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

LiDAR Surveys and Flood Mapping of Guinale River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Naga University

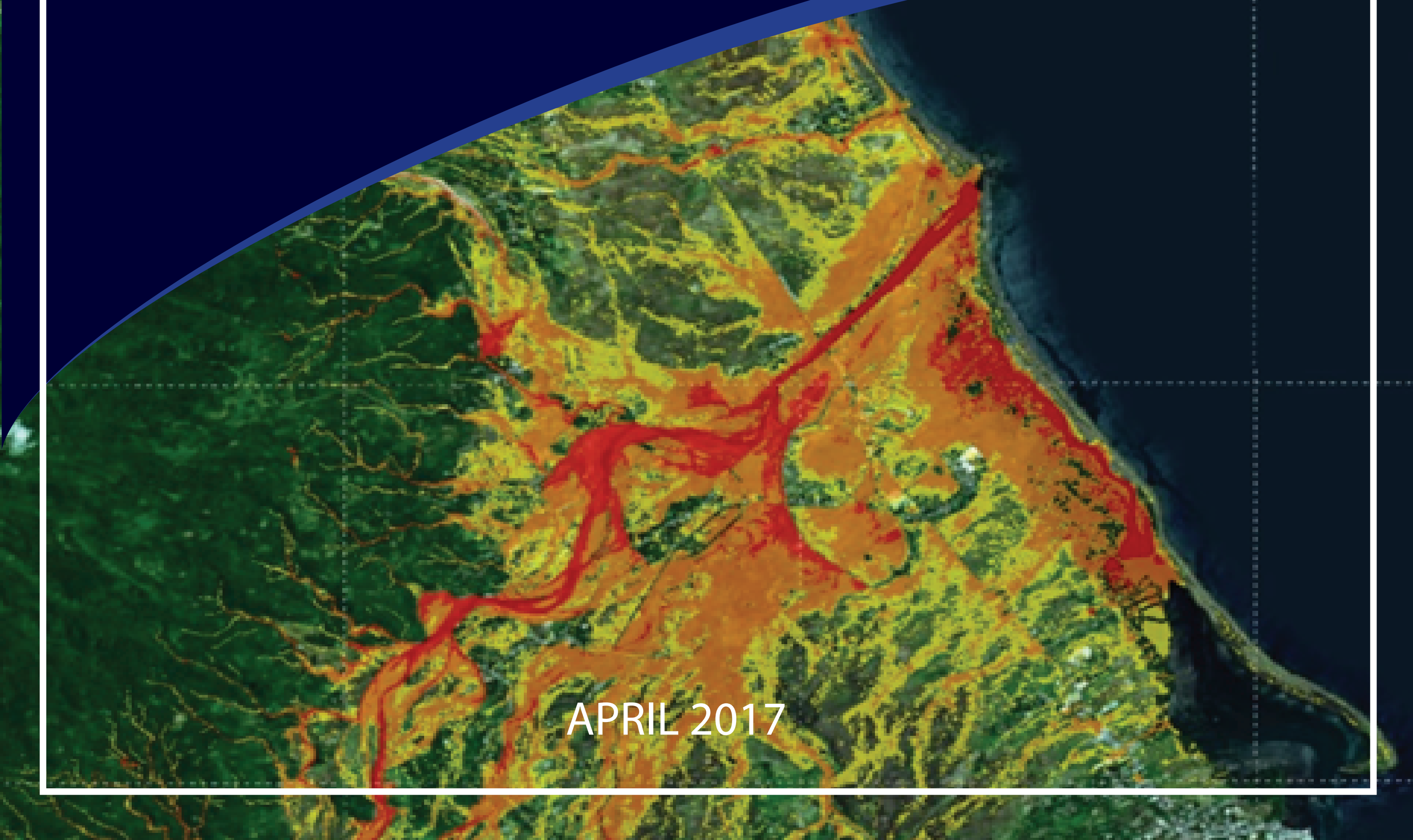

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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
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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND GUINALE RIVER

Enrico C. Paringit, Dr. Eng., Dr. George Puno, and Eric Bruno

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 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 the Department of Science and Technology (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 Ateneo de Naga University (ADNU). ADNU 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 twenty-four (24) river basins in the Bicol Region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Guinale River Basin

The Guinale River Basin is under the jurisdiction of two (2) component cities: Ligao and Tabaco Cities; and five (5) municipalities: Polangui, Oas, Malilipot, Tiwi and Malinao, in the province of Albay. The Department of Environment and Natural Resources River Basin Control Office (DENR RCBO) identified the basin to have a drainage area of 103 km2, and an estimated 139 million cubic meter (MCM) annual run-off (RBCO, 2015).

The basin's main stem, the Guinale River, is part of the twenty-four (24) river systems in the Bicol Region. The Guinale River discharges into the southern portion of the Pacific, facing the Lagonoy Gulf.

The river basin is bound to the northwest by Mt. Malinao, to the southwest by Mt. Masaraga, and to the south by the Mayon Volcano. The river has a total length of 139.64 km., with headwaters from all three (3) mountains. Mt. Malinao is 1,543 mASL tall, and is categorized as a volcano. It does not a have a history of eruptions, but it serves as a source of renewable energy in terms of geothermal resources. Mt. Masaraga is 1,328 mASL tall, with no known historical eruptions.

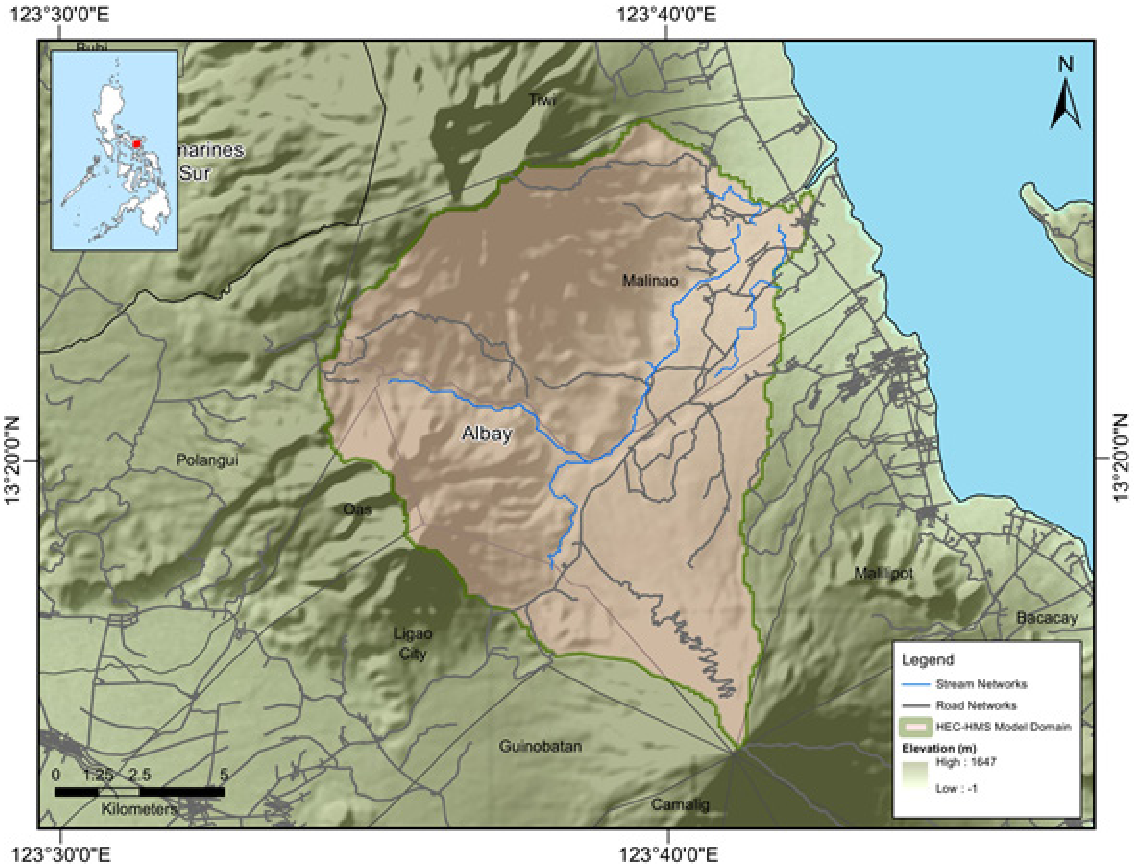


Figure 1. Location map of the Guinale River Basin (in brown)

The Municipality of Polangui has a total of 88,221 residents in forty-four (44) barangays. The Municipality of Oas has fifty-three (53) barangays, with a total population of 67,960. The Municipality of Malilipot is home to 37,785 residents from eighteen (18) barangays. The Municipality of Malinao has a total of twenty-nine (29) barangays, housing 45,301 residents. And the Municipality of Tiwi has twenty-five (25) barangays, with a total population of 53,120 residents.

According to the 2015 national census of the National Statistics Office (NSO), the population of residents within the immediate vicinity of the Guinale River is 17,671 people, distributed among eleven (11) barangays in the Municipality of Malinao in the province of Albay.

Agriculture is the main industry in Albay. Major products include coconuts, rice, pili nuts, sugar, corn, cacao, and abaca. Fishing is the main source of livelihood of those in the municipalities near the shores (Valmero, 2015).

The area experiences maximum rainfall from November to January, with no distinct dry season. This climate type lends the province lush vegetation, which explains the locals' heavy reliance on agriculture. In August 2011, Typhoon Reming caused one of the most destructive flood events in the province, which brought about lahar flow (http://www.voxbikol.com/article/juaning-left-bikol-reeling-floods-mudflows-landslides).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE GUINALE FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, For. Ma. Verlina Tonga, and Jasmine Alviar

The methods applied in this Chapter were based on the DREAM methods manual (Sarmiento, 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 Guinale floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Albay, Camarines Sur, and Sorsogon. These missions were planned for ten (10) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The Gemini LiDAR system was used for the flight missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 illustrates the flight plans for Guinale floodplain survey.

Table 1. 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)
BLK19A	900	40	50	125	40	130	5
BLK19J	1100	30	40	100	50	130	5
BLK19N	1100	30	40	100	50	130	5
BLK19O	1100	30	40	100	50	130	5
BLK19AS	1100	30	40	100	50	130	5
BLK19ASJ	1000	30	40	100	50	130	5
BLK19BS	1000	30	40	100	50	130	5
BLK19ASL	1000	30	40	100	50	130	5
BLK19AI	1000	30	40	100	50	130	5
BLK19ACS	1000	30	40	100	50	130	5
BLK19DS	1000	30	40	100	50	130	5
BLK19I	1000	30	40	100	50	130	5
BLK19Q	1000	30	40	100	50	130	5

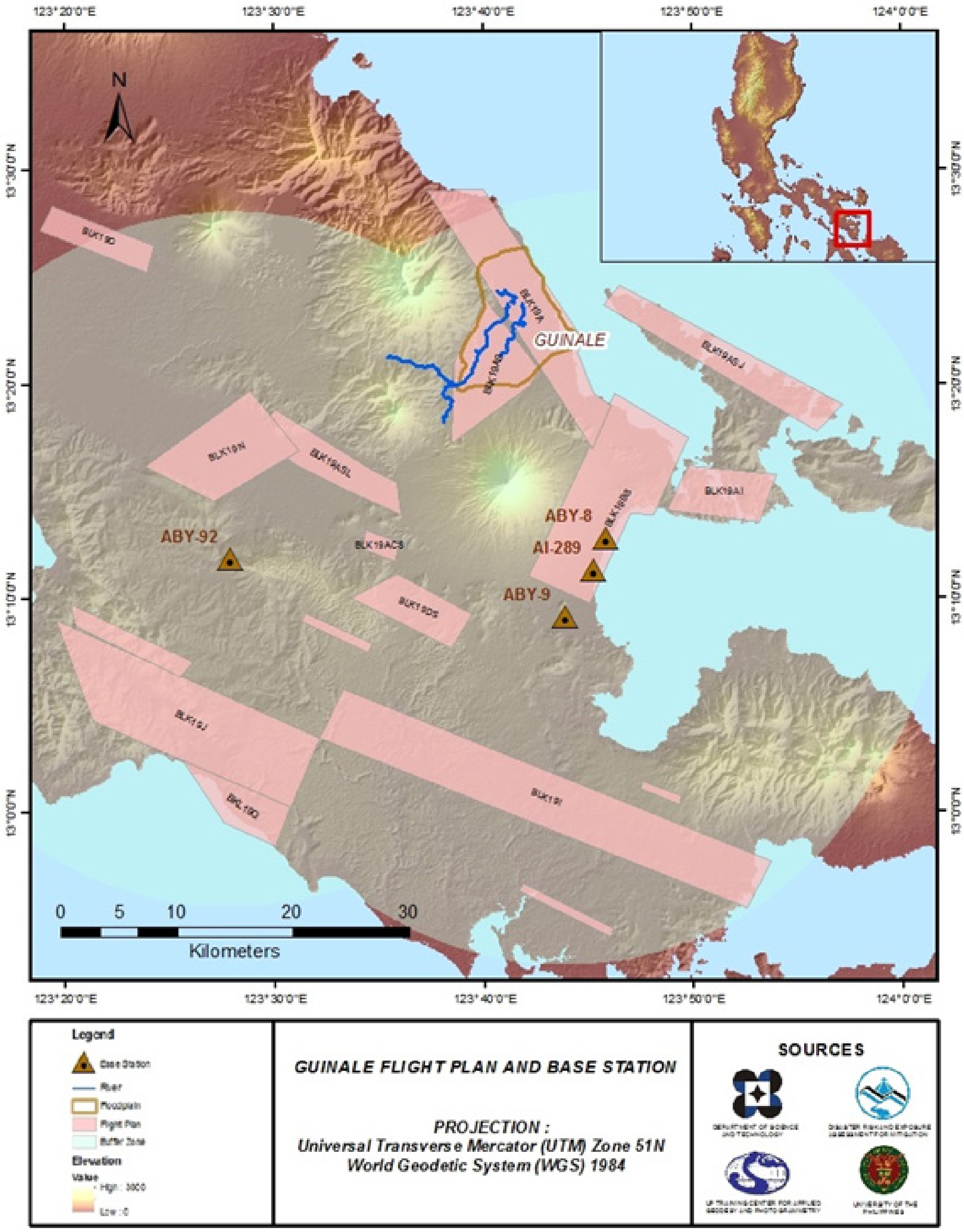


Figure 2. Flight plans and base stations used to cover the Guinale floodplain.

2.2 Ground Base Stations

The field team for this undertaking was able to recover three (3) NAMRIA horizontal ground control points: ABY-08 and ABY-92, which are of second (2nd) order accuracy; and ABY-9, which is of third (3rd) order accuracy,. One (1) NAMRIA benchmark was recovered, AL-289, which is of second (2nd) order accuracy. The benchmark was used as vertical reference point, and was also established as ground control point. The certifications for the base stations are found in Annex 2, while the baseline processing reports for the established ground control points are found in Annex 3. These were used as base stations during the flight operations for the entire duration of the survey, held on March 29 – April 28, 2014, and on March 7 - 20, 2016, especially on the days that the flight missions were conducted. The base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 882 and SPS 985. The flight plans and the locations of the base stations used during the aerial LiDAR acquisition in the Guinale floodplain are shown in Figure 2. The composition of the project team is found in Annex 4.

Figure 3 to Figure 6 depict the recovered NAMRIA reference points within the area. Table 2 to Table 5 provide the details about the following NAMRIA control stations and established points, and Table 6 lists all ground control points occupied during the acquisition with the corresponding dates of survey.

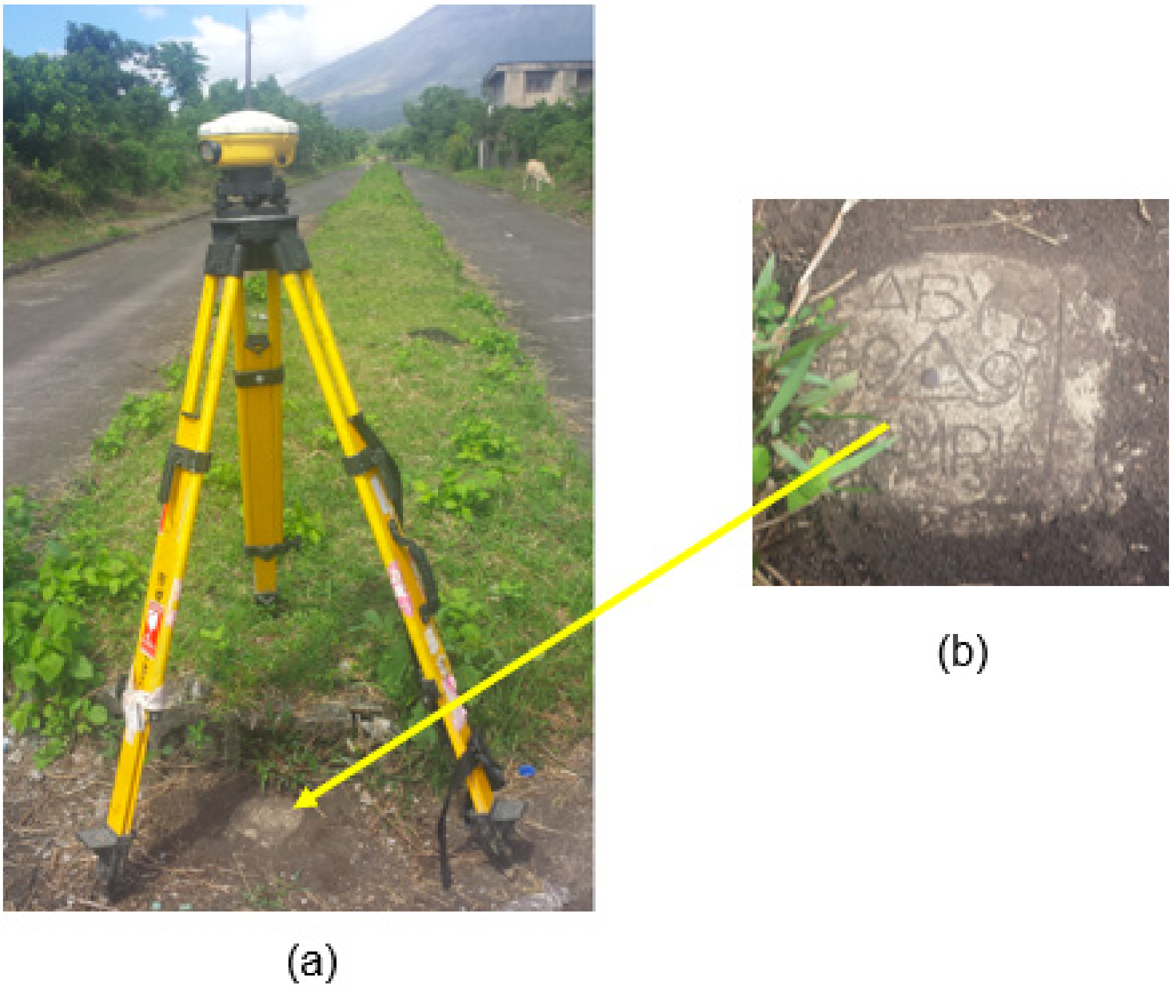


Figure 3. (a) GPS set-up over ABY-8 at the center of the island of the Mayon Riviera Subdivision, and (b) NAMRIA reference point ABY-8, as established by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ABY-08, used as base station for the LiDAR acquisition.

Station Name	ABY-8	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 12’ 51.92876” North
	Longitude	123° 45’ 45.95336” East
	Ellipsoidal Height	6.33900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	582646.93 meters
	Northing	1460883.61 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 12’ 47.06720” North
	Longitude	123° 45’ 50.94829” East
	Ellipsoidal Height	60.47000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	582646.93 meters
	Northing	1460883.61 meters

(a)

(b)

Figure 4. (a) GPS set-up over ABY-92 located beside the baseline of the basketball court, about 19 meters from the Barangay Allang Hall, Ligao City, and (b) NAMRIA reference point ABY-92, as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ABY-92, used as base station for the LiDAR acquisition.

Station Name	ABY-92	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 11’ 56.27238” North
	Longitude	123° 27’ 47.60156” East
	Ellipsoidal Height	127.309000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	550210.89 meters
	Northing	1459605.458 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 11’ 51.38974” North
	Longitude	123° 27’ 52.59990” East
	Ellipsoidal Height	180.74900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	550193.31 meters
	Northing	1459094.57 meters

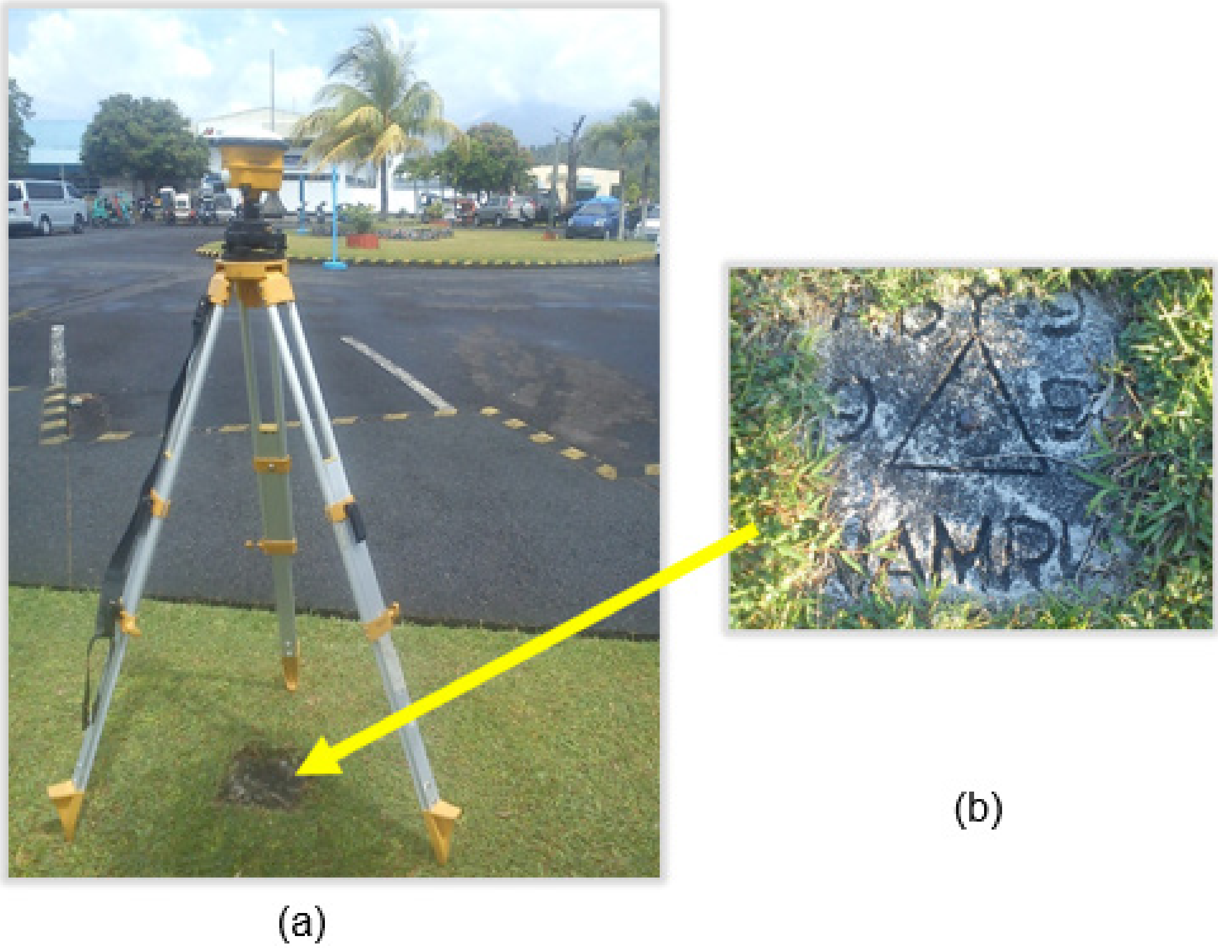
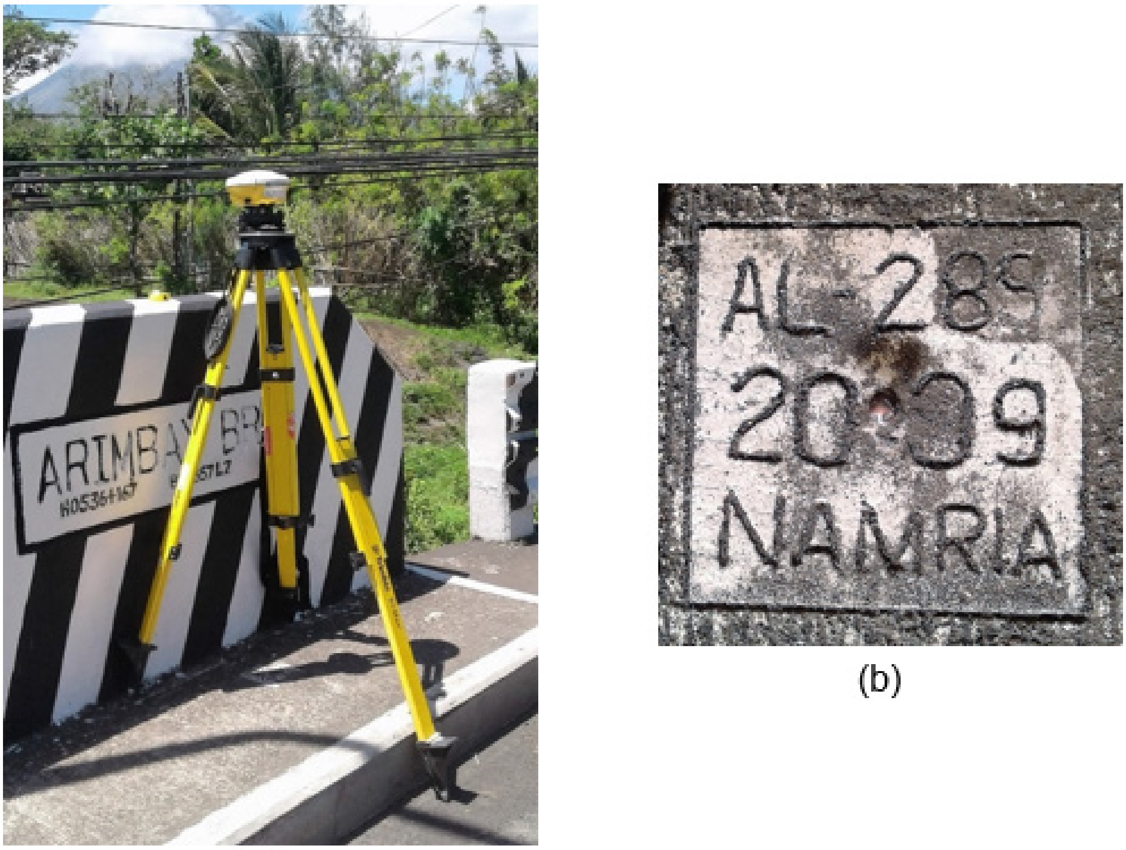


Figure 5. (a) GPS set-up over ABY-9 inside the Legaspi Airport Compound 52.0 meters SE of Legaspi Airport Flagpole, 35 meters NE of Legaspi Airport Welcome Post 3.30 meters NW of Lamp, and (b) NAMRIA reference point ABY-9, as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ABY-9, used as base station for the LiDAR acquisition.

Station Name	ABY-9	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 9' 11.38733" North
	Longitude	123° 43' 45.95874" East
	Ellipsoidal Height	14.54010 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	579082.538 meters
	Northing	1454607.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 9' 6.53800" North
	Longitude	123° 43' 50.95900" East
	Ellipsoidal Height	68.754 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	579054.86 meters
	Northing	1454097.98 meters



(a) (b)

Figure 6. (a) GPS set-up over AL-289 located at Arimbay bridge along the Tiwi-Legazpi National Road of Barangay Bigaa, Legazpi City, Albay, and (b) NAMRIA reference point AL-289, as recovered by the field team.

Table 5. Details of the recovered NAMRIA vertical control point AL-289, used as vertical reference point for the LiDAR acquisition with established coordinates.

Station Name	AL-289	
Order of Accuracy (benchmark)	2nd	
Elevation (Mean Sea Level)	8.9801 meters	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 11’ 22.18920” North
	Longitude	123° 45’ 09.03476” East
	Ellipsoidal Height	10.065 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 11’ 17.33275” North
	Longitude	123° 45’ 14.03173” East
	Ellipsoidal Height	64.238 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	581543.975 meters
	Northing	1458123.495 meters

Table 6. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
07-Mar-16	3855G	2BLK19AS067A	ABY-08; AL-289
10-Mar-16	3869G	2BLK19ASBSI070A	ABY-08; AL-289
16-Mar-16	3891G	2BLK19ACS076A	ABY-08; AL-289
16-Mar-16	3893G	2BLK19AJS076B	ABY-08; AL-289
20-Apr-14	7200GC	2BLK19JS110A & 2BLK-19N110A	ABY-8; ABY-92
22-Apr-14	7204GC	2BLK19A112A	ABY-8; ABY-92
26-Apr-14	7213GC	2BLK19OS116B & VOIDS	ABY-8; ABY-9; ABY-92
28-Apr-14	7216GC	2BLK19AS118A & VOIDS	ABY-8; ABY-92

2.3 Flight Missions

A total of eight (8) flight missions were conducted to complete the LiDAR data acquisition in the Guinale floodplain, for a total of twenty nine (29) hours and one (1) minute (29+1) of flying time for RP-C9022 and RPC-9322. All missions were acquired using the Gemini LiDAR system. Annex 6 provides the flight logs of the missions. Table 7 indicates the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for the LiDAR data acquisition in the Guinale floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within Floodplain (km^2)	Area Surveyed Outside Floodplain (km^2)	Flying Hours	
						Hr	Min
07-Mar-16	3855G	49.65	46.28	24.9249	21.36	3	11
10-Mar-16	3869G	193.41	144.44	6.95118	137.49	4	36
16-Mar-16	3891G	71.93	135.78	-	135.78	4	48
16-Mar-16	3893G	87.95	180.84	42.0468	138.80	2	59
20-Apr-14	7200GC	295.56	180.65	0.83338	179.82	4	5
22-Apr-14	7204GC	238.37	129.43	31.3811	98.05	3	41

Table 8. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3855G	600 and 900	40	50	125	40	130	5
3869G	900	40	50	125	40	130	5
3891G	650	40	50	125	40	130	5
3893G	900	40	50	125	40	130	5
7200GC	1300	50	40	100	50	130	5
7204GC	1300	40	34	100	50	130	5
7213GC	1100	30	40	100	50	130	5
7216GC	1300	50	34 and 40	100	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Guinale floodplain (See Annex 7 for the flight status reports). The Guinale floodplain is located in the provinces of Albay, Camarines Sur, and Sorsogon, with majority of the floodplain situated within the Municipality of Bacacay and Tabaco City in Albay. The list of municipalities and cities surveyed is given in Table 9. The actual coverage of the LiDAR acquisition for the Guinale floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during the Guinale floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Albay	Bacacay	115.20	72.17	63%
	Tabaco City	112.24	67.04	60%
	Malinao	106.78	58.87	55%
	Pio Duran	133.24	69.73	52%
	Malilipot	45.42	19.75	43%
	Tiwi	124.40	41.24	33%
	Jovellar	82.35	25.01	30%
	Guinobatan	174.07	48.64	28%
	Santo Domingo	60.83	15.62	26%
	Polangui	148.89	34.34	23%
	Ligao City	258.51	56.15	22%
	Camalig	136.54	29.59	22%
	Oas	239.58	50.84	21%
	Libon	222.82	28.26	13%
	Daraga	135.66	7.78	6%
	Legazpi City	153.18	5.72	4%
Camarines Sur	Baao	106.50	19.75	19%
	Nabua	96.61	2.78	3%
	Iriga City	130.05	2.78	2%

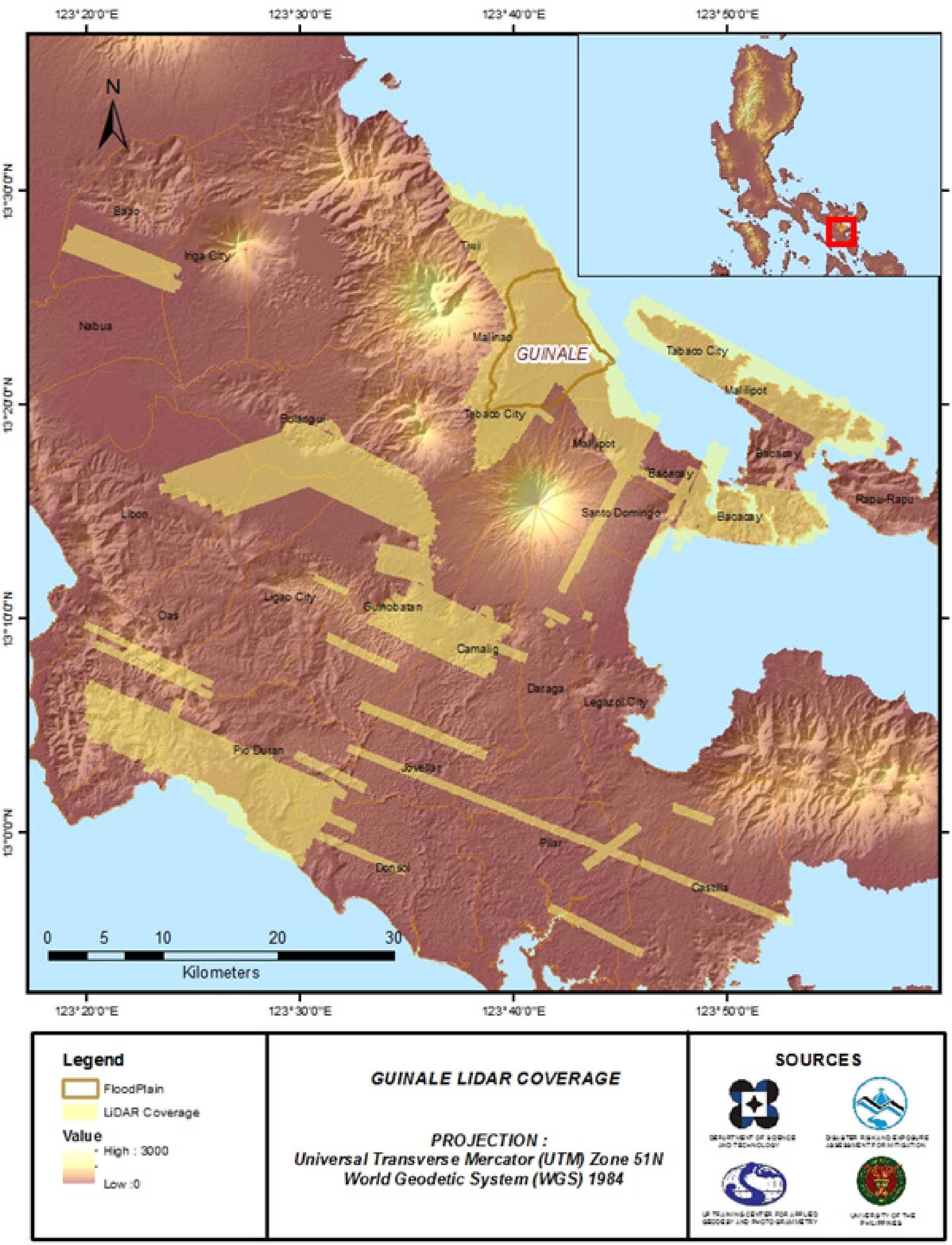


Figure 7. Actual LiDAR survey coverage of the Guinale floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE GUINALE 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 DAC were 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 was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models (DEMs), such as Digital Terrain Model (DTM) and Digital Surface Model (DSM).
Using the elevation of points gathered in the field, the LiDAR-derived digital models were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry, measured from the field by the Data Validation and Bathymetry Component (DVBC). LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was accomplished through the help of the georectified point clouds, and the metadata containing the time the image was captured. These processes are summarized in the diagram in Figure 8.

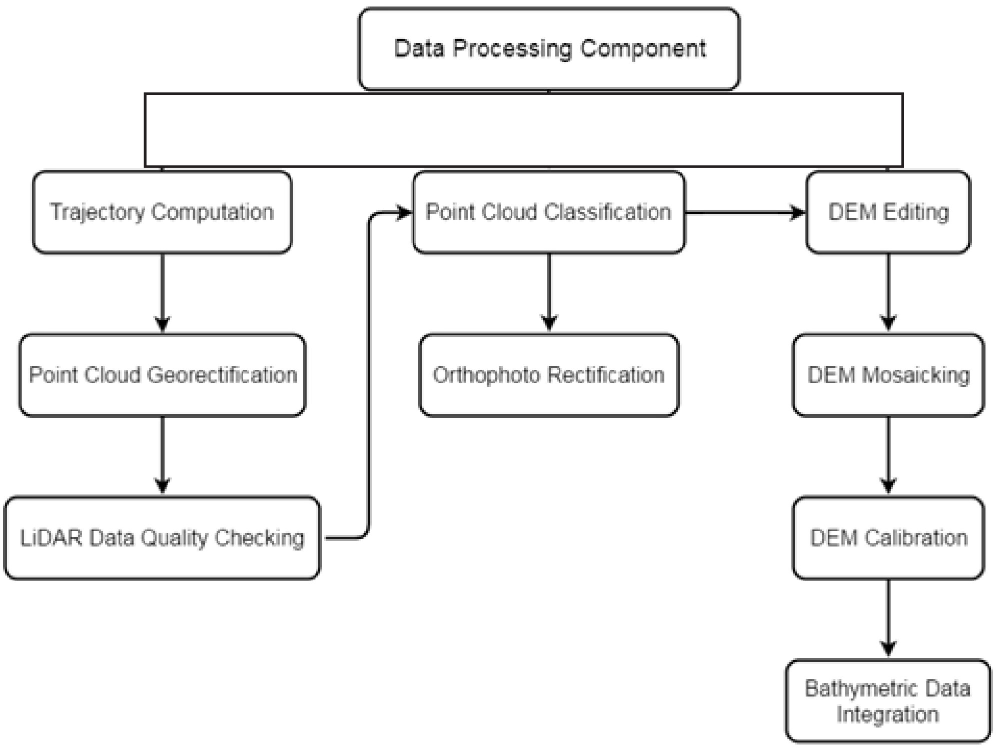


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for the Guinale floodplain can be found in Annex 5. Missions flown during the first survey conducted in May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system, while missions acquired during the second survey in March 2016 were flown using the Gemini system over Malinao, Albay. The DAC transferred a total of 126.15 Gigabytes of Range data, 1.68 Gigabytes of POS data, 67.39 Megabytes of GPS base station data, and 263.80 Gigabytes of raw image data to the data server on May 5, 2014 for the first survey, and on March 28, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Guinale was fully transferred on March 31, 2016, as indicated on the data transfer sheets for the Guinale floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3891G, one of the Guinale flights, which are the North, East, and Down position RMSE values, are presented in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on March 28, 2016 at 00:00 hrs. on that week. The y-axis is the RMSE value for that particular position.

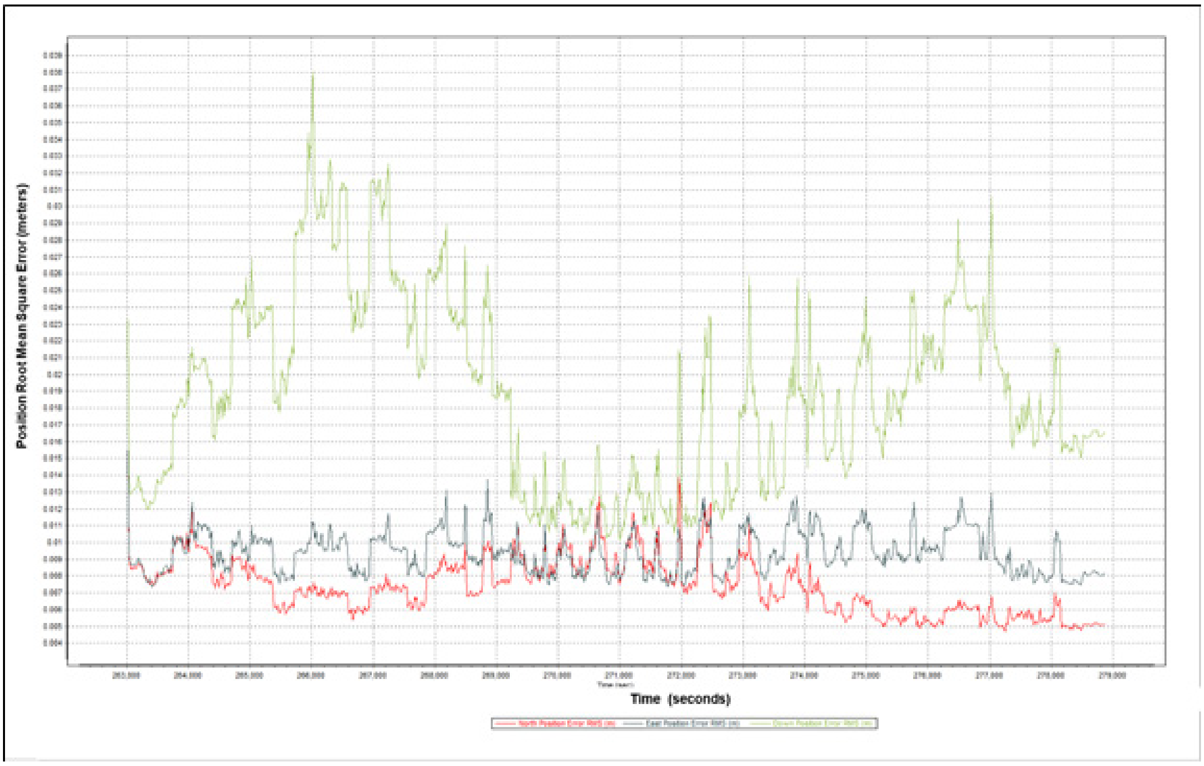


Figure 9. Smoothed Performance Metric Parameters of a Guinale Flight 1444A.

The time of flight was from 263,000 seconds to 278,800 seconds, which corresponds to afternoon of May 28, 2016. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized 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 peaked at 1.40 centimeters, the East position RMSE peaked at 1. 40 centimeters, and the Down position RMSE peaked at 3.80 centimeters, which are all within the prescribed accuracies described in the methodology.

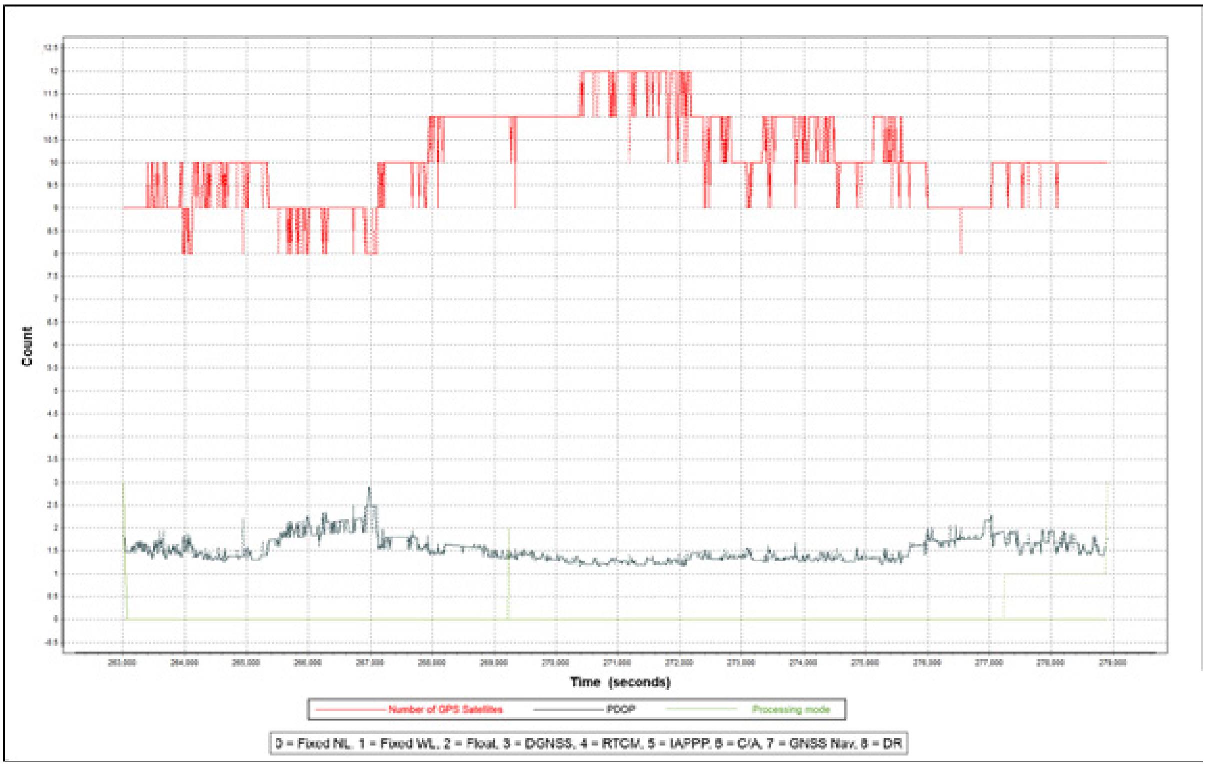


Figure 10. Solution Status Parameters of Guinale Flight 1444A.

The Solution Status parameters of flight 3891G, one of the Guinale flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are illustrated in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to six (6). Majority of the time, the number of satellites tracked was between eight (8) and twelve (12). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode stayed at the value of zero (0) for majority of the survey, with some peaks up to two (2) attributed to the turns performed by the aircraft. The value of zero (0) corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Guinale flights is exhibited in Figure 11.

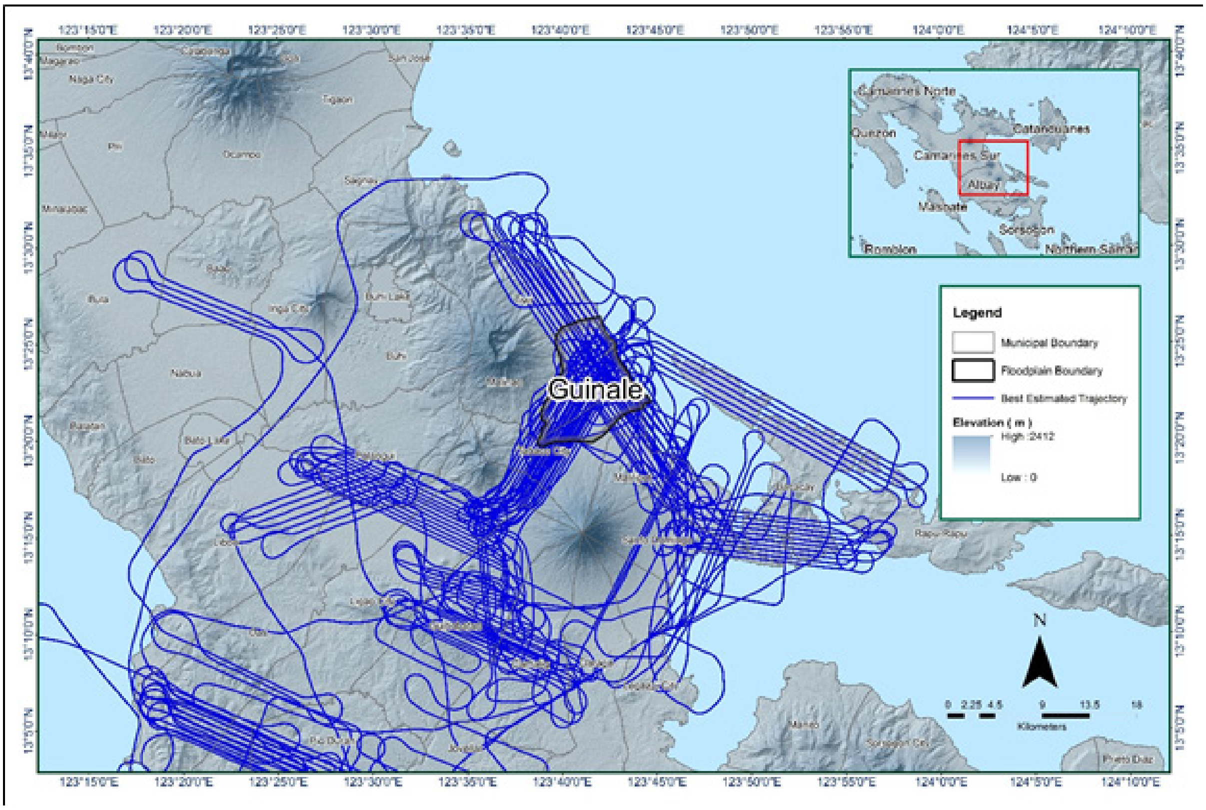


Figure 11. The best estimated trajectory conducted over the Guinale floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains seventy-seven (77) flight lines, with each flight line containing one (1) channel, since the since the Gemini system contains only one (1) channel. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Guinale floodplain is given in Table 10.

Table 10. Self-calibration results for the Guinale flights.

Parameter	Value
Boresight Correction stdev (<0.001degrees)	0.000488
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000986
GPS Position Z-correction stdev (<0.01meters)	0.0021

Optimum accuracy was obtained for all Guinale flights, based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for the individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Guinale floodplain are illustrated in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

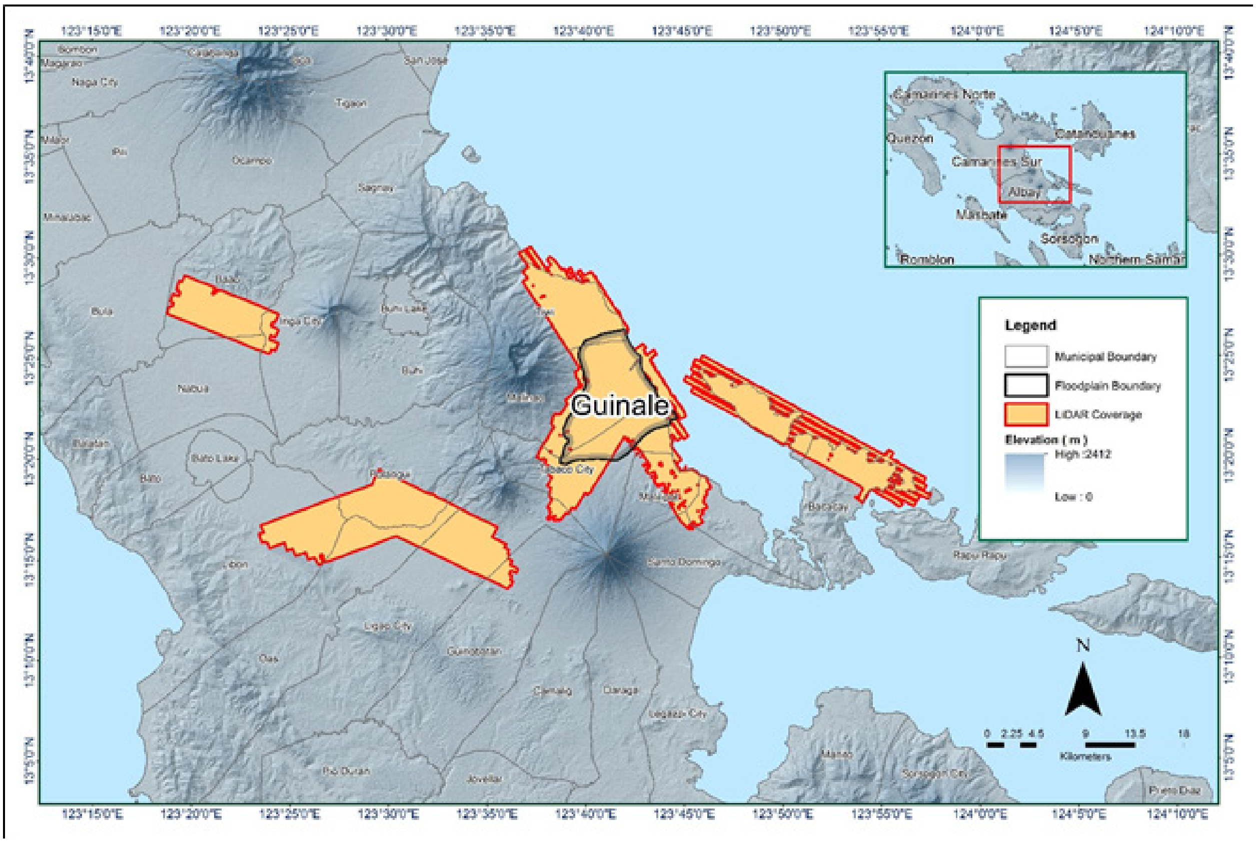


Figure 12. Boundaries of the processed LiDAR data over the Guinale floodplain.

The total area covered by the Guinale missions is 510.66 sq. km., comprised of eleven (11) flight acquisitions grouped and merged into nine (9) blocks, as shown in Table 11.

Table 11. List of LiDAR blocks for Guinale floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Albay_Sorsogon_Blk19A	7200G	121.83
	7204G	
	7216G	
Albay_Sorsogon_Blk19O	7213G	37.30
Albay_Sorsogon_Blk19N	7200G	56.25
Albay_Sorsogon_reflights_BlkA_supplement1	3855G	43.23
Albay_Sorsogon_reflights_Blk19A	3893G	64.81
Albay_Sorsogon_reflights_Blk19T	3893G	75.51
Albay_Sorsogon_reflights_Blk19N	3891G	69.12
Albay_Sorsogon_reflights_Blk19A_supplement3	3893G	24.00
Albay_Sorsogon_reflights_Blk19A_supplement2	3869G	18.61
	TOTAL	**510.66 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 13. Since the Gemini system employs only one (1) channel, it is expected to have 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 (3) or more overlapping flight lines.

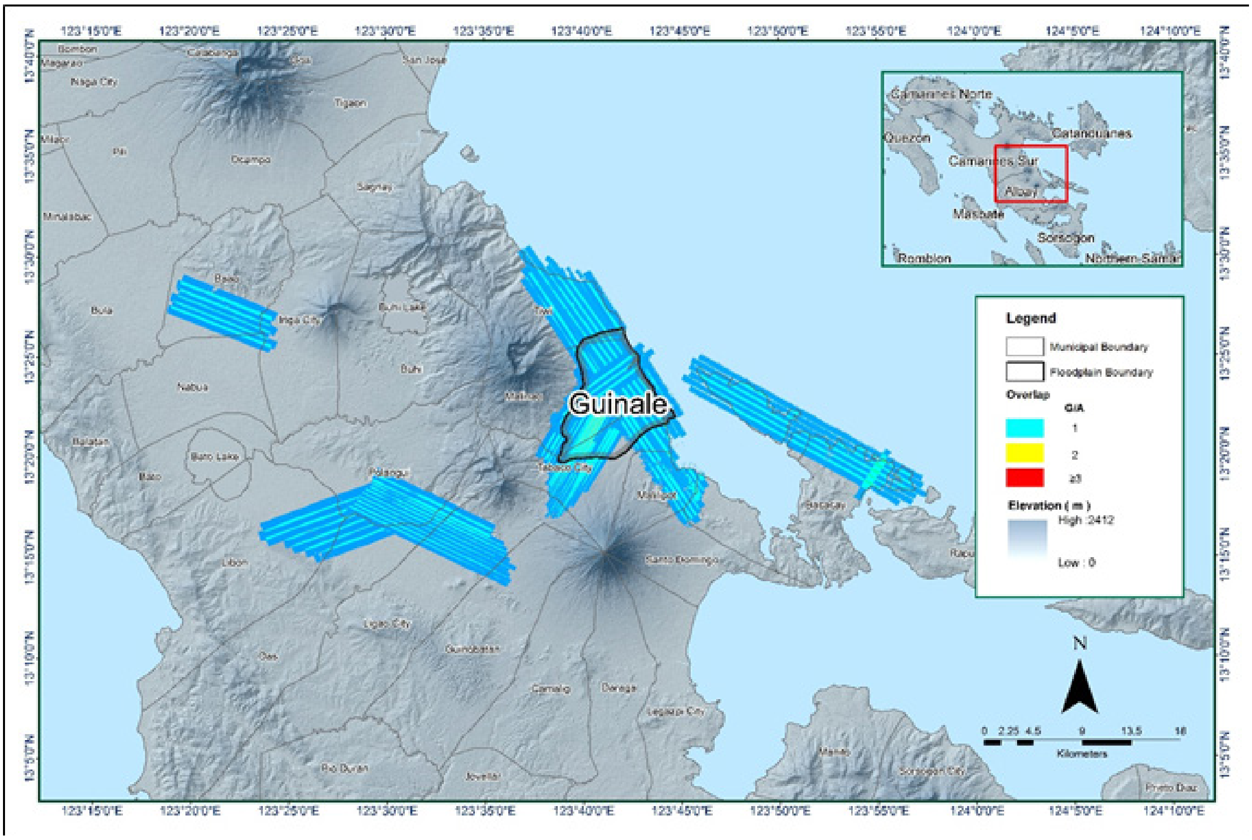


Figure 13. Image of data overlap for Guinale floodplain

The overlap statistics per block for the Guinale floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 27.10% and 45.61% respectively, which satisfy 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 provided in Figure 14. It was determined that all LiDAR data for the Guinale floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.94 points per square meter.

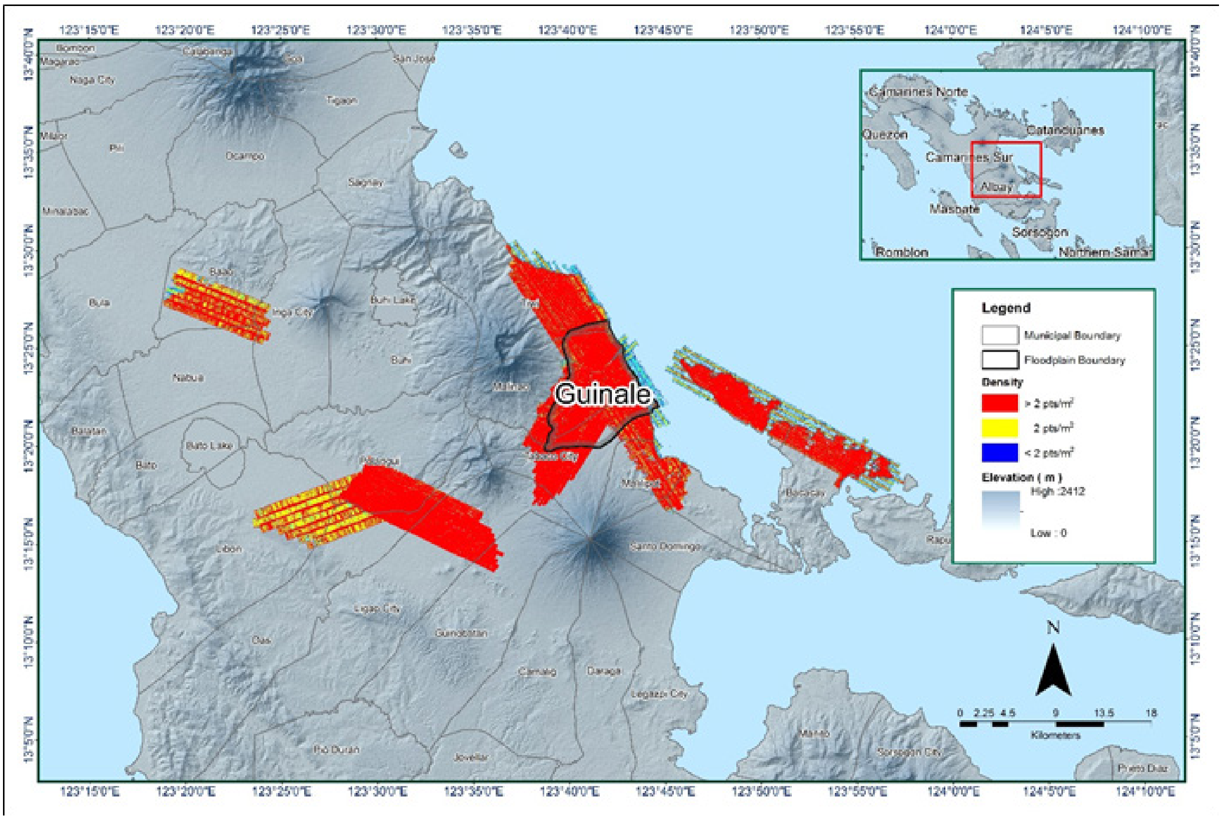


Figure 14. Pulse density map of merged LiDAR data for the Guinale floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to elevations of its adjacent flight line. Areas with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

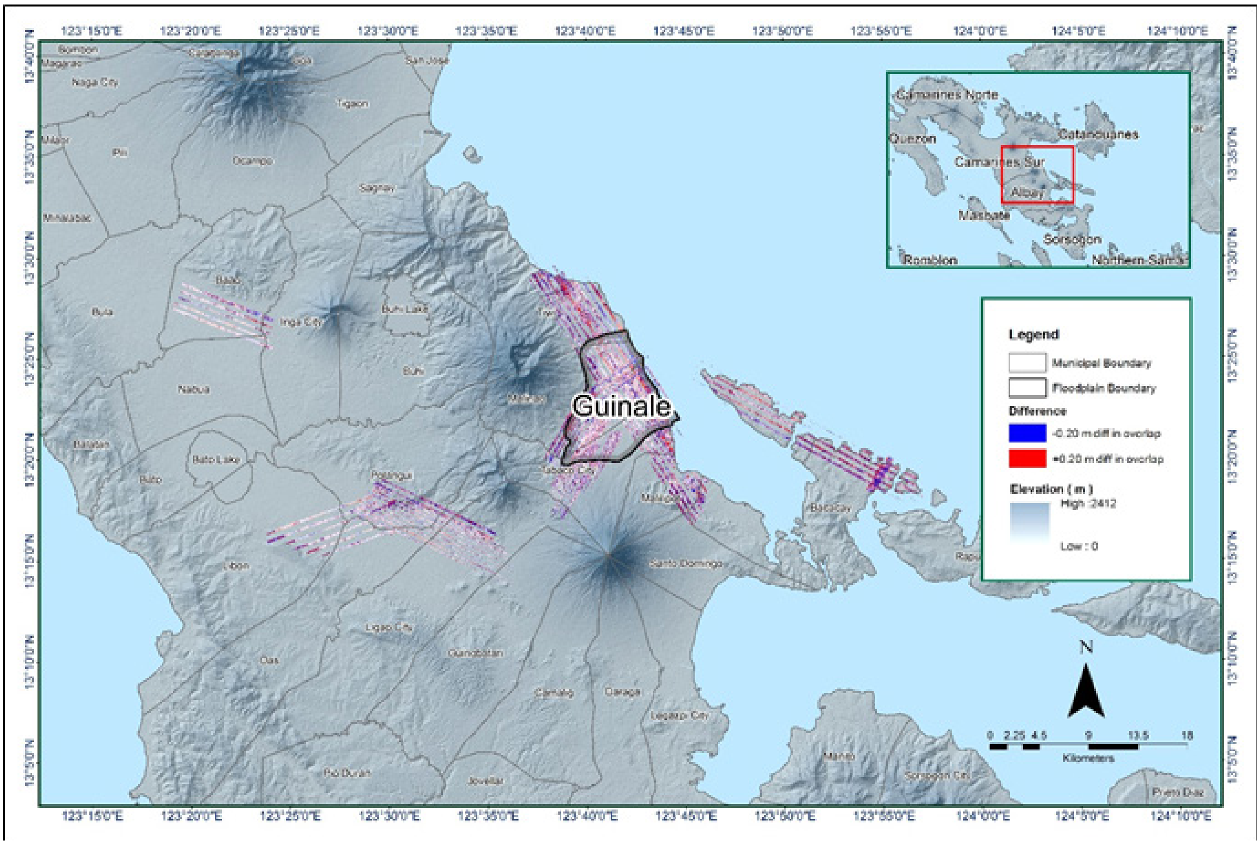


Figure 15. Elevation difference map between flight lines for the Guinale floodplain

A screen capture of the processed LAS data from a Guinale flight 1444A loaded in the QT Modeler is presented in Figure 16. The upper left image shows the elevations of the points from two (2) 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 were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

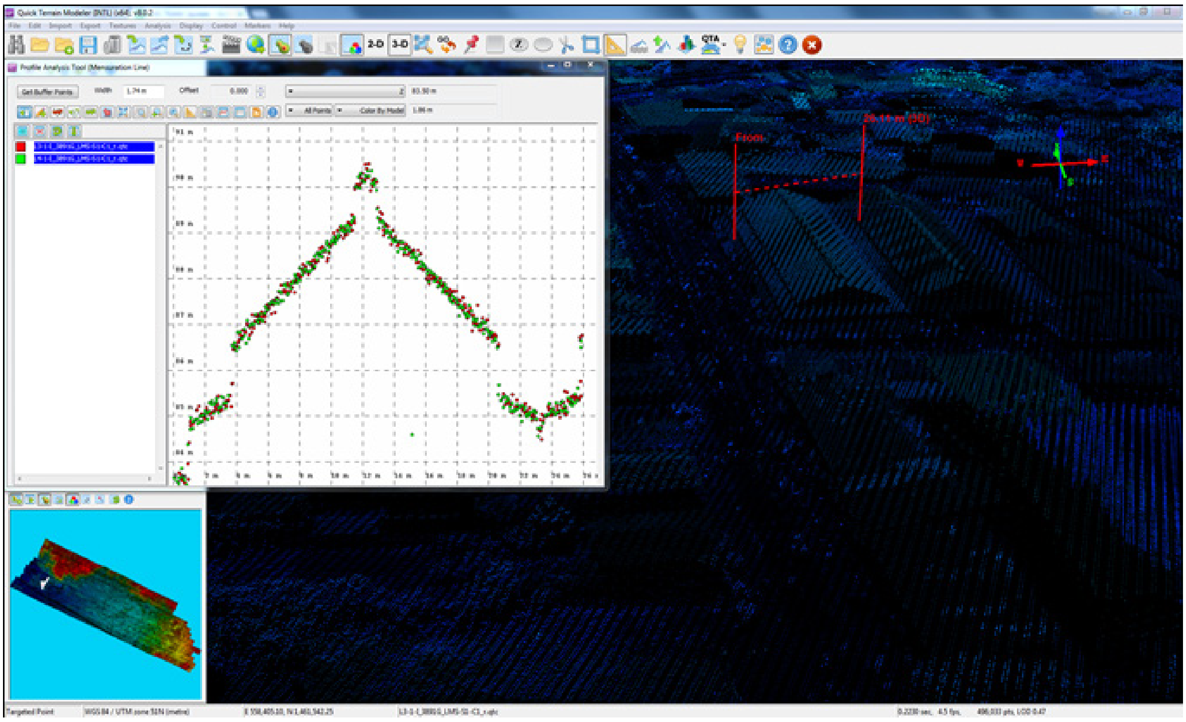


Figure 16. Quality checking for a Guinale flight 1444A, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Guinale classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	215,943,367
Low Vegetation	257,930,817
Medium Vegetation	659,656,449
High Vegetation	559,350,286

The tile system that the TerraScan employed for the LiDAR data and the final classification image for a block in the Guinale floodplain is illustrated in Figure 17. A total of 814 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is indicated in Table 12. The point cloud had a maximum and minimum height of 550.23 meters and 51.64 meters, respectively.

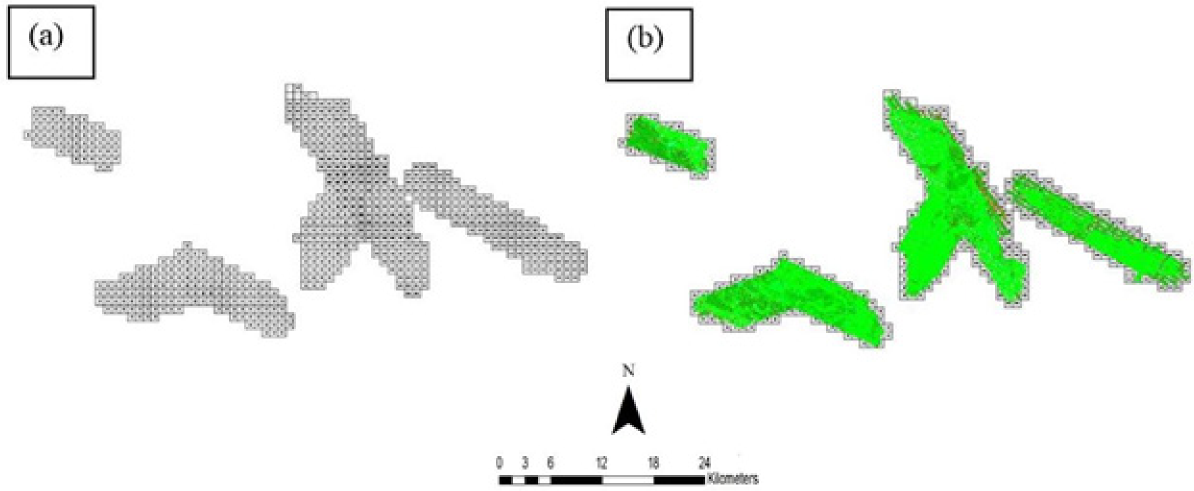


Figure 17. (a) Tiles for the Guinale floodplain, (b) and classification results in TerraScan

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

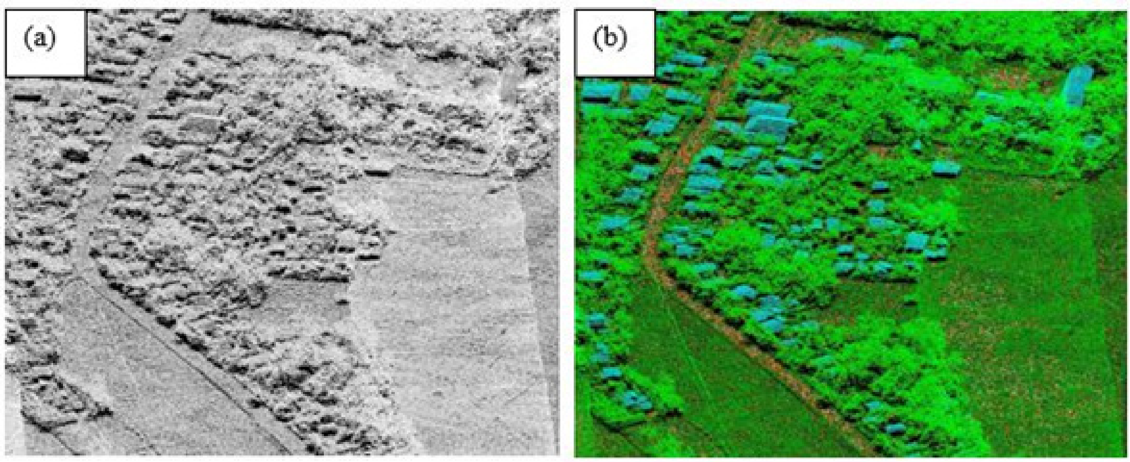


Figure 18. Point cloud (a) before and (b) after classification

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

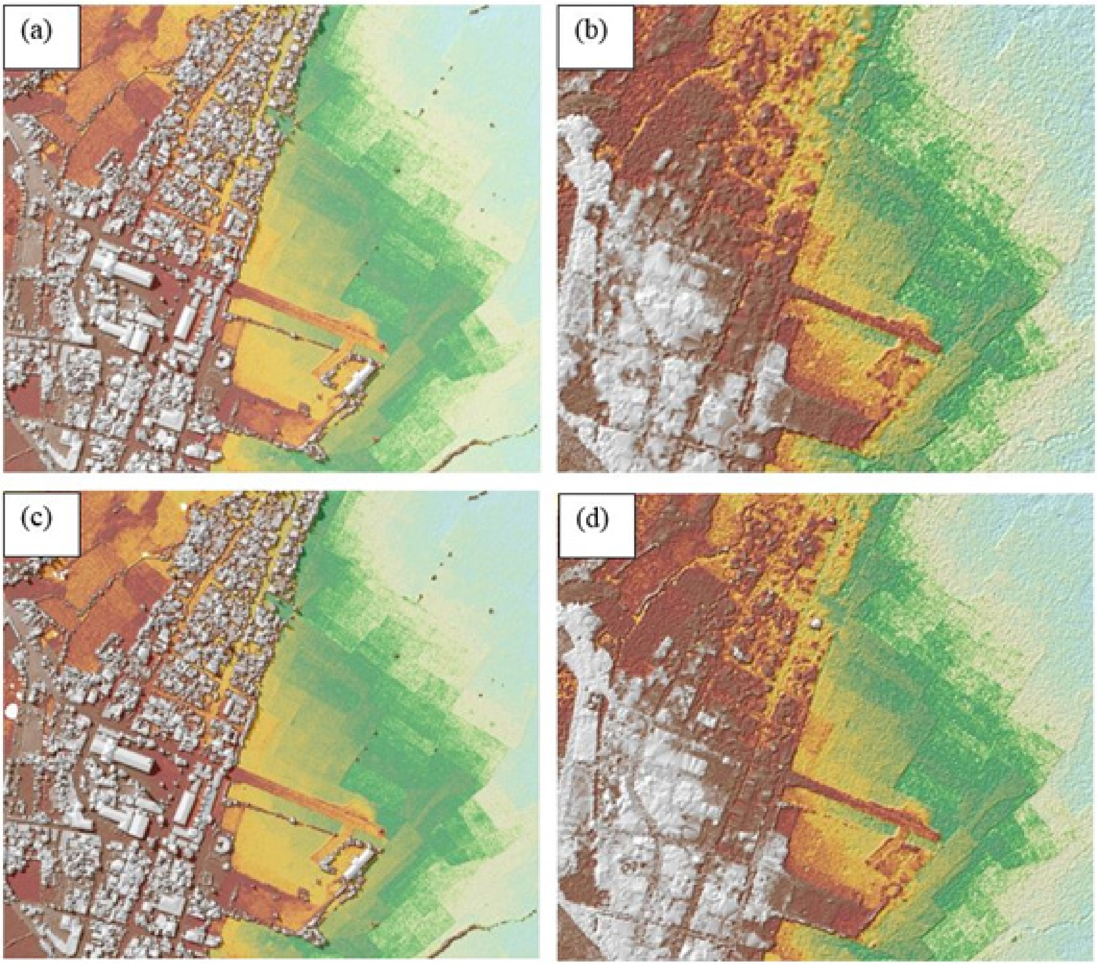


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of the Guinale floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 470 1km by 1km tiles area covered by the Guinale floodplain is presented in Figure 20. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Guinale floodplain survey attained a total of 202.25 sq. km. in orthophotographic coverage, comprised of 1,569 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are shown in Figure 21.

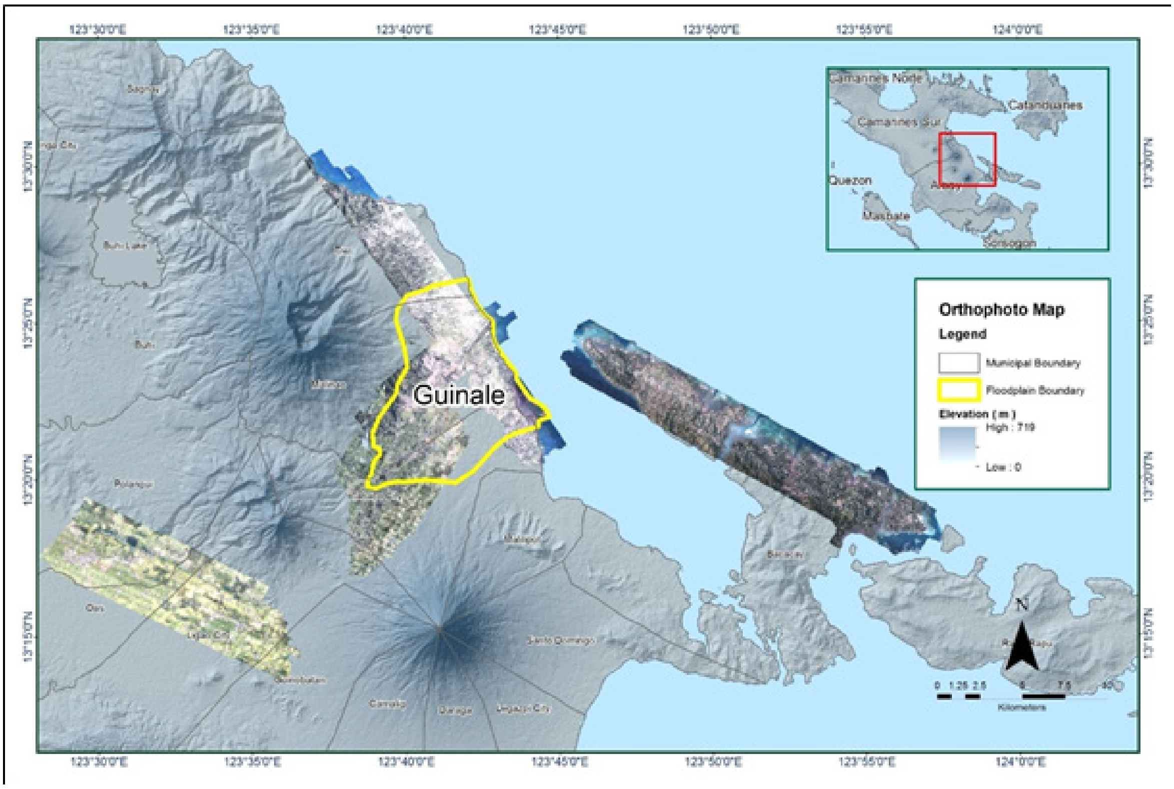


Figure 20. The Guinale floodplain with available orthophotographs

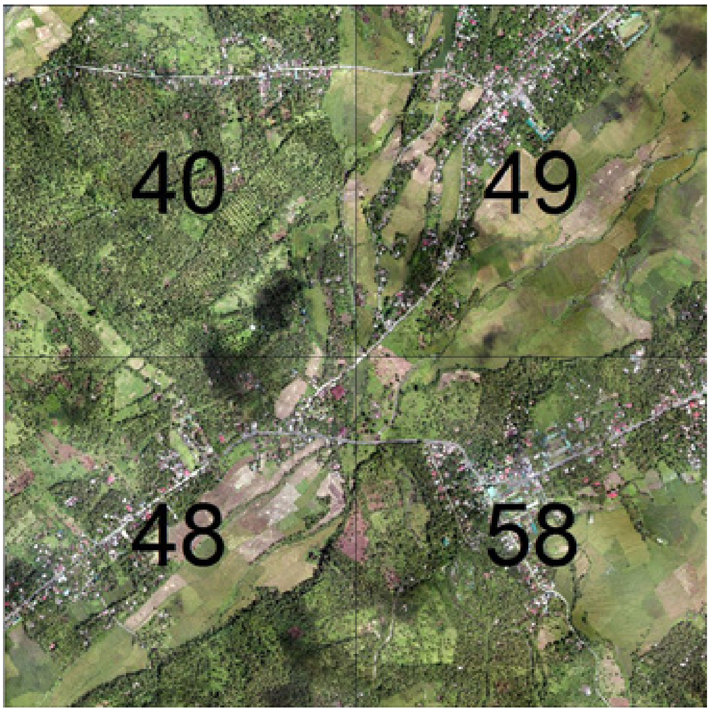


Figure 21. Sample orthophotograph tiles for the Guinale floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for the Guinale floodplain. These blocks are composed of AlbaySorsogon and AlbaySorsogon reflights, with a total area of 510.66 square kilometers. Table 13 indicates the name and corresponding area of each block, in square kilometers.

Table 13. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Albay_Sorsogon_Blk19A	121.83
Albay_Sorsogon_Blk19O	37.30
Albay_Sorsogon_Blk19N	56.25
Albay_Sorsogon_reflights_Blk19A	64.81
Albay_Sorsogon_reflights_Blk19A_supplement1	43.23
Albay_Sorsogon_reflights_Blk19A_supplement2	18.61
Albay_Sorsogon_reflights_Blk19A_supplement3	24.00
Albay_Sorsogon_reflights_Blk19T	75.51
Albay_Sorsogon_reflights_Blk19N	69.12
TOTAL	510.66 sq.km

Portions of the DTM before and after manual editing are exhibited in Figure 22. The riverbank and pond furrow (Figure 22a) had been misclassified and removed during classification process, and had to be retrieved to complete the surface (Figure 22b) to allow for the correct flow of water. The triangulated riverbank (Figure 22c) was also considered to be an impedance to the flow of water along the river, and had to be removed (Figure 22d) in order to hydrologically correct the river.

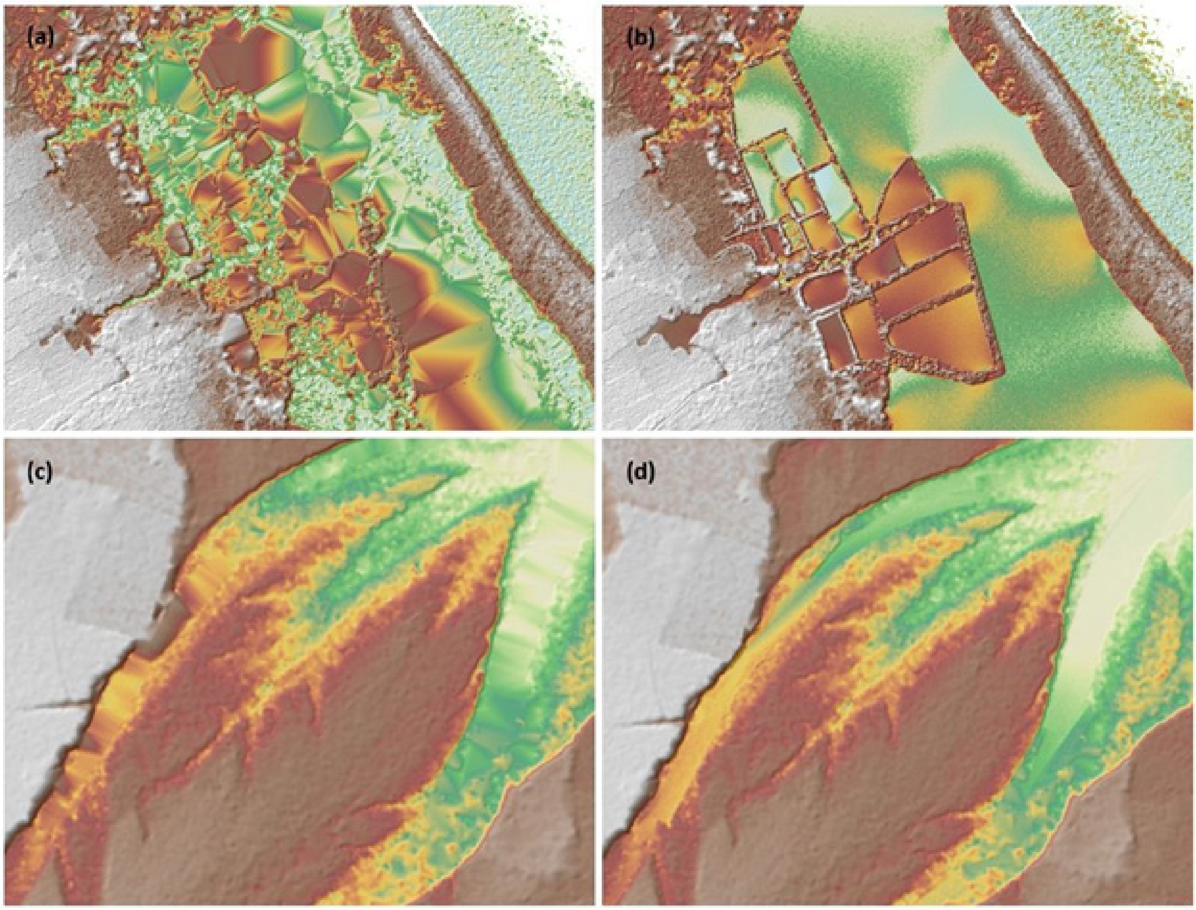


Figure 22. Portions in the DTM of the Guinale floodplain – a riverbank and pond furrow (a) before and (b) after data retrieval; a triangulated riverbank (c) before and (d) after manual editing.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Albay_Sorsogon DEM, overlapping with the blocks to be mosaicked. Table 14 provides the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for the Guinale floodplain is presented in Figure 23. It is visible that the entire Guinale floodplain is 96.4% covered by LiDAR data.

Table 14. Shift values of each LiDAR block of the Guinale floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Albay_Sorsogon_Blk19A	0.00	-1.00	2.90
Albay_Sorsogon_Blk19O	0.00	0.00	0.00
Albay_Sorsogon_Blk19N	2.75	-2.00	0.70
Albay_Sorsogon_reflights_Blk19A	0.00	0.00	-0.06
Albay_Sorsogon_reflights_Blk19A_supplement1	Reference Raster		
Albay_Sorsogon_reflights_Blk19A_supplement2	0.00	0.00	-0.06
Albay_Sorsogon_reflights_Blk19A_supplement3	0.00	0.00	0.02
Albay_Sorsogon_reflights_Blk19T	0.00	0.00	0.00
Albay_Sorsogon_reflights_Blk19N	3.00	-4.00	0.48

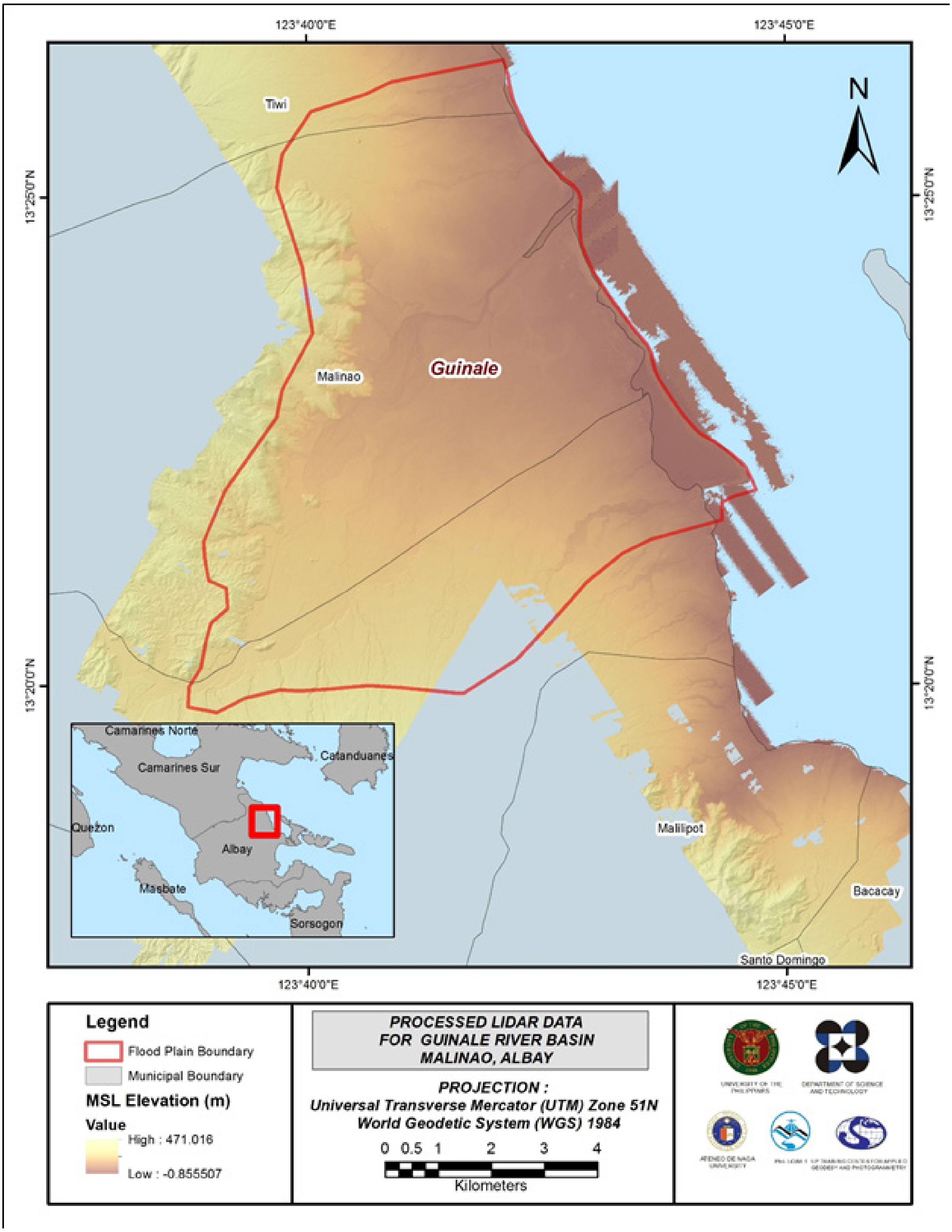


Figure 23. Map of processed LiDAR data for the Guinale floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Guinale floodplain. The extent of the validation survey done in Guinale to collect points with which the LiDAR dataset was validated is illustrated in Figure 24, with the validation survey points highlighted in green. A total of 26,665 survey points were used for calibration and validation of the Guinale LiDAR data. Random selection of 80% of the survey points was performed and resulted in 23,990 points, which were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points, to assess the quality of data and to obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 1.85 meters, with a standard deviation of 0.14 meters. Calibration of Guinale LiDAR data was done by subtracting the height difference value, 1.85 meters, from the Guinale mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the LiDAR data and the calibration data.

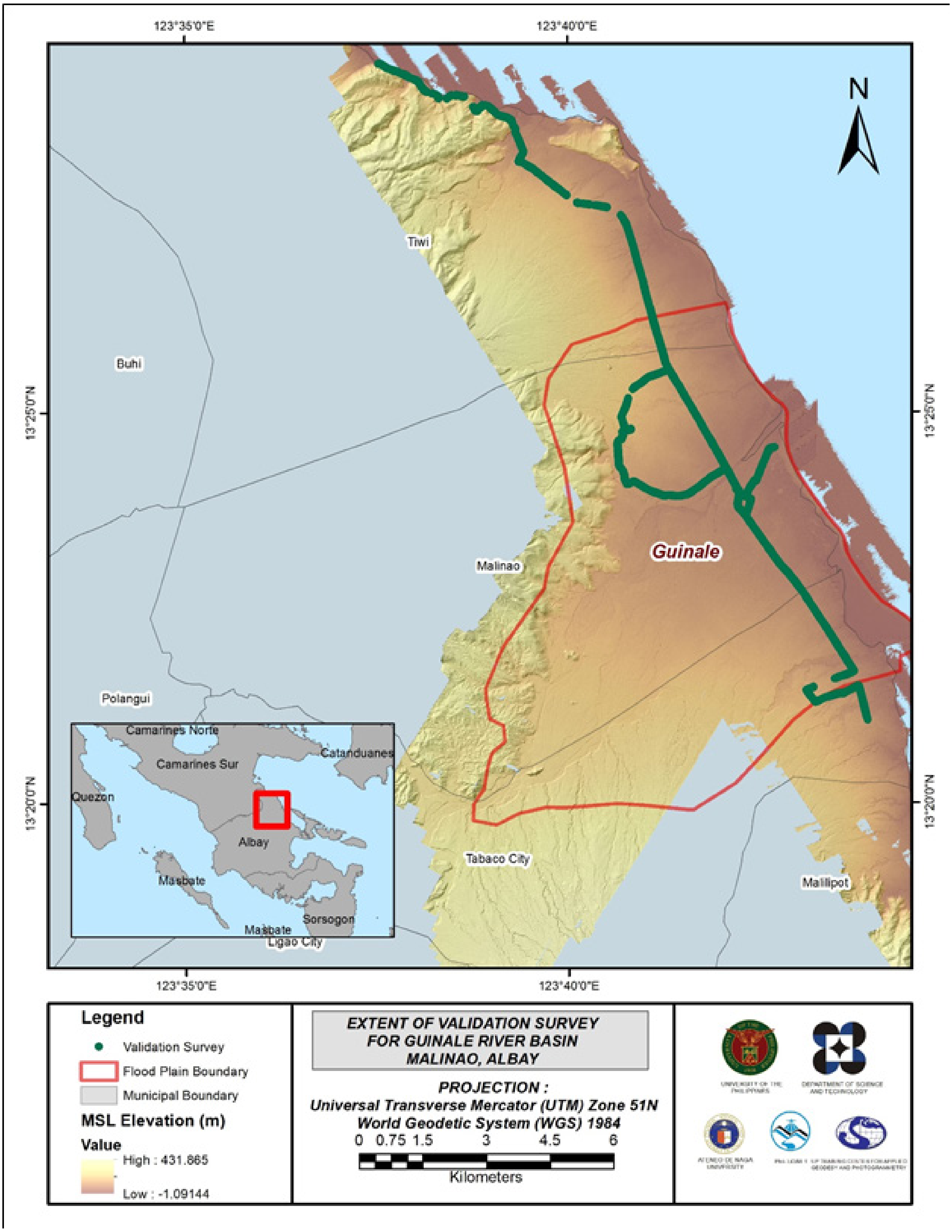


Figure 24. Map of Guinale floodplain, with validation survey points in green

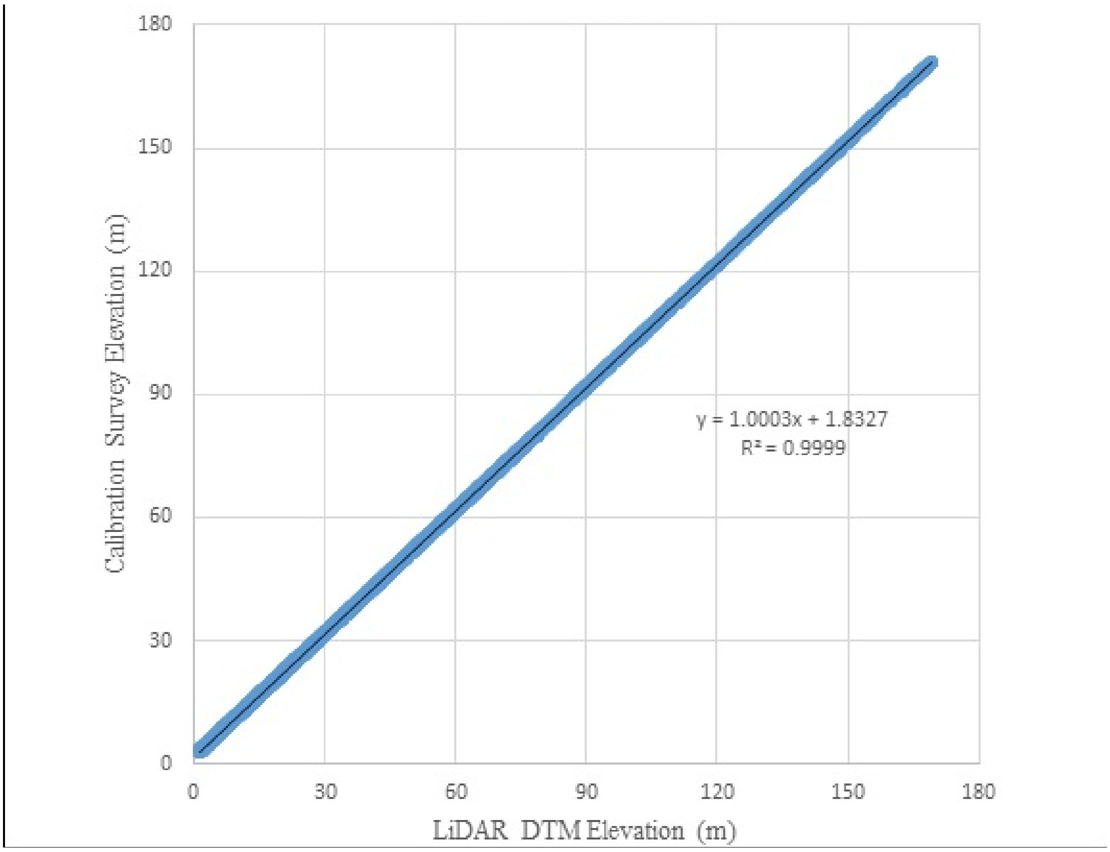


Figure 25. Correlation plot between the calibration survey points and the LiDAR data

Table 15. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	1.85
Standard Deviation	0.14
Average	-1.85
Minimum	-2.13
Maximum	-1.56

A total of 4,909 points were collected by the DVBC for the Guinale River Basin. Random selection of points resulted in 667 points, which were used for the validation of calibrated Guinale 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 the validation elevation values is 0.12 meters, with a standard deviation of 0.12 meters, as indicated in Table 16.

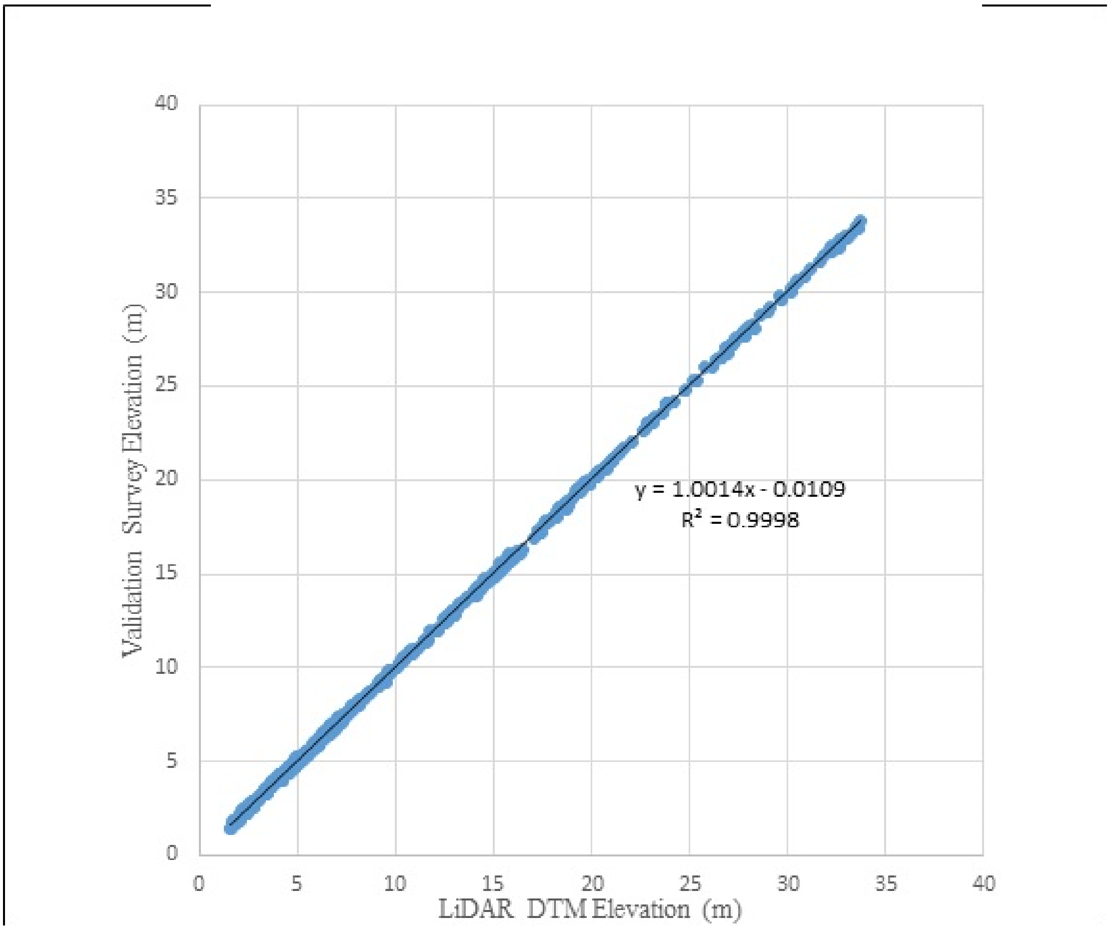


Figure 26. Correlation plot between the validation survey points and the LiDAR data

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.12
Average	-0.004
Minimum	-0.25
Maximum	0.25

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Guinale, with 10,009 bathymetric survey points. The resulting raster surface produced was done by employing the Kernel Interpolation with barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.25 meters. The extent of the bathymetric survey done by the DVBC in Guinale, integrated with the processed LiDAR DEM, is presented in Figure 27.

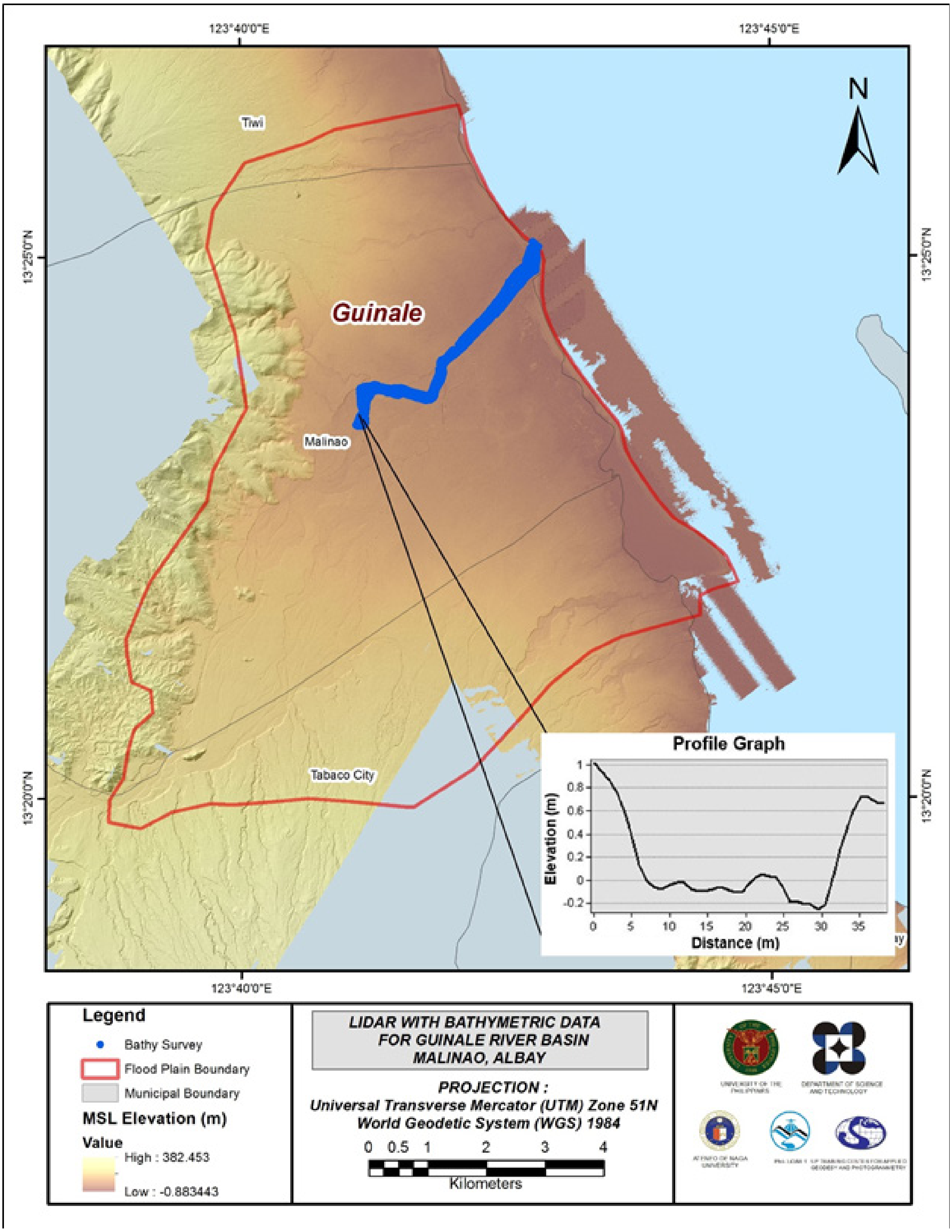


Figure 27. Map of the Guinale floodplain with bathymetric survey points shown in blue

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 DEM with a 1-meter resolution was used to delineate footprints of building features, consisting of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks, comprised of main thoroughfares such as highways and municipal and barangay roads, are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Guinale floodplain, including its 200-meter buffer zone, has a total area of 83.33 sq. km. Of this area, a total of 5.0 sq. km., corresponding to a total of 1,139 building features, were considered for quality checking (QC). Figure 28 shows the QC blocks for the Guinale floodplain.

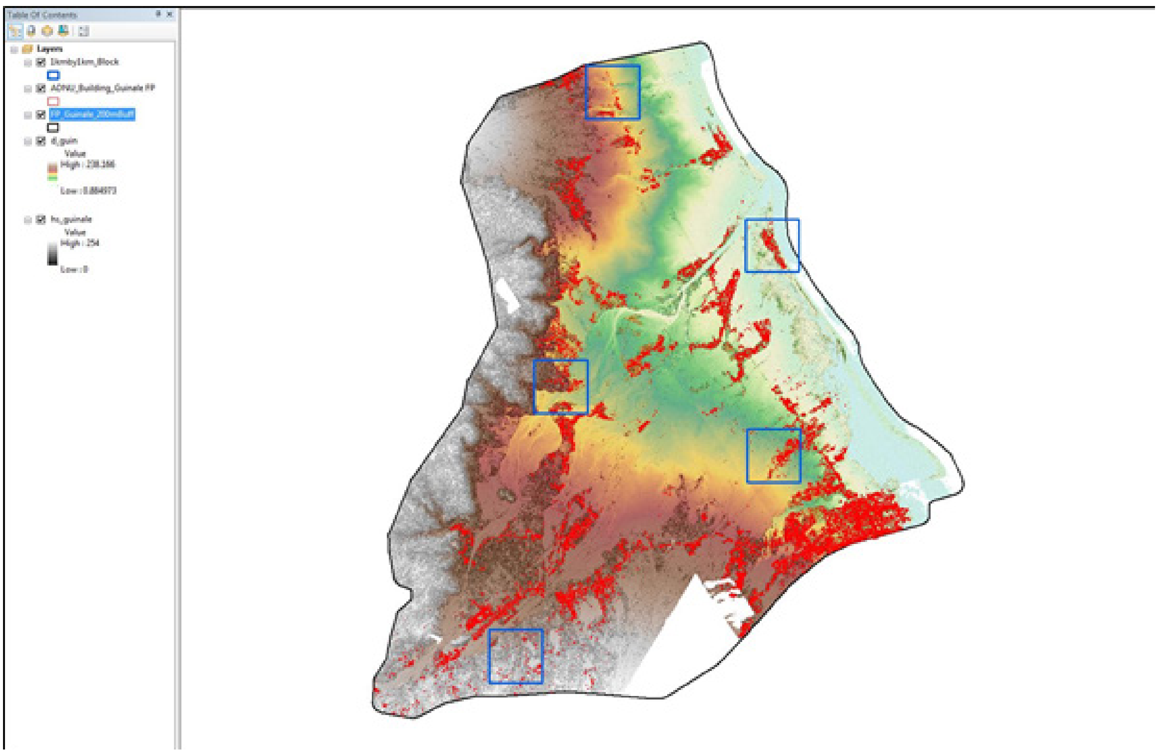


Figure 28. Blocks (in blue) of Guinale building features that were subjected to QC

Quality checking of Guinale building features resulted in the ratings given in Table 17.

Table 17. Quality checking ratings for the Guinale building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Guinale	96.77	99.65	82.14	PASSED

3.12.2 Height Extraction

Height extraction was done for 19,319 building features in the Guinale floodplain. Of these building features, 599 were filtered out after height extraction, resulting in 18,720 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 10.56 m.

3.12.3 Feature Attribution

Feature Attribution was done for 18,720 building features in the Guinale floodplain, with the use of participatory mapping and innovations. The participatory mapping approach employed the creation of feature extracted maps in the area, and the presentation of spatial knowledge to the community, with the premise that the local community representatives are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an Android application called the Resource Extraction for Geographic Information System (reGIS). The application was developed to supplement and increase the field gathering procedures done by the ADNU Phil-LiDAR 1 Team. The reGIS application allows the user to automate some procedures in data gathering and feature attribution, to further improve and accelerate the geotagging process. The application lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy, and additional remarks. This is all done through a few swipes, with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

Table 18 summarizes the number of building features extracted per type. Table 19 indicates the total length of each road type, and Table 20 provides the number of water features extracted per type.

Table 18. Building features extracted for the Guinale floodplain

Facility Type	No. of Features
Residential	17,777
School	466
Market	9
Agricultural/Agro-Industrial Facilities	45
Medical Institutions	38
Barangay Hall	34
Military Institution	0
Sports Center/Gymnasium/Covered Court	8
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	44
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	3
Water Supply/Sewerage	14
Religious Institutions	62
Bank	0
Factory	0
Gas Station	5
Fire Station	1
Other Government Offices	44
Other Commercial Establishments	169
Total	18,720

Table 19. Total length of extracted roads for the Guinale floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Guinale	116.47	11.76	18.27	10.54	0.00	**157.04**

Table 20. Number of extracted water bodies for the Guinale floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Guinale	1	78	1	0	0	**80**

A total of thirty-nine (39) 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 completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

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

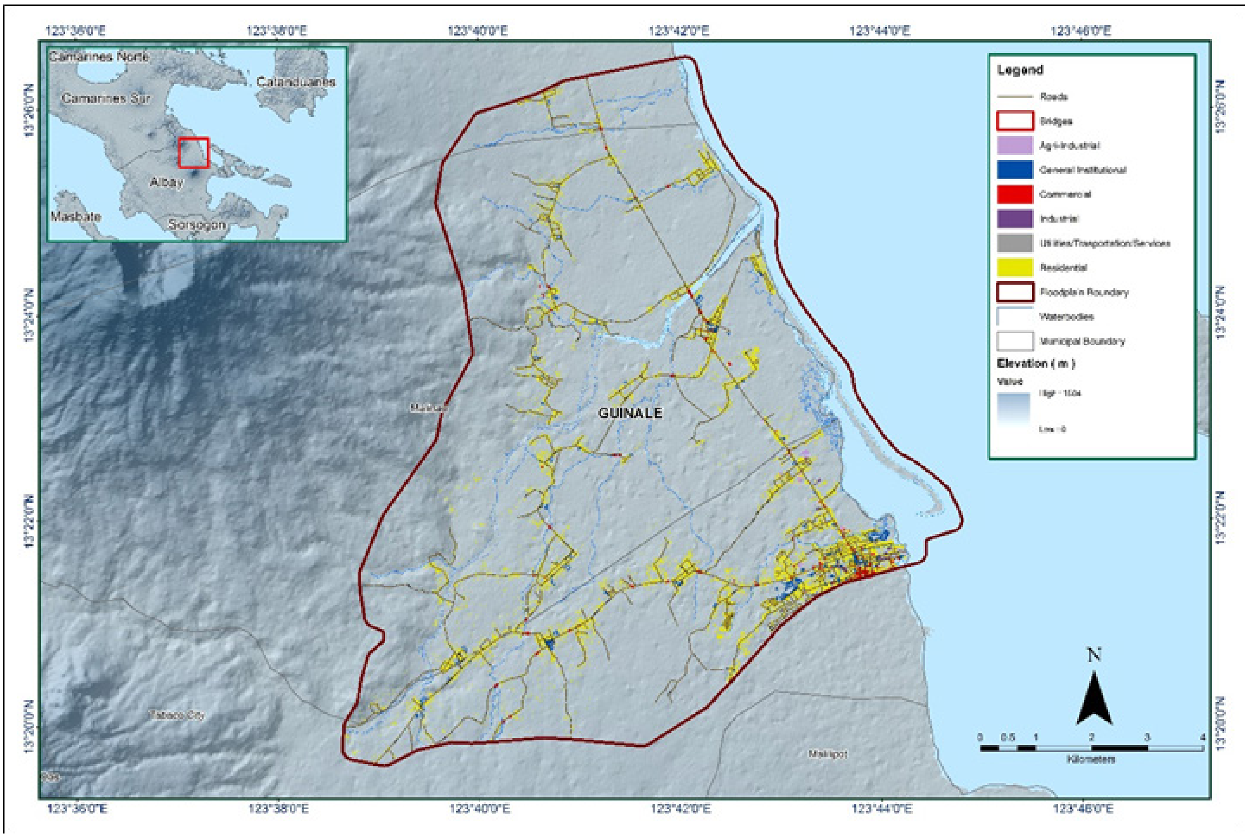


Figure 29. Extracted features of the Guinale floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto.

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Guinale River on June 22 – July 6, 2016. The scope of work was comprised of the following: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built survey at the Imperial Bridge in Barangay Balza, Municipality of Malinao, Albay; (iv.) validation points acquisition of about 29 km. covering the Guinale River Basin area; and (v.) bathymetric survey from the upstream side of the river in Barangay Matalipni to the mouth of the river located in Barangay Jonop, both in the Municipality of Malinao, with an approximate length of 5.157 km., using Trimble® SPS 882 GNSS PPK survey technique (Figure 30).

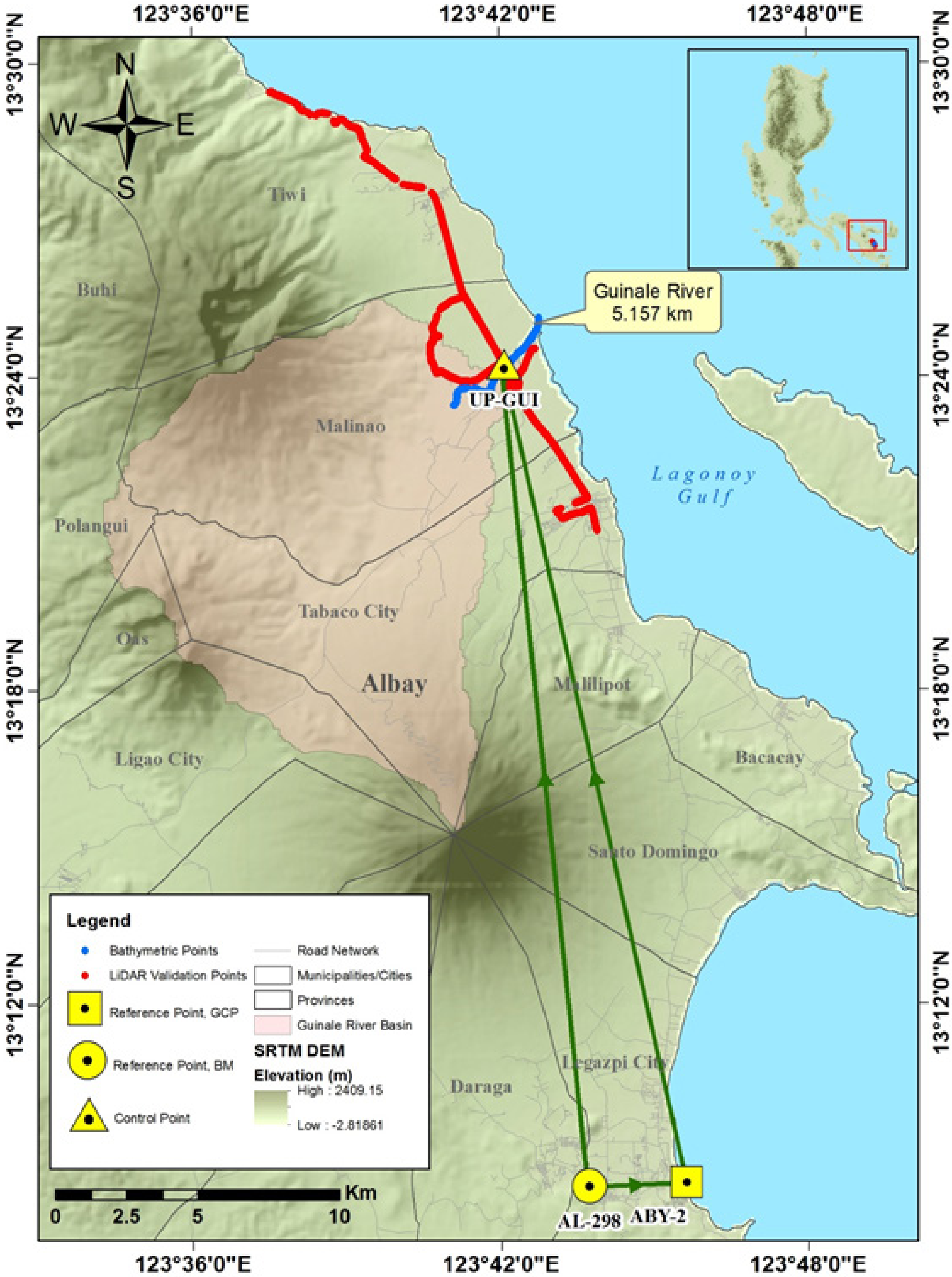


Figure 30. Extent of the bathymetric survey (in blue line) in the Guinale River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for the Guinale River Basin is composed of a loop established on July 2, 2016, occupying the following reference points: (i.) ABY-2, a first-order GCP located in Barangay 31 Centro Baybay, Legazpi City, Albay; and (ii.) AL-298, a first order BM, located in Barangay 1 Ems Barrio, also in Legazpi City, Albay.

A control point was established at the approach of the Imperial Bridge: UP-GUI, located in Barangay Balza, Municipality of Malinao, Albay.

The summary of reference and control points and their corresponding locations is provided in Table 21, while the GNSS network established is illustrated in Figure 31.

Table 21. List of reference and control points occupied for the Guinale River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84 N)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
ABY-2	1st order, GCP	13°08'35.29707"N	123°45'3716782"E	118.144	-	07-02-16
AL-298	1st order, BM	-	-	65.015	11.696	07-02-16
UP-GUI	Used as Marker	-	-	-	-	07-02-16

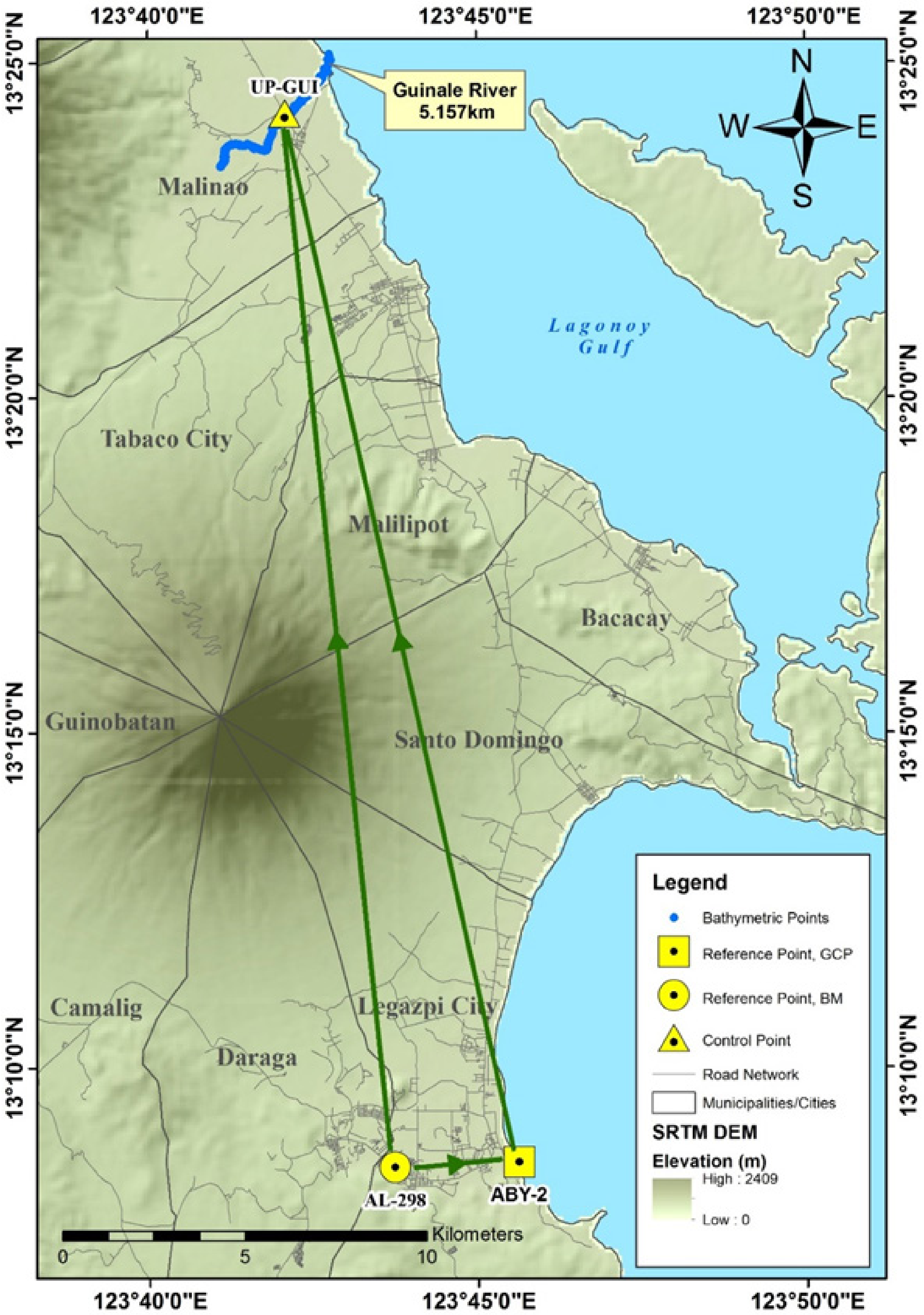


Figure 31. GNSS Network covering the Guinale River

The GNSS set-ups on the recovered reference points and established control points in the Guinale River are depicted in Figure 32 to Figure 34.

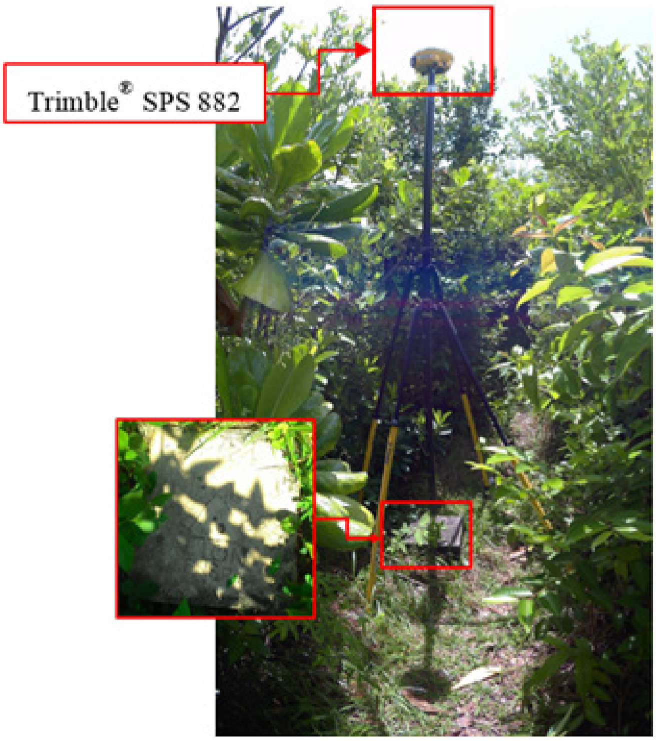


Figure 32. GNSS base set-up, Trimble® SPS 882, at ABY-2, situated on the top of a hill in Barangay 31 Centro Baybay, Legazpi City, Albay

Figure 33. GNSS receiver set-up, Trimble® SPS 882, at AL-298, located at the approach of the Sagpon Bridge in Barangay 1-Em's Barrio, Legazpi City, Albay

Figure 34. GNSS receiver set-up, Trimble® SPS 852, at UP-GUI, located at the approach of the Imperial Bridge in Barangay Balza, Municipality of Malinao, Albay

4.3 Baseline Processing

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 of portions of baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of the control points in the Guinale River Basin generated by the TBC software is summarized in Table 22.

Table 22. Baseline Processing Summary Report for the Guinale River Survey.

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
AL-298 --- ABY-2 (B333)	07-02-16	Fixed	0.003	0.012	87°41'17"	3411.380	53.126
AL-298 --- UP-GUI (B335)	07-02-16	Fixed	0.003	0.017	354°09'54"	29145.260	-6.002
ABY-2 --- UP-GUI (B334)	07-02-16	Fixed	0.003	0.012	347°33'22"	29551.702	-59.132

As shown Table 22, a total of three (3) baselines were processed, with reference points ABY-2 and AL-298 held fixed for coordinate and elevation values. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates in Table 24 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, or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 26 for complete details.

The four (4) control points – ANY-2, AL-298, UP-GUI, and ABY-2 – were occupied and observed simultaneously to form a GNSS loop. Coordinates of ABY-2, and elevation values of AL-298 were held fixed during the processing of the control points, as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ABY-2	Global	Fixed	Fixed		
AL-298	Grid				Fixed
Fixed = 0.000001 (Meter)					

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 24. The fixed control ABY-2 has no values for grid errors, while AL-298 has no values for elevation errors.

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ABY-2	582405.288	?	1453089.242	?	64.886	0.007	LL
AL-298	578998.183	0.001	1452941.820	0.001	11.696	?	e
UP-GUI	575951.543	0.001	1481917.879	0.001	6.415	0.008	

With the mentioned equation, $\sqrt{(x_e)^2+(y_e)^2}<20cm$ for horizontal and $z_e<10$ cm for the vertical, the computations for accuracy are as follows:

a. ABY-2
Horizontal Accuracy = Fixed
Vertical Accuracy = 0.7 cm < 10 cm

b. AL-298
Horizontal Accuracy = $\sqrt{((0.1)^2 + (0.1)^2}$
= $\sqrt{(0.01 + 0.01)}$
= 0.14 < 20 cm
Vertical Accuracy = Fixed

c. UP-GUI
Horizontal Accuracy = $\sqrt{((0.1)^2 + (0.1)^2}$
= $\sqrt{(0.01 + 0.01)}$
= 0.14 < 20 cm
Vertical Accuracy = 0.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two (2) occupied control points are within the required precision.

Table 25. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
ABY-2	N13°08'52.12609"	E123°29'44.20763"	104.205	0.056	LL
AL-298	N13°48'11.94074"	E123°20'04.40925"	57.480	?	e
UP-GUI	N13°44'36.29589"	E123°31'48.99957"	61.737	0.055	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as reflected in Table 25. Based on the results of the computations, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of the reference and control points utilized in the Guinale River GNSS Static Survey is indicated in Table 26.

Table 26. Reference and control points used and their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ABY-2	2nd order, GCP	13°08'35.29707"N	123d45'37.16782"E	118.144	1453089.242	582405.288	64.886
AL-298	1st order, BM	13°08'30.82614"N	123d43'43.99011"E	65.015	1452941.82	578998.183	11.696

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

The cross-section and bridge as-built surveys were conducted on July 3, 2016 at the downstream side of the Imperial Bridge in Barangay Balza in the Municipality of Malinao, Albay, as depicted in Figure 35. A survey-grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey.

Figure 35. A) Cross-section survey in B) Imperial Bridge facing downstream

The cross-sectional line surveyed at the Imperial Bridge is about 146 meters with one hundred thirty-nine (139) cross-sectional points, using the control point UP-GUI as the GNSS base station. The location map, cross-section diagram, and the bridge data form are presented in Figure 36, Figure 37, and Figure 38, respectively.

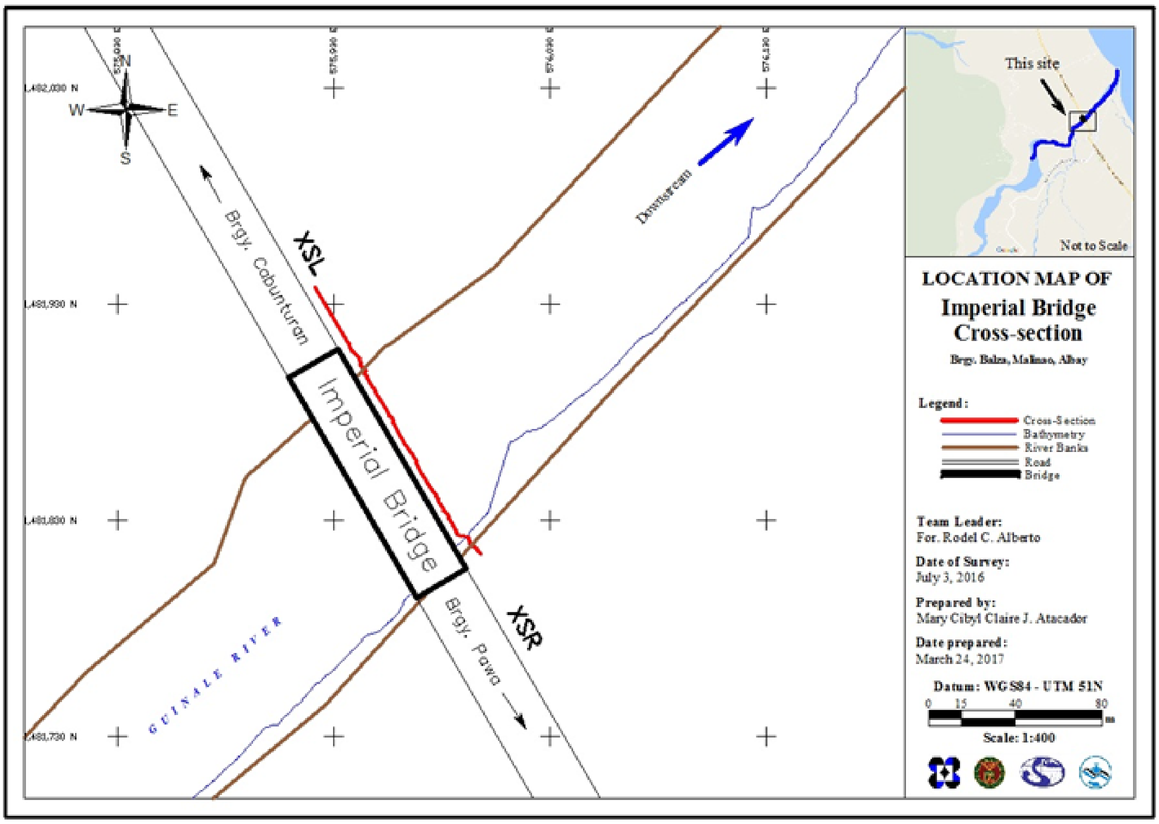


Figure 36. Imperial bridge cross-section location map

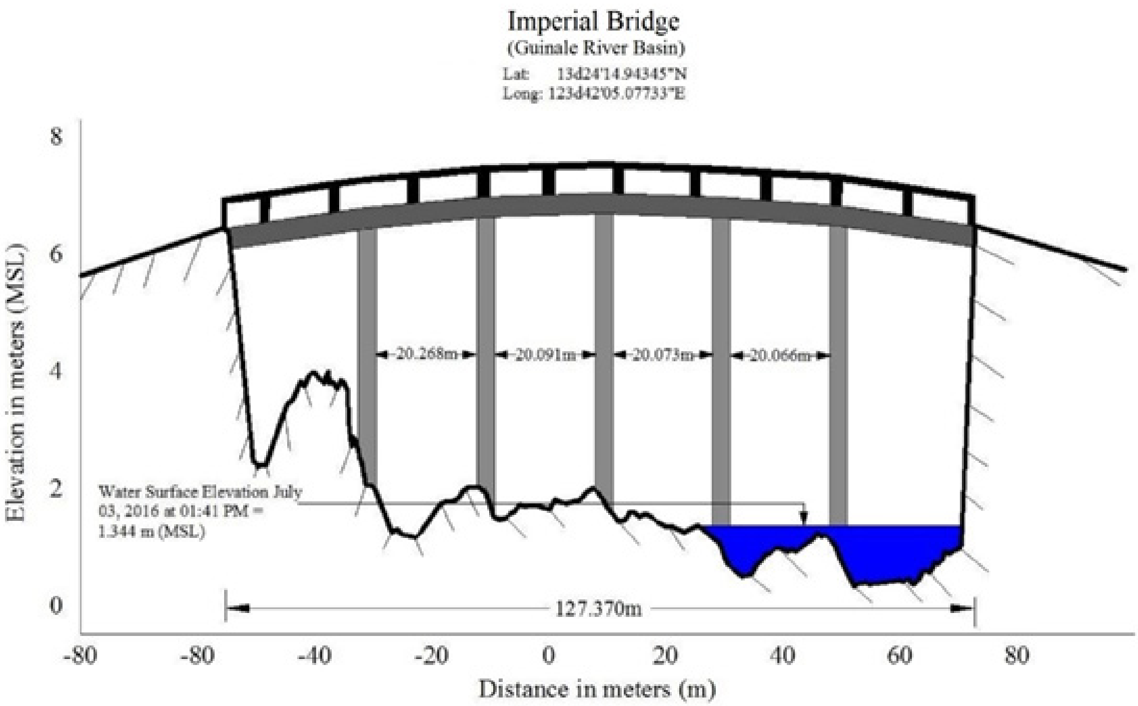
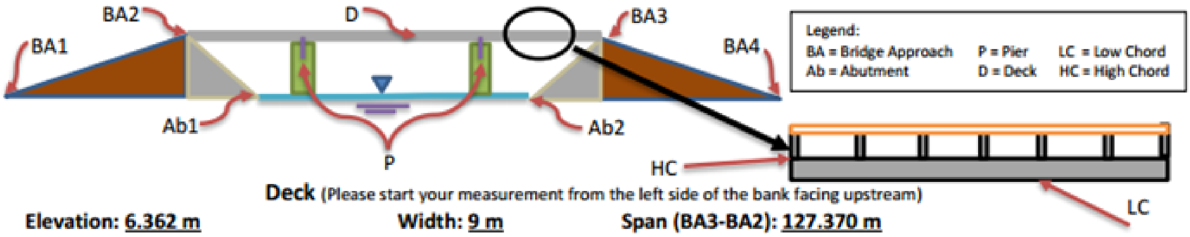


Figure 37. Imperial Bridge cross-section diagram

Bridge Data Form

Bridge Name: Imperial Bridge	**Date:** July 3, 2016
River Name: Quinale River	**Time:** 1:41 PM
Location (Brgy, City,Region): Brgy. Balza, Municipality of Malinao, Albay	
Survey Team: Rodel Alberto, Cybil Atacador, Russel Andrade	
Flow condition: normal	**Weather Condition:** fair
Latitude: 13°24'14.23157" N	**Longitude:** 123°42'05.250326" E



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

Elevation: 6.362 m **Width:** 9 m **Span (BA3-BA2):** 127.370 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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	5.612 m	BA3	152.714 m	6.453 m
BA2	25.344 m	6.362 m	BA4	178.512 m	5.700 m

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

	Station (Distance from BA1)	Elevation
Ab1	24.193 m	6.408 m
Ab2	152.518 m	5.809 m

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

Shape: Flat oval Number of Piers: 5 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	48.796 m	6.771 m	NA
Pier 2	69.064 m	6.955 m	NA
Pier 3	89.155 m	7.021 m	NA
Pier 4	109.228 m	6.944 m	NA
Pier 5	129.294 m	6.811 m	NA

NOTE: Use the center of the pier as reference to its station

Figure 38. Bridge as-built form of the Imperial Bridge

The water surface elevation of the Guinale River was determined using a survey-grade GNSS receiver Trimble® SPS 882 in PPK survey technique on July 3, 2016 at 13:41 hrs., with a value of 1.344 m in MSL, as shown in Figure 37. This was translated into markings on the bridge's deck using the same technique, resulting in the value of 6.746 m in MSL, as exhibited in Figure 39. This served as a reference for flow data gathering and depth gauge deployment of the ADNU Phil-LiDAR 1 Team.

Figure 39. Water-level markings on the Imperial Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on July 2, 2016, using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted in front of a vehicle, as shown in Figure 40. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.255 meters, 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-GUI occupied as the GNSS base station during the conduct of the survey.

Figure 40. Validation points acquisition survey set-up along the Guinale River Basin

The survey started at the Imperial Bridge in Barangay Balza in the Municipality of Malinao; and headed, north covering six (6) barangays in Municipality of Malinao and eleven (11) barangays in Municipality of Tiwi, which ended in Barangay Bariis. The survey then traveled south, covering another six (6) barangays in Municipality of Malinao, and twelve (12) barangays in Tabaco City, ending in Barangay Tagas. The survey gathered a total of 6,135 points with an approximate length of 29 km., using UP-GUI as the GNSS base station for the entire extent of the validation points acquisition survey. This is illustrated in the map in Figure 41.

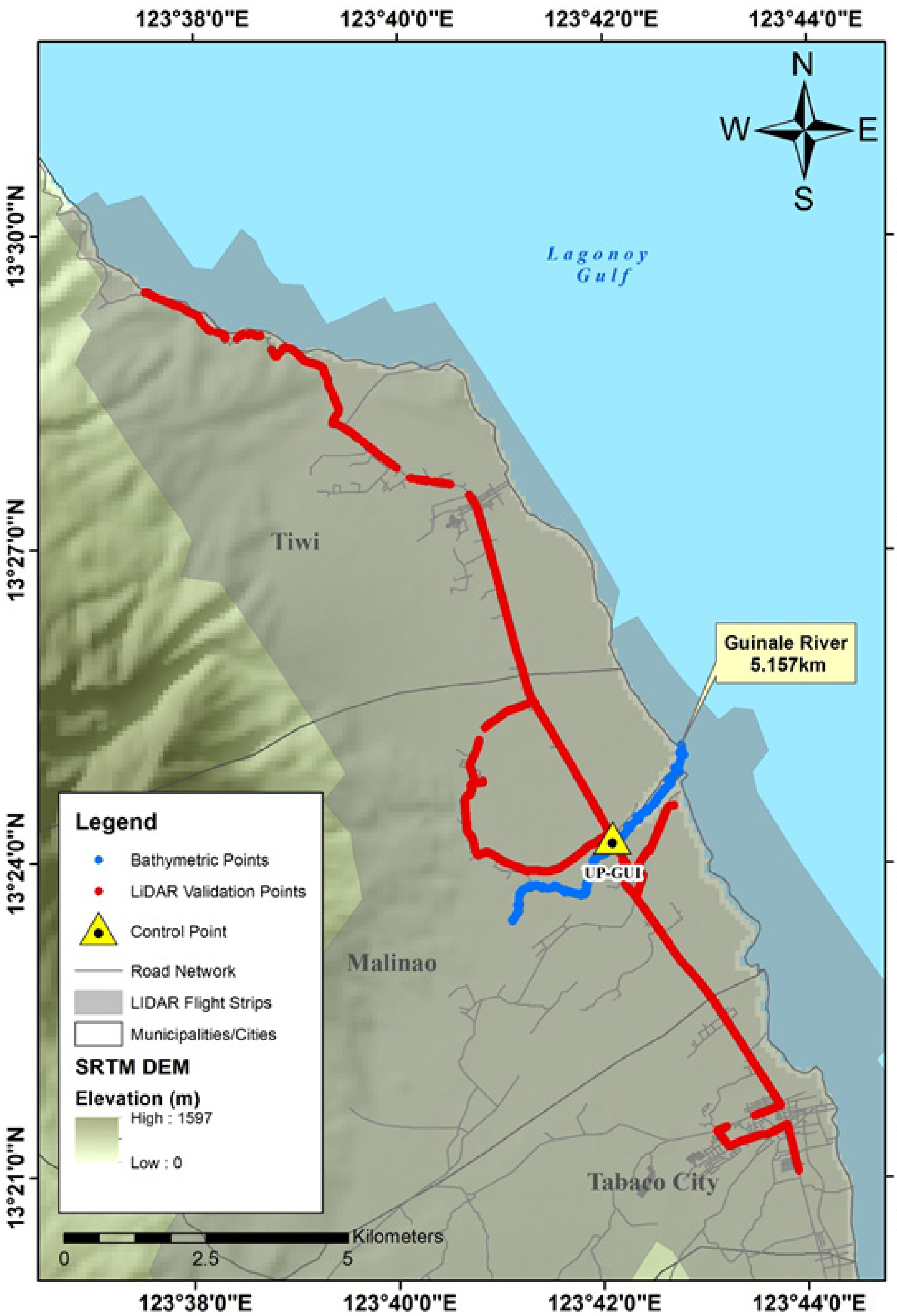


Figure 41. Extent of the LiDAR ground validation survey of the Guinale River basin

4.7 Bathymetric Survey

A manual bathymetric survey was executed on June 25, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode, as exhibited in Figure 42. The survey started in the upstream portion at Barangay Matalipni in the Municipality of Malinao, with coordinates 13°23’27.34608”N, 123°41’06.36760”E; and ended at the mouth of the river at Barangay Jonop, also in the Municipality of Malinao, with coordinates 13°25’07.26666”N, 123°42’46.04937”E. The control point UP-GUI was used as the GNSS base station all throughout the survey.

Figure 42. Bathymetric survey using Trimble® SPS 882 in GNSS PPK survey in the Guinale River

The bathymetric survey for the Guinale River gathered a total of 10,174 points covering 5.157 km. of the river, traversing ten (10) barangays in Municipality of Malinao: Matalpini, Tuliw, Sugcad, Libod, Pawa, Balza, Bagumbayan, Poblacion, Baybay, and Jonop. A CAD drawing was also produced to illustrate the riverbed profile of the Guinale River, provided in Figure 44. The profile shows that the riverbed elevation had an 8-meter difference. The highest elevation observed was 7.254 meters above MSL, located at the upstream portion of the river in Barangay Matalpini; while the lowest was -1.098 meters below MSL, located at the downstream portion of the river in Barangay Jonop. An additional length of 750 meters was surveyed upstream because ADNU’s deployment site in Barangay Matalipni was more accessible than the starting point of the planned bathymetric line, as seen in Figure 43.

Figure 43. Extent of the bathymetric survey of the Guinale River

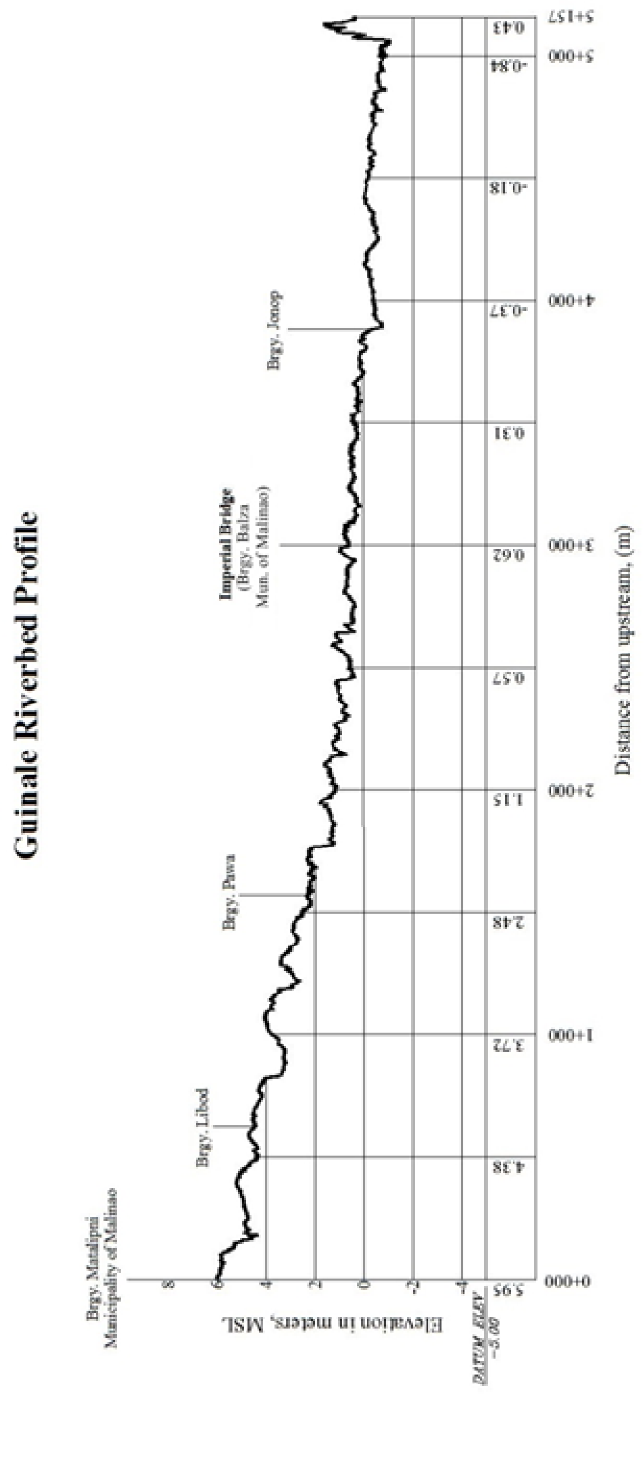


Figure 44. Guinale Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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The methods applied in this Chapter were based on the DREAM methods manual (Lagmay, 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

Rainfall, water level, and flow in a certain period of time, which are components and data that affect the hydrologic cycle of the river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from one (1) automatic rain gauge (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The said rain gauge is the San Rafael St. Vaisala (Figure 45). The precipitation data collection was held on December 14, 2015 at 10:00 hrs. until December 15, 2015 at 17:30 hrs., with a 15-minute recording interval.

The total precipitation for this event in the San Rafael St. Vaisala was 61.71mm. It had a peak rainfall of 7.07mm on December 14, 2015 at 05:45 hrs. The lag time between the peak rainfall and discharge was eight (8) hours and five (5) minutes.

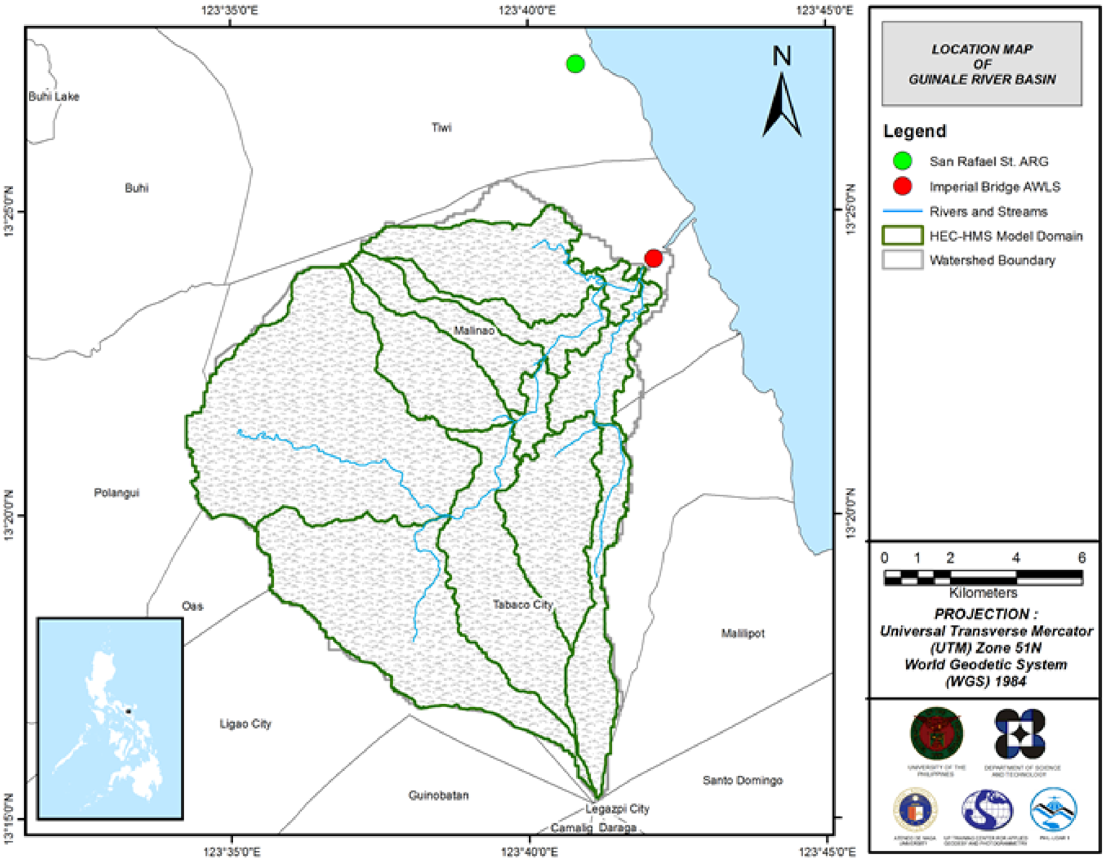

Figure 45. The location map of the Guinale HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 46) at the Imperial Bridge in Malinao, Albay (13°24'12.6"N, 123°42'6.44"E) to establish the relationship between the observed water levels (H) at the Imperial Bridge and the outflow (Q) of the watershed at this location.

For the Imperial Bridge, the rating curve is expressed as Q = 9.2602e.0.9427h, as shown in Figure 47.

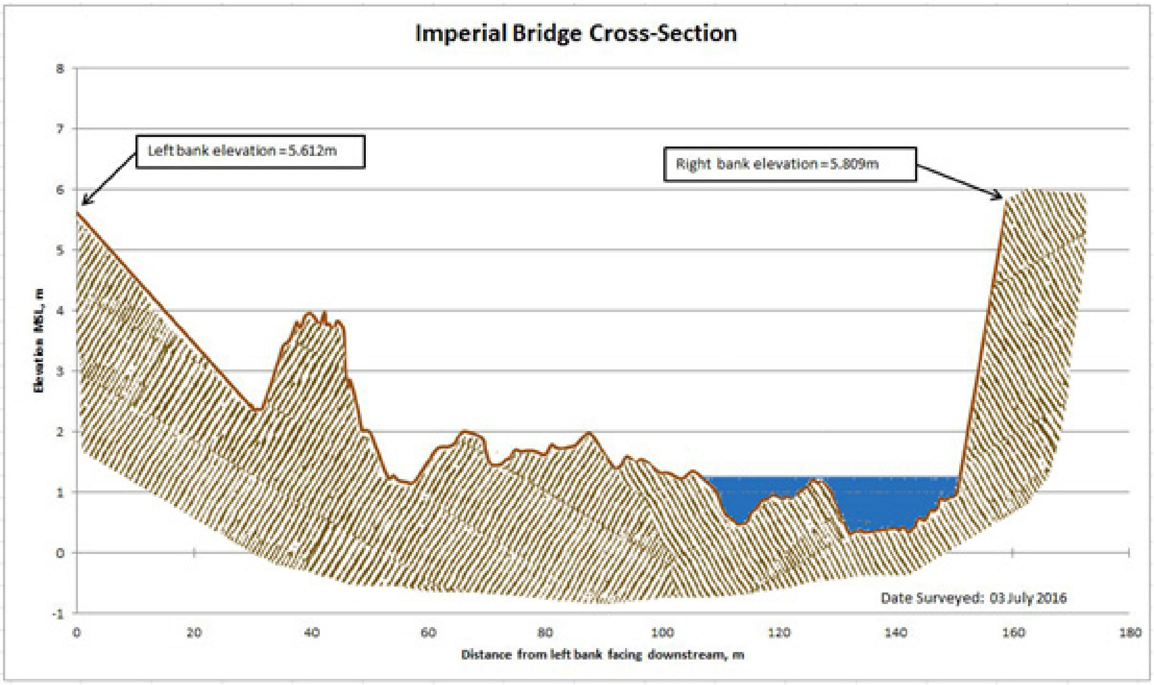

Figure 46. Cross-section plot of the Imperial Bridge

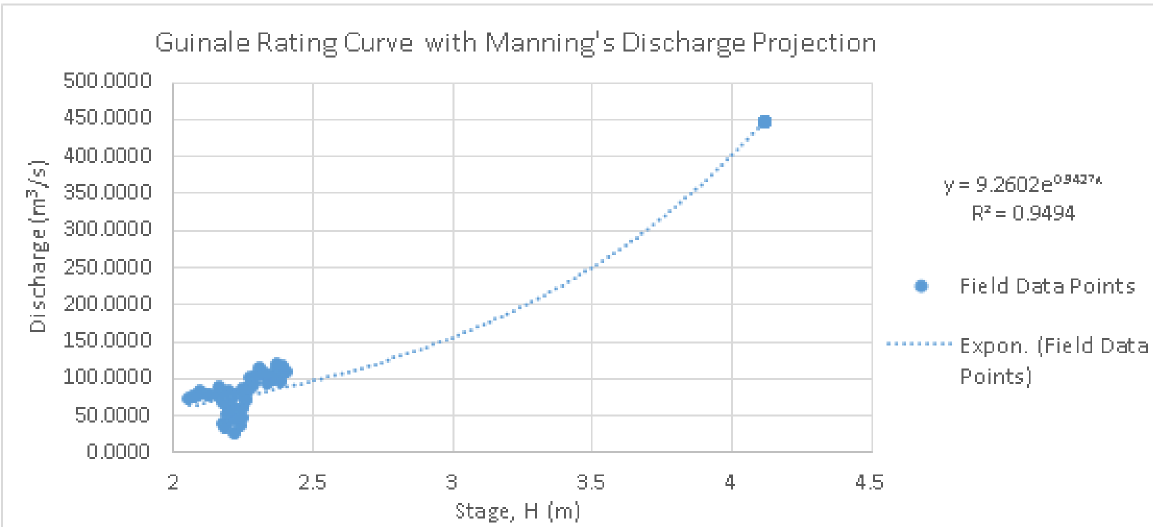

Figure 47. The rating curve of the Imperial Bridge in Malinao, Albay

This rating curve equation was used to compute for the river outflow at the Imperial Bridge for the calibration of the HEC-HMS model, shown in Figure 48. The total rainfall for this event was 61.71mm, and the peak discharge was 264.0349 m3/s on December 15, 2015 at 01:50 hrs.

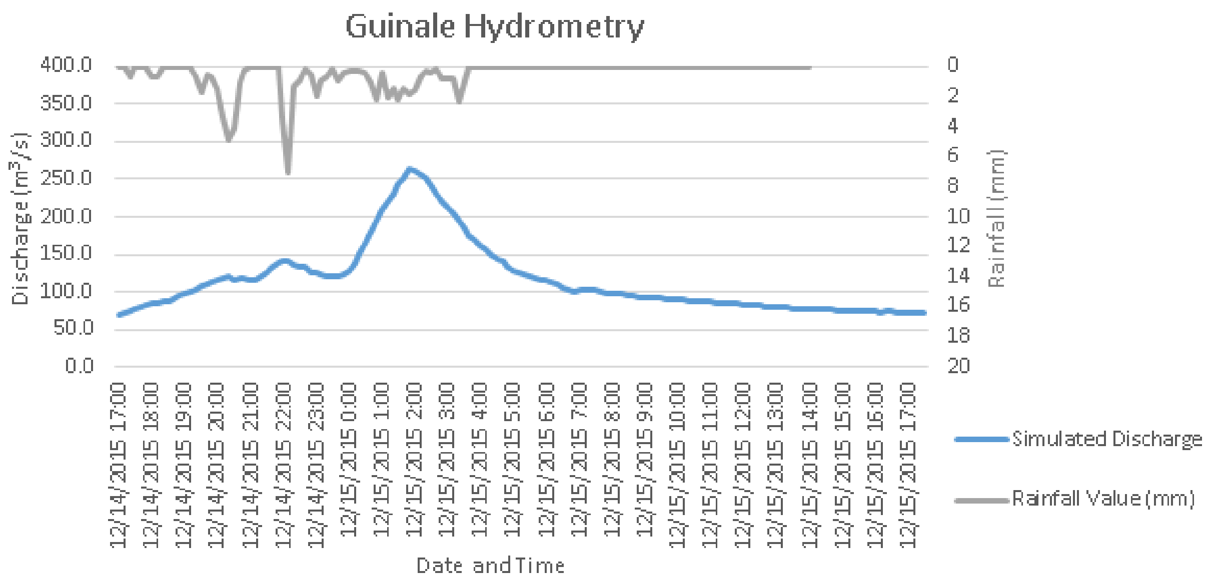

Figure 48. Rainfall and outflow data of the Guinale River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Legazpi RIDF Station (Table 27). This station was selected based on its proximity to the Guinale watershed (Figure 49). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 26-year record.

Table 27. RIDF values for the Guinale Rain Gauge 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
2	21	31.9	39.6	53.4	74.5	89.3	119.2	145.5	176.4
5	29.1	43.8	54.5	76.7	113.4	138.5	189.8	228.7	260.5
10	34.5	51.6	64.3	92.2	139.1	171.1	236.6	283.8	316.1
15	37.5	56	69.8	100.9	153.6	189.4	263	314.8	347.5
20	39.6	59.1	73.7	107	163.7	202.3	281.5	336.6	369.5
25	41.3	61.5	76.7	111.7	171.6	212.2	295.7	353.4	386.4
50	46.3	68.9	85.9	126.2	195.7	242.7	339.6	405	438.6
100	51.3	76.2	95.1	140.5	219.6	273.1	383.1	456.2	490.3

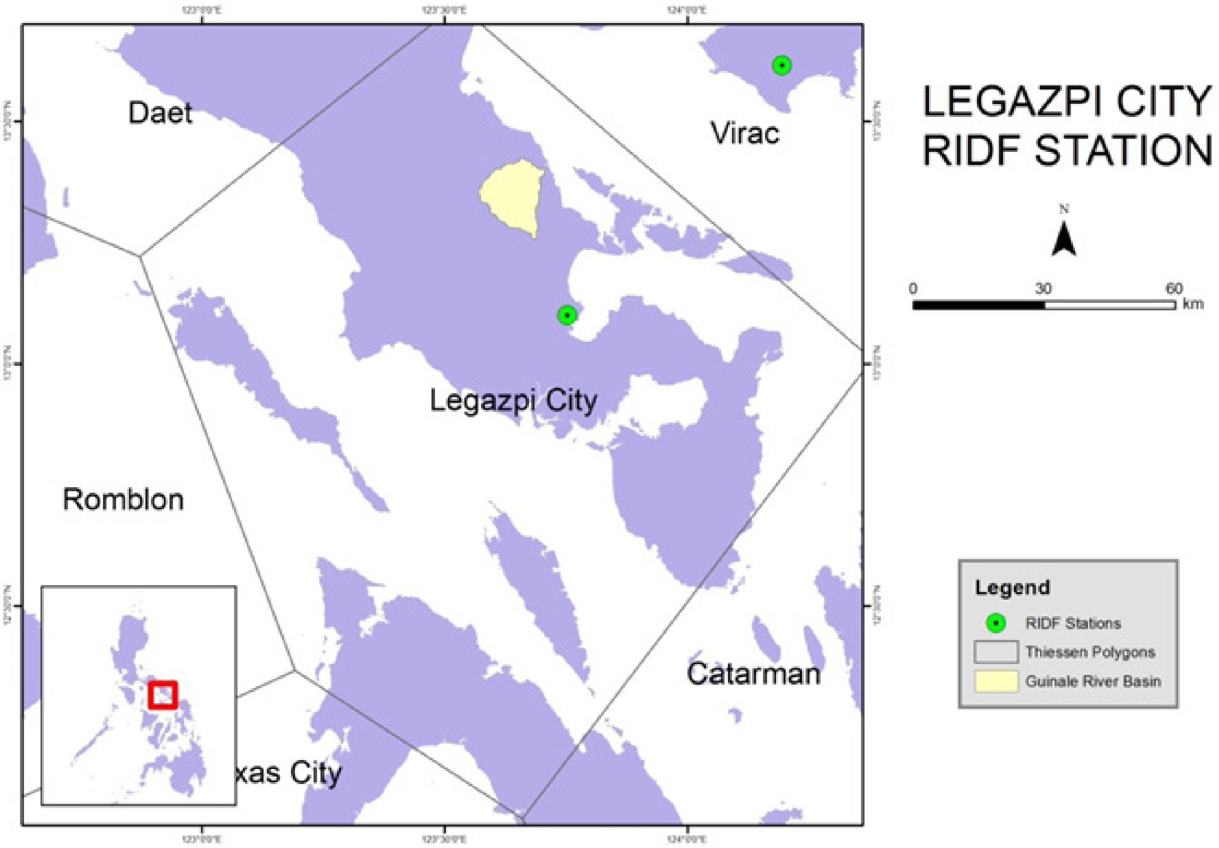

Figure 49. The location of the Legazpi City RIDF Station relative to the Guinale River Basin

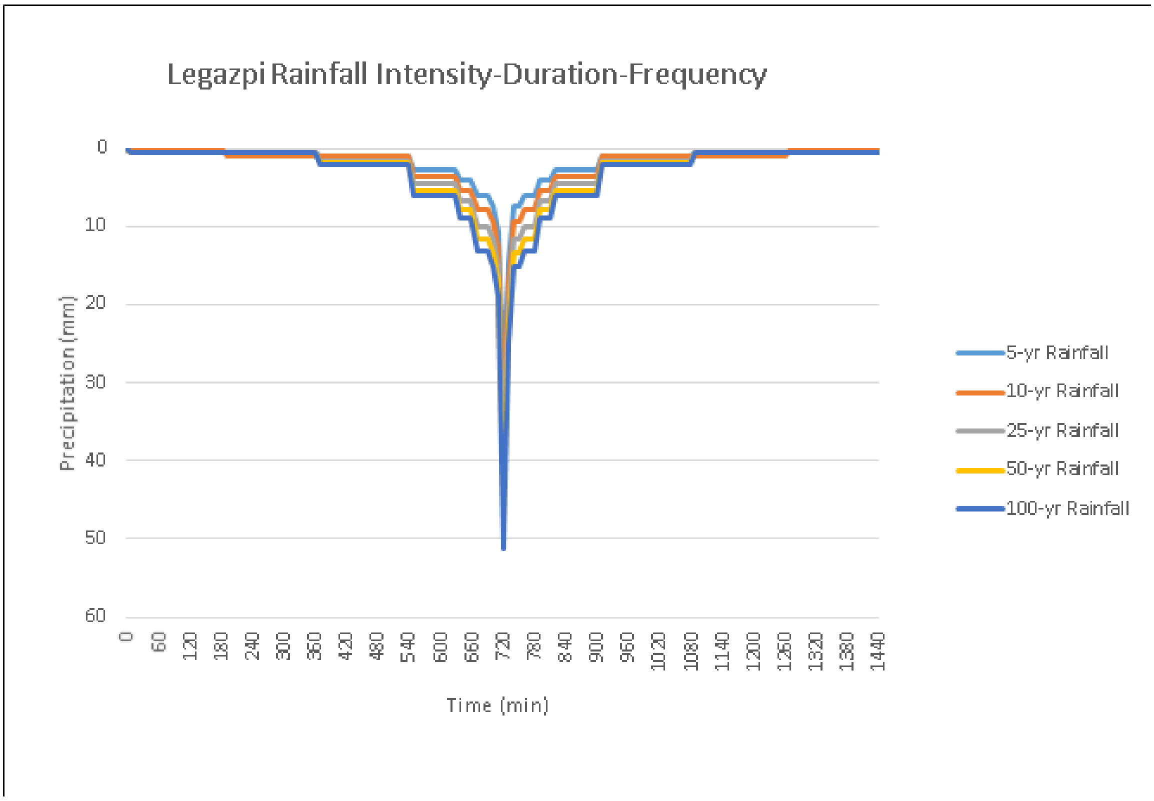

Figure 50. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Guinale River Basin are shown in Figures 51 and 52, respectively.

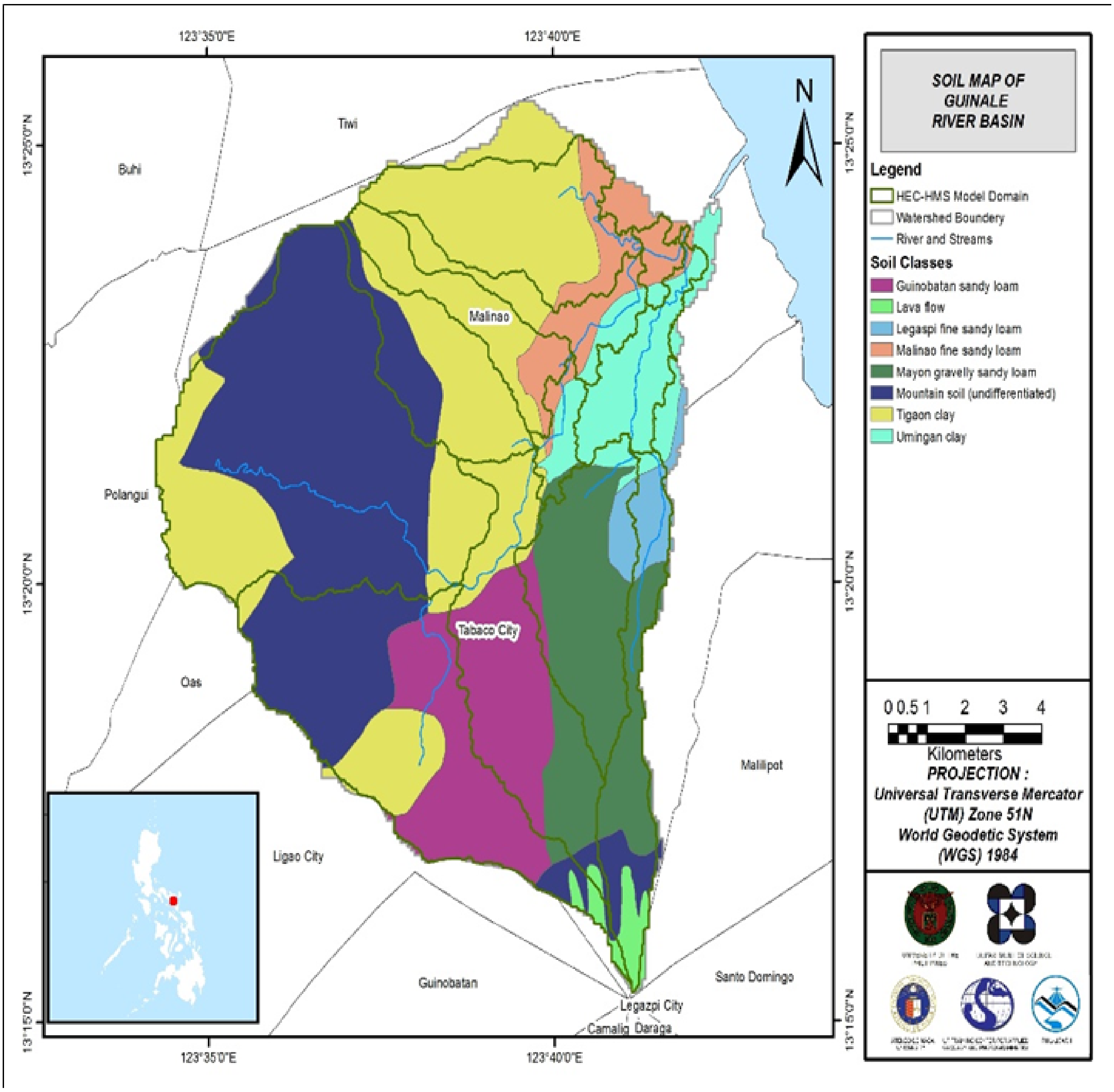

Figure 51. Soil map of the Guinale River Basin (Source: DA)

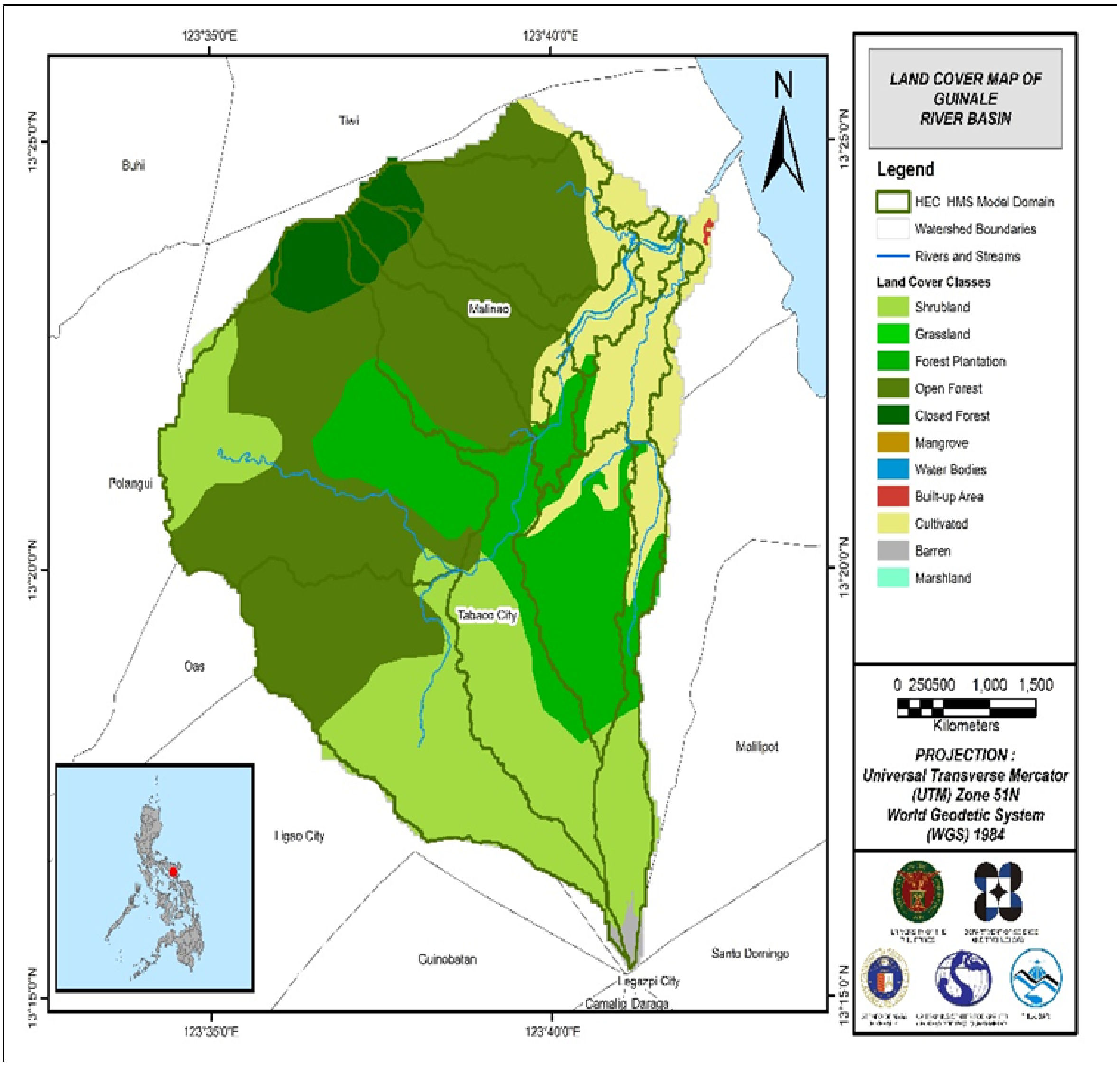

Figure 52. Land cover map of the Guinale River Basin (Source: NAMRIA)

For Guinale, eight (8) soil classes were identified. These are Guinobatan sandy loam, Legaspi fine sandy loam, Malinao fine sandy loam, Mayon gravelly sandy loam, Tigaon clay, Umingan clay, lava flow, and undifferentiated mountain soil. Moreover, six (6) land cover classes were identified: shrubland, grassland, open and closed forests, cultivated land, and built-up areas.

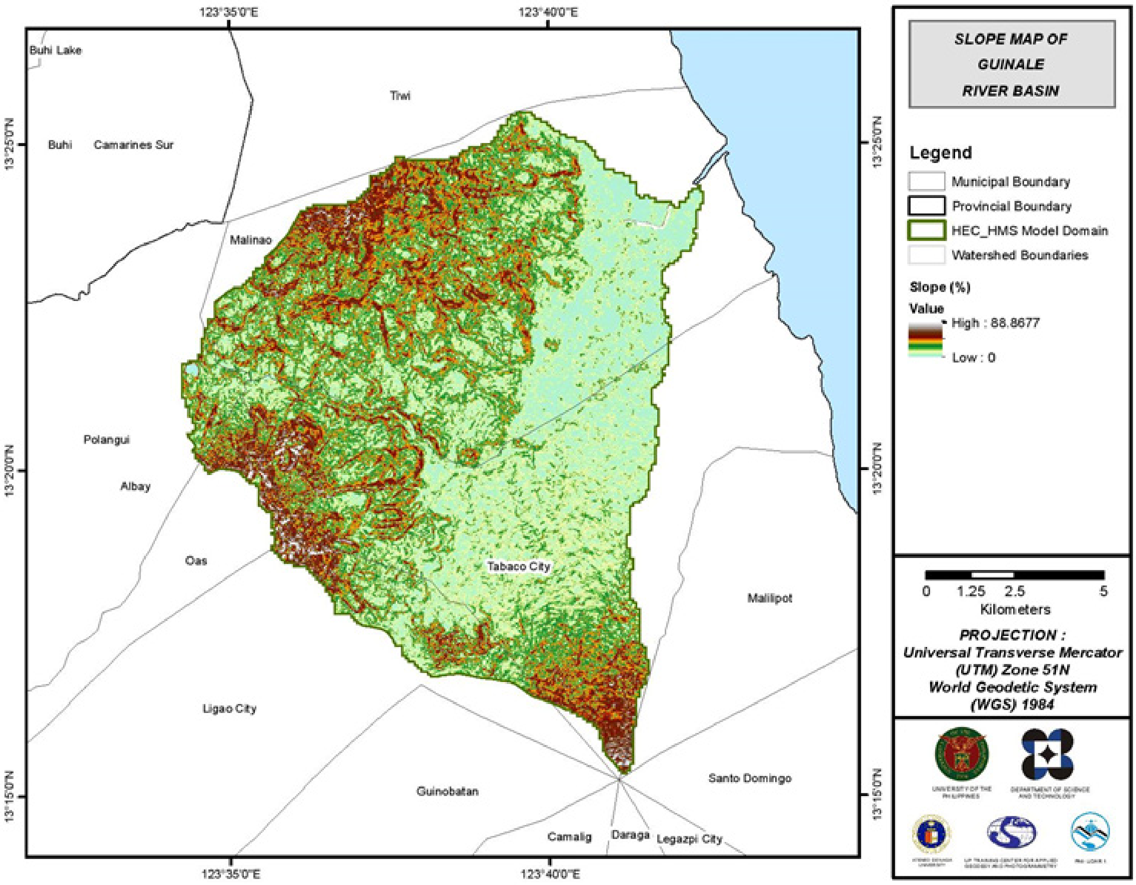

Figure 53. Slope map of the Guinale River Basin

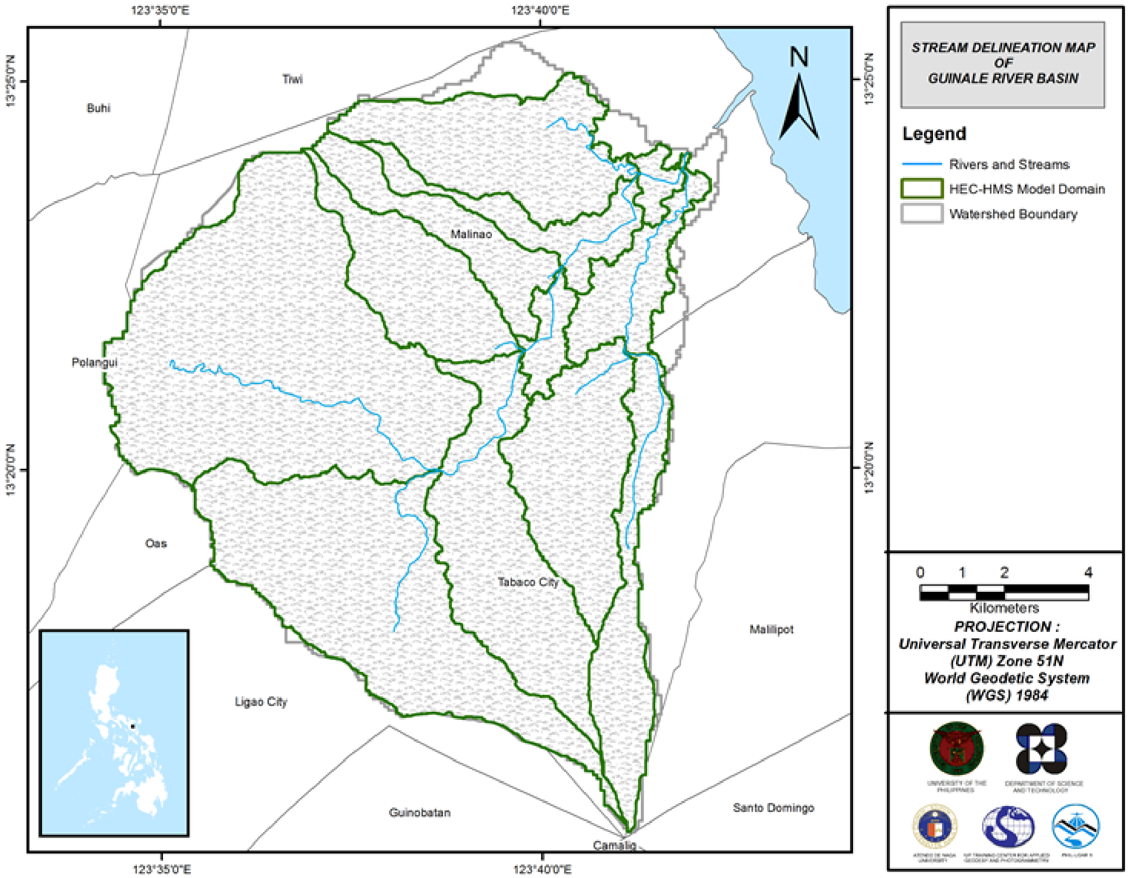

Figure 54. Stream delineation map of the Guinale River Basin

Using the SAR-based DEM, the Guinale basin was delineated and further divided into sub basins. The model consists of thirteen (13) sub basins, six (6) reaches, and six (6) junctions, as shown in Figure 55. The main outlet is at the Imperial Bridge. See Annex 10 for the Guinale Model Reach Parameters.

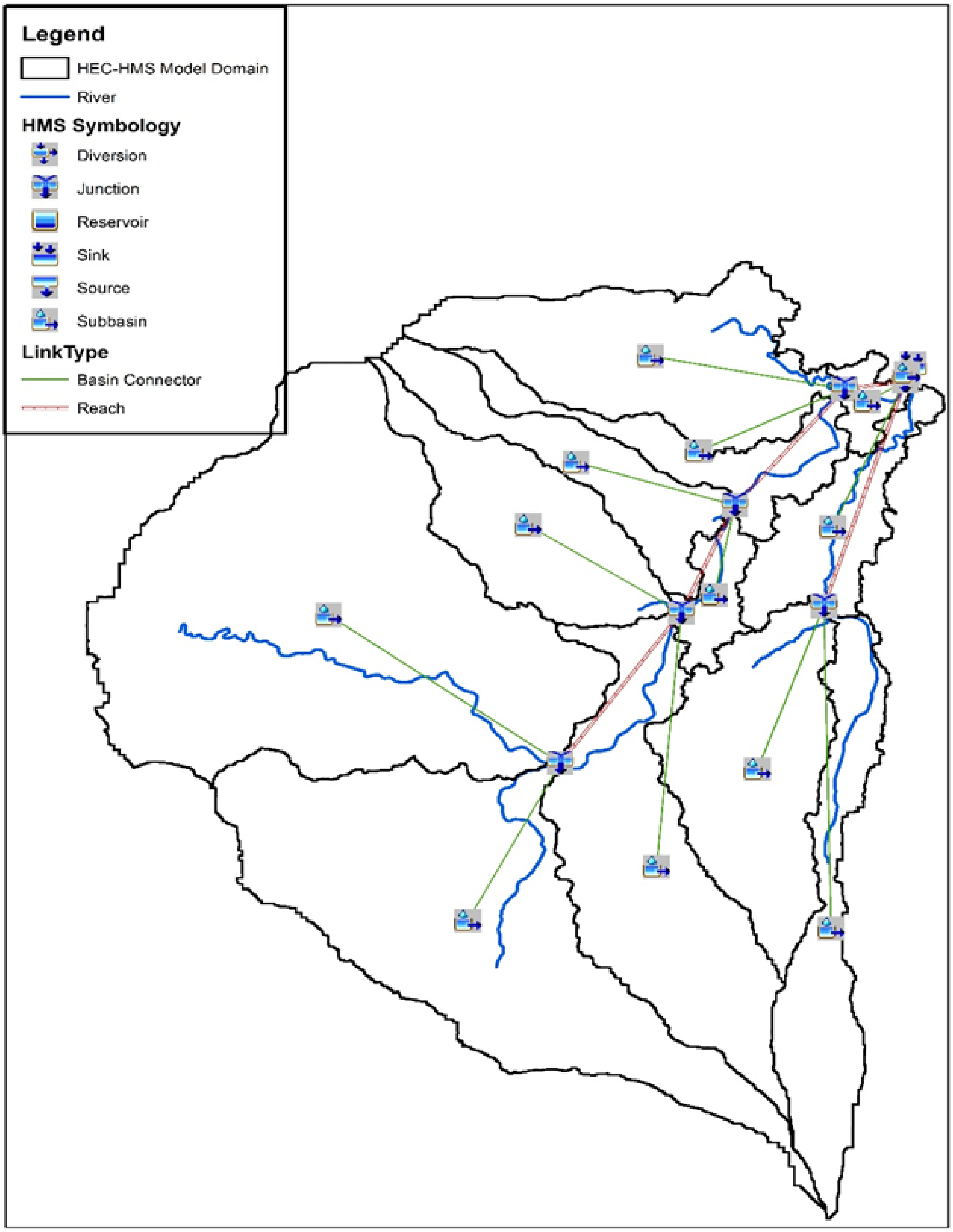

Figure 55. The Guinale River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 56).

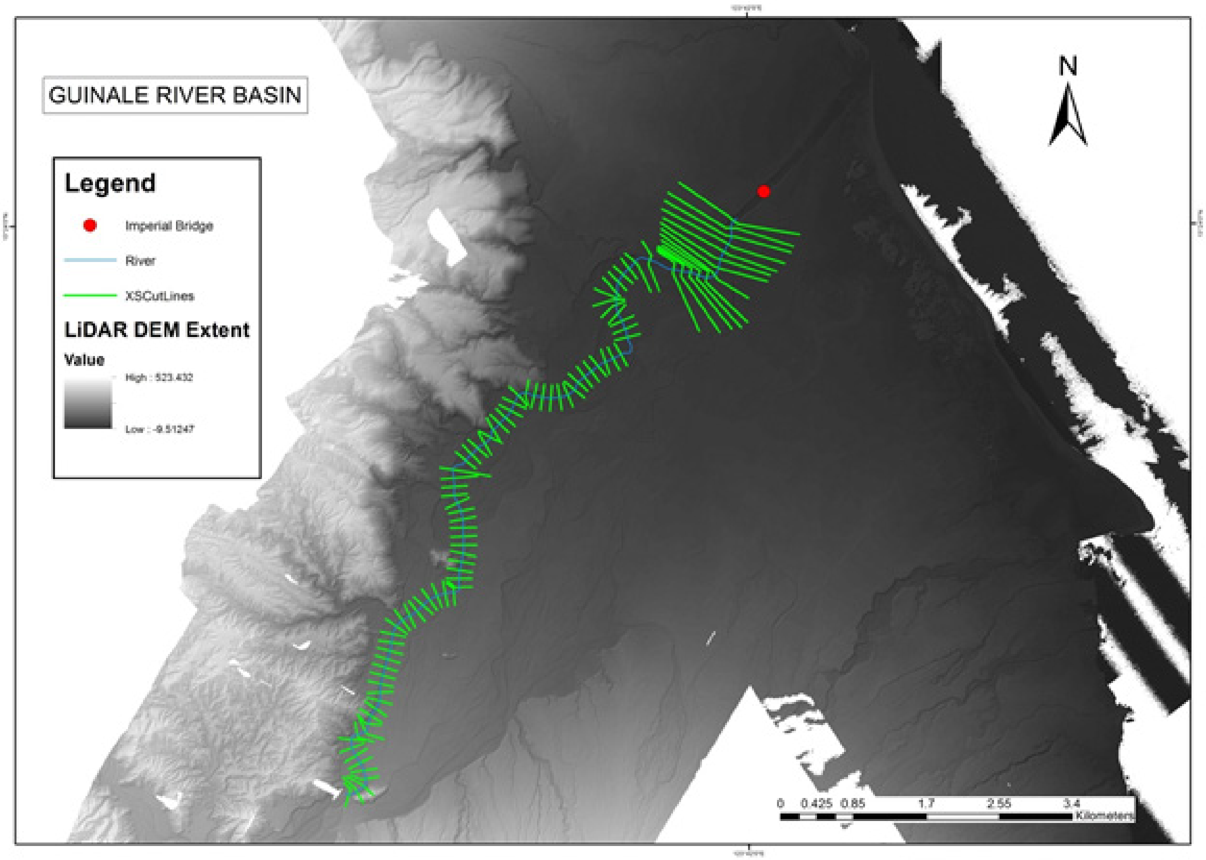

Figure 56. River cross-section of the Guinale River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. Each element was then attributed with the parameters required for modeling, such as x-and y-coordinates of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it is observed that the water will generally flow from the southwest of the model to the northeast, following the main channel. As such, boundary elements northwest of the model were assigned as the outflow elements.

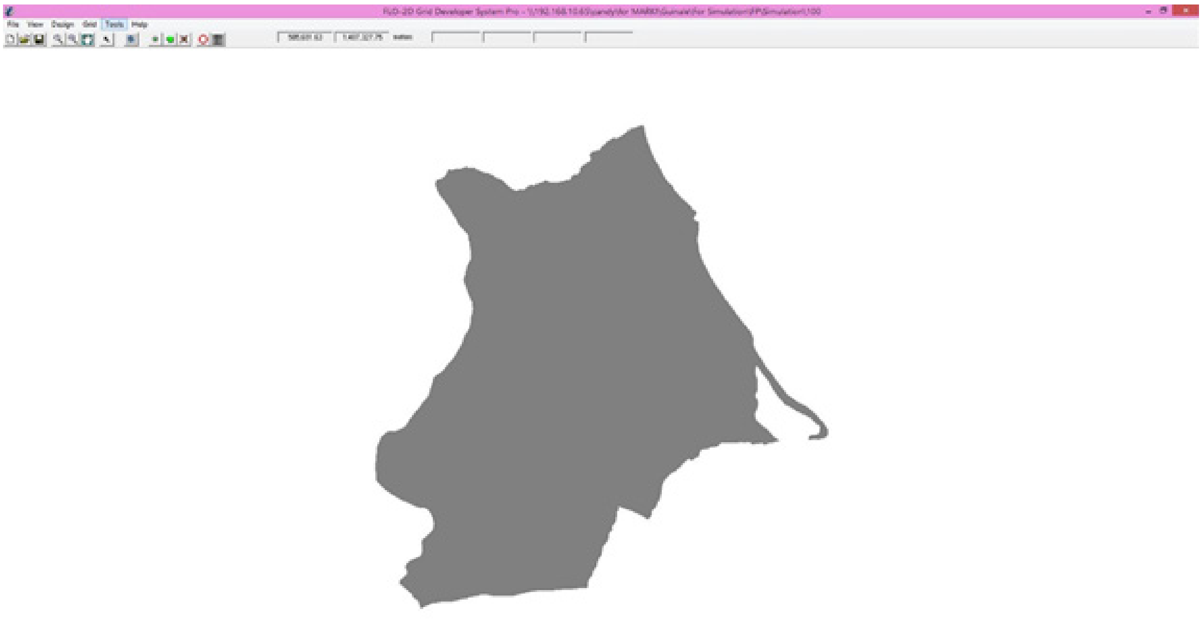

Figure 57. Screenshot of a sub catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 44.69 hours. After the simulation, the FLO-2D Mapper Pro was 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 created the flood hazard maps. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 m, while the minimum vh (product of maximum velocity (v) and maximum depth (h)) was set at 0 m2/s. The generated hazard maps for the Guinale floodplain are in Figures 61, 63, and 65.

The creation of flood hazard maps from the model also automatically created flow depth maps, depicting the maximum amount of inundation for every grid element. The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 68,866,656.00 m2. The generated flood depth maps for Guinale are in Figures 62, 64, and 66.

There was a total of 24,676,494.27 m3 of water that entered the Guinale model. 24,507,668.93 m3 of which was due to rainfall, and 168,825.35 m3 was inflow from basins upstream. 6,450,876.00 m3 of this water was lost to infiltration and interception, while 3,622,213.98 m3 was stored by the floodplain. The rest, amounting to up to 14,603,410.79 m3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Guinale HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 58 illustrates the comparison between the two discharge data. The Guinale Model Basin Parameters are found in Annex 9.

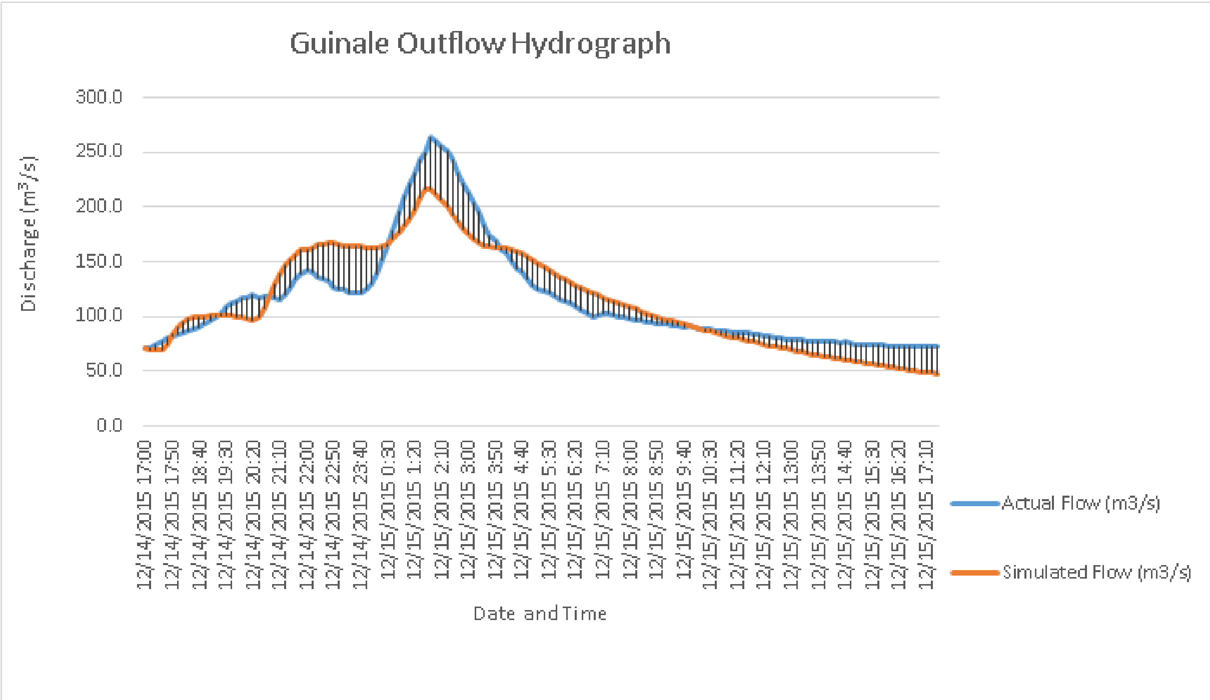

Figure 58. Outflow Hydrograph of Guinale produced by the HEC-HMS model, compared with observed outflow.

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of calibrated values for the Guinale River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.02-67
			Curve Number	43-99
	Transform	Clark Unit Hydro-graph	Time of Concentration (hr)	0.02-64
			Storage Coefficient (hr)	0.02-43
	Baseflow	Recession	Recession Constant	0.00001-0.1
			Ratio to Peak	0.0003-1
Reach	Routing	Muskingum-Cunge	Slope	0.001-0.01
			Manning’s n	0.0001-0.5

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 0.02mm to 67mm for initial abstraction means that there is a minimal to average amount of infiltration or rainfall interception by vegetation.

The 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 the curve number increases. The range of 43-99 for the curve number is wider than the advisable range for Philippine watersheds (i.e., 70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Guinale, the basin mostly consists of shrubland and open forests; and the soil consists of mountain soil, Tigaon clay, and Guinobatan sandy loam.

The time of concentration and the storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 64 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The 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. For Guinale, it will take twelve (12) hours and fifty (50) minutes from the peak discharge to return to the initial discharge.

A Manning's roughness coefficient of 0.0001-0.5 corresponds to the common roughness for Philippine watersheds. The Guinale River Basin is determined to be a built-up area that is concrete and float-finished (Brunner, 2010).

Table 29. Summary of the Efficiency Test of the Guinale HMS Model

Accuracy Measure	Value
RMSE	21.23
r2	0.81
NSE	0.80
PBIAS	1.19
RSR	0.45

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 21.23 (m3/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 was measured at 0.81. 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 0.80.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is 1.19.
The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model has an RSR value of 0.45.

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 59) reflects the Guinale outflow using the Legazpi RIDF curves in five (5) different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the PAGASA data. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

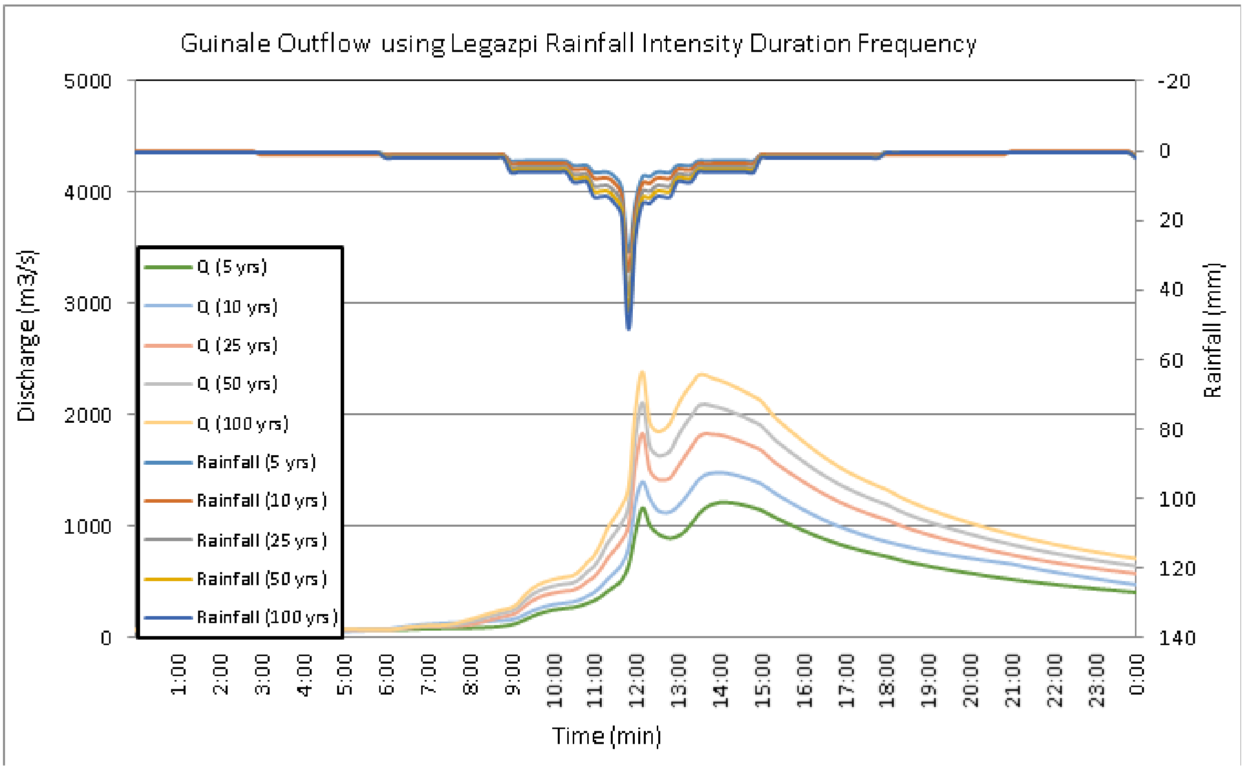

Figure 59. The outflow hydrograph at the Guinale Basin, generated using the simulated rain events for a 24-hour period for the Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Guinale discharge using the Legazpi RIDF curves in five (5) different return periods is outlined in Table 30.

Table 30. Peak values of the Guinale HEC-HMS Model outflow using the Legazpi RIDF 24-hour

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	260.50	29.1	1217.4	4 hours, 50 minutes
10-Year	316.10	34.5	1485.8	4 hours, 40 minutes
25-Year	386.40	41.3	1835.9	4 hours, 40 minutes
50-Year	438.40	46.3	2111.4	4 hours, 50 minutes
100-Year	490.30	51.3	2387.6	4 hours, 50 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 the extent of real-time flood inundation of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map of the river is presented, since only the ADNU-DVC base flow was calibrated. Figure 60 shows a generated sample map of the Guinale River using the calibrated HMS base flow.

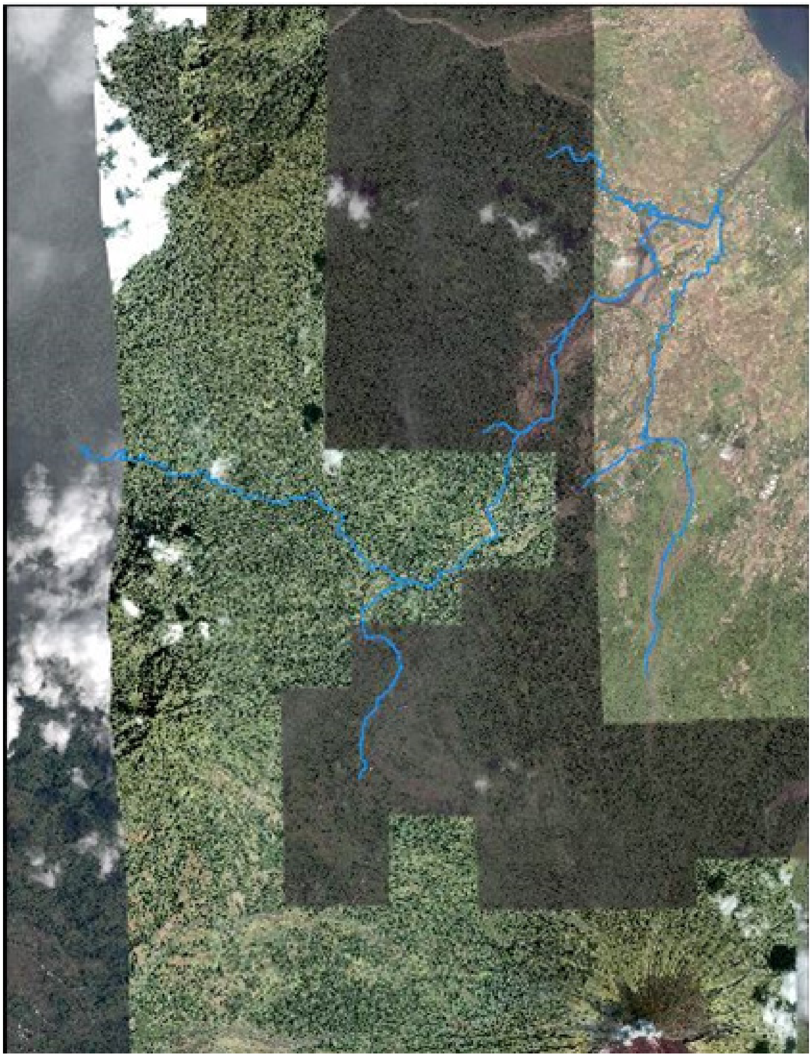

Figure 60. Sample output map of the Guinale RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10-meter resolution. Figures 61 to 66 exhibit the 5-, 25-, and 100-year rain return scenarios for the Guinale floodplain. The floodplain, with an area of 68.85km2, covers three (3) municipalities: Malinao, Tabaco City, and Tiwi. Table 31 summarizes the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in the Guinale floodplain

Municipality	Total Area (km2)	Area Flooded (km2)	% Flooded
Malinao	327.24	52.58	16.07
Tabaco City	112.24	13.84	12.33
Tiwi	124.4	0.94	0.75

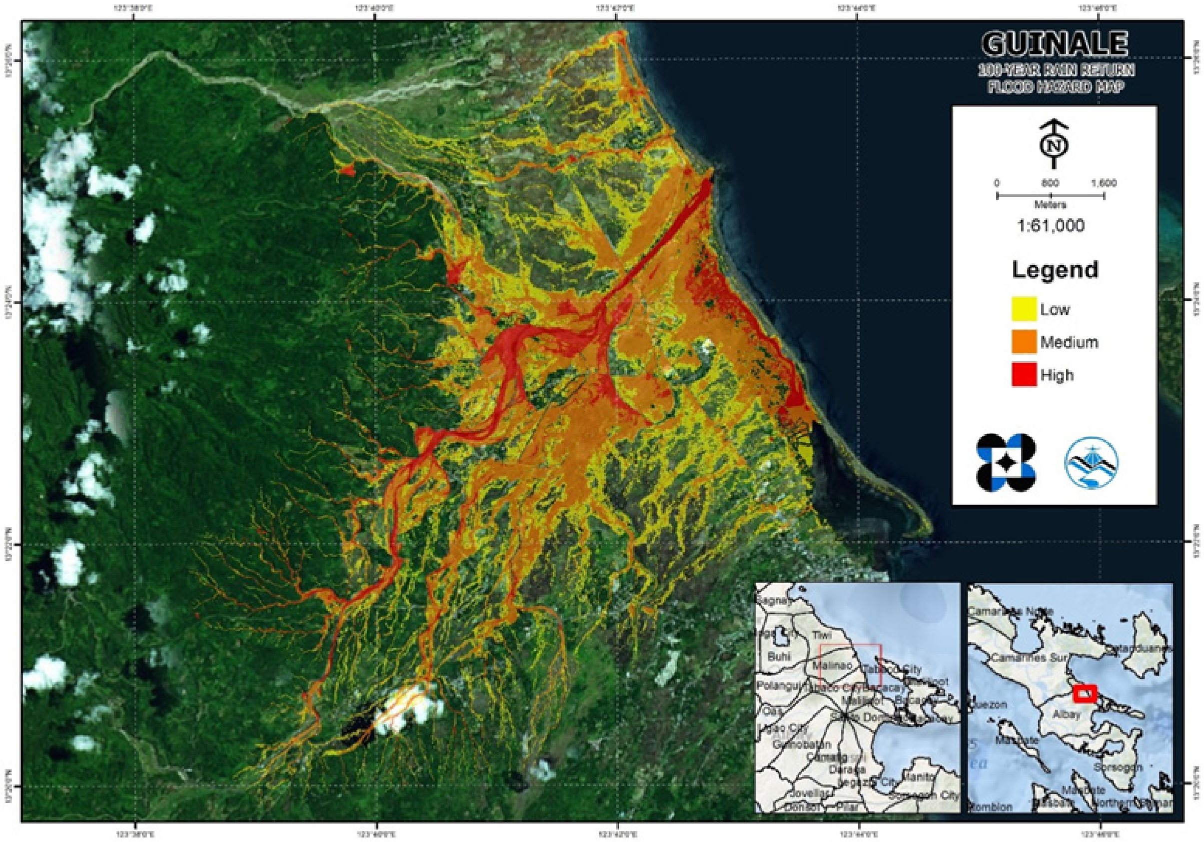

Figure 61. 100-year flood hazard map for the Guinale floodplain overlaid on Google Earth imagery

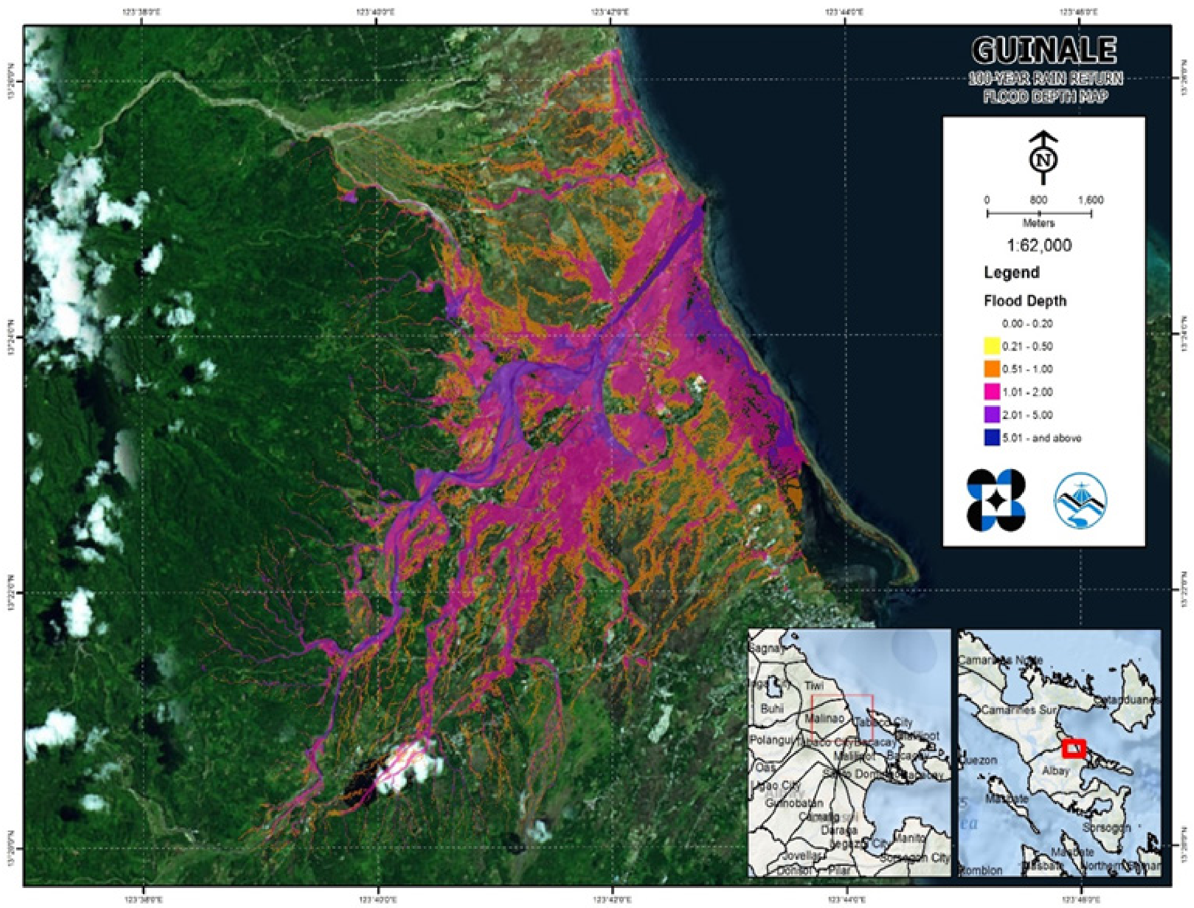

Figure 62. 100-year flow depth map for the Guinale floodplain overlaid on Google Earth imagery

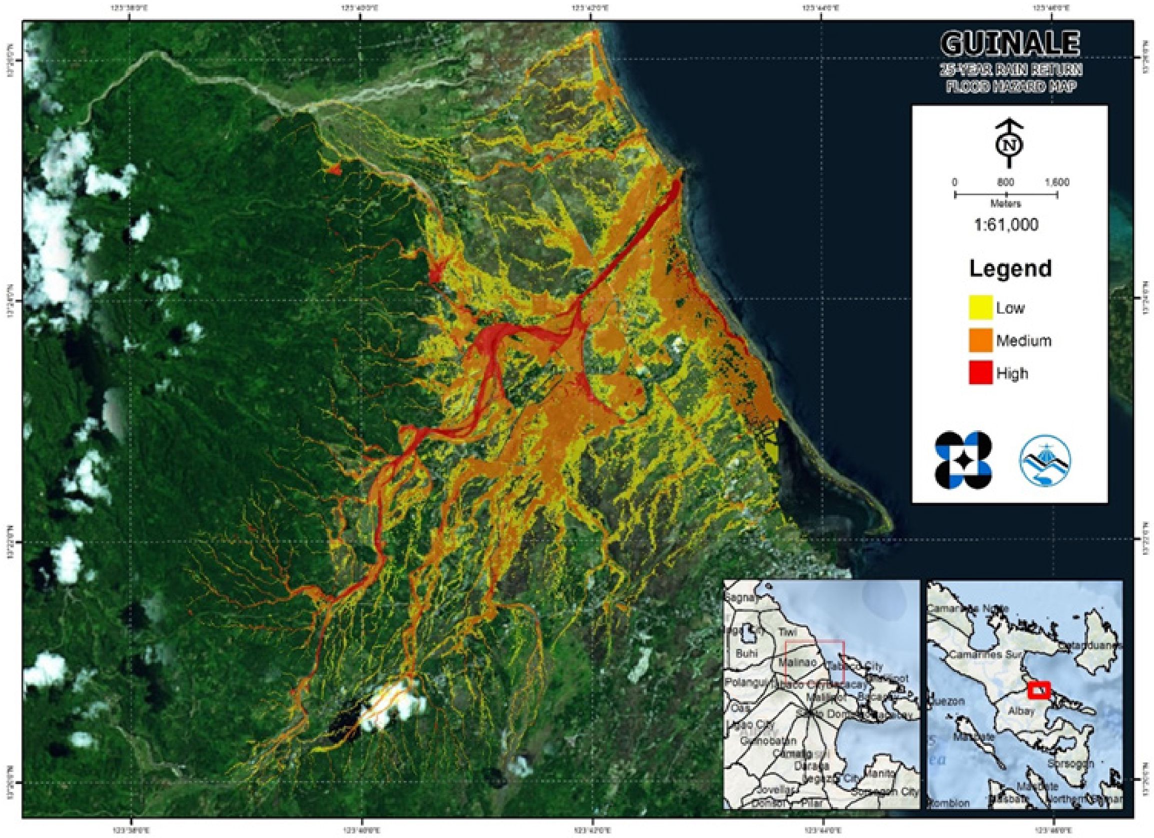

Figure 63. 25-year flood hazard map for the Guinale floodplain overlaid on Google Earth imagery

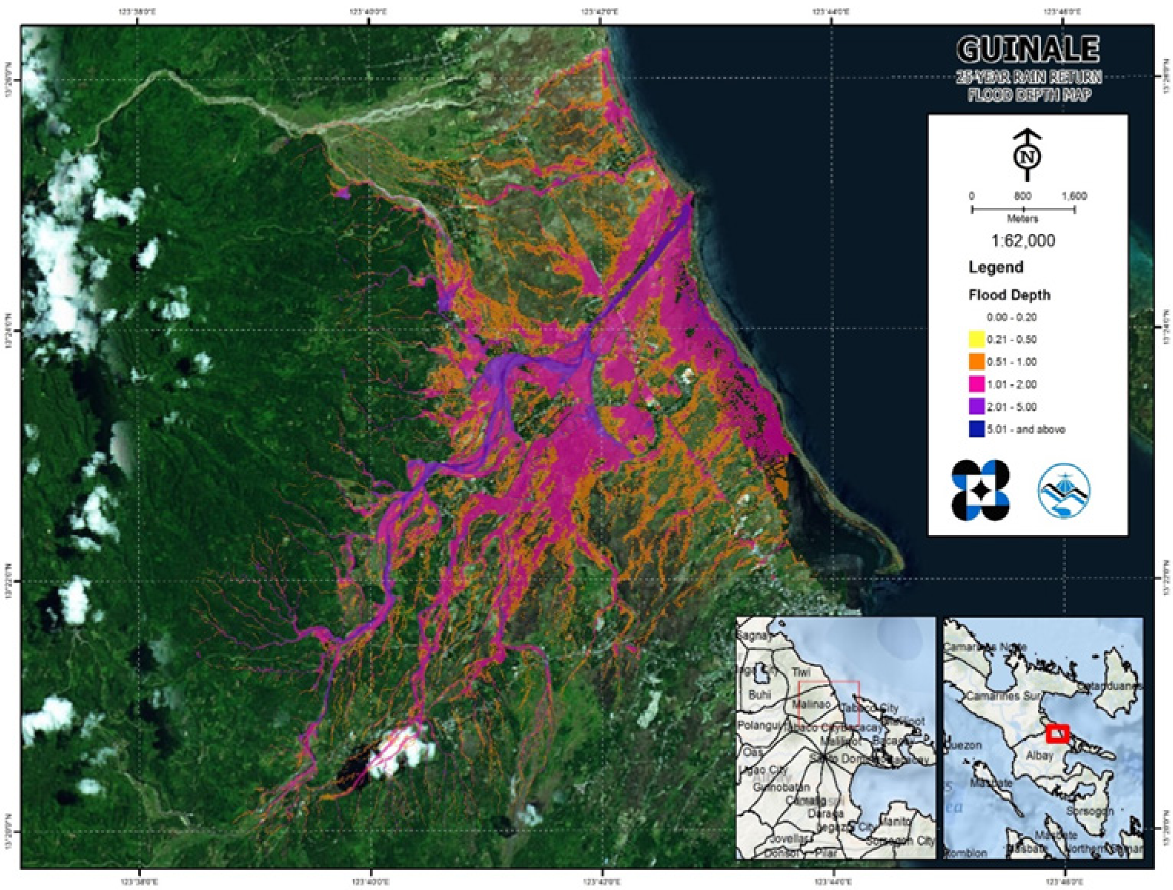

Figure 64. 25-year flow depth map for the Guinale floodplain overlaid on Google Earth imagery

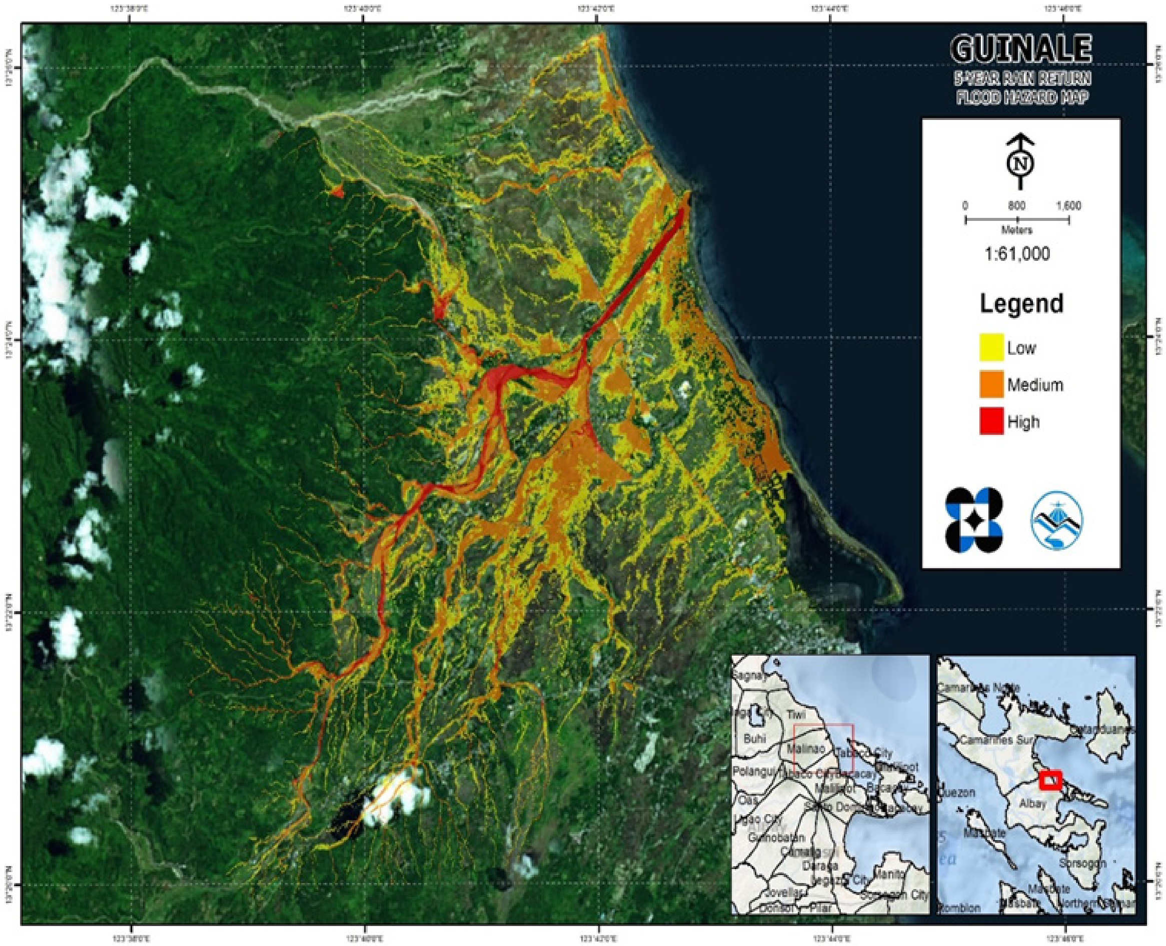

Figure 65. 5-year flood hazard map for the Guinale floodplain overlaid on Google Earth imagery

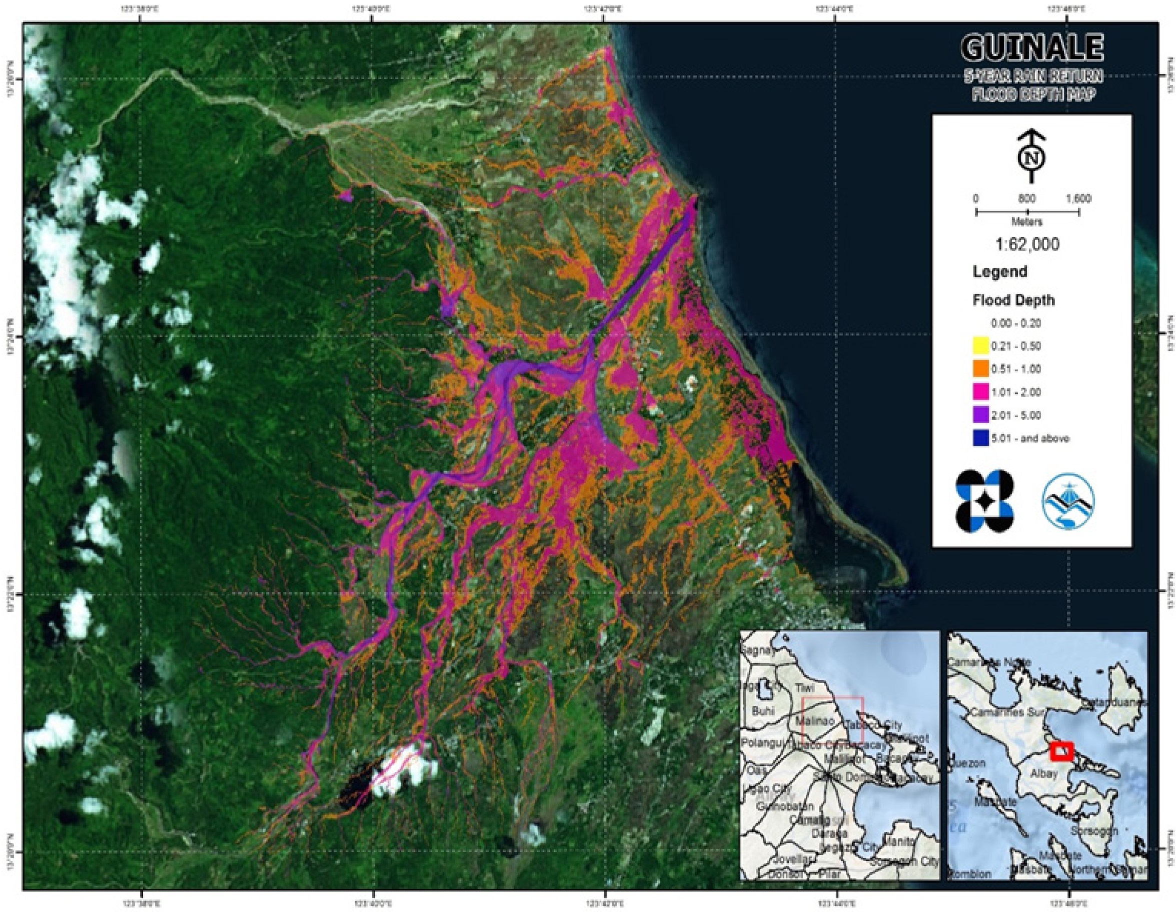

Figure 66. 5-year flow depth map for the Guinale floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Guinale River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of forty-six (46) barangays are projected to experience flooding when subjected to the three (3) rainfall return period scenarios.

For the 5-year rainfall return period, 11.18% of the Municipality of Malinao, with an area of 327.24 sq. km., will experience flood levels of less than 0.20 meters. 2.54% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.57%, 0.61%, 0.17%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 32 depicts the areas affected in Malinao, in square kilometers, by flood depth per barangay.

Table 32. Affected Areas in Malinao, Albay during the 5-Year Rainfall Return Period

Malolos	Matalipni	Ogob	Pawa	Payahan	Poblacion	Santa Elena	Soa	Sugcad	Tagoytoy	Tanawan	Tuliw
1.55	1.95	3.29	0.4	0.23	0.17	1.95	1.58	1.39	1.96	2.71	0.65
0.17	0.31	0.21	0.21	0.21	0.15	0.18	0.076	0.17	0.23	0.46	0.33
0.13	0.2	0.19	0.3	0.091	0.086	0.046	0.051	0.11	0.057	0.12	0.45
0.15	0.091	0.19	0.11	0.00036	0.0054	0.023	0.022	0.097	0.021	0.081	0.25
0.031	0.024	0.056	0.068	0	0	0.0066	0.0027	0.019	0.0043	0.036	0.082
0	0.0002	0	0.0003	0	0	0	0	0.0004	0	0.0004	0

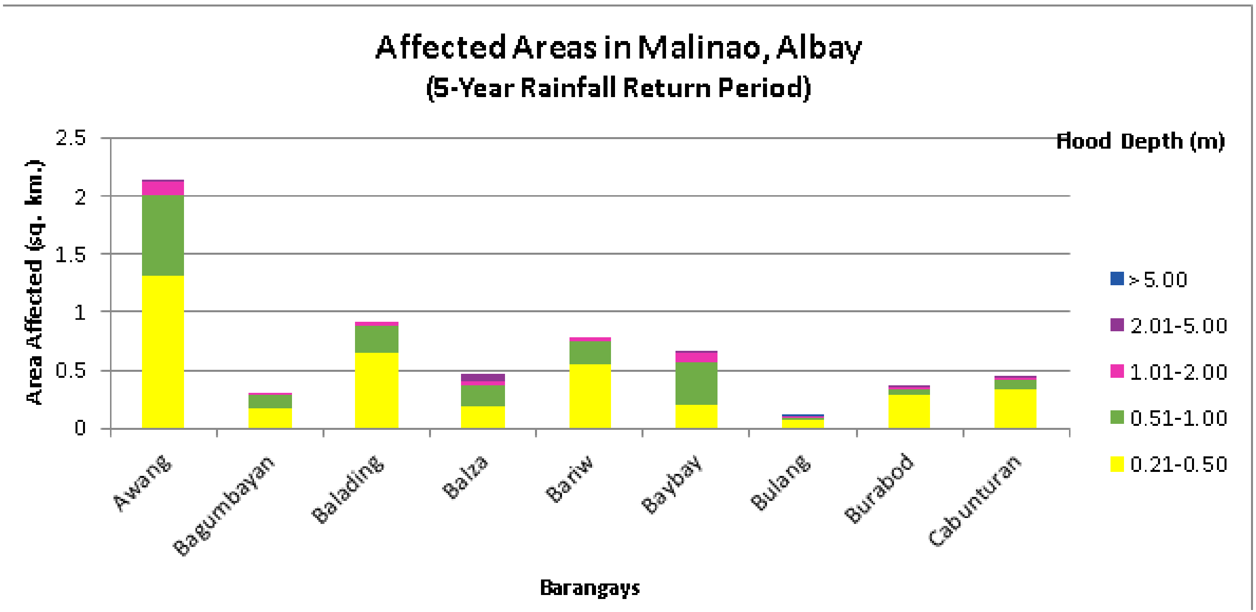

Figure 67. Affected Areas in Malinao, Albay during the 5-Year Rainfall Return Period

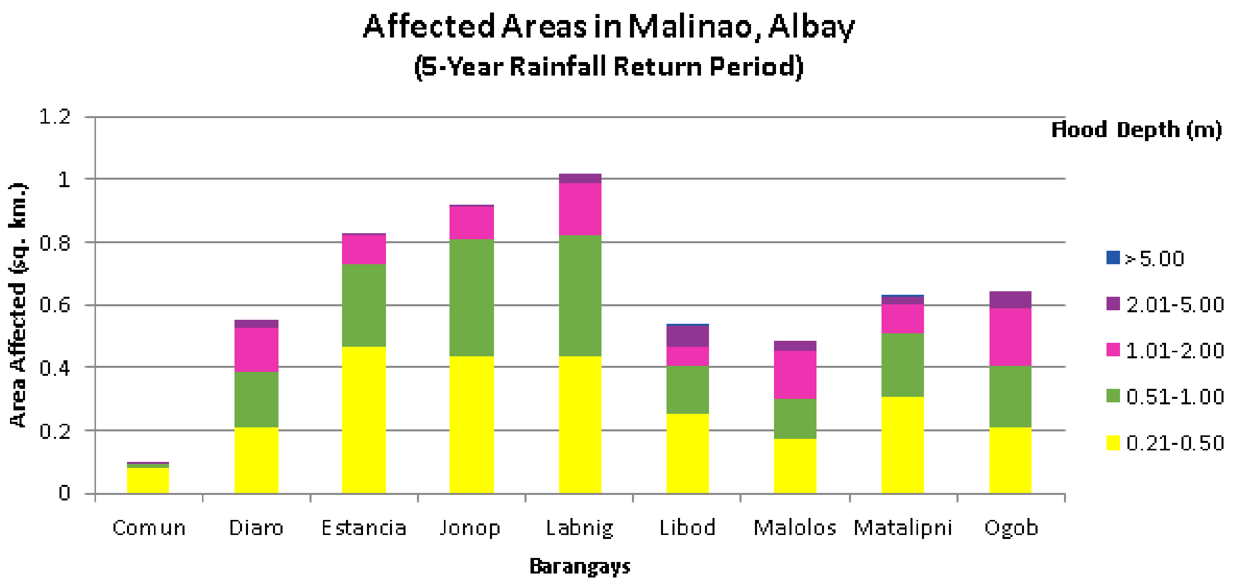

Figure 68. Affected Areas in Malinao, Albay during the 5-Year Rainfall Return Period

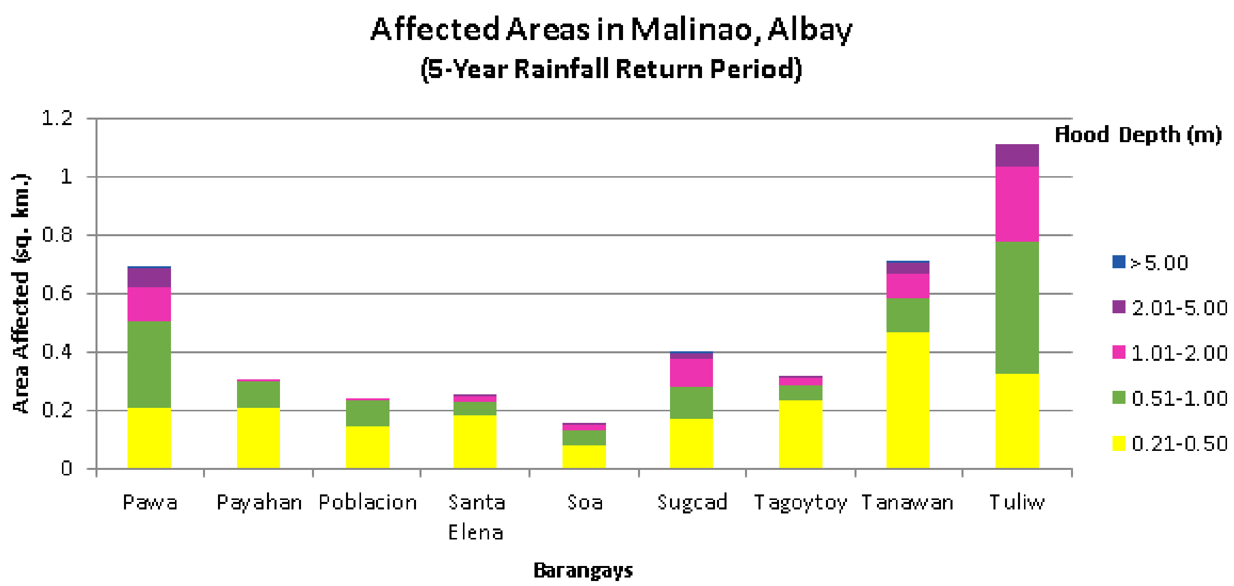

Figure 69. Affected Areas in Malinao, Albay during the 5-Year Rainfall Return Period

For Tabaco City, with an area of 112.24 sq. km., 10.66% will experience flood levels of less than 0.20 meters in the 5-year scenario. 1.19% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.37%, 0.1%, 0.01%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively Table 33 depicts the areas affected in Tabaco City, in square kilometers, by flood depth per barangay.

Table 33. Affected Areas in Tabaco City, Albay during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City										
	Bacolod	Bangkilingan	Bantayan	Basagan	Bombon	Bonot	Buhian	Cormidal	Mariroc	Matagbac	Pawa
0.03-0.20	0.16	0.0084	0.97	1.07	0.074	0.7	0.035	0.019	0.000032	0.3	0.37
0.21-0.50	0.011	0.00014	0.075	0.065	0.0018	0.023	0.00014	0.0021	0	0.027	0.076
0.51-1.00	0.0028	0	0.036	0.015	0.00062	0.0093	0.0001	0.0002	0	0.0073	0.017
1.01-2.00	0	0	0.01	0.0039	0	0.0046	0	0	0	0	0.0023
2.01-5.00	0	0	0.0012	0.0016	0	0.0028	0.000019	0	0	0	0
>5.00	0	0	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City									
	Quinastillojan	San Antonio	San Carlos	San Vicente	Tabiguian	Tayhi				
0.03-0.20	1.71	2.41	0.53	2.17	0.11	1.32				
0.21-0.50	0.14	0.26	0.13	0.24	0.0033	0.28				
0.51-1.00	0.093	0.11	0.01	0.085	0.0012	0.023				
1.01-2.00	0.037	0.033	0.00011	0.014	0.0012	0.00072				
2.01-5.00	0.0058	0.0048	0	0	0.0006	0				
>5.00	0.001	0.0004	0	0	0	0				

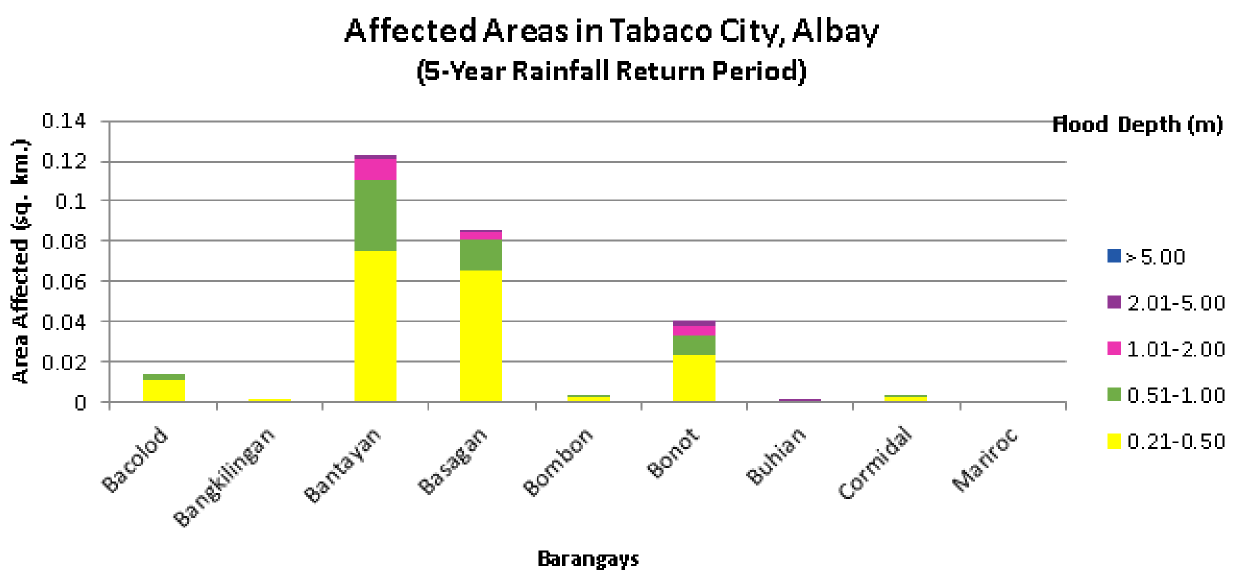

Figure 70. Affected Areas in Tabaco City, Albay during the 5-Year Rainfall Return Period

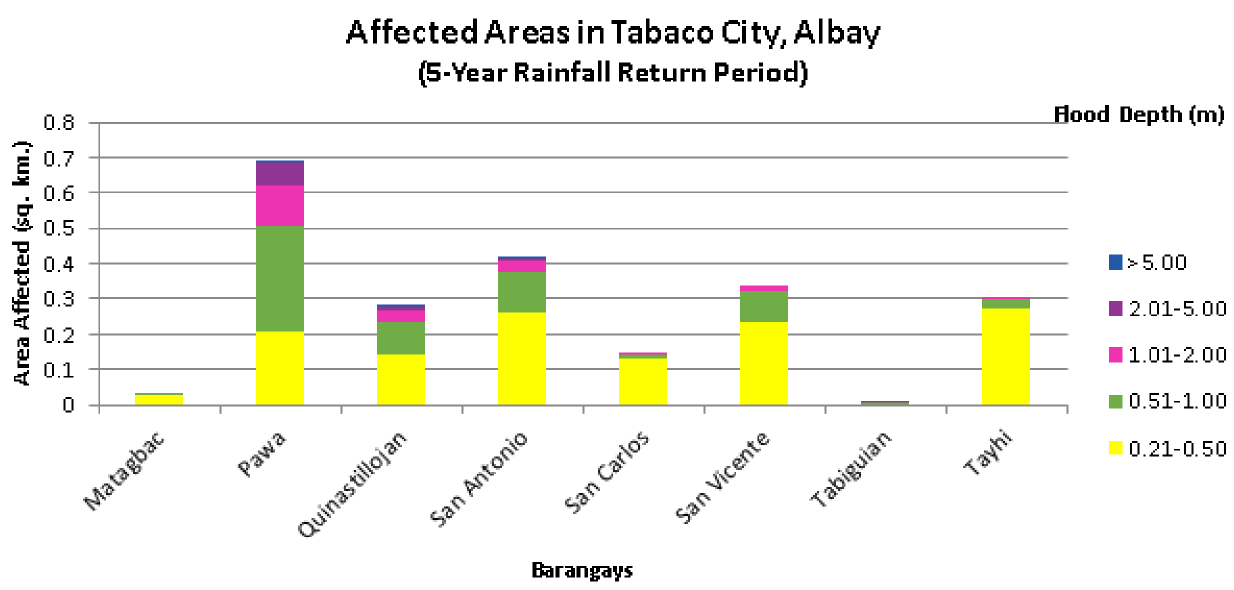

Figure 71. Affected Areas in Tabaco City, Albay during the 5-Year Rainfall Return Period

For the Municipality of Tiwi, with an area of 124.4 sq. km., 0.61% will experience flood levels of less than 0.20 meters in the 5-year rainfall return scenario. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03%, 0.02%, and 0.0004% 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. Table 34 depicts the areas affected in Tiwi, in square kilometers, by flood depth per barangay.

Table 34. Affected Areas in Tiwi, Albay during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tiwi	
	Nagas	San Bernardo
0.03-0.20	0.47	0.29
0.21-0.50	0.1	0.016
0.51-1.00	0.038	0.0046
1.01-2.00	0.023	0.0019
2.01-5.00	0	0.0005
>5.00	0	0

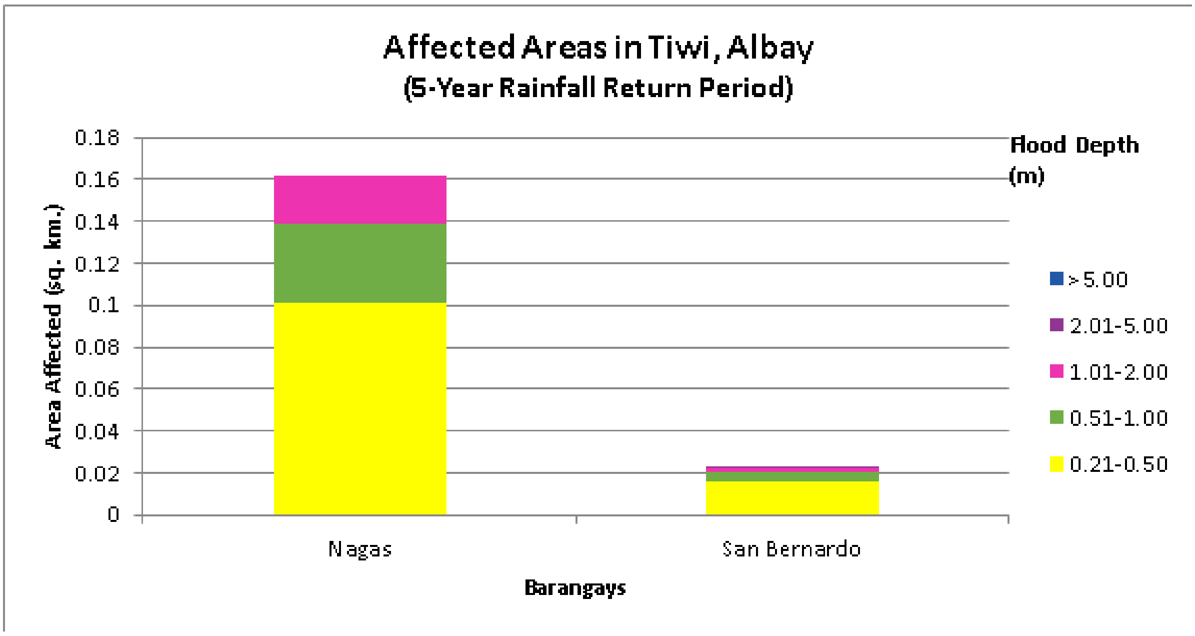

Figure 72. Affected Areas in Tiwi, Albay during the 5-Year Rainfall Return Period

For the 25-year rainfall return period, 10% of the Municipality of Malinao, with an area of 327.24 sq. km., will experience flood levels of less than 0.20 meters. 2.66% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.06%, 1.09%, 0.25%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 35 depicts the areas affected in Malinao, in square kilometers, by flood depth per barangay.

Table 35. Affected Areas in Malinao, Albay during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malinao										
	Awang	Bagumbayan	Balading	Balza	Bariw	Baybay	Bulang	Burabod	Cabunturan	Comun	Diaro
0.03-0.20	2.86	0.3	1.26	0.38	1	0.39	2.08	1.44	1.31	0.89	1.52
0.21-0.50	1.31	0.16	0.65	0.18	0.55	0.2	0.064	0.29	0.33	0.079	0.21
0.51-1.00	0.69	0.11	0.23	0.2	0.19	0.36	0.027	0.044	0.081	0.012	0.18
1.01-2.00	0.12	0.019	0.034	0.033	0.038	0.082	0.01	0.017	0.012	0.0016	0.14
2.01-5.00	0.0058	0	0	0.068	0	0.000069	0.0043	0.0008	0.001	0.0013	0.028
>5.00	0	0	0	0	0	0	0.0001	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malinao											
	Diaro	Estancia	Jonop	Labnig	Libod	Malolos	Matalipni	Ogob	Pawa	Payahan	Poblacion	Santa Elena
0.03-0.20	1.52	2.37	1.12	1.15	0.7	1.55	1.95	3.29	0.4	0.23	0.17	1.95
0.21-0.50	0.21	0.46	0.43	0.43	0.25	0.17	0.31	0.21	0.21	0.21	0.15	0.18
0.51-1.00	0.18	0.26	0.38	0.39	0.15	0.13	0.2	0.19	0.3	0.091	0.086	0.046
1.01-2.00	0.14	0.097	0.1	0.17	0.06	0.15	0.091	0.19	0.11	0.00036	0.0054	0.023
2.01-5.00	0.028	0.0043	0.0013	0.03	0.07	0.031	0.024	0.056	0.068	0	0	0.0066
>5.00	0	0	0	0	0.0025	0	0.0002	0	0.0003	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malinao										
	Soa	Sugcad	Tagoytoy	Tanawan	Tuliw						
0.03-0.20	1.58	1.39	1.96	2.71	0.65						
0.21-0.50	0.076	0.17	0.23	0.46	0.33						
0.51-1.00	0.051	0.11	0.057	0.12	0.45						
1.01-2.00	0.022	0.097	0.021	0.081	0.25						
2.01-5.00	0.0027	0.019	0.0043	0.036	0.082						
>5.00	0	0.0004	0	0.0004	0						

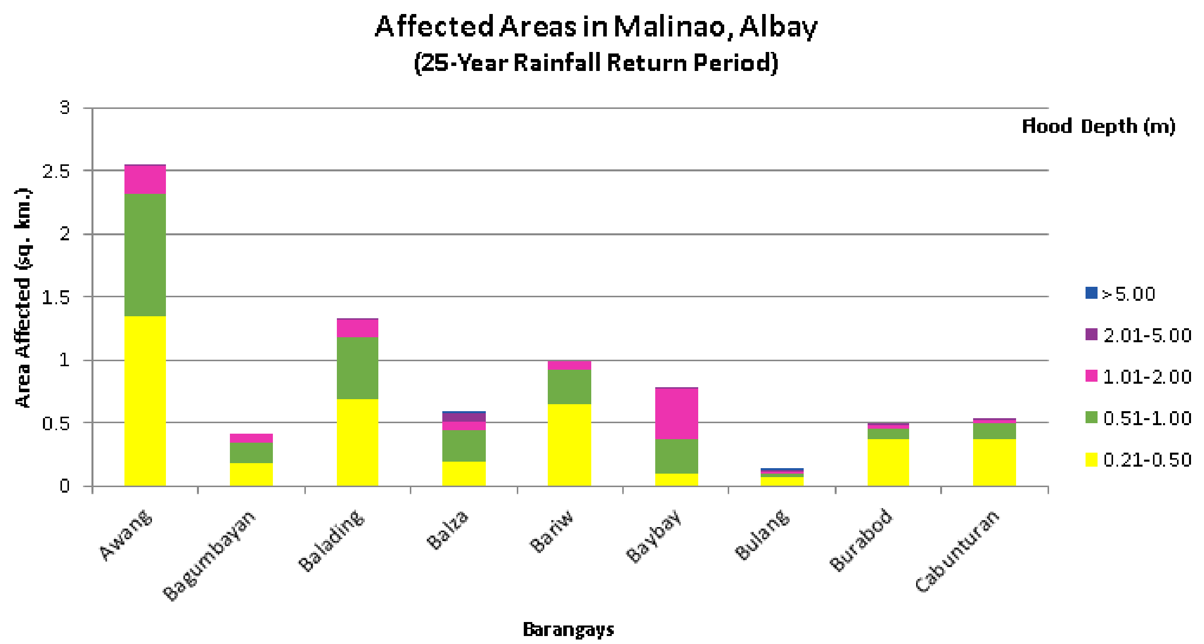

Figure 73. Affected Areas in Malinao, Albay during the 25-Year Rainfall Return Period

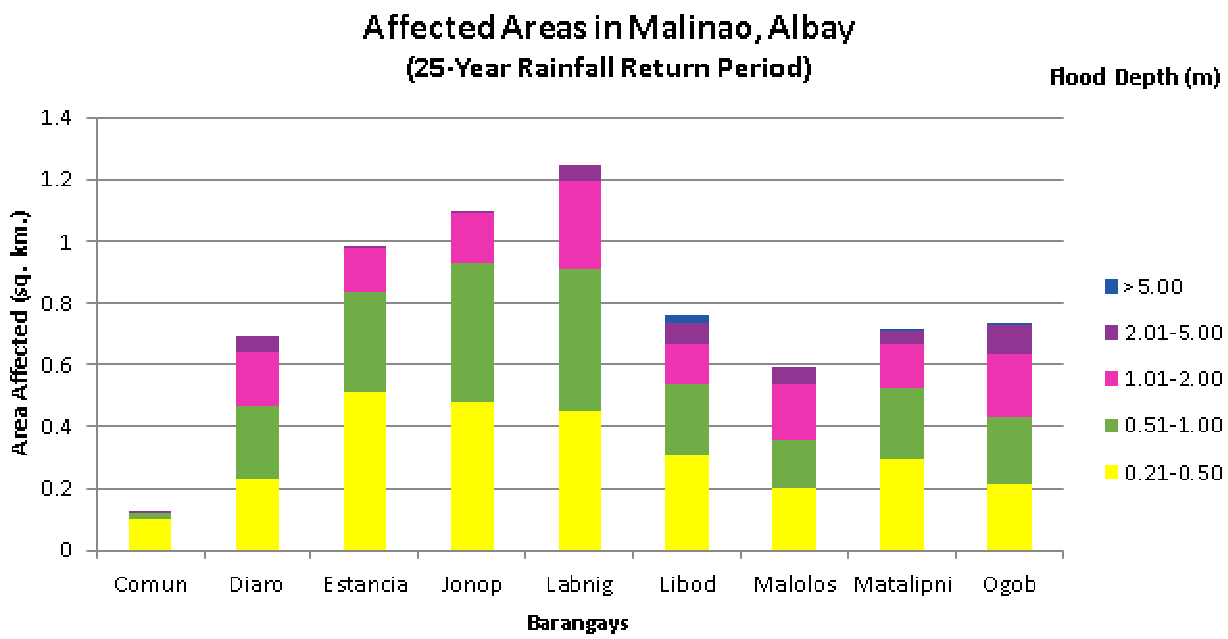

Figure 74. Affected Areas in Malinao, Albay during the 25-Year Rainfall Return Period

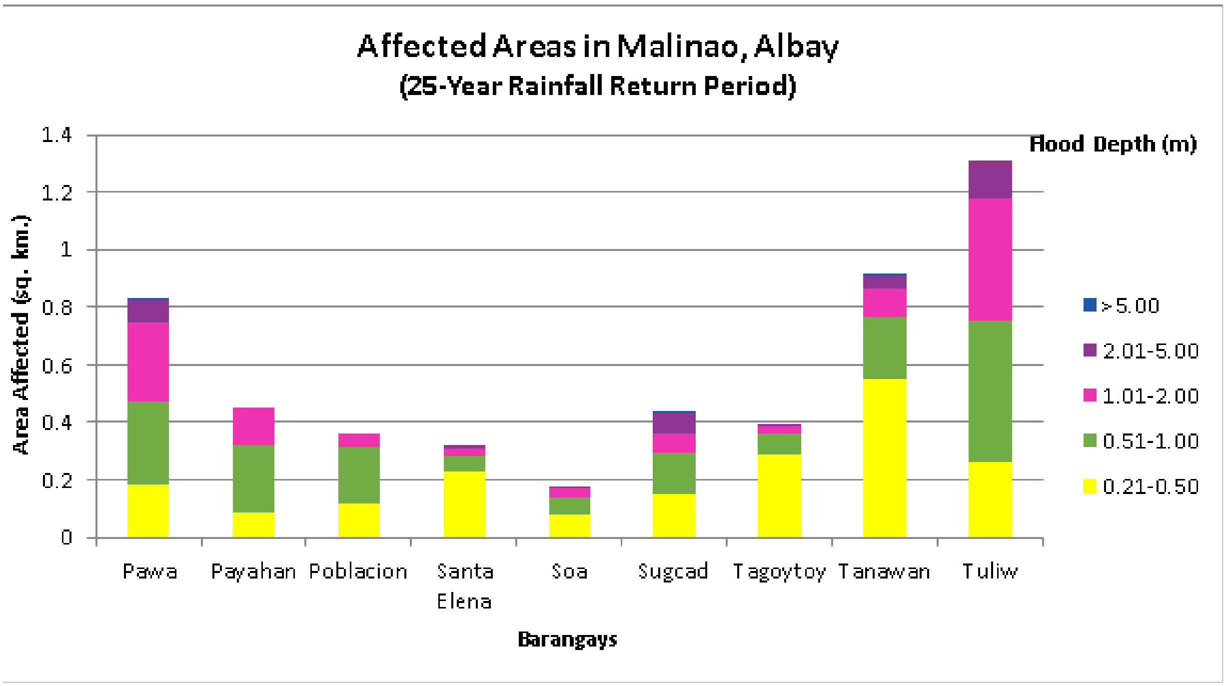

Figure 75. Affected Areas in Malinao, Albay during the 25-Year Rainfall Return Period

For Tabaco City, with an area of 112.24 sq. km., 10.25% will experience flood levels of less than 0.20 meters in the 25-year rainfall return scenario. 1.46% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.47%, 0.13%, 0.02%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 36 depicts the areas affected in Tabaco City, in square kilometers, by flood depth per barangay.

Table 36. Affected Areas in Tabaco City, Albay during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City										
	Bacolod	Bangkilingan	Bantayan	Basagan	Bombon	Bonot	Buhian	Cormidal	Mariroc	Matagbac	Pawa
0.03-0.20	0.15	0.0083	0.95	1.05	0.073	0.69	0.035	0.019	0.000032	0.28	0.34
0.21-0.50	0.014	0.00024	0.084	0.079	0.0023	0.027	0.0002	0.0028	0	0.041	0.099
0.51-1.00	0.0032	0	0.042	0.02	0.00072	0.011	0.0001	0.0003	0	0.0094	0.022
1.01-2.00	0	0	0.014	0.0045	0	0.0047	0	0	0	0.00052	0.0033
2.01-5.00	0	0	0.0015	0.0021	0	0.0033	0.000019	0	0	0	0
>5.00	0	0	0	0	0	0.0004	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City								
	Quinastillojan	San Antonio	San Carlos	San Vicente	Tabiguian	Tayhi			
0.03-0.20	1.66	2.33	0.47	2.1	0.11	1.22			
0.21-0.50	0.16	0.3	0.19	0.28	0.0042	0.36			
0.51-1.00	0.1	0.14	0.019	0.11	0.0014	0.042			
1.01-2.00	0.052	0.042	0.00031	0.026	0.001	0.00082			
2.01-5.00	0.0072	0.0075	0	0.0001	0.001	0			
>5.00	0.001	0.0004	0	0	0	0			

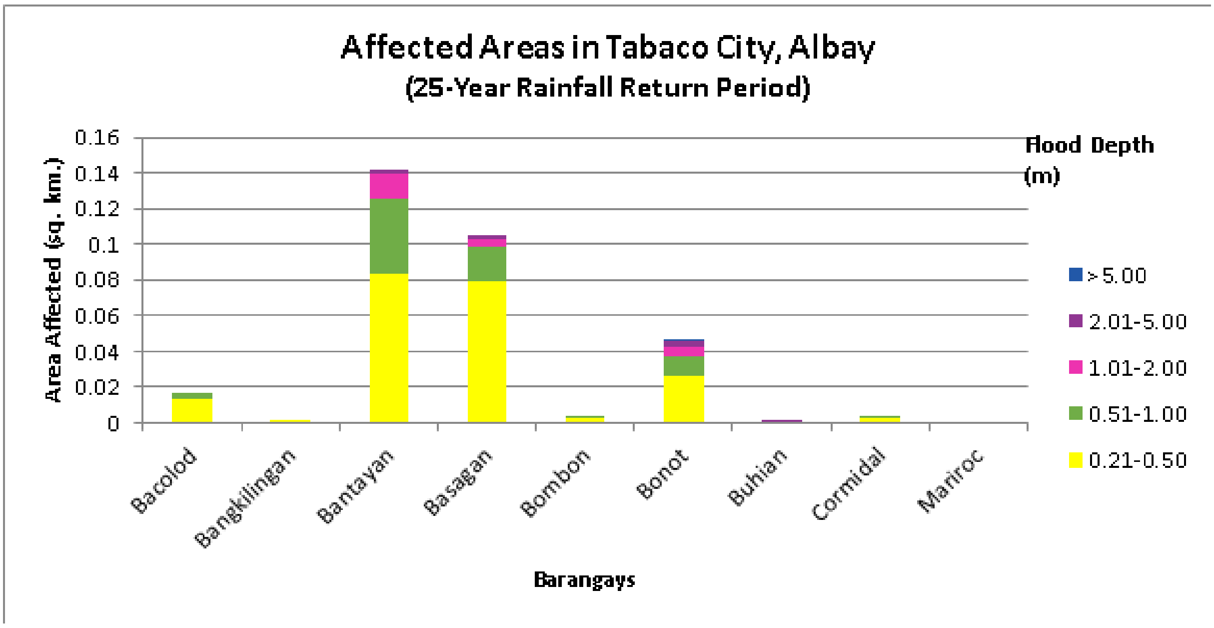

Figure 76. Affected Areas in Tabaco City, Albay during the 25-Year Rainfall Return Period

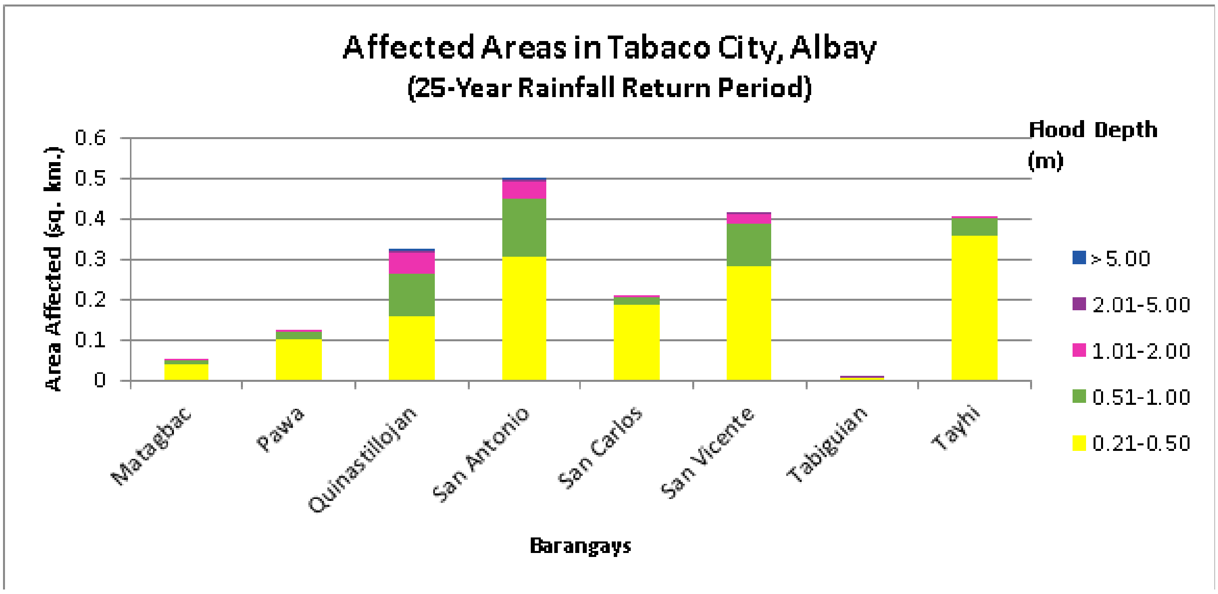

Figure 77. Affected Areas in Tabaco City, Albay during the 25-Year Rainfall Return Period

For the Municipality of Tiwi, with an area of 124.4 sq. km., 0.57% will experience flood levels of less than 0.20 meters in the 25-year scenario. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.02%, and 0.0007% 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. Table 37 depicts the areas affected in Tiwi, in square kilometers, by flood depth per barangay.

Table 37. Affected Areas in Tiwi, Albay during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tiwi	
	Nagas	San Bernardo
0.03-0.20	0.43	0.28
0.21-0.50	0.12	0.02
0.51-1.00	0.058	0.0061
1.01-2.00	0.028	0.0018
2.01-5.00	0	0.0009

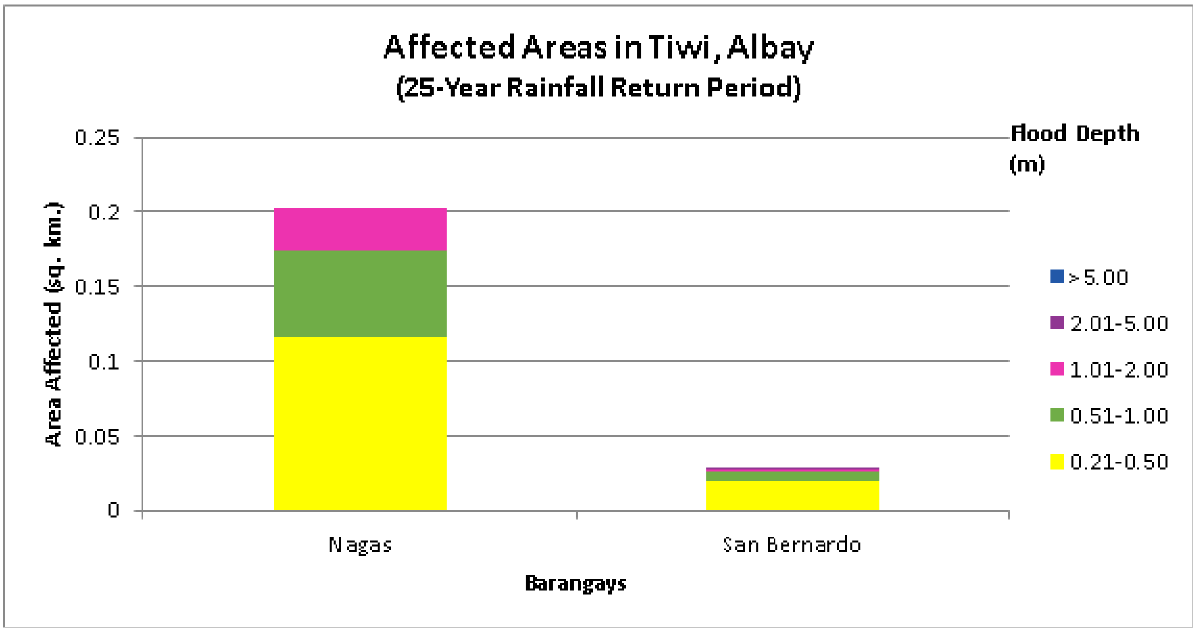

Figure 78. Affected Areas in Tiwi, Albay during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 9.09% of the Municipality of Malinao, with an area of 327.24 sq. km., will experience flood levels of less than 0.20 meters. 2.66% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.29%, 1.65%, 0.37%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Malinao, in square kilometers, by flood depth per barangay.

Table 38. Affected Areas in Malinao, Albay during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malinao										
	Awang	Bagumbayan	Balading	Balza	Bariw	Baybay	Bulang	Burabod	Cabunturan	Comun	Diaro
0.03-0.20	2.08	0.084	0.6	0.19	0.64	0.19	2.04	1.17	1.12	0.83	1.26
0.21-0.50	1.35	0.17	0.59	0.17	0.66	0.061	0.078	0.48	0.41	0.12	0.24
0.51-1.00	1.22	0.21	0.64	0.29	0.34	0.17	0.038	0.11	0.17	0.023	0.29
1.01-2.00	0.32	0.13	0.35	0.13	0.14	0.54	0.015	0.026	0.03	0.0025	0.21
2.01-5.00	0.014	0	0.005	0.066	0.00022	0.077	0.0061	0.002	0.0012	0.0024	0.071
>5.00	0	0	0	0.01	0	0	0.0001	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malinao										
	Estancia	Jonop	Labnig	Libod	Malolos	Matalipni	Ogob	Pawa	Payahan	Poblacion	Santa Elena
0.03-0.20	2.06	0.78	0.73	0.31	1.37	1.8	3.12	0.18	0.029	0.0078	1.83
0.21-0.50	0.56	0.52	0.46	0.26	0.19	0.27	0.23	0.16	0.034	0.05	0.26
0.51-1.00	0.37	0.46	0.51	0.28	0.19	0.24	0.22	0.25	0.12	0.18	0.073
1.01-2.00	0.19	0.26	0.41	0.28	0.19	0.19	0.23	0.39	0.34	0.17	0.031
2.01-5.00	0.017	0.013	0.07	0.09	0.097	0.075	0.14	0.097	0.00076	0	0.016
>5.00	0	0	0	0.031	0	0.0008	0.0001	0.015	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malinao							
	Soa	Sugcad	Tagoytoy	Tanawan	Tuliw			
0.03-0.20	1.54	1.32	1.79	2.38	0.3			
0.21-0.50	0.09	0.15	0.36	0.53	0.23			
0.51-1.00	0.059	0.16	0.087	0.33	0.46			
1.01-2.00	0.04	0.06	0.032	0.12	0.59			
2.01-5.00	0.0057	0.1	0.01	0.058	0.18			
>5.00	0	0.0006	0	0.0018	0.0041			

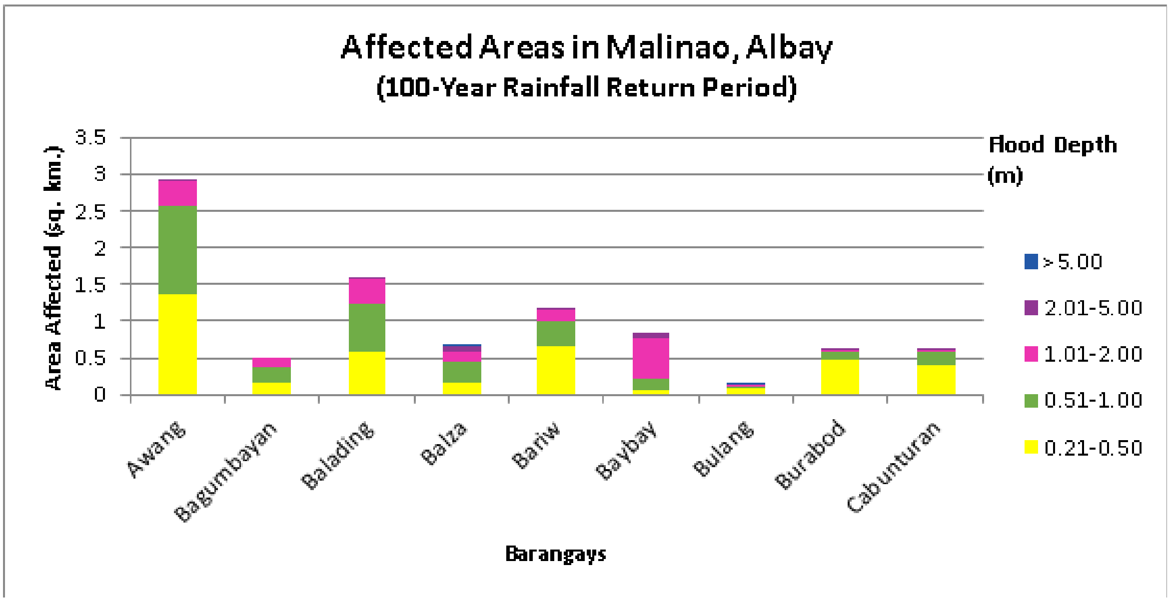

Figure 79. Affected Areas in Malinao, Albay during the 100-Year Rainfall Return Period

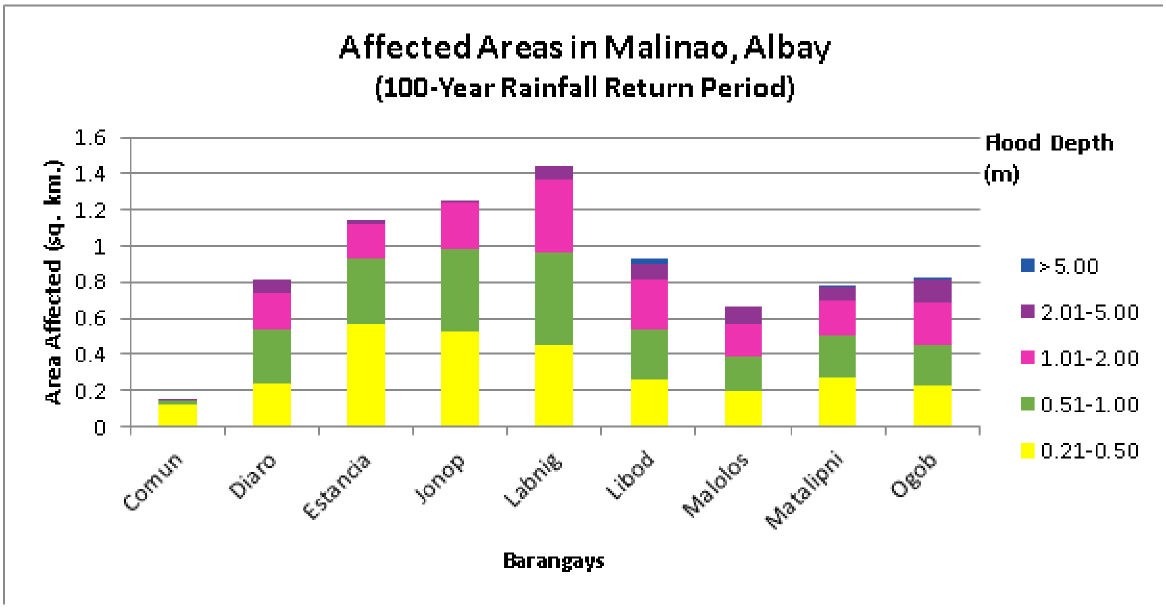

Figure 80. Affected Areas in Malinao, Albay during the 100-Year Rainfall Return Period

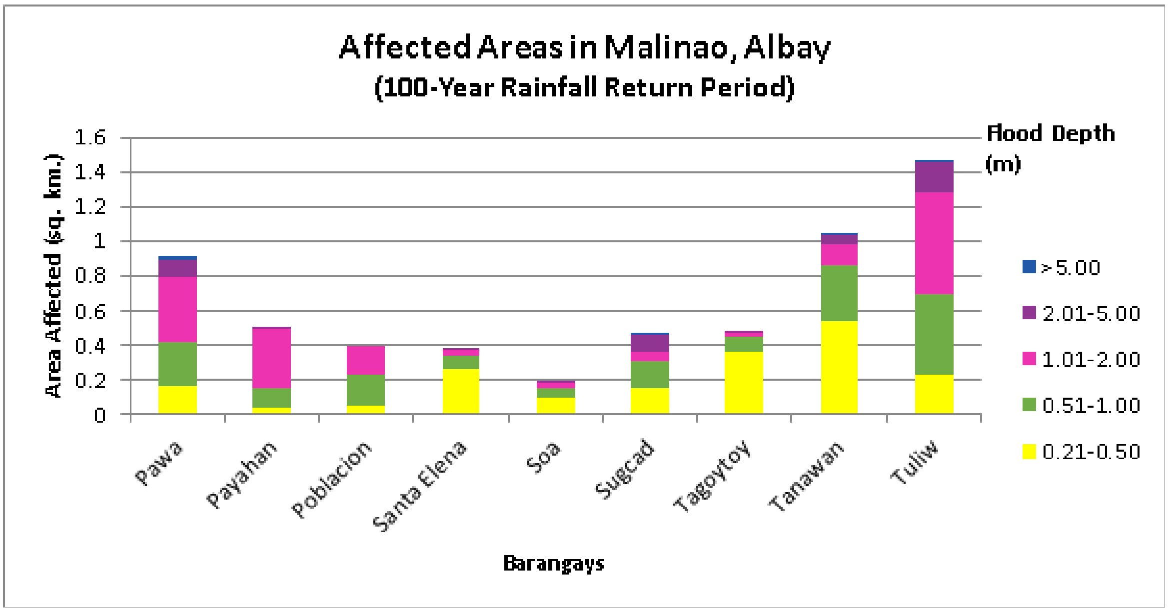

Figure 81. Affected Areas in Malinao, Albay during the 100-Year Rainfall Return Period

For Tabaco City, with an area of 112.24 sq. km., 9.82% will experience flood levels of less than 0.20 meters in the 100-year rainfall return period. 1.74% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.56%, 0.19%, 0.03%, 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 greater than 5 meters, respectively. Table 39 depicts the areas affected in Tabaco City, in square kilometers, by flood depth per barangay.

Table 39. Affected Areas in Tabaco City, Albay during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City										
	Bacolod	Bangkilingan	Bantayan	Basagan	Bombon	Bonot	Buhian	Cormidal	Mariroc	Matagbac	Pawa
0.03-0.20	0.15	0.0083	0.93	1.03	0.072	0.68	0.034	0.018	0.000032	0.26	0.31
0.21-0.50	0.018	0.00024	0.095	0.096	0.0035	0.032	0.0005	0.0029	0	0.061	0.12
0.51-1.00	0.0039	0	0.048	0.023	0.00072	0.013	0	0.0005	0	0.01	0.031
1.01-2.00	0	0	0.019	0.0057	0	0.0055	0.0001	0	0	0.0019	0.0047
2.01-5.00	0	0	0.002	0.0023	0	0.0034	0.000019	0	0	0	0
>5.00	0	0	0	0	0	0.0005	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City							
	Quinastillojan	San Antonio	San Carlos	San Vicente	Tabiguian	Tayhi		
0.03-0.20	1.61	2.25	0.42	2.02	0.11	1.11		
0.21-0.50	0.19	0.35	0.22	0.33	0.005	0.44		
0.51-1.00	0.11	0.17	0.037	0.12	0.0016	0.065		
1.01-2.00	0.072	0.055	0.0013	0.041	0.0012	0.0011		
2.01-5.00	0.009	0.01	0	0.0005	0.001	0		
>5.00	0.0011	0.0004	0	0	0	0		

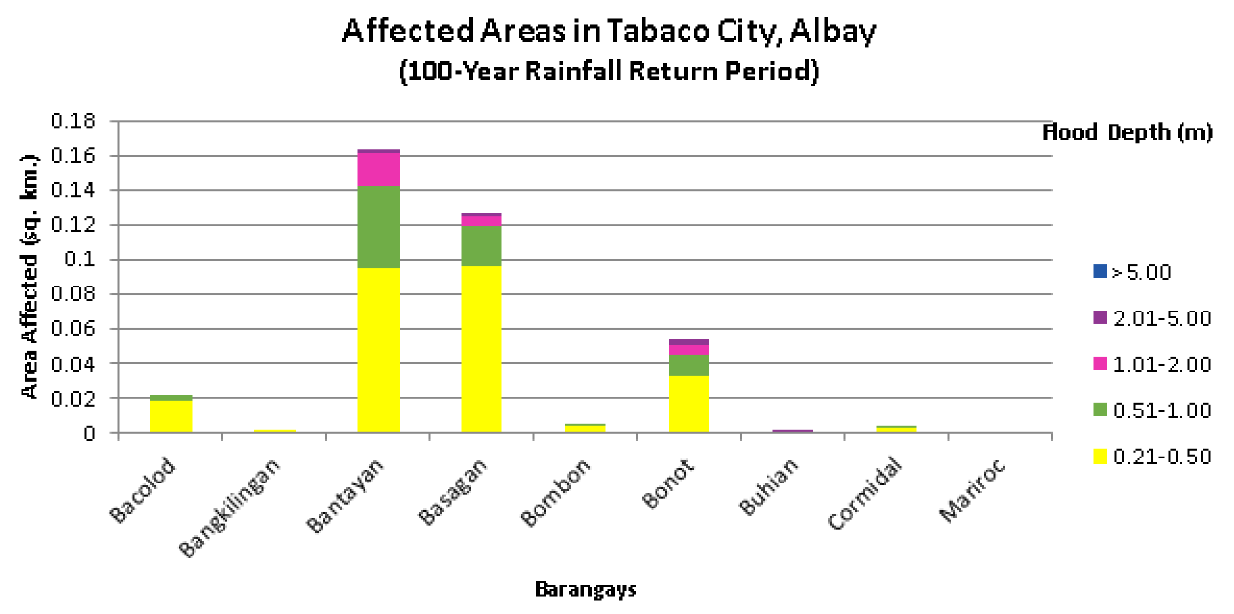

Figure 82. Affected Areas in Tabaco City, Albay during the 100-Year Rainfall Return Period

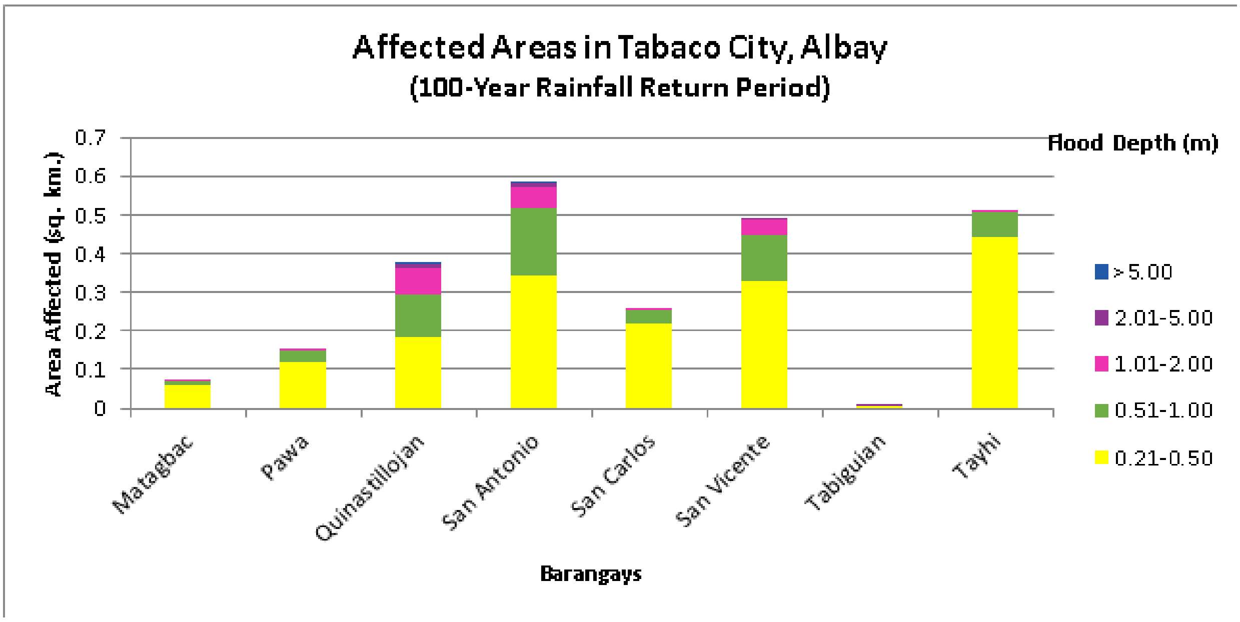

Figure 83. Affected Areas in Tabaco City, Albay during the 100-Year Rainfall Return Period

For the Municipality of Tiwi, with an area of 124.4 sq. km., 0.57% will experience flood levels of less than 0.20 meters during the 100-year scenario. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.02%, and 0.0007% 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. Table 40 depicts the areas affected in Tiwi, in square kilometers, by flood depth per barangay.

Table 40. Affected Areas in Tiwi, Albay during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tabaco City	
	Nagas	San Bernardo
0.03-0.20	0.39	0.28
0.21-0.50	0.12	0.022
0.51-1.00	0.089	0.0074
1.01-2.00	0.034	0.0025
2.01-5.00	0	0.0011

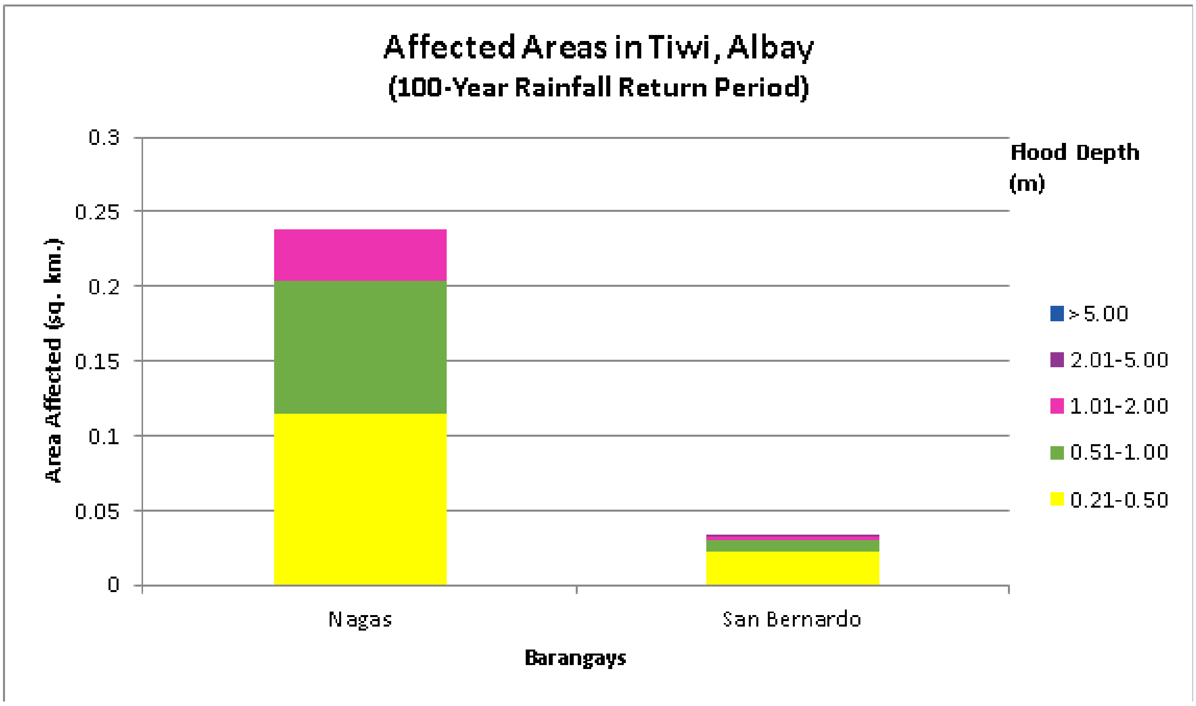

Figure 84. Affected Areas in Tiwi, Albay during the 100-Year Rainfall Return Period

Among the barangays in the Municipality of Malinao, Awang is projected to have the highest percentage of area that will experience flood levels, at 1.53%. Meanwhile, Ogob posted the second highest percentage of area that may be affected by flood depths, at 1.2%.

Among the barangays in Tabaco City, San Antonio is projected to have the highest percentage of area that will experience flood levels, at 2.52%. Meanwhile, San Vicente posted the second highest percentage of area that may be affected by flood depths, at 2.24%.

Among the barangays in the Municipality of Tiwi, Nagas is projected to have the highest percentage of area that will experience flood levels, at 0.51%. Meanwhile, San Bernardo posted the second highest percentage of area that may be affected by flood depths, at 0.25%.

The generated flood hazard maps for the Guinale floodplain were also used to assess the vulnerability of the educational and medical institutions within the floodplain. Using the flood depth units of PAGASA for the hazard maps – “Low”, “Medium”, and “High” – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year). The list of educational and medical institutions exposed to flooding in the Guinale floodplain are provided in Annex 12 and Annex 13, respectively.

Table 41. Area covered by each warning level, with respect to rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	10.14	10.83	11.12
Medium	7.51	10.56	12.49
High	1.36	2.08	3.42

Of the fifty (50) identified educational institutions in the Guinale floodplain, eleven (11) were assessed to be exposed to Low-level flooding, two (2) were assessed to be exposed to Medium-level flooding, and none was assessed to be subjected to High-level flooding during the 5-year scenario. In the 25-year scenario, sixteen (16) schools were assessed to be exposed to Low-level flooding, five (5) to Medium-level flooding, and none to High-level flooding. In the 100-year scenario, eighteen (18) were assessed to be exposed to Low-level flooding, eight (8) to Medium-level flooding, and none to High-level flooding.

Of the eleven (11) identified medical institutions in the Guinale floodplain, three (3) were assessed to be exposed to Low-level flooding, two (2) to Medium-level flooding, and none to High-level flooding. In the 25-year scenario, one (1) was assessed to be exposed to Low-level flooding, four (4) to Medium-level flooding, and none to High-level flooding. In the 100-year scenario, two (2) were assessed to be exposed to Low-level flooding, three (3) to Medium-level flooding, and one (1) to High-level flooding.

5.11 Flood Validation

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

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

The validation personnel then went to the specified points identified in the river basin and gathered data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents who have knowledge or experience of flooding in the particular area. After which, the actual data from the field were compared with 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 the corresponding validation depths are illustrated in Figure 86.

The flood validation consists of one hundred and thirty-five (135) points, randomly selected all over the Guinale floodplain. It has an RMSE value of 0.69439182. Table 42 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

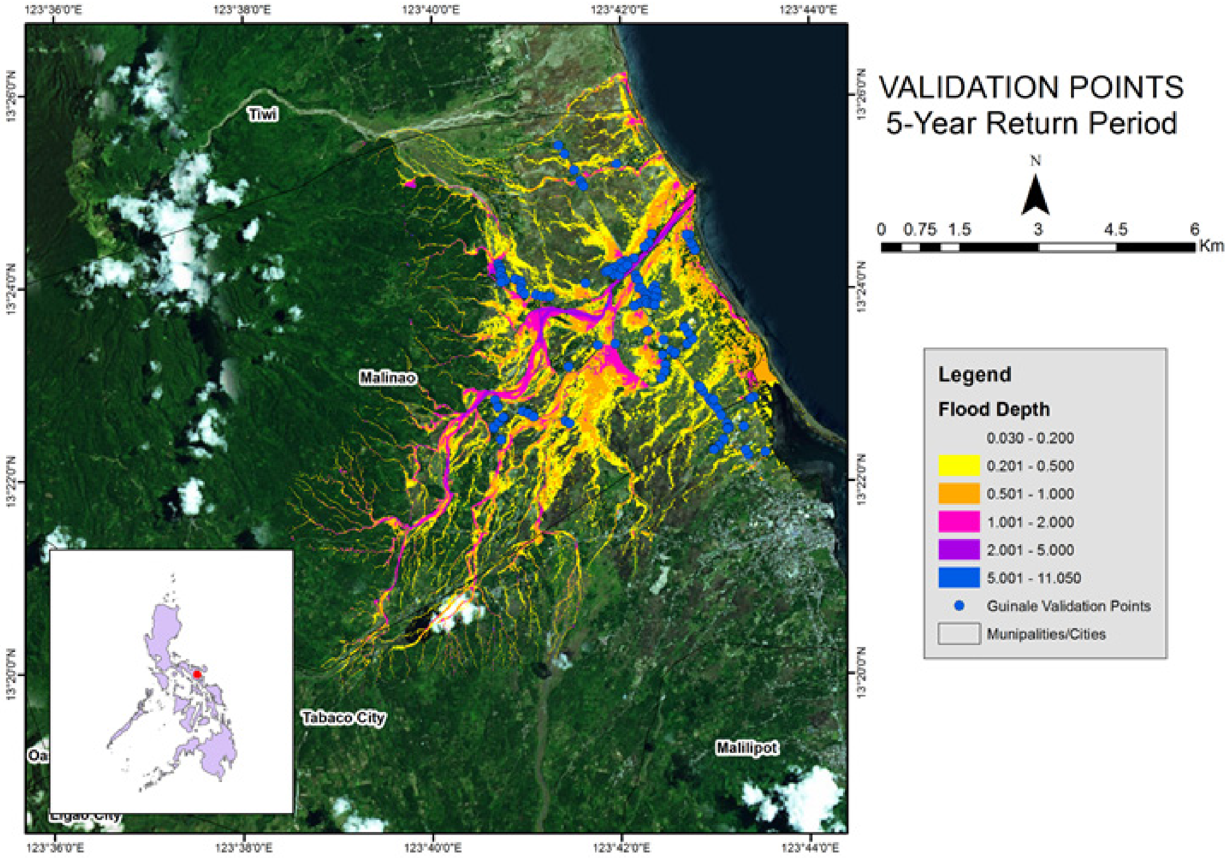

Figure 85. The validation points for the 5-Year flood depth map of the Guinale floodplain

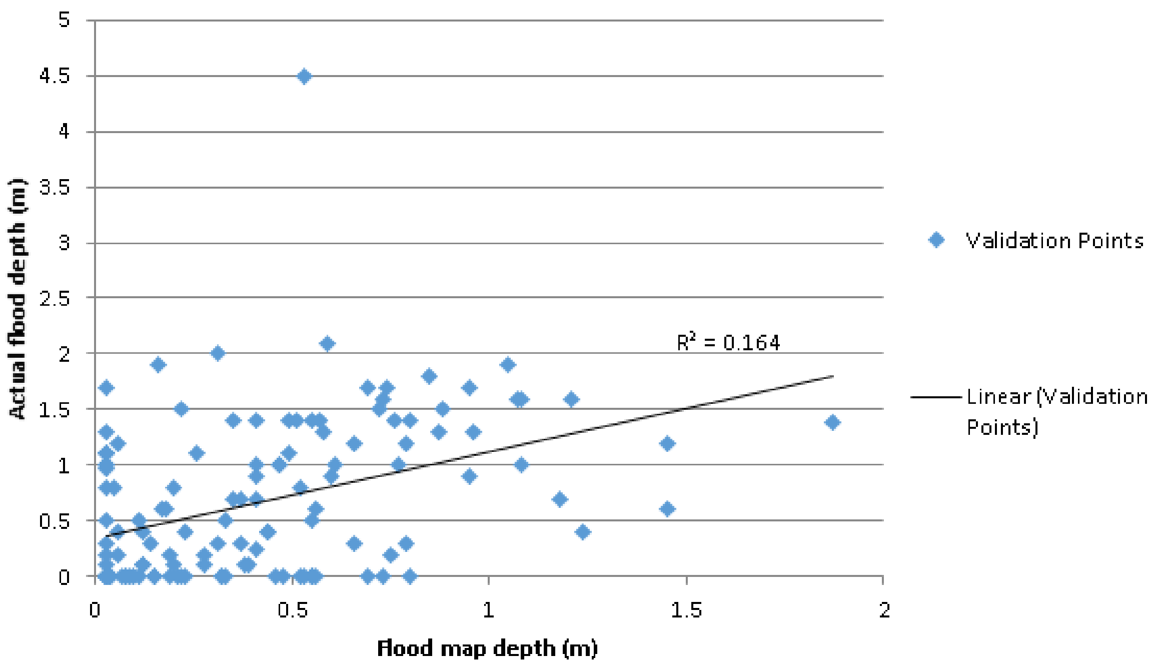

Figure 86. Flood map depth vs. Actual flood depth

Table 42. Actual flood vs. Simulated flood depth at different levels in the Guinale River Basin

GUINALE		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
Actual Flood Depth (m)	0-0.20	32	12	10	0	0	0	54
	0.21-0.50	6	7	3	1	0	0	17
	0.51-1.00	9	7	5	3	0	0	24
	1.01-2.00	7	7	18	6	0	0	38
	2.01-5.00	0	0	2	0	0	0	2
	> 5.00	0	0	0	0	0	0	0
	Total	54	33	38	10	0	0	135

The overall accuracy generated by the flood model is estimated at 37.04%, with fifty (50) points correctly matching the actual flood depths. There were forty-nine (49) points estimated one (1) level above and below the correct flood depths; twenty-nine (29) points estimated two (2) levels above and below; and seven (7) points estimated three (3) or more levels above and below the correct flood depths. A total of twenty-nine (29) points were overestimated, while a total of fifty-six (56) points were underestimated in the modeled flood depths of Guinale. Table 43 presents the summary of the accuracy assessment in the Guinale River Basin survey.

Table 43. Summary of the Accuracy Assessment in the Guinale River Basin Survey

GUINALE	No. of Points	%
Correct	50	**37.04**
Overestimated	29	21.48
Underestimated	56	41.48
Total	135	100

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.

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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.

ANNEXES

Annex 1. Technical Specifications of the Gemini LiDAR Sensor used in the Guinale Floodplain Survey

Figure A-1.1. Gemini Sensor

Table A-1.1. Specifications of the 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. ABY-08

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

April 10, 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: **ALBAY**
Station Name: **ABY-8**
Order: **2nd**

Island: **LUZON**
Municipality: **LEGASPI CITY**
Barangay: **LIDONG**

	PRS92 Coordinates	
Latitude: **13° 12' 51.92876"**	Longitude: **123° 45' 45.95336"**	Ellipsoidal Hgt: **6.33900 m.**
	WGS84 Coordinates	
Latitude: **13° 12' 47.06720"**	Longitude: **123° 45' 50.94829"**	Ellipsoidal Hgt: **60.47000 m.**
	PTM Coordinates	
Northing: **1461395.121 m.**	Easting: **582675.867 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,460,883.61**	Easting: **582,646.93**	Zone: **51**

Location Description

ABY-8
From Legaspi Pier, Legaspi City, Travel towards Tabaco Albay for about 8.0 km. upon reaching Legaspi-Santo Domingo boundary post, travel for about 200 m. ahead, turn right to second T road intersection of Mayon Riviera Subdivision and travel about 0.90 km. The station is located at the center end of the island of Mayon Riviera Subdivision. Highest prominent mark is the electric timber post 9.50 m. SE of the station. Station mark is 12.50 mm. dia. steel bar centered on a triangle on a 0.30 m. x 0.30 m. concrete block protruding 0.05 m. above ground surface and mark with NAMRIA ABY-8, 1990. Reference mark is Electric Timber Post.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-831**

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

9 9 0 4 1 0 2 0 1 4 1 4 0 3 1 1

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. ABY-08

2. ABY-92

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

February 24, 2016

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: **ALBAY**
Station Name: **ABY-82**
Order: **2nd**

Island: **LUZON**
Municipality: **JOVELLAR**
Barangay:
MSL Elevation:

		PRS92 Coordinates			
Latitude:	**13° 4' 16.27314"**	Longitude:	**123° 35' 53.17428"**	Ellipsoidal Hgt:	**39.77600 m.**
		WGS84 Coordinates			
Latitude:	**13° 4' 11.43271"**	Longitude:	**123° 35' 58.18268"**	Ellipsoidal Hgt:	**93.89000 m.**
		PTM / PRS92 Coordinates			
Northing:	**1445500.97 m.**	Easting:	**564865.27 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,444,995.02**	Easting:	**564,842.57**	Zone:	**51**

Location Description

ABY-82
From Guinobatan Town Proper, travel S for about 16 km. to reach Jovellar Town Proper. Station is located at the right corner (about 12 m.) of the Rizal monument in front of Jovellar Catholic Church and 12 m. from the road centerline. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "ABY-82 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0415**

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

9 9 0 2 2 4 2 0 1 6 1 4 0 5 2 1

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. ABY-92

3. ABY-09

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

April 10, 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: **ALBAY**
Station Name: **ABY-9**
Order: **3rd**

Island: **LUZON**
Municipality: **LEGASPI CITY**
Barangay:

PRS92 Coordinates

Latitude: **13° 9' 11.38733"**	Longitude: **123° 43' 45.95874"**	Ellipsoidal Hgt: **14.54010 m.**

WGS84 Coordinates

Latitude: **13° 9' 6.53800"**	Longitude: **123° 43' 50.95900"**	Ellipsoidal Hgt: **68.75400 m.**

PTM Coordinates

Northing: **1454607.115 m.**	Easting: **579082.538 m.**	Zone: **4**

UTM Coordinates

Northing: **1,454,097.98**	Easting: **579,054.86**	Zone: **51**

Location Description

ABY-9
From Albay Capitol Building, Legaspi City travel along Washington Drive about 2.0 km., turn left at road intersection and travel at about 1.0 km. to Legaspi Airport. Station is located at Legaspi Airport Compound, 52.0 m. SE of Legaspi Airport Flagpole, 35 m. NE of Legaspi Airport Welcome Post, 3.30 m. NW of Lamp. Station mark is 12.5 mm. dia. steel bar centered on a triangle on 0.30 m. x 0.30 m concrete block protruding 0.05 m. above the ground surface and mark with "NAMRIA ABY-9, 1990". Reference mark is Flagpole, Welcome Post, Lamp.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-832**

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

9904102014141548

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. ABY-09

4. AL-289

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

April 14, 2016

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: **ALBAY**
Station Name: **AL-289**

Island: **Luzon**	Municipality: **LEGAZPI CITY (CAPITAL)**	Barangay: **BGY. 49 - BIGAA**
Elevation: **8.9801 +/- 0.0175 m.**	Accuracy Class at 95% C.L: **2 cm**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

AL-289 is in the Province of Albay, City of Legazpi, Brgy. Bigaa, Ppppurol 4 along the Tiwi-Legazpi Natinal Road. The station is located at the NW end of Arimbay Bridge wing at KM 536+100 and about 3.1 m NW of the centerline of the road.

A brass rod is set on a drilled hole and cemented flushed on top of a 15 cm x 15 cm cmenet putty with inscription "AL-289, 2009, NAMRIA".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8084228 I**
T.N.:	**2016-0914**

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

Figure A-2.3. AL-289

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

1. AL-289

ABY-8 - AL-289 (7:37:43 AM-12:53:25 PM) (S1)

Baseline observation:	ABY-8 --- AL-289 (B1)
Processed:	6/14/2016 11:05:20 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.011 m
RMS:	0.002 m
Maximum PDOP:	4.060
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/7/2016 7:37:43 AM (Local: UTC+8hr)
Processing stop time:	3/7/2016 12:53:25 PM (Local: UTC+8hr)
Processing duration:	05:15:42
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	ABY-8				
Grid		**Local**		**Global**	
Easting	582646.935 m	**Latitude**	N13°12'51.92887"	**Latitude**	N13°12'47.06720"
Northing	1460883.610 m	**Longitude**	E123°45'45.95355"	**Longitude**	E123°45'50.94829"
Elevation	7.322 m	**Height**	6.340 m	**Height**	60.470 m

To:	AL-289				
Grid		**Local**		**Global**	
Easting	581543.975 m	**Latitude**	N13°11'22.18920"	**Latitude**	N13°11'17.33275"
Northing	1458123.495 m	**Longitude**	E123°45'09.03476"	**Longitude**	E123°45'14.03173"
Elevation	11.032 m	**Height**	10.065 m	**Height**	64.238 m

Vector					
ΔEasting	-1102.960 m	**NS Fwd Azimuth**	201°57'22"	**ΔX**	572.158 m
ΔNorthing	-2760.115 m	**Ellipsoid Dist.**	2973.273 m	**ΔY**	1144.314 m
ΔElevation	3.710 m	**ΔHeight**	3.726 m	**ΔZ**	-2683.944 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.003 m
σ ΔNorthing	0.001 m	**σ Ellipsoid Dist.**	0.001 m	**σ ΔY**	0.005 m
σ ΔElevation	0.006 m	**σ ΔHeight**	0.006 m	**σ ΔZ**	0.002 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. LOUIE P. BALICANTA</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td>LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>AUBREY MATIRA-PAGADOR</td><td rowspan="7">UP-TCAGP</td></tr>
<tr><td rowspan="4">LiDAR Operation</td><td rowspan="6">Research Associate (RA)</td><td>MA. VERLINA ENDICO TONGA</td></tr>
<tr><td>LARAH KRISELLE PARAGAS</td></tr>
<tr><td>KRISTINE ANDAYA</td></tr>
<tr><td>IRO NIEL ROXAS</td></tr>
<tr><td rowspan="2">Ground Survey, Data Download and Transfer</td><td>KENNETH QUISADO</td></tr>
<tr><td>JASMIN DOMINGO</td></tr>
<tr><td rowspan="5">LiDAR Operation</td><td>Airborne Security</td><td>TSG. BENJIE CARBOLLEDO</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="4">Pilot</td><td>CAPT. RAUL CZ SAMAR II</td><td rowspan="4">ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. CESAR ALFONSO III</td></tr>
<tr><td>CAPT. GEROME MOONEY</td></tr>
<tr><td>CAPT. DEXTER CAB-UDOL</td></tr>
</table>

Annex 5. Data Transfer Sheets for the Guinale Floodplain Flights

DATA TRANSFER SHEET
ALBAY/SORSOGON 3/28/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
7-Mar-16	3855G	2BLK19AS 067A	GEMINI	NA	NA	796	170	28.6	223	8.28	NA	11.5	1KB	1KB	36/30/28	NA	Z:\DAC\RAW DATA
9-Mar-16	3863G	2BLK19aC EFG069A	GEMINI	NA	545	1.34	262	46.6	359	25.9	NA	10.1	1KB	1KB	33/211	NA	Z:\DAC\RAW DATA
10-Mar-16	3869G	2BLK19AS BSI070A	GEMINI	NA	667	7.77	283	32.5	283	18.9	NA	10	1KB	1KB	28	NA	Z:\DAC\RAW DATA
11-Mar-16	3871G	2BLK19aC DGI071A	GEMINI	NA	1035	1.99	279	45.5	344	23.9	NA	18.8	1KB	1KB	33	NA	Z:\DAC\RAW DATA
11-Mar-16	3873G	2BLK19aH 071B	GEMINI	NA	352	749	189	35.4	250	17	NA	12.3	1KB	2KB	21/22	NA	Z:\DAC\RAW DATA
13-Mar-16	3879G	2BLK19aJ 073A	GEMINI	NA	565	1.14	267	52.7	404	26.8	NA	11.1	1KB	NA	18	4	Z:\DAC\RAW DATA
14-Mar-16	3883G	2BLK19JS KM074A	GEMINI	NA	1290	3.03	288	69.3	516	33.6	NA	15.5	1KB	1KB	17	1290	Z:\DAC\RAW DATA
14-Mar-16	3885G	2BLK19aK SMS074B	GEMINI	NA	70	1.79	197	17.2	161	16.2	NA	9.34	1KB	1KB	18	2	Z:\DAC\RAW DATA
15-Mar-16	3887G	2BLK19aK LS075A	GEMINI	NA	627	2.1	271	60.9	470	27.9	NA	17.8	1KB	1KB	15	4	Z:\DAC\RAW DATA
15-Mar-16	3889G	2BLK19aK LS075B	GEMINI	NA	239	1.4	166	22.3	187	10.4	NA	17.8	1KB	1KB	17	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name ANALYN M. NALDO
Position RA
Signature 3/31/2016

Figure A-5.1. Data Transfer Sheet for Guinale Floodplain – A

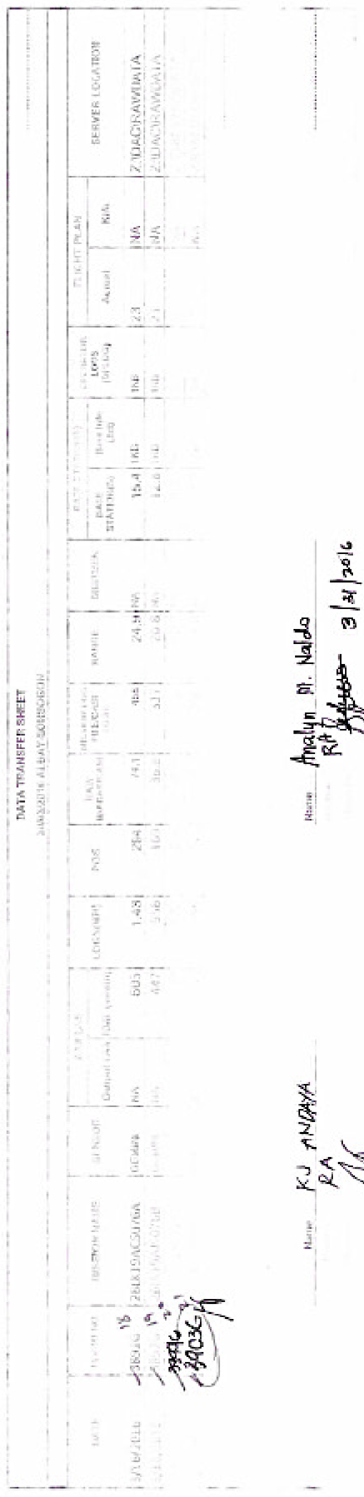


Figure A-5.2. Data Transfer Sheet for Guinale Floodplain – B

14-29

DATA TRANSFER SHEET
5/5/2014(ALBAY Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
4/20/2013	7200GC	2BLK19JS110A & 2BLK19N110A	GEMINI	NA	221KB	402KB	237MB	50.3	133	17.3	NA	7.61	1KB	1KB	151	24	Z:\Airborne_Raw\7200GC
4/22/2014	7204GC	2BLK19A112A	GEMINI	NA	130/20MB	359	206	NA	NA	15.1	N/A	1.14	1KB	1KB	384	7	Z:\Airborne_Raw\7204GC
4/26/2014	7212GC	2BLK19P116A & 2BLK190116A	GEMINI	NA	125	431	126	N/A	N/A	17.7	N/A	1.68	1KB	1KB	244	11	Z:\Airborne_Raw\7212GC
4/26/2014	7213GC	2BLK19OS116B & VOIDS	GEMINI	NA	33.6	263	141	N/A	N/A	8.77	N/A	1.68	1KB	1KB	311	3	Z:\Airborne_Raw\7213GC
4/28/2014	7216GC	2BLK19AS118A & VOIDS	GEMINI	NA	46.2	311	184	41.5	N/A	12.1	N/A	7.36	1KB	1KB	191	5kb/2kb	Z:\Airborne_Raw\7216P

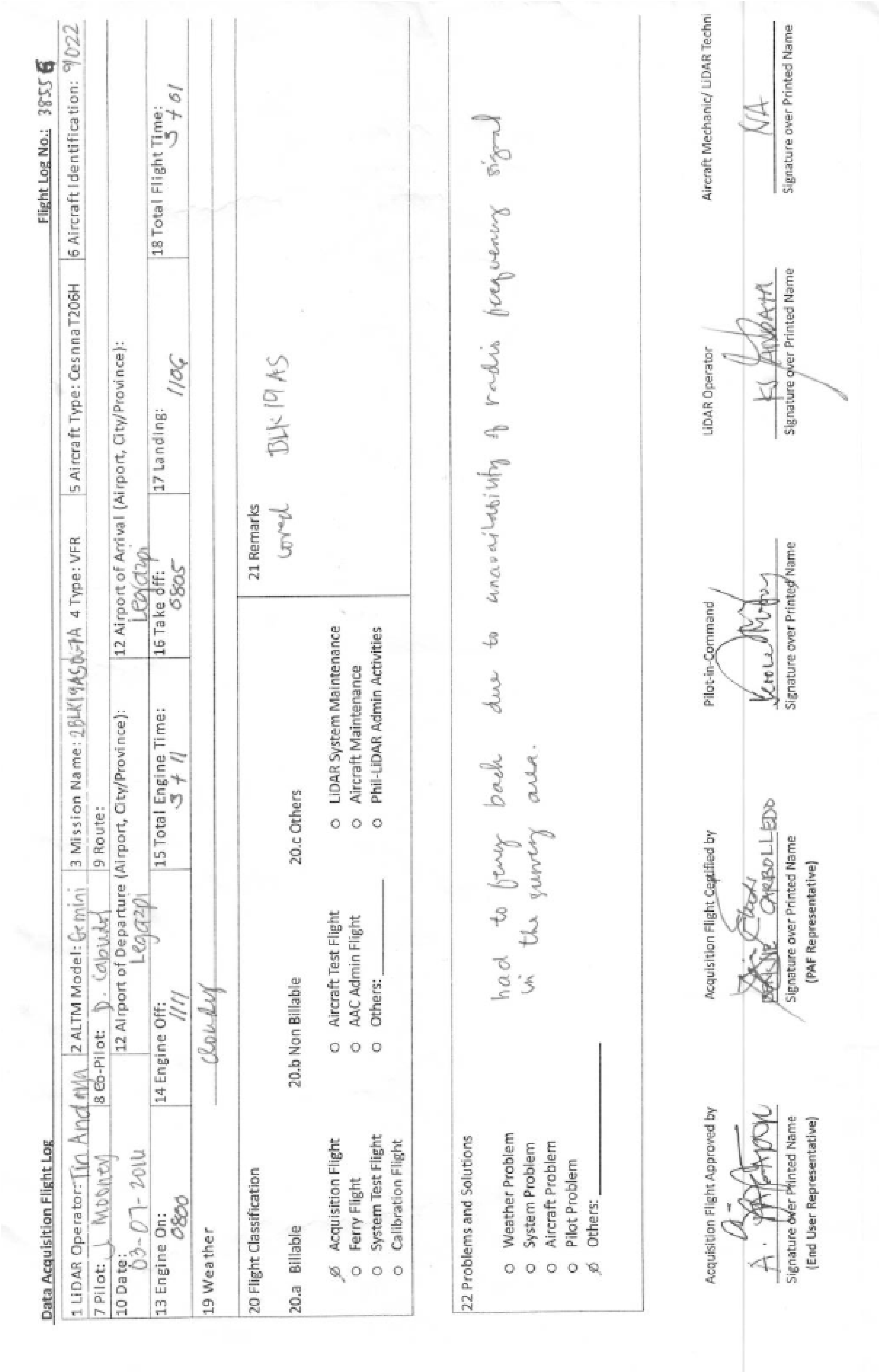
Received from
Name
Position
Signature

Received by
Name Benjamin Magallon
Position
Signature
5/5/2014

Figure A-5.3. Data Transfer Sheet for Guinale Floodplain – C

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 3855 G Mission


Data Acquisition Flight Log — Flight Log No.: 3855G

1 LiDAR Operator: Tin Andaya	2 ALTM Model: Gemini	3 Mission Name: 2BLK19AS067A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: J. Mosney	8 Co-Pilot: D. Cabrera	9 Route:			
10 Date: 03-07-2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 0800	14 Engine Off: 1111	15 Total Engine Time: 3+11	16 Take off: 0805	17 Landing: 1106	18 Total Flight Time: 3+01
19 Weather: cloudy					

20 Flight Classification

20.a Billable
- ø 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

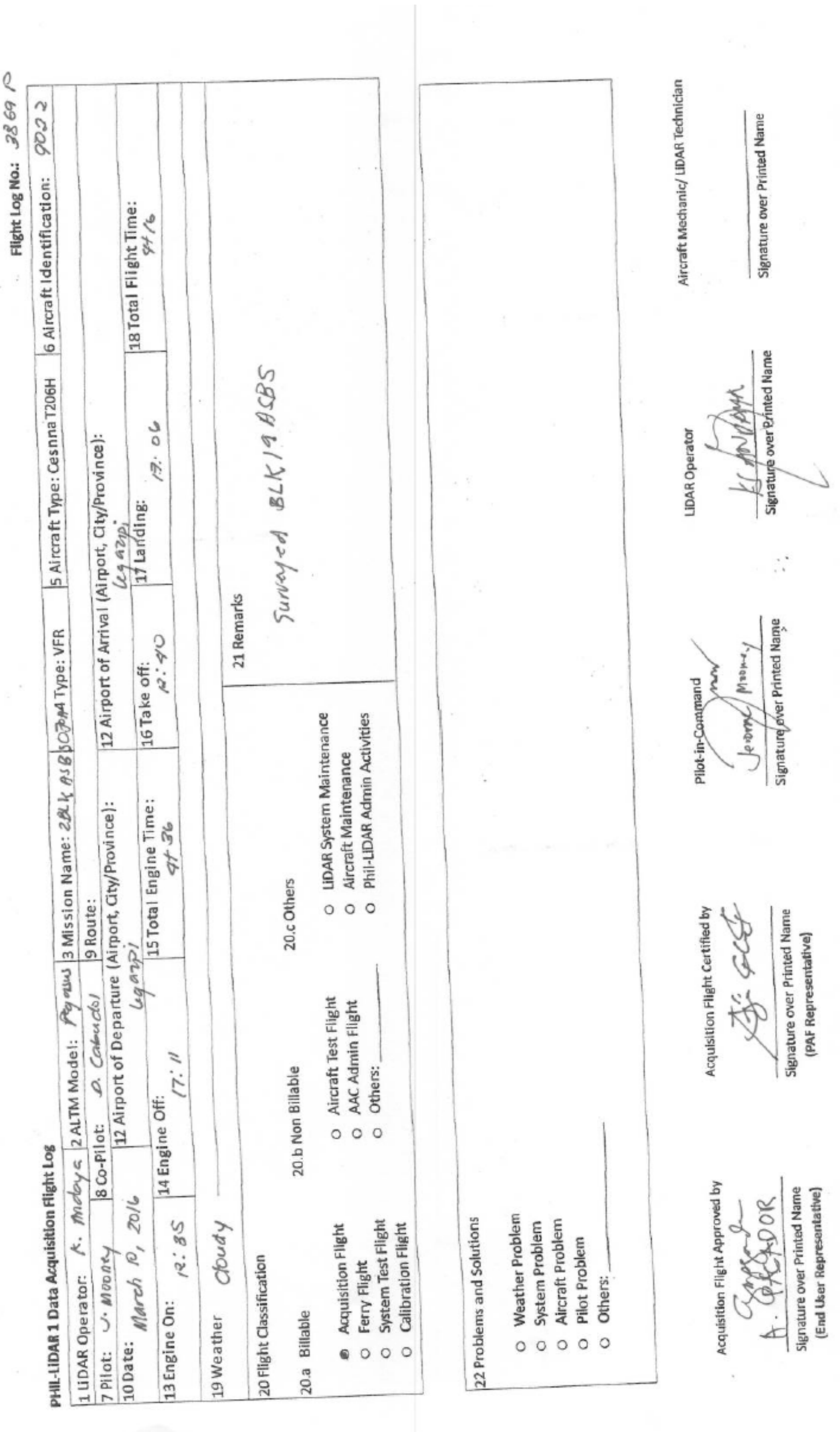
21 Remarks: covered BLK19AS

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- ø Others: had to ferry back due to unavailability of radio frequency signal in the survey area.

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
A. Antonio	... Carbolledo	K. Mosney	K. Andaya	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 3855 G

2. Flight Log for 3869 G Mission



Flight Log No.: 3869 P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: K. Mdoya	2 ALTM Model: Pegasus	3 Mission Name: 2BLK19ABS073A	4 Type: VFR	5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9022				
7 Pilot: J. Moody	8 Co-Pilot: D. Cabudol	9 Route:		
10 Date: March 10, 2016	12 Airport of Departure (Airport, City/Province): Legazpi	12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 12:35	14 Engine Off: 17:11	15 Total Engine Time: 4+36	16 Take off: 12:40	17 Landing: 17:06
18 Total Flight Time: 4+26				
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 BLK19ABS

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)

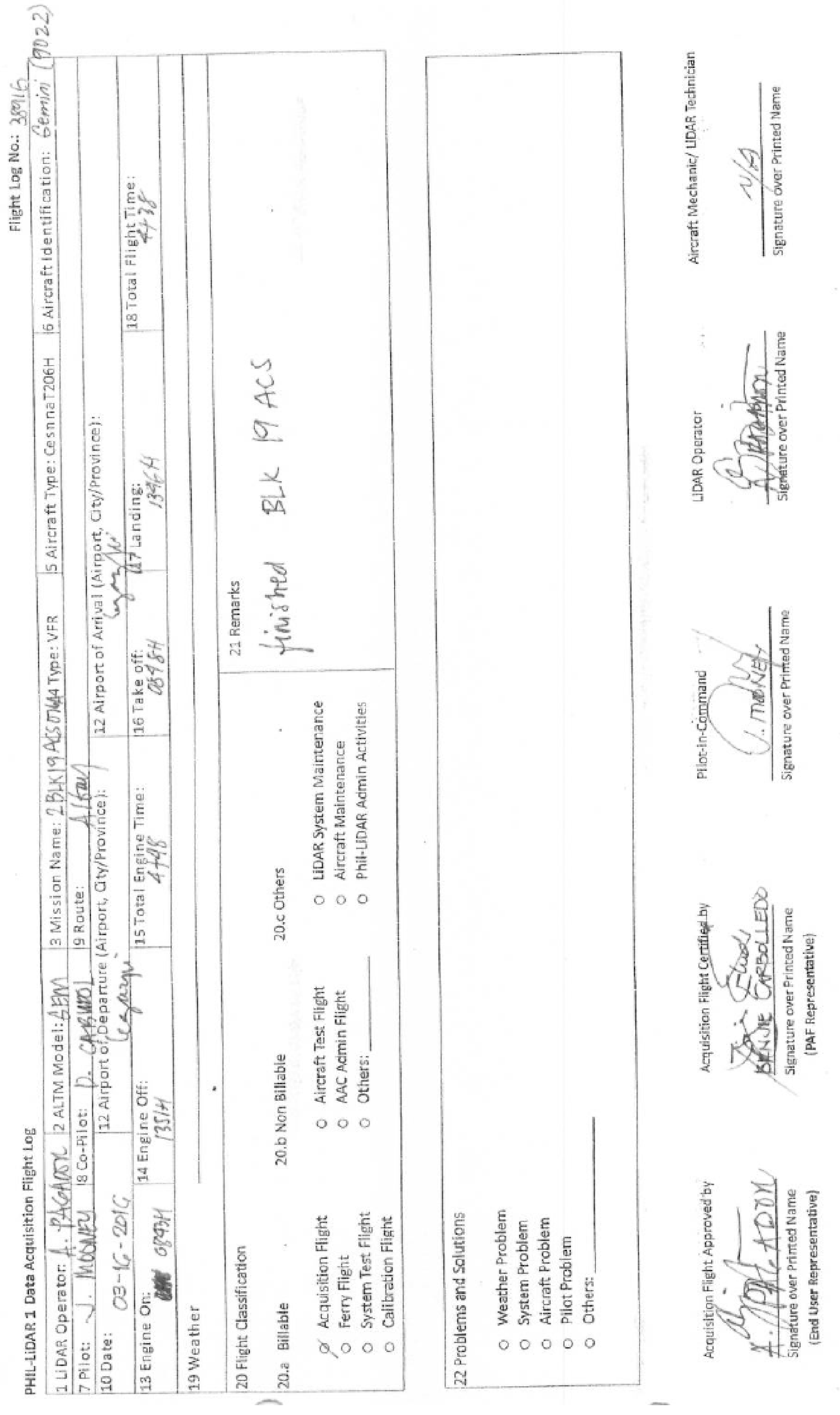
Pilot-in-Command: Signature over Printed Name

LIDAR Operator: Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.2. Flight Log for Mission 3869 G

3. Flight Log for 3891 G Mission



Flight Log No.: 3891G

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: A. BAGADION	2 ALTM Model: ABM	3 Mission Name: 2BLK19AGS074A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: Gemini (9022)
7 Pilot: J. MOONEY	8 Co-Pilot: D. CARBUNO	9 Route: Alfonso		
10 Date: 03-16-2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi	
13 Engine On: 0843H	14 Engine Off: 1351H	15 Total Engine Time: 4+08	16 Take off: 0848H	17 Landing: 1346H	18 Total Flight Time: 4+58
19 Weather				

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

finished BLK 19 ACS

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

Acquisition Flight Approved by: A. BAGADION — Signature over Printed Name (End User Representative)

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

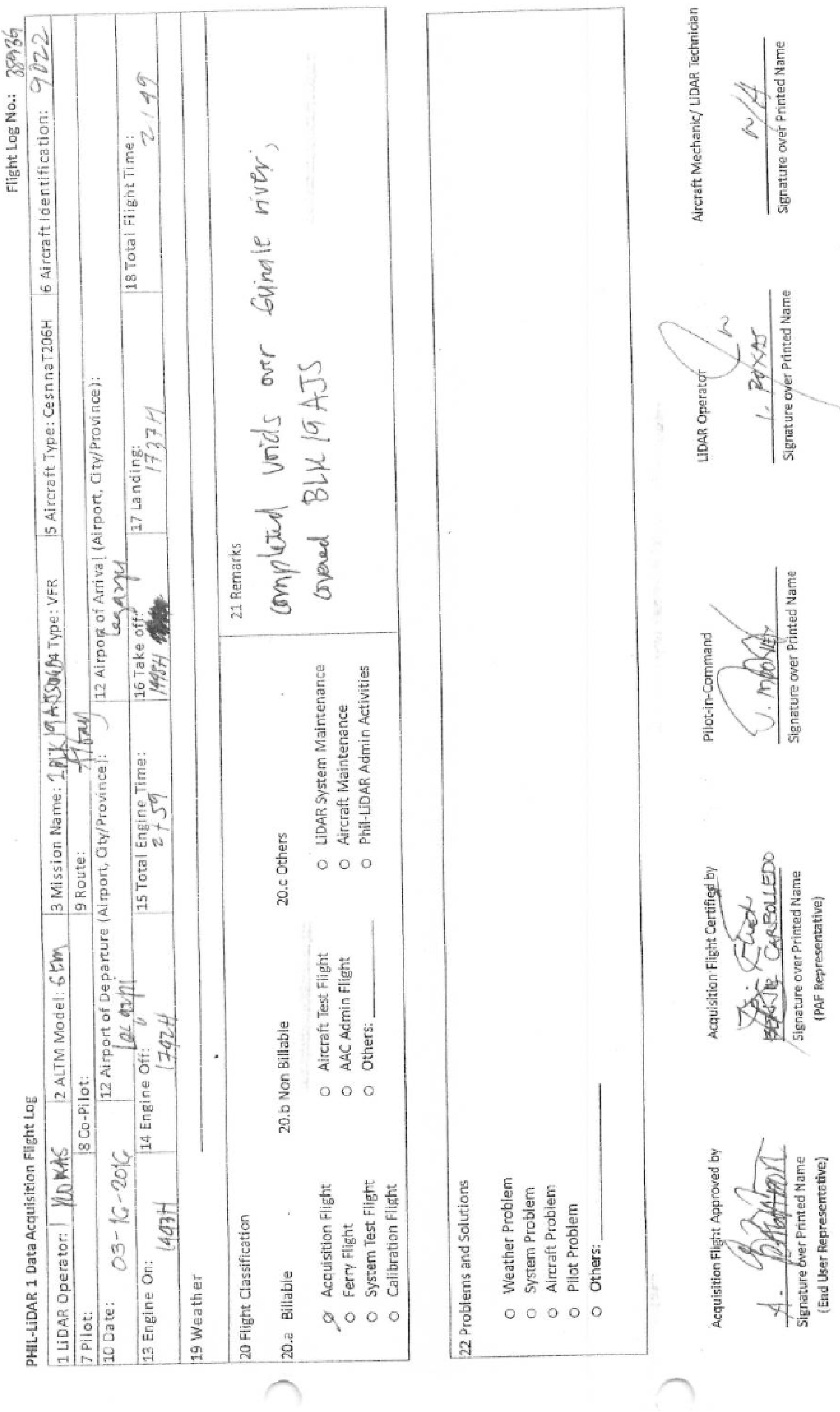
Pilot-in-Command: J. MOONEY — Signature over Printed Name

LiDAR Operator: A. BAGADION — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 3891 G

4. Flight Log for 3893 G Mission


Flight Log No.: 3893G

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: I. ROXAS | 2 ALTM Model: Gem | 3 Mission Name: 1BLK19AJS064A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9022

7 Pilot: | 8 Co-Pilot: | 9 Route: [illegible]

10 Date: 03-16-2016 | 12 Airport of Departure (Airport, City/Province): [illegible] | 12 Airport of Arrival (Airport, City/Province): [illegible]

13 Engine On: 1403H | 14 Engine Off: 1742H | 15 Total Engine Time: 2+59 | 16 Take off: 1408H | 17 Landing: 1737H | 18 Total Flight Time: 2+49

19 Weather

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

completed voids over Gingle river; covered BLK19AJS

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

Acquisition Flight Approved by: A. [illegible] — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: [illegible] CABALLEDO — Signature over Printed Name (PAF Representative)

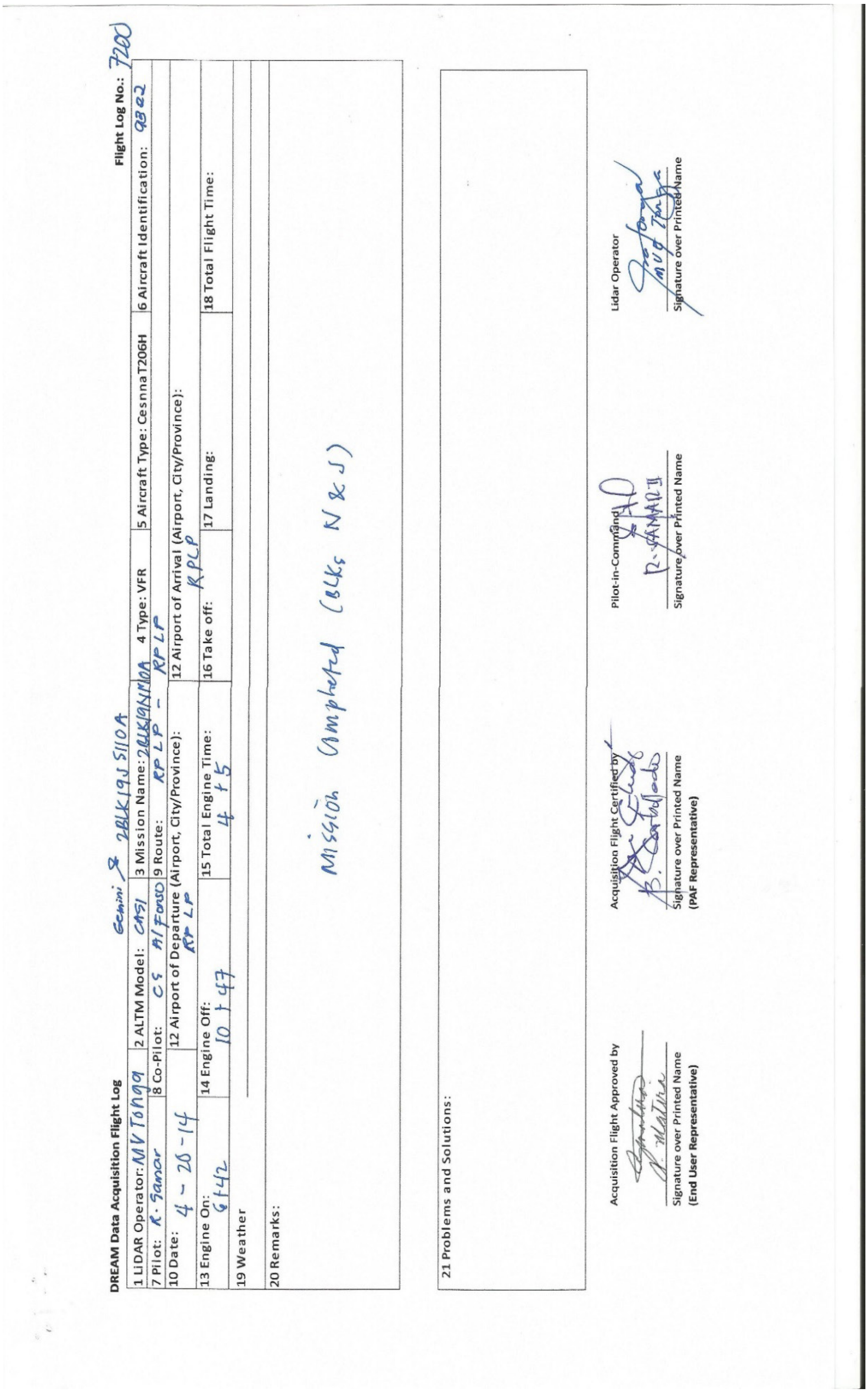
Pilot-in-Command: J. [illegible] — Signature over Printed Name

LIDAR Operator: I. ROXAS — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: N/A — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 3893 G

5. Flight Log for 7200 G Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7200

Gemini & 2BLK19J S110A

1 LiDAR Operator: MV Tongga	2 ALTM Model: CASI	3 Mission Name: 2BLK19JK110A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9822
7 Pilot: R. Samar	8 Co-Pilot: CS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-28-14	12 Airport of Departure (Airport, City/Province): RPLP	12 Airport of Arrival (Airport, City/Province): RPLP			
13 Engine On: 6+42	14 Engine Off: 10+47	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed (BLKs N & S)					
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: R. Samar II, Signature over Printed Name

Lidar Operator: MV Tongga, Signature over Printed Name

Figure A-6.5. Flight Log for Mission 7200 G

6. Flight Log for 7204 G Mission

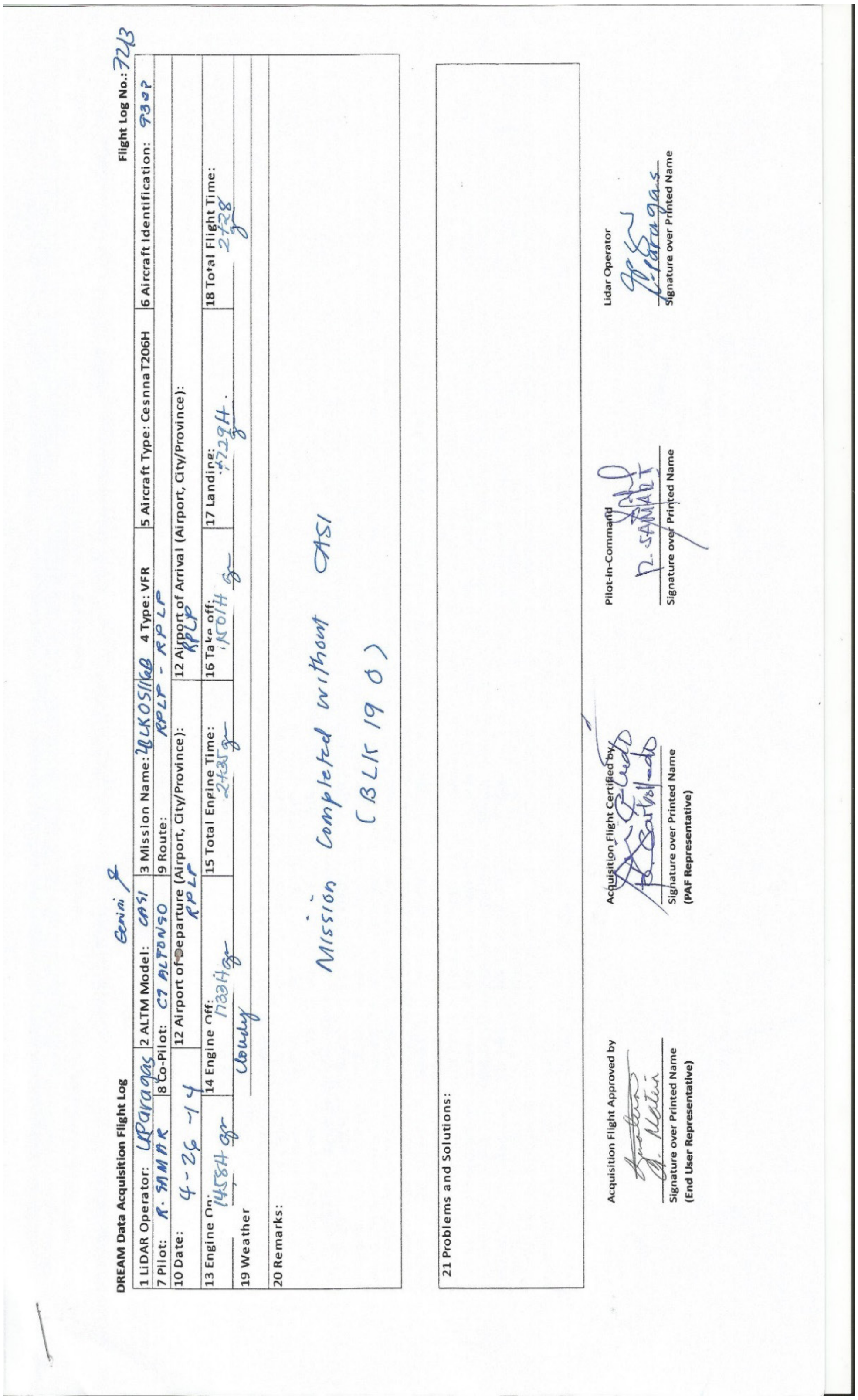
DREAM Data Acquisition Flight Log — Flight Log No.: 7204

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini / CASI	3 Mission Name: 2BLK19A112A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: R. Samar	8 Co-Pilot: CS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-22-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 6 lines at 19A & completed voids at BLK 19J					
21 Problems and Solutions:					

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	L. Paragas Signature over Printed Name

Figure A-6.6. Flight Log for Mission 7204 G

7. Flight Log for 7213 G Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7213

1 LiDAR Operator: L. Paragas	2 ALTM Model: CASI	3 Mission Name: 2BLK0S116B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9302
7 Pilot: R. Samar	8 Co-Pilot: C. Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-26-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 1458H	14 Engine Off: 1733H	15 Total Engine Time: 2+35	16 Take off: 1501H	17 Landing: 1729H	18 Total Flight Time: 2+28
19 Weather: Cloudy					

20 Remarks:

Mission completed without CASI (BLK 19 D)

21 Problems and Solutions:

Acquisition Flight Approved by: J. Matias — Signature over Printed Name (End User Representative)

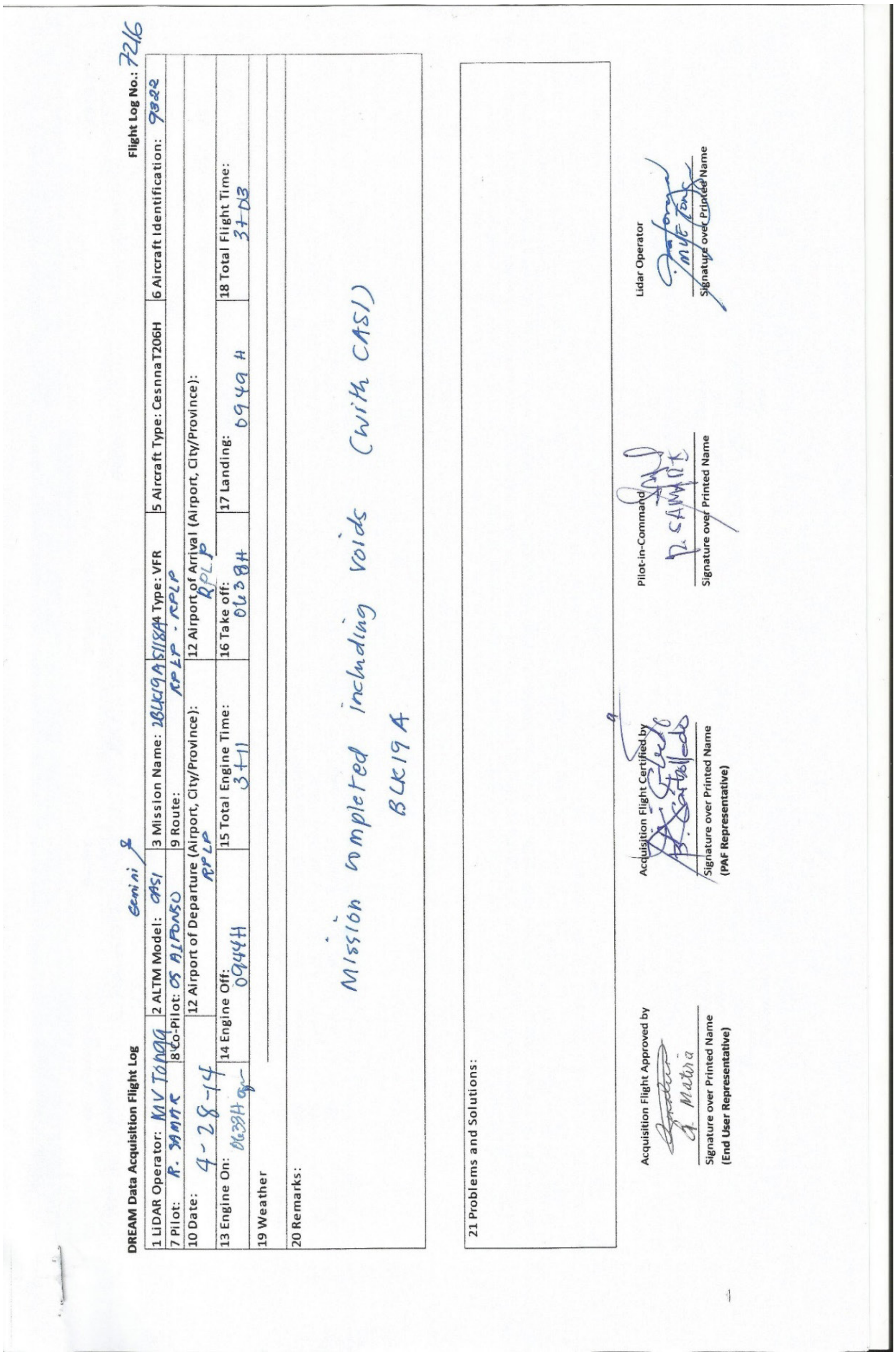
Acquisition Flight Certified by: B. Sarballedo — Signature over Printed Name (PAF Representative)

Pilot-in-Command: R. Samar — Signature over Printed Name

Lidar Operator: L. Paragas — Signature over Printed Name

Figure A-6.7. Flight Log for Mission 7213 G

8. Flight Log for 7216 G Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7216

1 LiDAR Operator: MV TONGA	2 ALTM Model: CASI (Gemini 2)	3 Mission Name: 2BLK19AS118A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMIR	8 Co-Pilot: CS ALFONSO	9 Route: RPLP - RPLP			
10 Date: 4-28-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0633H	14 Engine Off: 0944H	15 Total Engine Time: 3+11	16 Take off: 0638H	17 Landing: 0949H	18 Total Flight Time: 3+03
19 Weather					
20 Remarks: Mission completed including voids (with CASI) BLK19A					

21 Problems and Solutions:

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

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

Pilot-in-Command
D. SAMIR
Signature over Printed Name

Lidar Operator
MVE TONGA
Signature over Printed Name

Figure A-6.8. Flight Log for Mission 7216 G

Annex 7. Flight Status Reports

Table A-7-1. Flight Status Report

ALBAY AND SORSOGON
(March 7 - 20, 2016 and March 29 – April 28, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3855G	BLK19aS	2BLK19AS067A	KJ ANDAYA & A PAGADOR	07-Mar-16	Covered BLK19AS
3869G	BLK19aB	2BLK19ASBSI070A	KJ ANDAYA	10-Mar-16	Completed BLK19AS, BS, and AI
3891G	BLK19aC	2BLK19ACS076A	A PAGADOR	16-Mar-16	Finished voids over Ligao, Guinobatan; covered Polangui
3893G	BLK19aJ	2BLK19AJS076B	I ROXAS	16-Mar-16	Finished voids over Guinale river basin; covered Bacacay
7200GC	BLK19J and BLK19N	2BLK19JS110A & 2BLK19N110A	MVE TONGA	20-Apr-14	Mission completed (with CASI)
7204GC	BLK19A	2BLK19A112A	L. PARAGAS	22-Apr-14	Surveyed 6 lines at BLK19A and completed the voids at BLKJ (without CASI)
7213GC	BLK19O	2BLK19OS116B & VOIDS	L. PARAGAS	26-Apr-14	Completed the rest of BLK19O and rest of void data (NO CASI)
7216GC	BLK19 voids	2BLK19AS118A & VOIDS (BLK19Q)	MVE TONGA	28-Apr-14	Mission completed (with CASI)

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	3851G		
Area:	BLK19AS		
Mission Name:	2BLK19AS067A		
Parameters:	PRF: 125 kHz	SF: 40 Hz	FOV: 50 Degrees
Flying Height:	600 and 900 m		

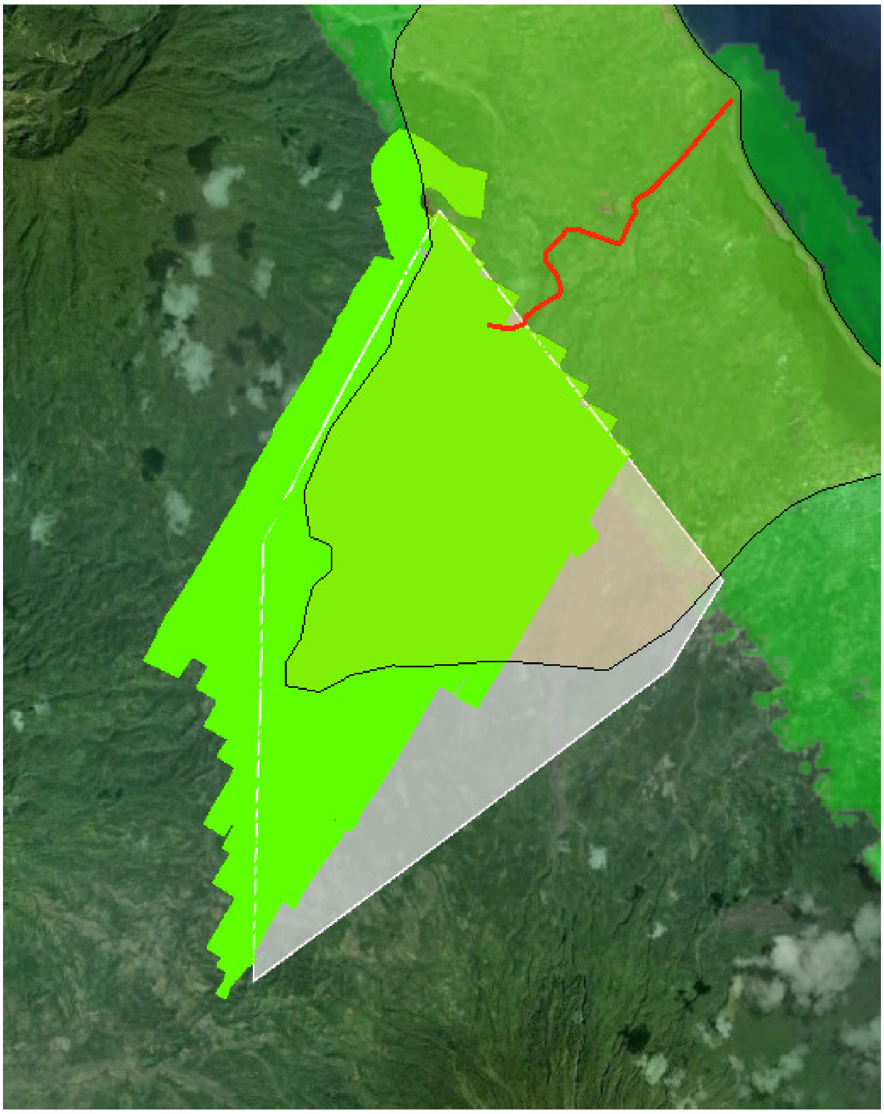


Figure A-7.1. Swath for Flight No. 3851G

Flight No. :	3869G		
Area:	BLK19ASBSAI		
Mission name:	2BLK19ASBSI070A		
Parameters:	PRF: 125 kHz	SF: 40 Hz	FOV: 50 degrees
Flying Height:	900 m		

LAS/SWATH

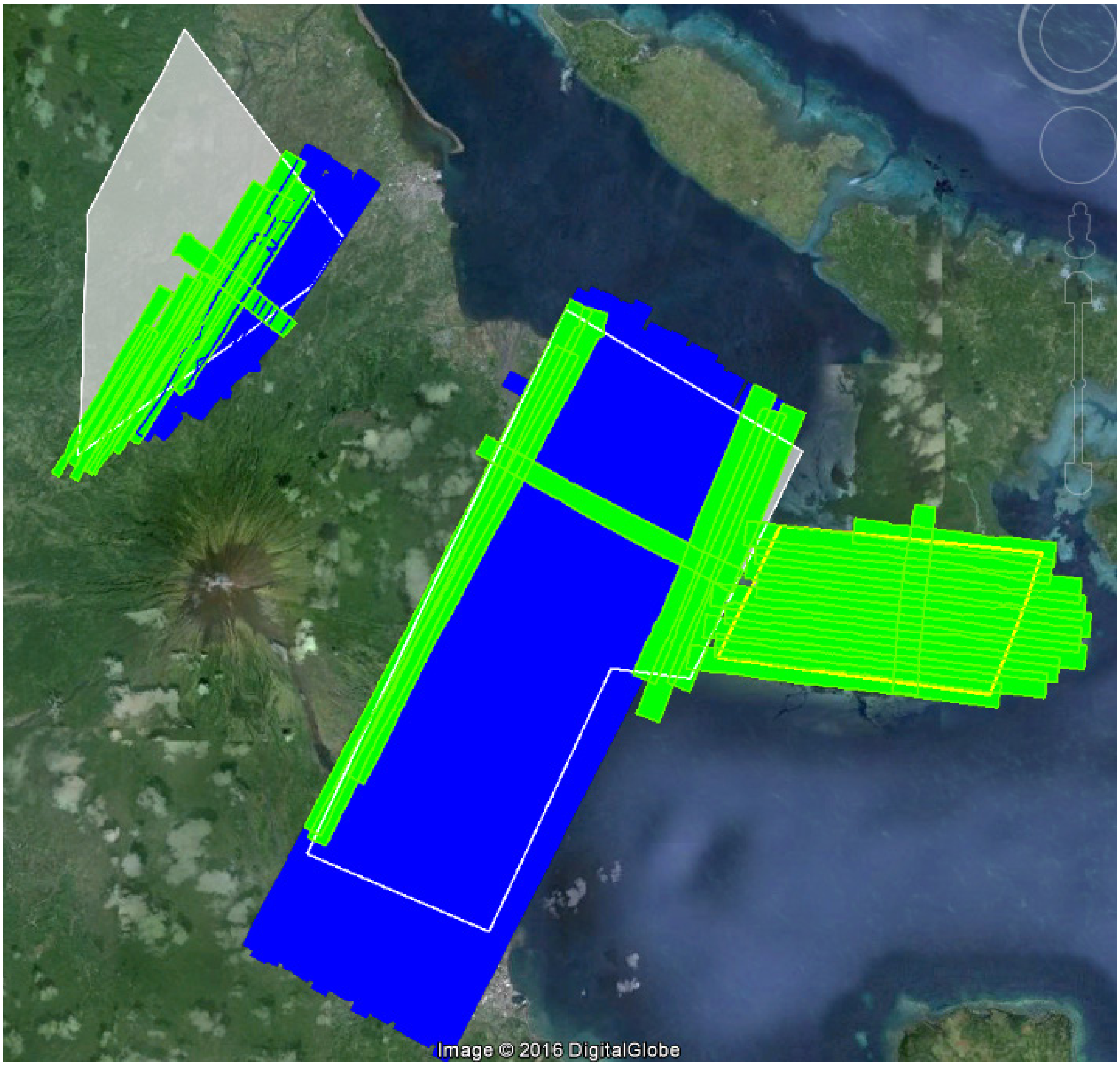


Figure A-7.2. Swath for Flight No. 3869G

Flight No. :	3891G		
Area:	BLK19A and voids		
Mission Name:	2BLK19ACS076A		
Parameters:	PRF: 125	SF: 40 Hz	FOV: 50 degrees
Flying Height:	650 m		

LAS/SWATH

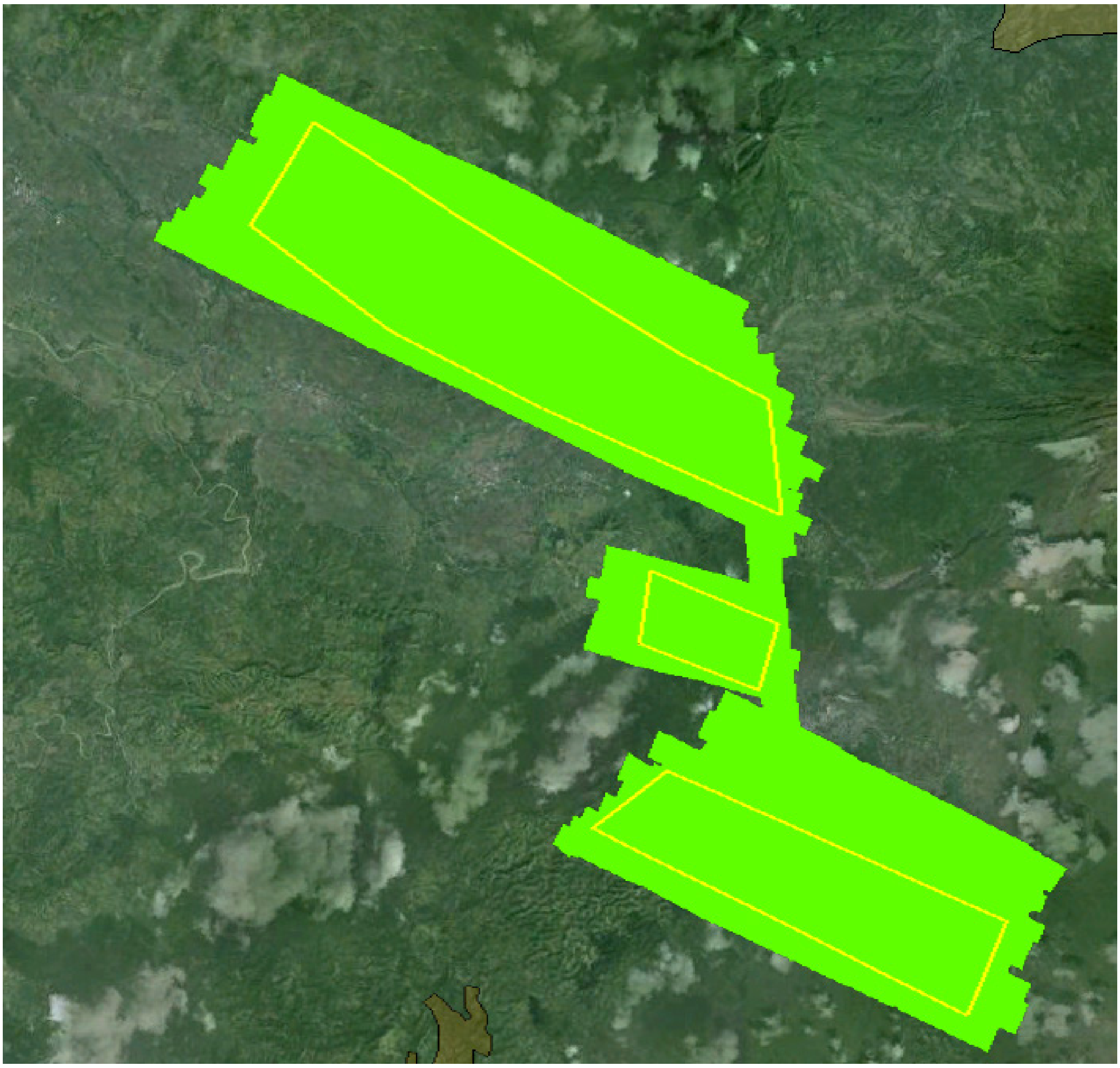


Figure A-7.3. Swath for Flight No. 3891G

Flight No. :	3893 G
Area:	BLK19AS
Mission Name:	2BLK19AJS076B
Parameters:	PRF: 125 SF: 40 Hz FOV: 50 degrees
Flying Height:	900 m

LAS/SWATH

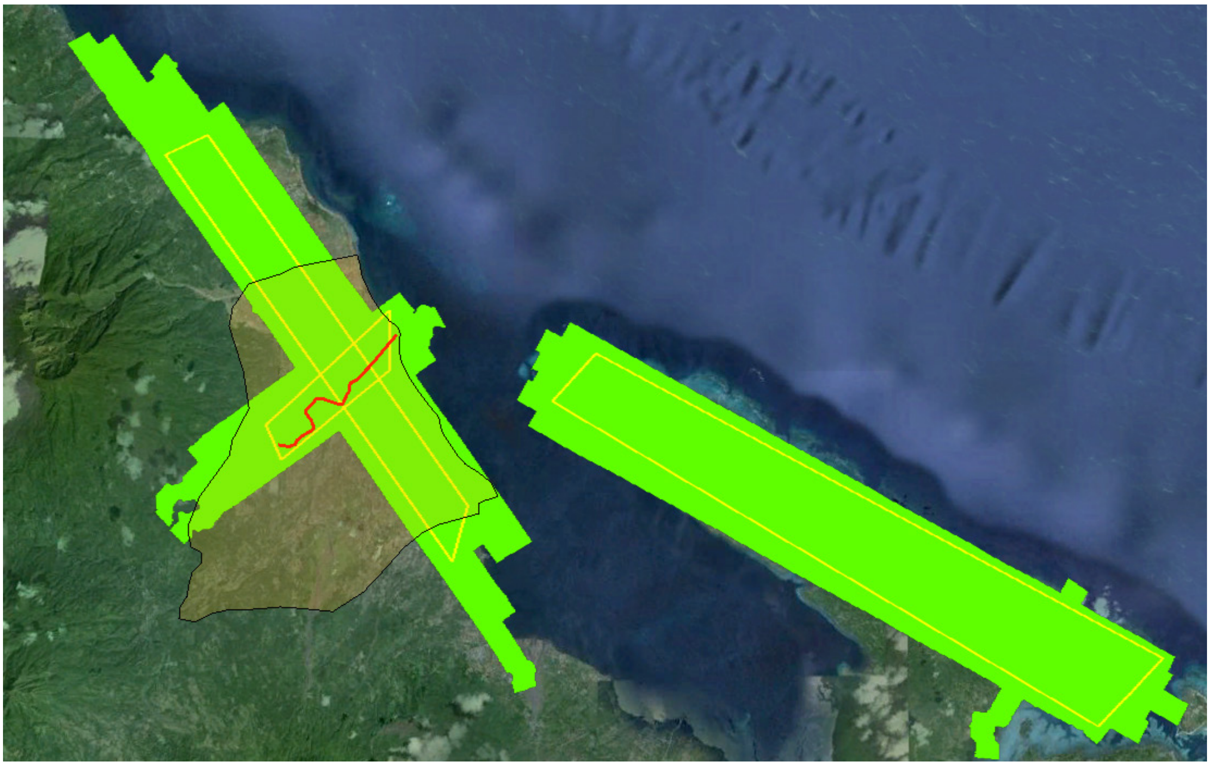


Figure A-7.4. Swath for Flight No. 3893G

Flight No. :	7200 GC
Area:	BLK19JS & BLK19N
Mission name:	2BLK19JS110A & 2BLK19N110A
Parameters:	PRF: 100 SF: 50 Hz FOV: 40 degrees
Flying Height:	1300 m

LAS/SWATH

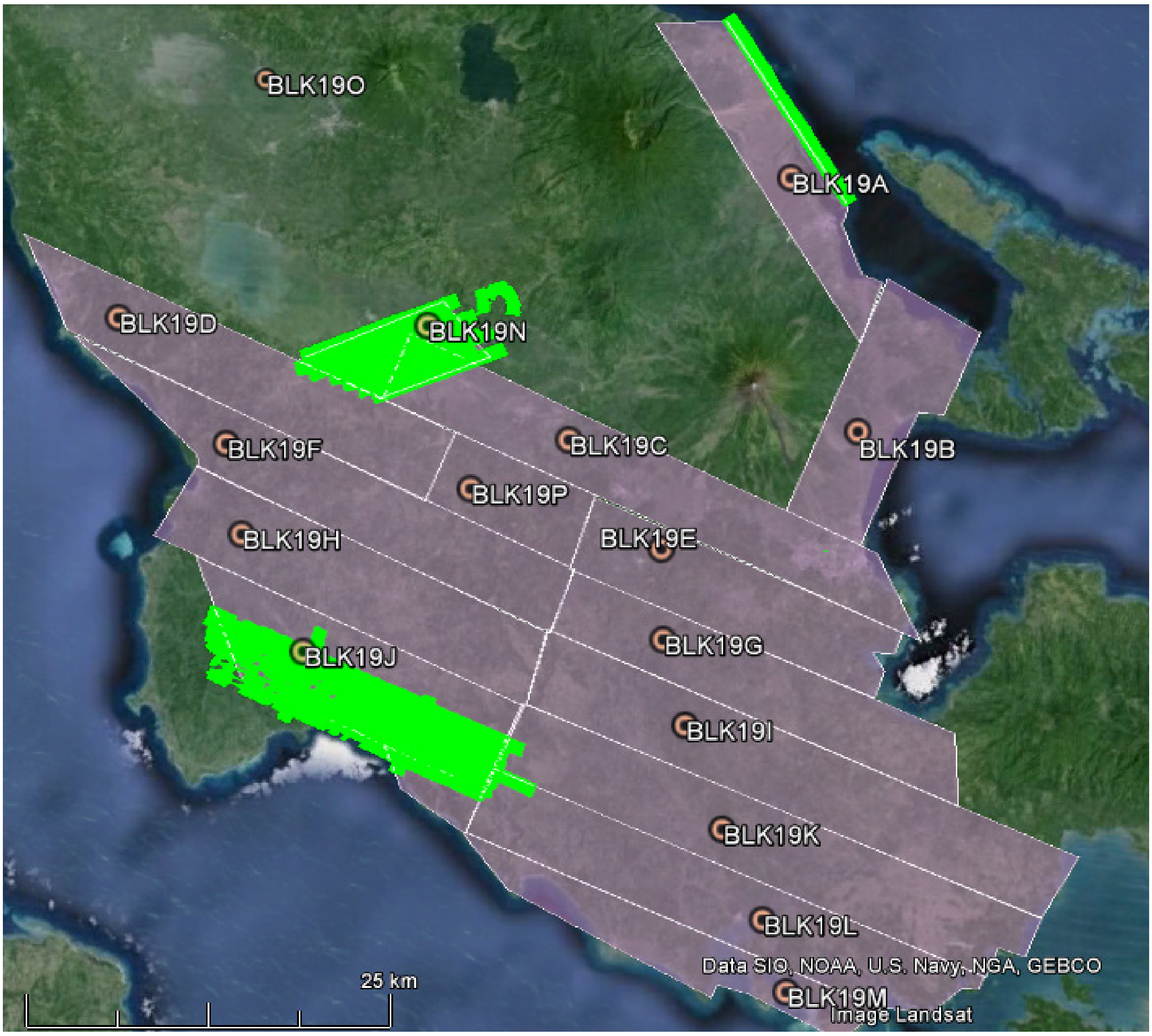


Figure A-7.5. Swath for Flight No. 7200GC

Flight No. :	7204 GC
Area:	BLK19A
Mission name:	2BLK19A112A
Parameters:	PRF: 100 SF: 50 Hz FOV: 34 degrees
Flying Height:	1300 m

LAS/SWATH

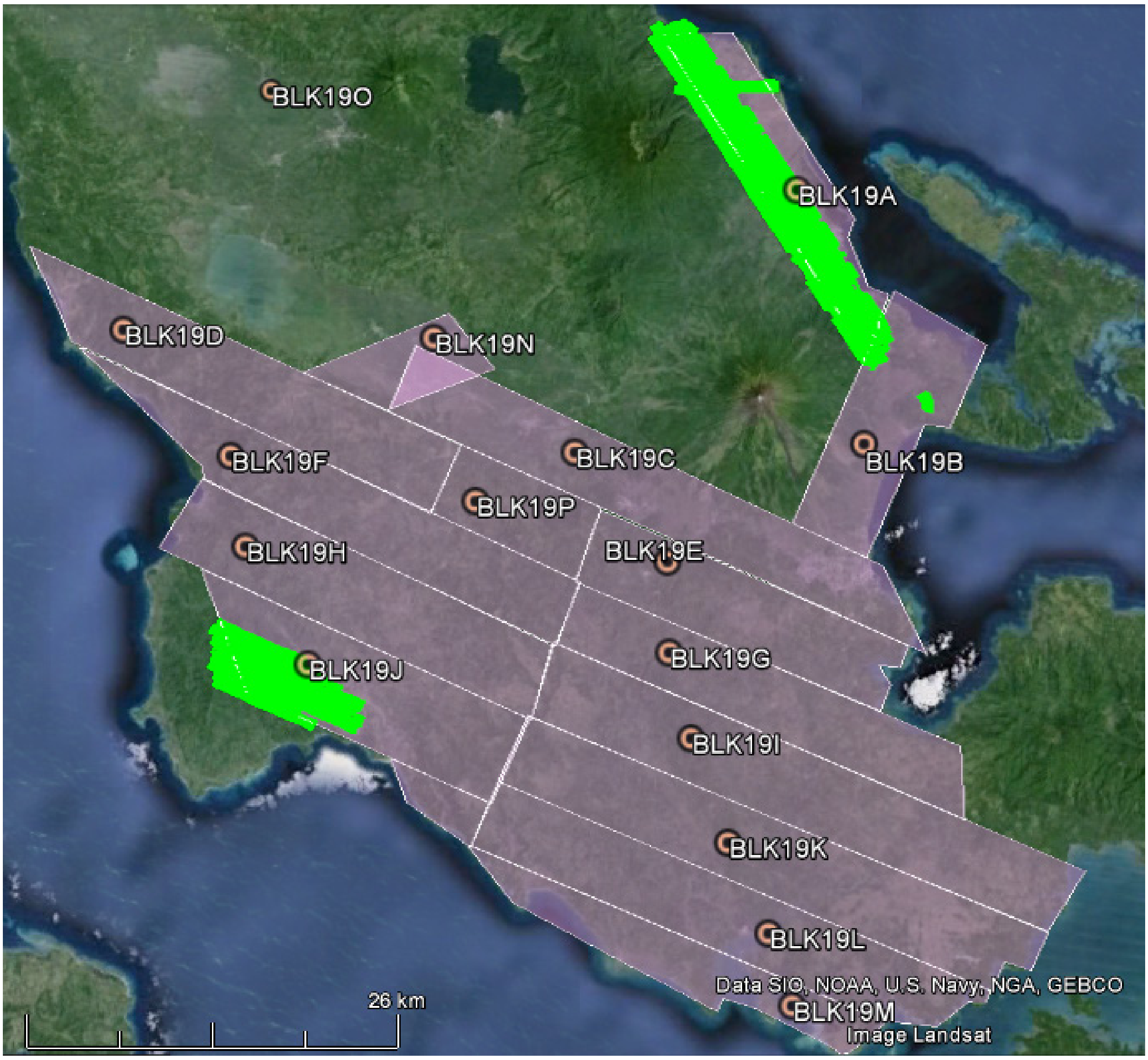


Figure A-7.6. Swath for Flight No. 7204GC

Flight No. :	7213 GC
Area:	BLK19O
Mission name:	2BLK19OS116B & VOIDS
Parameters:	PRF: 100 SF: 50 Hz FOV: 40 degrees
Flying Height:	1100 m

LAS/SWATH

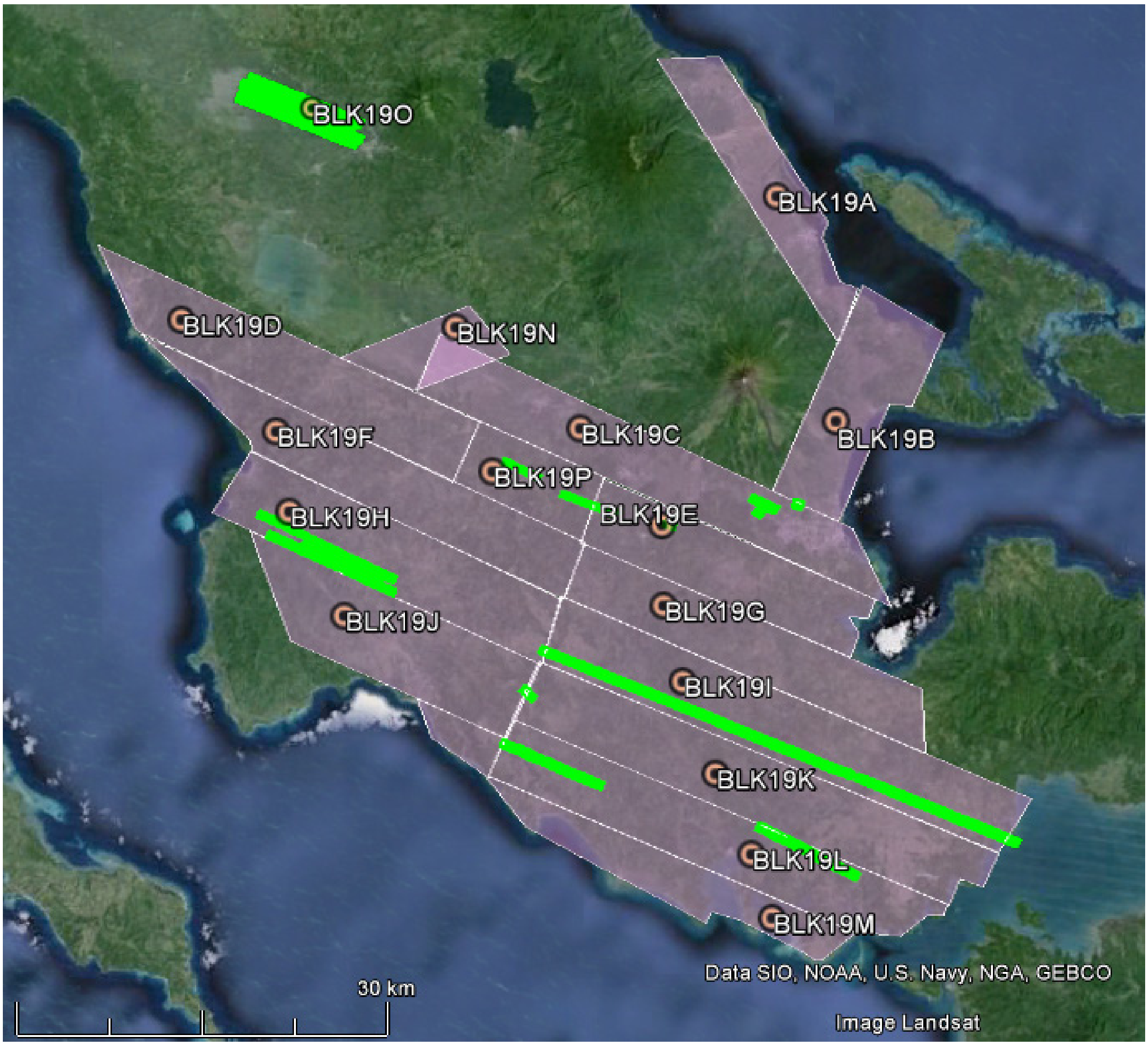


Figure A-7.7. Swath for Flight No. 7213GC

Flight No. :	7216 GC
Area:	BLK19A
Mission name:	2BLK19AS118A & VOIDS (BLK19Q)
Parameters:	PRF: 100 SF: 50 Hz FOV: 34 and 40 degrees
Flying Height:	1300 m

LAS/SWATH

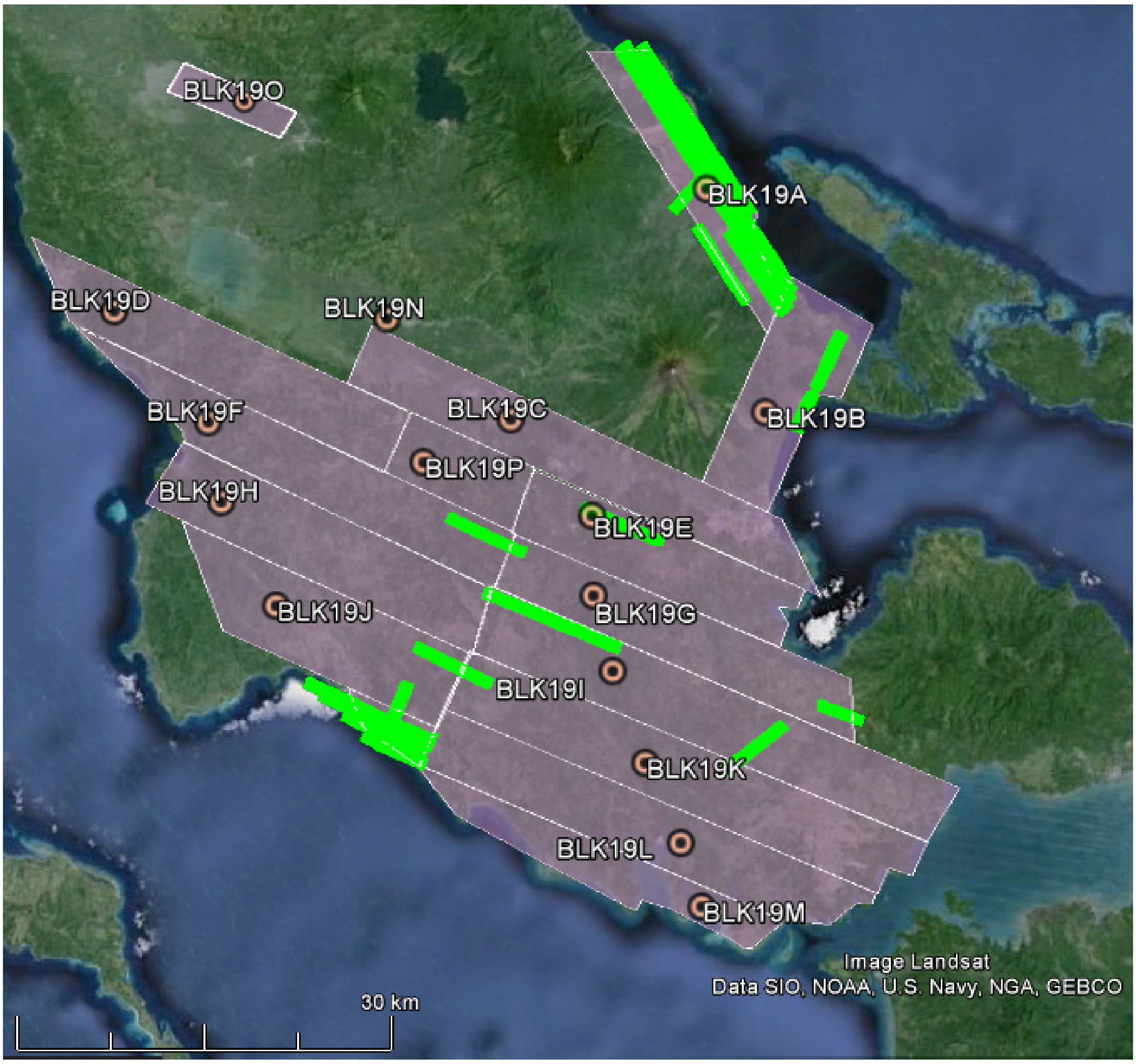


Figure A-7.8. Swath for Flight No. 7216GC

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk 19A

Flight Area	**ALBAY/SORSOGON**
Mission Name	**Blk 19A**
Inclusive Flights	7200GC, 7204GC, 7216GC
Range data size	44.5 GB
POS data size	627 MB
Base data size	16.1 MB
Image	N/A
Transfer date	May 05, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.36
RMSE for East Position (<4.0 cm)	1.80
RMSE for Down Position (<8.0 cm)	3.96
Boresight correction stdev (<0.001deg)	0.000276
IMU attitude correction stdev (<0.001deg)	0.001160
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	38.29 %
Ave point cloud density per sq.m. (>2.0)	3.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	183
Maximum Height	550.23
Minimum Height	52.51
Classification (# of points)	
Ground	48,448,343
Low vegetation	64,524,417
Medium vegetation	85,669,412
High vegetation	117,892,994
Building	7,184,632
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Charmaine Cruz, Engr. Gladys Mae Apat

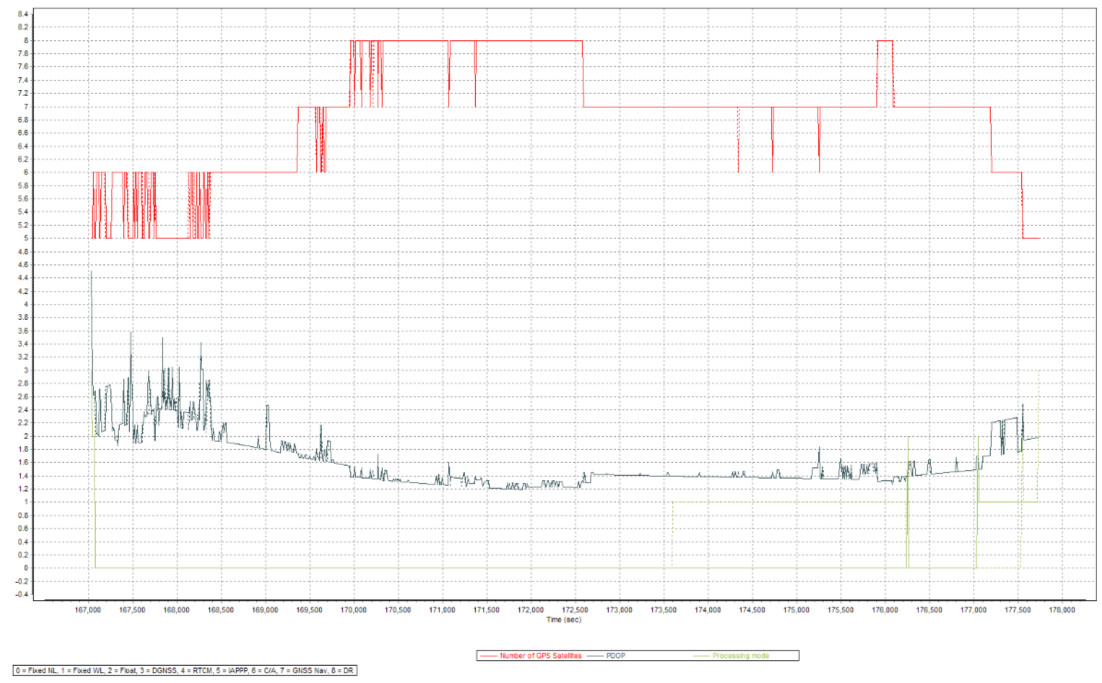


Figure A-8.1. Solution Status

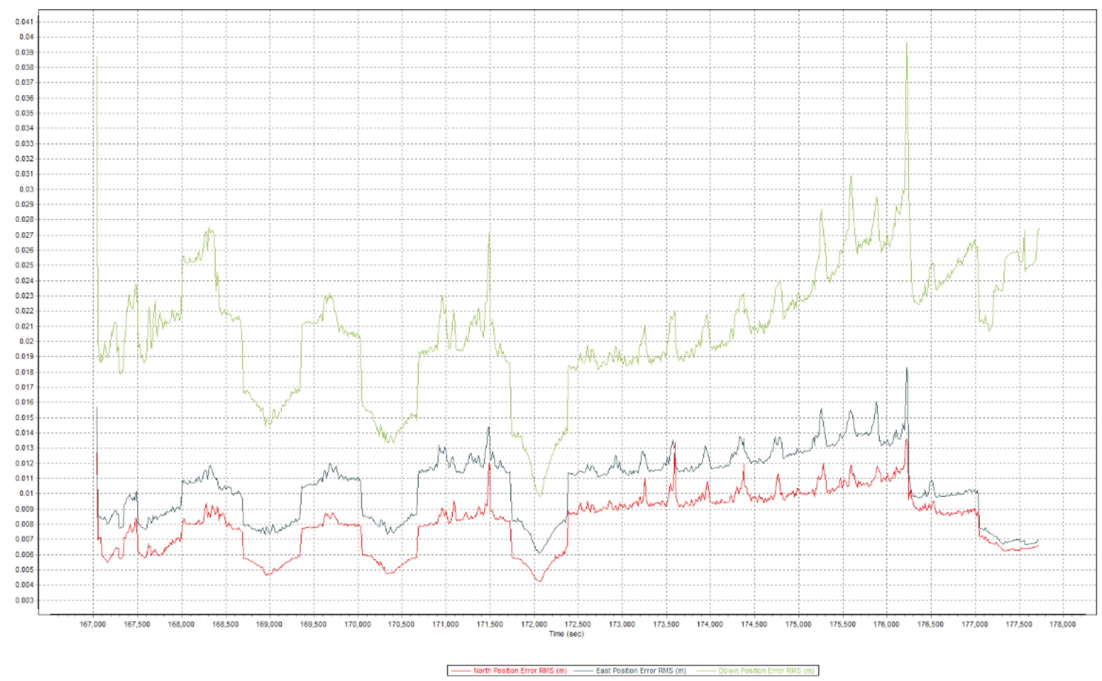


Figure A-8.2. Smoothed Performance Metric Parameters

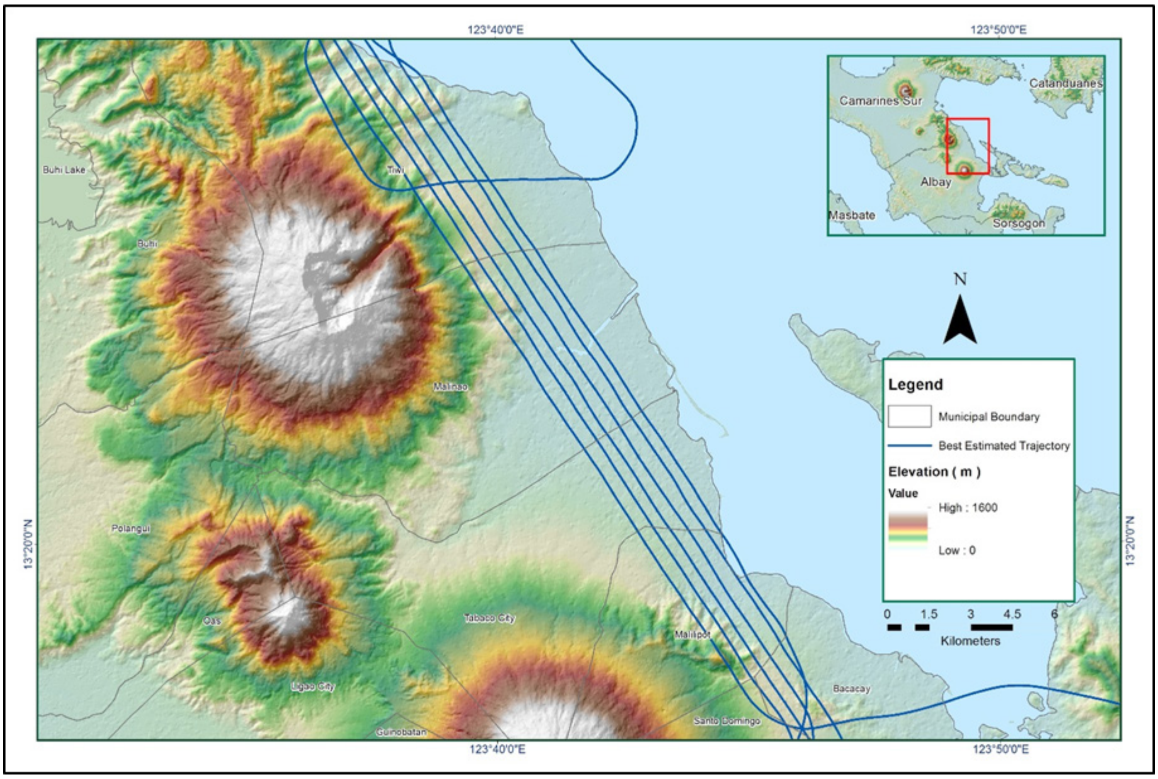


Figure A-8.3. Best Estimated Trajectory

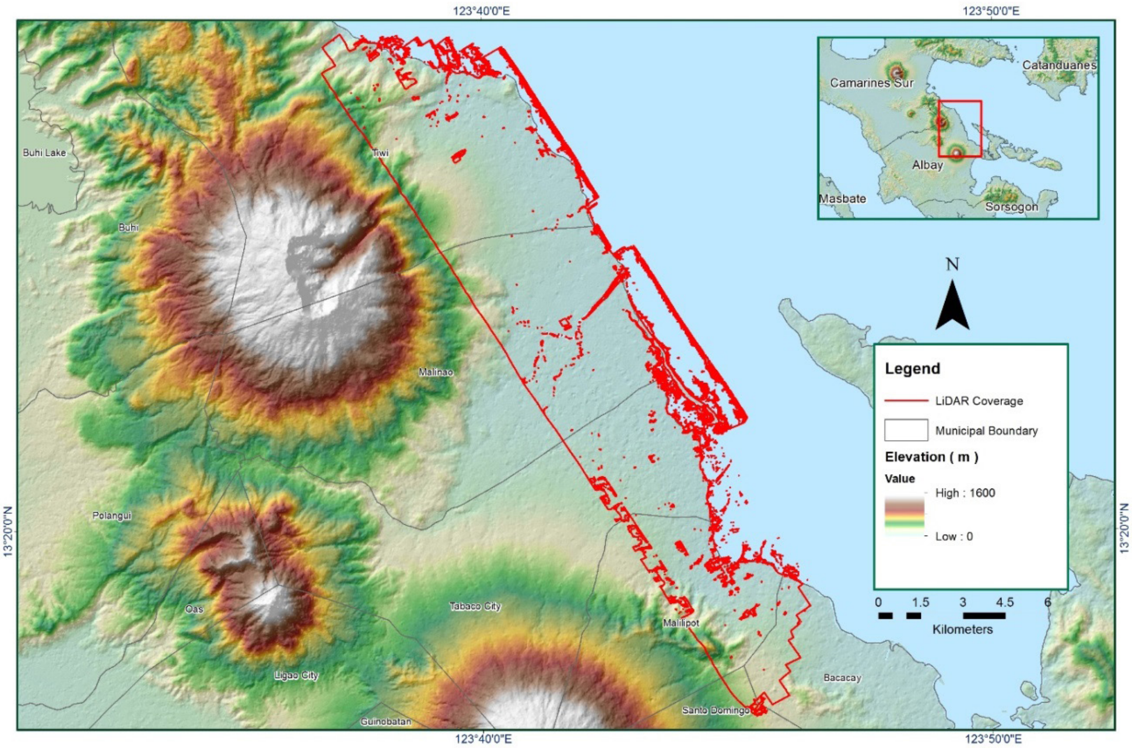


Figure A-8.4. Coverage of LiDAR data

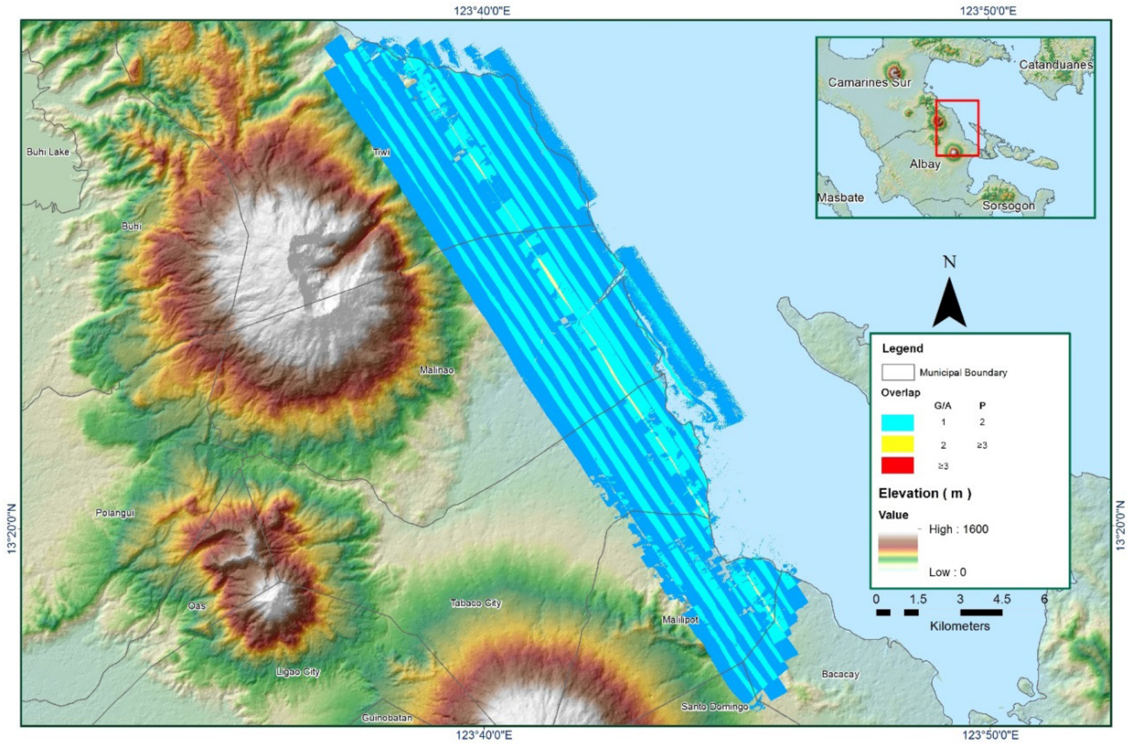


Figure A-8.5. Image of Data Overlap

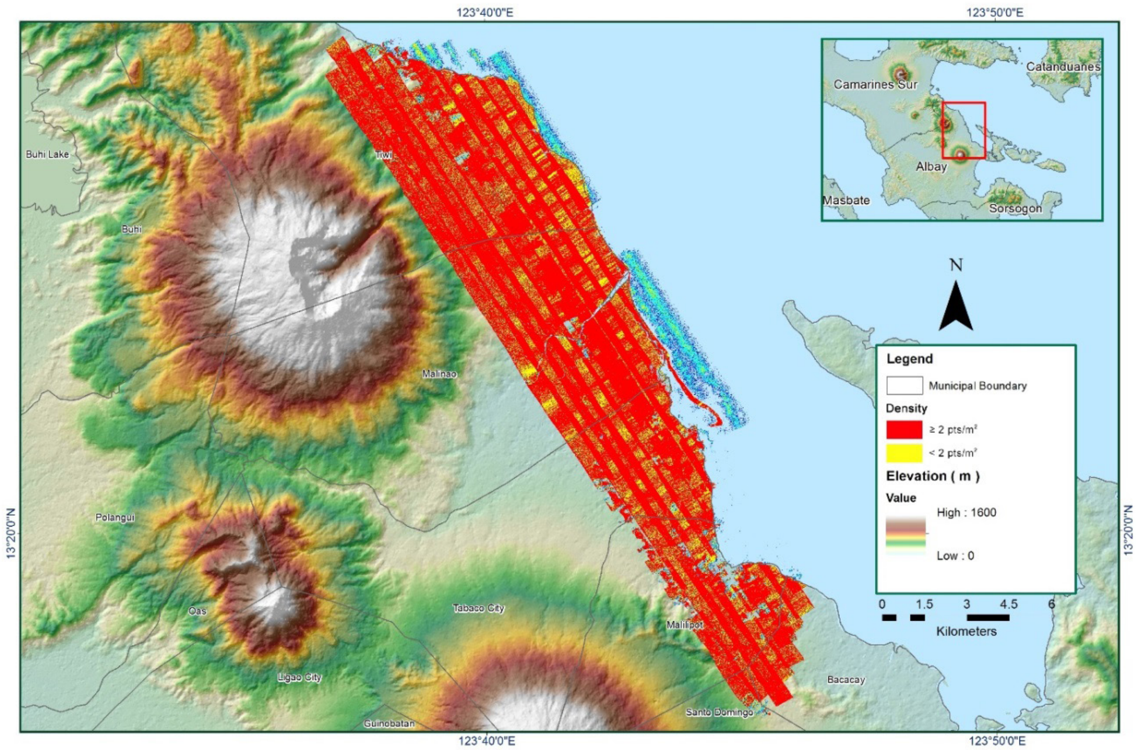


Figure A-8.6. Density Map

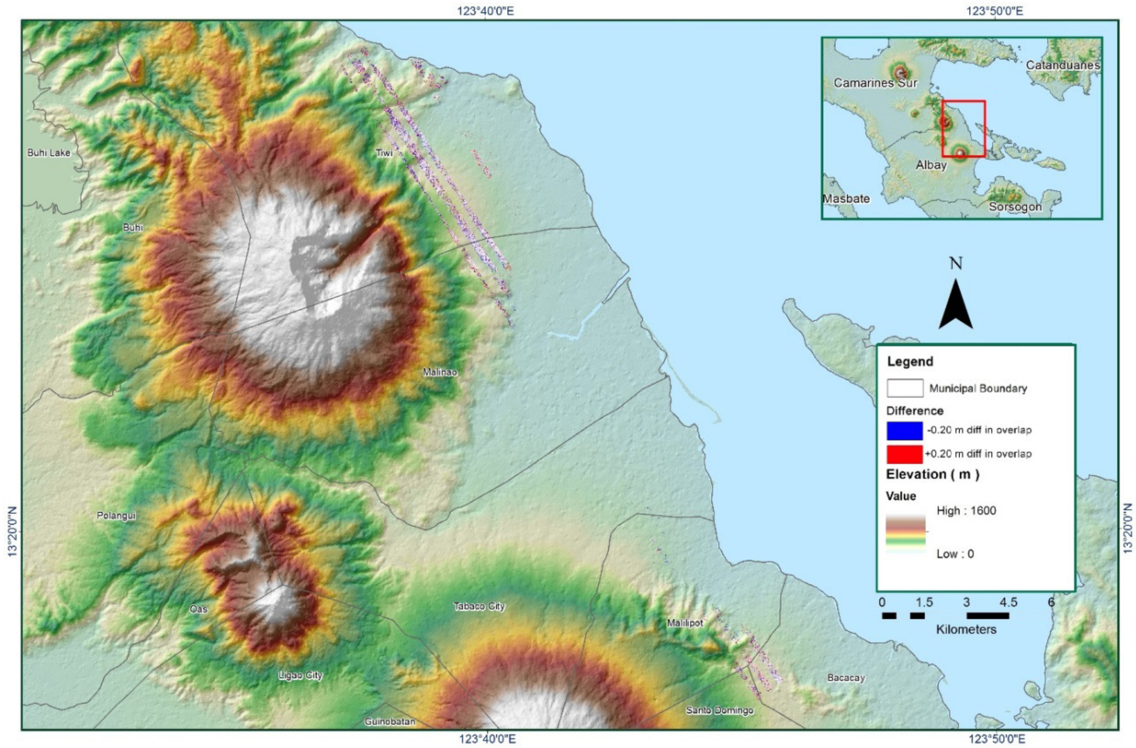


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk 19O

Flight Area	**ALBAY/SORSOGON**
Mission Name	**Blk 19O**
Inclusive Flights	7212GC, 7213GC
Range data size	26.47 GB
POS data size	267 MB
Base data size	3.4 MB
Image	N/A
Transfer date	May 05, 2014
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)	1.24
RMSE for East Position (<4.0 cm)	1.63
RMSE for Down Position (<8.0 cm)	2.46
Boresight correction stdev (<0.001deg)	0.000840
IMU attitude correction stdev (<0.001deg)	0.000981
GPS position stdev (<0.01m)	0.0143
Minimum % overlap (>25)	27.10 %
Ave point cloud density per sq.m. (>2.0)	2.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	59
Maximum Height	163.8
Minimum Height	57.29
Classification (# of points)	
Ground	18,943,376
Low vegetation	27,681,324
Medium vegetation	22,980,914
High vegetation	16,981,535
Building	1,175,292
Orthophoto	No
Processed by	Engr. Benjamin Jonah Magallon, Engr. Christy Lubiano, Engr. Gladys Mae Apat

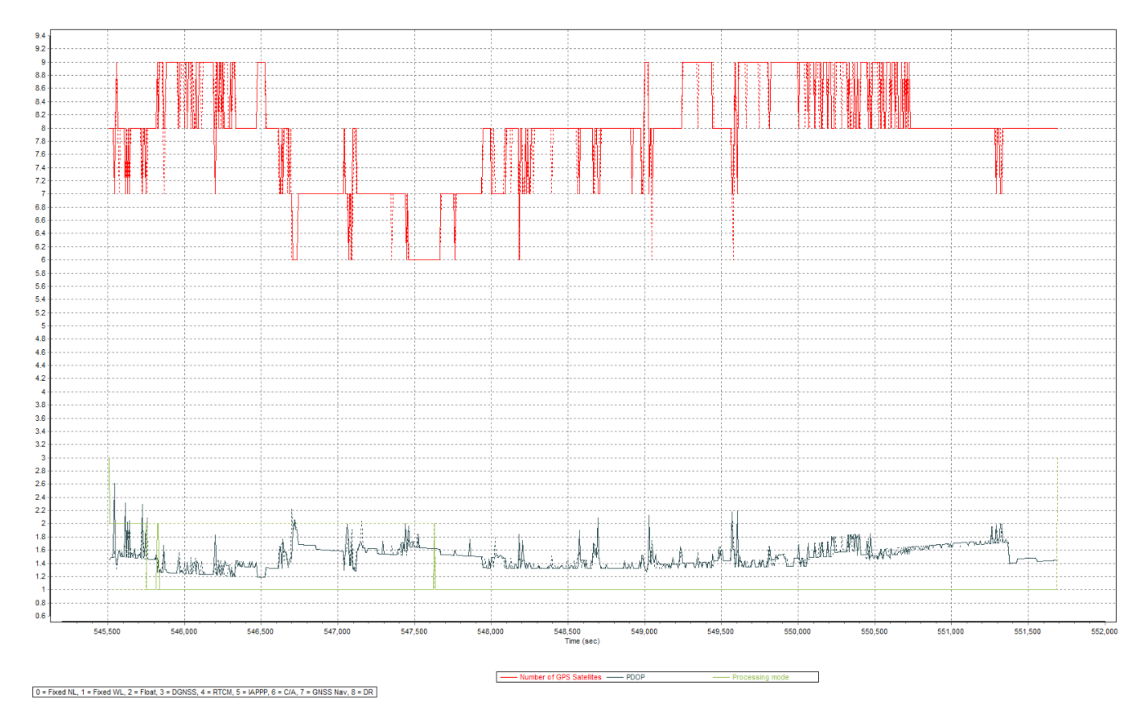


Figure A-8.8. Solution Status

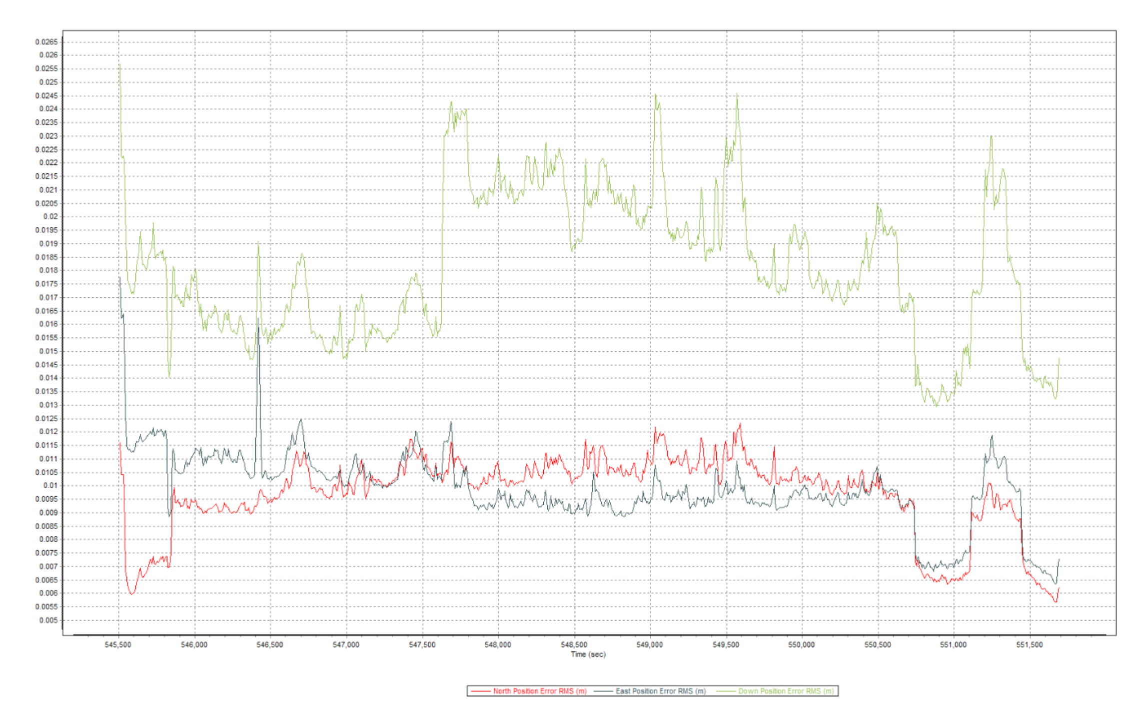


Figure A-8.9. Smoothed Performance Metric Parameters

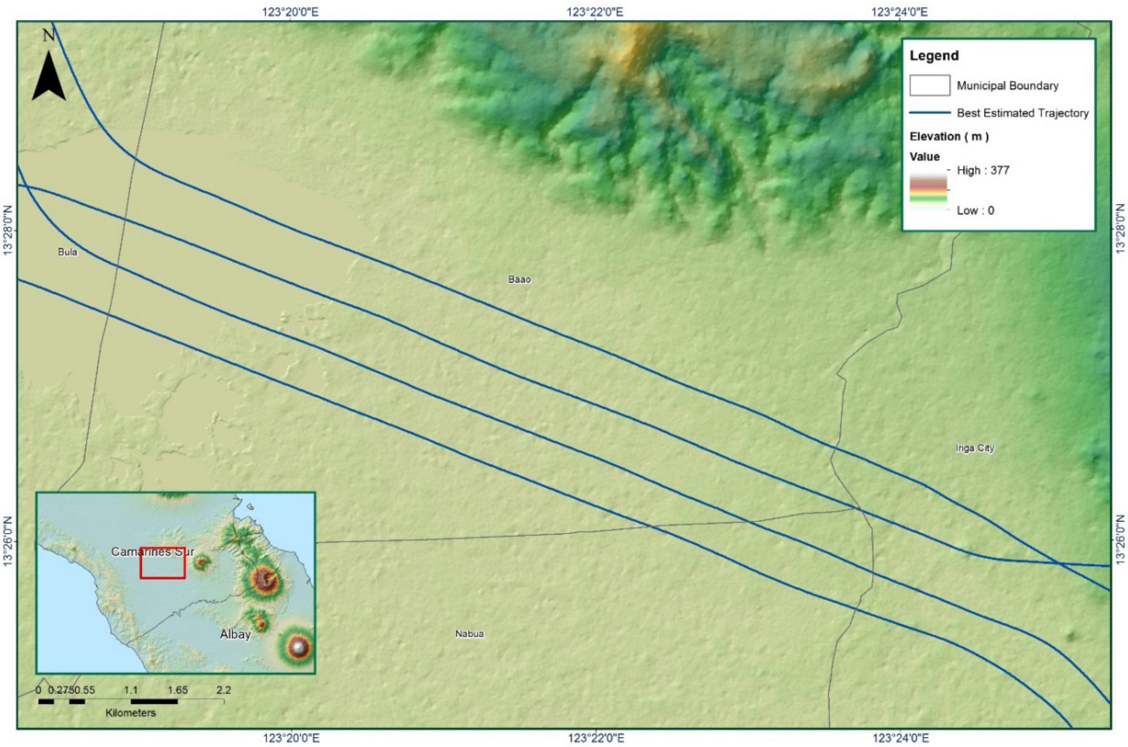


Figure A-8.10. Best Estimated Trajectory

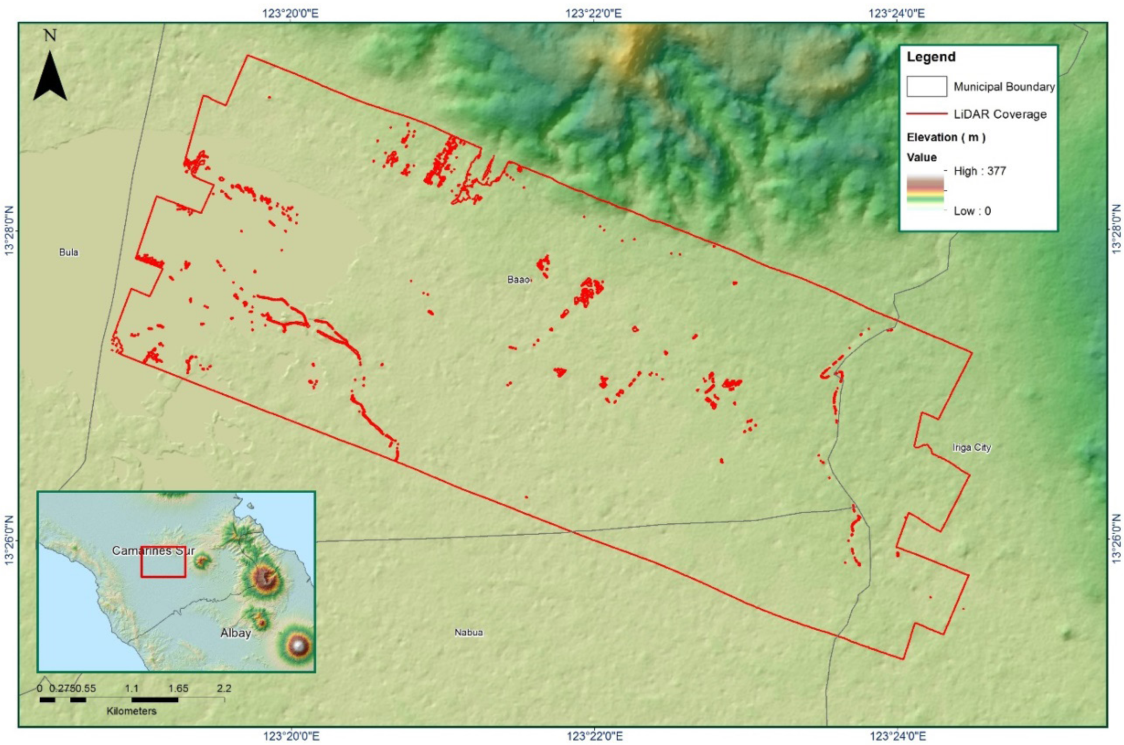


Figure A-8.11. Coverage of LiDAR data

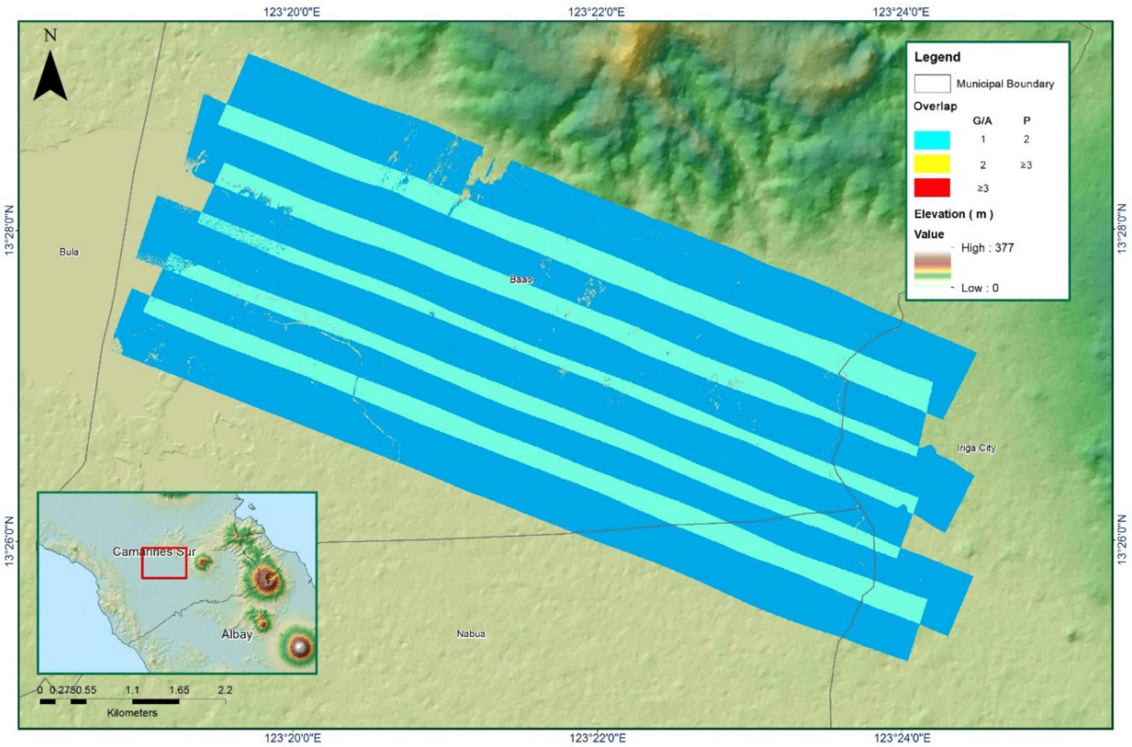


Figure A-8.12. Image of Data Overlap

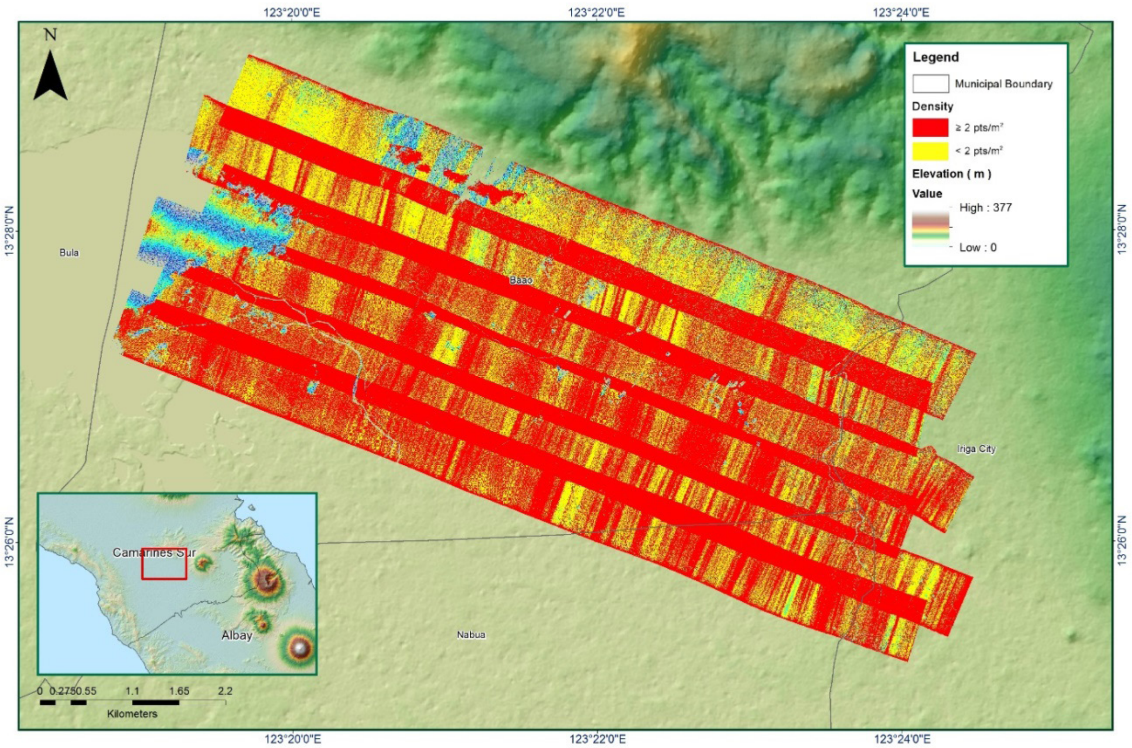


Figure A-8.13. Density Map

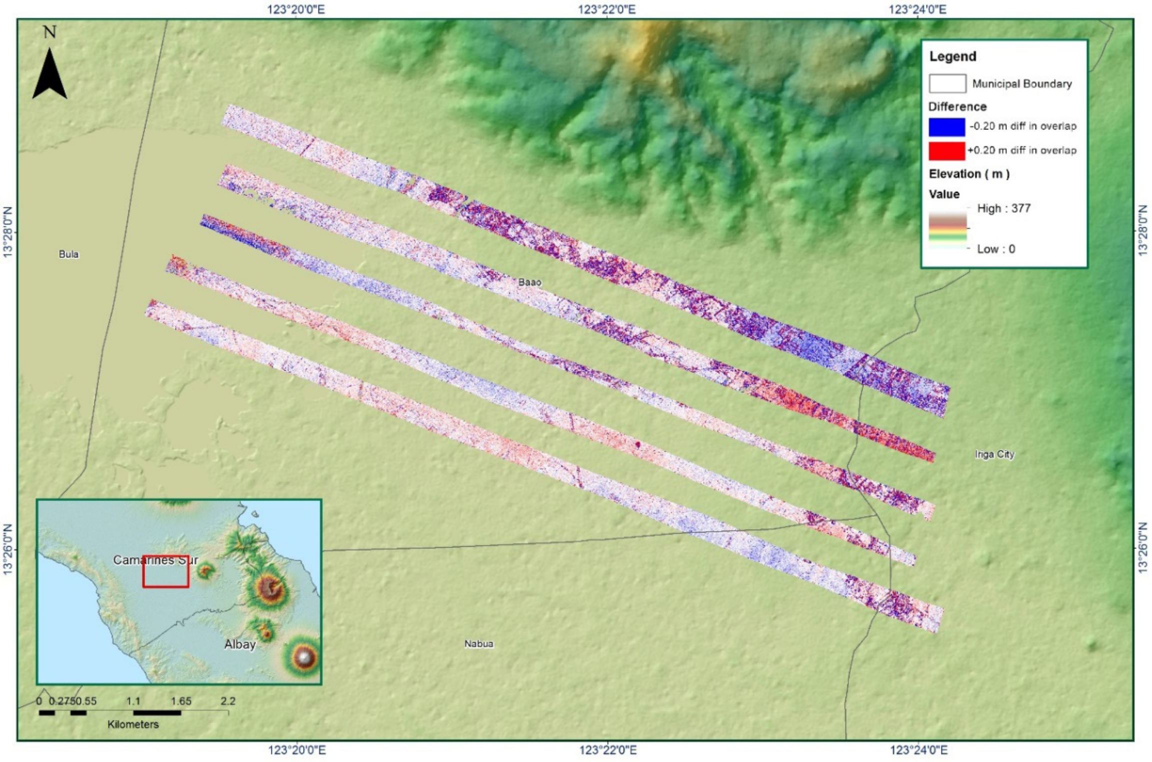


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk 19N

Flight Area	**ALBAY/SORSOGON**
Mission Name	**Blk 19N**
Inclusive Flights	7200GC
Range data size	17.3 GB
POS data size	237 MB
Base data size	7.6 MB
Image	N/A
Transfer date	May 05, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.35
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000997
IMU attitude correction stdev (<0.001deg)	0.001721
GPS position stdev (<0.01m)	0.0179
Minimum % overlap (>25)	19.82 %
Ave point cloud density per sq.m. (>2.0)	2.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	81
Maximum Height	344.94
Minimum Height	63.63
Classification (# of points)	
Ground	26,763,549
Low vegetation	33,607,834
Medium vegetation	36,151,225
High vegetation	20,587,117
Building	1,023,312
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

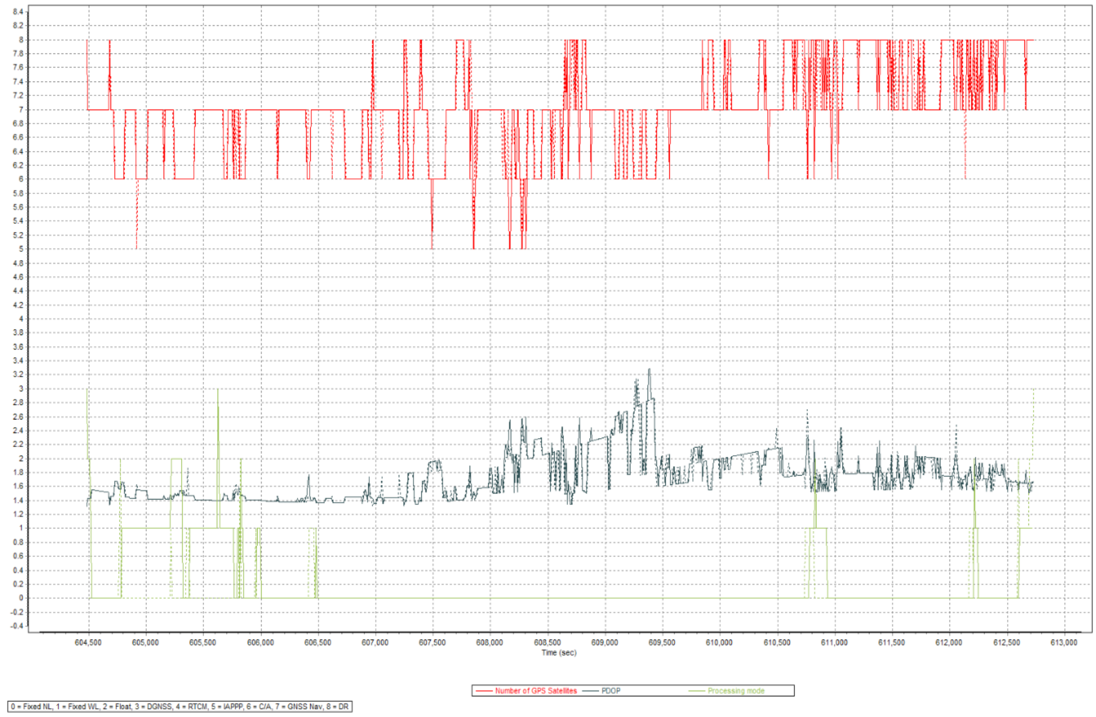


Figure A-8.15. Solution Status

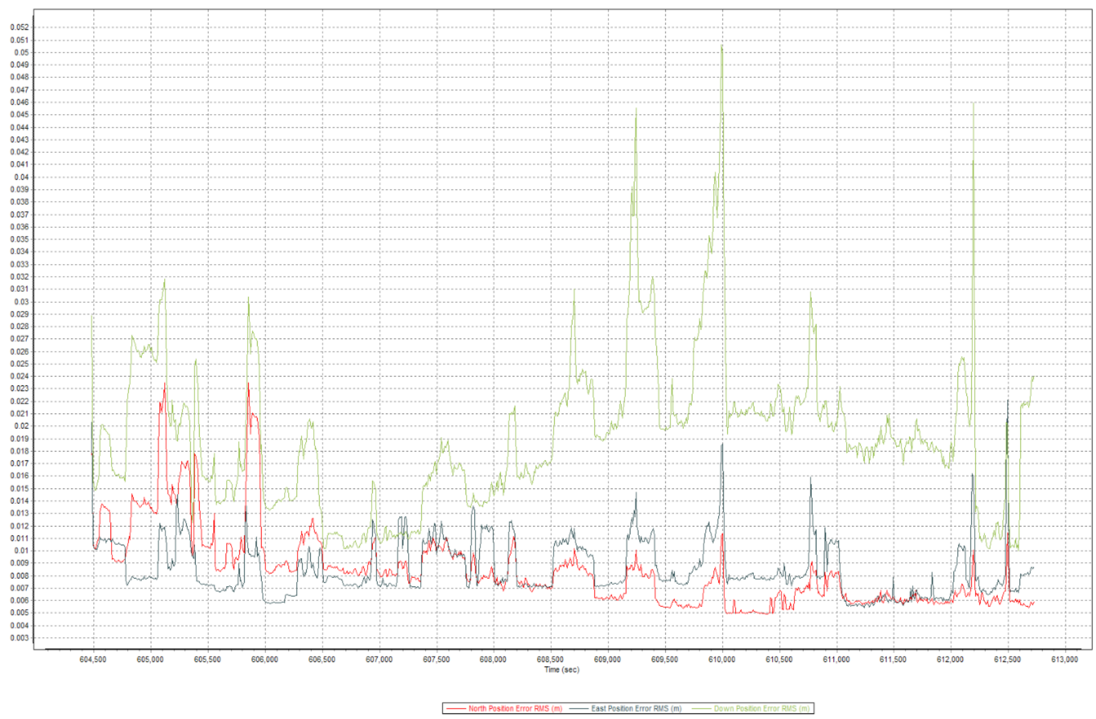


Figure A-8.16. Smoothed Performance Metric Parameters

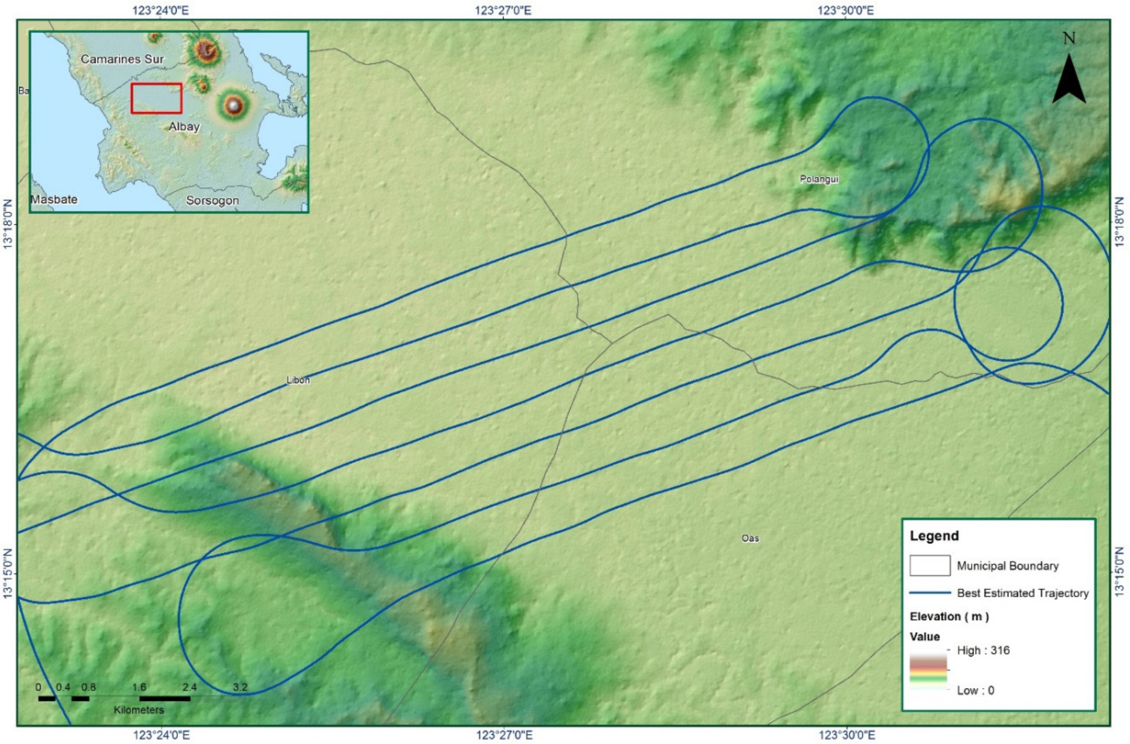


Figure A-8.17. Best Estimated Trajectory

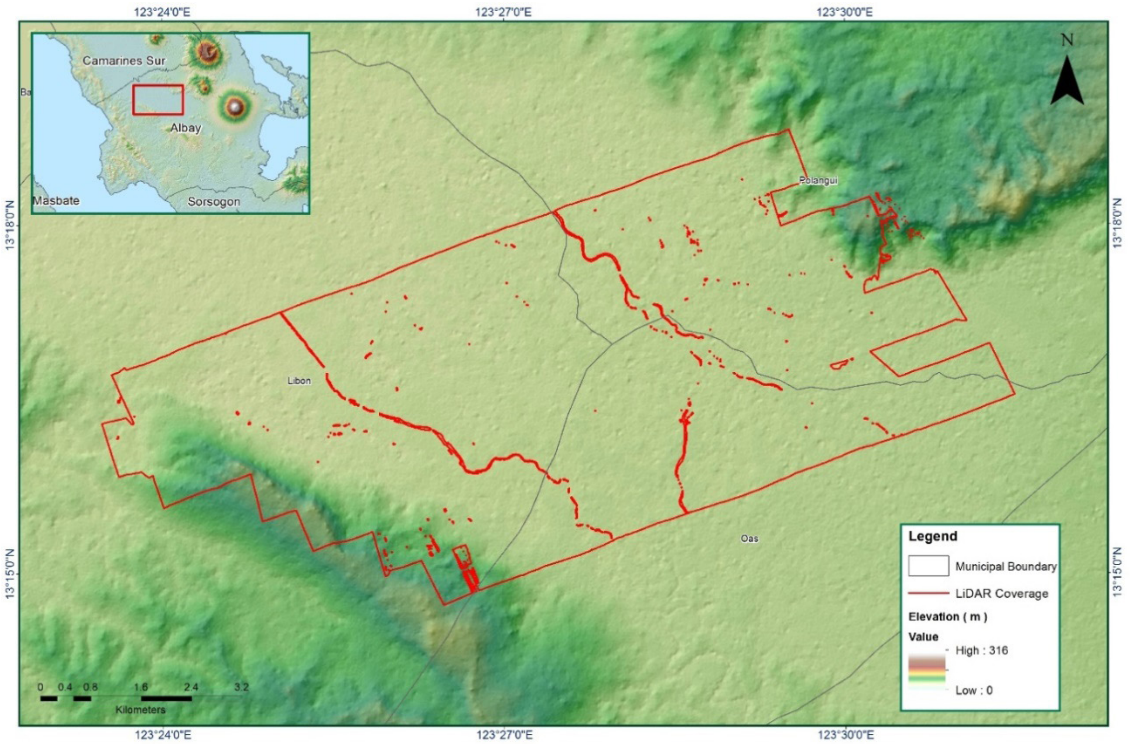


Figure A-8.18. Coverage of LiDAR data

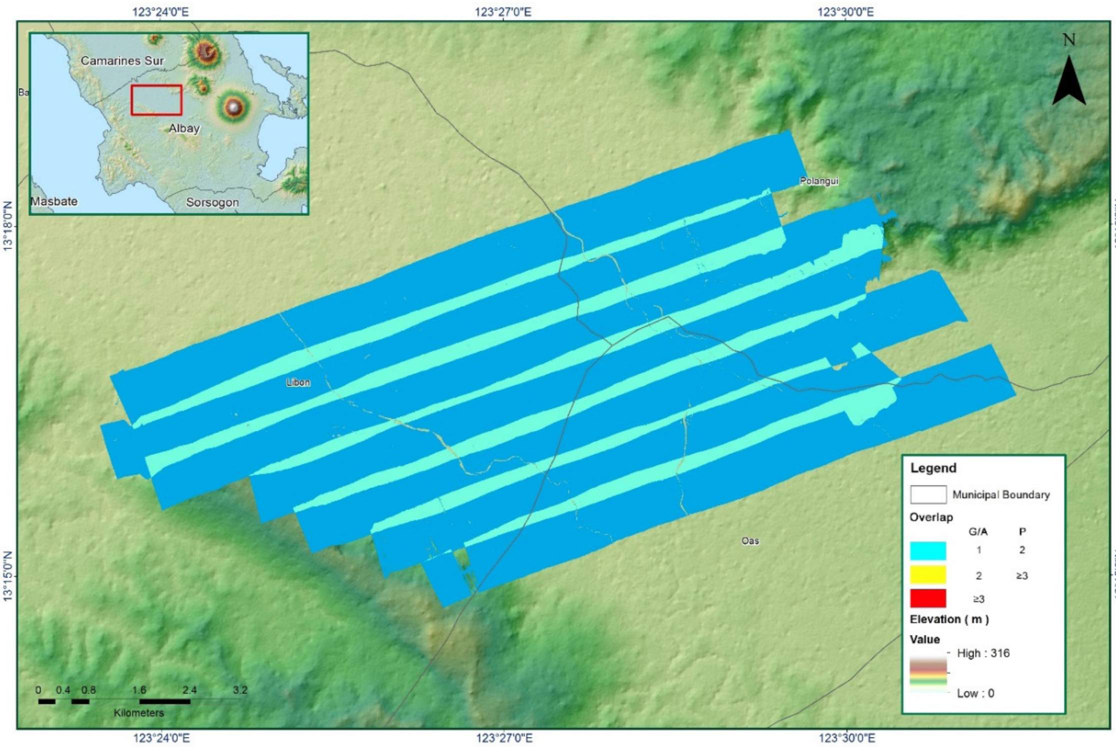


Figure A-8.19. Image of Data Overlap

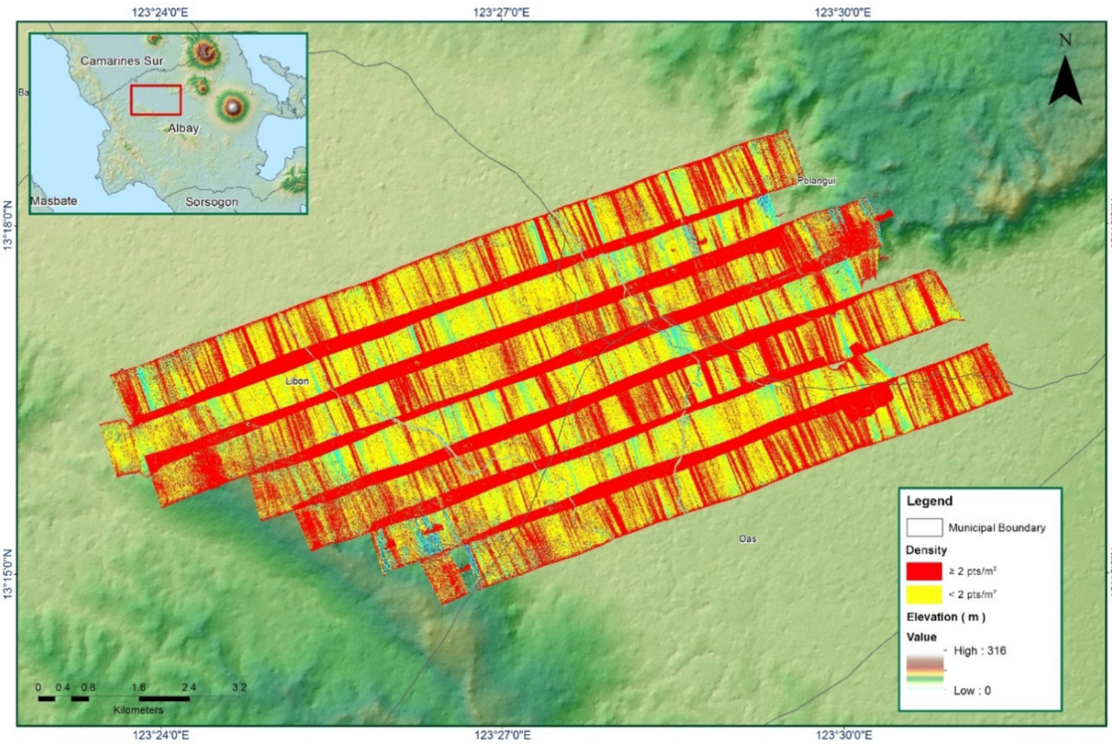


Figure A-8.20. Density Map

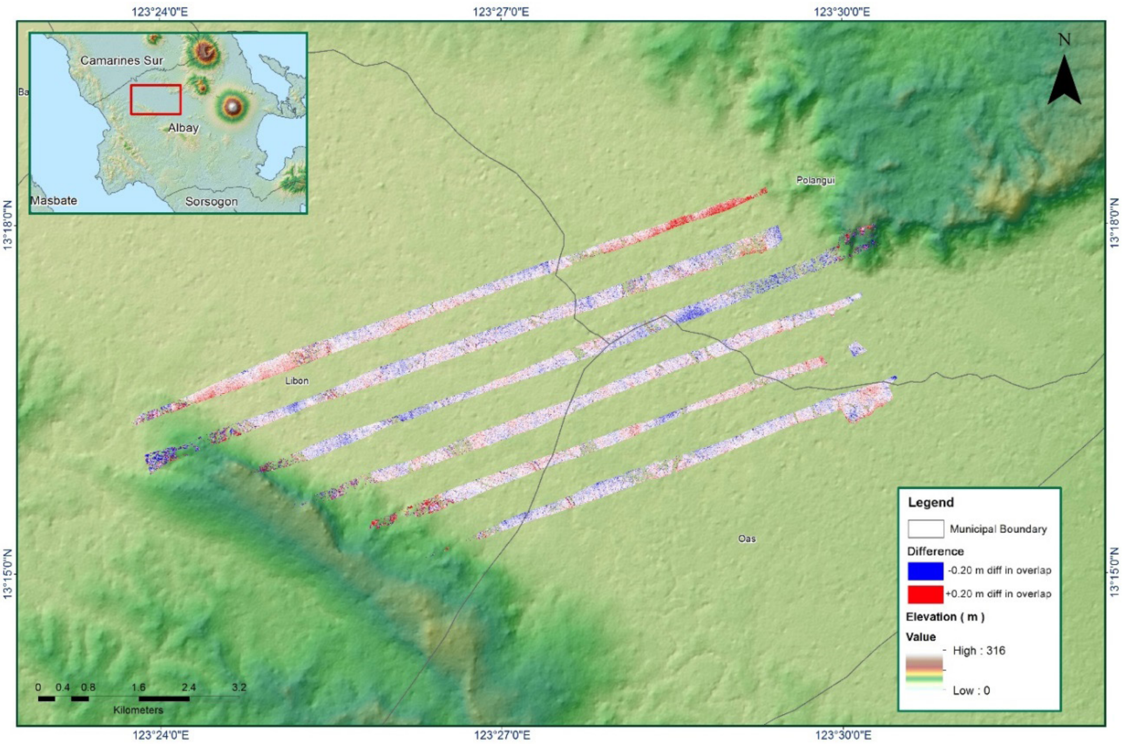


Figure A-8.21. Elevation difference between flight line

Table A-8.4. Mission Summary Report for Mission Blk 19A_supplement1

Flight Area	**Albay-Sorsogon**
Mission Name	Blk 19A_supplement1
Inclusive Flights	3855G
Range data size	8.28 GB
POS data size	170 MB
Base data size	11.5 MB
Image	28.6 MB
Transfer date	March 31, 2016
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)	1.75
RMSE for East Position (<4.0 cm)	1.675
RMSE for Down Position (<8.0 cm)	3.85
Boresight correction stdev (<0.001deg)	0.000333
IMU attitude correction stdev (<0.001deg)	0.001092
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	45.61 %
Ave point cloud density per sq.m. (>2.0)	5.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	75
Maximum Height	508.17 m
Minimum Height	63.54 m
Classification (# of points)	
Ground	26,715,015
Low vegetation	30,205,471
Medium vegetation	61,617,654
High vegetation	101,362,122
Building	2,001,304
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Velina Angela Bemida, Jovy Narisma

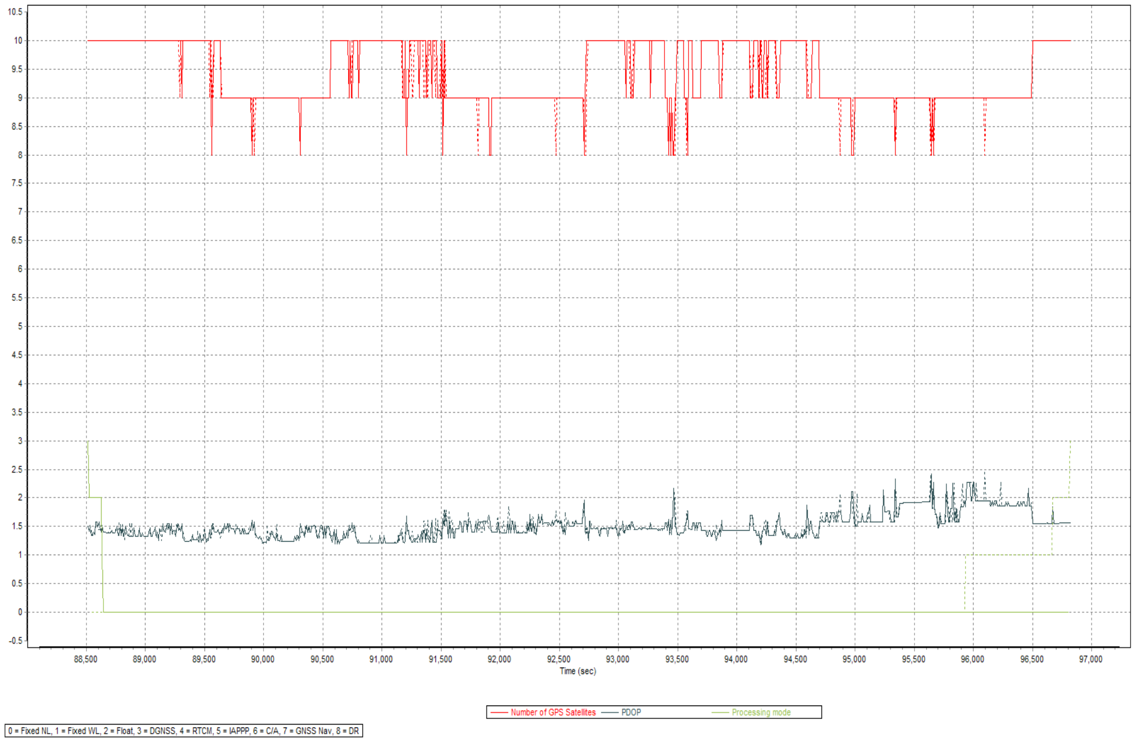


Figure A-8.22. Solution Status

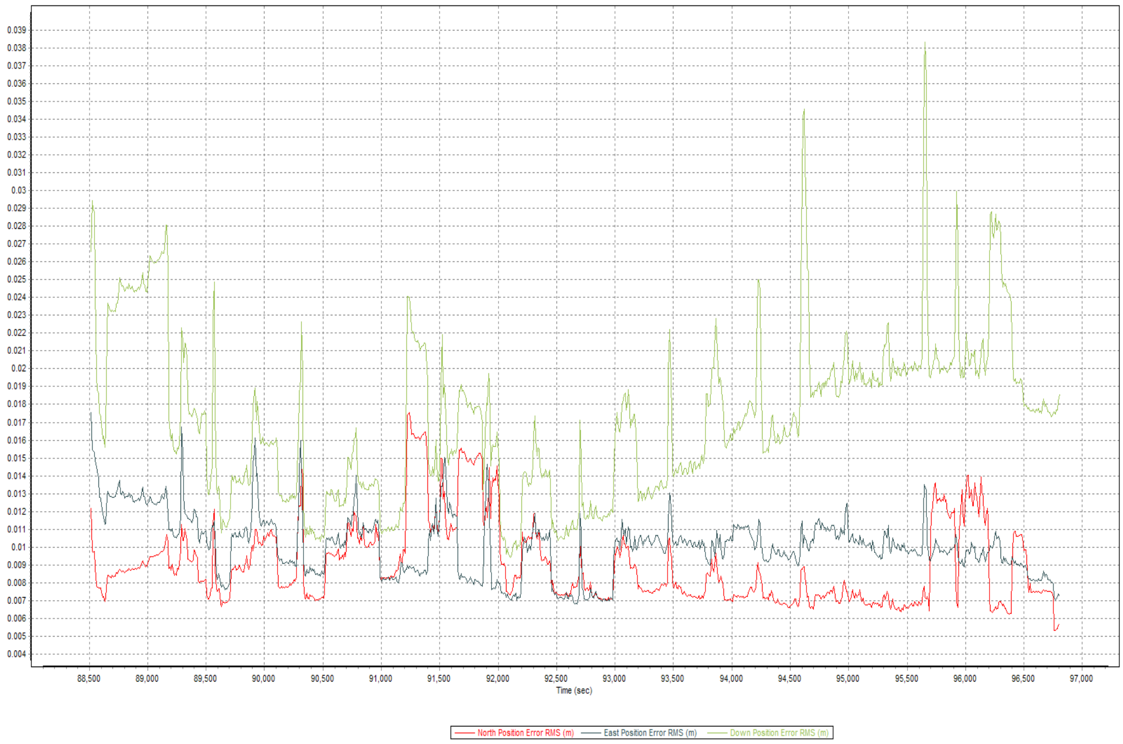


Figure A-8.23. Smoothed Performance Metric Parameters

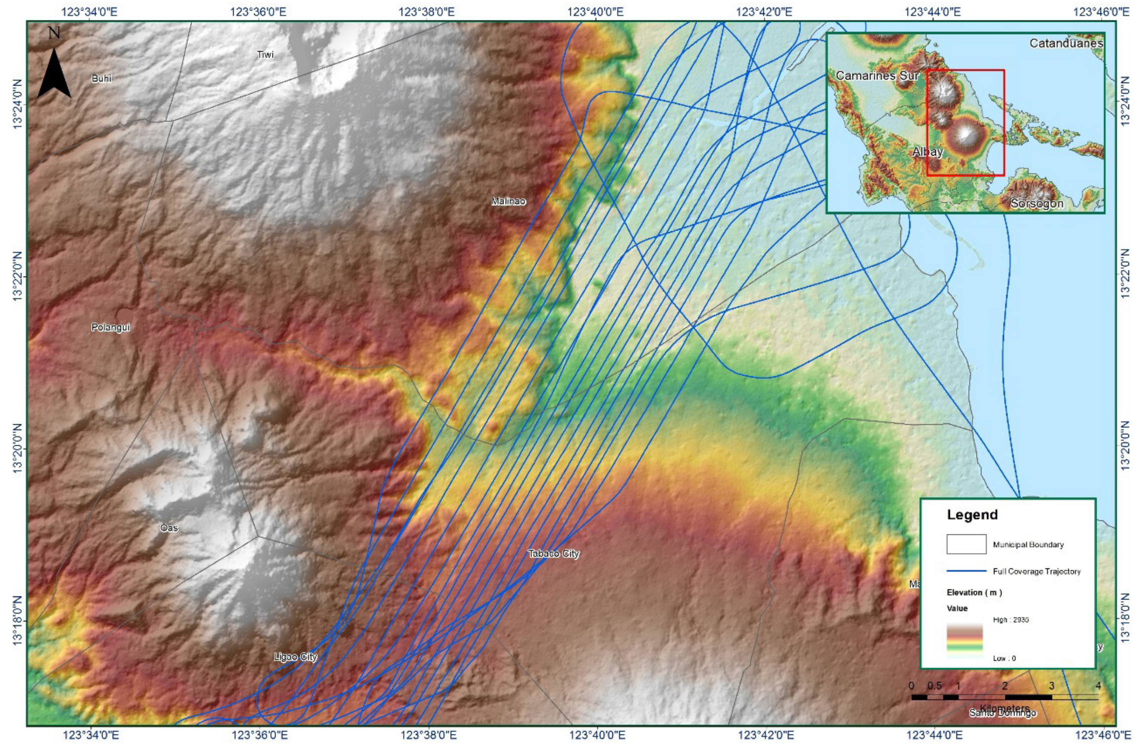


Figure A-8.24. Best Estimated Trajectory

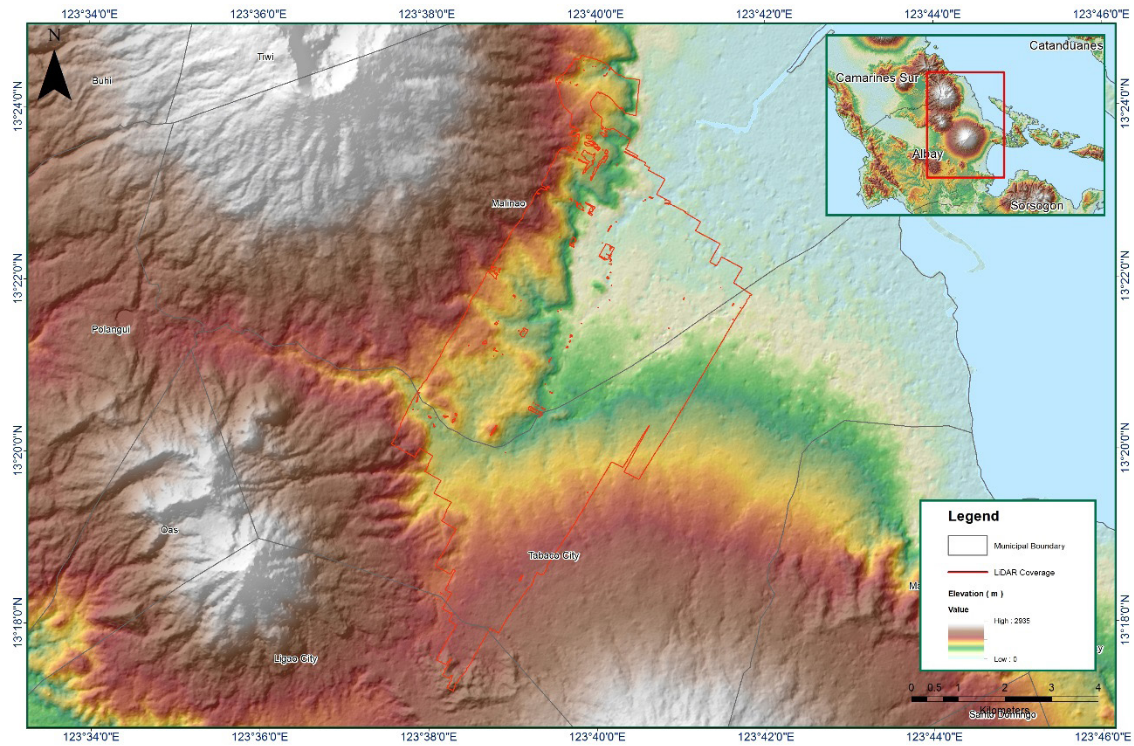


Figure A-8.25. Coverage of LiDAR Data

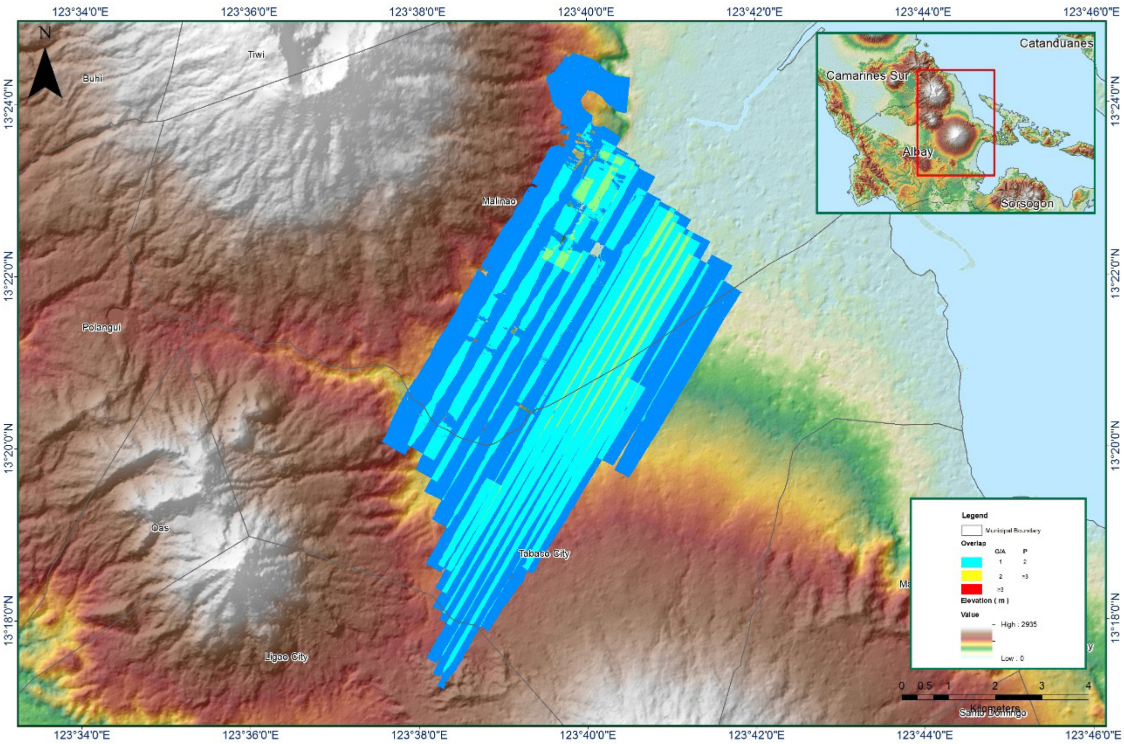


Figure **_A-8.26_**. Image of data overlap

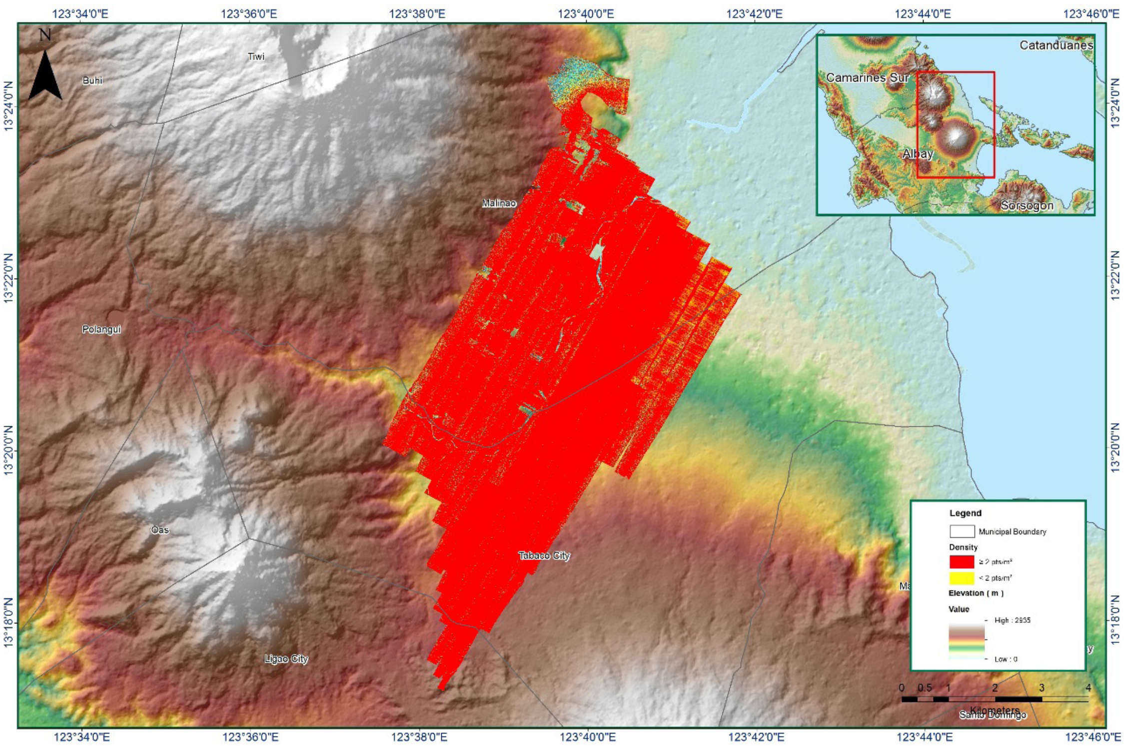


Figure A-8.27. Density map of merged LiDAR data

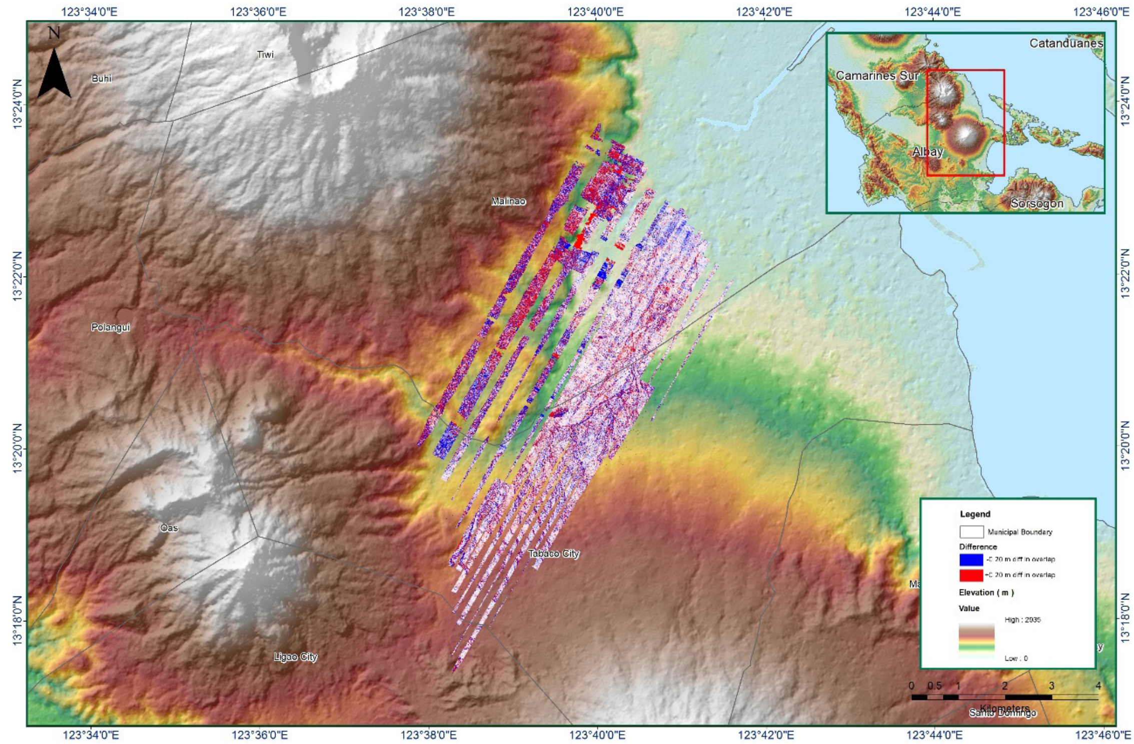


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk 19A

Flight Area	**Albay-Sorsogon**
Mission Name	Blk 19A
Inclusive Flights	3893G
Range data size	20.8 GB
POS data size	169 MB
Base data size	12.8 MB
Image	36.8 MB
Transfer date	March 31, 2016
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)	1.275
RMSE for East Position (<4.0 cm)	1.658
RMSE for Down Position (<8.0 cm)	5.850
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	22.87 %
Ave point cloud density per sq.m. (>2.0)	3.07
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	110
Maximum Height	295.13 m
Minimum Height	51.73 m
Classification (# of points)	
Ground	19,425,045
Low vegetation	15,274,237
Medium vegetation	102,260,443
High vegetation	55,340,884
Building	84,485
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Ma. Joanne Balaga, Maria Tamsyn Malabanan

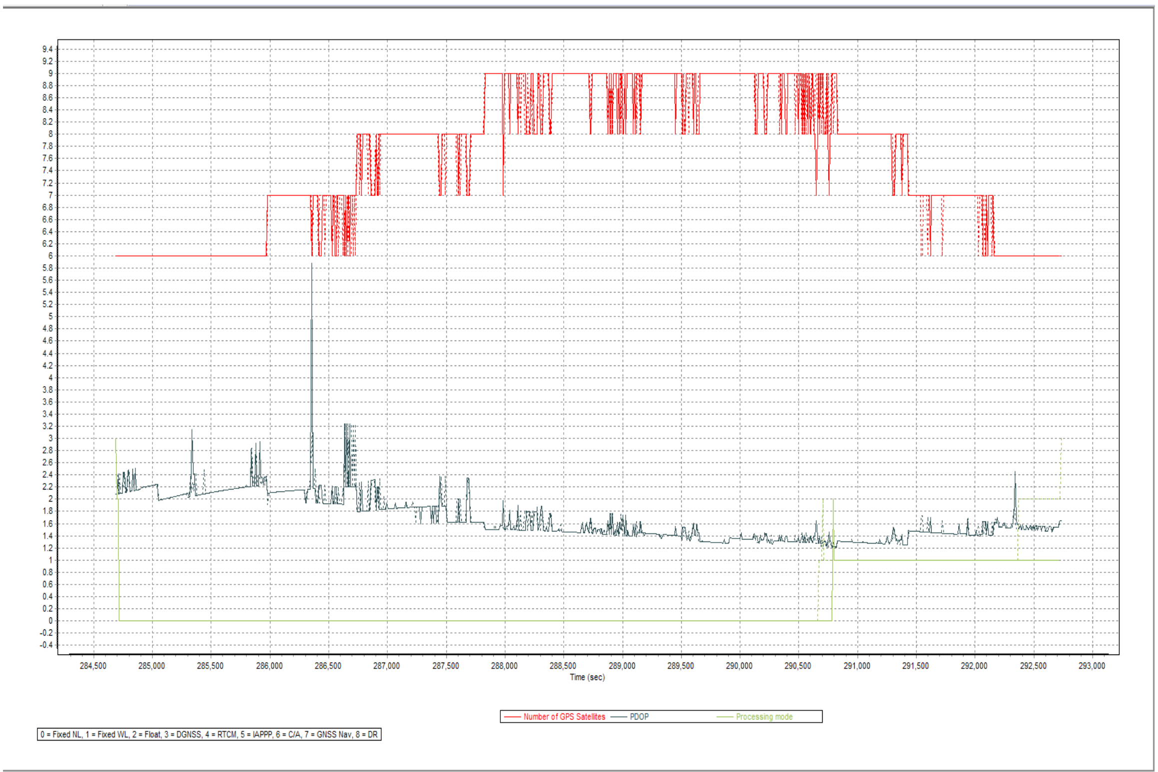


Figure A-8.29. Solution Status

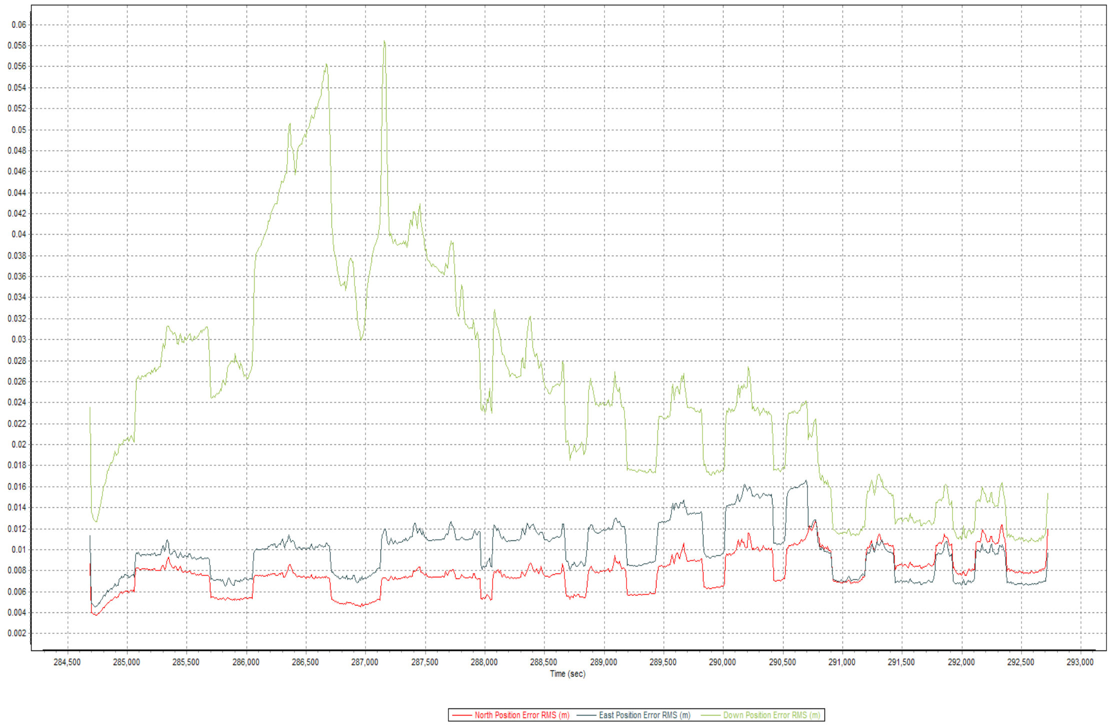


Figure A-8.30. Smoothed Performance Metric Parameters

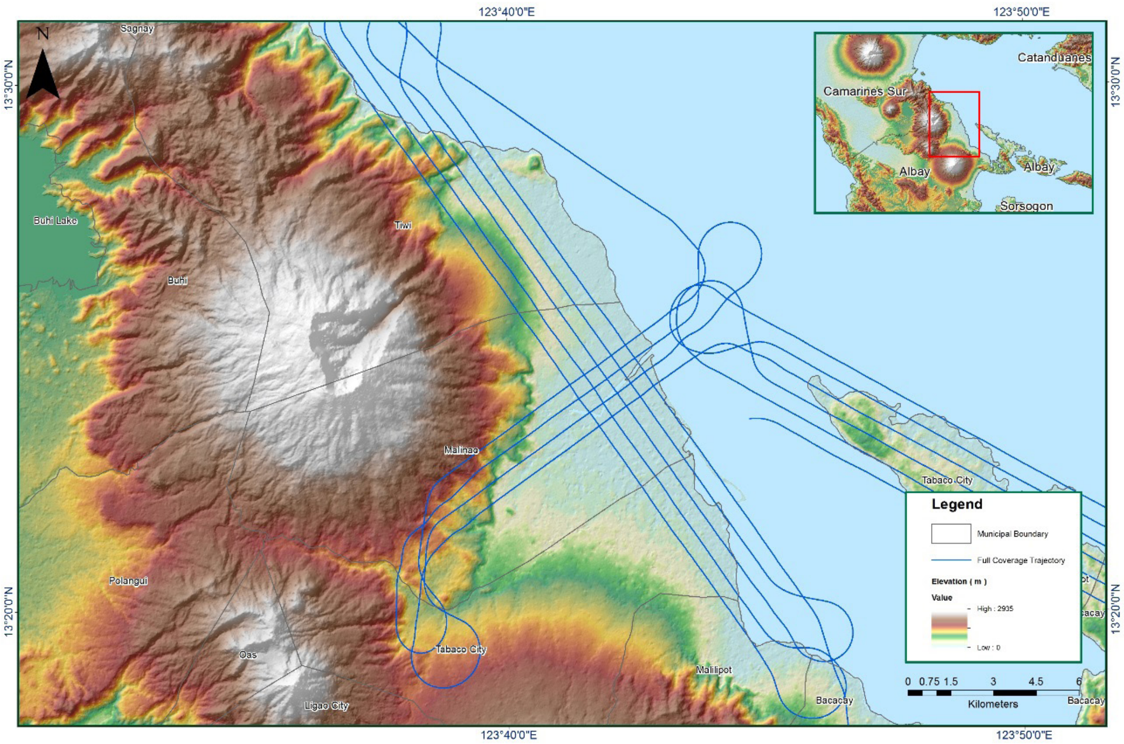


Figure A-8.31. Best Estimated Trajectory

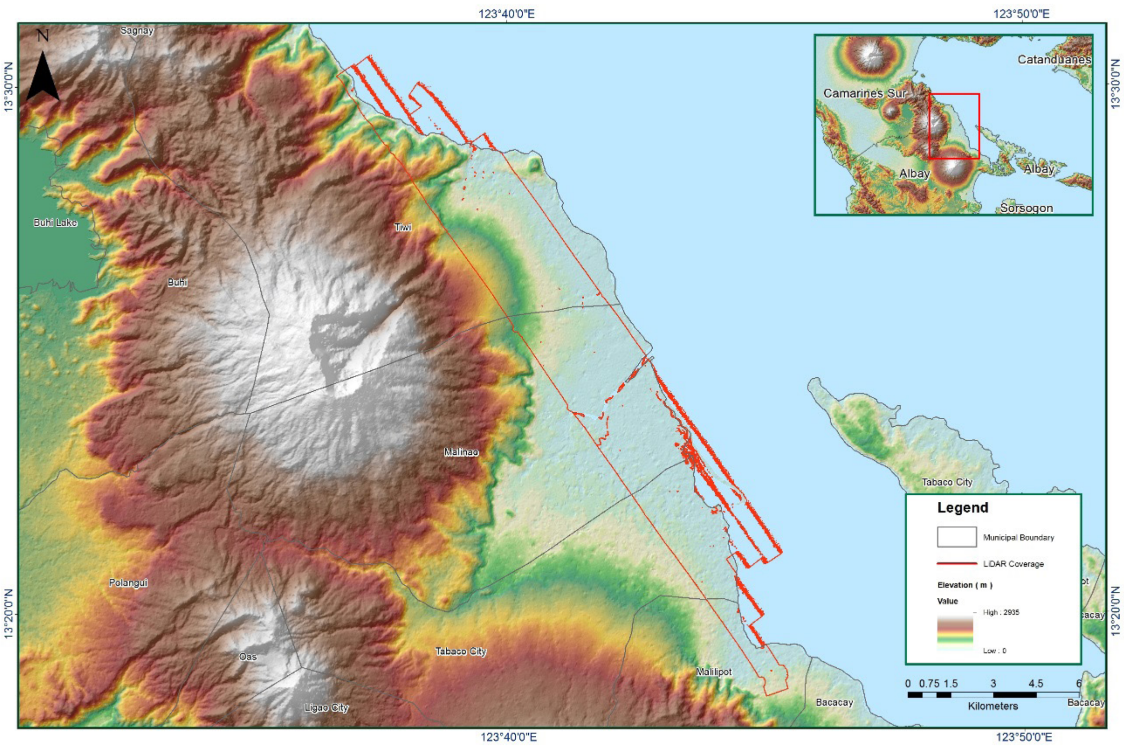


Figure A-8.32. Coverage of LiDAR Data

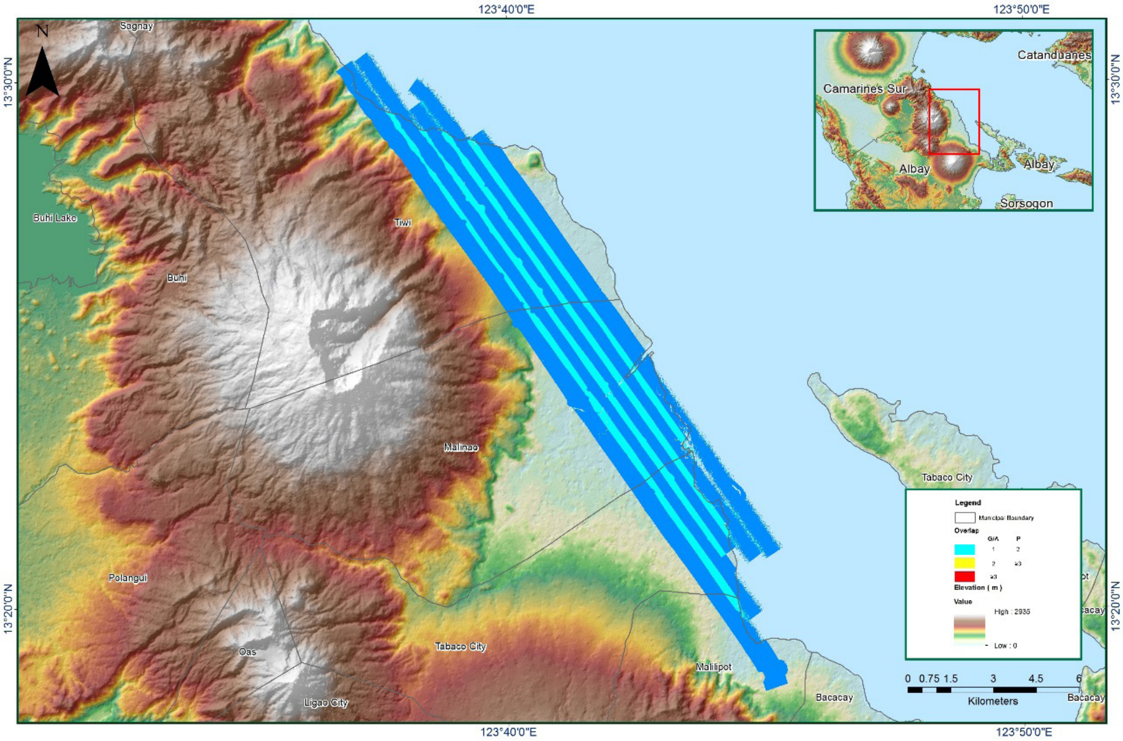


Figure ***A-8.33***. Image of data overlap

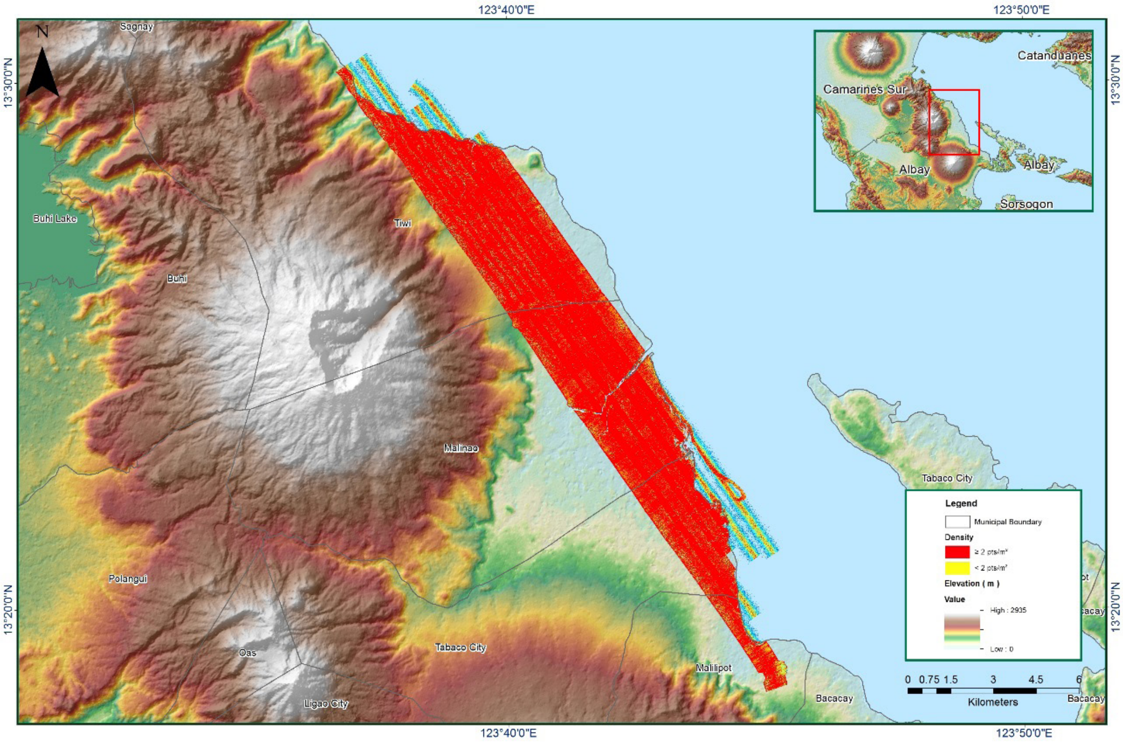


Figure A-8.34. Density map of merged LiDAR data

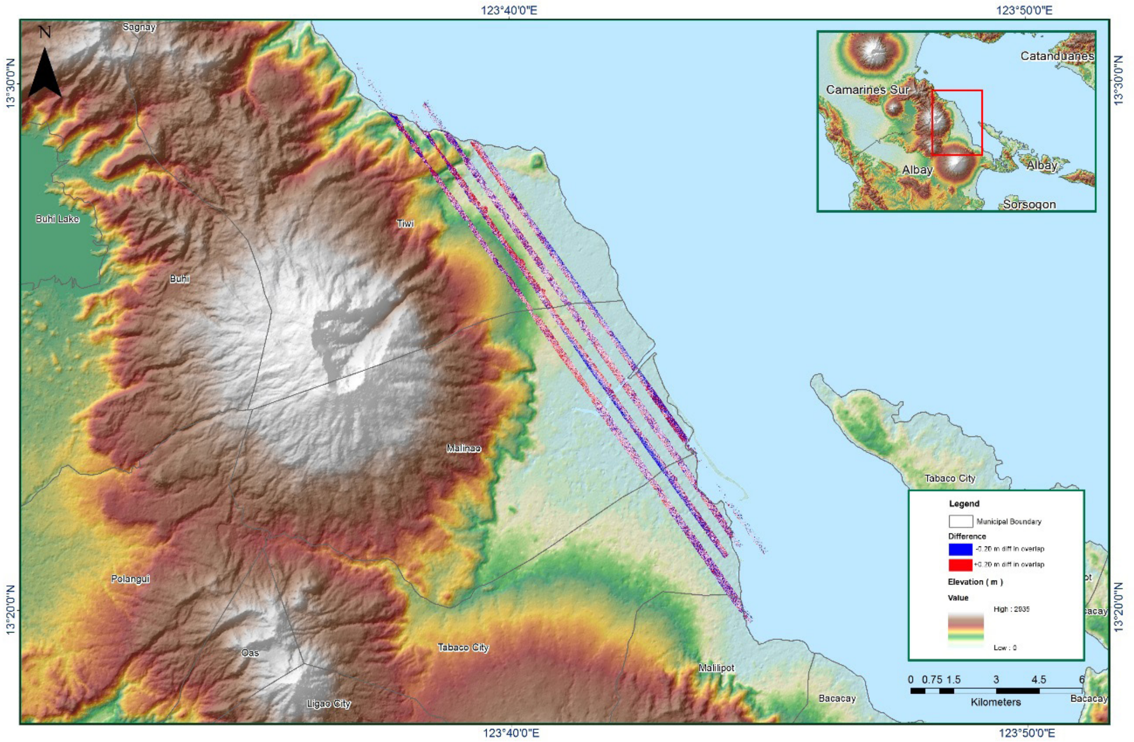


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk 19T

Flight Area	**Albay-Sorsogon**
Mission Name	Blk 19T
Inclusive Flights	3893G
Range data size	20.8 GB
POS data size	169 MB
Base data size	12.6 MB
Image	36.8 MB
Transfer date	March 31, 2016
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)	1.24
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	3.90
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	22.89 %
Ave point cloud density per sq.m. (>2.0)	2.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	189.66 m
Minimum Height	51.64 m
Classification (# of points)	
Ground	20,852,095
Low vegetation	13,768,066
Medium vegetation	85,654,845
High vegetation	80,501,990
Building	21,488
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Merven Matthew Natino, Alex John Escobido,

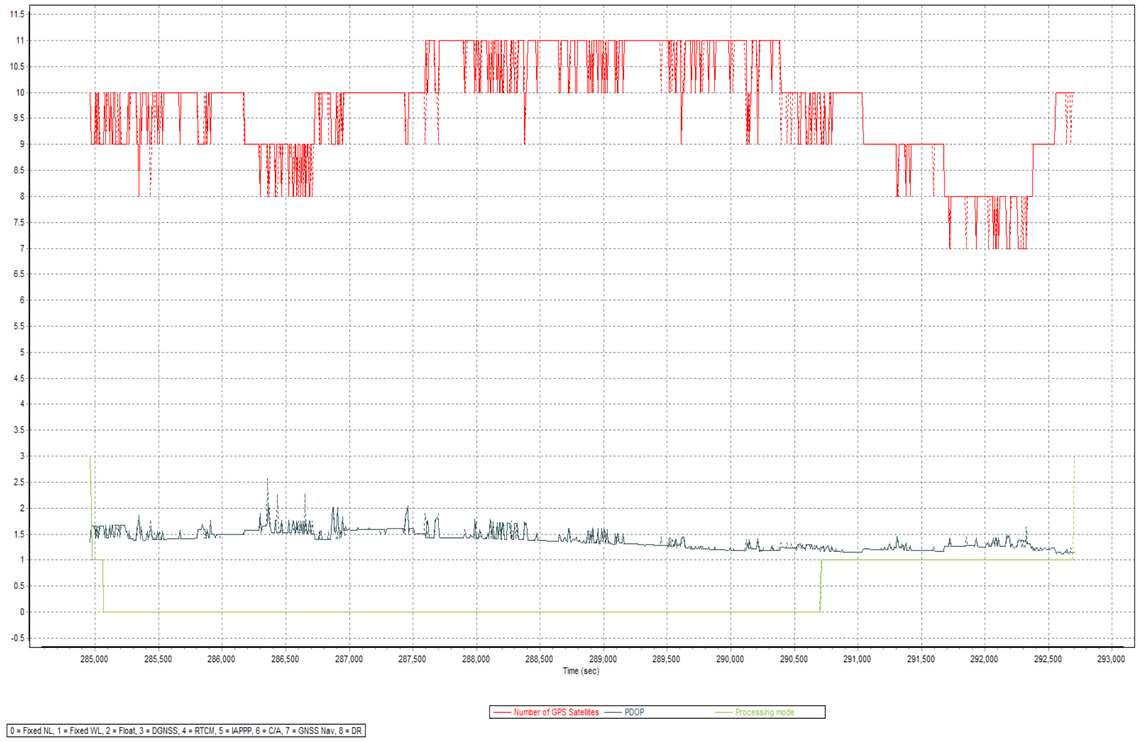


Figure A-8.36. Solution Status

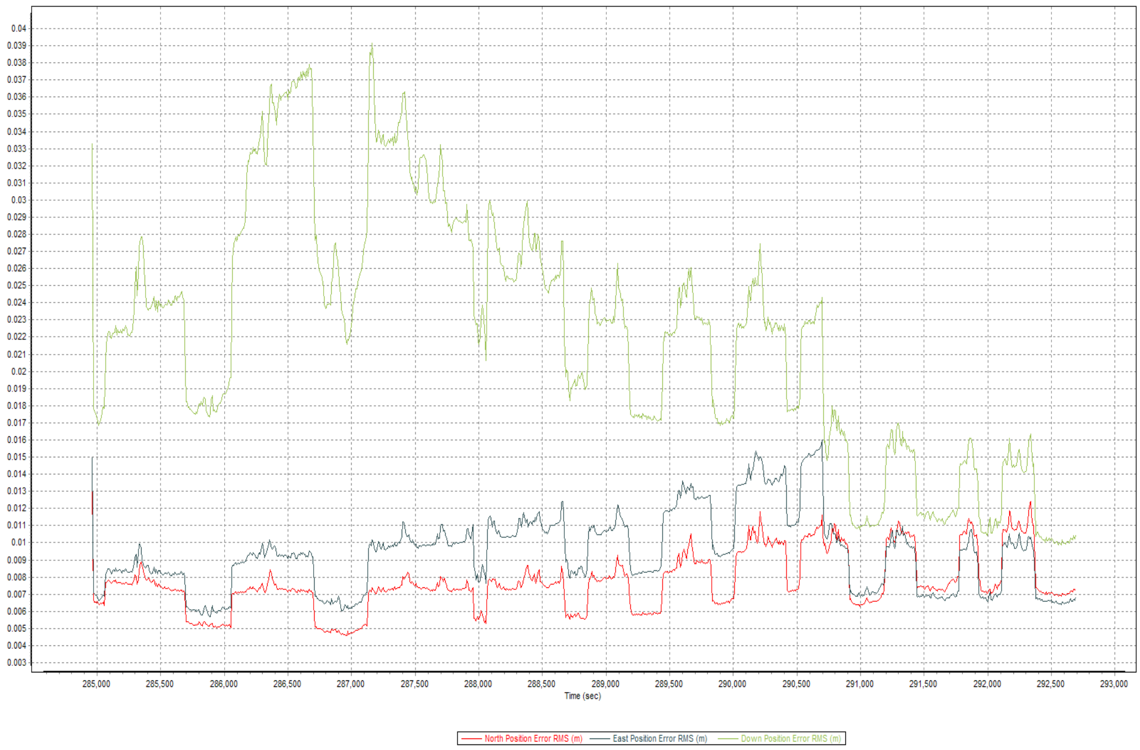


Figure A-8.37. Smoothed Performance Metric Parameters

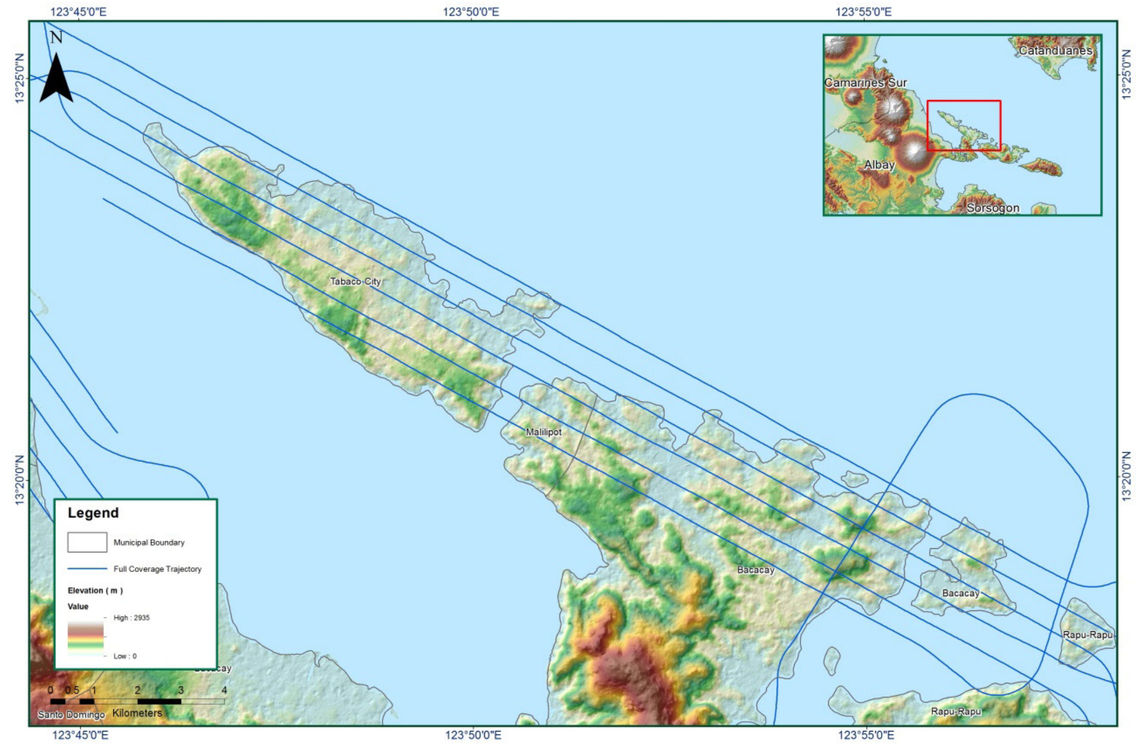


Figure A-8.38. Best Estimated Trajectory

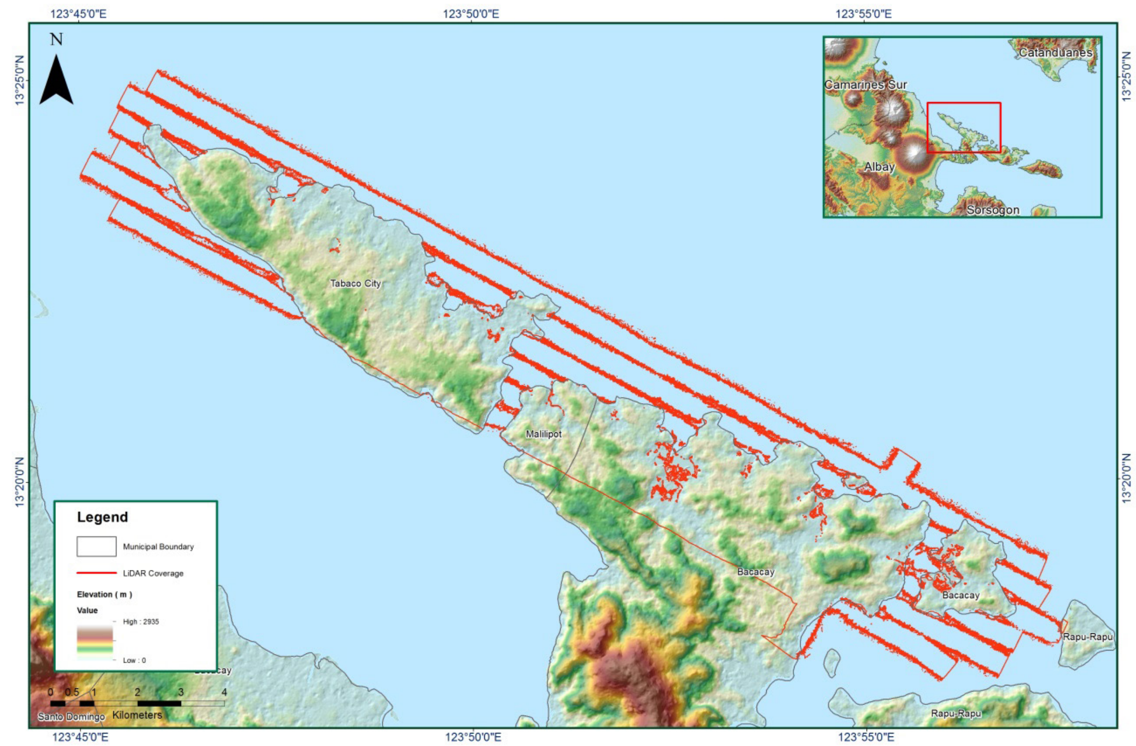


Figure ***A-8.39***. Coverage of LiDAR Data

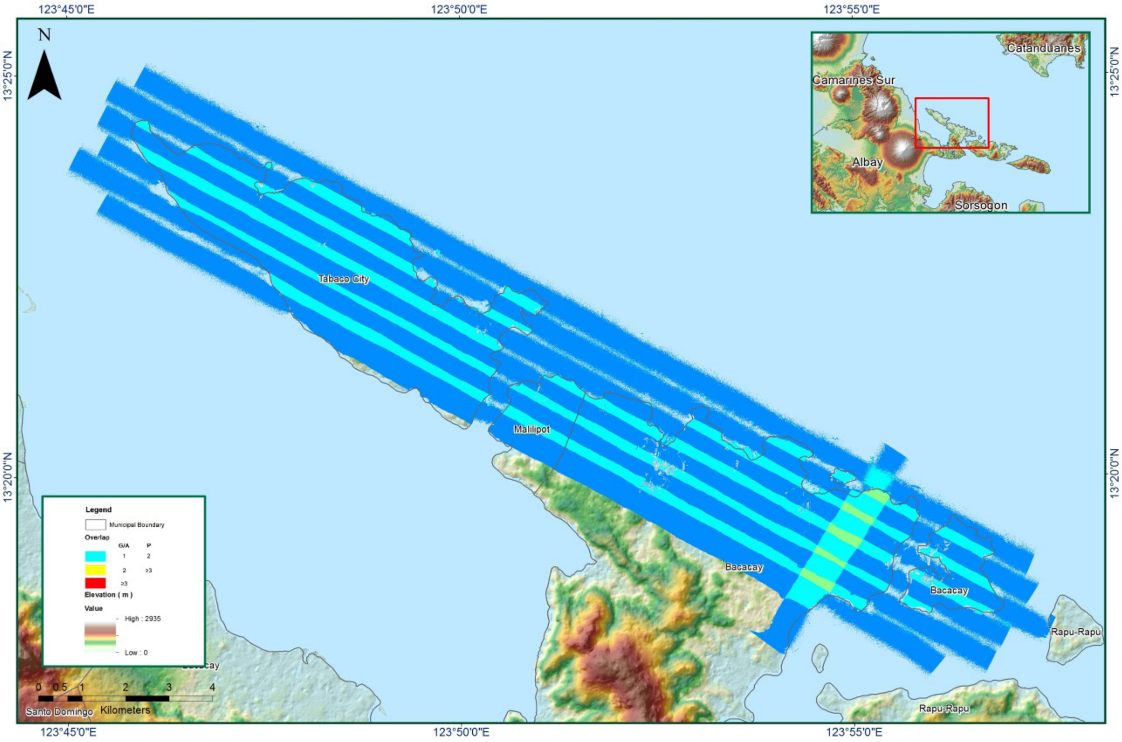


Figure ***A-8.40***. Image of data overlap

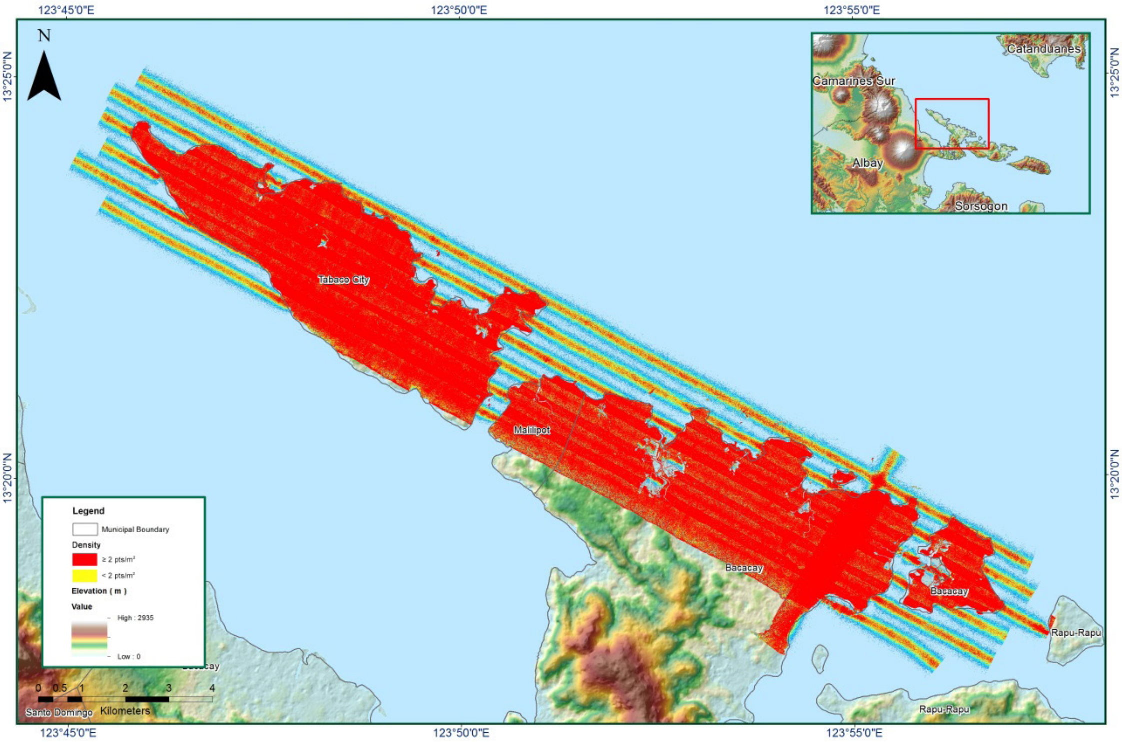


Figure A-8.41. Density map of merged LiDAR data

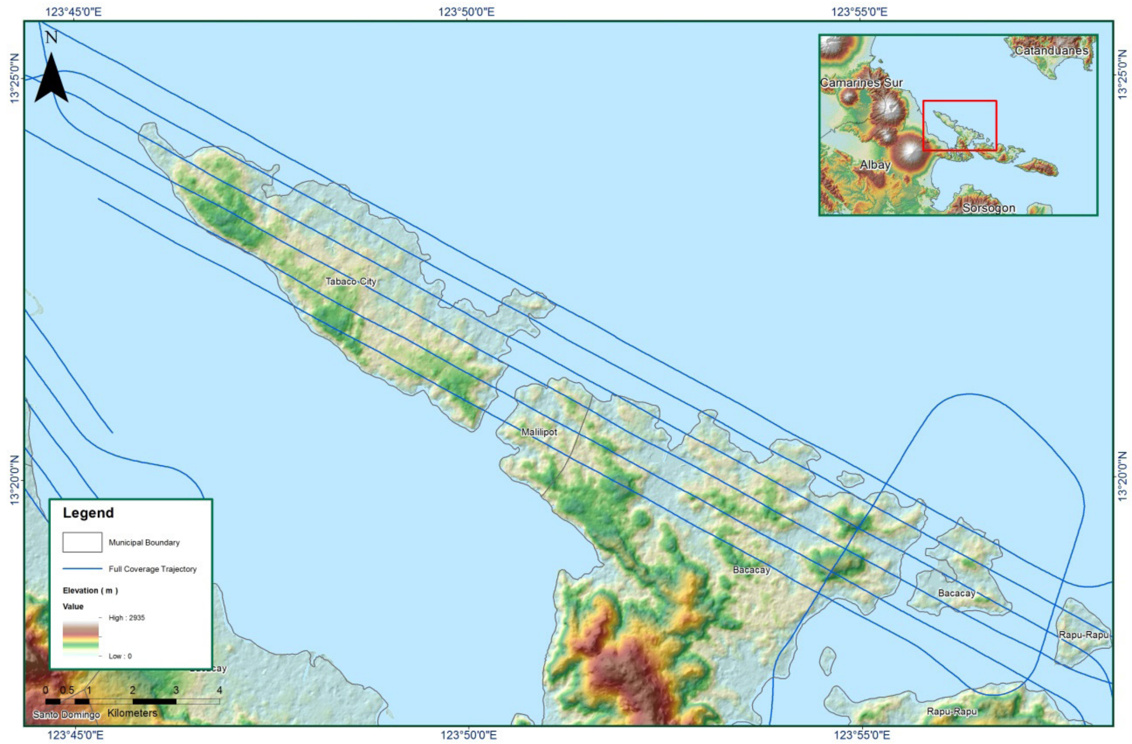


Figure ***A-8.42***. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk 19N

Flight Area	**Albay-Sorsogon**
Mission Name	Blk 19N
Inclusive Flights	3891G
Range data size	24.9 GB
POS data size	294 MB
Base data size	15.4 MB
Image	74.1 MB
Transfer date	March 31, 2016
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)	1.275
RMSE for East Position (<4.0 cm)	1.524
RMSE for Down Position (<8.0 cm)	3.333
Boresight correction stdev (<0.001deg)	0.000488
IMU attitude correction stdev (<0.001deg)	0.011844
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	27.39 %
Ave point cloud density per sq.m. (>2.0)	5.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	98
Maximum Height	404.88 m
Minimum Height	67.94 m
Classification (# of points)	
Ground	34,391,596
Low vegetation	51,785,710
Medium vegetation	177,035,510
High vegetation	81,052,571
Building	2,940,840
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Justine Francisco, Jovy Narisma

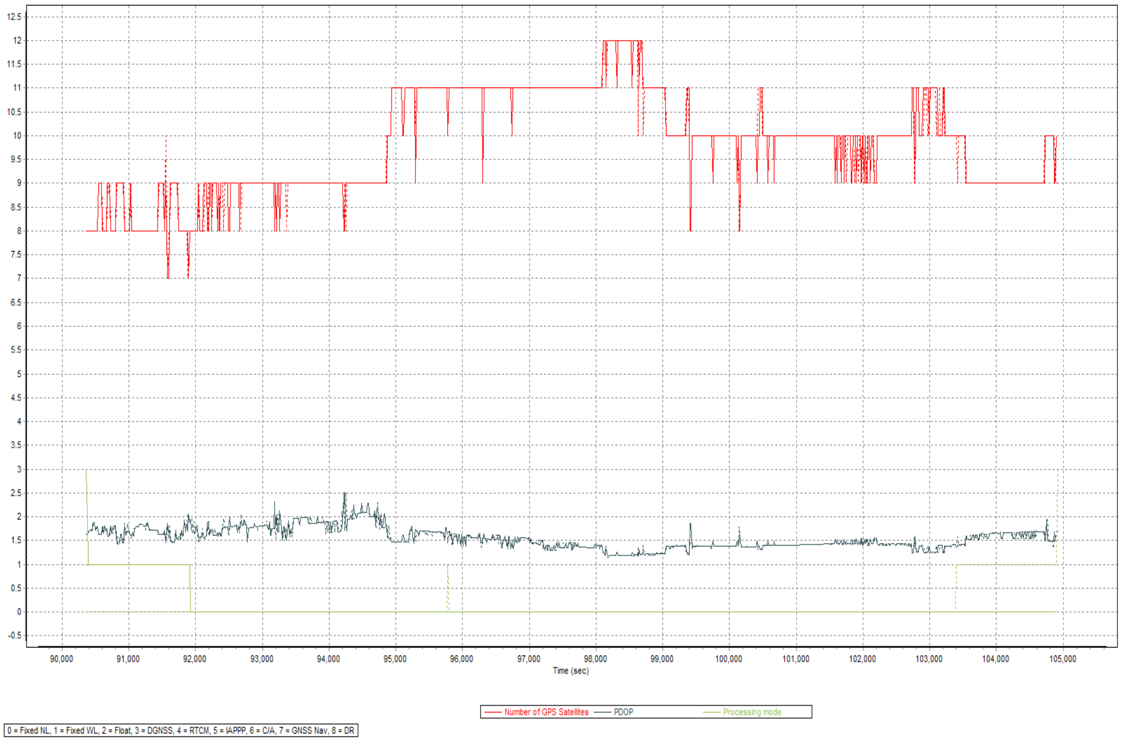


Figure A-8.43. Solution Status

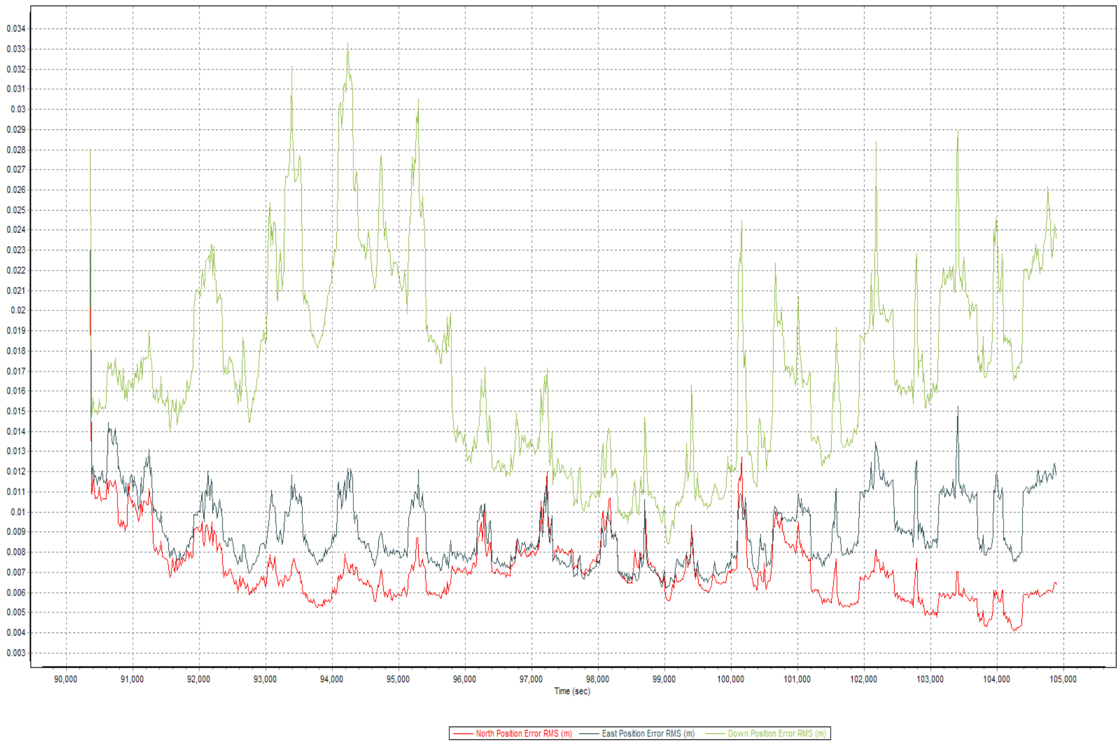


Figure A-8.44. Smoothed Performance Metric Parameters

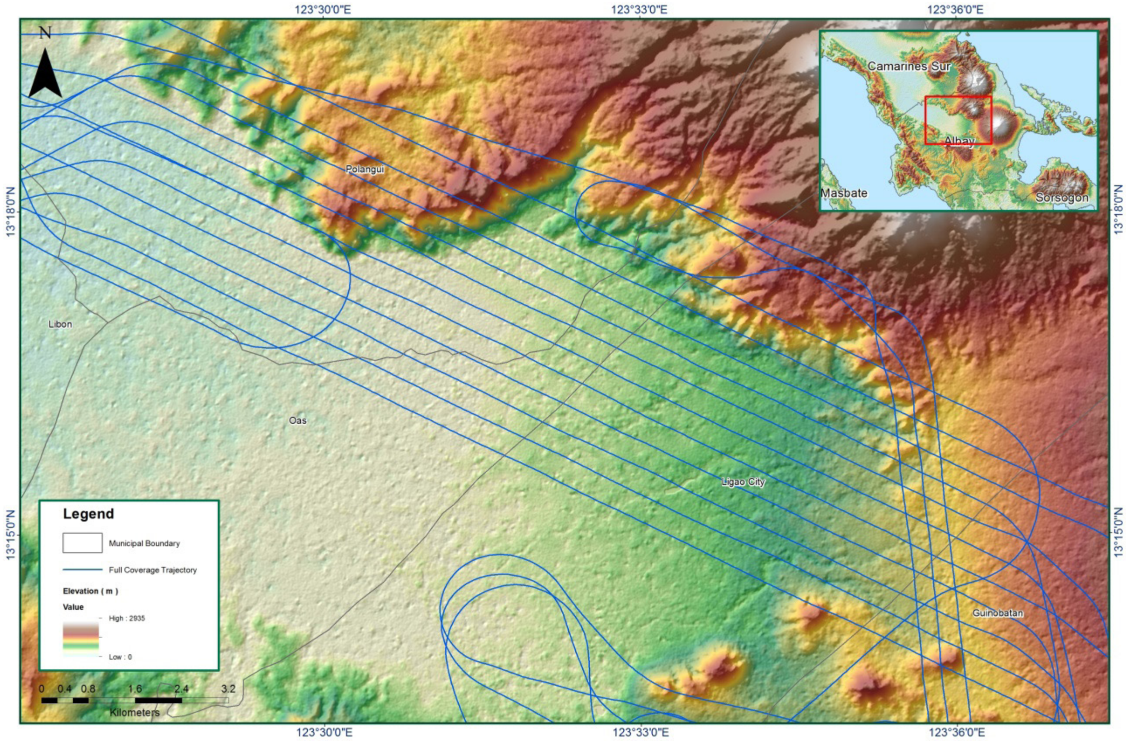


Figure A-8.45. Best Estimated Trajectory

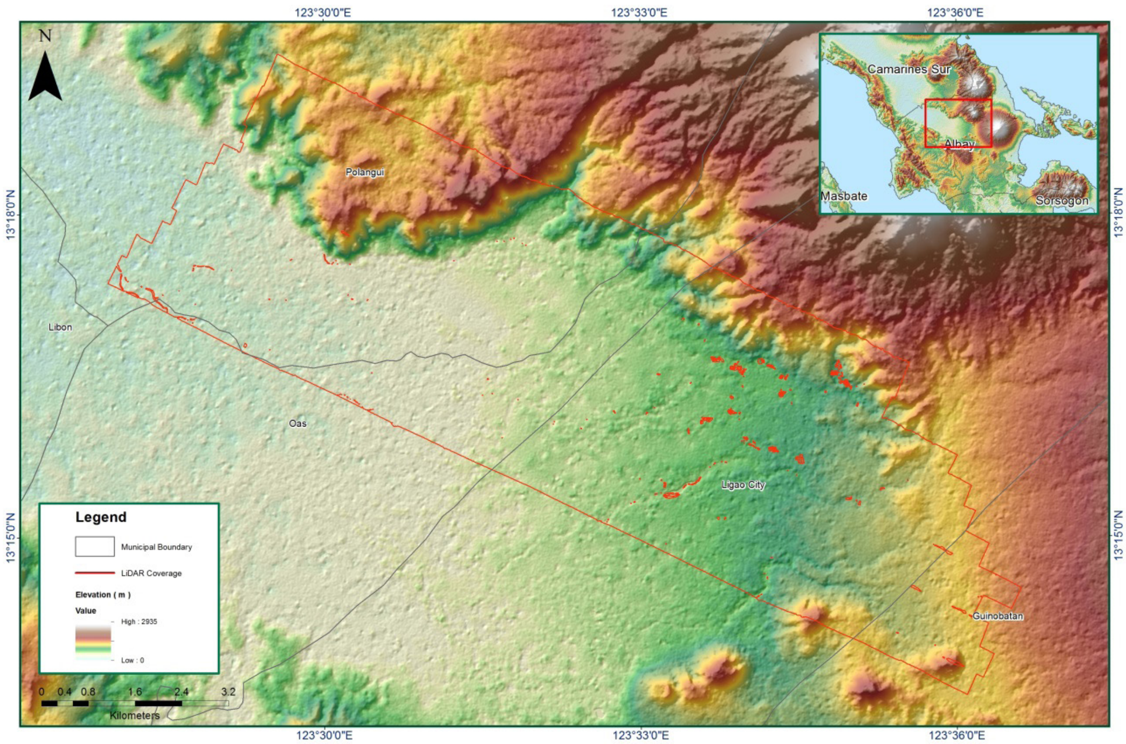


Figure ***A-8.46***. Coverage of LiDAR Data

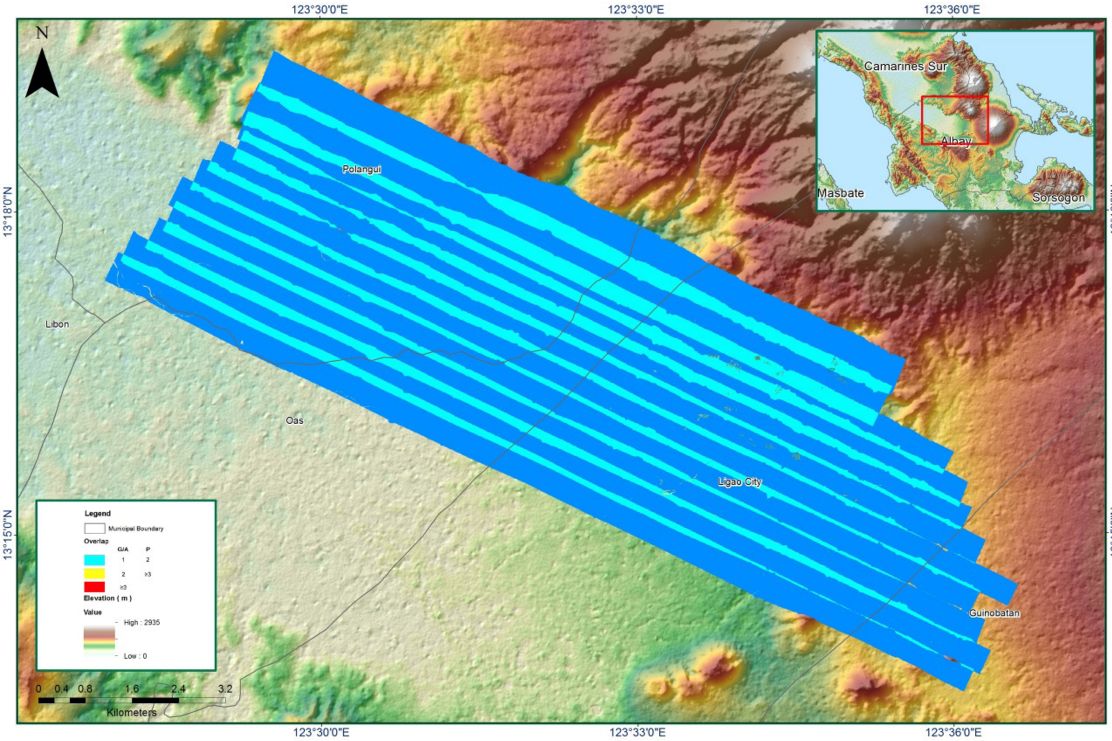


Figure ***A-8.47***. Image of data overlap

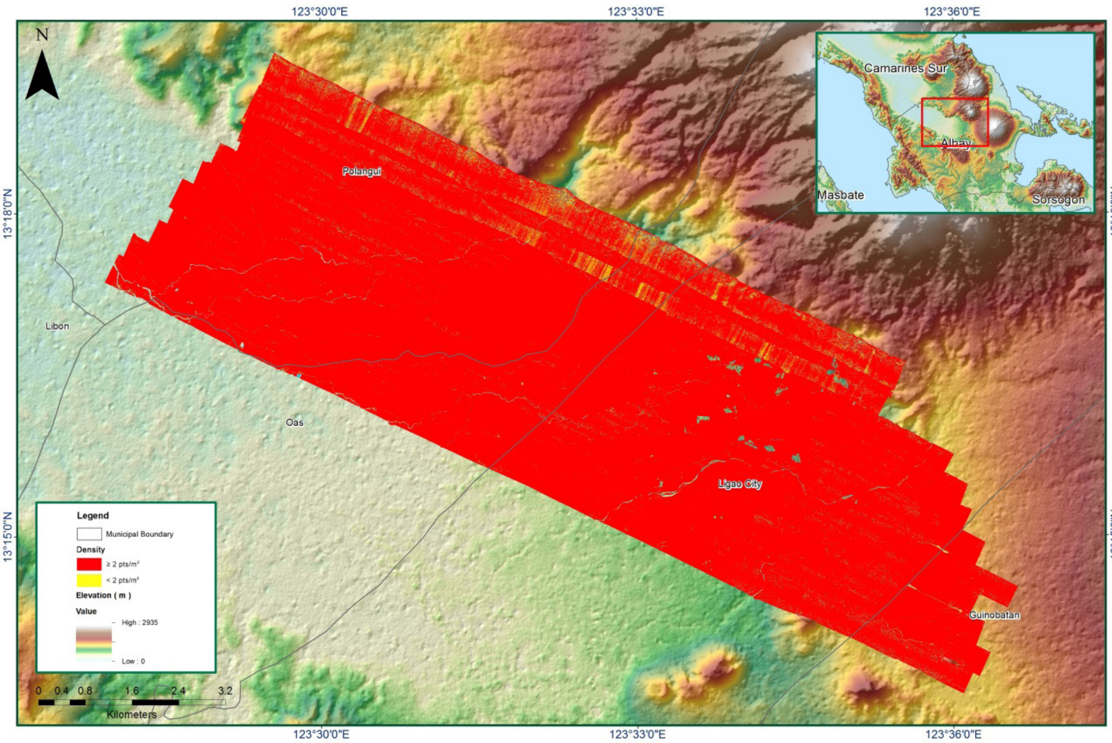


Figure A-8.48. Density map of merged LiDAR data

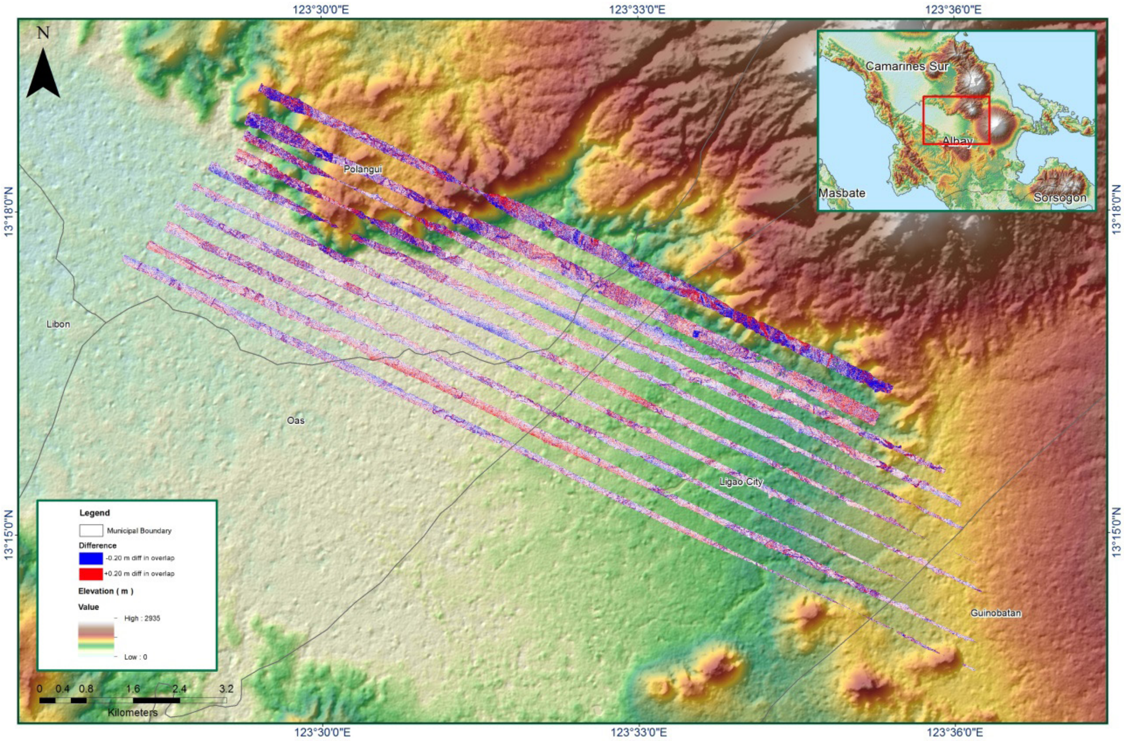


Figure ***A-8.49***. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk 19A_supplement3

Flight Area	**Albay-Sorsogon**
Mission Name	Blk 19A_supplement3
Inclusive Flights	3893G
Range data size	20.8 GB
POS data size	169 MB
Base data size	12.8 MB
Image	36.8 MB
Transfer date	March 31, 2016
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)	1.28
RMSE for East Position (<4.0 cm)	1.66
RMSE for Down Position (<8.0 cm)	5.85
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	20.45 %
Ave point cloud density per sq.m. (>2.0)	7.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	44
Maximum Height	446.57 m
Minimum Height	51.93 m
Classification (# of points)	
Ground	7,847,669
Low vegetation	5,991,388
Medium vegetation	37,200,403
High vegetation	27,990,185
Building	10,425
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Merven Matthew Natino, Marie Denise Bueno

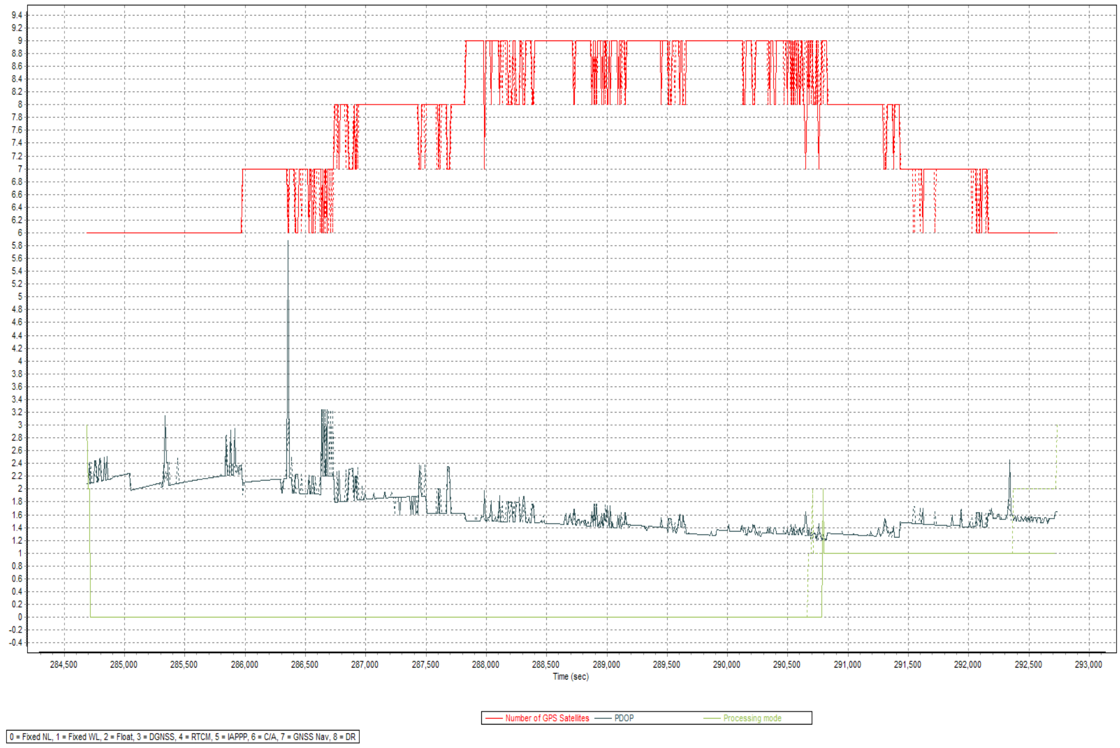


Figure A-8.50. Solution Status

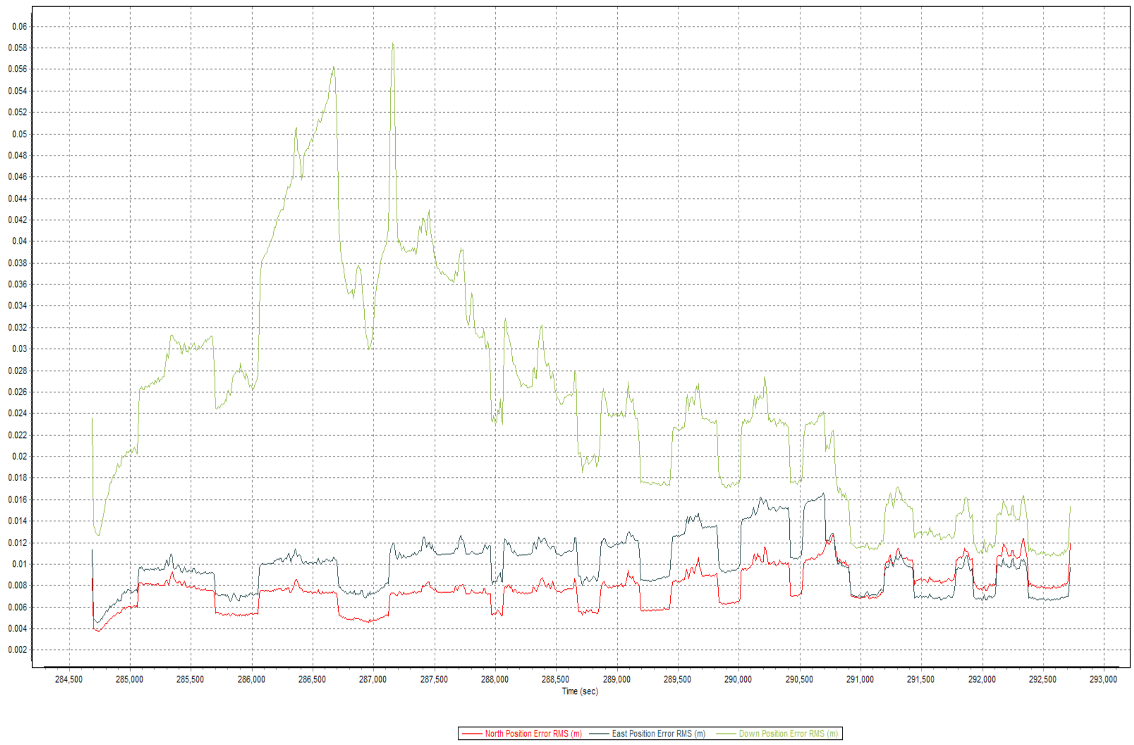


Figure A-8.51. Smoothed Performance Metric Parameters

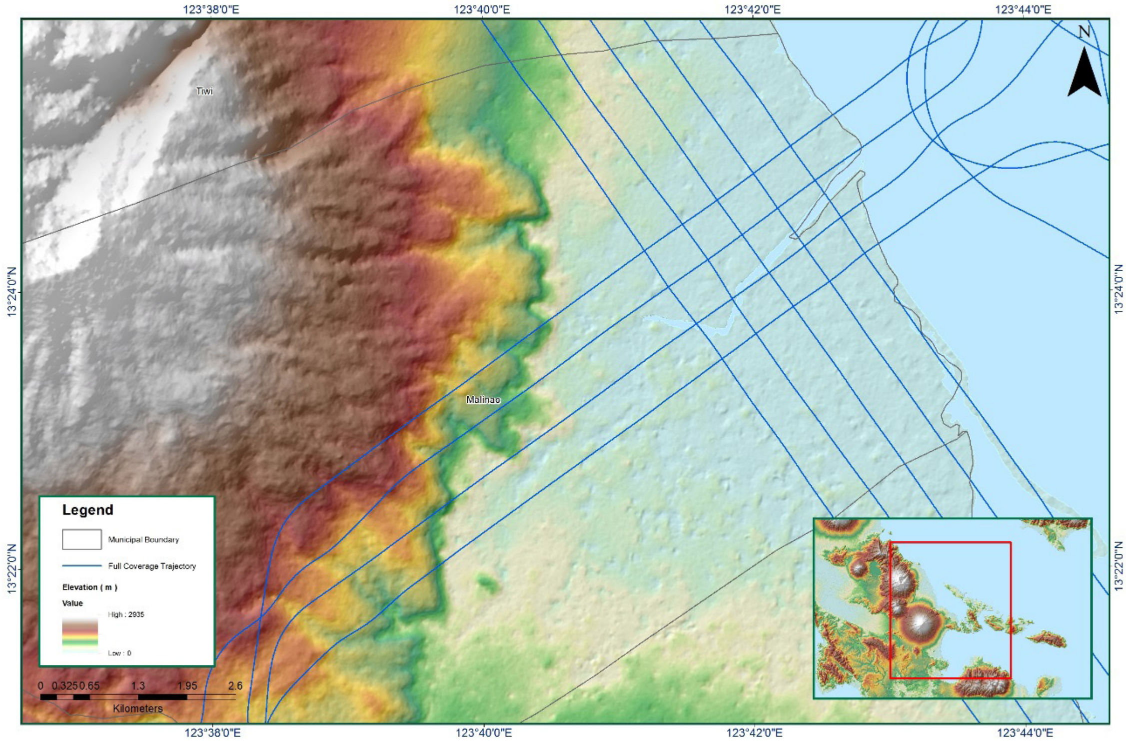


Figure A-8.52. Best Estimated Trajectory

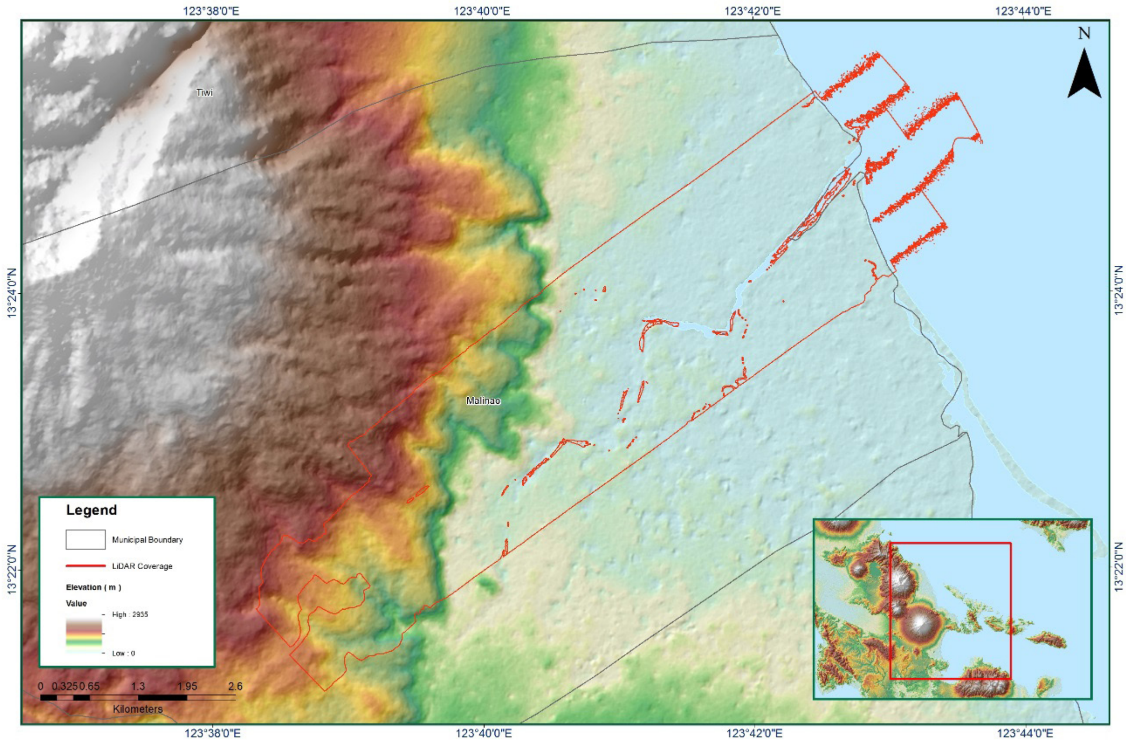


Figure ***A-8.53***. Coverage of LiDAR Data

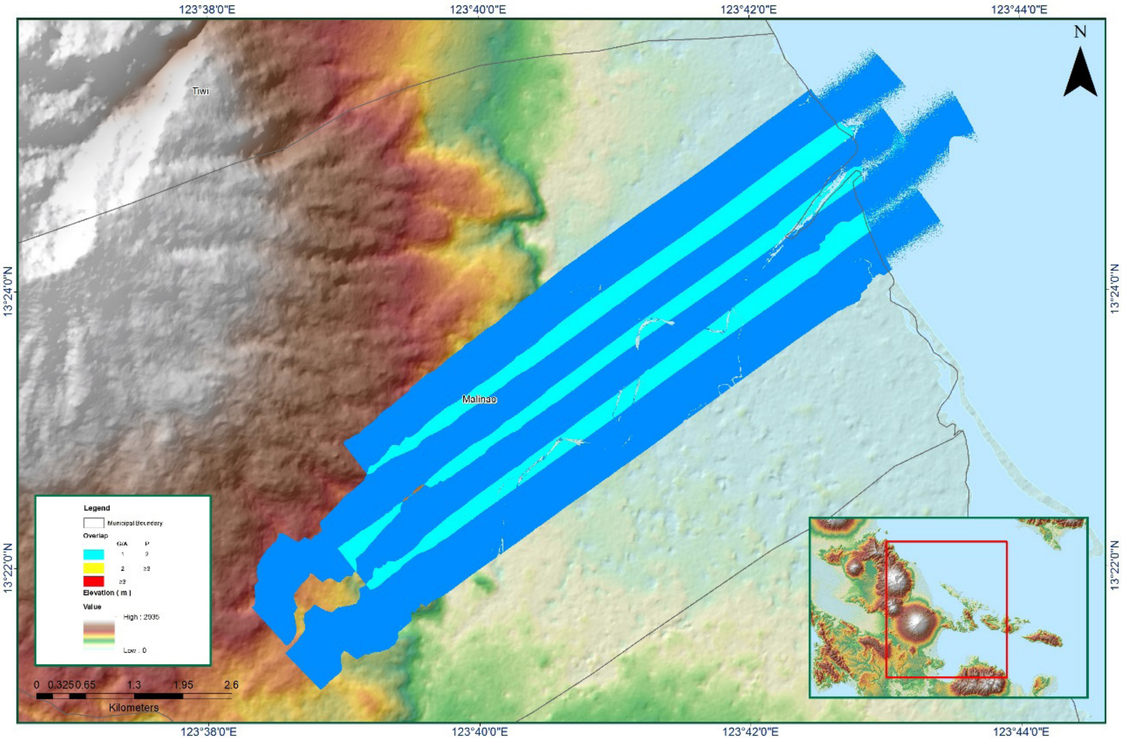


Figure ***A-8.54***. Image of data overlap

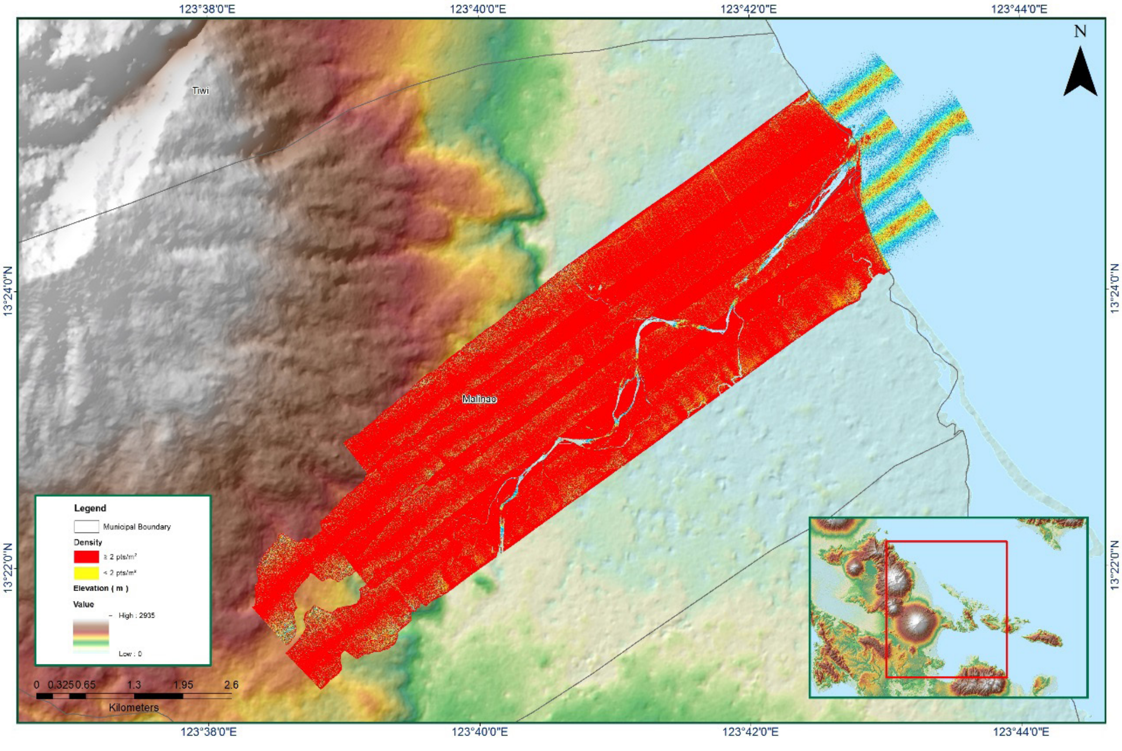


Figure A-8.55. Density map of merged LiDAR data

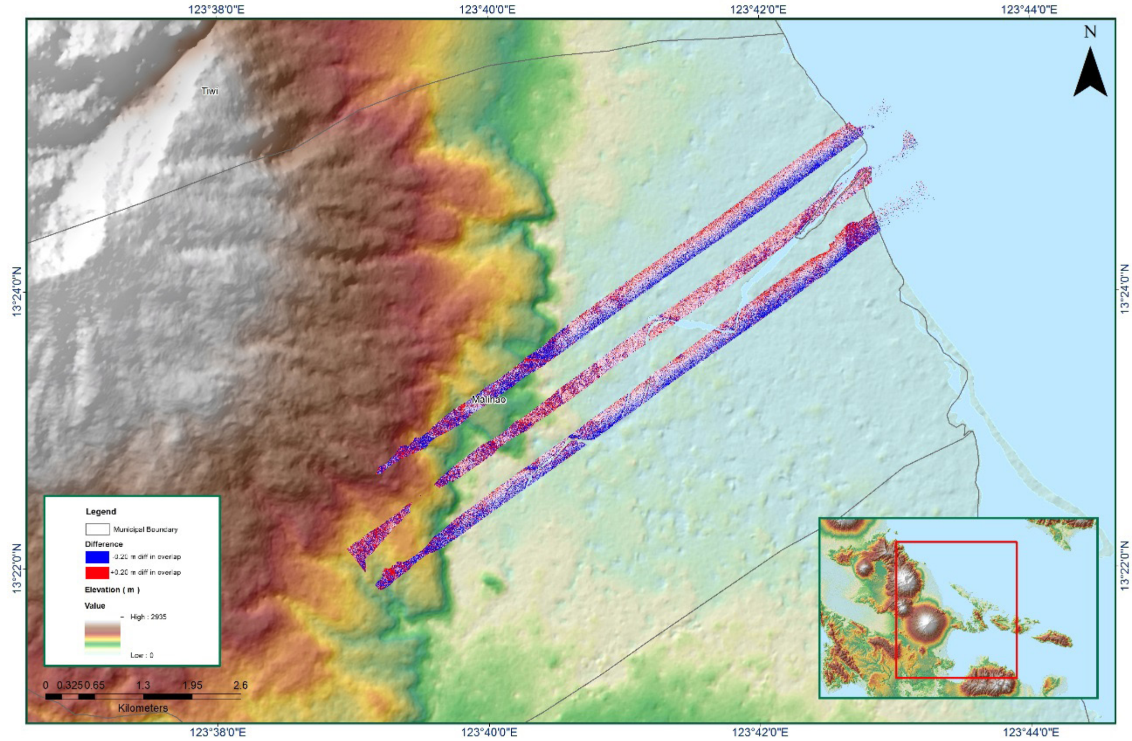


Figure ***A-8.56***. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk 19A_supplement 2

Flight Area	**Albay-Sorsogon**
Mission Name	Blk 19A_supplement 2
Inclusive Flights	3869G
Range data size	283 GB
POS data size	283 MB
Base data size	10 MB
Image	32.5 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.54
RMSE for East Position (<4.0 cm)	1.17
RMSE for Down Position (<8.0 cm)	6.05
Boresight correction stdev (<0.001deg)	0.002128
IMU attitude correction stdev (<0.001deg)	0.006361
GPS position stdev (<0.01m)	0.0161
Minimum % overlap (>25)	33.41 %
Ave point cloud density per sq.m. (>2.0)	7.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	36
Maximum Height	542.36 m
Minimum Height	71.06 m
Classification (# of points)	
Ground	12,556,679
Low vegetation	15,092,370
Medium vegetation	51,086,043
High vegetation	57,640,888
Building	1,253,174
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Merven Matthew Natino, Marie Denise Bueno

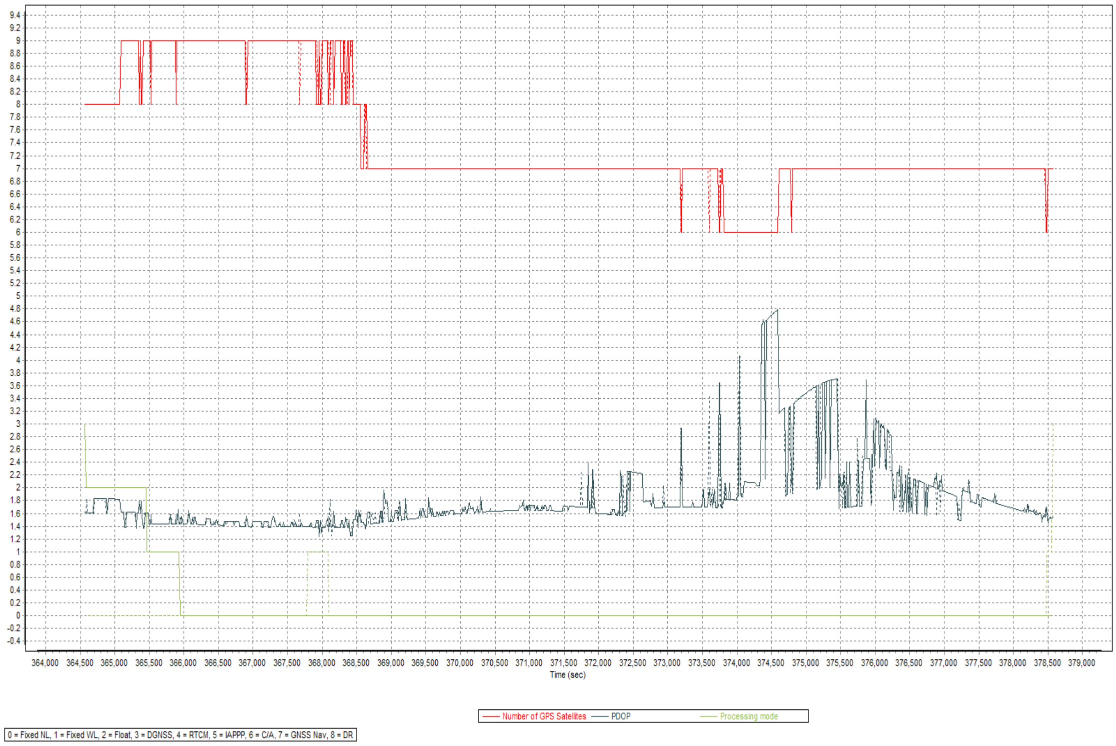


Figure A-8.57. Solution Status

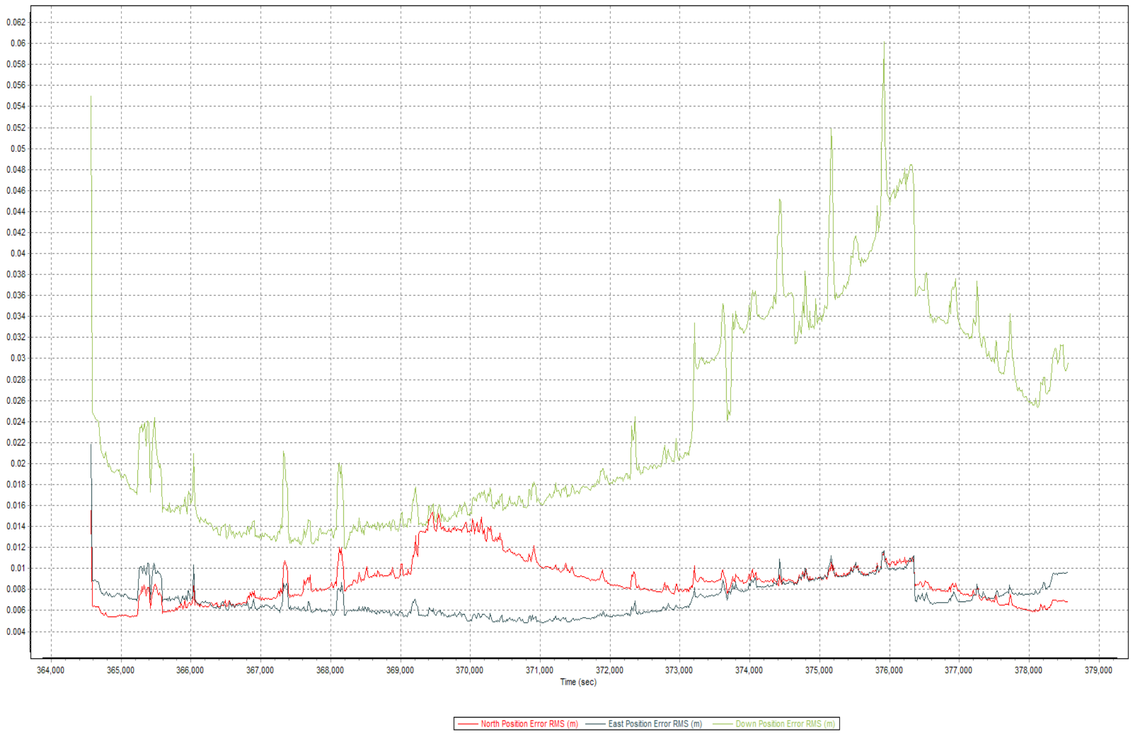


Figure A-8.58. Smoothed Performance Metric Parameters

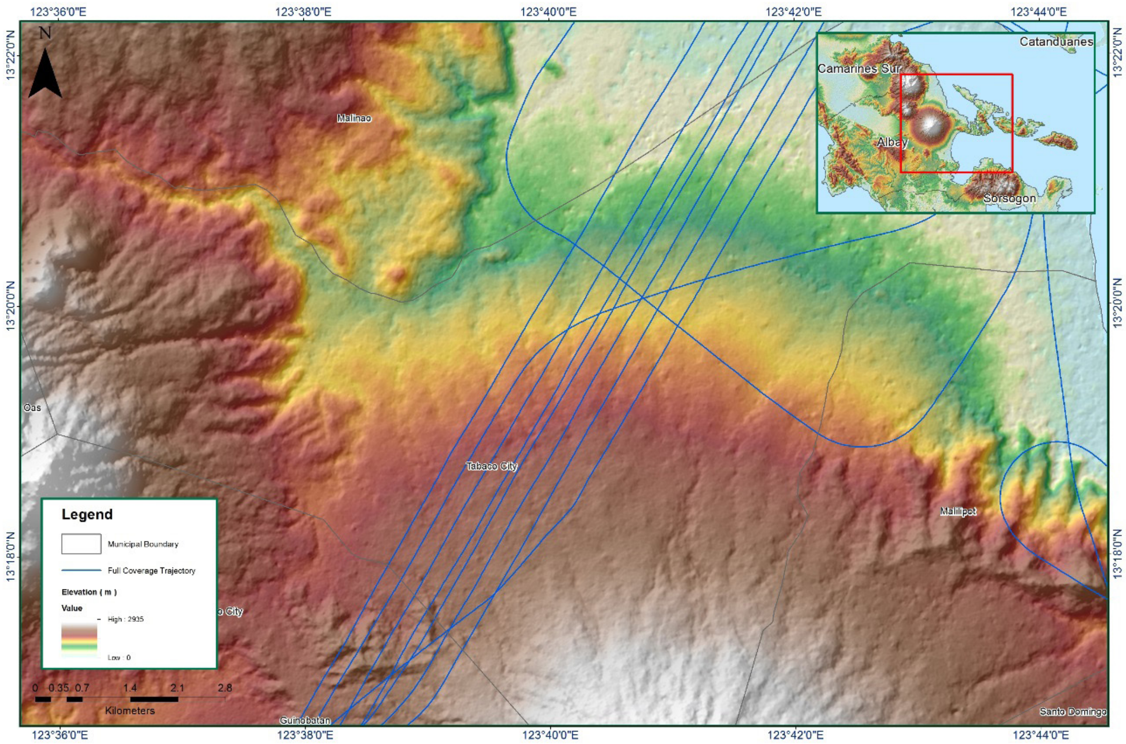


Figure A-8.59. Best Estimated Trajectory

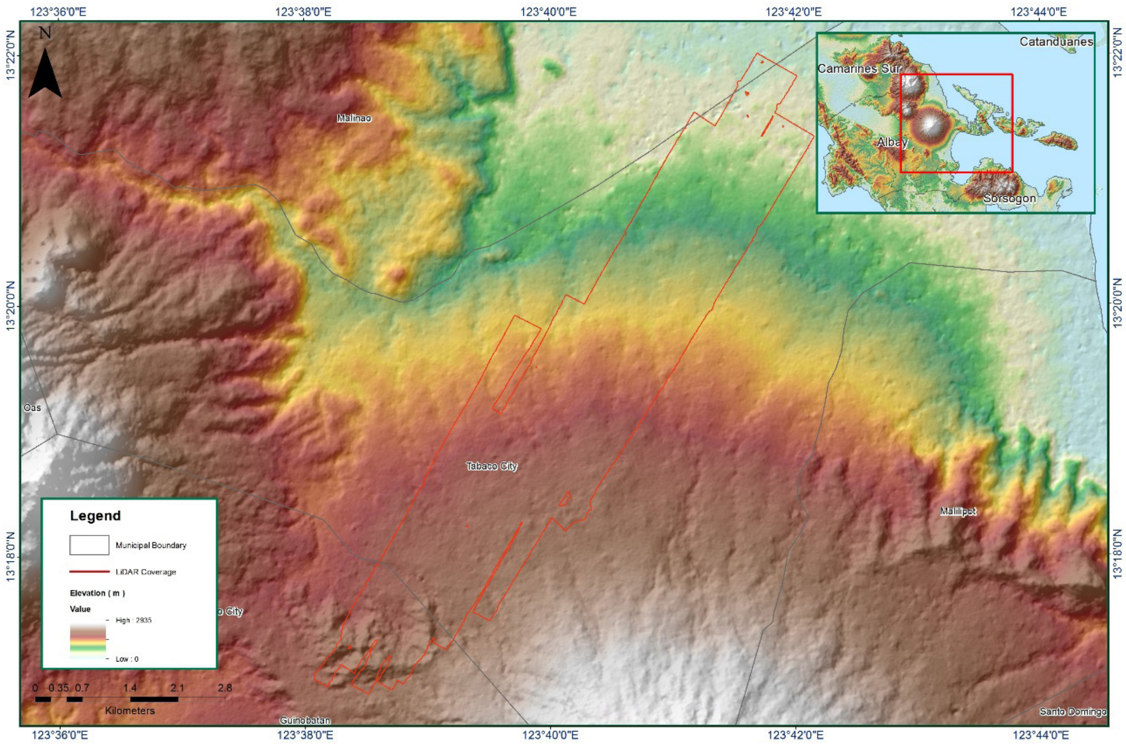


Figure A-8.60. Coverage of LiDAR Data

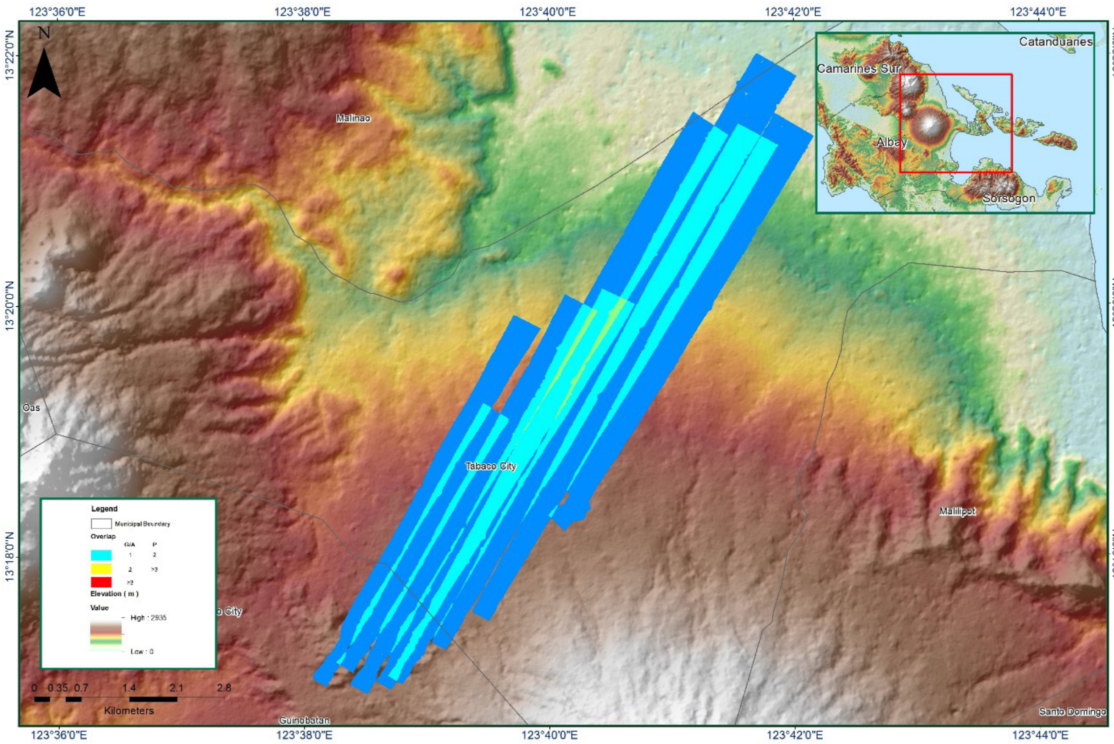


Figure ***A-8.61***. Image of data overlap

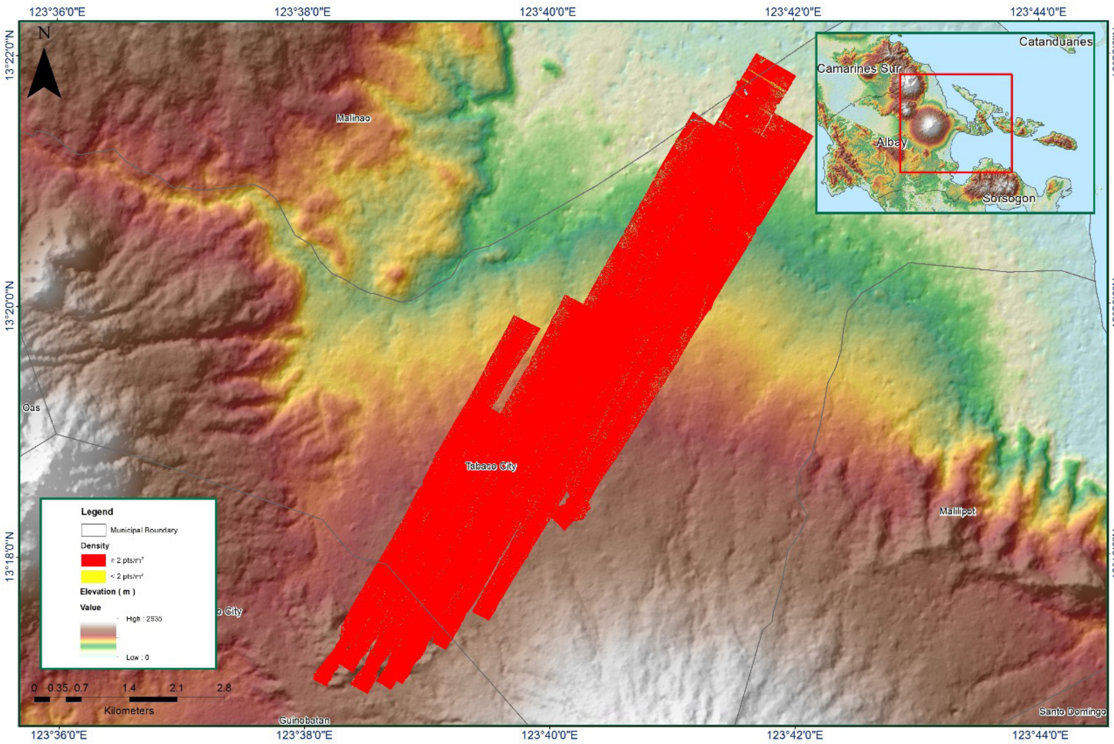


Figure A-8.62. Density map of merged LiDAR data

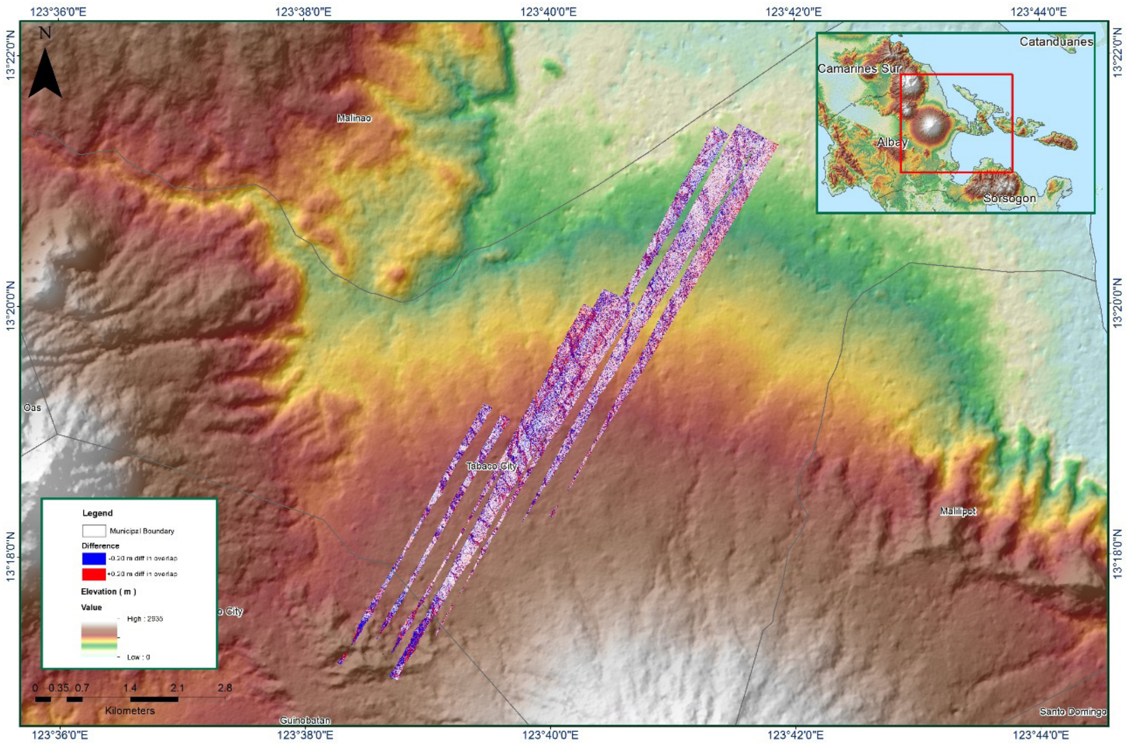


Figure A-8.63. Elevation difference between flight lines

Annex 9. Guinale Model Basin Parameters

Table A-9.1. Guinale Model Basin Parameters

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W140	2.338	99.000	0	0.154	0.01667	Discharge	6.2784	0.00001	Ratio to Peak	0.54807
W150	18.984	99.000	0	4.461	0.52318	Discharge	0.0286	0.00001	Ratio to Peak	0.99754
W160	2.987	99.000	0	0.142	0.06601	Discharge	0.6330	0.00001	Ratio to Peak	0.11711
W170	0.018	99.000	0	4.312	0.27095	Discharge	2.6439	0.00001	Ratio to Peak	0.00034
W180	1.566	98.651	0	3.798	0.32219	Discharge	2.4775	0.00001	Ratio to Peak	0.00028
W190	30.977	99.000	0	0.017	0.05911	Discharge	3.1286	0.00001	Ratio to Peak	0.22561
W200	30.129	99.000	0	0.017	0.07625	Discharge	1.0708	0.00001	Ratio to Peak	0.59612
W210	32.918	99.000	0	0.165	0.03113	Discharge	4.5212	0.00001	Ratio to Peak	0.00717
W220	51.190	49.809	0	61.278	26.60000	Discharge	5.9329	0.00002	Ratio to Peak	1.00000
W230	66.554	43.288	0	63.613	42.79800	Discharge	7.7089	0.00001	Ratio to Peak	1.00000
W240	55.842	47.636	0	44.212	26.53800	Discharge	4.2869	0.10323	Ratio to Peak	1.00000
W250	1.406	99.000	0	1.384	0.06671	Discharge	19.1140	0.10729	Ratio to Peak	0.93820
W260	48.937	50.934	0	44.205	20.72900	Discharge	12.7900	0.00001	Ratio to Peak	1.00000

Annex 10. Guinale Model Reach Parameters

Table A-10.1. Guinale Model Reach Parameters

Muskingum-Cunge Channel Routing								
	Reach Number	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side slope
1	R10	Automatic Fixed Interval	427.3	0.00486	0.00010	Trapezoid	152.518	1
2	R30	Automatic Fixed Interval	1389.8	0.00125	0.12327	Trapezoid	152.518	1
3	R40	Automatic Fixed Interval	3872.0	0.00154	0.00010	Trapezoid	152.518	1
4	R60	Automatic Fixed Interval	5723.2	0.00465	0.08450	Trapezoid	152.518	1
5	R80	Automatic Fixed Interval	2692.8	0.01111	0.00010	Trapezoid	152.518	1
6	R110	Automatic Fixed Interval	4529.6	0.01462	0.52344	Trapezoid	152.518	1

Annex 11. Guinale Field Validation Points

Table A-11.1. Guinale Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	13.40711008	123.7129216	0.53	4.5	-3.97	TY Juaning 2011	5-Year
2	13.40654617	123.71316	0.35	1.4	-1.05	TY Juaning 2011	5-Year
3	13.40769747	123.7125285	0.56	0.6	-0.04	TY Juaning 2011	5-Year
4	13.40864647	123.71209	0.47	1	-0.53	TY Juaning 2011	5-Year
5	13.40913279	123.7122183	1.08	1.6	-0.52	TY Juaning 2011	5-Year
6	13.40917033	123.7116985	0.69	1.7	-1.01	TY Juaning 2011	5-Year
7	13.40928332	123.7055951	0.41	1	-0.59	TY Juaning 2011	5-Year
8	13.40785149	123.7050793	0.51	1.4	-0.89	TY Juaning 2011	5-Year
9	13.40711346	123.7042947	0.31	2	-1.69	TY Juaning 2011	5-Year
10	13.40514152	123.7024012	0.52	0.8	-0.28	TY Juaning 2011	5-Year
11	13.40447735	123.7013728	0.33	0.5	-0.17	TY Juaning 2011	5-Year
12	13.40466425	123.7008503	0.55	1.4	-0.85	TY Juaning 2011	5-Year
13	13.40436015	123.7005106	0.8	1.4	-0.6	TY Juaning 2011	5-Year
14	13.40428114	123.7001491	0.37	0.7	-0.33	TY Juaning 2011	5-Year
15	13.40356525	123.6991124	0.03	1	-0.97	TY Juaning 2011	5-Year
16	13.4032946	123.698557	0.06	1.2	-1.14	TY Juaning 2011	5-Year
17	13.40277867	123.6974516	0.05	0.8	-0.75	TY Juaning 2011	5-Year
18	13.40235548	123.6988613	0.47	1	-0.53	TY Juaning 2011	5-Year
19	13.40218592	123.6998297	1.07	1.6	-0.53	TY Juaning 2011	5-Year
20	13.40345299	123.7007556	0.95	0.9	0.05	TY Juaning 2011	5-Year
21	13.40330505	123.7004864	0.49	1.1	-0.61	TY Juaning 2011	5-Year
22	13.40391475	123.7012914	0.73	1.6	-0.87	TY Juaning 2011	5-Year
23	13.40223162	123.7027469	1.18	0.7	0.48	TY Juaning 2011	5-Year
24	13.40157707	123.7027659	0.88	1.5	-0.62	TY Juaning 2011	5-Year
25	13.40136479	123.7032228	1.05	1.9	-0.85	TY Juaning 2011	5-Year
26	13.39995827	123.7032571	1.21	1.6	-0.39	TY Juaning 2011	5-Year
27	13.3998939	123.7037522	0.03	0.8	-0.77	TY Juaning 2011	5-Year
28	13.39733849	123.70348	0.22	1.5	-1.28	TY Juaning 2011	5-Year
29	13.39745649	123.7036743	0.74	1.7	-0.96	TY Juaning 2011	5-Year
30	13.39688643	123.702524	0.85	1.8	-0.95	TY Juaning 2011	5-Year
31	13.40037909	123.7060659	0.6	0.9	-0.3	TY Juaning 2011	5-Year
32	13.39977353	123.705791	0.49	1.4	-0.91	TY Juaning 2011	5-Year
33	13.39909416	123.7063381	0.76	1.4	-0.64	TY Juaning 2011	5-Year
34	13.39931916	123.7064828	0.66	1.2	-0.54	TY Juaning 2011	5-Year
35	13.39821771	123.706494	0.2	0.8	-0.6	TY Juaning 2011	5-Year
36	13.39835703	123.7059553	0.57	1.4	-0.83	TY Juaning 2011	5-Year
37	13.39906681	123.7043359	0.03	1.7	-1.67	TY Juaning 2011	5-Year
38	13.39864569	123.7046713	0.72	1.5	-0.78	TY Juaning 2011	5-Year
39	13.39803733	123.7044753	0.58	1.3	-0.72	TY Juaning 2011	5-Year
40	13.39782717	123.7044472	0.96	1.3	-0.34	TY Juaning 2011	5-Year

41	13.39733767	123.7047682	0.95	1.7	-0.75	TY Juaning 2011	5-Year
42	13.39720259	123.7055691	0.59	2.1	-1.51	TY Juaning 2011	5-Year
43	13.39699768	123.705967	0.26	1.1	-0.84	TY Juaning 2011	5-Year
44	13.39702639	123.7060507	0.61	1	-0.39	TY Juaning 2011	5-Year
1	13.42465885	123.6891332	0.1	0	0.1		5-Year
2	13.42318305	123.6901898	0.22	0	0.22		5-Year
3	13.42041004	123.6919021	0.28	0.2	0.08	STY Ruby 2014	5-Year
4	13.41863505	123.6930028	0.55	0	0.55		5-Year
5	13.41795921	123.6933346	0.19	0	0.19		5-Year
6	13.41760434	123.6935822	0.32	0	0.32		5-Year
7	13.42141137	123.6993897	0.04	0	0.04		5-Year
8	13.40419072	123.678478	1.87	1.38	0.49	TY Juaning 2011	5-Year
9	13.40374363	123.6786165	0.73	0	0.73		5-Year
10	13.40356828	123.6788083	0.55	0	0.55		5-Year
11	13.40313479	123.6788887	0.8	0	0.8		5-Year
12	13.40286991	123.6788941	0.56	0	0.56		5-Year
13	13.40214303	123.6789177	0.08	0	0.08		5-Year
14	13.40170872	123.6794592	0.03	0	0.03		5-Year
15	13.40120995	123.6796373	0.07	0	0.07		5-Year
16	13.4010572	123.6789831	0.03	0	0.03		5-Year
17	13.40148645	123.6816984	0.52	0	0.52		5-Year
18	13.40154213	123.6814376	0.23	0	0.23		5-Year
19	13.40124402	123.6823989	0.77	1.01	-0.24	STY Reming 2006	5-Year
20	13.40065144	123.6825451	0.75	0.2	0.55	STY Reming 2006	5-Year
21	13.39997455	123.6823768	0.21	0	0.21		5-Year
22	13.3995691	123.6825856	0.53	0	0.53		5-Year
23	13.39901428	123.6831444	0.32	0	0.32		5-Year
24	13.39884341	123.6851622	0.46	0	0.46		5-Year
25	13.3985589	123.6861632	0.69	0	0.69		5-Year
26	13.39847497	123.6870787	0.55	0	0.55		5-Year
27	13.39852942	123.687568	0.15	0	0.15		5-Year
28	13.4008201	123.6938051	0.87	1.3	-0.43	STY Reming 2006	5-Year
29	13.40295154	123.6978274	0.03	0.97	-0.94	TY Sening	5-Year
30	13.38640098	123.6908692	0.09	0	0.09		5-Year
31	13.37696337	123.6902501	0.48	0	0.48		5-Year
32	13.37660811	123.6910437	0.44	0.4	0.04	STY Reming 2006	5-Year
33	13.37379588	123.6788746	0.12	0.4	-0.28	TY Juaning 2011	5-Year
34	13.37574995	123.6776262	0.03	1	-0.97	TY Juaning 2011	5-Year
35	13.37601672	123.6776633	0.03	1	-0.97	TY Juaning 2011	5-Year
36	13.37685375	123.6785679	0.03	0	0.03		5-Year
37	13.37754208	123.679273	0.03	0	0.03		5-Year
38	13.37766561	123.6793998	0.03	0	0.03		5-Year
39	13.37767736	123.6792534	0.03	0	0.03		5-Year
40	13.38068691	123.6778121	1.08	1	0.08	TY Juaning 2011	5-Year
41	13.37946208	123.6783188	0.35	0.7	-0.35	TY Juaning 2011	5-Year
42	13.37868036	123.6826819	0.03	0	0.03		5-Year
43	13.37830726	123.6836837	0.04	0	0.04		5-Year

44	13.3777744	123.6846333	0.16	1.9	-1.74	TY Juaning 2011	5-Year
45	13.39012286	123.6960214	0.15	0	0.15		5-Year
46	13.39032032	123.6991162	0.04	0	0.04		5-Year
47	13.39253424	123.7048076	1.24	0.4	0.84	TY Juaning 2011	5-Year
1	13.391076	123.7076535	0.03	0.3	-0.27	TY Juaning 2011	5-Year
2	13.38912933	123.7089194	0.03	0	0.03	TY Juaning 2011	5-Year
3	13.38843283	123.707402	0.37	0.3	0.07	TY Juaning 2011	5-Year
4	13.38672121	123.707947	0.03	0.5	-0.47	TY Juaning 2011	5-Year
5	13.38547583	123.707779	0.44	0.4	0.04	TY Juaning 2011	5-Year
6	13.38434233	123.7071611	0.03	0	0.03		5-Year
7	13.38848951	123.7095524	0.03	1.3	-1.27	TY Juaning 2011	5-Year
8	13.38853186	123.7095461	0.03	1.1	-1.07	TY Juaning 2011	5-Year
9	13.38301438	123.7137823	0.23	0.4	-0.17	TY Juaning 2011	5-Year
10	13.3824191	123.7142397	1.45	0.6	0.85		5-Year
11	13.38241919	123.7142335	1.45	1.2	0.25	TY Juaning 2011	5-Year
12	13.38210615	123.7145273	0.79	1.2	-0.41	TY Juaning 2011	5-Year
13	13.38212327	123.714526	0.79	0.3	0.49		5-Year
14	13.38090447	123.7155586	0.55	0.5	0.05	TY Juaning 2011	5-Year
15	13.38039173	123.7159331	0.66	0.3	0.36	TY Juaning 2011	5-Year
16	13.38010102	123.7162342	0.06	0.2	-0.14	TY Juaning 2011	5-Year
17	13.37960658	123.7166258	0.2	0.1	0.1	TY Juaning 2011	5-Year
18	13.37899707	123.71713	0.03	0.1	-0.07	TY Juaning 2011	5-Year
19	13.37792476	123.7178058	0.03	0.2	-0.17	TY Juaning 2011	5-Year
20	13.37655571	123.7187725	0.31	0.3	0.01	STY Reming 2006	5-Year
21	13.37575534	123.7191819	0.39	0.1	0.29		5-Year
22	13.3755848	123.7189809	0.38	0.1	0.28	STY Reming 2006	5-Year
23	13.37562665	123.7188664	0.17	0.6	-0.43	STY Reming 2006	5-Year
24	13.37555622	123.7188872	0.28	0.1	0.18	TY Juaning 2011	5-Year
25	13.37373592	123.7182183	0.08	0	0.08	TY Juaning 2011	5-Year
26	13.37262604	123.7173203	0.41	0.7	-0.29	STY Reming 2006	5-Year
27	13.37201309	123.7165143	0.12	0.1	0.02	STY Reming 2006	5-Year
28	13.37200982	123.7165142	0.12	0.1	0.02	STY Reming 2006	5-Year
29	13.37159313	123.725603	0.33	0	0.33	STY Reming 2006	5-Year
30	13.37107976	123.7225272	0.14	0.3	-0.16	STY Reming 2006	5-Year
31	13.37187996	123.7220882	0.18	0.6	-0.42	STY Reming 2006, TY Juaning 2011	5-Year
32	13.37602213	123.7218053	0.41	0.9	-0.49	STY Reming 2006	5-Year
33	13.38070445	123.7228939	0.1	0	0.1		5-Year
34	13.38106565	123.7235247	0.41	1.4	-0.99	STY Reming 2006	5-Year
35	13.381078	123.7235359	0.41	0.25	0.16	TY Juaning 2011	5-Year
36	13.38081212	123.7230382	0.03	1.1	-1.07	TY Glenda 2014	5-Year
37	13.38069254	123.7164633	0.19	0.2	-0.01	STY Reming 2006	5-Year
38	13.38285714	123.7140471	0.11	0	0.11	TY Juaning 2011	5-Year
39	13.39030502	123.7118424	0.03	0	0.03	TY Juaning 2011	5-Year
40	13.3911627	123.7127479	0.03	0	0.03	TY Juaning 2011	5-Year
41	13.39224201	123.7119373	0.03	0	0.03	TY Juaning 2011	5-Year
42	13.39321862	123.7112372	0.11	0.5	-0.39	TY Juaning 2011	5-Year

43	13.39317268	123.7113222	0.06	0.4	-0.34	TY Juaning 2011	5-Year
44	13.38878415	123.7095943	0.03	1.1	-1.07	TY Juaning 2011	5-Year

Annex 12. Educational Institutions Affected by Flooding in Guinale Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Guinale Floodplain

Albay				
Malinao				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Awang Elementary School and Day Care Center	Awang		Low	Low
Labnig National High School	Awang			
Balza Elementary School	Bagumbayan	Medium	Medium	Medium
Malinao Central School	Bagumbayan	Low	Medium	Medium
Malinao High School	Bagumbayan	Low	Medium	Medium
Malinao Institute of Technology	Bagumbayan		Low	Low
Balading Day Care Center	Balading			
Balading Elementary School	Balading			
Balading Elementary School Extension	Balading			
Malinao High School	Balza		Low	Medium
Bariw Elementary School	Bariw		Low	Low
Baybay Day Care Center	Baybay		Low	Medium
Baybay Elementary School	Baybay		Medium	Medium
Burabod Elementary School	Cabunturan		Low	Low
Comun Elementary School	Comun			
Labnig Barangay Health Center	Diaro			
Estancia Day Care Center	Estancia			
Estancia Elementary School	Estancia			
Estancia High School	Estancia			
Jonop Elementary School	Jonop			
Labnig Barangay Health Center	Labnig			
Labnig Elementary School	Labnig	Low	Low	Low
Labnig National High School	Labnig			
Libod Day Care Center	Libod		Low	Low
Libod Elementary School	Libod	Medium	Medium	Medium
Malolos Day Care Center	Malolos			Low
Malolos Elementary School	Malolos			
Matalipni Elementary School	Matalipni	Low	Low	Low
Pawa Day Care Center	Pawa			
Malinao Institute of Technology	Payahan			Low
Malinao Institute of Technology	Poblacion			Low
Sugcad Elementary School	Sugcad			
Sugcad High School	Sugcad			
Sta. Elena Elementary School	Tagoytoy	Low	Low	Low
Tagoytoy Elementary School	Tagoytoy	Low	Low	Low
Tanawan Elementary School	Tanawan	Low	Low	Medium
Tuliw Day Care Center	Tuliw	Low	Low	Low
Tuliw Elementary School	Tuliw			

Tabaco City				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Bantayan Elementary School	Bantayan			Low
Bantayan National High School	Bantayan			
Bantayan National High School Extension	Bantayan			
San Antonio National High School	Basagan			
Comun Elementary School	Quinastillojan			
Quinastillojan Elementary School	Quinastillojan			
San Antonio Day Care Center	San Antonio			Low
San Antonio Elementary School	San Antonio	Low	Low	Low
San Antonio National High School	San Antonio			
San Vicente Day Care Center	San Vicente			
San Vicente Elementary School	San Vicente	Low	Low	Low
San Carlos Elementary School	Tayhi	Low	Low	Low

Annex 13. Medical Institutions Affected by Flooding in Guinale Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Guinale Floodplain

Albay				
Malinao				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Lianko's Medical Clinic	Bagumbayan	Medium	Medium	Medium
Malinao Health Center	Bagumbayan			Low
Balading Health Center	Balading			
Balza Health Center	Balza			
Cabunturan Health Center	Cabunturan	Low	Medium	Medium
Malinao Treatment and Rehab Center	Comun	Low	Low	Low
Matalipni Barangay Health Center	Matalipni	Low	Medium	Medium
Brgy. Sta. Elena Health Center	Santa Elena			
Tanawan Barangay Health Center	Tanawan	Medium	Medium	High
Tabaco City				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Quinastillojan Barangay Health Center	Quinastillojan			
Mnab Lying in and Medical Clinic	San Antonio			