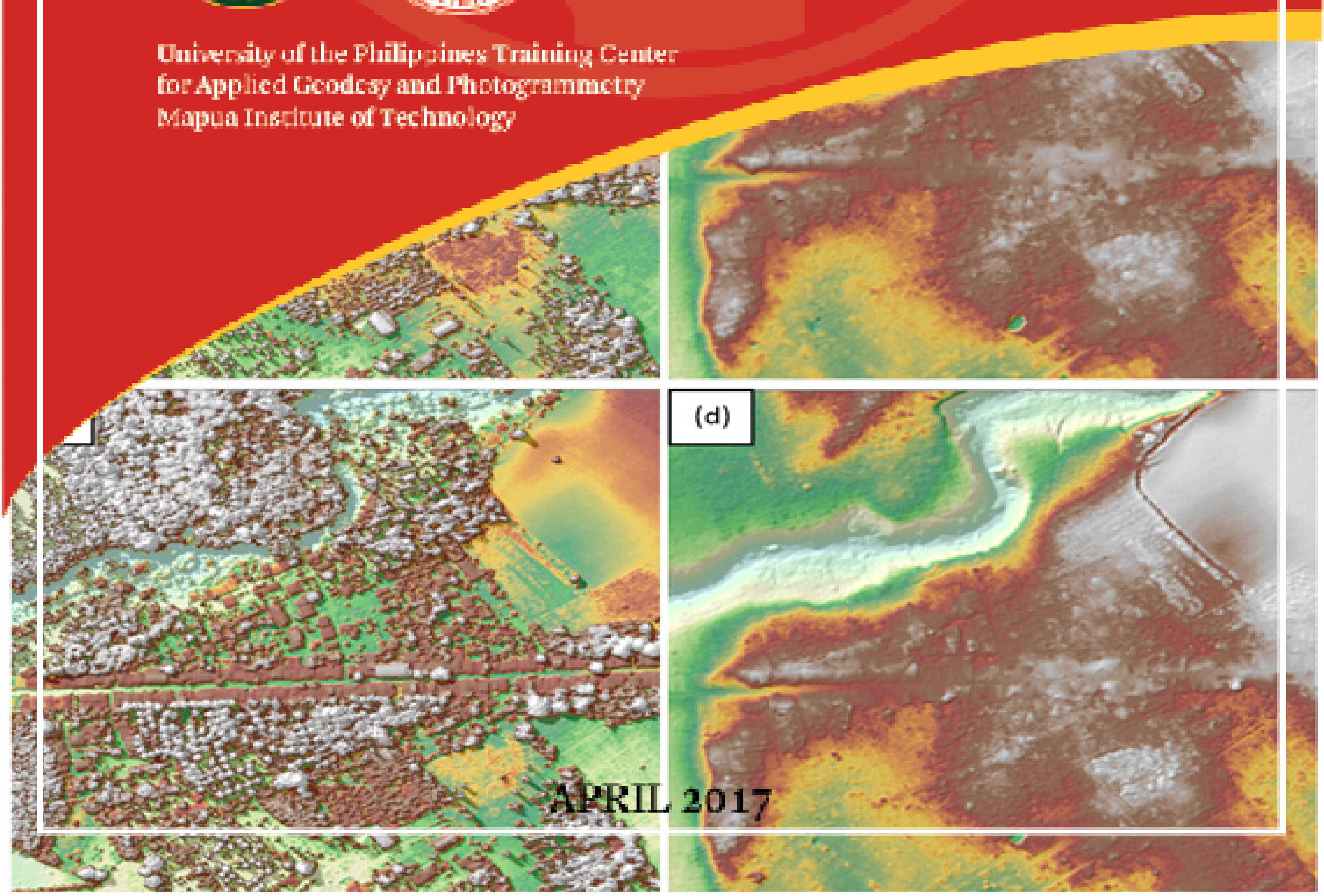
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Maapon River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mapua Institute of Technology



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MAAPON RIVER

Enrico C. Paringit, Dr. Eng., Dr. Francis Aldrine A. Uy, and Engr. Fibor Tan

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Baguio (UPB). UPB 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 12 river basins in the Ilocos Region and the Cordillera Administrative Region. The university is located in Baguio City in the province of Benguet.

1.2 Overview of the Maapon River Basin

The Maapon River Basin is located in the northern part of Quezon province. Specifically, it is bounded by the municipality of Cavinti, Laguna to the north; Lucban, Quezon to the south; Majayjay, Laguna to the west; and the Philippine Sea to the east. It traverses through the municipalities of Luisiana, Laguna to Sampaloc, Quezon and finally to Mauban, Quezon. For the local population, Maapon River serves a vital role in the everyday living of the communities, especially in Mauban. It is one of their major sources of livelihood, as they are dependent on agricultural industry and fishing. It also helps with tourism, commerce, and economic stability of Mauban, making it a first class municipality in Quezon. Meanwhile, in Sampaloc, the river delivers pure, clean, fresh and crystal clear water among the neighboring municipalities in the Quezon and Laguna provinces.

The river basin is a frequent pathway of severe typhoons. One of the strongest typhoons to hit the area was 'Rosing' in 1995. The strong winds and flooding caused by the slow-moving and unpredictable super typhoon was very destructive and killed a number of people and animals that were seen floating in Calauag Bay in its aftermath.

To prevent a similar outcome from happening again, a combination of several technologies could be employed to produce flood hazard maps. The first is LiDAR data, which primarily contains elevation. From elevation values, one can infer the presence and behavior of waterbodies (such as rivers, streams, ponds, and lakes) and structures (such as roads, bridges, and buildings). Next, important data such as discharge and rainfall events gathered through fieldwork are used as input the hydrological model. The gathered data is used to generate hydrographs that is used as input to create the calibrated model. These generated outputs, along with LiDAR data, will then be input for the river hydraulic model. The final output for these processes are flood hazard maps of different return periods of the river basin. The generated maps are used for urban planning and disaster risk reduction planning.

Maapon River Basin covers portions of the Municipalities of Mauban, Sampaloc, Luisiana and Lucban in Quezon Province. According to DENR – RCBO, it covers a drainage area of 201 km2 and has an estimated annual run-off of 322 million cubic meters.

Its main stem, Maapon River, is part of the 25 river in the Southern Tagalog Region. According to the 2010 national census of NSO, a total of 19,550 locals are residing in the immediate vicinity of the river. Whenever a typhoon or low-pressure area affects the area of Quezon, National Disaster Risk Reduction and Management Council always include Maapon River as one of the rivers that are expected overflow. Office of the Civil Defense Region IV-A reports that the river needs desilting to prevent the repeat of heavy flooding in connection to the major flood event induced by "Amihan" (Northeast Monsoon) which hit Quezon Province and Oriental Mindoro on December 2005.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MAAPON FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Maapon floodplain in Quezon. These missions were planned for 14 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 system are found in Table

Table 1. 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)
BLK 18W	1000	30	50	200	30	130	5
BLK 18V	1000	30	50	200	30	130	5
BLK 18T	1000	30	50	200	30	130	5

Table 2. Flight planning parameters for ALS-80 LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse in Air	Average Speed (kts)	Average Turn Time (Minutes)
BLK26B	1000	30	50	1	130	5

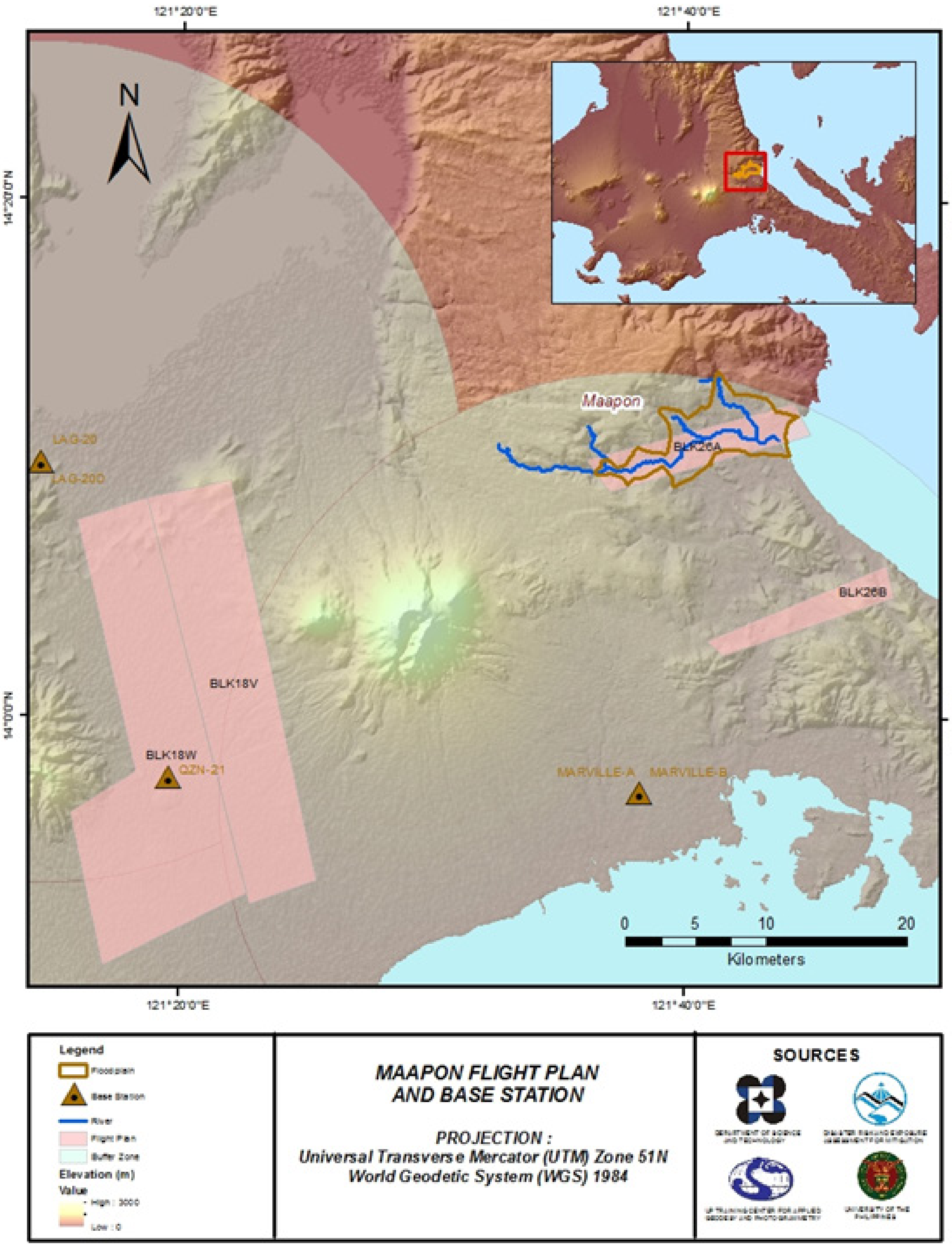

Figure 1. Flight plans and base stations used for Maapon floodplain.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points: QZN-21 and LAG-20 which are of second (2nd) order accuracy. The project team also established three (3) ground control points, LAG-20D, MARVILLE-A and MARVILLE-B. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 10-13, 2014, August 27, 2015 and January 21, 2017). Base stations were observed using dual frequency GPS receivers, TOPCON GR5, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Maapon floodplain are shown in Figure 1.

Figure 2 to Figure 4 show the recovered NAMRIA reference points within the area. Table 2 to Table 4 show the details about the following NAMRIA control stations and established points, while Table 5 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

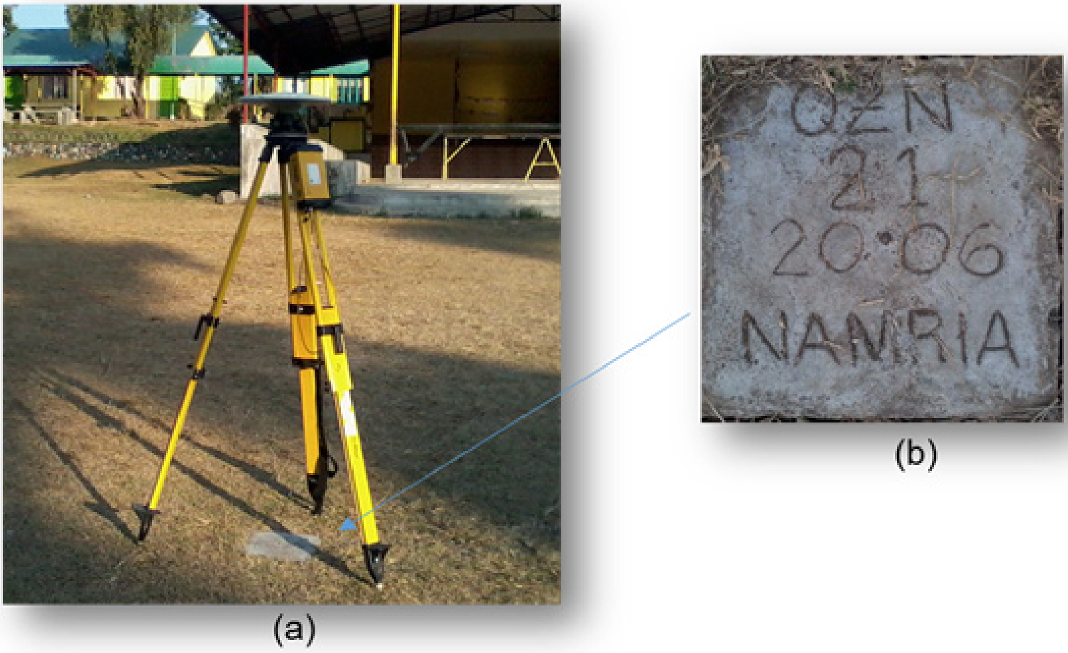

Figure 2. GPS set-up over QZN-21 inside Paaralang Elementarya ng Silangang Tiaong of Brgy. Poblacion III, Tiaong, Quezon Province (a) and NAMRIA reference point QZN-21 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point QZN-21 used as base station for the LiDAR acquisition.

Station Name	QZN-21	
Order of Accuracy	2^{nd} Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	113° 57’ 44.31576” North 121° 19’ 27.34822” East 51.25800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	535036.042 meters 1544027.063 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57’ 39.07397” North 121° 19’ 32.29499” East 97.38200 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	318981.12 meters 1544101.56 meters

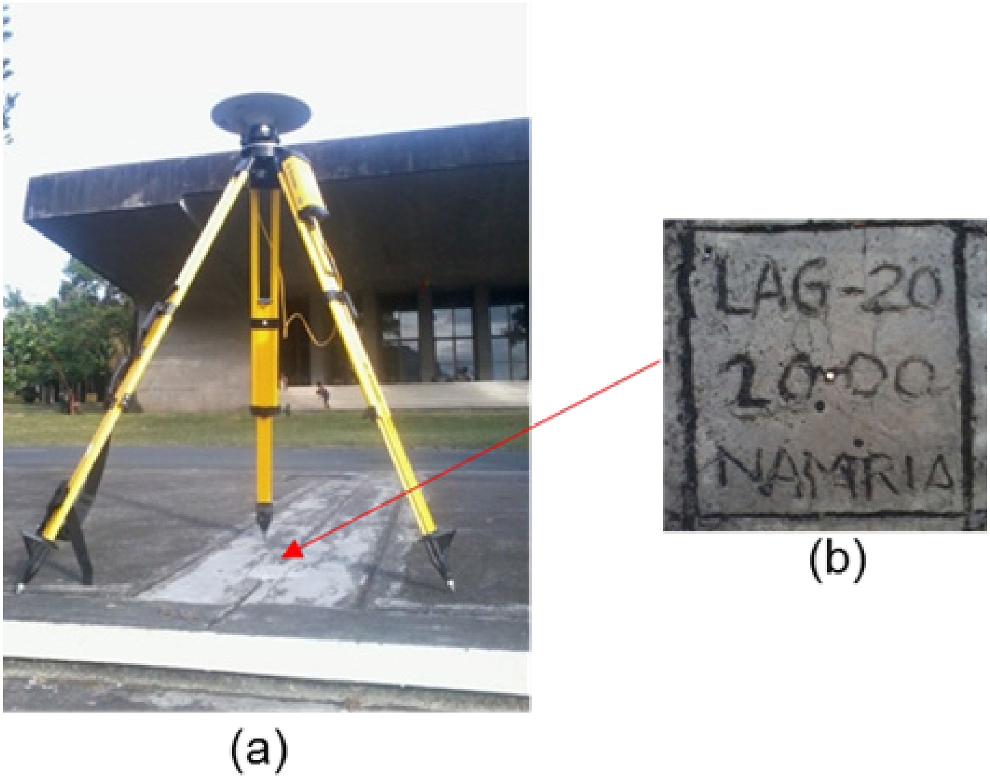

Figure 3. GPS set-up over LAG-20 near the freedom park in UP Los Baños (a) and NAMRIA reference point LAG-20 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point LAG-20 used as base station for the LiDAR acquisition.

Station Name	LAG-20	
Order of Accuracy	3rd Order	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 9' 53.86904" North 121° 14' 20.35180" East 39.91400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	525799.268 meters 1566435.481 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°9 '48.57270" North 121°14'25.28172"East 85.26600 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	309934.22 meters 1566588.99 meters

Figure 4. LAG-20D as established inside the UP Los Baños compound near LAG-20.

Table 5. Details of the established control point with processed coordinates LAG-20D used as base station for the LiDAR acquisition.

Station Name	LAG-20D	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 9’ 53.86923” 121° 14’ 20.35184” 39.914 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	309934.222 meters 1566588.991 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57’ 39.07397” North 121° 19’ 32.29499” East 97.38200 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	14° 9’ 48.57270” 121° 14’ 25.28172” 85.266 meters

Figure 5. MARVILLE-A as established in front of Belen Hurboda's house, Queensway St., Marville Subdivision, Lucena City.

Table 6. Details of the established control point with processed coordinates MARVILLE-A used as base station for the LiDAR acquisition.

Station Name	MARVILLE-A	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57' 11.82908" 121° 38' 07.97108" 36.198 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	352607.681 meters 1542888.002 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57' 06.61488" 121° 38' 12.91688" 83.108 meters

Figure 6. MARVILLE-B as located five (5) meters away from MARVILLE-A, in front of blank lot,

Table 7. Details of the established control point with processed coordinates MARVILLE-B used as base station for the LiDAR acquisition.

Station Name	MARVILLE-B	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57' 12.48851" 121° 38' 07.77177" 36.952 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	352601.816 meters 1542908.298 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57' 07.27426" 121° 38' 12.71755" 83.861 meters

Table 8. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
10 Feb 2014	1091P	1BLK18W41A	QZN-21
13 Feb 2014	1103P	1BLK18VWS44A	QZN-21
27 Aug 2015	3345P	1BLK18TS239A	LAG-20 and LAG-20D
21 Jan 2017	10308L	4BLK26AB21A	MARVILLE-A & MARVILLE-B

2.3 Flight Missions

Four (4) missions were conducted to complete LiDAR data acquisition in Maapon Floodplain, for a total of fourteen hours and fifty-one minutes (14+51) of flying time for RP-C9022 and RP-C9522. All missions were acquired using Pegasus and ALS80 LiDAR systems. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9 Flight missions for LiDAR data acquisition in Maapon floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
10 Feb 2014	1091P	223.96	244.10	NA	244.10	512	3	49
13 Feb 2014	1103P	389.16	249.99	NA	249.99	NA	3	44
27 Aug 2015	3345P	223.96	199.87	NA	199.87	NA	3	43
21 Jan 2017	10308L	39.33	90.89	31.90	58.99	NA	3	35
TOTAL		876.41	784.85	31.90	752.95	512	14	51

Table 10. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1091P	1000	30	50	200	30	130	5
1103P	1000	30	50	200	30	130	5
3345P	1000	15	50	200	30	130	5

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	Pulse in Air	Average Speed (kts)	Average Turn Time (Minutes)
10308L	1000	30	50	1	130	5

2.4 Survey Coverage

Maapon floodplain is located in the province of Quezon, with majority of the floodplain situated within the municipality of Mauban and Sampaloc. Municipalities of Tiaong and San Antonio in Quezon and San Pablo City in Laguna are mostly covered during the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Maapon Floodplain is presented in Figure 7.

Table 11. List of municipalities and cities surveyed during Maapon floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Quezon	Tiaong	109.11	101.07	92.64%
	San Antonio	60.34	47.89	79.36%
	Dolores	61.28	26.08	42.56%
	Candelaria	158.33	29.27	18.48%
	Mauban	430.04	47.58	11.06%
	Tayabas City	232.67	12.51	5.38%
Laguna	San Pablo City	180.93	148.97	82.34%
	Laguna	**79.44**	**43.71**	**55.03%**
	Alaminos	**60.56**	**8.39**	**13.85%**
	Bay	**40.80**	**4.73**	**11.59%**
	Nagcarlan	**81.20**	**8.49**	**10.46%**
	Rizal	**24.02**	**1.43**	**5.95%**
Batangas	**Padre Garcia**	**40.70**	**6.52**	**16.03%**
	Batangas	**197.03**	**22.73**	**11.54%**
Total		1756.45	509.37	30.00%

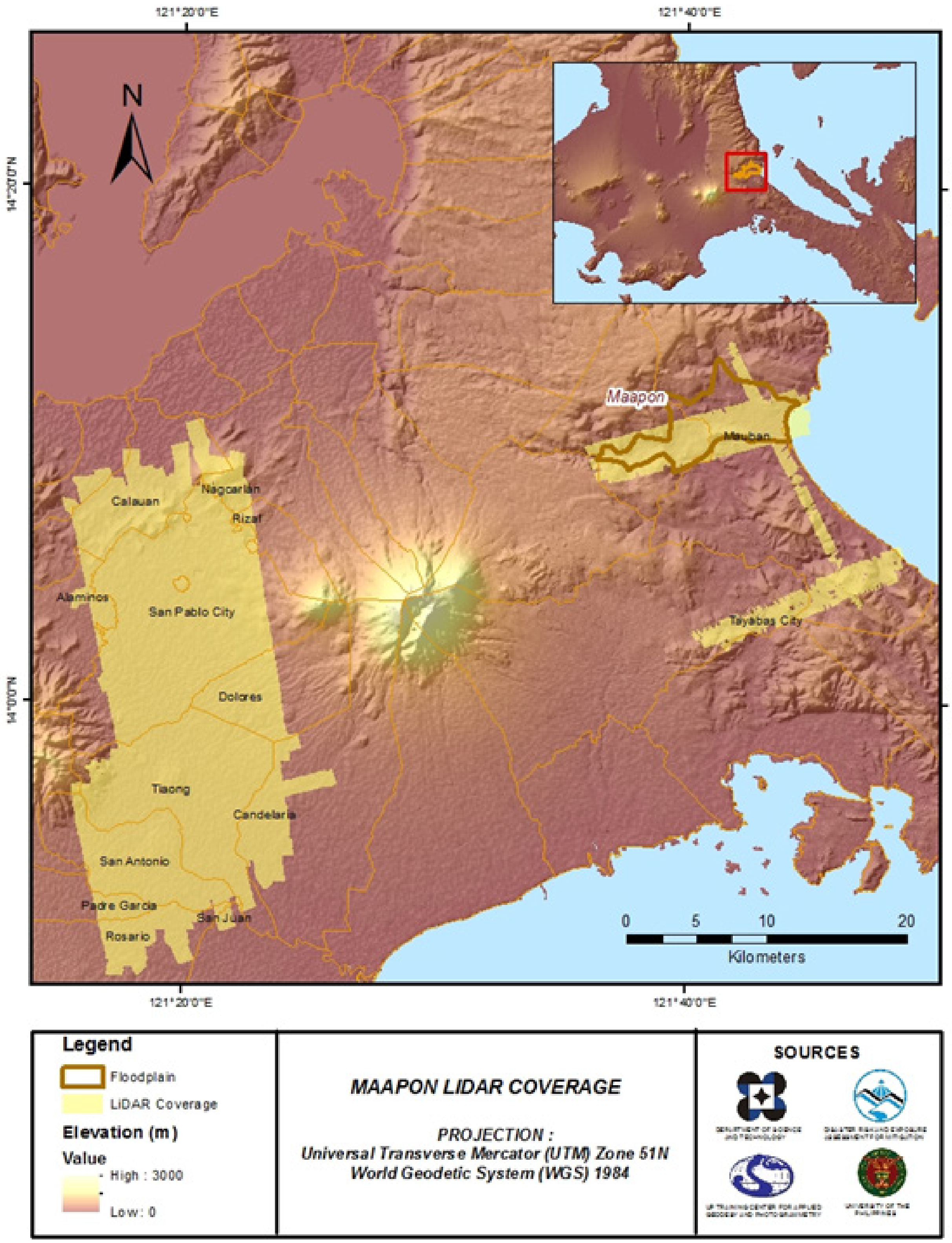

Figure 7. Actual LiDAR survey coverage for Maapon floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MAAPON FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

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

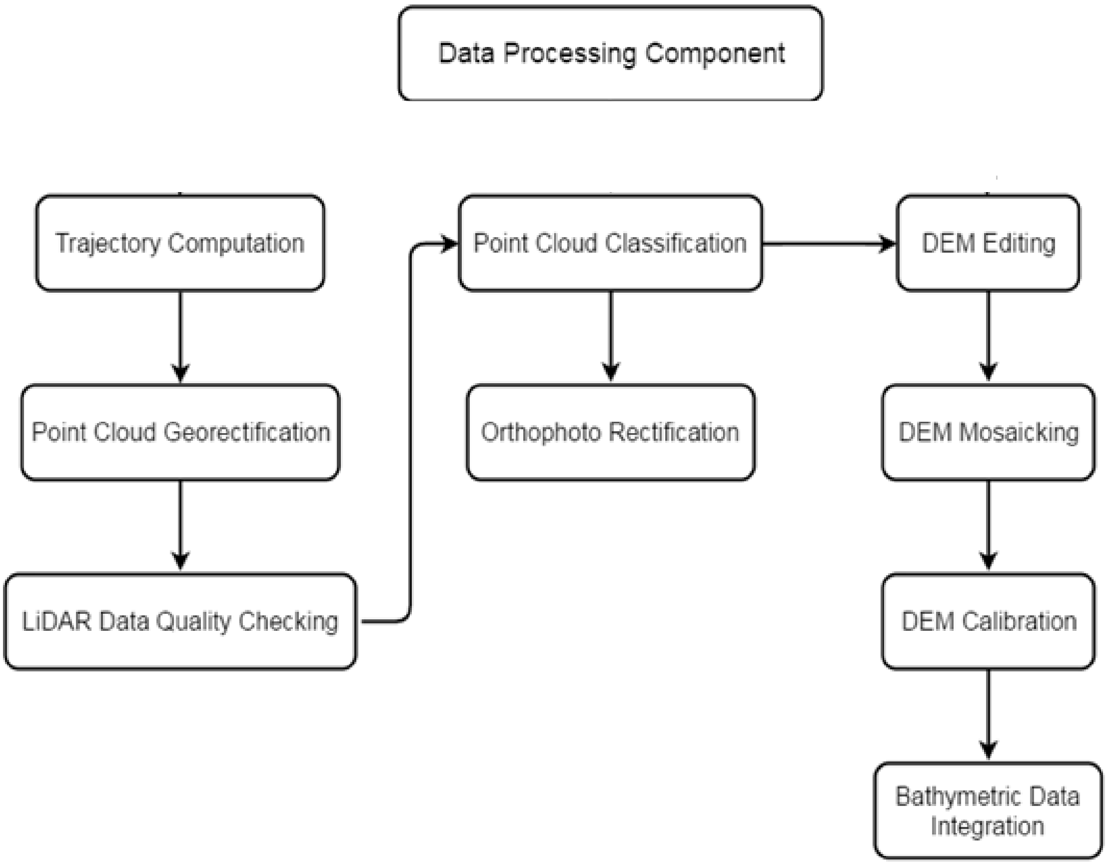

Figure 8. Schematic Diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Maapon floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. Missions acquired during the second survey on September 2015 were flown over Mauban, Quezon. The Data Acquisition Component (DAC) transferred a total of 72.47 Gigabytes of Range data, 722.69 Megabytes of POS data, 36.93 Megabytes of GPS base station data, and 32.74 Gigabytes of raw image data to the data server on February 17, 2014 for the first survey and September 7, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Maapon was fully transferred on September 8, 2015, as indicated on the Data Transfer Sheets for Maapon floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1103P, one of the Maapon flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 13, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

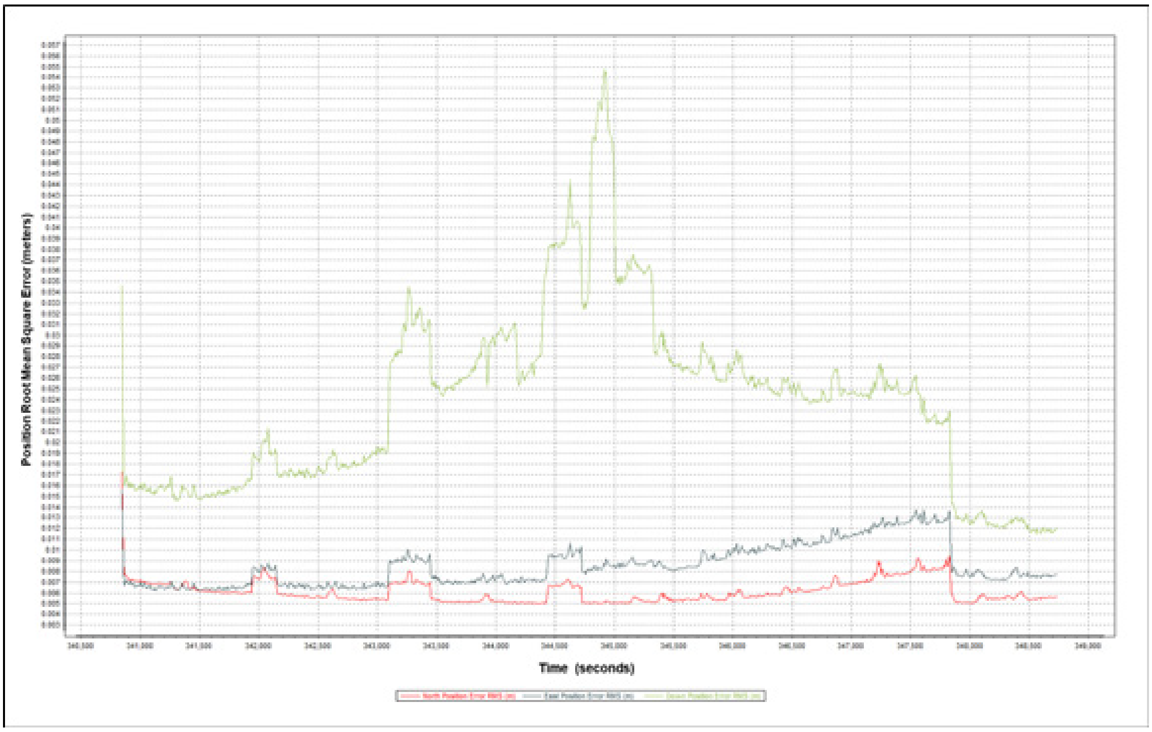

Figure 9. Smoothed Performance Metrics of a Maapon Flight 1103P

The time of flight was from 340750 seconds to 348750 seconds, which corresponds to morning of February 13, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 0.80 centimeters, the East position RMSE peaks at 1.08 centimeters, and the Down position RMSE peaks at 5.48 centimeters, which are within the prescribed accuracies described in the methodology.

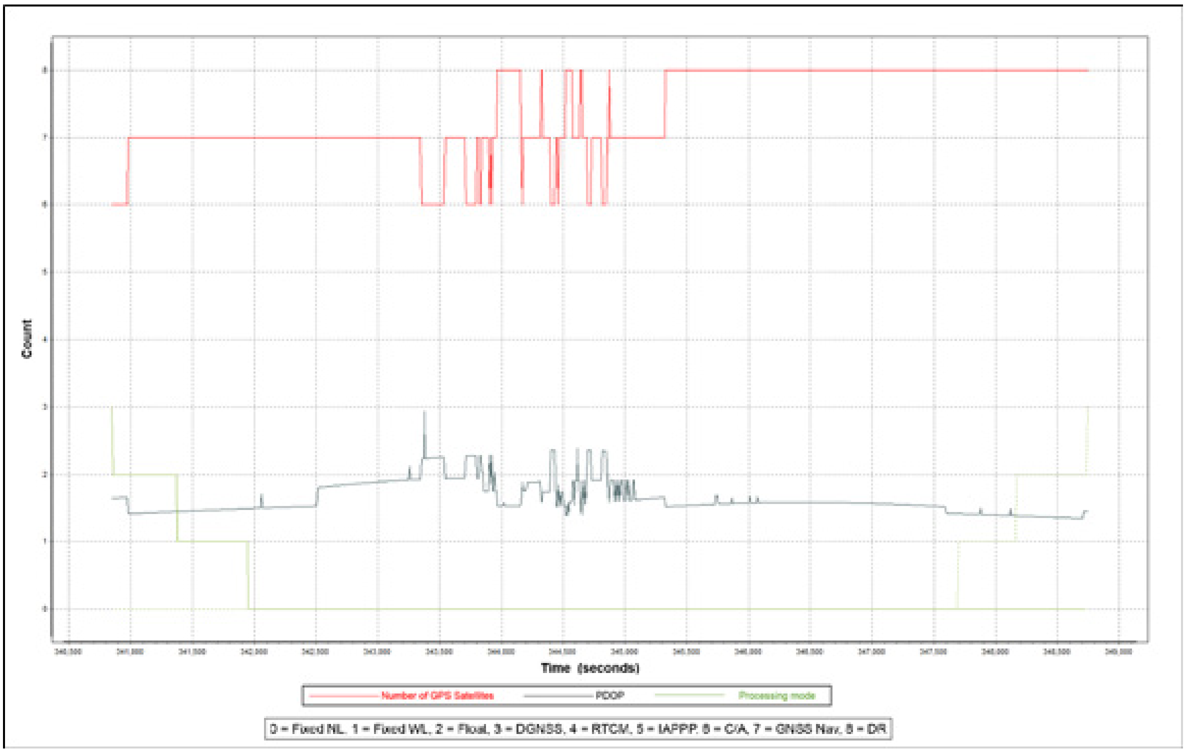

Figure 10. Solution Status Parameters of Maapon Flight 1103P.

The Solution Status parameters of flight 1103P, one of the Maapon flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 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 Maapon flights is shown in Figure 11.

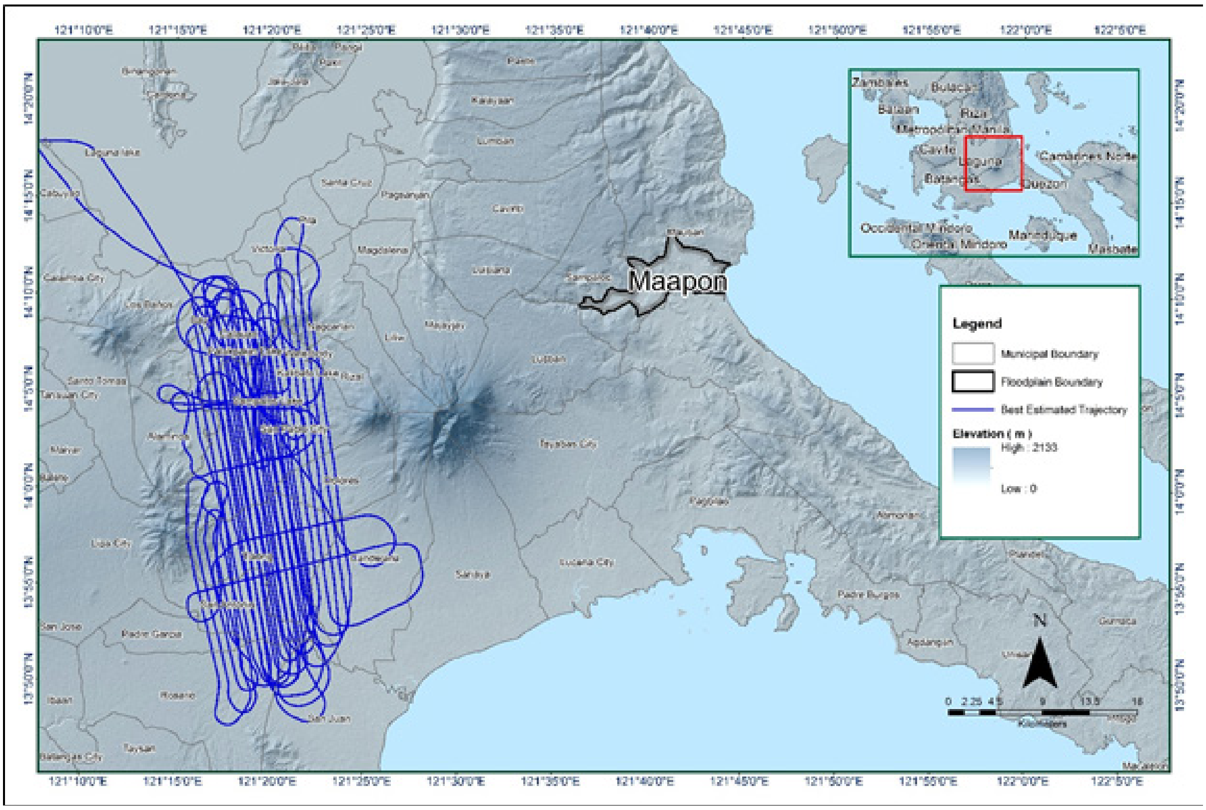

Figure 11. Best Estimated Trajectory for Maapon floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 37 flight lines, with each flight line containing one channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Maapon floodplain are given in Table B-1.

Table 12. Self-Calibration Results values for Maapon flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000547
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000996
GPS Position Z-correction stdev)	<0.01meters	0.0086

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

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Maapon Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

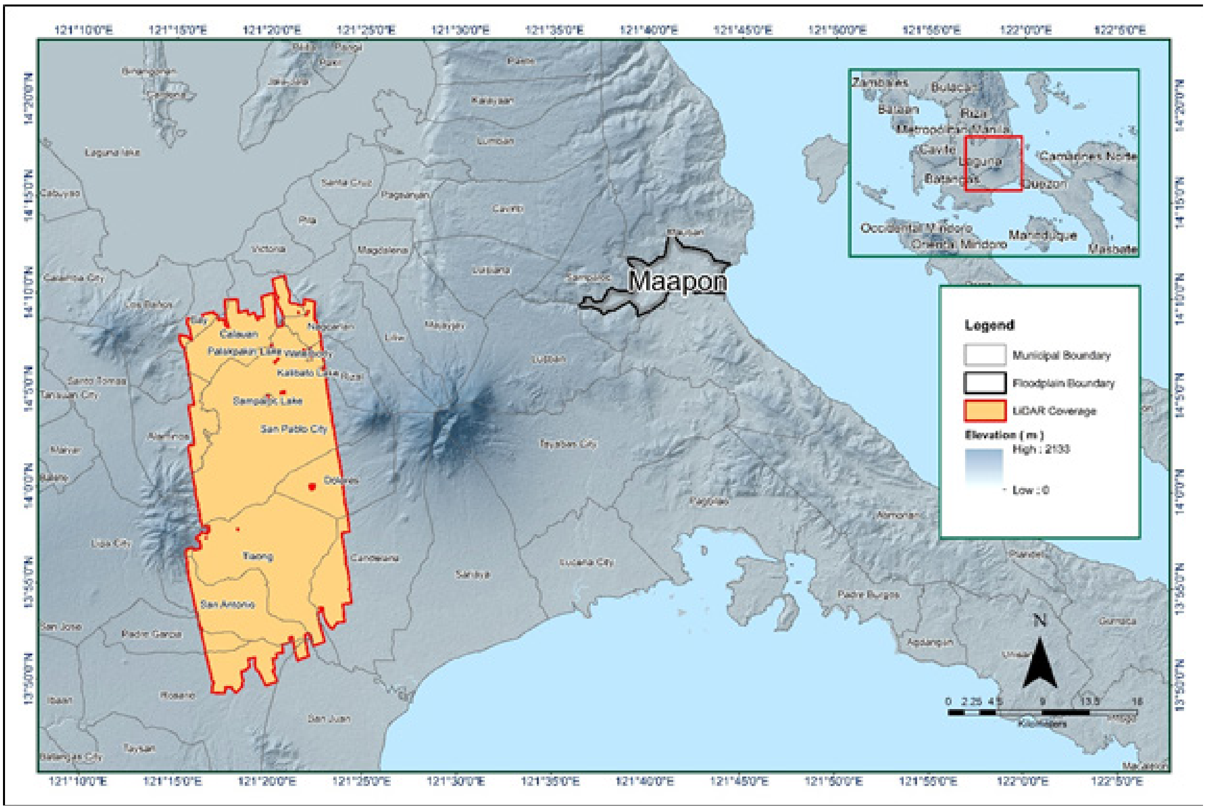

Figure 12. Boundary of the processed LiDAR data over Maapon Floodplain.

The total area covered by the Maapon missions is 733.28 sq.km that is comprised of four (4) flight acquisitions grouped and merged into three (3) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Maapon floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
CALABARZON_Blk18W_additional	3345P	258.51
	3347P	
Laguna_Blk18VW_supplement	1103P	232.87
Laguna_Blk18W	1091P	241.90
TOTAL		**733.28 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

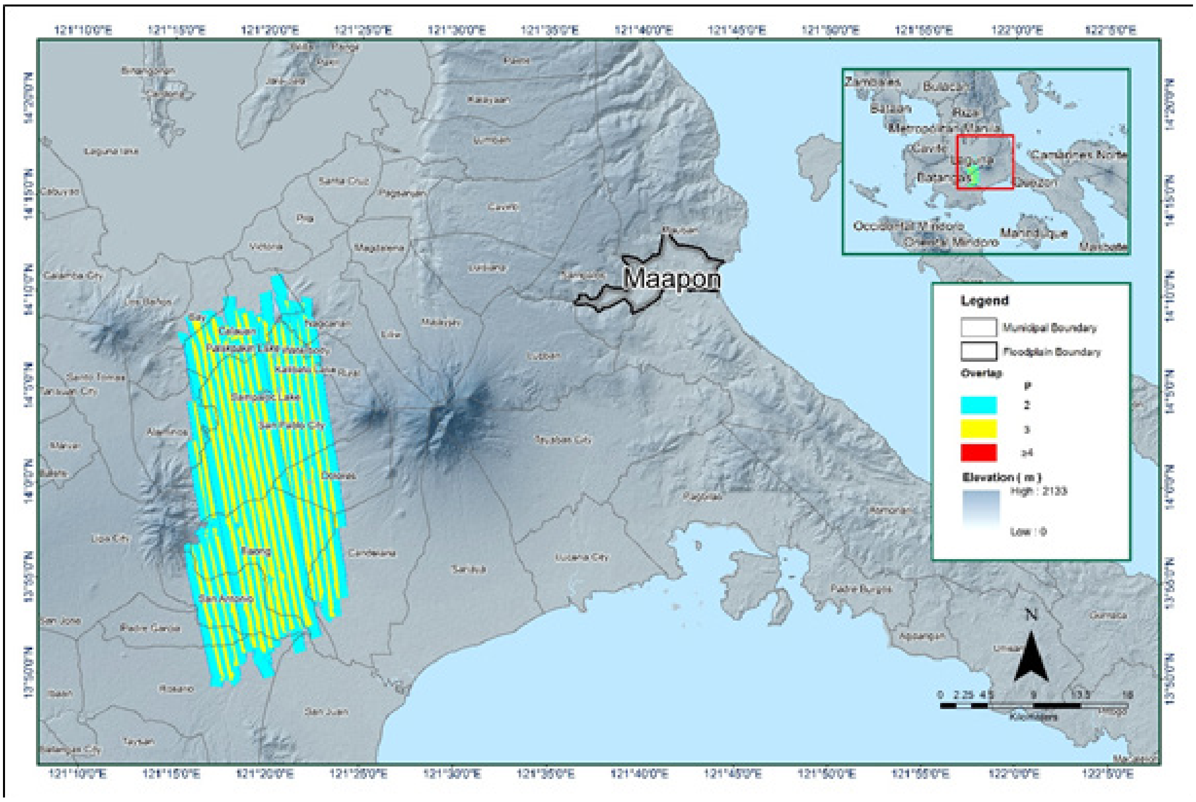

Figure 13. Image of data overlap for Maapon floodplain.

The overlap statistics per block for the Maapon floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 34.32% and 51.19% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Maapon floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.52 points per square meter.

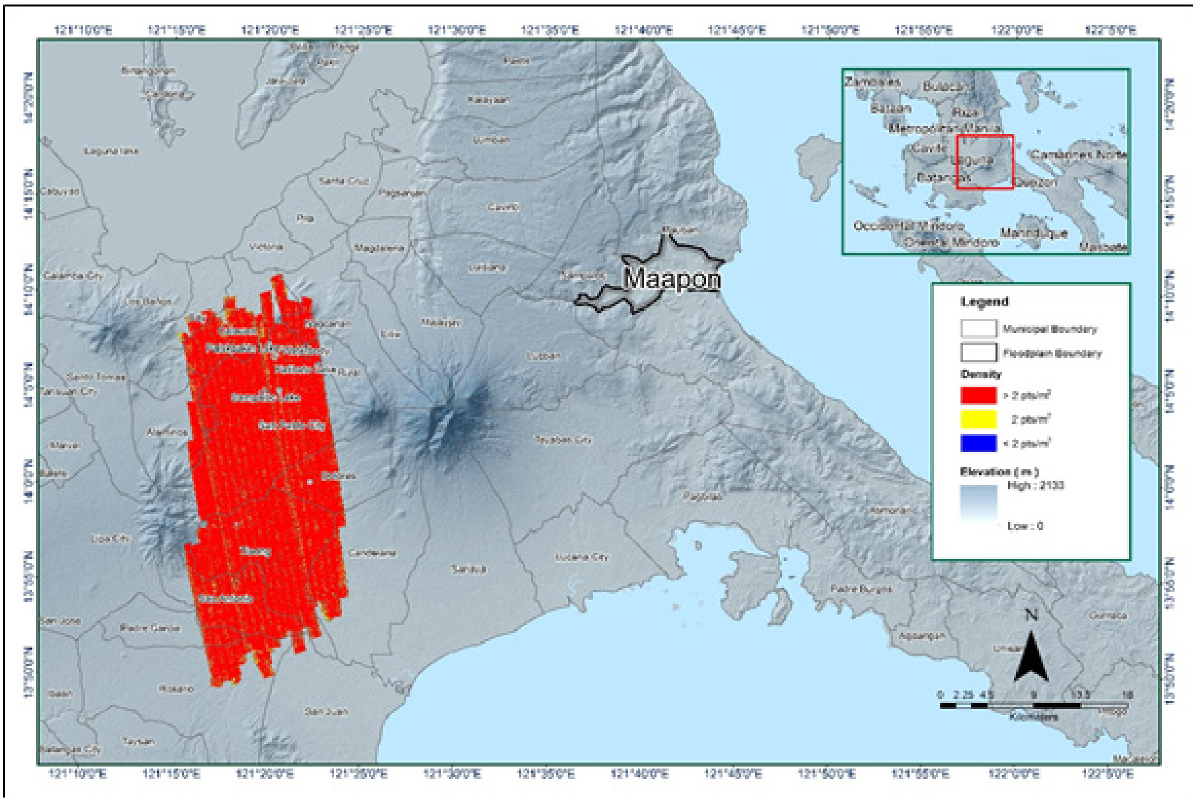

Figure 14. Density map of merged LiDAR data for Maapon floodplain.

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

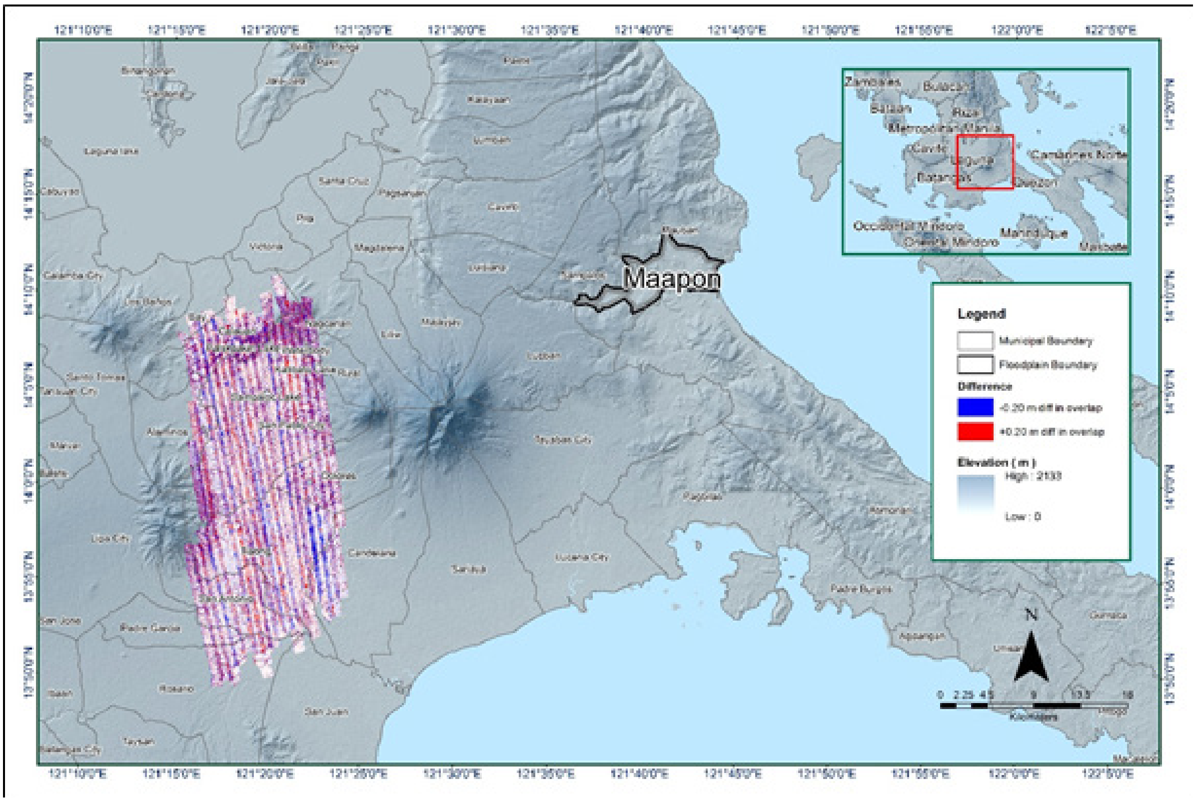

Figure 15. Elevation difference map between flight lines for Maapon floodplain.

A screen capture of the processed LAS data from a Maapon flight 1103P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

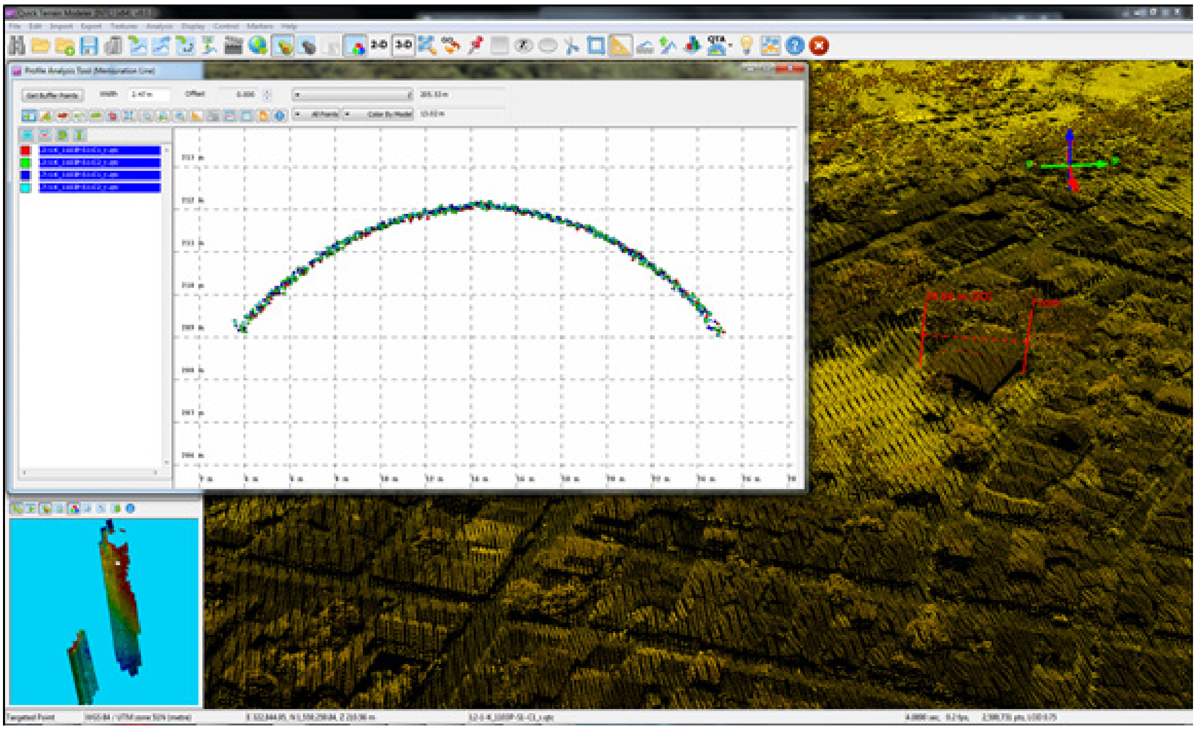

Figure 16. Quality checking for a Maapon flight 1103P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Maapon classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	627,299,235
Low Vegetation	622,552,269
Medium Vegetation	679,985,473
High Vegetation	723,017,002
Building	77,486,769

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block near Maapon floodplain is shown in Figure 17. A total of 920 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 712.23 meters and 53.13 meters respectively.

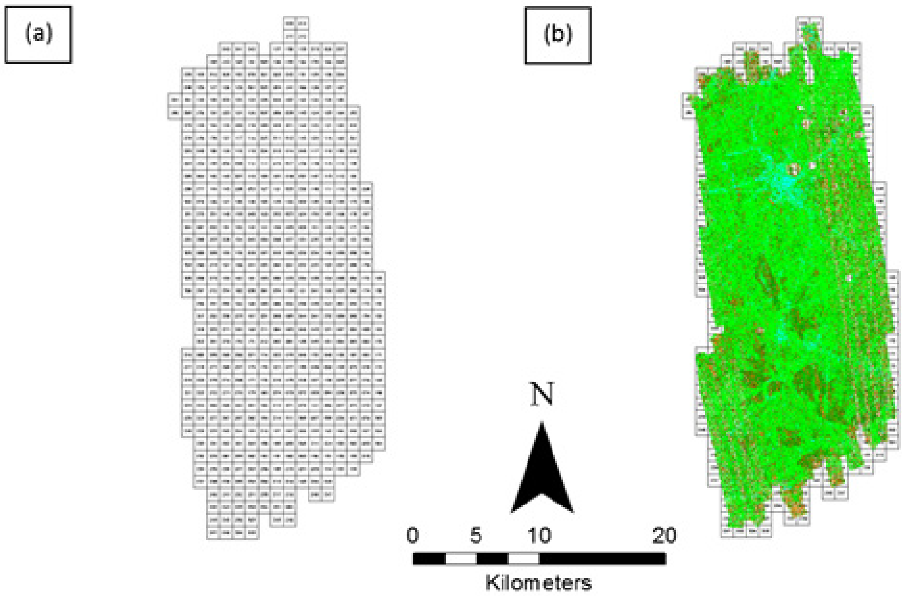

Figure 17. Tiles for Maapon floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are 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.

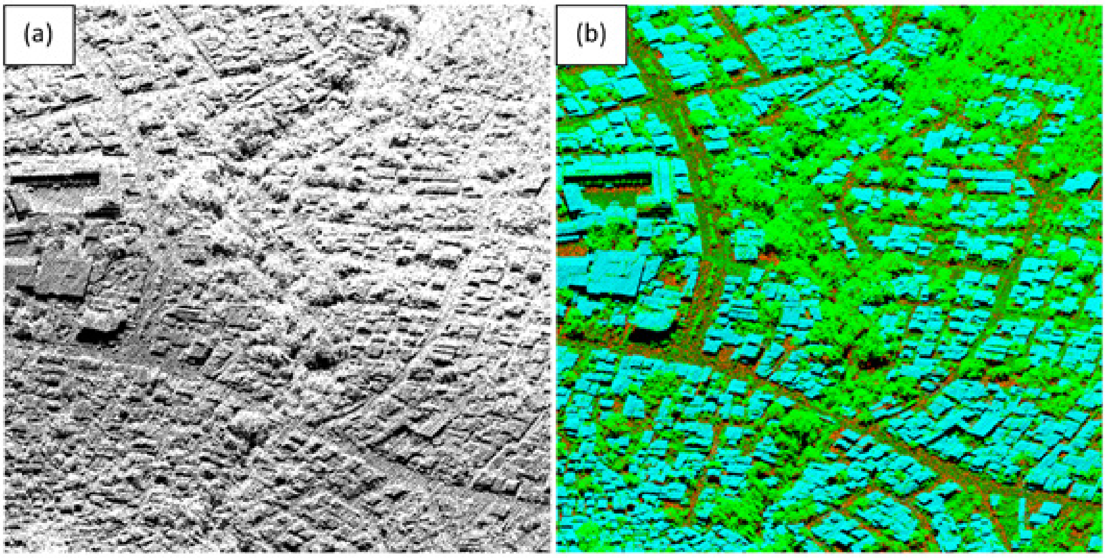

Figure 18. Point cloud before (a) and after (b) classification.

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 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

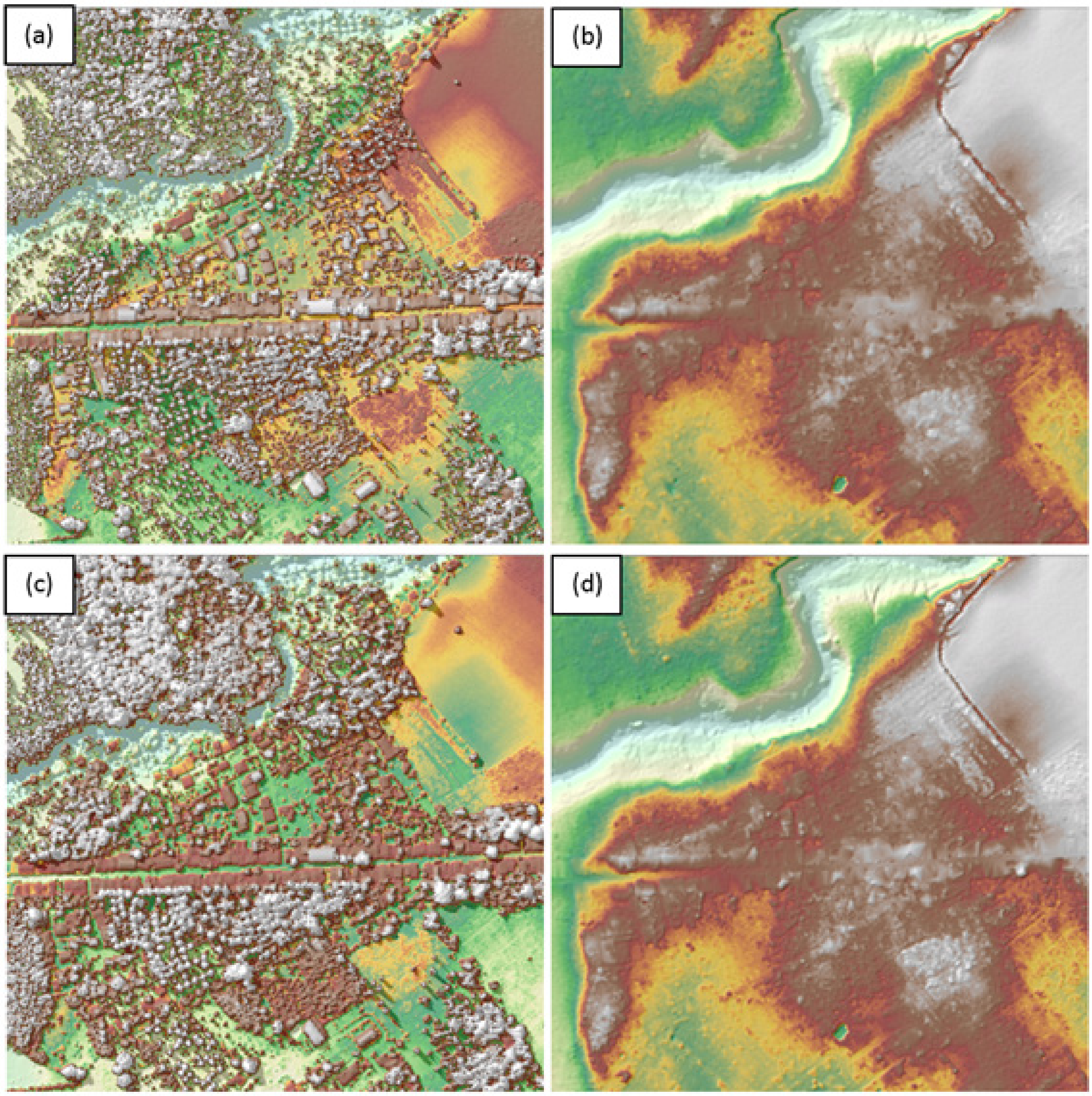

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion near Maapon floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 304 1km by 1km tiles area covered by Maapon floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Maapon floodplain has a total of 242.38 sq.km orthophotogaph coverage comprised of 507 images. However, the block does not have a complete set of orthophotographs and no orthophotographs cover the area of the Maapon floodplain.A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

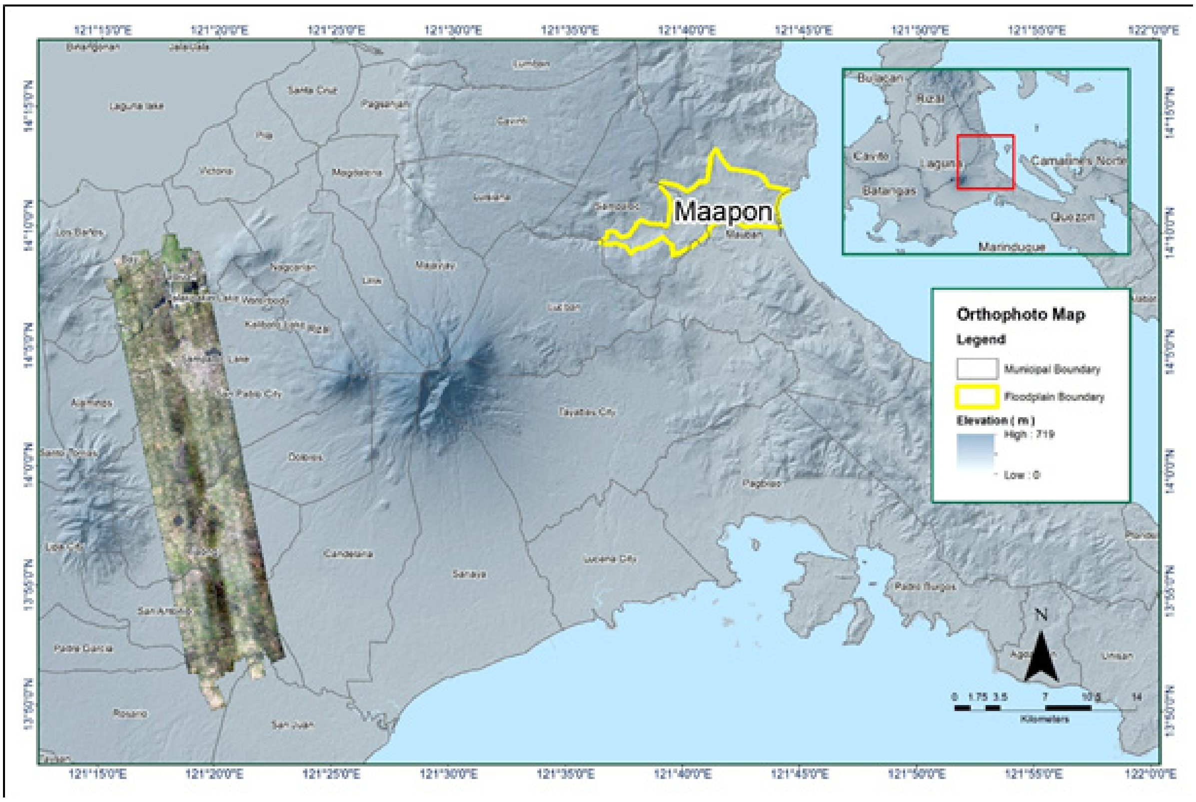

Figure 20. Available orthophotographs near Maapon floodplain.

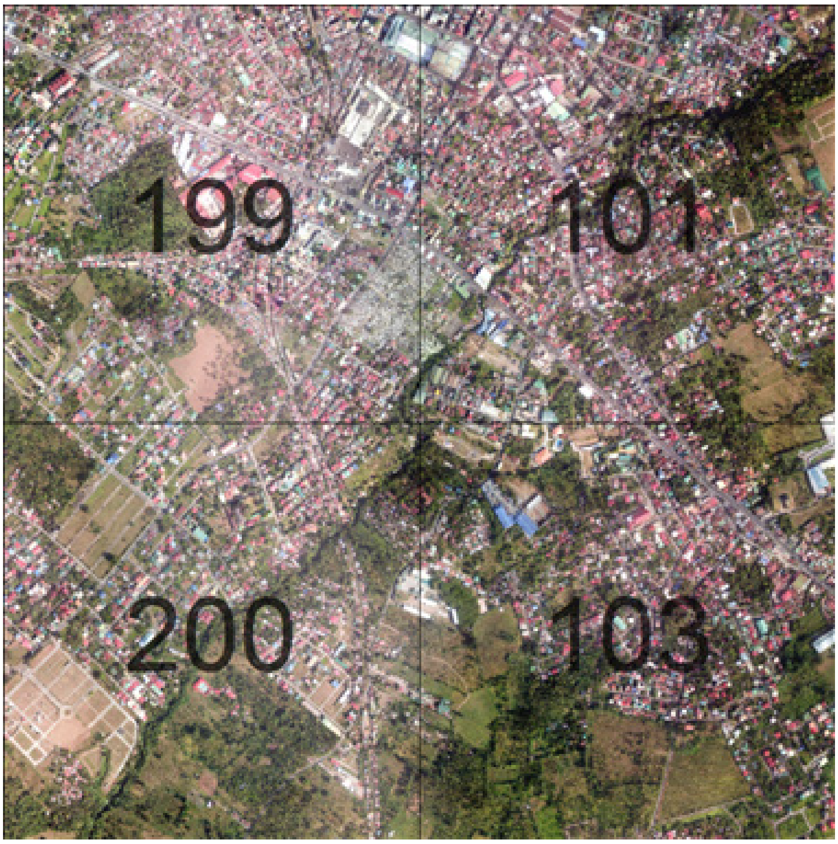

Figure 21. Sample orthophotograph tiles near Maapon floodplain.

3.8 DEM Editing and Hydro-Correction

Laguna_Blk18W, Laguna_BlkVW_supplement and Calabarzon_Blk18W_additional are the nearby blocks to the Maapon floodplain. It was processed in order to produce DEMs covering municipalities neighboring the Maapon floodplain. It has an area of 733.28 square kilometers. Table 15 shows the LiDAR block/s and their corresponding area in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
CALABARZON_Blk18W_additional	258.51
Laguna_Blk18VW_supplement	232.87
Laguna_Blk18W	241.90
TOTAL	733.28 sq.km

Portions of DTM before and after manual editing are shown in Figure 22. The bridge (Figure 22a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22b) in order to hydrologically correct the river. The embankment (Figure 22c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 22e) and has to be removed through manual editing (Figure 22f).

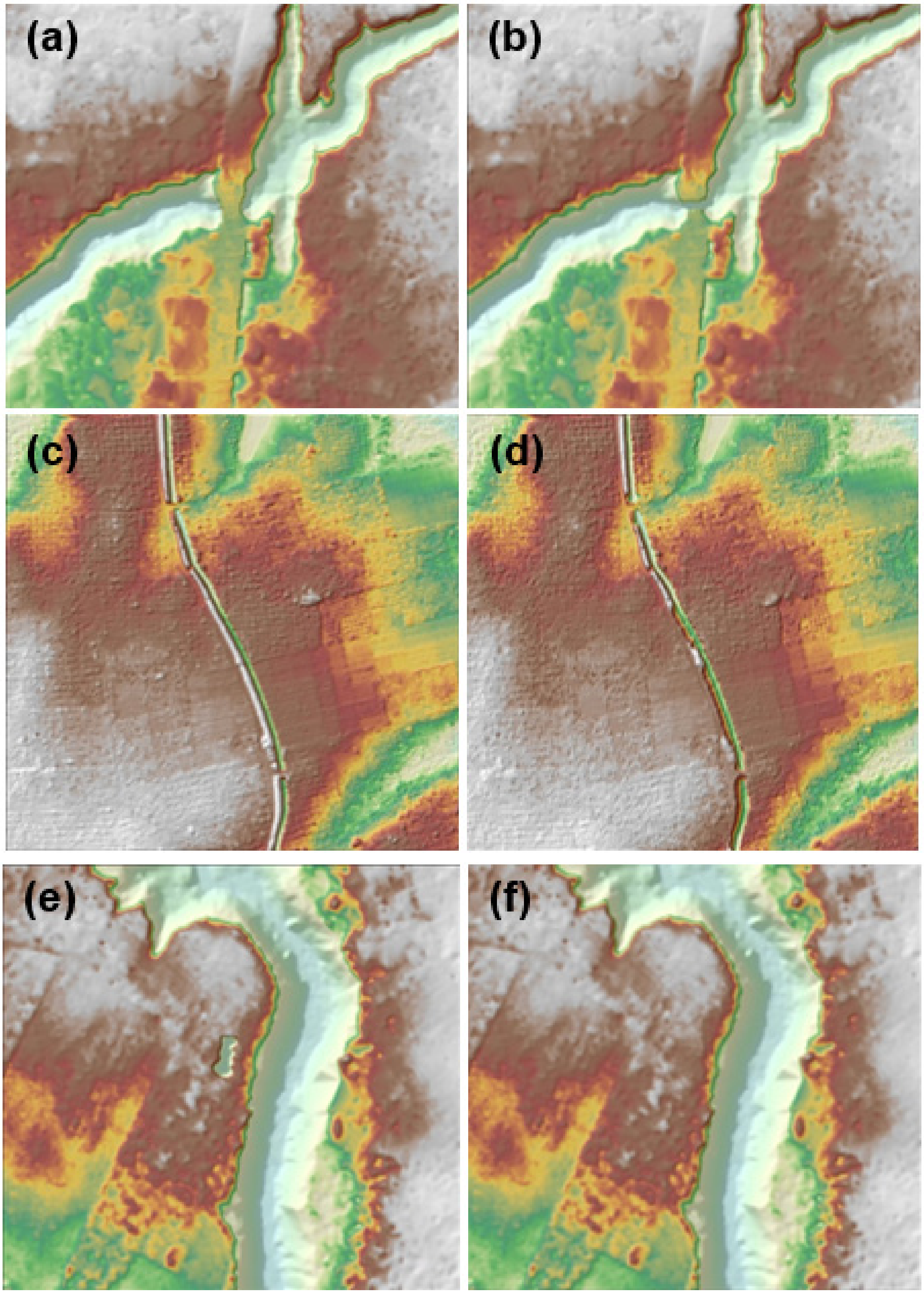

Figure 22. Portions in the DTM of Maapon floodplain – a bridge before (a) and after (b) manual editing; an embankment before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

The IFSAR data for Maapon flood plain located in Mauban, Quezon is mosaicked. This IFSAR data does not overlap the CALABARZON DEM but it has its nearby blocks Laguna_Blk18W, Laguna_BlkVW_supplement and CALABARZON_Blk18W_additional. Table 16 shows the shift values applied to the LiDAR/IFSAR during

IFSAR data for Maapon flood plain is shown in Figure 23.

Table 16. Shift Values of each LiDAR Block of Maapon floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_Blk18W_additional	0.00	0.00	0.50
Laguna_Blk18VW_supplement	0.00	0.00	-0.27
Laguna_Blk18W	0.00	0.00	0.00
3329-III-3-5,8-10,13-15	-1.51	1.79	0.00

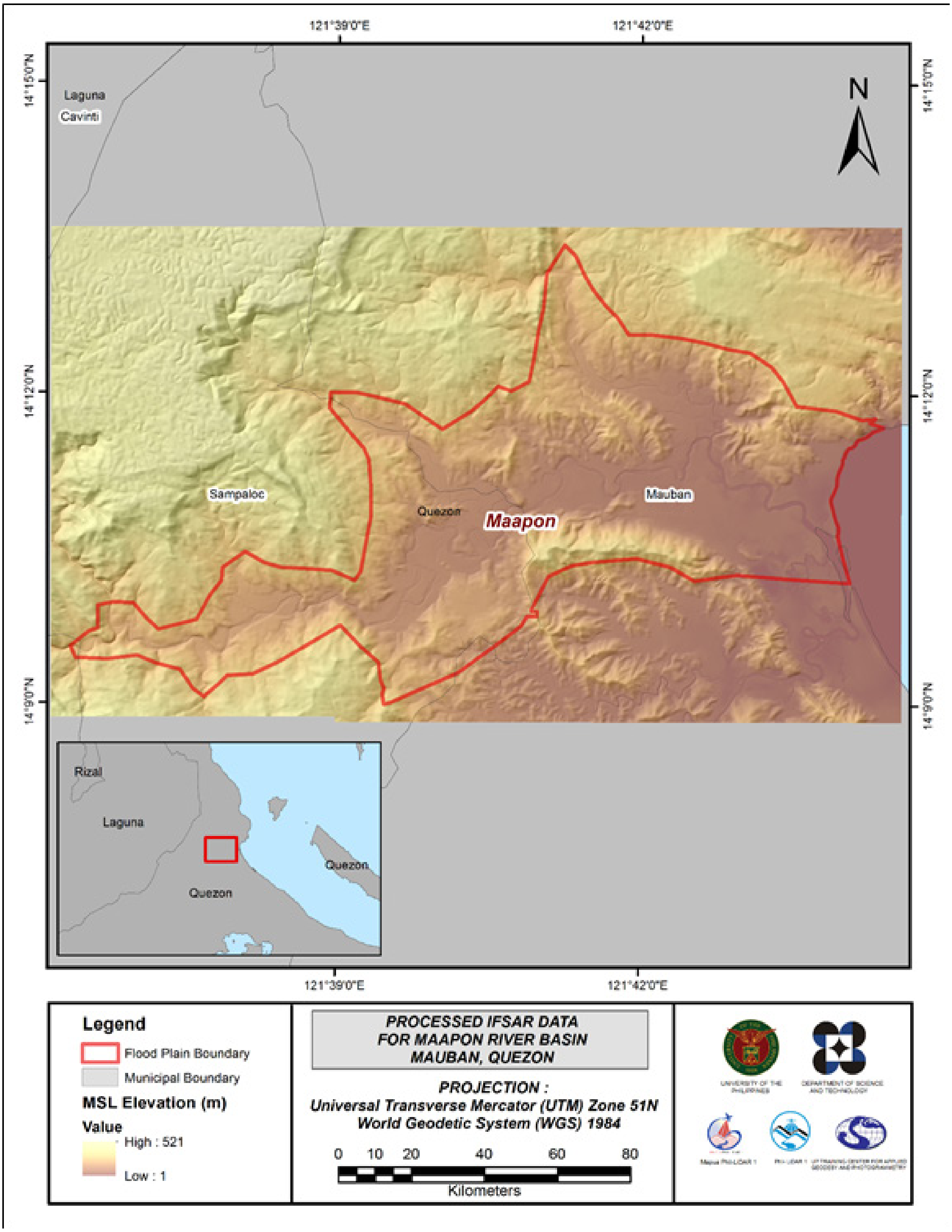

Figure 23. Map of Processed IFSAR Data for Maapon Flood Plain.

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 Maapon to collect points with which the IFSAR dataset is validated is shown in Figure 24. A total of 3,667 survey points were used for calibration and validation of Maapon IFSAR data. Random selection of 80% of the survey points that lie within the IFSAR data, resulting to 870 points, was used for calibration.

A good correlation between the uncalibrated Maapon IFSAR DTM and ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted IFSAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the IFSAR DTM and calibration points is 3.60 meters with a standard deviation of 0.78 meters. Calibration of Maapon IFSAR data was done by adding the height difference value, 3.60 meters, to Maapon mosaicked IFSAR data. Table 17 shows the statistical values of the compared elevation values between Maapon IFSAR data and calibration data.

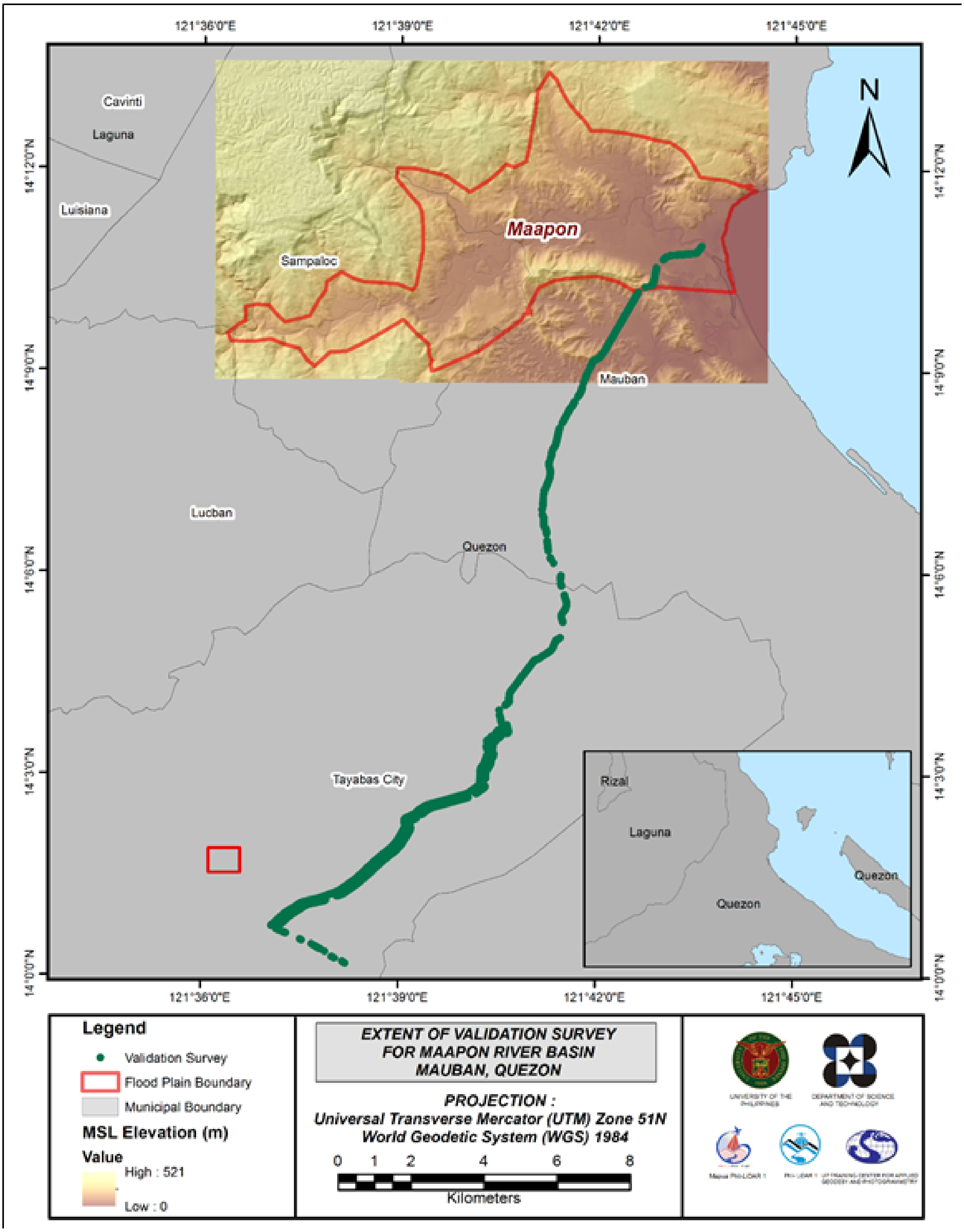

Figure 24. Map of Maapon Flood Plain with validation survey points in green.

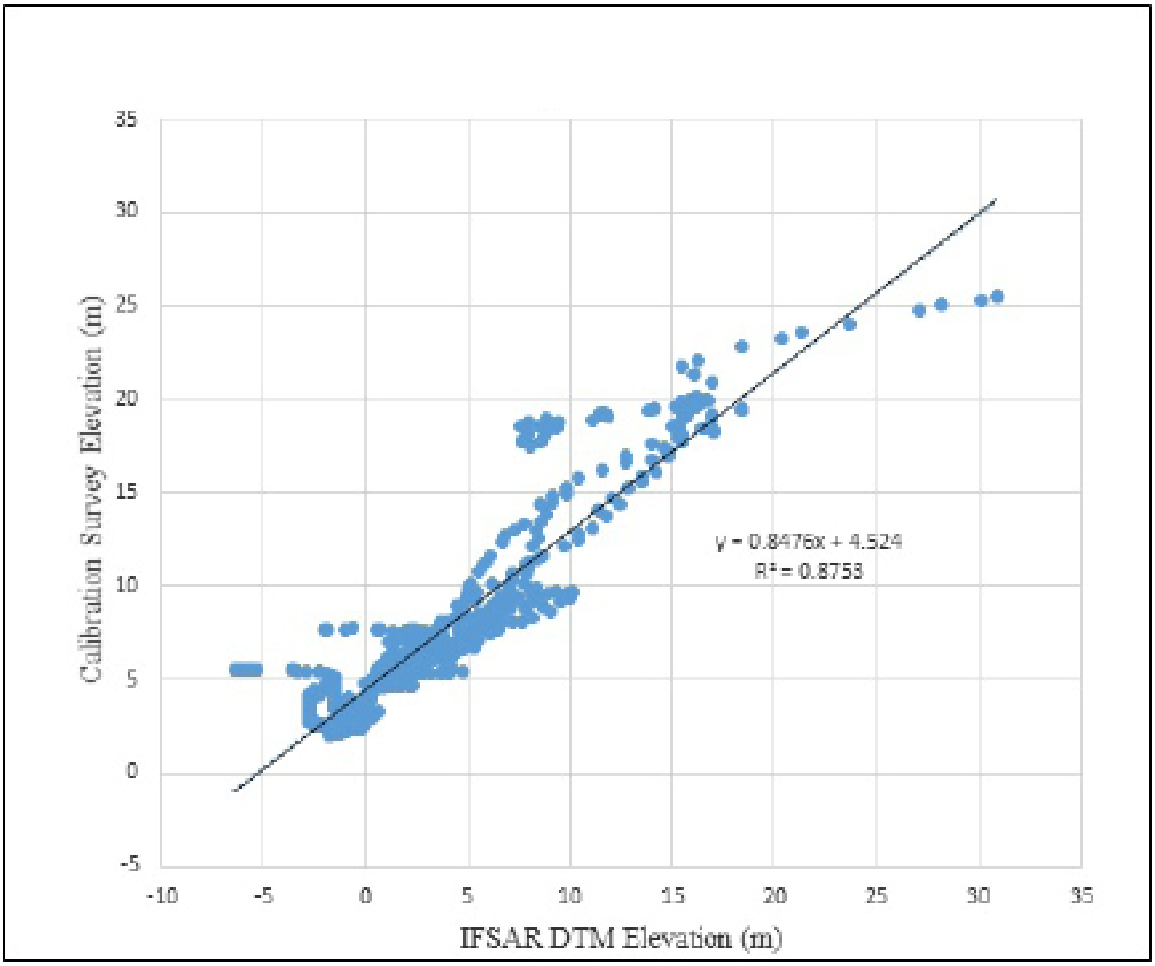

Figure 25. Correlation plot between calibration survey points and LiDAR data

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	3.60
Standard Deviation	0.78
Average	3.51
Minimum	1.46
Maximum	4.68

Note: Calibration points lie within the IFSAR data, thus, the Height Difference and Standard Deviation values obtained are still acceptable.

A total of 104 survey points were used for the validation of the calibrated Maapon DTM. A good correlation between the calibrated mosaicked IFSAR elevation values and the ground survey elevation, which reflects the quality of the IFSAR DTM is shown in Figure 26. The computed RMSE between the calibrated IFSAR DTM and validation elevation values is 3.25 meters with a standard deviation of 0.52 meters, as shown in Table 18.

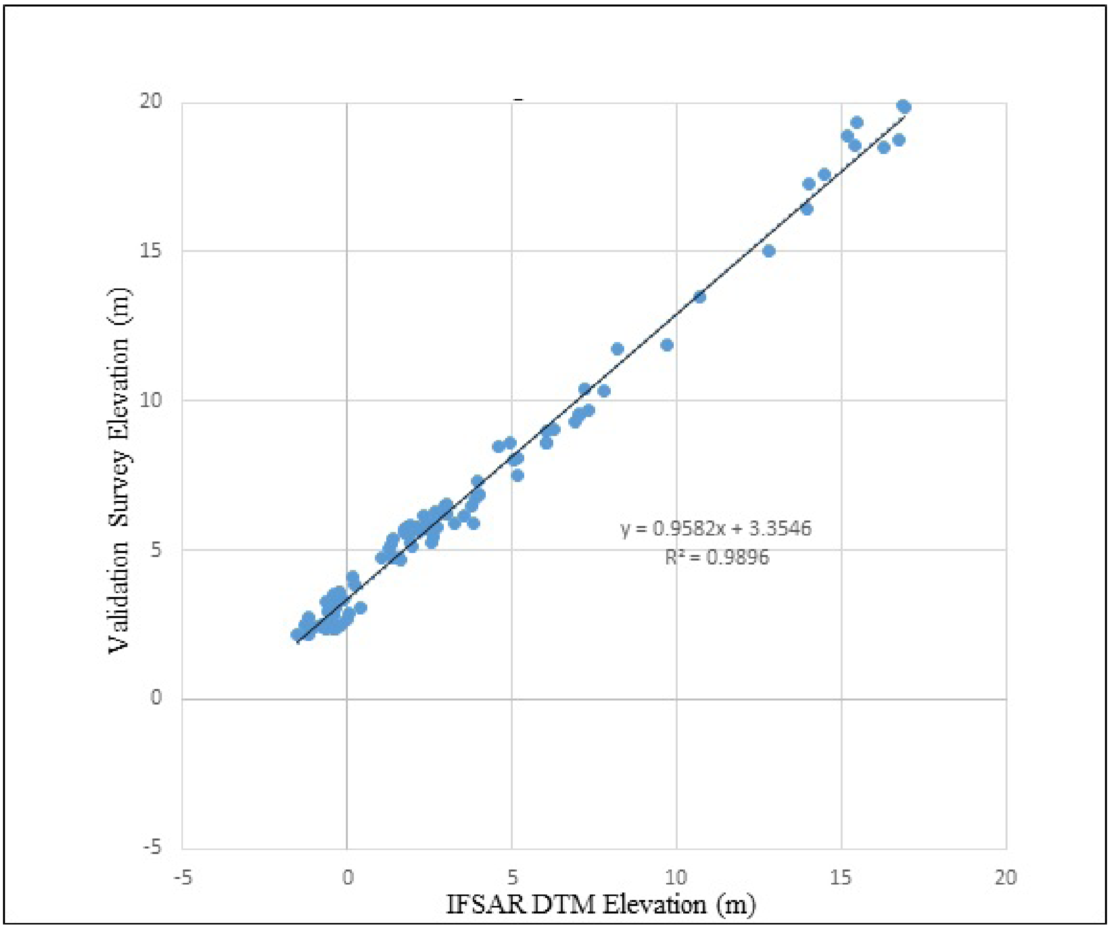

Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	3.25
Standard Deviation	0.52
Average	3.21
Minimum	2.00
Maximum	3.99

Note: Validation points lie within the IFSAR data, thus, the RMSE and Standard Deviation values obtained are still acceptable.

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Maapon with 10,372 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation (with barriers) method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.37 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Maapon integrated with the processed IFSAR DEM is shown in Figure 27.

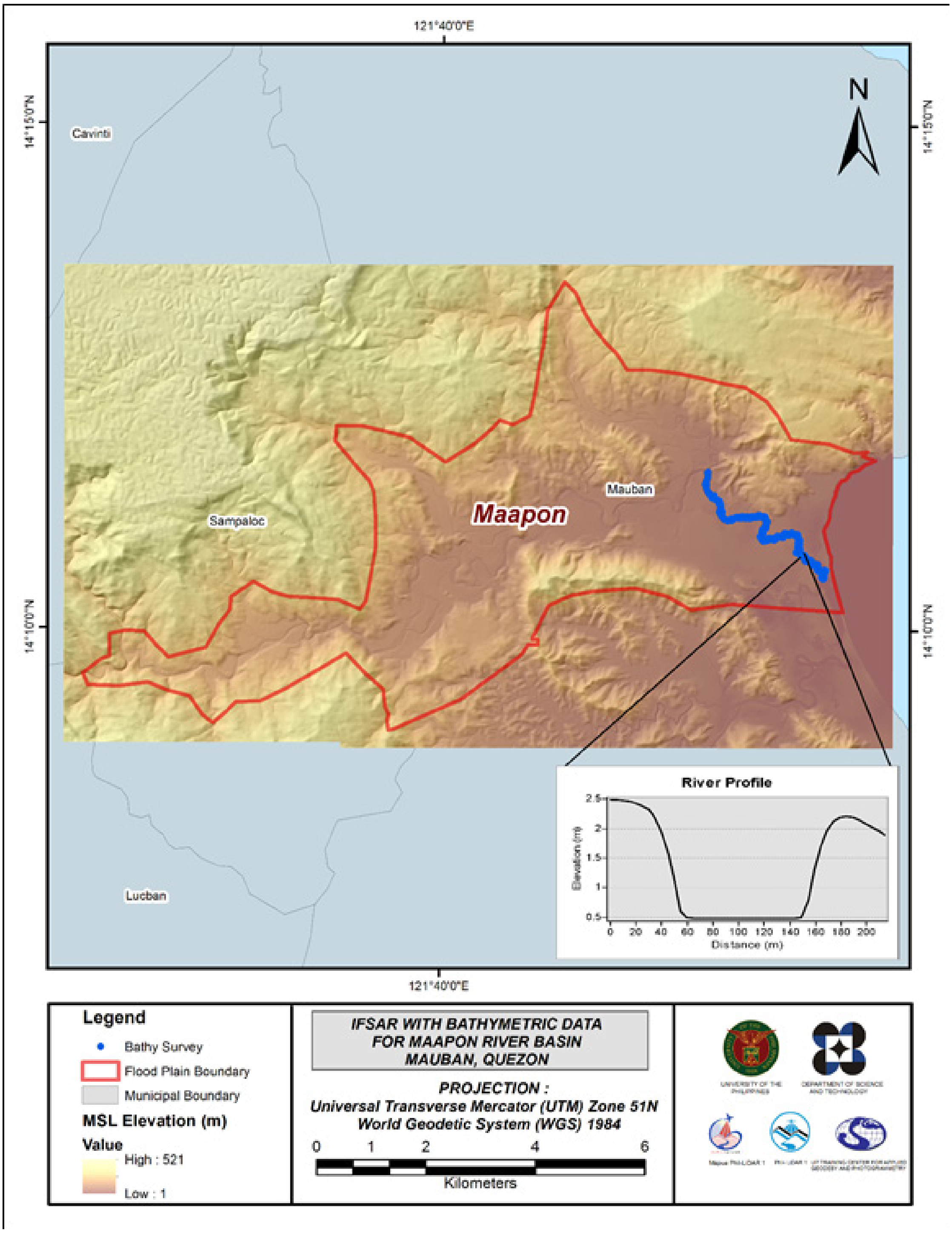

Figure 27. Map of Maapon Flood Plain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Maapon River. The survey was conducted on October 14 – 24, 2015 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section and as-built survey in Maapon Bridge in the Municipality of Mauban, Quezon; LiDAR Validation of about 30 km; and bathymetric survey from Brgy. Bato down to the mouth of the river in Brgy. Polo, with an estimated length of 3.388 km using an OHMEX™ Single Beam Echo Sounder and GNSS PPK survey technique.

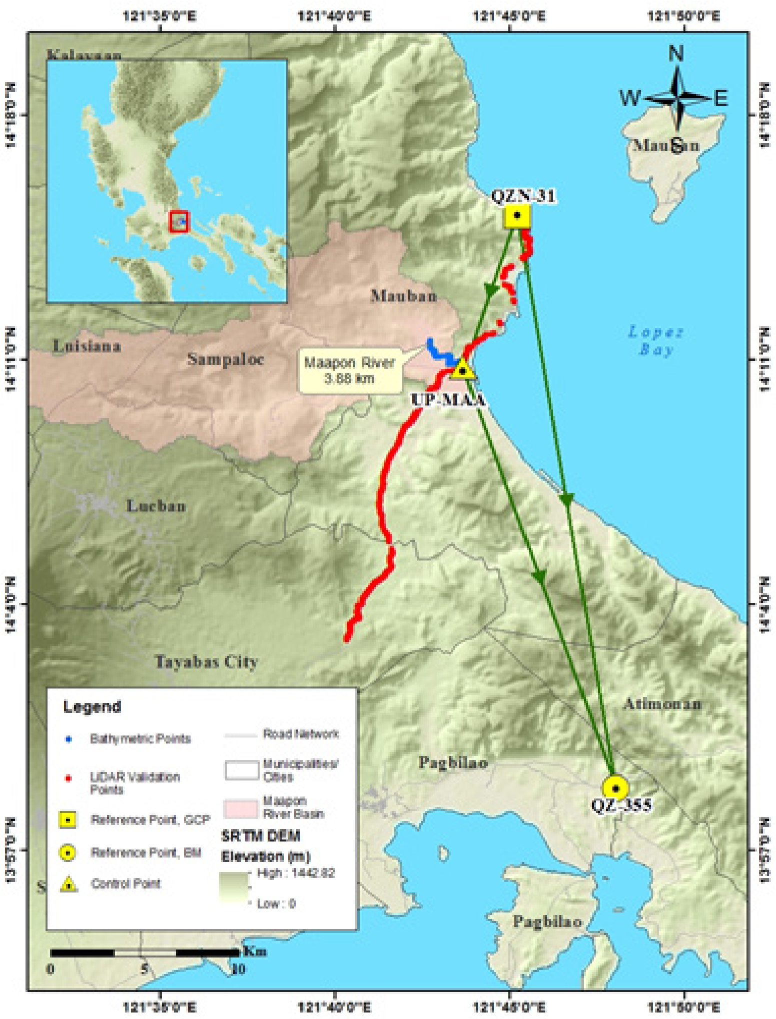


Figure 28. Maapon River survey extent

4.2 Control Survey

The GNSS network used in Maapon Survey was composed of a single loop established on October 21, 2015 using the following reference points: QZN-31, a second order GCP located on top of the highest rock along the coast in Brgy. Cagsiay II in the Municipality of Mauban, Quezon; and QZ-355, a first order benchmark located on top of a guard rail along Padre Burgos Road in Brgy. Amao Malikboy in the Municipality of Pagbilao, Quezon.

A control point namely UP-MAA was also established along approach of Maapon Bridge I Brgy. Polo, Municipality of Mauban, Quezon; to use as marker during the survey,

The summary of the control points used during the survey is shown in Table 19 while the GNSS network established is illustrated in Figure 29.

Table 19. List of references and control points used in Quezon Fieldwork on October 21, 2015 (Source: NAMRIA and UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				Date of Establishment
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	
QZN-31	2nd order, GCP	14°15'09.74601"	121°45'13.55835"	52.523	4.072	2007
QZ-355	1st order, BM	-	-	62.740	-	2006
UP-MAA	Used as Marker	-	-	-	-	10-21-2015

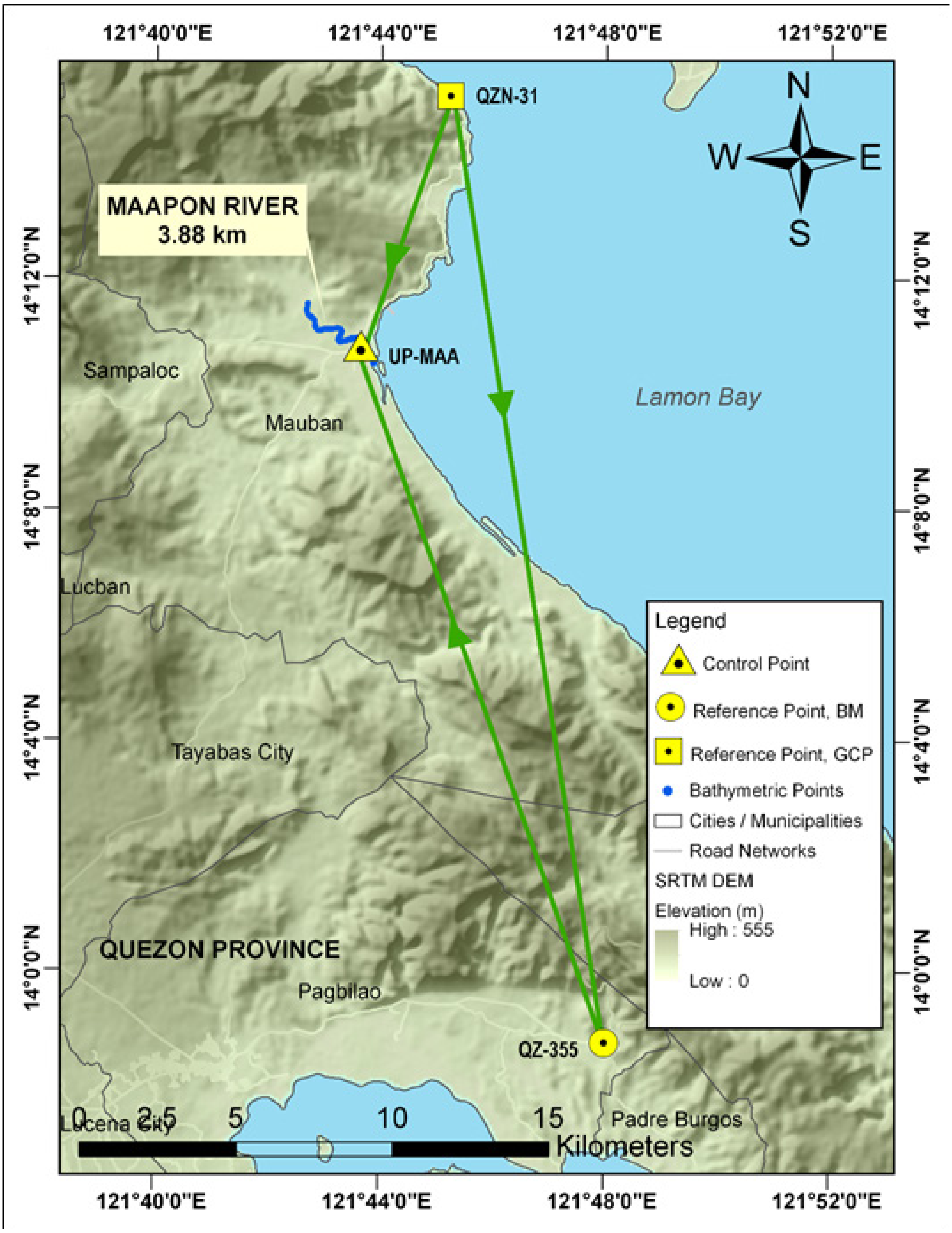


Figure 29. GNSS Network of Maapon River Field Survey.

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 30-Figure 32:

Figure 30. GNSS receiver set up, Trimble® SPS 882 at QZ-355 located on top of a guard rail along Padre Burgos Road in Brgy. Amao Malikboy in the Municipality of Pagbilao, Quezon.

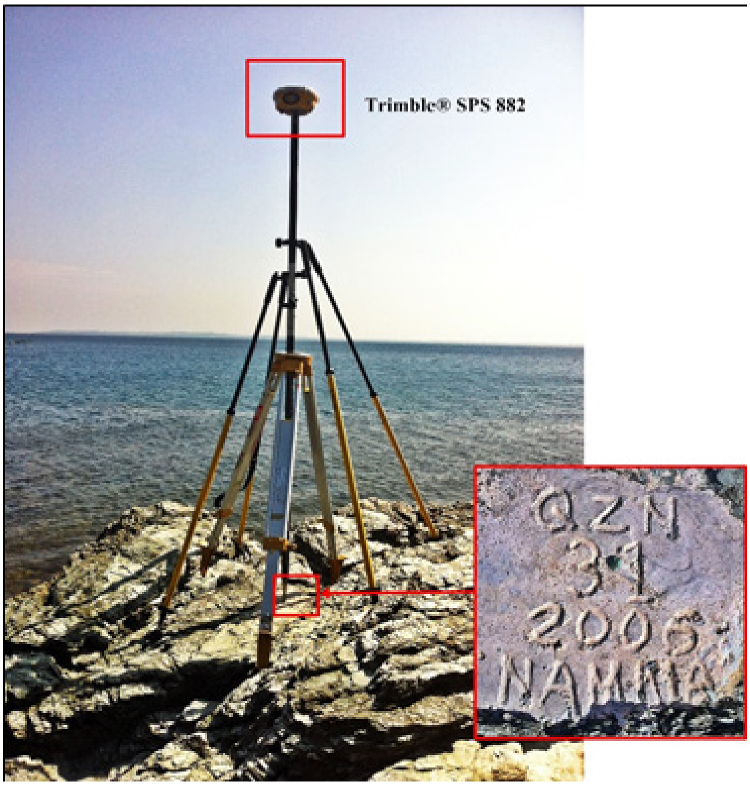


Figure 31. Trimble® SPS 882 receiver setup at QZN-31 located on top of the highest rock along the coast in Brgy. Cagsiay II in the Municipality of Mauban, Quezon.

Figure 32. GNSS base set up, Trimble® SPS 852 at UP-MAA located at the approach of Maapon Bridge along Sampaloc-Mauban Road in Brgy. Polo in the Municipality of Mauban, Quezon.

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 +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is 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 Maapon River Basin is summarized in Table 20 generated TBC software.

Table 20. Baseline Processing Report for Maapon River Survey.

Observation	Date of	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-MAA --- QZ-355 (B2427)	10-21-2015	Fixed	0.011	0.031	160°28'20"	23599.044	7.996
QZN-31 --- QZ-355 (B2428)	10-21-2015	Fixed	0.022	0.018	170°31'32"	30666.710	10.222
UP-MAA --- QZN-31 (B2426)	10-21-2015	Fixed	0.004	0.007	199°31'06"	8493.985	2.184

As shown in Table 20, three control points were occupied at the same time. The accuracies of the processed baselines are within the precision requirement of the program. The GCP was held fixed and used as control point for the network.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report in the next four tables below for complete details.

Table 21. Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
QZN-40	Global	Fixed	Fixed		
QZN-43	Global	Fixed	Fixed		
QZN-47	Global	Fixed	Fixed		
QZ-415	Grid				Fixed
Fixed = 0.000001(Meter)					

As shown in Table 21, the control point, SRS-54, in which the coordinates were fixed during the network adjustment. Through the GCP, SRS-54, the coordinates of the unknown control points will be computed.

Table 22. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
QZ-355	370443.699	0.033	1545765.626	0.019	14.855	0.066	
QZN-31	365557.229	?	1576034.779	?	5.926	?	LLh
UP-MAA	362677.086	0.015	1568045.546	0.011	7.935	0.030	

The network is fixed at reference point QZN-31 with known coordinates based from the certificate attained from NAMRIA. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2} < 20cm$ for horizontal and $ze < 10cm$ for the vertical; the computation for the accuracy for:

a. **QZN-31**

Horizontal accuracy	=	fixed
Vertical accuracy	=	fixed

b. **QZ-355**

horizontal accuracy	=	$\sqrt{((3.30)^2 + (1.90)^2)}$
	=	$\sqrt{(10.89 + 3.61)}$
	=	3.81 cm < 20 cm
vertical accuracy	=	6.60 cm < 10 cm

c. **UP-MAA**

horizontal accuracy	=	$\sqrt{((1.50)^2 + (1.10)^2)}$
	=	$\sqrt{(2.25 + 1.21)}$
	=	1.86 cm < 20 cm
vertical accuracy	=	3.00 cm < 10 cm

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

Table 23. Adjusted geodetic coordinates.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
QZ-355	N13°58'45.51225"	E121°48'01.75450"	62.740	0.066	
QZN-31	N14°15'09.74601"	E121°45'13.55835"	52.523	?	LLh
UP-MAA	N14°10'49.24881"	E121°43'38.91694"	54.710	0.030	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table23. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 24.

Table 24. 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 (m)	Easting (m)	BM Ortho (m)
QZN-31	41st order, GCP	14°15'09.74601"	121°45'13.55835"	52.523	1576034.779	365557.229	4.072
QZ-355	2nd order, BM	13°58'45.51225"	121°48'01.75450"	62.740	1545765.626	370443.699	13.001
UP-MAA	UP established	14°10'49.24881"	121°43'38.91694"	54.710	1568045.546	362677.086	6.081

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

Cross-section and as-built survey was performed along the downstream side of Maapon Bridge in the Municipality of Mauban, Quezon on October 24, 2015 with the application of PPK technique using a survey grade GPS, Trimble® SPS 882 as shown in Figure 33.

Figure 33. (a) As-built survey on the deck using Trimble® SPS 882.

The cross-sectional line of Maapon Bridge has an estimated length of 143.934 m with a total of 36 cross-sectional points gathered using UP-MAA as the GNSS base station. The cross-section diagram, location map, and the bridge data form are shown in Figure 34 to 36, respectively.

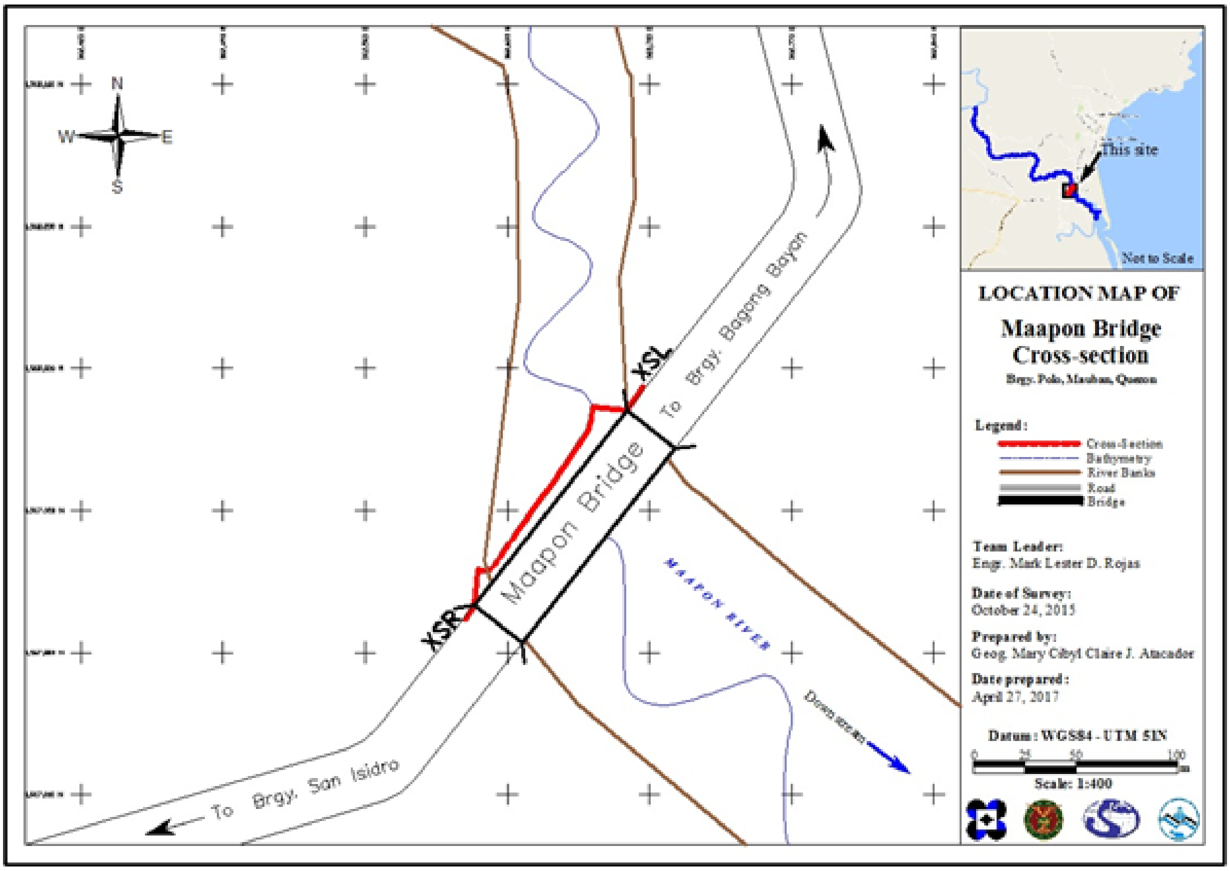


Figure 35. Maapon bridge cross-section location map

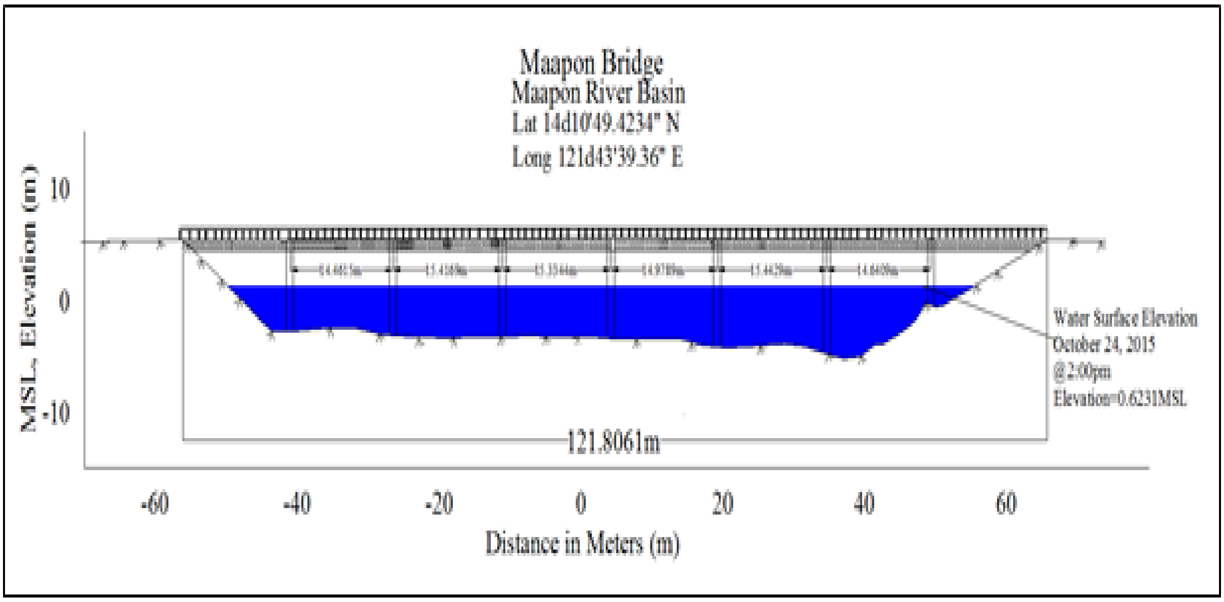


Figure 34. Maapon Bridge cross-section diagram.

Bridge Data Form

Bridge Name: MAAPON BRIDGE **Date:** October 19 , 2015

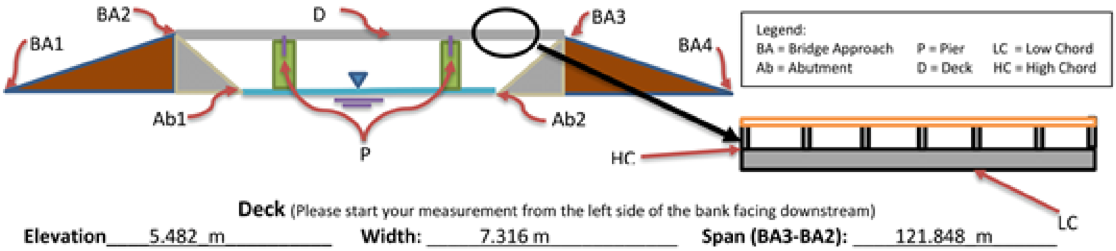
River Name: MAAPON RIVER BASIN **Time:** 10:00 AM

Location (Brgy, City, Region): Poblacion, Mauban, Quezon

Survey Team: Mark Lester D. Rojas, Dona Rina Patricia Tajora, Edjie Abalos, April Joy Lim

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

Latitude: 14d10'47.00682" N **Longitude:** 121d43'37.68286" E



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

Elevation 5.482 m **Width:** 7.316 m **Span (BA3-BA2):** 121.848 m

	Station	High Chord Elevation	Low Chord Elevation
1	43.951	5.432	
2	59.349	5.482	
3	74.702	5.498	
4	89.681	5.482	
5	105.124	5.419	

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0.000	5.115	BA3	135.711	5.362
BA2	13.863	5.316	BA4	143.934	5.201

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Oval **Number of Piers:** 7 **Height of column footing:** N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	28.879	5.377	
Pier 2	43.951	5.432	
Pier 3	59.349	5.482	
Pier 4	74.702	5.498	
Pier 5	89.681	5.482	
Pier 6	105.124	5.419	
Pier 7	120.317	5.377	

Figure 36. Maapon Bridge as-built survey data form.

The water surface elevation of Maapon River was acquired using PPK survey technique on October 24, 2015, 2015 at 2:00 pm. The resulting water surface elevation data was translated to 0.6335 m MSL. Water surface elevation marking was also done right after. One of the abutments was marked with MSL values using red and black paint, as seen in Figure 37, to serve as reference for depth gauge deployment and flow data gathering activities of Mapúa Institute of Technology PHIL-LiDAR 1.

Figure 37. Water-level marking at one of the abutments of Maapon Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 21, 2015. A Trimble® SPS 882 was attached on the side of a vehicle, as shown in Figure 38, to measure points utilizing continuous topo method in a PPK survey technique. The height of instrument was measured and noted a 2.404-meter distance from the ground up to the bottom of notch. Points were gathered along major concrete roads with the aid of a vehicle which moved at a speed of 20-40 kph, cutting across the flight strips of the DAC with the aid of available topographic maps and Google EarthTM images.

The validation points acquisition survey covered roads from Brgy. Cagsiay II in Municipality of Mauban to Brgy. Palale Ibaba in Tayabas City, Quezon via Tayabas, Mauban Road. The established point, UP-MAA was used as a base for this survey.

Figure 38. Validation points acquisition survey setup: A Trimble® SPS 882, mounted in a 2-meter pole and attached in front of the vehicle

The map in Figure 39 shows the extent of the ground validation survey which acquired 3,666 ground validation points with an approximate length of 30 km.

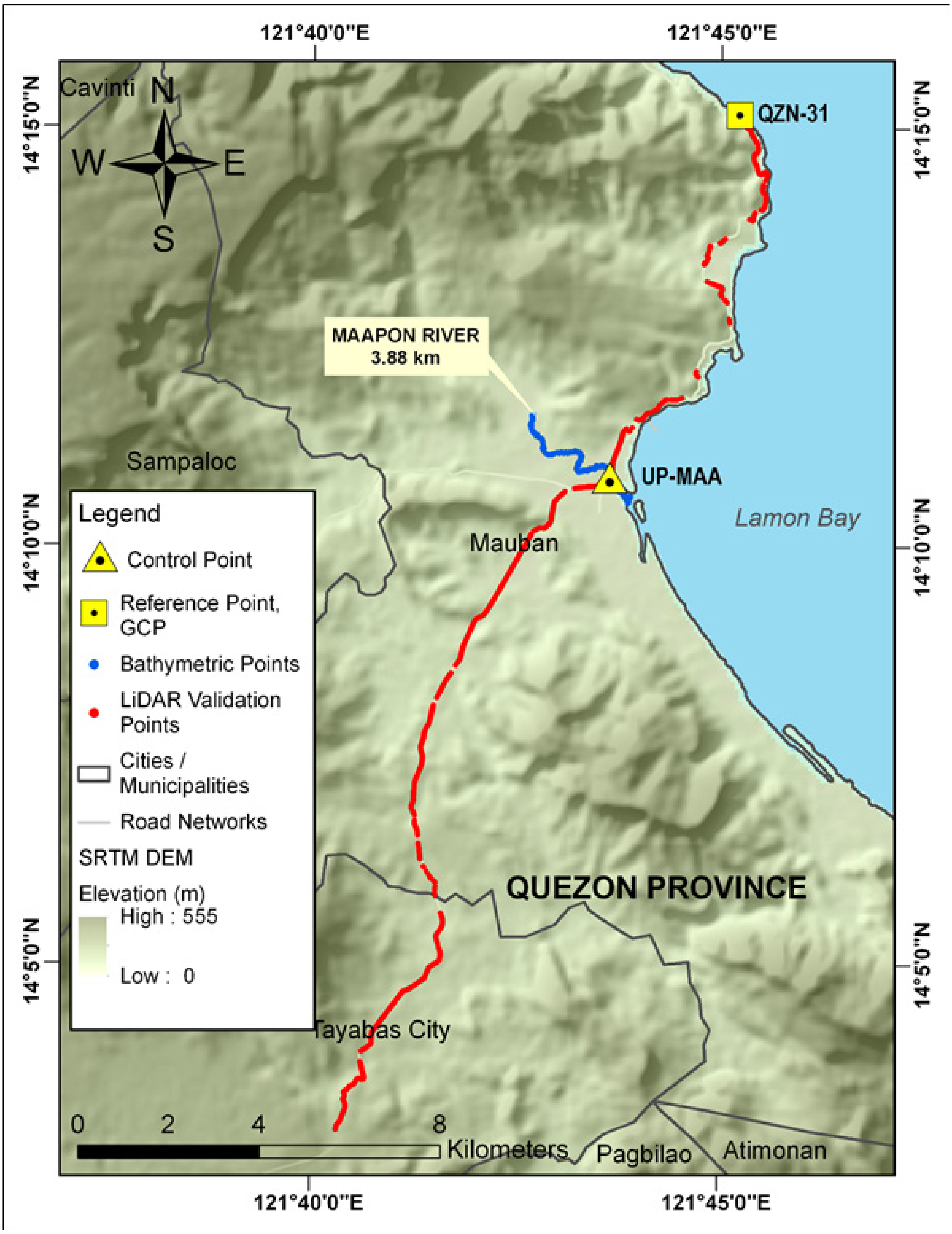


Figure 39. Validation points acquisition survey extent in Maapon River Basin.

4.7 River Bathymetric Survey

Bathymetric survey was conducted on October 24, 2015 using a boat with an installed Hi-Target™ single beam echo sounder and a mounted Trimble® SPS 882 GNSS receiver was used in this survey as shown in Figure 40. The survey began in the midstream part of the river in Brgy. Santol, Municipality of Mauban, Quezon with coordinates 14°11’07.16491” 121°43’02.48659”, and reached the mouth of the river in Brgy. Polo in the Municipality of Mauban, Quezon with coordinates 14°10’30.96196” 121°43’52.69421”.

Figure 40. Bathymetric survey set-up using Hi-Target™ single beam echo sounder and a mounted with a Trimble® SPS 882.

Manual bathymetric survey was also conducted on October 23, 2015 at Maapon River using Trimble® SPS 882 in GNSS PPK survey technique. The survey began at the upmost part of the river in Brgy. Concepcion, Municipality of Mauban, Quezon with coordinates 14°11’33.55241” 121°42’42.00870”, traversed down the river by foot and ended at the starting point of bathymetric survey using boat. The base station UP-MAA was used in this survey to cover the entire bathymetric survey in Maapon River.

The bathymetric survey gathered 1,534 points and produced a centerline profile covering 3.38 km of the river as shown in Figure 41.

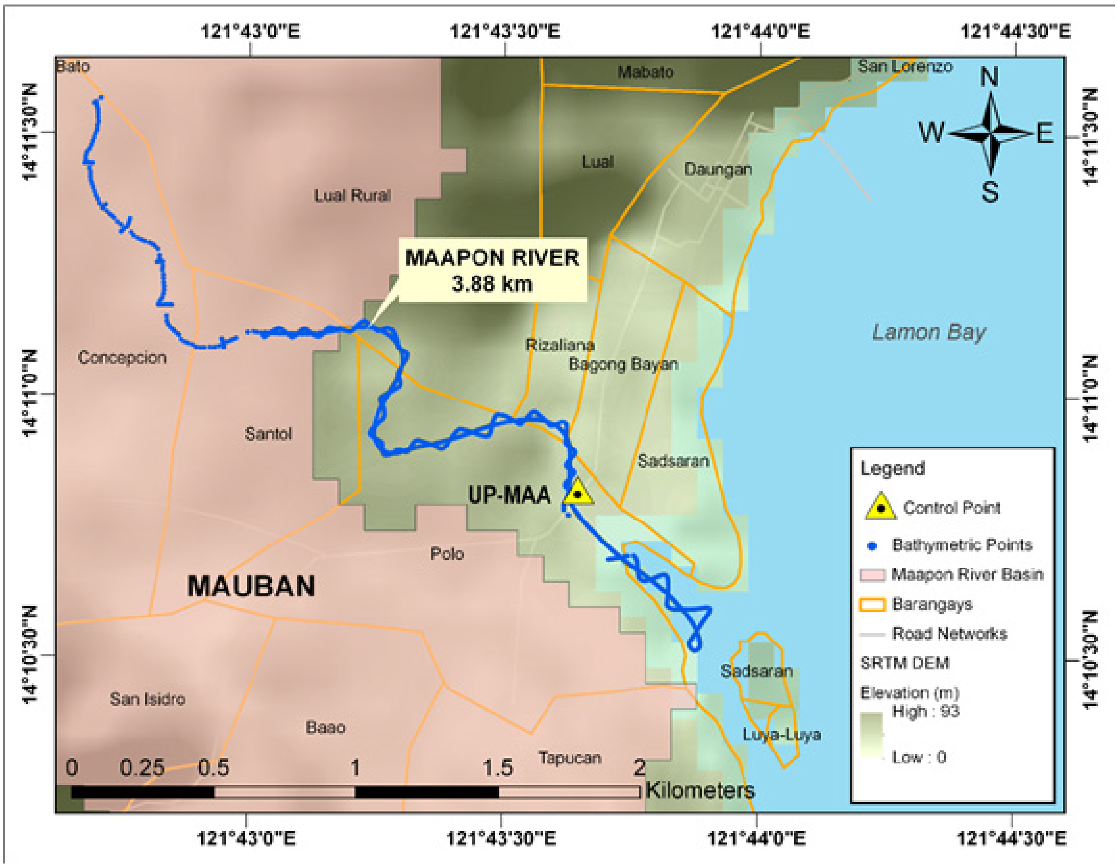


Figure 41. Bathymetric survey extent of Maapon River.

A CAD drawing was also produced to illustrate the Maapon riverbed profile. As shown in Figure 42, the highest and lowest elevation garnered 6-meter difference. The highest elevation observed was 0.856 meters located in Brgy. Concepcion, while the lowest was 5.179 m below MSL located in Brgy. Polo.

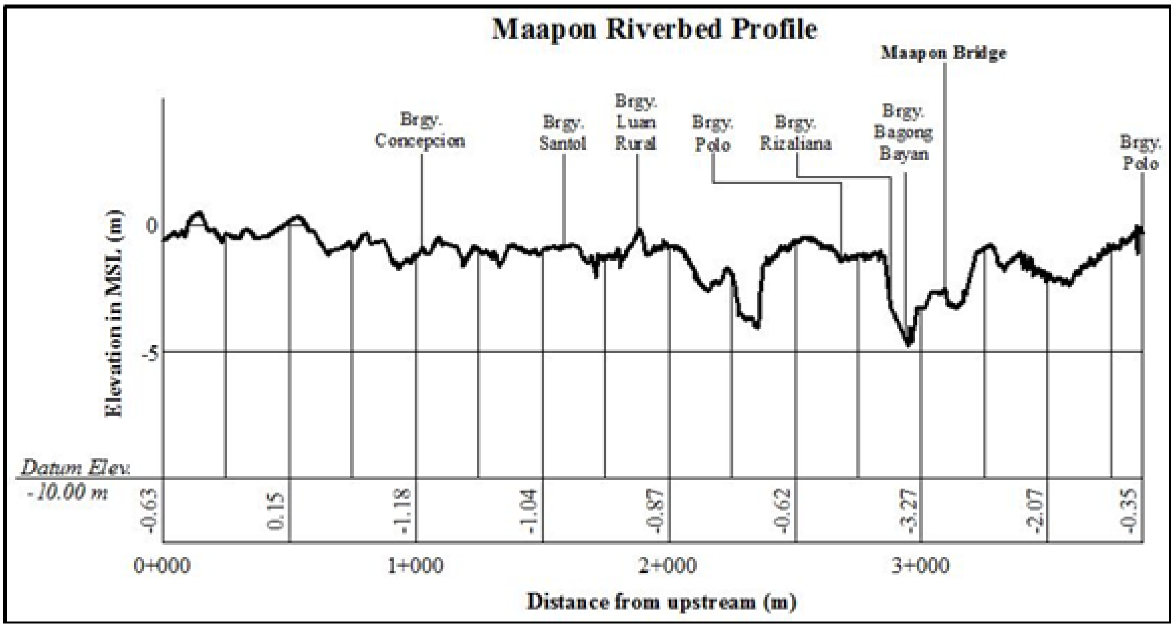


Figure 42. Riverbed profile of Maapon River.

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, Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology- Advance Science and Technology Institute (DOST-ASTI). The ARG was installed in Majayjay, Laguna specifically: 121°30'12.78"E 14° 6'54.43"N as shown in Figure 43. The precipitation data collection started from November 15, 2016 05:15 am to November 25, 2016 at 23:45 pm with a 15-minute recording interval.

The total precipitation for this event in Majayjay ARG was 82.5 mm. It has a peak rainfall of 13 mm on 15 November 2016 at 09:50 pm. The lag time between the peak rainfall and discharge is 8 hours and 40 minutes.

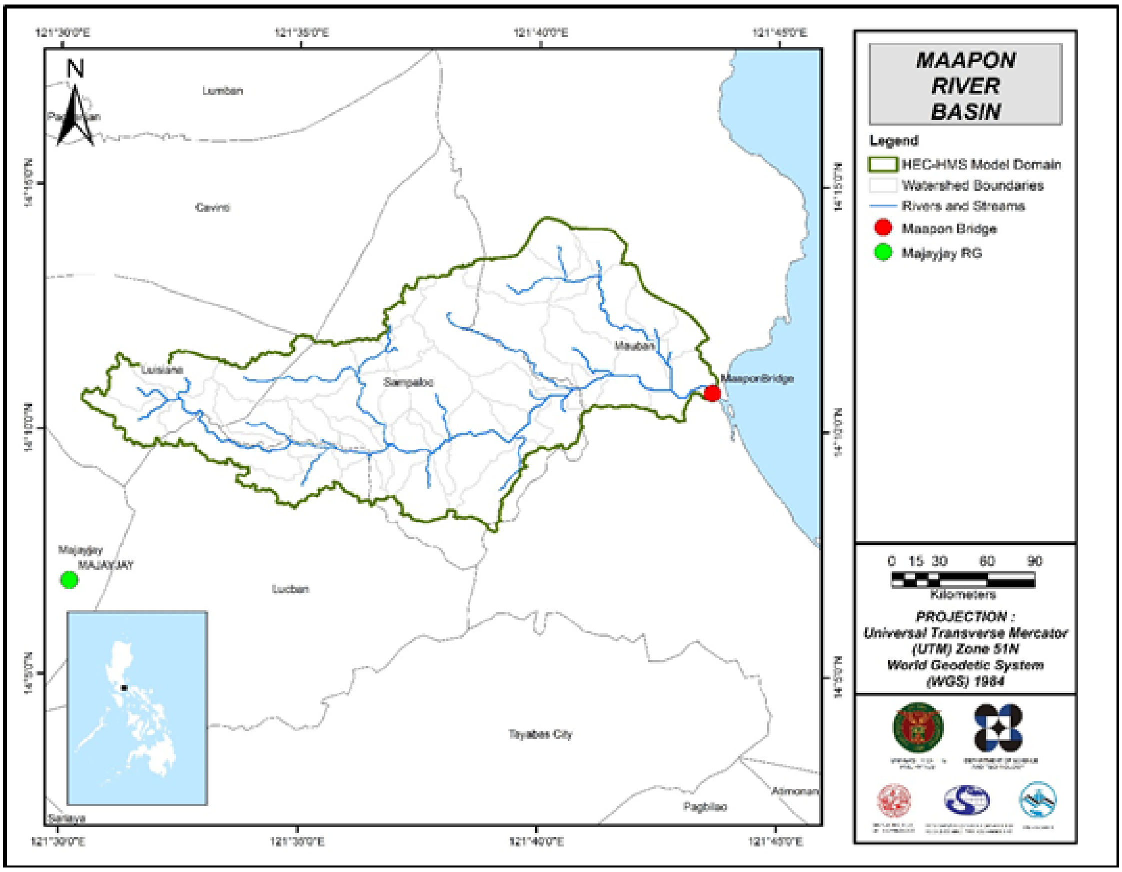


Figure 43. The location map of Maapon HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Maapon Bridge, Real, Quezon (121°43'38.13"E, 14°10'47.34"N). It gives the relationship between the observed water levels from the Maapon Bridge using depth gage and outflow of the watershed recorded using the flow meter at this location.

For Maapon Bridge, the rating curve is expressed as Q = 117.3e1.4782h as shown in Figure 45.

This river basin has no cross section plot.

Figure 44. Cross-Section Plot of Maapon Bridge.

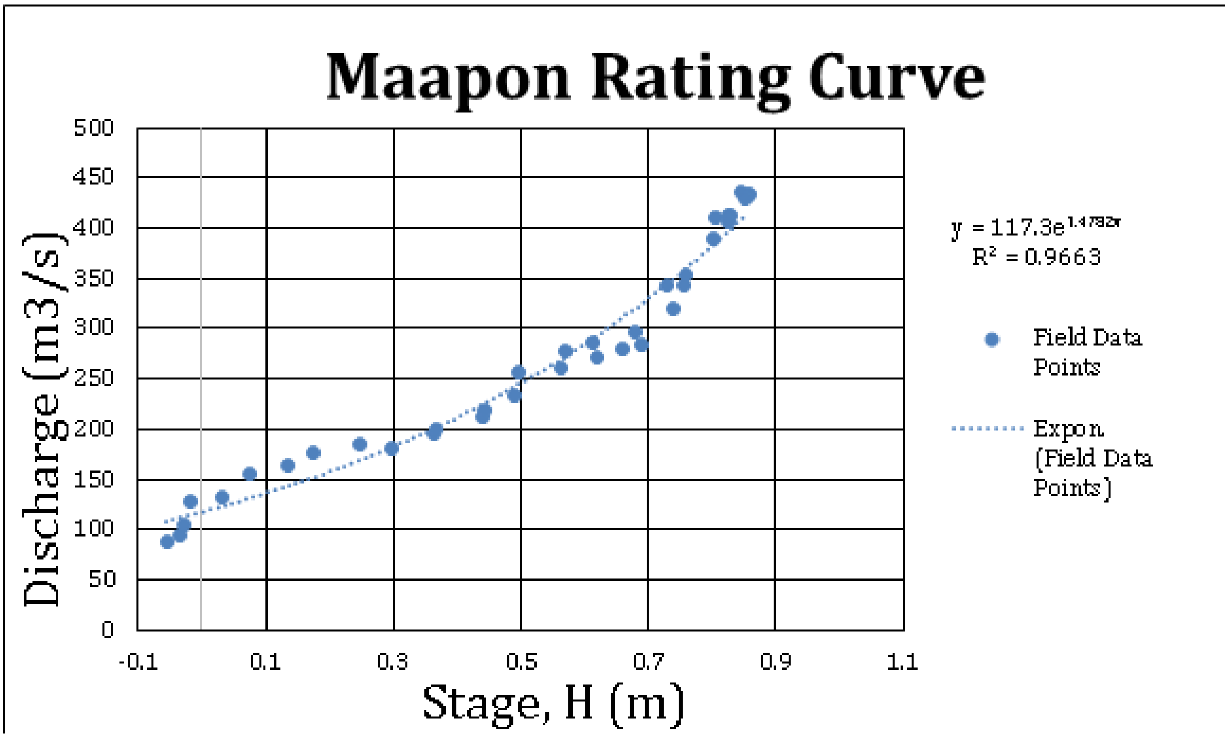


Figure 45. Rating Curve at Maapon Bridge Real Quezon.

This rating curve equation was used to compute the river outflow at Maapon Bridge for the calibration of the HEC-HMS model shown in Figure 43. Peak discharge is 180.2 m3/s at 16:20, November 22, 2016.

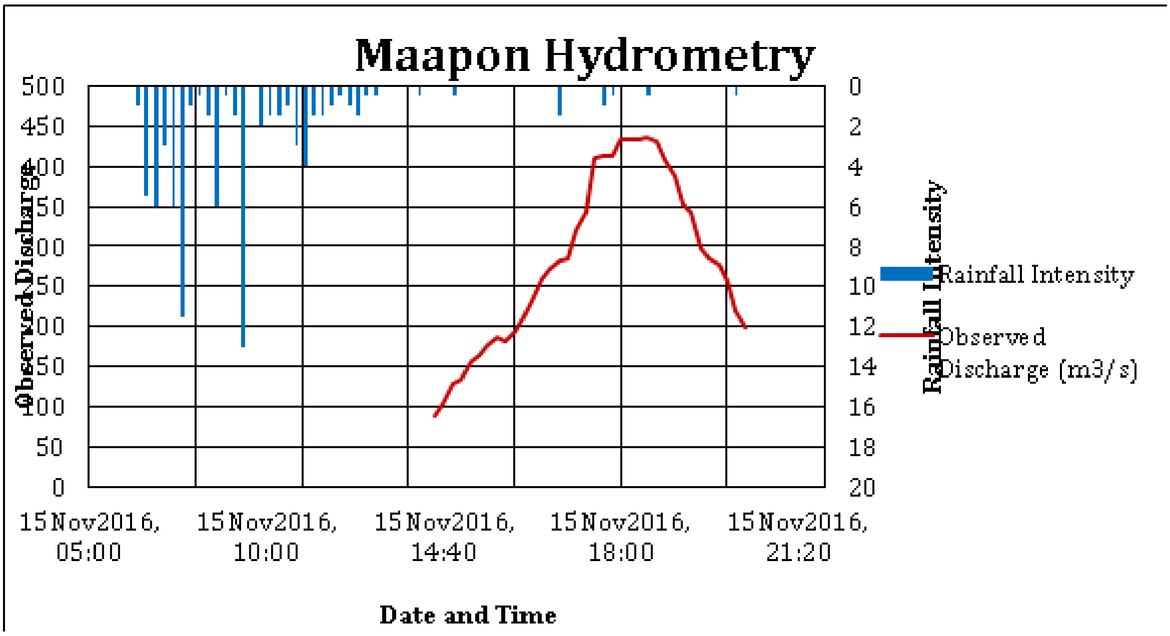


Figure 46. Rainfall and outflow data at Maapon used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Tayabas 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 is chosen based on its proximity to the Maapon watershed. The extreme values for this watershed were computed based on a 31-year record.

Table 25. RIDF values for Tayabas Rain Gauge computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	21	32.7	42	59.3	83	99.9	128.2	161.5	195.9
5	29.6	42.1	52.5	77.3	116.1	143	192.6	232.3	279.5
10	35.4	48.3	59.4	89.2	138	171.5	235.2	279.3	334.9
15	38.6	51.8	63.3	96	150.3	187.6	259.3	305.7	366.1
20	40.9	54.3	66.1	100.7	159	198.9	276.1	324.3	388
25	42.6	56.2	68.2	104.3	165.7	207.5	289.1	338.5	404.8
50	48	62	74.7	115.5	186.2	234.3	329.1	382.5	456.7
100	53.4	67.8	81.1	126.6	206.6	260.8	368.8	426.2	508.3

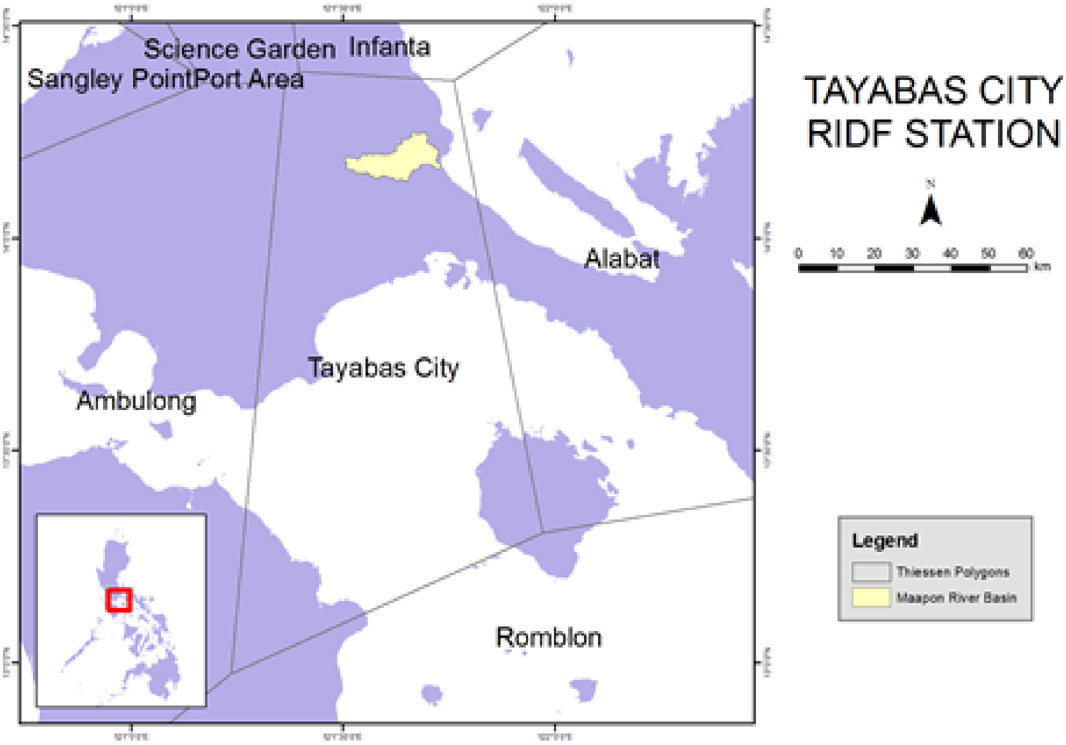


Figure 47. Tayabas RIDF location relative to Maapon River Basin.

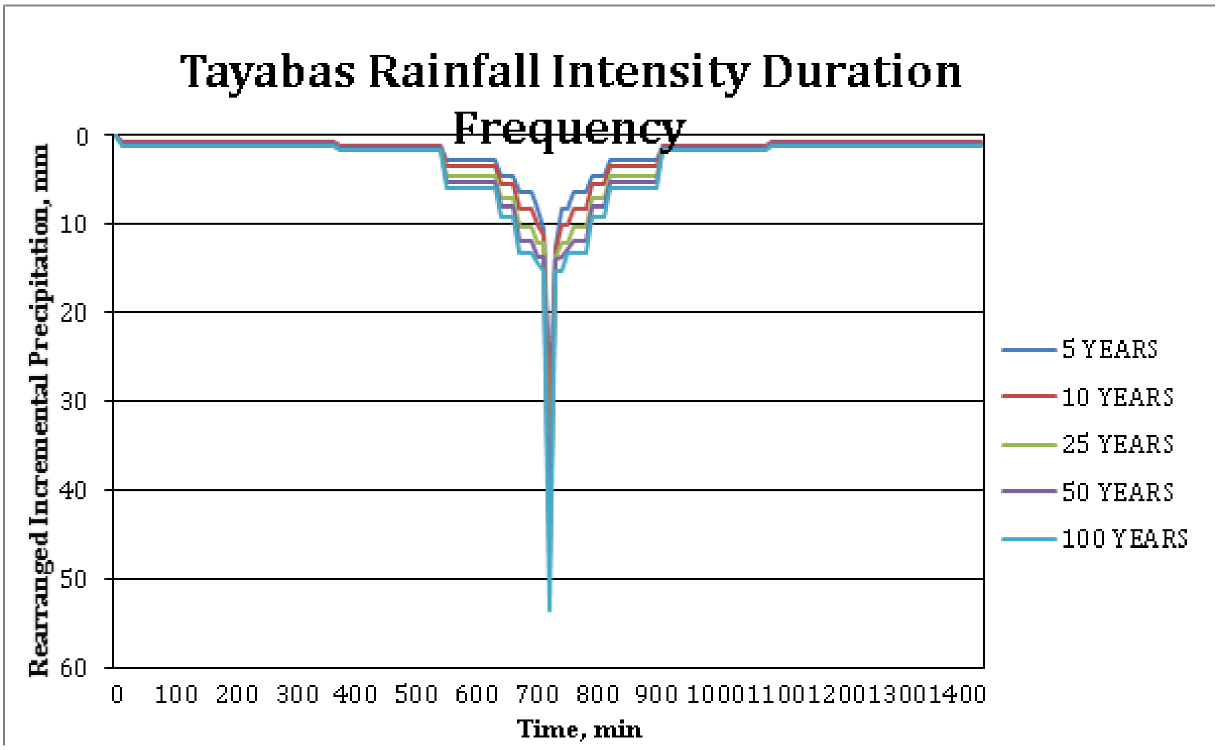


Figure 48. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Maapon River Basin are shown in Figures 49 and 50, respectively.

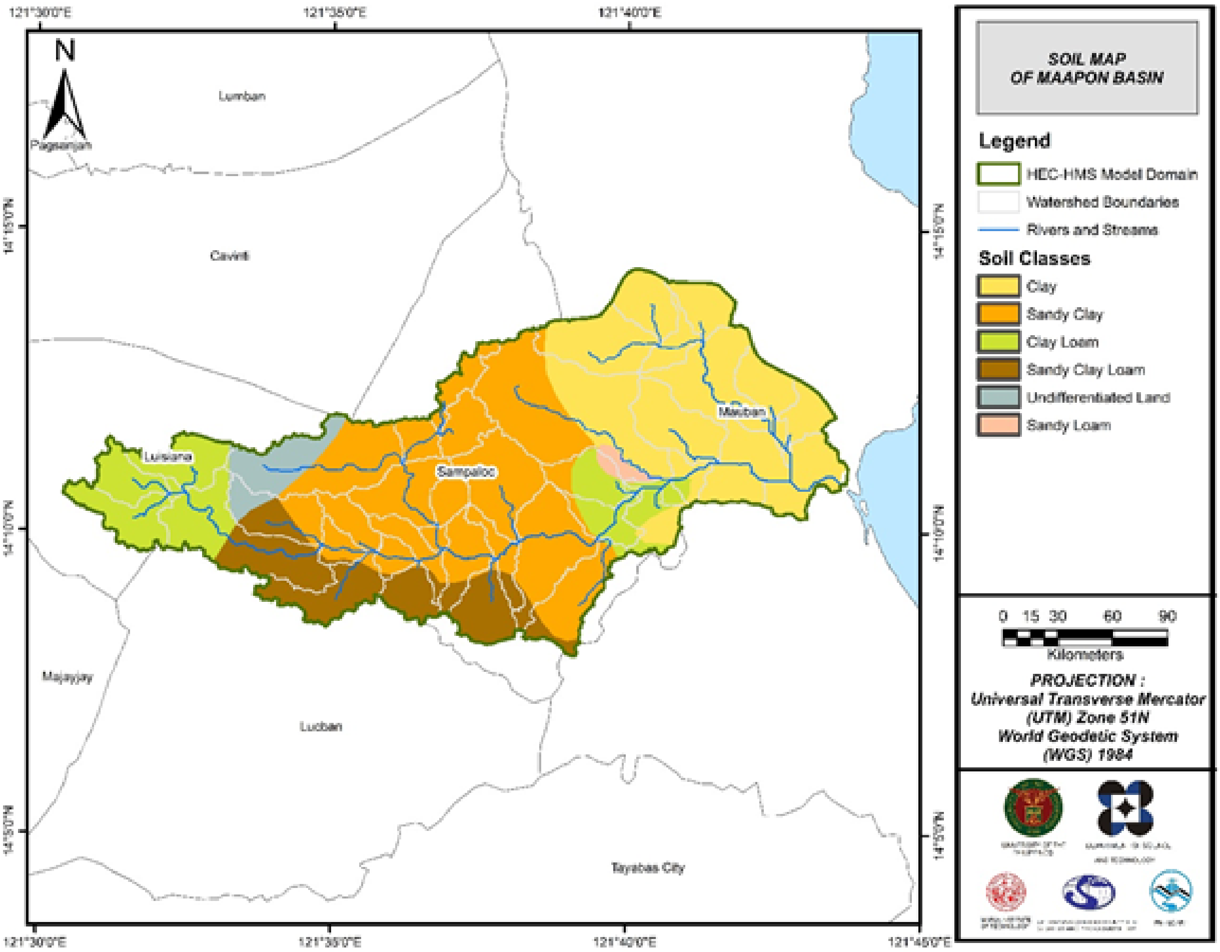


Figure 49. Soil Map of Maapon River Basin.

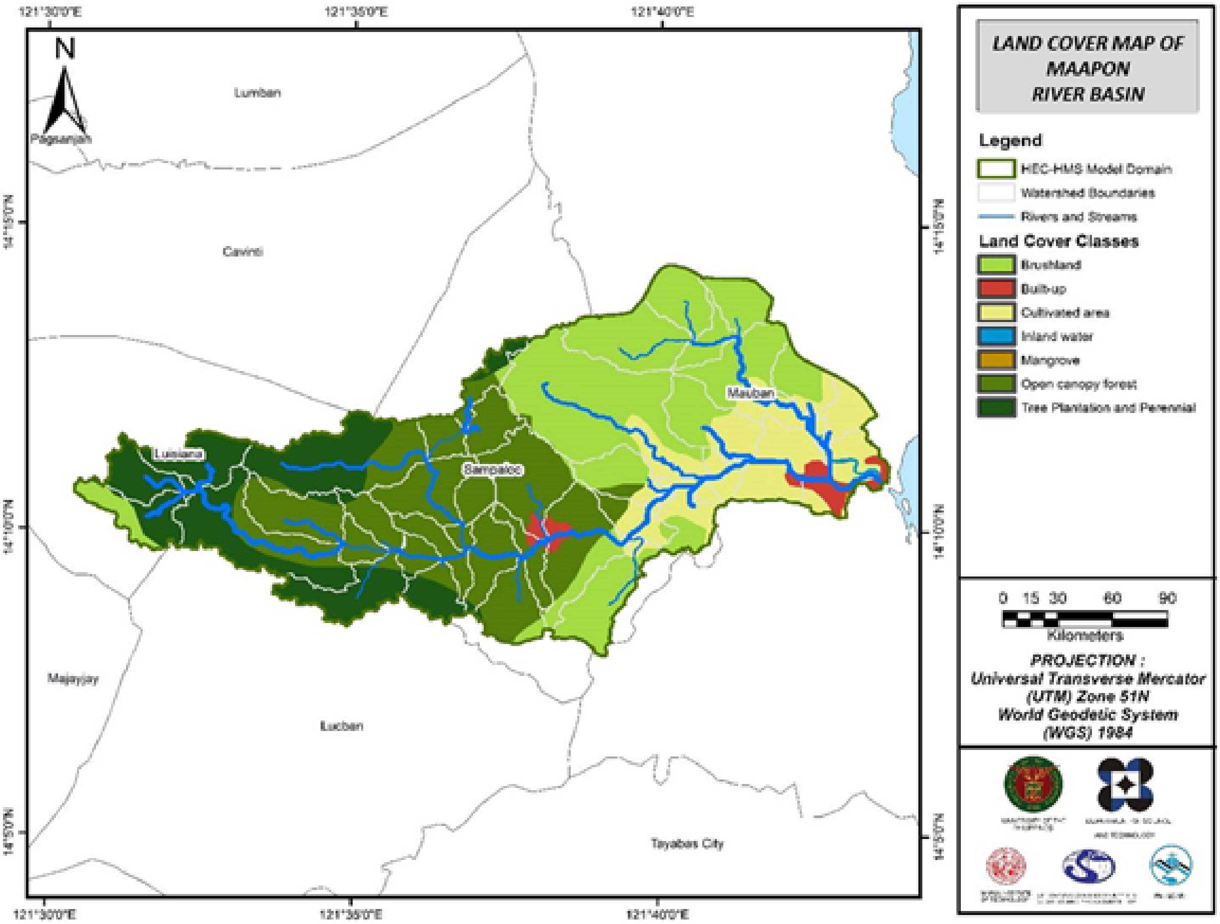


Figure 50. Land Cover Map of Maapon River Basin

For Maapon, six soil classes were identified. These are clay, sandy clay, clay loam, sandy clay loam, undifferentiated land and sandy loam. Moreover, seven land cover classes were identified. These are brushland, built-up, cultivated area, inland water, mangrove, open canopy forest and tree plantation and perennial.

This river basin has no slope map

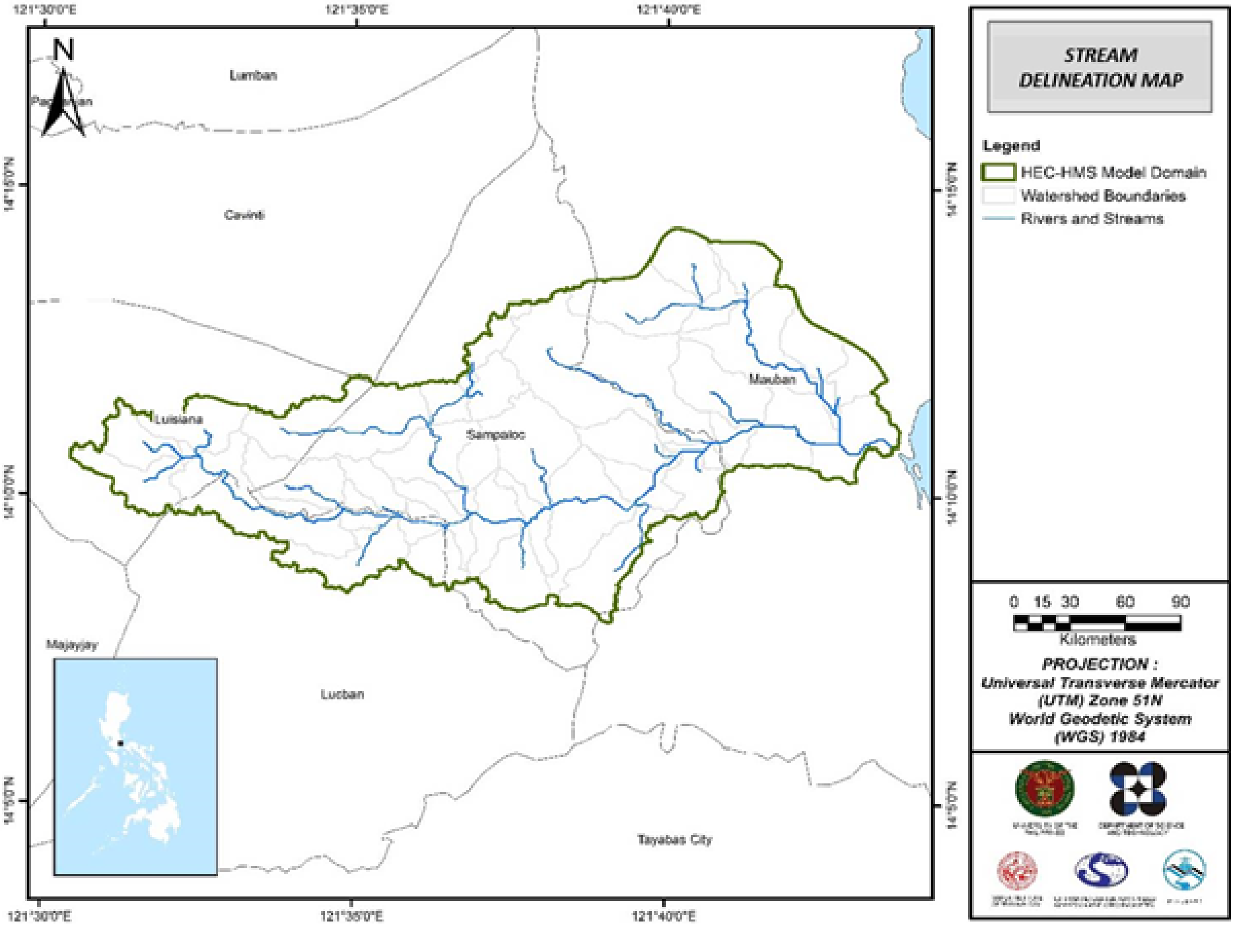


Figure 51. Stream Delineation Map of Maapon River Basin.

The Maapon basin model consists of 45 sub basins, 22 reaches, and 22 junctions. The main outlet is at the easternmost tip of the watershed. This basin model is illustrated in Figure 52. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from DOST-ASTI rain gauges. Finally, it was calibrated using data from the Maapon Bridge.

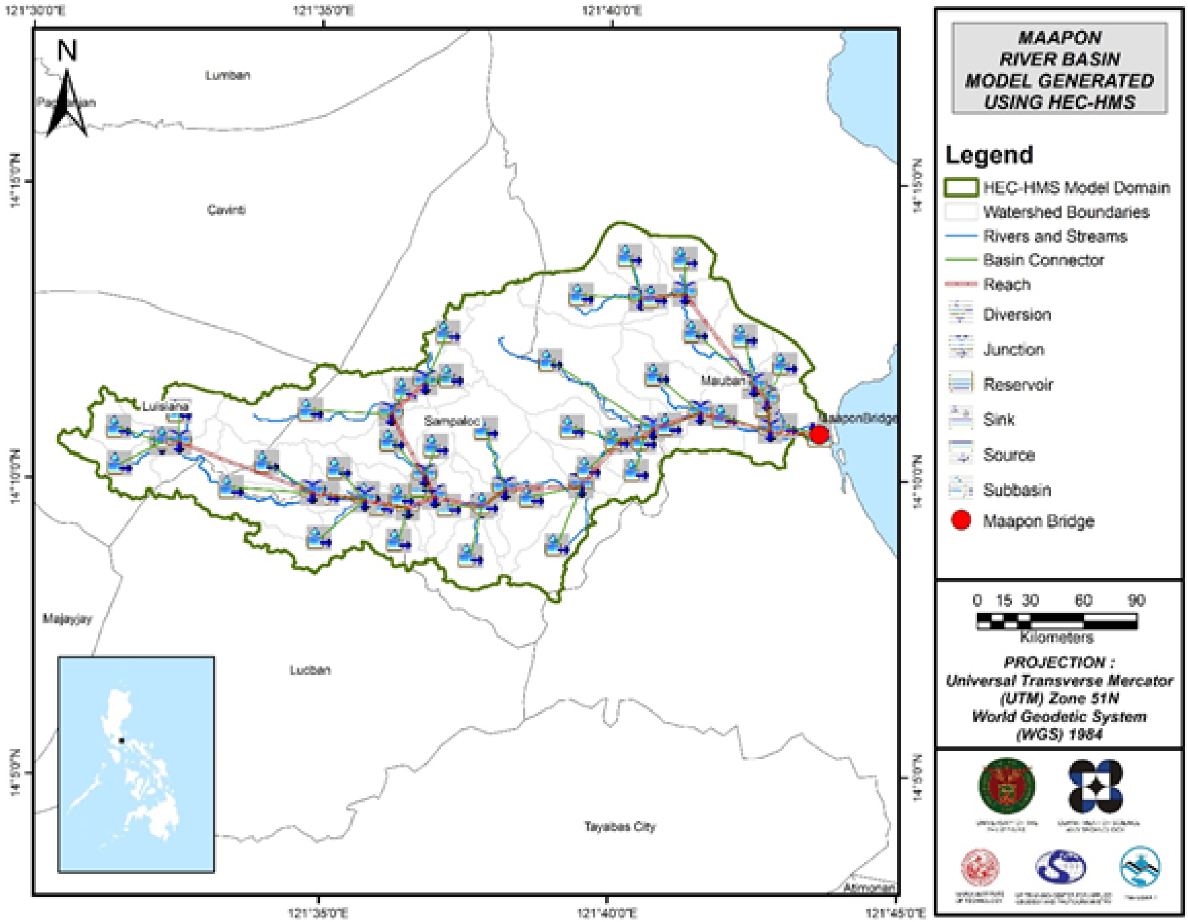


Figure 52. The Maapon River Basin model generated using HEC-HMS

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

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.

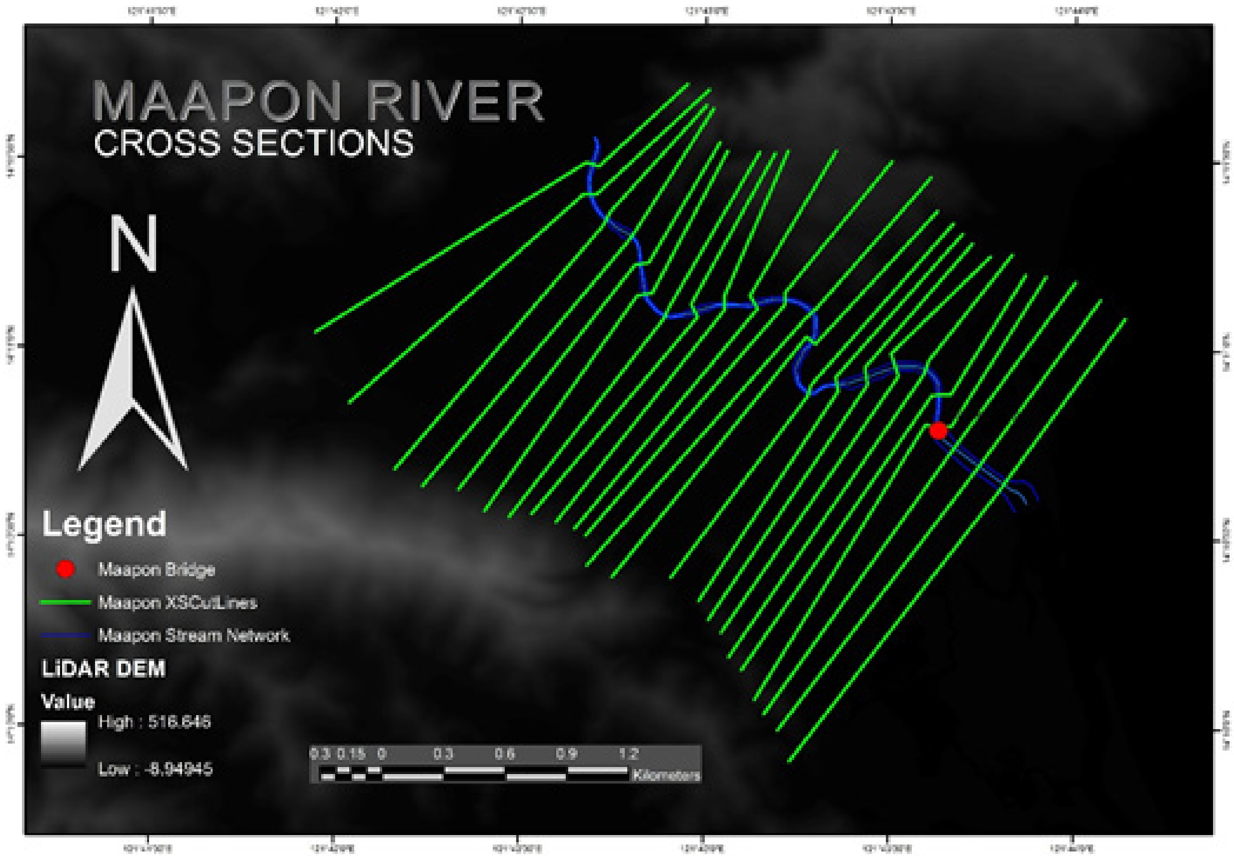


Figure 53. River cross-section of Maapon River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

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

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 94.50293 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 77 986 080.00 m2.

There is a total of 69 491 711.07 m3 of water entering the model. Of this amount, 39 985 912.20 m3 is due to rainfall while 29 505 798.87 m3 is inflow from other areas outside the model. 7 887 196.50 m3 of this water is lost to infiltration and interception, while 9 382 801.00 m3 is stored by the flood plain. The rest, amounting up to 52 221 734.93 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Maapon HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 55 shows the comparison between the two discharge data.

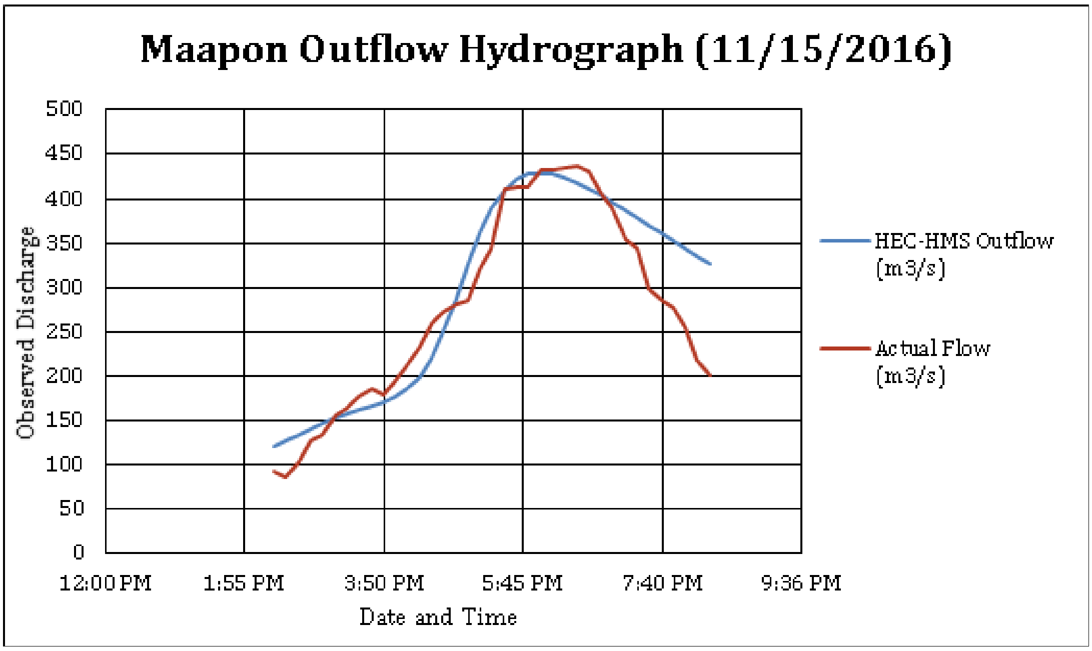


Figure 55. Outflow Hydrograph of Maapon produced by the HEC-HMS model compared with observed outflow.

Table 26 shows adjusted ranges of values of the parameters used in calibrating the model.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.04 – 0.51
			Curve Number	99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.65 – 17.54
			Storage Coefficient (hr)	0.02 – 0.96
	Baseflow	Recession	Recession Constant	0.00001 – 0.00002
			Ratio to Peak	0.79 – 1
Reach	Routing	Muskingum-Cunge	Slope	0.001 – 1
			Manning's n	0.0001-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.04 mm to 0.51 mm signifies that there is minimal amount of infiltration or rainfall interception by vegetation. The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The curve number of Maapon River Basin is 99. For Maapon, the basin mostly consists of brushland, open canopy forest and tree plantation and perennial and the soil mostly consists of clay, sandy clay and sandy clay loam.

The 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 0.02 hours to 17.54 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrographh also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.00001 - 0.00002 indicates that the basin is highly likely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.79 – 1 indicates a steep receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.001 - 1 corresponds to the common roughness in Maapon watershed, which is determined to have scattered brush with heavy weeds (Brunner, 2010).

Table 27. Summary of the Efficiency Test of Maapon HMS Model.

Accuracy Measure	Value
RMSE	0.8715
r2	0.84
NSE	-6.00
PBIAS	0.40
RSR	0.29

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 44.0 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8715.

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 0.84.

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 -6.00.

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 0.40.

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 56) shows the Maapon outflow using the Tayabas 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.

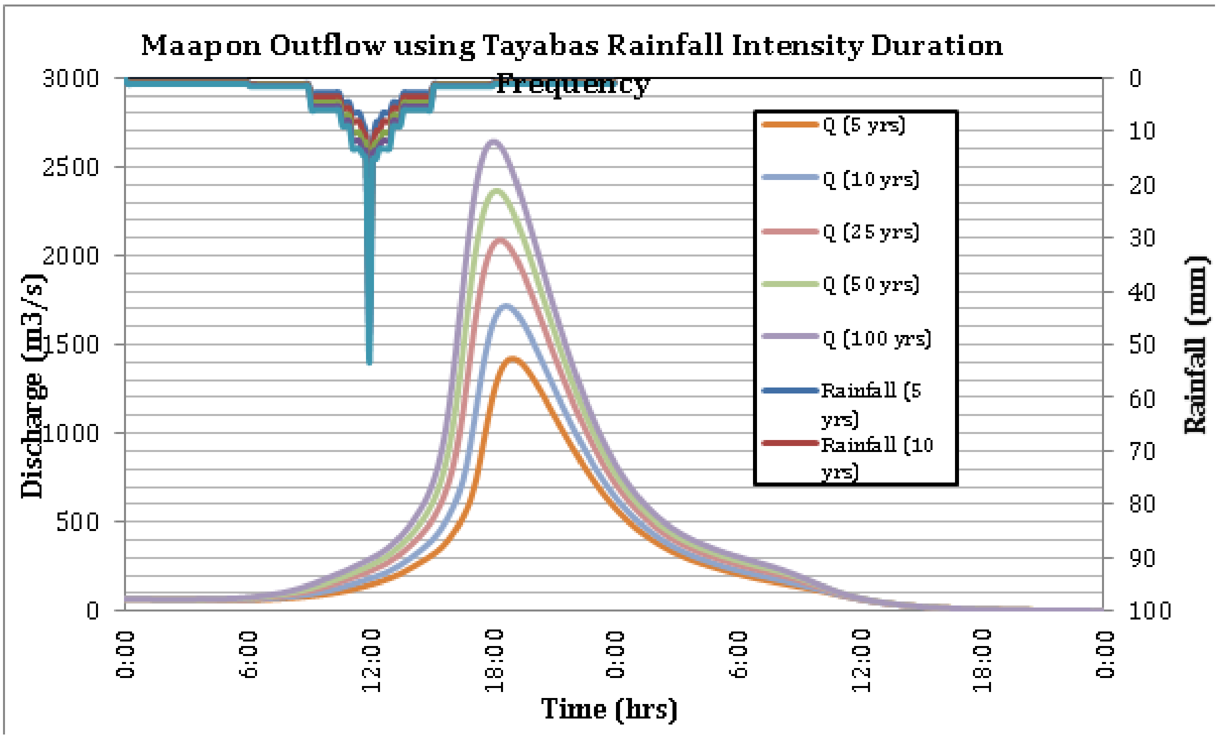


Figure 56. Outflow hydrograph at Maapon Station generated using Tayabas RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Maapon discharge using the Tayabas Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 28.

Table 28. Peak values of the Maapon HECHMS Model outflow using the Tayabas RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	278.84	29.6	1421.4	19 hours
10-Year	334.9	35.40	1717.50	18 hours, 40 minutes
25-Year	404.8	42.60	2087.50	18 hours, 20 minutes
50-Year	456.7	48	2365.20	18 hours, 10 minutes
100-Year	508.3	53.40	2640.60	18 hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Maapon River using the calibrated HMS event flow with 5-year rain return scenario is shown in Figure 57.

Figure 57. Sample output of Maapon RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 58 to Figure 63 shows the 5-, 25-, and 100-year rain return scenarios of the Maapon floodplain. The floodplain, with an area of 274.89 sq. km., covers two municipalities namely Mauban and Sampaloc. Table shows the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in Alaminos floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Mauban	430.04	43.13	10%
Sampaloc	93.05	35.27	38%

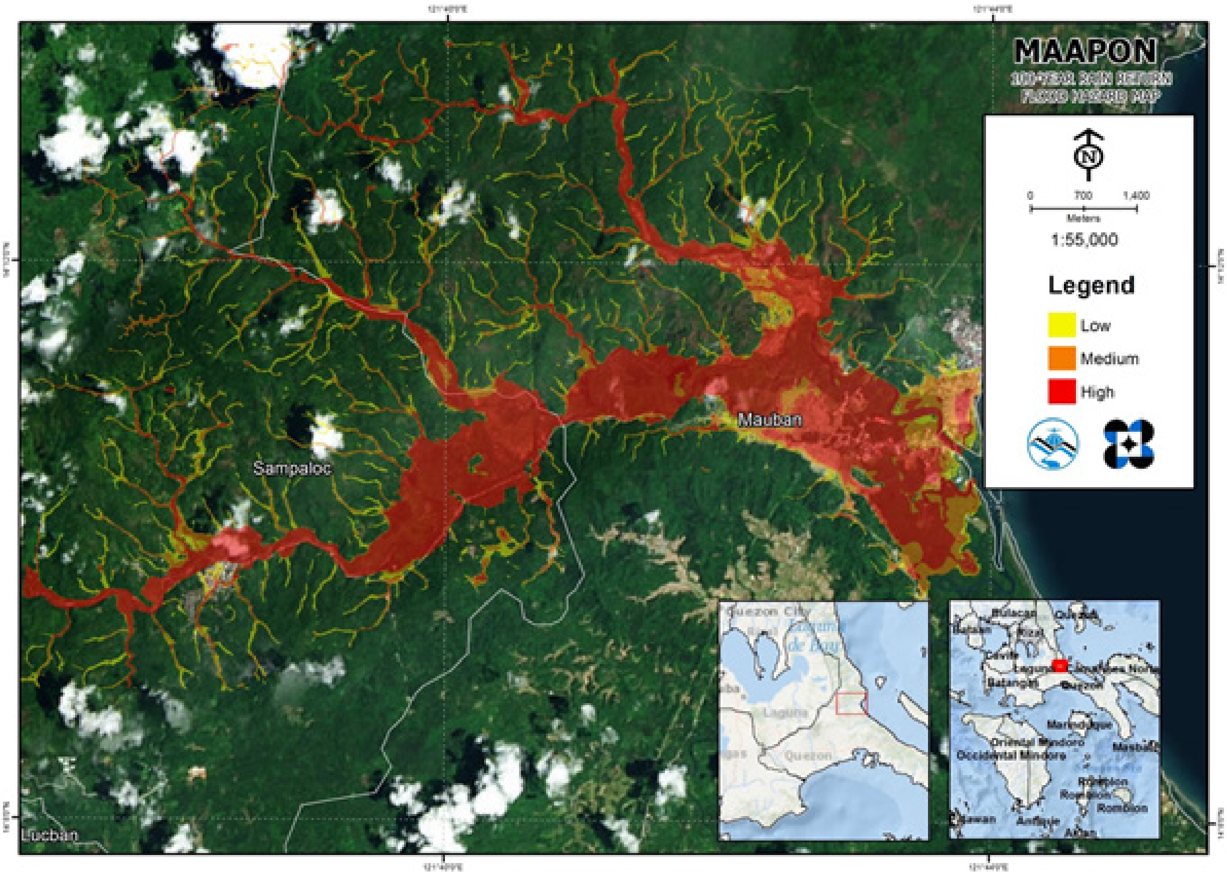


Figure 58. 100-year Flood Hazard Map for Maapon Floodplain.

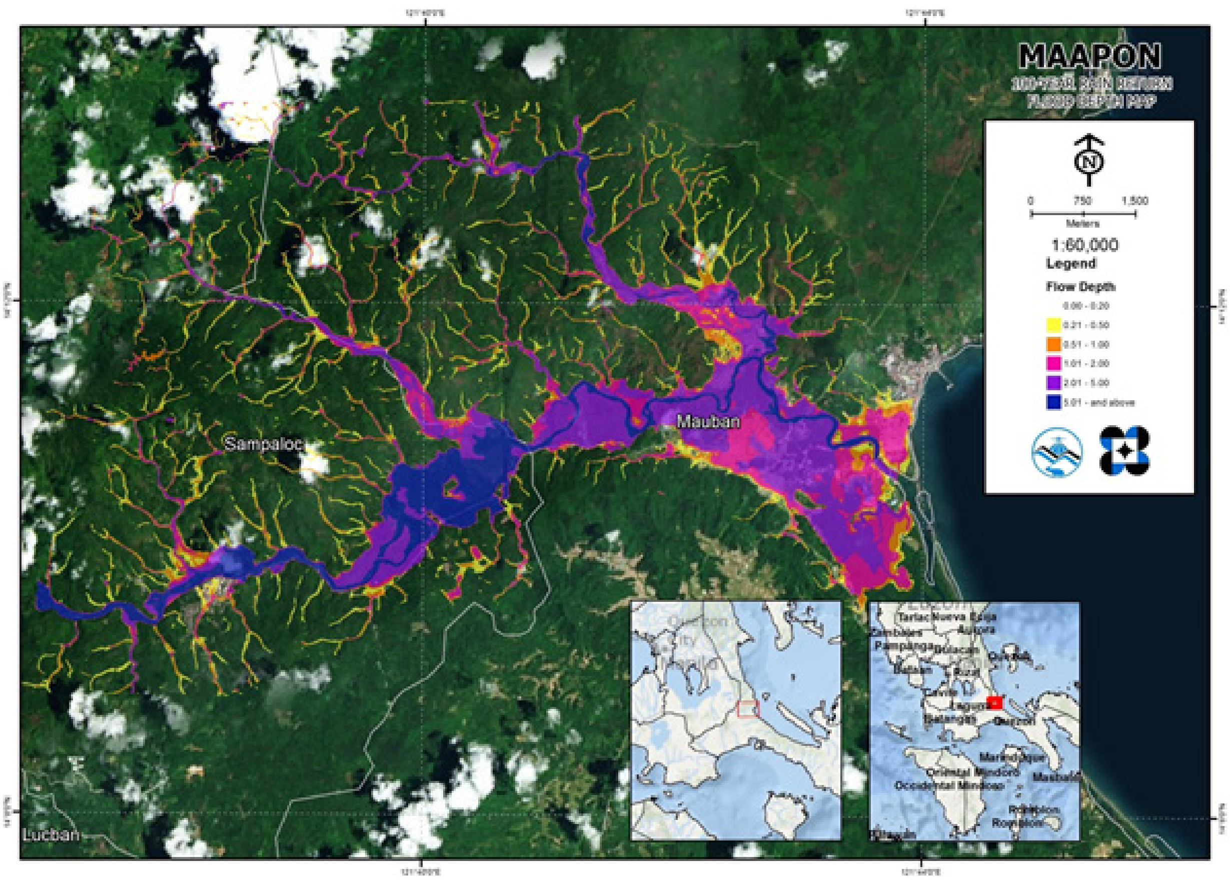


Figure 59. 100-year Flow Depth Map for Maapon Floodplain.

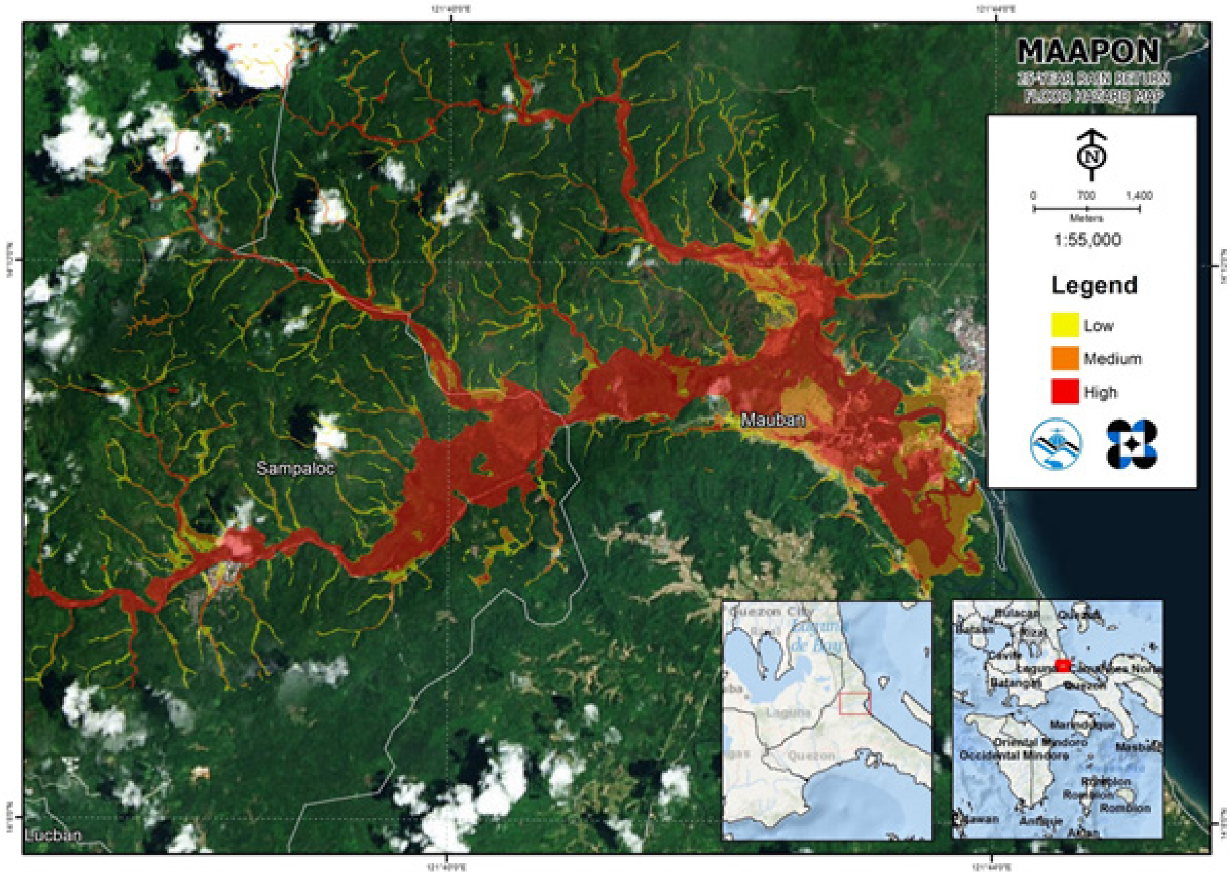


Figure 60. 25-year Flood Hazard Map for Maapon Floodplain.

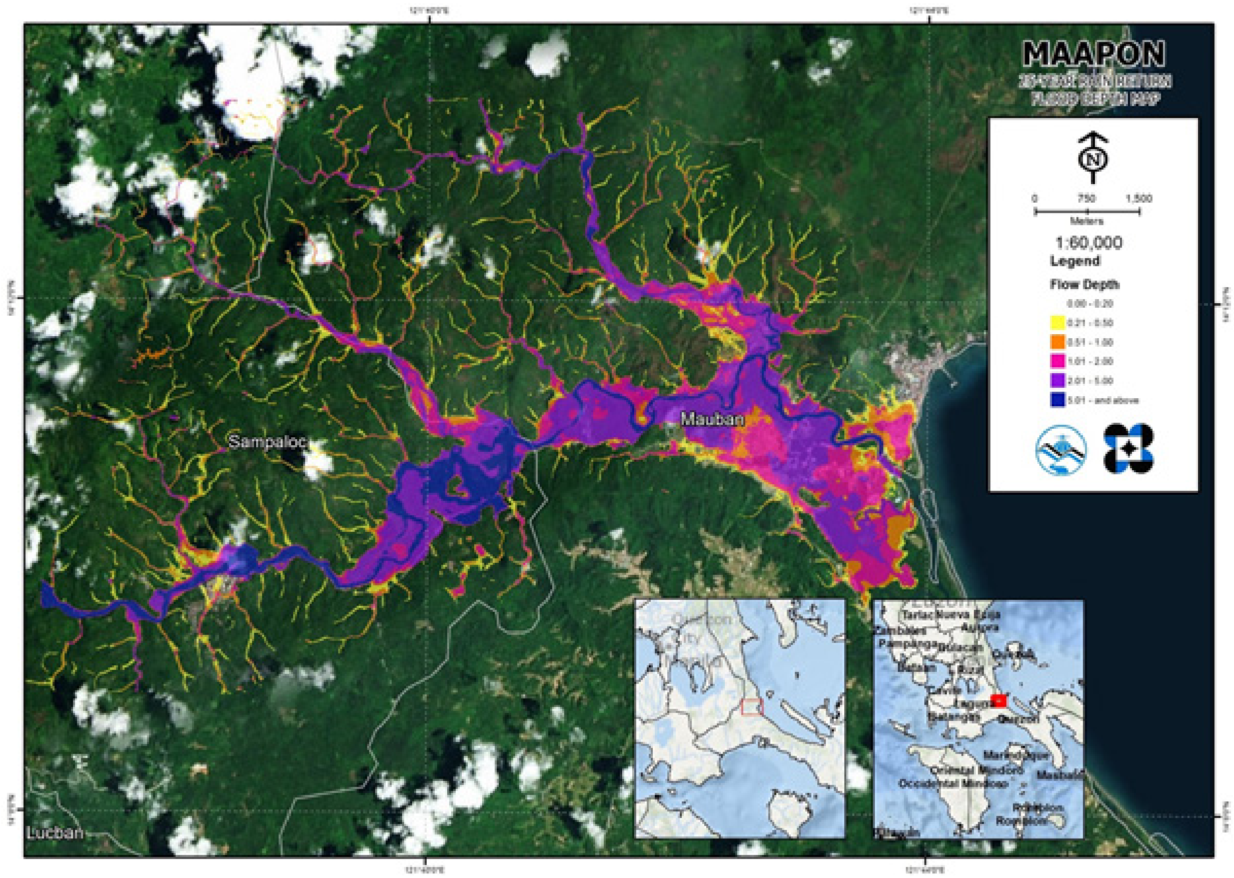


Figure 61. 25-year Flow Depth Map for Maapon Floodplain.

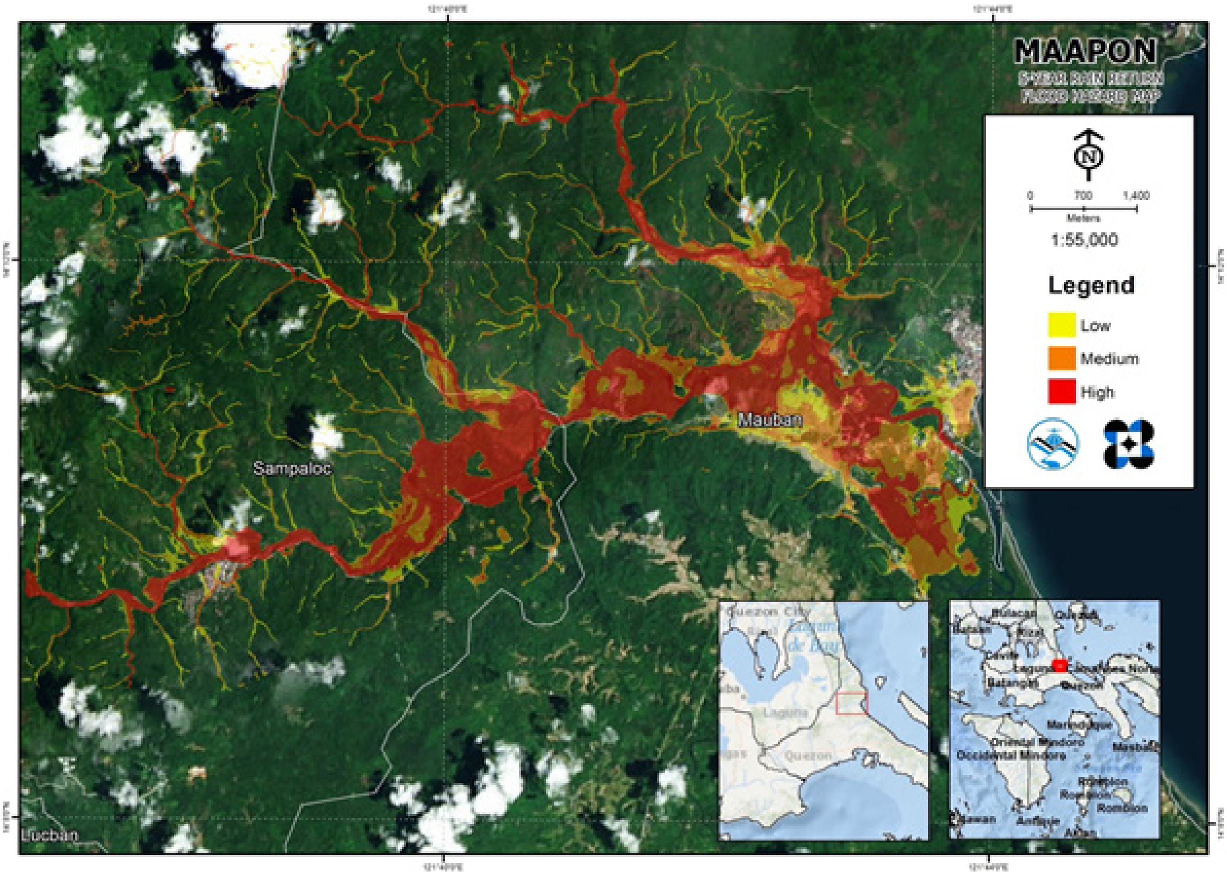


Figure 62. 5-year Flood Hazard Map for Maapon Floodplain.

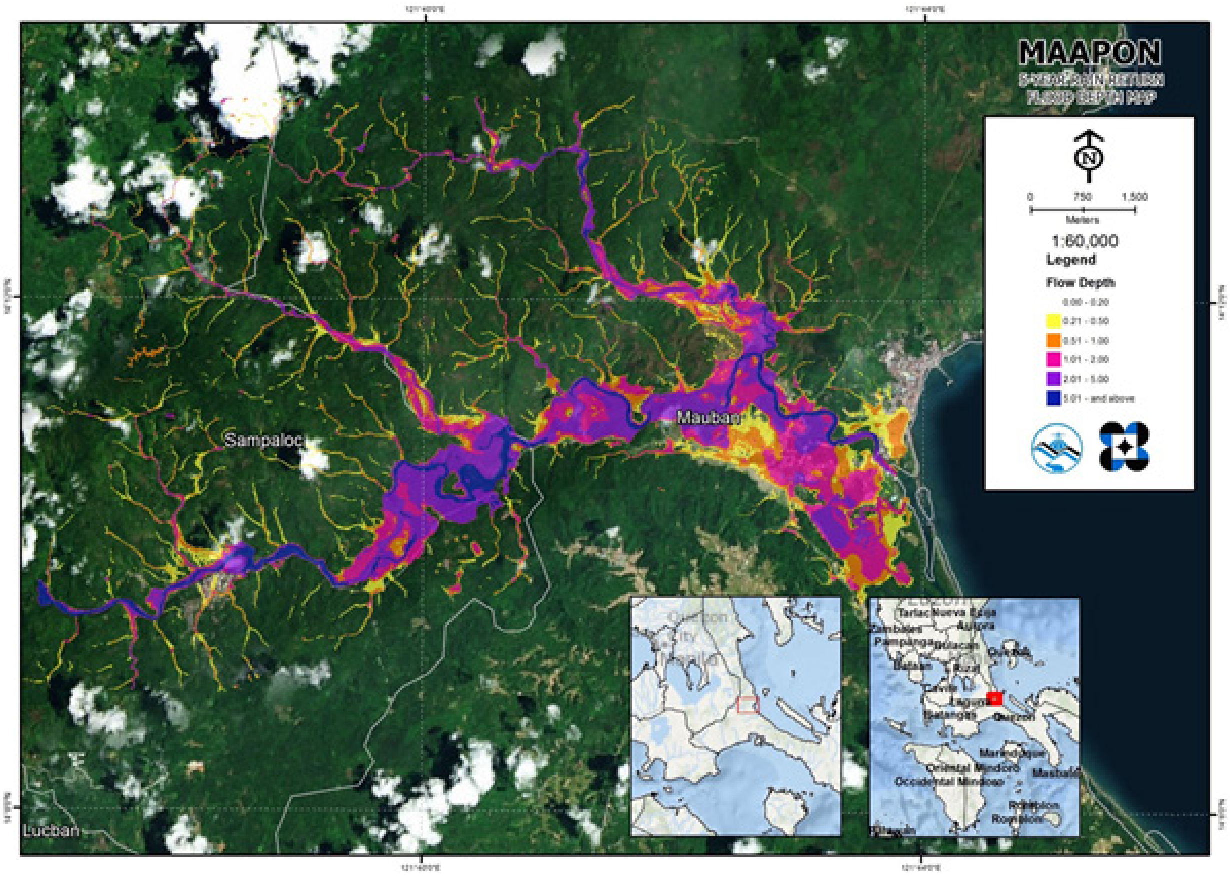


Figure 63. 5-year Flow Depth Map for Maapon Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Maapon river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 35 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

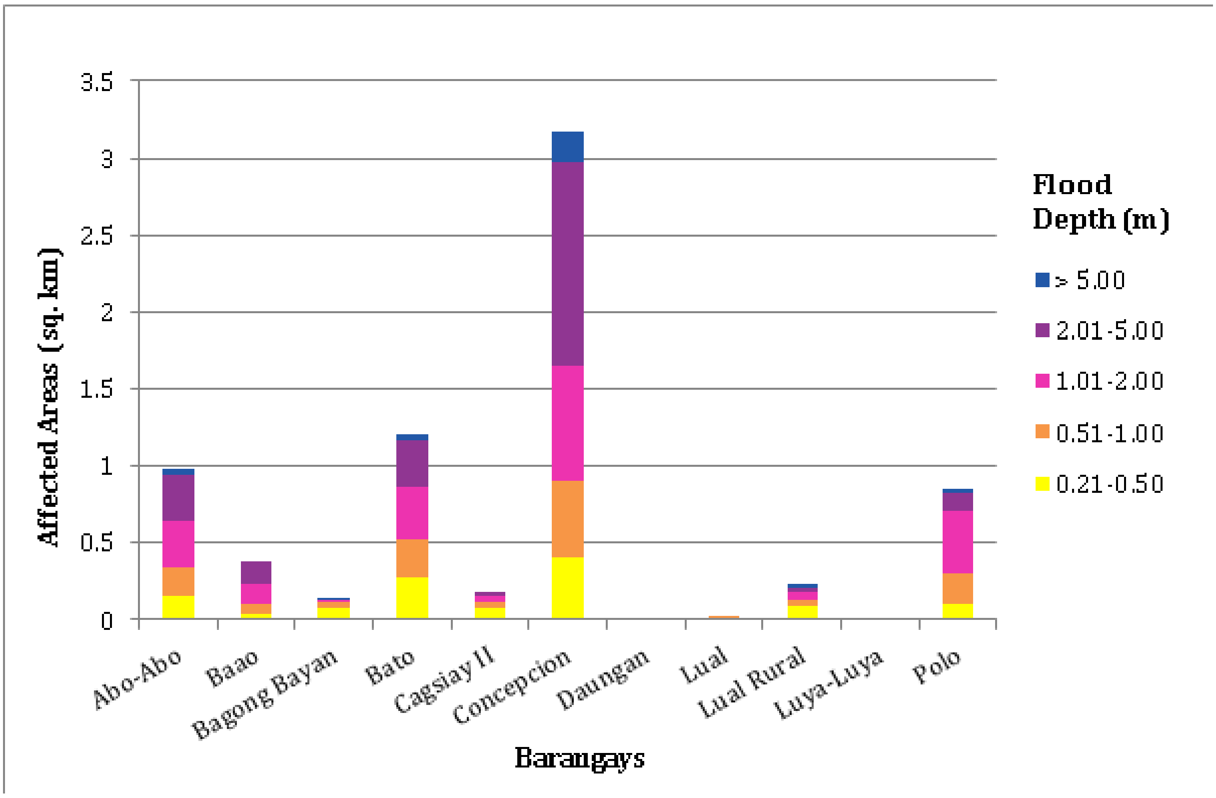
For the 5-year return period, 7.43% of the municipality of Mauban with an area of 430.04 sq. km. will experience flood levels of less than 0.20 meters. 0.56% of the area will experience flood levels of 0.21 to 0.50 meters while 0.54%, 0.76%, 0.65%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 30. Affected Areas in Mauban, Quezon during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)						
	Abo-Abo	Baao	Bagong Bayan	Bato	Cagsiay II	Concepcion	Daungan
0.03-0.20	4.07	0.61	0.078	2.33	2.22	1.91	0.093
0.21-0.50	0.16	0.043	0.082	0.27	0.075	0.4	0.0027
0.51-1.00	0.18	0.06	0.042	0.26	0.048	0.5	0
1.01-2.00	0.3	0.13	0.00028	0.33	0.037	0.75	0
2.01-5.00	0.3	0.15	0.0005	0.31	0.027	1.33	0
> 5.00	0.037	0	0.0022	0.034	0	0.19	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)						
	Lual	Lual Rural	Luya-Luya	Polo	Remedios I	Remedios II	Rizaliana
0.03-0.20	0.099	1.13	0.0012	0.23	2.86	7.38	0.025
0.21-0.50	0.0081	0.087	0.00096	0.1	0.21	0.29	0.056
0.51-1.00	0.0026	0.047	0	0.2	0.2	0.16	0.023
1.01-2.00	0	0.047	0	0.41	0.26	0.12	0.00075
2.01-5.00	0	0.031	0	0.11	0.098	0.055	0.0069
> 5.00	0	0.02	0	0.033	0.00011	0	0.0054

Affected area (sq. km.) by flood depth (in m.)	Areas of affected Barangays in Catanauan (in sq.km.)							
	Sadsaran	San Isidro	San Roque	San Vicente	Santo Angel	Santol	Soledad	Tapucan
0.03-0.20	0.095	1.06	3.94	2.01	0.013	0.0042	1.45	0.35
0.21-0.50	0.029	0.035	0.22	0.091	0	0.0027	0.038	0.21
0.51-1.00	0.084	0.026	0.1	0.086	0	0.027	0.0026	0.27
1.01-2.00	0.0007	0.033	0.023	0.061	0	0.32	0	0.45
2.01-5.00	0	0.0053	0.0057	0.0068	0	0.21	0	0.15
> 5.00	0	0	0.0051	0.0003	0	0.031	0	0



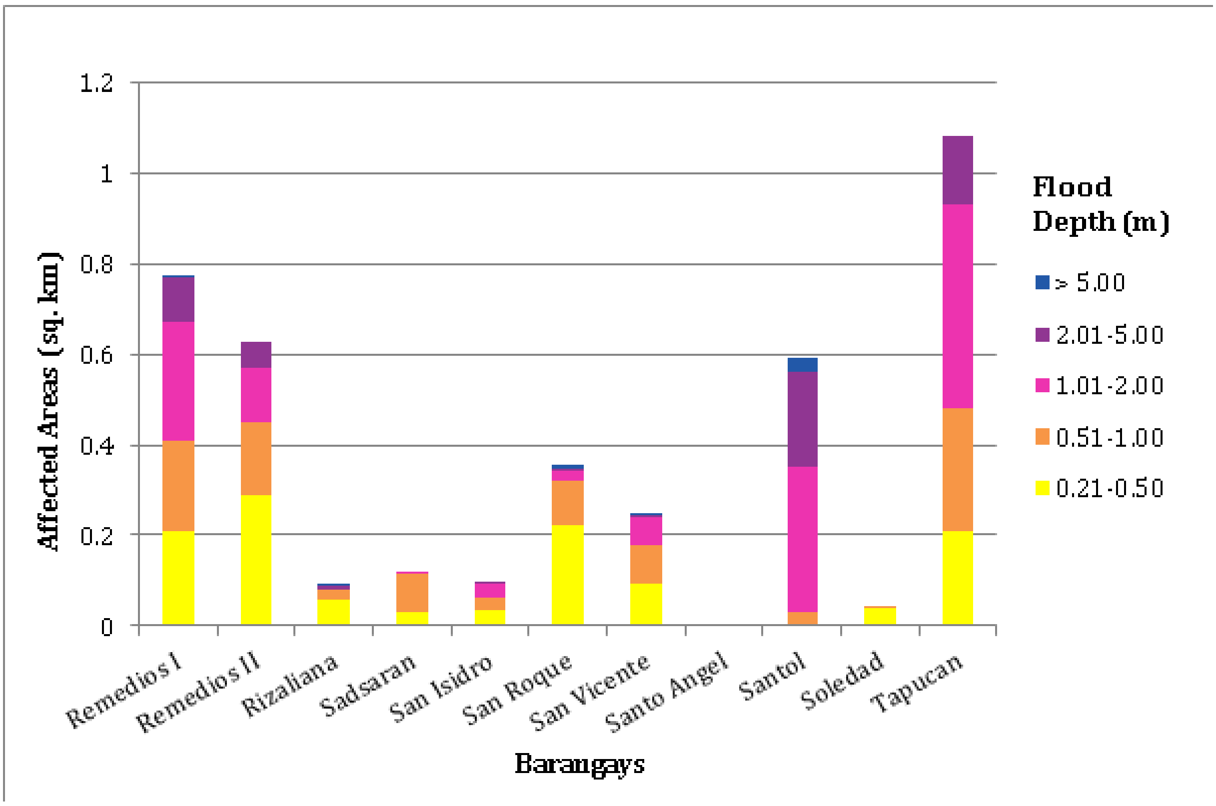


Figure 64. Affected Areas in Mauban, Quezon during 5-Year Rainfall Return Period.

For the 5-year return period, 31.41% of the municipality of Sampaloc with an area of 93.05 sq. km. will experience flood levels of less than 0.20 meters. 1.63% of the area will experience flood levels of 0.21 to 0.50 meters while 0.97%, 1.14%, 1.94%, and 0.85% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Sampaloc, Quezon during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sampaloc (in sq. km)					
	Alupay	Banot	Bataan	Bayongon	Bilucao	Caldong
0.03-0.20	1.67	0.81	2.1	0.97	0.37	4.85
0.21-0.50	0.088	0.036	0.071	0.066	0.065	0.2
0.51-1.00	0.075	0.07	0.035	0.03	0.043	0.13
1.01-2.00	0.076	0.21	0.053	0.022	0.14	0.068
2.01-5.00	0.36	0.44	0.069	0.037	0.11	0.016
> 5.00	0.27	0.084	0.12	0.019	0.025	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sampaloc (in sq. km)					
	Ibabang Owain	Ilayang Owain	Mamala	San Bueno	San Isidro	San Roque	Taquico
0.03-0.20	6.32	2.76	0.003	4.24	0.054	0.13	4.95
0.21-0.50	0.37	0.095	0	0.22	0.043	0.043	0.22
0.51-1.00	0.15	0.044	0	0.17	0.013	0.012	0.13
1.01-2.00	0.14	0.03	0	0.22	0.026	0.011	0.062
2.01-5.00	0.14	0.047	0	0.43	0.1	0.033	0.026
> 5.00	0.021	0.13	0	0.046	0.048	0.024	0

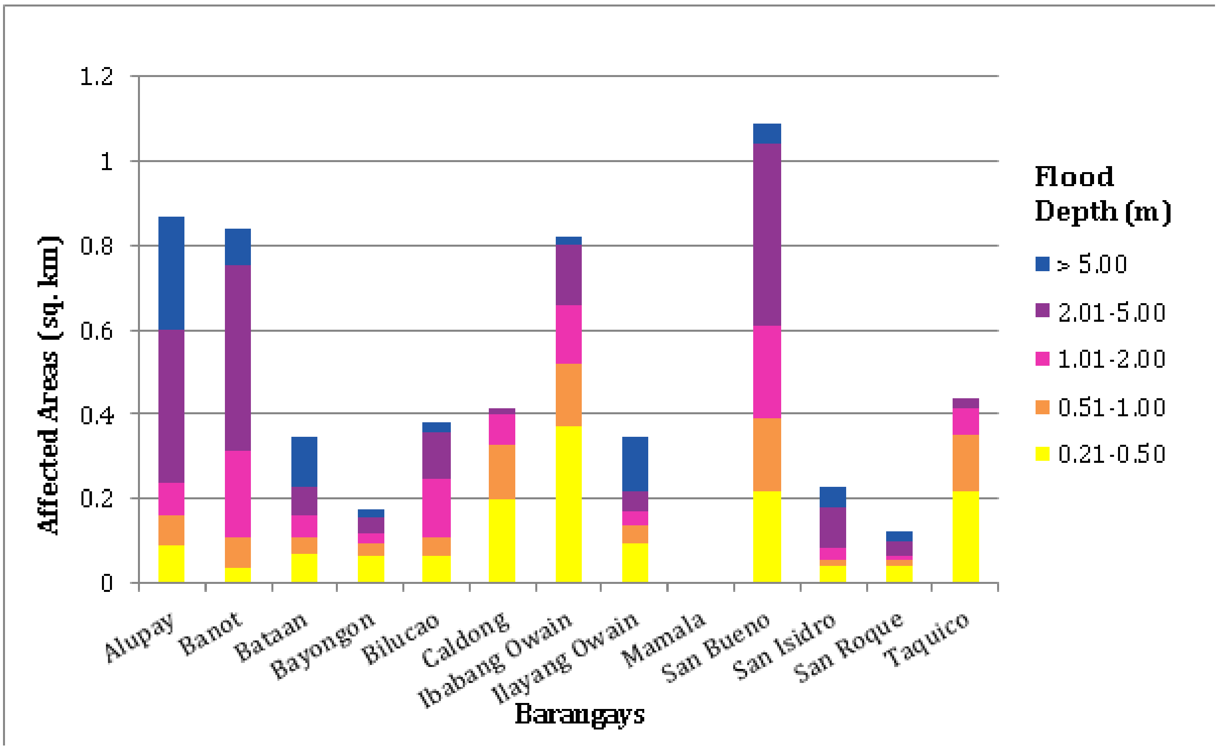


Figure 65. Affected Areas in Sampaloc, Quezon during 5-Year Rainfall Return Period.

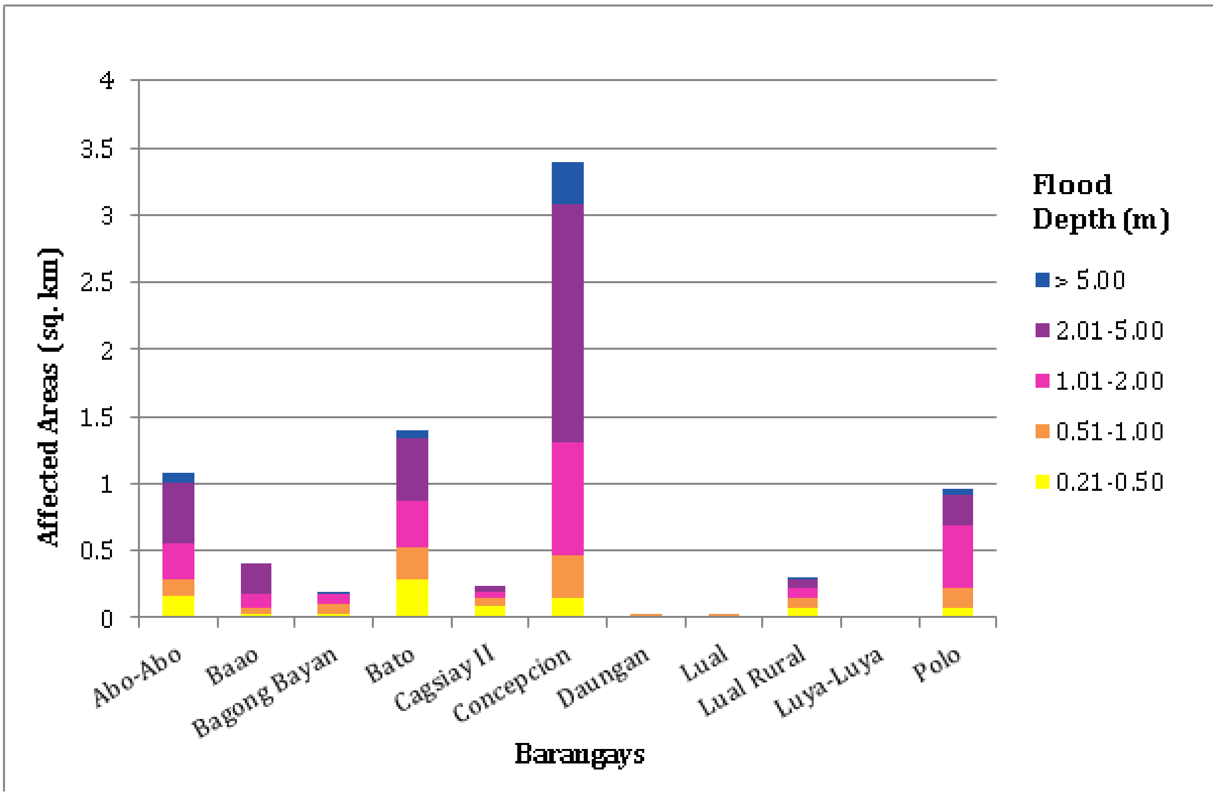
For the 25-year return period, 7.09% of the municipality of Mauban with an area of 430.04 sq. km. will experience flood levels of less than 0.20 meters. 0.47% of the area will experience flood levels of 0.21 to 0.50 meters while 0.48%, 0.81%, 1.04%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Mauban, Quezon during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)						
	Abo-Abo	Baao	Bagong Bayan	Bato	Cagsiay II	Concepcion	Daungan
0.03-0.20	3.95	0.58	0.017	2.14	2.18	1.7	0.085
0.21-0.50	0.16	0.033	0.033	0.29	0.09	0.15	0.01
0.51-1.00	0.13	0.042	0.078	0.23	0.057	0.31	0.00011
1.01-2.00	0.26	0.1	0.073	0.35	0.044	0.85	0
2.01-5.00	0.45	0.23	0.00078	0.46	0.042	1.77	0
> 5.00	0.081	0	0.0022	0.068	0	0.31	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)						
	Lual	Lual Rural	Luya-Luya	Polo	Remedios I	Remedios II	Rizaliana
0.03-0.20	0.095	1.06	0	0.11	2.74	7.22	0.017
0.21-0.50	0.011	0.076	0.0022	0.079	0.19	0.35	0.0069
0.51-1.00	0.0032	0.075	0	0.14	0.16	0.19	0.053
1.01-2.00	0	0.072	0	0.47	0.29	0.14	0.028
2.01-5.00	0	0.058	0	0.22	0.24	0.11	0.003
> 5.00	0	0.025	0	0.054	0.0092	0.0022	0.0098

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)							
	Sadsaran	San Isidro	San Roque	San Vicente	Santo Angel	Santol	Soledad	Tapucan
0.03-0.20	0.06	1.04	3.85	1.97	0.013	0.0021	1.43	0.25
0.21-0.50	0.017	0.035	0.26	0.091	0	0.00055	0.057	0.092
0.51-1.00	0.04	0.024	0.14	0.074	0	0.0013	0.0063	0.29
1.01-2.00	0.091	0.043	0.041	0.095	0	0.054	0.00014	0.49
2.01-5.00	0	0.027	0.01	0.023	0	0.5	0	0.31
> 5.00	0	0	0.0063	0.0041	0	0.034	0	0



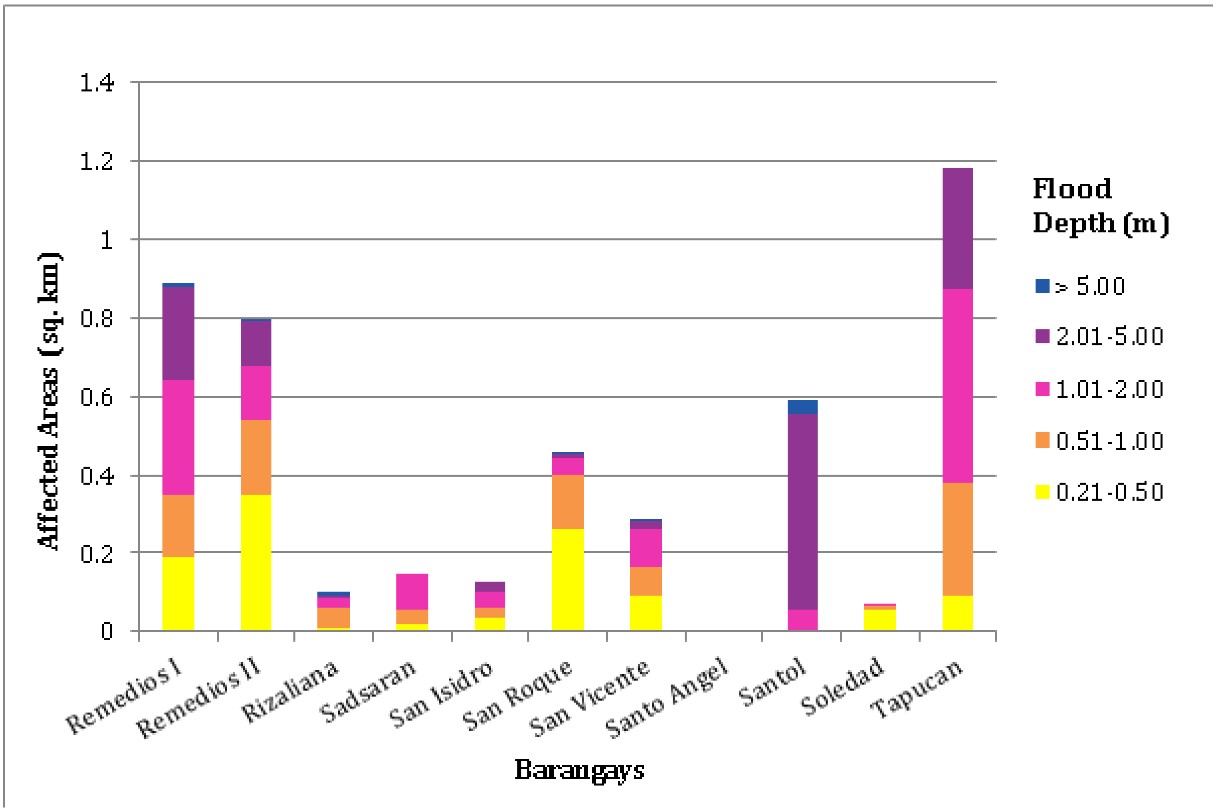


Figure 66. Affected Areas in Mauban, Quezon during 25-Year Rainfall Return Period.

For the 25-year return period, 30.38% of the municipality of Sampaloc with an area of 93.05 sq. km. will experience flood levels of less than 0.20 meters. 1.83% of the area will experience flood levels of 0.21 to 0.50 meters while 1.04%, 0.88%, 2.01%, and 1.78% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Sampaloc, Quezon during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sampaloc (in sq. km)					
	Alupay	Banot	Bataan	Bayongon	Bilucao	Caldong
0.03-0.20	1.57	0.77	2	0.93	0.34	4.76
0.21-0.50	0.11	0.03	0.095	0.074	0.06	0.22
0.51-1.00	0.081	0.023	0.04	0.038	0.037	0.15
1.01-2.00	0.089	0.071	0.049	0.022	0.052	0.096
2.01-5.00	0.19	0.52	0.081	0.041	0.2	0.035
> 5.00	0.5	0.23	0.19	0.037	0.055	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sampaloc (in sq. km)						
	Ibabang Owain	Ilayang Owain	Mamala	San Bueno	San Isidro	San Roque	Taquico
0.03-0.20	6.14	2.67	0.0023	4.12	0.033	0.1	4.83
0.21-0.50	0.41	0.14	0.000069	0.24	0.023	0.043	0.26
0.51-1.00	0.21	0.051	8.6E-06	0.15	0.011	0.017	0.16
1.01-2.00	0.092	0.034	0.00019	0.2	0.017	0.015	0.08
2.01-5.00	0.2	0.049	0.00041	0.4	0.069	0.033	0.048
> 5.00	0.092	0.16	0.000036	0.22	0.13	0.041	0.0048

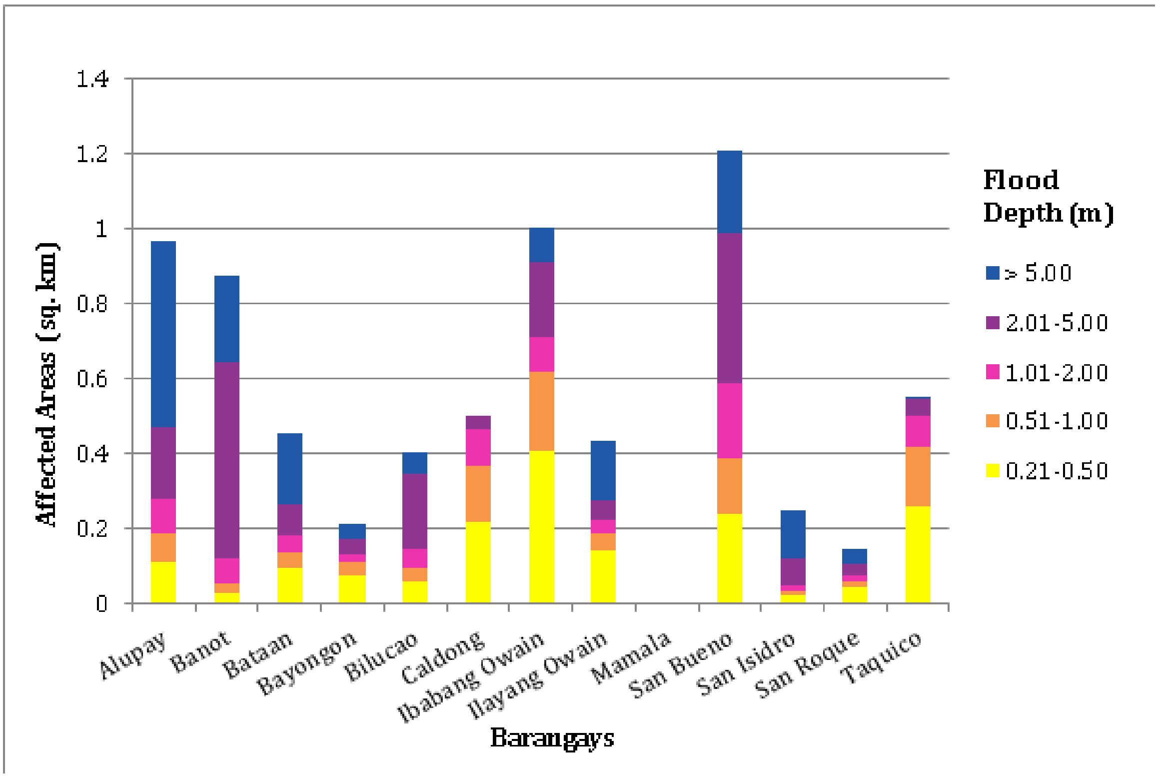


Figure 67. Affected Areas in Sampaloc, Quezon during 25-Year Rainfall Return Period.

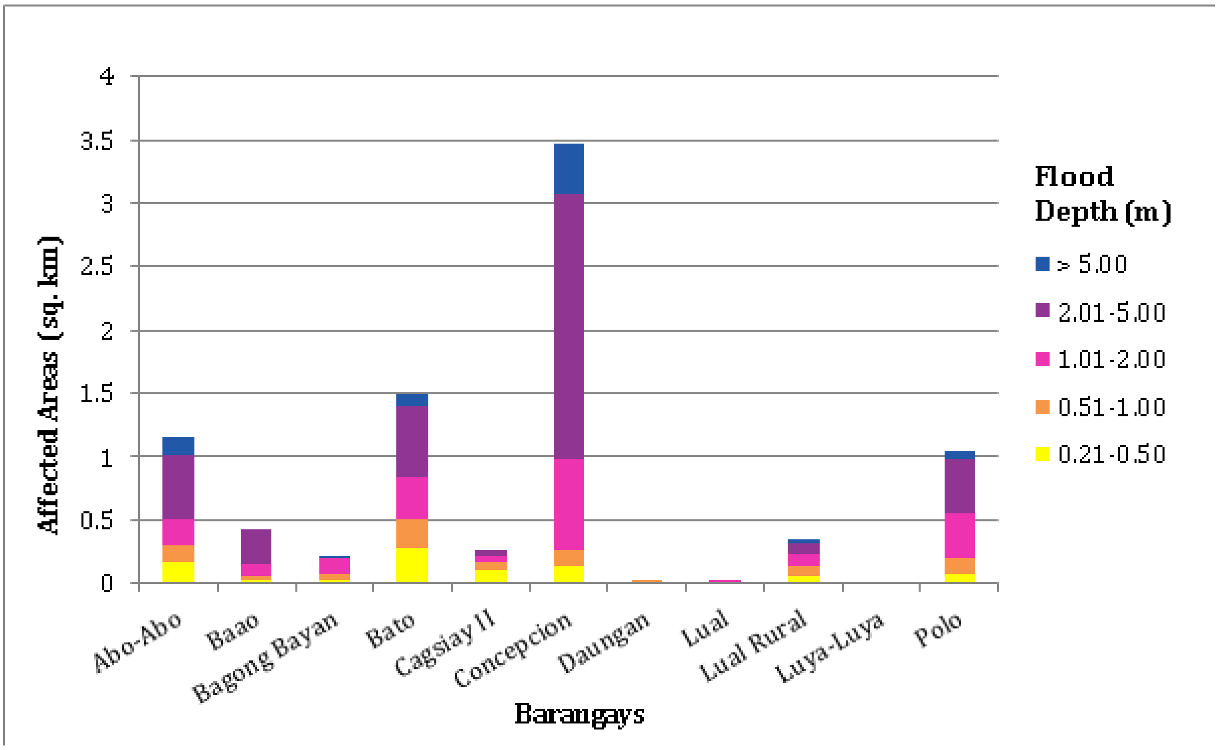
For the 100-year return period, 6.91% of the municipality of Mauban with an area of 430.04 sq. km. will experience flood levels of less than 0.20 meters. 0.48% of the area will experience flood levels of 0.21 to 0.50 meters while 0.39%, 0.77%, 1.29%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Mauban, Quezon during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)						
	Abo-Abo	Baao	Bagong Bayan	Bato	Cagsiay II	Concepcion	Daungan
0.03-0.20	3.89	0.57	0.0058	2.03	2.15	1.62	0.077
0.21-0.50	0.17	0.027	0.022	0.28	0.1	0.14	0.013
0.51-1.00	0.12	0.038	0.046	0.23	0.066	0.13	0.0045
1.01-2.00	0.21	0.082	0.13	0.33	0.05	0.71	0
2.01-5.00	0.52	0.27	0.00078	0.56	0.05	2.09	0
> 5.00	0.13	0	0.0022	0.098	0	0.4	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)						
	Lual	Lual Rural	Luya-Luya	Polo	Remedios I	Remedios II	Rizaliana
0.03-0.20	0.093	1.03	0	0.047	2.67	7.1	0.013
0.21-0.50	0.013	0.058	0.0019	0.072	0.19	0.41	0.0043
0.51-1.00	0.0037	0.077	0.00021	0.13	0.13	0.2	0.0091
1.01-2.00	0.0001	0.099	0	0.35	0.28	0.16	0.078
2.01-5.00	0	0.076	0	0.43	0.34	0.13	0.0018
> 5.00	0	0.028	0	0.061	0.021	0.007	0.011

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mauban (in sq. km)							
	Sadsaran	San Isidro	San Roque	San Vicente	Santo Angel	Santol	Soledad	Tapucan
0.03-0.20	0.038	1.02	3.78	1.94	0.013	0.0014	1.41	0.22
0.21-0.50	0.027	0.035	0.28	0.096	0	0.00034	0.073	0.07
0.51-1.00	0.032	0.024	0.16	0.07	0	0.00086	0.0099	0.19
1.01-2.00	0.11	0.036	0.062	0.079	0	0.0071	0.00044	0.54
2.01-5.00	0	0.049	0.013	0.064	0	0.54	0	0.4
> 5.00	0	0	0.0075	0.0052	0	0.035	0	0



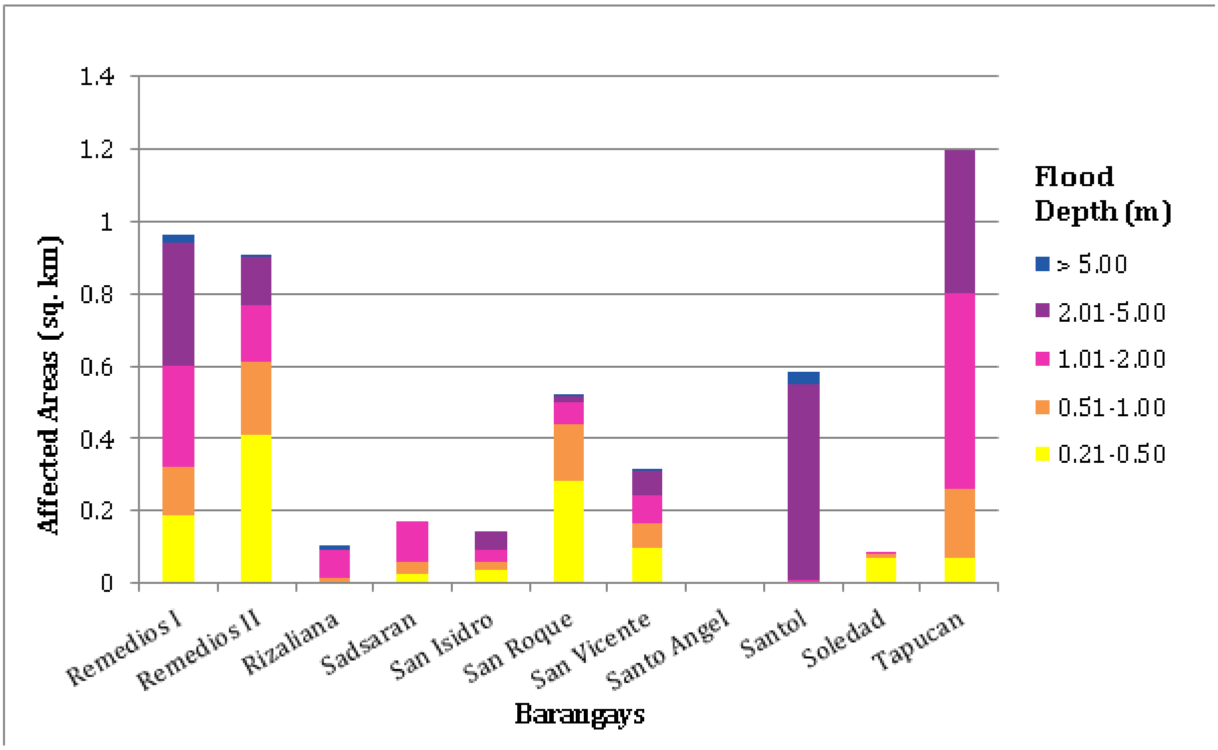


Figure 68. Affected Areas in Mauban, Quezon during 100-Year Rainfall Return Period.

For the 100-year return period, 29.70% of the municipality of Sampaloc with an area of 93.05 sq. km. will experience flood levels of less than 0.20 meters. 1.98% of the area will experience flood levels of 0.21 to 0.50 meters while 1.11%, 0.84%, 1.58%, and 2.68% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Sampaloc, Quezon during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sampaloc (in sq. km)					
	Alupay	Banot	Bataan	Bayongon	Bilucao	Caldong
0.03-0.20	1.51	0.74	1.94	0.91	0.33	4.69
0.21-0.50	0.12	0.032	0.11	0.072	0.05	0.24
0.51-1.00	0.086	0.024	0.046	0.045	0.04	0.16
1.01-2.00	0.096	0.031	0.041	0.029	0.035	0.11
2.01-5.00	0.11	0.28	0.086	0.032	0.22	0.05
> 5.00	0.62	0.53	0.22	0.054	0.075	0.0001

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sampaloc (in sq. km)						
	Ibabang Owain	Ilayang Owain	Mamala	San Bueno	San Isidro	San Roque	Taquico
0.03-0.20	6.01	2.62	0.002	4.03	0.026	0.082	4.75
0.21-0.50	0.43	0.16	0.00003	0.29	0.015	0.033	0.29
0.51-1.00	0.24	0.053	0.0001	0.14	0.0051	0.024	0.17
1.01-2.00	0.11	0.039	0	0.15	0.011	0.021	0.11
2.01-5.00	0.19	0.053	0.00042	0.32	0.049	0.034	0.05
> 5.00	0.16	0.18	0.00044	0.4	0.18	0.057	0.018

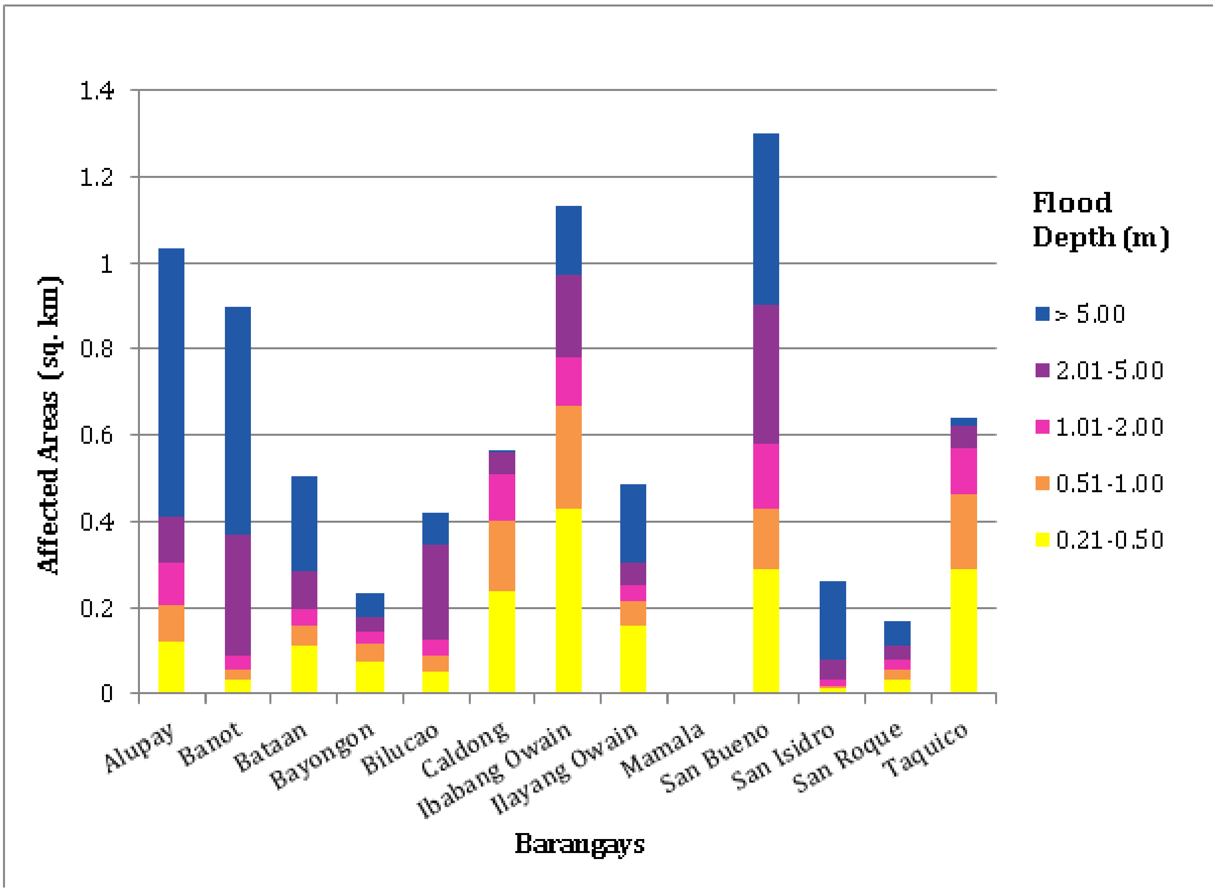


Figure 69. 5 Affected Areas in Sampaloc, Quezon during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Mauban in Quezon, Remedios II is projected to have the highest percentage of area that will experience flood levels at 1.86%. Meanwhile, Concepcion posted the second highest percentage of area that may be affected by flood depths at 1.18%.

Among the barangays in the municipality of Sampaloc in Quezon, Ibabang Owain is projected to have the highest percentage of area that will experience flood levels at 1.66%. Meanwhile, Taquico posted the second highest percentage of area that may be affected by flood depths at 1.25%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 70.

The flood validation consists of 160 points randomly selected all over the Maapon floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.22 m. Table 36 shows a contingency matrix of the comparison.

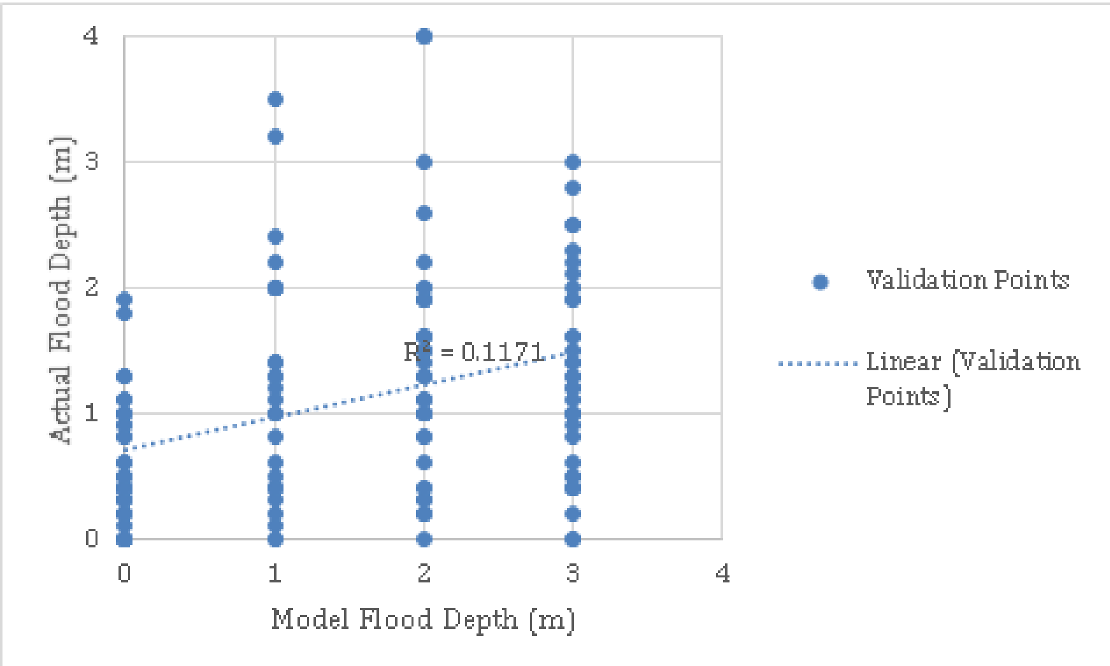


Figure 70. Model flood depth vs Actual flood depth.

Table 36. Actual Flood Depth vs Simulated Flood Depth in Maapon.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	13	0	4	4	3	0	24
0.21-0.50	17	0	7	4	6	0	34
0.51-1.00	11	0	5	9	8	0	33
1.01-2.00	6	0	12	21	13	0	52
2.01-5.00	0	0	4	6	7	0	17
> 5.00	0	0	0	0	0	0	0
Total	47	0	32	44	37	0	160

The overall accuracy generated by the flood model is estimated at 28.75% with 46 points correctly matching the actual flood depths. In addition, there were 64 points estimated one level above and below the correct flood depths while there were 31 points and 19 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 56 points were underestimated in the modelled flood depths of Maapon.

Table 37. Summary of Accuracy Assessment in Maapon River Basin Survey

	No. of Points	%
Correct	46	28.75
Overestimated	58	36.25
Underestimated	56	35.00
Total	160	100.00

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification

PEGASUS SENSOR

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

ALS-80 SENSOR

Parameter	Specification
Operational altitude	100 to 3500 m max AGL
Maximum measurement rate	1000 kHz
Maximum scan rate	200 Hz for sine; 158 for triangle;120 for raster
Field of view (degrees, full angle, user-adjustable)	0 to 72
Roll Stabilization (automatic adaptive, degrees)	72 – active FOV
Number of returns	unlimited
Number of intensity measurements	3(first, second and third)
Data Storage	ALS80: removable SSD hard disk (800GB each volume)
Power Consumption	922 W @ 22.0 -30.3 VDC
Dimensions and weight	Scanner:37 W x 68 L x 26 H cm; 47 kg; Control Electronics: 45 W x 47 D x 25 H cm; 33 kg
Operating temperature	0-40˚C

Annex 2. NAMRIA Certificate of Reference Points Used in the LiDAR Survey

1. QZN-21

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

February 13, 2014

CERTIFICATION

To whom it may concern:

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

Province: **QUEZON**
Station Name: **QZN-21**
Order: **2nd**

Island: **LUZON**
Municipality: **TIAONG**
Barangay: **POBLACION III**

		PRS92 Coordinates			
Latitude:	**13° 57' 44.31576"**	Longitude:	**121° 19' 27.34822"**	Ellipsoidal Hgt:	**51.25800 m.**
		WGS84 Coordinates			
Latitude:	**13° 57' 39.07397"**	Longitude:	**121° 19' 32.29499"**	Ellipsoidal Hgt:	**97.38200 m.**
		PTM Coordinates			
Northing:	**1544027.063 m.**	Easting:	**535036.042 m.**	Zone:	**3**
		UTM Coordinates			
Northing:	**1,544,101.56**	Easting:	**318,981.12**	Zone:	**51**

Location Description

QZN-21
From Tiaong Municipal Hall, travel along the highway going to Lucena, then turn left to Dia St. until reaching Paaralang Elementarya ng Silangang Tiaong. Station is located on the open ground of the said school, 30 m. NE from the entrance gate. It is approx. 21 m. WNW from the NW corner post in front of the stage and 13.4 m. ESE from the concrete wall of the school. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. concrete monument flushed on the ground, with inscriptions "QZN-21 2006 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8795355 A**
T.N.: **2014-320**

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

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

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

2. LAG-20

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **LAGUNA**	
	Station Name: **LAG-20**	
Island: **LUZON**	Order: **3rd**	Barangay: **POBLACION**
Municipality: **LOS BAÑOS**		
	PRS92 Coordinates	
Latitude: **14° 9' 53.86904"**	Longitude: **121° 14' 20.35180"**	Ellipsoidal Hgt: **39.91400 m.**
	WGS84 Coordinates	
Latitude: **14° 9' 48.57270"**	Longitude: **121° 14' 25.28172"**	Ellipsoidal Hgt: **85.26600 m.**
	PTM Coordinates	
Northing: **1566435.481 m.**	Easting: **525799.268 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,566,588.99**	Easting: **309,934.22**	Zone: **51**

Location Description

LAG-20
Is located inside the UP Los Baños compound 25 m. NW from the Umali Hall building along Sanggumay Rd.; at the center of a concrete pavement, 0.7 m. from the edge of the stairs. Mark is a 2 mm. dia. brass rod centered on a 0.13 m. x 0.13 m. cement putty with inscription "LAG-20 NAMRIA 2000"

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-199**

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

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

Annex 3. Baseline Processing Report

LAG-20D

Vector Components (Mark to Mark)

From:	LAG-20				
Grid		Local		Global	
Easting	309934.222 m	Latitude	N14°09'53.86923"	Latitude	N14°09'48.57270"
Northing	1566588.991 m	Longitude	E121°14'20.35184"	Longitude	E121°14'25.28172"
Elevation	39.976 m	Height	39.914 m	Height	85.266 m

To:	LAG-20D				
Grid		Local		Global	
Easting	309932.197 m	Latitude	N14°09'53.95582"	Latitude	N14°09'48.65929"
Northing	1566591.667 m	Longitude	E121°14'20.28364"	Longitude	E121°14'25.21352"
Elevation	39.990 m	Height	39.929 m	Height	85.281 m

Vector					
ΔEasting	-2.025 m	NS Fwd Azimuth	322°27'32"	ΔX	2.079 m
ΔNorthing	2.677 m	Ellipsoid Dist.	3.356 m	ΔY	0.516 m
ΔElevation	0.015 m	ΔHeight	0.015 m	ΔZ	2.584 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'26"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000004804		
Y	-0.0000002580	0.0000005806	
Z	-0.0000000914	0.0000001643	0.0000001374

MARVILLE-A

Vector Components (Mark to Mark)

From:	QZN-32 (TOPCON B) 1_WLC8				
Grid		Local		Global	
Easting	384187.230 m	Latitude	N14°00'07.34537"	Latitude	N14°00'02.14350"
Northing	1548118.700 m	Longitude	E121°55'39.46140"	Longitude	E121°55'44.40130"
Elevation	6.444 m	Height	6.782 m	Height	54.270 m

To:	MARVILLE-A (TOPCON A) 1_ECQW				
Grid		Local		Global	
Easting	352607.681 m	Latitude	N13°57'11.82908"	Latitude	N13°57'06.61488"
Northing	1542888.002 m	Longitude	E121°38'07.97108"	Longitude	E121°38'12.91688"
Elevation	35.965 m	Height	36.198 m	Height	83.108 m

Vector					
ΔEasting	-31579.549 m	NS Fwd Azimuth	260°20'10"	ΔX	26124.886 m
ΔNorthing	-5230.698 m	Ellipsoid Dist.	32015.727 m	ΔY	17753.009 m
ΔElevation	29.520 m	ΔHeight	29.416 m	ΔZ	-5227.927 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.008 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.011 m
σ ΔElevation	0.014 m	σ ΔHeight	0.014 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000631159		
Y	-0.0000776526	0.0001236507	
Z	-0.0000260348	0.0000374091	0.0000145992

MARVILLE-B

Vector Components (Mark to Mark)

From:	MARVILLE-A (TOPCON A) 1_ECQW				
Grid		Local		Global	
Easting	352607.681 m	Latitude	N13°57'11.82908"	Latitude	N13°57'06.61488"
Northing	1542888.002 m	Longitude	E121°38'07.97108"	Longitude	E121°38'12.91688"
Elevation	35.975 m	Height	36.208 m	Height	83.118 m

To:	MARVILLE-B (TOPCON B) 1_WLC8				
Grid		Local		Global	
Easting	352601.816 m	Latitude	N13°57'12.48851"	Latitude	N13°57'07.27426"
Northing	1542908.298 m	Longitude	E121°38'07.77177"	Longitude	E121°38'12.71755"
Elevation	36.719 m	Height	36.952 m	Height	83.861 m

Vector					
ΔEasting	-5.865 m	NS Fwd Azimuth	343°33'10"	ΔX	7.278 m
ΔNorthing	20.296 m	Ellipsoid Dist.	21.130 m	ΔY	-0.408 m
ΔElevation	0.744 m	ΔHeight	0.744 m	ΔZ	19.846 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'18"	σ ΔX	0.003 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.004 m
σ ΔElevation	0.004 m	σ ΔHeight	0.004 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000070743		
Y	-0.0000056030	0.0000128477	
Z	-0.0000016188	0.0000032567	0.0000039406

Occupations

	From	To
Point ID:	MARVILLE-A (TOPCON A) 1_ECQW	MARVILLE-B (TOPCON B) 1_WLC8
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\Quezon Base \MARVILLE-A (TOPCON A) 1.410M [01-21-17].17O	C:\Users\Windows User\Documents \Business Center - HCE\Quezon Base \MARVILLE-B (TOPCON B) 1.320M [01-21-17].17O
Receiver type:	GPR1	GPR1
Receiver serial number:	U034ESOECQW	U06AIR0WLC8
Antenna type:	CR.G5	CR.G5
Antenna serial number:	-Unknown-	-Unknown-
Antenna height (measured):	1.410 m	1.320 m
Antenna method:	Bottom of antenna mount	Bottom of antenna mount

Tracking Summary

Annex 4. The Survey Team

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016	ENGR. GRACE SINADJAN	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	ENGR. RENAN PUNTO	UP-TCAGP
	RA	ROWENA GABUA	UP-TCAGP
	RA	REMEDIOS VILLANUEVA	UP-TCAGP
	RA	MERLIN FERNANDO	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JASMIN DOMINGO	UP-TCAGP
		ENGR. IRO ROXAS	UP-TCAGP
		ENGR. BRYLLE ADAM CASTRO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. BENJIE CARBOLLEDO	PHILIPPINE AIR FORCE (PAF)
		SSG RAYMUND DOMINE	PAF
	Pilot	CAPT. DANTHONY LOGRONIO	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. DEXTER CABUDOL	AAC
		CAPT. MARK TANGONAN	AAC
		CAPT. FRANCO PEPITO	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. Data Transfer Sheet for Maapon Floodplain Flights

DATA TRANSFER SHEET - Calabarzon
28-02-2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2014-02-10	1091	1BLK18W41A	Pegasus	2.17 GB	66.58 KB	8.64 MB	171.94 MB	32.74 GB	256.61 KB	20.23 GB	0 B	10.18 MB	N/A	426 B	0 B	1091	Z:\DAC\RAWDATA\1091P
2014-02-13	1103	1BLK18VWS44A	Pegasus	2.13 GB	604.1 KB	9.23 MB	221.75 MB	0 B	N/A	19.89 GB	0 B	16.63 MB	305 B	429 B	0 B	1103	Z:\DAC\RAWDATA\1103P
2014-02-11	1095	1BLK18U42A	Pegasus	1.17 GB	76.99 KB	9.5 MB	235.93 MB	96.99 MB	1.62 KB	14.94 GB	0 B	11.41 MB	205 B	287 B	0 B	1095	Z:\DAC\RAWDATA\1095P
2014-02-08	1083	1BLK18J39A	Pegasus	1.48 GB	1.25 MB	7.49 MB	198.29 MB	22.62 GB	N/A	16.53 GB	0 B	12.44 MB	180 B	604 B	0 B	1083	Z:\DAC\RAWDATA\1083P
2014-02-04	1067	1BLK18H035A	Pegasus	921.78 MB	912.67 KB	6.39 MB	167.97 MB	11.65 GB	N/A	11.55 GB	0 B	5.03 MB	138 B	383 B	63.3 KB	1067	Z:\DAC\RAWDATA\1067P

Received from

Name R. Punto group
Position RA
Signature

Received by

Name AC Bongat group DPPC
Position SSRS
Signature 2/28/16

15-23

DATA TRANSFER SHEET
CALABARZON 9/7/2015

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	
15-Aug	3299P	1BLK18KS227A	PEGASUS	535	614	5.45	143	na	na	10.4	na	3.73	1KB	1KB	222	NA	Z:\DAC\RAW DATA
26-Aug	3341P	1BLK18AbS238A	PEGASUS	1.49	NA	10.1	240	na	na	16.1	na	7.02	1KB	1KB	69	NA	Z:\DAC\RAW DATA
26-Aug	3343P	1BLK18AcS238B	PEGASUS	1.84	NA	9.44	214	na	na	17.9	na	5.96	1KB	1KB	59	NA	Z:\DAC\RAW DATA
27-Aug	3345P	1BLK18TS239A	PEGASUS	2.5	NA	7.11	177	na	na	22.5	na	5.99	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
27-Aug	3347P	1BLK18TS239B	PEGASUS	0.99	NA	6.27	152	na	na	9.85	na	4.13	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
29-Aug	3353P	1BLK18QRS241A	PEGASUS	1.91	NA	10.3	246	na	na	18.8	na	7.19	1KB	1KB	87.1	NA	Z:\DAC\RAW DATA
1-Sep	3365P	1BLK18BCS244A	PEGASUS	1.92	NA	8.57	192	na	na	18.2	na	8.61	1KB	1KB	41	NA	Z:\DAC\RAW DATA
2-Sep	3369P	1BLK18CS245A	PEGASUS	1.34	NA	7.43	154	na	na	13.5	na	35	1KB	1KB	54	NA	Z:\DAC\RAW DATA

Received from

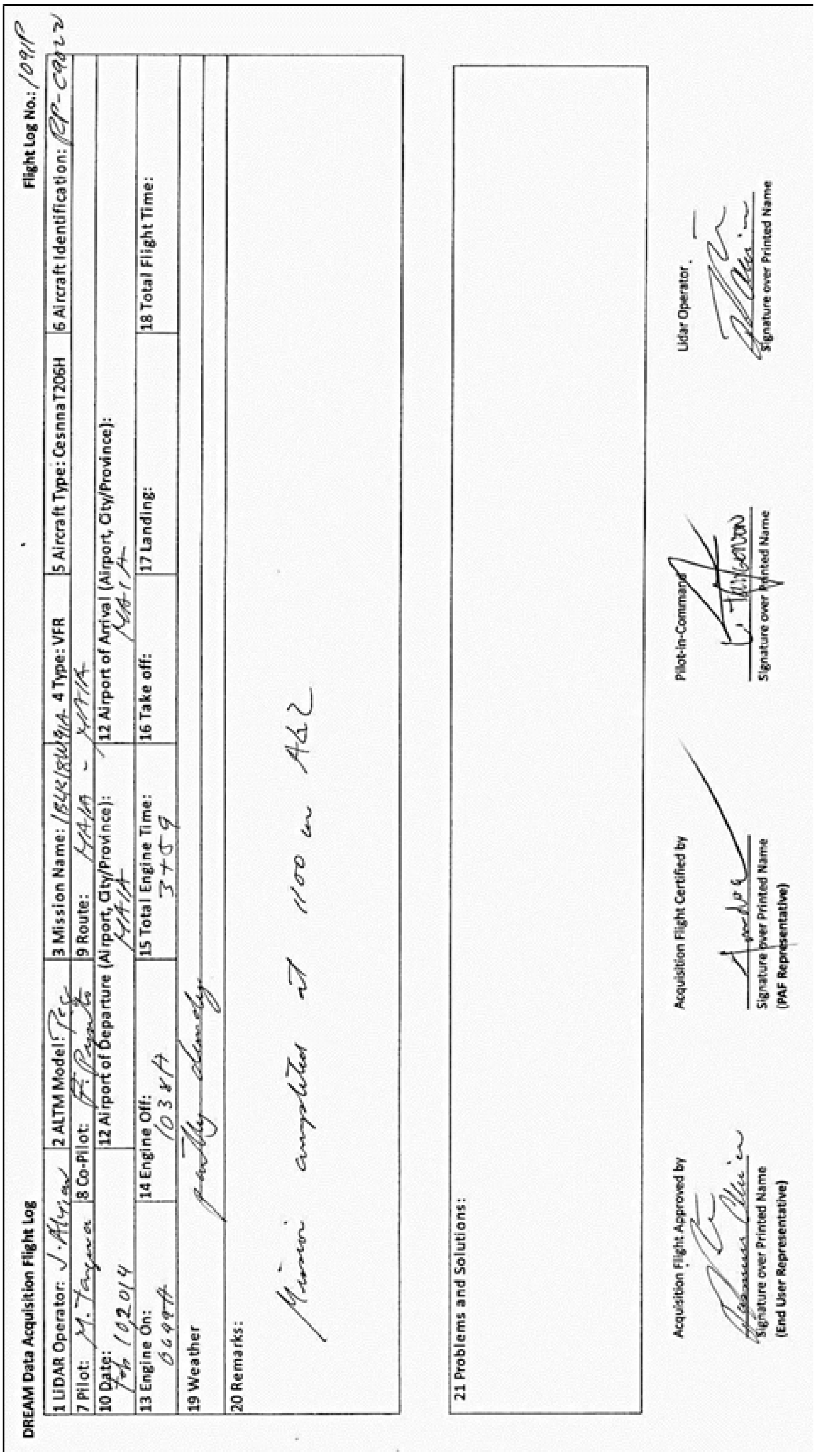
Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRA
Signature 9/8/15

Annex 6. Flight Logs

Flight log for 1091P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1091P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18W41A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. Tangonan	8 Co-Pilot: F. Pagente	9 Route: MAIA - MAIA			
10 Date: Feb 10 2014	12 Airport of Departure (Airport, City/Province): MAIA		12 Airport of Arrival (Airport, City/Province): MAIA		
13 Engine On: 0649H	14 Engine Off: 1034H	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Mission completed at 1100 m AGL

21 Problems and Solutions:

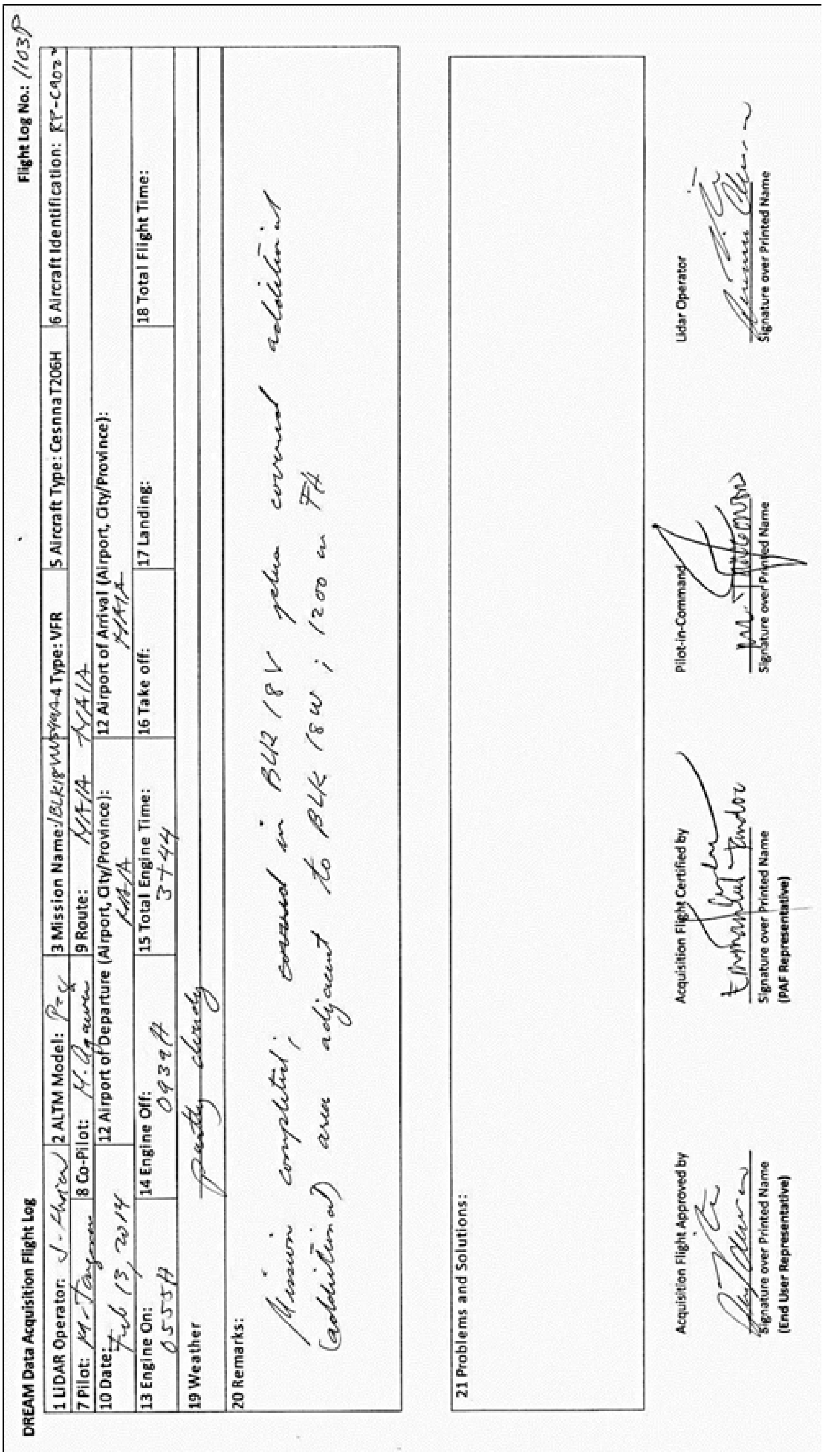
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight log for 1103P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1103P

1 LiDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK18VWS44A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. Tangonan	8 Co-Pilot: M. Agawin	9 Route: NAIA NAIA			
10 Date: Feb 13, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0555H	14 Engine Off: 0939H	15 Total Engine Time: 3+44	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Mission completed; covered in BLK 18V plus covered additional (additional) area adjacent to BLK 18W; 1200 m FH

21 Problems and Solutions:

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

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

Pilot-in-Command
M. Tangonan
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Flight Log for 3345P Mission

Data Acquisition Flight Log

Flight Log No.: 3345P

1 LiDAR Operator: LK PARAGAS / K Andaya	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18TS239A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Mooney	9 Route: NAIA - NAIA			
10 Date: AUG. 27, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0622H	14 Engine Off: 0956H	15 Total Engine Time: 3+34	16 Take off: 0627H	17 Landing: 0951H	18 Total Flight Time: 3+24
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
J. Alviar	Lee Jay Punzalan	M.L. Tangonan	K. Andaya	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 10308L Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10308L

1 LiDAR Operator: R. Gabua	2 ALTM Model: Aq 80	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9822
7 Pilot: D. Logronio	8 Co-Pilot: D. Cabudol	9 Route:			
10 Date: Jan 21, 2017	12 Airport of Departure (Airport, City/Province): Lipa Airbase		12 Airport of Arrival (Airport, City/Province): Lipa Airbase		
13 Engine On: 0728H	14 Engine Off: 1103H	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

SUCCESSFULLY ACQUIRED FLIGHT LINES OVER PART OF MAAPON & STA. LUCIA FLOODPLAINS WITH VOIDS DUE TO CLOUDS AND WIND

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
GRACE SINADJAN		DANTHONY O. LOGRONIO	ROWENA GABUA	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status Report

QUEZON

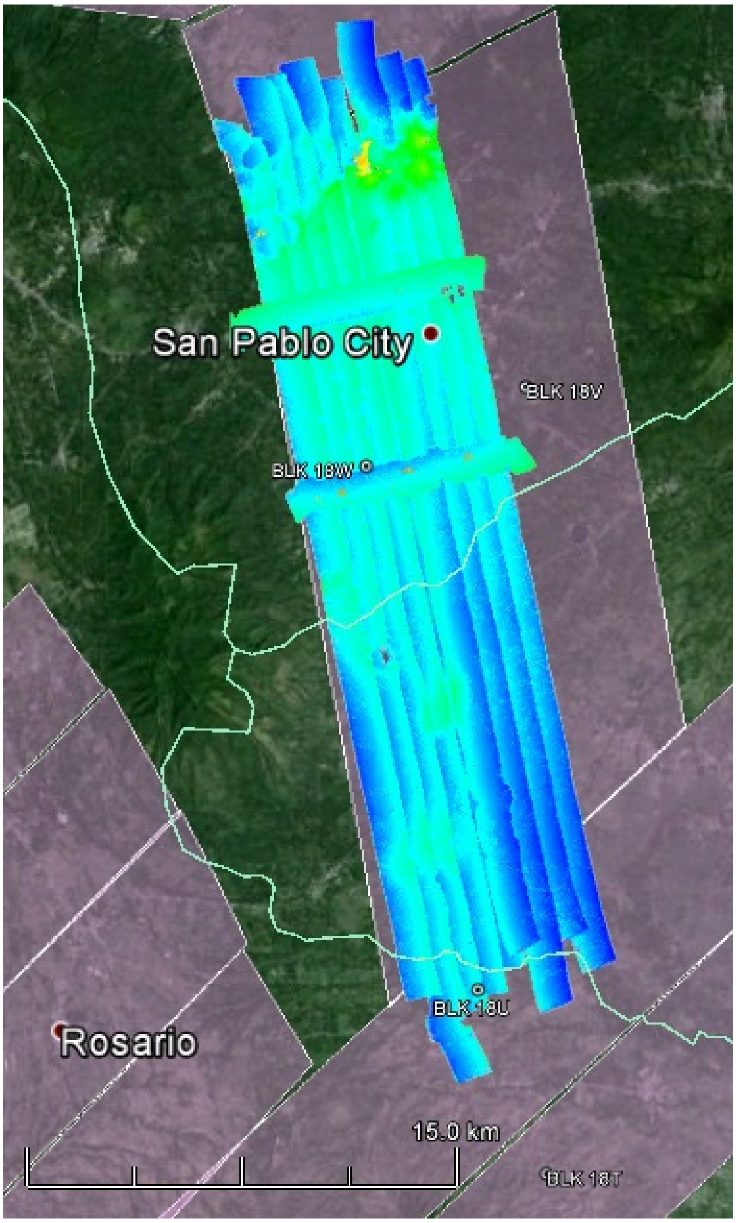
(FEBRUARY 10-13, 2014 ,AUGUST 27, 2015 and JANUARY 21, 2017)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1091P	BLK 18WV	1BLK18W41A	J. Alviar	10 Feb 2014	Mission completed at 1100m AGL
1103P	BLK 18VWS	1BLK18VWS44A	J. Alviar	13 Feb 2014	Mission completed in BLK 18V plus covered additional area adjacent to BLK 18W; 1200m Flying height
3345P	BLK 18TS	1BLK18TS239A	LK PARAGAS	27 Aug 2015	Calibration flight Experienced POSAV error Without Digitizer and Camera
10308L	Maapon and Sta. Lucia, Quezon Province	4BLK26AB21A	R. Gabua/G. Sinadjan	Jan 21, 2017	Successfully acquired flight lines over part of Maapon and Sta. Lucia Floodplains with voids due to clouds and wind

LAS BOUNDARIES PER FLIGHT

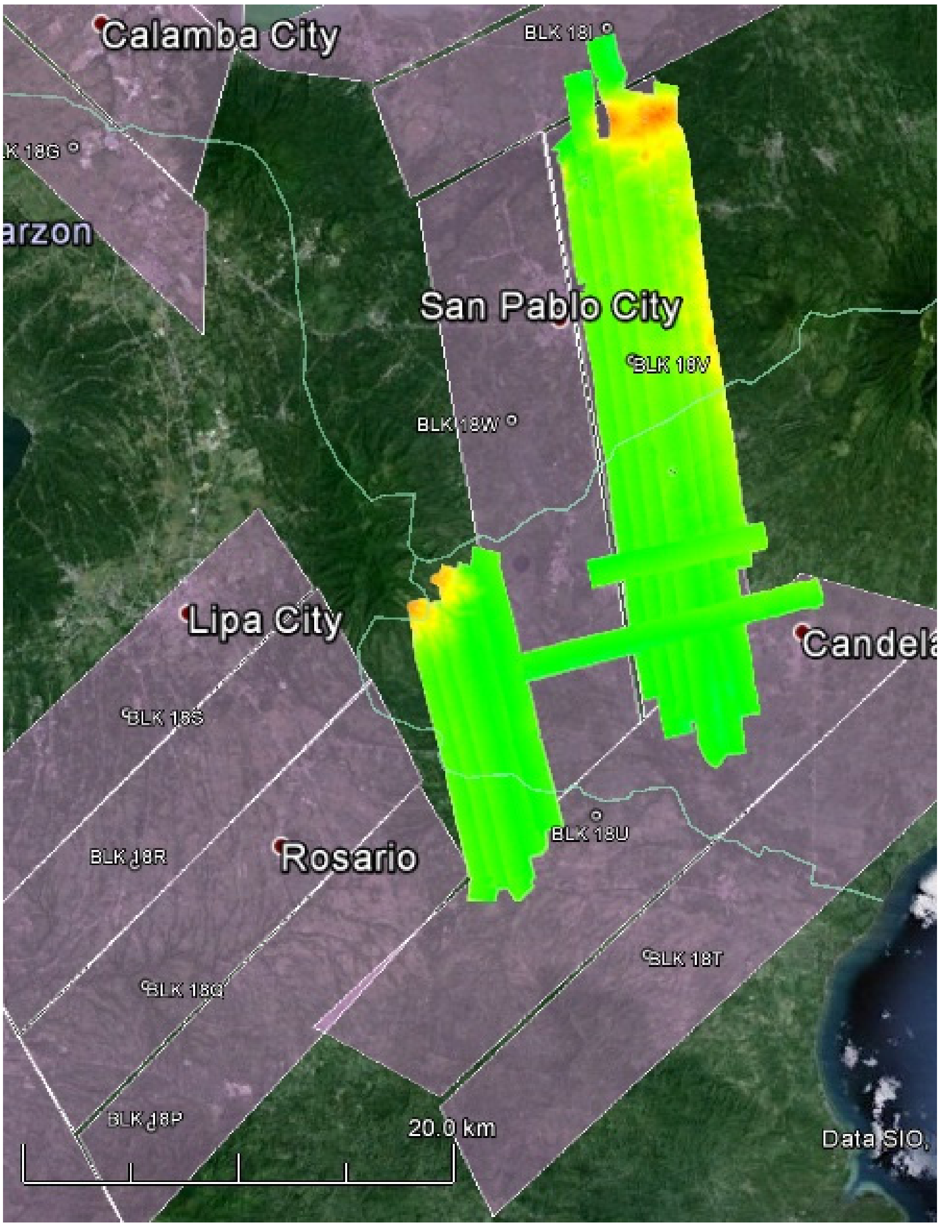
Flight No. : 1091P
Area: BLK 18WV
Mission Name: 1BLK18W41A

LAS



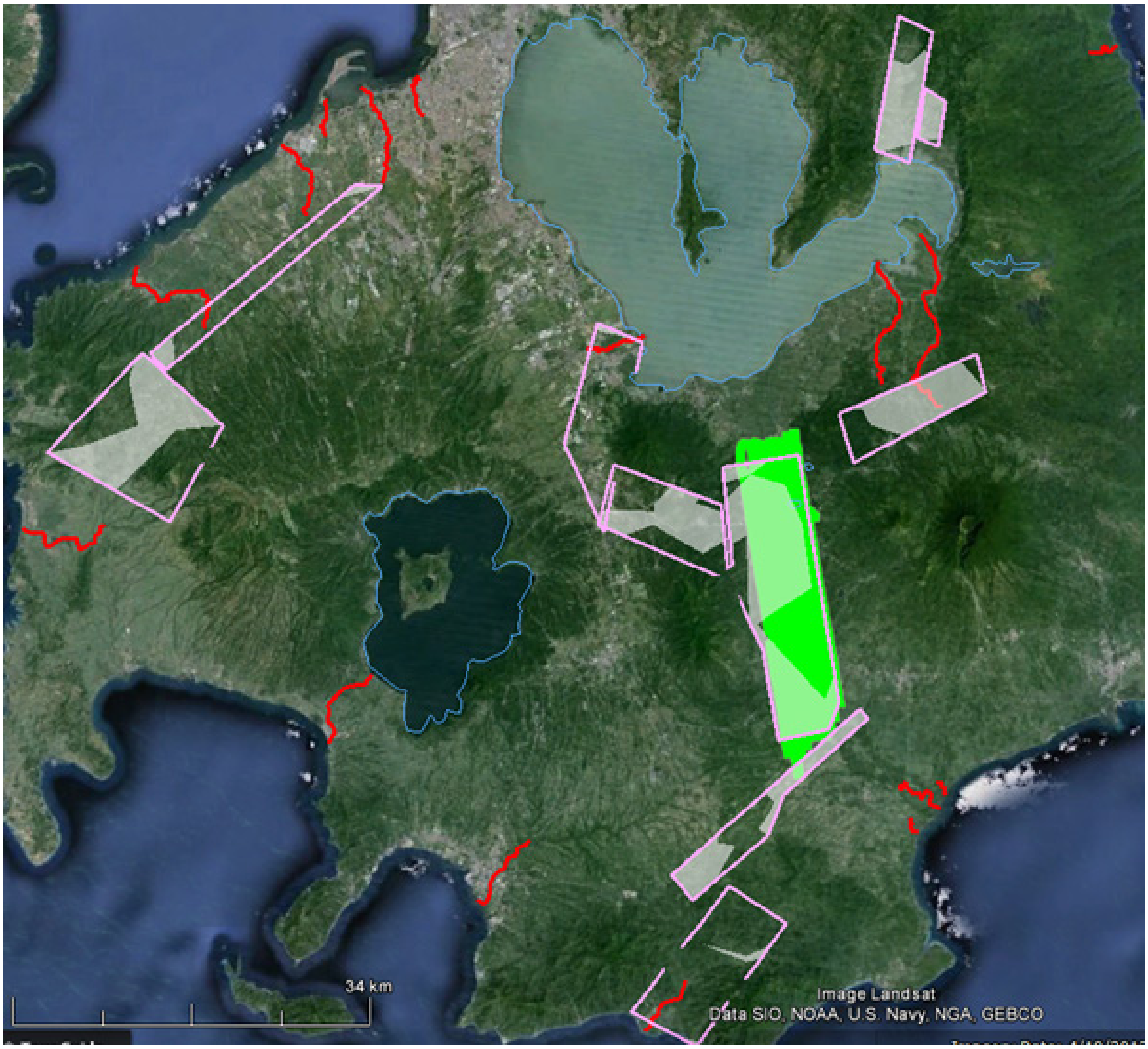
Flight No. : 1103P
Area: BLK 18VWS
Mission Name: 1BLK18VWS44A

LAS



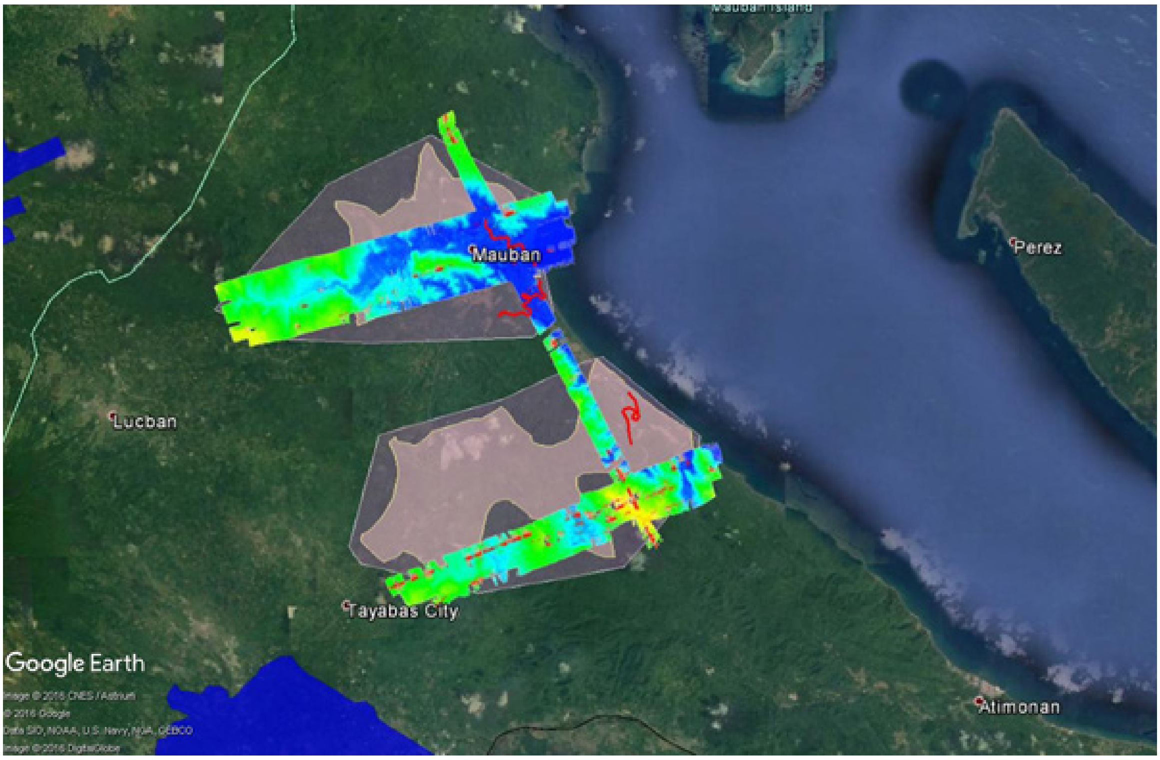
Flight No. : 3345P
Area: BLK 18TS
Mission Name: 1BLK18TS239A
Area: 200.3 sq. km

LAS



Flight No. : 10308L
Area: Maapon and Sta. Lucia FP, Quezon Province (Block 26 A&B)
Mission Name: 4BLK26B24A
Parameters: FOV 50 SIDELAP 30 PULSE IN AIR: 1 FLYING HT. 1000M

LAS/SWATH



Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk18W

Flight Area	CALABARZON
Mission Name	Blk18W
Inclusive Flights	1091P
Range data size	20.2 GB
POS	171 MB
Image	32.7 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000300
IMU attitude correction stdev (<0.001deg)	0.000519
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	44.87%
Ave point cloud density per sq.m. (>2.0)	2.22
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	305
Maximum Height	540.55 m
Minimum Height	53.13 m
Classification (# of points)	
Ground	199,914,206
Low vegetation	203,235,338
Medium vegetation	155,157,978
High vegetation	200,761,579
Building	25,340,833
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

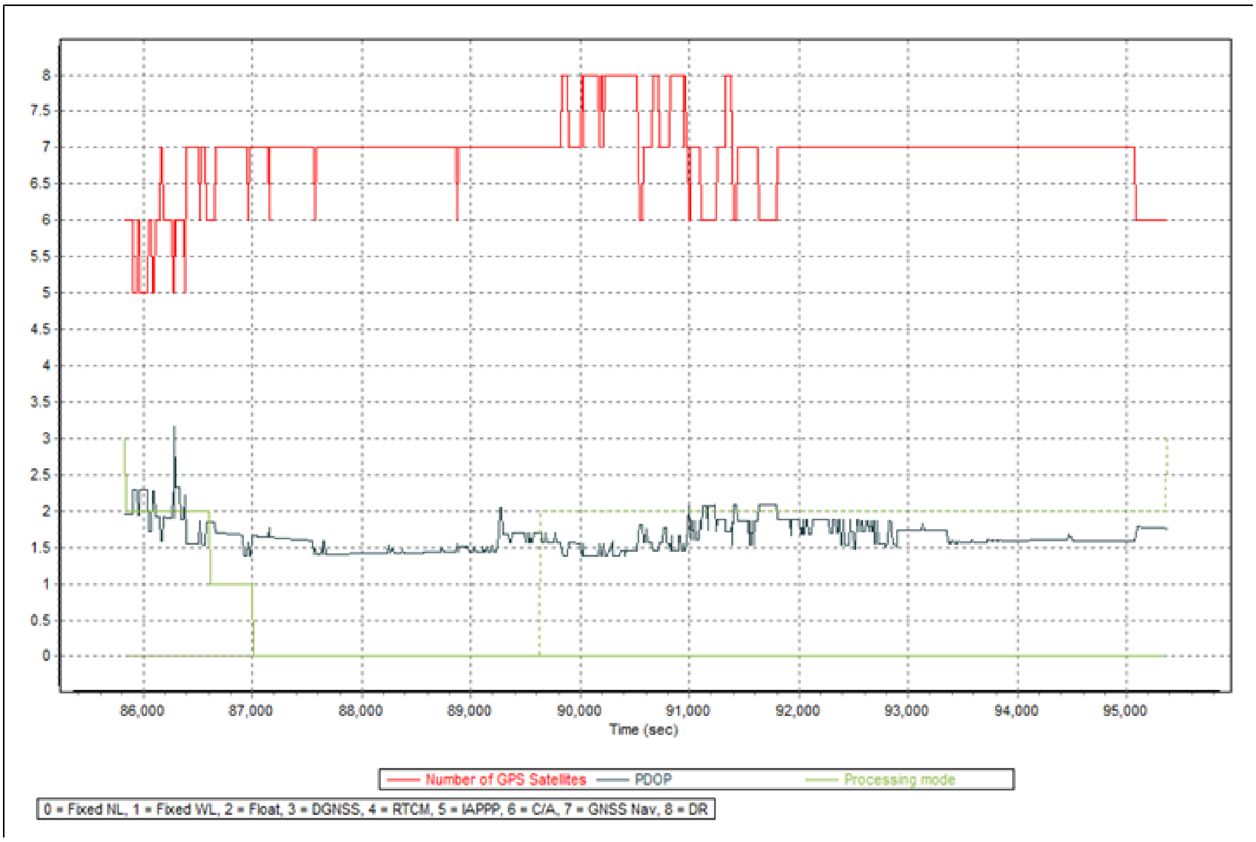


Figure A-8.1. Solution Status

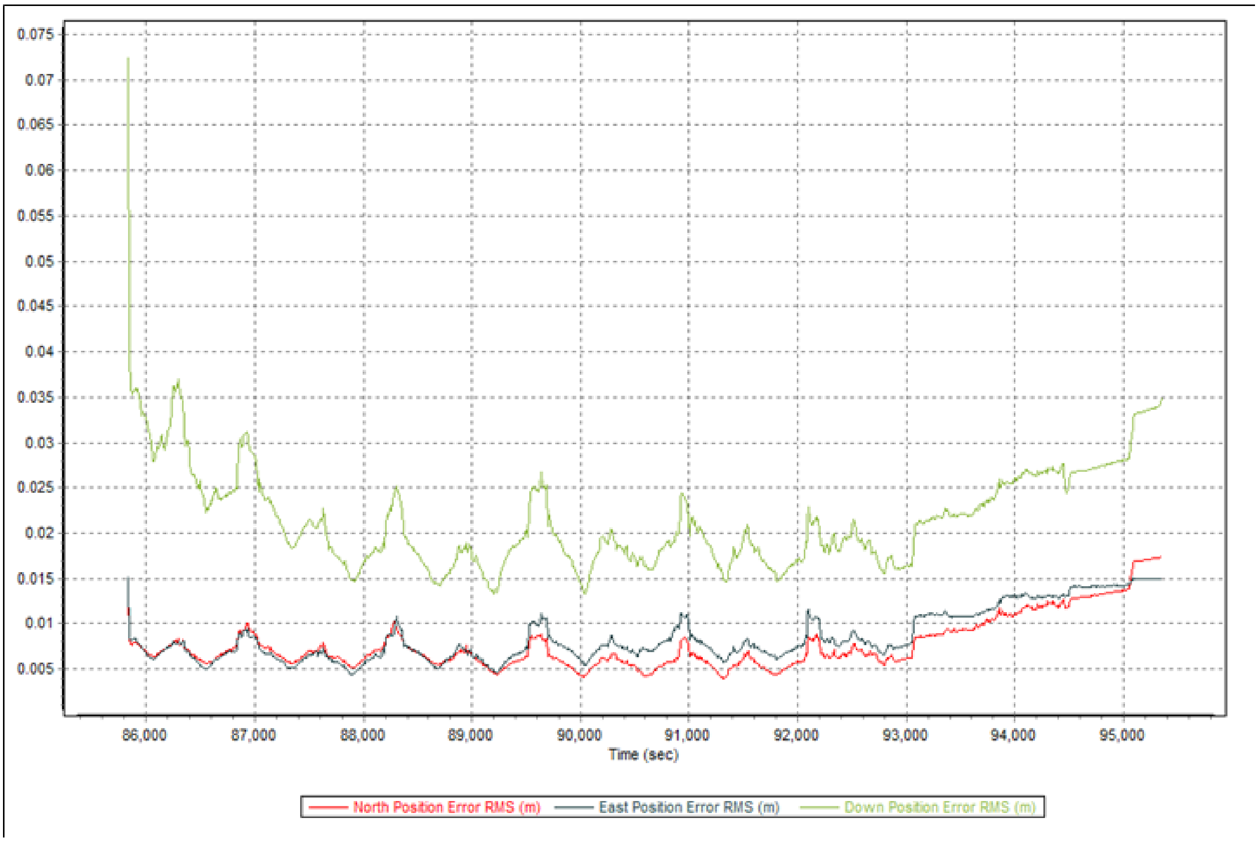


Figure A-8.2. Smoothed Performance Metric Parameters

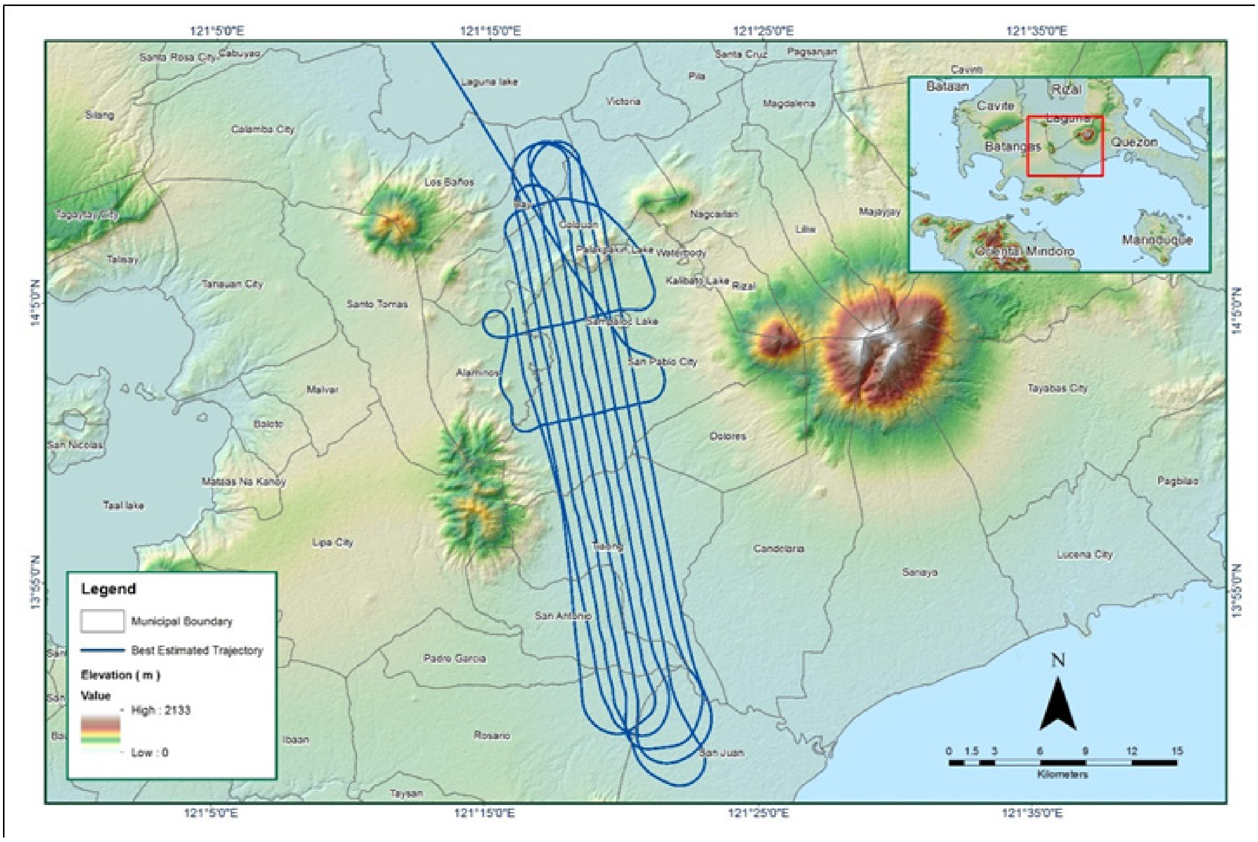


Figure A-8.3. Best Estimated Trajectory

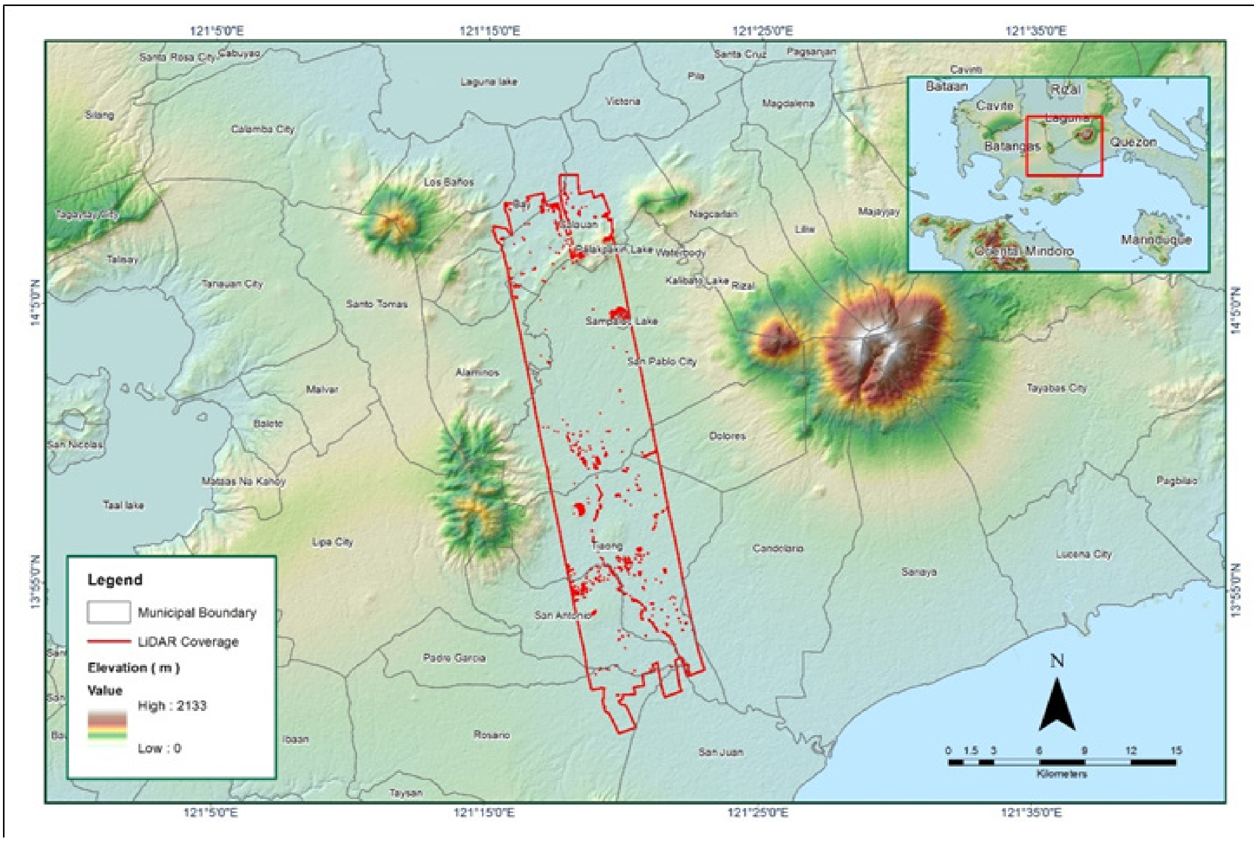


Figure A-8.4. Coverage of LiDAR data

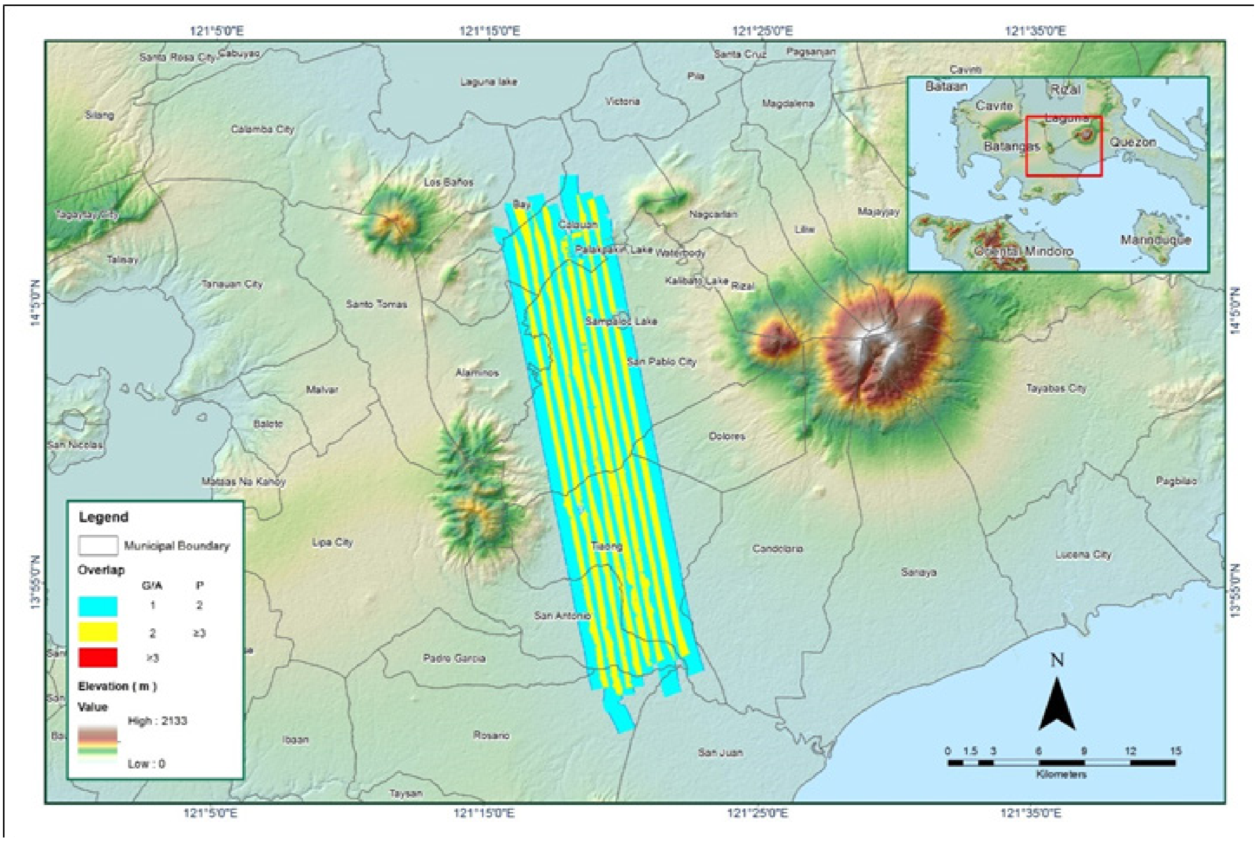


Figure A-8.5. Image of data overlap

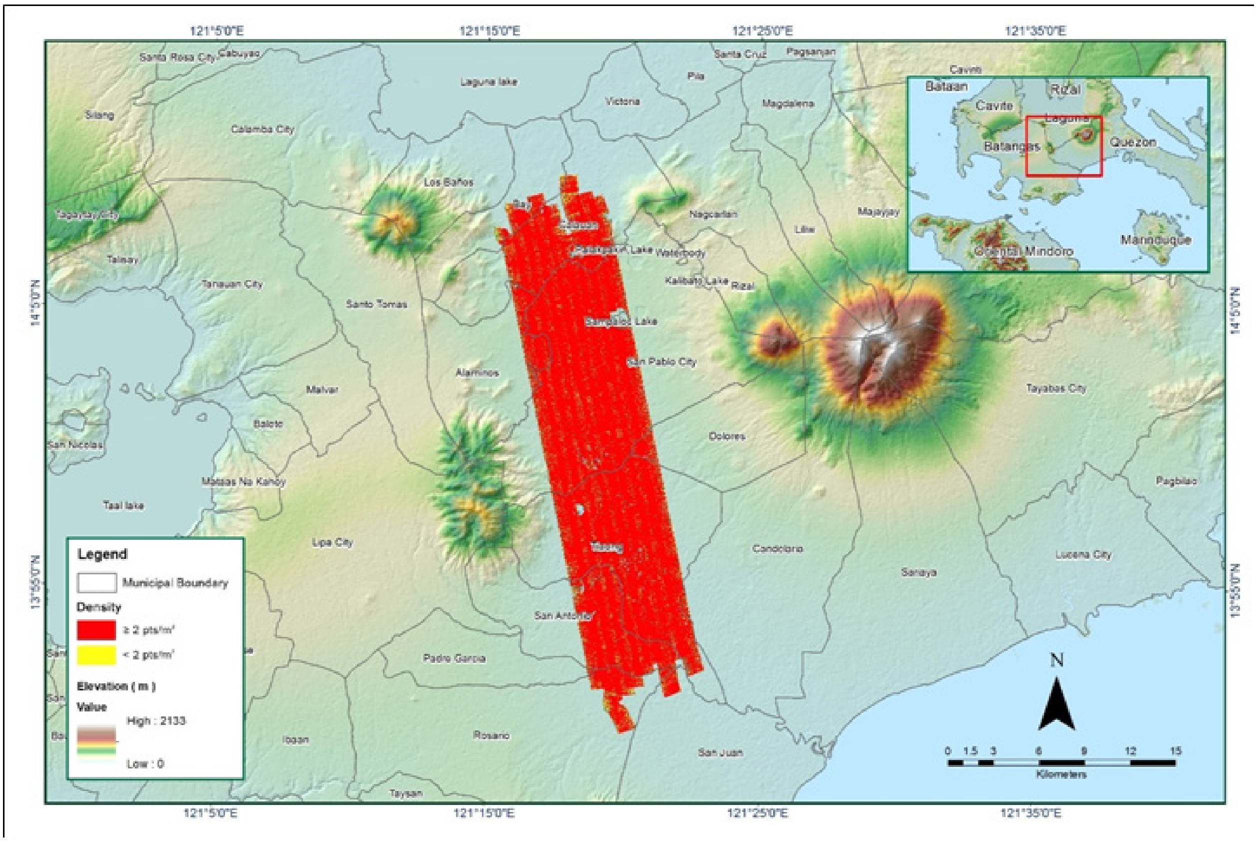


Figure A-8.6. Density map of merged LiDAR data

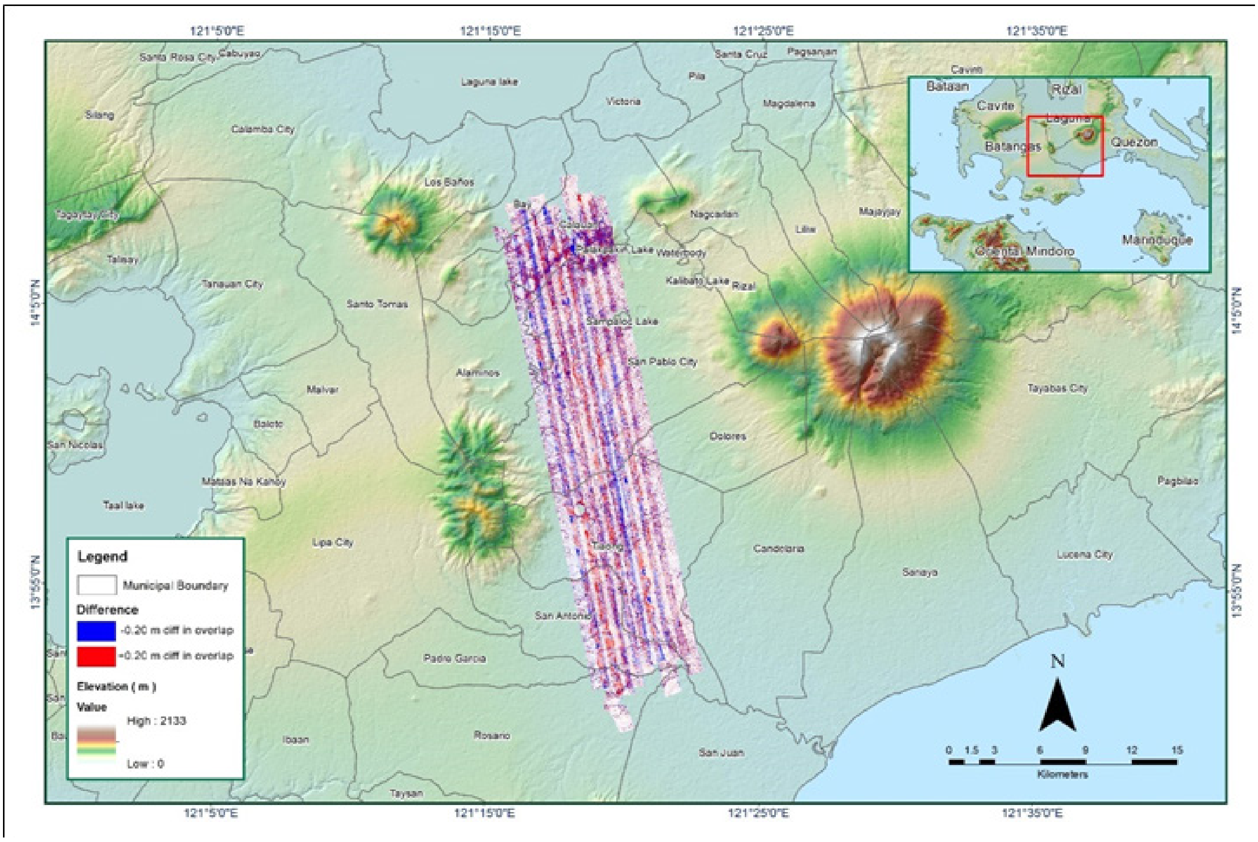


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk18VW_supplement

Flight Area	CALABARZON
Mission Name	Blk18VW_supplement
Inclusive Flights	1103P
Range data size	19.8 GB
POS	221 MB
Image	N/A
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.9
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	5.5
Boresight correction stdev (<0.001deg)	0.000547
IMU attitude correction stdev (<0.001deg)	0.001657
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	34.32%
Ave point cloud density per sq.m. (>2.0)	2.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	305
Maximum Height	712.23 m
Minimum Height	59.56 m
Classification (# of points)	
Ground	171,488,434
Low vegetation	168,868,841
Medium vegetation	161,212,850
High vegetation	246,176,725
Building	12,644,487
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Gladys Mae Apat

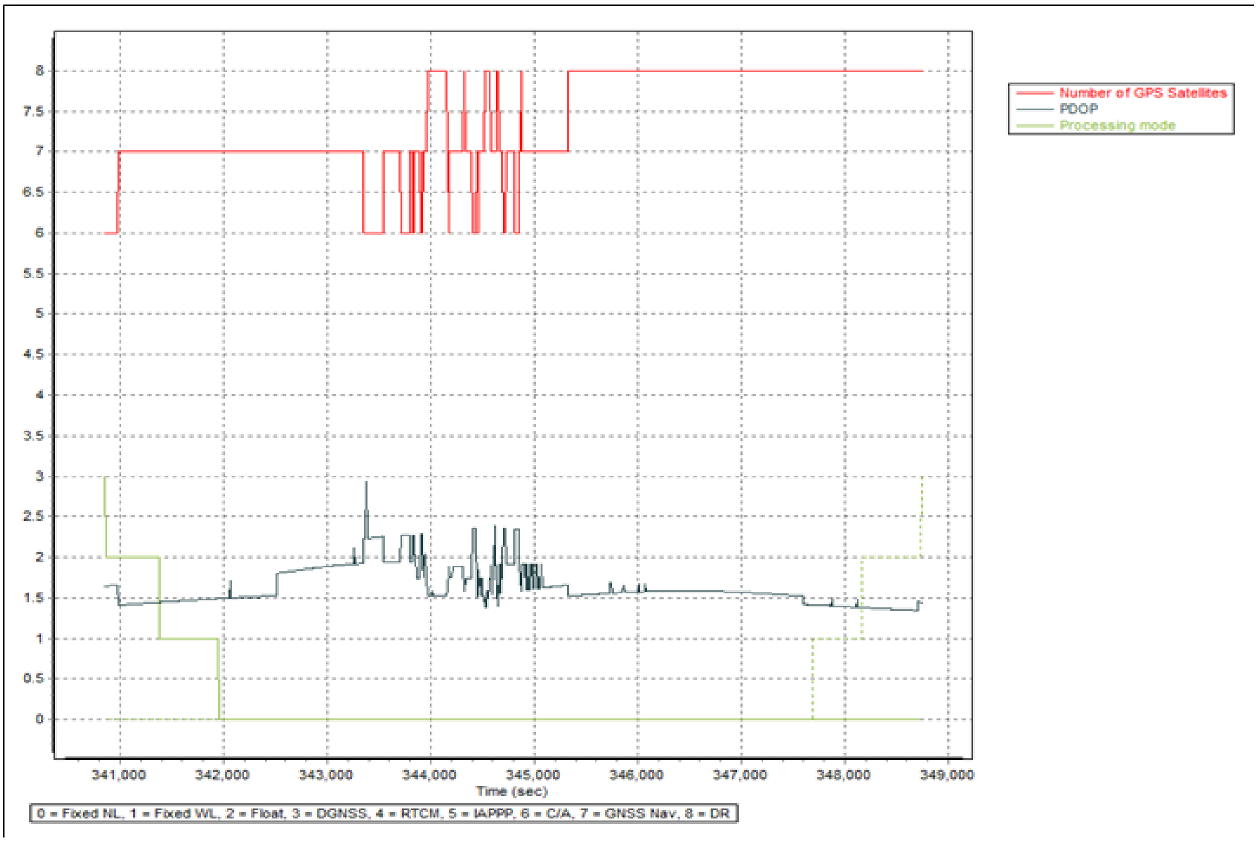


Figure A-8.8. Solution Status

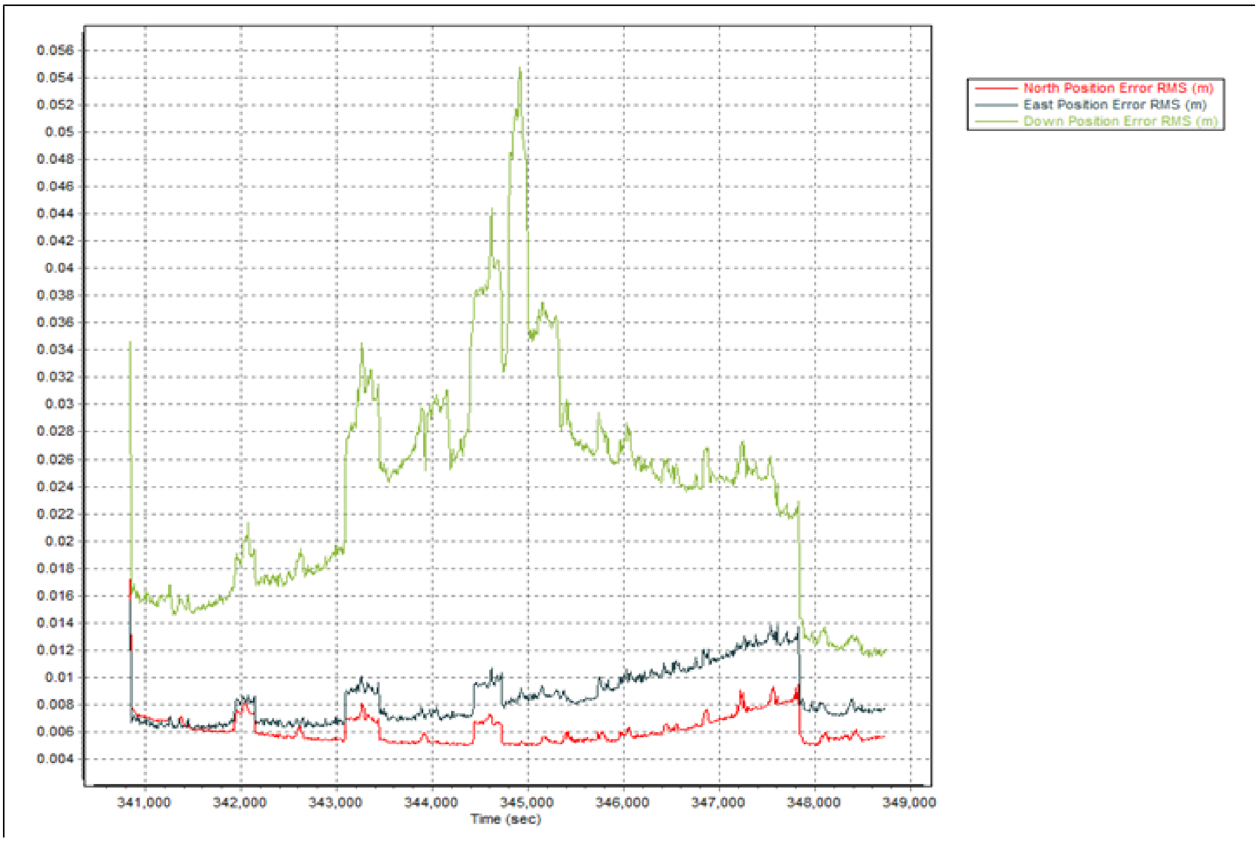


Figure A-8.9. Smoothed Performance Metric Parameters

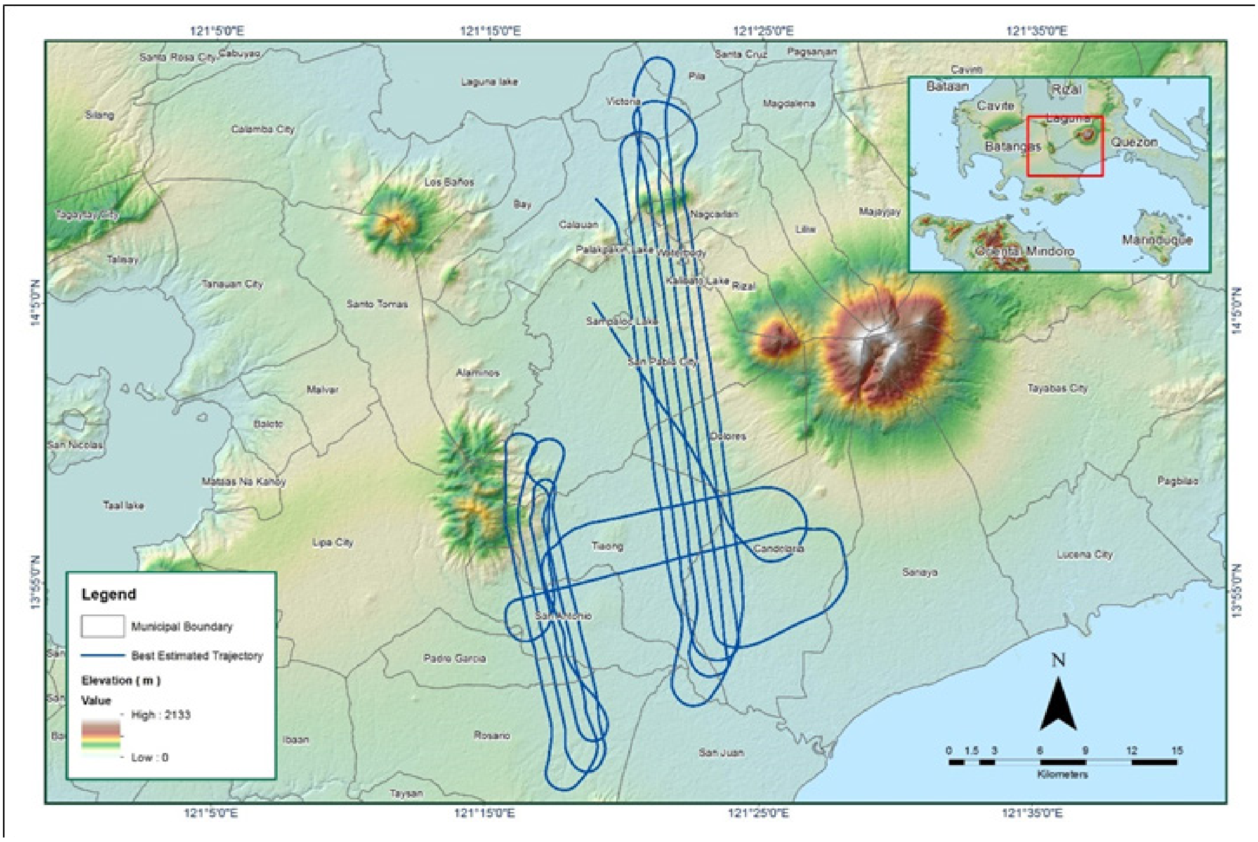


Figure A-8.10. Best Estimated Trajectory

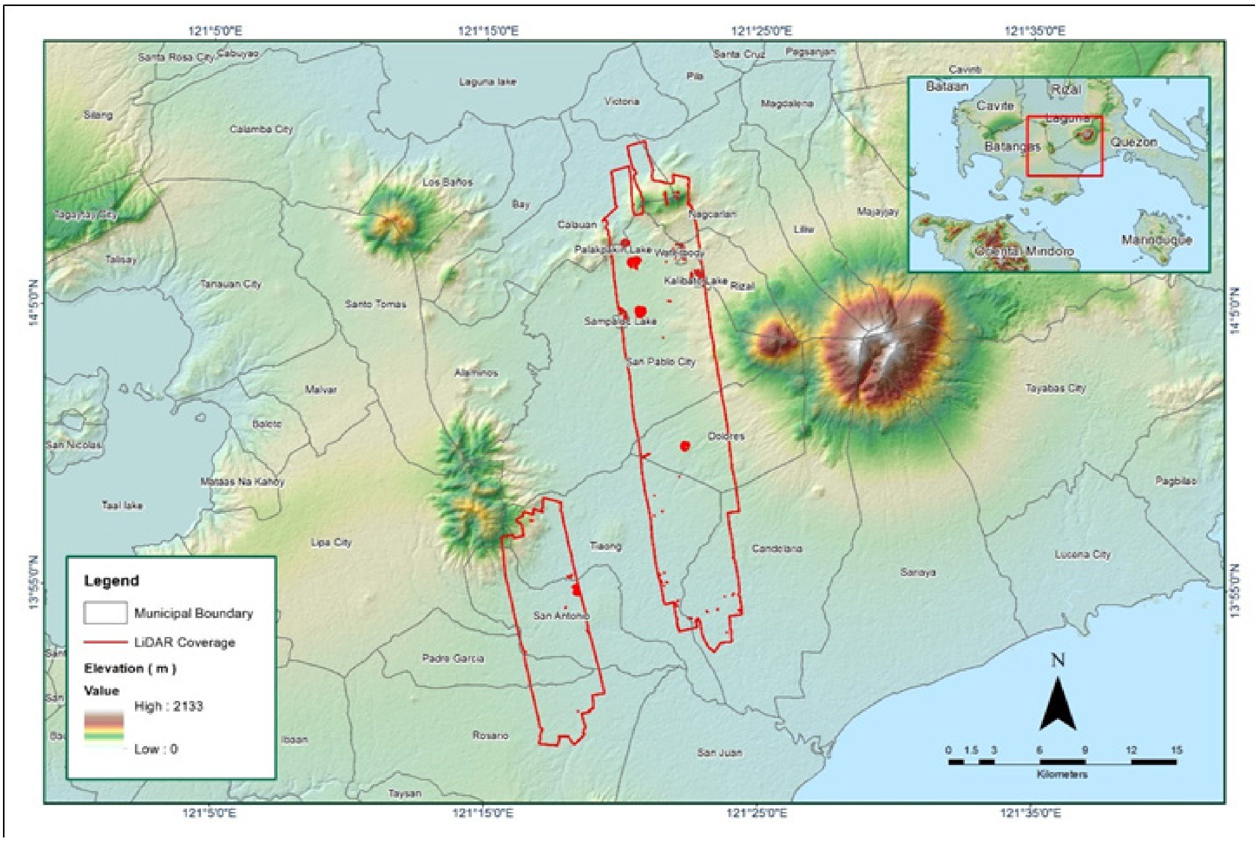


Figure A-8.11. Coverage of LiDAR data

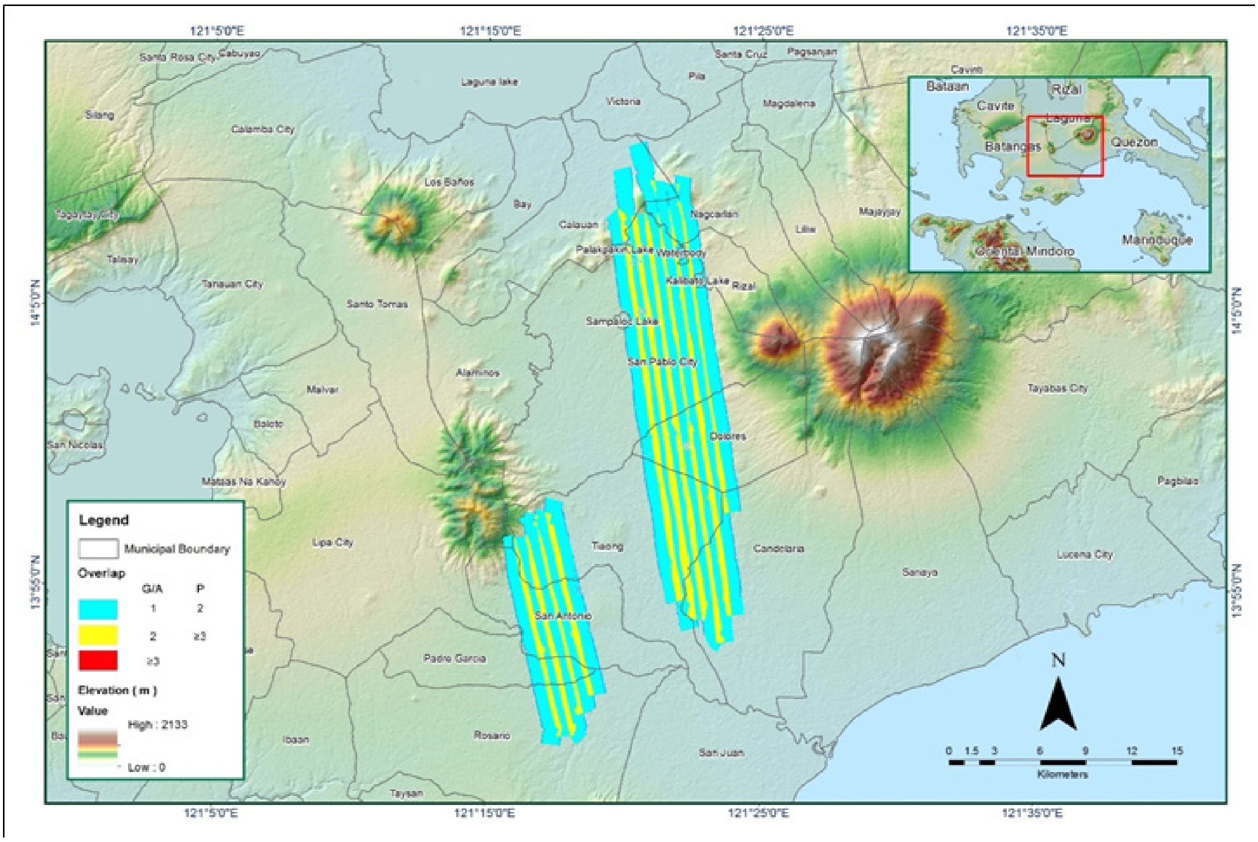


Figure A-8.12. Image of data overlap

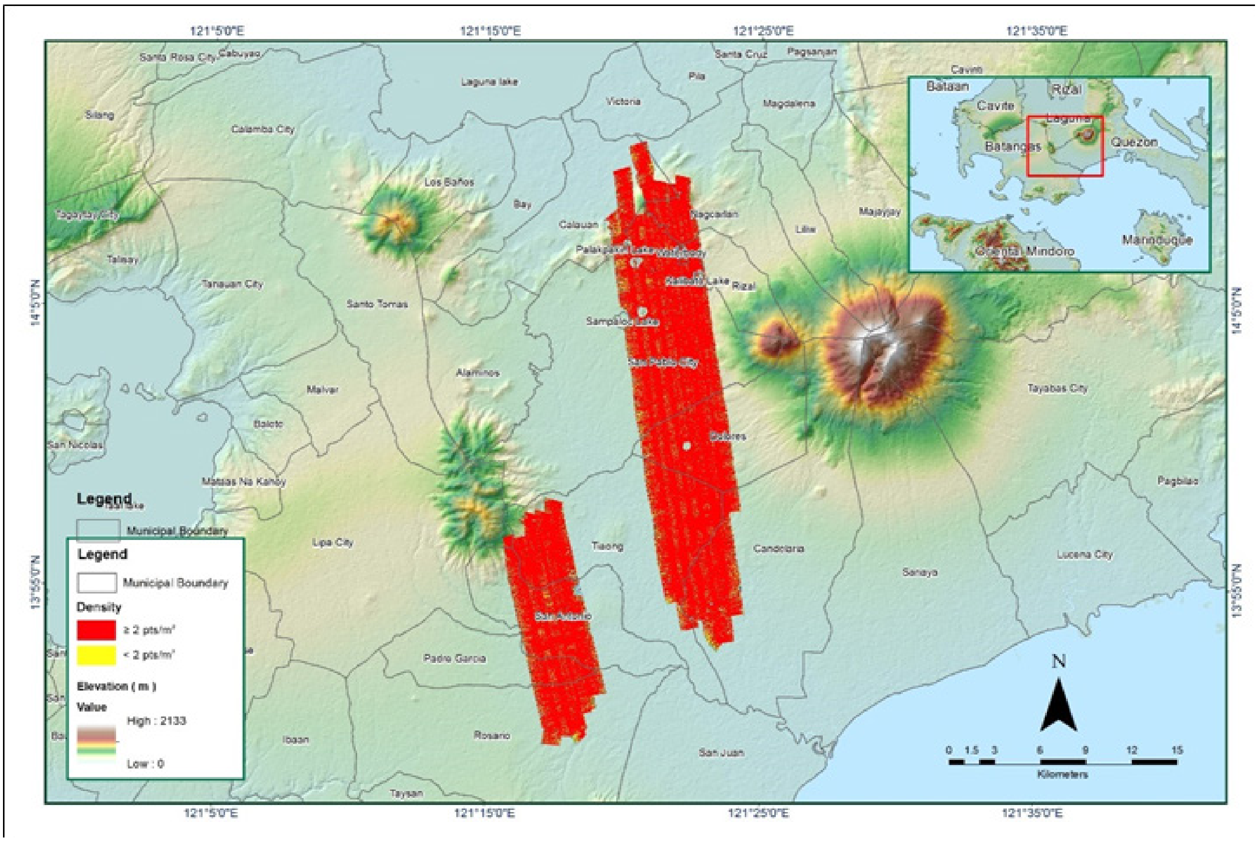


Figure A-8.13. Density map of merged LiDAR data

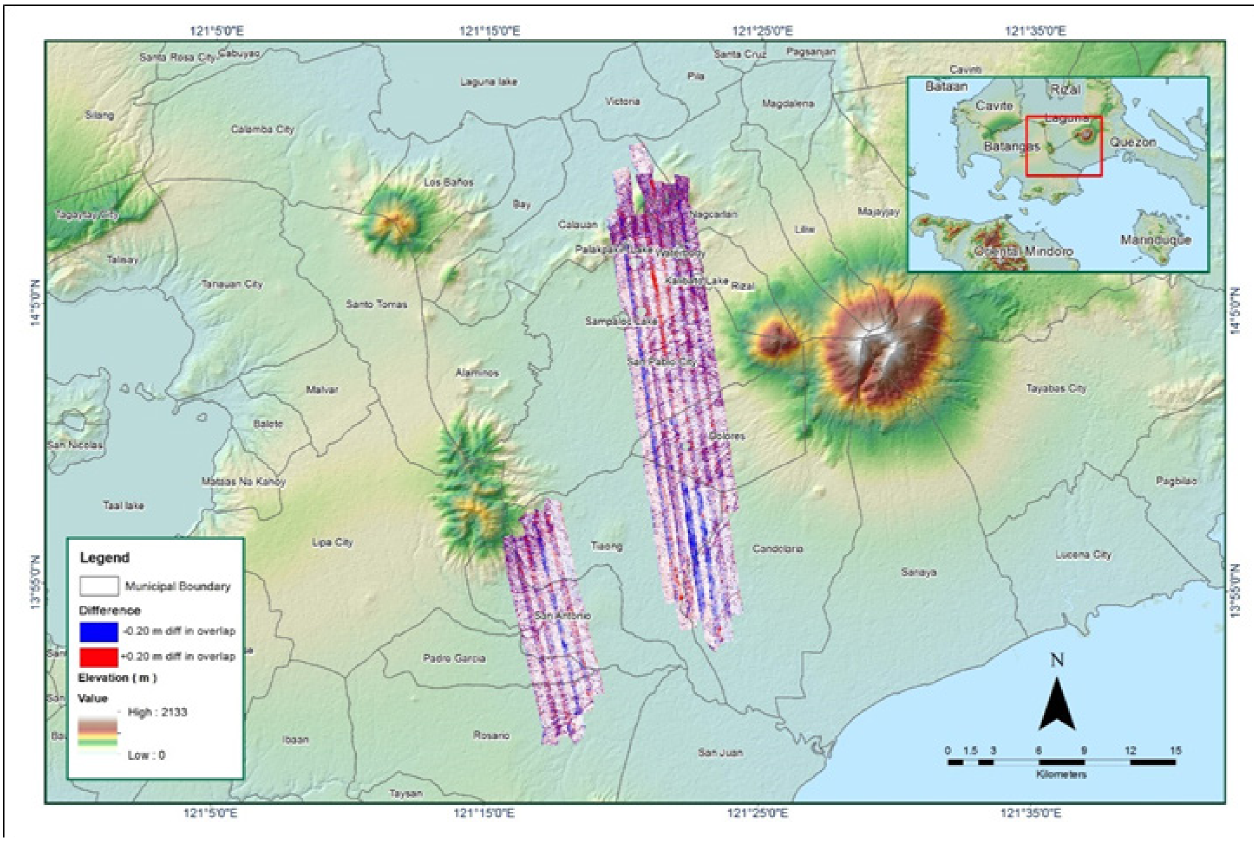


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk18W_additional

Flight Area	CALABARZON
Mission Name	Blk18W_additional
Inclusive Flights	3345P, 3347P
Range data size	32.35 GB
POS	329 MB
Image	N/A
Transfer date	9/8/2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.6
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000210
IMU attitude correction stdev (<0.001deg)	0.000571
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	51.19%
Ave point cloud density per sq.m. (>2.0)	3.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	310
Maximum Height	559.57 m
Minimum Height	59.37 m
Classification (# of points)	
Ground	255,896,595
Low vegetation	250,448,090
Medium vegetation	363,614,645
High vegetation	276,078,698
Building	39,501,449
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Harmond Santos, Engr. Gladys Mae Apat

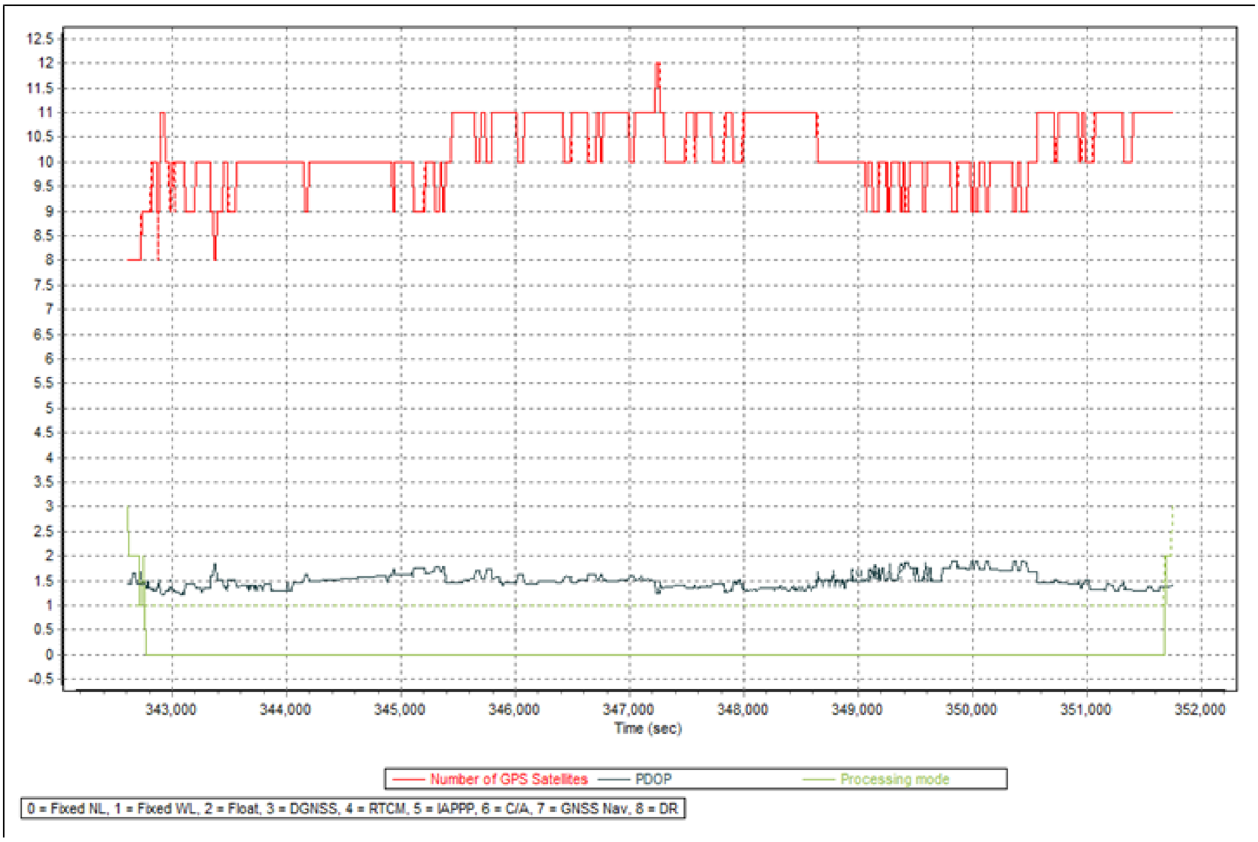


Figure A-8.15. Solution Status

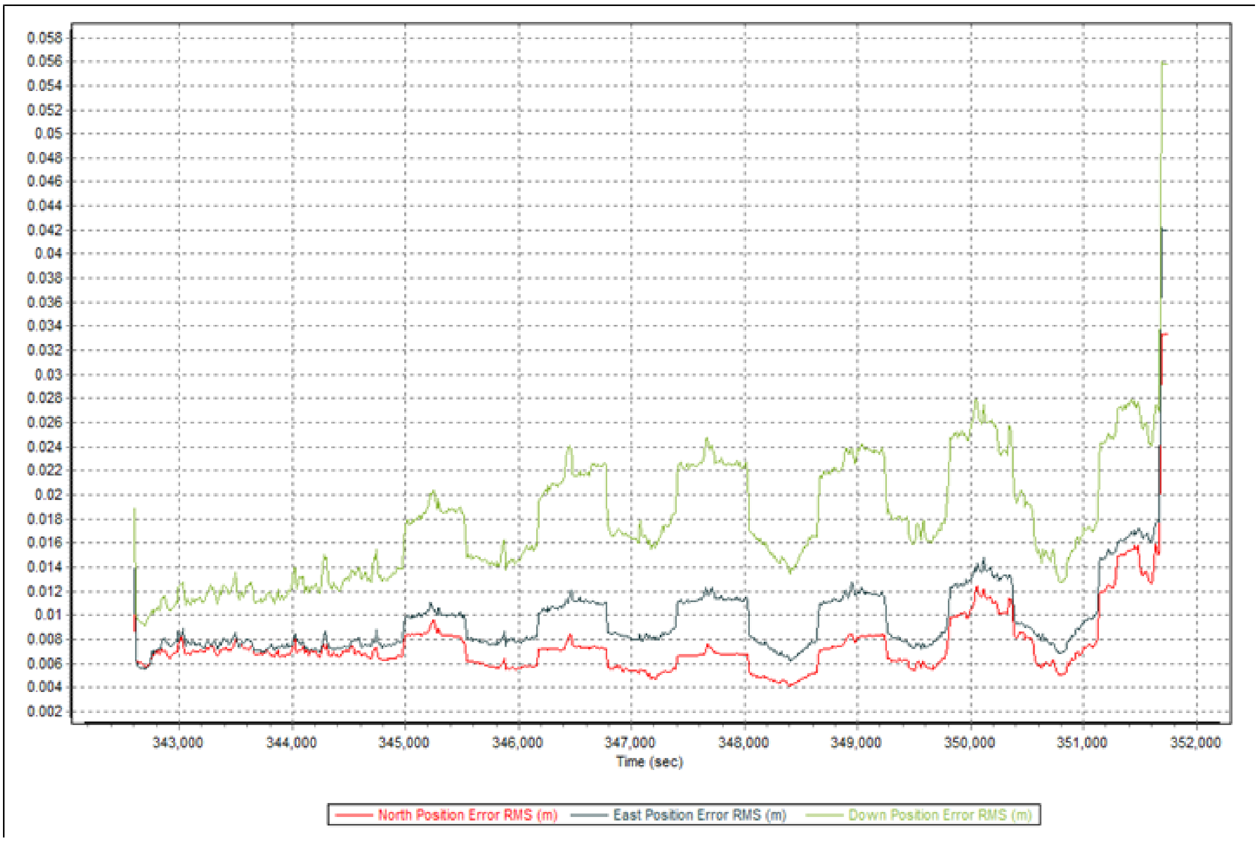


Figure A-8.16. Smoothed Performance Metric Parameters

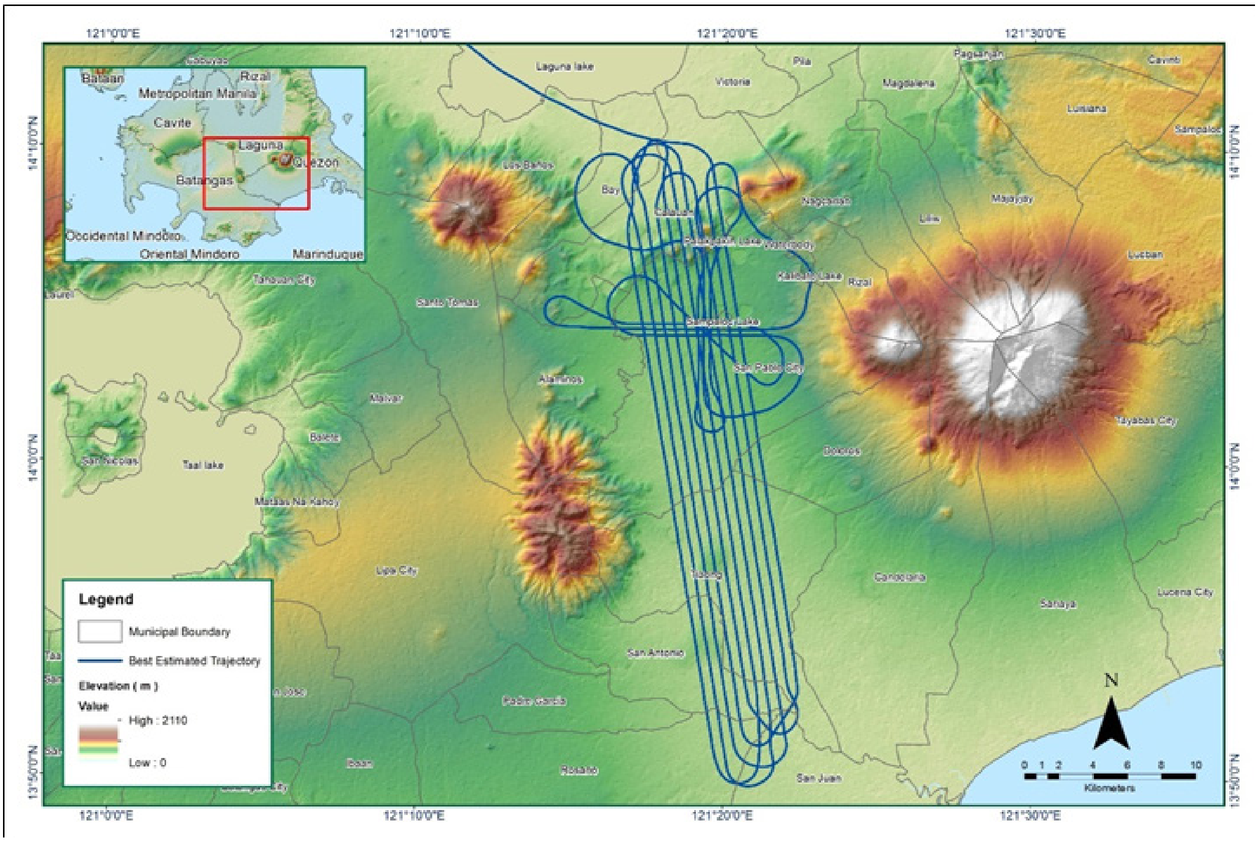


Figure A-8.17. Best Estimated Trajectory

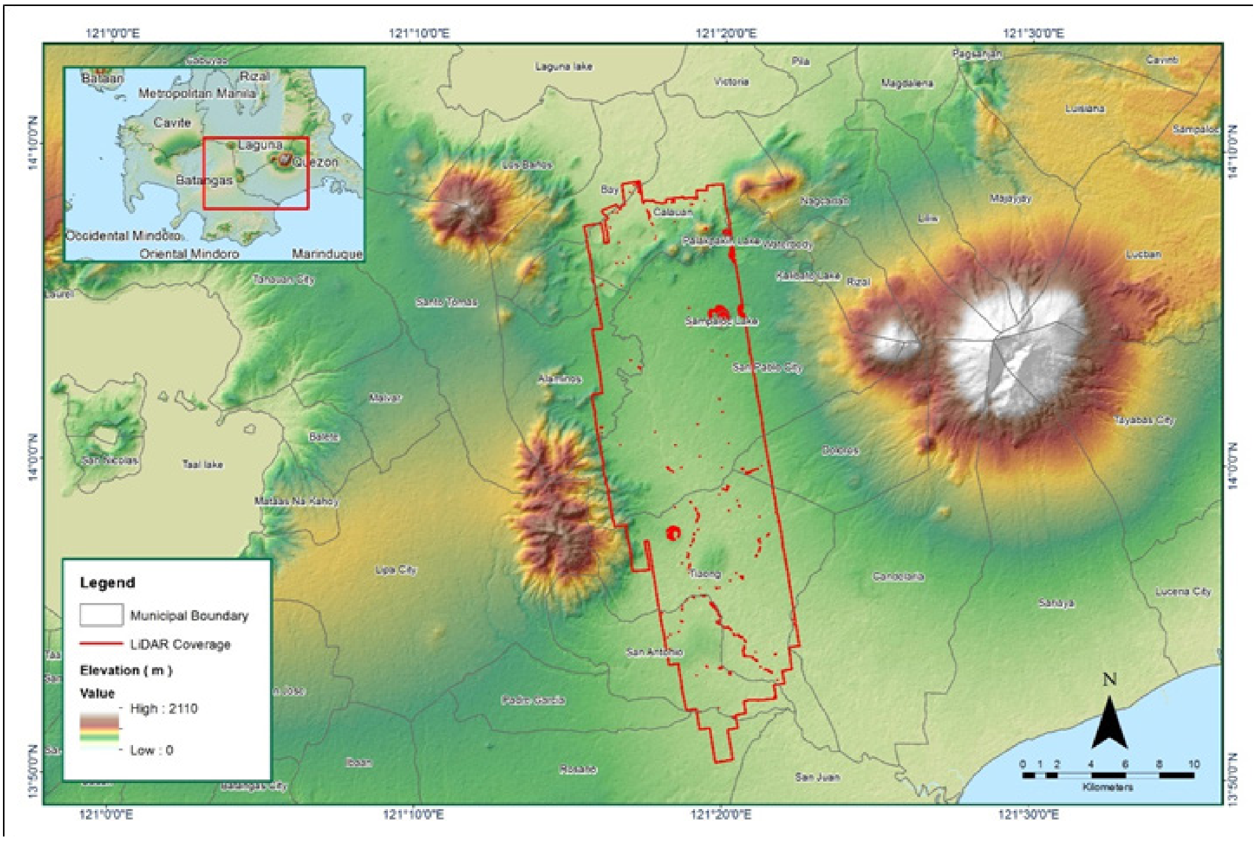


Figure A-8.18. Coverage of LiDAR data

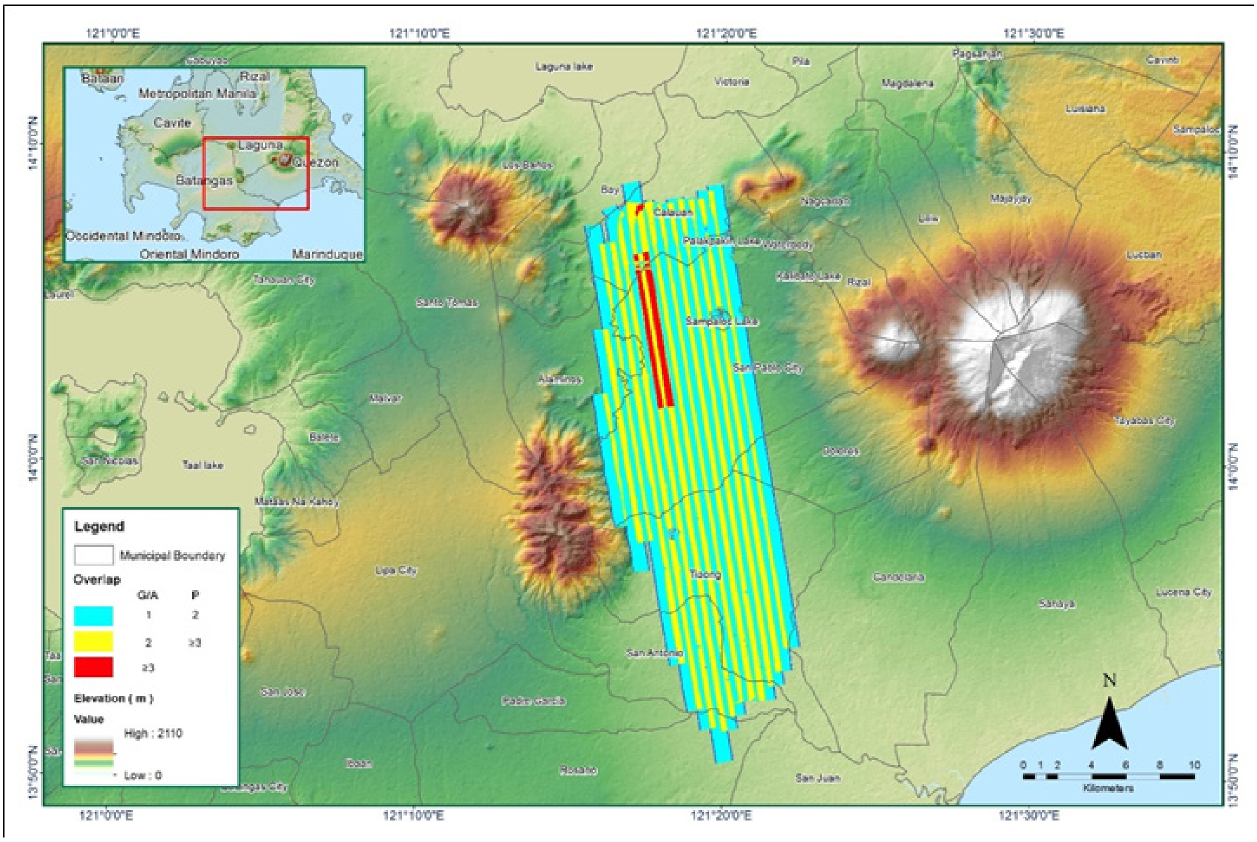


Figure A-8.19. Image of data overlap

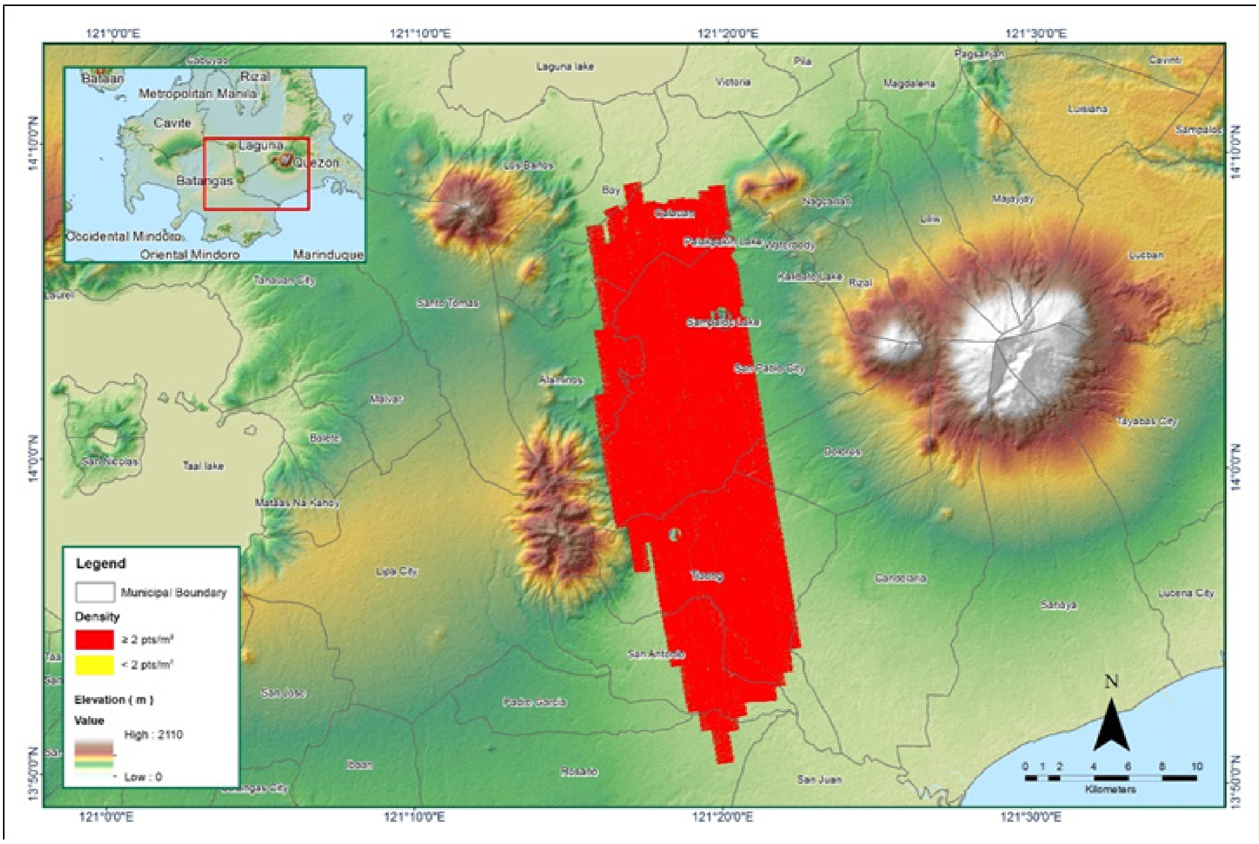


Figure A-8.20. Density map of merged LiDAR data

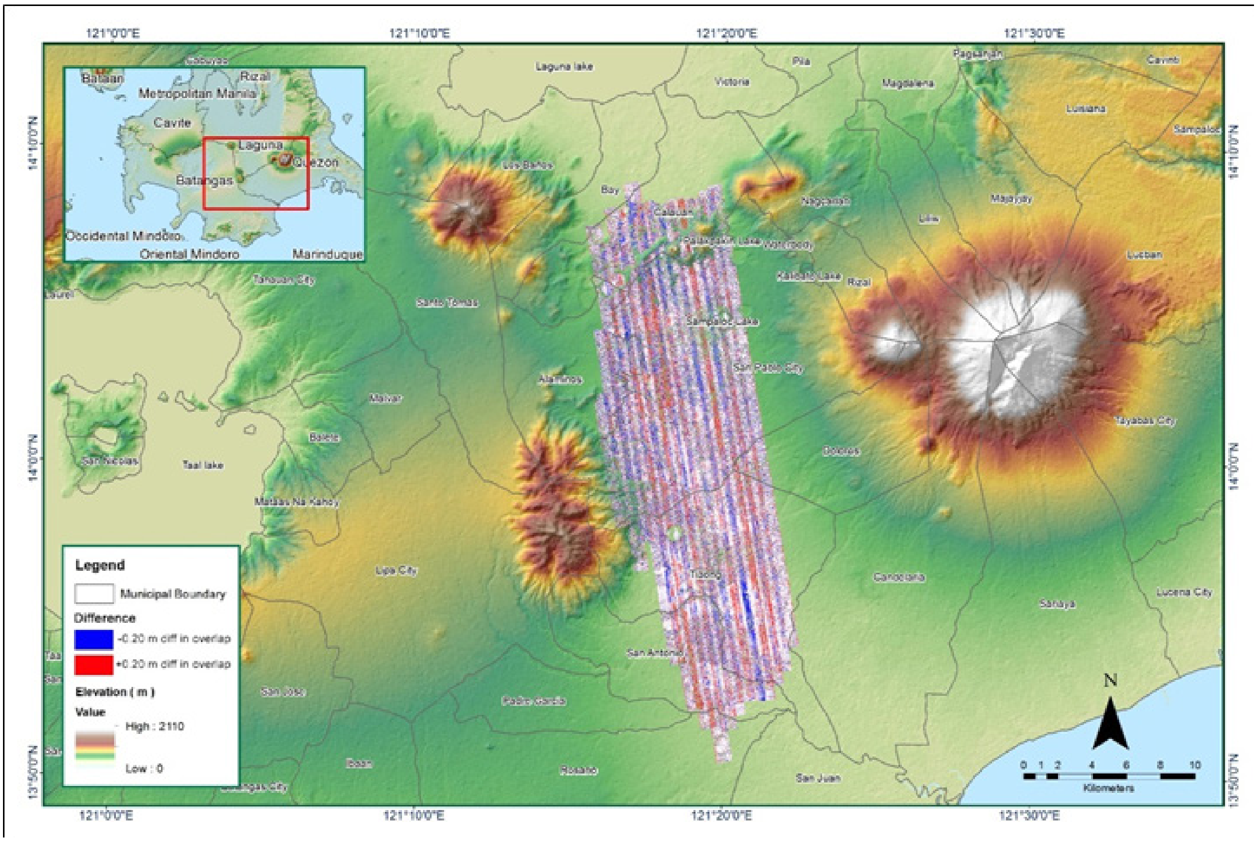


Figure A-8.21. Elevation difference between flight lines

ANNEX 9. Maapon 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
W460	0.43704	99	30	6.078578	0.294282	Discharge	2.465268	1.00E-05	Ratio to Peak	1
W470	0.43704	99	30	8.046159	0.0782116	Discharge	2.397564	1.00E-05	Ratio to Peak	1
W480	0.51057	99	30	11.78221	0.120753	Discharge	0.700068	1.00E-05	Ratio to Peak	1
W490	0.16557	99	30	10.062063	0.397701	Discharge	2.737332	1.00E-05	Ratio to Peak	1
W500	0.15678	99	30	7.6136555	0.185481	Discharge	3.06696	1.00E-05	Ratio to Peak	1
W510	0.0995213	99	30	7.966717	0.330003	Discharge	6.455904	1.00E-05	Ratio to Peak	1
W520	0.15325	99	30	3.859768	0.425781	Discharge	1.569672	1.00E-05	Ratio to Peak	1
W530	0.11935	99	30	0.68321	0.0249412	Discharge	0.7953504	1.00E-05	Ratio to Peak	1
W540	0.12651	99	30	11.5973935	0.148356	Discharge	1.1663028	1.00E-05	Ratio to Peak	1
W550	0.118188	99	30	1.791493	0.02	Discharge	1.0142496	1.00E-05	Ratio to Peak	1
W560	0.0576439	99	30	9.926708	0.96345	Discharge	1.374048	1.00E-05	Ratio to Peak	1
W570	0.054684	99	30	13.443155	0.137646	Discharge	0.0623184	1.00E-05	Ratio to Peak	1
W580	0.0367081	99	30	1.3068715	0.0177034	Discharge	0.6671184	1.52E-05	Ratio to Peak	0.90708
W590	0.1503846	99	30	11.4559665	0.33102	Discharge	0.0264022	1.00E-05	Ratio to Peak	1
W600	0.0762682	99	30	12.780295	0.277047	Discharge	0.4379076	1.00E-05	Ratio to Peak	1
W610	0.0539291	99	30	0.93642	0.0180389	Discharge	1.356888	1.00E-05	Ratio to Peak	0.7938
W620	0.0932238	99	30	4.459378	0.0255299	Discharge	2.334852	1.00E-05	Ratio to Peak	1
W630	0.11871	99	30	12.985225	0.155169	Discharge	1.91178	1.00E-05	Ratio to Peak	1
W640	0.0421456	99	30	12.1337535	0.172584	Discharge	1.2643956	1.00E-05	Ratio to Peak	1
W650	0.0639133	99	30	3.1127855	0.018	Discharge	1.2809628	1.00E-05	Ratio to Peak	1
W660	0.091728	99	30	2.7110215	0.0169693	Discharge	1.691352	1.00E-05	Ratio to Peak	1
W670	0.1173096	99	30	11.426745	0.391419	Discharge	1.4694732	1.00E-05	Ratio to Peak	1
W680	0.0652961	99	30	4.1667835	0.0860025	Discharge	2.563704	1.00E-05	Ratio to Peak	1
W690	0.0829681	99	30	14.515875	0.136557	Discharge	0.7231068	1.00E-05	Ratio to Peak	1

W700	0.091728	99	30	0.6485402	0.0177345	Discharge	1.98198	1.00E-05	Ratio to Peak	1
W710	0.19502	99	30	6.1351235	0.0867118	Discharge	2.445612	1.00E-05	Ratio to Peak	1
W720	0.084919	99	30	7.699296	0.151992	Discharge	2.652624	1.00E-05	Ratio to Peak	1
W730	0.12258	99	30	5.906791	0.073992	Discharge	0.0513479	1.00E-05	Ratio to Peak	1
W740	0.1233954	99	30	4.1364235	0.0174596	Discharge	0.10452	1.00E-05	Ratio to Peak	1
W750	0.16638	99	30	2.819938	0.0179226	Discharge	2.330952	1.00E-05	Ratio to Peak	1
W760	0.118188	99	30	6.012039	0.237537	Discharge	0.714948	1.00E-05	Ratio to Peak	1
W770	0.118188	99	30	1.073479	0.0181728	Discharge	3.639636	1.00E-05	Ratio to Peak	1
W780	0.11072	99	30	2.2708015	0.0167956	Discharge	1.741116	1.00E-05	Ratio to Peak	1
W790	0.1601748	99	30	5.9238685	0.209763	Discharge	2.7564	1.00E-05	Ratio to Peak	1
W800	0.11092	99	30	5.548037	0.351765	Discharge	1.92738	1.00E-05	Ratio to Peak	1
W810	0.1229	99	30	4.2105525	0.0730665	Discharge	0.8296704	1.00E-05	Ratio to Peak	1
W820	0.12429	99	30	17.53543	0.0219224	Discharge	0.5688852	1.00E-05	Ratio to Peak	1
W830	0.0848592	99	30	2.446004	0.0330098	Discharge	0.7935252	1.00E-05	Ratio to Peak	1
W840	0.118188	99	30	3.0874855	0.0348525	Discharge	0.0076932	1.00E-05	Ratio to Peak	1
W850	0.13743	99	30	2.4489135	0.018	Discharge	1.745172	1.00E-05	Ratio to Peak	1
W860	0.12654	99	30	4.2730435	0.0791776	Discharge	1.349244	1.00E-05	Ratio to Peak	1
W870	0.12113	99	30	3.254086	0.221877	Discharge	0.870402	1.00E-05	Ratio to Peak	1
W880	0.16171	99	30	3.282928	0.0345488	Discharge	0.5017272	1.00E-05	Ratio to Peak	1
W890	0.14321	99	30	4.4906235	0.057447	Discharge	1.4476644	1.00E-05	Ratio to Peak	1
W900	0.1461312	99	30	3.530615	0.0261284	Discharge	0.9584484	1.00E-05	Ratio to Peak	1

ANNEX 10. Maapon Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	336.27	0.0495922	0.001	Trapezoid	110	0.3
R110	Automatic Fixed Interval	305.56	0.0014976	0.001	Trapezoid	110	0.3
R130	Automatic Fixed Interval	1716.5	0.42932	0.05	Trapezoid	110	0.3
R150	Automatic Fixed Interval	1111.5	0.0014976	0.03	Trapezoid	110	0.3
R160	Automatic Fixed Interval	3533.9	0.18644	0.7	Trapezoid	110	0.3
R180	Automatic Fixed Interval	4238.9	0.0067994	0.5	Trapezoid	110	0.3
R200	Automatic Fixed Interval	2227	0.0144619	1	Trapezoid	110	0.3
R240	Automatic Fixed Interval	593.85	0.0327775	0.9	Trapezoid	110	0.3
R250	Automatic Fixed Interval	2887.8	0.0114494	0.8	Trapezoid	110	0.3
R260	Automatic Fixed Interval	526.98	0.0014976	1	Trapezoid	110	0.3
R290	Automatic Fixed Interval	4420.3	0.0130056	0.9	Trapezoid	110	0.3
R30	Automatic Fixed Interval	1525	0.10686	0.7	Trapezoid	110	0.3
R320	Automatic Fixed Interval	3705.8	0.020527	0.4	Trapezoid	110	0.3
R330	Automatic Fixed Interval	3817.5	0.14563	0.05	Trapezoid	110	0.3
R340	Automatic Fixed Interval	1811.5	0.20634	0.01	Trapezoid	110	0.3
R360	Automatic Fixed Interval	14.142	0.0014976	0.5	Trapezoid	110	0.3
R370	Automatic Fixed Interval	6204.7	0.0636022	0.001	Trapezoid	110	0.3
R380	Automatic Fixed Interval	932.55	0.0969605	1	Trapezoid	110	0.3
R390	Automatic Fixed Interval	1484.3	0.1516	1	Trapezoid	110	0.3
R400	Automatic Fixed Interval	2146.5	0.0373229	1	Trapezoid	110	0.3
R410	Automatic Fixed Interval	1221.2	0.0410902	1	Trapezoid	110	0.3
R50	Automatic Fixed Interval	4929.7	0.0607366	1	Trapezoid	110	0.3

ANNEX 11. Maapon Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	14.170098	121.668252	3	0	-3.000	Rosing Nov. 7,1995	5 -Year
2	14.185229	121.728785	0	0	0.000	Rosing Nov. 7,1995	5 -Year
3	14.182012	121.699791	0	0	0.000	Rosing Nov. 7,1995	5 -Year
4	14.182181	121.699555	0	0	0.000	Rosing Nov. 7,1995	5 -Year
5	14.181364	121.685076	0	0	0.000	Rosing Nov. 7,1995	5 -Year
6	14.184732	121.724586	0	0.1	0.100	Rosing Nov. 7,1995	5 -Year
7	14.185334	121.729569	1	0.1	-0.900	Rosing Nov. 7,1995	5 -Year
8	14.187341	121.729815	0	0.2	0.200	Rosing Nov. 7,1995	5 -Year
9	14.185344	121.729757	1	0.2	-0.800	Rosing Nov. 7,1995	5 -Year
10	14.18514	121.730211	2	0.2	-1.800	Rosing Nov. 7,1995	5 -Year
11	14.185001	121.730191	2	0.2	-1.800	Rosing Nov. 7,1995	5 -Year
12	14.178274	121.720872	2	0.2	-1.800	Rosing Nov. 7,1995	5 -Year
13	14.180222	121.727835	0	0.2	0.200	Rosing Nov. 7,1995	5 -Year
14	14.188572	121.665816	3	0.2	-2.800	Rosing Nov. 7,1995	5 -Year
15	14.184575	121.724753	0	0.2	0.200	Rosing Nov. 7,1995	5 -Year
16	14.188703	121.730412	0	0.2	0.200	Rosing Nov. 7,1995	5 -Year
17	14.185218	121.729536	1	0.3	-0.700	Rosing Nov. 7,1995	5 -Year
18	14.184999	121.729958	2	0.3	-1.700	Rosing Nov. 7,1995	5 -Year
19	14.177912	121.71866	2	0.3	-1.700	Rosing Nov. 7,1995	5 -Year
20	14.185717	121.731729	0	0.3	0.300	Rosing Nov. 7,1995	5 -Year
21	14.186853	121.729229	0	0.3	0.300	Rosing Nov. 7,1995	5 -Year
22	14.186826	121.728314	0	0.3	0.300	Rosing Nov. 7,1995	5 -Year
23	14.186605	121.728237	0	0.3	0.300	Rosing Nov. 7,1995	5 -Year
24	14.187427	121.728253	0	0.3	0.300	Rosing Nov. 7,1995	5 -Year
25	14.184819	121.72619	1	0.4	-0.600	Rosing Nov. 7,1995	5 -Year
26	14.183723	121.728936	2	0.4	-1.600	Rosing Nov. 7,1995	5 -Year
27	14.184465	121.731519	1	0.4	-0.600	Rosing Nov. 7,1995	5 -Year
28	14.185053	121.731683	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
29	14.18589	121.731713	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
30	14.18636	121.731508	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
31	14.186087	121.731137	1	0.4	-0.600	Rosing Nov. 7,1995	5 -Year
32	14.186148	121.731102	1	0.4	-0.600	Rosing Nov. 7,1995	5 -Year
33	14.171174	121.669039	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
34	14.186801	121.729077	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
35	14.186692	121.728284	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
36	14.186443	121.727782	1	0.4	-0.600	Rosing Nov. 7,1995	5 -Year
37	14.186732	121.727833	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
38	14.184531	121.730061	2	0.4	-1.600	Rosing Nov. 7,1995	5 -Year
39	14.182829	121.6756	3	0.4	-2.600	Rosing Nov. 7,1995	5 -Year
40	14.183094	121.674397	3	0.4	-2.600	Rosing Nov. 7,1995	5 -Year
41	14.190835	121.663966	3	0.4	-2.600	Rosing Nov. 7,1995	5 -Year

42	14.188917	121.714859	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
43	14.201071	121.695246	3	0.4	-2.600	Rosing Nov. 7,1995	5 -Year
44	14.16188	121.657773	0	0.4	0.400	Rosing Nov. 7,1995	5 -Year
45	14.171353	121.669206	0	0.5	0.500	Rosing Nov. 7,1995	5 -Year
46	14.174782	121.676387	3	0.5	-2.500	Rosing Nov. 7,1995	5 -Year
47	14.192952	121.662005	3	0.5	-2.500	Rosing Nov. 7,1995	5 -Year
48	14.186306	121.731781	0	0.5	0.500	Rosing Nov. 7,1995	5 -Year
49	14.185958	121.731257	1	0.5	-0.500	Rosing Nov. 7,1995	5 -Year
50	14.187393	121.729667	0	0.5	0.500	Rosing Nov. 7,1995	5 -Year
51	14.171645	121.669473	2	0.6	-1.400	Rosing Nov. 7,1995	5 -Year
52	14.190825	121.663825	3	0.6	-2.400	Rosing Nov. 7,1995	5 -Year
53	14.184697	121.725911	0	0.6	0.600	Rosing Nov. 7,1995	5 -Year
54	14.185497	121.731212	1	0.6	-0.400	Rosing Nov. 7,1995	5 -Year
55	14.186903	121.727848	0	0.6	0.600	Rosing Nov. 7,1995	5 -Year
56	14.174681	121.726336	2	0.8	-1.200	Rosing Nov. 7,1995	5 -Year
57	14.200907	121.695585	3	0.8	-2.200	Rosing Nov. 7,1995	5 -Year
58	14.186049	121.731744	0	0.8	0.800	Rosing Nov. 7,1995	5 -Year
59	14.18597	121.731471	0	0.8	0.800	Rosing Nov. 7,1995	5 -Year
60	14.187399	121.728885	1	0.8	-0.200	Rosing Nov. 7,1995	5 -Year
61	14.185289	121.730207	2	0.8	-1.200	Rosing Nov. 7,1995	5 -Year
62	14.186691	121.728949	0	0.9	0.900	Rosing Nov. 7,1995	5 -Year
63	14.186722	121.728709	0	0.9	0.900	Rosing Nov. 7,1995	5 -Year
64	14.164251	121.639008	3	0.9	-2.100	Rosing Nov. 7,1995	5 -Year
65	14.183783	121.728583	2	0	-2.000	Rosing Nov. 7,1995	5 -Year
66	14.186562	121.721844	0	0	0.000	Rosing Nov. 7,1995	5 -Year
67	14.189798	121.714464	0	0	0.000	Rosing Nov. 7,1995	5 -Year
68	14.200097	121.706597	3	0	-3.000	Rosing Nov. 7,1995	5 -Year
69	14.202207	121.690257	0	0	0.000	Rosing Nov. 7,1995	5 -Year
70	14.202581	121.689362	1	0	-1.000	Rosing Nov. 7,1995	5 -Year
71	14.184136	121.728135	1	0	-1.000	Rosing Nov. 7,1995	5 -Year
72	14.189224	121.724915	0	0	0.000	Rosing Nov. 7,1995	5 -Year
73	14.166057	121.652863	0	1.1	1.100	Rosing Nov. 7,1995	5 -Year
74	14.166551	121.652721	0	1.1	1.100	Rosing Nov. 7,1995	5 -Year
75	14.17167	121.669721	3	1.1	-1.900	Rosing Nov. 7,1995	5 -Year
76	14.183755	121.729401	2	1.1	-0.900	Rosing Nov. 7,1995	5 -Year
77	14.183694	121.72932	2	1.1	-0.900	Rosing Nov. 7,1995	5 -Year
78	14.183956	121.72967	2	1.1	-0.900	Rosing Nov. 7,1995	5 -Year
79	14.178601	121.72414	1	1.1	0.100	Rosing Nov. 7,1995	5 -Year
80	14.182696	121.675956	3	1.2	-1.800	Rosing Nov. 7,1995	5 -Year
81	14.184659	121.726634	1	1.2	0.200	Rosing Nov. 7,1995	5 -Year
82	14.16426	121.638586	3	1.2	-1.800	Rosing Nov. 7,1995	5 -Year
83	14.184549	121.729825	2	1.3	-0.700	Rosing Nov. 7,1995	5 -Year
84	14.180064	121.711449	2	1.3	-0.700	Rosing Nov. 7,1995	5 -Year
85	14.162363	121.658782	0	1.3	1.300	Rosing Nov. 7,1995	5 -Year
86	14.18192	121.727731	0	1.3	1.300	Rosing Nov. 7,1995	5 -Year

87	14.190643	121.664285	3	1.3	-1.700	Rosing Nov. 7,1995	5 -Year
88	14.193233	121.66123	3	1.3	-1.700	Rosing Nov. 7,1995	5 -Year
89	14.183698	121.729615	2	1.3	-0.700	Rosing Nov. 7,1995	5 -Year
90	14.187335	121.729088	1	1.3	0.300	Rosing Nov. 7,1995	5 -Year
91	14.180001	121.710548	1	1.3	0.300	Rosing Nov. 7,1995	5 -Year
92	14.174737	121.72566	2	1.4	-0.600	Rosing Nov. 7,1995	5 -Year
93	14.195829	121.711318	3	1.4	-1.600	Rosing Nov. 7,1995	5 -Year
94	14.184671	121.726829	1	1.4	0.400	Rosing Nov. 7,1995	5 -Year
95	14.184576	121.727119	1	1.4	0.400	Rosing Nov. 7,1995	5 -Year
96	14.164234	121.638852	3	1.4	-1.600	Rosing Nov. 7,1995	5 -Year
97	14.179967	121.71198	2	1.5	-0.500	Rosing Nov. 7,1995	5 -Year
98	14.18303	121.686536	3	1.5	-1.500	Rosing Nov. 7,1995	5 -Year
99	14.199445	121.705371	2	1.5	-0.500	Rosing Nov. 7,1995	5 -Year
100	14.184015	121.729975	2	1.5	-0.500	Rosing Nov. 7,1995	5 -Year
101	14.179965	121.710961	2	1.5	-0.500	Rosing Nov. 7,1995	5 -Year
102	14.182466	121.686618	3	1.6	-1.400	Rosing Nov. 7,1995	5 -Year
103	14.182326	121.686537	2	1.6	-0.400	Rosing Nov. 7,1995	5 -Year
104	14.182348	121.686687	2	1.6	-0.400	Rosing Nov. 7,1995	5 -Year
105	14.182095	121.686527	2	1.6	-0.400	Rosing Nov. 7,1995	5 -Year
106	14.184228	121.731031	2	1.6	-0.400	Rosing Nov. 7,1995	5 -Year
107	14.169834	121.667991	3	1.6	-1.400	Rosing Nov. 7,1995	5 -Year
108	14.182085	121.727822	0	1.8	1.800	Rosing Nov. 7,1995	5 -Year
109	14.174296	121.726003	2	1.9	-0.100	Rosing Nov. 7,1995	5 -Year
110	14.174536	121.726163	2	1.9	-0.100	Rosing Nov. 7,1995	5 -Year
111	14.174804	121.726106	2	1.9	-0.100	Rosing Nov. 7,1995	5 -Year
112	14.182833	121.675618	3	1.9	-1.100	Rosing Nov. 7,1995	5 -Year
113	14.184765	121.725628	0	1.9	1.900	Rosing Nov. 7,1995	5 -Year
114	14.184176	121.730684	2	1.9	-0.100	Rosing Nov. 7,1995	5 -Year
115	14.173664	121.675313	3	1.9	-1.100	Rosing Nov. 7,1995	5 -Year
116	14.189162	121.665468	3	1	-2.000	Rosing Nov. 7,1995	5 -Year
117	14.184128	121.730069	2	1	-1.000	Rosing Nov. 7,1995	5 -Year
118	14.184091	121.730258	2	1	-1.000	Rosing Nov. 7,1995	5 -Year
119	14.184186	121.730413	2	1	-1.000	Rosing Nov. 7,1995	5 -Year
120	14.18422	121.731224	1	1	0.000	Rosing Nov. 7,1995	5 -Year
121	14.186291	121.73123	0	1	1.000	Rosing Nov. 7,1995	5 -Year
122	14.187103	121.729257	1	1	0.000	Rosing Nov. 7,1995	5 -Year
123	14.187151	121.727967	0	1	1.000	Rosing Nov. 7,1995	5 -Year
124	14.185853	121.728932	0	1	1.000	Rosing Nov. 7,1995	5 -Year
125	14.184286	121.729721	2	1	-1.000	Rosing Nov. 7,1995	5 -Year
126	14.18484	121.72951	1	1	0.000	Rosing Nov. 7,1995	5 -Year
127	14.17681	121.717579	3	1	-2.000	Rosing Nov. 7,1995	5 -Year
128	14.17988	121.711786	2	1	-1.000	Rosing Nov. 7,1995	5 -Year
129	14.17172	121.670087	3	1	-2.000	Rosing Nov. 7,1995	5 -Year
130	14.172448	121.671403	3	1	-2.000	Rosing Nov. 7,1995	5 -Year
131	14.174724	121.676334	3	1	-2.000	Rosing Nov. 7,1995	5 -Year

132	14.181201	121.683203	0	1	1.000	Rosing Nov. 7,1995	5 -Year
133	14.181667	121.686546	0	1	1.000	Rosing Nov. 7,1995	5 -Year
134	14.179683	121.714366	2	1	-1.000	Rosing Nov. 7,1995	5 -Year
135	14.177079	121.71684	3	2.1	-0.900	Rosing Nov. 7,1995	5 -Year
136	14.181494	121.727539	2	2.2	0.200	Rosing Nov. 7,1995	5 -Year
137	14.183007	121.728066	1	2.2	1.200	Rosing Nov. 7,1995	5 -Year
138	14.174285	121.675381	3	2.2	-0.800	Rosing Nov. 7,1995	5 -Year
139	14.176476	121.717078	3	2.3	-0.700	Rosing Nov. 7,1995	5 -Year
140	14.184267	121.727709	1	2.4	1.400	Rosing Nov. 7,1995	5 -Year
141	14.191963	121.662436	3	2.5	-0.500	Rosing Nov. 7,1995	5 -Year
142	14.19125	121.663207	3	2.5	-0.500	Rosing Nov. 7,1995	5 -Year
143	14.184067	121.727519	2	2.6	0.600	Rosing Nov. 7,1995	5 -Year
144	14.174378	121.675729	3	2.8	-0.200	Rosing Nov. 7,1995	5 -Year
145	14.174622	121.725963	2	2	0.000	Rosing Nov. 7,1995	5 -Year
146	14.181166	121.727478	3	2	-1.000	Rosing Nov. 7,1995	5 -Year
147	14.182442	121.727815	1	2	1.000	Rosing Nov. 7,1995	5 -Year
148	14.18433	121.727302	1	2	1.000	Rosing Nov. 7,1995	5 -Year
149	14.184533	121.72757	1	2	1.000	Rosing Nov. 7,1995	5 -Year
150	14.18461	121.727569	1	2	1.000	Rosing Nov. 7,1995	5 -Year
151	14.184537	121.727919	1	2	1.000	Rosing Nov. 7,1995	5 -Year
152	14.184829	121.731646	1	2	1.000	Rosing Nov. 7,1995	5 -Year
153	14.174458	121.725718	2	2	0.000	Rosing Nov. 7,1995	5 -Year
154	14.182874	121.727985	1	3.2	2.200	Rosing Nov. 7,1995	5 -Year
155	14.18434	121.727942	1	3.5	2.500	Rosing Nov. 7,1995	5 -Year
156	14.174481	121.676024	3	3	0.000	Rosing Nov. 7,1995	5 -Year
157	14.16596	121.648212	2	3	1.000	Rosing Nov. 7,1995	5 -Year
158	14.174834	121.725933	2	4	2.000	Rosing Nov. 7,1995	5 -Year
159	14.174135	121.726032	2	4	2.000	Rosing Nov. 7,1995	5 -Year
160	14.174521	121.725556	2	4	2.000	Rosing Nov. 7,1995	5 -Year
				RMSE	1.2236		