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

LiDAR Surveys and Flood Mapping of Calauag River

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

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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CALAUAG RIVER

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

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 method described 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 Visayas MAPUA Institute of technology (MIT). MIT 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 26 river basins in the (Cavite, Batangas, Rizal, and Quezon) CABARZON Region. The university is located in Intramuros, Manila within Metro Manila.

1.2 Overview of the Calauag River Basin

The Calauag river basin traverses through the first class municipalities of Calauag and Lopez in the province of Quezon. Aside from these municipalities, this also serves as a catchment basin for Guinayangan, consequently covering a larger number of population. Throughout the years, these areas have also been hit by a number of typhoons, Sening (1970), Rosing (1995), Yoyong (2004), Milenyo (2006), Ondoy (2009), Glenda (2014), and Nina (2016) to name a few. Being exposed to numerous typhoons, several hazardous events could branch out resulting to higher risk for the lives of its people.

Though the residents in these municipalities practice a wide variety of livelihood activities (fishing, farming, etc.), a large number of the population still reside near the river. These residents are often faced with flooding problems in which according to them, sometimes the flood level causes the submersion of the bridge itself. Storm surge is also a given risk on these municipalities in which according to the Disaster Risk Reduction Climate Change Adaptation of Quezon province there was a storm surge incident in these municipalities during the September 2009 typhoon Ondoy.

Regardless of having a relatively higher economic class of the municipalities, there is no exception when it comes to the needed assistance in achieving higher level of resiliency.

In line with this, the Light Detection and Ranging (LiDAR) project by the Department of Science and Technology is definitely an integral part in obtaining this goal. Through collection of LiDAR data together with the rainfall and discharge data, more detailed flood hazard maps are produced. These would then serve as guide for more efficient community planning and responsiveness in times of calamities.

The Sumulong River Basin covers the Municipalities of Calauag, Lopez, Guinayangan, Buenavista and Catanauan in Quezon. According to DENR River Basin Control Office, it has a drainage area of 163 km2 and an estimated annual run-off of 261 million cubic meter (MCM) (RBCO, 2015).

Its main stem, Sumulong River, is part of the 28 river systems in the southern Luzon region. According to the 2010 national census of NSO, a total of 5,159 locals are residing in the immediate vicinity of the river which are distributed among the five (5) barangays in Municipality of Calauag namely, Bangjuruhan, Sumulong, Sumilang, Mabini and Biyan. Agriculture and fishing are the two primary source of living in the area. According to the locals, majority of the agricultural land is planted by coconuts, rice, citrus and vegetables. The most recent and significant flooding which even caused a storm surge in the area was on July 2014 caused by Typhoon "Glenda" as reported by Waga. B, July , 2014 in Kicker Daily News.

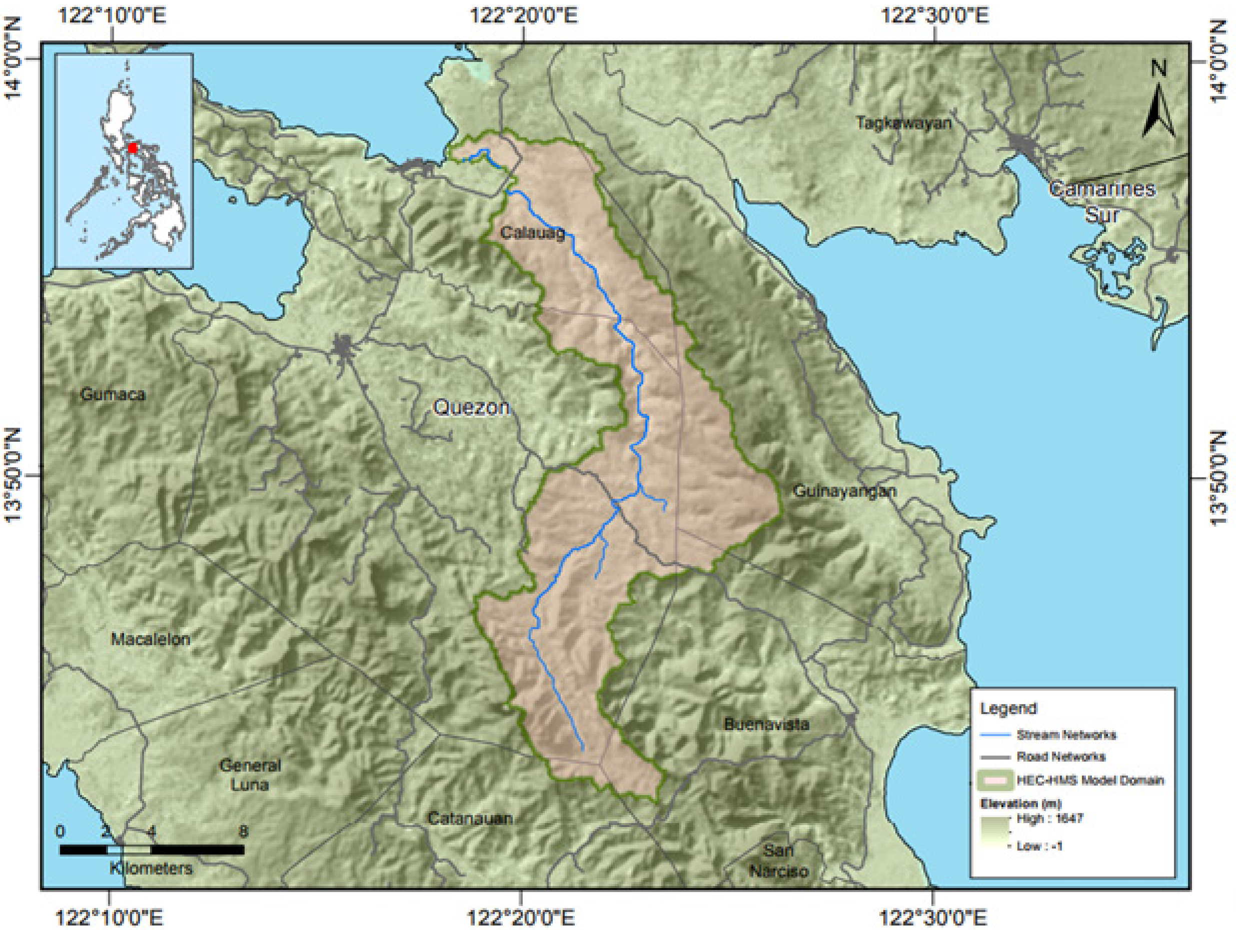

Figure 1. Map of the Calauag River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CALAUAG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuna, and Engr. Gerome Hipolito

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Calauag floodplain in Quezon Province. These missions were planned for 10 lines that run for at most four (4) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plans for Calauag floodplain.

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 20C	1000	30	50	200	30	130	5
BLK 20F	1000	30	50	200	30	130	5
BLK 20G	1000	30	50	200	30	130	5
BLK 20H	1000	30	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

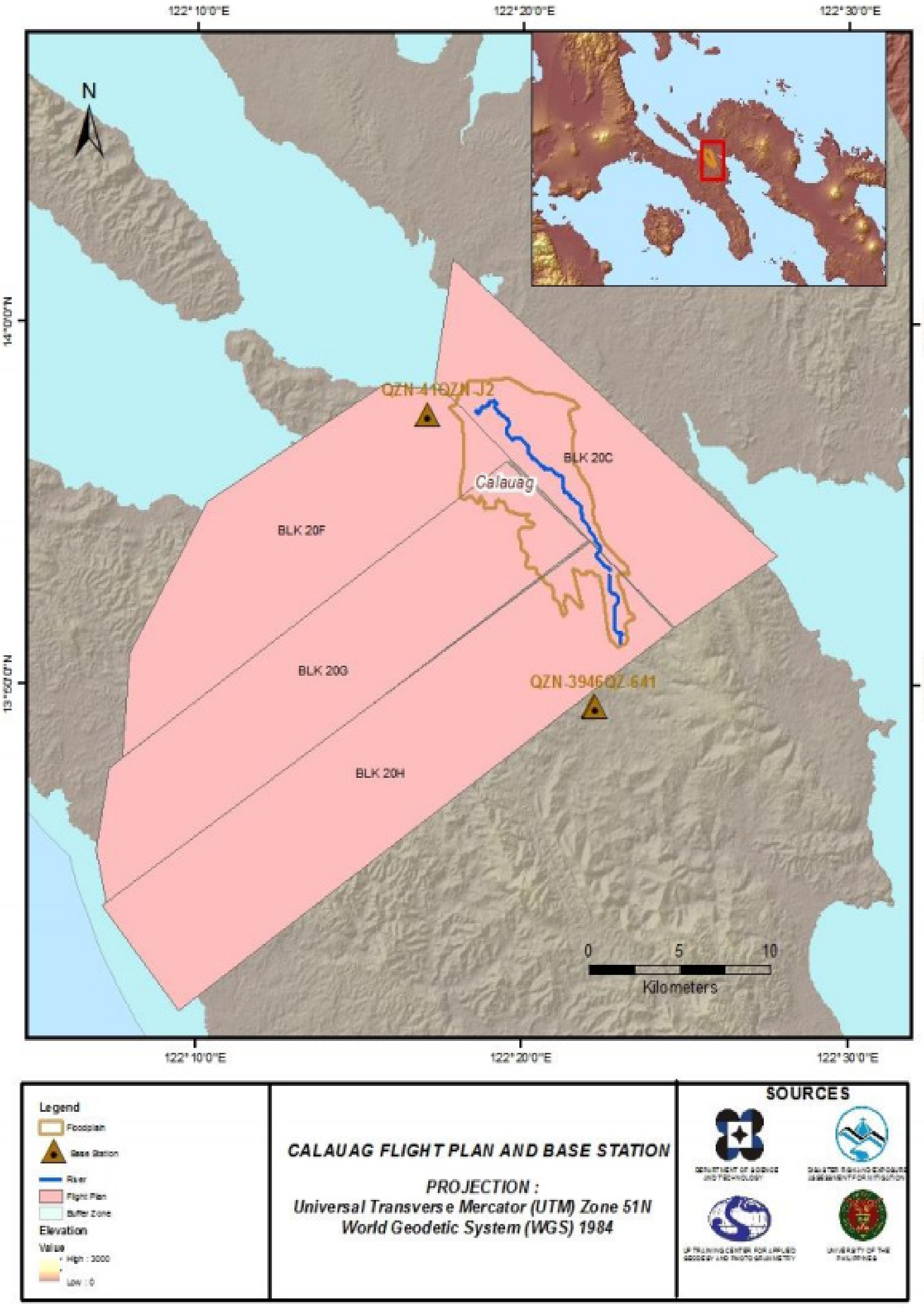

Figure 2. Flight Plan and base stations used for the Calauag Floodplain survey.

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point QZN-41 which is of second (2nd) order accuracy. The project team reprocessed one (1) benchmark QZ-641 and established two (2) ground control points, QZN-J2 and QZN-3946. The certification for the base station is found in Annex 2 while the baseline processing report for the reprocessed and established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (April 4-18, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TOPCON GR-5. Flight plans and location of base stations used during aerial LiDAR acquisition in Calauag floodplain are shown in Figure 2. The list of team members are found in Annex 4.

Figure 3 to Figure 5 show the recovered NAMRIA reference points and established points within the area. In addition, Table 2 to Table 5 show the details about the NAMRIA reference point and established control points, while Table 6 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

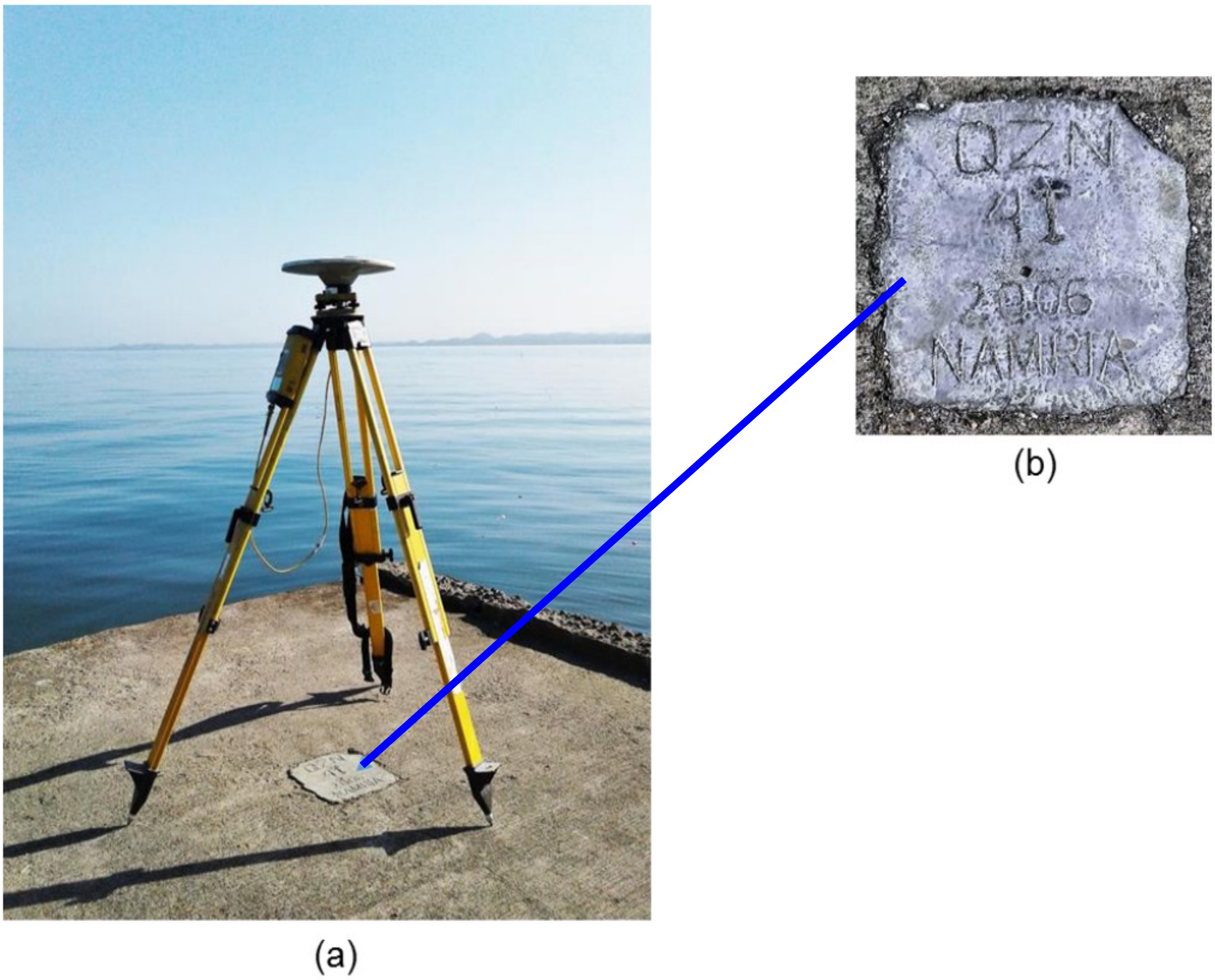

Figure 3. GPS set-up over QZN-41 at Barangay Sabang Uno, Calauag, Quezon (a) and NAMRIA reference point QZN-41 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point QZN-41 used as base station for the LiDAR Acquisition.

Station Name	QZN-41	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57' 35.21424" North 122° 16' 58.66932" East 3.94900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	422523.318 meters 1543840.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57' 30.05147" North 122° 17' 3.61061" East 52.42200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	422550.44 meters 1543300.04 meters

(a) (b)

Figure 4. GPS set-up over QZ-641 at Barangay Villa Aurora, Lopez, Quezon (a) and NAMRIA reference point QZ-641 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point SMR-56, which was used as a base station for the LiDAR acquisition.

Station Name	**QZN-41**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57’ 35.21424” North 122° 16’ 58.66932” East 3.94900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	422523.318 meters 1543840.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57’ 30.05147” North 122° 17’ 3.61061“ East 52.42200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	422550.44 meters 1543300.04 meters

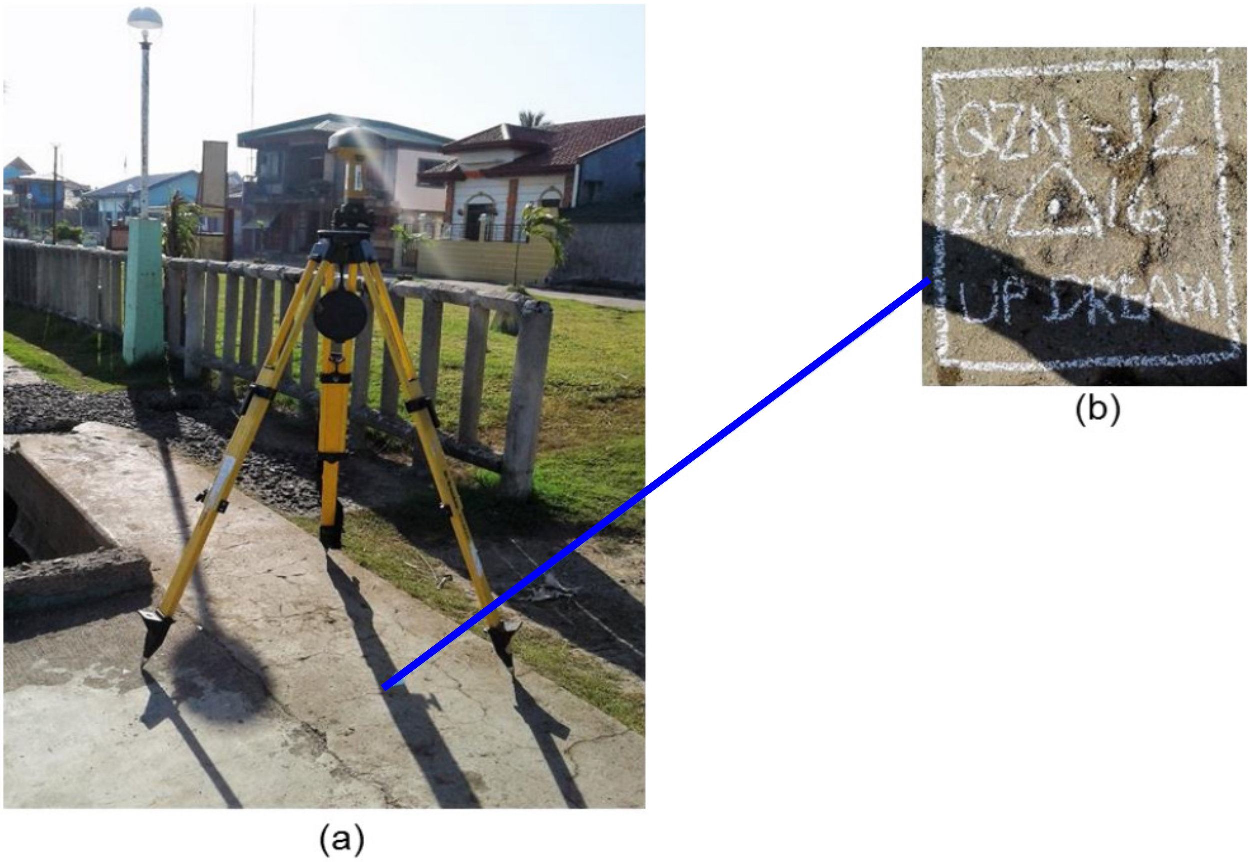

Figure 5. GPS set-up over QZN-J2 as established in at Barangay Sabang Uno, Calauag, Quezon (a) and reference point QZN-J2 (b) as established by the field team.

Table 4. Details of the established horizontal control point QZN-J2 used as base station for the LiDAR Acquisition.

Station Name	QZN-41	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 57' 35.21424" North 122° 16' 58.66932" East 3.94900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	422523.318 meters 1543840.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57' 30.05147" North 122° 17' 3.61061" East 52.42200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	422550.44 meters 1543300.04 meters

Table 5. Details of the recovered NAMRIA horizontal control point QZN-3946 used as base station for the LiDAR Acquisition.

Station Name	QZN-3946	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 49' 31.13621" North 122° 22' 07.97985" East 56.643 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	431791.932 meters 1528402.595 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 49' 26.01252" North 122° 22' 12.93209" East 105.699 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 3, 2014	1410A	AQUATACTF123A	SMR-56 and SM-286
May 4, 2014	1414A	AQUATACTF124A	SMR-56 and LYT-101
May 10, 2014	1438A	3BLK34O130A	SMR-56 and SM-286
May 10, 2014	1440A	3BLK34OSP130B	SMR-56 and SM-286
May 11, 2014	1442A	3BLK34PS131A	SMR-56 and SM-286
May 11, 2014	1444A	3BLK34PSQ131B	SMR-56 and SM-286
May 13, 2014	1450A	3BLK34QS133A	SMR-56 and SM-286
May 13, 2014	1452A	3BLK34QS133B	SMR-56 and SM-286
January 29, 2016	3727G	2BLK34IJ029B	SMR-53 and SM-271
January 30, 2016	3729G	2BLK34HJ030A	SMR-53 and LYT-104
February 5, 2016	3753G	2BLK34K33AB036A	SMR-58 and SM-309
February 6, 2016	3757G	2BLK34K037A	SMR-58 and SM-309

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR Data Acquisition in Calauag Floodplain, for a total of twenty hours and twenty minutes (20+20) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for the LiDAR data acquisition of the Calauag 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
11 APRIL 2016	23224P	125.22	104.15	34.26	69.89	NA	2	50
13 APRIL 2016	23250P	273.83	233.74	23.93	209.81	NA	4	35
13 APRIL 2016	23252P	125.22	82.31	12.70	69.61	NA	2	59
14 APRIL 2016	23254P	158.95	85.60	7.68	77.92	NA	2	53
15 APRIL 2016	23258P	199.83	190.38	7.38	183.00	NA	4	35
15 APRIL 2016	23260P	158.95	88.41	5.57	82.84	NA	2	28
TOTAL		1042	784.59	91.52	693.07	NA	20	20

Table 8. Actual parameters used during the LiDAR data acquisition of the Calauag Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23224P	1000	30	50	200	30	130	5
23250P	1000	30	50	200	30	130	5
23252P	1000	30	50	200	30	130	5
23254P	1000	30	50	200	30	130	5
23258P	1000	30	50	200	30	130	5
23260P	1000	30	50	200	30	130	5

2.4 Survey Coverage

Calauag floodplain is situated within the municipalities of Quezon. The municipality of San Narciso is mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Calauag Floodplain is presented in Figure 6.

Table 9. List of municipalities and cities surveyed of the Calauag Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Quezon	Macalelon	81.75	81.02	99.10%
	Lopez	378.81	256.35	67.67%
	Gumaca	199.62	82.68	41.42%
	Calauag	323.42	107.82	33.34%
	Guinayangan	236.85	57.26	24.18%
	Pitogo	72.29	20.59	28.48%
	General Luna	119.16	14.78	12.41%
	Catanauan	267.28	2.46	0.92%
Total		1679.18	622.96	38.44%

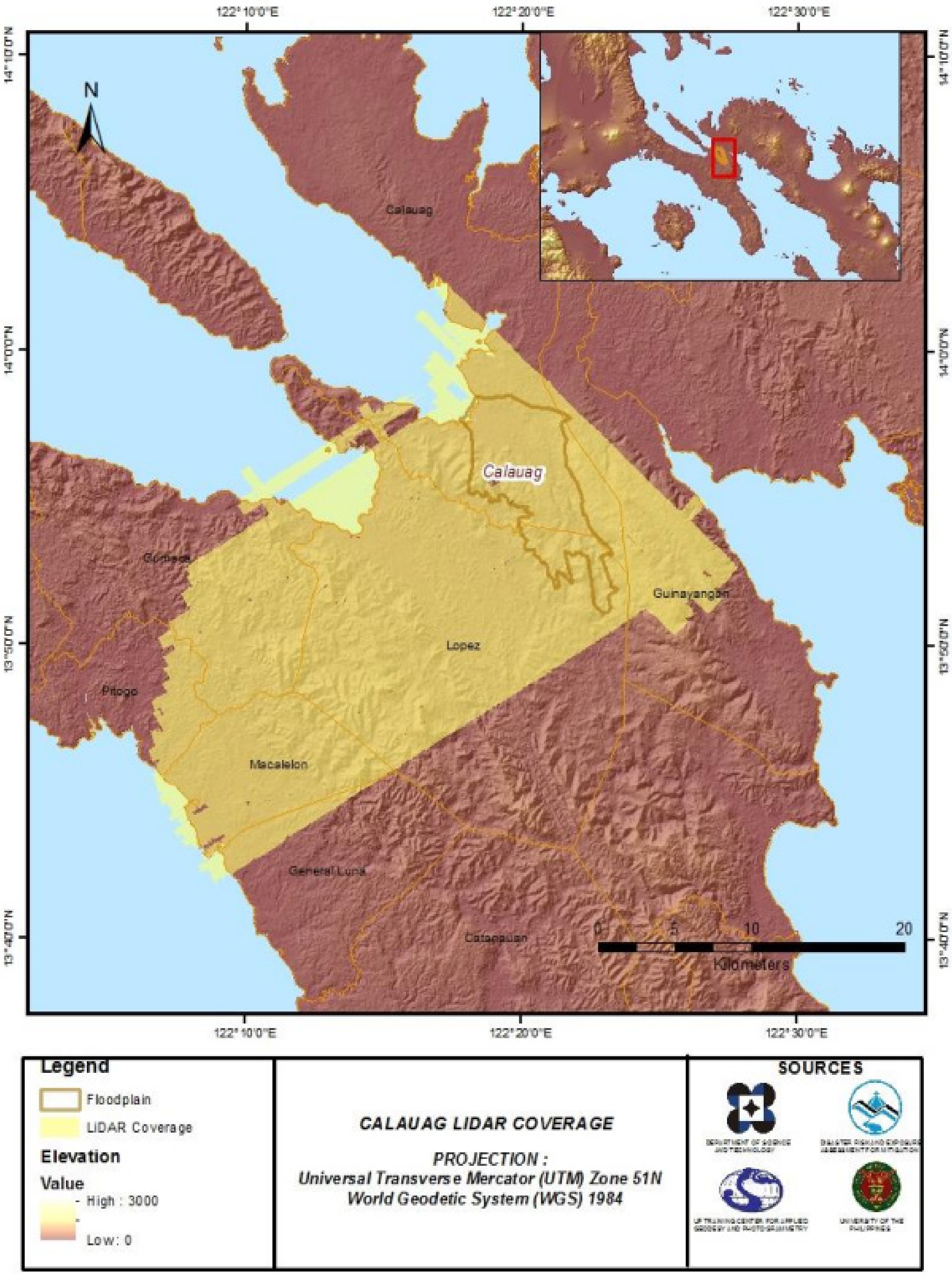

Figure 6. Actual LiDAR survey coverage of the Calauag Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE CALAUAG 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 7.

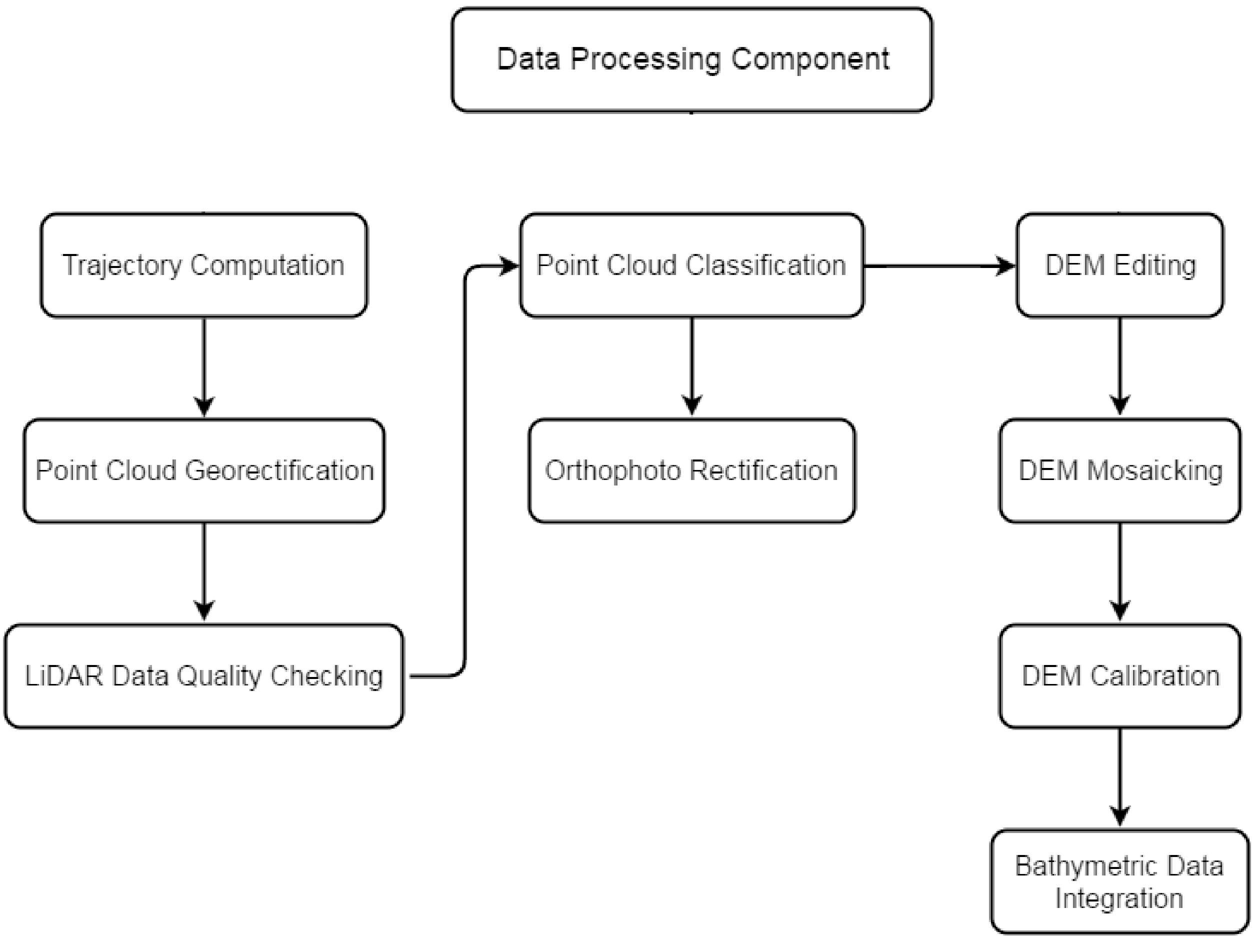


Figure 7. Schematic diagram for Data Pre-processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Calauag floodplain can be found in Annex 5. Missions flown during the first survey conducted on April 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Calauag, Quezon.

The Data Acquisition Component (DAC) transferred a total of 109.9 Gigabytes of Range data, 1.203 Gigabytes of POS data, 820 Megabytes of GPS base station data, and 795.6 Gigabytes of raw image data to the data server on May 16, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Calauag was fully transferred on May 16, 2016, as indicated on the Data Transfer Sheets for Calauag floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23258P, one of the Calauag flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on April 15, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

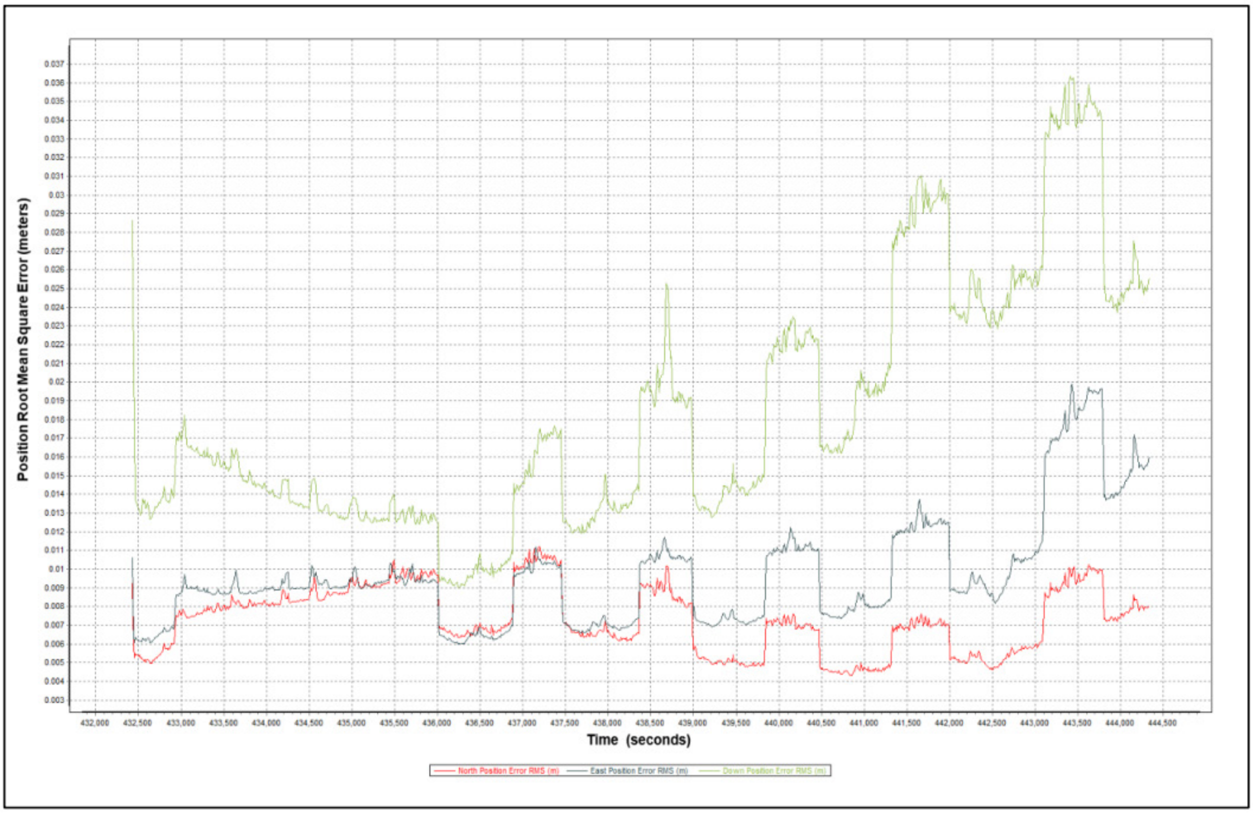


Figure 8. Smoothed Performance Metrics of Calauag Flight 23258P.

The time of flight was from 432000 seconds to 444500 seconds, which corresponds to morning of April 15, 2016. 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 9 shows that the North position RMSE peaks at 1.13 centimeters, the East position RMSE peaks at 1.98 centimeters, and the Down position RMSE peaks at 3.65 centimeters, which are within the prescribed accuracies described in the methodology.

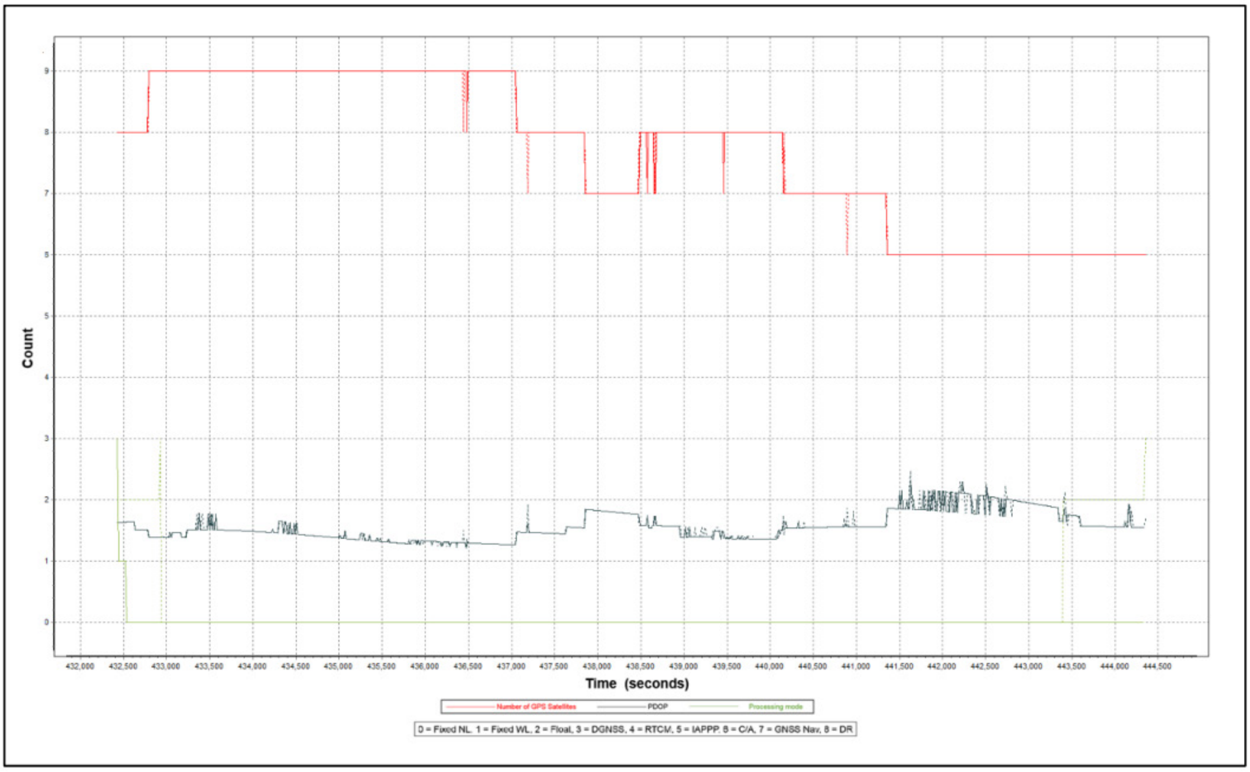


Figure 9. Solution Status Parameters of Silaga Flight 1444A.

The Solution Status parameters of flight 23258P, one of the Calauag flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure B-3. 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 9. 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 Calauag flights is shown in Figure 10.

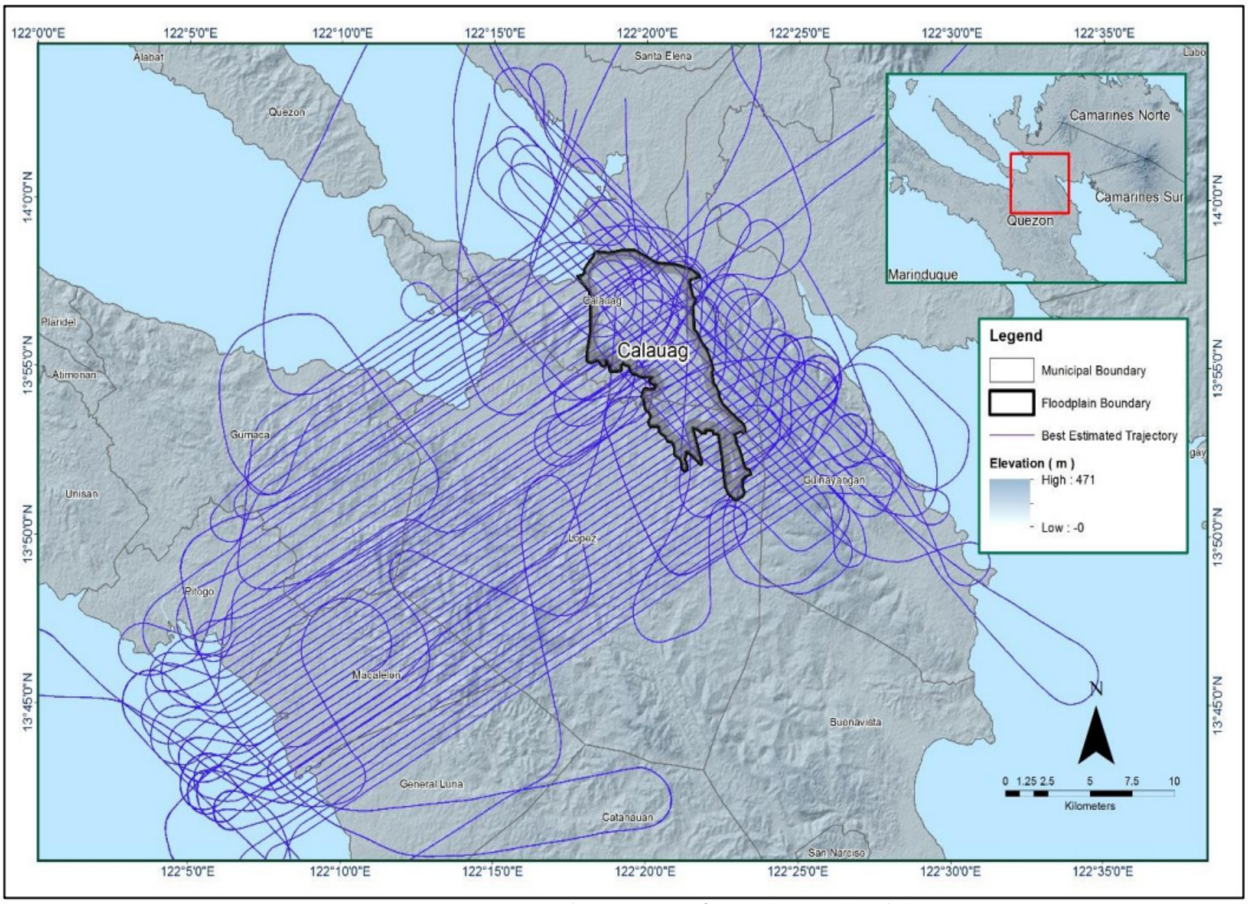


Figure 10. Best Estimated Trajectory for Calauag Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 73 flight lines, with each flight line containing two channels, since the Pegasus system contains two channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Calauag floodplain are given in Table 10.

Table 10. Self-calibration Results values for Calauag flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000384
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000401
GPS Position Z-correction stdev	(<0.01meters)	0.0012

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Calauag Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

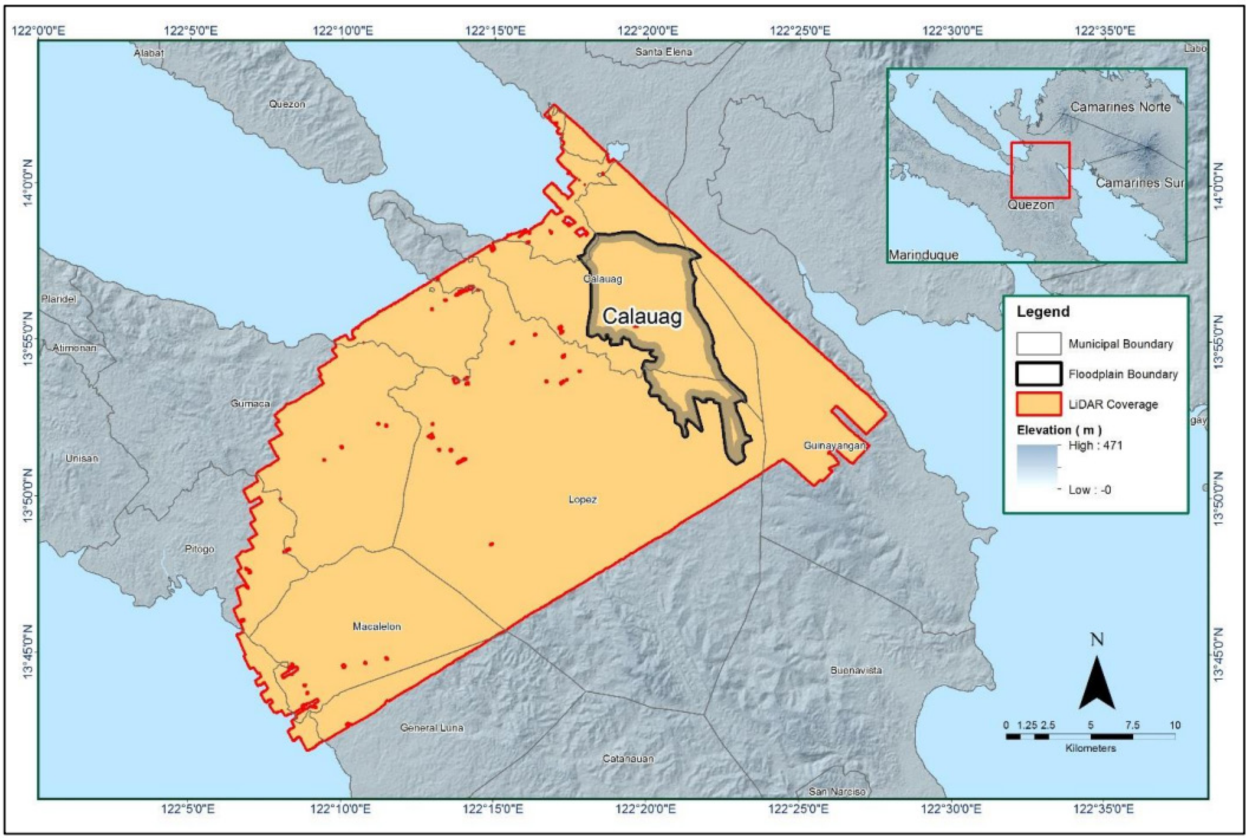


Figure 11. Boundaries of the processed LiDAR data over the Calauag Floodplain.

The total area covered by the Calauag missions is 786.32 sq.km that is comprised of six (6) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Calauag floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bagasbas_Blk21A	23244P	99.14
Bagasbas_Blk21A_supplement	23252P	76.75
Bagasbas_Blk21B	23254P	81.69
	23258P	
Bagasbas_Blk21B_additional	23260P	30.92
	23260P	87.17
Bagasbas_Blk21C	23250P	231.85
Bagasbas_Blk21D	23258P	178.80
TOTAL		786.32 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Pegasus system both 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.

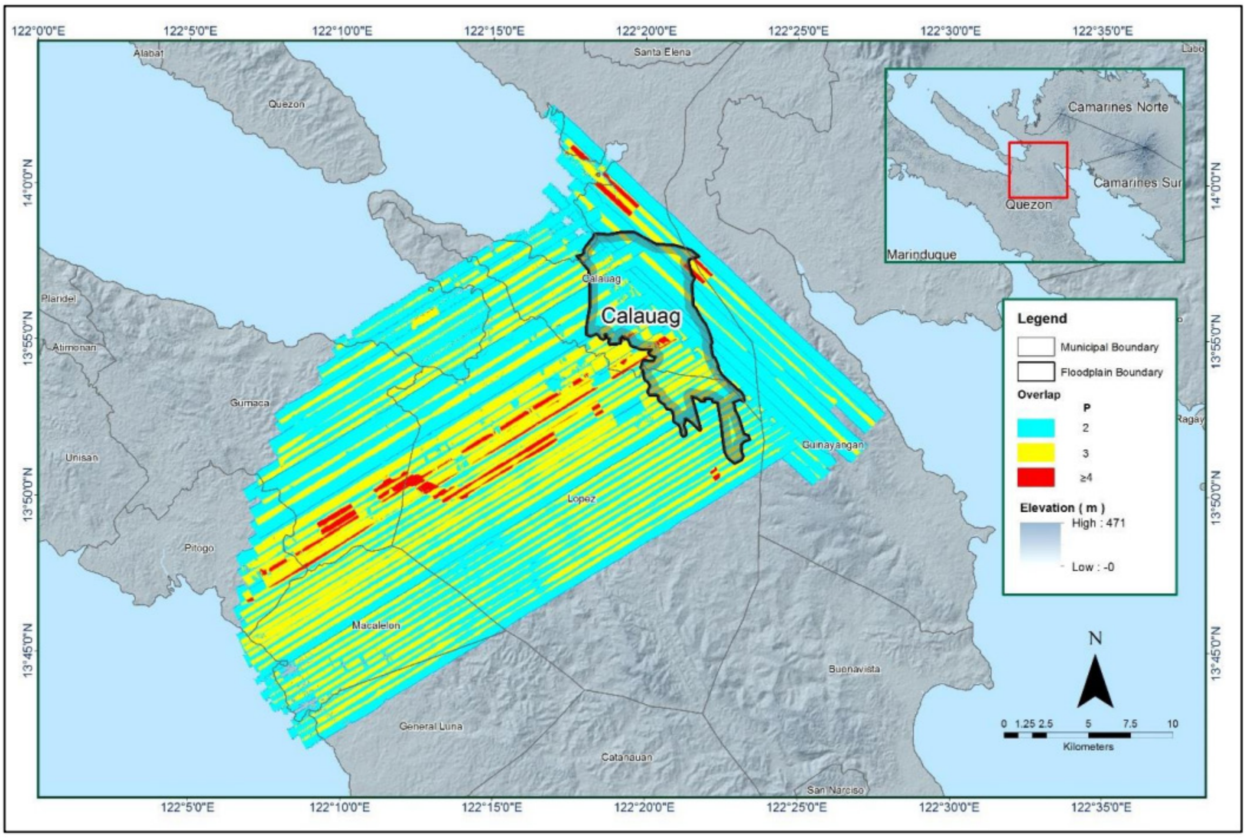


Figure 12. Image of data overlap for Calauag Floodplain.

The overlap statistics per block for the Calauag floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.97% and 97.02% 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 13. It was determined that all LiDAR data for Calauag floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.81 points per square meter.

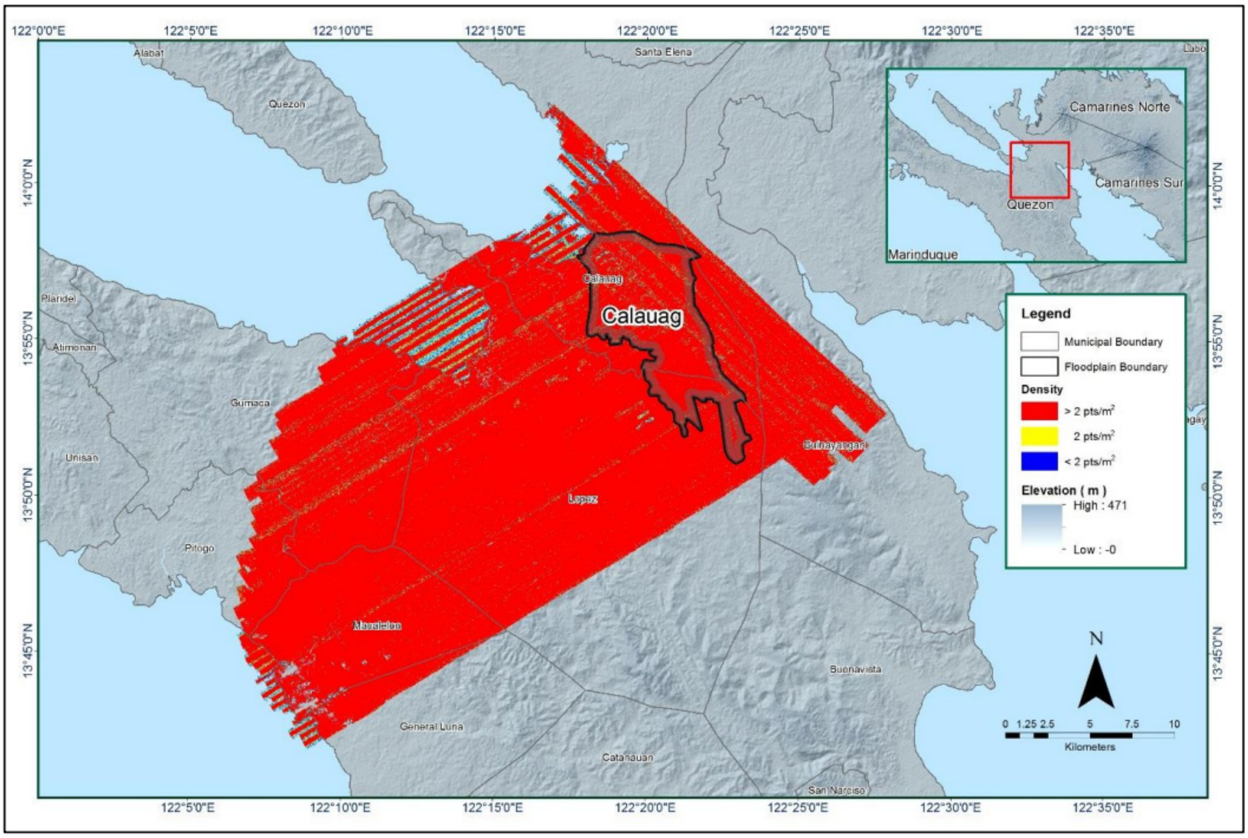


Figure 13. Pulse density map of merged LiDAR data for Calauag Floodplain.

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

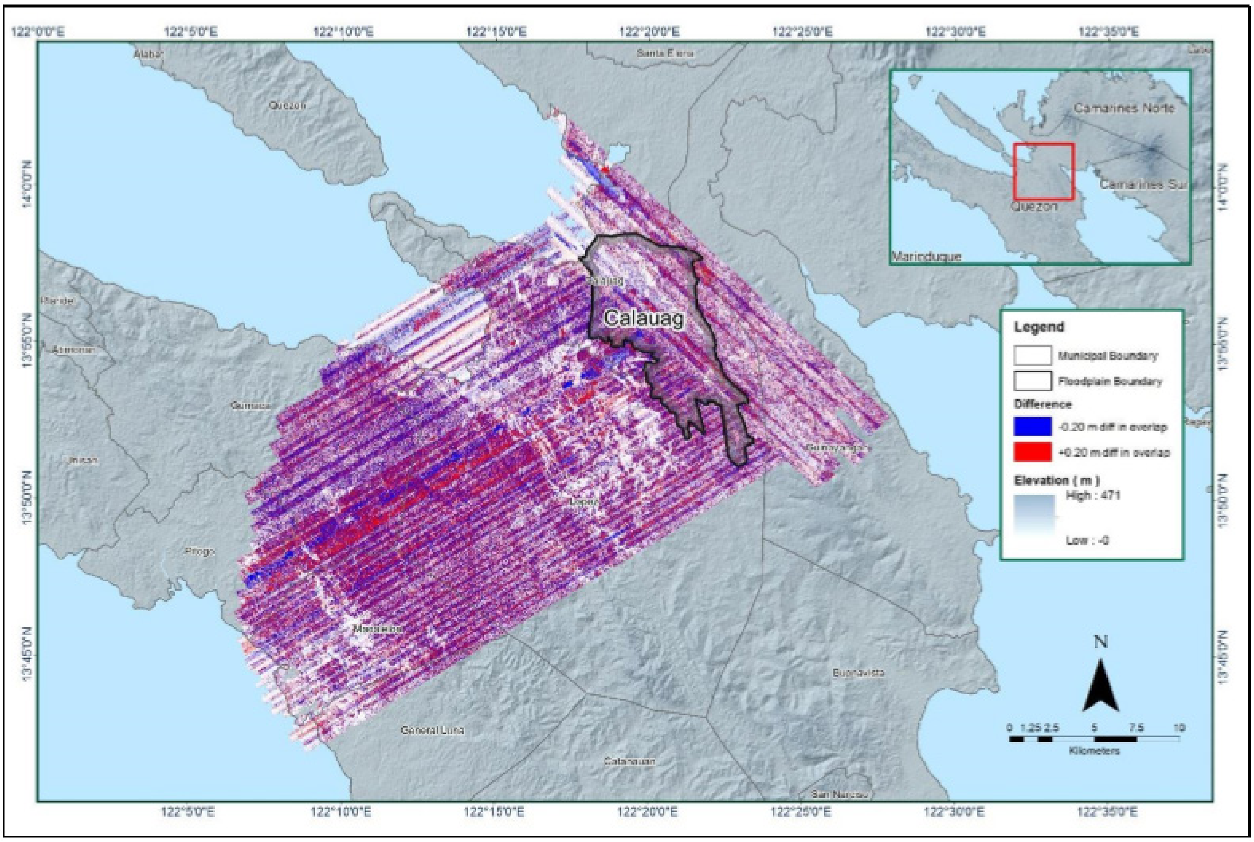


Figure 14. Elevation Difference Map between flight lines for Calauag Floodplain Survey.

A screen capture of the processed LAS data from a Calauag flight 23258P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed 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.

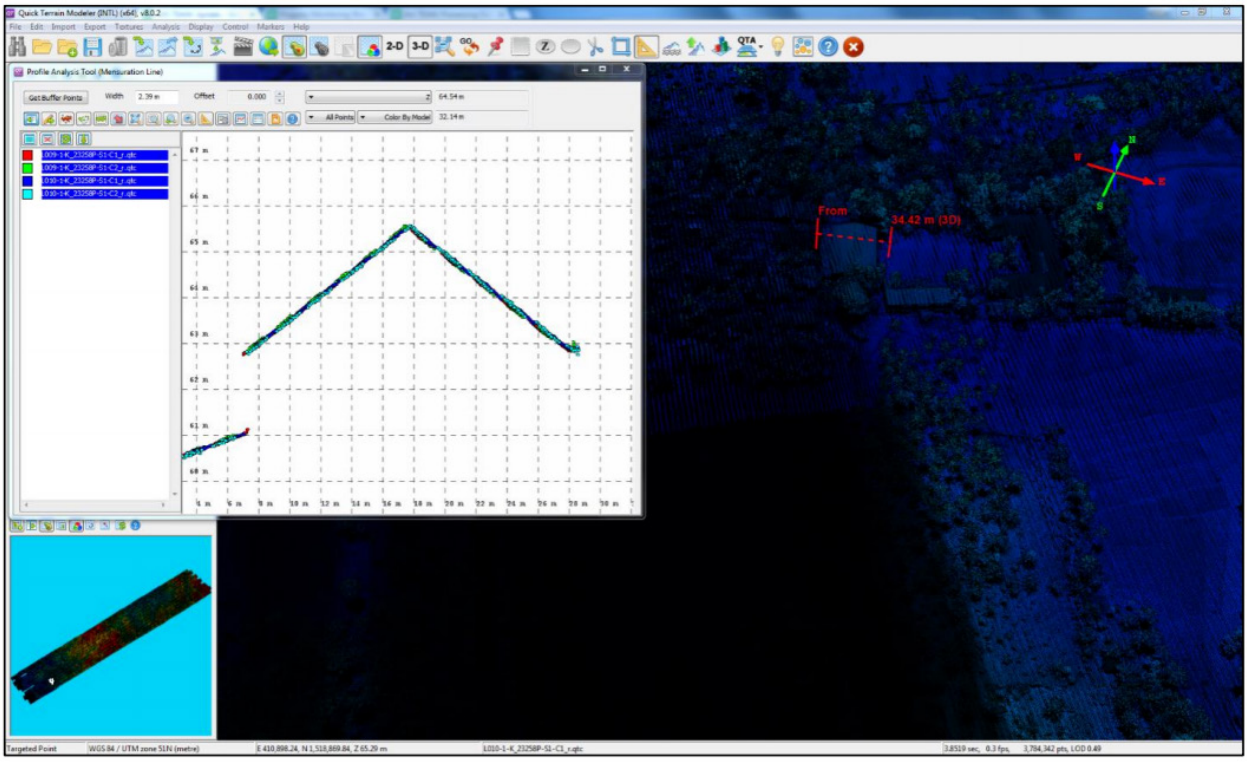


Figure 15. Quality checking for a Calauag flight 23258P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Calauag classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	658,139,063
Low Vegetation	510,356,437
Medium Vegetation	1,332,624,162
High Vegetation	3,663,061,696
Building	54,335,514

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Calauag floodplain is shown in Figure 16. A total of 1,214 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 440.17 meters and 38.84 meters respectively.

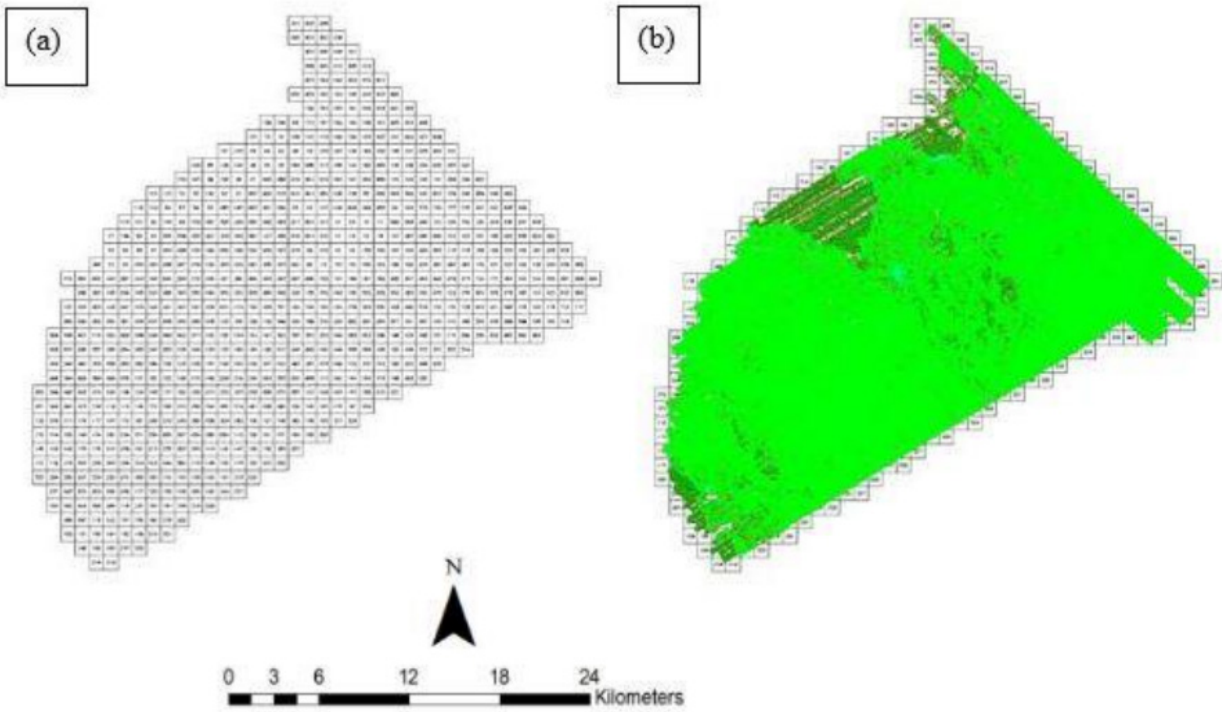


Figure 16. Tiles for Calauag Floodplain (a) and classification results (b) in TerraScan.

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

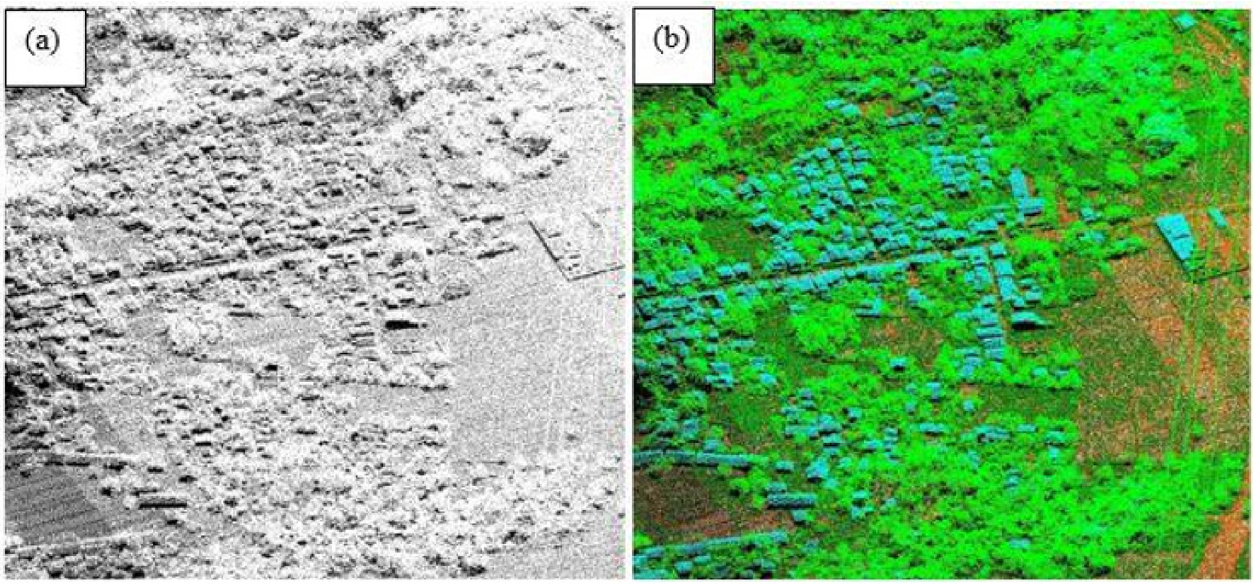


Figure 17. Point cloud before (a) and after (b) classification

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

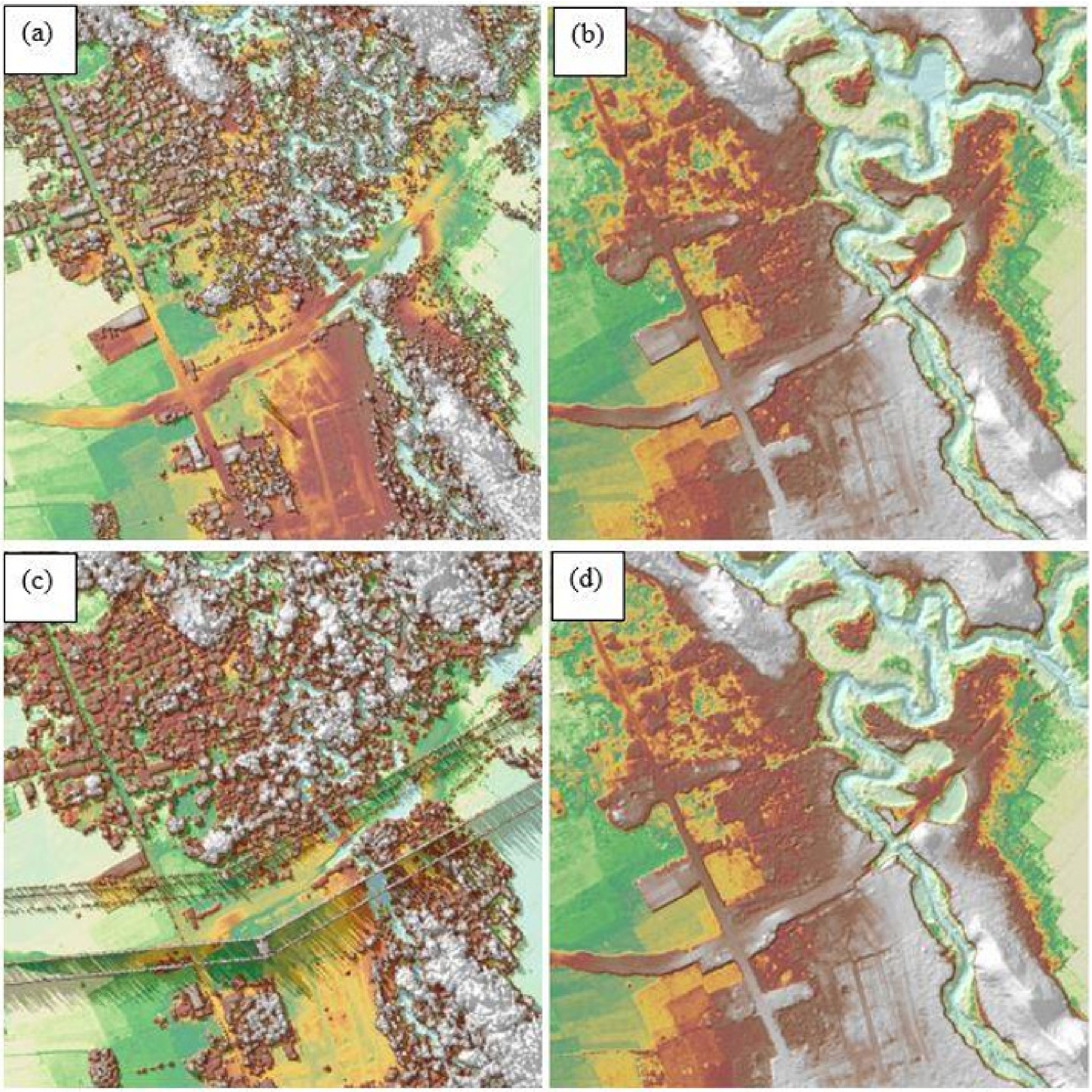


Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Calauag Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 706 1km by 1km tiles area covered by Calauag floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Calauag floodplain has a total of 409.86 sq.km orthophotogaph coverage comprised of 1,976 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 19.

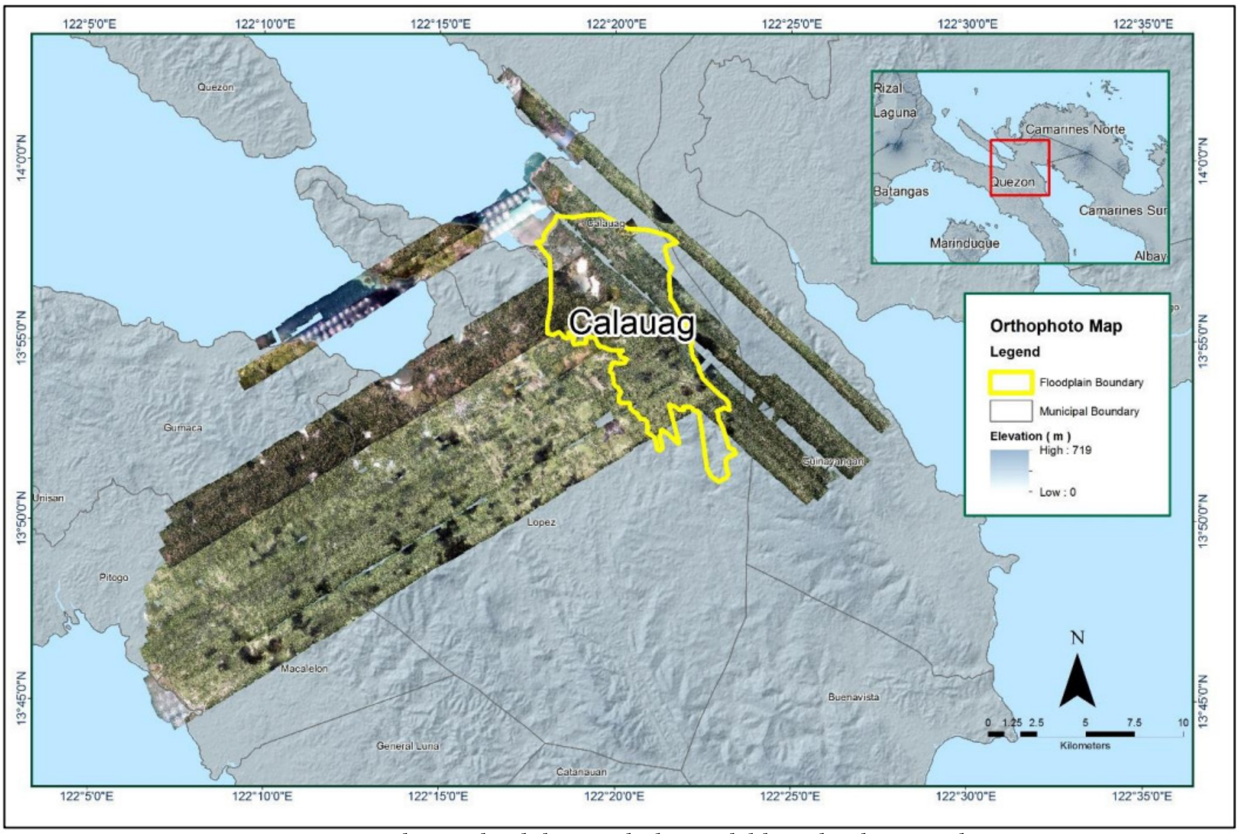


Figure 19. Calauag Floodplain with the available orthophotographs.

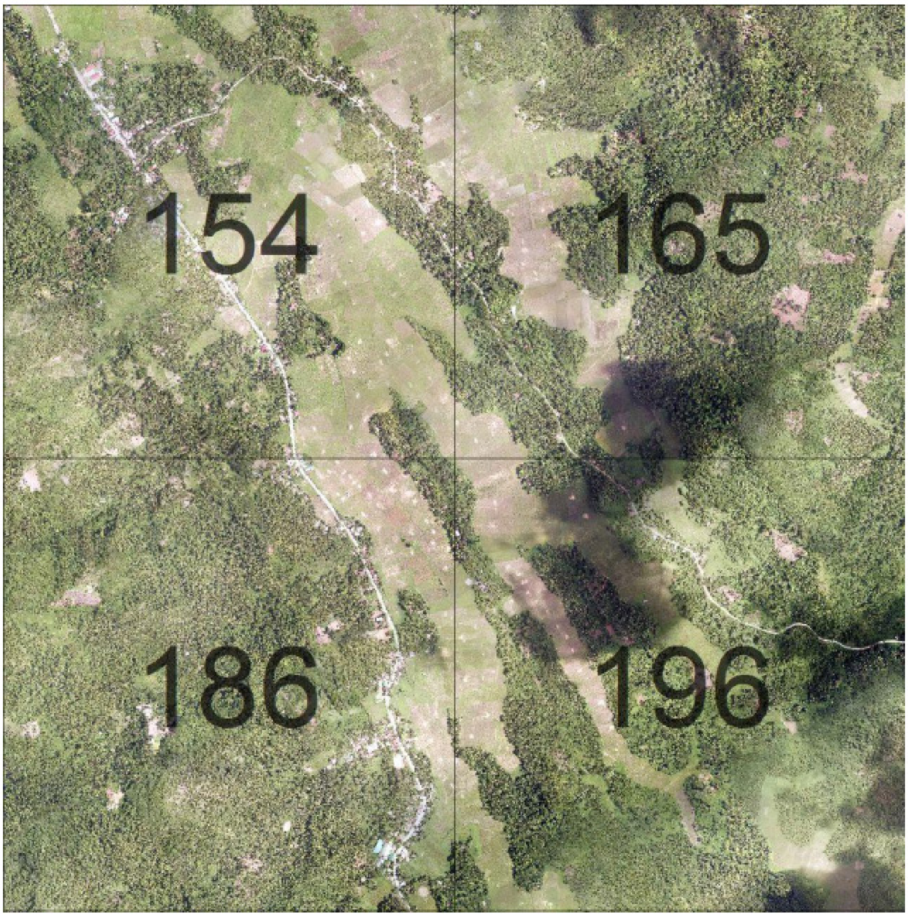


Figure 20. Sample orthophotograph tiles for Calauag Floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Calauag flood plain. These blocks are composed of Bagasbas blocks with a total area of 786.32 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Bagasbas_Blk21A	99.14
Bagasbas_Blk21A_supplement	76.75
Bagasbas_Blk21B	81.69
Bagasbas_Blk21B_additional	30.92
Bagasbas_Blk21B_supplement	87.17
Bagasbas_Blk21C	231.85
Bagasbas_Blk21D	178.80
TOTAL	786.32 sq.km

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. Some data in the mountainous areas were removed in the DTM after classification (Figure 21c) and has to be retrieved to complete the surface (Figure 21d).

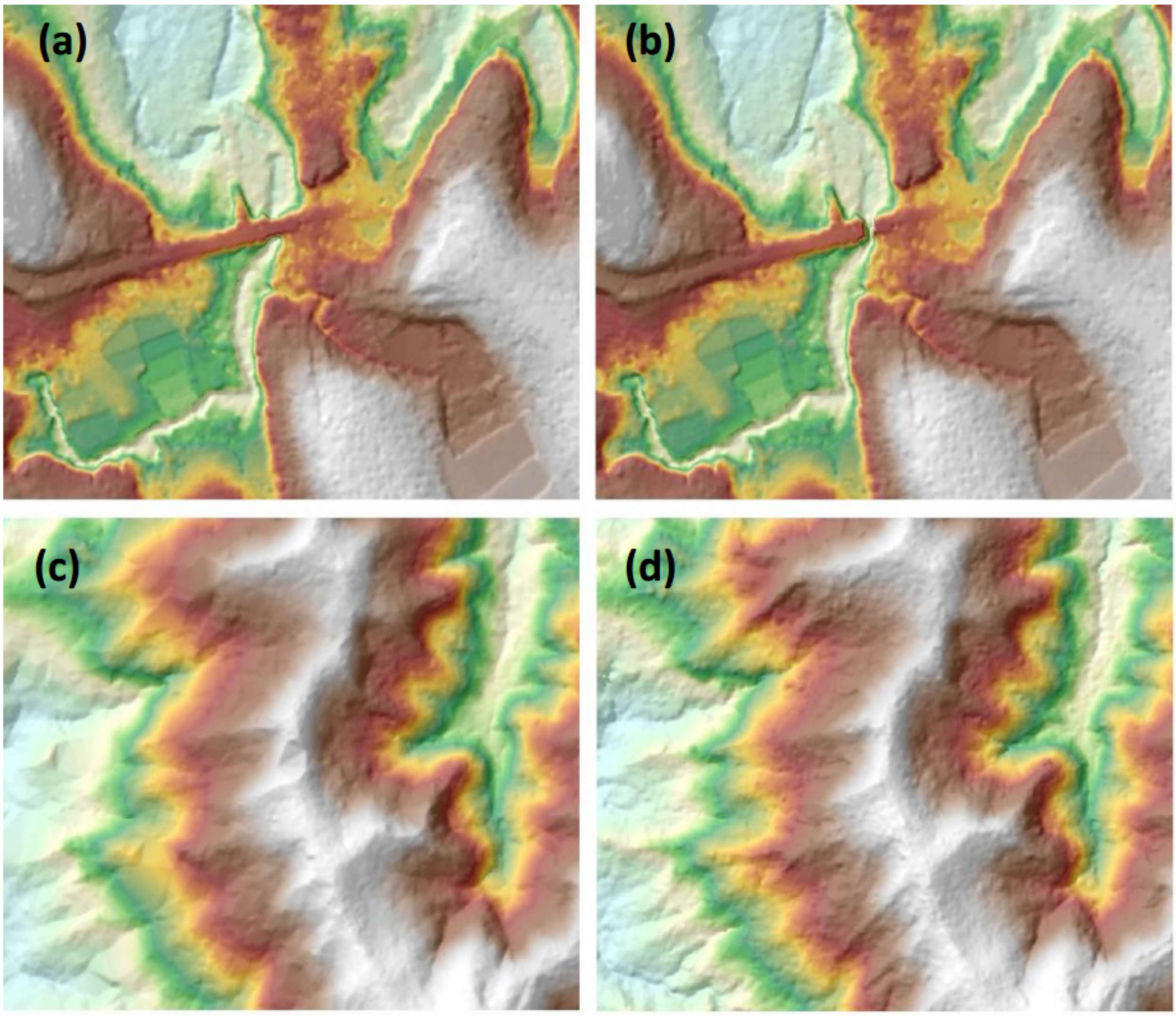


Figure 21. Portions in the DTM of Calauag Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Bagasbas_Blk20F was used as the reference block at the start of the mosaicking because this block is the one at the uppermost right of Bagasbas blocks that have common validation points. Bagasbas_Blk21A is the block nearest from the base block that overlaps the Calauag flood plain. Bagasbas blocks Blk21B and Blk21B_additional were each divided into upper and lower parts. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Calauag floodplain is shown in Figure 22. It can be seen that the entire Calauag floodplain is 100% covered by LiDAR data.

Table 14. Shift values of each LiDAR block of Calauag Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Bagasbas_Blk21A	-3.24	1.76	-0.05
Bagasbas_Blk21A_supplement	-3.24	1.76	0.4
Bagasbas_Blk21B (upper)	-2.47	3.00	0.07
Bagasbas_Blk21B (lower)	-2.47	3.00	-0.03
Bagasbas_Blk21B_additional (upper)	-2.47	3.00	0.07
Bagasbas_Blk21B_additional (lower)	-2.47	3.00	-0.03
Bagasbas_Blk21B_supplement	-2.43	-0.64	0.07
Bagasbas_Blk21C	-3.27	2.46	-0.1
Bagasbas_Blk21D	-1.27	-1.07	0.1

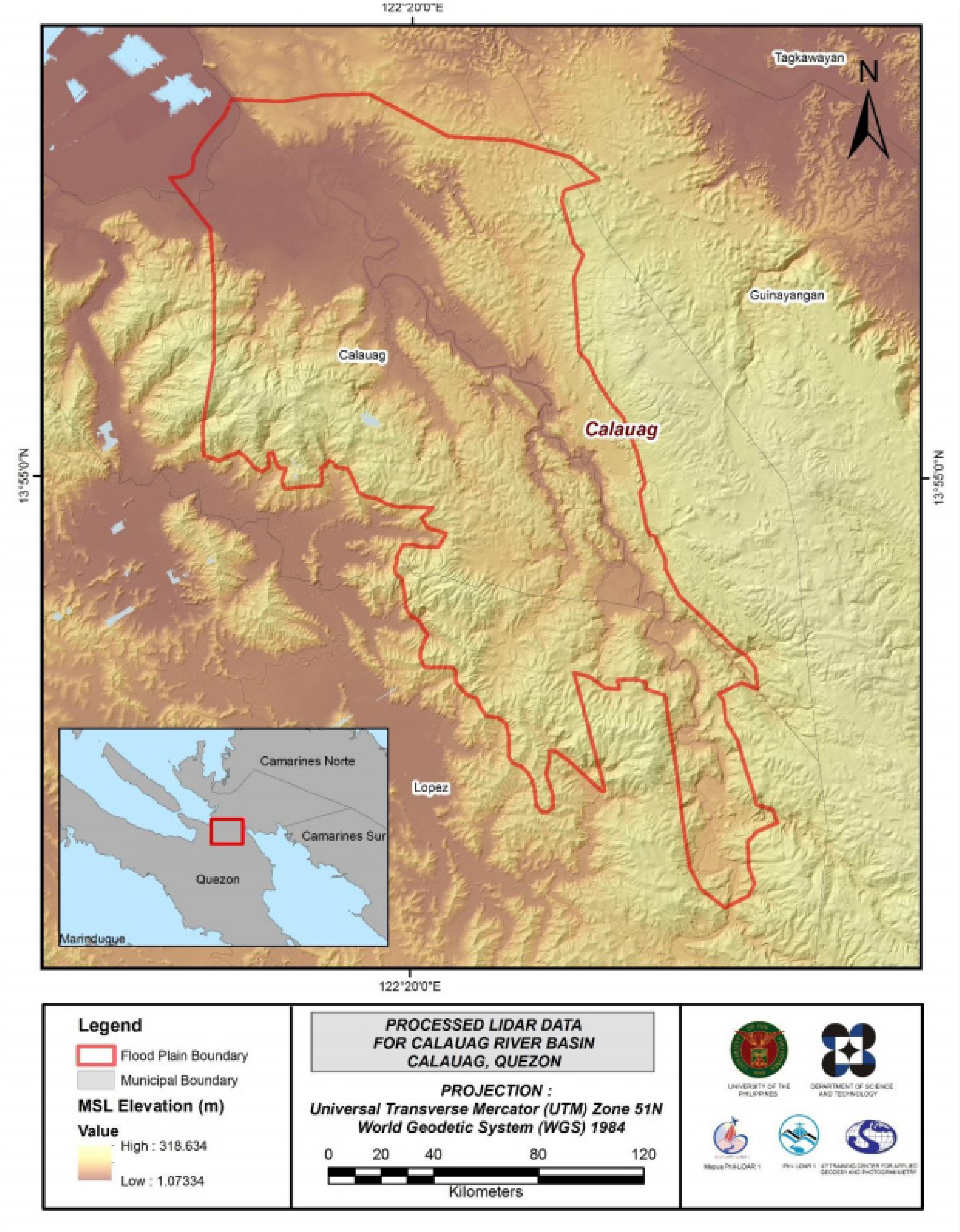


Figure 22. Map of processed LiDAR data for Calaaug Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Calauag to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 15,500 survey points were gathered for all the flood plains within the provinces of Quezon and Camarines Sur wherein the Calauag floodplain is located. Random selection of 80% of the survey points, resulting to 12,400 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 3.08 meters with a standard deviation of 0.17 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 3.08 meters, to the mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

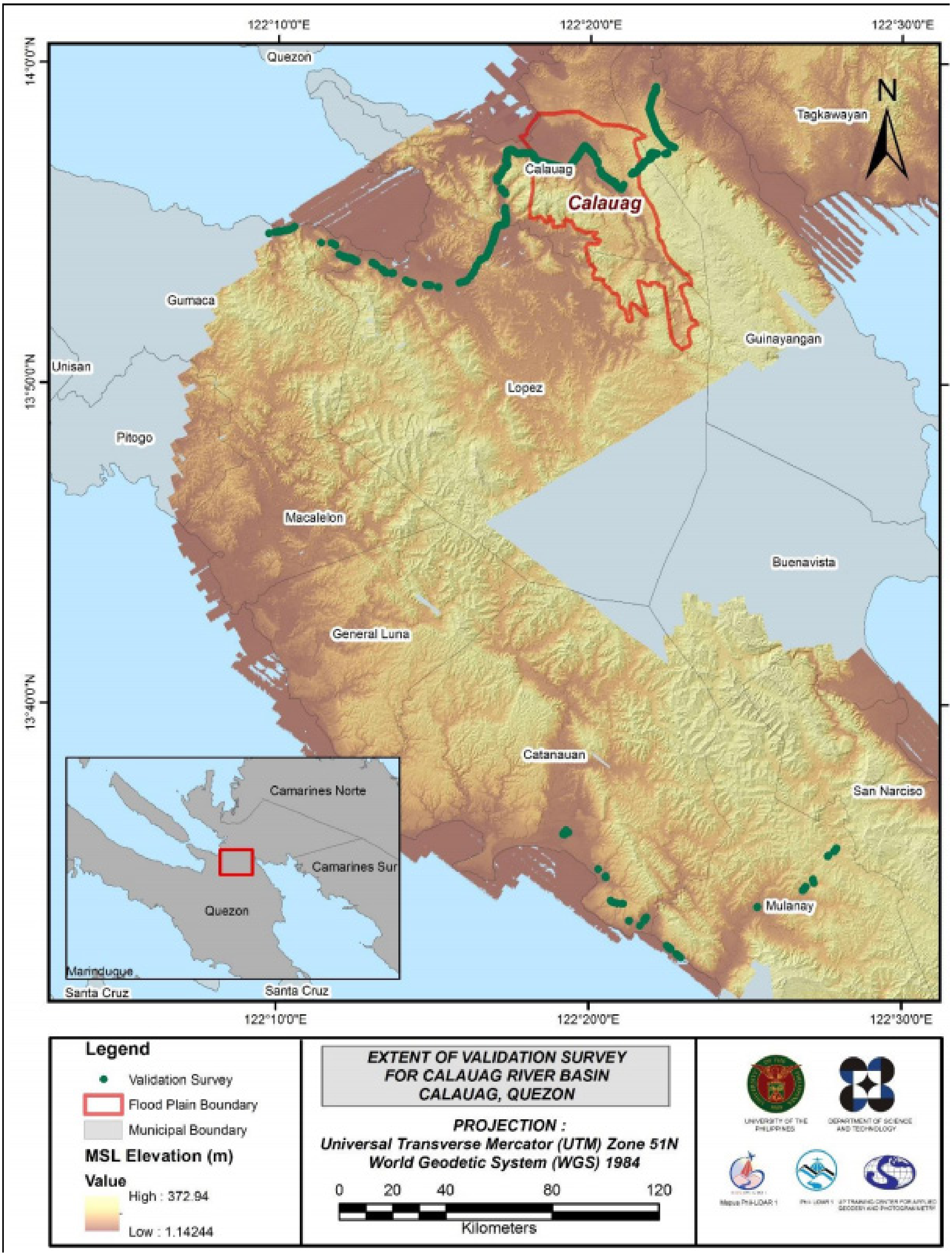


Figure 23. Map of processed LiDAR data for Calaaug Floodplain.

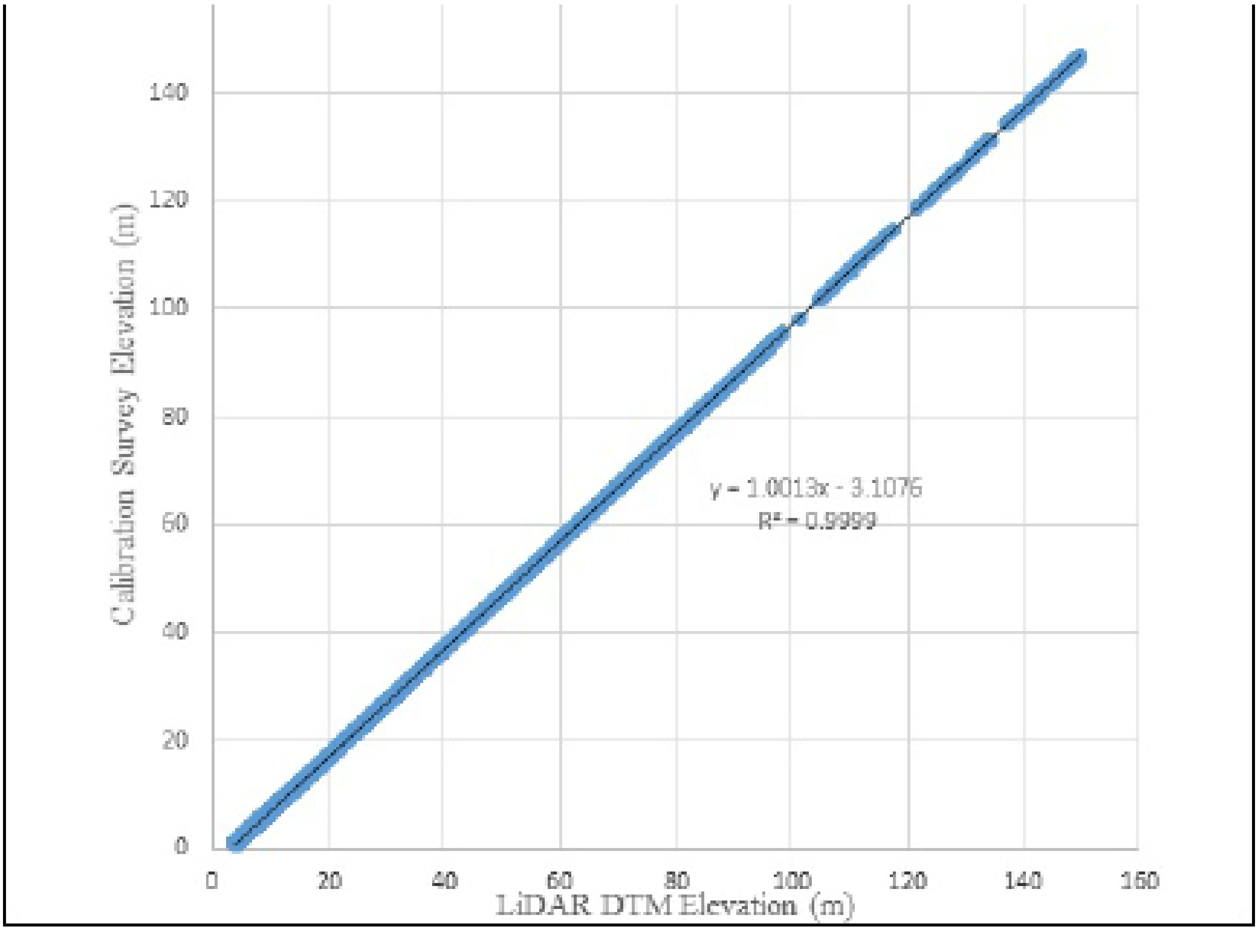


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	3.08
Standard Deviation	0.17
Average	-3.07
Minimum	-3.40
Maximum	-2.60

The remaining 20% of the total survey points that are near Calauag flood plain, resulting to 477 points, were used for the validation of calibrated Calauag DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.06 meters, as shown in Table 16.

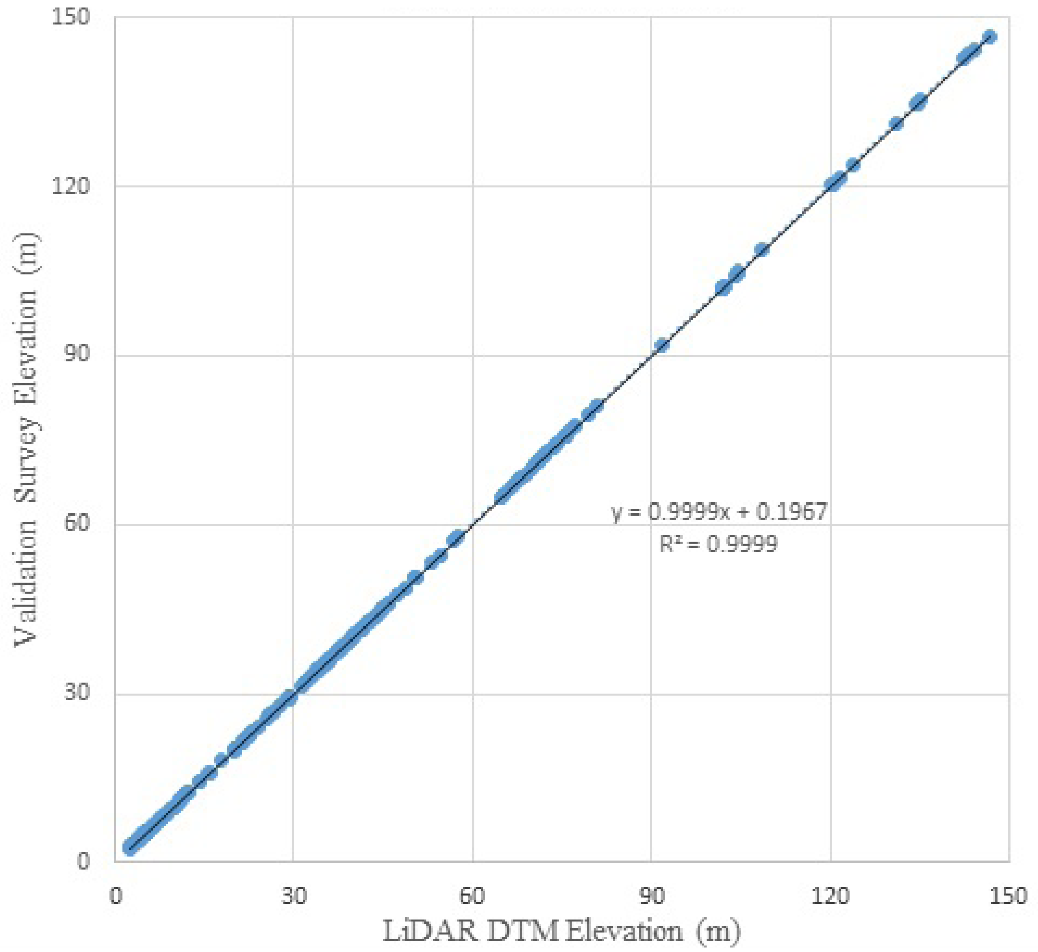


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.06
Average	0.19
Minimum	0.04
Maximum	0.29

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Calauag with 7107 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 0.47 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Calauag integrated with the processed LiDAR DEM is shown in Figure 26.

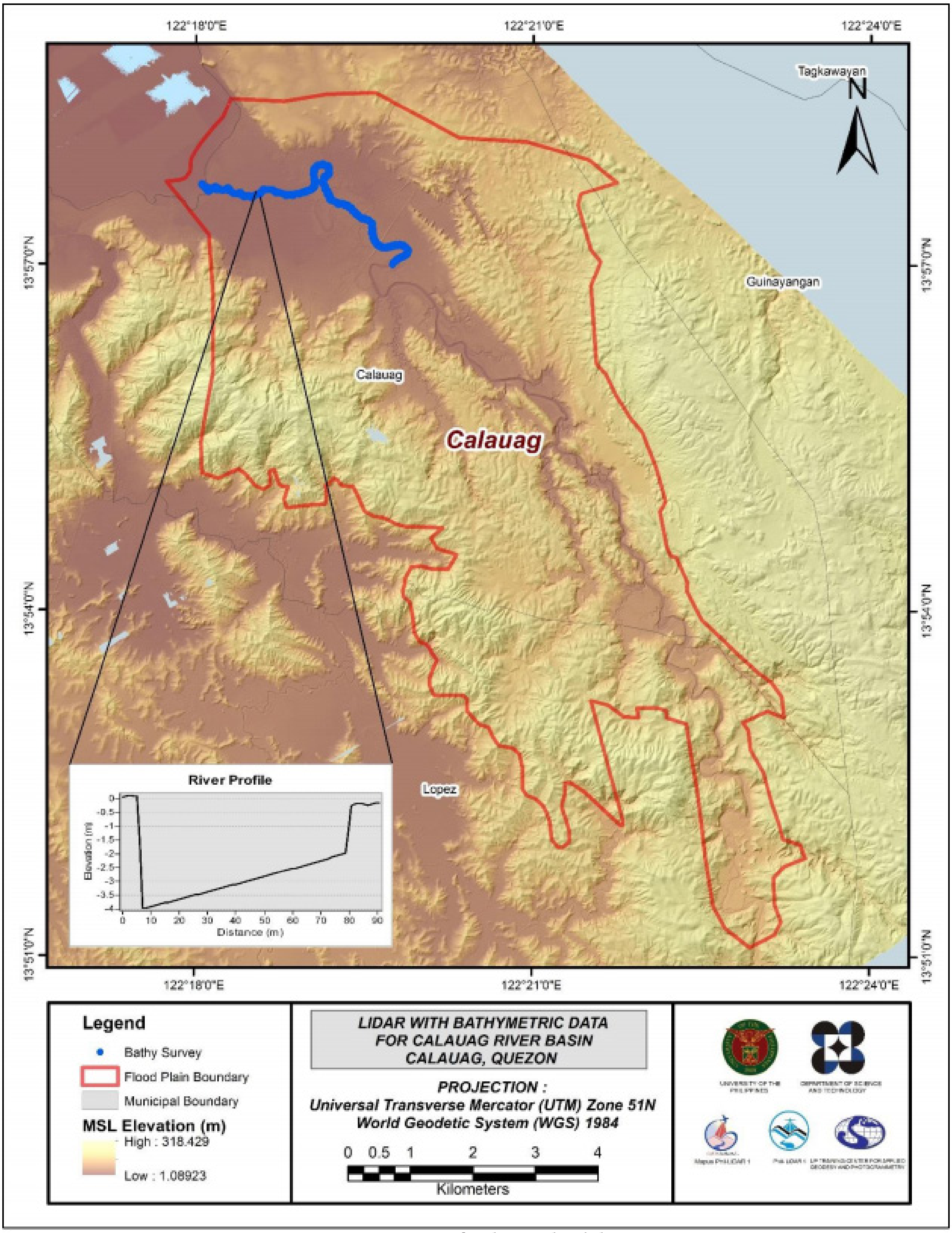


Figure 26. Map of Calauag Floodplain.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Calauag floodplain, including its 200 m buffer, has a total area of 71.17 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 717 building features, are considered for QC. Figure 27 shows the QC blocks for Calauag floodplain.

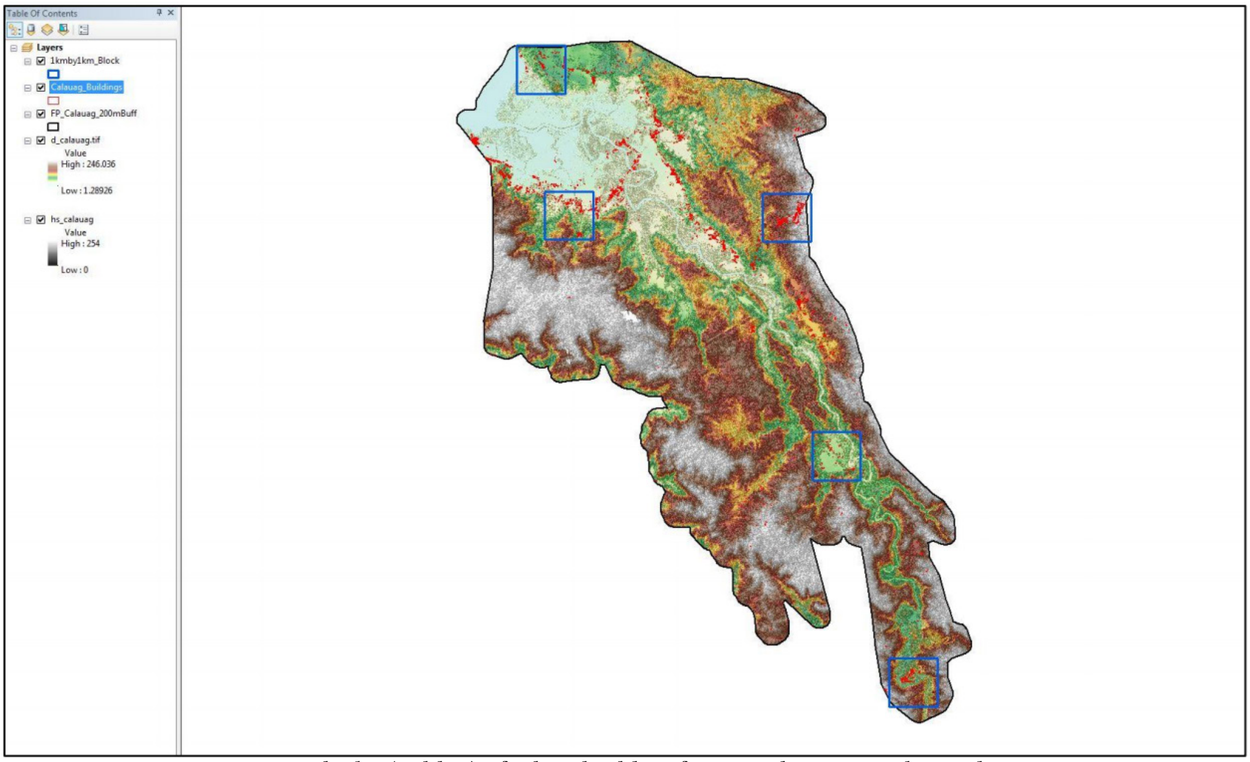


Figure 27. Blocks (in blue) of Silaga building features that were subjected to QC

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

Table 17. Quality Checking Ratings for Silaga Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Calauag	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 3014 building features in Calauag floodplain. Of these building features, 280 were filtered out after height extraction, resulting to 2734 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 6.63 m.

3.12.3 Feature Attribution

The attributes were obtained by field data gathering. GPS devices were used to determine the coordinates of important features. These points are uploaded and overlaid in ArcMap and are then integrated with the shapefiles.

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

Table 18. Building features extracted for Calauag Floodplain.

Facility Type	No. of Features
Residential	2,668
School	35
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	6
Barangay Hall	5
Military Institution	0
Sports Center/Gymnasium/Covered Court	6
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	7
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	1
Other Commercial Establishments	6
Total	2,734

Table 19. Total length of extracted roads for Calauag Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Calauag	28.53	0	6.01	12.58	0.00	47.12

Table 20. Number of extracted water bodies for Calauag Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Calauag	6	0	0	0	0	6

A total of 16 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

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

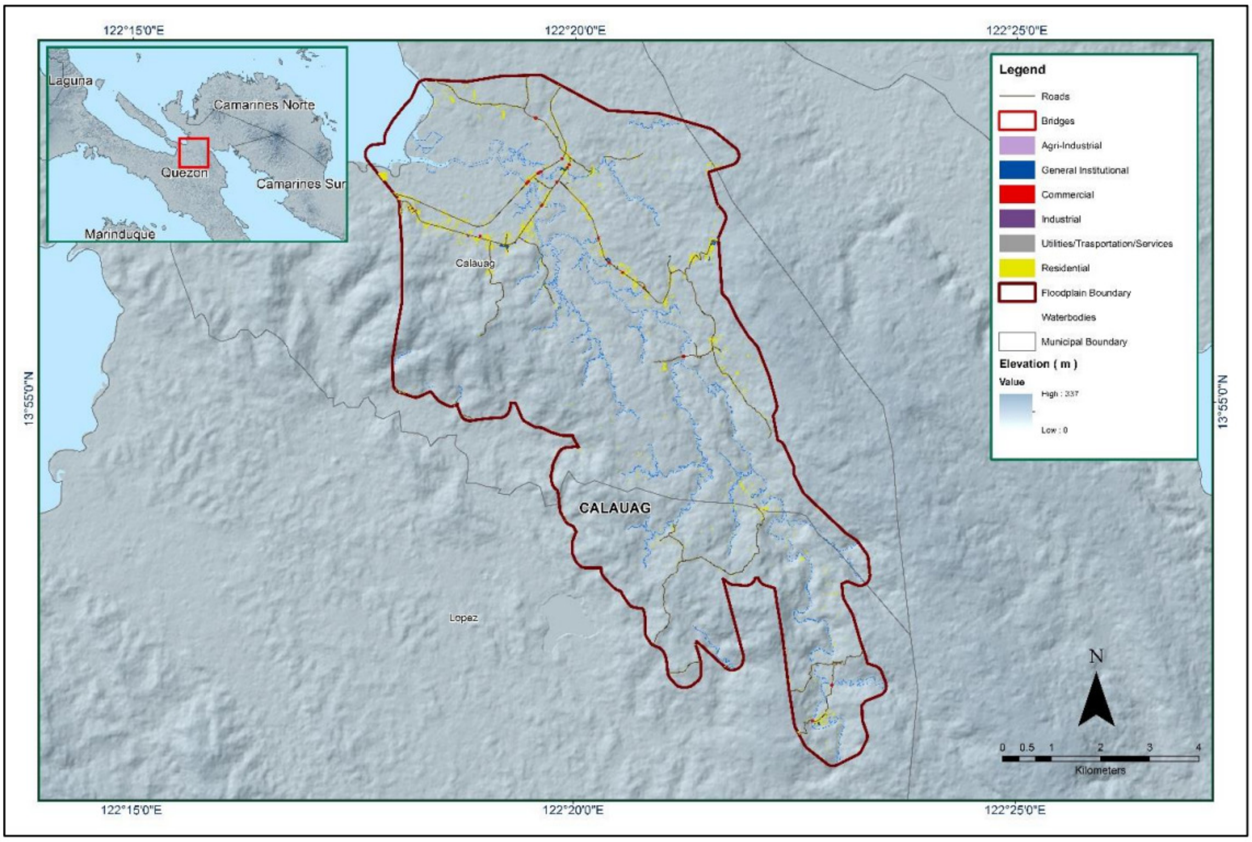


Figure 28. Extracted features of the Calauag Floodplain.

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

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

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

4.1 Summary of Activities

DVBC conducted a field survey in Sumulong River on May 2-16, 2016 with the following scope of work: reconnaissance; control survey; cross-section ans as-built survey at Sumulong Bridge in Brgy. Sumilang; validation points acquisition of about 67 km covering the Sumulong River Basin area; and bathymetric survey from its upstream in Brgy. Mabini down to the mouth of the river in Brgy. Bungkuruhn and Biyan, both in the Municipality of Calauag, with an approximate length of 4.995 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique.

Figure 29. Extent of the bathymetric survey (in blue line) in Calauag River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Sumulong River Basin is composed of nine (9) loops established on May 4 and 11, 2016 occupying the following reference points: QZN-40, a second-order GCP in Brgy. San Jose, Municipality of General Luna; QZN-43, a second-order GCP in Brgy. Matandang Sabang Silangan, Municipality of Catanauan; QZN-47, a second order GCP in Barangay II, Municipality of Mulanay; and QZ-415, a BM with Accuracy Class at 95% CL 8cm in Brgy. Pansol, Municipality of Lopez.

There are four (4) UP established control points located at the approach of bridges namely: UP-KAN, at Kanguinsa Bridge in Brgy. Silongin, Municipality of San Francisco; UP-TAL at Talisay Bridge in Brgy. Pagsangahan, also in the Municipality of San Francisco; and UP-VIG at Vigo Bridge in Brgy. Vigo Central, Municipality of San Narciso. The UP established control point UP-CAB is located in a residential court in Brgy. Aloneros, Municipality of Guinayangan. A NAMRIA established control point QZN-41 in Barangay I, Municipality of Calauag was also occupied and used as marker for the network.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 30.

Figure 30. The GNSS Network established in the Calauag River Survey.

Table 21. References used and control points established in the Calauag River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
QZN-40	2nd Order, GCP	13°41'32.47595" N	122°10'25.77273" E	51.703	-	2006
QZN-43	2nd Order, GCP	13°35'55.81611" N	122°19'13.53031" E	51.015	-	2006
QZN-47	2nd Order, GCP	13°31'29.52488" N	122°24'23.44821" E	53.862	-	2006
QZ-415	1st order Order, BM	-	-	57.290	8.613	2007
QZN-41	Used as Marker	-	-	-	-	2006
UP-CAB	UP Established	-	-	-	-	05-04-2016
UP-KAN	UP Established	-	-	-	-	05-11-2016
UP-TAL	UP Established	-	-	-	-	05-11-2016
UP-VIG	UP Established	-	-	-	-	05-11-2016

Figure 31 to Figure 39 depict the setup of the GNSS on recovered reference points and established control points in the Calauag River.

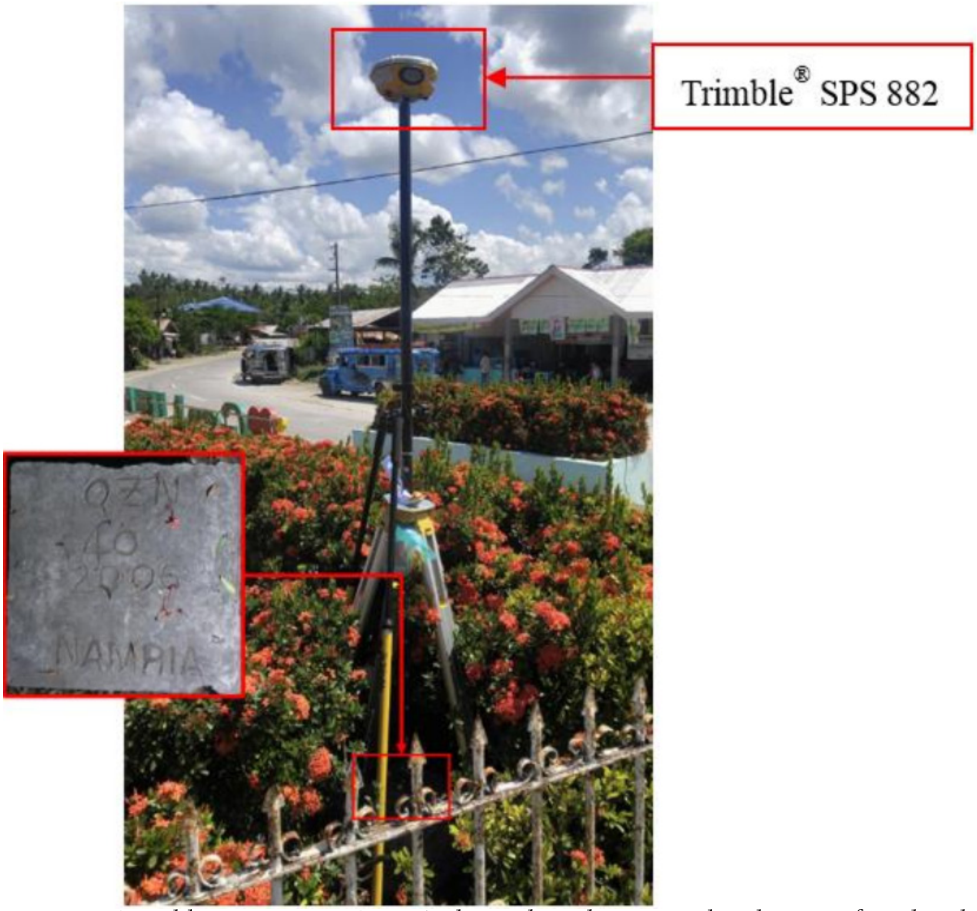


Figure 31. GNSS base set up, Trimble® SPS 882, at QZN-40, located inside a triangular plant area found at the center of a triangular island in Brgy. San Jose, Municipality of Gen. Luna, Quezon

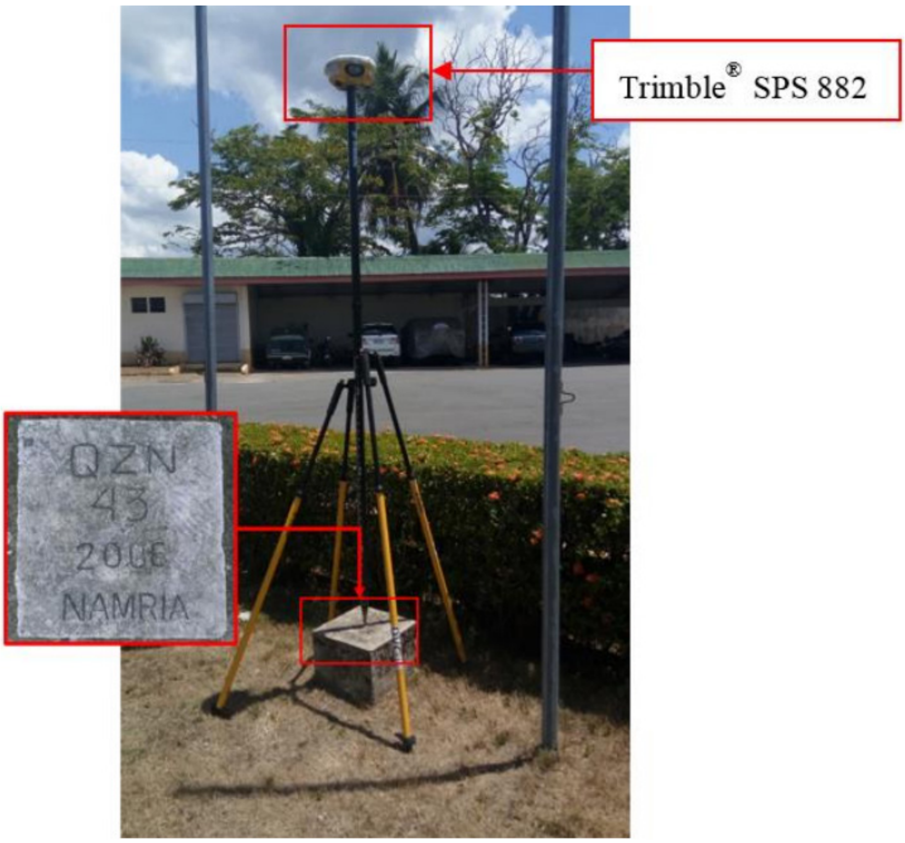


Figure 32. GNSS base set up, Trimble® SPS 882, at QZN-43, located inside the DPWH compound in Brgy. Matandang Sabang Silangan, Municipality of Catanauan, Quezon

Figure 33. GNSS base set up, Trimble® SPS 852, at QZN-47, located at the back of the Principal's Office of Mulanay Elementary School in Barangay II, Municipality of Mulanay, Quezon.

Figure 34. GNSS base set up, Trimble® SPS 985, at QZ-415, located at the approach of Pansol Bridge in Brgy. Pansol, Municipality of Lopez, Quezon.

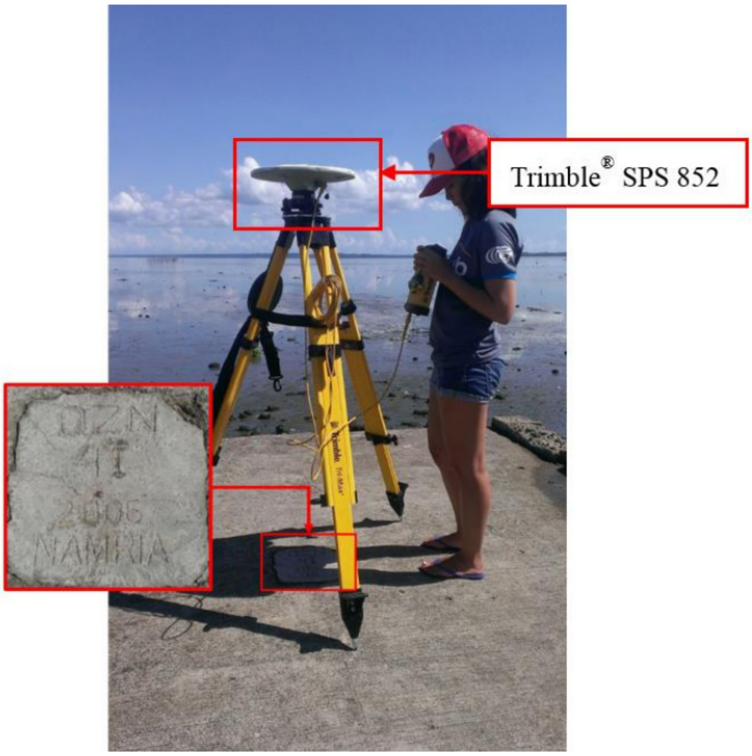


Figure 35. GNSS base set up, Trimble® SPS 852, at QZN-41, located in front of Brgy. Sabang basketball court found in Calauag Port, Barangay I, Municipality of Calauag, Quezon.

Figure 36. GNSS base set up, Trimble® SPS 882, at UP-CAB, located inside a basketball court in Brgy. Aloneros, Municipality of Guinayangan, Quezon.

Figure 37. GNSS base set up, Trimble® SPS 852, at UP-KAN, located at the approach of Kanguinsa Bridge in Brgy. Silongin, Municipality of San Francisco, Quezon

Figure 38. GNSS base set up, Trimble® SPS 852, at UP-TAL, located at the approach of Talisay Bridge in Brgy. Pagsangahan, Municipality of San Francisco, Quezon

Figure 39. GNSS base set up, Trimble® SPS 882, at UP-VIG, located at the approach of Vigo Bridge in Brgy. Vigo Central, Municipality of San Francisco, 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 +/- 20 cm and +/- 10 cm 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 Calauag River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline processing report for the Calauag River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
QZN-47 --- QZN-40	05-11-2016	Fixed	0.003	0.011	306°22'36"	31263.486	
QZN-47 --- QZN-43	05-11-2016	Fixed	0.003	0.013	131°16'56"	12401.416	
QZN-47 --- UP-VIG	05-11-2016	Fixed	0.003	0.012	103°58'19"	23335.323	
QZN-47 --- UP-KAN	05-11-2016	Fixed	0.005	0.019	146°21'08"	28388.037	
QZN-40 --- QZ-415	05-11-2016	Fixed	0.003	0.023	14°21'16"	22613.475	
UP-CAB --- QZ-415	05-04-2016	Fixed	0.004	0.025	234°09'16"	19401.067	
QZN-40 --- UP-KAN	05-11-2016	Fixed	0.011	0.027	135°49'24"	58749.581	
QZN-43 --- QZ-415	05-11-2016	Fixed	0.006	0.033	342°23'19"	33841.349	
QZN-43 --- UP-KAN	05-11-2016	Fixed	0.005	0.018	141°46'15"	40492.330	
UP-TAL --- UP-KAN	05-11-2016	Fixed	0.005	0.018	312°01'33"	16293.271	
UP-VIG --- UP-TAL	05-11-2016	Fixed	0.003	0.014	169°50'51"	29356.882	
UP-VIG --- QZN-43	05-11-2016	Fixed	0.003	0.014	293°25'54"	34821.073	
UP-VIG --- UP-KAN	05-11-2016	Fixed	0.005	0.021	201°04'03"	19280.526	
QZN-41 --- UP-CAB	05-04-2016	Fixed	0.004	0.024	247°44'12"	10141.643	
QZN-41 --- QZ-415	05-04-2016	Fixed	0.003	0.022	220°07'13"	9835.756	
QZN-40 --- QZN-43	05-11-2016	Fixed	0.003	0.014	303°07'59"	18937.828	
UP-CAB --- QZN-43	05-11-2016	Fixed	0.004	0.019	7°10'02"	43963.480	

As shown in Table 22, a total of seventeen (17) baselines were processed with reference points QZN-40, QZN-43 and QZN-47 fixed for grid values; and QZ-415 held fixed for elevation. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table 24 of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

where:

xe is the Easting Error,

ye is the Northing Error, and

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for the complete details.

The nine (9) control points, QZN-40, QZN-43, QZN-47, QZ-415, QZN-41, UP-CAB, UP-KAN, UP-TAL and UP-VIG were occupied and observed simultaneously to form a GNSS loop. Elevation value of QZ-415 and coordinates of points QZN-40, QZN-43 and QZN-47 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Constraints applied to the adjustment of the control points.

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)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control points CNS-21 and CA-130 has no values for grid and elevation errors, respectively.

Table 24. Adjusted grid coordinates for the control points used in the Calauag River Flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
QZN-40	410660.624	?	1513855.137	?	2.622	0.075	LL
QZN-43	426485.118	?	1503462.996	?	1.574	0.073	LL
QZN-47	435778.405	?	1495257.875	?	4.163	0.079	LL
QZ-415	416340.495	0.010	1535736.431	0.010	8.613	?	e
QZN-41	422699.129	0.014	1543236.263	0.014	1.392	0.082	
UP-CAB	432091.726	0.012	1547052.366	0.013	3.211	0.073	
UP-KAN	451445.231	0.012	1471596.832	0.011	25.095	0.086	
UP-TAL	463529.271	0.016	1460676.916	0.014	4.949	0.095	
UP-VIG	458401.312	0.010	1489570.998	0.008	6.030	0.083	

The network is fixed at reference points QZN-40, QZN-43, and QZN-47 with known coordinates, and QZ-415 with known elevation. As shown in Table 24, the standard errors (xe and ye) of QZ-415 are 1.0 cm and 1.0 cm. With the mentioned equation, $\sqrt{(x_e)^2+(y_e)^2}<20cm$ for horizontal and $z_e<10$ cm for the vertical; the computation for the accuracy of the reference and control points are as follows:

a.	QZN-40		
	horizontal accuracy	=	Fixed
	vertical accuracy	=	7.5 cm < 10 cm
b.	QZN-43		
	horizontal accuracy	=	Fixed
	vertical accuracy	=	7.3 cm < 10 cm
c.	QZN-47		
	horizontal accuracy	=	Fixed
	vertical accuracy	=	7.9 cm < 10 cm
d.	QZ-415		
	horizontal accuracy	=	$\surd((1.\ 0)^2 + (1.0)^2$
		=	$\surd\ (1.0 + 1.0)$
		=	1.41cm < 20 cm
	vertical accuracy	=	Fixed
e.	QZN-41		
	horizontal accuracy	=	$\surd((1.40)^2 + (1.40)^2$
		=	$\surd\ (1.96+ 1.96)$
		=	1.98cm < 20 cm
	vertical accuracy	=	8.2 cm < 10 cm
f.	UP-CAB		
	horizontal accuracy	=	$\surd((1.20)^2 + (1.30)^2$
		=	$\surd\ (1.44 + 1.69)$
		=	1.77 cm < 20 cm
	vertical accuracy	=	7.3 cm < 10 cm
g.	UP-KAN		
	horizontal accuracy	=	$\surd((1.20)^2 + (1.10)^2$
		=	$\surd\ (1.44 + 1.21)$
		=	1.63 cm < 20 cm
	vertical accuracy	=	8.6 cm < 10 cm
	vertical accuracy		= 9.5 cm < 10 cm
h.	UP-TAL		
	horizontal accuracy	=	$\surd((1.60)^2 + (1.40)^2$
		=	$\surd\ (2.56 + 1.96)$
		=	2.13 cm < 20 cm
	vertical accuracy	=	9.5 cm < 10 cm
i.	UP-VIG		
	horizontal accuracy	=	$\surd((1.10)^2 + (0.80)^2$
		=	$\surd\ (1.21 + 0.64)$
		=	1.36 cm < 20 cm
	vertical accuracy	=	8.3 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 25. Adjusted geodetic coordinates for control points used in the Calauag River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
QZN-40	N13°41'32.47595"	E122°10'25.77273"	51.703	0.075	LL
QZN-43	N13°35'55.81611"	E122°19'13.53031"	51.015	0.073	LL
QZN-47	N13°31'29.52488"	E122°24'23.44821"	53.862	0.079	LL
QZ-415	N13°53'25.29589"	E122°13'32.50380"	57.290	?	e
QZN-41	N13°57'30.05268"	E122°17'03.60722"	50.089	0.082	
UP-CAB	N13°59'35.12930"	E122°22'16.30558"	52.023	0.073	
UP-KAN	N13°18'40.40211"	E122°33'06.07511"	75.768	0.086	
UP-TAL	N13°12'45.55145"	E122°39'48.22322"	55.864	0.095	
UP-VIG	N13°28'25.87675"	E122°36'56.35787"	56.412	0.083	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

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

Table 26. Reference and control points utilized in the Calauag River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
QZN-40	2nd Order GCP	13°41'32.47595" N	122°10'25.77273" E	51.703	1513855.137	410660.624	2.622
QZN-43	2nd Order GCP	13°35'55.81611" N	122°19'13.53031" E	51.015	1503462.996	426485.118	1.574
QZN-47	2nd Order GCP	13°31'29.52488" N	122°24'23.44821" E	53.862	1495257.875	435778.405	4.163
QZ-415	1st Order BM	13°53'25.29589" N	122°13'32.50380" E	57.290	1535736.431	416340.495	8.613
QZN-41	Used as Marker	13°57'30.05268" N	122°17'03.60722" E	50.089	1543236.263	422699.129	1.392
UP-CAB	UP Established	13°59'35.12930" N	122°22'16.30558" E	52.023	1547052.366	432091.726	3.211
UP-KAN	UP Established	13°18'40.40211" N	122°33'06.07511" E	75.768	1471596.832	451445.231	25.095
UP-TAL	UP Established	13°12'45.55145" N	122°39'48.22322" E	55.864	1460676.916	463529.271	4.949
UP-VIG	UP Established	13°28'25.87675" N	122°36'56.35787" E	56.412	1489570.998	458401.312	6.030

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

Cross-section survey was conducted at the downstream part of Sumulong Bridge using three different techniques on May 4, 5 and 7, 2016. These techiques are: GNSS receiver, Trimble® SPS 882, in PPK survey technique as shown in Figure 40; Ohmex™ Single Beam Echosounder; and a Trimble Total Station in an Open Traverse Method as shown in Figure 41.

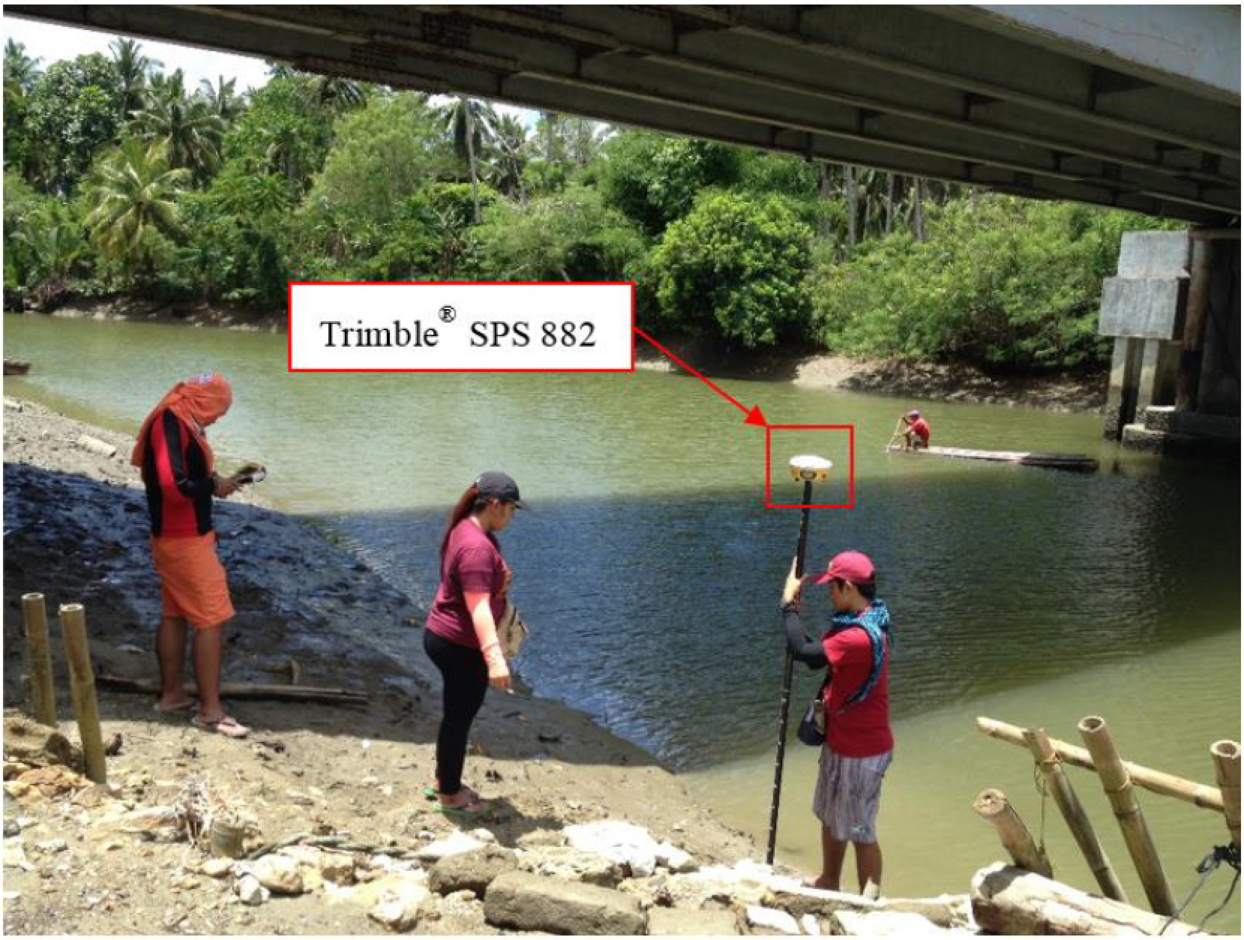


Figure 40. Cross-Section Survey for Calauag River using Trimble® SPS 882 in PPK survey technique

Figure 41. Cross-Section Survey for Calauag River using Trimble® SPS 882 in PPK survey technique

The cross-sectional line length for Calauag River is about 155.184 m with 103 cross-sectional points acquired using QZN-41 as the GNSS base station. The location map, cross section diagram, and the bridge as-built form are illustrated in Figure 42 to Figure 44, respectively.

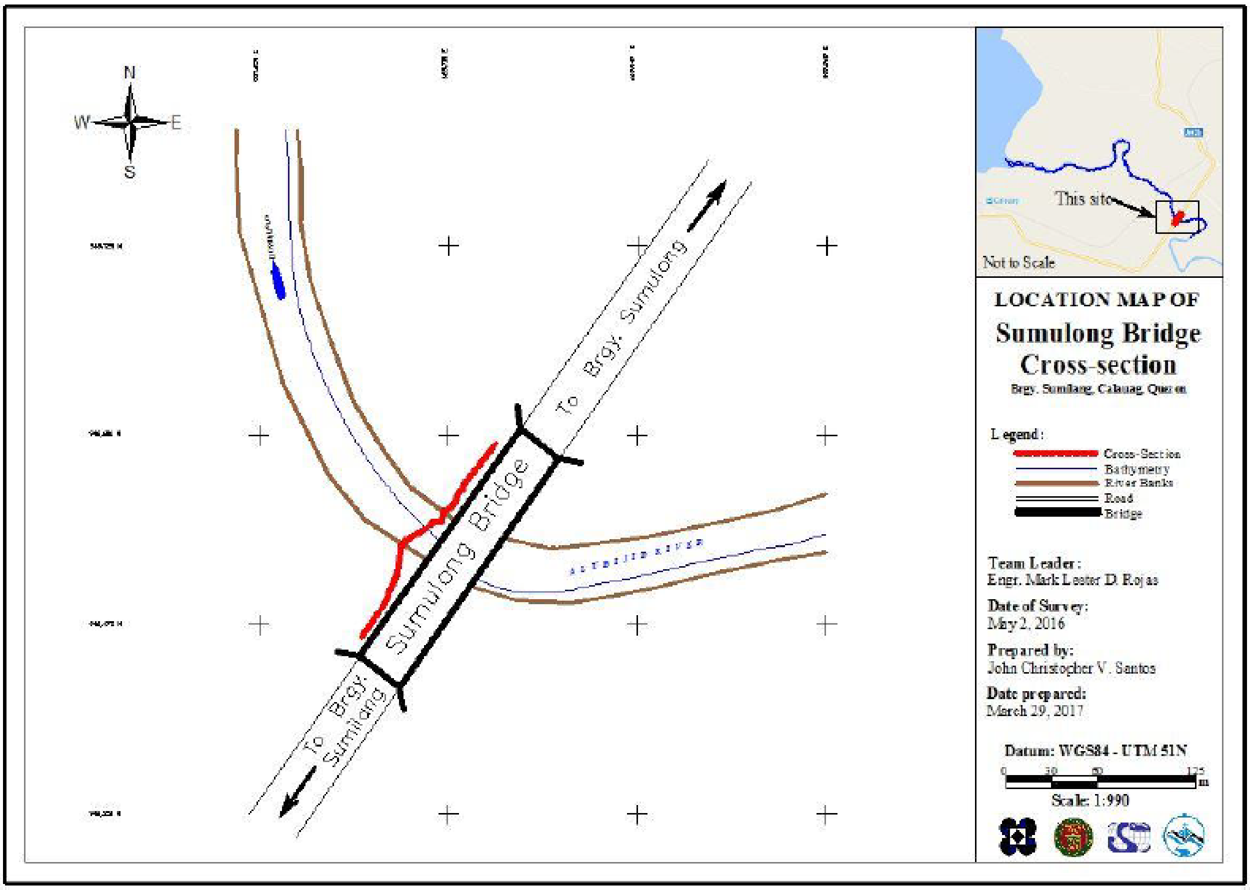


Figure 42. Location map of the Sumulong Bridge cross-section survey.

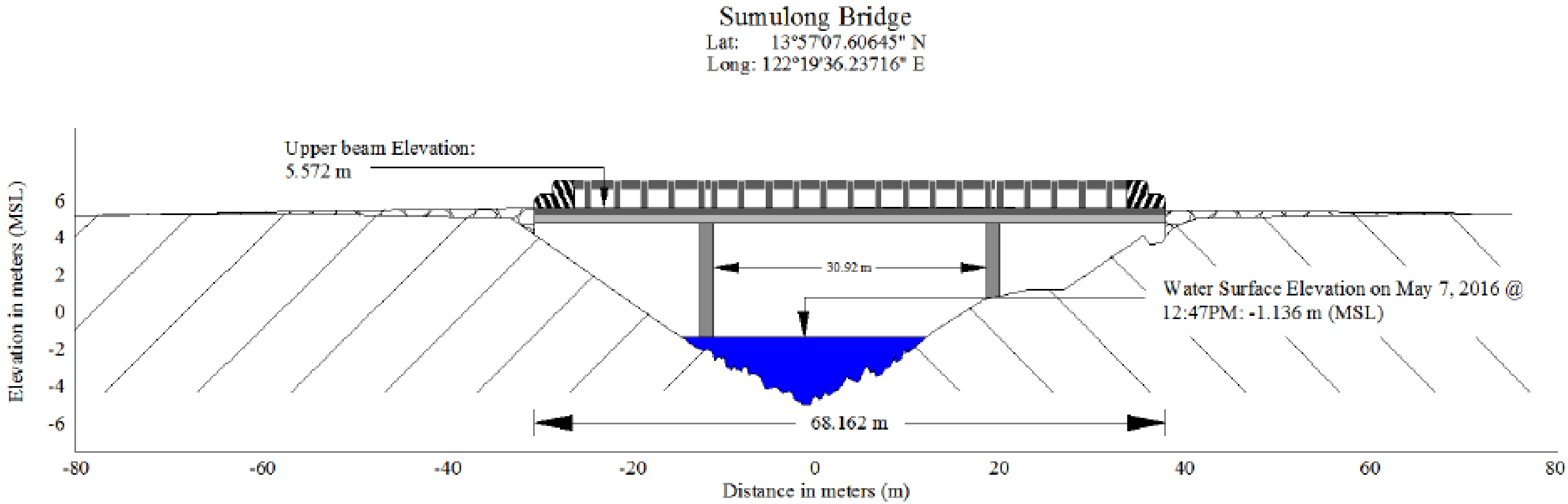
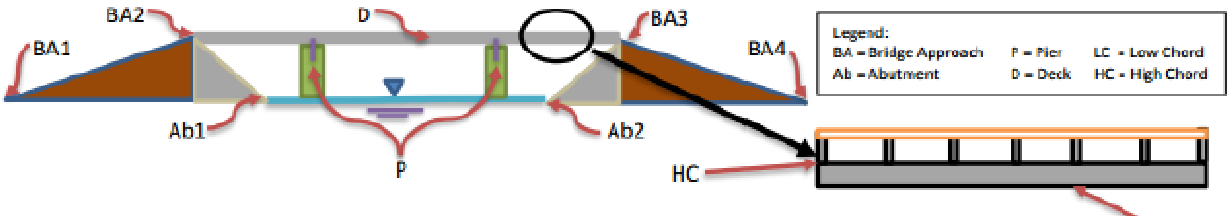


Figure 43. Sumulong Bridge Cross-section Diagram drawn to scale.

Bridge Data Form

Bridge Name: Sumulong Bridge	**Date: May 4, 2016**
River Name: Sumulong River	**Time: 10:33 AM**
Location: Brgy. Sumilang, Municipality of Calauag, Quezon	
Survey Team: Mark Rojas, Marla Morris, Pauline Racoma, Michael Labrador, Erlan Mendoza, Romalyn Boado	
Flow condition: low ✓ normal high	**Weather Condition:** ✓ fair rainy
Latitude: 13°57'07.60645"N	**Longitude: 122°19'36.23716"E**



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

Elevation: 5.572 m. **Width: 8 m.** **Span (BA3-BA2): 68.162 m.**

	Station	High Chord Elevation	Low Chord Elevation
1			

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	5.171	BA3	117.706	5.437
BA2	49.544	5.572	BA4	155.184	5.245

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: Cylindrical Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	68.150	5.573	8
Pier 2	99.070	5.598	8
Pier 3			
Pier 4			

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

Figure 44. The Sumulong Bridge as-built survey data.

Water surface elevation in MSL of Calauag River was determined using Trimble® Total Station in an Open Traverse Method on May 7, 2016 at 12:47 PM with a value of -1.136 m in MSL. This was translated onto marking on the bridge's pier as using digital level as shown in Figure 45. The markings will serve as their reference for flow data gathering and depth gauge deployment for Calauag River.

Figure 45. Painting of water level markings on Calauag Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on May 4, 5, and 6, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of the vehicle as shown in Figure 45. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was 1.895 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with QZN-41, QZN-43 and UP-CAB occupied as the GNSS base stations in the conduct of the survey.

Figure 46. Validation point acquisition survey setup using a GNSS receiver fixed in a van along the Calauag River Basin

The survey started from Brgy. Aloneros in the Municipality of Guinayangan, going west traversing the Municipalities of Calauag, Lopez and ended in Brgy. San Diego Poblacion, Municipality of Gumaca; and from Brgy. Matandang Sabang Silangan, Municipality of Catanauan going south towards Barangay II in Municipality of Mulanay, and ended in Brgy. Anonang also in Mulaay. This route aims to perpendicularly cut flight strips of the Data Acquisition Component. The survey gathered 5,788 points with approximate length of 67.44 km using QZN-41, QZN-43 and UP-CAB as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 47.

Figure 47. Extent of the LiDAR ground validation survey for the Calauag River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on May 5, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and an OHMEX™ Signle Beam Echosounder. The extent of the survey is from the upstream in Brgy. Mabini, Municipality of Calauag with coordinates 13°56'59.75883"N, 122°19'44.98394"E, and ended at the mouth of the river in Brgy. Biyan and Bangkuruhan with corrdinates 13°57'41.80077"N, 122°18'03.46832"E.

Figure 48. Bathymetry by boat set up for Calauag River survey

A CAD drawing was also produced to illustrate the riverbed profile of Bato River. As shown in Figure 49, the highest and lowest elevation has a 4-meter difference. The highest elevation observed is -0.682 m above MSL located at the downstream portion of the river in Brgy. Biyan while the lowest elevation observed is -5.059 m below MSL located near Sumulong Bridge in Brgy. Sumilang, both in Municipality of Calauag. The bathymetric survey gathered a total of 7,665 points covering 4.995 km of the river traversing Barangays Mabini, Sumilang, Sumulong, Bangkuruhan and Biyan in Municipality of Calauag.

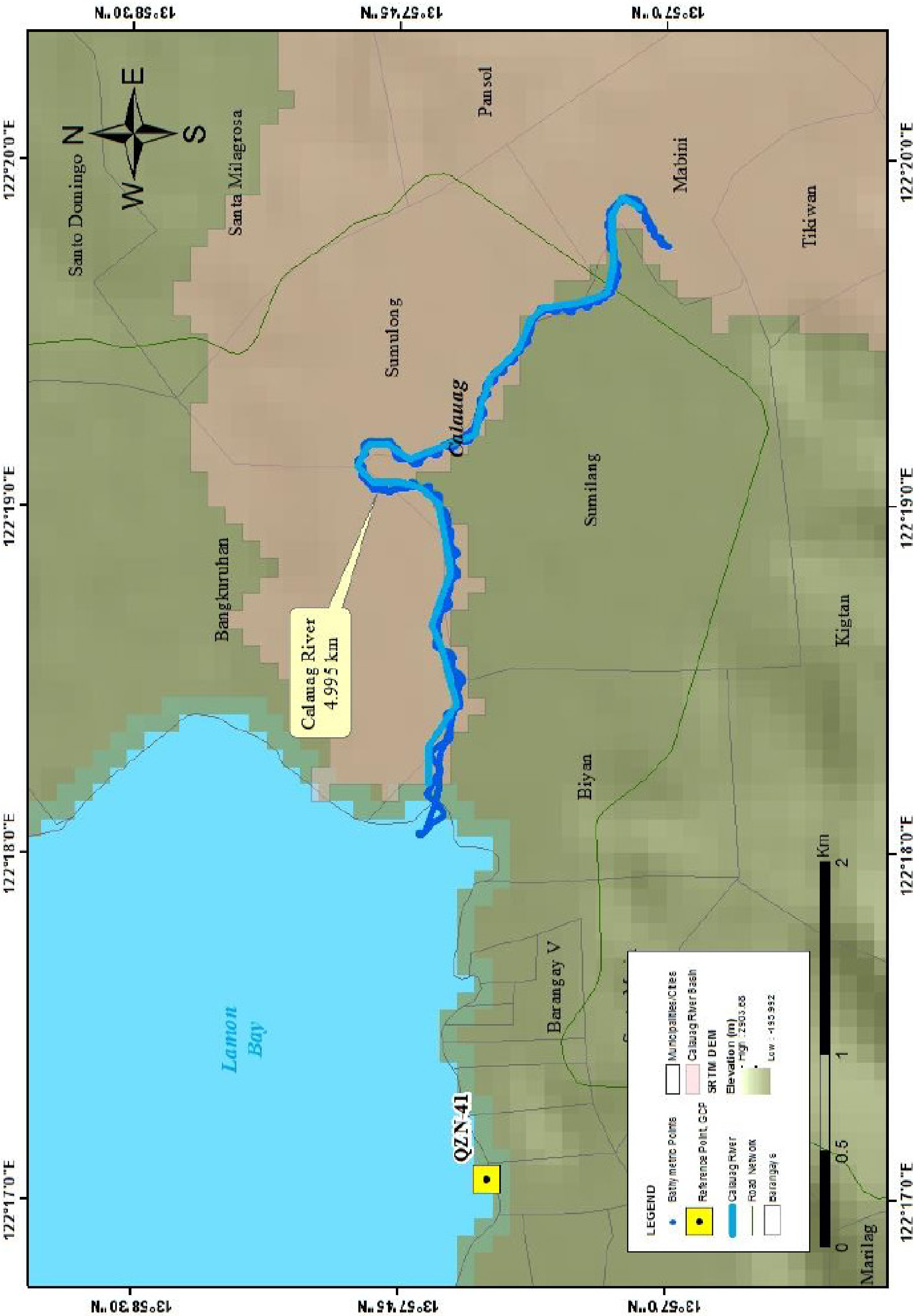


Figure 49. Extent of the Calauag River Bathymetry Survey

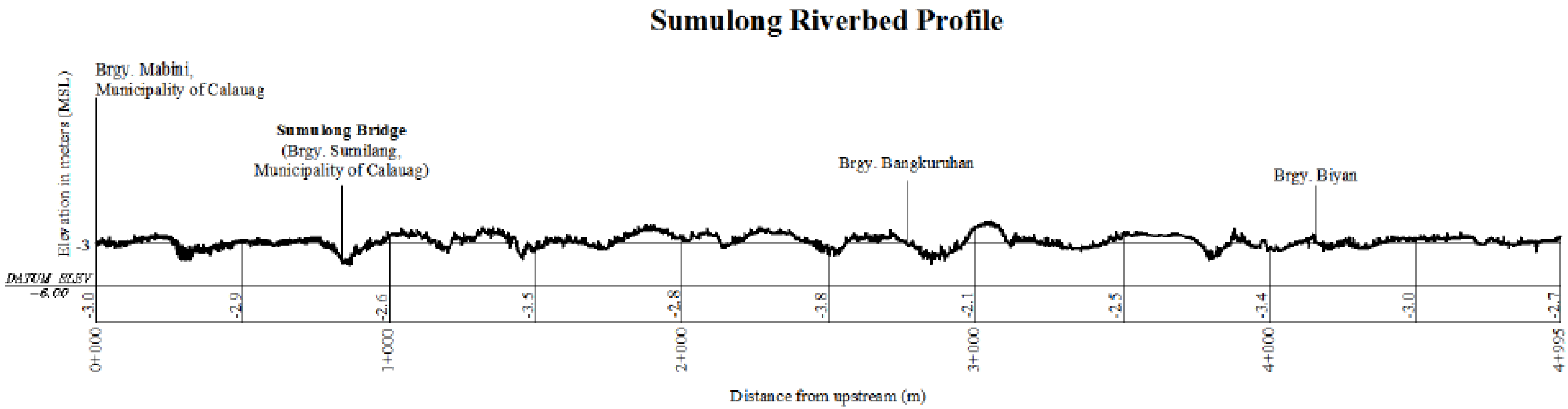


Figure 50. The Calauag river bed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Francisco A. Lagmay, Enrico C. Paringit, Dr. Eng., Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, and Neil R. Tingin

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from automatic rain gauges (ARG) deployed by the Mapua Institute of Technology under the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The ARGs were installed at Brgy. Villahermosa, and San Roque Ilaya HS (Figure 51).

The total rain from the Brgy. Villahermosa rain gauge is 25 mm. It peaked to 4.5 mm at 2:45 on October 15, 2016. The lag time between the peak rainfall and discharge is 13 hours and 35 minutes. For San Roque Ilaya HS rain gauge, the total rain is 52.2 mm. Peak rain of 16 mm at 1:45 was recorded on October 15, 2016. The lag time between the peak rainfall and discharge is 14 hours and 35 minutes.

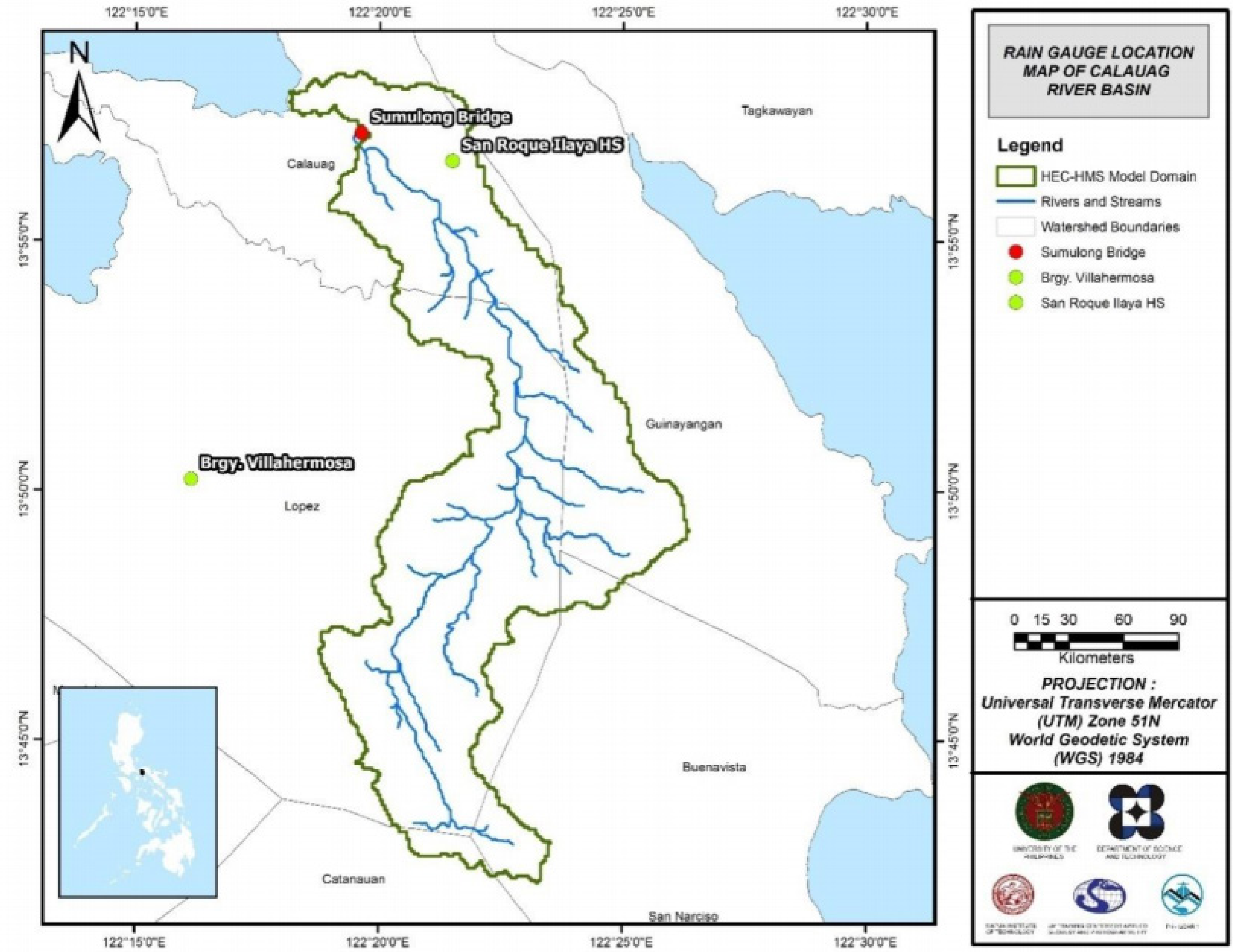


Figure 51. Location map of the Calauag HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sumulong Bridge, Calauag, Quezon Province (13°57'07.60645"N, 122°19'36.23716"E). It gives the relationship between the observed water levels and outflow of the watershed at this location.

For Calauag Bridge, the rating curve is expressed y = 47.132e1.9097x as shown in Figure 52.

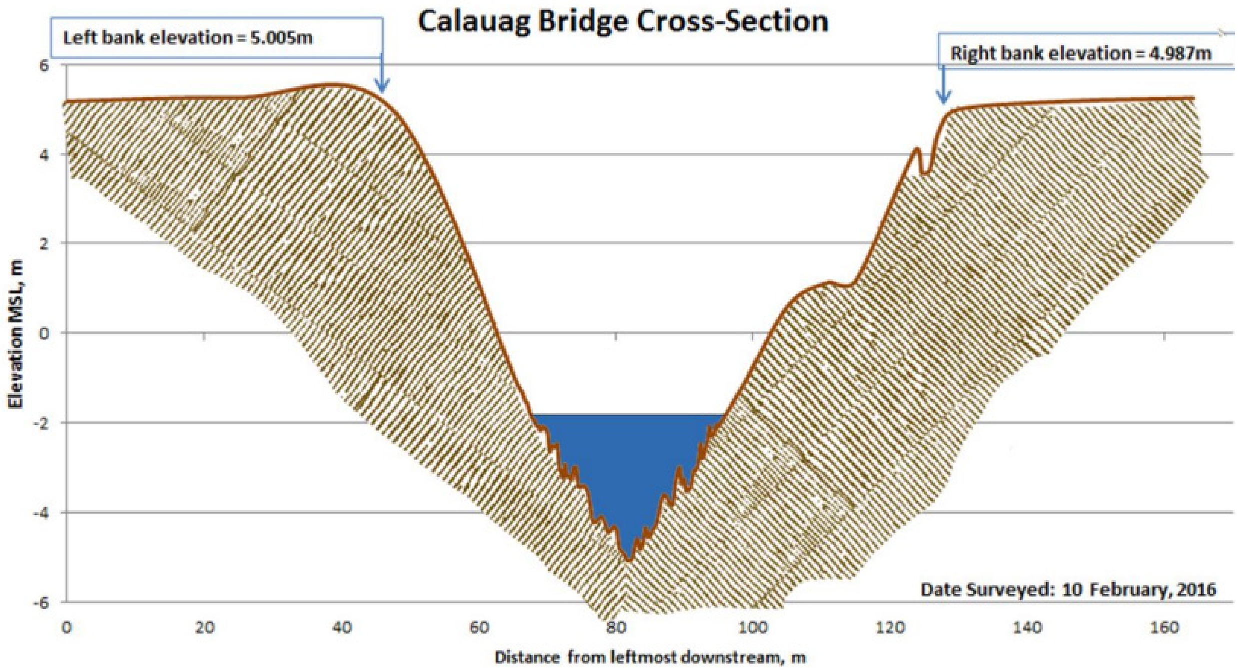


Figure 52. Cross-Section Plot of Calauag Bridge

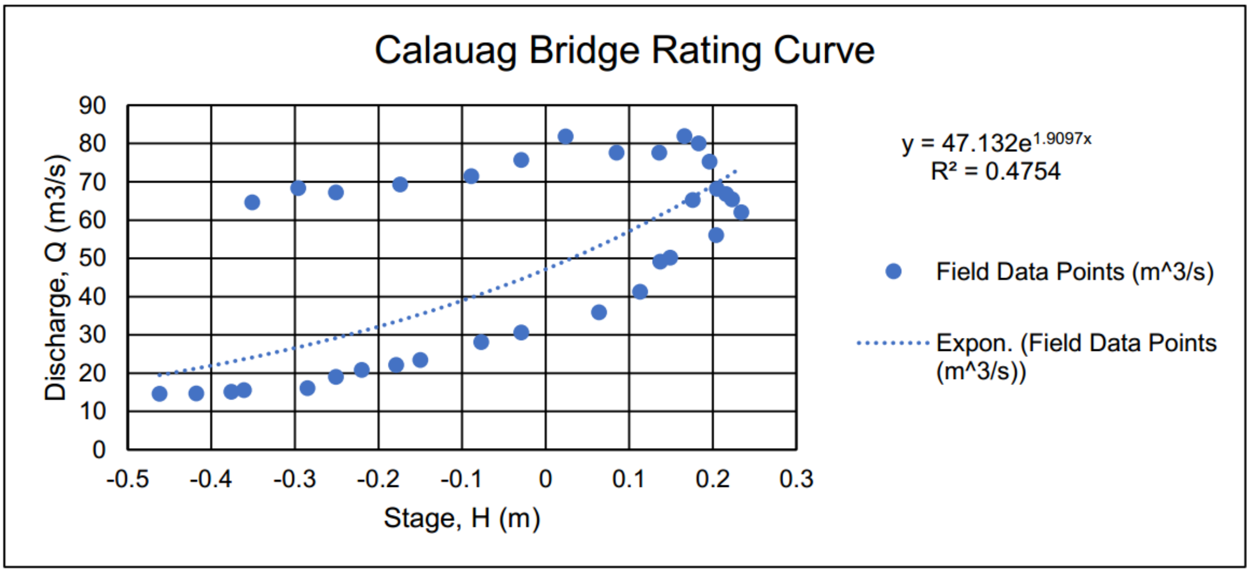


Figure 53. Rating curve of the Calauag Bridge, San Narciso, Quezon Province

This rating curve equation was used to compute the river outflow at Calauag Bridge for the calibration of the HEC-HMS model shown in Figure 53. Peak discharge is 81.9 m3/s at 16:20, October 15, 2016.

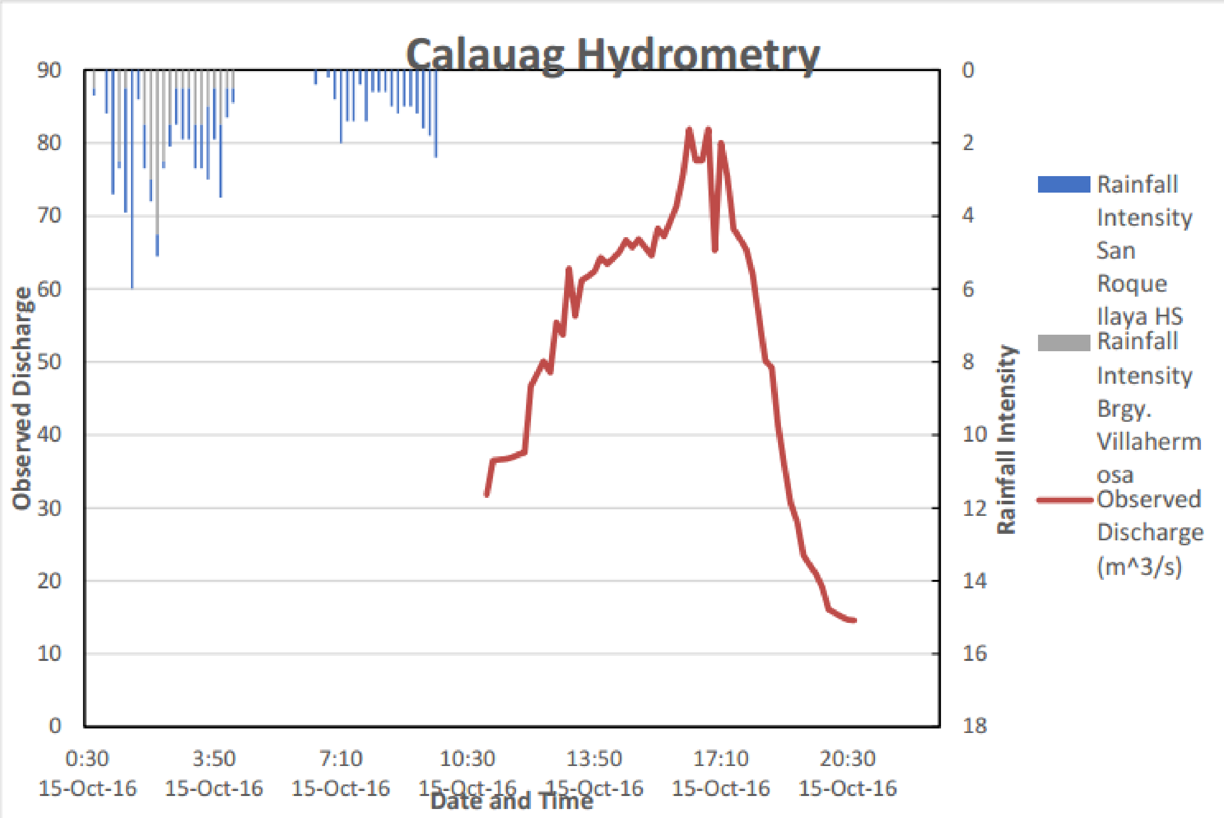


Figure 54. Rainfall and outflow data of the Calauag River Basin, which was used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Alabat Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Calauag watershed. The extreme values for this watershed were computed based on a 31-year record.

Table 27. RIDF values for Alabat 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	20.9	31.3	39.8	55.3	77	94.2	118.3	143.2	173.4
5	27.6	41.3	52.9	74.6	108.5	134.8	172.8	208.6	252
10	32.1	48	61.6	87.3	129.4	161.6	209	251.9	303.9
15	34.6	51.8	66.5	94.5	141.1	176.8	229.3	276.3	333.3
20	36.4	54.4	69.9	99.6	149.4	187.4	243.6	293.4	353.8
25	37.7	56.5	72.6	103.5	155.7	195.6	254.6	306.6	369.6
50	41.9	62.7	80.7	115.4	175.3	220.7	288.4	347.2	418.4
100	46.1	69	88.8	127.3	194.7	245.7	322	387.5	466.7

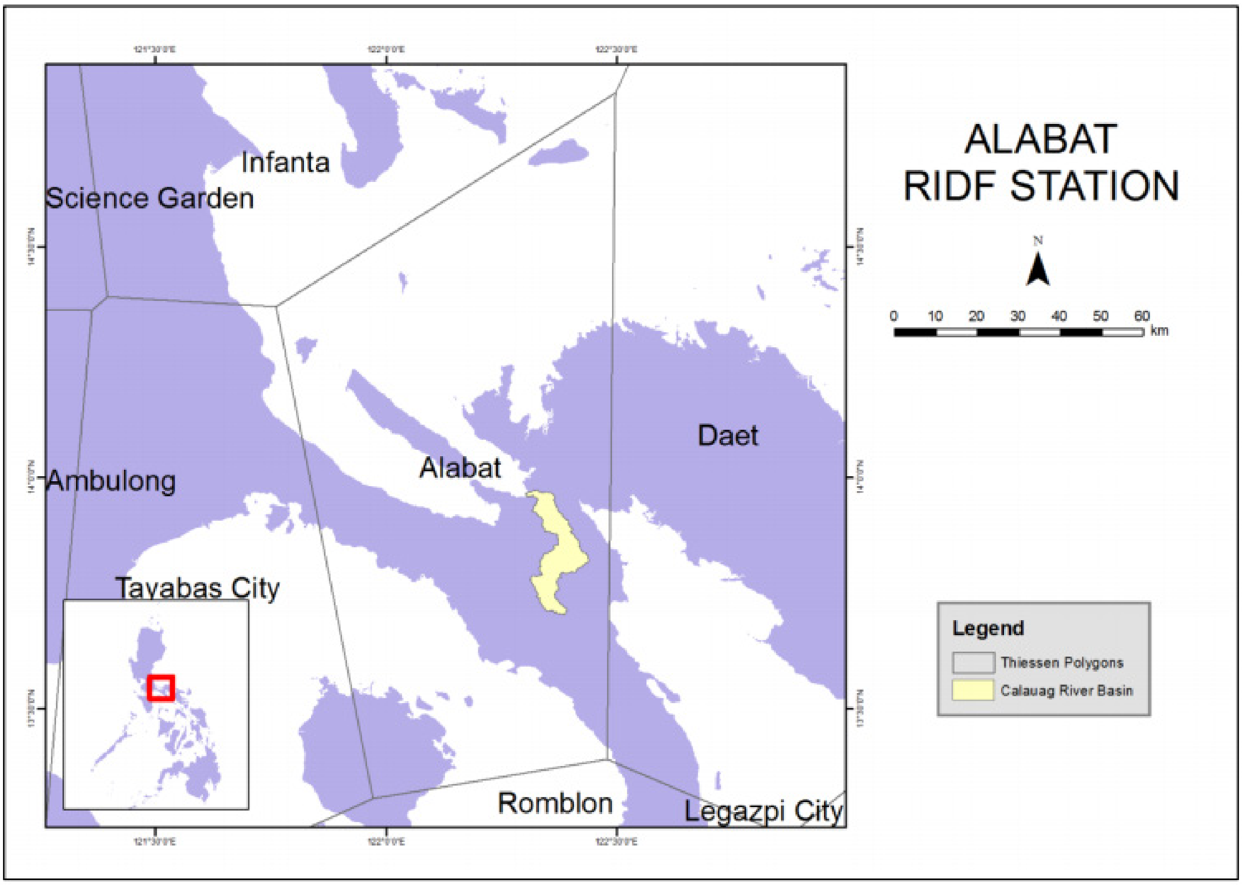


Figure 55. Alabat RIDF location relative to Calauag River Basin

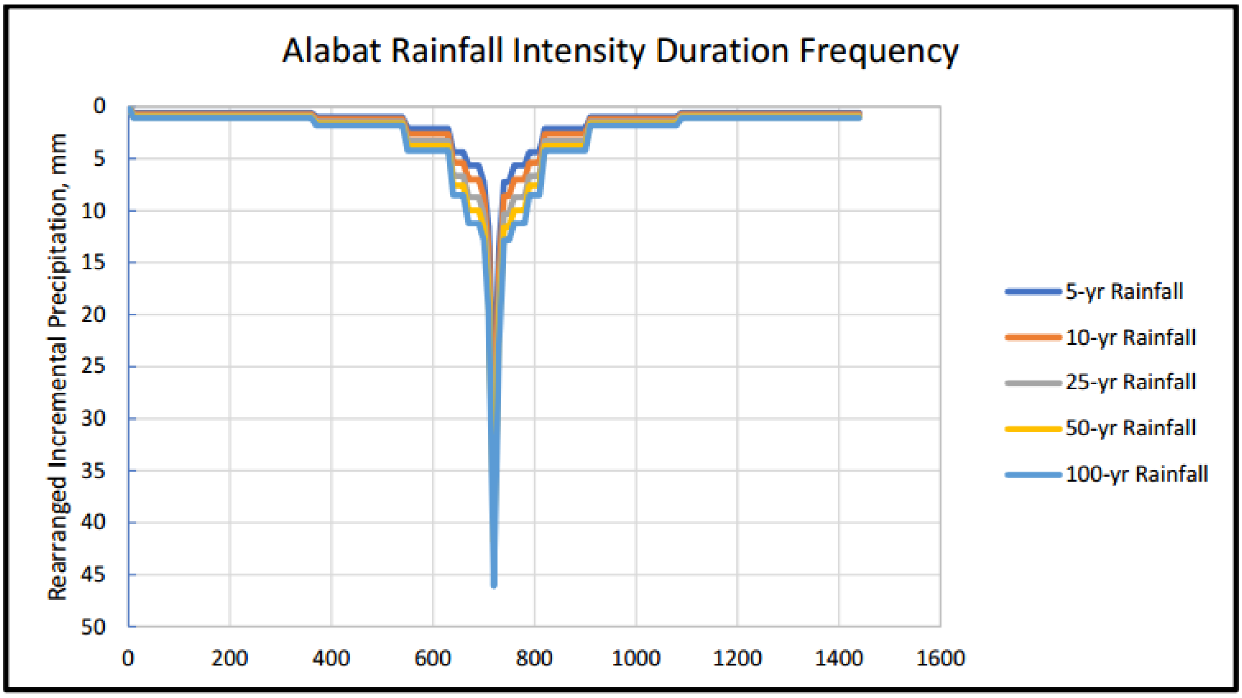


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken before 2004 from the Bureau of Soils under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA).

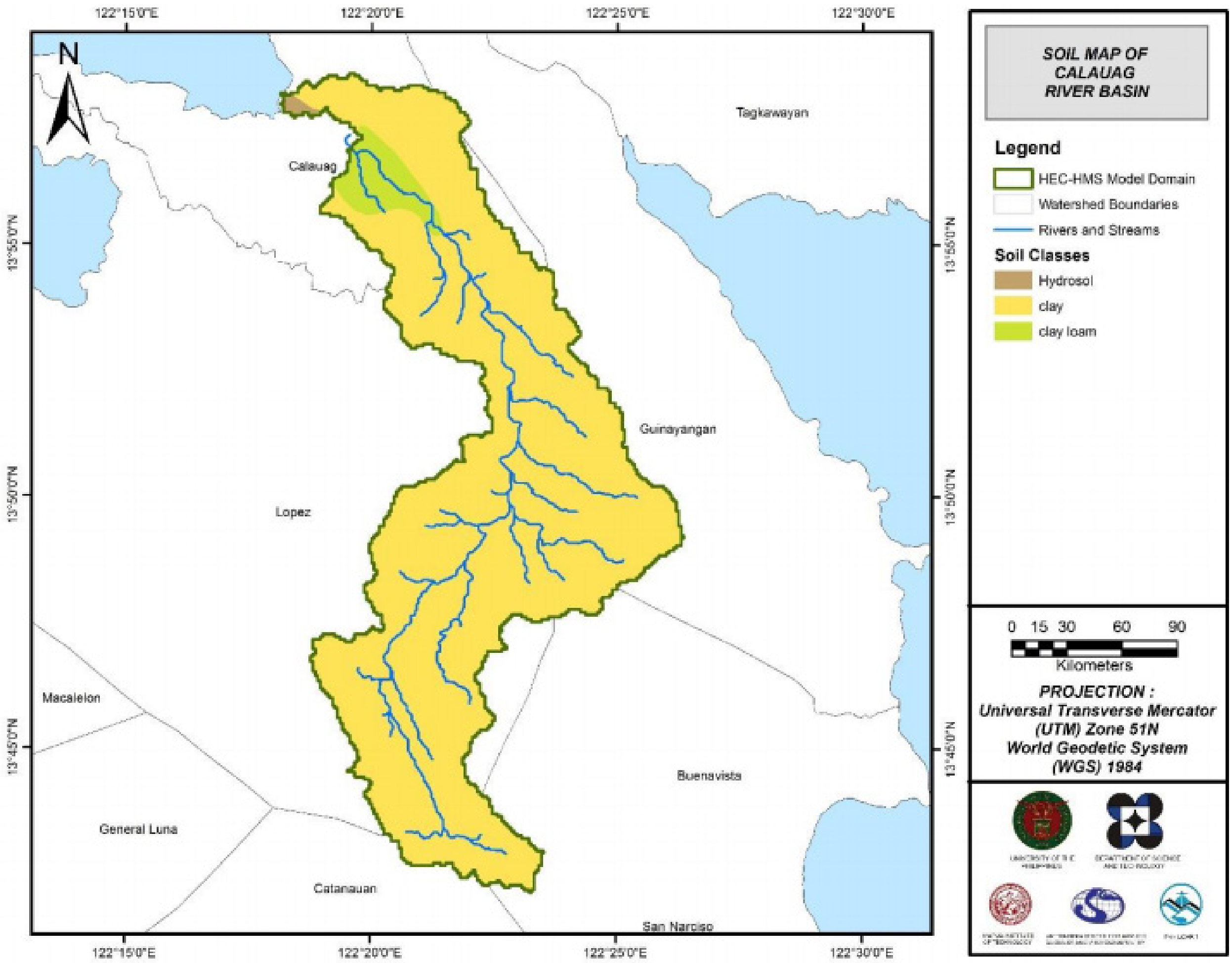


Figure 57. Soil Map of Calauag River Basin (Source: DA)

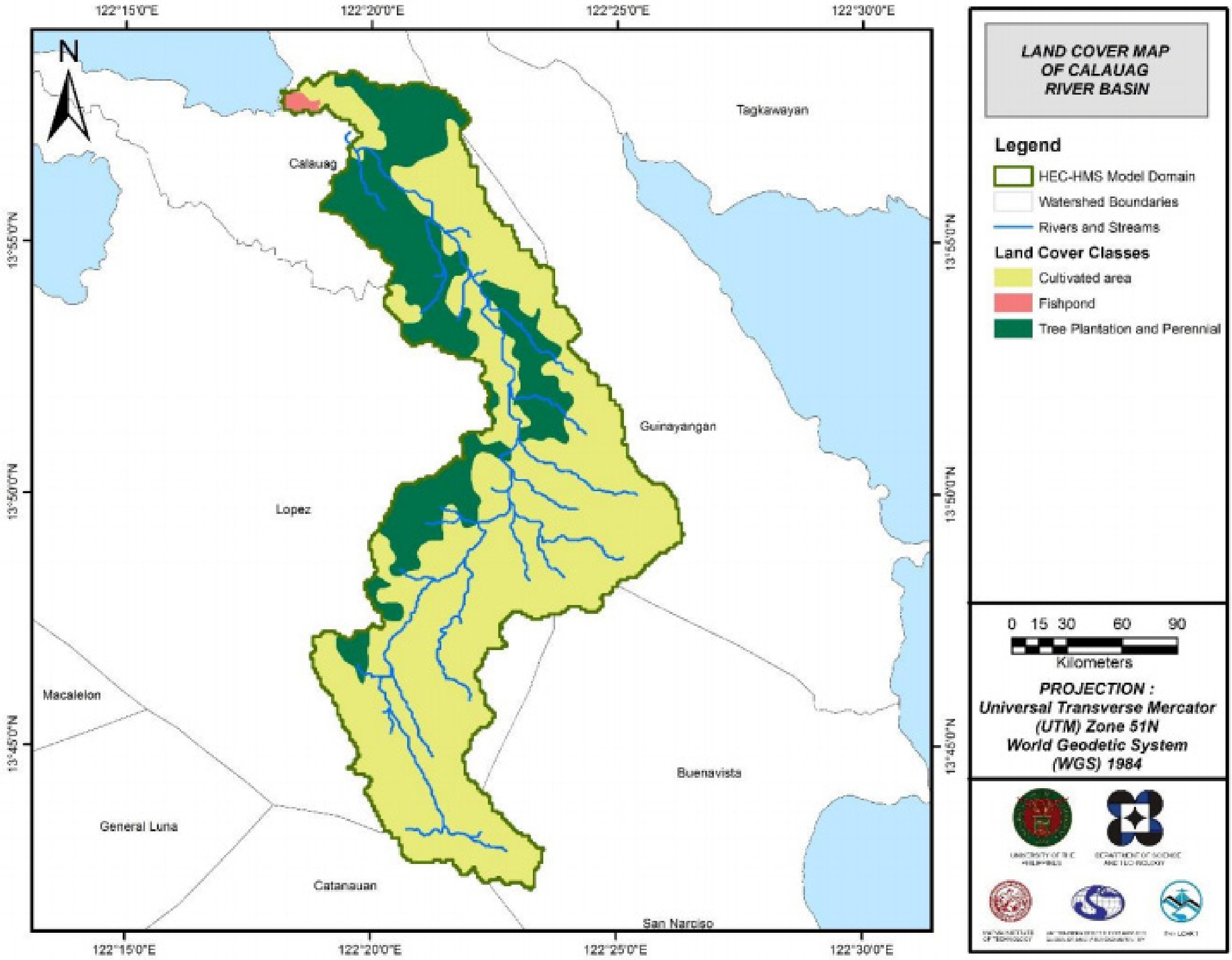


Figure 58. Land Cover Map of Calauag River Basin (Source: NAMRIA)

For Calauag, the major soil classes identified were mostly clay, hydrosol and clay loam. The major landcover types identified were fish pond, tree plantation and cultivated areas.

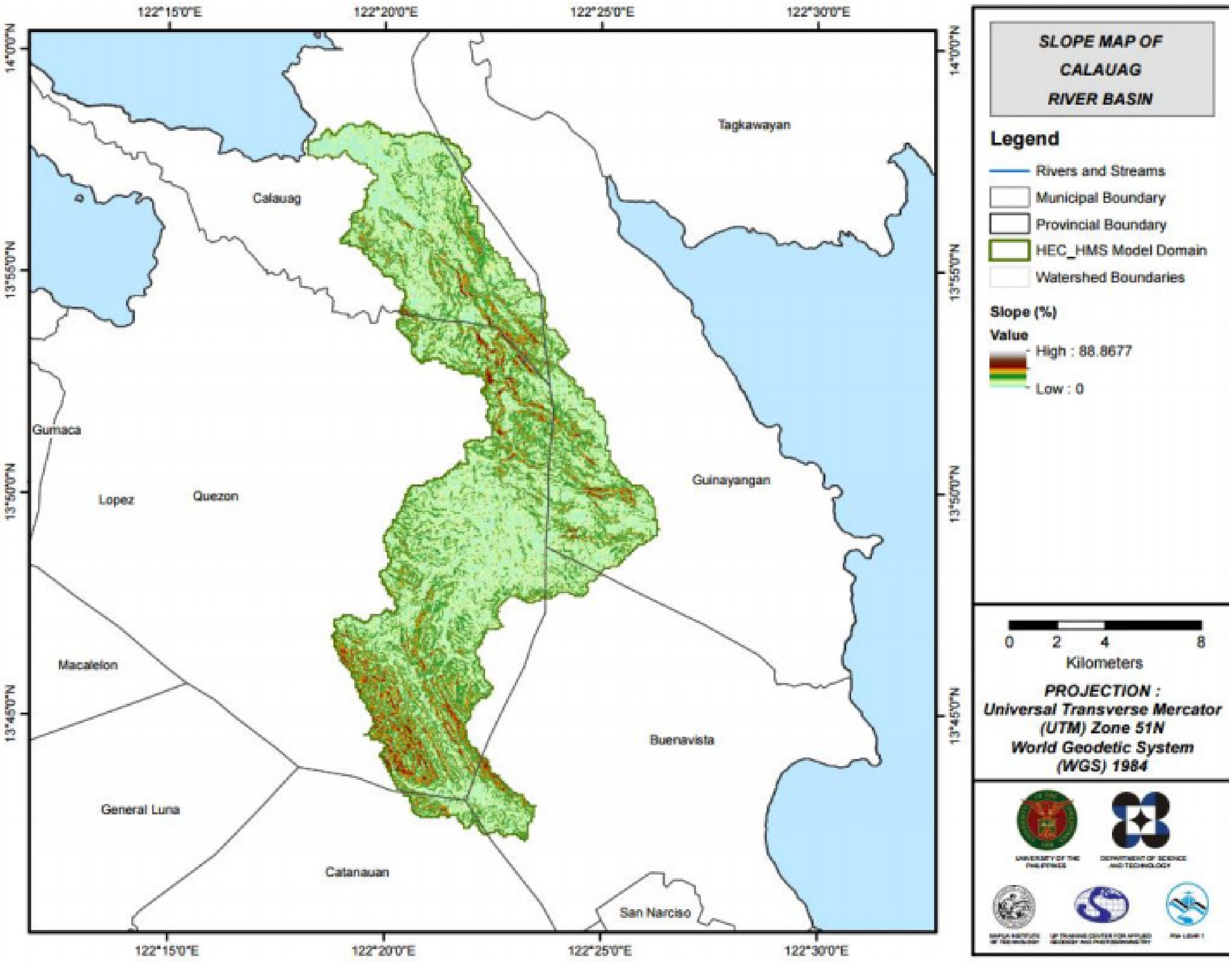


Figure 59. Slope Map of Calauag River Basin

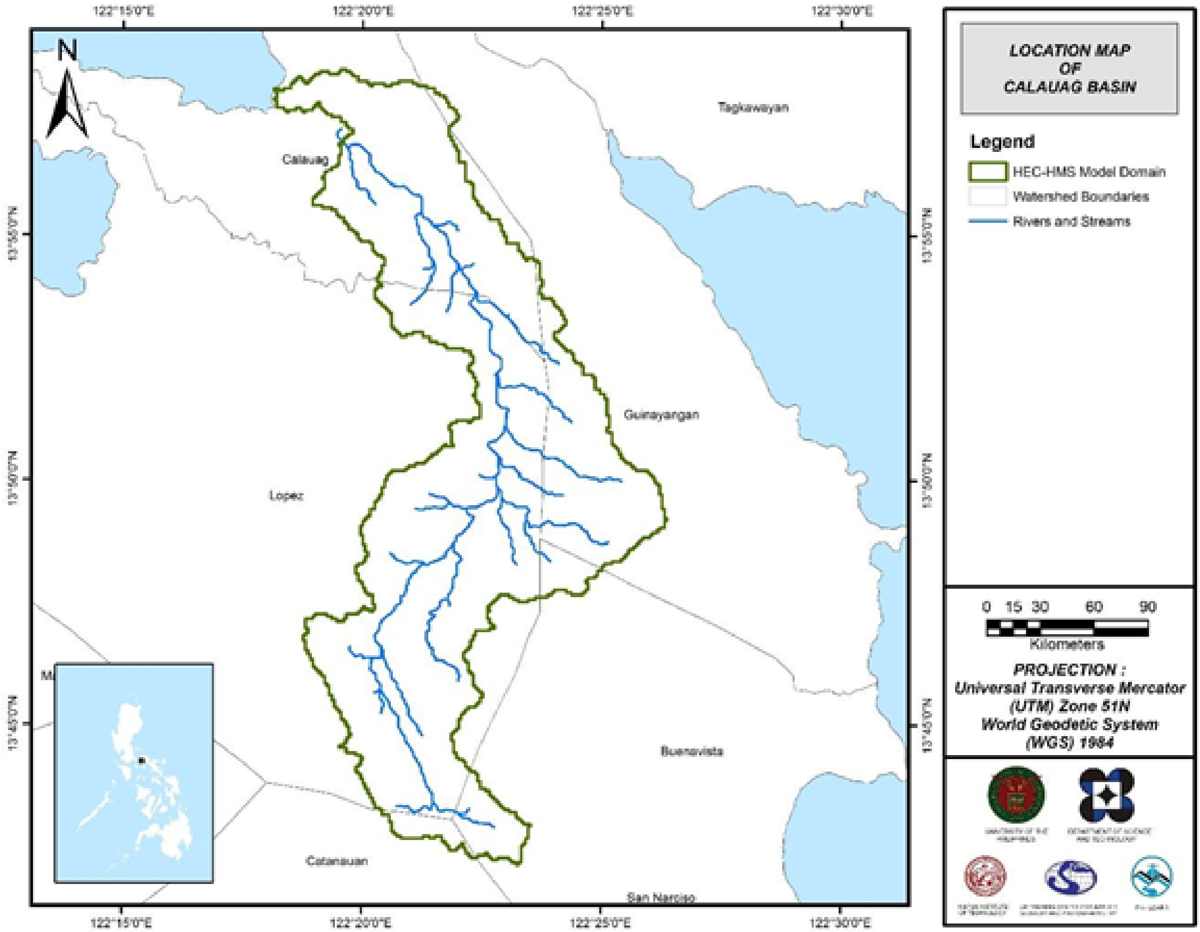


Figure 60. Stream Delineation Map of Calauag River Basin

Using the SAR-based DEM, the Silaga basin was delineated and further subdivided into subbasins. The model consists of 43 sub basins, 21 reaches, and 20 junctions as shown in Figure 61 (See Annex 10). The main outlet is at Silaga Bridge.

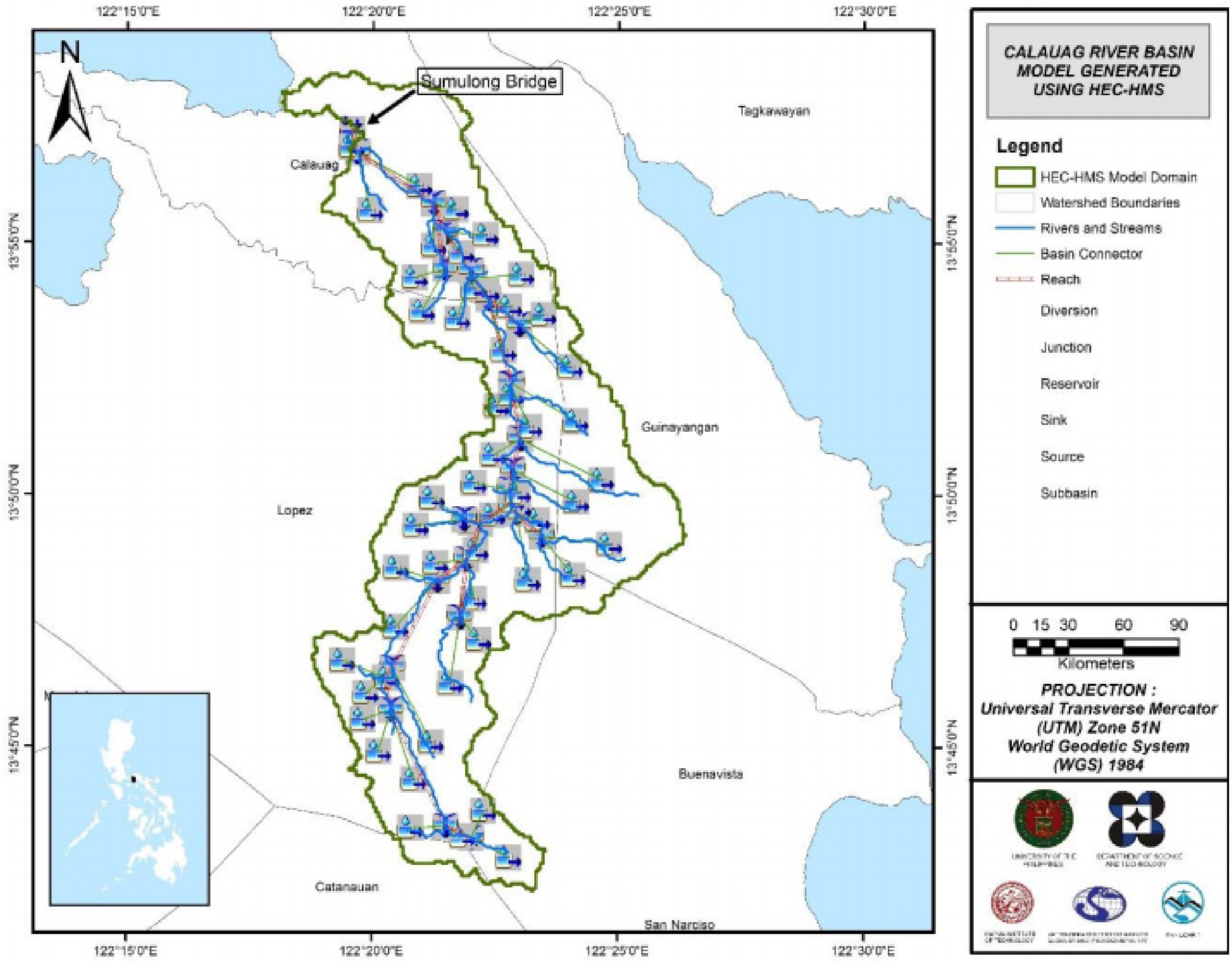


Figure 61. Calauag river basin model generated in HEC-HMS

5.4 Cross-section Data

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

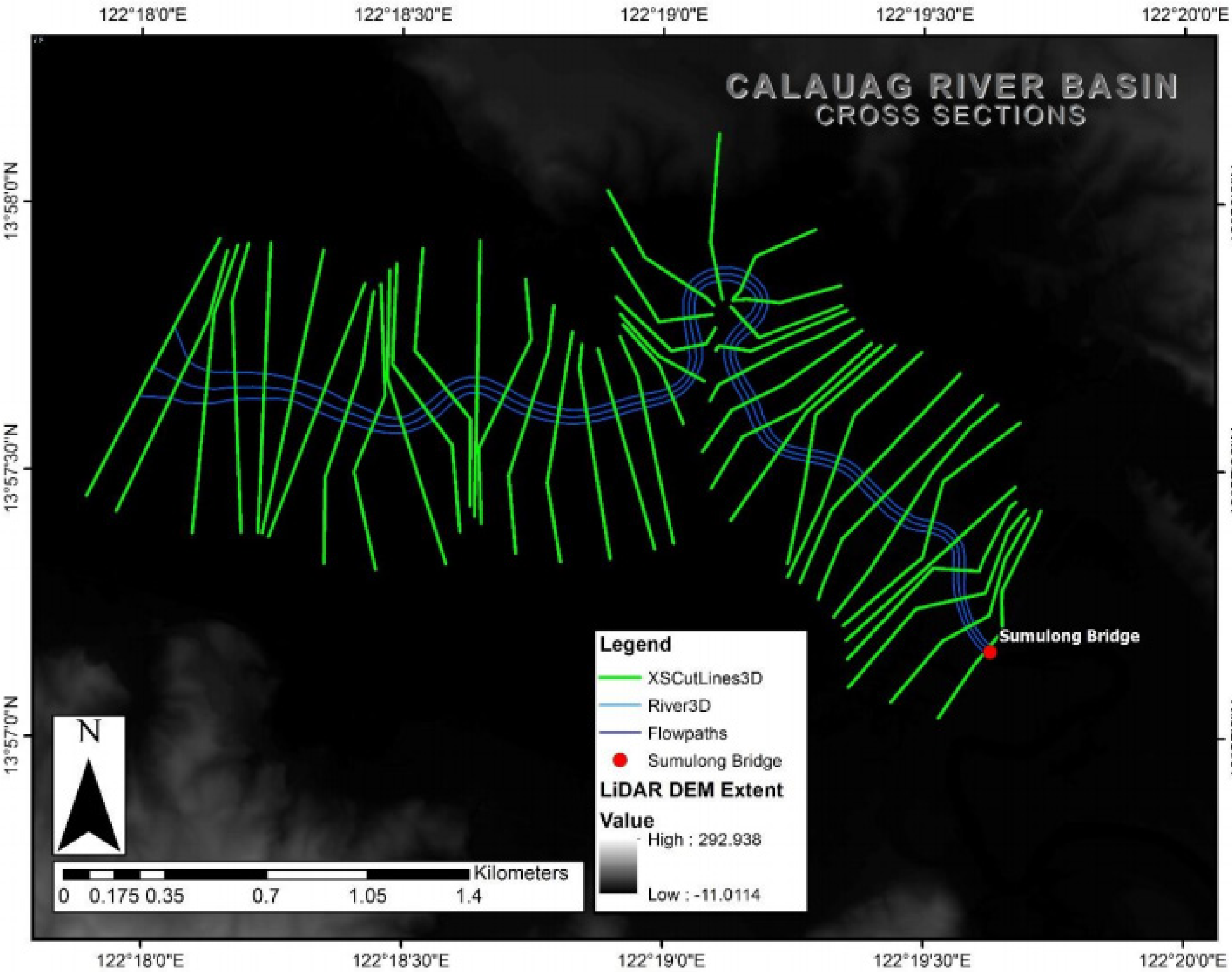


Figure 62. River cross-section of Calauag River generated through Arcmap HEC GeoRAS tool

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 south of the model to the northwest, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

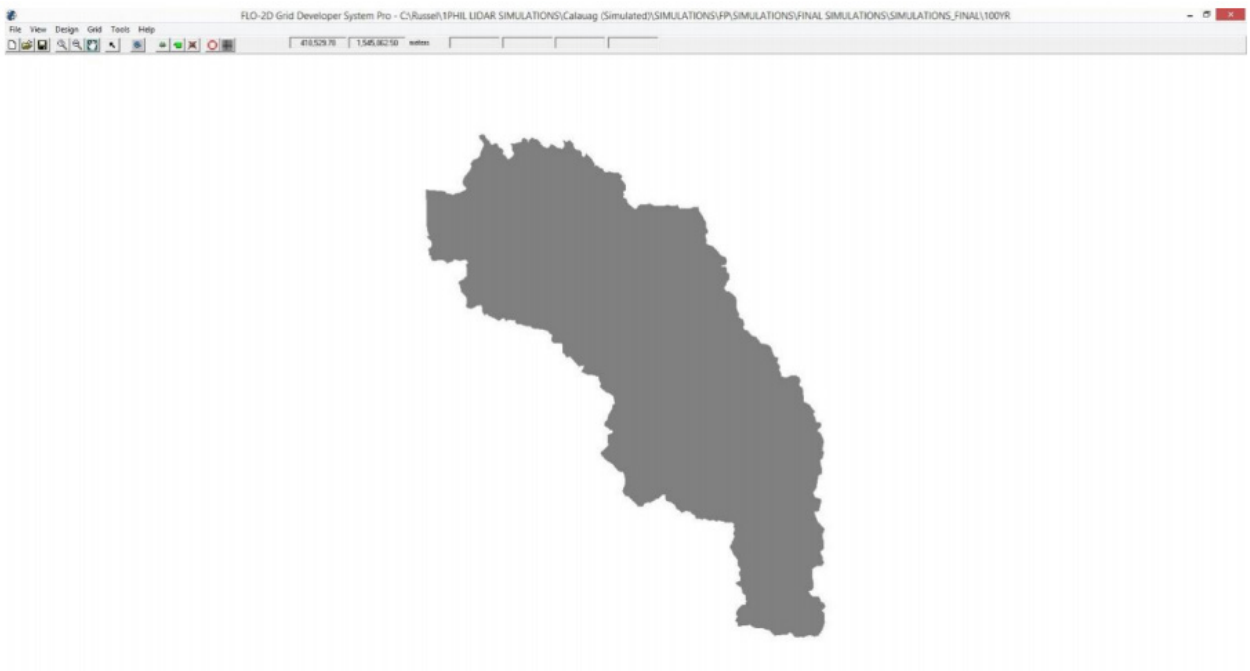


Figure 63. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 108.88916 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 generated hazard maps for Calauag are in Figures 65, 67, and 69.

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 67 327 584.00 m2. The generated flood depth maps for Calauag are in Figures 66, 68, and 70.

There is a total of 55 150 214.02 m3 of water entering the model. Of this amount, 29 000 269.81 m3 is due to rainfall while 26 149 944.21 m3 is inflow from other areas outside the model. 8 068 822.00 m3 of this water is lost to infiltration and interception, while 29 232 092.60 m3 is stored by the flood plain. The rest, amounting up to 17 849 286.65 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Calauag HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

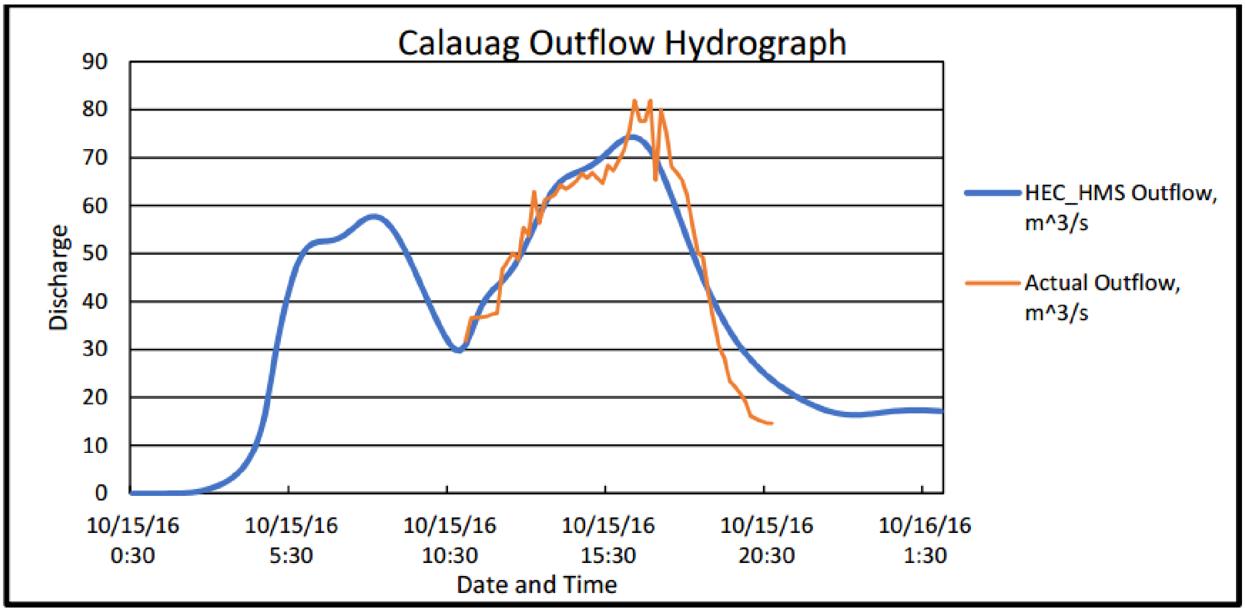


Figure 64. Outflow Hydrograph of Calauag produced by the HEC-HMS model compared with observed outflow

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

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

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.8 - 14
			Curve Number	63 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.18 - 22
			Storage Coefficient (hr)	0.08 - 24
	Baseflow	Recession	Recession Constant	0.00001
			Ratio to Peak	0.00015
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	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 5mm to 20mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation. Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area. For Calauag, the basin mostly consists of cultivated area, fishpond and tree plantation and perennial, and the soil consists of clay, and clay loam.

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 2 hours to 12 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. The default recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Calauag basin has a recession constant of 0.00001, which is the lowest posisible value, moving down the receding limb of the model. Ratio to peak of 0.00015 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Philippine watersheds. Calauag river basin has a Manning's Coefficient ranging from 0.0001 – 1.

Table 29. Efficiency Test of the Calauag HMS Model

Accuracy measure	Value
RMSE	6.120
r2	0.929
NSE	0.903
PBIAS	-1.595
RSR	0.311

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 6.120m3/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 0.929.

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 0.903.

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 -1.595.

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 0.311.

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

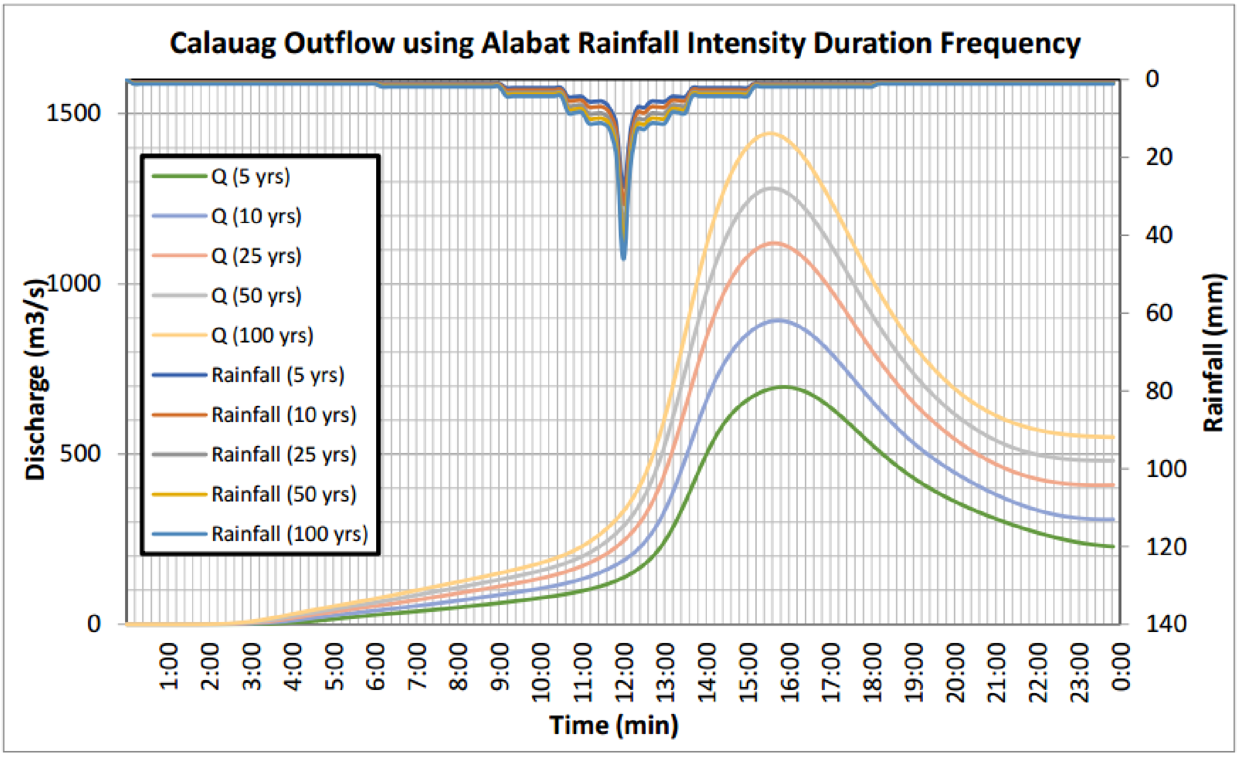


Figure 65. Outflow hydrograph at Calauag generated using Alabat RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Calauag HECHMS Model outflow using the Alabat RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	252	27.6	697.1	15 hours, 50 minutes
10-Year	303.9	32.1	891.7	15 hours, 40 minutes
25-Year	369.6	37.7	1119.4	15 hours, 40 minutes
50-Year	418.4	41.9	1280	15 hours, 40 minutes
100-Year	466.7	46.1	1441.6	15 hours, 30 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. For this publication, only a sample output map river was to be shown, since only the Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of Calauag River using the calibrated HMS base flow is shown in Figure 66.

Figure 66. Sample output of Calauag RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 67 to Figure 72 show the 5-, 25-, and 100-year rain return scenarios of the Calauag floodplain. The floodplain, with an area of 183.89 sq. km. Table 31 shows the percentage of area affected by flooding in that municipality.

Table 31. Municipalities affected in Calauag Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Calauag	323.42	51.82617	16.02%
Buenavista	157	8.430205	5.37%
Catanauan	267	2.484101	0.93%
Guinayangan	237	24.49944	10.34%
Lopez	379	96.53535	25.47%

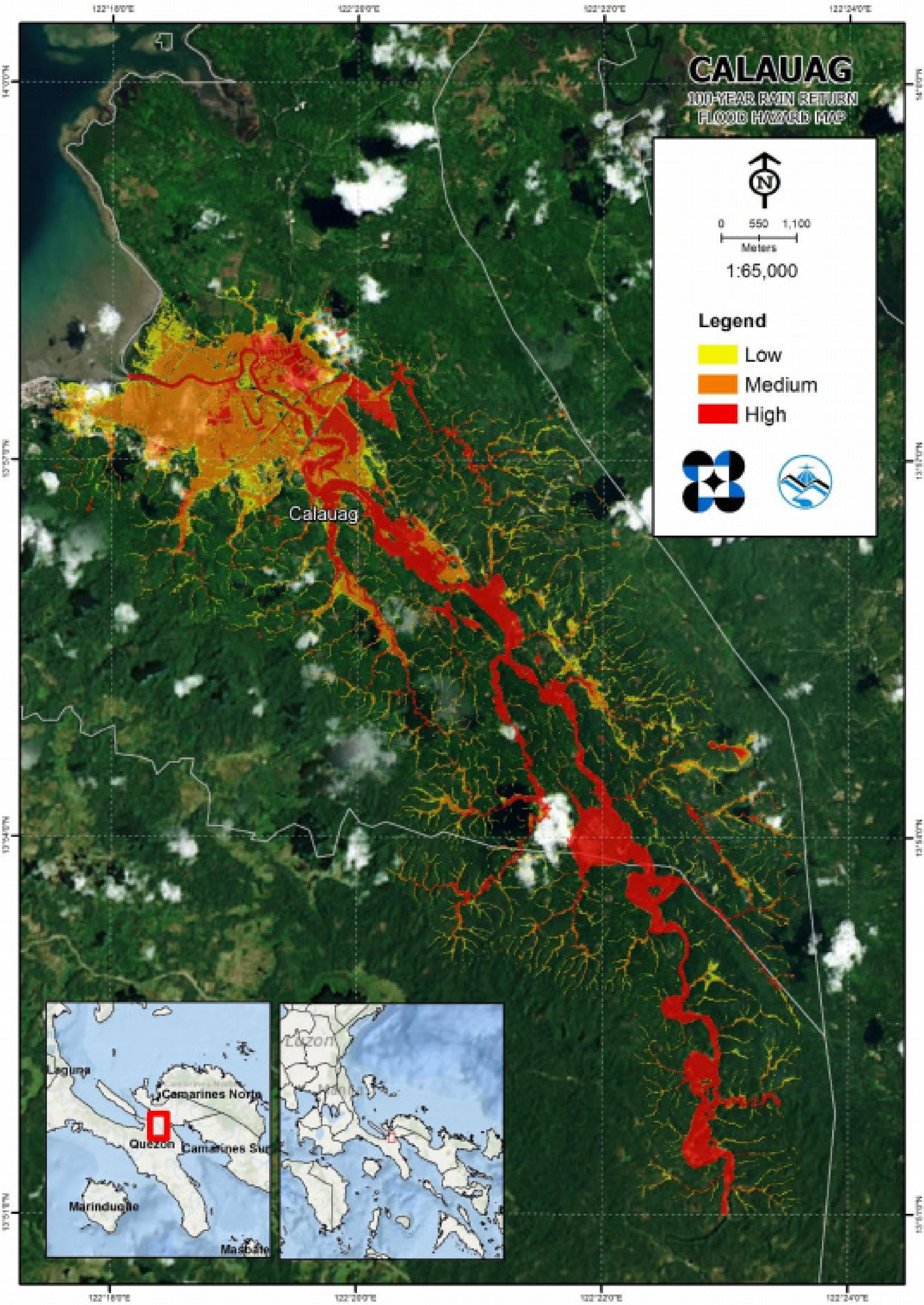


Figure 67. 100-year Rain Return Flood Hazard Map for Calauag Floodplain

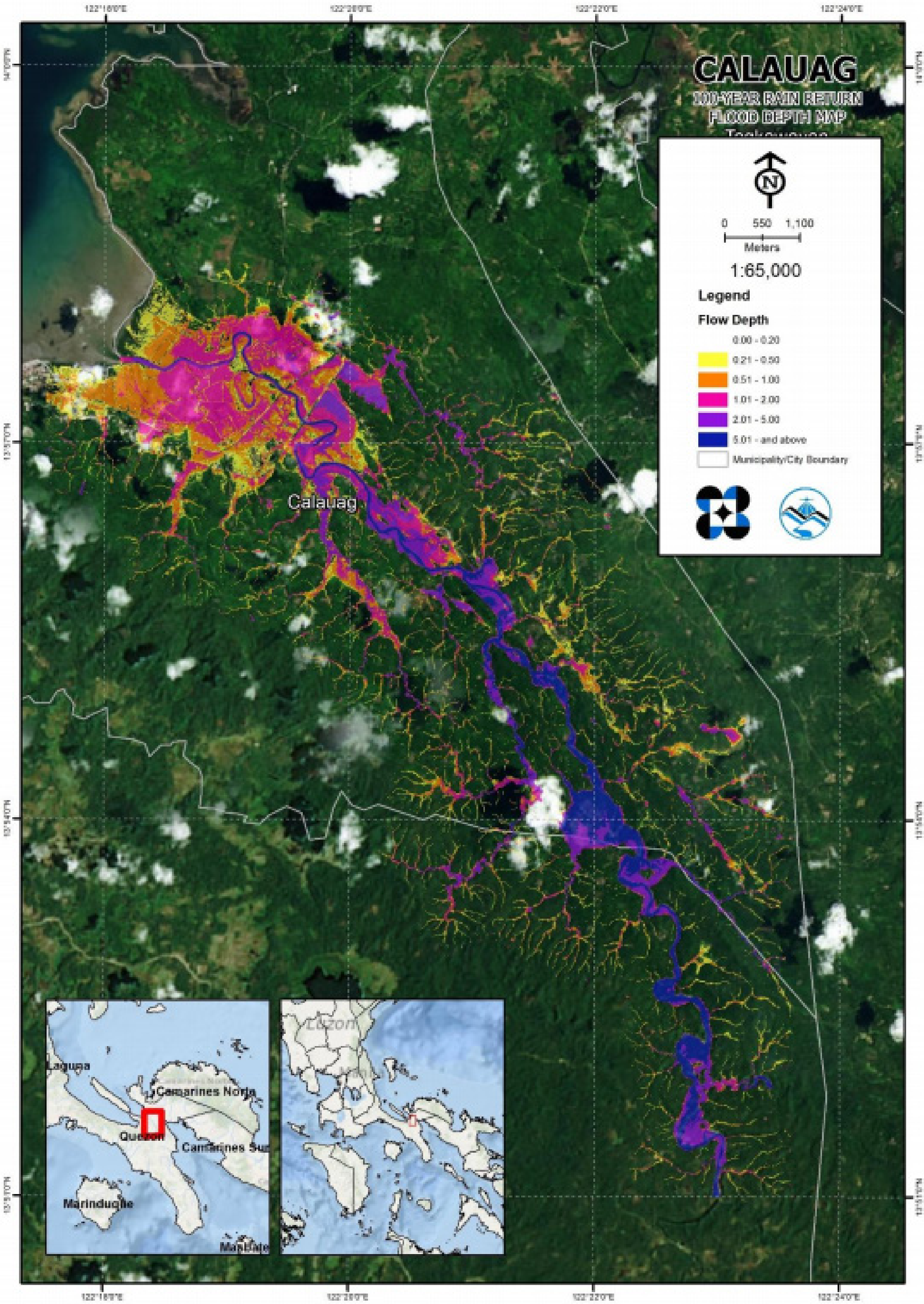


Figure 68. 100-year Rain Return Flood Depth Map for Calauag Floodplain

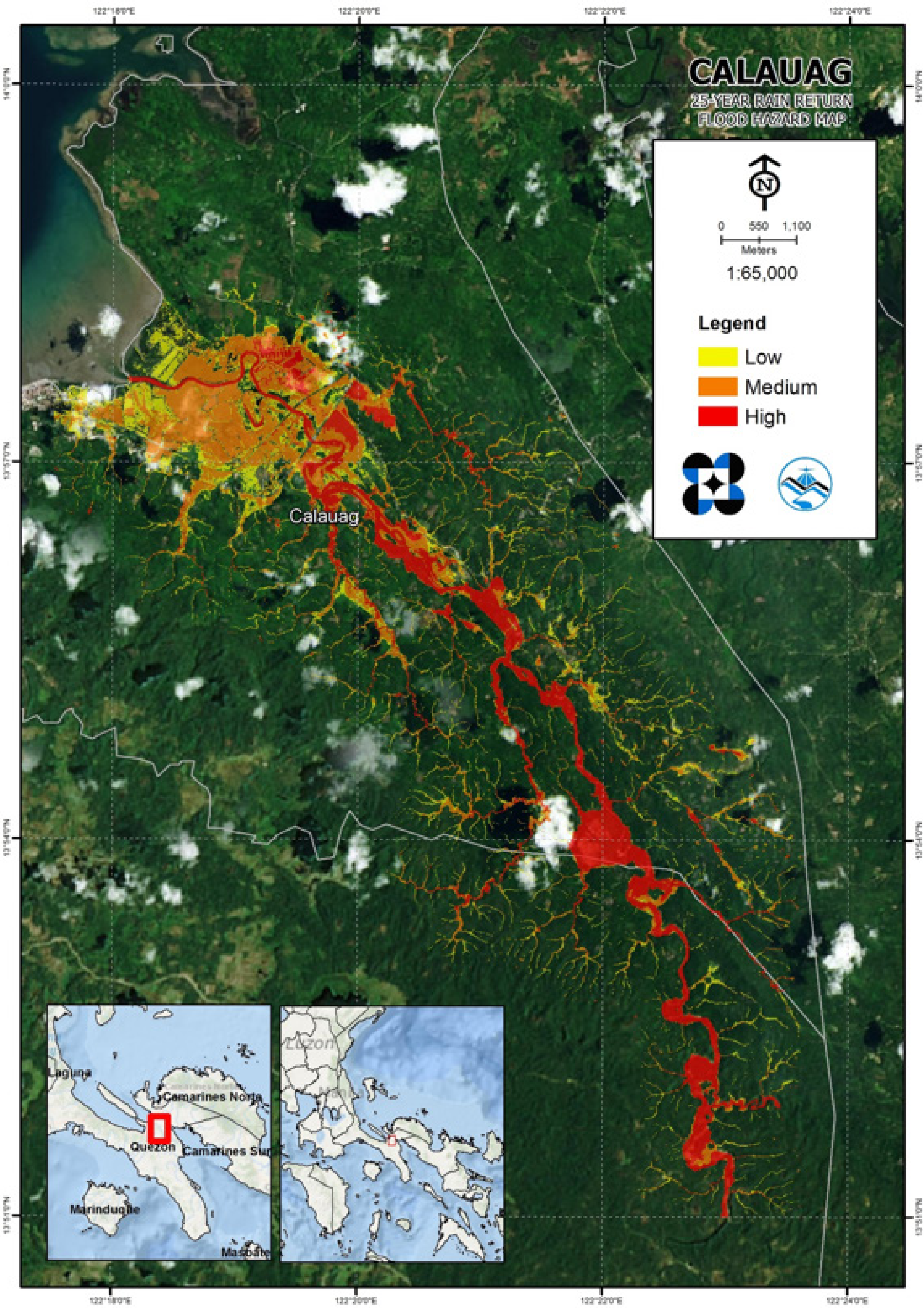


Figure 69. 25-year Rain Return Flood Hazard Map for Calauag Floodplain

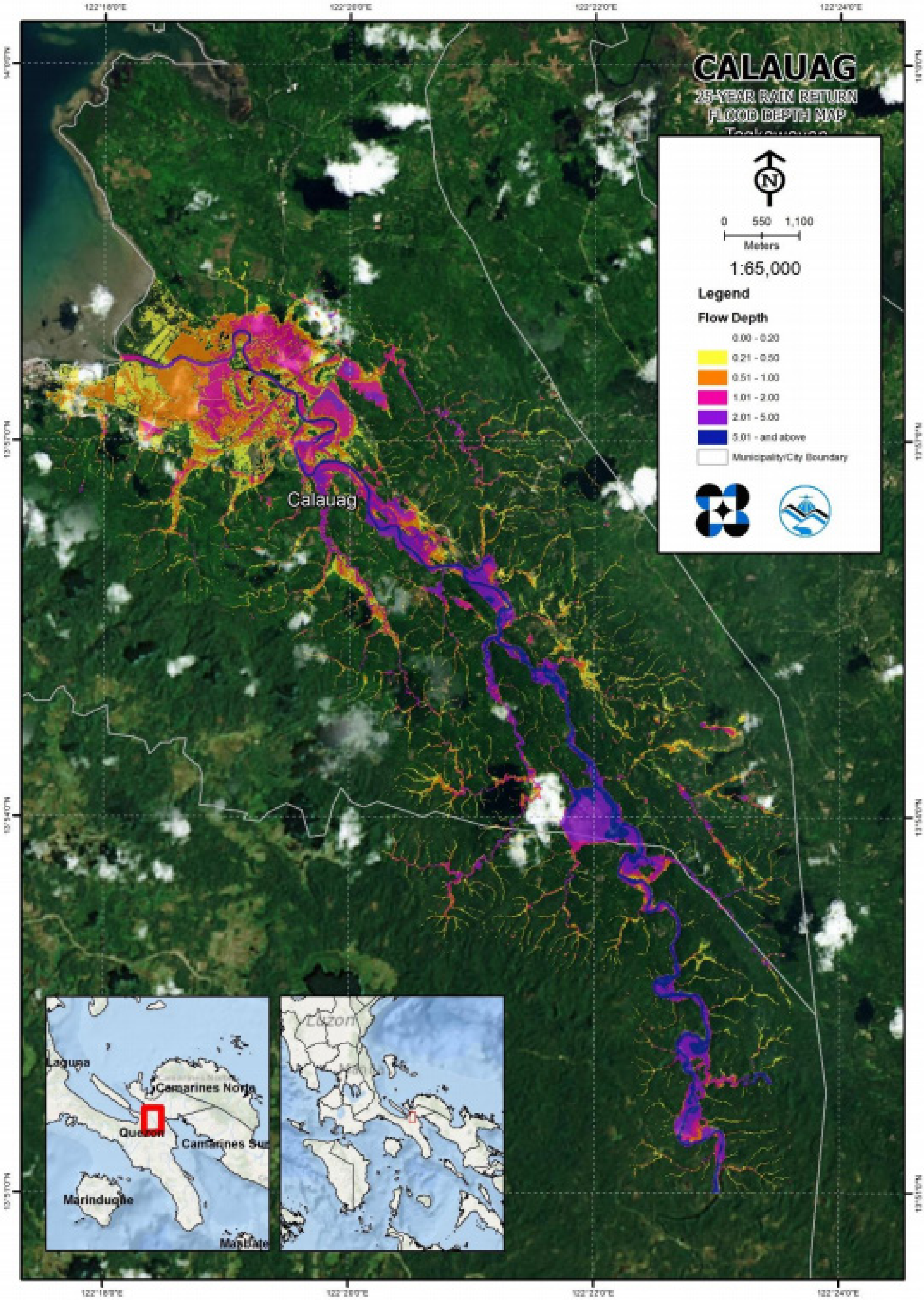


Figure 70. 25-year Rain Return Flood Depth Map for Calauag Floodplain

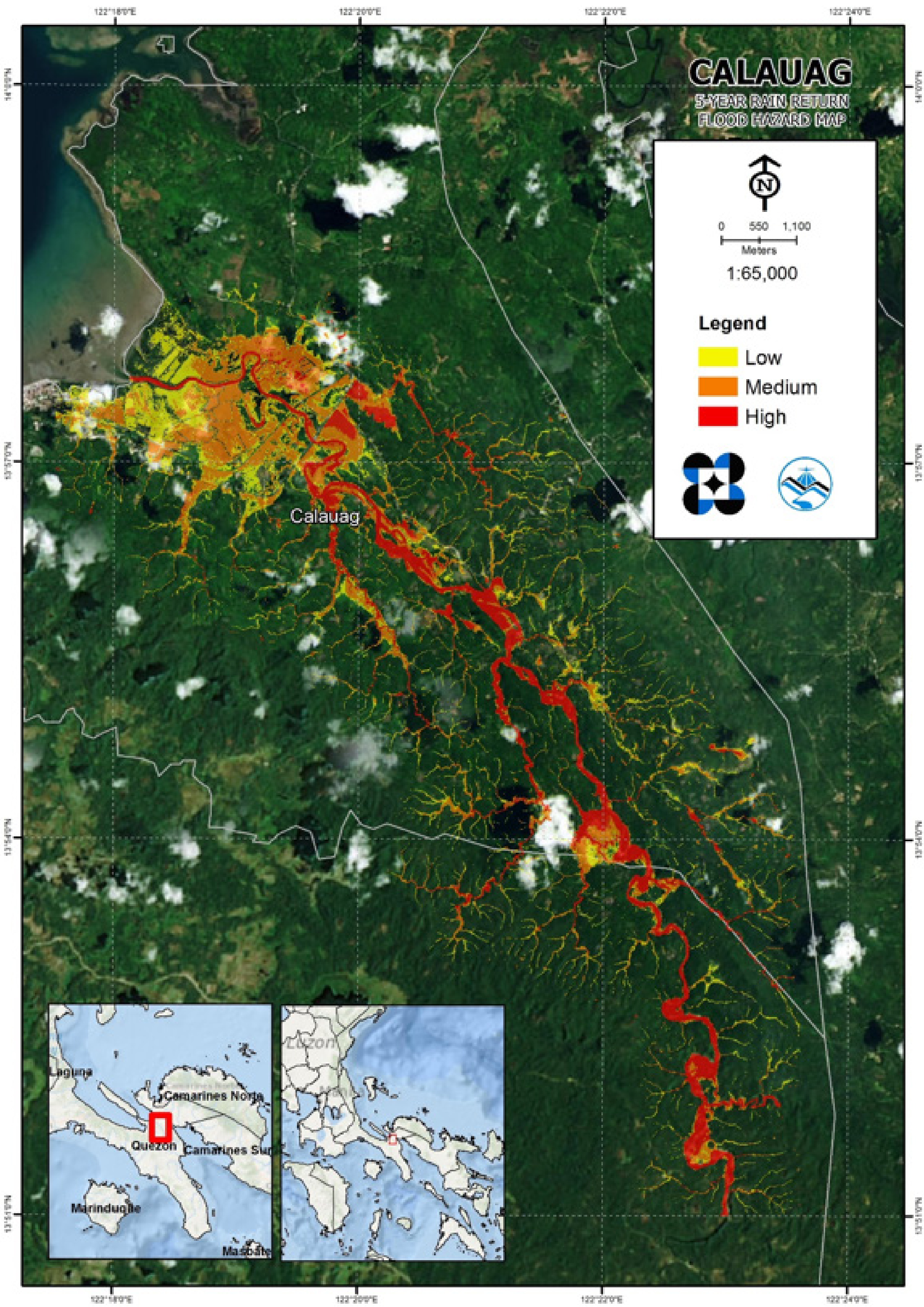


Figure 71. A 5-year Flood Hazard Map for Silaga Floodplain

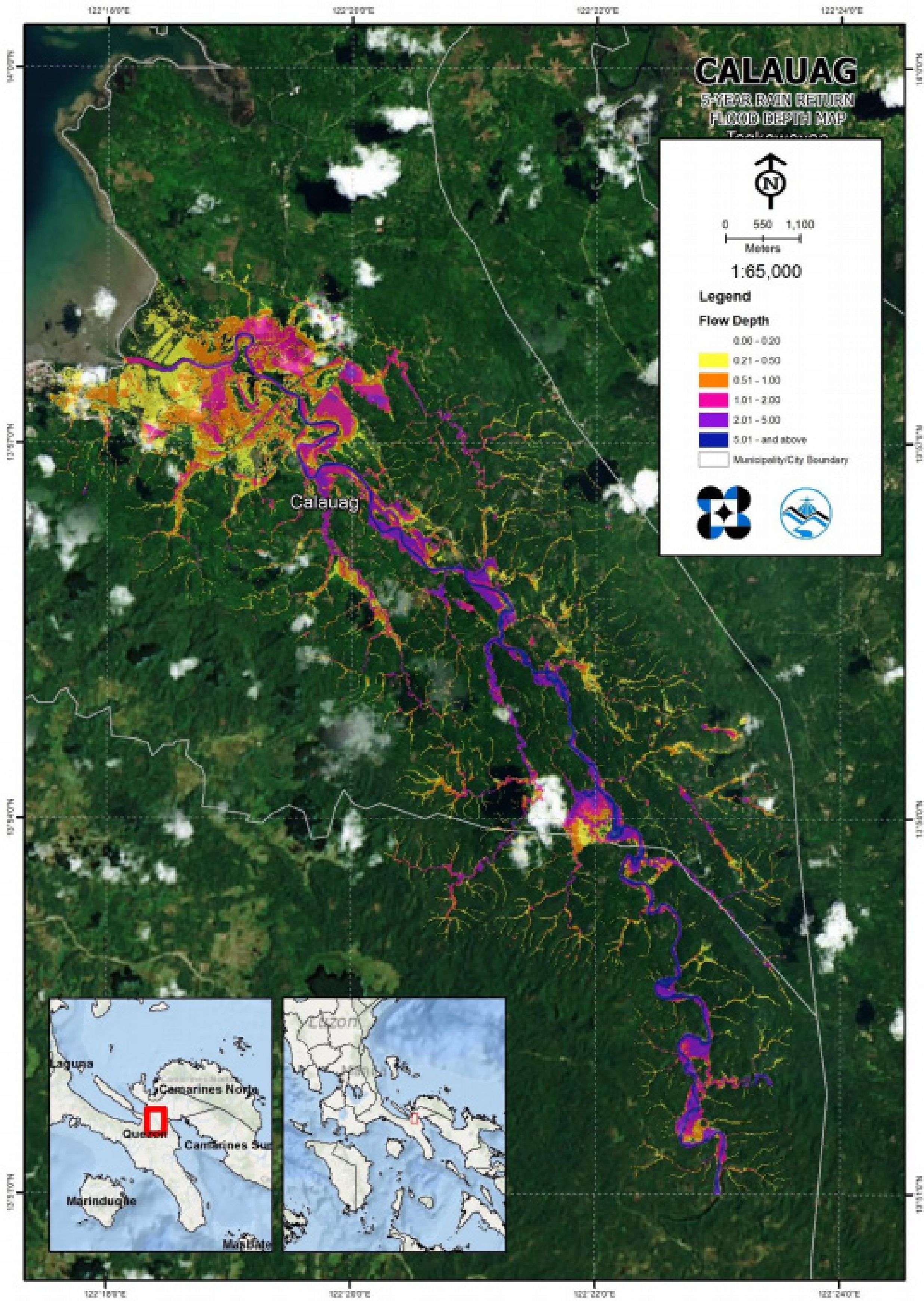


Figure 72. 5-year Rain Return Flood Depth Map for Calauag Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Calauag river basin, grouped by municipality, are listed below. For the said basin, eight municipalities consisting of 201 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 8.6% of the municipality of Buenavista with an area of 217.89 sq. km., 8.58% will experience flood levels of less 0.20 meters. 0.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.28%, 0.20%, 0.08%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 32 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Buenavista, Quezon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Buenavista, Quezon (in sq. km.)				
	Batabat Norte	Magallanes	Maligaya	Villa Magsaysay	Villa Veronica
0.03-0.20	0.07	2.63	1.22	0.048	3.7
0.21-0.50	0.00037	0.097	0.042	0.000041	0.13
0.51-1.00	0.00077	0.081	0.031	0.00045	0.14
1.01-2.00	0.00014	0.064	0.012	0.00039	0.11
2.01-5.00	0	0.014	0	0	0.055
> 5.00	0	0.035	0	0	0.0012

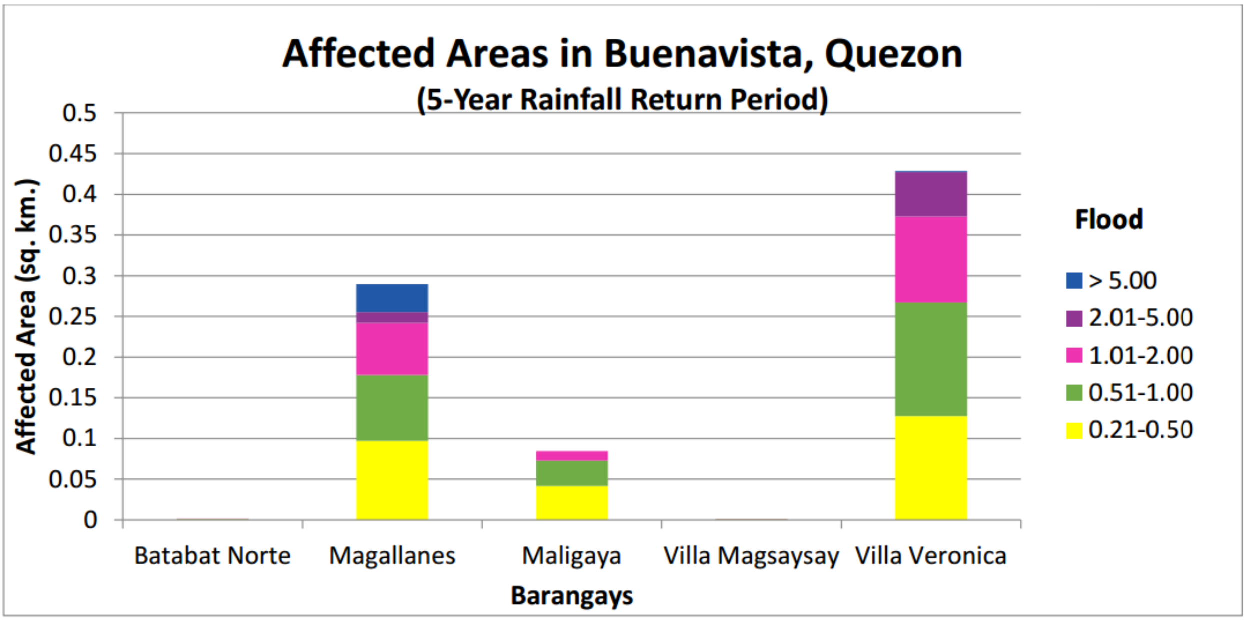


Figure 73. Affected Areas in Buenavista, Quezon during 5-Year Rainfall Return Period

For the municipality of Calauag, with an area of 106.91 sq. km., 34.55% will experience flood levels of less than 0.20 meters. 4.02% of the area will experience flood levels of 0.21 to 0.50 meters while 3.21%, 2.33%, 1.27%, and 0.50% 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.

Table 33. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag, Quezon (in sq. km.)											
	Anahawan	Baclaran	Bangkuruhan	Barangay V	Binutas	Biyan	Kigtan	Mabini	Maglipad	Mambaling	Pinagbayanan	Pinagtalleran
0.03-0.20	2.37	0.023	1.23	0.072	0.31	0.82	4.61	0.85	3.42	2	0.023	0.019
0.21-0.50	0.11	0.0025	0.47	0.04	0.01	0.49	0.23	0.12	0.22	0.076	0.035	0.0031
0.51-1.00	0.057	0	0.24	0.023	0.0041	0.23	0.14	0.16	0.19	0.066	0.0097	0.0002
1.01-2.00	0.039	0	0.022	0.0001	0.0025	0.067	0.06	0.25	0.12	0.11	0	0
2.01-5.00	0.011	0	0.022	0	0.0012	0.0088	0.012	0.067	0.1	0.23	0	0
> 5.00	0	0	0.0058	0	0.0001	0	0.0002	0.044	0.019	0.13	0	0

Table 34. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Perio4

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag, Quezon (in sq. km.)											
	Rizal Ibaba	Rizal Ilaya	Salvacion	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang	Sumulong	Tikiwan	Yaganak
0.03-0.20	0.66	1.51	4.34	1.52	2.33	0.49	0.75	1.03	1.1	0.79	0.53	7.25
0.21-0.50	0.089	0.085	0.25	0.13	0.11	0.073	0.034	0.046	0.77	0.27	0.061	0.5
0.51-1.00	0.084	0.052	0.26	0.078	0.04	0.039	0.017	0.016	0.93	0.36	0.057	0.26
1.01-2.00	0.097	0.048	0.28	0.032	0.0076	0.0032	0.014	0.0085	0.41	0.48	0.12	0.14
2.01-5.00	0.09	0.022	0.29	0.056	0.0025	0.0002	0.0083	0.0038	0.079	0.033	0.11	0.12
> 5.00	0.011	0	0.16	0.015	0	0	0	0	0.034	0.023	0.021	0.079

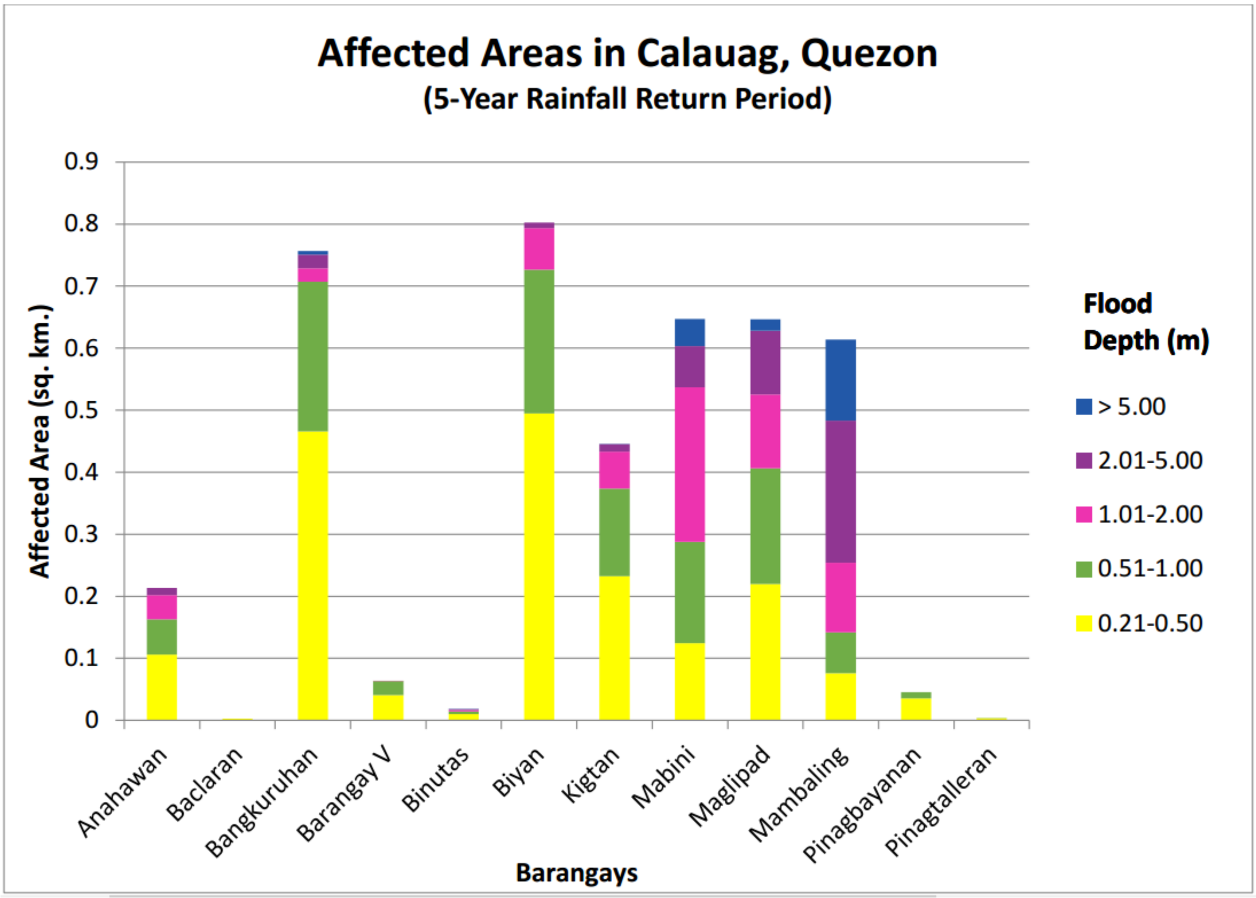


Figure 74. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period

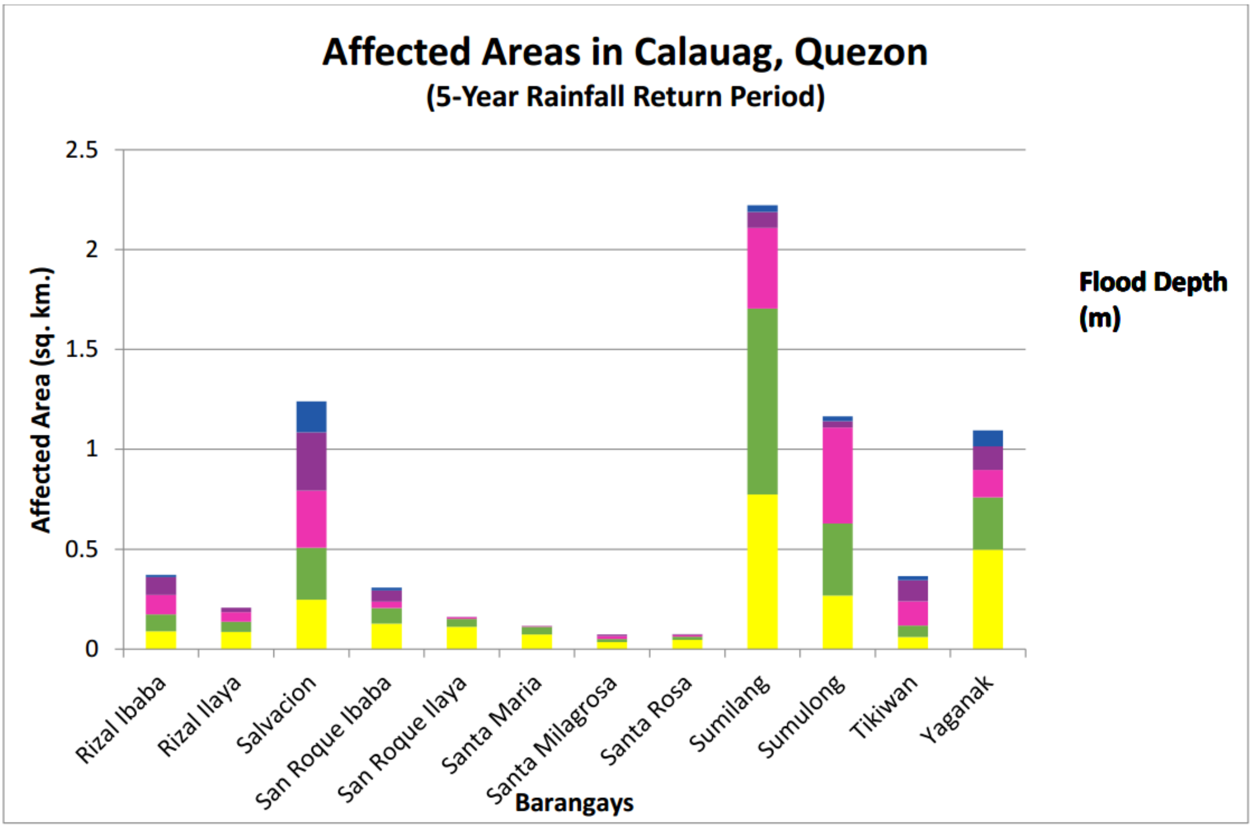


Figure 75. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period

For the municipality of Catanauan, with an area of 267.28 sq. km., 0.18% will experience flood levels of less 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.01%, and 0.00008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 and above respectively. Listed in Table 35 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Catanauan, Quezon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Catanauan, Quezon (in sq. km.)	
	Milagrosa	Santa Maria
0.03-0.20	2.23	0.12
0.21-0.50	0.058	0.0012
0.51-1.00	0.052	0.0013
1.01-2.00	0.027	0
2.01-5.00	0	0
> 5.00	0	0

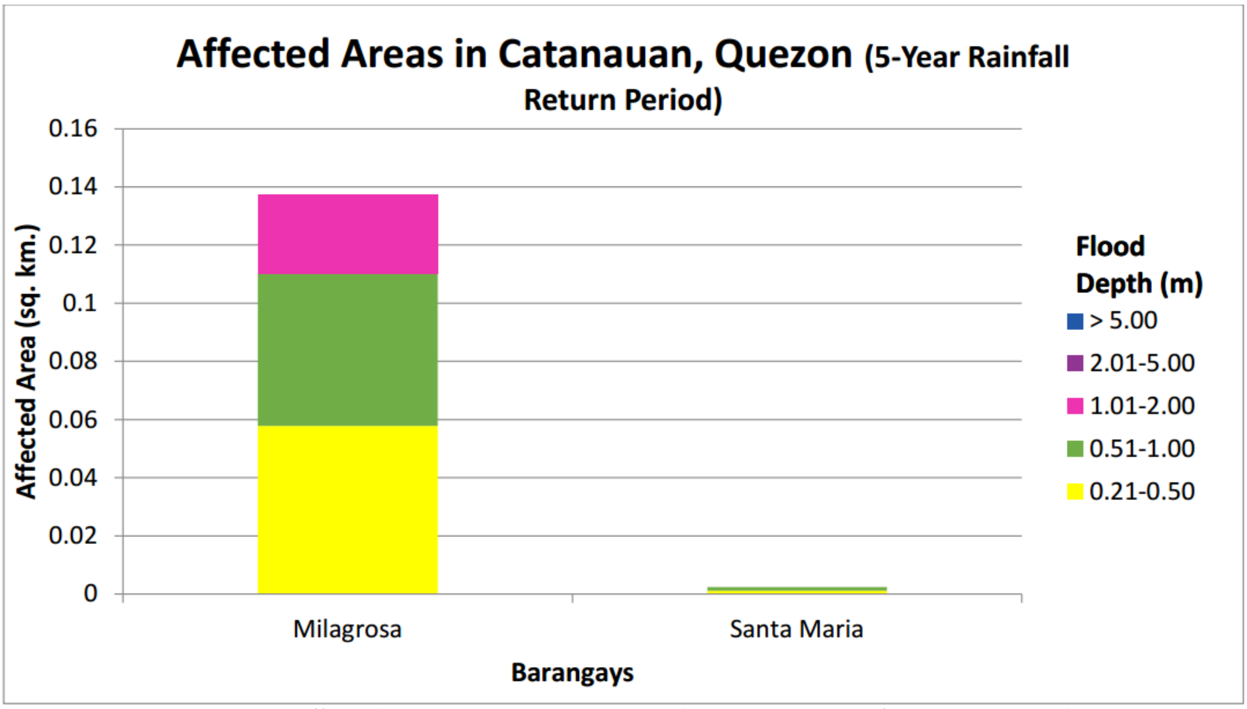


Figure 76. Affected Areas in Calauag, Quezon during 5-Year Rainfall Return Period

For the municipality of Guinayangan, with an area of 236.84 sq. km., 8.40% will experience flood levels of less 0.20 meters. 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.12%, 0.06%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan, Quezon (in sq. km.)								
	Rizal Ibaba	Rizal Ilaya	Salvacion	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang
0.03-0.20	4.23	2.33	2.87	5.61	0.000033	5.53	0.11	0.12	1.7
0.21-0.50	0.19	0.1	0.14	0.29	0	0.2	0.0024	0.00046	0.09
0.51-1.00	0.079	0.068	0.069	0.15	0.000006	0.079	0.0016	0	0.038
1.01-2.00	0.027	0.029	0.036	0.1	0	0.11	0.0023	0	0.021
2.01-5.00	0.013	0.0042	0.018	0.055	0	0.1	0	0	0.0014
> 5.00	0	0	0	0.035	0	0.00042	0	0	0

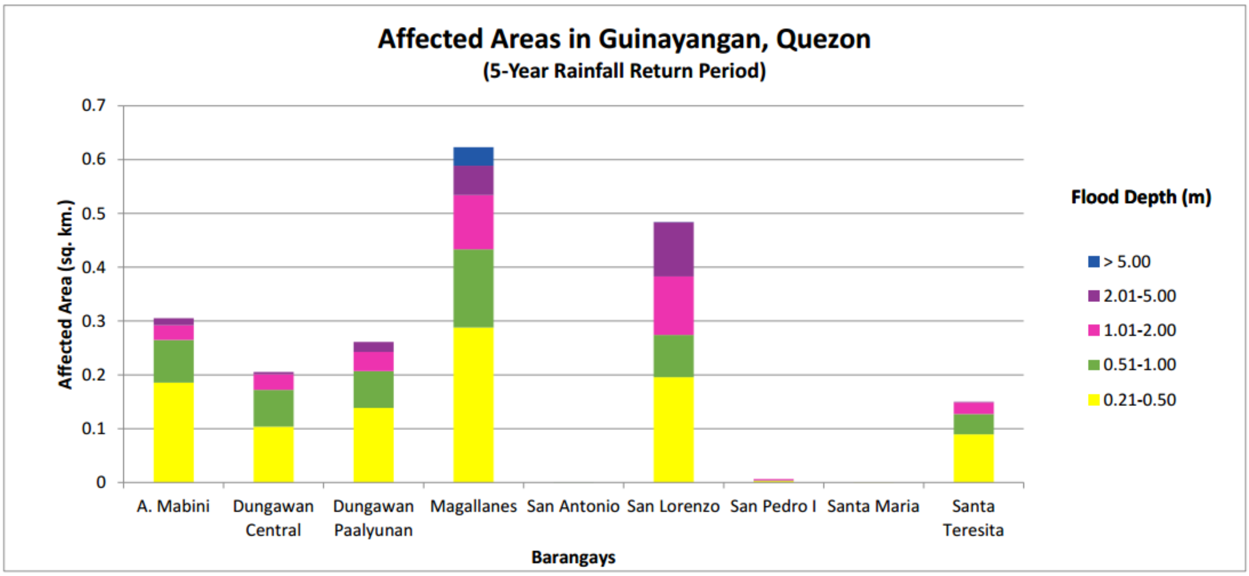


Figure 77. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period

For the municipality of Lopez, with an area of 378.81 sq. km., 17.94% will experience flood levels of less 0.20 meters. 0.68% of the area will experience flood levels of 0.21 to 0.50 meters while 0.60%, 0.60%, 0.57%, and 0.40% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in Table 37 and Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Lopez, Quezon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez, Quezon (in sq. km.)											
	Cagacag	Cawayanin	Guinuangan	Lalaguna	Mabanban	Magallanes	Monteclaro	Pisipis	San Andres	San Francisco B	Santa Catalina	Santa Rosa
0.03-0.20	1.01	16.66	2.84	0.16	7.04	3.65	1.71	3.18	2.96	0.42	13.07	1.22
0.21-0.50	0.033	0.41	0.072	0.0063	0.25	0.1	0.061	0.16	0.11	0.0062	0.47	0.035
0.51-1.00	0.021	0.35	0.069	0.0013	0.25	0.052	0.044	0.13	0.087	0.0019	0.5	0.025
1.01-2.00	0.024	0.35	0.056	0.00056	0.29	0.065	0.049	0.096	0.11	0.0004	0.5	0.017
2.01-5.00	0.011	0.4	0.014	0.0001	0.28	0.12	0.022	0.089	0.15	0	0.34	0.0004
> 5.00	0	0.29	0	0	0.22	0.035	0.000019	0.093	0.12	0	0.091	0

Table 38. Affected Areas in Lopez, Quezon during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez, Quezon (in sq. km.)							
	Santo Niño Ibaba	Santo Niño Ilaya	Sumalang	Vegaflor	Vergaña	Veronica	Villa Aurora	Villa Espina
0.03-0.20	6.7	3.5	10.5	3.7	1.5	1.45	1.3	2.3
0.21-0.50	0.20	0.13	0.29	0.16	0.07	0.039	0.03	0.08
0.51-1.00	0.21	0.11	0.24	0.06	0.10	0.03	0.02	0.043
1.01-2.00	0.28	0.12	0.21	0.07	0.11	0.03	0.01	0.021
2.01-5.00	0.28	0.17	0.14	0.17	0.17	0.06	0.0005	0.024
> 5.00	0.29	0.18	0.11	0.10	0.10	0.05	0	0.042

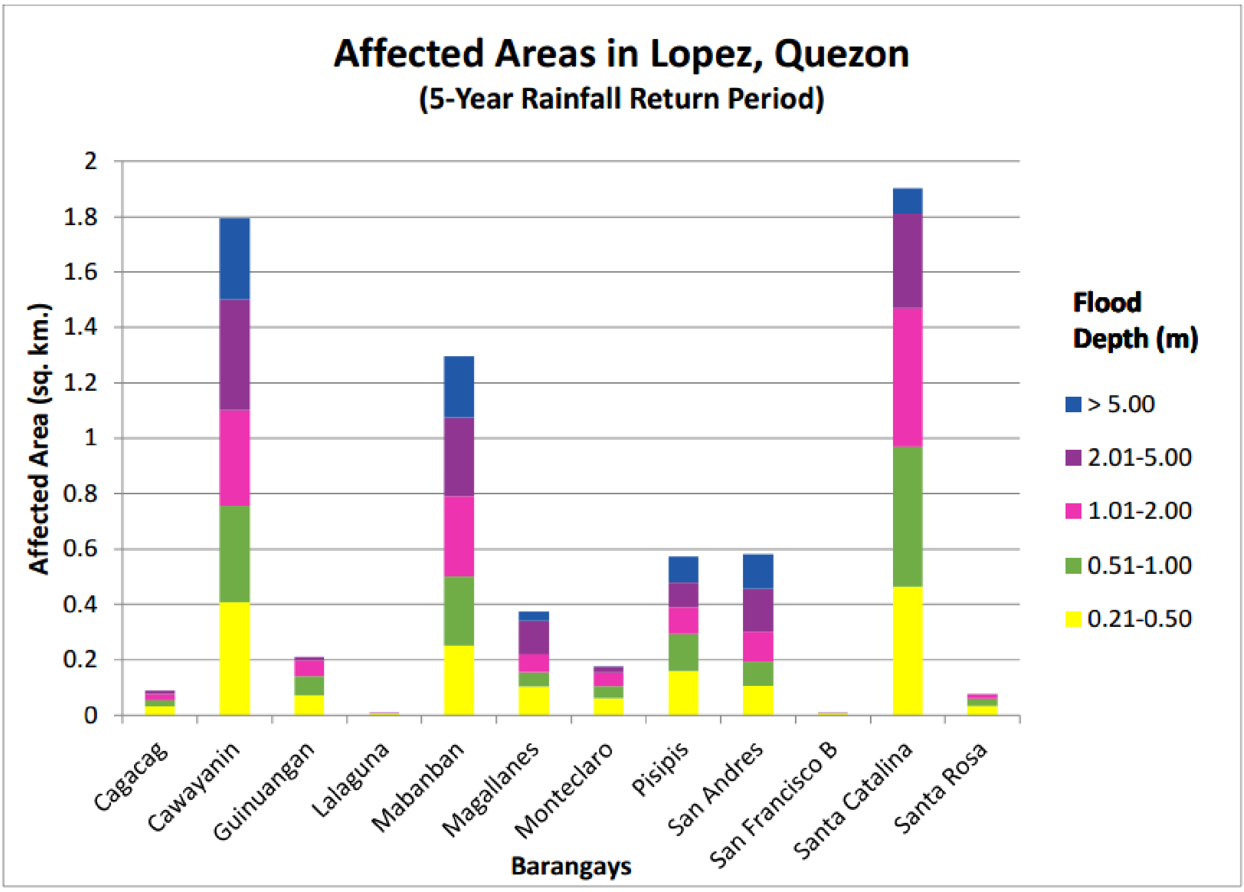


Figure 78. Affected Areas in Lopez, Quezon during 5-Year Rainfall Return Period

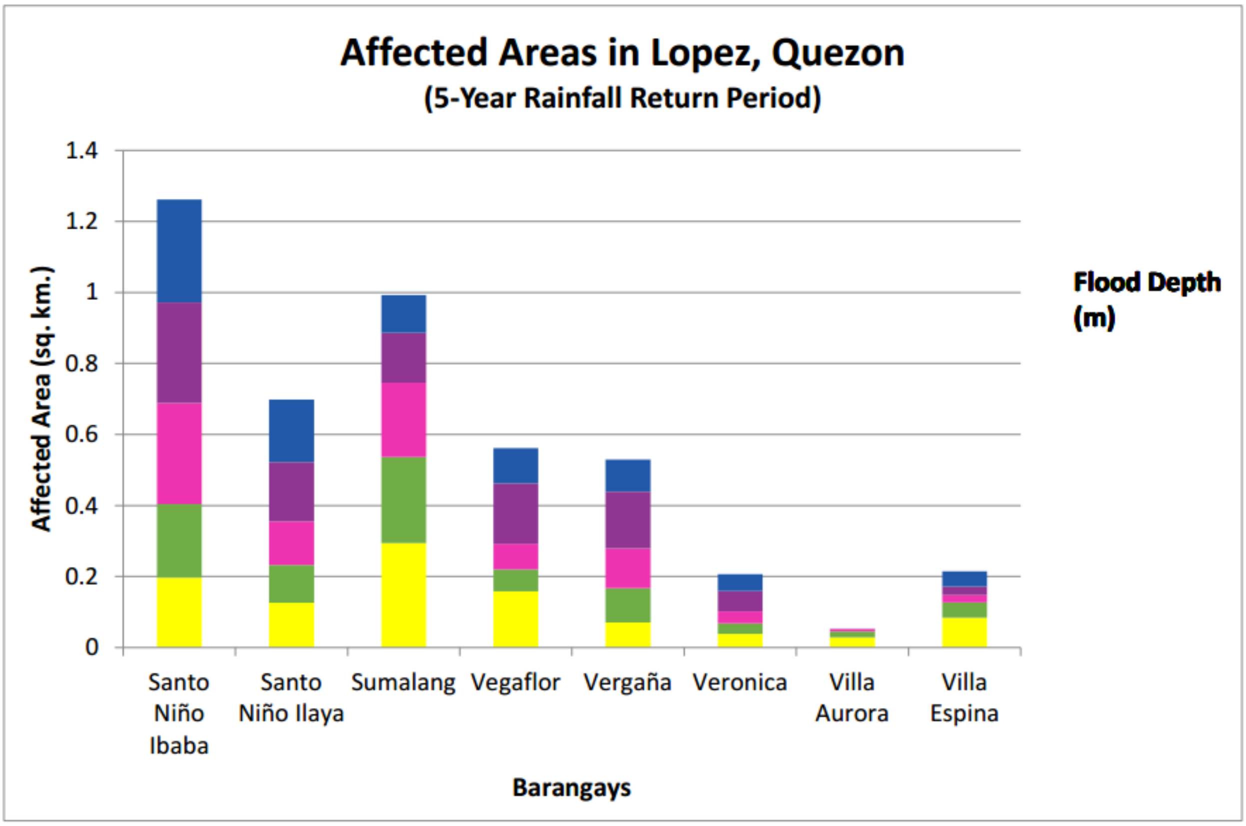


Figure 79. Affected Areas in Lopez, Quezon during 5-Year Rainfall Return Period

For the 25-year return period, 8.6% of the municipality of Buenavista with an area of 217.89 sq. km., 3.46% will experience flood levels of less 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.10%, 0.06%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Buenavista, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Buenavista, Quezon (in sq. km.)				
	Batabat Norte	Magallanes	Maligaya	Villa Magsaysay	Villa Veronica
0.03-0.20	0.07	2.58	1.21	0.048	3.64
0.21-0.50	0.00063	0.1	0.044	0.00018	0.12
0.51-1.00	0.00054	0.085	0.035	0.00029	0.14
1.01-2.00	0.00041	0.078	0.017	0.00059	0.13
2.01-5.00	0	0.032	0.0002	0	0.089
> 5.00	0	0.0012	0	0	0.0059

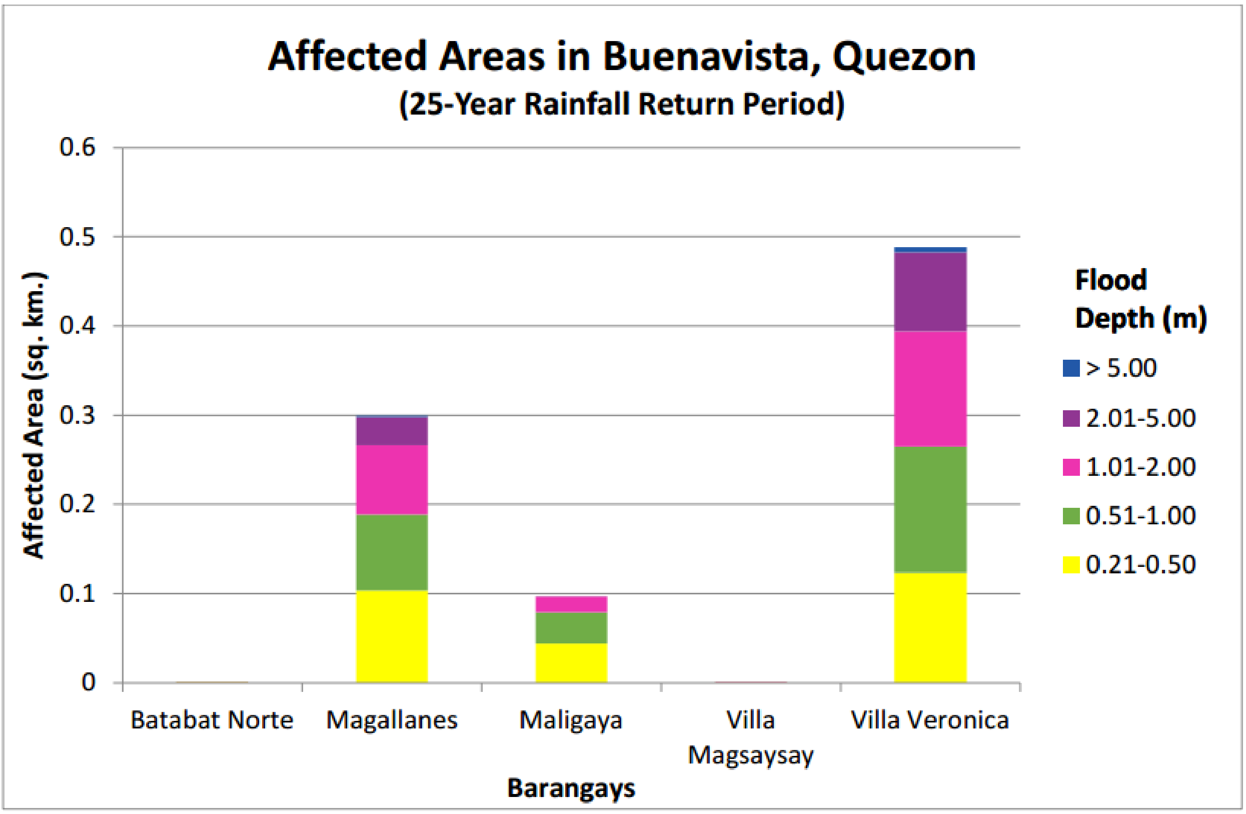


Figure 80. Affected Areas in Buenavista, Quezon during 25-Year Rainfall Return Period

For the municipality of Calauag, with an area of 106.91 sq. km., 27.27% will experience flood levels of less 0.20 meters. 3.55% of the area will experience flood levels of 0.21 to 0.50 meters while 3.55%, 2.58%, 1.70%, and 0.70% 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.

Table 40. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag, Quezon (in sq. km.)											
	Anahawan	Baclaran	Bangkuruhan	Barangay V	Binutas	Biyan	Kigtan	Mabini	Maglipad	Mambaling	Pansol	Pinagbayanan
0.03-0.20	2.37	0.023	1.17	0.072	0.31	0.75	4.61	0.76	3.42	1.96	1.68	0.023
0.21-0.50	0.11	0.0025	0.38	0.04	0.01	0.38	0.23	0.13	0.22	0.073	0.074	0.035
0.51-1.00	0.059	0	0.35	0.023	0.0041	0.41	0.14	0.15	0.19	0.075	0.11	0.0097
1.01-2.00	0.041	0	0.04	0.0001	0.0025	0.067	0.06	0.29	0.1	0.094	0.18	0
2.01-5.00	0.012	0	0.025	0	0.0012	0.012	0.012	0.12	0.12	0.25	0.088	0
> 5.00	0	0	0.0076	0	0.0001	0	0.0002	0.047	0.021	0.17	0.0007	0

Table 41. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag, Quezon (in sq. km.)												
	Pinagtalleran	Rizal Ibaba	Rizal Ilaya	Salvacion	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang	Sumulong	Tikiwan	Yaganak
0.03-0.20	0	0.56	1.51	4.27	0	2.33	0.49	0.75	0	0.91	0.68	0.51	0
0.21-0.50	0.0032	0.077	0.086	0.18	0.12	0.11	0.073	0.034	0.046	0.59	0.24	0.06	0.5
0.51-1.00	0.0002	0.11	0.052	0.16	0.072	0.04	0.039	0.017	0.016	1.11	0.36	0.052	0.26
1.01-2.00	0	0.13	0.048	0.14	0.05	0.0076	0.0032	0.014	0.0085	0.6	0.6	0.12	0.15
2.01-5.00	0	0.14	0.022	0.54	0.065	0.0025	0.0002	0.0083	0.0038	0.081	0.054	0.13	0.14
> 5.00	0	0.015	0	0.29	0.024	0	0	0	0	0.038	0.025	0.022	0.095

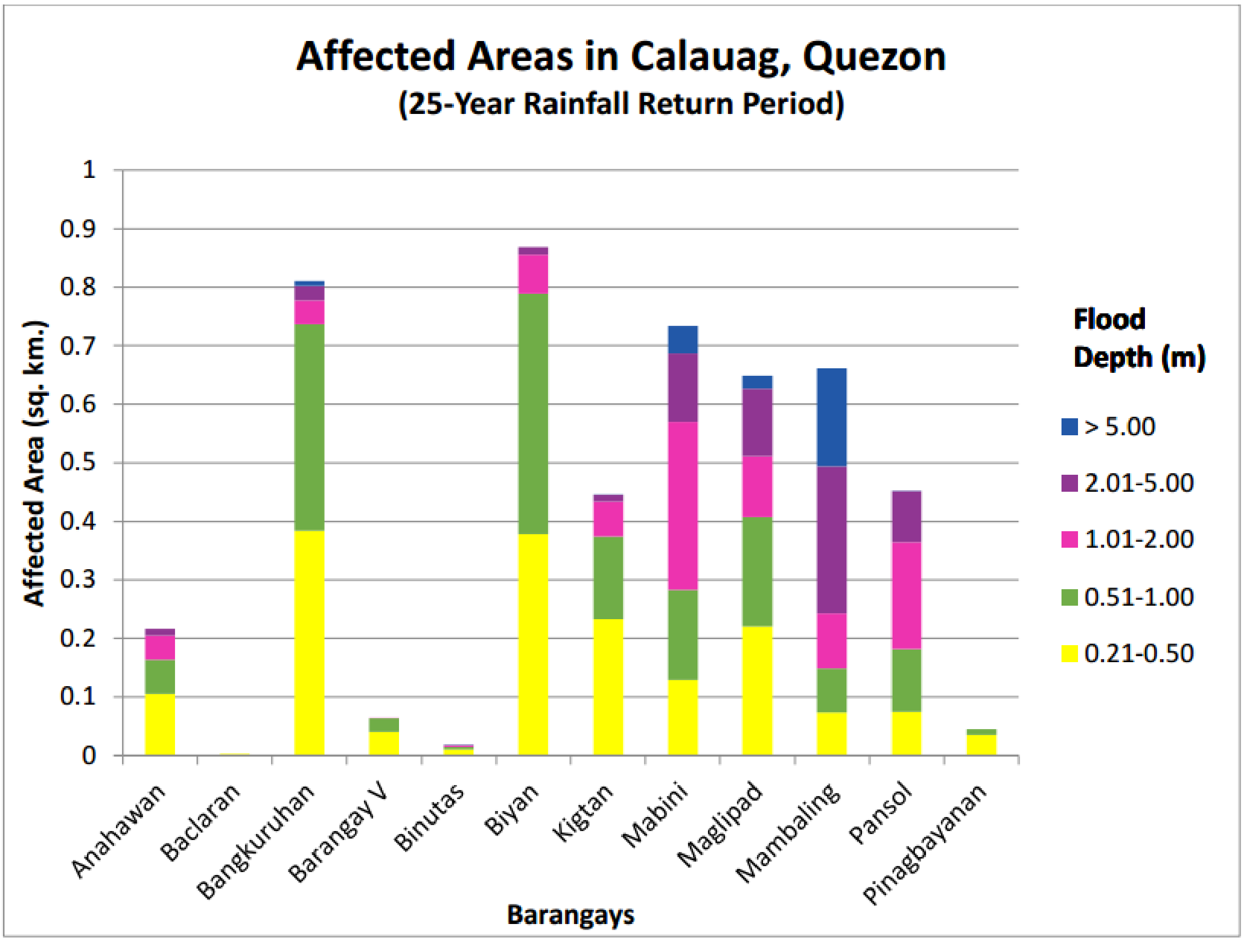


Figure 81. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period

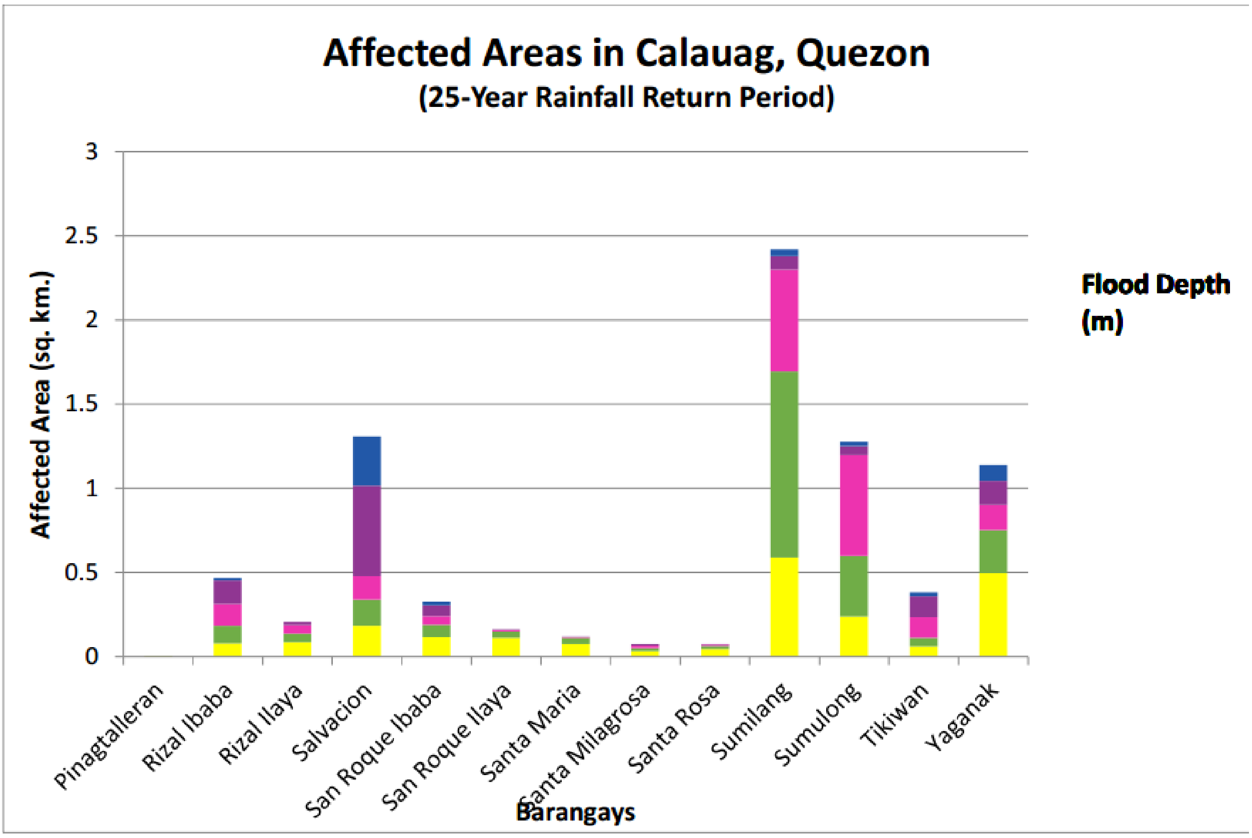


Figure 82. Affected Areas in Calauag, Quezon during 25-Year Rainfall Return Period

For the municipality of Catanauan, with an area of 267.28 sq. km., 0.87% will experience flood levels of less 0.20 meters. 0.023% of the area will experience flood levels of 0.21 to 0.50 meters while 0.021%, 0.015%, and 0.00019% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 and above respectively. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Catanauan, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Catanauan, Quezon (in sq. km.)	
	Milagrosa	Santa Maria
0.03-0.20	2.23	0.12
0.21-0.50	0.058	0.0012
0.51-1.00	0.052	0.0013
1.01-2.00	0.027	0
2.01-5.00	0	0
> 5.00	0	0

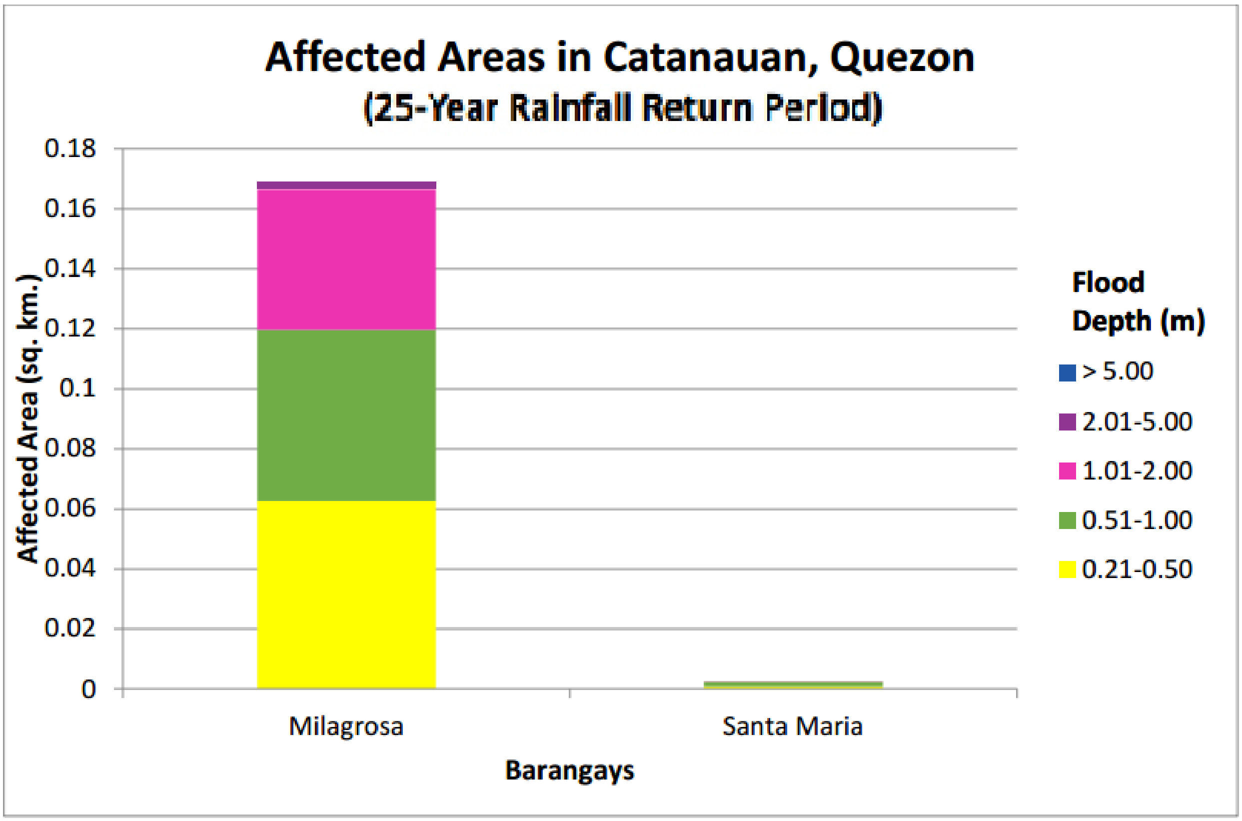


Figure 83. Affected Areas in Catanauan, Quezon during 25-Year Rainfall Return Period

For the municipality of Guinayangan, with an area of 236.84 sq. km., 8.40% will experience flood levels of less 0.20 meters. 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.12%, 0.06%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Guinayangan, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan, Quezon (in sq. km.)								
	Rizal Ibaba	Rizal Ilaya	Salvacion	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang
0.03-0.20	4.16	2.28	2.81	5.49	0.000033	0.11	0.12	1.67	1.7
0.21-0.50	0.22	0.12	0.15	0.31	0	0.003	0.00097	0.096	0.09
0.51-1.00	0.096	0.079	0.092	0.18	0.000006	0.0024	0.0016	0.047	0.038
1.01-2.00	0.044	0.047	0.055	0.12	0	0.0025	0	0.028	0.021
2.01-5.00	0.019	0.0057	0.026	0.092	0	0.0001	0	0.0061	0.0014
> 5.00	0	0	0	0.0012	0	0	0	0	0

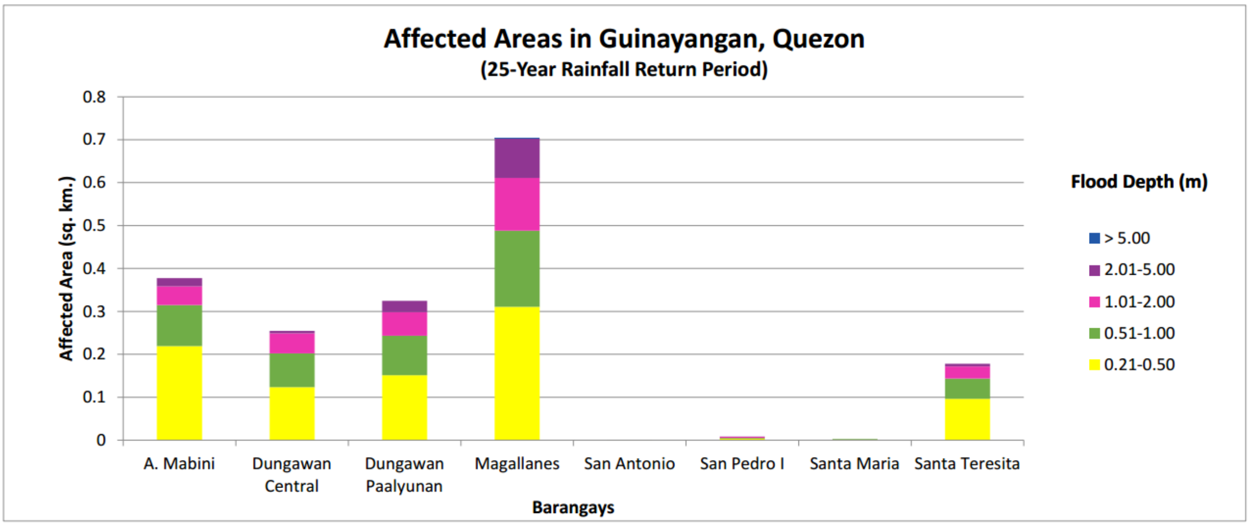


Figure 84. Affected Areas in Guinayangan, Quezon during 25-Year Rainfall Return Period

For the municipality of Lopez, with an area of 378.81 sq. km., 20.18% will experience flood levels of less 0.20 meters. 0.73% of the area will experience flood levels of 0.21 to 0.50 meters while 0.58%, 0.73%, 0.90%, and 0.68% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in Table 44 and Table 45 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected Areas in Lopez, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez, Quezon (in sq. km.)											
	Cagacag	Cawayanin	Guinuangan	Lalaguna	Mabanban	Magallanes	Monteclaro	Pisipis	San Andres	San Francisco B	Santa Catalina	Santa Rosa
0.03-0.20	1	16.37	2.8	0.16	6.83	3.6	1.71	3.08	2.85	0.42	12.61	1.21
0.21-0.50	0.037	0.43	0.082	0.0062	0.26	0.12	0.061	0.12	0.11	0.0085	0.47	0.041
0.51-1.00	0.026	0.35	0.071	0.0013	0.24	0.053	0.044	0.099	0.081	0.0019	0.47	0.028
1.01-2.00	0.023	0.38	0.073	0.00056	0.34	0.056	0.05	0.15	0.12	0.0007	0.63	0.02
2.01-5.00	0.02	0.5	0.024	0.0001	0.36	0.13	0.021	0.2	0.18	0	0.63	0.0025
> 5.00	0	0.43	0	0	0.3	0.06	0.000019	0.11	0.2	0	0.16	0

Table 45. Affected Areas in Lopez, Quezon during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez, Quezon (in sq. km.)							
	Santo Niño Ibaba	Santo Niño Ilaya	Sumalang	Vegaflor	Vergaña	Veronica	Villa Aurora	Villa Espina
0.03-0.20	0	3.35	10.24	3.63	1.5	1.42	1.33	2.31
0.21-0.50	0.21	0.13	0.31	0.16	0.05	0.041	0.034	0.084
0.51-1.00	0.2	0.1	0.24	0.058	0.058	0.03	0.018	0.04
1.01-2.00	0.29	0.13	0.28	0.05	0.11	0.033	0.0071	0.018
2.01-5.00	0.41	0.22	0.25	0.17	0.21	0.055	0.00055	0.029
> 5.00	0.44	0.3	0.15	0.17	0.13	0.079	0	0.051

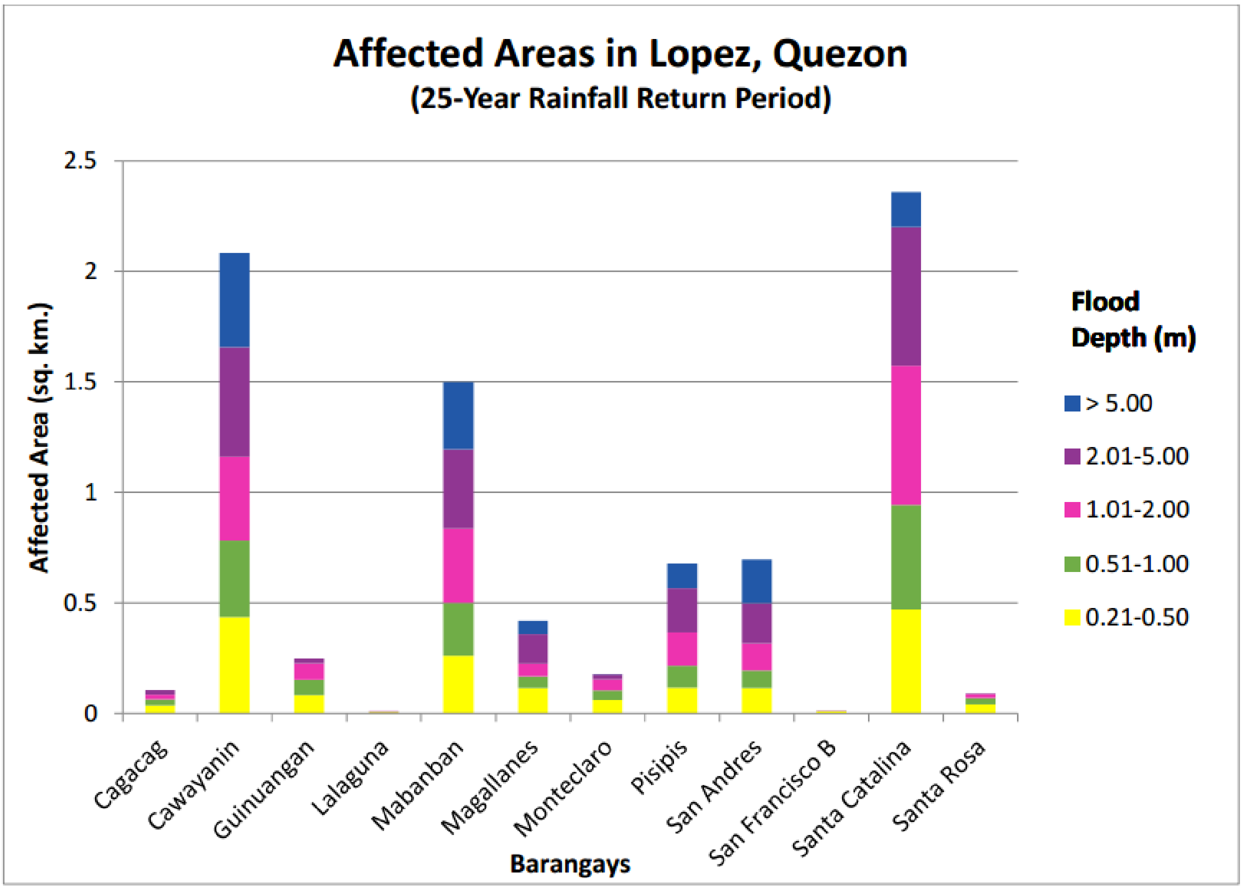


Figure 85. Affected Areas in Lopez, Quezon during 25-Year Rainfall Return Period

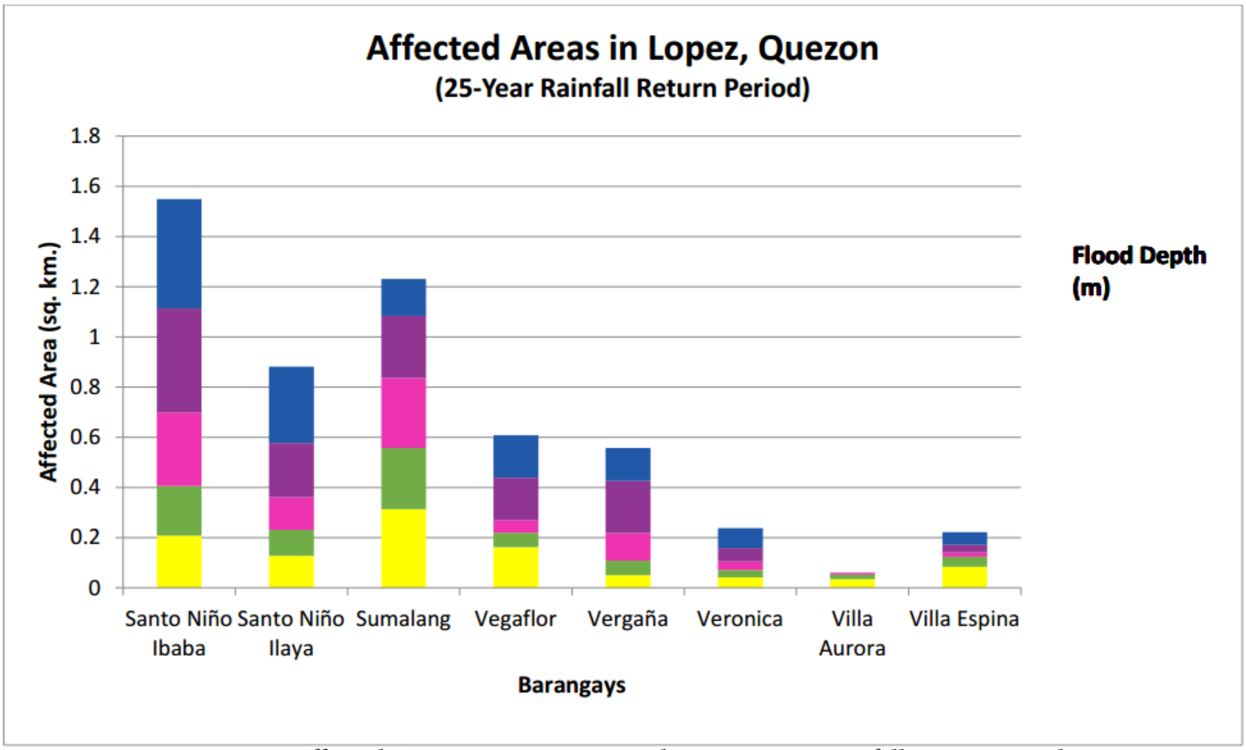


Figure 86. Affected Areas in Lopez, Quezon during 25-Year Rainfall Return Period

For the 100-year return period, 8.6% of the municipality of Buenavista with an area of 217.89 sq. km., 3.42% will experience flood levels of less 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.12%, 0.07%, and 0.008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Buenavista, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Buenavista, Quezon (in sq. km.)				
	Batabat Norte	Magallanes	Maligaya	Villa Magsaysay	Villa Veronica
0.03-0.20	0.07	2.63	1.22	0.048	3.7
0.21-0.50	0.00037	0.097	0.042	0.000041	0.13
0.51-1.00	0.00077	0.081	0.031	0.00045	0.14
1.01-2.00	0.00014	0.064	0.012	0.00039	0.11
2.01-5.00	0	0.014	0	0	0.055
> 5.00	0	0.035	0	0	0.0012

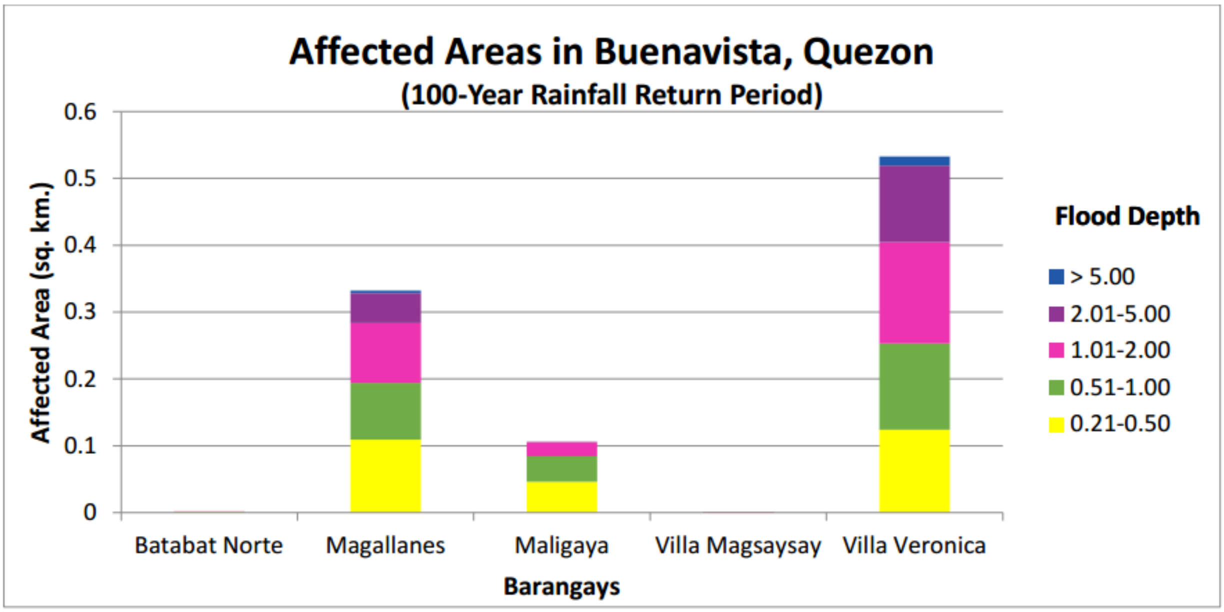


Figure 87. Affected Areas in Buenavista, Quezon during 100-Year Rainfall Return Period

For the municipality of Calauag, with an area of 106.91 sq. km., 34.38% will experience flood levels of less 0.20 meters. 3.59% of the area will experience flood levels of 0.21 to 0.50 meters while 3.89%, 4.08%, 1.95%, and 1.32% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively.

Table 47. Affected Areas in Calauag, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag, Quezon (in sq. km.)											
	Anahawan	Baclaran	Bangkuruhan	Barangay V	Binutas	Biyan	Kigtan	Mabini	Maglipad	Mambaling	Pansol	Pinagbayanan
0.03-0.20	2.37	0.023	1.17	0.072	0.31	0.75	4.61	0.76	3.42	1.96	1.68	0.023
0.21-0.50	0.11	0.0025	0.38	0.04	0.01	0.38	0.23	0.13	0.22	0.073	0.074	0.035
0.51-1.00	0.059	0	0.35	0.023	0.0041	0.41	0.14	0.15	0.19	0.075	0.11	0.0097
1.01-2.00	0.041	0	0.04	0.0001	0.0025	0.067	0.06	0.29	0.1	0.094	0.18	0
2.01-5.00	0.012	0	0.025	0	0.0012	0.012	0.012	0.12	0.12	0.25	0.088	0
> 5.00	0	0	0.0076	0	0.0001	0	0.0002	0.047	0.021	0.17	0.0007	0

Table 48. Affected Areas in Calauag, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag, Quezon (in sq. km.)												
	Pinagtalleran	Rizal Ibaba	Rizal Ilaya	Salvacion	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang	Sumulong	Tikiwan	Yaganak
0.03-0.20	0	0.56	1.51	4.27	0	2.33	0.49	0.75	0	0.91	0.68	0.51	0
0.21-0.50	0.0032	0.077	0.086	0.18	0.12	0.11	0.073	0.034	0.046	0.59	0.24	0.06	0.5
0.51-1.00	0.0002	0.11	0.052	0.16	0.072	0.04	0.039	0.017	0.016	1.11	0.36	0.052	0.26
1.01-2.00	0	0.13	0.048	0.14	0.05	0.0076	0.0032	0.014	0.0085	0.6	0.6	0.12	0.15
2.01-5.00	0	0.14	0.022	0.54	0.065	0.0025	0.0002	0.0083	0.0038	0.081	0.054	0.13	0.14
> 5.00	0	0.015	0	0.29	0.024	0	0	0	0	0.038	0.025	0.022	0.095

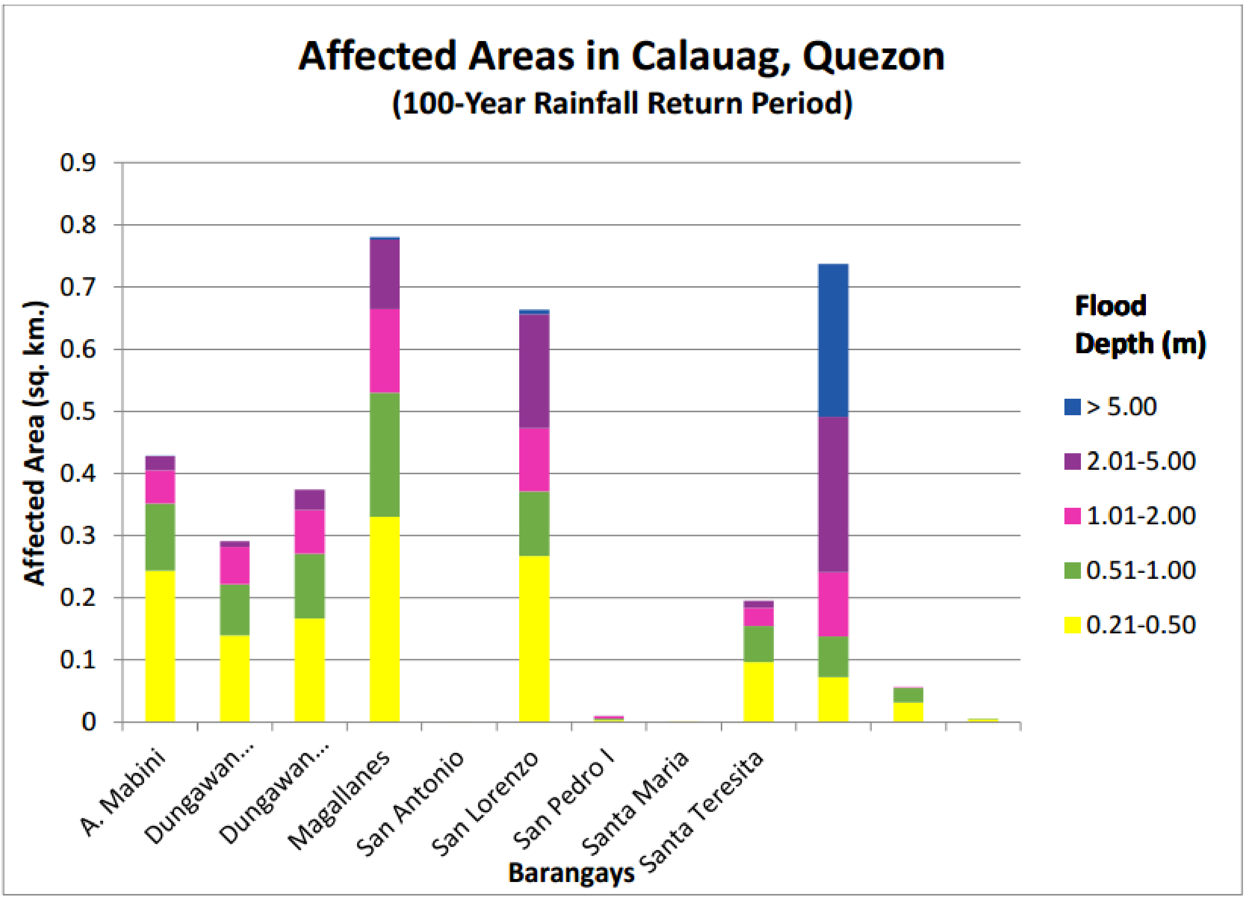


Figure 88. Affected Areas in Calauag, Quezon during 100-Year Rainfall Return Period

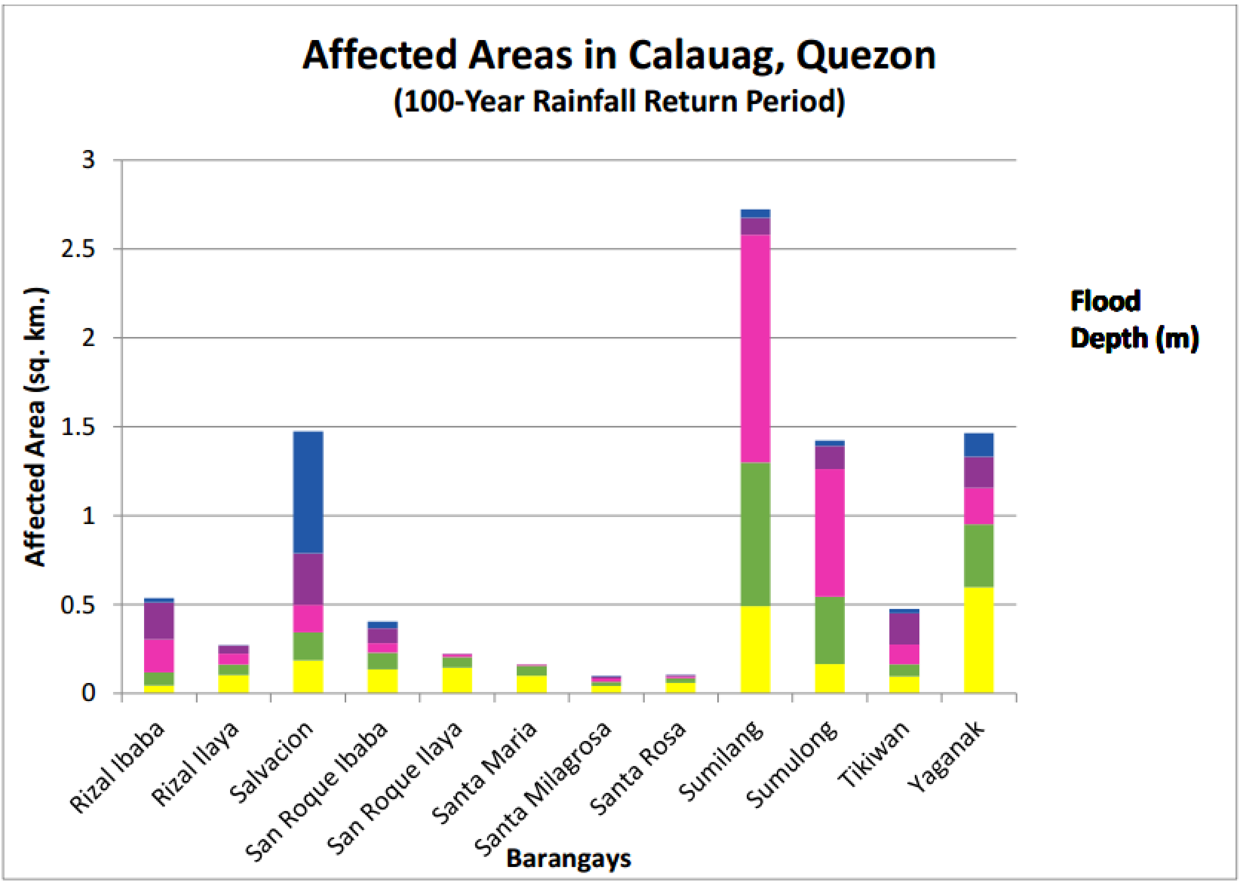


Figure 89. Affected Areas in Calauag, Quezon during 100-Year Rainfall Return Period

For the municipality of Catanauan, with an area of 267.28 sq. km., 0.87% will experience flood levels of less 0.20 meters. 0.024% of the area will experience flood levels of 0.21 to 0.50 meters while 0.022%, 0.017%, and 0.0009% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 and above respectively. Listed in Table 49 are the affected areas in square kilometres by flood depth per barangay.

Table 49. Affected Areas in Catanauan, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Catanauan, Quezon (in sq. km.)	
	Milagrosa	Santa Maria
0.03-0.20	2.23	0.12
0.21-0.50	0.058	0.0012
0.51-1.00	0.052	0.0013
1.01-2.00	0.027	0
2.01-5.00	0	0
> 5.00	0	0

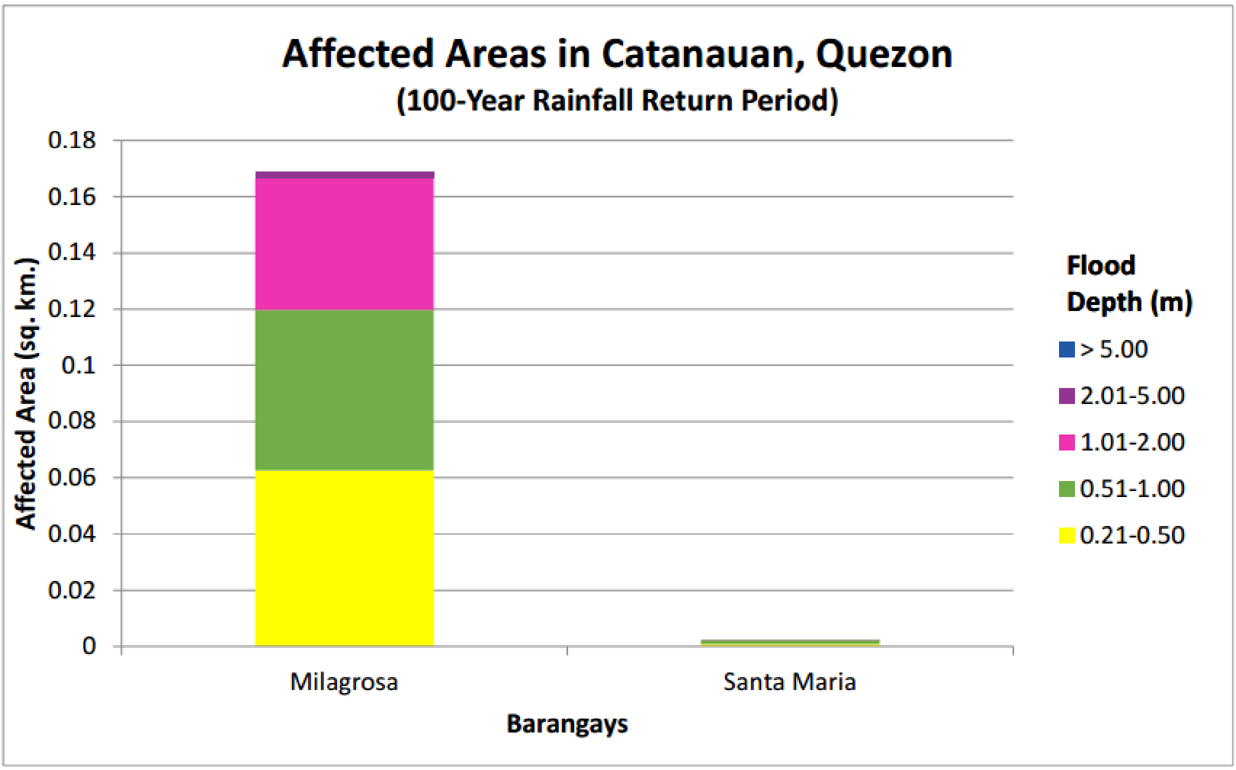


Figure 90. Affected Areas in Catanauan, Quezon during 100-Year Rainfall Return Period

For the municipality of Guinayangan, with an area of 236.84 sq. km., 8.02% will experience flood levels of less 0.20 meters. 0.46% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.16%, 0.14%, and 0.005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in Table 50 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan, Quezon (in sq. km.)								
	Rizal Ibaba	Rizal Ilaya	Salvacion	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang
0.03-0.20	4.16	2.28	2.81	5.49	0.000033	0.11	0.12	1.67	1.7
0.21-0.50	0.22	0.12	0.15	0.31	0	0.003	0.00097	0.096	0.09
0.51-1.00	0.096	0.079	0.092	0.18	0.000006	0.0024	0.0016	0.047	0.038
1.01-2.00	0.044	0.047	0.055	0.12	0	0.0025	0	0.028	0.021
2.01-5.00	0.019	0.0057	0.026	0.092	0	0.0001	0	0.0061	0.0014
> 5.00	0	0	0	0.0012	0	0	0	0	0

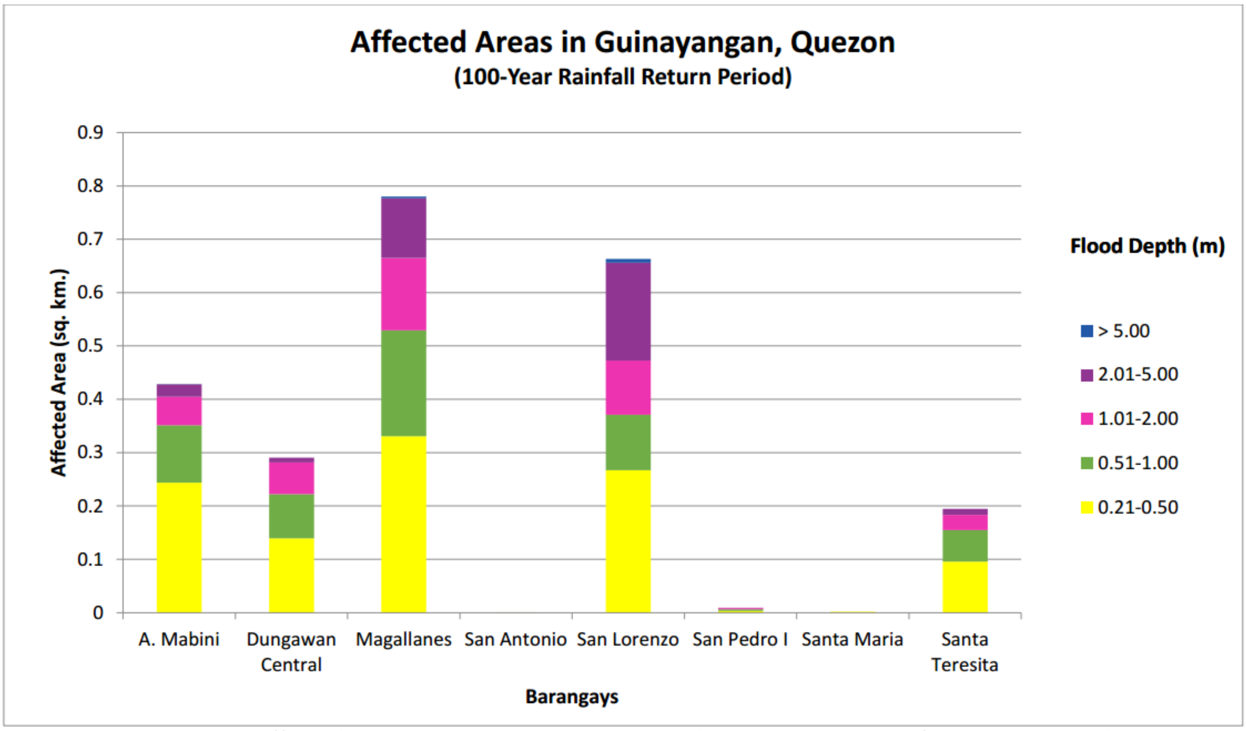


Figure 91. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period

For the municipality of Lopez, with an area of 378.81 sq. km., 20.63% will experience flood levels of less 0.20 meters. 0.78% of the area will experience flood levels of 0.21 to 0.50 meters while 0.57%, 0.71%, 1.09%, and 0.94% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters respectively. Listed in Table 52 are the affected areas in square kilometres by flood depth per barangay.

Table 51. Affected Areas in Lopez, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez, Quezon (in sq. km.)											
	Cagacag	Cawayanin	Guinuangan	Lalaguna	Mabanban	Magallanes	Monteclaro	Pisipis	San Andres	San Francisco B	Santa Catalina	Santa Rosa
0.03-0.20	1	16.37	2.8	0.16	6.83	3.6	1.71	3.08	2.85	0.42	12.61	1.21
0.21-0.50	0.037	0.43	0.082	0.0062	0.26	0.12	0.061	0.12	0.11	0.0085	0.47	0.041
0.51-1.00	0.026	0.35	0.071	0.0013	0.24	0.053	0.044	0.099	0.081	0.0019	0.47	0.028
1.01-2.00	0.023	0.38	0.073	0.00056	0.34	0.056	0.05	0.15	0.12	0.0007	0.63	0.02
2.01-5.00	0.02	0.5	0.024	0.0001	0.36	0.13	0.021	0.2	0.18	0	0.63	0.0025
> 5.00	0	0.43	0	0	0.3	0.06	0.000019	0.11	0.2	0	0.16	0

Table 52. Affected Areas in Lopez, Quezon during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez, Quezon (in sq. km.)							
	Santo Niño Ibaba	Santo Niño Ilaya	Sumalang	Vegaflor	Vergaña	Veronica	Villa Aurora	Villa Espina
0.03-0.20	0	3.35	10.24	3.63	1.5	1.42	1.33	2.31
0.21-0.50	0.21	0.13	0.31	0.16	0.05	0.041	0.034	0.084
0.51-1.00	0.2	0.1	0.24	0.058	0.058	0.03	0.018	0.04
1.01-2.00	0.29	0.13	0.28	0.05	0.11	0.033	0.0071	0.018
2.01-5.00	0.41	0.22	0.25	0.17	0.21	0.055	0.00055	0.029
> 5.00	0.44	0.3	0.15	0.17	0.13	0.079	0	0.051

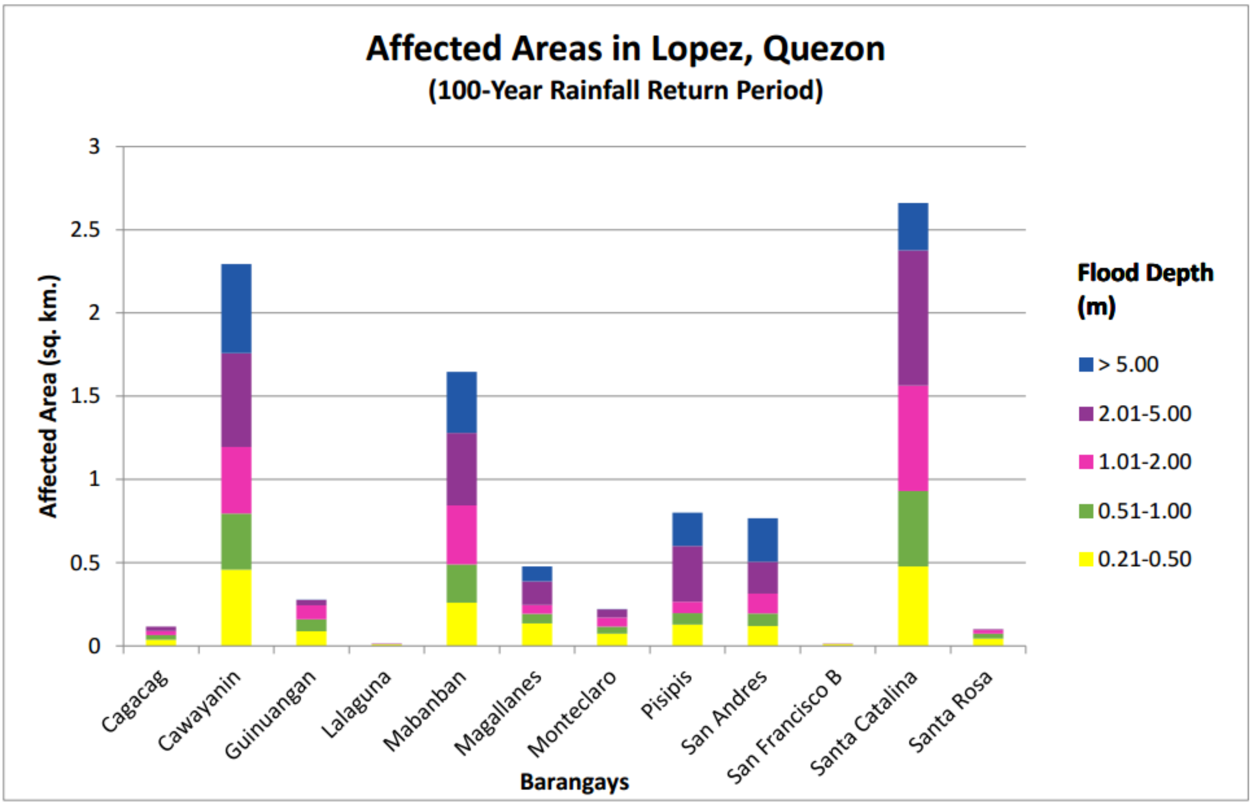


Figure 92. Affected Areas in Lopez, Quezon during 100-Year Rainfall Return Period

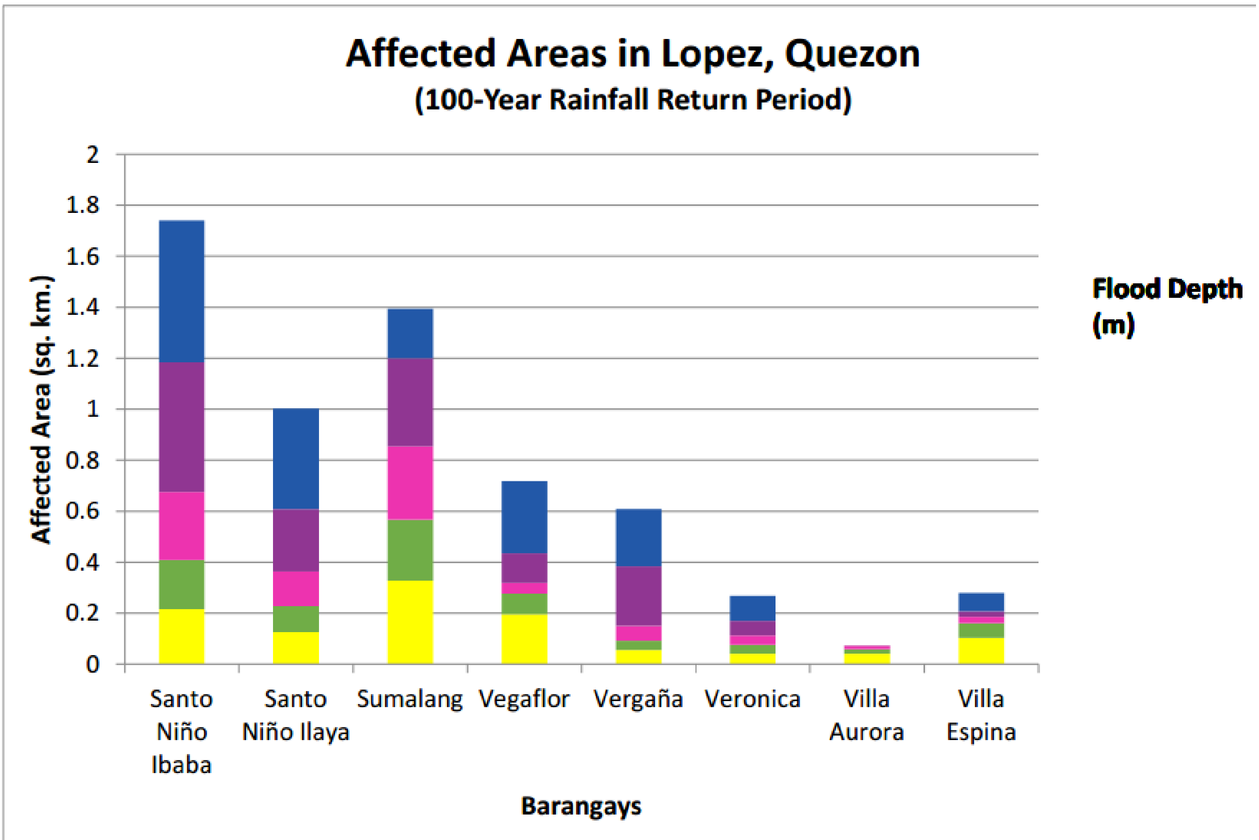


Figure 93. Affected Areas in Lopez, Quezon during 100-Year Rainfall Return Period

Among the barangays in the municipality of Buenavista, Villa Veronica is projected to have the highest percentage of area that will experience flood levels at 54.72%. Meanwhile, Magallanes posted the second highest percentage of area that may be affected by flood depths at 33.89%.

Among the barangays in the municipality of Calauag, Sumilang is projected to have the highest percentage of area that will experience flood levels at 17.68%. Meanwhile, Yaganak posted the second highest percentage of area that may be affected by flood depths at 9.65%.

Among the two barangays in the municipality of Catanauan, Milagrosa is projected to have the higher percentage of the municipality area that will experience flood levels of at 98.54%. Meanwhile, Igot posted the percentage of area that may be affected by flood depths of at 1.46%.

Among the barangays in the municipality of Guinayangan, Magallanes is projected to have the highest percentage of municipality area that will experience flood levels at 28.42%. Meanwhile, San Lorenzo posted the second highest percentage of area that may be affected by flood depths of at 24.18%.

Lastly, among the barangays in the municipality of Lopez, Santa Catalina is projected to have the highest percentage of municipality area that will experience flood levels at 17.19%. Meanwhile, Cawayanin posted the second highest percentage of area that may be affected by flood depths of at 14.82%.

Table 53. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	8.32	8.06	8.21
Medium	9.4	10.14	11.43
High	9.2	12.3	15.5

Of the 7 identified Education Institute in Calauag Flood plain, 2 schools were assessed to be exposed to the Low level flooding during a 5 year scenario while also 2 schools were assessed to be exposed to medium level flooding in the same scenario. In the 25 year scenario, 1 school was assessed to be exposed to the Low level flooding while 3 schools were assessed to be exposed to medium level flooding. For the 100 year scenario, no school was assessed for Low level flooding, and 3 schools for Medium level flooding. In the same scenario, 2 schools were assessed to be exposed to High level flooding. Both schools are located in Barangay Vergaña, Calauag.

Five (5) Medical Institutions were identified in Calauag Floodplain, 3 were assessed to be exposed to Low flooding level and 1 to medium flooding level during a 5 year scenario. In the 25 year scenario, 2 were exposed to low level and another 2 exposed to medium level flooding. The same applies to the 100 year scenario.

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 gather secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

The validation personnel will then go to the specified points identified in a river basin and will gather 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 will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 180 points randomly selected all over the Calauag flood plain. It has an RMSE value of 0.98.

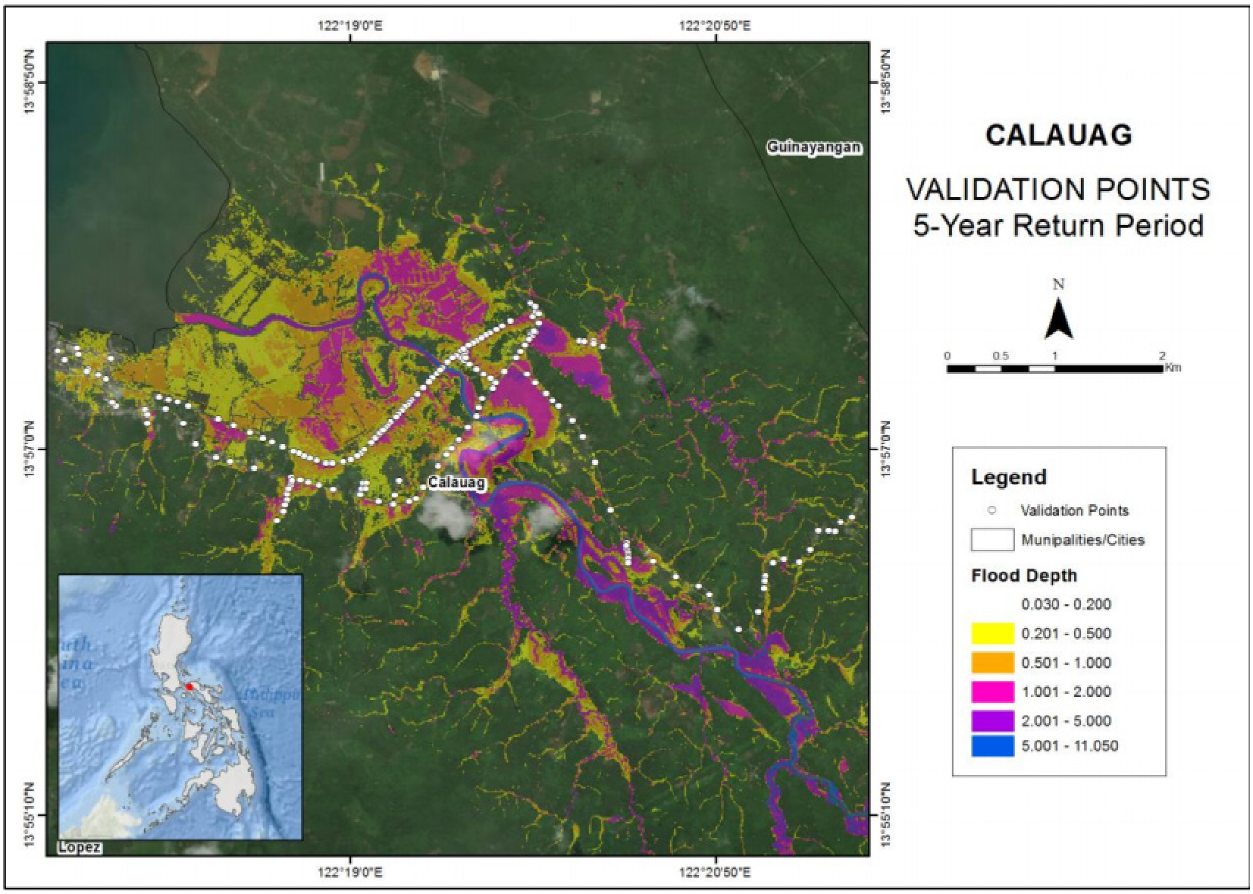


Figure 94. Validation points for a 5-year Flood Depth Map of the Calauag Floodplain.

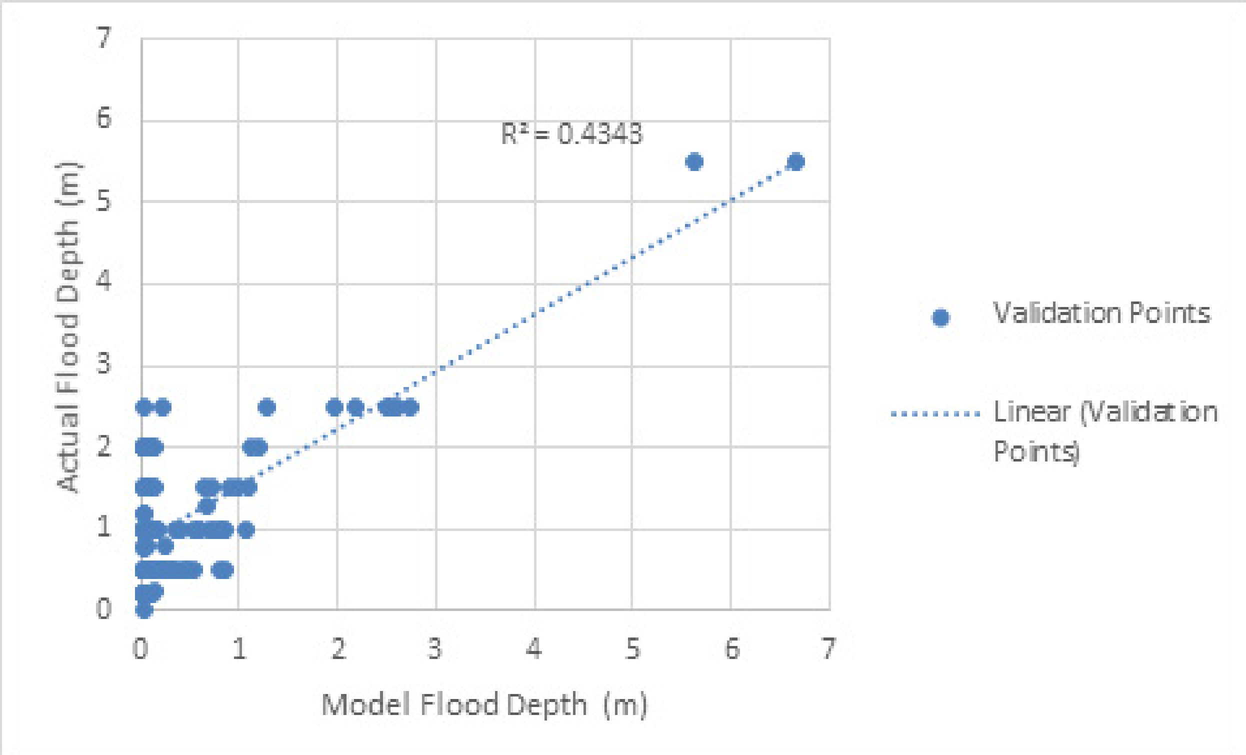


Figure 95 . Flood map depth vs actual flood depth

Table 54. Actual flood vs simulated flood depth at differnent levels in the Calauag River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	34	0	0	0	0	0	34
0.21-0.50	36	10	3	0	0	0	49
0.51-1.00	27	3	8	1	7	0	46
1.01-2.00	39	0	5	3	0	0	47
2.01-5.00	1	1	0	2	5	0	9
> 5.00	0	0	0	0	0	2	2
Total	137	14	16	6	12	2	187

The overall accuracy generated by the flood model is estimated at 33.16%, with 187 points correctly matching the actual flood depths. In addition, there were 50 points estimated one level above and below the correct flood depths while there were 84 points and 125 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 11 points were overestimated while a total of 114 points were underestimated in the modelled flood depths of Calauag.

Table 55. Summary of the Accuracy Assessment in the Calauag River Basin Survey

	No. of Points	%
Correct	62	33.16
Overestimated	11	5.88
Underestimated	114	60.96
Total	187	100.00

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor

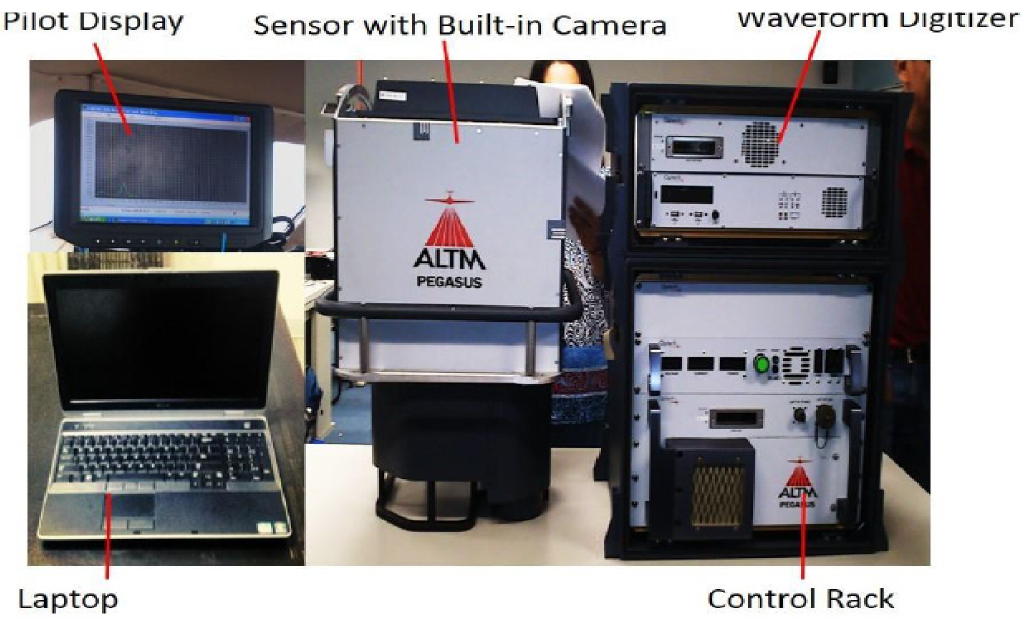


Figure A-1.1 Pegasus

Table A-1.1 Pegasus

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

Annex 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

1. QZN-41

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

April 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: **QUEZON**
Station Name: **QZN-41**
Order: **2nd**

Island: **LUZON**	Barangay: **SABANG 1**	
Municipality: **CALAUAG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **13° 57' 35.21424"**	Longitude: **122° 16' 58.66932"**	Ellipsoidal Hgt: **3.94900 m.**
	WGS84 Coordinates	
Latitude: **13° 57' 30.05147"**	Longitude: **122° 17' 3.61061"**	Ellipsoidal Hgt: **52.42200 m.**
	PTM / PRS92 Coordinates	
Northing: **1543840.411 m.**	Easting: **422523.318 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,543,300.04**	Easting: **422,550.44**	Zone: **51**

Location Description

QZN-41
Is located 1 m. from the offshore end of a 10 m. pier on the Calauag Port at the front of Brgy. Sabang I basketball court. It is approx. 30 m. NE of Sabang 1 Brgy. Hall and Police Outpost. The main pier of Calauag Port is located 100 m. E of the station. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty flushed and leveled on the ground, with inscriptions "QZN-41 2006 NAMRIA".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8084228 I**
T.N.:	**2016-0911**

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

9904162016153305

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 QZN-41

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

1. QZN-41

QZN-41 - QZ-641 (8:08:46 AM-11:25:41 AM) (S13)

Baseline observation:	QZN-41 --- QZ-641 (B14)
Processed:	4/17/2016 10:31:48 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.007 m
Vertical precision:	0.028 m
RMS:	0.019 m
Maximum PDOP:	4.965
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/16/2016 8:08:58 AM (Local: UTC+8hr)
Processing stop time:	4/16/2016 11:25:41 AM (Local: UTC+8hr)
Processing duration:	03:16:43
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	QZN-41				
Grid		**Local**		**Global**	
Easting	422550.436 m	**Latitude**	N13°57'35.21425"	**Latitude**	N13°57'30.05147"
Northing	1543300.040 m	**Longitude**	E122°16'58.86932"	**Longitude**	E122°17'03.61061"
Elevation	3.725 m	**Height**	3.949 m	**Height**	52.422 m

To:	QZ-641				
Grid		**Local**		**Global**	
Easting	431753.157 m	**Latitude**	N13°49'32.33799"	**Latitude**	N13°49'27.21419"
Northing	1528439.616 m	**Longitude**	E122°22'06.88507"	**Longitude**	E122°22'11.63727"
Elevation	57.450 m	**Height**	57.552 m	**Height**	106.606 m

Vector					
ΔEasting	9202.722 m	**NS Fwd Azimuth**	148°03'32"	**ΔX**	-9747.995 m
ΔNorthing	-14860.424 m	**Ellipsoid Dist.**	17485.040 m	**ΔY**	-1890.601 m
ΔElevation	53.726 m	**ΔHeight**	53.603 m	**ΔZ**	-14392.145 m

Figure A-3.1 QZN-41

2. QZN-3946

From:	QZN-41				
Grid		Local		Global	
Easting	422550.436 m	Latitude	N13°57'35.21425"	Latitude	N13°57'30.05147"
Northing	1543300.040 m	Longitude	E122°16'58.66932"	Longitude	E122°17'03.61061"
Elevation	3.725 m	Height	3.949 m	Height	52.422 m

To:	QZN-3946				
Grid		Local		Global	
Easting	431791.932 m	Latitude	N13°49'31.13621"	Latitude	N13°49'26.01252"
Northing	1528402.595 m	Longitude	E122°22'07.97985"	Longitude	E122°22'12.93209"
Elevation	56.542 m	Height	56.643 m	Height	105.699 m

Vector					
ΔEasting	9241.496 m	NS Fwd Azimuth	148°00'53"	ΔX	-9785.092 m
ΔNorthing	-14897.445 m	Ellipsoid Dist.	17536.953 m	ΔY	-1904.711 m
ΔElevation	52.817 m	ΔHeight	52.694 m	ΔZ	-14428.223 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000153210		
Y	-0.0000228657	0.0000393522	
Z	-0.0000069693	0.0000116854	0.0000042683

Figure A-3.2 QZN-3946

2. QZN-J2

QZN-41 - QZN-J2 (7:40:15 AM-5:03:12 PM) (S6)

Baseline observation:	QZN-41 --- QZN-J2 (B7)
Processed:	4/17/2016 10:34:34 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.000 m
Maximum PDOP:	3.898
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/11/2016 7:40:15 AM (Local: UTC+8hr)
Processing stop time:	4/11/2016 5:03:12 PM (Local: UTC+8hr)
Processing duration:	09:22:57
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	QZN-41				
Grid		**Local**		**Global**	
Easting	422550.436 m	**Latitude**	N13°57'35.21425"	**Latitude**	N13°57'30.05147"
Northing	1543300.040 m	**Longitude**	E122°16'58.66932"	**Longitude**	E122°17'03.61061"
Elevation	3.725 m	**Height**	3.949 m	**Height**	52.422 m

To:	QZN-J2				
Grid		**Local**		**Global**	
Easting	422553.956 m	**Latitude**	N13°57'34.99489"	**Latitude**	N13°57'29.83213"
Northing	1543293.290 m	**Longitude**	E122°16'58.78731"	**Longitude**	E122°17'03.72860"
Elevation	3.819 m	**Height**	4.043 m	**Height**	52.516 m

Vector					
ΔEasting	3.520 m	**NS Fwd Azimuth**	152°17'06"	**ΔX**	-3.911 m
ΔNorthing	-6.750 m	**Ellipsoid Dist.**	7.615 m	**ΔY**	-0.440 m
ΔElevation	0.094 m	**ΔHeight**	0.094 m	**ΔZ**	-6.519 m

Figure A-3.3 QZN-J2

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LIDAR Survey Team Composition - A

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. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
		LOVELY GRACIA ACUÑA	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	ENGR. LOVELYN ASUNCION	UP-TCAGP

Table A-4.1. The LIDAR Survey Team Composition - B

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. KENNETH QUISADO	UP-TCAGP
		JERIEL PAUL ALAMBAN	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JASMINE DOMINGO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. BENJIE CARBOLLEDO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. KHALIL ANTHONY CHI	AAC

Annex 5. Data Transfer Sheet for Calauag Floodplain

DATA TRANSFER SHEET
BAGASBAS 5/11/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
April 7,2016	23226P	1BLK20D098A	PEGASUS	NA	506	11.3	226	NA	NA	26.6	NA	130	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 8,2016	23230P	1BLK20A099A	PEGASUS	NA	587	14	287	NA	NA	29.8	NA	112	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 9,2016	23234P	1BLK20D100A	PEGASUS	NA	213	5.3	132	24	202	12.6	NA	138	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 11,2016	23242P	1BLK20A102A	PEGASUS	NA	32	14.2	291	66	478	29	NA	165	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 11,2016	23244P	1BLK20B102B	PEGASUS	NA	247	6.06	158	24.3	180	12.9	NA	165	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April13,2016	23250P	1BLK20G104A	PEGASUS	NA	NA	15.4	306	69.7	520	34.4	NA	90.5	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 13,2016	23252P	1BLK20C104B	PEGASUS	NA	NA	6.34	174	687	7.8	14.5	NA	90.5	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 14,2016	23254P	1BLK20F105A	PEGASUS	NA	NA	6.96	176	14.6	114	8.7	NA	106	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 15,2016	23258P	1BLK20H106A	PEGASUS	NA	NA	13.7	295	NA	NA	28.3	NA	184	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 15,2016	23260P	1BLK20F106B	PEGASUS	NA	NA	4.92	93.7	NA	NA	11.1	NA	184	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

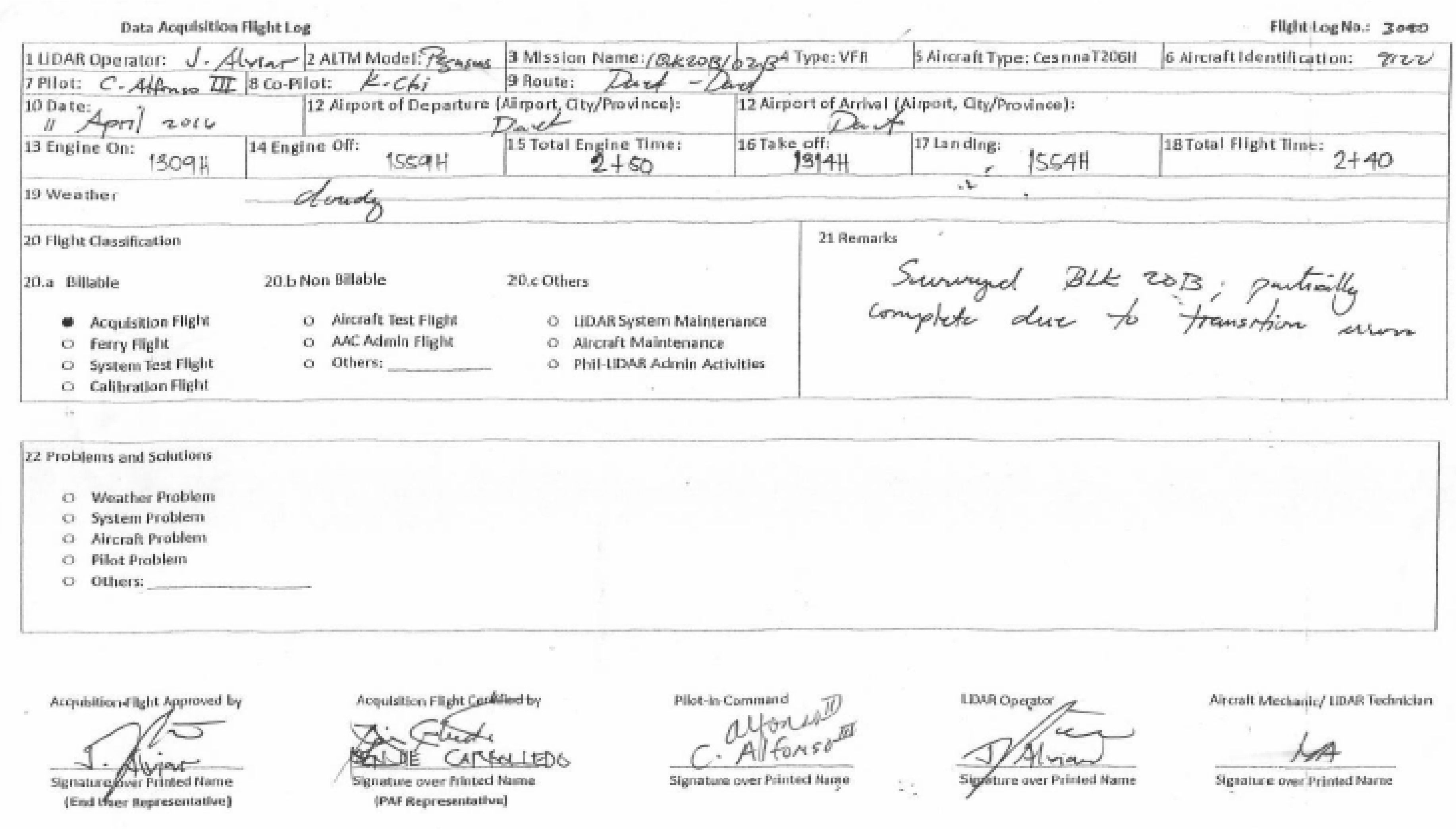
Received by

Name AC Bongat
Position SSRS
Signature ACBongat 5/16/16

Figure A-5.1. Data Transfer Sheet for Calauag Floodplain

Annex 6. Flight logs for the flight missions

1. Flight Log for 23244P Mission



Data Acquisition Flight Log

Flight Log No.: 3040

1 LIDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20B/02B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Davt - Davt			
10 Date: 11 April 2016	12 Airport of Departure (Airport, City/Province): Davt		12 Airport of Arrival (Airport, City/Province): Davt		
13 Engine On: 1309H	14 Engine Off: 1559H	15 Total Engine Time: 2+50	16 Take off: 1314H	17 Landing: 1554H	18 Total Flight Time: 2+40
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20B; partially complete due to transition error

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

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

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

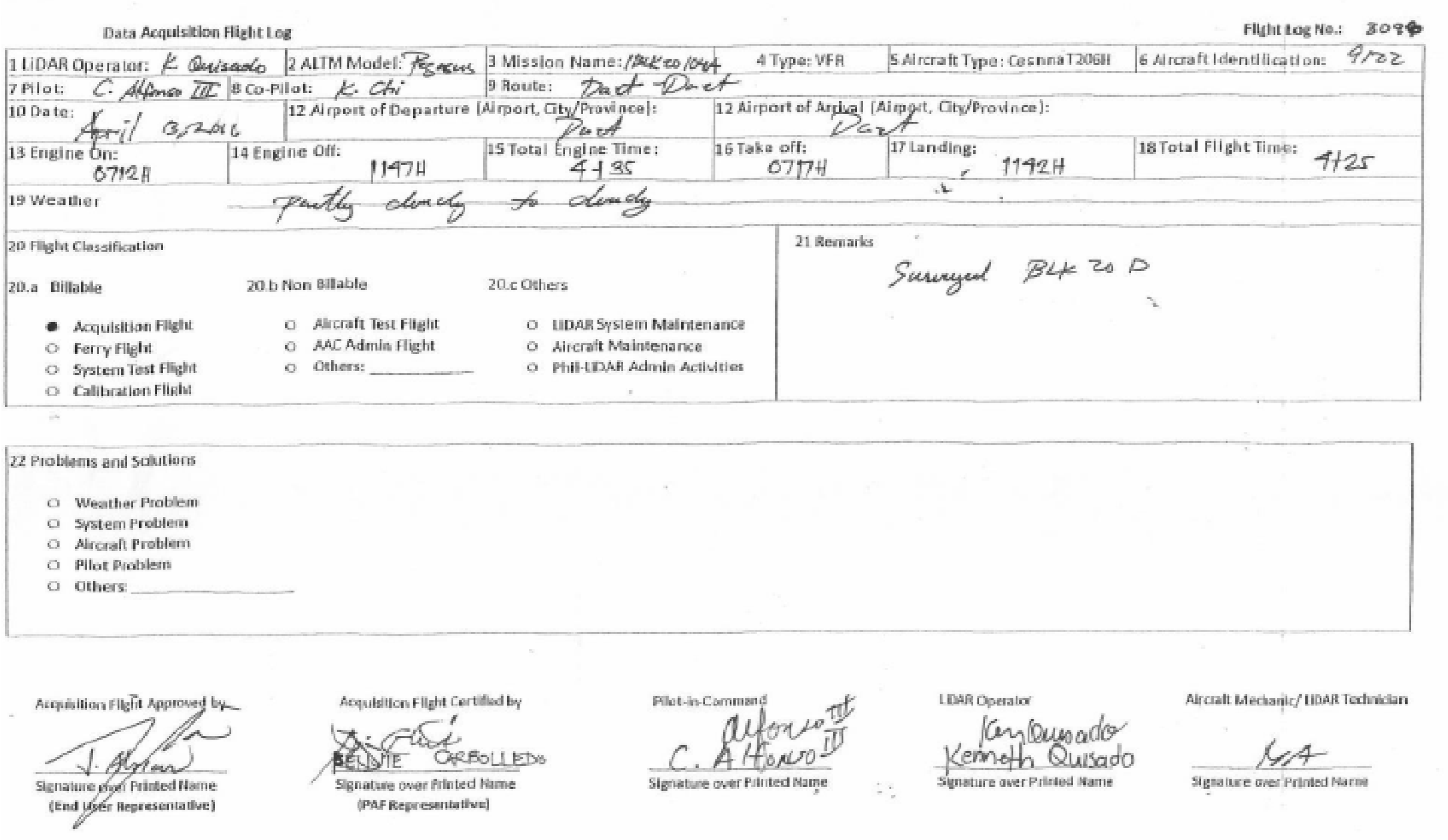
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LIDAR Operator: J. Alviar — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — Signature over Printed Name

Figure A-6.1. Flight Log for 23244P Mission

2. Flight Log for 23250P Mission



Data Acquisition Flight Log

Flight Log No.: 3098

1 LiDAR Operator: K Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20/104A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 13, 2016	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0712H	14 Engine Off: 1147H	15 Total Engine Time: 4+35	16 Take off: 0717H	17 Landing: 1142H	18 Total Flight Time: 4+25
19 Weather: partly cloudy to cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20 D

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
J. Alviar	Bennie Carbolledo	C. Alfonso III	Kenneth Quisado	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for 23250P Mission

3. Flight Log for 23252P Mission

Data Acquisition Flight Log

Flight Log No.: 2098

1 LIDAR Operator: JP Almalvan	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20/C49B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 18, 2016	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of ~~Arrival~~ (Airport, City/Province): Daet		
13 Engine On: 1311H	14 Engine Off: 1610H	15 Total Engine Time: 2+59	16 Take off: 1316H	17 Landing: 1605H	18 Total Flight Time: 2+49
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

Surveyed BLK 20 C

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
J. Alviar	BENJIE CARBOLLEDO	C. ALFONSO III	JP ALMALVAN	MD
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for 23252P Mission

4. Flight Log for 23254P Mission

Data Acquisition Flight Log

Flight Log No.: 3100

1 LiDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 14, 2014	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0716H	14 Engine Off: 1009H	15 Total Engine Time: 2+53	16 Take off: 0721H	17 Landing: 1004H	18 Total Flight Time: 2+43
19 Weather: heavy build up					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20G

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
J. Alviar	Ferdie Caraolledo	C. Alfonso III	K. Quisado	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for 23254P Mission

5. Flight Log for 23258P Mission

Data Acquisition Flight Log

Flight Log No.: 3109

1 LIDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20H106A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 15, 2014	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0726H	14 Engine Off: 1201H	15 Total Engine Time: 4+35	16 Take off: 0731H	17 Landing: 1156H	18 Total Flight Time: 4+25
19 Weather: very cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20H

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
J. Alviar	BELLIE CABALLERO	C. Alfonso III	K. Quisado	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.5.Flight Log for 23258P Mission

6. Flight Log for 23260P Mission

Data Acquisition Flight Log

Flight Log No.: 3106

1 LiDAR Operator: J. Almar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20F106B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Dact - Dact			
10 Date: April 15, 2016	12 Airport of Departure (Airport, City/Province): Dact		12 Airport of Arrival (Airport, City/Province): Dact		
13 Engine On: 1332H	14 Engine Off: 1600H	15 Total Engine Time: 2+28	16 Take off: 1337H	17 Landing: 1555H	18 Total Flight Time: 2+18
19 Weather: very cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20F

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
J. Almar	Renrie Cabalquinto	C. Alfonso III		
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.6. Flight Log for 23260P Mission

Annex 7. Flight Status R

Table A-7.1.Flight Status R

Camarines Sur & Quezon
April 4-18, 2016

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23244P	BLK 20C	1BLK20B102B	J ALVIAR	11-Apr	SURVEYED VINAS FP 103.27 sq.km.
23250P	BLK 20G	1BLK20G104A	K QUISADO	13-Apr	SURVEYED MACALELON, CALAUAG, PANDANAN FPs 239.58 sq.km.
23252P	BLK 20C	1BLK20C104B	J ALAMBAN	13-Apr	SURVEYED VINAS, CALAUAG FPs 82.65 sq.km.
23254P	BLK 20F	1BLK20F105A	K QUISADO	14-Apr	SURVEYED PANDANAN, MACALELON, CALAUAG FPs 93.79 sq.km.
23258P	BLK 20H	1BLK20H106A	K QUISADO	15-Apr	SURVEYED MACALELON, CALAUAG, PANDANAN FPs 187.12 sq.km.
23260P	BLK 20F	1BLK20F106B	J ALVIAR	15-Apr	SURVEYED PANDANAN AND CALAUAG FPs AT 800M, LAST LINE AT 1000M 84.71 sq.km.

LAS BOUNDARIES PER FLIGHT

Flight No. : 23244P
Parameters: PRF 200SF 30 FOV 50

LAS/ SWATH

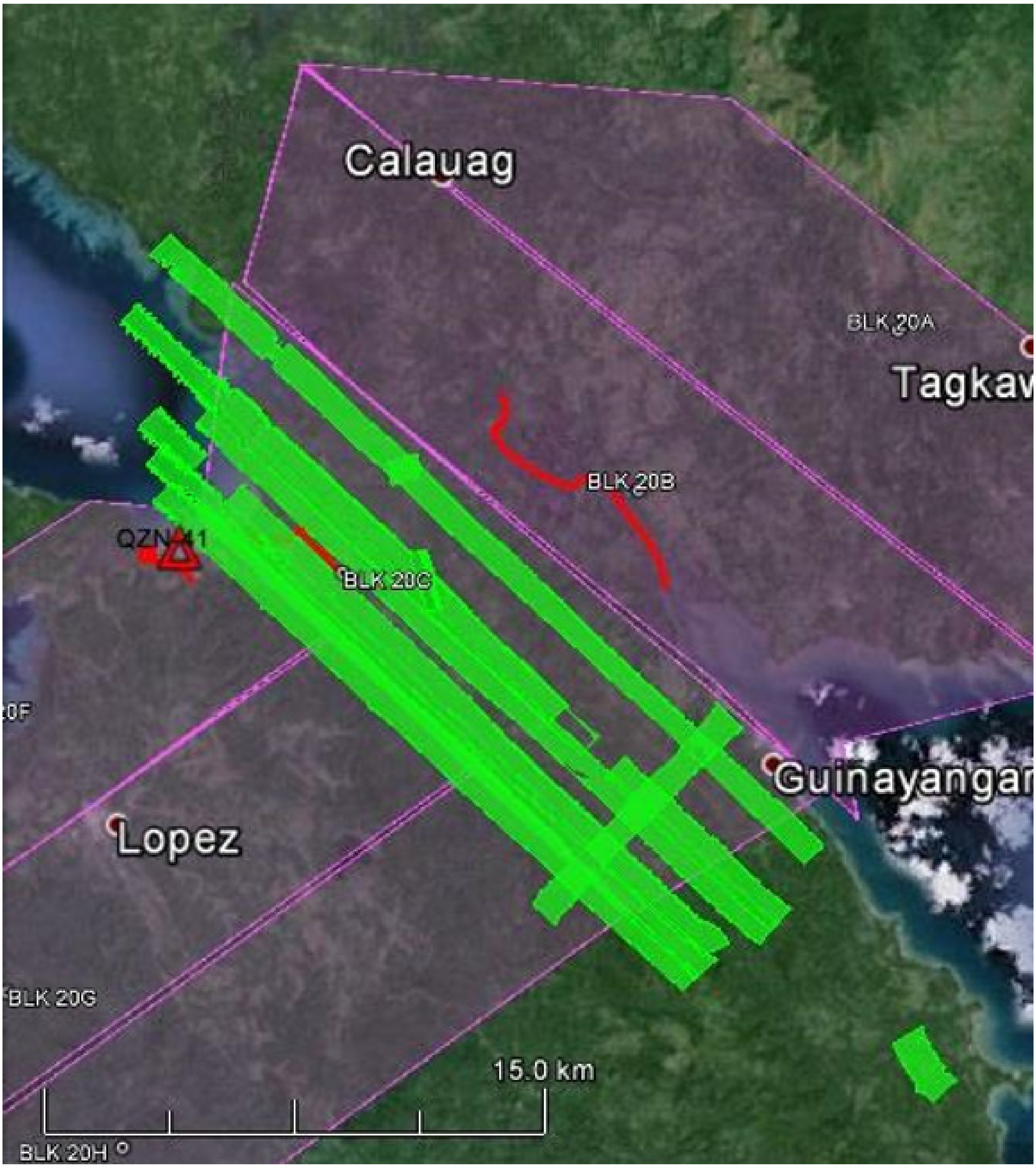


Figure A-7.1.23244P

Flight No. :	23250P			
Parameters:	PRF 200SF	30	FOV	50

LAS/ SWATH

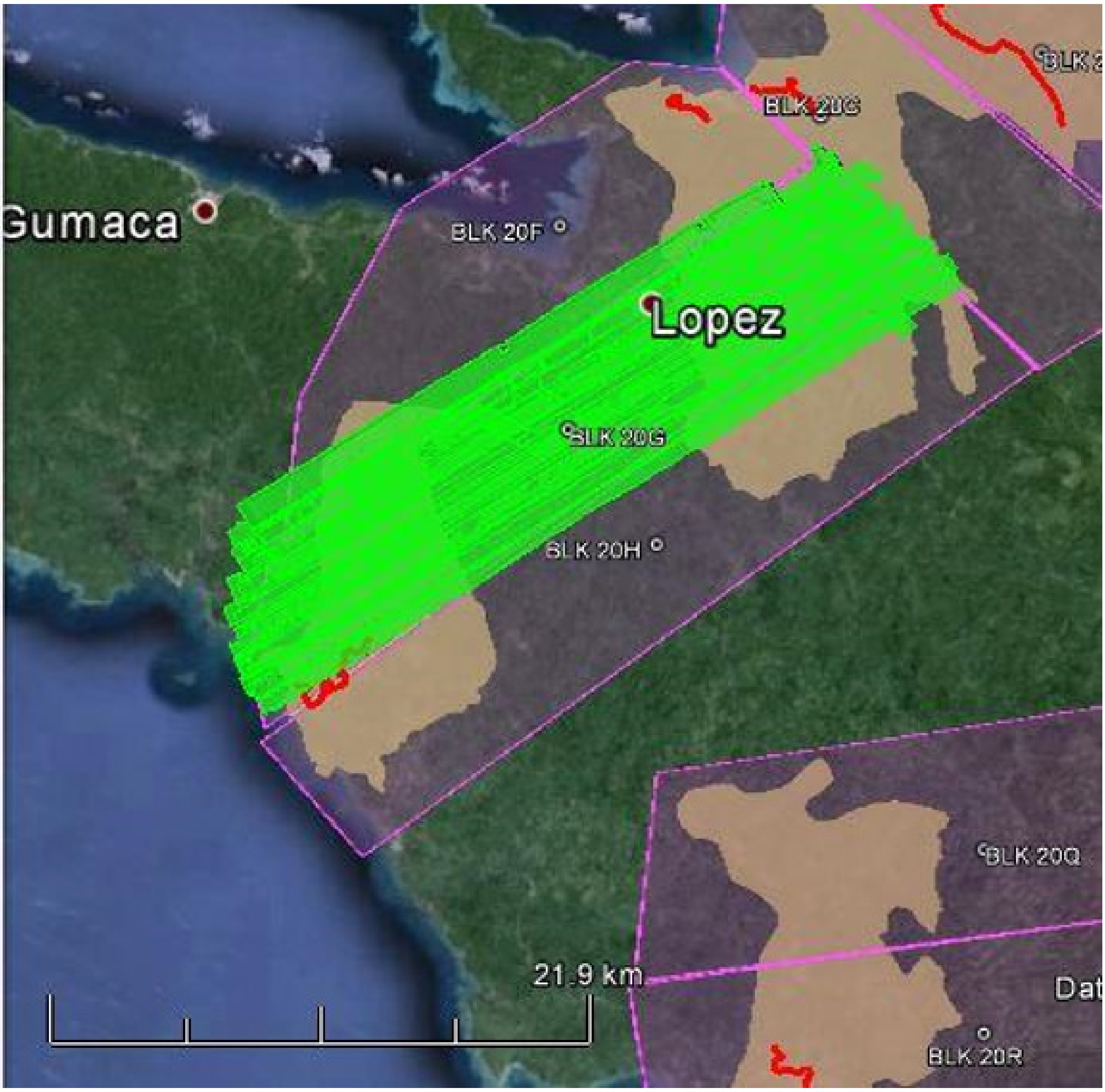


Figure A-7.2. 23250P

Flight No. : 23252P
Parameters: PRF 200SF 30 FOV 50

LAS/ SWATH

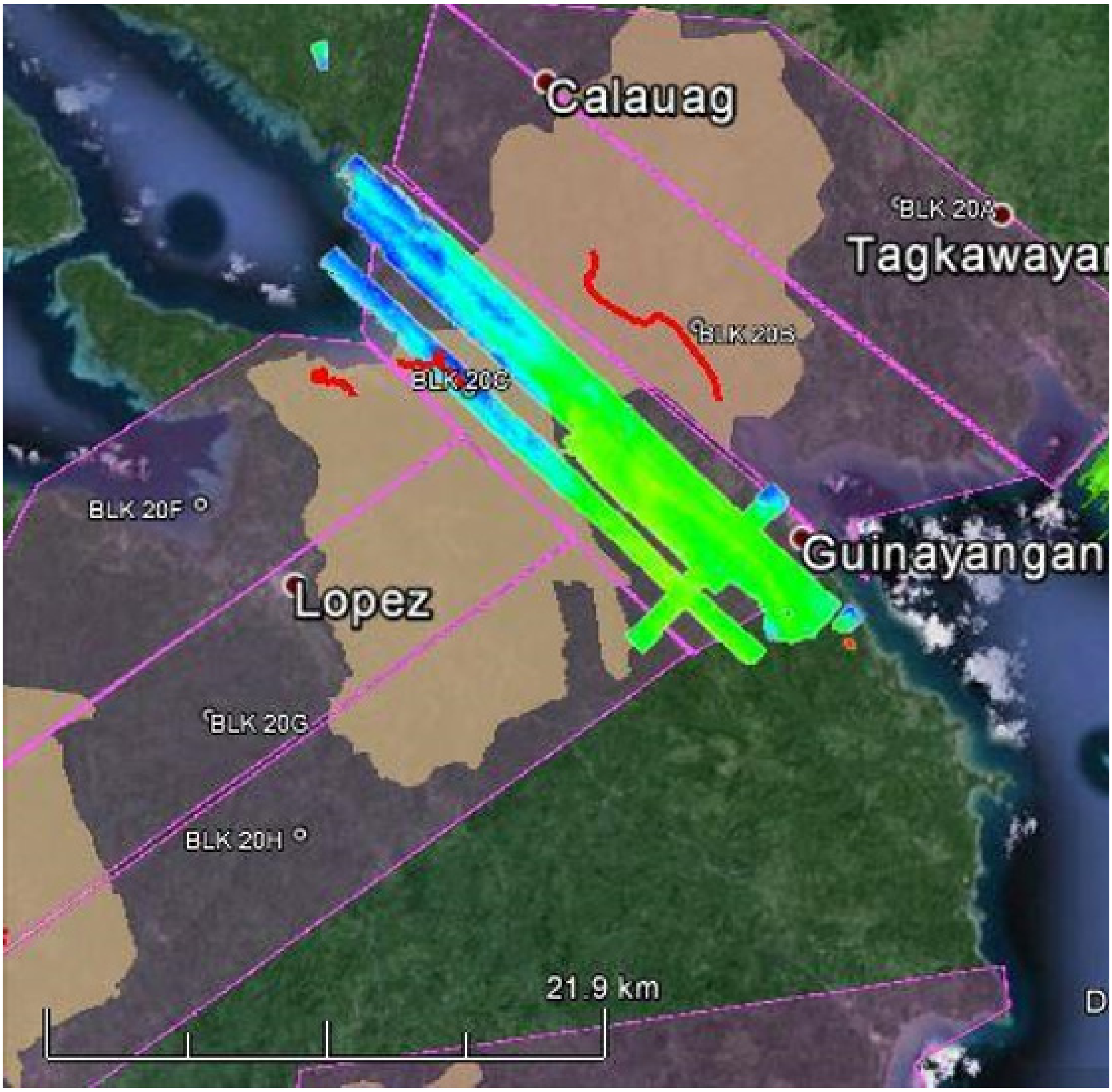


Figure A-7.3.23252P

Flight No. : 23254P
Parameters: PRF 200SF 30 FOV 50

LAS/ SWATH

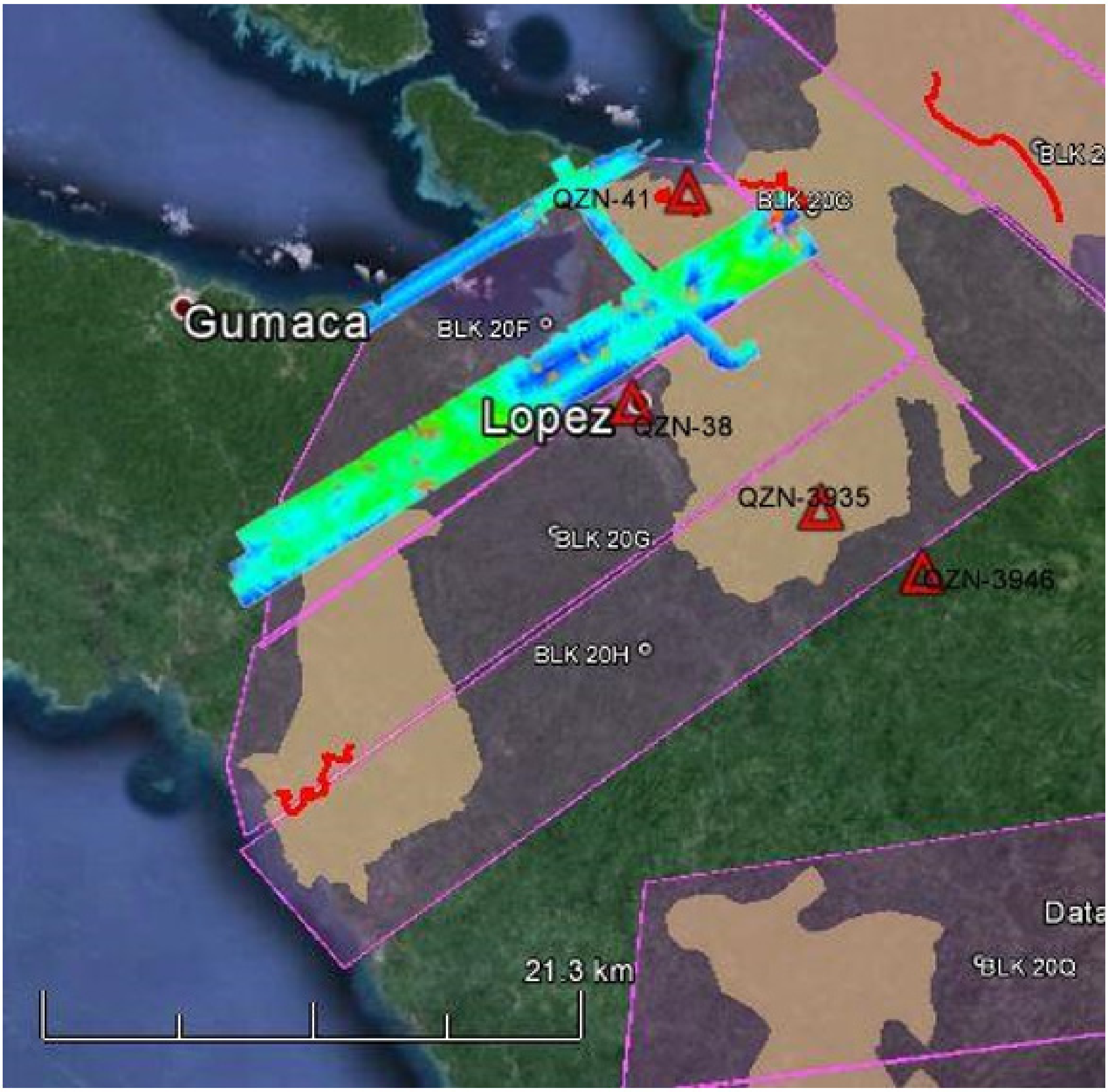


Figure A-7.4. 23250P

Flight No. : 23258P
Parameters: PRF 200SF 30 FOV 50

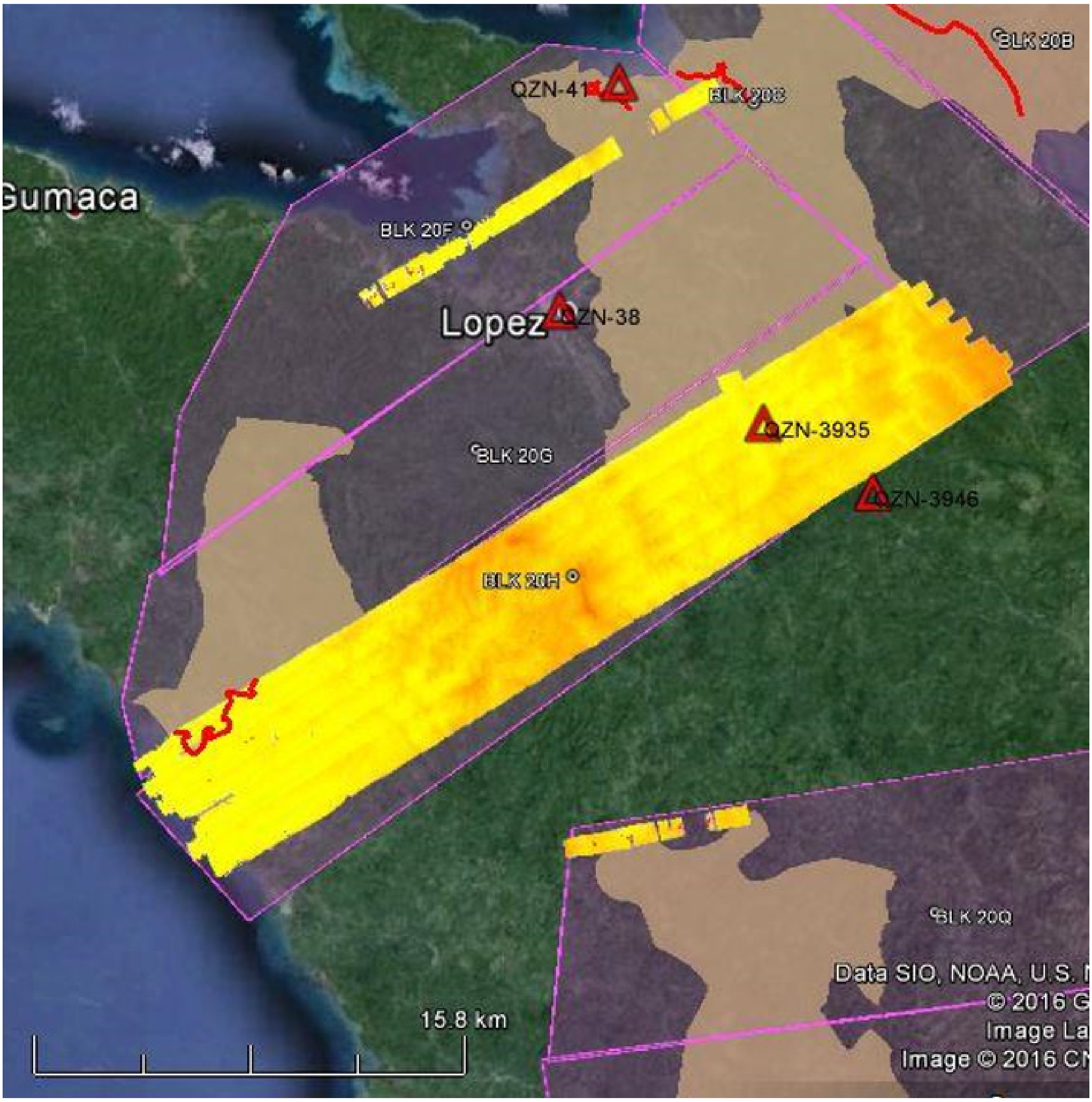


Figure A-7.5. 23258P

Flight No. : 23260P
Parameters: PRF 200SF FOV 50

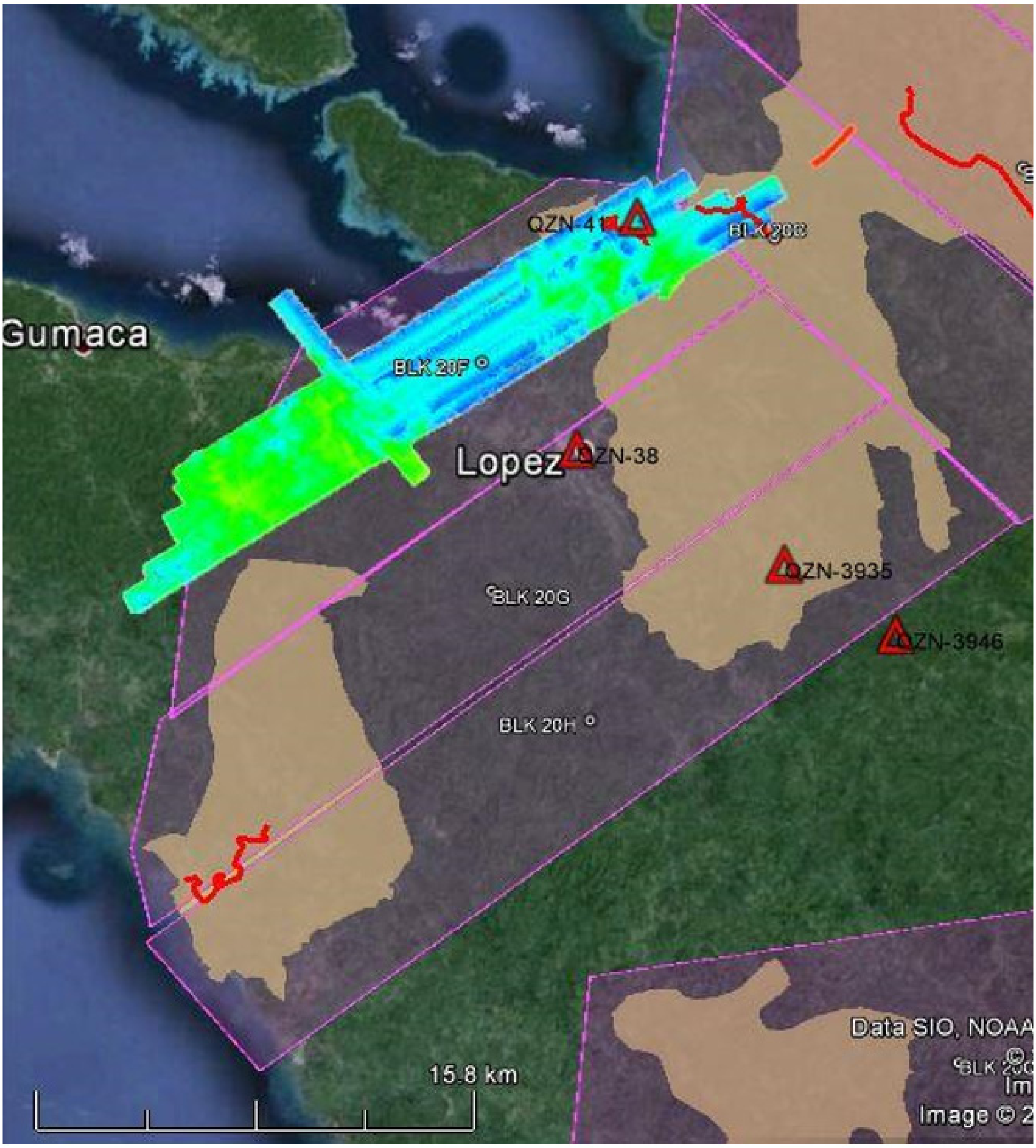


Figure A-7.6. 23260P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Bagasbasa_Blk21A

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21A
Inclusive Flights	23244P
Range data size	12.9 GB
POS data size	158 MB
Base data size	165 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000384
IMU attitude correction stdev (<0.001deg)	0.000401
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	17.77%
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	191
Maximum Height	379.74
Minimum Height	49.16
Classification (# of points)	
Ground	79054250
Low vegetation	56911616
Medium vegetation	133134430
High vegetation	353037263
Building	3644040
Orthophoto	Yes
Processed by	Engr. Shiela-Maye Santillan, Engr. Velina Bemida, Engr. Monalyne Rabino

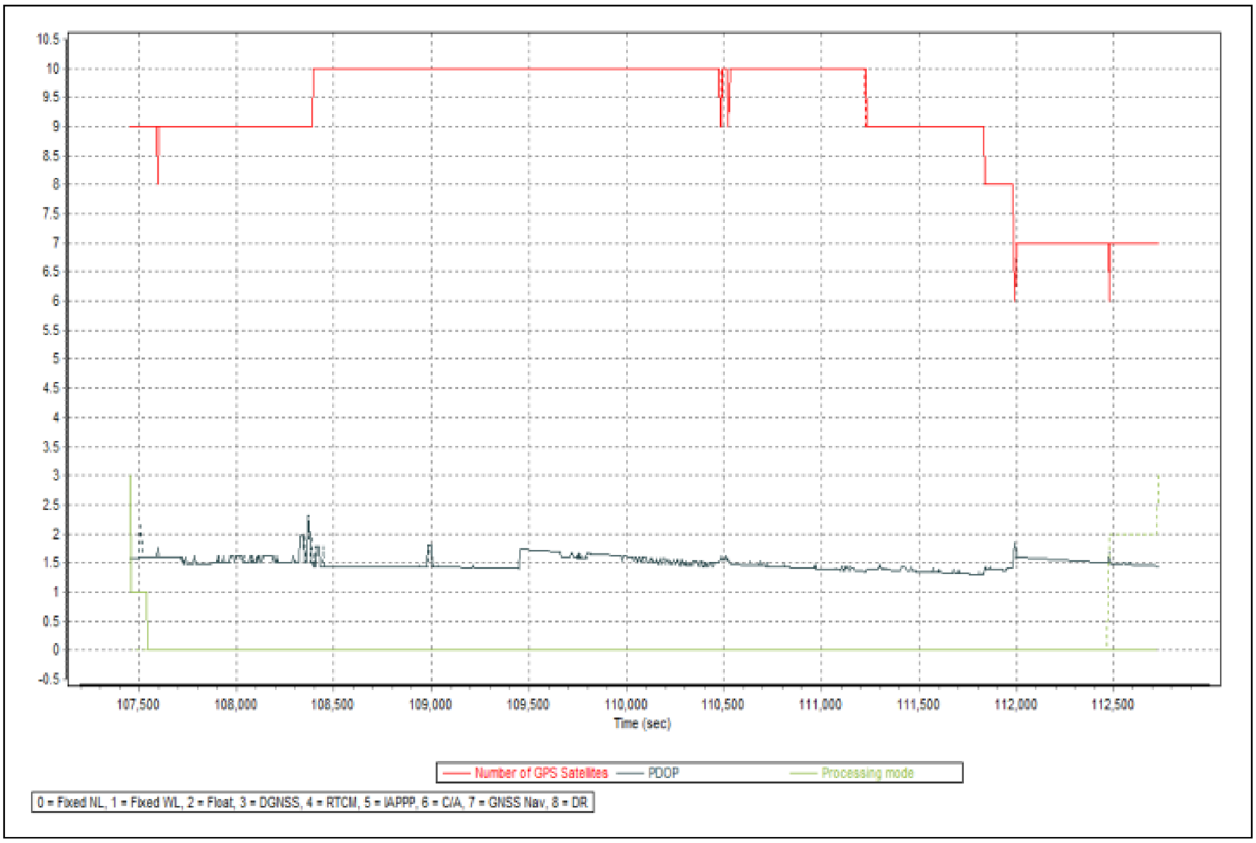


Figure-A.8.1. Solution Status

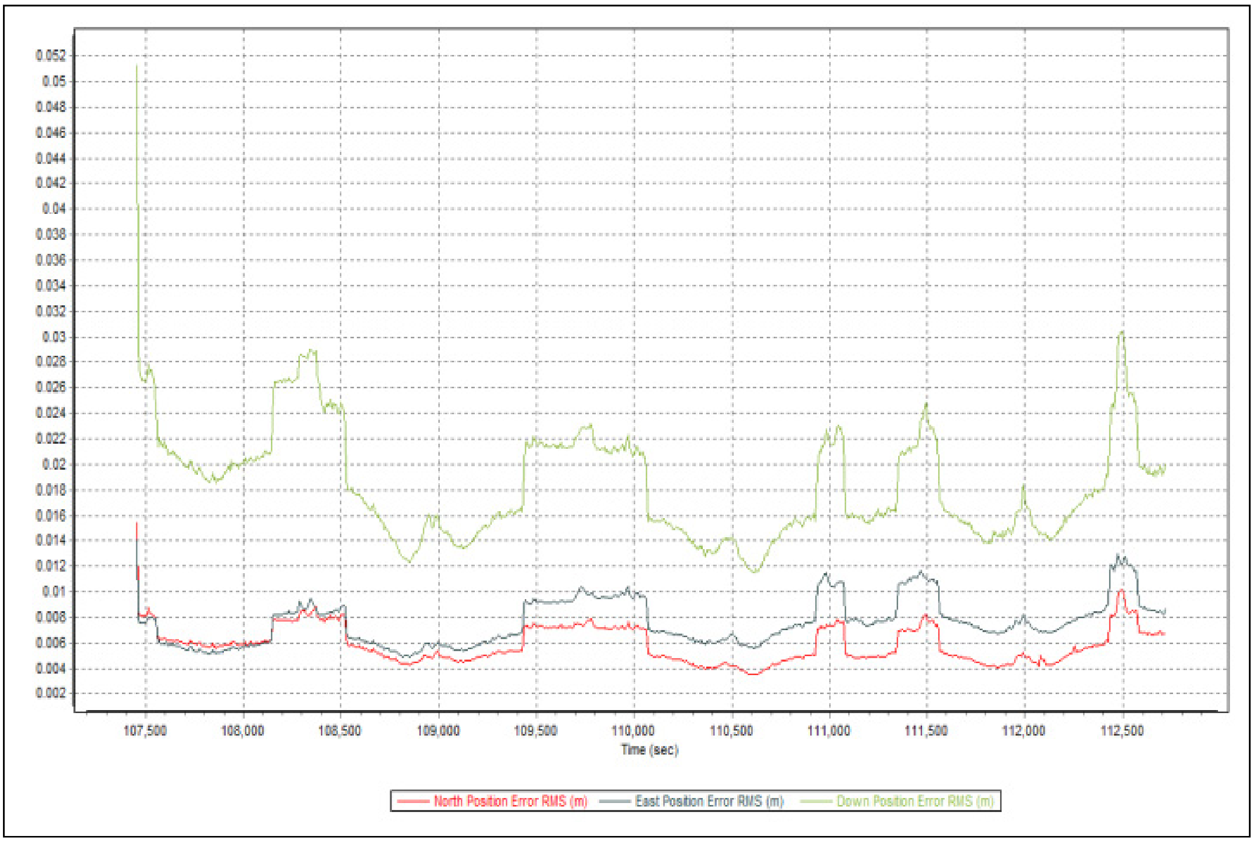


Figure-A.8.2.Smoothed Performance Metrics Parameters

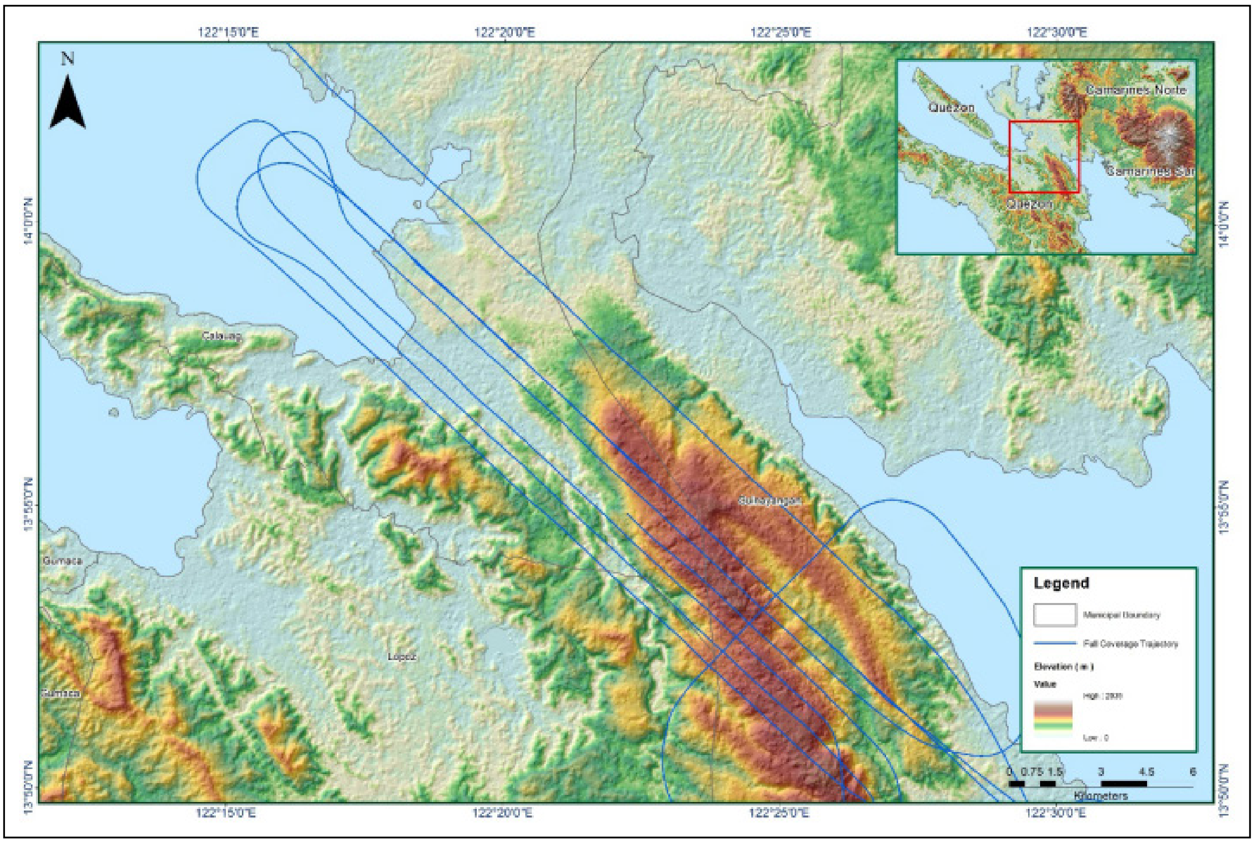


Figure-A.8.3.Best Estimated Trajectory

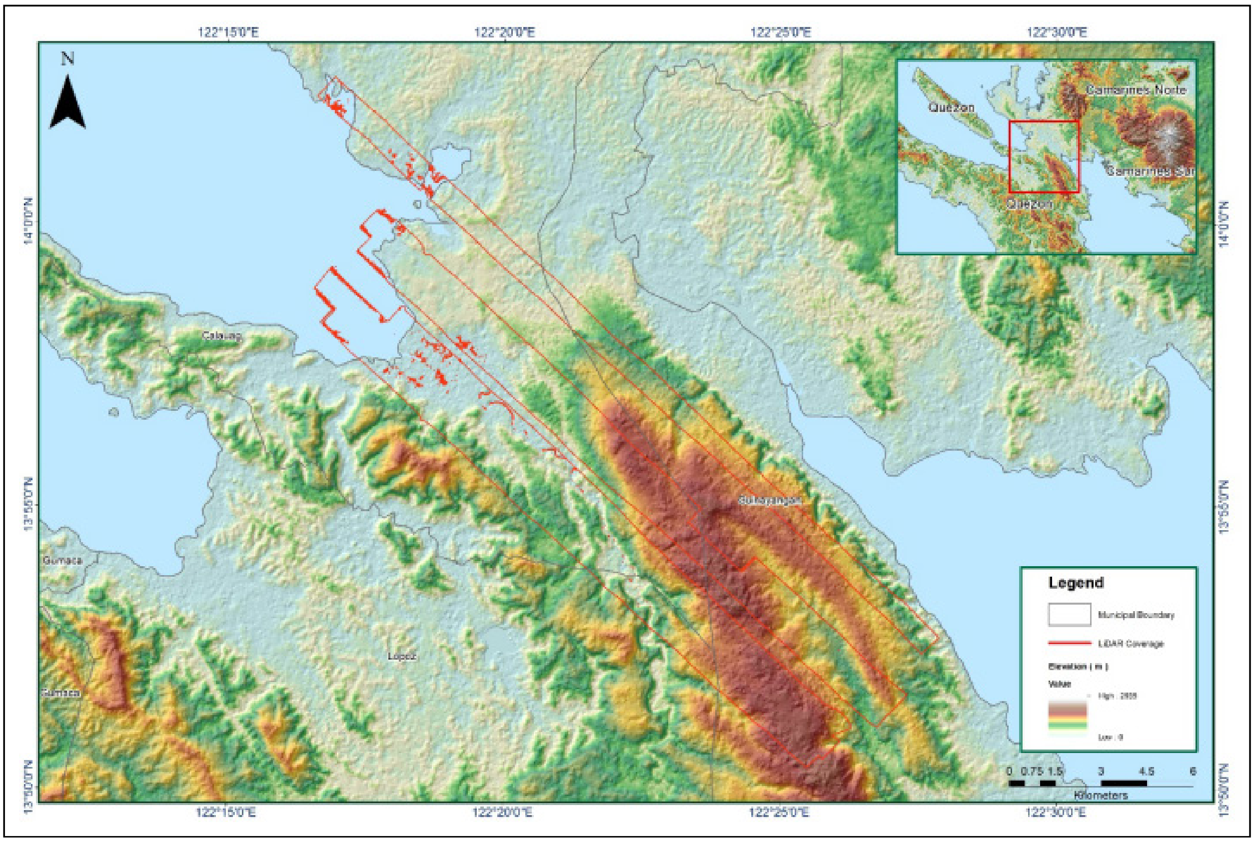


Figure-A.8.4.Coverage of LiDAR data

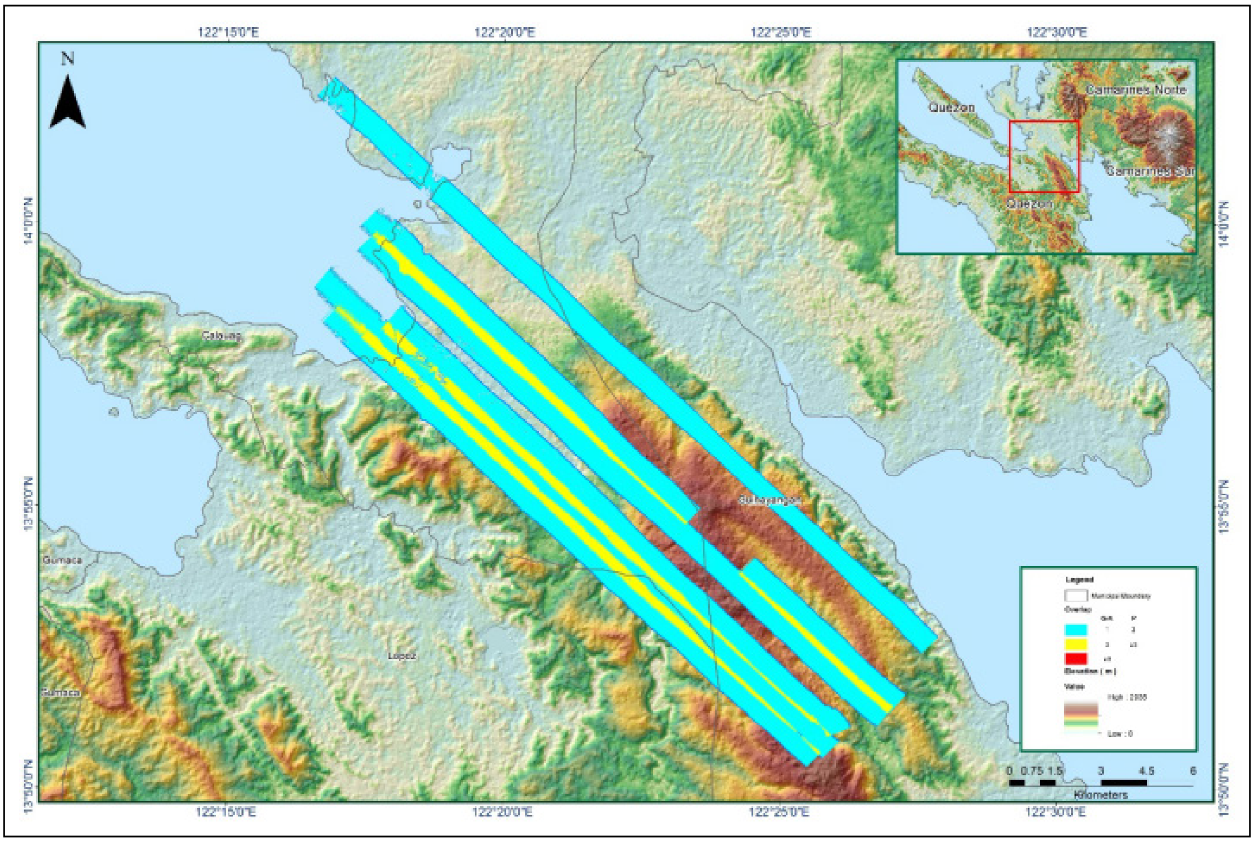


Figure-A.8.5. Image of Data Overlap

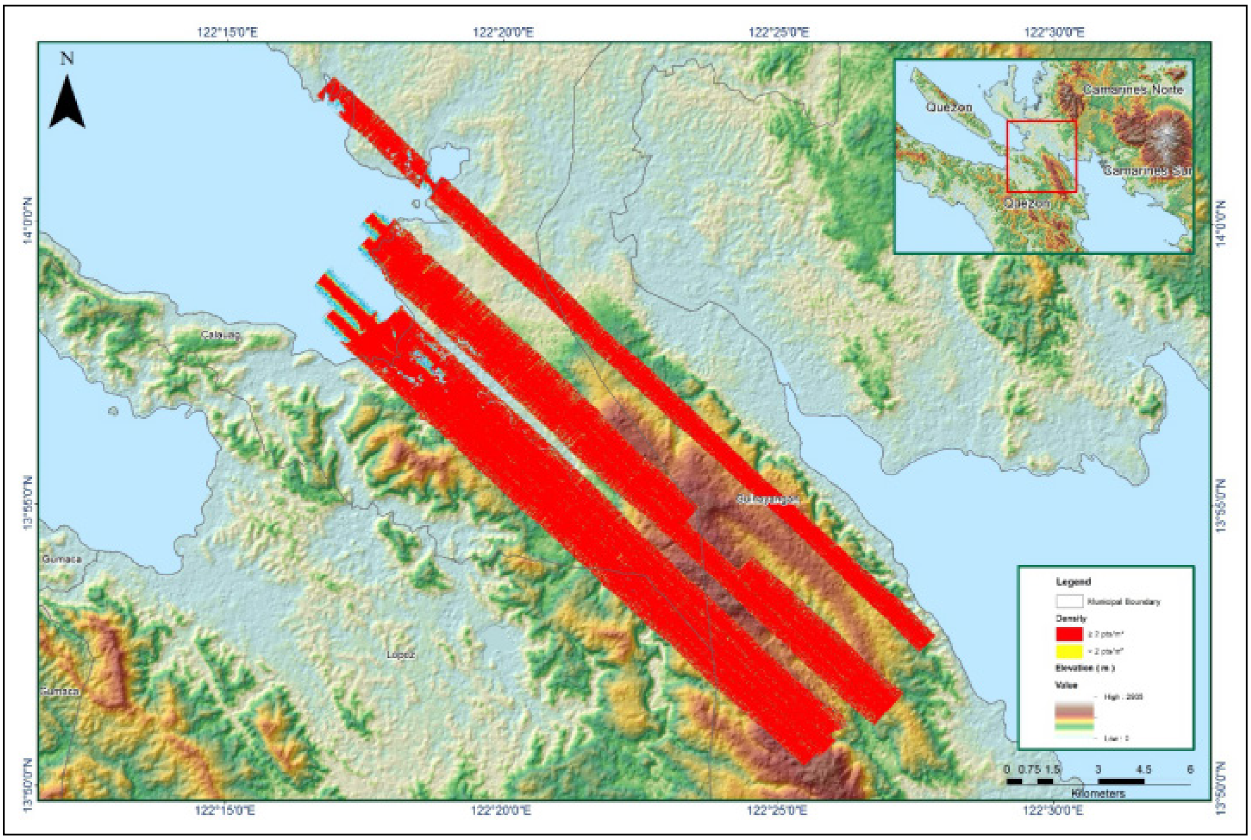


Figure-A.8.6.Density map of merged LiDAR data

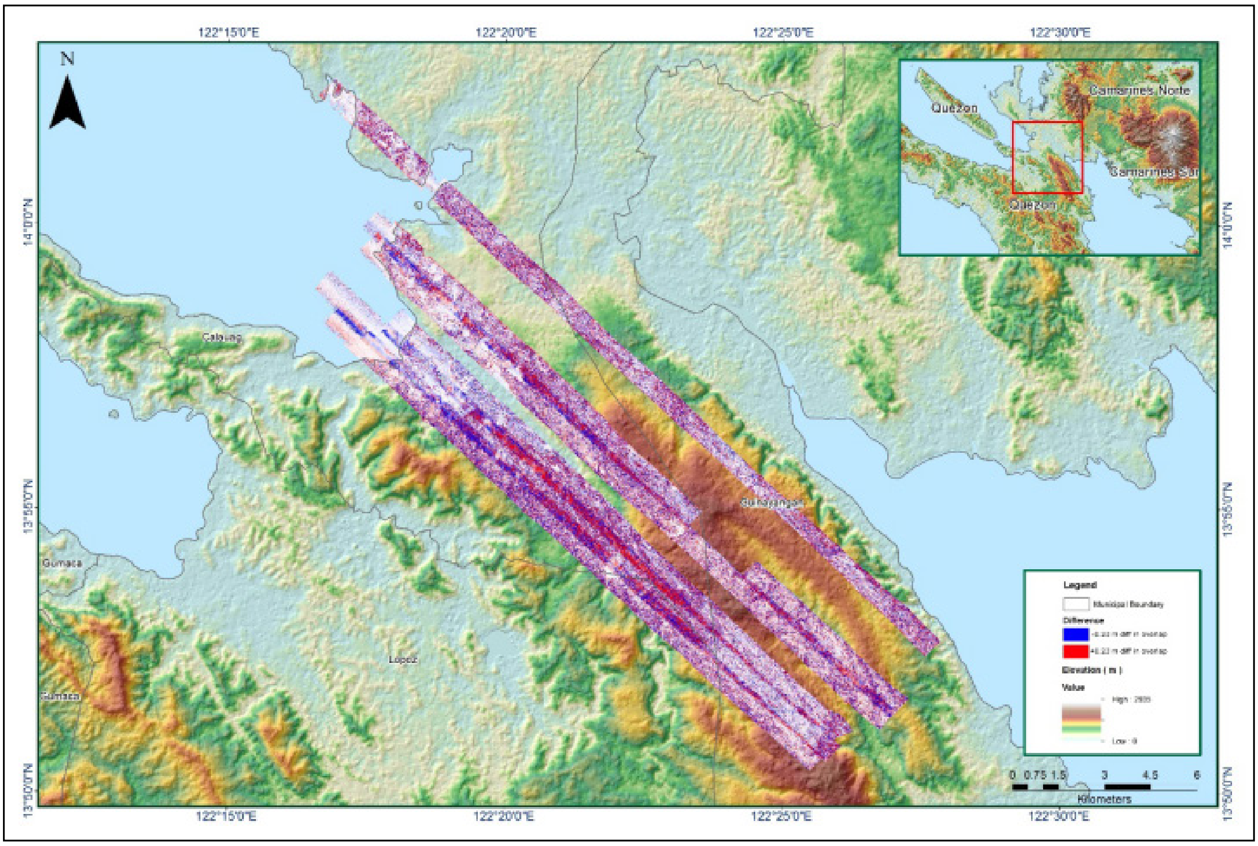


Figure-A.8.7.Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Bagasbasa_Blk21A_supplement

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21A_supplement
Inclusive Flights	23252P
Range data size	14.5 GB
POS data size	174 MB
Base data size	90.5 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	0.3
Boresight correction stdev (<0.001deg)	0.000333
IMU attitude correction stdev (<0.001deg)	0.000415
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	20.12%
Ave point cloud density per sq.m. (>2.0)	3.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	137
Maximum Height	942.63
Minimum Height	39.34
Classification (# of points)	
Ground	63155780
Low vegetation	25760357
Medium vegetation	111178310
High vegetation	267413755
Building	3382392
Orthophoto	Yes
Processed by	Engr. Shiela-Maye Santillan, Erica Erin Elazegui, Engr. Monalyne Rabino

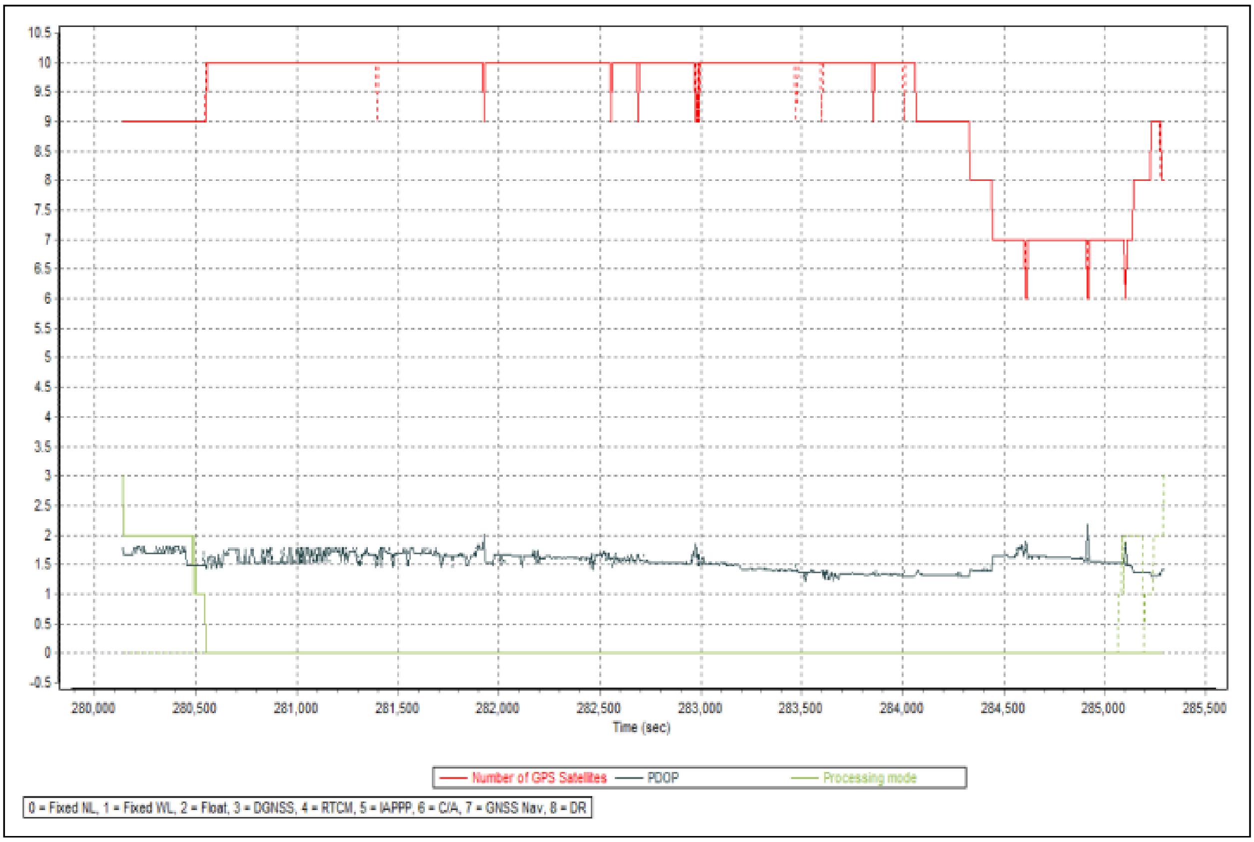


Figure-A.8.8.Solution Status Parameters

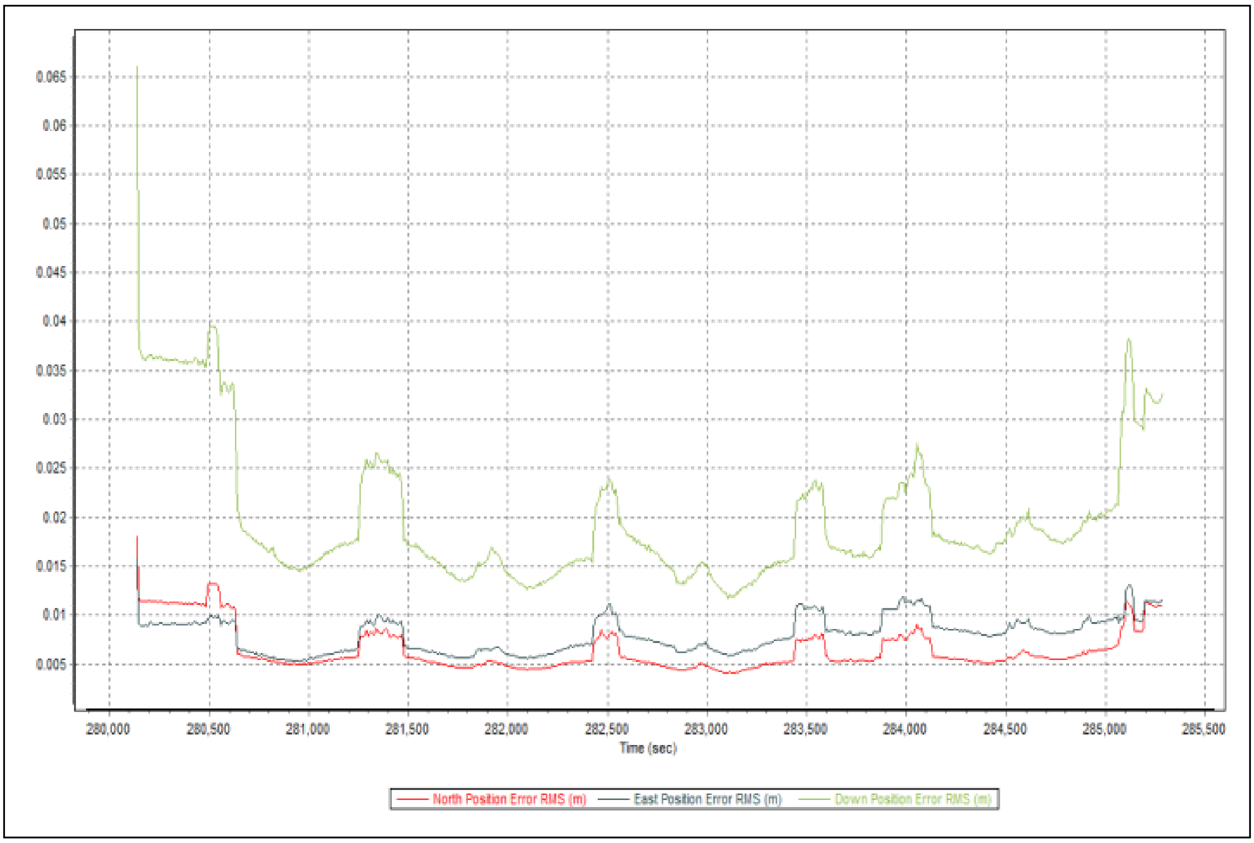


Figure-A.8.9. Smoothed Performance Metrics Parameters

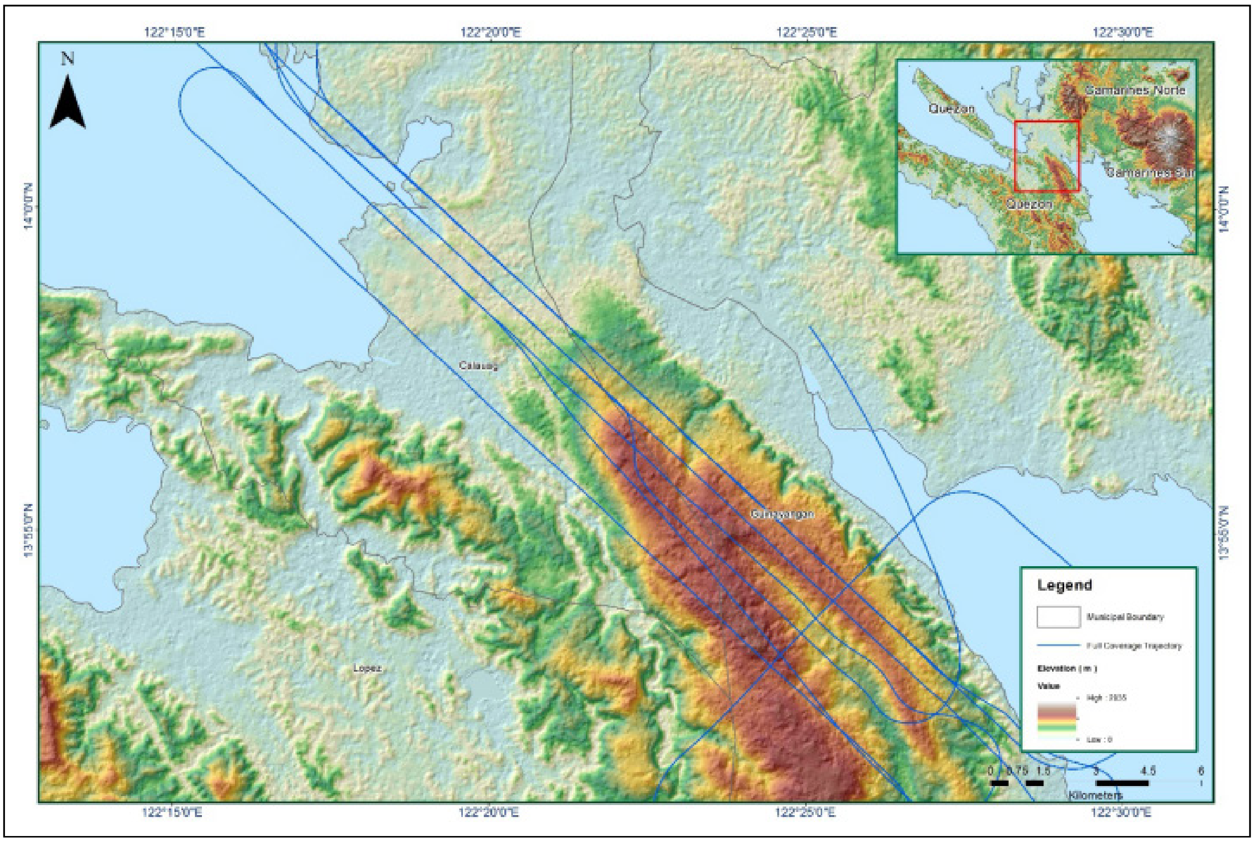


Figure-A.8.10. Best Estimated Trajectory

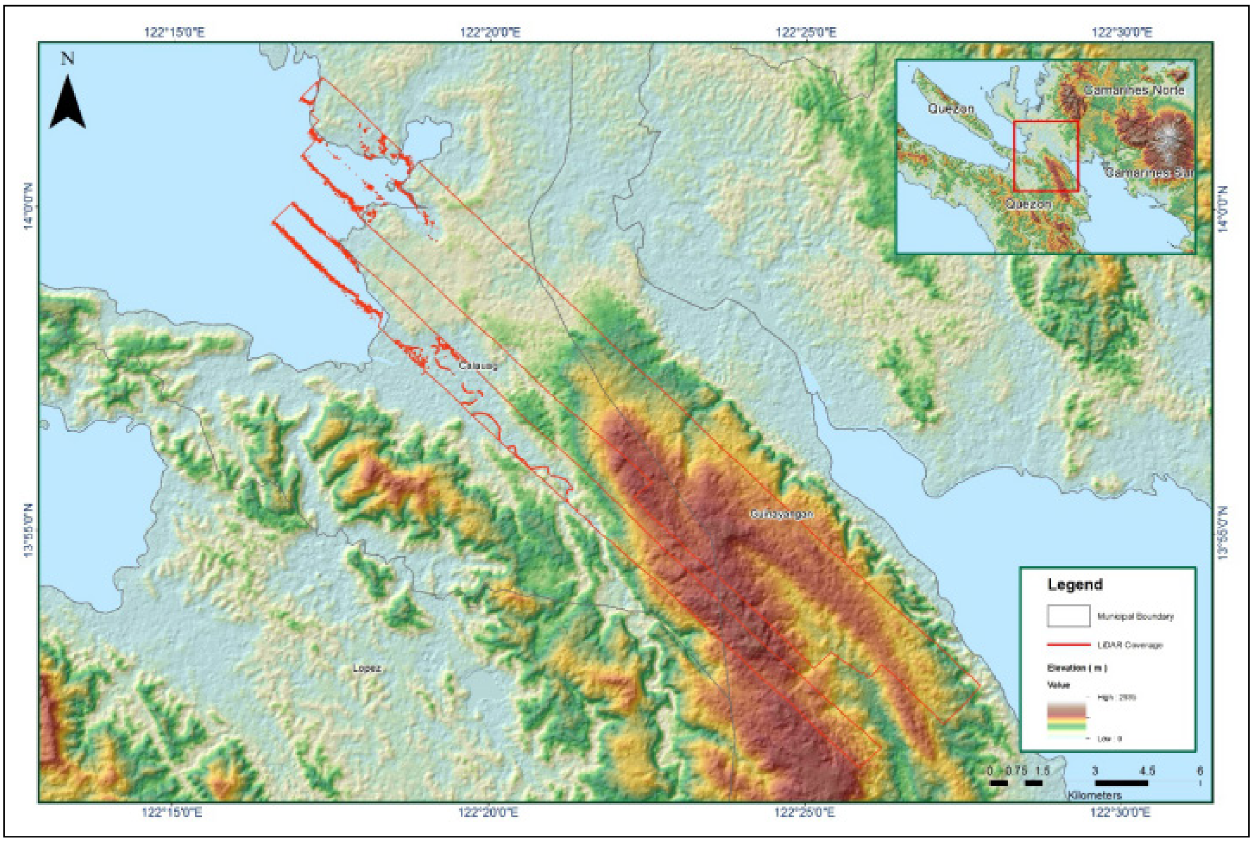


Figure-A.8.11. Coverage of LiDAR data

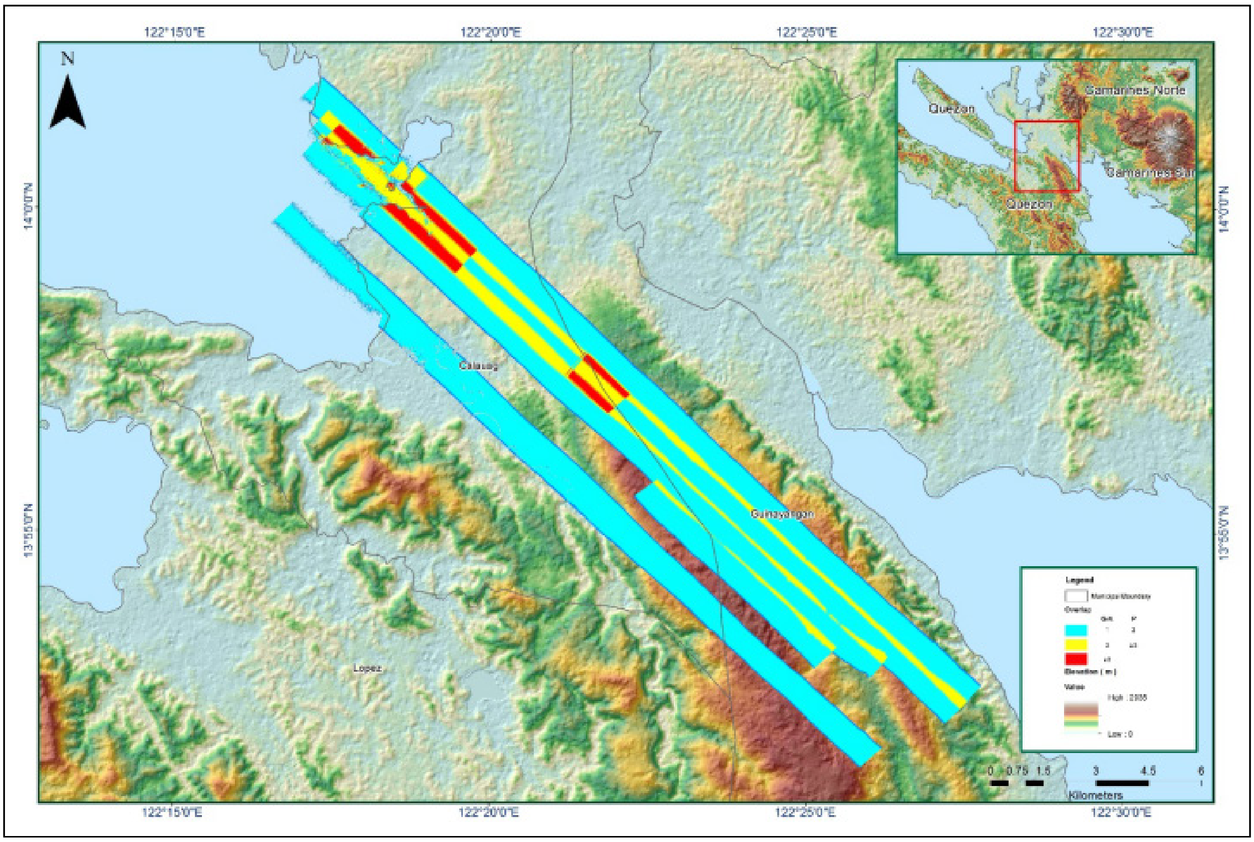


Figure-A.8.12. Image of Data Overlap

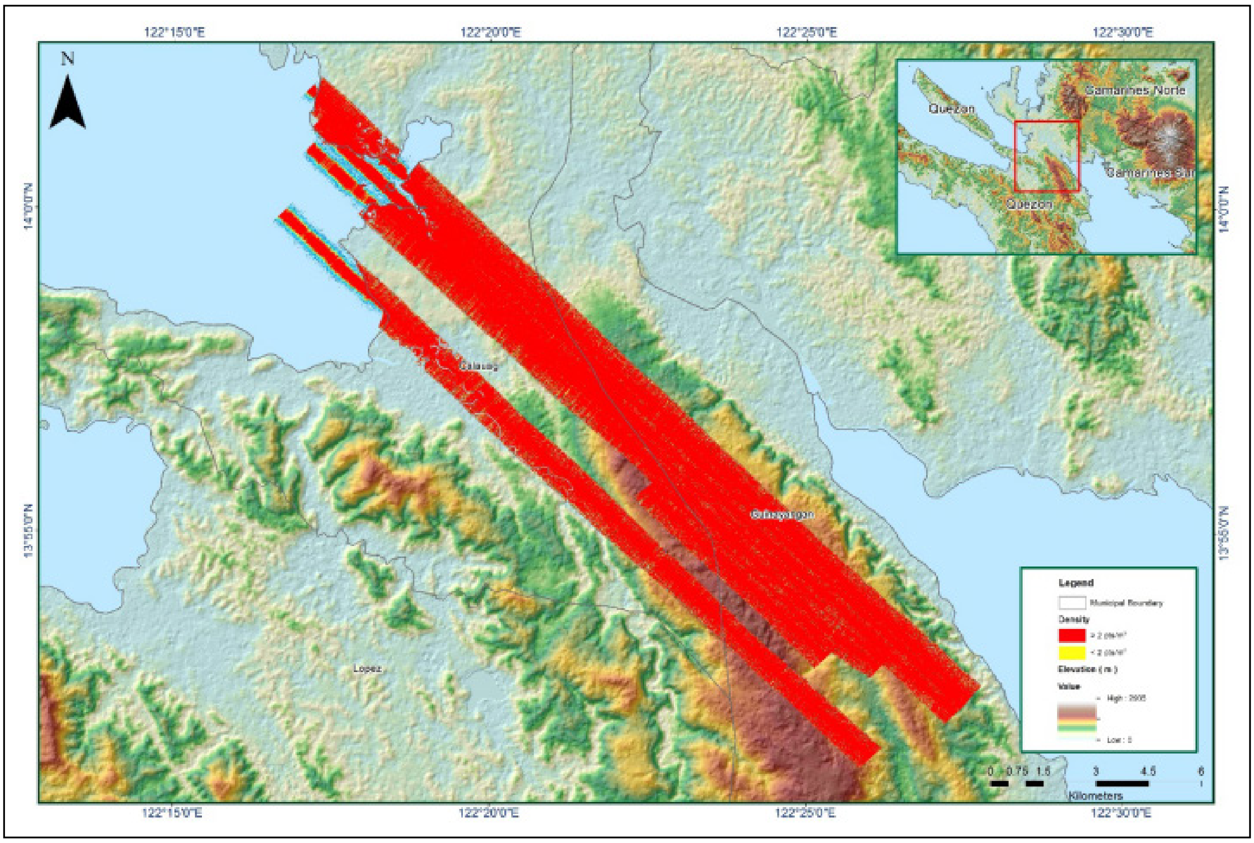


Figure-A.8.13. Density map of merged LiDAR data

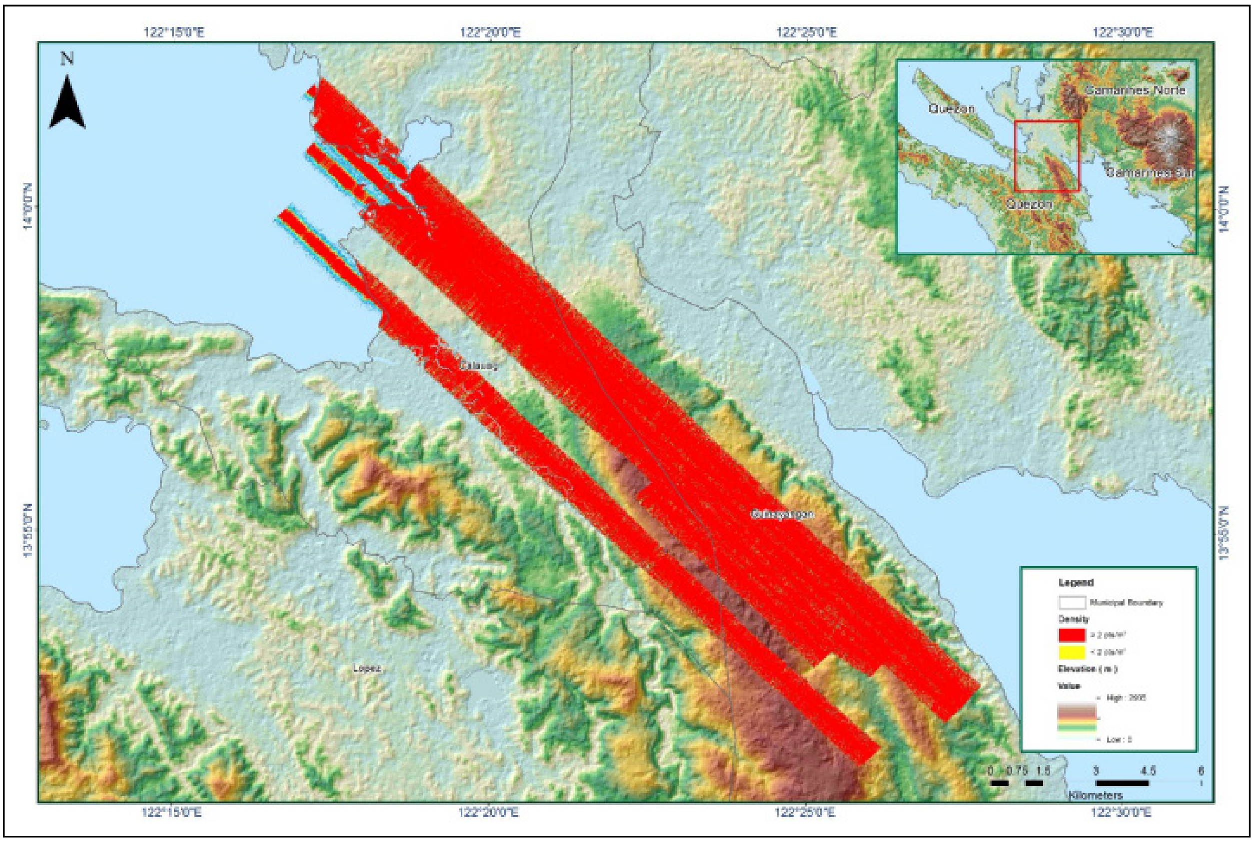


Figure-A.8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Bagasbasa_Blk21D

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21D
Inclusive Flights	23258P
Range data size	28.3 GB
POS data size	295 MB
Base data size	184 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000180
IMU attitude correction stdev (<0.001deg)	0.001185
GPS position stdev (<0.01m)	0.0061
Minimum % overlap (>25)	41.33%
Ave point cloud density per sq.m. (>2.0)	5.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	237
Maximum Height	600.05 m
Minimum Height	39.63 m
Classification (# of points)	
Ground	169,018,375
Low vegetation	156,847,288
Medium vegetation	376,661,780
High vegetation	1,065,078,241
Building	15,157,802
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Ma. Joanne Balaga, Alex John Escobido

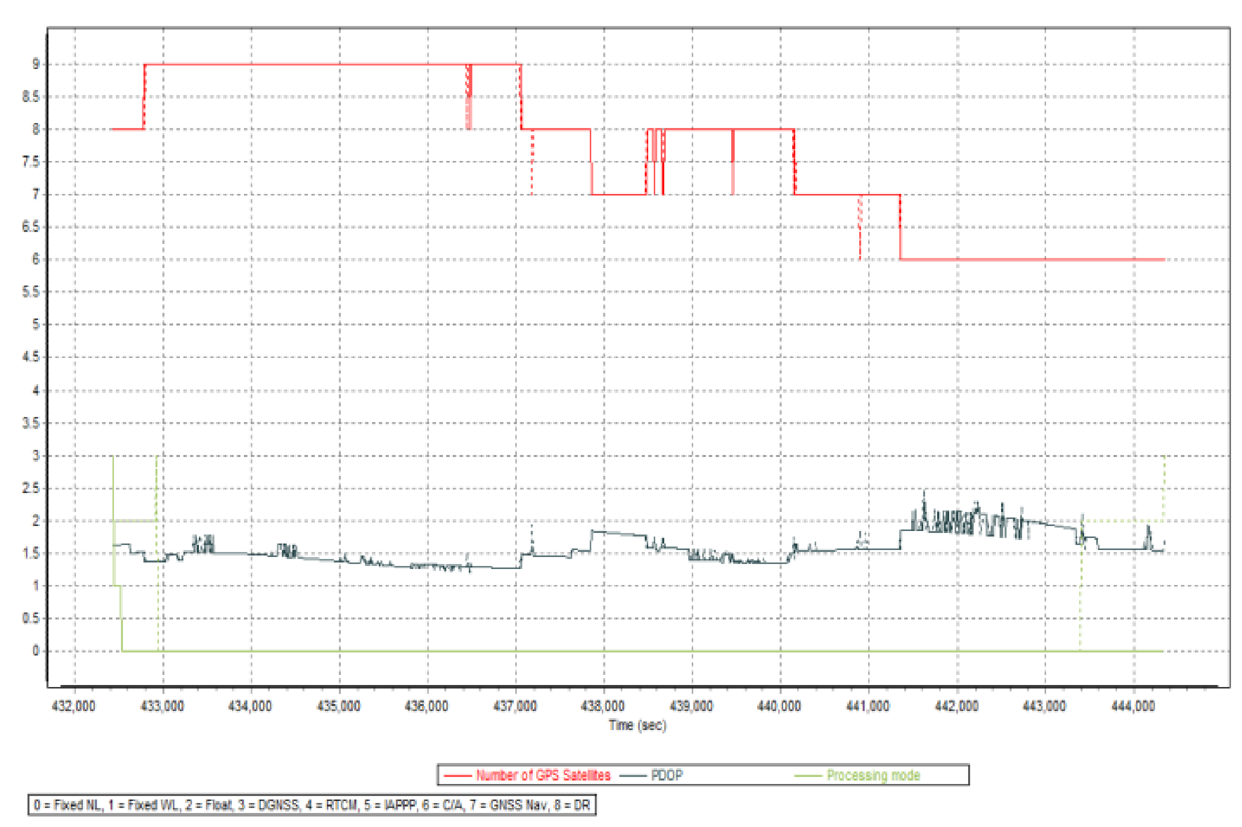


Figure-A.8.15. Solution Status

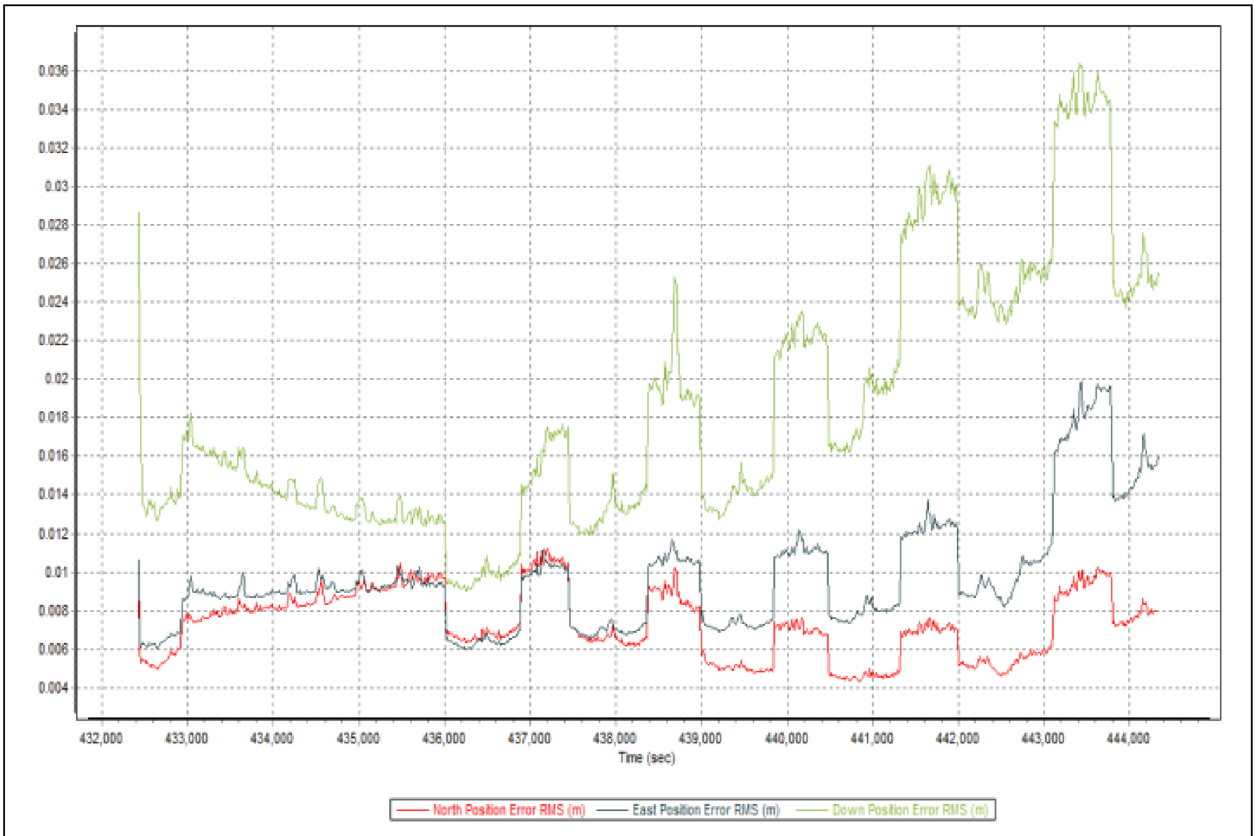


Figure-A.8.16. Smoothed Performance Metric Parameters

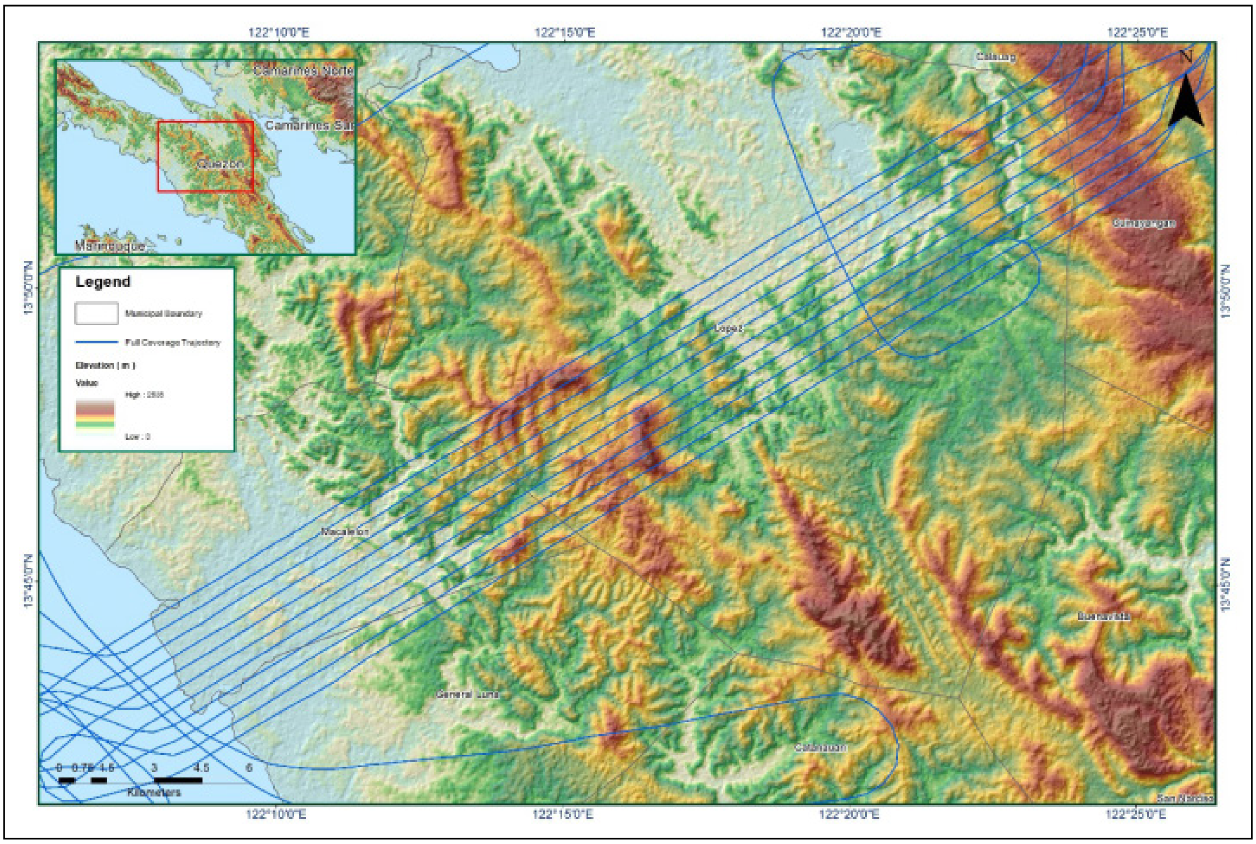


Figure-A.8.17. Best Estimated Trajectory

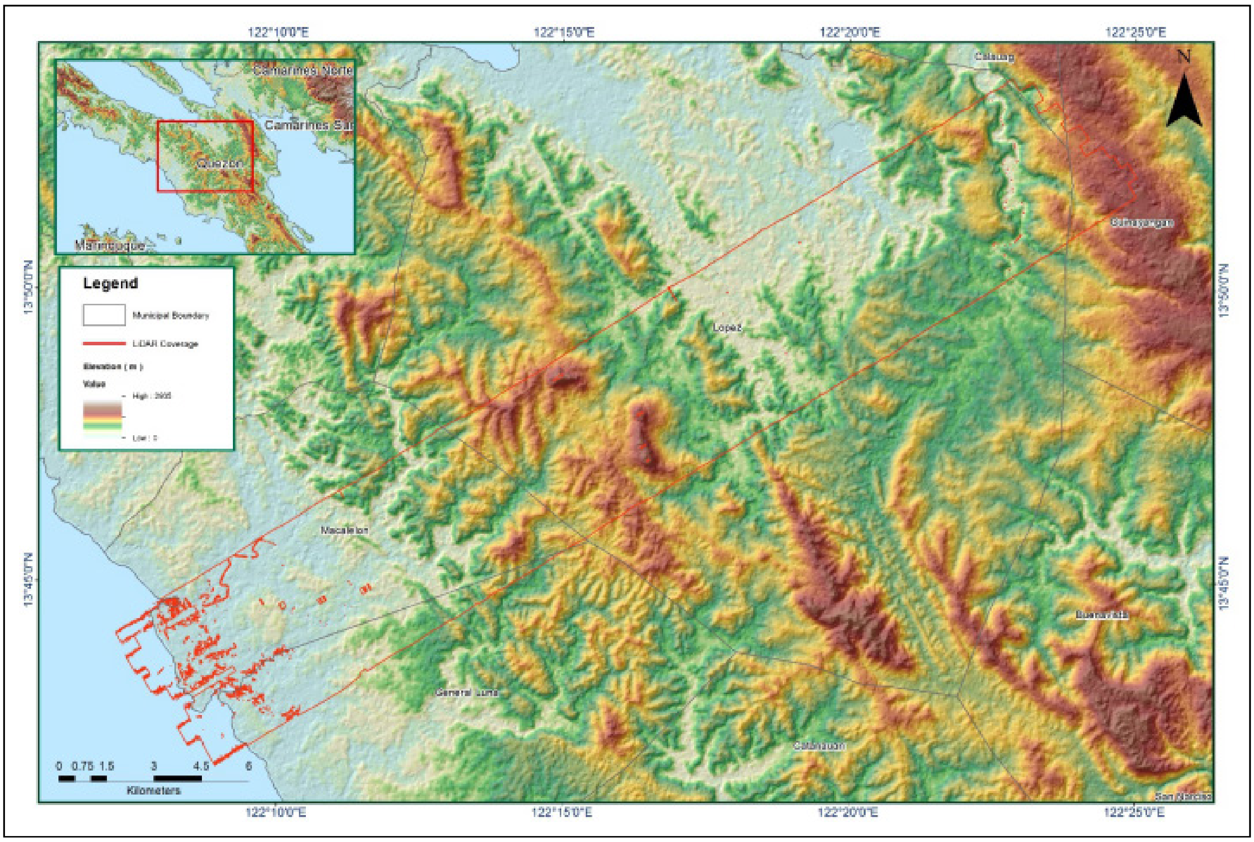


Figure-A.8.18. Coverage of LiDAR data

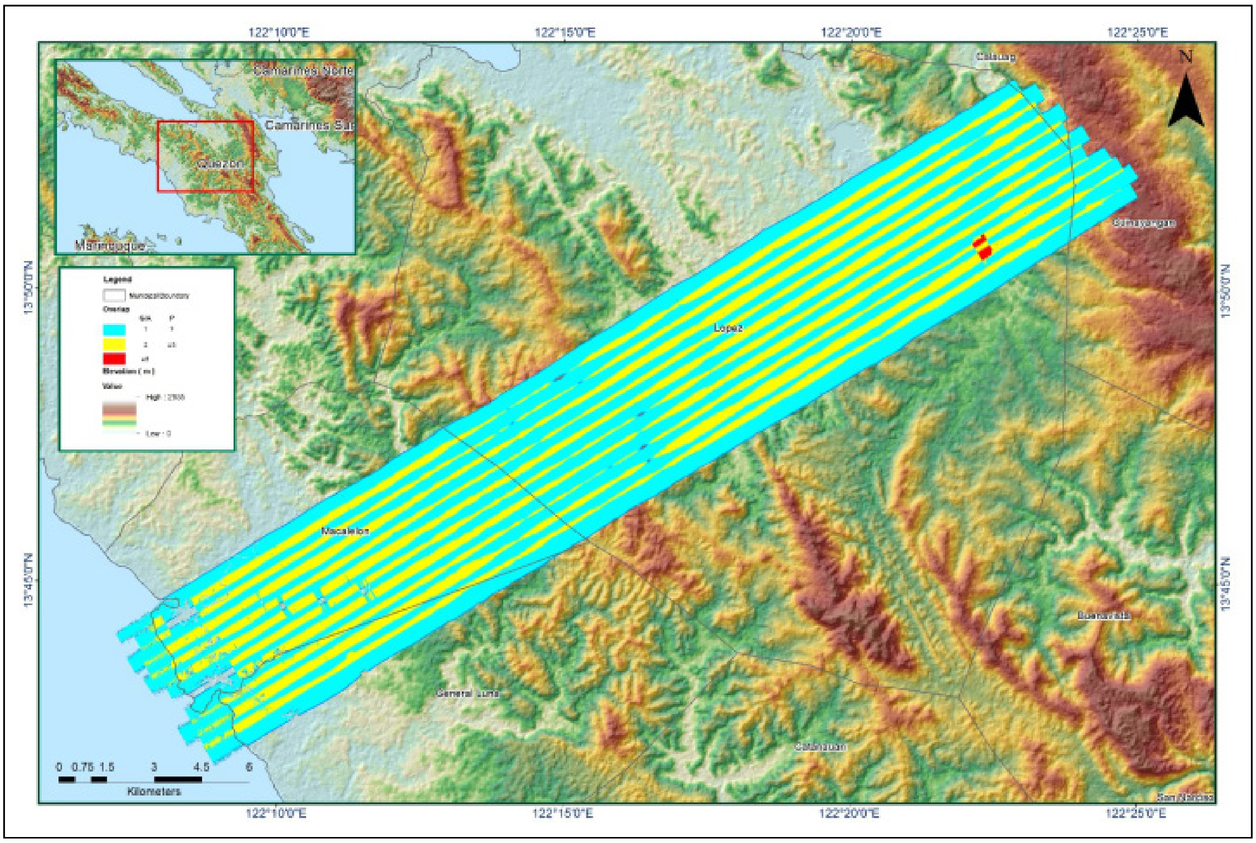


Figure-A.8.19. Image of Data Overlap

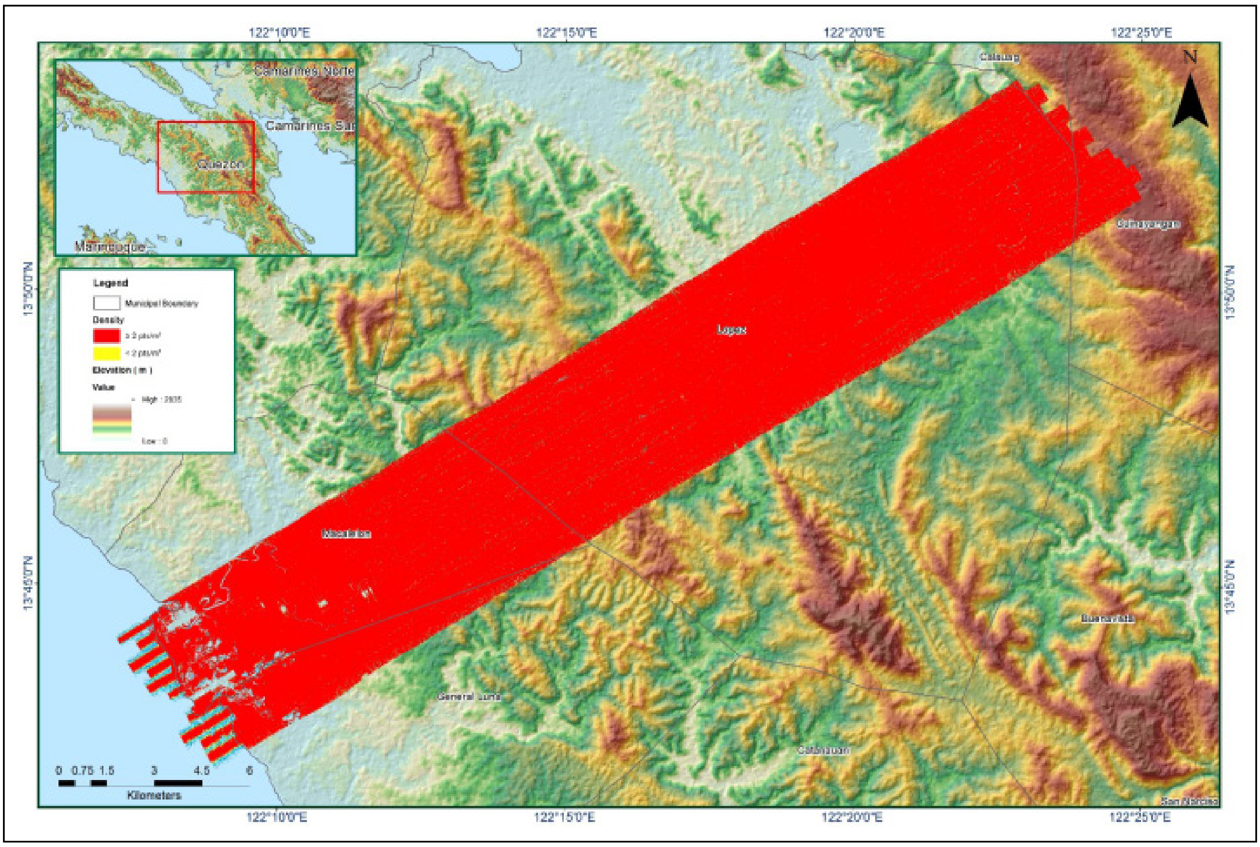


Figure-A.8.19. Density map of merged LiDAR data

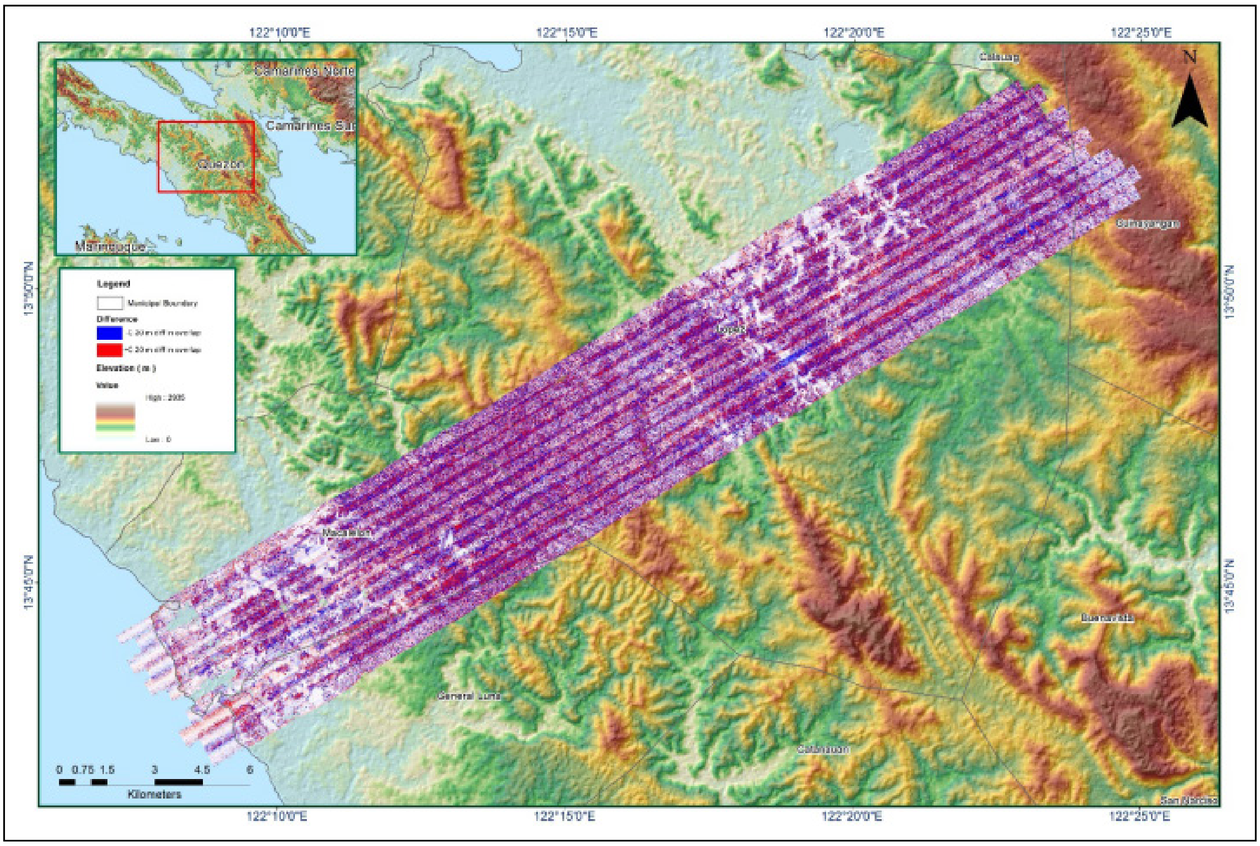


Figure-A.8.20. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Bagasbasa_Blk21C

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21C
Inclusive Flights	23250P
Range data size	34.4 GB
POS data size	306 MB
Base data size	90.5 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
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)	1.9
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000162
IMU attitude correction stdev (<0.001deg)	0.000366
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	64.92%
Ave point cloud density per sq.m. (>2.0)	5.14
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	290
Maximum Height	448.83
Minimum Height	50.13
Classification (# of points)	
Ground	200881690
Low vegetation	182754278
Medium vegetation	486076060
High vegetation	1342019390
Building	23114427
Orthophoto	Yes
Processed by	Engr. Don Mathew Banatin, Engr. Merven Natino, Engr. Elainne Lopez

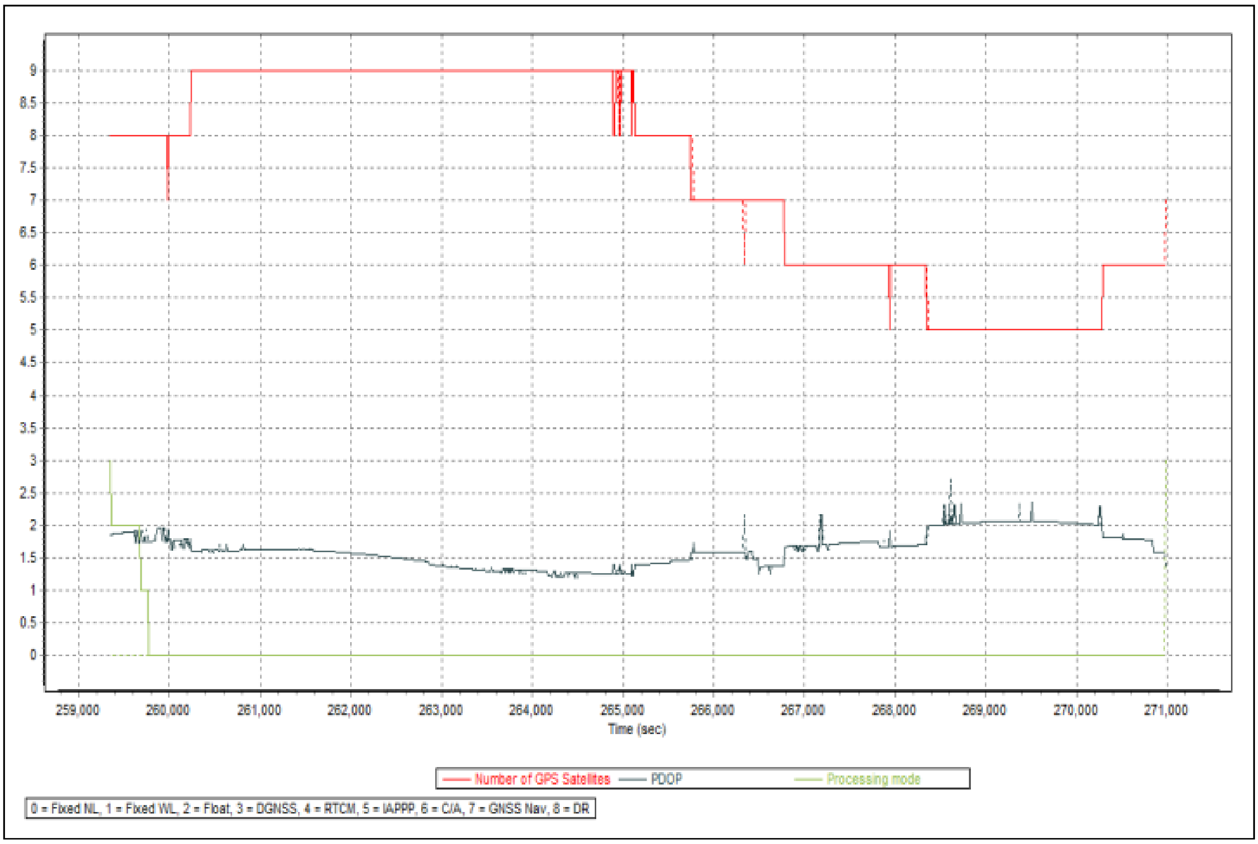


Figure-A.8.21. Solution Status

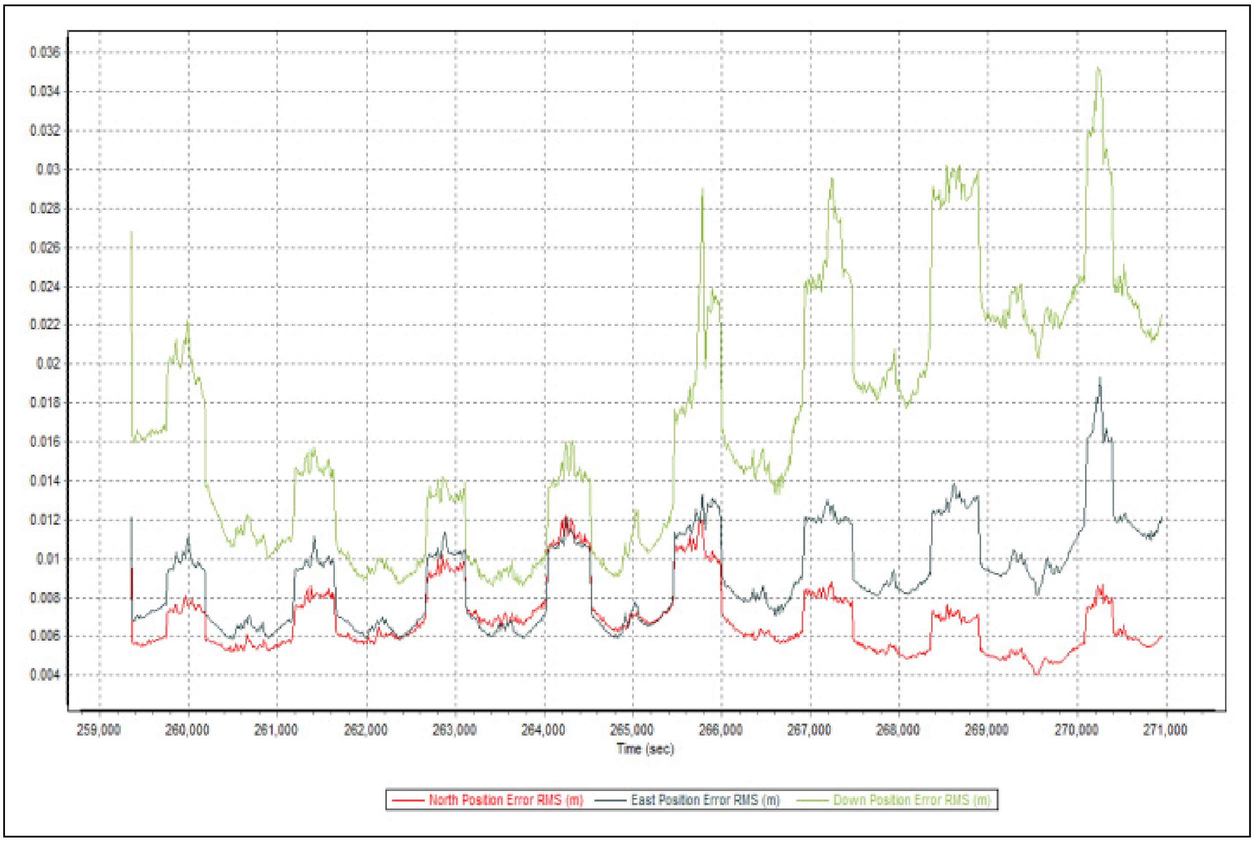


Figure-A.8.22. Smoothed Performance Metric Parameters

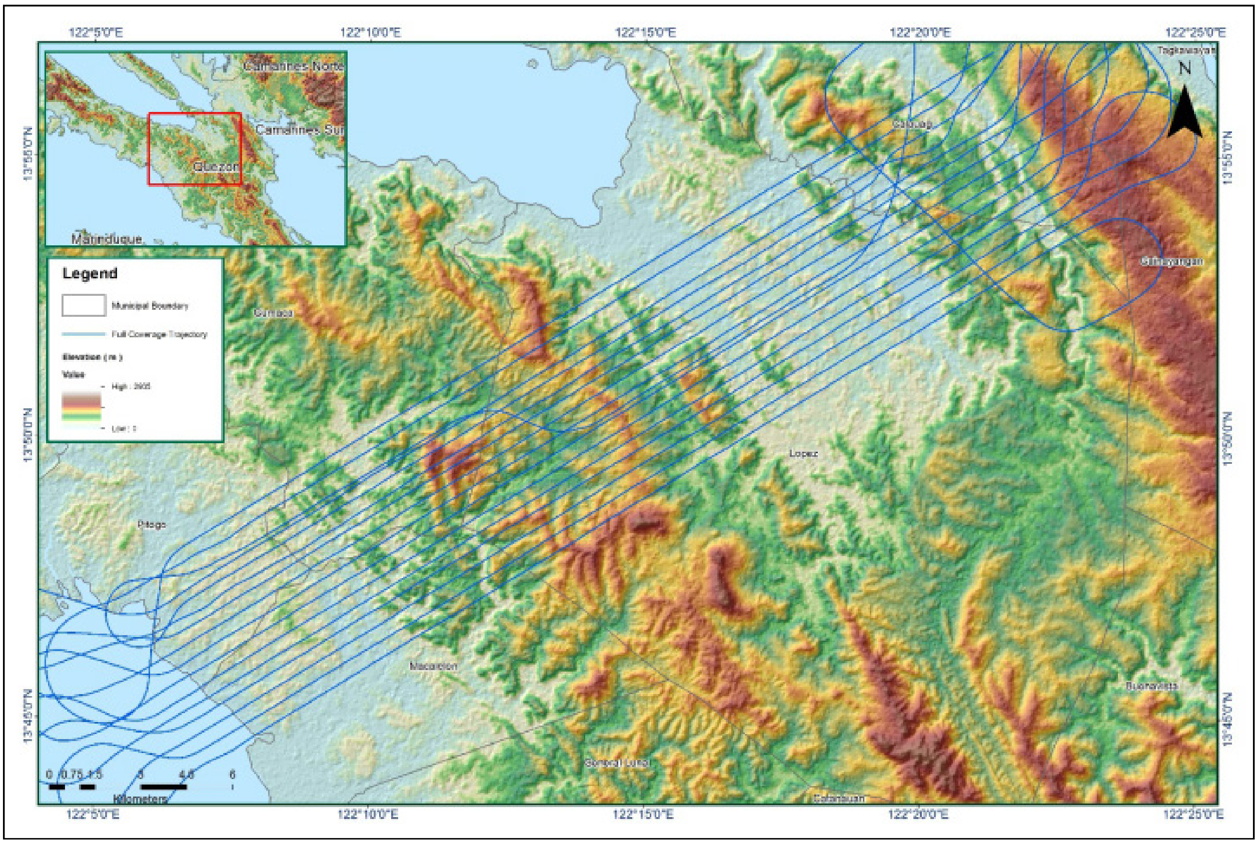


Figure-A.8.23. Best Estimated Trajectory

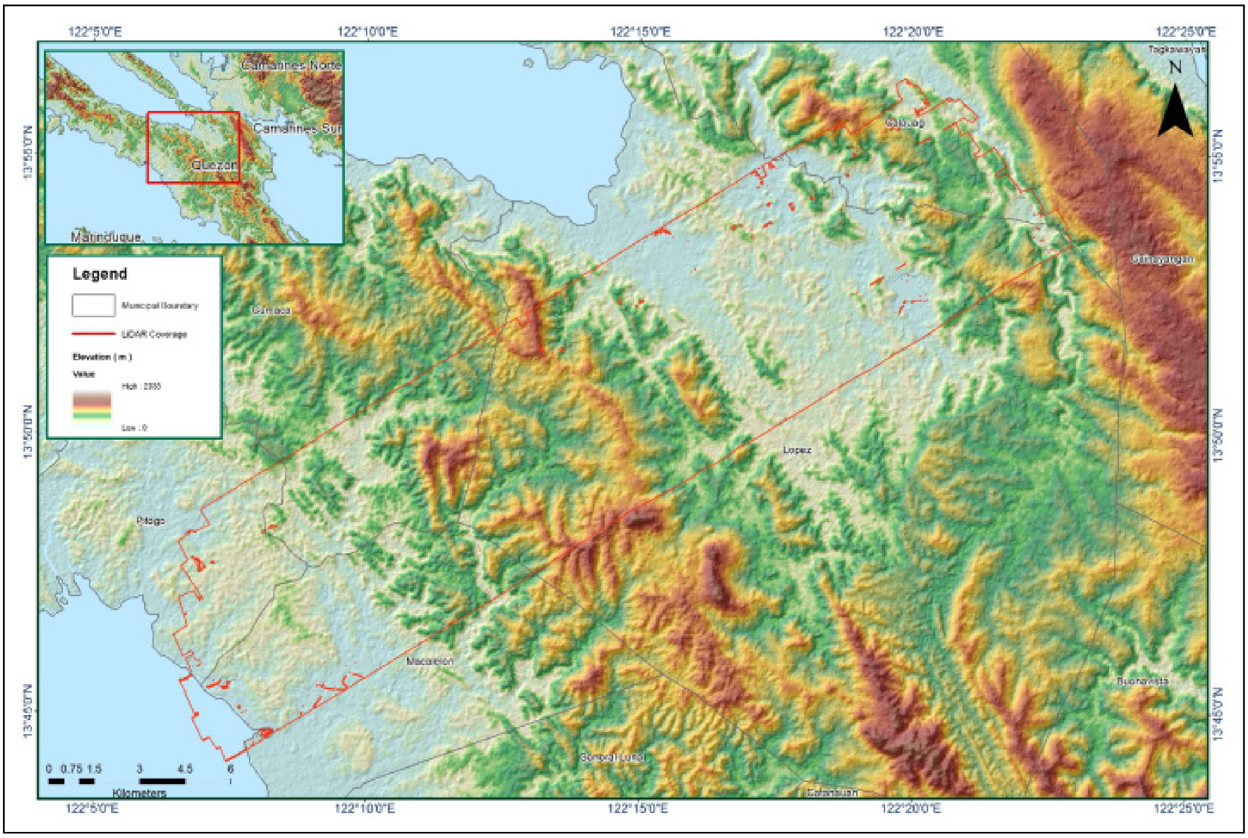


Figure-A.8.24. Coverage of LiDAR data

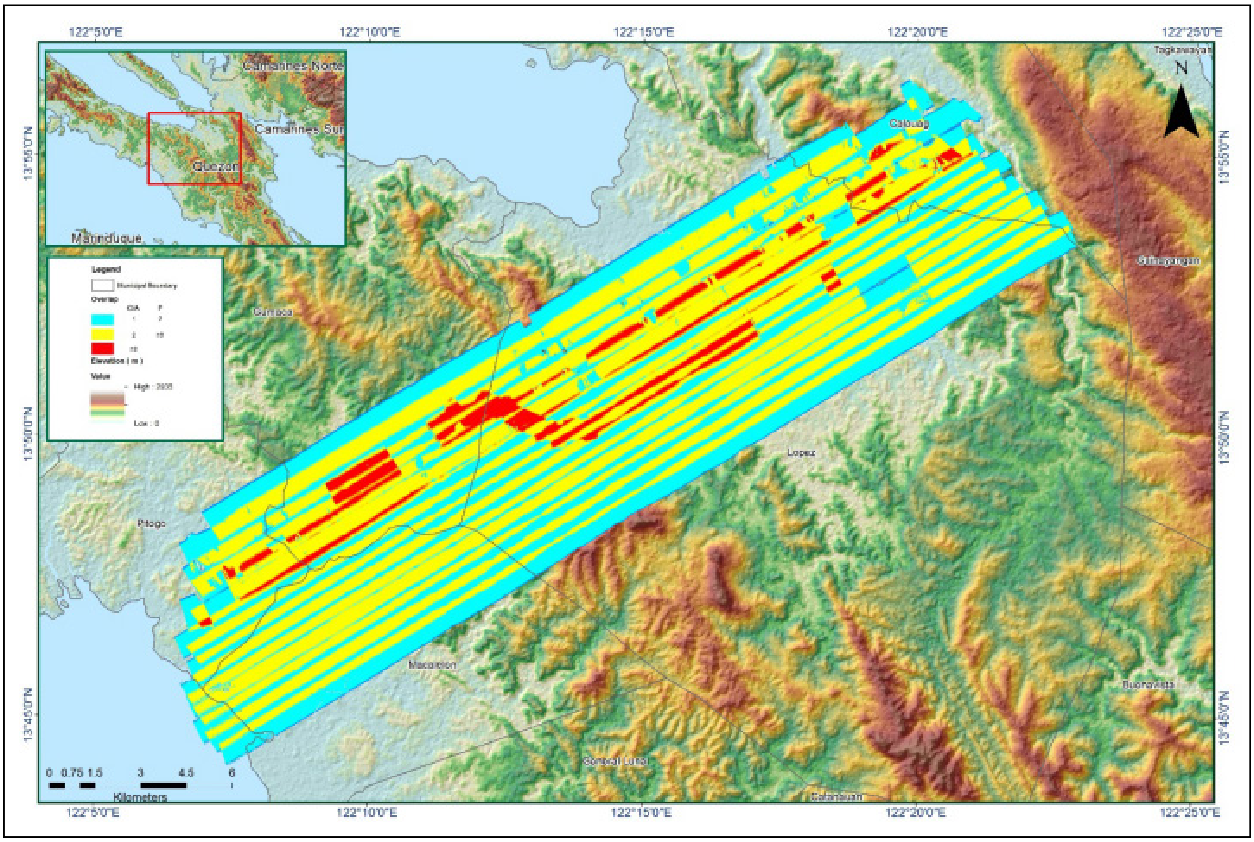


Figure-A.8.25. Image of Data Overlap

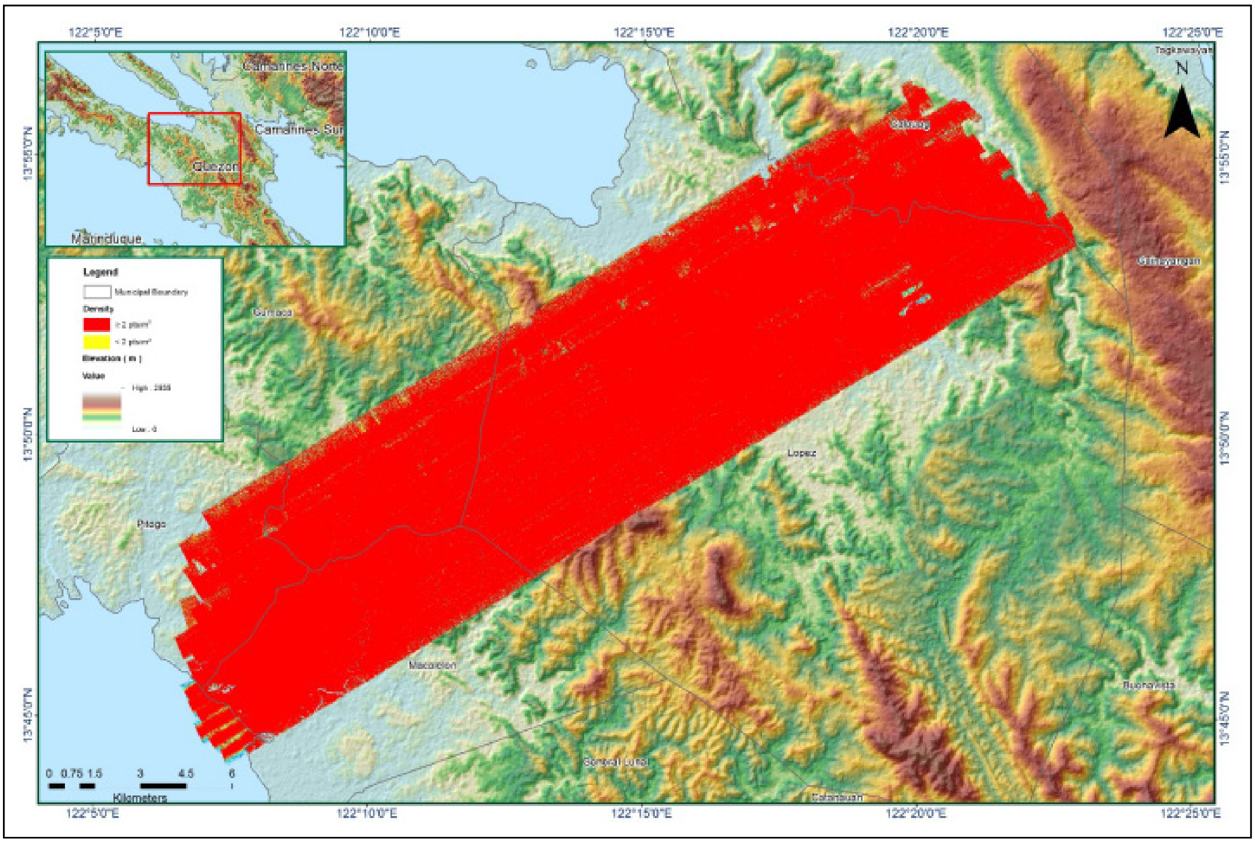


Figure-A.8.26. Density map of merged LiDAR data

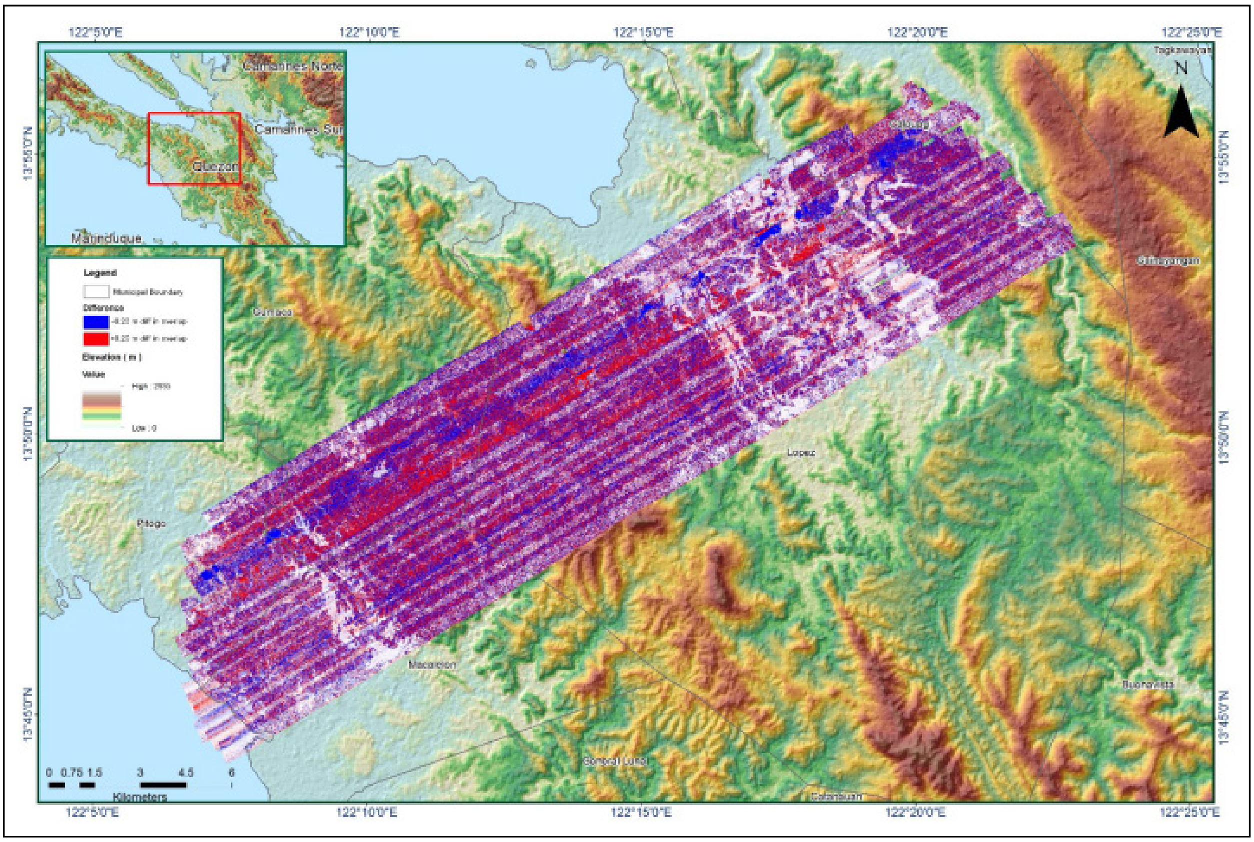


Figure-A.8.27. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Bagasbasa_Blk21B

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21B
Inclusive Flights	23254P
Range data size	8.7 GB
POS data size	176 MB
Base data size	106 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.4
Boresight correction stdev (<0.001deg)	0.000292
IMU attitude correction stdev (<0.001deg)	0.000389
GPS position stdev (<0.01m)	0.0004
Minimum % overlap (>25)	22.62%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	146
Maximum Height	667.8
Minimum Height	49.57
Classification (# of points)	
Ground	63116805
Low vegetation	26844522
Medium vegetation	78513440
High vegetation	244022525
Building	2787091
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Merven Matthew Natino, Engr. Monalyne Rabino

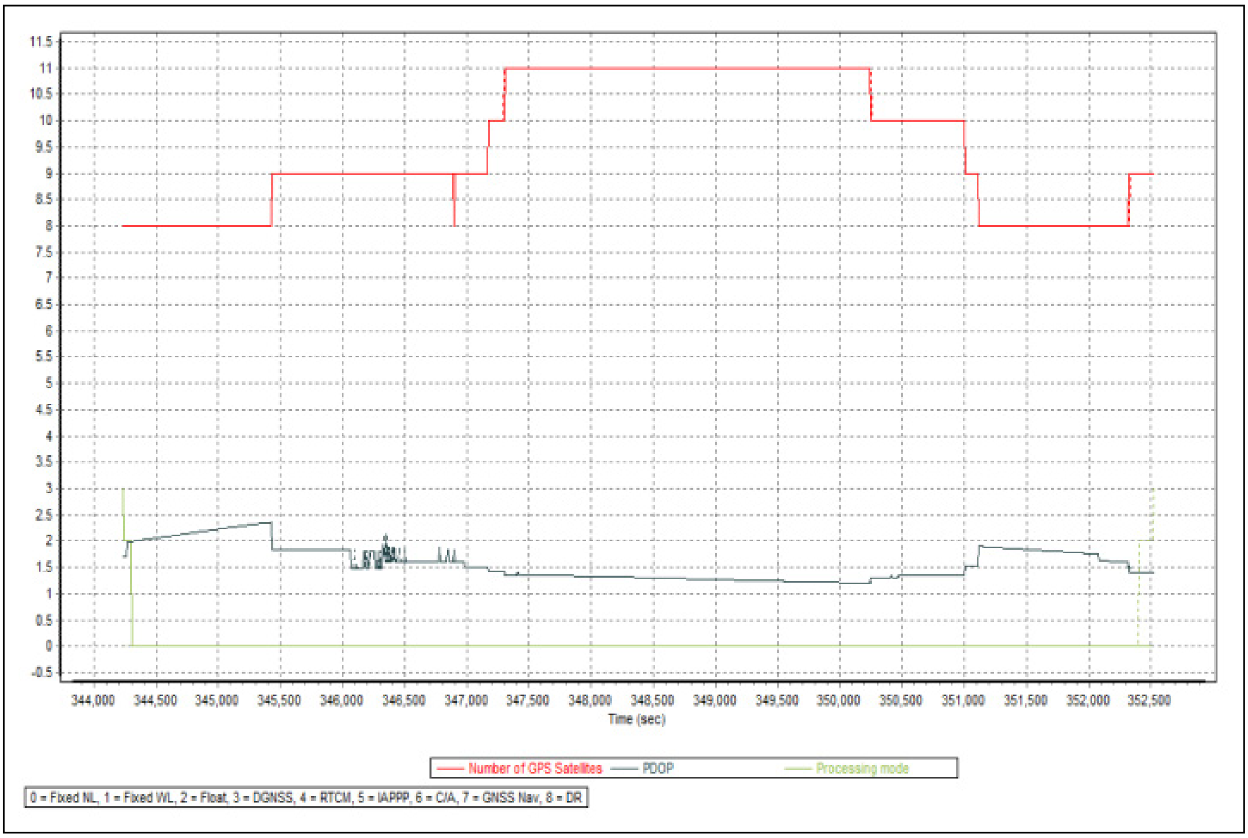


Figure-A.8.28. Solution Status

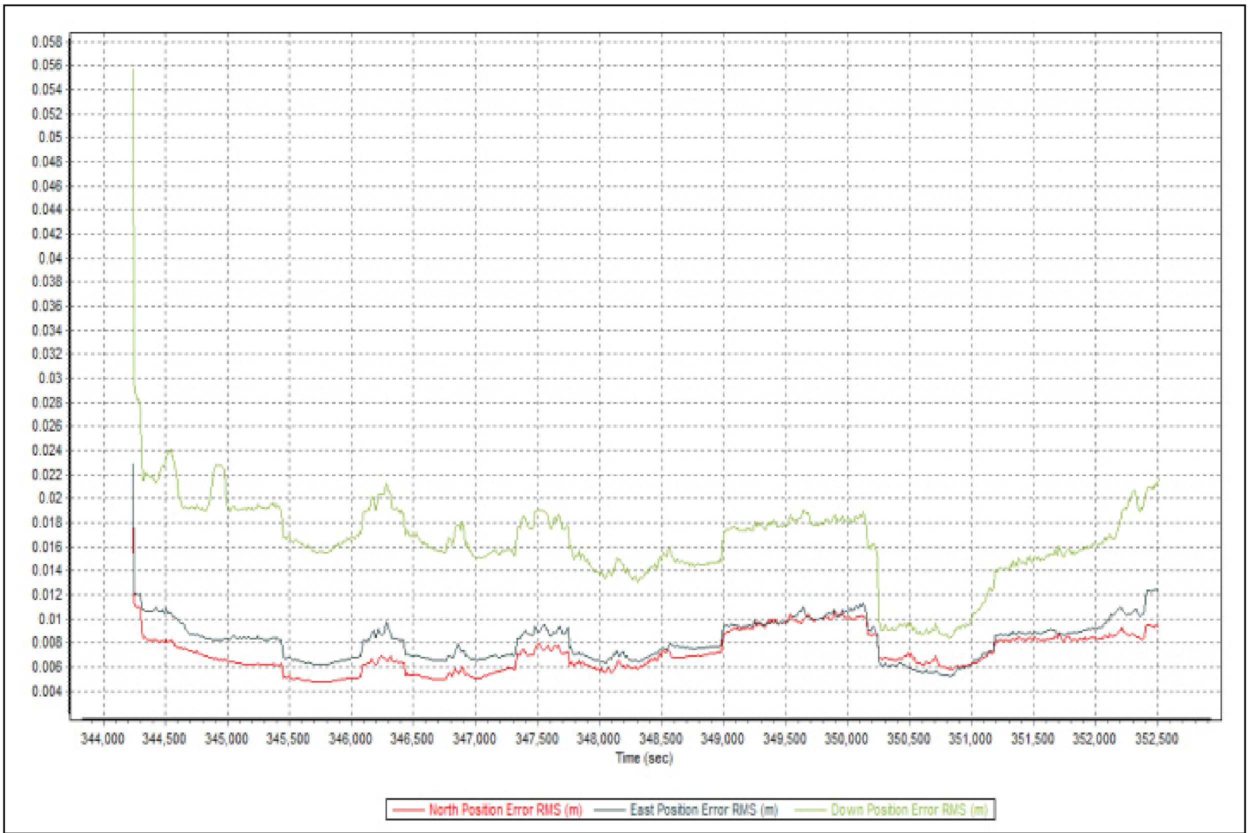


Figure-A.8.29. Smoothed Performance Metric Parameters

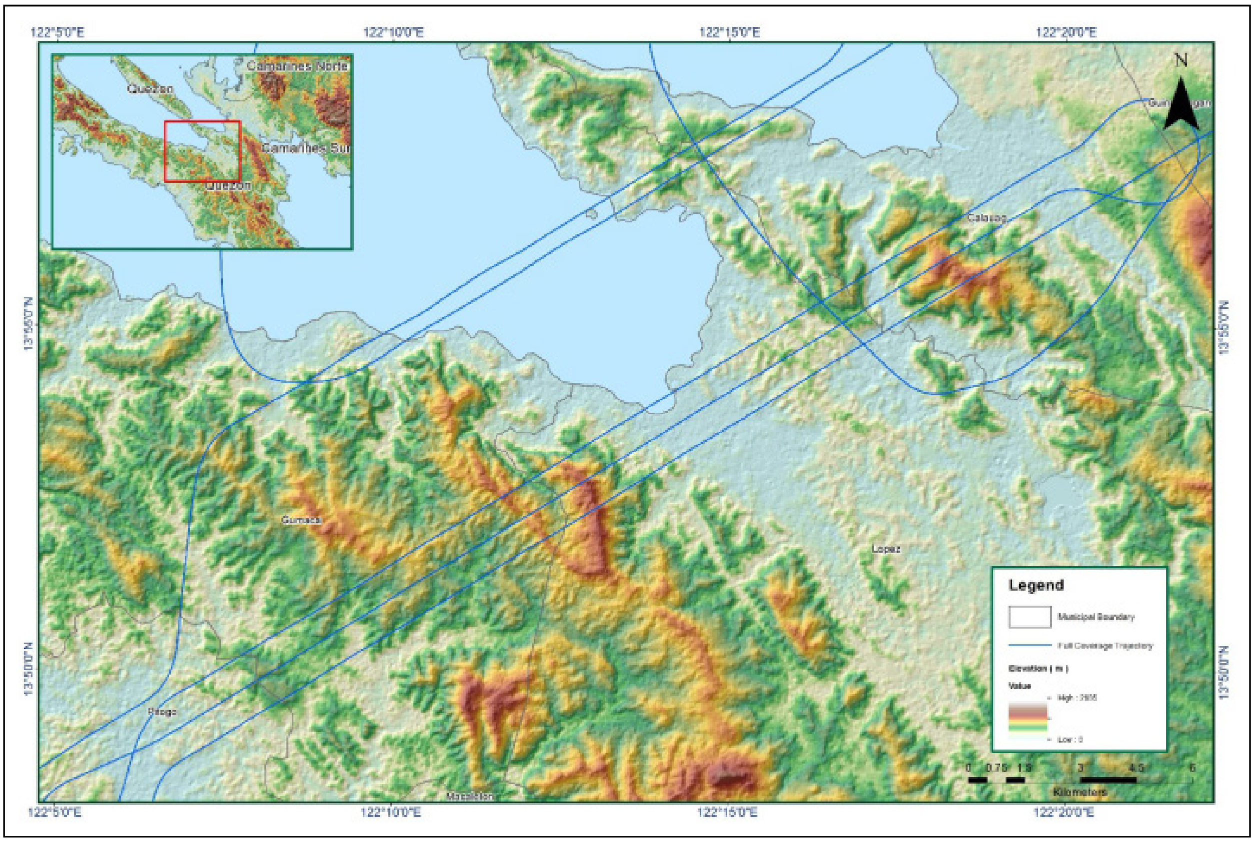


Figure-A.8.30. Best Estimated Trajectory

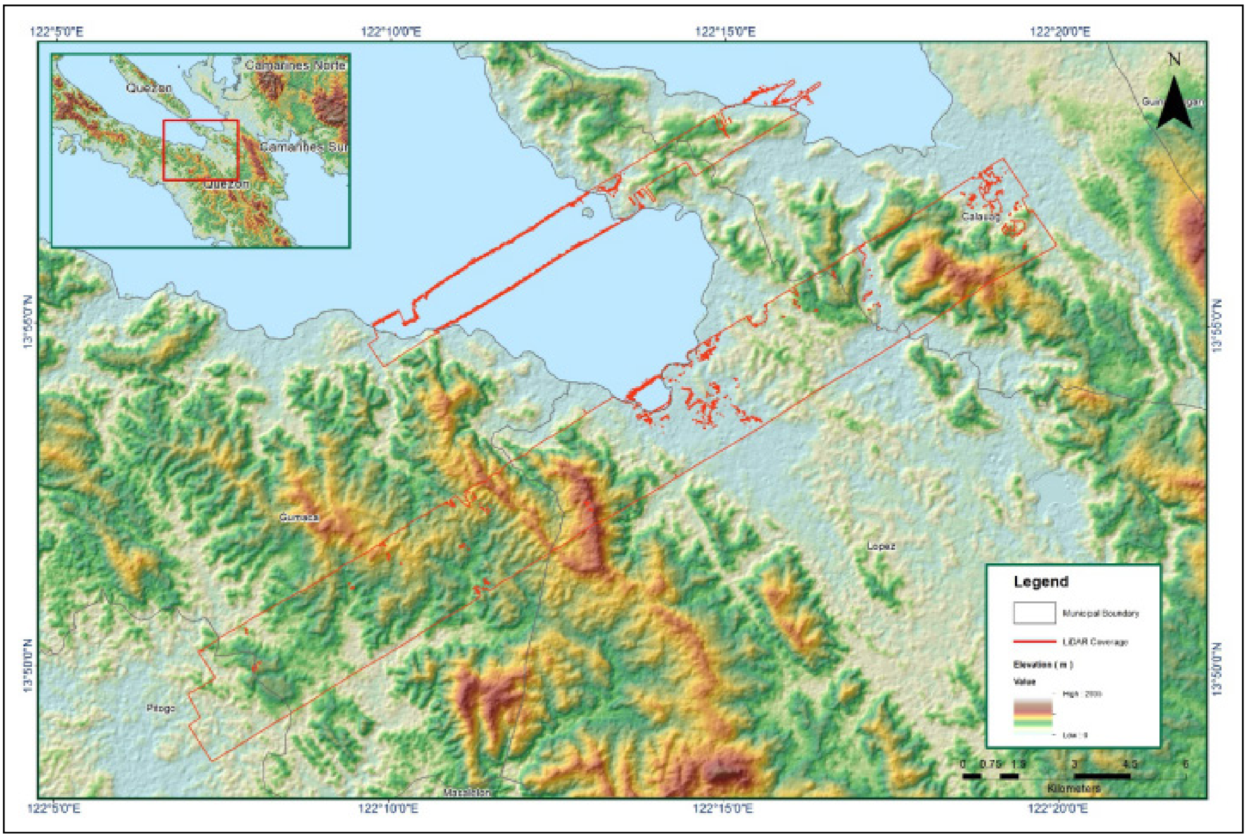


Figure-A.8.31. Coverage of LiDAR data

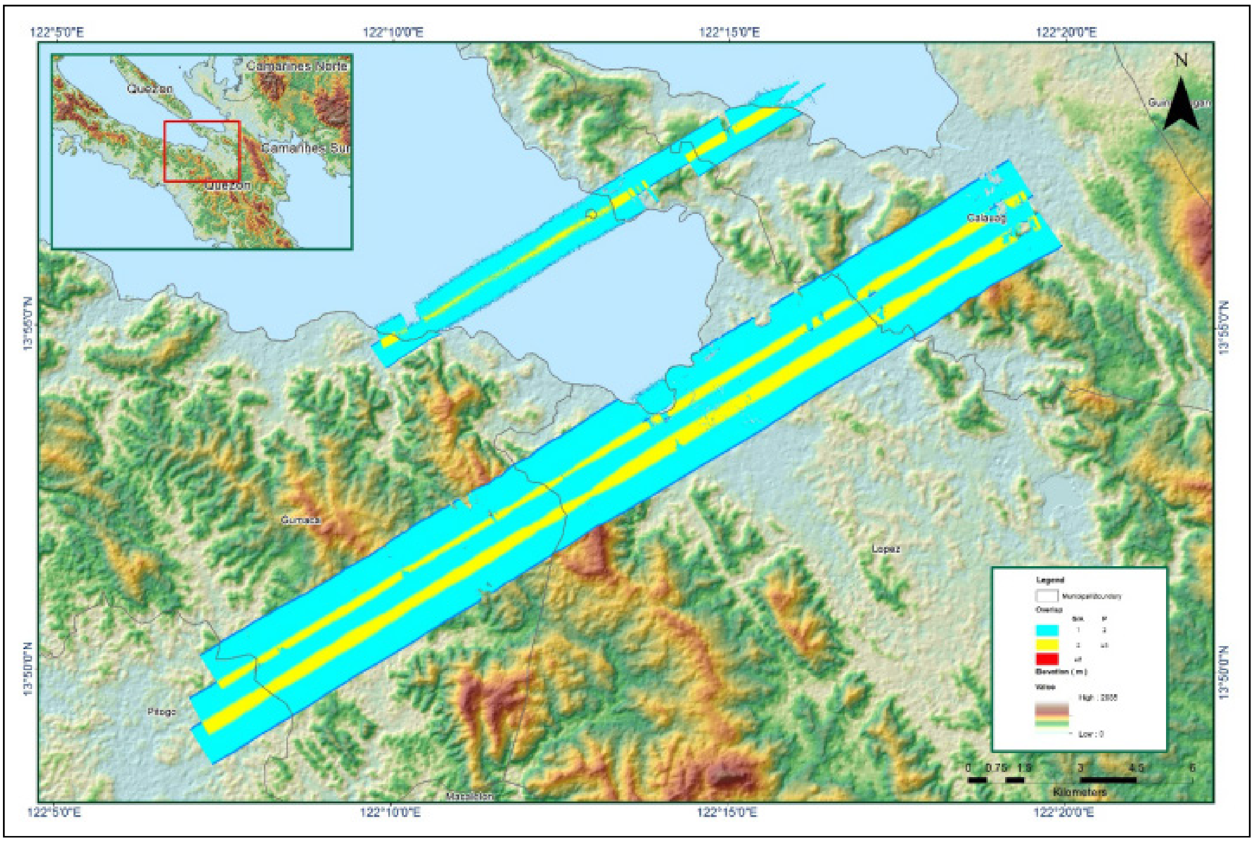


Figure-A.8.31 Image of Data Overlap

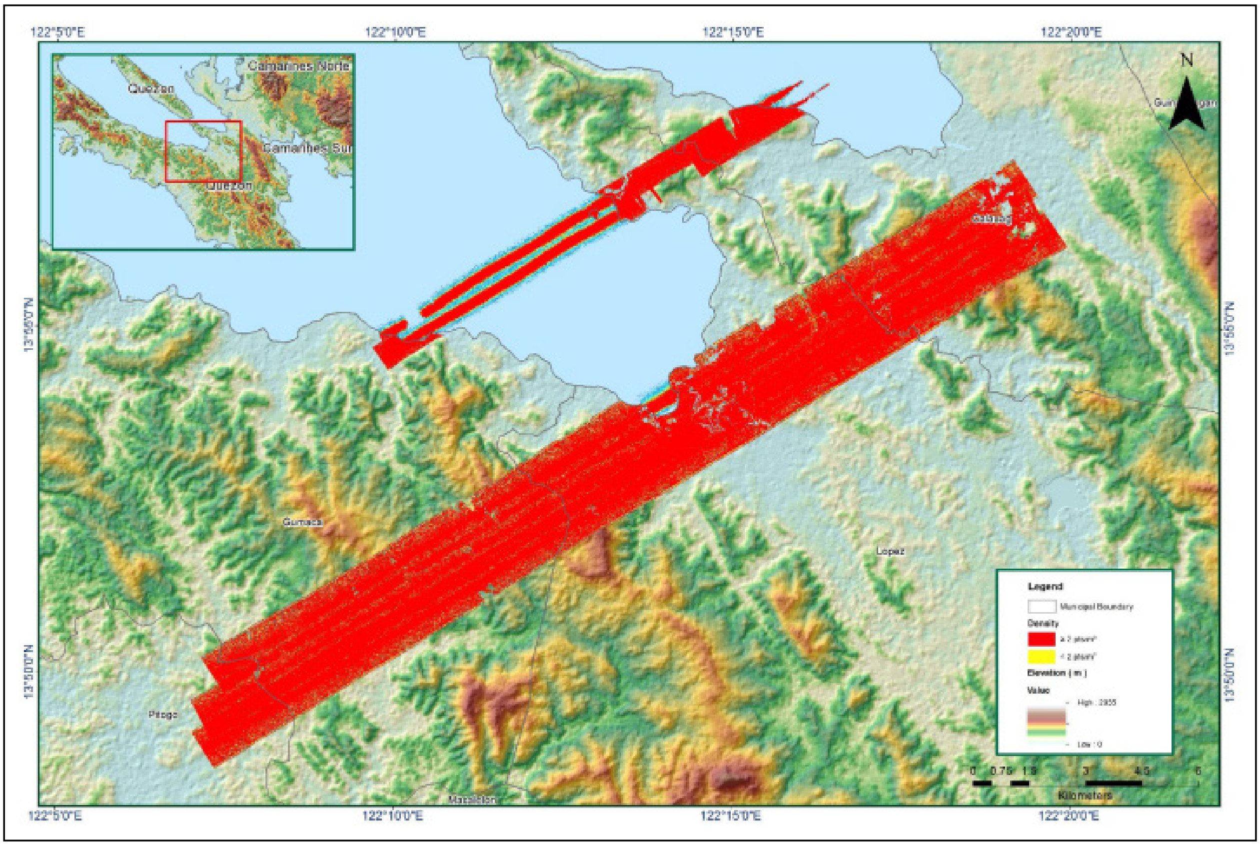


Figure-A.8.32. Density map of merged LiDAR data

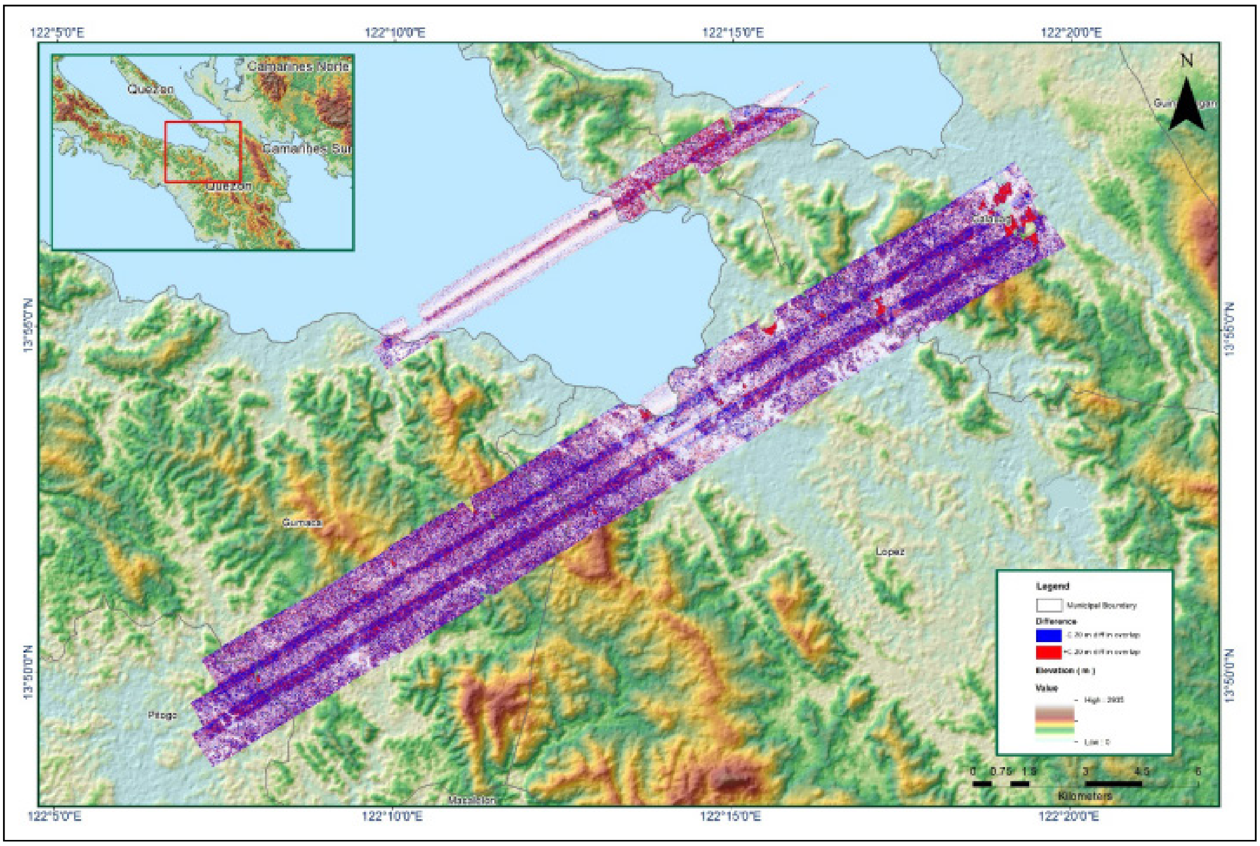


Figure-A.8.33. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Bagasbasa_Blk21B_additional

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21B_additional
Inclusive Flights	23262P
Range data size	15.8 GB
POS data size	222 MB
Base data size	83 MB
Image	n/a
Transfer date	May 18 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.001549
IMU attitude correction stdev (<0.001deg)	0.001477
GPS position stdev (<0.01m)	0.0227
Minimum % overlap (>25)	25.97%
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	86
Maximum Height	358.5
Minimum Height	49.4
Classification (# of points)	
Ground	20178037
Low vegetation	10422237
Medium vegetation	24858467
High vegetation	82408047
Building	605906
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Engr. Czarina Jean Añonuevo

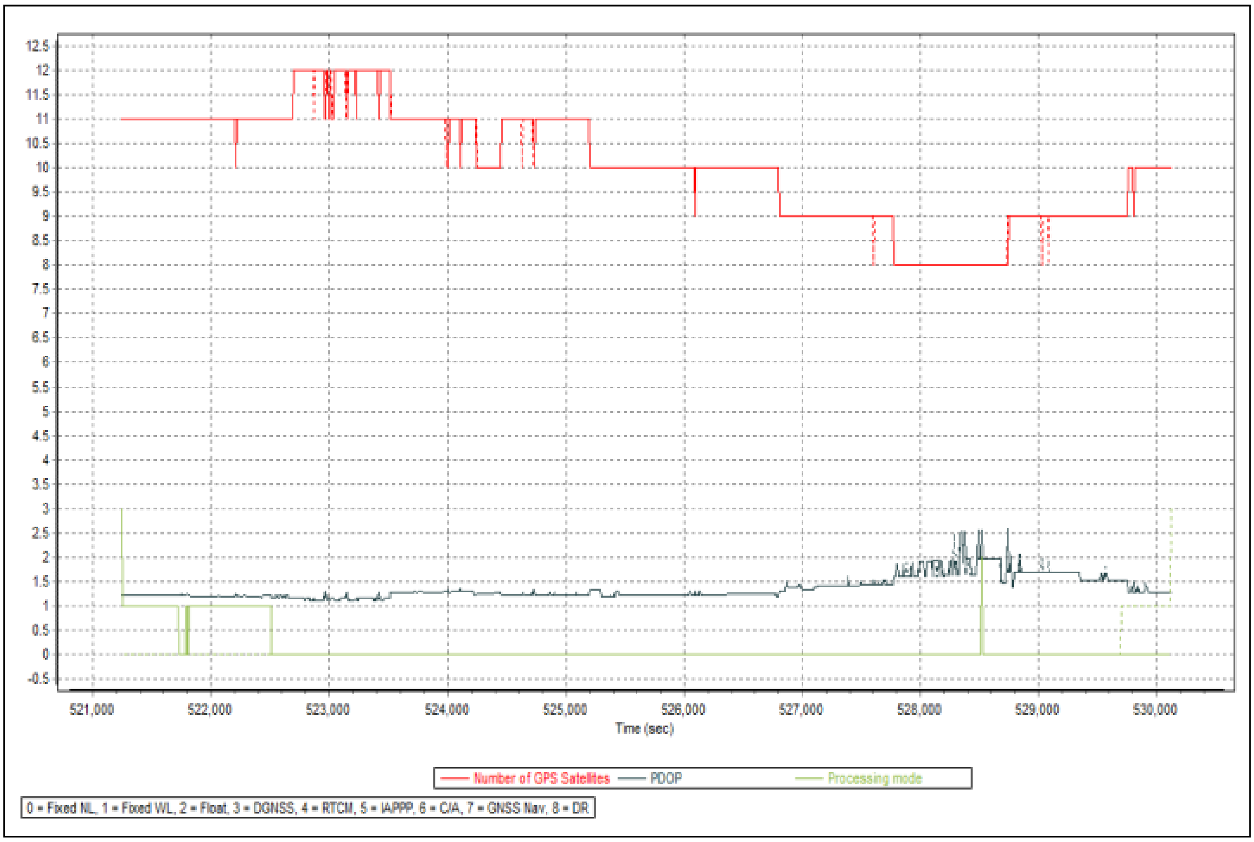


Figure-A.8.34. Solution Status

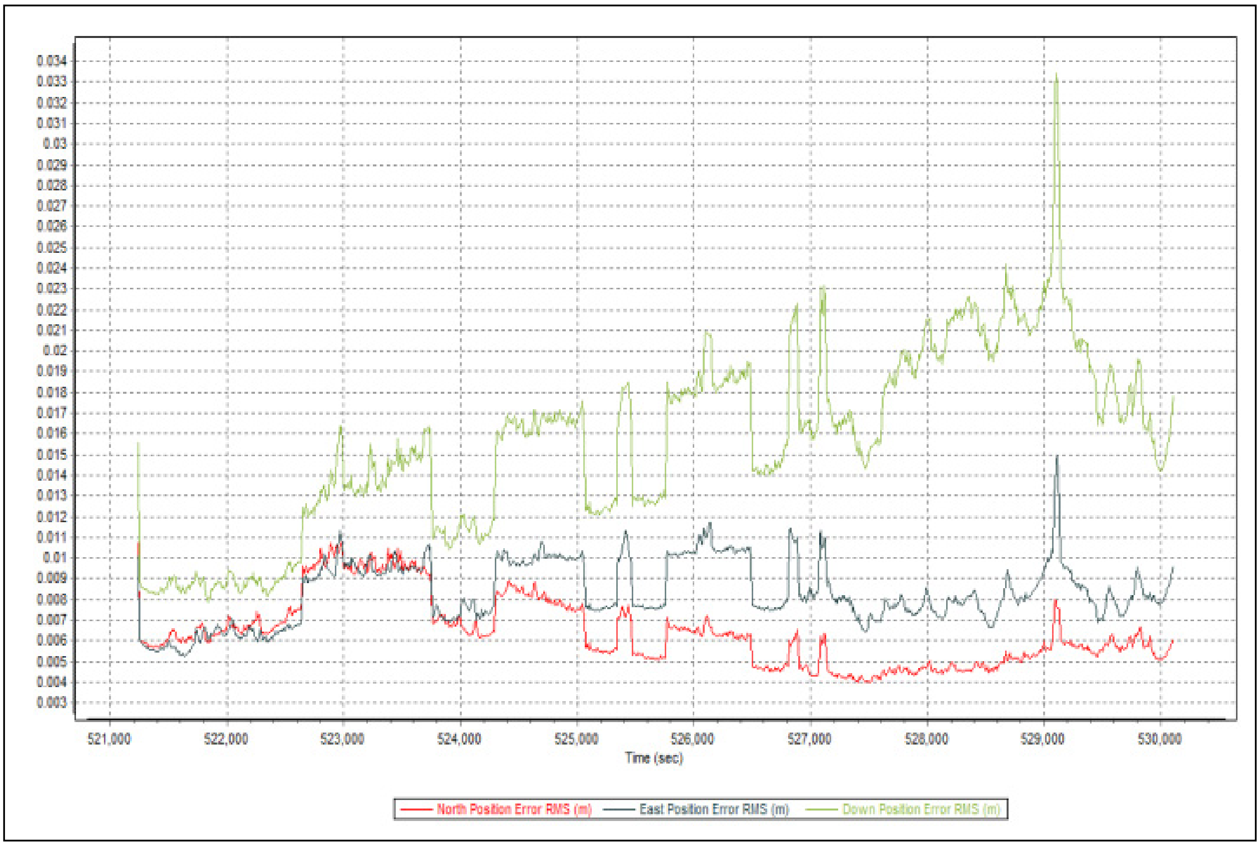


Figure-A.8.35. Smoothed Performance Metric Parameters

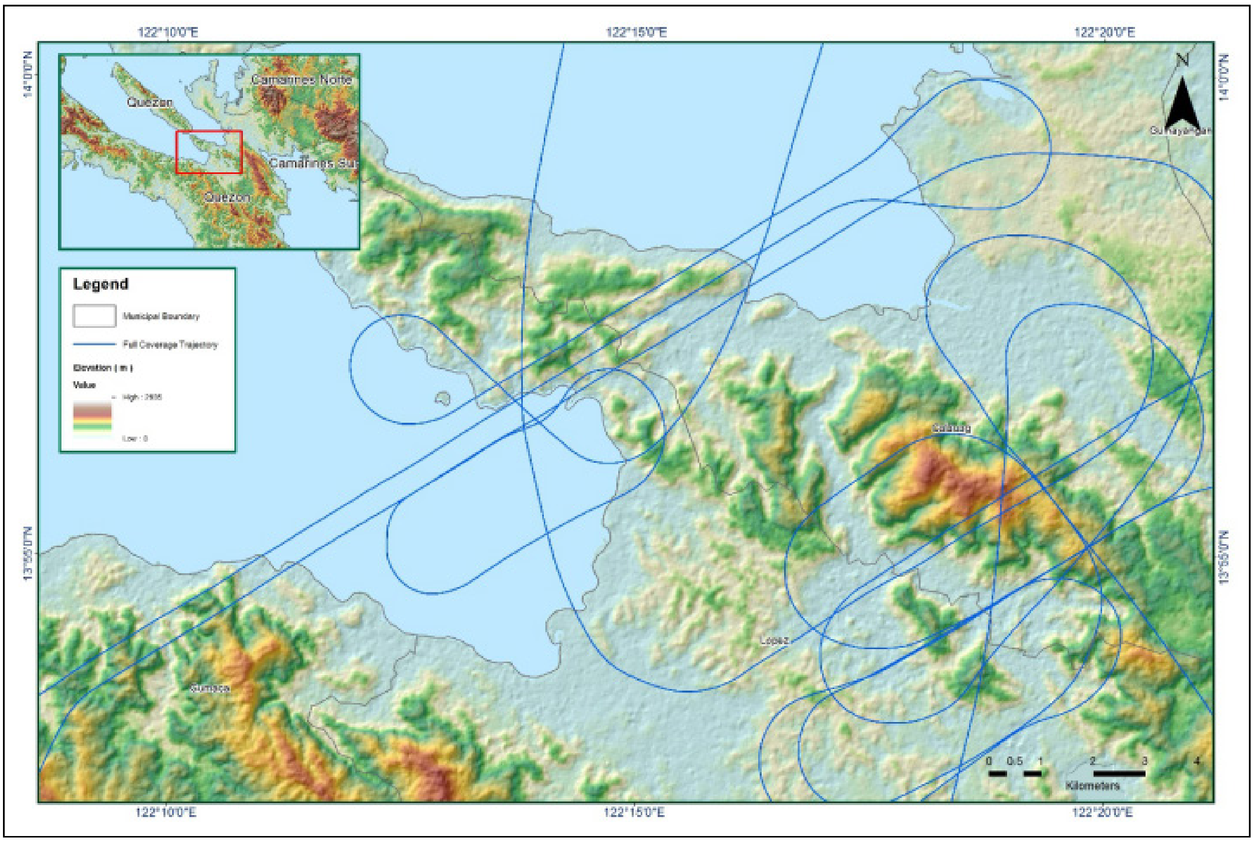


Figure-A.8.35. Best Estimated Trajectory

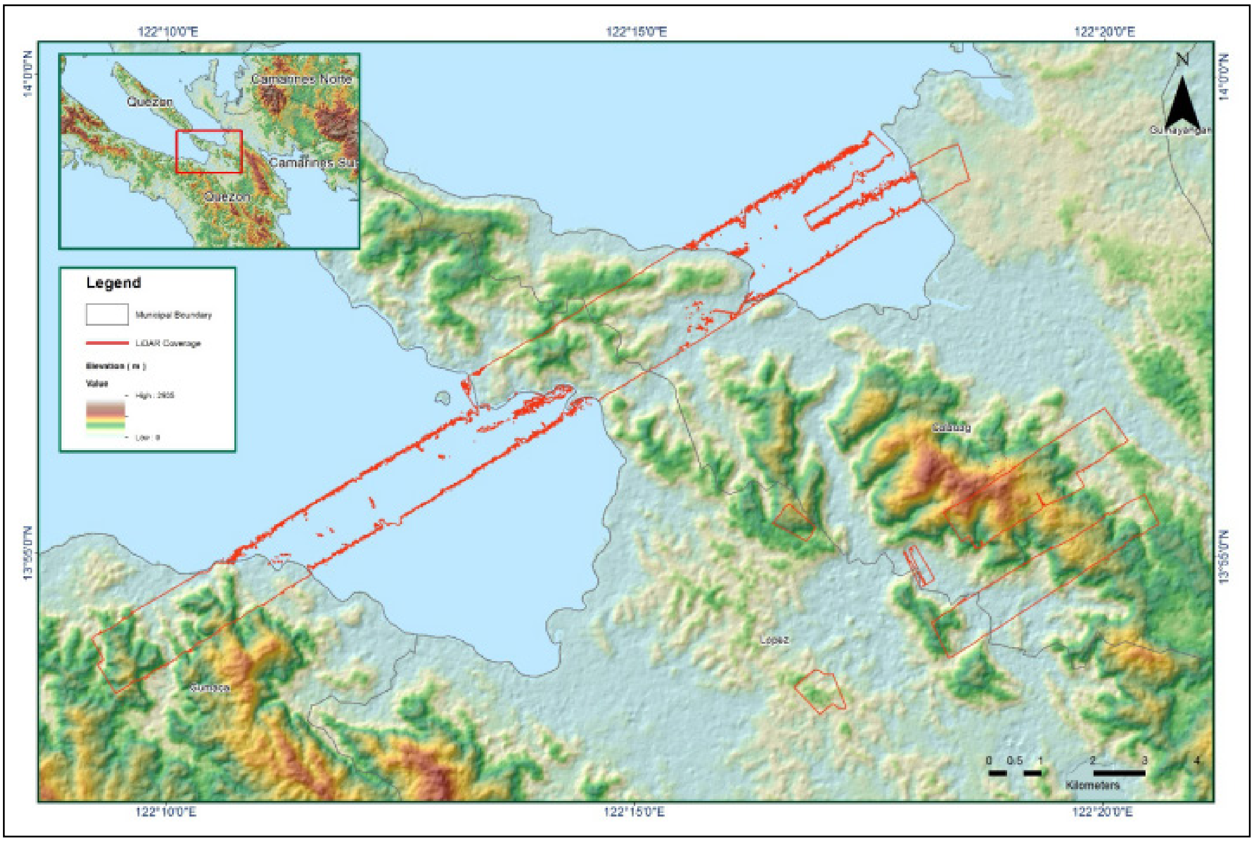


Figure-A.8.36. Coverage of LiDAR data

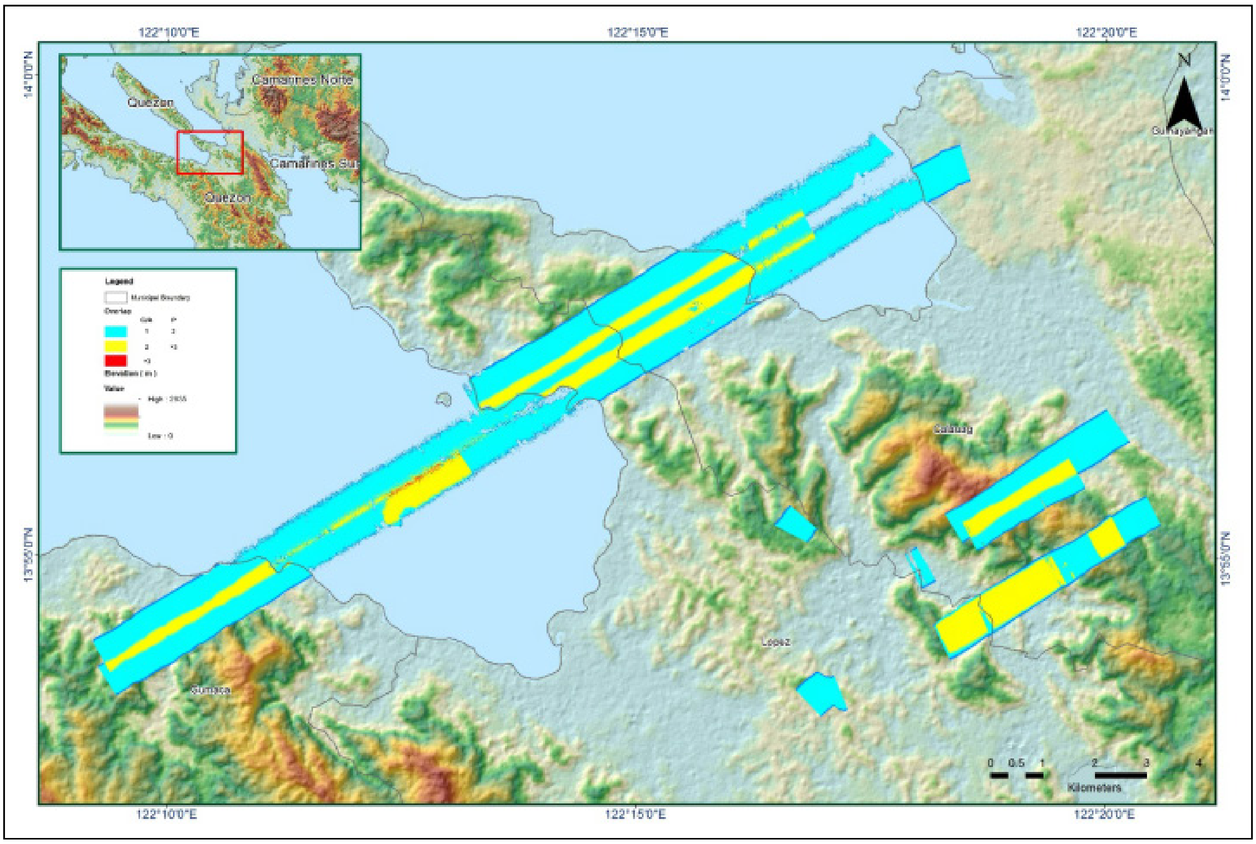


Figure-A.8.37. Image of Data Overlap

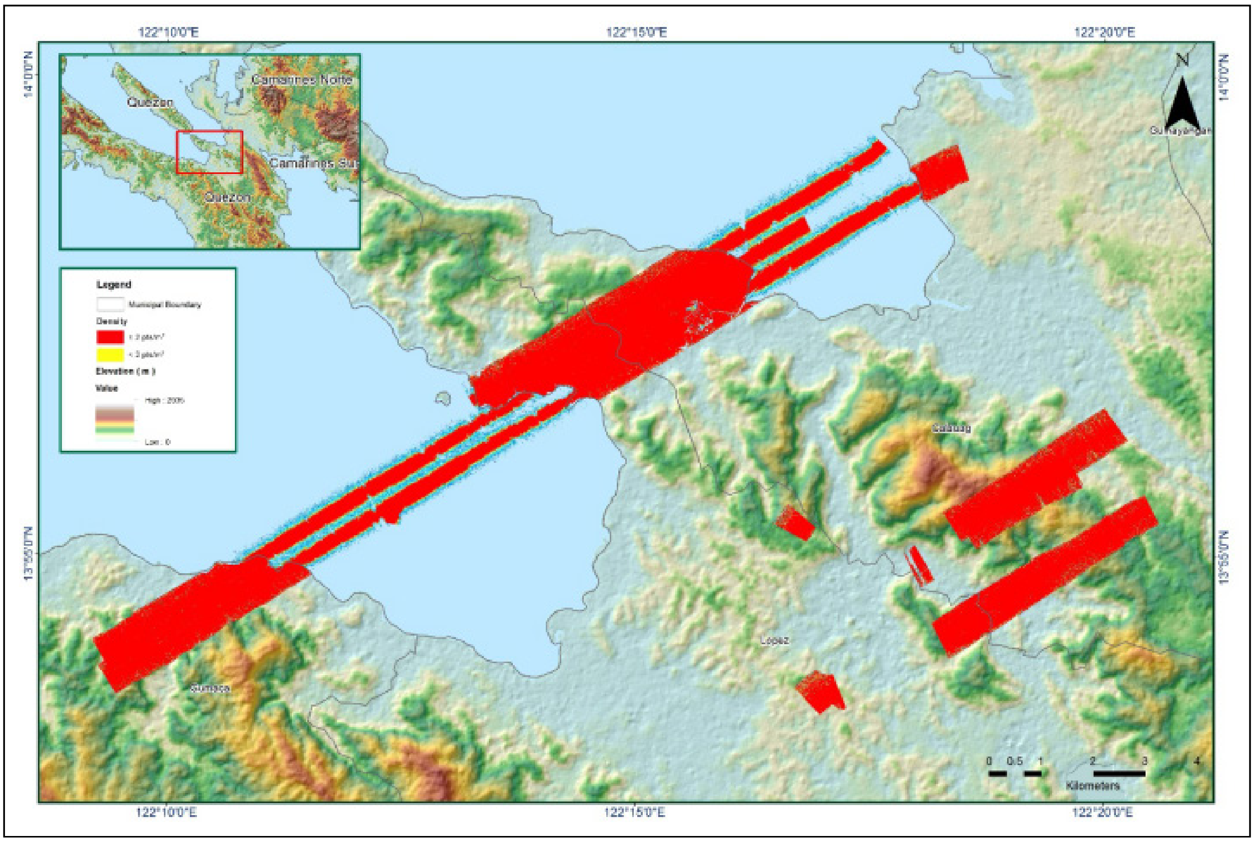


Figure-A.8.38. Density map of merged LiDAR data

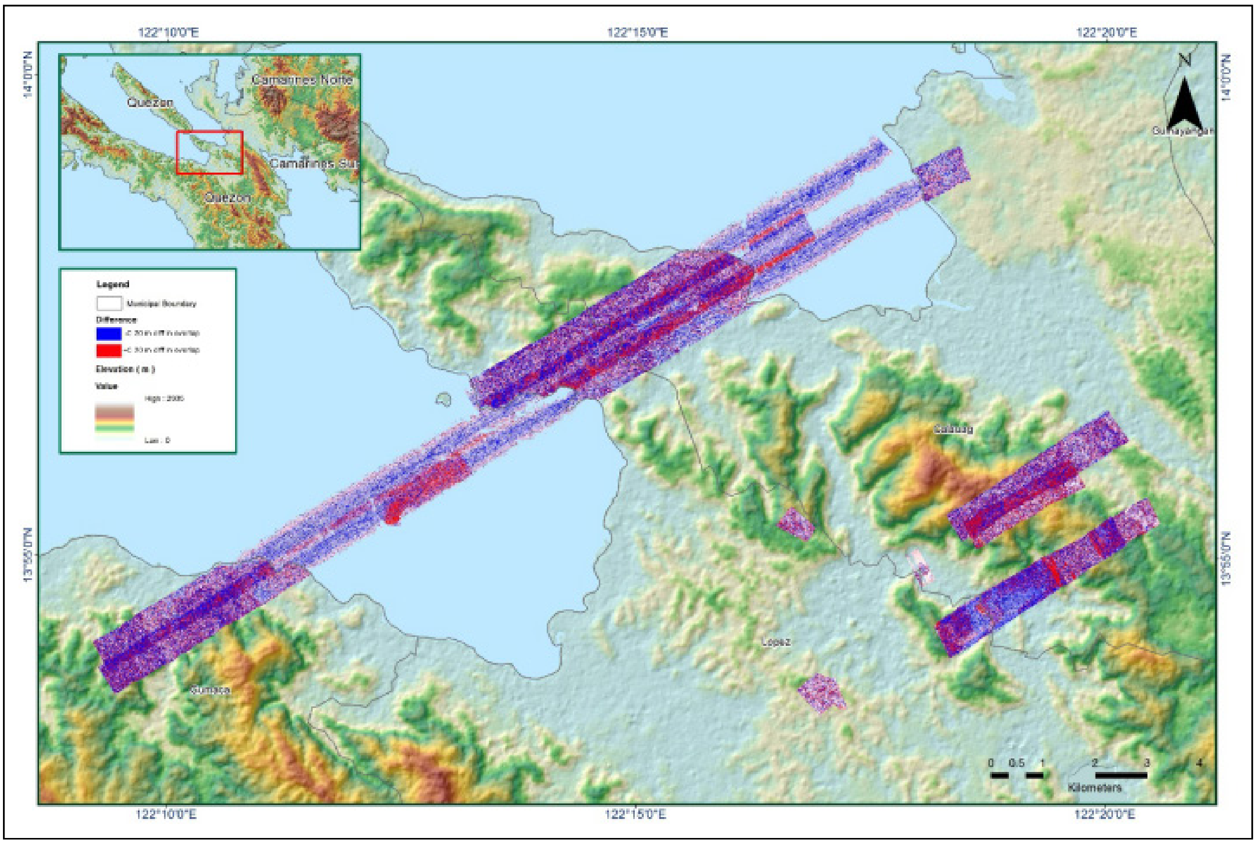


Figure-A.8.39. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Bagasbasa_Blk21B_supplement

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk21B_supplement
Inclusive Flights	23254P
Range data size	8.7 GB
POS data size	176 MB
Base data size	106 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	1.8
Boresight correction stdev (<0.001deg)	0.000292
IMU attitude correction stdev (<0.001deg)	0.000389
GPS position stdev (<0.01m)	0.0004
Minimum % overlap (>25)	33.21%
Ave point cloud density per sq.m. (>2.0)	3.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	127
Maximum Height	371.43
Minimum Height	38.84
Classification (# of points)	
Ground	62734126
Low vegetation	50816139
Medium vegetation	122201673
High vegetation	309082483
Building	5643856
Orthophoto	No
Processed by	Engr. Regis Guhiting, Ma. Joanne Balaga, Engr. Monalyne Rabino

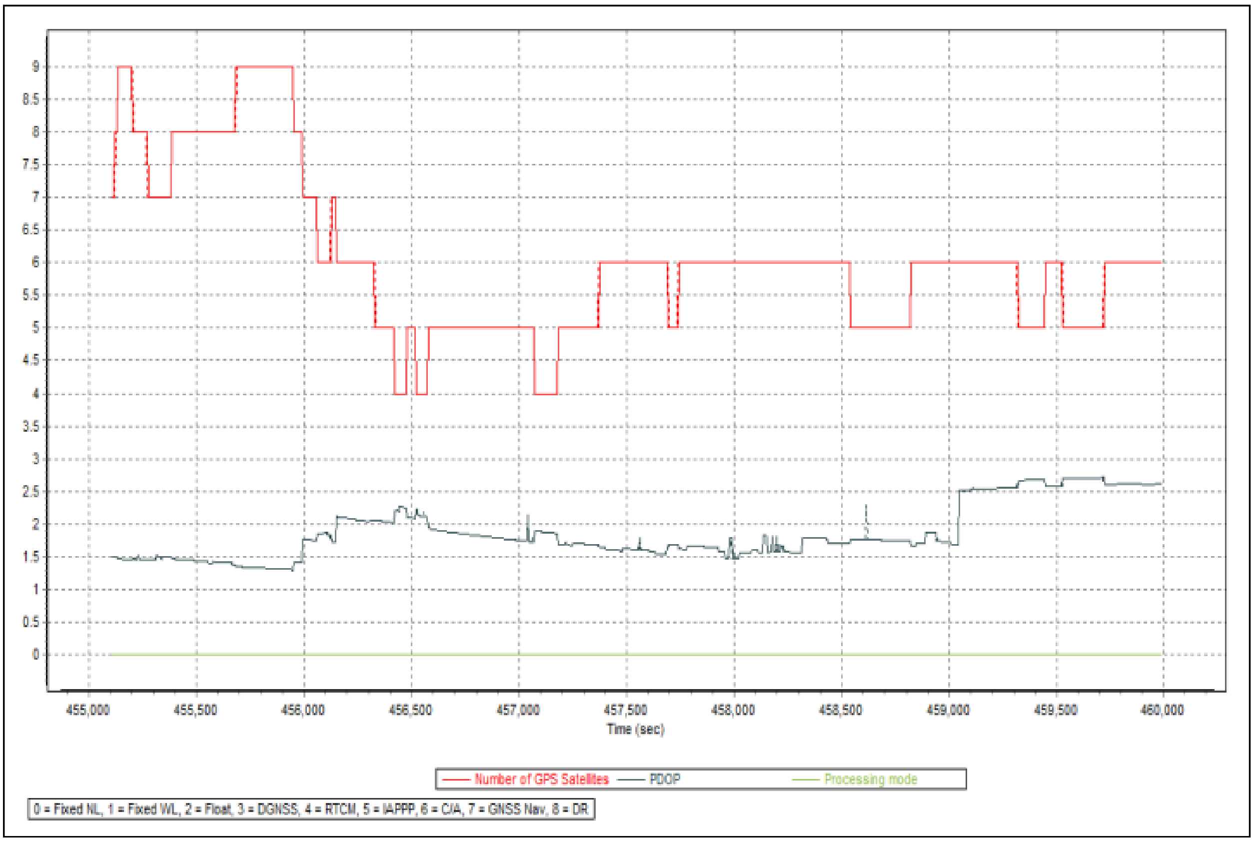


Figure-A.8.40. Solution Status

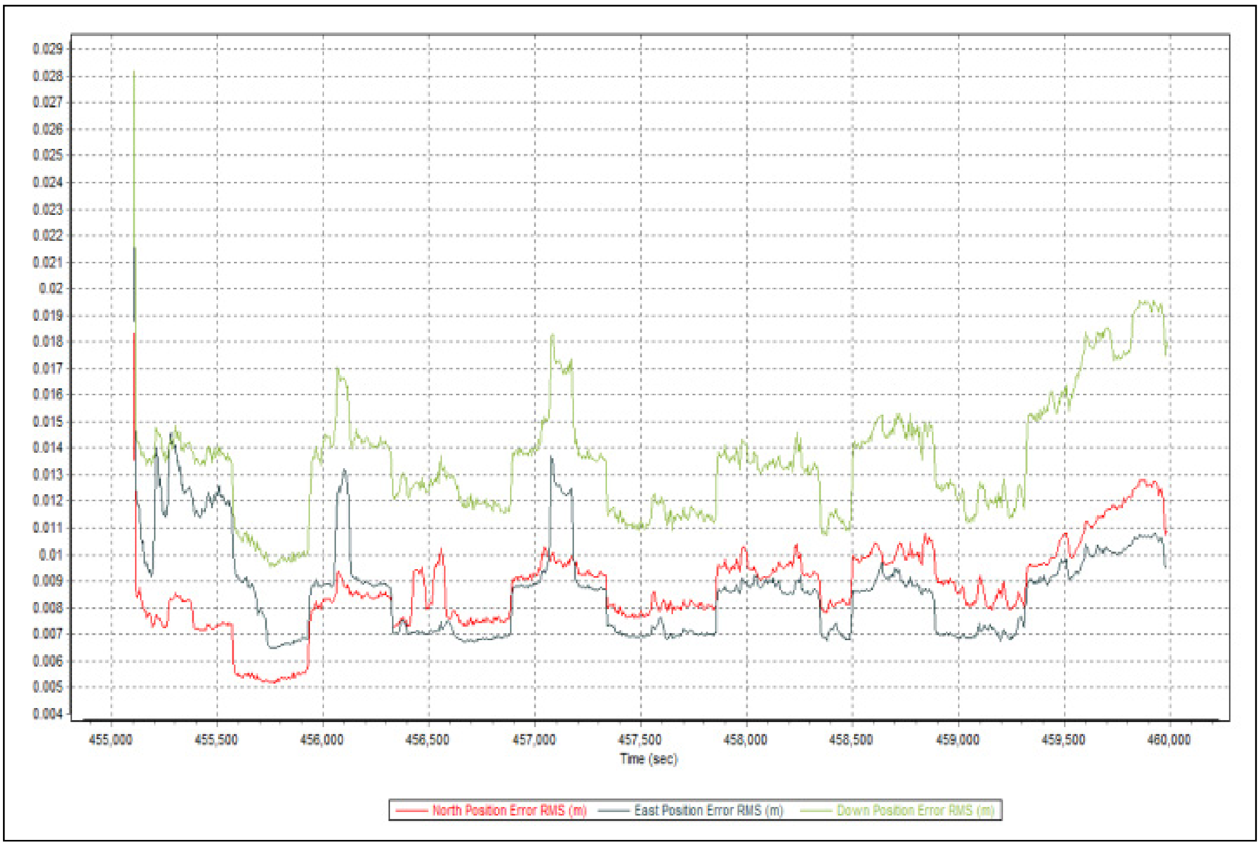


Figure-A.8.41. Smoothed Performance Metric Parameters

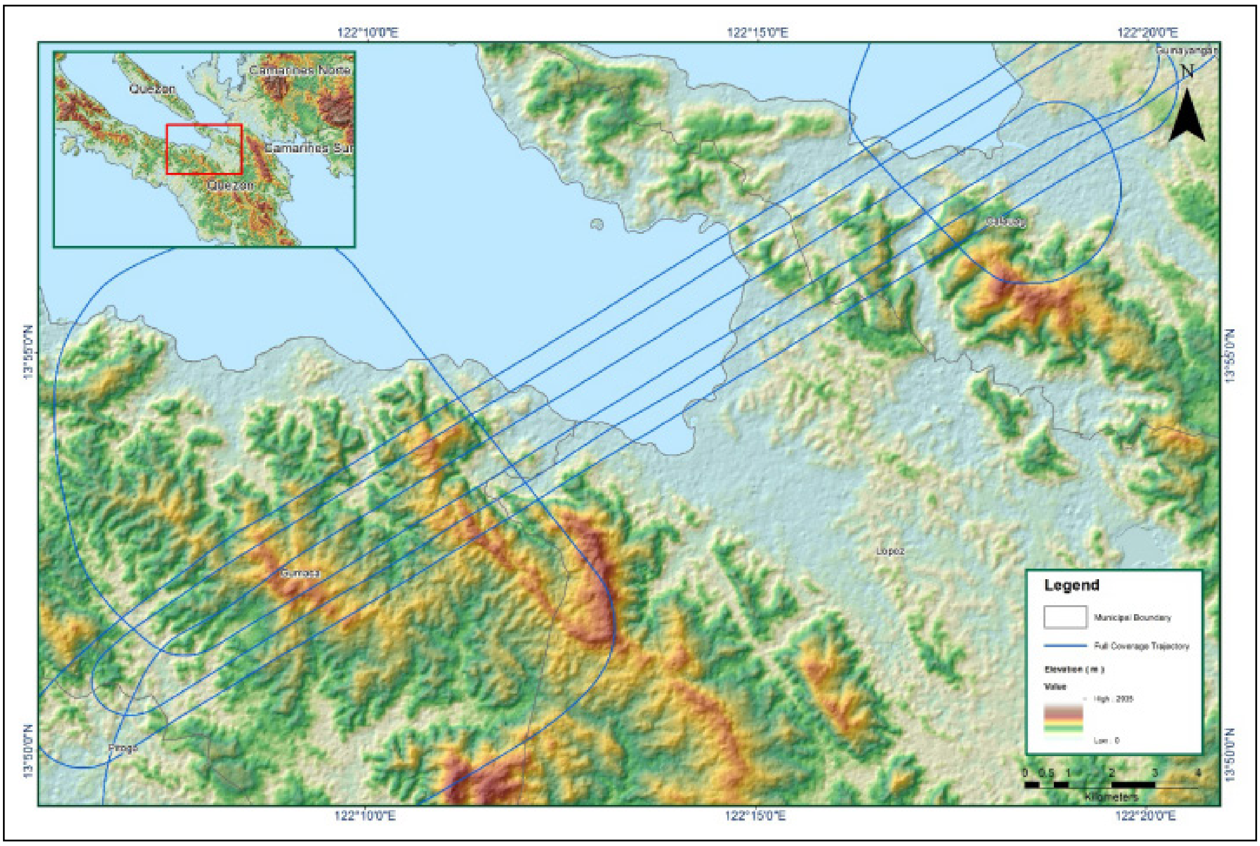


Figure-A.8.42. Best Estimated Trajectory

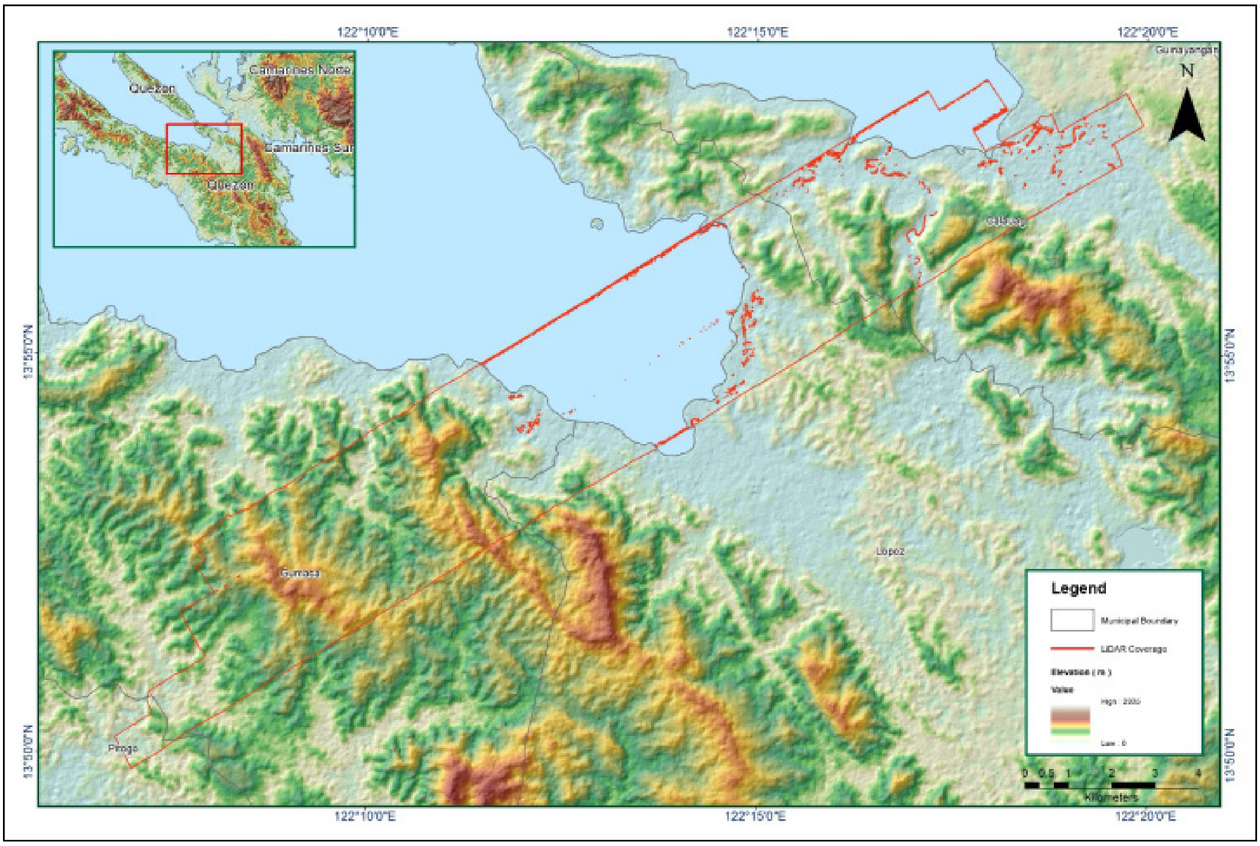


Figure-A.8.43. Coverage of LiDAR data

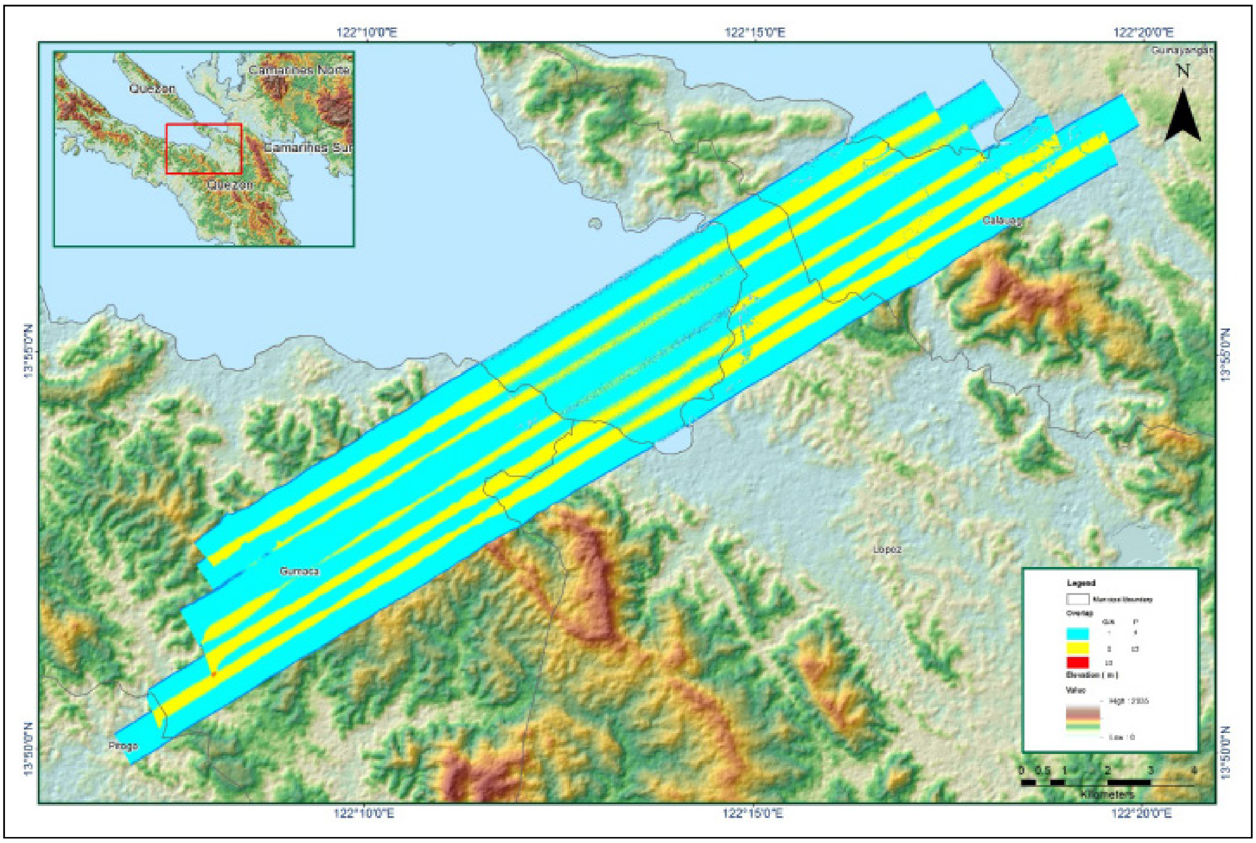


Figure-A.8.44. Image of Data Overlap

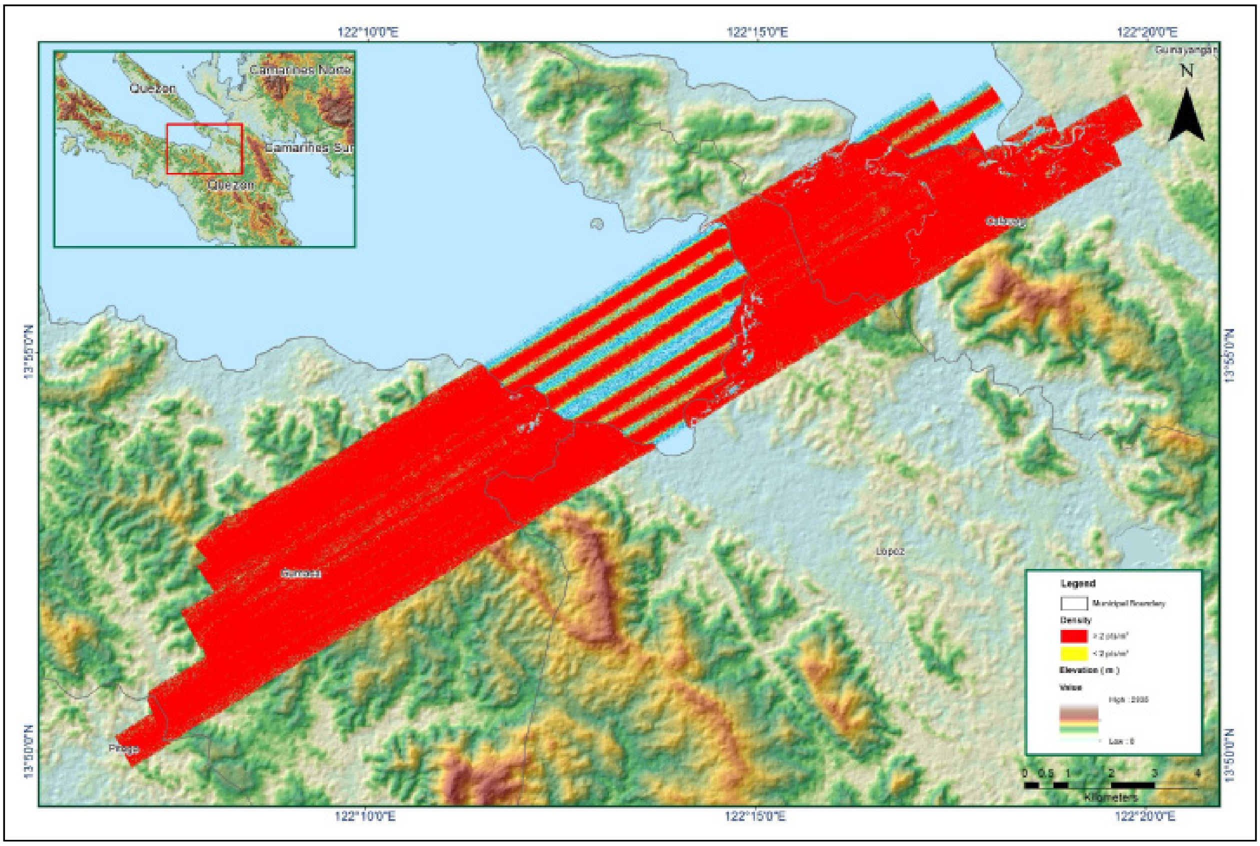


Figure-A.8.45. Density map of merged LiDAR data

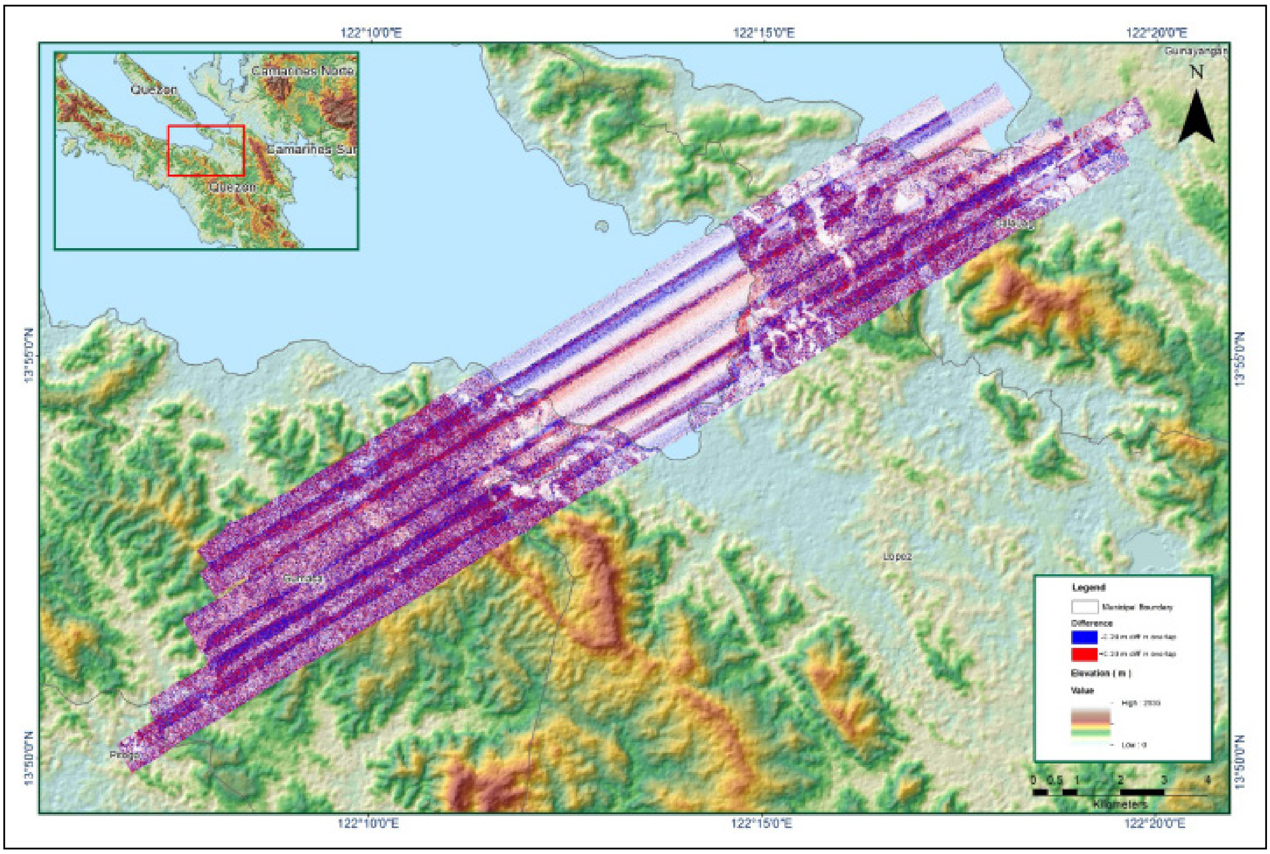


Figure-A.8.46. Elevation difference between flight lines

Annex 9. Calauag Model Basin Parameters

Table A-9.1. Calauag 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
W1000	3.1828	99	0	9.5563	4.8595	Discharge	2.71E-04	1.00E-05	Ratio to Peak	0.0002
W1010	4.8517	98.501	0	4.0221	3.0745	Discharge	6.25E-05	1.00E-05	Ratio to Peak	0.0002
W1020	2.8005	69.6	0	2.4548	2.4552	Discharge	9.59E-05	1.00E-05	Ratio to Peak	0.0002
W1030	3.2162	66	0	4.8581	1.9096	Discharge	9.88E-05	1.00E-05	Ratio to Peak	0.0002
W1040	3.742	99	0	4.8554	4.887	Discharge	4.58E-04	1.00E-05	Ratio to Peak	0.0002
W1050	2.79	98.01	0	4.3521	1.9371	Discharge	4.18E-04	1.00E-05	Ratio to Peak	0.0002
W1060	2.79	98.654	0	3.3452	1.489	Discharge	8.26E-05	1.00E-05	Ratio to Peak	0.0002
W1070	2.79	98.654	0	4.0576	1.806	Discharge	9.99E-05	1.00E-05	Ratio to Peak	0.0002
W1080	2.79	99	0	4.3533	1.9376	Discharge	3.50E-04	1.00E-05	Ratio to Peak	0.0002
W550	1.7183	99	0	4.6184	1.963	Discharge	5.30E-06	1.00E-05	Ratio to Peak	0.0002
W560	3.248	66.928	0	6.0261	0.8205	Discharge	9.53E-04	1.00E-05	Ratio to Peak	0.0002
W570	4.0841	99	0	5.0472	1.7145	Discharge	9.80E-04	1.00E-05	Ratio to Peak	0.0002
W580	4.1088	99	0	4.8195	0.4307	Discharge	4.38E-05	1.00E-05	Ratio to Peak	0.0002
W590	2.6526	99	0	5.1947	0.9691	Discharge	5.12E-05	1.00E-05	Ratio to Peak	0.0002
W600	2.5034	99	0	3.1397	0.8616	Discharge	2.54E-04	1.00E-05	Ratio to Peak	0.0002
W610	3.1489	99	0	2.7437	1.0688	Discharge	3.01E-05	1.00E-05	Ratio to Peak	0.0002
W620	4.08	99	0	3.1559	0.2833	Discharge	1.15E-04	1.00E-05	Ratio to Peak	0.0002
W630	2.3651	99	0	2.3489	0.5787	Discharge	2.57E-04	1.00E-05	Ratio to Peak	0.0002
W640	3.8003	99	0	3.222	0.8266	Discharge	2.37E-04	1.00E-05	Ratio to Peak	0.0002
W650	3.1229	99	0	3.0118	0.8298	Discharge	1.17E-06	1.00E-05	Ratio to Peak	0.0002
W660	2.5206	99	0	3.4587	1.0106	Discharge	1.88E-04	1.00E-05	Ratio to Peak	0.0002
W670	2.7743	99	0	2.7077	0.8431	Discharge	1.65E-05	1.00E-05	Ratio to Peak	0.0002
W680	3.5078	99	0	2.1008	0.7125	Discharge	4.16E-05	1.00E-05	Ratio to Peak	0.0002

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
W690	2.9551	99	0	1.3365	0.3887	Discharge	7.67E-05	1.00E-05	Ratio to Peak	0.0002
W700	2.9377	99	0	2.3292	0.795	Discharge	4.38E-04	1.00E-05	Ratio to Peak	0.0002
W710	3.3345	99	0	22.118	14.762	Discharge	5.23E-04	1.00E-05	Ratio to Peak	0.0002
W720	1.6813	99	0	1.4494	0.4417	Discharge	5.76E-08	1.00E-05	Ratio to Peak	0.0002
W730	3.2946	99	0	1.2914	0.5313	Discharge	8.38E-05	1.00E-05	Ratio to Peak	0.0002
W740	3.1841	99	0	1.0291	1.3916	Discharge	6.21E-05	1.00E-05	Ratio to Peak	0.0002
W750	2.1387	97.594	0	4.4643	0.6037	Discharge	1.12E-03	1.00E-05	Ratio to Peak	0.0002
W760	3.364	99	0	3.2418	1.0246	Discharge	1.75E-04	1.00E-05	Ratio to Peak	0.0002
W770	2.4715	99	0	3.1044	0.612	Discharge	8.26E-06	1.00E-05	Ratio to Peak	0.0002
W780	3.6014	97.001	0	3.0273	0.9431	Discharge	1.39E-04	1.00E-05	Ratio to Peak	0.0002
W790	1.1254	99	0	0.5534	0.1073	Discharge	2.12E-08	1.00E-05	Ratio to Peak	0.0002
W800	2.7487	98.36	0	18.997	5.6975	Discharge	1.43E-03	1.00E-05	Ratio to Peak	0.0002
W810	1.988	98.682	0	2.8457	0.9192	Discharge	3.90E-05	1.00E-05	Ratio to Peak	0.0002
W820	0.7978	99	0	0.175	0.0779	Discharge	1.23E-06	1.00E-05	Ratio to Peak	0.0002
W830	2.5779	98.256	0	17.939	6.9377	Discharge	4.35E-04	1.00E-05	Ratio to Peak	0.0002
W840	4.2017	98.981	0	2.3483	0.699	Discharge	1.95E-04	1.00E-05	Ratio to Peak	0.0002
W850	2.5898	99	0	3.1222	1.5256	Discharge	4.90E-04	1.00E-05	Ratio to Peak	0.0001
W860	2.5734	98.815	0	2.643	0.2907	Discharge	3.86E-05	1.00E-05	Ratio to Peak	0.0002
W870	1.8907	99	0	1.683	1.6201	Discharge	1.56E-04	1.00E-05	Ratio to Peak	0.0001
W880	1.2059	98.647	0	3.0208	0.3395	Discharge	3.92E-06	1.00E-05	Ratio to Peak	0.0002

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
W890	2.8657	99	0	2.4692	3.4354	Discharge	2.43E-04	1.00E-05	Ratio to Peak	0.0002
W900	1.7567	99	0	6.1791	0.8955	Discharge	9.49E-04	1.00E-05	Ratio to Peak	0.0002
W910	2.1364	99	0	6.7302	1.4658	Discharge	1.46E-04	1.00E-05	Ratio to Peak	0.0002
W920	0.816	99	0	2.8781	4.8204	Discharge	2.71E-04	1.00E-05	Ratio to Peak	0.0002
W930	1.8115	99	0	5.3519	1.7131	Discharge	4.29E-04	1.00E-05	Ratio to Peak	0.0002
W940	11.056	99	0	8.3048	9.2443	Discharge	1.94E-04	1.00E-05	Ratio to Peak	0.0002
W950	3.4817	99	0	19.105	8.5876	Discharge	9.78E-04	1.00E-05	Ratio to Peak	0.0002
W960	6.0588	99	0	21.079	5.476	Discharge	1.75E-03	1.00E-05	Ratio to Peak	0.0002
W970	2.6359	98.864	0	5.1565	1.1336	Discharge	1.11E-04	1.00E-05	Ratio to Peak	0.0002
W980	14.054	63.386	0	2.6192	2.1153	Discharge	1.24E-06	1.00E-05	Ratio to Peak	0.0002
W990	2.7888	98.574	0	20.593	23.839	Discharge	0.000678	1.00E-05	Ratio to Peak	0.0002

Annex 10. Calauag Model Reach Parameters

Table A-10.1. Calauag Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	1116.2	0.00918	0.28539	Trapezoid	45	0.5
R110	Automatic Fixed Interval	983.68	0.00266	0.03389	Trapezoid	45	0.5
R140	Automatic Fixed Interval	1725.1	0.01279	0.22579	Trapezoid	45	0.5
R170	Automatic Fixed Interval	3968.9	0.0047	0.10086	Trapezoid	45	0.5
R180	Automatic Fixed Interval	56.569	0.0405	0.97862	Trapezoid	45	0.5
R20	Automatic Fixed Interval	3959	0.00063	0.01209	Trapezoid	45	0.5
R210	Automatic Fixed Interval	2319.1	0.00788	0.5707	Trapezoid	45	0.5
R220	Automatic Fixed Interval	1692.8	0.00632	0.18906	Trapezoid	45	0.5
R230	Automatic Fixed Interval	783.85	0.00571	0.37034	Trapezoid	45	0.5
R260	Automatic Fixed Interval	470.71	0.01233	1	Trapezoid	45	0.5
R280	Automatic Fixed Interval	470.42	0.00052	0.03028	Trapezoid	45	0.5
R300	Automatic Fixed Interval	1660.5	0.00023	1	Trapezoid	45	0.5
R310	Automatic Fixed Interval	681.13	0.00282	0.0001	Trapezoid	45	0.5
R330	Automatic Fixed Interval	1643.7	0.00647	0.22045	Trapezoid	45	0.5
R340	Automatic Fixed Interval	1840.4	3.84E-05	0.18439	Trapezoid	45	0.5
R390	Automatic Fixed Interval	1624.1	0.00473	1	Trapezoid	45	0.5
R40	Automatic Fixed Interval	1300.8	0.00832	0.25258	Trapezoid	45	0.5
R400	Automatic Fixed Interval	2506.5	0.00456	0.32967	Trapezoid	45	0.5
R420	Automatic Fixed Interval	4363.2	0.00317	1	Trapezoid	45	0.5
R430	Automatic Fixed Interval	638.28	0.00249	0.9	Trapezoid	45	0.5
R460	Automatic Fixed Interval	1479.5	0.00572	0.83034	Trapezoid	45	0.5
R500	Automatic Fixed Interval	5084.3	0.00289	0.98507	Trapezoid	45	0.5
R520	Automatic Fixed Interval	1234.7	0.00238	0.0001	Trapezoid	45	0.5
R60	Automatic Fixed Interval	2791.4	0.01075	0.12377	Trapezoid	45	0.5
R70	Automatic Fixed Interval	1867.2	0.00126	0.03247	Trapezoid	45	0.5
R90	Automatic Fixed Interval	309.71	0.01873	0.25128	Trapezoid	45	0.5

Annex 11. Calauag Field Validation Points

Table A-11.1. Calauag Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.95949	122.33171	0.03	0.75	0.72	Rosing/November 2,1995	5 -Year
2	13.95851	122.337773	0.07	0.8	0.73	Rosing/November 2,1995	5 -Year
3	13.95901	122.337017	0.25	0.8	0.55	Rosing/November 2,1995	5 -Year
4	13.95901	122.335816	0.03	0.8	0.77	Rosing/November 2,1995	5 -Year
5	13.95991	122.332028	0.03	1.2	1.17	Rosing/November 2,1995	5 -Year
6	13.96104	122.331927	0.67	1.3	0.63	Rosing/November 2,1995	5 -Year
7	13.95943	122.331922	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
8	13.95892	122.336249	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
9	13.95423	122.327722	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
10	13.9555	122.32885	0.03	1	0.97	Rosing/November 2,1995	5 -Year
11	13.96143	122.332196	0.03	1	0.97	Rosing/November 2,1995	5 -Year
12	13.95875	122.337002	0.71	1	0.29	Rosing/November 2,1995	5 -Year
13	13.95974	122.332133	0.03	1	0.97	Rosing/November 2,1995	5 -Year
14	13.9576	122.325941	0.05	2	1.95	Rosing/November 2,1995	5 -Year
15	13.95346	122.327403	0.03	2	1.97	Rosing/November 2,1995	5 -Year
16	13.95817	122.292236	0.14	0.25	0.11	Rosing/November 2,1995	5 -Year
17	13.95665	122.294815	0.04	1.2	1.16	Rosing/November 2,1995	5 -Year
18	13.95743	122.292859	0.17	1	0.83	Rosing/November 2,1995	5 -Year
19	13.9502	122.311066	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
20	13.95059	122.310134	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
21	13.95089	122.309411	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
22	13.95135	122.308323	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
23	13.9484	122.308707	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
24	13.94695	122.314097	0.1	0.5	0.4	Rosing/November 2,1995	5 -Year
25	13.94664	122.315283	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
26	13.94623	122.317527	0.1	0.5	0.4	Rosing/November 2,1995	5 -Year
27	13.94667	122.317644	0.08	0.5	0.42	Rosing/November 2,1995	5 -Year
28	13.94716	122.317741	0.09	0.5	0.41	Rosing/November 2,1995	5 -Year
29	13.94717	122.318053	0.12	0.5	0.38	Rosing/November 2,1995	5 -Year
30	13.94903	122.313869	0.22	0.5	0.28	Rosing/November 2,1995	5 -Year
31	13.94924	122.313286	0.33	0.5	0.17	Rosing/November 2,1995	5 -Year
32	13.94943	122.312837	0.32	0.5	0.18	Rosing/November 2,1995	5 -Year
33	13.94961	122.312395	0.19	0.5	0.31	Rosing/November 2,1995	5 -Year
34	13.9476	122.311756	0.09	0.5	0.41	Rosing/November 2,1995	5 -Year
35	13.94981	122.311944	0.08	0.5	0.42	Rosing/November 2,1995	5 -Year
36	13.94624	122.311416	0.87	0.5	-0.37	Rosing/November 2,1995	5 -Year
37	13.94573	122.311407	0.8	0.5	-0.3	Rosing/November 2,1995	5 -Year
38	13.94529	122.311239	0.54	0.5	-0.04	Rosing/November 2,1995	5 -Year
39	13.94479	122.311105	0.48	0.5	0.02	Rosing/November 2,1995	5 -Year
40	13.94401	122.310602	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
41	13.9474	122.312509	0.28	0.5	0.22	Rosing/November 2,1995	5 -Year
42	13.9472	122.313186	0.31	0.5	0.19	Rosing/November 2,1995	5 -Year
43	13.94893	122.306693	0.09	0.5	0.41	Rosing/November 2,1995	5 -Year
44	13.94882	122.314658	0.12	1.5	1.38	Rosing/November 2,1995	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)		Error	Event/Date	Rain Return / Scenario
	Lat	Long					
45	13.94699	122.311699	0.82	1	0.18	Rosing/November 2,1995	5 -Year
46	13.94667	122.31155	0.87	1	0.13	Rosing/November 2,1995	5 -Year
47	13.94965	122.317566	0.03	1	0.97	Rosing/November 2,1995	5 -Year
48	13.94942	122.317251	0.03	1	0.97	Rosing/November 2,1995	5 -Year
49	13.94891	122.316116	0.06	1	0.94	Rosing/November 2,1995	5 -Year
50	13.94879	122.315207	0.1	1	0.9	Rosing/November 2,1995	5 -Year
51	13.95195	122.306949	0.58	1	0.42	Rosing/November 2,1995	5 -Year
52	13.9525	122.30567	0.03	1	0.97	Rosing/November 2,1995	5 -Year
53	13.94732	122.311816	0.6	1	0.4	Rosing/November 2,1995	5 -Year
54	13.94913	122.316726	0.03	0	-0.03	Rosing/November 2,1995	5 -Year
55	13.94312	122.357187	0.04	0.2	0.16	Rosing/November 2,1995	5 -Year
56	13.94391	122.357628	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
57	13.94433	122.35857	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
58	13.94318	122.356626	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
59	13.95103	122.336119	0.06	0.2	0.14	Rosing/November 2,1995	5 -Year
60	13.95234	122.335216	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
61	13.95405	122.333584	0.12	0.5	0.38	Rosing/November 2,1995	5 -Year
62	13.95356	122.334082	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
63	13.94887	122.337136	0.19	0.5	0.31	Rosing/November 2,1995	5 -Year
64	13.95461	122.333017	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
65	13.9555	122.332147	0.55	1	0.45	Rosing/November 2,1995	5 -Year
66	13.9562	122.331434	0.75	1	0.25	Rosing/November 2,1995	5 -Year
67	13.93492	122.349131	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
68	13.93641	122.350766	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
69	13.93785	122.34668	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
70	13.93659	122.347342	0.19	0.5	0.31	Rosing/November 2,1995	5 -Year
71	13.93858	122.345802	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
72	13.94218	122.33978	1.1	1.5	0.4	Rosing/November 2,1995	5 -Year
73	13.94487	122.338456	0.03	1	0.97	Rosing/November 2,1995	5 -Year
74	13.94171	122.339737	2.56	2.5	-0.06	Rosing/November 2,1995	5 -Year
75	13.94153	122.339842	2.51	2.5	-0.01	Rosing/November 2,1995	5 -Year
76	13.9413	122.3399	2.6	2.5	-0.1	Rosing/November 2,1995	5 -Year
77	13.94106	122.339899	2.19	2.5	0.31	Rosing/November 2,1995	5 -Year
78	13.94089	122.339909	1.97	2.5	0.53	Rosing/November 2,1995	5 -Year
79	13.9405	122.339907	1.27	2.5	1.23	Rosing/November 2,1995	5 -Year
80	13.94064	122.342008	0.22	2.5	2.28	Rosing/November 2,1995	5 -Year
81	13.93935	122.343864	0.03	2.5	2.47	Rosing/November 2,1995	5 -Year
82	13.94194	122.339744	2.74	2.5	-0.24	Rosing/November 2,1995	5 -Year
83	13.93837	122.351266	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
84	13.93941	122.351362	0.46	0.5	0.04	Rosing/November 2,1995	5 -Year
85	13.94049	122.35201	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
86	13.9408	122.352914	0.13	0.5	0.37	Rosing/November 2,1995	5 -Year
87	13.9406	122.354222	0.08	0.5	0.42	Rosing/November 2,1995	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
88	13.93895	122.351329	0.41	0.5	0.09	Rosing/November 2,1995	5 -Year
89	13.9432	122.355822	0.05	1	0.95	Rosing/November 2,1995	5 -Year
90	13.94159	122.355107	0.4	1	0.6	Rosing/November 2,1995	5 -Year
91	13.94926	122.305464	0.08	0.2	0.12	Rosing/November 2,1995	5 -Year
92	13.95356	122.303181	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
93	13.95388	122.302263	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
94	13.95411	122.301533	0.06	0.2	0.14	Rosing/November 2,1995	5 -Year
95	13.95432	122.300762	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
96	13.95579	122.296299	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
97	13.95755	122.296714	0.07	0.2	0.13	Rosing/November 2,1995	5 -Year
98	13.95616	122.295667	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
99	13.95646	122.294702	0.11	0.2	0.09	Rosing/November 2,1995	5 -Year
100	13.9584	122.293875	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
101	13.9533	122.301262	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
102	13.95212	122.302724	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
103	13.95041	122.303755	0.07	0.2	0.13	Rosing/November 2,1995	5 -Year
104	13.95353	122.297102	0.1	0.2	0.1	Rosing/November 2,1995	5 -Year
105	13.95382	122.296834	0.14	0.5	0.36	Rosing/November 2,1995	5 -Year
106	13.95216	122.299746	1	1.5	0.5	Rosing/November 2,1995	5 -Year
107	13.95328	122.299578	0.8	1	0.2	Rosing/November 2,1995	5 -Year
108	13.95286	122.299729	1.07	1	-0.07	Rosing/November 2,1995	5 -Year
109	13.9579	122.293956	0.03	1	0.97	Rosing/November 2,1995	5 -Year
110	13.9582	122.325906	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
111	13.94536	122.320271	0.06	0.2	0.14	Rosing/November 2,1995	5 -Year
112	13.95778	122.325536	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
113	13.95723	122.324779	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
114	13.95827	122.326255	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
115	13.95644	122.329545	0.1	0.5	0.4	Rosing/November 2,1995	5 -Year
116	13.94563	122.319063	0.08	0.5	0.42	Rosing/November 2,1995	5 -Year
117	13.94613	122.320429	0.27	0.5	0.23	Rosing/November 2,1995	5 -Year
118	13.94732	122.320768	0.2	0.5	0.3	Rosing/November 2,1995	5 -Year
119	13.94682	122.322809	0.15	0.5	0.35	Rosing/November 2,1995	5 -Year
120	13.94952	122.324721	0.12	0.5	0.38	Rosing/November 2,1995	5 -Year
121	13.95661	122.327248	0.06	0.5	0.44	Rosing/November 2,1995	5 -Year
122	13.95706	122.326656	0.06	0.5	0.44	Rosing/November 2,1995	5 -Year
123	13.95733	122.326199	0.06	0.5	0.44	Rosing/November 2,1995	5 -Year
124	13.9467	122.31798	0.21	0.5	0.29	Rosing/November 2,1995	5 -Year
125	13.95178	122.326546	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
126	13.95502	122.328618	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
127	13.95804	122.326332	0.91	1.5	0.59	Rosing/November 2,1995	5 -Year
128	13.95782	122.326314	0.72	1.5	0.78	Rosing/November 2,1995	5 -Year
129	13.95759	122.326325	0.65	1.5	0.85	Rosing/November 2,1995	5 -Year
130	13.95079	122.325743	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
131	13.94587	122.322178	0.03	1	0.97	Rosing/November 2,1995	5 -Year
132	13.94857	122.324019	0.03	1	0.97	Rosing/November 2,1995	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
133	13.95009	122.325142	0.35	1	0.65	Rosing/November 2,1995	5 -Year
134	13.95585	122.328449	0.18	1	0.82	Rosing/November 2,1995	5 -Year
135	13.95624	122.327809	0.12	1	0.88	Rosing/November 2,1995	5 -Year
136	13.9576	122.325201	0.03	1	0.97	Rosing/November 2,1995	5 -Year
137	13.94559	122.321577	0.03	1	0.97	Rosing/November 2,1995	5 -Year
138	13.95677	122.324373	5.62	5.5	-0.12	Rosing/November 2,1995	5 -Year
139	13.95271	122.327205	6.65	5.5	-1.15	Rosing/November 2,1995	5 -Year
140	13.96217	122.331756	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
141	13.96183	122.332136	0.03	0.2	0.17	Rosing/November 2,1995	5 -Year
142	13.96124	122.332451	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
143	13.9559	122.323565	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
144	13.95814	122.330899	0.03	0.5	0.47	Rosing/November 2,1995	5 -Year
145	13.95105	122.31895	0.08	1.5	1.42	Rosing/November 2,1995	5 -Year
146	13.95086	122.318771	0.14	1.5	1.36	Rosing/November 2,1995	5 -Year
147	13.95053	122.318446	0.06	1.5	1.44	Rosing/November 2,1995	5 -Year
148	13.94995	122.317883	0.03	1.5	1.47	Rosing/November 2,1995	5 -Year
149	13.95129	122.319184	0.07	1.5	1.43	Rosing/November 2,1995	5 -Year
150	13.96025	122.329393	0.03	1	0.97	Rosing/November 2,1995	5 -Year
151	13.95998	122.328922	0.03	1	0.97	Rosing/November 2,1995	5 -Year
152	13.95964	122.328334	0.03	1	0.97	Rosing/November 2,1995	5 -Year
153	13.95904	122.327256	0.03	1	0.97	Rosing/November 2,1995	5 -Year
154	13.95628	122.32393	0.03	1	0.97	Rosing/November 2,1995	5 -Year
155	13.95863	122.331254	0.09	1	0.91	Rosing/November 2,1995	5 -Year
156	13.95836	122.326168	0.03	2	1.97	Rosing/November 2,1995	5 -Year
157	13.95658	122.324223	1.12	2	0.88	Rosing/November 2,1995	5 -Year
158	13.95557	122.323251	0.03	2	1.97	Rosing/November 2,1995	5 -Year
159	13.95507	122.322795	0.03	2	1.97	Rosing/November 2,1995	5 -Year
160	13.95459	122.322325	0.06	2	1.94	Rosing/November 2,1995	5 -Year
161	13.95408	122.321832	0.06	2	1.94	Rosing/November 2,1995	5 -Year
162	13.95389	122.321664	0.11	2	1.89	Rosing/November 2,1995	5 -Year
163	13.95369	122.321474	0.06	2	1.94	Rosing/November 2,1995	5 -Year
164	13.95347	122.321258	0.08	2	1.92	Rosing/November 2,1995	5 -Year
165	13.95319	122.321	0.06	2	1.94	Rosing/November 2,1995	5 -Year
166	13.95914	122.331598	0.04	2	1.96	Rosing/November 2,1995	5 -Year
167	13.9529	122.320719	0.09	2	1.91	Rosing/November 2,1995	5 -Year
168	13.95268	122.320515	0.08	2	1.92	Rosing/November 2,1995	5 -Year
169	13.95222	122.320083	0.03	2	1.97	Rosing/November 2,1995	5 -Year
170	13.95197	122.319834	0.03	2	1.97	Rosing/November 2,1995	5 -Year
171	13.95173	122.319597	0.03	2	1.97	Rosing/November 2,1995	5 -Year
172	13.95155	122.319427	0.13	2	1.87	Rosing/November 2,1995	5 -Year
173	13.95977	122.332046	0.03	2	1.97	Rosing/November 2,1995	5 -Year
174	13.96047	122.332435	0.12	2	1.88	Rosing/November 2,1995	5 -Year
175	13.96066	122.330108	0.03	2	1.97	Rosing/November 2,1995	5 -Year
176	13.95946	122.328018	0.03	2	1.97	Rosing/November 2,1995	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
177	13.95924	122.327628	0.03	2	1.97	Rosing/November 2,1995	5 -Year
178	13.95885	122.32694	0.03	2	1.97	Rosing/November 2,1995	5 -Year
179	13.95864	122.326586	1.2	2	0.8	Rosing/November 2,1995	5 -Year
180	13.9576	122.330549	0.03	2	1.97	Rosing/November 2,1995	5 -Year

Annex 12. Educational Institutions Affected by flooding in Calauag Floodplain

Table A-12.1. Educational Institutions Affected by flooding in Calauag Floodplain

Quezon				
Calauag				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Rizal Ibaba Elem	Rizal Ibaba			Medium
San Roque Elem School	San Roque Ilaya			
San roque Ilaya Highschool	San Roque Ilaya			
Sumilang Elementary School	Sumilang	Medium	Medium	Medium
Sumulong Elem School	Sumulong	Low	Low	Medium
TOCALIN Elem School	Vergaña	Low	Medium	High
VILLA ESPINA Elem School	Vergaña	Medium	Medium	High

Annex 13. Health Institutions affected by flooding in Calauag Floodplain

Table A-13.1. Health Institutions Affected by flooding in Calauag Floodplain

Quezon				
Calauag				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Calauag Hospital	Kigtan	Low	Low	Low
Brgy. Pansol Health Center	Pansol	Low	Medium	Medium
San Roque Ilaya Health Center	San Roque Ilaya			
Calauag Hospital	Sumilang	Low	Low	Low
Health Care	Sumulong	Medium	Medium	Medium