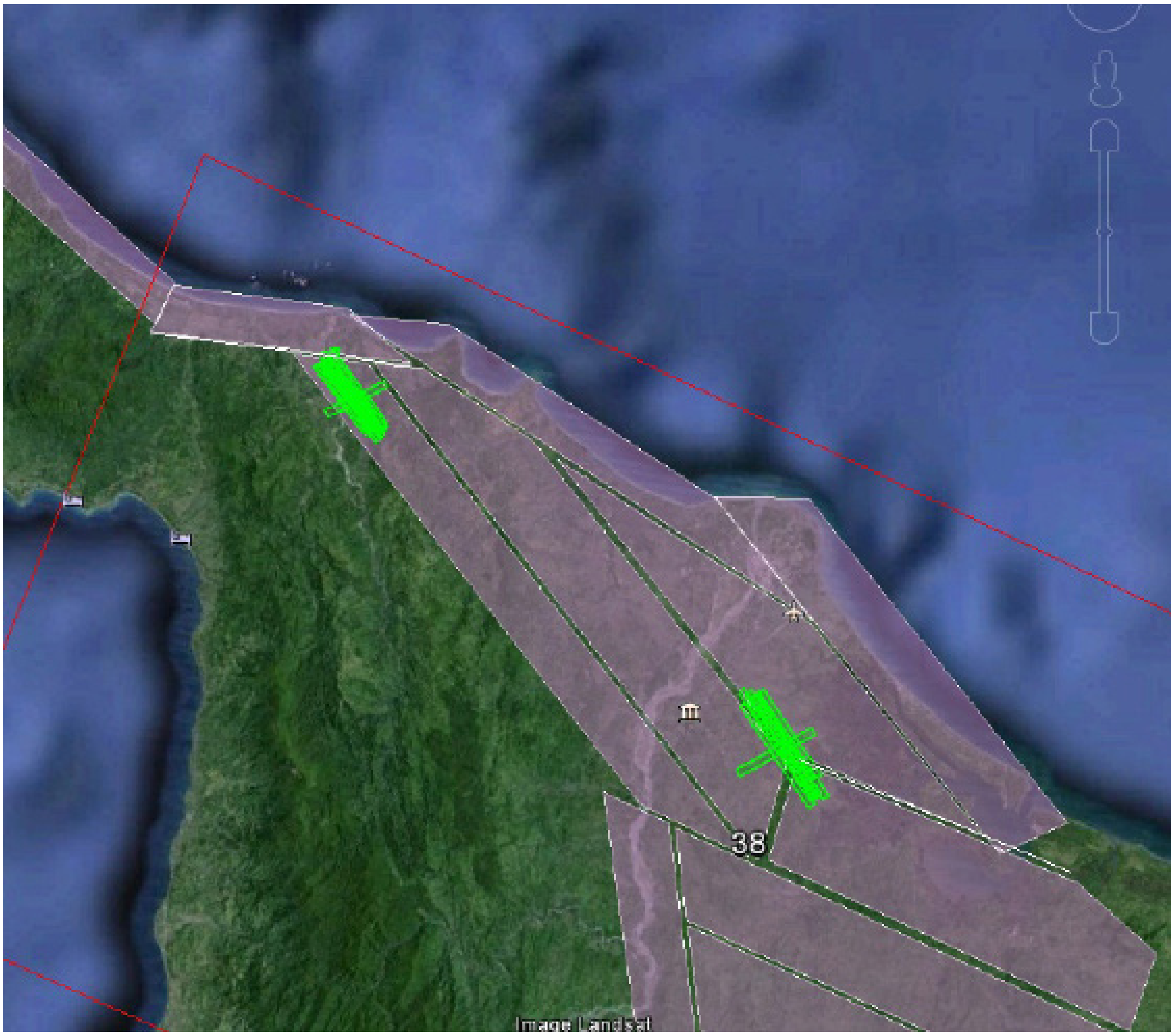


Figure A-7.5. Swath for Flight No. 1242A

Flight No. : 2742G
Area: BLK38D
Mission Name: 2BLK38D261A
Parameters: Alt: 1000m; Scan Fz: 50; Scan angLe: 15; Overlap: 30%, PRF:100
Alt: 800m; Scan Fz: 40; Scan angLe: 25; Overlap: 30%, PRF:142
Alt: 600m; Scan Fz: 40; Scan angLe: 25; Overlap: 30%, PRF:125
Area surveyed: 113.23 sq km.

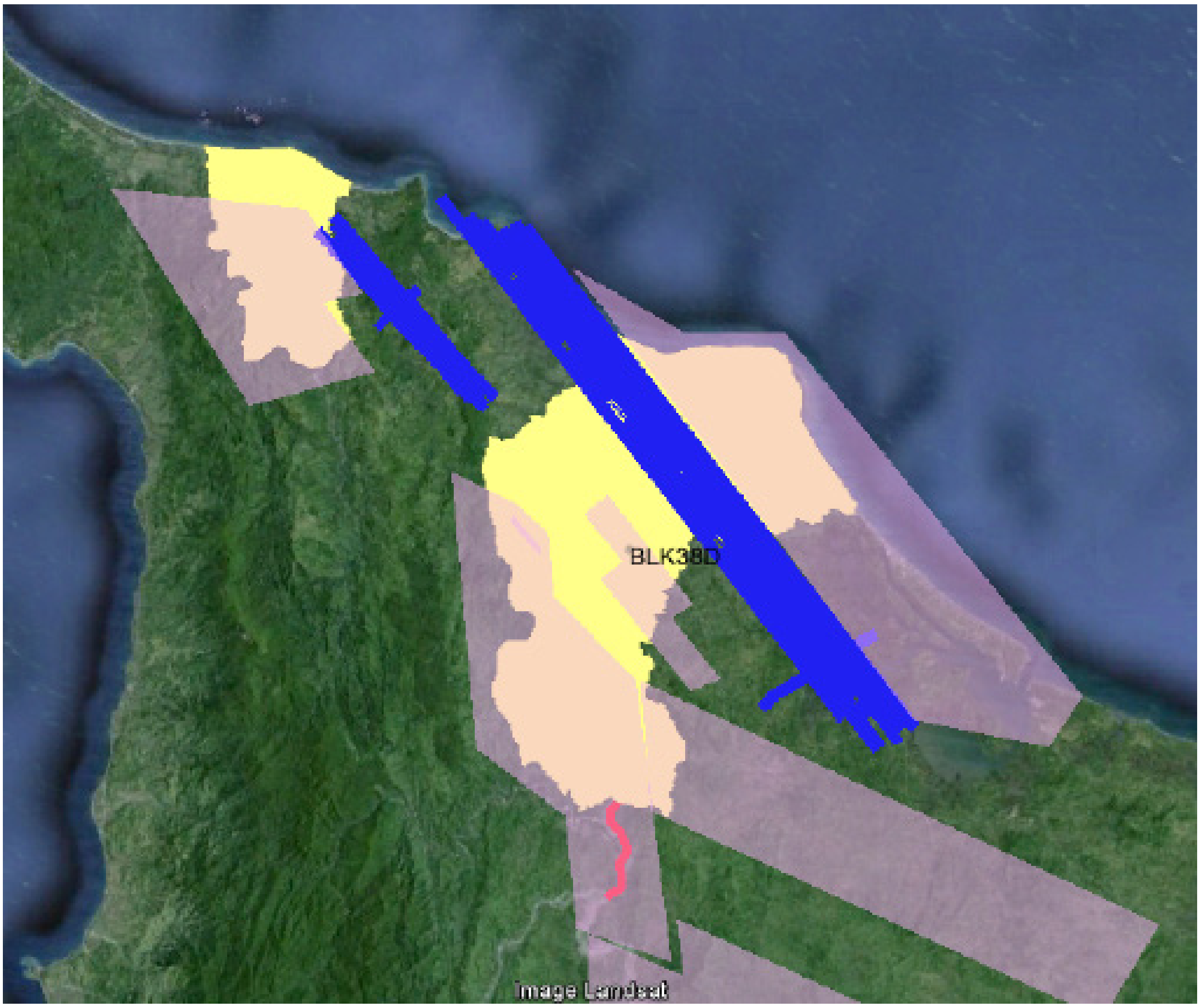


Figure A-7.6. Swath for Flight No. 2742G

Flight No. : 2746G
Area: BLKs38 A, D & E
Mission Name: 2BLK38ADSE262A
Parameters: For BLK38E: Alt: 800m; Scan Fz: 50; Scan angle: 20; Overlap: 30%
For BLK38D: Alt: 800 & 600m; Scan Fz: 50; Scan angle: 20; Overlap: 30%
Area surveyed: 164.92 sq km

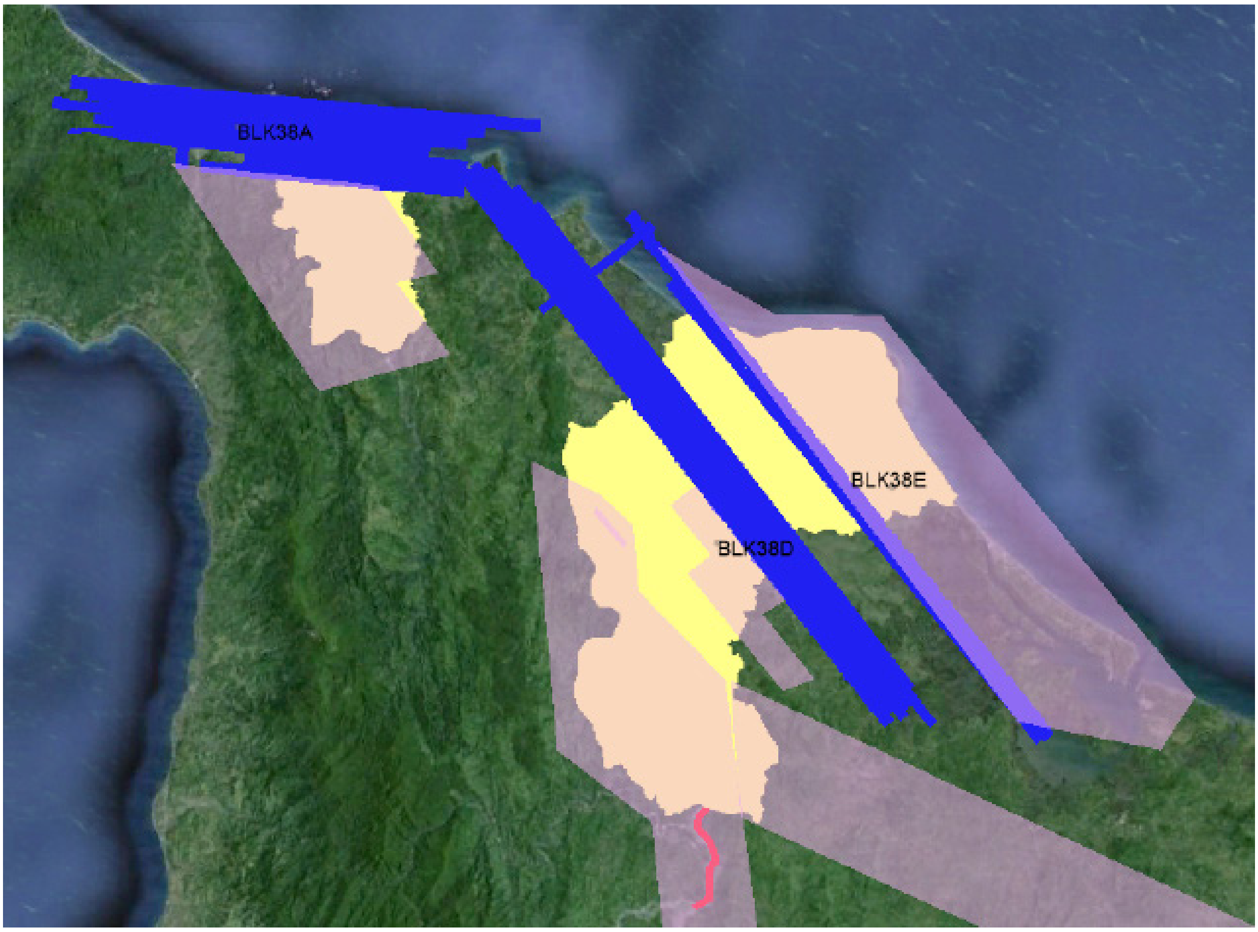


Figure A-7.7. Swath for Flight No. 2746G

Flight No. : 2766G
Area: BLK38C
Mission Name: 2BLK38C267A
Parameters: Alt: 800m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed: 148.14 sq km.

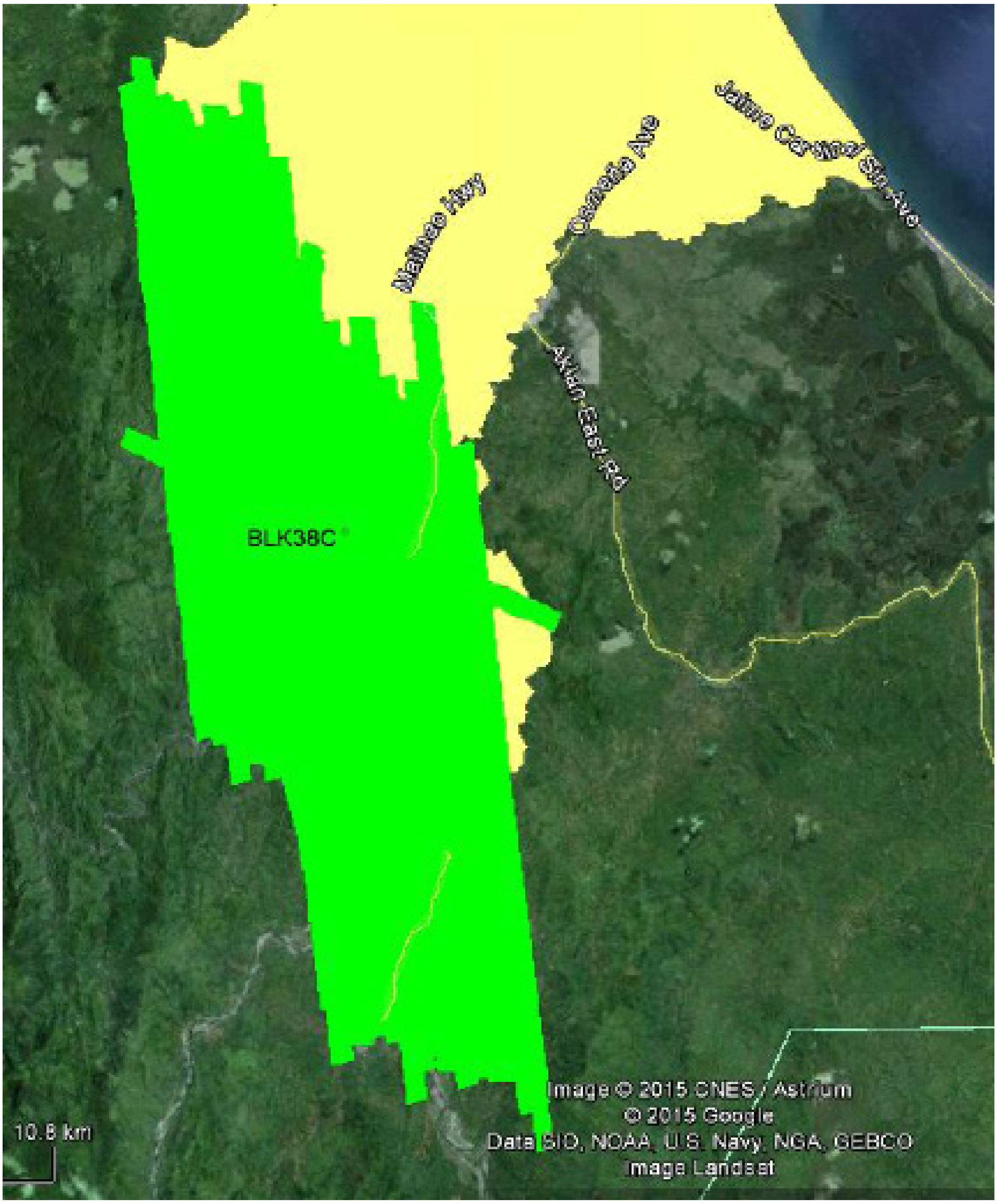


Figure A-7.8. Swath for Flight No. 2766G

Flight No. : 2770G
Area: BLKs38 B, D & E
Mission Name: 2BLK38BDVES268A
Parameters: Alt: 800m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed: 188.62 sq km.

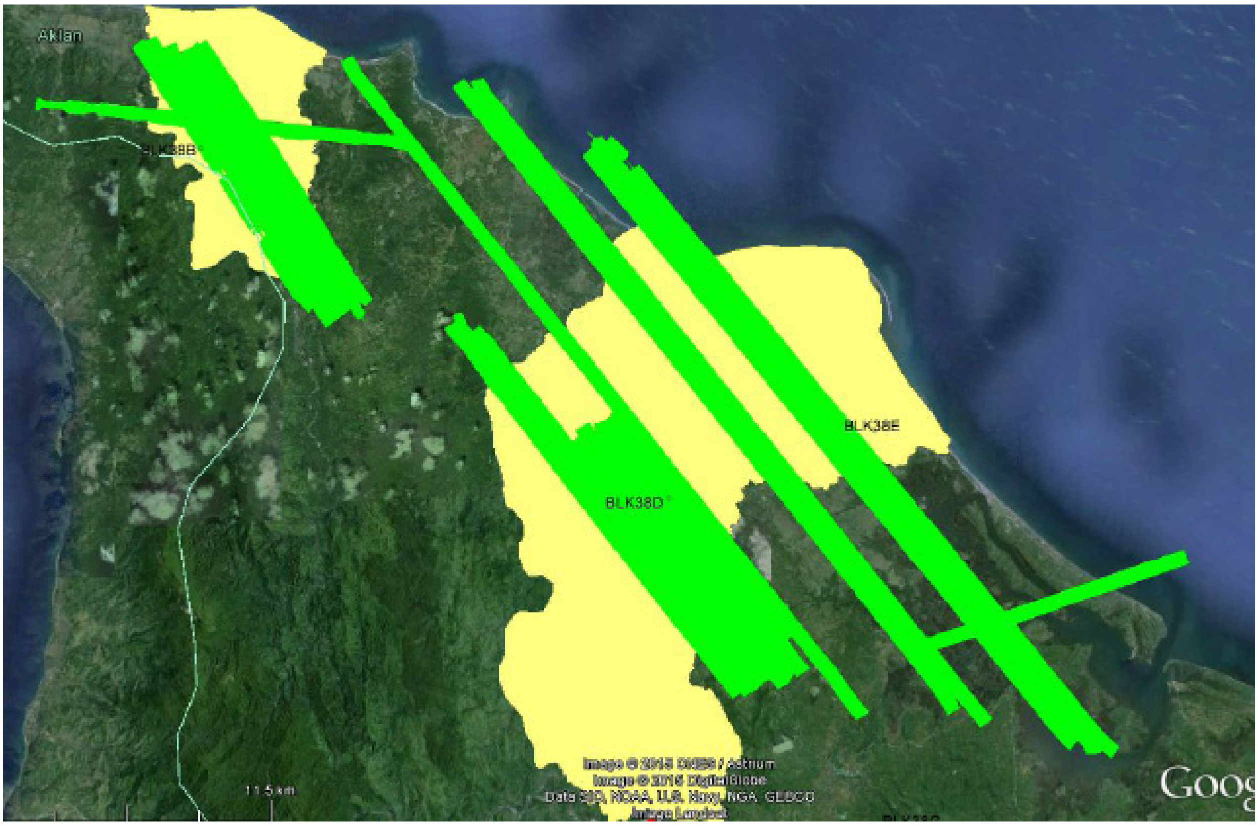


Figure A-7.9. Swath for Flight No. 2770G

Flight No. : 2790G
Area: BLKs38 B & F
Mission Name: 2BLK38BSF273A
Parameters: Alt: 800m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed: 153.45 sq km.

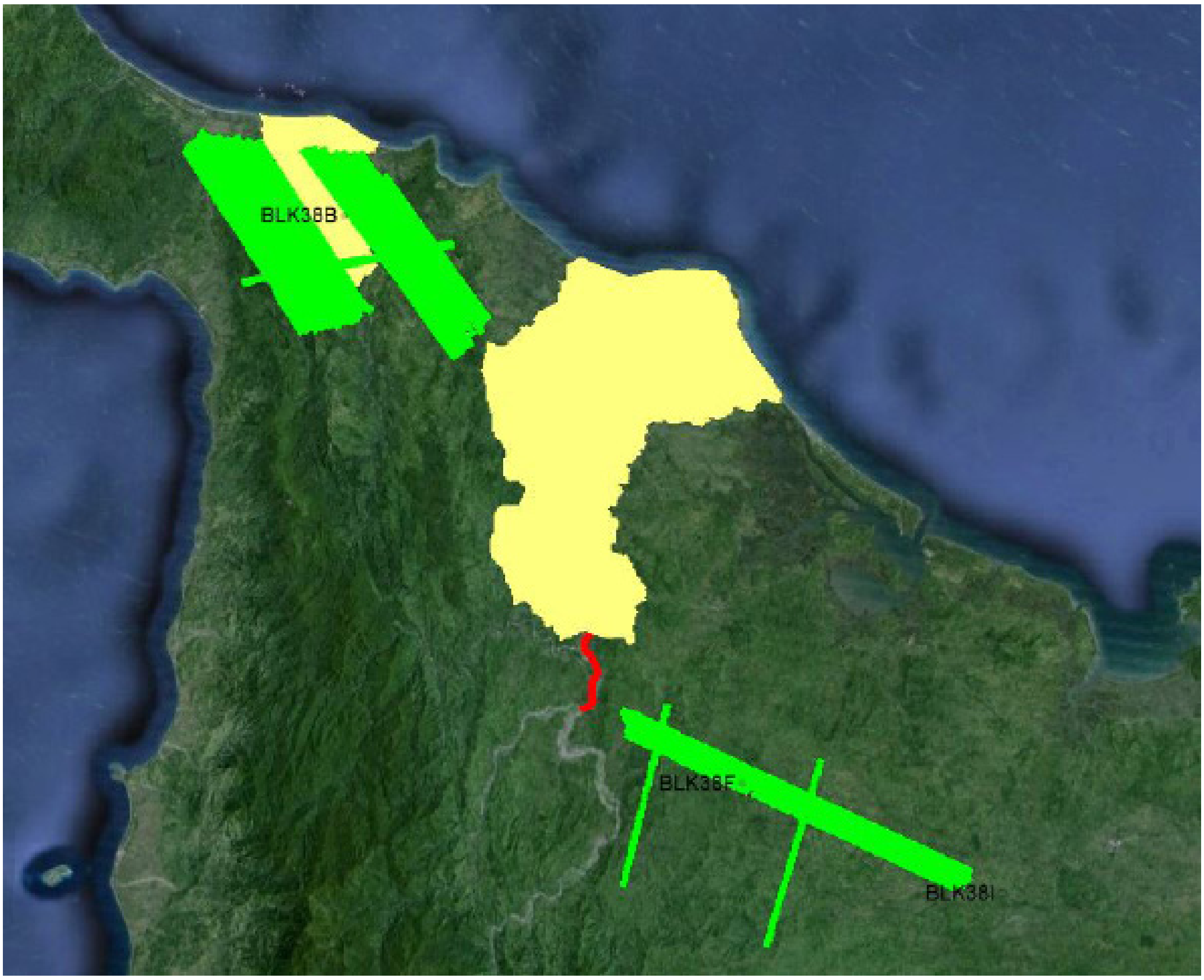


Figure A-7.10. Swath for Flight No. 2790G

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk65CD

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65CD
Inclusive Flights	1698A & 1702A
Range data size	22.20 GB
Base data size	15.99 MB
POS	377 MB
Image	98.40 MB
Transfer date	August 5, 2014 & July 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.85
RMSE for East Position (<4.0 cm)	3.10
RMSE for Down Position (<8.0 cm)	4.00
Boresight correction stdev (<0.001deg)	0.000440
IMU attitude correction stdev (<0.001deg)	0.004612
GPS position stdev (<0.01m)	0.0097
Minimum % overlap (>25)	77.15
Ave point cloud density per sq.m. (>2.0)	4.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	170
Maximum Height	371.95 m
Minimum Height	47.81 m
Classification (# of points)	
Ground	43,795,160
Low vegetation	57,597,183
Medium vegetation	98,661,251
High vegetation	185,453,527
Building	5,549,843
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos

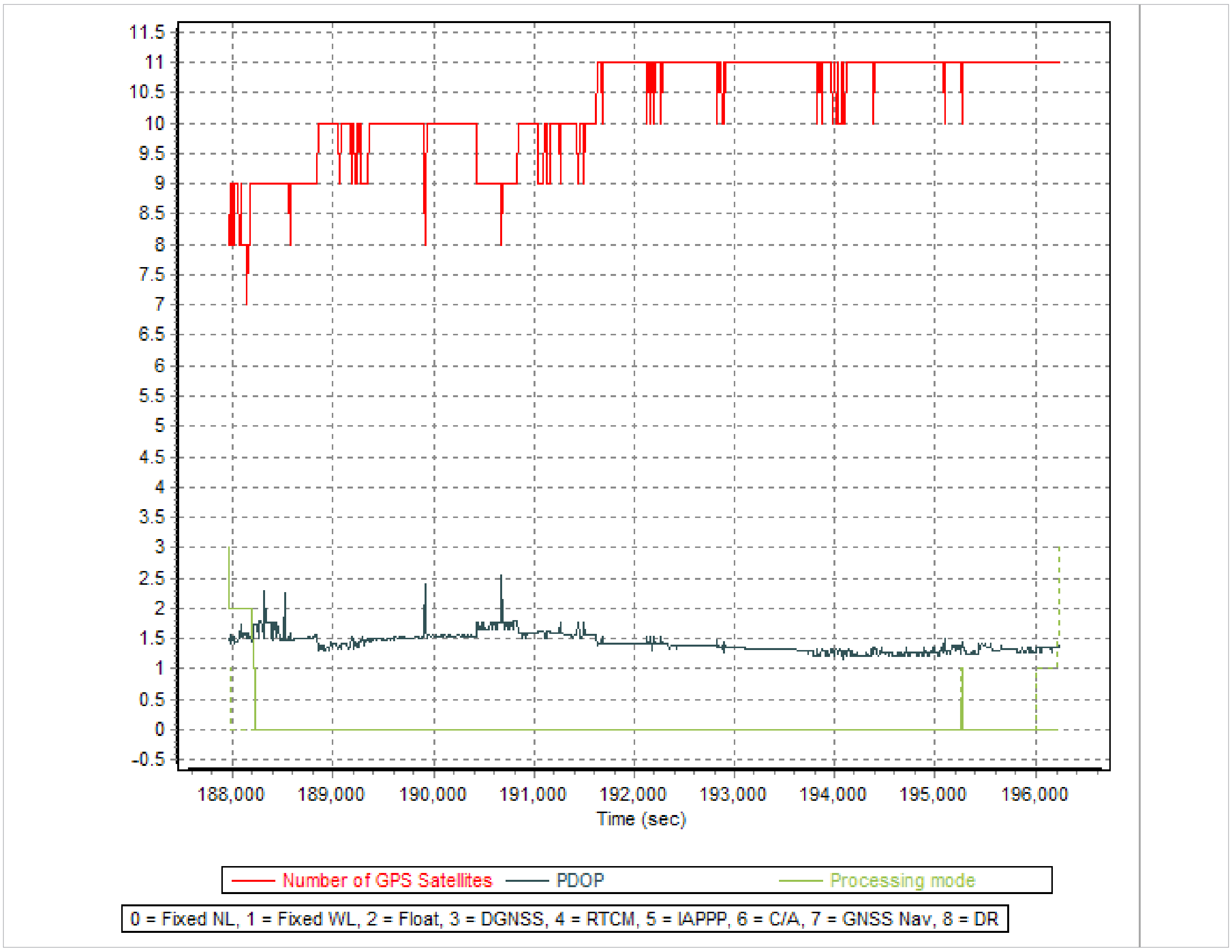


Figure A-8.1 Solution Status

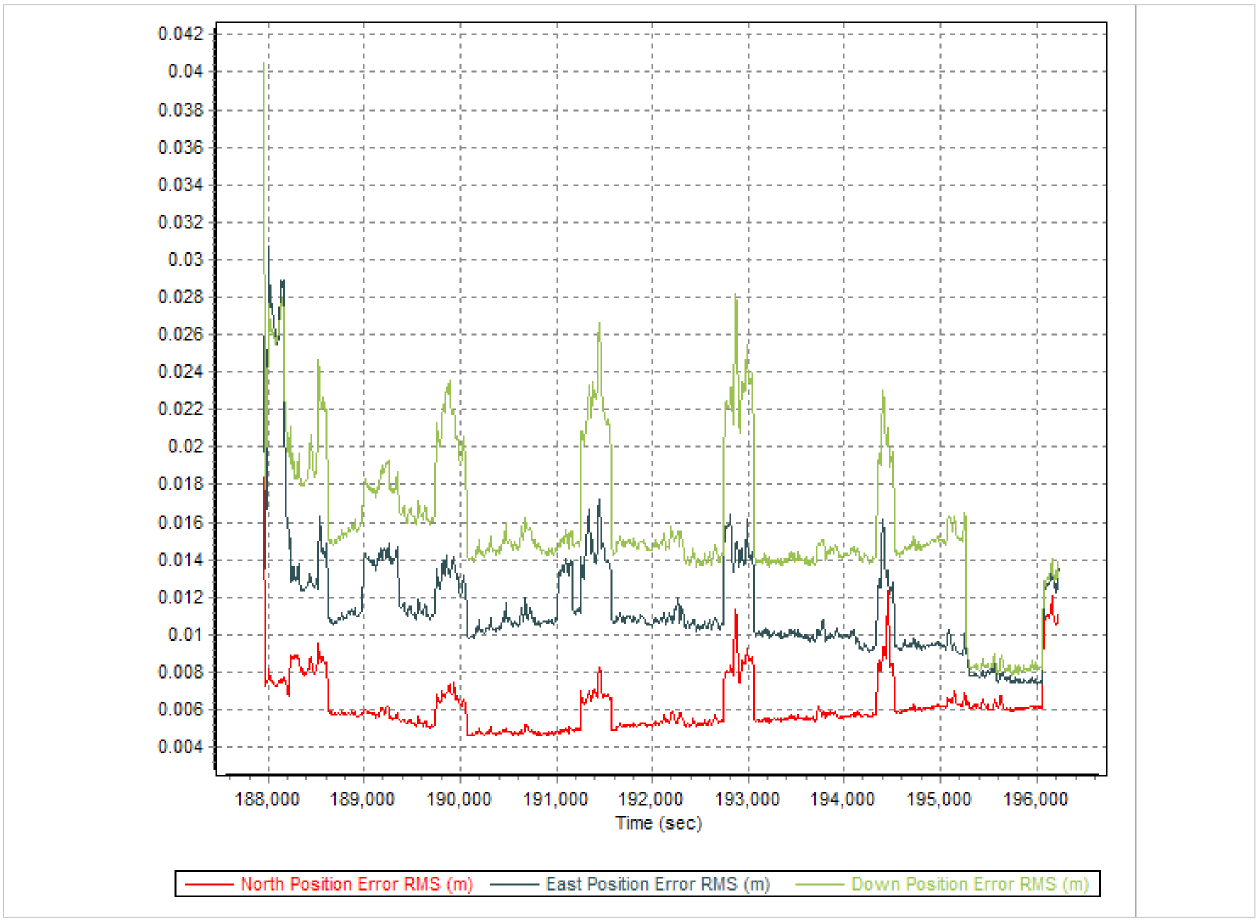


Figure A-8.2 Smoothed Performance Metric Parameters

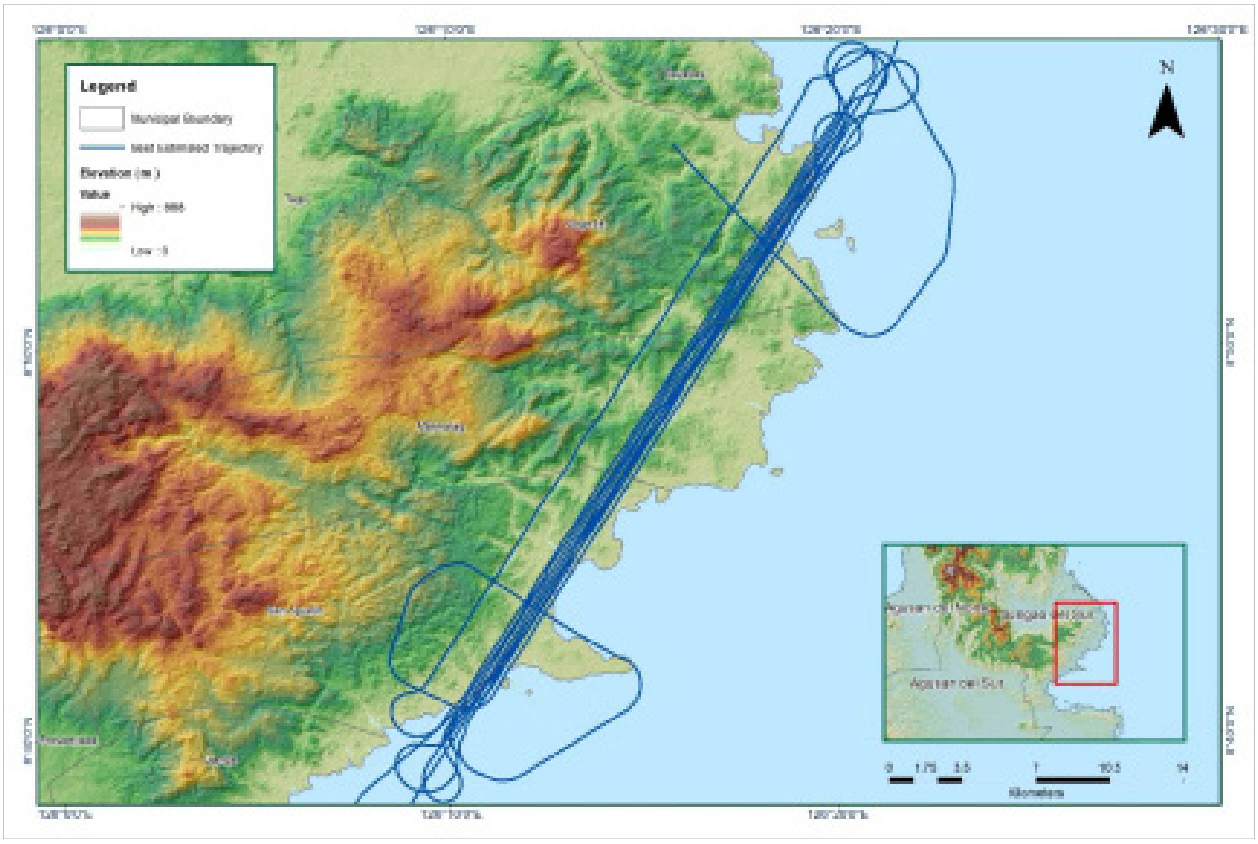


Figure A-8.3 Best Estimated Trajectory

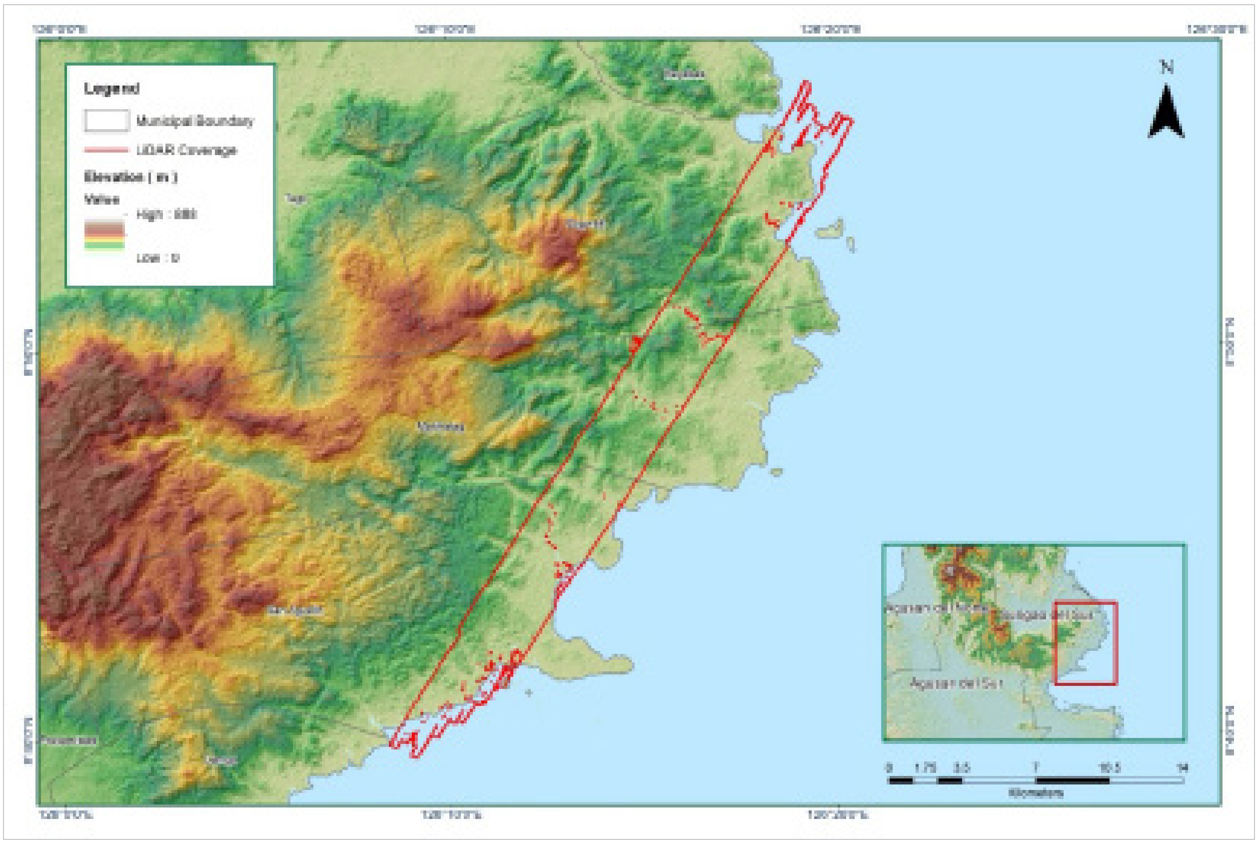


Figure A-8.4 Coverage of LiDAR data

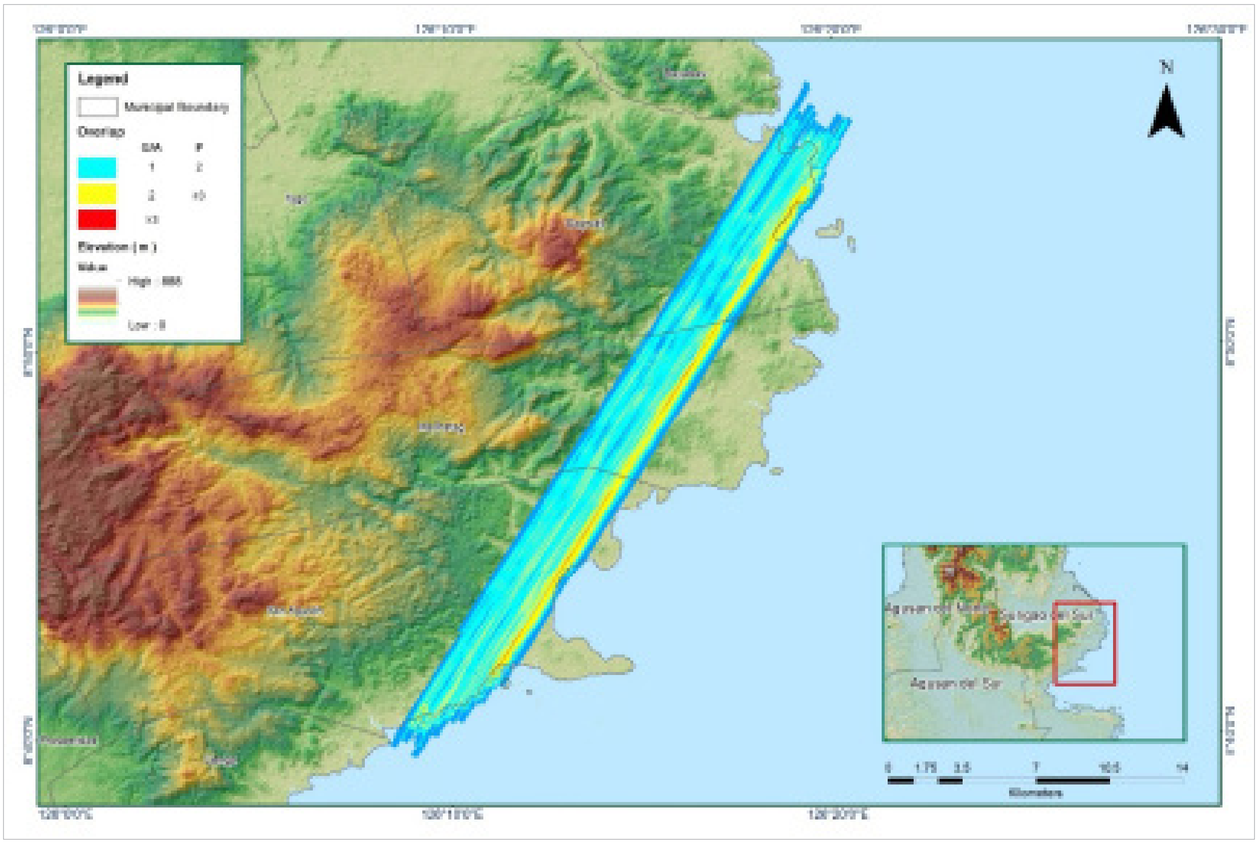


Figure A-8.5 Image of data overlap

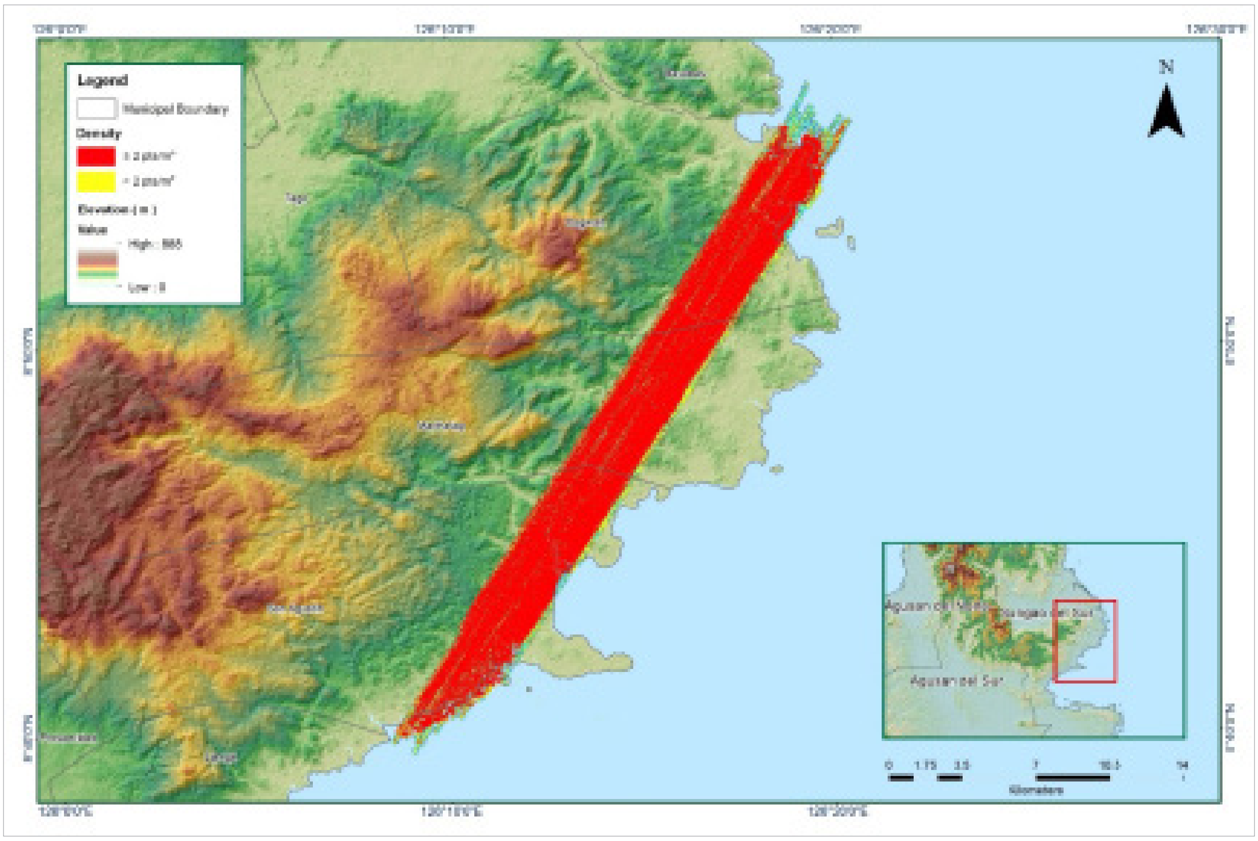


Figure A-8.6 Density map of merged LiDAR data

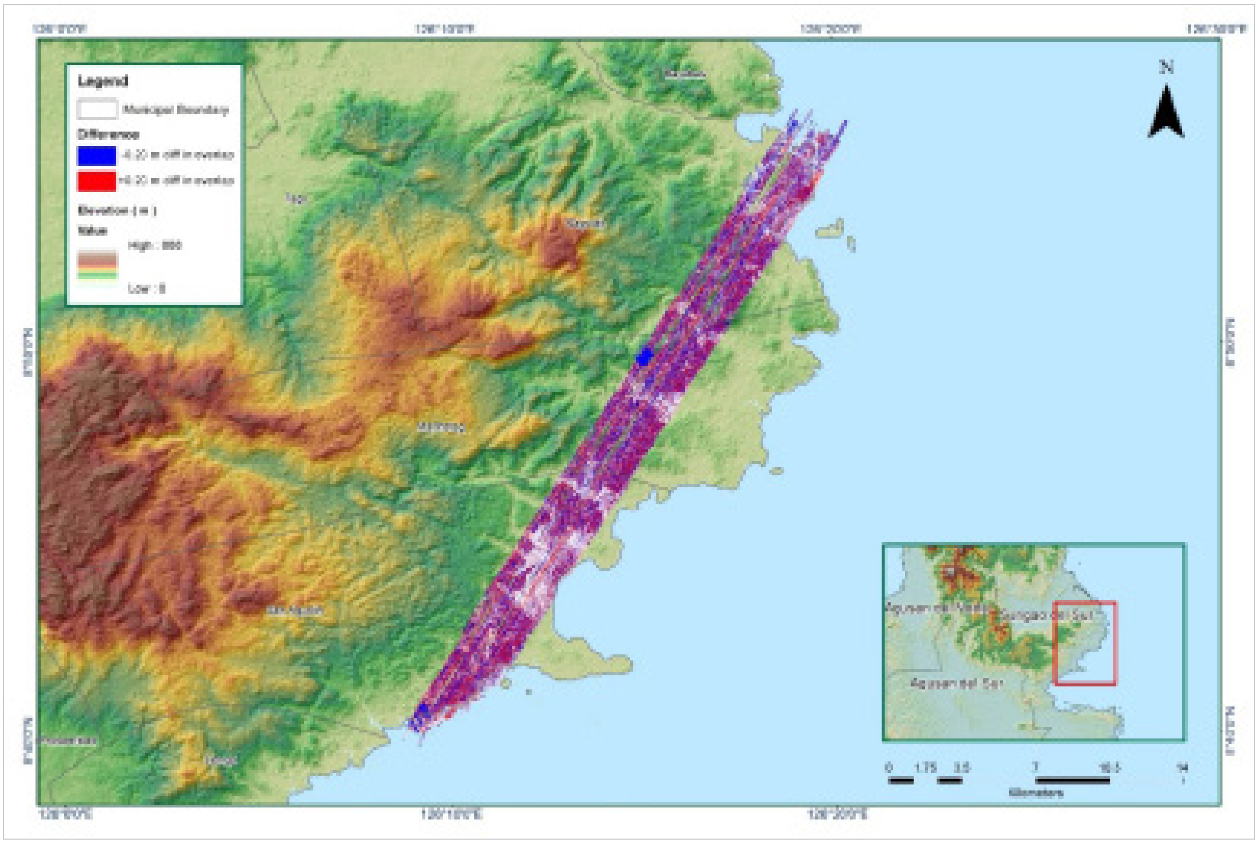


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk65AB

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65AB
Inclusive Flights	1706A & 1726A
Range data size	24.20 GB
Base data size	25.45 MB
POS	491MB
Image	136.70 MB
Transfer date	July 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.10
RMSE for East Position (<4.0 cm)	2.70
RMSE for Down Position (<8.0 cm)	3.50
Boresight correction stdev (<0.001deg)	0.000728
IMU attitude correction stdev (<0.001deg)	0.010218
GPS position stdev (<0.01m)	0.0082
Minimum % overlap (>25)	42.61
Ave point cloud density per sq.m. (>2.0)	2.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	357.22 m
Minimum Height	40.03 m
Classification (# of points)	
Ground	67,240,480
Low vegetation	68,127,741
Medium vegetation	81,511,695
High vegetation	76,902,555
Building	3,337,429
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Analyn Naldo Engr. Chelou Prado, Engr. Gladys Apat

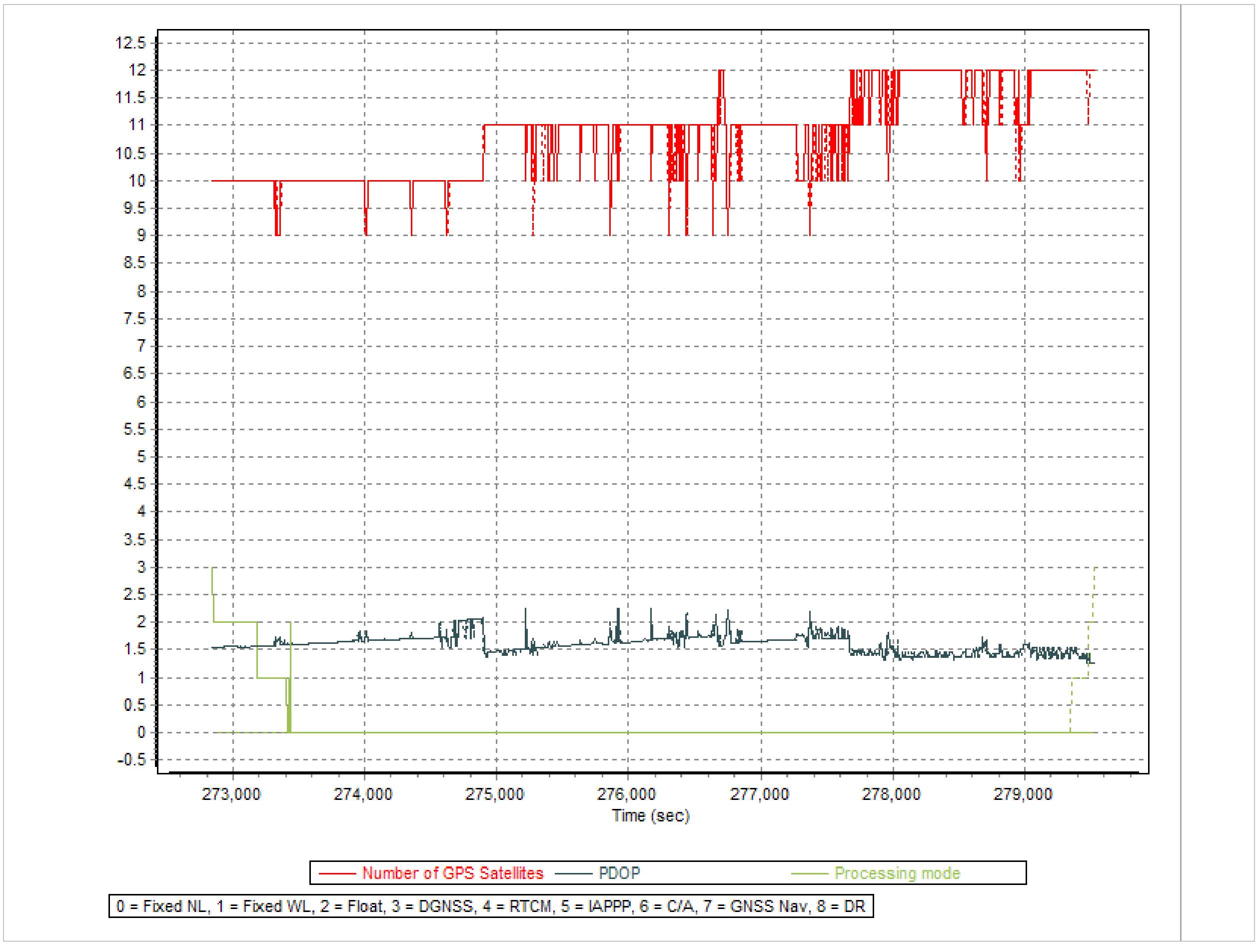


Figure A-8.8 Solution Status

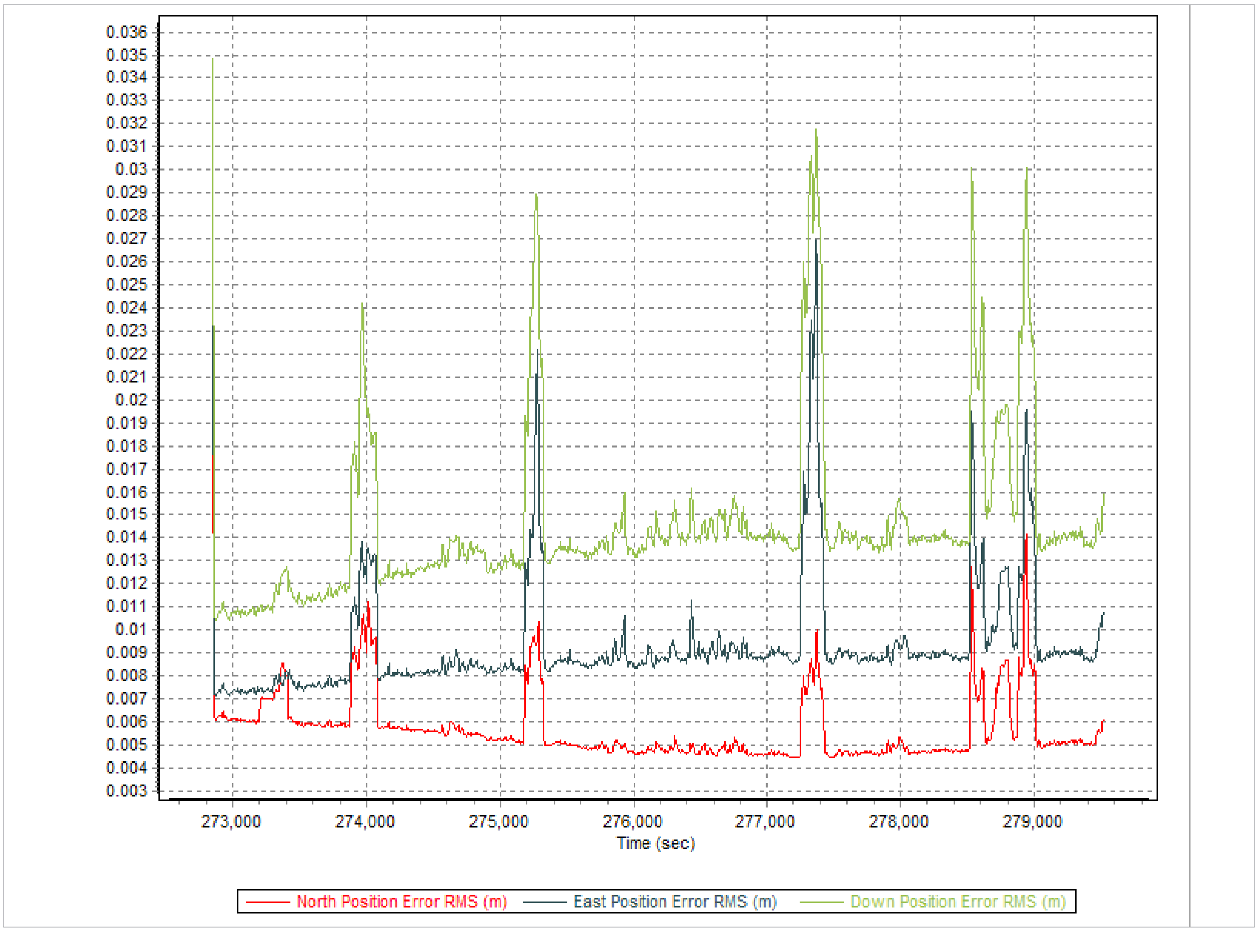


Figure A-8.9 Smoothed Performance Metric Parameters

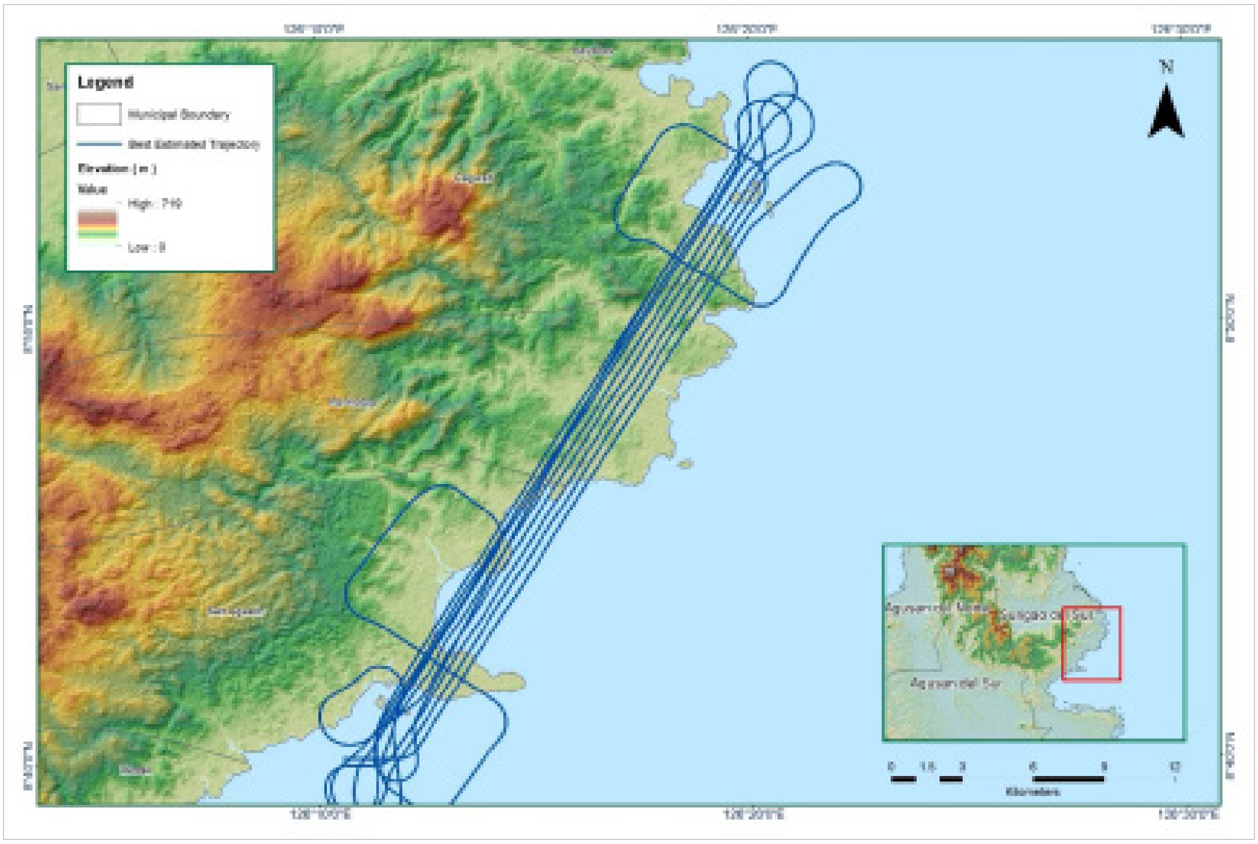


Figure A-8.10 Best Estimated Trajectory

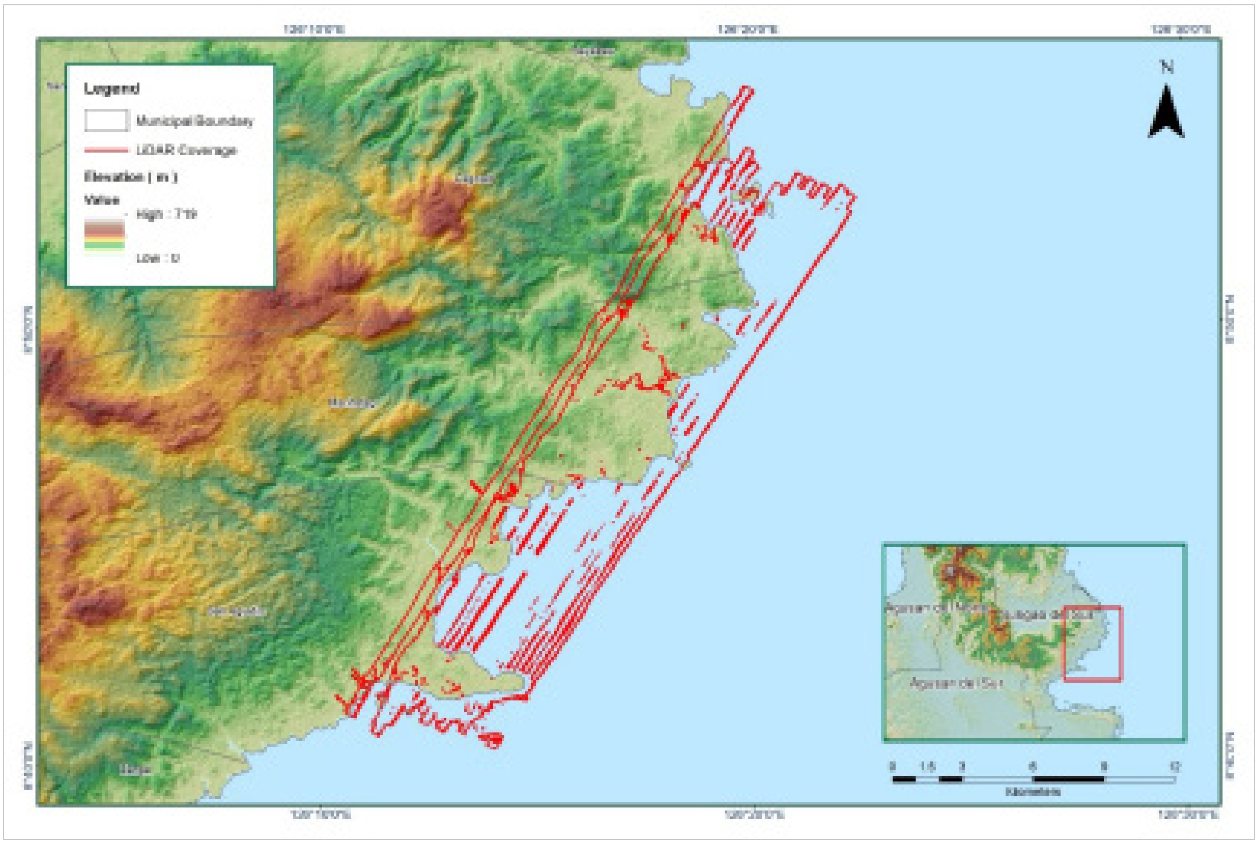


Figure A-8.11 Coverage of LiDAR data

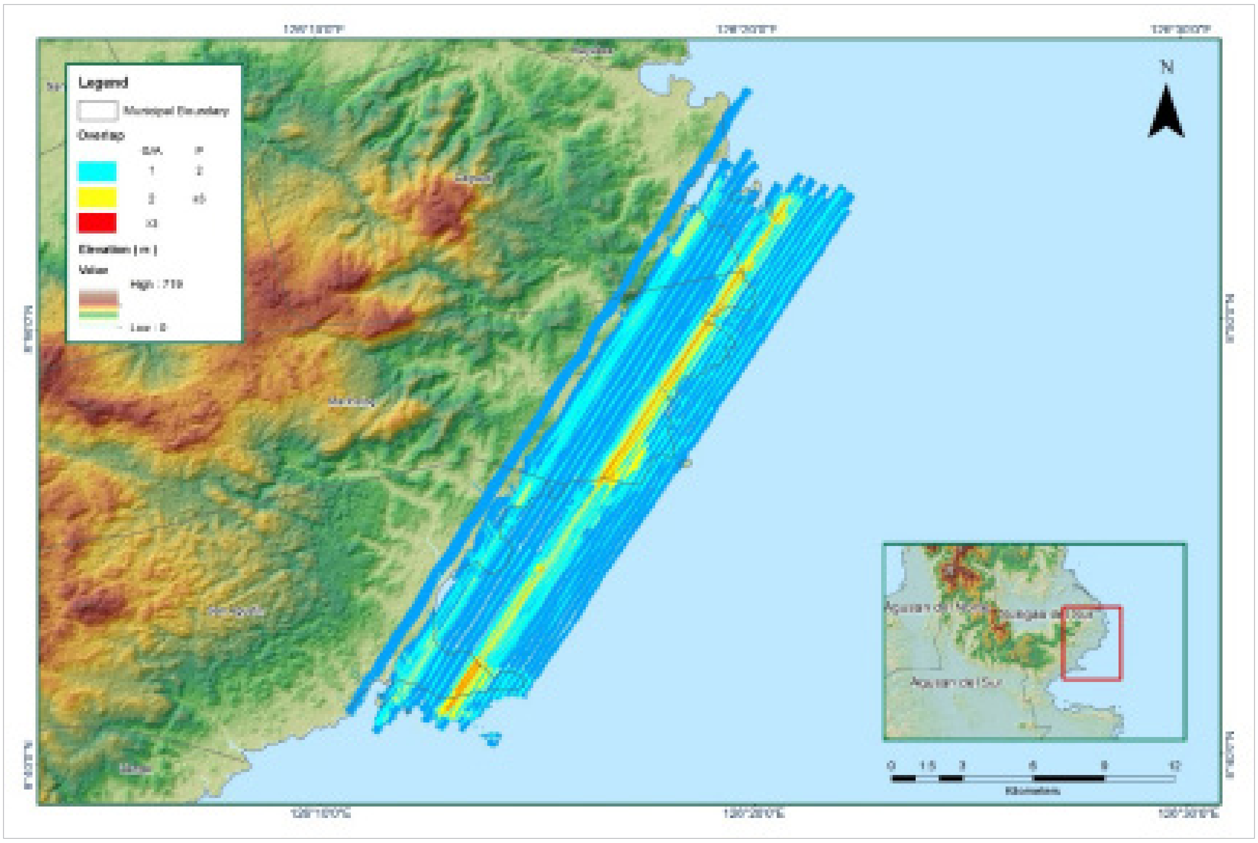


Figure A-8.12 Image of data overlap

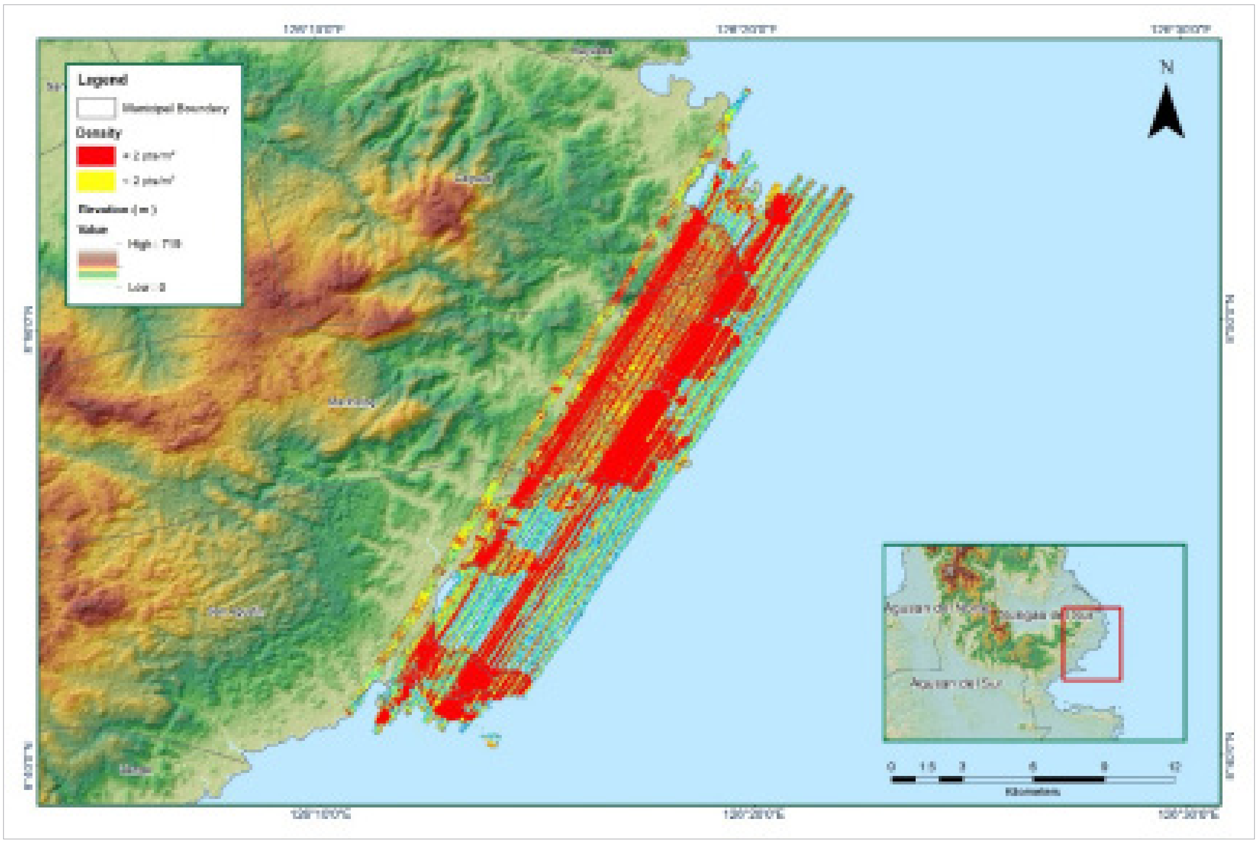


Figure A-8.13 Density map of merged LiDAR data

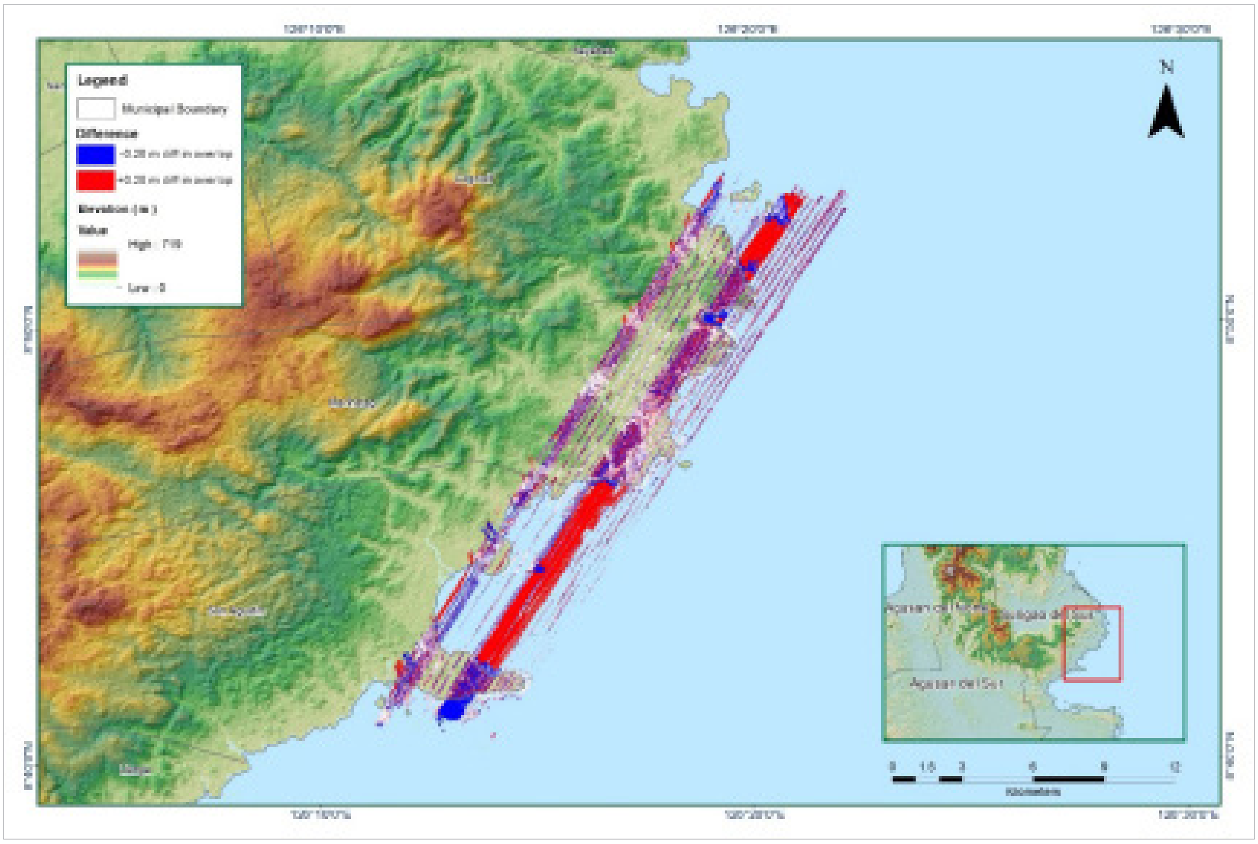


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk65E

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65E
Inclusive Flights	1690A & 1694A
Range data size	22.70 GB
Base data size	20.29 MB
POS	506 MB
Image	69.70 MB
Transfer date	August 5, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.75
RMSE for East Position (<4.0 cm)	2.00
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000428
IMU attitude correction stdev (<0.001deg)	0.002691
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	55.88
Ave point cloud density per sq.m. (>2.0)	4.61
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	142
Maximum Height	471.84 m
Minimum Height	53.27 m
Classification (# of points)	
Ground	28,059,412
Low vegetation	26,073,517
Medium vegetation	70,629,052
High vegetation	207,464,655
Building	5,418,951
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. Melissa Fernandez

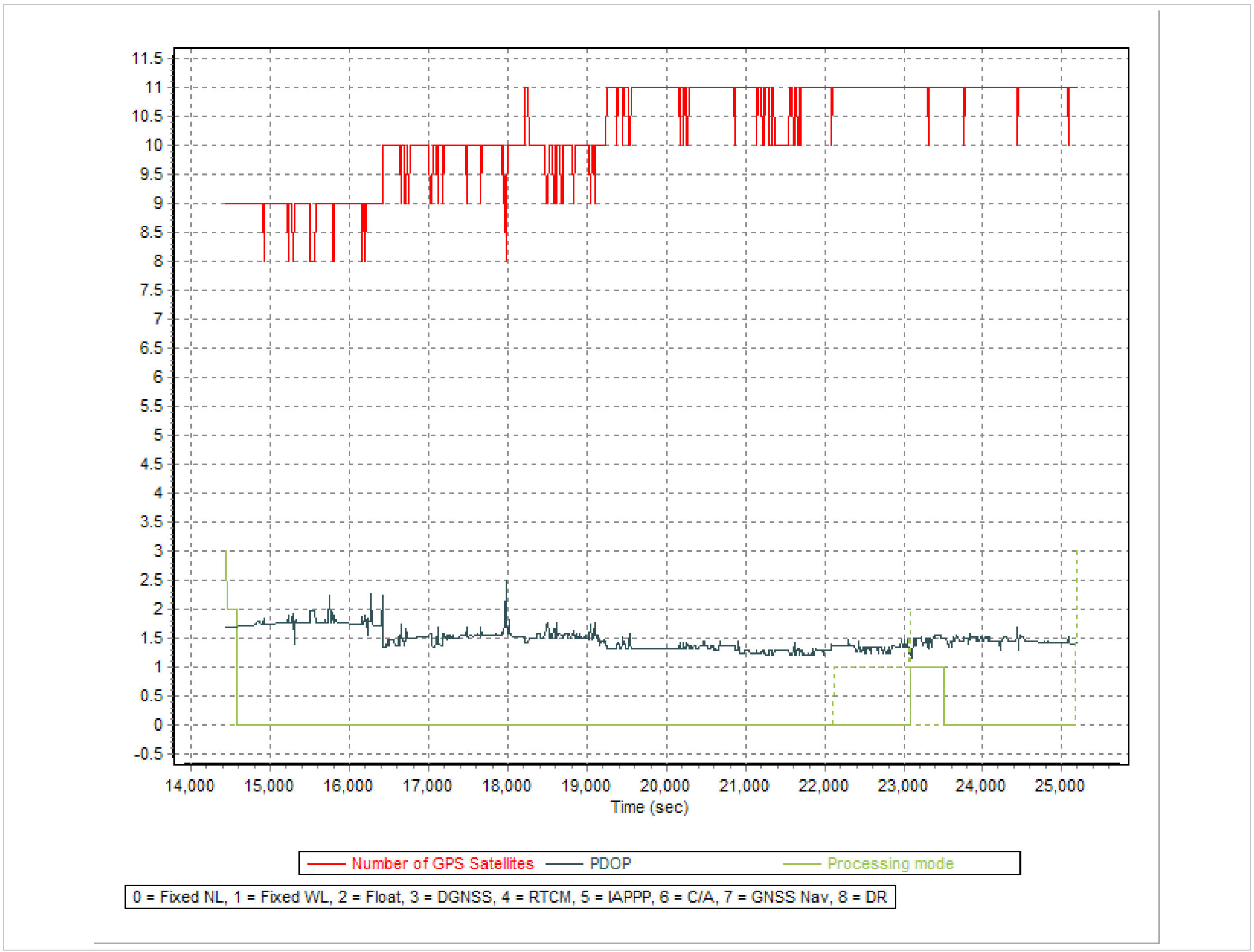


Figure A-8.15 Solution Status

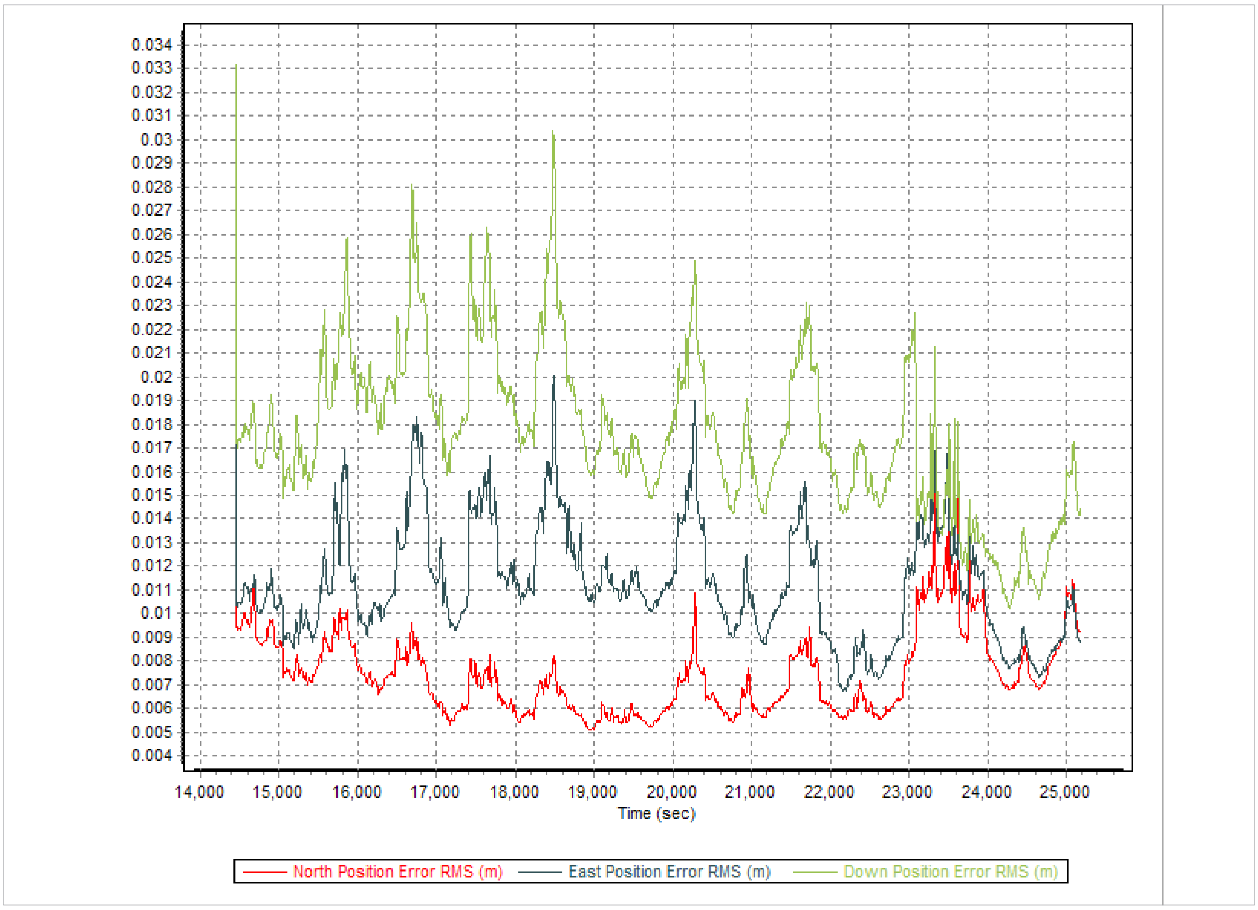


Figure A-8.16 Smoothed Performance Metric Parameters

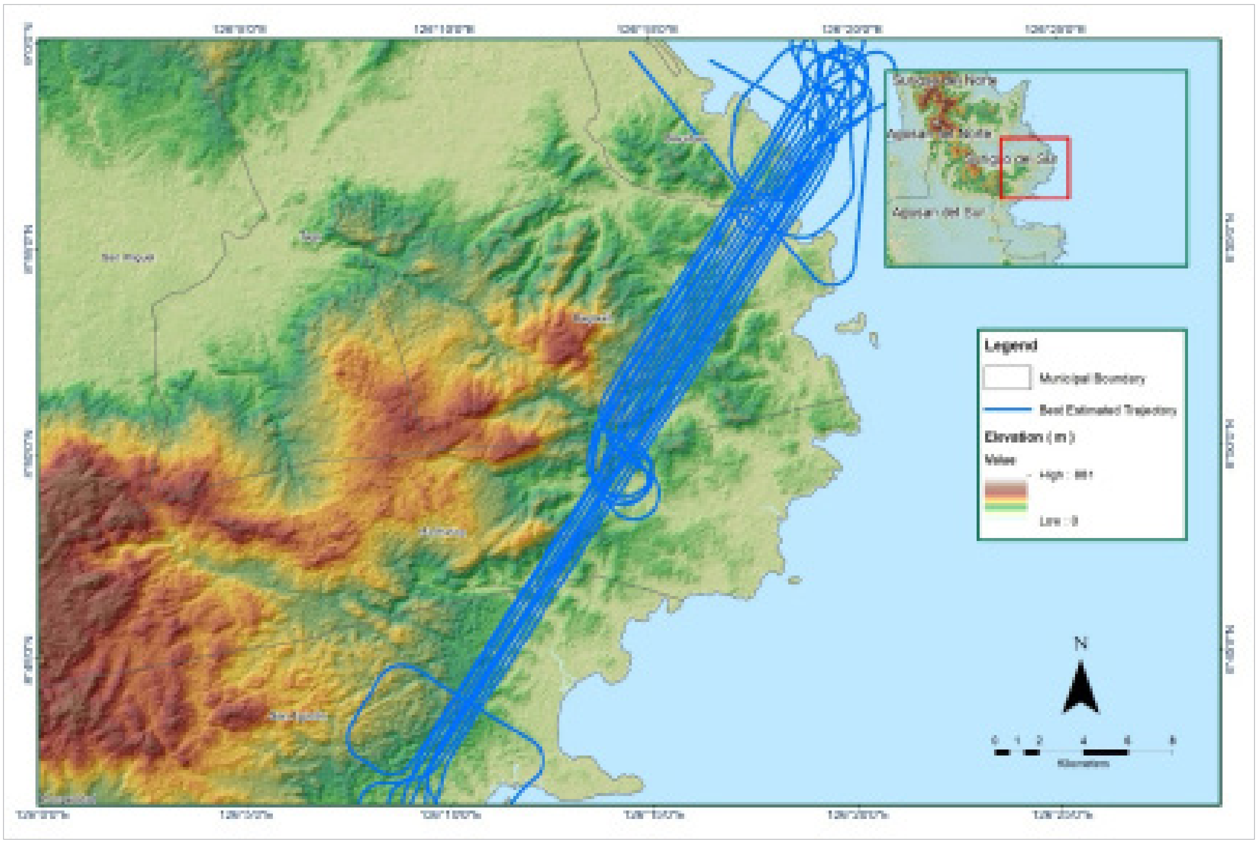


Figure A-8.17 Best Estimated Trajectory

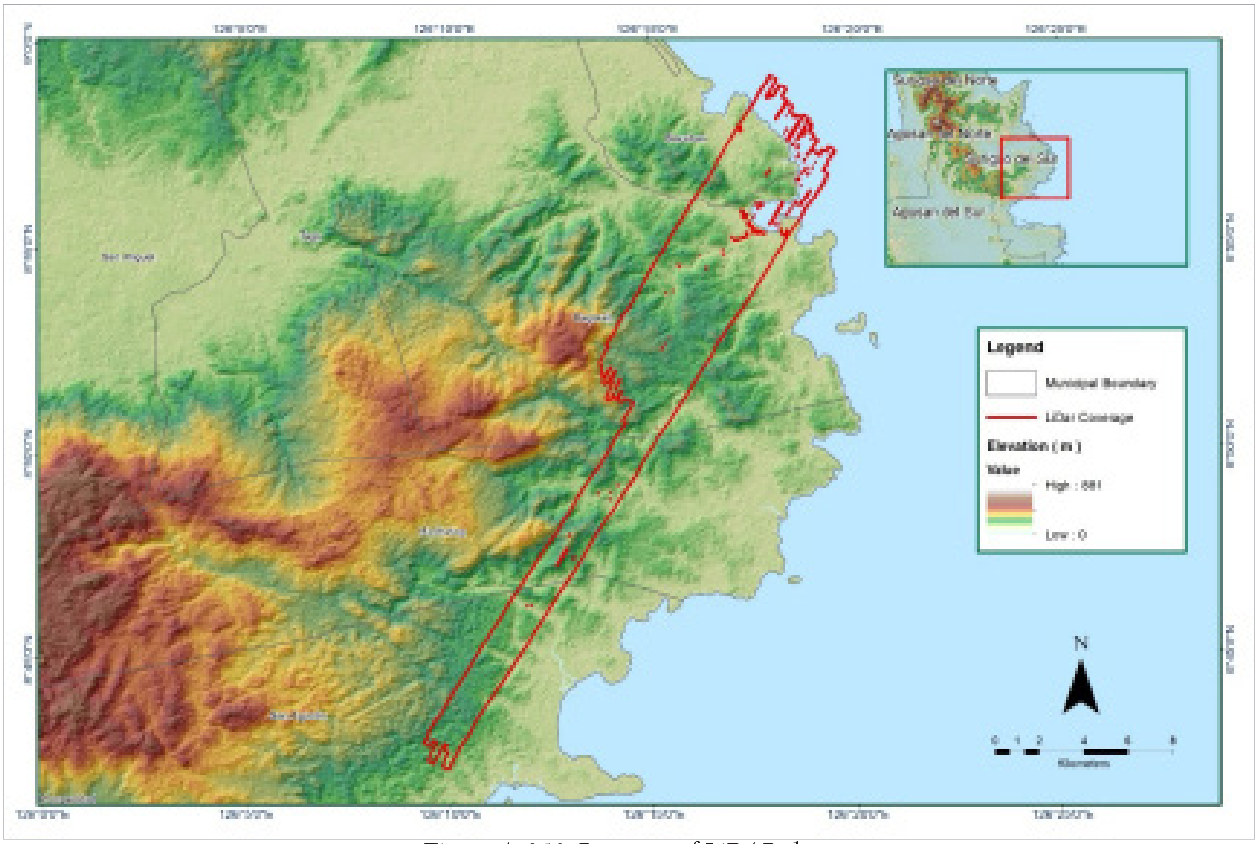


Figure A-8.18 Coverage of LiDAR data

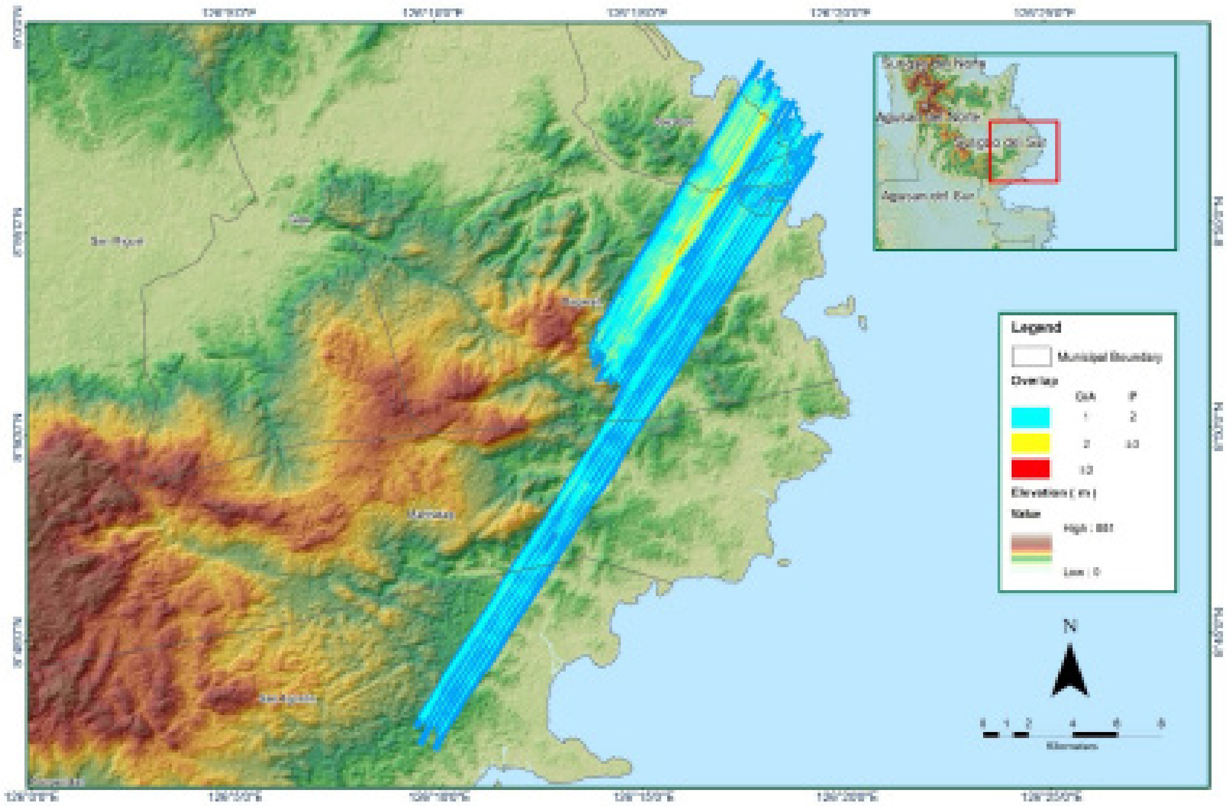


Figure A-8.19 Image of data overlap

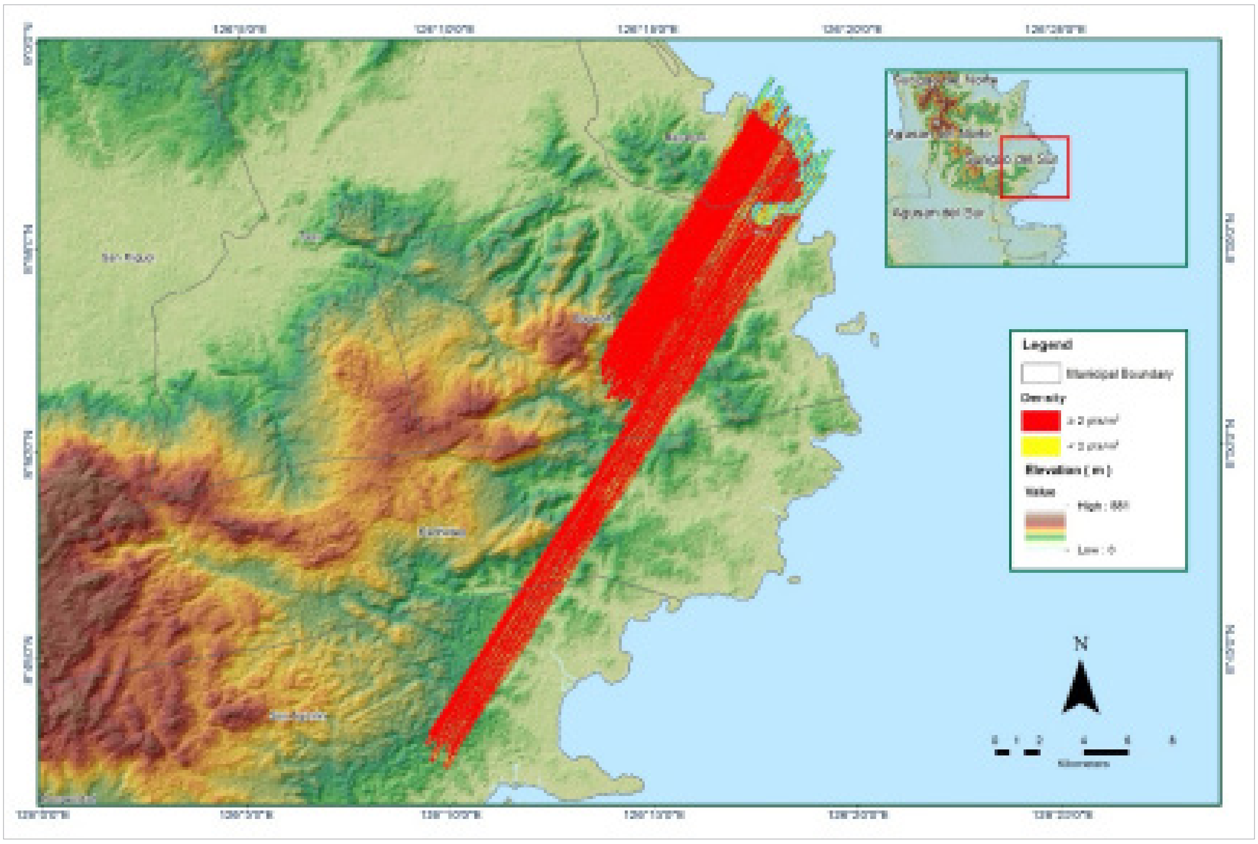


Figure A-8.20 Density map of merged LiDAR data

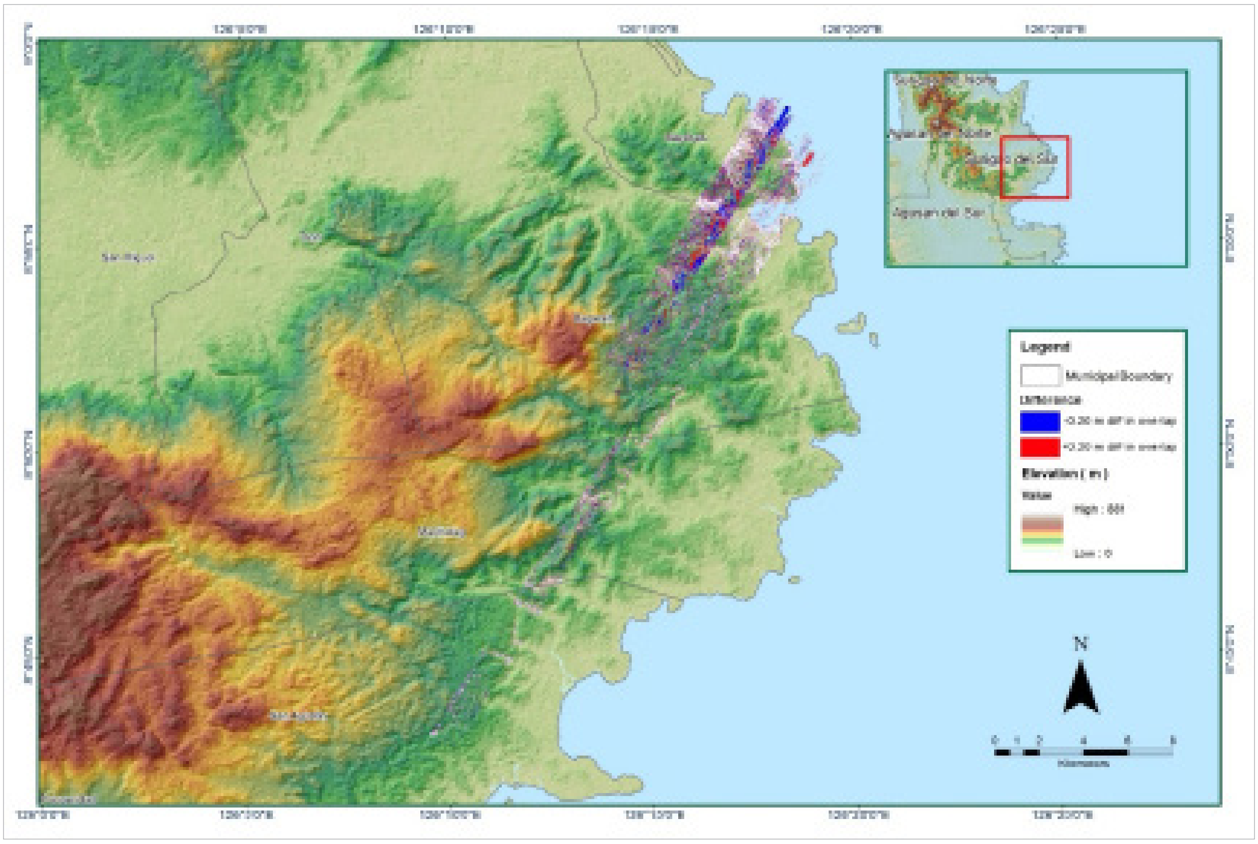


Figure A-8.21 Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk65FG

Flight Area	Tandag (Surigao Del Sur)
Mission Name	Block 65FG
Inclusive Flights	1714A & 1734A
Range data size	20.08 GB
Base data size	23.09 MB
POS	440 MB
Image	114.90 MB
Transfer date	July 31, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000467
IMU attitude correction stdev (<0.001deg)	0.001135
GPS position stdev (<0.01m)	0.0072
Minimum % overlap (>25)	59.75
Ave point cloud density per sq.m. (>2.0)	3.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	179
Maximum Height	388.37 m
Minimum Height	45.74 m
Classification (# of points)	
Ground	35,792,604
Low vegetation	37,451,825
Medium vegetation	74,379,583
High vegetation	155,910,057
Building	6,109,884
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgar Gubatanga, Jr., Jovy Narisma

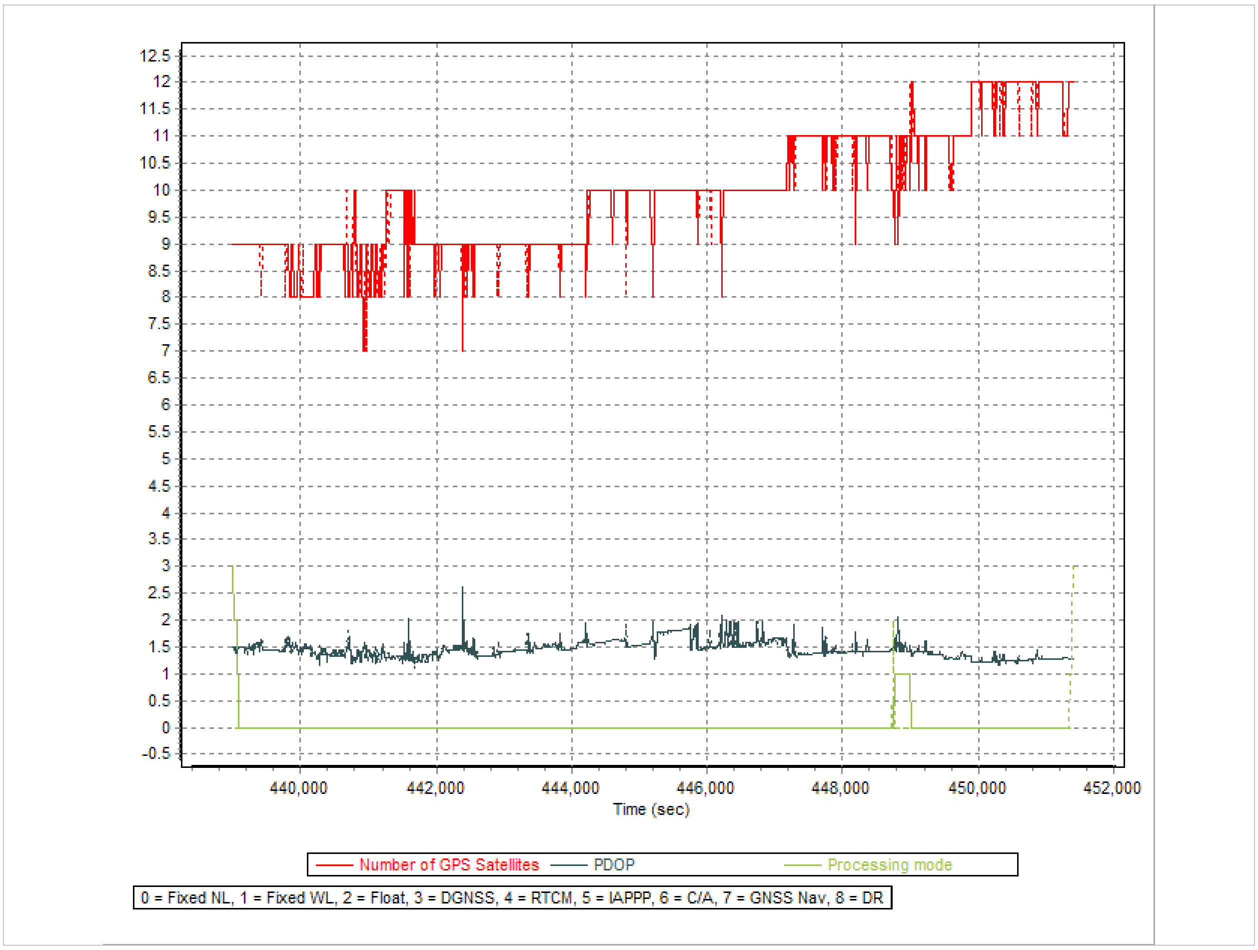


Figure A-8.22 Solution Status

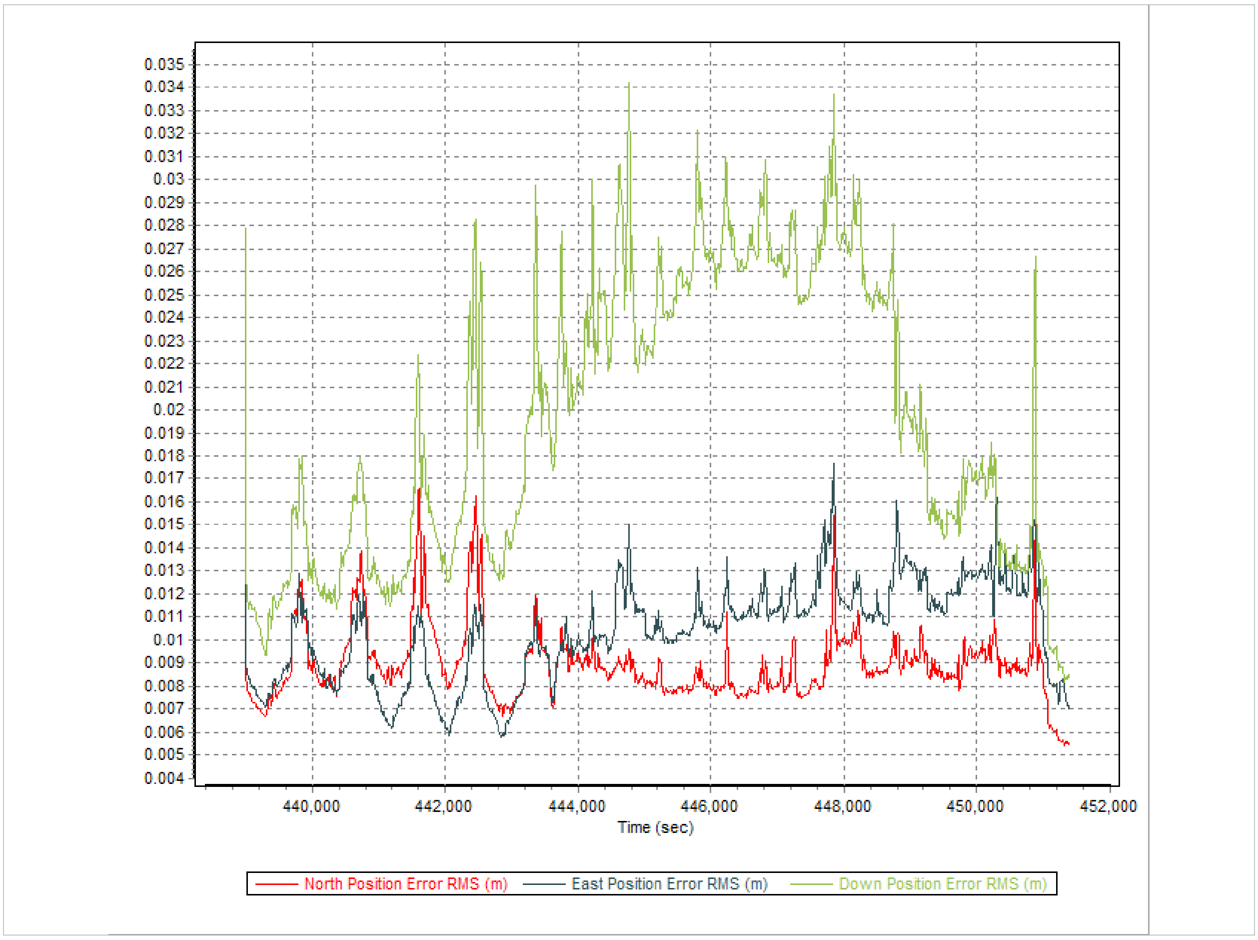


Figure A-8.23 Smoothed Performance Metric Parameters

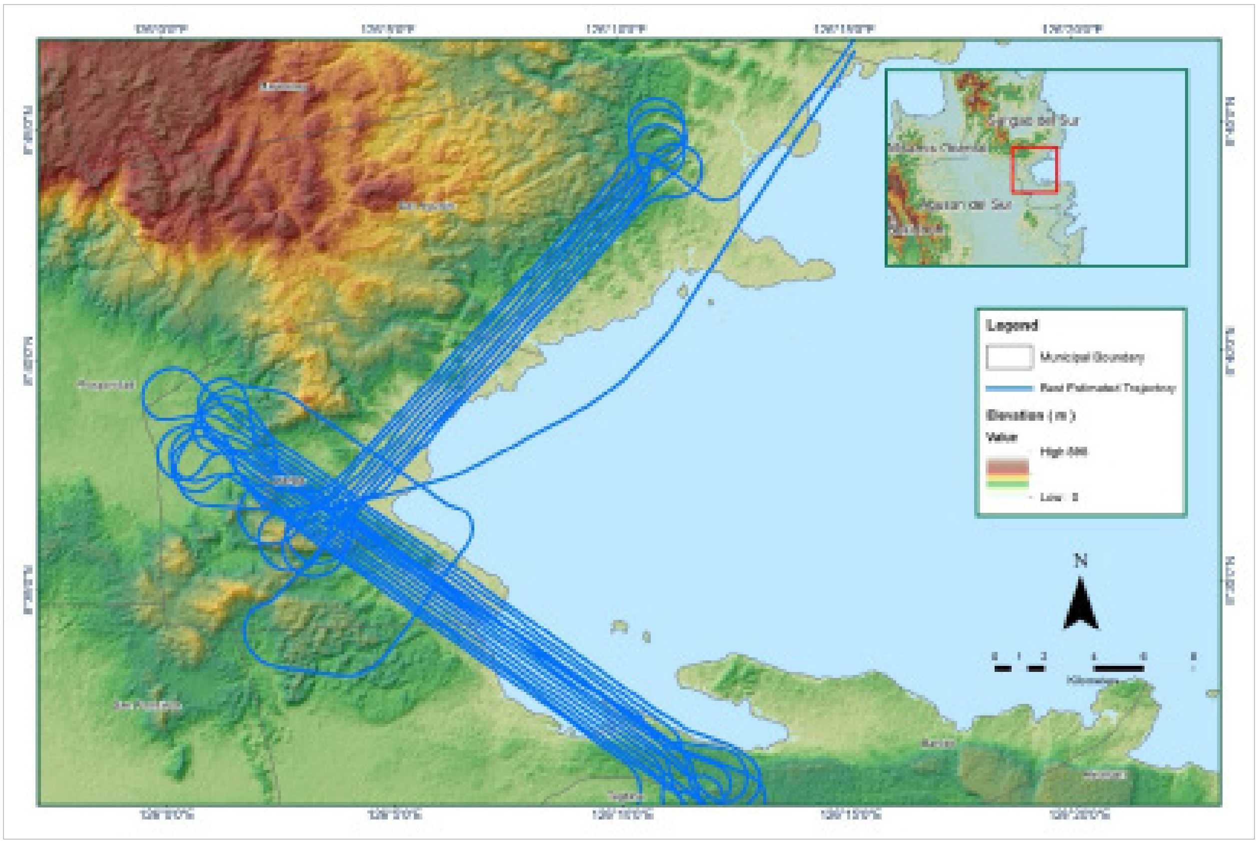


Figure A-8.24 Best Estimated Trajectory

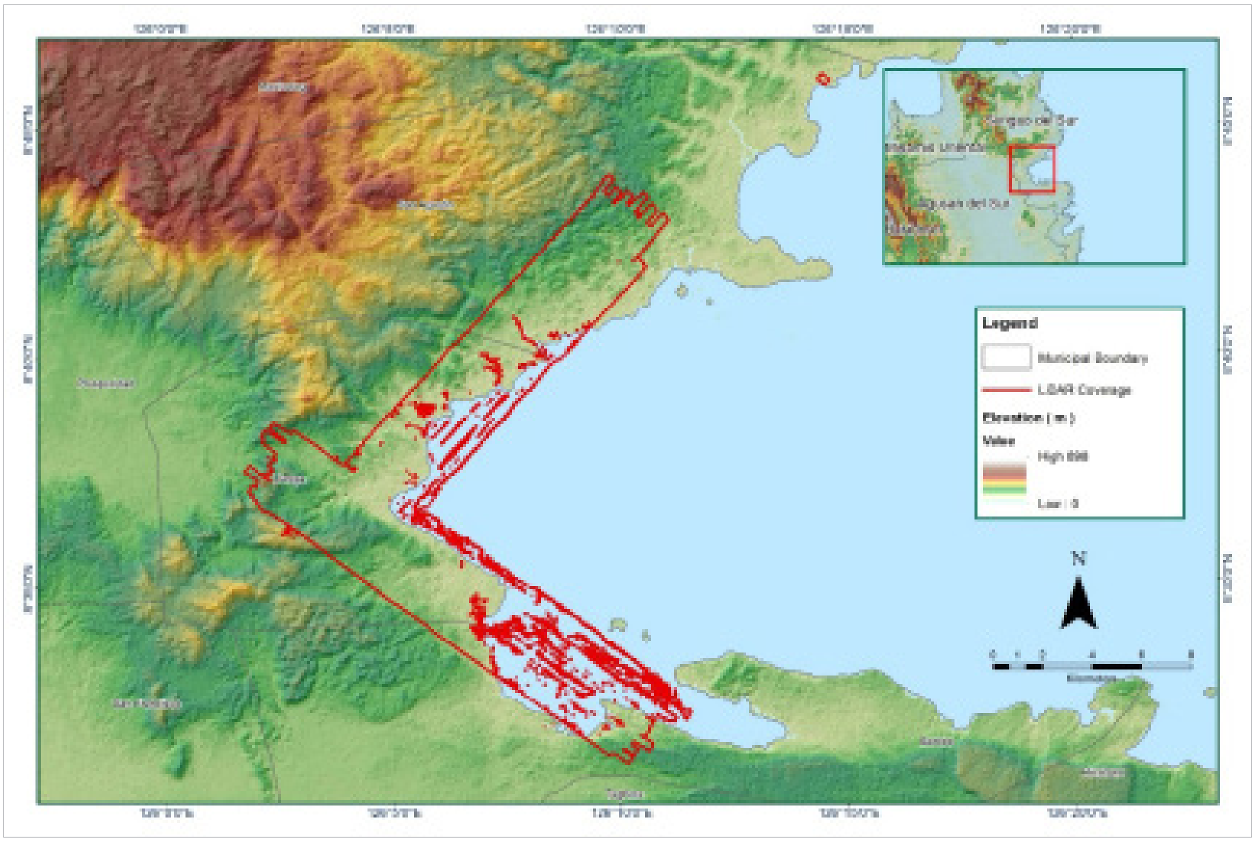


Figure A-8.25 Coverage of LiDAR data

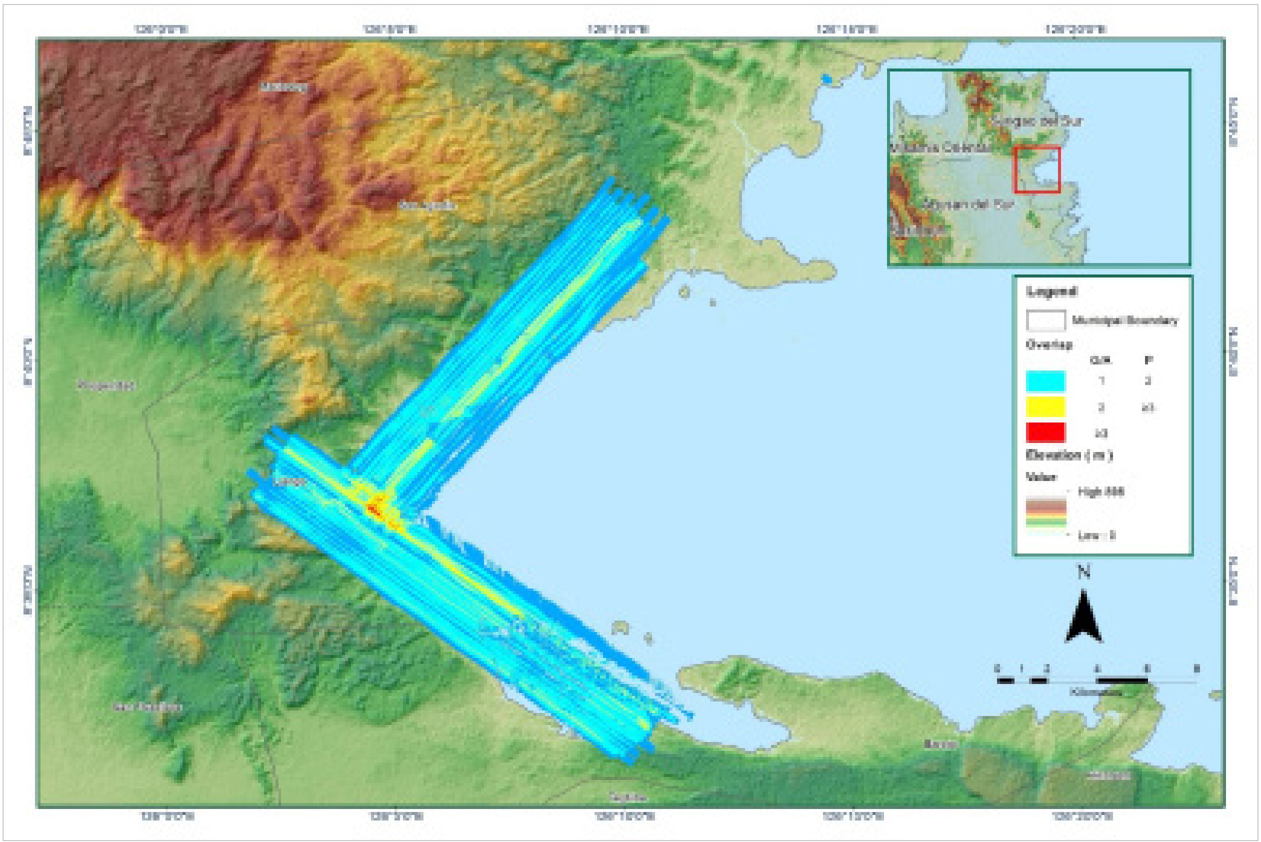


Figure A-8.26 Image of data overlap

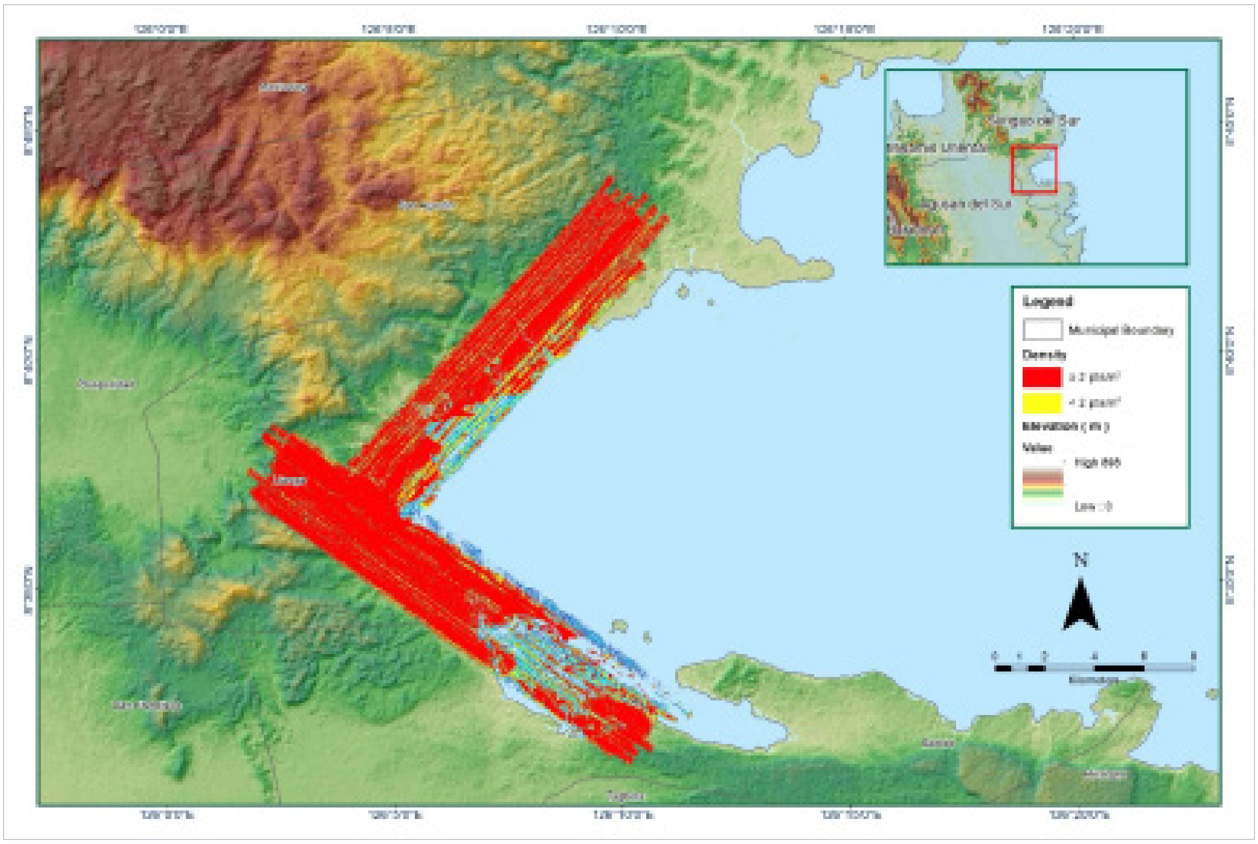


Figure A-8.27 Density map of merged LiDAR data

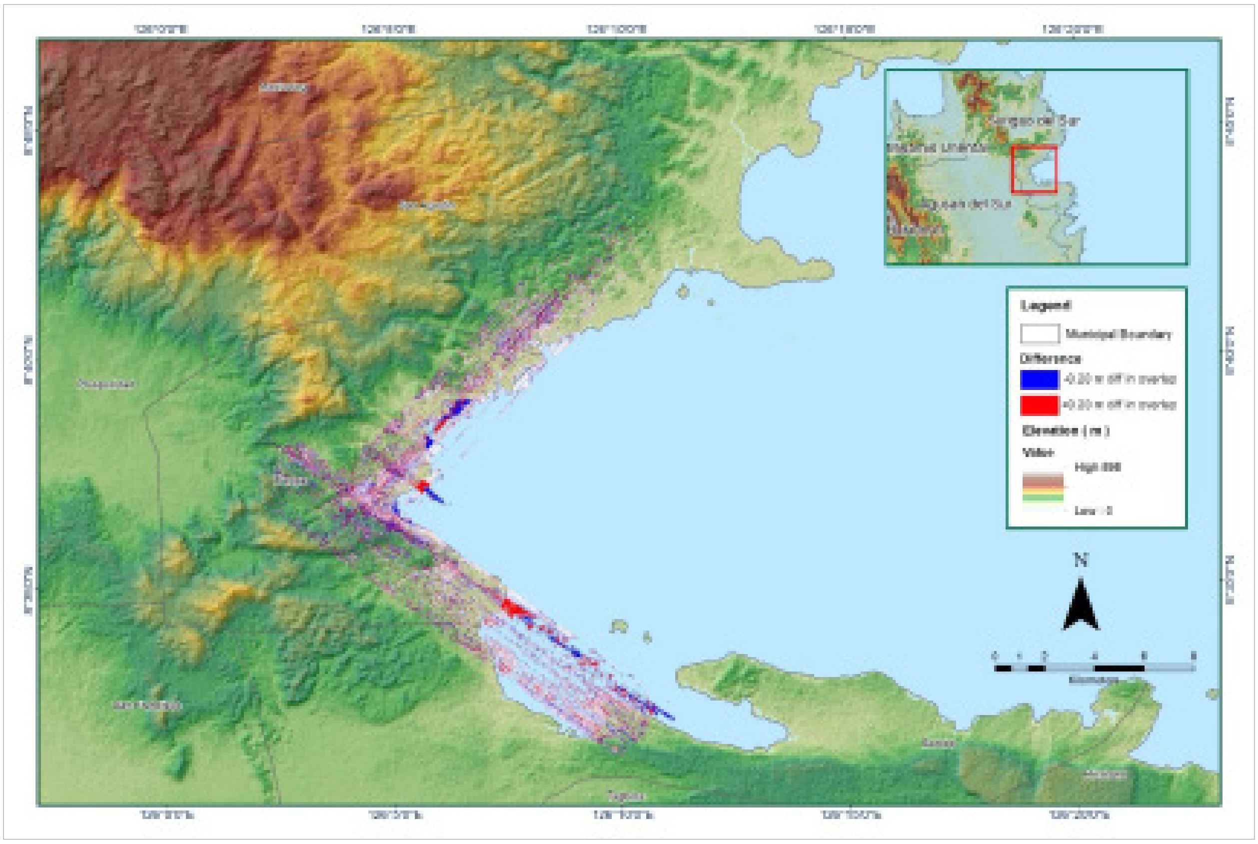


Figure A-8.28 Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk65E

Flight Area	Tandag
Mission Name	Blk65E
Inclusive Flights	23616P
Range data size	6.16 GB
Base data size	354 MB
POS	142 MB
Image	NA
Transfer date	January 3, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.50
RMSE for East Position (<4.0 cm)	3.96
RMSE for Down Position (<8.0 cm)	7.06
Boresight correction stdev (<0.001deg)	0.000429
IMU attitude correction stdev (<0.001deg)	0.000528
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	3.45
Ave point cloud density per sq.m. (>2.0)	2.14
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	60
Maximum Height	230.72 m
Minimum Height	64.93 m
Classification (# of points)	
Ground	22,379,198
Low vegetation	16,075,670
Medium vegetation	21,650,971
High vegetation	61,848,018
Building	1,405,453
Ortophoto	No
Processed by	

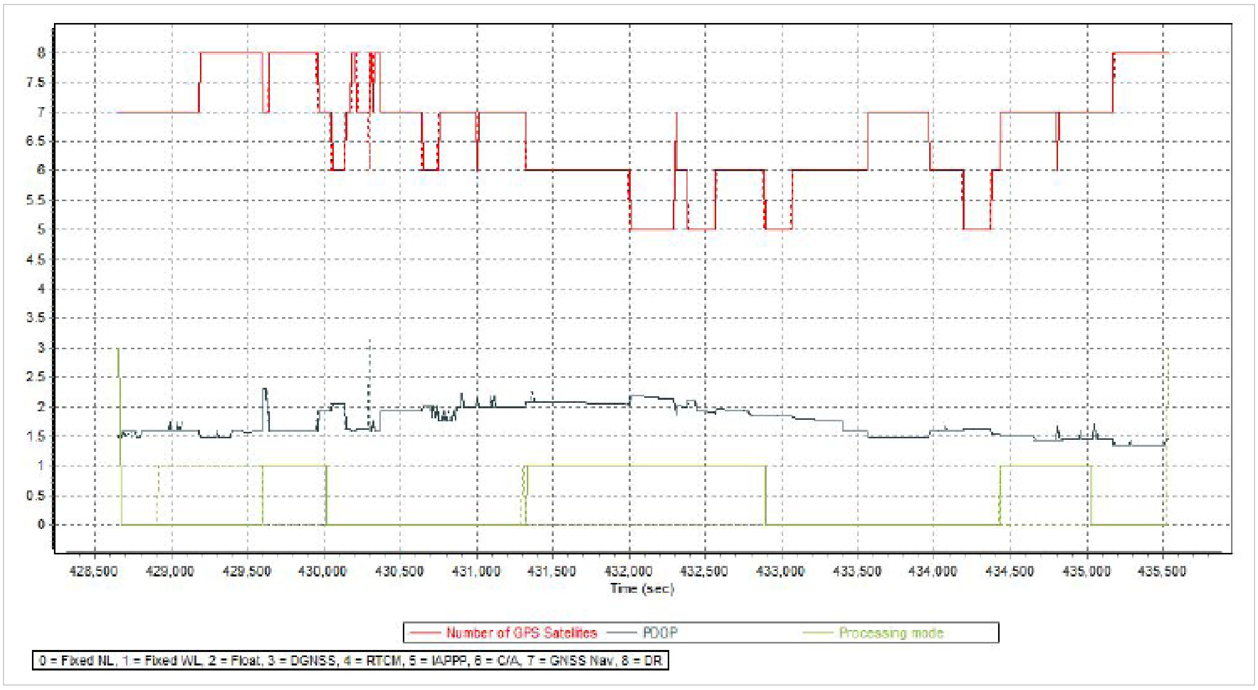


Figure A-8.29. Solution Status

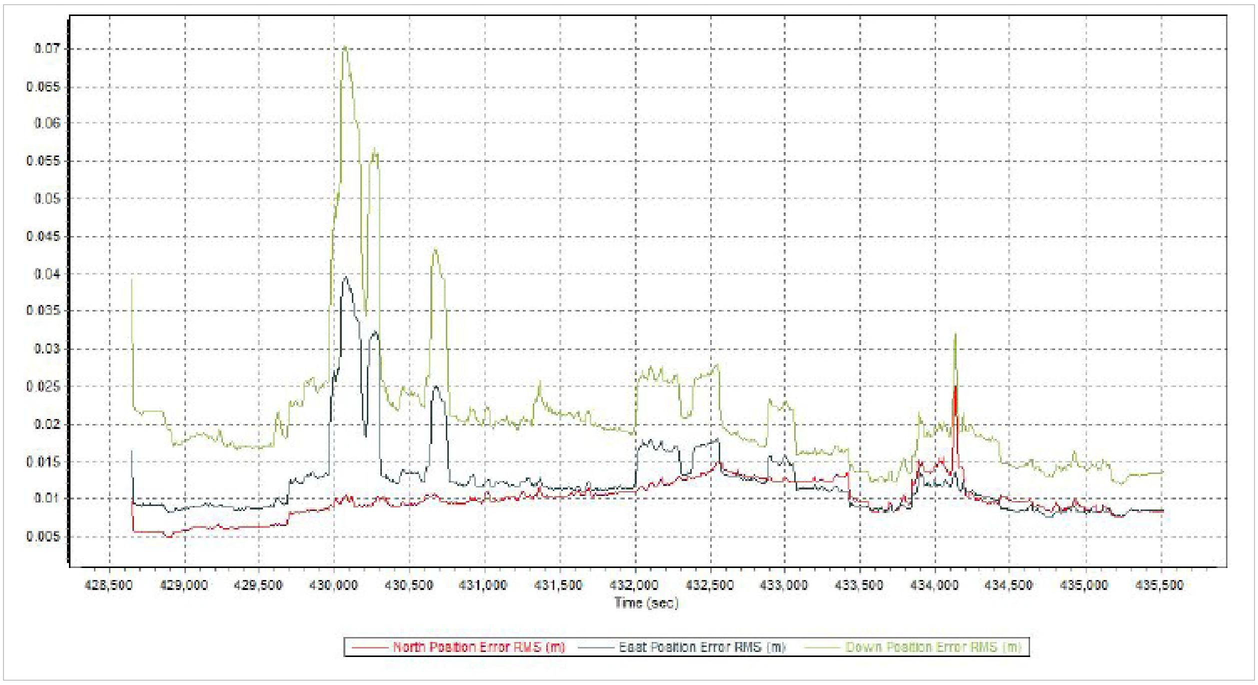


Figure A-8.30. Smoothed Performance Metric Parameters

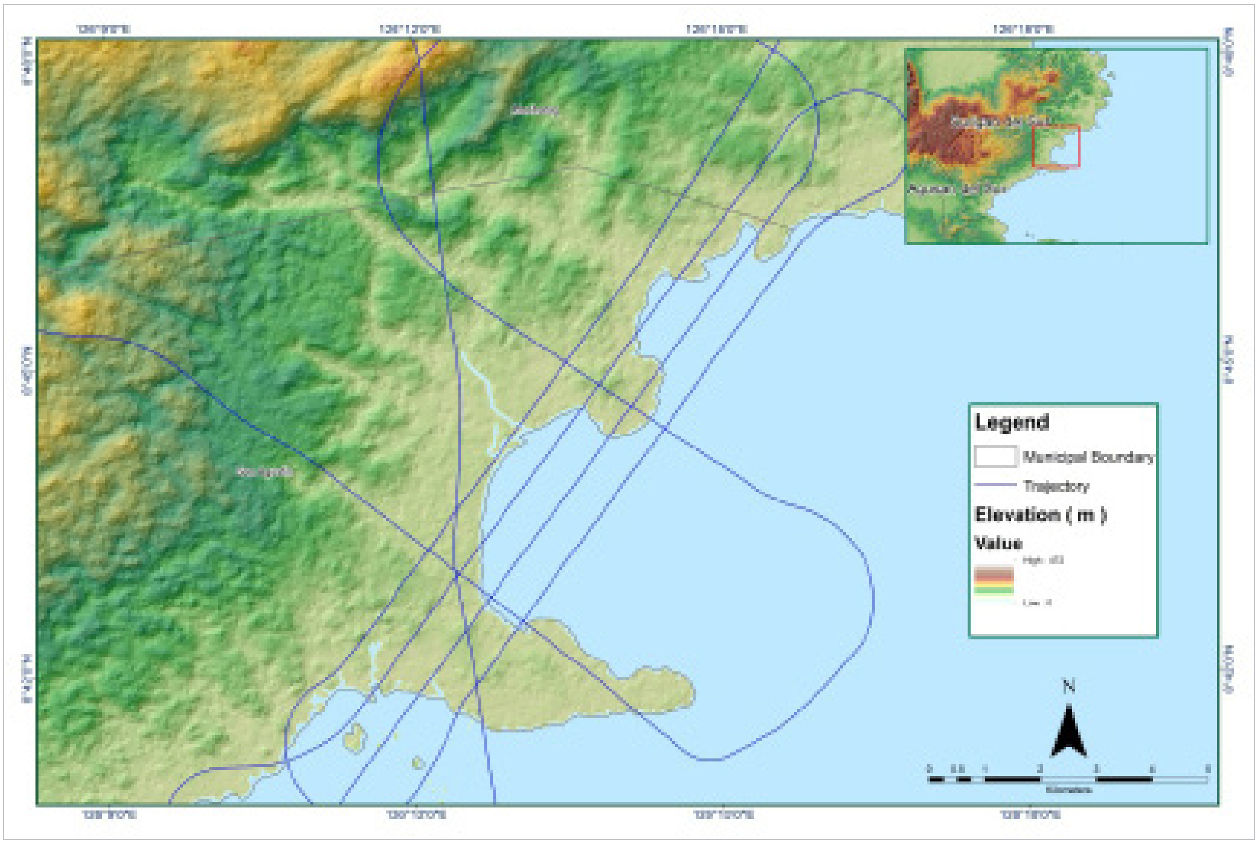


Figure A-8.31 Best Estimated Trajectory

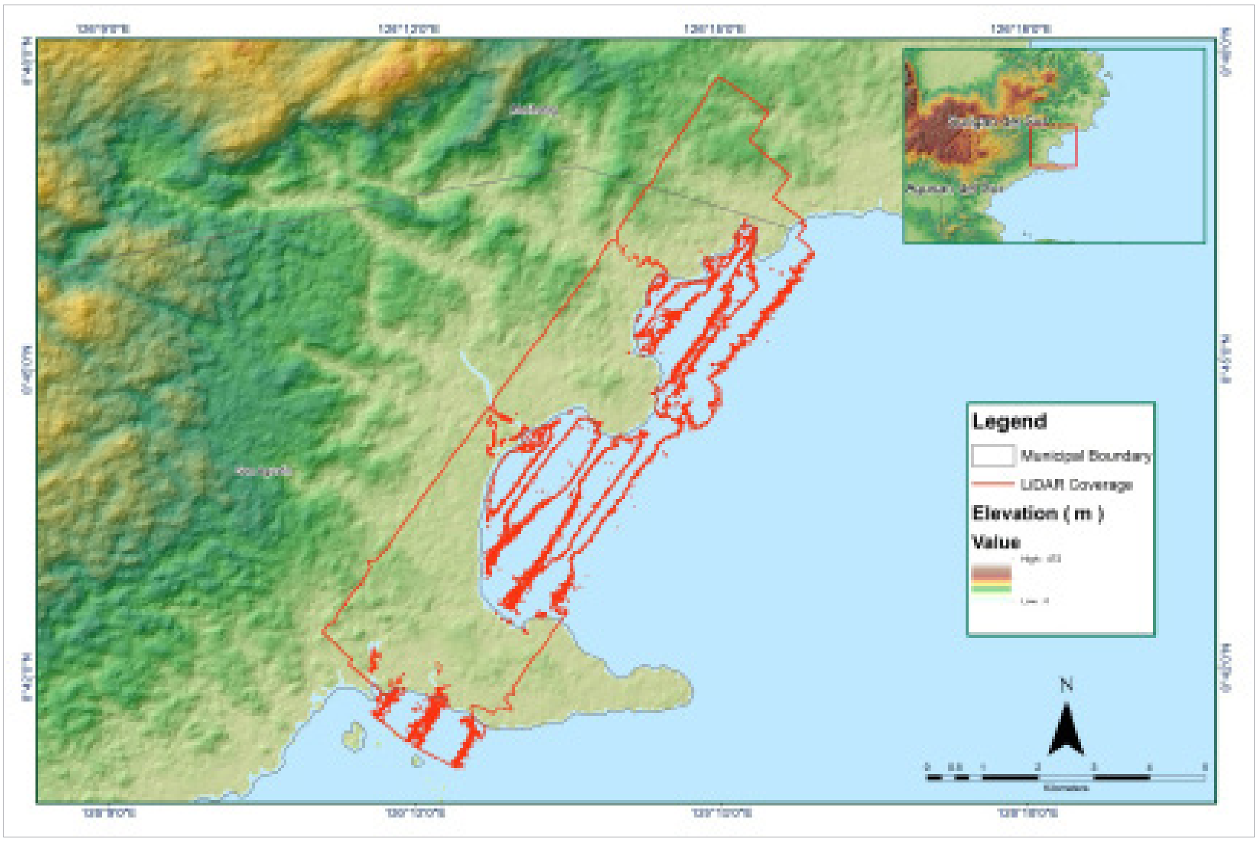


Figure A-8.32 Coverage of LiDAR data

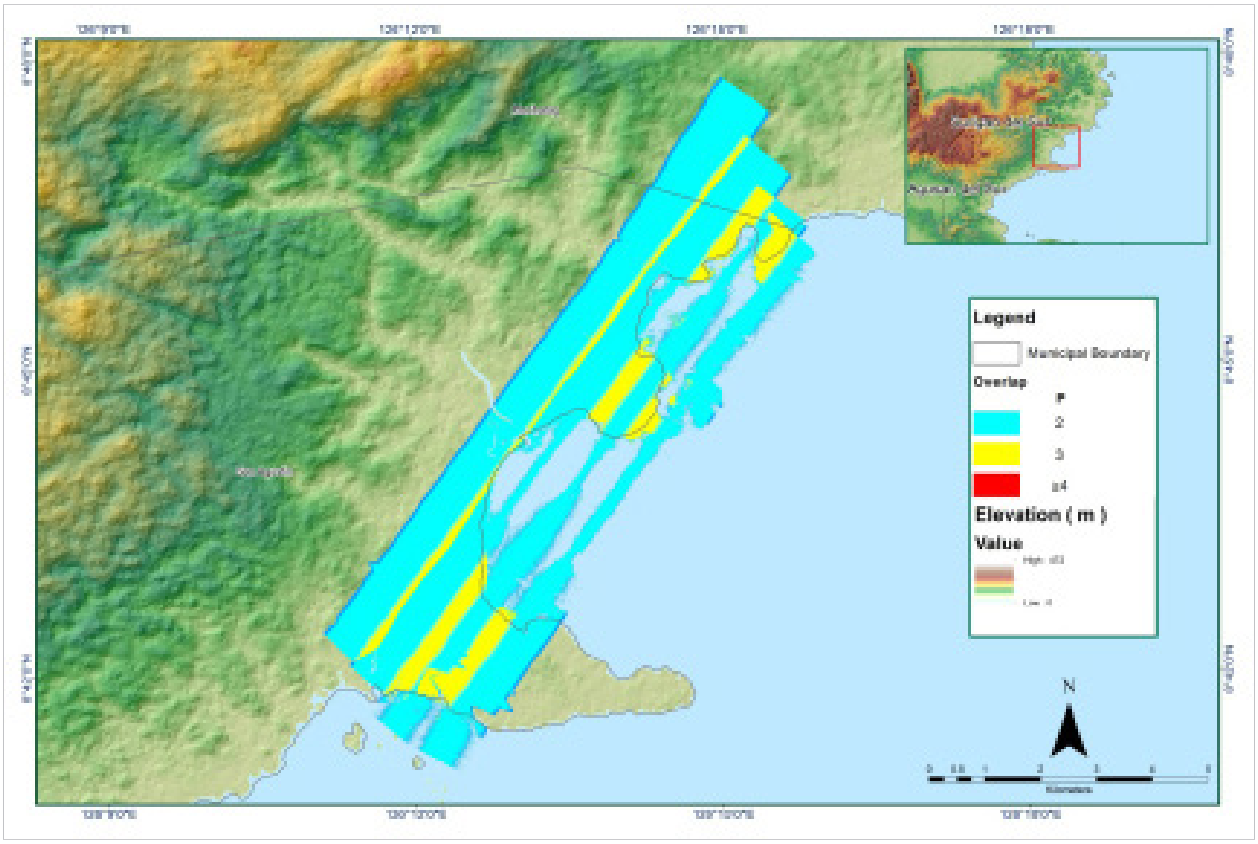


Figure A-8.33 Image of data overlap

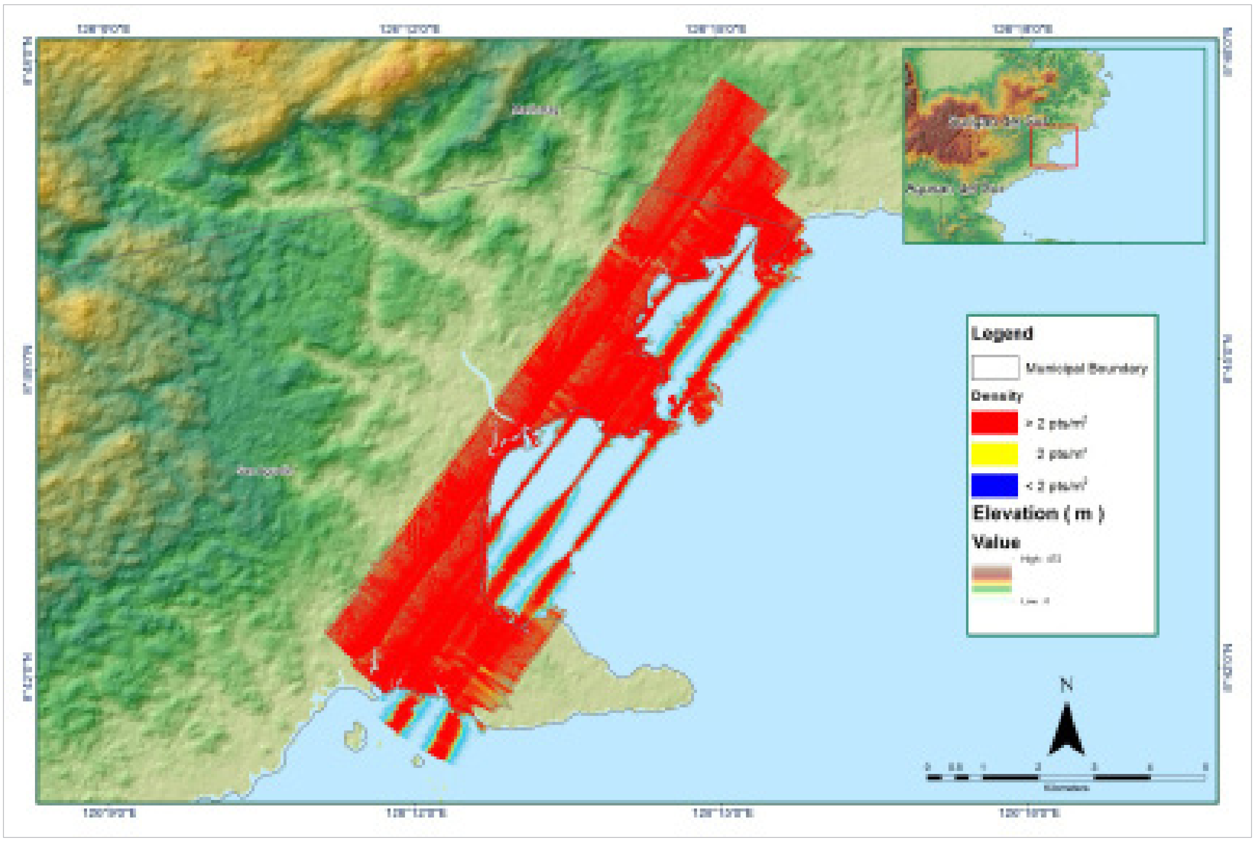


Figure A-8.34 Density Map of merged LiDAR data

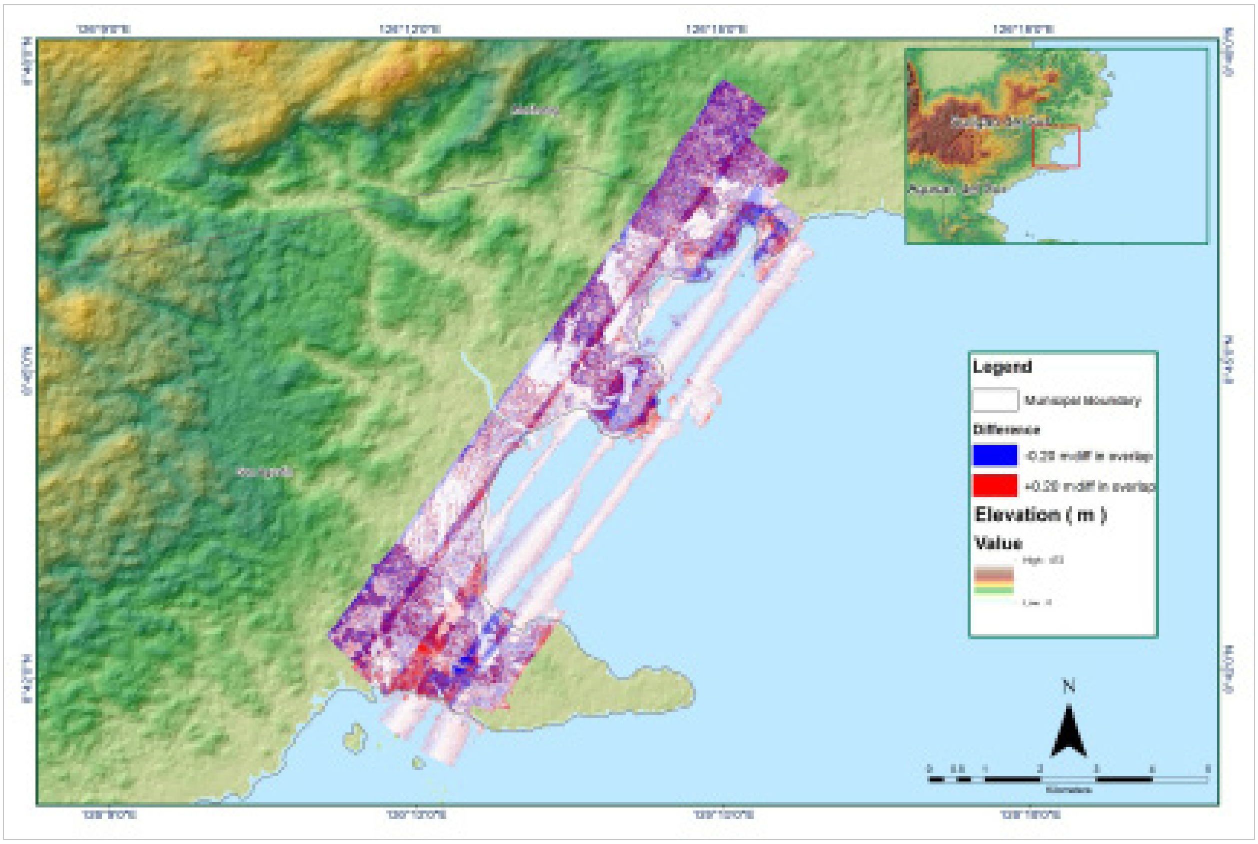


Figure A-8.35 Elevation Difference Between flight lines

Table A-8.6. Mission Summary Report for Mission Blk65F

Flight Area	Tandag
Mission Name	Blk65F
Inclusive Flights	23620P
Range data size	15.2 GB
Base data size	315 MB
POS	202 MB
Image	NA
Transfer date	January 6, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.80
RMSE for East Position (<4.0 cm)	1.95
RMSE for Down Position (<8.0 cm)	3.27
Boresight correction stdev (<0.001deg)	0.001319
IMU attitude correction stdev (<0.001deg)	0.001098
GPS position stdev (<0.01m)	0.0130
Minimum % overlap (>25)	0.55
Ave point cloud density per sq.m. (>2.0)	1.82
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	38
Maximum Height	152.61 m
Minimum Height	66.5 m
Classification (# of points)	
Ground	12,528,426
Low vegetation	11,331,749
Medium vegetation	9,431,920
High vegetation	20,774,167
Building	587,718
Ortophoto	No
Processed by	

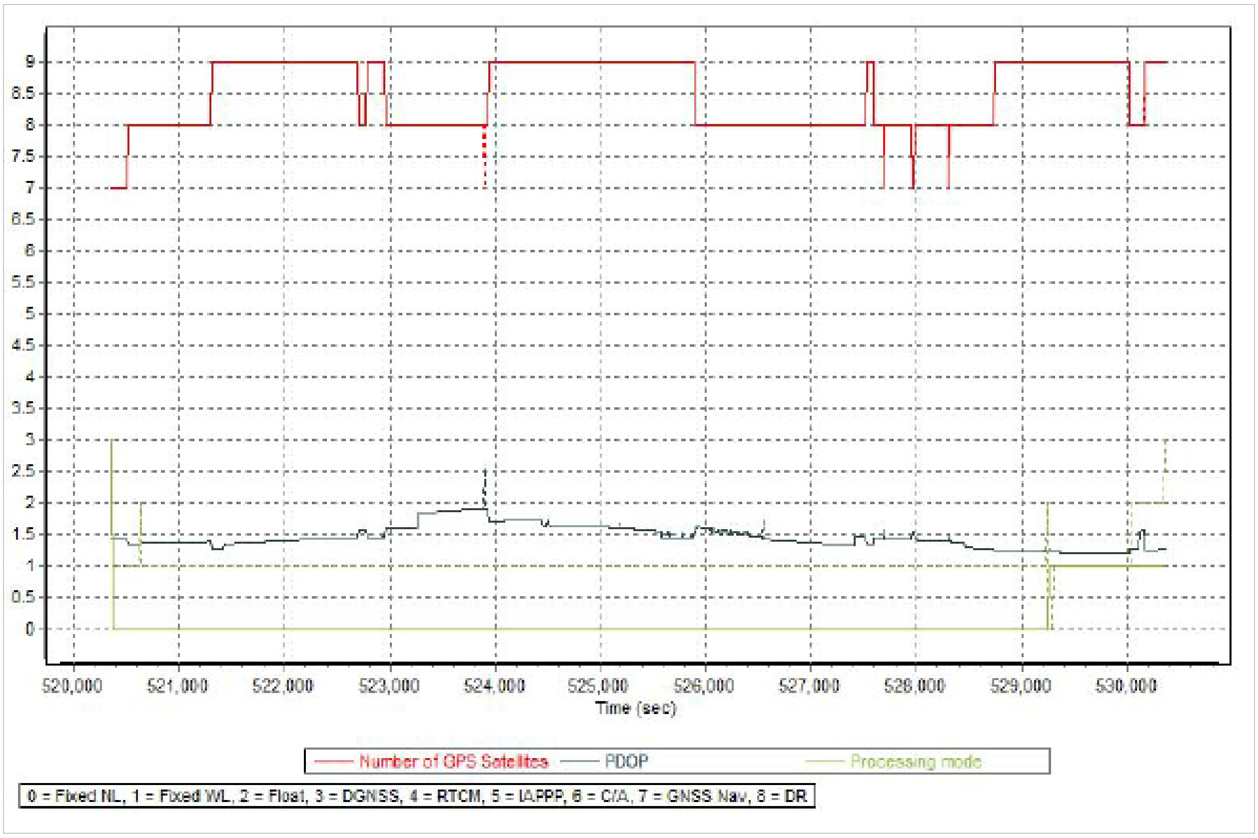


Figure A-8.36. Solution Status

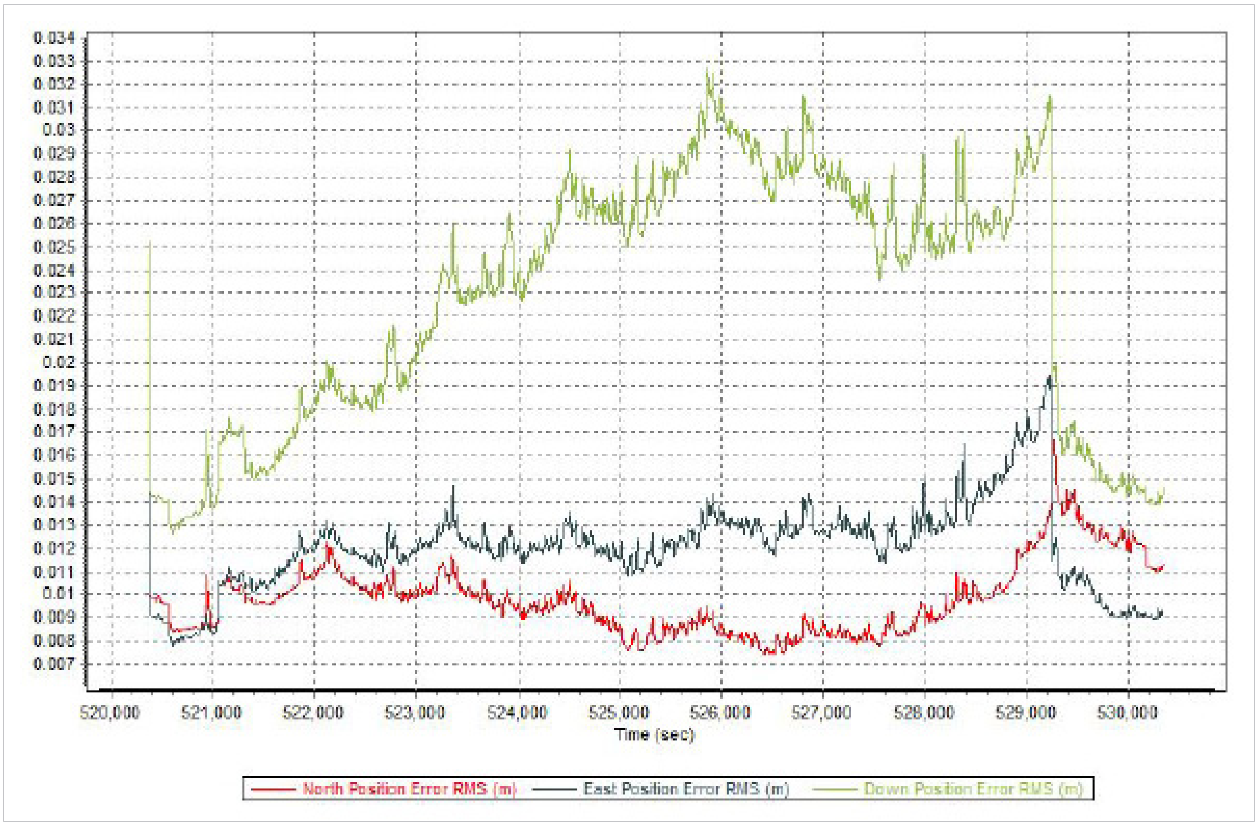


Figure A-8.37. Smoothed Performance Metric Parameters

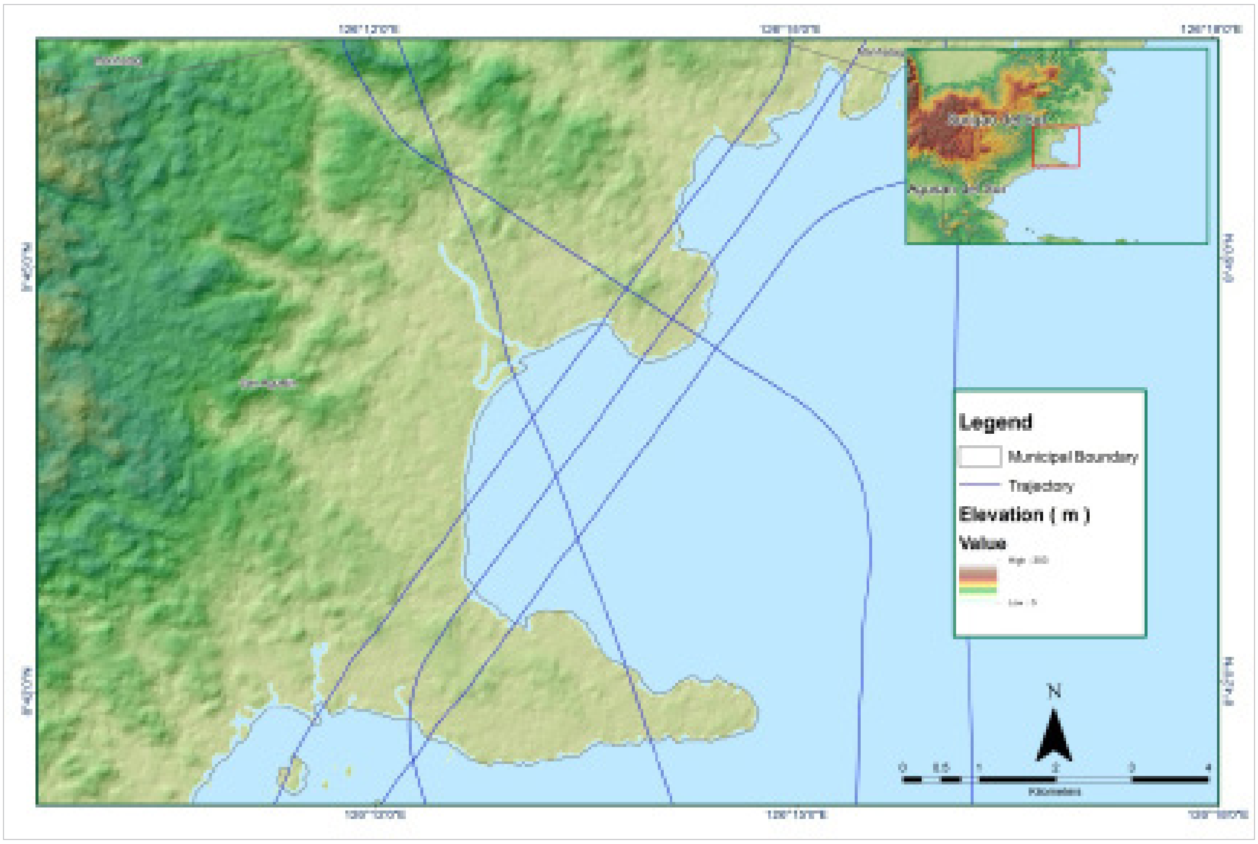


Figure A-8.38 Best Estimated Trajectory

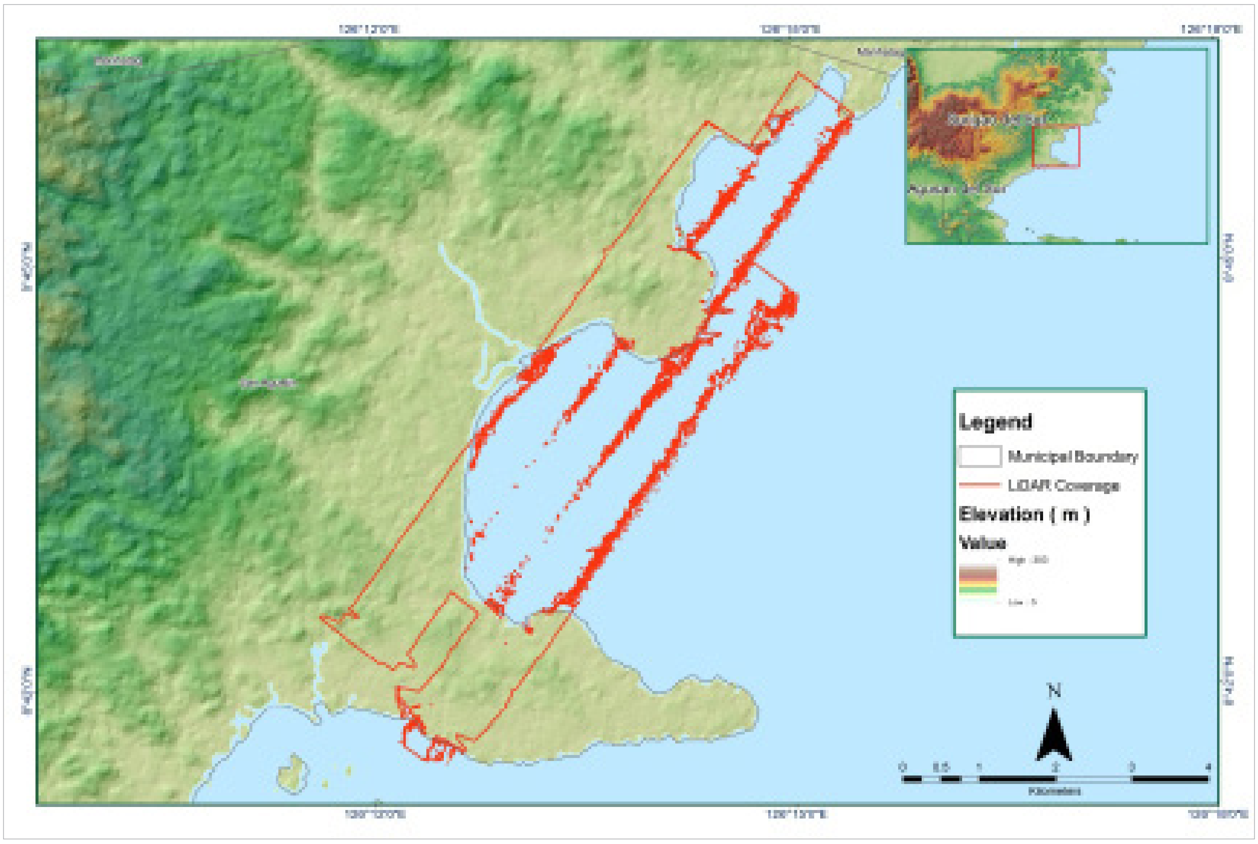


Figure A-8.39 Coverage of LiDAR data

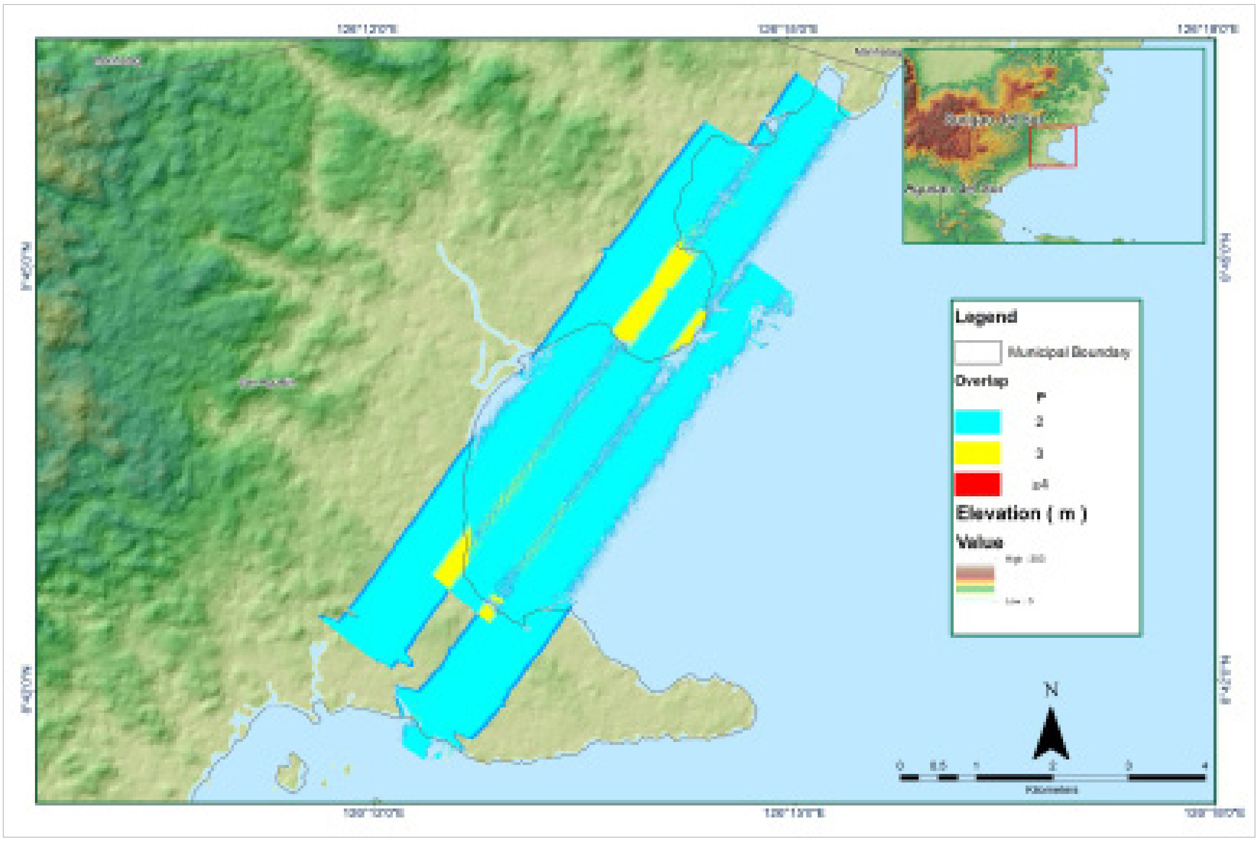


Figure A-8.40 Image of data overlap

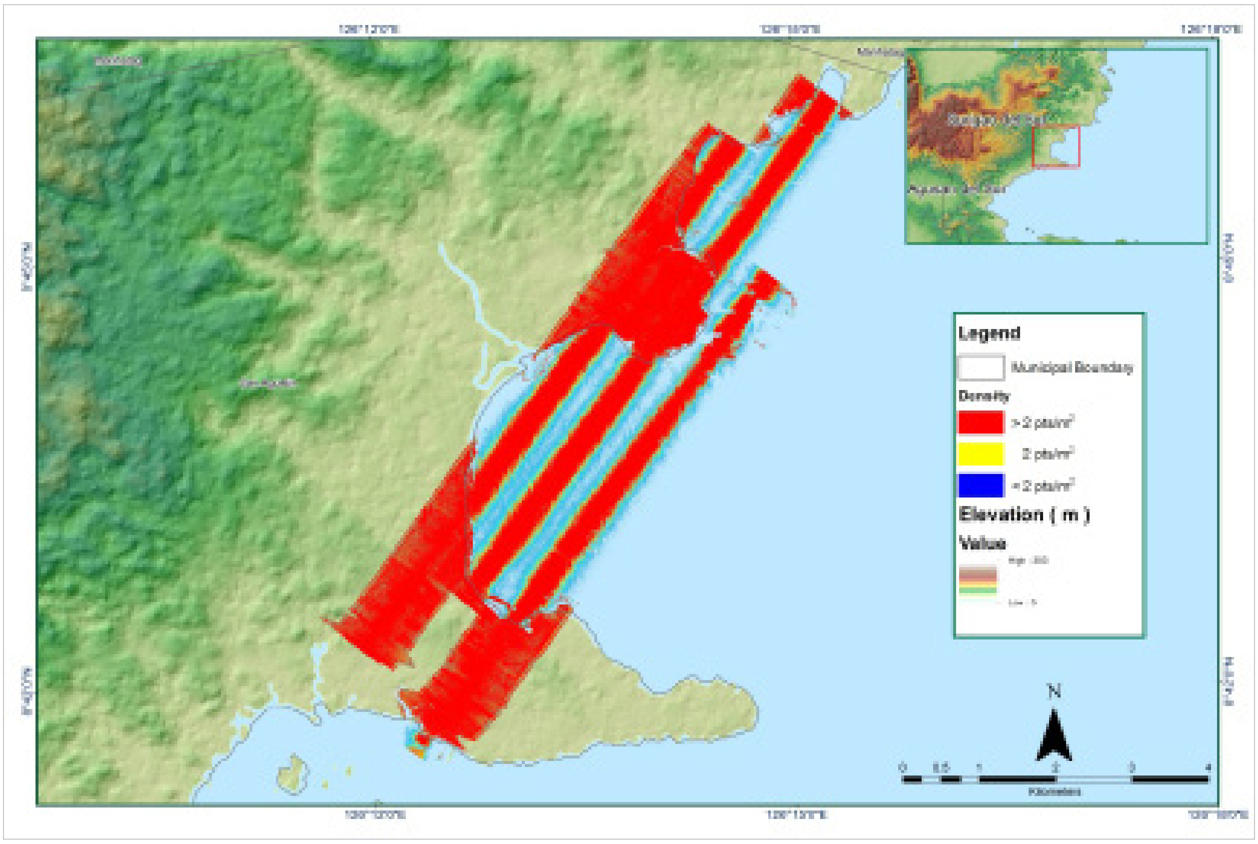


Figure A-8.41 Density Map of merged LiDAR data

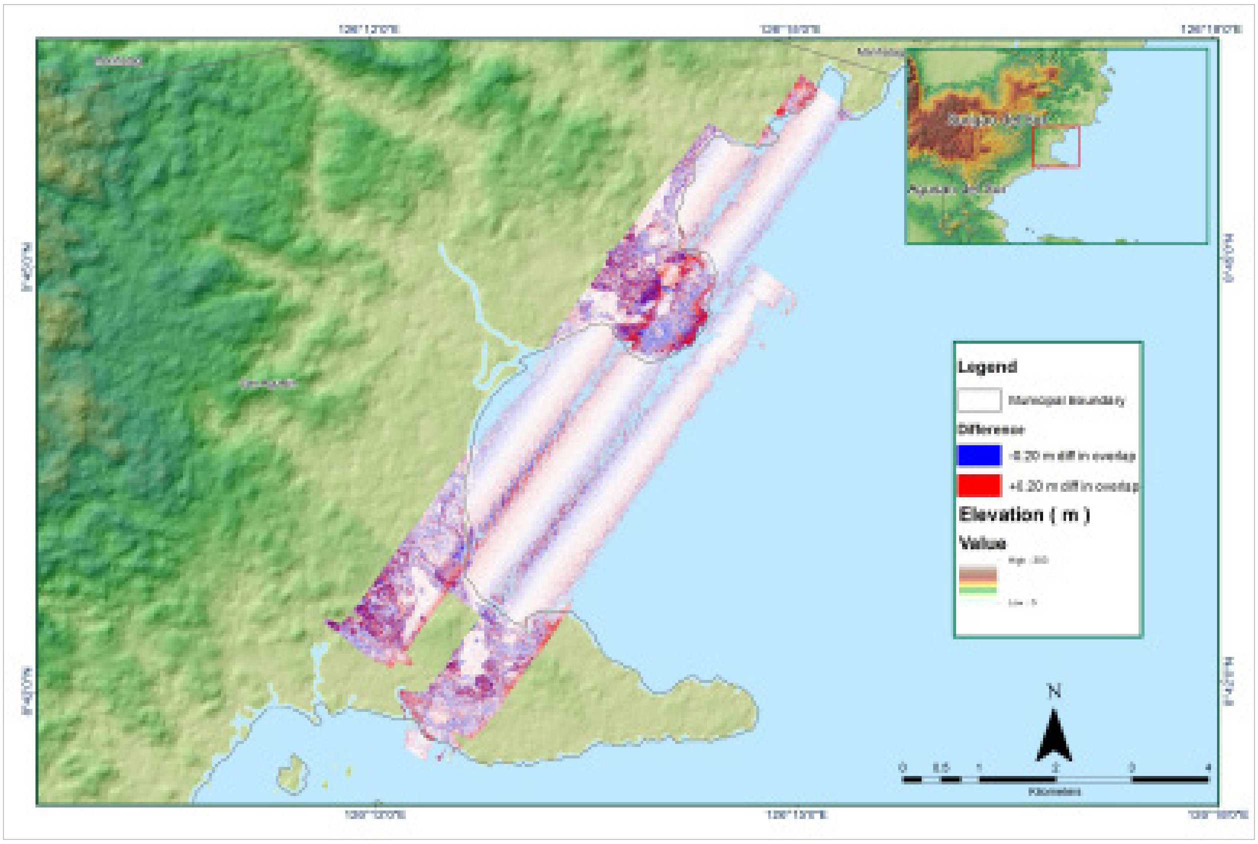


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7. Mission Summary Report for Mission Blk65F_additional

Flight Area	Tandag
Mission Name	Blk65F_additional
Inclusive Flights	23640P
Range data size	13.7 GB
Base data size	273 MB
POS	163 MB
Image	NA
Transfer date	January 6, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.59
RMSE for East Position (<4.0 cm)	1.59
RMSE for Down Position (<8.0 cm)	3.50
Boresight correction stdev (<0.001deg)	0.000861
IMU attitude correction stdev (<0.001deg)	0.010847
GPS position stdev (<0.01m)	0.0220
Minimum % overlap (>25)	NA
Ave point cloud density per sq.m. (>2.0)	2.68
Elevation difference between strips (<0.20 m)	YES
Number of 1km x 1km blocks	24
Maximum Height	184.49 m
Minimum Height	57.69 m
Classification (# of points)	
Ground	3,462,027
Low vegetation	1,390,696
Medium vegetation	6,281,842
High vegetation	5,002,447
Building	99,942
Ortophoto	No
Processed by	

Figure A-8.43. Solution Status

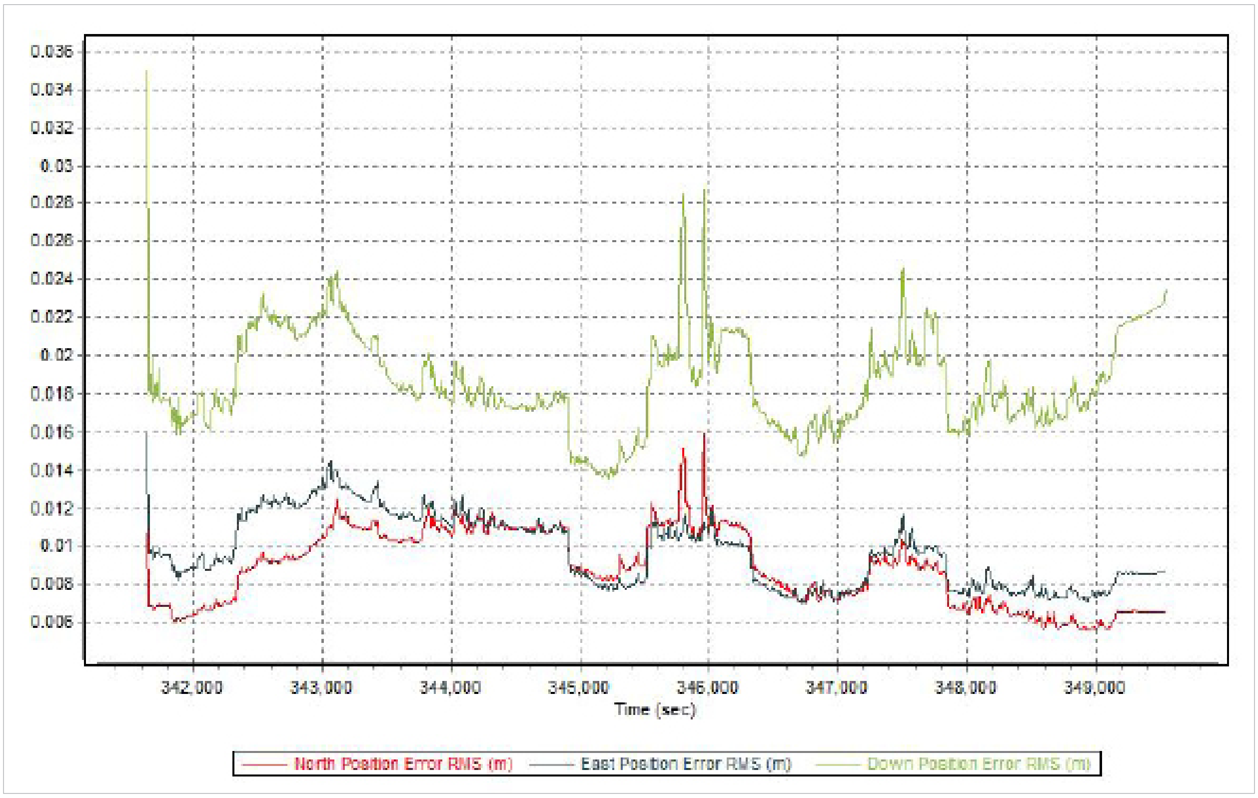


Figure A-8.44. Smoothed Performance Metric Parameters

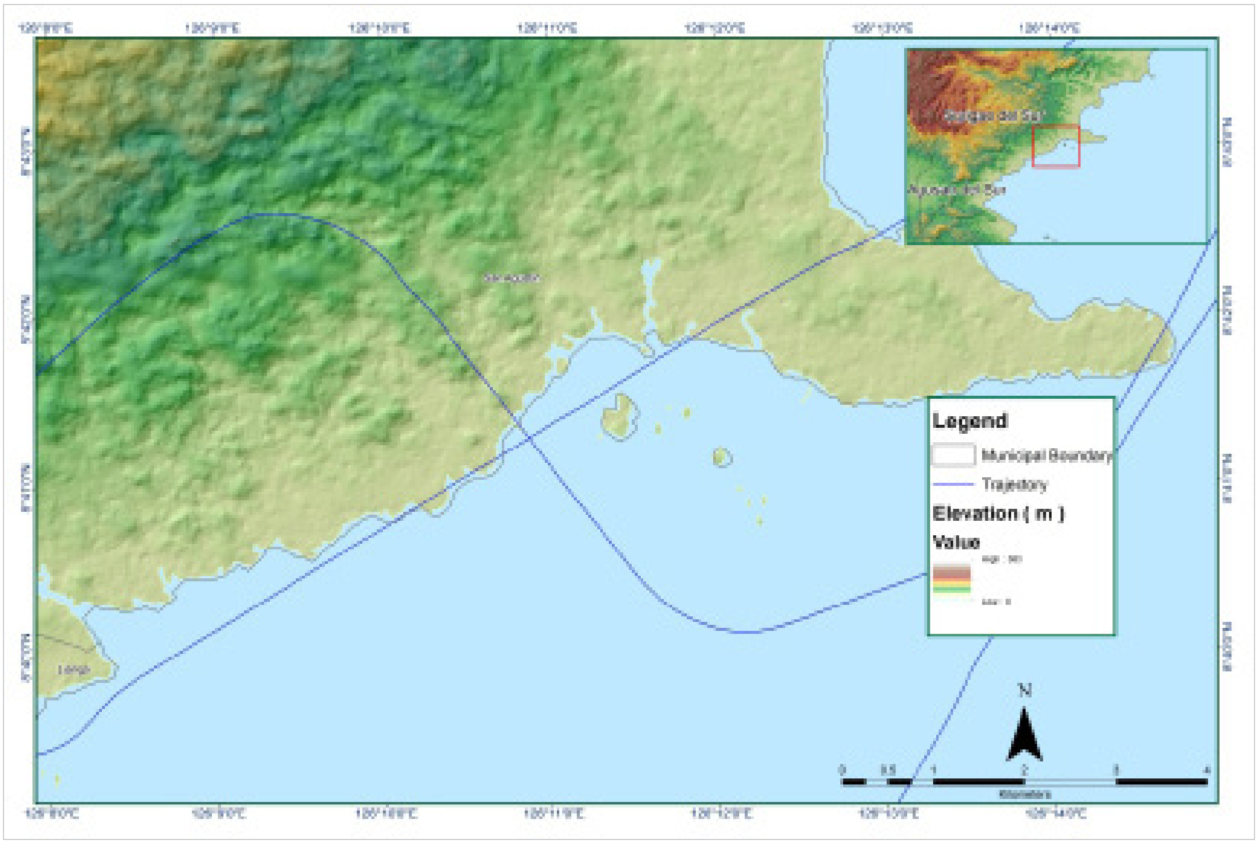


Figure A-8.45 Best Estimated Trajectory

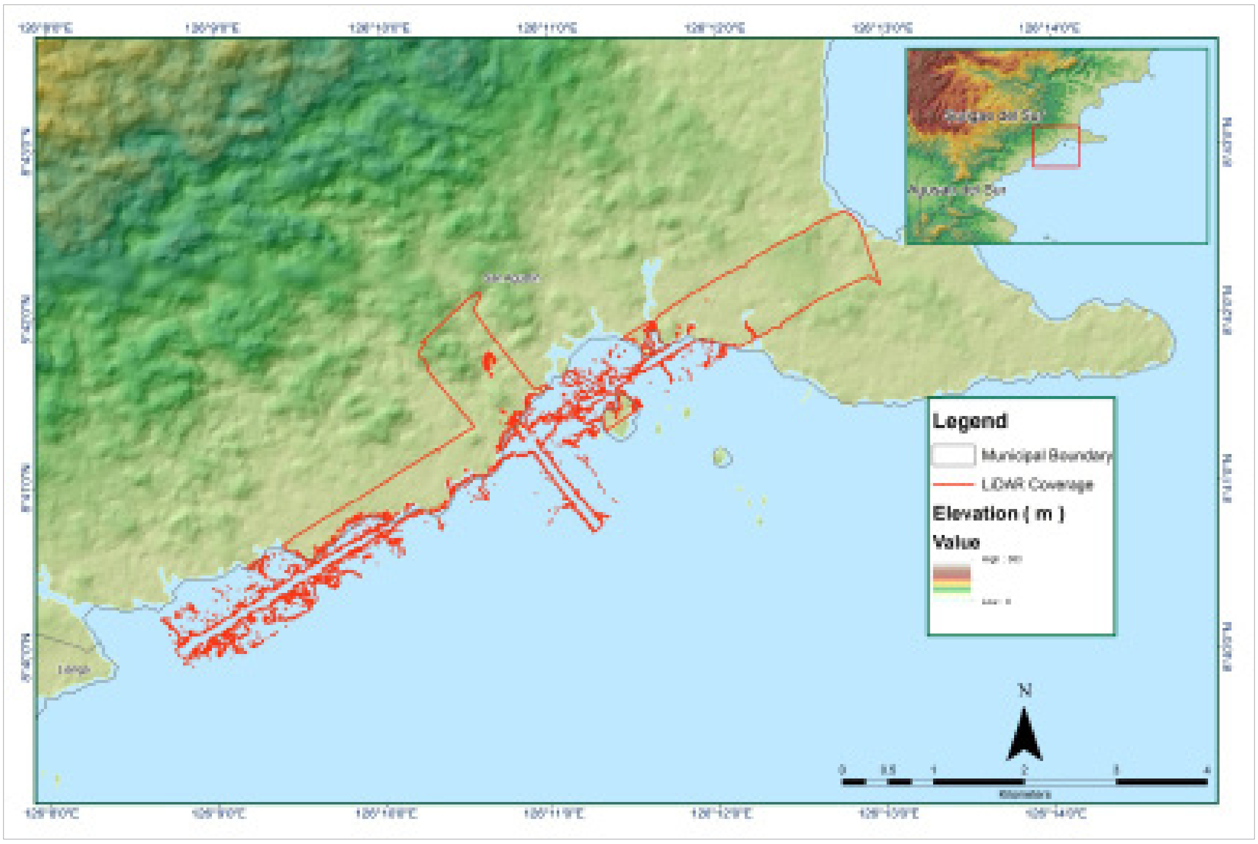


Figure A-8.46 Coverage of LiDAR data

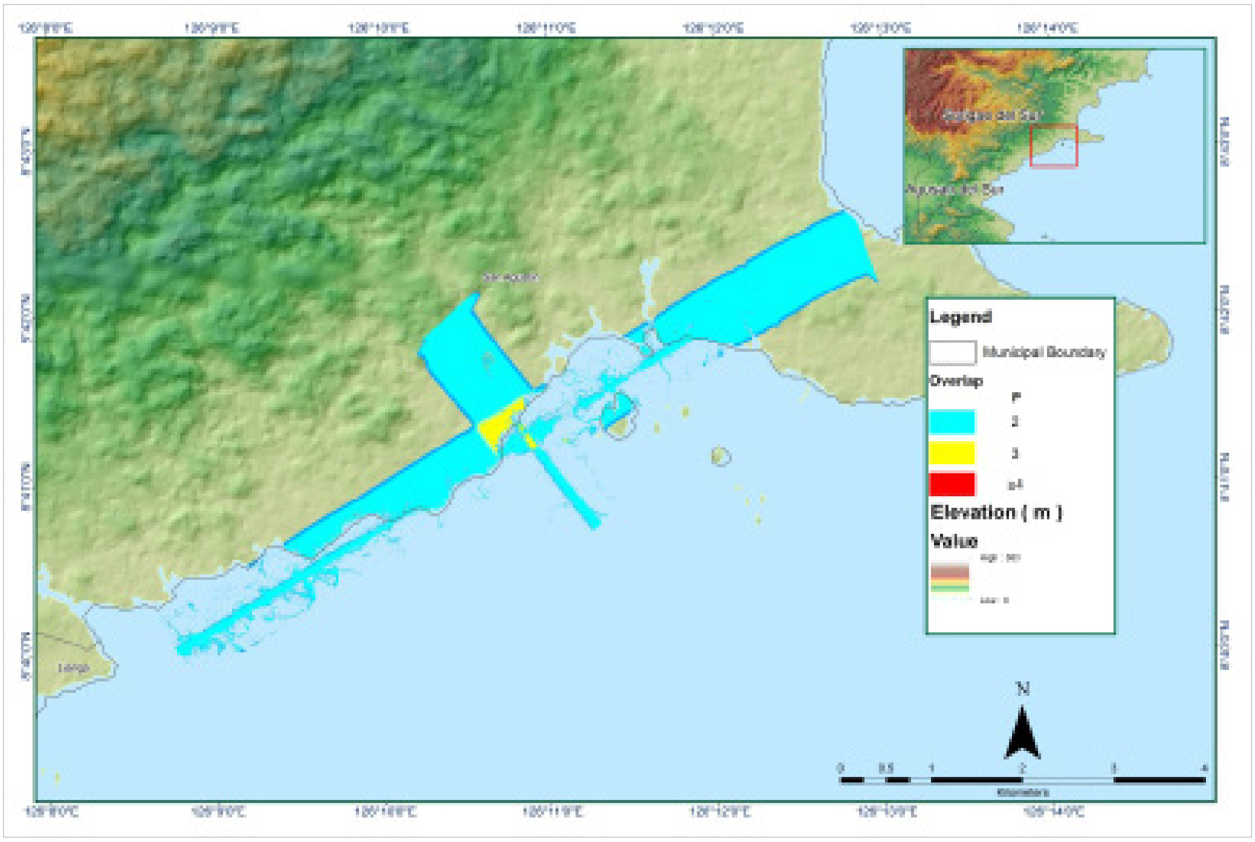


Figure A-8.47 Image of data overlap

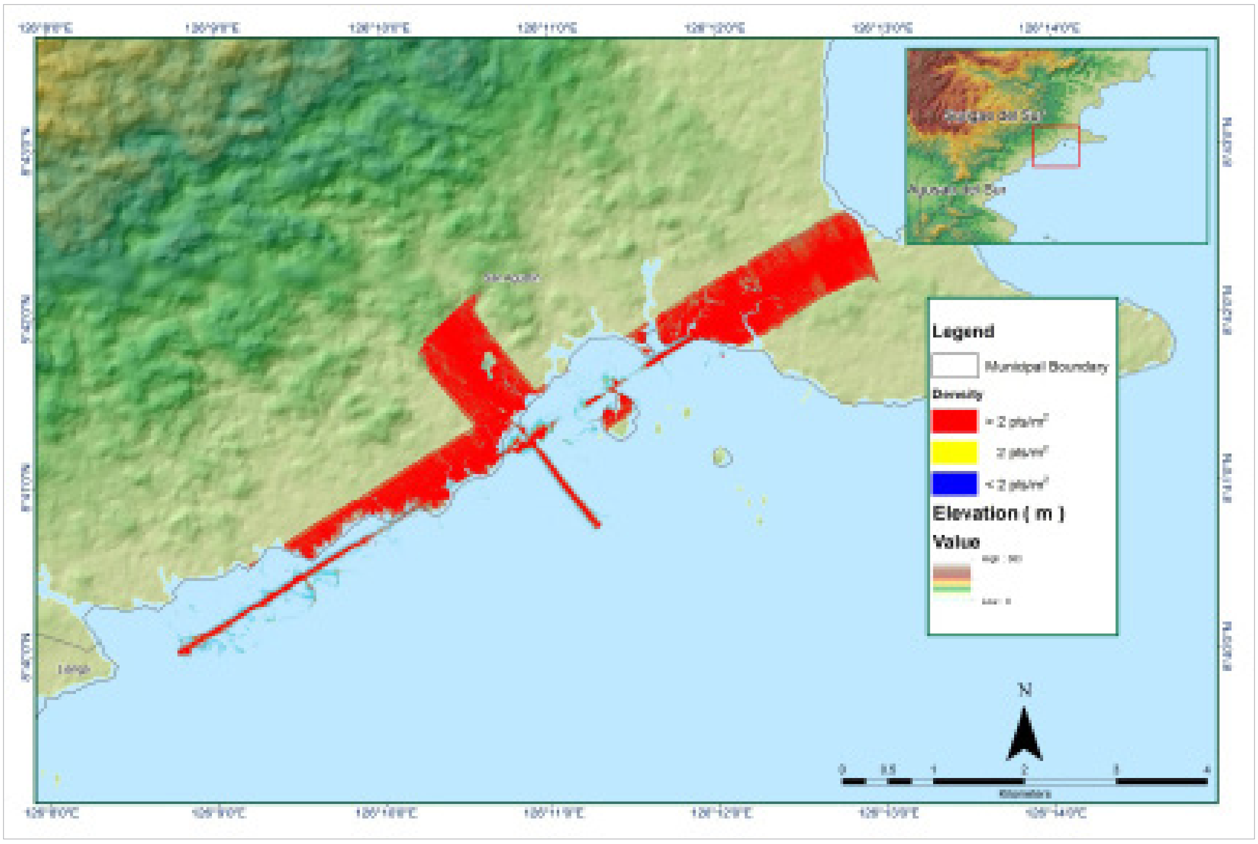


Figure A-8.48 Density Map of merged LiDAR data

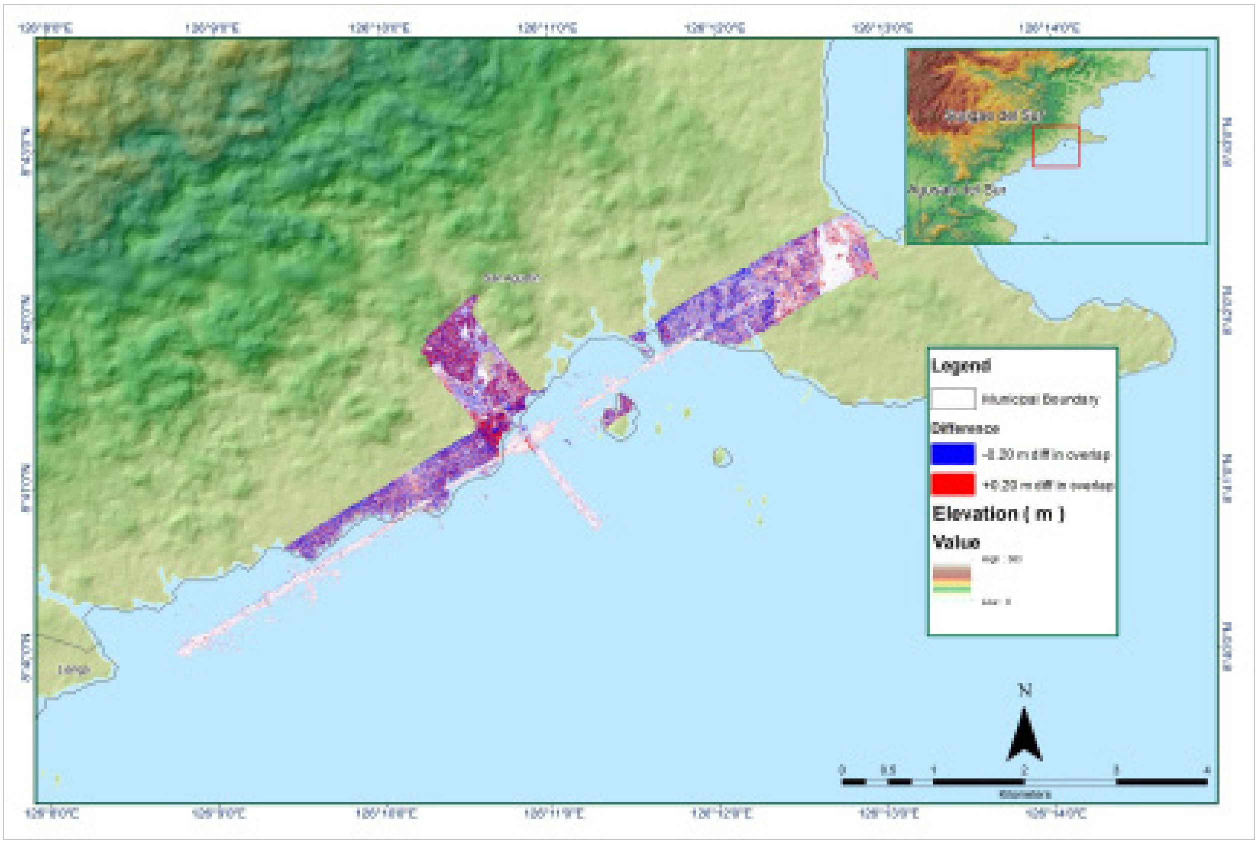


Figure A-8.49 Elevation Difference Between flight lines

ANNEX 9. Ibajay Model Basin Parameters

Table A-9.1. Ibajay Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W180	4.1491905	46.705	0	6.8679	4.802625	Discharge	3.580591	0.9991	Ratio to Peak	0.9998
W190	6.707064	47.601	0	2.02033	1.42845	Discharge	1.212487	0.9991	Ratio to Peak	0.9998
W200	7.418775	45.606	0	1.52464	1.0779	Discharge	0.168023	0.9991	Ratio to Peak	0.9998
W210	7.4767875	45.451	0	1.688765	1.194	Discharge	0.916467	0.9991	Ratio to Peak	0.9998
W220	7.52934	45.311	0	5.400135	3.81795	Discharge	3.672836	0.9991	Ratio to Peak	0.9998
W230	5.767125	46.774	0	1.661335	1.7511	Discharge	0.15328	0.9991	Ratio to Peak	0.9998
W240	6.4636	48.326	0	1.476215	1.0437	Discharge	0.309434	0.9991	Ratio to Peak	0.9998
W250	6.3857	44.988	0	4.00036	2.829075	Discharge	1.936241	0.9991	Ratio to Peak	0.9998
W260	6.406	44.93	0	2.326935	3.666075	Discharge	1.140605	0.9991	Ratio to Peak	0.9998
W270	6.4623	48.33	0	3.02094	2.13585	Discharge	2.174619	0.9991	Ratio to Peak	0.9998
W280	6.5087295	48.19	0	2.426645	1.715625	Discharge	0.594625	0.9991	Ratio to Peak	0.9998
W290	6.9048525	47.028	0	3.46437	2.44935	Discharge	1.779728	0.9991	Ratio to Peak	0.9998
W300	6.742554	47.497	0	1.348425	0.9534	Discharge	0.31992	0.9991	Ratio to Peak	0.9998
W310	7.0236075	46.692	0	1.895595	1.340175	Discharge	0.990198	0.9991	Ratio to Peak	0.9998
W320	7.063875	46.5	0	1.97418	1.39575	Discharge	1.132022	0.9991	Ratio to Peak	0.9998
W330	6.889155	47.074	0	1.8122	1.281225	Discharge	1.012519	0.9991	Ratio to Peak	0.9998
W340	6.5102	48.186	0	4.110405	2.9061	Discharge	1.56042	0.9991	Ratio to Peak	0.9998

ANNEX 10. Ibajay Model Reach Parameters

Table A-10.1. Ibajay Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	8394.3	0.0070951	0.09	Trapezoid	74.02	1
R30	Automatic Fixed Interval	1579.5	0.0129697	0.09	Trapezoid	74.02	1
R50	Automatic Fixed Interval	6116.6	0.0064787	0.09	Trapezoid	74.02	1
R60	Automatic Fixed Interval	1125.3	0.0293639	0.09	Trapezoid	74.02	1
R80	Automatic Fixed Interval	1326.3	0.0418082	0.09	Trapezoid	74.02	1
R100	Automatic Fixed Interval	3146.6	0.0050274	0.09	Trapezoid	74.02	1
R120	Automatic Fixed Interval	2066	0.04035	0.09	Trapezoid	74.02	1
R140	Automatic Fixed Interval	4944.6	0.0565223	0.09	Trapezoid	74.02	1

ANNEX 11. Ibajay Field Validation Points

Table A-11.1. Ibajay Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
0	11.04404016	122.0643791	0.090000004	0.3	0.044	FRANK	100-Year
1	11.04719627	122.0663977	0.349999994	0.4	0.003	FRANK	100-Year
2	11.06351053	122.0677705	0.039999999	1.2	1.346	FRANK	100-Year
3	11.00539743	122.0456257	0.129999995	0.9	0.593	FRANK	100-Year
4	11.02699656	122.0551218	0.039999999	0.35	0.096	FRANK	100-Year
5	11.04017385	122.0687581	0.050000001	0.35	0.090	FRANK	100-Year
6	10.95677243	122.0074533	0.129999995	0.3	0.029	FRANK	100-Year
7	11.06796347	122.0646525	0.230000004	0.4	0.029	FRANK	100-Year
8	10.94428104	121.9983045	0.029999999	6	35.641	FRANK	100-Year
9	11.00387028	122.1306623	0.079999998	4	15.366	FRANK	100-Year
10	11.00514439	122.129631	1.980000019	4	4.080	FRANK	100-Year
11	11.00990291	122.0634626	0.200000003	6	33.640	FRANK	100-Year
12	11.06532562	122.0816394	0.029999999	5	24.701	FRANK	100-Year
13	10.97468923	122.0217892	0.050000001	4	15.602	FRANK	100-Year
14	11.04346102	122.0638124	0.029999999	5.57	30.692	FRANK	100-Year
15	11.04348437	122.0613686	0.159999996	6	34.106	FRANK	100-Year
16	11.00606276	122.0470849	0.029999999	5	24.701	FRANK	100-Year
17	11.06772967	122.0827564	0.029999999	1.25	1.488	FRANK	100-Year
18	11.04149721	122.068553	0.029999999	1.4	1.877	YOLANDA	5-Year
19	10.98812702	122.0928609	0.029999999	0.4	0.137	FRANK	100-Year
20	11.01691689	122.0528669	0.029999999	1.5	2.161	YOLANDA	5-Year
21	11.06558671	122.0813709	0.029999999	1	0.941	FRANK	100-Year
22	11.04670697	122.0652931	0.029999999	1.2	1.369	YOLANDA	5-Year
23	11.03026556	122.0566565	0.029999999	1	0.941	FRANK	100-Year
24	11.0069148	122.0498218	0.109999999	3.3	10.176	FRANK	100-Year
25	11.06059115	122.0784158	0.430000007	2	2.465	FRANK	100-Year
26	11.04139844	122.0521073	0.129999995	0.4	0.073	FRANK	100-Year
27	11.062625	122.0801022	0	0.9	0.810	FRANK	100-Year
28	11.04856519	122.0678507	0.319999993	4	13.542	FRANK	100-Year
29	10.9643594	122.0148831	0.079999998	4	15.366	FRANK	100-Year
30	10.9472019	122.033573	0.150000006	5	23.522	FRANK	100-Year
31	10.95911653	122.0094681	0.07	5	24.305	FRANK	100-Year
32	11.047771	122.0657988	0.230000004	1.4	1.369	FRANK	100-Year
33	11.0607562	122.078375	0.07	4	15.445	FRANK	100-Year
34	11.00725319	122.048641	0.029999999	4	15.761	FRANK	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
35	11.02790262	122.0567448	0.129999995	1.3	1.369	FRANK	100-Year
36	11.0186245	122.0524383	0.400000006	0	0.160	YOLANDA	5-Year
37	11.02249607	122.0490881	0.029999999	0	0.001	YOLANDA	5-Year
38	10.98090202	122.0297158	0.140000001	0	0.020	YOLANDA	5-Year
39	11.00986712	122.0640066	0.140000001	0.52	0.144	MARCE	5-Year
40	11.04588023	122.0511686	0.100000001	1.7	2.560	FRANK	100-Year
41	11.01102341	122.0621546	0.529999971	1.09	0.314	FRANK	100-Year
42	11.01053478	122.0655382	0.100000001	0.75	0.422	YOLANDA	5-Year
43	11.02196988	122.0473721	0.029999999	0.38	0.123	YOLANDA	5-Year
44	11.00339685	122.1306646	0.140000001	0.72	0.336	FRANK	100-Year
45	10.98151275	122.0302327	0.029999999	0.08	0.003	MARCE	5-Year
46	11.04558119	122.0598263	0.129999995	1.778	2.716	FRANK	100-Year
47	10.97746062	122.0243589	0.170000002	0.13	0.002	YOLANDA	5-Year
48	11.00458605	122.1295053	0.029999999	1.1	1.145	FRANK	100-Year
49	11.05069275	122.0495481	0.189999998	1.0414	0.725	FRANK	100-Year
50	11.02284123	122.0491835	0.029999999	1.8542	3.328	FRANK	100-Year
51	11.00551415	122.1304933	0.519999981	1.0414	0.272	FRANK	100-Year
52	11.00059276	122.0839586	0.029999999	1.4	1.877	FRANK	100-Year
53	11.0223437	122.0495761	0.519999981	1.8288	1.713	FRANK	100-Year
54	11.0045539	122.1300589	0.270000011	2.032	3.105	FRANK	100-Year
55	11.02741051	122.055324	0.029999999	2.159	4.533	YOLANDA	5-Year
56	11.00298074	122.1308145	0.029999999	0.9	0.757	FRANK	100-Year
57	11.06623469	122.0665362	0.310000002	1.1	0.624	YOLANDA	5-Year
58	11.06617004	122.0661093	0.029999999	2.4384	5.800	FRANK	100-Year
59	11.04290752	122.067271	0.029999999	3.048	9.108	FRANK	100-Year
60	11.0443049	122.06588	0.140000001	2.7432	6.777	FRANK	100-Year
61	11.00978012	122.0666671	0.029999999	2.159	4.533	YOLANDA	5-Year
62	11.01965115	122.051459	0	2.1336	4.552	FRANK	100-Year
63	11.04550668	122.0652323	0	2.1336	4.552	FRANK	100-Year
64	11.00056741	122.0838646	0.400000006	1.4	1.000	FRANK	100-Year
65	11.01065581	122.0651629	0.5	0.65	0.023	ONDOY	5-Year
66	11.04641037	122.0592663	0	0.65	0.423	ONDOY	5-Year
67	11.01834642	122.0521678	0.059999999	2.84	7.728	FRANK	100-Year
68	11.01912883	122.0519958	0.419999987	2.21	3.204	ONDOY	5-Year
69	10.95756417	122.0085821	0	1.02	1.040	FRANK	100-Year
70	11.08717759	122.0483329	0.300000012	2.84	6.452	FRANK	100-Year
71	10.96952395	122.0702749	0	2.84	8.066	FRANK	100-Year
72	10.93302146	122.0299397	0.519999981	1.02	0.250	FRANK	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
73	11.00447685	122.0714727	0	2.84	8.066	FRANK	100-Year
74	11.02724908	122.0515141	0.75	2.21	2.132	ONDOY	5-Year
75	11.01931613	122.0511899	0	2.84	8.066	FRANK	100-Year
76	11.01081041	122.0641007	0	2.21	4.884	ONDOY	5-Year
77	11.0787808	122.0864507	0	2.84	8.066	FRANK	100-Year
78	11.06489892	122.080985	0	0	0.000	YOLANDA	5-Year
79	11.01820445	122.0517452	0.239999995	0	0.058	YOLANDA	5-Year
80	11.01793002	122.052489	0.670000017	0.18	0.240	YOLANDA	5-Year
81	11.01766187	122.0520374	0.360000014	0.16	0.040	YOLANDA	5-Year
82	10.98374448	122.0293631	1.480000019	0.1	1.904	UNDANG	5-Year
83	11.00303965	122.1308857	0.059999999	0.18	0.014	YOLANDA	5-Year
84	11.04328321	122.0589588	0.340000004	0.18	0.026	YOLANDA	5-Year
85	11.07132661	122.0611982	0.889999986	0.18	0.504	YOLANDA	5-Year
86	11.07236273	122.0612561	1.049999952	0.18	0.757	YOLANDA	5-Year
87	11.00475658	122.1306831	0	0.18	0.032	YOLANDA	5-Year
88	11.01092881	122.0640487	1.200000048	0.18	1.040	YOLANDA	5-Year
89	11.00361797	122.1313115	1.120000005	0.18	0.884	YOLANDA	5-Year
90	10.9562659	122.0072416	0	0.18	0.032	YOLANDA	5-Year
91	11.02647552	122.0551956	0	0.18	0.032	YOLANDA	5-Year
92	10.95728511	122.0084105	0.029999999	0.18	0.023	YOLANDA	5-Year
93	11.01771548	122.0515164	0	0.18	0.032	YOLANDA	5-Year
94	11.04570445	122.0595503	0.730000019	0.18	0.303	YOLANDA	5-Year
95	11.04048376	122.0698528	0	0.18	0.032	YOLANDA	5-Year
96	11.0058659	122.1299482	0.029999999	0.18	0.023	YOLANDA	5-Year
97	11.045929	122.0659367	0.310000002	0.18	0.017	YOLANDA	5-Year
98	11.03307078	122.0574816	0.029999999	0.18	0.023	YOLANDA	5-Year
99	11.00378924	122.1312014	0.029999999	0.18	0.023	YOLANDA	5-Year
100	11.00405804	122.1304097	0	0.18	0.032	YOLANDA	5-Year
101	11.02263259	122.0475884	1.700000048	0.18	2.310	YOLANDA	5-Year
102	11.0228817	122.0481969	1.450000048	0.18	1.613	YOLANDA	5-Year
103	11.02297139	122.0475469	1.299999952	0.18	1.254	YOLANDA	5-Year
104	10.93902928	122.00096	0	0.18	0.032	YOLANDA	5-Year
105	11.04839076	122.0504137	0	0.18	0.032	YOLANDA	5-Year
106	11.0184566	122.0527233	0	0.18	0.032	YOLANDA	5-Year
107	10.96238128	122.0129551	0	0.18	0.032	YOLANDA	5-Year
108	11.01683328	122.0514692	0	0.18	0.032	YOLANDA	5-Year
109	10.93818813	122.0004052	0	0.18	0.032	YOLANDA	5-Year
110	10.95733435	122.0089883	0	0.18	0.032	YOLANDA	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
111	11.00617698	122.0423088	0	0.18	0.032	YOLANDA	5-Year
112	10.99594444	122.0376456	0	0.18	0.032	YOLANDA	5-Year
113	11.09183229	122.0491072	0	5	25.000	FRANK	100-Year
114	11.00337	122.1152199	0	5	25.000	FRANK	100-Year
115	10.95301962	122.0467185	0	6	36.000	FRANK	100-Year
116	11.01227141	122.0749224	0	6	36.000	FRANK	100-Year
117	11.07317951	122.0596864	0	6	36.000	FRANK	100-Year
118	11.06323004	122.0803316	0	6	36.000	FRANK	100-Year
119	11.00741574	122.04953	0	6	36.000	FRANK	100-Year
120	11.04462489	122.0666026	0	6	36.000	FRANK	100-Year
121	11.04654608	122.0510006	0	6	36.000	FRANK	100-Year
122	11.00747152	122.0490977	0	1.0922	1.193	FRANK	100-Year
123	11.07236169	122.0599095	0	0.6858	0.470	FRANK	100-Year
124	10.9882584	122.0932951	0	0.762	0.581	FRANK	100-Year
125	11.07423165	122.0589754	0	0.508	0.258		
126	11.04099561	122.0599162	0	0.9906	0.981	FRANK	100-Year
127	11.04154949	122.0598305	0	0.4318	0.186	UNDANG	5-Year
128	10.95831095	122.0091025	0	0.8	0.640	FRANK	100-Year
129	11.04110331	122.0600576	0	1.905	3.629	FRANK	100-Year
130	10.93912026	122.0005094	0	0.9906	0.981	FRANK	100-Year
131	11.0635018	122.0804025	0	0.8001	0.640	FRANK	100-Year
132	11.06543641	122.0670378	0	1.016	1.032	FRANK	100-Year
133	10.98129457	122.0300494	0	1	1.000	FRANK	100-Year
134	11.04590623	122.066167	1.139999986	0.4318	0.502	ONDANG	5-Year
135	10.96132227	122.0116239	4.179999828	0.8636	10.999	FRANK	100-Year
136	10.98090285	122.0272562	9.029999733	1.3716	58.651	FRANK,	100-Year
137	10.9856868	122.0304904	8.369999886	0.7112	58.657	FRANK	100-Year
138	10.98839633	122.0932863	5.980000019	1.7272	18.086	FRANK	100-Year
139	10.98111316	122.0270303	3.859999895	1.8288	4.126	FRANK	100-Year
140	10.98239872	122.0281314	3.690000057	0.9144	7.704	FRANK	100-Year
141	11.07910275	122.0869321	8.149999619	0.9144	52.354	FRANK	100-Year
142	10.96344521	122.013216	6.570000172	2.032	20.593	FRANK	100-Year
144	11.01676874	122.0520638	6	0.9144	25.863	FRANK	100-Year
145	11.04401352	122.0675853	1.679999948	1.5748	0.011	FRANK	100-Year
146	10.97709184	122.023969	7.460000038	0.9144	42.845	FRANK	100-Year
147	10.98109472	122.0267944	8.489999771	2.032	41.706	FRANK	100-Year
148	11.05691499	122.0747468	8.350000381	0.8255	56.618	FRANK	100-Year
149	10.98080224	122.029657	0.319999993	1.524	1.450	FRANK	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
150	11.04072998	122.0597225	6.849999905	0.2286	43.843	FRANK	100-Year
151	10.97971731	122.0264843	7.429999828	1.8	31.697	FRANK	100-Year
152	11.04168683	122.0595851	6.869999886	1.27	31.360	FRANK	100-Year
153	11.00440142	122.1284697	6.429999828	0	41.345	FRANK	100-Year
154	11.01243081	122.0462698	7.78000021	0.4	54.464	FRANK	100-Year
155	11.00646542	122.0476812	0	1.42	2.016	FRANK	100-Year
156	10.98157903	122.0306475	5.96999979	0	35.641	FRANK	100-Year
157	11.06512587	122.0670823	3.450000048	1.4	4.203	FRANK	100-Year
158	10.98146296	122.030666	7.420000076	0.5	47.886	FRANK	100-Year
159	11.0794905	122.0862415	6.150000095	1.07	25.806	FRANK	100-Year
160	10.98103898	122.0268701	6.679999828	1.04	31.810	FRANK	100-Year
161	10.97966006	122.0268104	3.730000019	0.4	11.089	FRANK	100-Year
162	10.9804275	122.0271406	5.710000038	1.4	18.576	FRANK	100-Year
163	11.08405689	122.0699887	7.96999979	1.8	38.069	FRANK	100-Year
164	10.97967395	122.0268262	6.960000038	0	48.442	FRANK	100-Year
165	10.98107147	122.0275426	8.229999542	1.07	51.266	FRANK	100-Year
166	11.07942484	122.0861501	3.450000048	0.77	7.182	FRANK	100-Year
167	11.04593258	122.0664922	8.390000343	1.72	44.489	FRANK	100-Year
168	11.08353347	122.069716	0.029999999	1.8	3.133	FRANK	100-Year
169	11.08398962	122.0701109	0	1.04	1.082	FRANK	100-Year
170	11.06499585	122.0671901	0.029999999	1.8	3.133	FRANK	100-Year
171	10.9811327	122.0269276	0.029999999	1.25	1.488	FRANK	100-Year
172	11.07497908	122.0582821	0.050000001	1.04	0.980	FRANK	100-Year
173	10.97990772	122.0270326	0.159999996	1.8	2.690	FRANK	100-Year
174	10.9409221	122.0022297	0.029999999	1.25	1.488	FRANK	100-Year
175	10.94080426	122.0022703	0.319999993	1.25	0.865	FRANK	100-Year
176	10.98069322	122.0272587	0.029999999	1.4	1.877	FRANK	100-Year
177	10.97997077	122.0268854	0.050000001	1.524	2.173	FRANK	100-Year
178	10.98099951	122.0269326	0.029999999	1.7526	2.967	YOLANDA	5-Year
179	11.06495718	122.067188	0.090000004	0.2286	0.019	FRANK	100-Year
180	10.9741688	122.0217356	0.379999995	1.905	2.326	FRANK	100-Year
181	10.99081792	122.1056756	0	1.13	1.277	FRANK	100-Year
182	10.99565957	122.1081703	0.300000012	2.1	3.240	FRANK	100-Year
183	11.01238652	122.0539349	0.280000001	4	13.838	FRANK	100-Year
184	11.01233518	122.0533474	0.029999999	4	15.761	FRANK	100-Year
185	11.00407644	122.1258538	0.159999996	1.26	1.210	FRANK	100-Year
186	10.98852432	122.0931485	0.029999999	0.17	0.020	MARCE	5-Year
187	10.98852499	122.0931581	0	0.17	0.029	MARCE	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
188	10.98847308	122.0927102	0.170000002	0.17	0.000	MARCE	5-Year
189	10.98852445	122.0929701	0	0.17	0.029	MARCE	5-Year
190	10.98852613	122.0929961	0.419999987	0.17	0.062	MARCE	5-Year
191	10.98843399	122.0926764	0.300000012	0.39	0.008	MARCE	5-Year
192	10.94875837	122.0123536	0	0.39	0.152	MARCE	5-Year
193	11.04022992	122.0654246	0	0.17	0.029	MARCE	5-Year
194	11.04053401	122.0655372	0	0.17	0.029	MARCE	5-Year
195	11.04276383	122.0633928	0.100000001	0.17	0.005	MARCE	5-Year
196	11.04112576	122.065616	0.25	0.17	0.006	MARCE	5-Year
197	11.04111978	122.0617529	0	0.08	0.006	MARCE	5-Year
198	11.04089228	122.0652058	0	0.08	0.006	MARCE	5-Year
199	11.04090424	122.061831	0.029999999	0.08	0.003	MARCE	5-Year
200	11.04144654	122.0636882	0.850000024	0.6	0.063	FRANK	100-Year
201	11.04037941	122.0656982	0	0.9	0.810	FRANK	100-Year
202	11.03996699	122.0612946	0	0.8	0.640	FRANK	100-Year
203	11.04139822	122.063124	0	0.5	0.250	YOLANDA	5-Year
204	11.04037019	122.0617322	0	1.9	3.610	FRANK	100-Year
205	11.04020404	122.0615645	0	4	16.000	FRANK	100-Year
206	11.03989981	122.0612067	0	6	36.000	FRANK	100-Year
207	11.04080279	122.0617169	0	2.2	4.840	FRANK	100-Year
208	11.03953202	122.0608205	0	0.9	0.810	FRANK	100-Year
209	11.04033129	122.0616462	0	0.6	0.360	FRANK	100-Year

ANNEX 12. Educational Institutions Affected by flooding in Ibajay Flood Plain

Table A-12.1. Educational Institutions in San Agustin, Surigao del Sur affected by flooding in Ibajay Floodplain

Aklan				
Ibajay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Agbago Elementary School	Agbago	Low	Medium	Medium
Barangay Agbago Day Care Center	Agbago	Low	Low	Low
Agdugayan Day Care Center	Agdugayan			
Agdugayan Elementary School	Agdugayan	Low	Low	Low
Aslum Day Care Center	Aslum			
Integrated Learning Center	Aslum		Low	Low
Bacayan Day Care Center	Bagacay			
Batuan Day Care Center	Batuan	Low	Low	Low
Batuan Primary School	Batuan			
Capilijan Day Care Center	Capilijan			
Capilijan Primary School	Capilijan			
Aklan State University - Ibajay Campus	Colongcolong			
Colong-colong Barangay Day Care Center	Colongcolong			
Ibajay National High School	Colongcolong		Low	Low
Seventh Day Adventist Multi-grade School	Colongcolong			
Laguinbanua Day Care Center	Laguinbanua			
Laguinbanua Elementary School	Laguinbanua			
Melchor Memorial School, Inc. Main building	Laguinbanua			Low
Old Melchor Memorial School	Laguinbanua			
Maloco Elementary School	Maloco			
Maloco National High School	Maloco			
Barangay Naile Daycare Center	Naile			
Naile Elementary School	Naile		Low	Low
Naile National High School	Naile		Low	Low
Naligusan Primary School	Naligusan			Low
Ondoy Elementary School	Ondoy		Low	Medium
Ondoy National High School	Ondoy	Medium	Medium	Medium
Ibajay Academy	Poblacion	Low	Low	Low
Ibajay Central School	Poblacion		Low	Low
St. Peter Parochial School	Poblacion		Low	Low
Polo Day Care Center	Polo			
Rizal Elementary School	Rizal	Low	Low	Low
Barangay Santa Cruz Day Care Center	Santa Cruz	Medium	Medium	Medium

Aklan				
Ibajay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Santa Cruz Elementary School	Santa Cruz			
Tagbaya Barangay Day Care Center	Tagbaya	Medium	Medium	Medium
Tagbaya Elementary School	Tagbaya	Medium	Medium	Medium
Tul-ang Barangay Day Care Center	Tul-Ang			
Tul-ang Primary School	Tul-Ang			
Unat-Bagacay Elementary School	Unat			
Unat Day Care Center	Unat			

ANNEX 13. Health Institutions affected by flooding in Ibajay Floodplain

Table A-13.1. Health Institutions affected by flooding in Ibajay Floodplain

Aklan				
Ibajay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Ibajay District Hospital	Agbago			
New Rural Health Center	Maloco			
Old HealthCenter	Maloco			
Rural Health Unit I	Naile		Low	Low
Ascaayo Medical Clinic	Poblacion			
Health Unit II	Poblacion			
Unat Health Center	Unat			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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Naressa Belle Saripada
Jao Hallen Bañados
Michael Angelo Palomar
Glory Ann Jotea