HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LID

LiDAR Surveys and Flood Mapping of Macalelon River

University of the Philippines Training Center for Applied Geodes
and Photogrammetry
MAPUA Institute of Technology

APRIL 2017

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

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

E. C. Paringit and F. A. Uy (eds.) (2017), LiDAR Surveys and Flood Mapping of Macalelon River, Quezon City: University of the Philippines Training Center on Applied Geodesy and Photogrammetry-156pp.

For questions/queries regarding this report, contact:

Dr. Francis Aldrine A. Uy
Project Leader, Phil-LiDAR 1 Program
MAPUA Institute of Technology
City of Manila, Metro Manila 1002
E-mail: faauy@mapua.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-056-3

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

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
MCM	
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
RCBO	River Basin Control Office
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
MSU-IIT	Mindanao State University - Iligan Institute of Technology
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 MACALELON 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, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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-Quezon (CABARZON) Region. The university is located in the City of Manila within Metro Manila in the National Capital Region.

1.2 Overview of the Macalelon River Basin

The Macalelon River Basin is one of the major river basins in the province of Quezon. The Macalelon River Basin covers the Municipalities of Macalelon and Gumaca, and small portions of the Municipalities of Lopez and Pitogo in Quezon Province. The DENR River Basin Control Office identified the basin to have a drainage area of 165 km2 and an estimated annual runoff of 264 million cubic meter (MCM) (RBCO, 2015).

Its main stem, Macalelon River, is part of the twenty six (26) river systems in Quezon Region. According to the 2015 national census of NSO, a total of 6,301 persons are residing within the immediate vicinity of the river which is distributed among six barangays in Municipality of Macalelon namely: Tubigan Ibaba, Pinagbayanan, Damayan, Masipag, Amontay, and Pag-Asa.

The communities in the Macalelon River Basin have several sources of livelihood, similar to the rest of Quezon Province. The province of Quezon is the top contributor in the CALABARZON Region in terms of agricultural produce such as corn, rice, other staple food, and especially coconut. The province is also a top producer of fish and other marine produce since it has several marine resources, natural and man-made. Natural marine resources include Calauag Bay, Lamon Bay, Polillo Strait, Ragay Gulf, and Tayabas Bay; whereas man-made resources are fishponds for cultivation. In the Municipality of Macalelon, rice crop cultivation and aquaculture are its major source of economy (Source: http://drive.daprdp.net/iplan/pcip/QUEZON%20%20PCIP.pdf).

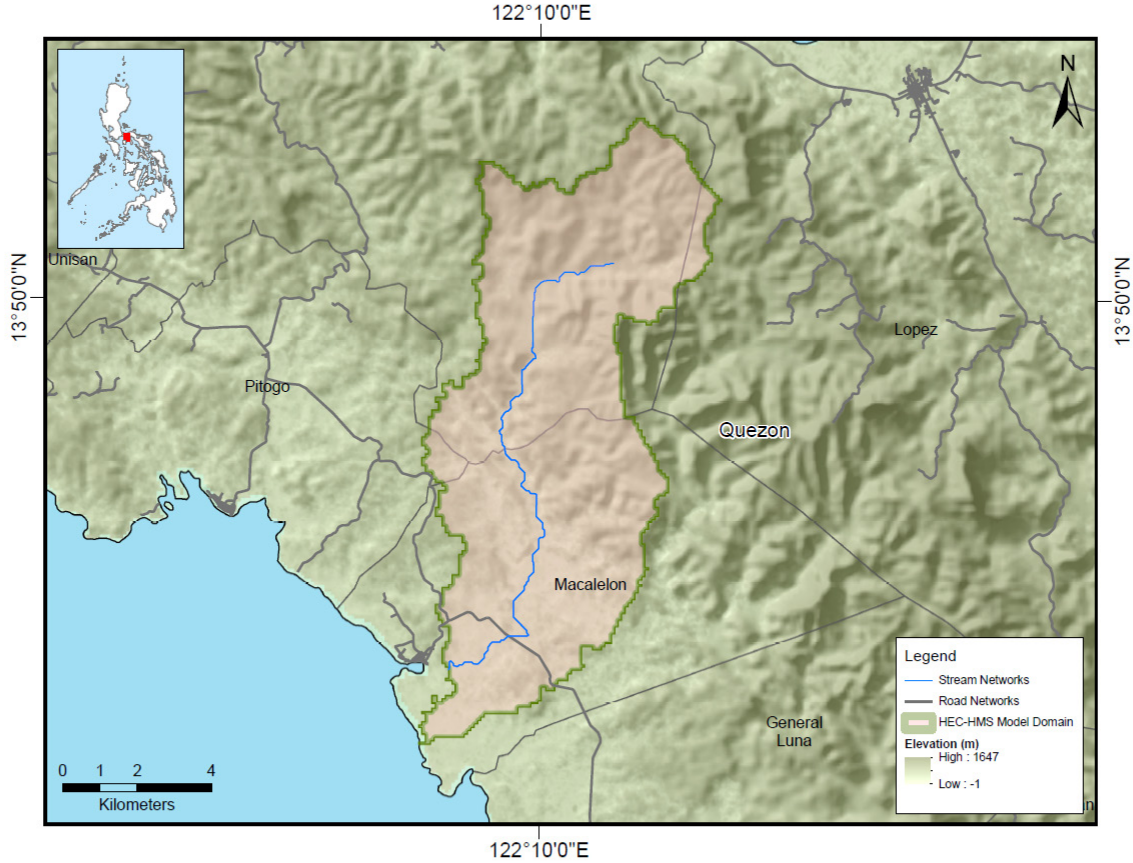


Figure 1. Map of Macalelon River Basin

One of the biggest challenges of the Macalelon river basin is flooding. It is often hit by typhoons, particularly later in the year, and it has been victim to typhoons Glenda and Nina in recent years. During flood events, there have been some reported casualties and property damage due to debris flowing downstream. Last July 2014, Typhoon Glenda, internationally known as Rammasun, dealt damages to 55,000 homes in CALABARZON; moreover, the province of Quezon was declared under state of calamity by the National Disaster Risk Reduction and Management Council. The estimated damage to agriculture rose up to millions from rice, corn, other crops, and livestock. In the Municipality of Macalelon, a hanging bridge, and several crops were damaged by the typhoon (Source: http://newsinfo.inquirer.net/621328/quezon-hardest-hit and http://ndrrmc.gov.ph/index.php/2-uncategorised/1741-collapsed-hanging-bridge-in-macalelon-quezon).

In order to prevent or at least minimize the effects of the flooding hazard for the people and crops in the river basin, a combination of several technologies have been employed to produce a flood hazard map. The first is LiDAR data, which primarily contains elevation. From elevation values, one can infer the presence and behavior of waterbodies (such as rivers, streams, ponds, and lakes) and structures (such as roads, bridges, and buildings). Next, important data such as discharge and rainfall events gathered through fieldwork are used as inputs to the hydrological model. The gathered data is used to generate hydrographs that is used to create the calibrated model. These generated outputs, along with LiDAR data, will then be input for the river hydraulic model. The final output for these processes will be flood hazard maps of the river basin. The generated maps are used for urban planning and disaster risk reduction planning.

The flood hazard map is significant for the region because of the presence of several communities. A sizeable one is located at the mouth of the main channel, and it contains most of the main government infrastructure of the municipality of Macalelon. There are also other communities along the Gumaca-Pitogo-Mulanay-San-Narciso Road. Thus, the generated flood hazard map can serve as a tool for LGUs of Macalelon and Gamaca to come up with better methods for disaster risk reduction and management in their communities.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MACALELON FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, Ms. Rowena M. Gabua

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 Macalelon floodplain in Quezon Province. These missions were planned for 19 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Macalelon floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
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

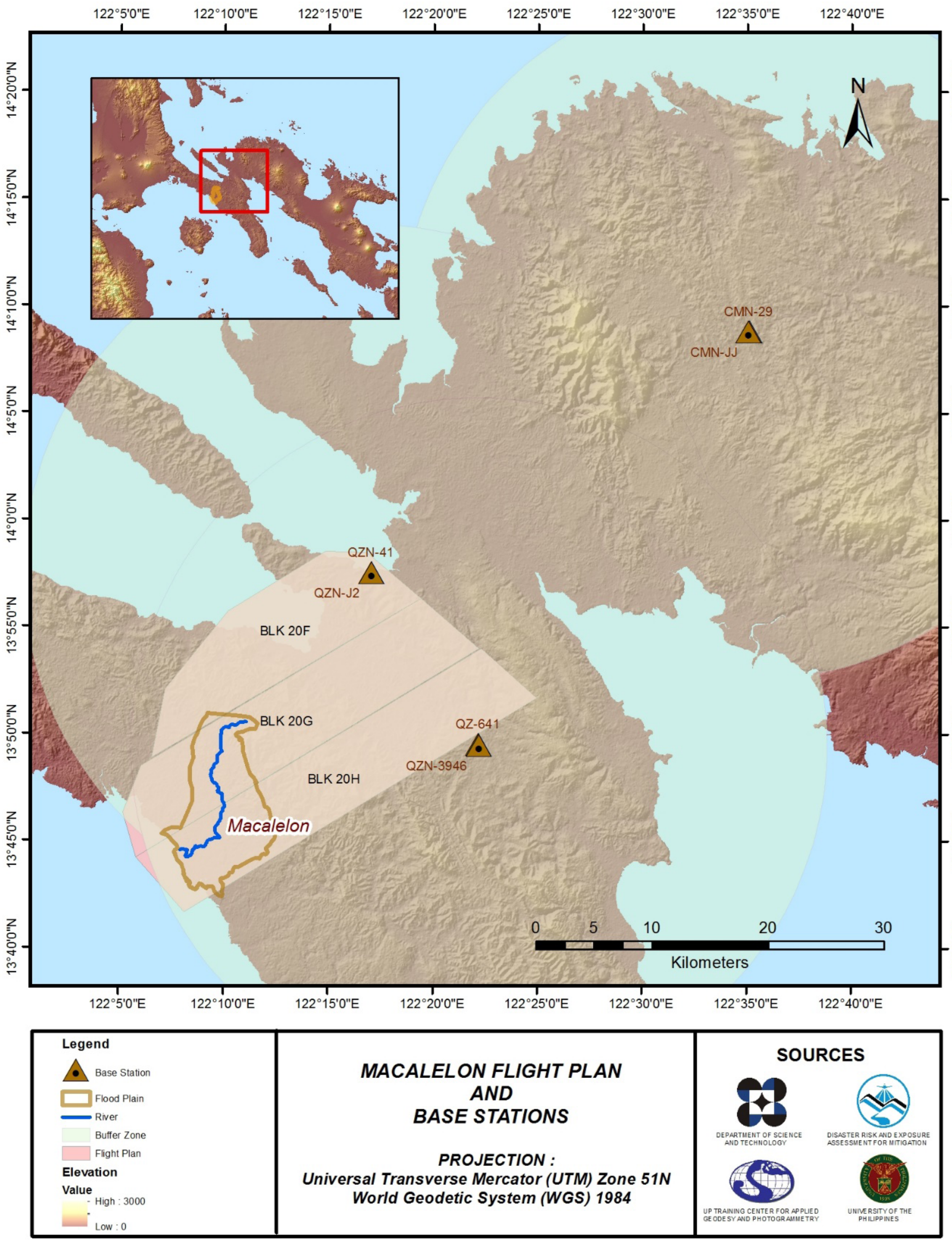


Figure 2. Flight plan and base stations for Pegasus System used for Macalelon Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: QZN-41 and CMN-29 which are of second (2nd) order accuracy. The team also re-established ground control point QZN-3946 a NAMRIA reference point of fourth (4th) order accuracy. One (1) NAMRIA benchmark was recovered: QZ-641. This benchmark was used as a vertical reference point, and was also established as a ground control point. The team also established two (2) ground control points, QZN-J2 and CMN-JJ. The certifications for the NAMRIA reference points are found in Annex 2, while the baseline processing reports for the established reference points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (April 13 - 16, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS852 and Topcon GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Macalelon floodplain are shown in Figure 2. The list of team members for LiDAR data acquisition is found in Annex 4.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area, in addition Table 2 to Table 7 show the details about the following NAMRIA control stations and established points, Table 8 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

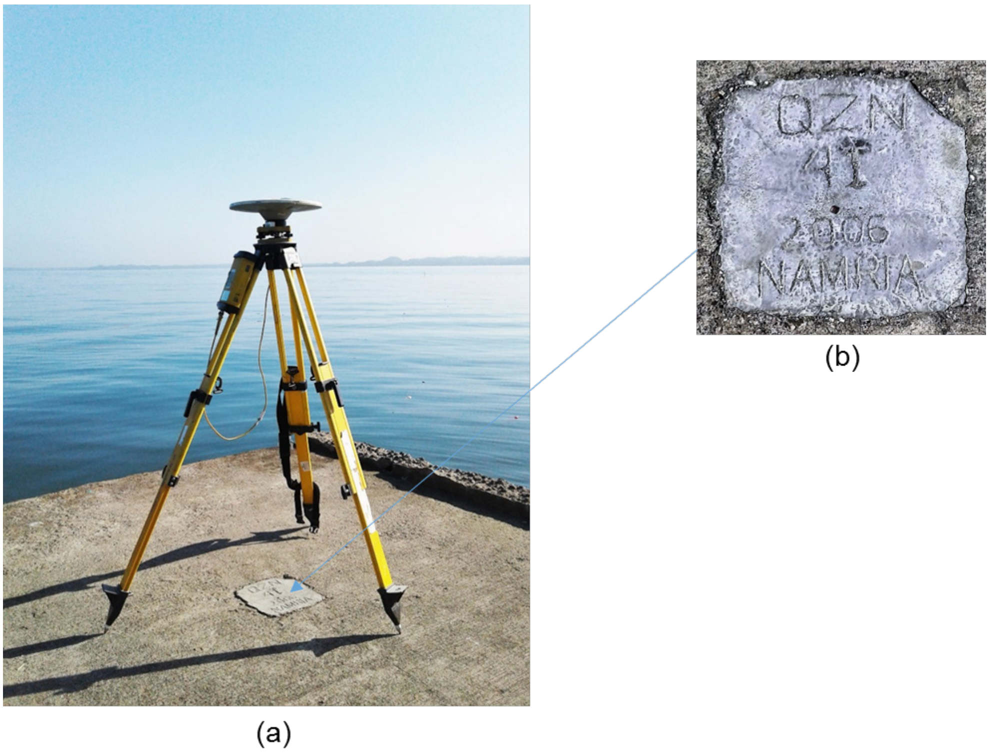


Figure 3. GPS set-up over QZN-41 as recovered at Barangay Sabang Uno, Calauag, Quezon (a) and NAMRIA reference point QZN-41 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGN-138 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 5 (PTM Zone 5 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 92)	Easting Northing	422550.44 meters 1543300.04 meters

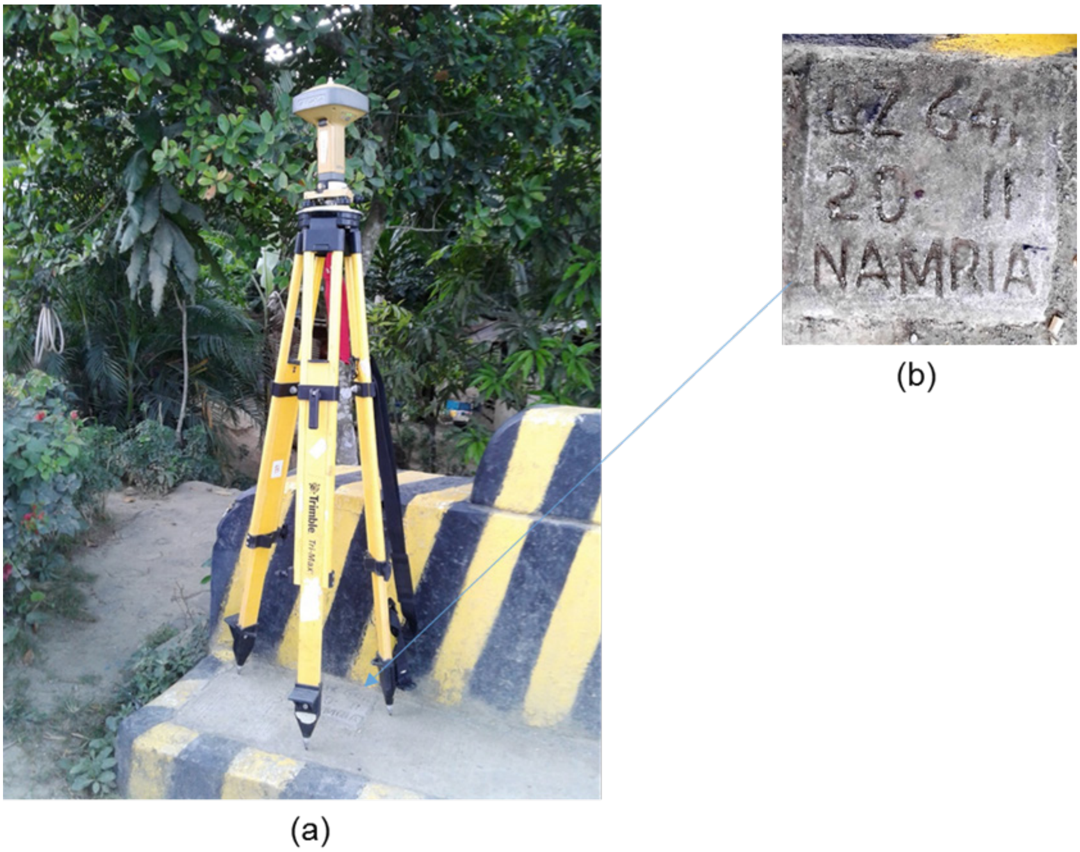


Figure 4. GPS set-up over QZ-641 as recovered at Barangay Villa Aurora, Lopez, Quezon (a) and NAMRIA reference point QZ-641 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA Benchmark QZ-641 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	QZ-641	
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' 32.33799" North 122° 22' 06.68507" East 57.552 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	431753.157 meters 1528439.6161meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 49' 27.21419" North 122° 22' 11.63727" East 106.606 meters

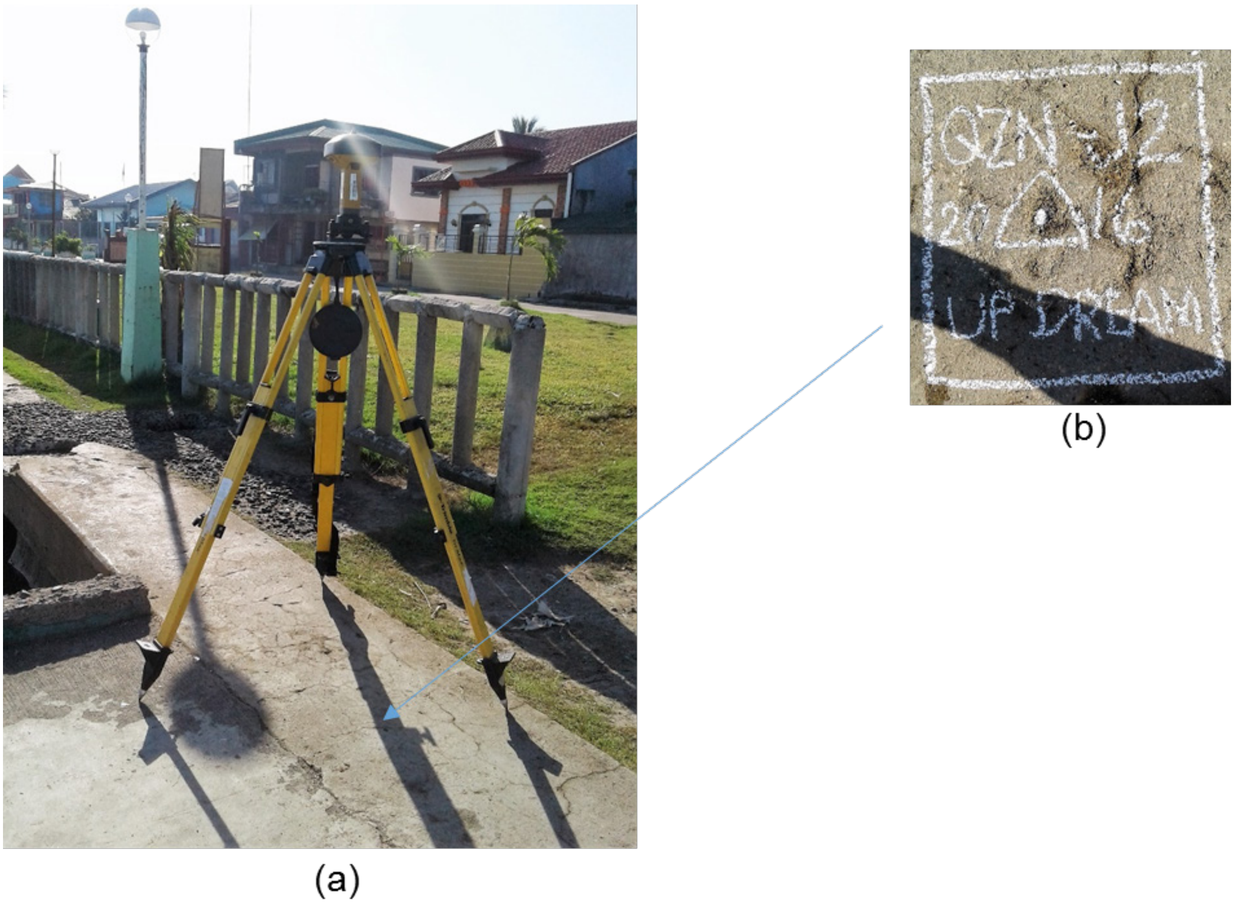


Figure 5. GPS set-up over QZN-J2 as established at Barangay Sabang Uno, Calauag, Quezon (a) reference point QZN-J2 (b) as established by the field team.

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

Station Name	**QZN-J2**	
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' 34.99489" North 122° 16' 58.78731" East 4.043 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	422553.956 meters 1543293.290 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57' 29.83213" North 122° 17' 03.72860" East 52.516 meters

(a)

(b)

Figure 6. GPS set-up over CMN-29 as recovered at Barangay Malibago, Labo, Camarines Norte (a) and NAMRIA reference point CMN-29 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point CMN-29 used as base station for the LiDAR acquisition.

Station Name	CMN-29	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 08’ 52.17466”North 122° 34’ 59.83481” East 40.92600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	455011.114 meters 1564566.419 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 8’ 46.99182” North 122° 35’ 4.75796“ East 89.60600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	455026.86 meters 1564018.79 meters

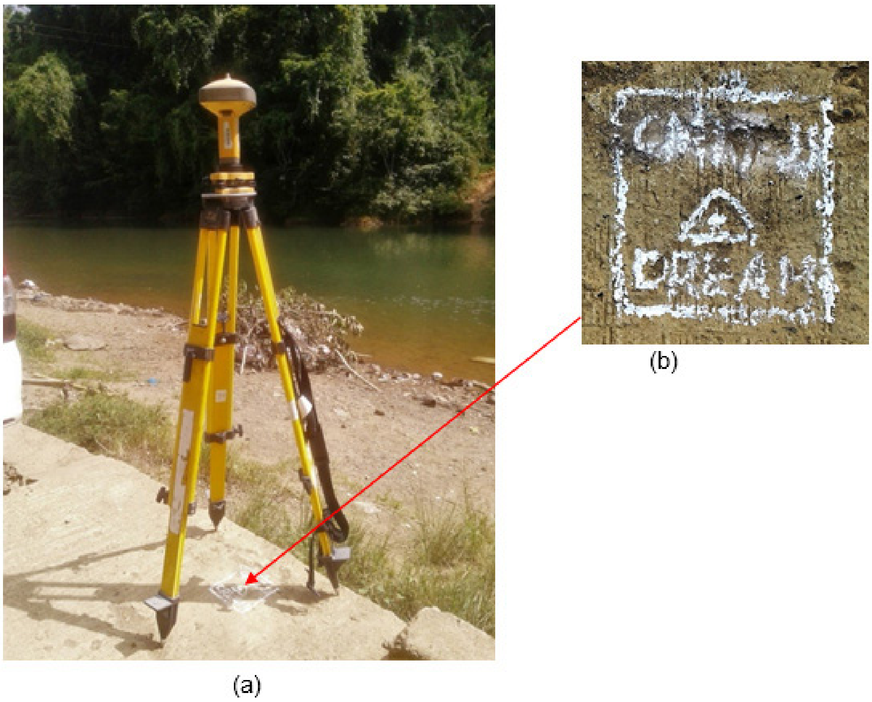


Figure 7. GPS set-up over CMN-JJ as established at Barangay Malibago, Labo, Camarines Norte (a) and reference point CMN-JJ (b) as established by the field team.

Table 6. Details of the established horizontal control point CMN-JJ used as base station for the LiDAR acquisition.

Station Name	CMN-JJ	
Order of Accuracy (benchmark)	2nd	
Elevation (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 08' 52.67538" North 122° 35' 02.50945" East 41.172 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 08' 47.49257" North 122° 35' 07.43258" East 89.854 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	455107.072 meters 1564034.034 meters

Table 7. Details of the recovered and re-established NAMRIA horizontal control point QZN-3946 used as base station for the LiDAR acquisition.

Station Name	QZN-3946	
Order of Accuracy (benchmark)	2nd	
Elevation (horizontal positioning)	1 in 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 5 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 8. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
13-Apr-16	23250P	1BLK20BC104A	QZN-41, QZN-J2
14-Apr-16	23254P	1BLK20CE105A	QZN-41, QZN-J2
15-Apr-16	23258P	1BLK20CE106A	QZ-641, QZN-41, QZN-3946
16-Apr-16	23262P	1BLK20S107A	CMN-29, CMN-JJ

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR Data Acquisition in Macalelon floodplain, for a total of fifteen hours and fifty-three minutes (15+53) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for LiDAR data acquisition in Macalelon 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
13-Apr-16	23250P	121.22	233.75	49.28	184.47	1027	4	35
14-Apr-16	23254P	160.09	85.62	4.92	80.70	226	2	53
15-Apr-16	23258P	98.03	190.38	35.17	155.21	NA	4	35
16-Apr-16	23262P	160.09	104.69	13.51	91.18	548	3	50
TOTAL		539.43	614.44	102.88	511.56	511.56	15	53

Table 10. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23250P	1000	30	50	200	30	130	5
23254P	1000	30	50	200	30	130	5
23258P	1000	30	50	200	30	130	5
23262P	1100, 700	30	50	200	30	130	5

2.4 Survey Coverage

Four (4) missions were conducted to complete the LiDAR Data Acquisition in Macalelon floodplain, for a total of fifteen hours and fifty-three minutes (15+53) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 11. List of municipalities and cities surveyed during Macalelon Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Quezon	Macalelon	81.75	81.75	100.00%
	Lopez	378.81	278.09	73.41%
	Gumaca	199.62	56.43	28.27%
	General Luna	119.16	32.08	26.92%
	Pitogo	72.29	19.84	27.45%
	Calauag	323.42	44.09	13.63%
	Guinayangan	236.85	9.6	4.05%
	Catanauan	267.28	2.46	0.92%
Total		1679.18	524.34	34.33%

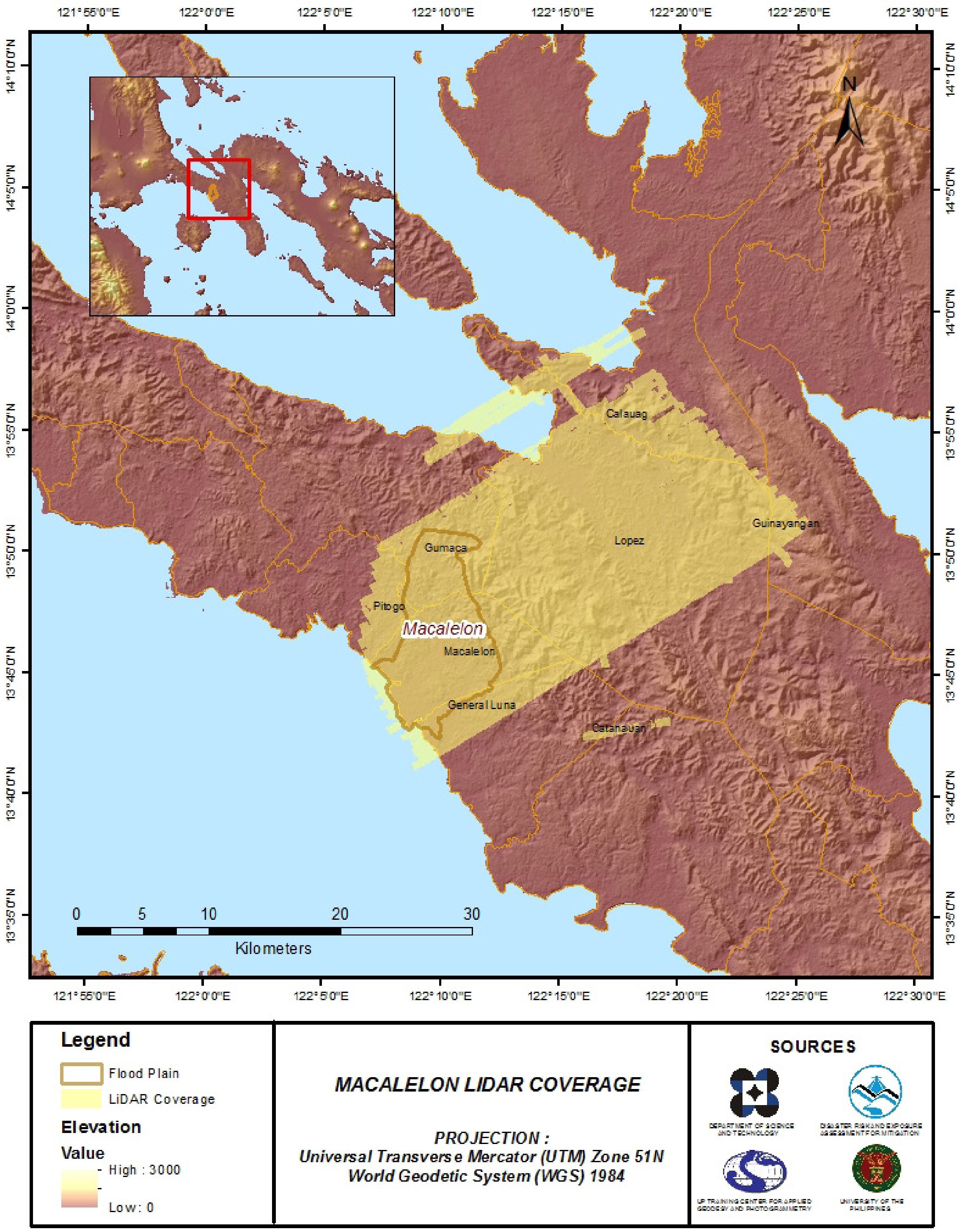


Figure 8. Actual LiDAR survey coverage for Macalelon Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MACALELON FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Engr. Melissa F. Fernandez , Engr. Ma. Ailyn L. Olanda, Engr. Sheila-Maye F. Santillan, Engr. Velina Angela S. Bemida , Engr. Ezzo Marc C. Hibionada, Ziarre Anne P. Mariposa

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 9.

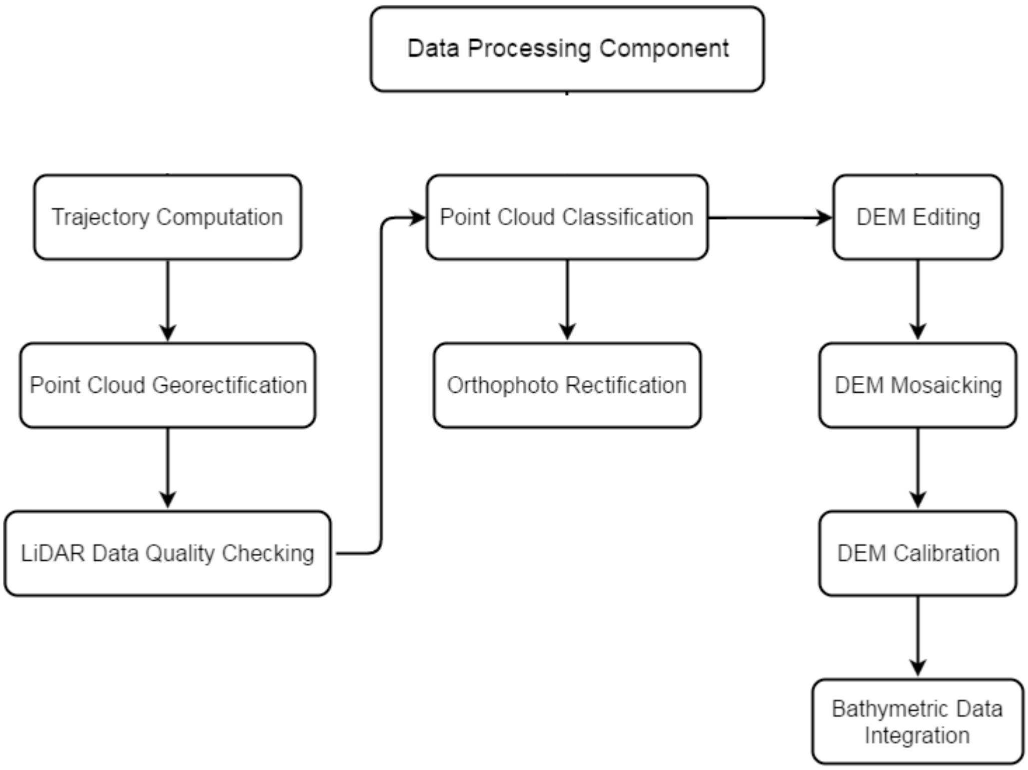


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Macalelon floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Macalelon, Quezon.

The Data Acquisition Component (DAC) transferred a total of 87.2 Gigabytes of Range data, 999 Megabytes of POS data, 463.5 Megabytes of GPS base station data, and 120.6 Gigabytes of raw image data to the data server on May 17, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Macalelon was fully transferred on May 18, 2016, as indicated on the Data Transfer Sheets for Macalelon floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23250P, one of the Macalelon flights, which is the North, East, and Down position RMSE values are shown in Figure 10. 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 13, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

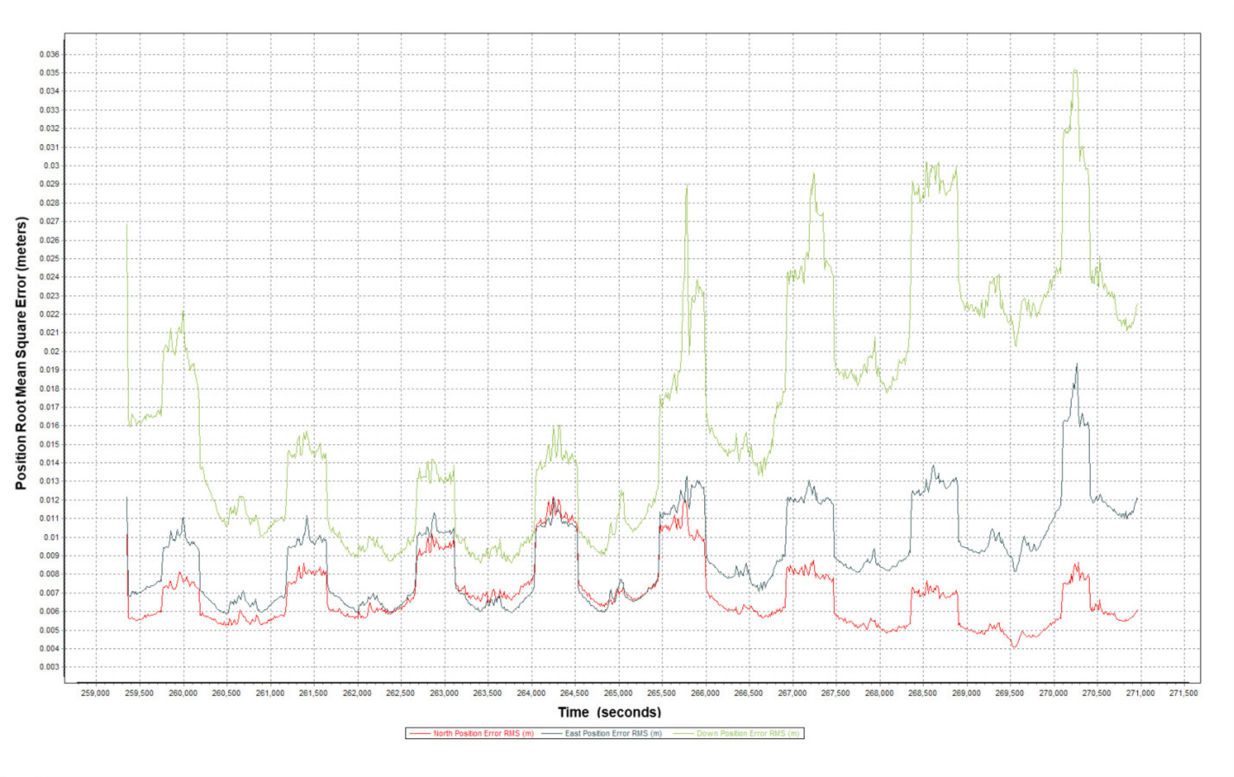


Figure 10. Smoothed Performance Metrics of Macalelon Flight 23250P.

The time of flight was from 259500 seconds to 271000 seconds, which corresponds to afternoon of April 13, 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 10 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1. 90 centimeters, and the Down position RMSE peaks at 3.50 centimeters, which are within the prescribed accuracies described in the methodology.

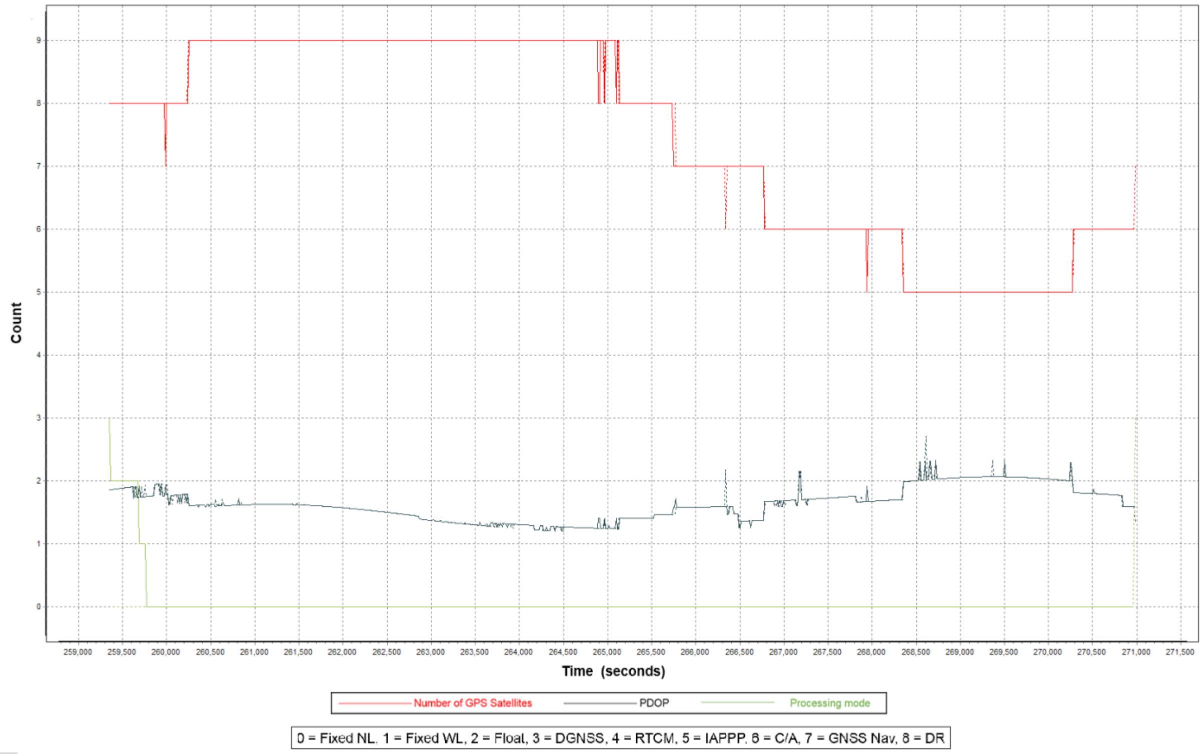


Figure 11. Solution Status Parameters of Macalelon Flight 23250P.

The Solution Status parameters of flight 23250P, one of the Macalelon flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 4. Majority of the time, the number of satellites tracked was between 5 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 Macalelon flights is shown in Figure 12.

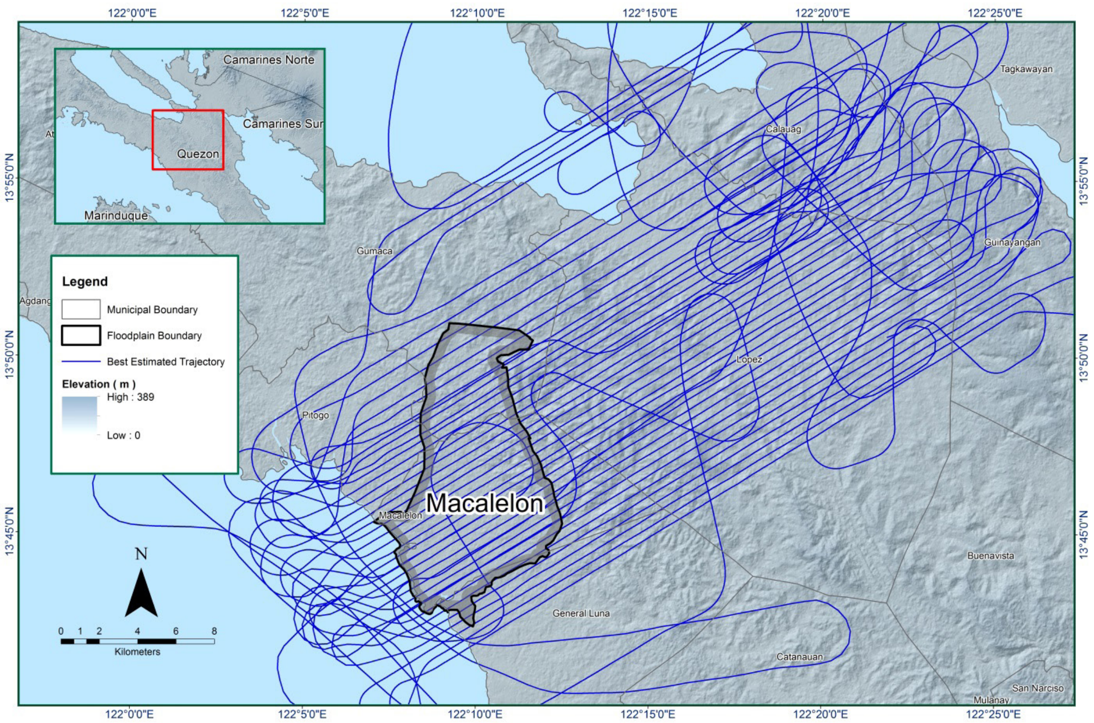


Figure 12. Best Estimated Trajectory for Macalelon Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 48 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Macalelon floodplain are given in Table 12.

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

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000162
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000366
GPS Position Z-correction stdev (<0.01meters)	0.0017

The optimum accuracy is obtained for all Macalelon 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 Macalelon Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

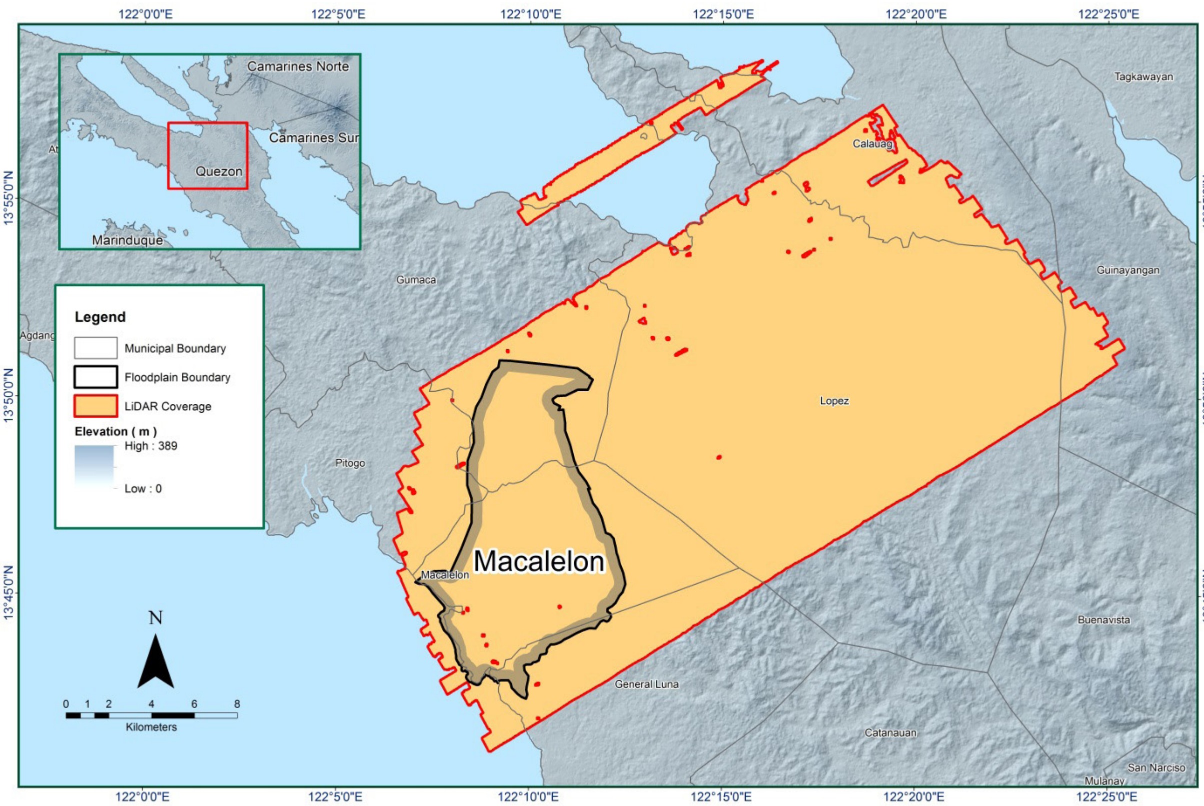


Figure 13. Boundary of the processed LiDAR data over Macalelon Floodplain

The total area covered by the Macalelon missions is 565.09 sq.km that is comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Macalelon Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bagasbas_Blk21B	23254P	81.69
	23258P	
Bagasbas_Blk21C	23250P	231.85
Bagasbas_Blk21D	23258P	178.80
Bagasbas_Blk21D_additional	23262P	72.75
TOTAL		565.09 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 14. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

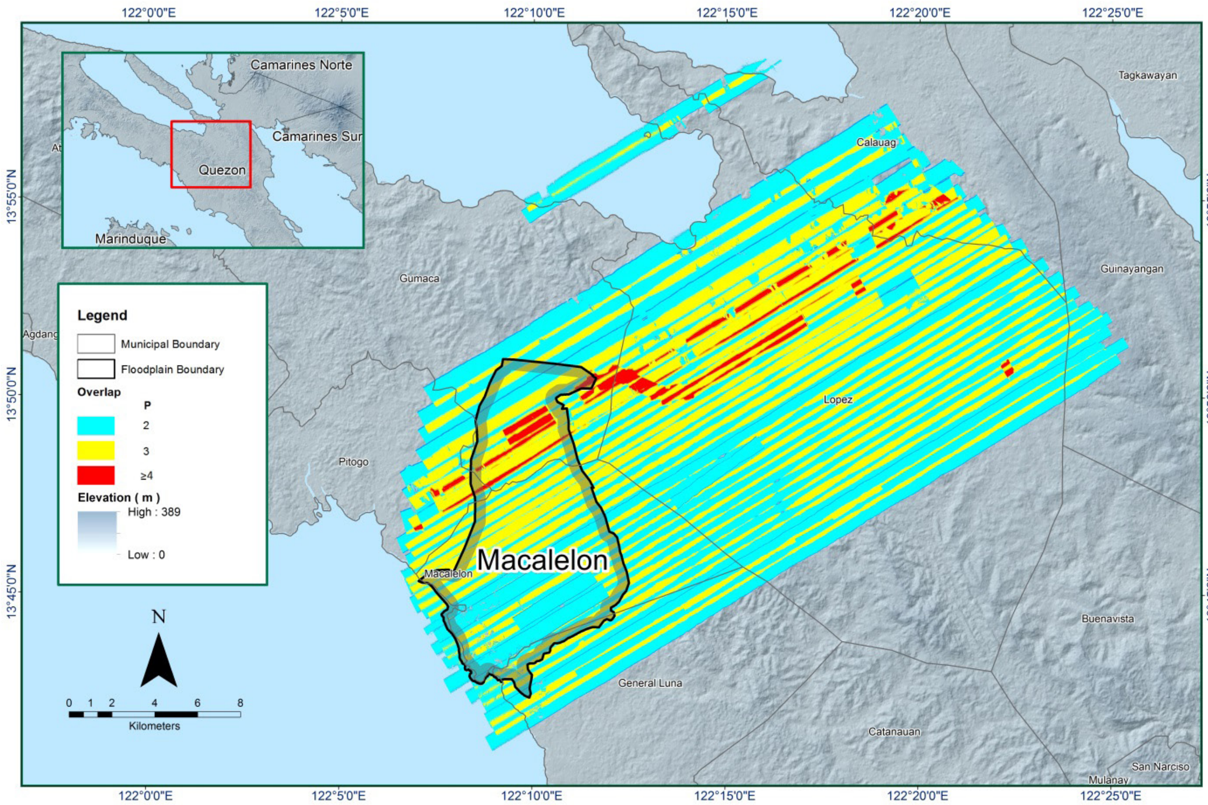


Figure 14. Image of data overlap for Macalelon Floodplain.

The overlap statistics per block for the Macalelon floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 41.33% and 64.92% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Macalelon floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.29 points per square meter.

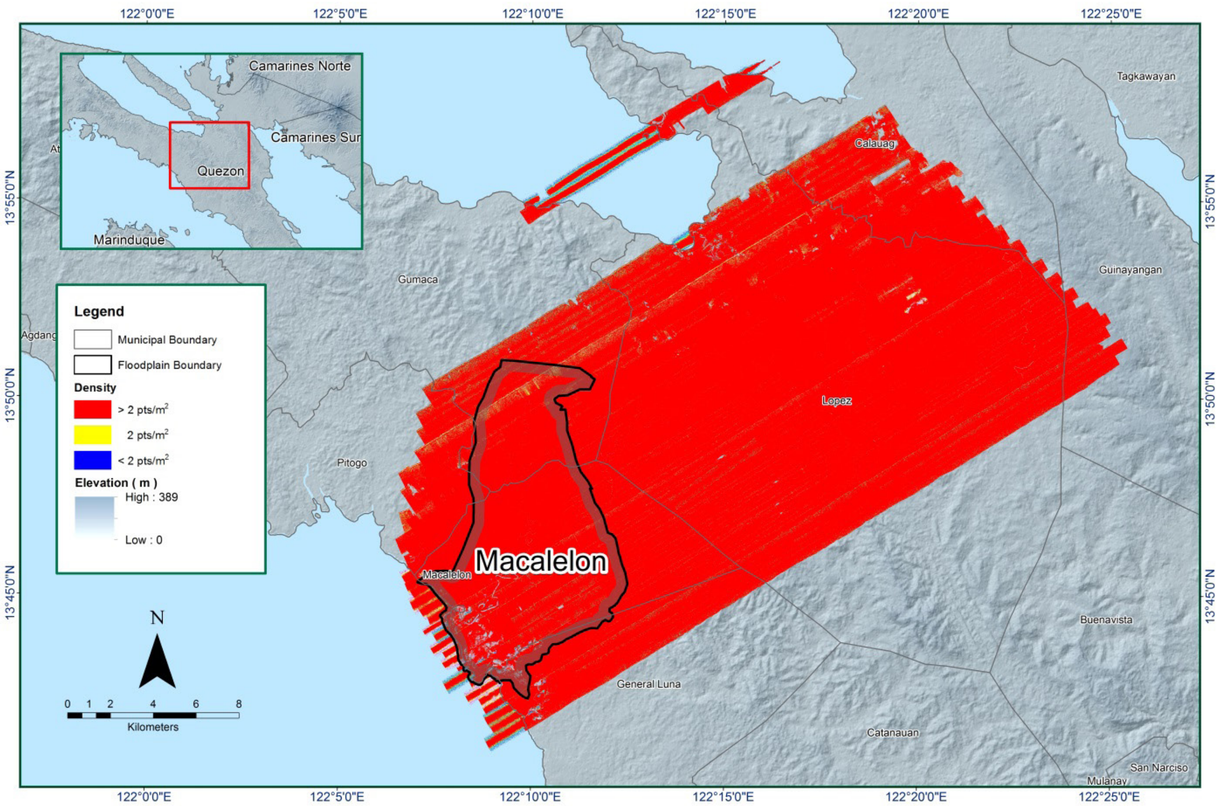


Figure 15. Pulse density map of merged LiDAR data for Macalelon Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

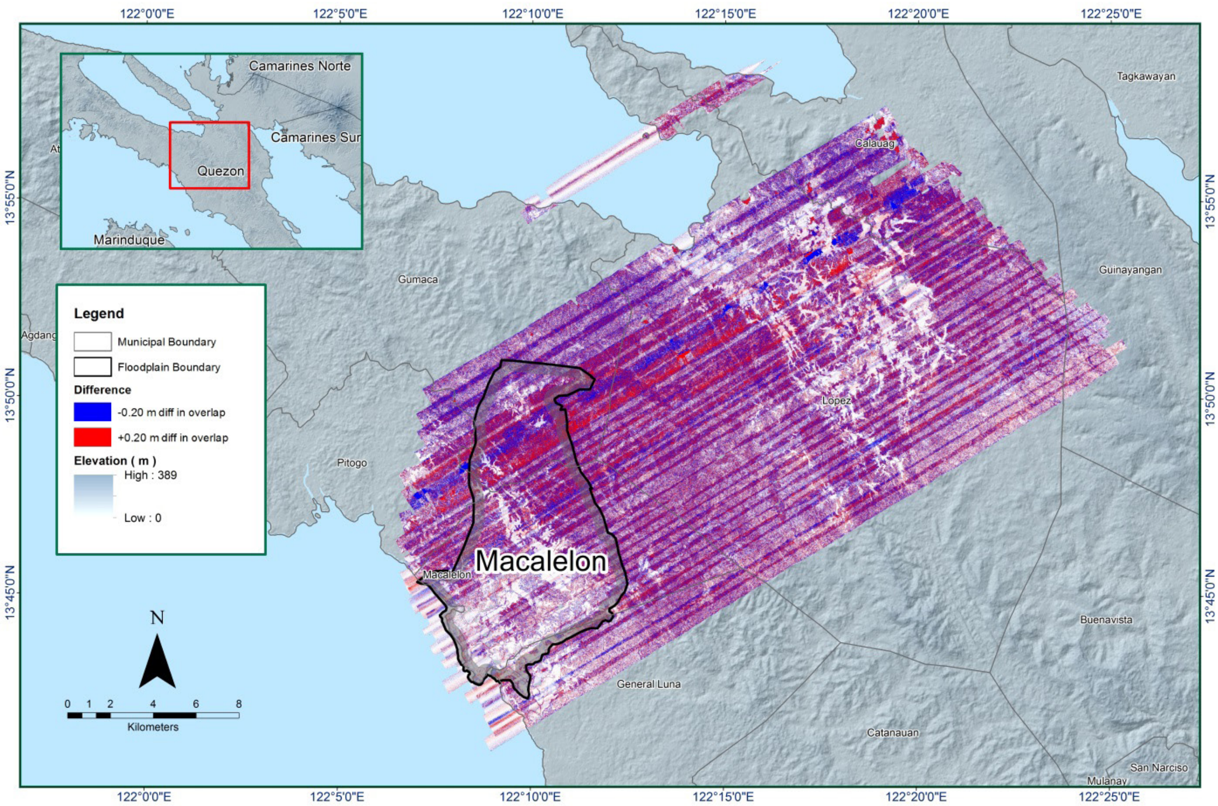


Figure 16. Elevation difference map between flight lines for Macalelon Floodplain.

A screen capture of the processed LAS data from a Macalelon flight 23250P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

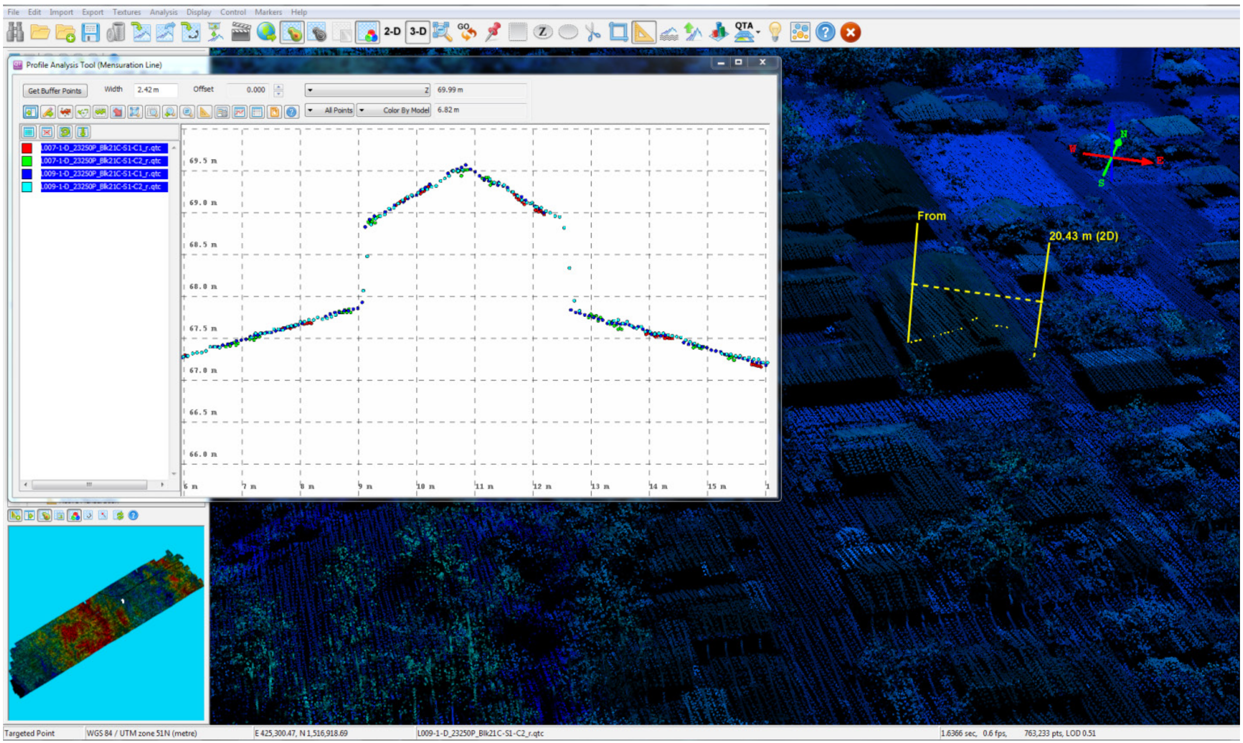


Figure 17. Quality checking for Macalelon flight 23250 using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Macalelon classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	536,374,327
Low Vegetation	412,824,009
Medium Vegetation	1,050,461,522
High Vegetation	2,970,248,741
Building	43,476,019

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Macalelon floodplain is shown in Figure 18. A total of 830 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 440.17 meters and 39.63 meters respectively.

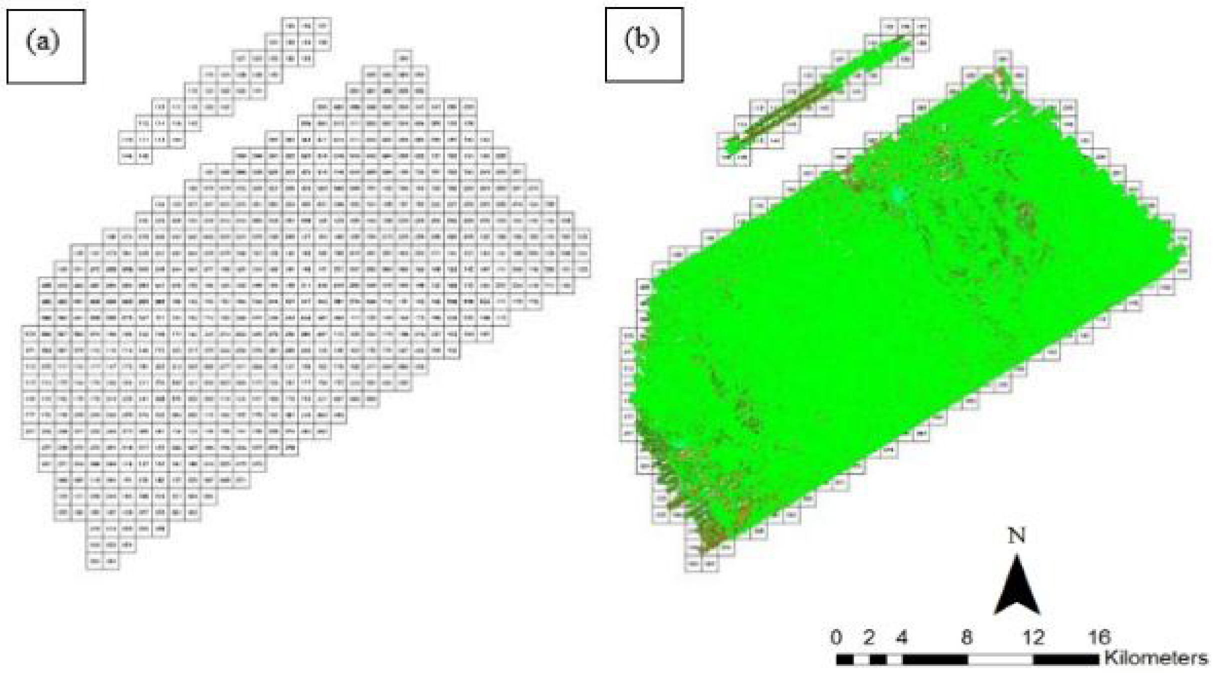


Figure 18. Tiles for Macalelon Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

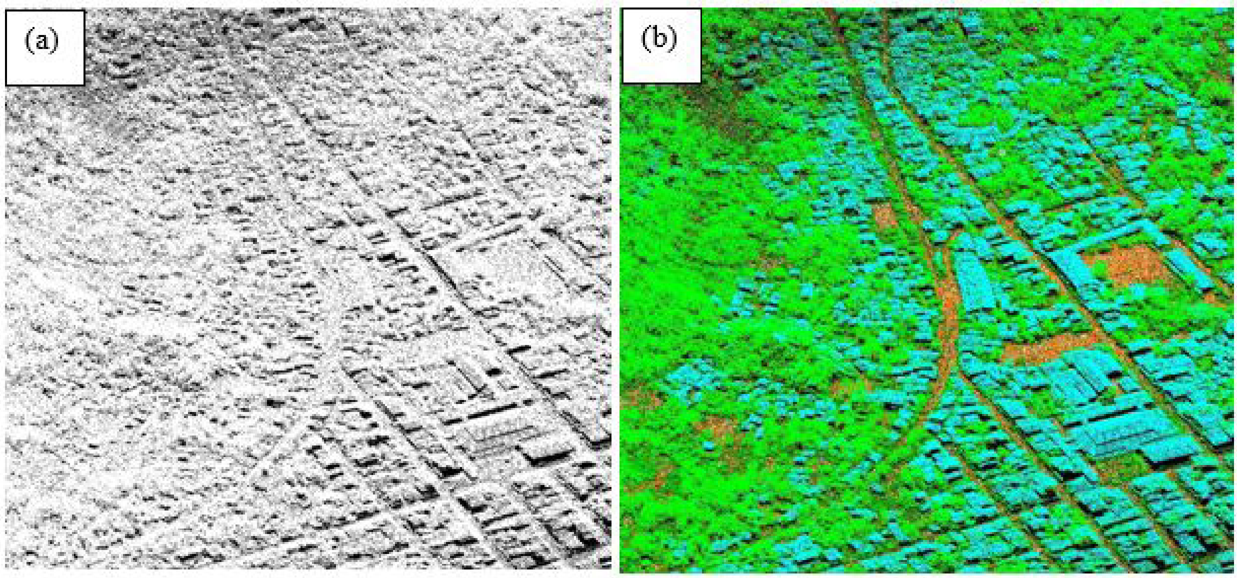


Figure 19. Point cloud before (a) and after (b) classification.

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

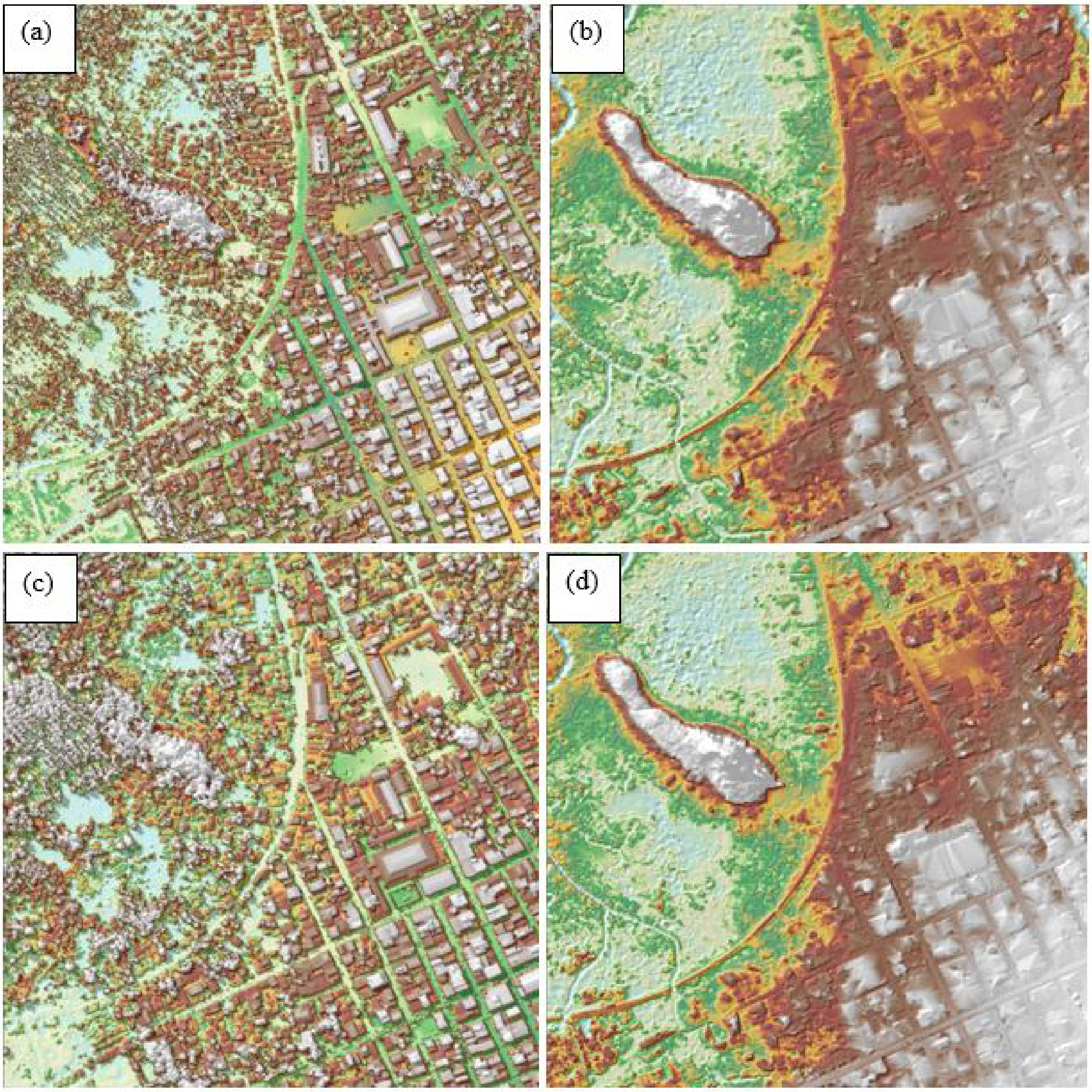


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Macalelon Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 575 1km by 1km tiles area covered by Macalelon floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Macalelon floodplain has a total of 375.469 sq.km orthophotogaph coverage comprised of 871 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

Figure 21. Macalelon Floodplain with available orthophotographs.

Figure 22. Sample orthophotograph tiles for Macalelon Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Macalelon flood plain. These blocks are composed of Bagasbas blocks with a total area of 565.09 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Bagasbas_Blk21B	81.69
Bagasbas_Blk21C	231.85
Bagasbas_Blk21D	178.80
Bagasbas_Blk21D_additional	72.75
TOTAL	565.09 sq.km

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. The paddy field (Figure 23c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 23e) and has to be removed through manual editing (Figure 23f).

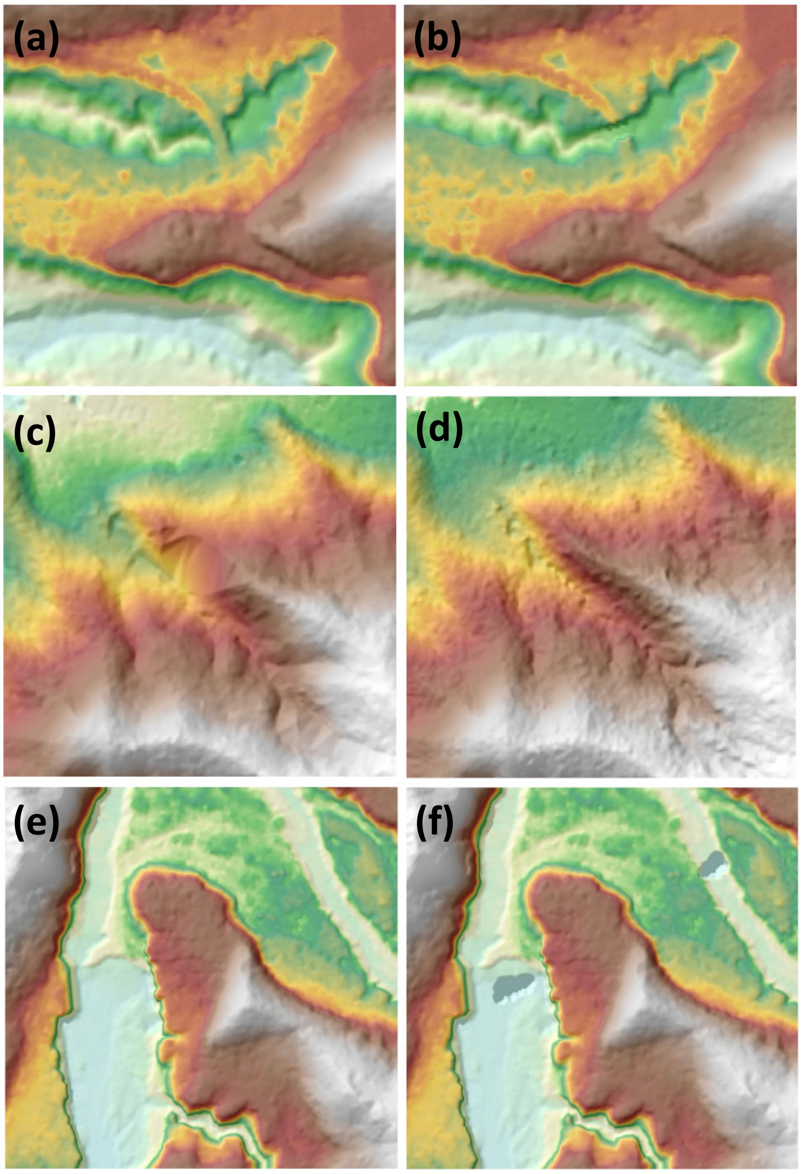


Figure 23. Portions in the DTM of Macalelon Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Bagasbas_Blk20F was used as the reference block at the start of mosaicking because this block is the one used as a base for other floodplains covered by Bagasbas blocks. Bagasbas_Blk21C is the block closest to the reference block that covers Macalelon floodplain. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Macalelon floodplain is shown in Figure 24. It can be seen that the entire Macalelon floodplain is 99.94% covered by LiDAR data.

Table 16. Shift Values of each LiDAR Block of Macalelon Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Bagasbas_Blk21B (Upper)	-2.47	3.00	0.07
Bagasbas_Blk21B (Lower)	-2.47	3.00	-0.03
Bagasbas_Blk21C	-3.27	2.46	-0.10
Bagasbas_Blk21D	-1.27	-1.07	0.10
Bagasbas_Blk21D_additional	2.18	0.97	0.20

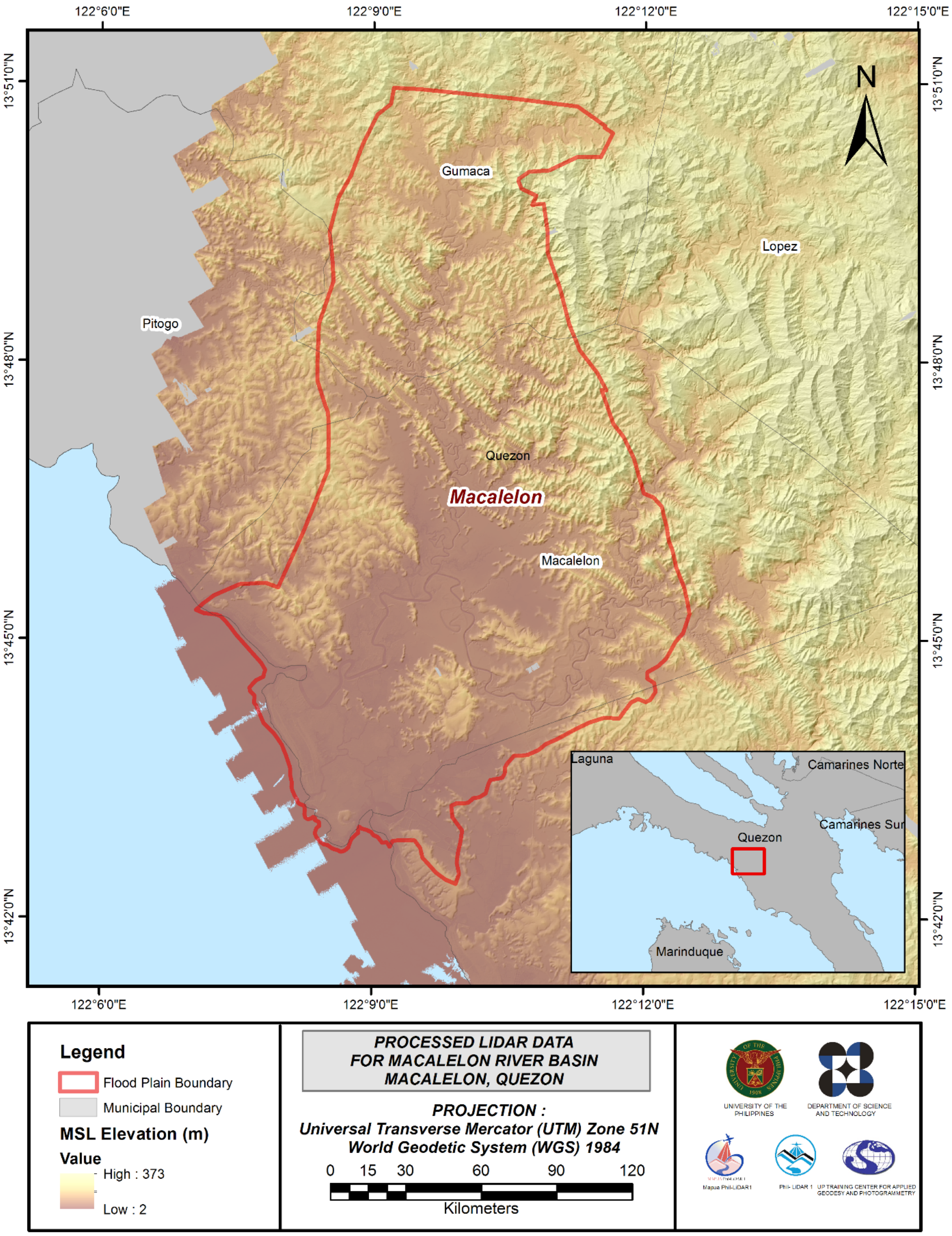


Figure 24. Map of Processed LiDAR Data for Macalelon Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Macalelon to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 15,500 survey points were gathered for all the flood plains within the provinces of Quezon and Camarines Sur wherein the Macalelon floodplain is located. Random selection of 80% of the survey points, resulting to 12400 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 26. 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 17 shows the statistical values of the compared elevation values between

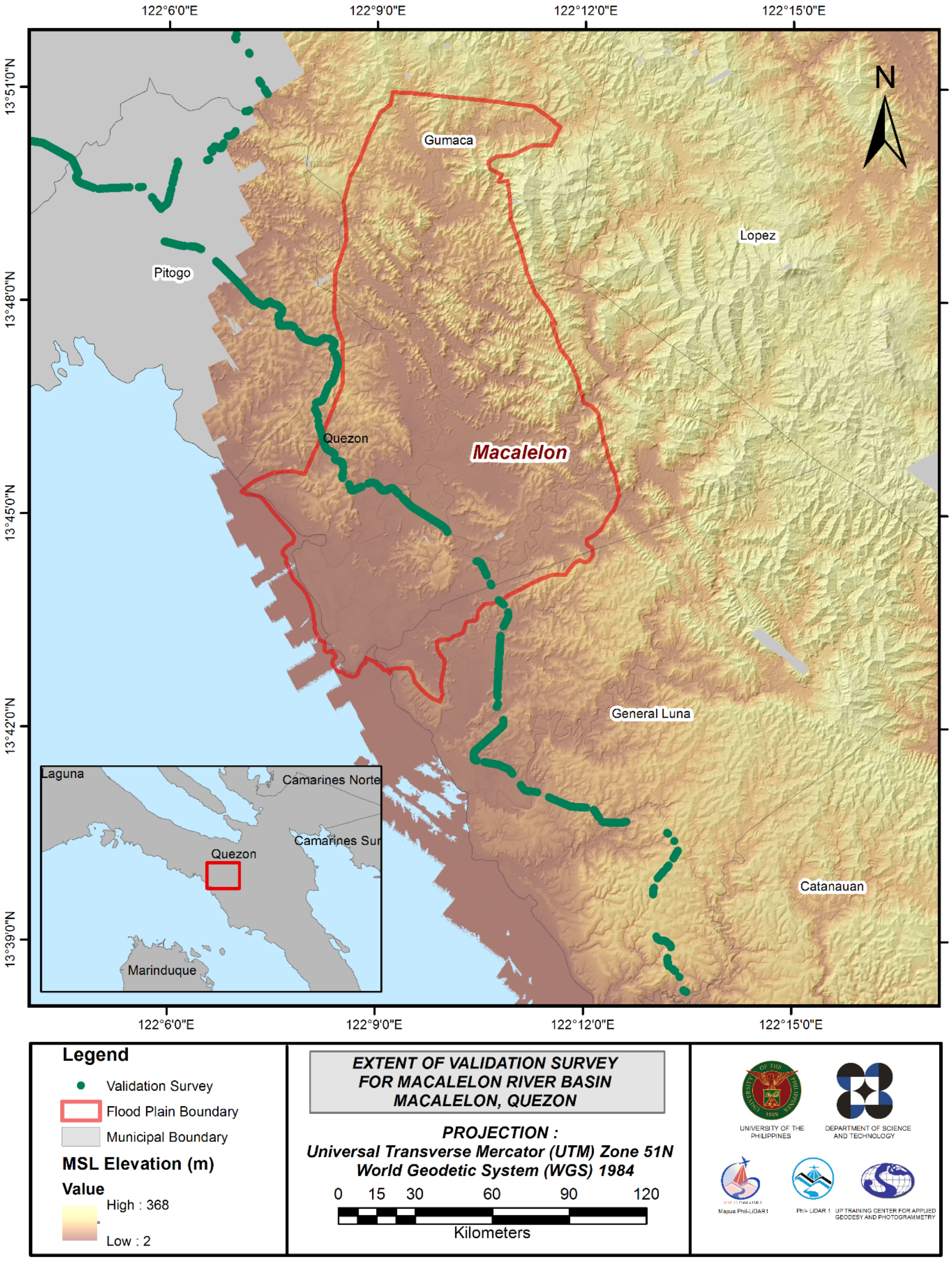


Figure 25. Map of Macalelon Floodplain with validation survey points in green.

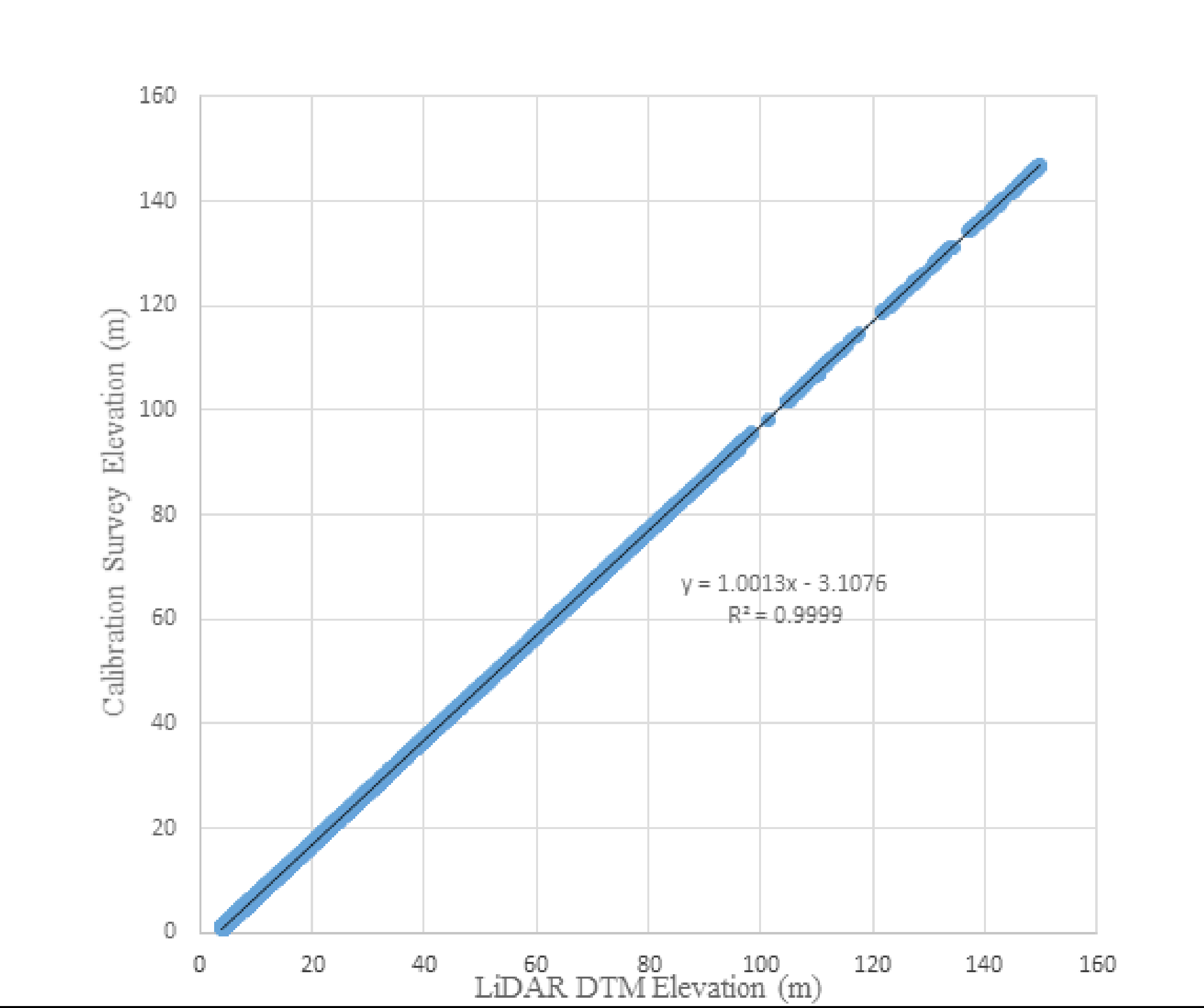


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 17. 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 were intersected to the floodplain, resulting to 83 points, were used for the validation of calibrated Macalelon 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19 meters with a standard deviation of 0.08 meters, as shown in Table 18.

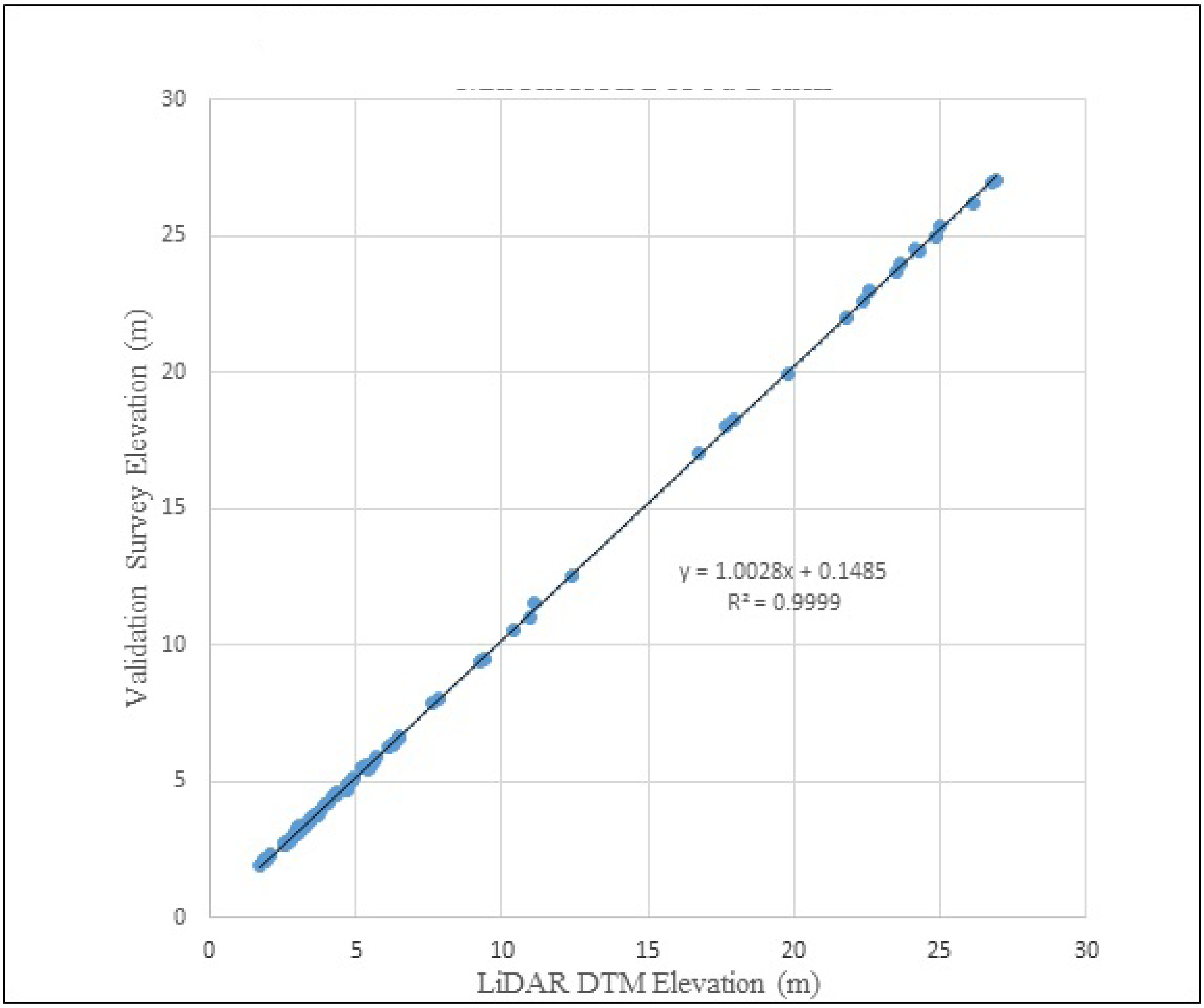


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.08
Average	0.17
Minimum	-0.02
Maximum	0.41

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Macalelon with 8,975 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 0.45 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Macalelon integrated with the processed LiDAR DEM is shown in Figure 28.

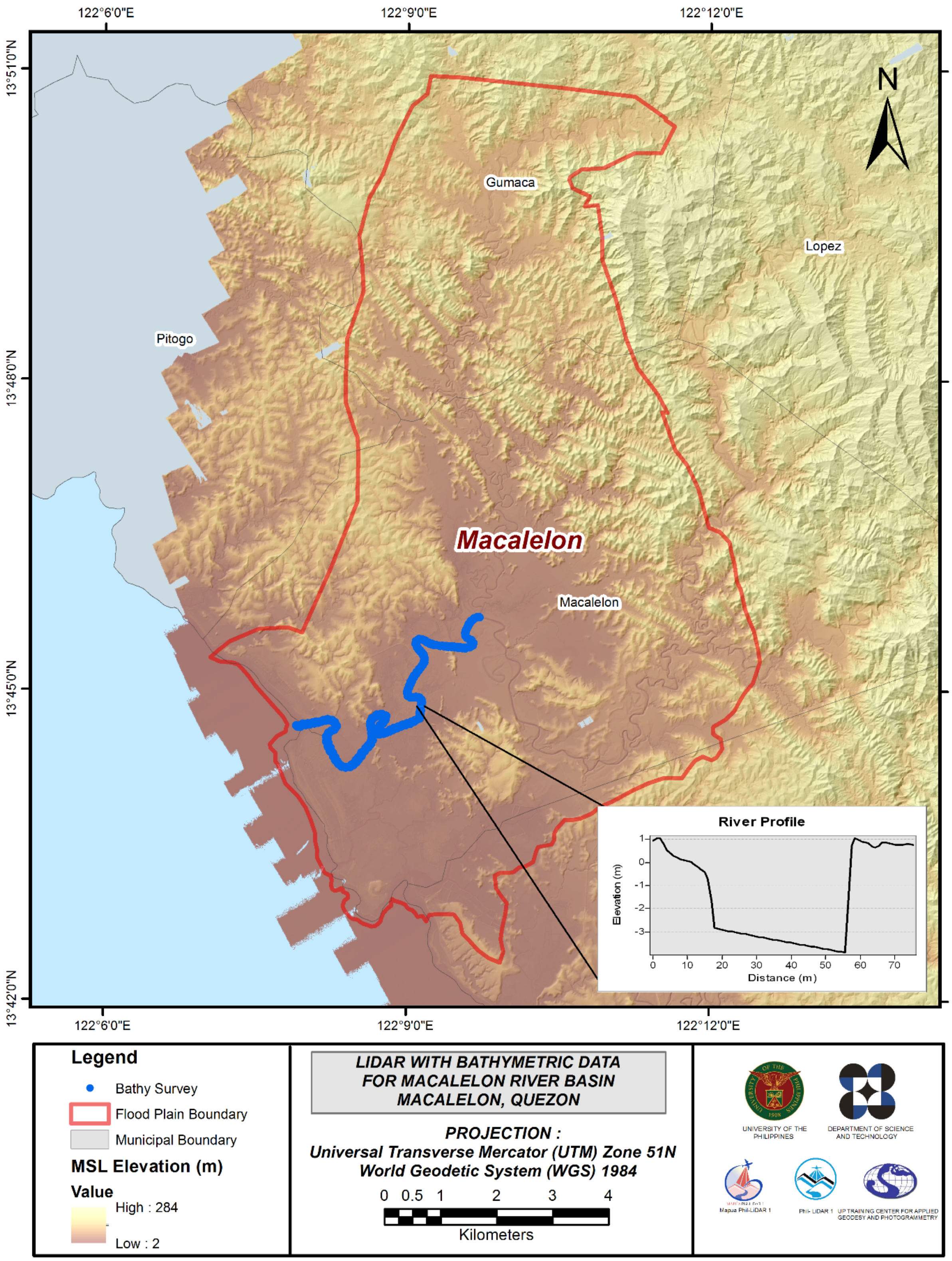


Figure 28. Map of Macalelon Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, 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

Macalelon floodplain, including its 200 m buffer, has a total area of 94.61 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 488 building features, are considered for QC. Figure 29 shows the QC blocks for Macalelon floodplain.

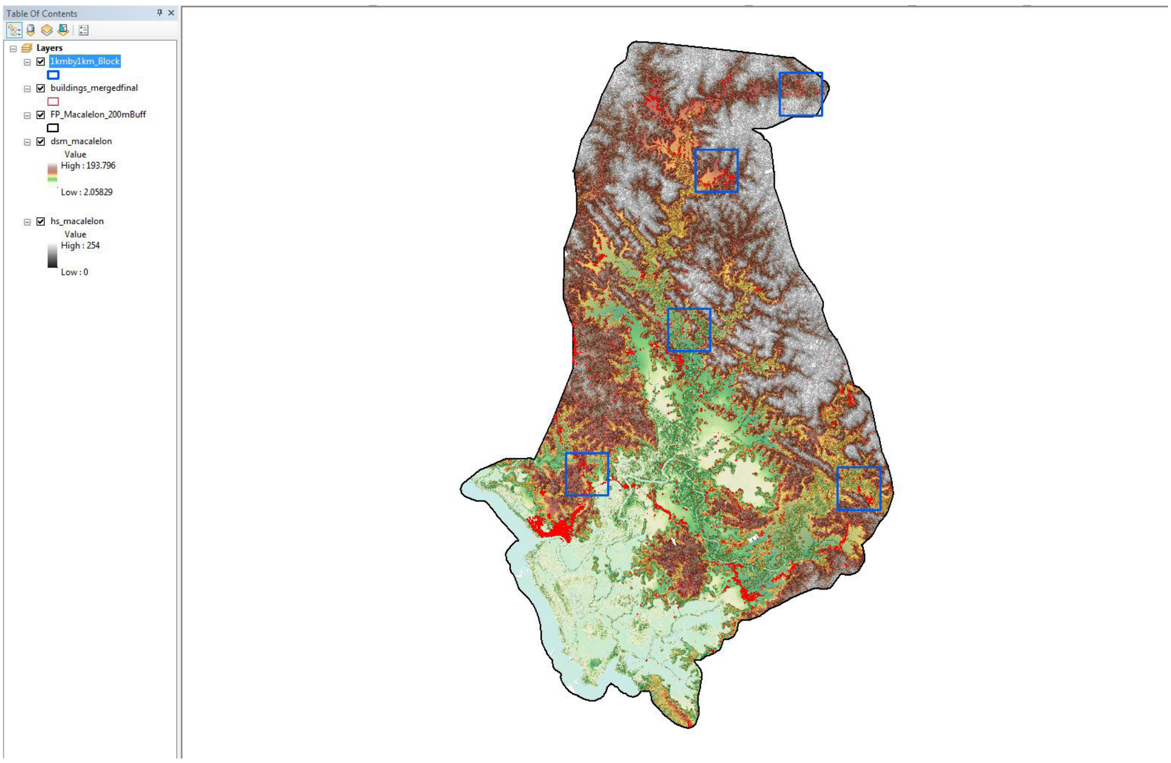


Figure 29. QC blocks for Macalelon building features.

Quality checking of Macalelon building features resulted in the ratings shown in Table 19.

Table 19. Quality Checking Ratings for Macalelon Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Macalelon	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,592 building features in Macalelon floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,592 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 14.37 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 20 summarizes the number of building features per type. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Building Features Extracted for Macalelon Floodplain.

Facility Type	No. of Features
Residential	5424
School	92
Market	3
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	5
Barangay Hall	26
Military Institution	0
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	6
Water Supply/Sewerage	1
Religious Institutions	22
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	5
Other Commercial Establishments	6
Total	5,592

Table 21. Total Length of Extracted Roads for Macalelon Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Macalelon	45.04	16.81	8.41	0.00	0.00	70.26

Table 22. Number of Extracted Water Bodies for Macalelon Floodplain.

Floodplain	Water Body Type						Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Macalelon	158	5	1	0	0	0	164

A total of 44 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 30 shows the Digital Surface Model (DSM) of Macalelon floodplain overlaid with its ground features.

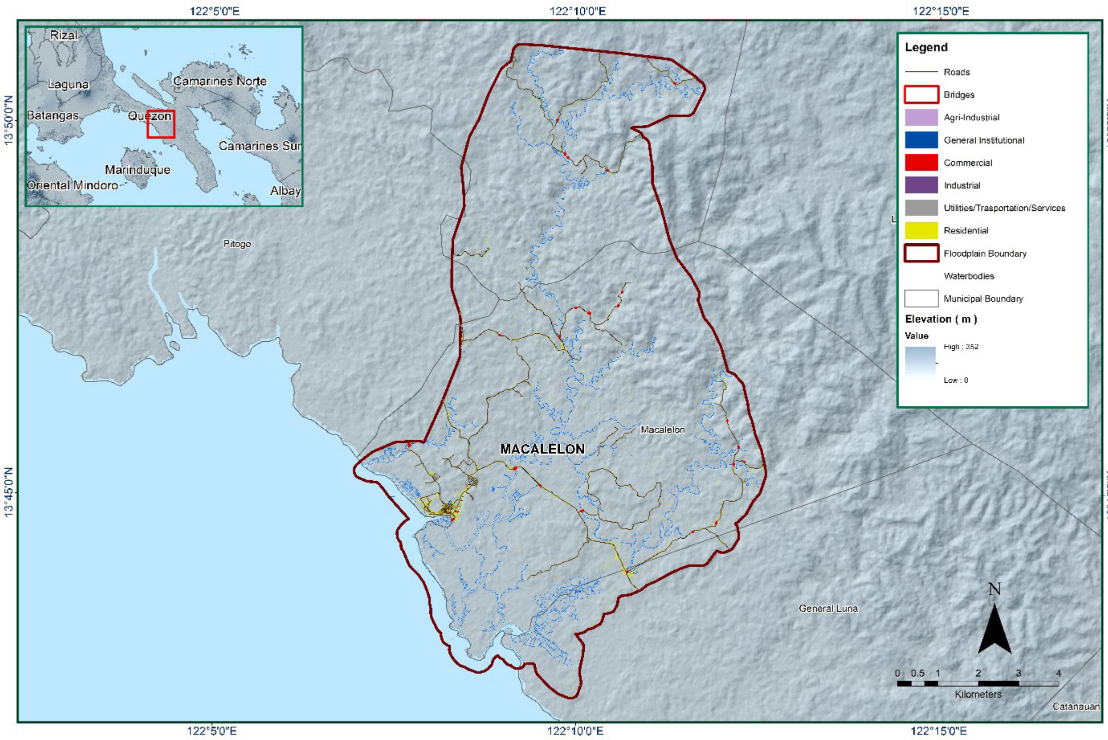


Figure 30. Extracted features for Macalelon Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF MACALELON RIVER BASIN

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Macalelon River on August 24 – September 2, 2016 and January 17-31, 2017 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey of Macalelon Bridge in Brgy. Pinagbayanan, Municipality of Macalelon; validation points acquisition of about 97.055 km covering the Macalelon River Basin area; and bathymetric survey from its upstream in Brgy. Tubigan Ibaba down to the mouth of the river located in Brgy. Pag-Asa in Municipality of Macalelon, with an approximate length of 7.663 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 31).

Figure 31. Macalelon River Survey Extent

4.2 Control Survey

A GNSS network was established for a previous PHIL-LIDAR 1 DVBC fieldwork in Maapon River on October 21, 2015 occupying the control points QZN-321, a 2nd order GCP in Brgy. Cagsiay II, Municipality of Mauban, Quezon; QZ-355, a 1st order Benchmark in Brgy. Silangan Malicboy, Municipality of Pagbilao, Quezon; and, UP-MAA, a UP established control point in Brgy. Polo, Municipality of Mauban, Quezon.

The GNSS network used for Macalelon River Basin is composed of six (6) loops established on August 28, 2016 occupying the following reference points: QZN-40, a second order GCP in Brgy. San Jose, Municipality of General Luna; QZ-355, a first order BM in Brgy. Silangan Malicboy, Municipality of Pagbilao; QZ-415, a first order BM in Brgy. Pansol, Municipality of Lopez; and UP-MAA, a UP Established control point in Brgy. Polo, Municipality of Mauban; all in the province of Quezon.

A UP control point, namely UP-MAC was established along the approach of Macalelon Bridge in Brgy. Pinagbayanan, Municipality of Macalelon. NAMRIA established control points namely: QZN-32, located in Barangay Zone 4, Municipality of Antimonan; QZ-511, located in Brgy. Palale Ibaba, Tayabas City; QZ-585, located in Brgy. Poblacion II, Municipality of Agdangan, were also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 23 while GNSS network established is illustrated in Figure 32.

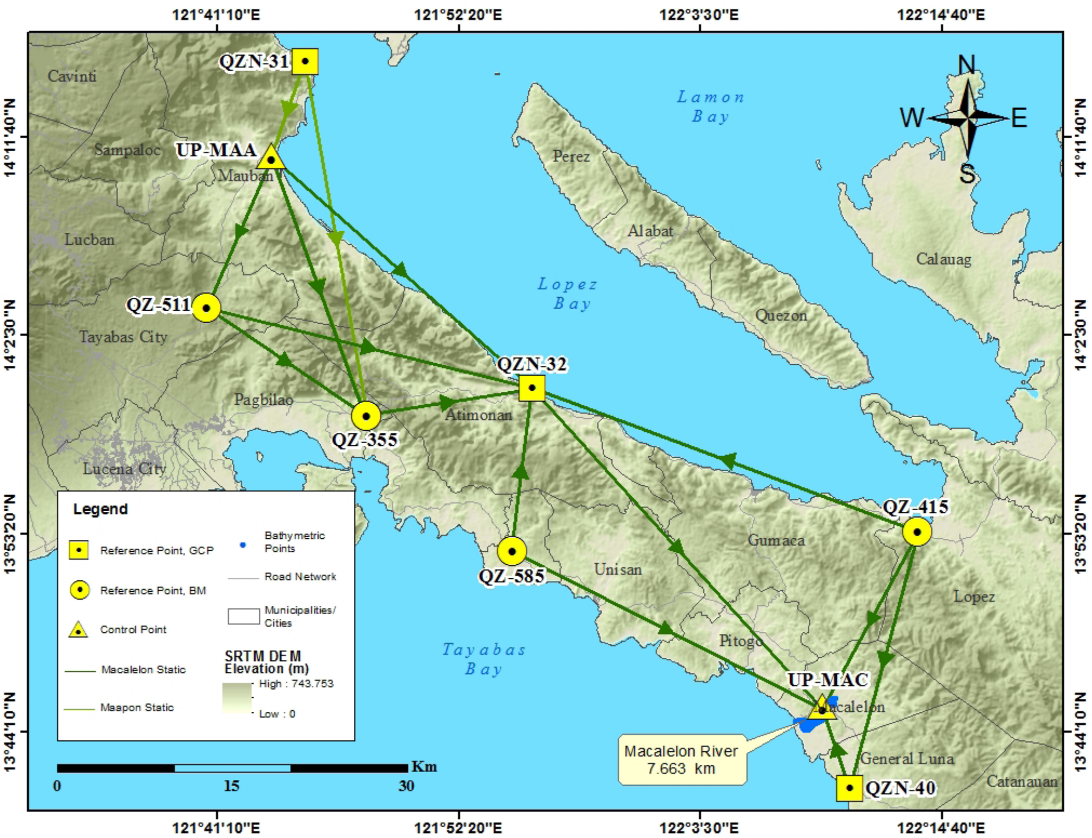


Figure 32. GNSS Network of Macalelon River field survey

Table 23. List of Reference and Control Points occupied for Macalelon 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°41'32.47597"	122°10'25.77273"	51.703	2.622	8-28-2016
QZN-32	Used as Marker	-	-	49.973	-	8-26-2016
QZ-355	1st order, BM	-	-	60.886	13.001	8-26-2016
QZ-415	1st order, BM	-	-	57.29	8.613	-
QZ-511	Used as Marker	-	-	125.759	-	8-26-2016
QZ-585	Used as Marker	-	-	55.363	-	-
UP-MAA	UP established	14°10'49.24881"	121°43'38.91696"	52.857	6.081	-
UP-MAC	UP established	-	-	53.565	-	8-28-2016

The GNSS set-ups on recovered reference points and established control points in Macalelon River are shown in Figure 33 to Figure 40.

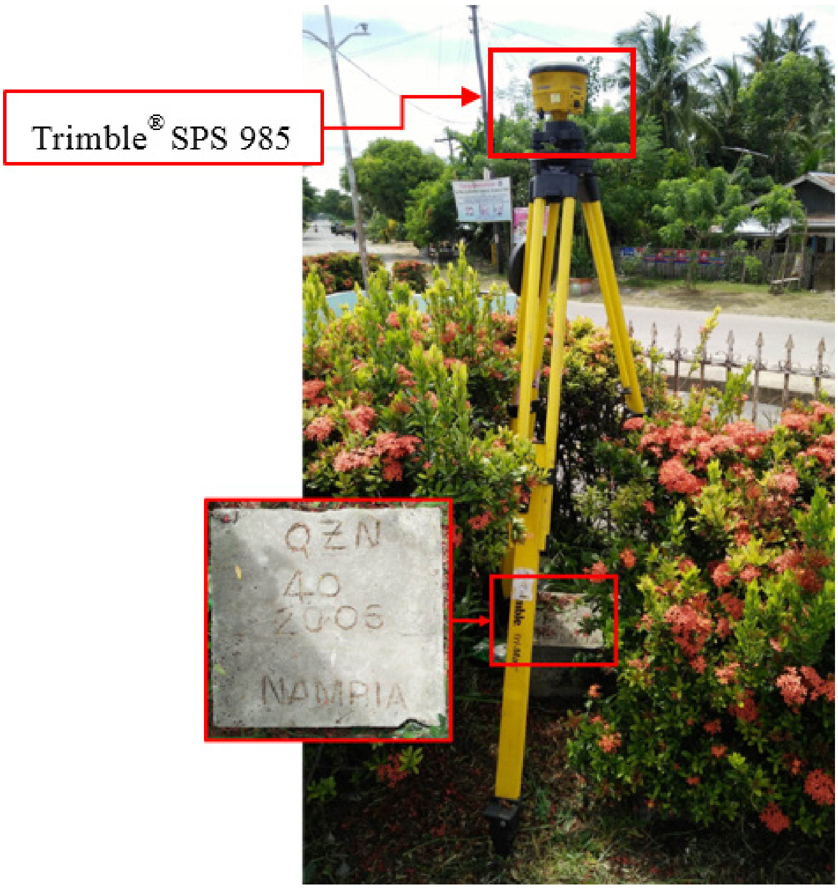


Figure 33. GNSS base set up, Trimble® SPS 985, at QZN-40, located in Brgy. San Jose, Municipality of General Luna, Quezon

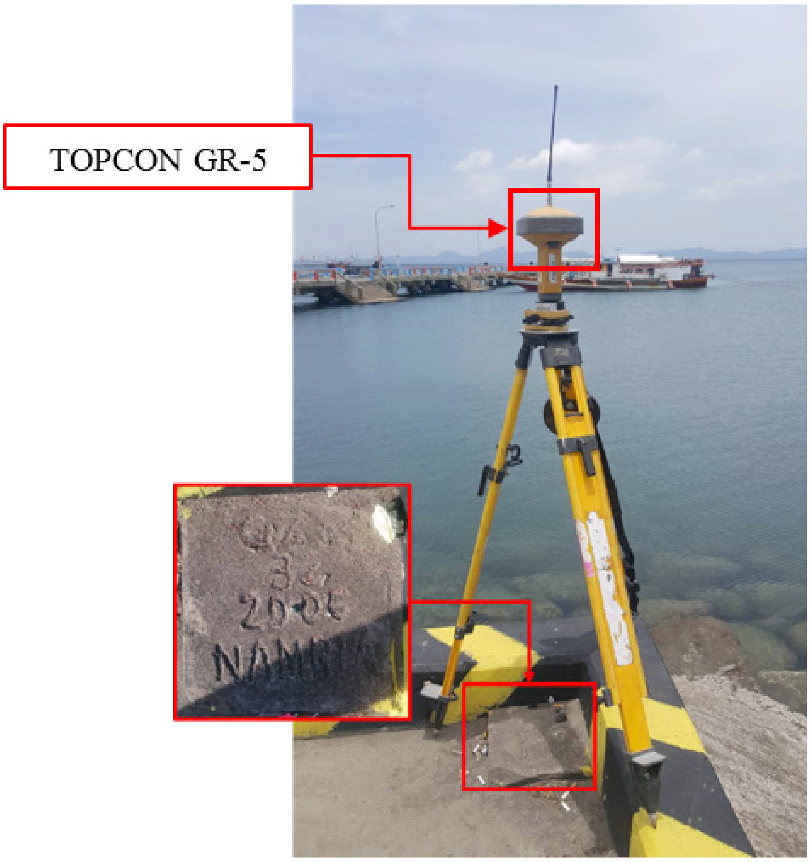


Figure 34. GNSS receiver setup, TOPCON GR-5, at QZN-32, located in Barangay Zone 4, Municipality of Antimonan, Quezon

Figure 35. GNSS receiver setup TOPCON GR-5, at QZ-355, located in Brgy. Silangan Malicboy, Municipality of Pagbilao, Quezon

Figure 36. GNSS receiver setup, Trimble® SPS 985, at QZ-415, located in Brgy. Pansol, Municipality of Lopez, Quezon

Figure 37. GNSS receiver setup, Trimble® SPS 855, at QZ-511, located in Brgy. Palale Ibaba, Tayabas City, Quezon

Figure 38. GNSS receiver setup, Trimble® SPS 882, at QZ-585, located in Brgy. Poblacion II, Municipality of Agdangan, Quezon

Figure 39. GNSS receiver setup, Trimble® SPS 882, at UP-MAA, located at the approach of Maapon Bridge, in Brgy. Polo, Municipality of Mauban

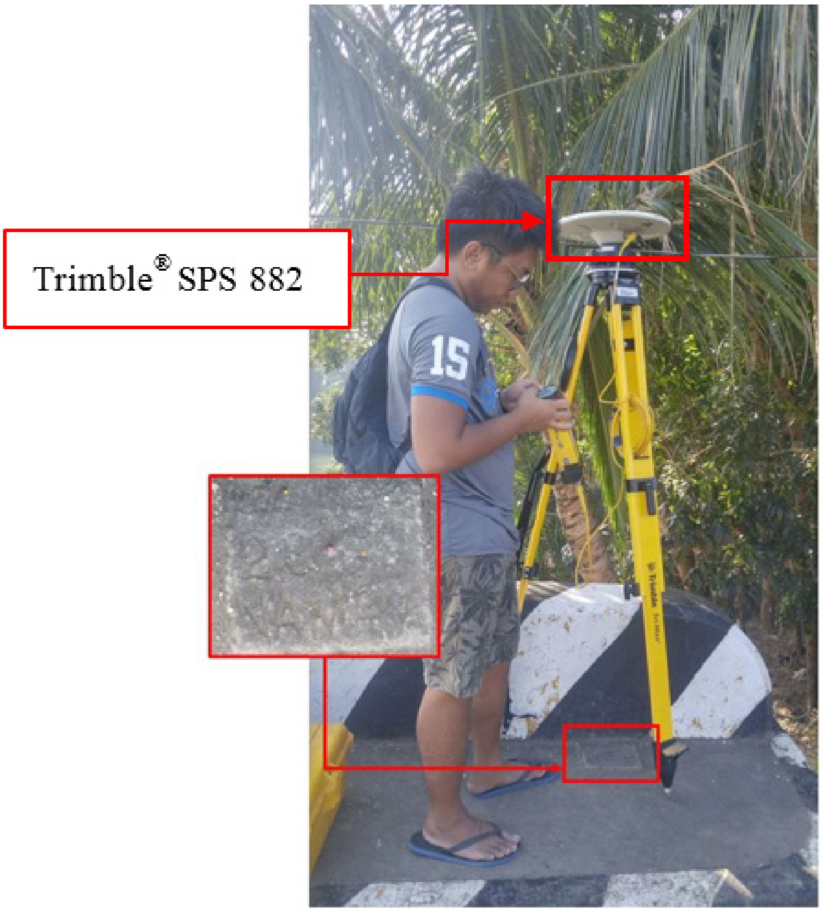


Figure 40. GNSS receiver setup, Trimble® SPS 882, at UP-MAC, located at the approach of Macalelon Bridge in Brgy. Pinagbayanan, Municipality of Macalelon, Quezon

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 Yabaan River Basin is summarized in Table 24 generated by TBC software.

Table 24. Baseline Processing Summary Report for Macalelon River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
QZN32 --- UPMAC (B11)	08-28-16	Fixed	0.004	0.022	138°15'59"	36306.611	3.700
QZ415 --- QZN32 (B10)	08-28-16	Fixed	0.004	0.020	290°51'48"	34302.330	-7.700
QZ585 --- UPMAC (B8)	08-28-16	Fixed	0.007	0.042	116°58'12"	29115.090	-1.509
QZ355 --- QZN32 (B4)	08-28-16	Fixed	0.003	0.019	80°21'27"	14082.721	-10.678
QZN40 --- UPMAC (B3)	08-28-16	Fixed	0.004	0.017	341°44'22"	7369.429	1.905
QZ415 --- QZN40 (B7)	08-28-16	Fixed	0.004	0.023	194°22'01"	22613.358	-5.870
QZ511 --- QZN32 (B1)	08-28-16	Fixed	0.004	0.022	104°04'38"	28015.440	-75.441
QZ511 --- QZ355 (B5)	08-28-16	Fixed	0.005	0.027	124°37'56"	16153.736	-64.738
QZ415 --- UPMAC (B6)	08-28-16	Fixed	0.007	0.038	207°58'38"	16880.013	-4.012
UPMAA --- QZN32 (B17)	08-28-16	Fixed	0.003	0.016	132°23'52"	29481.331	-2.729
UPMAA --- QZ355 (B16)	08-28-16	Fixed	0.003	0.018	160°28'20"	23599.127	7.938
UPMAA --- QZ511 (B18)	08-28-16	Fixed	0.006	0.029	202°28'15"	14131.522	72.695
QZ585 --- QZN32 (B13)	08-28-16	Fixed	0.003	0.019	7°17'55"	14001.171	-5.230

As shown in Table 24, a total of thirteen (13) baselines were processed with reference points QZN-40 and UP-MAA held fixed for coordinate values; and, QZ-35, QZ-415, QZN-40, and UP-MAA fixed for elevation values. 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 22) of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

Xe is the Easting Error,
Ye is the Northing Error, and
Ze is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 25 to Table 27 for the complete details.

The eight (8) control points, QZN-40, QZN-32, QZ-355, QZ-415, QZ-511, QZ-585, UP-MAC, and UP-MAA were occupied and observed simultaneously to form a GNSS loop. Coordinates of QZN-40 and UP-MAA; and elevation values of QZ-355, QZ-415, QZN-40, and UP-MAA were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 25. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
QZ355	Grid				Fixed
QZ415	Grid				Fixed
QZN40	Grid	Fixed	Fixed		Fixed
UPMAA	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 26. The fixed controls QZN-40 and UP-MAA have no values for grid errors while QZ-355, QZ-415, QZN-40, and UP-MAA have no value for elevation error.

Table 26. Adjusted Grid Coordinates

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
QZN40	410660.624	?	1513855.137	?	2.622	?	ENe
QZN32	384336.229	0.003	1548053.699	0.003	2.148	0.019	
QZ355	370443.723	0.004	1545765.640	0.003	13.001	?	e
QZ415	416340.504	0.004	1535736.293	0.005	8.613	?	e
QZ511	357206.025	0.005	1555018.529	0.004	78.580	0.034	
QZ585	382494.468	0.006	1534177.515	0.006	7.103	0.045	
UPMAA	362677.086	?	1568045.546	?	6.081	?	ENe
UPMAC	408376.133	0.004	1520859.190	0.005	4.726	0.027	

With the mentioned equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for the horizontal and $z_e < 10\ cm$ for the vertical; the computation for the accuracy for:

a.	**QZN-40**		
	horizontal accuracy	=	Fixed
	vertical accuracy	=	Fixed
b.	**QZN-32**		
	horizontal accuracy	=	$\surd((0.3)^2 + (0.3)^2$
		=	$\surd\ (0.09 + 0.09)$
		=	0.42 < 20 cm
	vertical accuracy	=	1.9 cm < 10 cm
c.	**QZ-355**		
	horizontal accuracy	=	$\surd((0.4)^2 + (0.3)^2$
		=	$\surd\ (0.16 + 0.09)$
		=	0.5 < 20 cm
	vertical accuracy	=	Fixed
d.	**QZ-415**		
	horizontal accuracy	=	$\surd((0.4)^2 + (0.5)^2$
		=	$\surd\ (0.16 + 0.25)$
		=	0.41 < 20 cm
	vertical accuracy	=	Fixed
e.	**QZ-511**		
	horizontal accuracy	=	$\surd((0.5)^2 + (0.4)^2$
		=	$\surd\ (0.25 + 0.16)$
		=	0.64 < 20 cm
	vertical accuracy	=	3.4 cm < 10 cm
f.	**QZ-585**		
	horizontal accuracy	=	$\surd((0.6)^2 + (0.6)^2$
		=	$\surd\ (0.36 + 0.36)$
		=	0.85 < 20 cm
	vertical accuracy	=	4.5 cm < 10 cm
g.	**UP-MAA**		
	horizontal accuracy	=	Fixed
	vertical accuracy	=	Fixed
h.	**UP-MAC**		
	horizontal accuracy	=	$\surd((0.4)^2 + (0.5)^2$
		=	$\surd\ (0.16 + 0.25)$
		=	0.64 < 20 cm
	vertical accuracy	=	2.7 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 27. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
QZN40	N13°41'32.47597"	E122°10'25.77273"	51.703	?	ENe
QZN32	384336.229	0.003	1548053.699	0.003	2.148
QZ355	370443.723	0.004	1545765.640	0.003	13.001
QZ415	416340.504	0.004	1535736.293	0.005	8.613
QZ511	357206.025	0.005	1555018.529	0.004	78.580
QZ585	382494.468	0.006	1534177.515	0.006	7.103
UPMAA	362677.086	?	1568045.546	?	6.081
UPMAC	408376.133	0.004	1520859.190	0.005	4.726

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 28. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (meter)	Northing (m)	Easting (m)	MSL Elevation (m)
QZN-40	2nd order, GCP	13°41'32.47597"	122°10'25.77273"	51.703	1513855.137	410660.624	2.622
QZN-32	Used as Marker	14°00'02.14305"	121°55'44.40141"	49.973	1548053.699	384336.229	2.148
QZ-355	1st order, BM	13°58'45.51270"	121°48'01.75528"	60.886	1545765.640	370443.723	13.001
QZ-415	1st order, BM	13°53'25.29139"	122°13'32.50411"	57.29	1535736.293	416340.504	8.613
QZ-511	Used as Marker	14°03'44.33369"	121°40'38.88397"	125.759	1555018.529	357206.025	78.58
QZ-585	Used as Marker	13°52'30.26306"	121°54'45.12957"	55.363	1534177.515	382494.468	7.103
UP-MAA	UP established	14°10'49.24881"	121°43'38.91696"	52.857	1568045.546	362677.086	6.081
UP-MAC	UP established	13°45'20.18923"	122°09'08.90651"	53.565	1520859.190	408376.133	4.726

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

Cross-section and as-built survey were conducted on January 24, 2017 at the downstream side of Macalelon Bridge in Brgy. Pinagbayanan, Municipality of Macalelon, Quezon as shown in Figure 41. A Trimble® SPS 985 GNSS in PPK survey technique was used as shown in Figure 42.

Figure 41. Macalelon Bridge facing upstream

Figure 42. Bridge As-Built Survey using PPK Technique.

The cross-sectional line of Macalelon Bridge is about 64 m with 166 cross-sectional points using the control point UP-MAC as the GNSS base station. The location map, cross-section diagram, and the bridge data form are illustrated in Figure 43 to Figure 45.

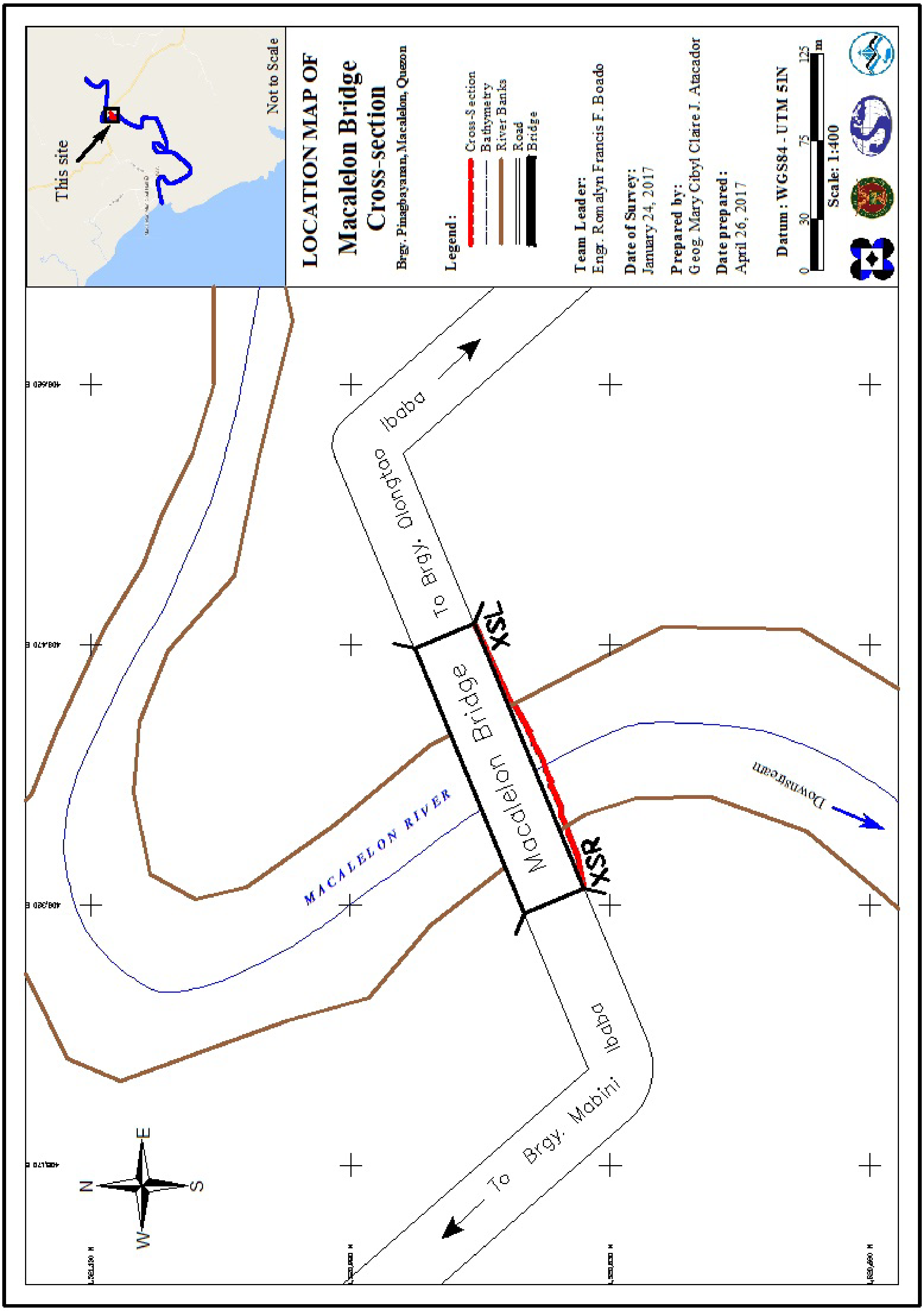


Figure 43. Location map of Macalelon Bridge cross-section

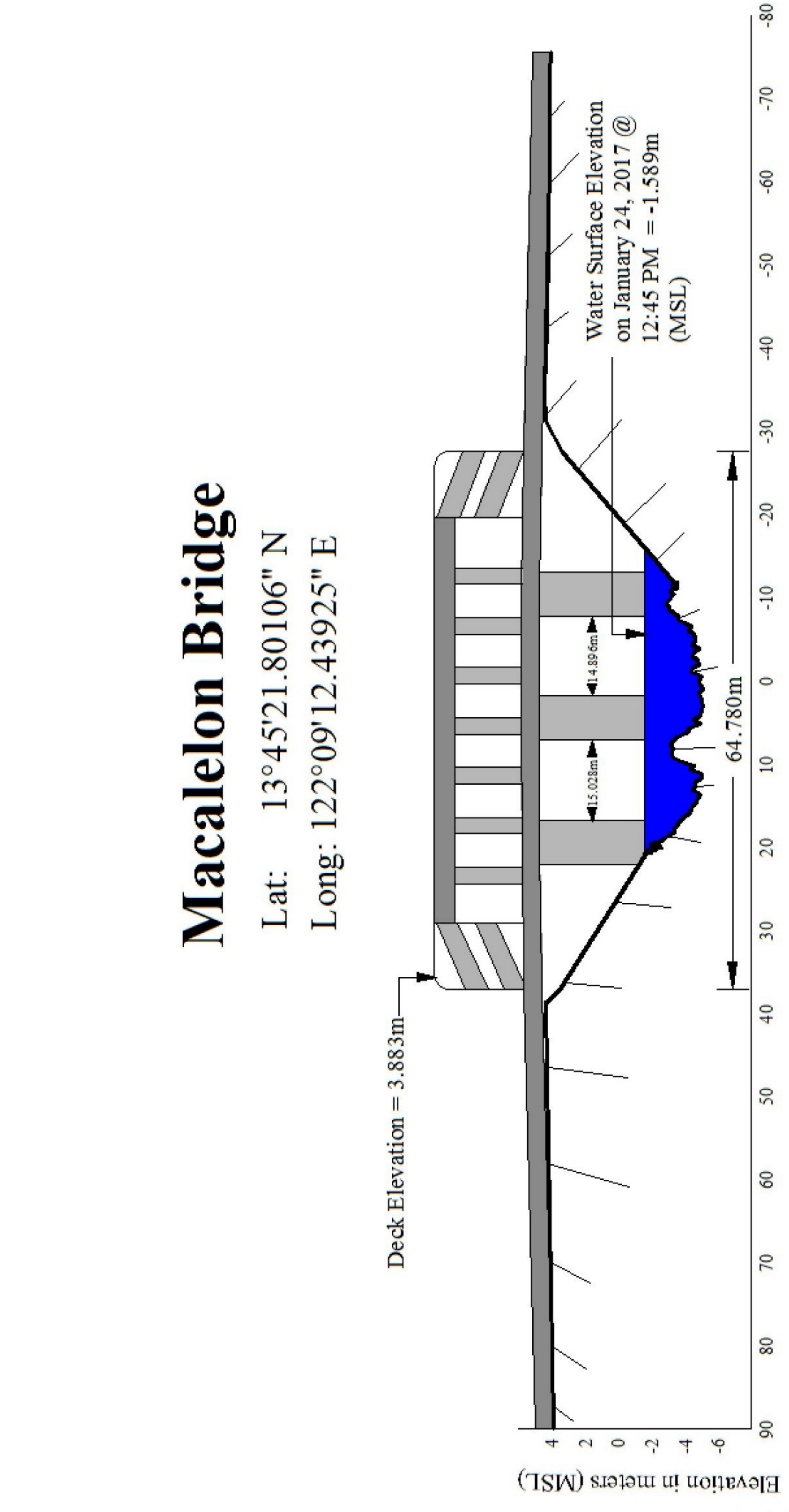
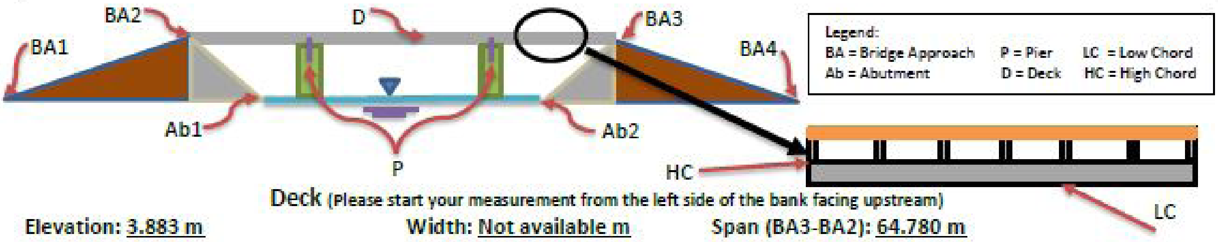


Figure 44. Macalelon Bridge cross-section diagram

Bridge Data Form

Bridge Name: Macalelon Bridge	Date: January 24, 2017
River Name: Macalelon River	Time: 12:45 AM
Location (Brgy, City,Region): Brgy. Pinagbayanan, Municipality of Macalelon, Quezon	
Survey Team: Romalyn Boado, Cibyl Atacador, Lorenz Taguse	
Flow condition: normal	Weather Condition: fair
Latitude: 13°45'21.80106" N	Longitude: 122°09'12.43925" E



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

Elevation: 3.883 m Width: Not available m Span (BA3-BA2): 64.780 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	3.883 m	BA3	117.61 m	4.592 m
BA2	52.841 m	4.581 m	BA4	165.509 m	4.067 m

Abutment: Is the abutment sloping? Yes; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available

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

Shape: Oblong Number of Piers: 3 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	70.305	4.701	Not available
Pier 2	85.329	4.72	Not available
Pier 3	100.225	4.725	Not available

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 45. Bridge as-built form of Macalelon Bridge

Water surface elevation of Macalelon River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on January 24, 2017 at 12:45 PM with a value of -1.589 m in MSL as shown in Figure 46. This was translated into marking on the Macalelon Bridge's abutment using the same technique as shown in Figure 46. This will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for Macalelon river, the MAPUA Institute of Technology.

Figure 46. Water-Level Markings on Macalelon Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on August 26, 27, 28, 2016 and January 19 and 25, 2017 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on top of a vehicle as shown in Figure 47. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.787 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 QZ-511, QZN-40, and UP-MAC occupied as the GNSS base stations.

Figure 47. Validation points acquisition survey set up along Macalelon River Basin

The conducted survey on August 26, 2016 started from Brgy. Lakawan, Tayabas City, going north traversing Tayabas City and the Municipality of Mauban. On August 27 and 28, 2016, the survey started in Brgy. Bacong Ilaga, Municipality of General Luna going northwest traversing the Municipalities of General Luna, Macalelon, and Pitogo. The next survey, conducted on January 19 and 25, 2017, started in Brgy. Villa Nava, Municipality of Gumaca going west traversing the Municipalities of Gumaca, Pitogo, Unisan, Agdangan, Padre Burgos, Pagbilao, and Tayabas City. A total of 11,938 points were gathered with approximate length of 97.055 km using QZ-511, QZN-40, UP-MAC as GNSS base stations for the entire extent validation points acquisition survey, as illustrated in the map in Figure 48.

Figure 48. LiDAR validation points acquisition survey for Macalelon River Basin

4.7 Bathymetric Survey

Bathymetric survey was executed on January 24, 2017 using an Ohmex™ single beam echo sounder and Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 49. The survey started in the upstream part of the river in Brgy. Tubigan Ibaba, Municipality of Macalelon with coordinates 13°45'42.26561"N, 122°09'43.58925"E, and ended at the mouth of the river with coordinates 13°44'39.08279"N, 122°07'54.34391"E in Brgy. Pag-Asa, Municipality of Macalelon, Quezon. The control UP-MAC was used as GNSS base station all throughout the entire survey.

Figure 49. Bathymetric survey using Ohmex™ single beam echo sounder in Macalelon River

The bathymetric survey for Macalelon River gathered a total of 9,427 points covering 7.663 km of the river traversing Brgy. Tubigan Ibaba, Municipality of Macalelon, Quezon downstream to Brgy. Pag-Asa in the same Municipality, as shown in Figure 50.

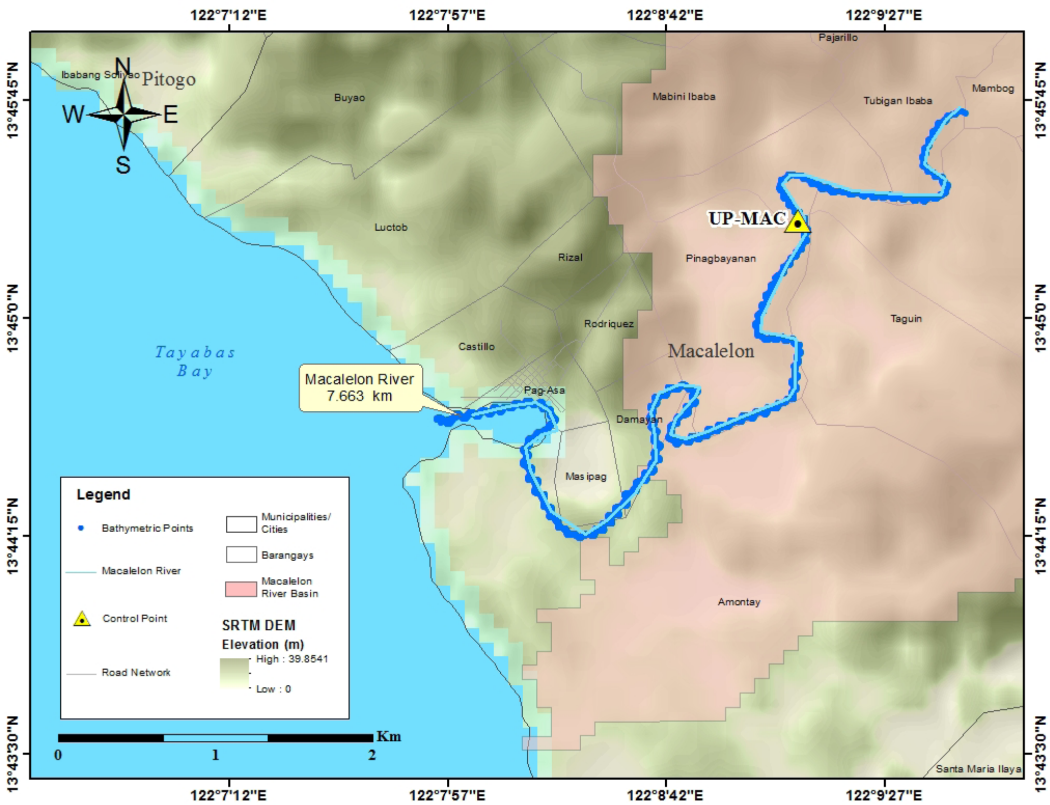


Figure 50. Bathymetric points gathered from Macalelon River

A CAD drawing was also produced to illustrate the riverbed profile of Macalelon River. As shown in Figure 51, the highest and lowest elevation has a 6.722-m difference for Macalelon River. The highest elevation observed was –1.5 m below MSL located at the middle part of Macalelon river; while the lowest was –8.22 m below MSL located in the downstream portion of the river.

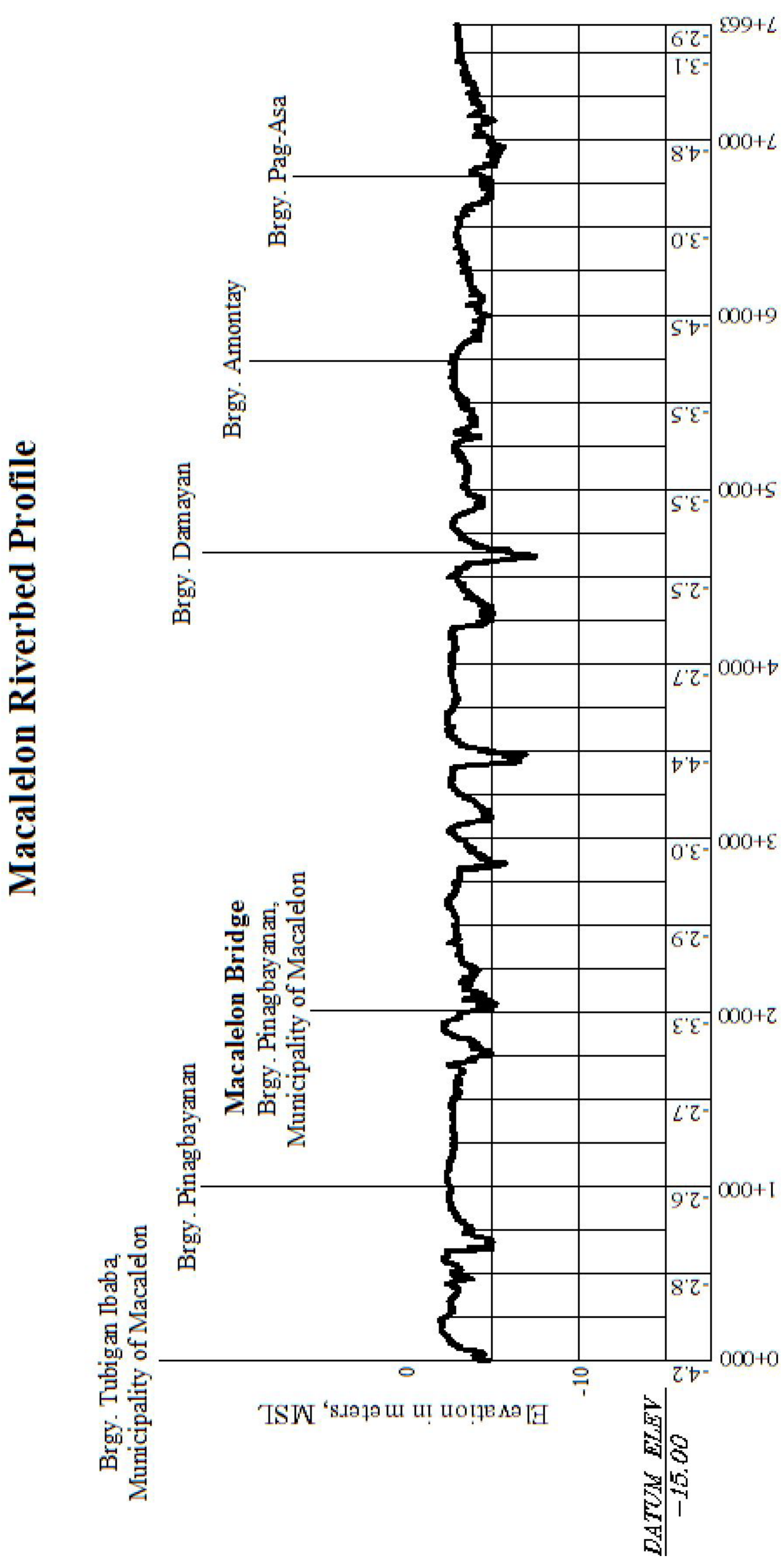


Figure 51. Macalelon riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Pauline Racoma

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

5.1 Data used in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All data that affect the hydrologic cycle of the Macalelon 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 Macalelon River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the Mapua Institute of Technology under the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI) The ARG was installed in a government official property along Gumaca-Pitogo-Mulanay-SanNarciso Road, specifically 13°45’20.12”N, 122° 9’16.22”E as shown in Figure 52.

The precipitation data collection started from October 12, 2016 00:00 am to October 12, 2016 at 23:45 am with a 15-minute recording interval.

The total precipitation for this event in Macalelon ARG was 36mm. It has a peak rainfall of 19 mm on 12 October 2016 at 14:15 pm. The lag time between the peak rainfall and discharge is 4 hours and 55 minutes, as shown in Figure 55.

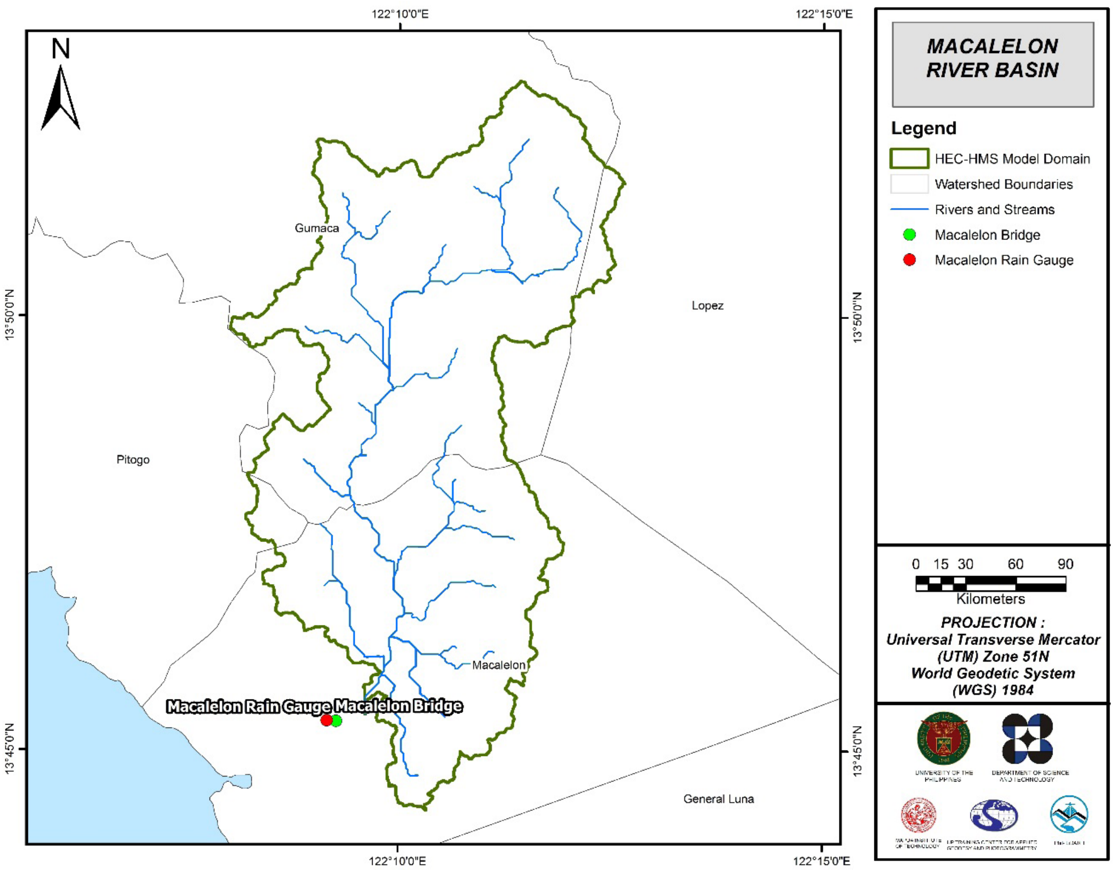


Figure 52. Location map of Macalelon HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Macalelon Bridge, Real, Quezon (13°45'20.58"N, (122° 9'9.62"E). It gives the relationship between the observed water levels from the Macalelon Bridge using depth gage and outflow of the watershed recorded using the flow meter at this location.

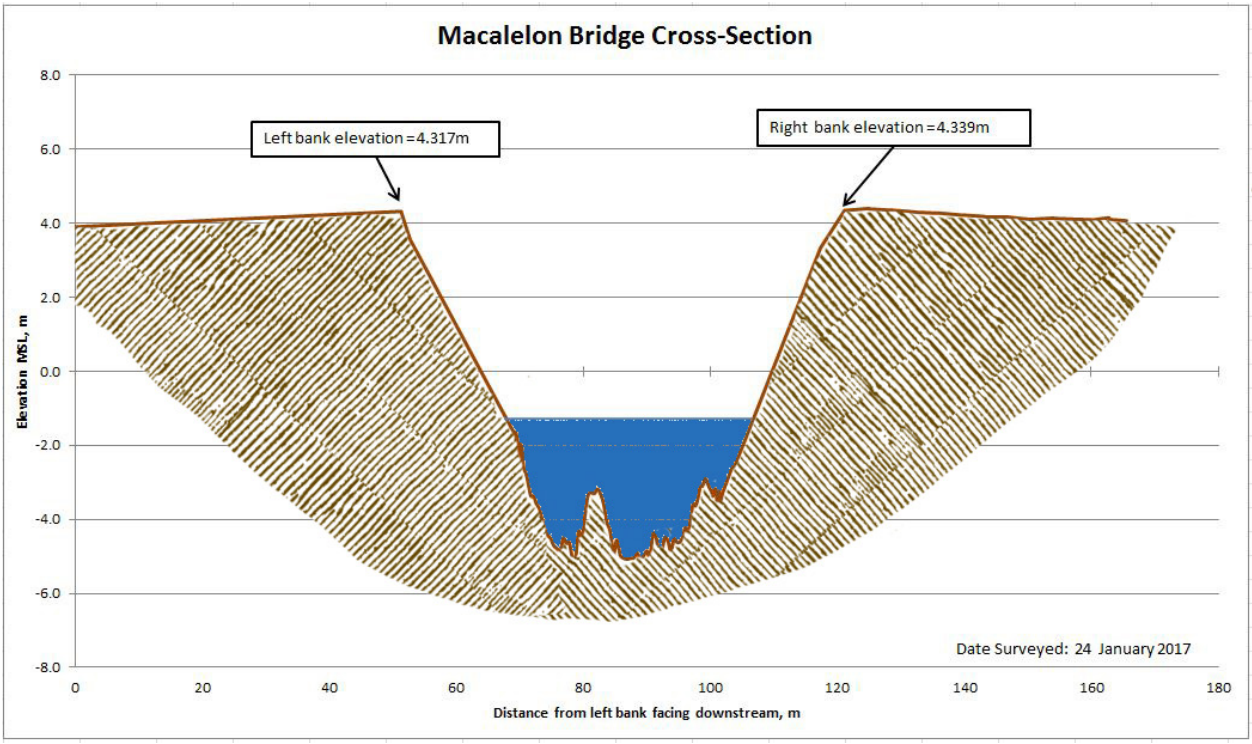


Figure 53. Cross-Section Plot of Macalelon Bridge

For Macalelon Bridge, the rating curve is expressed as Q = 63784e4.1143h as shown in Figure 54.

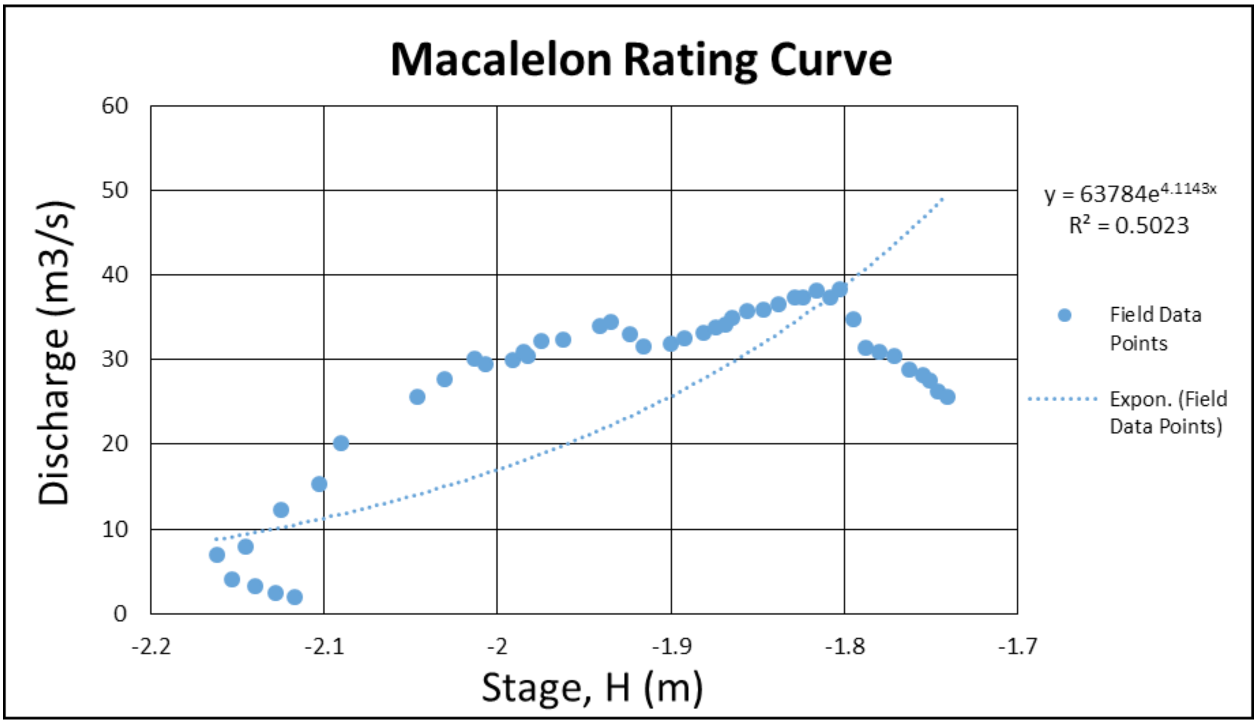


Figure 54. Rating curve at Macalelon Bridge, Real, Quezon

This rating curve equation was used to compute the river outflow at Macalelon Bridge for the calibration of the HEC-HMS model shown in Figure 55. Peak discharge is 38.31 m3/s at 07:10 am, October 12, 2016.

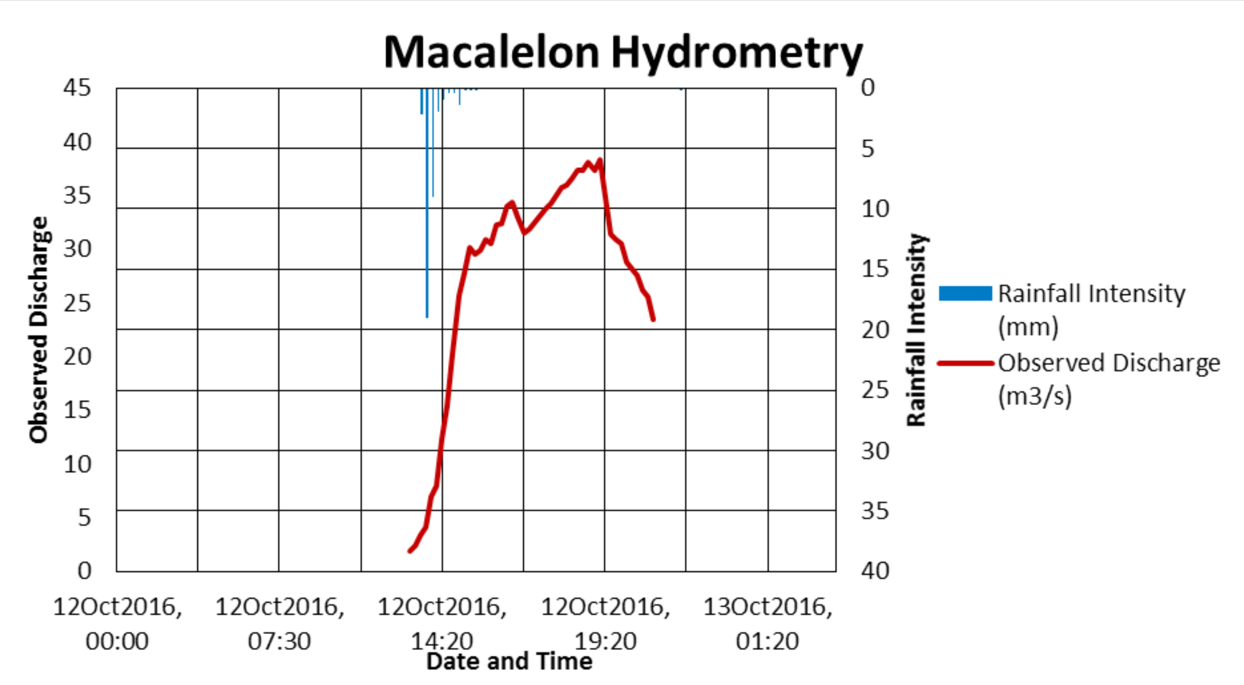


Figure 55. Rainflow and outflow data at Macalelon River used for modeling

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 value in such a way certain peak value will be attained at a certain time. This station is chosen based on its proximity to the Macalelon watershed. The extreme values for this watershed were computed based on a 31-year record, as shown in Table 29.

Table 29. 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

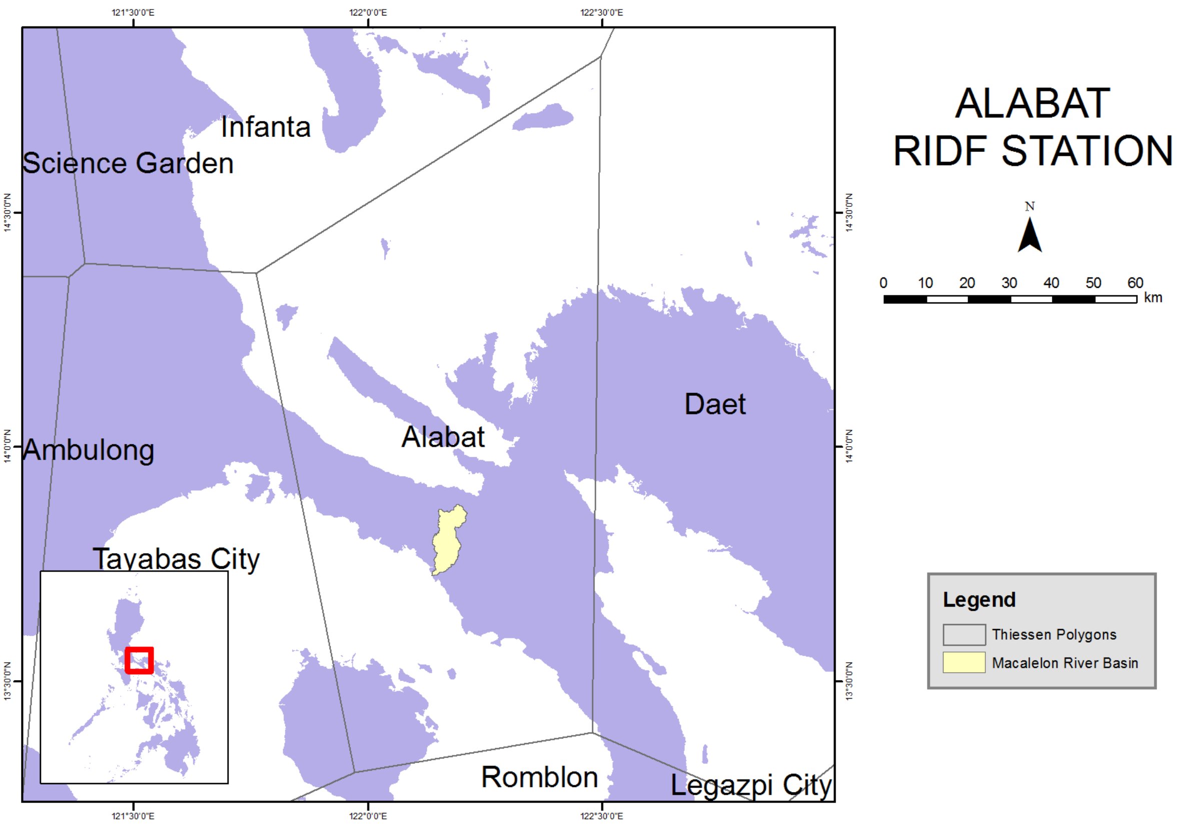


Figure 56. Romblon RIDF location relative to Macalelon River Basin

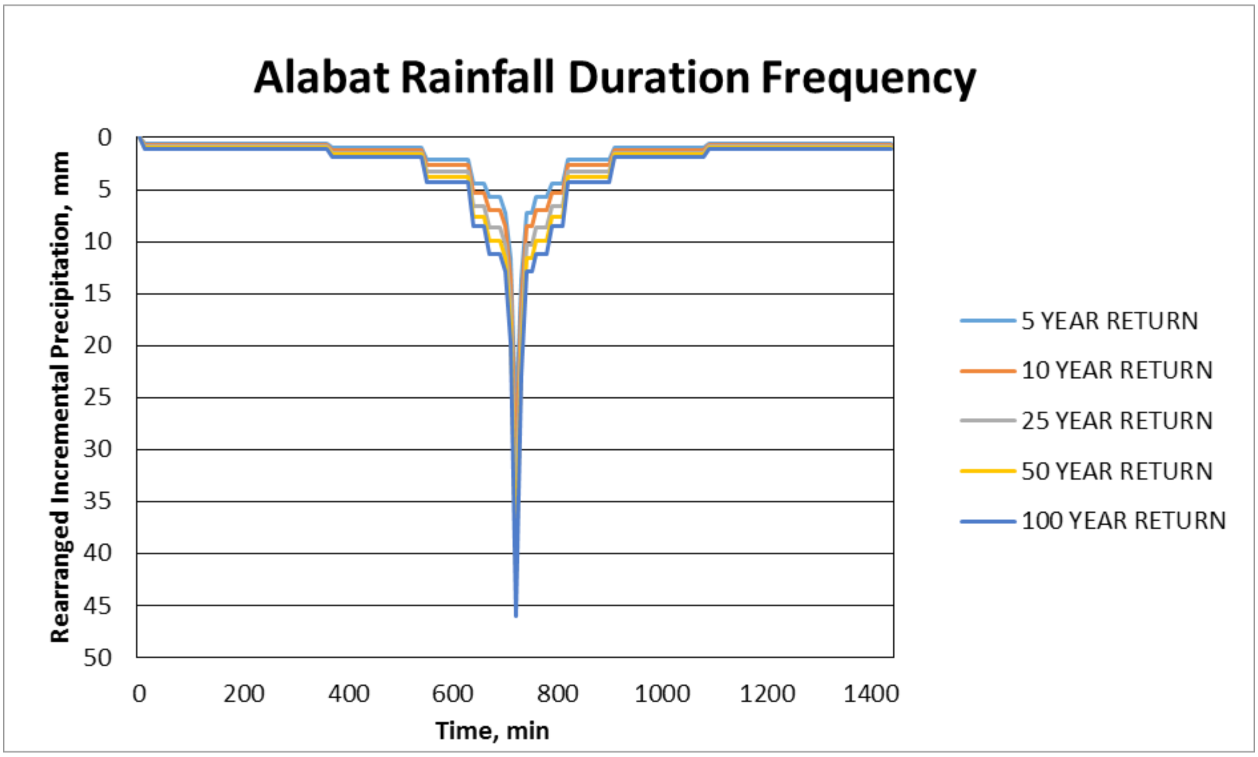


Figure 57. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soil and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Macalelon River Basin are shown in Figure 58 and Figure 59, respectively.

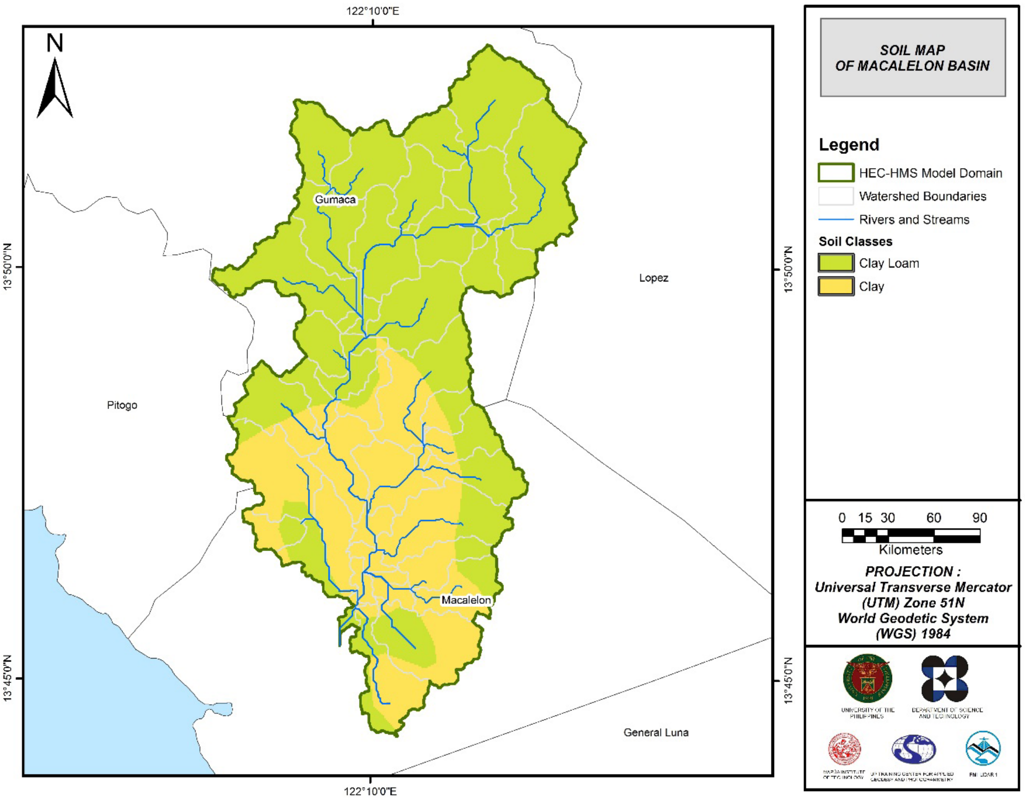


Figure 58. Soil map of the Macalelon River Basin

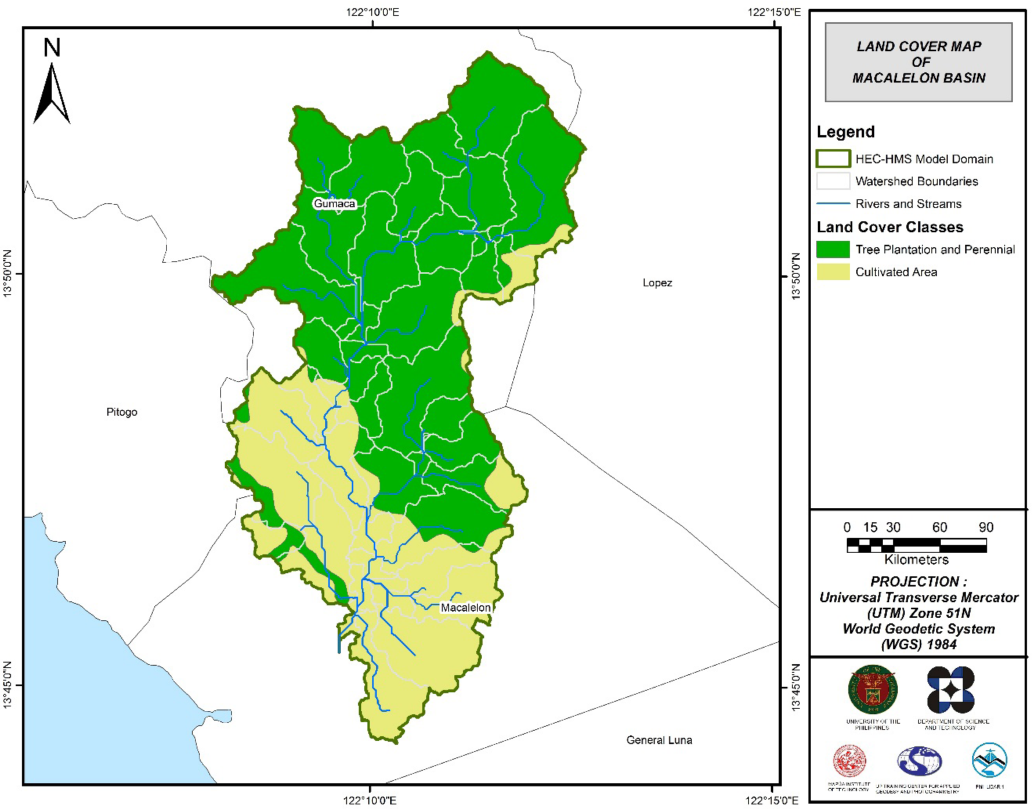


Figure 59. Land cover map of Macalelon River Basin

For Macalelon, the two (2) soil classes identified were clay loam and clay. The two (2) land cover types identified were tree plantations and cultivated areas.

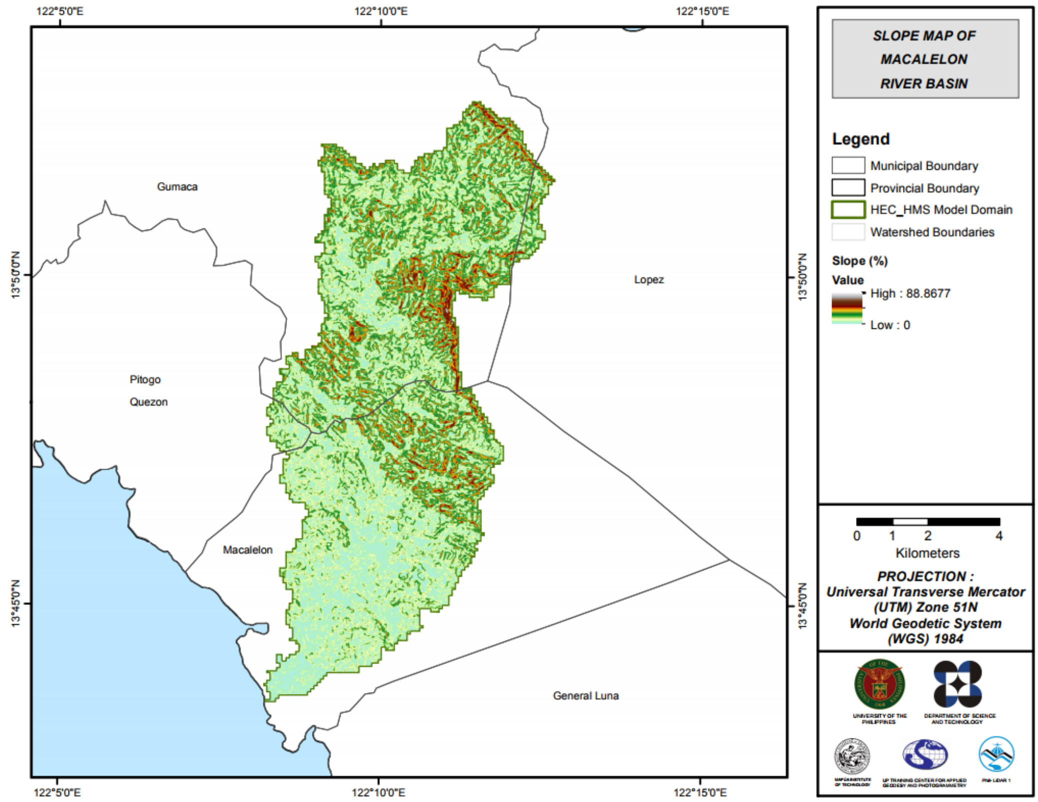


Figure 60. Slope map of Macalelon River Basin

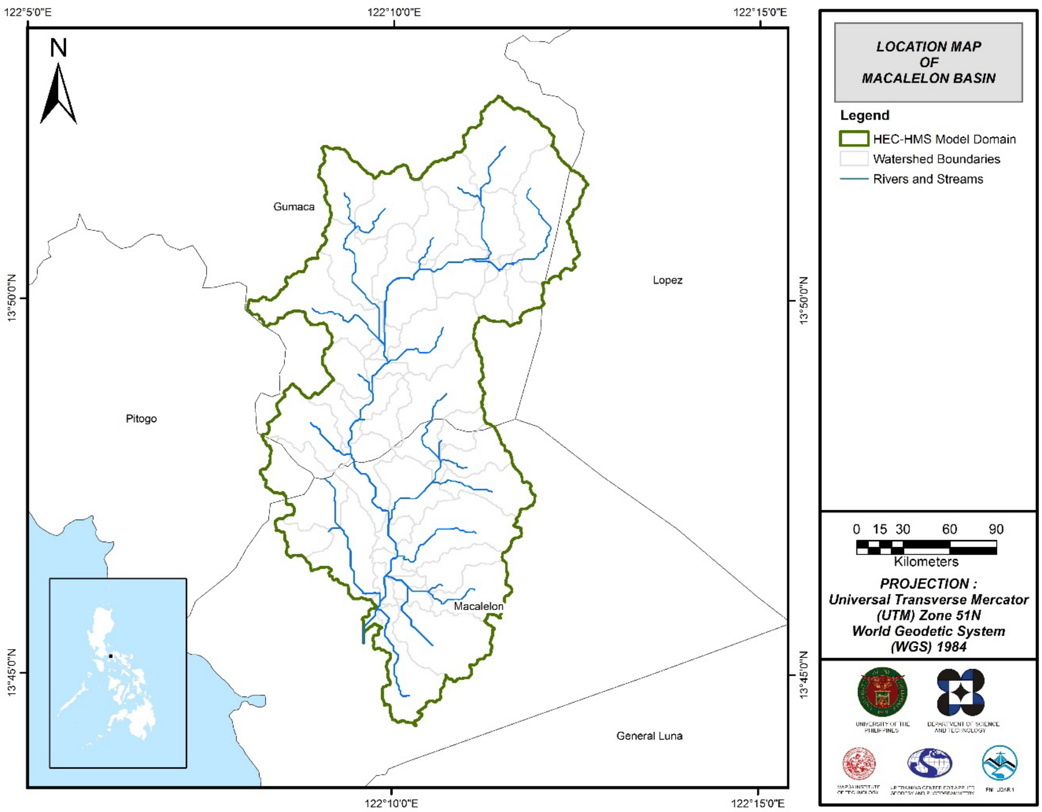


Figure 61. Stream delineation map of Macalelon River Basin

The Macalelon basin model consists of 17 sub basins, 8 reaches, and 8 junctions. The main outlet is at the easternmost tip of the watershed. This basin model is illustrated in Figure 62. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from DOST rain gauges. Finally, it was calibrated using data from the Macalelon Bridge.

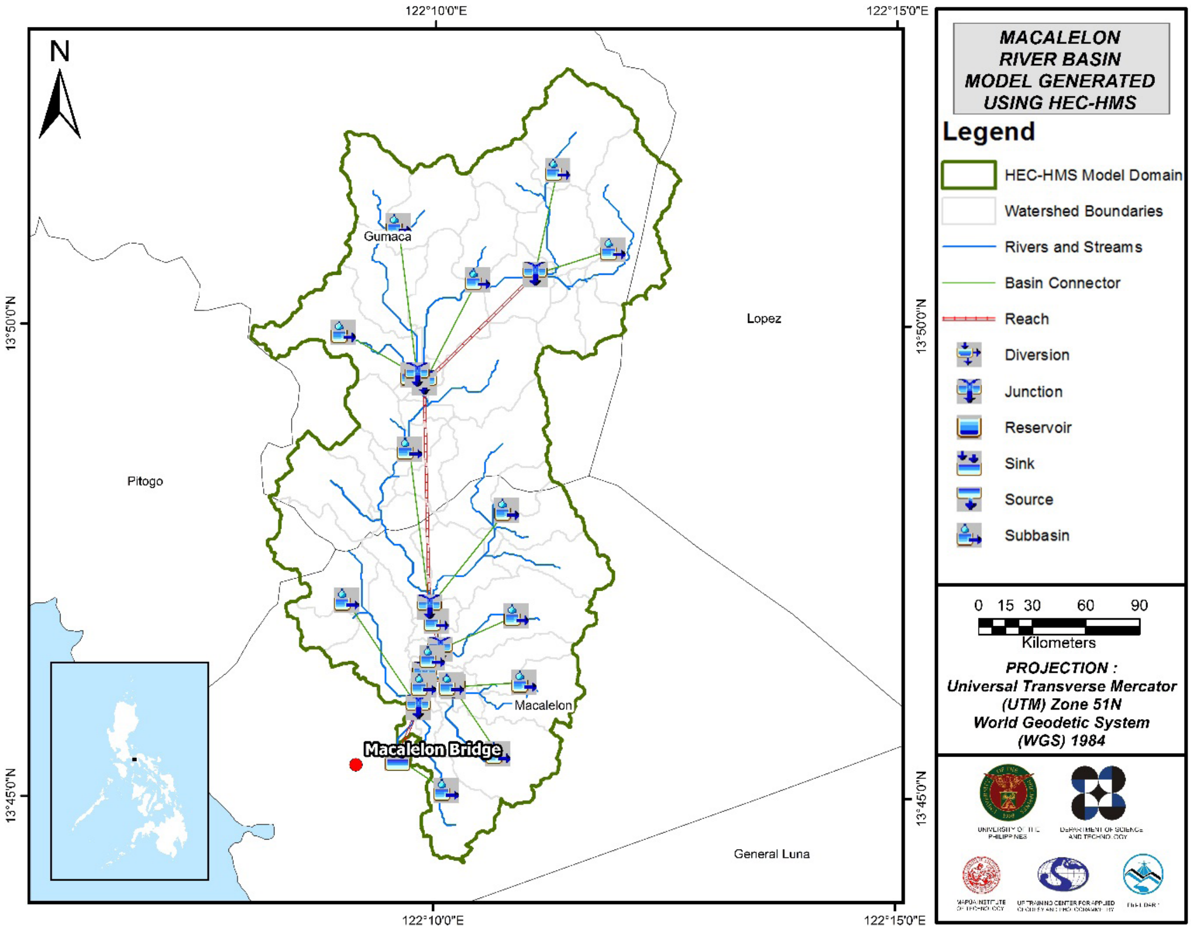


Figure 62. HEC-HMS generated Macalelon River Basin Model.

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. This is illustrated in Figure 63.

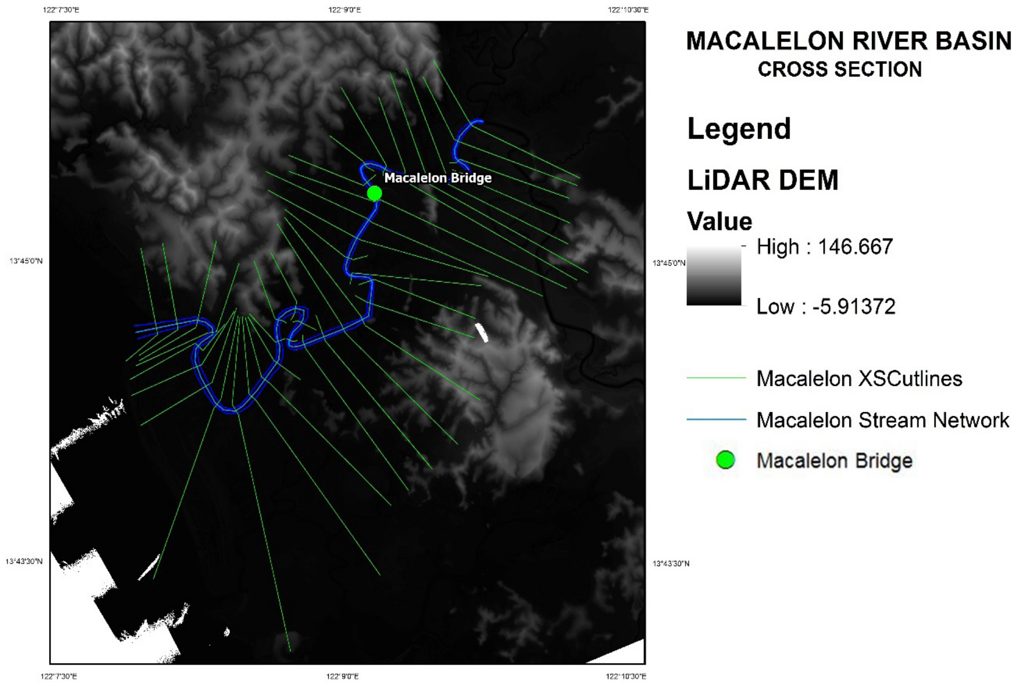


Figure 63. River cross-section of Macalelon River generated through Arcmap HEC GeoRAS tool

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

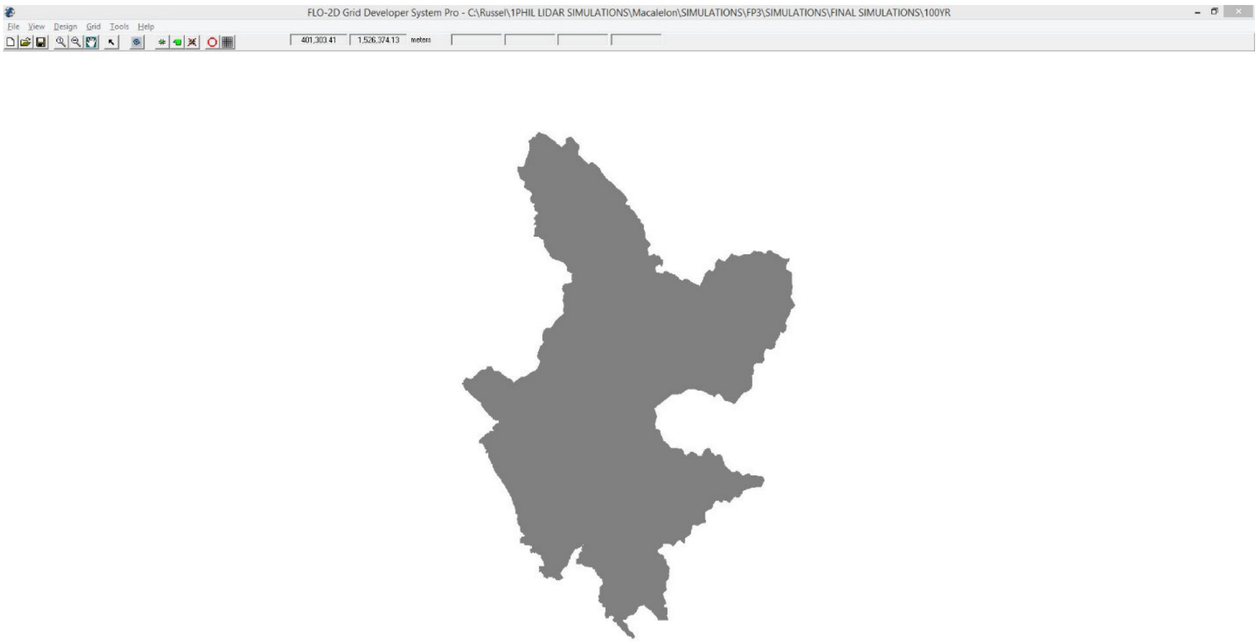


Figure 64. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 46.95752 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.

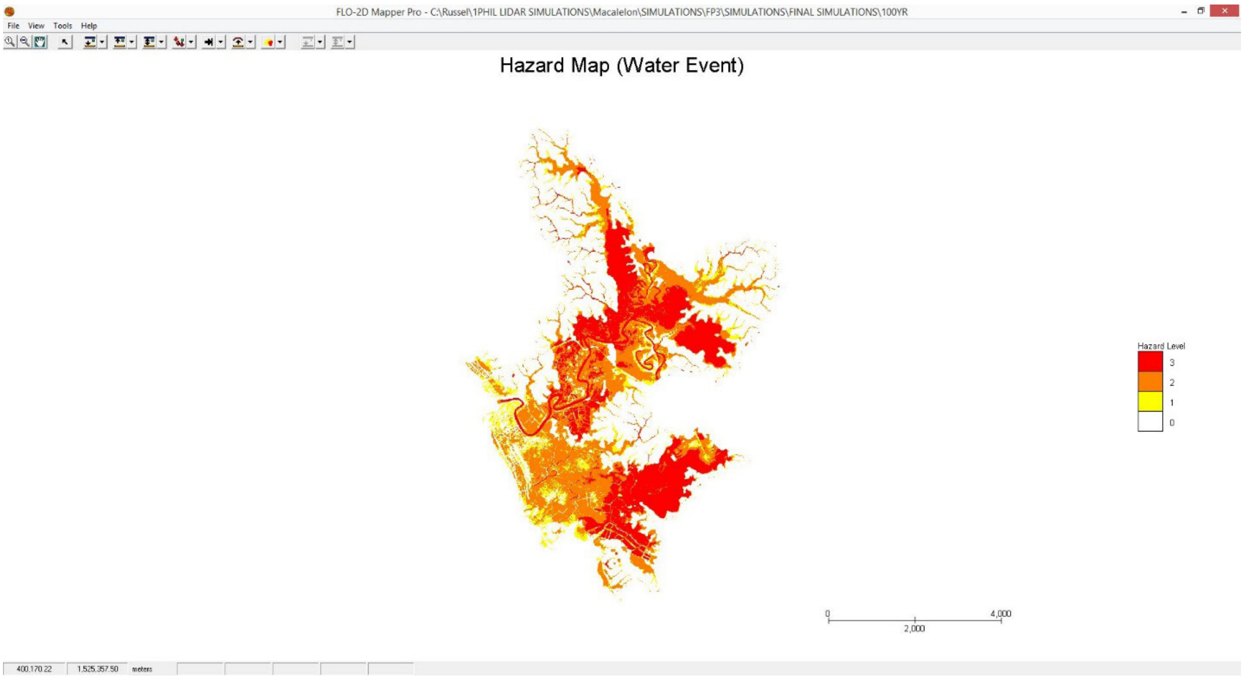


Figure 65. Generated 100-year Rain Return Hazard Map from FLO-2D Mapper

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 38 016 700.00 m2.

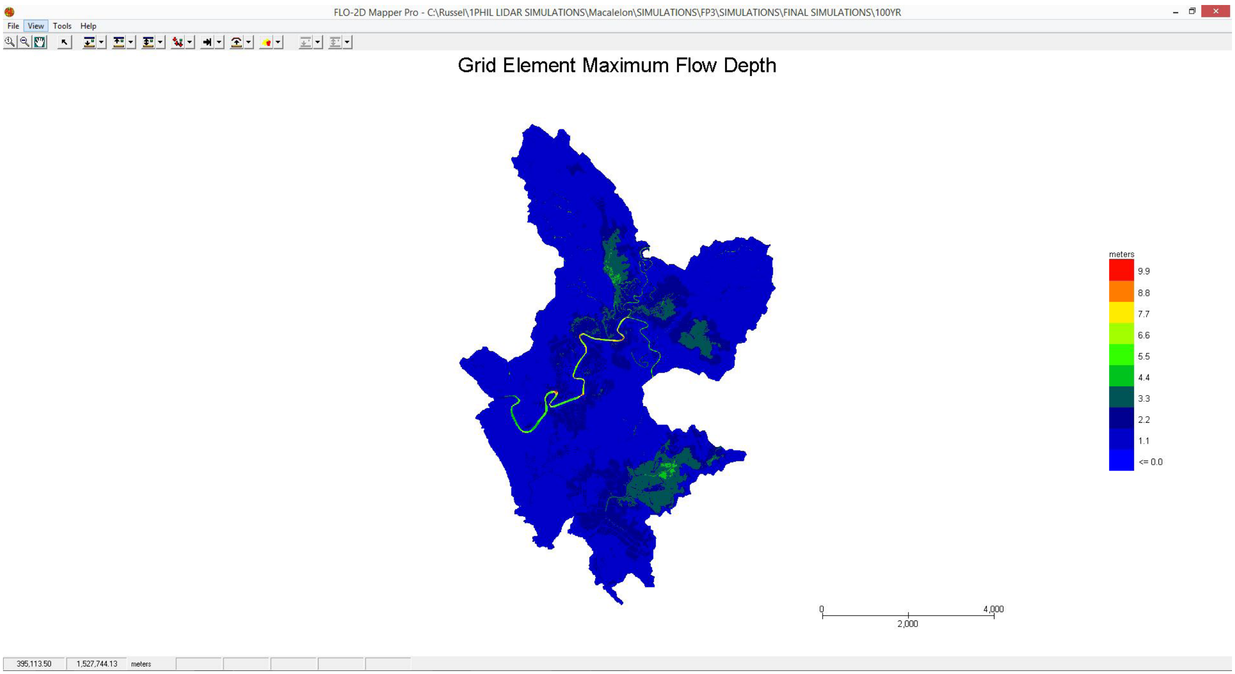


Figure 66. Generated 100-year Rain Return Flow Depth Map from FLO-2D Mapper

There is a total of 40 651 505.85 m3 of water entering the model. Of this amount, 16 370 246.67 m3 is due to rainfall while 24 281 259.18 m3 is inflow from other areas outside the model. 6 802 629.50 m3 of this water is lost to infiltration and interception, while 19 374 124.16 m3 is stored by the flood plain. The rest, amounting up to 14 474 758.55 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Macalelon HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 67 shows the comparison between the two discharge data.

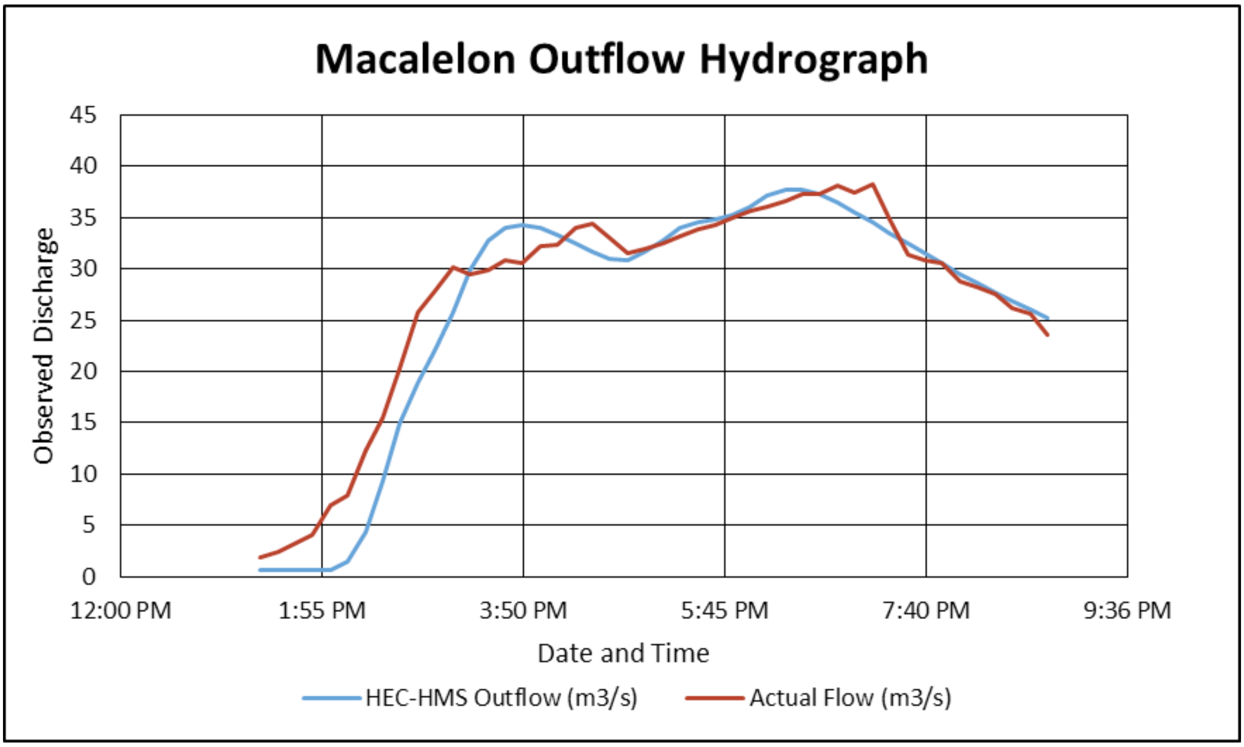


Figure 67. Outflow Hydrograph of Macalelon produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 30 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of Calibrated Values for Macalelon

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.12 – 1.87
			Curve Number	83 - 89
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.018 – 0.073
			Storage Coefficient (hr)	0.88 – 5.78
	Baseflow	Recession	Recession Constant	0.01
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0043 – 0.16

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 1.12mm to 1.87mm means that there is a minimal 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. This basin's curve number ranges from 83 to 89. For Macalelon, the soil classes identified were clay loam and clay. The land cover types identified were tree plantations and cultivated areas.
Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.018 hours to 5.78 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 Recession Constant for this basin is 0.01 and the Ratio to Peak is 0.5. These values influence the characteristics of the receding limb of the outflow hydrograph, which could be described as moderately likely to return to its original discharge values in a short time.

The Manning's roughness coefficient ranges from 0.0043 to 0.16 corresponds to the common roughness in Macalelon watershed. (Brunner, 2010).

Table 31. Summary of the Efficiency Test of Macalelon HMS Model

Accuracy measure	Value
RMSE	3
r2	0.96
NSE	0.92
PBIAS	4.09
RSR	0.29

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 3 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.96.

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 0.92.

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 4.09.

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 0.29.

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 68) shows the Macalelon 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 (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

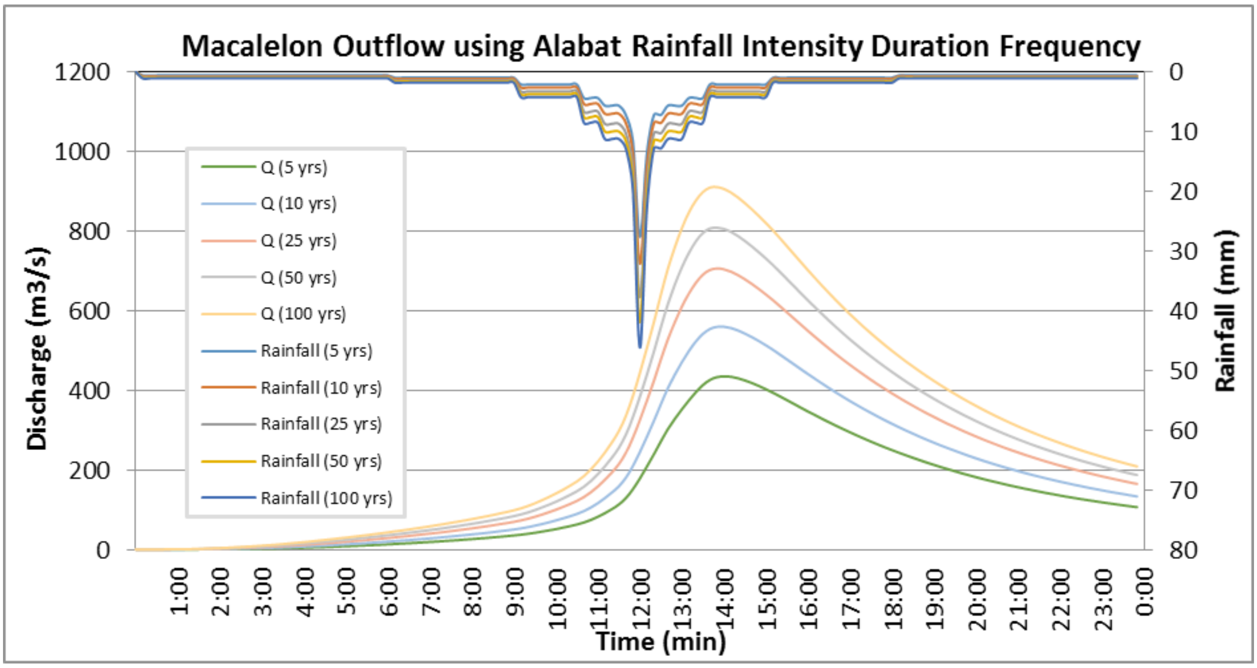


Figure 68. Outflow hydrograph at Macalelon Station generated using Romblon RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Macalelon discharge using the Alabat Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 32.

Table 32. Peak values of the Macalelon 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	436.1	14 hours, 0 minutes
10-Year	303.9	32.1	560.5	14 hours, 0 minutes
25-Year	369.6	37.7	706.8	13 hours, 50 minutes
50-Year	418.4	41.9	809.2	13 hours, 50 minutes
100-Year	466.7	46.1	910.9	13 hours, 50 minutes

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Macalelon River using the calibrated HMS event flow with 50-year rain return scenario is shown in Figure 64.

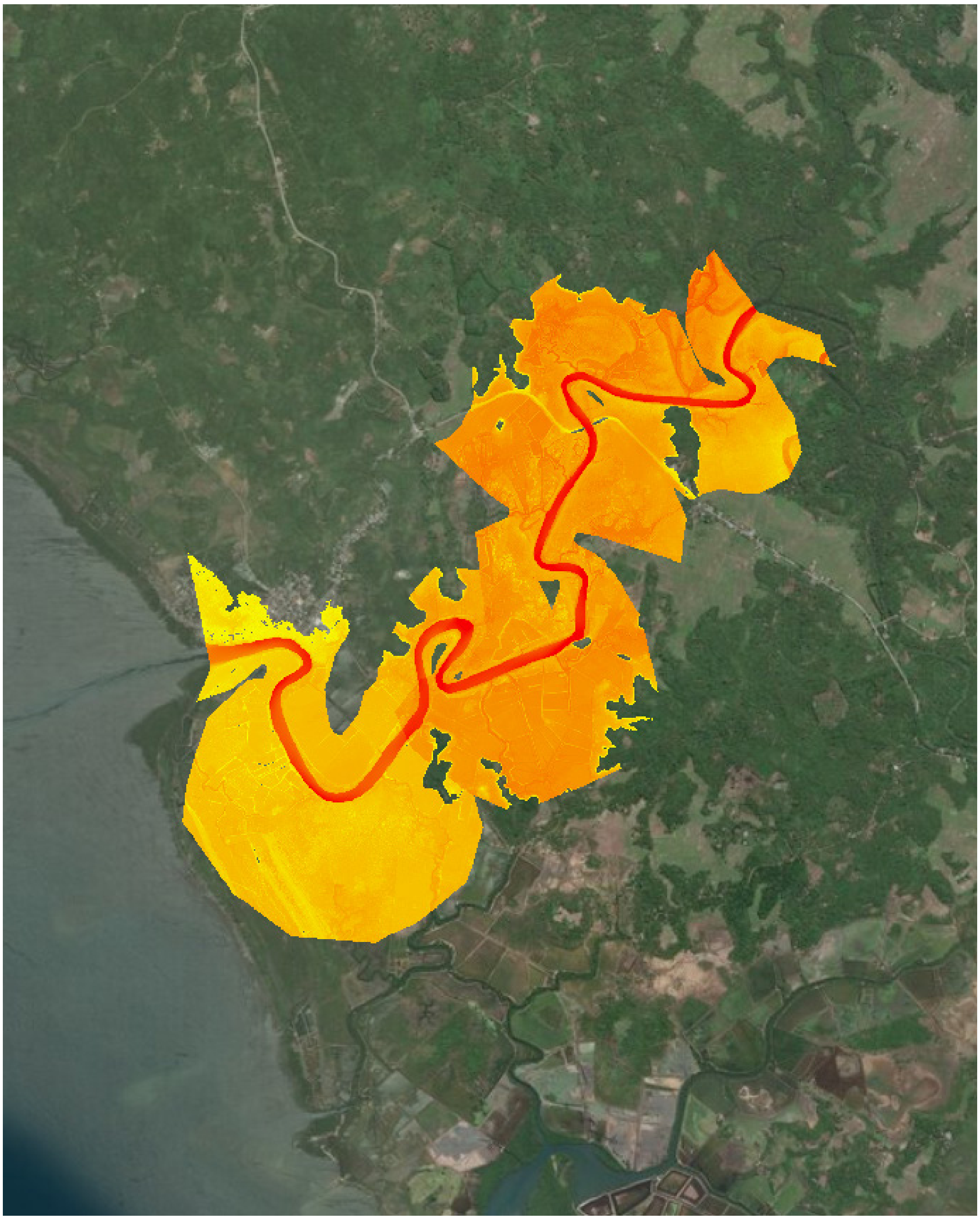


Figure 69. Sample output of Macalelon RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 70 to Figure 75 shows the 5-, 25-, and 100-year rain return scenarios of the Macalelon floodplain. Table 33 shows the municipalities affected in Macalelon Floodplain.

Table 33. Municipalities affected in Macalelon Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
General Luna	119.16	22.25	18.67%
Gumaca	199.62	19.20	18.98%
Lopez	378.81	5.98	1.58%
Macalelon	81.75	58.75	71.86%
Pitogo	72.29	1.13	1.56%

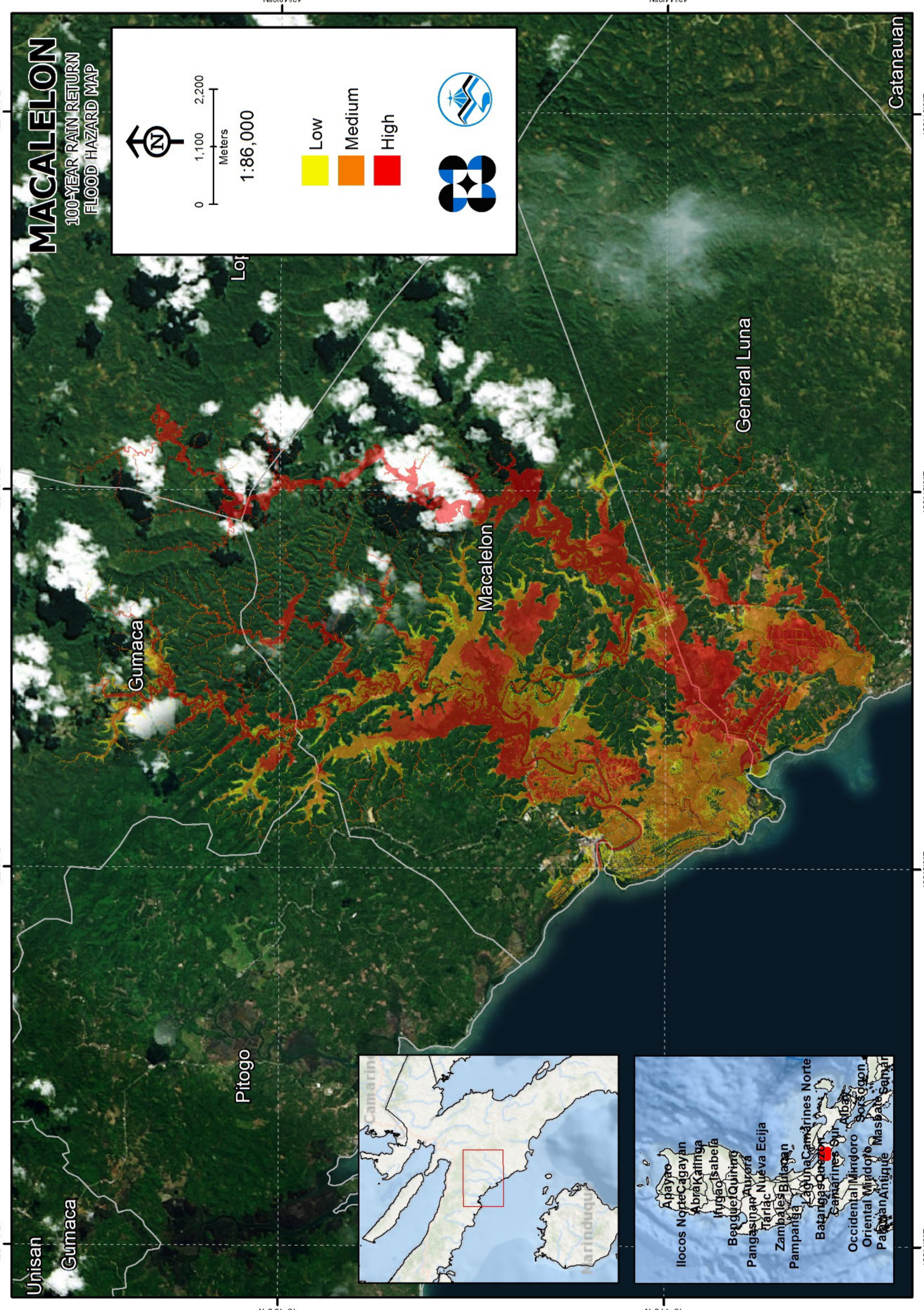


Figure 70. 100-year Flood Hazard Map for Macalelon Floodplain overlaid on Google Earth imagery

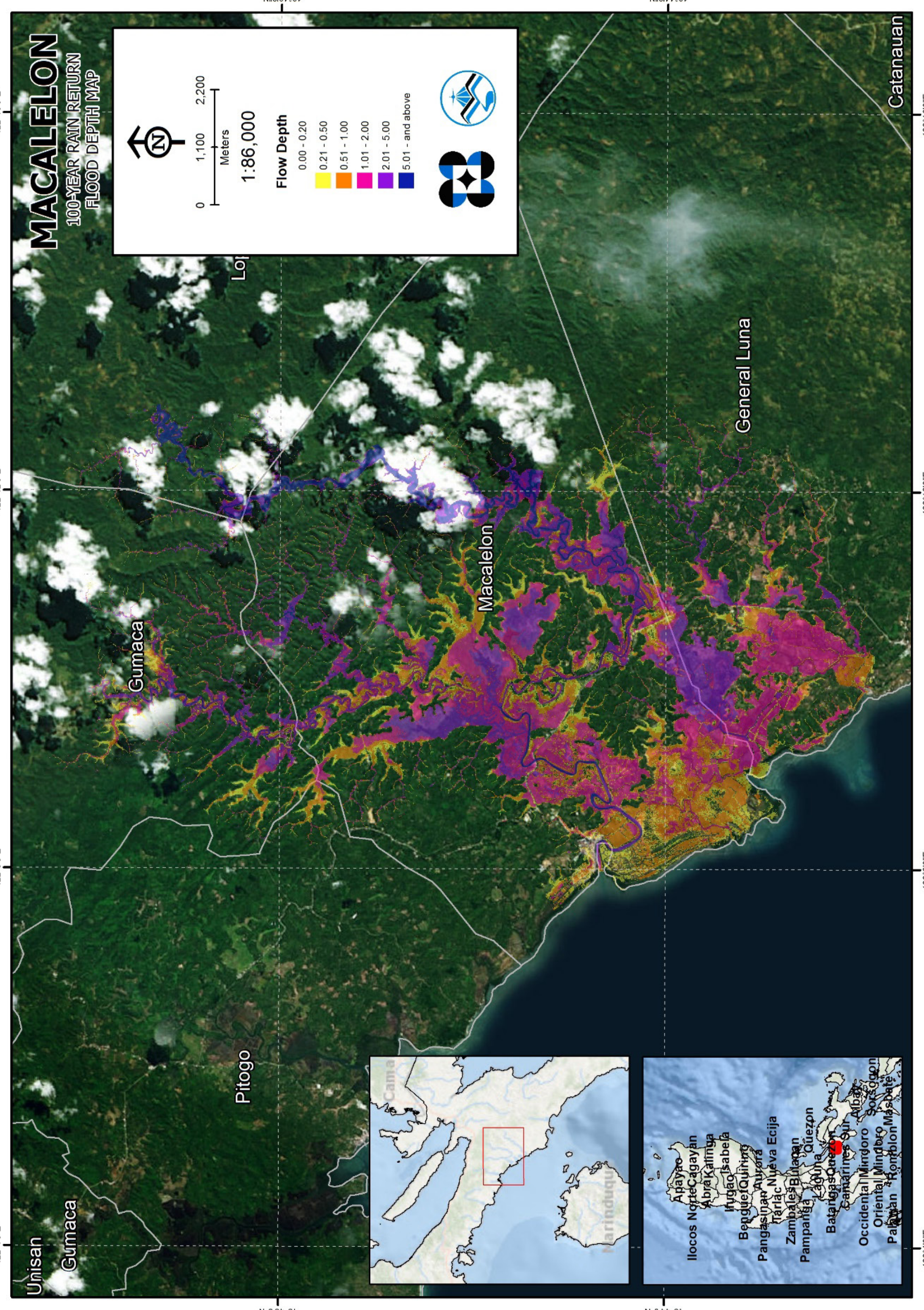


Figure 71. 100-year Flow Depth Map for Macalelon Floodplain overlaid on Google Earth imagery

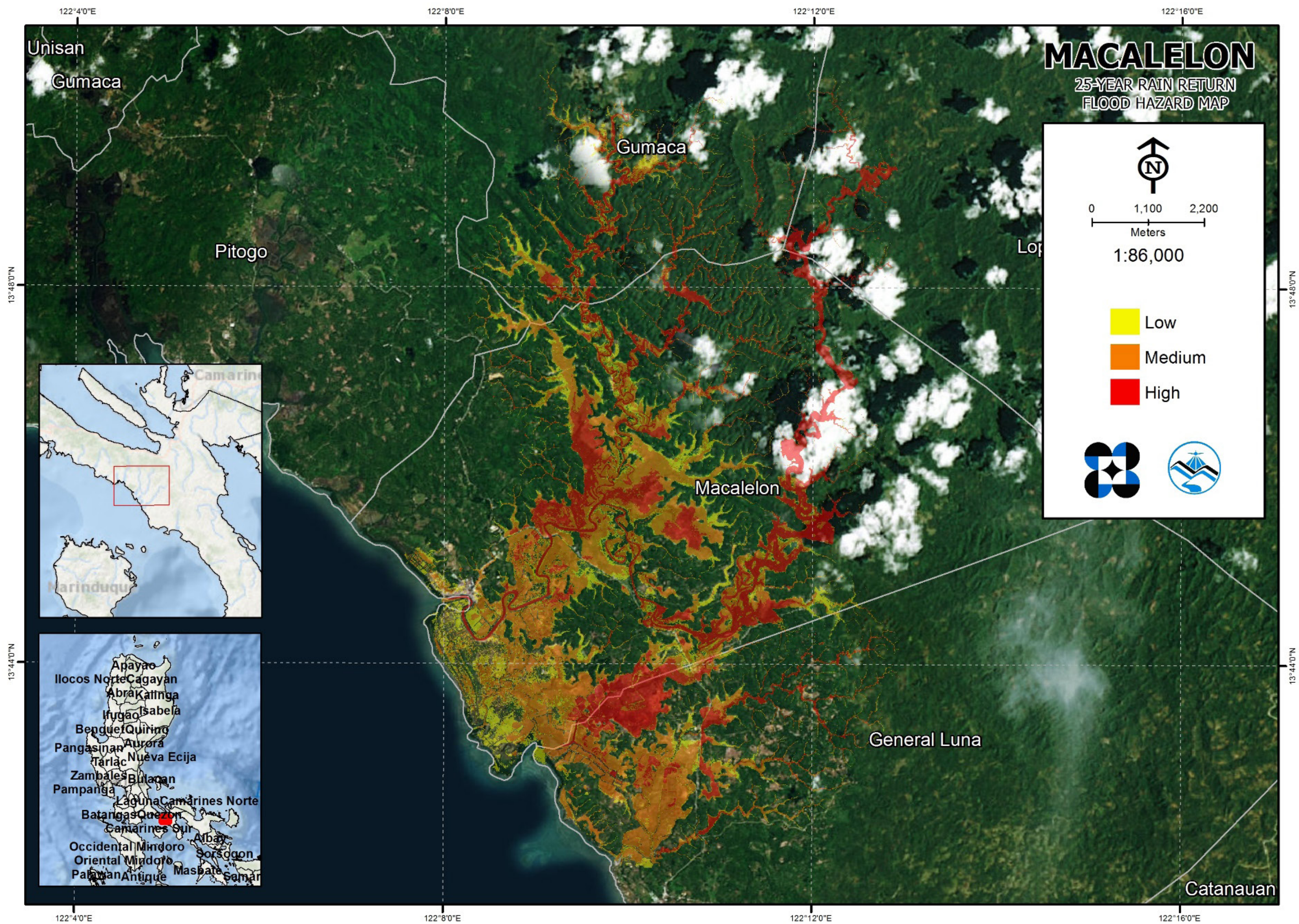


Figure 72. 25-year Flood Hazard Map for Macalelon Floodplain overlaid on Google Earth imagery

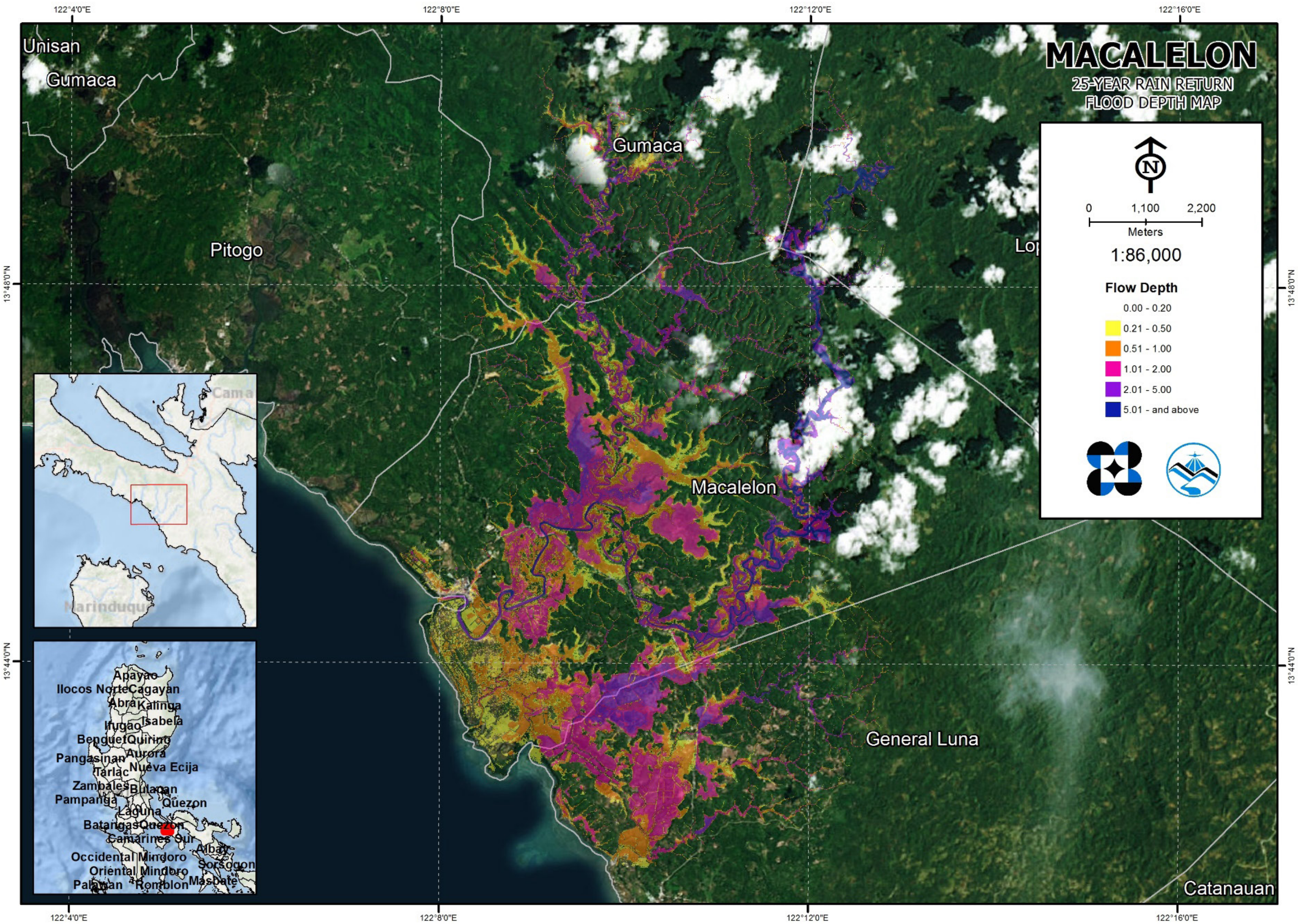


Figure 73. 25-year Flow Depth Map for Macalelon Floodplain overlaid on Google Earth imagery

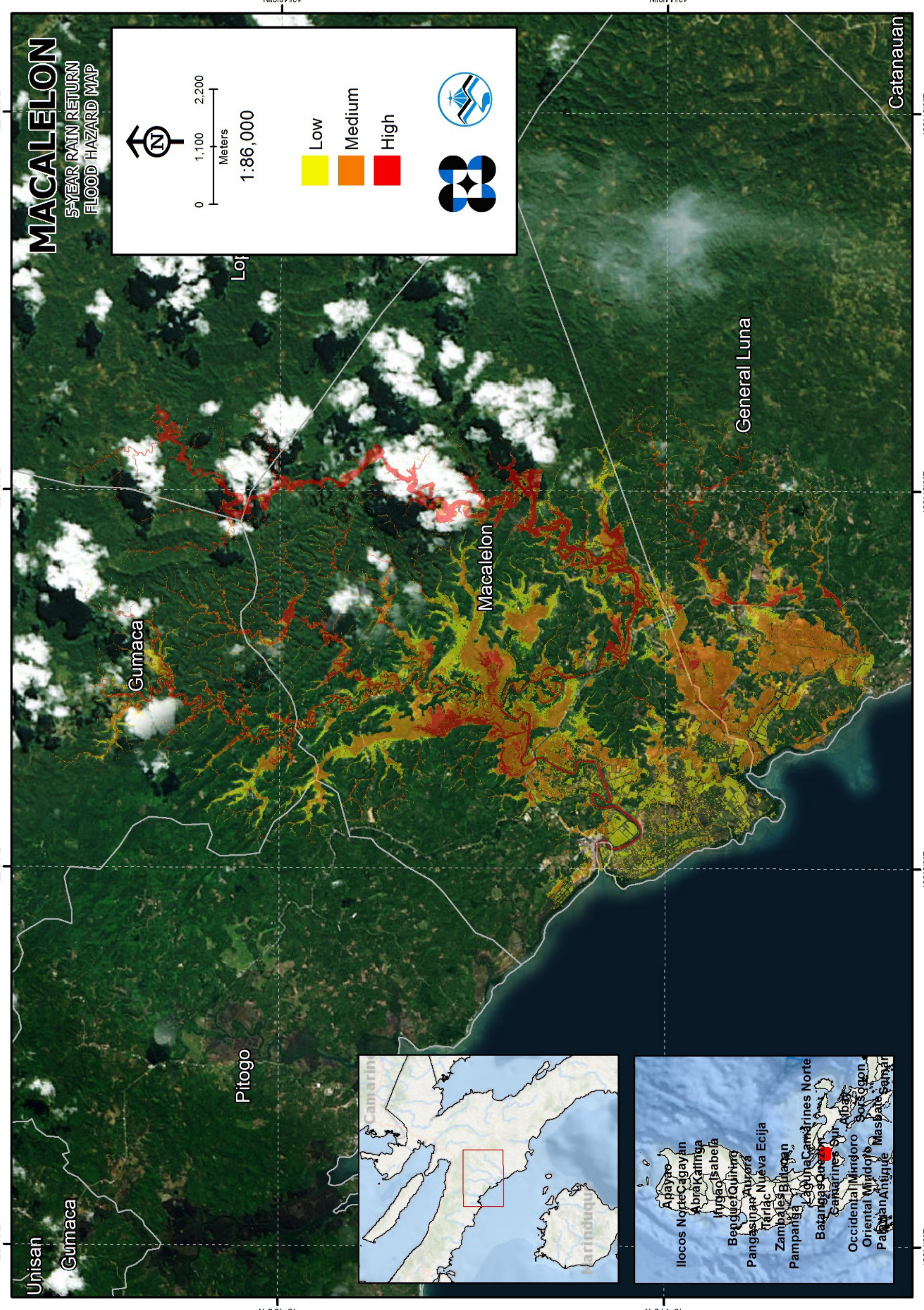


Figure 74. 5-year Flood Hazard Map for Macalelon Floodplain overlaid on Google Earth imagery

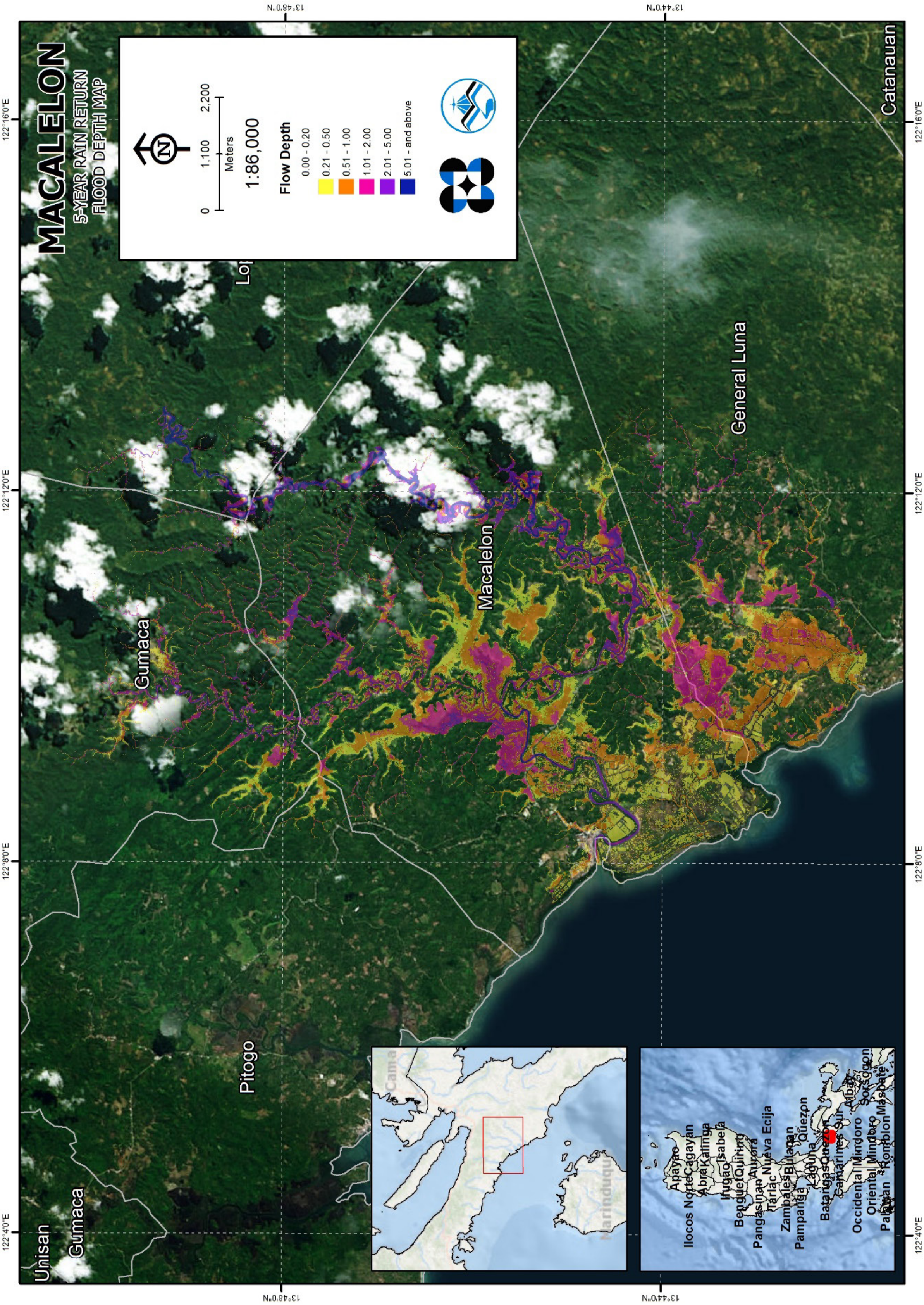


Figure 75. 5-year Flood Depth Map for Macalelon Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Macalelon River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of 42 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 13.33% of the municipality of General Luna with an area of 119.16 sq. km. will experience flood levels of less than 0.20 meters. 1.33% of the area will experience flood levels of 0.21 to 0.50 meters while 2.42%, 1.42%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 34 and shown in Figure 76 are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Alabel, Sarangani during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Luna (in sq. km)						
	Barangay 8	San Ignacio Ibaba	San Ignacio Ilaya	San Jose	Santa Maria Ibaba	Santa Maria Ilaya	Sumilang
0.03-0.20	0.0091	0.22	10.13	1.23	1.86	1.69	0.75
0.21-0.50	0	0.16	0.42	0.15	0.45	0.39	0.013
0.51-1.00	0	0.54	0.44	0.42	0.5	0.97	0.012
1.01-2.00	0	0.16	0.38	0.14	0.054	0.95	0.0091
2.01-5.00	0	0.0016	0.14	0.027	0.0002	0.015	0.0011
> 5.00	0	0	0.0042	0.0002	0	0	0

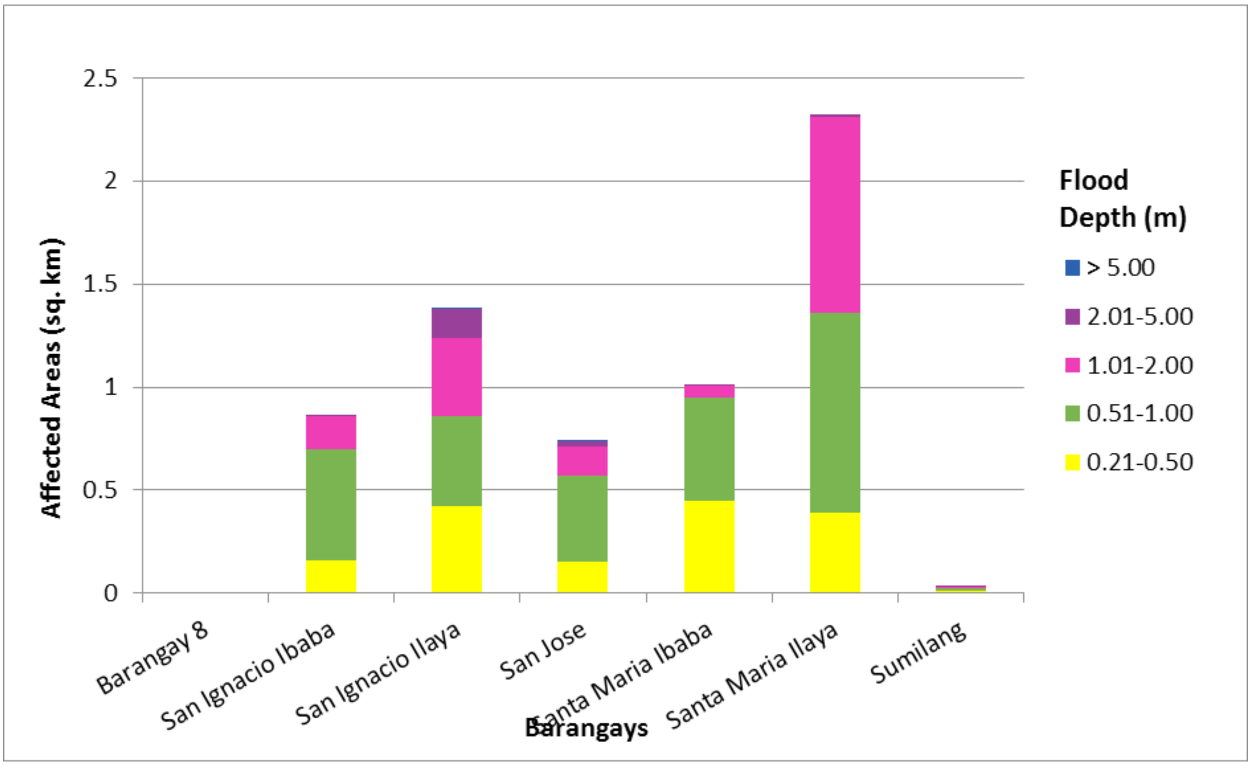


Figure 76. Affected areas in General Luna, Quezon during a 5-Year Rainfall Return Period.

For the 5-year return period, 8.25% of the municipality of Gumaca with an area of 199.62 sq. km. will experience flood levels of less than 0.20 meters. 0.41% of the area will experience flood levels of 0.21 to 0.50 meters while 0.33%, 0.32%, 0.19%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 and shown in Figure 77 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Gumaca, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gumaca (in sq. km)			
	Anonangin	Bantad	Cawayan	Gayagayaan
0.03-0.20	6.13	1.2	0.0095	9.12
0.21-0.50	0.42	0.11	0	0.29
0.51-1.00	0.35	0.082	0	0.23
1.01-2.00	0.34	0.064	0	0.23
2.01-5.00	0.23	0.03	0	0.12
> 5.00	0.045	0.00082	0	0.0032

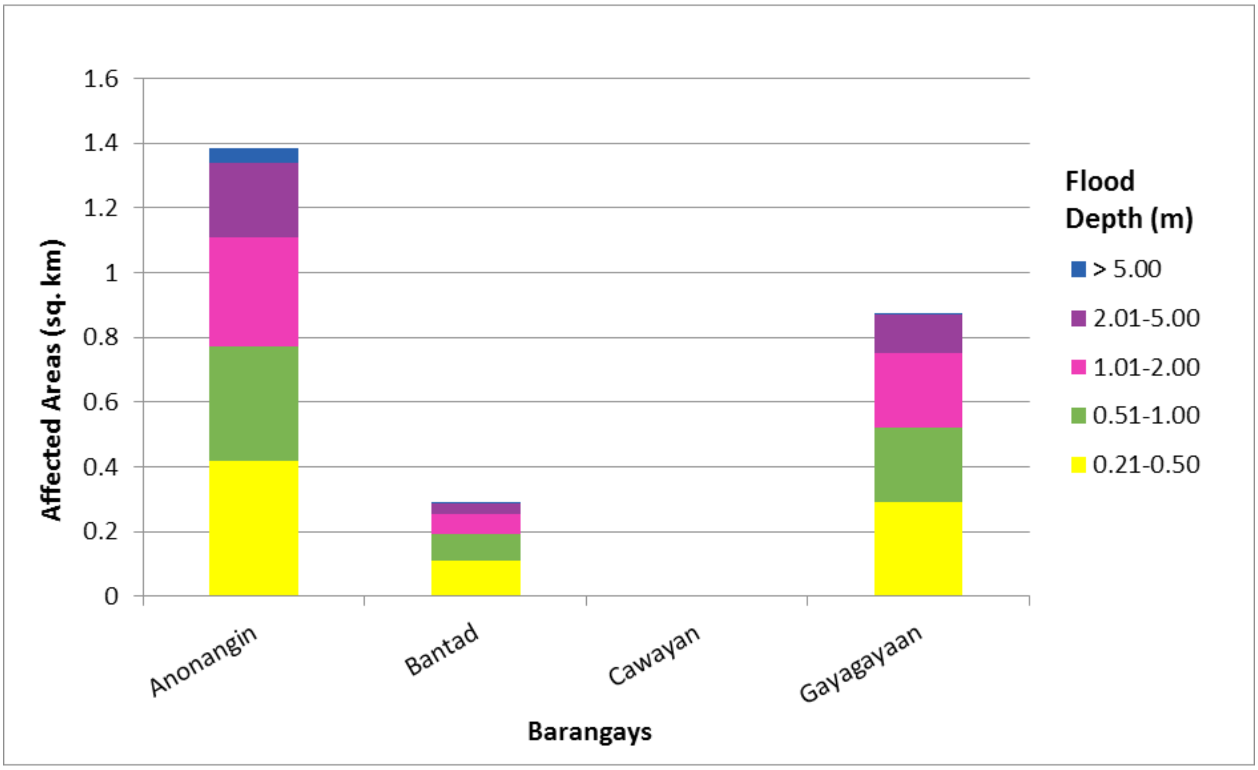


Figure 77. Affected areas in Gumaca, Quezon for a 5-Year Return Period rainfall event.

For the 5-year return period, 1.39% of the municipality of Lopez with an area of 378.81 sq. km. will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.03%, 0.05%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 and shown in Figure 78 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km)			
	Ilayang Ilog A	Mabini	Santa Elena	Villanacaob
0.03-0.20	1.43	0.65	3.15	0.053
0.21-0.50	0.022	0.0095	0.06	0.0003
0.51-1.00	0.0079	0.0071	0.056	0.0003
1.01-2.00	0.012	0.0079	0.1	0.0004
2.01-5.00	0.016	0.0062	0.15	0.00011
> 5.00	0.0048	0	0.22	0

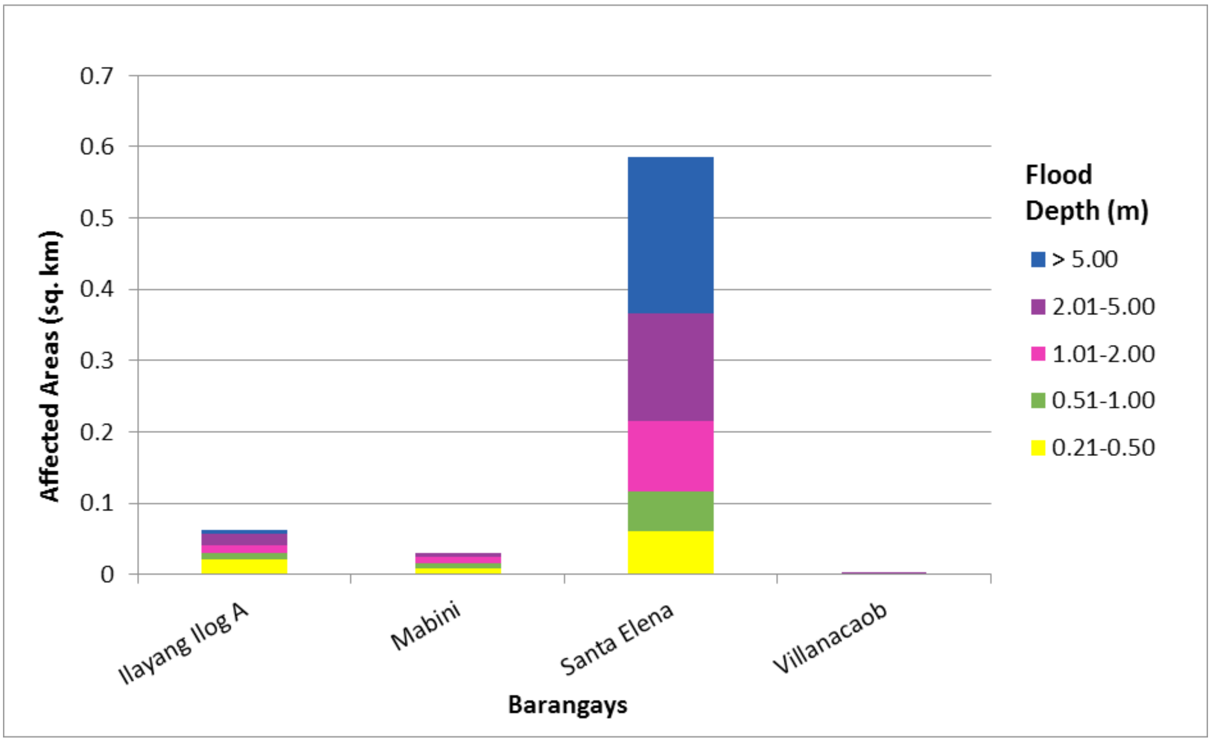


Figure 78. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period.

For the 5-year return period, 49.15% of the municipality of Macalelon with an area of 81.75 sq. km. will experience flood levels of less than 0.20 meters. 7.91% of the area will experience flood levels of 0.21 to 0.50 meters while 6.67%, 4.61%, 2.53%, and 0.99% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and Table 38, and shown in Figure 79 and Figure 80 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Macalelon, Quezon by flood level for a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Macalelon (in sq. km)												
	Amon-tay	Anos	Calantas	Candangal	Castillo	Damayan	Lahing	Luctob	Mabini Ibaba	Mabini Ilaya	Mambog	Masipag	Olongtao Ibaba
0.03-0.20	5.24	1.08	1.59	2.51	0.37	0.18	3.22	0.38	0.88	0.27	1.46	0.057	2.92
0.21-0.50	2.04	0.27	0.071	0.36	0.052	0.046	0.19	0.065	0.045	0.0088	0.46	0.15	0.47
0.51-1.00	0.94	0.32	0.049	0.27	0.034	0.021	0.23	0.031	0.035	0.0082	0.38	0.019	0.39
1.01-2.00	0.26	0.1	0.038	0.35	0.0036	0.0014	0.17	0.0034	0.054	0.0062	0.42	0.0001	0.34
2.01-5.00	0.058	0.0052	0.011	0.33	0.0013	0.035	0.058	0	0.011	0.0017	0.056	0.0075	0.26
> 5.00	0.0029	0	0	0.1	0	0.000019	0.0004	0	0	0	0.000095	0	0.082

Table 38. . Affected areas in Macalelon, Quezon by flood level for a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Macalelon (in sq. km)												
	Olongtao Ilaya	Padre Herre-ra	Pag-Asa	Pajarillo	Pinag-bayanan	Rizal	Ro-driquez	San Isidro	San Nico-las	Taguin	Tubigan Ibaba	Tubigan Ilaya	Vista Hermosa
0.03-0.20	0.0009	5.86	0.14	0.51	0.77	0.18	0.32	3.32	1.86	1.86	0.26	0.44	4.5
0.21-0.50	0	0.24	0.033	0.011	0.28	0.005	0.021	0.7	0.068	0.54	0.11	0.14	0.09
0.51-1.00	0.000077	0.29	0.035	0.022	0.32	0.0036	0.024	0.73	0.1	0.66	0.21	0.23	0.097
1.01-2.00	0.000029	0.37	0.0025	0.071	0.32	0.001	0.0044	0.19	0.13	0.21	0.28	0.3	0.14
2.01-5.00	0	0.29	0.0063	0.049	0.077	0	0.0001	0.067	0.23	0.066	0.082	0.046	0.32
> 5.00	0	0.015	0	0	0.046	0	0	0.023	0.19	0.017	0.022	0.0013	0.31

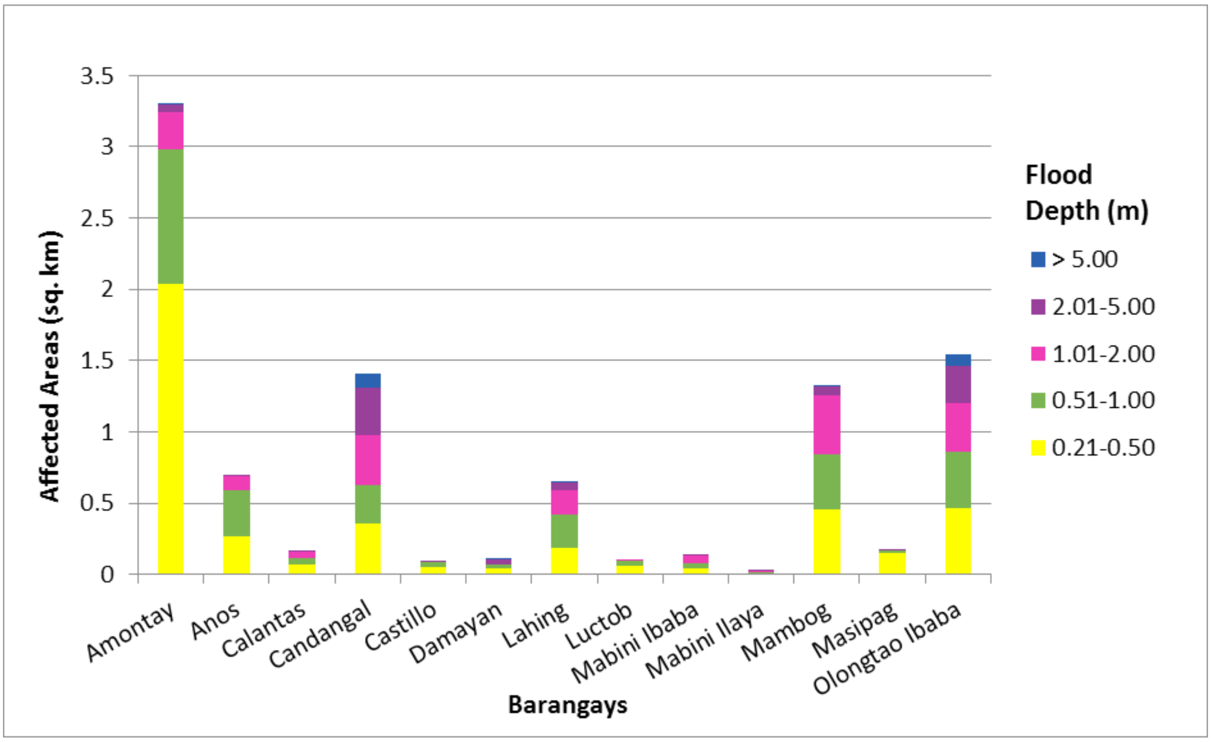


Figure 79. Affected Areas in Macalelon, Quezon during a 5-Year Rainfall Return Period

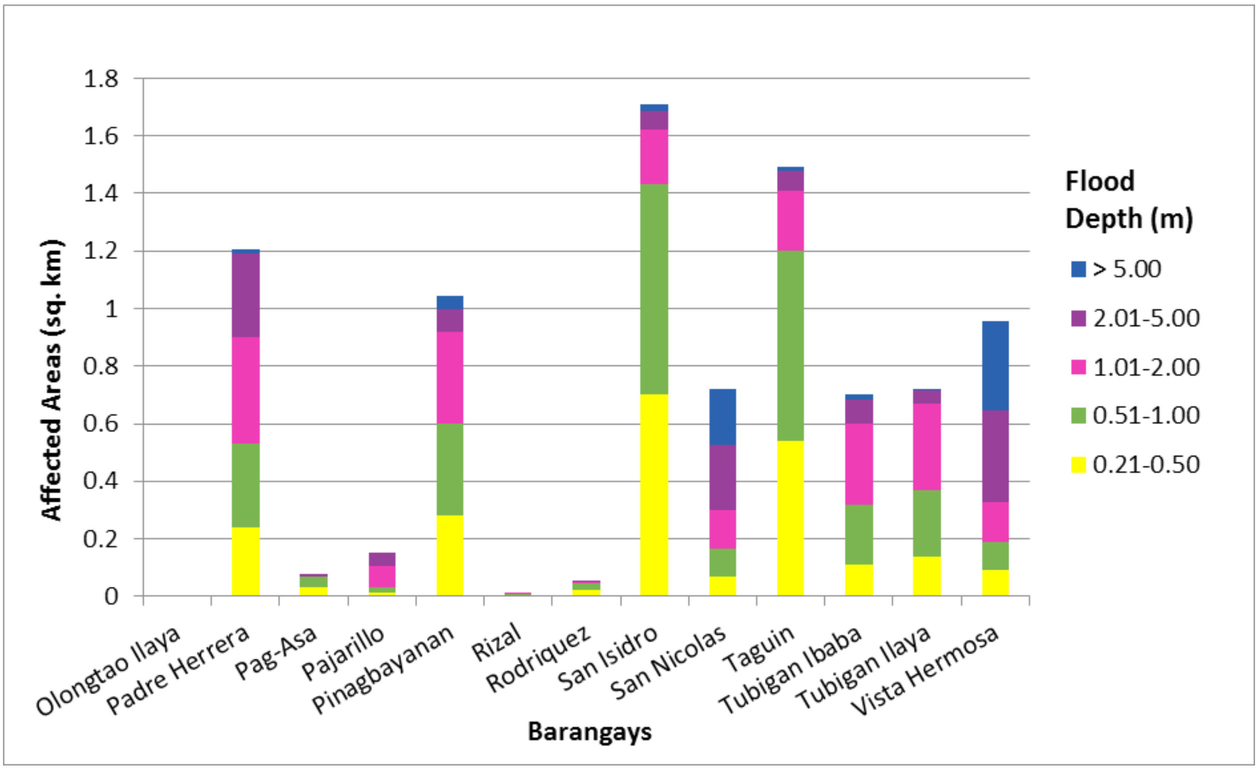


Figure 80. Affected Areas in Macalelon, Quezon during a 5-Year Rainfall Return Period

For the 5-year return period, 1.29% of the municipality of Pitogo with an area of 72.29 sq. km. will experience flood levels of less than 0.20 meters. 0.14% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 39 and shown in Figure 81 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Pitogo, Quezon by flood level for a 5-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Pitogo (in sq. km)
	Ilayang Pacatin
0.03-0.20	0.93
0.21-0.50	0.1
0.51-1.00	0.088
1.01-2.00	0.0078
2.01-5.00	5.1E-06
> 5.00	0

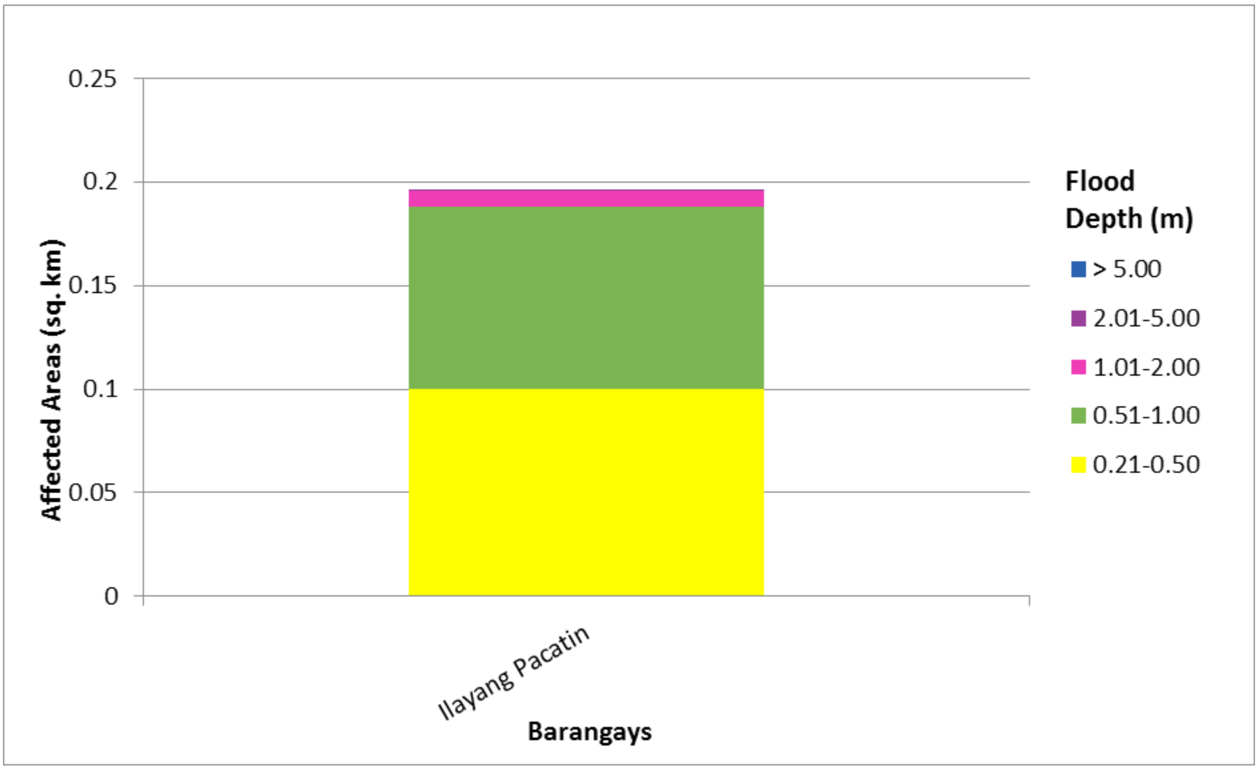


Figure 81. Affected Areas in Pitogo, Quezon during a 5-Year Rainfall Return Period

For the 25-year return period, 12.58% of the municipality of General Luna with an area of 119.16 sq. km. will experience flood levels of less than 0.20 meters. 0.88% of the area will experience flood levels of 0.21 to 0.50 meters while 1.50%, 2.79%, 0.91%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 and shown in Figure 82 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Luna (in sq. km)						
	Barangay 8	San Ignacio Ibaba	San Ignacio Ilaya	San Jose	Santa Maria Ibaba	Santa Maria Ilaya	Sumilang
0.03-0.20	0.0091	0.15	9.92	1.15	1.68	1.33	0.75
0.21-0.50	0	0.098	0.37	0.11	0.25	0.2	0.015
0.51-1.00	0	0.3	0.42	0.2	0.48	0.38	0.012
1.01-2.00	0	0.53	0.55	0.46	0.45	1.32	0.011
2.01-5.00	0	0.004	0.25	0.044	0.0019	0.78	0.0018
> 5.00	0	0	0.0072	0.0003	0	0	0

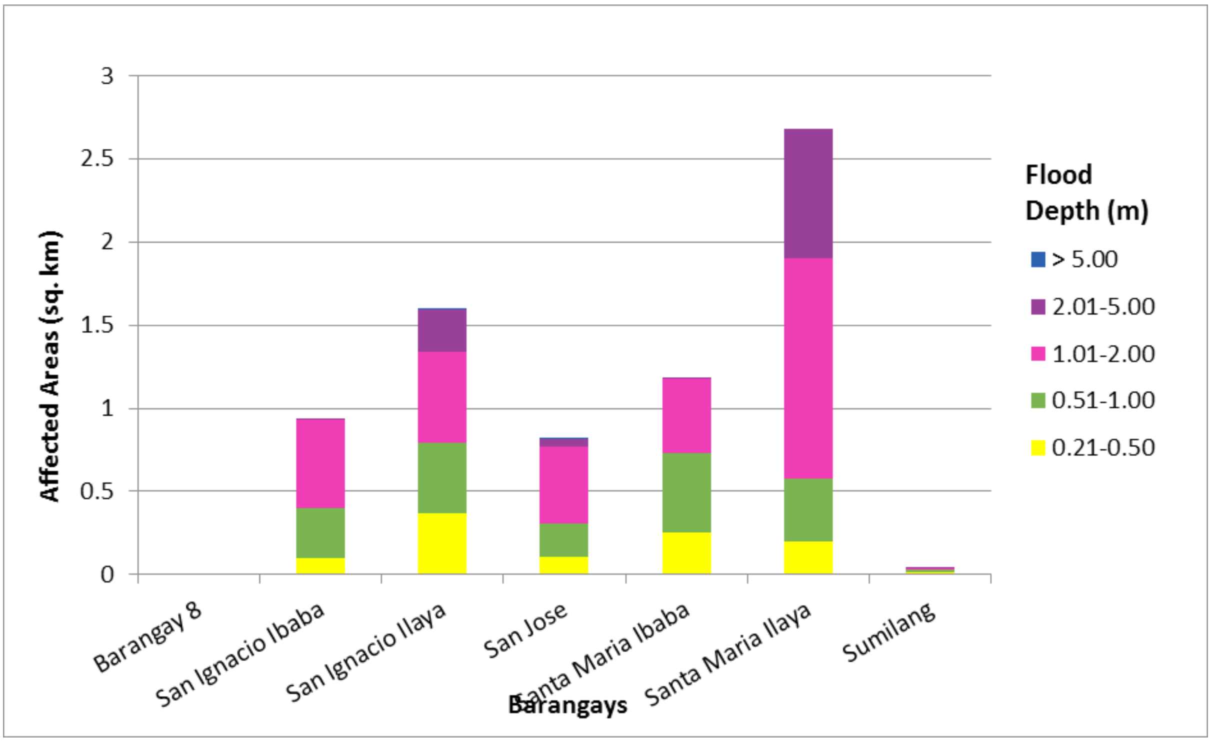


Figure 82. Affected Areas in General Luna, Quezon during 25-Year Rainfall Return Period

For the 25-year return period, 8.01% of the municipality of Gumaca with an area of 199.62 sq. km. will experience flood levels of less than 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.38%, 0.40%, 0.28%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and shown in Figure 83 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gumaca (in sq. km)			
	Anonangin	Bantad	Cawayan	Gayagayaan
0.03-0.20	5.85	1.14	0.0095	9
0.21-0.50	0.36	0.12	0	0.3
0.51-1.00	0.43	0.09	0	0.24
1.01-2.00	0.44	0.086	0	0.27
2.01-5.00	0.35	0.048	0	0.16

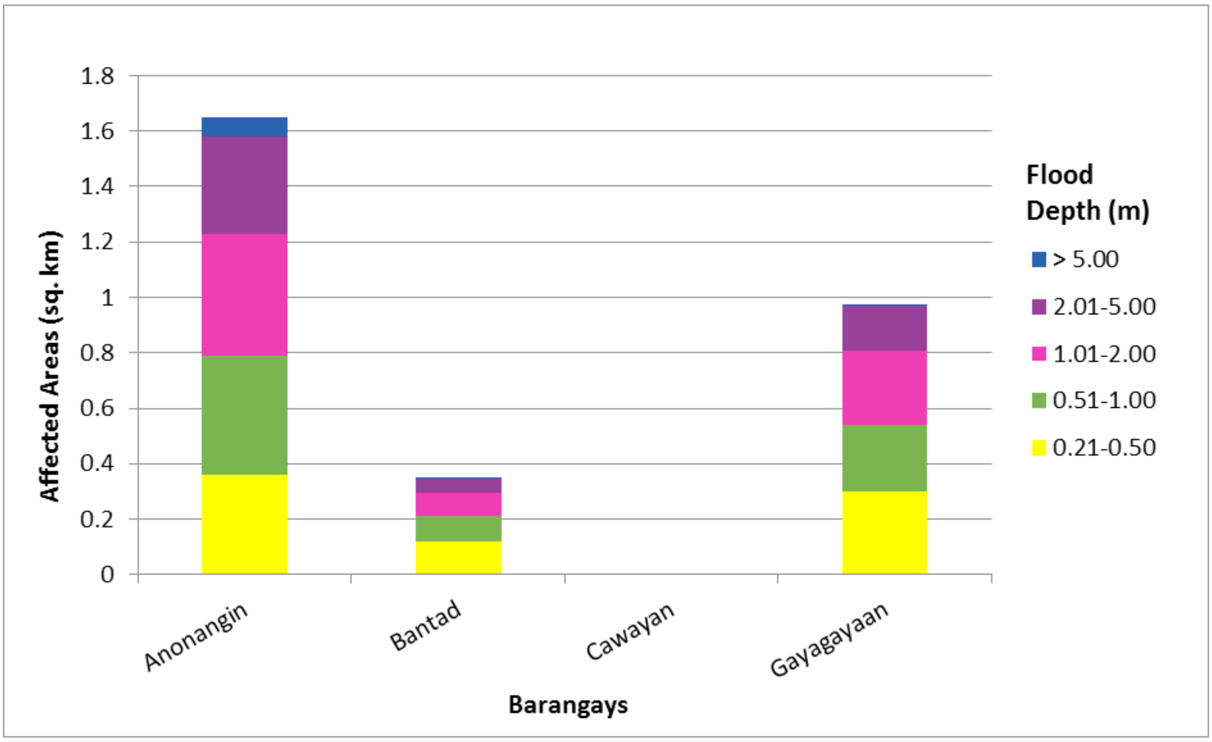


Figure 83. Affected Areas in Gumaca, Quezon during 25-Year Rainfall Return Period

For the 25-year return period, 1.37% of the municipality of Lopez with an area of 378.81 sq. km. will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.03%, 0.06%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 and shown in Figure 84 are the affected areas in square kilometers by flood depth per barangay.

Table 42. 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 (in sq. km)			
	Ilayang Ilog A	Mabini	Santa Elena	Villanacaob
0.03-0.20	1.42	0.65	3.07	0.053
0.21-0.50	0.024	0.01	0.06	0.00026
0.51-1.00	0.0088	0.008	0.05	0.0004
1.01-2.00	0.012	0.0088	0.09	0.0003
2.01-5.00	0.019	0.0074	0.19	0.00041

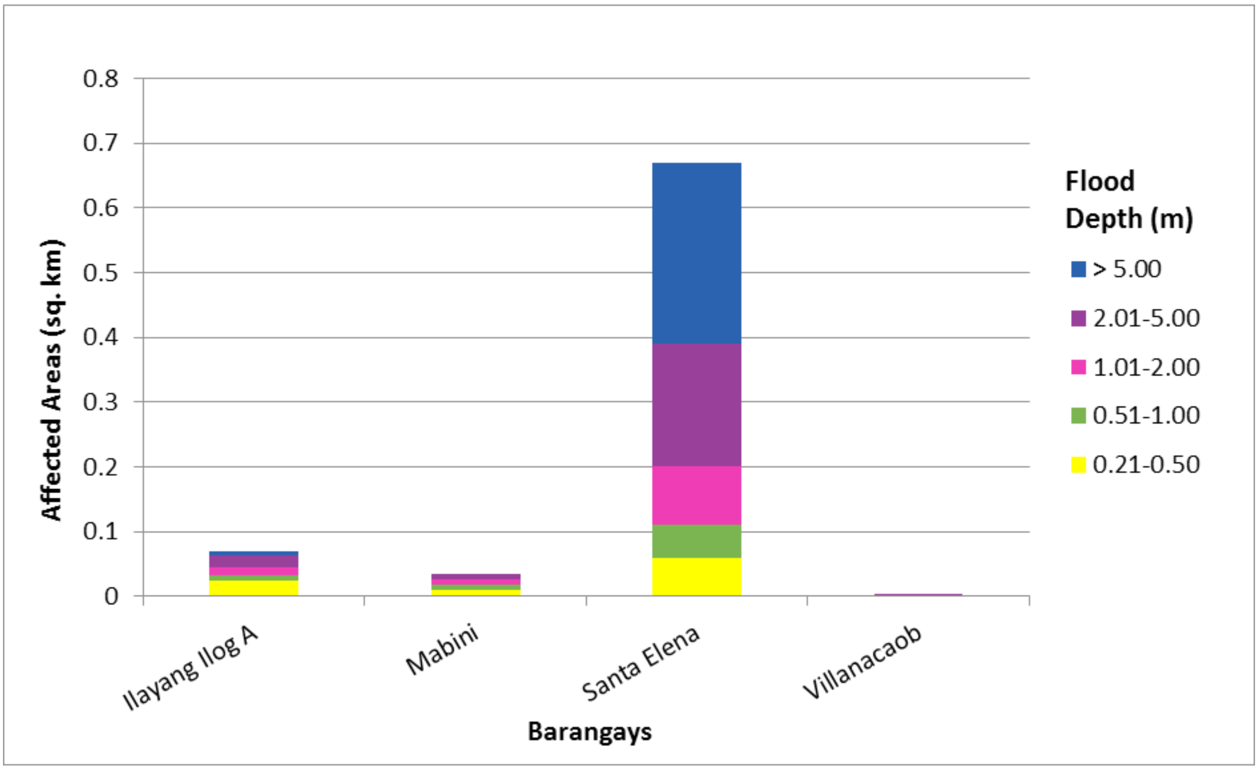


Figure 84. Affected Areas in Lopez, Quezon during 25-Year Rainfall Return Period

For the 25-year return period, 43.46% of the municipality of Macalelon with an area of 81.75 sq. km. will experience flood levels of less than 0.20 meters. 6.15% of the area will experience flood levels of 0.21 to 0.50 meters while 8.09%, 8.70%, 4.14%, and 1.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 and Table 44, and shown in Figure 85 and Figure 86 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Macalelon (in sq. km)												
	Amon-tay	Anos	Calantas	Candangal	Castillo	Damayan	Lahing	Luctob	Mabini Ibaba	Mabini Ilaya	Mambog	Masipag	Olongtao Ibaba
0.03-0.20	3.57	1	1.57	2.18	0.34	0.11	3.1	0.36	0.87	0.27	1.28	0.031	2.44
0.21-0.50	1.66	0.2	0.068	0.32	0.068	0.032	0.17	0.067	0.038	0.011	0.29	0.083	0.42
0.51-1.00	1.9	0.28	0.058	0.39	0.042	0.067	0.24	0.046	0.045	0.0083	0.45	0.11	0.45
1.01-2.00	1.14	0.26	0.042	0.48	0.0052	0.04	0.26	0.011	0.053	0.0077	0.58	0.00036	0.61
2.01-5.00	0.27	0.045	0.021	0.43	0.0014	0.029	0.092	0	0.023	0.0027	0.19	0.0077	0.44
> 5.00	0.011	0	0.0002	0.12	0	0.0082	0.0014	0	0	0	0.00027	0	0.11

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Macalelon (in sq. km)												
	Olongtao Ilaya	Padre Herre-ra	Pag-Asa	Pajarillo	Pinag-bayanan	Rizal	Ro-driquez	San Isidro	San Nico-las	Taguin	Tubigan Ibaba	Tubigan Ilaya	Vista Hermosa
0.03-0.20	0.0009	5.62	0.13	0.5	0.46	0.18	0.31	2.92	1.78	1.58	0.16	0.37	4.4
0.21-0.50	1.7E-07	0.27	0.037	0.015	0.16	0.0051	0.021	0.43	0.051	0.39	0.056	0.084	0.084
0.51-1.00	0	0.28	0.04	0.011	0.36	0.0037	0.03	0.62	0.073	0.72	0.15	0.17	0.073
1.01-2.00	0.00011	0.43	0.0068	0.033	0.68	0.0013	0.0079	0.91	0.17	0.56	0.42	0.3	0.1
2.01-5.00	0	0.44	0.0063	0.1	0.095	0.0001	0.0001	0.11	0.27	0.078	0.16	0.23	0.34
> 5.00	0	0.03	0	0	0.064	0	0	0.032	0.24	0.018	0.023	0.003	0.45

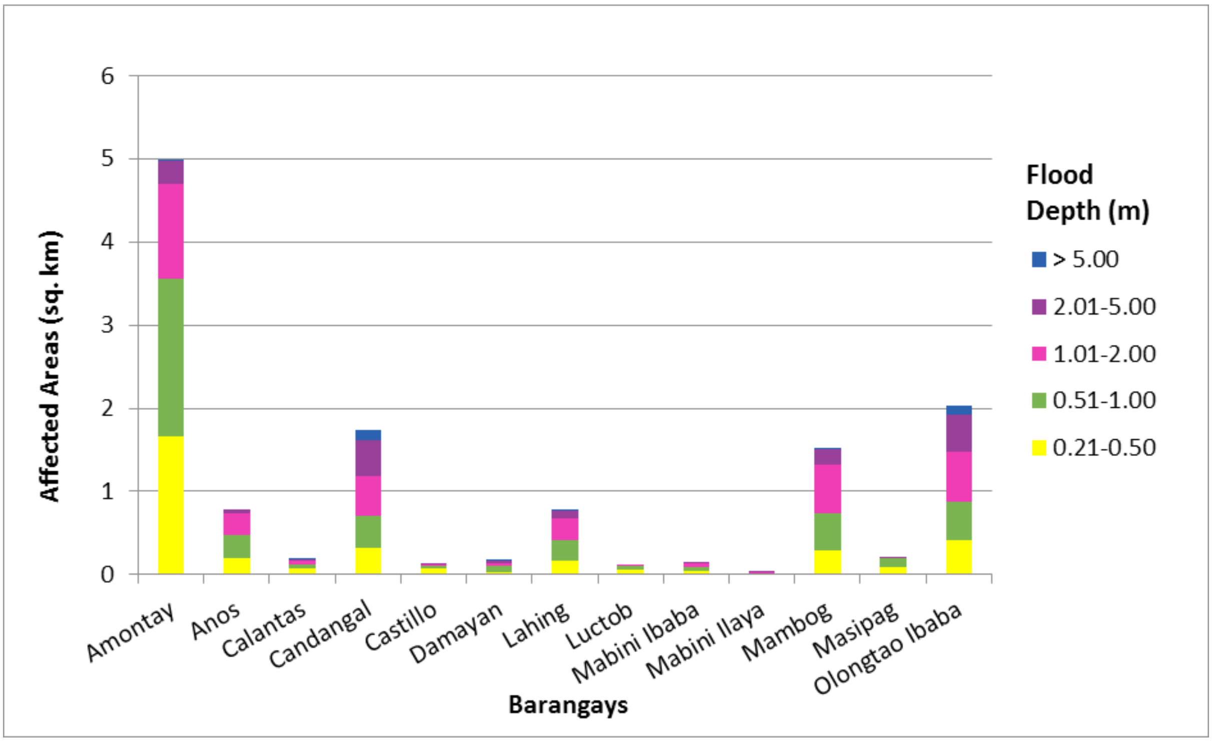


Figure 85. Affected Areas in Macalelon, Quezon during 25-Year Rainfall Return Period

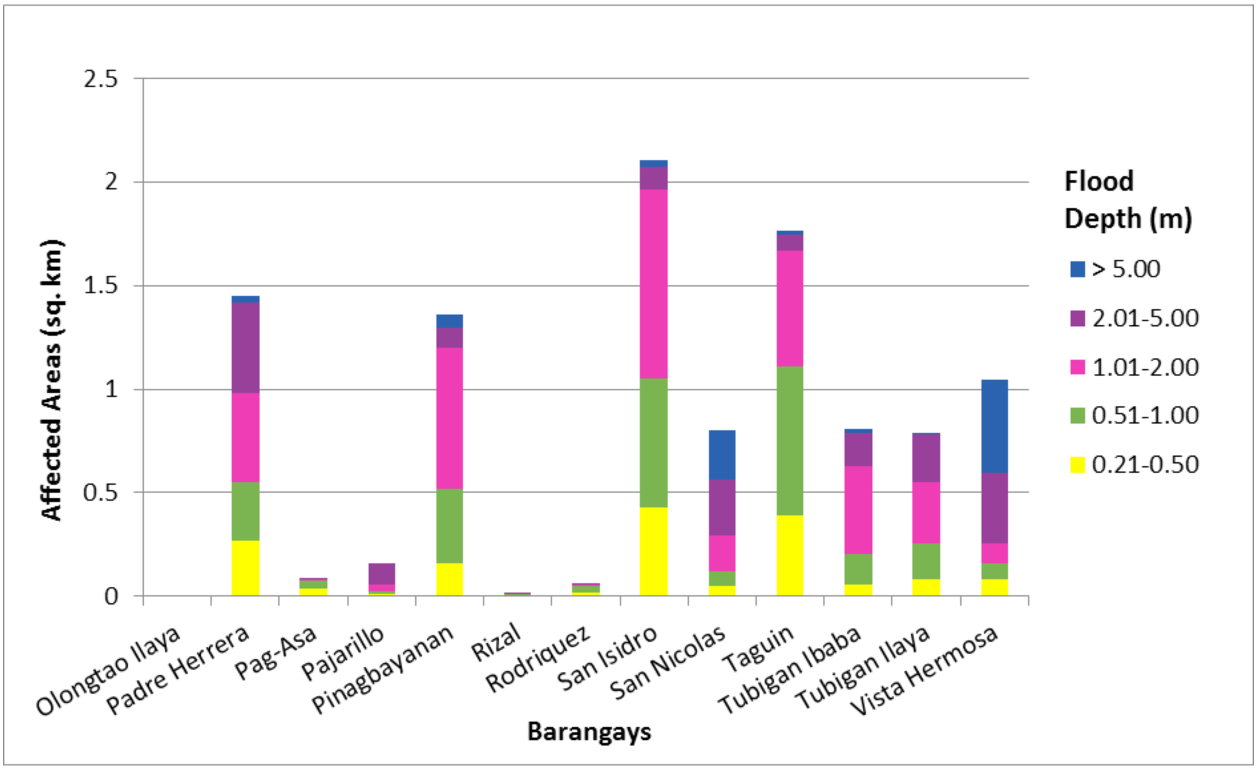


Figure 86. Affected Areas in Macalelon, Quezon during 25-Year Rainfall Return Period

For the 25-year return period, 1.26% of the municipality of Pitogo with an area of 72.29 sq. km. will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters while 0.17% and 0.02% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 45 and shown in Figure 87 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Pitogo (in sq. km)
	Ilayang Pacatin
0.03-0.20	0.91
0.21-0.50	0.079
0.51-1.00	0.12
1.01-2.00	0.014
2.01-5.00	0.00011
> 5.00	0

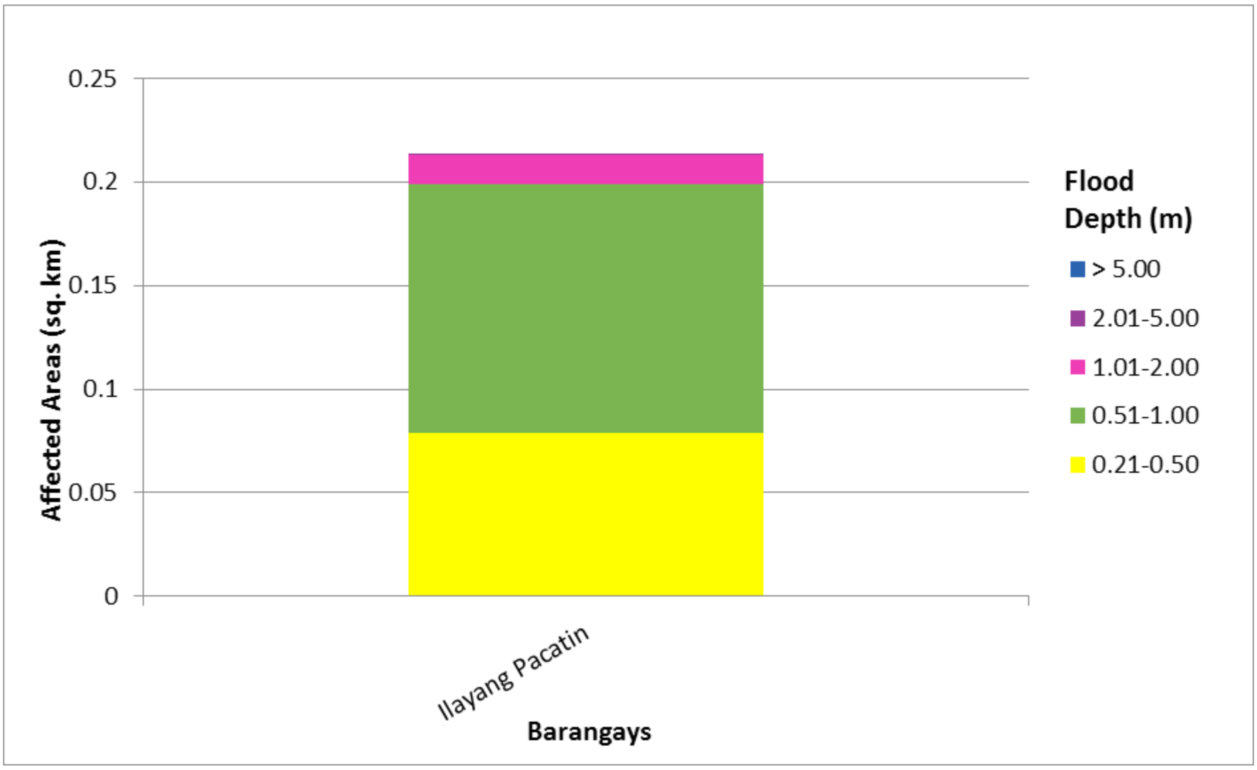


Figure 87. Affected Areas in Pitogo, Quezon during 25-Year Rainfall Return Period

For the 100-year return period, 12.22% of the municipality of General Luna with an area of 119.16 sq. km. will experience flood levels of less than 0.20 meters. 0.70% of the area will experience flood levels of 0.21 to 0.50 meters while 1.26%, 3.03%, 1.45%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 and shown in Figure 88 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in General Luna (in sq. km)						
	Barangay 8	San Ignacio Ibaba	San Ignacio Ilaya	San Jose	Santa Maria Ibaba	Santa Maria Ilaya	Sumilang
0.03-0.20	0.0091	0.12	9.81	1.1	1.56	1.22	0.74
0.21-0.50	0	0.043	0.34	0.08	0.22	0.13	0.018
0.51-1.00	0	0.19	0.41	0.18	0.44	0.27	0.012
1.01-2.00	0	0.69	0.58	0.54	0.64	1.15	0.012
2.01-5.00	0	0.038	0.36	0.07	0.0098	1.25	0.0033
> 5.00	0	0	0.01	0.0006	0	0.0004	0

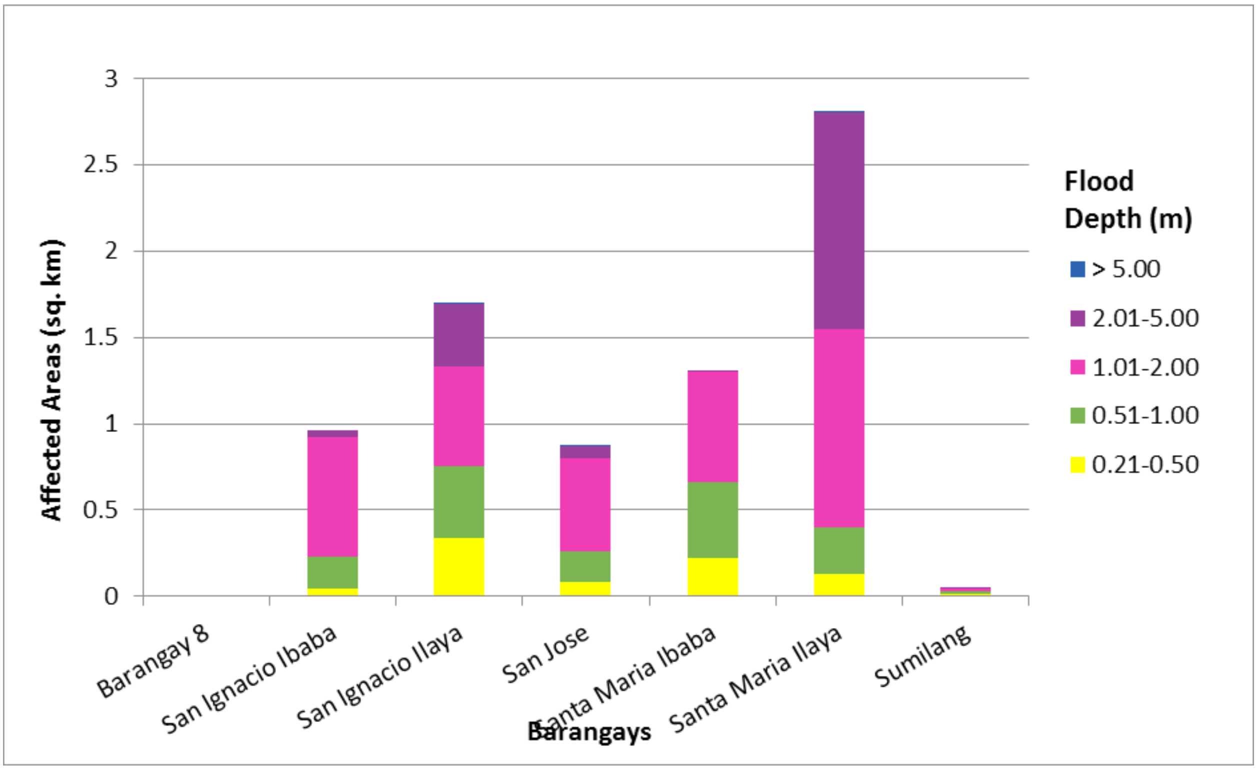


Figure 88. Affected Areas in General Luna, Quezon during 100-Year Rainfall Return Period

For the 100-year return period, 7.85% of the municipality of Gumaca with an area of 199.62 sq. km. will experience flood levels of less than 0.20 meters. 0.38% of the area will experience flood levels of 0.21 to 0.50 meters while 0.41%, 0.43%, 0.38%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 and shown in Figure 89 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Gumaca (in sq. km)			
	Anonangin	Bantad	Cawayan	Gayagayaan
0.03-0.20	5.67	1.09	0.0095	8.91
0.21-0.50	0.32	0.13	0	0.3
0.51-1.00	0.46	0.099	0	0.26
1.01-2.00	0.48	0.097	0	0.29
2.01-5.00	0.49	0.061	0	0.21

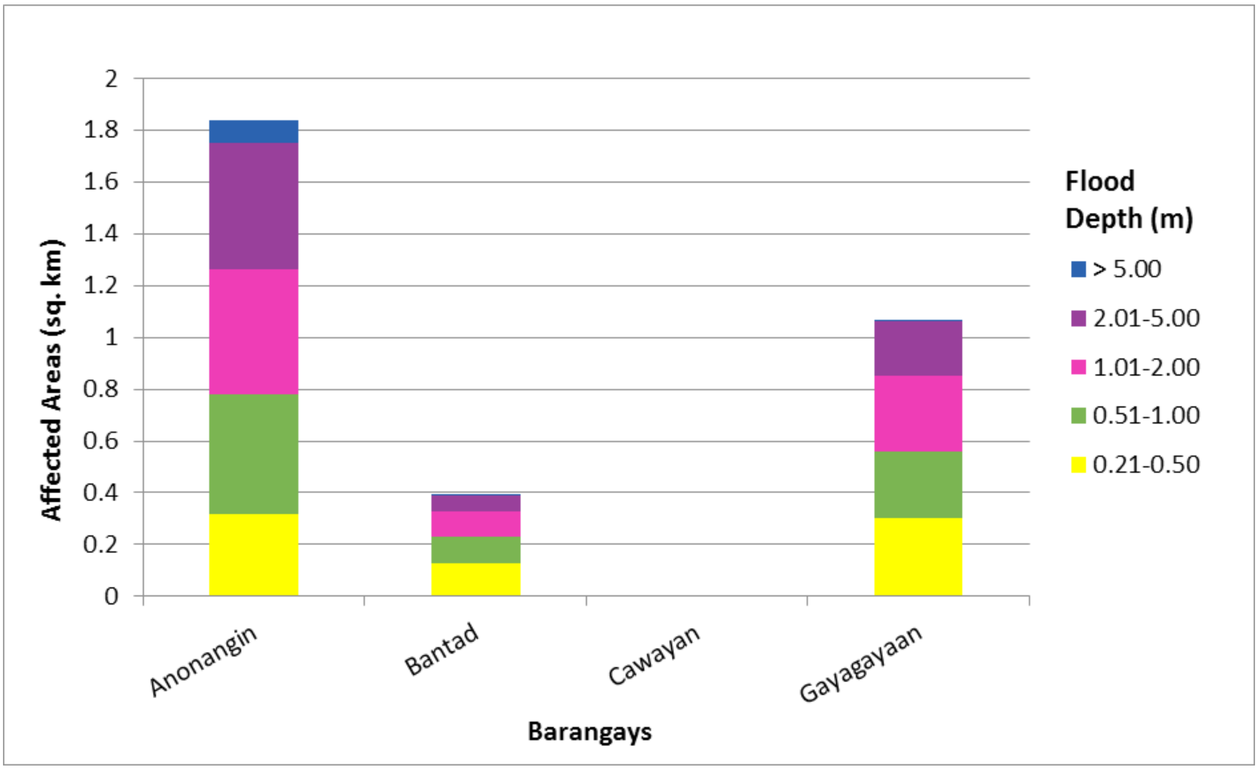


Figure 89. Affected Areas in Gumaca, Quezon during 100-Year Rainfall Return Period

For the 100-year return period, 7.85% of the municipality of Gumaca with an area of 199.62 sq. km. will experience flood levels of less than 0.20 meters. 0.38% of the area will experience flood levels of 0.21 to 0.50 meters while 0.41%, 0.43%, 0.38%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 and shown in Figure 89 are the affected areas in square kilometers by flood depth per barangay.

Table 48. 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 (in sq. km)			
	Ilayang Ilog A	Mabini	Santa Elena	Villanacaob
0.03-0.20	1.42	0.65	3	0.053
0.21-0.50	0.026	0.011	0.066	0.00036
0.51-1.00	0.011	0.0074	0.051	0.0003
1.01-2.00	0.011	0.0093	0.076	0.0004
2.01-5.00	0.02	0.0085	0.21	0.00051

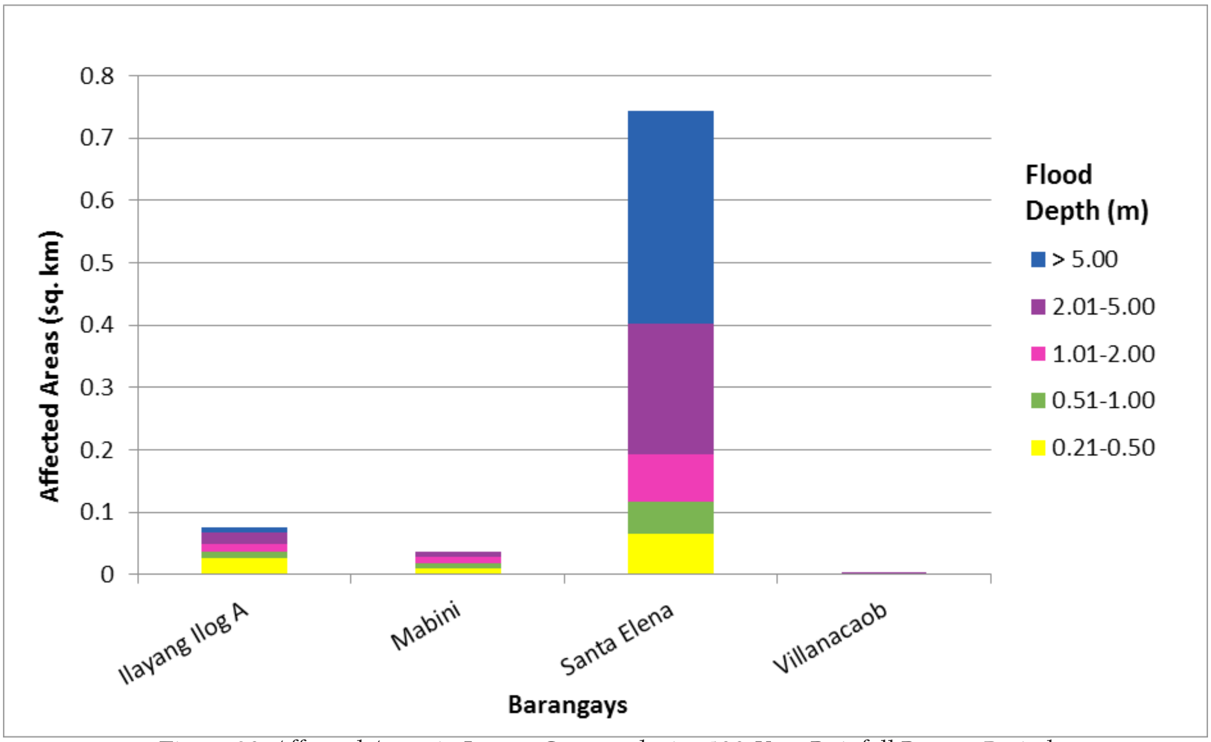


Figure 90. Affected Areas in Lopez, Quezon during 100-Year Rainfall Return Period

For the 100-year return period, 41.00% of the municipality of Macalelon with an area of 81.75 sq. km. will experience flood levels of less than 0.20 meters. 4.45% of the area will experience flood levels of 0.21 to 0.50 meters while 7.79%, 10.33%, 6.54%, and 1.74% 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 49 and Table 50, and shown in Figure 91 and Figure 92 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Macalelon (in sq. km)												
	Amon-tay	Anos	Calantas	Candangal	Castillo	Damayan	Lahing	Luctob	Mabini Ibaba	Mabini Ilaya	Mambog	Masipag	Olongtao Ibaba
0.03-0.20	2.78	0.96	1.56	2.06	0.32	0.09	3.05	0.34	0.86	0.27	1.21	0.018	2.25
0.21-0.50	1.14	0.14	0.065	0.26	0.087	0.02	0.13	0.063	0.035	0.011	0.18	0.016	0.29
0.51-1.00	2.35	0.26	0.065	0.29	0.045	0.061	0.24	0.054	0.048	0.0084	0.34	0.15	0.4
1.01-2.00	1.85	0.29	0.044	0.6	0.008	0.074	0.32	0.02	0.044	0.0088	0.67	0.034	0.67
2.01-5.00	0.4	0.12	0.028	0.55	0.0014	0.024	0.13	0	0.039	0.0038	0.38	0.0078	0.72
> 5.00	0.02	0	0.0003	0.14	0	0.017	0.0024	0	0	0	0.00055	0.00002	0.14

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

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Macalelon (in sq. km)												
	Olongtao Ilaya	Padre Herre-ra	Pag-Asa	Pajarillo	Pinag-bayanan	Rizal	Ro-driquez	San Isidro	San Nico-las	Taguin	Tubigan Ibaba	Tubigan Ilaya	Vista Hermosa
0.03-0.20	0.0009	5.5	0.12	0.49	0.39	0.17	0.31	2.79	1.75	1.43	0.13	0.33	4.34
0.21-0.50	1.7E-07	0.2	0.042	0.015	0.085	0.0058	0.019	0.33	0.031	0.31	0.028	0.046	0.087
0.51-1.00	0	0.29	0.041	0.013	0.29	0.0043	0.033	0.52	0.038	0.55	0.094	0.11	0.076
1.01-2.00	0.00011	0.47	0.011	0.023	0.81	0.0016	0.012	0.66	0.14	0.9	0.42	0.28	0.086
2.01-5.00	0	0.54	0.0047	0.12	0.18	0.0001	0.0001	0.69	0.34	0.14	0.27	0.38	0.28
> 5.00	0	0.065	0.0019	0	0.071	0	0	0.039	0.29	0.018	0.024	0.0054	0.59

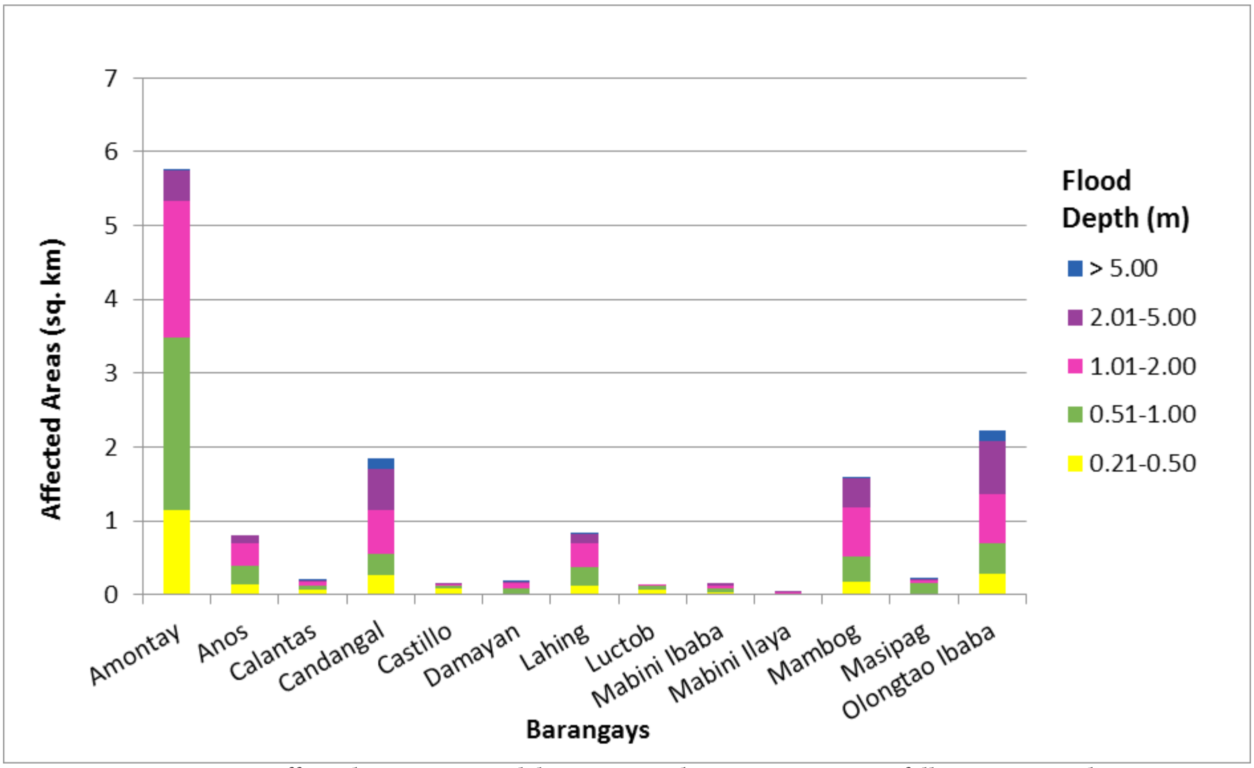


Figure 91. Affected Areas in Macalelon, Quezon during 100-Year Rainfall Return Period

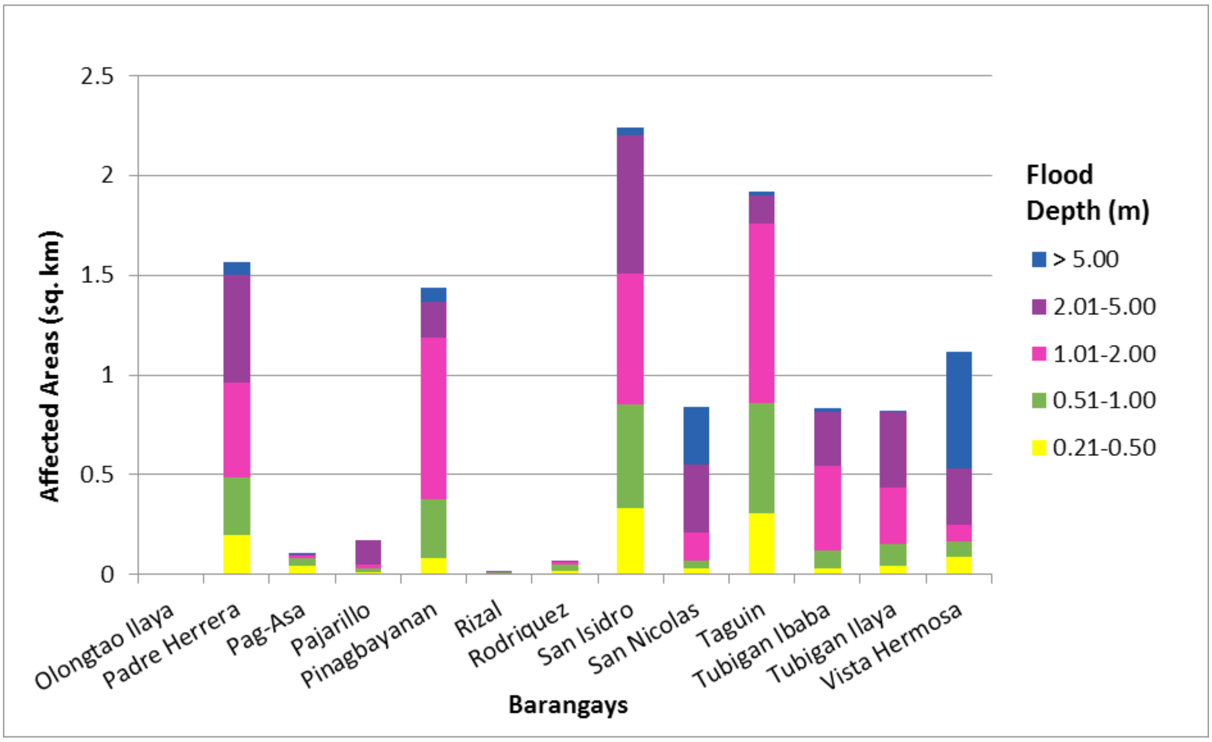


Figure 92. Affected Areas in Macalelon, Quezon during 100-Year Rainfall Return Period

For the 100-year return period, 1.35% of the municipality of Lopez with an area of 378.81 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.03%, 0.06%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 and shown in Figure 93 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Pitogo (in sq. km)
	Ilayang Pacatin
0.03-0.20	0.9
0.21-0.50	0.069
0.51-1.00	0.13
1.01-2.00	0.029
2.01-5.00	0.00041
> 5.00	0

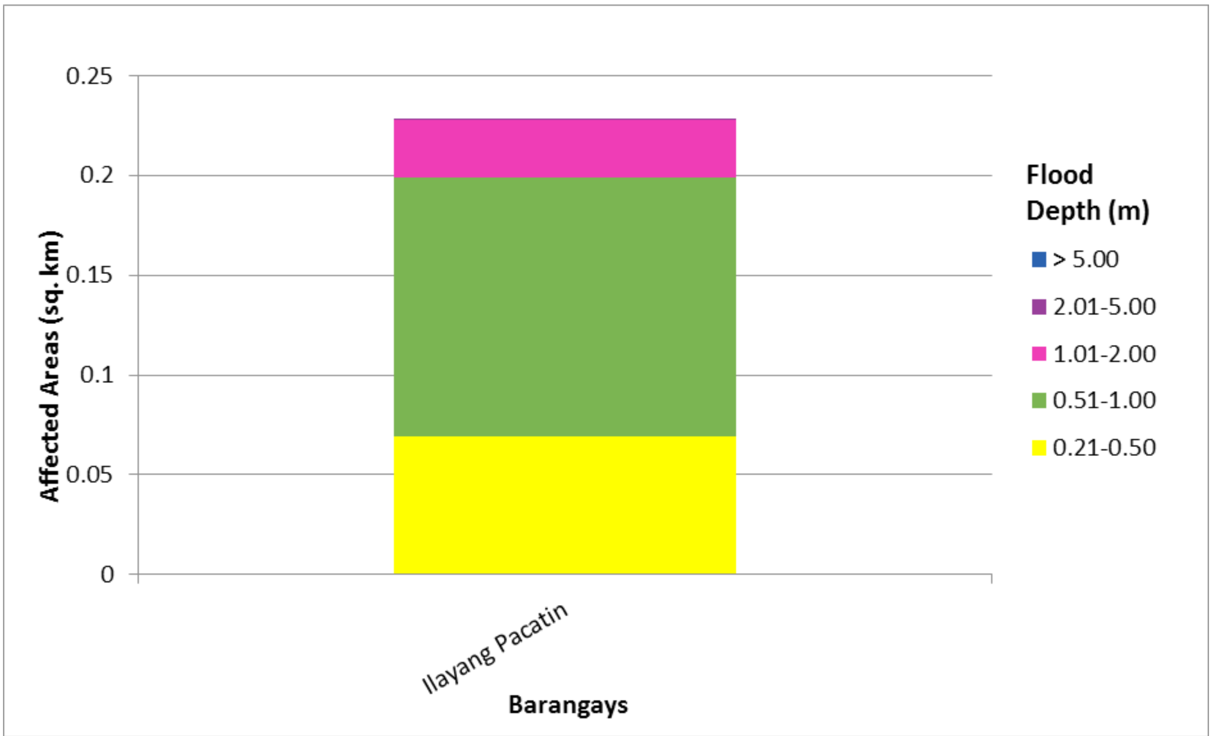


Figure 93. Affected Areas in Pitogo, Quezon during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Macalelon Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps (“Low”, “Medium”, and “High”), the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-year, 25-year, and 10-year).

Table 52. 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	9.058	6.87	5.23
Medium	13.54	16.46	15.59
High	6.17	11.47	16.80
TOTAL	**28.77**	**34.81**	**37.61**

Of the 30 identified Education Institutes in Macalelon Floodplain, three (3) schools were discovered exposed to Low-level flooding during a 5-year scenario, while five(5) schools were found exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, five (5) schools were found exposed to Low-level flooding, while one (1) school was discovered exposed to Medium-level flooding. Five (5) schools were found exposed to high-level flooding.

For the 100-year scenario, seven (7) institutions were found exposed to medium-level flooding while five (5) were exposed to high-level flooding. The list of educational institutions affected by flooding are found in Annex 12.

Apart from this, five (5) Medical Institutions were identified in the Macalelon Floodplain, with one being exposed to Medium-level flooding for the 5-year scenario.

For the 25-year scenario, one (1) each was exposed to low- and medium-level flooding.

For the 100-year scenario, two (2) were exposed to low-level flooding while one (1) was exposed to medium-level flooding. The list of medical or health institutions affected by flooding are found in Annex 13.

5.11 Flood Validation

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

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

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 95.

The flood validation consisted of 245 points randomly selected all over the Macalelon floodplain (Figure 94). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 2.58m. Table 53 shows a contingency matrix of the comparison.

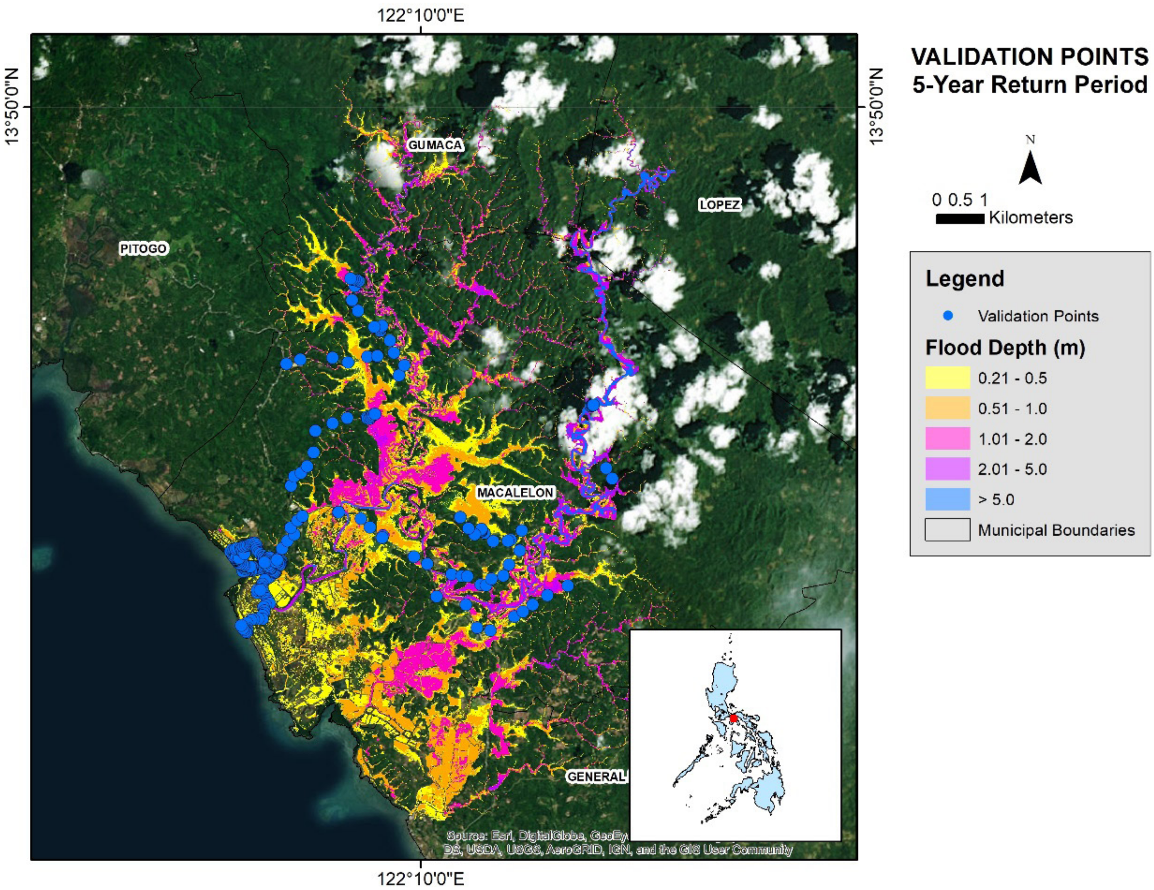


Figure 94. Validation points for 5-year Flood Depth Map of Macalelon Floodplain

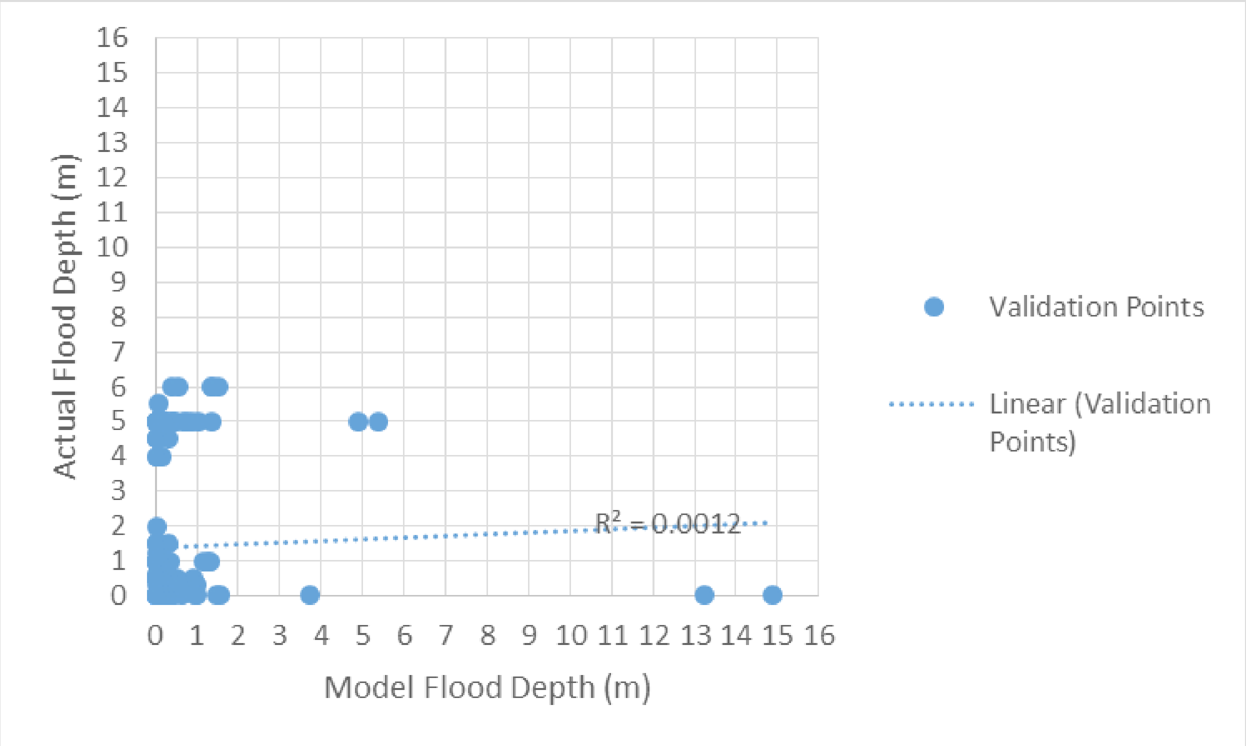


Figure 95. Flood map depth vs. actual flood depth

Table 53. Actual flood vs simulated flood depth at different levels in the Macalelon 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	83	11	3	2	1	2	102
0.21-0.50	23	11	5	0	0	0	39
0.51-1.00	36	4	0	3	0	0	43
1.01-2.00	6	1	0	0	0	0	7
2.01-5.00	34	7	3	2	1	1	48
> 5.00	1	1	1	3	0	0	6
Total	183	35	12	10	2	3	245

The overall accuracy generated by the flood model is estimated at 38.78% with 95 points correctly matching the actual flood depths. In addition, there were 45 points estimated one level above and below the correct flood depths while there were 46 points and 55 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 122 points were underestimated in the modelled flood depths of Macalelon. Table 54 depicts the summary of the Accuracy Assessment in the Macalelon River Basin Survey.

Table 54. Actual flood vs simulated flood depth at different levels in the Macalelon River Basin.

	No. of Points	%
Correct	95	**38.78**
Overestimated	28	11.43
Underestimated	122	49.80
Total	245	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.

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

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

Paringit, E.C., Balicanta, L.P., Ang, M.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

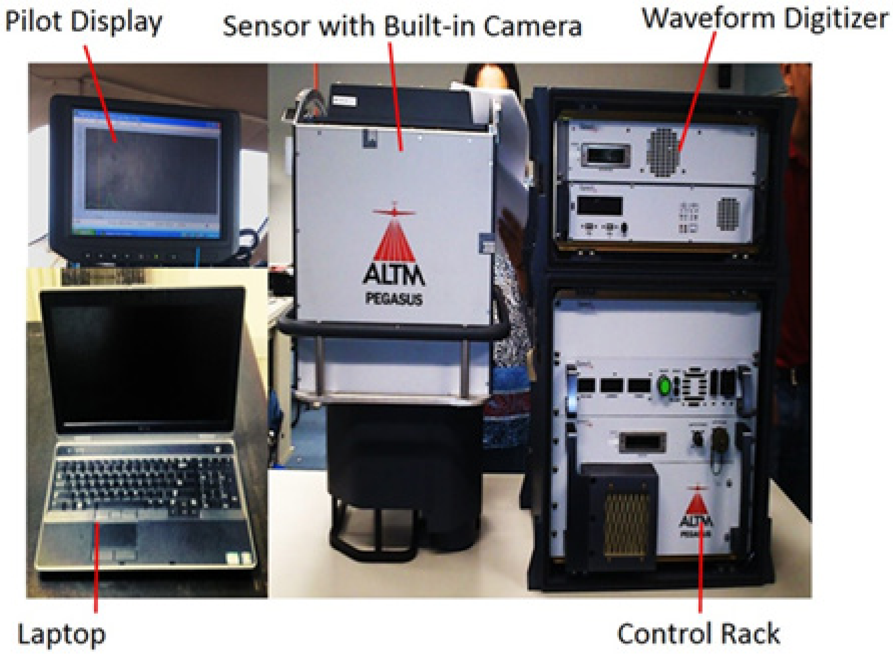


Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Wave-form 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

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20°
4 Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certificates of Reference Points Used

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

9904142016153305

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

CIP/4701/12/09/814

Figure A-2.1 QZN-41

2. QZN-641

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: **QZ-641**

Island: **LUZON**	Municipality: **LOPEZ**	Barangay: **VILLA AURORA**
Elevation: **54.5494 +/- 0.0850 m.**	Accuracy Class at 95% C.L: **8 cm**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

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

Location Description

Mark is the head of a 4 in. copper nail set flush on 15 cm. x 15 cm. cement putty with inscriptions "QZ-641, 2011, NAMRIA".

BM-QZ-641 is in the Province of Quezon, Municipality of Lopez, Brgy. Villa Aurora along the Lopez-Catanauan National Highway. The station is located at the northwest end of the sidewalk of Calauag Bridge near KM. Post 233.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0919**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Figure A-2.2 QZN-641

3. CMN-29

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: **CAMARINES NORTE**
Station Name: **CMN-29**
Order: **2nd**

Island: **LUZON**		Barangay: **TANAWAN**			
Municipality: **BAGONG SILANG**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**14° 8' 52.17466"**	Longitude:	**122° 34' 59.83481"**	Ellipsoidal Hgt:	**40.92600 m.**
		WGS84 Coordinates			
Latitude:	**14° 8' 46.99182"**	Longitude:	**122° 35' 4.75796"**	Ellipsoidal Hgt:	**89.60600 m.**
		PTM / PRS92 Coordinates			
Northing:	**1564566.419 m.**	Easting:	**455011.114 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,564,018.79**	Easting:	**455,026.86**	Zone:	**51**

Location Description

CMN-29

From Mun. of Labo, travel W along Maharlika highway for approx. 30 Km. then turn left to a road going to Brgy. Malaya, passing through Malibago Elem. School for about 3 Km. Station is located at Brgy. Malibago. It was established at Basigan, NW of spillway. Mark is the head of a 4 in. copper nail centered on a drilled hole with cement putty, embedded at concrete pavement with inscriptions, "CMN-29, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0910**

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

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

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3 CMN-29

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

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°16'58.66932"	**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°22'06.68507"	**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 Baseline Processing Report - A

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 Baseline Processing Report - B

CMN-29 - CMN-JJ (1:53:33 PM-4:04:50 PM) (S12)

Baseline observation:	CMN-29 --- CMN-JJ (B13)
Processed:	4/17/2016 10:30:22 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.012 m
RMS:	0.001 m
Maximum PDOP:	3.418
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/16/2016 1:53:46 PM (Local: UTC+8hr)
Processing stop time:	4/16/2016 4:04:50 PM (Local: UTC+8hr)
Processing duration:	02:11:04
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	CMN-29				
Grid		**Local**		**Global**	
Easting	455026.861 m	**Latitude**	N14°08'52.17466"	**Latitude**	N14°08'46.99182"
Northing	1564018.794 m	**Longitude**	E122°34'59.83481"	**Longitude**	E122°35'04.75796"
Elevation	40.487 m	**Height**	40.926 m	**Height**	89.606 m

To:	CMN-JJ				
Grid		**Local**		**Global**	
Easting	455107.072 m	**Latitude**	N14°08'52.67538"	**Latitude**	N14°08'47.49257"
Northing	1564034.034 m	**Longitude**	E122°35'02.50945"	**Longitude**	E122°35'07.43258"
Elevation	40.732 m	**Height**	41.172 m	**Height**	89.854 m

Vector					
ΔEasting	80.211 m	**NS Fwd Azimuth**	79°08'25"	**ΔX**	-65.691 m
ΔNorthing	15.240 m	**Ellipsoid Dist.**	81.677 m	**ΔY**	-46.166 m
ΔElevation	0.245 m	**ΔHeight**	0.246 m	**ΔZ**	14.984 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	**σ NS fwd Azimuth**	0°00'04"	**σ ΔX**	0.004 m
σ ΔNorthing	0.002 m	**σ Ellipsoid Dist.**	0.002 m	**σ ΔY**	0.005 m
σ ΔElevation	0.006 m	**σ ΔHeight**	0.006 m	**σ ΔZ**	0.002 m

2

Figure A-3.3 Baseline Processing Report - C

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-3.4 Baseline Processing Report - D

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Acquisition Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. KENNETH QUISADO	UP-TCAGP
		JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JASMIN 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 Yabaan Floodplain Flights

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	6.95	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 Macalelon Floodplain – A

DATA TRANSFER SHEET
BAGASBAS 5/17/2016

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 16,2016	23262P	1BLK20S107A	PEGASUS	NA	296	9.26	222	36.3	277	15.8	NA	83	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 16,2016	23264P	1BLK20DS107B	PEGASUS	NA	295	6.01	456	18.5	1KB	16	NA	83	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 17,2016	23266P	1BLK20S108A	PEGASUS	NA	352	8.08	198	32.5	229	18.1	NA	154	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 17,2016	23268P	1BLK20S108B	PEGASUS	NA	359	8.74	203	3.68	65	18.7	NA	154	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 18,2016	23270P	1BLK20S109A	PEGASUS	NA	112	3.36	99	455	7.2	5.52	NA	29.1	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

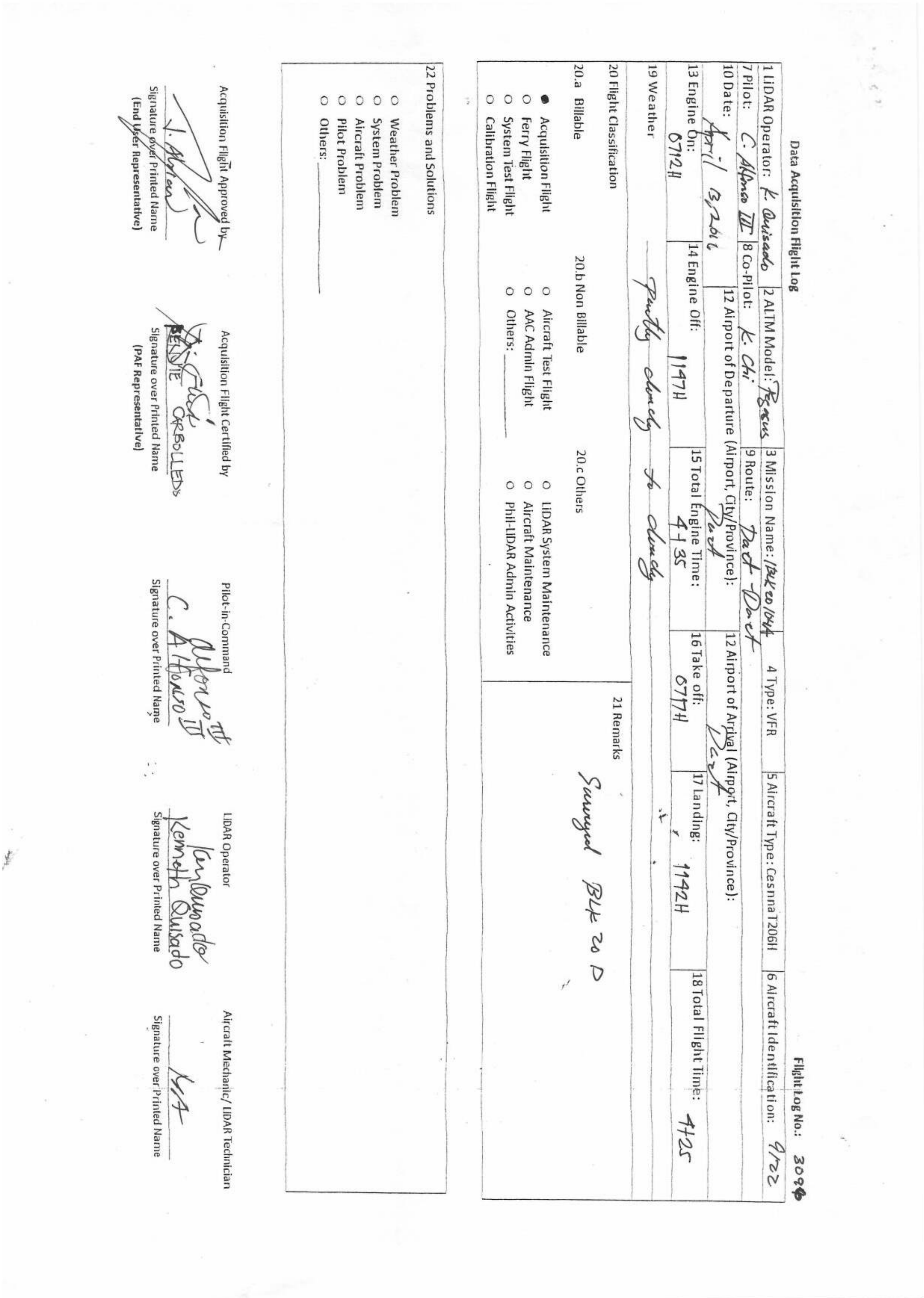
Received by

Name AC Bongat
Position SSRS
Signature 5/18/16

Figure A-5.2 Data Transfer Sheet for Macalelon Floodplain – B

Annex 6. Flight Logs

1. Flight Log for 1BLK20BC104A Mission



Data Acquisition Flight Log

Flight Log No.: 3096

1 LiDAR Operator: K. Quisado
2 ALTM Model: Pegasus
3 Mission Name: 1BLK20104A
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 13, 2016
12 Airport of Departure (Airport, City/Province): Dact
12 Airport of Arrival (Airport, City/Province): Dact
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
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ______

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

21 Remarks

Surveyed BLK 20 D

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

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

Acquisition Flight Certified by: BERNTE CABALLERO — Signature over Printed Name (PAF Representative)

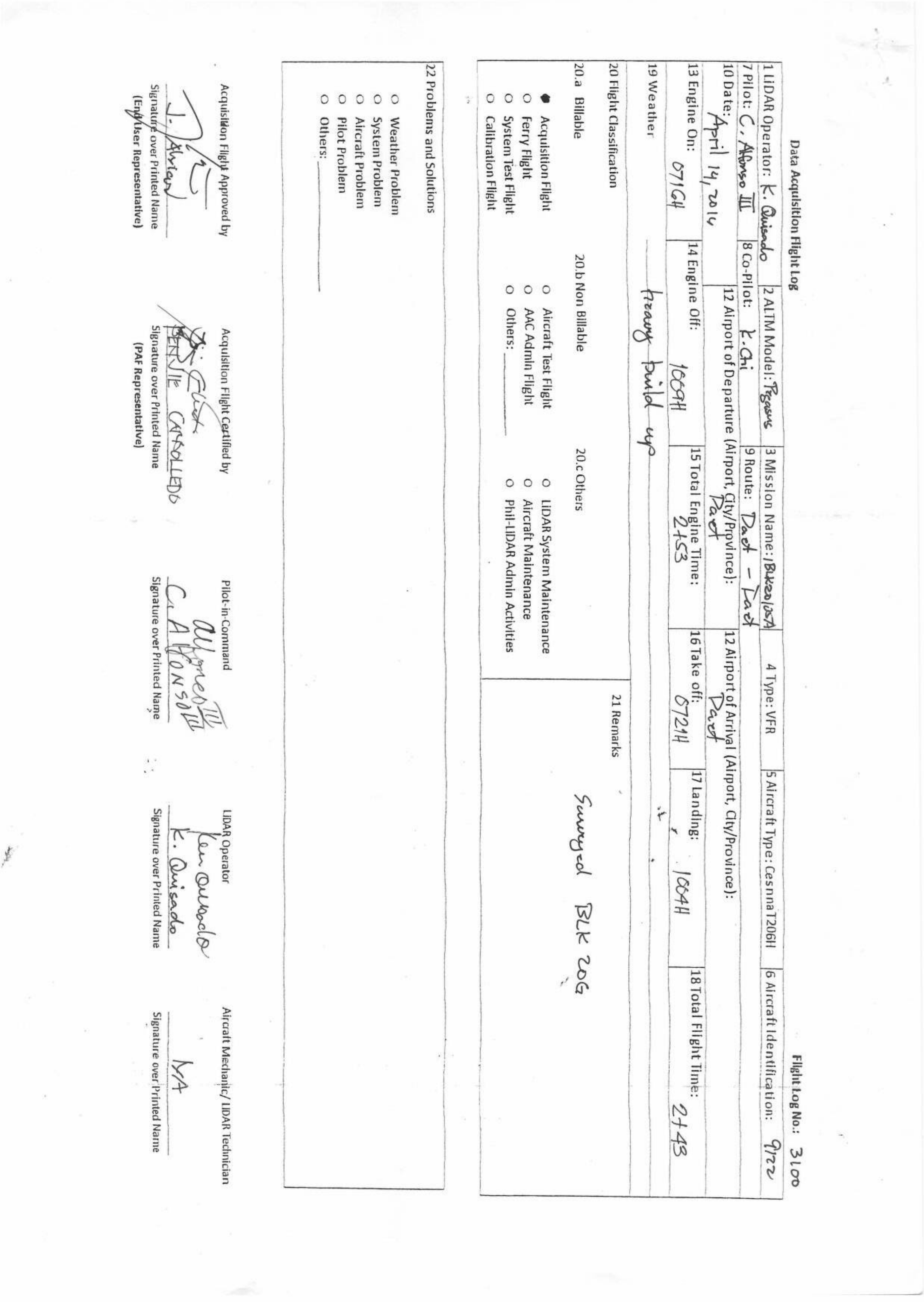
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LiDAR Operator: Kenneth Quisado — Signature over Printed Name

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

Figure A-6.1 Flight log for 1BLK20BC104A Mission

2. Flight Log for 1BLK20CE105A Mission



Data Acquisition Flight Log — **Flight Log No.:** 3100

1 LiDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20105A	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 14, 2016	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

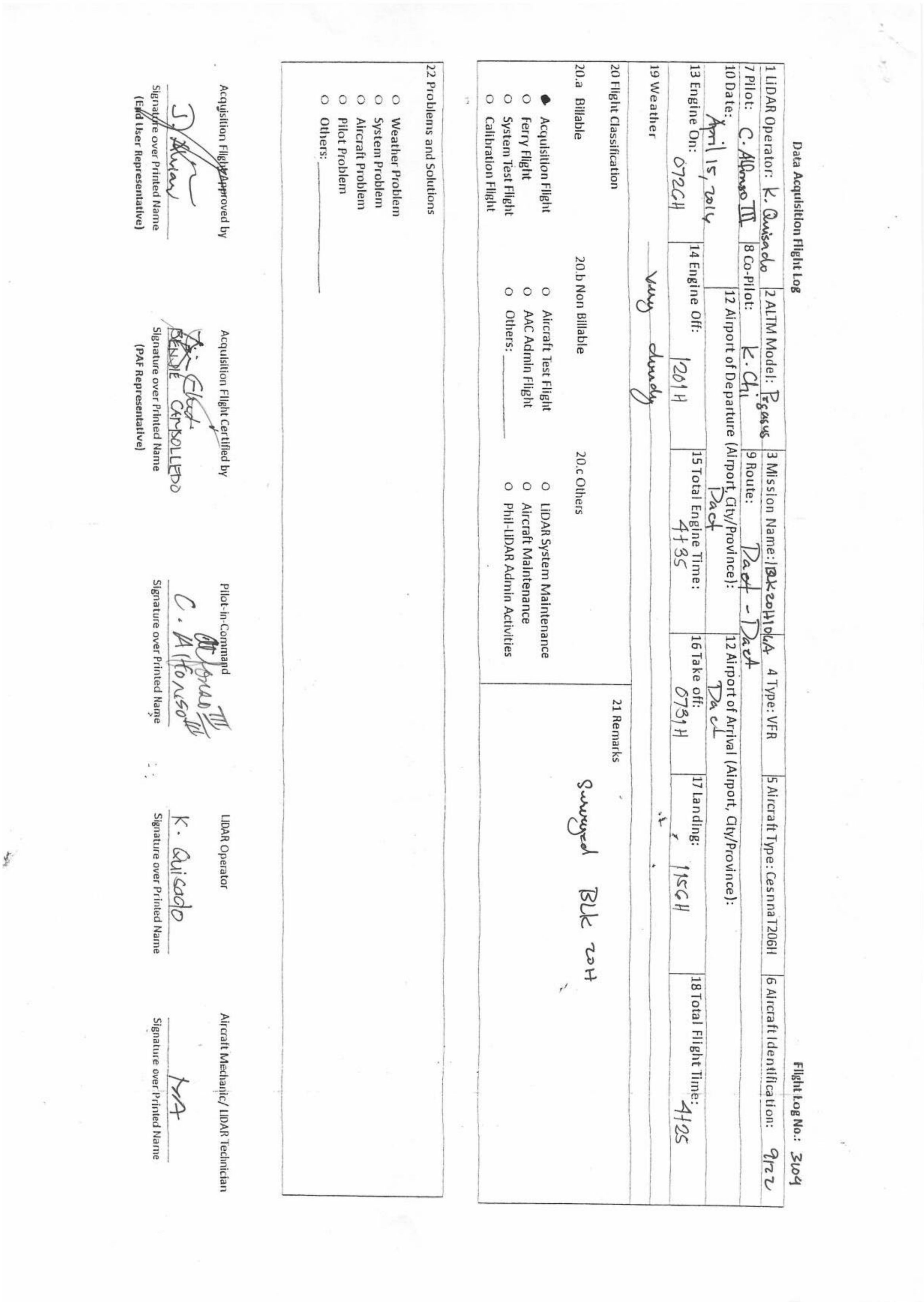
Surveyed BLK 20G

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	Bengie Carbolledo	C. Alfonso III	K. Quisado	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for 1BLK20CE105A Mission

3. Flight Log for 1BLK20CE106A Mission



Data Acquisition Flight Log

Flight Log No.: 3104

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: 0724H	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	BERNIE CAMBOLLEDO	C. Alfonso III	K. Quisado	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3 Flight Log for 1BLK20CE106A Mission

4. Flight Log for 1BLK20S107A Mission

Data Acquisition Flight Log

Flight Log No.: 3108

1 LiDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20107A	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 14, 2014	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0800H	14 Engine Off: 1153 H	15 Total Engine Time: 3+53	16 Take off: 0805H	17 Landing: 1148H	18 Total Flight Time: 3+43
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 20F, S

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	Bendie Catrolledo	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-6.4 Flight Log for 1BLK20S107A Mission

Annex 7. Flight Status Report

Table A-7.1 Flight Status Report

MACALELON FLOODPLAIN
(April 13-16, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23250P	BLK 20G	1BLK20G104A	K. Quisado	13-Apr-16	Surveyed Macalelon, Calauag, Pandanan FPS
23254P	BLK 20F	1BLK20F105A	K. Quisado	14-Apr-16	Surveyed Pandanan, Macalelon, Calauag FPS
23258P	BLK 20H	1BLK20H106A	K. Quisado	15-Apr-16	Surveyed Macalelon, Calauag, Pandanan FPS
23262P	BLK 20F & FS	1BLK20S107A	K. Quisado	16-Apr-16	Surveyed Remaining Areas in BLK 20FS

LAS BOUNDARIES PER FLIGHT

FLIGHT LOG NO. 23250P
AREA: BLOCK 20G
MISSION NAME: 1BLK20BC104A

Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

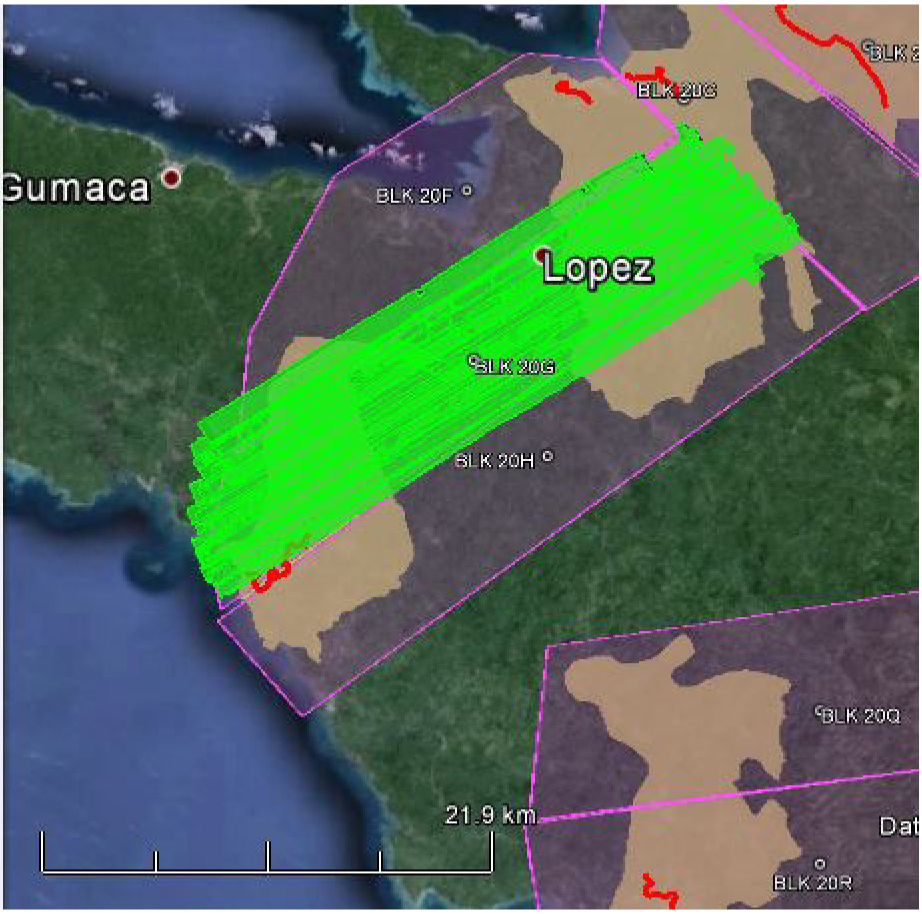


Figure A-7.1 Swath for Flight No. 23250P

FLIGHT LOG NO. 23254P
AREA: BLOCK 20F
MISSION NAME: 1BLK20CE105A
Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

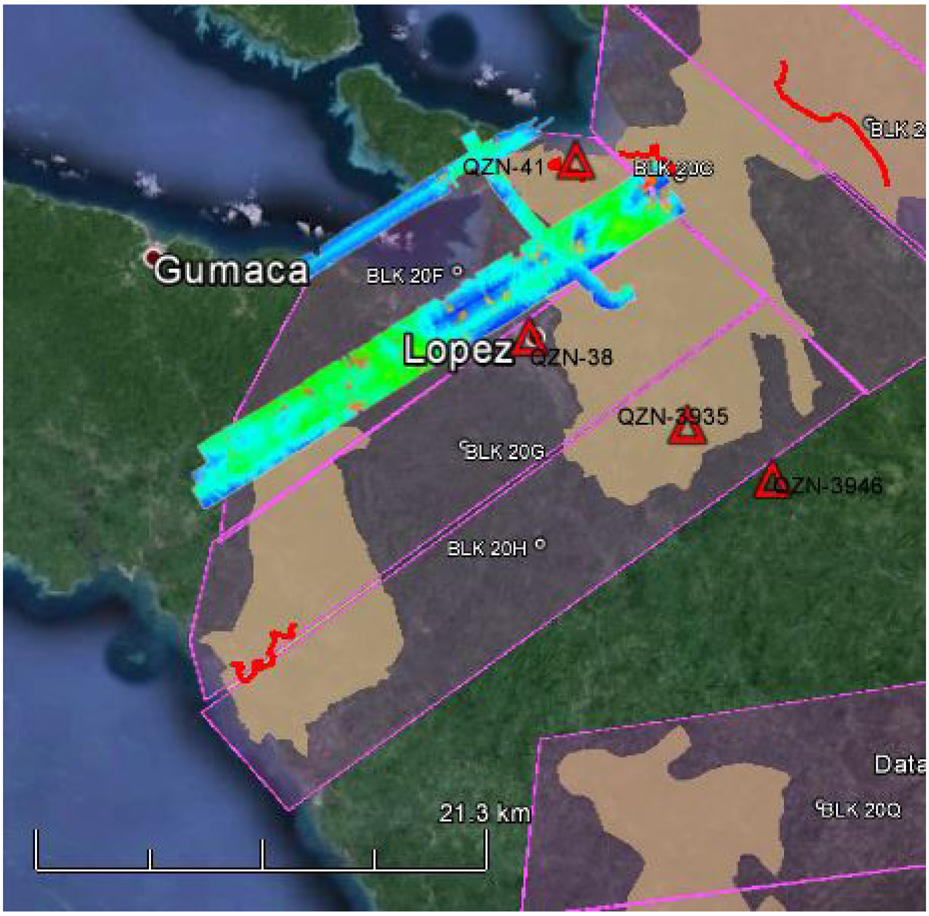


Figure A-7.2 Swath for Flight No. 23254P

FLIGHT LOG NO. 23258P
AREA: BLOCK 20H
MISSION NAME: 1BLK20CE106A

Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

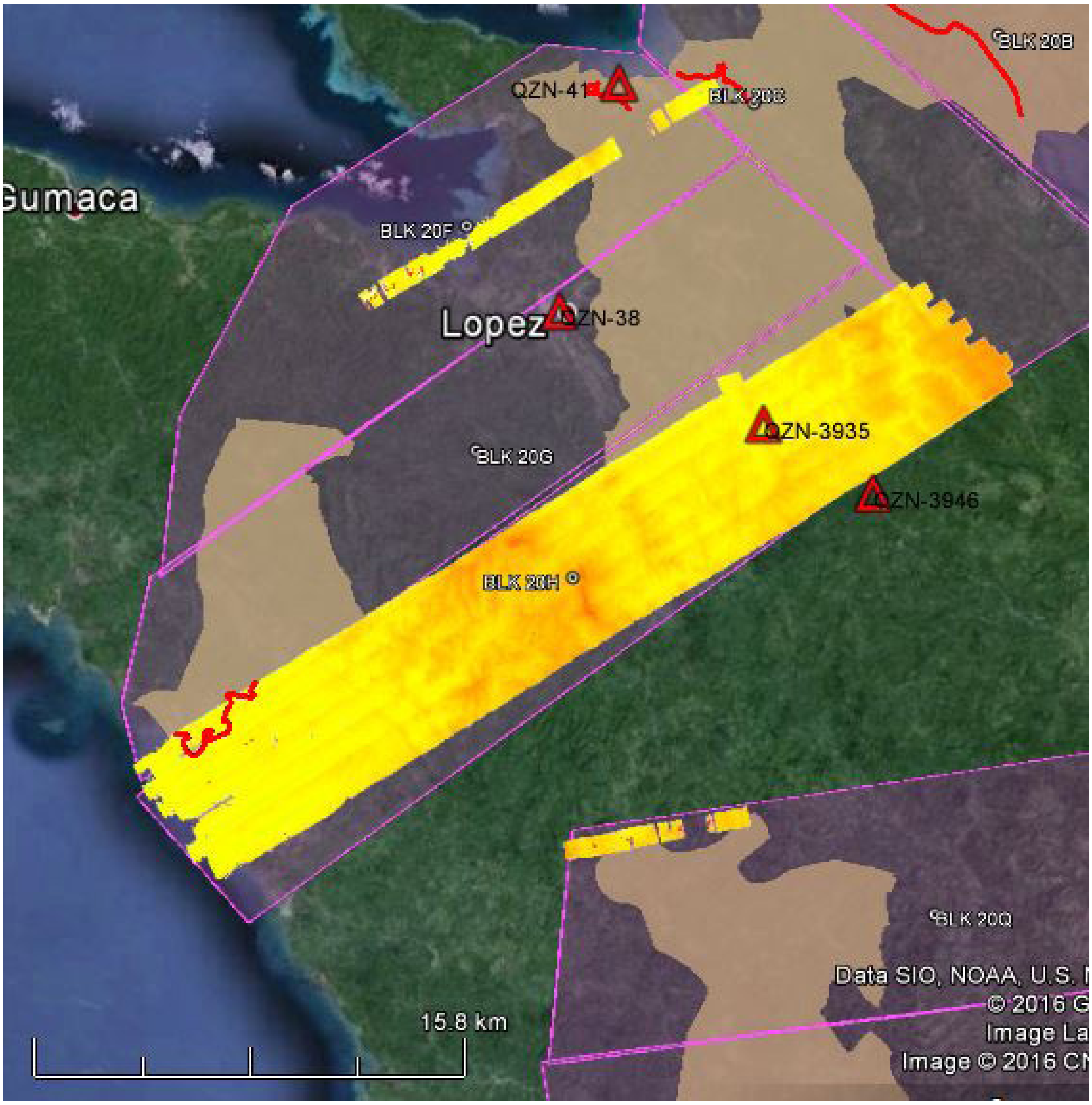


Figure A-7.3 Swath for Flight No. 23258P

FLIGHT LOG NO. 23262P
AREA: BLOCK 20F & FS
MISSION NAME: 1BLK20S107A

Scan Freq: 30 Hz
Scan Angle: 25 deg
PRF: 200

SURVEY COVERAGE:

Figure A-7.3 Swath for Flight No. 23262P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report of Mission Blk21B

Flight Area	Bagasbas
Mission Name	Blk21B
Inclusive Flights	23254P
Range data size	8.7 GB
POS	176 MB
Image	106 MB
Base Station Data	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 (<0.20m)	Yes
Number of 1km x 1km blocks	146
Maximum Height	667.8 m
Minimum Height	49.57 m

Classification (# of points)	
Ground	63,116,805
Low vegetation	26,844,522
Medium vegetation	78,513,440
High vegetation	244,022,525
Building	2,787,091
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Merven Matthew Natino, Engr. Monalyne Rabino

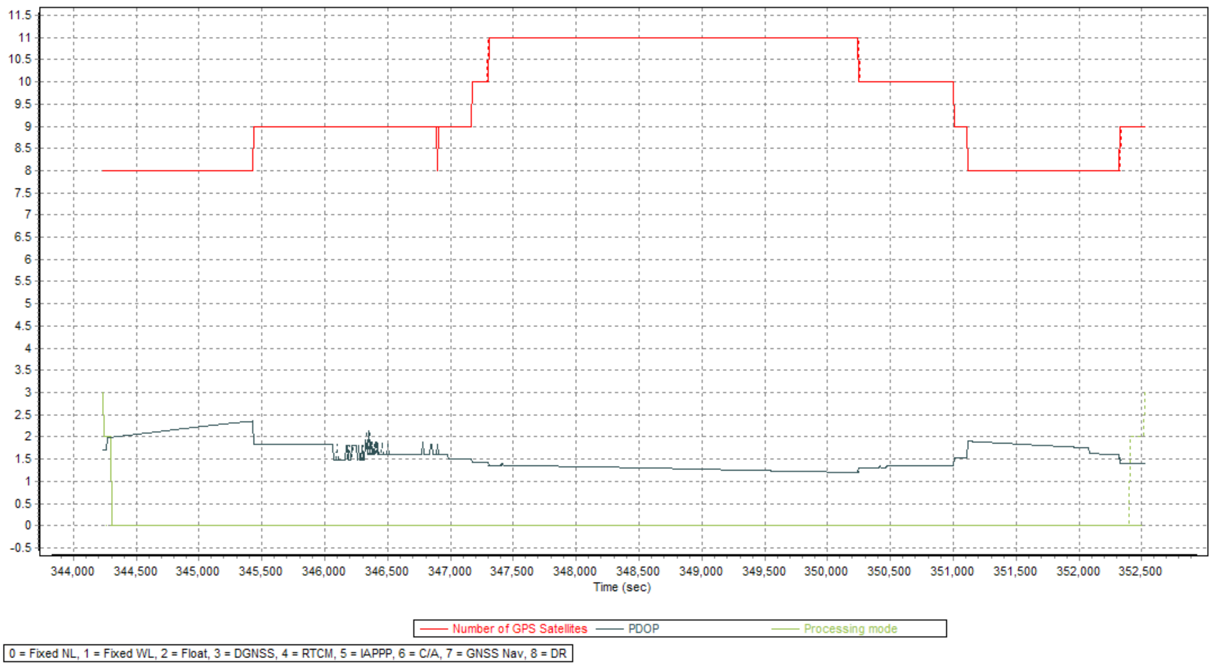


Figure A-8.1 Solution Status

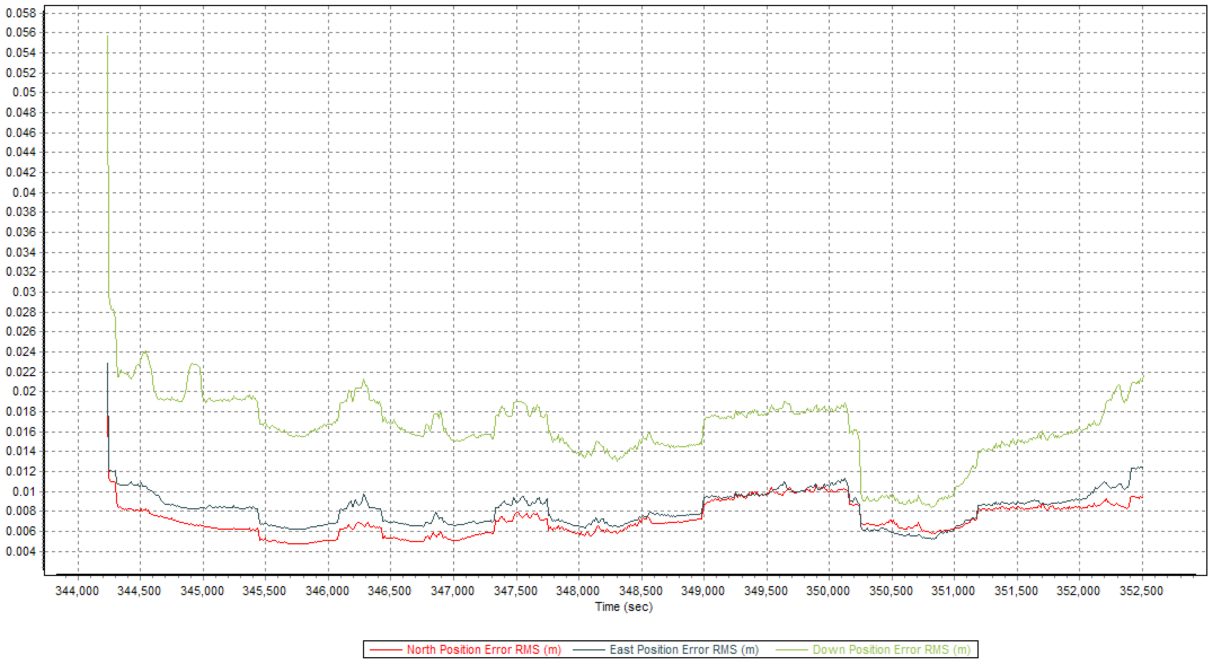


Figure A-8.2. Smoothed Performance Metrics Parameters

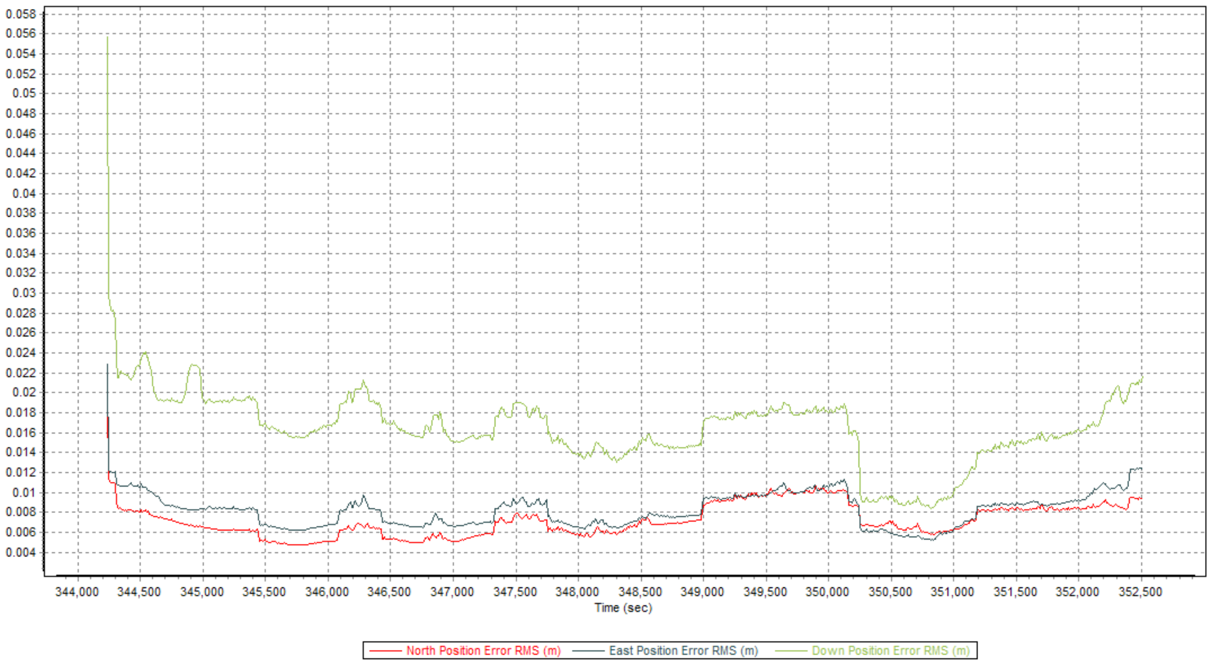


Figure A-8.2. Smoothed Performance Metrics Parameters

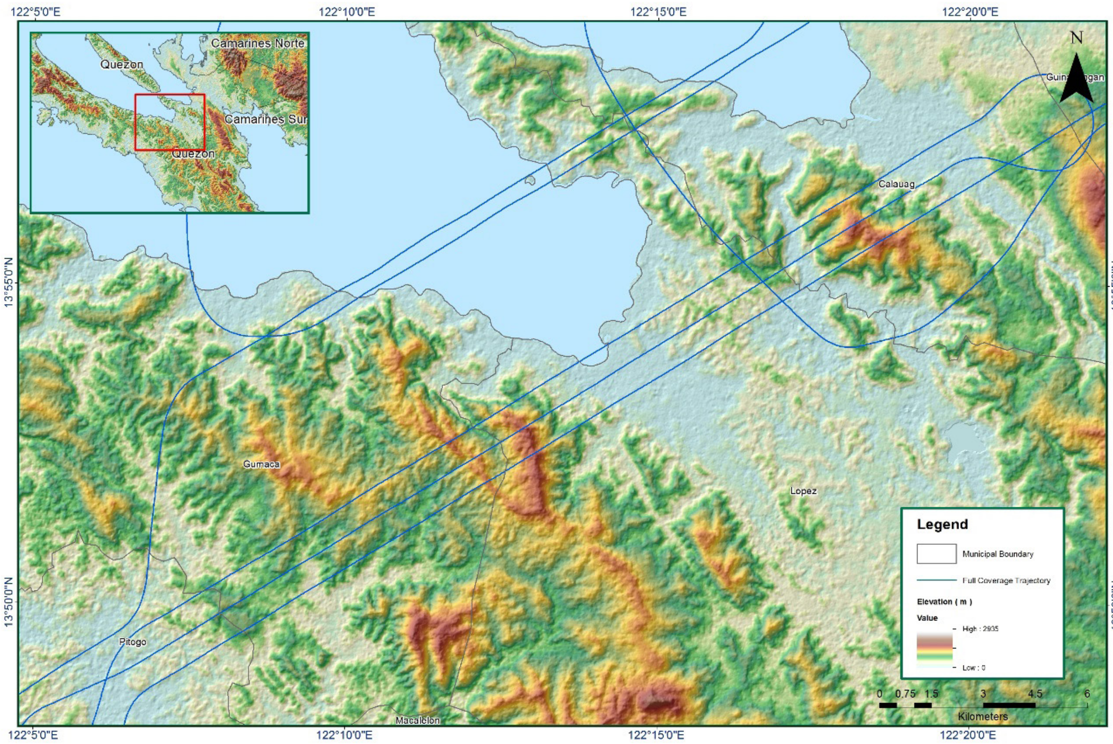


Figure A-8.3. Best Estimated Trajectory

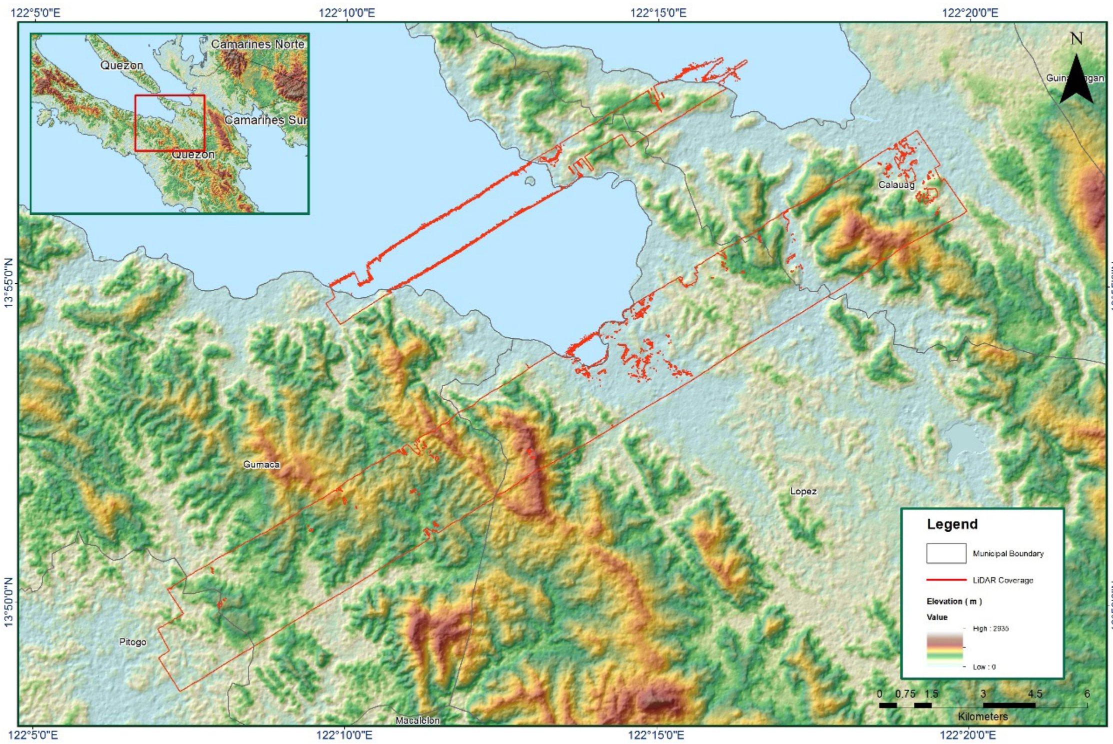


Figure A-8.4. Coverage of LiDAR data

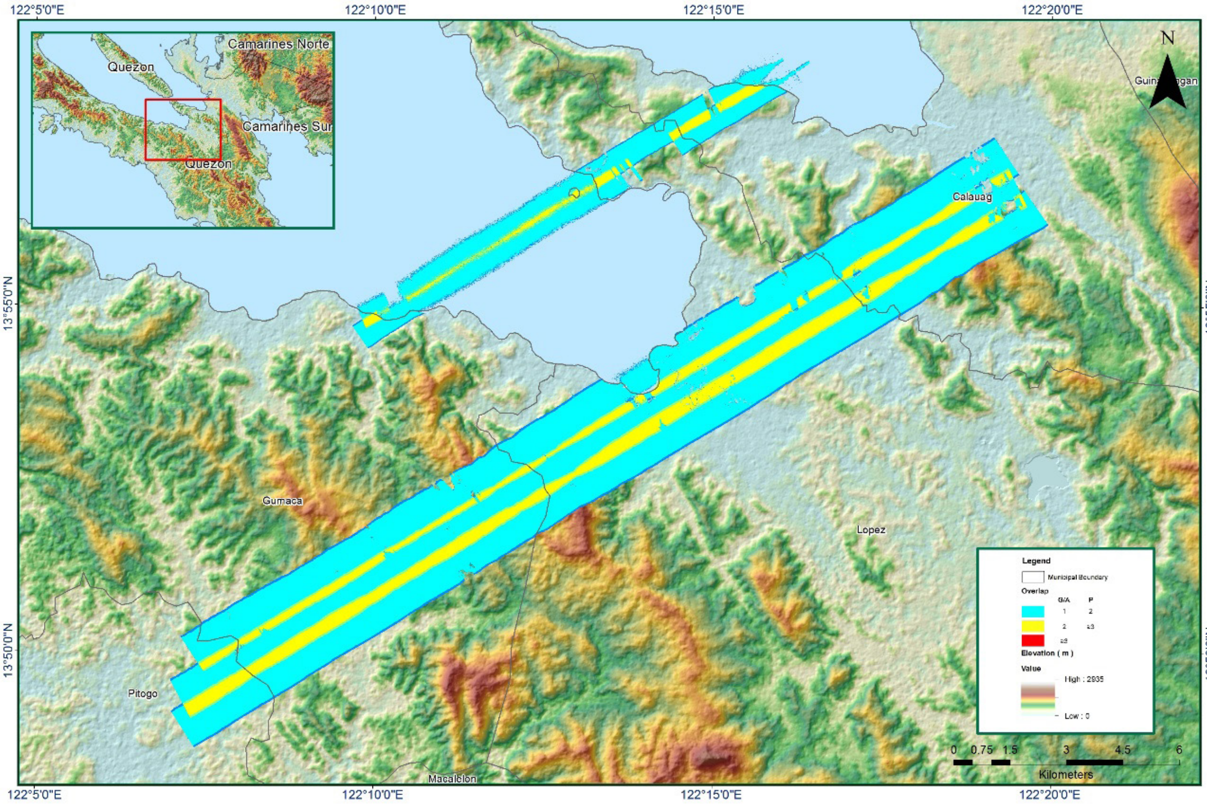


Figure A-8.5. Image of data overlap

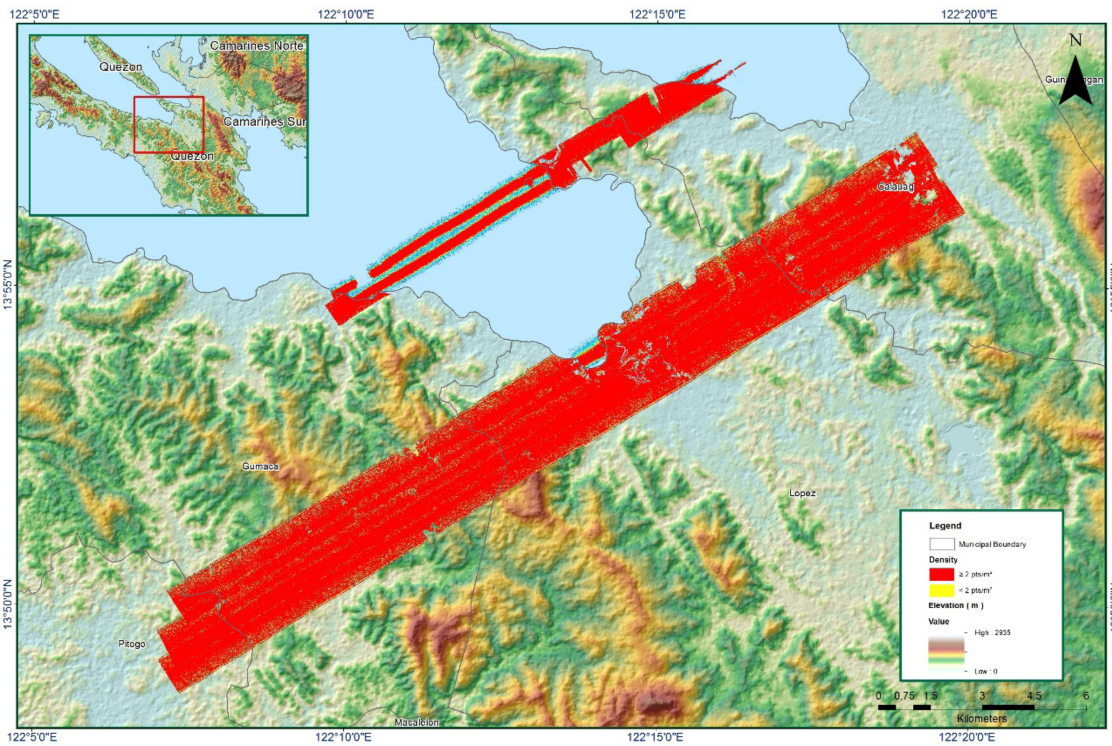


Figure A-8.6. Density map of merged LiDAR data

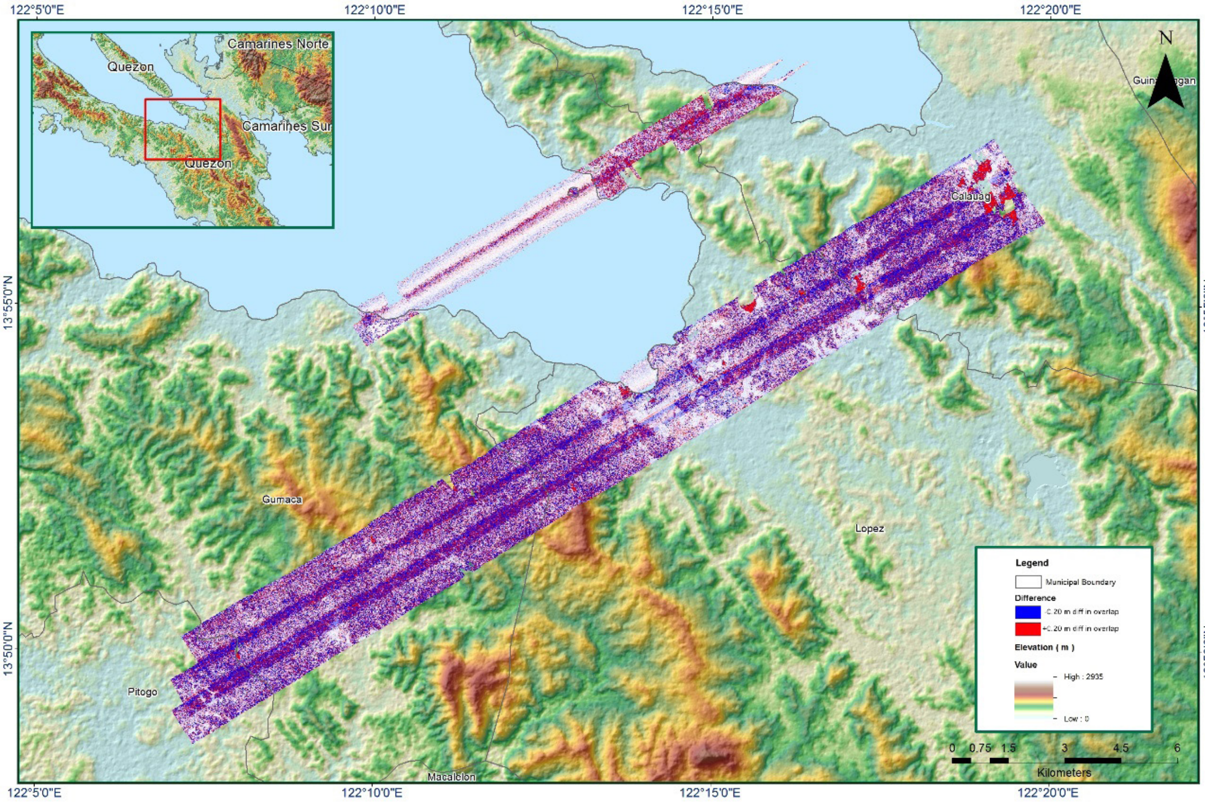


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk21C

Flight Area	Bagasbas
Mission Name	Blk21C
Inclusive Flights	23250P
Range data size	34.4 GB
POS	306 MB
Image	90.5 MB
Base Station Data	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 (<0.20m)	Yes
Number of 1km x 1km blocks	290
Maximum Height	448.83 m
Minimum Height	50.13 m

Classification (# of points)	
Ground	200,881,690
Low vegetation	182,754,278
Medium vegetation	486,076,060
High vegetation	1,342,019,390
Building	23,114,427
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Merven Natino, Engr. Elainne Lopez
	Engr. Don Matthew Banatin, Engr. Merven Natino, Engr. Elainne Lopez

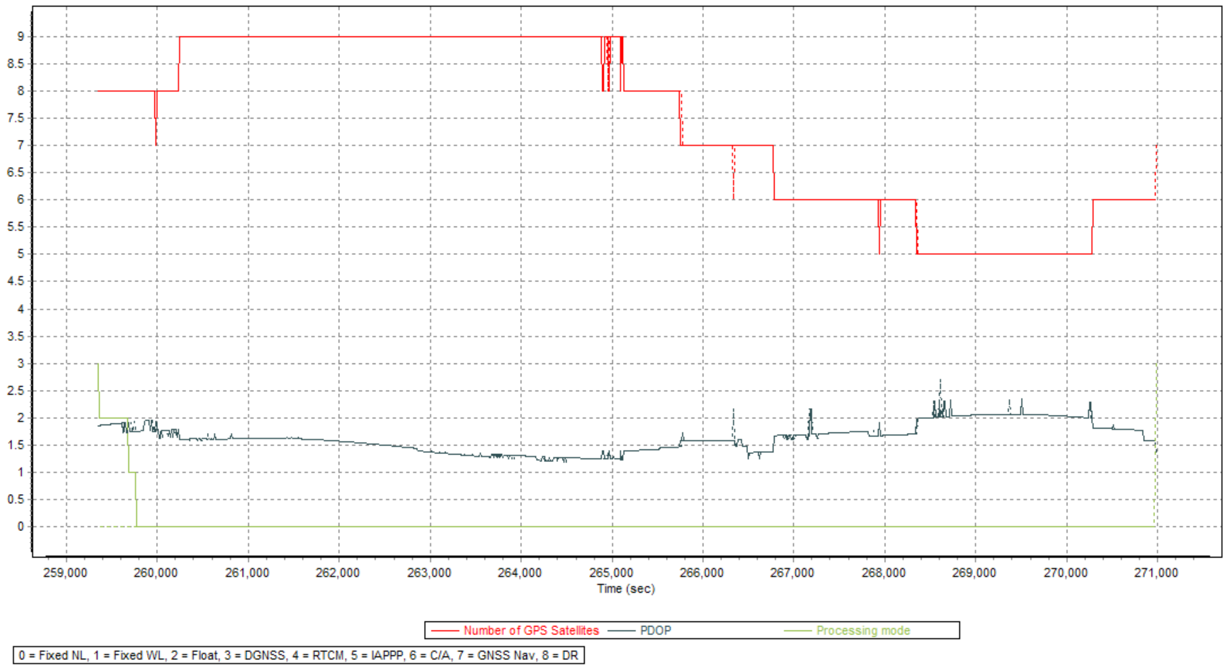


Figure A-8.8. Solution Status

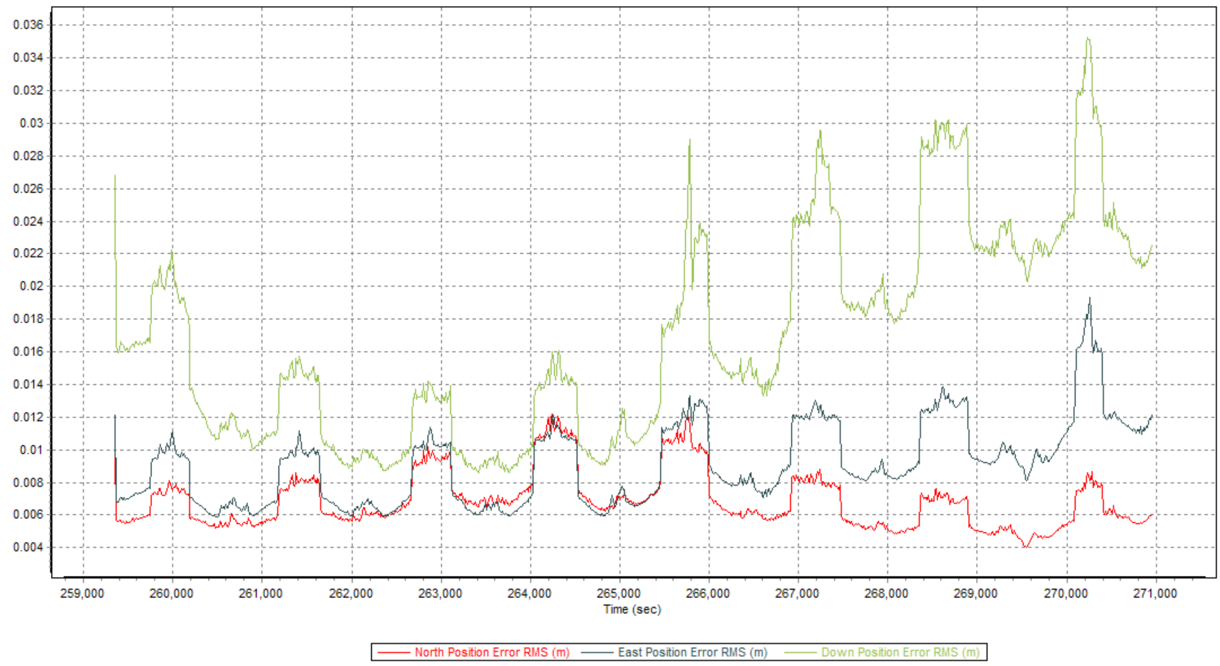


Figure A-8.9. Smoothed Performance Metrics Parameters

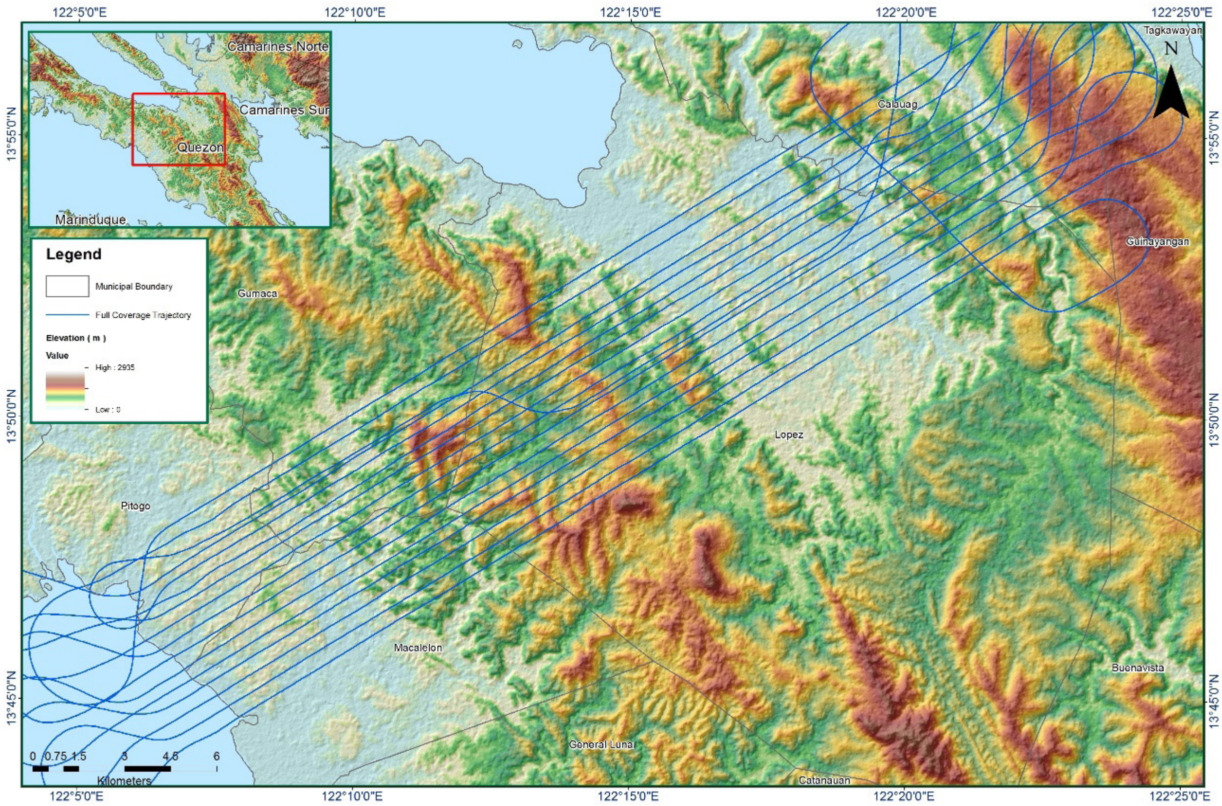


Figure A-8.10. Best Estimated Trajectory

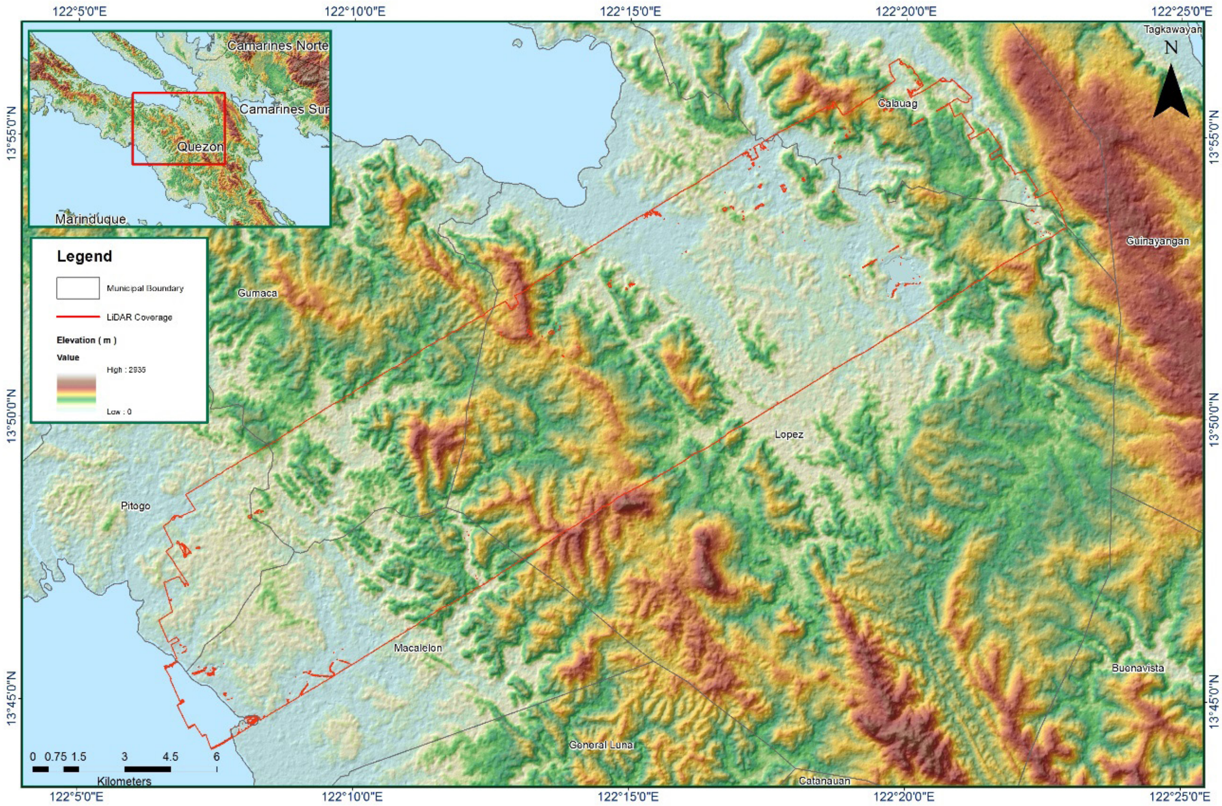


Figure A-8.11. Coverage of LiDAR data

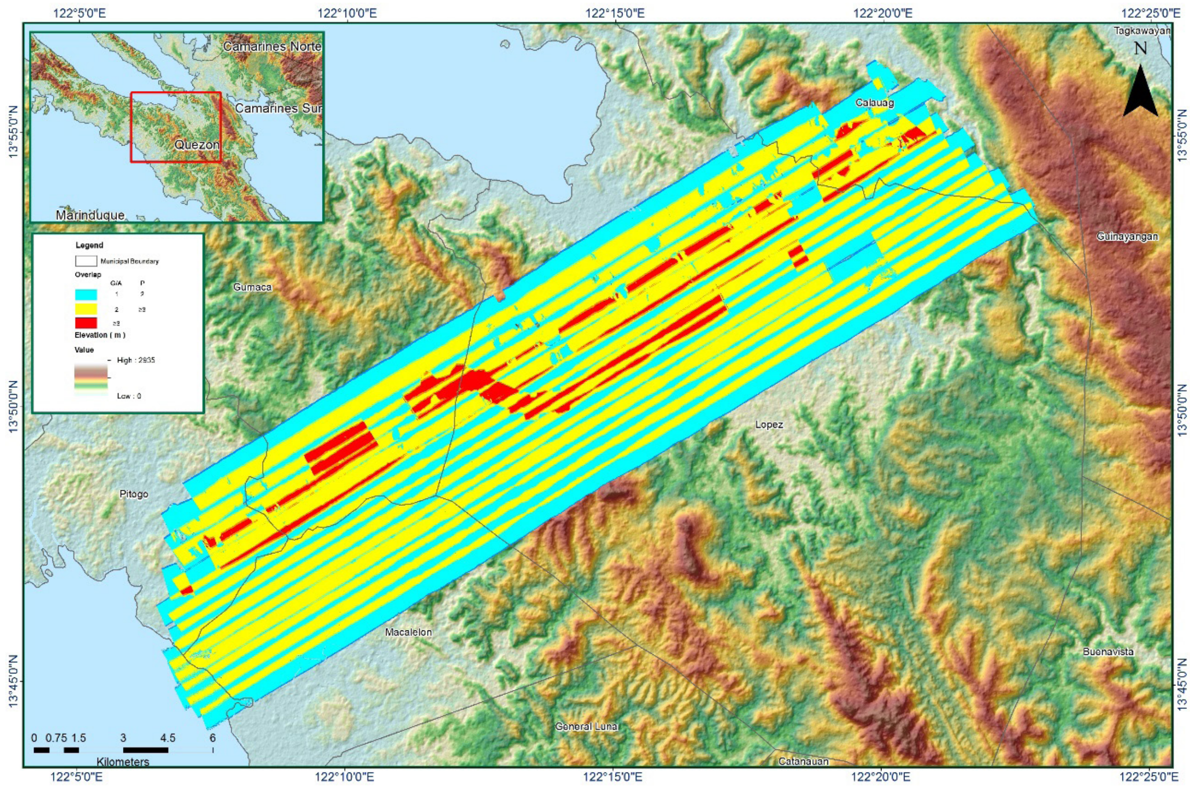


Figure A-8.12. Image of data overlap

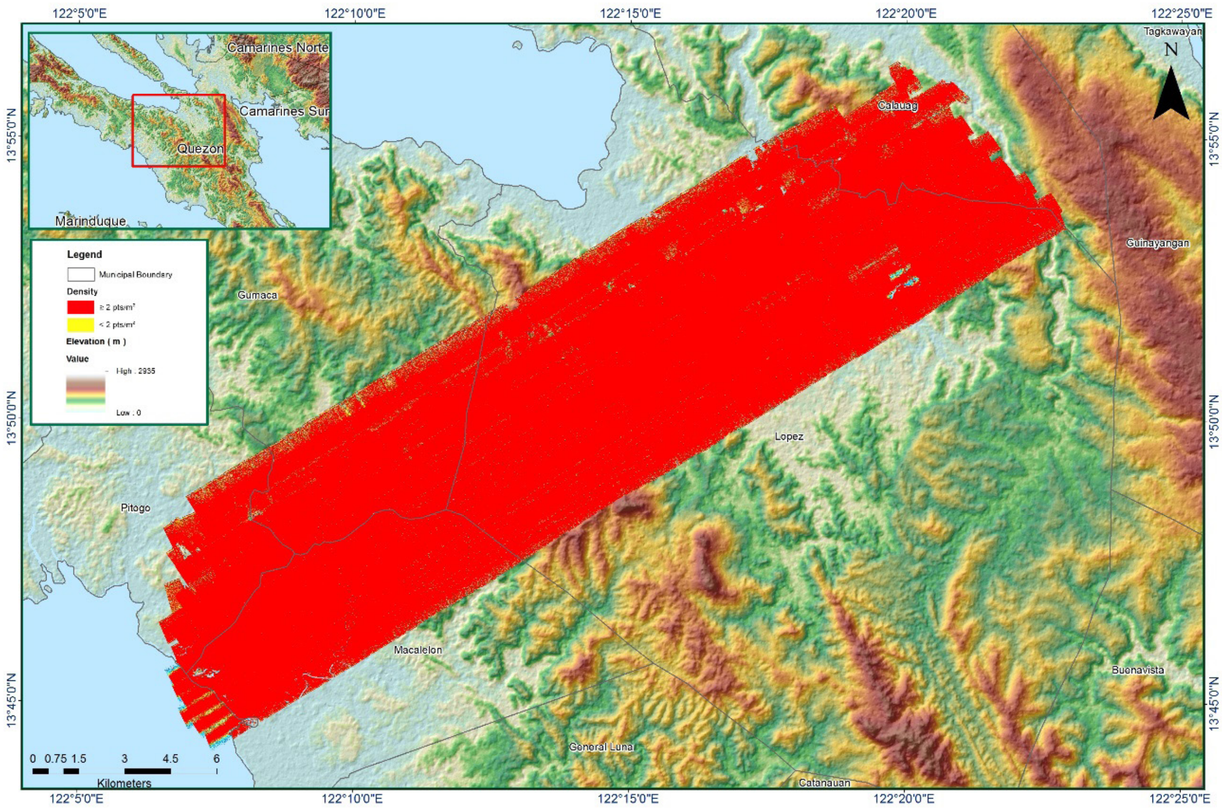


Figure A-8.13. Density map of merged LiDAR data

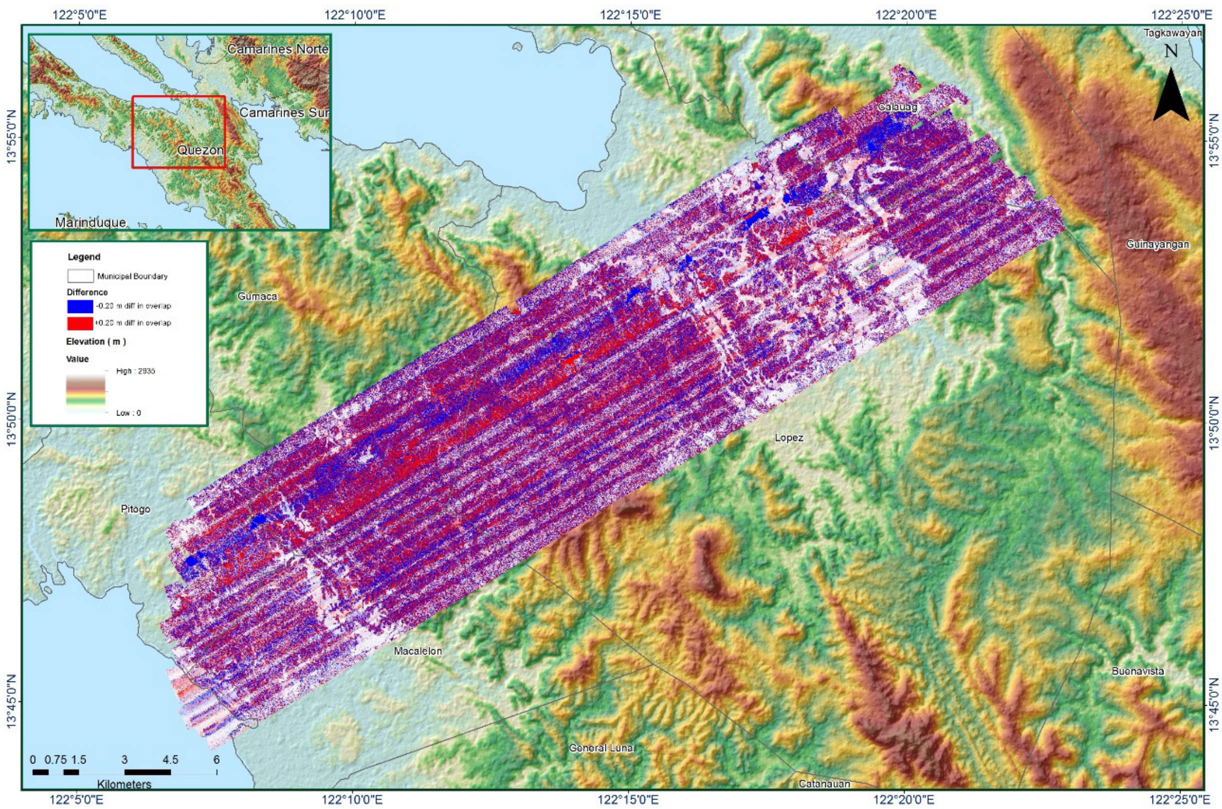


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk21D

Flight Area	Bagasbas
Mission Name	Blk21D
Inclusive Flights	23258P
Range data size	28.3 GB
POS	295 MB
Image	184 MB
Base Station Data	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 (<0.20m)	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, Engr. Ma. Joanne Balaga, Alex John Escobido
	Engr. Don Matthew Banatin, Engr. Merven Natino, Engr. Elainne Lopez

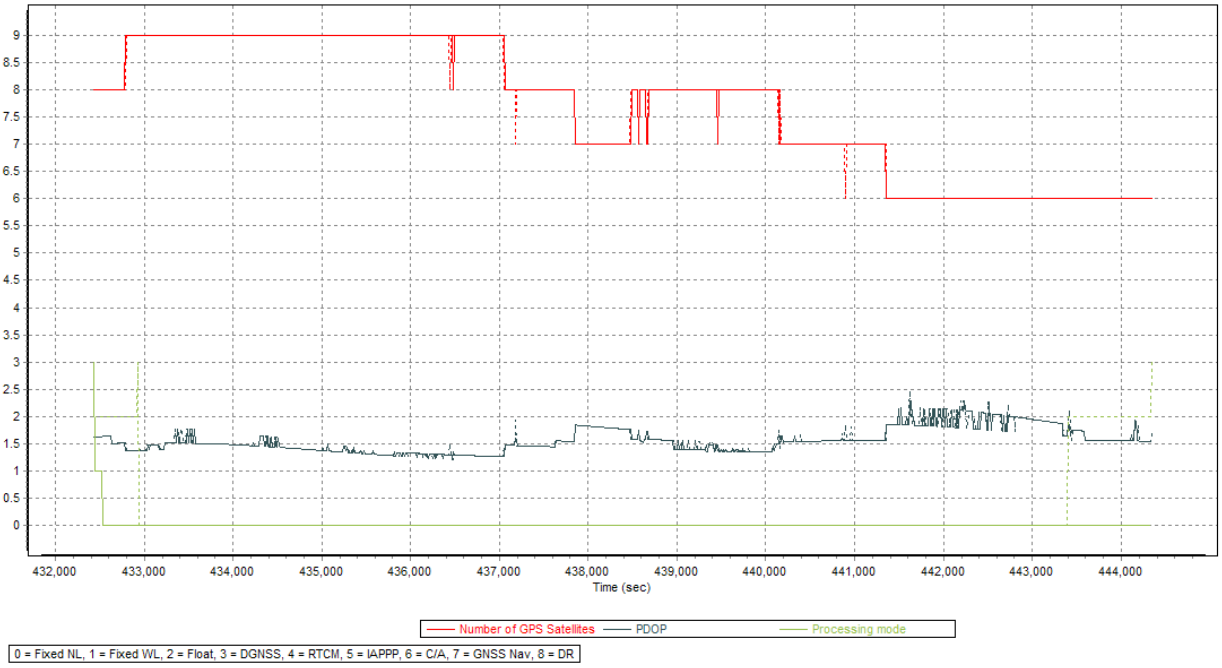


Figure A-8.15. Solution Status

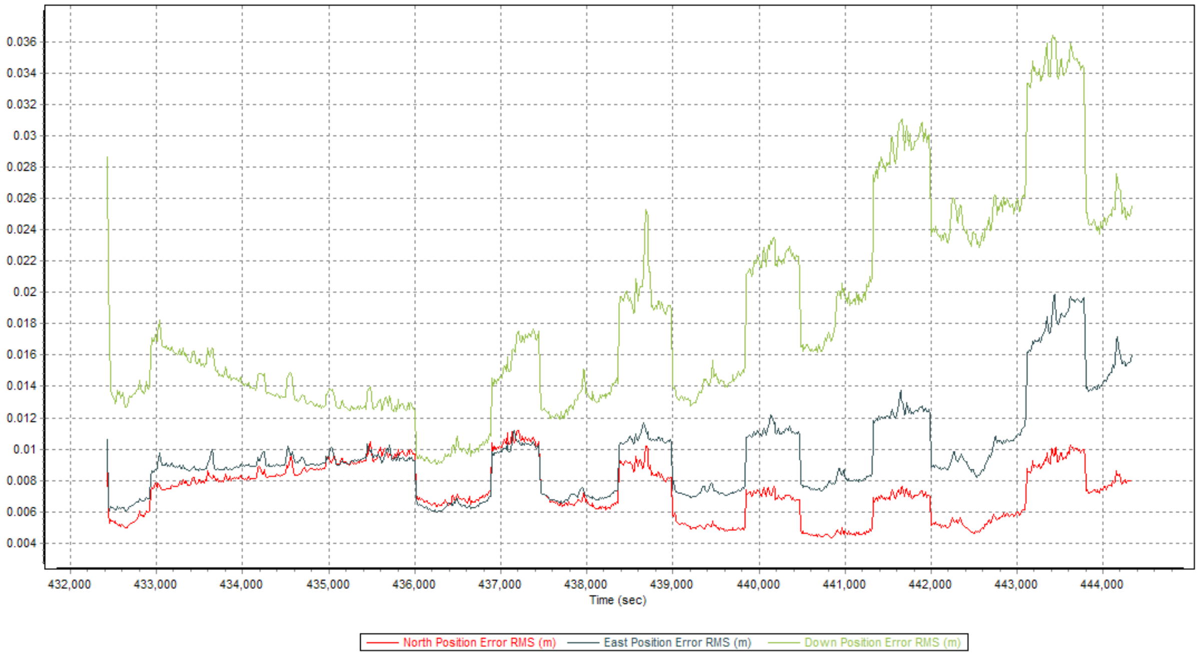


Figure A-8.16. Smoothed Performance Metrics Parameters

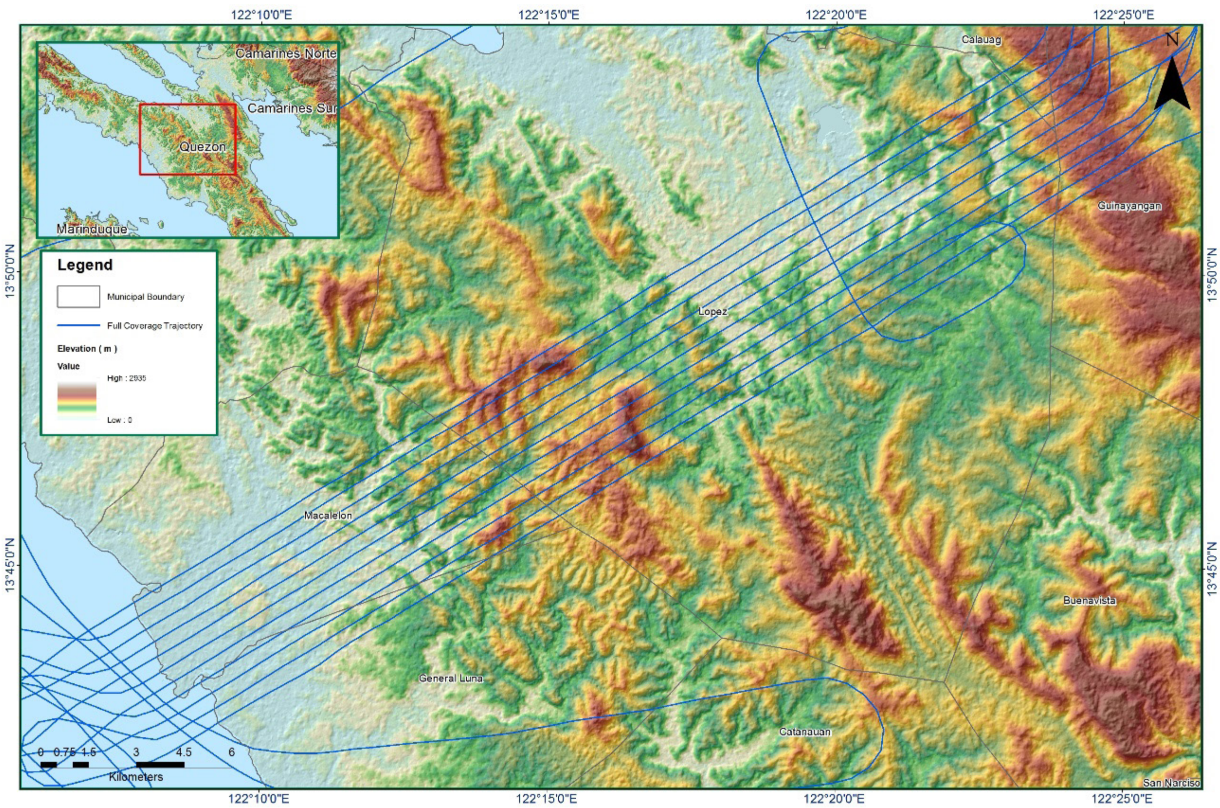


Figure A-8.17. Best Estimated Trajectory

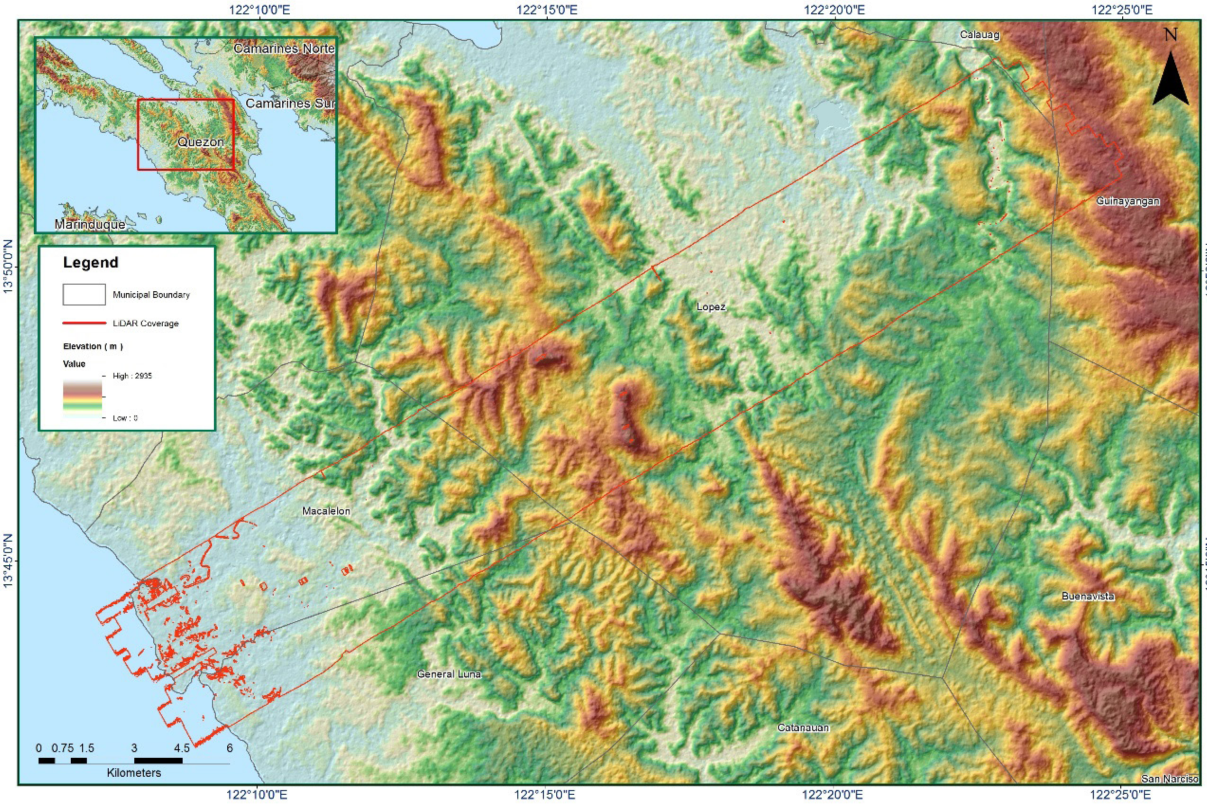


Figure A-8.18. Coverage of LiDAR data

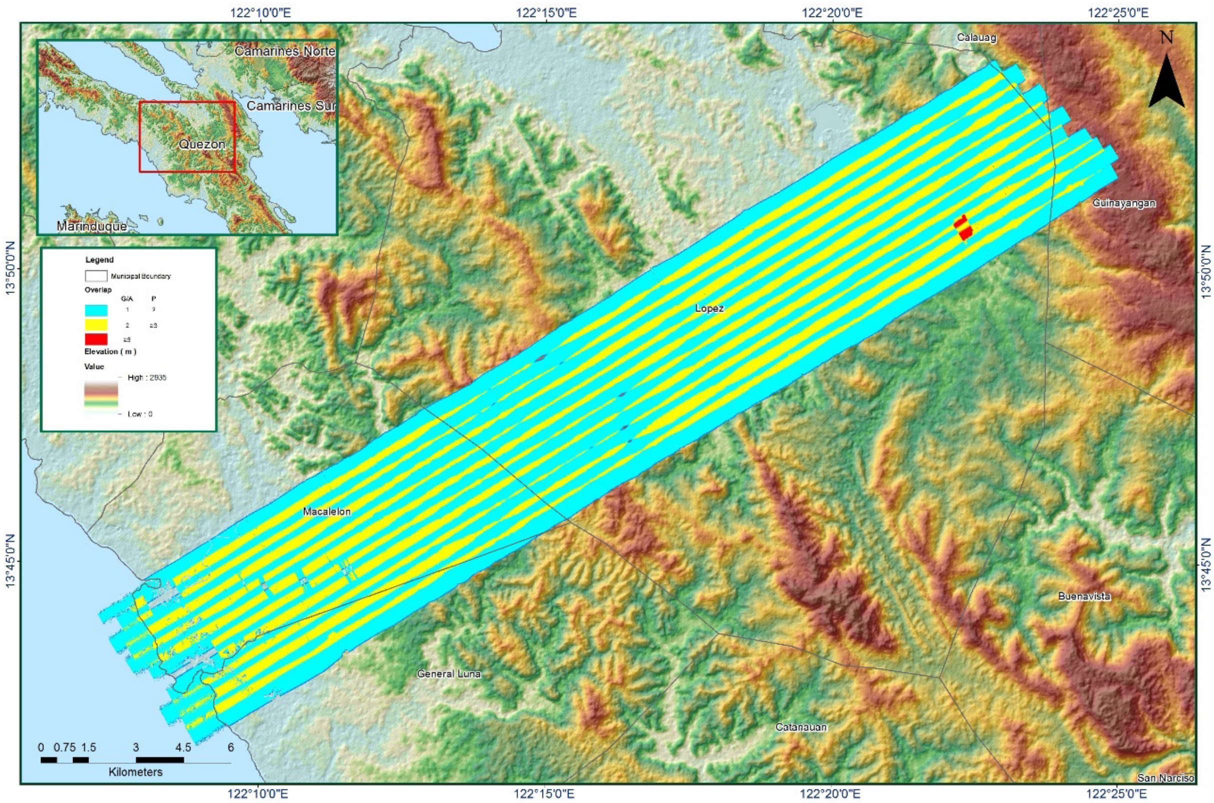


Figure A-8.19. Image of data overlap

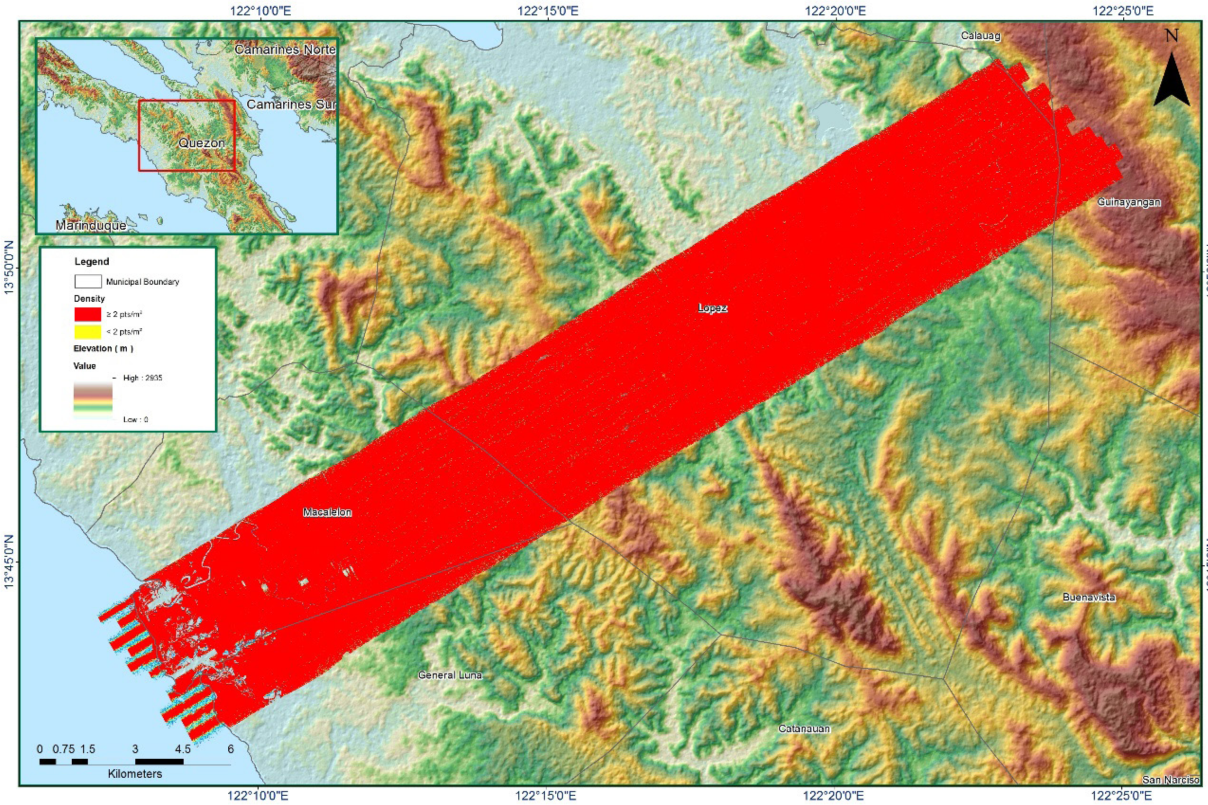


Figure A-8.20. Density map of merged LiDAR data

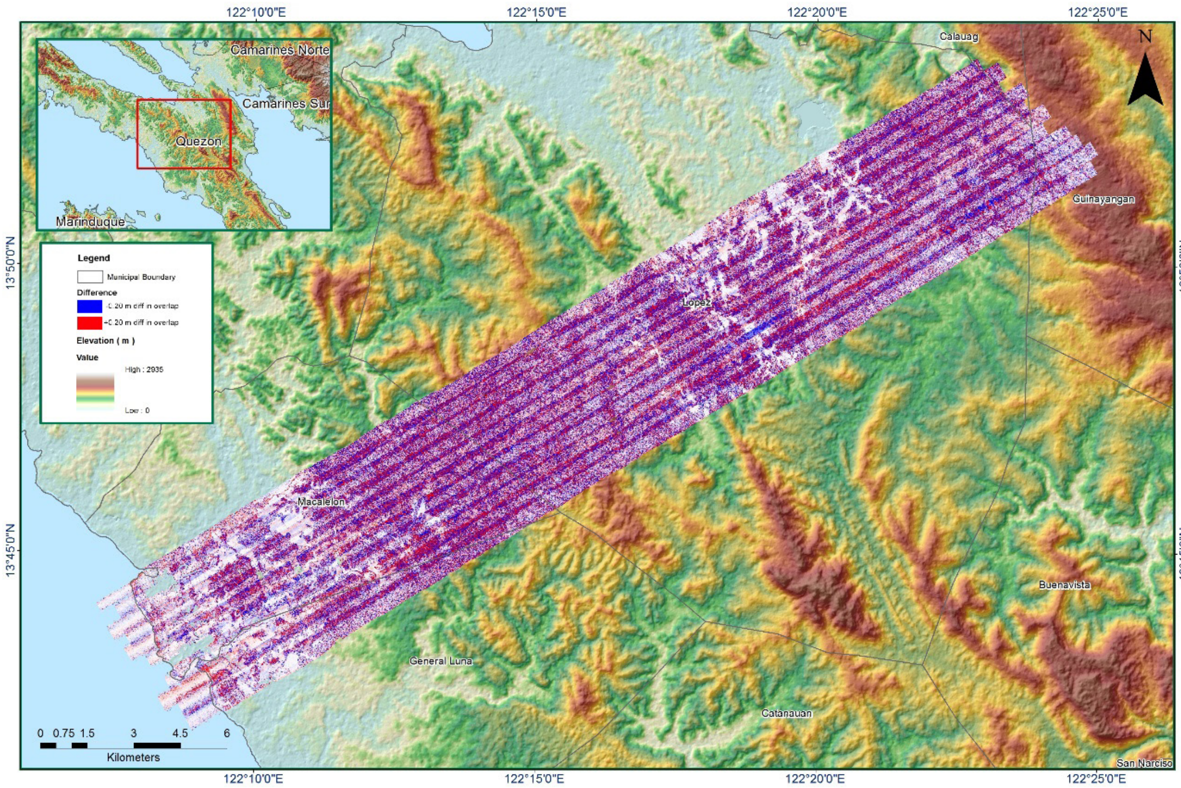


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk21D_additional

Flight Area	Bagasbas
Mission Name	Blk21D_additional
Inclusive Flights	23262P
Range data size	15.8 GB
POS	222 MB
Image	83 MB
Base Station Data	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)	0.000249
IMU attitude correction stdev (<0.001deg)	0.004144
GPS position stdev (<0.01m)	0.0119
Minimum % overlap (>25)	18.94%
Ave point cloud density per sq.m. (>2.0)	4.16
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	157
Maximum Height	386.51 m
Minimum Height	41.77 m

Classification (# of points)	
Ground	103,357,457
Low vegetation	46,377,921
Medium vegetation	109,210,240
High vegetation	319,128,593
Building	2,416,699
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Justine Francisco, Engr. Czarina Jean Añonuevo

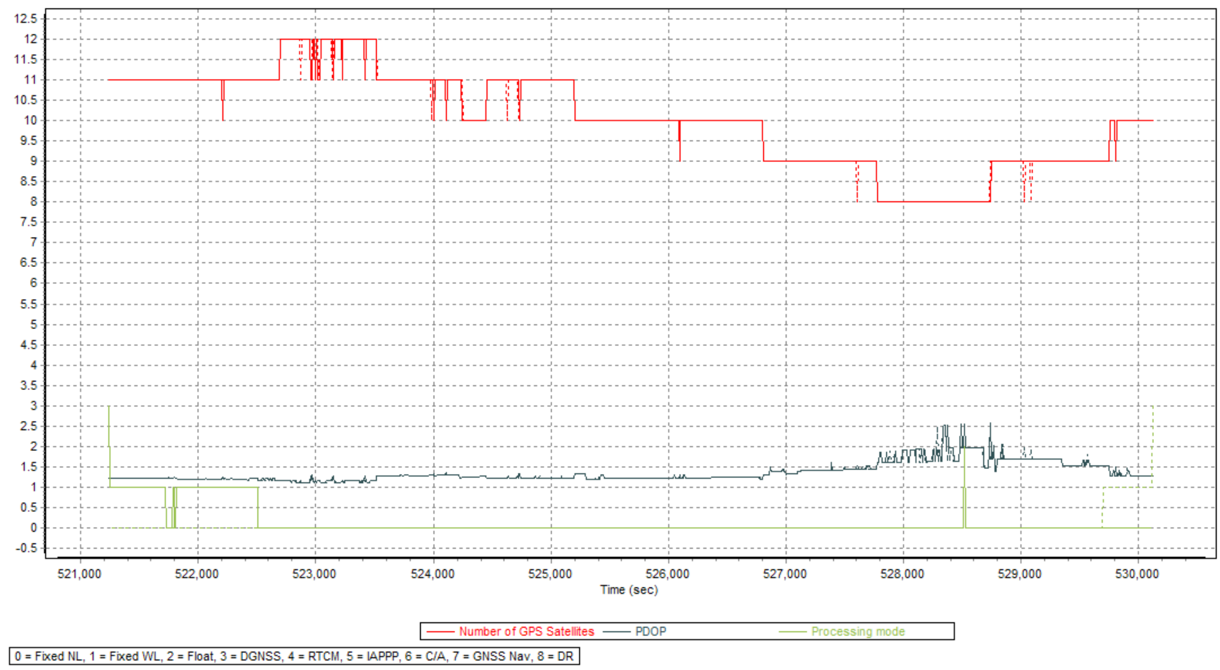


Figure A-8.22. Solution Status

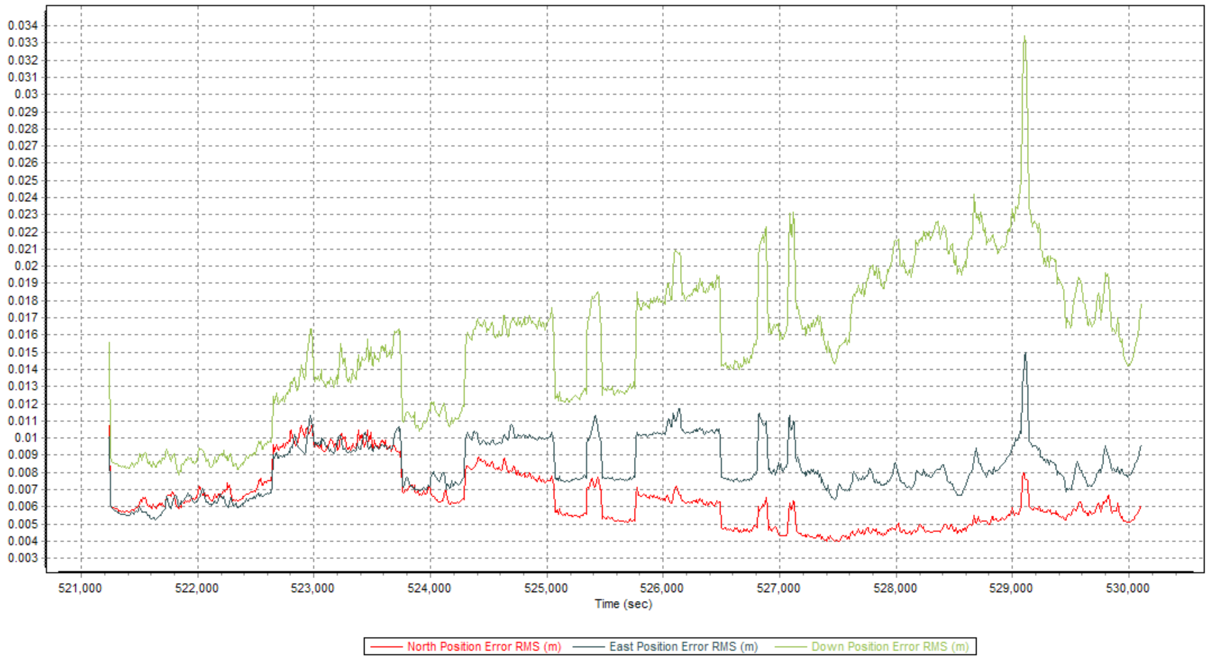


Figure A-8.23. Smoothed Performance Metrics Parameters

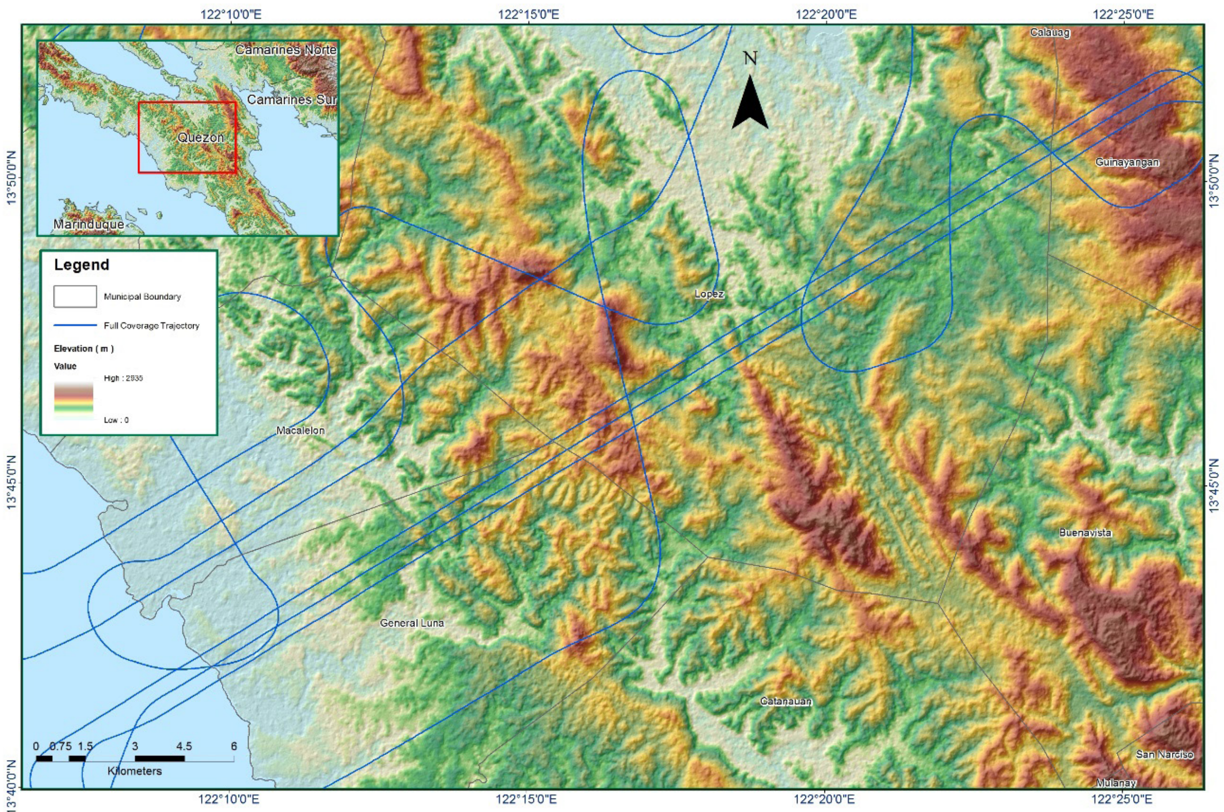


Figure A-8.24. Best Estimated Trajectory

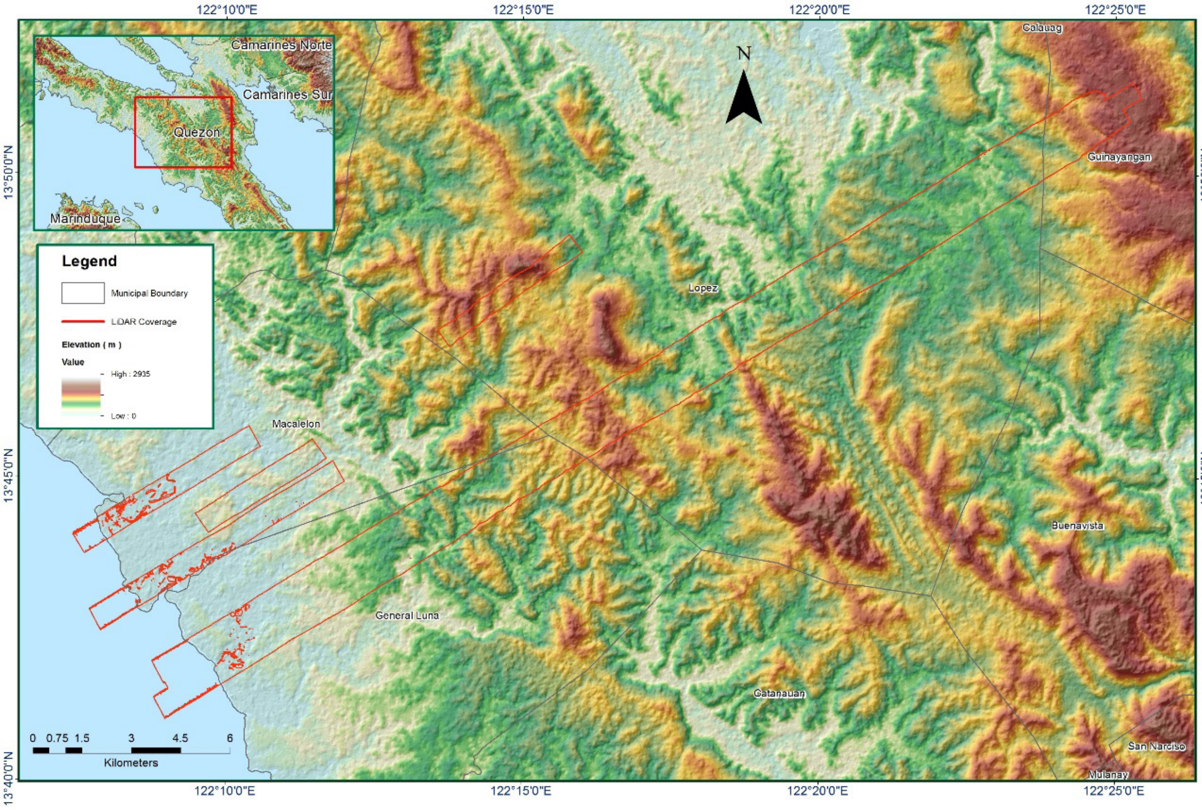


Figure A-8.25. Coverage of LiDAR data

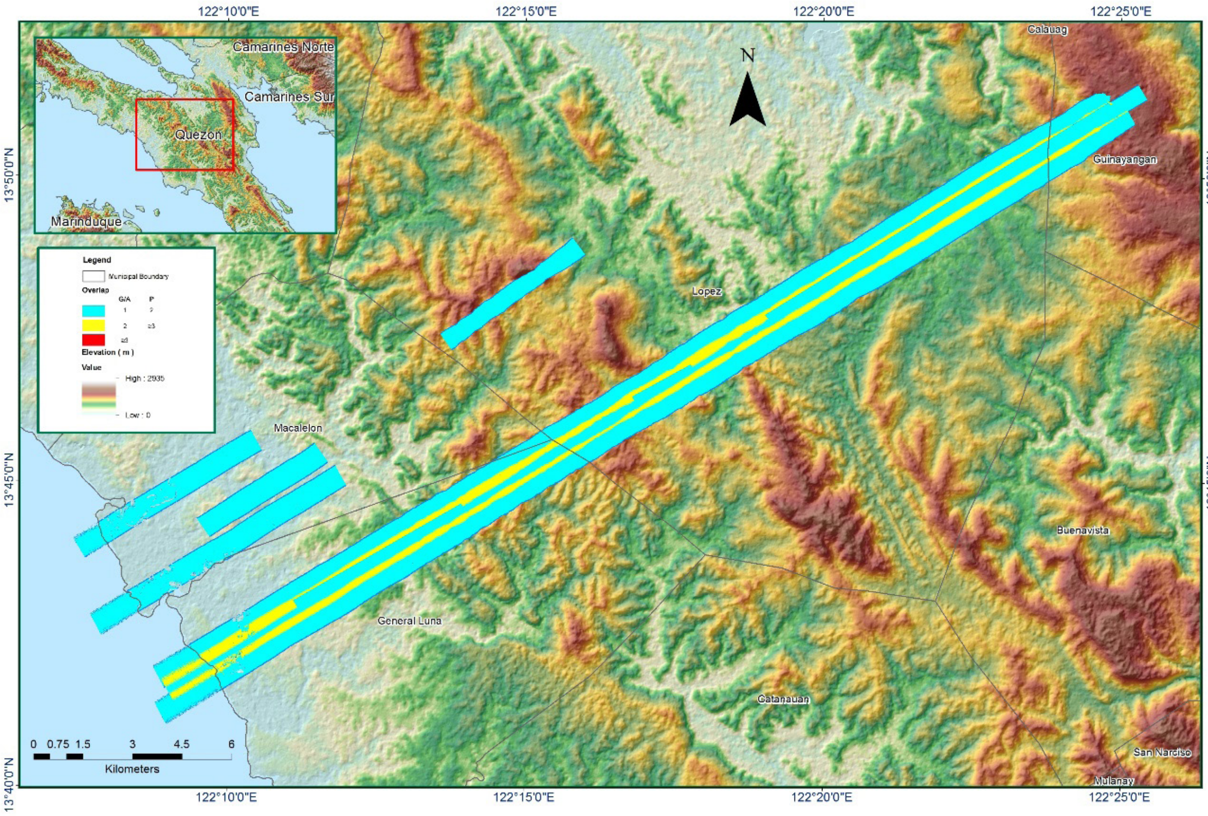


Figure A-8.26. Image of data overlap

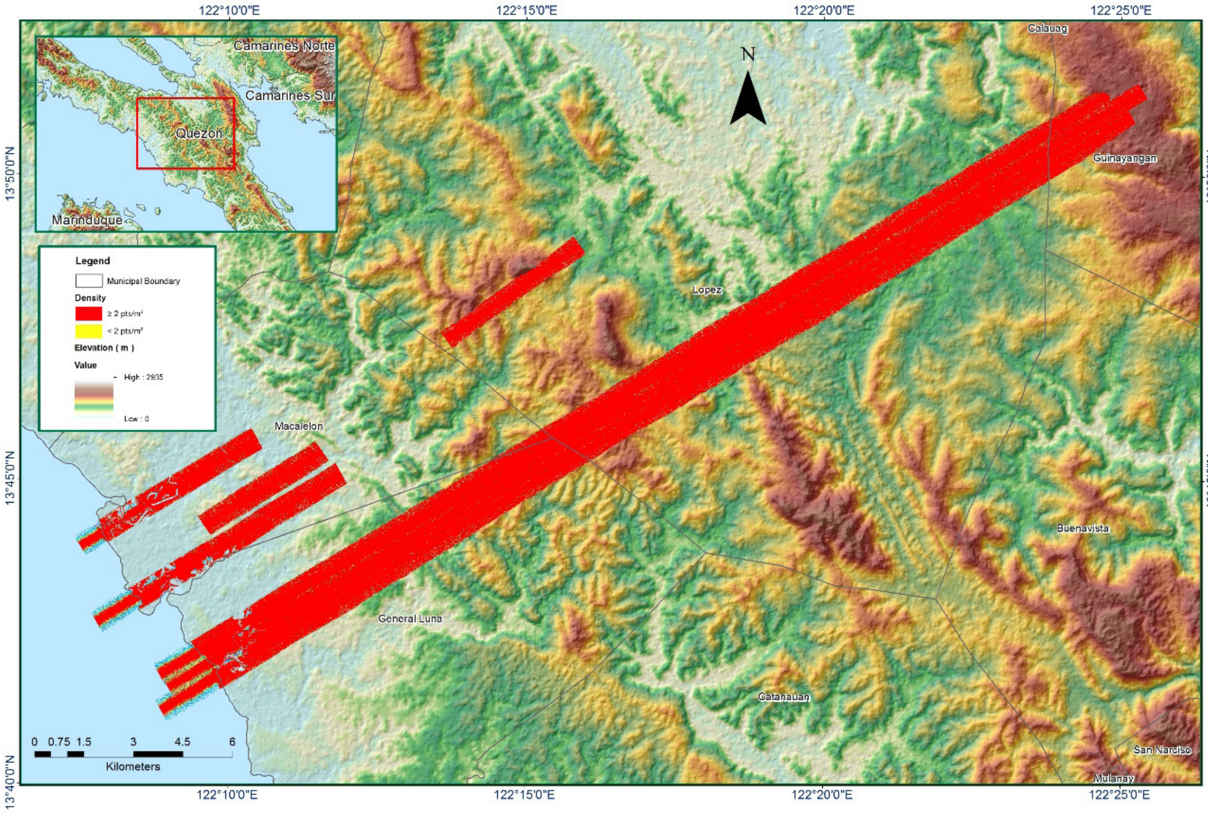


Figure A-8.27. Density map of merged LiDAR data

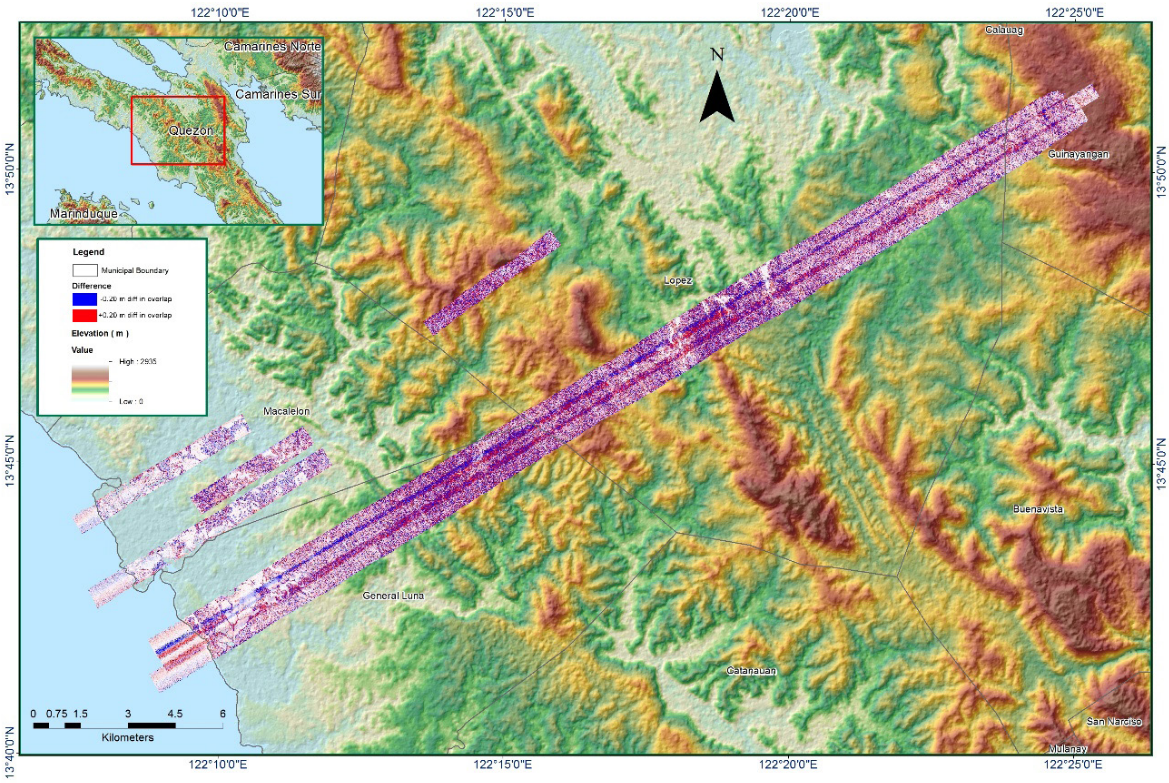


Figure A-8.28. Elevation difference between flight lines

Annex 9. Macalelon Model Basin Parameters

Table A-9.1 Macalelon Model Basin Parameters

Subbasin	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
W180	1.872	83	0.0	0.0389223	3.0955	Discharge	0.18163	0.01	Ratio to Peak	0.5
W190	1.872	83	0.0	0.0542241	4.3125	Discharge	0.17046	0.01	Ratio to Peak	0.5
W200	1.84932	83.178	0.0	0.0414996	3.3005	Discharge	0.17446	0.01	Ratio to Peak	0.5
W210	1.872	83	0.0	0.0421460	3.352	Discharge	0.15771	0.01	Ratio to Peak	0.5
W220	1.872	83	0.0	0.0411282	3.271	Discharge	0.0910007	0.01	Ratio to Peak	0.5
W230	1.872	83	0.0	0.0219872	1.7487	Discharge	0.0071981	0.01	Ratio to Peak	0.5
W240	1.544256	85.552	0.0	0.0597296	4.7504	Discharge	0.31973	0.01	Ratio to Peak	0.5
W250	1.788696	83.639	0.0	0.0391850	3.1164	Discharge	0.26094	0.01	Ratio to Peak	0.5
W260	1.153512	88.798	0.0	0.018	0.87669	Discharge	0.0164144	0.01	Ratio to Peak	0.5
W270	1.116	89	0.0	0.018	1.1898	Discharge	0.0109126	0.01	Ratio to Peak	0.5
W280	1.645632	84.748	0.0	0.0324052	2.5772	Discharge	0.0923120	0.01	Ratio to Peak	0.5
W290	1.192464	88.464	0.0	0.0186751	1.4853	Discharge	0.0104593	0.01	Ratio to Peak	0.5
W300	1.116	89	0.0	0.018	1.1873	Discharge	0.0096269	0.01	Ratio to Peak	0.5
W310	1.116	89	0.0	0.0387049	3.0782	Discharge	0.0893986	0.01	Ratio to Peak	0.5
W320	1.169712	88.659	0.0	0.0270207	2.149	Discharge	0.0950573	0.01	Ratio to Peak	0.5
W330	1.291824	87.621	0.0	0.0726367	5.7769	Discharge	0.17753	0.01	Ratio to Peak	0.5
W340	1.149192	88.835	0.0	0.0704062	5.5995	Discharge	0.0725024	0.01	Ratio to Peak	0.5

Annex 10. Macalelon Model Reach Parameters

Reach	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R110	Automatic Fixed Interval	645.27	0.004	0.16234	Trapezoid	50	0.5
R120	Automatic Fixed Interval	653.55	0.004	0.00909	Trapezoid	50	0.5
R150	Automatic Fixed Interval	728.70	.000692118293	0.007211	Trapezoid	50	0.5
R170	Automatic Fixed Interval	1160.7	0.0072700	0.00432	Trapezoid	50	0.5
R50	Automatic Fixed Interval	207.99	0.004	0.07009	Trapezoid	50	0.5
R60	Automatic Fixed Interval	3998.7	0.0037483	0.04933	Trapezoid	59	0.5
R70	Automatic Fixed Interval	5690.4	0.0030597	0.048	Trapezoid	50	0.5
R90	Automatic Fixed Interval	915.27	0.0013056	0.071	Trapezoid	50	0.5
R180	Automatic Fixed Interval	5751.3	0.0213533	0.001	Trapezoid	79.68	1
R210	Automatic Fixed Interval	1225.8	0.0171314	0.001	Trapezoid	79.68	1
R230	Automatic Fixed Interval	641.76	0.0140239	0.001	Trapezoid	79.68	1
R250	Automatic Fixed Interval	2493.9	0.0068167	0.001	Trapezoid	79.68	1
R290	Automatic Fixed Interval	1280.5	0.0288951	0.001	Trapezoid	79.68	1
R310	Automatic Fixed Interval	4757.4	0.0025224	0.001	Trapezoid	79.68	1
R340	Automatic Fixed Interval	1758.1	0.0369714	0.001	Trapezoid	79.68	1
R360	Automatic Fixed Interval	4032.2	0.004464	0.001	Trapezoid	79.68	1
R450	Automatic Fixed Interval	927.26	0.0905064	0.001	Trapezoid	79.68	1
R470	Automatic Fixed	2435.8	0.0057477	0.001	Trapezoid	79.68	1

Annex 11. Macalelon Flood Validation Data

Table A-11.1 Macalelon Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.74686	122.137065	0.15	0	-0.150	Glenda July 15,2014	5 -Year
2	13.746666	122.136861	0.07	0	-0.070	Glenda July 15,2015	5 -Year
3	13.746433	122.136634	0.08	0	-0.080	Glenda July 15,2016	5 -Year
4	13.746198	122.136505	0.25	0	-0.250	Glenda July 15,2017	5 -Year
5	13.745954	122.136318	0.03	0	-0.030	Glenda July 15,2018	5 -Year
6	13.74556	122.135922	0.06	0	-0.060	Glenda July 15,2019	5 -Year
7	13.74553	122.136239	0.16	0.5	0.340	Glenda July 15,2020	5 -Year
8	13.745377	122.136352	0.03	0.5	0.470	Glenda July 15,2021	5 -Year
9	13.7454	122.136133	0.09	0.5	0.410	Glenda July 15,2022	5 -Year
10	13.74533	122.13604	0.03	0.5	0.470	Glenda July 15,2023	5 -Year
11	13.745216	122.135531	0.03	0.5	0.470	Glenda July 15,2024	5 -Year
12	13.745305	122.135622	0.03	0.5	0.470	Glenda July 15,2025	5 -Year
13	13.745533	122.135424	0.06	0	-0.060	Glenda July 15,2026	5 -Year
14	13.745543	122.135021	0.03	0	-0.030	Glenda July 15,2027	5 -Year
15	13.745516	122.134652	0.03	0	-0.030	Glenda July 15,2028	5 -Year
16	13.74556	122.134634	0.86	5	4.140	Glenda July 15,2029	5 -Year
17	13.745671	122.13465	0.08	5	4.920	Glenda July 15,2030	5 -Year
18	13.745733	122.134676	0.68	5	4.320	Glenda July 15,2031	5 -Year
19	13.745746	122.1346	0.46	5	4.540	Glenda July 15,2032	5 -Year
20	13.745528	122.134365	0.03	0	-0.030	Glenda July 15,2033	5 -Year
21	13.745381	122.134121	0.03	0.5	0.470	Glenda July 15,2034	5 -Year
22	13.74498	122.134109	0.03	1	0.970	Glenda July 15,2035	5 -Year
23	13.745	122.134283	0.03	1	0.970	Glenda July 15,2036	5 -Year
24	13.745022	122.134447	0.03	1	0.970	Glenda July 15,2037	5 -Year
25	13.744955	122.133983	0.33	1	0.670	Glenda July 15,2038	5 -Year
26	13.744926	122.133778	0.15	1	0.850	Glenda July 15,2039	5 -Year
27	13.74494	122.133427	0.03	1.5	1.470	Glenda July 15,2040	5 -Year
28	13.745127	122.133433	0.03	1.5	1.470	Glenda July 15,2041	5 -Year
29	13.745222	122.133495	0.3	1.5	1.200	Glenda July 15,2042	5 -Year
30	13.744861	122.133182	0.03	1	0.970	Glenda July 15,2043	5 -Year
31	13.744877	122.132866	0.03	1	0.970	Glenda July 15,2044	5 -Year
32	13.745434	122.133157	0.03	0.5	0.470	Glenda July 15,2045	5 -Year
33	13.745608	122.133161	0.07	0.5	0.430	Glenda July 15,2046	5 -Year
34	13.745862	122.133239	0.09	0.5	0.410	Glenda July 15,2047	5 -Year
35	13.745923	122.133277	0.13	0.5	0.370	Glenda July 15,2048	5 -Year
36	13.745917	122.133523	0.32	0.5	0.180	Glenda July 15,2049	5 -Year
37	13.745862	122.133798	0.11	0.5	0.390	Glenda July 15,2050	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
38	13.745806	122.134051	0.27	0.5	0.230	Glenda July 15,2051	5 -Year
39	13.745745	122.134255	0.05	0.5	0.450	Glenda July 15,2052	5 -Year
40	13.746003	122.133068	0.03	0.5	0.470	Glenda July 15,2053	5 -Year
41	13.746241	122.132805	0.29	0.5	0.210	Glenda July 15,2054	5 -Year
42	13.746274	122.132313	0.21	0.5	0.290	Glenda July 15,2055	5 -Year
43	13.746486	122.131988	0.19	0.5	0.310	Glenda July 15,2056	5 -Year
44	13.746791	122.131745	0.15	0.5	0.350	Glenda July 15,2057	5 -Year
45	13.74696	122.131535	0.03	0.5	0.470	Glenda July 15,2058	5 -Year
46	13.747065	122.131619	0.14	4	3.860	Glenda July 15,2059	5 -Year
47	13.747134	122.131474	0.03	4	3.970	Glenda July 15,2060	5 -Year
48	13.747225	122.131432	0.03	4	3.970	Glenda July 15,2061	5 -Year
49	13.747368	122.13134	0.06	4	3.940	Glenda July 15,2062	5 -Year
50	13.747479	122.131335	0.12	5	4.880	Glenda July 15,2063	5 -Year
51	13.747541	122.131221	0.2	5	4.800	Glenda July 15,2064	5 -Year
52	13.74777	122.131075	0.11	5	4.890	Glenda July 15,2065	5 -Year
53	13.748298	122.130759	0.03	5	4.970	Glenda July 15,2066	5 -Year
54	13.748671	122.130487	0.03	5	4.970	Glenda July 15,2067	5 -Year
55	13.748966	122.130764	0.03	5	4.970	Glenda July 15,2068	5 -Year
56	13.748837	122.131077	0.41	5	4.590	Glenda July 15,2069	5 -Year
57	13.74855	122.131278	0.43	5	4.570	Glenda July 15,2070	5 -Year
58	13.748103	122.131581	0.03	5	4.970	Glenda July 15,2071	5 -Year
59	13.747801	122.131789	0.14	5	4.860	Glenda July 15,2072	5 -Year
60	13.747665	122.131614	0.03	5	4.970	Glenda July 15,2073	5 -Year
61	13.747427	122.132076	0.44	5	4.560	Glenda July 15,2074	5 -Year
62	13.749197	122.131399	0.03	4.5	4.470	Glenda July 15,2075	5 -Year
63	13.749305	122.131825	0.1	4.5	4.400	Glenda July 15,2076	5 -Year
64	13.749412	122.132416	0.03	4.5	4.470	Glenda July 15,2077	5 -Year
65	13.749029	122.132612	0.31	4.5	4.190	Glenda July 15,2078	5 -Year
66	13.748585	122.132872	0.04	4.5	4.460	Glenda July 15,2079	5 -Year
67	13.748237	122.13316	0.03	4.5	4.470	Glenda July 15,2080	5 -Year
68	13.749583	122.132924	0.03	0	-0.030	Glenda July 15,2081	5 -Year
69	13.749722	122.133306	0.03	0	-0.030	Glenda July 15,2082	5 -Year
70	13.749862	122.133719	0.03	0	-0.030	Glenda July 15,2083	5 -Year
71	13.75003	122.134129	0.05	0	-0.050	Glenda July 15,2084	5 -Year
72	13.750124	122.134431	0.04	0	-0.040	Glenda July 15,2085	5 -Year
73	13.750236	122.134746	0.03	0	-0.030	Glenda July 15,2086	5 -Year
74	13.750239	122.135085	0.03	0	-0.030	Glenda July 15,2087	5 -Year
75	13.750005	122.135409	0.04	0	-0.040	Glenda July 15,2088	5 -Year
76	13.749568	122.135455	0.03	0	-0.030	Glenda July 15,2089	5 -Year
77	13.749077	122.135481	0.03	0	-0.030	Glenda July 15,2090	5 -Year
78	13.748781	122.135644	0.03	0	-0.030	Glenda July 15,2091	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
79	13.748415	122.135914	0.03	0	-0.030	Glenda July 15,2092	5 -Year
80	13.748195	122.136167	0.03	0	-0.030	Glenda July 15,2093	5 -Year
81	13.747871	122.136582	0.03	0	-0.030	Glenda July 15,2094	5 -Year
82	13.747578	122.136913	0.03	0	-0.030	Glenda July 15,2095	5 -Year
83	13.747435	122.136766	0.03	0	-0.030	Glenda July 15,2096	5 -Year
84	13.747343	122.137073	0.38	0	-0.380	Glenda July 15,2097	5 -Year
85	13.747061	122.137378	0.03	0	-0.030	Glenda July 15,2098	5 -Year
86	13.747413	122.137709	0.03	0	-0.030	Glenda July 15,2099	5 -Year
87	13.747582	122.137907	0.03	0	-0.030	Glenda July 15,2100	5 -Year
88	13.747212	122.137942	0.03	0	-0.030	Glenda July 15,2101	5 -Year
89	13.747387	122.138138	0.03	0	-0.030	Glenda July 15,2102	5 -Year
90	13.746822	122.137643	0.24	0	-0.240	Glenda July 15,2103	5 -Year
91	13.746448	122.13798	0.03	0	-0.030	Glenda July 15,2104	5 -Year
92	13.74661	122.137431	0.03	0	-0.030	Glenda July 15,2105	5 -Year
93	13.74623	122.137688	0.03	0	-0.030	Glenda July 15,2106	5 -Year
94	13.745992	122.137846	0.03	0	-0.030	Glenda July 15,2107	5 -Year
95	13.74559	122.138296	0.05	0	-0.050	Glenda July 15,2108	5 -Year
96	13.745195	122.138663	0.04	0.5	0.460	Glenda July 15,2109	5 -Year
97	13.744766	122.139063	0.25	0.5	0.250	Glenda July 15,2110	5 -Year
98	13.744601	122.13889	0.05	1	0.950	Glenda July 15,2111	5 -Year
99	13.744112	122.138105	0.03	1	0.970	Glenda July 15,2112	5 -Year
100	13.744338	122.137932	0.03	1	0.970	Glenda July 15,2113	5 -Year
101	13.743824	122.137977	0.03	1	0.970	Glenda July 15,2114	5 -Year
102	13.743599	122.13754	0.03	1	0.970	Glenda July 15,2115	5 -Year
103	13.743251	122.136989	0.03	1	0.970	Glenda July 15,2116	5 -Year
104	13.742435	122.136557	0.03	1	0.970	Glenda July 15,2117	5 -Year
105	13.741958	122.136468	0.03	1	0.970	Glenda July 15,2118	5 -Year
106	13.741443	122.136546	0.03	1	0.970	Glenda July 15,2119	5 -Year
107	13.740851	122.136777	0.03	1	0.970	Glenda July 15,2120	5 -Year
108	13.740178	122.137105	0.03	1	0.970	Glenda July 15,2121	5 -Year
109	13.739671	122.137404	0.03	1	0.970	Glenda July 15,2122	5 -Year
110	13.739213	122.137612	0.03	1	0.970	Glenda July 15,2123	5 -Year
111	13.738773	122.137931	0.03	1	0.970	Glenda July 15,2124	5 -Year
112	13.738428	122.137191	0.03	1	0.970	Glenda July 15,2125	5 -Year
113	13.738035	122.136723	0.03	1	0.970	Glenda July 15,2126	5 -Year
114	13.737362	122.136983	0.03	1	0.970	Glenda July 15,2127	5 -Year
115	13.736853	122.136847	0.03	1	0.970	Glenda July 15,2128	5 -Year
116	13.736507	122.136524	0.22	1	0.780	Glenda July 15,2129	5 -Year
117	13.735771	122.136516	0.03	1	0.970	Glenda July 15,2130	5 -Year
118	13.735826	122.135804	0.03	1	0.970	Glenda July 15,2131	5 -Year
119	13.735699	122.134869	0.27	1	0.730	Glenda July 15,2132	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
120	13.735608	122.134367	0.03	1	0.970	Glenda July 15,2133	5 -Year
121	13.735061	122.133633	0.03	2	1.970	Glenda July 15,2134	5 -Year
122	13.734052	122.133689	0.07	5	4.930	Glenda July 15,2135	5 -Year
123	13.733739	122.133617	0.18	5	4.820	Glenda July 15,2136	5 -Year
124	13.733467	122.133753	0.23	5	4.770	Glenda July 15,2137	5 -Year
125	13.733233	122.133537	0.03	5	4.970	Glenda July 15,2138	5 -Year
126	13.733377	122.13336	0.03	5	4.970	Glenda July 15,2139	5 -Year
127	13.733723	122.133082	0.03	5	4.970	Glenda July 15,2140	5 -Year
128	13.733999	122.132877	0.03	1	0.970	Glenda July 15,2141	5 -Year
129	13.734531	122.132515	0.03	1	0.970	Glenda July 15,2142	5 -Year
130	13.740855	122.13553	0.34	1	0.660	Glenda July 15,2143	5 -Year
131	13.741301	122.135619	0.09	0	-0.090	Glenda July 15,2144	5 -Year
132	13.741336	122.136114	0.21	0	-0.210	Glenda July 15,2145	5 -Year
133	13.744686	122.138804	0.04	0	-0.040	Glenda July 15,2146	5 -Year
134	13.744881	122.138679	0.03	0	-0.030	Glenda July 15,2147	5 -Year
135	13.745087	122.138445	0.05	0.3	0.250	Glenda July 15,2148	5 -Year
136	13.745411	122.138178	0.03	0	-0.030	Glenda July 15,2149	5 -Year
137	13.745328	122.137993	0.07	0	-0.070	Glenda July 15,2150	5 -Year
138	13.745536	122.138041	0.06	0	-0.060	Glenda July 15,2151	5 -Year
139	13.745787	122.137791	0.05	0	-0.050	Glenda July 15,2152	5 -Year
140	13.746046	122.137529	0.03	0	-0.030	Glenda July 15,2153	5 -Year
141	13.746396	122.137122	0.09	0.6	0.510	Glenda July 15,2154	5 -Year
142	13.746611	122.136959	0.1	0.6	0.500	Glenda July 15,2155	5 -Year
143	13.747429	122.139541	0.49	0.3	-0.190	Glenda July 15,2156	5 -Year
144	13.747345	122.139717	0.32	0.3	-0.020	Glenda July 15,2157	5 -Year
145	13.747004	122.139633	0.6	0.3	-0.300	Glenda July 15,2158	5 -Year
146	13.746923	122.139846	0.51	0.5	-0.010	Glenda July 15,2159	5 -Year
147	13.746784	122.140255	0.03	0.5	0.470	Glenda July 15,2160	5 -Year
148	13.746497	122.140194	0.41	0.3	-0.110	Glenda July 15,2161	5 -Year
149	13.746326	122.140135	0.38	0.3	-0.080	Glenda July 15,2162	5 -Year
150	13.746302	122.14002	0.99	0.3	-0.690	Glenda July 15,2163	5 -Year
151	13.746244	122.139925	0.39	0.5	0.110	Glenda July 15,2164	5 -Year
152	13.746125	122.139804	0.9	0.5	-0.400	Glenda July 15,2165	5 -Year
153	13.746311	122.139612	0.63	0	-0.630	Glenda July 15,2166	5 -Year
154	13.746521	122.139256	0.44	0	-0.440	Glenda July 15,2167	5 -Year
155	13.746632	122.139136	0.1	0.5	0.400	Glenda July 15,2168	5 -Year
156	13.747065	122.13935	0.25	0.5	0.250	Glenda July 15,2169	5 -Year
157	13.74927	122.140334	0.03	0.6	0.570	Glenda July 15,2170	5 -Year
158	13.750691	122.141358	0.4	0	-0.400	Glenda July 15,2171	5 -Year
159	13.751892	122.142606	0.36	0	-0.360	Glenda July 15,2172	5 -Year
160	13.753195	122.141938	0.03	0	-0.030	Glenda July 15,2173	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
161	13.754542	122.143218	0.15	1	0.850	Rosing Nov. 7,1995	5 -Year
162	13.755373	122.144202	0.03	0.5	0.470	Glenda July 15,2175	5 -Year
163	13.756127	122.150937	0.03	1	0.970	Rosing Nov. 7,1995	5 -Year
164	13.756161	122.151072	1.34	1	-0.340	Rosing Nov. 7,1995	5 -Year
165	13.754946	122.155337	0.74	5	4.260	Glenda July 15,2014	5 -Year
166	13.753276	122.157012	0.06	0.5	0.440	Glenda July 15,2015	5 -Year
167	13.751619	122.159471	0.98	0	-0.980	Glenda July 15,2016	5 -Year
168	13.751311	122.159347	0.28	0	-0.280	Glenda July 15,2017	5 -Year
169	13.747659	122.165401	0.03	0	-0.030	Glenda July 15,2018	5 -Year
170	13.746278	122.16795	3.71	0	-3.710	Glenda July 15,2019	5 -Year
171	13.744333	122.172632	0.03	0	-0.030	Glenda July 15,2020	5 -Year
172	13.743961	122.174536	0.03	0	-0.030	Glenda July 15,2021	5 -Year
173	13.743901	122.175612	0.03	0	-0.030	Glenda July 15,2022	5 -Year
174	13.742342	122.178136	0.94	0	-0.940	Glenda July 15,2023	5 -Year
175	13.742216	122.179179	0.03	0	-0.030	Glenda July 15,2024	5 -Year
176	13.743442	122.180161	0.03	0	-0.030	Glenda July 15,2025	5 -Year
177	13.744047	122.182418	0.03	0	-0.030	Glenda July 15,2026	5 -Year
178	13.746168	122.183562	0.03	0	-0.030	Glenda July 15,2027	5 -Year
179	13.748836	122.185591	0.03	0	-0.030	Glenda July 15,2028	5 -Year
180	13.752647	122.186018	0.03	0	-0.030	Glenda July 15,2029	5 -Year
181	13.750901	122.18386	0.030	0	-0.030	Glenda July 15,2030	5 -Year
182	13.750709	122.183305	0.030	0	-0.030	Glenda July 15,2031	5 -Year
183	13.75061	122.180555	0.030	5	4.970	Glenda July 15,2032	5 -Year
184	13.752212	122.178823	0.030	5	4.970	Glenda July 15,2033	5 -Year
185	13.752497	122.178237	0.080	5	4.920	Glenda July 15,2034	5 -Year
186	13.752663	122.178261	0.070	5.5	5.430	Glenda July 15,2035	5 -Year
187	13.752817	122.178278	0.030	0	-0.030	Glenda July 15,2036	5 -Year
188	13.752915	122.178285	0.030	0	-0.030	Glenda July 15,2037	5 -Year
189	13.751937	122.176957	0.030	0	-0.030	Glenda July 15,2038	5 -Year
190	13.753099	122.17581	0.030	0	-0.030	Glenda July 15,2039	5 -Year
191	13.755158	122.174269	0.030	0	-0.030	Glenda July 15,2040	5 -Year
192	13.740091	122.169707	0.030	0	-0.030	Glenda July 15,2041	5 -Year
193	13.738501	122.175334	0.030	0	-0.030	Glenda July 15,2042	5 -Year
194	13.734137	122.177449	0.360	0	-0.360	Glenda July 15,2043	5 -Year
195	13.733617	122.179974	0.310	0	-0.310	Glenda July 15,2044	5 -Year
196	13.736278	122.184575	0.030	0	-0.030	Glenda July 15,2045	5 -Year
197	13.737241	122.186202	0.030	0	-0.030	Glenda July 15,2046	5 -Year
198	13.738533	122.18805	0.030	0	-0.030	Glenda July 15,2047	5 -Year
199	13.740299	122.190842	0.030	0	-0.030	Glenda July 15,2048	5 -Year
200	13.742132	122.194707	0.030	0	-0.030	Glenda July 15,2049	5 -Year
201	13.762577	122.203169	0.030	0	-0.030	Glenda July 15,2050	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
202	13.764554	122.202025	0.030	5	4.970	Glenda July 15,2051	5 -Year
203	13.776382	122.199088	1.020	5	3.980	Glenda July 15,2052	5 -Year
204	13.776423	122.199322	4.880	5	0.120	Glenda July 15,2053	5 -Year
205	13.776471	122.199422	5.380	5	-0.380	Glenda July 15,2054	5 -Year
206	13.776484	122.199531	13.250	0	-13.250	Glenda July 15,2055	5 -Year
207	13.776562	122.199598	14.890	0	-14.890	Glenda July 15,2056	5 -Year
208	13.761225	122.142041	0.030	0	-0.030	Glenda July 15,2057	5 -Year
209	13.762986	122.142614	0.030	0	-0.030	Glenda July 15,2058	5 -Year
210	13.763625	122.143949	0.030	0	-0.030	Glenda July 15,2059	5 -Year
211	13.764891	122.14506	0.030	0	-0.030	Glenda July 15,2060	5 -Year
212	13.767567	122.146291	0.030	0	-0.030	Glenda July 15,2061	5 -Year
213	13.771658	122.146656	0.030	0	-0.030	Glenda July 15,2062	5 -Year
214	13.773088	122.149962	0.030	5	4.970	Rosing Nov. 7,1995	5 -Year
215	13.774107	122.152713	0.030	5	4.970	Rosing Nov. 7,1996	5 -Year
216	13.774233	122.156446	0.380	6	5.620	Rosing Nov. 7,1995	5 -Year
217	13.774009	122.156526	0.540	6	5.460	Glenda July 15,2066	5 -Year
218	13.773965	122.156948	1.370	6	4.630	Glenda July 15,2067	5 -Year
219	13.774216	122.157175	1.360	6	4.640	Glenda July 15,2068	5 -Year
220	13.774482	122.157391	1.510	6	4.490	Glenda July 15,2069	5 -Year
221	13.774739	122.157635	1.500	0	-1.500	Glenda July 15,2070	5 -Year
222	13.774842	122.157992	1.560	0	-1.560	Glenda July 15,2071	5 -Year
223	13.784414	122.141139	0.030	0.000	-0.030	Glenda July 15,2072	5 -Year
224	13.785217	122.143816	0.030	0.000	-0.030	Glenda July 15,2073	5 -Year
225	13.785555	122.149897	0.040	0.000	-0.040	Glenda July 15,2074	5 -Year
226	13.784688	122.152855	0.030	0.000	-0.030	Glenda July 15,2075	5 -Year
227	13.785779	122.156571	0.310	0.000	-0.310	Glenda July 15,2076	5 -Year
228	13.78593	122.158465	0.030	0.000	-0.030	Glenda July 15,2077	5 -Year
229	13.782247	122.162575	0.030	1.000	0.970	Glenda July 15,2078	5 -Year
230	13.786561	122.161573	0.030	1.200	1.170	Glenda July 15,2079	5 -Year
231	13.788877	122.160829	0.030	1.500	1.470	Glenda July 15,2080	5 -Year
232	13.790724	122.159021	0.040	1.500	1.460	Glenda July 15,2081	5 -Year
233	13.791128	122.158972	1.170	1.000	-0.170	Glenda July 15,2082	5 -Year
234	13.791404	122.159143	1.270	1.000	-0.270	Rosing Nov. 7,1995	5 -Year
235	13.79167	122.159335	0.190	0.000	-0.190	Rosing Nov. 7,1996	5 -Year
236	13.791444	122.157876	0.040	0.000	-0.040	Rosing Nov. 7,1995	5 -Year
237	13.794502	122.154764	0.070	0.000	-0.070	Rosing Nov. 7,1995	5 -Year
238	13.796563	122.153629	0.030	0.600	0.570	Rosing Nov. 7,1996	5 -Year
239	13.799255	122.154191	0.150	5.000	4.850	Glenda July 15,2088	5 -Year
240	13.800166	122.154945	0.030	5.000	4.970	Glenda July 15,2089	5 -Year
241	13.800414	122.154522	0.030	5.000	4.970	Glenda July 15,2090	5 -Year
242	13.800487	122.154022	0.190	5.000	4.810	Glenda July 15,2091	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Valida-tion Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
243	13.800561	122.153679	0.650	0.300	-0.350	Glenda July 15,2092	5 -Year
244	13.800685	122.153374	1.380	5.000	3.620	Glenda July 15,2093	5 -Year
245	13.784151	122.163583	0.270	5.000	4.730	Glenda July 15,2094	5 -Year

RMSE: 2.57

Annex 12. Educational Institutions Affected in Macalelon Floodplain

Table A-12.1 Educational Institutions in Macalelon, Quezon affected by flooding in Macalelon Floodplain

QUEZON				
MACALELON				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Amontay	Amontay Elementary School	None	None	None
Amontay	Day Care Center	None	None	None
Anos	Day Care Center	None	None	None
Calantas	Calantas Elementary School	None	None	None
Calantas	Calantas National High School	None	None	None
Calantas	Day Care Center	Low	Low	Medium
Candangal	Day Care Center	None	None	None
Candangal	San Isidro Elementary School	None	None	None
Castillo	Macalelon Elementary School	None	None	None
Castillo	Macalelon High School	None	None	None
Lahing	Day Care Center	Medium	High	High
Mabini Ibaba	Day Care Center	None	None	None
Mabini Ibaba	Mabini Ibaba Elementary School	None	None	None
Mambog	Mambugan Elementary School	Low	Medium	Medium
Padre Herrera	Padre Herrera Elementary School	Medium	High	High
Pag-Asa	Macalelon Elementary School	None	None	None
Pag-Asa	Mary Immaculate School	None	None	None
Rodriquez	Day Care Center	Low	Low	Medium
Taguin	Day Care Center	None	Low	Medium
Taguin	Taguin Elementary School	None	Low	Medium
Tubigan Ilaya	Tubigan Ilaya Elementary School	None	None	Medium
Vista Hermosa	Day Care Center	Medium	High	High
Vista Hermosa	Vista Hermosa Elementary School	Medium	High	High

Table A-12.2 Educational Institutions in Gumaca, Quezon affected by flooding in Macalelon Floodplain

QUEZON				
GUMACA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Anonangin	Anonangin Elementary School	None	None	None
Anonangin	Anos Elementary School	None	None	None
Anonangin	Day Care Center	None	None	None
Bantad	Bantad National High School	None	Low	Medium
Gayagayaan	Day Care Center	None	None	None
Gayagayaan	Gayagayaan Elementary School	None	None	None

Table A-12.3 Educational Institutions in General Luna, Quezon affected by flooding in Macalelon Floodplain

QUEZON				
GENERAL LUNA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
San Ignacio Ilaya	Olangtao National High School	Medium	High	High

Annex 13. Health Institutions Affected in Macalelon Floodplain

Table A-13.1 Health Institutions in Macalelon, Quezon affected by flooding in Macalelon Floodplain

QUEZON				
MACALELON				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Calantas	Health Center	None	None	None
Castillo	Health Center	None	None	Low
Rodriquez	Phil Health Center	None	Low	Low
Rodriquez	Rural Health Unit	None	None	None
Taguin	Health Center	Medium	Medium	Medium