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

LiDAR Surveys and Flood Mapping of Cangaranan River

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for Applied Geodesy and Photogrammetry
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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CANGARANAN RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program 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 University of the Philippines Cebu (UPC). UPC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the twenty-two (22) river basins in the Western Visayas region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Cangaranan River Basin

The Cangaranan River Basin is located in the province of Antique, located at the west of the Panay Island. The floodplain area and drainage area of 51.23 km2 and 35.443 km2, respectively, cover the Municipalities of Bugasong, Tapaz, Lambunao, and Valderrama in Antique.

The Department of Environment and Natural Resources (DENR) River Basin Control Office (RBCO) identified Cangaranan as one of the four hundred and twenty-one (421) river basins in the Philippines, having a drainage area of 294 km2 and an estimated 374 million cubic meter annual run-off. It is also one of the seven (7) major river basins in the province of Antique.

The basin's main stem, the Cangaranan River, passes along the Municipalities of Valderrama and Bugasong. The Cangaranan River is among of the twenty-three (23) river systems in the Western Visayas Region.

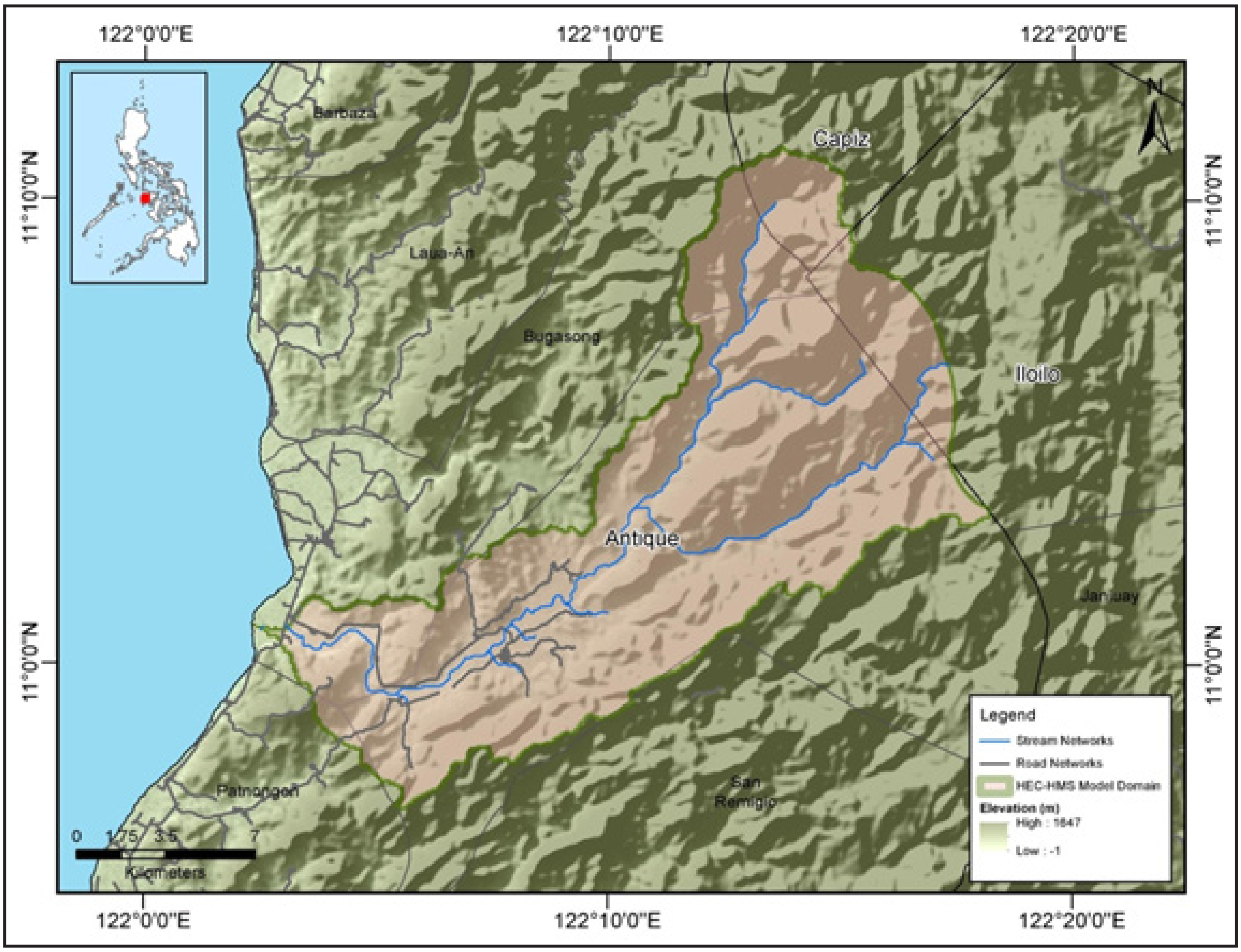

Figure 1. Location map of the Cangaranan River Basin (in brown)

The population of residents within the immediate vicinity of the river is around 11,175 people, distributed among nine (9) barangays: Pandanan, Ubos, Igmasandig, and Tigmamale in the Municipality of Valderrama; and Bagtason, Arangote, Igbalangao, Zaragoza, and Ilaures in the Municipality of Bugasong (NSO, 2010).

The riverbed is rich in good quality gravel and sand, which are extracted by local private quarry companies, and exported abroad (Guntan, 2015).

The most dreadful flooding event that occurred in the province was during the landfall of Typhoon Frank in 2008. Locals and officials claim that the flood water level reached around 2 meters, in MSL value, in their communities.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CANGARANAN FLOODPLAIN

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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 Cangaranan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Antique and Iloilo. These missions were planned for fourteen (14) lines and ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Gemini and Pegasus LiDAR systems were used for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR systems are found in Table 1 and Table 2. Figure 2 illustrates the flight plans and base stations used for the Cangaranan floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK43 B	1000	30	50	100	50	120	5
BLK43 C	1000	30	50	100	50	120	5

Table 2. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK43B	1500	30	50	200	30	130	5
BLK43 D	1500	30	50	200	30	130	5
BLK43 E	1500	30	50	200	30	130	5
BLK43 F	1500	30	50	200	30	130	5

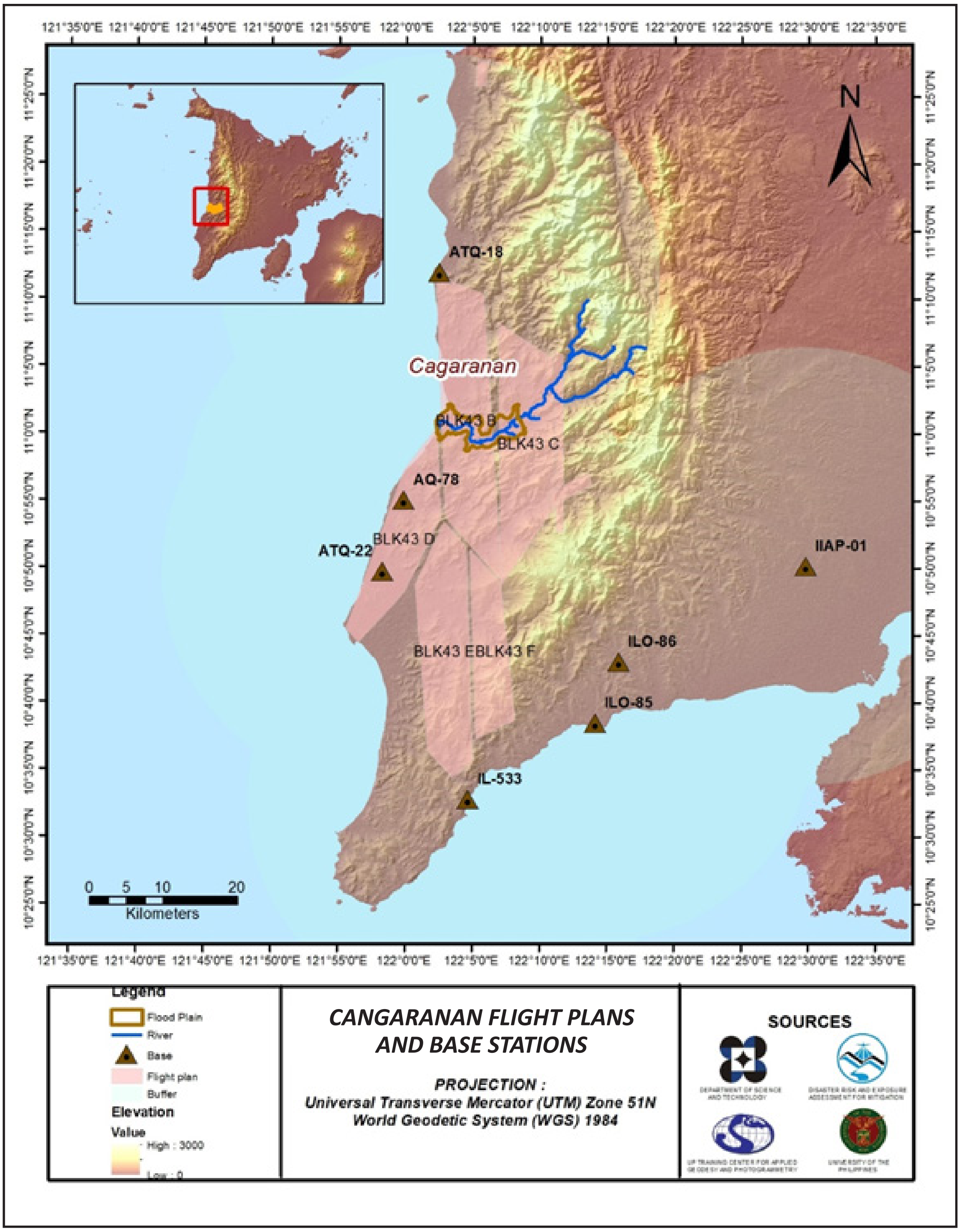


Figure 2. Flight plans and base stations used to cover the Cangaranan floodplain

2.2 Ground Base Stations

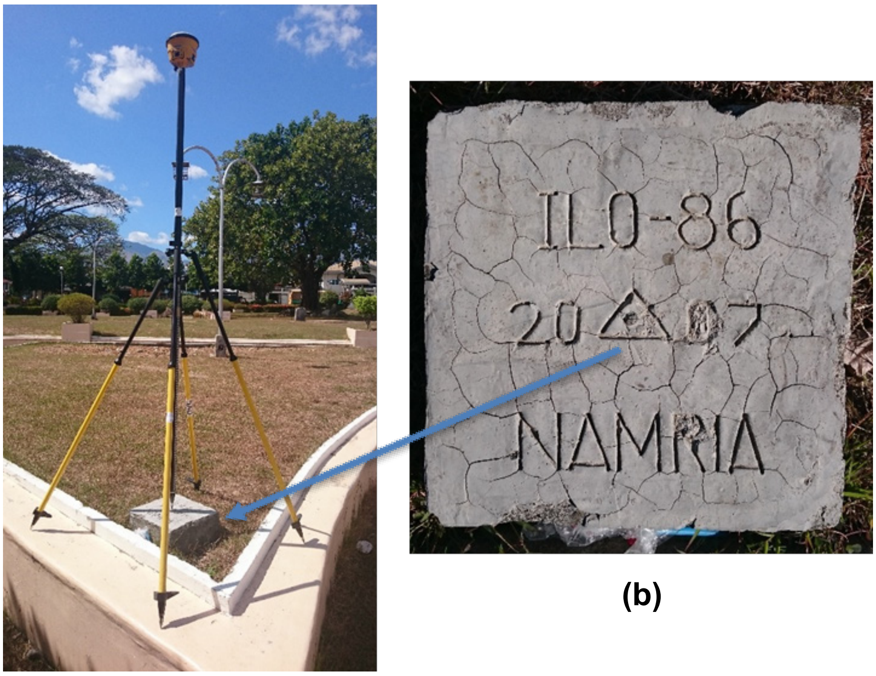
The field team for this undertaking was able to recover four (4) NAMRIA reference points: ILO-85, ILO-86, ATQ-18, and ATQ-22, which are all of second (2nd) order accuracy. The field team also re-established two (2) ground control points: IL-533 and AQ-78, which are NAMRIA reference points of third (3rd) order accuracy. One (1) NAMRIA benchmark was recovered, IIAP-01, which is of second (2nd) order accuracy. These benchmarks were used as vertical reference points, and were also established as ground control points. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2, and the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey, held in February 2015. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. The flight plans and locations of the base stations used during the aerial LiDAR acquisition in the Cangaranan floodplain are presented in Figure 2. The composition of the full project team is shown in Annex 4.

Figure 3 to Figure 9 exhibit the recovered NAMRIA control stations within the area. Table 3 to Table 9 provide the details about the NAMRIA control stations and established points, and Table 10 lists all the ground control points occupied during the acquisition, with the corresponding dates utilization.

Figure 3. (a) GCP set-up over ILO-85, located at the Town Plaza in Miag-ao, Iloilo; and (b) NAMRIA reference point ILO-85, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ILO-85, used as a base station for the LiDAR acquisition

Station Name	ILO-85	
Order of Accuracy	2nd Order	
Relative Error (Horizontal positioning)	1:20000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 38’ 33.11352” 122° 14’ 3.70560” 21.96200m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	416226.997m 1176896.034m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 38’ 28.75996” 122° 14’ 8.93597” 78.82800m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	416256.32m 1176484.10m



(b)

(a)

Figure 4. (a) GCP set-up over ILO-86 in Barangay Poblacion, Igbaras, Province of Iloilo; and (b) NAMRIA reference point ILO-86, as recovered by the field team

Table 4. Details of the recovered NAMRIA vertical control point ILO-86, used as a base station for the LiDAR acquisition

Station Name	**ILO-86**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 43’ 04.36044” 122° 15’ 48.62123” 47.315 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 4 PRS 92)	Easting Northing	419306.197 meters 1185284.087 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 42’ 59.99043” North 122° 15’ 53.84473” East 104.076 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	419463.955 meters 1184807.437 meters

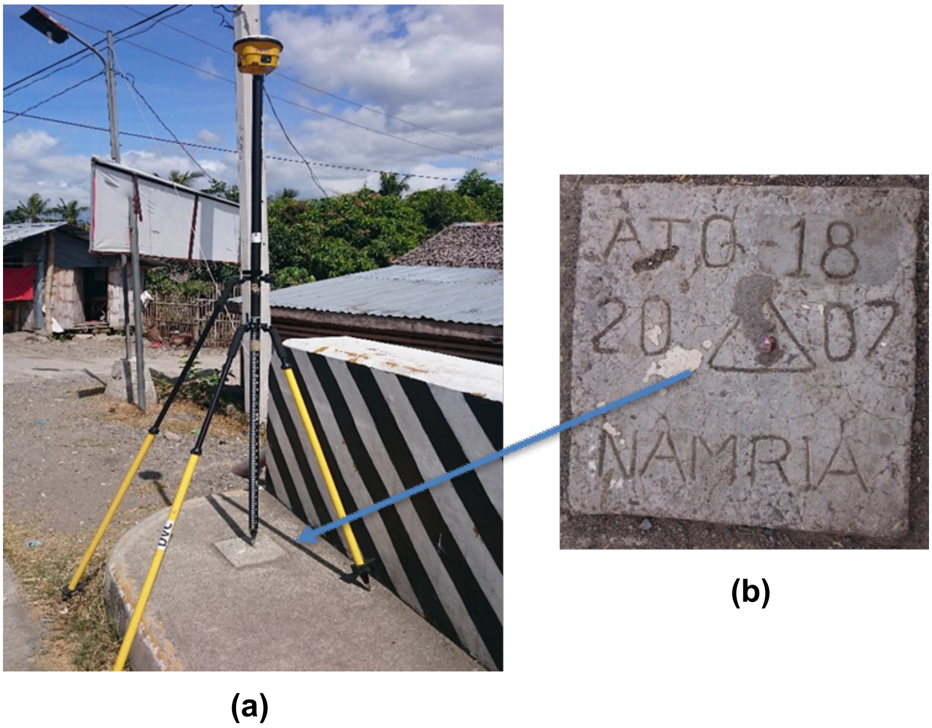
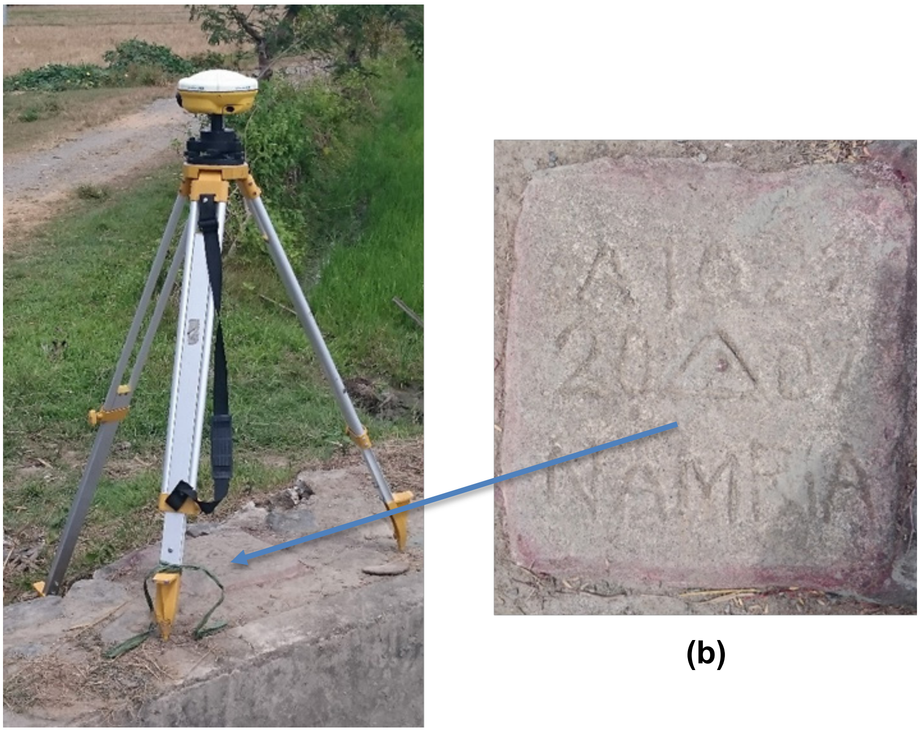


Figure 5. (a) GCP set-up over ATQ-18 in Barangay Cubay, Barbaza, Province of Antique; and (b) NAMRIA reference point ATQ-18, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point ATQ-18, used as a base station for the LiDAR acquisition

Station Name	ATQ-18	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 11’ 58.67081” 122° 2’ 22.83300” 10.902 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	395155.157 meters 1238579.674 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 11’ 54.16068” North 122° 2’ 28.01549” East 65.961 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	395155.87 meters 1238146.15 meters

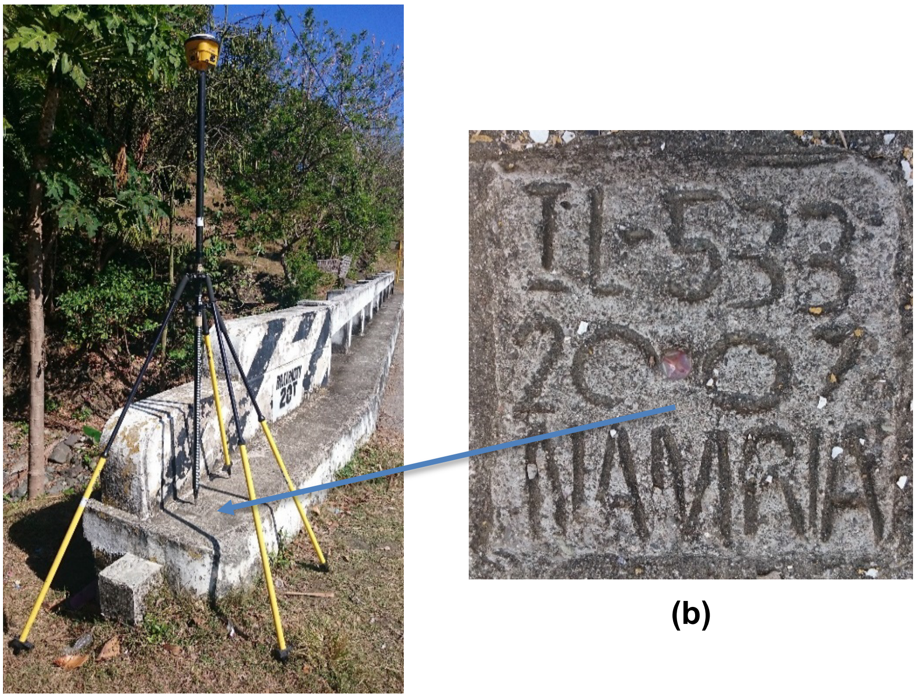


(a) (b)

Figure 6 . (a) GPS set-up over ATQ-22 in Barangay Concepcion, Belison, Province of Antique; and (b) NAMRIA reference point ATQ-22, as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point ATQ-22, used as a base station for the LiDAR acquisition

Station Name	**ATQ-22**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 49' 46.66618" 121° 58' 11.90221" 12.250 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	387365.279 meters 1197676.056 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49' 42.24271" North 121° 58' 17.11770" East 68.022 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	387404.70 meters 1197256.85 meters



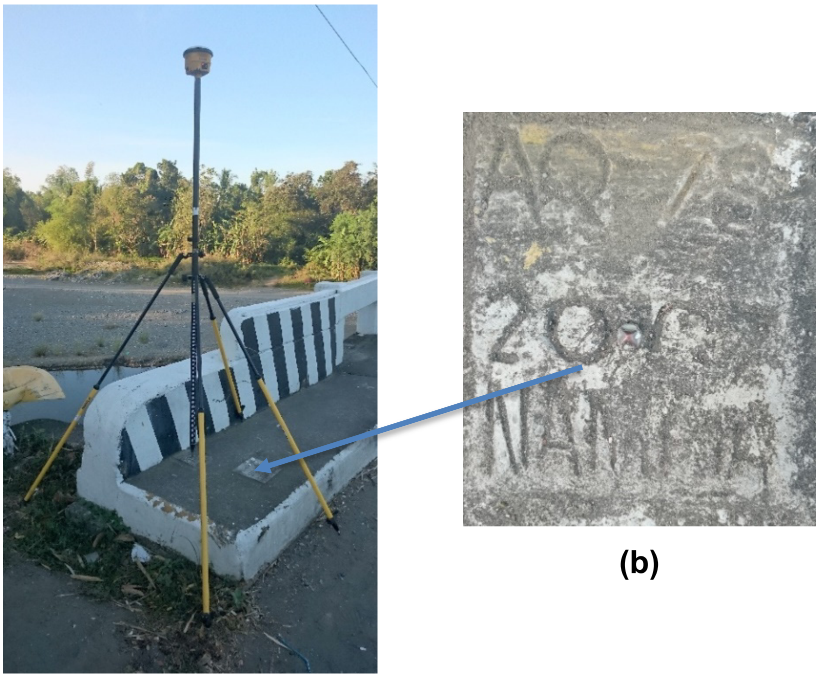
(b)

(a)

Figure 7. (a) GPS set-up over IL-533 in Barangay Amboyu-an, San Joaquin, Province of Iloilo; and (b) NAMRIA reference point IL-533, as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point ATQ-22, used as a base station for the LiDAR acquisition

Station Name	**IL-533**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 32’ 49.29908” 122° 04’ 37.25566” 51.412 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	398848.891 meters 1166439.919 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 32’ 44.95602” North 122° 04’ 42.49544” East 64.135 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	387404.70 meters 1165970.645 meters



(b)

(a)

Figure 8. (a) GPS set-up over AQ-78 in Barangay Ipayo, Patnongon, Province of Antique; and (b) NAMRIA reference point AQ-78, as recovered by the field team

Table 8. Details of the recovered NAMRIA horizontal control point AQ-78, used as a base station for the LiDAR acquisition

Station Name	**AQ-78**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 55' 03.77330" 121° 59' 46.81987" 48.448 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	390150.425 meters 1207471.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 54' 59.33002" North 121° 59' 52.02741" East 66.5525 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	390319.320 meters 1206987.603 meters

Table 9. Details of IIAP-01 GCP, used as a base station for the LiDAR acquisition

Station Name	**IIAP-01**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 50’ 08.21923” 122° 29’ 48.82359” 43.390 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	445007.365 m 1197773.97 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 50’ 03.83971” 122° 29’ 54.03518” 100.449 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	445007.365 m 1197773.97 m

Table 10. Ground Control Points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
14 FEB 15	2569P	1BLK43D045A	IIAP-01 and ILO-85
17 FEB 15	2583P	1BLK43D048B	ILO-85 and IL-533
18 FEB 15	2587P	1BLK43ED049B	ILO-85 and ILO-86
19 FEB 15	2589P	1BLK43EFD050A	ILO-85 and ILO-86
20 FEB 15	2593P	1BLK43BDG051A	ATQ-18 and ATQ-22
23 FEB 15	2594G	2BLK43C054A	ATQ-22 and AQ-78
25 FEB 15	2602G	2BLK43B056A	ATQ-22 and AQ-78
26 FEB 15	2606G	2BLK43BV057A	ATQ-22 and AQ-78
27 FEB 15	2610G	2BLK43BV058A	ATQ-22 and AQ-78

2.3 Flight Missions

A total of nine (9) missions were conducted to complete the LiDAR data acquisition in the Cangaranan floodplain, for a total of thirty-two hours and nine minutes (32+9) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus and Gemini LiDAR systems. Annex 6 presents the flight logs of the missions. Table 11 indicates the total area of actual coverage per mission and the corresponding flying hours for each mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for the LiDAR data acquisition in the Cangaranan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
14 FEB 15	2569P	248.27	78.21	0.19	78.02	69	3	39
17 FEB 15	2583P	248.27	114.06	5.90	108.16	253	2	53
18 FEB 15	2587P	352.53	153.08	-	153.08	338	3	47
19 FEB 15	2589P	459.17	132.26	-	132.26	261	3	41
20 FEB 15	2593P	398.78	20.02	-	20.02	427	3	29
23 FEB 15	2594G	223.80	254.86	9.99	244.87	391	4	23
25 FEB 15	2602G	248.27	89.82	13.01	76.81	119	3	17
26 FEB 15	2606G	248.27	221.78	17.68	204.10	319	4	05
27 FEB 15	2610G	248.27	34.35	0.78	33.57	46	3	05
TOTAL		931.24	1098.44	47.55	1050.89	2223	32	09

Table 12. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2569P	2000	30	50	200	50	120	5
2583P	2000	30	50	200	50	120	5
2587P	2000	30	50	200	50	120	5
2589P	2000	30	50	200	50	120	5
2593P	2000	30	50	200	50	120	5
2594G	1500	30	20	70	50	125	5
2602G	1500	30	34	70	56	125	5
2606G	1500	30	34	70	56	125	5
2610G	1500	30	34	70	56	125	5

2.4 Survey Coverage

The Cangaranan floodplain is located in the provinces of Antique and Iloilo, with majority of the floodplain situated within the Municipalities of Bugasong and Valderrama in Antique. The Municipalities of Patnongon and Belison were mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Cangaranan floodplain is presented in Figure 10. The flight status reports are found in Annex 7.

Table 8. The list of municipalities and cities surveyed of the Cangaranan Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Masbate	Patnongon	135.69	133.57	98%
	Belison	36.8	34.45	93%
	San Jose	44.26	39.74	89%
	Bugasong	178.8	109.14	61%
	Laua-An	165.65	86.56	52%
	San Remigio	370.9	177.63	48%
	Valderrama	309.67	119.61	39%
	Sibalom	240.55	72.57	30%
	Hamtic	139.85	22.58	16%
	Barbaza	171.23	14.34	8%
Iloilo	San Joaquin	200.06	54.61	27%
	Igbaras	132.37	8.04	6%
	Miagao	170.53	3.12	2%
TOTAL		2,296.36	875.96	38.15%

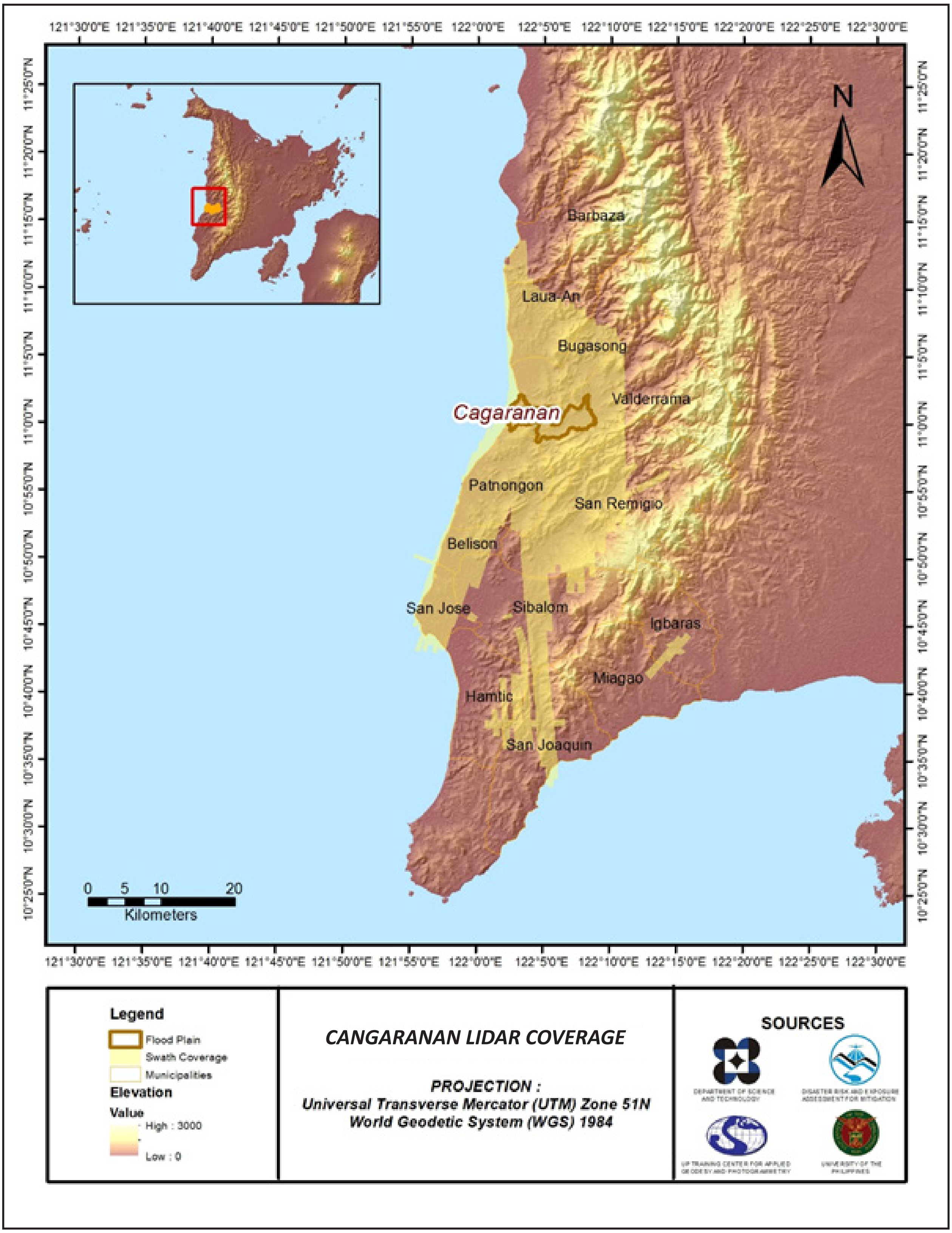


Figure 9. Actual LiDAR survey coverage of the Cangaranan floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE CANGARANAN 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 the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

Using the elevation of points gathered from 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 shown in Figure 10.

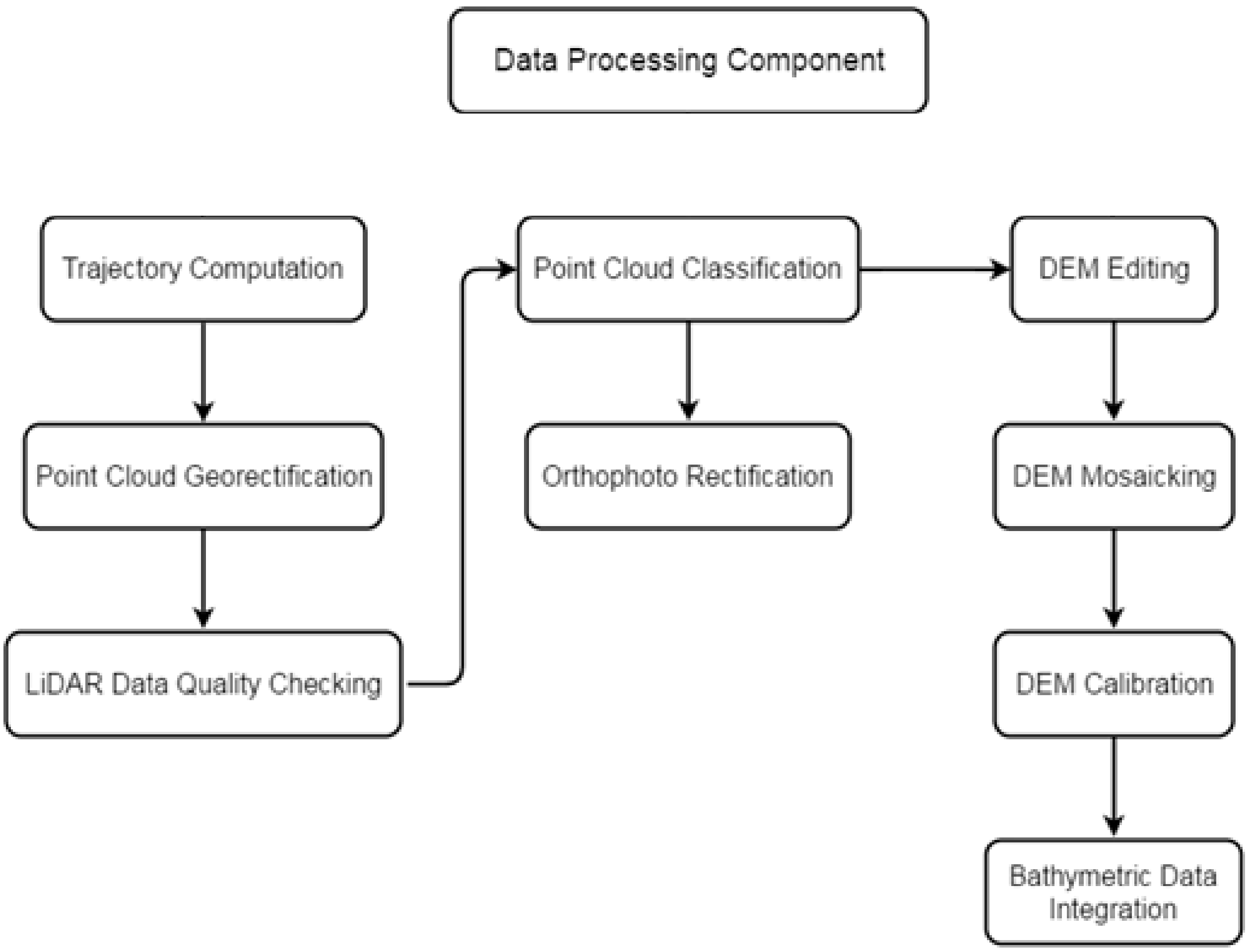


Figure 10. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Cangaranan floodplain can be found in Annex 5. Missions flown during the first survey conducted in March 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system; while missions acquired during the second survey in July 2015 were flown using the Gemini system over Valderrama, Antique.

The Data Acquisition Component (DAC) transferred a total of 109.6 Gigabytes of Range data, 1.974 Gigabytes of POS data, 105.15 Megabytes of GPS base station data, and 151.32 Gigabytes of raw image data to the data server on March 23, 2015 for the first survey, and on July 3, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Cangaranan floodplain survey was fully transferred on July 3, 2015, as indicated on the data transfer sheets for the Cangaranan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2589P, one of the Cangaranan flights, which are the North, East, and Down position RMSE values are illustrated in Figure 11. The x-axis corresponds to the time of flight, measured by the number of seconds from the midnight of the start of the GPS week, which fell on February 19, 2015 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

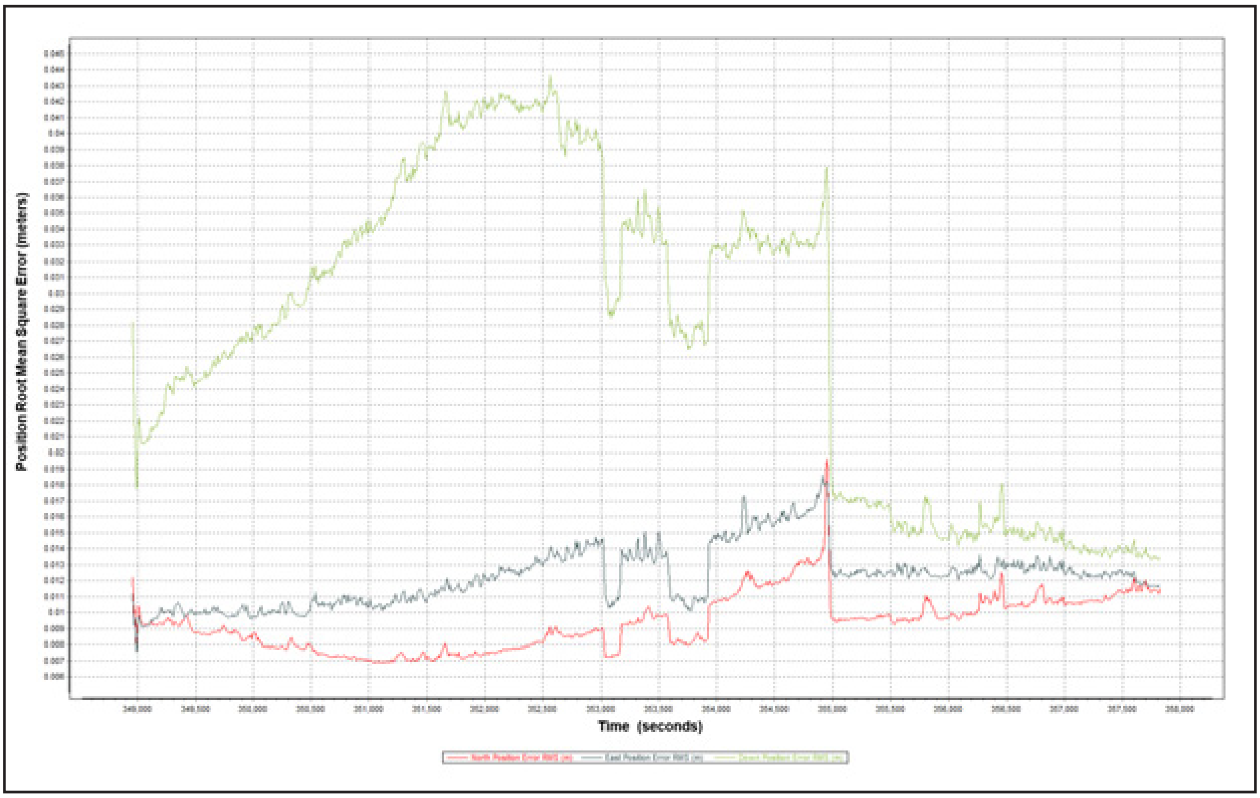


Figure 11. Smoothed Performance Metrics of a Cangaranan Flight 2589P

The time of flight was from 349000 seconds to 358000 seconds, which corresponds to the afternoon of February 19, 2015. 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 corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 depicts that the North position RMSE peaked at 2.00 centimeters, the East position RMSE peaked at 1.90 centimeters, and the Down position RMSE peaked at 4.40 centimeters, which are all within the prescribed accuracies described in the methodology.

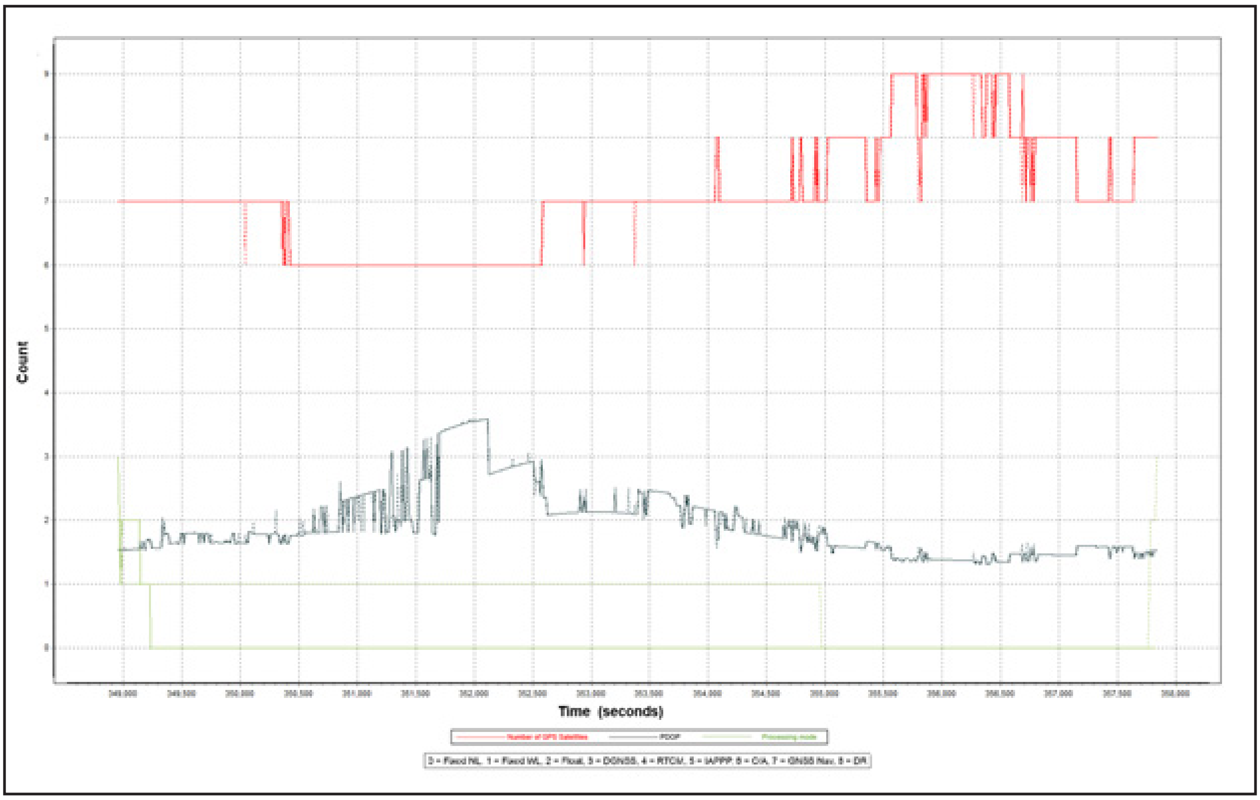


Figure 12. Solution Status Parameters of a Cangaranan Flight 2589P

The Solution Status parameters of flight 2589P, one of the Cangaranan flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are exhibited in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to six (6). Most of the time, the number of satellites tracked was between six (6) and nine (9). The PDOP value also did not go above the value of 3.6, which indicates optimal GPS geometry. The processing mode remained at zero (0) for majority of the survey, with some peaks to up to one (1), 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 Cangaranan flights is shown in Figure 13.

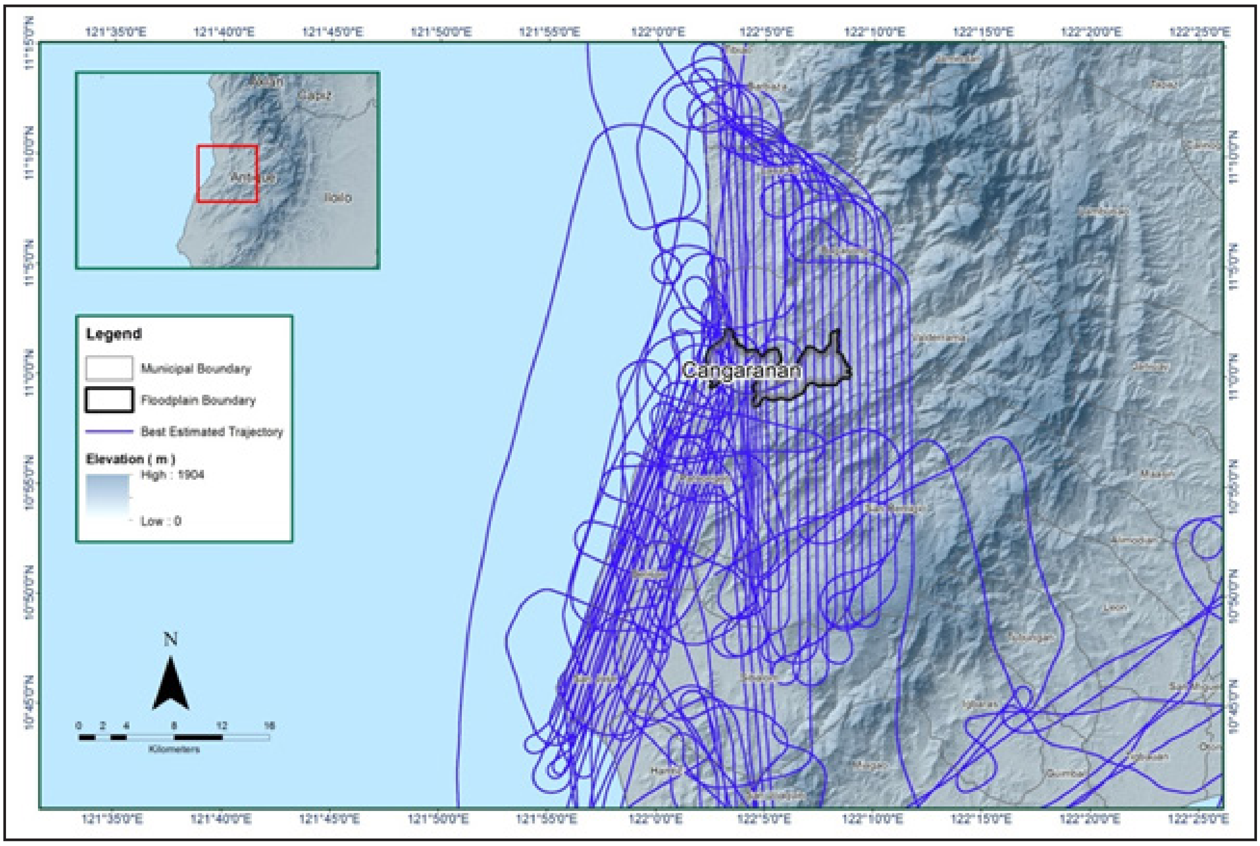


Figure 13. The best estimated trajectory conducted over the Cangaranan Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains fifty-four (54) flight lines, with twenty-seven (27) flight lines containing two (2) channels and the rest containing only one (1) channel; since the Pegasus system contains two (2) channels, and the Gemini system contains one (1) channel. The summary of the self-calibration results for all flights over Cangaranan floodplain, obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 14.

Table 14. Self-calibration results for the Cangaranan flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000326
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000943
GPS Position Z-correction stdev)	<0.01meters	0.0090

Optimum accuracy was obtained for all the Cangaranan flights, based on the computed standard deviations of the corrections of the orientation parameters. The 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 are represented in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

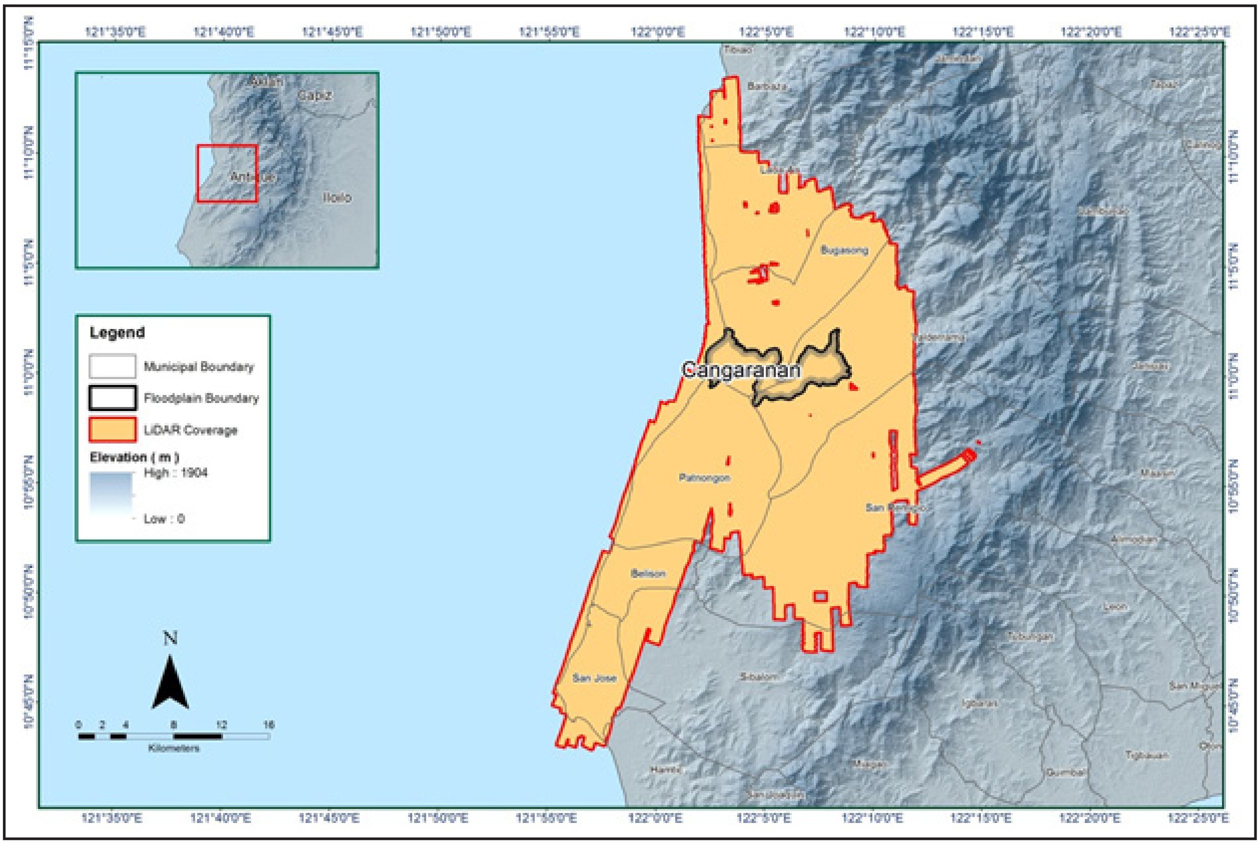


Figure 14. Boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Cangaranan Floodplain.

The total area covered by the Cangaranan missions is 835.72 sq. km., comprised of nine (9) flight acquisitions grouped and merged into four (4) blocks, as shown in Table 15.

Table 15. List of LiDAR blocks for the Cangaranan floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk43B	2593P	136.14
Iloilo_Blk43B_additional	2602G	226.06
	2606G	
	2610G	
Iloilo_Blk43C	2594G	261.60
Iloilo_Blk43D	2569P	211.95
	2583P	
	2587P	
	2589P	
	2593P	
TOTAL		835.72 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 15. Since the Gemini system employs one (1) channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. On the other hand, for the Pegasus system, which employs two (2) channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

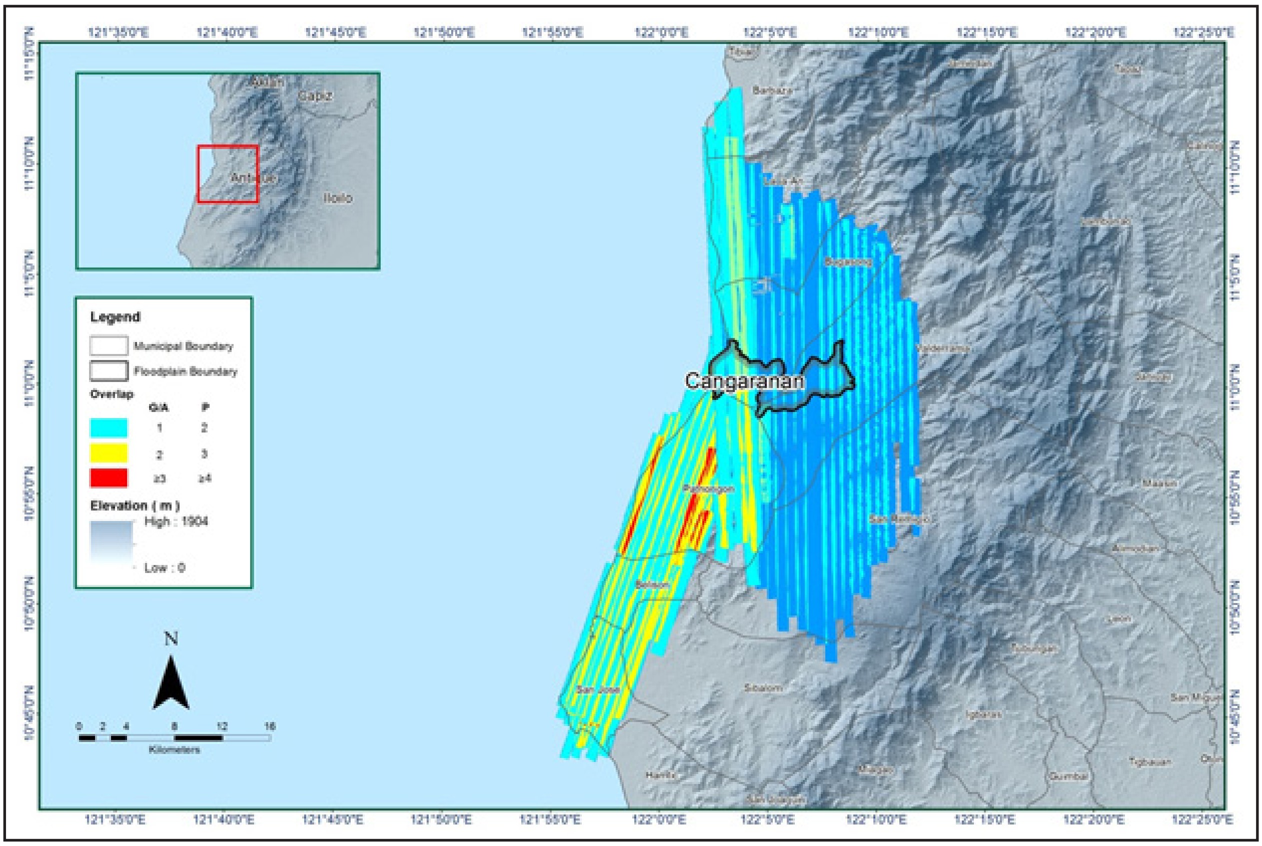


Figure 15. Image of data overlap for the Cangaranan Floodplain

The overlap statistics per block for the Cangaranan 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 are 25.93% and 42.59%, respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is illustrated in Figure 16. It was determined that all LiDAR data for the Cangaranan floodplain satisfy the point density requirement, and that the average density for the entire survey area is 2.62 points per square meter.

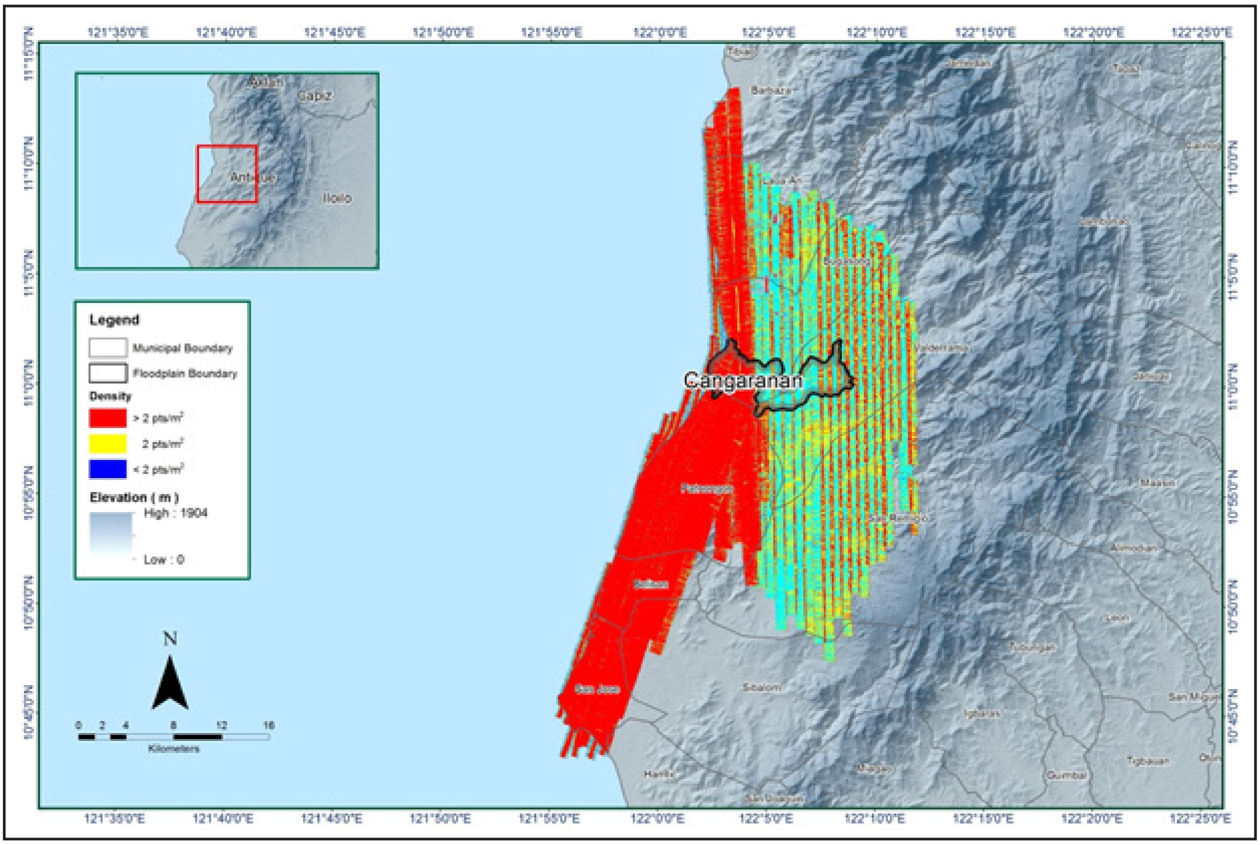


Figure 16. Pulse density map of merged LiDAR data for the Cangaranan Floodplain

The elevation difference between overlaps of adjacent flight lines is depicted in Figure 17. The default color range is from blue to red. Bright blue areas represent 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.

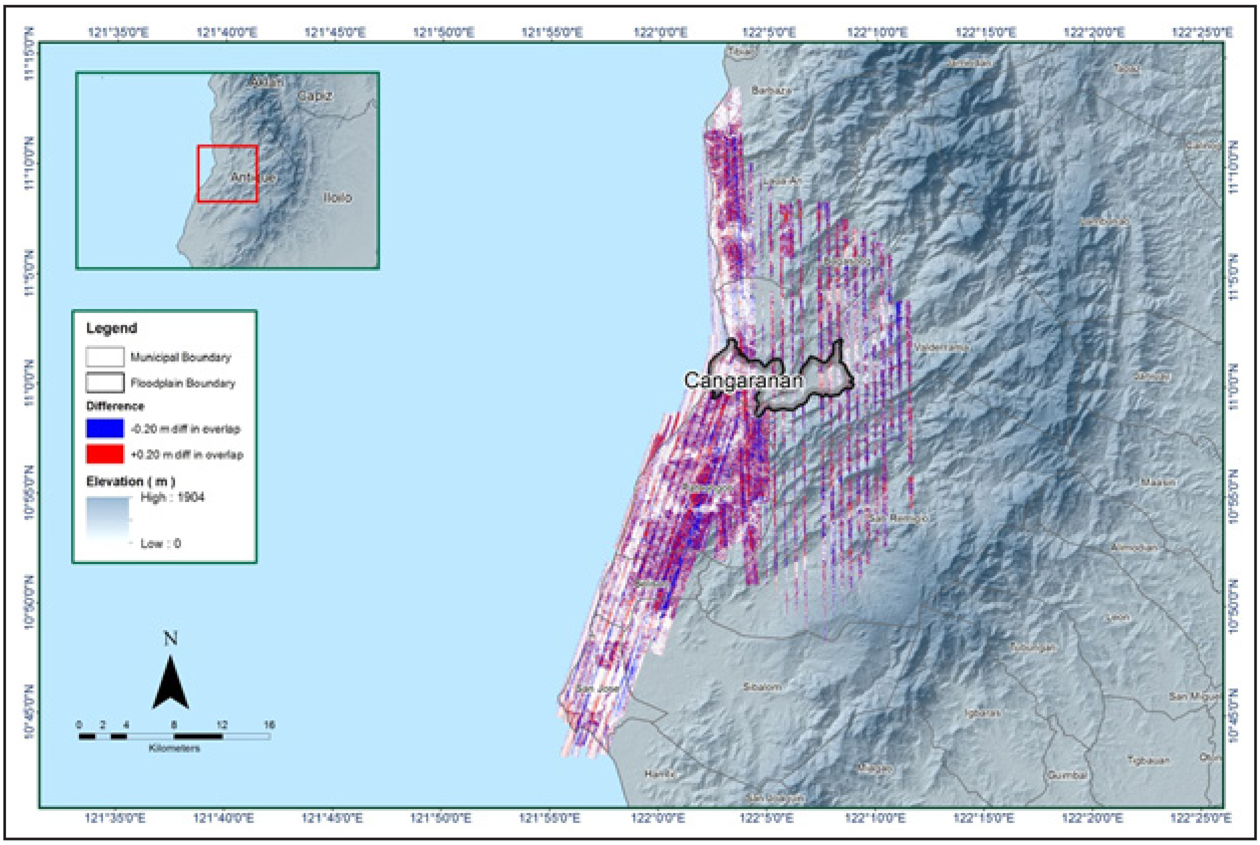


Figure 17. Elevation difference map between flight lines for the Cangaranan Floodplain

A screen capture of the processed LAS data from a Cangaranan flight 2589P loaded in the QT Modeler is presented in Figure 18. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow 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.

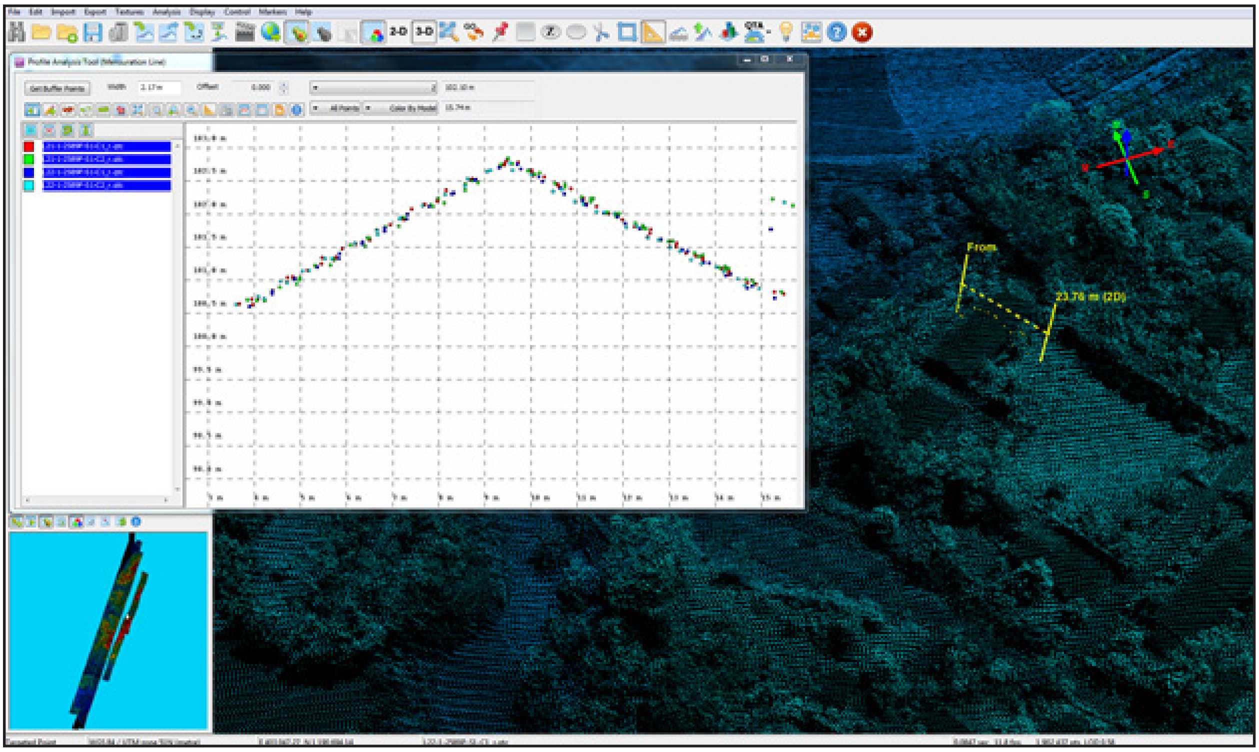


Figure 18. Quality checking for a Cangaranan flight 2589P, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Cangaranan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	706,244,913
Low Vegetation	374,993,936
Medium Vegetation	636,658,430
High Vegetation	826,678,482
Building	20,041,149

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Cangaranan floodplain, are exhibited in Figure 19. A total of 1,088 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 16. The point cloud had a maximum and minimum height of 1,015.40 meters and 52.12 meters, respectively.

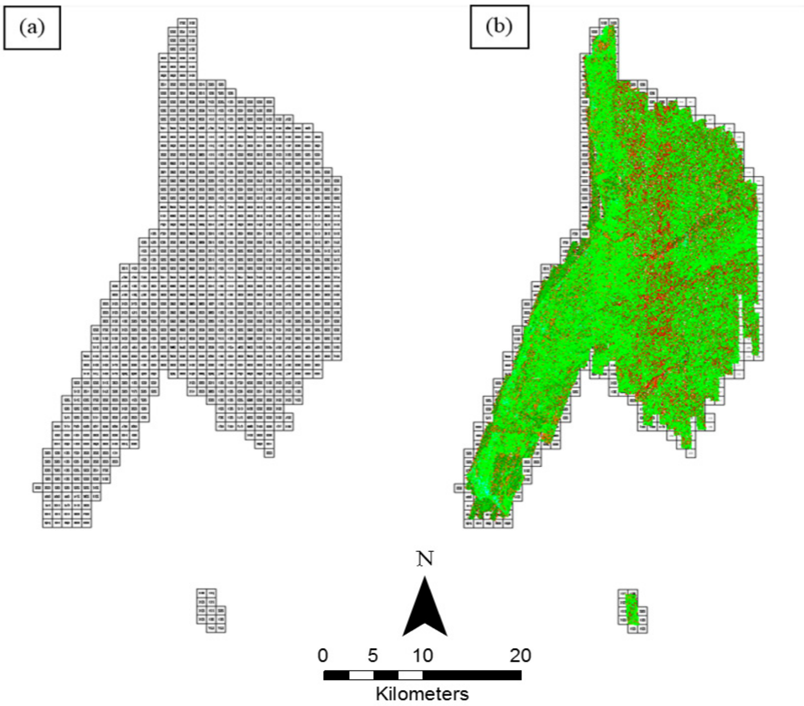


Figure 19. (a) Tiles for the Cangaranan Floodplain, and (b) the classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

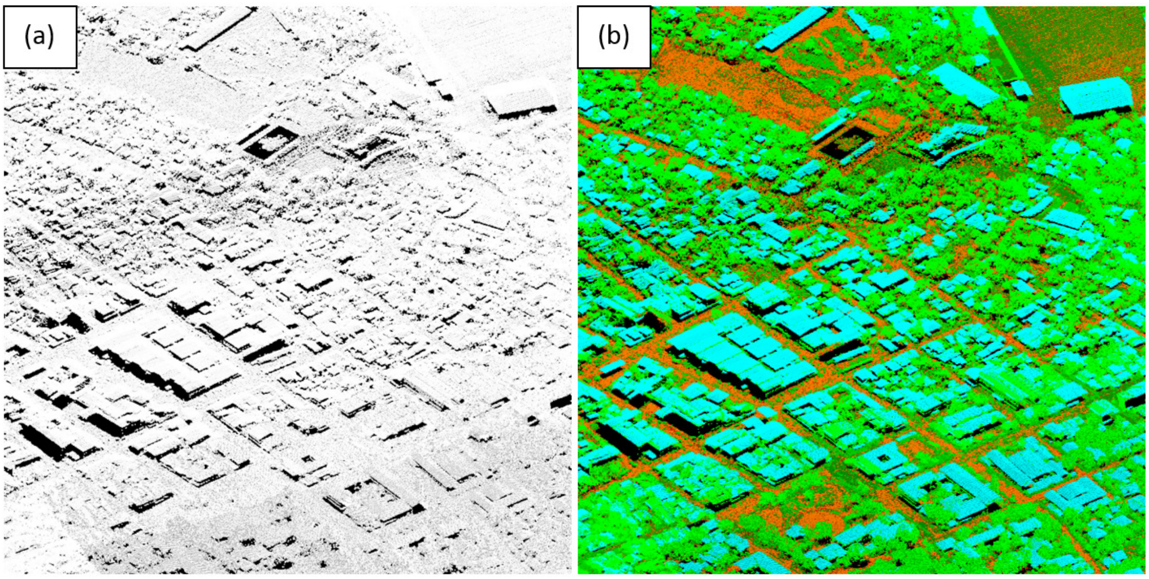


Figure 20. Point cloud before (a) and after (b) classification.

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 are illustrated in Figure 21, in top view display. It shows that DTMs are a representation of the bare earth; while the DSMs represent all features that are present, such as buildings and vegetation.

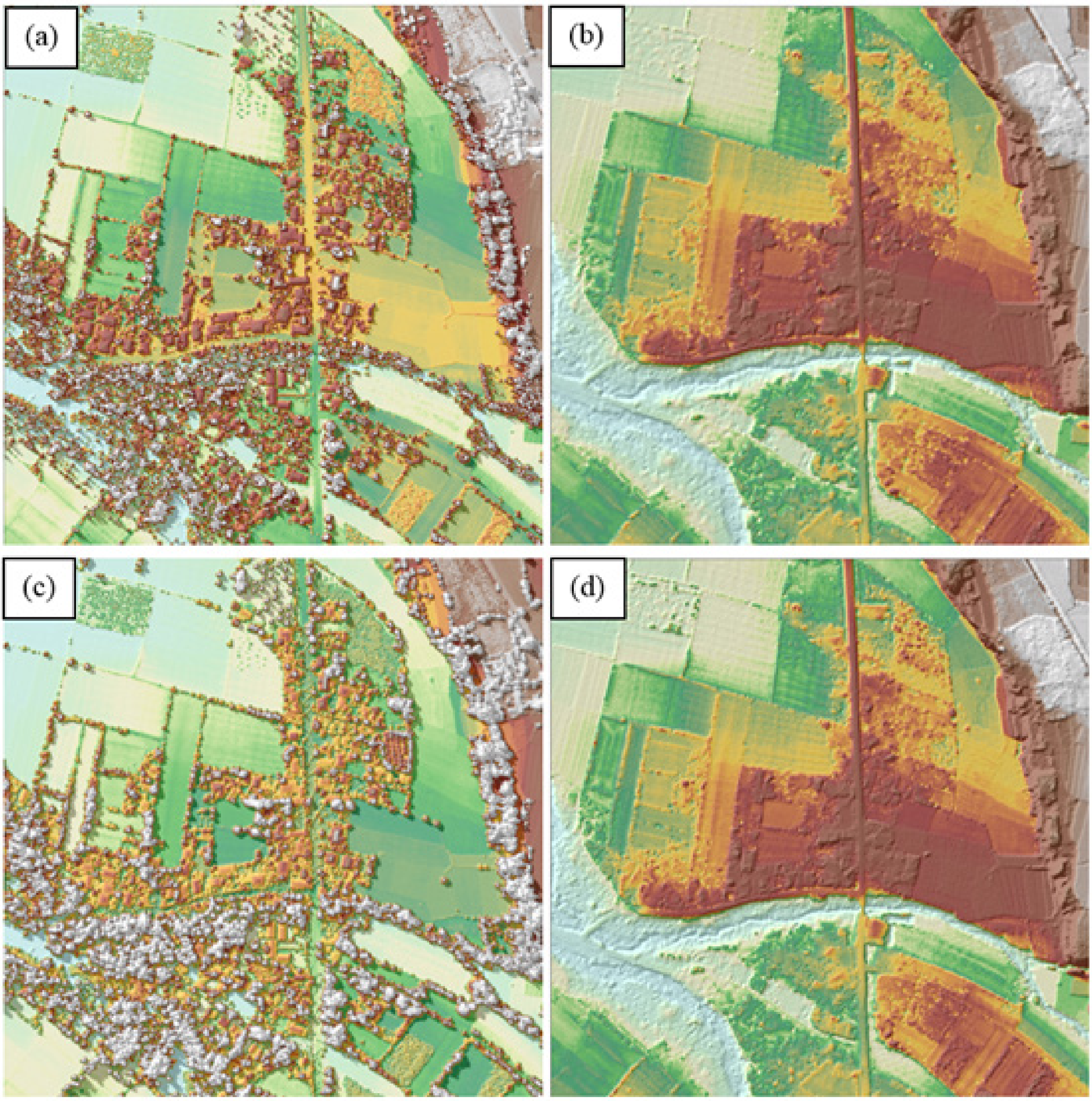


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of the Cangaranan Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,049 1km by 1km tiles area covered by the Cangaranan floodplain is shown in Figure 22. 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 Cangaranan floodplain survey attained a total of 207.45 sq. km. in orthophotographic coverage, comprised of 1,814 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 23.

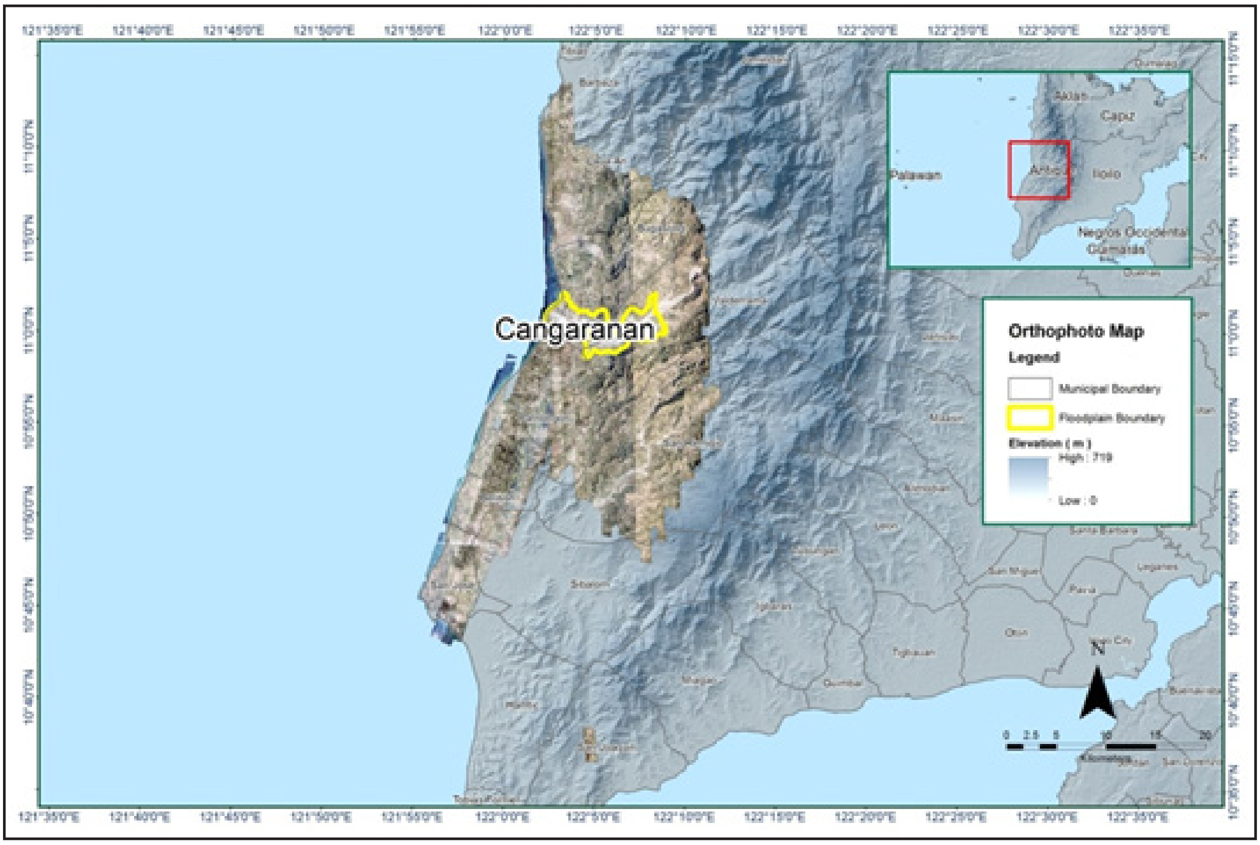


Figure 22. The Cangaranan Floodplain with available orthophotographs

Figure 23. Sample orthophotograph tiles for the Cangaranan Floodplain

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for the Cangaranan floodplain. These blocks are composed of Iloilo blocks, with a total area of 835.72 square kilometers. Table 17 indicates the name and corresponding area of each block, in square kilometers.

Table 17. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Iloilo_Blk43B	136.14
Iloilo_Blk43B_additional	226.06
Iloilo_Blk43C	261.60
Iloilo_Blk43D	211.92
TOTAL	835.72 sq.km

Portions of the DTM before and after manual editing are exhibited in Figure 24. It shows that the paddy field (Figure 24a) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 24b). The bridge (Figure 24c) would impede the flow of water along the river, and had to be removed (Figure 24d) in order to hydrologically correct the river. Another case is a road that was misclassified (Figure 24e), and had to be retrieved through manual editing (Figure 24f).

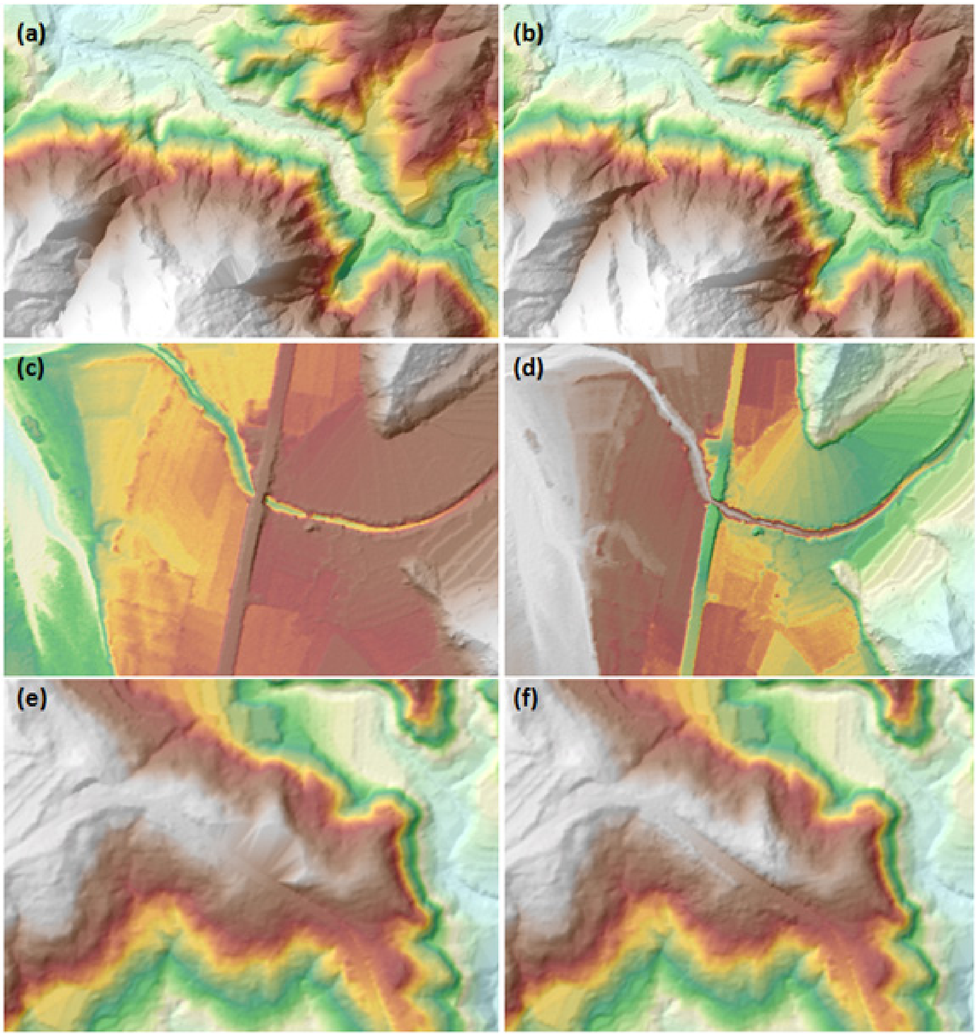


Figure 24. Portions in the DTM of the Cangaranan Floodplain – a paddy field (a) before and (b) after data retrieval; a bridge (c) before and (d) after manual editing ; and a road (e) before and (f) after data retrieval

3.9 Mosaicking of Blocks

The block Iloilo_Blk43B was used as the reference block at the start of mosaicking, because it was referred to a base station with an acceptable order of accuracy. Table 18 indicates the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for the Cangaranan floodplain is presented in Figure 25. It demonstrates that the entire Cangaranan floodplain is 100% covered by LiDAR data.

Table 18. Shift values of each LiDAR block of the Cangaranan Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_Blk43B	0.00	0.00	-1.42
Iloilo_Blk43B_additional (left portion)	0.00	0.00	-1.20
Iloilo_Blk43B_additional (right portion)	0.00	1.00	-1.27
Iloilo_Blk43C	0.00	2.00	-1.25
Iloilo_Blk43D	0.00	0.00	-1.23

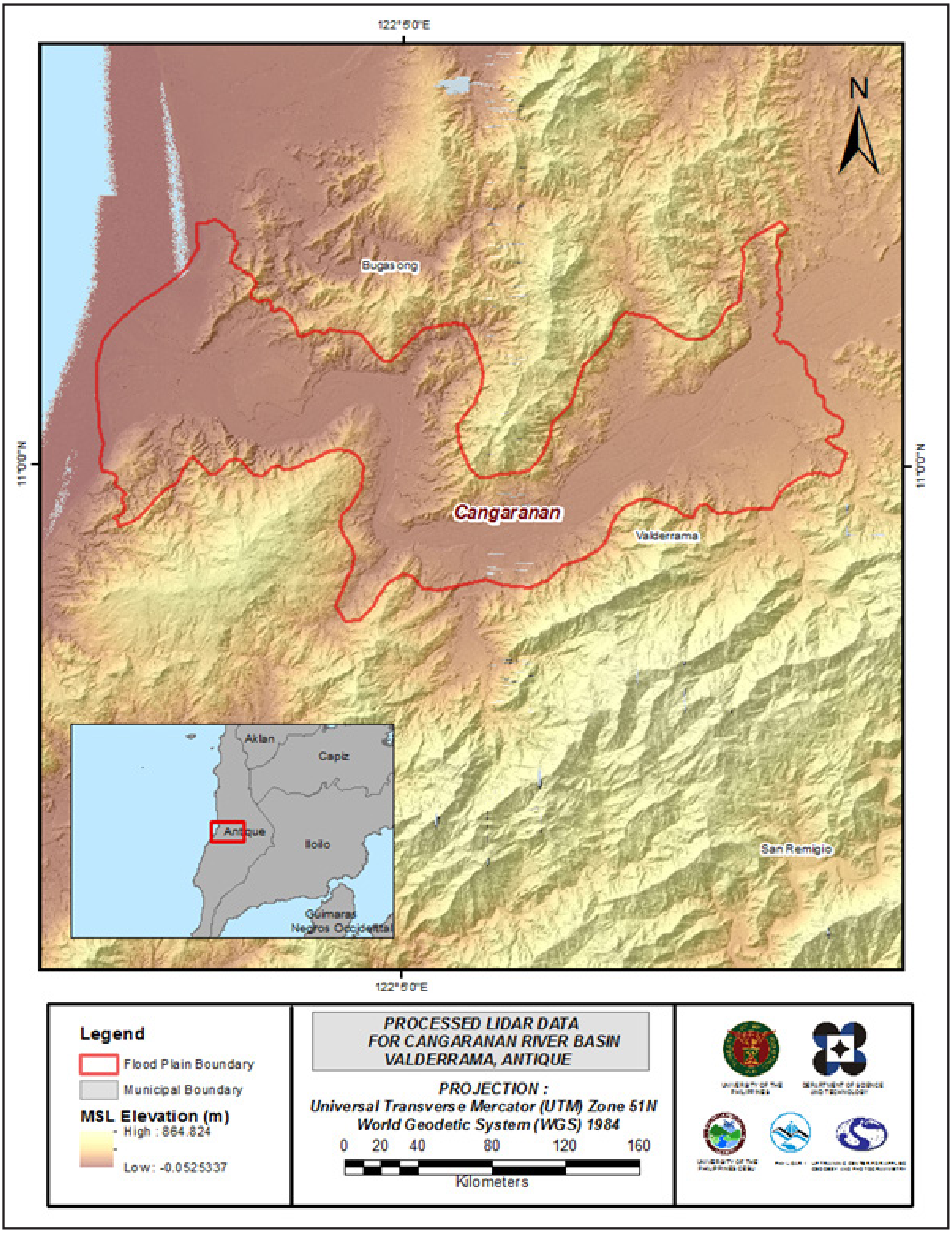


Figure 25. Map of processed LiDAR data for the Cangaranan Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Cangaranan to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 7511 points were gathered for all the floodplains within the Province of Antique wherein the Cangaranan is located. However, the point dataset was not used for the calibration of the LiDAR data for Cangaranan because during the mosaicking process, each LiDAR block was referred to the calibrated Jalaur DEM. Therefore, the mosaicked DEM of Cangaranan can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Jalaur LiDAR DTM and ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 1.71 meters with a standard deviation of 0.17 meters. Calibration of Jalaur LiDAR data was done by subtracting the height difference value, 1.71 meters, to Jalaur mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between Jalaur LiDAR data and calibration data. These values were also applicable to the Cangaranan DEM.

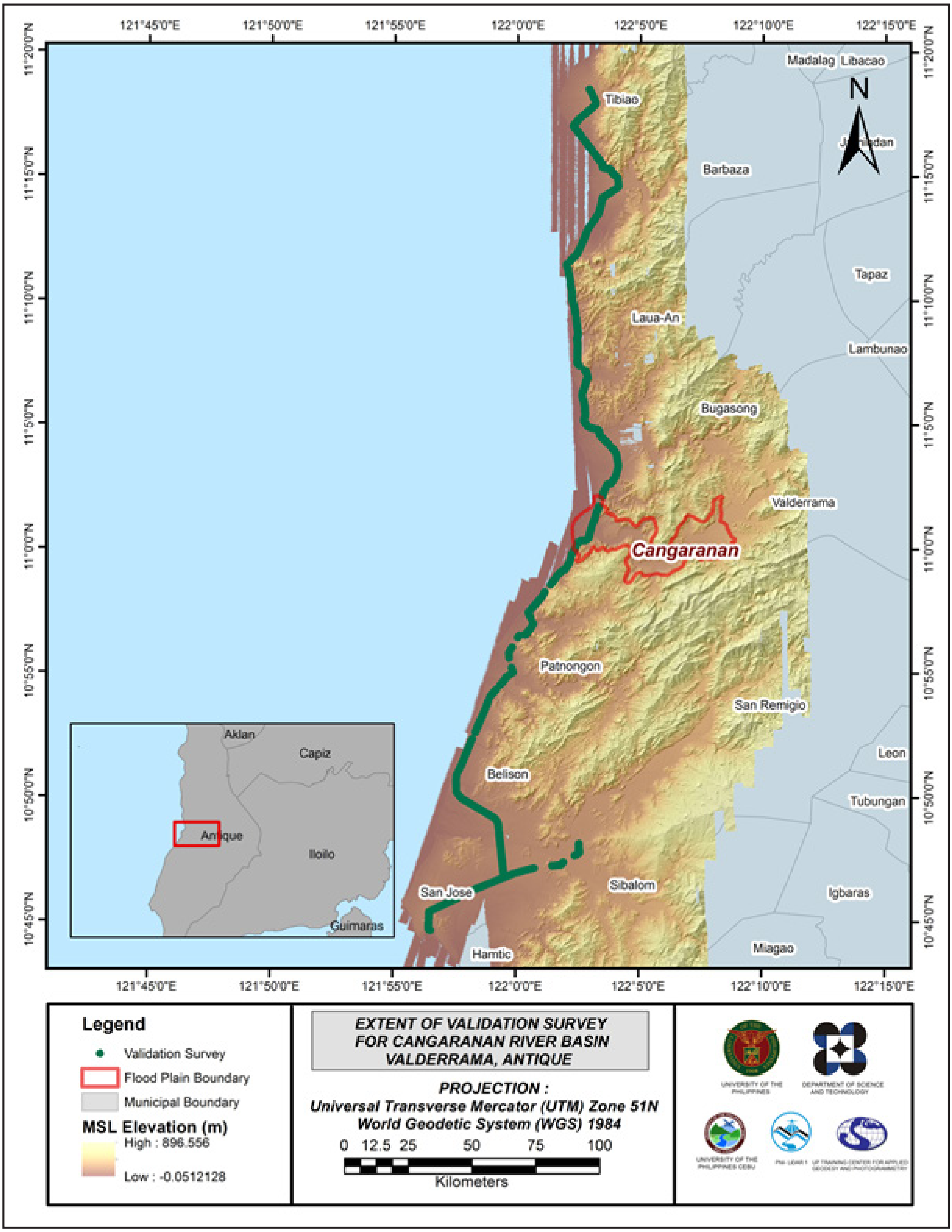


Figure 26. Map of the Cangaranan Floodplain, with validation survey points in green

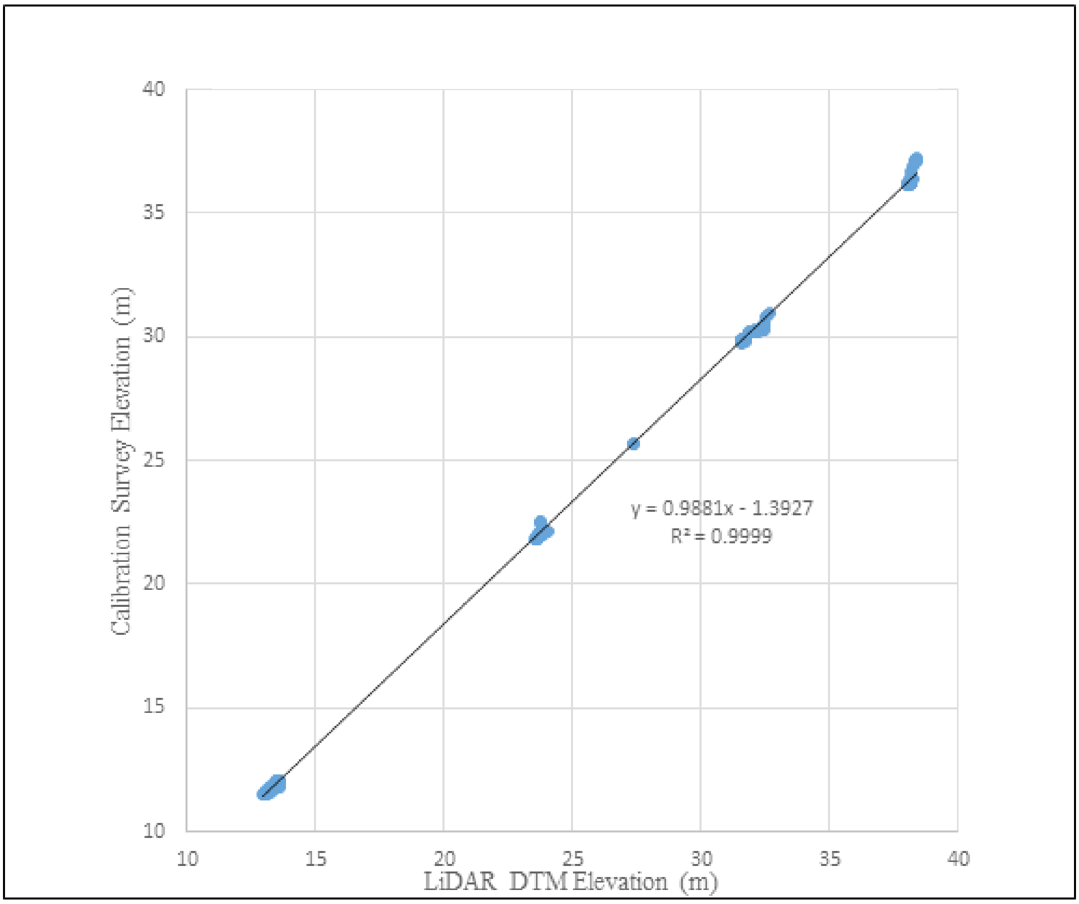


Figure 27. Correlation plot between the calibration survey points and the LiDAR data

Table 19. Calibration statistical measures

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

A total of 190 survey points that are within Cangaranan flood plain were used for the validation of the calibrated Cangaranan 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.06 meters with a standard deviation of 0.05 meters, as shown in Table 20.

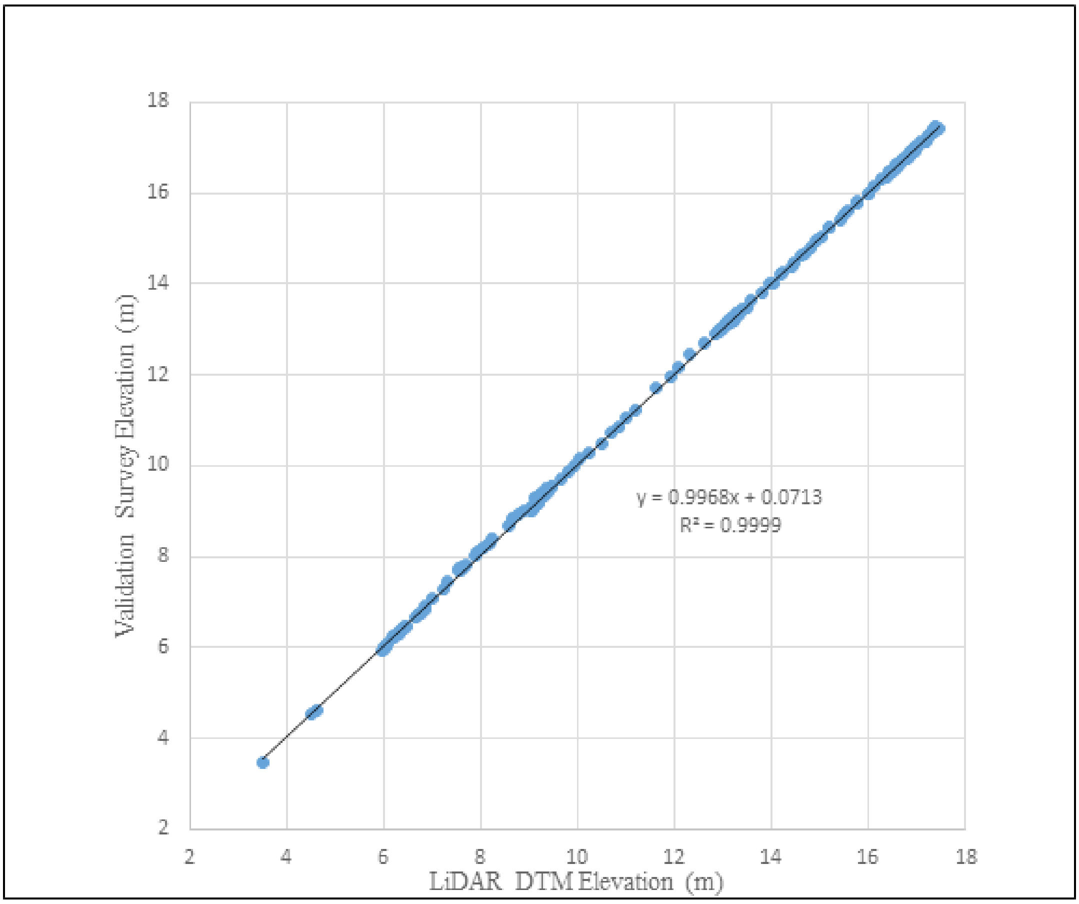


Figure 28. Correlation plot between the validation survey points and the LiDAR data

Table 20. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.06
Standard Deviation	0.05
Average	0.03
Minimum	-0.04
Maximum	0.03

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Cangaranan, with 363 bathymetric survey points. The resulting raster surface produced was obtained through the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.45 meters. The extent of the bathymetric survey done by the DVBC in the Cangaranan floodplain, integrated with the processed LiDAR DEM, is illustrated in Figure 29.

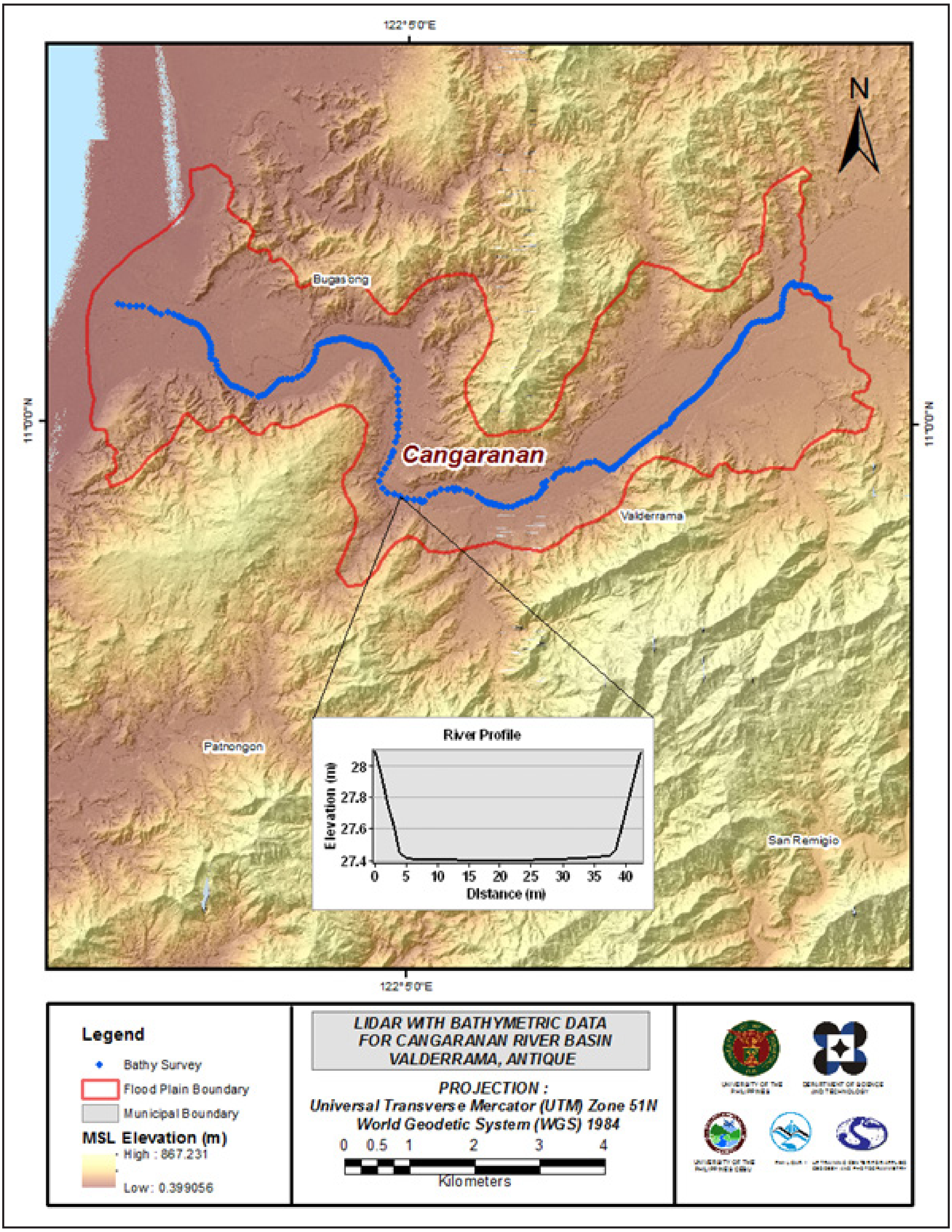


Figure 29. Map of the Cangaranan Floodplain, with bathymetric survey points shown in blue

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, which consist 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 Cangaranan floodplain, including its 200-meter buffer zone, has a total area of 44.55 sq. km. Of this area, a total of 5.00 sq. km., corresponding to a total of 1,977 building features, was considered for quality checking (QC). Figure 30 presents the QC blocks for the Cangaranan floodplain.

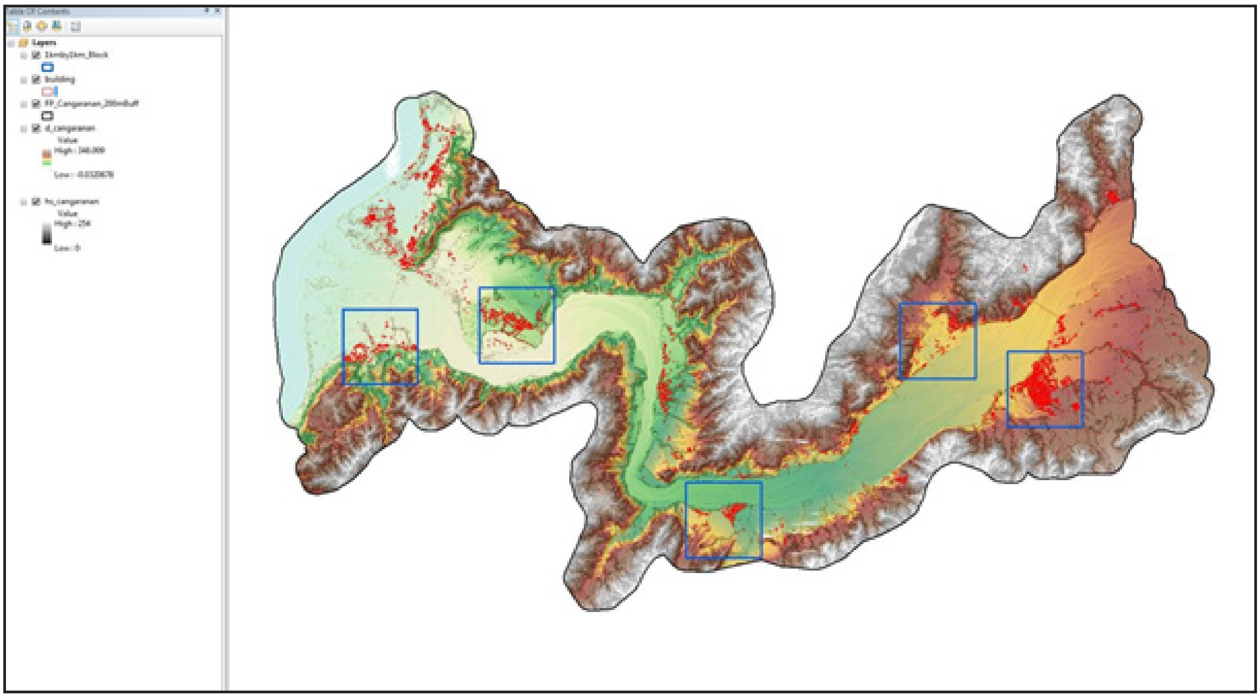


Figure 30. Blocks (in blue) of the Cangaranan building features that were subjected to QC

Quality checking of the Cangaranan building features resulted in the ratings given in Table 21.

Table 21. Quality checking ratings for the Cangaranan building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Cangaranan	99.50	100.00	99.39	99.50

3.12.2 Height Extraction

Height extraction was done for 4,407 building features in the Cangaranan floodplain. Of these building features, sixty-six (66) were filtered out after height extraction, resulting in 4,341 buildings with height attributes. The lowest building height is at 2.0 meters, while the highest building is at 6.78 meters.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping, in coordination with the local government units (LGUs) of the municipalities. The research associates of the UPC Phil-LiDAR 1 Team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge in their local environments to identify and map out the building features.

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

Table 22 summarizes the number of building features per type. Table 23 indicates the total length of each road type, and Table 24 lists the number of water features extracted per type.

Table 22. Building features extracted for the Cangaranan Floodplain

Facility Type	No. of Features
Residential	4,080
School	103
Market	29
Agricultural/Agro-Industrial Facili-ties	28
Medical Institutions	10
Barangay Hall	4
Military Institution	0
Sports Cen-ter/Gymnasium/Covered Court	6
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	30
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	2
Religious Institutions	16
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	18
Other Commercial Establishments	15
Total	4,341

Table 23. Total length of extracted roads for the Cangaranan Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Cangaranan	33.67	3.62	0.00	18.88	0.00	56.17

Table 24. Number of extracted water bodies for the Cangaranan Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cangaranan	7	0	0	0	0	7

A total of eighteen (18) 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 comprised the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

Figure 31 exhibits the Digital Surface Model (DSM) of the Cangaranan floodplain, overlaid with its ground features.

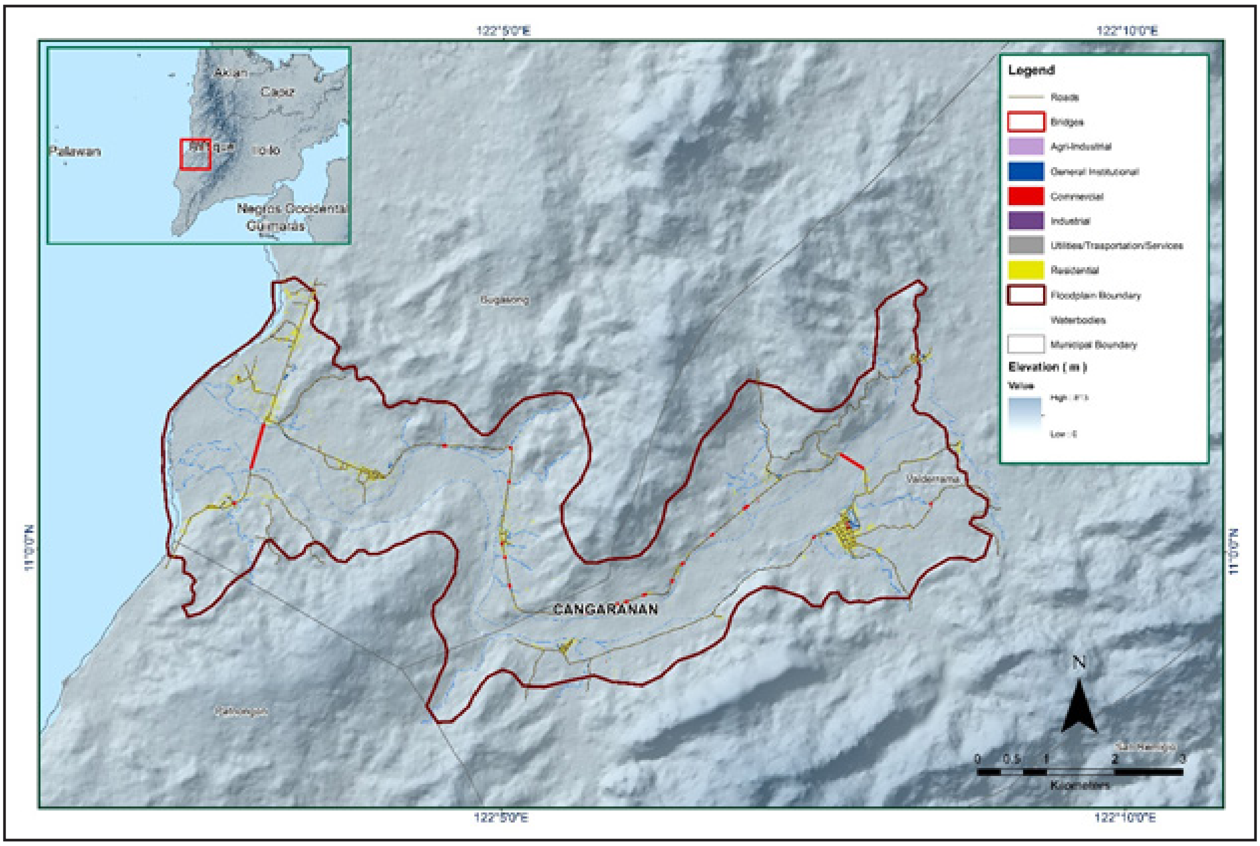


Figure 31. Extracted features for the Cangaranan floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, 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. Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field surveys in the Cangaranan River on September 25 – October 9, 2014, with the following scope of work: (i.) reconnaissance; (ii.) control survey for the establishment of a control point; (iii.) cross-section and bridge as-built surveys of the Cangaranan Bridge and Valderrama Bridge piers; (iv.) ground validation data acquisition of about 82.264 km. for the whole province of Antique; and (v.) bathymetric survey from Barangay Pandanan, Municipality of Valderrama, Antique, down to Barangay Ilaures, Municipality of Bugasong, Antique, with an estimated length of 16.964 km., using GNSS PPK survey technique. The extent of the survey is illustrated in Figure 32.

Figure 32. Extent of the bathymetric survey (in blue line) in the Cangaranan River and the LiDAR data validation survey (in red)

4.3 Control Survey

The GNSS network used in the Cangaranan River survey is composed of a single loop established on September 26, 2014, occupying the following reference points: (i.) ATQ-20, a second-order GCP, located in Barangay Zaragoza, Municipality of Bugasong, Antique; and (ii.) AQ-72, a first-order BM, located in Barangay Delima, Municipality of Belison, Antique.

A control point was established on the approach of Tipuluan Bridge: TPN-1, located in Barangay Pasong, Municipality of Sibalom, Antique. This was used as a marker during the survey.

The summary of references and control points used in the Cangaranan survey is shown in Table 25, while the GNSS network established is illustrated in Figure 33.

Table 25. List of references and control points used in the Cangaranan River survey
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
ATQ-20	2nd	11°00'38.44240" N	122°02'59.27039" E	66.094	-	2009
AQ-72	1st	-	-	61.541	5.5842	2007
TPN-1	-	-	-	--	-	September 26, 2014

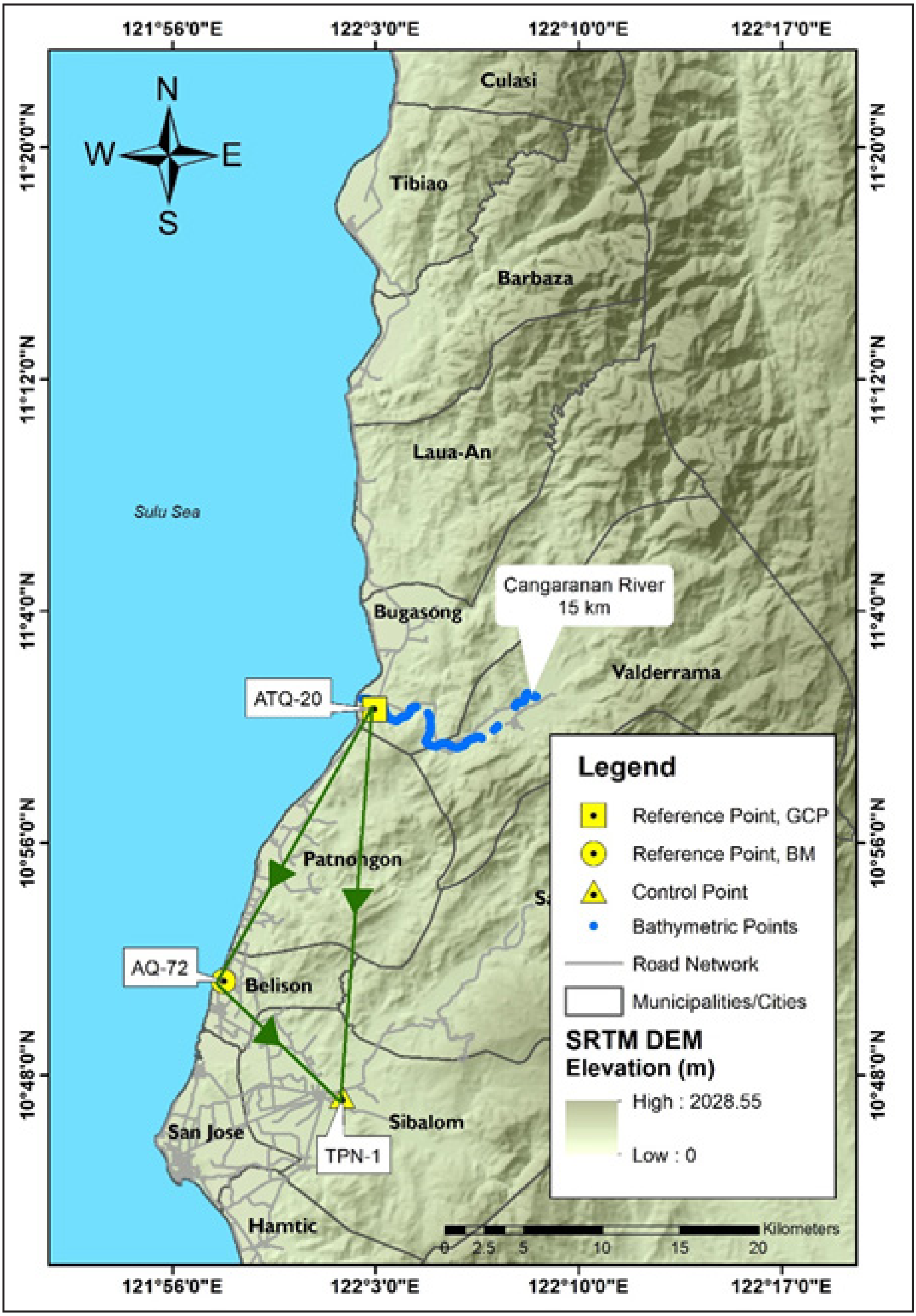


Figure 33. Cangaranan River Basin GNSS network survey

The GNSS set-up of the reference and control points are exhibited in Figure 34 to Figure 36.

Figure 34. GNSS base receiver set-up, Trimble® SPS 852, at ATQ-20 in Barangay Zaragoza, Municipality of Bugasong, Antique

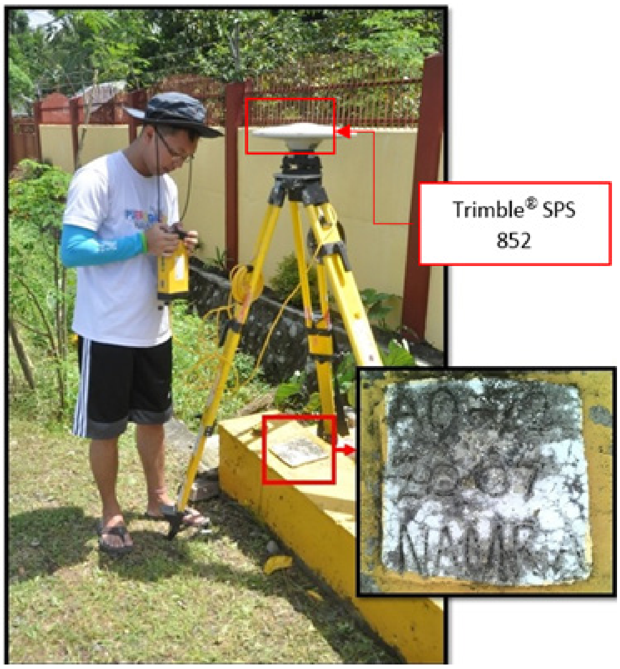


Figure 35. Benchmark AQ-72, with Trimble® SPS 852, in Barangay Delima, Municipality of Belison, Antique

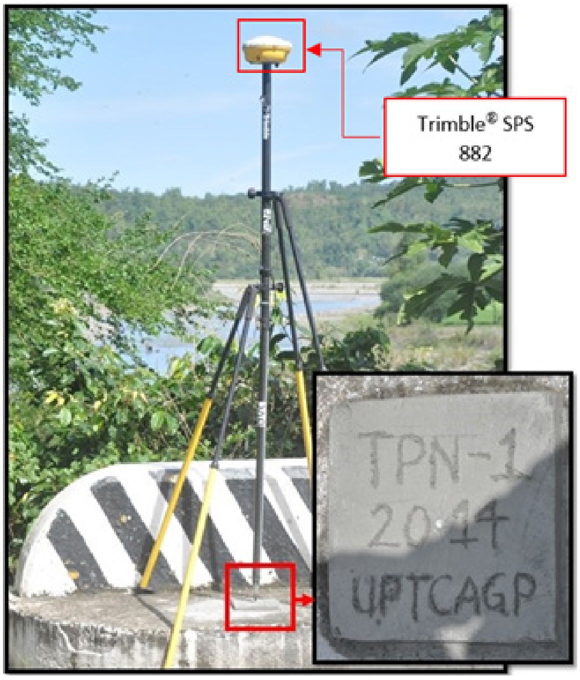


Figure 36. UP-TCAGP-established control point, TPN-1, with Trimble® SPS 882, on the Tipuluan Bridge in Barangay Pasong, Municipality of Sibalom, Antique

4.4 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of these 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 Cangaranan River Basin, generated by TBC software, are summarized in Table 26.

Table 26. Baseline Processing Report for the Cangaranan River static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ATQ-20 --- AQ-72 (B4775)	09-26-2014	Fixed	0.007	0.022	208°43'33"	19743.041	-4.554
ATQ-20 --- TPN-1 (B4775)	09-26-2014	Fixed	0.006	0.021	184°45'37"	24723.786	22.496
AQ-72 --- TPN-1 (B4776)	09-26-2014	Fixed	0.005	0.014	134°32'57"	10438.795	27.074

As shown in Table 26, a total of three (3) baselines were processed, with reference points ATQ-20 and AQ-72 held fixed for coordinate and elevation values, respectively. All of the baselines satisfied the required accuracy.

4.5 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates 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 and $z_e < 10\ cm$

where:

xe is the Easting Error,
ye is the Northing Error, and
ze is the Elevation Error

for each control point. Tables 27 to 30 present the results of GNSS network adjustment.

The control point with the coordinates were held fixed during the network adjustment is given in Table 27. Through this reference point, the coordinates of the unknown control points were computed.

Table 27. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ATQ-20	Global	Fixed	Fixed	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, are indicated in Table 28. The fixed control point, ATQ-20, had no values for standard errors. A difference in elevation of 0.9288 meters between the geoid (EGM2008) and MSL values of the reference point AQ-72 was applied for referring the elevation of the control points to MSL.

Table 28. Adjusted grid coordinates for the control points used in the Cangaranan floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
AQ-72	386654.679	0.063	1200045.589	0.033	6.513	0.256	
ATQ-20	396195.506	?	1217324.5 63	?	10.798	?	LLh
TPN-1	394067.041	0.058	1192699.1 27	0.031	33.065	0.259	

The network was fixed at the reference point, ATQ-20, with known coordinates. With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}$<20cm for horizontal accuracy, and z_e<10 cm for vertical accuracy; the computations for the horizontal and vertical accuracies are as follows:

a. AQ-72

Horizontal Accuracy	=	$\sqrt{((6.3)^2 + (3.3)^2}$
	=	$\sqrt{(39.69 + 10.89)}$
	=	7.11 cm < 20 cm

b. TPN-1

Horizontal Accuracy	=	$\sqrt{((5.8)^2 + (3.1)^2}$
	=	$\sqrt{(33.64 + 9.61)}$
	=	6.58 cm < 20 cm

The adjusted geodetic coordinates; i.e., latitude, longitude, height, and computed standard errors of the control points in the network, are enumerated in Table 29.

Table 29. Adjusted geodetic coordinates for control points used in the Cangaranan River floodplain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
AQ-72	N10°51'14.92748"	E121°57'46.85471"	61.541	0.256	
ATQ-20	N11°00'38.44240"	E122°02'59.27039"	66.094	?	LLh
TPN-1	N10°47'16.56550"	E122°01'51.73167"	88.644	0.259	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as demonstrated in Table 29. Based on the results of the computations, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Cangaranan River GNSS Static Survey are indicated in Table 30.

Table 30. Reference and control points used in the Cangaranan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ATQ-20	2nd Order GCP	11°00'38.44240"	122°02'59.27039"	66.094	1217324.563	396195.506	9.8692
AQ-72	1st Order BM	10°51'14.92748"	121°57'46.85471"	61.541	1200045.589	386654.679	5.5842
TPN-1	UP Established	10°47'16.56550"	122°01'51.73167"	88.644	1192699.127	394067.041	32.1362

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

The Cross-section and bridge as-built surveys were conducted on September 27, 2014 along the downstream side of the Cangaranan Bridge in Barangay Ilaures, Municipality of Bugasong; and on September 29, 2014 along the downstream side of the Valderrama Bridge in Barangay Ubos, Municipality of Valderrama. A GNSS receiver, Trimble® SPS 882, in PPK survey technique was used to acquire the cross-sections of the river, as depicted in Figure 37.

Figure 37. Cross section surveys (A) in Cangaranan Bridge, Municipality of Bugasong, and (B) in Valderrama Bridge, Municipality of Valderrama

The length of the cross-sectional line surveyed in the Cangaranan Bridge is about 661.06 meters with forty (40) points, while that of the cross-sectional line surveyed in the Valderrama Bridge is about 418.85 meters with thirty one (31) points. Both were acquired using the control point ATQ-20 as the GNSS base station. The location maps, cross-section diagrams, and accomplished bridge data forms of the two (2) bridges are shown in Figure 38 to Figure 43.

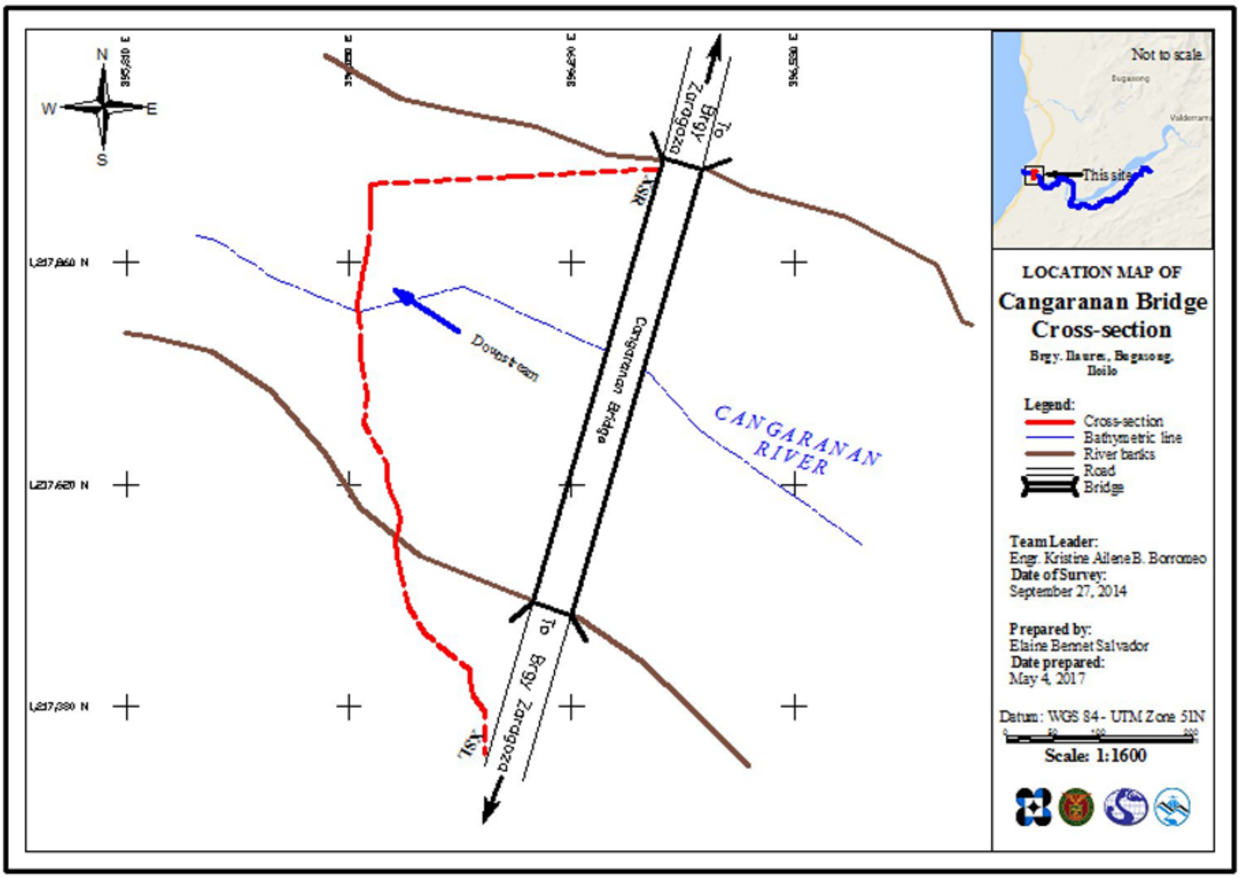


Figure 38. Cangaranan bridge cross-section location map

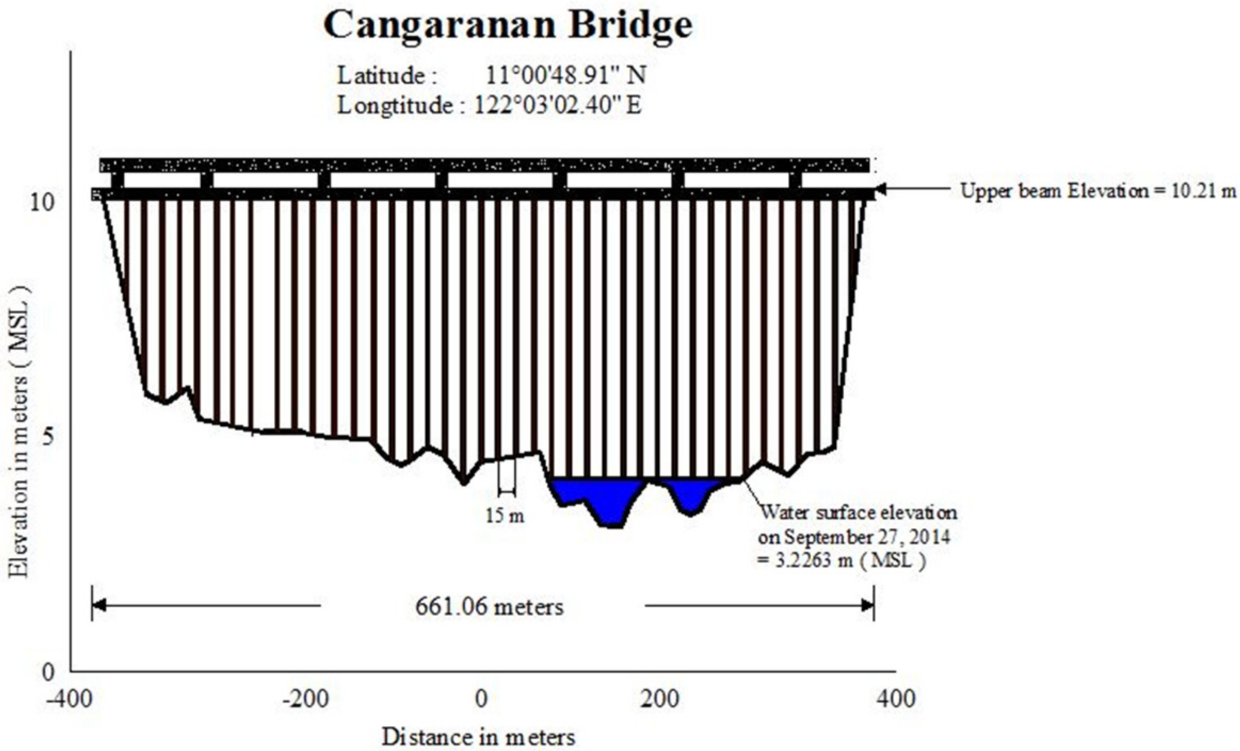


Figure 39. Cangaranan Bridge cross section diagram

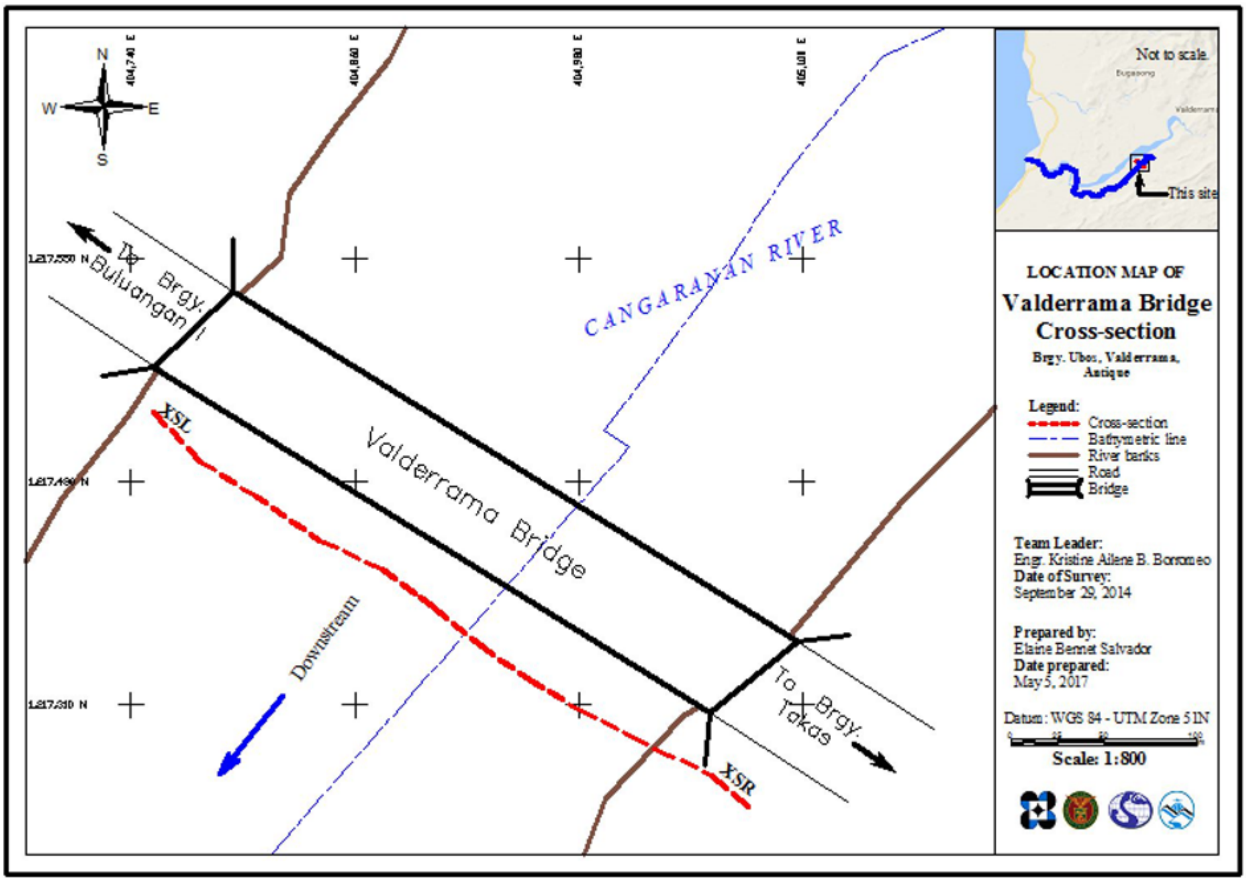


Figure 40. Valderrama bridge cross-section location map

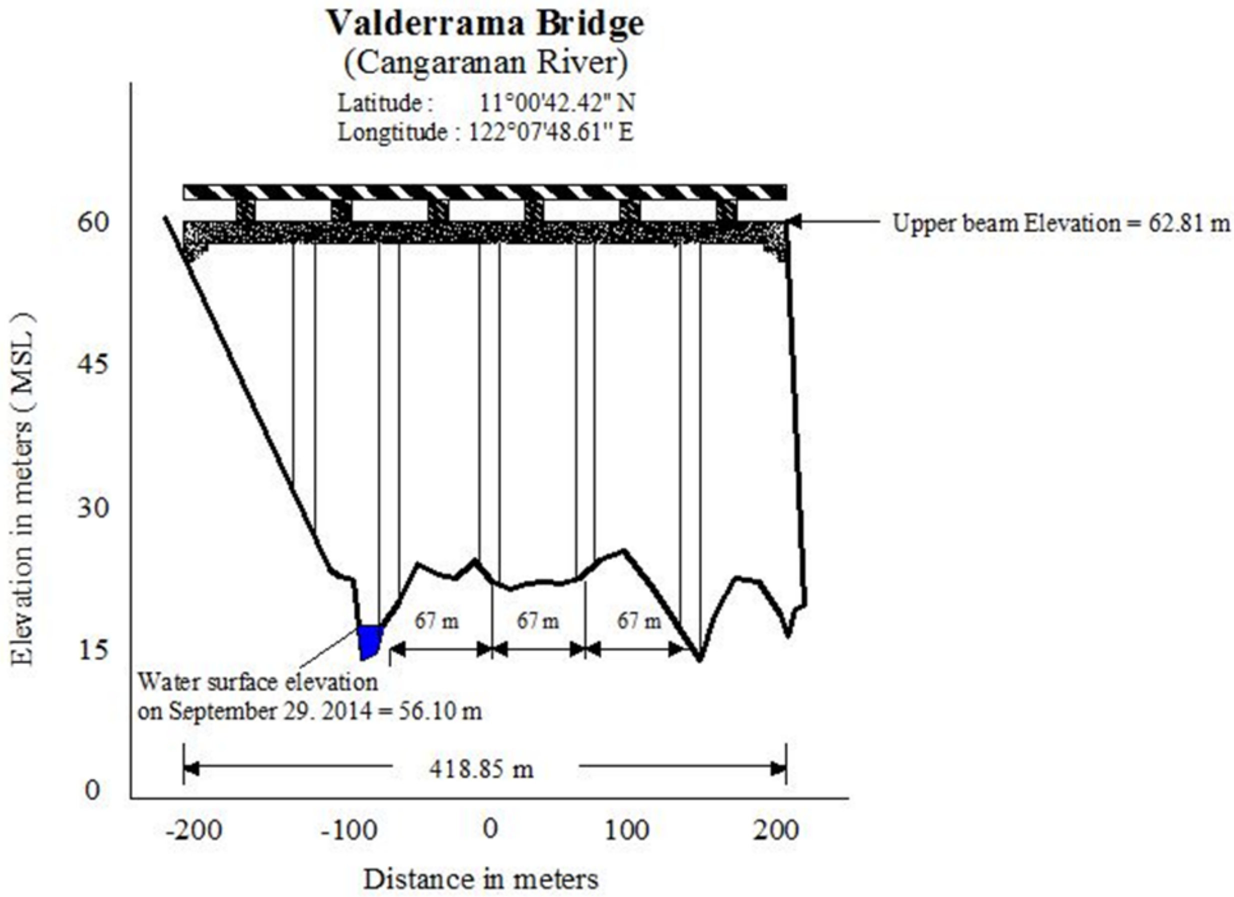


Figure 41. Valderrama Bridge cross section diagram

Bridge Data Form

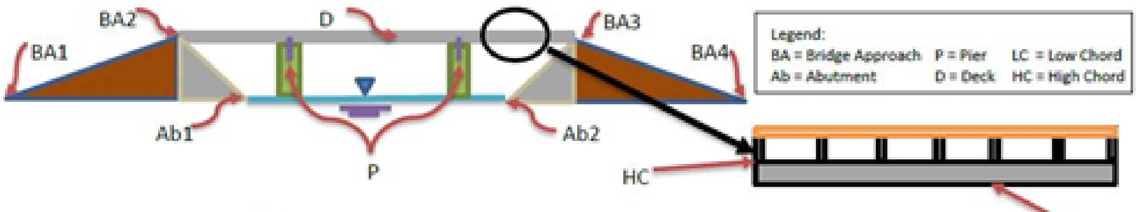
Bridge Name: Cangaranan Bridge **Date:** September 27, 2014

River Name: Cangaranan River **Time:** 2:40 PM

Location (Brgy, City, Region): Bugasong, Antique

Survey Team: Borromeo, Labrador, Salvador, Garcia

Flow condition: low normal high **Weather Condition:** fair rainy



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

Elevation 10.4002m **Width:** - **Span (BA3-BA2):** 327.3069m

Latitude: 11d00'48.90596" N **Longitude:** 122d03'02.40107"E

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	10.2092 m	**BA3**	-	-
BA2	-	-	**BA4**	661.0468 m	10.1052 m

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

	Station (Distance from BA1)	Elevation
Ab1	-	-
Ab2	-	-

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

Shape: Round **Number of Piers:** 41 **Height of column footing:** -

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	9.0071 m	10.2132 m	-
Pier 2	30.6206 m	10.2262 m	-
Pier 3	45.4285 m	10.2192 m	-
Pier 4	60.5183 m	10.2252 m	-
Pier 5	75.2283 m	10.2262 m	-
Pier 6	89.9169 m	10.2342 m	-
Pier 7	105.3290 m	10.2162 m	-
Pier 8	120.2168 m	10.1952 m	-
Pier 9	135.6213 m	10.1922 m	-
Pier 10	158.0386 m	10.2392 m	-
Pier 11	172.7983 m	10.2122 m	-
Pier 12	202.6793 m	10.2122 m	-
Pier 13	225.1531 m	10.2122 m	-
Pier 14	240.4227 m	10.2122 m	-
Pier 15	255.4079 m	10.2122 m	-
Pier 16	270.3125 m	10.2122 m	-
Pier 17	285.3979 m	10.2122 m	-
Pier 18	300.5136 m	10.1712 m	-
Pier 19	315.4518 m	10.1922 m	-
Pier 20	330.5893 m	10.1892 m	-
Pier 21	345.4813 m	10.1872 m	-
Pier 22	360.4443 m	10.1872 m	-
Pier 23	375.3560 m	10.1872 m	-
Pier 24	390.4866 m	10.1872 m	-
Pier 25	405.6020 m	10.1872 m	-
Pier 26	420.4014 m	10.1872 m	-
Pier 27	435.4488 m	10.1872 m	-
Pier 28	449.9355 m	10.1872 m	-
Pier 29	465.4877 m	10.1872 m	-
Pier 30	480.2716 m	10.1872 m	-
Pier 31	495.3240 m	10.2042 m	-
Pier 32	510.6334 m	10.2042 m	-
Pier 33	525.4832 m	10.2262 m	-
Pier 34	540.4720 m	10.2572 m	-
Pier 35	555.4480 m	10.2232 m	-

Figure 42. Cangaranan Bridge Data Form

Bridge Data Form

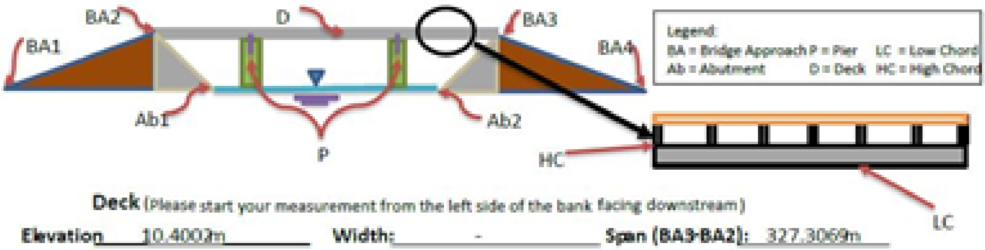
Bridge Name: Valderrama Bridge **Date:** September 29, 2014

River Name: Cangaranan River **Time:** 10:30 AM

Location (Brgy, City, Region): Valderrama, Antique

Survey Team: Borromeo, Labrador, Salvador, Garcia

Flow condition: low normal high **Weather Condition:** fair rainy



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

Elevation 10.4002m **Width:** - **Span (BA3-BA2):** 327.3069m

Latitude: 11d00'42.42401" N **Longitude:** 122d07'48.61528" E

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	62.8162 m	**BA3**	414.0641 m	63.1582 m
BA2	6.6466 m	63.1882 m	**BA4**	418.8488 m	62.8062 m

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

	Station (Distance from BA1)	Elevation
Ab1	-	-
Ab2	-	-

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

Shape: Round **Number of Piers:** 5 **Height of column footing:** -

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	344.4732 m	63.2412 m	-
Pier 2	344.4576 m	63.2412 m	-
Pier 3	344.4351 m	63.2392 m	-
Pier 4	344.4501 m	63.2462 m	-
Pier 5	344.4572 m	63.2482 m	-

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

Figure 43. Valderrama Bridge Data Form

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 3, 5, and 6, 2014 using a survey-grade GNSS rover receiver, Trimble® SPS 882. The receiver was mounted on a pole that was attached in front of a vehicle, as demonstrated in Figure 44. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.53 meters, measured from the ground up to the bottom of notch of the GNSS Rover receiver. The survey was conducted using PPK technique, set on a continuous topo mode.

The first day of the ground validation survey started in the Municipality of Tibiao, and traversed major roads going to the Municipality of Patnongon. Meanwhile, the second day of survey started in the Municipality of San Jose, and traveled up to the Municipality of Patnongon. The third ground validation survey covered the remaining areas. The reference point ATQ-20 was used as the GNSS base station all throughout the conduct of the survey.

Figure 44. (A) Set-up of Trimble® SPS 882 attached to a vehicle and (B) Setting up of GNSS base station at ATQ-20

The survey acquired 9,787 ground validation points, with an approximate length of 82.264 km. The extent of the survey is illustrated in Figure 45.

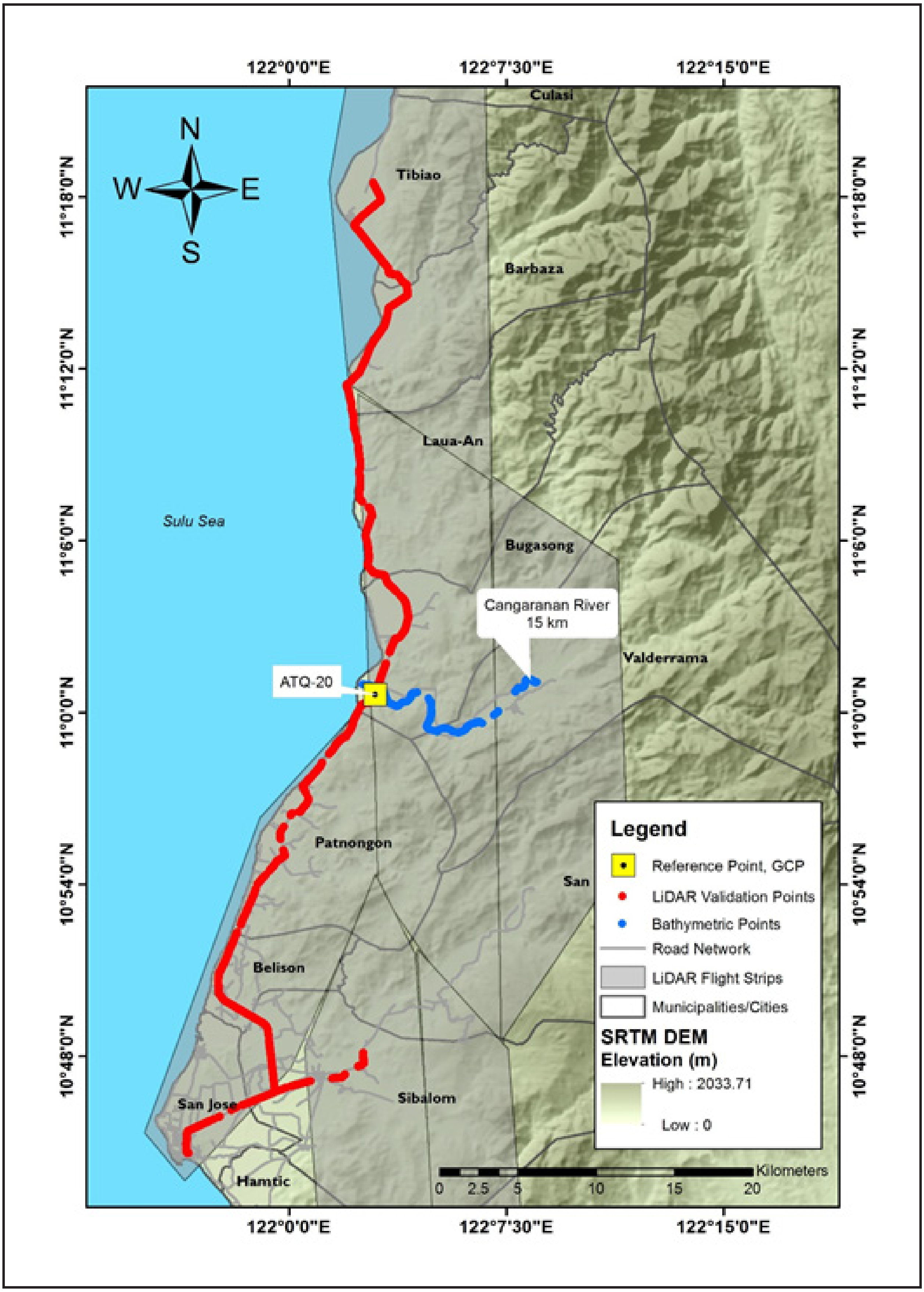


Figure 45. Extent of the LiDAR ground validation survey along Antique Province

4.7 River Bathymetric Survey

A manual bathymetric survey was executed on September 29 and October 7, 2014 using Trimble® SPS 882 Rover in GNSS PPK survey technique, as exhibited in Figure 46. With assistance from the MDRRMO of Sibalom, the survey started upstream in Barangay Pandanan in Municipality of Valderrama, with coordinates 11°01’03.16842” 122°08’33.66617”; and traversed down the river by foot, ending in Barangay Ilaures in Municipality of Bugasong, with coordinates 11°00’58.75198” 122°02’32.98224”.

Figure 46. Manual bathymetric survey along the Cangaranan River

The bathymetric survey gathered a total of 214 points covering 15 km., using ATQ-20 as the GNSS base station. This is represented by the generated map in Figure 47. A CAD drawing was also produced to illustrate the Cangaranan riverbed profile, presented in Figure 48 and Figure 49. The gaps in the gathered bathymetric points are uncollected data, due to the rapids encountered in the river during the fieldwork. In the extent of the river from the upstream in Barangay Pandanan, Municipality of Valderrama, going downstream in Barangay Bagtason, Municipality of Bugasong, there was an abrupt change in elevation of about 39.7 meters, which covers 9 km. of the said extent. The highest elevation was at 65.27 meters in MSL in Barangay Pandanan, while the lowest elevation was at -0.72 meters in MSL in Barangay Llaures.

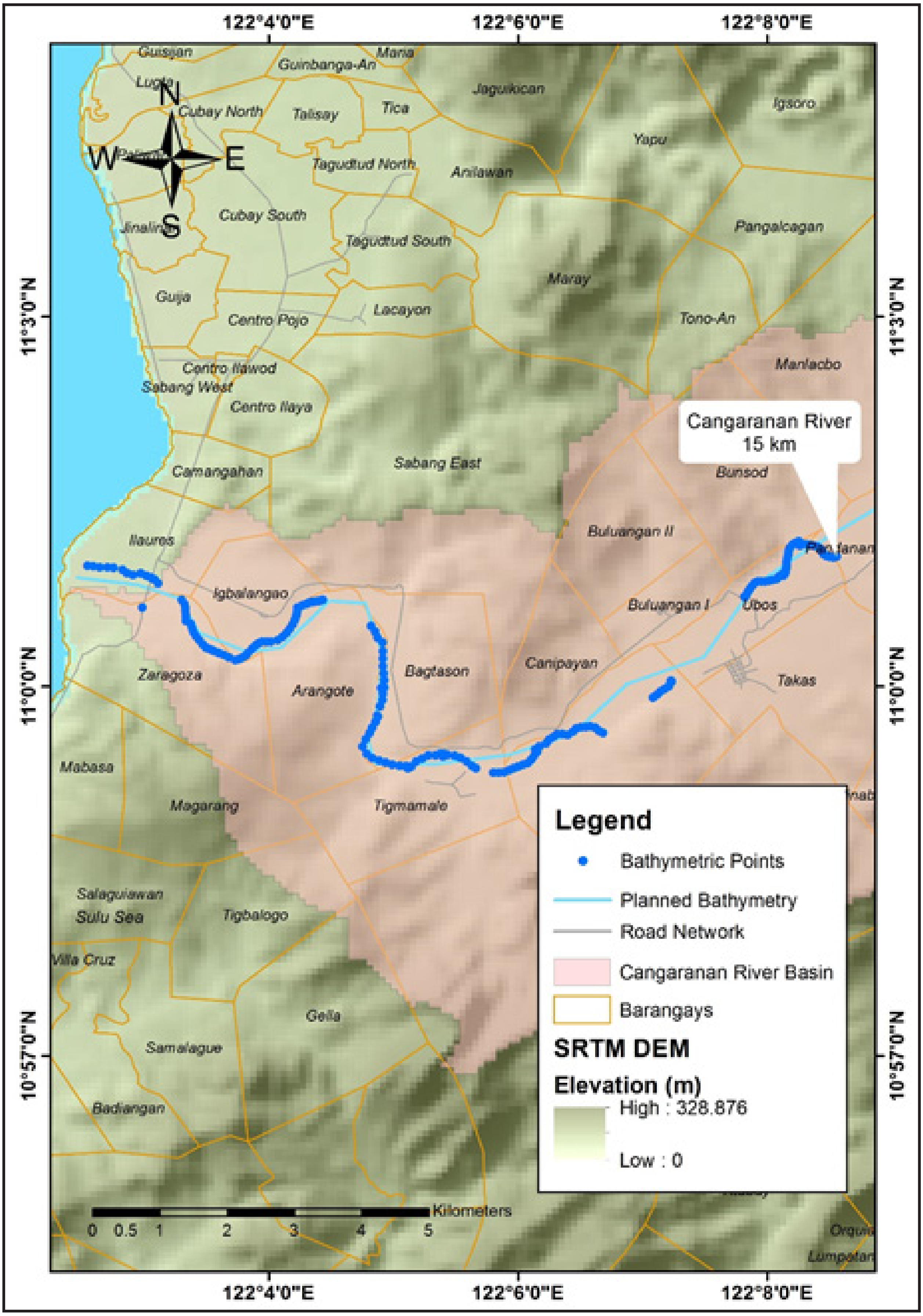


Figure 47. Extent of the bathymetric survey of the Cangaranan River

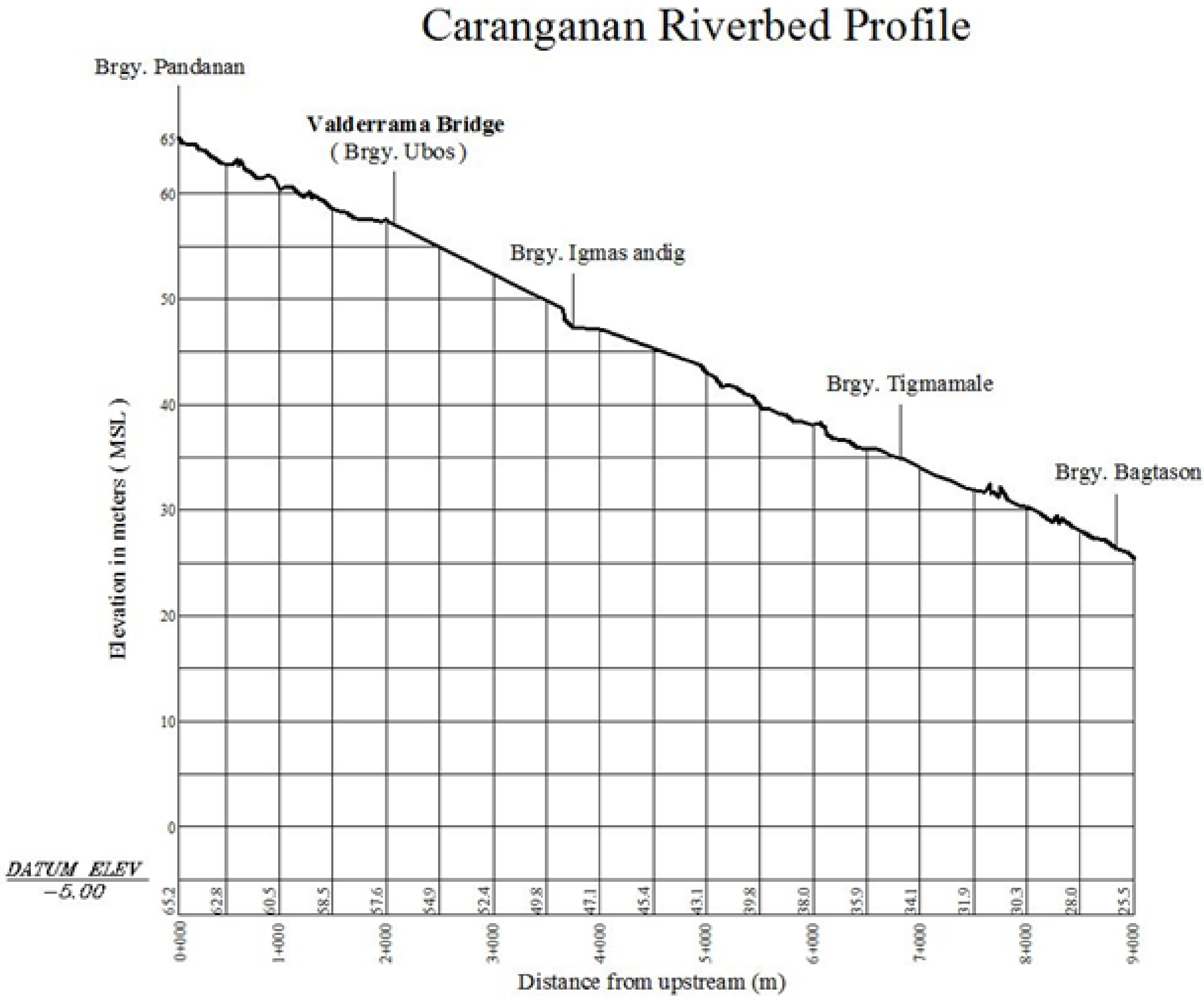


Figure 48. The Cangaranan riverbed profile from Barangay Pandanan, Municipality of Valderrama, down to Barangay Bagtason, Municipality of Bugasong

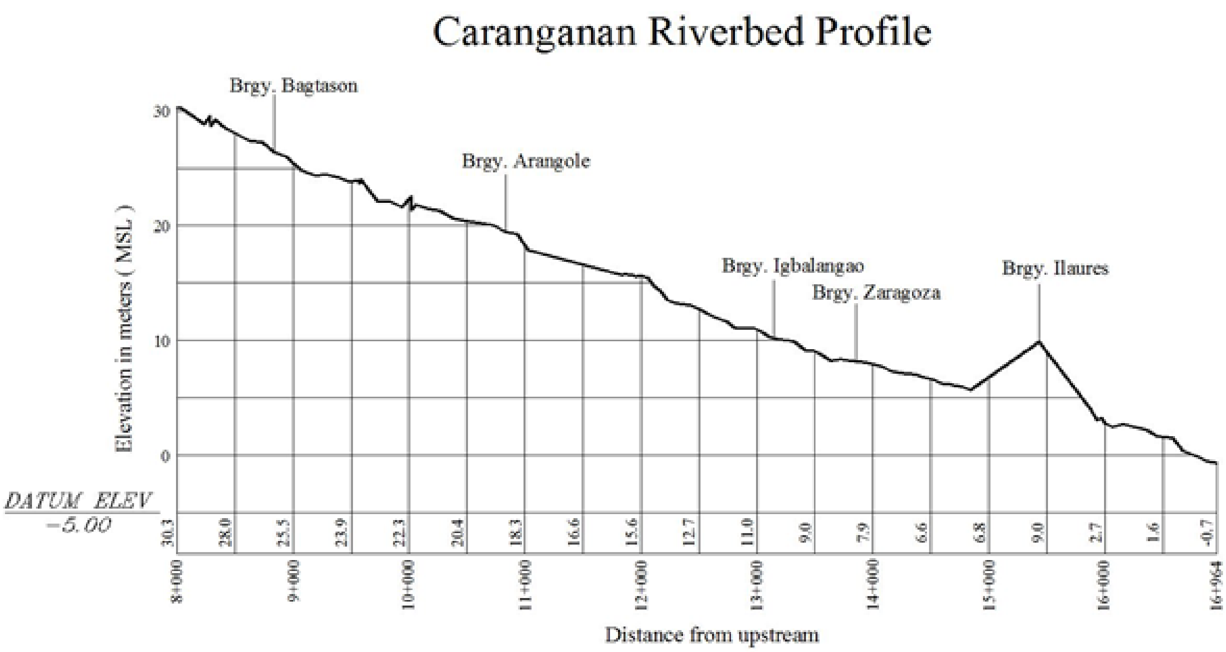


Figure 49. The Cangaranan riverbed profile from Barangay Bagtason, Municipality of Bugasong, down to Barangay Ilaures, Municipality of Bugasong

CHAPTER 5: FLOOD MODELING AND MAPPING

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

The methods applied in this Chapter were based on the DREAM methods manual (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 all components and data that affect the hydrologic cycle of the Cangaranan River Basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UPC Flood Modeling Component (FMC). The ARG was installed at Barangay Ubos, Valderrama, Antique (Figure 53). The precipitation data collection occurred on August 10, 2016 at 21:30 hrs. until August 11, 2016 at 2:00 hrs., with a recording interval of ten (10) minutes.

The total precipitation for this event in the Barangay Ubos ARG was 7 mm, with a peak rainfall of 2 mm. on August 10, 2016 at 23:00 hrs. The lag time between the peak rainfall and discharge was nine (9) hours.

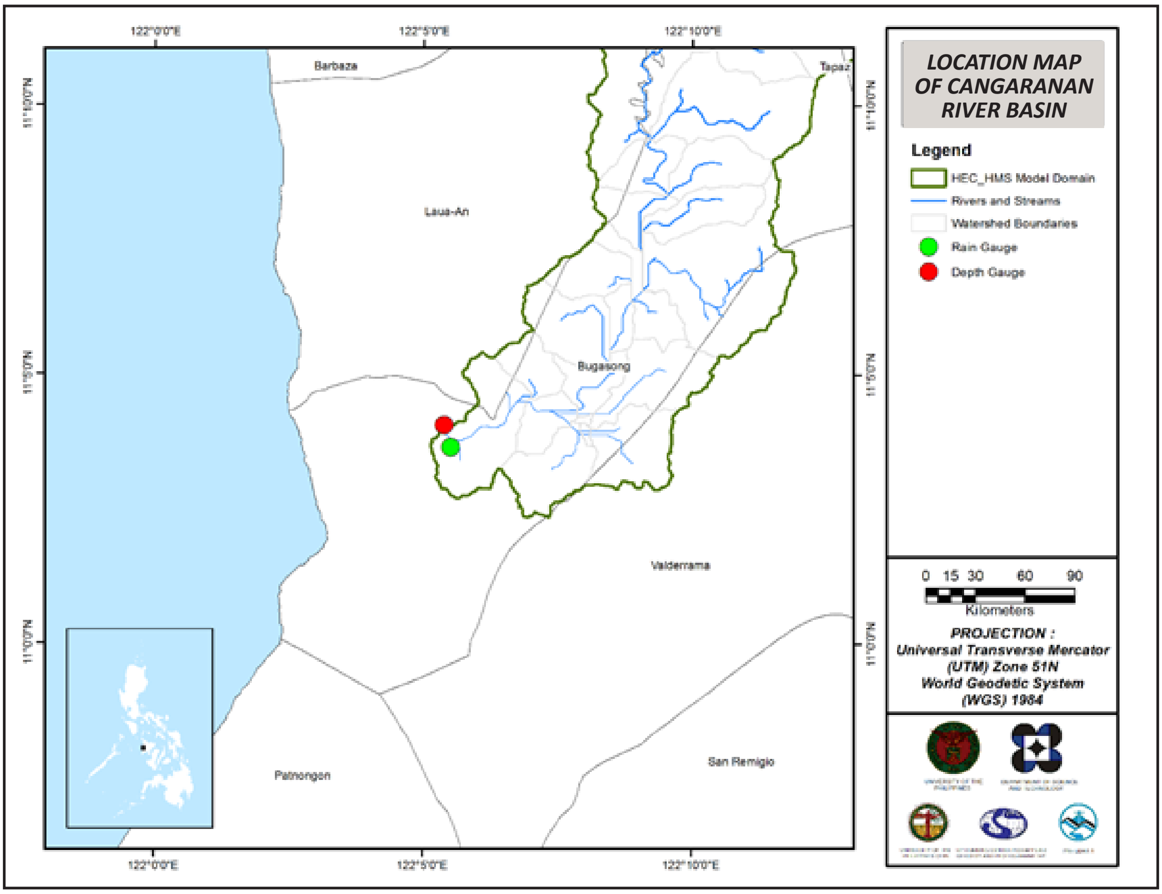


Figure 50. Location Map of the Cangaranan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 51) at the Valderrama Bridge, Valderrama, Antique (11° 0’42.23”N, 122° 7’48.31”E) to establish the relationship between the observed water levels (H) at the Valderrama Bridge and the outflow (Q) of the watershed at this location.

For the Valderrama Bridge, the rating curve is expressed as Q = 1E-180e7.4138x, as demonstrated in Figure 52 (see y formula).

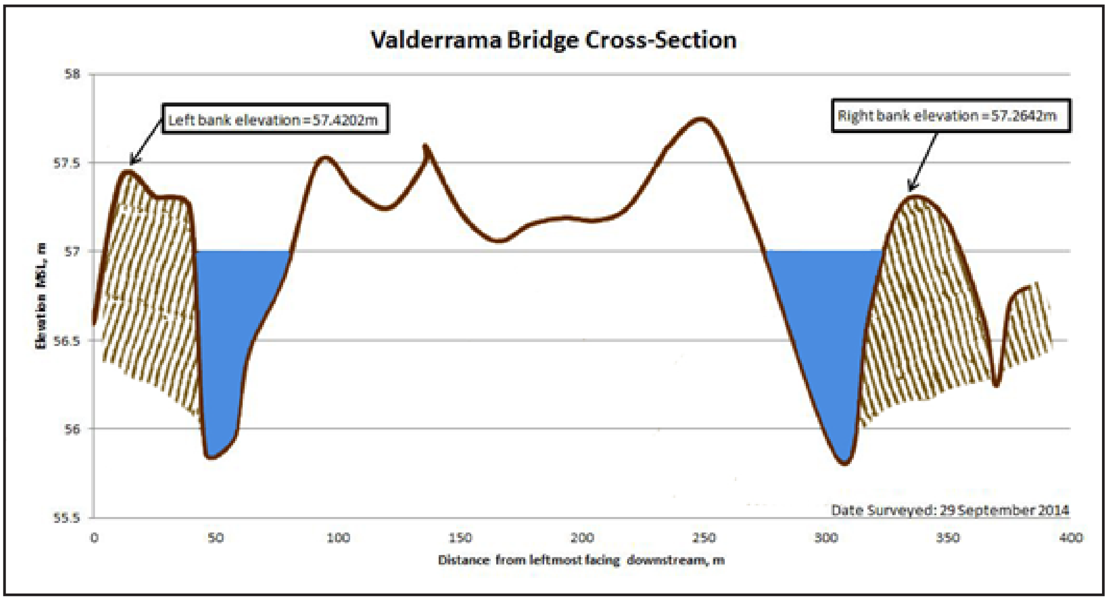


Figure 51. Cross-section plot of the Valderrama Bridge

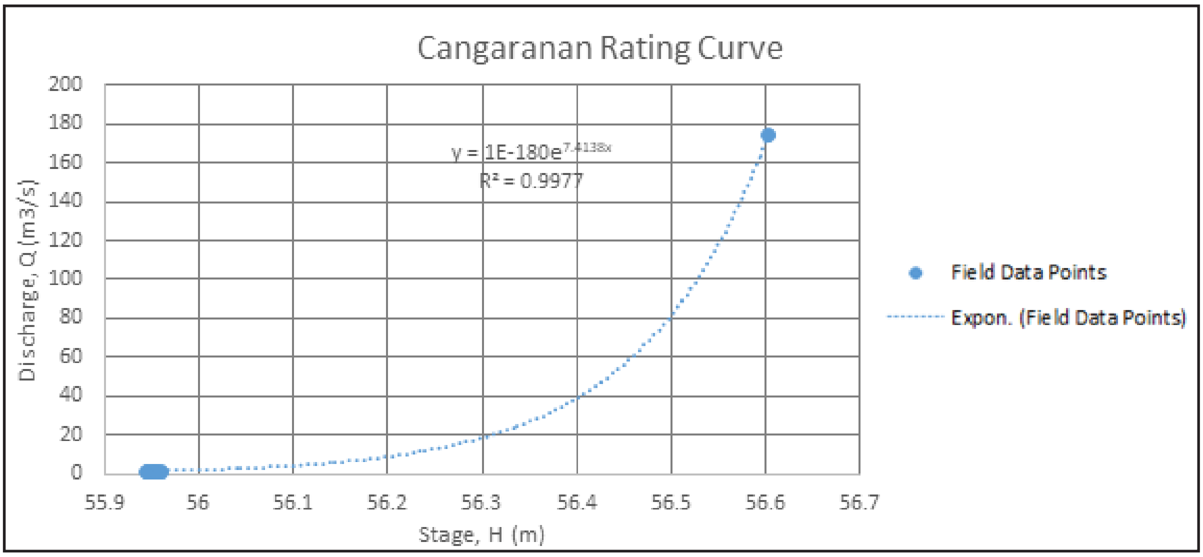


Figure 52. Rating curve at the Valderrama Bridge, Valderrama, Antique

This rating curve equation was used to compute for the river outflow at the Valderrama Bridge, for the calibration of the HEC-HMS model illustrated in Figure 53. The total rainfall for this event was 2mm, and the peak discharge was 56.450 cubic meters per second on August 11, 2016 7:20 hrs.

This rating curve equation was used to compute for the river outflow at the Valderrama Bridge, for the calibration of the HEC-HMS model illustrated in Figure 56. The total rainfall for this event was 2mm, and the peak discharge was 56.450 cubic meters per second on August 11, 2016 7:20 hrs.

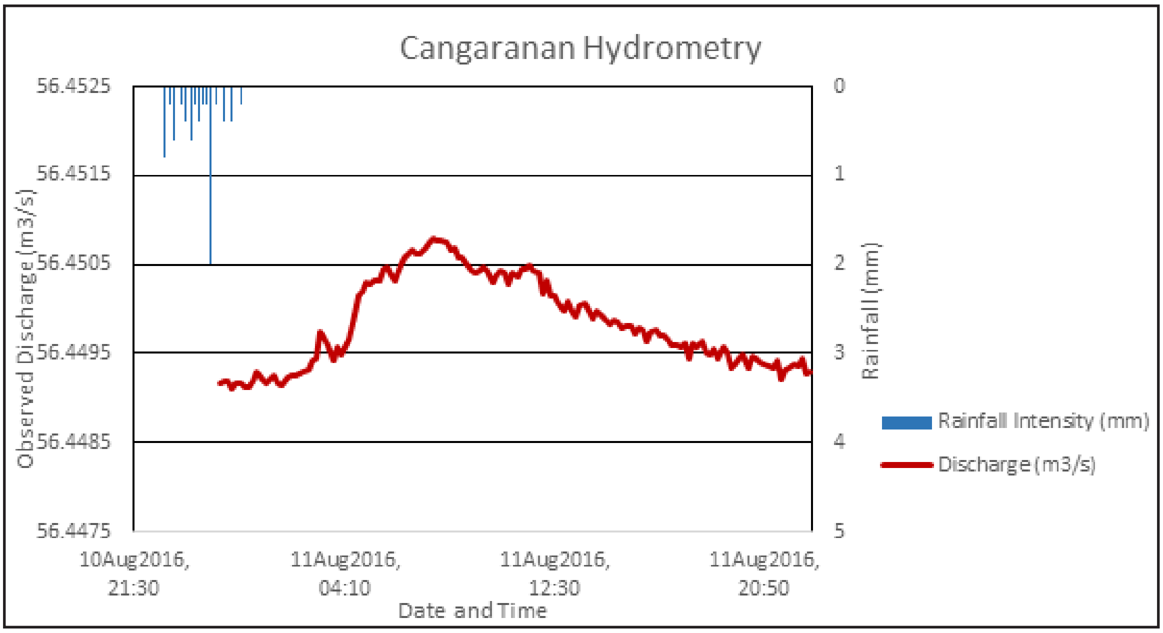


Figure 53. Rainfall and outflow data of the Cangaranan River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge (Table 31). This station chosen based on its proximity to the Cangaranan watershed (Figure 54). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values in such that certain peak values were attained at a certain time (Figure 55). The extreme values for this watershed were computed based on a 59-year record.

Table 31. RIDF values for Iloilo 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**
5	28.7	39.4	48	59.4	74.9	90	114.7	131.7	165.2
10	33.9	45.6	55.6	68.1	85	103.6	133.6	155.4	198.9
25	40.5	53.5	65.3	79.2	97.6	120.8	157.6	185.3	241.5
50	45.4	59.4	72.4	87.3	107	133.5	175.3	207.4	273.1
100	50.3	65.2	79.5	95.4	116.4	146.2	193	229.4	304.5

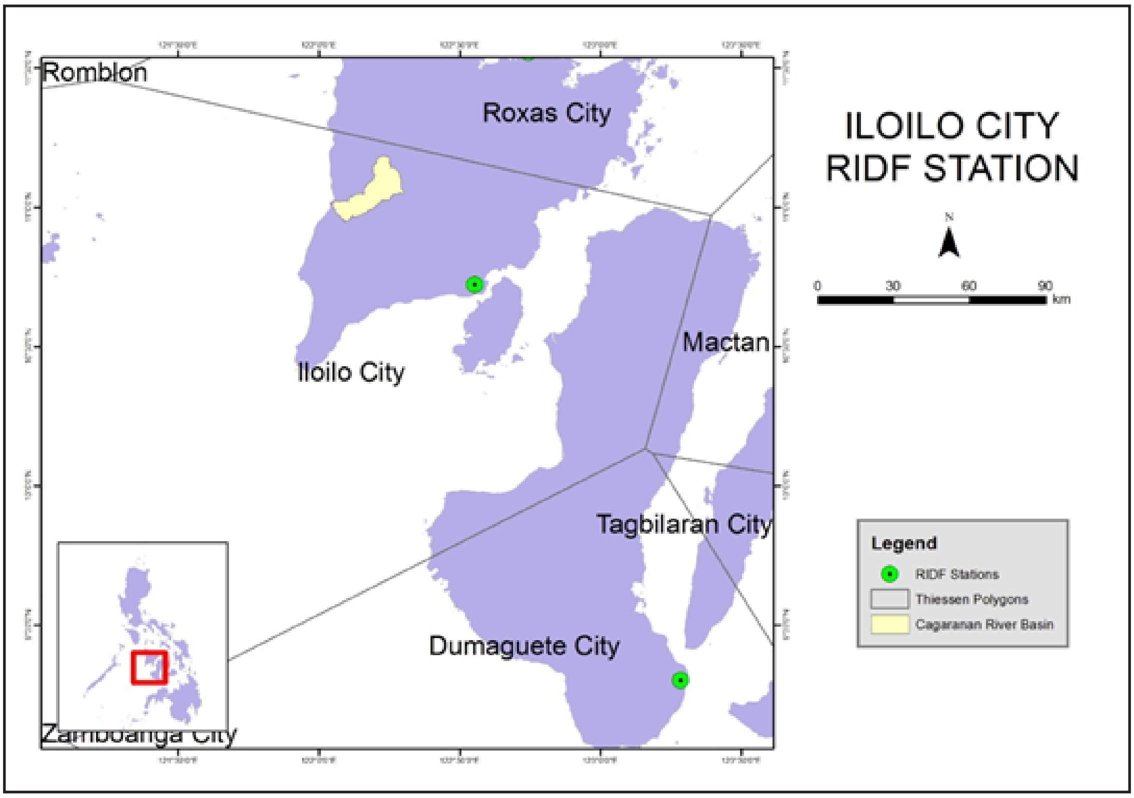


Figure 54. The location of the Iloilo RIDF station relative to the Cangaranan River Basin

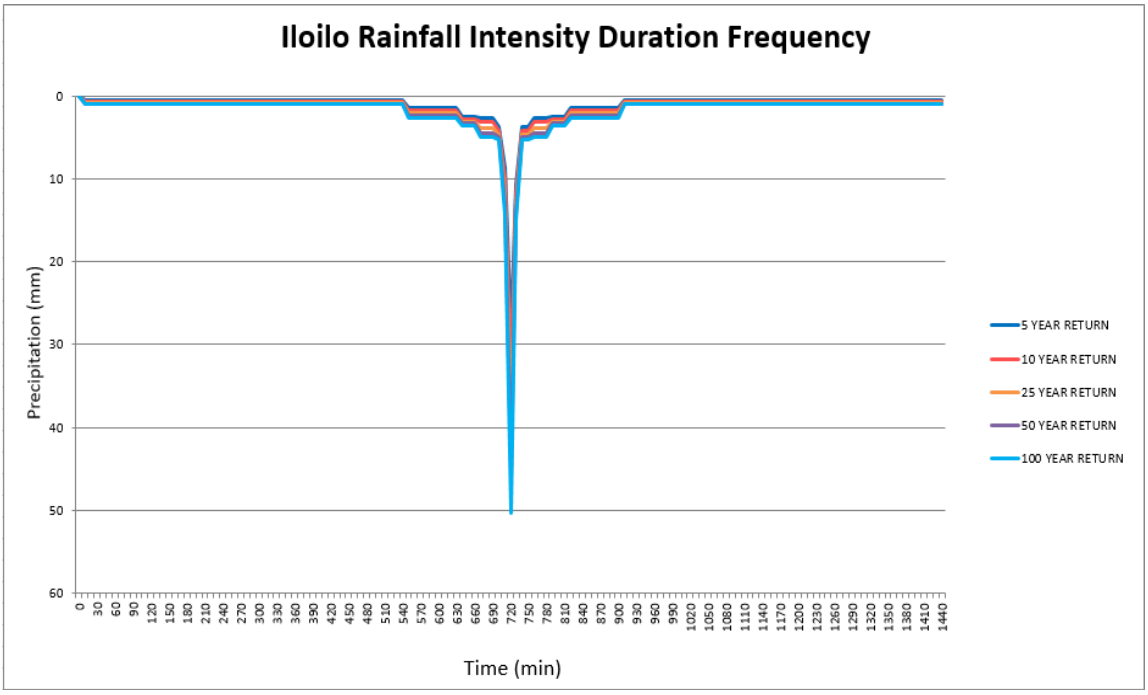


Figure 55. The synthetic storm generated from a 24-hr period rainfall, for various return periods

5.3 HMS Model

The soil dataset 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 of the Cangaranan River Basin are shown in Figures 56 and 57, respectively.

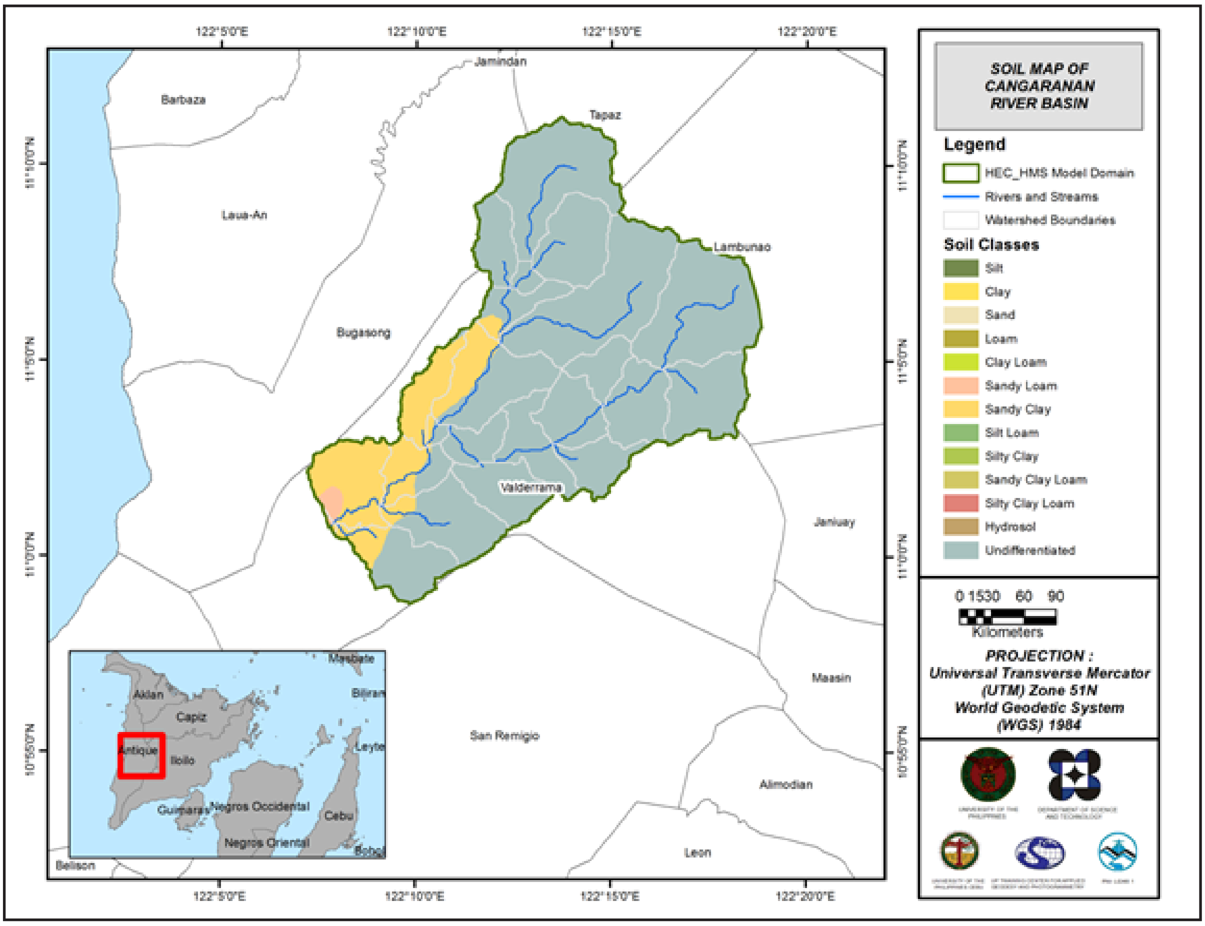


Figure 56. Soil map of the Cangaranan River Basin (Source: DA)

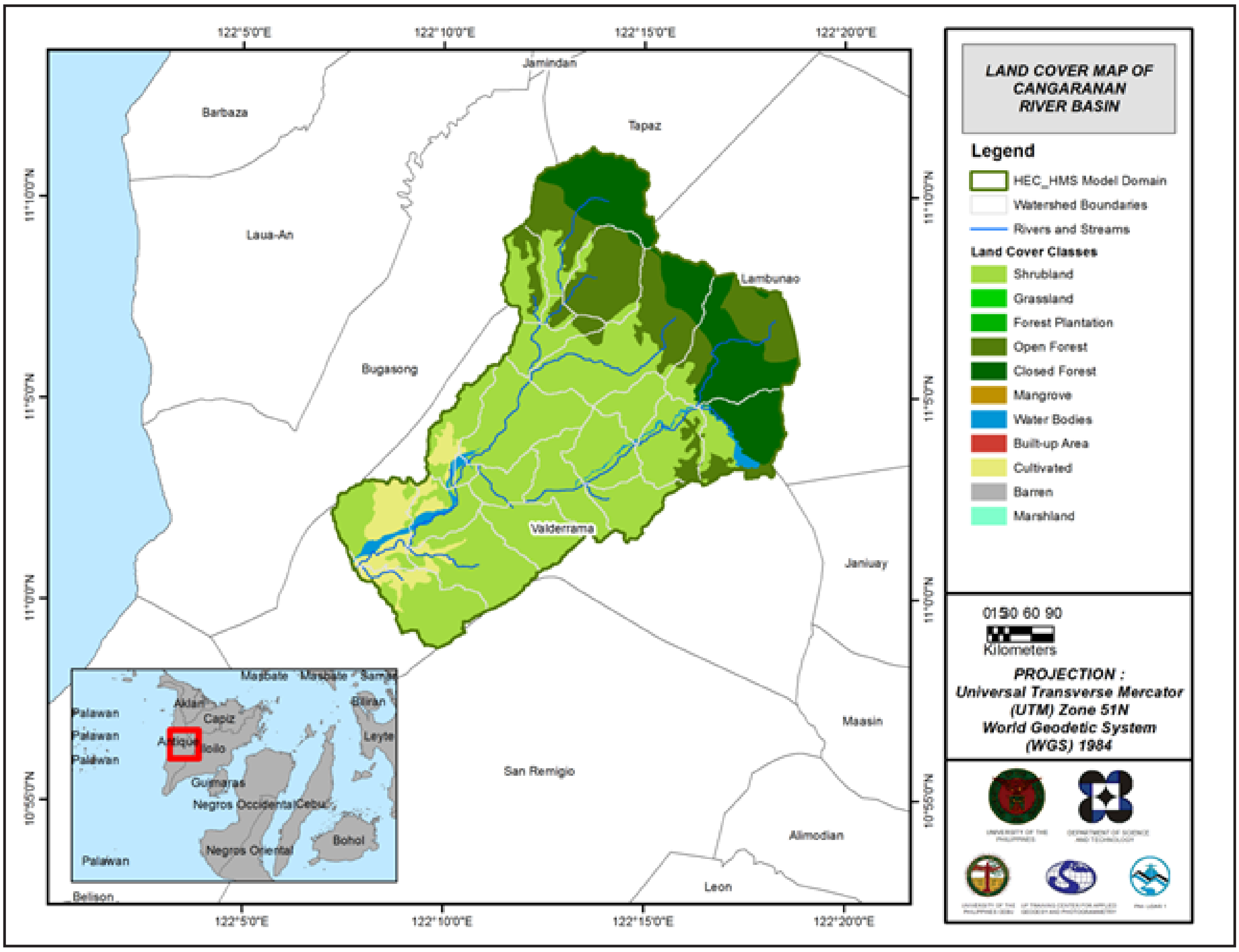


Figure 57. Land cover map of the Cangaranan River Basin (Source: NAMRIA)

Three (3) soil classes and four (4) land cover classes were identified in the Cangaranan River Basin. The soil classes are clay, sandy loam, and undifferentiated soil. The land cover classes are shrub lands, open forests, closed forests, and cultivated areas.

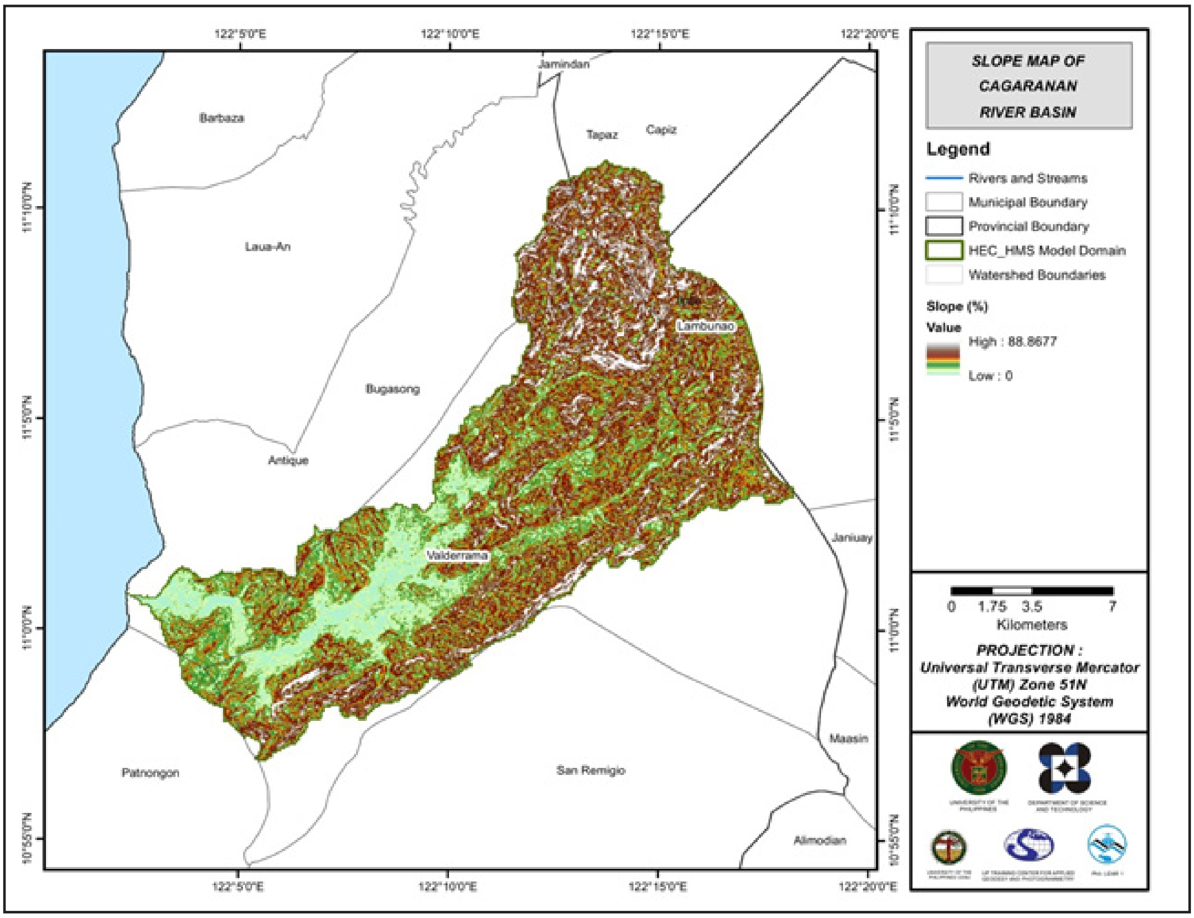


Figure 58. Slope map of the Cangaranan River Basin

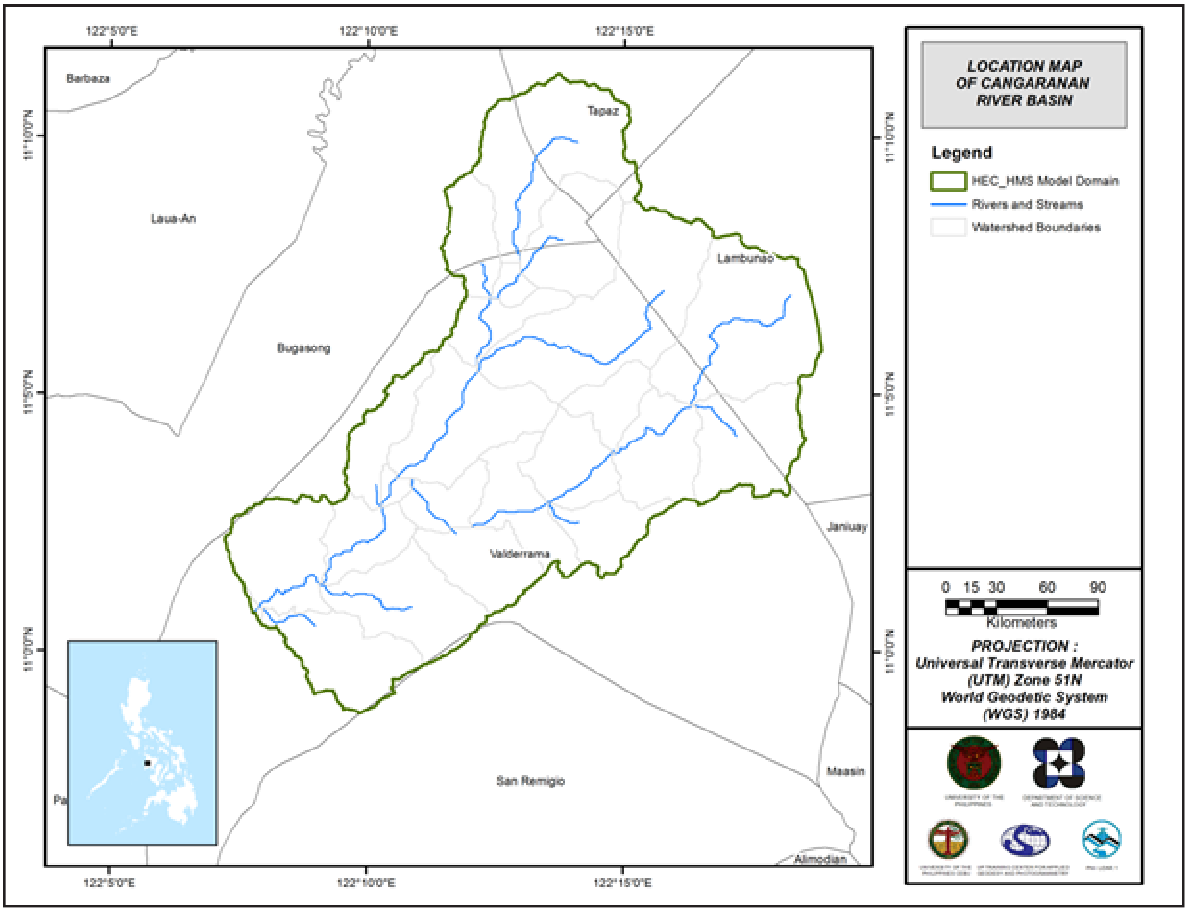


Figure 59. Stream delineation map of the Cangaranan River Basin

Using the SAR-based DEM, the Cangaranan basin was delineated and further subdivided into sub-basins. The model consists of twenty-three (23) sub-basins, eleven (11) reaches, and eleven (11) junctions, as exhibited in Figure 60. The main outlet is at the Valderrama Bridge. The Cangaranan Model Reach Parameters are presented in Annex 10.

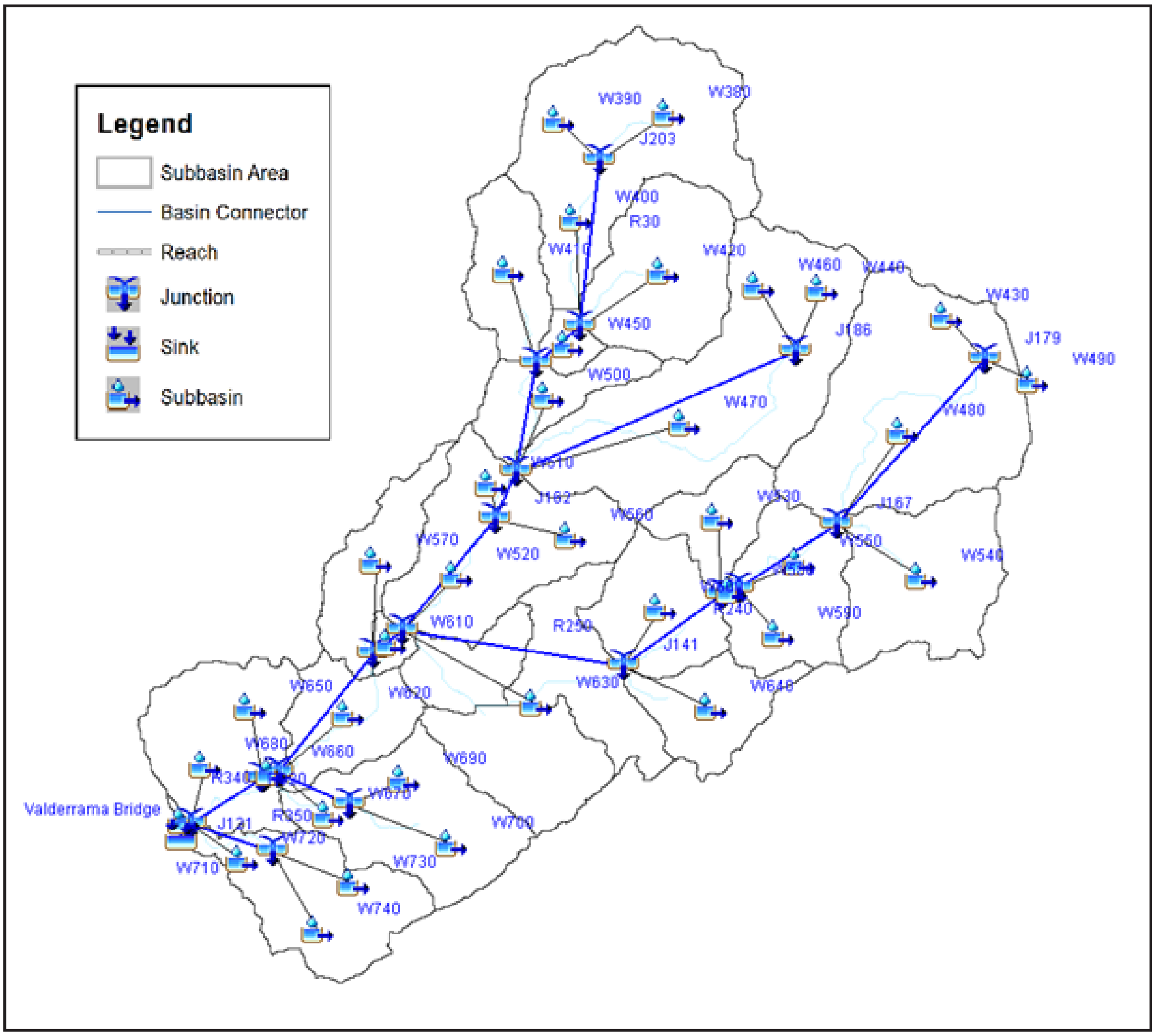


Figure 60. The Cangaranan River Basin model, generated using HEC-HMS

5.4 Cross-section Data

The 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, which was defined using the Arc GeoRAS tool, and was post-processed in ArcGIS (Figure 61).

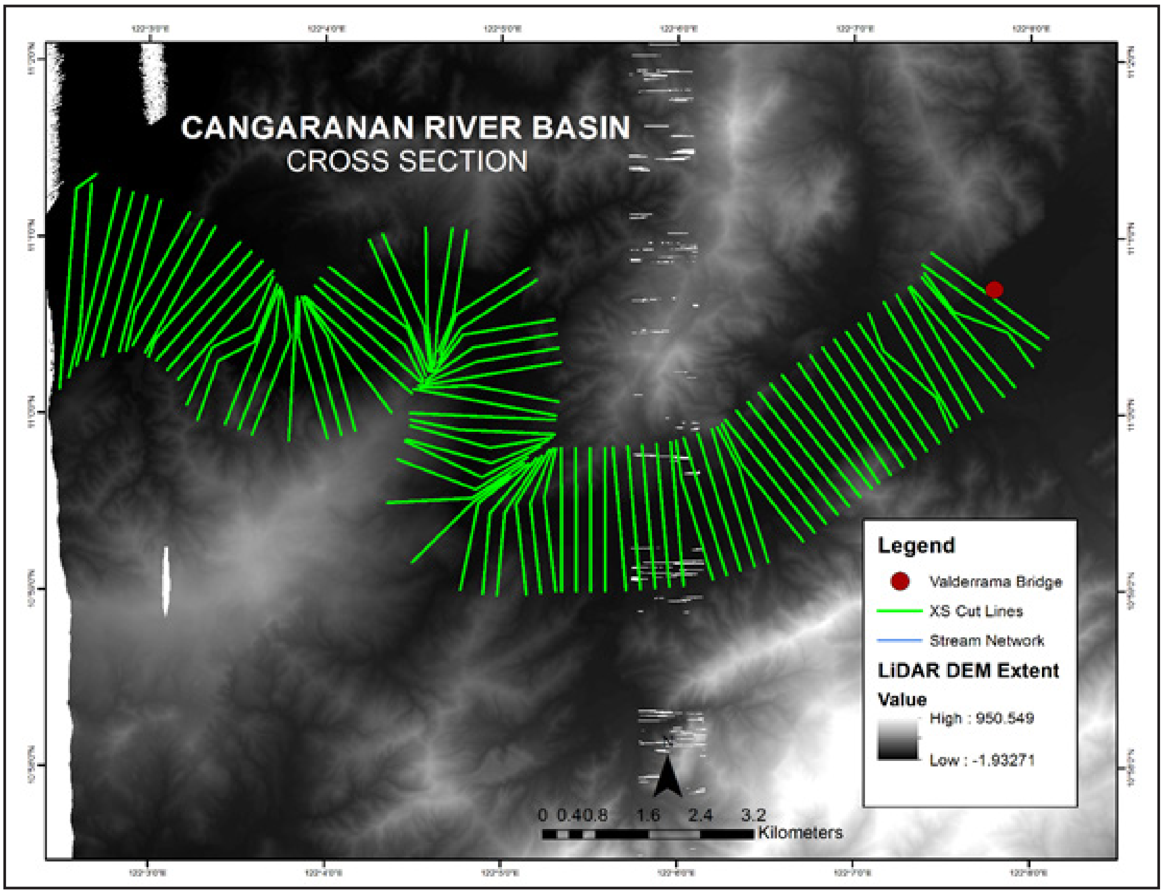


Figure 61. River cross-section of the Cangaranan River, generated through ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area 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. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. 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 was observed that the water will generally flow from the south of the model to the northeast, following the main channel. As such, boundary elements in these particular regions of the model were assigned as inflow and outflow elements, respectively.

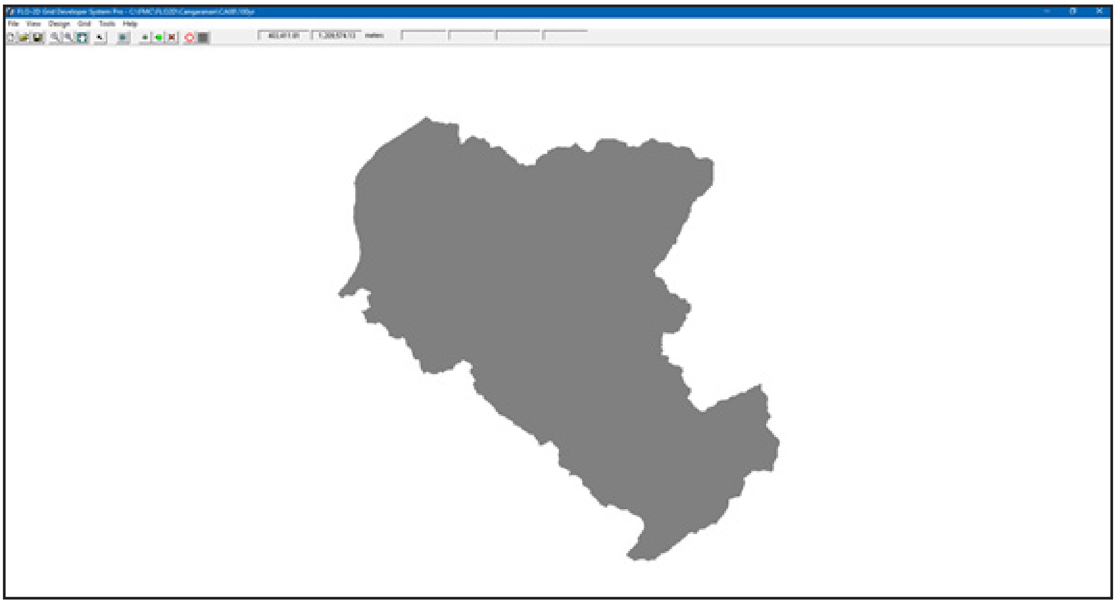


Figure 62. Screenshot of sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 27.09912 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 following flood hazard map. 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 meters, 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 Cangaranan floodplain are in Figure 63.

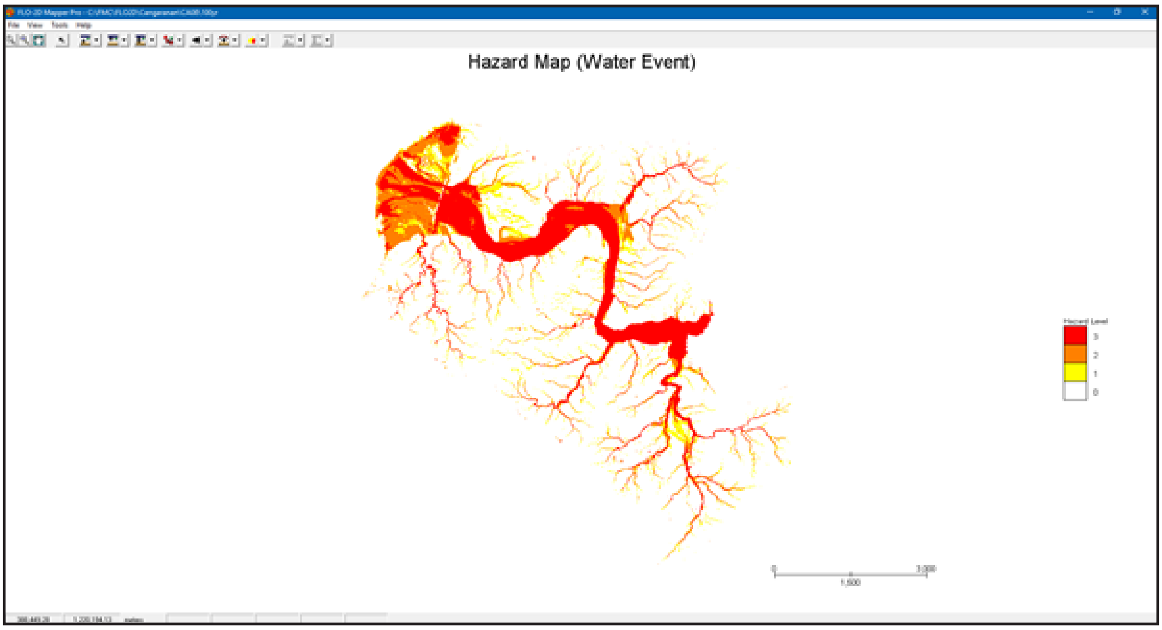


Figure 63. Generated 100-year rain return hazard map from the FLO-2D Mapper

The creation of a flood hazard map from the model also automatically created a flow depth map, 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 41 579 700.00 m2. The generated flood depth maps for the Cangaranan floodplain are in Figure 64.

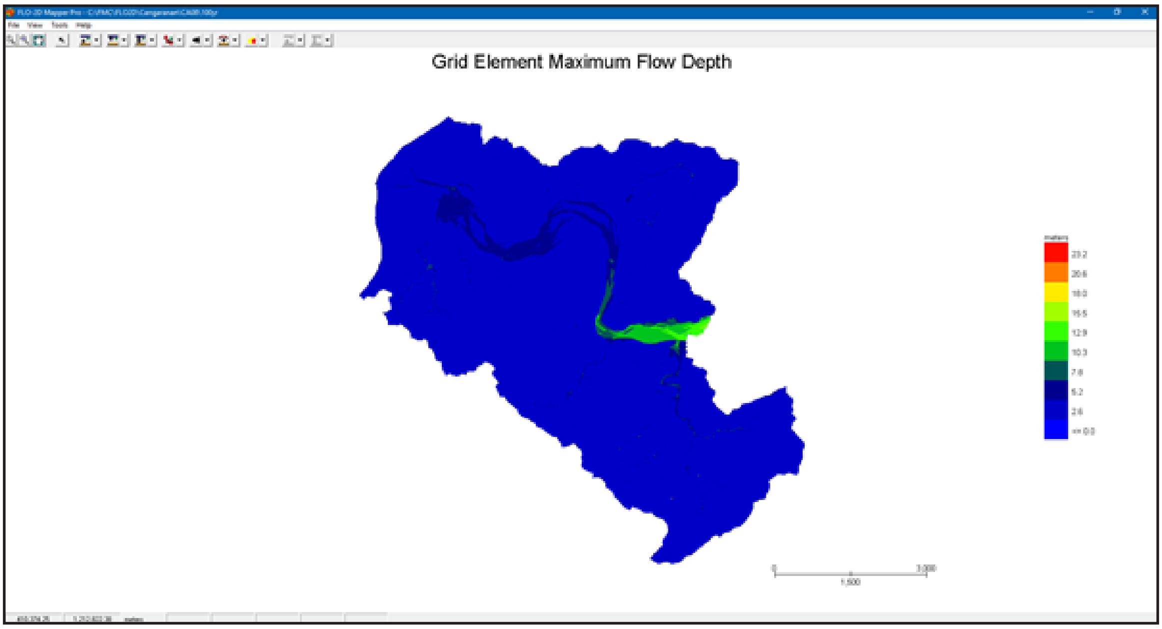


Figure 64. Generated 100-year rain return flow depth map from the FLO-2D Mapper

There is a total of 47 459 035.02 m3 of water entering the model. Of this amount, 12 649 153.72 m3 is due to rainfall while 34 809 881.30 m3 is inflow from other areas outside the model. 5 120 198.00 m3 of this water is lost to infiltration and interception, while 3 032 201.62 m3 is stored by the flood plain. The rest, amounting up to 39 306 628.36 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Cangaranan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 65 presents the comparison between the two (2) discharge data. The Cangaranan Model Basin Parameters are available in Annex 9.

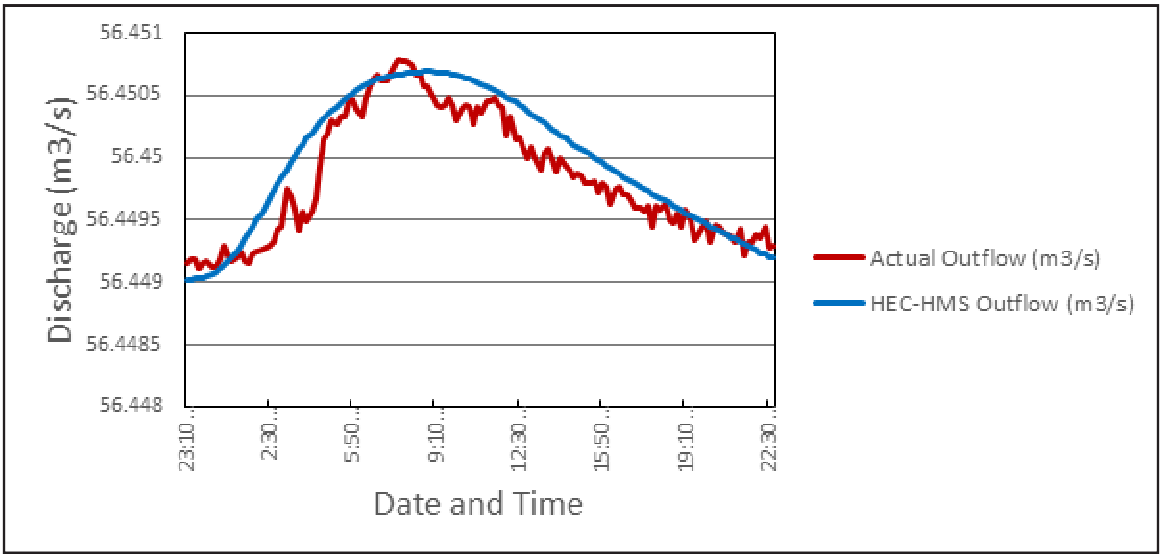


Figure 65. Outflow Hydrograph of Cangaranan produced by the HEC-HMS model, compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 32. Range of calibrated values for the Cangaranan model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.119-2.42
			Curve Number	56.5-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	3.9-53.2
			Storage Coefficient (hr)	5.09-69.5
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.0001
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.01

The initial abstraction parameter 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 0.119 mm - 2.42 mm for the 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 56.5 - 99 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Cangaranan, the basin mostly consists of shrub lands, closed and open forests, and cultivated lands; and the soil consists of sandy loam, clay, and undifferentiated soils.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 3.9 hours to 69.5 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 the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.99555 - 1 indicates that the basin is unlikely to quickly return to its original discharge, and will be higher instead. A ratio to peak of 0.0001 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.01 for the Cangaranan River Basin is lower than the usual Manning's n value for Philippine watersheds (Brunner, 2010).

Table 33. Summary of the Efficiency Test of the Cangaranan HMS Model

Accuracy measure	Value
RMSE	0.00022
r2	0.9481
NSE	0.81
PBIAS	0.44
RSR	-0.00025

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.00022 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. An r2 value close to 1 represents an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.9481.

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 0.81.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -0.00025.

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 0.44.

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 66) shows the Cangaranan outflow using the Iloilo RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods – from 165.2m3 in a 5-year return period to 304.5m3 for a 100-year return period.

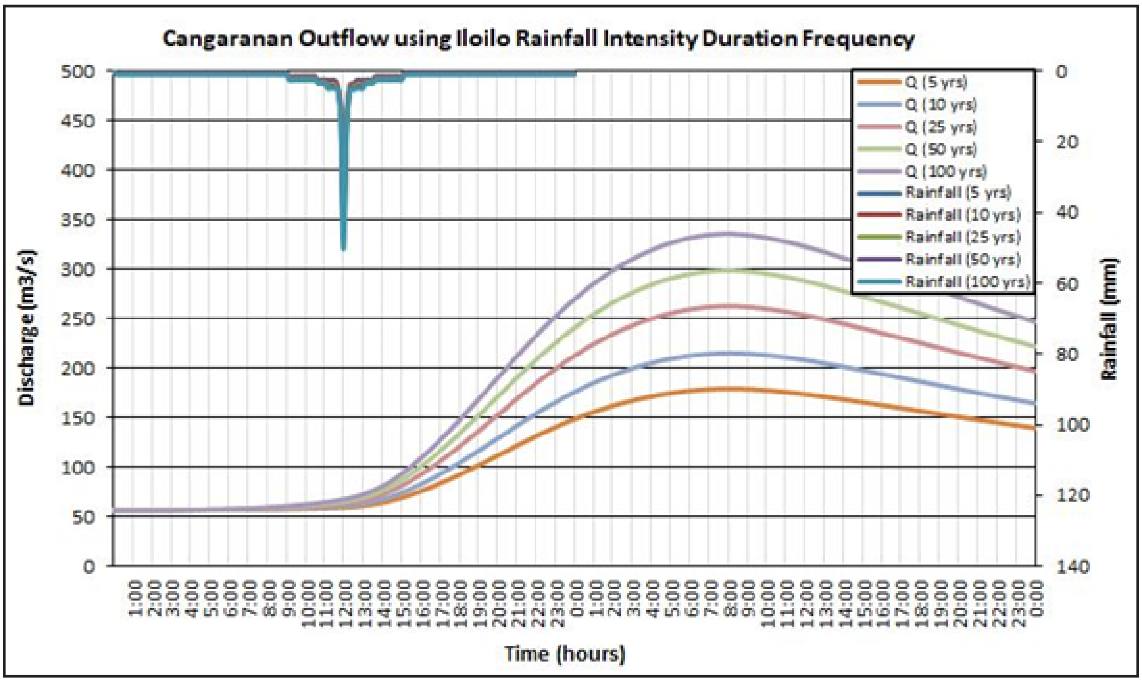


Figure 66. Outflow hydrograph at the Cangaranan Station generated using Iloilo RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Cangaranan discharge using the Iloilo RIDF curves in five (5) different return periods is provided in Table 34.

Table 34. Peak values of the Cangaranan HEC-HMS Model outflow using the Iloilo RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	165.2	28.7	179.06	20 hours, 10 minutes
10-Year	198.9	33.9	215.06	20 hours, 10 minutes
25-Year	241.5	40.5	262.53	20 hours
50-Year	273.1	45.4	298.75	20 hours
100-Year	304.5	50.3	335.41	20 hours

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 was 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. The sample generated map of the Cangaranan River using the calibrated HMS event flow is presented in Figure 67.

Figure 67. Sample output map of the Cangaranan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10-meter resolution. Figure 68 to Figure 73 illustrate the 5-year, 25-year, and 100-year rain return scenarios of the Cangaranan floodplain. The floodplain, with an area of 611.747 sq. km., covers nine (9) municipalities, namely, Barbaza, Bugasong, Laua-An, Patnongon, San Remigio, Valderrama, Jamindan, Tapaz, and Lambunao.

Table 35. Municipalities covered in the Cangaranan floodplain

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Barbaza	176.521	9.896553	5.606445
Bugasong	174.084	178.5685	102.576
Laua-An	159.768	81.86157	51.23777
Patnongon	132.218	50.27842	38.02691
San Remigio	394.42	0.457505	0.115994
Valderrama	308.427	215.671	69.9261
Jamindan	471.364	9.486631	2.012591
Tapaz	523.206	23.79695	4.548295
Lambunao	405.387	41.69371	10.28492

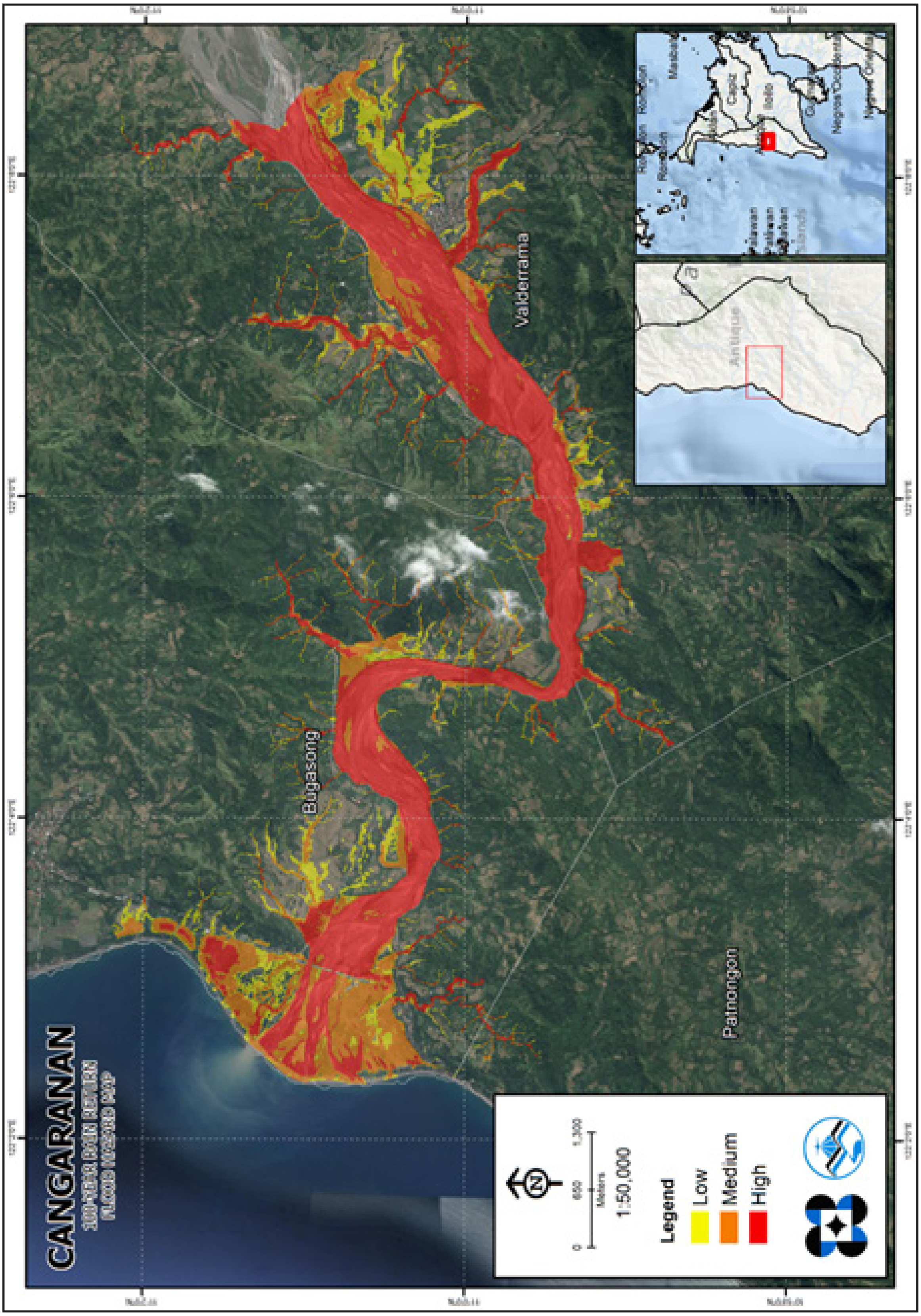


Figure 68. 100-year flood hazard map for the Cangaranan Floodplain, overlaid on Google Earth imagery

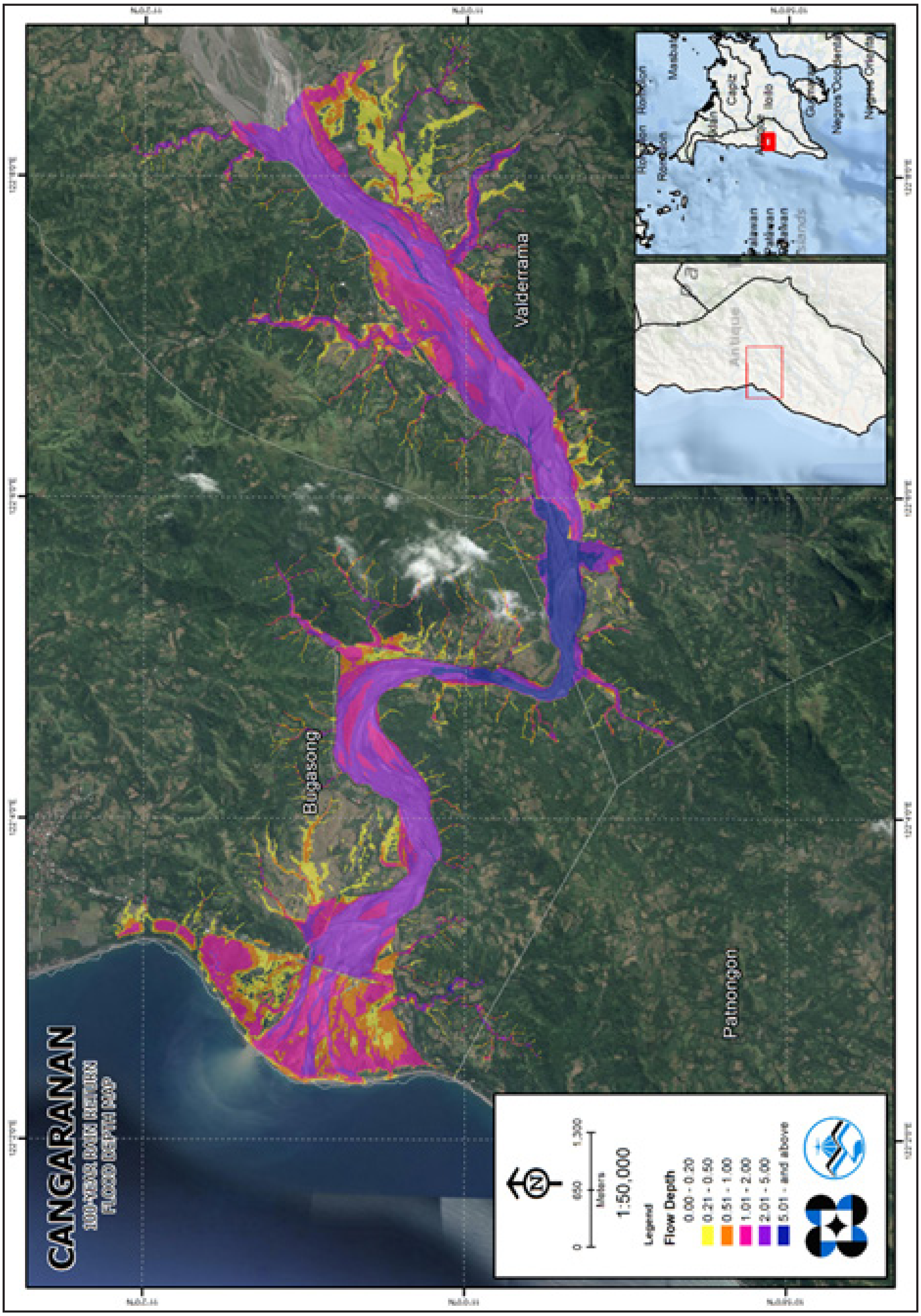


Figure 69. 100-year flow depth map for the Cangaranan floodplain, overlaid on Google Earth imagery

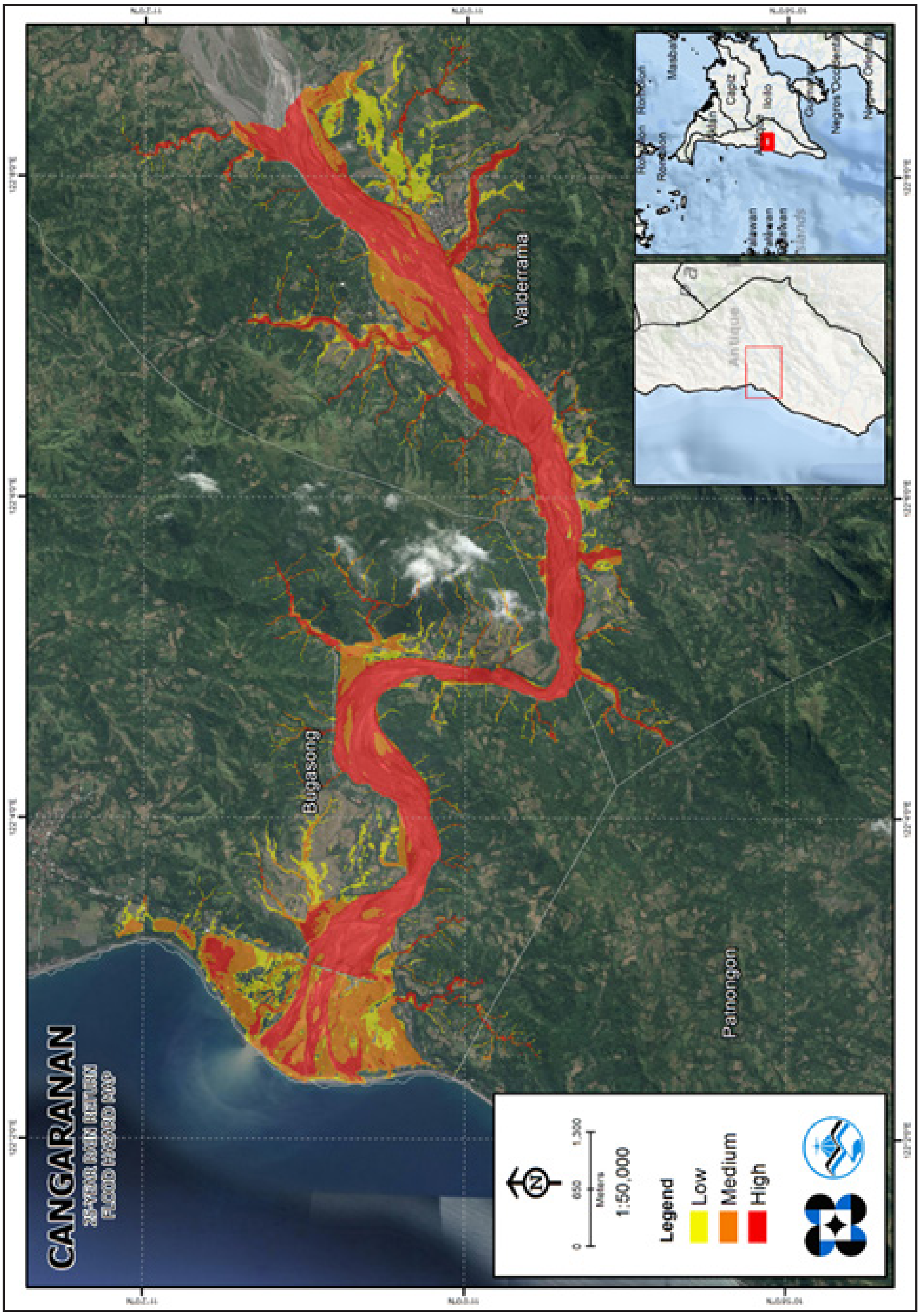


Figure 70. 25-year flood hazard map for the Cangaranan floodplain, overlaid on Google Earth imagery

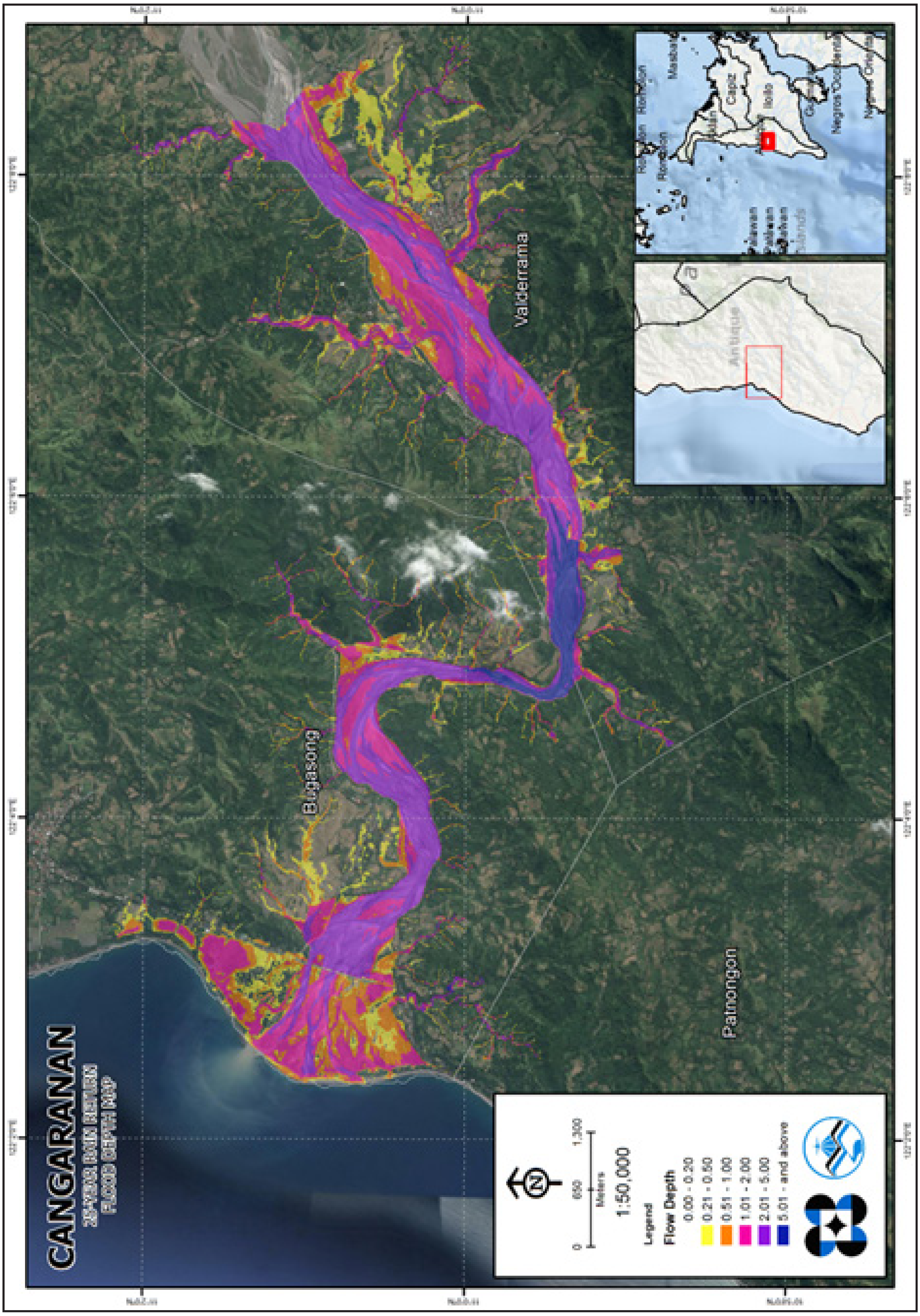


Figure 71. 25-year flow depth map for the Cangaranan floodplain, overlaid on Google Earth imagery

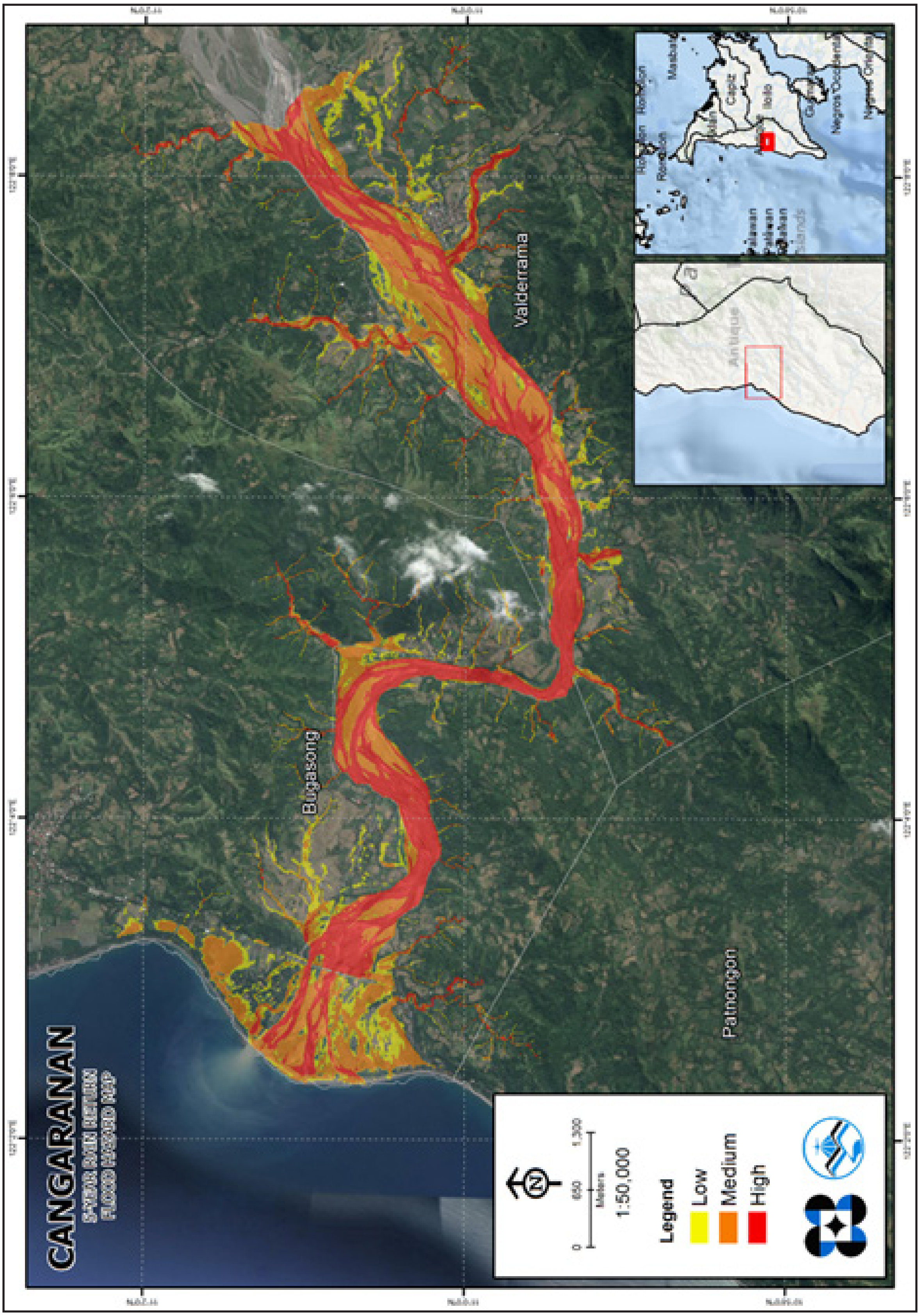


Figure 72. 5-year flood hazard map for the Cangaranan floodplain, overlaid on Google Earth imagery

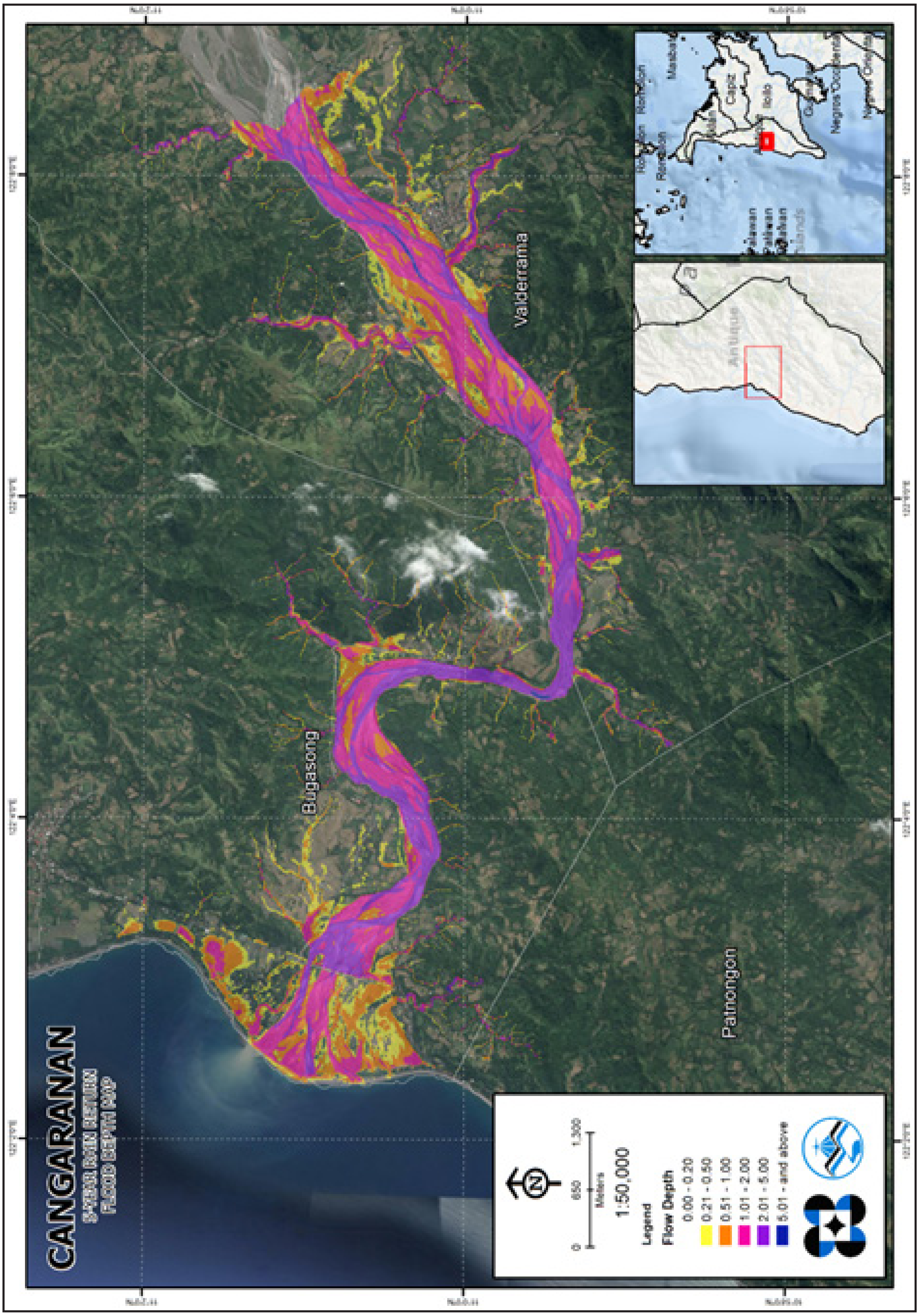


Figure 73. 5-year flood depth map for the Cangaranan floodplain, overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Cangaranan River Basin, grouped by municipality, are listed below. For the said basin, two (2) municipalities consisting of sixteen (16) barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 5.43% of the Municipality of Barbaza, with an area of 176.52 sq. km., will experience flood levels of less than 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.35%, 0.22%, 0.017%, and 0.016% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected areas in Barbaza, Antique during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Barbaza (in sq. km.)
	Langcaon
0.03-0.20	9.58
0.21-0.50	0.16
0.51-1.00	0.061
1.01-2.00	0.038
2.01-5.00	0.029
>5.00	0.028

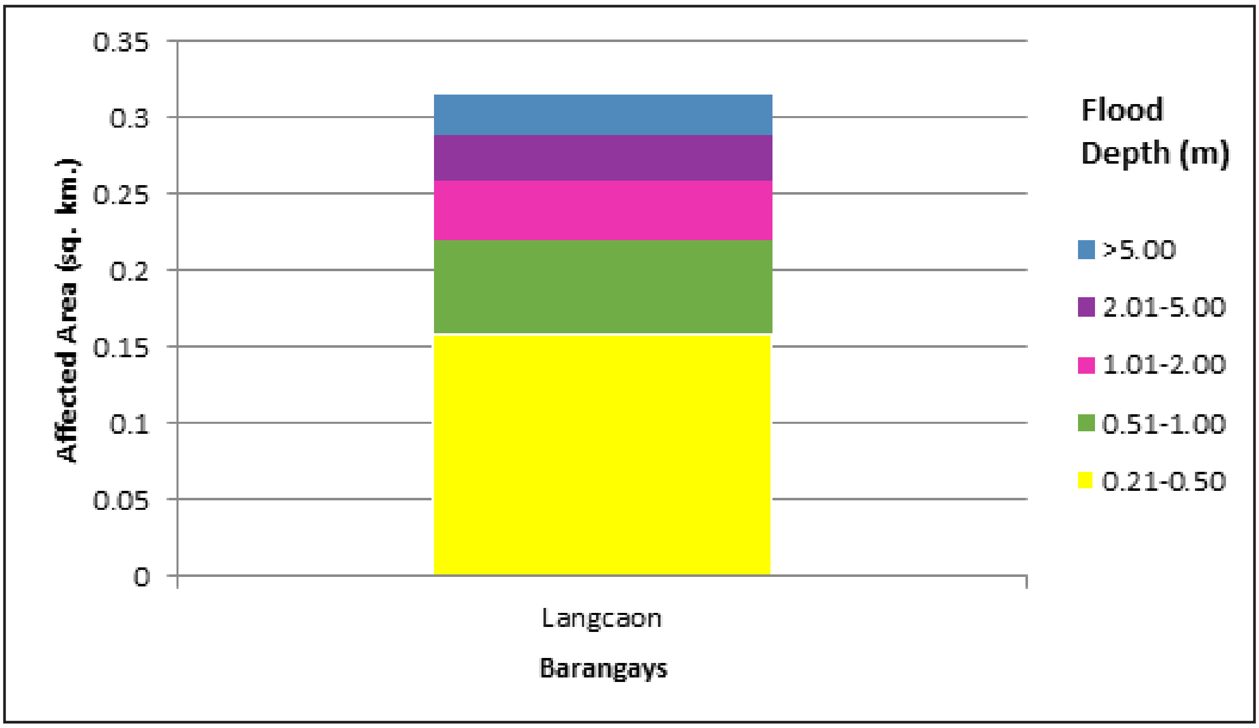


Figure 74. Affected areas in Barbaza, Antique during a 5-year rainfall return period

For the Municipality of Bugasong, with an area of 99.87 sq. km., 90.33% will experience flood levels of less than 0.20 meters. 4.26% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.81%, 2.66%, 2%, and 0.52% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Bugasong, Antique during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bugasong (in sq. km.)								
	Anilawan	Arangote	Bagtason	Camangahan	Centro Ilawod	Centro Ilaya	Centro Pojo	Cubay North	Cubay South
0.03-0.20	1.85	3.24	3.06	1.17	0.17	1.57	1.15	0.66	3.29
0.21-0.50	0.16	0.11	0.19	0.061	0.0016	0.054	0.25	0.17	0.6
0.51-1.00	0.15	0.13	0.18	0.066	0.0023	0.062	0.11	0.21	0.14
1.01-2.00	0.15	0.43	0.19	0.028	0.0051	0.086	0.045	0.14	0.029
2.01-5.00	0.057	0.41	0.27	0.01	0.0071	0.13	0.012	0.034	0.0013
>5.00	0.0009	0.0077	0.0027	0	0.0008	0.0021	0	0.0013	0
Affected area (sq. km.) by flood depth (in m.)	**Guija**	**Igbalangao**	**Igsoro**	**Ilaures**	**Jinalinan**	**Lacayon**	**Maray**	**Paliwan**	**Pangalcagan**
0.03-0.20	0.94	1.7	93.41	1.58	0.91	1.4	6.07	0.99	2.92
0.21-0.50	0.3	0.19	2.09	0.4	0.17	0.083	0.22	0.2	0.22
0.51-1.00	0.15	0.06	1.1	0.48	0.071	0.03	0.13	0.16	0.17
1.01-2.00	0.085	0.12	1.01	0.56	0.038	0.03	0.11	0.093	0.14
2.01-5.00	0.0087	0.14	1.21	0.26	0.004	0.017	0.059	0.0016	0.11
>5.00	0	0	0.86	0.0004	0	0.0028	0.0021	0	0.0029
Affected area (sq. km.) by flood depth (in m.)	**Sabang East**	**Sabang West**	**Tagudtud North**	**Tagudtud South**	**Talisay**	**Tica**	**Tono-An**	**Yapu**	**Zaragoza**
0.03-0.20	15.76	0.5	0.93	2.08	0.76	0.45	2.36	4.52	3.79
0.21-0.50	0.47	0.22	0.13	0.14	0.24	0.12	0.079	0.21	0.34
0.51-1.00	0.27	0.17	0.084	0.071	0.23	0.062	0.075	0.15	0.41
1.01-2.00	0.29	0.15	0.063	0.041	0.14	0.029	0.057	0.13	0.42
2.01-5.00	0.24	0.0027	0.0058	0.0055	0.0071	0.0022	0.055	0.11	0.31
>5.00	0.0079	0	0	0	0	0	0.0034	0.0075	0.0026

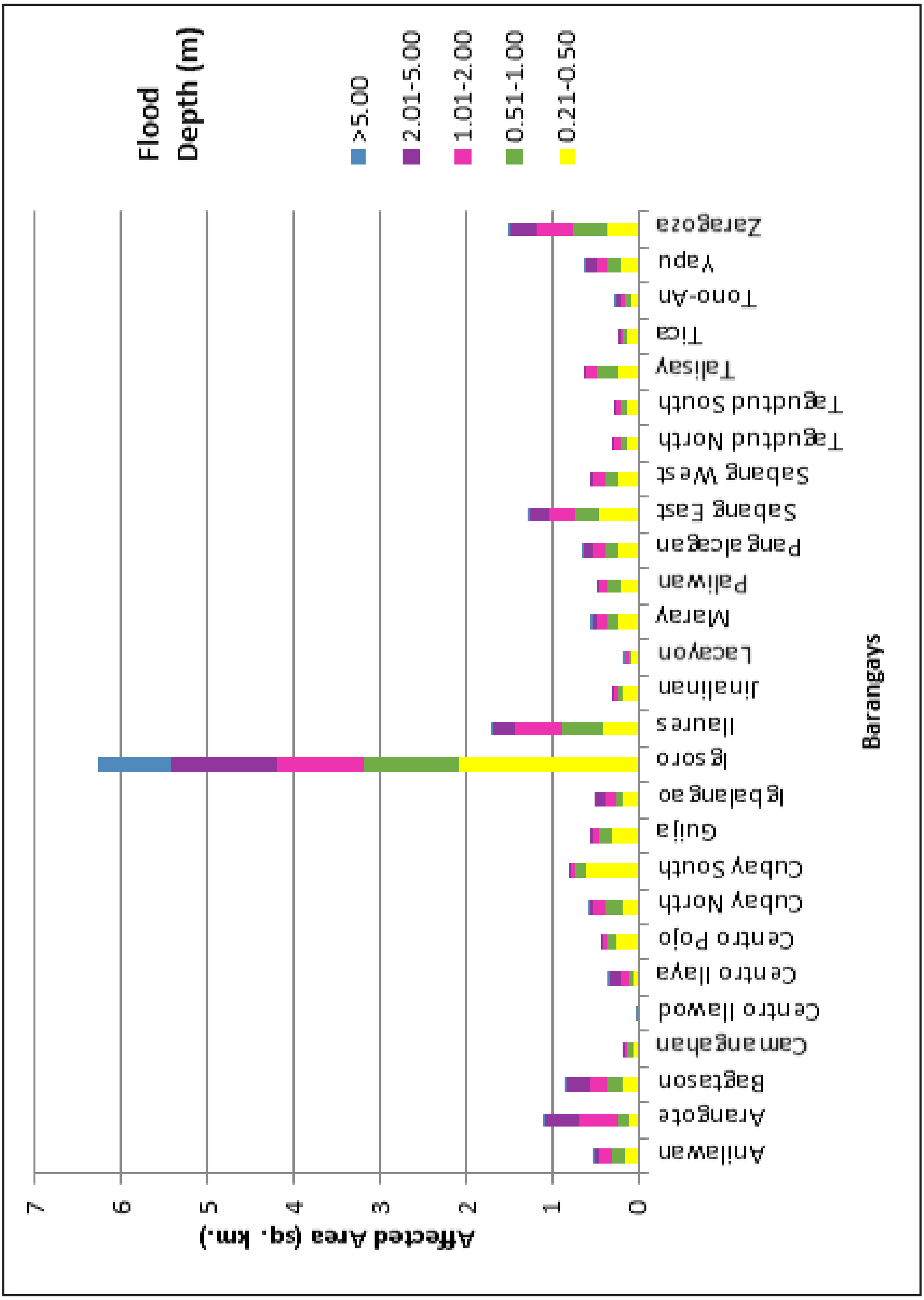


Figure 75. Affected areas in Bugasong, Antique during a 5-year rainfall return period

For the Municipality of Laua-An, with an area of 159.768 sq. km., 47.59% will experience flood levels of less than 0.20 meters. 1.41% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.75%, 0.58%, 0.53%, and 0.38% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Laua-An, Antique during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Laua-An (in sq. km.)					
	Bagongbayan	Cadajug	Capnayan	Guinbanga-An	Guisijan	Jaguikican
0.03-0.20	1.65	0.26	4.37	0.91	2.76	3.96
0.21-0.50	0.067	0.0031	0.12	0.06	0.16	0.11
0.51-1.00	0.037	0.0015	0.053	0.03	0.12	0.034
1.01-2.00	0.031	0.0019	0.03	0.023	0.079	0.016
2.01-5.00	0.023	0.0009	0.0089	0.025	0.029	0.0084
>5.00	0.0035	0	0.0003	0.0002	0.002	0.00019
Affected area (sq. km.) by flood depth (in m.)	Liberato	Loon	Lugta	Maria	Maybunga	Pandanan
0.03-0.20	0.69	1.34	1.58	0.96	12.46	3.84
0.21-0.50	0.017	0.095	0.24	0.041	0.34	0.13
0.51-1.00	0.01	0.058	0.17	0.029	0.14	0.064
1.01-2.00	0.0074	0.051	0.088	0.044	0.11	0.056
2.01-5.00	0.0081	0.045	0.01	0.062	0.12	0.064
>5.00	0.0013	0.0015	0.00017	0.032	0.06	0.016
Affected area (sq. km.) by flood depth (in m.)	Paningayan	Pascuala	San Ramon	Santiago	Tibacan	Virginia
0.03-0.20	2.45	0.4	26.86	6.73	0.25	4.57
0.21-0.50	0.13	0.0097	0.4	0.23	0.0052	0.093
0.51-1.00	0.13	0.0042	0.16	0.12	0.0038	0.039
1.01-2.00	0.1	0.002	0.13	0.11	0.0034	0.033
2.01-5.00	0.075	0.00076	0.19	0.12	0.0051	0.049
>5.00	0.0097	0	0.39	0.031	0.0008	0.063

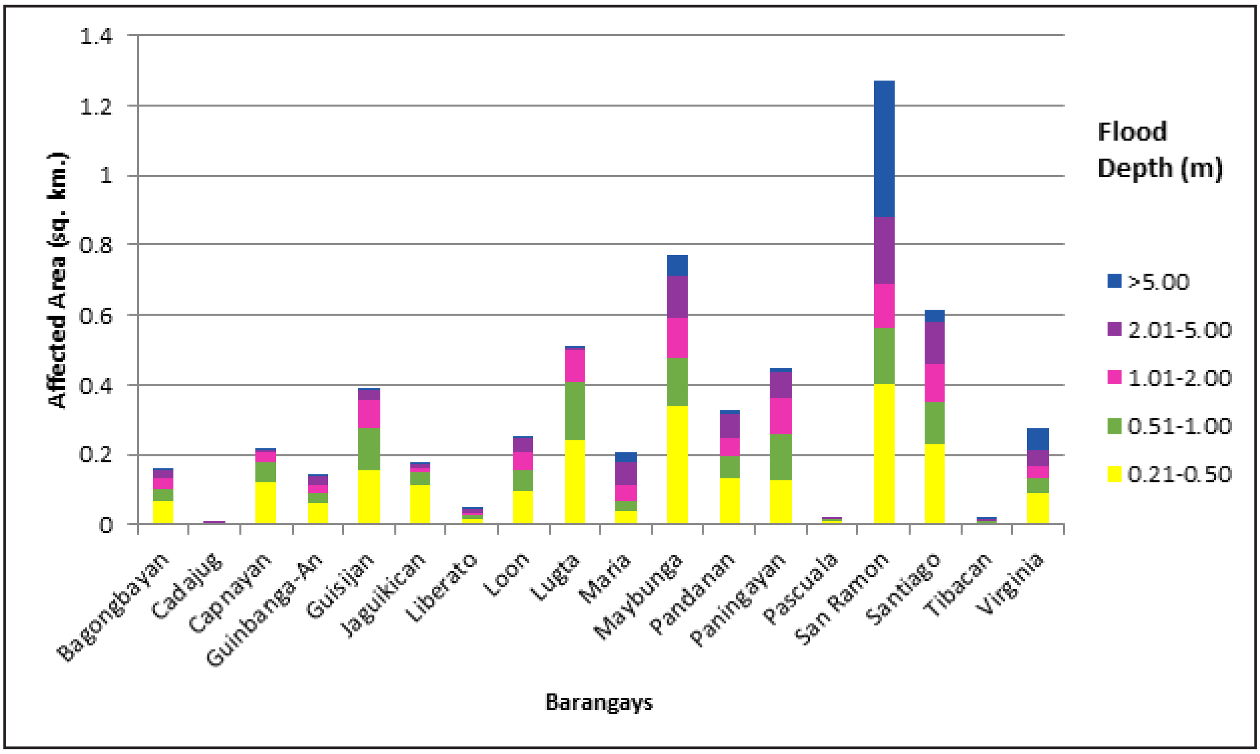


Figure 76. Affected areas in Laua-An, Antique during a 5-year rainfall return period

For the Municipality of Patnongon, with an area of 132.218 sq. km., 33.80% will experience flood levels of less than 0.20 meters. 1.49% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1%, 0.94%, 0.75%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Patnongon, Antique during 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Patnongon (in sq. km.)						
	Amparo	Badiangan	Carit-An	Gella	Igbarawan	Igbobon	La Rioja
0.03-0.20	0.12	2.8	2.4	5.45	2.16	0.12	4.1
0.21-0.50	0.0032	0.12	0.25	0.15	0.1	0.017	0.28
0.51-1.00	0.003	0.11	0.18	0.09	0.074	0.0052	0.15
1.01-2.00	0.0018	0.091	0.12	0.09	0.063	0.0042	0.12
2.01-5.00	0	0.051	0.073	0.08	0.055	0.0005	0.18
>5.00	0	0.0046	0.016	0.01	0.0002	0	0.0087
Affected area (sq. km.) by flood depth (in m.)	Mabasa	Macarina	Magarang	Pandanan	Quezon	Salaguiawan	Samalague
0.03-0.20	3.4	2.2	3.7	2.73	0.23	3.6	2.88
0.21-0.50	0.12	0.096	0.11	0.17	0.0004	0.12	0.15
0.51-1.00	0.077	0.06	0.036	0.15	0	0.058	0.1
1.01-2.00	0.066	0.05	0.016	0.17	0	0.057	0.09
2.01-5.00	0.042	0.026	0.0089	0.12	0	0.037	0.13
>5.00	0.0025	0.0006	0.00014	0.013	0	0.011	0.01
Affected area (sq. km.) by flood depth (in m.)	Tamayoc	Tigbalogo	Villa Cruz	Villa Flores	Villa Laua-An	Villa Sal	
0.03-0.20	0.27	3.6	3	0.27	0.39	1	
0.21-0.50	0.0091	0.13	0.1	0	0.012	0.019	
0.51-1.00	0.0061	0.095	0.11	0.0016	0.0031	0.009	
1.01-2.00	0.0053	0.14	0.13	0.0025	0.002	0.0092	
2.01-5.00	0.0061	0.067	0.12	0.0019	0.0015	0.0048	
>5.00	0.0002	0.0013	0.0042	0.0001	0	0.0001	

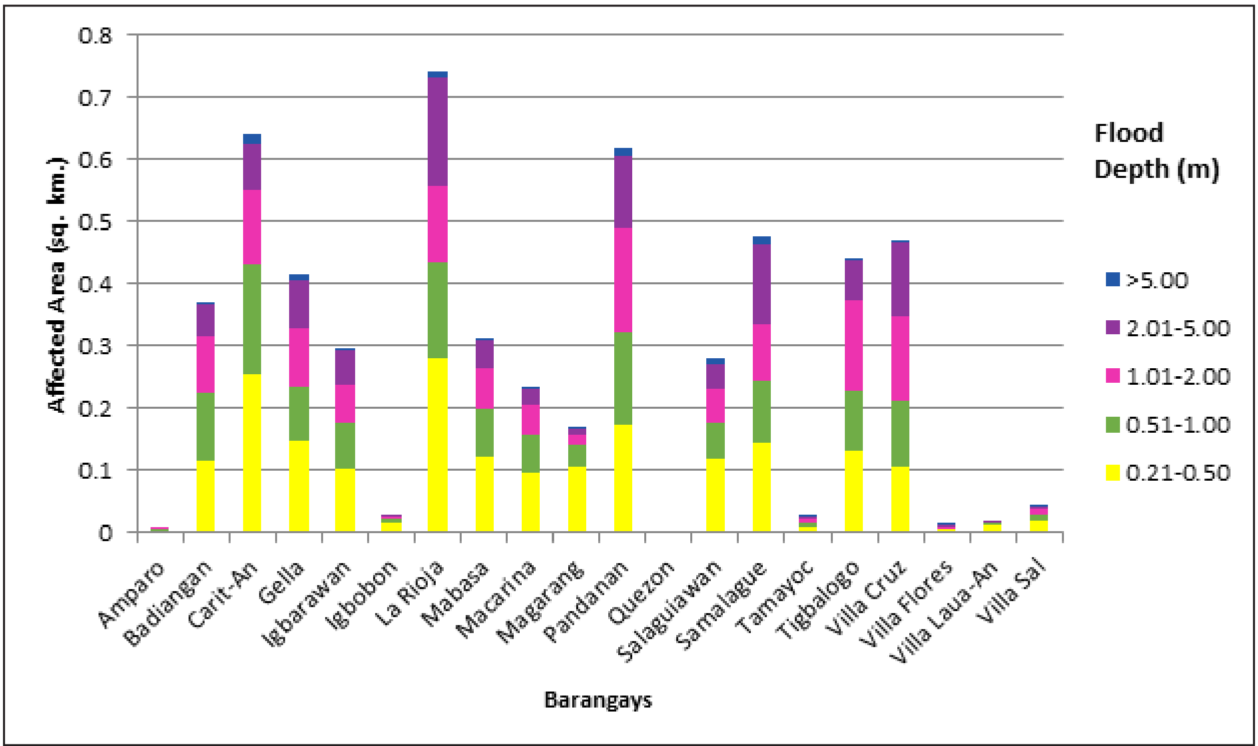


Figure 77. Affected areas in Patnongon, Antique during 5-year rainfall return period

For the Municipality of San Remigio, with an area of 394.42001 sq. km., 0.12% will experience flood levels of less than 0.20 meters. 0.0002% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.000003% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in San Remigio, Antique during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Remigio (in sq. km.)	
	Banbanan	General Fullon
0.03-0.20	0.071	0.39
0.21-0.50	0.0005	0.00038
0.51-1.00	0	0.000013
1.01-2.00	0	0
2.01-5.00	0	0
>5.00	0	0

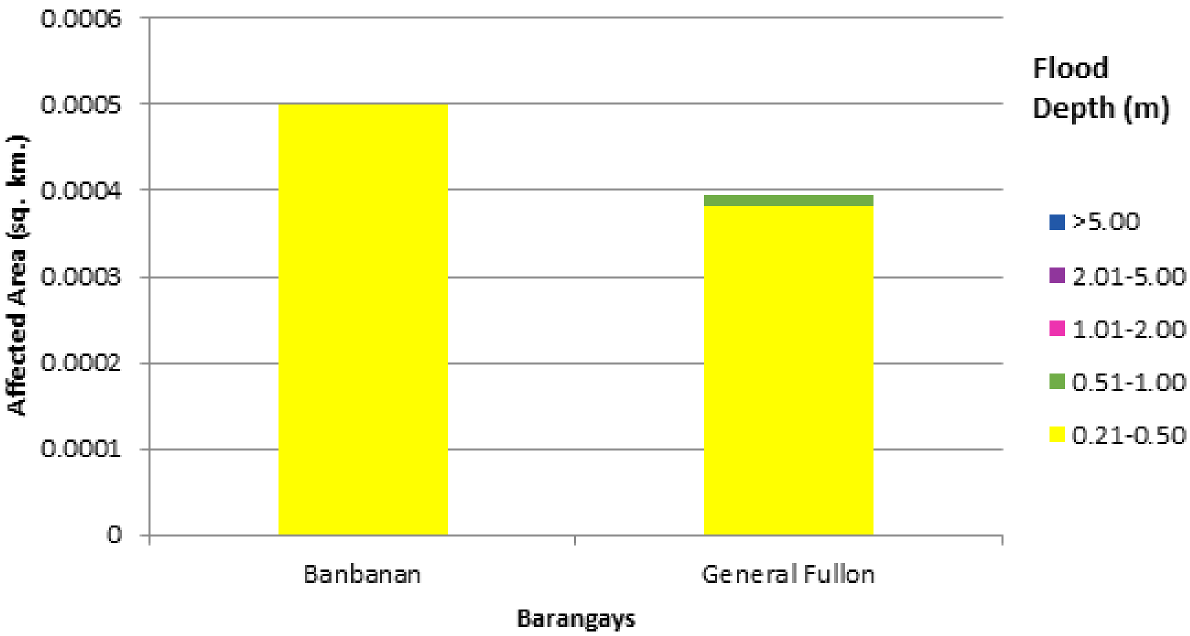


Figure 78. Affected areas in San Remigio, Antique during a 5-year rainfall return period

For the Municipality of Valderrama, with an area of 308.427 sq. km., 62.49% will experience flood levels of less than 0.20 meters. 2.27% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.62%, 1.99%, 1.32%, and 0.24% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Valderrama, Antique during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valderrama (in sq. km.)										
	Alon	Bakiang	Binanogan	Borocboroc	Bugnay	Buluangan I	Buluangan II	Bunsod	Busog	Cananghan	Canipayan
0.03-0.20	9.66	3.81	6.77	7.29	8.02	1.17	3.05	4.66	15.1	13.35	2.41
0.21-0.50	0.26	0.088	0.19	0.39	0.36	0.14	0.14	0.17	0.42	0.33	0.082
0.51-1.00	0.11	0.041	0.075	0.22	0.18	0.11	0.073	0.22	0.19	0.15	0.053
1.01-2.00	0.075	0.028	0.068	0.29	0.15	0.08	0.062	0.26	0.19	0.22	0.048
2.01-5.00	0.1	0.021	0.052	0.13	0.079	0.022	0.031	0.087	0.22	0.4	0.042
>5.00	0.0069	0.0049	0.0013	0.0032	0.0039	0	0	0.0022	0.076	0.056	0.0004
Affected area (sq. km.) by flood depth (in m.)	Cansilayan	Culyat	Iglinab	Igmasandig	Lublub	Manlacbo	Pandanan	San Agustin	Takas	Tigmamale	Ubos
0.03-0.20	13.68	14.54	7.11	5.79	8.56	5.34	9.61	44.8	3.93	3.32	0.75
0.21-0.50	0.44	0.38	0.23	0.39	0.36	0.27	0.67	0.95	0.33	0.18	0.23
0.51-1.00	0.22	0.18	0.15	0.46	0.42	0.19	0.96	0.36	0.13	0.12	0.39
1.01-2.00	0.2	0.13	0.13	0.91	0.49	0.17	1.12	0.31	0.13	0.24	0.83
2.01-5.00	0.23	0.081	0.036	0.35	0.39	0.12	0.31	0.45	0.12	0.45	0.34
>5.00	0.085	0.056	0.0012	0	0.0082	0.0021	0.016	0.4	0.0018	0.0021	0.019

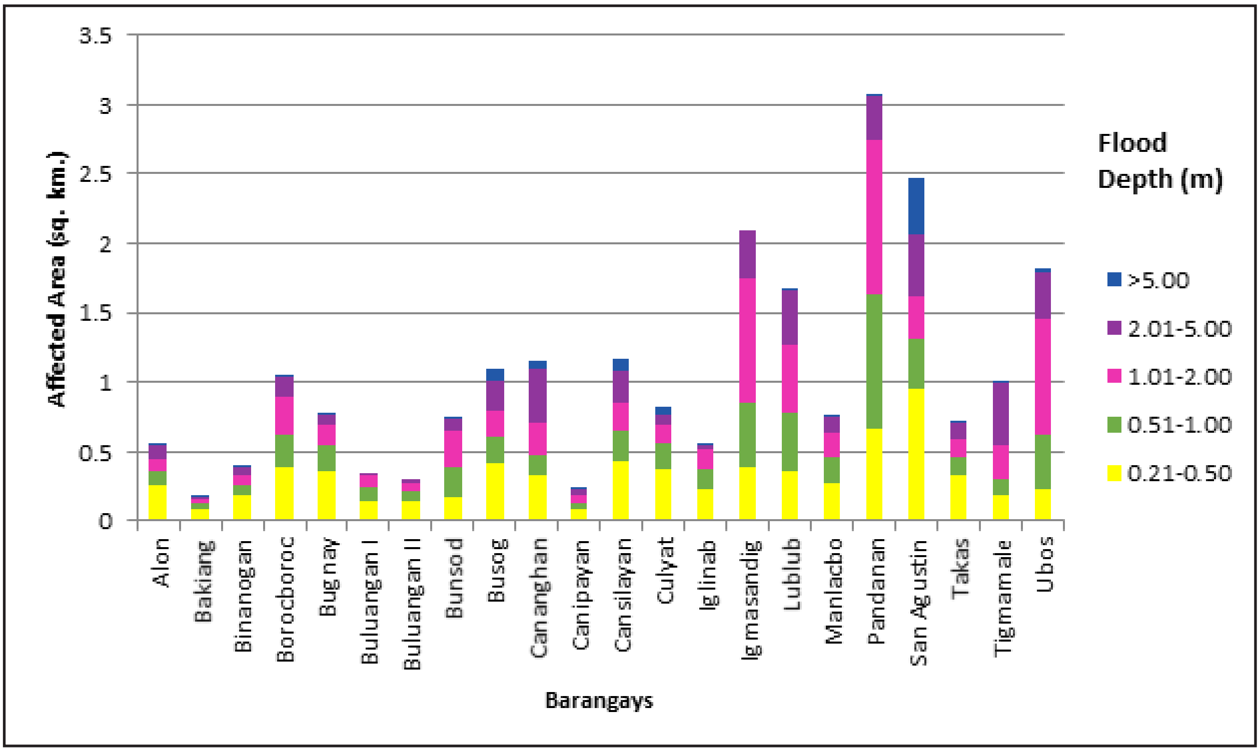


Figure 79. Affected areas in Valderrama, Antique during a 5-year rainfall return period

For the Municipality of Jamindan, with an area of 471.364 sq. km., 1.93% will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.014%, 0.01%, 0.013%, 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 more than 5 meters, respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in Jamindan, Capiz during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jamindan (in sq. km.)
	Jaena Sur
0.03-0.20	9.09
0.21-0.50	0.18
0.51-1.00	0.068
1.01-2.00	0.046
2.01-5.00	0.063
>5.00	0.049

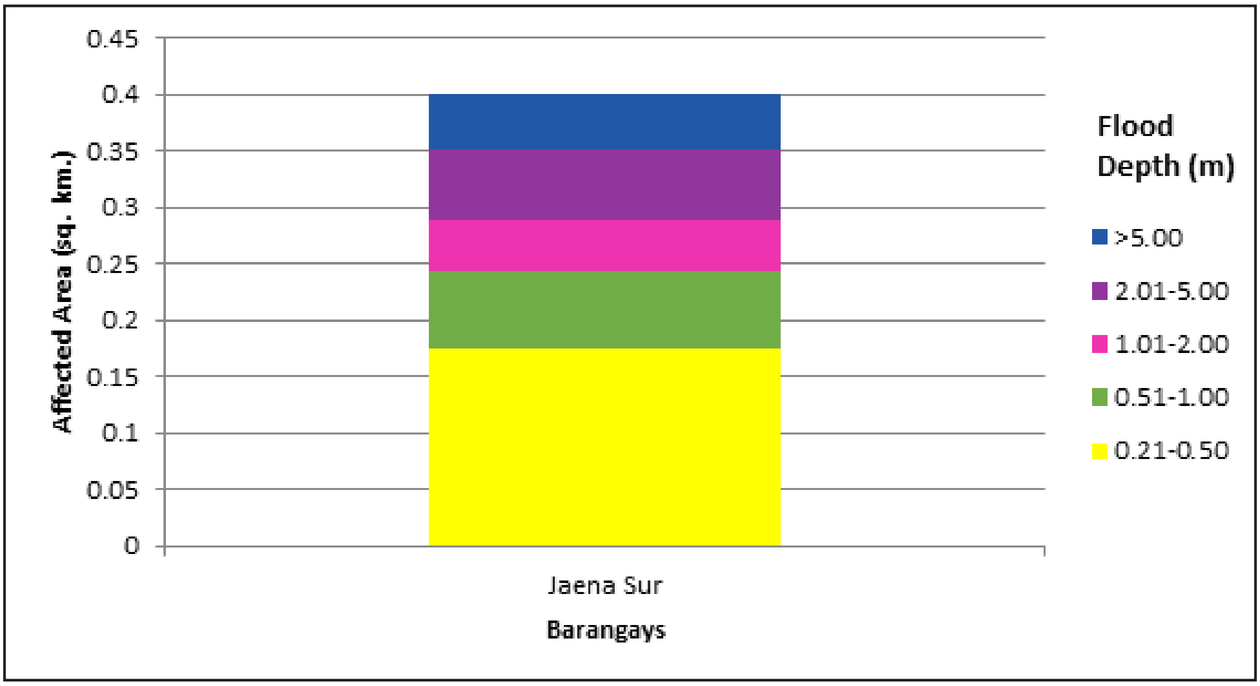


Figure 80. Affected areas in Jamindan, Capiz during a 5-year rainfall return period

For the Municipality of Tapaz, with an area of 523.206 sq. km., 4.36% will experience flood levels of less than 0.20 meters. 0.1% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.04%, 0.02%, 0.018%, 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 more than 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected Areas in Tapaz, Capiz during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tapaz (in sq. km.)
	Minan
0.03-0.20	22.84
0.21-0.50	0.5
0.51-1.00	0.19
1.01-2.00	0.11
2.01-5.00	0.093
>5.00	0.067

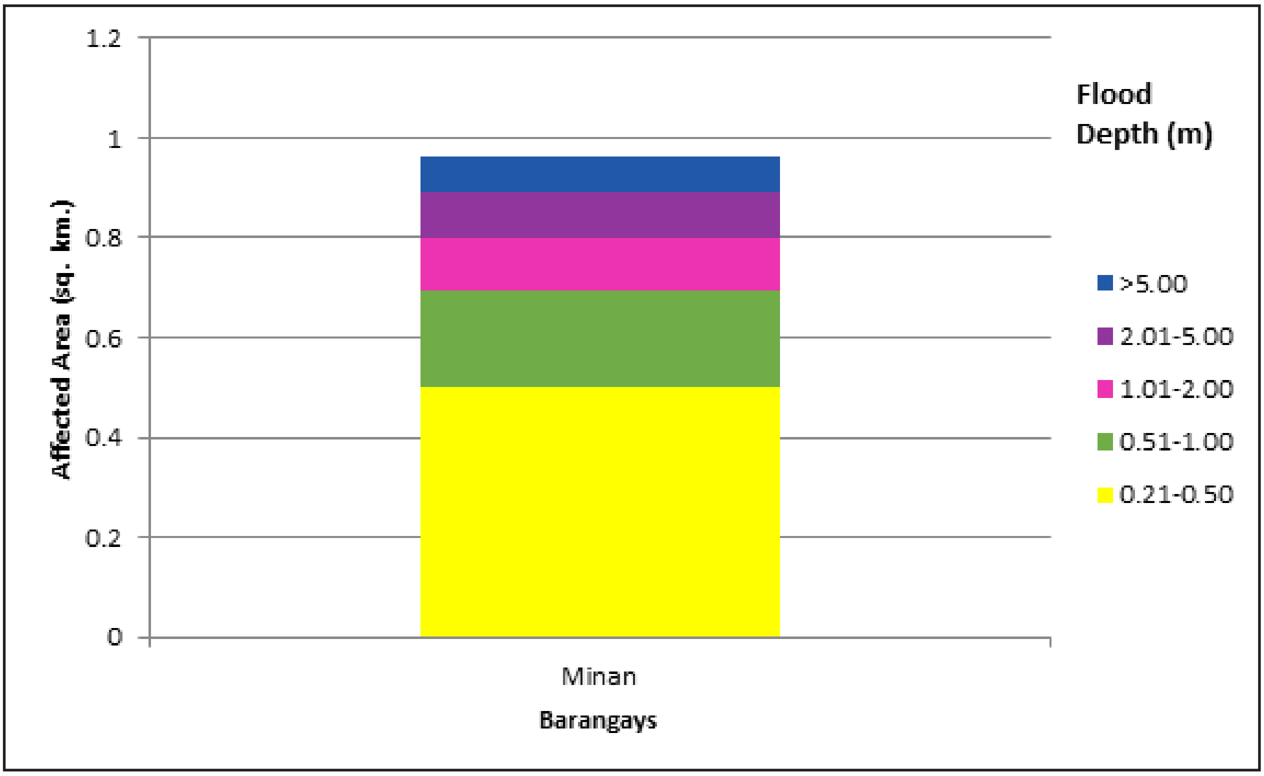


Figure 81. Affected areas in Tapaz, Capiz during a 5-year rainfall return period

For the Municipality of Lambunao, with an area of 405.387 sq. km., 9.80% will experience flood levels of less than 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.08%, 0.061%, 0.067%, and 0.056% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Lambunao, Iloilo during 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lambunao (in sq. km.)
	Cabatangan
0.03-0.20	39.73
0.21-0.50	0.88
0.51-1.00	0.34
1.01-2.00	0.25
2.01-5.00	0.27
>5.00	0.22

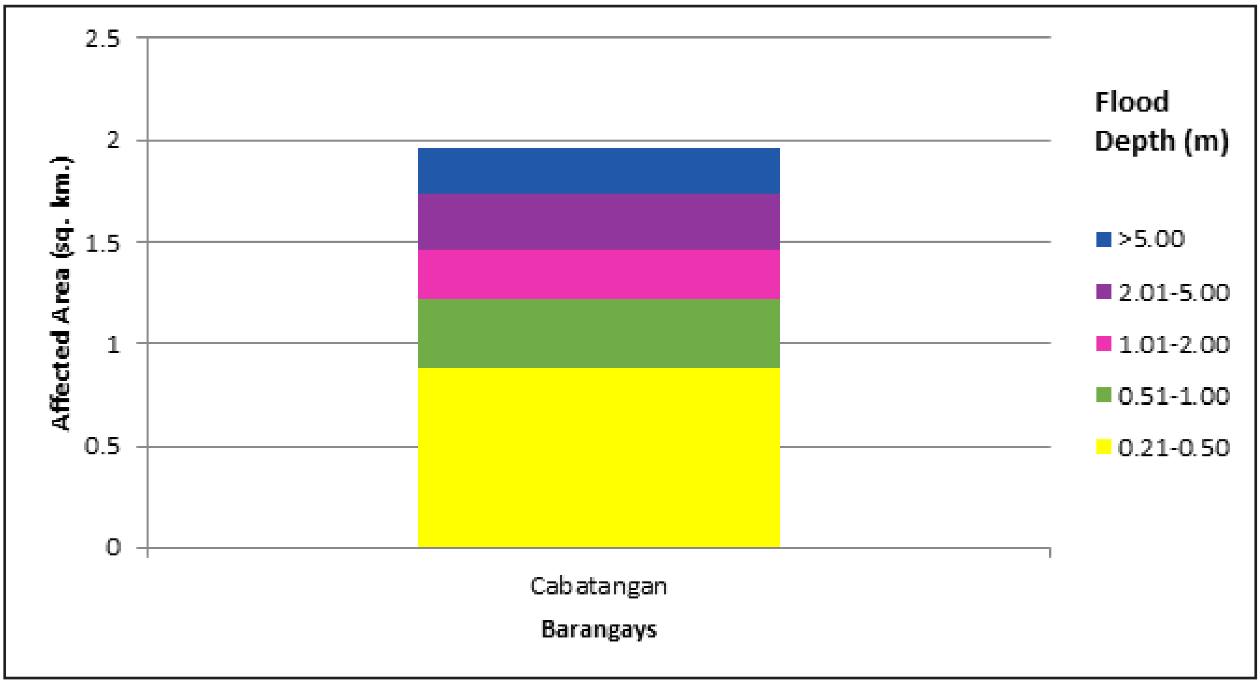


Figure 82. Affected areas in Lambunao, Iloilo during a 25-year rainfall return period

For the 25-year return period, 5.37% of the Municipality of Barbaza, with an area of 176.52 sq. km., will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.04%, 0.03%, 0.02%, 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 more than 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Barbaza, Antique during 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Barbaza (in sq. km.)
	Langcaon
0.03-0.20	9.49
0.21-0.50	0.2
0.51-1.00	0.078
1.01-2.00	0.05
2.01-5.00	0.04
>5.00	0.036

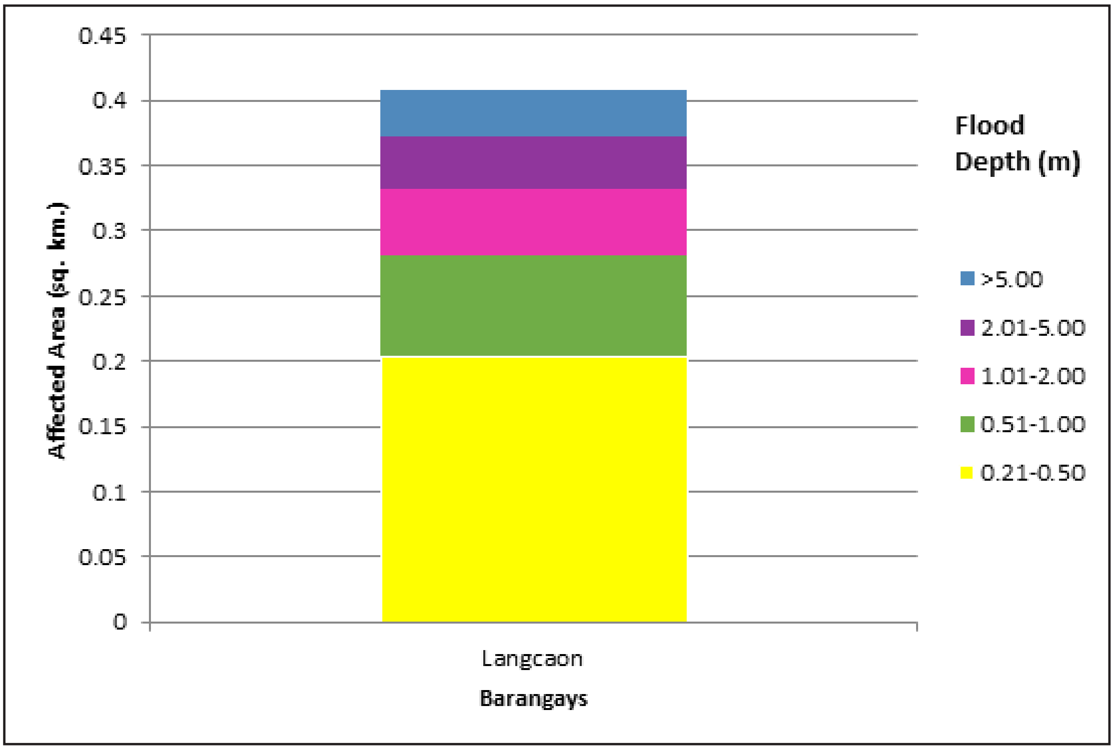


Figure 83. Affected areas in Barbaza, Antique during a 25-year rainfall return period

For the Municipality of Bugasong, with an area of 99.87 sq. km., 87.23% will experience flood levels of less than 0.20 meters. 4.75% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.29%, 3.44%, 2.94%, and 0.94% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Bugasong, Antique during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bugasong (in sq. km.)								
	Anilawan	Arangote	Bagtason	Camangahan	Centro Ilawod	Centro Ilaya	Centro Pojo	Cubay North	Cubay South
0.03-0.20	1.74	3.16	2.97	1.11	0.16	1.49	0.97	0.53	2.86
0.21-0.50	0.16	0.14	0.2	0.082	0.0038	0.06	0.33	0.09	0.88
0.51-1.00	0.17	0.063	0.15	0.06	0.0045	0.057	0.17	0.18	0.25
1.01-2.00	0.18	0.28	0.19	0.077	0.0053	0.094	0.064	0.31	0.07
2.01-5.00	0.1	0.66	0.26	0.013	0.0086	0.18	0.04	0.098	0.003
>5.00	0.0011	0.035	0.12	0.0002	0.0026	0.019	0	0.0021	0
Affected area (sq. km.) by flood depth (in m.)	**Guija**	**Igbalangao**	**Igsoro**	**Ilaures**	**Jinalinan**	**Lacayon**	**Maray**	**Paliwan**	**Pangalcagan**
0.03-0.20	0.74	1.57	91.8	1.22	0.68	1.35	5.94	0.87	2.71
0.21-0.50	0.23	0.21	2.53	0.32	0.19	0.12	0.27	0.16	0.27
0.51-1.00	0.31	0.11	1.21	0.5	0.13	0.044	0.15	0.21	0.22
1.01-2.00	0.17	0.093	1.22	0.83	0.14	0.031	0.14	0.18	0.19
2.01-5.00	0.034	0.22	1.56	0.4	0.053	0.024	0.091	0.02	0.15
>5.00	0	0	1.37	0.0019	0	0.0033	0.004	0	0.015
Affected area (sq. km.) by flood depth (in m.)	**Sabang East**	**Sabang West**	**Tagudtud North**	**Tagudtud South**	**Talisay**	**Tica**	**Tono-An**	**Yapu**	**Zaragoza**
0.03-0.20	15.52	0.41	0.83	1.97	0.59	0.37	2.3	4.36	3.63
0.21-0.50	0.54	0.19	0.17	0.2	0.2	0.13	0.091	0.23	0.26
0.51-1.00	0.3	0.21	0.1	0.086	0.31	0.1	0.074	0.17	0.4
1.01-2.00	0.32	0.23	0.088	0.064	0.25	0.057	0.076	0.18	0.45
2.01-5.00	0.34	0.0047	0.022	0.011	0.034	0.0045	0.077	0.18	0.54
>5.00	0.026	0	0	0	0	0	0.0079	0.014	0.0062

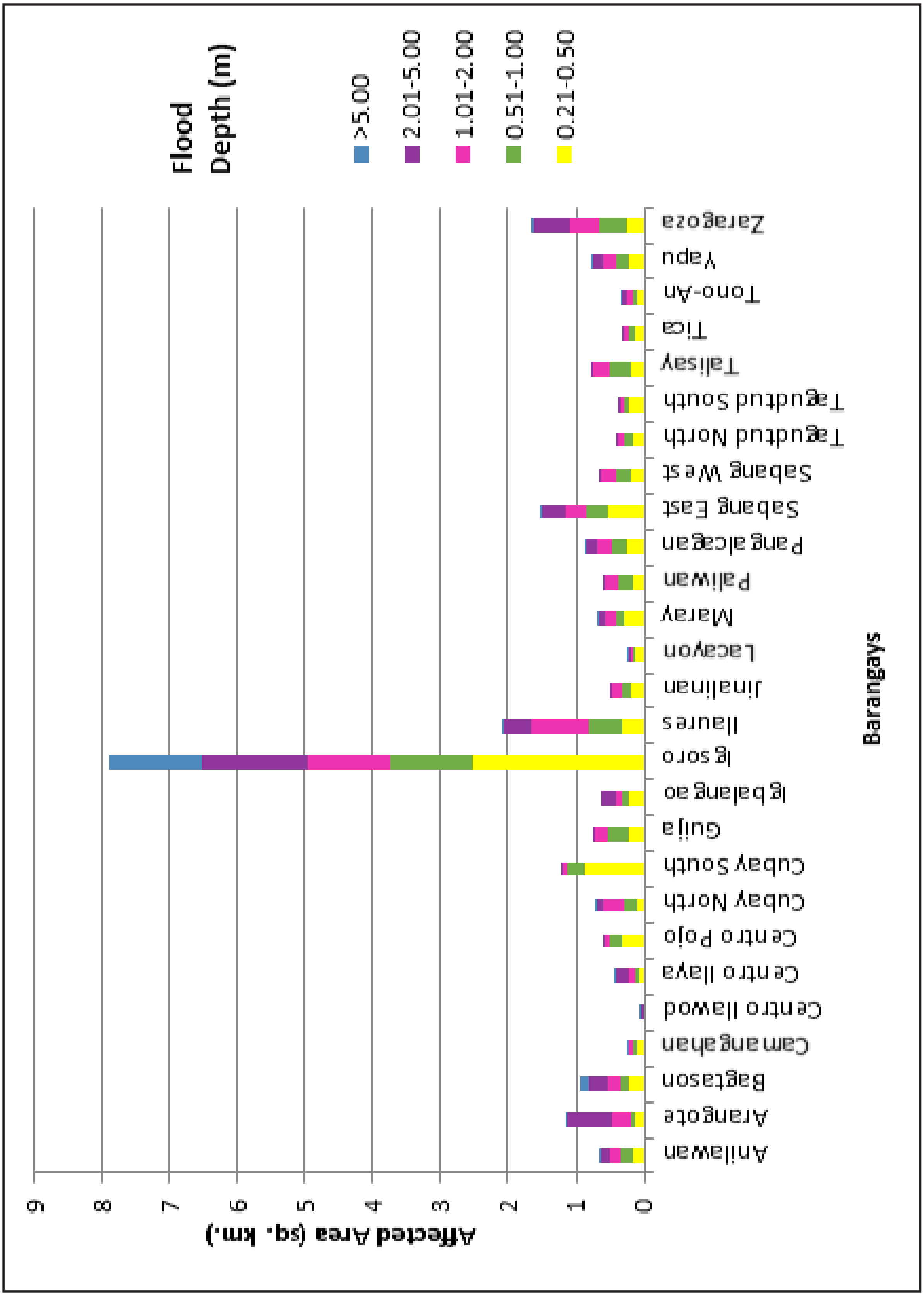


Figure 84. Affected areas in Bugasong, Antique during a 25-year rainfall return period

For the Municipality of Laua-An, with an area of 159.768 sq. km., 46.49% will experience flood levels of less than 0.20 meters. 1.65% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile 0.93%, 0.80%, 0.77%, and 0.61% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Laua-An, Antique during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Laua-An (in sq. km.)					
	Bagongbayan	Cadajug	Capnayan	Guinbanga-An	Guisijan	Jaguikican
0.03-0.20	1.59	0.26	4.31	0.85	2.6	3.91
0.21-0.50	0.081	0.0042	0.16	0.071	0.18	0.15
0.51-1.00	0.058	0.0016	0.064	0.04	0.16	0.044
1.01-2.00	0.036	0.0022	0.039	0.03	0.14	0.023
2.01-5.00	0.033	0.0013	0.014	0.046	0.062	0.012
>5.00	0.0082	0	0.0005	0.019	0.0085	0.0002
Affected area (sq. km.) by flood depth (in m.)	**Liberato**	**Loon**	**Lugta**	**Maria**	**Maybunga**	**Pandanan**
0.03-0.20	0.68	1.22	1.4	0.89	12.28	3.77
0.21-0.50	0.025	0.081	0.27	0.055	0.4	0.14
0.51-1.00	0.012	0.064	0.23	0.032	0.17	0.082
1.01-2.00	0.01	0.091	0.16	0.043	0.12	0.062
2.01-5.00	0.0095	0.12	0.032	0.084	0.14	0.082
>5.00	0.0015	0.02	0.0017	0.063	0.11	0.033
Affected area (sq. km.) by flood depth (in m.)	**Paningayan**	**Pascuala**	**San Ramon**	**Santiago**	**Tibacan**	**Virginia**
0.03-0.20	2.33	0.39	26.52	6.53	0.24	4.51
0.21-0.50	0.13	0.013	0.51	0.27	0.0054	0.12
0.51-1.00	0.11	0.0048	0.2	0.15	0.0037	0.048
1.01-2.00	0.16	0.0029	0.15	0.15	0.0055	0.037
2.01-5.00	0.15	0.00085	0.21	0.18	0.0059	0.054
>5.00	0.018	0	0.55	0.054	0.0018	0.082

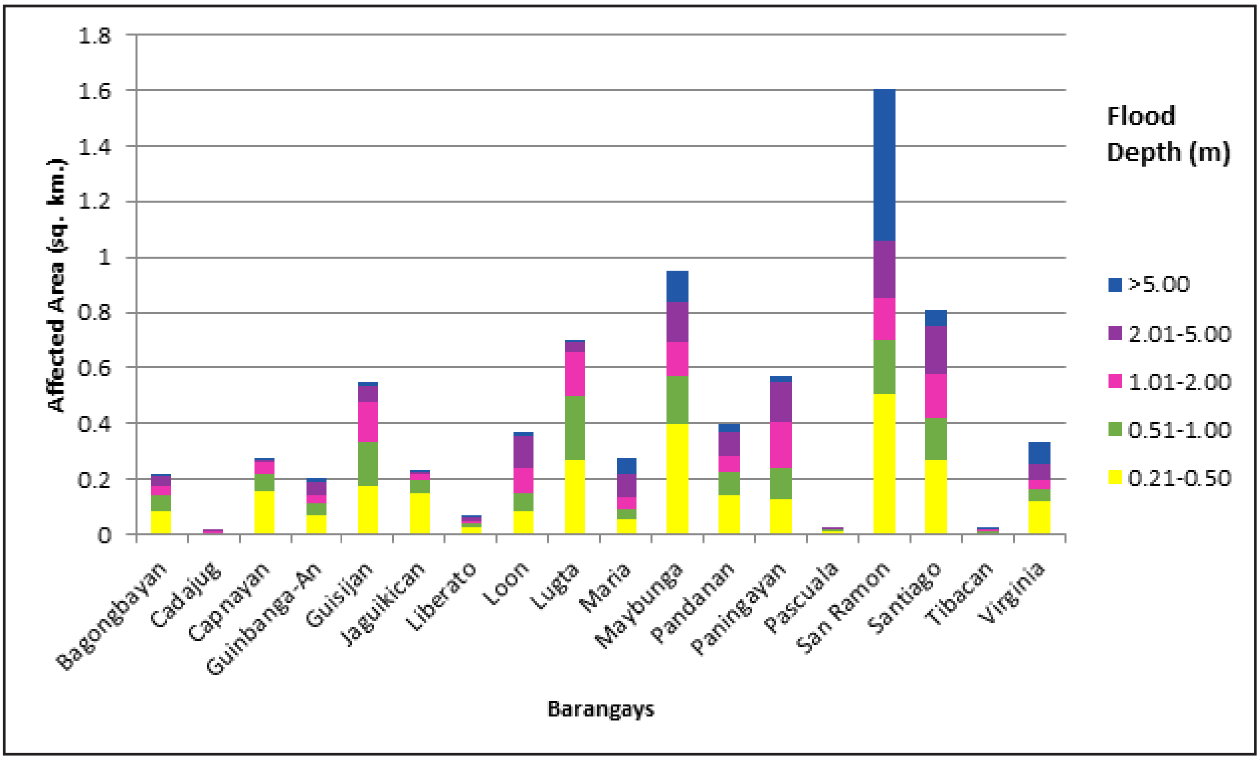


Figure 85. Affected areas in Laua-An, Antique during a 25-year rainfall return period

For the Municipality of Patnongon, with an area of 132.218 sq. km., 32.59% will experience flood levels of less than 0.20 meters. 1.73% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile 1.16%, 1.17%, 1.91%, and 0.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Patnongon, Antique during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Patnongon (in sq. km.)						
	Amparo	Badiangan	Carit-An	Gella	Igbarawan	Igbobon	La Rioja
0.03-0.20	0.12	2.7	2.2	5.36	2.08	0.1	3.9
0.21-0.50	0.0031	0.13	0.24	0.19	0.14	0.025	0.32
0.51-1.00	0.0039	0.1	0.28	0.09	0.089	0.011	0.2
1.01-2.00	0.0028	0.13	0.21	0.1	0.076	0.0041	0.16
2.01-5.00	0	0.093	0.087	0.11	0.078	0.0038	0.26
>5.00	0	0.011	0.045	0.01	0.0007	0	0.07
Affected area (sq. km.) by flood depth (in m.)	Mabasa	Macarina	Magarang	Pandanan	Quezon	Salaguiawan	Samalague
0.03-0.20	3.3	2.1	3.7	2.55	0.23	3.6	2.77
0.21-0.50	0.15	0.13	0.13	0.17	0.0003	0.16	0.17
0.51-1.00	0.094	0.076	0.046	0.16	0.0002	0.072	0.12
1.01-2.00	0.082	0.075	0.023	0.23	0	0.067	0.1
2.01-5.00	0.064	0.039	0.012	0.22	0	0.055	0.15
>5.00	0.0043	0.0008	0.00024	0.02	0	0.015	0.04
Affected area (sq. km.) by flood depth (in m.)	Tamayoc	Tigbalogo	Villa Cruz	Villa Flores	Villa Laua-An	Villa Sal	
0.03-0.20	0.26	3.6	2.9	0.27	0.39	1	
0.21-0.50	0.011	0.15	0.11	0.01	0.015	0.031	
0.51-1.00	0.0066	0.095	0.076	0.0022	0.0044	0.012	
1.01-2.00	0.0065	0.13	0.13	0.0027	0.002	0.01	
2.01-5.00	0.0078	0.14	0.25	0.0023	0.002	0.0053	
>5.00	0.0008	0.0019	0.019	0.0003	0	0.0004	

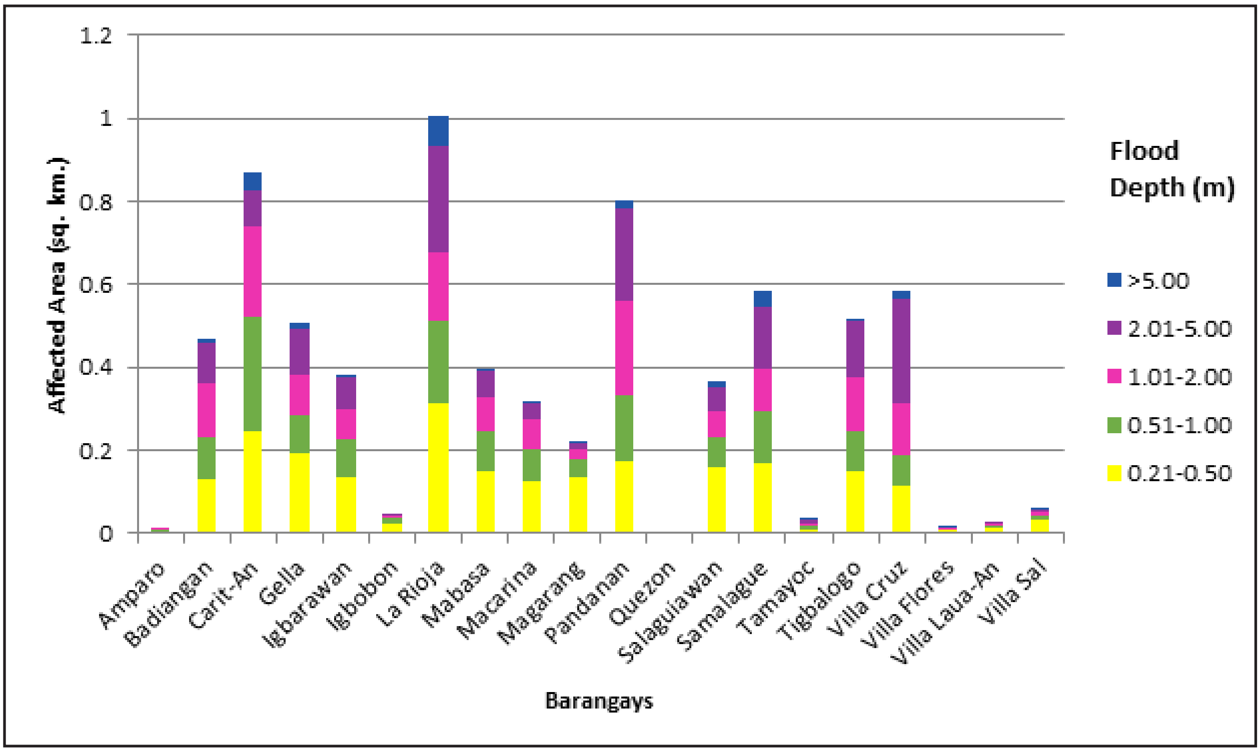


Figure 86. Affected areas in Patnongon, Antique during a 25-year rainfall return period

For the Municipality of San Remigio, with an area of 394.42001 sq. km., 0.12% will experience flood levels of less than 0.20 meters. 0.0002% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.00008%, and 0.000003 of the area will experience flood depths of 0.51 to 1, and 1.01 to 2.00 meters, respectively. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in San Remigio, Antique during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Remigio (in sq. km.)	
	Banbanan	General Fullon
0.03-0.20	0.071	0.39
0.21-0.50	0.0004	0.00028
0.51-1.00	0.0002	0.0001
1.01-2.00	0	0.000013
2.01-5.00	0	0
>5.00	0	0

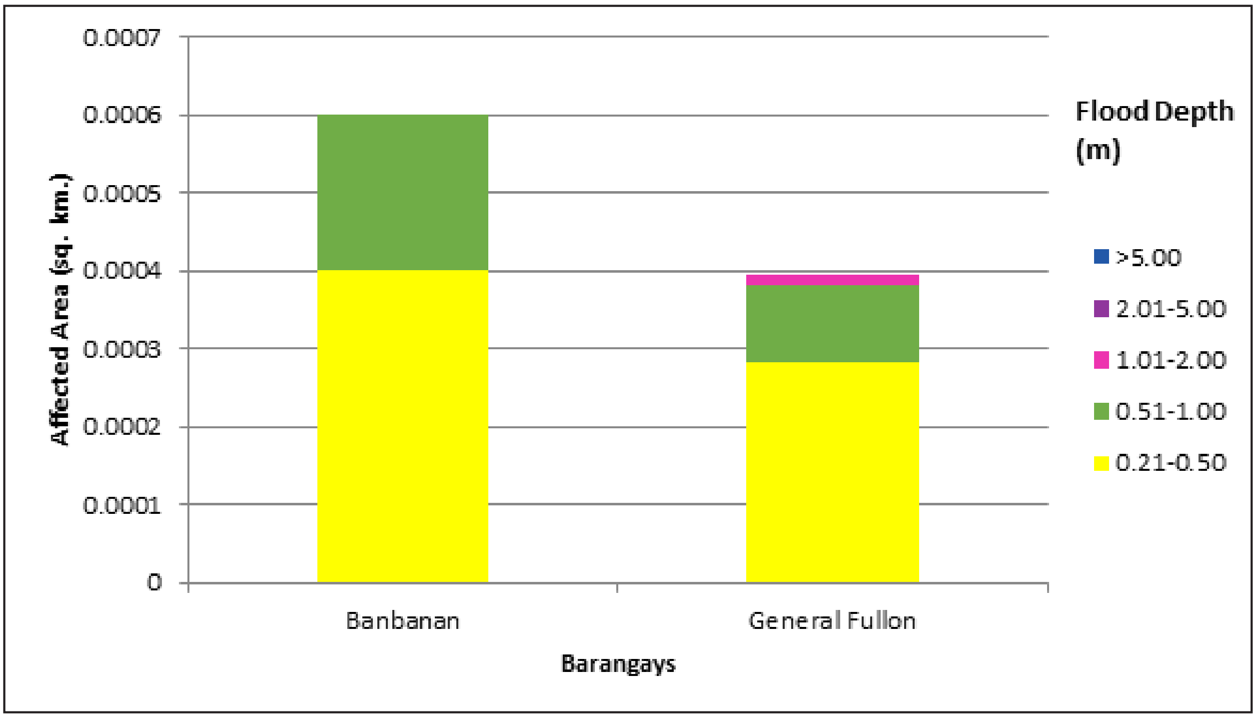


Figure 87. Affected areas in San Remigio, Antique during a 25-year rainfall return period

For the Municipality of Valderrama, with an area of 308.427 sq. km., 61.11% will experience flood levels of less than 0.20 meters. 2.53% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.48%, 2.13%, 2.12%, and 0.56% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Valderrama, Antique during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valderrama (in sq. km.)										
	Alon	Bakiang	Binanogan	Borocboroc	Bugnay	Buluangan I	Buluangan II	Bunsod	Busog	Cananghan	Canipayan
0.03-0.20	9.53	3.77	6.68	7.06	7.86	1.1	2.99	4.59	14.86	13.13	2.37
0.21-0.50	0.32	0.1	0.23	0.46	0.4	0.08	0.16	0.14	0.51	0.42	0.082
0.51-1.00	0.13	0.049	0.09	0.23	0.22	0.15	0.085	0.16	0.21	0.17	0.055
1.01-2.00	0.083	0.037	0.073	0.31	0.18	0.15	0.078	0.3	0.2	0.18	0.052
2.01-5.00	0.11	0.026	0.08	0.27	0.12	0.041	0.05	0.21	0.28	0.47	0.074
>5.00	0.034	0.0058	0.0039	0.005	0.0079	0	0.0002	0.0041	0.14	0.13	0.0048
Affected area (sq. km.) by flood depth (in m.)	Cansilayan	Culyat	Iglinab	Igmasandig	Lublub	Manlacbo	Pandanan	San Agustin	Takas	Tigmamale	Ubos
0.03-0.20	13.42	14.31	6.97	5.63	8.37	5.17	9.2	44.11	3.66	3.14	0.57
0.21-0.50	0.52	0.49	0.28	0.3	0.37	0.3	0.54	1.21	0.48	0.18	0.23
0.51-1.00	0.24	0.2	0.17	0.22	0.28	0.2	0.76	0.43	0.17	0.14	0.24
1.01-2.00	0.22	0.16	0.16	0.74	0.54	0.24	1.52	0.31	0.15	0.17	0.69
2.01-5.00	0.27	0.14	0.074	1	0.65	0.18	0.64	0.59	0.17	0.29	0.81
>5.00	0.19	0.078	0.0031	0.007	0.026	0.0075	0.022	0.63	0.0041	0.41	0.026

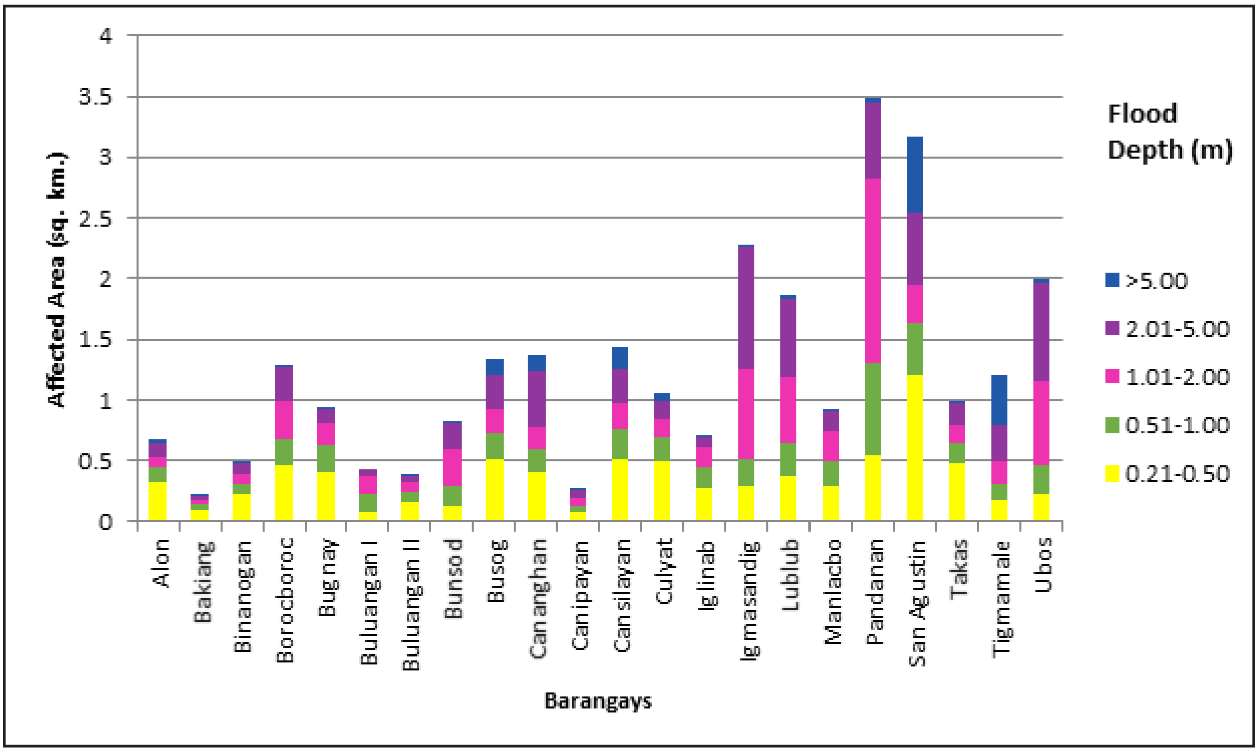


Figure 88. Affected areas in Valderrama, Antique during a 25-year rainfall return period

For the Municipality of Jamindan, with an area of 471.364 sq. km., 1.91% will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.019%, 0.01%, 0.015%, and 0.014% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Jamindan, Capiz during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jamindan (in sq. km.)
	Jaena Sur
0.03-0.20	8.98
0.21-0.50	0.23
0.51-1.00	0.087
1.01-2.00	0.052
2.01-5.00	0.072
>5.00	0.065

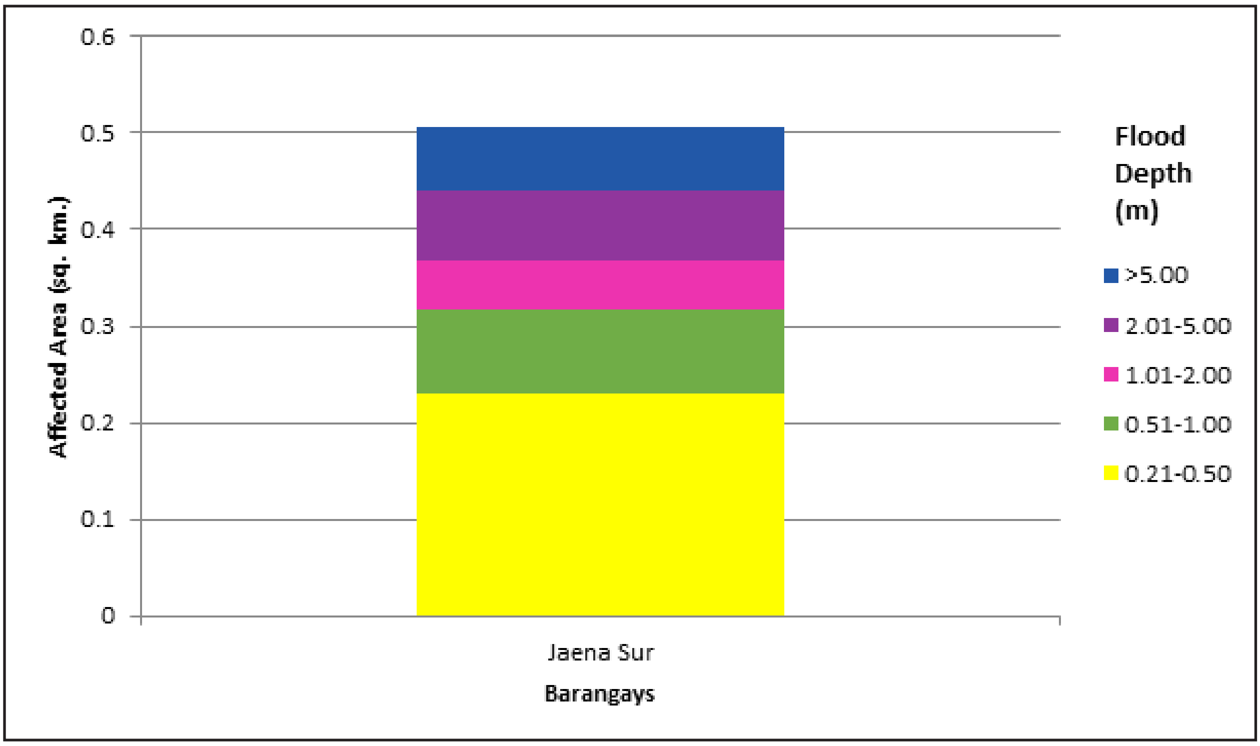


Figure 89. Affected areas in Jamindan, Capiz during a 25-year rainfall return period

For the Municipality of Tapaz, with an area of 523.206 sq. km., 4.32% will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.03%, 0.02%, and 0.017% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Tapaz, Capiz during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tapaz (in sq. km.)
	Minan
0.03-0.20	22.59
0.21-0.50	0.62
0.51-1.00	0.24
1.01-2.00	0.14
2.01-5.00	0.12
>5.00	0.088

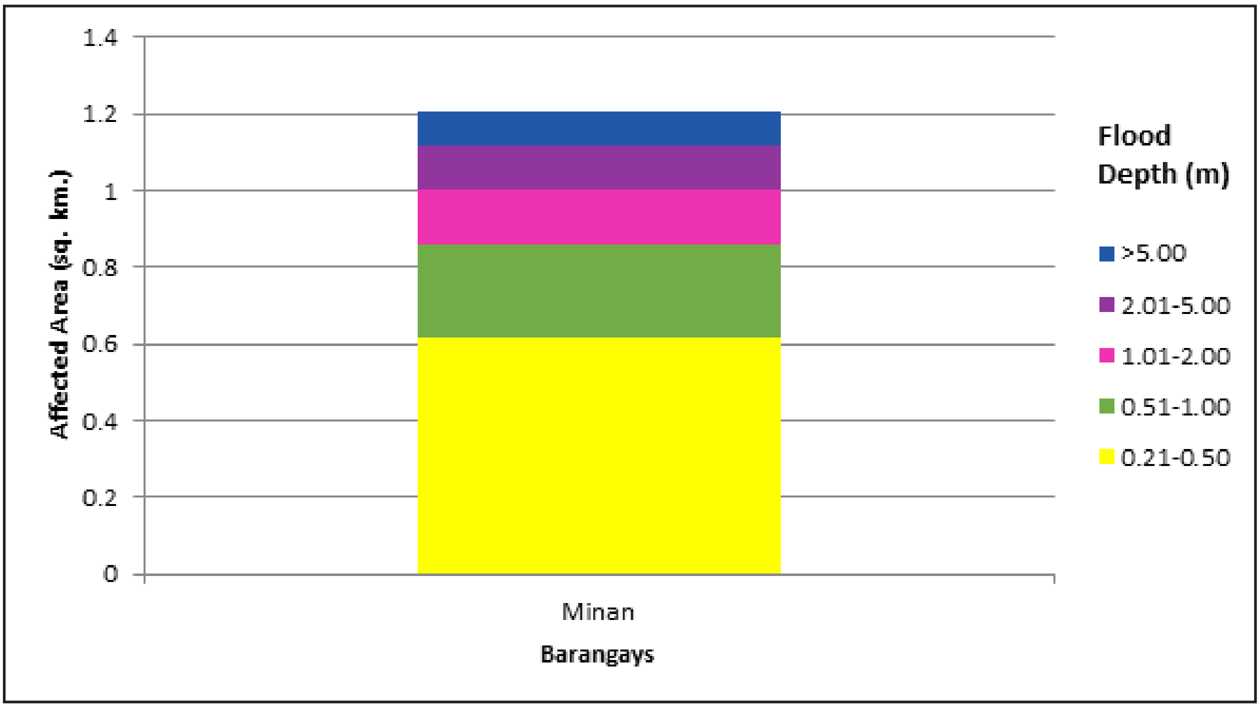


Figure 90. Affected areas in Tapaz, Capiz during a 25-year rainfall return period

For the Municipality of Lambunao, with an area of 405.387 sq. km., 9.66% will experience flood levels of less than 0.20 meters. 0.27% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.11%, 0.077%, 0.08%, and 0.087% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 53 are the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Lambunao, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lambunao (in sq. km.)
	Cabatangan
0.03-0.20	39.15
0.21-0.50	1.11
0.51-1.00	0.44
1.01-2.00	0.31
2.01-5.00	0.33
>5.00	0.35

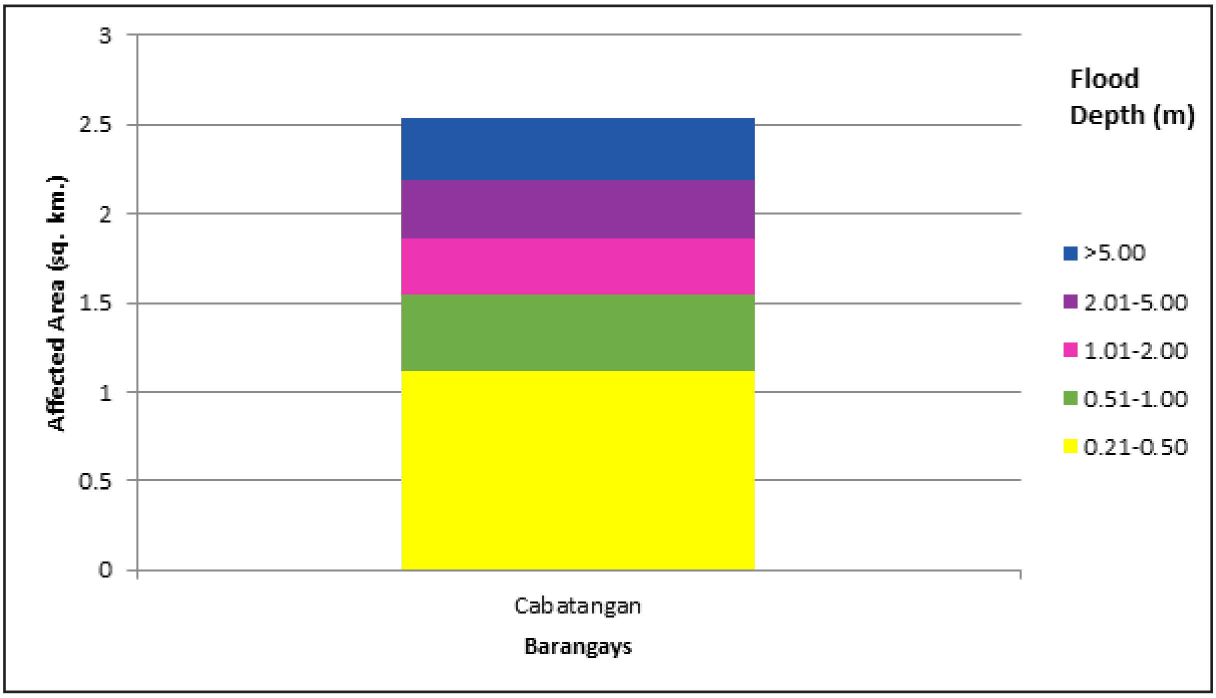


Figure 91. Affected areas in Lambunao, Iloilo during a 25-year rainfall return period

For the 100-year return period, 5.34% of the Municipality of Barbaza, with an area of 176.52 sq. km., will experience flood levels of less than 0.20 meters. 0.14% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.033%, 0.03%, 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 more than 5 meters, respectively. Listed in Table 54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 54. Affected areas in Barbaza, Antique during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Barbaza (in sq. km.)
	Langcaon
0.03-0.20	9.42
0.21-0.50	0.24
0.51-1.00	0.082
1.01-2.00	0.057
2.01-5.00	0.049
>5.00	0.041

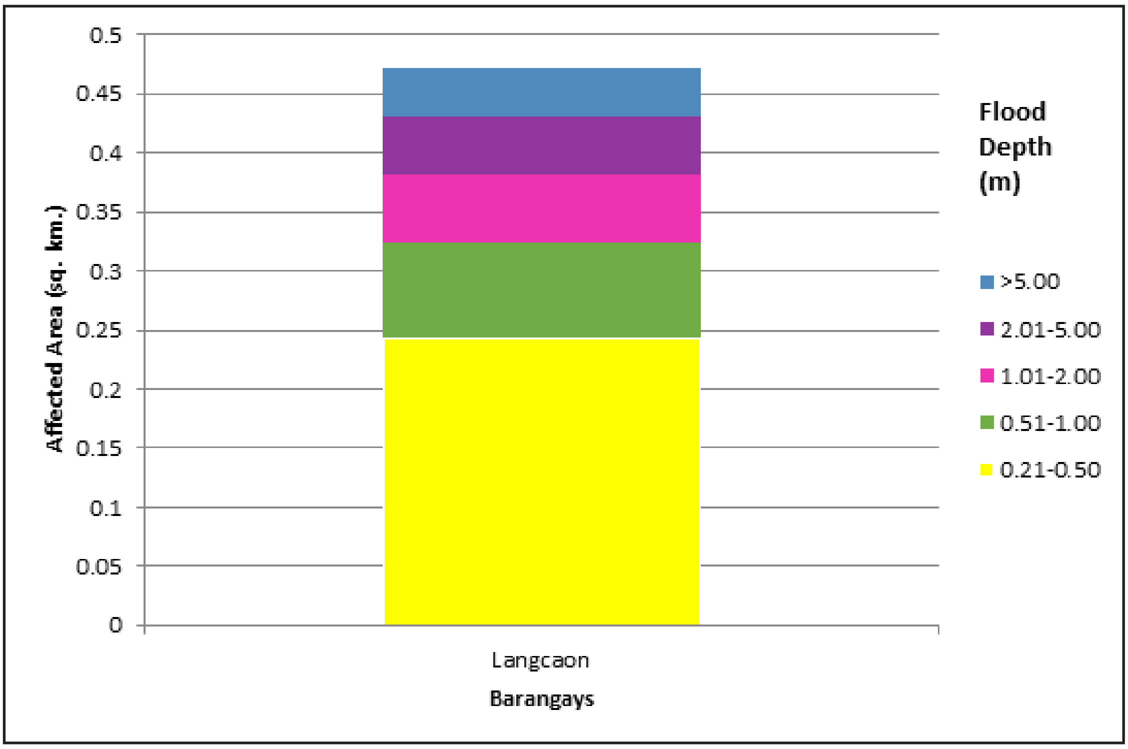


Figure 92. Affected areas in Barbaza, Antique during a 100-year rainfall return period

For the Municipality of Bugasong, with an area of 99.87 sq. km., 85.53% will experience flood levels of less than 0.20 meters. 5.15% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.44%, 3.82%, 3.44%, and 1.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in Bugasong, Antique during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bugasong (in sq. km.)								
	Anilawan	Arangote	Bagtason	Camangahan	Centro Ilawod	Centro Ilaya	Centro Pojo	Cubay North	Cubay South
0.03-0.20	1.68	3.11	2.91	1.08	0.16	1.44	0.85	0.48	2.58
0.21-0.50	0.18	0.16	0.22	0.096	0.0058	0.071	0.35	0.077	1.02
0.51-1.00	0.17	0.067	0.15	0.061	0.0011	0.059	0.2	0.12	0.36
1.01-2.00	0.2	0.23	0.19	0.091	0.0086	0.096	0.13	0.35	0.098
2.01-5.00	0.13	0.7	0.25	0.016	0.0093	0.18	0.051	0.19	0.015
>5.00	0.0015	0.061	0.17	0.0003	0.0034	0.052	0	0.0024	0
Affected area (sq. km.) by flood depth (in m.)	Guija	Igbalangao	Igsoro	Ilaures	Jinalinan	Lacayon	Maray	Paliwan	Pangalcagan
0.03-0.20	0.66	1.49	90.77	1.15	0.61	1.3	5.86	0.81	2.57
0.21-0.50	0.21	0.26	2.86	0.31	0.19	0.15	0.31	0.14	0.29
0.51-1.00	0.31	0.099	1.31	0.48	0.14	0.053	0.15	0.2	0.25
1.01-2.00	0.25	0.11	1.26	0.87	0.15	0.033	0.15	0.24	0.23
2.01-5.00	0.06	0.24	1.79	0.44	0.1	0.028	0.12	0.041	0.19
>5.00	0	0.0017	1.7	0.0058	0	0.0037	0.005	0	0.024
Affected area (sq. km.) by flood depth (in m.)	Sabang East	Sabang West	Tagudtud North	Tagudtud South	Talisay	Tica	Tono-An	Yapu	Zaragoza
0.03-0.20	15.37	0.36	0.77	1.91	0.51	0.33	2.27	4.27	3.58
0.21-0.50	0.58	0.16	0.19	0.25	0.19	0.14	0.1	0.23	0.24
0.51-1.00	0.31	0.24	0.11	0.094	0.3	0.11	0.073	0.17	0.38
1.01-2.00	0.32	0.26	0.11	0.075	0.33	0.077	0.087	0.21	0.48
2.01-5.00	0.41	0.0062	0.033	0.016	0.053	0.0076	0.09	0.24	0.59
>5.00	0.039	0.0002	0	0	0	0	0.013	0.018	0.01

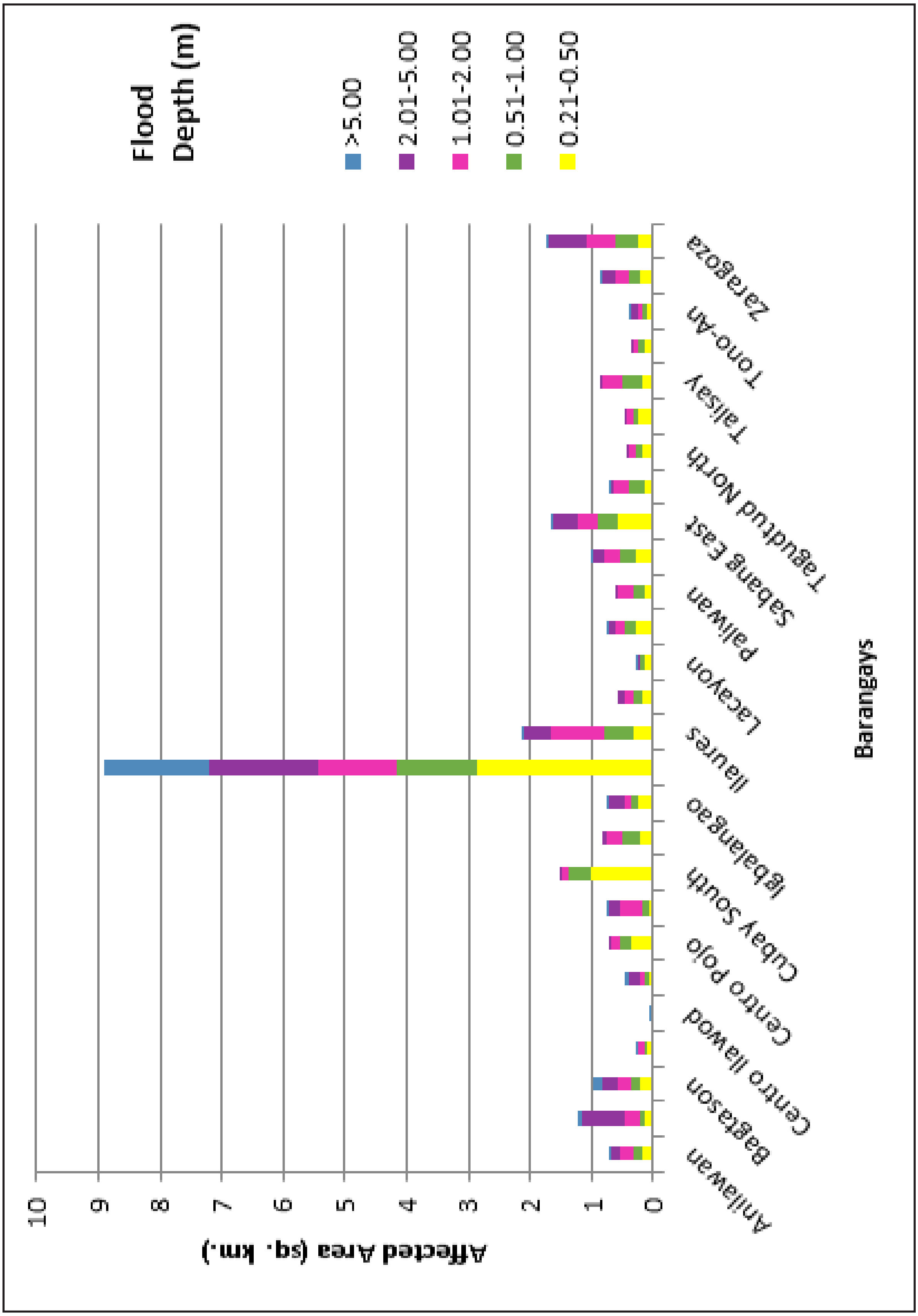


Figure 93. Affected areas in Bugasong, Antique during a 100-year rainfall return period

For the Municipality of Laua-An, with an area of 159.768 sq. km., 45.85% will experience flood levels of less than 0.20 meters. 1.80% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1%, 0.90%, 0.91%, and 0.77% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 56 are the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in Laua-An, Antique during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Laua-An (in sq. km.)					
	Bagongbayan	Cadajug	Capnayan	Guinbanga-An	Guisijan	Jaguikican
0.03-0.20	1.56	0.26	4.27	0.81	2.49	3.87
0.21-0.50	0.085	0.0051	0.18	0.081	0.19	0.17
0.51-1.00	0.067	0.0022	0.07	0.039	0.17	0.052
1.01-2.00	0.047	0.0023	0.046	0.034	0.21	0.029
2.01-5.00	0.038	0.0013	0.02	0.052	0.082	0.013
>5.00	0.0095	0	0.0005	0.035	0.011	0.0006
Affected area (sq. km.) by flood depth (in m.)	**Liberato**	**Loon**	**Lugta**	**Maria**	**Maybunga**	**Pandanan**
0.03-0.20	0.67	1.18	1.3	0.85	12.16	3.73
0.21-0.50	0.03	0.075	0.26	0.058	0.43	0.15
0.51-1.00	0.013	0.057	0.24	0.044	0.2	0.09
1.01-2.00	0.012	0.056	0.22	0.048	0.14	0.066
2.01-5.00	0.01	0.18	0.056	0.076	0.16	0.089
>5.00	0.002	0.049	0.0033	0.091	0.15	0.046
Affected area (sq. km.) by flood depth (in m.)	**Paningayan**	**Pascuala**	**San Ramon**	**Santiago**	**Tibacan**	**Virginia**
0.03-0.20	2.27	0.39	26.31	6.44	0.24	4.47
0.21-0.50	0.13	0.014	0.57	0.29	0.005	0.14
0.51-1.00	0.1	0.0051	0.22	0.17	0.0038	0.056
1.01-2.00	0.17	0.0036	0.16	0.16	0.0049	0.038
2.01-5.00	0.19	0.00085	0.22	0.21	0.0083	0.056
>5.00	0.027	0	0.65	0.068	0.0022	0.093

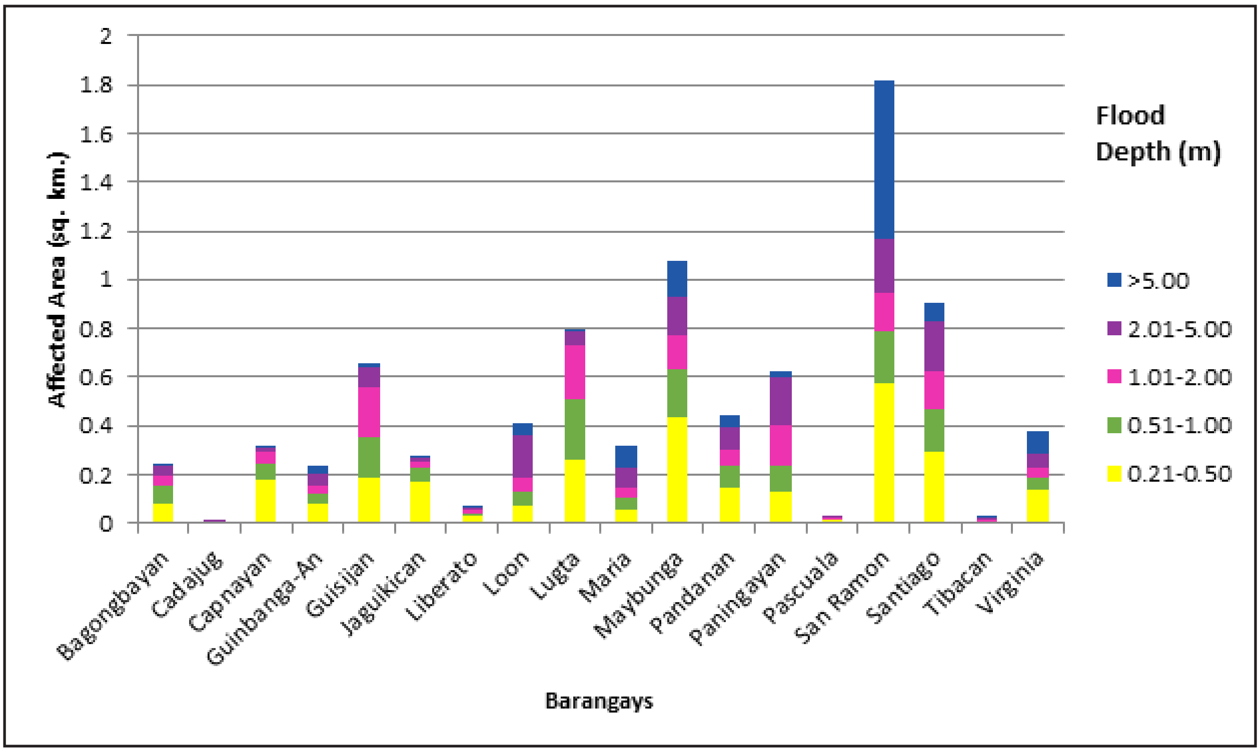


Figure 94. Affected areas in Laua-An, Antique during a 100-year rainfall return period

For the Municipality of Patnongon, with an area of 132.218 sq. km., 31.94% will experience flood levels of less than 0.20 meters. 1.86% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.28%, 1.25%, 1.39%, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 57 are the affected areas, in square kilometers, by flood depth per barangay.

Table 57. Affected areas in Patnongon, Antique during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Patnongon (in sq. km.)						
	Amparo	Badiangan	Carit-An	Gella	Igbarawan	Igbobon	La Rioja
0.03-0.20	0.12	2.7	2.1	5.3	2.03	0.091	3.8
0.21-0.50	0.004	0.15	0.23	0.21	0.16	0.025	0.3
0.51-1.00	0.0033	0.099	0.3	0.1	0.1	0.019	0.26
1.01-2.00	0.0035	0.14	0.27	0.1	0.085	0.0049	0.18
2.01-5.00	0.0001	0.13	0.11	0.13	0.089	0.0047	0.26
>5.00	0	0.016	0.054	0.02	0.0013	0	0.13
Affected area (sq. km.) by flood depth (in m.)	Mabasa	Macarina	Magarang	Pandanan	Quezon	Salaguiawan	Samalague
0.03-0.20	3.2	2.1	3.6	2.47	0.23	3.5	2.71
0.21-0.50	0.17	0.14	0.16	0.18	0.0006	0.19	0.18
0.51-1.00	0.11	0.085	0.054	0.14	0.0002	0.082	0.14
1.01-2.00	0.087	0.082	0.027	0.24	0	0.07	0.12
2.01-5.00	0.074	0.052	0.016	0.3	0	0.066	0.15
>5.00	0.0076	0.0012	0.00054	0.027	0	0.018	0.06
Affected area (sq. km.) by flood depth (in m.)	Tamayoc	Tigbalogo	Villa Cruz	Villa Flores	Villa Laua-An	Villa Sal	
0.03-0.20	0.26	3.5	2.8	0.26	0.38	0.99	
0.21-0.50	0.012	0.16	0.14	0.01	0.018	0.037	
0.51-1.00	0.0074	0.11	0.074	0.0032	0.0049	0.014	
1.01-2.00	0.007	0.12	0.1	0.0032	0.0023	0.011	
2.01-5.00	0.0088	0.18	0.27	0.0022	0.0025	0.0063	
>5.00	0.0014	0.0021	0.067	0.0005	0	0.0004	

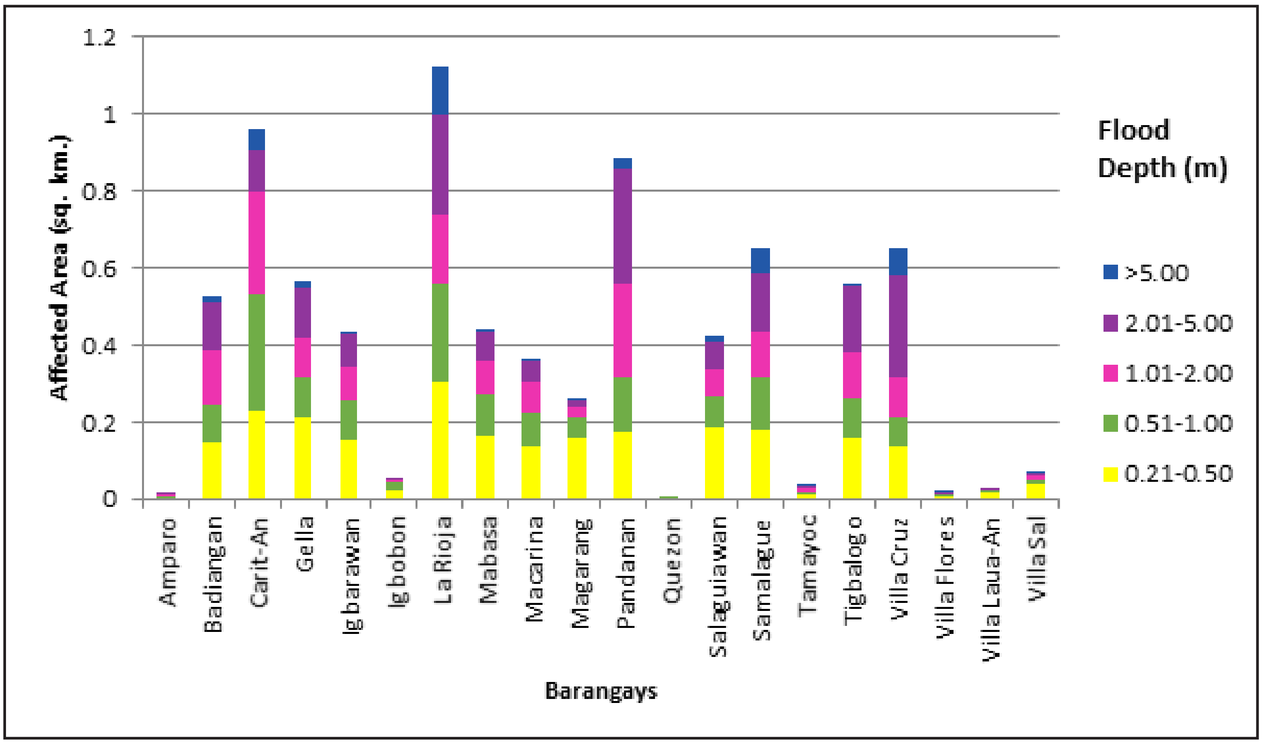


Figure 95. Affected areas in Patnongon, Antique during a 100-year rainfall return period

For the Municipality of San Remigio, with an area of 394.42001 sq. km., 0.12% will experience flood levels of less than 0.20 meters. 0.0002% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.0001%, and 0.000003 of the area will experience flood depths of 0.51 to 1, and 1.01 to 2.00 meters, respectively. Listed in Table 58 are the affected areas, in square kilometers, by flood depth per barangay.

Table 58. Affected areas in San Remigio, Antique during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Remigio (in sq. km.)	
	Banbanan	General Fullon
0.03-0.20	0.071	0.39
0.21-0.50	0.0004	0.0002
0.51-1.00	0.0002	0.0003
1.01-2.00	0	0.000013
2.01-5.00	0	0
>5.00	0	0

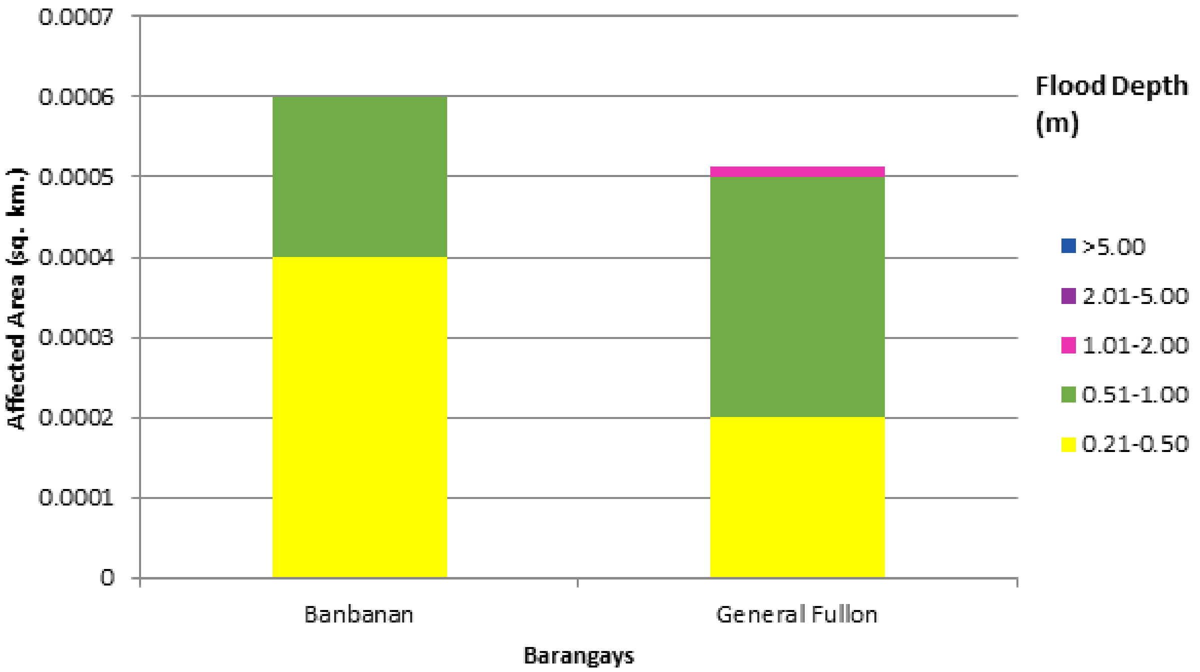


Figure 96. Affected areas in San Remigio, Antique during a 100-year rainfall return period

For the Municipality of Valderrama, with an area of 308.427 sq. km., 60.24% will experience flood levels of less than 0.20 meters. 2.81% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.46%, 2.1%, 2.51%, and 0.87% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 59 are the affected areas, in square kilometers, by flood depth per barangay.

Table 59. Affected areas in Valderrama, Antique during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Valderrama (in sq. km.)										
	Alon	Bakiang	Binanogan	Borocboroc	Bugnay	Buluangan I	Buluangan II	Bunsod	Busog	Cananghan	Canipayan
0.03-0.20	9.43	3.74	6.61	6.92	7.76	1.07	2.95	4.55	14.67	12.99	2.33
0.21-0.50	0.38	0.12	0.27	0.5	0.44	0.08	0.17	0.15	0.58	0.48	0.09
0.51-1.00	0.14	0.056	0.1	0.25	0.24	0.11	0.096	0.11	0.24	0.19	0.057
1.01-2.00	0.097	0.04	0.074	0.31	0.19	0.2	0.084	0.3	0.19	0.18	0.053
2.01-5.00	0.11	0.031	0.095	0.34	0.15	0.059	0.063	0.27	0.33	0.49	0.058
>5.00	0.055	0.006	0.0068	0.0078	0.014	0	0.0007	0.0067	0.19	0.17	0.049
Affected area (sq. km.) by flood depth (in m.)	**Cansilayan**	**Culyat**	**Iglinab**	**Igmasandig**	**Lublub**	**Manlacbo**	**Pandanan**	**San Agustin**	**Takas**	**Tigmamale**	**Ubos**
0.03-0.20	13.23	14.14	6.87	5.56	8.25	5.07	9.03	43.61	3.51	3.02	0.49
0.21-0.50	0.58	0.56	0.31	0.31	0.41	0.34	0.52	1.41	0.54	0.18	0.24
0.51-1.00	0.26	0.22	0.19	0.19	0.22	0.2	0.63	0.5	0.19	0.11	0.19
1.01-2.00	0.23	0.18	0.17	0.5	0.55	0.27	1.62	0.32	0.18	0.14	0.6
2.01-5.00	0.27	0.17	0.1	1.32	0.74	0.21	0.85	0.57	0.21	0.28	1.02
>5.00	0.28	0.093	0.0048	0.17	0.058	0.013	0.029	0.87	0.012	0.63	0.031

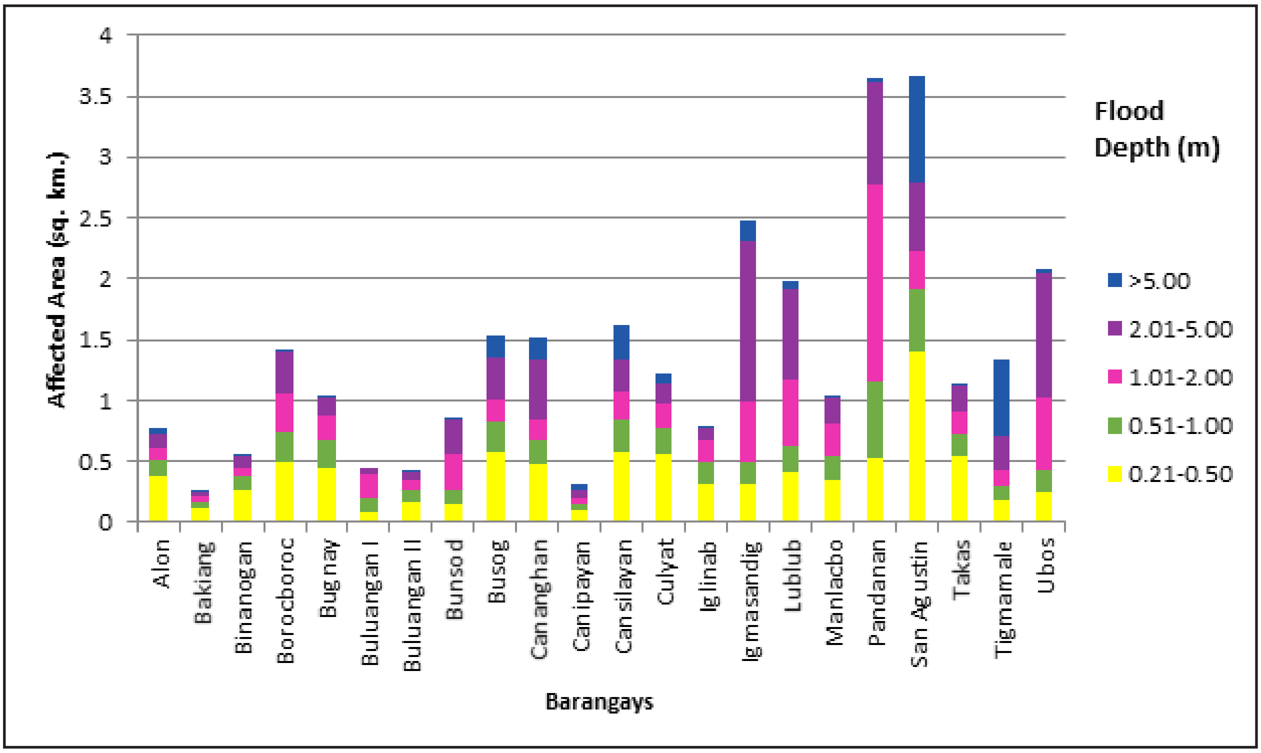


Figure 97. Affected areas in Valderrama, Antique during a 100-year rainfall return period

For the Municipality of Jamindan, with an area of 471.364 sq. km., 1.89% will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.02%, 0.01%, 0.016%, and 0.015% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 60 are the affected areas, in square kilometers, by flood depth per barangay.

Table 60. Affected areas in Jamindan, Capiz during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Jamindan (in sq. km.)
	Jaena Sur
0.03-0.20	8.91
0.21-0.50	0.27
0.51-1.00	0.093
1.01-2.00	0.057
2.01-5.00	0.077
>5.00	0.075

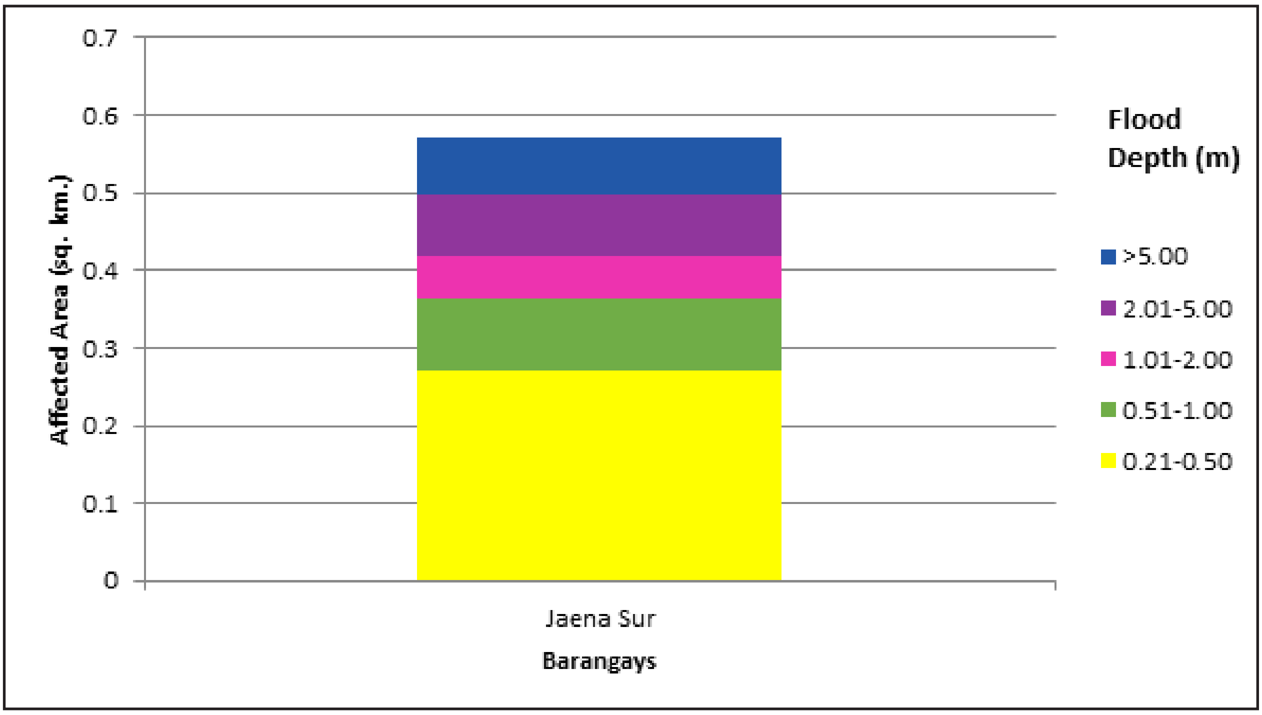


Figure 98. Affected areas in Jamindan, Capiz during a 100-year rainfall return period

For the Municipality of Tapaz, with an area of 523.206 sq. km., 4.3% will experience flood levels of less than 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.03%, 0.03%, 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 more than 5 meters, respectively. Listed in Table 61 are the affected areas, in square kilometers, by flood depth per barangay.

Table 61. Affected areas in Tapaz, Capiz during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tapaz (in sq. km.)
	Minan
0.03-0.20	22.42
0.21-0.50	0.7
0.51-1.00	0.27
1.01-2.00	0.16
2.01-5.00	0.14
>5.00	0.1

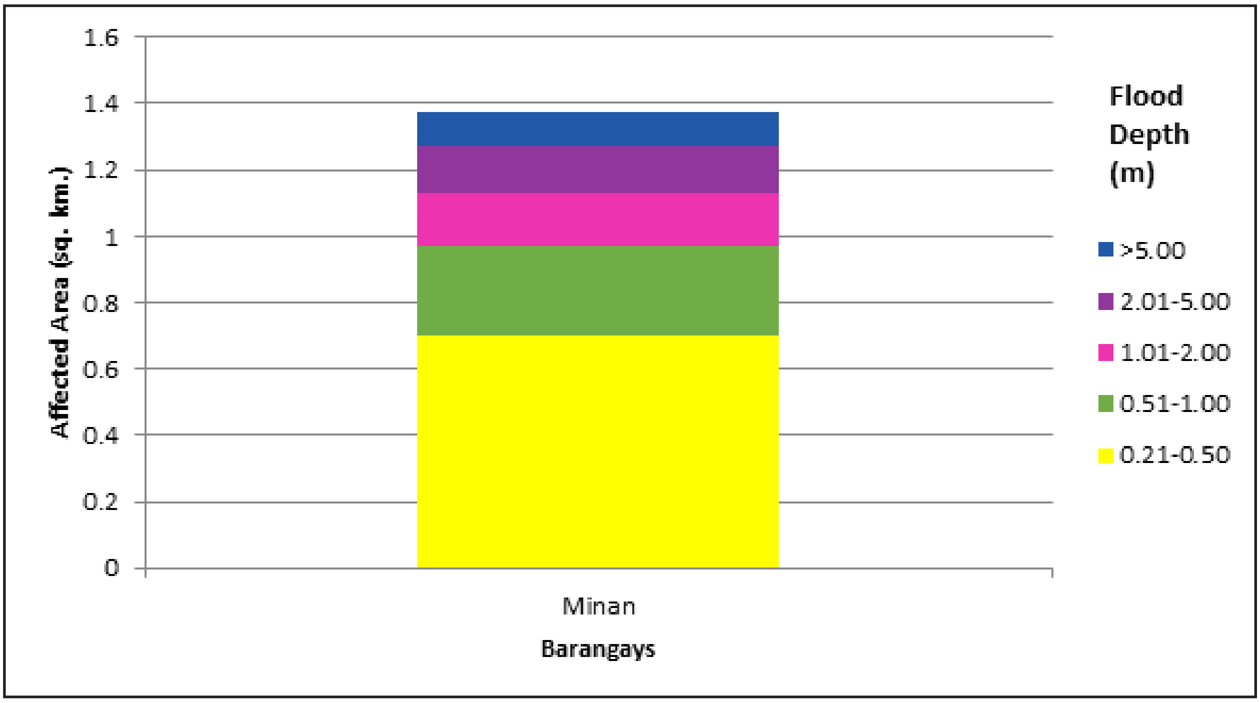


Figure 99. Affected areas in Tapaz, Capiz during a 100-year rainfall return period

For the Municipality of Lambunao, with an area of 405.387 sq. km., 9.57% will experience flood levels of less than 0.20 meters. 0.31% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.13%, 0.084%, 0.09%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 62 are the affected areas, in square kilometers, by flood depth per barangay.

Table 62. Affected areas in Lambunao, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lambunao (in sq. km.)
	Cabatangan
0.03-0.20	38.78
0.21-0.50	1.27
0.51-1.00	0.51
1.01-2.00	0.34
2.01-5.00	0.37
>5.00	0.42

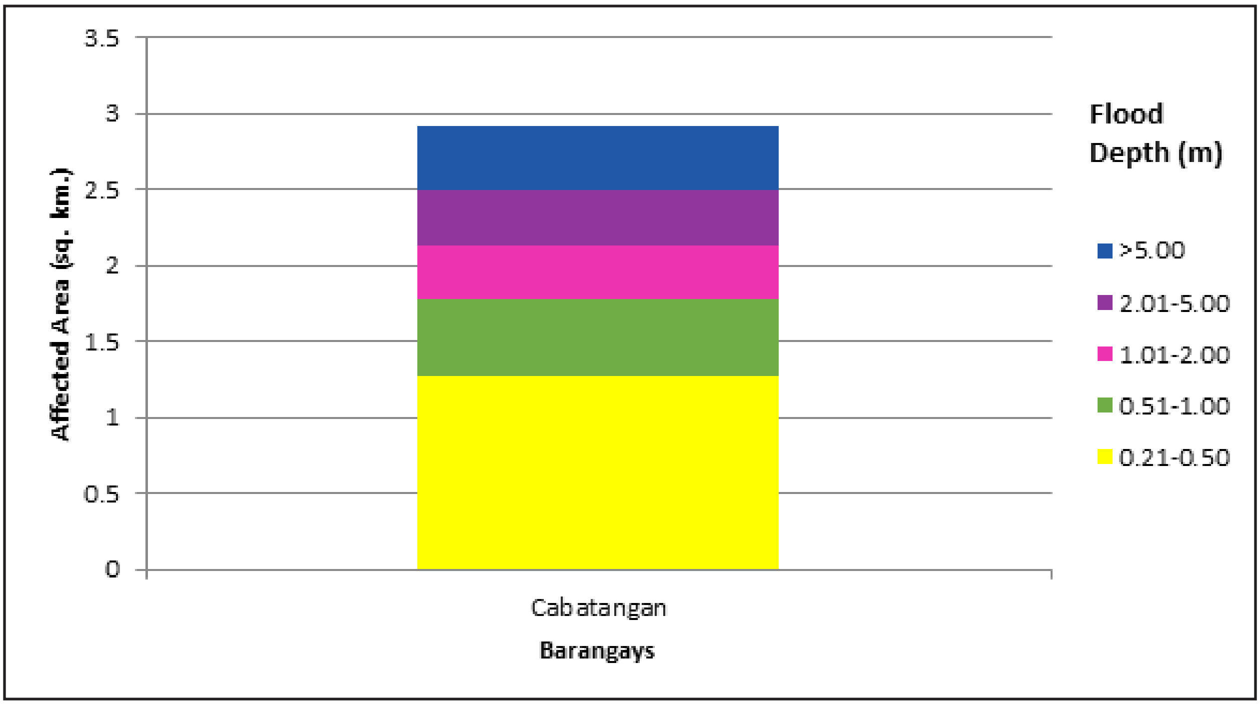


Figure 100. Affected areas in Lambunao, Iloilo during a 100-year rainfall return period

Among the barangays in the Municipality of Barbaza, Langcaon is projected to have the highest percentage of area that will experience flood levels, at 5.61%.

Among the barangays in the Municipality of Bugasong, Igosoro is projected to have the highest percentage of area that will experience flood levels, at 57.26%. Meanwhile, Sabang East posted the second highest percentage of area that may be affected by flood depths, at 9.78%.

Among the barangays in the Municipality of Laua-An, San Ramon is projected to have the highest percentage of area that will experience flood levels, at 17.61%. Meanwhile, Maybunga posted the second highest percentage of area that may be affected by flood depths, at 8.28%.

Among the barangays in the Municipality of Patnongon, Gella is projected to have the highest percentage of area that will experience flood levels, at 4.44%. Meanwhile, La Rioja posted the second highest percentage of area that may be affected by flood depths, at 3.69%.

Among the barangays in the Municipality of San Remigio, General Fullon is projected to have the highest percentage of area that will experience flood levels, at 0.1%. Meanwhile, Banbanan posted the second highest percentage of area that may be affected by flood depths, at 0.02%.

Among the barangays in the Municipality of Valderrama, San Agustin is projected to have the highest percentage of area that will experience flood levels, at 15.33%. Meanwhile, Busog posted the second highest percentage of area that may be affected by flood depths, at 5.25%.

Among the barangays in the Municipality of Jamindan, Jaena Sur is projected to have the highest percentage of area that will experience flood levels, at 2.01%.

Among the barangays in the Municipality of Tapaz, Minan is projected to have the highest percentage of area that will experience flood levels, at 4.55%.

Among the barangays in the Municipality of Lambunao, Cabatangan is projected to have the highest percentage of area that will experience flood levels, at 10.28%.

The generated flood hazard maps for the Cangaranan floodplain were also used to assess the vulnerability of the educational and medical institutions in 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 (5-year, 25-year, and 100-year).

Table 63. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5-year	25-year	100-year
Low	17.03	19.25	21.13
Medium	21.69	23.49	24.13
High	22.25	32.24	37.90

Of the twenty-three (23) identified educational institutions in the Cangaranan floodplain, three (3) schools were assessed to be exposed to Low-level flooding during a 5-year scenario; while one (1) school was assessed to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, three (3) schools were assessed to be exposed to Low-level flooding, while two (2) schools were assessed to be exposed to Medium-level flooding. For the 100-year scenario, five (5) schools were assessed to be exposed to Low-level flooding, and two (2) schools to Medium-level flooding. See Annex 12 for a detailed enumeration of schools exposed to flooding in the Cangaranan floodplain.

Nine (9) medical institutions were identified in the Cangaranan Floodplain, and one (1) s was assessed to be exposed to Low-level flooding during a 5-year scenario. In the 25-year scenario, two (2) were assessed to be exposed to Low-level flooding. For the 100-year scenario, two (2) institutions were assessed to be subjected to Low-level flooding. See Annex 13 for a detailed enumeration of hospitals and clinics exposed to flooding in the Cangaranan floodplain.

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. For this purpose, 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 went to the specified points identified in a river basin to gather 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 knowledge or experience of flooding in a particular area. The flood validation points were obtained on December 13, 2016.

After which, the actual data gathered 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 102.

The flood validation consists of one hundred and fifty-nine (159) points, randomly selected all over the Cangaranan-Paliwan floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.768 meters. Table 64 presents a contingency matrix of the comparison. The field validation points are found in Annex 11.

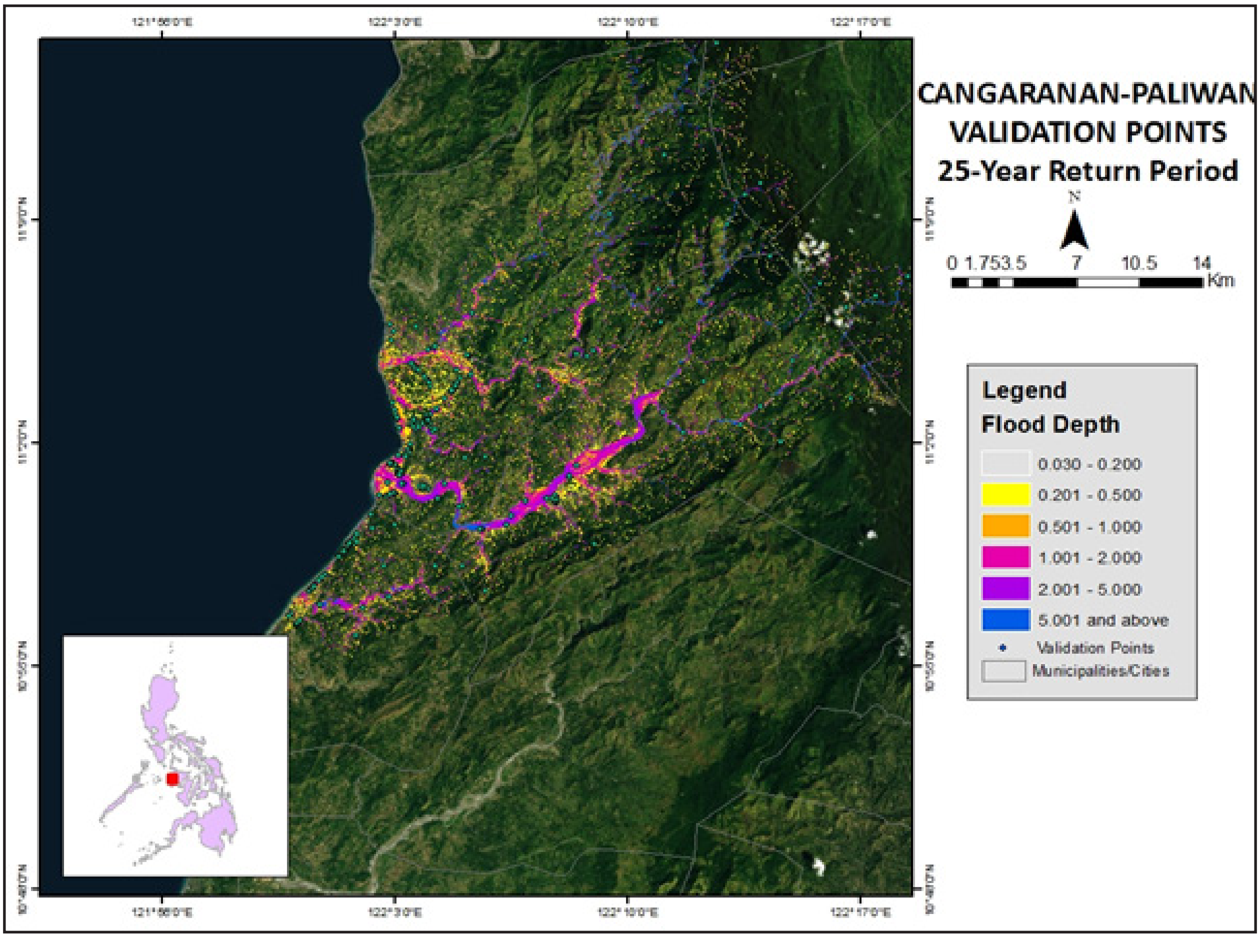


Figure 101. Validation points for a 25-year flood depth map of the Cangaranan-Paliwan floodplain

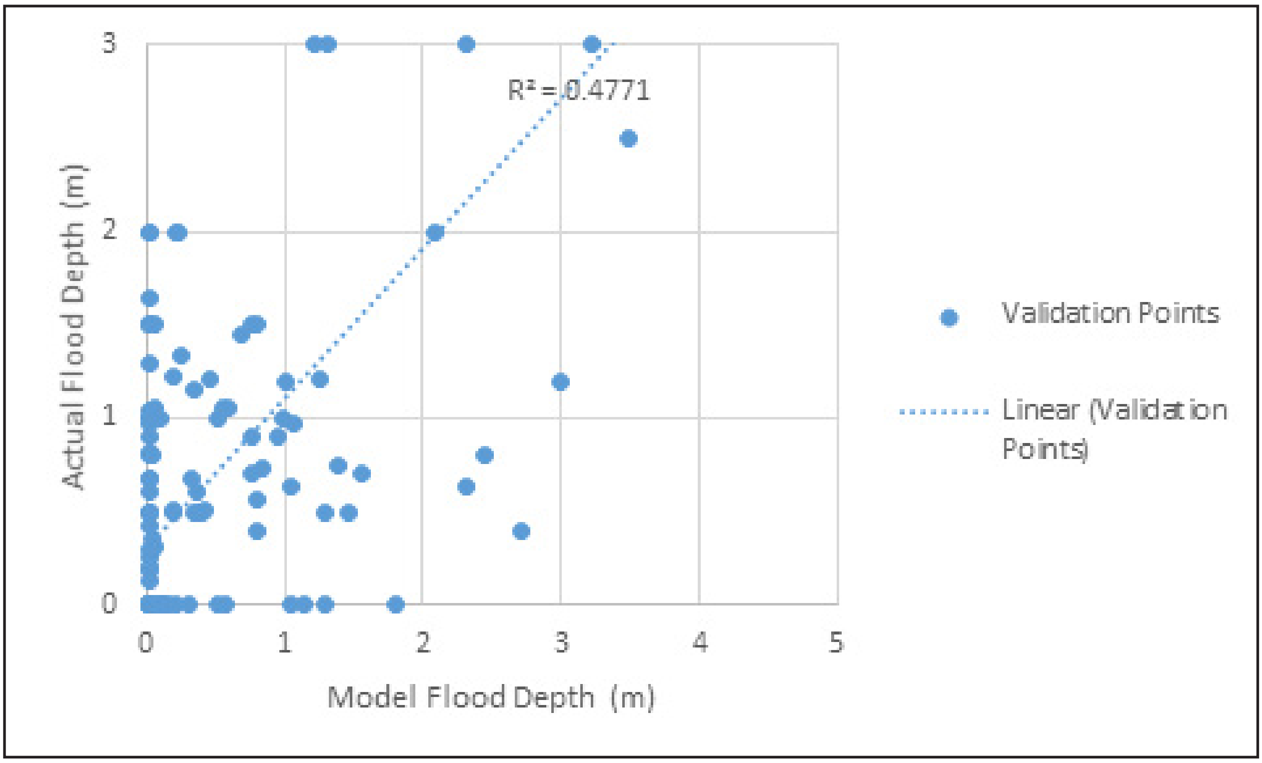


Figure 102. Flood map depth vs. actual flood depth

Table 64. Actual flood depth vs. simulated flood depth at different levels in the Cangaranan-Paliwan River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	65	2	2	4	0	0	73
0.21-0.50	11	3	1	2	1	0	18
0.51-1.00	12	4	7	4	2	0	29
1.01-2.00	11	6	6	1	2	0	26
2.01-5.00	0	0	0	4	9	0	13
> 5.00	0	0	0	0	0	0	0
Total	99	15	16	15	14	0	159

The overall accuracy generated by the flood model is estimated at 53.46%, with eighty-five (85) points correctly matching the actual flood depths. There were thirty (30) points estimated one (1) level above and below the correct flood depths; while there were twenty-four (24) points and sixteen (16) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood, respectively. A total of four (4) points were overestimated, while a total of fifty-four (54) points were underestimated in the modeled flood depths of the Cangaranan-Paliwan floodplain. Table 65 depicts the summary of the Accuracy Assessment in the Cangaranan-Paliwan River Basin Survey.

Table 65. Summary of Accuracy Assessment in the Cangaranan-Paliwan River Basin Survey

CANGARANAN	No. of Points	%
Correct	85	53.46
Overestimated	20	12.58
Underestimated	54	33.96
Total	159	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Cangaranan Floodplain Survey

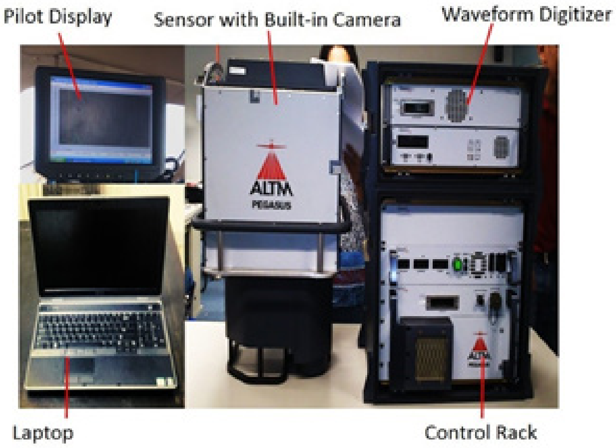


Figure A-1.1. Pegasus Sensor

Table A-1.1. Specifications of the Pegasus sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
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)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

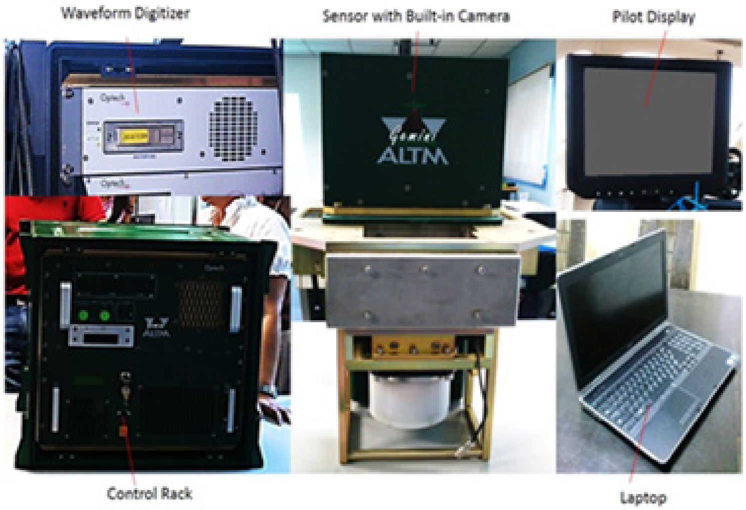


Figure A-1.2. Gemini Sensor

Table A-1.2. 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

Table A-1.3. Specifications of the D-8900 Aerial Digital Camera

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. ILO-85

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: **ILOILO**
Station Name: **ILO-85**
Order: **2nd**

Island: **VISAYAS**
Municipality: **MIAG-AO**
Barangay: **UBOS ILAWOD (POB.)**

	PRS92 Coordinates	
Latitude: **10° 38' 33.11352"**	Longitude: **122° 14' 3.70560"**	Ellipsoidal Hgt: **21.96200 m.**
	WGS84 Coordinates	
Latitude: **10° 38' 28.75996"**	Longitude: **122° 14' 8.93597"**	Ellipsoidal Hgt: **78.82800 m.**
	PTM Coordinates	
Northing: **1176896.034 m.**	Easting: **416226.997 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,176,484.10**	Easting: **416,256.32**	Zone: **51**

Location Description

ILO-85
From Iloilo City, travel W for about 40 km. to the Mun. of Miag-ao. Then proceed directly to the Town Plaza, where the station is located. Station is located at the corner of a planting strip and sidewalk, about 14 m. fronting the Rizal monument. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-85 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-836**

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

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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. ILO-85

2. ILO-86

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: **ILOILO**
Station Name: **ILO-86**
Order: **2nd**

Island: **VISAYAS**
Municipality: **IGBARAS**
Barangay: **BARANGAY 3 POBLACION**

PRS92 Coordinates

Latitude: **10° 43' 4.36044"**	Longitude: **122° 15' 48.62123"**	Ellipsoidal Hgt: **47.31500 m.**

WGS84 Coordinates

Latitude: **10° 42' 59.99043"**	Longitude: **122° 15' 53.84473"**	Ellipsoidal Hgt: **104.07600 m.**

PTM Coordinates

Northing: **1185222.285 m.**	Easting: **419435.758 m.**	Zone: **4**

UTM Coordinates

Northing: **1,184,807.44**	Easting: **419,463.96**	Zone: **51**

Location Description

ILO-86
From Iloilo City, travel W to the Mun. of Igbaras. Then proceed directly to the Town Plaza, where the station is located. Station is located about 12 m. from the circular fountain at the center of the said plaza.

Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-86 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-837**

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

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Figure A-2.2. ILO-86

3. ATQ-18

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

March 02, 2015

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: **ANTIQUE**
Station Name: **ATQ-18**
Order: **2nd**

Island: **VISAYAS**	Barangay: **CUBAY**		
Municipality: **BARBAZA**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **11° 11' 58.67081"**	Longitude: **122° 2' 22.83300"**	Ellipsoidal Hgt:	**10.90200 m.**
	WGS84 Coordinates		
Latitude: **11° 11' 54.16068"**	Longitude: **122° 2' 28.01549"**	Ellipsoidal Hgt:	**65.96100 m.**
	PTM / PRS92 Coordinates		
Northing: **1238579.674 m.**	Easting: **395119.157 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **1,238,146.15**	Easting: **395,155.87**	Zone:	**51**

Location Description

ATQ-18
From San Jose, travel N to the Mun. of Barbaza. Then from the town proper, proceed to Brgy. Cubay. Station is located on the NE approach of Binangbang Bridge, about 600 m. NE of Barbaza Town Hall, 4 m. from the road centerline, 50 m. SE of Barbaza Multi-Purpose Coop./Natco Network and 25 m. SE of a funeral service outlet. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ATQ-18 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8077754 I**
T.N.: **2015-0504**

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

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Figure A-2.3. ATQ-18

4. ATQ-22

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

March 02, 2015

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: **ANTIQUE**
Station Name: **ATQ-22**
Order: **2nd**

Island: **VISAYAS**	Barangay: **CONCEPCION**		
Municipality: **BELISON**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **10° 49' 46.66618"**	Longitude: **121° 58' 11.90221"**	Ellipsoidal Hgt:	**12.25000 m.**
	WGS84 Coordinates		
Latitude: **10° 49' 42.24271"**	Longitude: **121° 58' 17.11770"**	Ellipsoidal Hgt:	**68.02200 m.**
	PTM / PRS92 Coordinates		
Northing: **1197676.056 m.**	Easting: **387365.279 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **1,197,256.85**	Easting: **387,404.70**	Zone:	**51**

Location Description

ATQ-22

From San Jose, travel N to Belison for about 20 km. Station is located on top of the N edge of the NW draft on an irrigation canal, 60 m. NE to the nat'l. highway centerline, 120 m. N of the road going to the brgy. proper and about 300 m. E of Km. Post No. 110. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ATQ-22 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8077754 I**
T.N.: **2015-0503**

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

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CIP/4701/12/09/854

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Figure A-2.4. ATQ-22

5. IL-533

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

March 02, 2015

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: **ILOILO**
Station Name: **IL-533**

Island: **PANAY**	Municipality: **SAN JOAQUIN**	Barangay: **AMBOYU-AN**
Elevation: **8.0971 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 32' 45.00000"**	Longitude: **122° 4' 42.48000"**	

Location Description

BM IL-533
Station is located at the sidewalk of Ambuyuan bridge 0.30m. from thr edge. Mark is the head of a 4in. copper nail set flush on a cement putty with inscriptions " IL-533, 2007, NAMRIA."

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8077754 I**
T.N.: **2015-0505**

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

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Figure A-2.5. IL-533

6. AQ-78

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

March 02, 2015

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: **ANTIQUE**
Station Name: **AQ-78**

Island: **Visayas**	Municipality: **PATNONGON**	Barangay: **IPAYO**
Elevation: **10.6092 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 54' 59.40000"**	Longitude: **121° 59' 52.10000"**	

Location Description

BM AQ-78
Station is located at the northwestern side of the side walk of Ipayo Bridge km. 122+244.79. Mark is the head of a 4in. copper nail set flush on a cement putty with inscriptions "AQ-78,2007,NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8077754 I**
T.N.: **2015-0506**

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

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Figure A-2.6. AQ-76

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

Table A-3.1. IIAP-01

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
IIAP-01 --- ILO-85 (B1)	ILO-85	IIAP-01	Fixed	0.005	0.021	53°20'16"	35787.597	21.428
IIAP-01 --- ILO-85 (B2)	ILO-85	IIAP-01	Fixed	0.004	0.019	53°20'16"	35787.597	21.398

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	ILO-85				
Grid		Local		Global	
Easting	416256.319 m	Latitude	N10°38'33.11352"	Latitude	N10°38'28.75996"
Northing	1176484.099 m	Longitude	E122°14'03.70561"	Longitude	E122°14'08.93597"
Elevation	22.539 m	Height	21.962 m	Height	78.828 m

To:	IIAP-01				
Grid		Local		Global	
Easting	445007.365 m	Latitude	N10°50'08.21923"	Latitude	N10°50'03.83971"
Northing	1197773.997 m	Longitude	E122°29'48.82359"	Longitude	E122°29'54.03518"
Elevation	42.806 m	Height	43.390 m	Height	100.449 m

Vector					
ΔEasting	28751.046 m	NS Fwd Azimuth	53°20'16"	ΔX	-22136.041 m
ΔNorthing	21289.898 m	Ellipsoid Dist.	35787.597 m	ΔY	-18716.081 m
ΔElevation	20.268 m	ΔHeight	21.428 m	ΔZ	20987.226 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.003 m

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME B. HIPOLITO	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
		REGINA FELISMINO	UP-TCAGP
		KRISTINE ANDAYA	UP-TCAGP
		REMEDIOS VILLANUEVA	UP-TCAGP
		MARY CATHERINE BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
		JONATHAN ALMALVEZ	UP-TCAGP
		IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG LEEJAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG JAYCO MANZANO	
	Pilot	CAPT. ALBERT PAUL LIM	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JEFFREY ALAJAR	
		CAPT. JERICHO JECIEL	
		CAPT. NIEL AGAWIN	

Annex 5. Data Transfer Sheets for the Cangaranan Floodplain Flights

DATA TRANSFER SHEET
[illegible]

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Feb-15	2569P	1BLK43DO45A	pegasus	1.20	940	6.06	106	10.6	10/43	14.4	na	10.5	1KB	1KB	26	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43M047B	pegasus	1.77	1.21	10.4	221	26.4	251	19.1	na	17.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MN048A	pegasus	2.06	1.35	9.99	253	34.3	265	21.4	na	20.2	1KB	1KB	74/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43DO48B	pegasus	3.11	715	6.58	170	14	127	11.4	na	20.2	1KB	1KB	80/73	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EF049A	pegasus	2.91	1.71	9.97	283	42	314	27.8	na	14.3	1KB	1KB	95/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43ED049B	pegasus	1.7	1.02	9.55	130	19.3	16/71	17.4	na	7.48	1KB	1KB	1/92/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.78	417	17.3	133	13.3	na	16.7	1KB	1KB	[illegible]	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37I050B	pegasus	5.55	1.02	9.47	126	49.9	343	26.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2593P	1BLK43BDG051A	pegasus	3.14	1.01	7.62	213	27	218	16.3	na	11	1KB	1KB	116	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43N052A	pegasus	2.09	1.29	6.69	257	37.8	274	21	na	11.5	1KB	1KB	52	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37FV053A	pegasus	2.13	1.27	9.06	225	32.2	256	20.7	na	17.7	1KB	1KB	101/76	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
3/23/2015

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

DATA TRANSFER SHEET
03/23/2015(Iloilo-pegs)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Feb-15	2569P	1BLK43DO45A	pegasus	1.28	840	6.96	196	10.6	1048	14.4	na	10.5	1KB	1KB	26	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43MO47B	pegasus	1.77	1.21	10.4	221	26.4	251	13.1	na	17.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MNO48A	pegasus	2.06	1.35	9.59	253	34.3	265	21.4	na	20.2	1KB	1KB	76/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43DO48B	pegasus	1.11	716	6.56	170	14	127	11.4	na	20.2	1KB	1KB	90/71	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EFO49A	pegasus	2.91	1.71	9.97	283	42	314	27.8	na	14.3	1KB	1KB	95/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43EDO49B	pegasus	1.7	1.02	9.55	130	19.9	1071	17.4	na	7.48	1KB	1KB	140/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.76	417	17.3	153	12.3	na	16.7	1KB	1KB	90/77/026/102 1	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37IO50B	pegasus	5.55	1.03	9.47	195	49.9	343	25.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2595P	1BLK43RDGO51A	pegasus	3.14	1.81	7.62	213	27	218	16.3	na	11	1KB	1KB	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43NO52A	pegasus	2.09	1.29	9.69	257	37.9	274	21	na	11.3	1KB	1KB	32	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37FVO53A	pegasus	2.13	1.27	9.06	225	52.2	250	20.7	na	17.7	1KB	1KB	101/76	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
3/23/2015

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

DATA TRANSFER SHEET
7/3/2014(Iloilo)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
25-Feb-15	2602G	2BLK43B056A	GEMINI	NA	278	402	167	8.44	61	5.95	NA	9.49	1KB	1KB	12	17	Z:\DAC\RAW DATA
26-Feb-15	2606G	2BLK43BV057A	GEMINI	NA	739	932	208	22.5	92	12.6	NA	9.26	1KB	1KB	12	18	Z:\DAC\RAW DATA
27-Feb-15	2610G	2BLK43BV058A	GEMINI	NA	100	190	173	2.88	25	2.95	NA	8.94	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
5-Mar-15	2634G	2BLK37FV064A	GEMINI	NA	298	532	170	14.6	122	5.2	NA	22.7	1KB	1KB	8	13	Z:\DAC\RAW DATA
5-Mar-15	2636G	2BLK43OS064B	GEMINI	NA	468	770	205	23.2	106	5.05	NA	22.7	1KB	1KB	8	18	Z:\DAC\RAW DATA
6-Mar-15	2638G	2BLK43OS065A	GEMINI	NA	581	894	234	27.5	[illegible]	12.5	NA	20.1	1KB	1KB	13	21	Z:\DAC\RAW DATA
25-Feb-15	2613P	1BLK37IFV056A	PEGASUS	1.94	652	6.14	151	17.6	134	10	NA	16.6	1KB	1KB	101/76	NA	Z:\DAC\RAW DATA
26-Feb-15	2617P	1BLK37OP057A	PEGASUS	7.28	2.14	12.3	260	55.2	457	34.5	NA	18.7	1KB	1KB	196	NA	Z:\DAC\RAW DATA
27-Feb-15	2621P	1BLK37P058A	PEGASUS	3.11	1.93	12.8	245	48.1	414	27.3	NA	15.5	1KB	1KB	160	NA	Z:\DAC\RAW DATA
3-Mar-15	2637P	1BLK43NO062A	PEGASUS	1.82	1.15	9.81	245	32.8	237	18.3	NA	10.7	1KB	1KB	21/107	NA	Z:\DAC\RAW DATA
3-Mar-15	2639P	1BLK37M062B	PEGASUS	858	510	4.92	114	9.94	89	8.09	1.65	10.7	1KB	1KB	172	NA	Z:\DAC\RAW DATA
5-Mar-15	2645P	1BLK37Q064A	PEGASUS	2.74	.99	10.1	263	35.8	264	18.3	53.5	22.7	1KB	1KB	185/188	NA	Z:\DAC\RAW DATA
5-Mar-15	2647P	1BLK37MQ064B	PEGASUS	NA	1.16	9.62	235	71.5	4	17.8	NA	22.7	1KB	1KB	238/154	NA	Z:\DAC\RAW DATA
6-Mar-15	2649P	1BLK37Q065A	PEGASUS	582	505	5.92	202	15.1	105	7.9	50.4	20.1	1KB	1KB	231/210	NA	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position
Signature

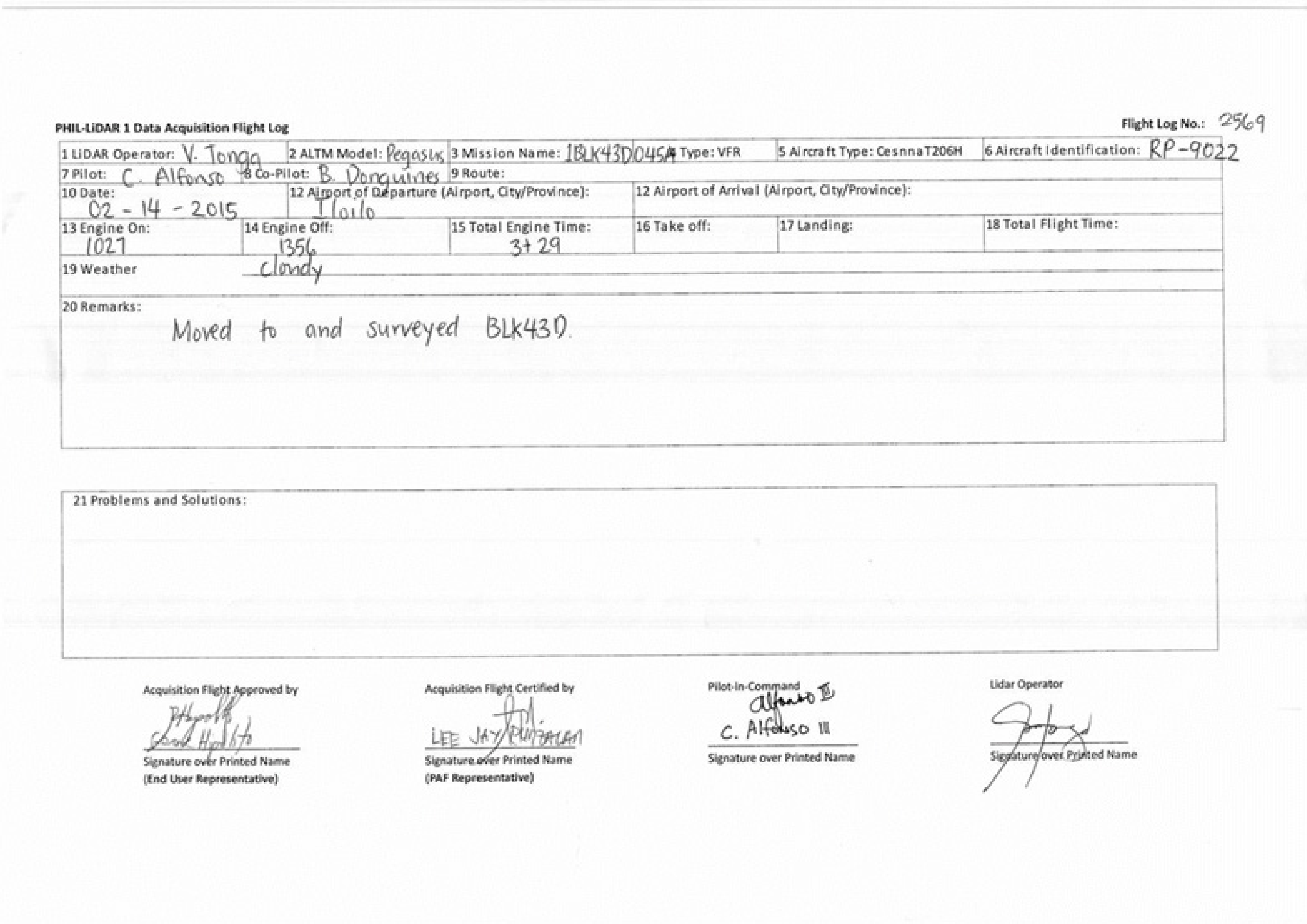
Received by

Name Angelo Carlo Bragat
Position
Signature

Figure A-5.3. Data Transfer Sheet for Cangaranan Floodplain – B

Annex 6. Flight logs for the flight missions

1. Flight Log for 2569P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2569

1 LiDAR Operator: V. Tonga	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43D045A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route:			
10 Date: 02-14-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1027	14 Engine Off: 1356	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

Moved to and surveyed BLK43D.

21 Problems and Solutions:

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

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

Pilot-in-Command — C. Alfonso III — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2569P

2. Flight Log for 2583P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2583

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43D048B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: A. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02-17-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1428	14 Engine Off: 1721	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Moved to and surveyed BLK 43D

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	LJ Pumarian	C. Alfonso III	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 2583P

3. Flight Log for 2587P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log — Flight Log No.: 2587

1 LiDAR Operator: KJ. Andaya	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43ED049B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02 - 18 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1407	14 Engine Off: 1754	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				

20 Remarks:

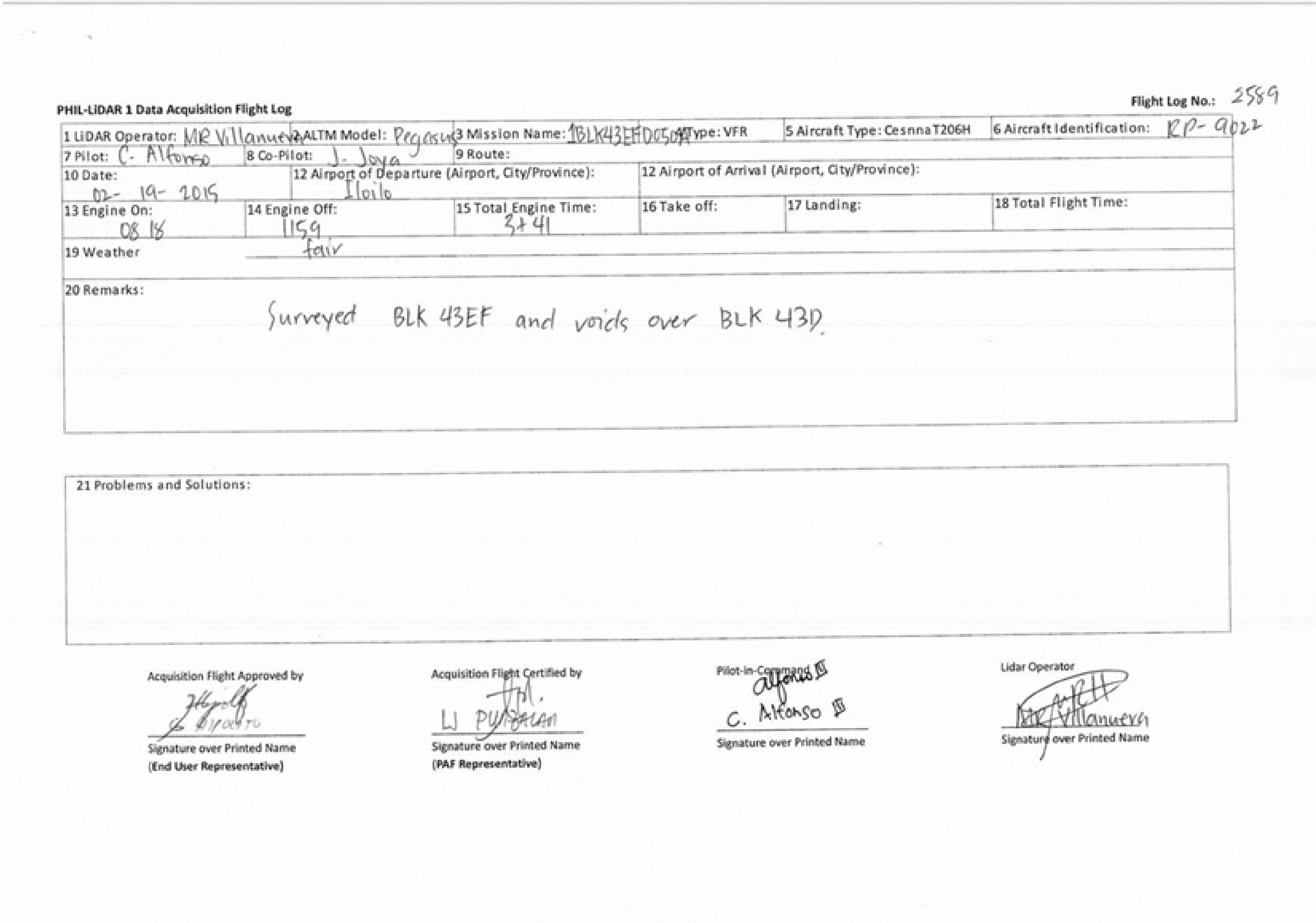
Surveyed voids over BLK 43E and gaps over BLK 43D.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Z Alial Jr.	LJ Puzalan	C. Alfonso III	KJ Andaya
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1289P

4. Flight Log for 2589P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2589

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43EFD050A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02-19-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0818	14 Engine Off: 1159	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				

20 Remarks:

Surveyed BLK 43EF and voids over BLK 43D.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[illegible]	LJ Puyaoan	C. Alfonso III	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2589P

5. Flight Log for 2593P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2593

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43BDG051A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joyd	9 Route:			
10 Date: 02-20-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1341	14 Engine Off: 1710	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				

20 Remarks:

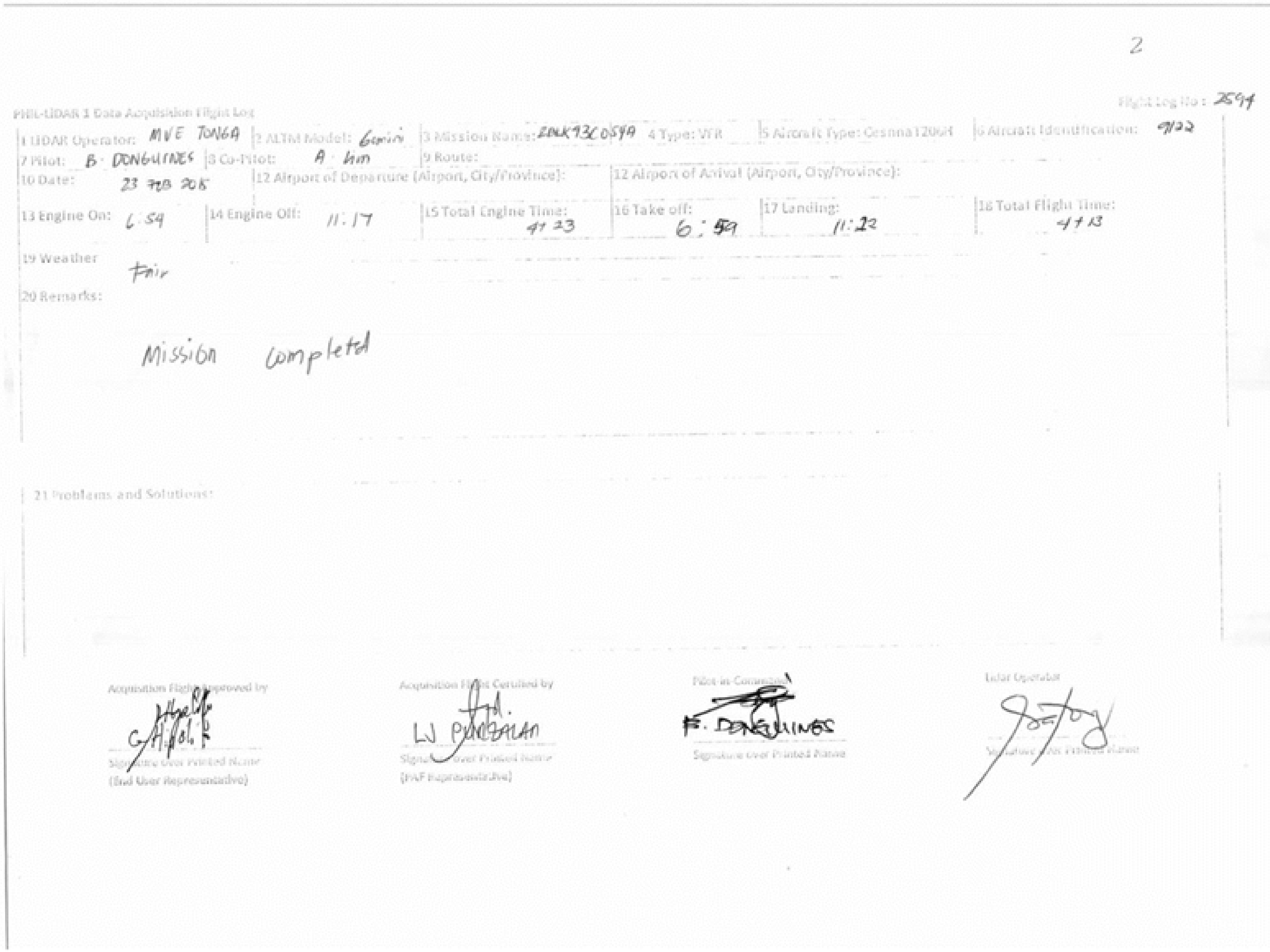
Surveyed BLK 43B and voids over BLK 43D and 43G.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
S. Nyolto	LJ Purzlan	C. Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2593P

6. Flight Log for 2594G Mission


2

PHIL-LIDAR 1 Data Acquisition Flight Log

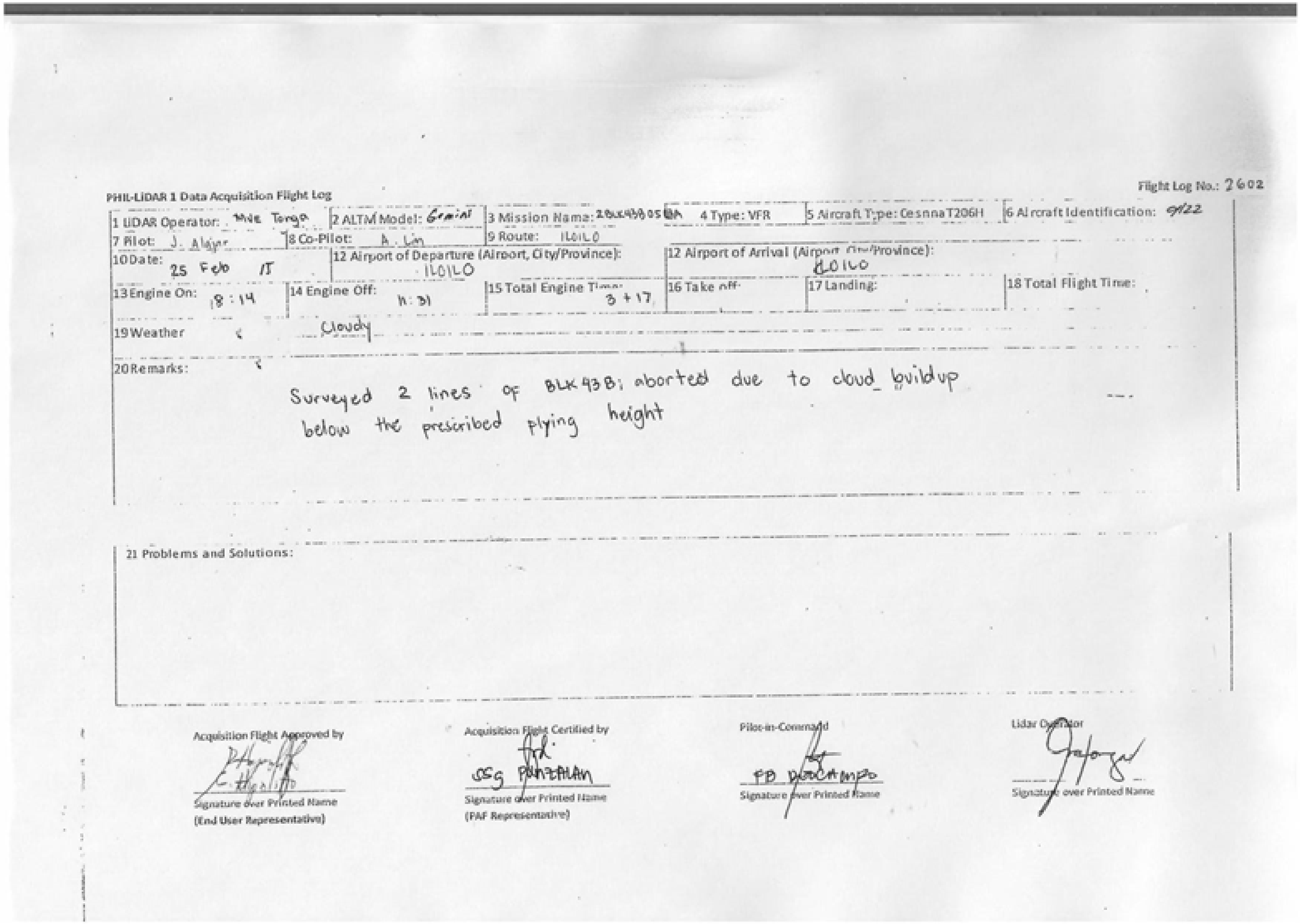
Flight Log No.: 2594

1 LiDAR Operator: MVE TONGA	2 ALTM Model: Gemini	3 Mission Name: 2BLK93C059A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. DONGUINES	8 Co-Pilot: A. Lim	9 Route:			
10 Date: 23 FEB 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:54	14 Engine Off: 11:17	15 Total Engine Time: 4+23	16 Take off: 6:59	17 Landing: 11:22	18 Total Flight Time: 4+13
19 Weather: Fair					
20 Remarks: Mission completed					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipol	LJ Pungalan	F. Donguines	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6. Flight Log for Mission 2594G

7. Flight Log for 2602G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2602

1 LIDAR Operator: Mie Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43B056A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 25 Feb 17	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 8:14	14 Engine Off: 11:31	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 2 lines of BLK43B; aborted due to cloud buildup below the prescribed flying height

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Alconitio	SSg Pantalan	FB Docampo	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 2602G

8. Flight Log for 2606G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2606

1 LiDAR Operator: MA Felismino	2 ALTM Model: Gemini	3 Mission Name: 2BLK43BV057B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: 26 FEB 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:00	14 Engine Off: 11:05	15 Total Engine Time: 4+5	16 Take off: 7:05	17 Landing: 11:00	18 Total Flight Time: 3+55
19 Weather: cloudy					

20 Remarks:

Surveyed 10 lines of BLK 43B

21 Problems and Solutions:

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

Acquisition Flight Certified by: Lt. Pungtilan — Signature over Printed Name (PAF Representative)

Pilot-in-Command: P. Dongulnes — Signature over Printed Name

Lidar Operator: mafelismino — Signature over Printed Name

Figure A-6.8. Flight Log for Mission 2606G

9. Flight Log for 2610G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2610

1 LiDAR Operator: MVF Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43BV53A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Donguines	8 Co-Pilot: A. Lim	9 Route:			
10 Date: 27 FEB 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:03	14 Engine Off: 10:08	15 Total Engine Time: 3+5	16 Take off: 7:08	17 Landing: 10:03	18 Total Flight Time: 2+55
19 Weather: Cloudy					
20 Remarks: Surveyed voids of BLK43B; mission aborted due to cloud buildup and strong wind					
21 Problems and Solutions:					

Acquisition Flight Approved by: C. Alcbil, Jr. — Signature over Printed Name (End User Representative)

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

Pilot-in-Command: B. Donguines — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.9. Flight Log for Mission 2610G

Annex 7. Flight status reports

Table A-7-1. Flight Status Report

FLIGHT STATUS REPORT
CANGARANAN
FEBRUARY 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2569P	BLK 43D	1BLK43D045A	MVE TONGA	14 FEB 15	Moved to and surveyed BLK 43D
2583P	BLK 43D	1BLK43D048B	MR VILLANUEVA	17 FEB 15	Moved to and surveyed BLK43D
2587P	BLK 43E, 43D	1BLK43ED049B	KJ ANDAYA	18 FEB 15	Surveyed voids on BLK43E and gaps on BLK43D
2589P	BLK 43E, 43F, 43D	1BLK43EFD050A	MR VILLANUEVA	19 FEB 15	Surveyed BLK 43E to 43F and voids on BLK43D
2593P	BLK 43B, 43D, 43G	1BLK43BDG051A	IRO ROXAS	20 FEB 15	Surveyed BLK43B and voids on BLK 43D and 43G
2602G	BLK 43B	2BLK43B056A	MVE TONGA	25 FEB 15	Surveyed 2 lines of BLK43B; aborted due to cloud buildup below the prescribed flying height
2606G	BLK 43B	2BLK43BV057A	RA FELISMINO	26 FEB 15	Surveyed 10 lines of BLK43B
2610G	BLK 43B, 43C	2BLK43BV058A	MVE TONGA	27 FEB 15	Surveyed voids of BLK43B; mission aborted due to cloud buildup and strong wind

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. : 2569P
Area: BLK 43D
Mission Name: 1BLK43D045A
Total Area Surveyed: 79.3627 sq. km

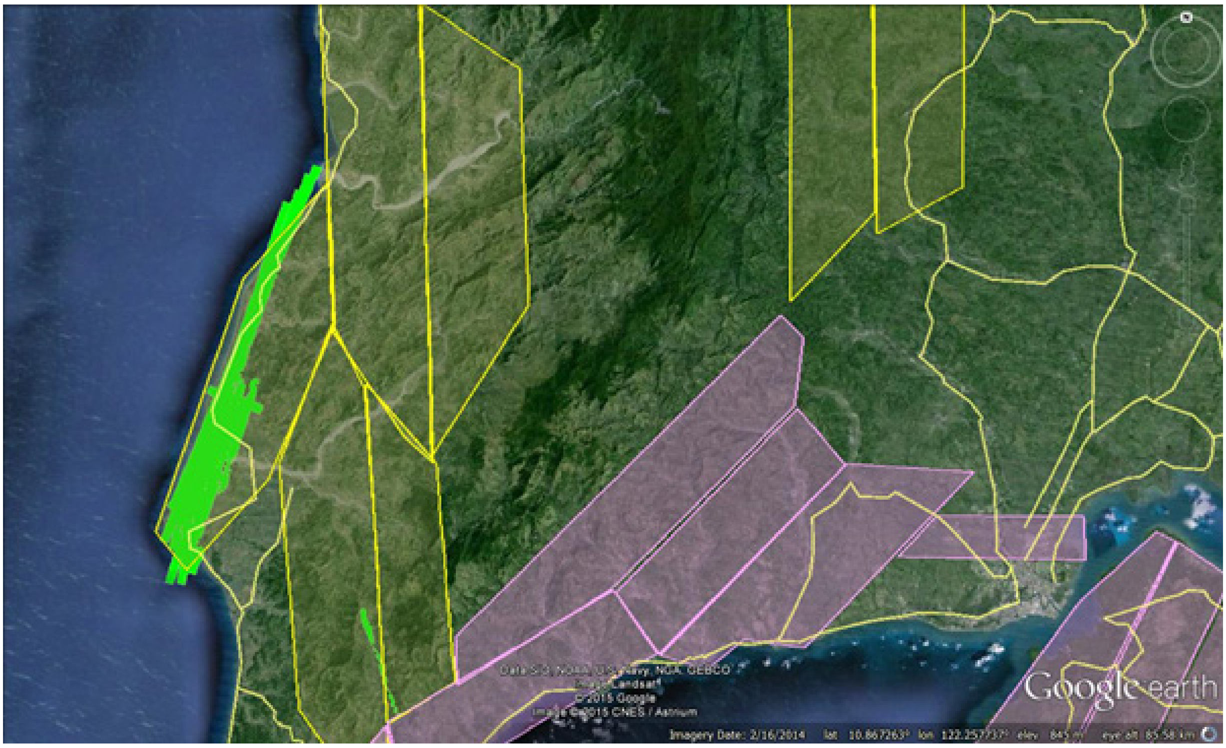


Figure A-7.1. Swath for Flight No. 2569P

Flight No. : 2583P
Area: BLK 43D
Mission Name: 1BLK43D048B
Total Area Surveyed: 114.061 sq. km

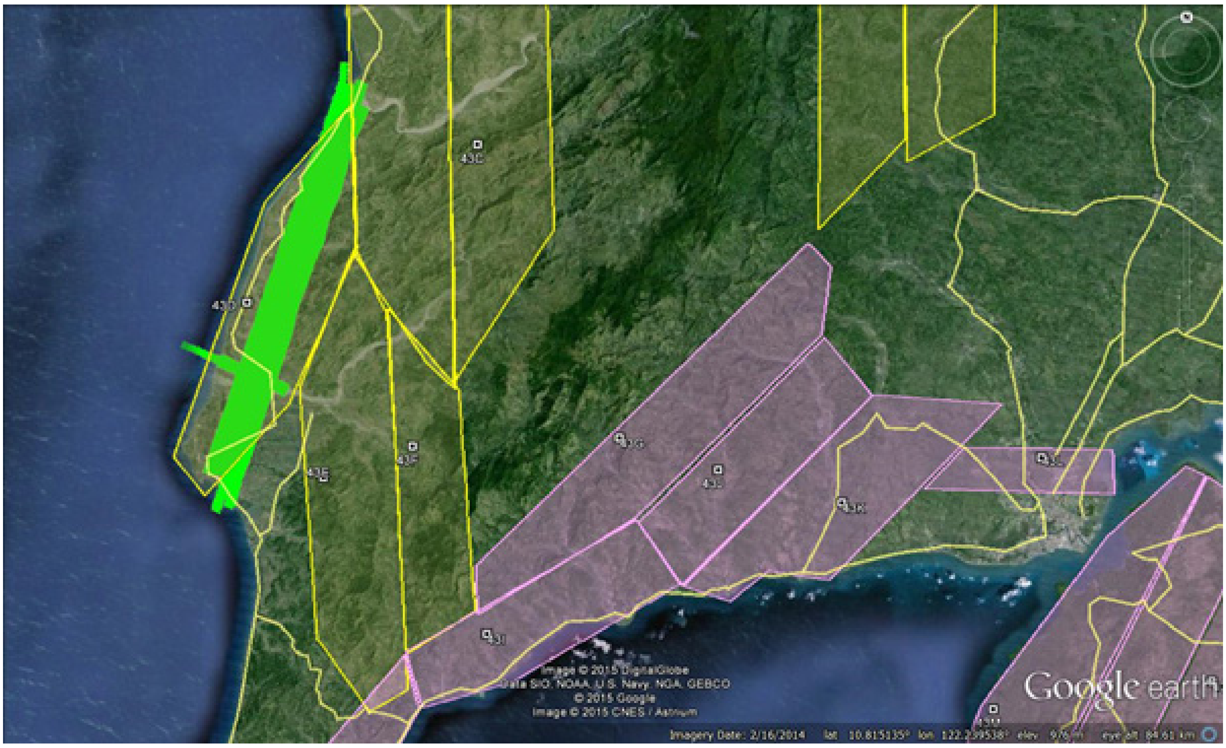


Figure A-7.2. Swath for Flight No. 2583P

Flight No. : 2587P
Area: BLK 43E, 43D
Mission Name: 1BLK43EF049B
Total Area Surveyed: 153.076 sq. km

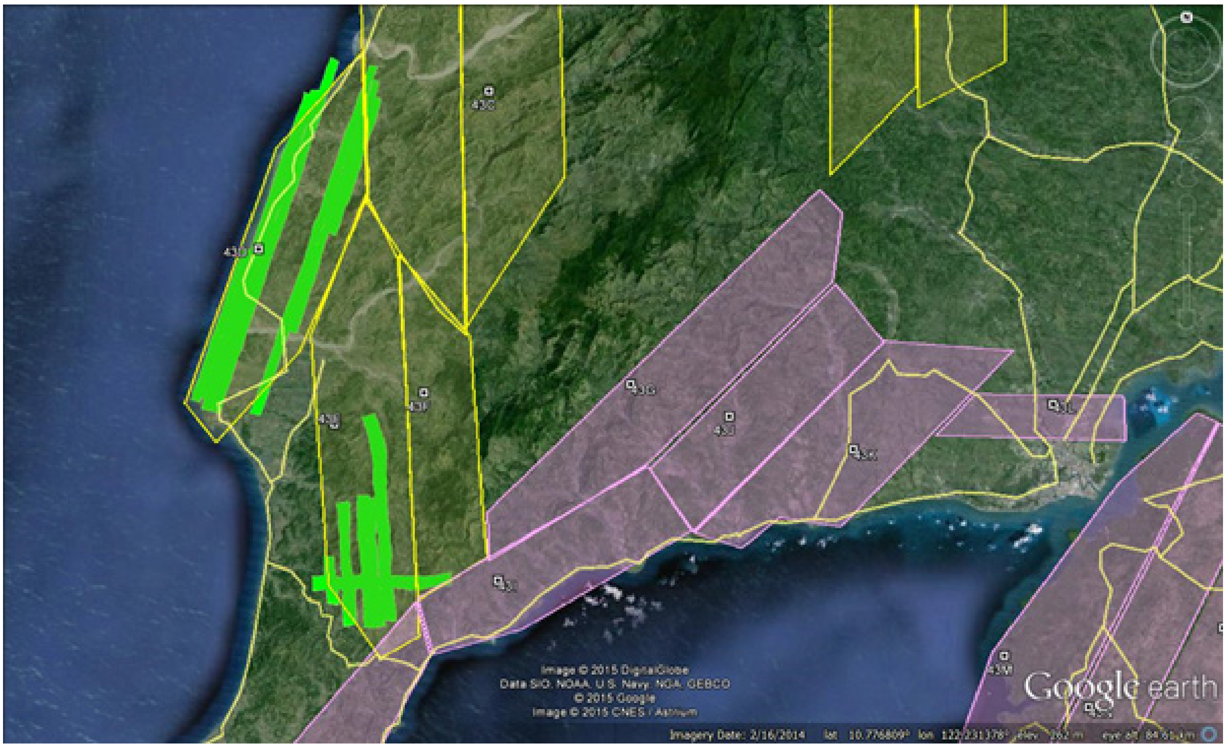


Figure A-7.3. Swath for Flight No. 2587P

Flight No. : 2589P
Area: BLK 43E, 43F, 43D
Mission Name: 1BLK43EF050A
Total Area Surveyed: 132.258 sq. km

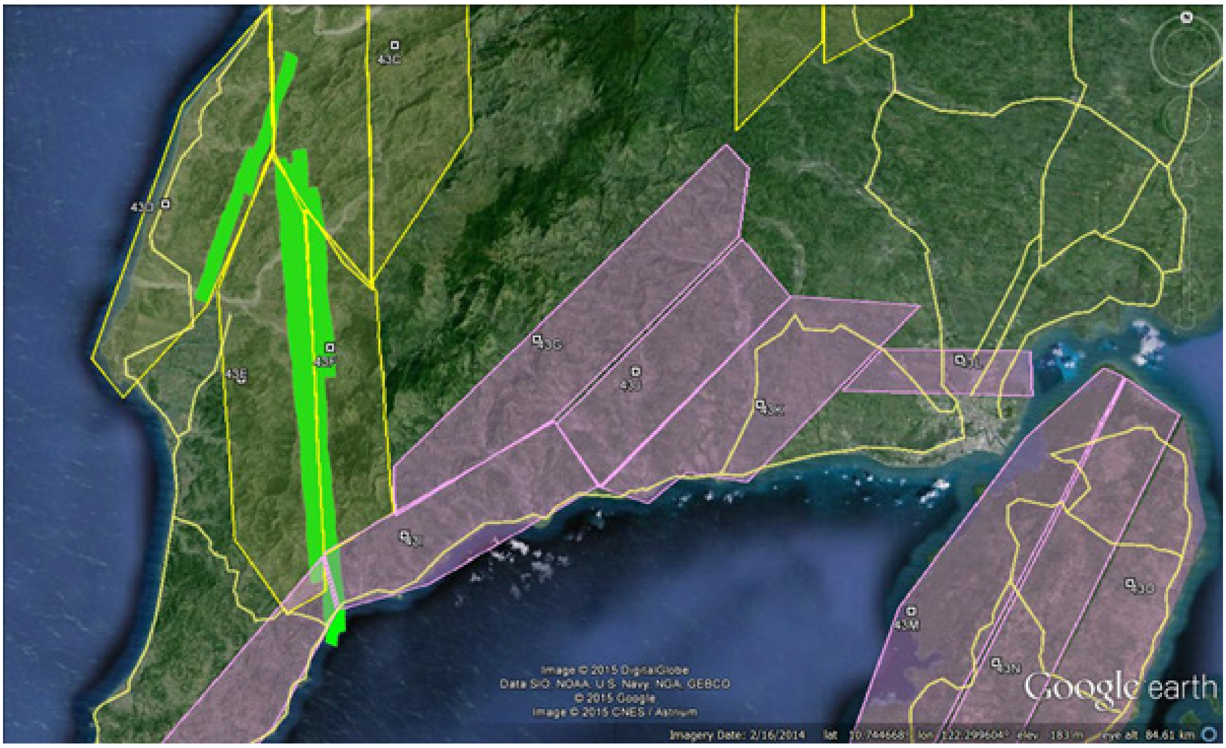


Figure A-7.4. Swath for Flight No. 2589P

Flight No. : 2593P
Area: BLK 43B, 43D, 43G
Mission Name: 1BLK43BC051A
Total Area Surveyed: 181.2 sq. km

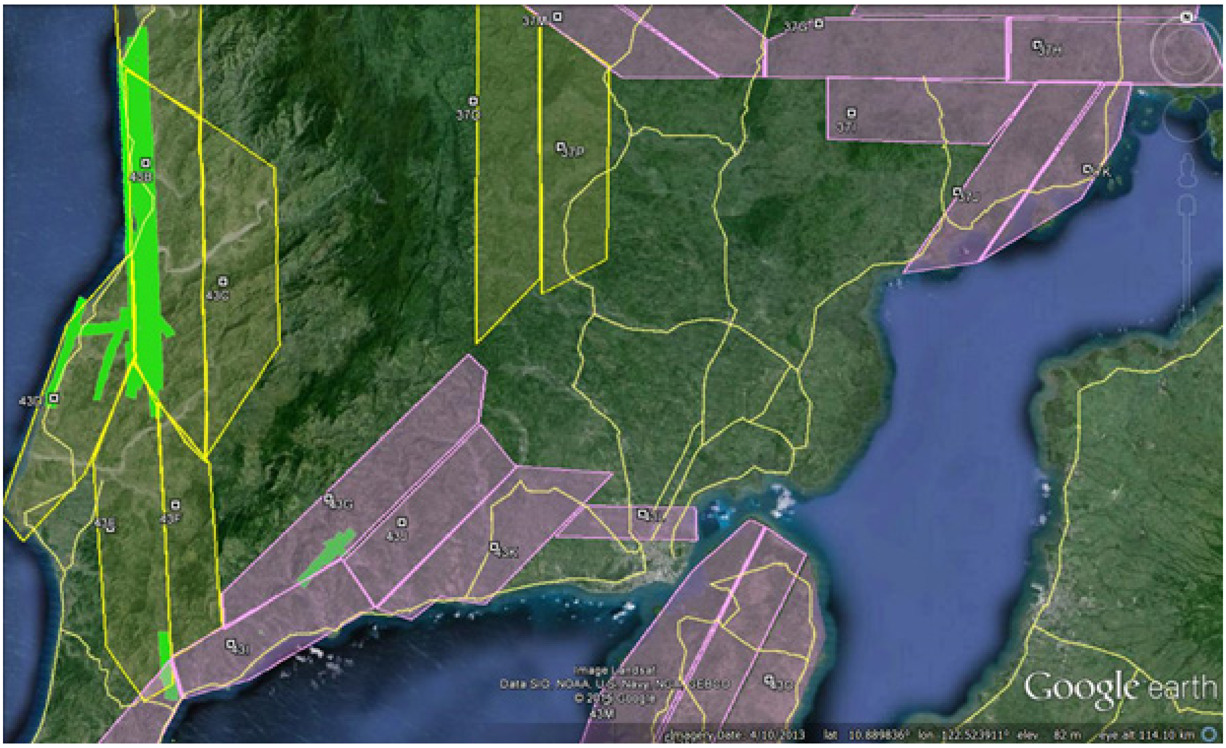


Figure A-7.5. Swath for Flight No. 2593P

Flight No. : 2594G
Area: BLK 43C
Mission Name: 2BLK43C054A
Total Area Surveyed: 252.831 sq. km

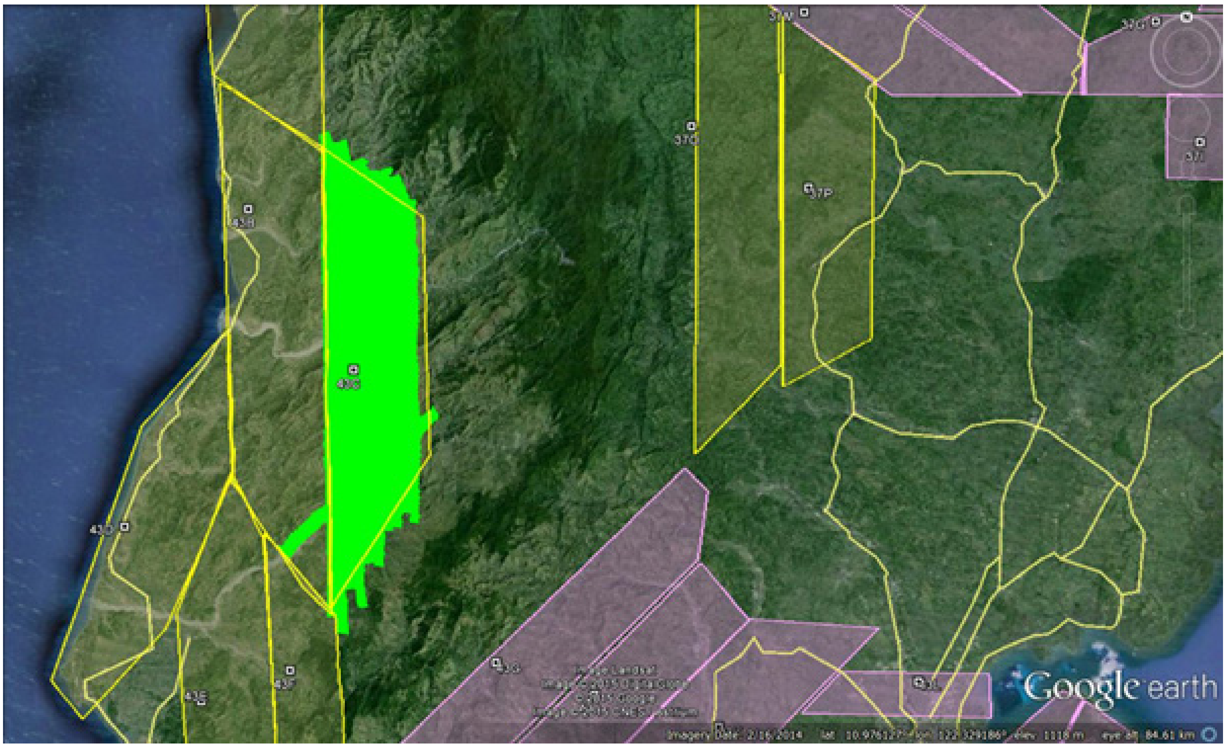


Figure A-7.6. Swath for Flight No. 2594G

Flight No. :	2602G
Area:	BLK 43B
Mission Name:	2BLK43B056A
Total Area Surveyed:	89.4442 sq. km

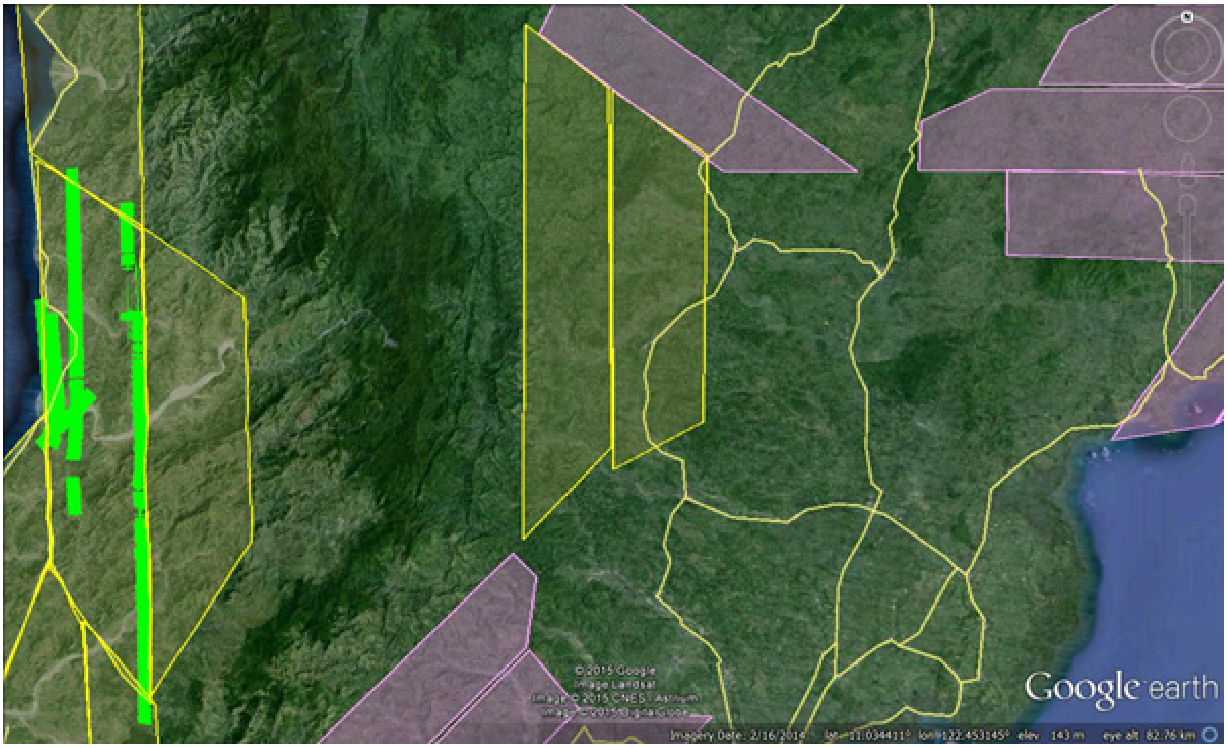


Figure A-7.7. Swath for Flight No. 2602G

Flight No. :	2606G
Area:	BLK 43B
Mission Name:	2BLK43BV057A
Total Area Surveyed:	221.78 sq. km

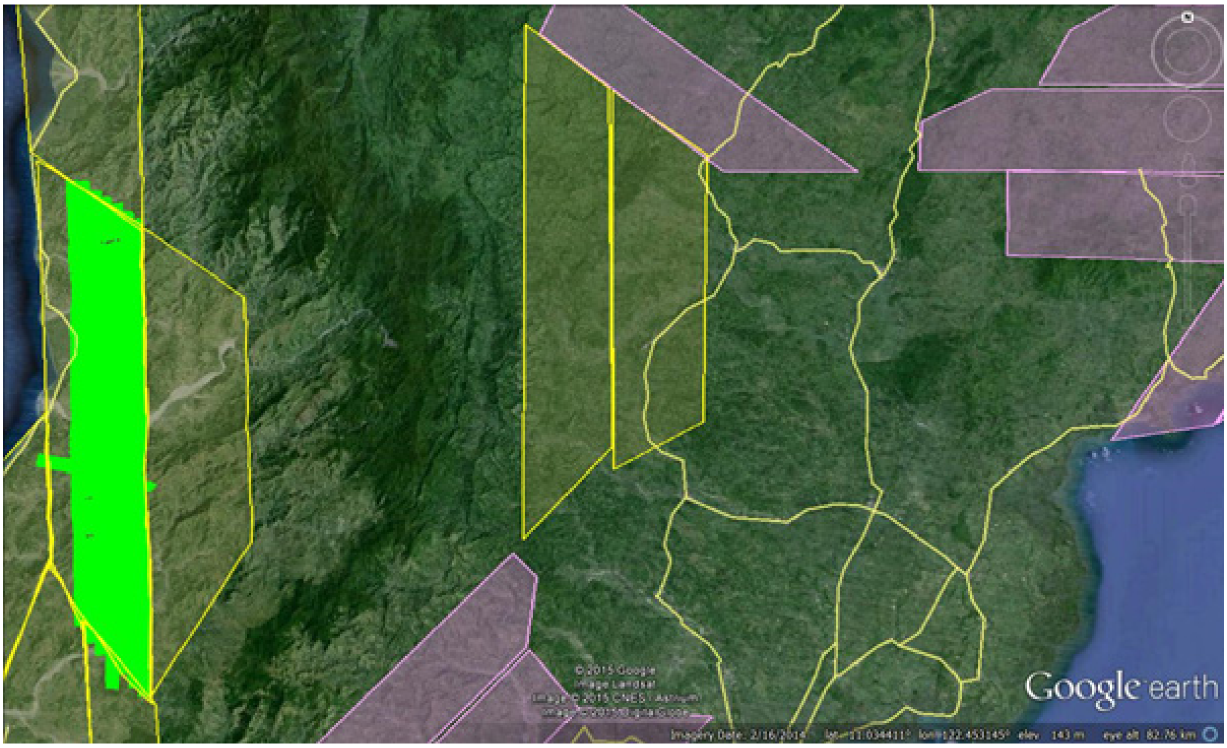


Figure A-7.8. Swath for Flight No. 2606G

Flight No. :	2610G
Area:	BLK 43B, 43C
Mission Name:	2BLK43BV058A
Total Area Surveyed:	34.3481 sq. km

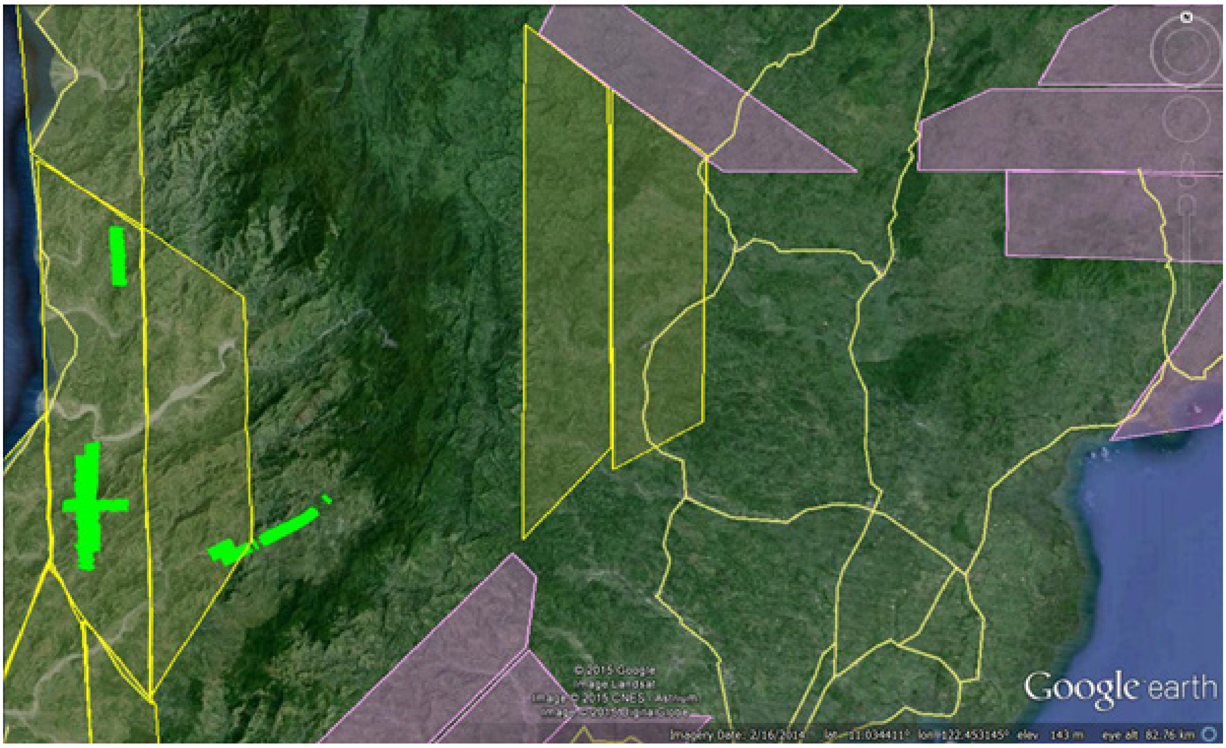


Figure A-7.9. Swath for Flight No. 2610G

FLIGHT NO. :	1291P
AREA:	BLK32K & BLK32L
MISSION NAME:	1BLK32KL091A
PARAMETERS:	Altitude: 800m;
	Scan Frequency: 30Hz;
	Scan Angle: 25deg;
	Overlap: 30%

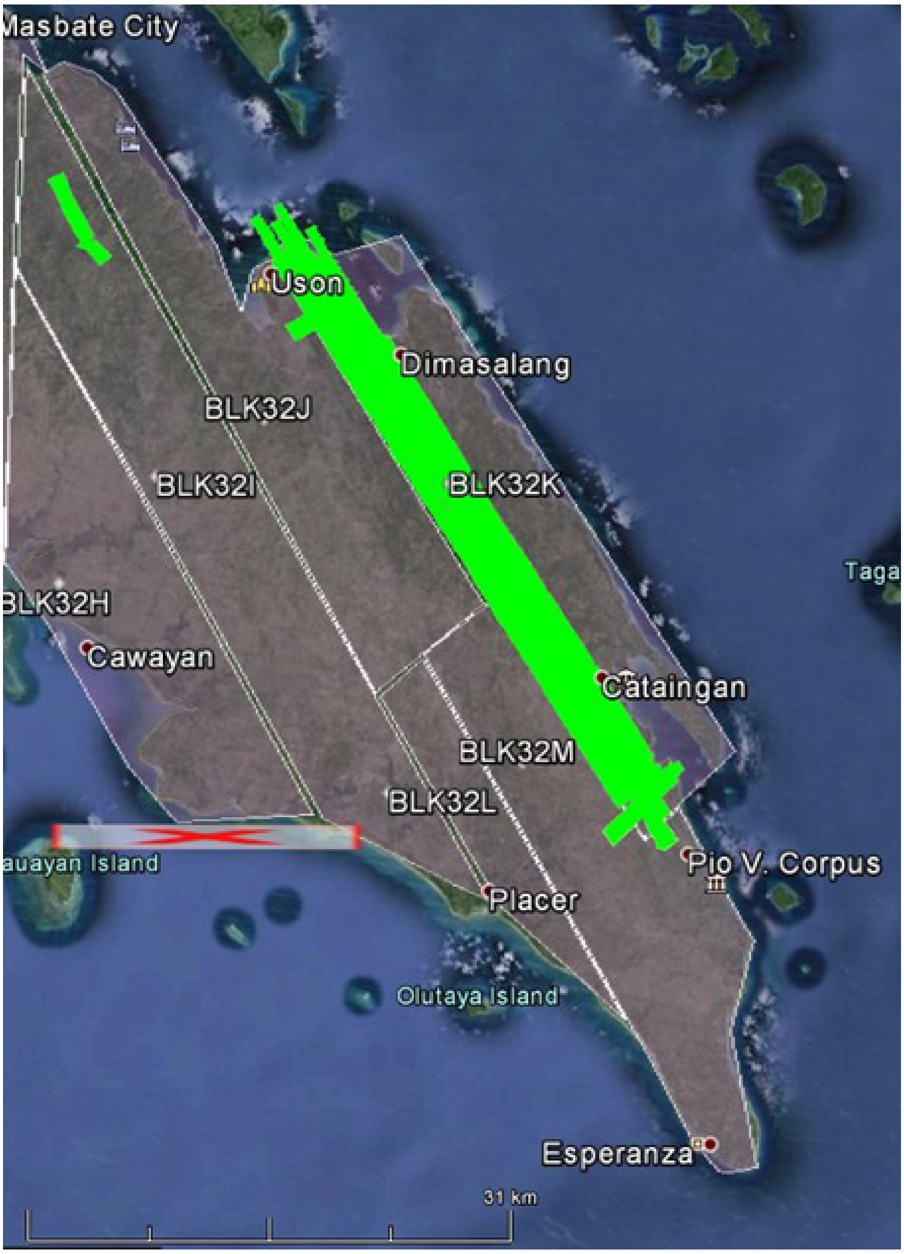


Figure A-7.4. Swath for Flight No. 1291P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk43B

Flight Area	Iloilo
Mission Name	Blk43B
Inclusive Flights	2593P
Range data size	16.3 GB
POS	213 MB
Base data size	11 MB
Image	27 GB
Transfer date	March 23, 2015
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)	1.01
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000371
IMU attitude correction stdev (<0.001deg)	0.000661
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	25.93%
Ave point cloud density per sq.m. (>2.0)	2.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	200
Maximum Height	594.49 m
Minimum Height	54.70 m
Classification (# of points)	
Ground	152,186,273
Low vegetation	75,056,947
Medium vegetation	152,053,797
High vegetation	281,227,721
Building	4,634,683
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Melissa Fernandez

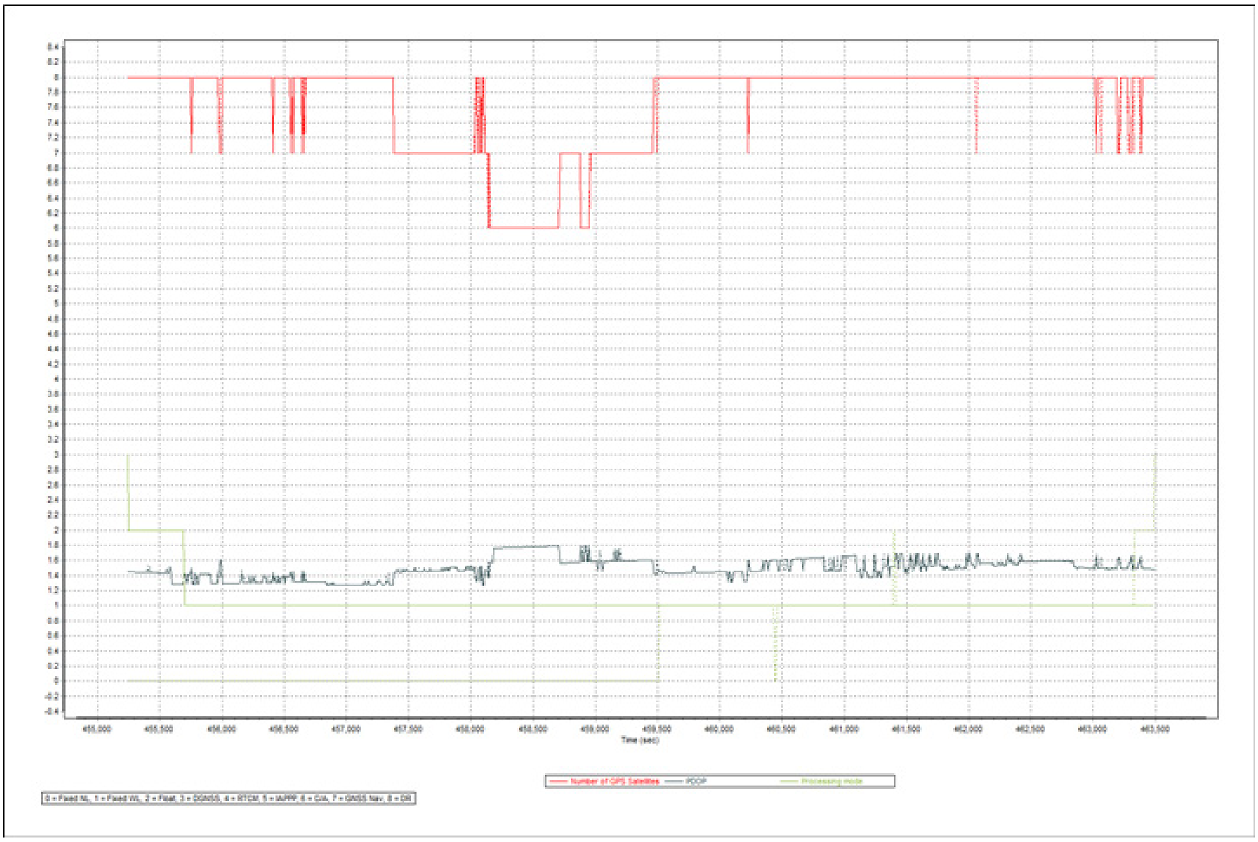


Figure A-8.1. Solution Status

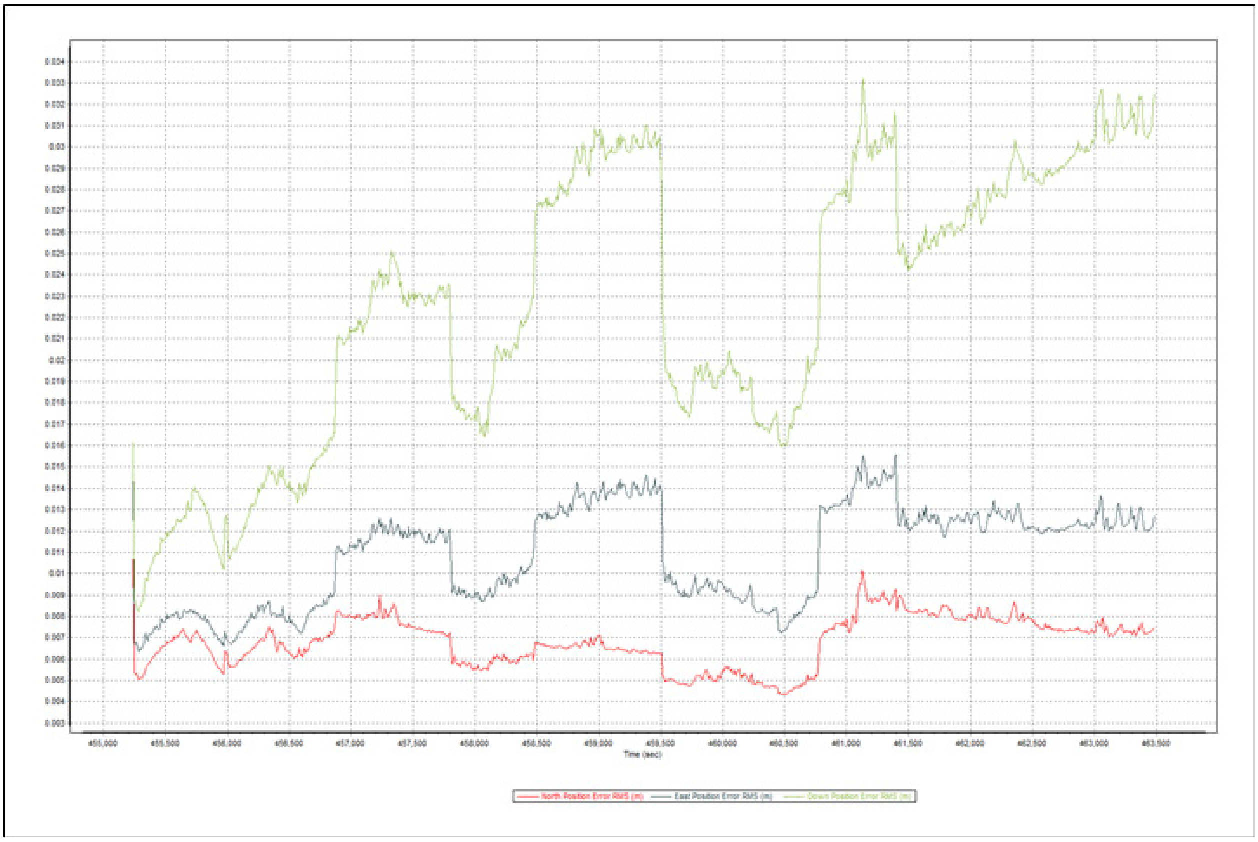


Figure A-8.2. Smoothed Performance Metric Parameters

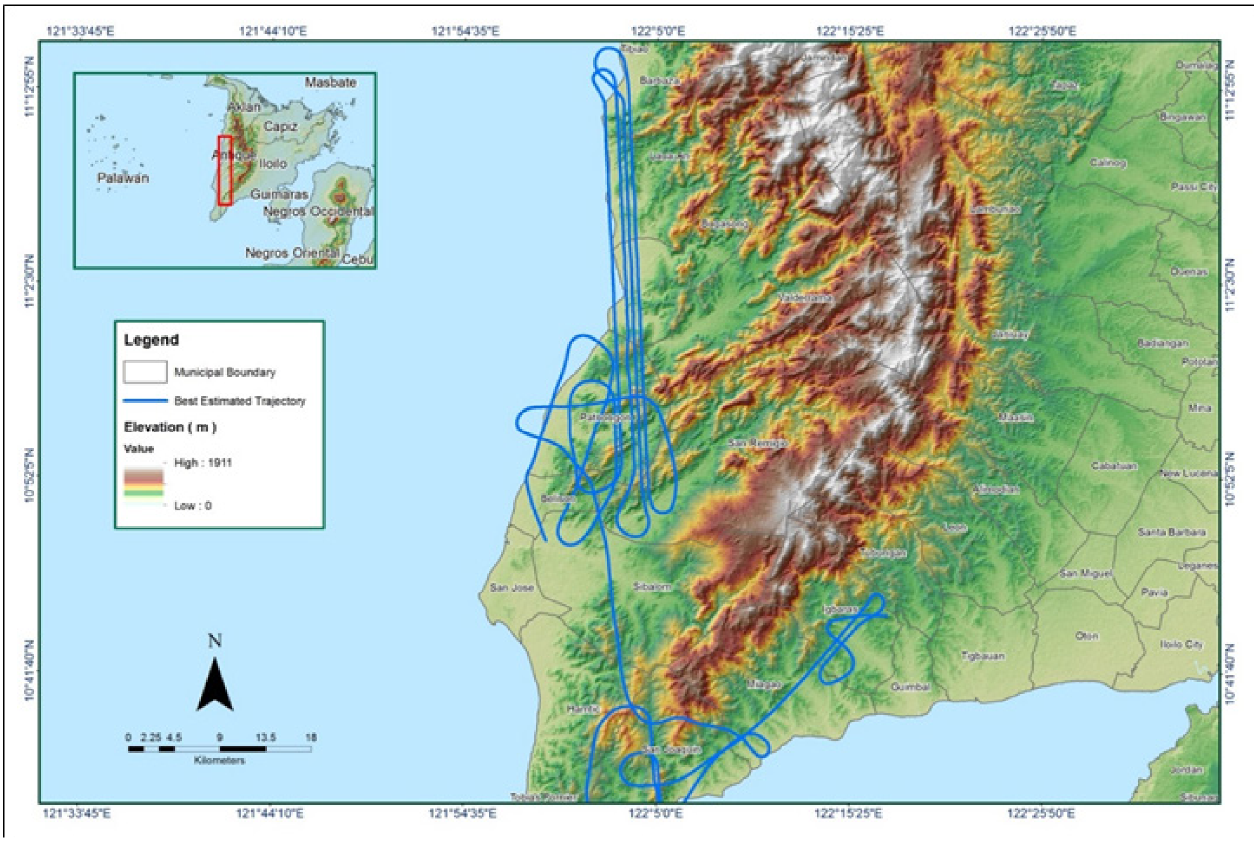


Figure A-8.3. Best Estimated Trajectory

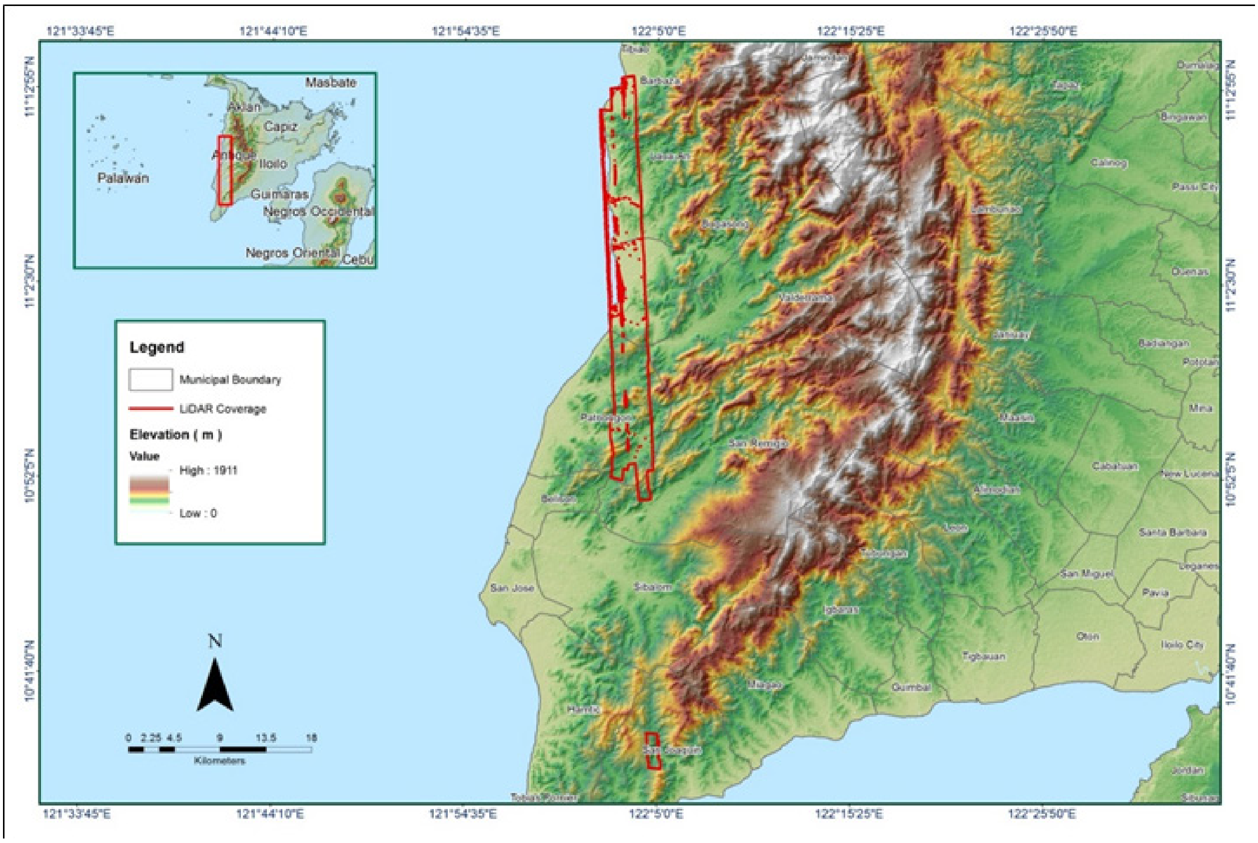


Figure A-8.4. Coverage of LiDAR data

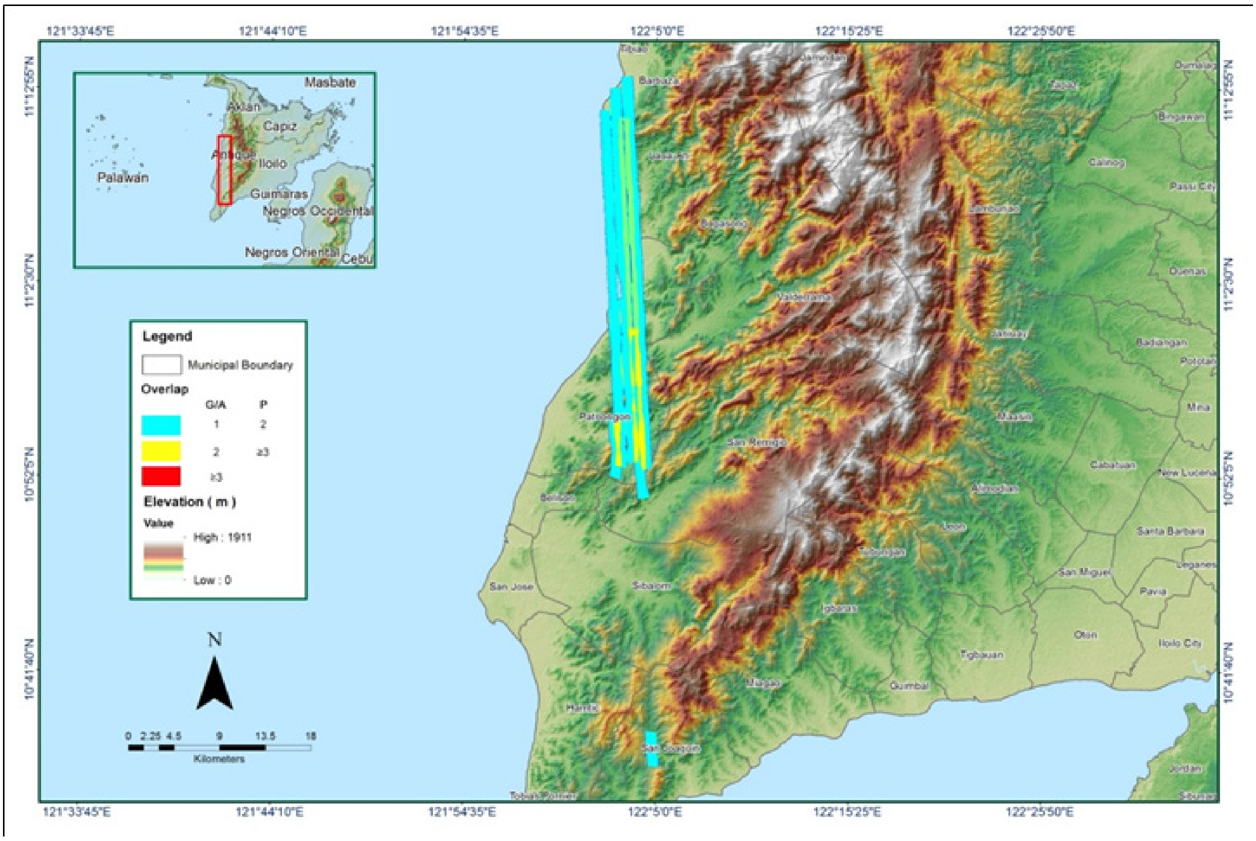


Figure A-8.5. Image of data overlap

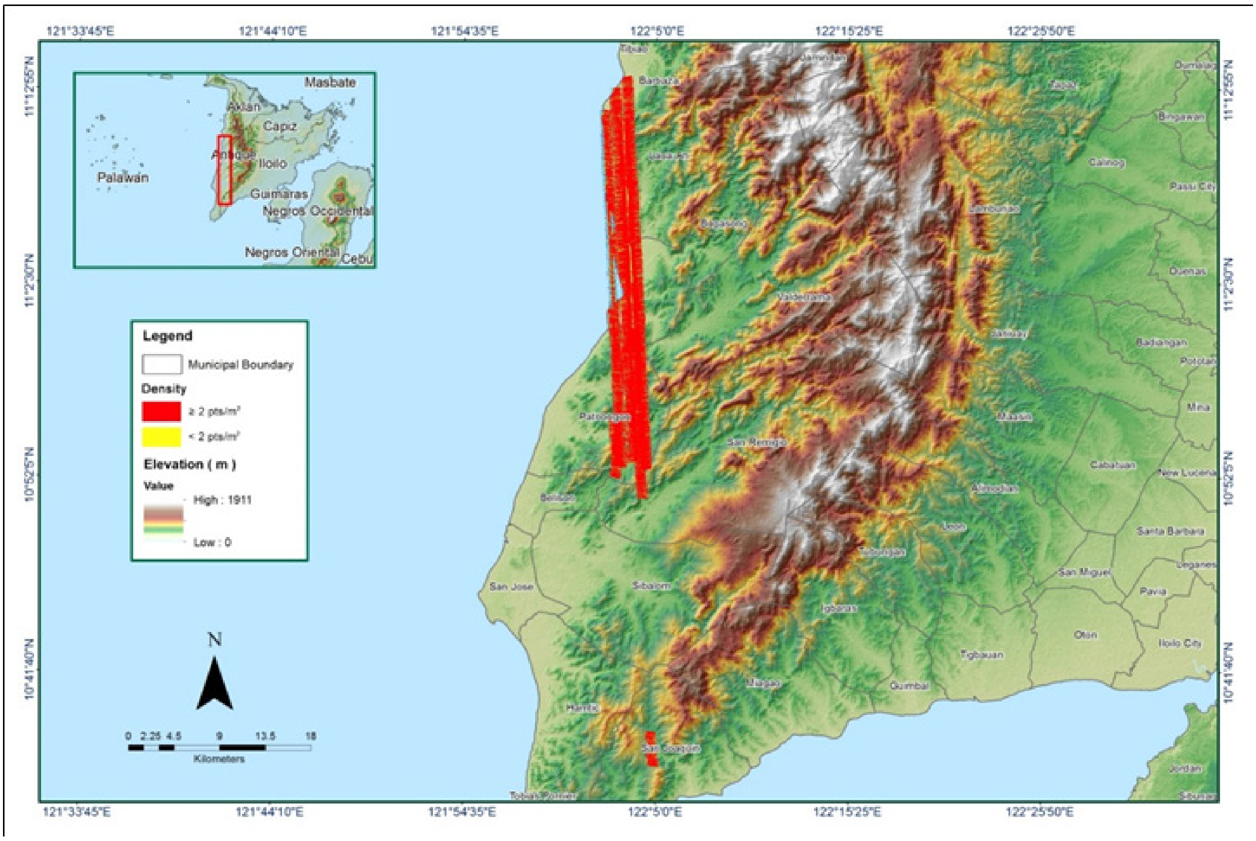


Figure A-8.6. Density map of merged LiDAR data

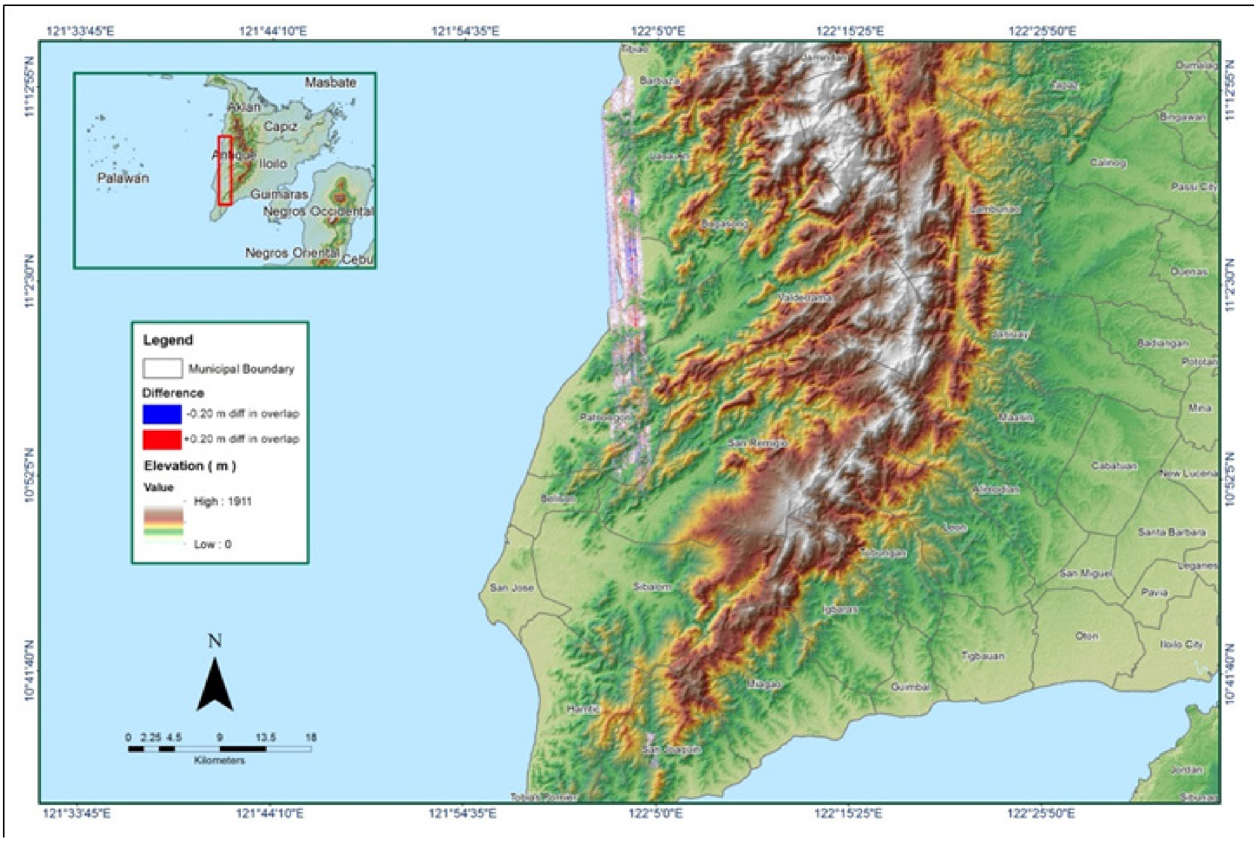


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk43B_additional

Flight Area	**Iloilo**
Mission Name	Blk43B_additional
Inclusive Flights	2602G, 2606G, 2610G
Range data size	21.5 GB
POS	548 MB
Base data size	27.69 MB
Image	33.82 GB
Transfer date	July 07, 2015
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)	1.34
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	3.95
Boresight correction stdev (<0.001deg)	0.000279
IMU attitude correction stdev (<0.001deg)	0.017983
GPS position stdev (<0.01m)	0.0032
Minimum % overlap (>25)	24.04%
Ave point cloud density per sq.m. (>2.0)	1.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	285
Maximum Height	925.04 m
Minimum Height	54.48 m
Classification (# of points)	
Ground	140,989,825
Low vegetation	27,006,829
Medium vegetation	75,243,562
High vegetation	157,821,764
Building	629,138
Orthophoto	Yes
Processed by	Engr. Irish Cortez, , Engr. Melanie Hingpit, Maria Tamsyn Malabanan

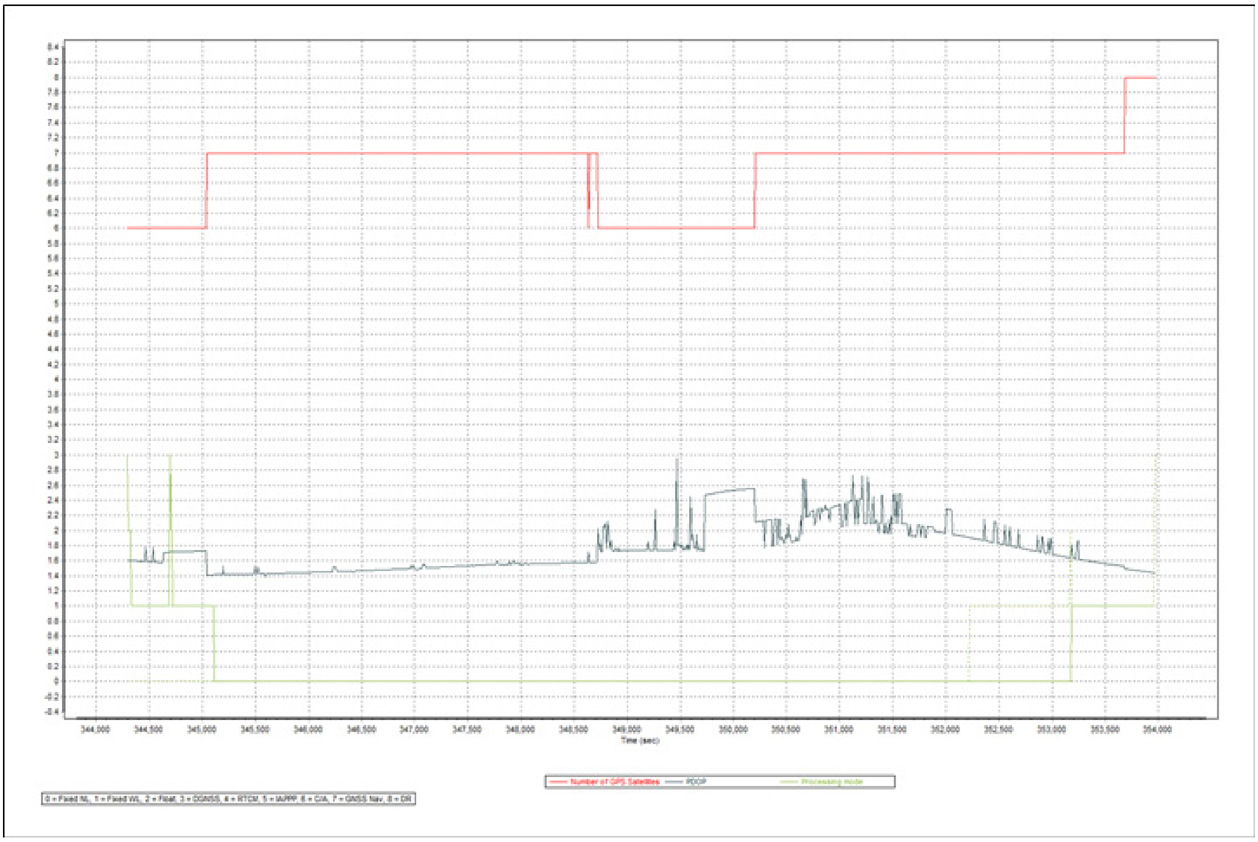


Figure A-8.8. Solution Status

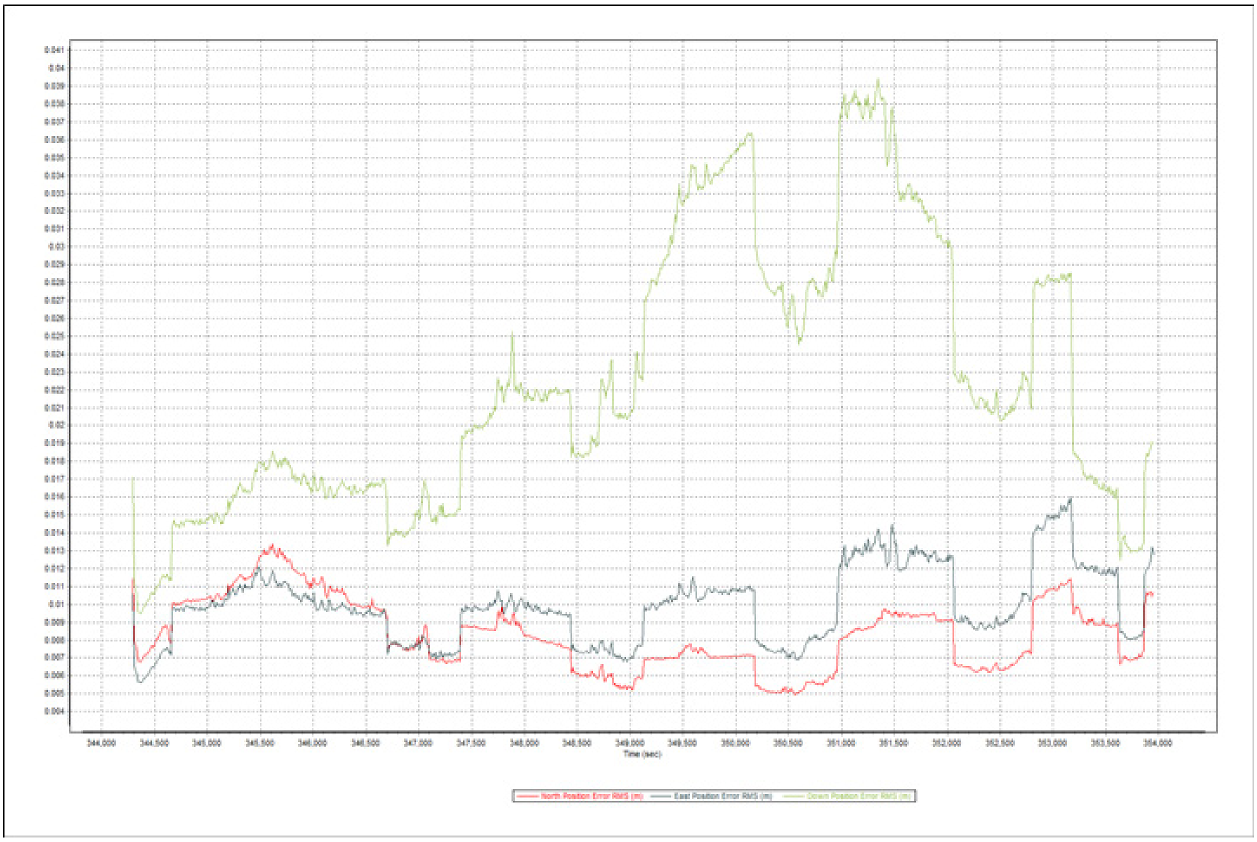


Figure A-8.9. Smoothed Performance Metric Parameters

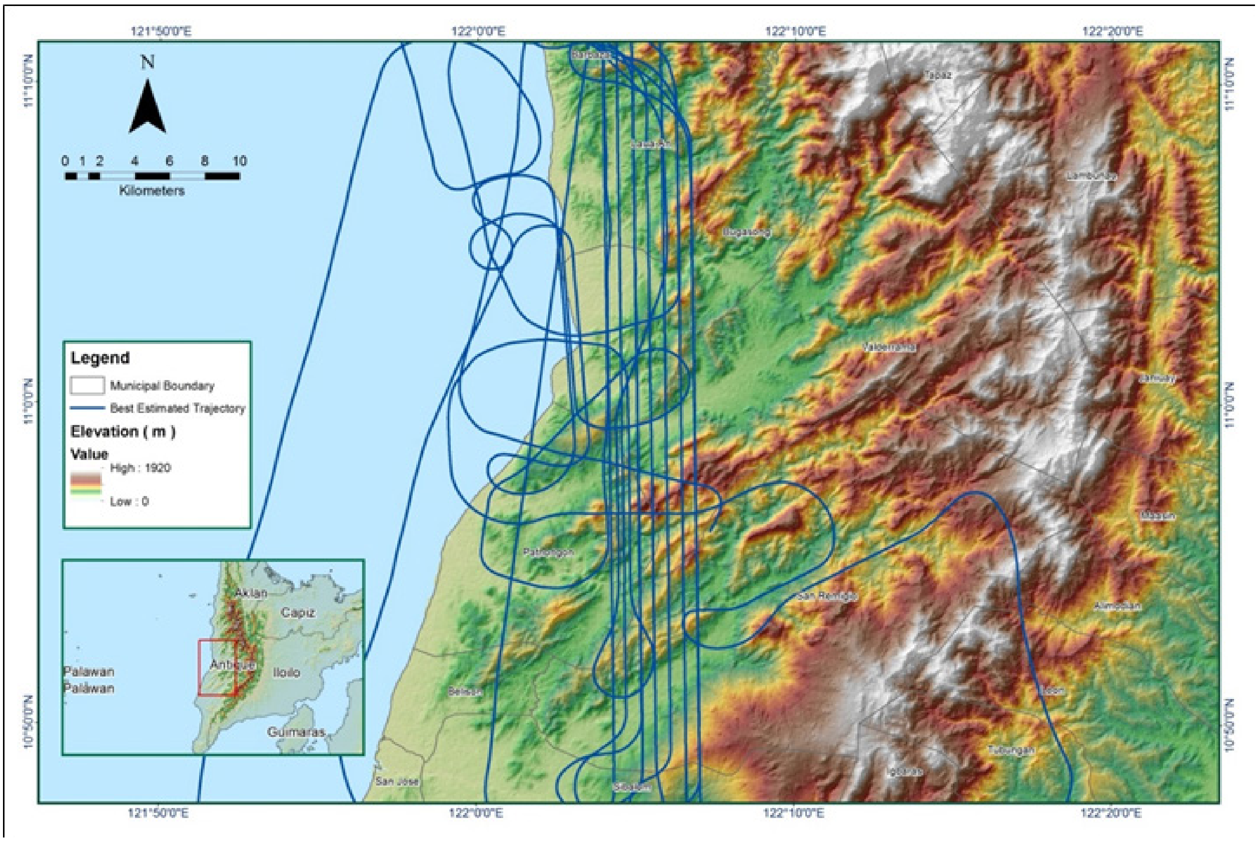


Figure A-8.10. Best Estimated Trajectory

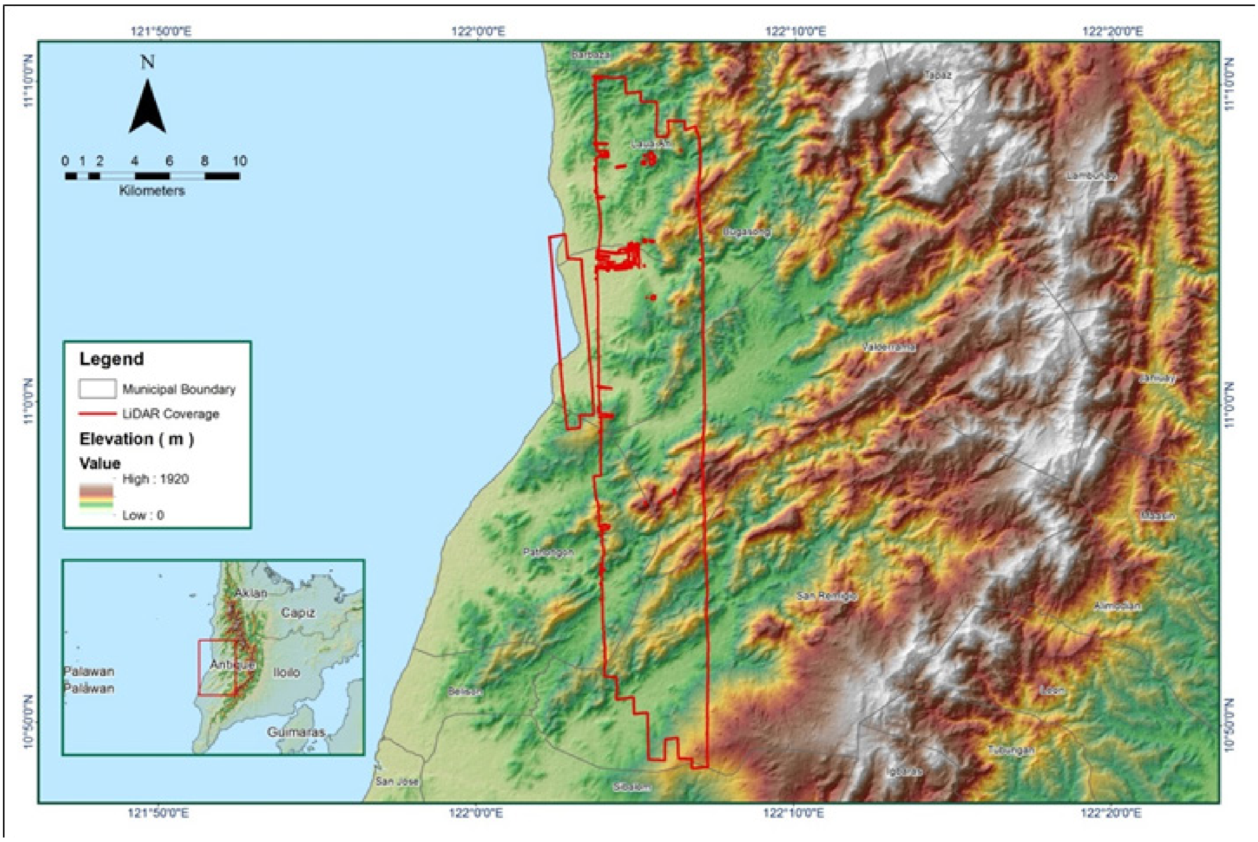


Figure A-8.11. Coverage of LiDAR data

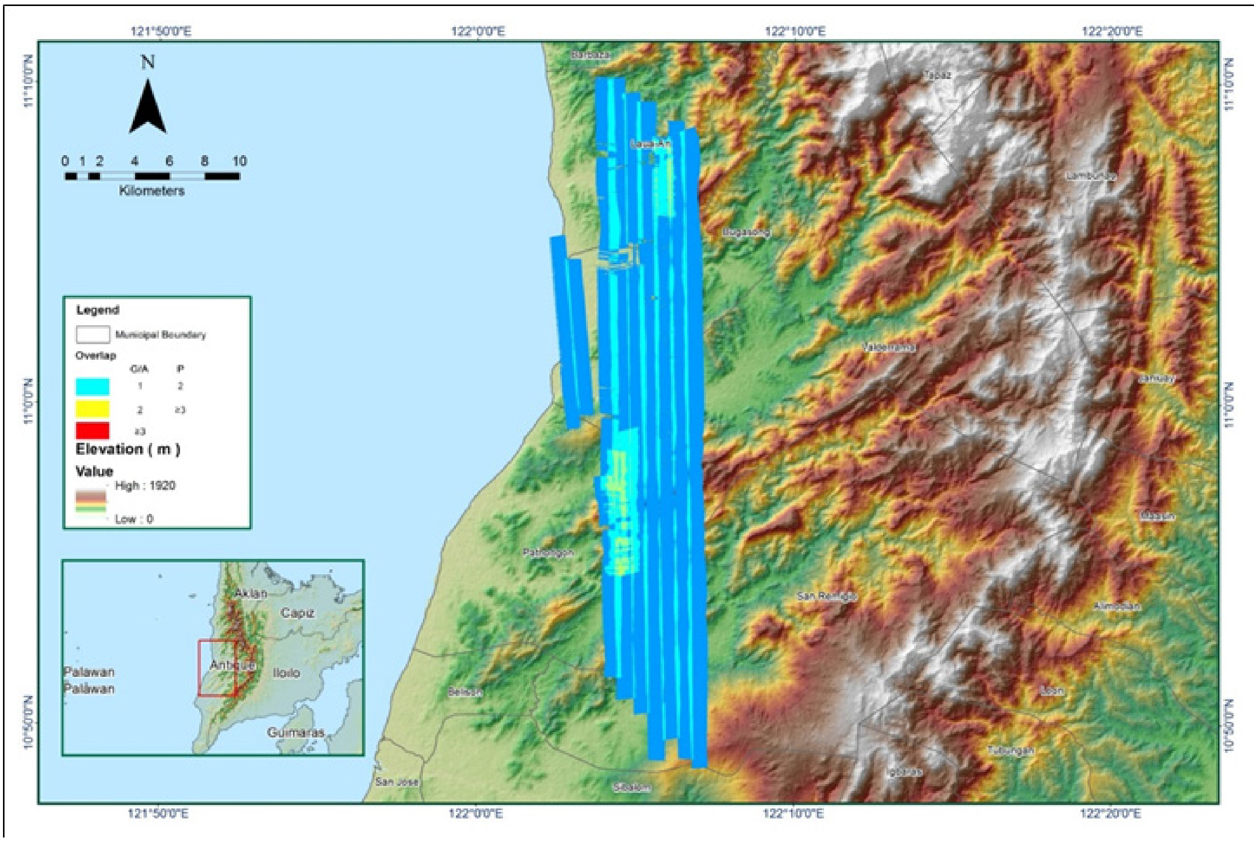


Figure A-8.12. Image of data overlap

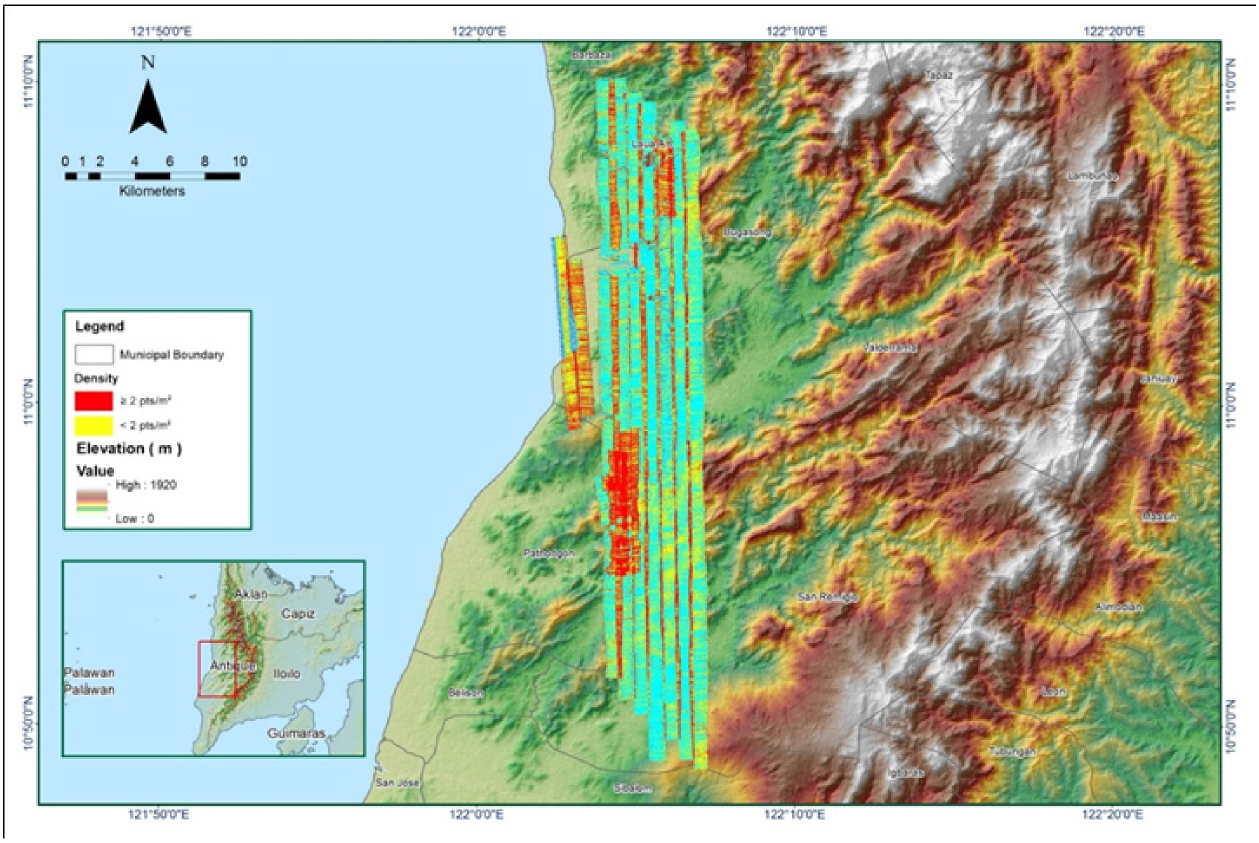


Figure A-8.13. Density map of merged LiDAR data

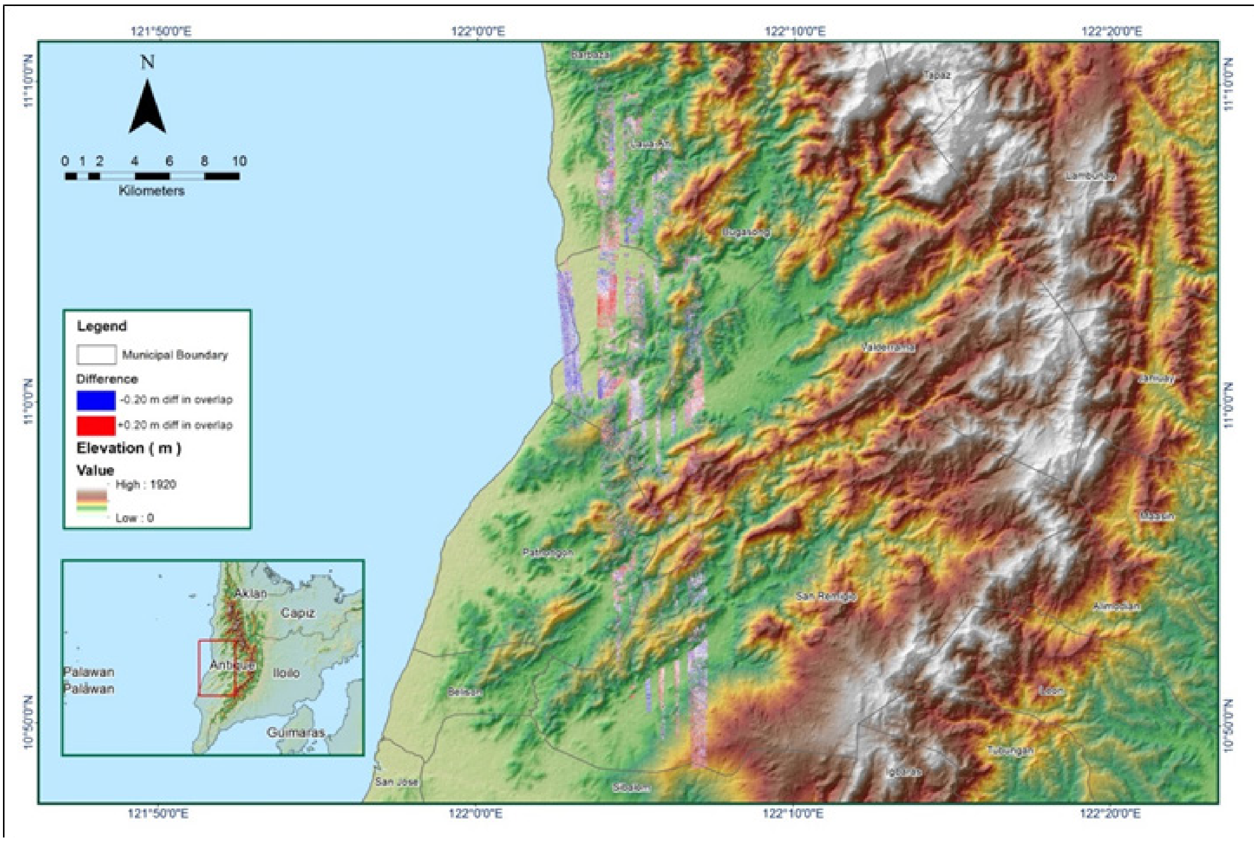


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk43C

Flight Area	Iloilo
Mission Name	Blk43C
Inclusive Flights	2594G
Range data size	16.3 GB
POS	240 MB
Base data size	11.6 MB
Image	28.2 GB
Transfer date	March 23, 2015
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)	1.21
RMSE for East Position (<4.0 cm)	1.37
RMSE for Down Position (<8.0 cm)	3.69
Boresight correction stdev (<0.001deg)	0.000326
IMU attitude correction stdev (<0.001deg)	0.001908
GPS position stdev (<0.01m)	0.0171
Minimum % overlap (>25)	31.86%
Ave point cloud density per sq.m. (>2.0)	2.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	323
Maximum Height	1015.40 m
Minimum Height	96.06 m
Classification (# of points)	
Ground	112,046,992
Low vegetation	45,394,815
Medium vegetation	138,554,082
High vegetation	209,757,089
Building	1,546,227
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Alex John Escobido

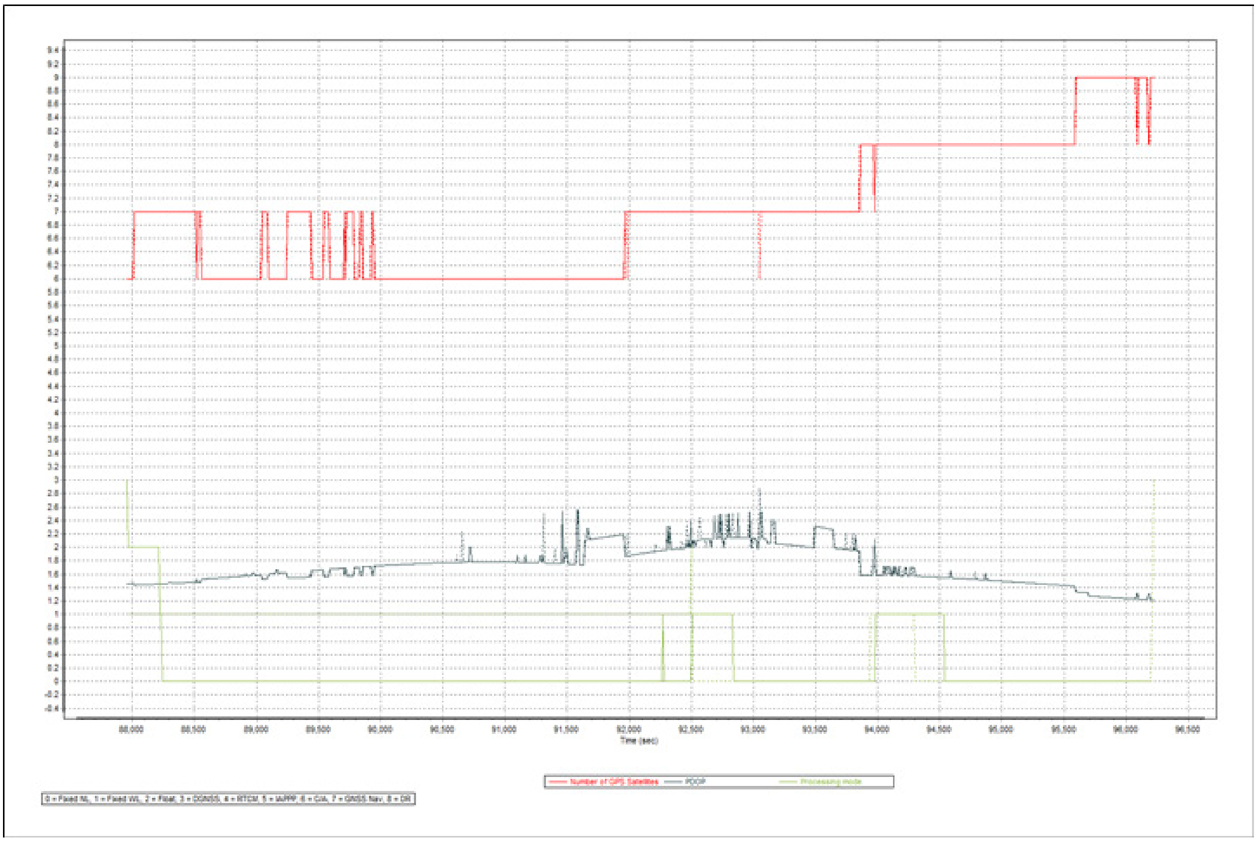


Figure A-8.15. Solution Status

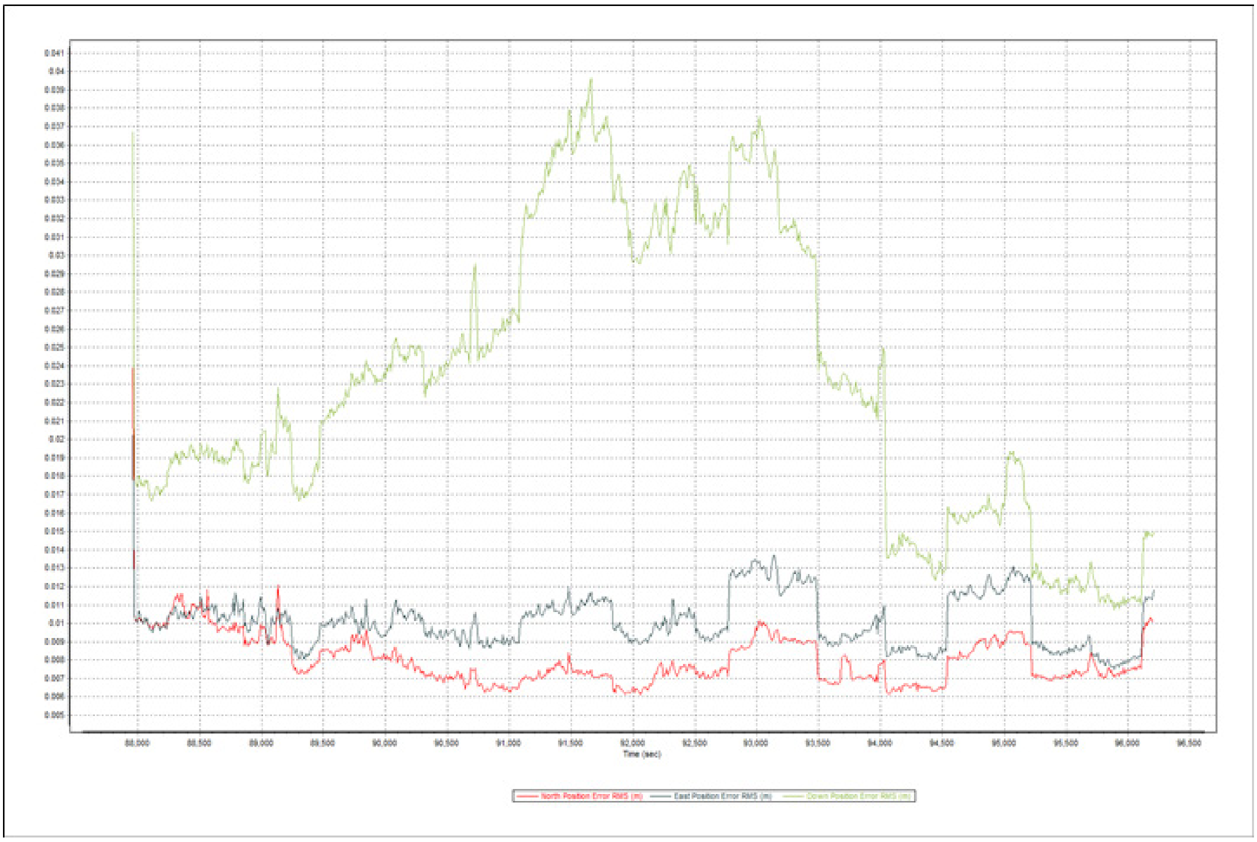


Figure A-8.16. Smoothed Performance Metric Parameters

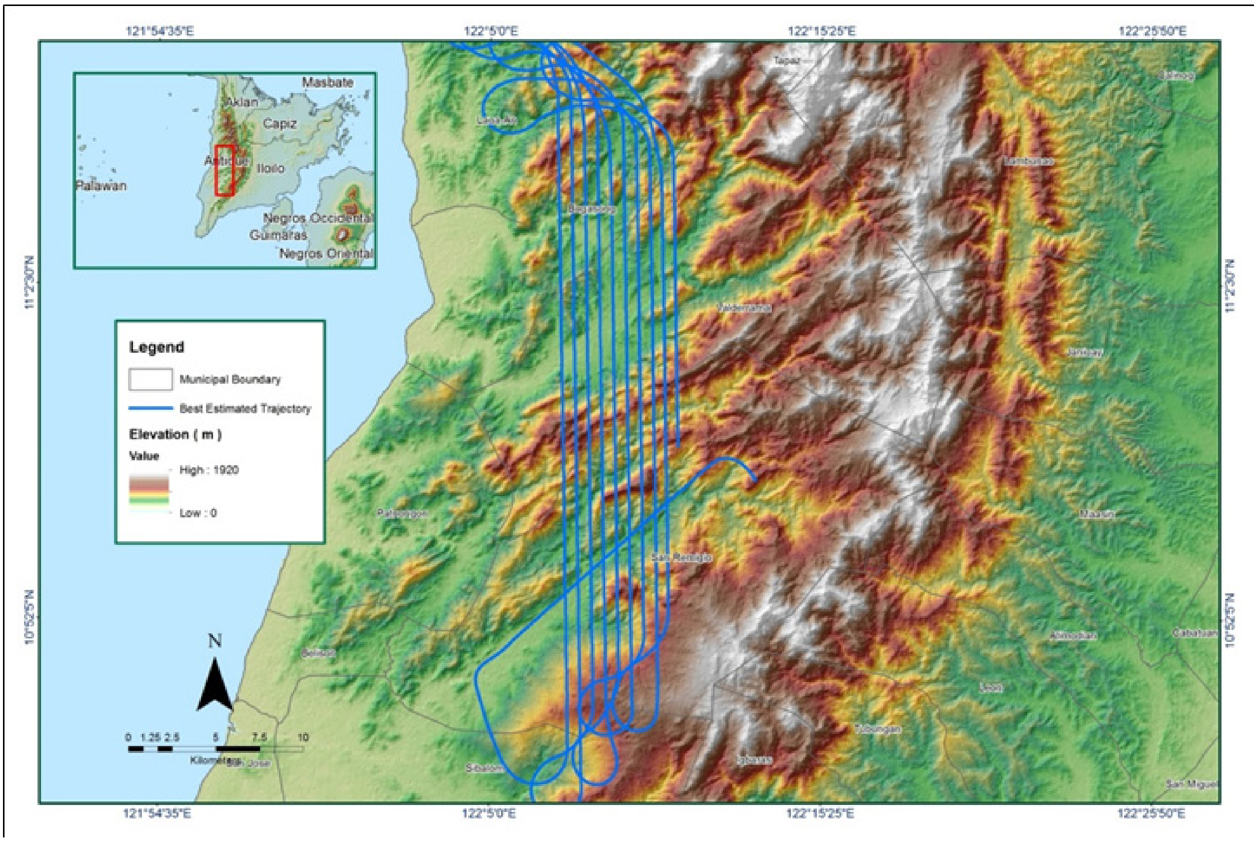


Figure A-8.17. Best Estimated Trajectory

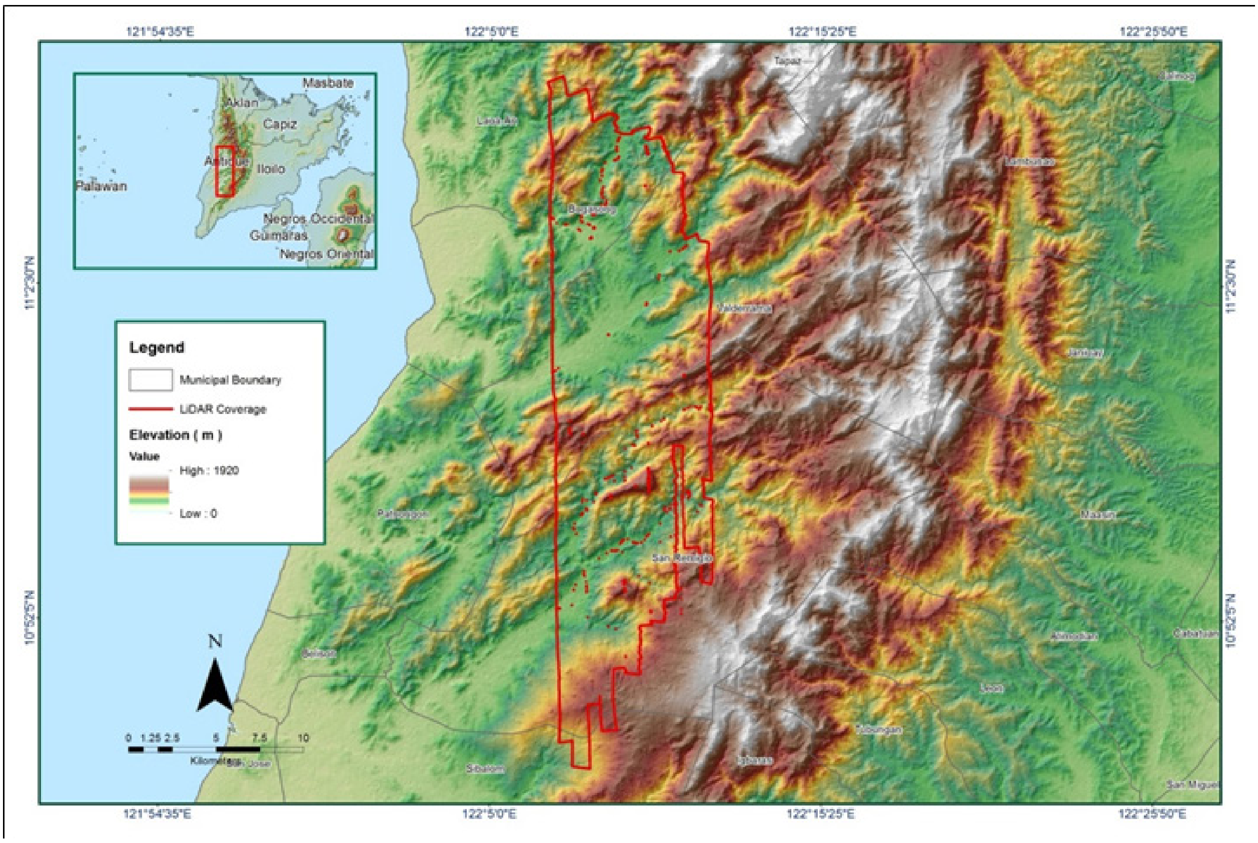


Figure A-8.18. Coverage of LiDAR data

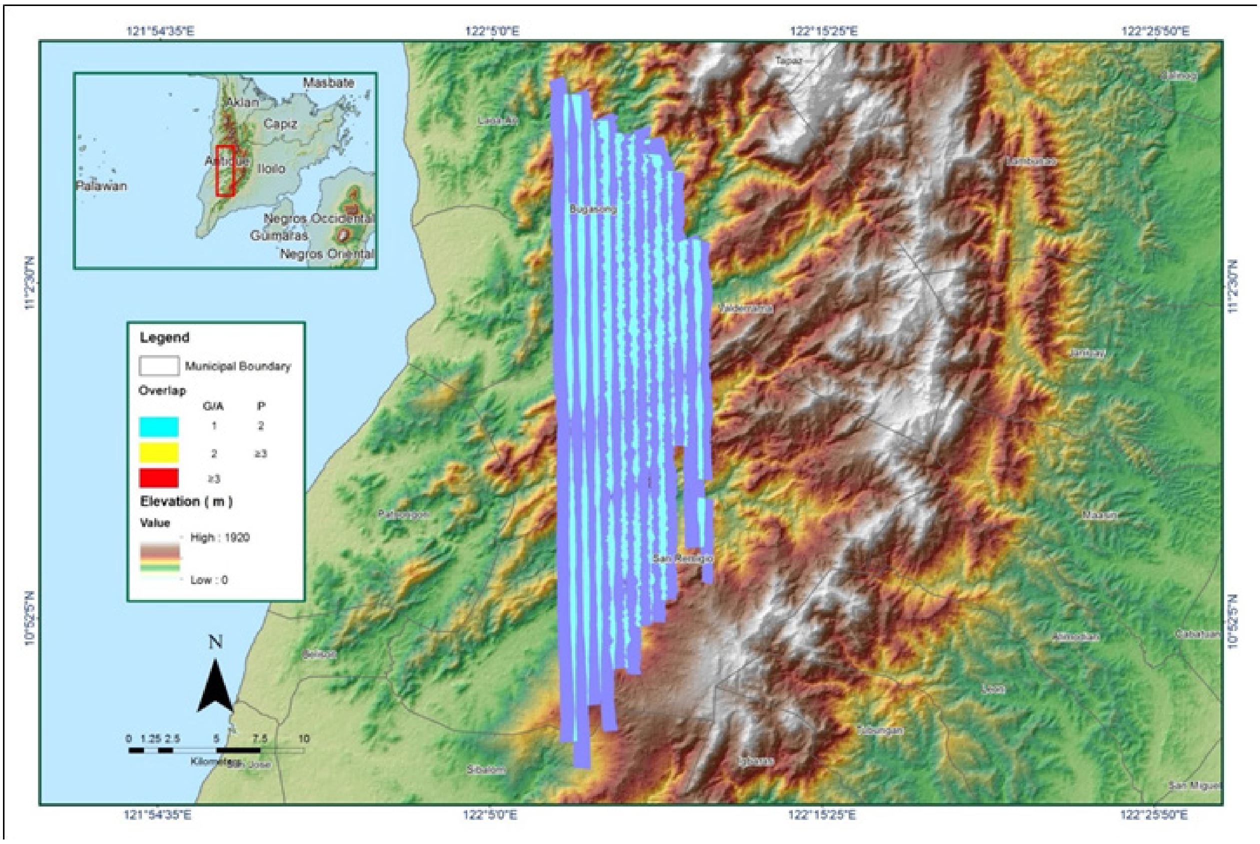


Figure A-8.19. Image of data overlap

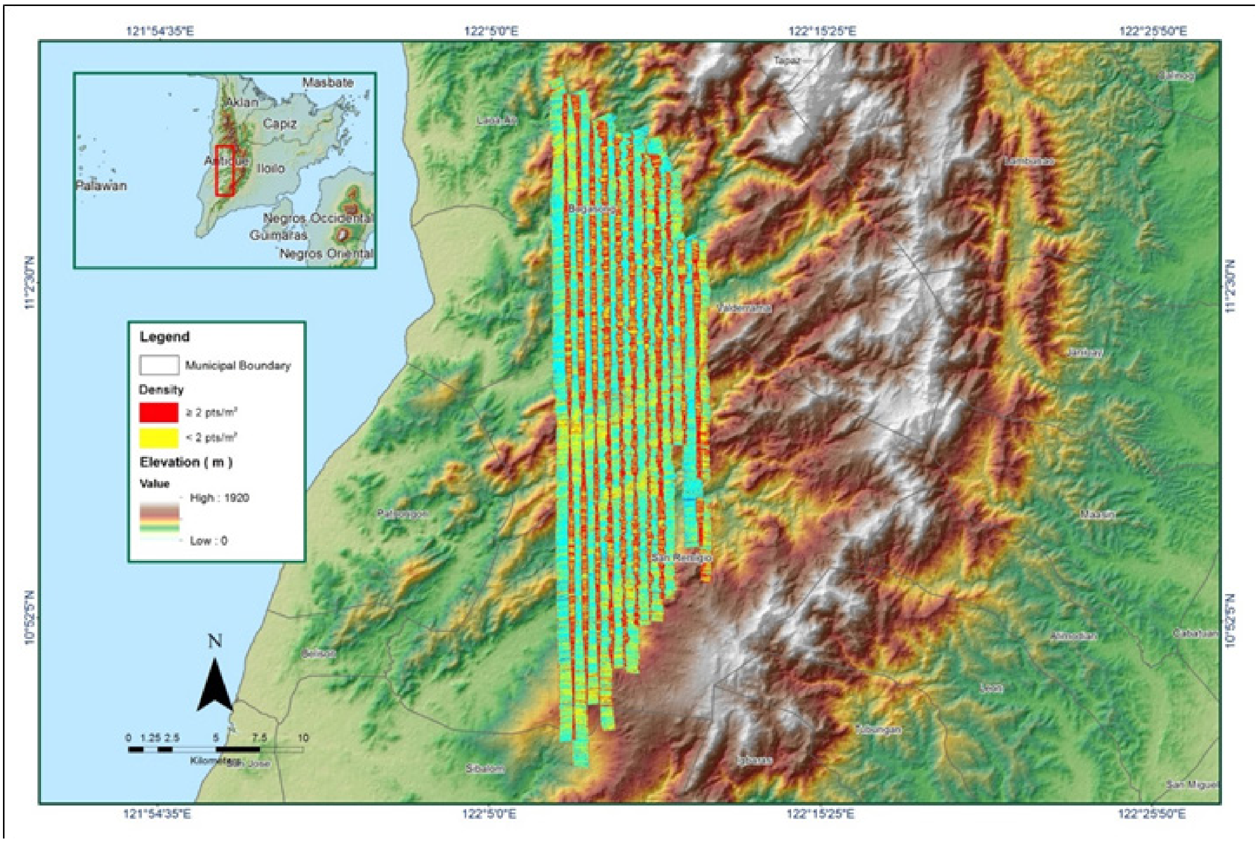


Figure A-8.20. Density map of merged LiDAR data

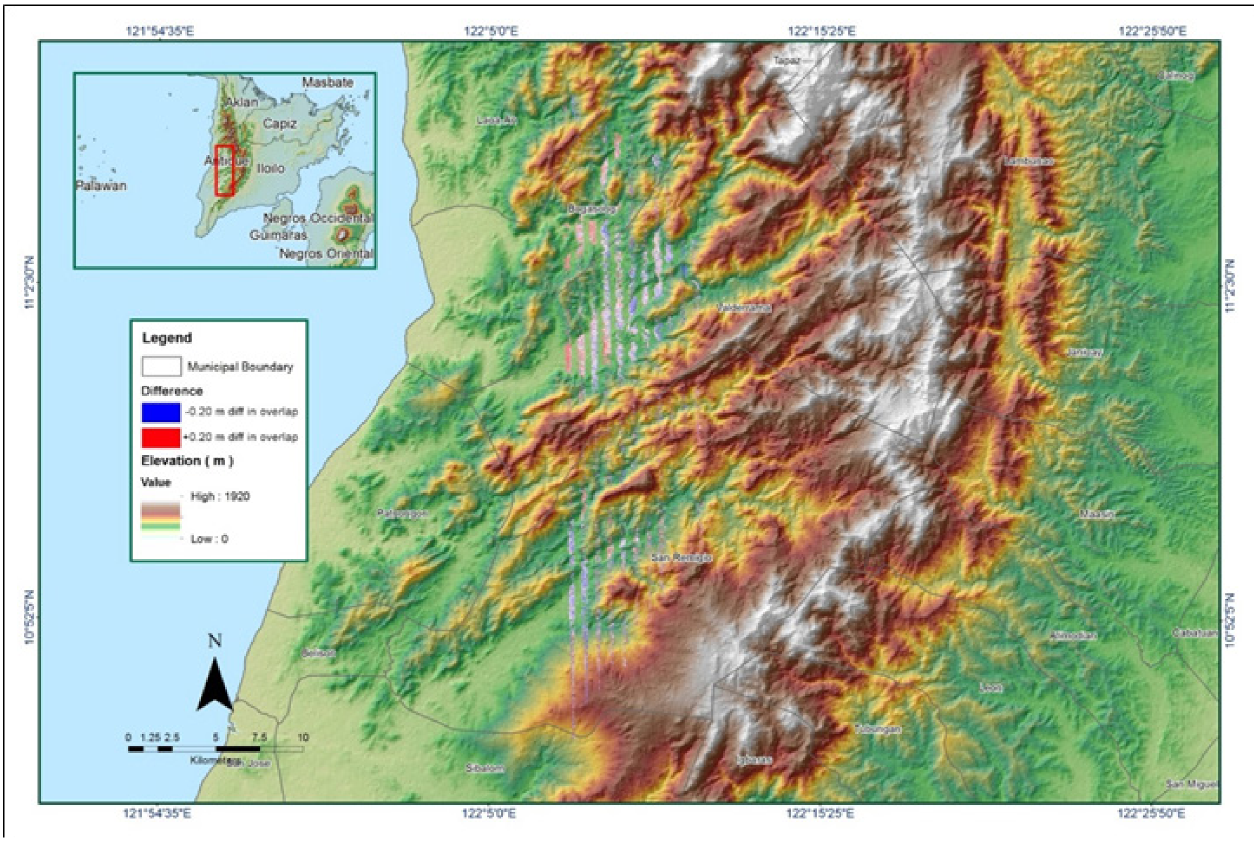


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk43D

Flight Area	Iloilo
Mission Name	Blk43D
Inclusive Flights	2569P, 2583P, 2587P, 2589P, 2593P
Range data size	71.8 GB
POS	999 MB
Base data size	65.86 MB
Image	88.8 GB
Transfer date	March 23, 2015
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)	1.26
RMSE for East Position (<4.0 cm)	2.44
RMSE for Down Position (<8.0 cm)	5.4
Boresight correction stdev (<0.001deg)	0.000352
IMU attitude correction stdev (<0.001deg)	0.001171
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	42.59%
Ave point cloud density per sq.m. (>2.0)	3.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	280
Maximum Height	545.37 m
Minimum Height	52.12 m
Classification (# of points)	
Ground	301,021,823
Low vegetation	227,535,345
Medium vegetation	270,806,989
High vegetation	177,871,908
Building	13,231,101
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Analyn Naldo, Engr. Krisha Marie Bautista

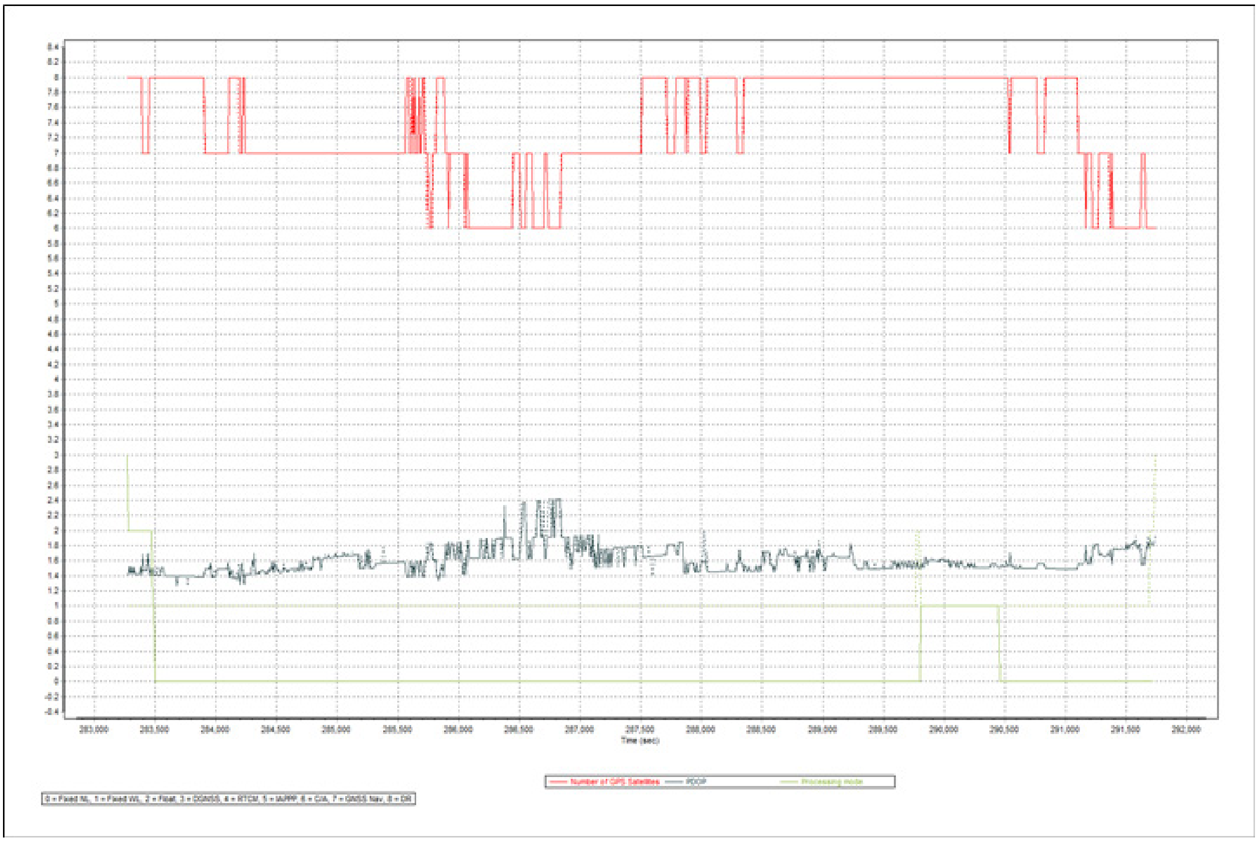


Figure A-8.22. Solution Status

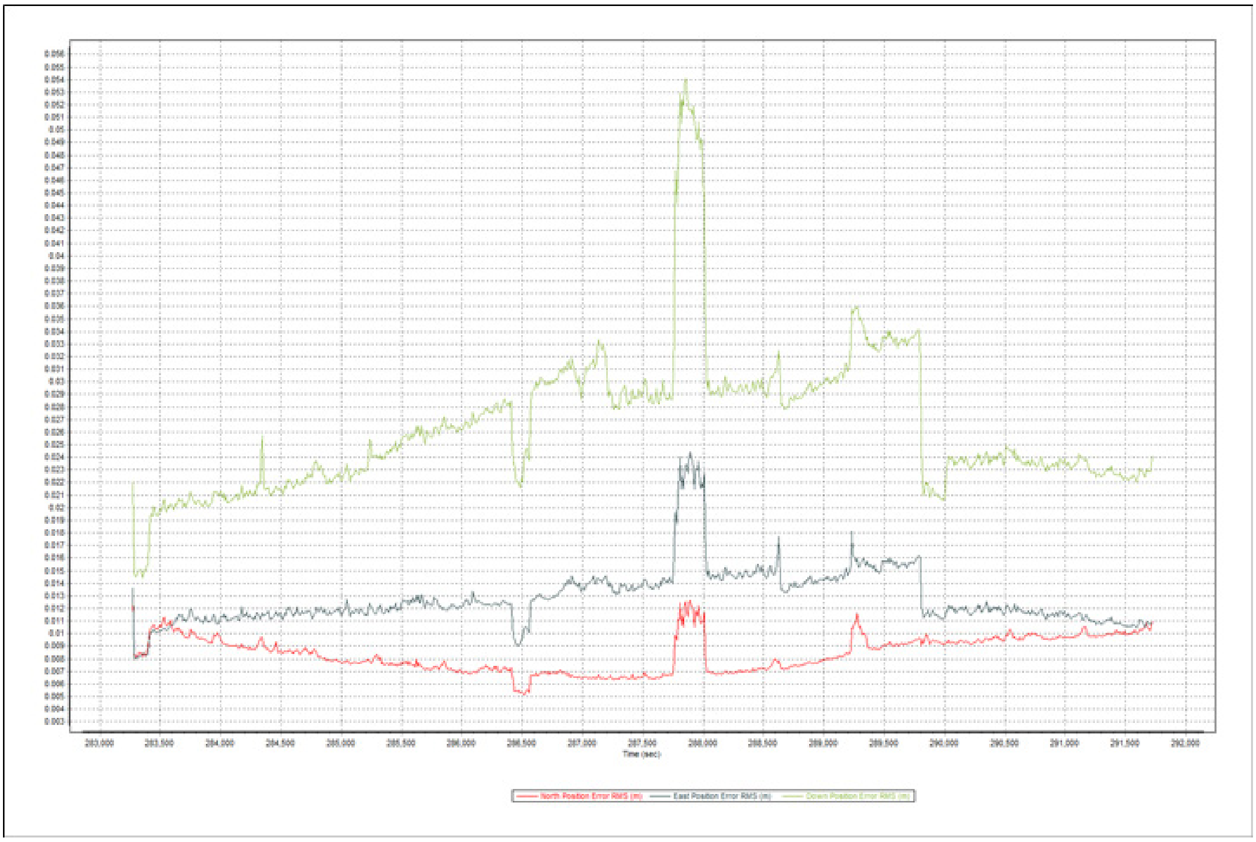


Figure A-8.23. Smoothed Performance Metric Parameters

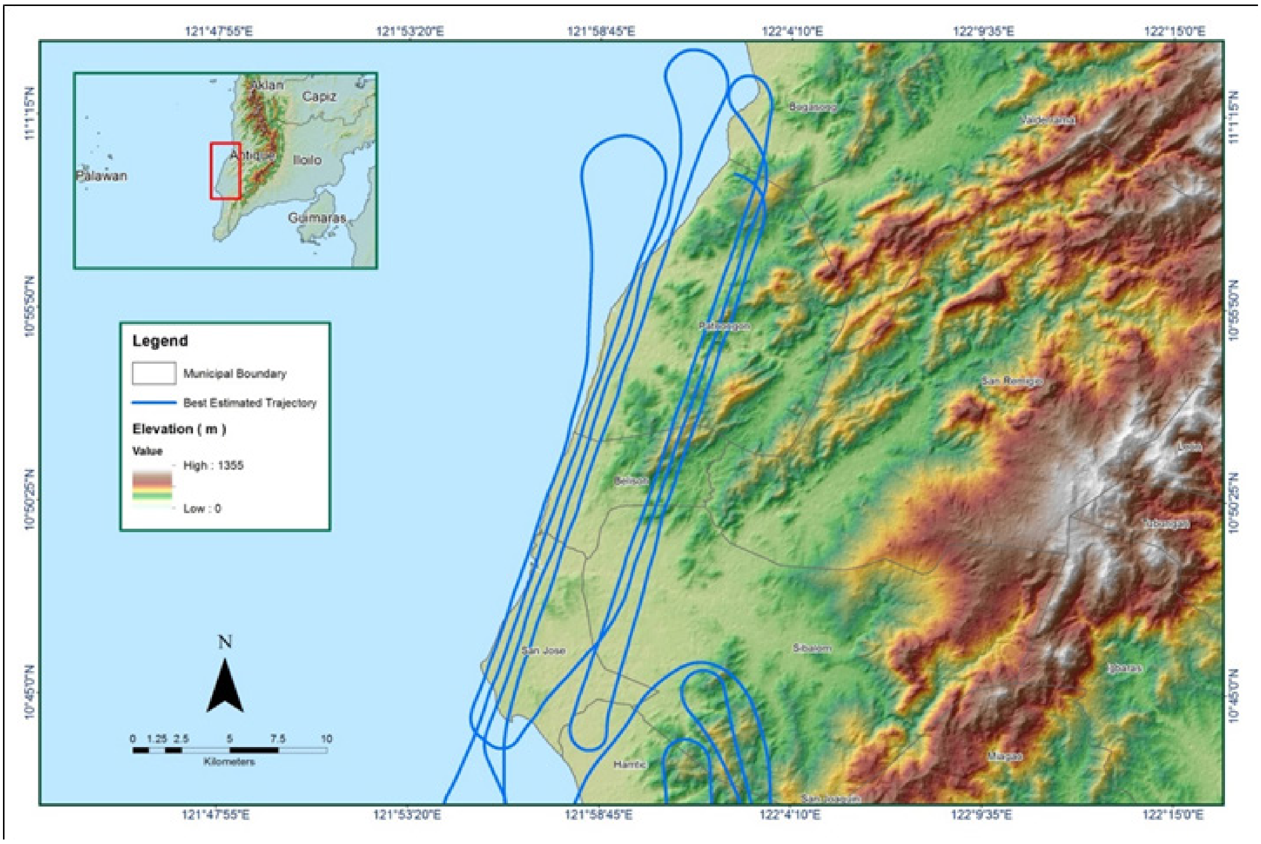


Figure A-8.24. Best Estimated Trajectory

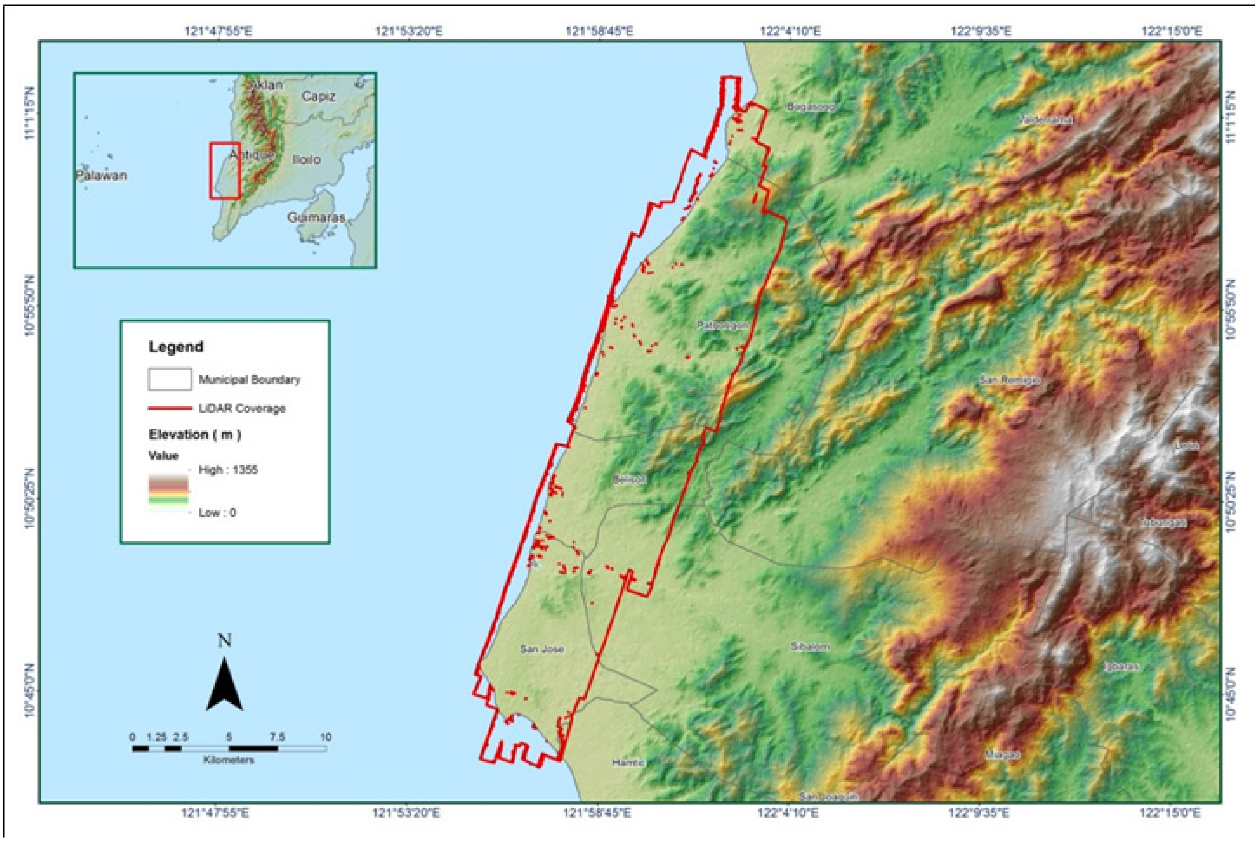


Figure A-8.25. Coverage of LiDAR data

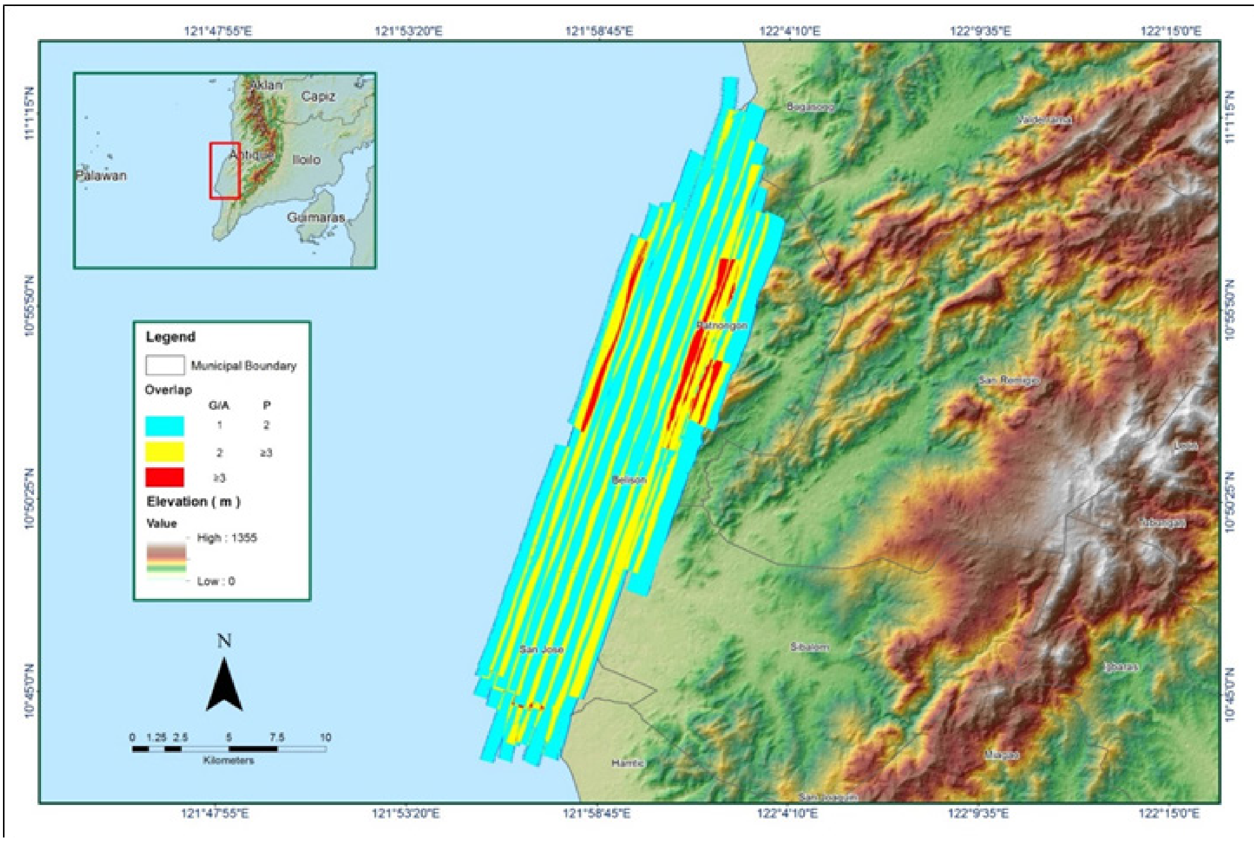


Figure A-8.26. Image of data overlap

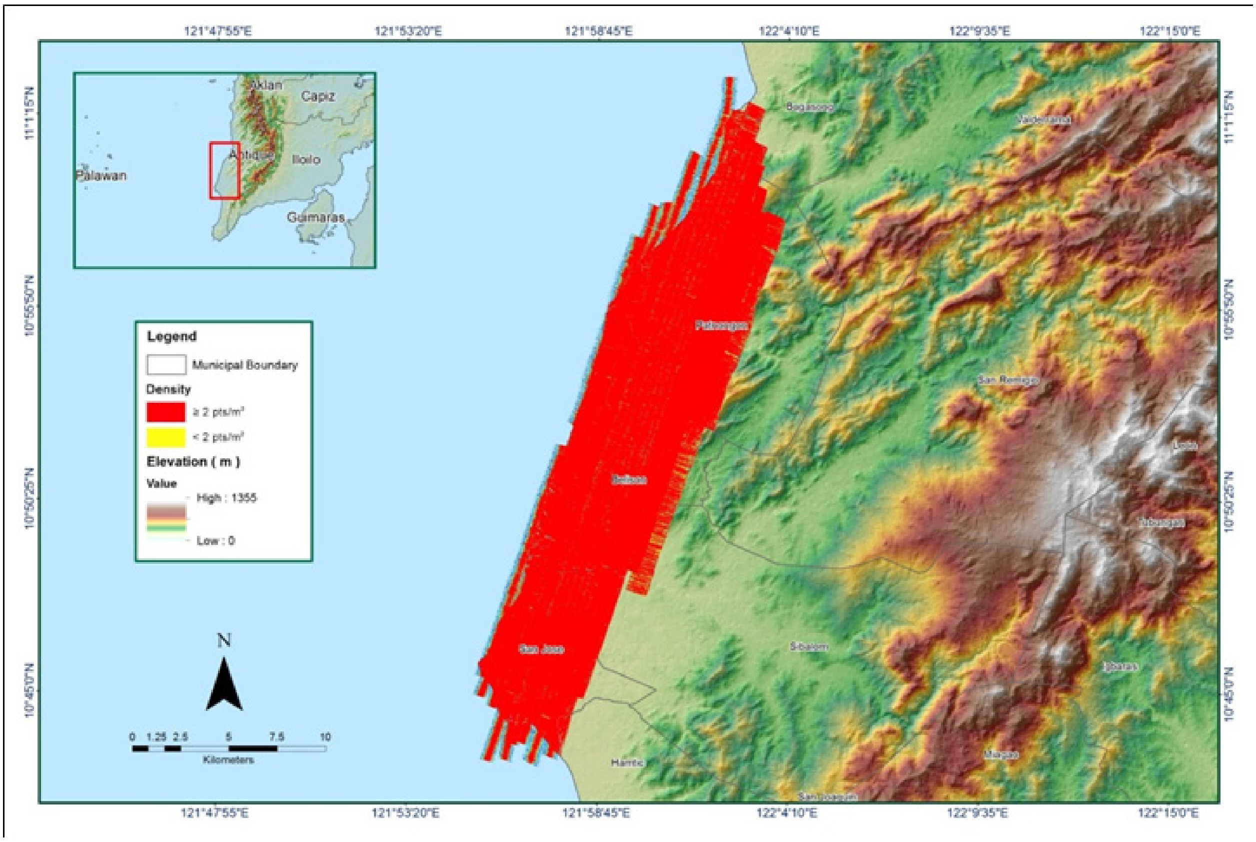


Figure A-8.27. Density map of merged LiDAR data

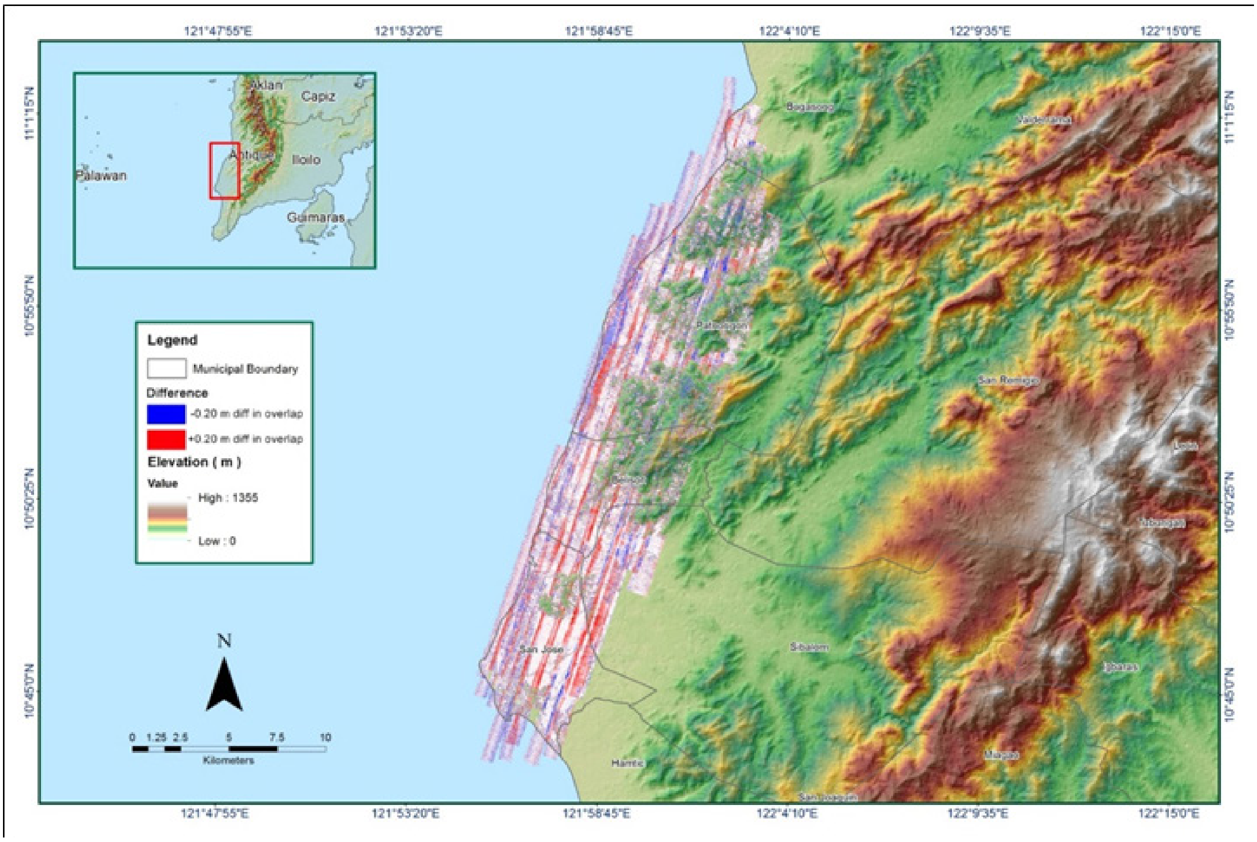


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk43B_supplement

Flight Area	Iloilo Reflights
Mission Name	Blk43B_supplement
Inclusive Flights	8515AC
Range data size	3.35 GB
Base data size	104 MB
POS	189 MB
Image	NA
Transfer date	October 27, 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)	Yes
RMSE for East Position (<4.0 cm)	Yes
RMSE for Down Position (<8.0 cm)	Yes
Boresight correction stdev (<0.001deg)	0.000392
IMU attitude correction stdev (<0.001deg)	0.000914
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	42.86
Ave point cloud density per sq.m. (>2.0)	3.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	38
Maximum Height	481.19 m
Minimum Height	58.9 m
Classification (# of points)	
Ground	23,696,880
Low vegetation	10,611,556
Medium vegetation	9,775,696
High vegetation	13,078,875
Building	590,106
Ortophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Engr. Wilbert Ian San Juan

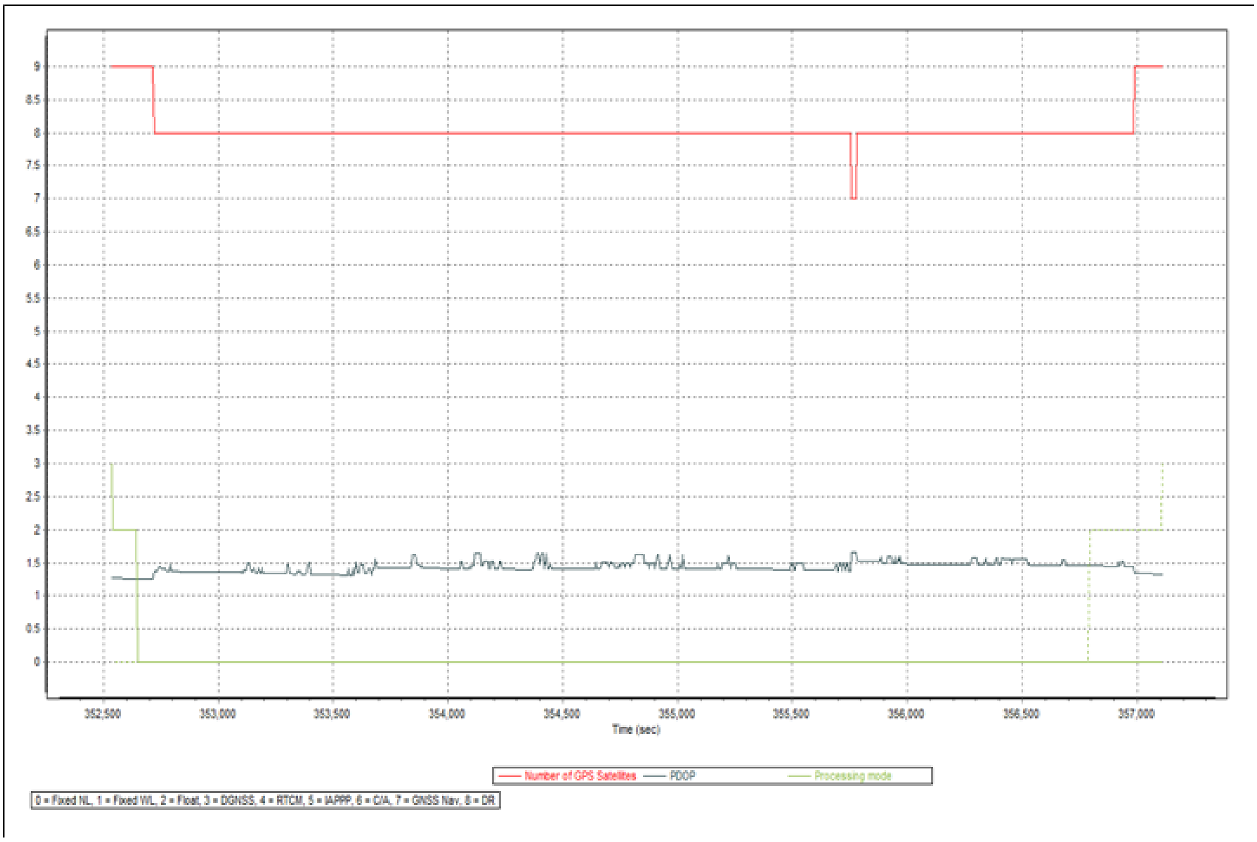


Figure A-8.29. Solution Status

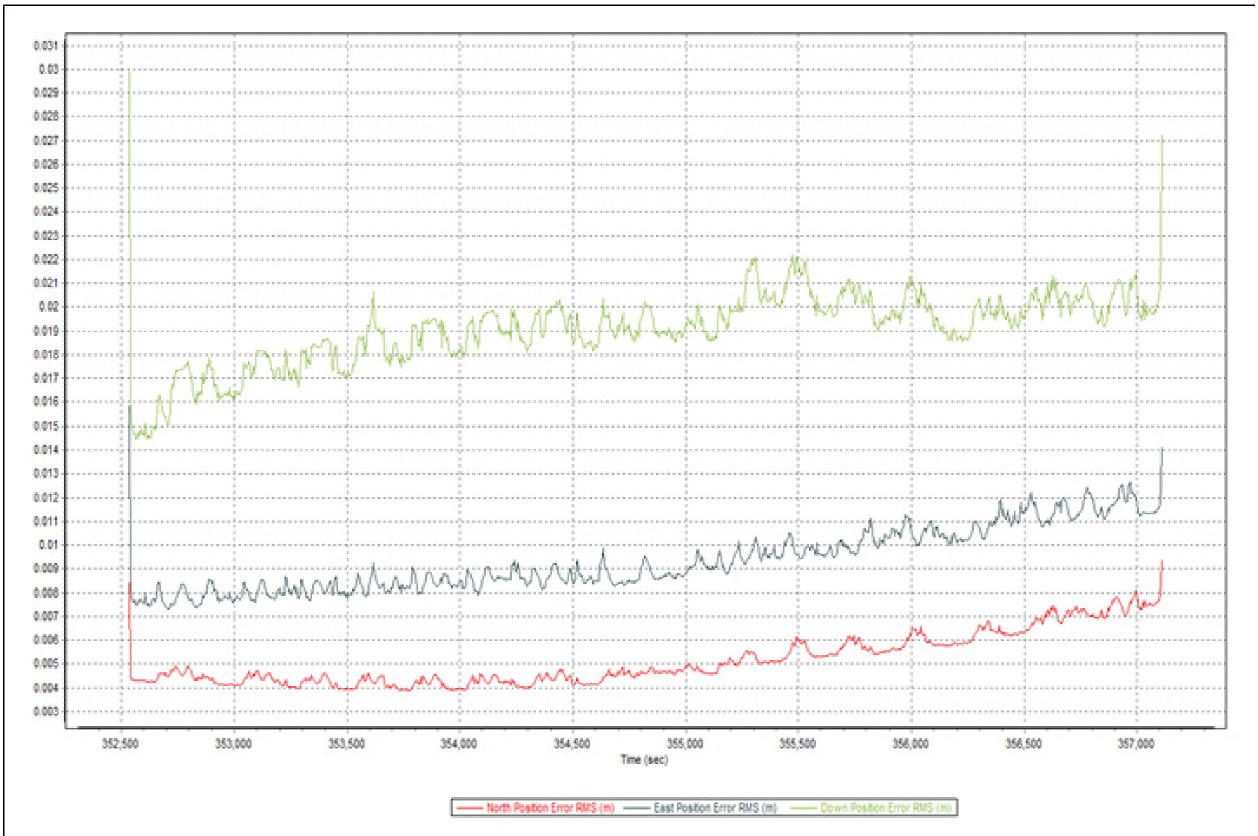


Figure A-8.30. Smoothed Performance Metric Parameters

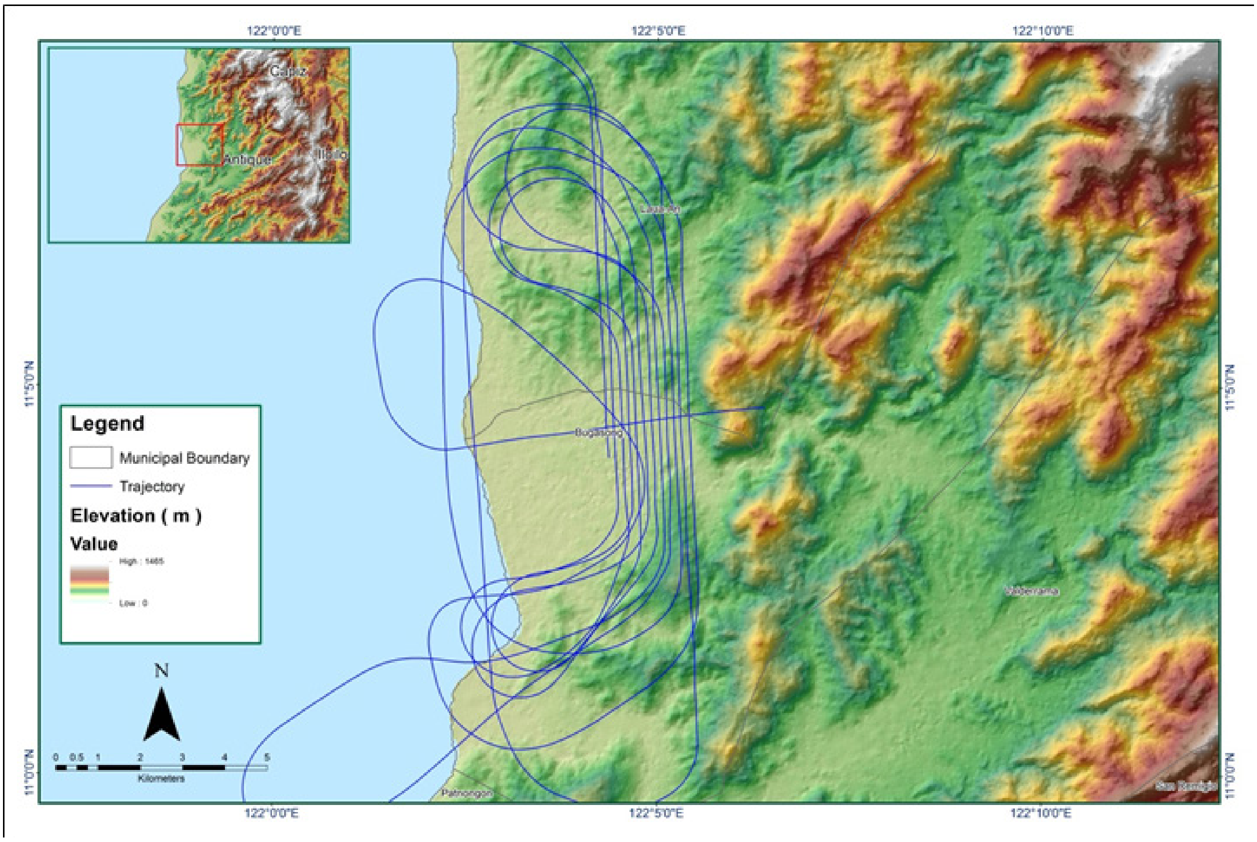


Figure A-8.31. Best Estimated Trajectory

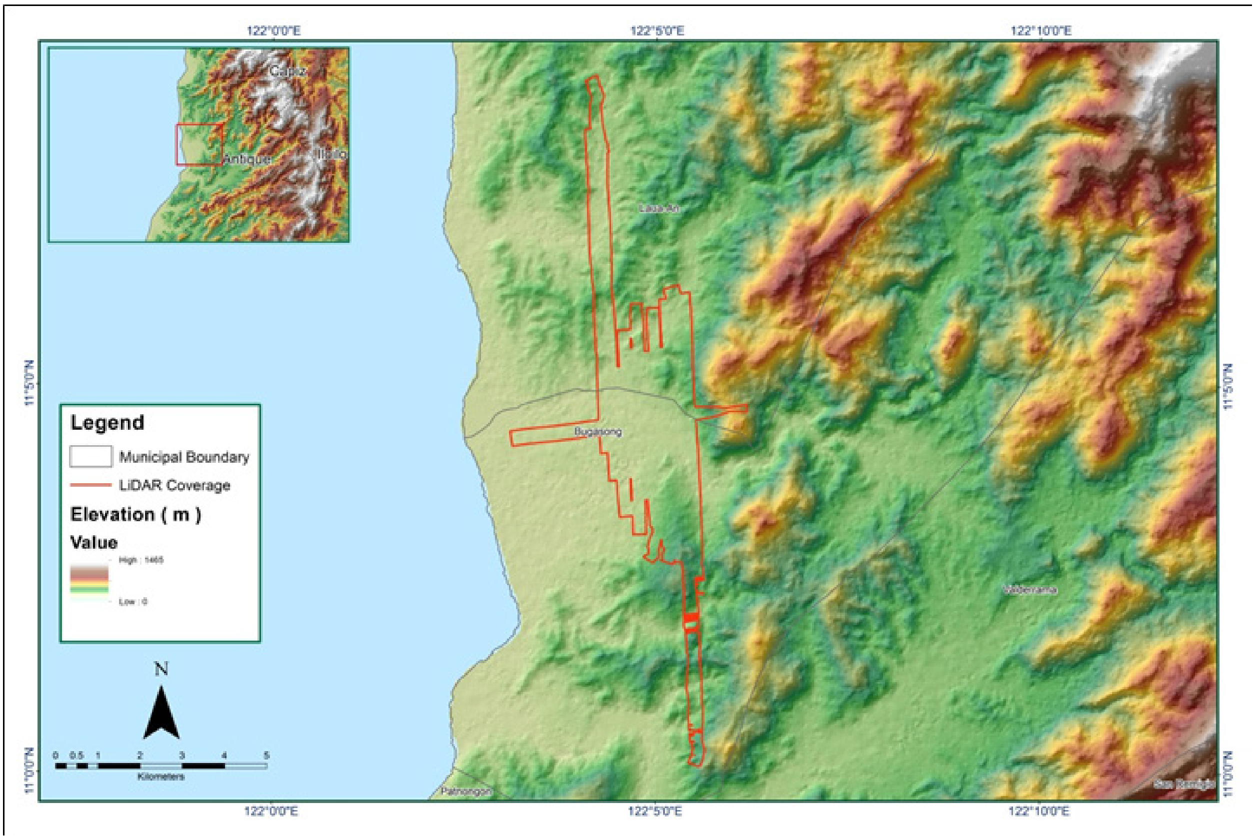


Figure A-8.32. Coverage of LiDAR data

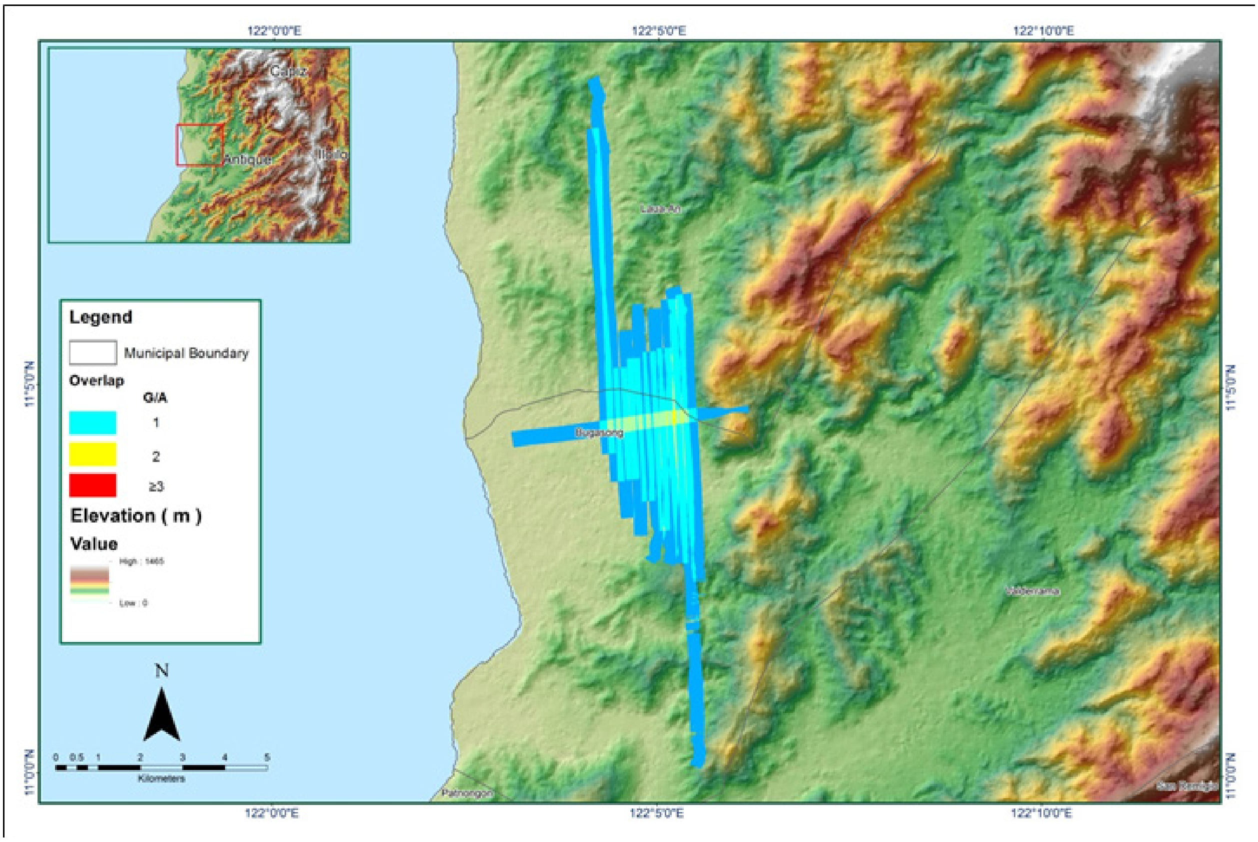


Figure A-8.33. Image of data overlap

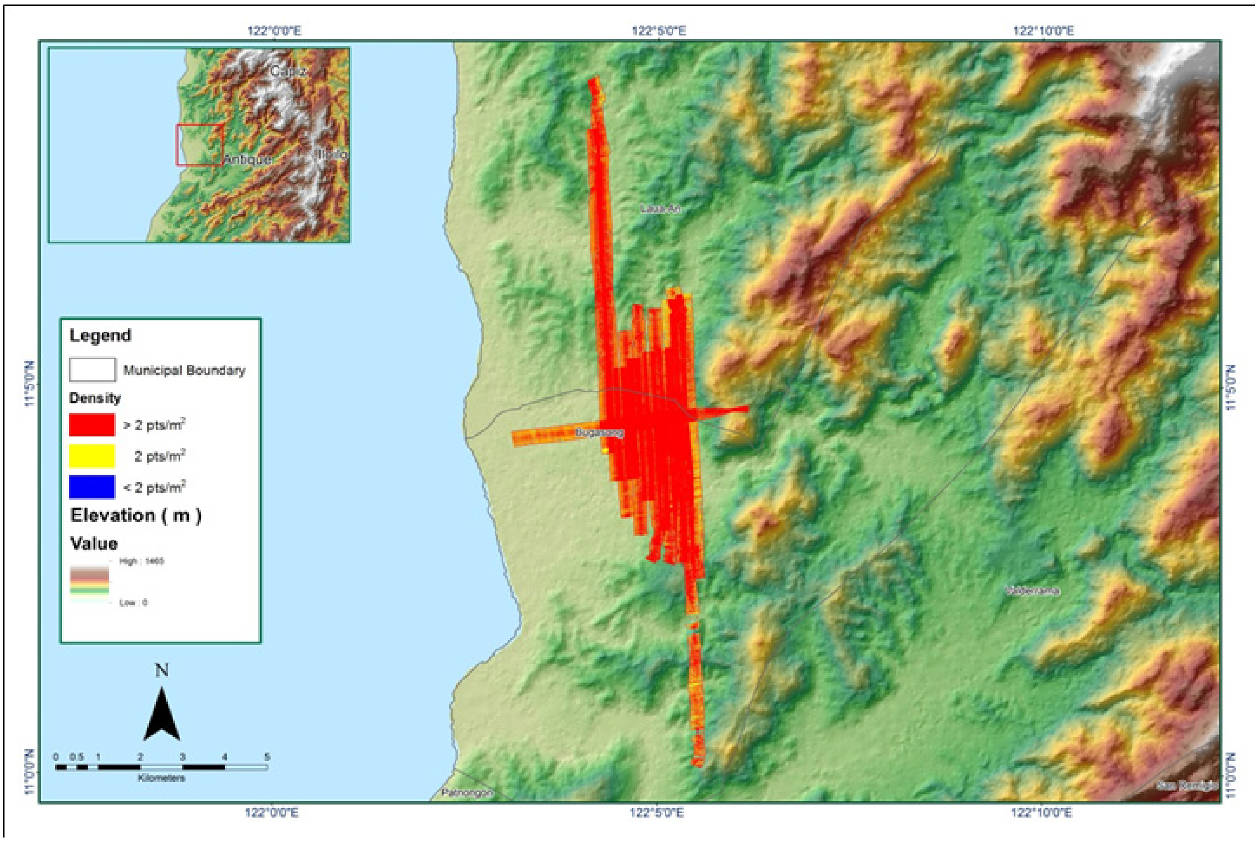


Figure A-8.34. Density map of merged LiDAR data

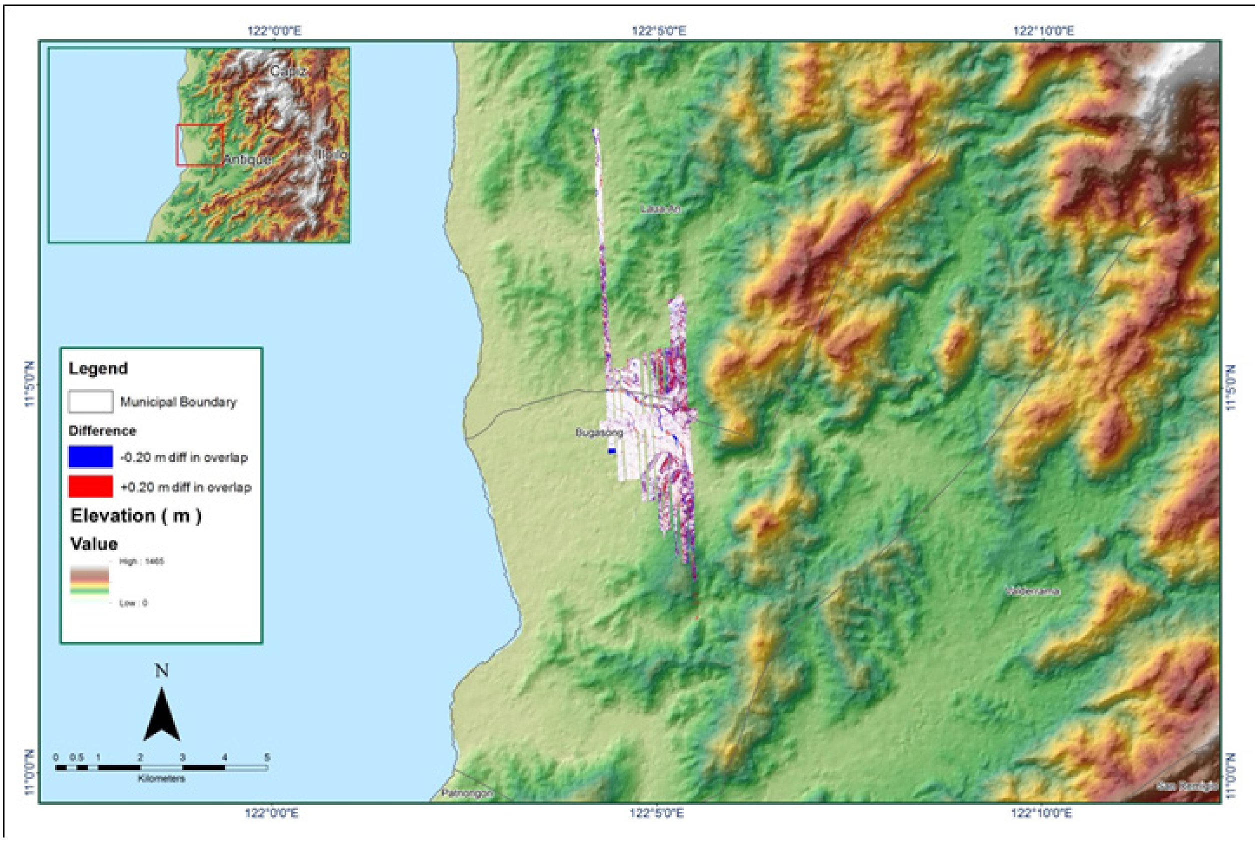


Figure A-8.35. Elevation difference between flight lines

Annex 9. Cangaranan Model Basin Parameters

Table A-9.1. Cangaranan 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
W380	1.8231	63.5424	0	19.22359	25.09832	Discharge	1.0709	1	Ratio to Peak	0.0001
W390	1.5734	67.1538	0	8.49154	11.086552	Discharge	1.1741	1	Ratio to Peak	0.0001
W400	1.8273	63.4845	0	19.46439	25.412704	Discharge	0.53216	1	Ratio to Peak	0.0001
W410	1.9972	61.2768	0	19.15695	25.01132	Discharge	0.0768153	1	Ratio to Peak	0.0001
W420	1.5939	66.84	0	16.15813	21.096064	Discharge	1.5898	1	Ratio to Peak	0.0001
W430	1.6161	66.5035	0	23.01291	30.045656	Discharge	0.91941	1	Ratio to Peak	0.0001
W440	1.8199	63.5861	0	12.83259	16.754232	Discharge	1.7299	1	Ratio to Peak	0.0001
W450	1.9557	61.7994	0	11.12937	14.530512	Discharge	0.7365864	1	Ratio to Peak	0.0001
W460	1.535	67.7511	0	11.1967	14.618416	Discharge	0.025301	0.99846	Ratio to Peak	0.0001
W470	2.1112	59.8912	0	47.07602	61.462448	Discharge	1.1495	1	Ratio to Peak	0.0001
W480	1.7519	64.5255	0	34.62876	45.211312	Discharge	1.5563	1	Ratio to Peak	0.0001
W490	1.4850875	68.5	0	12.29836	16.056736	Discharge	5.5456	1	Ratio to Peak	0.0001
W500	1.8993	62.5265	0	17.9918	23.490096	Discharge	1.7435	1	Ratio to Peak	0.0001
W510	1.2327808	72.9199	0	10.2978	13.444808	Discharge	0.14979	0.99555	Ratio to Peak	0.0001
W520	1.5419	67.6429	0	20.95185	27.354736	Discharge	1.9542	1	Ratio to Peak	0.0001
W530	2.4165625	56.5	0	21.05001	27.482896	Discharge	0.93779	1	Ratio to Peak	0.0001

W540	1.6906	65.4013	0	18.59071	24.272032	Discharge	0.0584516	1	Ratio to Peak	0.0001
W550	2.049	60.638	0	22.58742	29.490144	Discharge	1.6024	1	Ratio to Peak	0.0001
W560	2.4165625	56.5	0	17.96774	23.45868	Discharge	1.0651	1	Ratio to Peak	0.0001
W570	0.71623	84.2067	0	19.14927	25.001288	Discharge	1.3442	1	Ratio to Peak	0.0001
W580	1.8608	63.0347	0	5.59475	7.304512	Discharge	3.045	1	Ratio to Peak	0.0001
W590	2.2684	58.0961	0	13.57897	17.728704	Discharge	1.2154	1	Ratio to Peak	0.0001
W600	2.3235	57.4961	0	21.55598	28.143488	Discharge	1.8865	1	Ratio to Peak	0.0001
W610	0.47374	90.9913	0	3.90175	5.094128	Discharge	0.80582	1	Ratio to Peak	0.0001
W620	0.79095	82.3354	0	24.44969	31.92152	Discharge	1.318	1	Ratio to Peak	0.0001
W630	2.3958	56.7309	0	53.18099	69.433112	Discharge	0.76054	1	Ratio to Peak	0.0001
W640	2.4131	56.5508	0	24.29645	31.72144	Discharge	4.4048	1	Ratio to Peak	0.0001
W650	0.41104	92.9482	0	12.71373	16.599048	Discharge	4.6222	1	Ratio to Peak	0.0001
W660	0.11992	99	0	6.88627	8.990712	Discharge	0.9594707	1	Ratio to Peak	0.0001
W670	0.92416	79.2191	0	13.77724	17.987568	Discharge	0.37973	0.99962	Ratio to Peak	0.0001
W680	0.87244	80.3973	0	20.4785	26.736736	Discharge	0.98374	1	Ratio to Peak	0.0001
W690	2.2111	58.7358	0	24.04646	31.395056	Discharge	1.4129	1	Ratio to Peak	0.0001
W700	2.319	57.5446	0	21.2444	27.736688	Discharge	2.8605	1	Ratio to Peak	0.0001
W710	2.2509	58.2897	0	7.02447	9.171152	Discharge	1.604	1	Ratio to Peak	0.0001
W720	0.41682	92.764	0	10.80537	14.107488	Discharge	1.5574	1	Ratio to Peak	0.0001
W730	1.7866	64.0423	0	19.81335	25.868304	Discharge	0.77852	1	Ratio to Peak	0.0001
W740	2.0891	60.1541	0	23.34513	30.479408	Discharge	2.8927	1	Ratio to Peak	0.0001

Annex 10. Cangaranan Model Reach Parameters

Table A-10.1. CangarananModel Reach Parameters

Reach Number	Muskingum-Cunge Channel Routing						
	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side slope
R30	Automatic Fixed Interval	4500.49	0.073821	0.01	Trapezoid	387.27	1
R90	Automatic Fixed Interval	1580.95	0.021318	0.01	Trapezoid	387.27	1
R110	Automatic Fixed Interval	3278.77	3.27E-02	0.01	Trapezoid	387.27	1
R120	Automatic Fixed Interval	9826.85	0.049368	0.01	Trapezoid	387.27	1
R130	Automatic Fixed Interval	1359.53	0.008738	0.01	Trapezoid	387.27	1
R140	Automatic Fixed Interval	7340.39	0.062146	0.01	Trapezoid	387.27	1
R170	Automatic Fixed Interval	4037.06	0.024542	0.01	Trapezoid	387.27	1
R190	Automatic Fixed Interval	502.132	0.015913	0.01	Trapezoid	387.27	1
R210	Automatic Fixed Interval	3965.58	0.014337	0.01	Trapezoid	387.27	1
R230	Automatic Fixed Interval	998.112	0.010164	0.01	Trapezoid	387.27	1
R240	Automatic Fixed Interval	3269.19	0.017553	0.01	Trapezoid	387.27	1
R250	Automatic Fixed Interval	8596.93	0.010067	0.01	Trapezoid	387.27	1
R270	Automatic Fixed Interval	4786.17	0.005058	0.01	Trapezoid	387.27	1
R290	Automatic Fixed Interval	417.279	0.000086	0.01	Trapezoid	387.27	1
R310	Automatic Fixed Interval	2602.08	0.016719	0.01	Trapezoid	387.27	1
R320	Automatic Fixed Interval	2221.79	0.005876	0.01	Trapezoid	387.27	1
R340	Automatic Fixed Interval	351.985	0.006937	0.01	Trapezoid	387.27	1
R350	Automatic Fixed Interval	2563.62	0.013392	0.01	Trapezoid	387.27	1

Annex 11. Cangaranan Floodplain Field Validation Points

Table A-11.1. Cangaranan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	11.04404016	122.0643791	0.059999999	0	0.004		
2	11.04719627	122.0663977	0.029999999	0	0.001		
3	11.06351053	122.0677705	0.029999999	0.43	0.160	Yolanda	5-Year
4	11.00539743	122.0456257	0.100000001	0	0.010		
5	11.02699656	122.0551218	0.029999999	0	0.001		
6	11.04017385	122.0687581	0.579999983	0	0.336		
7	10.95677243	122.0074533	0.039999999	0.3	0.068	Frank	100-Year
8	11.06796347	122.0646525	0.200000003	0.51	0.096	Yolanda	5-Year
9	10.94428104	121.9983045	0.029999999	0.2	0.029	Yolanda	5-Year
10	11.00387028	122.1306623	0.419999987	0.51	0.008		
11	11.00514439	122.129631	0.029999999	0	0.001		
12	11.00990291	122.0634626	0.050000001	0	0.003		
14	11.06532562	122.0816394	0.029999999	0	0.001		
15	10.97468923	122.0217892	0.090000004	0	0.008		
16	11.04346102	122.0638124	0.029999999	0	0.001		
17	11.04348437	122.0613686	0.029999999	0.5	0.221	Undang	5-Year
18	11.00606276	122.0470849	0.07	0	0.005		
19	11.06772967	122.0827564	0.029999999	0	0.001		
20	11.04149721	122.068553	0.029999999	0	0.001		
21	10.98812702	122.0928609	2.539999962	0	6.452		
22	11.01691689	122.0528669	0.029999999	0	0.001		
24	11.06558671	122.0813709	0	0	0.000		
25	11.04670697	122.0652931	0.029999999	0	0.001		
26	11.03026556	122.0566565	0.029999999	0	0.001		
27	11.0069148	122.0498218	0.129999995	0	0.017		
28	11.06059115	122.0784158	0.100000001	0	0.010		
29	11.04139844	122.0521073	1	1.2	0.040	Frank	100-Year
30	11.062625	122.0801022	0.029999999	0	0.001		
31	11.04856519	122.0678507	1.460000038	0.49	0.941	Frank	100-Year
34	10.9643594	122.0148831	0.029999999	0	0.001		
36	10.9472019	122.033573	0.059999999	0	0.004		
38	10.95911653	122.0094681	0.029999999	0.2	0.029	Yolanda	5-Year
50	11.047771	122.0657988	0.029999999	0	0.001		
51	11.0607562	122.078375	0	0	0.000		
52	11.00725319	122.048641	1.289999962	0	1.664		
53	11.02790262	122.0567448	0.029999999	0	0.001		
54	11.0186245	122.0524383	0.589999974	1.06	0.221	Frank	100-Year
55	11.02249607	122.0490881	0.460000008	1.21	0.562	Frank	100-Year
56	10.98090202	122.0297158	0.150000006	0	0.023		
58	11.00986712	122.0640066	0	0	0.000		

59	11.04588023	122.0511686	0.029999999	0.97	0.884	Frank	100-Year
60	11.01102341	122.0621546	0.209999993	0	0.044		
61	11.01053478	122.0655382	0.059999999	0.31	0.063	Yolanda	5-Year
62	11.02196988	122.0473721	0.029999999	0.82	0.624	Ruping	5-Year
63	11.00339685	122.1306646	0	0.51	0.260		
64	10.98151275	122.0302327	0.029999999	0	0.001		
65	11.04558119	122.0598263	0.029999999	0.5	0.221	Frank	100-Year
66	10.97746062	122.0243589	0.029999999	0	0.001		
67	11.00458605	122.1295053	0	0	0.000		
68	11.05069275	122.0495481	0.029999999	0	0.001		
69	11.02284123	122.0491835	0	1.21	1.464	Frank	100-Year
70	11.00551415	122.1304933	0.119999997	0	0.014		
71	11.00059276	122.0839586	0.100000001	0	0.010		
72	11.0223437	122.0495761	0.330000013	0.68	0.122	Frank	100-Year
73	11.0045539	122.1300589	0	0	0.000		
74	11.02741051	122.055324	0.119999997	0	0.014		
75	11.00298074	122.1308145	0	0.93	0.865	Frank	100-Year
76	11.06623469	122.0665362	0.810000002	0.56	0.063	Frank	100-Year
77	11.06617004	122.0661093	0	0.9	0.810	Frank	100-Year
78	11.04290752	122.067271	0.029999999	0	0.001		
79	11.0443049	122.06588	0.029999999	0.26	0.053	Frank	100-Year
80	11.00978012	122.0666671	0.029999999	0	0.001		
81	11.01965115	122.051459	0	1.04	1.082	Frank/ Nitang	100-Year
82	11.04550668	122.0652323	0.029999999	0	0.001		
83	11.00056741	122.0838646	0	0	0.000		
84	11.01065581	122.0651629	0	0.31	0.096	Yolanda	5-Year
85	11.04641037	122.0592663	0.360000014	0.5	0.020	Frank	100-Year
86	11.01834642	122.0521678	0.560000002	1.06	0.250	Frank	100-Year
87	11.01912883	122.0519958	0	0.5	0.250	Yolanda	5-Year
88	10.95756417	122.0085821	0.029999999	0	0.001		
91	11.08717759	122.0483329	0.029999999	0.9	0.757	Yolanda	5-Year
94	10.96952395	122.0702749	0.029999999	0	0.001		
95	10.93302146	122.0299397	0.050000001	0	0.003		
99	11.02724908	122.0515141	0.400000006	0.5	0.010	Frank	100-Year
100	11.01931613	122.0511899	0	1.25	1.563	Frank	100-Year
101	11.01081041	122.0641007	0.07	0	0.005		
102	11.0787808	122.0864507	0.07	0	0.005		
103	11.06489892	122.080985	0.029999999	0	0.001		
104	11.01820445	122.0517452	0	1.06	1.124	Frank	100-Year
105	11.01793002	122.052489	0.029999999	0	0.001		
106	11.01766187	122.0520374	0	0.95	0.903	Frank	100-Year
107	10.98374448	122.0293631	0.029999999	0.68	0.423	Frank	100-Year
108	11.00303965	122.1308857	0	0	0.000		
109	11.04328321	122.0589588	0.039999999	0.35	0.096	Frank	100-Year

110	11.07132661	122.0611982	0.029999999	1	0.941	Frank	100-Year
111	11.07236273	122.0612561	1.25999999	1.21	0.002	Frank	100-Year
112	11.00475658	122.1306831	0.349999994	0.5	0.023	Frank	100-Year
113	11.01092881	122.0640487	0	0	0.000		
114	11.00361797	122.1313115	0	1.21	1.464	Frank	100-Year
115	10.9562659	122.0072416	0	0.3	0.090	Frank	100-Year
117	11.02647552	122.0551956	0	0	0.000		
118	10.95728511	122.0084105	0	0	0.000		
119	11.01771548	122.0515164	0	1.63	2.657	Frank	100-Year
120	11.04570445	122.0595503	0	0.5	0.250	Frank	100-Year
121	11.04048376	122.0698528	0	1	1.000	Frank	100-Year
122	11.0058659	122.1299482	0.219999999	2	3.168	Lawin	5-Year
123	11.045929	122.0659367	0.029999999	0	0.001		
124	11.03307078	122.0574816	0.029999999	0	0.001		
125	11.00378924	122.1312014	0	1.21	1.464	Frank	100-Year
126	11.00405804	122.1304097	0.310000002	0	0.096		
127	11.02263259	122.0475884	0.829999983	0.73	0.010	Frank	100-Year
128	11.0228817	122.0481969	0	1.25	1.563	Frank	100-Year
129	11.02297139	122.0475469	0	0.96	0.922	Lawin	5-Year
130	10.93902928	122.00096	0.029999999	0	0.001		
131	11.04839076	122.0504137	0.99000001	1	0.000	Frank	100-Year
132	11.0184566	122.0527233	0	0	0.000	Frank	100-Year
133	10.96238128	122.0129551	0.029999999	0	0.001		
134	11.01683328	122.0514692	0.689999998	1.45	0.578	Frank	100-Year
137	10.93818813	122.0004052	0.029999999	0	0.001		
138	10.95733435	122.0089883	0	0.7	0.490	Frank	100-Year
139	11.00617698	122.0423088	0.75999999	1.5	0.548	Frank	100-Year
140	10.99594444	122.0376456	0.029999999	0	0.001		
141	11.09183229	122.0491072	0.029999999	0	0.001		
142	11.00337	122.1152199	0.769999981	0.9	0.017	Frank	100-Year
143	10.95301962	122.0467185	0.360000014	0.61	0.062		
148	11.01227141	122.0749224	2.420000076	6.39		Frank	100-Year
150	11.07317951	122.0596864	1.299999952	0.5	0.640	Frank	100-Year
151	11.06323004	122.0803316	0	0	0.000		
152	11.00741574	122.04953	0	0.52	0.270	Frank	100-Year
153	11.04462489	122.0666026	0	0	0.000		
154	11.04654608	122.0510006	1.070000052	0.97	0.010	Frank	100-Year
155	11.00747152	122.0490977	0	0	0.000		
156	11.07236169	122.0599095	0.029999999	0.6	0.325	Yolanda	5-Year
157	11.07812	122.0563	0.029999999	1	0.941	Frank	100-Year
158	11.08272	122.068	1.25999999	1.21	0.002	Frank	100-Year
159	11.07956	122.0548	0.349999994	0.5	0.023	Frank	100-Year

Annex 12. Educational Institutions affected by flooding in Cangaranan Floodplain

Table A-12.1. Educational Institutions affected by flooding in the Cangaranan Floodplain

Antique				
Bugasong				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bagtason Elementary School	Bagtason			Low
Department of Education Office	Igbalangao			
Southern Bugasong National High School	Igbalangao			
Camangahan Elementary School	Ilaures			
Ilaures School	Ilaures			
Zaragoza Elementary School	Zaragoza			
Valderrama				
Buluangan 1 Day Care Center	Buluangan I			
Buluangan 1 Day Care Center 1	Buluangan I			
Buluangan 1 Day Care Center 2	Buluangan I			
Buluangan 1 Elementary School	Buluangan I			
Bunsod Elementary School	Bunsod			
Canipayan Elementary School	Canipayan			
Igmasandig Day Care Center	Igmasandig			
Igmasandig Elementary School	Igmasandig			Low
Valderrama National High School	Pandanan	Medium	Medium	Medium
Pandanon Elementary School	Takas			
St. Luke's Academy	Takas	Low	Low	Low
St. Luke's Academy (Canteen)	Takas		Low	Low
Valderrama Central Elementary School	Takas	Low	Medium	Medium
Tigmamale Elementary School	Tigmamale			
Tigmamale Elementary School	Tigmamale			
St. Luke's Academy	Ubos	Low	Low	Low
Valderrama Central Elementary School	Ubos			

Annex 13. Medical Institutions Affected by flooding in Cangaranan Floodplain

Table A-13.1. Medical institutions affected by flooding in the Cangaranan floodplain

Antique				
Bugasong				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bugasong Medicare Community Hospital	Ilaures			
Valderrama				
Buluangan 1 Health Center	Buluangan I			
Barangay Ubos DOTS Center	Takas	Low	Low	Low
Barangay Ubos Health Center	Takas			
Valderrama Municipal Hospital	Takas			
Tigmamale Health Center	Tigmamale			
Barangay Ubos DOTS Center	Ubos		Low	Low
Barangay Ubos Health Center	Ubos			
Valderrama Municipal Hospital	Ubos			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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