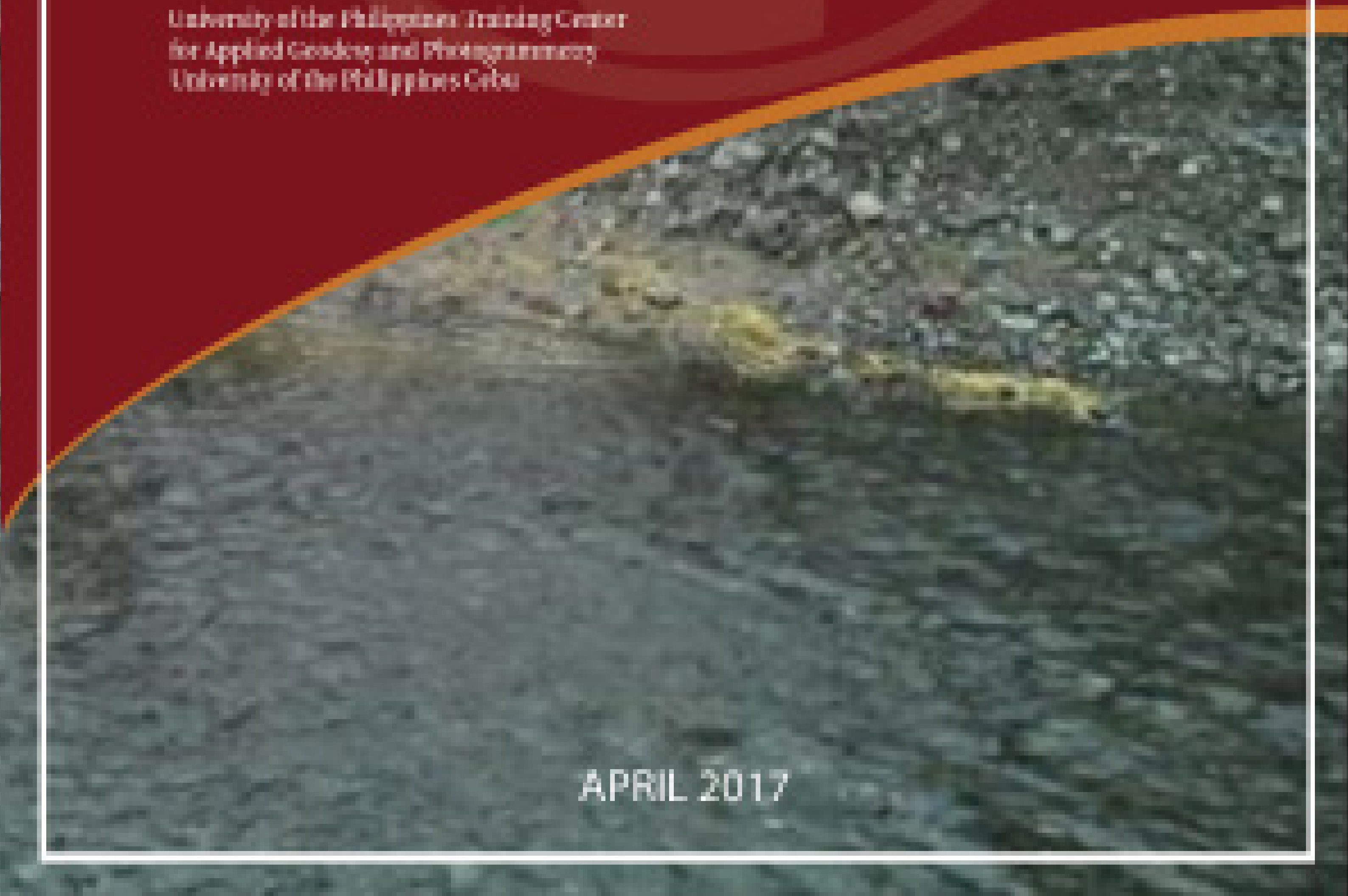
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Cairawan River

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



APRIL 2017

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

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

E.C. Paringit, and **J.R. Sinogaya**, (Eds.). (2017), LiDAR Surveys and Flood Mapping Report of Cairawan River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LiDAR-128pp

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National Library of the Philippines
ISBN: 978-621-430-100-3

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CHAPTER 1: OVERVIEW OF THE PROGRAM AND CAIRAWAN RIVER

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) Grant-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.

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The 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 Cairawan River Basin

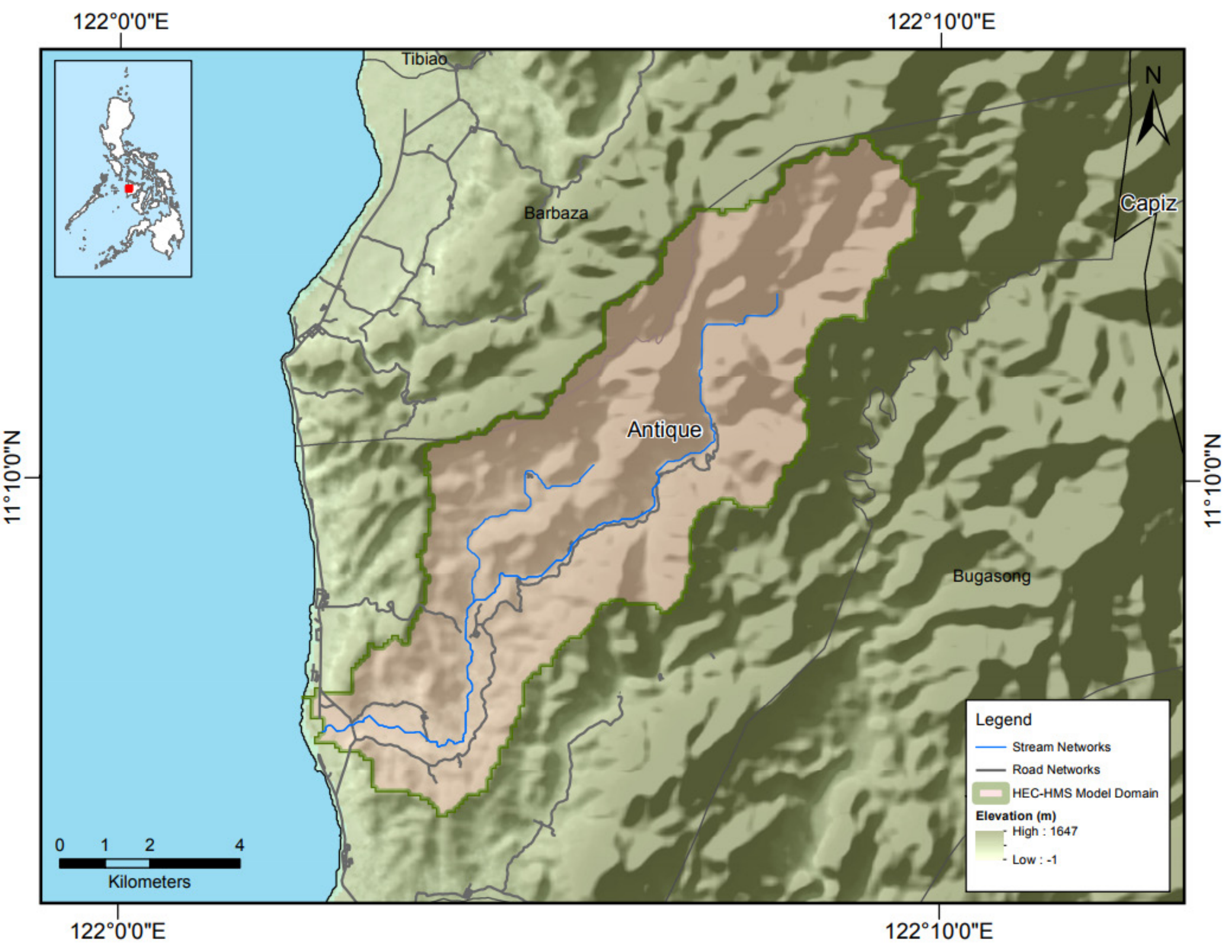

Figure 1. Map of Cairawan River Basin

The Cairawan River Basin is located in the Province of Antique, west of Panay Island. The floodplain and drainage area of 35.7 km^2 and 27.335 km^2 respectively traverses areas of the Municipality of Laua-an. The floodplain is 99.35% covered with LiDAR data which compromises 5 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.02 and then bathy burned. The bathy survey conducted reached a total length of 6.12 km starting from Lupa-an Footbridge, Lupa-an up to the river mouth with 423 points surveyed. There are 2824 buildings, 25.65km roads, 3 waterbodies and 1 bridge digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 2,683 of them are Residential, 49 are schools and 2 are Medical Institutions.

The produced flood hazard map covers the 8.94 km^2, 10.29 km^2, 11.12 km^2 for the 5-year, 25-year, and 100 year rainfall return period in Barbaza affecting eight (8) barangays as well as in Laua-an with thirty one (31) barangays affected. A flood depth validation was conducted using 258 randomly generated points which was spread throughout the six (6) ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded 0.699 m RMSE.

A rating curve was developed at KALAHI CIDSS Foot Bridge, Brgy Latazon, Laua-an, Antique, which shows the relationship between the observed water levels at KALAHI CIDSS Foot Bridge and the outflow of the watershed at this location. This rating curve equation, expressed as Q = 6E-19e1.0753x, was used to compute the river outflow at KALAHI CIDSS Foot Bridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded in the DREAM website.

CHAPTER 2: LIDAR DATA ACQUISITION OF CAIRAWAN 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

Plans were made to acquire LiDAR data within the delineated priority area for Cairawan Floodplain in Antique. These missions were planned for twelve (12) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR Systems are found in Table 1 and Table 2. Figure 2 shows the flight plans for Cairawan Floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK43A	1200	30	36	70	50	125	5

Table 2. Flight planning parameters for Pegasus LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK43B	1500	30	50	150	30	130	5

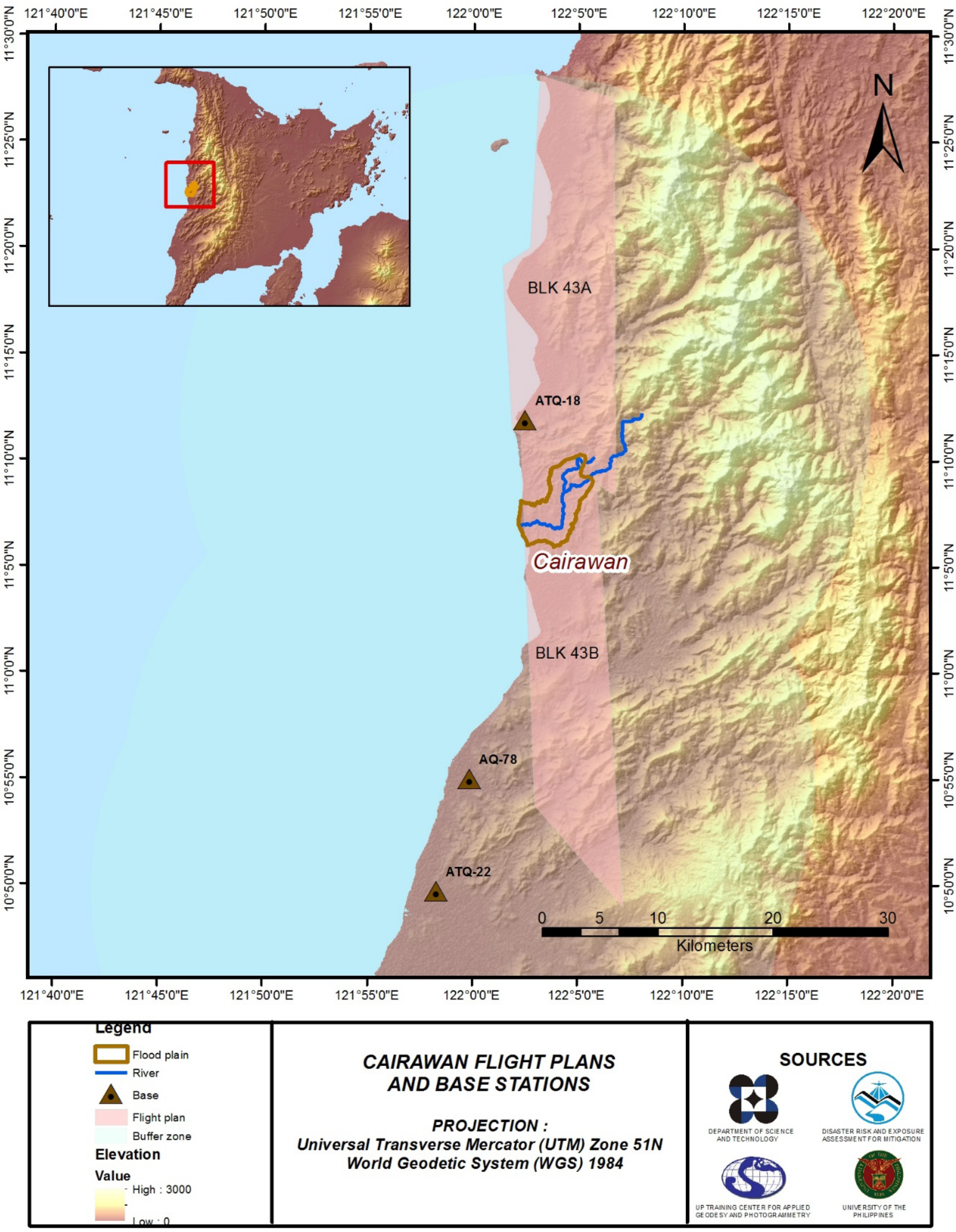

Figure 2. Flight plan and base stations used for Cairawan Floodplain

2.2 Ground Base Station

The Project Team was able to recover three (3) NAMRIA reference points: ATQ-18, ATQ-22 and AQ-78 which are of second (2nd) order accuracy. The certification for the NAMRIA reference points are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (February 20 - 27, 2015). Base stations were observed using Dual Frequency GPS Receivers, TRIMBLE SPS 852 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR Acquisition in Cairawan Floodplain are shown in Figure 2.

Figures 3 to 5 show the recovered NAMRIA control station within the area. In addition, Tables 3 to 5 show the details about the following NAMRIA control stations , while Table 7 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a)

Figure 3. GPS set-up over ATQ-18 in Barangay Cubay, Barbaza, Antique (a) and NAMRIA reference point ATQ-18 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ATQ-18 used as 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 4 (PTM Zone 4 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 4. GPS set-up over ATQ-22 in Barangay Concepcion, Belison, Antique (a) and NAMRIA reference point ATQ-22 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ATQ-22 used as 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” North 121° 58’ 11.90221” East 12.250 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 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

(a)

(b)

Figure 5. GPS set-up over AQ-78 in Barangay Ipayo, Patnongon, Antique (a) and NAMRIA reference point AQ-78 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA vertical control point AQ-78used as base station for the LiDAR acquisition with established coordinates

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” North 121° 59’ 46.81987” East 48.448 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 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 6. Ground control points used during LiDAR data acquisiton

Date Surveyed	Flight Number	Mission Name	Ground Control Points
Feb. 20, 2015	2582G	2BLK43A051A	ATQ-18 and ATQ-22
Feb. 21, 2015	2586G	2BLK43A052A	ATQ-18 and ATQ-22
Feb. 22, 2015	2590G	2BLK43A053A	ATQ-18 and ATQ-22
Feb. 20, 2015	2593P	1BLK43BDG051A	ATQ-18 and ATQ-22
Feb. 25, 2015	2602G	2BLK43B056A	ATQ-22 and AQ-78
Feb. 26, 2015	2606G	2BLK43BV057A	ATQ-22 and AQ-78
Feb. 27, 2015	2610G	2BLK43BV058A	ATQ-22 and AQ-78

2.3 Flight Missions

Seven (7) missions were conducted to complete the LiDAR Data Acquisition in Cairawan Floodplain, for a total of twenty-four and fifty nine (24+59) hours of flying time for RP-C9122 and RP-C9022. All missions were acquired using the Pegasus and Gemini LiDAR Systems. Table 7 shows the total area of actual coverage per mission and the flying length for each mission and Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Cairawan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the River Systems (km^2)	Area Surveyed Outside the River Systems (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
Feb. 20, 2015	2582G	268.69	36.48	0	36.48	113	2	59
Feb. 21, 2015	2586G		163.52	0.16	163.36	224	3	59
Feb. 22, 2015	2590G		198.57	4.36	194.21	317	4	05
Feb. 20, 2015	2593P	248.28	180.57	12.77	167.80	427	3	29
Feb. 25, 2015	2602G	268.69	89.82	7.68	82.14	119	3	17
Feb. 26, 2015	2606G		221.78	16.94	204.84	319	4	05
Feb. 27, 2015	2610G		34.35	0	34.35	47	3	05
TOTAL		516.97	925.09	41.91	883.18	1566	24	59

Table 8. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (Hz)	Scan	Speed of Plane (Kts)	Average Turn times (Minutes)
2582G	1100	30	40	100	50	120	5
2586G	1600	30	40	70	50	125	5
2590G	1700	30	40	70	50	125	5
2593P	1800	30	40	200	50	120	5
2602G	1200	30	40	100	50	120	5
2606G	1800	30	40	200	50	120	5
2610G	2000	30	34	70	56	110	5

2.4 Survey Coverage

The Cairawan Floodplain is located in the Provinces of Antique with majority of the floodplain situated within the Municipality of Laua-An. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Cairawan floodplain is presented in Figure 6.

Table 9. List of Municipalities/Cities Surveyed during Cairawan Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Antique	Patnongon	135.69	79.96	58.93%
	Laua-An	165.65	82.01	49.51%
	Bugasong	178.8	69.82	39.05%
	Tibiao	95.95	36.24	37.77%
	Barbaza	171.23	32.84	19.18%
	San Remigio	370.9	59.9	16.15%
	Valderrama	309.67	39.53	12.77%
	Culasi	201.84	17.64	8.74%
	Belison	36.8	2.14	5.82%
	Sibalom	240.55	2.6	1.08%

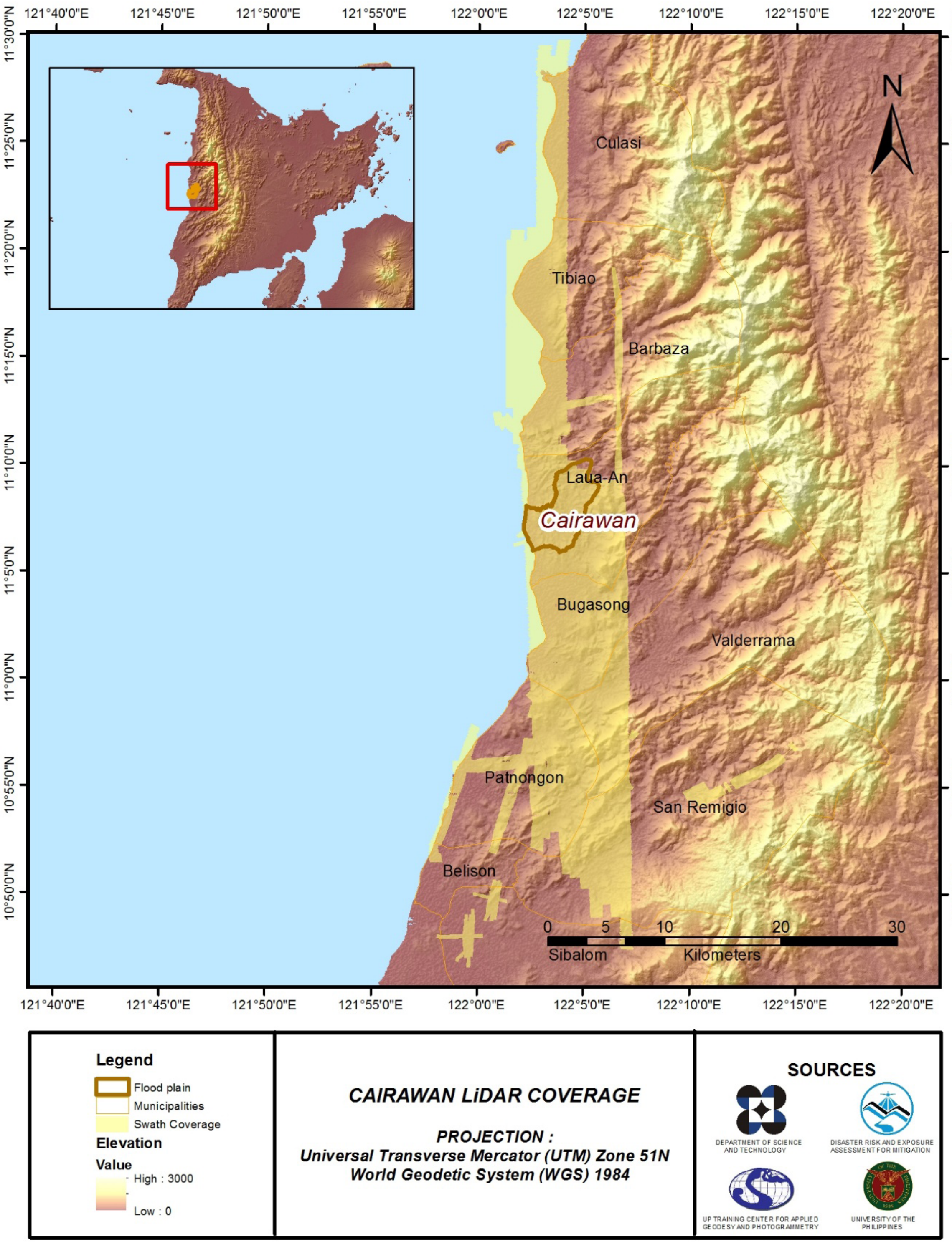

Figure 6. Actual LiDAR survey coverage for Cairawan Floodplain

CHAPTER 3. LIDAR DATA PROCESSING OF THE CAIRAWAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component 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 correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality check to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models 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. 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 done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 7.

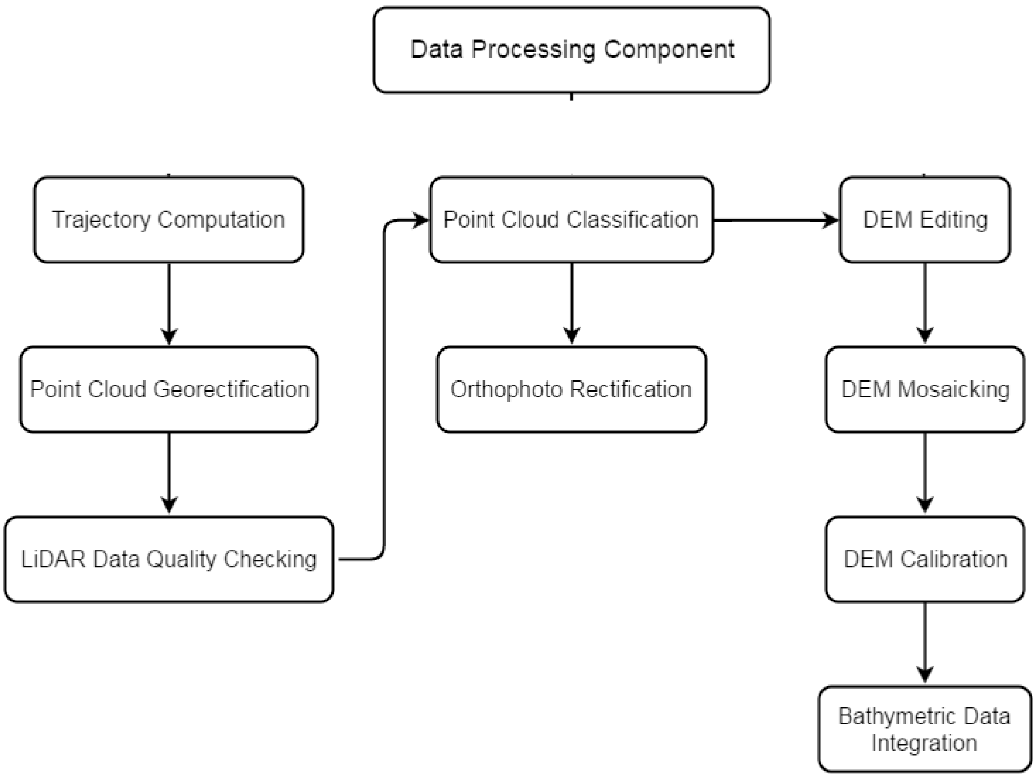


Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of the Acquired LiDAR Data

Data Transfer Sheets for all the LiDAR missions for Cairawan Floodplain can be found in Annex 5. Missions flown during the survey conducted in February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System most of the time with one mission using the Pegasus System. The Data Acquisition Component (DAC) started transferring a total of 71.11 Gigabytes of Range data, 1.65 Gigabytes of POS data, 253.89 Megabytes of GPS base station data, and 104.26 Gigabytes of raw image data to the data server on March 7, 2015 and followed by another transfer on March 23, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Cairawan was fully transferred on November 22, 2016 as indicated on the Data Transfer Sheets for Cairawan Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2610G, one of the Cairawan flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 22, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

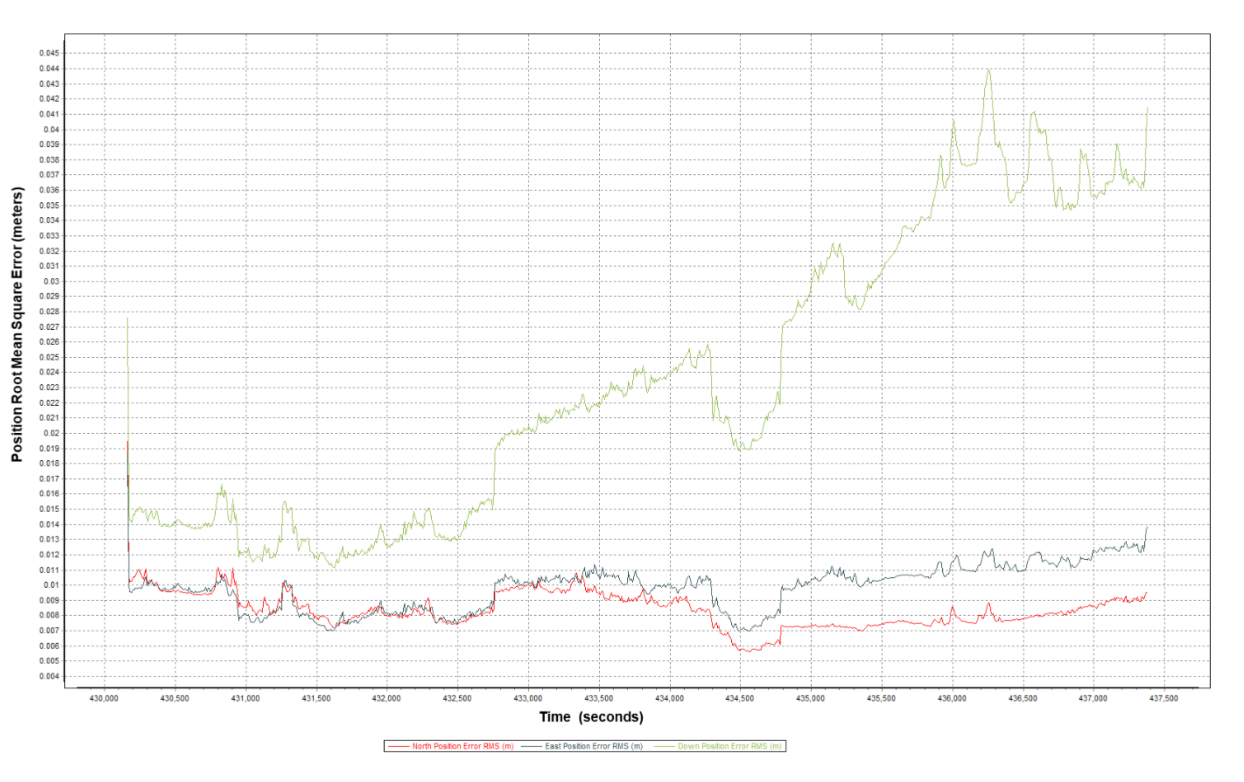


Figure 8. Smoothed Performance Metrics of a Cairawan Flight 2610G.

The time of flight was from 430000 seconds to 437500 seconds, which corresponds to afternoon of February 27, 2015. The initial spike seen on the data corresponds to the time when the aircraft was getting into position to start the acquisition, and when the POS system started computing 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 made a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.10 centimeters, the East position RMSE peaks at 1. 40 centimeters, and the Down position RMSE peaks at 4.40 centimeters, which are within the prescribed accuracies described in the methodology.

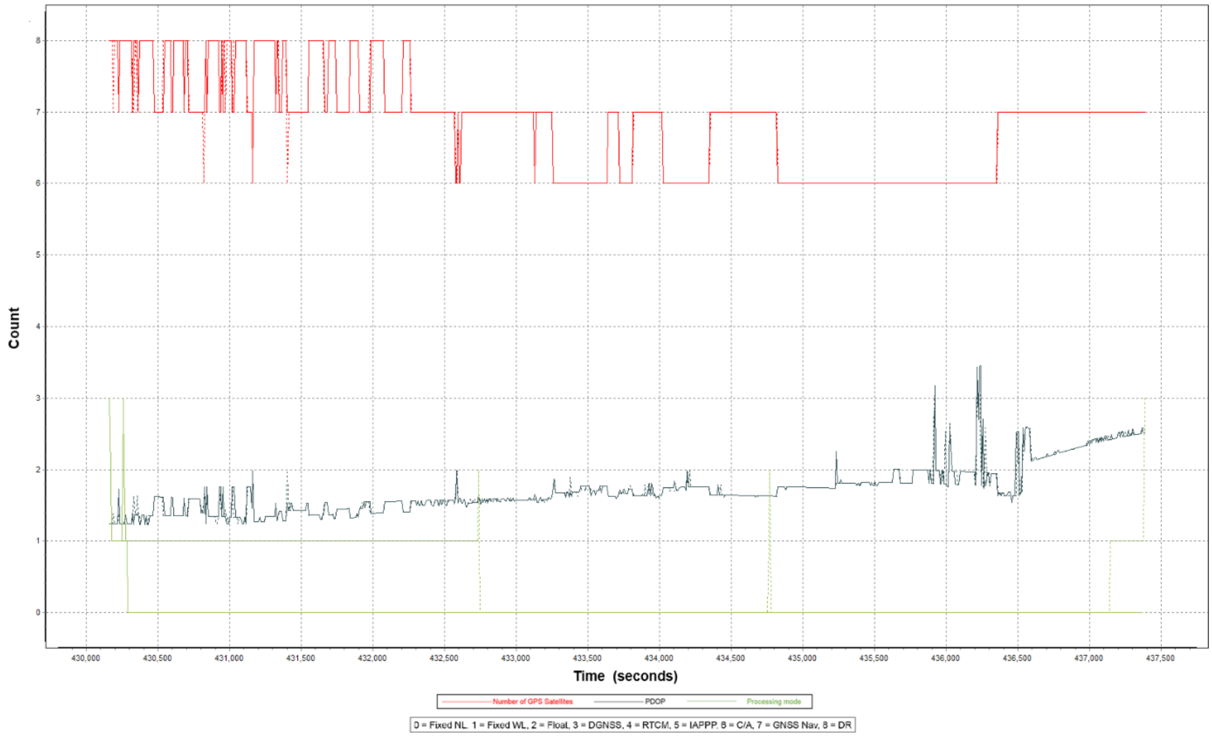


Figure 9. Solution Status Parameters of Cairawan Flight 2610G.

The Solution Status parameters of flight 2610G, one of the Cairawan flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to five (5). Most of the time, the number of satellites tracked was between six (6) and eight (8). The PDOP value also did not go above the value of four (4), which indicates optimal GPS geometry. The processing mode remained at zero (0) for majority of the survey with some peaks up to three (3) 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 adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Cairawan flights is shown in Figure 10.

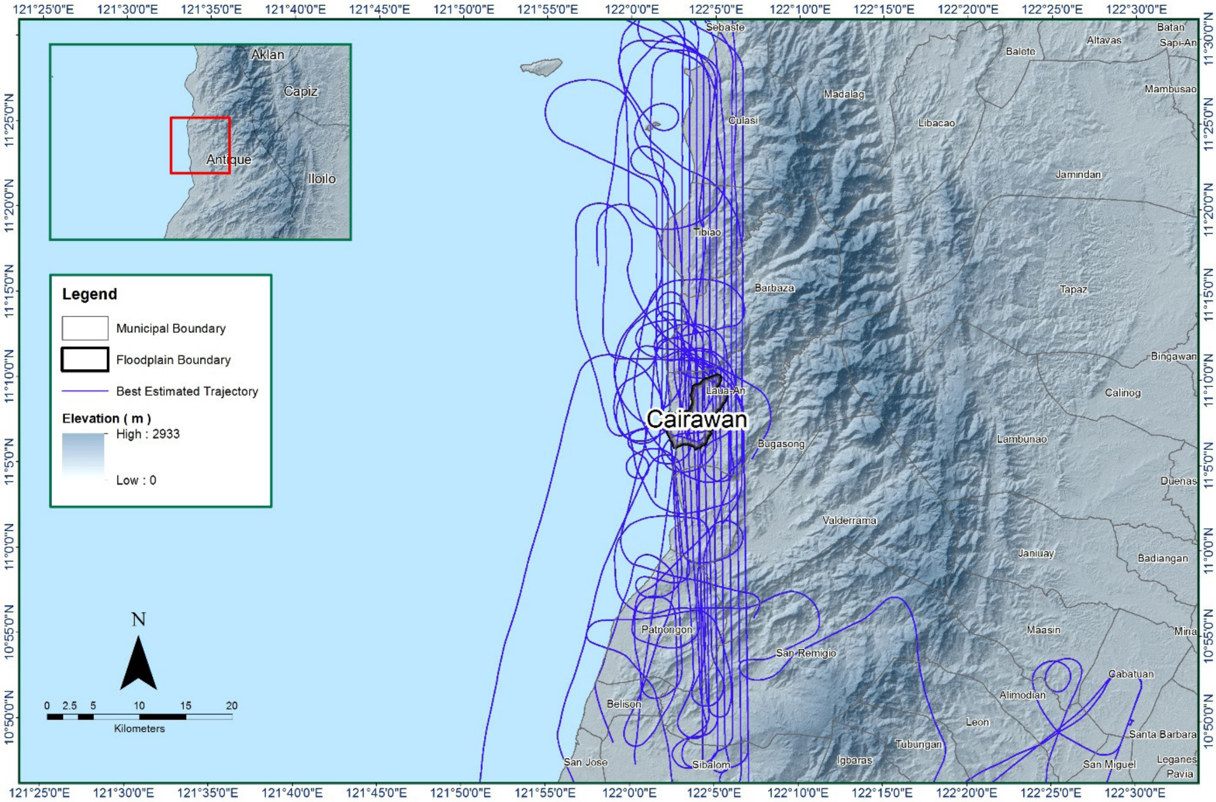


Figure 10. Best Estimated Trajectory for Cairawan Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contain thirty six (36) flight lines, with each flight line containing one (1) channel for both Gemini and Aquarius-CASI systems and two (2) channels for the Pegasus System. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Cairawan Floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Cairawan flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000592
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000705
GPS Position Z-correction stdev	(<0.01meters)	0.0075

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

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

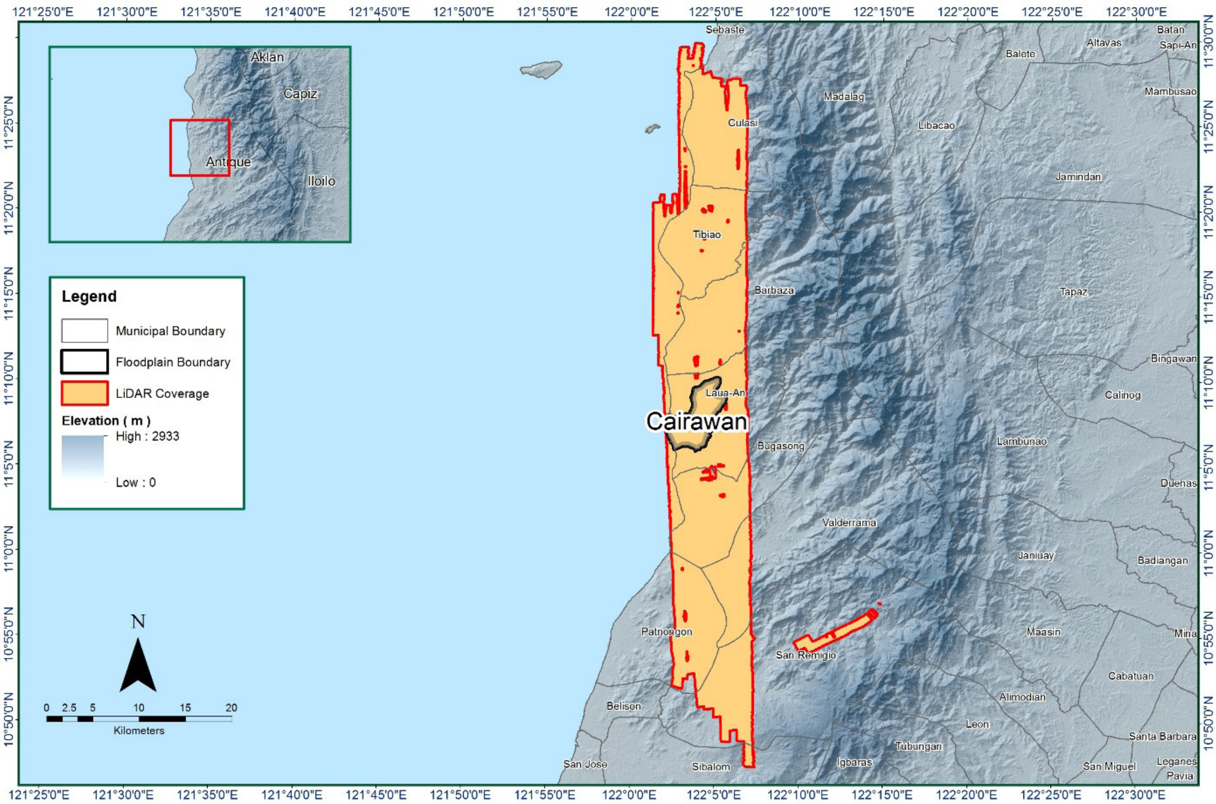


Figure 11. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Cairawan Floodplain.

The total area covered by the Cairawan missions is 692.63 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into three (5) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Cairawan Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk43A	2582G 2586G 2590G	309.60
Iloilo_Blk43B	2593P	141.22
Iloilo_Blk43B_additional	2602G 2606G 2610G	229.08
Iloilo_reflights_Blk43B	8511AC	15.69
Iloilo_reflights_Blk43B_supplement	8515AC	17.23
	TOTAL	**692.63 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Gemini and Aquaruis-CASI systems both employ one (1) channel, we would expect an average value of 1 (blue) for areas where there was limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two (2) channels, we would expect an average value of 2 (blue) for areas where there was limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

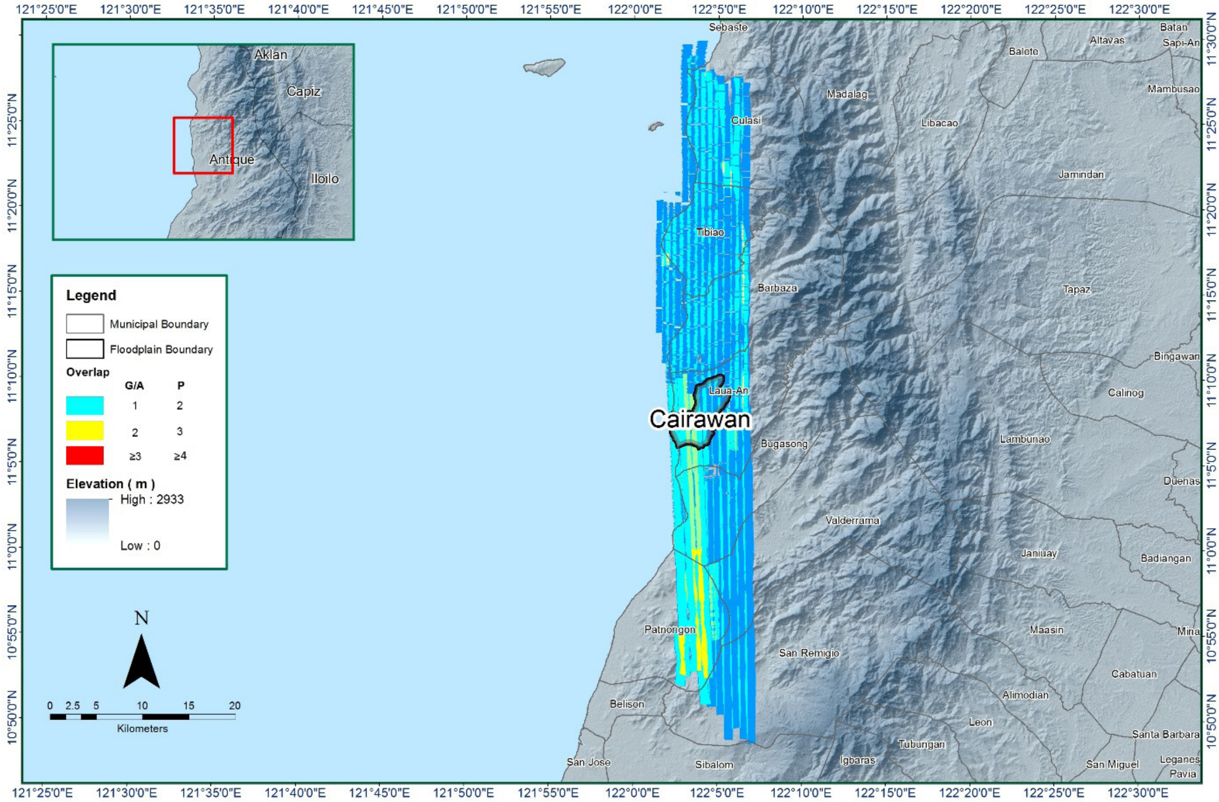


Figure 12. Image of data overlap for Cairawan Floodplain

The overlap statistics per block for the Cairawan floodplain can be found in Annex 7. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.93% and 38.72% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Cairawan Floodplain satisfied the point density requirement, and the average density for the entire survey area is 2.29 points per square meter.

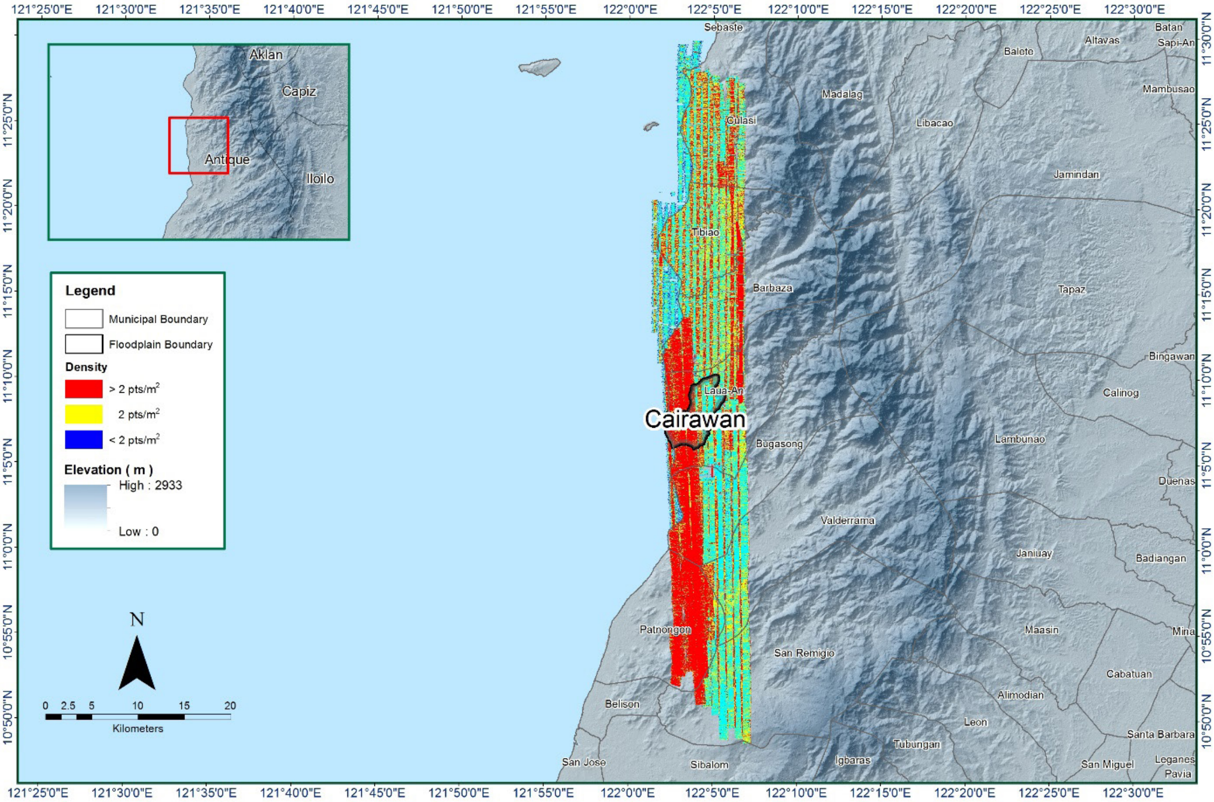


Figure 13. Pulse density map of merged LiDAR data for Cairawan Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

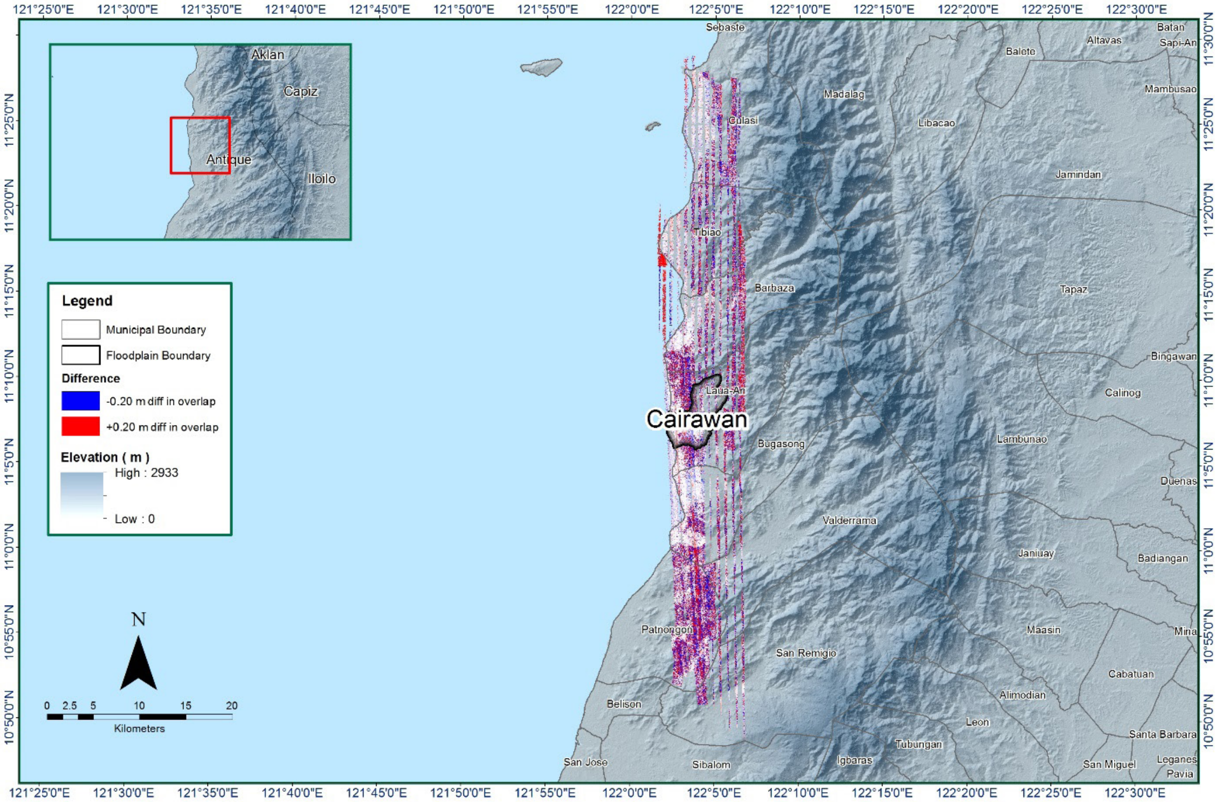


Figure 14. Elevation difference map between flight lines for Cairawan Floodplain

A screen capture of the processed LAS data from a Cairawan flight 2610G loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two 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 are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

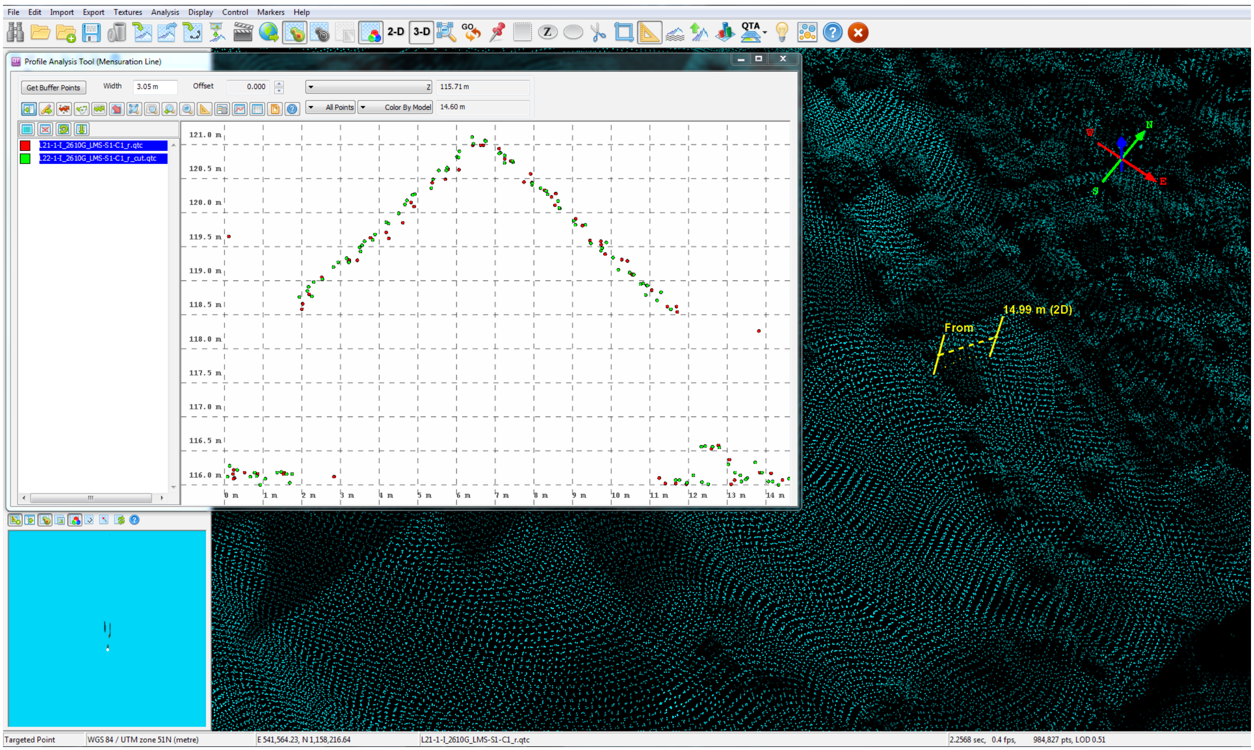


Figure 15. Quality checking for a Cairawan flight 2610G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Cairawan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	333,208,087
Low Vegetation	120,256,581
Medium Vegetation	275,253,602
High Vegetation	469,616,838
Building	5,525,373

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Cairawan Floodplain is shown in Figure 16. A total of 594 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 925.04 meters and 54.48 meters respectively.

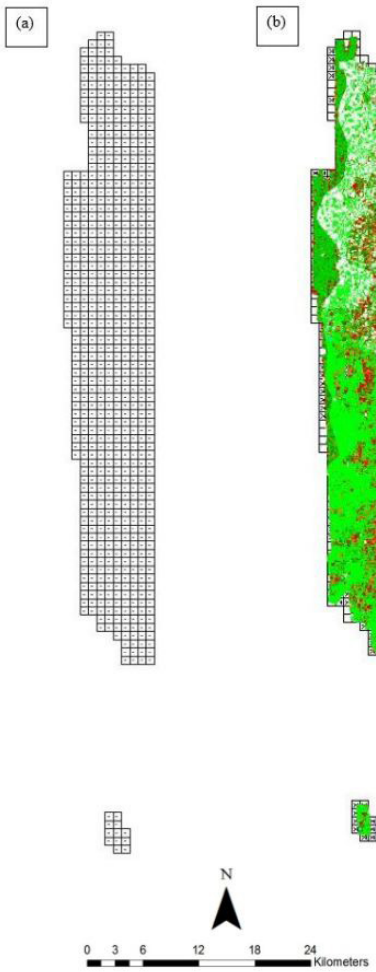


Figure 16. Tiles for Cairawan Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

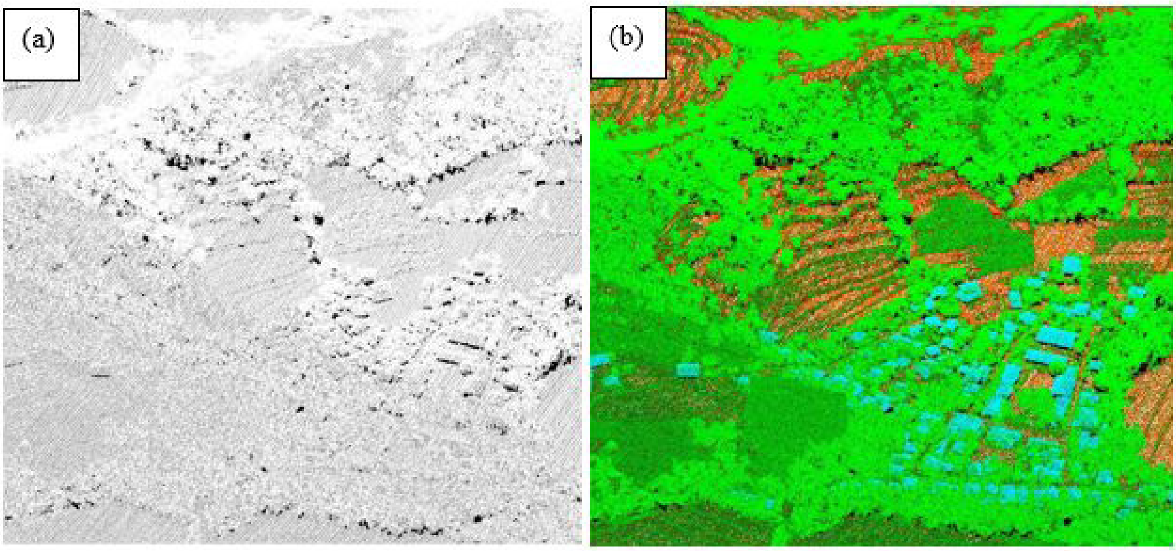


Figure 17. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 18. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

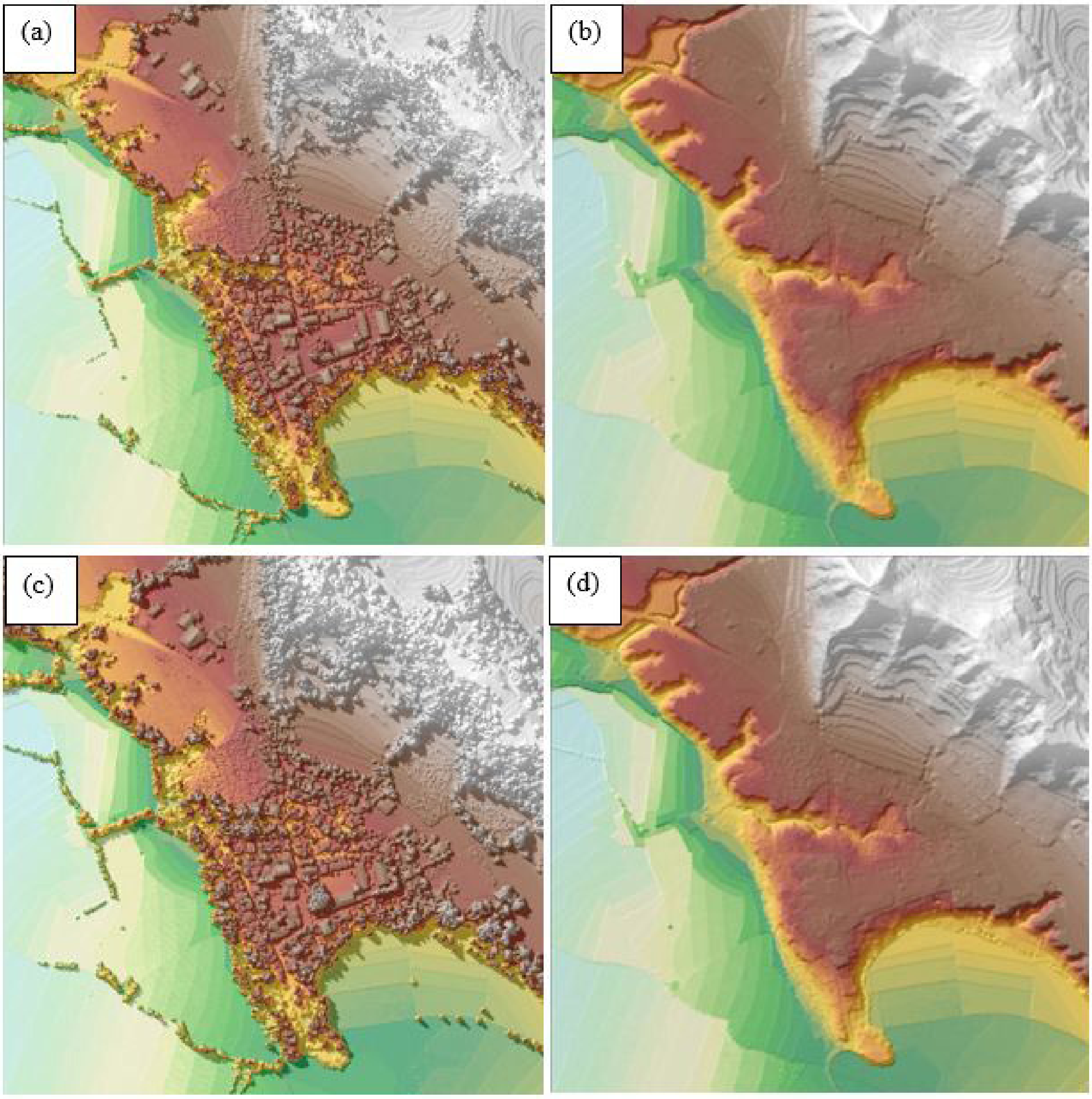


Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Cairawan Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 823 1km by 1km tiles area covered by Cairawan Floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Cairawan Floodplain has a total of 594.12 sq.km orthophotogaph coverage comprised of 1,279 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

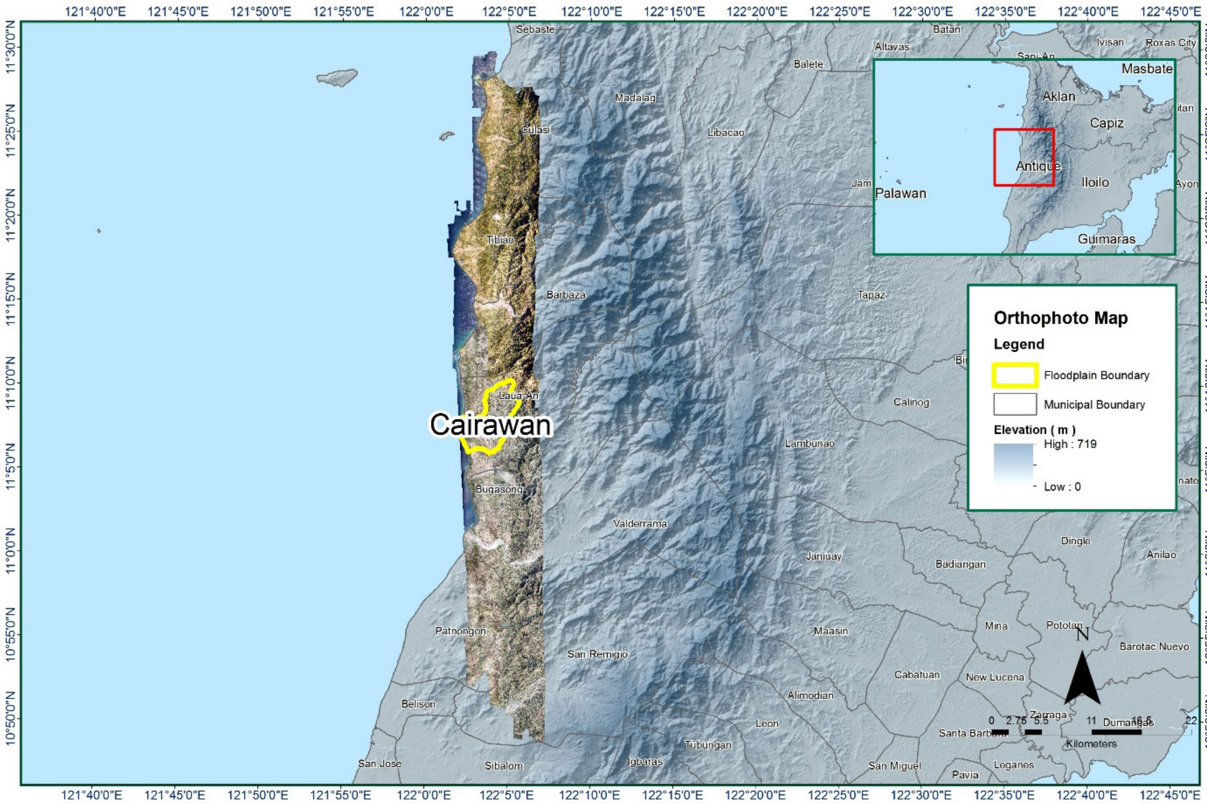


Figure 19. Cairawan Floodplain with available orthophotographs

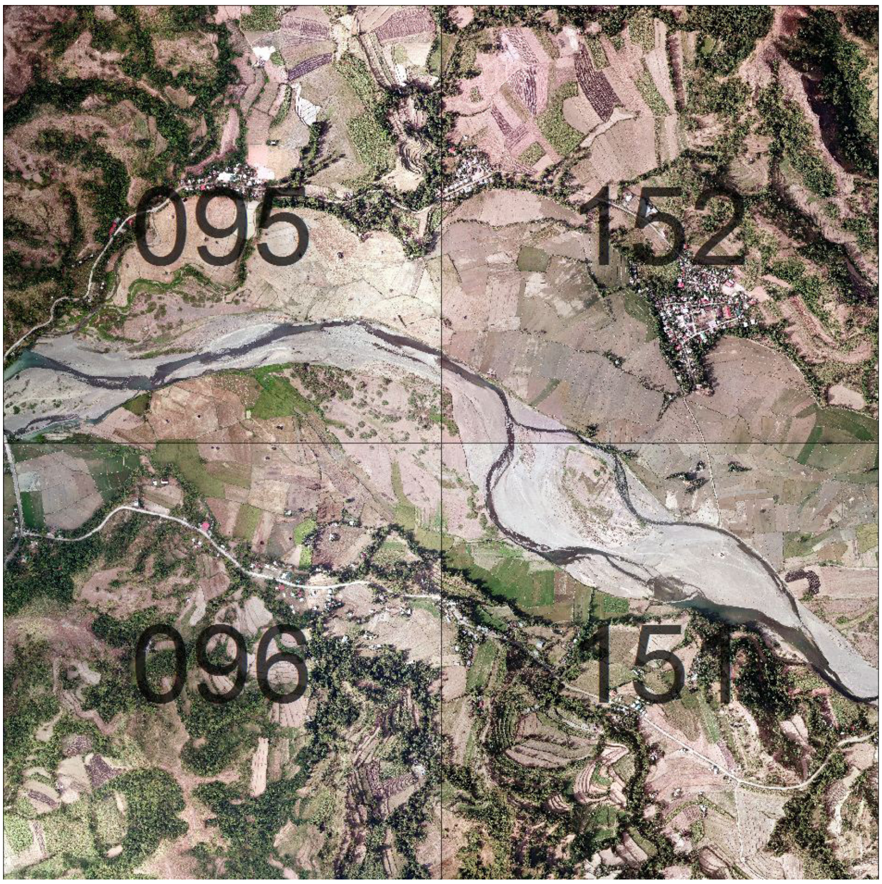


Figure 20. Sample orthophotograph tiles for Cairawan Floodplain

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Cairawan Floodplain. These blocks are composed of Iloilo blocks with a total area of 692.63 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Iloilo_Blk43A	297.51
Iloilo_Blk43B	136.14
Iloilo_Blk43B_additional	226.06
Iloilo_reflights_Blk43B	15.69
Iloilo_reflights_Blk43B_supplement	17.23
TOTAL	**692.63 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) would be an impedance to the flow of water along the river thus has to be removed (Figure 21b) in order to hydrologically correct the river. Also, it shows that the mountain (Figure 21c) has been misclassified, was removed during classification process, and has to be retrieved to complete the surface (Figure 21d).

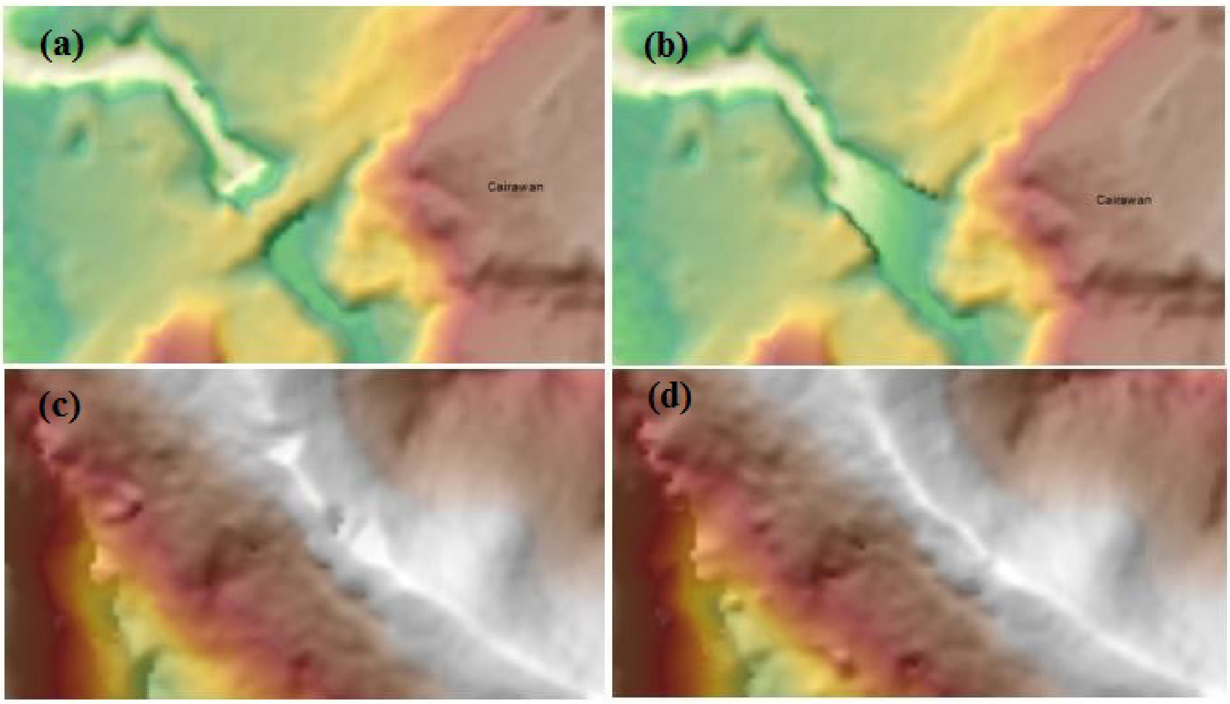


Figure 21. Portions in the DTM of Cairawan Floodplain – a bridge before (a) and after (b) data retrieval; a mountain before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

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 14 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Cairawan Floodplain is shown in Figure 22. It can be seen that the entire Cairawan Floodplain is 99.35% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Cairawan 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_Blk43A	0.00	0.00	-1.29
Iloilo_reflights_Blk43B	0.00	0.00	-0.48
Iloilo_reflights_Blk43B_supplement	0.00	0.00	-0.59

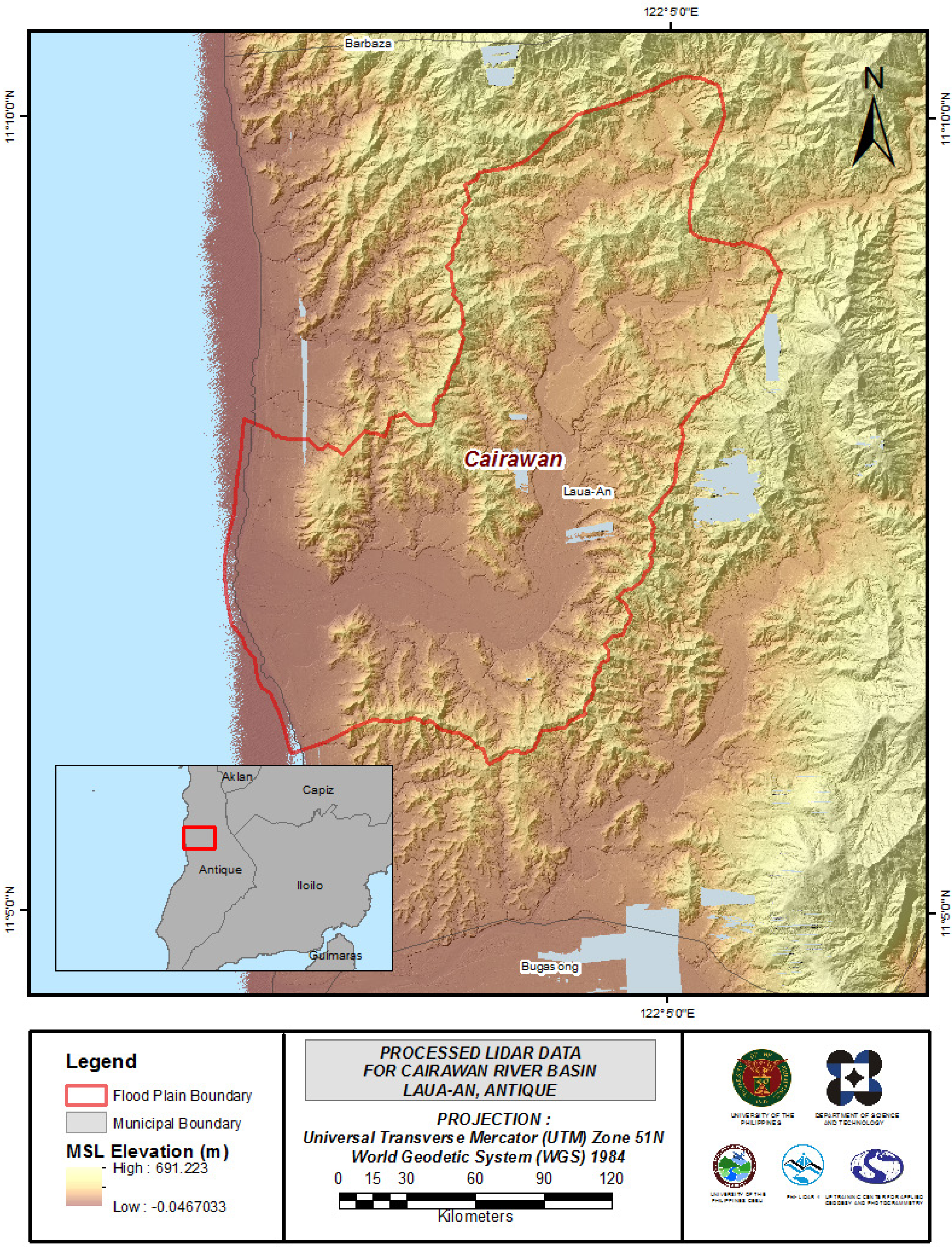


Figure 22. Map of Processed LiDAR Data for Cairawan Floodplain

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 Cairawan to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 7511 points were gathered for all the floodplains within the Province of Antique wherein the Cairawan is located. However, the point dataset was not used for the calibration of the LiDAR data for Cairawan because during the mosaicking process, each LiDAR block was referred to the calibrated Jalaur DEM. Therefore, the mosaicked DEM of Cairawan 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 24. 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 15 shows the statistical values of the compared elevation values between Jalaur LiDAR data and calibration data. These values were also applicable to the Cairawan DEM.

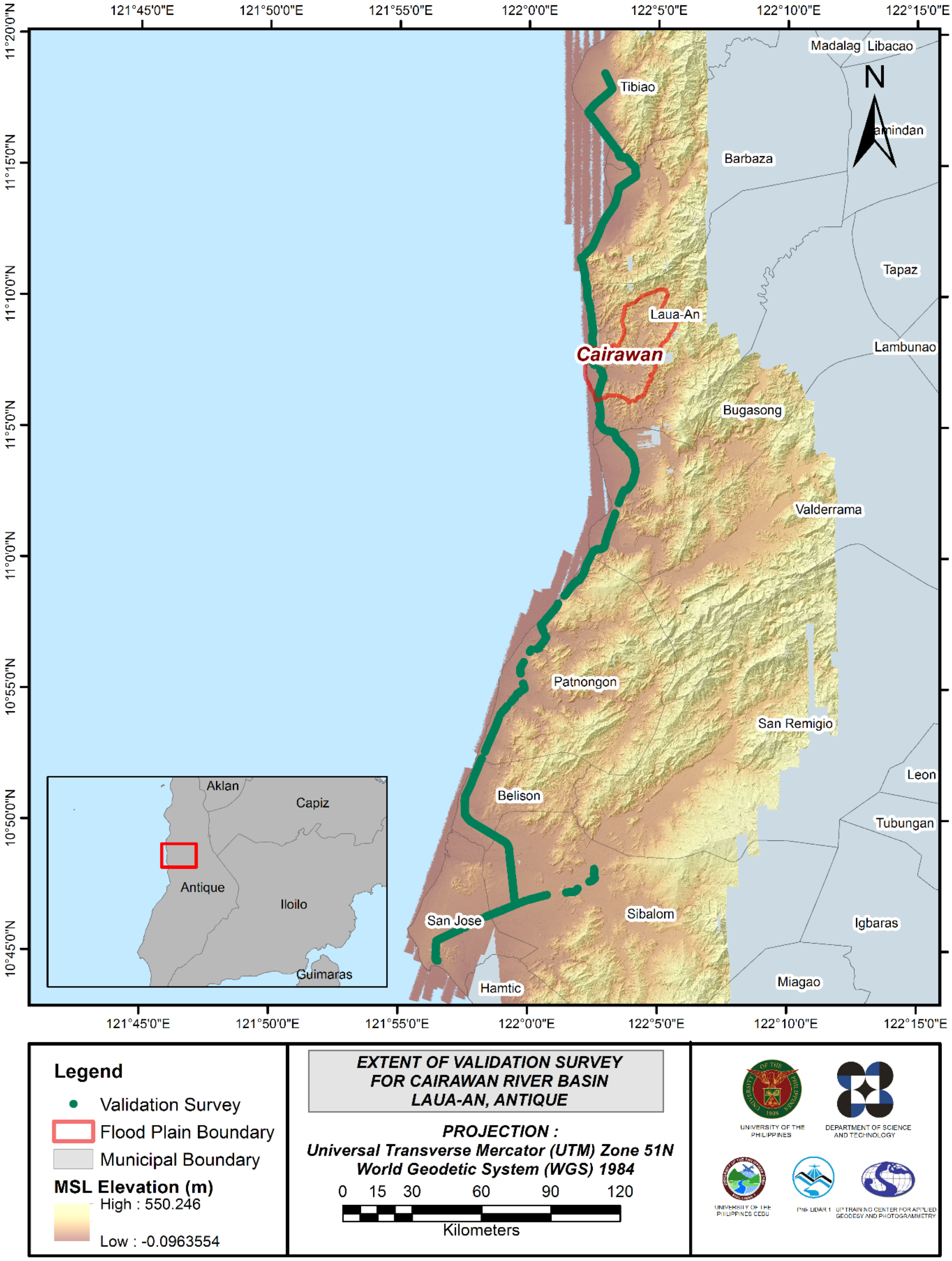


Figure 23. Map of Cairawan Floodplain with validation survey points in green

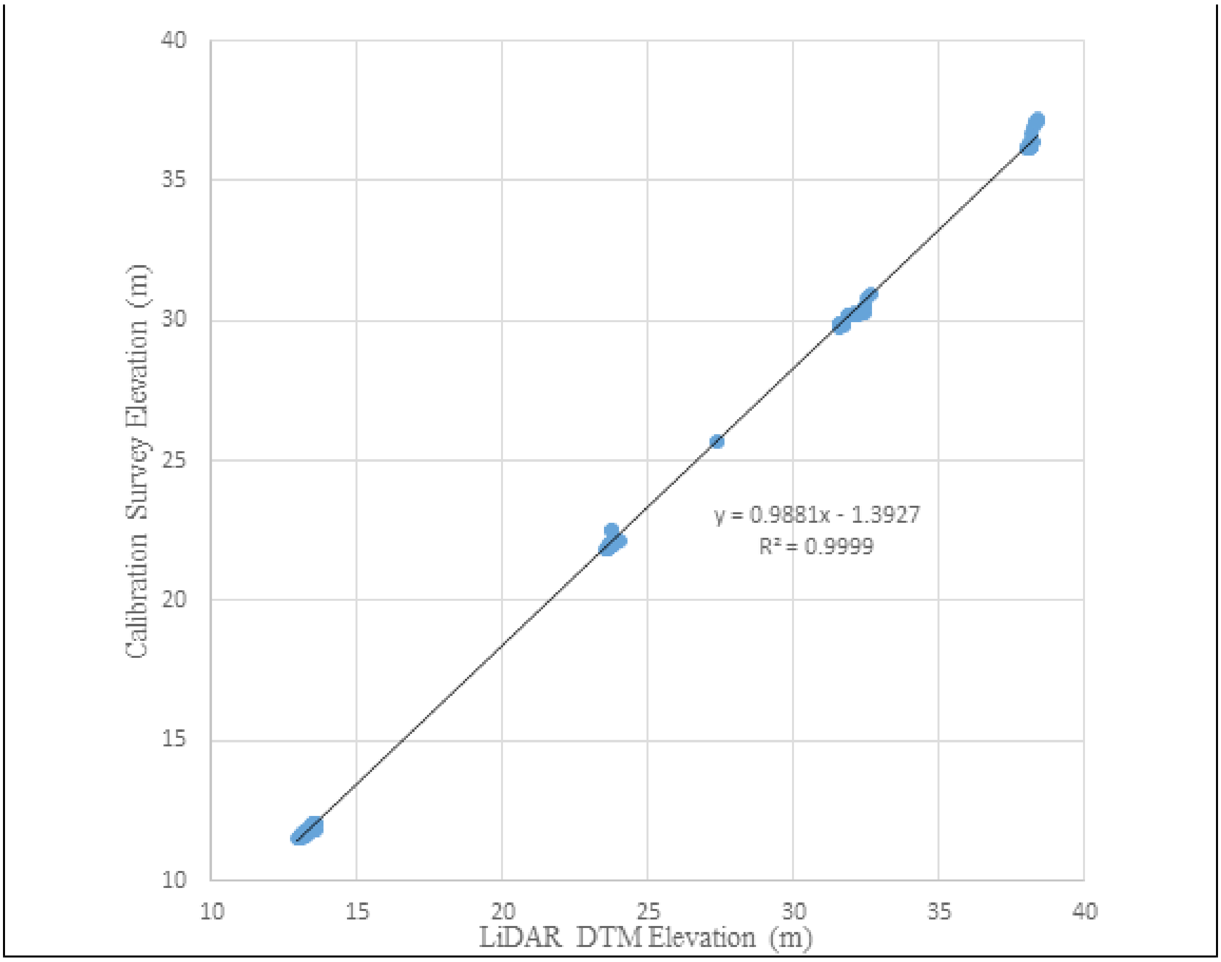


Figure 24. Correlation plot between calibration survey points and LiDAR data

Table 15. 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 125 survey points that are within Cairawan flood plain were used for the validation of the calibrated Cairawan 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.03 meters with a standard deviation of 0.02 meters, as shown in Table 16.

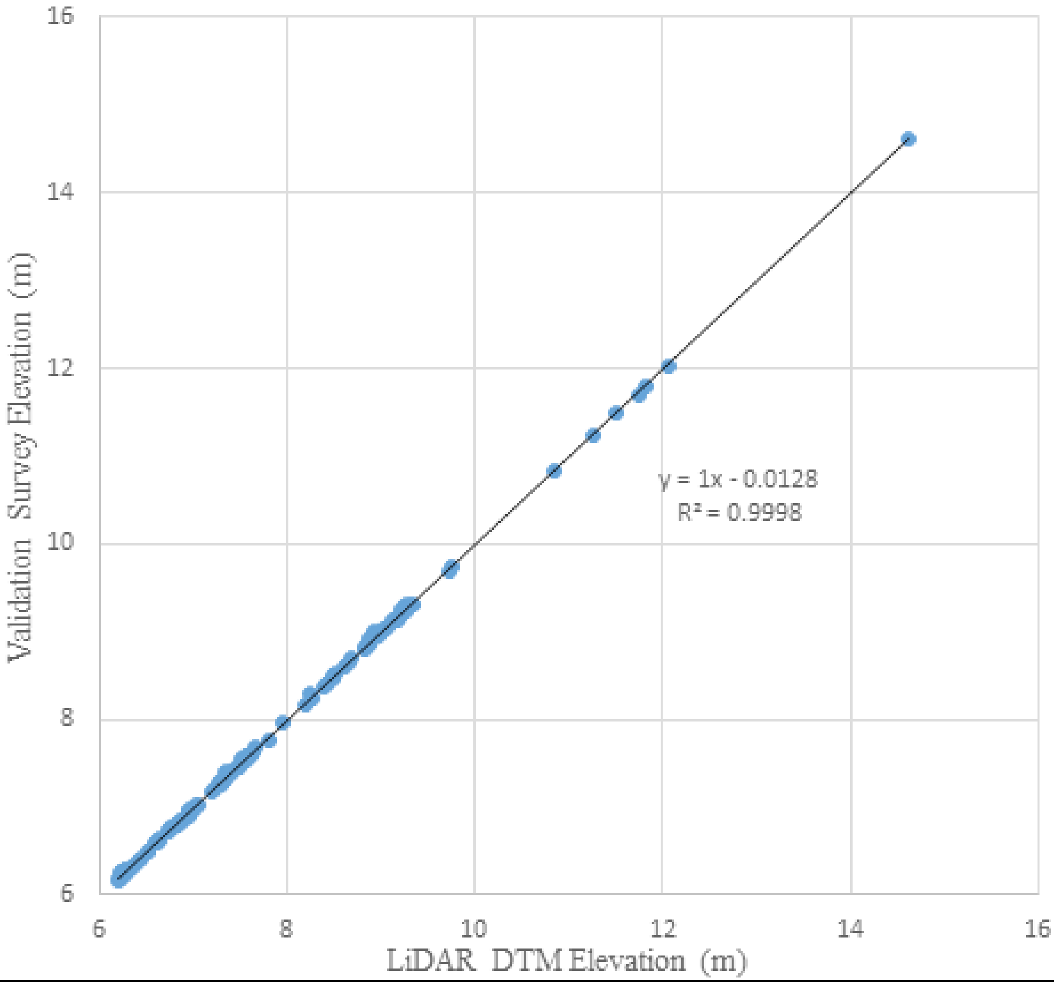


Figure 25. Correlation plot between validation survey points and LiDAR data

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.03
Standard Deviation	0.02
Average	-0.01
Minimum	-0.04
Maximum	-0.01

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Cairawan with 423 bathymetric survey points. The produced resulting raster surface was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.12 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Cairawan integrated with the processed LiDAR DEM is shown in Figure 26.

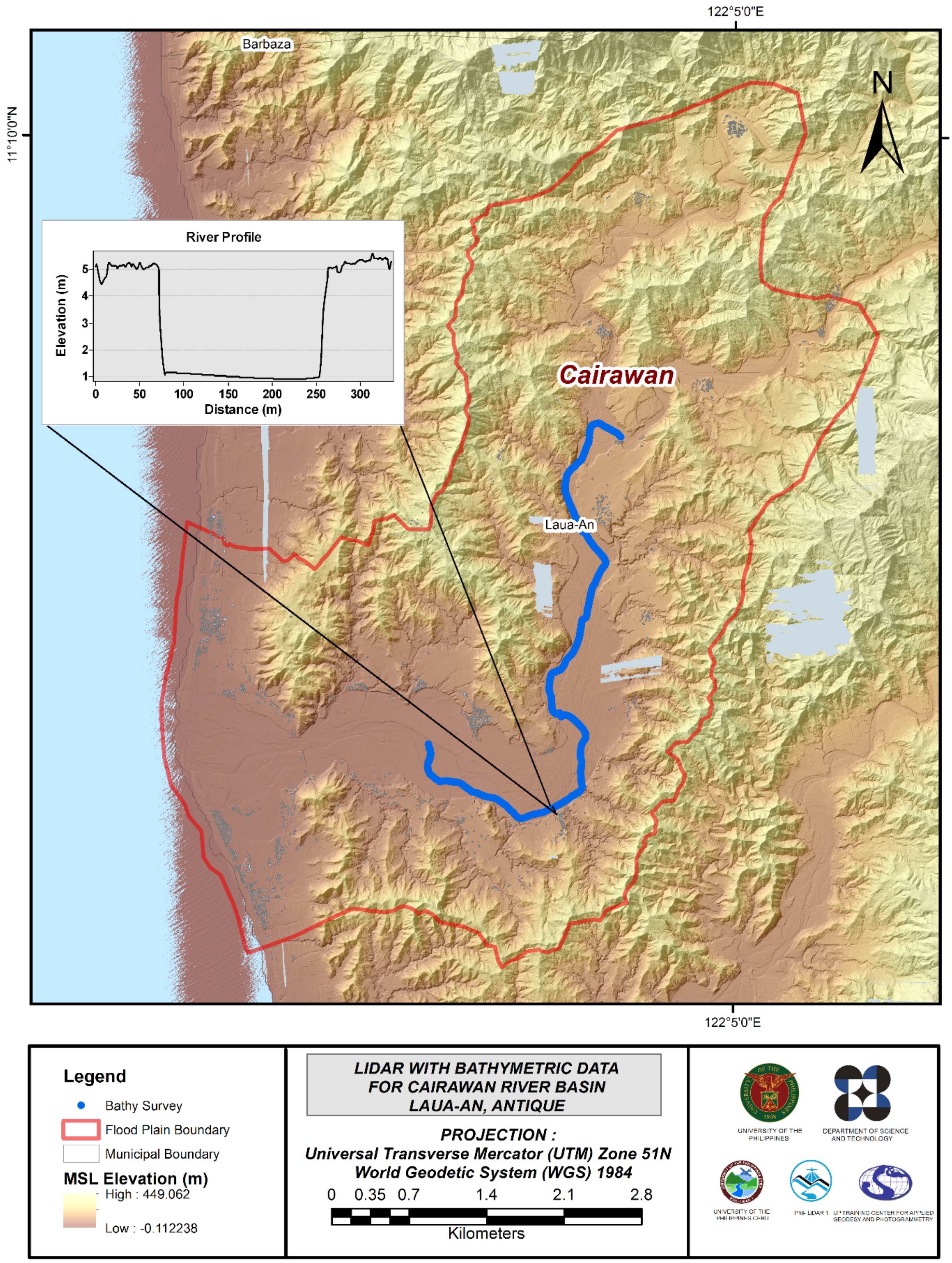


Figure 26. Map of Cairawan Floodplain with bathymetric survey points shown in blue

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 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, 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 essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Cairawan Floodplain, including its 200 m buffer, has a total area of 32.71 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,135 building features, are considered for QC. Figure 27 shows the QC blocks for Cairawan Floodplain.

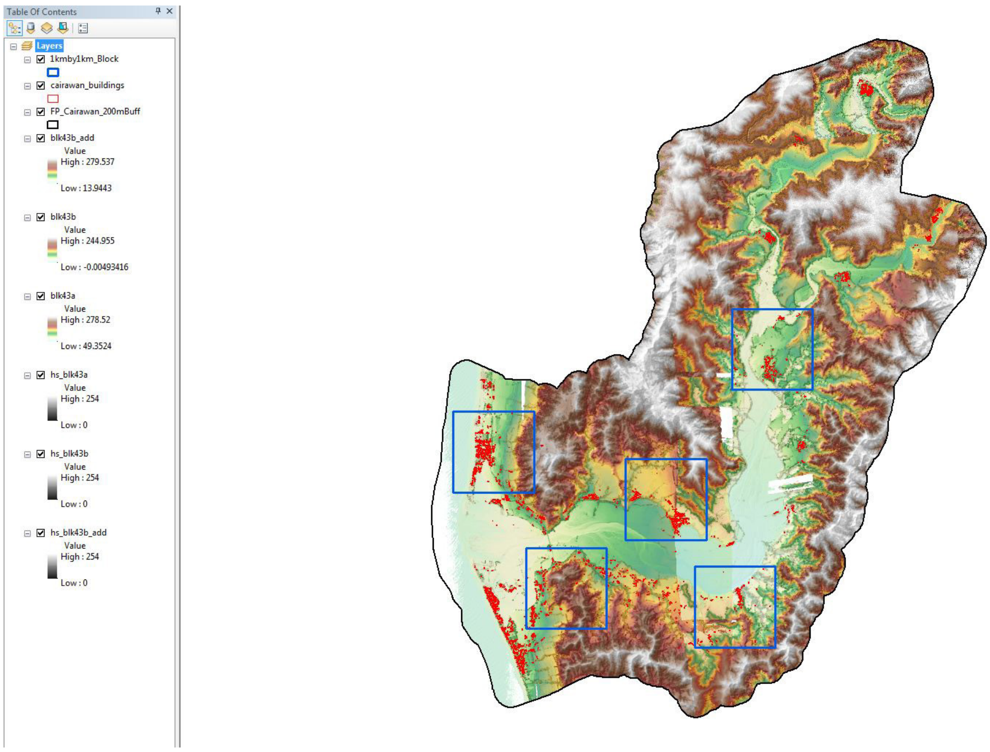


Figure 27. QC blocks for Cairawan building features

Quality checking of Cairawan building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Cairawan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Cairawan	99.49	99.49	90.88	PASSED

3.12.2 Height Extraction

Height extraction was done for 2,866 building features in Cairawan Floodplain. Out of these building features, forty two (42) were filtered out after height extraction, resulting to 2,824 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 5.28 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

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

Table 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Cairawan Floodplain

Facility Type	No. of Features
Residential	2,683
School	49
Market	0
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	2
Barangay Hall	17
Military Institution	0
Sports Center/Gymnasium/Covered Court	4
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	22
Bank	0
Factory	0
Gas Station	2
Fire Station	0
Other Government Offices	16
Other Commercial Establishments	28
Total	**2,824**

Table 19. Total Length of Extracted Roads for Cairawan Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Cairawan	8.75	0	12.40	4.50	0.00	**25.65**

Table 20. Number of Extracted Water Bodies for Cairawan Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cairawan	3	0	0	0	0	**3**

A total of one (1) bridge 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 completed the feature extraction phase of the project.

Figure 28 shows the Digital Surface Model (DSM) of Cairawan Floodplain overlaid with its ground features.

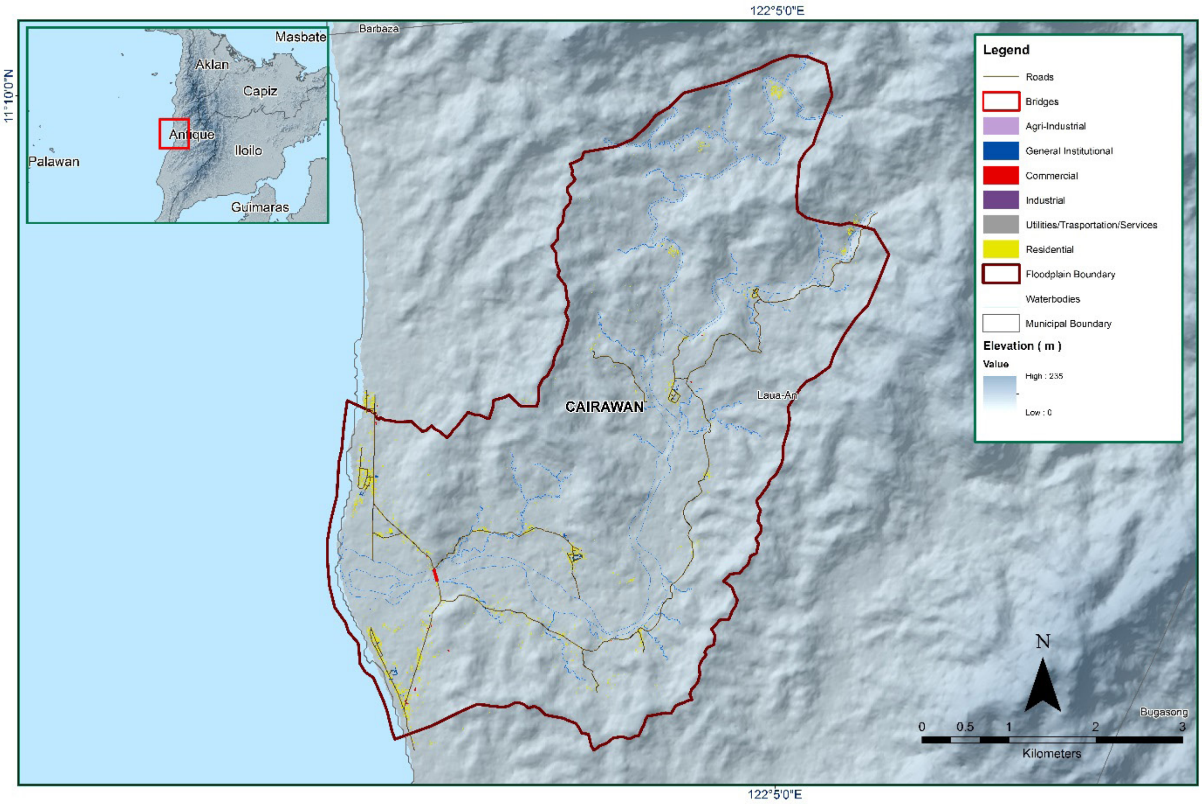


Figure 28. Extracted features for Cairawan Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE CAIRAWAN RIVER BASIN

Engr. L

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Cairawan River from September 25 to October 9, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built of Cairawan Bridge piers; ground validation data acquisition survey of about 82.264 km for the whole province of Antique; and bathymetric survey from Brgy. Lupa-An, Municipality of Laua-An, Antique down to Brgy. Liberato, Municipality of Laua-An, Antique with an estimated length of 6 km using GNSS PPK survey technique.

4.2 Control Survey

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

A control point was established on the approach of Tipuluan Bridge, namely: TPN-1, in Brgy. Pasong, Brgy. Sibalom, Antique, to use as marker during the survey.

The summary of references and control points used in Cairawan Survey is shown in Table 21, while the GNSS network established is illustrated in Figure 29.

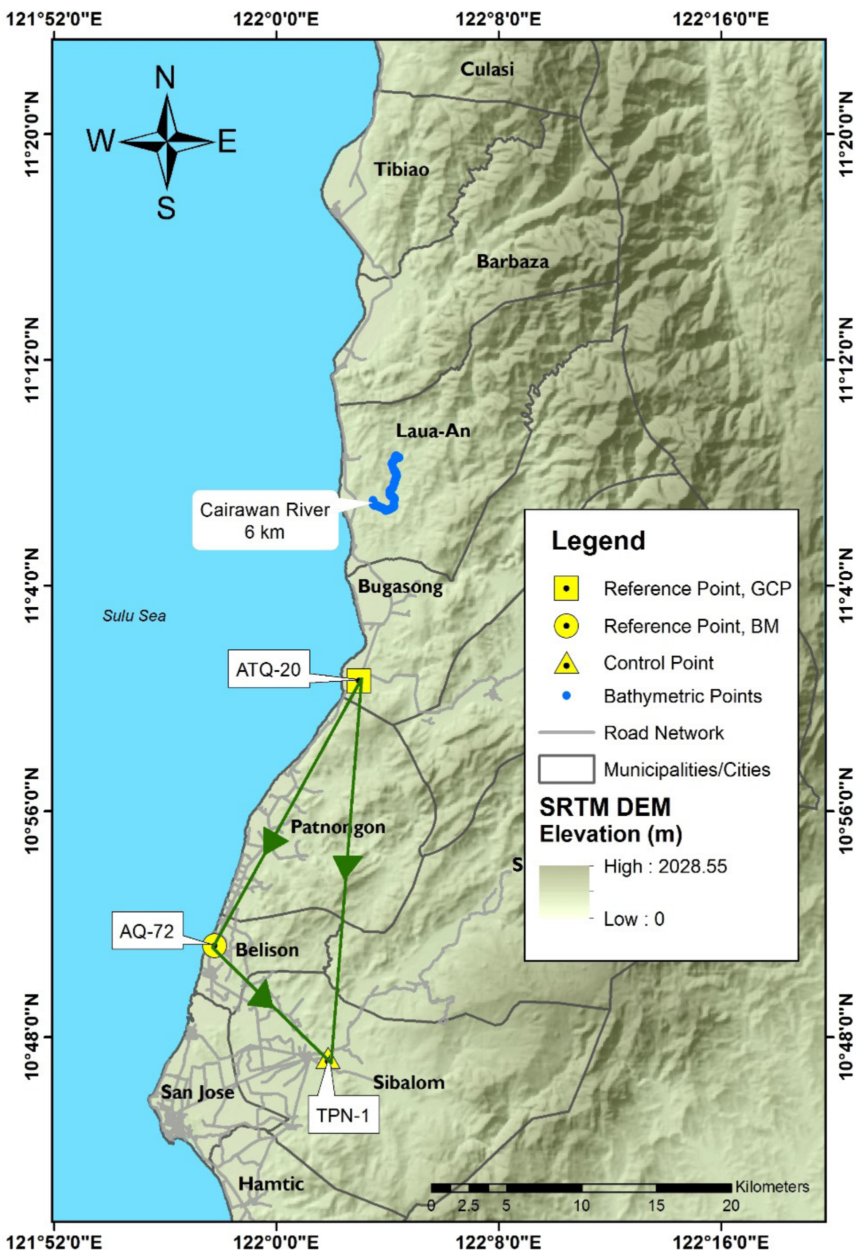


Figure 29. Cairawan GNSS network survey

Table 21. List of references and control points used in Cairawan River survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	BM Ortho (Meter)	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

The GNSS set up of each reference and control points are exhibited in Figures 30 to 33.

Figure 30. GNSS base receiver setup, Trimble® SPS 852 at ATQ-20 in Brgy. Zaragoza, Municipality of Bugasong, Antique

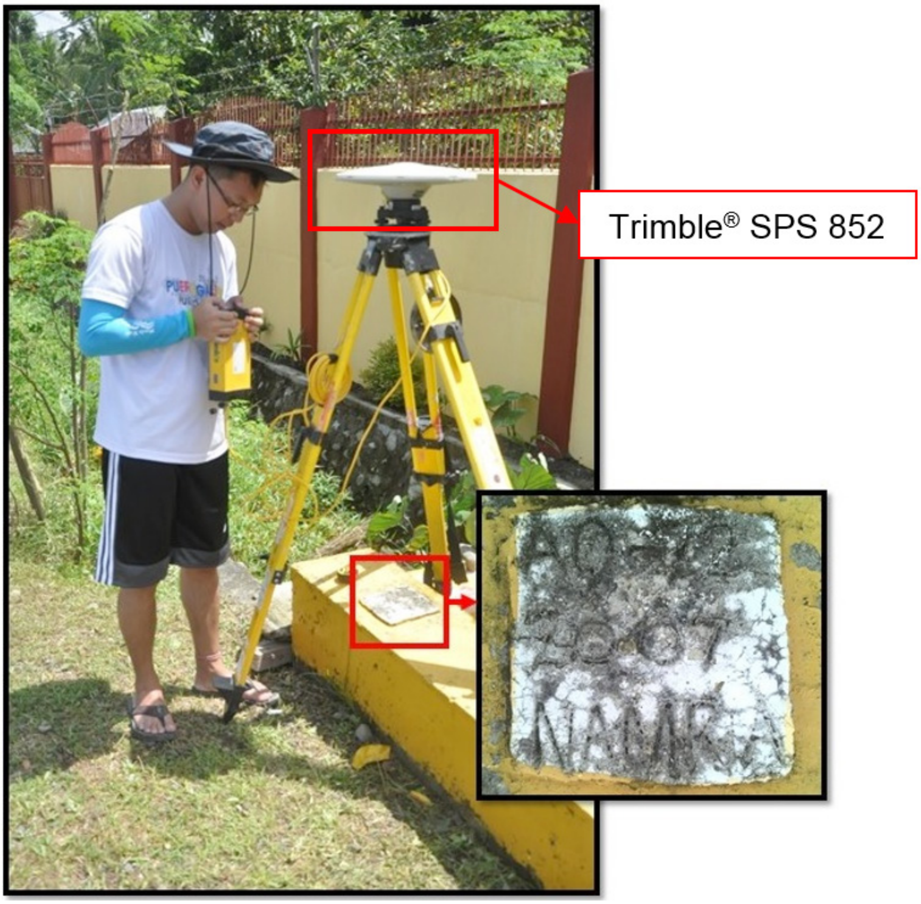


Figure 31. Benchmark, AQ-72, with Trimble® SPS 852 in Brgy. Delima, Municipality of Belison, Antique

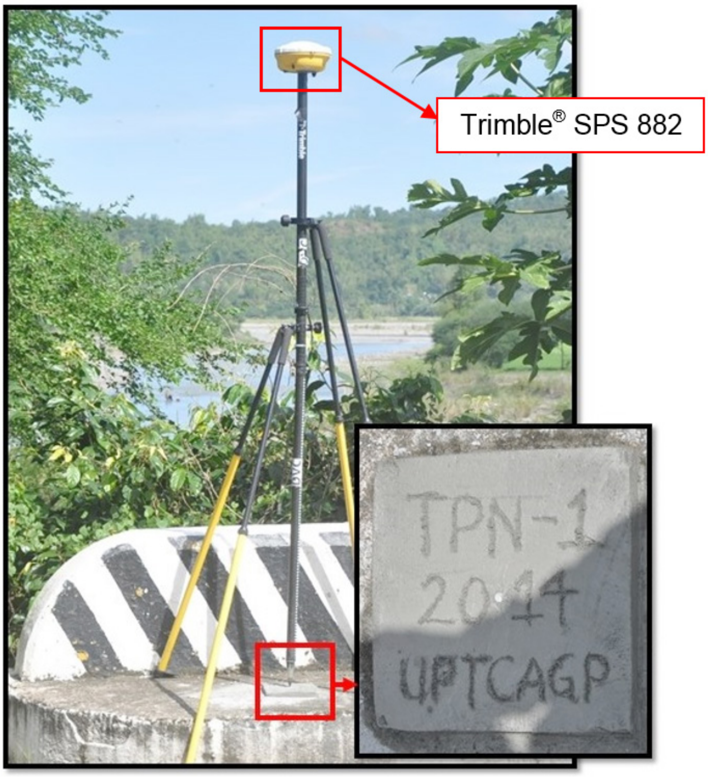


Figure 32. UP-TCAGP established control point, TPN-1, with Trimble® SPS 882 on Tipuluan Bridge in Brgy. Pasong, Municipality of Sibalom, Antique

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking 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, resurvey is initiated. Baseline processing result of control points in Cairawan River Basin is summarized in Table 22 generated by TBC software.

Table 22**.** Baseline Processing Report for Cairawan 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 22, 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 them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. Tables 23 to 26 show the results of GNSS network adjustment.
The control point in which the coordinates were fixed during the network adjustment is shown in Table 23. Through this reference point, the coordinates of the unknown control points were computed. A difference in elevation of 0.9288 m between geoid (EGM2008) and MSL values of the reference point AQ-72 was applied for referring the elevation of the control points to MSL.

Table *23.* Control Point Constraints

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 is indicated in Table 24. The fixed control point, ATQ-20, has no values for standard errors.

Table 24. Adjusted Grid Coordinates

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 is fixed at the reference point, ATQ-20, with known coordinates. With the mentioned equation, for horizontal and for the vertical; the computation for the horizontal and vertical accuracy are as follows:

a. AQ-72
horizontal accuracy = √((6.3)² + (3.3)²
= √(39.69 + 10.89)
= 7.11 cm < 20 cm

b. TPN-1
horizontal accuracy = √((5.8)² + (3.1)²
= √(33.64 + 9.61)
= 6.58 cm < 20 cm

The list of adjusted geodetic coordinates: Latitude, Longitude, Height and computed standard errors of the control points in the network are shown in Table 25.

Table 25. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	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 shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (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

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

Cross-section and as-built survey were conducted on October 1, 2014 along the downstream side of Cairawan Bridge, Brgy. Liya-Liya, Municipality of Laua-An using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 33.

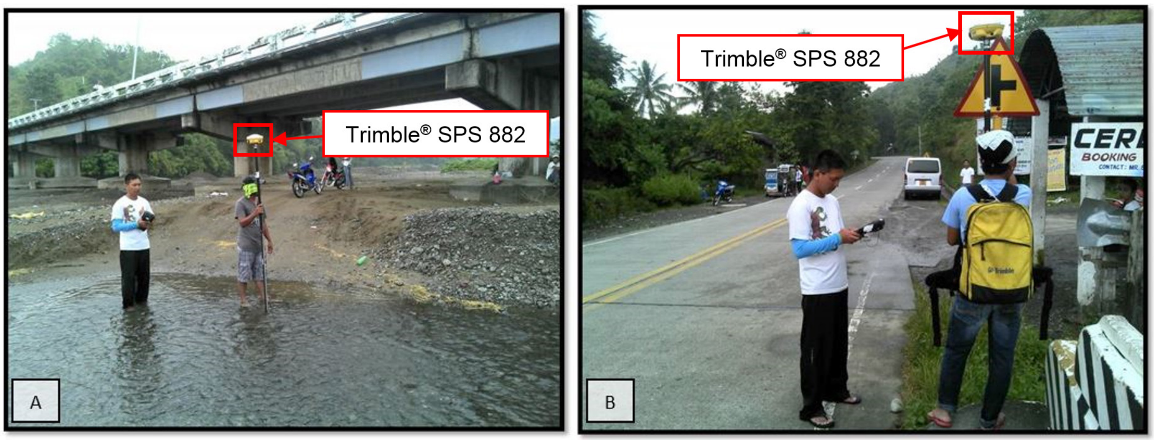


Figure 33. (A) Cross section survey and (B) As-built survey in Cairawan Bridge, Municipality of Laua-An

The cross-sectional line for Cairawan Bridge is about 124.59 m with 18 points gathered using ATQ-20 as the GNSS base station. The summary of gathered location map, cross-section, and as-built data of the bridge are indicated in Figures 34 to 36.

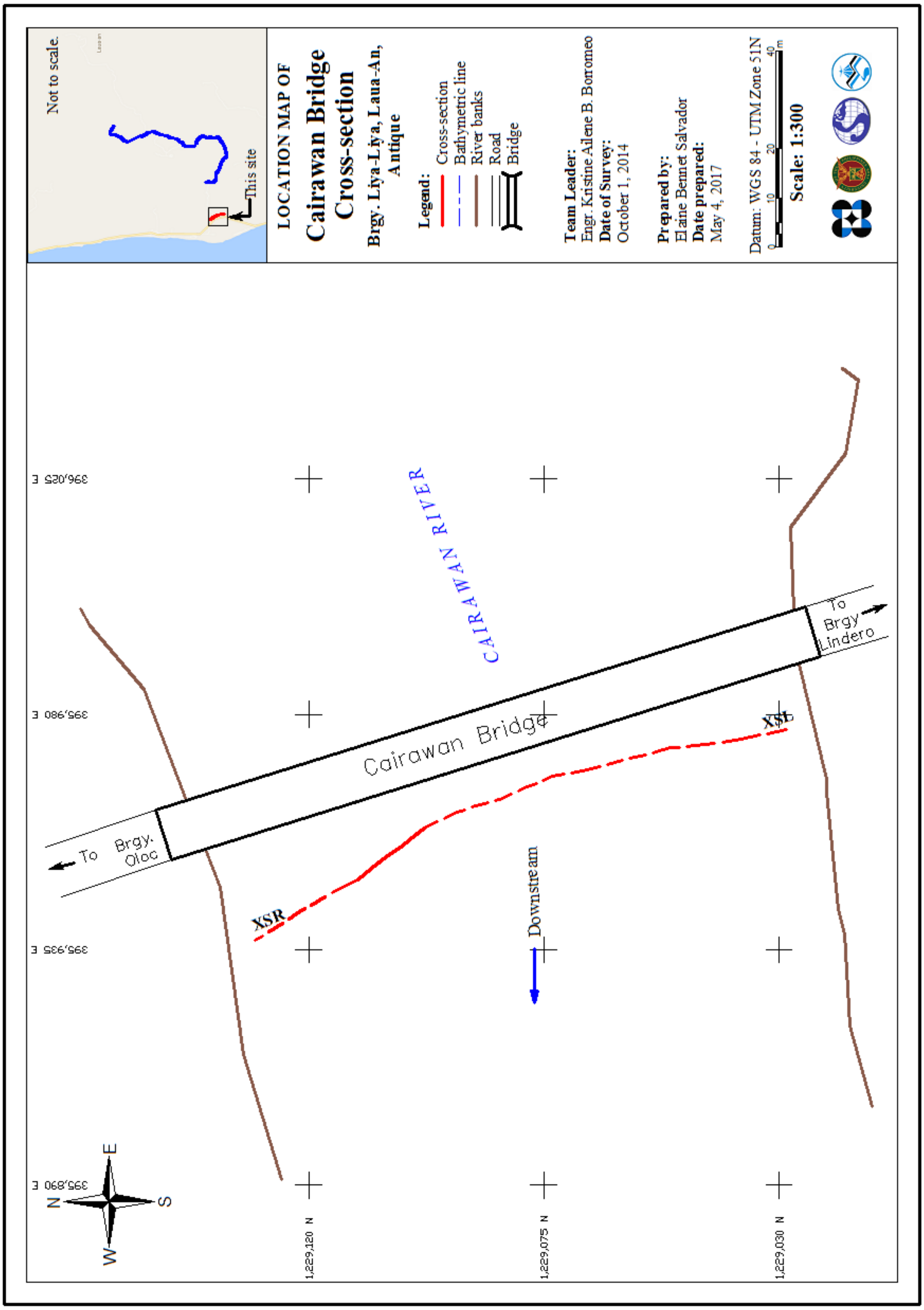


Figure 34. Location Map of Cairawan Bridge cross-section

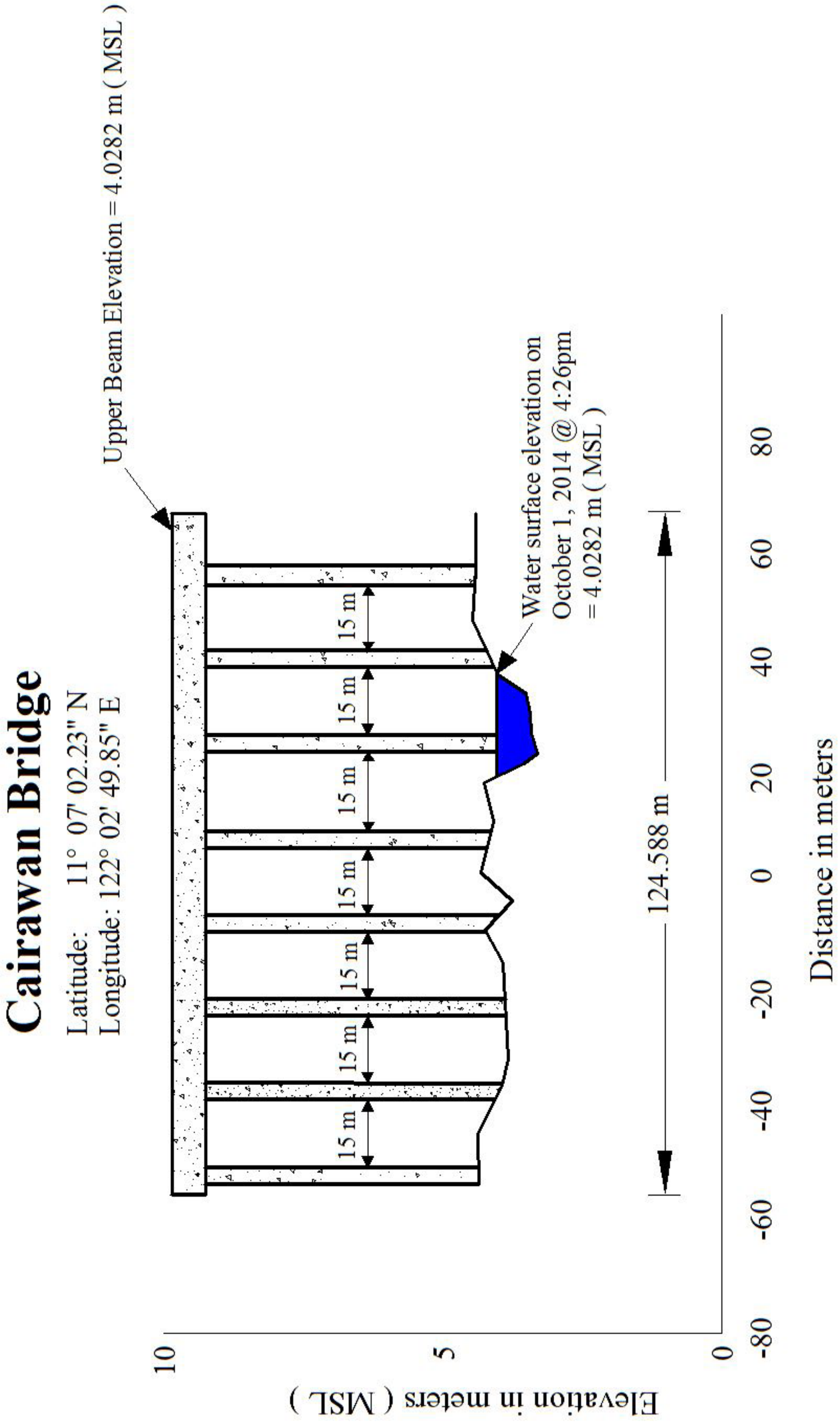


Figure 35. Cairawan Bridge cross-section diagram

Bridge Data Form

Culvert Name: **Cairawan Bridge** **Date:** **October 1, 2014**

River Name: **Cairawan River** **Time:** **4:36PM**

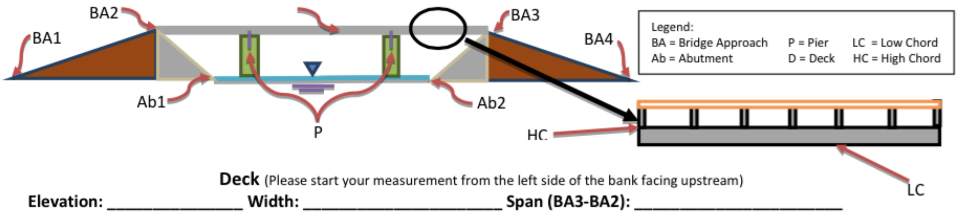
Location (Brgy, City,Region): **Municipality of Lauan-An, Antique Province**

Survey Team: **Antique Survey Team**

Flow condition: low **normal** high

Weather Condition: **fair** raining

Latitude: **11d07'02.23"** **Longitude:** **122d02'49.85"**



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

Elevation: _______________ **Width:** ______________________ **Span (BA3-BA2):** _______________________

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

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

	Station(Distance from BA3)	Elevation		Station(Distance from BA1)	Elevation (MSL)
BA1	n/a	n/a	BA3	0	9.87 m
BA2	n/a	n/a	BA4	n/a	n/a

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

	Station (Distance from BA1)	Elevation
Ab1	n/a	n/a
Ab2	n/a	n/a

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

Shape: rectangular Number of Piers: 8 Height of column footing: _______________

	Station (Distance from BA3)	Elevation (MSL)	Pier Width
Pier 1	17.31 m	9.87 m	n/a
Pier 2	32.14 m	9.87 m	n/a
Pier 3	47.10 m	9.87 m	n/a
Pier 4	62.59 m	9.82 m	n/a
Pier 5	79.48 m	9.86 m	n/a
Pier 6	94.44 m	9.99 m	n/a
Pier 7	109.40 m	9.88 m	n/a
Pier 8	124.58 m	9.86 m	n/a

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

Figure 36. Cairawan Bridge Data Form

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 3, 5, and 6, 2014 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 37. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 1.53 m was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topography mode.

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

Figure 37. (A) Setup 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 using the base station ATQ-20, as shown in the map in Figure 38.

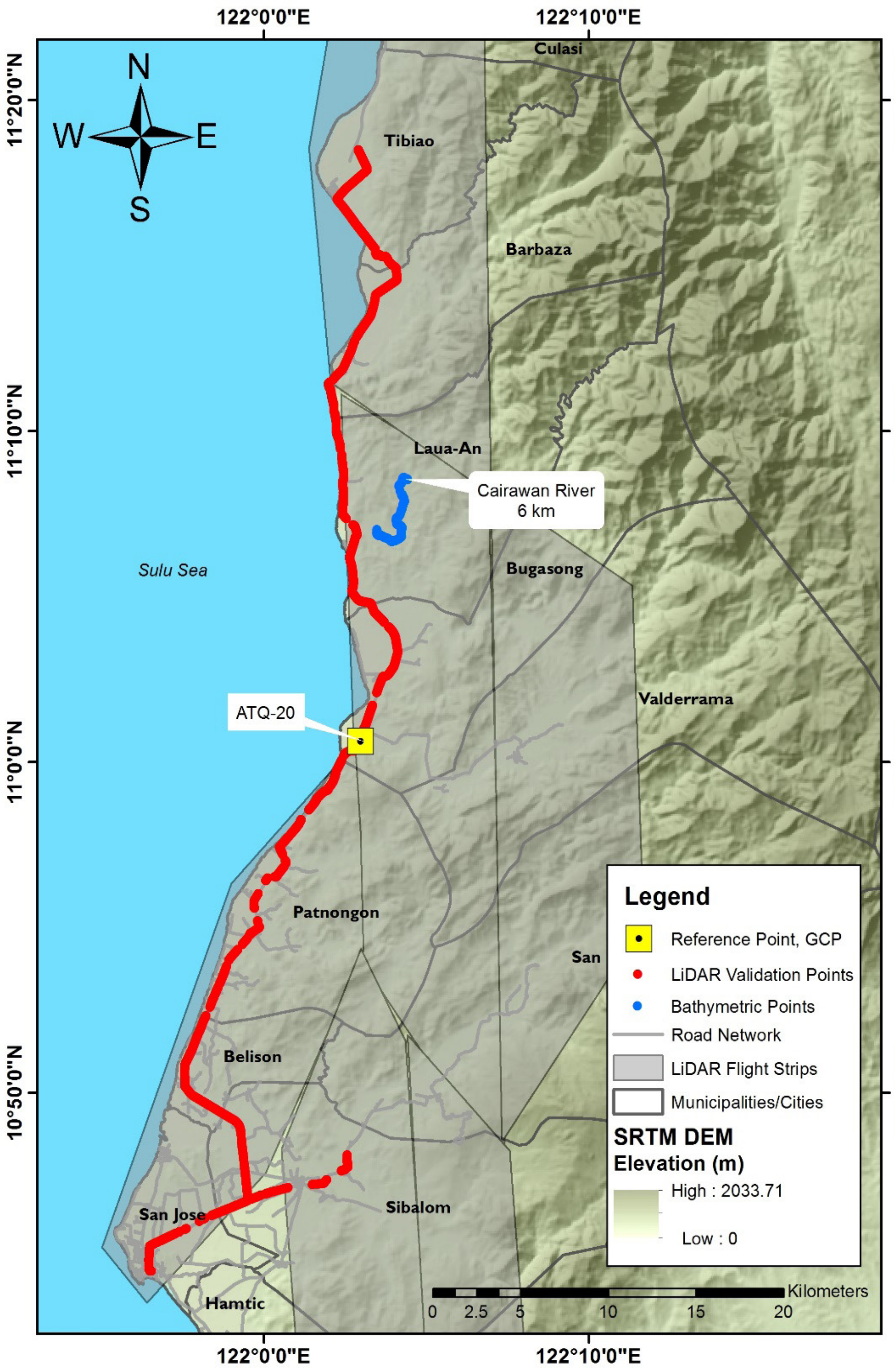


Figure 38. Validation Points Acquisition Survey along Antique Province

4.7 River Bathymetric Survey

Manual Bathymetric Survey was executed on October 7, 2014 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 39. The survey team, with the assistance of personnel from the Municipality of Laua-An, started upstream in Brgy. Lupa-An, Municipality of Laua-An with coordinates 11°08'31.79733" 122°04'26.20547", traversed down the river by foot, and ended the survey in Brgy. Casit-An, Municipality of Laua-An with coordinates 11°06'59.40475" 122°03'29.76569". Heavy rains prohibited the continuation of the survey down to the mouth of the river in Brgy. Liya-Liya.

Figure 39. Execution of Bathymetric Survey along Cairawan River accompanied by personnel from the Municipality

The bathymetric line has an estimated length of 6 km with 279 points gathered using ATQ-20 as GNSS base station. The processed data were generated into a map using GIS and processed further using CAD for plotting the centerline of the river. Figure 40 shows the generated map that exhibits the bathymetric survey coverage while Figure 41 illustrates the Cairawan Riverbed profile. There is an abrupt change in elevation of about 25 m from upstream to downstream within the 3.7 km length covered during the bathymetric survey. The highest elevation was 37.88 m in MSL located in the upstream part of the river while the lowest was 8.60 m in MSL located in Brgy. Casit-An.

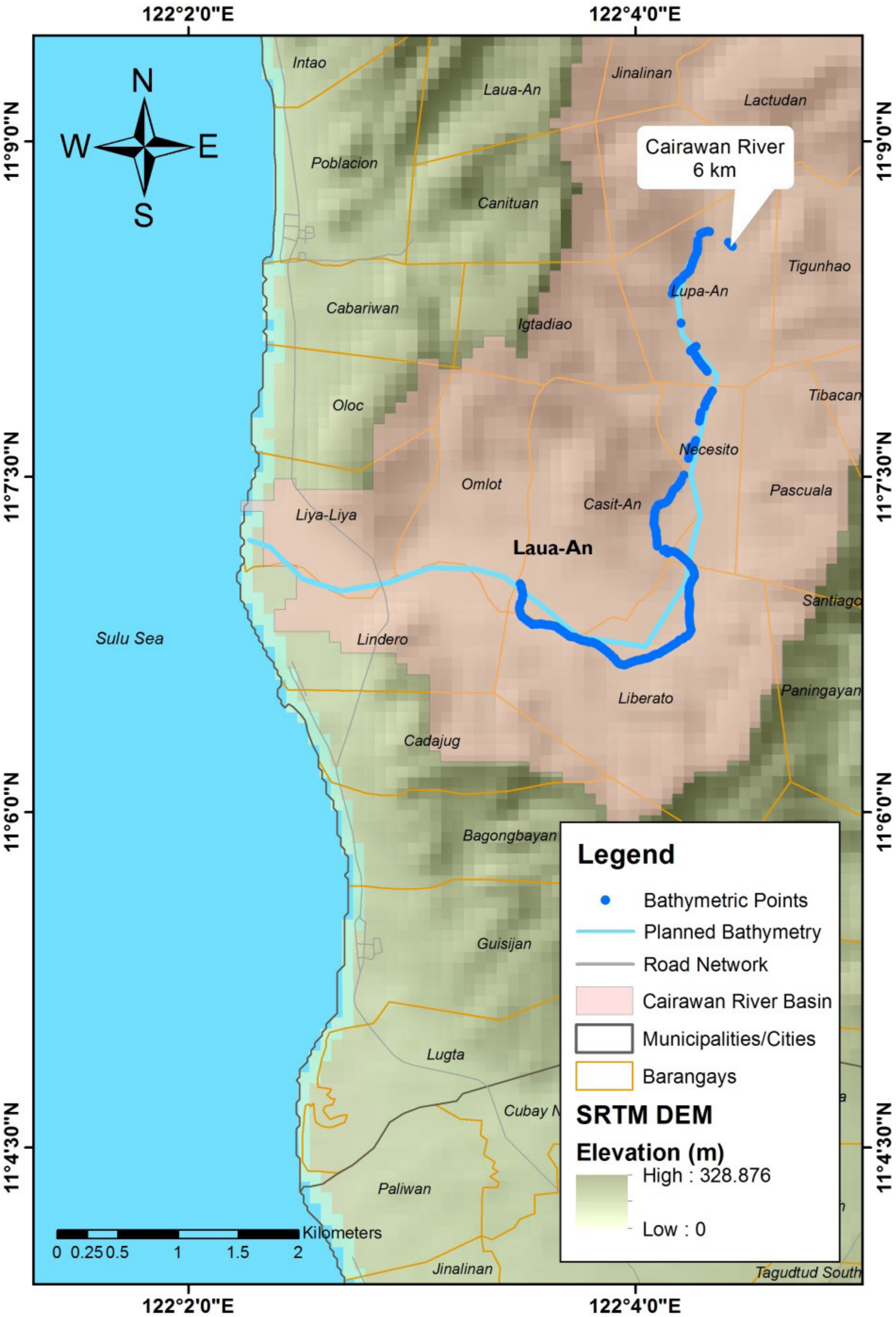


Figure 40. Bathymetric points gathered from Cairawan River

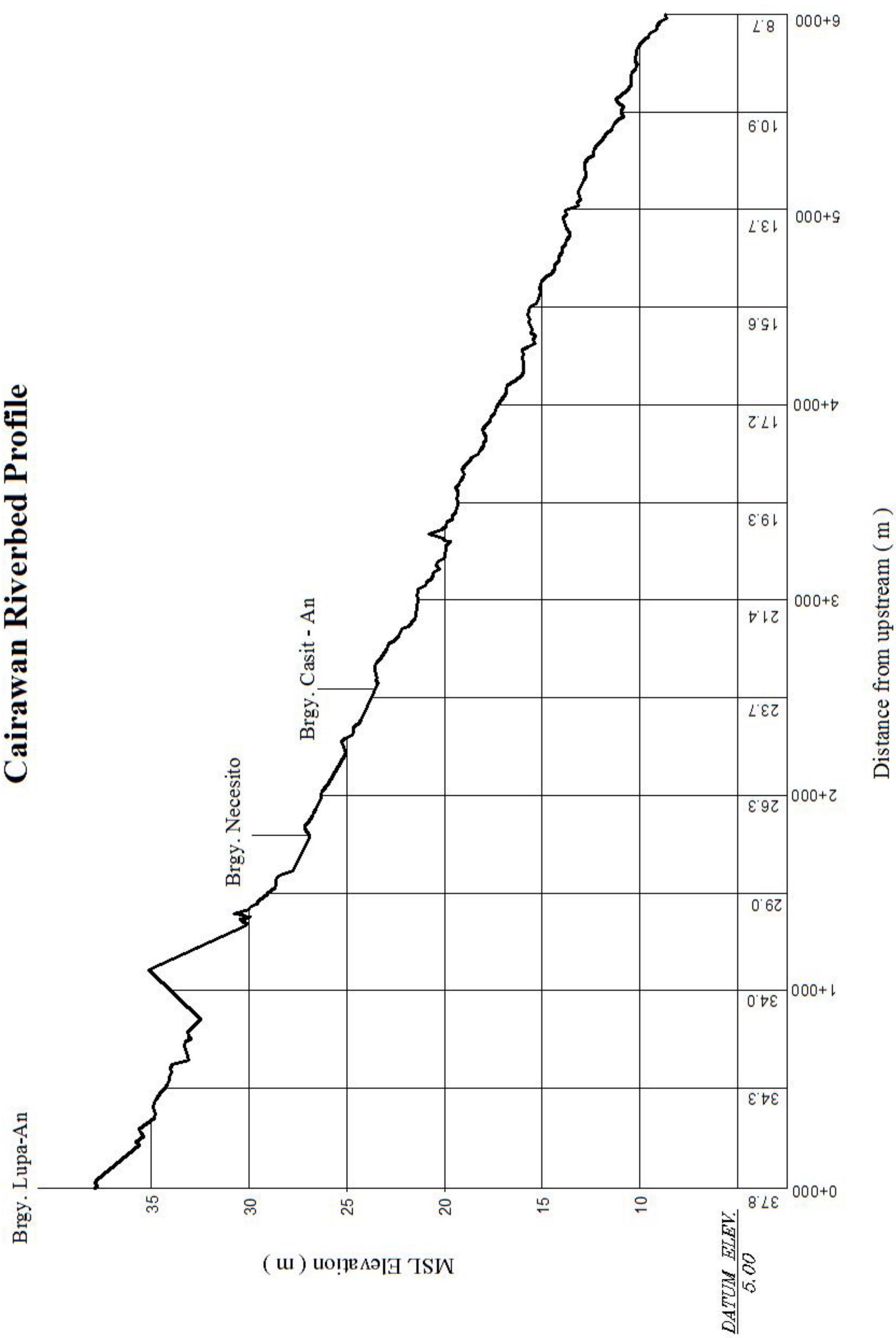


Figure 41. Riverbed Profile of Cairawan River

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, 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

The components and data that affect the hydrologic cycle of the river basin were monitored, collected, and analyzed. These include the rainfall, water level, and the flow in a certain period of time.

5.1.2 Precipitation

Precipitation data were taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Latazon, Laua-an, Antique (Figure 1). The precipitation data collection started from December 14, 2016 at 1:00 PM to 8:00 PM with 10 minutes recording interval.

The total precipitation for this event in Brgy Latazon ARG was 12.6 mm. It has a peak rainfall of 3 mm. on December 14, 2016 at 12:55 in the afternoon. The lag time between the peak rainfall and discharge is 1 hour and 10 minutes.

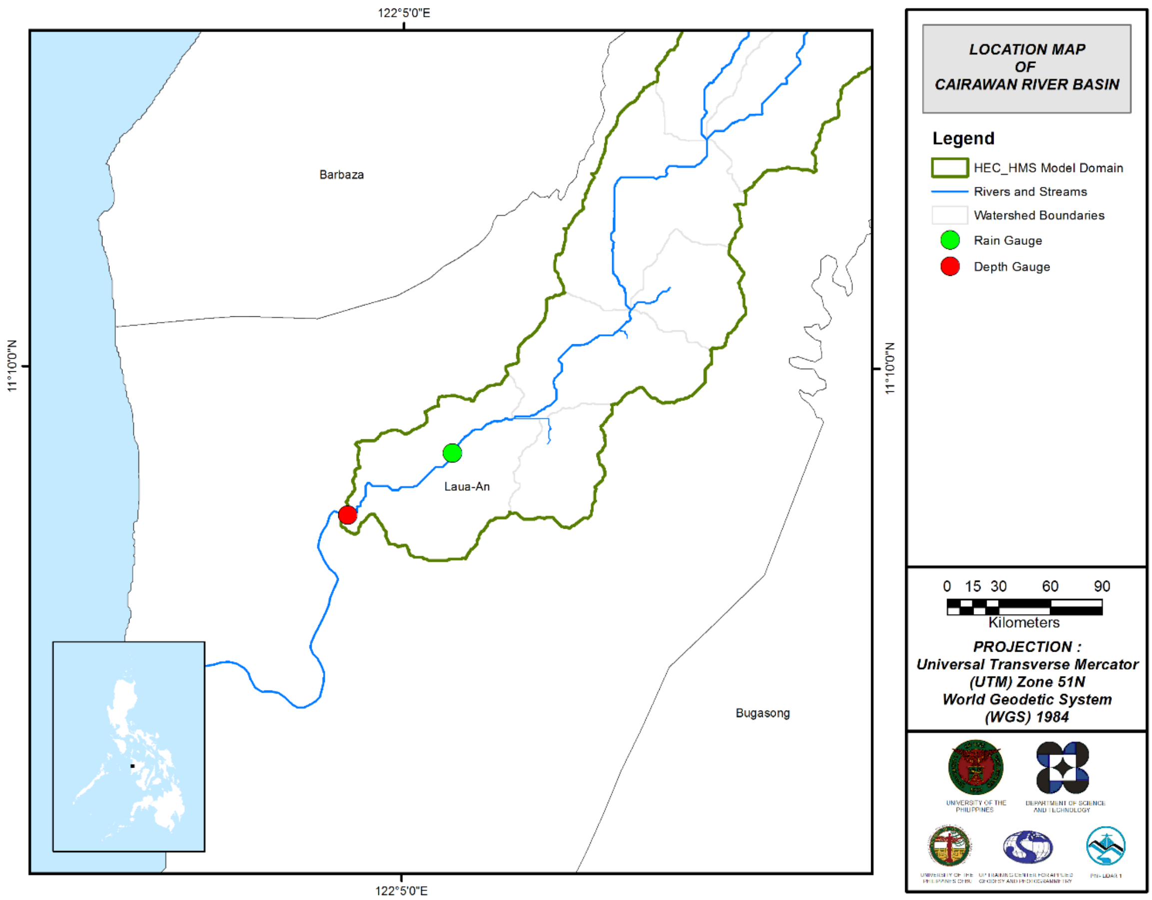


Figure 42. The location map of Cairawan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Kalahi CIDSS Foot Bridge, Brgy Latazon, Laua-an, Antique (11° 8'31.30"N, 122° 4'26.92"E). It gives the relationship between the observed water levels at Himogaan Bridge and outflow of the watershed at this location.
For Kalahi Footbridge, the rating curve is expressed as Q = 6E-19e$^{1.0753x}$ [see y formula] as shown in Figure 44.

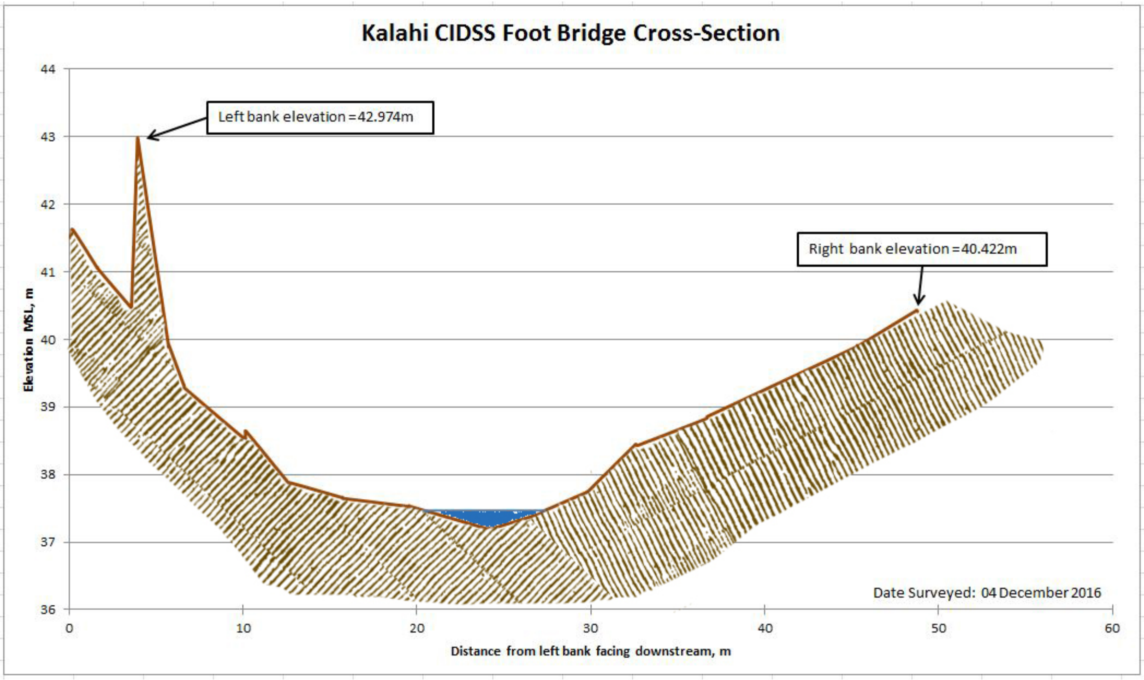


Figure 43. Cross-Section Plot of Kalahi Footbridge

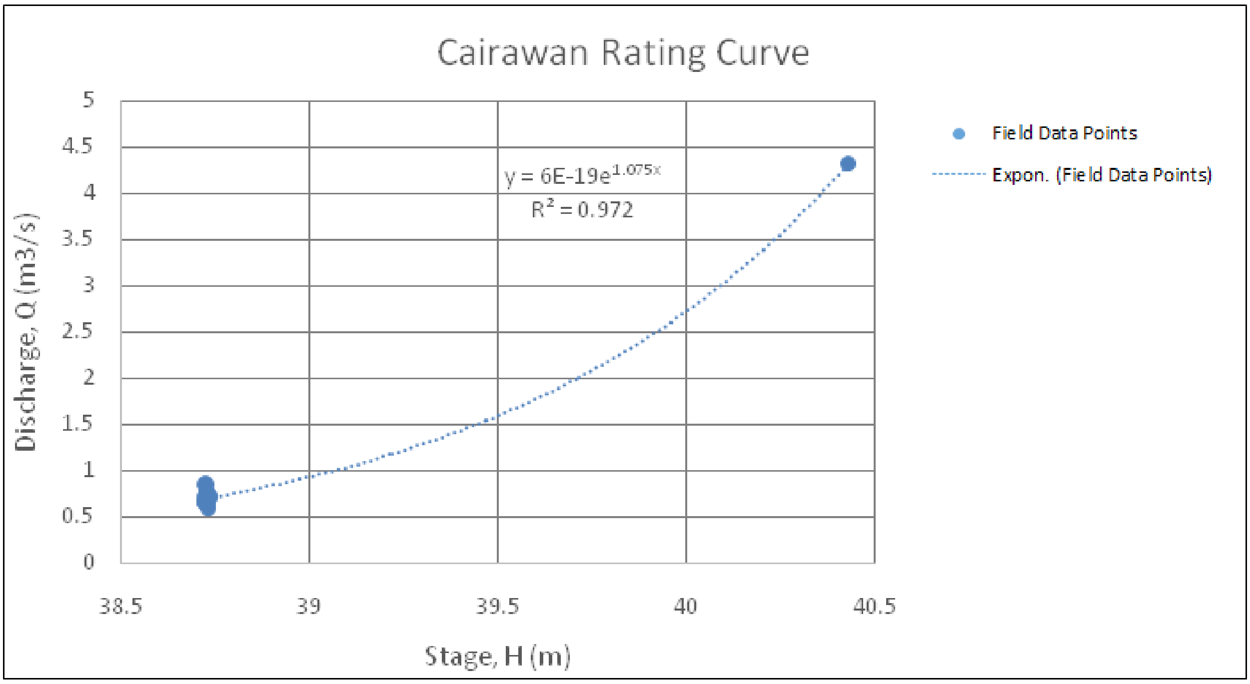


Figure 44. Rating Curve at Kalahi CIDSS Foot Bridge, Brgy Latazon, Laua-an, Antique

This rating curve equation was used to compute the river outflow at Kalahi Footbridge for the calibration of the HEC-HMS model shown in Figure 45. Peak discharge is 60.91 cubic meters per second at 3:30 PM, December 14, 2016.

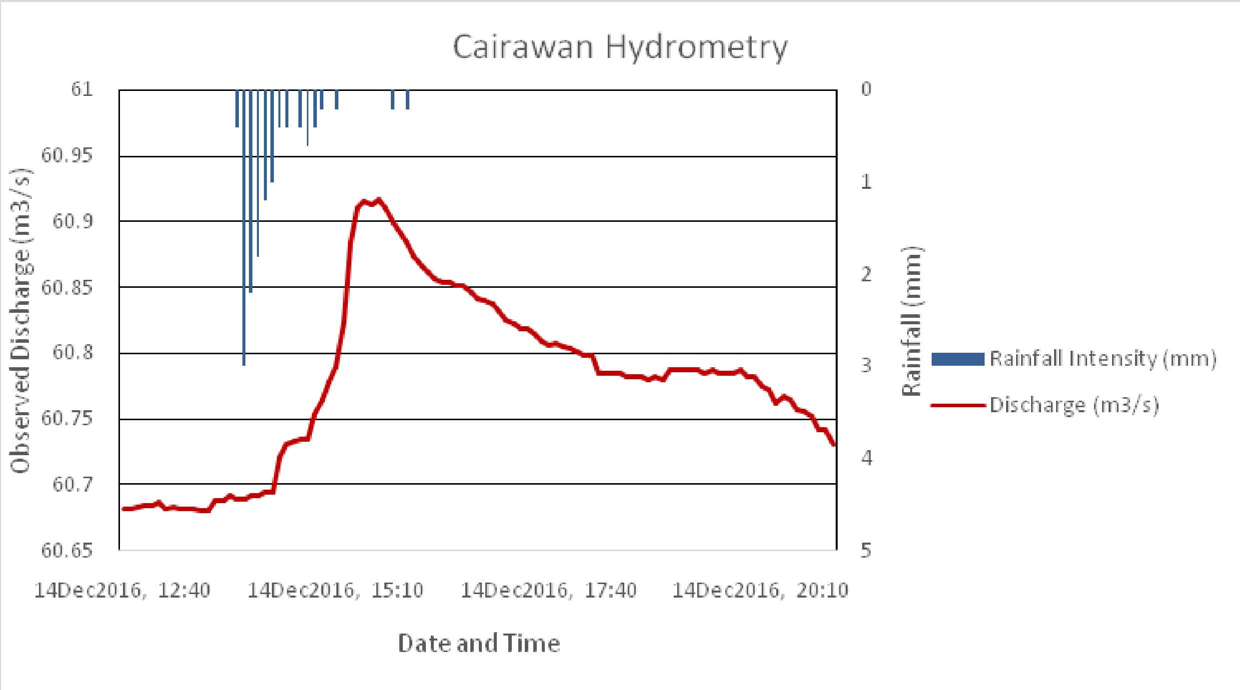


Figure 45. Rainfall and outflow data at Cairawan used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Cairawan watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 27. 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

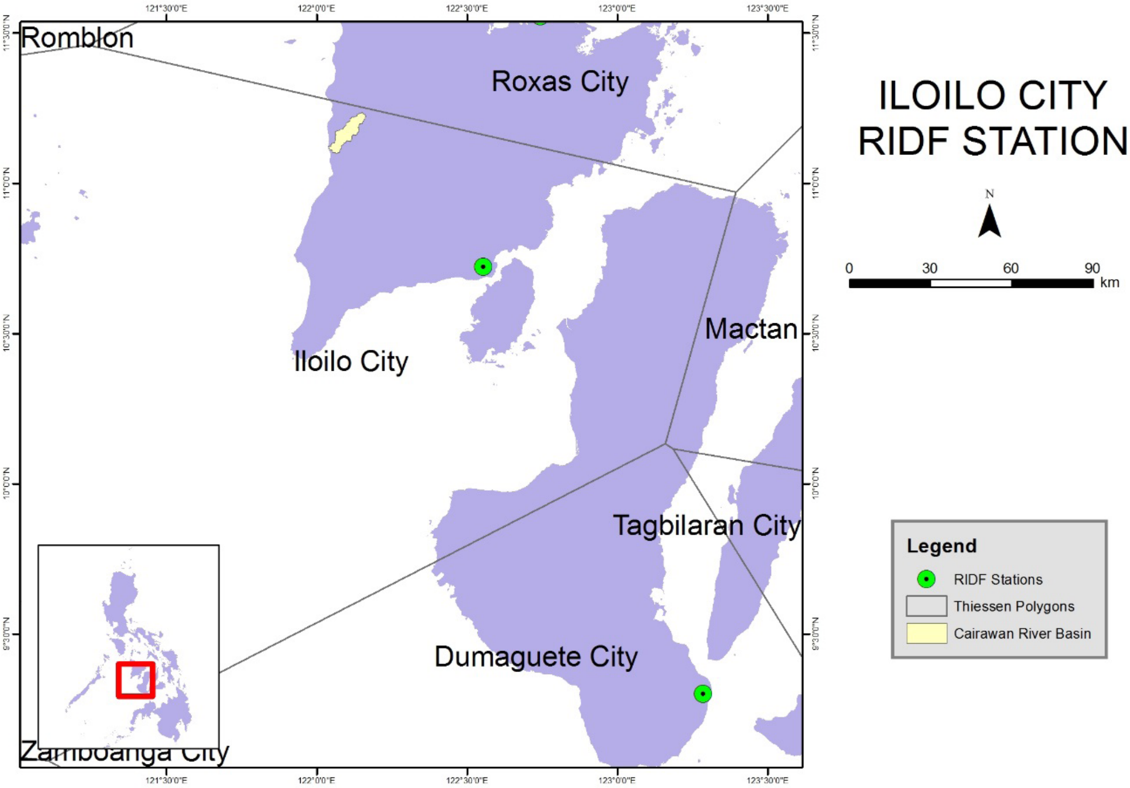


Figure 46. Location of Iloilo RIDF station relative to Cairawan River Basin

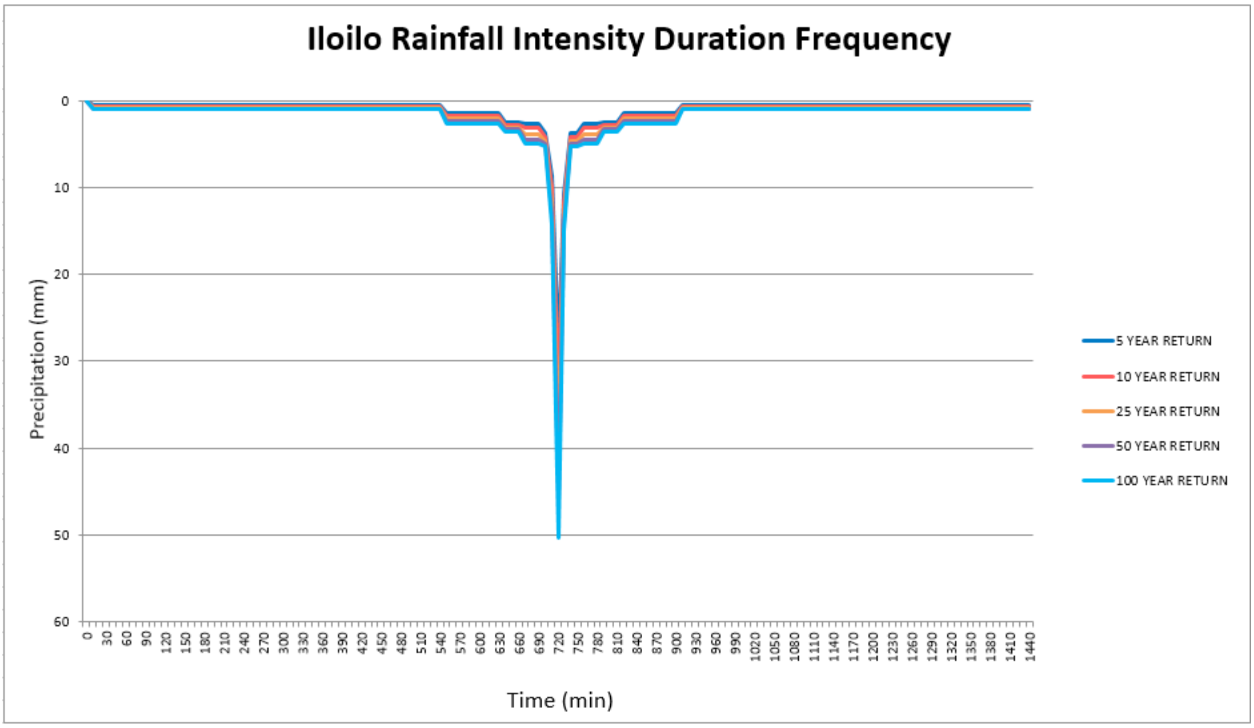


Figure 47. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management; this is nder the Department of Agriculture. The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Cairawan River Basin are shown in Figure 48 and Figure 49, respectively.

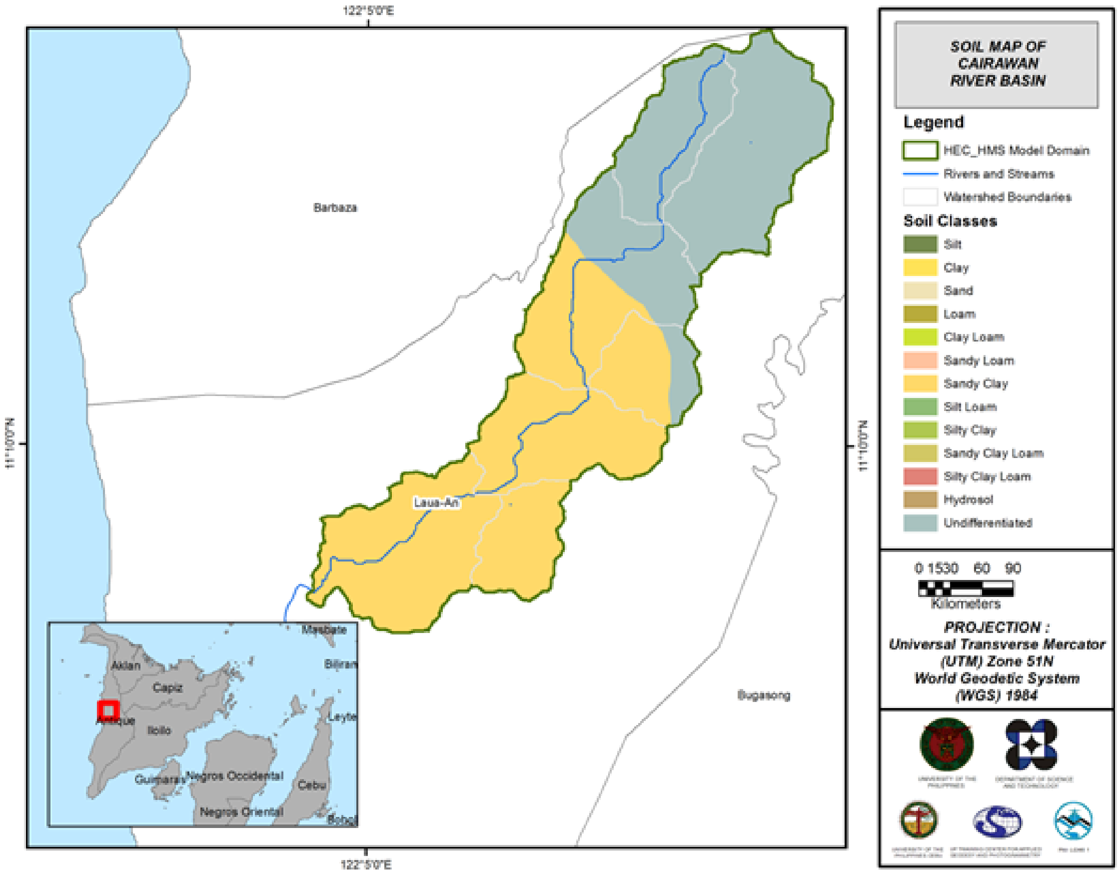


Figure 48. Soil map of the Cairawan River Basin

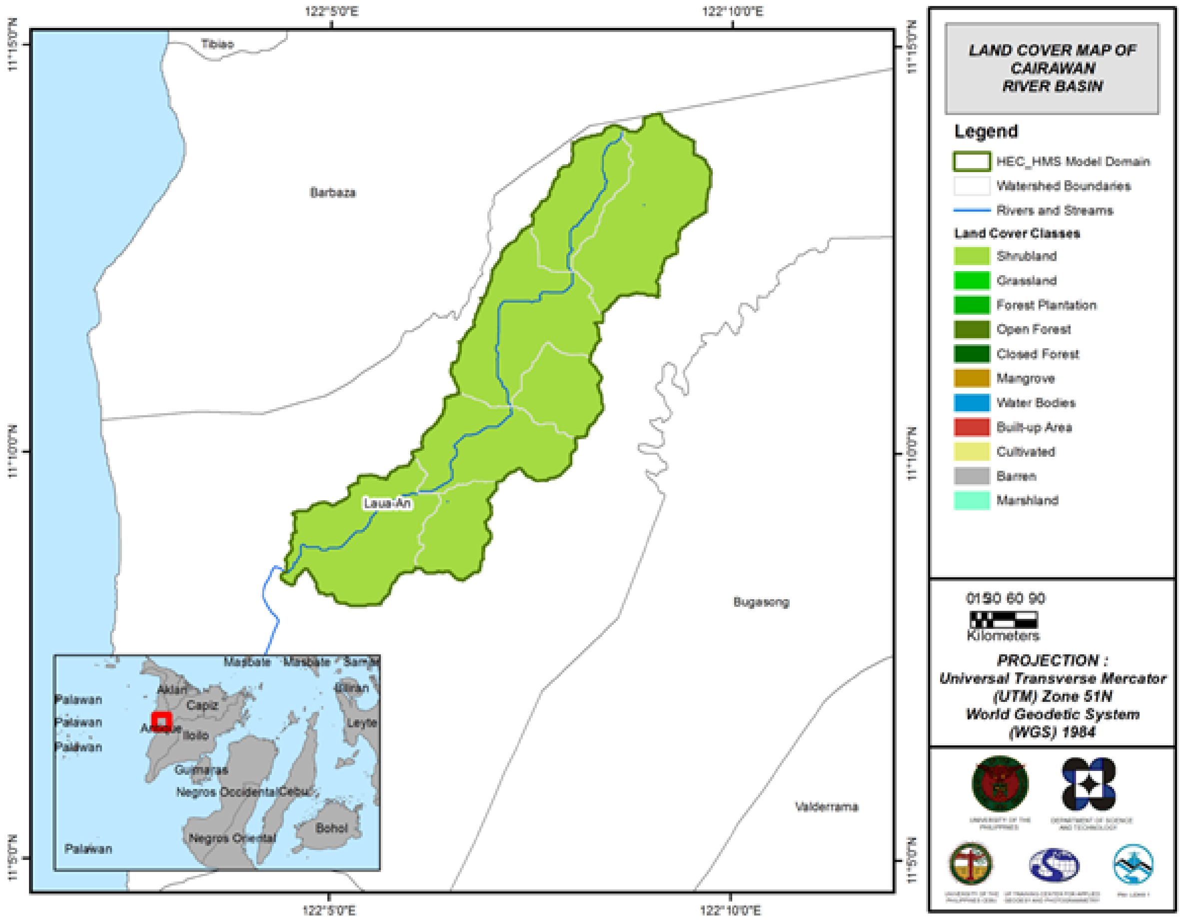


Figure 49. Land cover map of the Cairawan River Basin

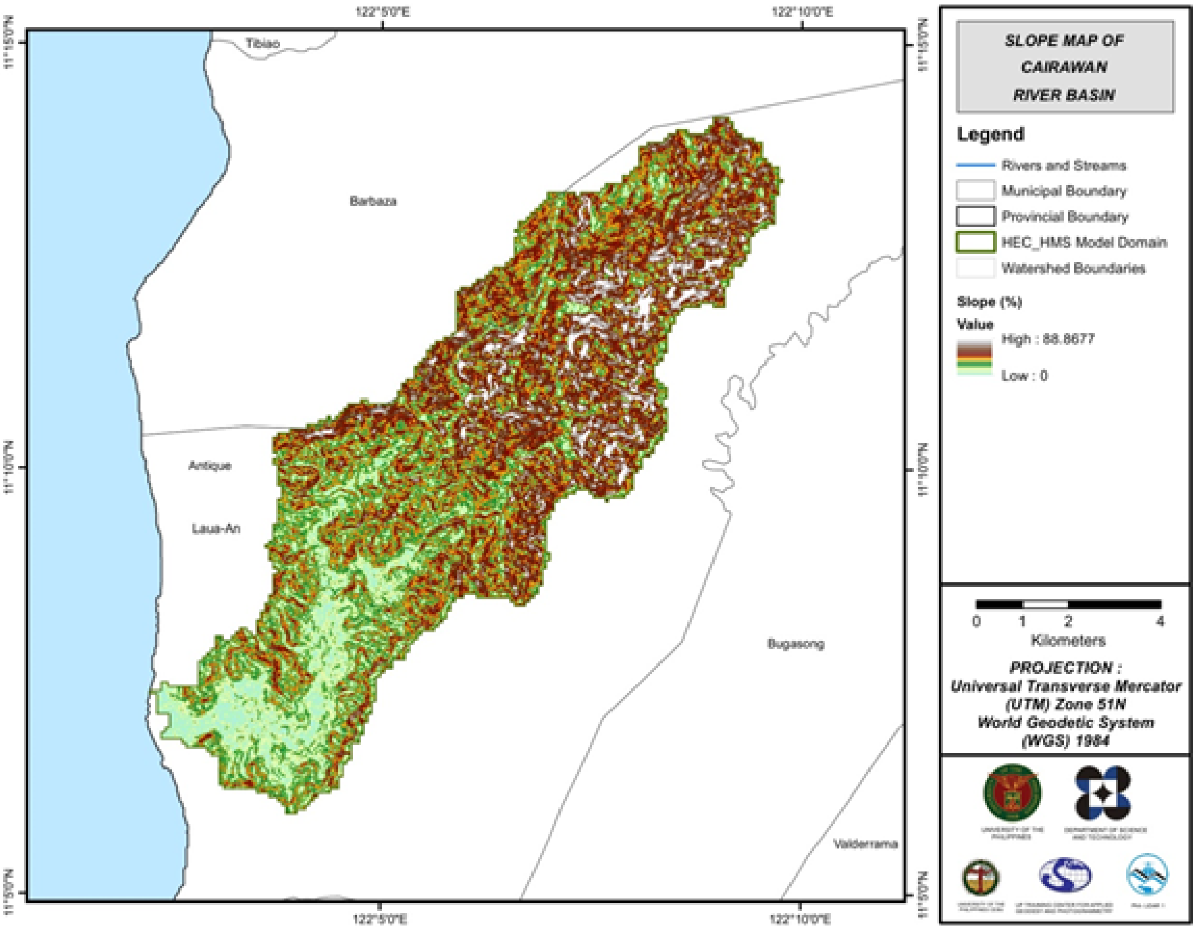


Figure 50. Slope map of the Cairawan River Basin

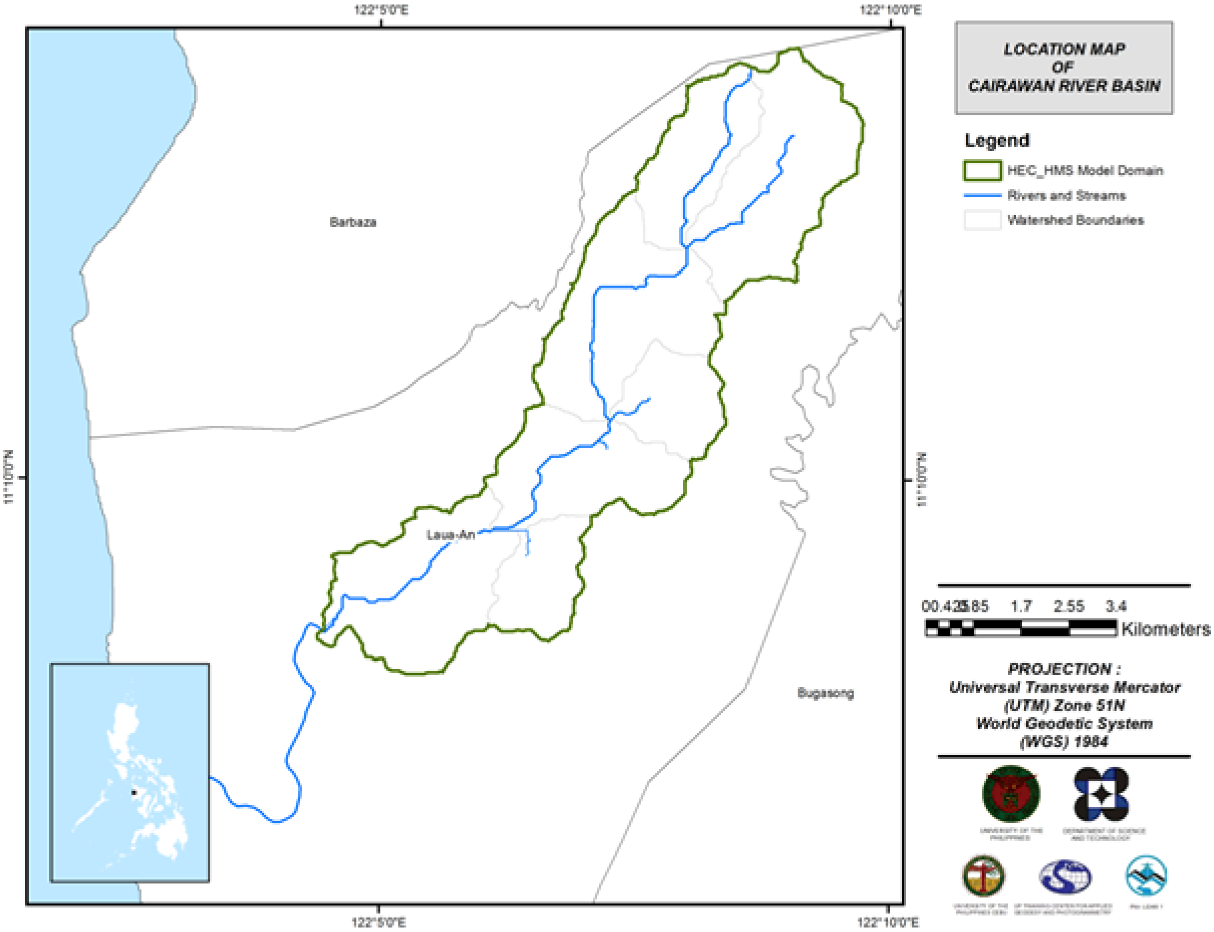


Figure 51. Stream delineation map of the Cairawan River Basin

Using the SAR-based DEM, the Cairawan basin was delineated and further subdivided into subbasins. The model consists of 3 sub basins, 1 reaches, and 1 junctions as shown in Figure 52. The main outlet is at Kalahi Footbridge.

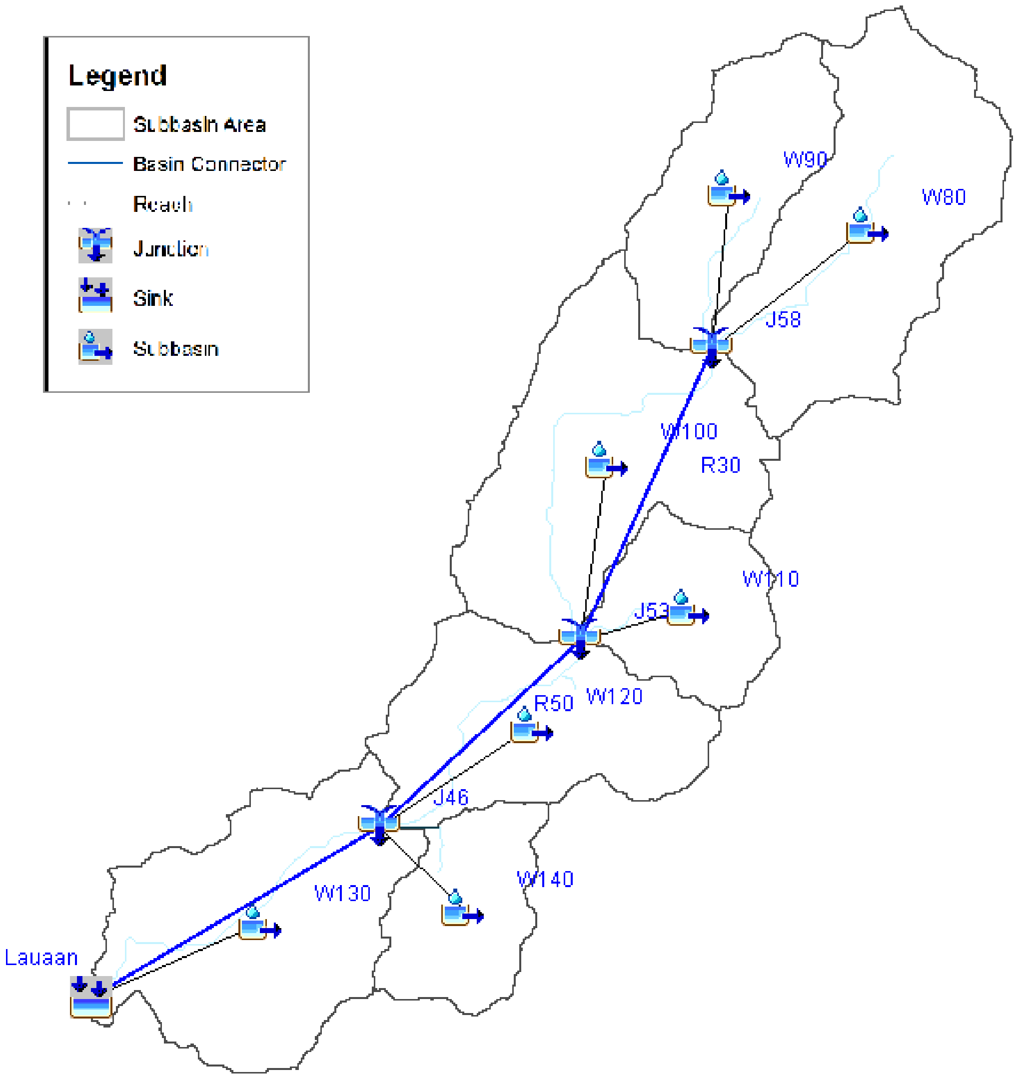


Figure 52. The Cairawan river basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

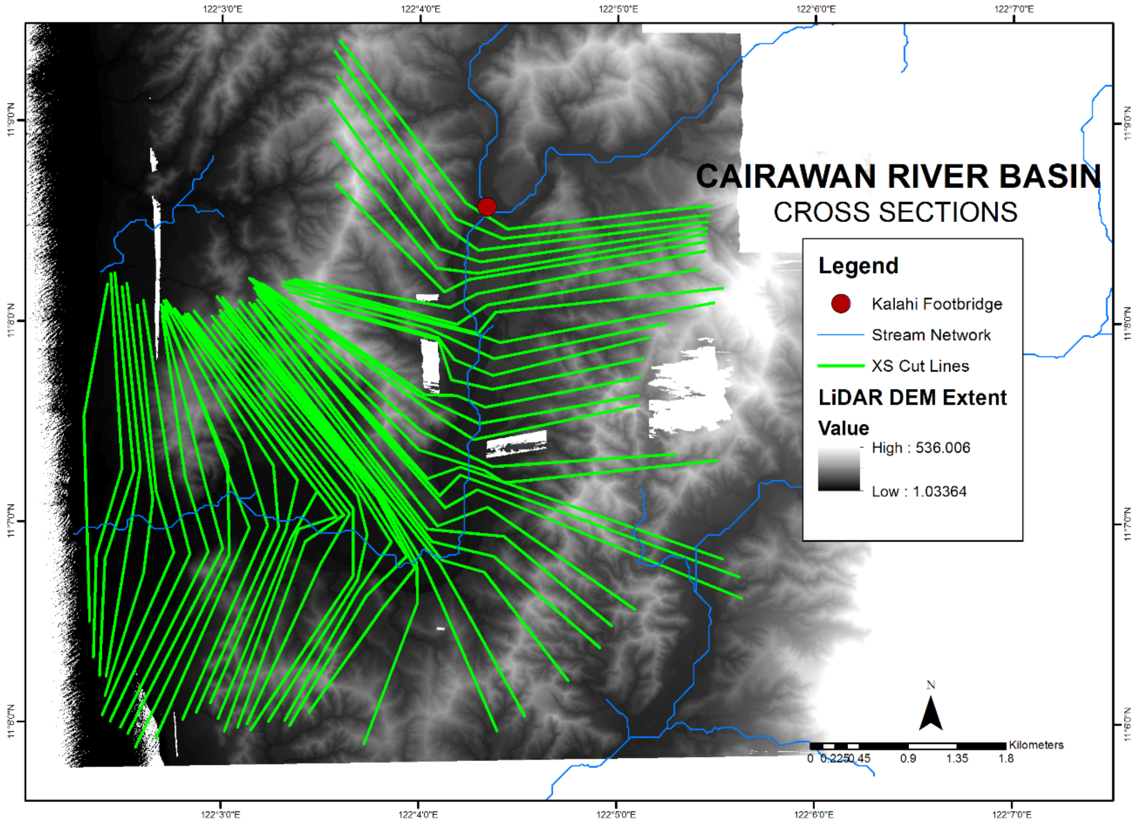


Figure 53. River cross-section of Cairawan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

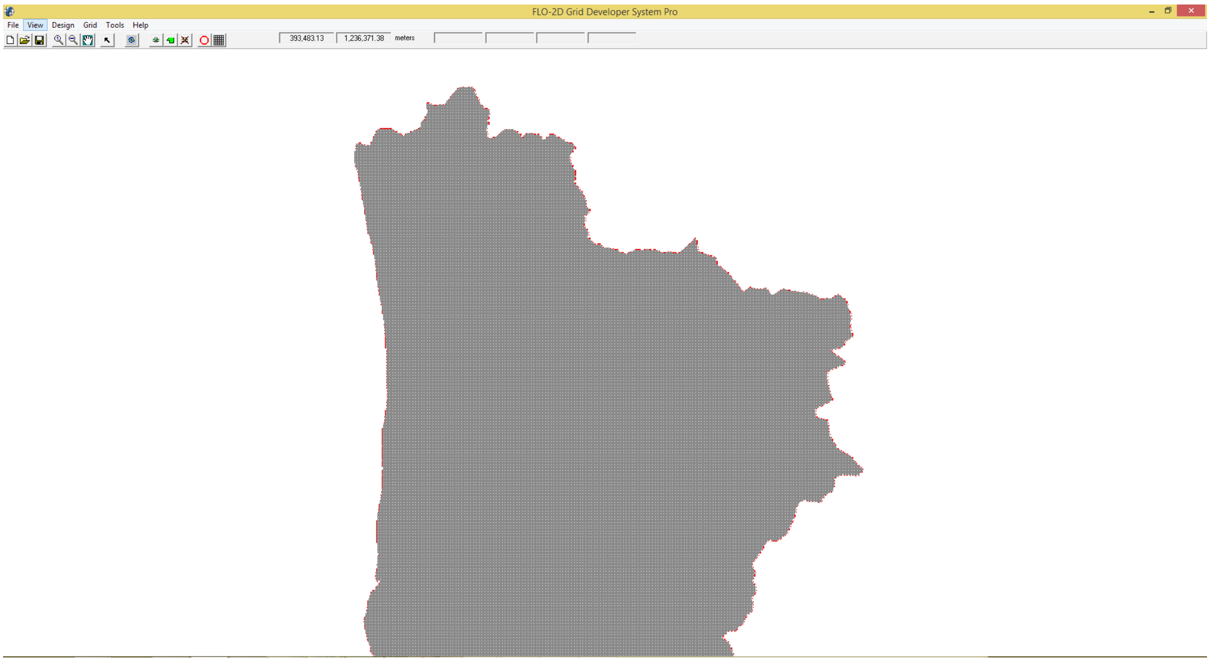


Figure 54. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

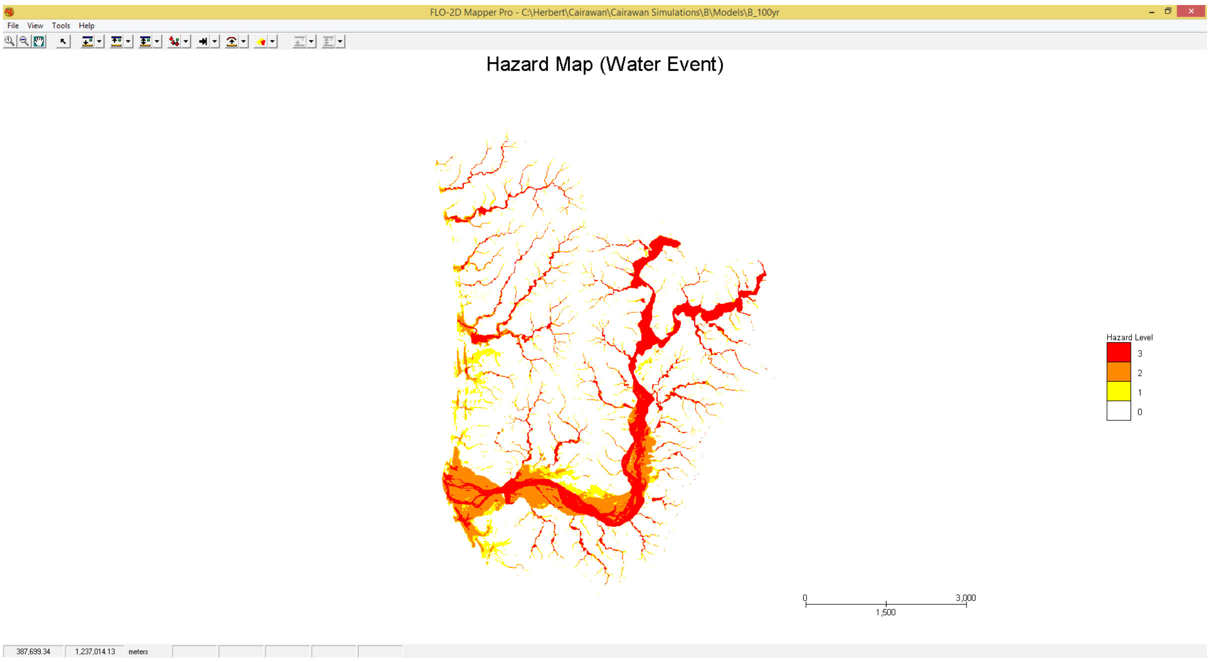


Figure 55. Generated 100-year rain return hazard map from FLO-2D Mapper

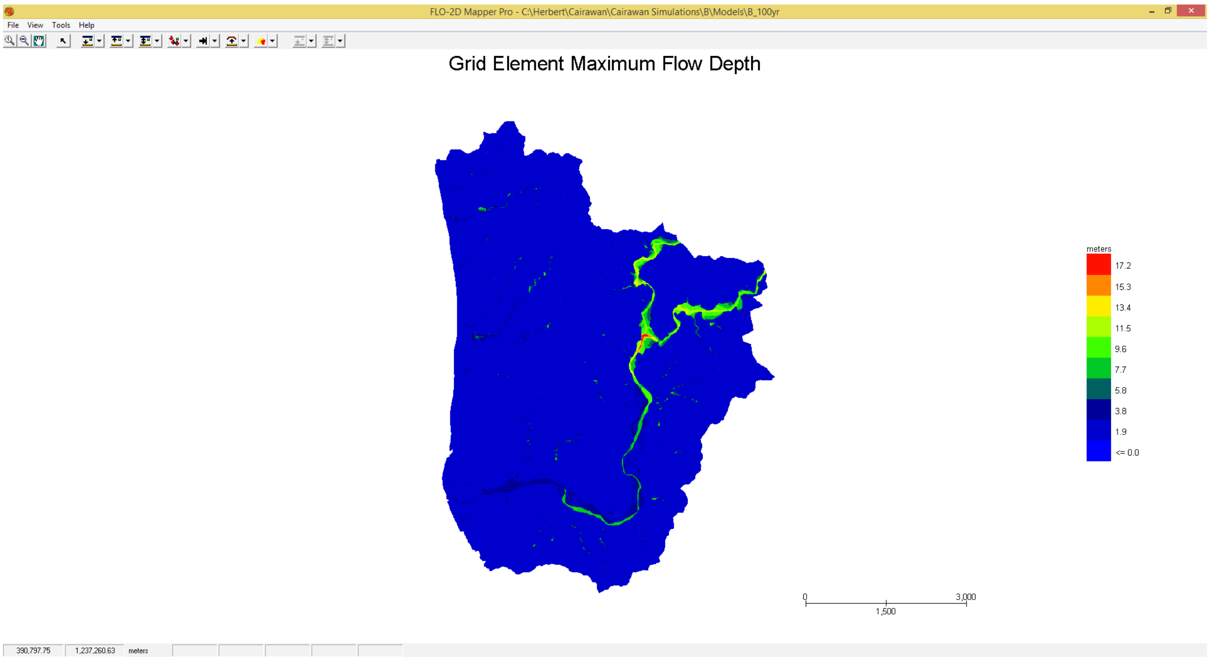


Figure 56. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

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

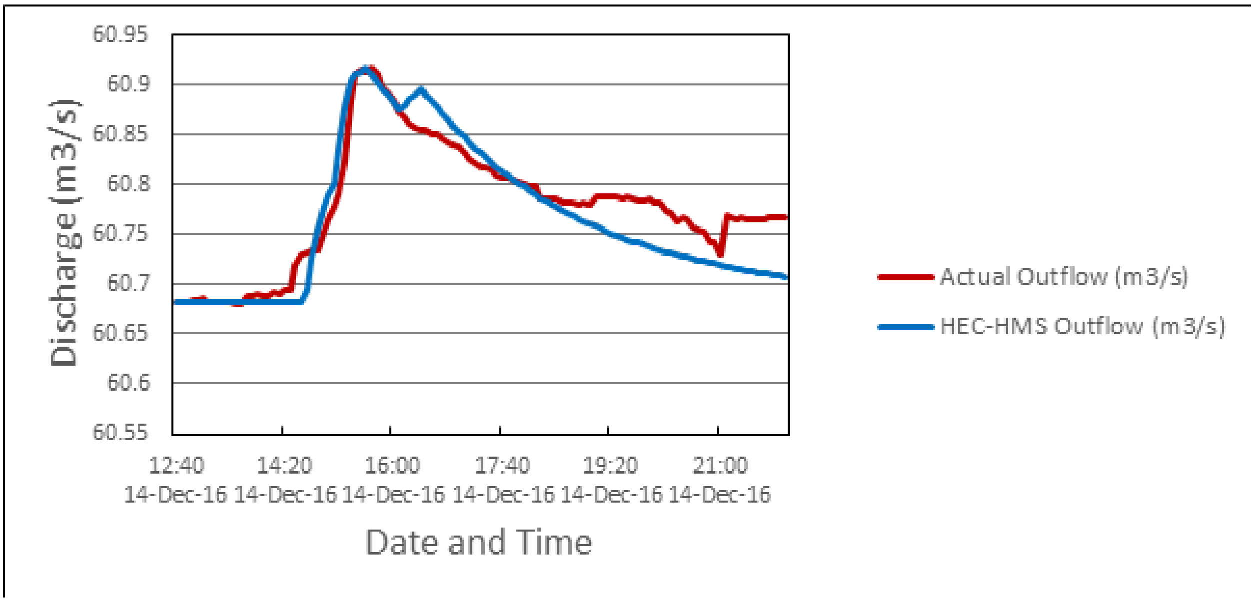


Figure 57. Outflow Hydrograph of Cairawan produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of Calibrated Values for Cairawan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	6.9-20.7
			Curve Number	45-64.6
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.05-0.85
			Storage Coefficient (hr)	1.2-3.2
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.9
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0002-0.0016

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 6.9 mm - 20.7mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 45 - 64.6 falls short for the curve number advisable for Philippine watersheds depending on the soil and land cover of the area. For Cairawan, the basin mostly consists of shrublands, and the soil consists of clay, and undifferentiated soils.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.05 hours to 3.2 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.9 indicates a smooth receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0002-0.0016 for the Cairawan river basin is lower than the usual Manning's n value in the Philippines (Brunner, 2010).

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

RMS Error	0.0286
r^2	0.9394
NSE	0.79
RSR	0.46
PBIAS	0.02

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.0286 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9394.

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 0.79.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 0.02.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.46.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 58) shows the Cairawan outflow using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

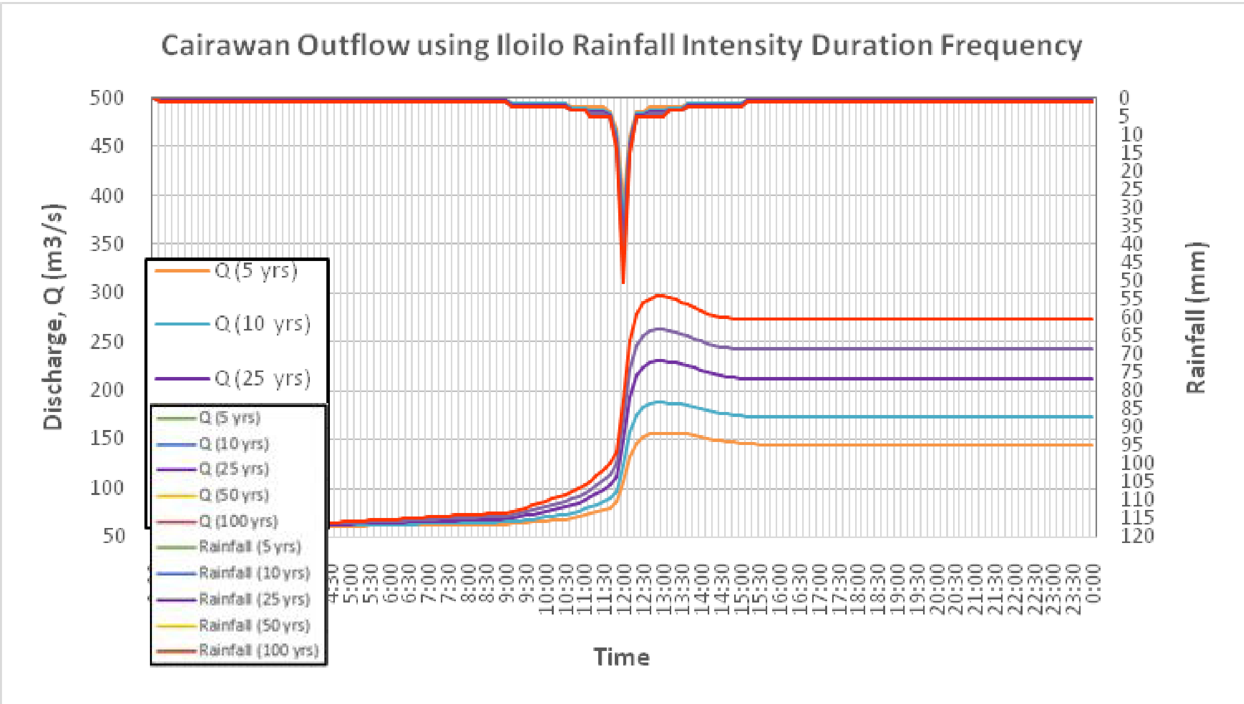


Figure 58. Outflow hydrograph at Cairawan Station generated using Iloilo RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Cairawan discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Cairawan 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	156.15	1 hour
10-Year	198.9	33.9	187.46	1 hour
25-Year	241.5	40.5	230.11	1 hour
50-Year	273.1	45.4	262.9	1 hour
100-Year	304.5	50.3	296.47	1 hour

5.8 River Analysis Model Simulation

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

Figure 59. Sample output of Cairawan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 60 to Figure 65 shows the 5-, 25-, and 100-year rain return scenarios of the Cairawan Floodplain.

Table 31. Municipalities affected in the Cairawan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Barbaza	176.5	4.562	2.5844
Laua-An	159.8	82.55074	51.66913

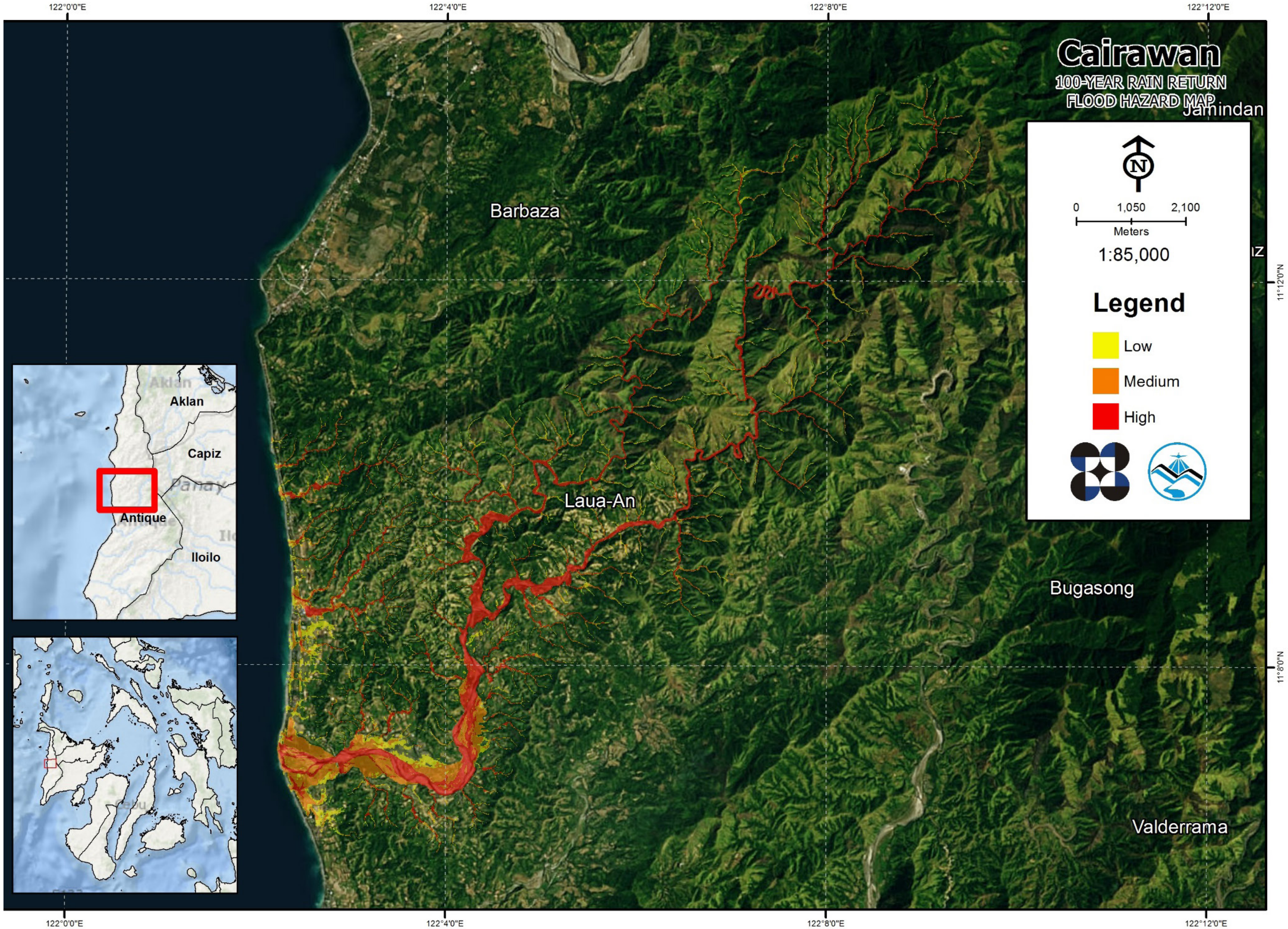


Figure 60. 100-year Flood Hazard Map for Cairawan Floodplain

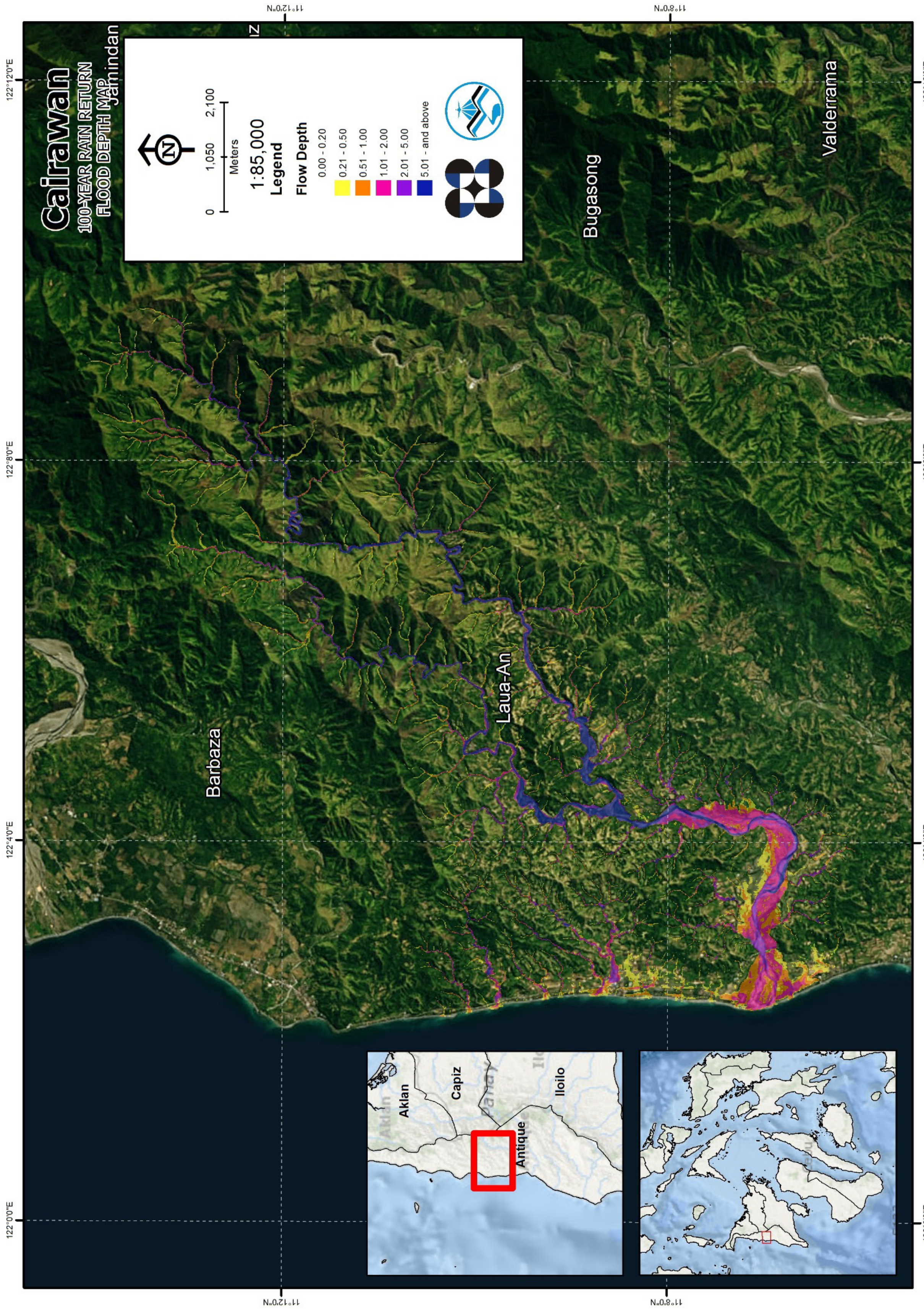


Figure 61. 100-year Flow Depth Map for Cairawan Floodplain

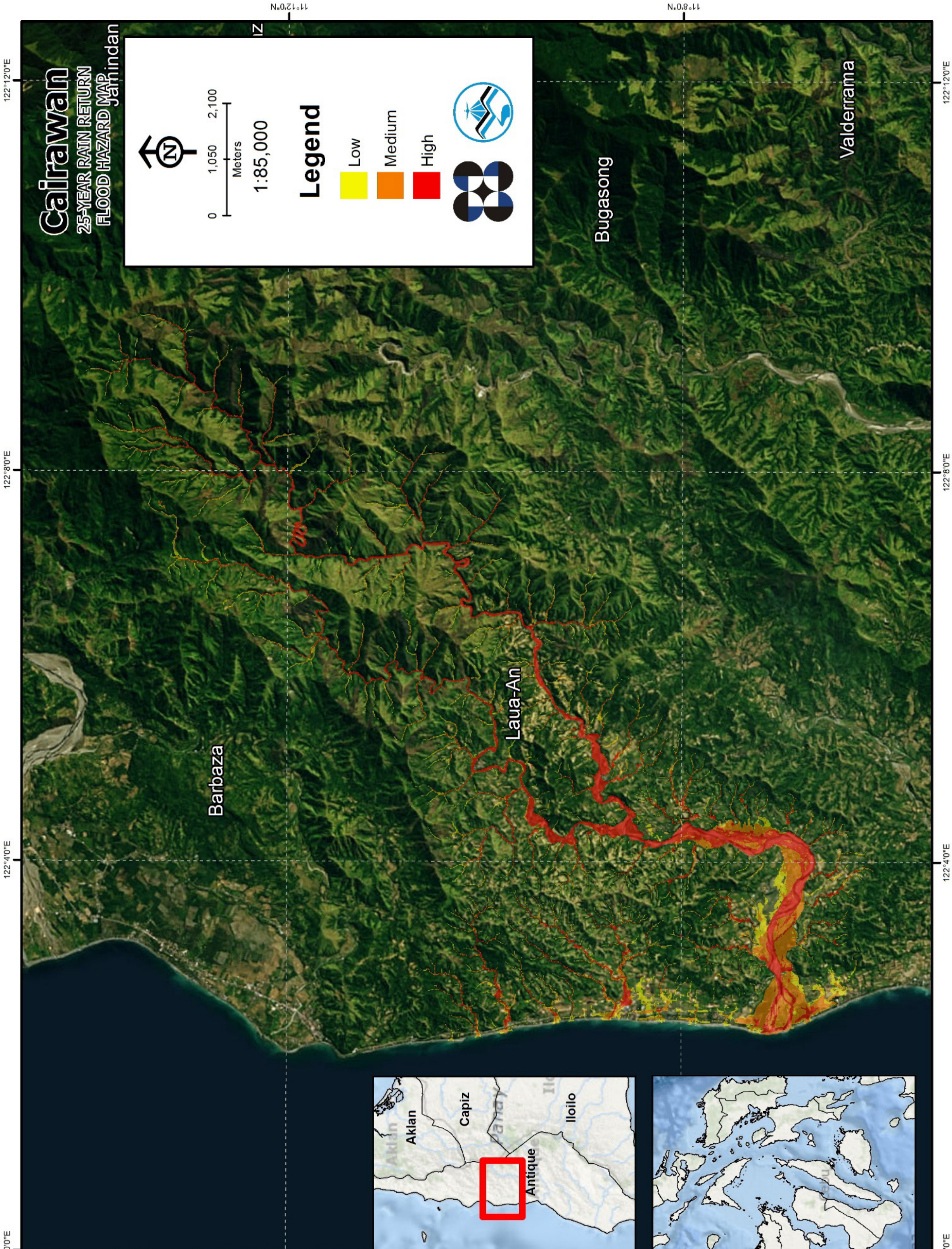


Figure 62. 25-year Flood Hazard Map for Cairawan Floodplain

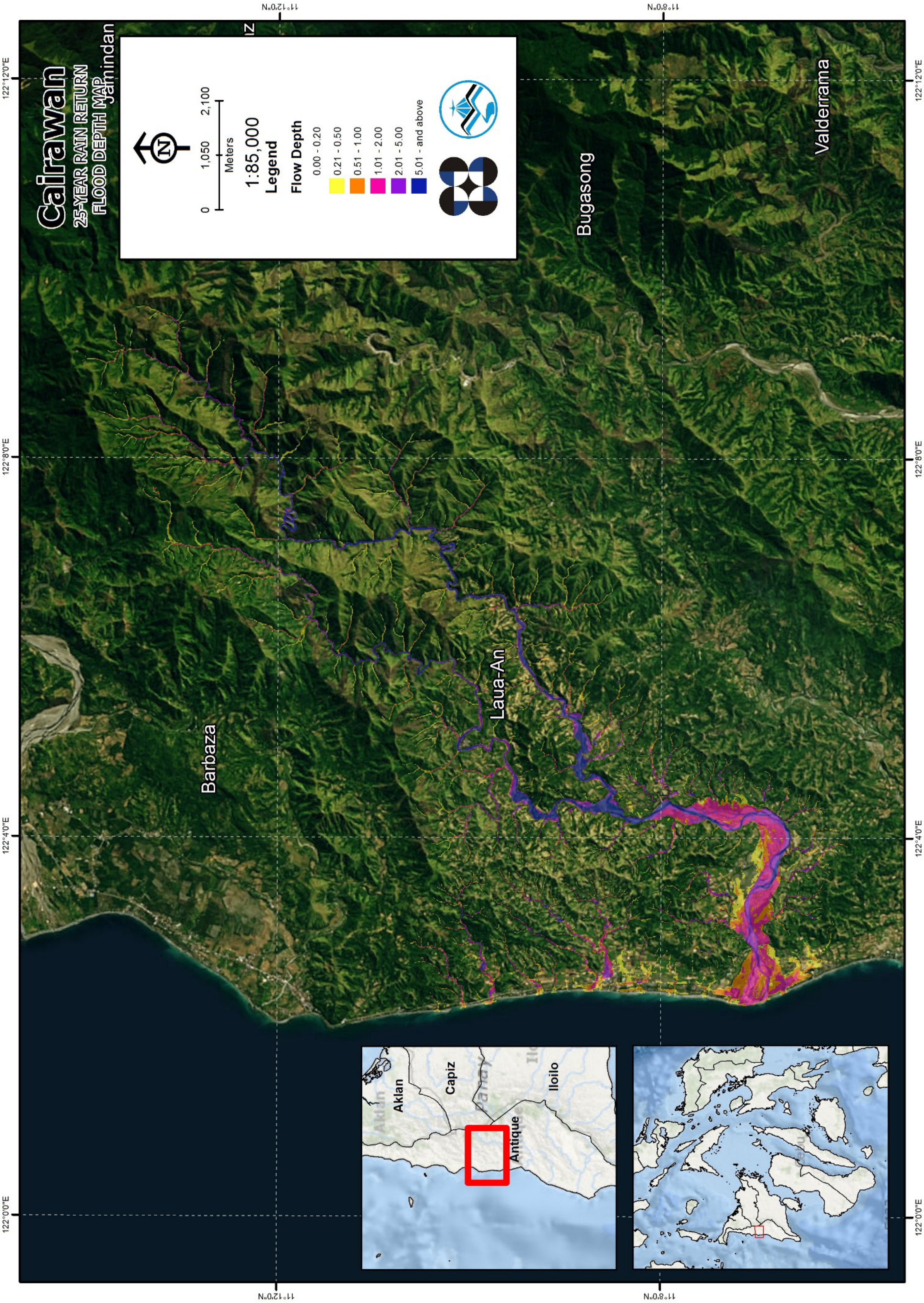


Figure 63. 25-year Flow Depth Map for Cairawan Floodplain

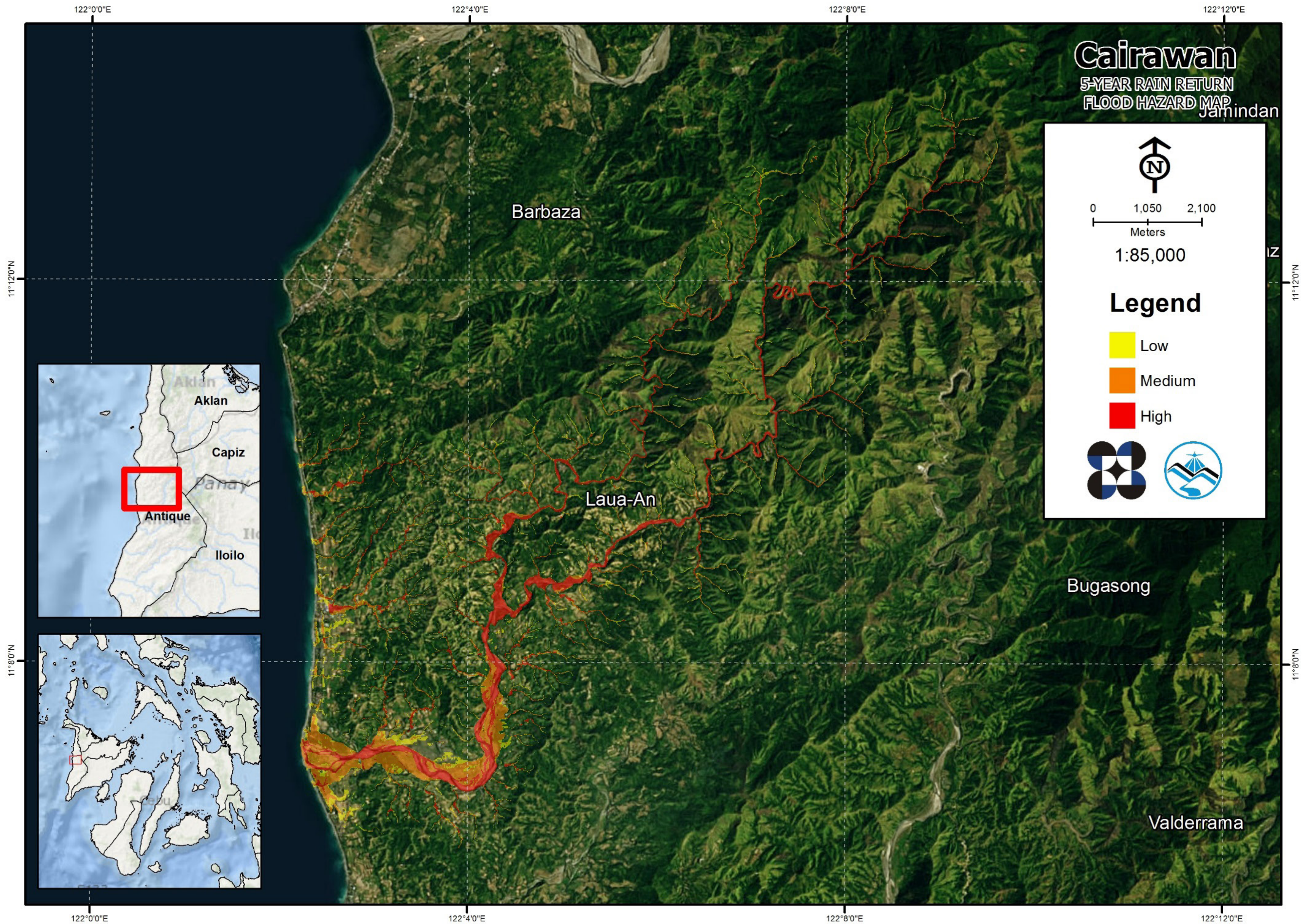


Figure 64. 5-year Flood Hazard Map for Cairawan Floodplain

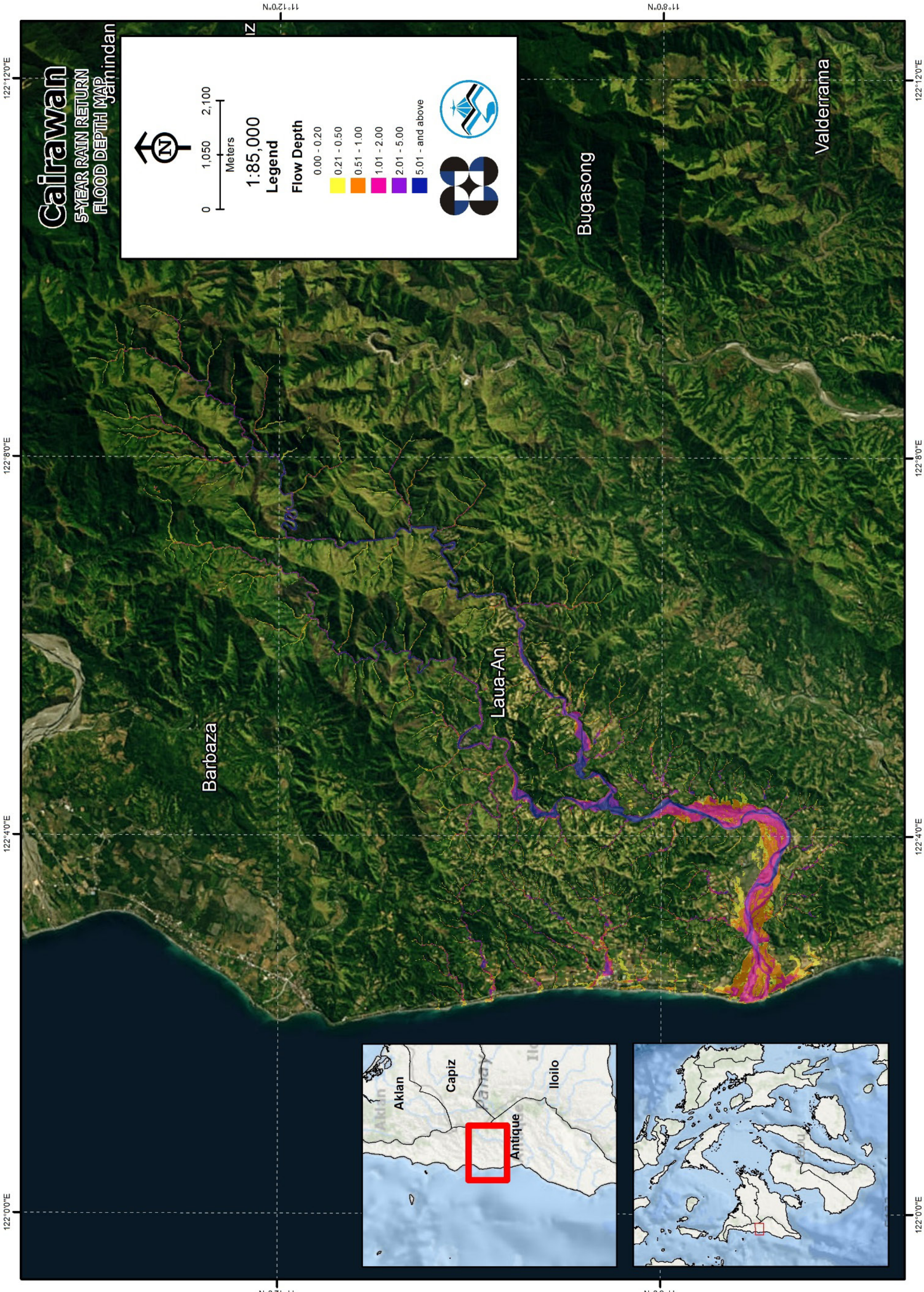


Figure 65. 5-year Flood Depth Map for Cairawan Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

The affected barangays in the Cairawan Riverbasin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of forty (40) barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 2.5% of the municipality of Barbaza with an area of 176.52 sq. km. will experience flood levels of less 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.005%, 0.003%, and 0.0002% 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 32 are the affected areas in square kilometres by flood depth per barangay.

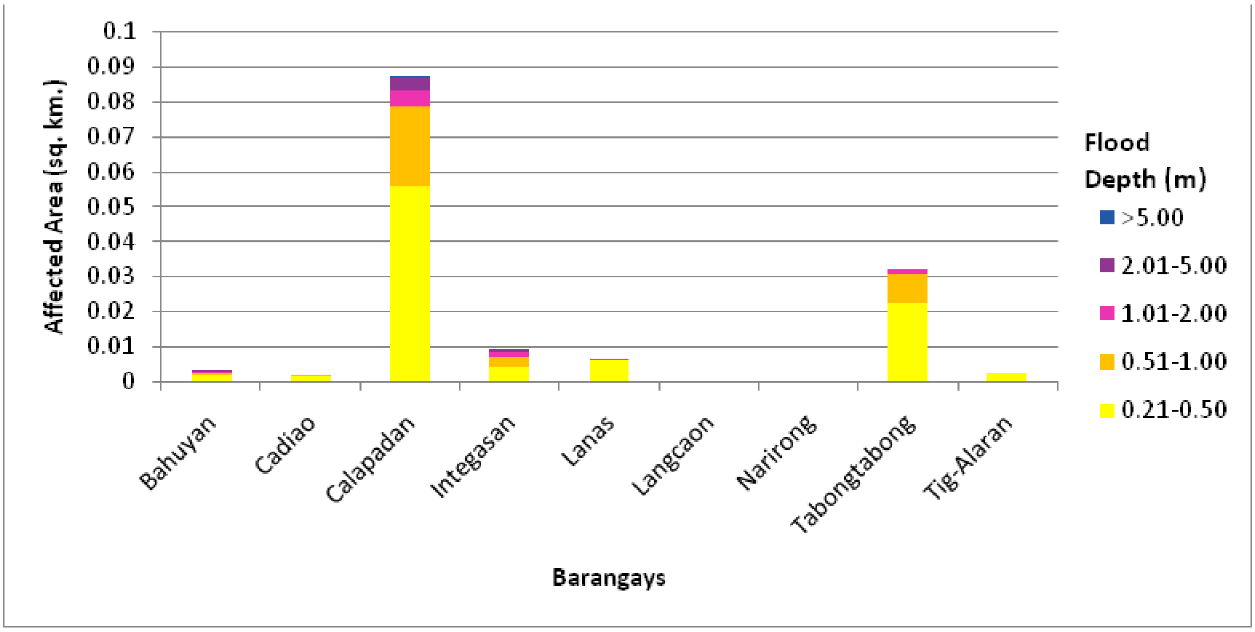


Figure 66. Affected Areas in Barbaza, Antique during 5-Year Rainfall Return Period

Table 32. Affected Areas in Barbaza, Antique during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Barbaza (in sq. km.)				
	Bahuyan	Cadiao	Calapadan	Integasan	Lanas
0.03-0.20	0.14	0.067	2.6	0.22	0.44
0.21-0.50	0.002	0.0017	0.056	0.0043	0.0058
0.51-1.00	0.0005	0.0001	0.023	0.0026	0.00043
1.01-2.00	0.0004	0	0.0047	0.0014	0.0001
2.01-5.00	0.00014	0	0.0035	0.00077	0
> 5.00	0	0	0.0004	0	0
	Langcaon	Narirong	Tabongtabong	Tig-Alaran	
0.03-0.20	0.00041	0.029	0.6	0.34	
0.21-0.50	0	0.0001	0.022	0.0023	
0.51-1.00	0	0	0.008	0	
1.01-2.00	0	0	0.0013	0	
2.01-5.00	0	0	0	0	
> 5.00	0	0	0	0	

For the municipality of Laua-An, with an area of 159.77 sq. km., 46.24% will experience flood levels of less 0.20 meters. 1.4% of the area will experience flood levels of 0.21 to 0.50 meters while 1.27%, 1.29%, 0.89%, and 0.57% 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 33 are the affected areas in square kilometres by flood depth per barangay.

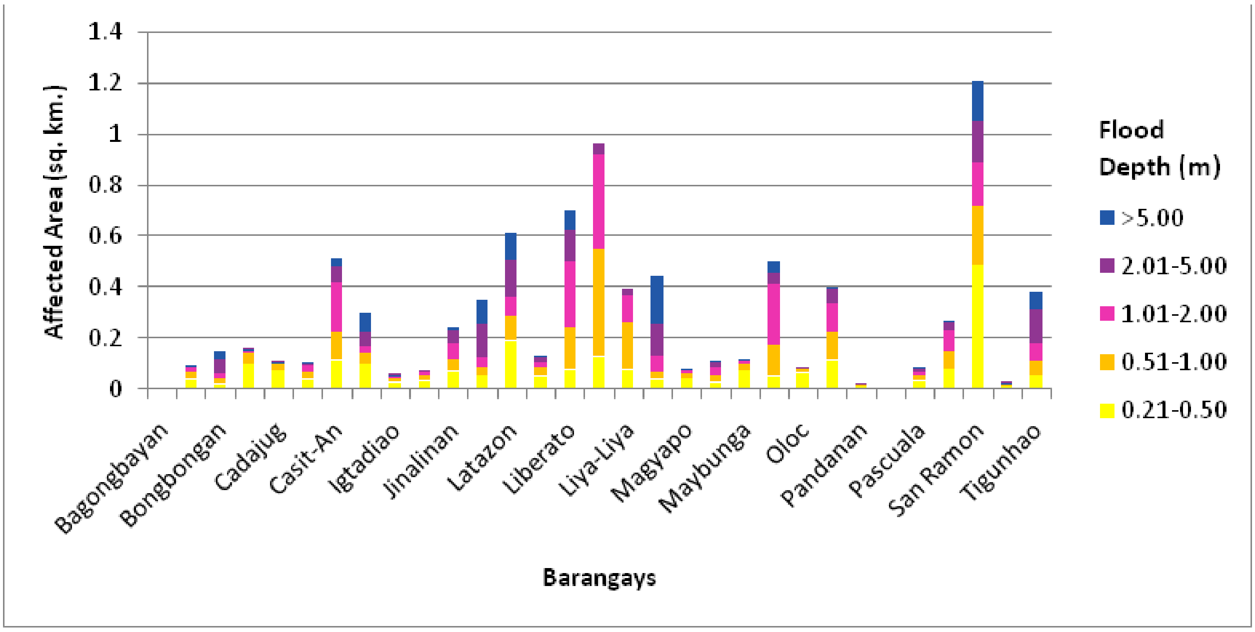


Figure 67. Affected Areas in Laua-An, Antique during 5-Year Rainfall Return Period

Table 33. Affected Areas in Laua-An, Antique during 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	Banban	Bongbongan	Cabariwan	Cadajug	Canituan	Casit-An	Guiamon	Igtadiao	Intao	Jinalinan
0.03-0.20	0.093	1.37	0.92	1.05	1.05	1.46	1.79	4.93	1.32	0.95	3.48
0.21-0.50	0.0006	0.038	0.02	0.098	0.073	0.037	0.11	0.098	0.027	0.03	0.07
0.51-1.00	0.0011	0.025	0.017	0.039	0.024	0.029	0.11	0.044	0.012	0.022	0.046
1.01-2.00	0.0003	0.021	0.024	0.014	0.0041	0.024	0.2	0.022	0.011	0.015	0.064
2.01-5.00	0.0003	0.0078	0.059	0.0051	0.005	0.016	0.064	0.058	0.009	0.0052	0.05
> 5.00	0	0.0001	0.032	0.0002	0.0017	0.0016	0.033	0.076	0.0015	0	0.016
	Lactudan	Latazon	Laua-An	Liberato	Lindero	Liya-Liya	Lupa-An	Magyapo	Mauno	Maybunga	Necesito
0.03-0.20	2.41	7.55	2.35	2.1	0.86	0.95	1.22	1.63	0.64	3.19	0.28
0.21-0.50	0.054	0.19	0.052	0.076	0.12	0.075	0.041	0.041	0.025	0.073	0.051
0.51-1.00	0.027	0.093	0.029	0.16	0.42	0.18	0.027	0.02	0.027	0.025	0.12
1.01-2.00	0.041	0.08	0.02	0.26	0.37	0.1	0.06	0.01	0.03	0.01	0.24
2.01-5.00	0.14	0.15	0.02	0.13	0.04	0.03	0.13	0.01	0.03	0	0.04
> 5.00	0.09	0.11	0	0.08	0	0	0.19	0	0	0	0.04

	Oloc	Omlot	Pandanan	Paningayan	Pascuala	Poblacion	San Ramon	Tibacan	Tigunhao
0.03-0.20	1.13	1.04	1.02	0.11	1.19	1.52	23.82	0.51	1.91
0.21-0.50	0.062	0.11	0.012	0.0031	0.031	0.079	0.49	0.011	0.054
0.51-1.00	0.017	0.11	0.0048	0.0013	0.021	0.07	0.23	0.009	0.058
1.01-2.00	0.0047	0.11	0.0009	0.000043	0.016	0.076	0.17	0.0047	0.065
2.01-5.00	0.001	0.065	0.0009	0.00003	0.016	0.041	0.16	0.0026	0.13
> 5.00	0	0.0015	0	0	0.001	0.0007	0.16	0.00031	0.073

For the 25-year return period, 2.48% of the municipality of Barbaza with an area of 176.52 sq. km. will experience flood levels of less 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.006%, 0.003%, and 0.0005% 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 34 are the affected areas in square kilometres by flood depth per barangay.

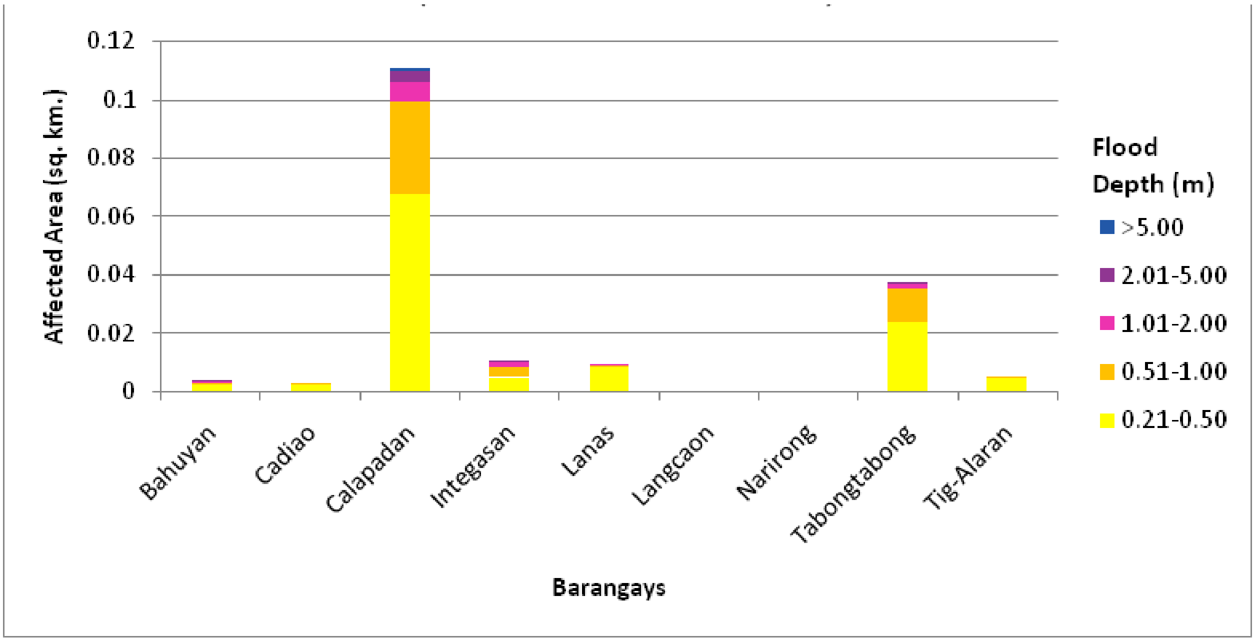


Figure 68. Affected Areas in Barbaza, Antique during 25-Year Rainfall Return Period

Table 34. 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.)				
	Bahuyan	Cadiao	Calapadan	Integasan	Lanas
0.03-0.20	0.14	0.066	2.57	0.21	0.43
0.21-0.50	0.0022	0.0023	0.068	0.0047	0.0083
0.51-1.00	0.0008	0.0004	0.032	0.0034	0.0011
1.01-2.00	0.0005	0	0.0062	0.0017	0.0001
2.01-5.00	0.00014	0	0.0044	0.00087	0
> 5.00	0	0	0.00089	0	0
	Langcaon	Narirong	Tabongtabong	Tig-Alaran	
0.03-0.20	0.00041	0.029	0.59	0.34	
0.21-0.50	0	0.0001	0.024	0.0045	
0.51-1.00	0	0	0.011	0.0002	
1.01-2.00	0	0	0.0022	0	
2.01-5.00	0	0	0.0001	0	
> 5.00	0	0	0	0	

For the municipality of Laua-An, with an area of 159.77 sq. km., 46.03% will experience flood levels of less 0.20 meters. 1.63% of the area will experience flood levels of 0.21 to 0.50 meters while 1.19%, 1.59%, 1.13%, and 0.9% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

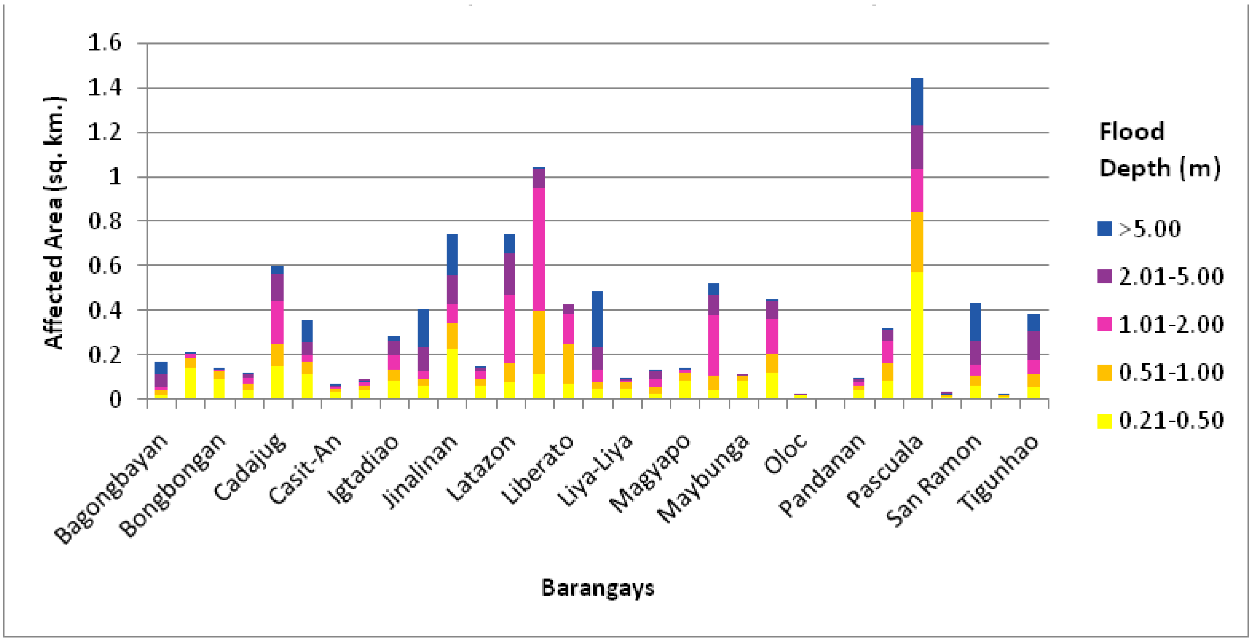


Figure 69. Affected Areas in Laua-An, Antique during 25-Year Rainfall Return Period

Table 35. Affected Areas in Laua-An, Antique during 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	Banban	Bongbongan	Cabariwan	Cadajug	Canituan	Casit-An	Guiamon	Igtadiao	Intao	Jinalinan
0.03-0.20	0.093	1.36	0.9	1	1.01	1.45	1.7	4.87	1.31	0.93	3.44
0.21-0.50	0.0005	0.041	0.022	0.14	0.093	0.04	0.15	0.11	0.031	0.037	0.082
0.51-1.00	0.0012	0.028	0.016	0.048	0.038	0.03	0.096	0.052	0.014	0.026	0.048
1.01-2.00	0.0002	0.025	0.02	0.019	0.0062	0.029	0.19	0.03	0.013	0.019	0.067
2.01-5.00	0.0004	0.011	0.057	0.0065	0.0053	0.021	0.12	0.057	0.01	0.0068	0.069
> 5.00	0	0.0003	0.058	0.0002	0.0021	0.0018	0.034	0.1	0.0027	0.0001	0.022
	Lactudan	Latazon	Laua-An	Liberato	Lindero	Liya-Liya	Lupa-An	Magyapo	Mauno	Maybunga	Necesito
0.03-0.20	2.36	7.42	2.33	2.06	0.78	0.92	1.17	1.62	0.62	3.16	0.26
0.21-0.50	0.062	0.23	0.059	0.074	0.11	0.066	0.05	0.051	0.027	0.083	0.039
0.51-1.00	0.028	0.11	0.035	0.092	0.29	0.18	0.029	0.023	0.028	0.036	0.064
1.01-2.00	0.038	0.09	0.03	0.31	0.55	0.13	0.06	0.01	0.04	0.01	0.27
2.01-5.00	0.11	0.13	0.02	0.19	0.09	0.04	0.1	0.01	0.04	0.01	0.1
> 5.00	0.17	0.18	0.01	0.09	0	0	0.24	0	0.01	0	0.05
	Oloc	Omlot	Pandanan	Paningayan	Pascuala	Poblacion	San Ramon	Tibacan	Tigunhao		
0.03-0.20	1.1	0.99	1.01	0.11	1.18	1.46	23.58	0.5	1.86		
0.21-0.50	0.083	0.12	0.016	0.0025	0.037	0.082	0.57	0.012	0.06		
0.51-1.00	0.021	0.089	0.0068	0.0019	0.023	0.077	0.27	0.0098	0.044		
1.01-2.00	0.0058	0.15	0.0011	0.00044	0.02	0.1	0.19	0.0058	0.052		
2.01-5.00	0.0018	0.089	0.0013	0.00003	0.019	0.062	0.19	0.003	0.11		
> 5.00	0	0.0024	0	0	0.0017	0.0009	0.21	0.00051	0.17		

For the 100-year return period, 2.47% of the municipality of Barbaza with an area of 176.52 sq. km. will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.008%, 0.003%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

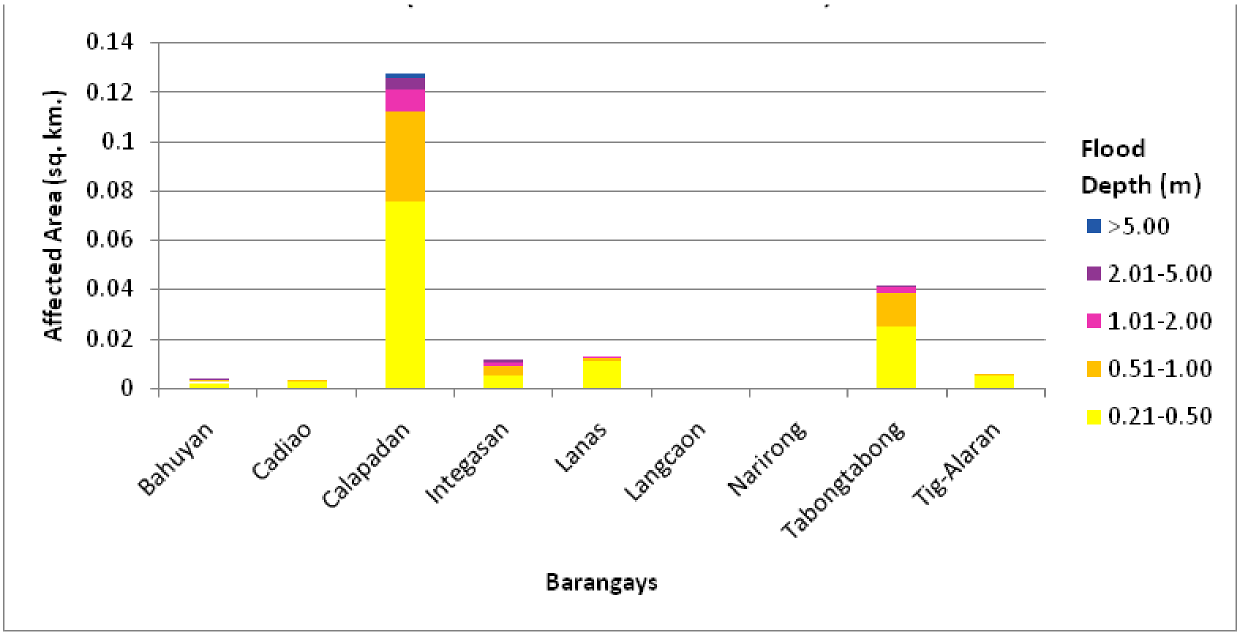


Figure 70. Affected Areas in Barbaza, Antique during 100-Year Rainfall Return Period

Table 36. Affected Areas in Barbaza, Antique during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Barbaza (in sq. km.)				
	Bahuyan	Cadiao	Calapadan	Integasan	Lanas
0.03-0.20	0.14	0.065	2.56	0.21	0.43
0.21-0.50	0.0023	0.0026	0.076	0.0051	0.011
0.51-1.00	0.001	0.0005	0.036	0.0036	0.0017
1.01-2.00	0.0004	0	0.0091	0.0018	0.0001
2.01-5.00	0.00024	0	0.0044	0.0012	0
> 5.00	0	0	0.0018	0	0
	Langcaon	Narirong	Tabongtabong	Tig-Alaran	
0.03-0.20	0.00041	0.029	0.59	0.33	
0.21-0.50	0	0.0001	0.025	0.0054	
0.51-1.00	0	0	0.013	0.00044	
1.01-2.00	0	0	0.0033	0	
2.01-5.00	0	0	0.0002	0	
> 5.00	0	0	0	0	

For the municipality of Laua-An, with an area of 159.77 sq. km., 44.94% will experience flood levels of less 0.20 meters. 1.8% of the area will experience flood levels of 0.21 to 0.50 meters while 1.27%, 1.57%, 1.07%, and 1.02% 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 37 are the affected areas in square kilometres by flood depth per barangay.

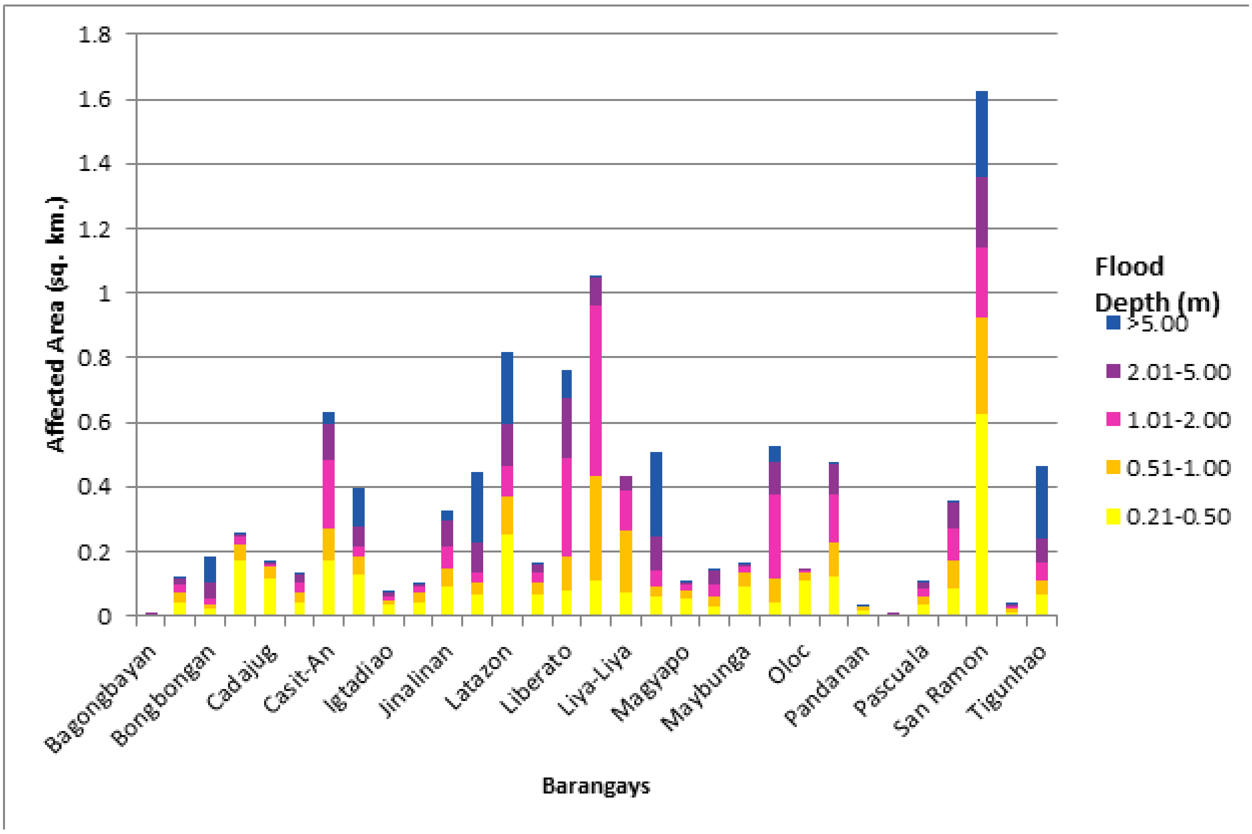


Figure 71. Affected Areas in Laua-An, Antique during 25-Year Rainfall Return Period

Table 37. Affected Areas in Laua-An, Antique during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Laua-An (in sq. km.)										
	Bagong-bayan	Banban	Bongbongan	Cabariwan	Cadajug	Canituan	Casit-An	Guiamon	Igtadiao	Intao	Jinalinan
0.03-0.20	0.093	1.35	0.89	0.96	0.99	1.44	1.67	4.83	1.3	0.92	3.4
0.21-0.50	0.00053	0.044	0.022	0.17	0.11	0.042	0.17	0.13	0.035	0.043	0.093
0.51-1.00	0.0012	0.029	0.016	0.054	0.04	0.03	0.1	0.056	0.014	0.028	0.053
1.01-2.00	0.0003	0.027	0.018	0.022	0.0086	0.031	0.21	0.033	0.014	0.021	0.069
2.01-5.00	0.0004	0.015	0.048	0.0076	0.0061	0.027	0.11	0.059	0.012	0.009	0.083
> 5.00	0	0.0003	0.081	0.0002	0.0022	0.002	0.034	0.12	0.0032	0.0002	0.028
	Lactudan	Latazon	Laua-An	Liberato	Lindero	Liya-Liya	Lupa-An	Magyapo	Mauno	Maybunga	Necesito
0.03-0.20	2.32	7.34	2.31	2.04	0.77	0.91	1.15	1.61	0.61	3.14	0.25
0.21-0.50	0.07	0.25	0.064	0.081	0.11	0.076	0.061	0.054	0.032	0.093	0.041
0.51-1.00	0.032	0.12	0.039	0.1	0.32	0.19	0.029	0.026	0.027	0.043	0.074
1.01-2.00	0.035	0.09	0.03	0.3	0.52	0.12	0.05	0.02	0.04	0.01	0.26
2.01-5.00	0.091	0.13	0.03	0.19	0.09	0.04	0.1	0.01	0.05	0.01	0.1
> 5.00	0.22	0.22	0.01	0.09	0	0	0.27	0	0.01	0	0.05
	Oloc	Omlot	Pandanan	Paningayan	Pascuala	Poblacion	San Ramon	Tibacan	Tigunhao		
0.03-0.20	1.07	0.97	1.01	0.11	1.17	1.43	23.4	0.5	1.83		
0.21-0.50	0.11	0.12	0.02	0.0023	0.037	0.086	0.63	0.013	0.064		
0.51-1.00	0.025	0.11	0.0076	0.0022	0.025	0.085	0.3	0.0099	0.045		
1.01-2.00	0.0063	0.15	0.0017	0.00054	0.021	0.1	0.22	0.0069	0.054		
2.01-5.00	0.0024	0.094	0.0012	0.00003	0.021	0.08	0.22	0.0035	0.075		
> 5.00	0	0.0038	0.0001	0	0.0032	0.0014	0.26	0.00051	0.22		

Among the barangays in the Municipality of Barbaza, Calapadan is projected to have the highest percentage of area that will experience flood levels at 1.52%. Meanwhile, Tabong-tabong posted the second highest percentage of area that may be affected by flood depths at 0.36%.

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 15.67%. Meanwhile, Latazon posted the second highest percentage of area that may be affected by flood depths at 5.1%.

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

Table 38. 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	2.174	2.4765	2.7589
Medium	3.2176	3.2336	34471
High	3.5559	4.5962	4.9345

Of the twenty-two (22) identified education institutions in the Cairawan floodplain, one (1) school was assessed to be exposed to the Low level flooding during a 5 year scenario, while two (2) schools were assessed to be exposed to medium level flooding in the same scenario, and two (2) schools were assessed to be exposed to high level flooding . In the 25 year scenario, two (2) schools were assessed to be exposed to the Low level flooding while one (1) school was assessed to be exposed to medium level flooding and three (3) schools were assessed to be exposed to high level flooding. For the 100 year scenario, two (2) schools were assessed to be exposed to the Low level flooding, two (2) schools were assessed to be exposed to medium level flooding, and three (3) schools were assessed to be exposed to the high level flooding. The educational institutions exposed to flooding in the Cairawan floodplain is found in Annex 12.

Two (2) Medical Institutions were identified in Cairawan floodplain, and one (1) was assessed to be exposed to low level flooding in both 25 and 100 year scenarios. The medical or health institutions exposed to flooding in the Cairawan floodplain is found in Annex 13.

5.11 Flood Validation

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

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios are identified for validation.

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and interview of some residents with knowledge of or have had experienced flooding in a particular area. The flood validation data were obtained on December 13, 2016.

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consisted of 255 points randomly selected all over the Cairawan Floodplain. It has an RMSE value of 1.16.

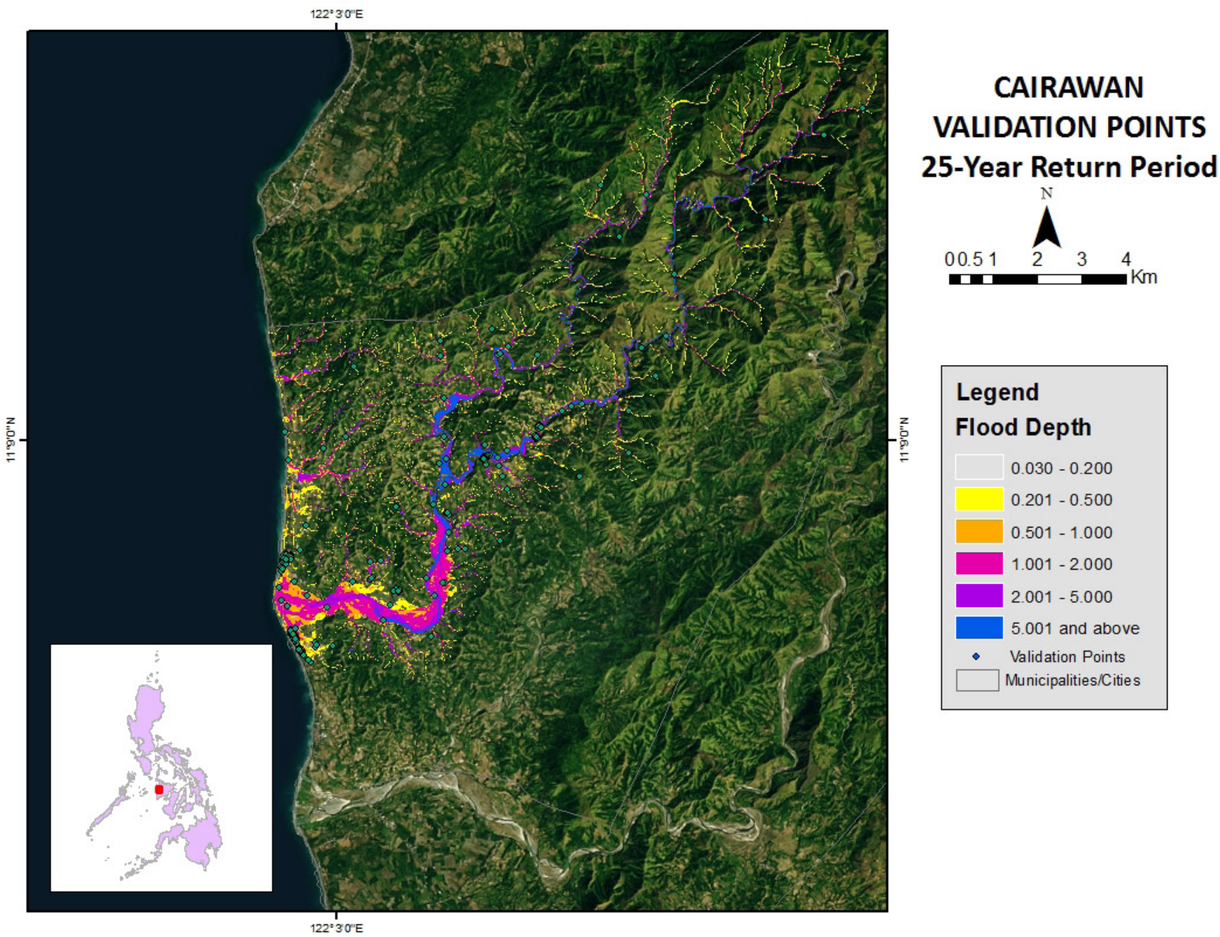


Figure 72. Validation points for 25-year flood depth map of Cairawan Floodplain

Table 39. Actual Flood Depth vs Simulated Flood Depth in Cairawan

Affected Area (in sq.km.) by flood depth (in 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	8	5	2	6	4	90
0.21-0.50	17	3	4	6	1	0	31
0.51-1.00	35	2	8	7	3	2	57
1.01-2.00	18	1	1	7	7	4	38
2.01-5.00	8	1	3	5	10	8	35
> 5.00	3	1	0	0	1	2	7
Total	146	16	21	27	28	20	258

The overall accuracy generated by the flood model is estimated at 36.82%, with 95 points correctly matching the actual flood depths. In addition, there were 34 points estimated one level above and below the correct flood depths while there were 26 points and 21 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 67 points were overestimated while a total of 96 points were underestimated in the modelled flood depths of Cairawan.

Table 40. Summary of Accuracy Assessment in Cairawan

	No. of Points	%
Correct	95	**36.82**
Overestimated	67	25.97
Underestimated	96	37.21
Total	258	100

REFERENCES

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

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Paringit, E.C., Balicanta, L.P., Ang, M.C., Lagmay, A.F., 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.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition 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.

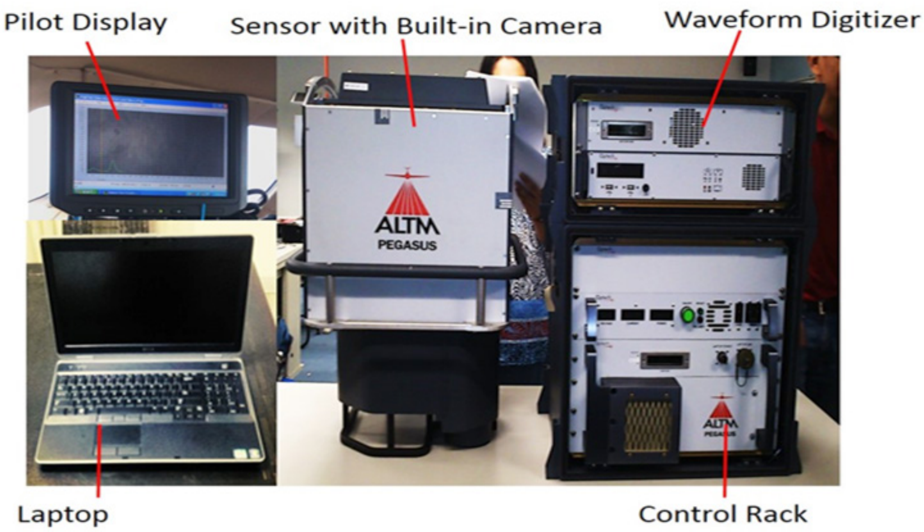
ANNEXES

Annex 1. Technical Specifications of The LiDAR Sensors Used In The Cairawan Floodplain `Survey

Annex 1a. OPTECH TECHNICAL SPECIFICATION OF THE AQUARIUS SENSOR

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

ANNEX A-2. OPTECH TECHNICAL SPECIFICATION OF THE GEMINI 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

Annex 2. Namria Certificates of Reference Points Used

1. 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**
Municipality: **BARBAZA**
Barangay: **CUBAY**
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

9 9 0 3 0 2 2 0 1 5 1 3 1 3 4 6

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. 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**
Municipality: **BELISON**
Barangay: **CONCEPCION**
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

9 9 0 3 0 2 2 0 1 5 1 3 0 9 5 8

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. 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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Reports of Reference Points Used

There are no baseline processing reports for the Cairawan river basin.

Annex 4. The LiDAR Survey Team

<table>
<tr><th>Data Acquisition Component Sub -Team</th><th>Designation</th><th>Name</th><th>Agency / Affiliation</th></tr>
<tr><td>PHIL-LiDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="4">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>GEROME HIPOLITO;</td><td>UP-TCAGP</td></tr>
<tr><td>Research Associate (RA)</td><td>VERLINA TONGA</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>REGINA FELISMINO</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>CATHERINE BALIGUAS</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Ground Survey, Data Download and Transfer</td><td>RA</td><td>JONATHAN ALMALVEZ</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>KENNETH QUISADO</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>IRO NIEL ROXAS</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="5">LiDAR Operation</td><td>Airborne Security</td><td>SSG. LEE JAY PUNZALAN</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td>Airborne Security</td><td>SSG. JAYCO MANZANO</td><td>PAF</td></tr>
<tr><td rowspan="3">Pilot</td><td>CAPT. JEFFREY JEREMY ALAJAR</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. JERICHO JECIEL</td><td>AAC</td></tr>
<tr><td>CAPT. ALBERT LIM</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheet for Cairawan Floodplain

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

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	
16-Feb-15	2566G	2BLK37V047A	gemini	na	1517	1.13	209	28	206	13	1.36	10.7	1KB	1KB	19	19	Z:\DAC\RAW DATA
16-Feb-15	2568G	2BLK37GSIV047B	gemini	na	952	1.34	222	46.8	383	21.9	2.12	6.61	1KB	1KB	7/4	15/12	Z:\DAC\RAW DATA
17-Feb-15	2570G	2BLK43H048A	gemini	na	1078	1.43	222	48.5	342	21.7	3.4	14.4	1KB	1KB	3	3	Z:\DAC\RAW DATA
19-Feb-15	2578G	2BLK43GV050A	gemini	na	586	891	184	8.07	67.8	19.4	na	11.1	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Feb-15	2580G	2BLK43F050B	gemini	na	740	990	163	25.6	203	16.2	3.29	4.11	1KB	1KB	4	8	Z:\DAC\RAW DATA
20-Feb-15	2582G	2BLK43A051A	gemini	na	169	254	106	6.84	57.4	4.65	ns	11	1KB	1KB	6	13	Z:\DAC\RAW DATA
21-Feb-15	2586G	2BLK43A052A	gemini	na	613	670	182	15.4	63.9	8.3	1.43	11.5	1KB	1KB	5	10	Z:\DAC\RAW DATA
22-Feb-15	2590G	2BLK43A053A	gemini	na	694	0.97	198	21.2	94.4/628	12.1	na	17	1KB	1KB	5	10	Z:\DAC\RAW DATA
23-Feb-15	2594G	2BLK43C054A	gemini	na	856	1.05	240	28.2	17.2/163	16.3	na	11.6	1KB	1KB	6	14	Z:\DAC\RAW DATA

Received from

Name C-JOAQUIN
Position FA
Signature

Received by

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

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

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	940	6.06	196	10.5	35/48	14.4	na	10.5	1KB	1KB	76	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43MO47B	pegasus	1.77	1.21	10.4	221	26.4	251	19.5	na	12.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MN048A	pegasus	2.06	1.35	9.99	263	34.5	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	6.06	170	14	127	11.4	na	20.2	1KB	1KB	96/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EFO49A	pegasus	2.91	1.71	9.97	263	42	314	27.8	na	14.3	1KB	1KB	99/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43ED049B	pegasus	1.7	1.02	9.05	190	19.9	1671	17.4	na	7.46	1KB	1KB	1/607/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.76	417	17.3	133	12.3	na	16.7	1KB	1KB	86/77/J26/821	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37I050B	pegasus	5.53	1.02	9.47	199	49.9	343	25.3	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	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43N052A	pegasus	2.09	1.29	9.69	257	37.9	274	21	na	11.5	1KB	1KB	52	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFV053A	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

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	190	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 Bongat
Position SSRS
Signature

Annex 6. Flight logs for Flight Missions

1. Flight Log for 2582G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2582

1 LIDAR Operator: MA Felismino	2 ALTM Model: Gemini	3 Mission Name: 2BLK43A051A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Dongguines	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: 20 FEB 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 8:55	14 Engine Off: 12:54	15 Total Engine Time: 3+59	16 Take off: 9:00	17 Landing: 12:49	18 Total Flight Time: 3+49
19 Weather: Fair					

20 Remarks:

Surveyed 3 lines of BLK43A but flight was cut due to strong wind

21 Problems and Solutions:

Acquisition Flight Approved by: G. Hipolito
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command: B. Dongguines
Signature over Printed Name

Lidar Operator: mafelismino
Signature over Printed Name

2. Flight Log for 2586G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2586

1 LiDAR Operator: MVF TONGA	2 ALTM Model: Gemini	3 Mission Name: 2BLK43A052A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Donguines	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: 21 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 9:05	14 Engine Off: 13:04	15 Total Engine Time: 3+59	16 Take off: 9:10	17 Landing: 12:57	18 Total Flight Time: 3+49
19 Weather: fair					

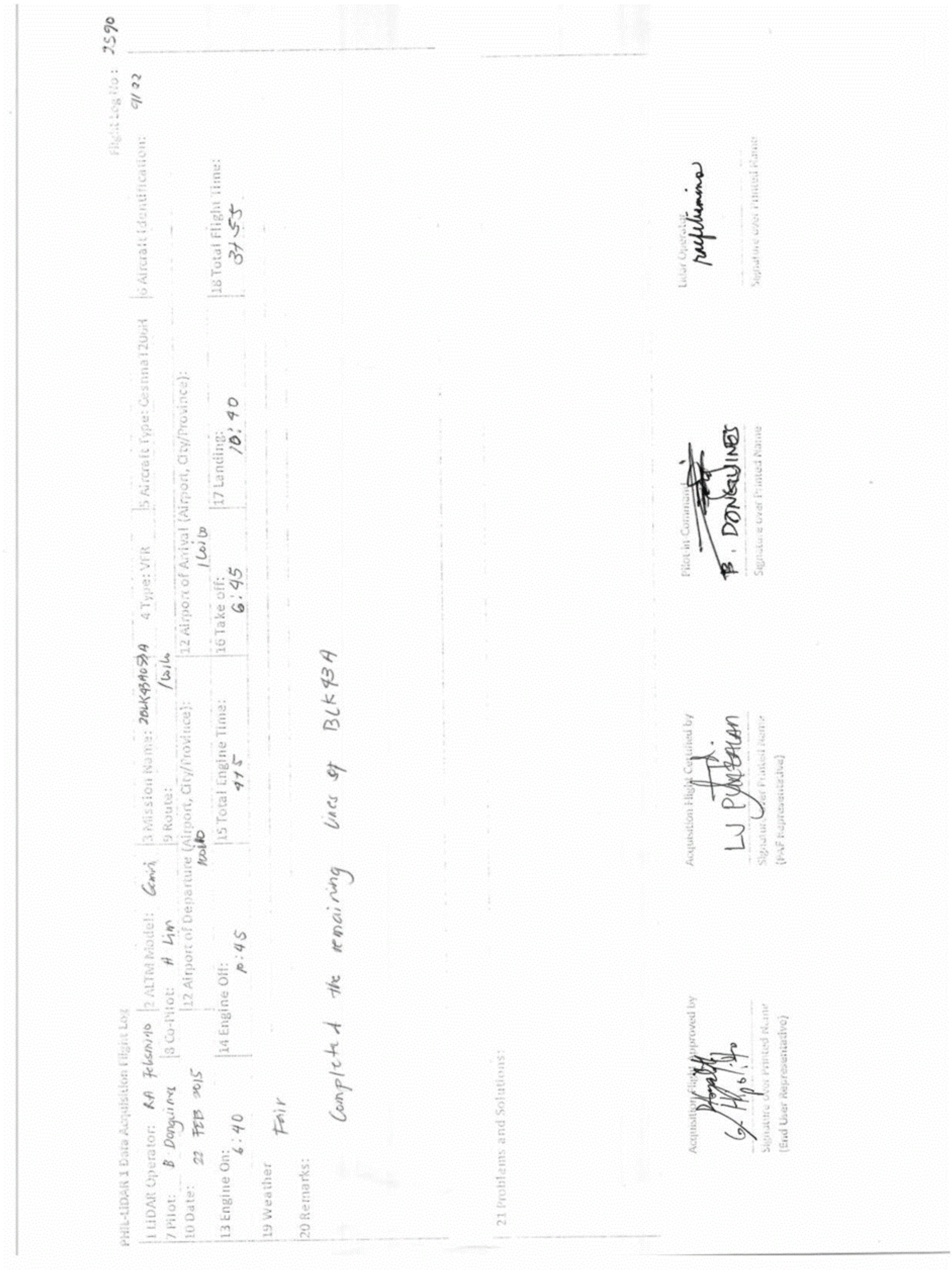
20 Remarks:

Surveyed 6 lines of BLK43A

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	LJ Puncalan	B. DONGUINES	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 2590G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2590

1 LIDAR Operator: RA Felsmino	2 ALTM Model: Gemini	3 Mission Name: 2BLK43A053A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B Donguines	8 Co-Pilot: A Lim	9 Route: Iloilo			
10 Date: 22 FEB 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 6:40	14 Engine Off: 10:45	15 Total Engine Time: 4+5	16 Take off: 6:45	17 Landing: 10:40	18 Total Flight Time: 3+55

19 Weather: Fair

20 Remarks:

Completed the remaining lines of BLK43A

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito	LJ Pungalan	B. DONGUINES	rafelsmino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. 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. Joya	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				

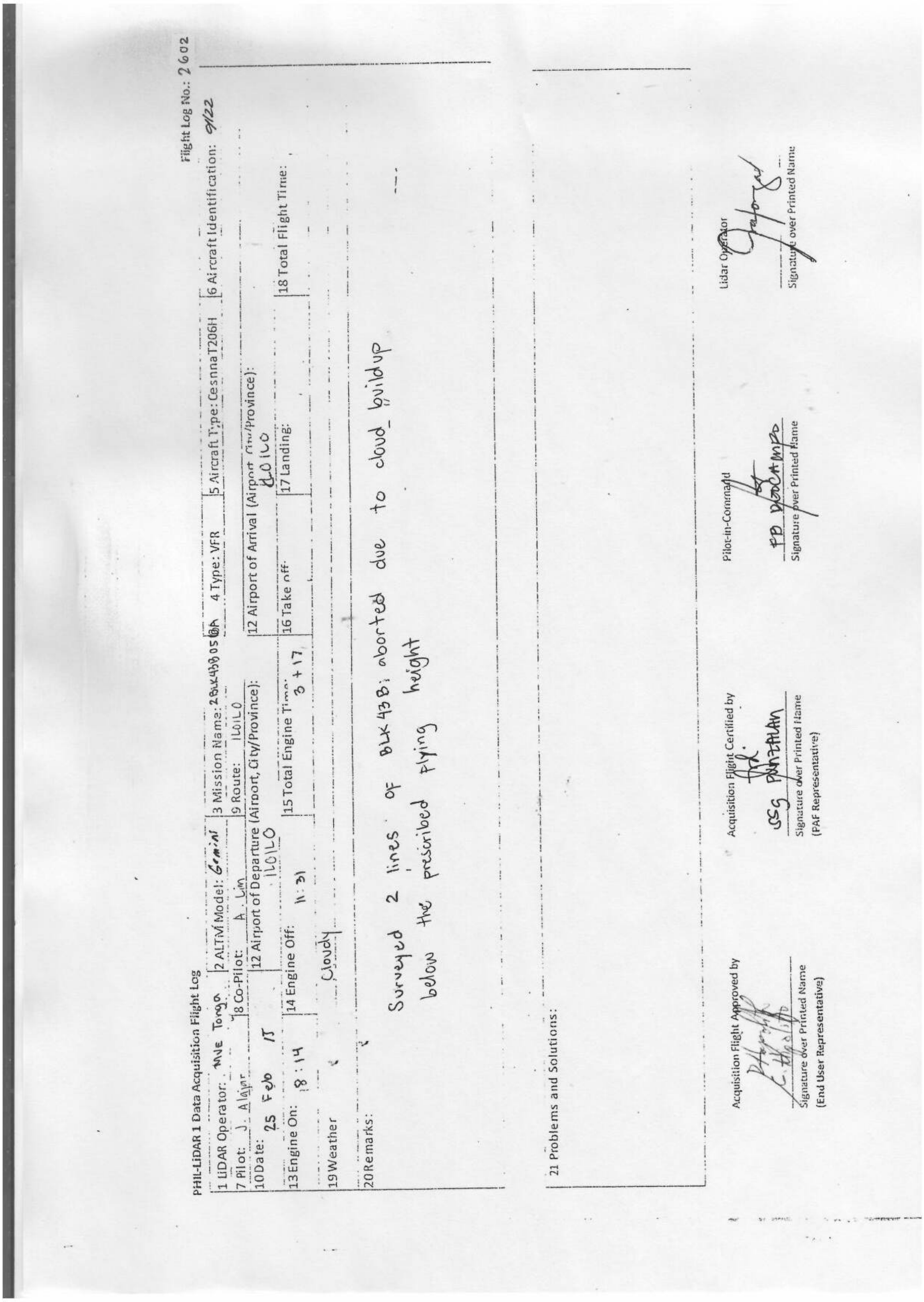
20 Remarks:

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. Hipolito	LJ Puzalan	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

5. Flight Log for 2602G



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2602

1 LIDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43B056A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 25 Feb 15	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 BLK 43B; 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. Hipolito	SSG PANZALAN	FB DEOCAMPO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight log for 2606G

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2606

1 LiDAR Operator: RA Felismino	2 ALTM Model: Gemini	3 Mission Name: 2BLK43BV057B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
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					

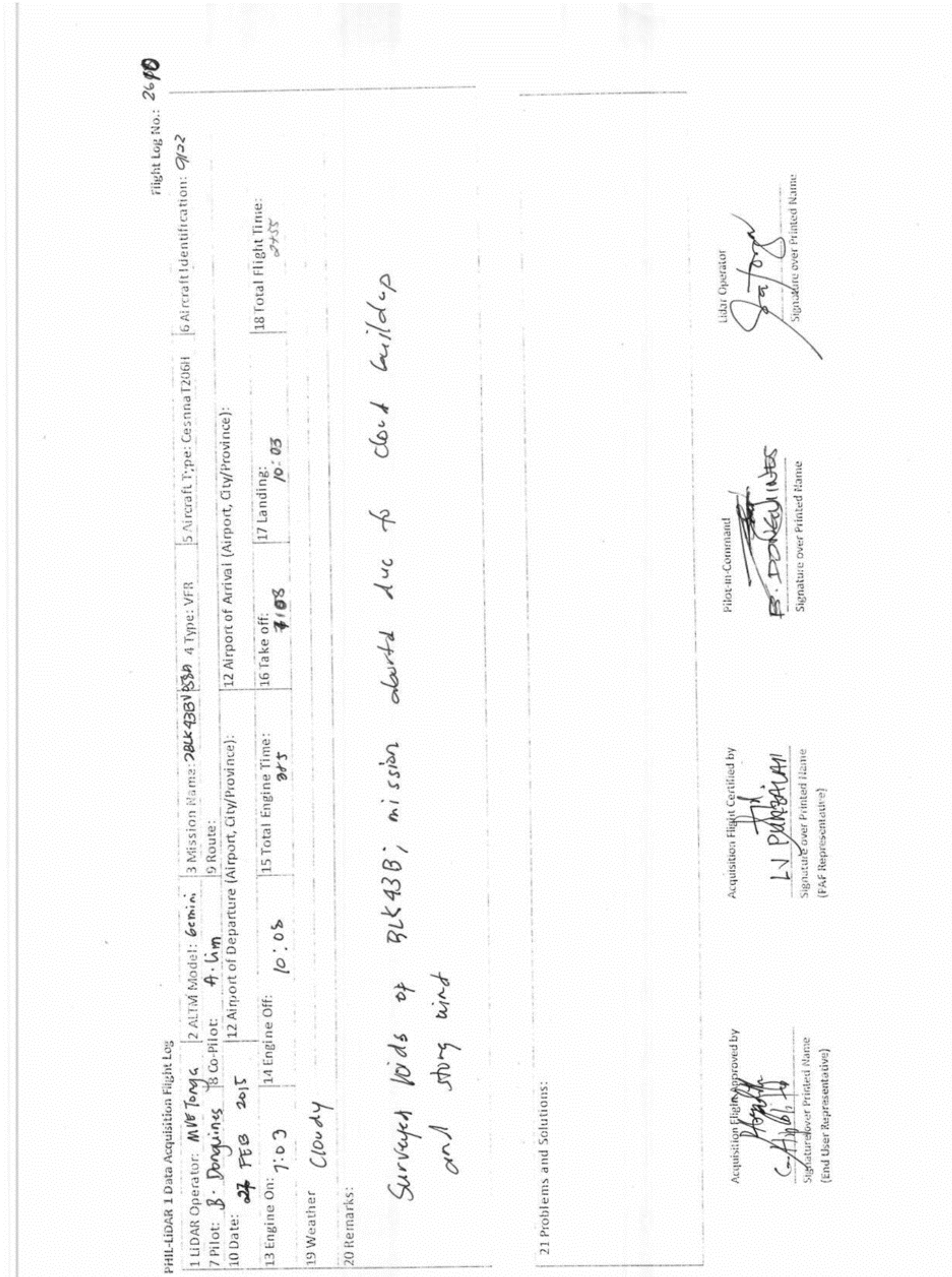
20 Remarks:

Surveyed 10 lines of BLK 43B

21 Problems and Solutions:

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

7. Flight log for 2610G



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2610

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43BV058A	4 Type: VFR	5 Aircraft Type: Cessna 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+05	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 — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — B. DONGUINES — Signature over Printed Name

Lidar Operator — Signature over Printed Name

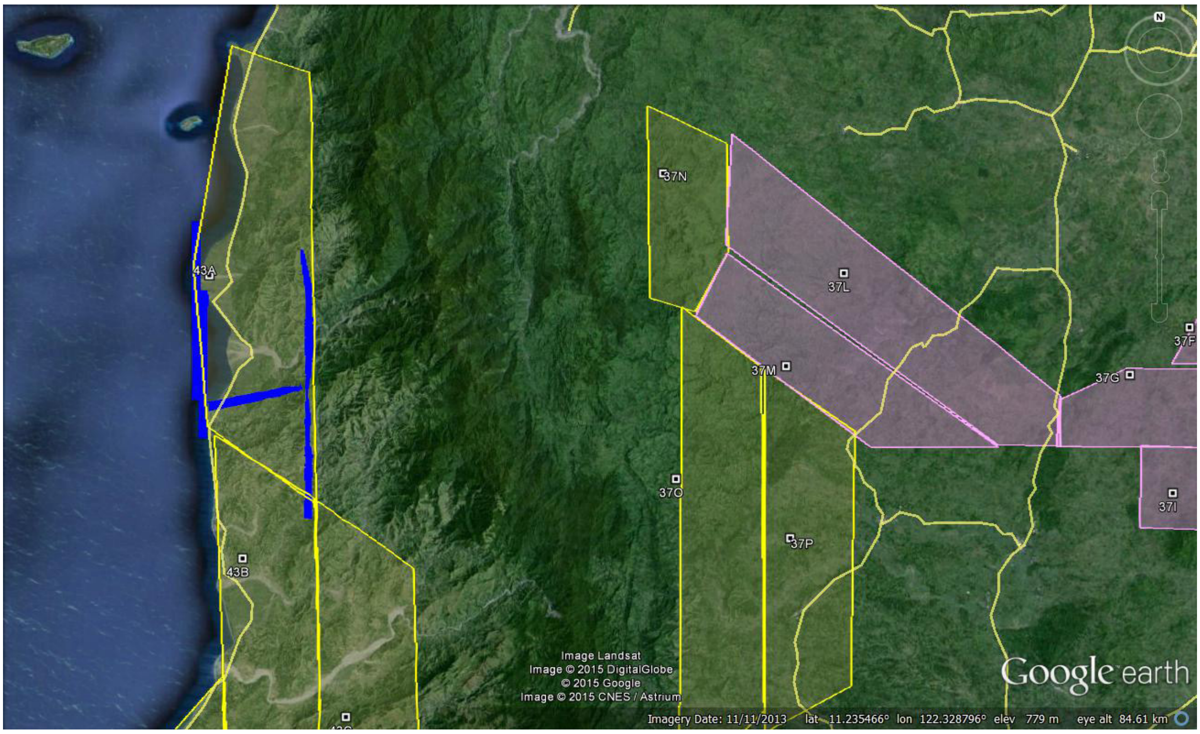
ANNEX 7. MISSION SUMMARY REPORT

Annex 8. Flight Status Report

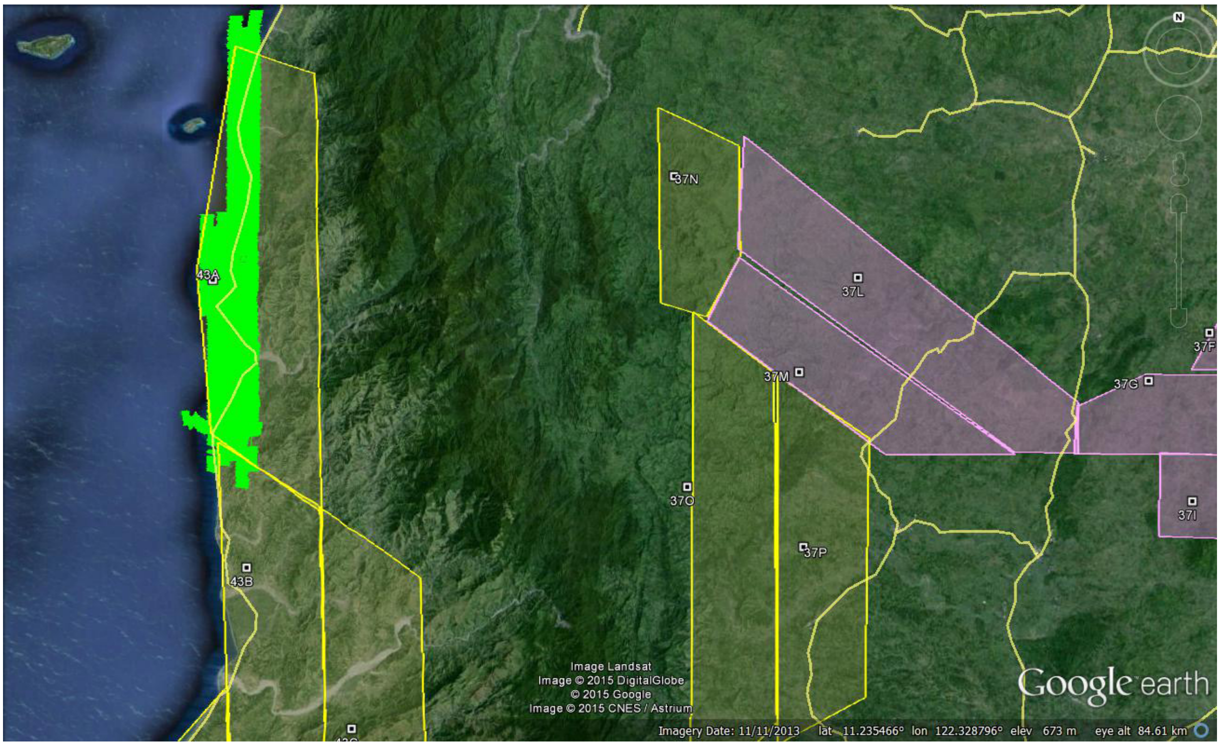
FLIGHT STATUS REPORT CAIRAWAN (February 2015)					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
2582G	BLK 43A	2BLK43A051A	RA FELISMINO	20 FEB 15	3 lines of BLK43A. Aborted due to strong winds
2586G	BLK 43A	2BLK43A052A	MVE TONGA	21 FEB 15	6 lines 43A
2590G	BLK 43A	2BLK43A053A	RA FELISMINO	22 FEB 15	Completed remaining BLK 43A
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 BOUNDARIES PER MISSION FLIGHT

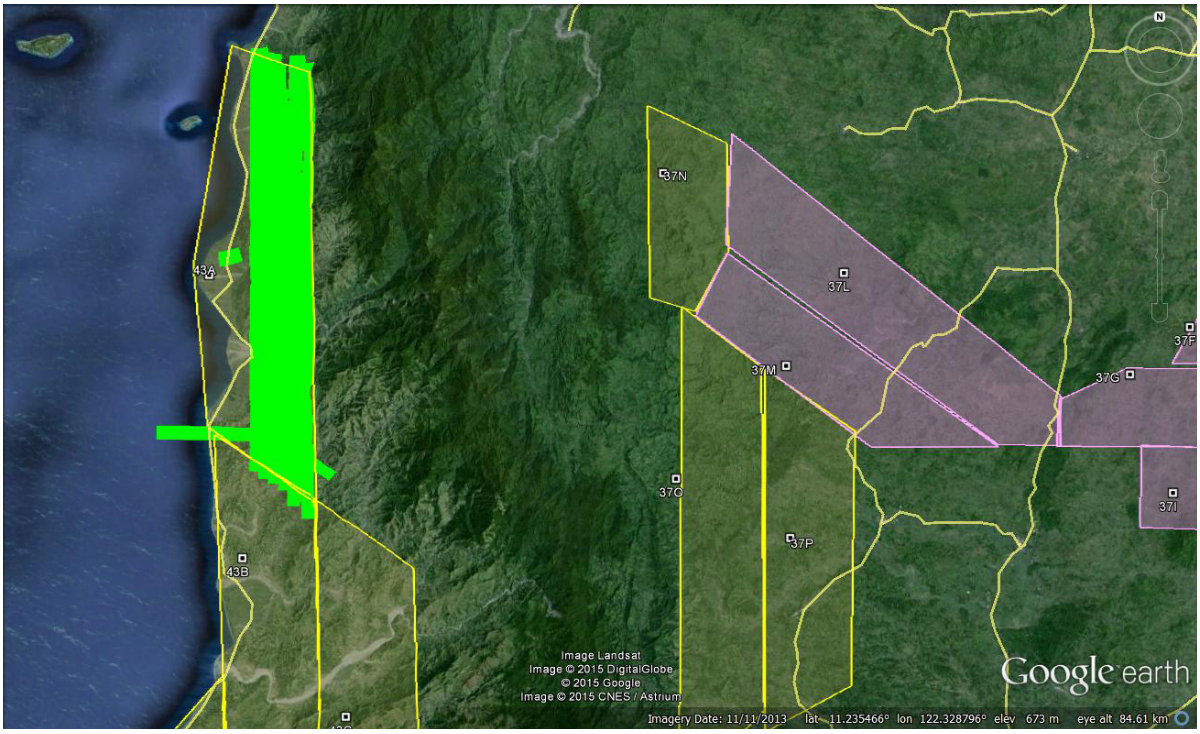
Flight No. : 2582G
Area: BLK 43A
Mission Name: 2BLK43A051A
Total Area Surveyed: 36.4833 sq km



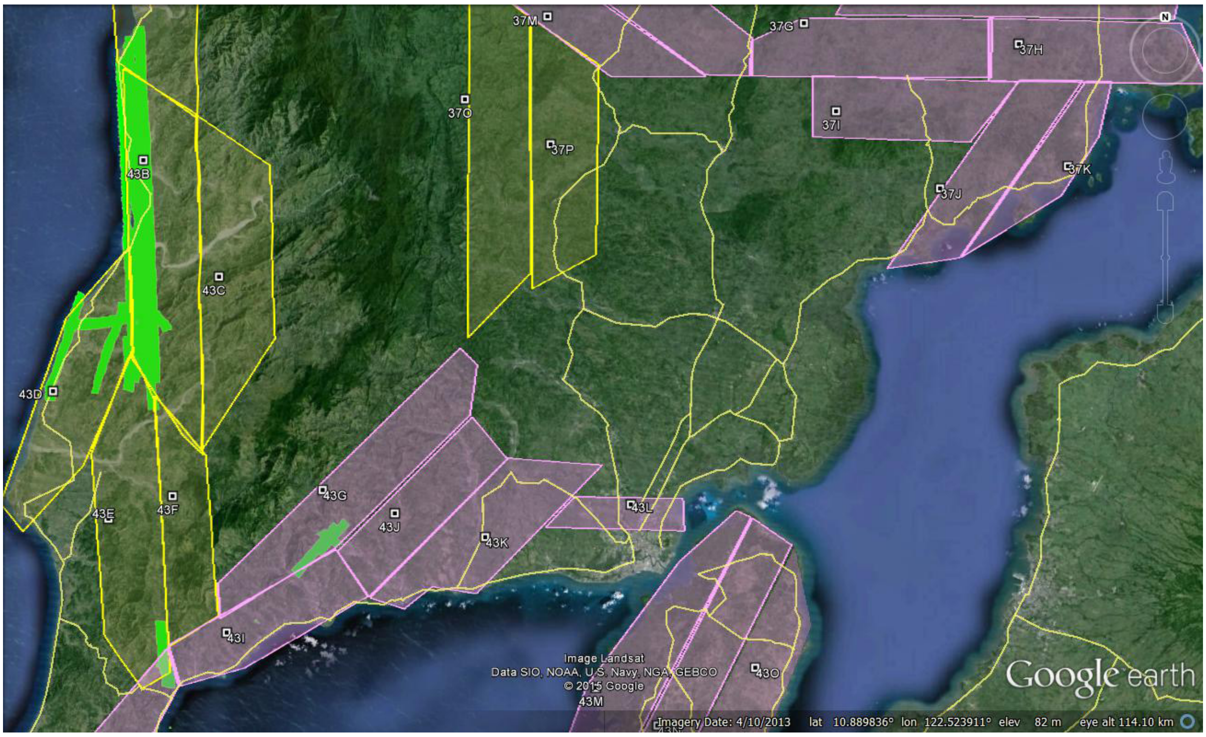
Flight No. :	2586G
Area:	BLK 43A
Mission Name:	2BLK43A052A
Total Area Surveyed:	137.706 sq km



Flight No. :	2590G
Area:	BLK 43A
Mission Name:	2BLK43A053A
Total Area Surveyed:	200.818 sq km

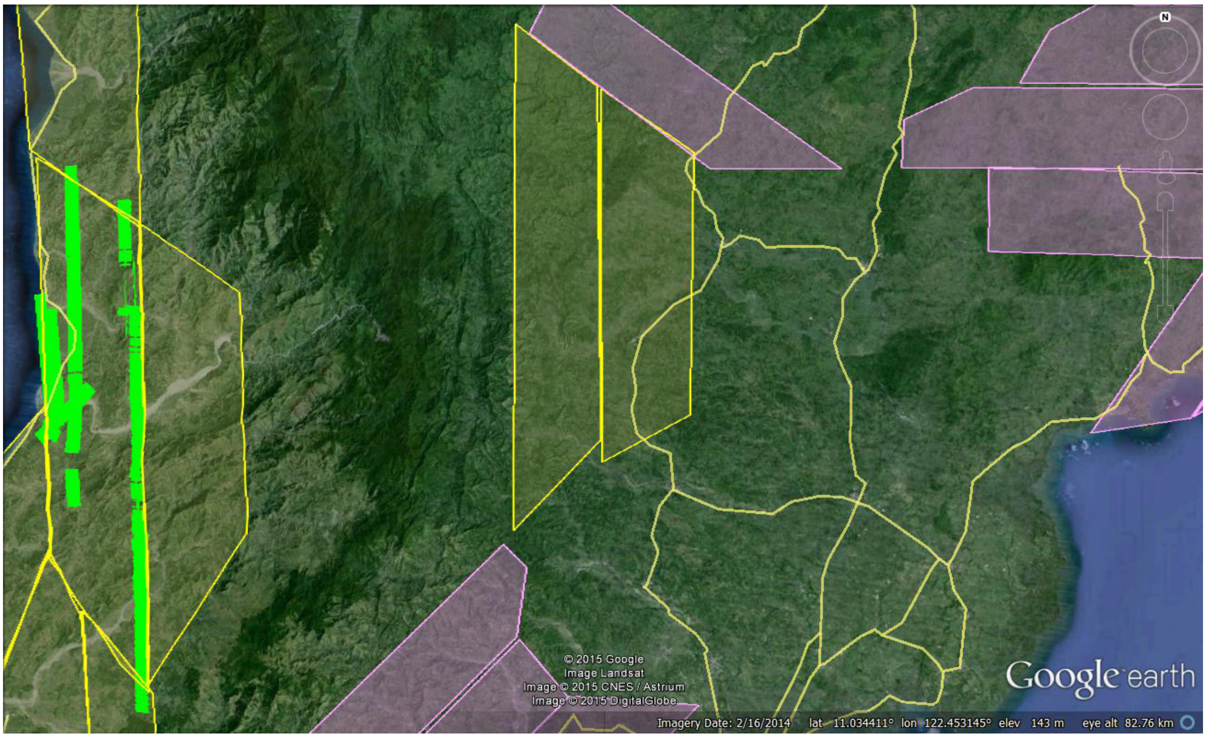


Flight No. 2593P
Area: BLK 43B, 43D, 43G
Mission Name: 1BLK43BC051A
Total Area Surveyed: 181.2 sq km

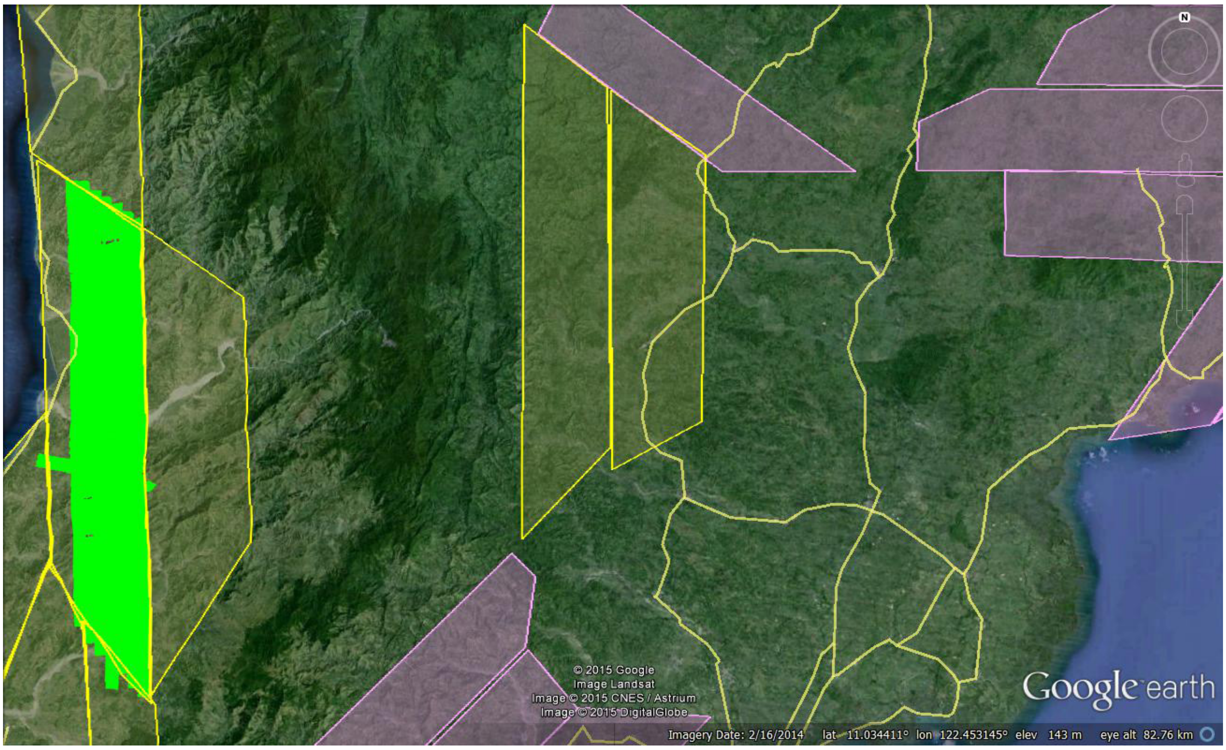


Flight No. : 2602

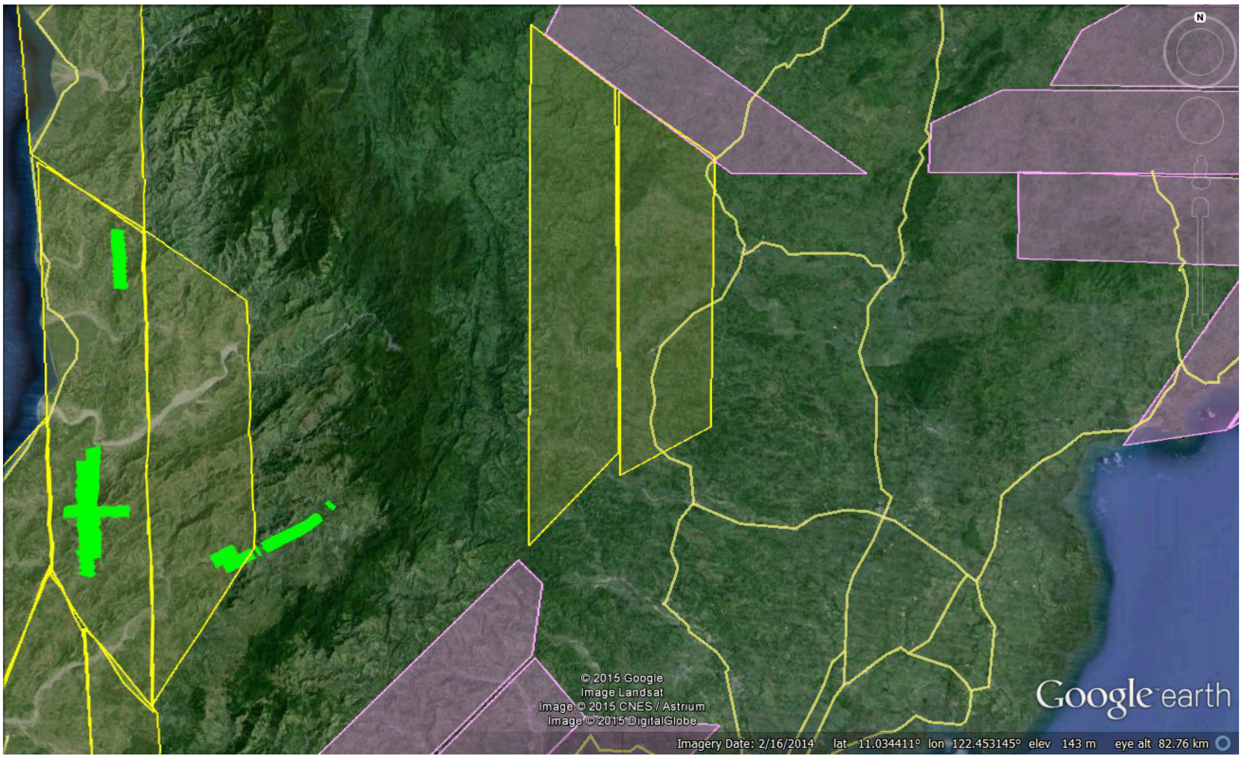
Area:	BLK 43B
Mission Name:	2BLK43B056A
Total Area Surveyed:	89.4442 sq km



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



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



Annex 9. Cairawan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W100	12.33276	52.158	0	0.8499	2.9183	Discharge	12.053	1	Ratio to Peak	0.9
W110	9.9002775	57.927	0	0.0661556	1.204	Discharge	4.7464	1	Ratio to Peak	0.9
W120	6.975	62.009	0	0.0538087	3.1556	Discharge	8.7908	1	Ratio to Peak	0.9
W130	6.975	62.009	0	0.0714671	2.808575	Discharge	11.648	1	Ratio to Peak	0.9
W140	6.975	64.566	0	0.0748536	2.032625	Discharge	4.6136	1	Ratio to Peak	0.9
W80	20.625	45	0	0.4098525	3.121475	Discharge	12.13	1	Ratio to Peak	0.9
W90	20.625	45	0	0.3073125	2.3405375	Discharge	6.6998	1	Ratio to Peak	0.9

Annex 10. Cairawan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	4793.5	0.050254	0.0016905	Trapezoid	153	1
R50	Automatic Fixed Interval	583.701	0.096283	0.00019753	Trapezoid	153	1
R70	Automatic Fixed Interval	3560.9	0.028844	0.00019753	Trapezoid	153	1

Annex 11. Cairawan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/ Scenario
	Lat	Long					
0	11.10900485	122.0456148	0.039999999	0	0.002		
2	11.11017642	122.0693125	0.029999999	0	0.001		
3	11.1240772	122.0387982	0.059999999	0.018	0.002	Frank	100-Year
4	11.134859	122.0729101	4.429999828	0	19.625		
5	11.12697916	122.0396987	0.029999999	0	0.001		
6	11.12124692	122.0414606	0.079999998	0	0.006		
7	11.12797349	122.0761419	0.029999999	0	0.001		
8	11.12540196	122.039347	0.029999999	0.04	0.000	Frank	100-Year
9	11.13544882	122.0724581	0.029999999	0	0.001		
10	11.12682429	122.0393788	0.079999998	0.05	0.001	Frank	100-Year
11	11.13536763	122.072539	0	0	0.000		
12	11.12388816	122.0390291	0.779999971	0.018	0.581	Frank	100-Year
13	11.10845476	122.0460139	0.029999999	0.2	0.029	Yolanda	5-Year
14	11.12677435	122.0398489	0	0	0.000		
15	11.1253384	122.0392033	0	0.04	0.002	Frank	100-Year
16	11.1510177	122.0904809	0.029999999	0.08	0.003	Undang	5-Year
17	11.15758966	122.099947	0.029999999	0.914	0.781	Yolanda	5-Year
18	11.12788589	122.0748581	0.059999999	0	0.004		
19	11.12590277	122.0403944	0.910000026	1	0.008	Frank	100-Year
20	11.12547219	122.0389872	0	0.4	0.160	Frank	100-Year
21	11.12653348	122.0407423	0.059999999	0	0.004		
22	11.11939817	122.0615505	0.029999999	0	0.001		
23	11.12647979	122.0407445	0	0	0.000		
24	11.1465296	122.0806824	0.050000001	0	0.003		
25	11.12570322	122.0391682	0.600000024	0.4	0.040	Frank	100-Year
26	11.12578853	122.0403527	0	1	1.000	Frank	100-Year
27	11.11948639	122.0617555	0	0	0.000		
28	11.10929872	122.0415146	0.730000019	0.75	0.000	Frank	100-Year
29	11.12552688	122.0393252	0.029999999	0.4	0.137	Frank	100-Year
30	11.10736162	122.0423454	0.029999999	0.4	0.137	Frank	100-Year
31	11.12582964	122.0391021	0	0.4	0.160	Frank	100-Year
32	11.12604957	122.0393908	0	0.5	0.250	Frank	100-Year
33	11.12137004	122.0532414	0.029999999	0.2	0.029	Frank	100-Year
34	11.10930725	122.0415777	0	0.75	0.563	Frank	100-Year
35	11.12552092	122.0391593	0	0.4	0.160	Frank	100-Year
36	11.12647382	122.0405456	0	0	0.000		
37	11.10745043	122.0423647	0	0.8	0.640	Frank	100-Year
38	11.12483914	122.0398266	0.140000001	0	0.020		
39	11.12529207	122.0568722	0.039999999	0	0.002		
40	11.11661489	122.0610564	0.25999999	0	0.068		
41	11.13285551	122.0438713	0.189999998	0.62	0.185	Yolanda	5-Year
42	11.15181966	122.0394653	0.119999997	0.053	0.004	Frank	100-Year
43	11.10974475	122.0415956	1.179999948	0.8	0.144	Frank	100-Year
44	11.10981346	122.0412352	0.790000021	0.9	0.012	Ruping	5-Year

45	11.11007536	122.0413815	0	0.8	0.640	Frank	100-Year
46	11.11012936	122.0413787	0.860000014	0.8	0.004	Frank	100-Year
47	11.12637443	122.0407	0	0.6	0.360	Frank	100-Year
48	11.15055587	122.0905844	0.029999999	0.08	0.003	Undang	5-Year
49	11.12630856	122.0406767	0	0.6	0.360	Frank	100-Year
50	11.12576664	122.0403613	0	1	1.000	Frank	100-Year
51	11.10911778	122.04161	0	7	49.000	Frank	100-Year
52	11.11003591	122.0411565	0	1.1	1.210	Frank	100-Year
53	11.10963492	122.0413328	0	0.9	0.810	Ruping	5-Year
54	11.12633863	122.0408075	0	0.6	0.360	Frank	100-Year
55	11.10743528	122.0424915	0	0.8	0.640	Frank	100-Year
56	11.12594546	122.0406187	0.059999999	0.5	0.194	Frank	100-Year
58	11.12574046	122.0398314	0.649999976	0.7	0.003	Frank	100-Year
59	11.10985036	122.0412865	0	0.9	0.810	Ruping	5-Year
60	11.11844237	122.0440281	0.800000012	1	0.040	Frank	100-Year
61	11.12554157	122.0591617	4.050000191	0	16.403		
62	11.14611581	122.0401953	0.74000001	0.53	0.044	Frank	100-Year
63	11.1451818	122.0805167	0.059999999	0	0.004		
64	11.1106022	122.0410051	1.720000029	1.1	0.384	Frank	100-Year
65	11.11100432	122.0408487	0.519999981	1.6	1.166	Undang	5-Year
66	11.11150977	122.0406145	1.470000029	1.1	0.137	Frank	100-Year
67	11.11089092	122.0408999	0	1.1	1.210	Frank	100-Year
68	11.10983771	122.041652	0	1.4	1.960	Frank	100-Year
69	11.11139337	122.0408362	0	1.1	1.210	Yolanda	5-Year
70	11.1220536	122.0571961	0.029999999	0	0.001		
71	11.11096899	122.0407761	0	1.6	2.560	Undang	5-Year
72	11.15053728	122.0907318	6.25	0.08	38.069	Undang	5-Year
73	11.12167866	122.0569548	0.029999999	0.4	0.137	Undang	5-Year
74	11.11147631	122.0407454	0	1.1	1.210	Frank	100-Year
75	11.10987771	122.0416782	0	1.4	1.960	Frank	100-Year
76	11.15315627	122.0913653	3.089999914	0	9.548		
77	11.11131506	122.0408597	0	1.1	1.210	Yolanda	5-Year
78	11.15321329	122.0912788	0	0	0.000		
79	11.1507184	122.0906435	0	0.08	0.006	Undang	5-Year
80	11.11132702	122.0406317	0	1.1	1.210	Frank	100-Year
81	11.12209535	122.0571987	0	0	0.000		
82	11.11600112	122.0481866	1.690000057	1	0.476	Frank	100-Year
83	11.12118039	122.072116	0.810000002	0.08	0.533	Yolanda	5-Year
84	11.12109955	122.0715957	0.899999976	0.08	0.672	Yolanda	5-Year
85	11.11841887	122.0700187	1.899999976	0.457	2.082	Yolanda	5-Year
86	11.12751374	122.0726433	1.139999986	0.305	0.697	Frank	100-Year
87	11.15278768	122.0915405	8.079999924	0	65.286		
88	11.15065189	122.0907975	0	0.61	0.372	Undang	5-Year
89	11.15274547	122.0911744	0	0	0.000		
90	11.15290124	122.0912673	0	0	0.000		
91	11.15269297	122.0913319	0	0	0.000		
92	11.15071239	122.0908862	0	0.61	0.372	Undang	5-Year
93	11.15305519	122.0913972	0	0	0.000		

94	11.15072261	122.0908486	0	0.61	0.372	Undang	5-Year
95	11.14665362	122.0805706	0	0	0.000		
96	11.15251522	122.0911165	0	0	0.000		
97	11.1526119	122.0911597	0	0	0.000		
98	11.15090781	122.0908242	0	0.08	0.006	Undang	5-Year
99	11.15306963	122.0912977	0	0	0.000		
100	11.13139977	122.072787	0.029999999	0.305	0.076	Frank	100-Year
101	11.11350576	122.0596248	0.870000005	0.335	0.286	Frank	100-Year
102	11.12198693	122.068274	1.549999952	0.457	1.195	Yolanda	5-Year
103	11.14697209	122.0807342	0.980000019	0.165	0.664	Undang	5-Year
104	11.14702486	122.0808739	0	0.8	0.640	Undang	5-Year
105	11.14676	122.080161	4.639999866	0.5	17.140	Frank	100-Year
106	11.15287276	122.09167	0.029999999	1.219	1.414	Yolanda	5-Year
107	11.14700874	122.0807681	0	0.165	0.027	Undang	5-Year
108	11.14625182	122.0799632	4.71999979	1.1	13.104	Frank	100-Year
109	11.14664296	122.0800036	0	0.5	0.250	Frank	100-Year
110	11.14098018	122.0721741	3.670000076	0	13.469		
111	11.15704761	122.0977787	0.029999999	0.914	0.781	Yolanda	5-Year
112	11.15616514	122.0960195	3.299999952	0.914	5.693	Yolanda	5-Year
113	11.14797526	122.0847473	2.900000095	0	8.410		
114	11.1449992	122.0830728	5.630000114	0	31.697		
115	11.110964	122.040699	0	0.9	0.810	Frank	100-Year
116	11.111285	122.040957	0	0.7	0.490	Frank	100-Year
117	11.110371	122.041316	0	0.8	0.640	Frank	100-Year
118	11.110103	122.0414	0	1.6	2.560	Undang	5-Year
119	11.110274	122.041531	1.279999971	0	1.638		
120	11.109647	122.041494	0	0.8	0.640	Frank	100-Year
121	11.108973	122.041591	0	2	4.000	Frank	100-Year
122	11.108858	122.041876	0	0.8	0.640	Frank	100-Year
123	11.107628	122.042147	0.730000019	0.8	0.005	Frank	100-Year
124	11.107024	122.042441	0	0.8	0.640	Frank	100-Year
125	11.10774	122.043086	0.029999999	0.8	0.593	Undang	5-Year
126	11.104507	122.044666	0.07	0.7	0.397	Frank	100-Year
127	11.108991	122.045851	0	0.8	0.640	Frank	100-Year
128	11.116	122.04769	1.269999981	0.5	0.593	Frank	100-Year
129	11.120141	122.045202	0.029999999	0.7	0.449	Yolanda	5-Year
130	11.121066	122.040785	0.519999981	0	0.270		
131	11.12641	122.040488	0	0	0.000		
132	11.126455	122.04067	0	0.2	0.040	Yolanda	5-Year
133	11.121485	122.057039	0.029999999	0	0.001		
134	11.122051	122.0576	0	0	0.000		
135	11.119161	122.062657	0.029999999	0.4	0.137	Frank	100-Year
136	11.119626	122.062662	0.100000001	0	0.010		
137	11.119759	122.062587	0.050000001	0	0.003		
138	11.119975	122.062061	0.079999998	0.4	0.102	Yolanda	5-Year
139	11.128368	122.04191	0.059999999	0	0.004		
140	11.11457732	122.0590908	4.409999847	1	11.628	Yolanda	5-Year
141	11.1199247	122.0685413	1.99000001	0.8	1.416	Ruping	5-Year

142	11.11204171	122.0688511	5	3	4.000	Undang	5-Year
143	11.11759516	122.0486658	2.019999981	3	0.960	Frank	100-Year
144	11.11464717	122.0613745	1.879999995	4.5	6.864	Undang	5-Year
145	11.11573347	122.0592624	1.379999995	1	0.144	Yolanda	5-Year
146	11.1156182	122.0584164	1.850000024	2.5	0.422	Yolanda	5-Year
147	11.12075236	122.068322	3.880000114	3	0.774	Ruping	5-Year
148	11.13092307	122.0695498	0.519999981	3	6.150	Undang	5-Year
149	11.11857172	122.0532391	1.919999957	3	1.166	Yolanda	5-Year
150	11.11748144	122.0698627	1.549999952	3	2.103	Undang	5-Year
151	11.11774265	122.0500288	2.460000038	3	0.292	Undang	5-Year
152	11.1287509	122.0707783	1.779999971	1	0.608	Undang	5-Year
153	11.12036179	122.0681574	6.489999771	3	12.180	Ruping	5-Year
154	11.11678926	122.0485038	2.779999971	3	0.048	Frank	100-Year
155	11.11954663	122.0688955	2.369999886	3	0.397	Ruping	5-Year
156	11.11836166	122.0549838	2.190000057	3	0.656	Yolanda	5-Year
157	11.15258381	122.0460849	0.059999999	0.8	0.548	Frank	100-Year
158	11.11784816	122.0517836	2.24000001	1.5	0.548	Yolanda	5-Year
159	11.12789458	122.0714359	1.710000038	1.5	0.044	Undang	5-Year
160	11.14095929	122.0719692	0	2	4.000	Ruping	5-Year
161	11.12082376	122.0682409	0	3	9.000	Ruping	5-Year
162	11.1396287	122.0703876	0.029999999	6	35.641	Undang	5-Year
163	11.14144902	122.0715854	7.880000114	2	34.574	Ruping	5-Year
164	11.11302516	122.06249	5.880000114	5	0.774	Undang	5-Year
165	11.14050932	122.0709816	6.760000229	5	3.098	Yolanda	5-Year
166	11.11350961	122.0598125	4.050000191	1	9.303	Yolanda	5-Year
167	11.13276259	122.0721057	8.539999962	3	30.692	Undang	5-Year
168	11.12455293	122.0699901	1.470000029	1	0.221	Ruping	5-Year
169	11.13782846	122.0694146	5.21999979	6	0.608	Undang	5-Year
170	11.13386477	122.0717844	7.300000191	3	18.490	Undang	5-Year
171	11.12637189	122.0709189	1.399999976	2	0.360	Undang	5-Year
172	11.11203008	122.0642469	0.029999999	4.5	19.981	Undang	5-Year
173	11.13805497	122.0701175	4.389999866	6	2.592	Undang	5-Year
174	11.13764269	122.0702227	0.029999999	6	35.641	Undang	5-Year
175	11.12678295	122.0707058	7.239999771	1.5	32.948	Undang	5-Year
176	11.11346267	122.0597839	0	1	1.000	Yolanda	5-Year
178	11.12610376	122.0705203	3.059999943	2	1.124	Undang	5-Year
179	11.14008246	122.0702754	12.93000031	6	48.025	Undang	5-Year
180	11.12278059	122.0567525	0.029999999	2	3.881	Yolanda	5-Year
181	11.1220411	122.0567796	0	2	4.000	Yolanda	5-Year
182	11.16272421	122.0388489	2.25	2	0.063	Marce	5-Year
183	11.14462094	122.0410643	0.340000004	0	0.116		
184	11.14334695	122.0422685	1.690000057	0	2.856		
185	11.1442228	122.0418681	0.689999998	0.305	0.148	Yolanda	5-Year
186	11.14475314	122.0409279	0.430000007	0	0.185		
187	11.1434834	122.0421876	0	0	0.000		
188	11.14416125	122.0425389	0.029999999	3	8.821	Yolanda	5-Year
189	11.13749314	122.0412076	2.609999895	0	6.812		
190	11.14416169	122.0425739	0	3	9.000	Yolanda	5-Year

191	11.16279892	122.0388332	0	2	4.000	Marce	5-Year
192	11.16083217	122.0387565	0.050000001	0	0.003		
193	11.1548434	122.0399736	1.50999999	0.4	1.232	Yolanda	5-Year
194	11.14242814	122.0403152	0.209999993	0.15	0.004	Frank	100-Year
195	11.14333966	122.0405546	0.100000001	0.3	0.040	Frank	100-Year
196	11.15705989	122.0395793	0.029999999	0	0.001		
197	11.1426626	122.0400117	0	0.3	0.090	Frank	100-Year
198	11.14288622	122.0400144	0.129999995	0.3	0.029	Frank	100-Year
199	11.13477751	122.0403306	0.239999995	0.3	0.004	Frank	100-Year
200	11.14300457	122.0404447	0.200000003	0.3	0.010	Frank	100-Year
201	11.16149187	122.0391198	0.029999999	0	0.001		
202	11.16136068	122.038615	0.029999999	0	0.001		
203	11.14411713	122.0419778	0.100000001	0	0.010		
204	11.14378686	122.0410386	0.200000003	0	0.040		
205	11.1439818	122.0423425	0	3	9.000	Yolanda	5-Year
206	11.14462452	122.0401479	0.349999994	0.7	0.123	Frank	100-Year
207	11.1438462	122.0416984	0.310000002	0	0.096		
208	11.14393024	122.0413043	0	0	0.000		
209	11.14078029	122.0411645	0.140000001	0.9	0.578	Frank	100-Year
210	11.14398106	122.0412543	0	0	0.000		
211	11.16180322	122.0385225	0.029999999	0.8	0.593	Frank	100-Year
212	11.16245119	122.0383068	0.029999999	0	0.001		
213	11.14420694	122.0417838	0	0.305	0.093	Yolanda	5-Year
214	11.1436976	122.0414052	0	0	0.000		
215	11.14448202	122.0409807	0	0	0.000		
216	11.14375565	122.0416597	0	0	0.000		
217	11.14393108	122.0415667	0	0	0.000		
218	11.14045009	122.0408591	0.07	0.9	0.689	Frank	100-Year
219	11.14390407	122.0418186	0	0	0.000		
220	11.16250733	122.0382062	0.029999999	0	0.001		
221	11.11874168	122.0490781	1.580000043	2	0.176	Undang	5-Year
222	11.11747136	122.0477088	2.5	3	0.250	Frank	100-Year
223	11.11819767	122.0486221	2.809999943	3	0.036	Frank	100-Year
224	11.11768278	122.0574138	0.409999996	2.5	4.368	Yolanda	5-Year
225	11.11470098	122.0581559	5.909999847	1	24.108	Yolanda	5-Year
226	11.11353515	122.0612728	6.449999809	5	2.102	Undang	5-Year
227	11.11102027	122.0667745	0.050000001	3	8.702	Undang	5-Year
228	11.11564453	122.0707886	6.050000191	3	9.303	Undang	5-Year
229	11.11754464	122.0711488	3.099999905	3	0.010	Undang	5-Year
230	11.135011	122.07069	7.730000019	3	22.373	Undang	5-Year
231	11.134757	122.070562	0	3	9.000	Undang	5-Year
232	11.130774	122.06997	0.860000014	3	4.580	Undang	5-Year
233	11.130477	122.070314	0.99000001	3	4.040	Undang	5-Year
234	11.128312	122.070984	6.550000191	1.5	25.503	Undang	5-Year
235	11.124768	122.069788	6.690000057	0.9	33.524	Ruping	5-Year
236	11.122823	122.06886	1.919999957	1.5	0.176	Ruping	5-Year
237	11.119347	122.069782	3.180000067	2	1.392	Undang	5-Year
238	11.115094	122.068724	1.00999999	2	0.980	Undang	5-Year

239	11.11818	122.052885	2.359999895	1.5	0.740	Undang	5-Year
240	11.117676	122.050859	2.700000048	2	0.490	Undang	5-Year
241	11.1114812	122.0696114	1.690000057	4.84	9.922	Undang	5-Year
242	11.11630449	122.0504595	1.080000043	0.4	0.462	Undang	5-Year
243	11.11557847	122.0496378	0.029999999	0.4	0.137	Undang	5-Year
244	11.11684994	122.0513733	0.75	0.4	0.123	Undang	5-Year
245	11.12031168	122.0745279	0.090000004	1.64	2.402	Frank	100-Year
246	11.12058055	122.0751821	0.439999998	1.64	1.440	Frank	100-Year
247	11.12029287	122.0752943	0	1.64	2.690	Frank	100-Year
248	11.11175235	122.0695678	0.029999999	4.84	23.136	Undang	5-Year
249	11.11484985	122.047992	0.270000011	0.3	0.001	Undang	5-Year
250	11.11396579	122.0544042	0.119999997	0.2	0.006	Yolanda	5-Year
251	11.11396032	122.0526646	0.029999999	0.9	0.757	Undang	5-Year
252	11.11473092	122.0520617	0.49000001	0	0.240		
253	11.11435113	122.047755	0.029999999	0.8	0.593	Frank	100-Year
254	11.11032416	122.0466333	0.039999999	0	0.002	Yolanda	5-Year
255	11.10800179	122.0459964	0.310000002	0.73	0.176	Yolanda	5-Year
256	11.11373563	122.0538556	0.419999987	0.2	0.048	Yolanda	5-Year
257	11.113546	122.0528122	1.25	0.9	0.123	Undang	5-Year

Annex 12. Educational Institutions Affected in Cairawan Floodplain

Antique				
Laua-An				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Lactudan Day Care Center	Bongbongan	Low	Low	Low
Lactudan Primary School	Bongbongan			
Lindero-Cadajug Elementary School	Cadajug			
Casit-an Day Care Center	Casit-An			
Casit-an Elementary School	Casit-An			
Bongbongan Primary School	Igtadiao			
Latazan Day Care Center	Latazon	High	High	High
Latazon Day Care Ceneter	Latazon	High	High	High
Latazon Elementary School	Latazon	Medium	High	High
Municipal HBCC Nursery	Liberato			
Lindero Day Care Center	Lindero	Medium	Medium	Medium
Sitio Malamawan Day Care Center - Lindero	Lindero			
Liya-Liya Day Care Center	Liya-Liya			
Oloc Elementary School	Liya-Liya			
Lupaan Day Care Center	Lupa-An			
Lupaan Elementary School	Lupa-An			
Igtadiao Day Care Center	Omlot			
Igtadiao Pre School	Omlot			
Omlot Day Care Center	Omlot		Low	Medium
TESDA	Omlot			Low
Tigunhao Primary School	Tigunhao			

Annex 13. Health Institutions Affected by Flooding in Cairawan Floodplain

Antique				
Laua-An				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Lindero Health Center & Birthing Clinic	Lindero		Low	Low

Annex 14. UPC Phil-LiDAR 1 Team Composition

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