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

LiDAR Surveys and Flood Mapping of Pandanan River

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

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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
BSWM	Bureau of Soil and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
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
MIT	MAPUA Institute of Technology
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND PANDANAN 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 in 2017 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 Pandanan River Basin

The Pandanan River Basin is located within the municipalities of Calauag and Lopez in Quezon Province. According to DENR River Basin Control Office, it has a drainage area of 154 km^2 and an estimated annual run-off of 246 million cubic meter (MCM) (RBCO, 2015).

Its main stem, Pandanan River, is part of the 26 river systems in the Southern Tagalog Region. According to the 2010 national census of NSO, a total of 7,627 locals are residing in the immediate vicinity of the river which are distributed among the six (6) barangays in Municipality of Calauag namely, Sabang I, Pinagkamaligan, Barangay I, Patitihan, Binutas, and Marilag. Agriculture and fishing are the two primary source of living in the area. According to the locals, coconuts, rice, citrus and vegetables are the major crops planted in the area. The region is also home to many festivals, making it a popular tourist destination and bringing in income for the locals.

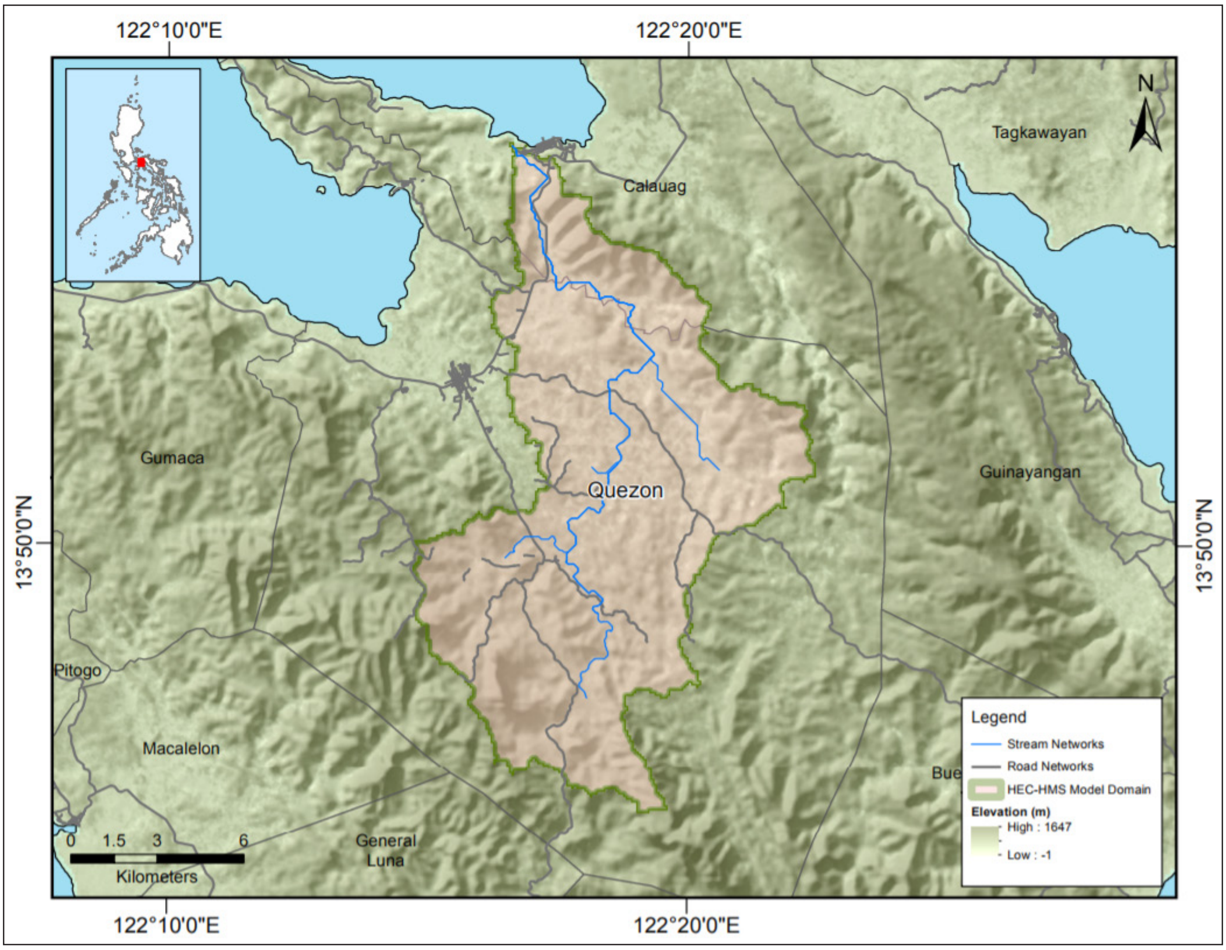

Figure 1. Map of Pandanan River Basin

Meanwhile, the Pandanan River Basin area is the pathway of severe typhoons, such as Sening in 1970, Rosing in 1995, Yoyong in 2004, and Milenyo in 2006. The most recent and significant flooding in the area was on July 2014 caused by Typhoon "*Glenda"* with reported casualties of at least 10 persons and 75 others injured. The estimated damage to the crops, livestock and farm facilities reached to P4.6 billion (http://newsinfo.inquirer.net/620640/typhoon-glenda-leaves-20-dead, 2014). The worst typhoon that devastated the province was typhoon Rosing that caused flooding and storm surges that hit Calauag and caused landslide to occur in the municipality of Paracale, Camarines Norte. Rosing was so powerful that one-third of the nearby Bicol Region experienced power outage.

In order to prevent or at least minimize the effects of flood hazard to the communities in the river basin, a combination of several technologies have been employed to produce flood hazard maps. The first is Light Detection and Ranging (LiDAR) data, which primarily contains elevation data. 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 fieldworks are used as input into hydrologic models, to generate hydrographs. These generated outputs, along with LiDAR data, will then be input for the river hydraulic model which would create 3D images of the river basins. The final output for these processes will be a flood hazard map of the river basin.

The flood hazard map would indicate the area where flood might occur during heavy rainfall and typhoon events. With this, the community will be able to prepare for upcoming strong typhoons more efficiently. This will also help LGUs draft evacuation plans for their barangay and pinpoint further developments needed to manage and minimize calamities brought about by flooding.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PANDANAN FLOODPLAIN

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

2.1 Flight Plans

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

Table 1. Flight planning parameters for Pegasus LiDAR system.

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

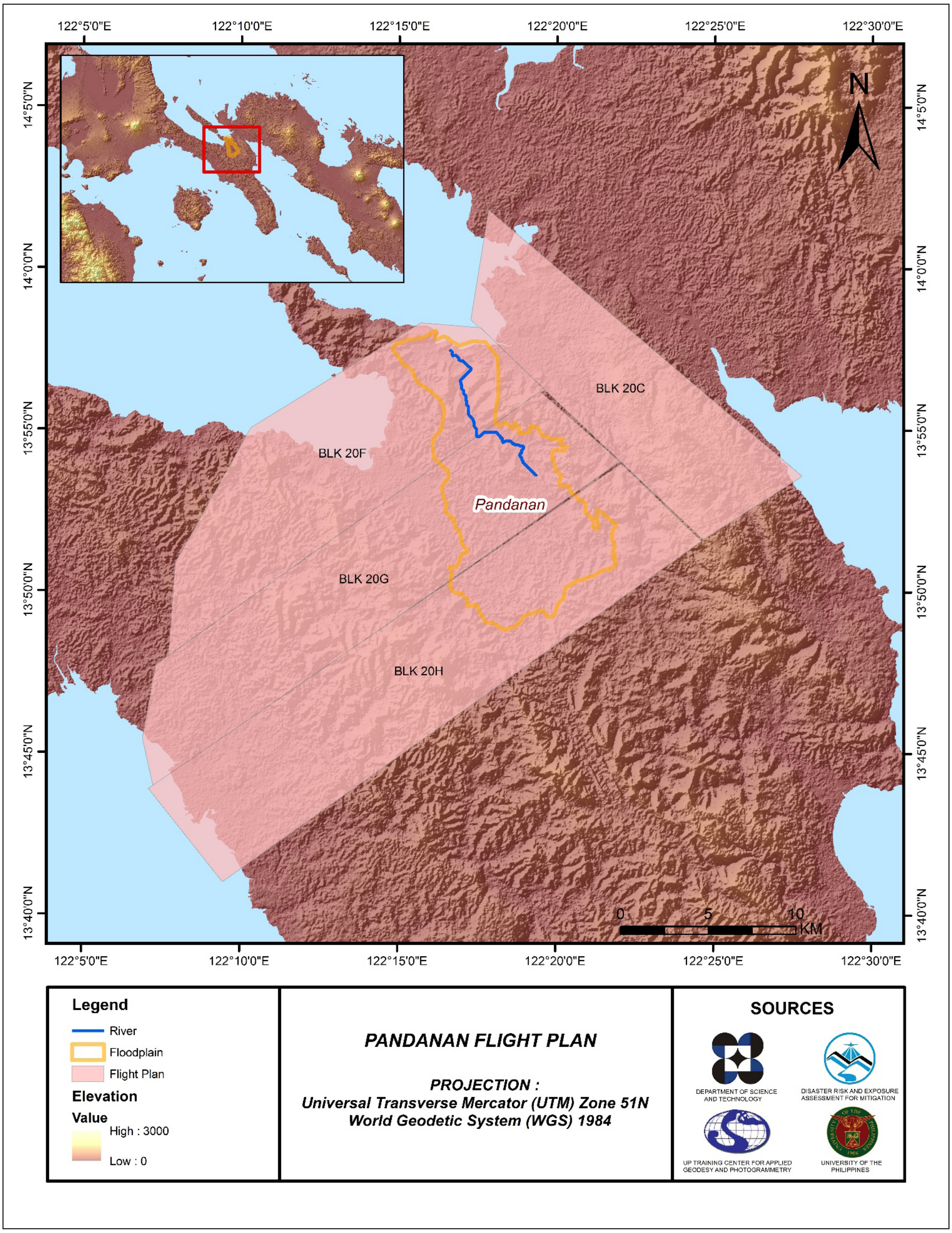


Figure 2. Flight plans for Pegasus System used for Pandanan Floodplain

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point QZN-41 which is of second (2nd) order accuracy. The project team reprocessed one (1) benchmark QZ-641 and established two (2) ground control points, QZN-J2 and QZN-3946. The certification for the base station is found in Annex B while the baseline processing report for the reprocessed and established ground control points are found in Annex C. These were used as base stations during flight operations for the entire duration of the survey (April 11 - 16, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TOPCON GR-5. Flight plans and location of base stations used during aerial LiDAR acquisition in Pandanan floodplain are shown in Figure 3.

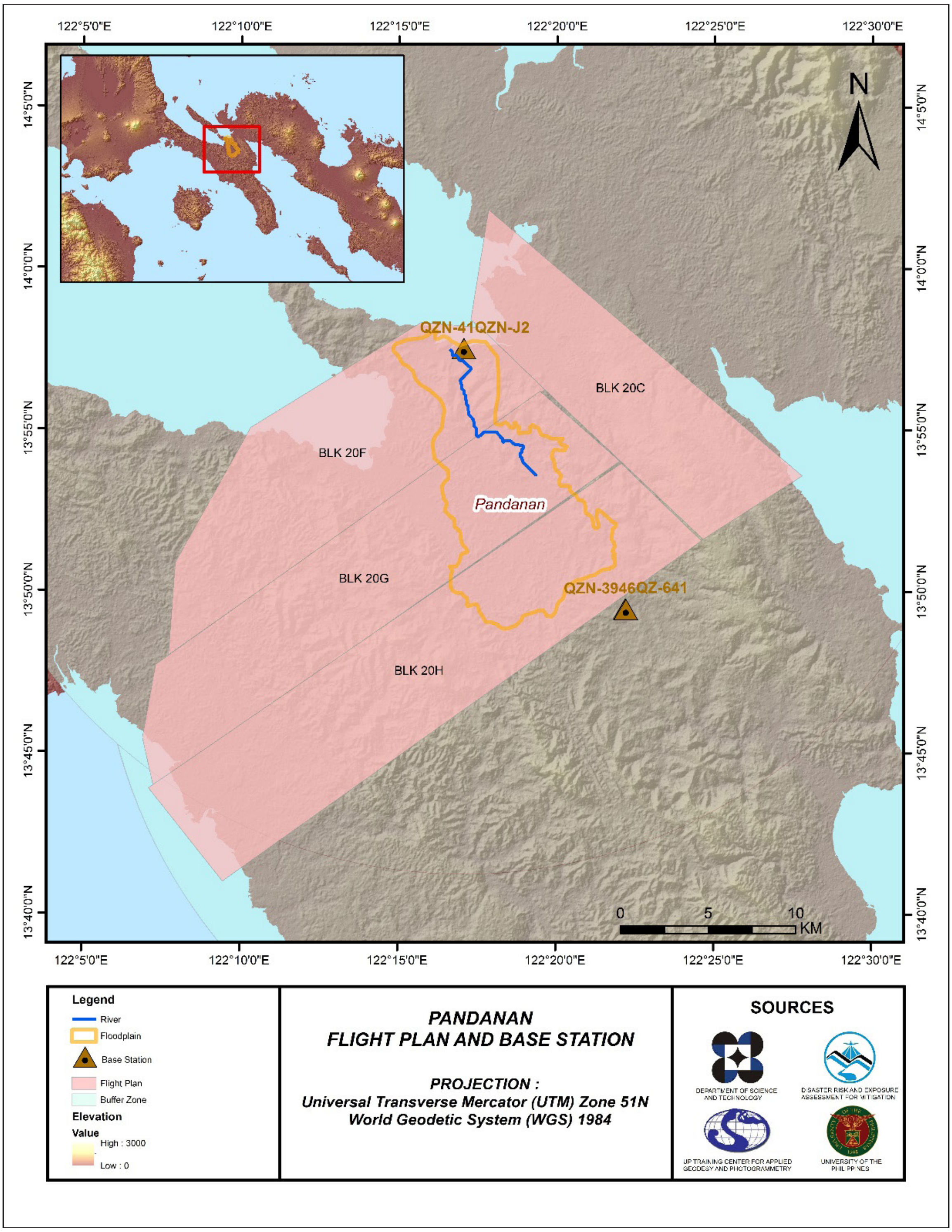
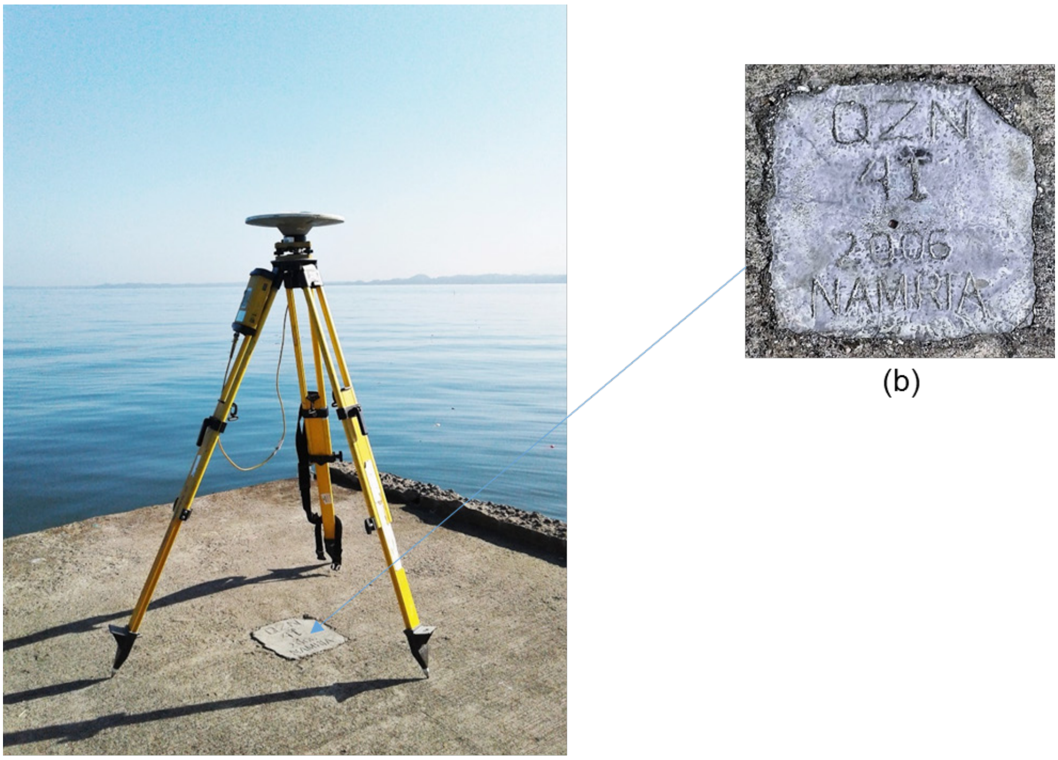


Figure 3. Flight plans and base stations for Pandanan floodplain.

Figure 4 to Figure 6 show the recovered NAMRIA reference point and established points within the area. In addition, Table 2 to Table 5 show the details about the NAMRIA reference point and established control points, while Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(b)

(a)

Figure 4. GPS set-up over QZN-41 at Barangay Sabang Uno, Pandanan, Quezon (a) and NAMRIA reference point QZN-41 (b) as recovered by the field team.

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

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

(a) (b)

Figure 5. GPS set-up over QZ-641 at Barangay Villa Aurora, Lopez, Quezon (a) and NAMRIA reference point QZ-641 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA 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	13° 49’ 32.33799” North
	Longitude	122° 22’ 06.68507” East
	Ellipsoidal Height	57.552 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	431753.157 meters
	Northing	1528439.616 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 49’ 27.21419” North
	Longitude	122° 22’ 11.63727” East
	Ellipsoidal Height	106.606 meters

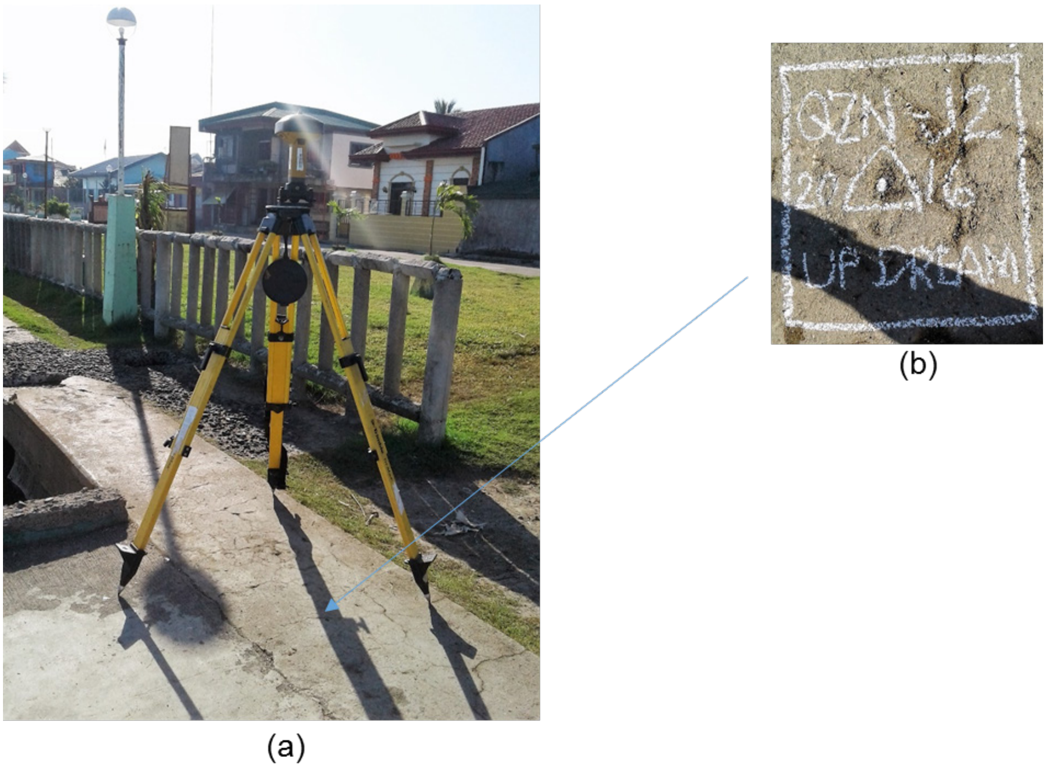


Figure 6. GPS set-up over QZN-J2 as established in at Barangay Sabang Uno, Pandanan, Quezon (a) and reference point QZN-J2 (b) as established by the field team.

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

Station Name	**QZN-J2**	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 57' 34.99489" North
	Longitude	122° 16' 58.78731" East
	Ellipsoidal Height	4.043 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting	422553.956 meters
	Northing	1543293.290 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 57' 29.83213" North
	Longitude	122° 17' 03.72860" East
	Ellipsoidal Height	52.516 meters

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

Station Name	QZN-3946	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 49' 31.13621" North
	Longitude	122° 22' 07.97985" East
	Ellipsoidal Height	56.643 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting	431791.932 meters
	Northing	1528402.595 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 49' 26.01252" North
	Longitude	122° 22' 12.93209" East
	Ellipsoidal Height	105.699 meters

Table 6. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
11 APRIL 2016	23244P	1BLK20B102B	QZN-41 & QZN-J2
13 APRIL 2016	23250P	1BLK20G104A	QZN-41 & QZN-J2
14 APRIL 2016	23254P	1BLK20F105A	QZN-41 & QZN-J2
15 APRIL 2016	23258P	1BLK20H106A	QZN-41 & QZN-3946
15 APRIL 2016	23260P	1BLK20F106B	QZN-41 & QZ-641
16 APRIL 2016	23262P	1BLK20S107A	QZN-41 & QZ-641

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR Data Acquisition in Pandanan floodplain, for a total of nineteen hours and twenty six minutes (19+26) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

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

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within the Floodplain (km²)	Area Surveyed Outside the Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
11 APRIL 2016	23224P	125.22	104.15	34.26	69.89	357	2	50
13 APRIL 2016	23250P	273.83	233.74	23.93	209.81	1027	4	35
14 APRIL 2016	23254P	158.95	85.60	7.68	77.92	NA	2	53
15 APRIL 2016	23258P	199.83	190.38	7.38	183.00	NA	4	35
15 APRIL 2016	23260P	158.95	88.41	5.57	82.84	NA	2	28
16 APRIL 2016	23262P	374.68	104.69	3.39	101.30	548	2	5
TOTAL		1291.46	806.97	82.21	724.76	1932	19	26

Table 8. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23224P	1000	30	50	200	30	130	5
23252P	1000	30	50	200	30	130	5
23254P	1000	30	50	200	30	130	5
23258P	1000	30	50	200	30	130	5
23260P	1000	30	50	200	30	130	5
23262P	1000	30	50	200	30	130	5

2.4. Survey Coverage

Pandanan floodplain is situated within the municipalities of Quezon. The municipality of Calauag is fully covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Pandanan Floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during Pandanan Floodplain LiDAR survey in Quezon.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Quezon	Calauag	81.75	81.74	100%
	Catanauan	378.81	282.05	74%
	General Luna	199.62	85.41	43%
	Guinayangan	72.29	20.63	29%
	Gumaca	323.42	92.10	28%
	Lopez	119.16	32.09	27%
	Macalelon	236.85	42.39	18%
	Pitogo	267.28	2.46	1%
Total		1679.18	638.87	38.05%

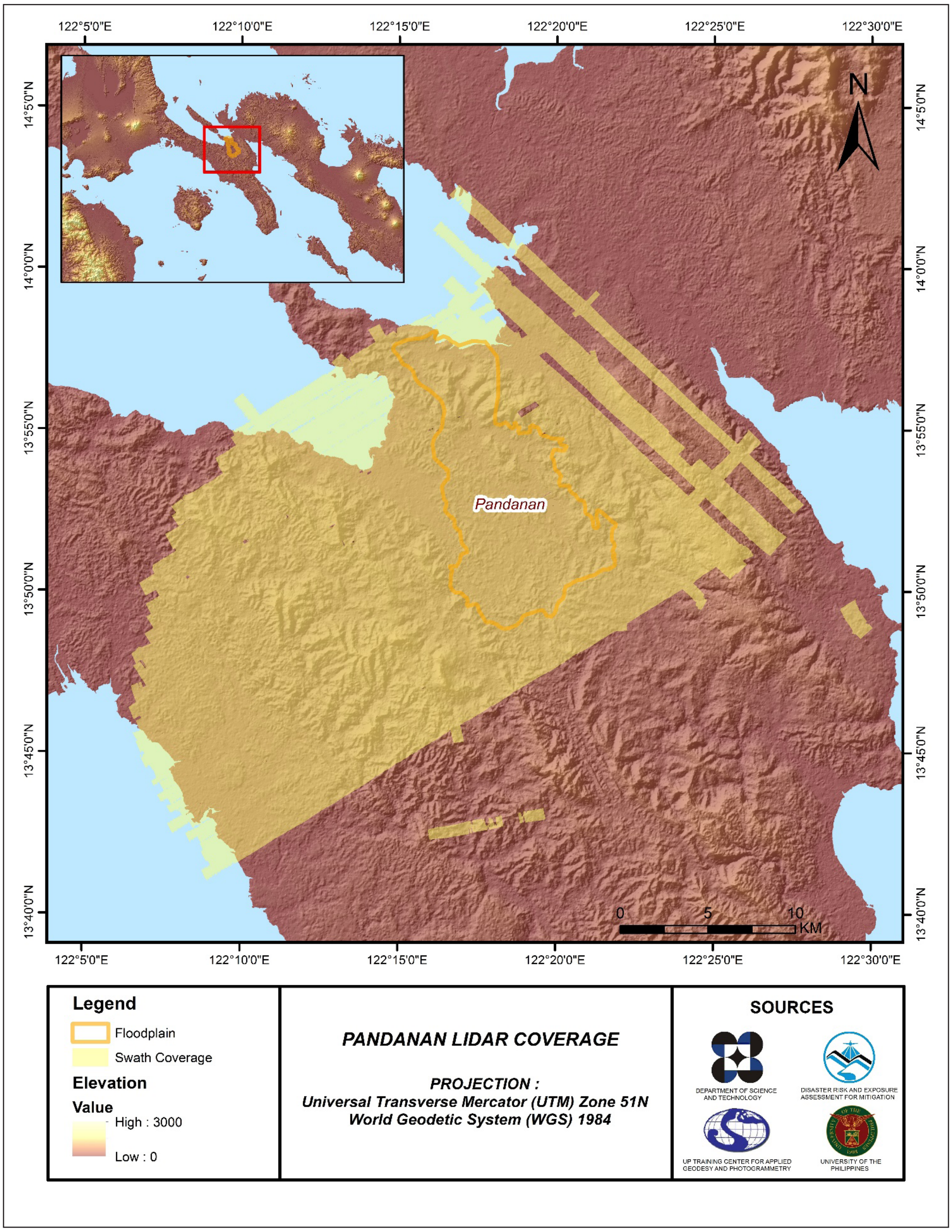


Figure 7. Actual LiDAR survey coverage for Pandanan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE PANDANAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

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

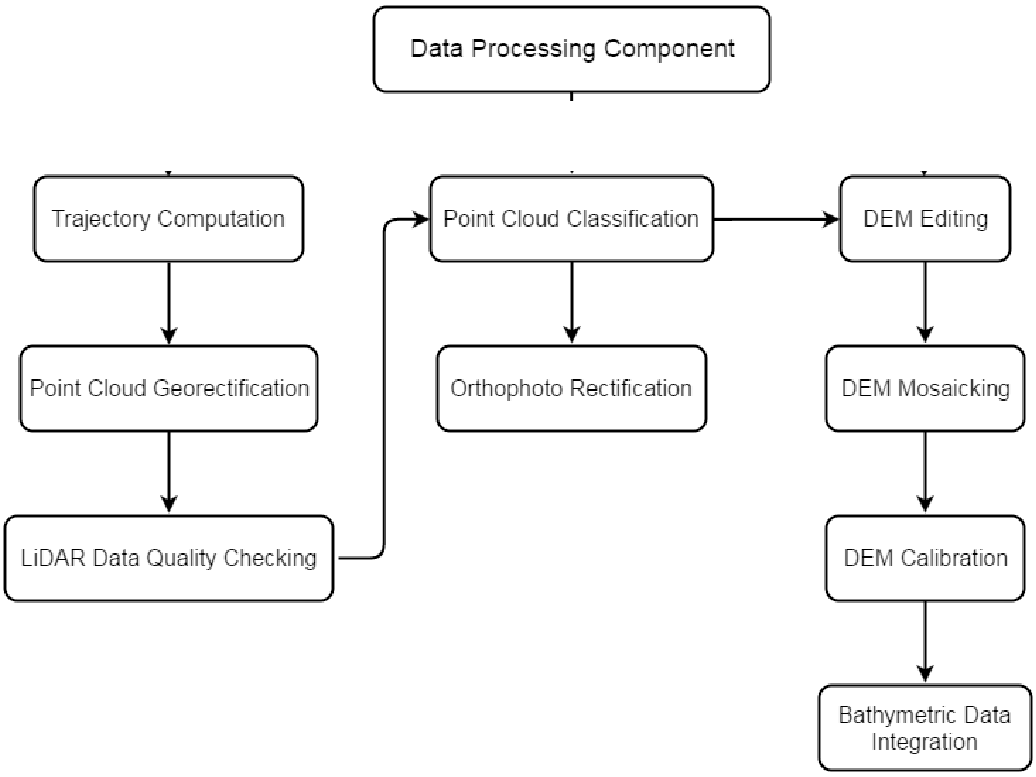


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pandanan floodplain can be found in Annex 5. Missions flown during the survey conducted on April 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Lopez, Quezon. The Data Acquisition Component (DAC) transferred a total of 111.2 Gigabytes of Range data, 1.25 Gigabytes of POS data, 812.5 Megabytes of GPS base station data, and 144.9 Gigabytes of raw image data to the data server on April 16, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pandanan was fully transferred on May 18, 2016, as indicated on the Data Transfer Sheets for Pandanan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23244P, one of the Pandanan flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on April 11, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

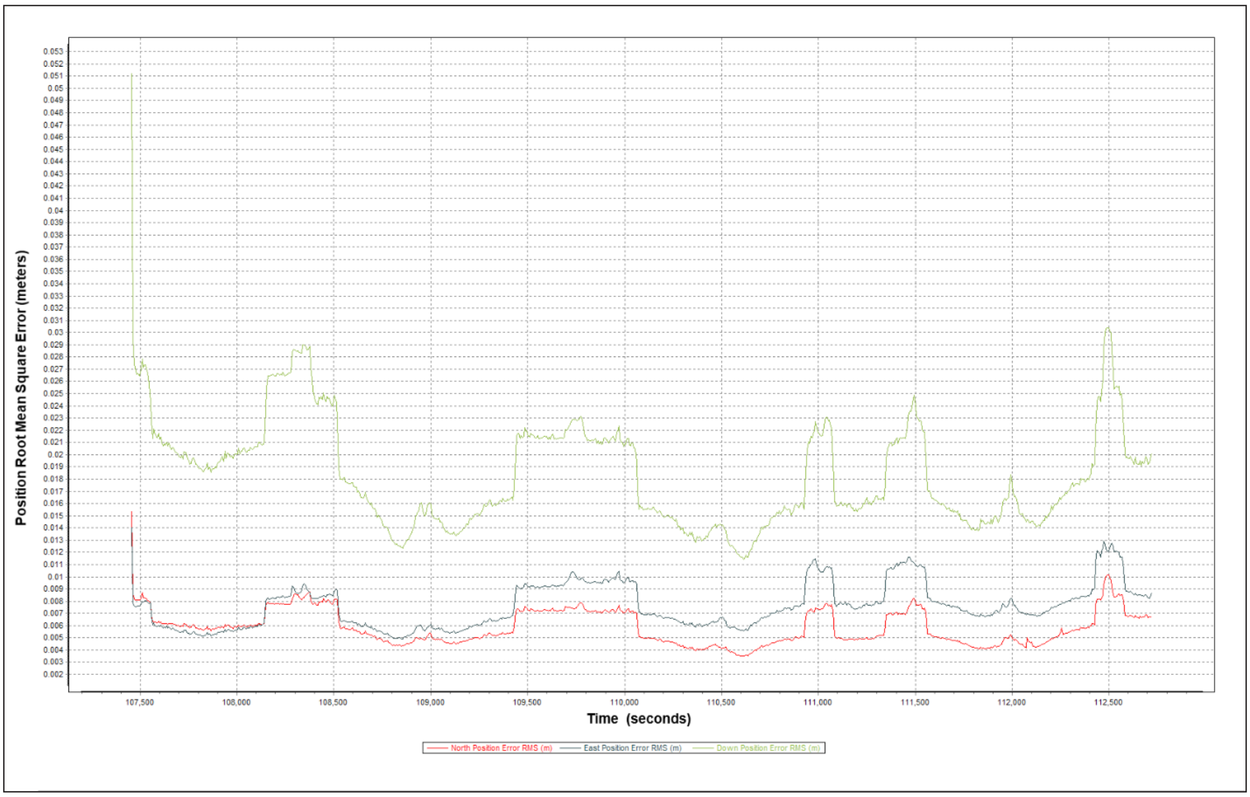


Figure 9. Smoothed Performance Metrics of Pandanan Flight 23244P.

The time of flight was from 107400 seconds to 112700 seconds, which corresponds to afternoon of April 11, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.0 centimeters, the East position RMSE peaks at 1. 30 centimeters, and the Down position RMSE peaks at 3.0 centimeters, which are within the prescribed accuracies described in the methodology.

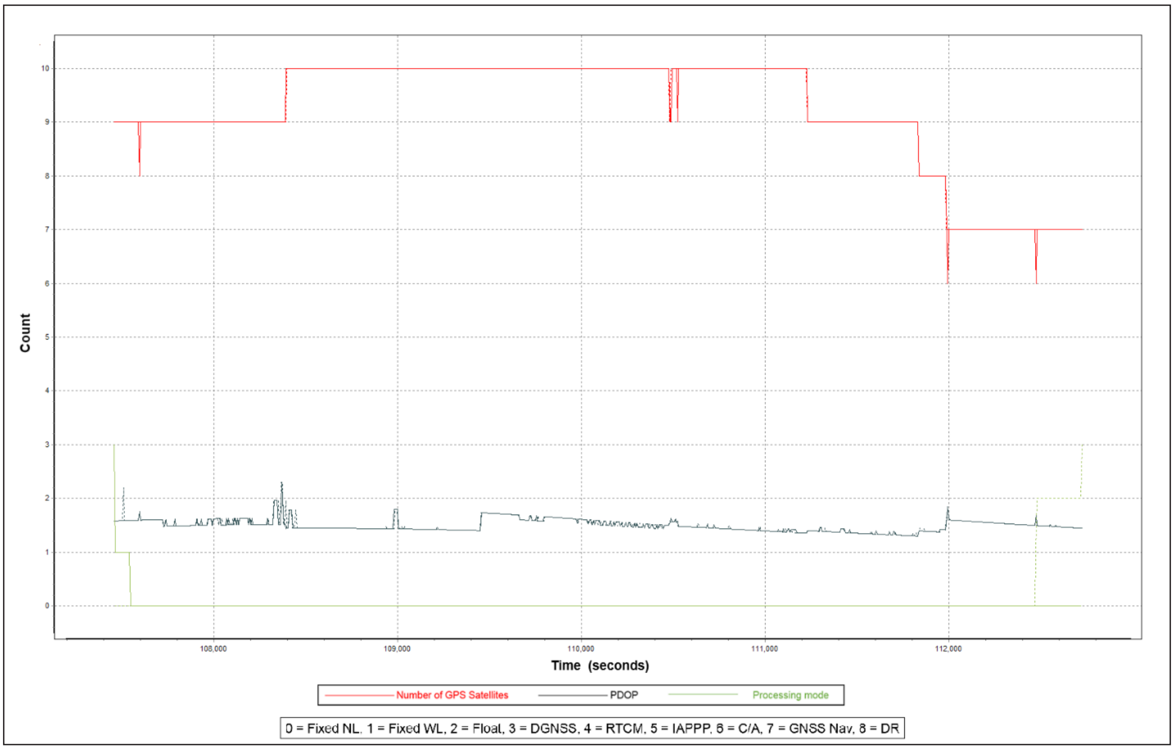


Figure 10. Solution Status Parameters of Pandanan Flight 23244P.

The Solution Status parameters of flight 23244P, one of the Pandanan flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 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 Pandanan flights is shown in Figure 11.

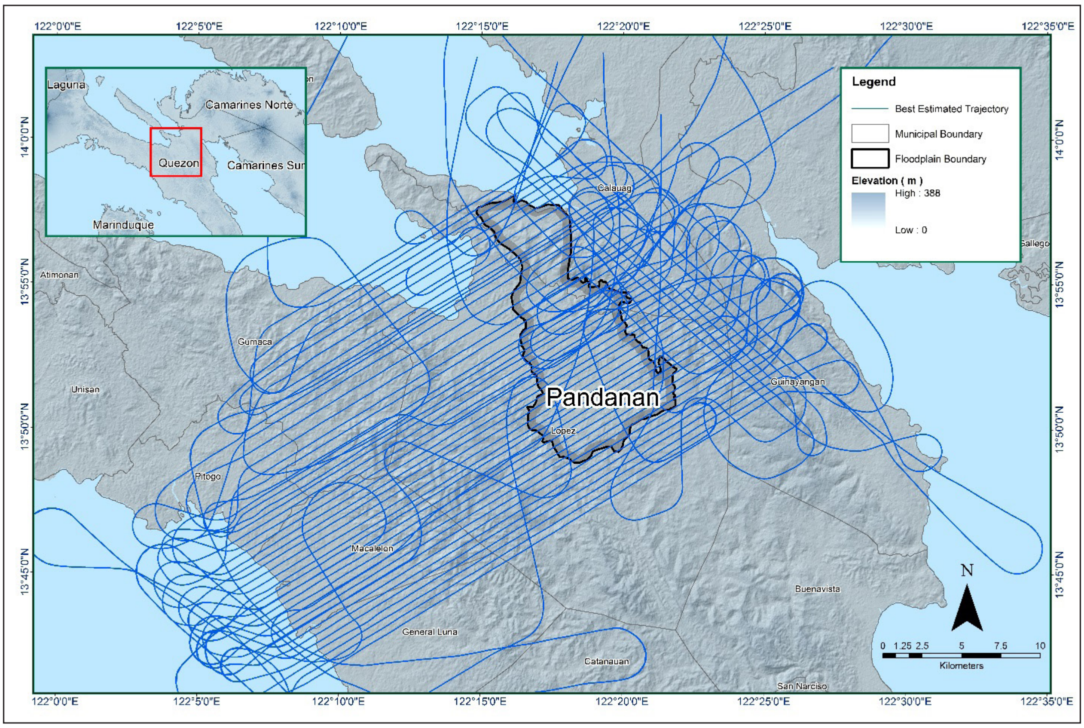


Figure 11. Best estimated trajectory for Pandanan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 59 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 Pandanan floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Pandanan flights.

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

The optimum accuracy is obtained for all Pandanan 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 is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

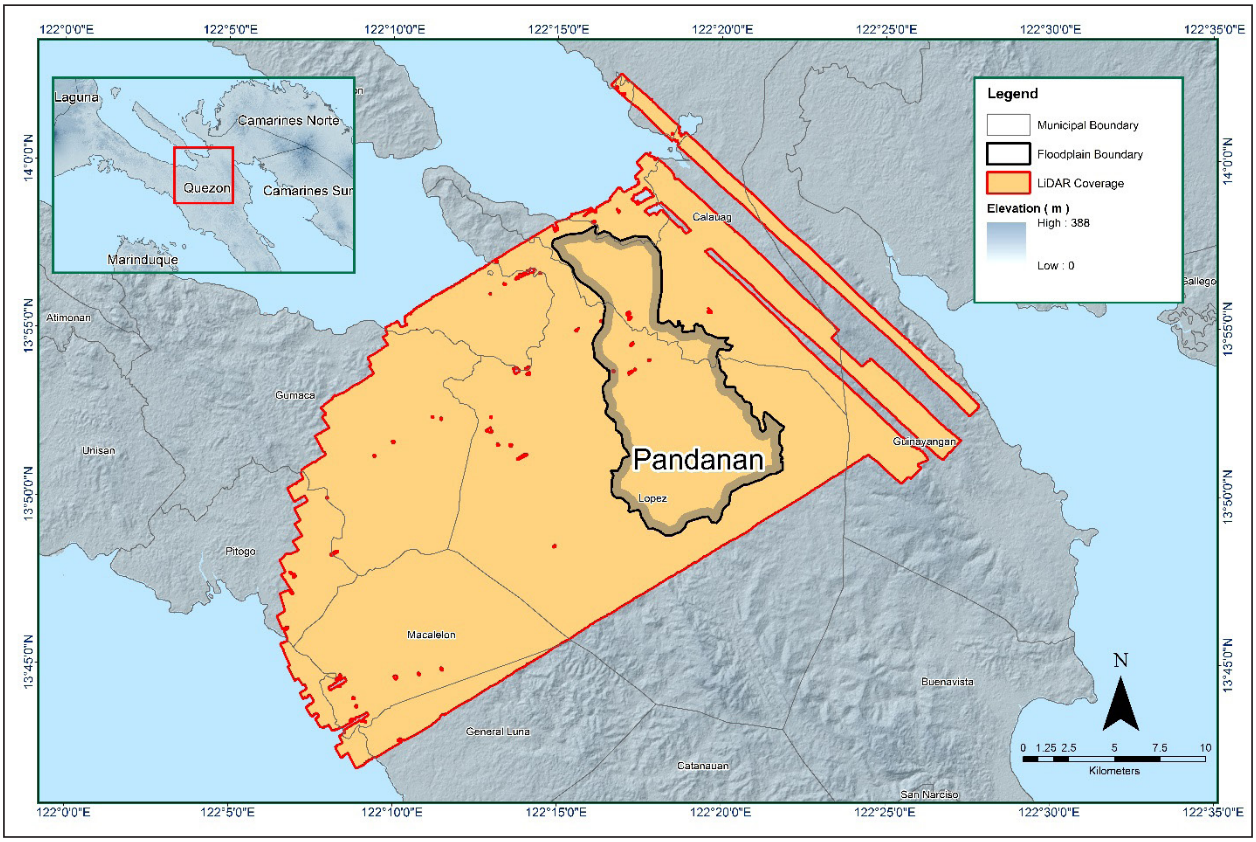


Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Pandanan Floodplain

The total area covered by the Pandanan missions is 709.56 sq.km that is comprised of six (6) flight acquisitions grouped and merged into six (6) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Pandanan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bagasbas_Blk21A	23244P	99.14
Bagasbas_Blk21B	23254P	81.69
	23258P	
Bagasbas_Blk21B_additional	23262P	30.91
Bagasbas_Blk21B_supplement	23260P	87.17
Bagasbas_Blk21C	23250P	231.85
Bagasbas_Blk21D	23258P	178.80
TOTAL		709.56 sq.km

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

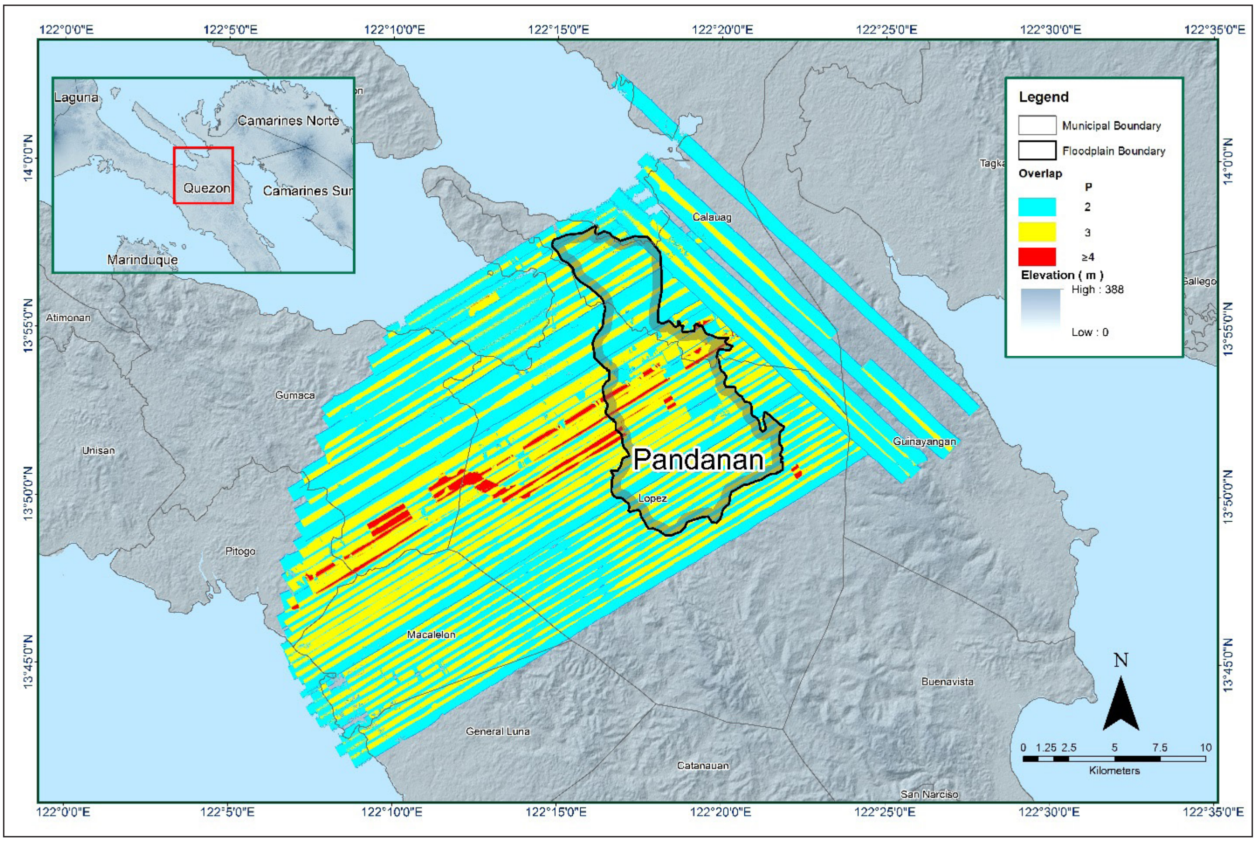


Figure 13. Image of data overlap for Pinantan Floodplain.

The overlap statistics per block for the Pandanan 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 25.97% and 97.02% 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 14. It was determined that all LiDAR data for Pandanan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.89 points per square meter.

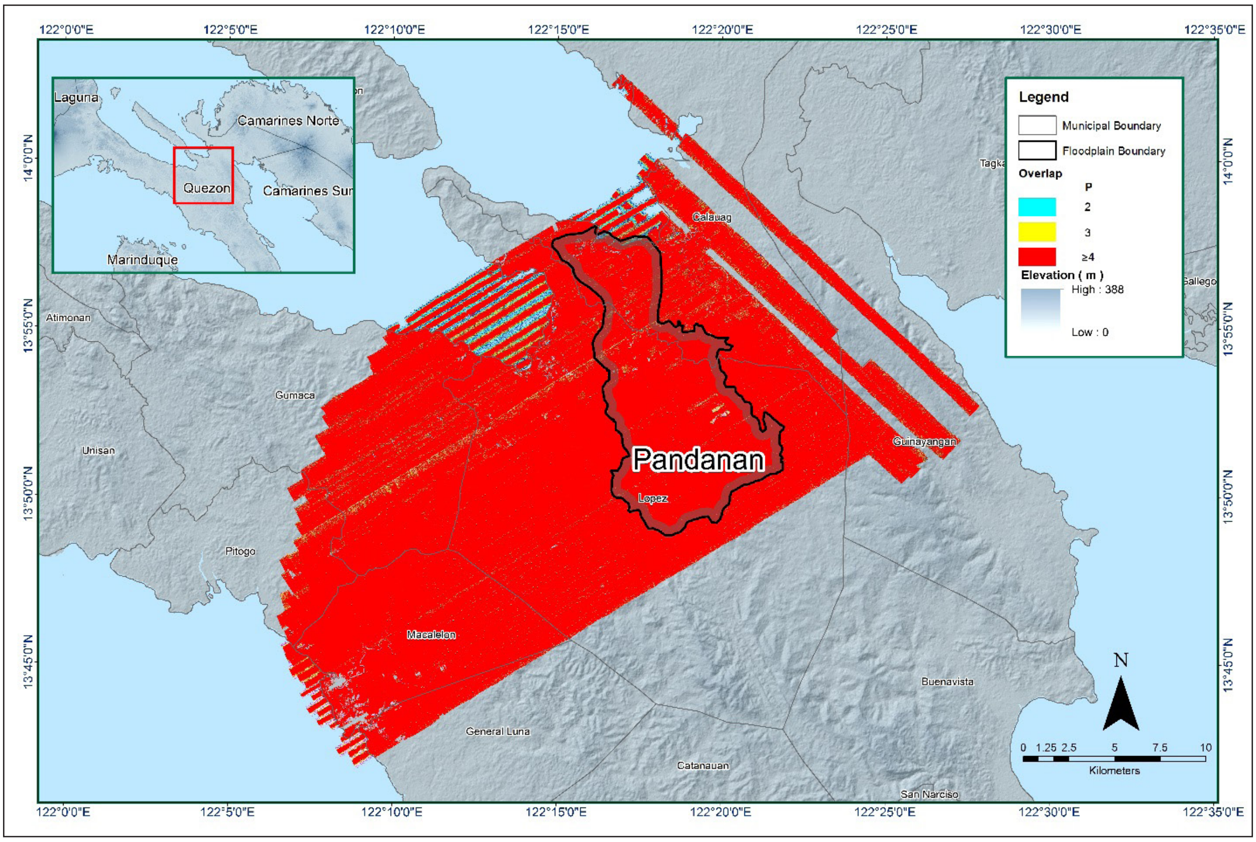


Figure 14. Pulse density map of merged LiDAR data for Pandanan Floodplain.

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

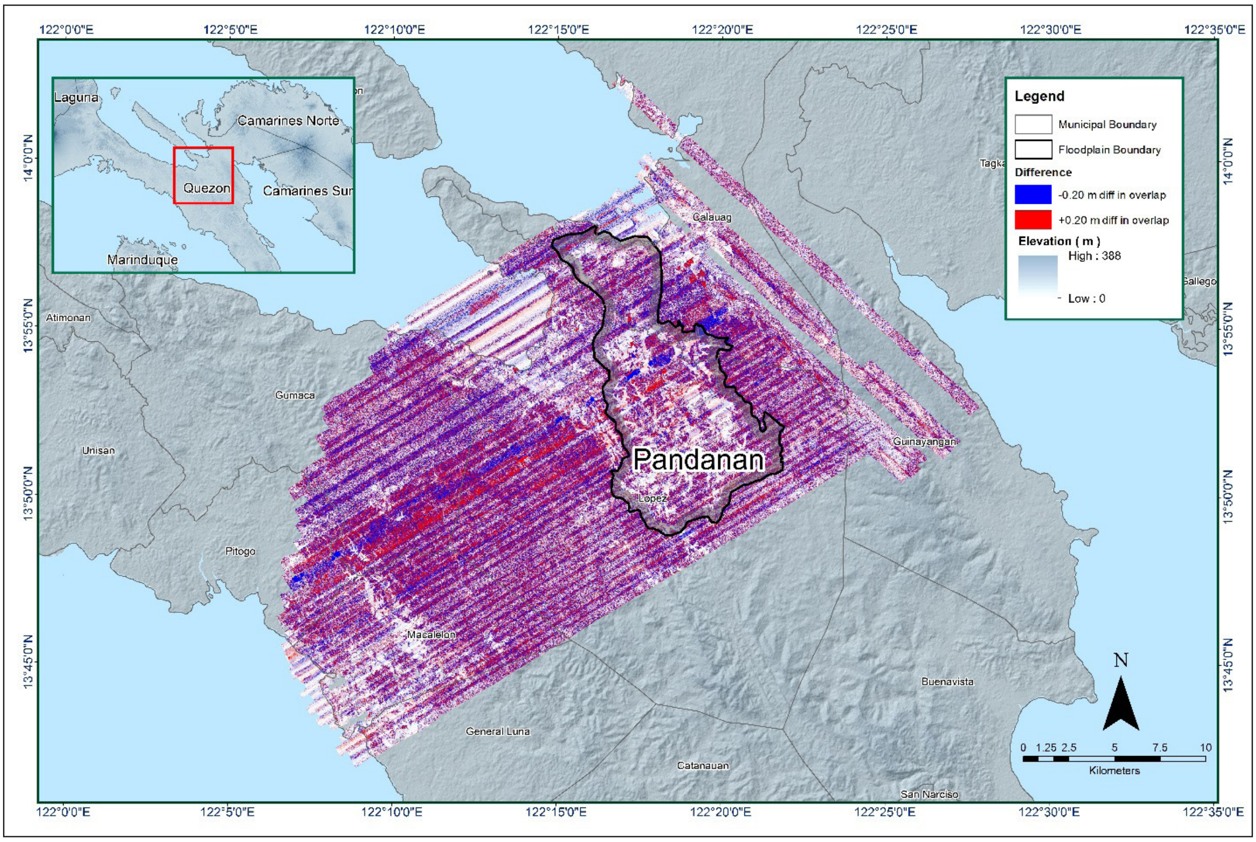


Figure 15. Elevation difference map between flight lines for Pandanan Floodplain.

A screen capture of the processed LAS data from a Pandanan flight 23244P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

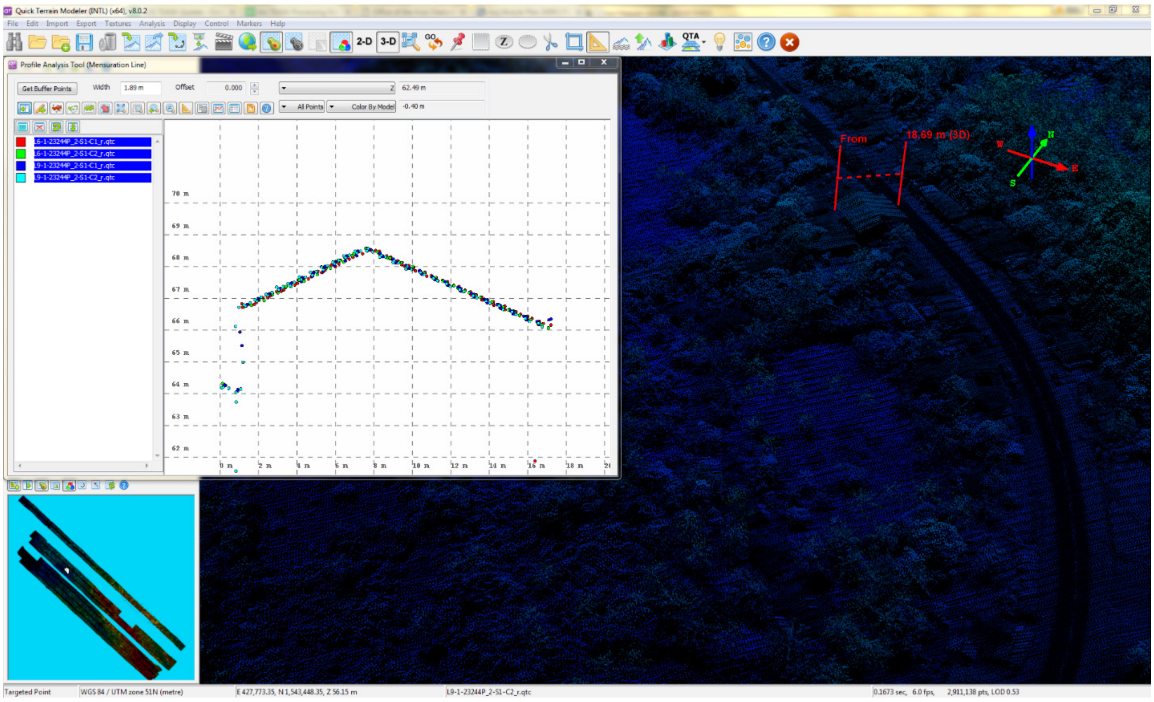


Figure 16. Quality checking for *Pandanan flight 23244P* using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Pandanan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	594,983,283
Low Vegetation	484,596,080
Medium Vegetation	1,221,445,850
High Vegetation	3,395,647,949
Building	50,953,122

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pandanan floodplain is shown in Figure 17. A total of 1,077 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 600.05 meters and 39.63 meters respectively.

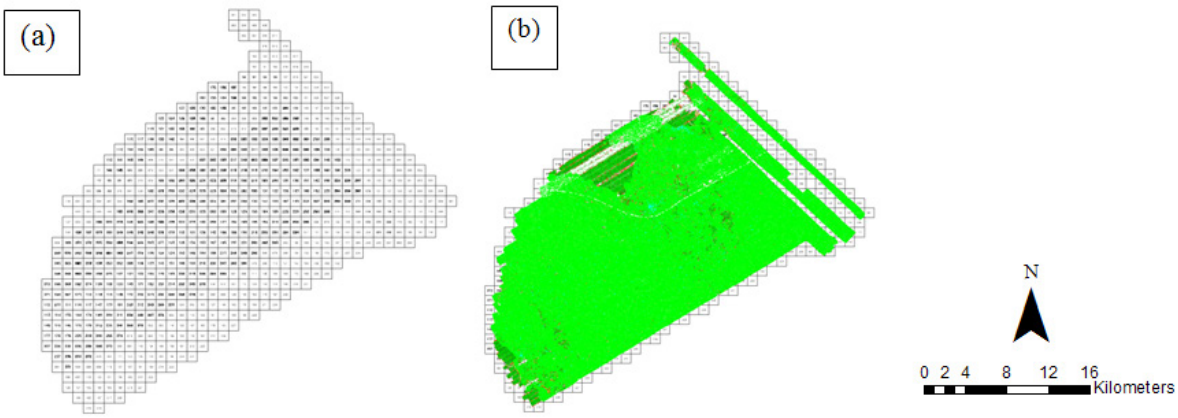


Figure 17. Tiles for Pandanan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

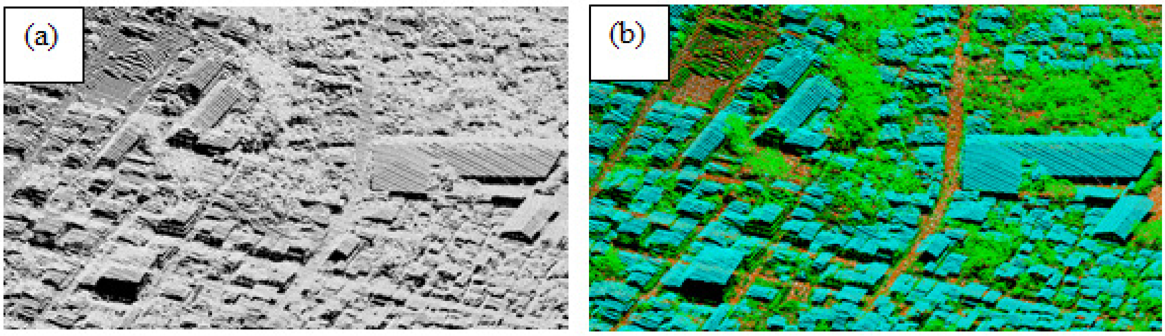


Figure 18. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

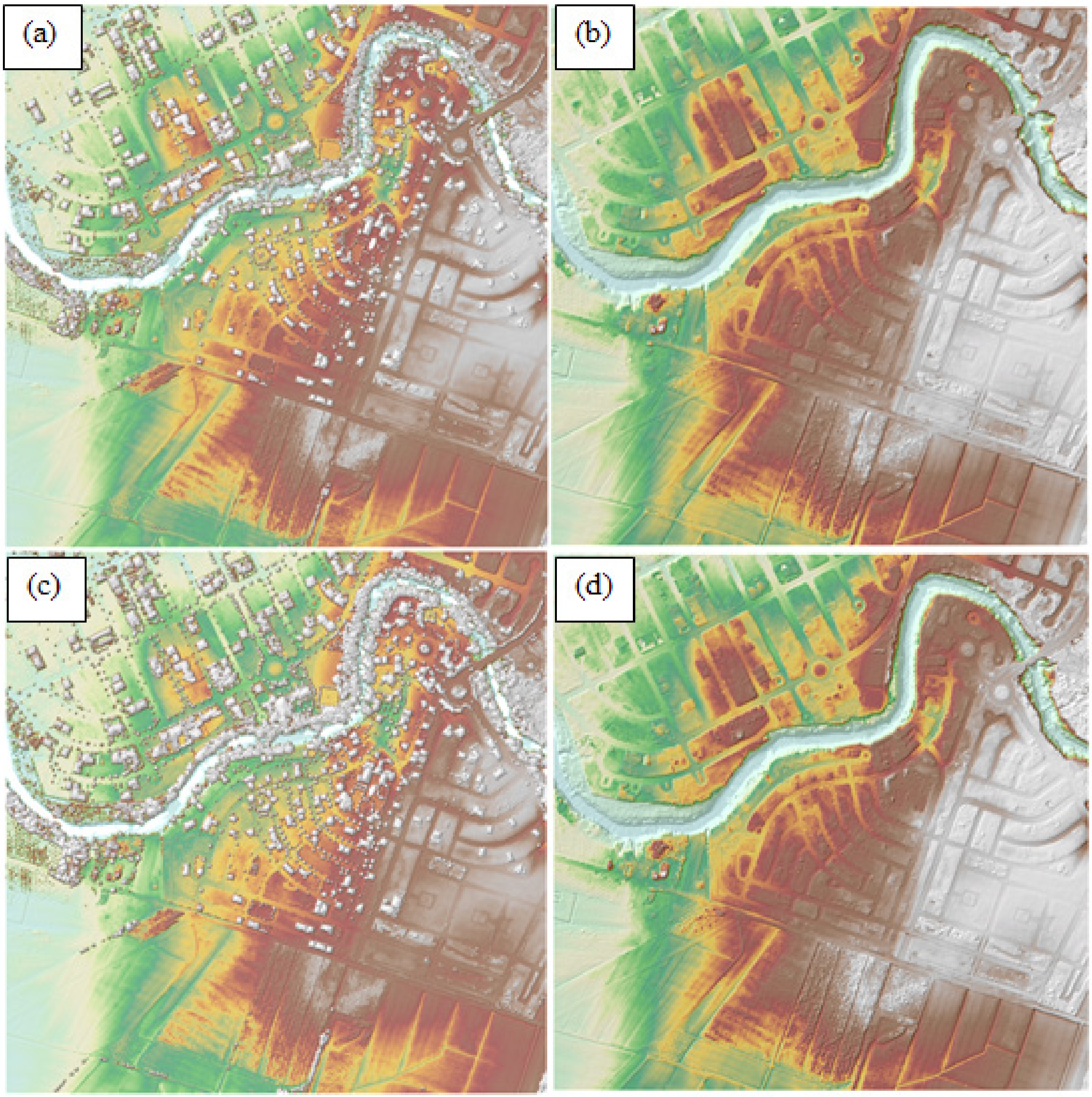


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pandanan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 690 1km by 1km tiles area covered by Pandanan floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Pandanan floodplain has a total of 445.14 sq.km orthophotogaph coverage comprised of 1,344 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

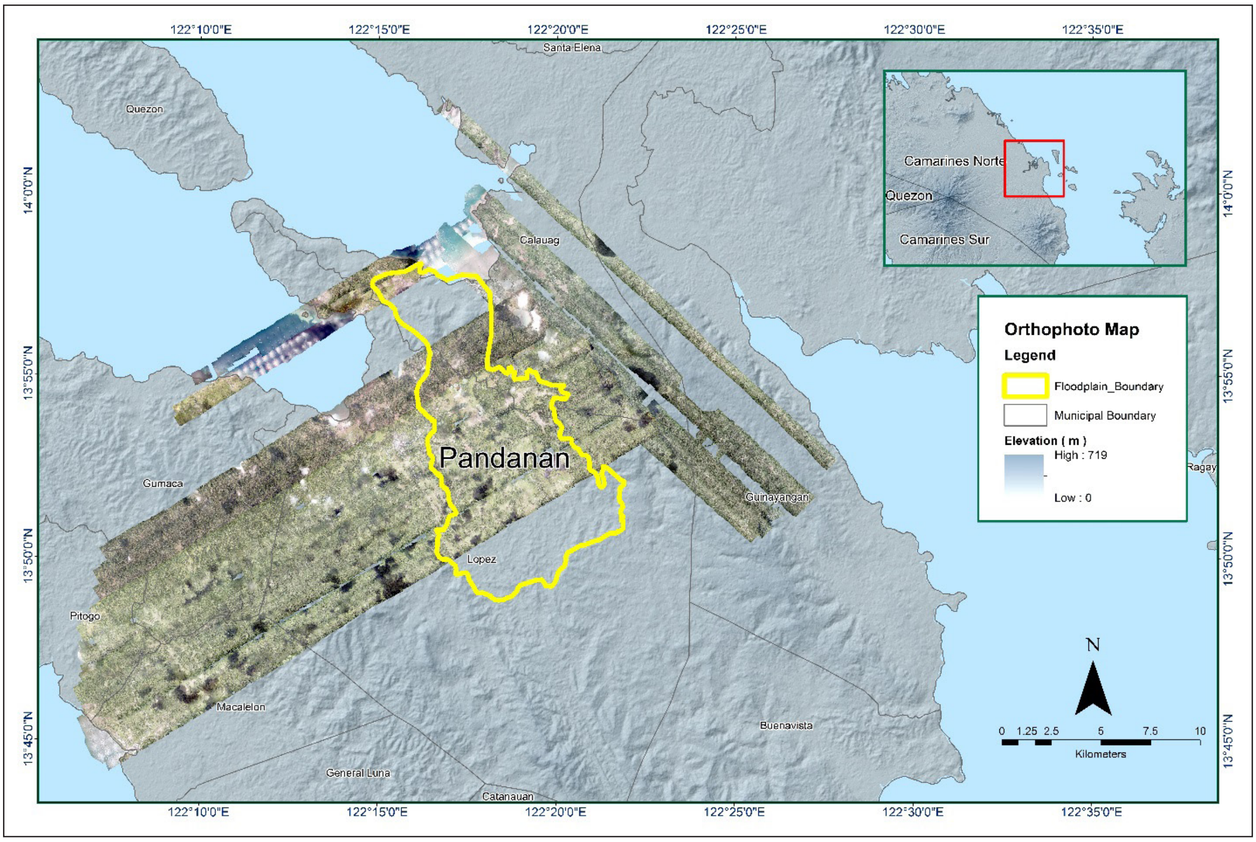


Figure 20. Pandanan Floodplain with available orthophotographs.

Figure 21. Sample orthophotograph tiles for Pandanan Floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Pandanan flood plain. These blocks are composed of Bagasbas blocks with a total area of 709.56 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Bagasbas_Blk21A	99.14
Bagasbas_Blk21B	81.69
Bagasbas_Blk21B_additional	30.91
Bagasbas_Blk21B_supplement	87.17
Bagasbas_Blk21C	231.85
Bagasbas_Blk21D	178.80
TOTAL	**709.56 sq.km**

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

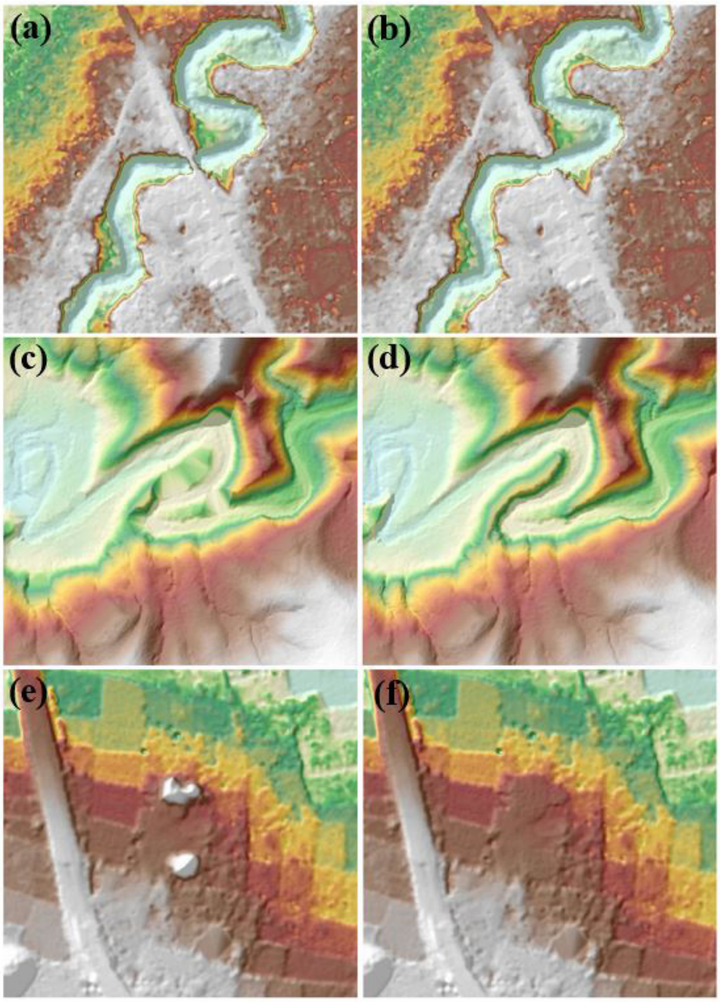


Figure 22. Portions in the DTM of Pandanan floodplain – a bridge before (a) and after (b) manual editing; a ridge before (c) and after (d) data retrieval; and a building before (a) and after (b) manual editing.

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_Blk21A is the block closest to the reference block that covers Macalelon floodplain. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Pandanan floodplain is shown in Figure 23. It can be seen that the entire Pandanan floodplain is 99.76% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 14. Shift Values of each LiDAR Block of Pandanan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Bagasbas_Blk21A	-3.24	1.76	-0.05
Bagasbas_Blk21B (Upper)	-2.47	3.00	0.07
Bagasbas_Blk21B (Lower)	-2.47	3.00	-0.03
Bagasbas_Blk21B_additional	-5.37	1.74	-0.13
Bagasbas_Blk21B_supplement	-2.43	-0.64	0.07
Bagasbas_Blk21C	-3.27	2.46	-0.10
Bagasbas_Blk21D	-1.27	-1.07	0.10

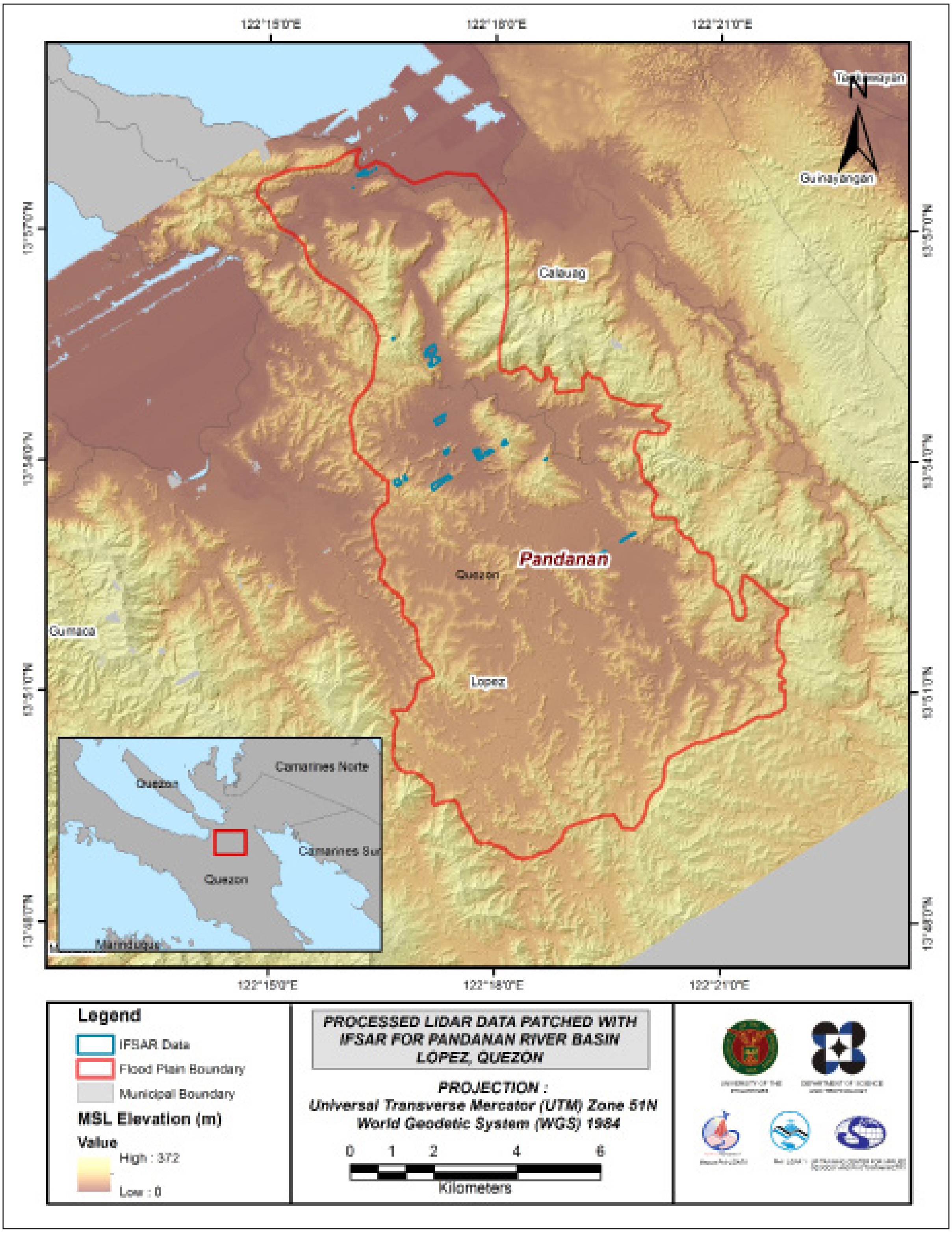


Figure 23. Map of Processed LiDAR Data for Pandanan Floodplain.

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 Pandanan to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 15,500 survey points were gathered for all the flood plains within the provinces of Quezon and Camarines Sur wherein the Pandanan floodplain is located. Random selection of 80% of the survey points, resulting to 12,400 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 3.08 meters with a standard deviation of 0.17 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 3.08 meters, to the mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

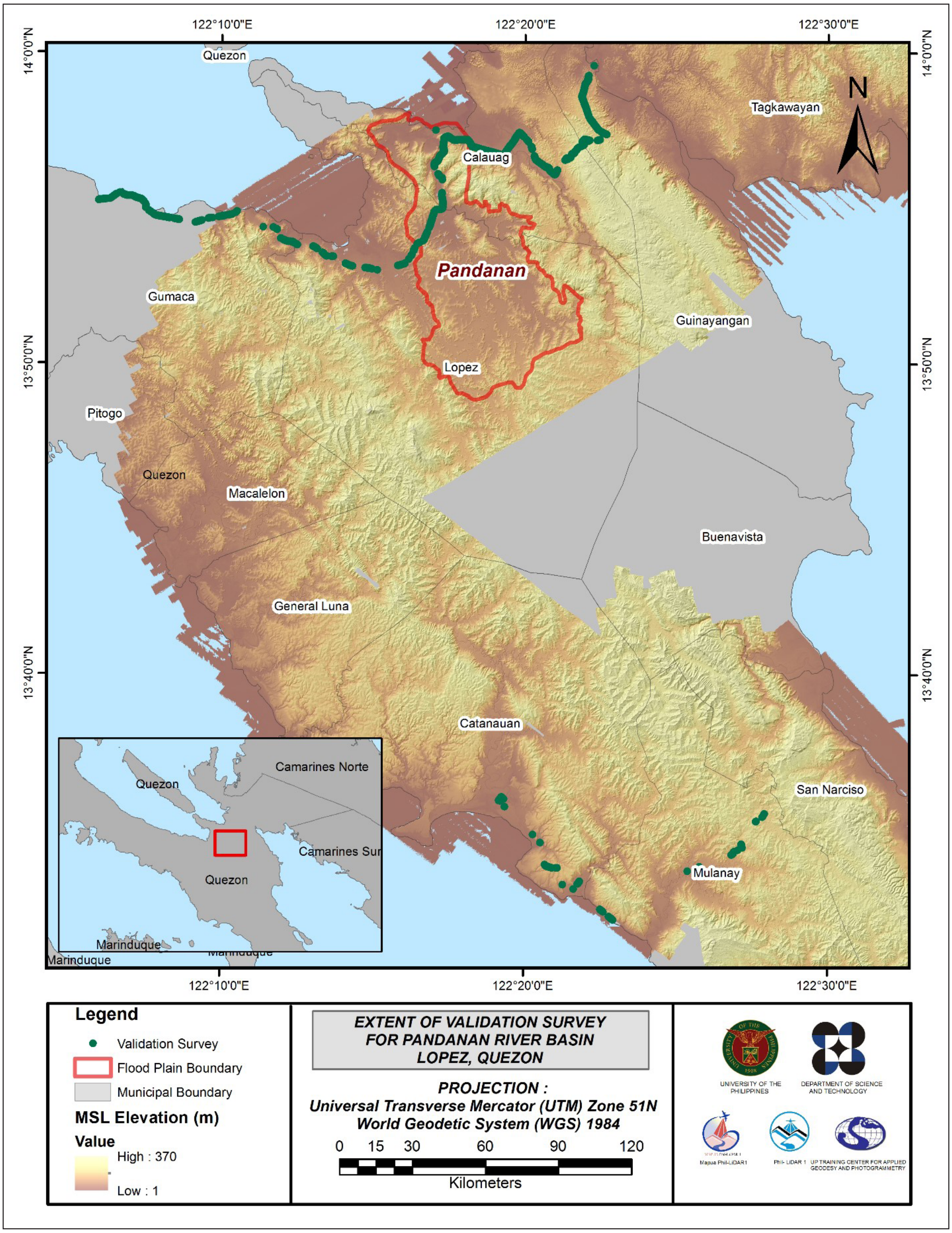


Figure 24. Map of Pandanan Floodplain with validation survey points in green.

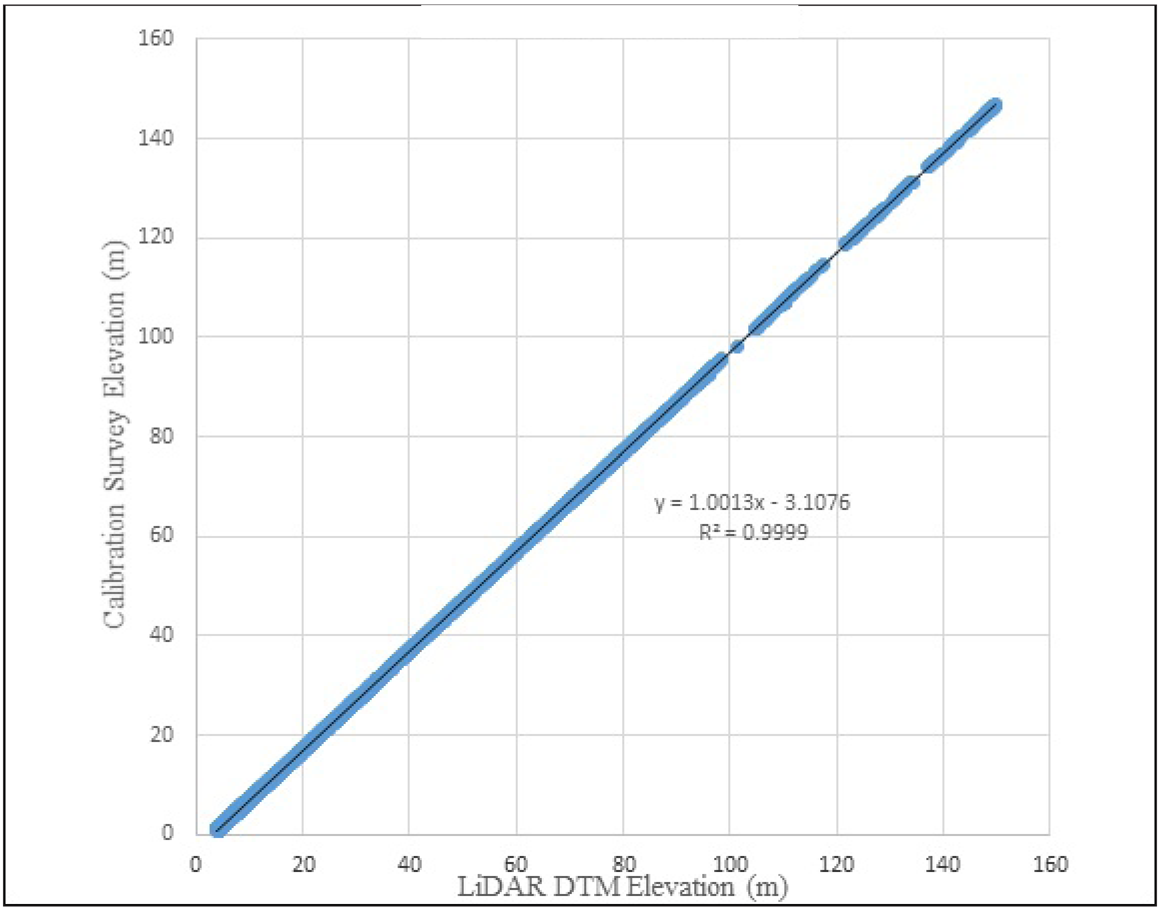


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

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

The remaining 20% of the total survey points that are near to the Pandanan flood plain, resulting to 477 points, were used for the validation of calibrated Pandanan 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.06 meters, as shown in Table 16.

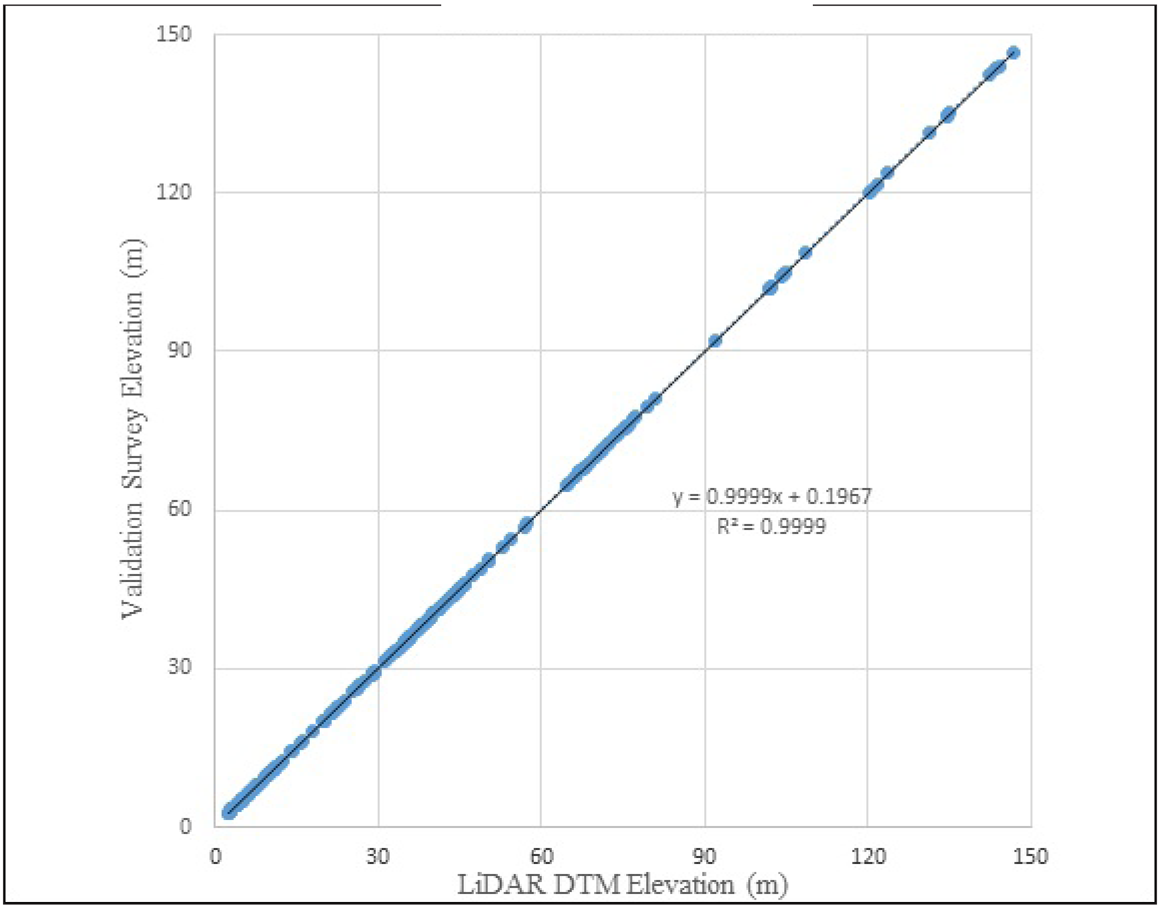


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

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

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Pandanan with 10,372 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation (with barriers) method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.07 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Pandanan integrated with the processed LiDAR DEM is shown in Figure 27.

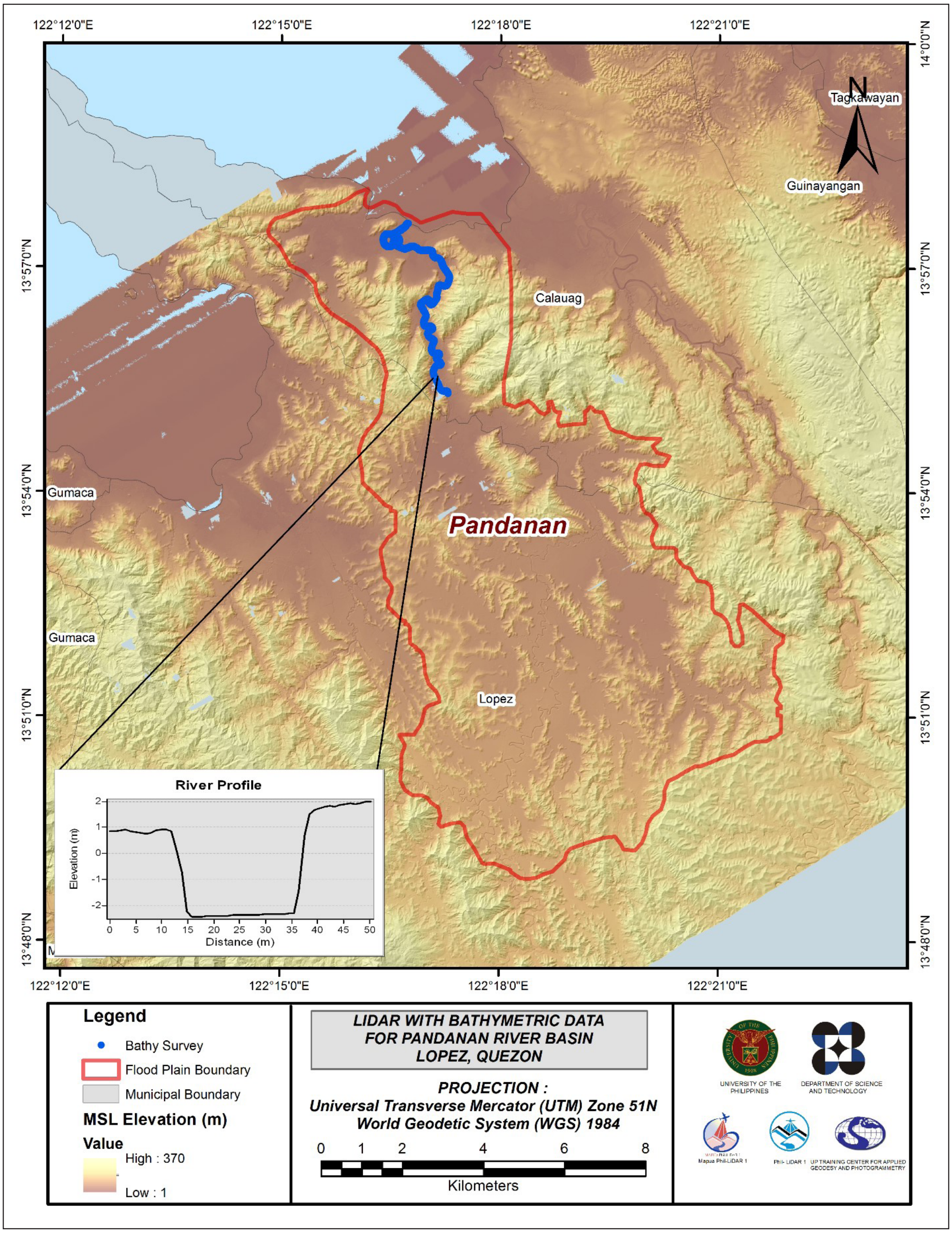


Figure 27. Map of Pandanan Floodplain with bathymetric survey points shown in blue.

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

Pandanan floodplain, including its 200 m buffer, has a total area of 112.26 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,230 building features, are considered for QC. Figure 28 shows the QC blocks for Pandanan floodplain.

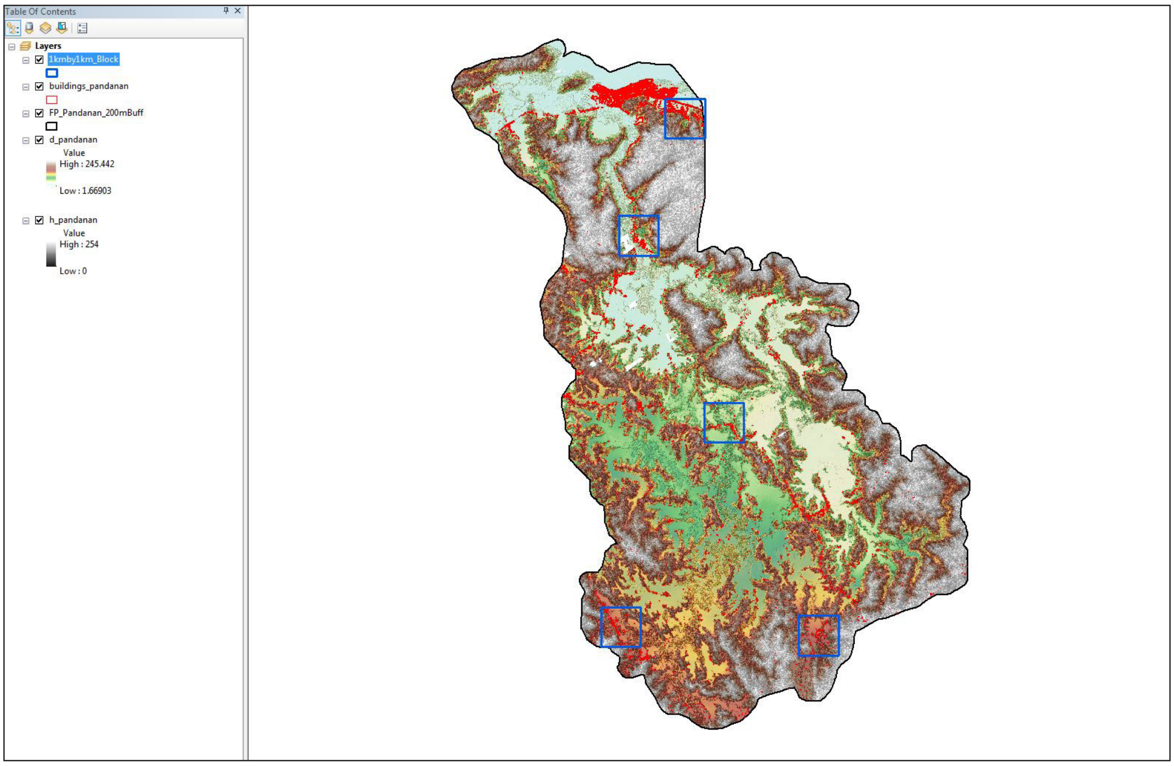


Figure 28. QC blocks for Pandanan building features.

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

Table 17. Quality Checking Ratings for Pandanan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Pandanan	98.04	97.72	82.93	PASSED

3.12.2 Height Extraction

Height extraction was done for 9,856 building features in Pandanan floodplain. Of these building features, none was filtered out after height extraction, resulting to 8,860 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.44 m.

3.12.3 Feature Attribution

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

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

Table 18. Building Features Extracted for Pandanan Floodplain.

Facility Type	No. of Features
Residential	8,787
School	38
Market	0
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	3
Barangay Hall	12
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	1
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	13
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	3
Other Commercial Establishments	2
Total	**8,860**

Table 19. Total Length of Extracted Roads for Pandanan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Pandanan	36.18	35	13.66	15.29	0.00	**100.13**

Table 20. Number of Extracted Water Bodies for Pandanan Floodplain.

Floodplain	Water Body Type						Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Pandanan	2	8	1	0	0	**11**	Pandanan

A total of 38 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 29 shows the Digital Surface Model (DSM) of Pandanan floodplain overlaid with its ground features.

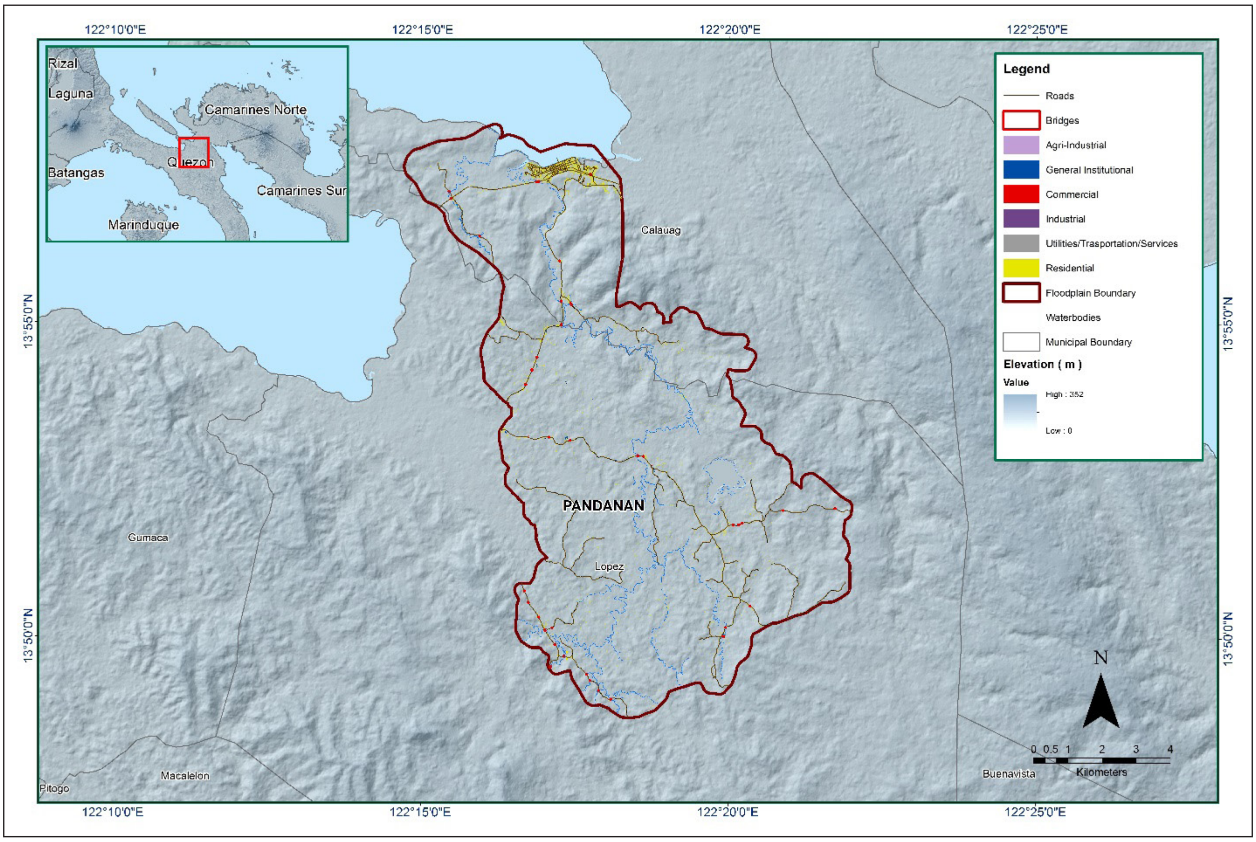


Figure 29. Extracted features for Pandanan Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF PANDANAN 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, Cybil Claire Atacador, Engr. Lorenz R. Taguse

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 Pandanan River on May 2-16, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Pandanan Bridge in Brgy. Binutas, Municipality of Calauag, Quezon Province; validation points acquisition of about 67 km covering the Pandanan River Basin area; and bathymetric survey from its upstream in Brgy. Binutas down to the mouth of the river in Brgy. Sabang I, both in Municipality of Calauag, with an approximate length of 7.772 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 30)

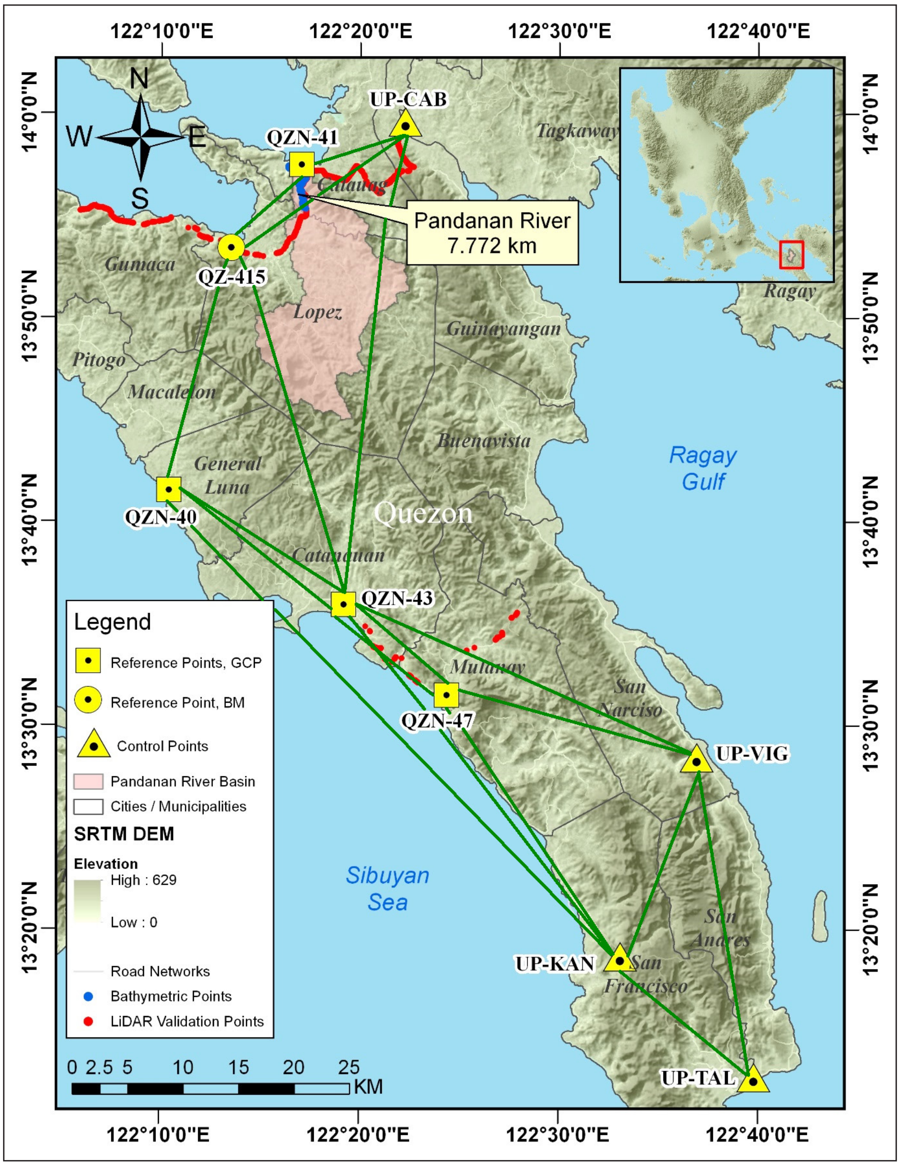


Figure 30. Pandanan River Survey Extent

4.2 Control Survey

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

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

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 31.

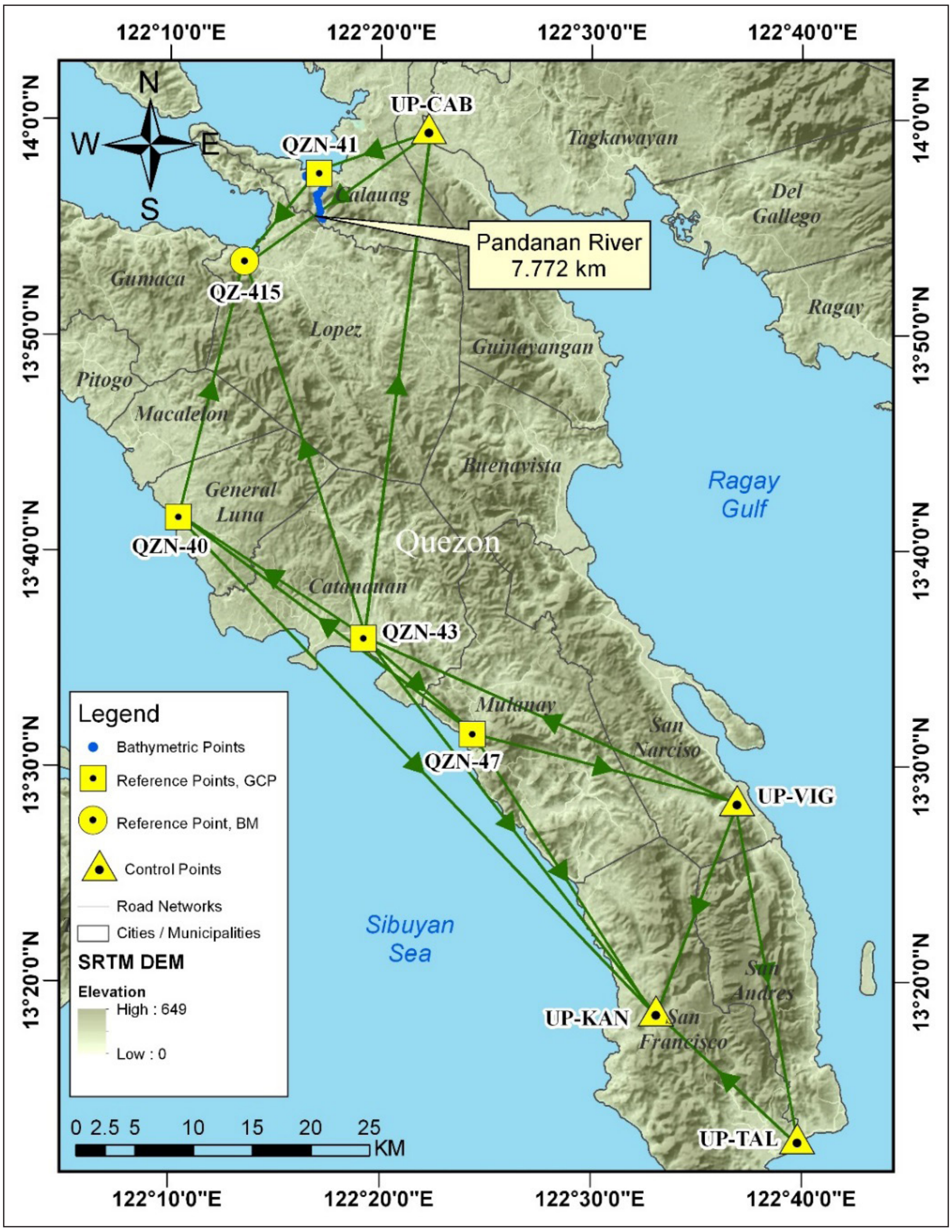


Figure 31. GNSS Network of Pandanan River field survey

Table 21. List of Reference and Control Points occupied for Pandanan River Survey (Source: NAMRIA; UP-TCAGP)

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

The GNSS set-ups of the reference and control points are exhibited are shown in Figure 32 to Figure 40.

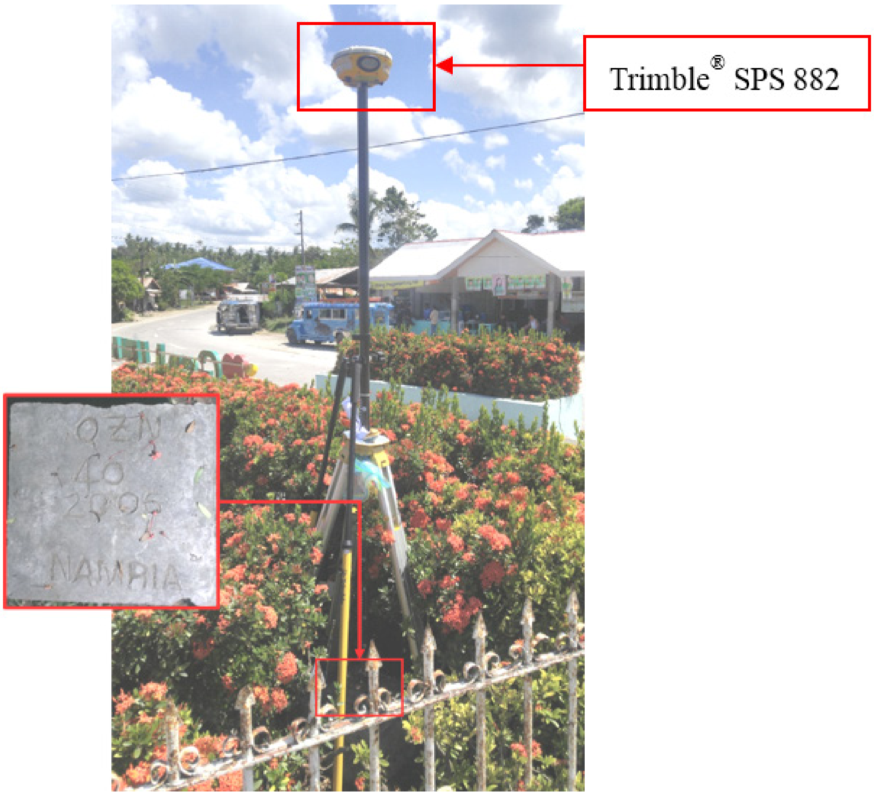


Figure 32. GNSS base set up, Trimble® SPS 882, at QZN-40, located inside a triangular plant area found at the center of a triangular island in Brgy. San Jose, Municipality of Gen. Luna, Quezon

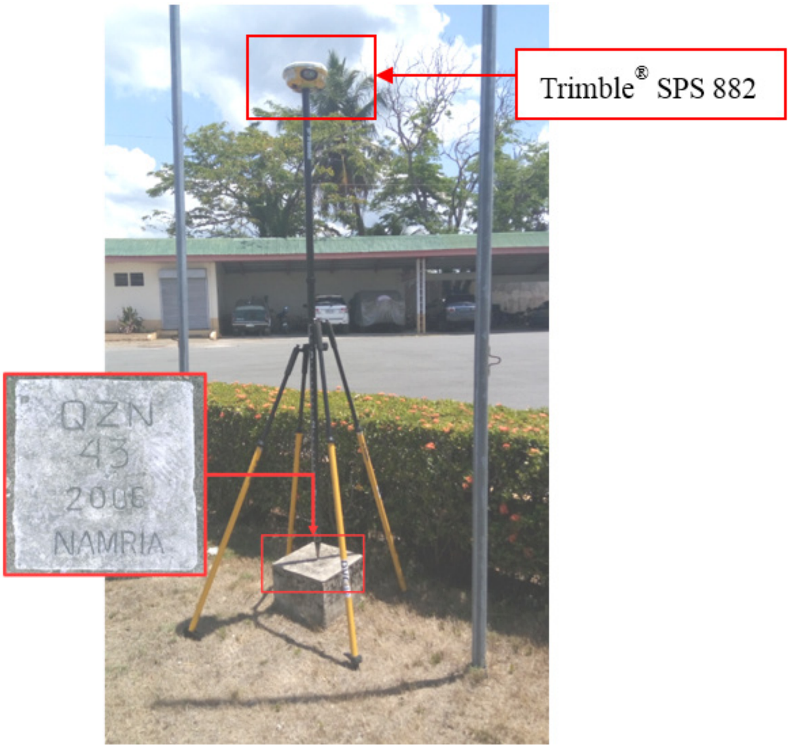


Figure 33. GNSS base set up, Trimble® SPS 882, at QZN-43, located inside the DPWH compound in Brgy. Matandang Sabang Silangan, Municipality of Catanauan, Quezon

Figure 34. GNSS base set up, Trimble® SPS 852, at QZN-47, located at the back of the Principal's Office of Mulanay Elementary School in Barangay II, Municipality of Mulanay, Quezon

Figure 35. GNSS base set up, Trimble® SPS 985, at QZ-415, located at the approach of Pansol Bridge in Brgy. Pansol, Municipality of Lopez, Quezon

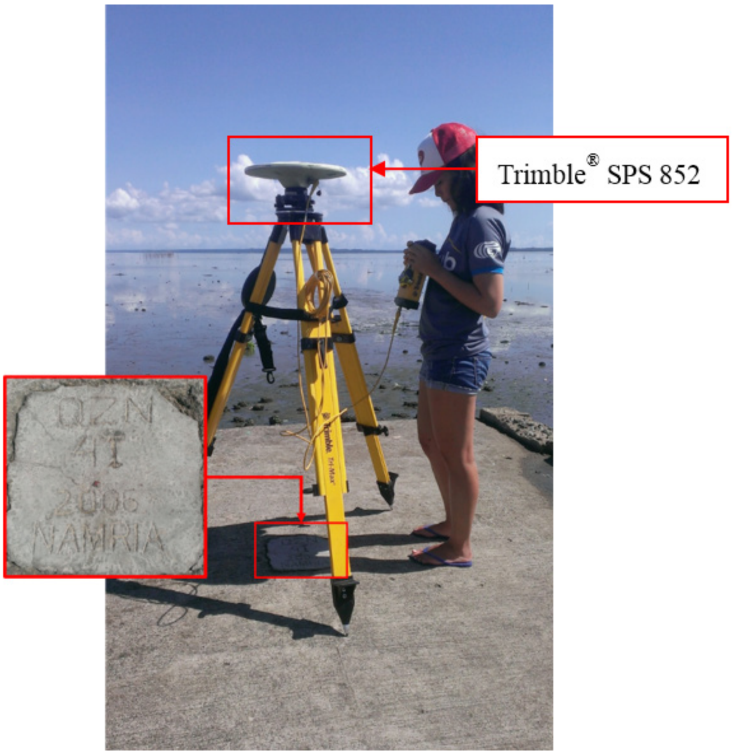


Figure 36. GNSS base set up, Trimble® SPS 852, at QZN-41, located in front of Brgy. Sabang basketball court found in Calauag Port, Barangay I, Municipality of Calauag, Quezon

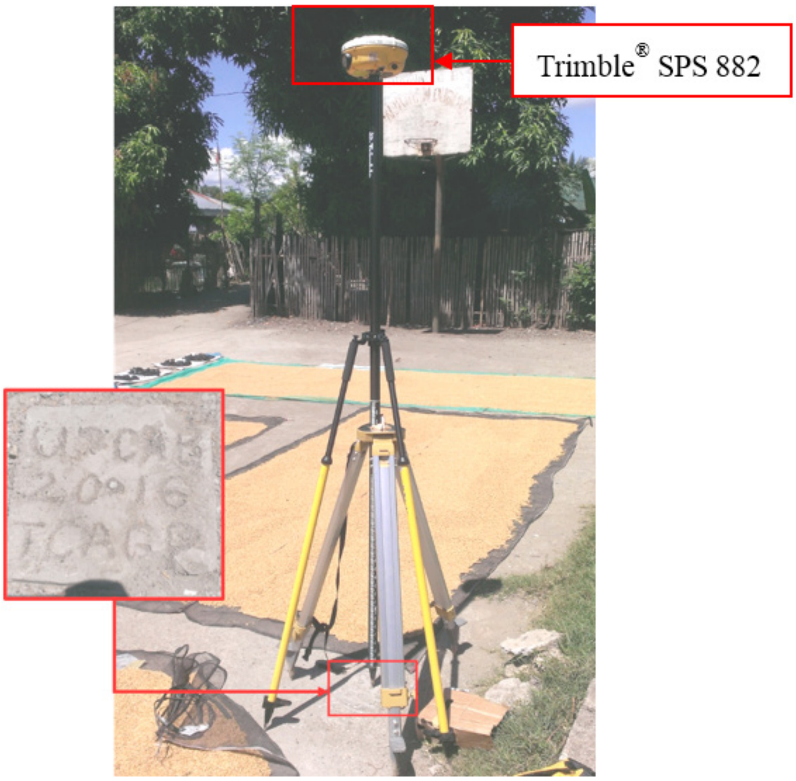


Figure 37. GNSS base set up, Trimble® SPS 882, at UP-CAB, located inside a basketball court in Brgy. Aloneros, Municipality of Guinayangan, Quezon

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

Figure 39. GNSS base set up, Trimble® SPS 852, at UP-TAL, located at the approach of Talisay Bridge in Brgy. Pagsangahan, Municipality of San Francisco, Quezon

Figure 40. GNSS base set up, Trimble® SPS 882, at UP-VIG, located at the approach of Vigo Bridge in Brgy. Vigo Central, Municipality of San Francisco, Quezon

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Pandanan River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Summary Report for Pandanan River Survey

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

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

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

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

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

Table 23. Control Point Constraints

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

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control points QZN-40, QZN-43 and QZN-47 has no values for grid and elevation errors, respectively.

Table 24. Adjusted Grid Coordinates

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

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

a. QZN-40

horizontal accuracy	=	Fixed
vertical accuracy	=	7.5 cm < 10 cm

b. QZN-43

horizontal accuracy	=	Fixed
vertical accuracy	=	7.3 cm < 10 cm

c. QZN-47

horizontal accuracy	=	Fixed
vertical accuracy	=	7.9 cm < 10 cm

d. QZ-415

horizontal accuracy	=	√((1. 0)^2 + (1.0)^2
	=	√ (1.0 + 1.0)
	=	1.41cm < 20 cm
vertical accuracy	=	Fixed

e. QZN-41

horizontal accuracy	=	√((1.40)^2 + (1.40)^2
	=	√ (1.96+ 1.96)
	=	1.98cm < 20 cm
vertical accuracy	=	8.2 cm < 10 cm

f. UP-CAB

horizontal accuracy	=	√((1.20)^2 + (1.30)^2
	=	√ (1.44 + 1.69)
	=	1.77 cm < 20 cm
vertical accuracy	=	7.3 cm < 10 cm

g. UP-KAN

horizontal accuracy	=	√((1.20)^2 + (1.10)^2
	=	√ (1.44 + 1.21)
	=	1.63 cm < 20 cm
vertical accuracy	=	8.6 cm < 10 cm

h. UP-TAL

horizontal accuracy	=	√((1.60)^2 + (1.40)^2
	=	√ (2.56 + 1.96)
	=	2.13 cm < 20 cm
vertical accuracy	=	9.5 cm < 10 cm

i. UP-VIG

horizontal accuracy = $\sqrt{((1.10)^2 + (0.80)^2}$

= $\sqrt{(1.21 + 0.64)}$

= 1.36 cm < 20 cm

vertical accuracy = 8.3 cm < 10 cm

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

Table 25. Adjusted Geodetic Coordinates

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

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the 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 26.

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

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

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

Cross-section survey was conducted at the downstream part of Pandanan Bridge in Brgy. Binutas, Municipality of Calauag on May 4, 2016 using a GNSS receiver, Trimble® SPS 882, in PPK survey technique, as shown in Figure 41, paired with an Ohmex™ singlebeam echosounder.

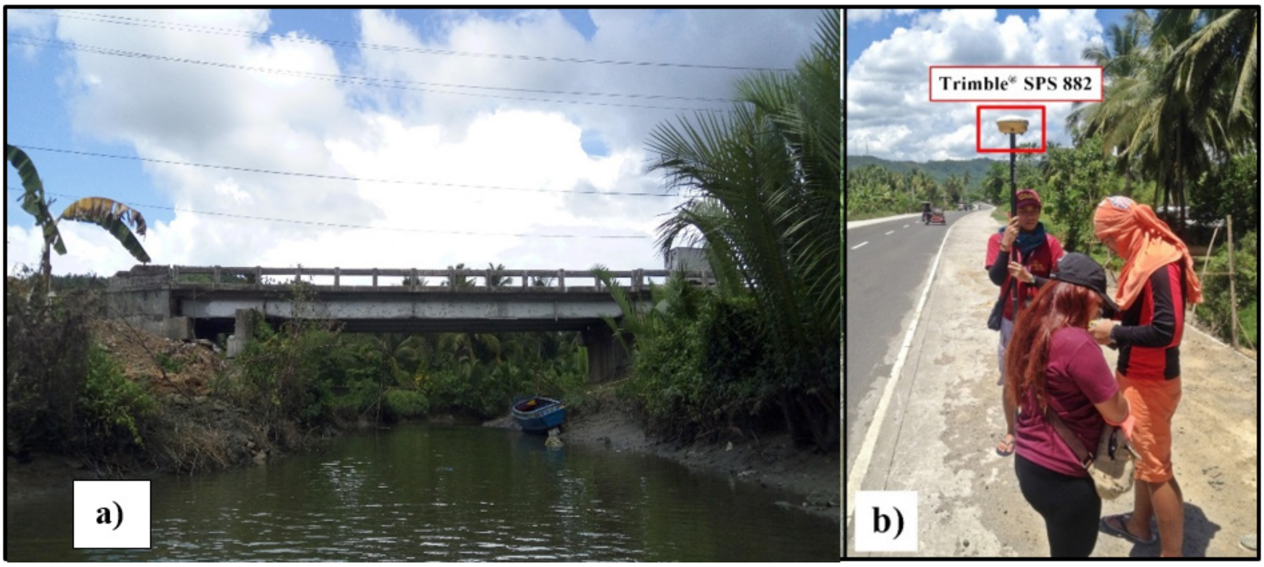


Figure 41. (a) Pandanan Bridge facing upstream and, (b) Cross-Section Survey for using Trimble® SPS 882 in PPK mode

The cross-sectional line length for Pandanan River is about 134.18 m with 98 cross-sectional points acquired using QZN-41 as the GNSS base station. The cross section diagram, location map, and bridge as-built form are illustrated in Figure 42 to Figure 44, respectively.

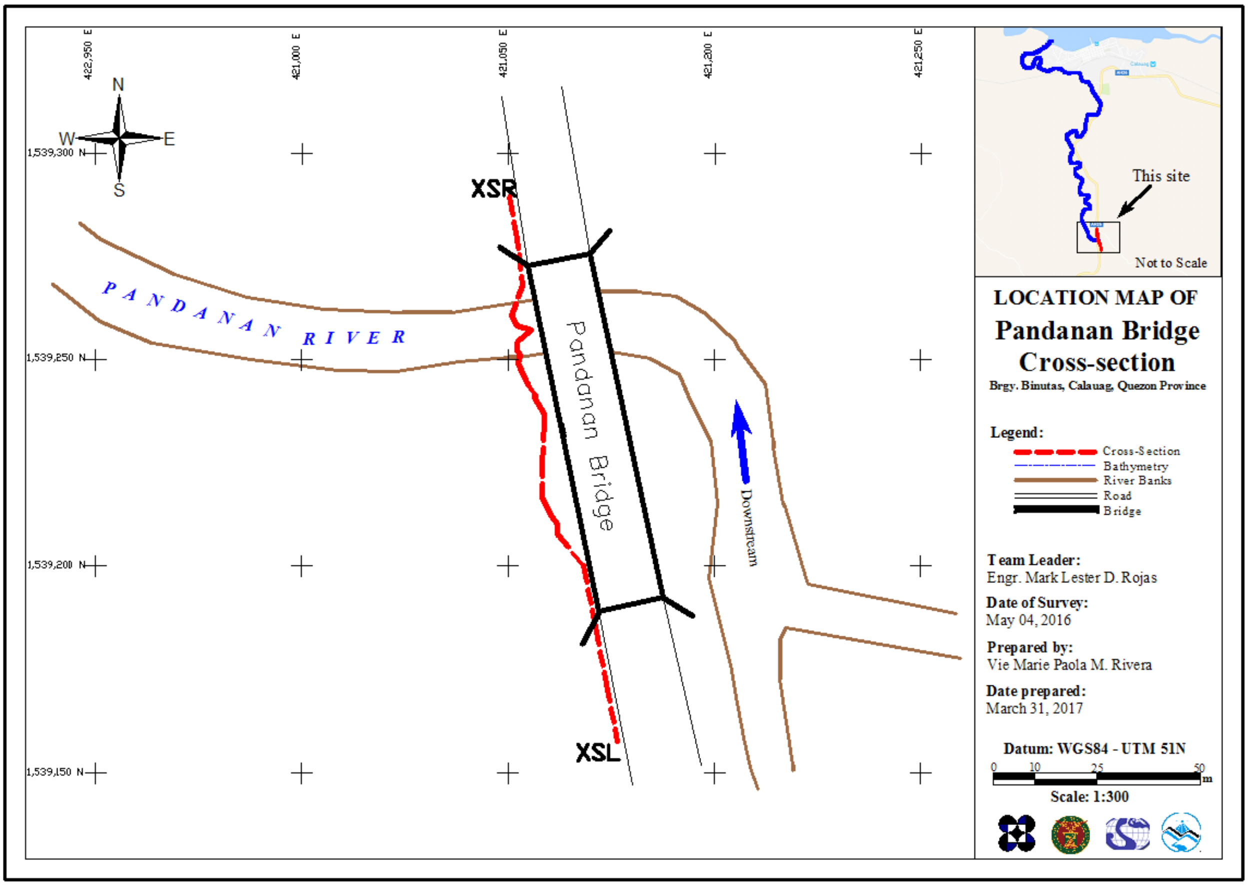


Figure 42. Location map of Pandanan Bridge cross-section

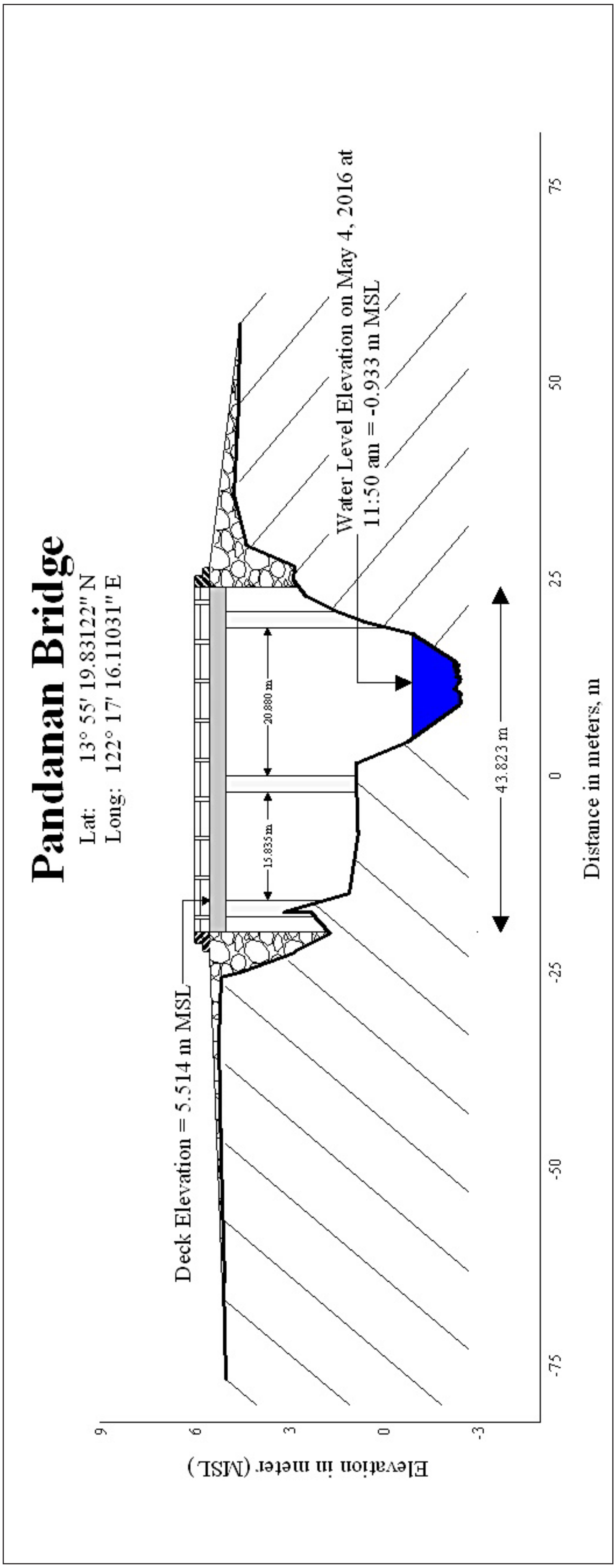


Figure 43. Pandanan Bridge cross-section diagram

Bridge Data Form

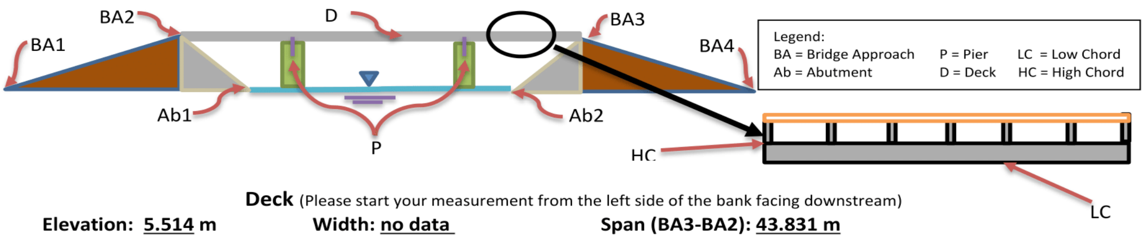
Bridge Name: Pandanan Bridge **Date:** May 4, 2016

River Name: Pandanan River **Time:** 11:50 am

Location (Brgy, City, Region): Brgy. Binutas, Municipality of Calauag, Quezon Province
Survey Team: Quezon Team (Mike & Mark)

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

Latitude: 13° 55' 19.83122" N **Longitude:** 122° 17' 16.11031" E



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

Elevation: 5.514 m **Width:** no data **Span (BA3-BA2):** 43.831 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	5.526 m	N/A
2	Pier 2	5.532 m	N/A
3	Pier 3	5.416 m	N/A

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.01	**BA3**	100.695	5.381
BA2	56.875	5.516	**BA4**	134.181	4.552

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Rectangular **Number of Piers:** seven (7) **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	59.861	5.526 m	N/A
Pier 2	75.696	5.532 m	N/A
Pier 3	96.576	5.416 m	N/A

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

Figure 44. Bridge as-built form of Pandanan Bridge

Water surface elevation in MSL of Pandanan River was determined using Trimble® SPS 882 in PPK survey mode on May 4, 2016 at 11:50 AM with a value of -0.933 m below MSL. This was translated onto marking on the one side of a bridge's piers as shown in Figure 45. The markings will serve as the reference of the partner HEI, Mapúa PHIL-LiDAR 1, for flow data gathering and depth gauge deployment for Pandanan River.

Figure 45. Mean Sea Level (MSL) elevation markings for Pandanan River

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on May 4, 5, and 6, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of the vehicle as shown in Figure 46. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was 1.895 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with QZN-41, QZN-43 and UP-CAB occupied as the GNSS base stations in the conduct of the survey.

Figure 46. Validation points acquisition survey set up along Pandanan River Basin

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

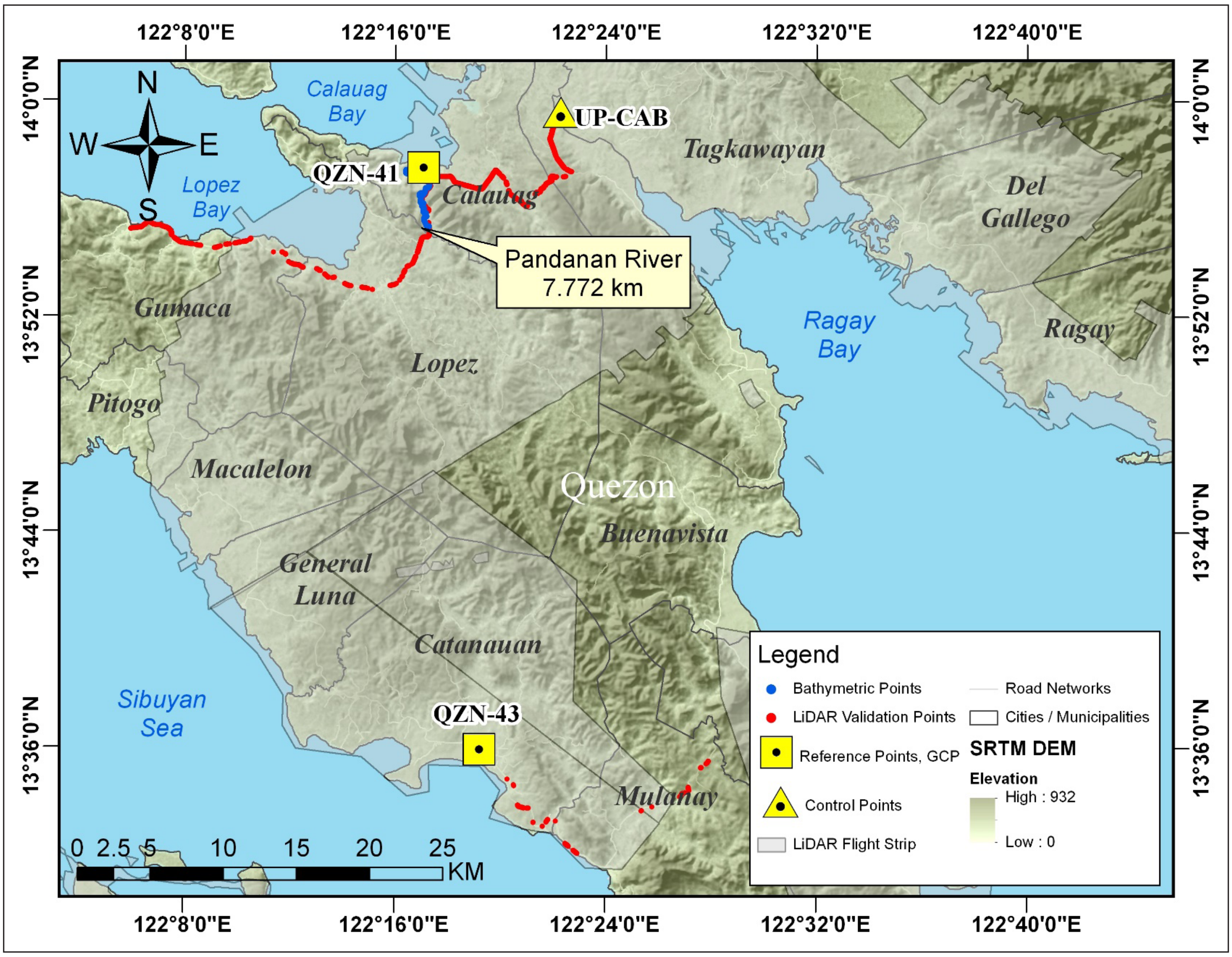


Figure 47. Validation point acquisition survey of Pandanan River basin

4.7 Bathymetric Survey

Bathymetric survey was executed on May 5, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and Ohmex™ single beam echo sounder, as illustrated in Figure 40. The extent of the survey is from the upstream part of the river in Brgy. Binutas with coordinates 13°55’19.04392”N, 122°17’17.32065”E , down to the mouth of the river in Brgy. Sabang I with coordinates 13°57’35.43275”N, 122°16’43.57816”E, both in Municipality of Calauag.

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

A CAD drawing was also produced to illustrate the riverbed profile of Pandanan River. As shown in Figure 49, the highest and lowest elevation has a 3-meter difference. The highest elevation observed is 1.576 m below MSL located at the upstream portion of the river near around the Pandanan Bridge in Brgy. Binutas while the lowest elevation observed is 5.144 m below MSL located at the midportion of the river in Brgy. Patihan. The bathymetric survey gathered a total of 3,838 points covering 7.772 km of the river traversing Barangays Binutas, Marilag, Patihan, I, Pinagkamaligan, and Sabang I in Municipality of Calauag. The survey was extended by about 4.6 km to reach the deployment site of the partner HEI, MIT.

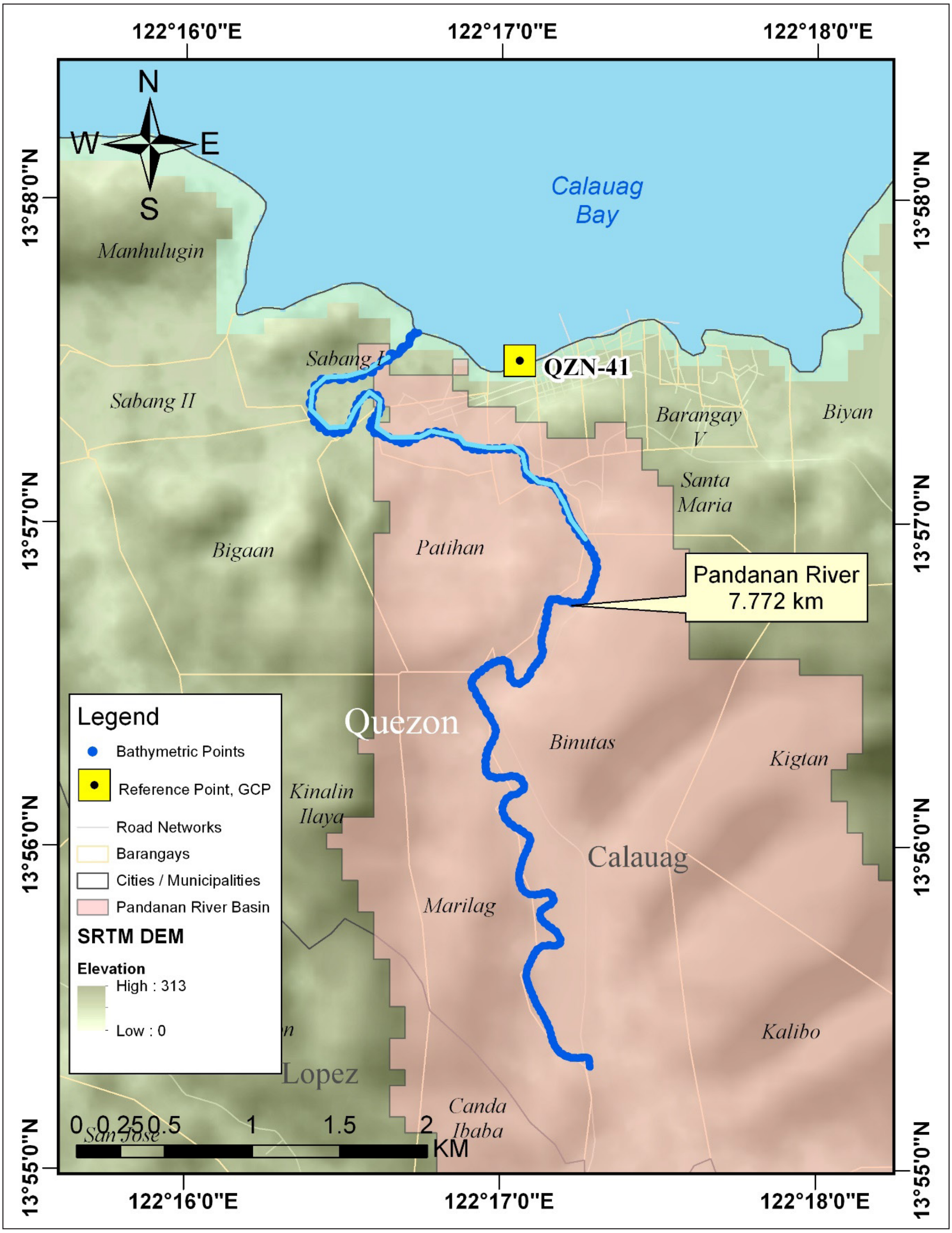


Figure 49. Bathymetric Survey of Pandanan River

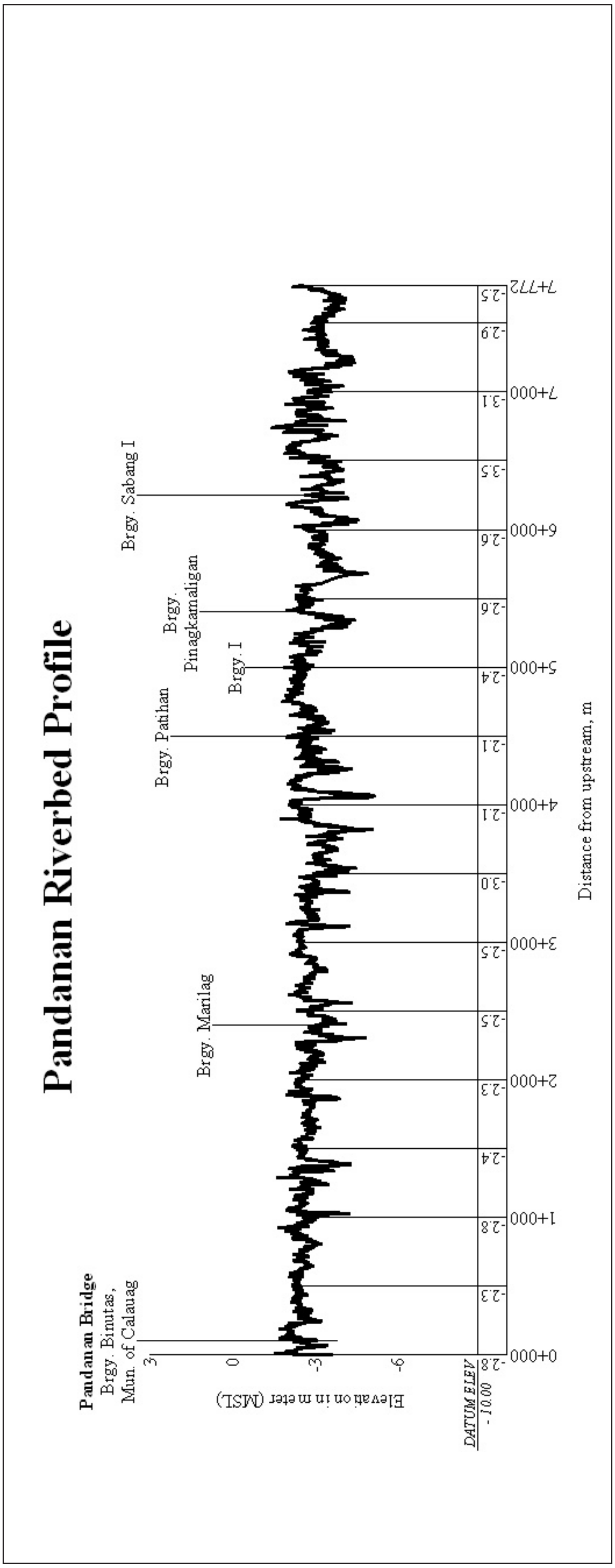


Figure 50. Pandanan Riverbed Profile

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

5.1.2 Precipitation

Precipitation data was taken from two automatic rain gauges (ARG). The first rain gauge is located at Lopez, Quezon and installed by the Weather Philippines. The second rain gauge is located at Calauag, Quezon and installed by Mapua-Phil-LiDAR1. The location of the rain gauges is as shown in Figure 51.

The total rain from the Lopez and Calauag rain gauges are 44 mm and 61.2 mm, respectively. Precipitation peak to 4 mm in November 25, 2016 at 4:50 a.m. The lag time between the peak rainfall and discharge is 9 hours and 30 minutes, as shown in Figure 53.

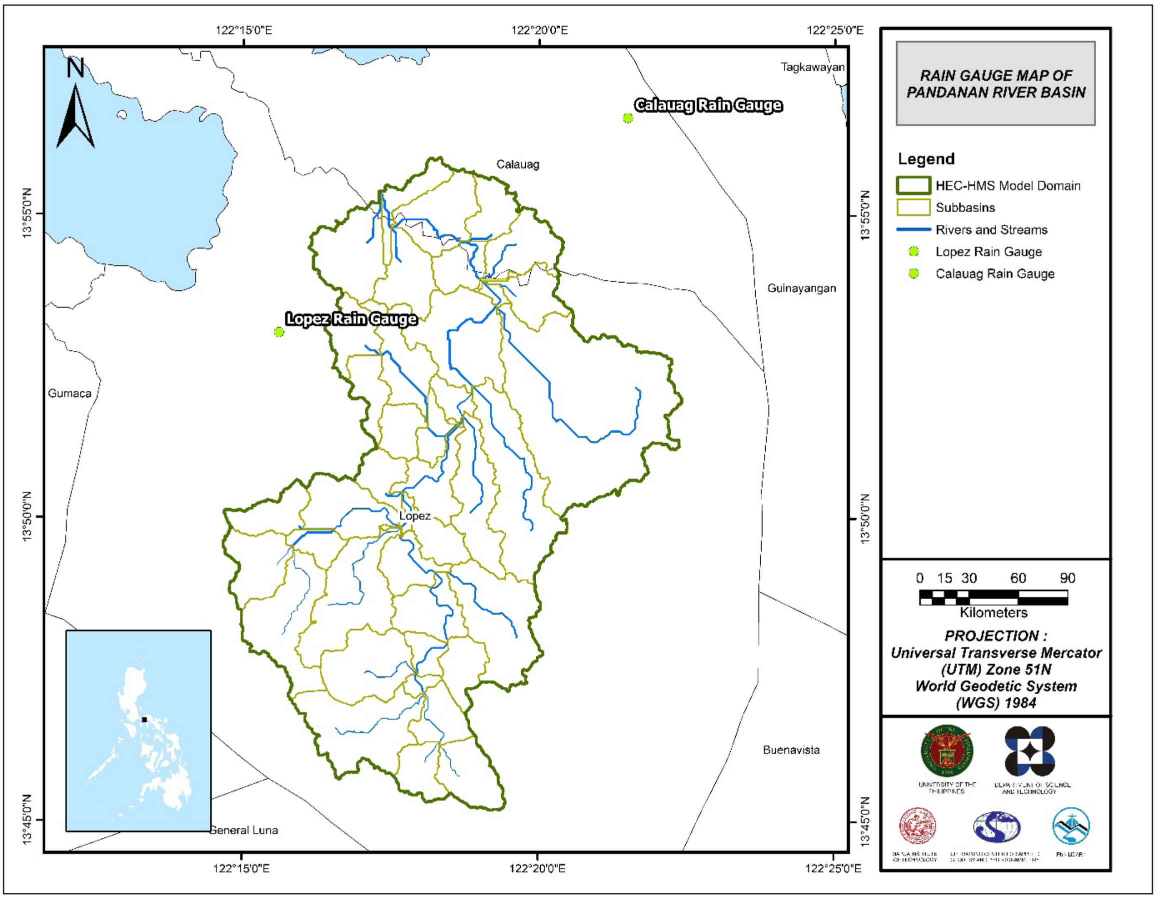


Figure 51. Location map of Pandanan HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Pandanan Bridge, Lopez, Quezon (13°55'20.97"N, 122°17'16.05"E). It gives the relationship between the observed water levels and outflow of the watershed at this location. It is expressed in the form of the following equation:

$$Q=a^{nh}$$

where, Q : Discharge (m^3/s),

h : Gauge height (reading from Pandanan bridge), and;

a and n : Constants.

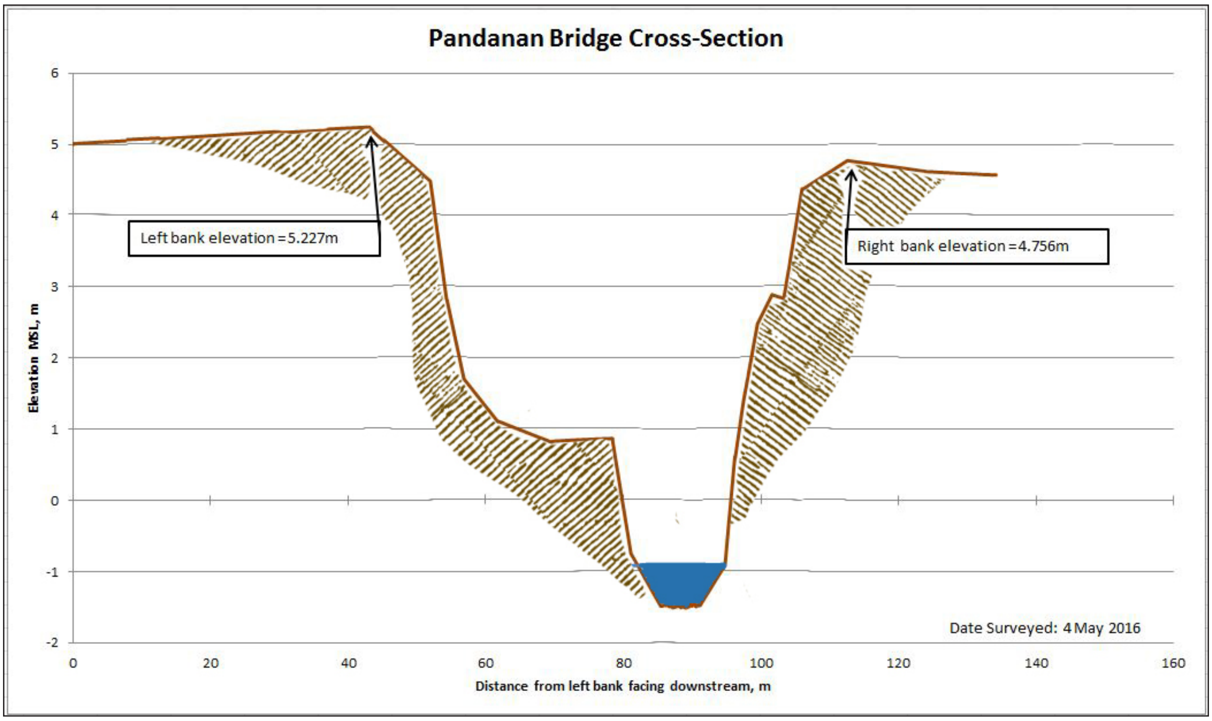


Figure 52. Cross-Section Plot of Pandanan Bridge

For Pandanan Bridge, the rating curve is expressed y = 1.5385e2.3683x as shown in Figure 53.

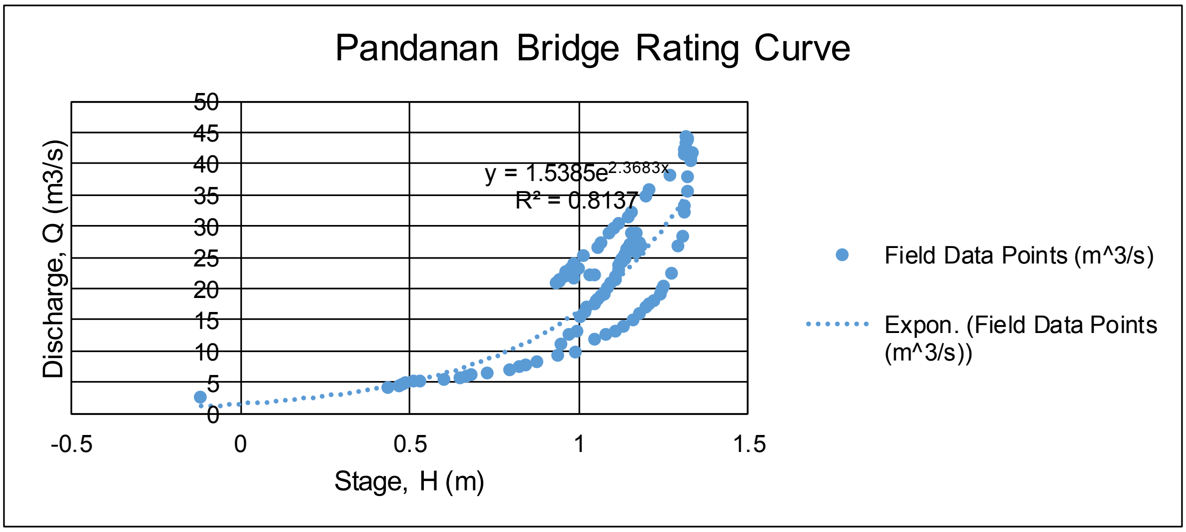


Figure 53. Rating curve at Pandanan Bridge, Lopez, Quezon

This rating curve equation was used to compute the river outflow at Pandanan Bridge for the calibration of the HEC-HMS model shown in Figure 54. Peak discharge is 44.12 m^3/s at 18:00, November 26, 2016.

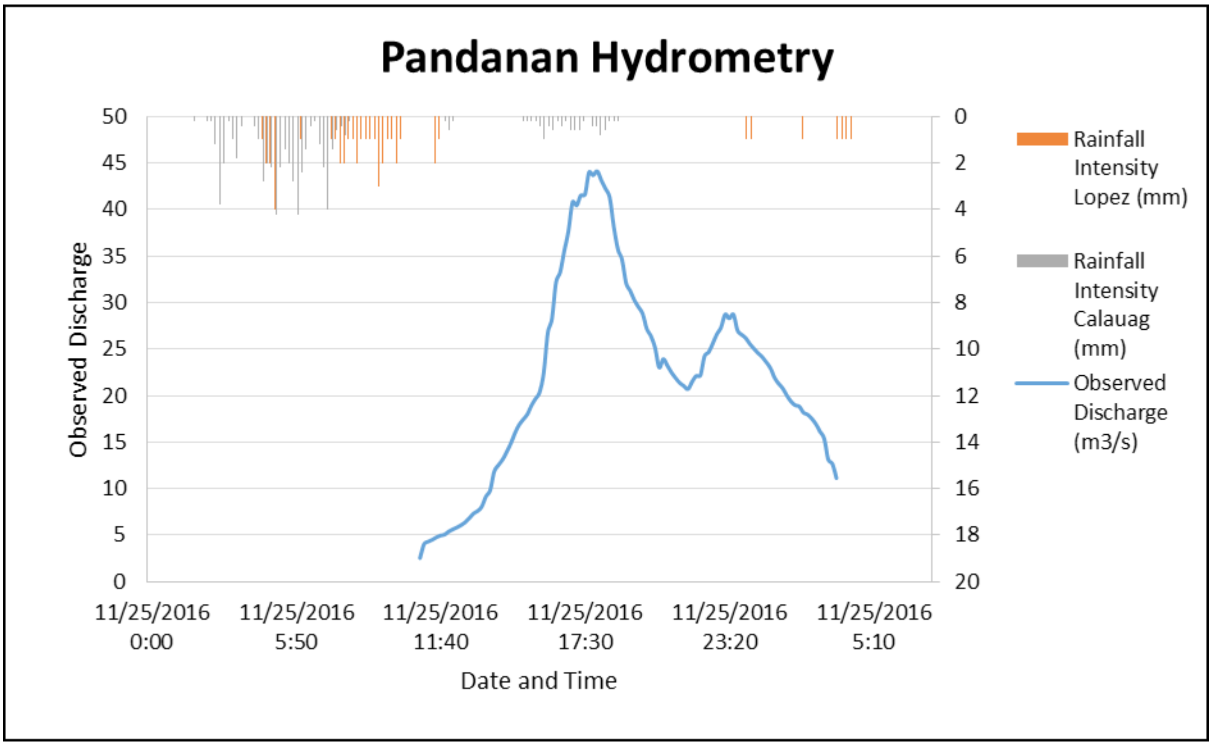


Figure 54. Rainflow and outflow data at Pandanan used for modeling

5.2 RIDF Station

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

Table 27. RIDF values for Alabat Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	20.9	31.3	39.8	55.3	77	94.2	118.3	143.2	173.4
5	27.6	41.3	52.9	74.6	108.5	134.8	172.8	208.6	252
10	32.1	48	61.6	87.3	129.4	161.6	209	251.9	303.9
15	34.6	51.8	66.5	94.5	141.1	176.8	229.3	276.3	333.3
20	36.4	54.4	69.9	99.6	149.4	187.4	243.6	293.4	353.8
25	37.7	56.5	72.6	103.5	155.7	195.6	254.6	306.6	369.6
50	41.9	62.7	80.7	115.4	175.3	220.7	288.4	347.2	418.4
100	46.1	69	88.8	127.3	194.7	245.7	322	387.5	466.7

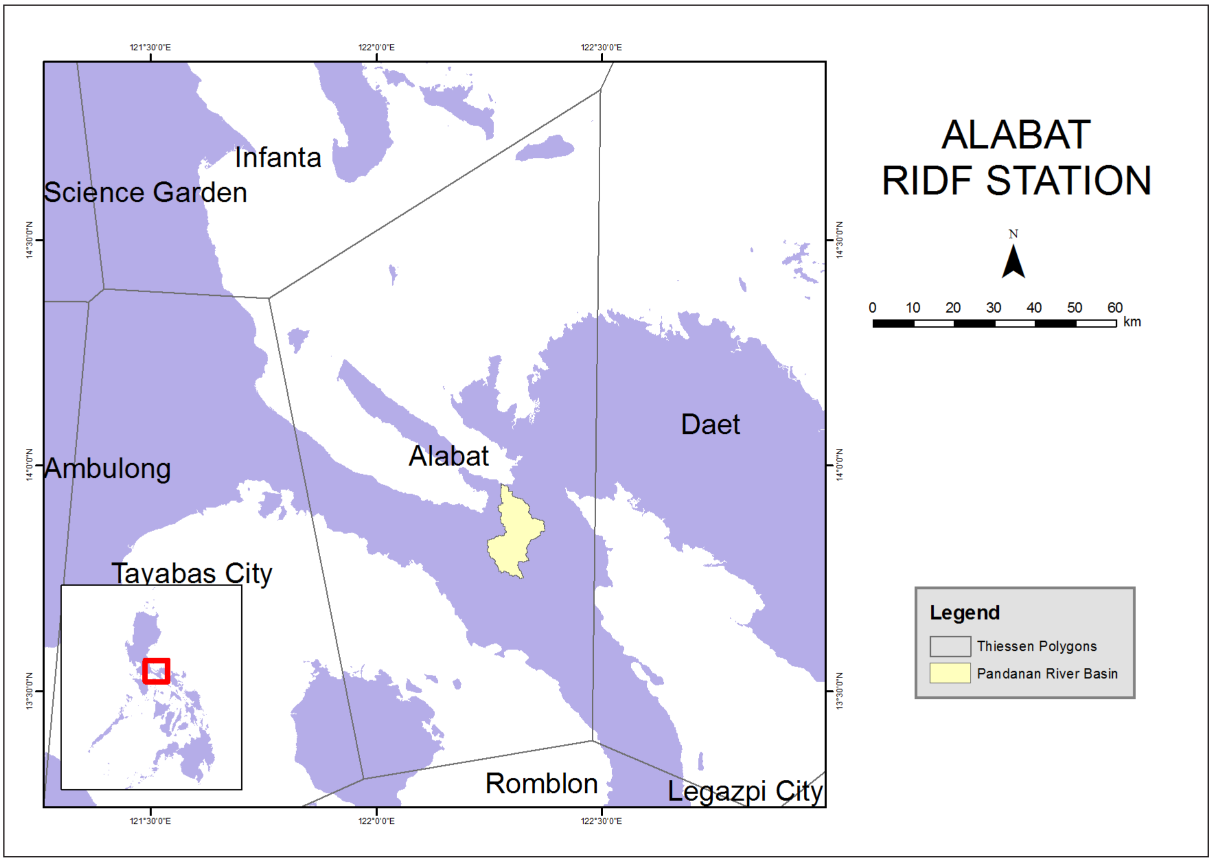


Figure 55. Location of Alabat RIDF location relative to Pandanan River Basin

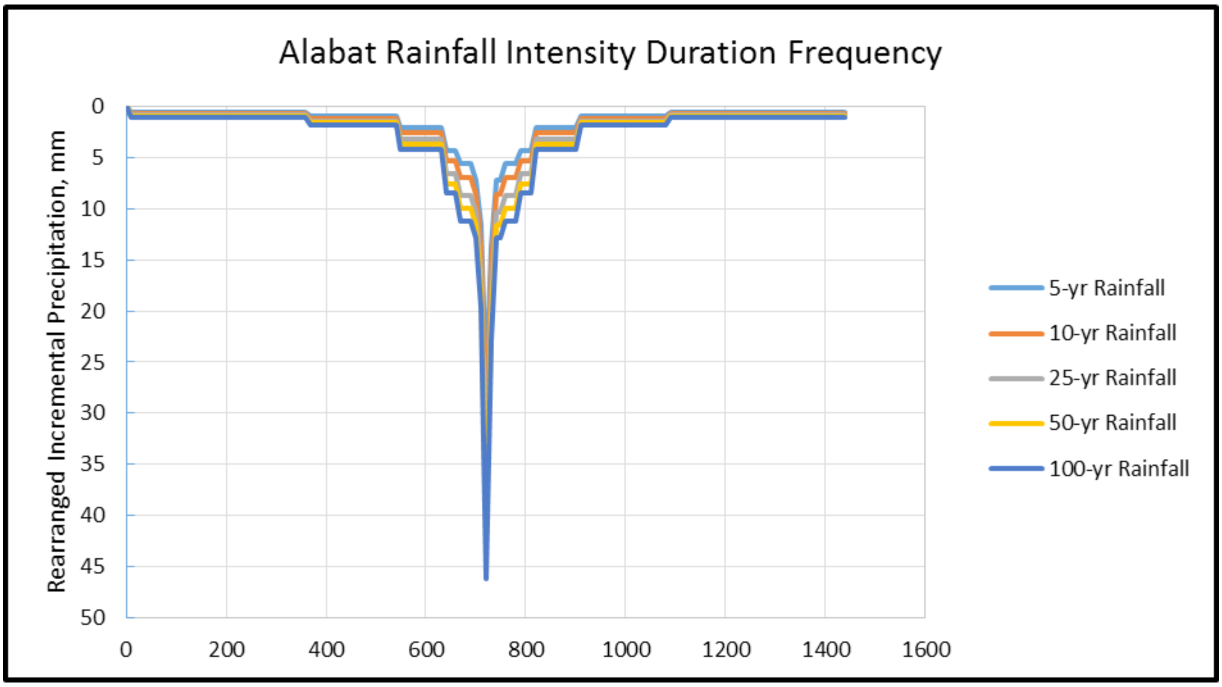


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was 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 Pinantan River Basin are shown in Figure 57 and Figure 58, respectively.

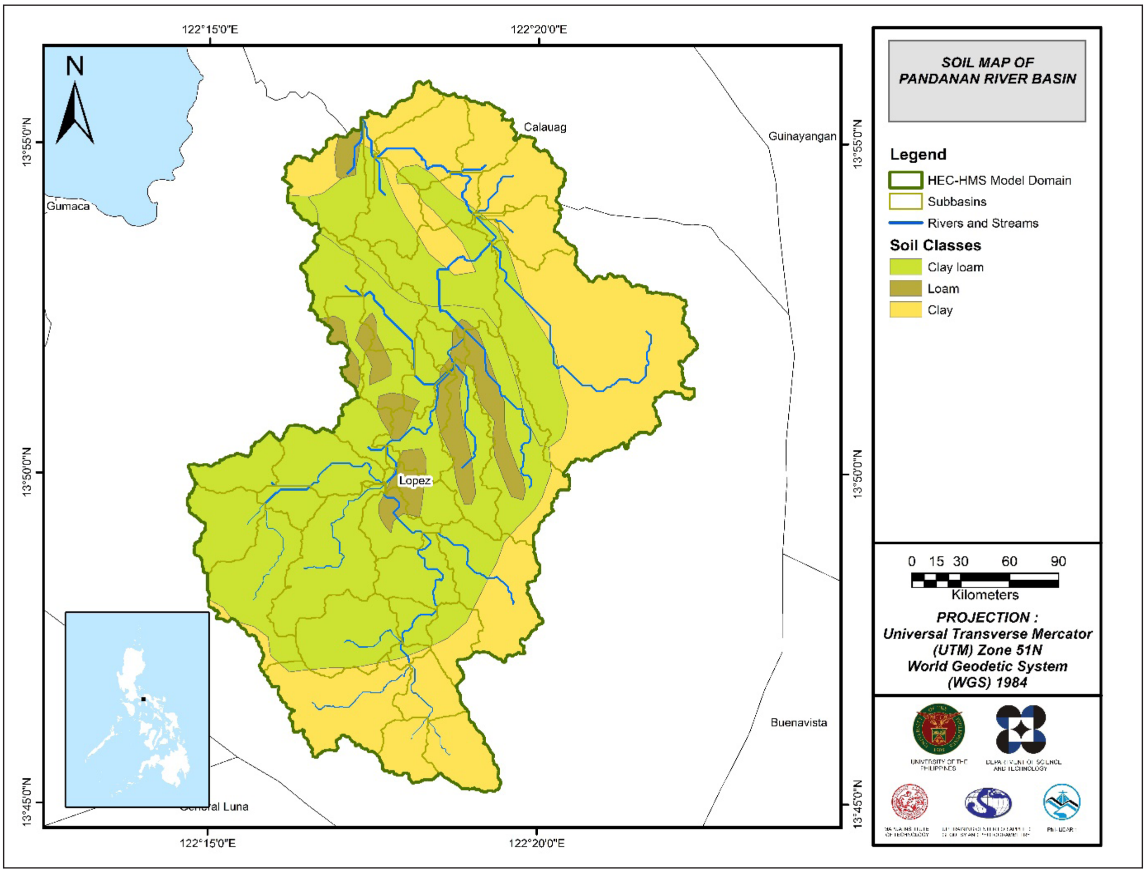


Figure 57. Soil map of the Pandanan River Basin

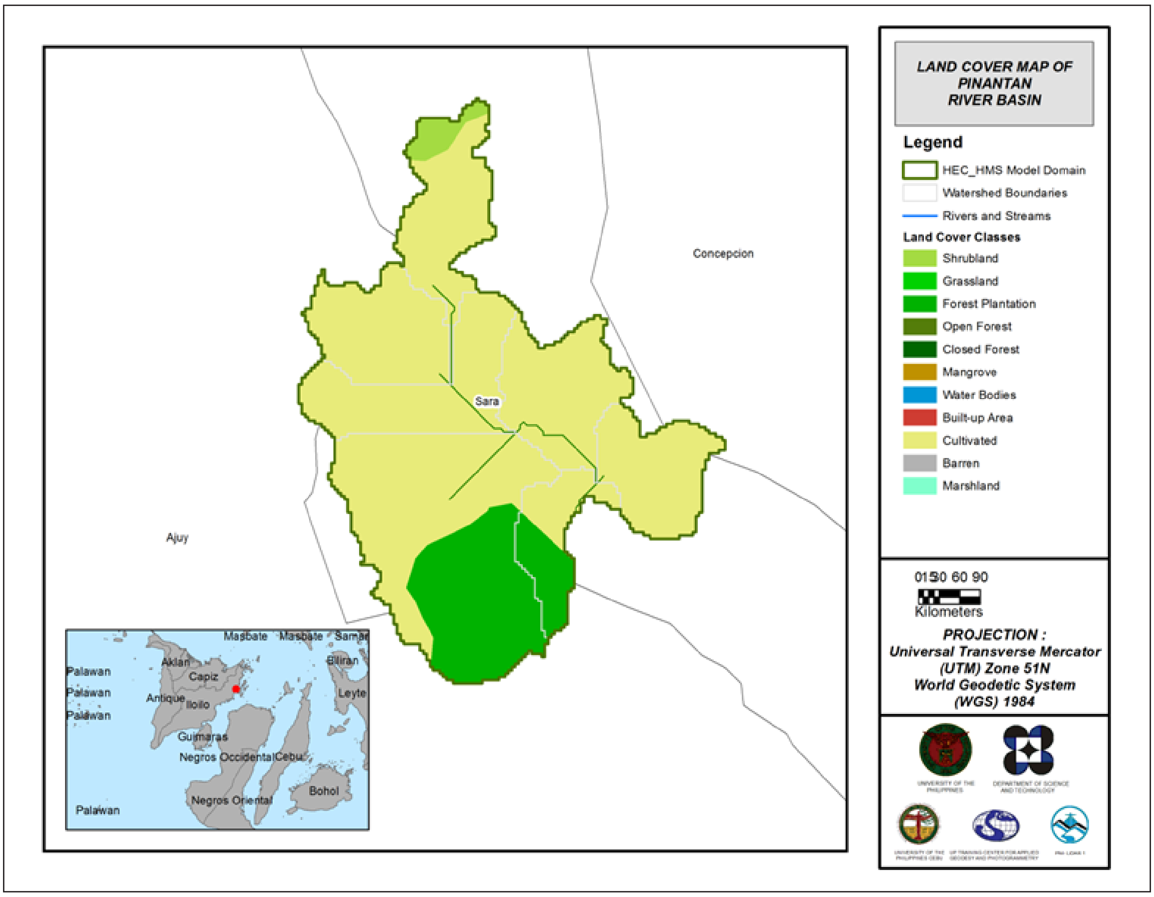


Figure 58. Land cover map of Pandanan River Basin

For Pandanan, three (3) soil classes were identified: clay loam, clay, and loam. The three (3) land cover types identified were brushland, and cultivated areas and tree plantations.

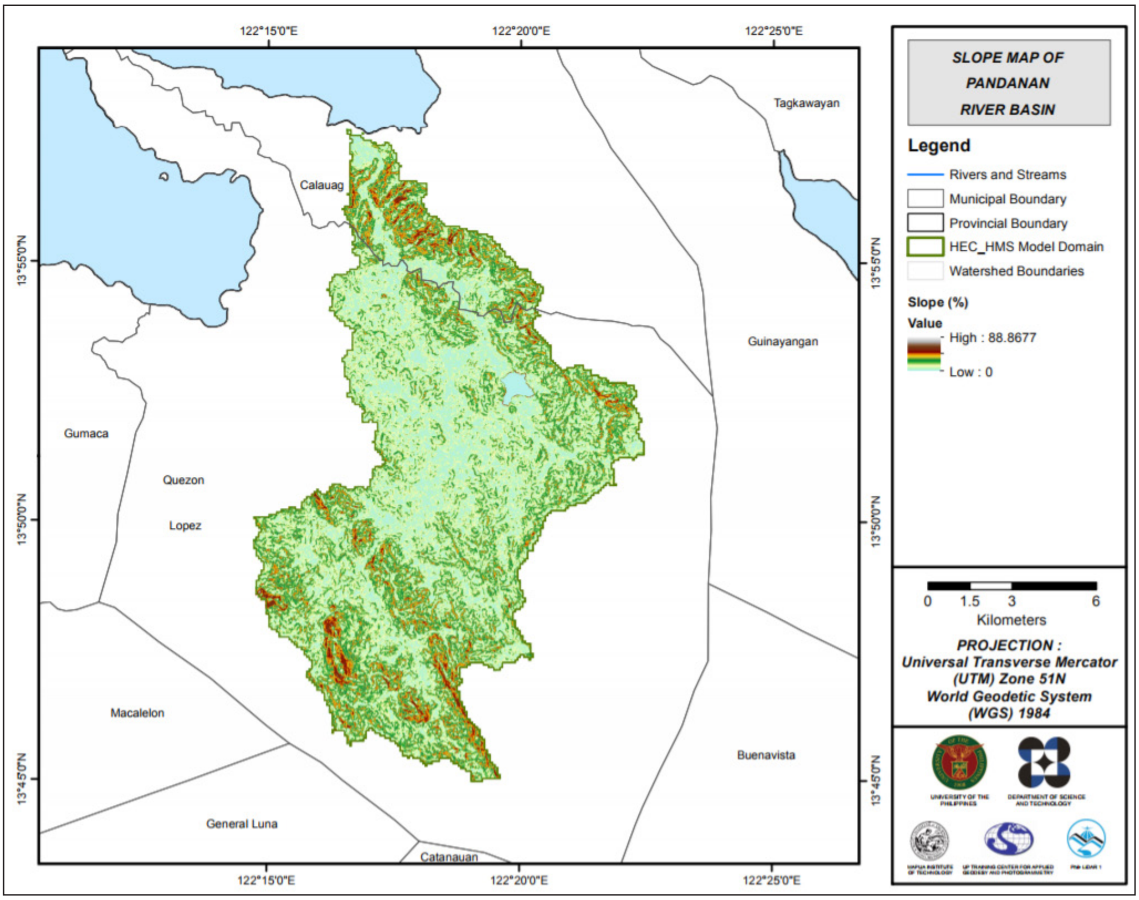


Figure 59. Slope map of Pandanan River Basin

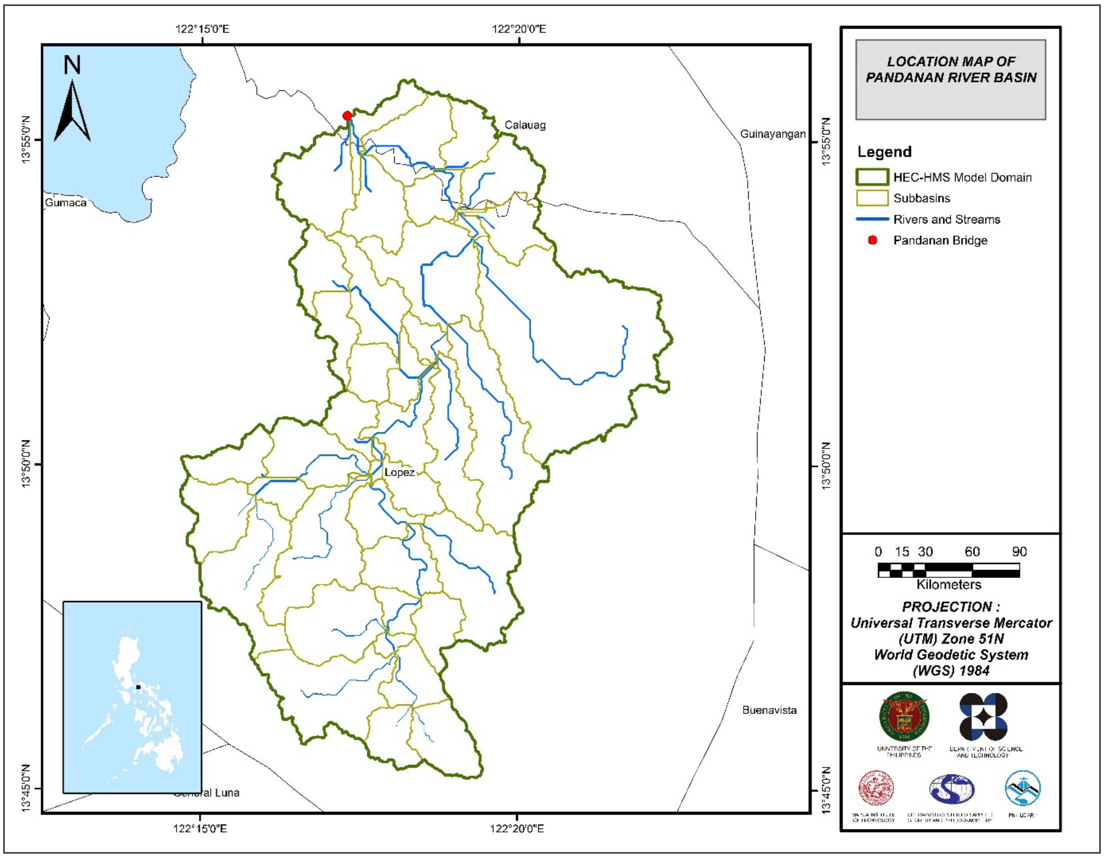


Figure 60. Stream delineation map of Pandanan river basin

The Pandanan basin model comprises 45 sub basins, 22 reaches, and 22 junctions. The main outlet is outlet 2. This basin model is illustrated in Figure 61. The basins were identified based on soil and land cover characteristic of the area. Precipitation was taken from an installed Rain Gauge near and inside the river basin. Finally, it was calibrated using the data from actual discharge flow gathered in the Pandanan Bridge.

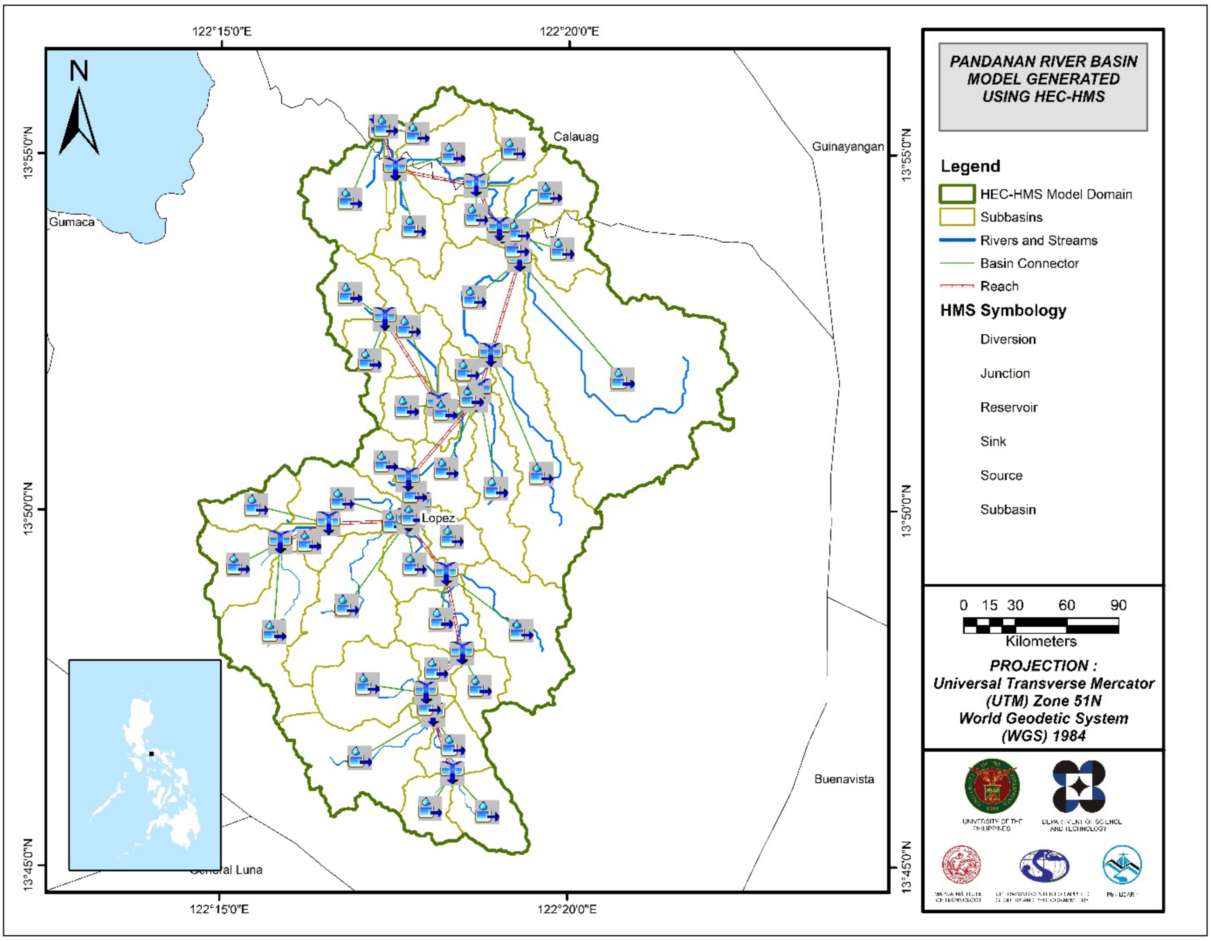


Figure 61. HEC-HMS generated Pandanan River Basin Model.

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 62.

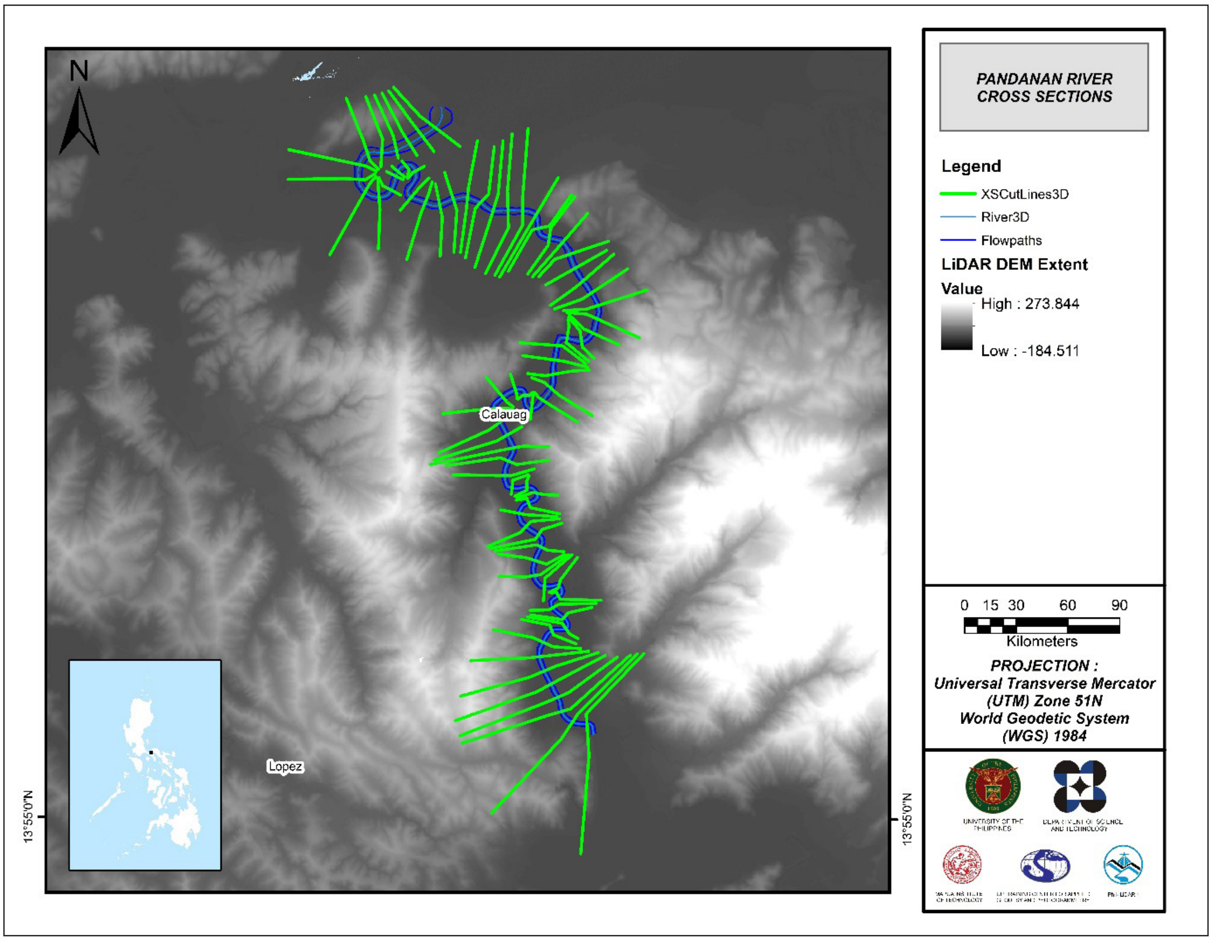


Figure 62. River cross-section of Pandanan River generated through Arcmap HEC GeoRAS tool

5.4.1 Manning's *n*

The Manning's *n* is a constant value that depends on the nature of the channel and its surface. Determining the roughness coefficient of the channel is important in determining the water flow. Appropriate selection of Manning's n values is based on the land cover type of the watershed area.

A look-up table was derived to have a standardized Manning's *n* value for the HEC-RAS model.

Table 28. Look-up table for Manning's n values (Source: Brunner, 2010)

Land-cover Class	Corresponding Manning's *n* Class	Manning's *n*
Barren Land	Cultivated areas, no crop	0.030
Built-up Area	Concrete, float finished	0.015
Cultivated land, annual crop	Cultivated areas, mature field crops	0.040
Cultivated land, perennial crop	Cultivated areas, mature field crops	0.035
Fishpond	Excavated earth, straight and uniform	0.018
Inland Water	Main channel, clean, straight, no rifts or deep pools	0.030
Grassland	Pasture, no brush, short grass	0.030
Mangrove Forest	Tress, heavy stand, flow into branches	0.120
Shrubland	Medium to dense brush	0.100

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

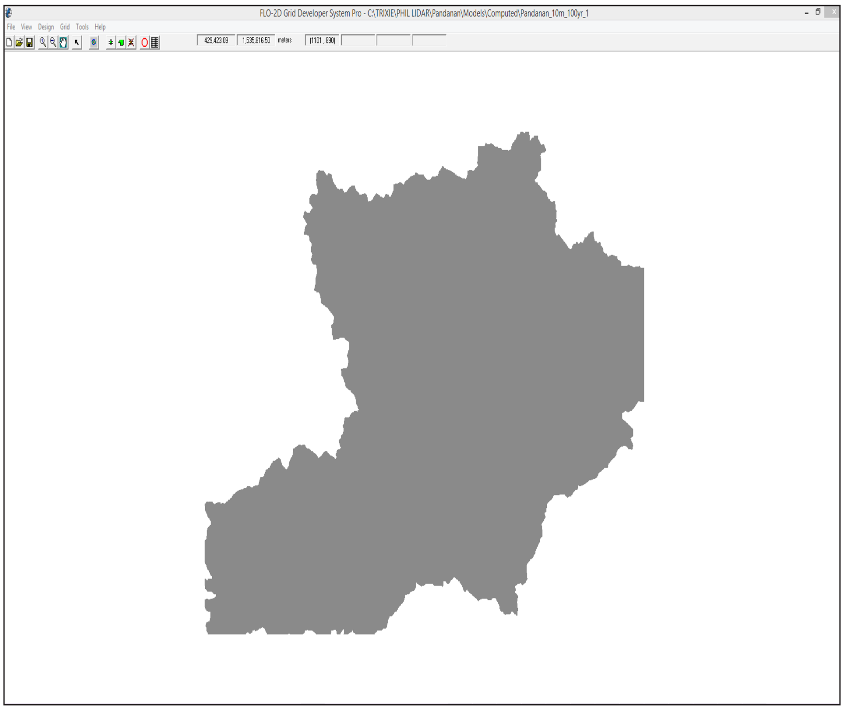


Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 87.65039 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 m^2/s.

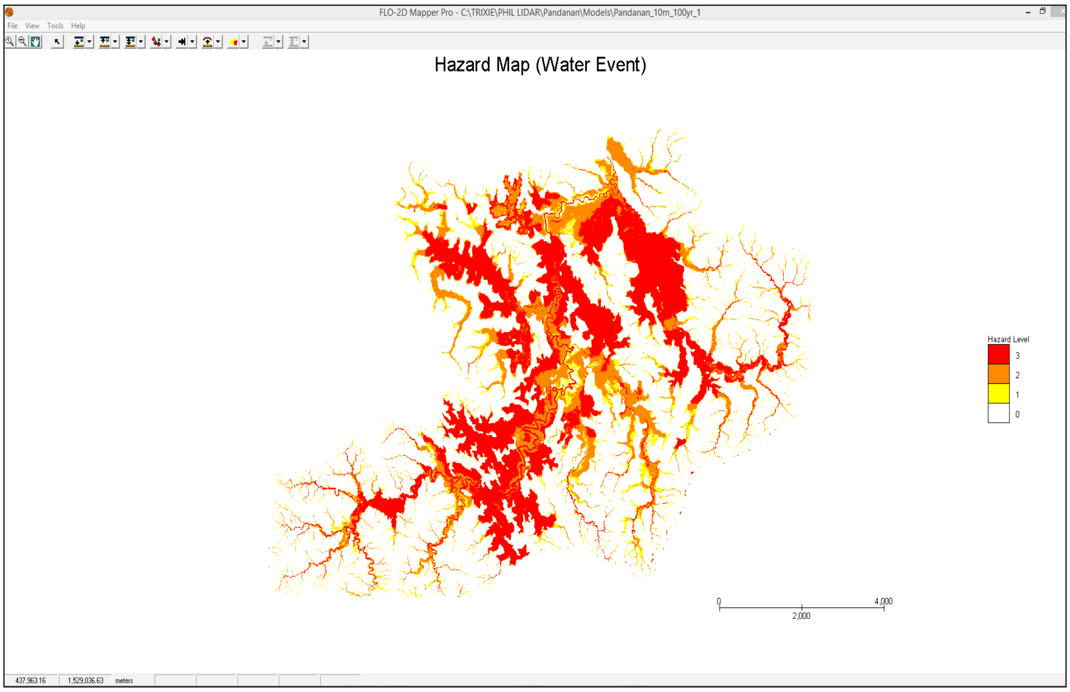


Figure 64. Generated 100-year rain return hazard map from FLO-2D Mapper

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 81 620 352.00m^2.

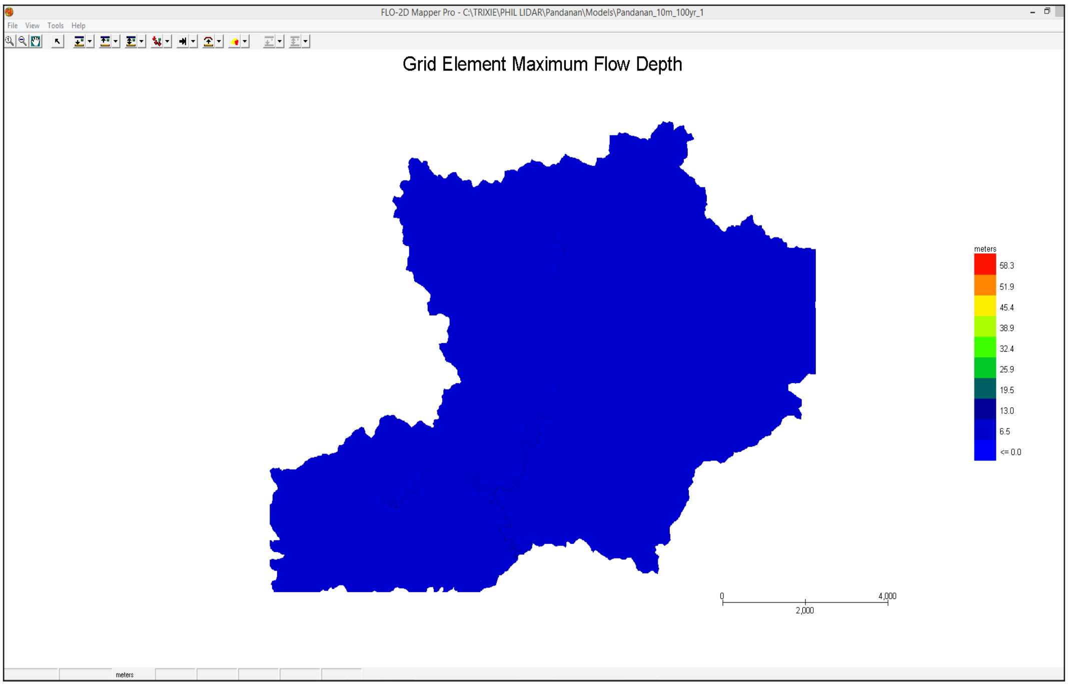


Figure 65. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 46 149 620.26 m^3 of water entering the model. Of this amount, 35 669 892.07 m^3 is due to rainfall while 10 479 728.19 m^3 is inflow from other areas outside the model. 11 144 001.00 m^3 of this water is lost to infiltration and interception, while 31 913 498.51 m^3 is stored by the flood plain. The rest, amounting up to 3 092 054.45 m^3, is outflow.

5.5.1 Discharge data using Dr. Horritts's recommended hydrologic method

The river discharge values for the two rivers entering the floodplain are shown in Figure 66 to Figure 67 and the peak values are summarized in Table 4 to 5.

PANDANAN (1)

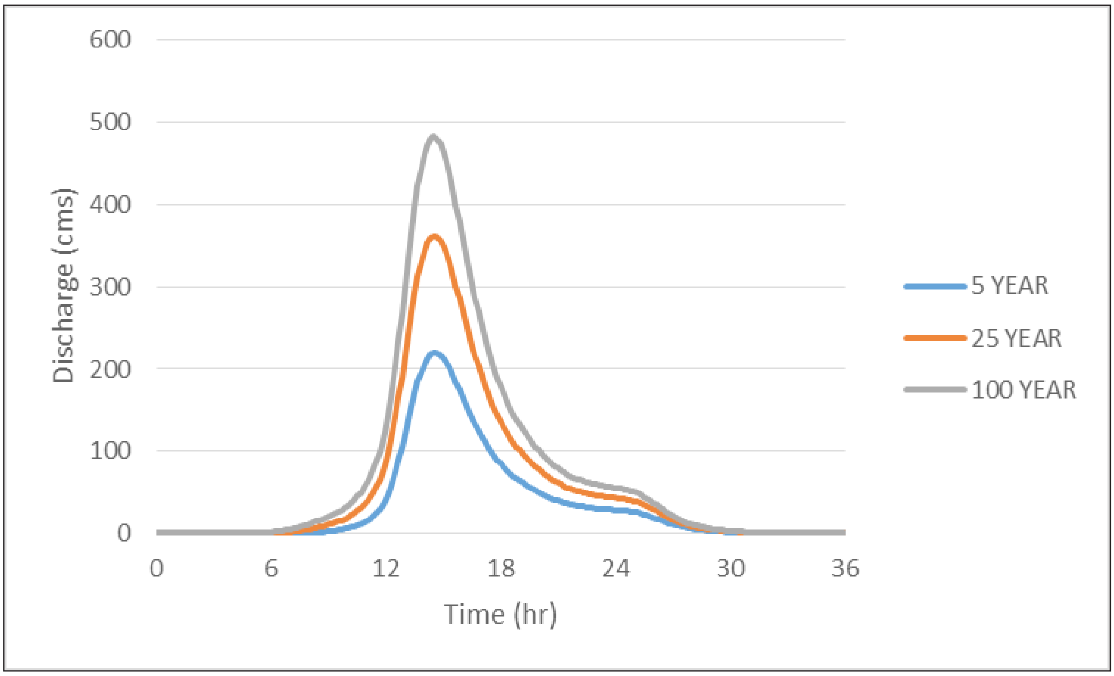


Figure 66. Pandanan river (1) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

PANDANAN (2)

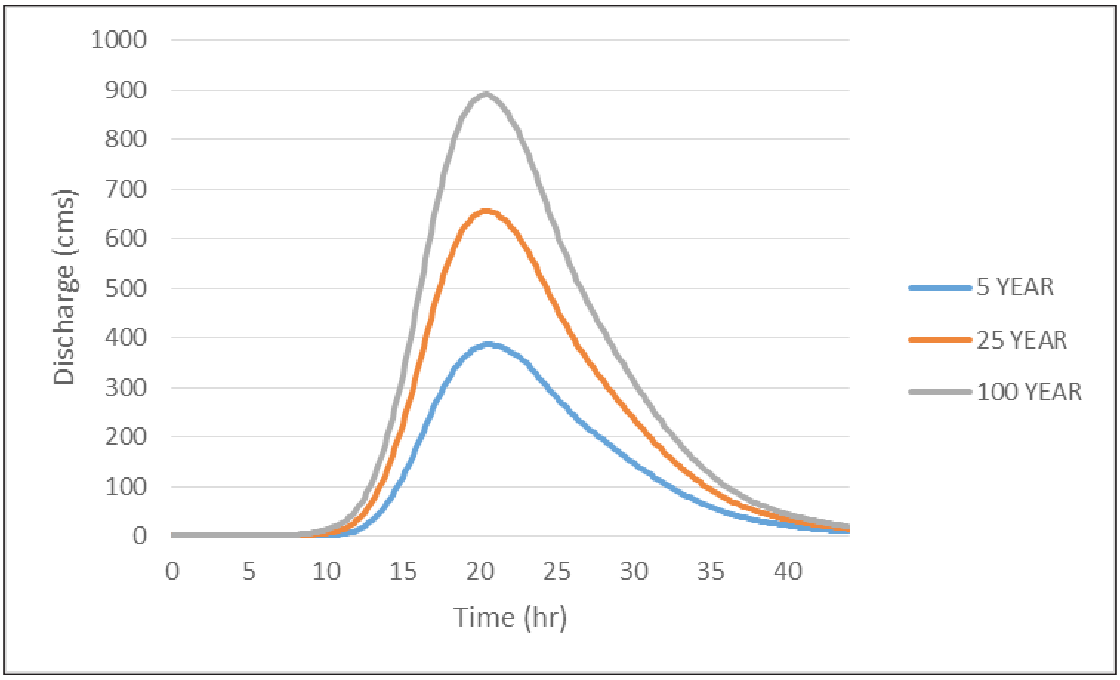


Figure 67. Pandanan river (2) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 29. Summary of Pandanan river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	482.6	145 minutes
25-Year	361.9	145 minutes
5-Year	219.3	145 minutes

Table 30. Summary of Pandanan river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	891.5	468.35 minutes
25-Year	656.3	468.35 minutes
5-Year	386.5	468.35 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 31.

Table 31. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Pandanan (1)	192.984	359.420	298.827	Pass	Pass
Pandanan (2)	340.120	499.657	757.497	Pass	Fail

All of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.6 Results of HMS Calibration

After calibrating the Pandanan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 68 shows the comparison between the two discharge data.

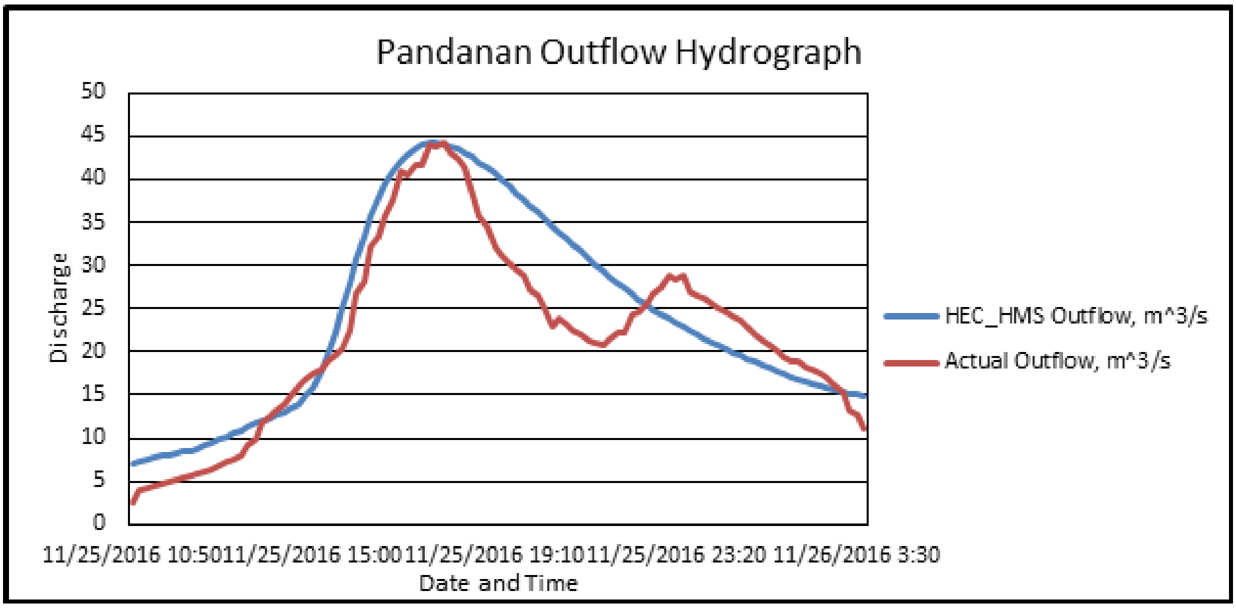


Figure 68. Outflow Hydrograph of Pandanan produced by the HEC-HMS model compared with observed outflow.

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

Table 32. Range of Calibrated Values for Pandanan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.83 – 26.074
			Curve Number	79.90 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.40 – 11.44
			Storage Coefficient (hr)	0.20 – 5.99
	Baseflow	Recession	Recession Constant	0.0001
			Ratio to Peak	0.017
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0073 – 0.30

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 1.83mm to 26.074mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 79.90 to 98 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Pandanan, the soil classes identified were clay loam, clay, and loam. The land cover types identified were brushland, and cultivated areas and tree plantations.

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 0.20 hours to 11.44 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 all subbasins is 0.0001 and the ratio to peak value is 0.017. The receding limb of the outflow hydrograph is not likely to quickly return to its original discharge values.

Manning's roughness coefficient of 0.0073-0.30 corresponds to the common roughness among the subbasins in Pandanan watershed (Brunner, 2010).

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

Accuracy measure	Value
RMSE	-2.1
r^2	0.8137
NSE	0.80
PBIAS	-8.69
RSR	0.45

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at -2.1 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8137.

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 0.80.

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 -8.69.

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 0.45.

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

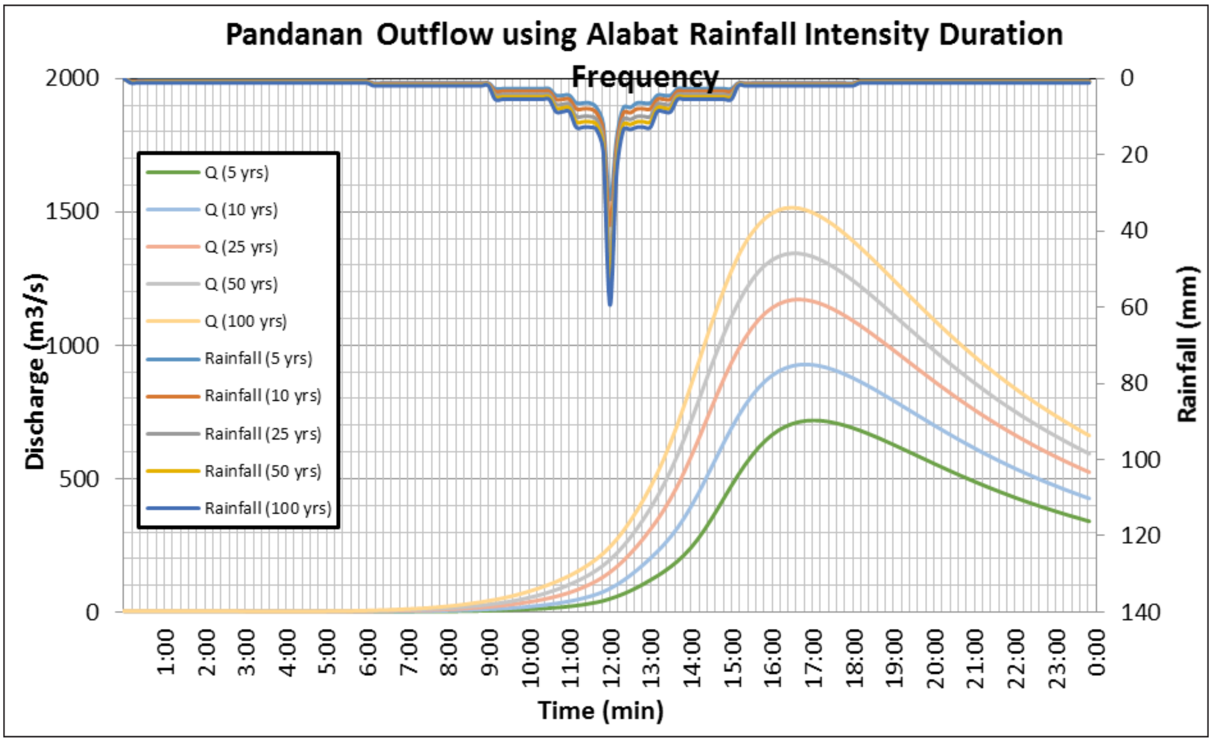


Figure 69. Outflow hydrograph at Pandanan Station generated using Alabat RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Pandanan River discharge using the Alabat Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Pandanan HECHMS Model outflow using the Alabat RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3s)	Time to Peak
5-Year	252.0	27.6	718.7	5 hours
10-Year	303.9	32.1	928.4	4 hours, 50 minutes
25-Year	369.6	37.7	1172.1	4 hours, 20 minutes
50-Year	418.4	41.9	1344.8	4 hours, 30 minutes
100-Year	466.7	46.1	1516.3	4 hours, 30 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. For this publication, only a sample output map river was to be shown, since only the Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of Pandanan River using the calibrated HMS base flow is shown in Figure 70.

Figure 70. Sample output of Pandanan RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 71 to Figure 76 shows the 5-, 25-, and 100-year rain return scenarios of the Pandanan floodplain.

Table 35. Municipalities affected in Pandanan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Lopez	376.22	131.75	35.02%
Guinayangan	255.57	1.82	0.81%
Calauag	312.32	73.54	23.55%

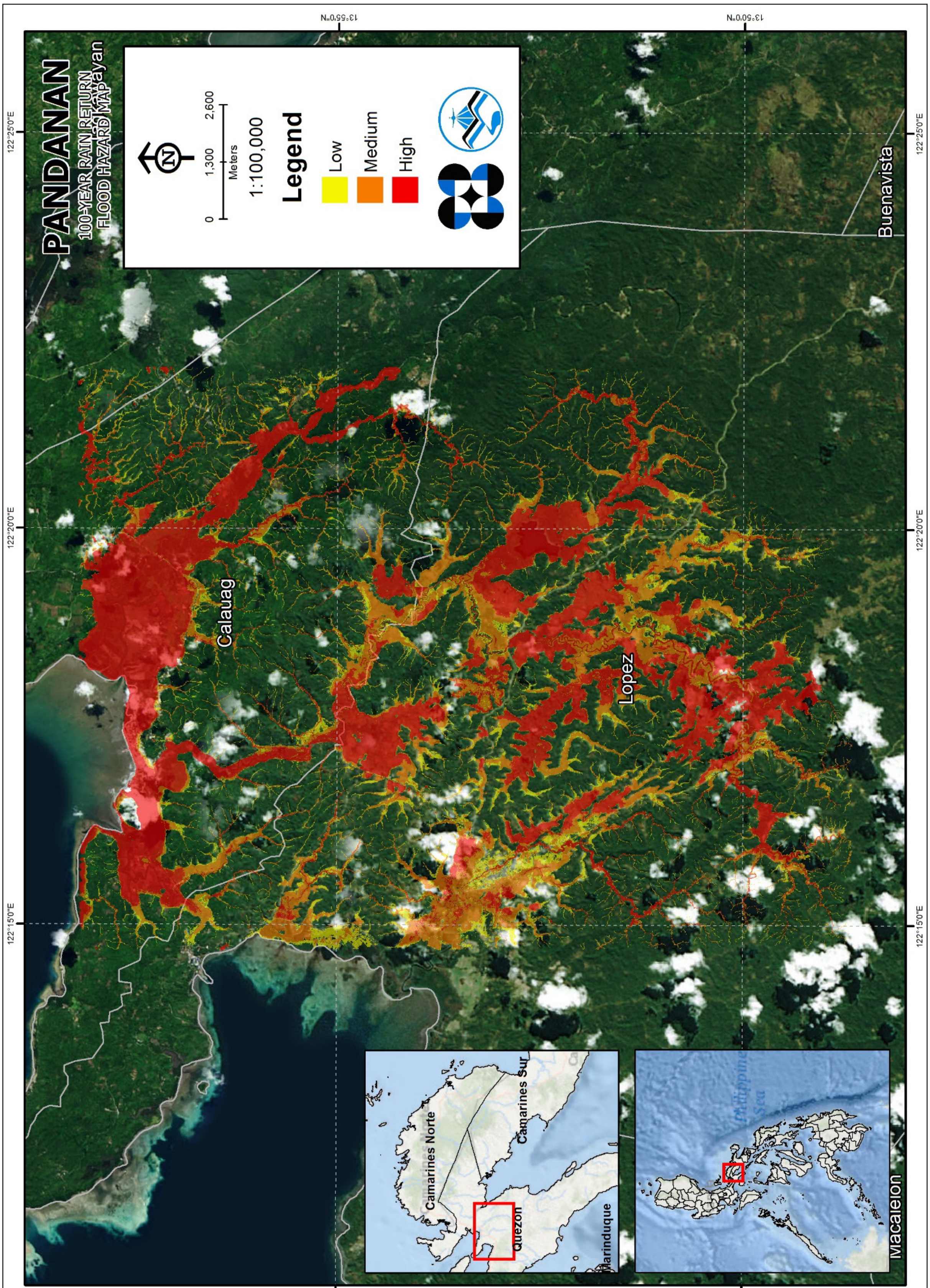


Figure 71. 100-year Flood Hazard Map for Pandanan Floodplain overlaid on Google Earth imagery

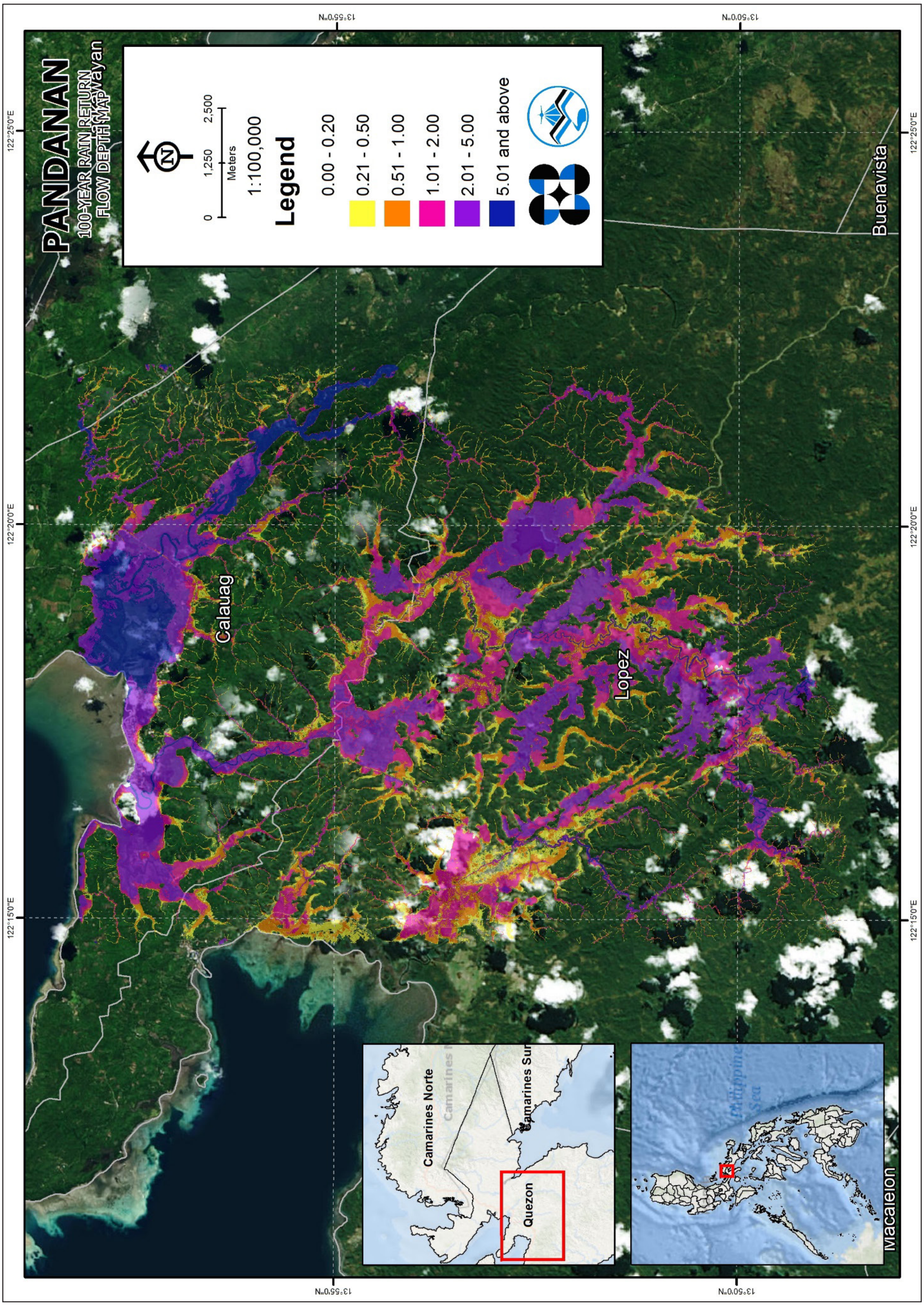


Figure 72. 100-year Flow Depth Map for Pandanan Floodplain overlaid on Google Earth imagery

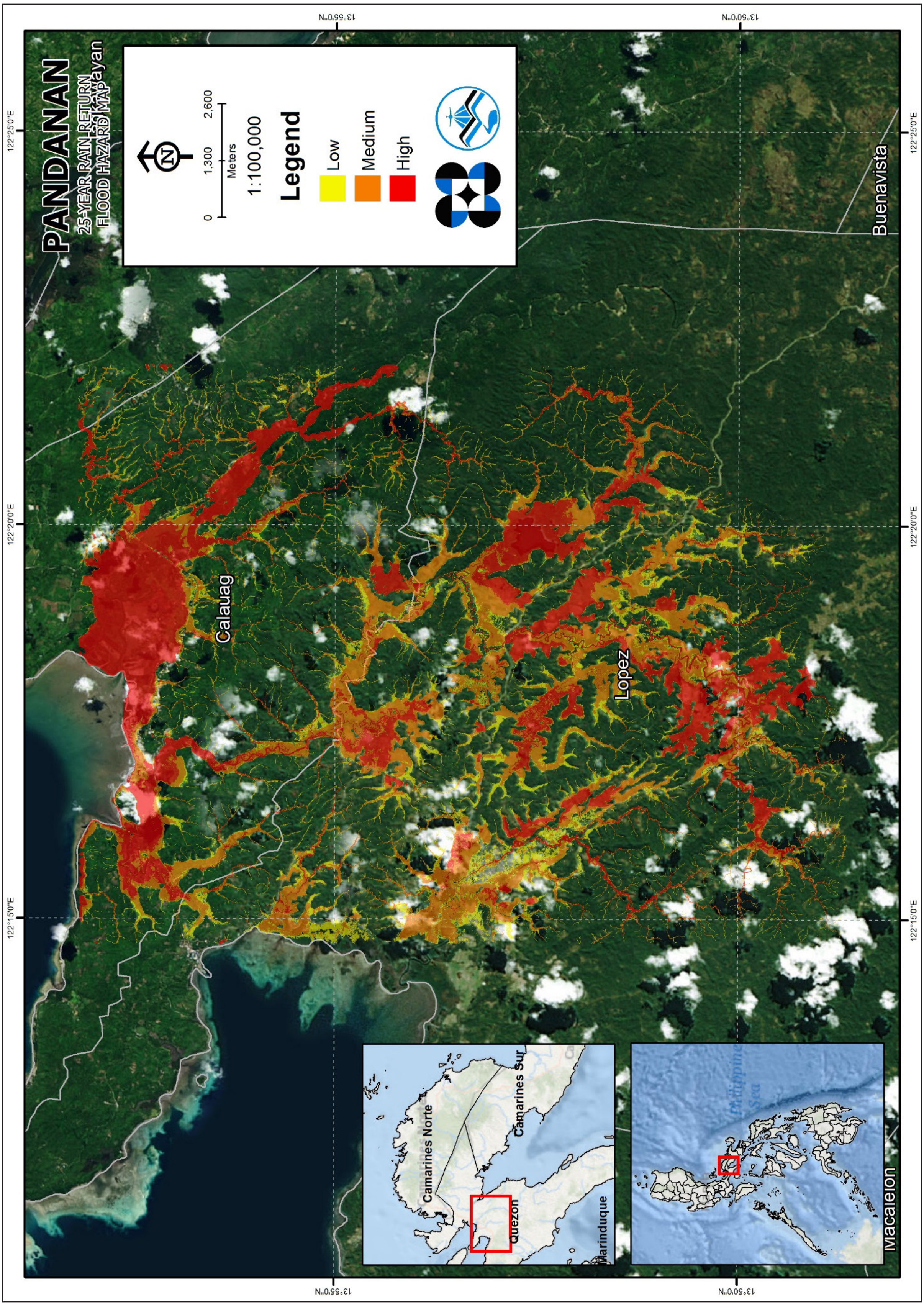


Figure 73. 25-year Flood Hazard Map for Pandanan Floodplain overlaid on Google Earth imagery

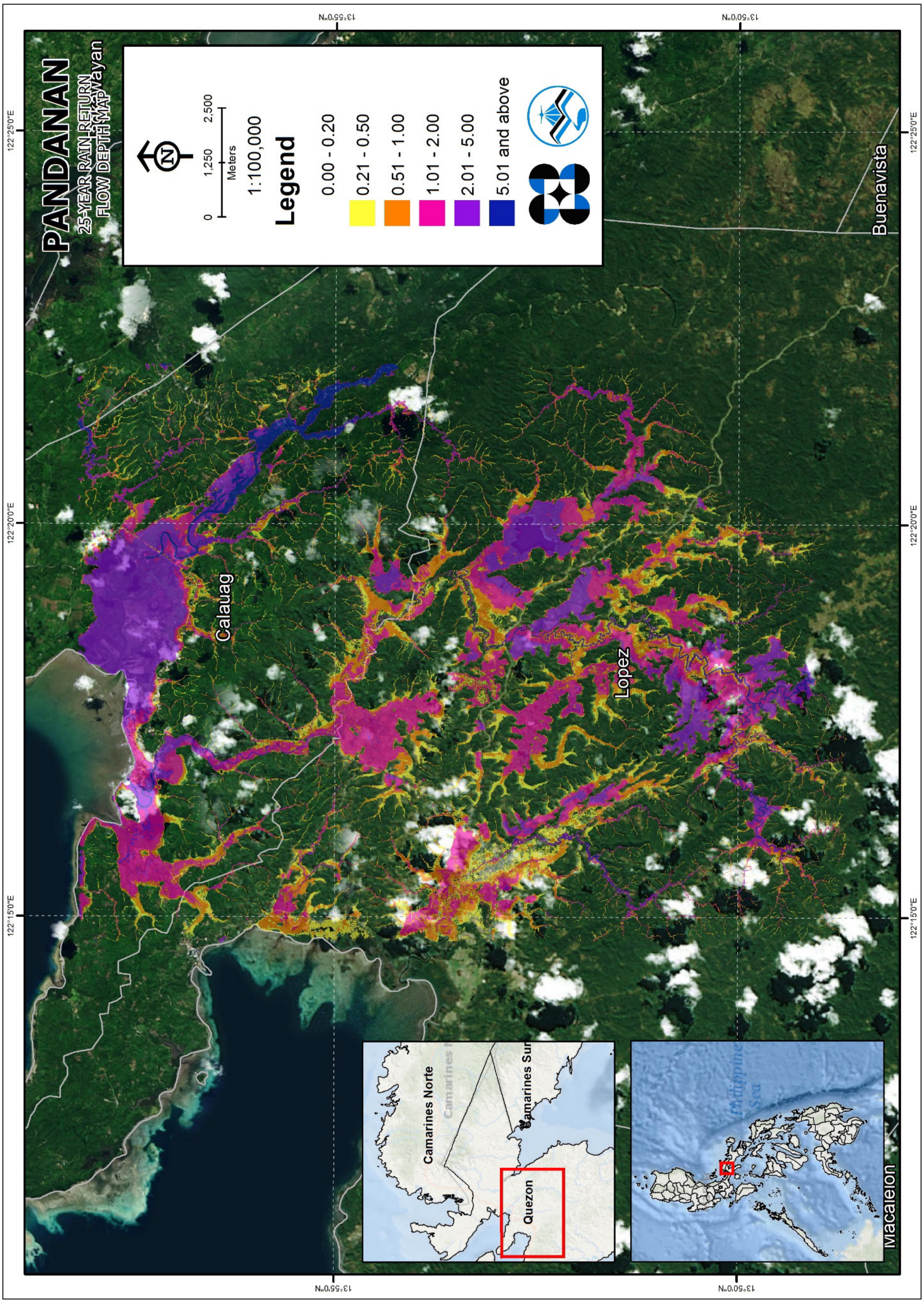


Figure 74. 25-year Flow Depth Map for Pandanan Floodplain overlaid on Google Earth imagery

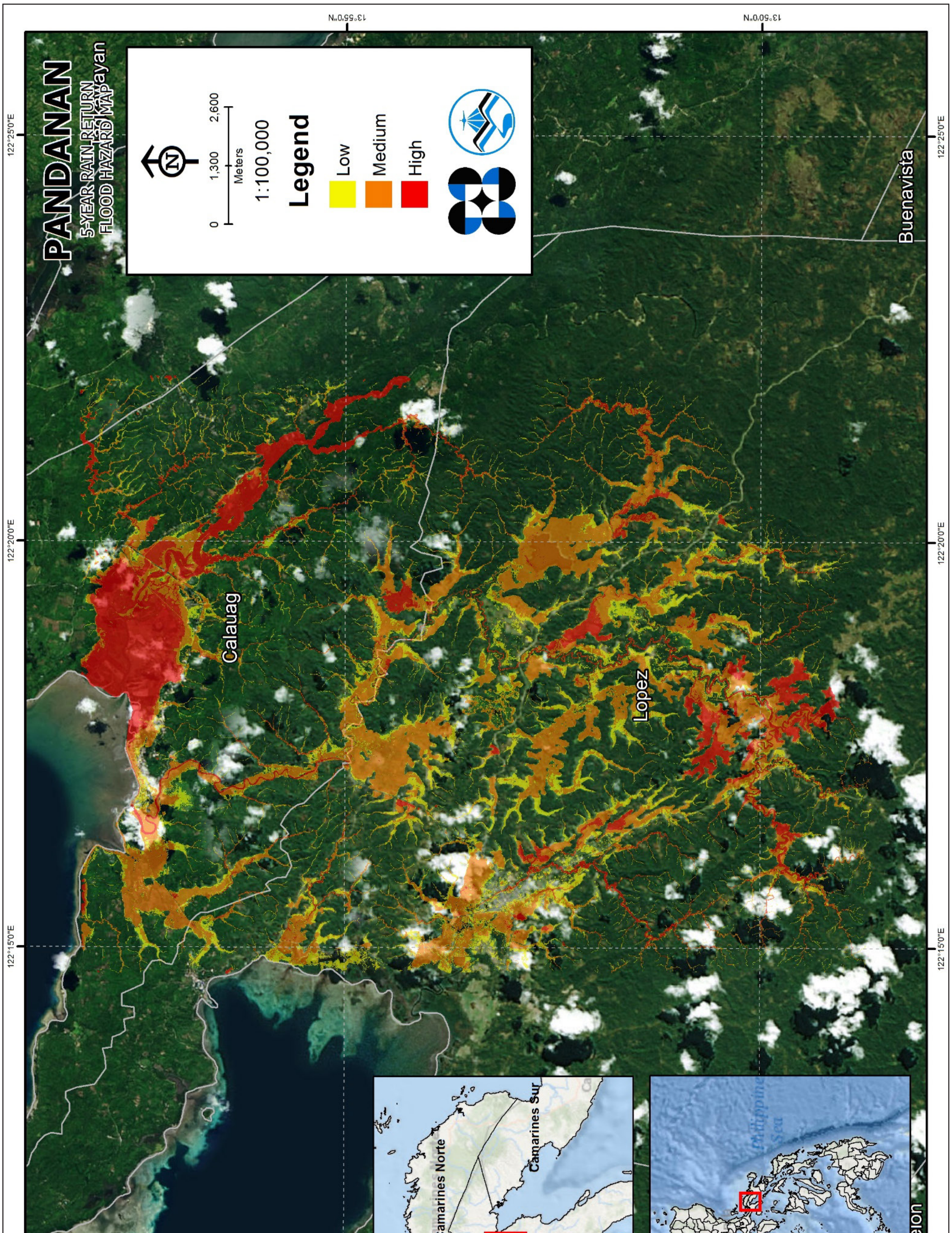


Figure 75. 5-year Flood Hazard Map for Pandanan Floodplain overlaid on Google Earth imagery

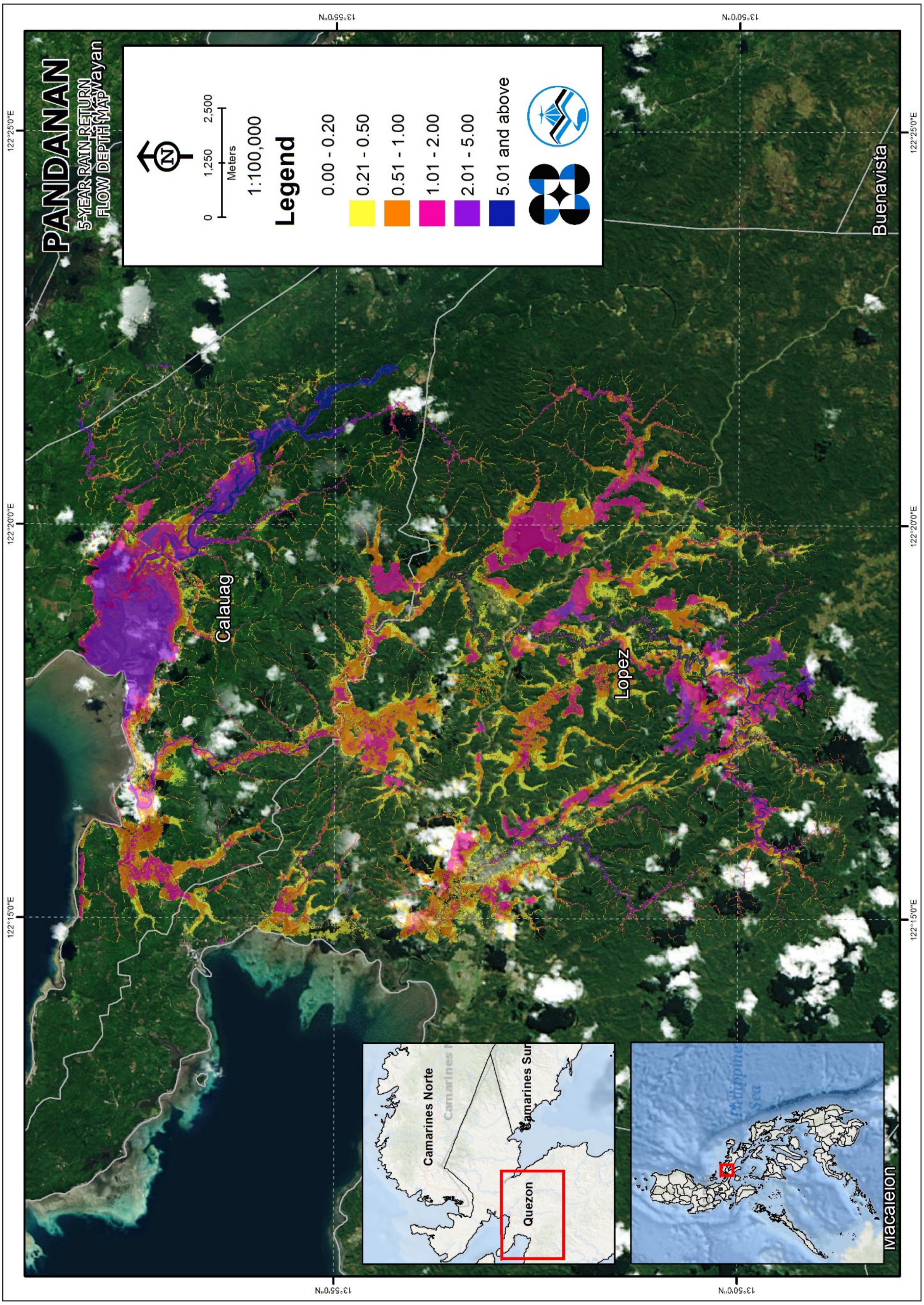


Figure 76. 5-year Flood Depth Map for Pandanan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Pandanan River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 113 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 25.50% of the municipality of Lopez with an area of 376.22 sq. km. will experience flood levels of less than 0.20 meters. 3.01% of the area will experience flood levels of 0.21 to 0.50 meters while 3.29%, 2.44%, 0.68%, 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 36 to Table 42, and shown in Figure 77 to Figure 83 are the affected areas in square kilometres 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.)										
	Bacungan	Bagacay	Banabahin Ibaba	Banabahin Ilaya	Bayabas	Bebito	Bigajo	Binahian A	Binahian B	Binahian C	Bocboc
0.03-0.20	1.52	0.76	1.09	0.53	2.13	0.96	0.82	3.09	1	0.013	2.13
0.21-0.50	0.2	0.18	0.32	0.17	0.28	0.079	0.027	0.18	0.069	0	0.37
0.51-1.00	0.074	0.14	0.16	0.16	0.39	0.066	0.028	0.12	0.035	0	0.25
1.01-2.00	0.022	0.028	0.34	0.084	0.19	0.052	0.016	0.1	0.021	0	0.1
2.01-5.00	0.0003	0.0023	0.21	0.0062	0.013	0	0.00021	0.069	0.0087	0	0.0092
> 5.00	0	0	0.0078	0.00091	0.0058	0	0	0.015	0	0	0.0011

Table 37. 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.)										
	Buenavista	Burgos	Buyacanin	Cagacag	Canda Ibaba	Canda Ilaya	Cawayan	Cogorin Ibaba	Cogorin Ilaya	Concepcion	Danlagan
0.03-0.20	1.84	0.062	0.43	0.67	0.8	1.83	2.84	0.67	1.71	2.9	1.1
0.21-0.50	0.55	0.074	0.096	0.027	0.083	0.22	0.41	0.018	0.094	0.21	0.2
0.51-1.00	0.58	0.12	0.3	0.029	0.38	0.18	0.34	0.009	0.15	0.18	0.14
1.01-2.00	0.27	0.085	0.088	0.0078	0.18	0.15	0.11	0.0074	0.52	0.077	0.16
2.01-5.00	0.072	0.0014	0	0.0004	0.0026	0.0045	0.032	0.0059	0.44	0.031	0.000098
> 5.00	0.036	0	0	0	0	0	0	0.004	0.089	0	0.000003

Table 38. 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.)										
	De La Paz	Del Pilar	Del Rosario	Esperanza Ibaba	Esperanza Ilaya	Gomez	Guhay	Guinuangan	Hondagua	Ilayang Ilog A	Ilayang Ilog B
0.03-0.20	1.38	0.39	1.39	1.15	0.72	0.19	0	2.75	0.41	2.67	7.82
0.21-0.50	0.16	0.077	0.12	0.15	0.082	0.11	0	0.19	0.023	0.077	0.38
0.51-1.00	0.13	0.049	0.25	0.17	0.3	0.14	0	0.074	0.0037	0.06	0.33
1.01-2.00	0.076	0.013	0.52	0.037	0.023	0.082	0	0.048	0.0063	0.069	0.32
2.01-5.00	0.014	0	0.0067	0.026	0.0063	0	0	0.018	0.0037	0.041	0.19
> 5.00	0	0	0	0	0	0	0	0	0	0.0001	0.03

Table 39. 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.)										
	Inalusan	Lalaguna	Lourdes	Magsaysay	Maguilayan	Mahayod-Hayod	Manguisian	Matinik	Monteclaro	Pamampangin	Peñafrancia
0.03-0.20	1.77	1.72	0.11	0.17	0.7	1.29	0.45	0.4	2.86	1.49	0.85
0.21-0.50	0.13	0.16	0.0022	0.055	0.15	0.19	0.27	0.16	0.098	0.22	0.18
0.51-1.00	0.083	0.32	0.000006	0.02	0.22	0.14	0.37	0.21	0.079	0.1	0.15
1.01-2.00	0.053	0.96	0	0.0072	0.014	0.064	0.064	0.053	0.054	0.026	0.17
2.01-5.00	0.18	0.0059	0	0.0047	0	0.0043	0	0.0002	0.022	0.011	0.043
> 5.00	0.0001	0	0	0	0	0	0	0	0	0	0.003

Table 40. 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.)										
	Pisipis	Rizal	Rosario	Samat	San Antonio	San Isidro	San Jose	San Pedro	San Roque	Santa Lucia	Santa Rosa
0.03-0.20	0.95	1.73	3.33	1.74	1.74	1.44	1.92	0.95	1.1	2.13	0.47
0.21-0.50	0.036	0.31	0.4	0.32	0.36	0.043	0.36	0.024	0.38	0.21	0.024
0.51-1.00	0.013	0.59	0.32	0.4	0.32	0.026	0.23	0.018	0.93	0.094	0.0074
1.01-2.00	0.01	0.39	0.14	0.42	0.26	0.023	0.091	0.019	0.23	0.026	0.0044
2.01-5.00	0.018	0.0043	0.26	0.21	0.045	0.017	0.014	0.01	0.005	0.0015	0.0014
> 5.00	0	0	0	0.041	0	0.00042	0	0.00039	0	0	0

Table 41. 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.)										
	Santa Teresa	Santo Niño Ibaba	Santo Niño Ilaya	Silang	Talolong	Tan-Ag Ibaba	Tan-Ag ilaya	Tocalin	Vergaña	Veronica	Villa Aurora
0.03-0.20	0.42	0.0034	0.0023	0.96	0.13	1.18	0.94	1.92	0.2	1.78	1.24
0.21-0.50	0.11	0	0.000046	0.23	0.015	0.3	0.18	0.19	0.011	0.078	0.049
0.51-1.00	0.18	0.000002	0	0.47	0.0068	0.22	0.19	0.21	0.011	0.18	0.069
1.01-2.00	0.031	0.000065	0.000044	0.78	0.0072	0.078	0.085	0.64	0.015	0.13	0.052
2.01-5.00	0	0.000023	0	0.22	0.011	0.019	0.018	0.0023	0.0065	0.029	0.045
> 5.00	0	0	0	0.046	0.0012	0	0.0045	0	0	0	0

Table 42. 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.)				
	Villa Espina	Villa Geda	Villa Hermosa	Villamonte	Villanacaob
0.03-0.20	2.28	2.69	2.25	2.04	0.81
0.21-0.50	0.075	0.14	0.24	0.36	0.023
0.51-1.00	0.069	0.13	0.062	0.61	0.0097
1.01-2.00	0.043	0.13	0.055	0.24	0.0055
2.01-5.00	0.018	0.0058	0.11	0	0.0004
> 5.00	0	0	0.048	0	0

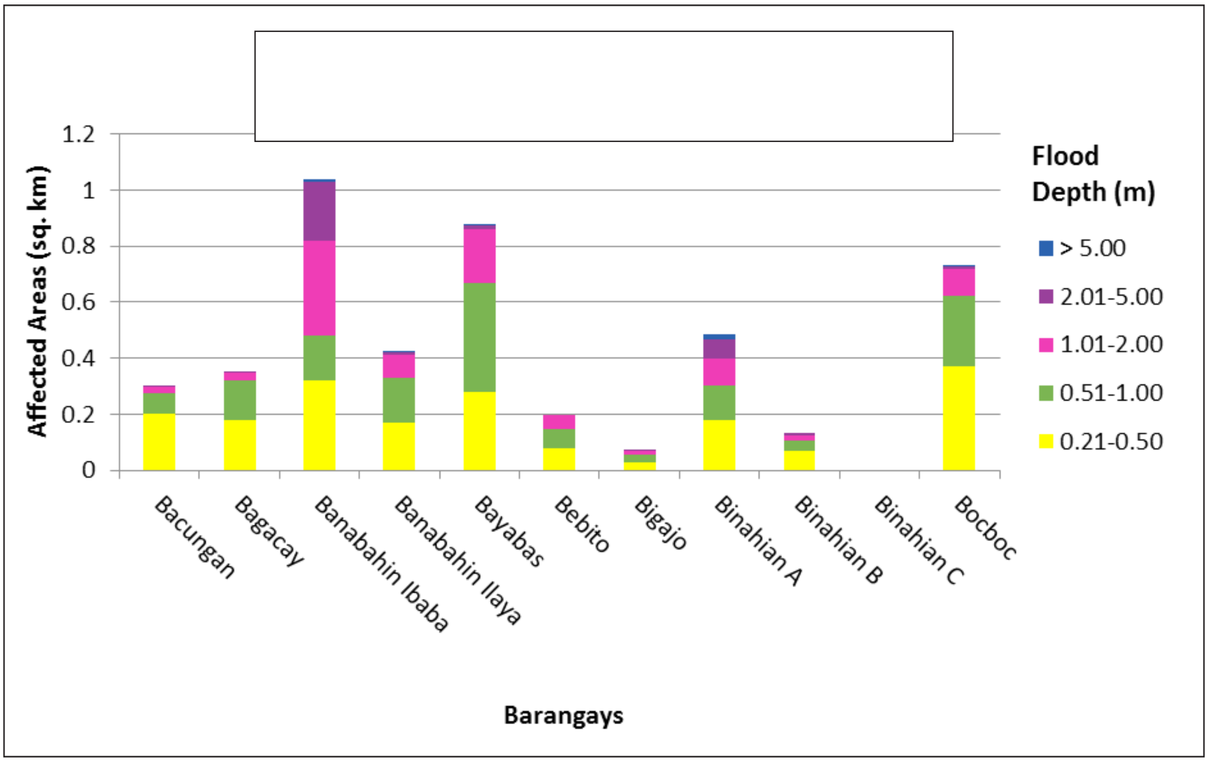


Figure 77. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

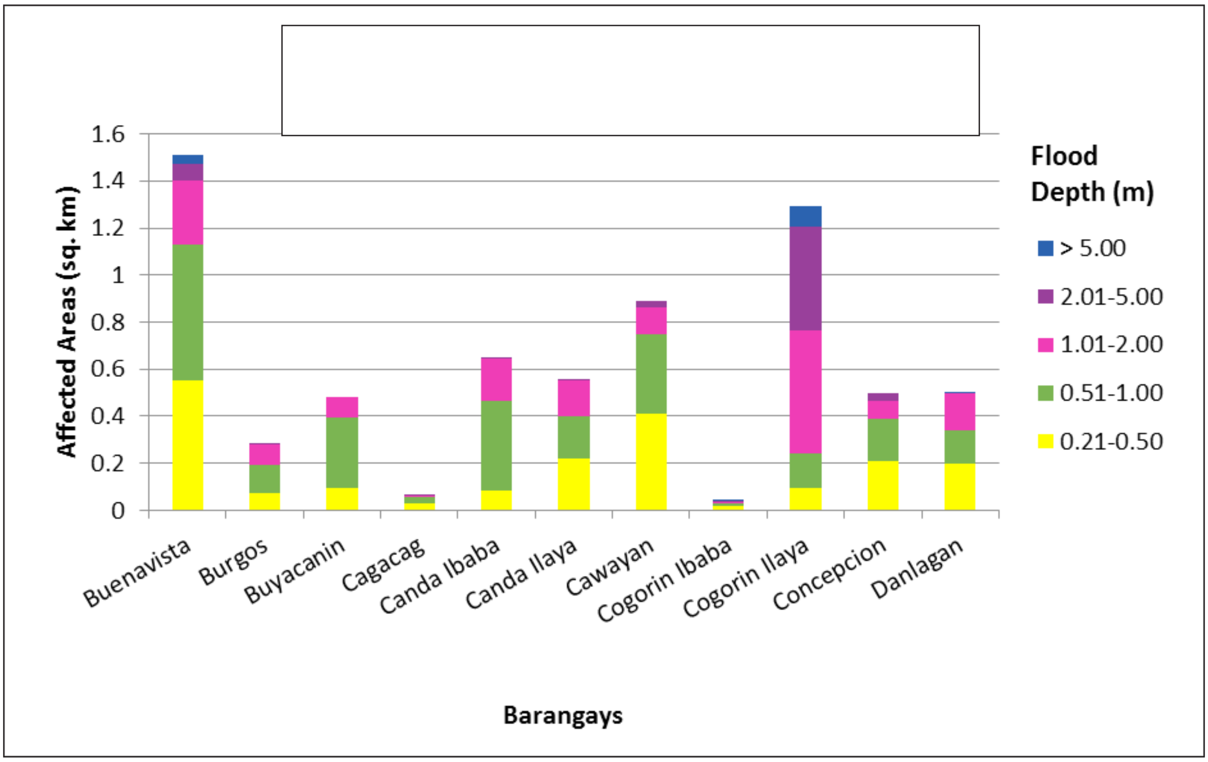


Figure 78. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

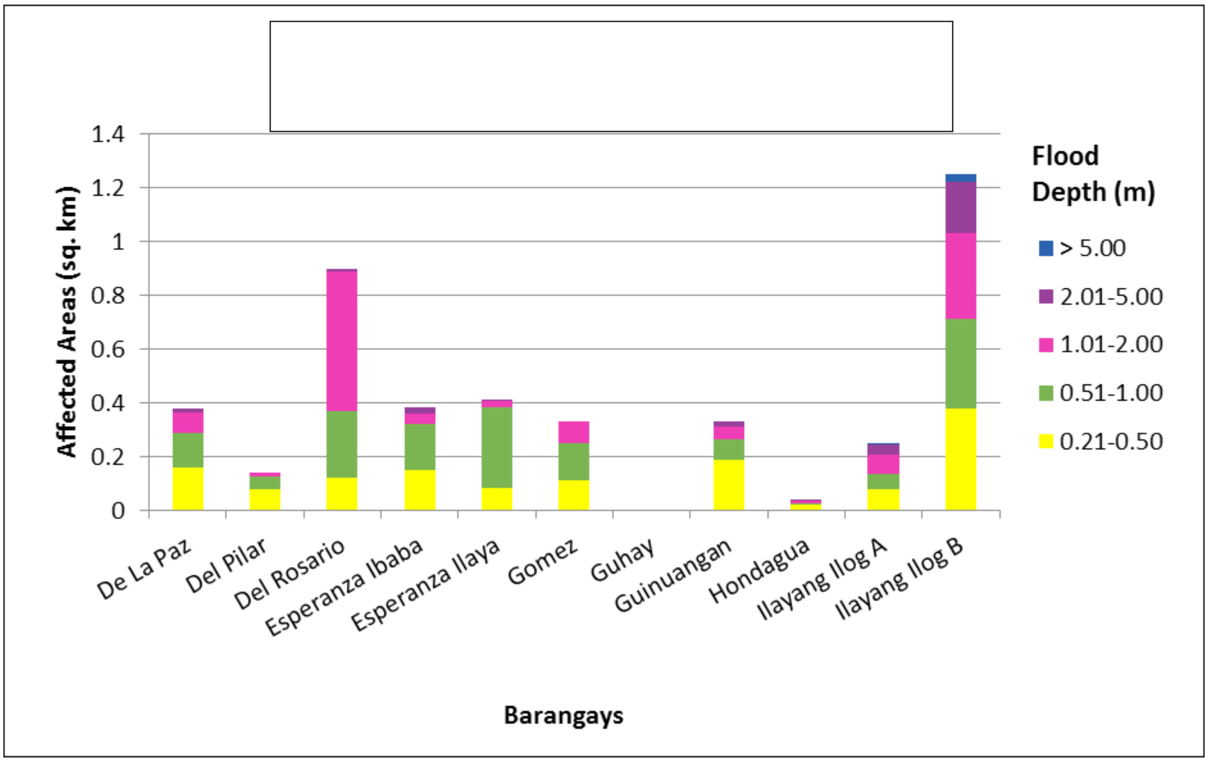


Figure 79. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

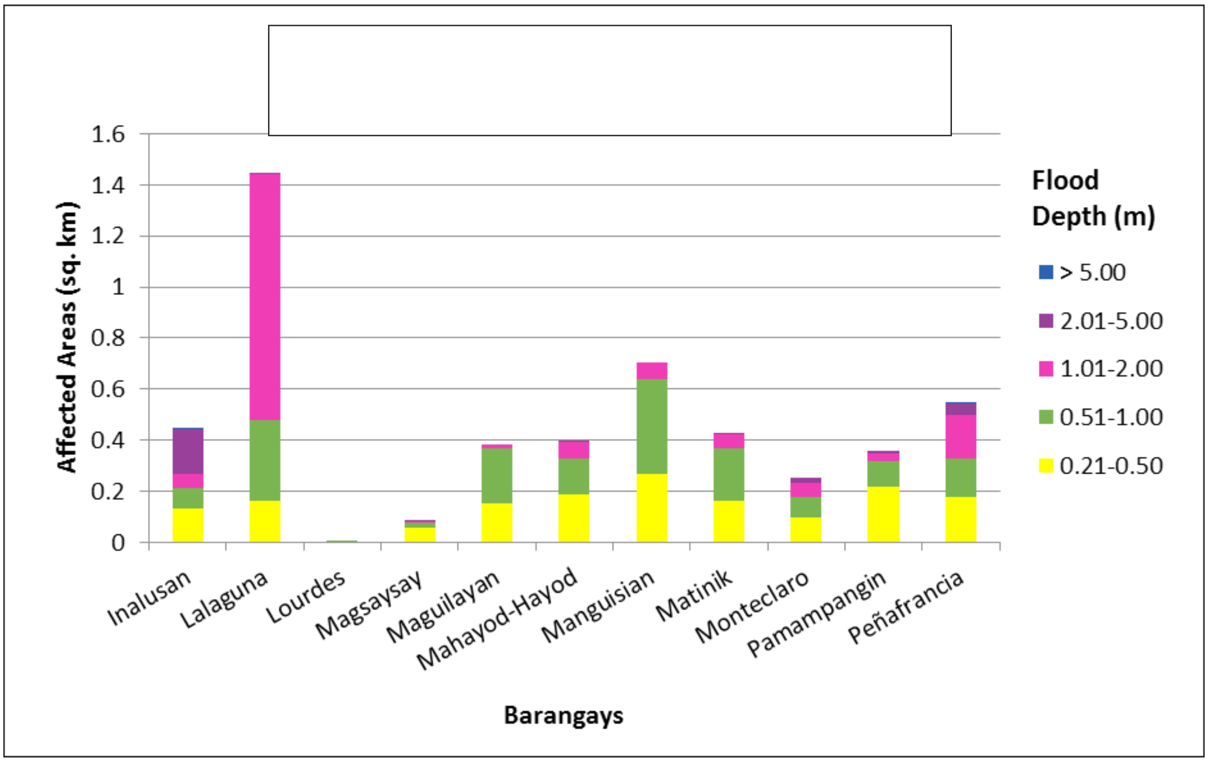


Figure 80. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

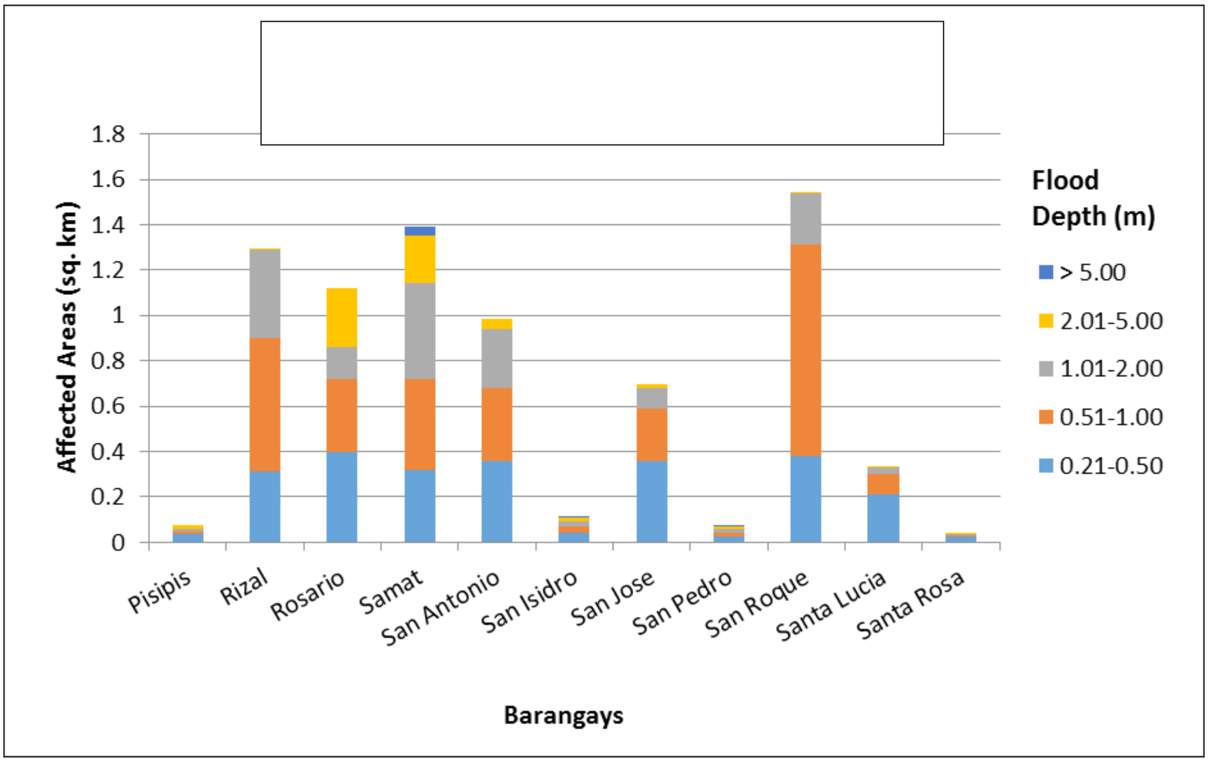


Figure 81. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

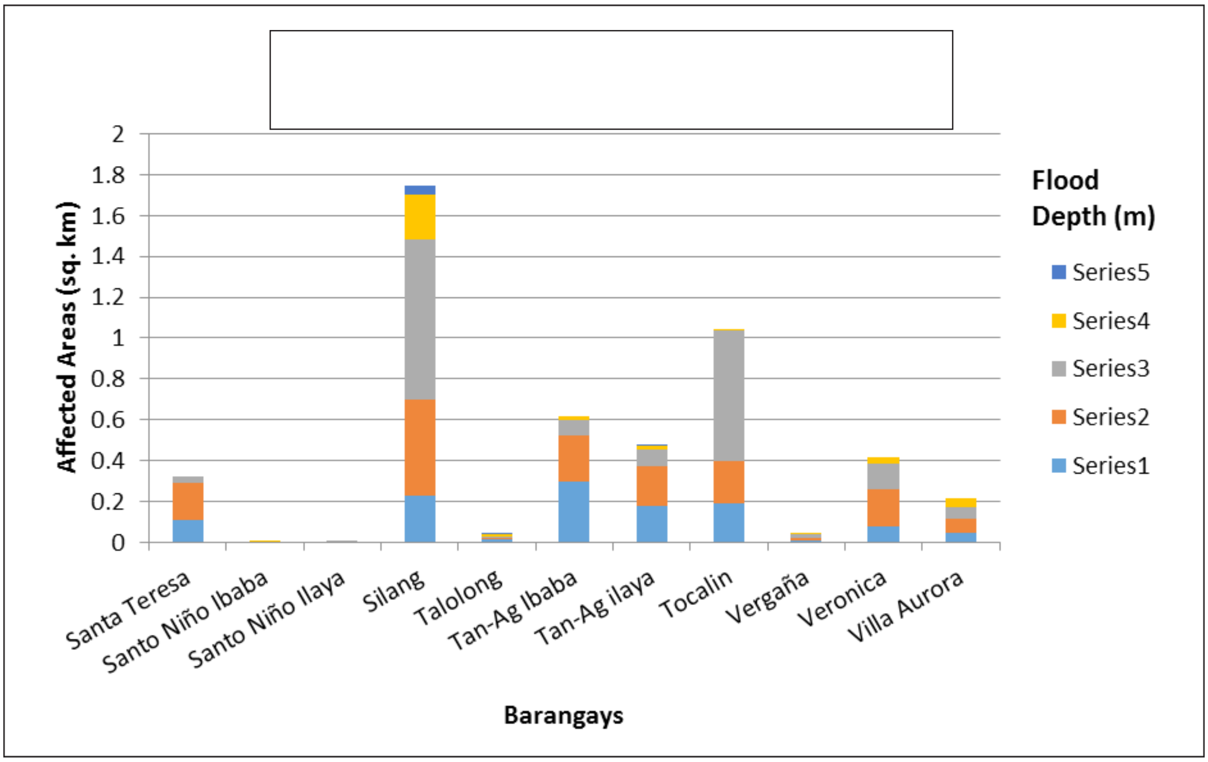


Figure 82. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

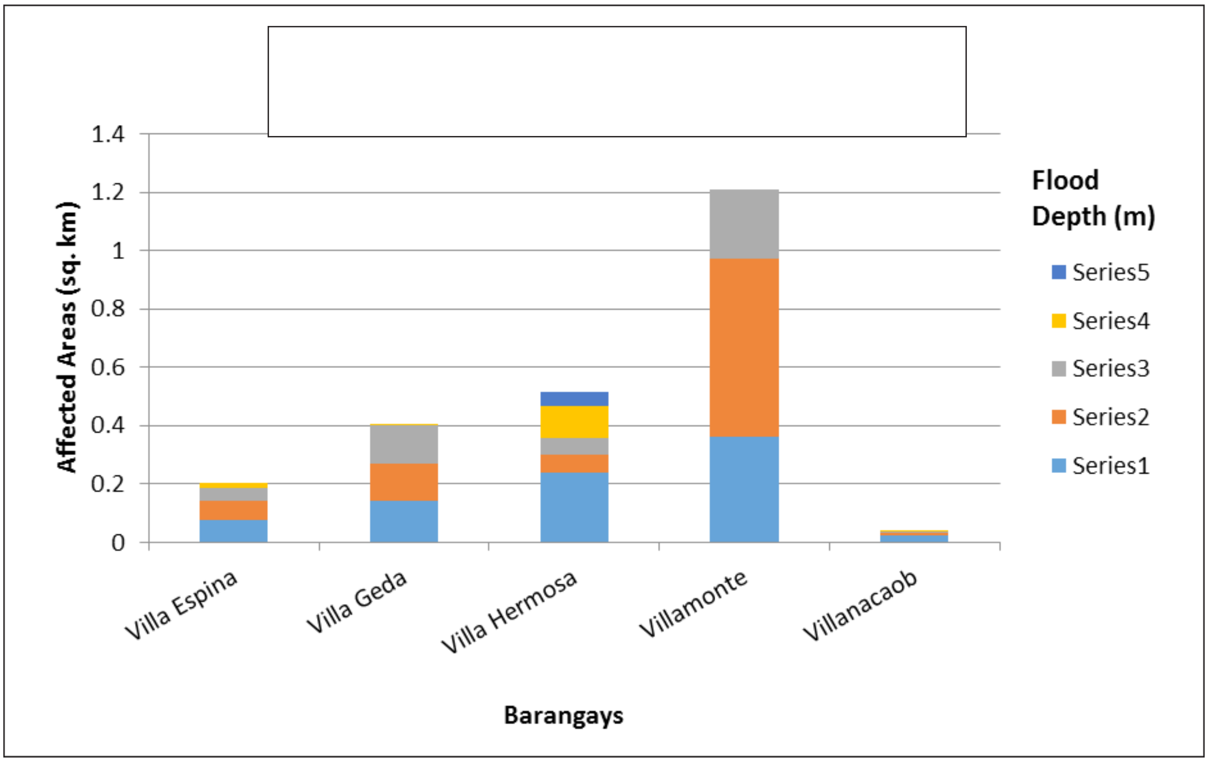


Figure 83. Affected areas in Lopez, Quezon during a 5-Year Rainfall Return Period

For the 5-year return period, 0.70% of the municipality of Guinayangan with an area of 225.57 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.02%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 and shown in Figure 84 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected areas in Guinayangan, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)		
	Danlagan Batis	Ermita	San Antonio
0.03-0.20	0.84	0.00084	0.73
0.21-0.50	0.06	0	0.034
0.51-1.00	0.038	0	0.024
1.01-2.00	0.026	0	0.012
2.01-5.00	0.028	0	0.013
> 5.00	0.013	0	0.003

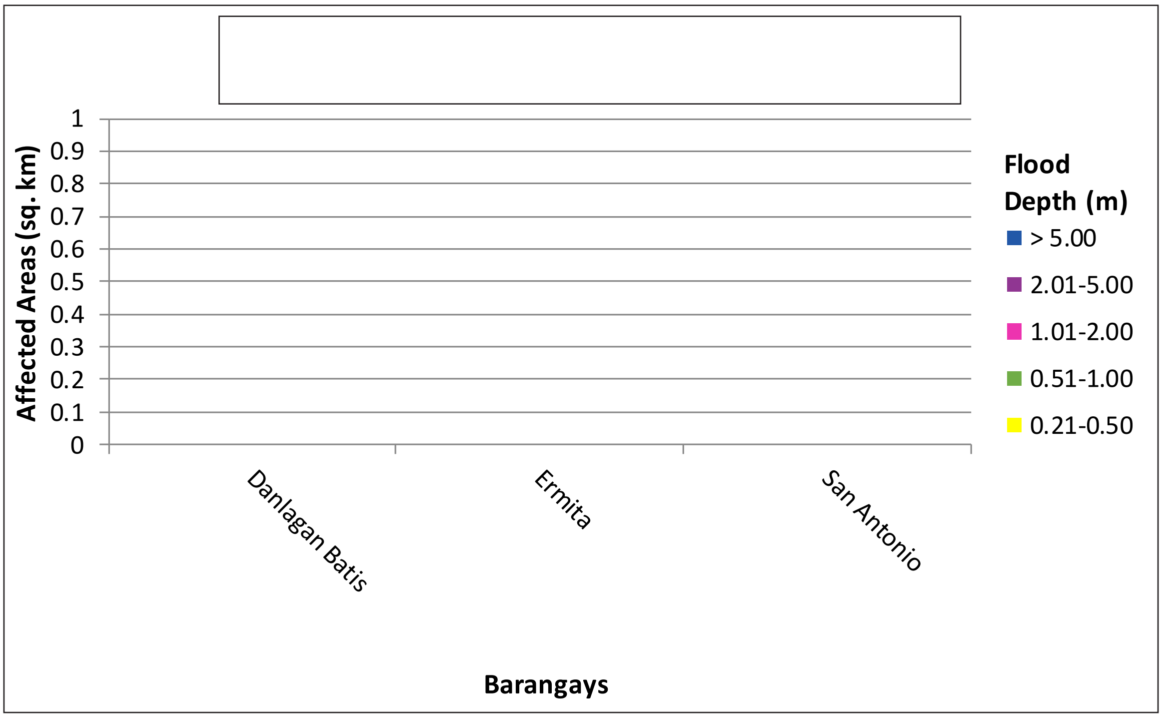


Figure 84. Affected Areas in Guinayangan, Quezon during 5-Year Rainfall Return Period

For the 5-year return period, 16.54% of the municipality of Calauag with an area of 312.32 sq. km. will experience flood levels of less than 0.20 meters. 1.35% of the area will experience flood levels of 0.21 to 0.50 meters while 1.51%, 1.48%, 1.92%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 to Table 47, and shown in Figure 85 to Figure 88 are the affected areas in square kilometres by flood depth per barangay.

Table 44. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Bangkuruhan	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Bigaan	Binutas	Biyan	Dominlog
0.03-0.20	0.25	0.095	0.14	0.12	0.056	0.063	1.43	2.64	0.5	0.093
0.21-0.50	0.013	0.042	0.013	0.014	0.014	0.029	0.15	0.29	0.046	0.0028
0.51-1.00	0.026	0.047	0.018	0.019	0.015	0.081	0.18	0.38	0.049	0.00056
1.01-2.00	0.18	0.0062	0.00092	0.0072	0.0081	0.035	0.019	0.19	0.094	0.00042
2.01-5.00	1.05	0.011	0.000017	0.00075	0	0.00034	0.0019	0.11	0.92	0.0011
> 5.00	0	0	0	0	0	0	0.000003	0.0005	0	0.00038

Table 45. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Kalibo	Kigtan	Kinalin Ibaba	Kinalin Ilaya	Kumaludkud	Mabini	Maglipad	Mambaling	Manhulugin	Marilag
0.03-0.20	2.74	6.55	1.55	1.44	1.02	0.63	4.34	1.87	1.94	1.21
0.21-0.50	0.1	0.28	0.17	0.038	0.16	0.092	0.26	0.07	0.19	0.074
0.51-1.00	0.11	0.16	0.4	0.016	0.19	0.18	0.13	0.067	0.36	0.094
1.01-2.00	0.1	0.074	0.28	0.015	0.13	0.31	0.1	0.086	0.22	0.054
2.01-5.00	0.0068	0.0084	0.012	0.0083	0	0.23	0.14	0.15	0.0063	0.029
> 5.00	0	0	0	0	0	0.049	0.045	0.37	0	0

Table 46. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Pandanan	Pansol	Patihan	Pinagkamaligan	Pinagtalleran	Rizal Ibaba	Rizal Ilaya	Sabang I	Sabang II	Salvacion
0.03-0.20	1.45	3.08	0.92	0.067	0.00009	0.45	1.62	0.37	0.039	3.5
0.21-0.50	0.43	0.22	0.19	0.037	0.0031	0.031	0.089	0.11	0.039	0.19
0.51-1.00	0.59	0.19	0.15	0.068	0.011	0.037	0.055	0.14	0.31	0.12
1.01-2.00	0.22	0.22	0.043	0.038	0.0066	0.13	0.047	0.078	0.13	0.1
2.01-5.00	0.042	0.058	0.02	0.028	0.00081	0.32	0.021	0.056	0	0.13
> 5.00	0	0.0009	0.0001	0	0	0.056	0	0.0053	0	0.18

Table 47. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)								
	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang	Sumulong	Tikiwan	Yaganak
0.03-0.20	1.47	2.19	0.61	1.2	3.48	0.54	0.39	0.47	1.55
0.21-0.50	0.11	0.099	0.045	0.064	0.19	0.23	0.081	0.053	0.12
0.51-1.00	0.066	0.029	0.036	0.05	0.22	0.34	0.15	0.049	0.04
1.01-2.00	0.031	0.0026	0.063	0.055	0.35	0.73	0.54	0.099	0.024
2.01-5.00	0.077	0.0001	0.11	0.084	0.013	1.47	0.68	0.19	0.063
> 5.00	0.068	0	0	0.012	0	0.013	0	0.038	0.19

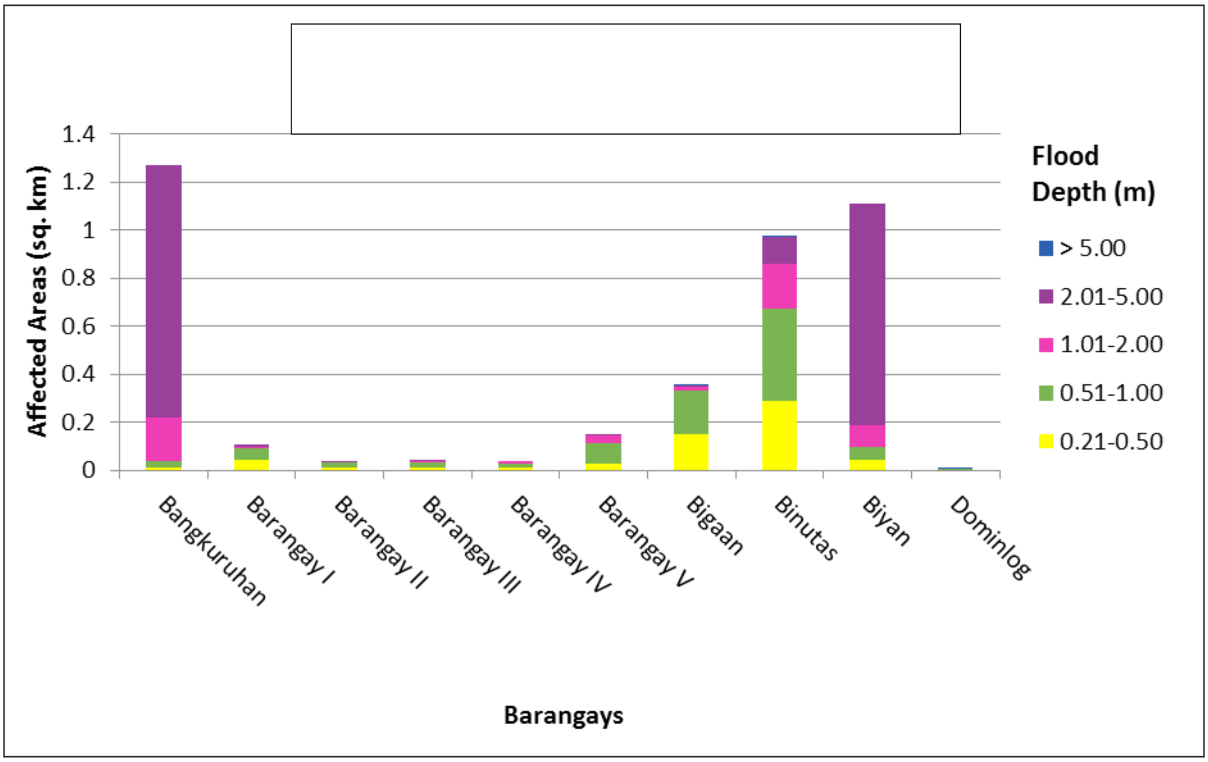


Figure 85. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

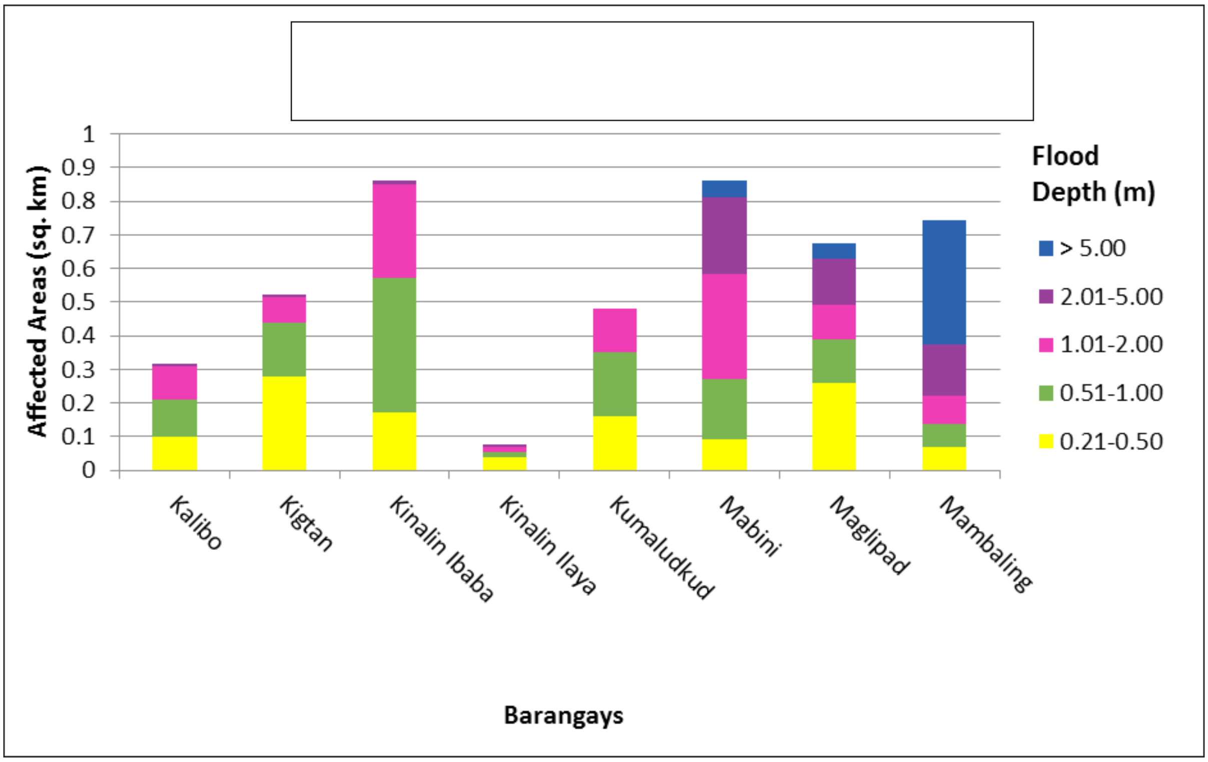


Figure 86. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

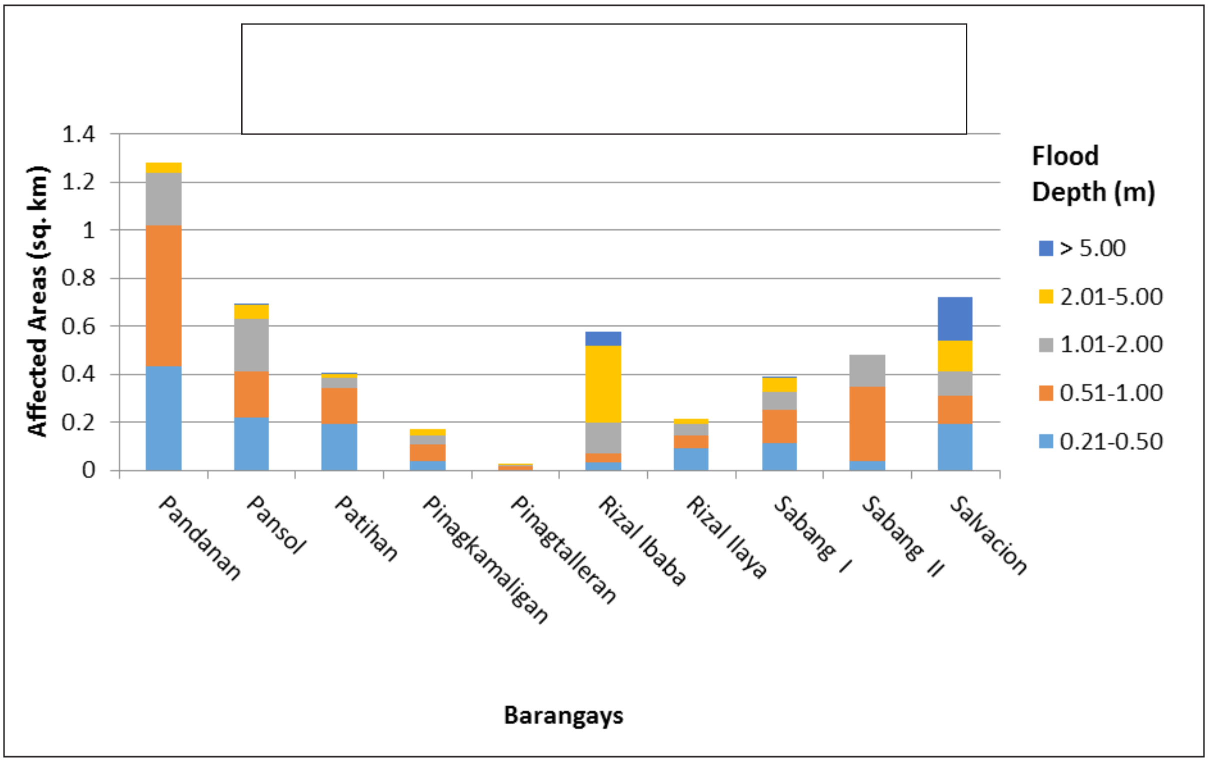


Figure 87. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

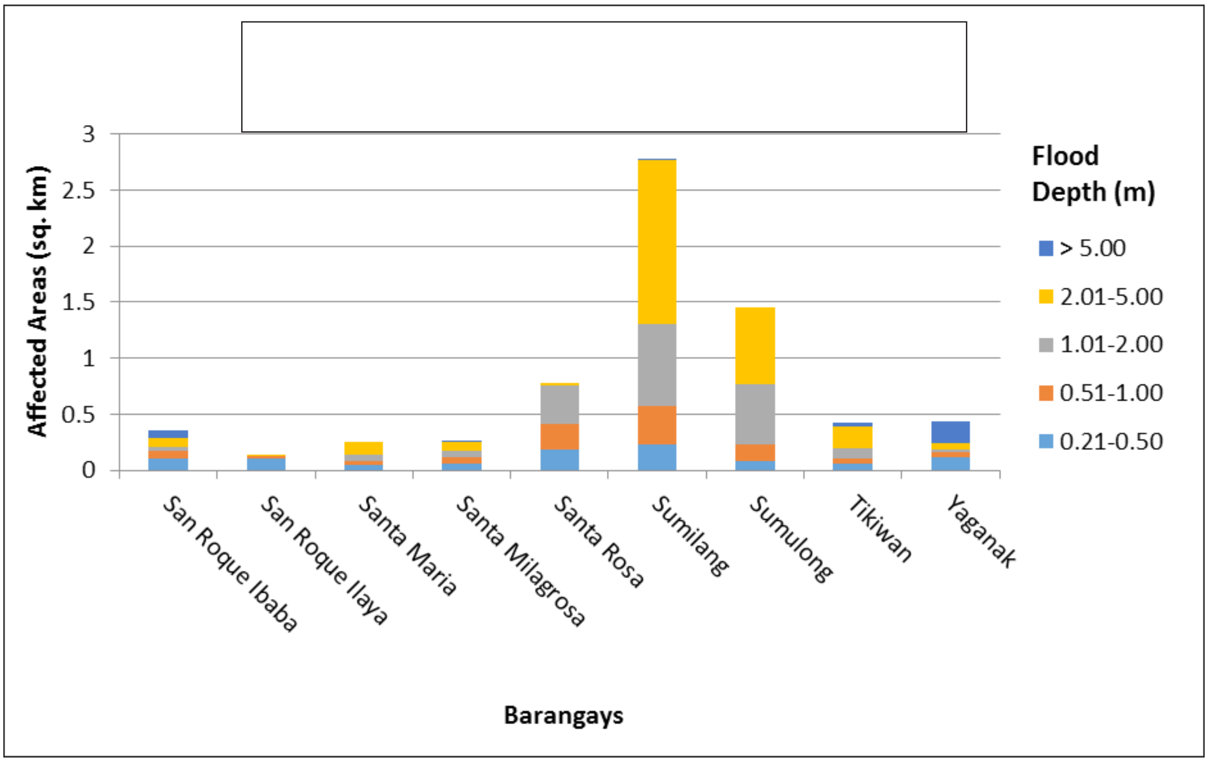


Figure 88. Affected areas in Calauag, Quezon during a 5-Year Rainfall Return Period.

For the 25-year return period, 23.73% of the municipality of Lopez with an area of 376.22 sq. km. will experience flood levels of less than 0.20 meters. 2.48% of the area will experience flood levels of 0.21 to 0.50 meters while 2.81%, 3.94%, 1.92%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 to Table 54, and shown in Figure 89 to Figure 95 are the affected areas in square kilometres by flood depth per barangay.

Table 48. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Bacungan	Bagacay	Banabahin Ibaba	Banabahin Ilaya	Bayabas	Bebito	Bigajo	Binahian A	Binahian B	Binahian C	Bocboc
0.03-0.20	1.48	0.72	0.73	0.46	1.99	0.94	0.81	3.01	0.98	0.013	1.93
0.21-0.50	0.19	0.15	0.16	0.14	0.29	0.076	0.027	0.16	0.074	0	0.4
0.51-1.00	0.09	0.17	0.26	0.17	0.28	0.064	0.025	0.15	0.044	0	0.36
1.01-2.00	0.058	0.062	0.41	0.17	0.43	0.081	0.026	0.13	0.028	0	0.16
2.01-5.00	0.0007	0.0039	0.56	0.012	0.026	0	0.0024	0.088	0.012	0	0.012
> 5.00	0	0	0.017	0.00091	0.0061	0	0	0.017	0	0	0.0017

Table 49. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Buenavista	Burgos	Buyacanin	Cagacag	Canda Ibaba	Canda Ilaya	Cawayan	Cogorin Ibaba	Cogorin Ilaya	Concepcion	Danlagan
0.03-0.20	**1.18**	**0.022**	**0.39**	**0.66**	**0.75**	**1.76**	**2.71**	**0.66**	**1.64**	**2.8**	**1.04**
0.21-0.50	**0.34**	**0.067**	**0.037**	**0.03**	**0.049**	**0.21**	**0.37**	**0.021**	**0.082**	**0.19**	**0.18**
0.51-1.00	**0.68**	**0.1**	**0.06**	**0.033**	**0.066**	**0.14**	**0.39**	**0.011**	**0.073**	**0.24**	**0.14**
1.01-2.00	**0.88**	**0.15**	**0.43**	**0.011**	**0.56**	**0.24**	**0.2**	**0.0089**	**0.37**	**0.12**	**0.23**
2.01-5.00	**0.23**	**0.0018**	**0.0053**	**0.0011**	**0.015**	**0.024**	**0.046**	**0.0073**	**0.72**	**0.043**	**0.016**
> 5.00	**0.044**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0048**	**0.12**	**0**	**0.000029**

Table 50. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	De La Paz	Del Pilar	Del Rosario	Esperanza Ibaba	Esperanza Ilaya	Gomez	Guhay	Guinuangan	Hondagua	Ilayang Ilog A	Ilayang Ilog B
0.03-0.20	1.33	0.35	1.34	0.99	0.7	0.13	0	2.68	0.4	2.64	7.68
0.21-0.50	0.12	0.088	0.083	0.18	0.065	0.1	0	0.2	0.026	0.082	0.35
0.51-1.00	0.17	0.061	0.14	0.17	0.27	0.15	0	0.11	0.0073	0.064	0.33
1.01-2.00	0.12	0.025	0.56	0.16	0.086	0.15	0	0.057	0.0024	0.072	0.34
2.01-5.00	0.019	0	0.17	0.031	0.01	0.00061	0	0.026	0.0099	0.062	0.32
> 5.00	0	0	0	0	0	0	0	0	0	0.0014	0.048

Table 51. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Inalusan	Lalaguna	Lourdes	Magsaysay	Maguilayan	Mahayod-Hayod	Manguisian	Matinik	Monteclaro	Pamampangin	Peñafrancia
0.03-0.20	1.7	1.64	0.11	0.11	0.61	1.1	0.3	0.36	2.82	1.35	0.81
0.21-0.50	0.14	0.1	0.0029	0.084	0.1	0.11	0.21	0.1	0.11	0.22	0.11
0.51-1.00	0.1	0.13	0.00011	0.042	0.1	0.15	0.41	0.26	0.086	0.14	0.12
1.01-2.00	0.069	0.32	0	0.015	0.27	0.28	0.24	0.099	0.07	0.12	0.26
2.01-5.00	0.2	0.97	0	0.0057	0.0033	0.05	0	0.0002	0.034	0.022	0.1
> 5.00	0.00052	0	0	0	0	0.0001	0	0	0.0001	0	0.007

Table 52. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Pisipis	Rizal	Rosario	Samat	San Antonio	San Isidro	San Jose	San Pedro	San Roque	Santa Lucia	Santa Rosa
0.03-0.20	0.93	1.61	3.22	1.48	1.56	1.42	1.76	0.93	0.99	2.04	0.46
0.21-0.50	0.044	0.24	0.31	0.19	0.28	0.047	0.39	0.028	0.17	0.26	0.028
0.51-1.00	0.017	0.36	0.35	0.34	0.32	0.027	0.28	0.021	0.3	0.12	0.0089
1.01-2.00	0.011	0.69	0.22	0.59	0.36	0.027	0.15	0.023	1.16	0.038	0.0052
2.01-5.00	0.023	0.13	0.36	0.48	0.18	0.023	0.018	0.013	0.019	0.0023	0.0025
> 5.00	0.00046	0	0	0.046	0	0.0027	0	0.002	0	0	0

Table 53. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Santa Teresa	Santo Niño Ibaba	Santo Niño Ilaya	Silang	Talolong	Tan-Ag Ibaba	Tan-Ag ilaya	Tocalin	Vergaña	Veronica	Villa Aurora
0.03-0.20	0.38	0.0033	0.0022	0.82	0.099	0.5	0.71	1.72	0.19	1.75	1.22
0.21-0.50	0.091	0.000018	0.00011	0.13	0.037	0.17	0.086	0.11	0.012	0.074	0.051
0.51-1.00	0.13	0.000059	0.000046	0.28	0.012	0.39	0.14	0.13	0.008	0.11	0.053
1.01-2.00	0.14	0.000002	0.000044	0.8	0.0078	0.52	0.28	0.34	0.018	0.22	0.072
2.01-5.00	0	0.000088	0	0.61	0.012	0.21	0.2	0.67	0.01	0.045	0.058
> 5.00	0	0	0	0.053	0.0018	0	0.012	0	0	0	0.0001

Table 54. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)				
	Villa Espina	Villa Geda	Villa Hermosa	Villamonte	Villanacaob
0.03-0.20	2.26	2.64	2.07	1.86	0.81
0.21-0.50	0.081	0.13	0.3	0.23	0.027
0.51-1.00	0.063	0.097	0.14	0.31	0.012
1.01-2.00	0.063	0.14	0.068	0.8	0.0069
2.01-5.00	0.025	0.091	0.12	0.053	0.0008
> 5.00	0	0	0.066	0	0

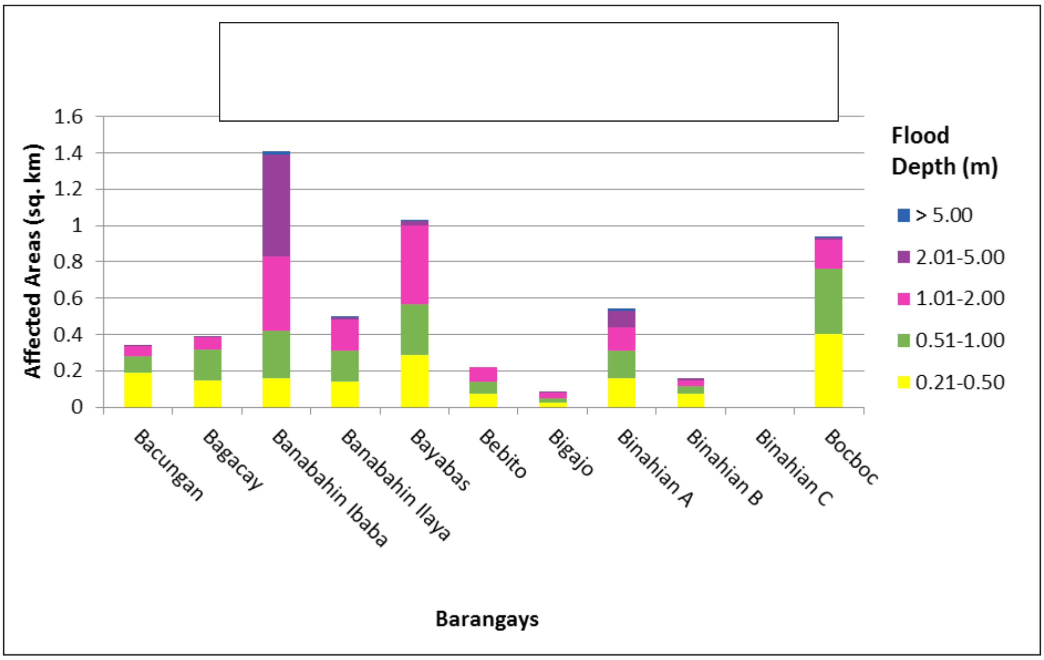


Figure 89. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

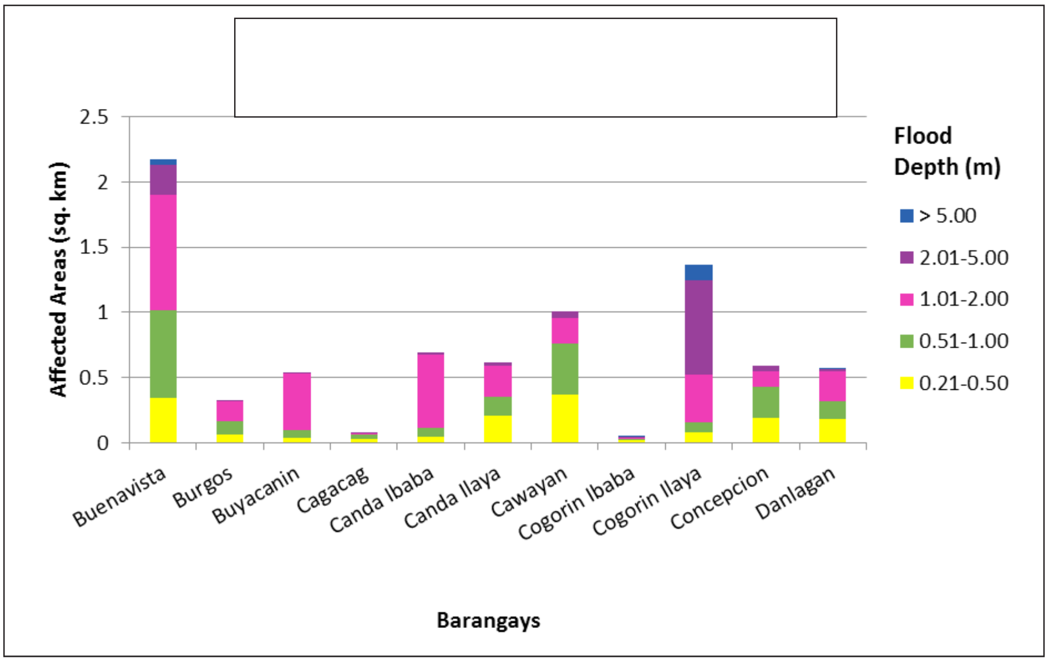


Figure 90. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

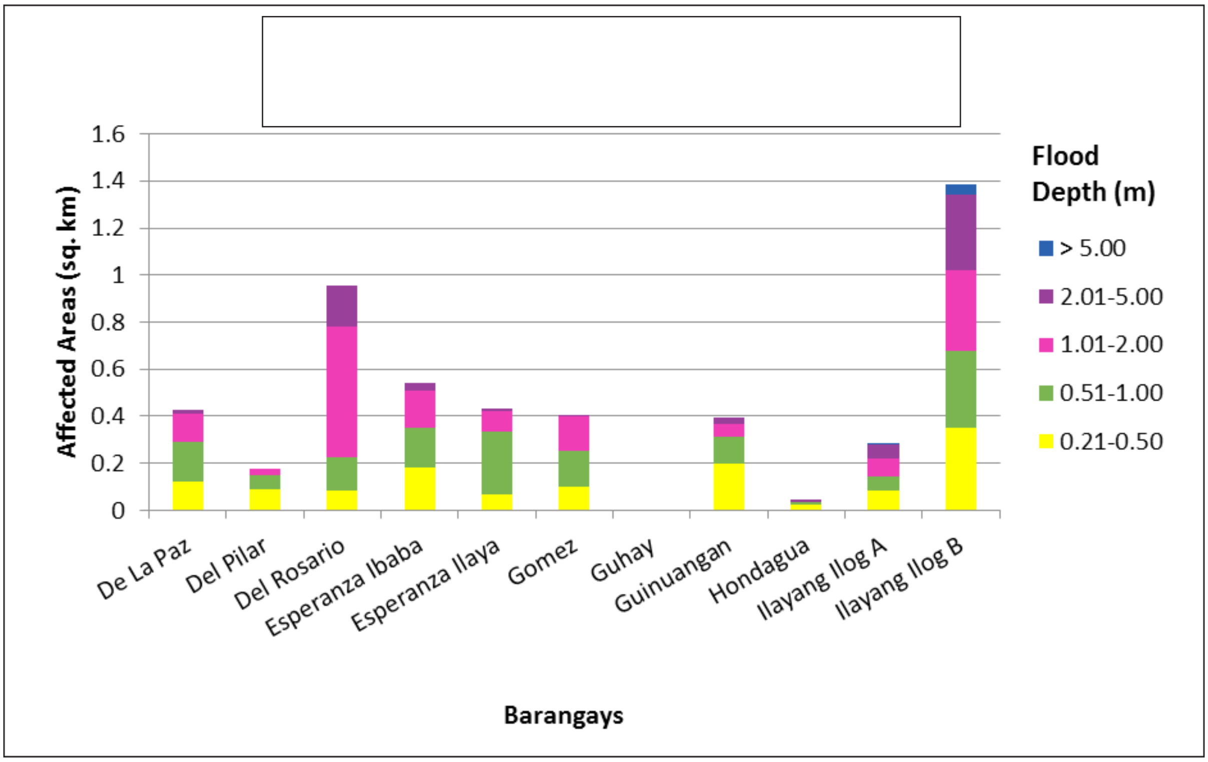


Figure 91. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

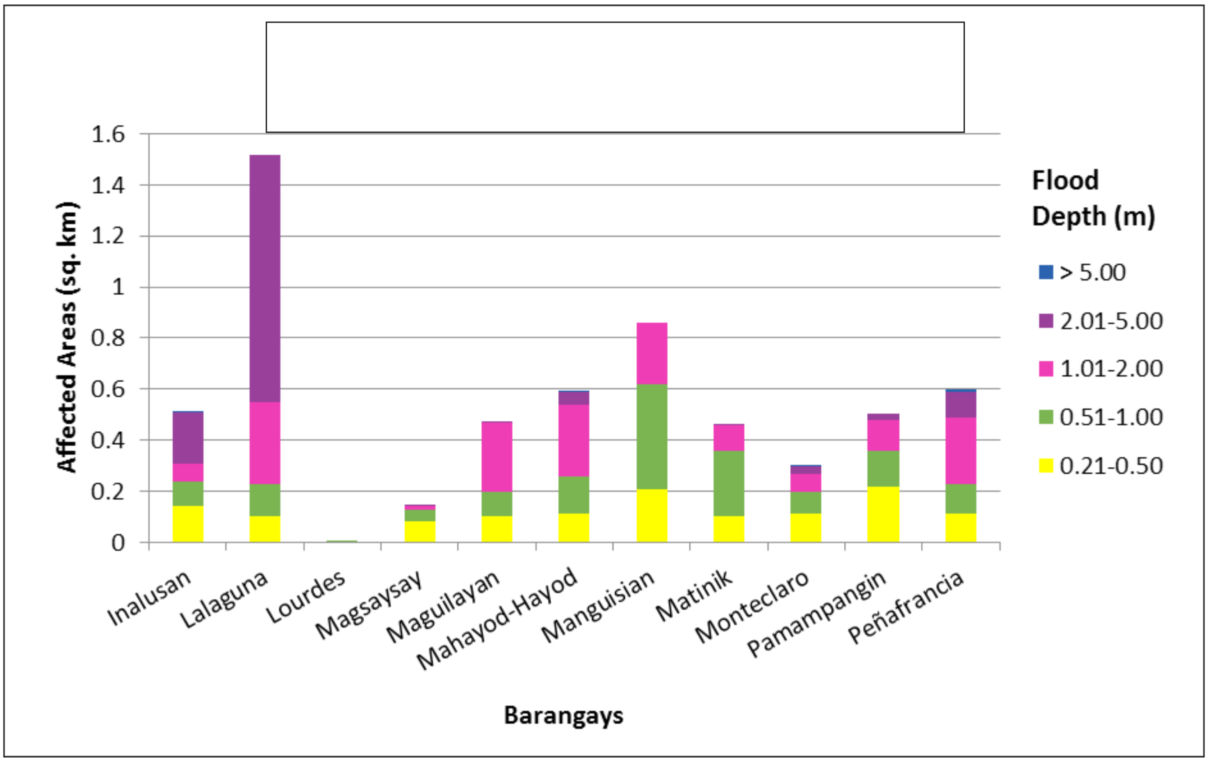


Figure 92. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

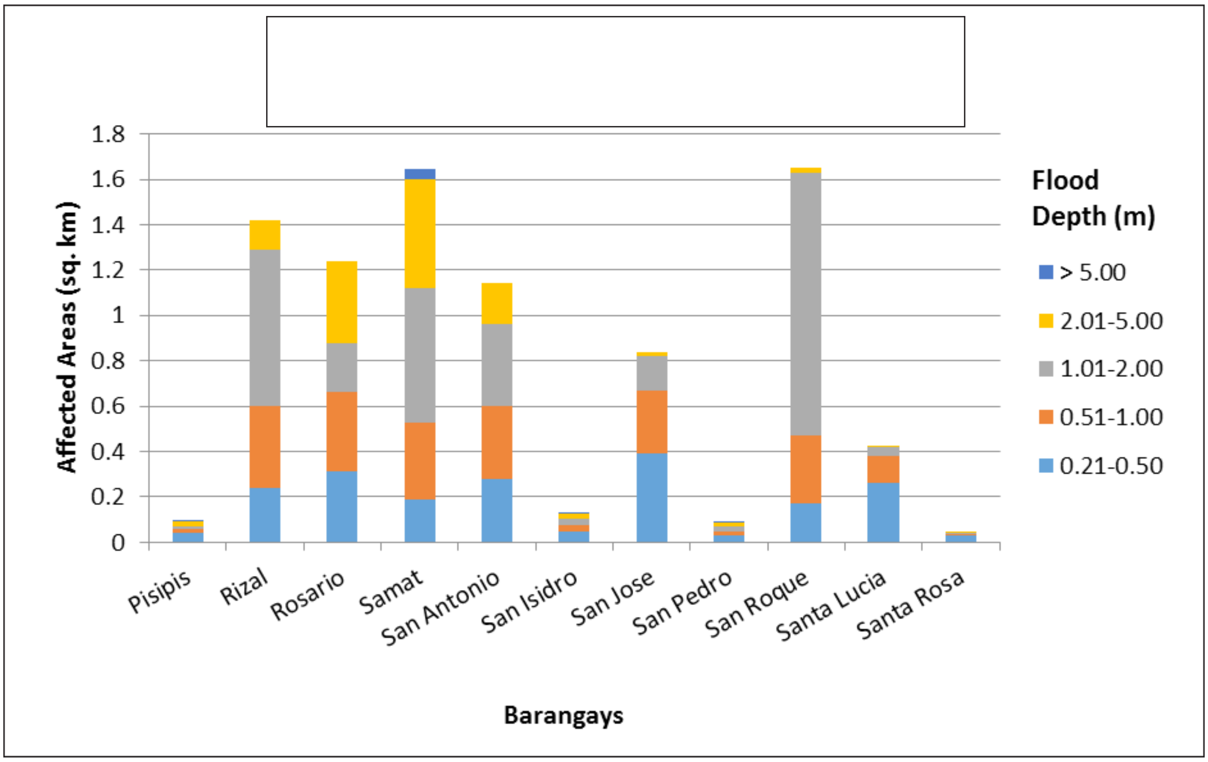


Figure 93. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

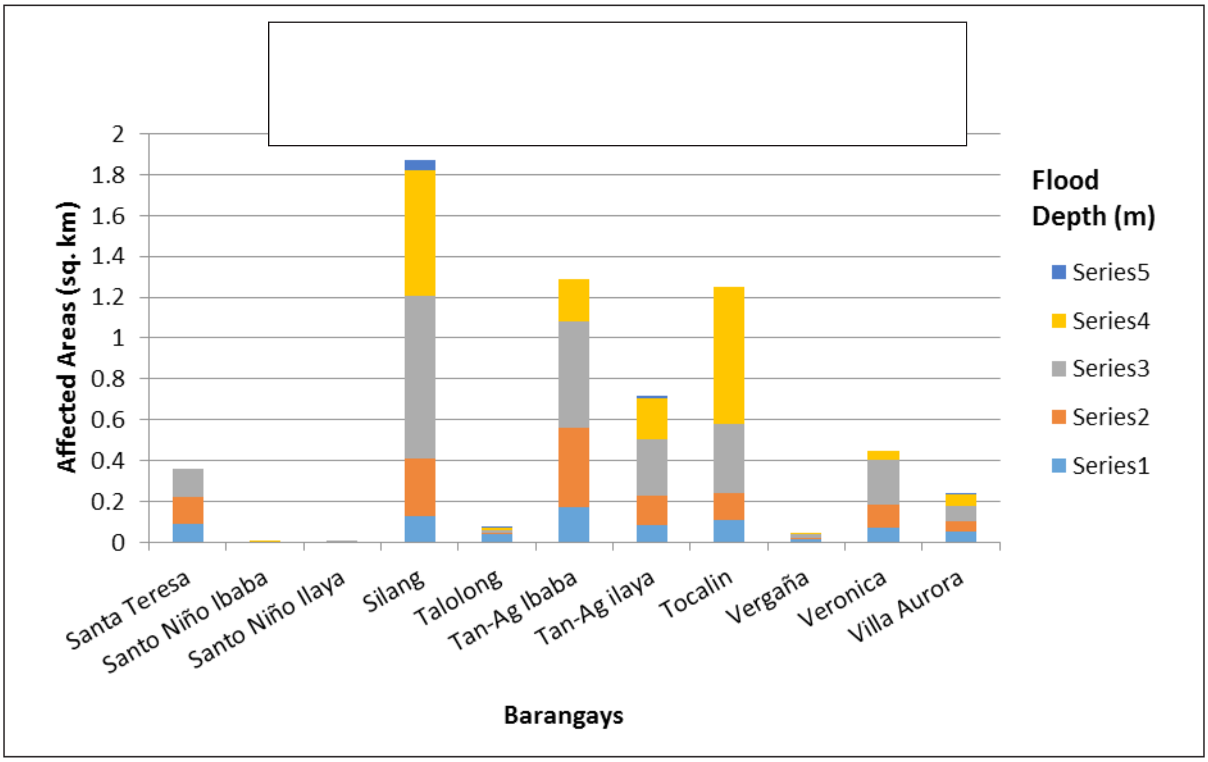


Figure 94. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

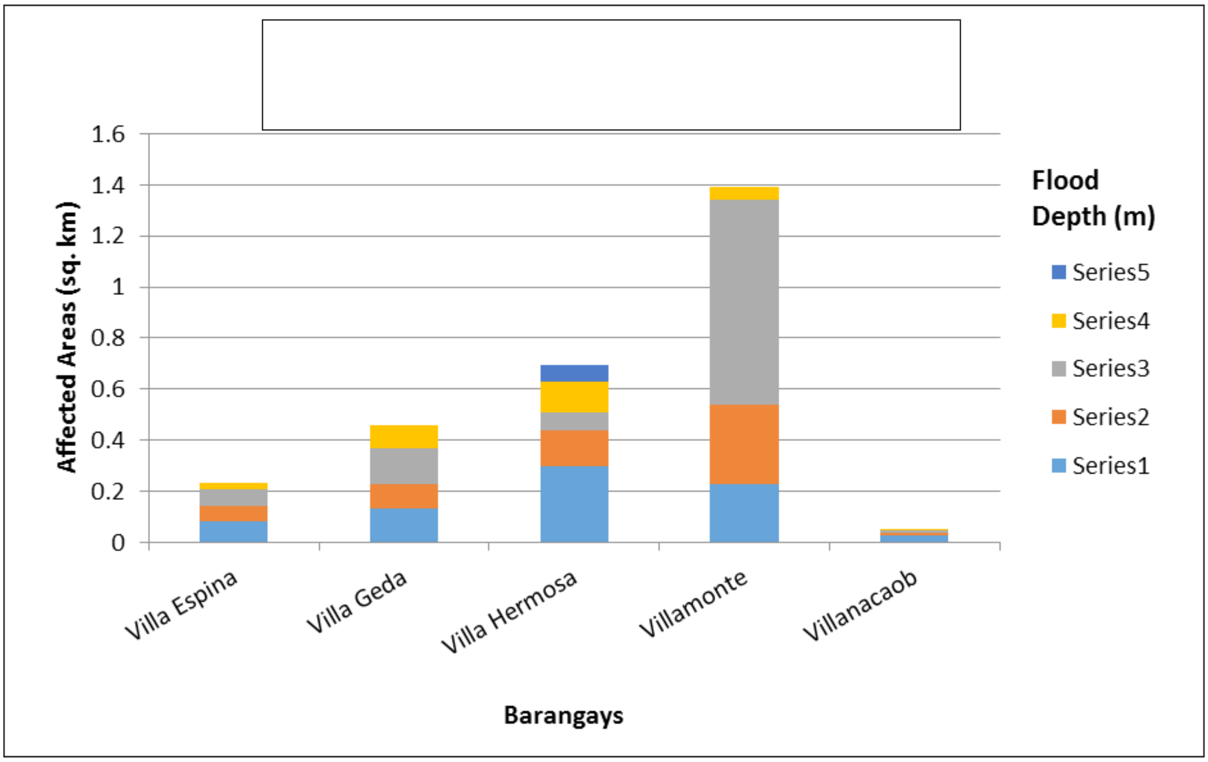


Figure 95. Affected areas in Lopez, Quezon during a 25-Year Rainfall Return Period

For the 25-year return period, 0.67% of the municipality of Guinayangan with an area of 225.57 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, 0.02%, 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 55 and shown in Figure 96 are the affected areas in square kilometres by flood depth per barangay.

Table 55. Affected areas in Guinayangan, Quezon during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)		
	Danlagan Batis	Ermita	San Antonio
0.03-0.20	0.81	0.00084	0.71
0.21-0.50	0.061	0	0.038
0.51-1.00	0.048	0	0.026
1.01-2.00	0.028	0	0.016
2.01-5.00	0.035	0	0.018
> 5.00	0.018	0	0.0079

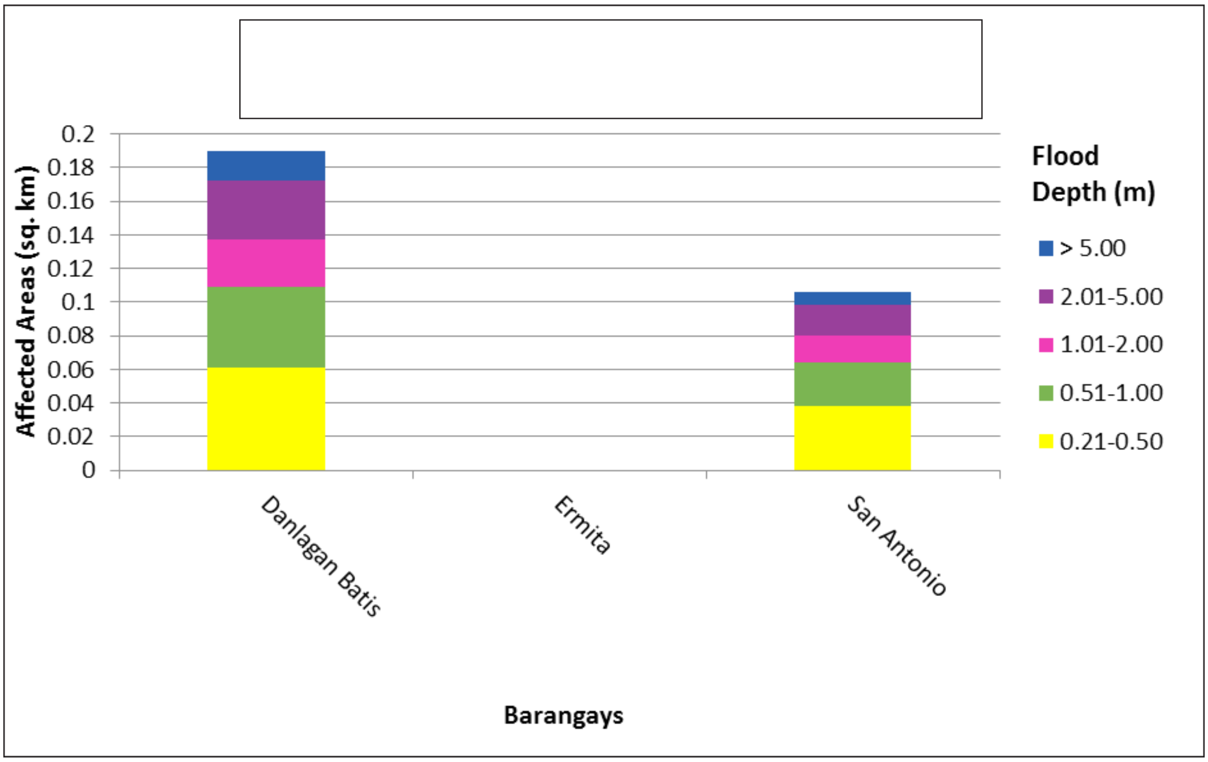


Figure 96. Affected areas in Guinayangan, Quezon during a 25-Year Rainfall Return Period.

For the 25-year return period, 15.77% of the municipality of Calauag with an area of 312.32 sq. km. will experience flood levels of less than 0.20 meters. 1.11% of the area will experience flood levels of 0.21 to 0.50 meters while 1.15%, 1.95%, 3.05%, and 0.51% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 56 to Table 59, and shown in Figure 97 to Figure 100 are the affected areas in square kilometres by flood depth per barangay.

Table 56. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Bangkuruhan	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Bigaan	Binutas	Biyan	Dominlog
0.03-0.20	0.24	0.061	0.12	0.096	0.041	0.028	1.34	2.49	0.46	0.09
0.21-0.50	0.009	0.0045	0.0052	0.0083	0.0044	0.0058	0.088	0.24	0.035	0.0045
0.51-1.00	0.0045	0.0096	0.0089	0.0099	0.0086	0.014	0.091	0.24	0.038	0.001
1.01-2.00	0.012	0.073	0.033	0.034	0.029	0.091	0.24	0.45	0.051	0.00069
2.01-5.00	1.27	0.046	0.0018	0.009	0.01	0.068	0.025	0.16	1.03	0.00062
> 5.00	0	0.0066	0	0	0	0	0.0011	0.022	0.00053	0.001

Table 57. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Kalibo	Kigtan	Kinalin Ibaba	Kinalin Ilaya	Kumaludkud	Mabini	Maglipad	Mambaling	Manhulugin	Marilag
0.03-0.20	2.69	6.45	1.48	1.42	0.96	0.57	4.19	1.81	1.77	1.16
0.21-0.50	0.1	0.3	0.13	0.048	0.099	0.057	0.26	0.074	0.12	0.06
0.51-1.00	0.09	0.2	0.29	0.017	0.14	0.058	0.22	0.06	0.12	0.062
1.01-2.00	0.16	0.1	0.5	0.016	0.29	0.27	0.13	0.068	0.59	0.14
2.01-5.00	0.017	0.016	0.021	0.012	0.011	0.45	0.13	0.15	0.12	0.041
> 5.00	0	0	0	0	0	0.093	0.086	0.46	0	0.0005

Table 58. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Pandanan	Pansol	Patihan	Pinagkamaligan	Pinagtalleran	Rizal Ibaba	Rizal Ilaya	Sabang I	Sabang II	Salvacion
0.03-0.20	1.27	2.99	0.7	0.0023	0	0.41	1.57	0.26	0.0034	3.38
0.21-0.50	0.34	0.21	0.063	0.0026	0	0.024	0.1	0.019	0.0076	0.19
0.51-1.00	0.64	0.19	0.067	0.0095	0	0.019	0.061	0.026	0.025	0.13
1.01-2.00	0.36	0.25	0.3	0.092	0.011	0.046	0.055	0.24	0.38	0.12
2.01-5.00	0.12	0.13	0.18	0.11	0.011	0.39	0.036	0.17	0.096	0.13
> 5.00	0	0.005	0.006	0.02	0	0.14	0	0.042	0	0.25

Table 59. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)								
	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang	Sumulong	Tikiwan	Yaganak
0.03-0.20	1.42	2.16	0.57	1.14	3.42	0.33	0.29	0.38	1.48
0.21-0.50	0.12	0.12	0.044	0.063	0.19	0.12	0.02	0.055	0.14
0.51-1.00	0.08	0.042	0.026	0.054	0.19	0.18	0.038	0.083	0.051
1.01-2.00	0.031	0.0056	0.035	0.054	0.27	0.28	0.15	0.094	0.034
2.01-5.00	0.073	0.0002	0.19	0.12	0.18	2.39	1.34	0.23	0.039
> 5.00	0.1	0	0.000008	0.04	0	0.034	0.007	0.05	0.24

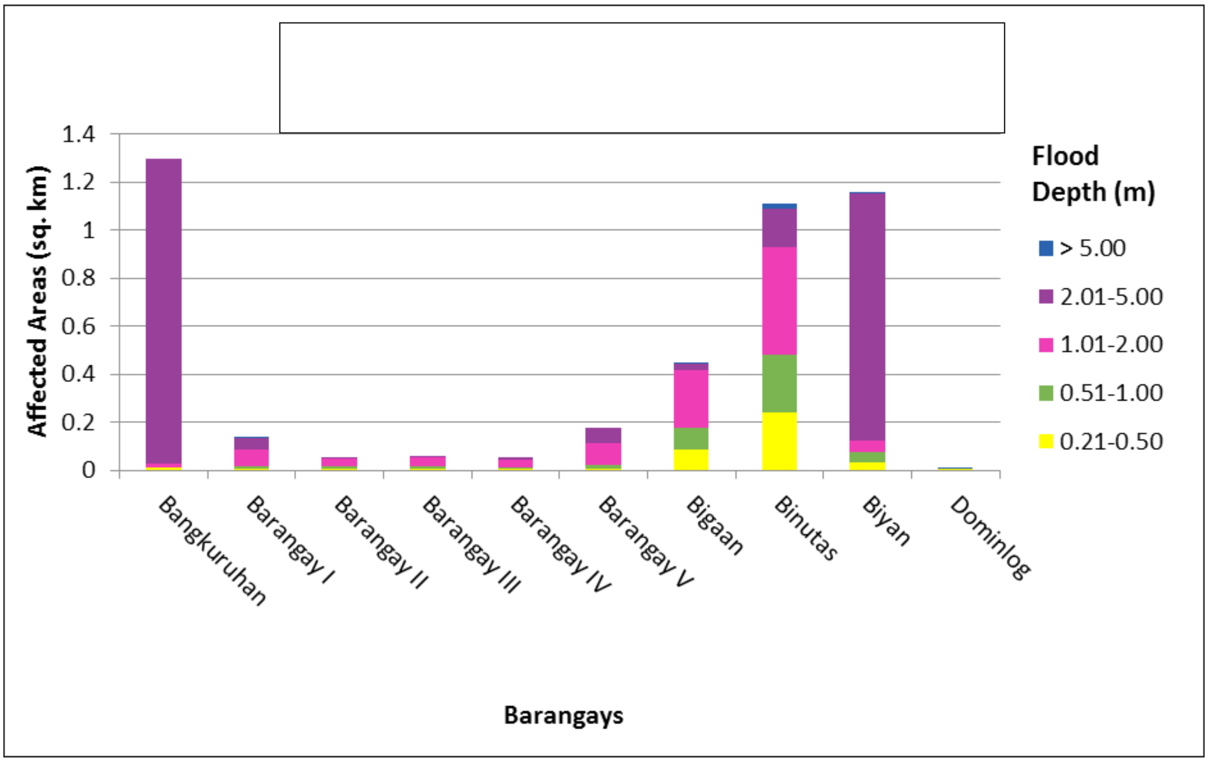


Figure 97. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

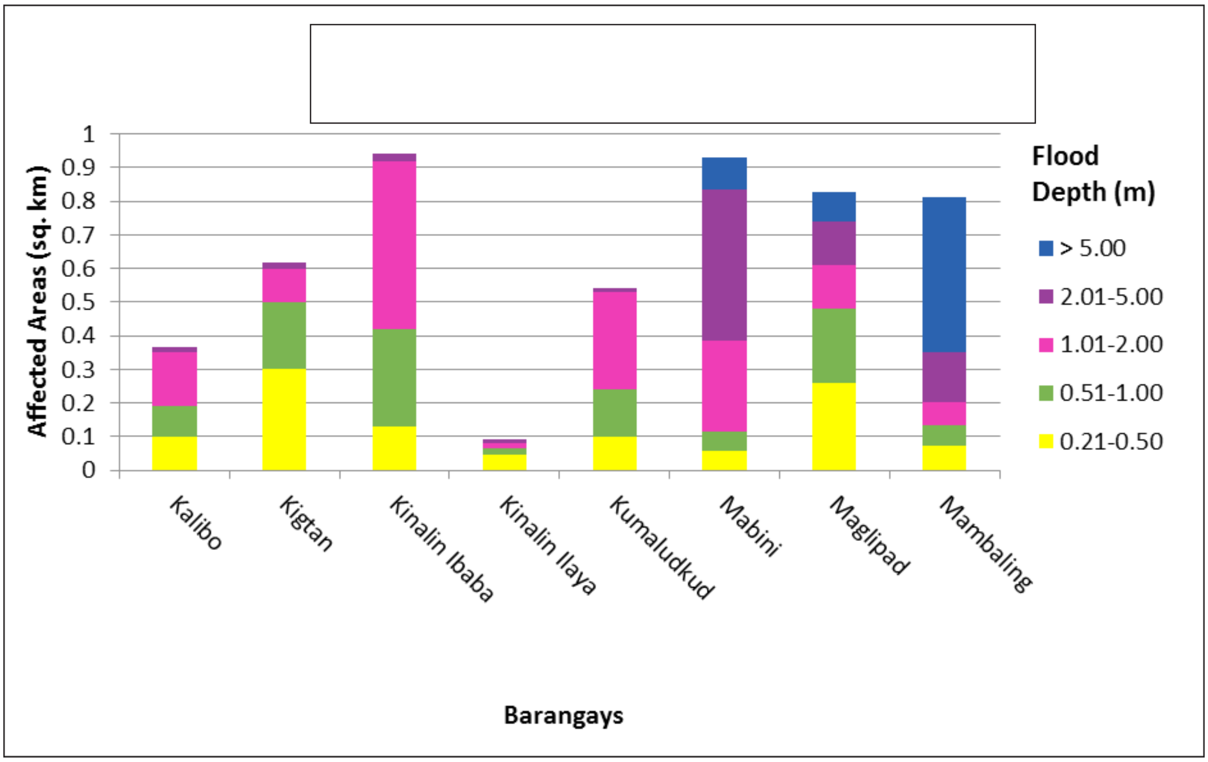


Figure 98. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

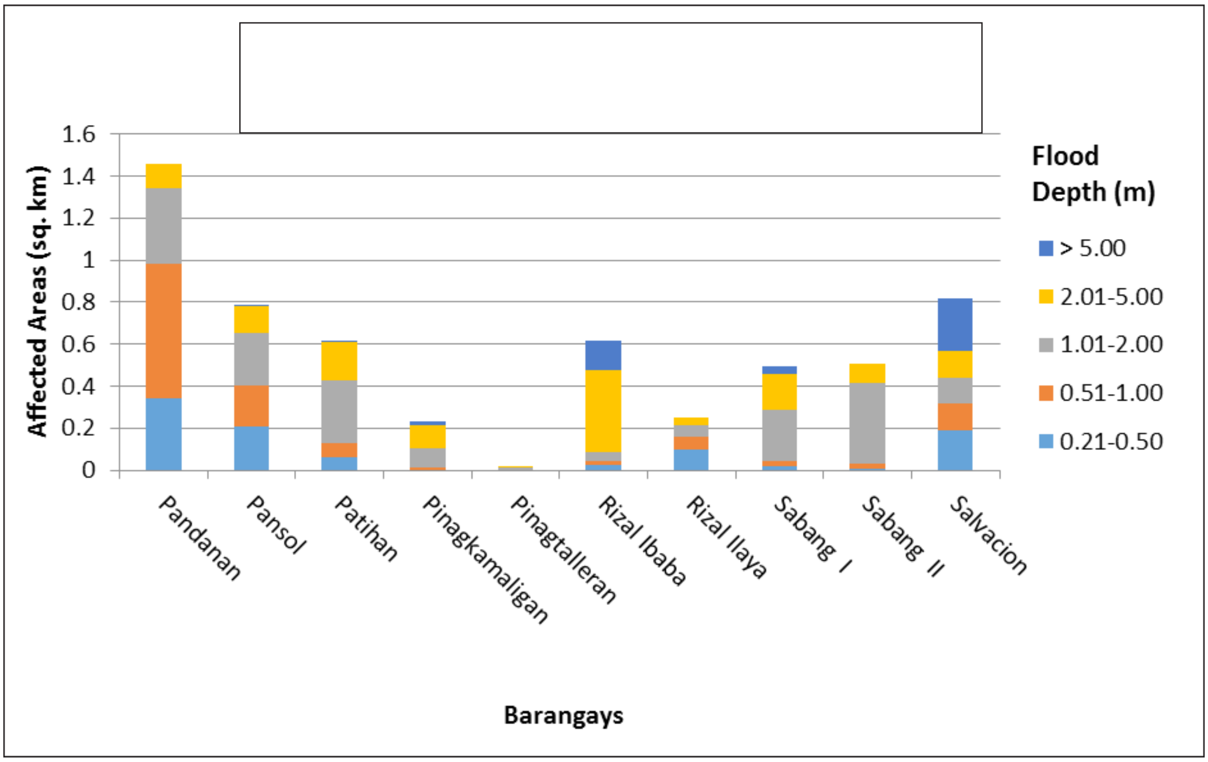


Figure 99. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

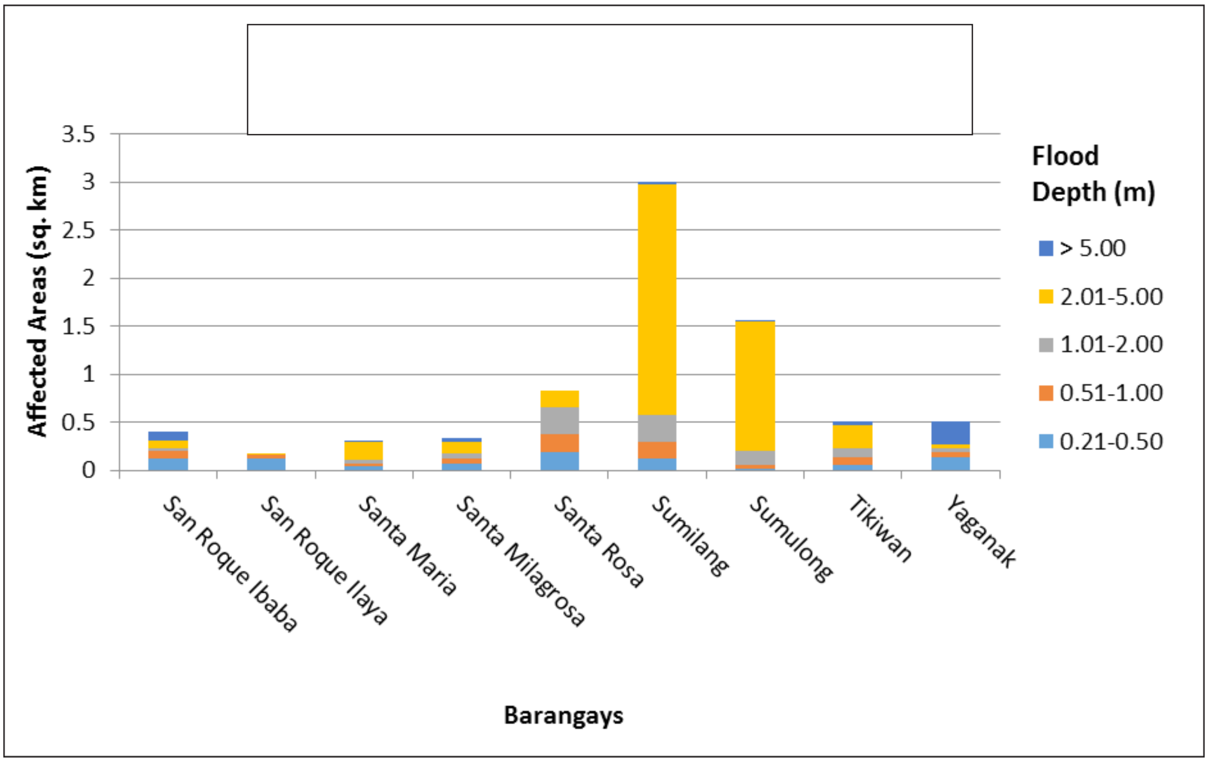


Figure 100. Affected areas in Calauag, Quezon during a 25-Year Rainfall Return Period.

For the 100-year return period, 22.92% of the municipality of Lopez with an area of 376.22 sq. km. will experience flood levels of less than 0.20 meters. 2.16% of the area will experience flood levels of 0.21 to 0.50 meters while 2.55%, 3.64%, 3.60%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 60 to Table 66, and shown in Figure 101 to Figure 107 are the affected areas in square kilometres by flood depth per barangay.

Table 60. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Bacungan	Bagacay	Banabahin Ibaba	Banabahin Ilaya	Bayabas	Bebito	Bigajo	Binahian A	Binahian B	Binahian C	Bocboc
0.03-0.20	1.45	0.69	0.63	0.39	1.88	0.92	0.81	2.97	0.97	0.013	1.83
0.21-0.50	0.15	0.12	0.061	0.12	0.27	0.075	0.028	0.16	0.074	0	0.36
0.51-1.00	0.13	0.14	0.14	0.19	0.31	0.063	0.022	0.16	0.051	0	0.45
1.01-2.00	0.083	0.14	0.46	0.2	0.46	0.099	0.032	0.15	0.032	0	0.2
2.01-5.00	0.0052	0.021	0.82	0.054	0.093	0.0022	0.005	0.11	0.014	0	0.026
> 5.00	0	0	0.028	0.001	0.0068	0	0	0.019	0	0	0.0021

Table 61. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Buenavista	Burgos	Buyacanin	Cagacag	Canda Ibaba	Canda Ilaya	Cawayan	Cogorin Ibaba	Cogorin Ilaya	Concepcion	Danlagan
0.03-0.20	1	0.0084	0.36	0.65	0.72	1.73	2.63	0.65	1.6	2.76	1.01
0.21-0.50	0.15	0.053	0.023	0.032	0.043	0.19	0.33	0.023	0.08	0.16	0.15
0.51-1.00	0.41	0.073	0.029	0.036	0.037	0.17	0.43	0.011	0.064	0.26	0.15
1.01-2.00	1.08	0.2	0.14	0.013	0.18	0.13	0.28	0.0092	0.19	0.16	0.27
2.01-5.00	0.66	0.0087	0.38	0.0015	0.46	0.16	0.054	0.0094	0.92	0.053	0.034
> 5.00	0.052	0	0	0	0	0	0	0.0053	0.16	0	0.000029

Table 62. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	De La Paz	Del Pilar	Del Rosario	Esperanza Ibaba	Esperanza Ilaya	Gomez	Guhay	Guinuangan	Hondagua	Ilayang Ilog A	Ilayang Ilog B
0.03-0.20	1.31	0.33	1.31	0.86	0.67	0.078	0	2.63	0.39	2.61	7.58
0.21-0.50	0.1	0.098	0.069	0.17	0.06	0.096	0	0.21	0.026	0.089	0.35
0.51-1.00	0.16	0.062	0.1	0.26	0.19	0.13	0	0.14	0.01	0.063	0.32
1.01-2.00	0.16	0.039	0.38	0.21	0.2	0.2	0	0.067	0.0023	0.074	0.34
2.01-5.00	0.028	0.0001	0.43	0.037	0.016	0.01	0	0.033	0.012	0.077	0.42
> 5.00	0	0	0	0	0	0	0	0.000052	0.0001	0.0033	0.064

Table 63. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Inalusan	Lalaguna	Lourdes	Magsaysay	Maguilayan	Mahayod-Hayod	Manguisian	Matinik	Monteclaro	Pamampangin	Peñafrancia
0.03-0.20	1.65	1.58	0.11	0.078	0.57	1.05	0.23	0.34	2.79	1.28	0.78
0.21-0.50	0.15	0.1	0.0031	0.093	0.072	0.083	0.14	0.085	0.12	0.15	0.074
0.51-1.00	0.12	0.11	0.00035	0.057	0.078	0.14	0.34	0.24	0.089	0.15	0.089
1.01-2.00	0.077	0.14	0	0.025	0.23	0.35	0.45	0.15	0.078	0.23	0.2
2.01-5.00	0.22	1.25	0	0.0062	0.14	0.071	0.0004	0.0008	0.045	0.032	0.25
> 5.00	0.0011	0	0	0	0	0.0005	0	0	0.00052	0	0.01

Table 64. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Pisipis	Rizal	Rosario	Samat	San Antonio	San Isidro	San Jose	San Pedro	San Roque	Santa Lucia	Santa Rosa
0.03-0.20	0.92	1.52	3.15	1.43	1.48	1.4	1.68	0.92	0.93	1.99	0.46
0.21-0.50	0.051	0.21	0.26	0.11	0.24	0.051	0.38	0.029	0.13	0.28	0.028
0.51-1.00	0.019	0.27	0.36	0.26	0.31	0.029	0.31	0.021	0.14	0.14	0.012
1.01-2.00	0.012	0.61	0.27	0.61	0.35	0.028	0.21	0.025	0.58	0.052	0.0059
2.01-5.00	0.024	0.41	0.41	0.66	0.34	0.03	0.022	0.018	0.86	0.0037	0.0031
> 5.00	0.0021	0	0	0.05	0.0003	0.0043	0	0.0041	0	0	0

Table 65. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)										
	Santa Teresa	Santo Niño Ibaba	Santo Niño Ilaya	Silang	Talolong	Tan-Ag Ibaba	Tan-Ag ilaya	Tocalin	Vergaña	Veronica	Villa Aurora
0.03-0.20	0.36	0.0033	0.0022	0.77	0.078	0.38	0.68	1.68	0.19	1.73	1.21
0.21-0.50	0.078	0.000002	0.00011	0.089	0.045	0.14	0.067	0.087	0.011	0.071	0.058
0.51-1.00	0.12	0.000018	0.000046	0.2	0.022	0.25	0.11	0.1	0.0092	0.095	0.036
1.01-2.00	0.19	0.000061	0.000044	0.61	0.0099	0.55	0.31	0.22	0.016	0.24	0.086
2.01-5.00	0	0.000088	0	0.98	0.012	0.47	0.25	0.88	0.015	0.064	0.068
> 5.00	0	0	0	0.057	0.002	0	0.014	0	0	0	0.0004

Table 66. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lopez (in sq. km.)				
	Villa Espina	Villa Geda	Villa Hermosa	Villamonte	Villanacaob
0.03-0.20	2.24	2.6	1.97	1.77	0.8
0.21-0.50	0.086	0.14	0.31	0.14	0.03
0.51-1.00	0.061	0.089	0.19	0.25	0.013
1.01-2.00	0.072	0.097	0.076	0.34	0.0087
2.01-5.00	0.032	0.16	0.12	0.75	0.0009
> 5.00	0	0	0.076	0	0

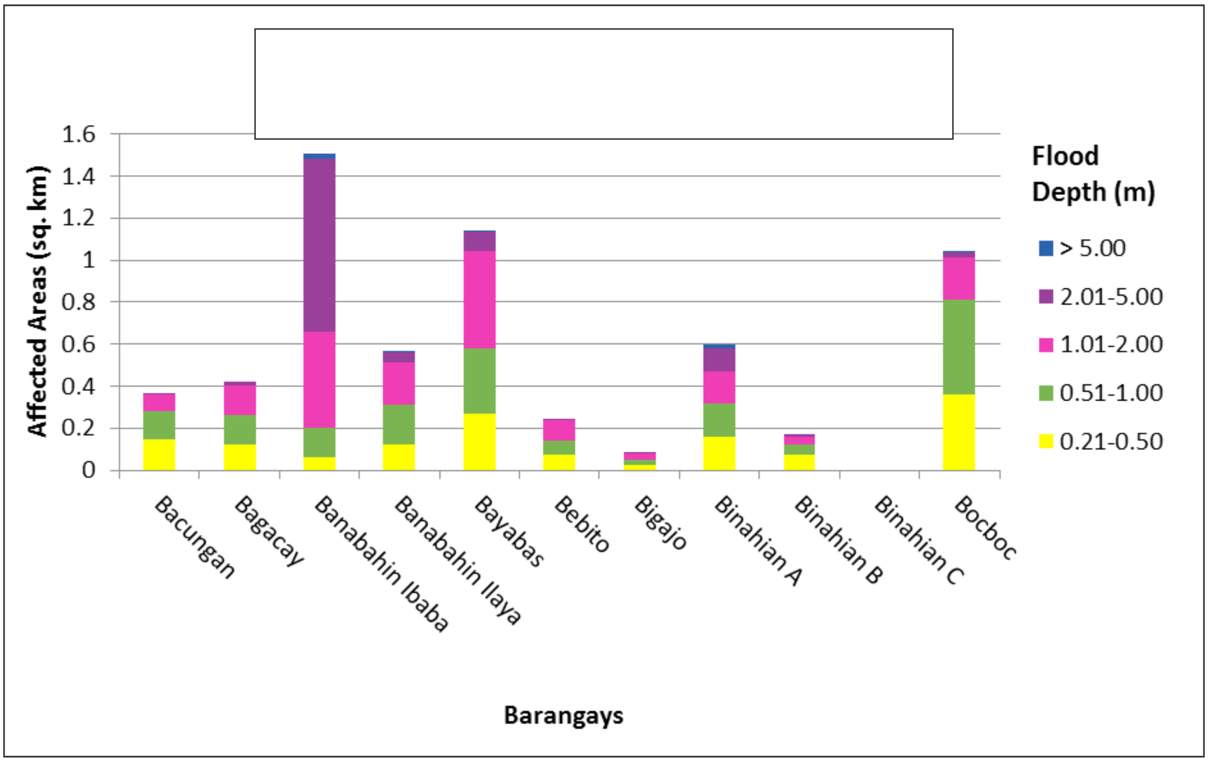


Figure 101. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

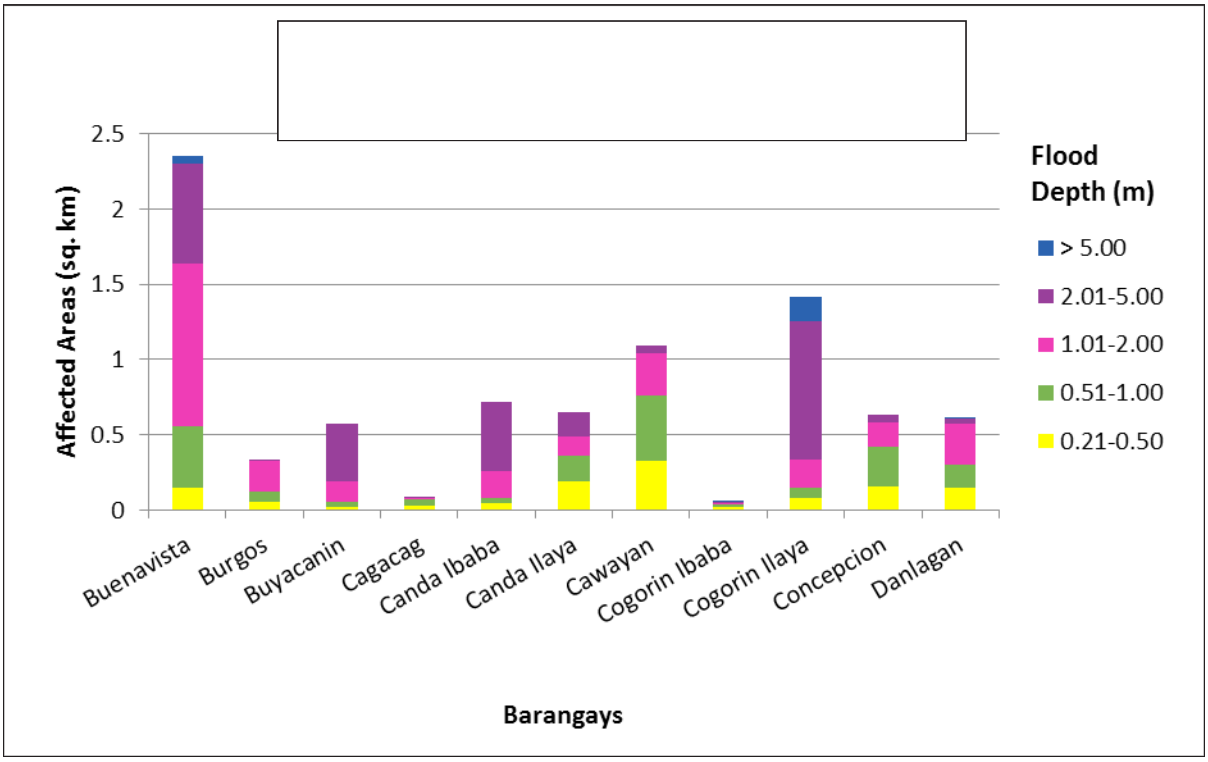


Figure 102. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

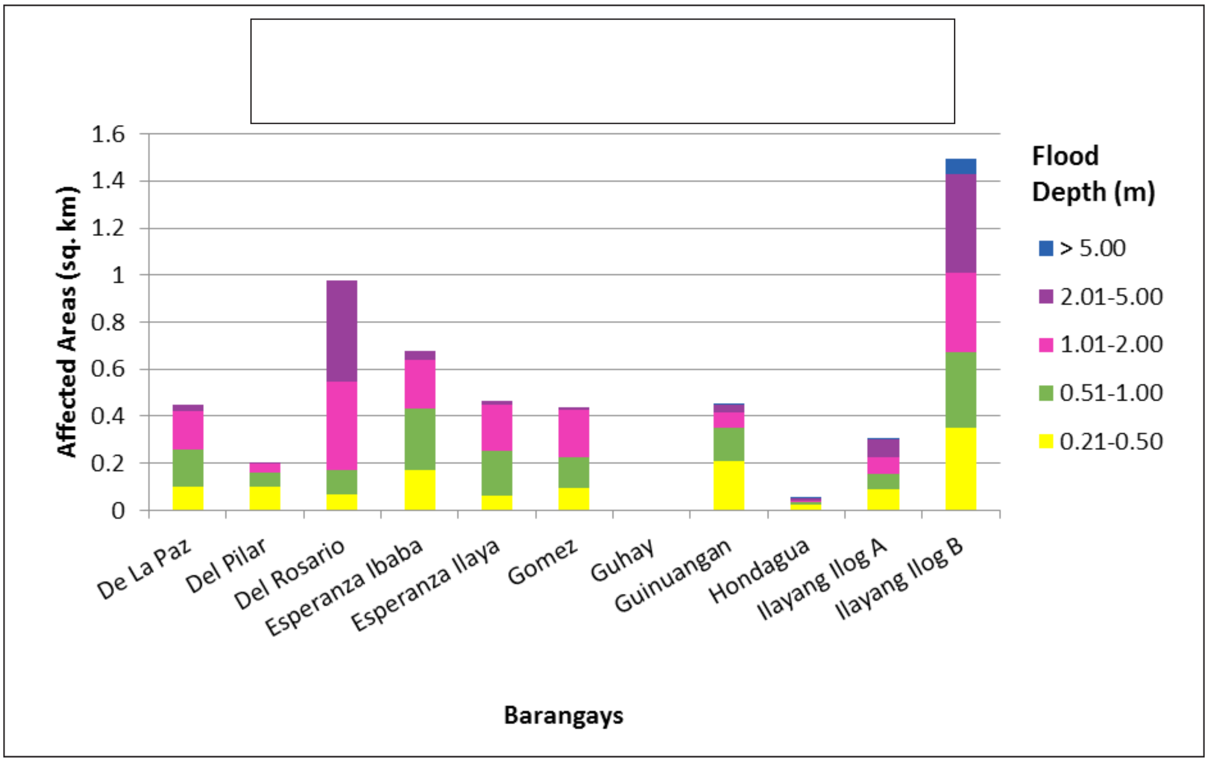


Figure 103. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

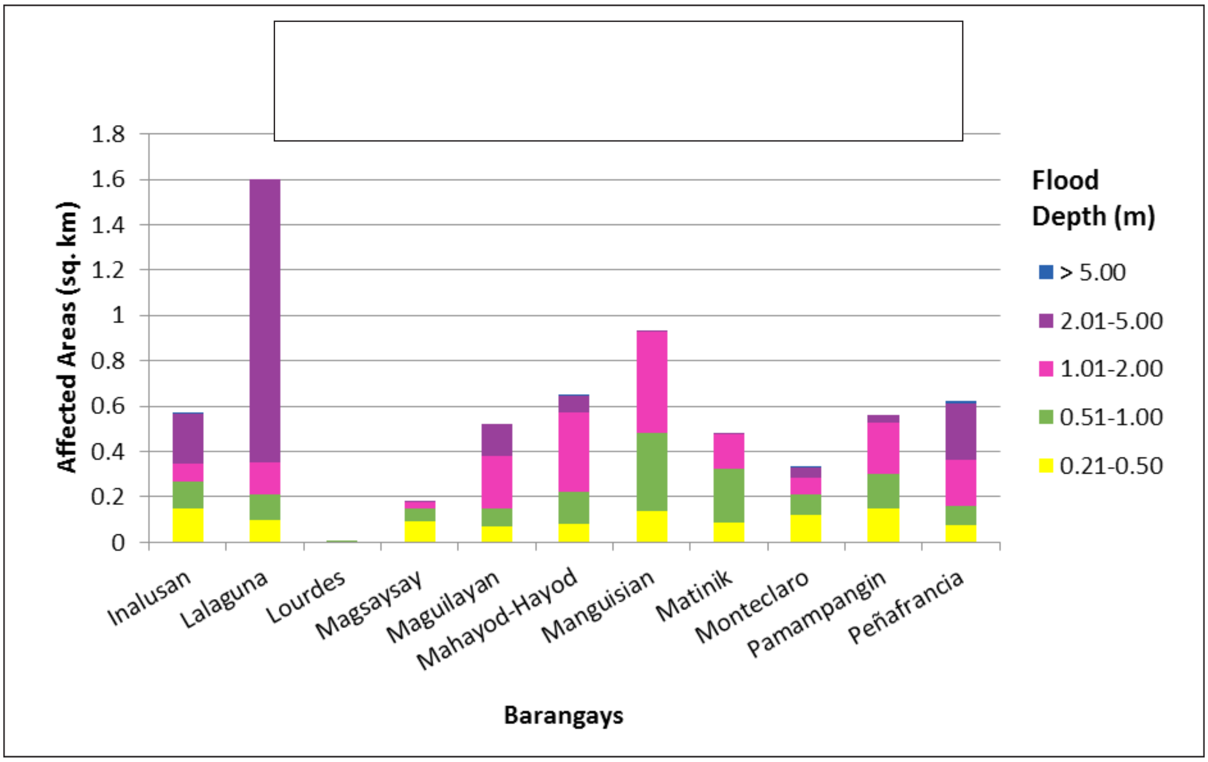


Figure 104. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

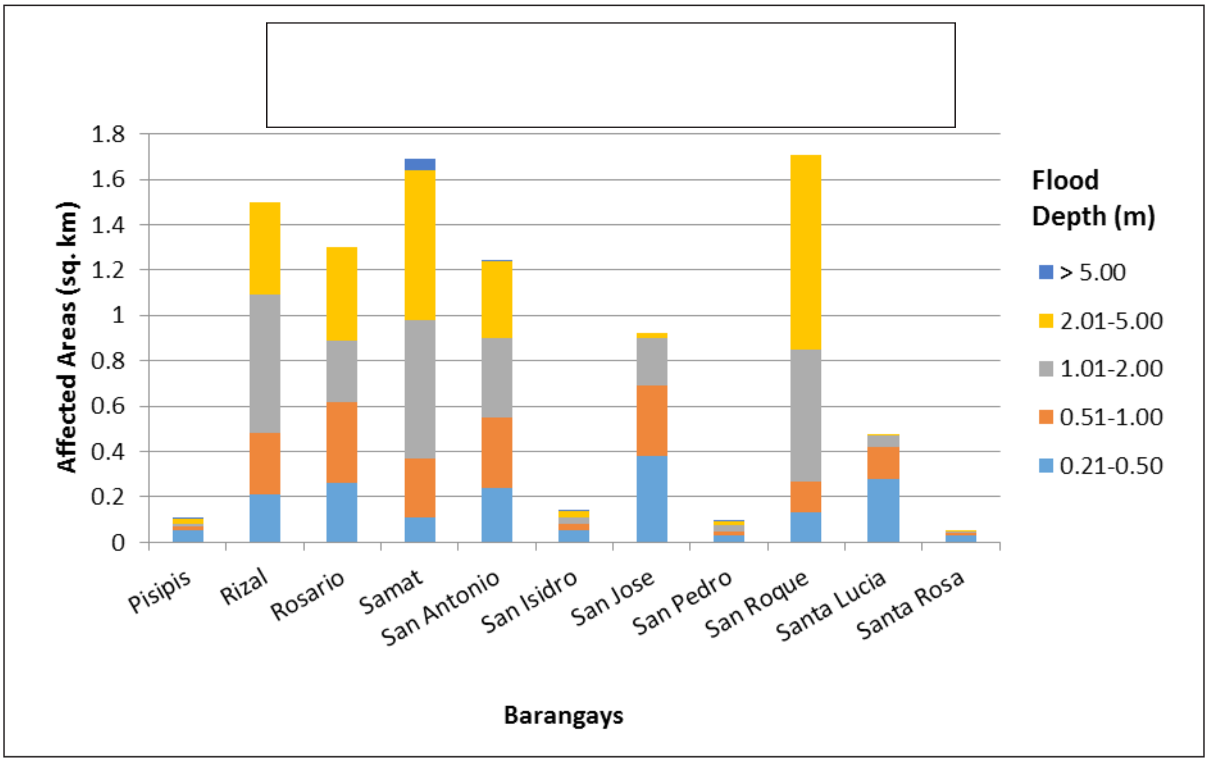


Figure 105. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

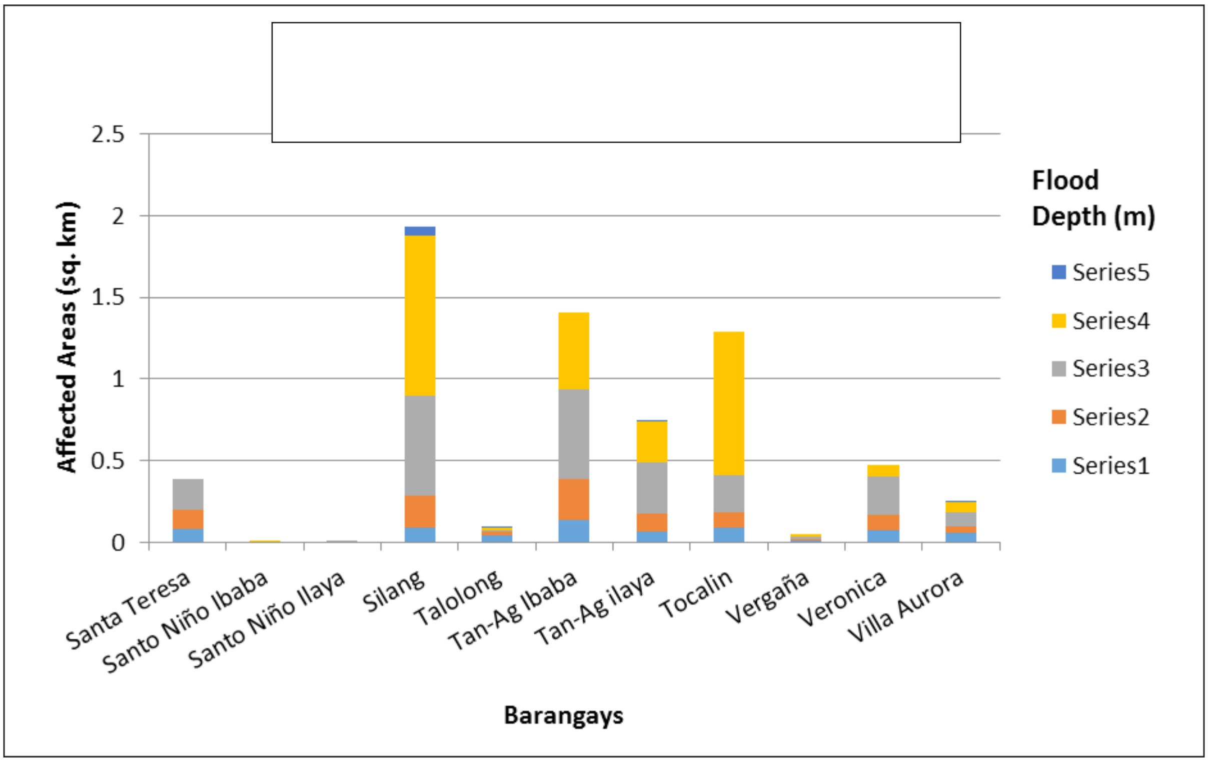


Figure 106. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

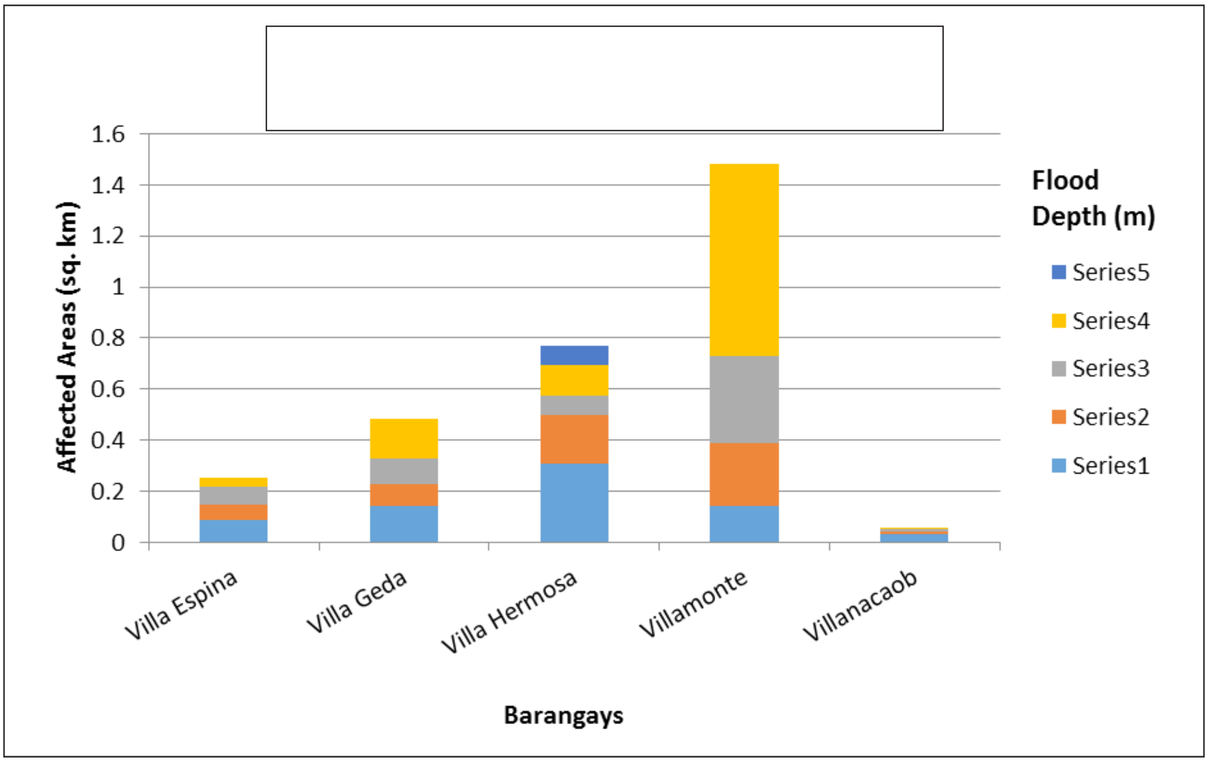


Figure 107. Affected areas in Lopez, Quezon during a 100-Year Rainfall Return Period

For the 100-year return period, 0.66% of the municipality of Guinayangan with an area of 225.57 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.02%, 0.03%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 67 and shown in Figure 108 are the affected areas in square kilometres by flood depth per barangay.

Table 67. Affected areas in Guinayangan, Quezon during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guinayangan (in sq. km.)		
	Danlagan Batis	Ermita	San Antonio
0.03-0.20	0.79	0.00084	0.7
0.21-0.50	0.063	0	0.039
0.51-1.00	0.052	0	0.029
1.01-2.00	0.034	0	0.019
2.01-5.00	0.039	0	0.019
> 5.00	0.021	0	0.014

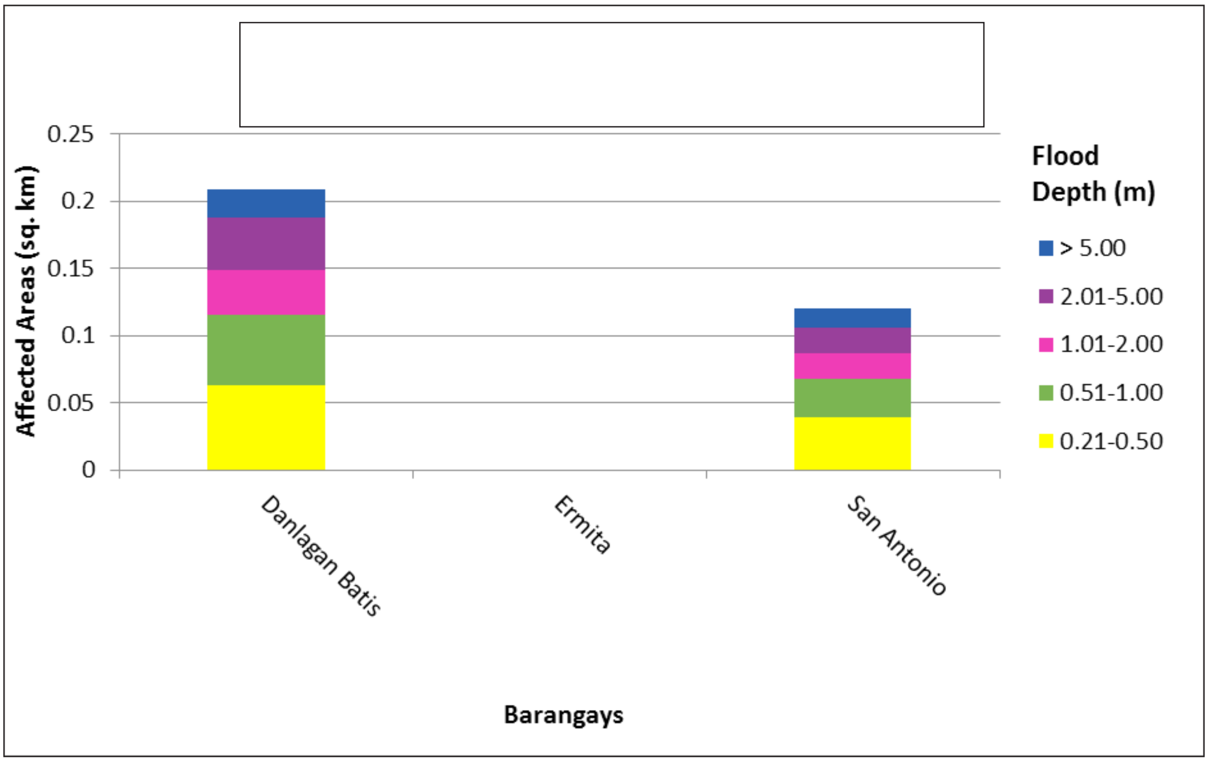


Figure 108. Affected Areas in Guinayangan, Quezon during 100-Year Rainfall Return Period

For the 100-year return period, 15.19% of the municipality of Calauag with an area of 312.32 sq. km. will experience flood levels of less than 0.20 meters. 1.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.93%, 1.32%, 2.84%, and 1.81% 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 68 to Table 71, and shown in are the affected areas in square kilometres by flood depth per barangay.

Table 68. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Bangkuruhan	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Bigaan	Binutas	Biyan	Dominlog
0.03-0.20	0.23	0.036	0.11	0.082	0.038	0.02	1.29	2.42	0.44	0.089
0.21-0.50	0.008	0.009	0.0073	0.0091	0.0017	0.0027	0.076	0.21	0.029	0.005
0.51-1.00	0.0049	0.014	0.0064	0.0088	0.0021	0.0051	0.059	0.14	0.032	0.001
1.01-2.00	0.0071	0.015	0.015	0.019	0.014	0.023	0.11	0.35	0.04	0.0008
2.01-5.00	0.4	0.12	0.033	0.039	0.037	0.16	0.25	0.43	0.2	0.00077
> 5.00	0.88	0.0093	0	0	0	0	0.0015	0.068	0.87	0.0014

Table 69. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Kalibo	Kigtan	Kinalin Ibaba	Kinalin Ilaya	Kumaludkud	Mabini	Maglipad	Mambaling	Manhulugin	Marilag
0.03-0.20	2.65	6.38	1.43	1.4	0.92	0.52	4.12	1.77	1.69	1.13
0.21-0.50	0.11	0.32	0.1	0.056	0.076	0.052	0.26	0.08	0.12	0.052
0.51-1.00	0.06	0.21	0.21	0.021	0.09	0.036	0.24	0.053	0.083	0.037
1.01-2.00	0.12	0.12	0.4	0.017	0.14	0.12	0.15	0.072	0.21	0.1
2.01-5.00	0.12	0.025	0.27	0.015	0.28	0.65	0.13	0.15	0.63	0.13
> 5.00	0	0	0	0	0	0.12	0.1	0.5	0	0.015

Table 70. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)									
	Pandanan	Pansol	Patihan	Pinagkamaligan	Pinagtalleran	Rizal Ibaba	Rizal Ilaya	Sabang I	Sabang II	Salvacion
0.03-0.20	1.17	2.92	0.62	0	0	0.4	1.54	0.22	0	3.3
0.21-0.50	0.28	0.2	0.045	0	0	0.023	0.11	0.011	0	0.2
0.51-1.00	0.45	0.19	0.054	0.0001	0	0.018	0.069	0.019	0.0019	0.14
1.01-2.00	0.66	0.24	0.11	0.014	0	0.029	0.058	0.056	0.039	0.14
2.01-5.00	0.17	0.22	0.47	0.2	0.022	0.35	0.049	0.39	0.48	0.13
> 5.00	0	0.0087	0.017	0.026	0	0.22	0.0002	0.054	0	0.3

Table 71. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calauag (in sq. km.)								
	San Roque Ibaba	San Roque Ilaya	Santa Maria	Santa Milagrosa	Santa Rosa	Sumilang	Sumulong	Tikiwan	Yaganak
0.03-0.20	1.38	2.13	0.55	1.1	3.38	0.22	0.24	0.3	1.43
0.21-0.50	0.13	0.13	0.048	0.058	0.2	0.063	0.019	0.039	0.14
0.51-1.00	0.084	0.052	0.023	0.06	0.18	0.12	0.023	0.053	0.063
1.01-2.00	0.04	0.0097	0.032	0.057	0.22	0.24	0.067	0.13	0.038
2.01-5.00	0.052	0.0003	0.2	0.13	0.28	1.31	0.92	0.28	0.032
> 5.00	0.14	0	0.012	0.066	0	1.37	0.57	0.085	0.27

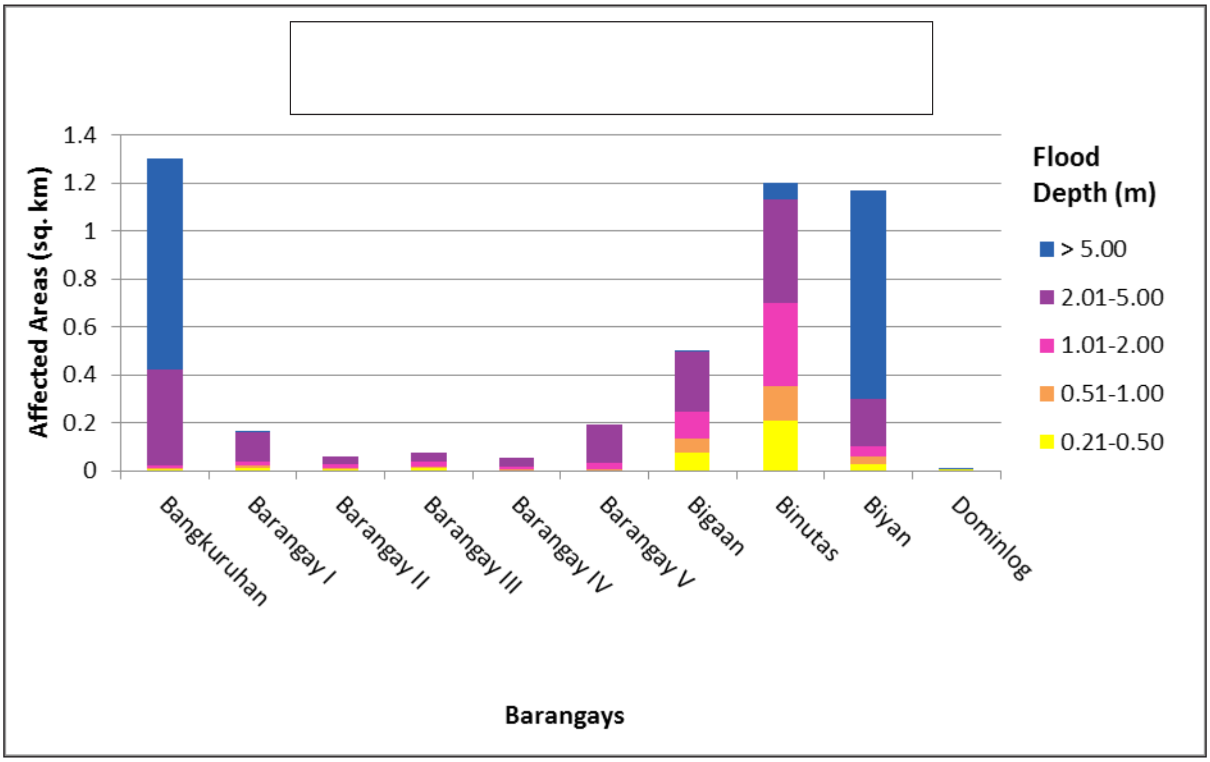


Figure 109. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

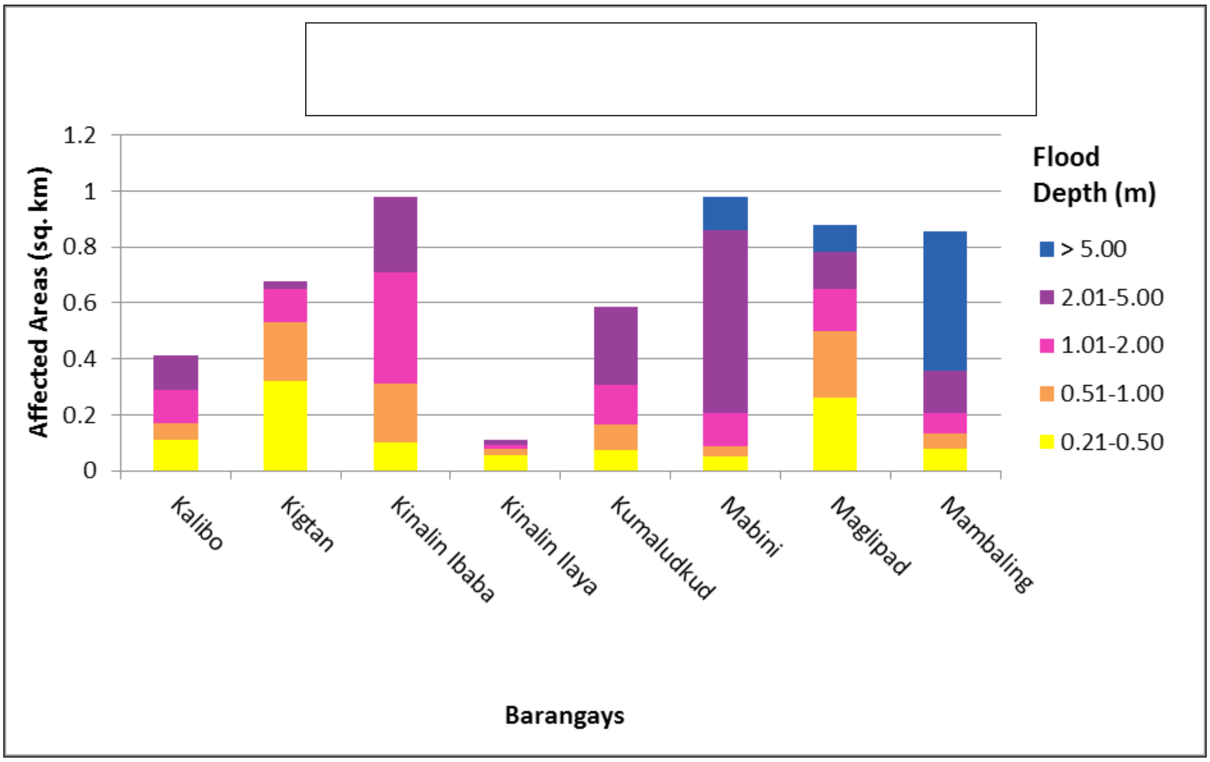


Figure 110. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

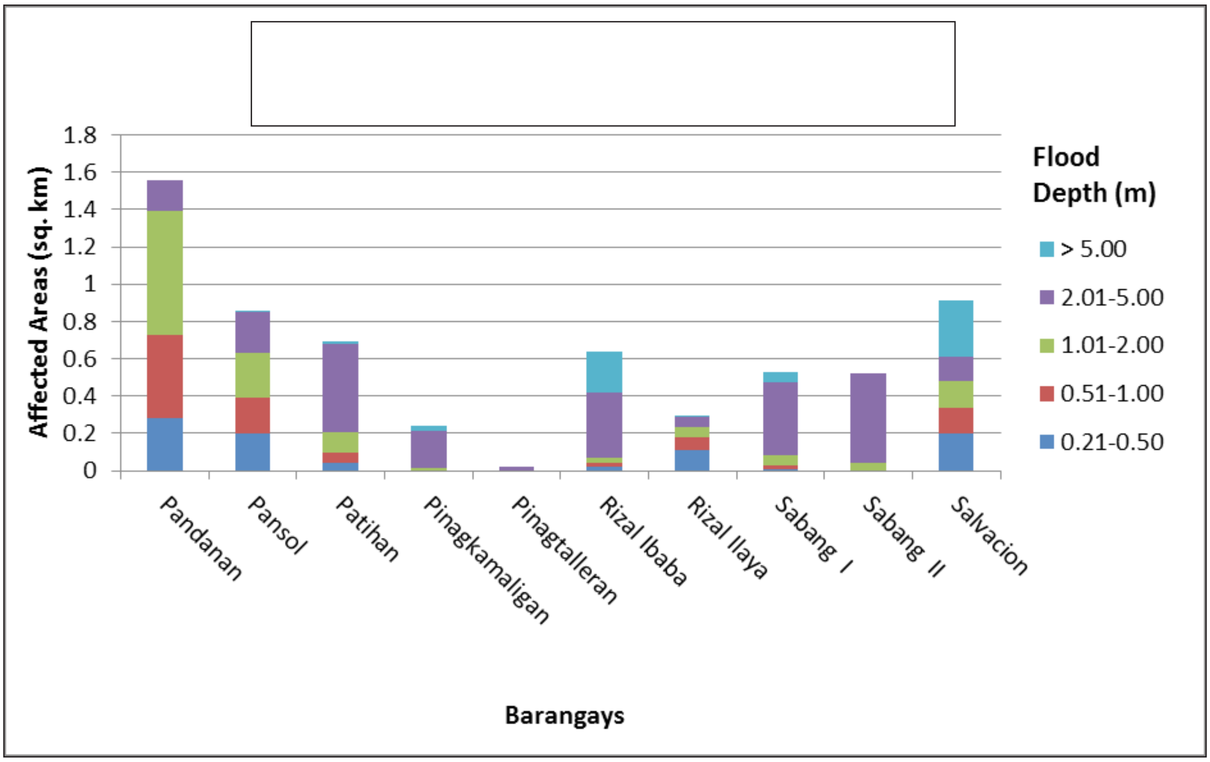


Figure 111. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

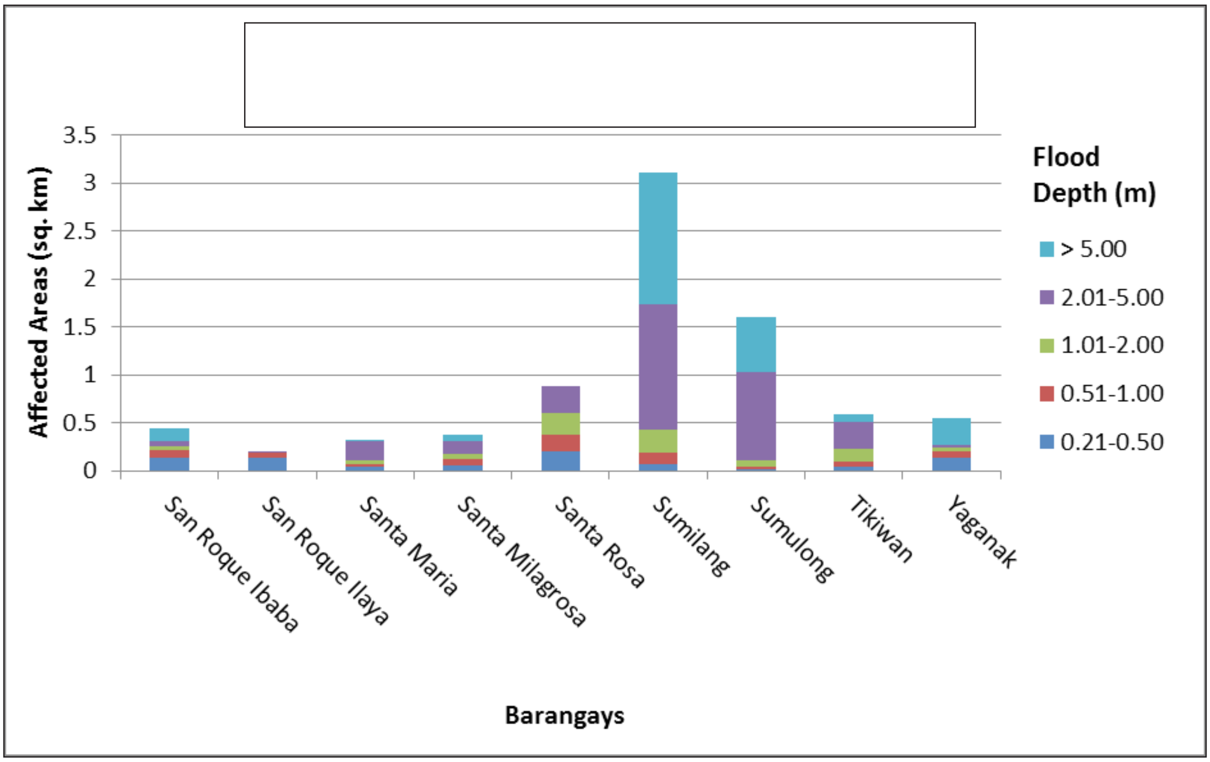


Figure 112. Affected areas in Calauag, Quezon during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Lopez, Quezon…

Among the barangays in the municipality of Guinayangan, Quezon...

Among the barangays in the municipality of Calauag, Quezon…

Moreover, the generated flood hazard maps for the Pandanan 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 72. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	16.24	13.26	11.73
Medium	28.25	26.41	22.47
High	14.63	28.94	39.054
TOTAL	59.12	68.61	73.25

Of the 9 identified Education Institute in Pandanan Flood plain, one (1) school was discovered exposed to Low-level flooding during the 5-year scenario. In the 25-year scenario, two (2) schools were found exposed to Low-level flooding. For the 100-year scenario, one (1) school was discovered exposed to Low-level flooding while two were exposed to Medium-level flooding. The educational institutions exposed to flooding are shown in Annex 12

Apart from this, three (3) Medical Institutions were identified in the Pandanan Floodplain, yet only one (1) was discovered exposed to Medium-level flooding in the 100-year scenario. The medical institutions exposed to 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 113.

The flood validation consisted of 184 points randomly selected all over the Pandanan floodplain (Figure 114). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.91m. Table 73 shows a contingency matrix of the comparison.

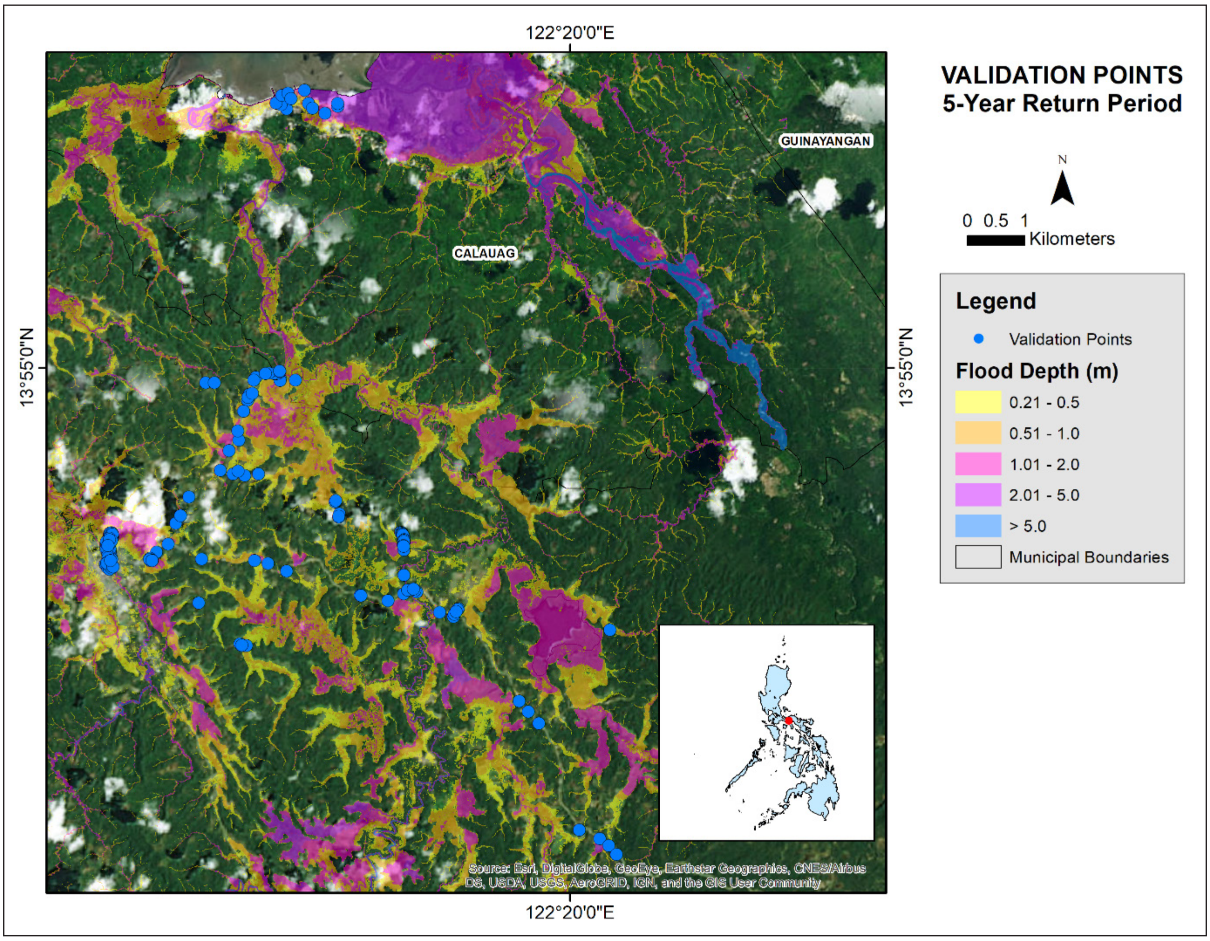


Figure 113. Pandanan Flood Validation Points

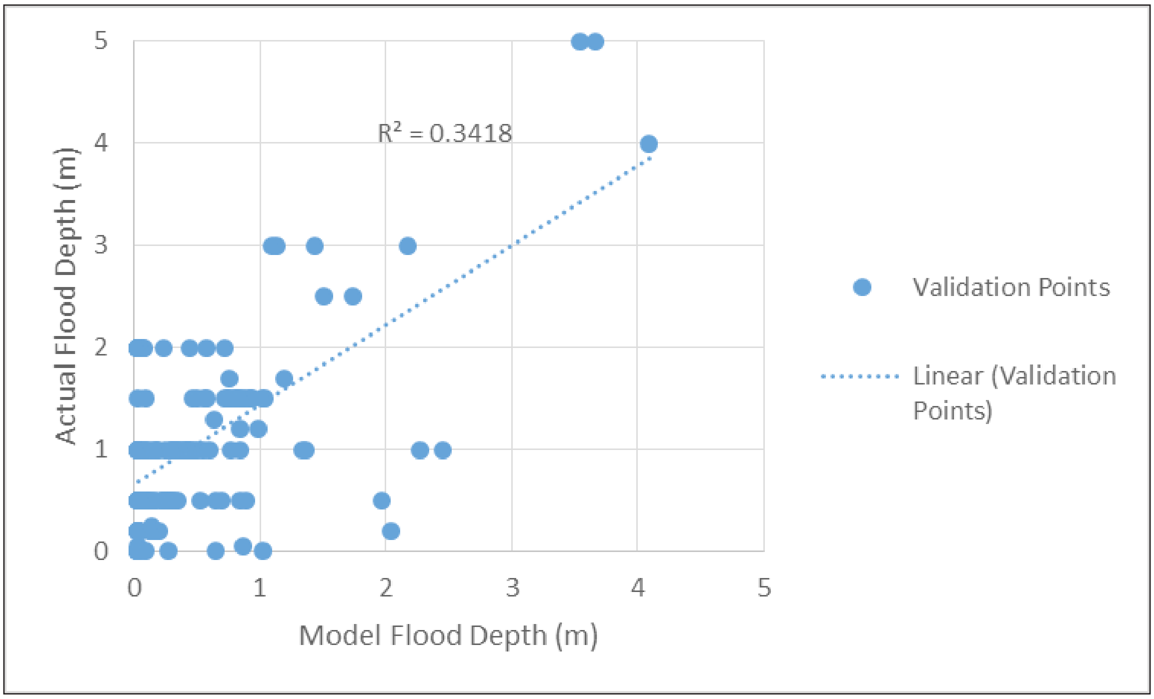


Figure 114. Flood map depth vs. actual flood depth

Table 73. Actual flood vs simulated flood depth at different levels in the Pandanan 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	33	1	2	1	1	0	38
0.21-0.50	26	13	5	1	0	0	45
0.51-1.00	19	17	4	2	2	0	44
1.01-2.00	20	4	21	3	0	0	48
2.01-5.00	0	0	0	5	4	0	9
> 5.00	0	0	0	0	0	0	0
Total	98	35	32	12	7	0	184

The overall accuracy generated by the flood model is estimated at 30.98% with 57 points correctly matching the actual flood depths. In addition, there were 60 points estimated one level above and below the correct flood depths while there were 28 points and 22 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 112 points were underestimated in the modelled flood depths of Pandanan. Table 74 depicts the summary of the Accuracy Assessment in the Pinantan River Basin Survey.

Table 74. Summary of the Accuracy Assessment in the Pandanan River Basin Survey

	No. of Points	%
Correct	57	**30.98**
Overestimated	15	**8.15**
Underestimated	112	**60.87**
Total	184	**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

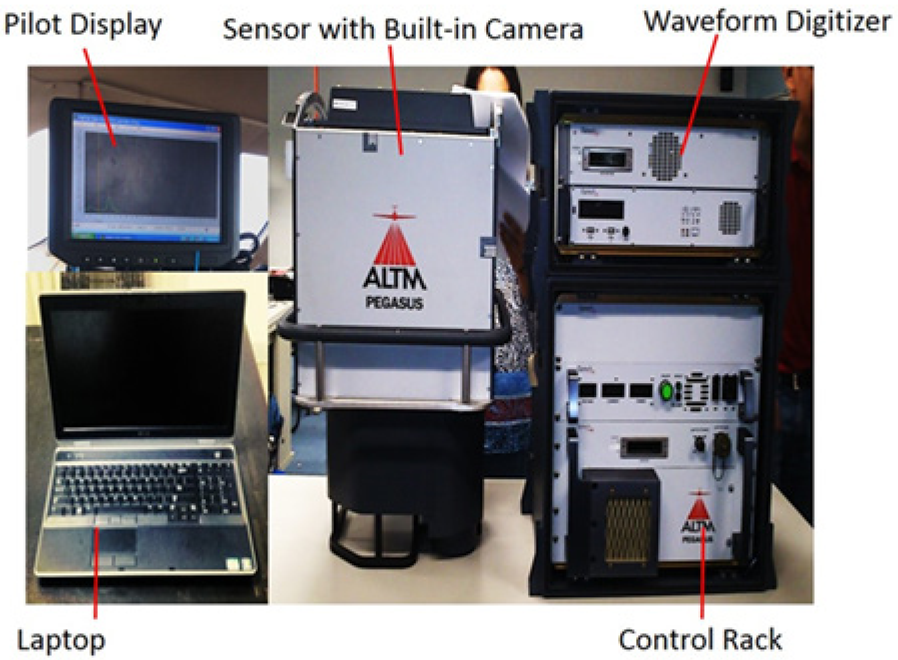


Figure A-1.1 Pegasus Sensor

Table A-1.1 Pegasus Sensor Parameters and Specification

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

Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

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**

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

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

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

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

1. QZ-641

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. QZ-641

2. QZN-3946

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

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

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

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

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

Figure A-3.2. QZN-3946

3. QZN-J2

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

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

Vector Components (Mark to Mark)

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

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

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

Figure A-3.3. QZN-J2

Annex 4. The LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. LOUIE P. BALICANTA</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUNA</td><td>UP TCAGP</td></tr>
<tr><td>ENGR. LOVELYN ASUNCION</td><td>UP TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>JASMINE ALVIAR</td><td>UP-TCAGP</td></tr>
<tr><td>Research Associate (RA)</td><td>ENGR. KENNETH QUISADO</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>JERIEL PAUL ALAMBAN</td><td>UP-TCAGP</td></tr>
<tr><td>Ground Survey, Data Download & Transfer</td><td>RA</td><td>JASMIN DOMINGO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Airborne Security</td><td>TSG. BENJIE CARBOLLEDO</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="2">Pilot</td><td>CAPT. CESAR ALFONSO III</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. KHALIL ANTHONY CHI</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheet for Pandanan 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 5/16/16

16-30

Figure A-5.1 Data Transfer Sheet for Pandanan 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

16-31

Figure A-5.2 Data Transfer Sheet for Pandanan Floodplain - B

Annex 6. FLIGHT LOGS

1. Flight Log for 23244P (3090P) Mission

Data Acquisition Flight Log

Flight Log No.: 3090

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20B102B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Dart - Dart			
10 Date: 11 April 2016	12 Airport of Departure (Airport, City/Province): Dart		12 Airport of Arrival (Airport, City/Province): Dart		
13 Engine On: 1309H	14 Engine Off: 1559H	15 Total Engine Time: 2+50	16 Take off: 1314H	17 Landing: 1554H	18 Total Flight Time: 2+40
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20B; partially complete due to transition errors

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	[illegible] Carballedo	C. Alfonso III	J. Alviar	[illegible]
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-6.1 Flight log for 23244P (3090P) Mission

2. Flight Log for 23250P (3094P) Mission

Data Acquisition Flight Log

Flight Log No.: 3094

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
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

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

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

21 Remarks

Surveyed BLK 20 D

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Alviar	Bendie Carbolleds	C. Alfonso III	Kenneth Quisado	M.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 23250P (3094P) Mission

3. Flight Log for 23254P (3100P) 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, 2014	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0716H	14 Engine Off: 1009H	15 Total Engine Time: 2+53	16 Take off: 0721H	17 Landing: 1004H	18 Total Flight Time: 2+43
19 Weather: heavy build up					

20 Flight Classification

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

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

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

21 Remarks

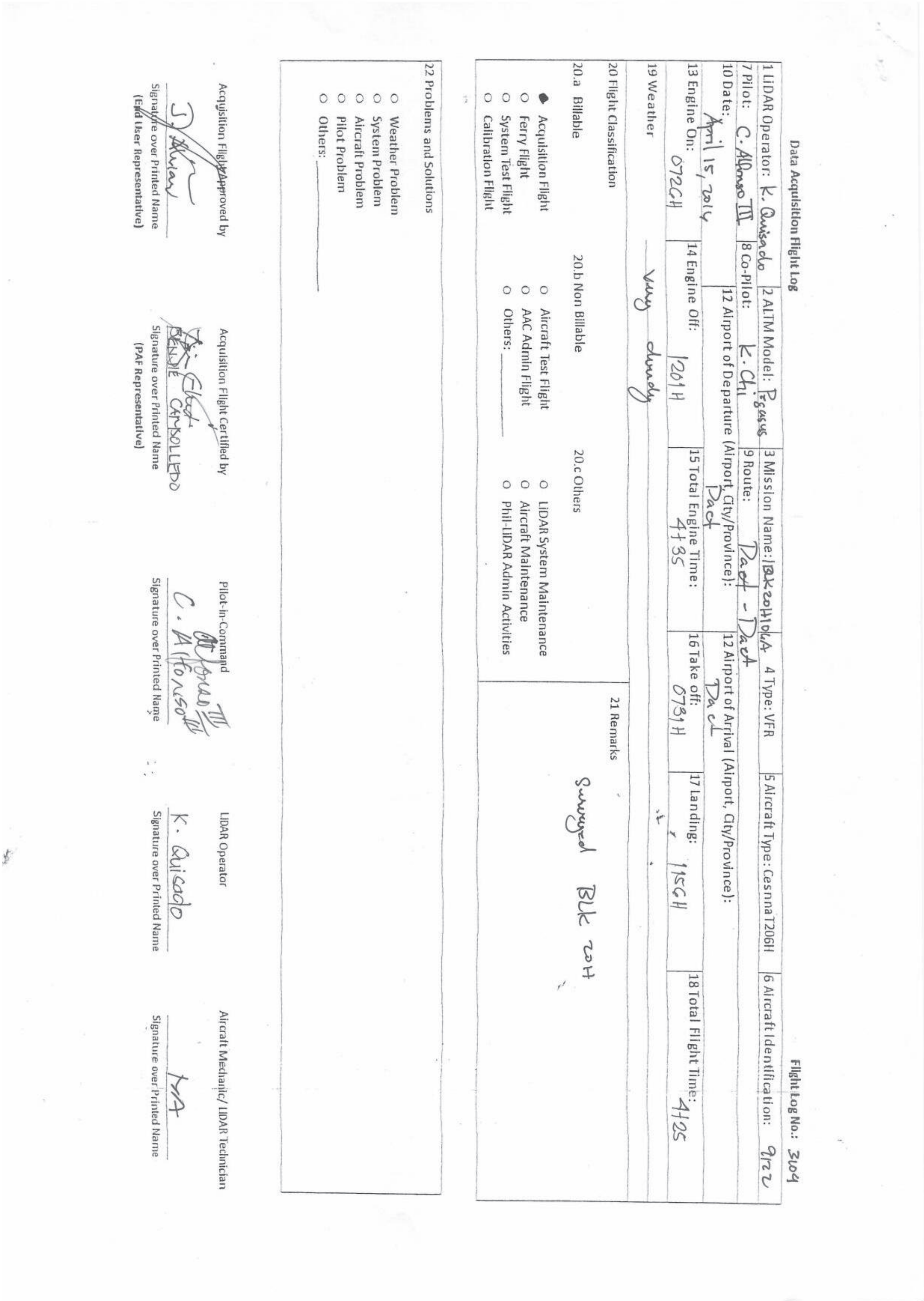
Surveyed BLK 20G

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Alviar	Bennie Carbolledo	C. Alfonso III	K. Quisado	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3 Flight log for 23254P (3100P) Mission

Flight Log for 23258P (3104P) 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: Pact - Pact			
10 Date: April 15, 2014	12 Airport of Departure (Airport, City/Province): Pact		12 Airport of Arrival (Airport, City/Province): Pact		
13 Engine On: 0726H	14 Engine Off: 1201H	15 Total Engine Time: 4+35	16 Take off: 0731H	17 Landing: 1156H	18 Total Flight Time: 4+25
19 Weather	very cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20H

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

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

Acquisition Flight Certified by: Bendie Cambolledo — Signature over Printed Name (PAF Representative)

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

LiDAR Operator: K. Quisado — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: — Signature over Printed Name

Figure A-6.4 Flight log for 23258P (3104P) Mission

Flight Log for 23260P (3106P) Mission

Data Acquisition Flight Log

Flight Log No.: 3106

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

20 Flight Classification

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

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

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

21 Remarks

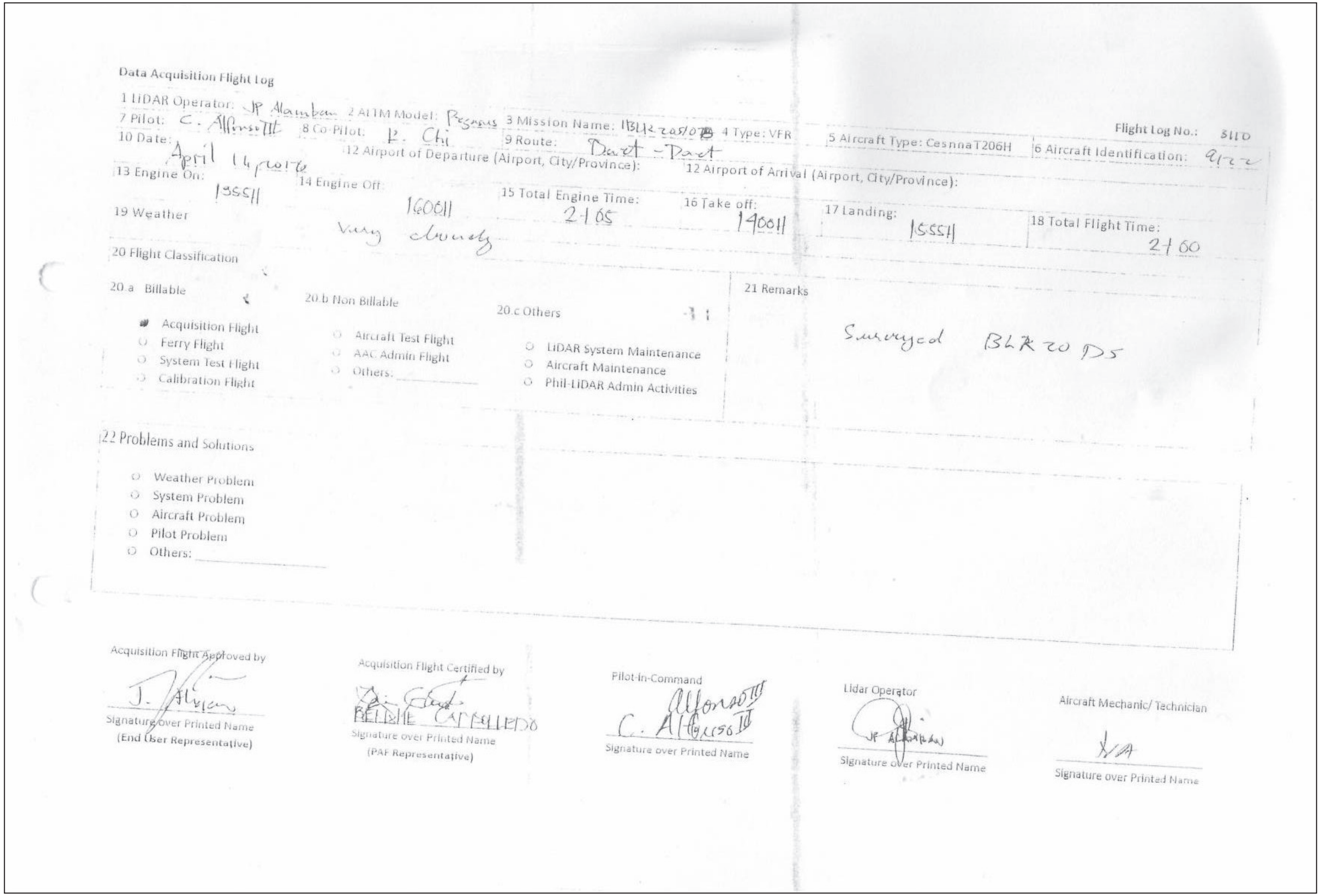
Surveyed BLK 20F

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Alviar	Bernie Carbolledo	C. Alfonso III	[signature]	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight log for 23260P (3106P) Mission

4. Flight Log for 23262P (3110P) Mission



Data Acquisition Flight Log

1 LiDAR Operator: JP Alambra 2 ALTM Model: Pegasus 3 Mission Name: 1BLK20S107B 4 Type: VFR 5 Aircraft Type: CesnnaT206H Flight Log No.: 3110
7 Pilot: C. Alfonso III 8 Co-Pilot: P. Chi 9 Route: Davt - Davt 6 Aircraft Identification: 9122
10 Date: April 14, 2016 12 Airport of Departure (Airport, City/Province): 12 Airport of Arrival (Airport, City/Province):
13 Engine On: 1355H 14 Engine Off: 1600H 15 Total Engine Time: 2+05 16 Take off: 1400H 17 Landing: 1555H 18 Total Flight Time: 2+00
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 BLK20DS

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

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

Acquisition Flight Certified by: Beldie Capellado — Signature over Printed Name (PAF Representative)

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

Lidar Operator: JP Alambra — Signature over Printed Name

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

Figure A-6.6 Flight log for 23262P (3110P) Mission

Annex 7. Flight Status Report

CAMARINES SUR & QUEZON

(April 4-18, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23244P	BLK 20C	1BLK20B102B	J ALVIAR	APRIL 11	SURVEYED VINAS FP
23250P	BLK 20G	1BLK20G104A	K QUISADO	APRIL 13	SURVEYED MACALELON, PANDANAN, PANDANAN FPs
23254P	BLK 20F	1BLK20F105A	K QUISADO	APRIL 14	SURVEYED PANDANAN, MACALELON, PANDANAN FPs
23258P	BLK 20H	1BLK20H106A	K QUISADO	APRIL 15	SURVEYED MACALELON, PANDANAN, PANDANAN FPs
23260P	BLK 20F	1BLK20F106B	J ALVIAR	APRIL 15	SURVEYED PANDANAN AND PANDANAN FPs AT 800M, LAST LINE AT 1000M
23262P	BLK 20HFG GAPS	1BLK20S107A	K QUISADO	APRIL 16	SURVEYED BLK 20FGH GAPS

LAS BOUNDARIES PER FLIGHT

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

LAS/SWATH

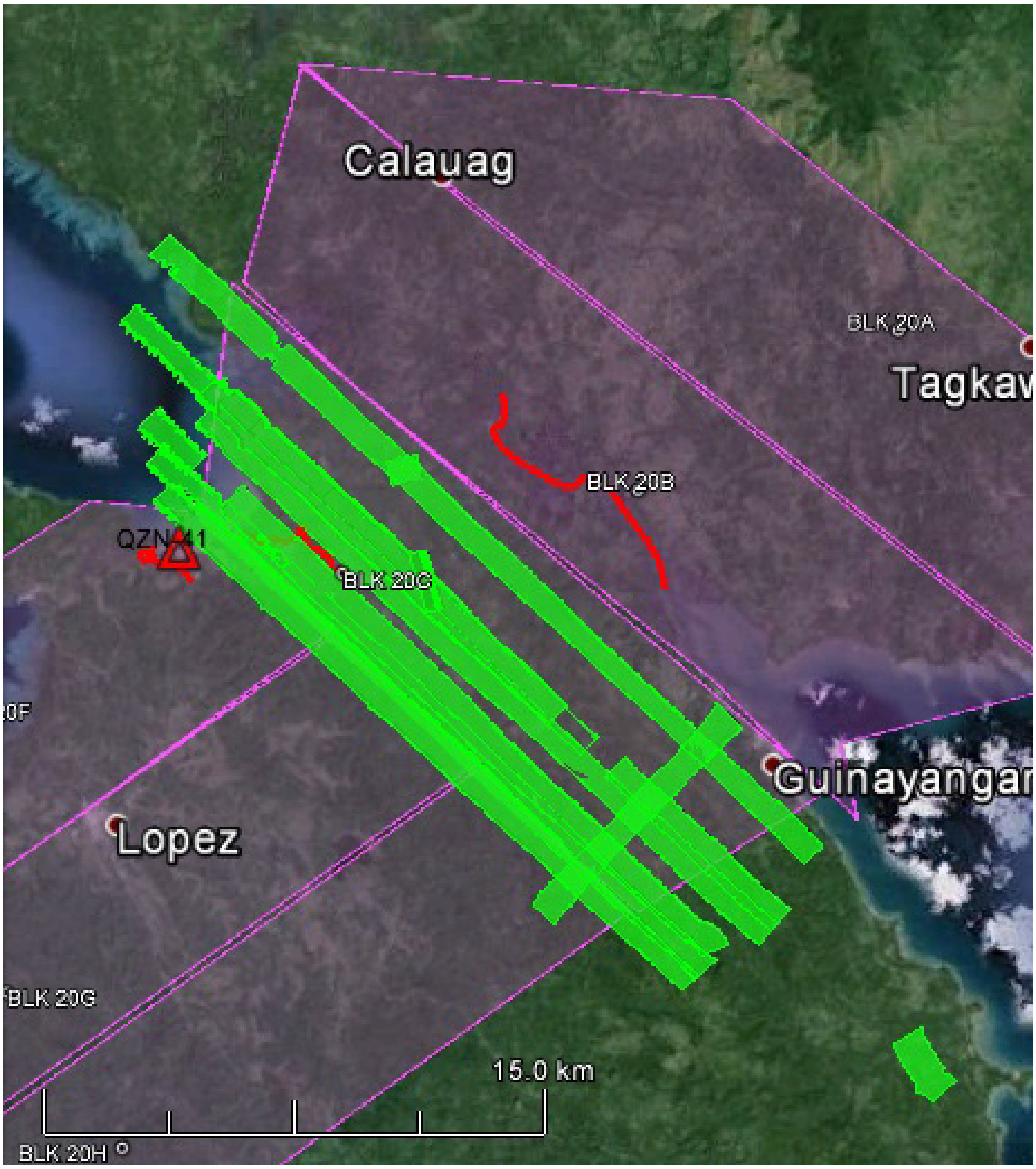


Figure A-7.1 Swath for Flight No. 23244P

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

LAS/SWATH

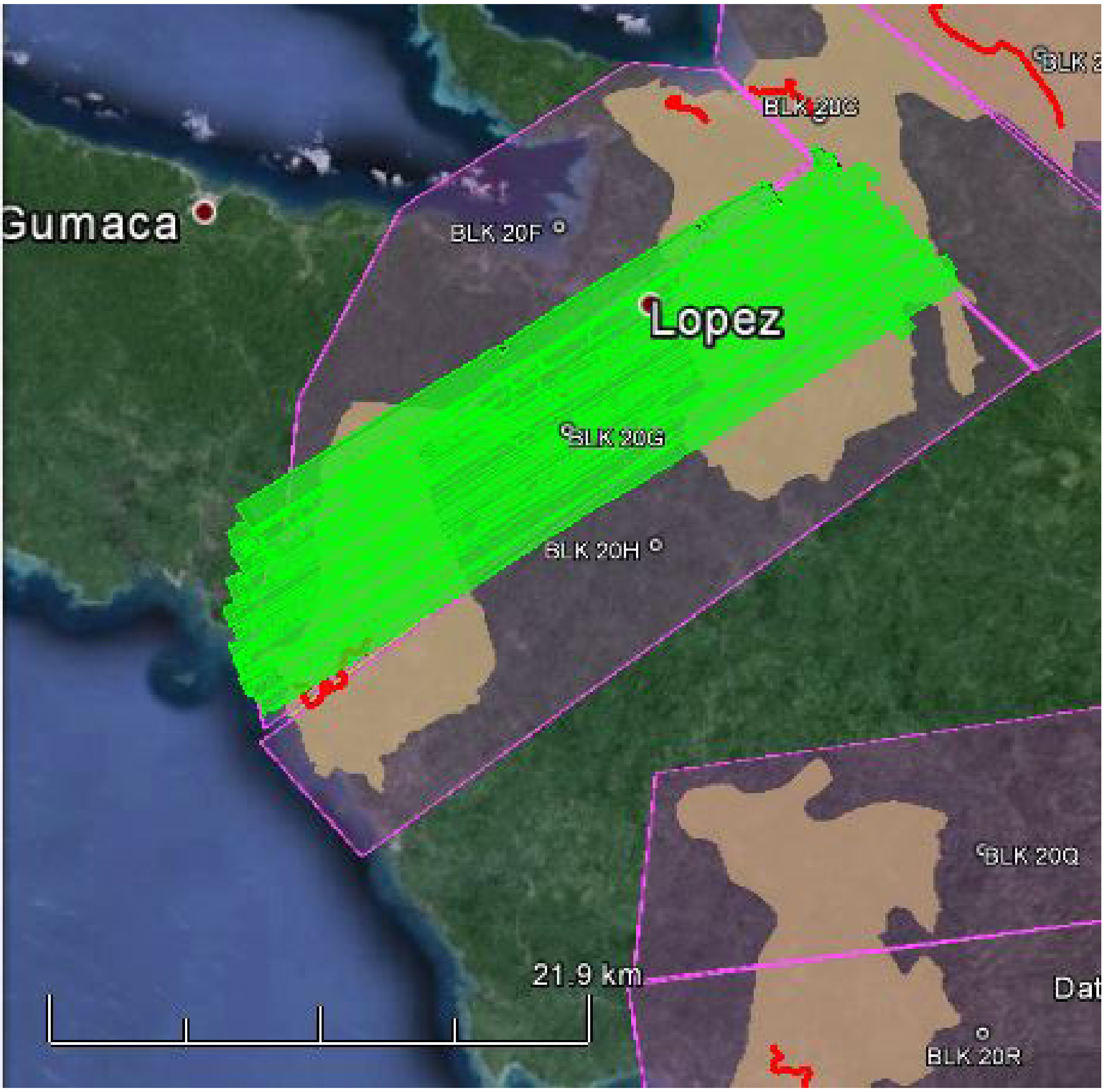


Figure A-7.2 Swath for Flight No. 23250P

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

LAS/SWATH

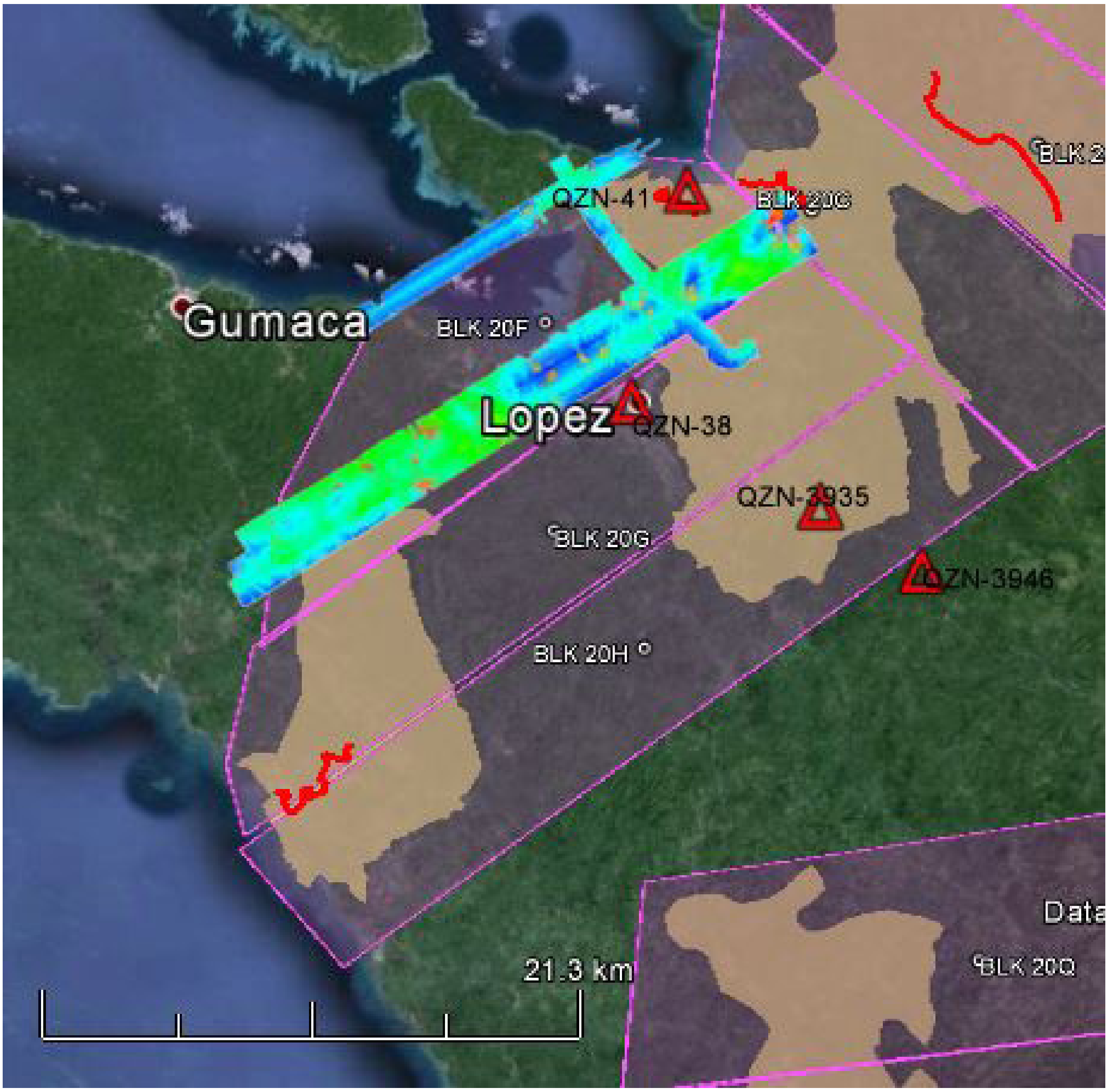


Figure A-7.3 Swath for Flight No. 23254P

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

LAS/SWATH

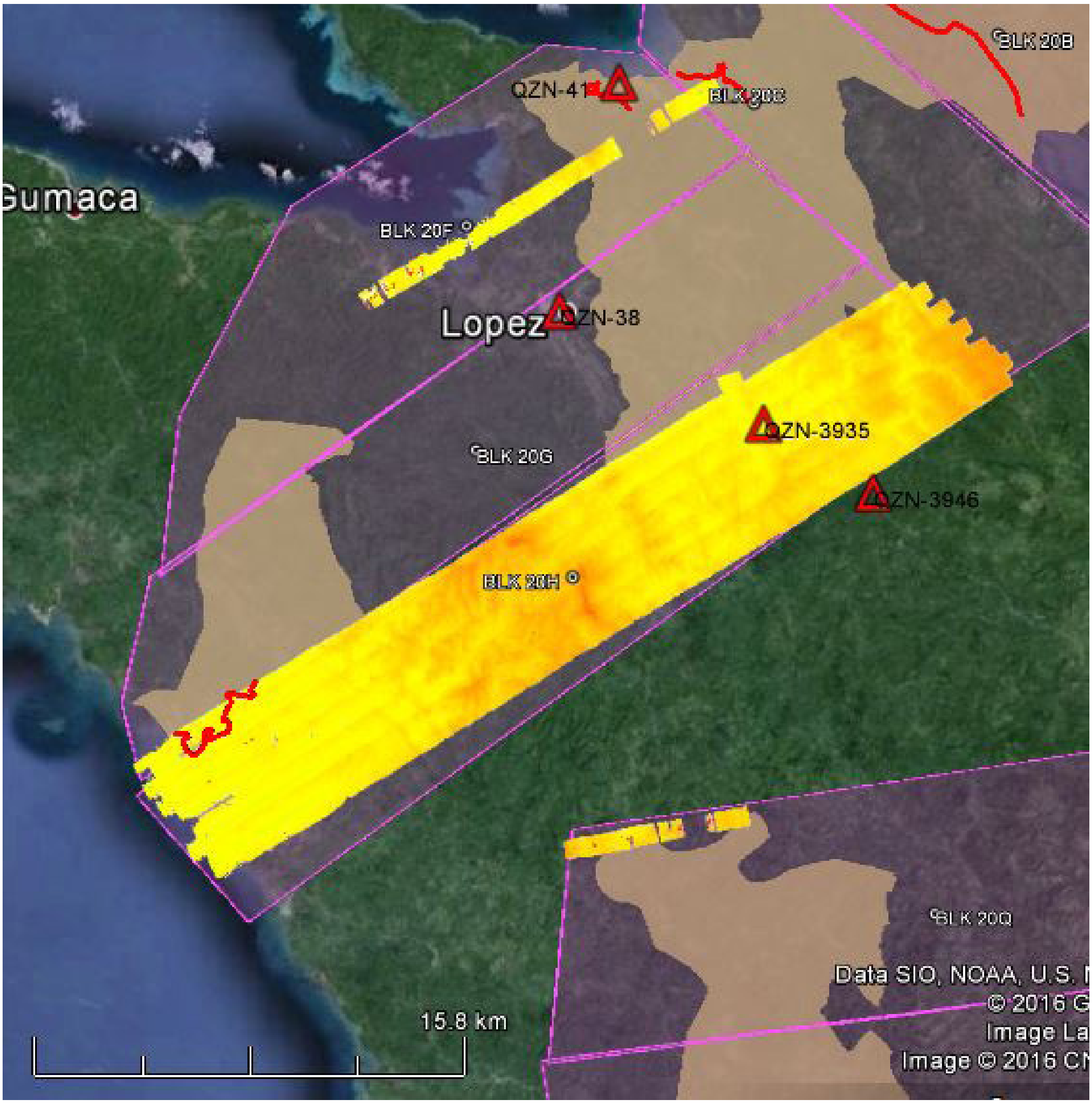


Figure A-7.4 Swath for Flight No. 23258P

Flight No. : 23260P
Parameters: PRF 200 SF 30 FOV 50

LAS/SWATH

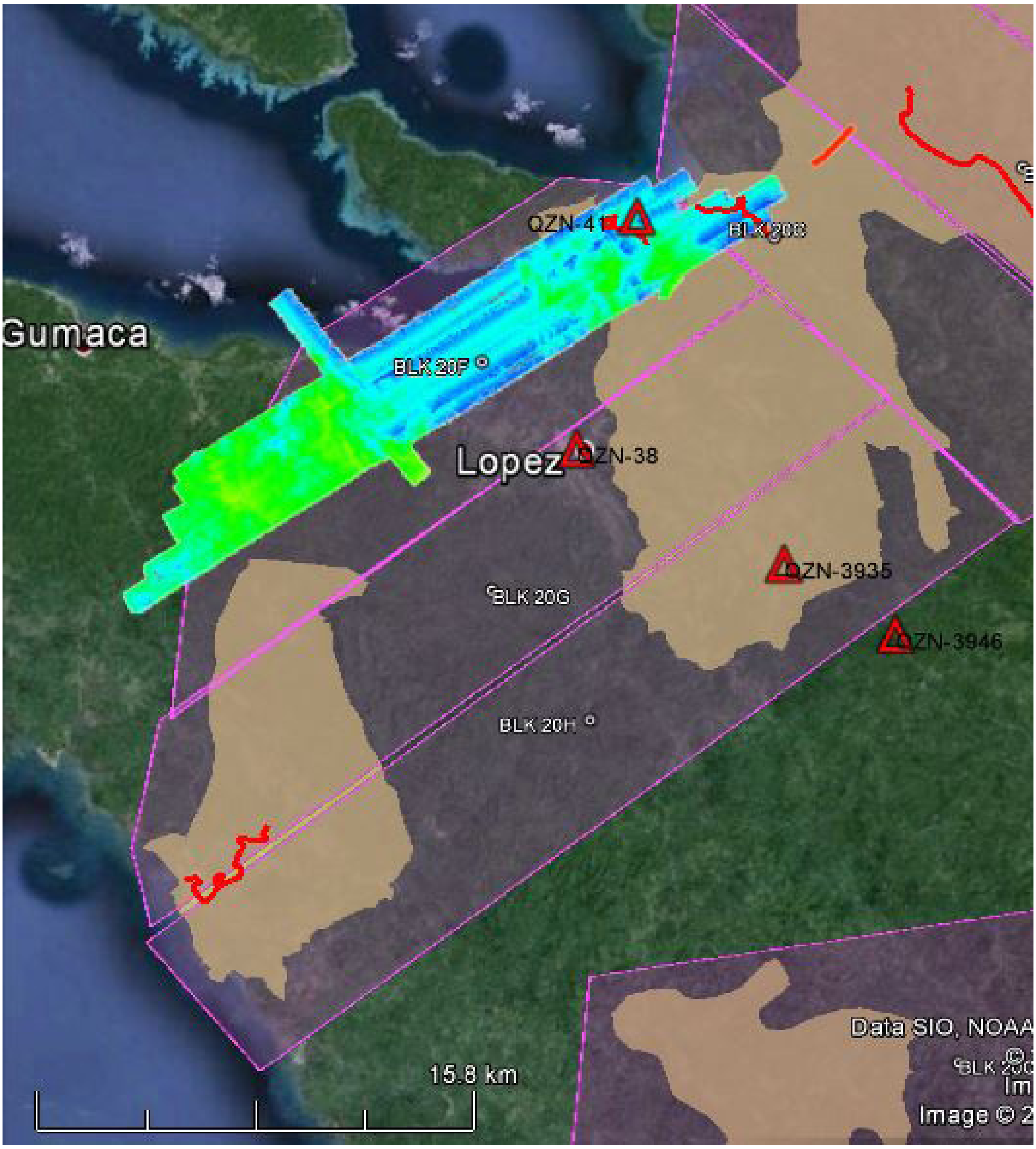


Figure A-7.5 Swath for Flight No. 23260P

Flight No. : 23262P
Parameters: PRF 200 SF 30 FOV 50

LAS/SWATH

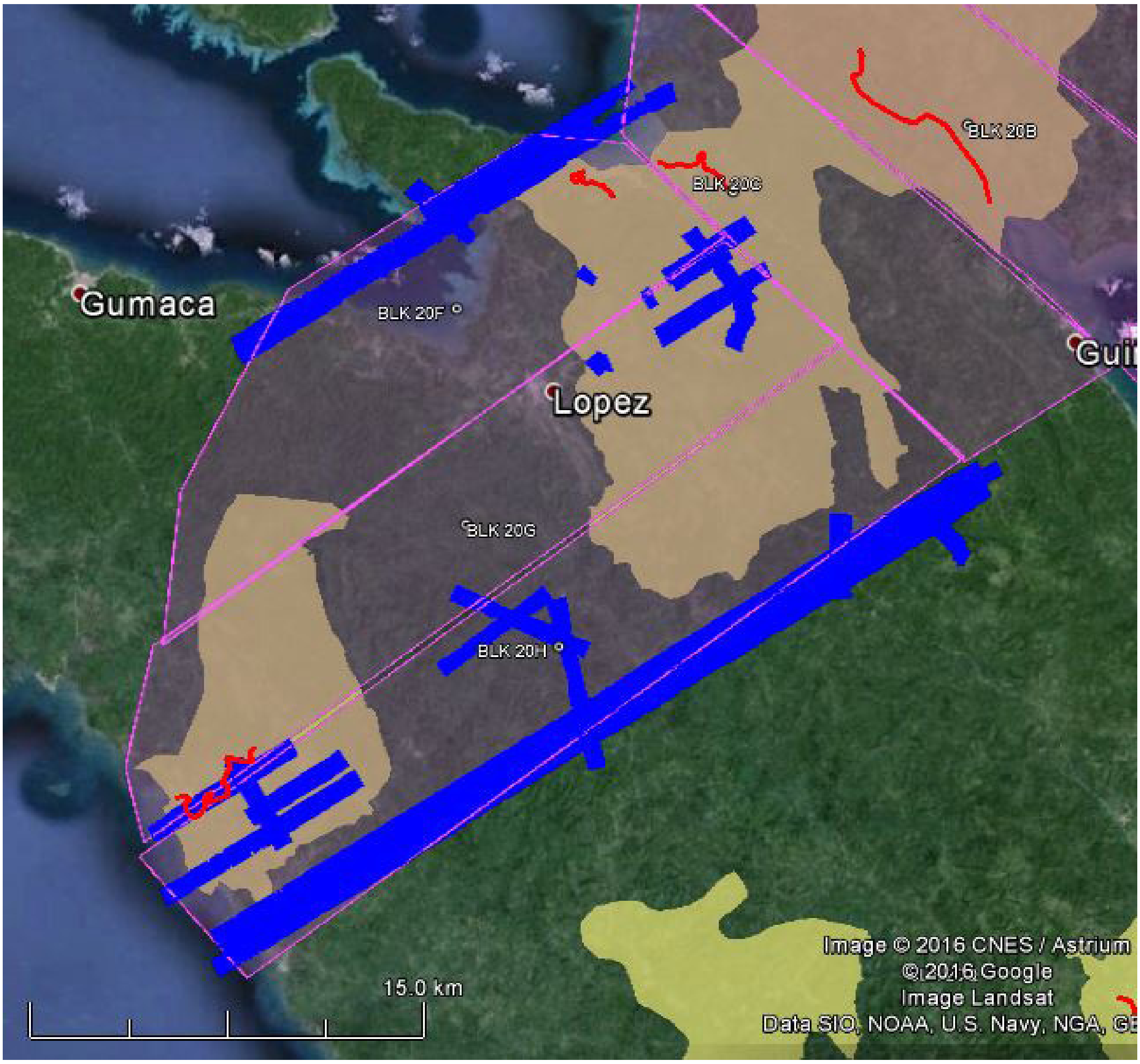


Figure A-7.6 Swath for Flight No. 23262P

Annex 8. Mission Summary Report

Annex 9. Pandanan Model Basin Parameters

Table A-9.1 Pandanan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W460	26.0739	83.518	0.0	0.3959	0.202536	Discharge	7.49674E-5	0.0001	Ratio to Peak	0.001625
W470	13.4037	79.896	0.0	2.462825	4.2301312	Discharge	0.13215	0.0001	Ratio to Peak	0.001625
W480	23.9382	83.196	0.0	0.949575	0.7070912	Discharge	0.0525050	0.0001	Ratio to Peak	0.001625
W490	9.6669	87.22	0.0	2.3825	4.0934776	Discharge	0.0888780	0.0001	Ratio to Peak	0.001625
W500	25.6941	83.152	0.0	1.640225	4.2064632	Discharge	0.11459	0.0001	Ratio to Peak	0.001625
W510	22.8159	81.406	0.0	1.18045	3.027176	Discharge	0.0613622	0.0001	Ratio to Peak	0.001625
W520	25.8165	87.189	0.0	1.327225	1.5246848	Discharge	0.0559118	0.0001	Ratio to Peak	0.001625
W530	1.83024	84.246	0.0	3.331	2.5185856	Discharge	0.0909438	0.0001	Ratio to Peak	0.001625
W540	19.1709	87.22	0.0	1.12445	0.9454008	Discharge	0.0039955	0.0001	Ratio to Peak	0.001625
W550	17.1513	84.559	0.0	6.589	2.236044	Discharge	0.0674707	0.0001	Ratio to Peak	0.001625
W560	10.3914	87.22	0.0	2.135025	1.6223056	Discharge	0.0104677	0.0001	Ratio to Peak	0.001625
W570	12.5739	86.997	0.0	6.1985	3.139696	Discharge	0.19247	0.0001	Ratio to Peak	0.001625
W580	10.512	87.095	0.0	3.8495	2.9846512	Discharge	0.0676234	0.0001	Ratio to Peak	0.001625
W590	9.9846	86.529	0.0	7.0405	5.3296456	Discharge	0.0990569	0.0001	Ratio to Peak	0.001625
W600	11.9268	83.252	0.0	2.1305	1.6188912	Discharge	0.0562839	0.0001	Ratio to Peak	0.001625
W610	11.4525	83.789	0.0	5.1345	2.6053424	Discharge	0.0316196	0.0001	Ratio to Peak	0.001625
W620	8.04483	82.926	0.0	8.713	4.4112496	Discharge	0.23244	0.0001	Ratio to Peak	0.001625
W630	9.9702	84.47	0.0	11.44075	5.7917536	Discharge	0.61534	0.0001	Ratio to Peak	0.001625
W640	12.1257	99	0.0	0.95615	0.48429	Discharge	0.0020685	0.0001	Ratio to Peak	0.001625
W650	10.0062	87.085	0.0	7.28925	5.5210848	Discharge	0.12906	0.0001	Ratio to Peak	0.001625
W660	16.7958	91.104	0.0	7.15125	1.6101224	Discharge	0.0387609	0.0001	Ratio to Peak	0.001625
W670	8.92629	84.373	0.0	7.93925	5.9946	Discharge	0.0830583	0.0001	Ratio to Peak	0.001625
W680	13.1238	81.909	0.0	3.8895	0.874552	Discharge	0.0523772	0.0001	Ratio to Peak	0.001625

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W690	13.4469	89.972	0.0	2.8355	1.4077416	Discharge	0.0526243	0.0001	Ratio to Peak	0.001625
W700	13.2138	88.75	0.0	1.963425	0.64975	Discharge	0.0053088	0.0001	Ratio to Peak	0.001625
W710	13.5405	86.097	0.0	4.04875	1.4307112	Discharge	0.10932	0.0001	Ratio to Peak	0.001625
W720	13.1067	82.421	0.0	2.447825	1.8229016	Discharge	0.0054254	0.0001	Ratio to Peak	0.001625
W730	18.4878	88.874	0.0	2.95275	1.5575096	Discharge	0.0523800	0.0001	Ratio to Peak	0.001625
W740	14.2002	86.22	0.0	3.2775	1.660252	Discharge	0.0663323	0.0001	Ratio to Peak	0.001625
W750	12.7629	88.227	0.0	1.23285	0.6245248	Discharge	0.0016604	0.0001	Ratio to Peak	0.001625
W760	11.916	85.931	0.0	5.72225	2.8988256	Discharge	0.18549	0.0001	Ratio to Peak	0.001625
W770	9.0639	83.369	0.0	2.787	1.4118544	Discharge	0.0657603	0.0001	Ratio to Peak	0.001625
W780	13.2003	87.582	0.0	2.162875	1.0956344	Discharge	0.0386499	0.0001	Ratio to Peak	0.001625
W790	14.7609	86.243	0.0	2.05795	1.0424784	Discharge	0.0939814	0.0001	Ratio to Peak	0.001625
W800	14.1102	87.401	0.0	5.13275	2.6001432	Discharge	0.16489	0.0001	Ratio to Peak	0.001625
W810	14.6241	86.736	0.0	3.01025	1.5249176	Discharge	0.0875897	0.0001	Ratio to Peak	0.001625
W820	14.0877	87.926	0.0	6.36825	3.2259096	Discharge	0.1892927	0.0001	Ratio to Peak	0.001625
W830	7.8094	89	0.0	1.970725	0.998324	Discharge	0.0595991	0.0001	Ratio to Peak	0.001625
W840	16.069	88.528	0.0	2.57	1.3018176	Discharge	0.0338686	0.0001	Ratio to Peak	0.001625
W850	8.0767	85.215	0.0	2.74175	1.3888072	Discharge	0.13601	0.0001	Ratio to Peak	0.001625
W860	16.641	89	0.0	1.34315	0.68040	Discharge	0.0144770	0.0001	Ratio to Peak	0.001625
W870	11.71	87.052	0.0	4.014	2.0333528	Discharge	0.18852	0.0001	Ratio to Peak	0.001625
W880	17.444	89	0.0	1.907	0.9660424	Discharge	0.0627838	0.0001	Ratio to Peak	0.001625
W890	23.544	89	0.0	1.941975	0.9837352	Discharge	0.0562256	0.0001	Ratio to Peak	0.001625
W900	24.583	89	0.0	2.4861	1.2593704	Discharge	0.0866068	0.0001	Ratio to Peak	0.001625

Annex 10. Pandanan Model Reach Parameters

Table A-10.1 Pandanan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	7.0711	0.8	0.0308	Trapezoid	44	45
R110	Automatic Fixed Interval	1003.4	0.0031913	0.0945637	Trapezoid	44	45
R140	Automatic Fixed Interval	4081.3	.0006276652613271062	0.0403118	Trapezoid	44	45
R150	Automatic Fixed Interval	1225.4	0.0043488	0.0199082	Trapezoid	44	45
R160	Automatic Fixed Interval	281.42	0.0056289	0.0331102	Trapezoid	44	45
R180	Automatic Fixed Interval	3055.0	.0007219900697655619	0.0130681	Trapezoid	44	45
R190	Automatic Fixed Interval	1222.7	0.0012276	0.0474628	Trapezoid	44	45
R20	Automatic Fixed Interval	1259.1	0.0004	0.0466018	Trapezoid	44	45
R210	Automatic Fixed Interval	3532.0	0.0023880	0.0432719	Trapezoid	44	45
R240	Automatic Fixed Interval	760.12	0.0040267	0.0321106	Trapezoid	44	45
R250	Automatic Fixed Interval	540.12	0.0064704	0.0072676	Trapezoid	44	45
R260	Automatic Fixed Interval	56.569	0.0004	0.0209727	Trapezoid	44	45
R280	Automatic Fixed Interval	3006.6	0.0058074	0.0079593	Trapezoid	44	45
R30	Automatic Fixed Interval	2752.8	0.0013174	0.0817509	Trapezoid	44	45
R310	Automatic Fixed Interval	1453.0	.0005528455234289976	0.0170751	Trapezoid	44	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R330	Automatic Fixed Interval	2272.5	0.0016695	0.0366080	Trapezoid	44	45
R370	Automatic Fixed Interval	3118.1	0.0026969	0.0234112	Trapezoid	44	45
R390	Automatic Fixed Interval	1696.1	0.0022548	0.0199934	Trapezoid	44	45
R410	Automatic Fixed Interval	702.55	0.0032783	0.222376	Trapezoid	44	45
R430	Automatic Fixed Interval	1981.4	0.0086170	0.0699141	Trapezoid	44	45
R70	Automatic Fixed Interval	1805.1	0.0010082	0.1057595	Trapezoid	44	45
R90	Automatic Fixed Interval	113.14	0.0075458	0.29947	Trapezoid	44	45

Annex 11. Pandanan Flood Validation Data

Table A-11.1 Pandanan Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.887724	122.268329	0.03	0.05	0.020	Rosing / November 2, 1995	5 -Year
2	13.873063	122.281726	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
3	13.889129	122.307186	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
4	13.900006	122.284375	0.09	0.5	0.410	Rosing / November 2, 1995	5 -Year
5	13.890865	122.30675	0.1	0.5	0.400	Rosing / November 2, 1995	5 -Year
6	13.890803	122.306901	0.3	0.5	0.200	Rosing / November 2, 1995	5 -Year
7	13.890699	122.30698	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
8	13.885349	122.261397	0.65	0.5	-0.150	Rosing / November 2, 1995	5 -Year
9	13.914937	122.287831	0.84	0.5	-0.340	Rosing / November 2, 1995	5 -Year
10	13.91468	122.287746	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
11	13.915188	122.283981	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
12	13.914725	122.283647	0.13	0.5	0.370	Rosing / November 2, 1995	5 -Year
13	13.912504	122.282943	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
14	13.911604	122.282665	0.7	0.5	-0.200	Rosing / November 2, 1995	5 -Year
15	13.892255	122.271378	0.53	0.5	-0.030	Rosing / November 2, 1995	5 -Year
16	13.886778	122.267292	1.97	0.5	-1.470	Rosing / November 2, 1995	5 -Year
17	13.916069	122.28767	0.06	0.5	0.440	Rosing / November 2, 1995	5 -Year
18	13.885984	122.285853	0.05	0	-0.050	Rosing / November 2, 1995	5 -Year
19	13.884756	122.288809	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
20	13.880966	122.300381	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
21	13.878287	122.312855	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
22	13.879784	122.274971	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
23	13.890259	122.307194	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
24	13.881218	122.307187	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
25	13.880138	122.304761	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
26	13.880913	122.300481	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
27	13.900034	122.280359	0.27	0	-0.270	Rosing / November 2, 1995	5 -Year
28	13.893488	122.27214	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
29	13.900614	122.278395	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
30	13.914367	122.27607	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
31	13.914331	122.277435	0.04	0	-0.040	Rosing / November 2, 1995	5 -Year
32	13.91203	122.282747	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
33	13.905322	122.281282	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
34	13.888982	122.270167	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
35	13.886683	122.275448	0.03	0	-0.030	Rosing / November 2, 1995	5 -Year
36	13.886415	122.283733	0.09	0	-0.090	Rosing / November 2, 1995	5 -Year
37	13.896377	122.273432	0.65	0	-0.650	Rosing / November 2, 1995	5 -Year
38	13.886464	122.267608	0.46	1.5	1.040	Rosing / November 2, 1995	5 -Year
39	13.873093	122.282267	0.5	1.5	1.000	Rosing / November 2, 1995	5 -Year
40	13.873104	122.2821	0.03	1.5	1.470	Rosing / November 2, 1995	5 -Year
41	13.886443	122.267614	0.09	1.5	1.410	Rosing / November 2, 1995	5 -Year
42	13.87772	122.315079	0.04	1	0.960	Rosing / November 2, 1995	5 -Year
43	13.877591	122.31505	0.42	1	0.580	Rosing / November 2, 1995	5 -Year
44	13.873092	122.282368	0.43	1	0.570	Rosing / November 2, 1995	5 -Year
45	13.873083	122.281949	0.44	1	0.560	Rosing / November 2, 1995	5 -Year
46	13.873073	122.281884	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
47	13.873326	122.281565	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
48	13.873354	122.281484	0.19	1	0.810	Rosing / November 2, 1995	5 -Year
49	13.890581	122.307024	0.14	1	0.860	Rosing / November 2, 1995	5 -Year
50	13.890466	122.307095	0.03	1	0.970	Rosing / November 2, 1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
51	13.889724	122.307294	0.5	1	0.500	Rosing / November 2, 1995	5 -Year
52	13.915907	122.28757	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
53	13.888945	122.307153	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
54	13.895644	122.296424	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
55	13.89376	122.297112	0.1	1	0.900	Rosing / November 2, 1995	5 -Year
56	13.89323	122.29699	0.55	1	0.450	Rosing / November 2, 1995	5 -Year
57	13.915923	122.287425	0.77	1	0.230	Rosing / November 2, 1995	5 -Year
58	13.915787	122.287183	0.3	1	0.700	Rosing / November 2, 1995	5 -Year
59	13.915777	122.286774	0.05	1	0.950	Rosing / November 2, 1995	5 -Year
60	13.915816	122.285983	0.04	1	0.960	Rosing / November 2, 1995	5 -Year
61	13.915797	122.285468	0.48	1	0.520	Rosing / November 2, 1995	5 -Year
62	13.886449	122.267364	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
63	13.886628	122.267256	2.27	1	-1.270	Rosing / November 2, 1995	5 -Year
64	13.916124	122.287716	0.32	1	0.680	Rosing / November 2, 1995	5 -Year
65	13.877988	122.315186	0.57	2	1.430	Rosing / November 2, 1995	5 -Year
66	13.87308	122.282517	0.44	2	1.560	Rosing / November 2, 1995	5 -Year
67	13.873124	122.281731	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
68	13.889608	122.307274	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
69	13.889437	122.307243	0.72	2	1.280	Rosing / November 2, 1995	5 -Year
70	13.888095	122.307274	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
71	13.884156	122.307234	0.07	2	1.930	Rosing / November 2, 1995	5 -Year
72	13.881802	122.307834	0.08	2	1.920	Rosing / November 2, 1995	5 -Year
73	13.895846	122.296532	0.04	2	1.960	Rosing / November 2, 1995	5 -Year
74	13.912701	122.283403	0.04	2	1.960	Rosing / November 2, 1995	5 -Year
75	13.893384	122.297007	0.07	2	1.930	Rosing / November 2, 1995	5 -Year
76	13.899813	122.28221	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
77	13.900499	122.281174	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
78	13.90369	122.279761	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
79	13.906787	122.281098	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
80	13.909853	122.282059	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
81	13.886422	122.267637	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
82	13.881485	122.30925	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
83	13.878881	122.31579	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
84	13.878727	122.315671	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
85	13.878425	122.315461	0.03	2	1.970	Rosing / November 2, 1995	5 -Year
86	13.916167	122.287717	0.24	2	1.760	Rosing / November 2, 1995	5 -Year
87	13.888765	122.307159	1.13	3	1.870	Rosing / November 2, 1995	5 -Year
88	13.888648	122.307188	1.09	3	1.910	Rosing / November 2, 1995	5 -Year
89	13.88172	122.308951	4.0900002	4	-0.090	Rosing / November 2, 1995	5 -Year
90	13.914741	122.290178	3.6600001	5	1.340	Rosing / November 2, 1995	5 -Year
91	13.881967	122.308765	3.54	5	1.460	Rosing / November 2, 1995	5 -Year
92	13.957339	122.288797	0.87	0.05	-0.820	Rosing / November 2, 1995	5 -Year
93	13.958167	122.292236	0.14	0.25	0.110	Rosing / November 2, 1995	5 -Year
94	13.958035	122.287948	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
95	13.958219	122.287125	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
96	13.858487	122.373725	1.02	0	-1.020	Rosing / November 2, 1995	5 -Year
97	13.959428	122.288067	0.84	1.2	0.360	Rosing / November 2, 1995	5 -Year
98	13.956645	122.294815	0.98	1.2	0.220	Rosing / November 2, 1995	5 -Year
99	13.959815	122.289016	0.63	1.3	0.670	Rosing / November 2, 1995	5 -Year
100	13.958931	122.2895	1.1900001	1.7	0.510	Rosing / November 2, 1995	5 -Year
101	13.960268	122.291597	0.76	1.7	0.940	Rosing / November 2, 1995	5 -Year
102	13.957431	122.292859	1.34	1	-0.340	Rosing / November 2, 1995	5 -Year
103	13.957731	122.296812	1.51	2.5	0.990	Rosing / November 2, 1995	5 -Year
104	13.958166	122.296811	1.74	2.5	0.760	Rosing / November 2, 1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
105	13.875517	122.339631	1.4299999	3	1.570	Rosing / November 2, 1995	5 -Year
106	13.862732	122.326811	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
107	13.860872	122.32846	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
108	13.864361	122.32536	0.14	0.2	0.060	Rosing / November 2, 1995	5 -Year
109	13.888405	122.26072	0.13	0.2	0.070	Rosing / November 2, 1995	5 -Year
110	13.888327	122.260463	0.17	0.2	0.030	Rosing / November 2, 1995	5 -Year
111	13.887996	122.260634	2.04	0.2	-1.840	Rosing / November 2, 1995	5 -Year
112	13.886643	122.26103	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
113	13.886542	122.261237	0.2	0.2	0.000	Rosing / November 2, 1995	5 -Year
114	13.888278	122.260873	0.17	0.5	0.330	Rosing / November 2, 1995	5 -Year
115	13.888259	122.260744	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
116	13.888546	122.260724	0.23	0.5	0.270	Rosing / November 2, 1995	5 -Year
117	13.889201	122.260432	0.05	0.5	0.450	Rosing / November 2, 1995	5 -Year
118	13.889029	122.26045	0.26	0.5	0.240	Rosing / November 2, 1995	5 -Year
119	13.888908	122.260453	0.24	0.5	0.260	Rosing / November 2, 1995	5 -Year
120	13.888775	122.260451	0.1	0.5	0.400	Rosing / November 2, 1995	5 -Year
121	13.888632	122.260457	0.08	0.5	0.420	Rosing / November 2, 1995	5 -Year
122	13.888469	122.260461	0.29	0.5	0.210	Rosing / November 2, 1995	5 -Year
123	13.887816	122.260658	0.22	0.5	0.280	Rosing / November 2, 1995	5 -Year
124	13.886793	122.261253	0.27	0.5	0.230	Rosing / November 2, 1995	5 -Year
125	13.88755	122.260681	0.13	0.5	0.370	Rosing / November 2, 1995	5 -Year
126	13.887381	122.260707	0.15	0.5	0.350	Rosing / November 2, 1995	5 -Year
127	13.886982	122.261187	0.09	0.5	0.410	Rosing / November 2, 1995	5 -Year
128	13.887174	122.261135	0.08	0.5	0.420	Rosing / November 2, 1995	5 -Year
129	13.887377	122.26112	0.23	0.5	0.270	Rosing / November 2, 1995	5 -Year
130	13.887601	122.261099	0.27	0.5	0.230	Rosing / November 2, 1995	5 -Year
131	13.887819	122.261073	0.32	0.5	0.180	Rosing / November 2, 1995	5 -Year
132	13.888076	122.261056	0.23	0.5	0.270	Rosing / November 2, 1995	5 -Year
133	13.888241	122.261033	0.28	0.5	0.220	Rosing / November 2, 1995	5 -Year
134	13.886655	122.261311	0.89	0.5	-0.390	Rosing / November 2, 1995	5 -Year
135	13.890737	122.261375	0.83	1.5	0.670	Rosing / November 2, 1995	5 -Year
136	13.890777	122.261255	1.03	1.5	0.470	Rosing / November 2, 1995	5 -Year
137	13.890746	122.261003	0.92	1.5	0.580	Rosing / November 2, 1995	5 -Year
138	13.8906	122.260968	0.79	1.5	0.710	Rosing / November 2, 1995	5 -Year
139	13.890383	122.260949	0.81	1.5	0.690	Rosing / November 2, 1995	5 -Year
140	13.890219	122.26093	0.74	1.5	0.760	Rosing / November 2, 1995	5 -Year
141	13.890066	122.260926	0.74	1.5	0.760	Rosing / November 2, 1995	5 -Year
142	13.886947	122.260698	0.94	1.5	0.560	Rosing / November 2, 1995	5 -Year
143	13.889995	122.261026	0.88	1.5	0.620	Rosing / November 2, 1995	5 -Year
144	13.890027	122.261156	0.82	1.5	0.680	Rosing / November 2, 1995	5 -Year
145	13.890047	122.261297	0.72	1.5	0.780	Rosing / November 2, 1995	5 -Year
146	13.890075	122.261446	0.75	1.5	0.750	Rosing / November 2, 1995	5 -Year
147	13.890183	122.26142	0.91	1.5	0.590	Rosing / November 2, 1995	5 -Year
148	13.890306	122.261425	0.85	1.5	0.650	Rosing / November 2, 1995	5 -Year
149	13.890434	122.261405	1.02	1.5	0.480	Rosing / November 2, 1995	5 -Year
150	13.890562	122.261387	0.57	1.5	0.930	Rosing / November 2, 1995	5 -Year
151	13.889936	122.260931	0.56	1.5	0.940	Rosing / November 2, 1995	5 -Year
152	13.889464	122.260701	0.33	1	0.670	Rosing / November 2, 1995	5 -Year
153	13.889424	122.260489	0.09	1	0.910	Rosing / November 2, 1995	5 -Year
154	13.888193	122.260457	0.08	1	0.920	Rosing / November 2, 1995	5 -Year
155	13.888165	122.260615	0.34	1	0.660	Rosing / November 2, 1995	5 -Year
156	13.887211	122.260725	1.36	1	-0.360	Rosing / November 2, 1995	5 -Year
157	13.886878	122.260775	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
158	13.886365	122.26103	0.29	1	0.710	Rosing / November 2, 1995	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
159	13.888953	122.260794	0.35	1	0.650	Rosing / November 2, 1995	5 -Year
160	13.88907	122.260918	0.25	1	0.750	Rosing / November 2, 1995	5 -Year
161	13.889172	122.261036	0.44	1	0.560	Rosing / November 2, 1995	5 -Year
162	13.889295	122.261023	0.4	1	0.600	Rosing / November 2, 1995	5 -Year
163	13.88944	122.260973	0.42	1	0.580	Rosing / November 2, 1995	5 -Year
164	13.889562	122.261077	0.6	1	0.400	Rosing / November 2, 1995	5 -Year
165	13.889593	122.261269	0.84	1	0.160	Rosing / November 2, 1995	5 -Year
166	13.88968	122.26097	0.18	1	0.820	Rosing / November 2, 1995	5 -Year
167	13.888791	122.260725	0.03	1	0.970	Rosing / November 2, 1995	5 -Year
168	13.885607	122.260681	0.06	0.5	0.440	Rosing / November 2, 1995	5 -Year
169	13.885792	122.261059	0.04	0.5	0.460	Rosing / November 2, 1995	5 -Year
170	13.885779	122.260331	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
171	13.885313	122.260646	0.03	0.5	0.470	Rosing / November 2, 1995	5 -Year
172	13.885075	122.26093	0.05	0.2	0.150	Rosing / November 2, 1995	5 -Year
173	13.885302	122.261251	0.14	0.2	0.060	Rosing / November 2, 1995	5 -Year
174	13.886278	122.260931	0.34	0.5	0.160	Rosing / November 2, 1995	5 -Year
175	13.886196	122.260801	0.06	0.5	0.440	Rosing / November 2, 1995	5 -Year
176	13.885662	122.260816	0.38	1	0.620	Rosing / November 2, 1995	5 -Year
177	13.885966	122.260374	0.31	1	0.690	Rosing / November 2, 1995	5 -Year
178	13.886059	122.26054	0.17	1	0.830	Rosing / November 2, 1995	5 -Year
179	13.885434	122.261495	2.45	1	-1.450	Rosing / November 2, 1995	5 -Year
180	13.886418	122.26112	2.1700001	3	0.830	Rosing / November 2, 1995	5 -Year
181	13.84412	122.334813	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
182	13.842753	122.338035	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
183	13.841686	122.339463	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
184	13.840277	122.340663	0.03	0.2	0.170	Rosing / November 2, 1995	5 -Year
				RMSE	0.90852574		

Annex 12. Educational Institutions Affected in Pandanan Floodplain

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

Quezon				
Lopez				
Barangay	Building	Rainfall Scenario		
		5-year	25-year	100-year
Bacungan	Bacungan Day Care Center	None	None	None
Peñafrancia	Buyacanin Day Care Center	None	None	None
Canda Ibaba	Canda Ibaba Day Care Center	None	None	None
Canda Ibaba	Canda Ibaba Elementary School	Low	Low	Low
Canda Ilaya	Canda Ilaya Elementary School	None	None	None
San Roque	Day Care Center	None	None	None
Pamampangin	Pamampangin Elementary School	None	Low	Medium
Pamampangin	Pamampangin National High School	None	None	None
Banabahin Ibaba	Tan-ag Ibaba Elementary School	None	None	None

Annex 13. Health Institutions Affected in Pandanan Floodplain

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

Quezon				
Lopez				
Barangay	Building	Rainfall Scenario		
		5-year	25-year	100-year
Pamampangin	Health Center	None	None	None
Tan-Ag Ibaba	Health Center	None	None	Medium
Canda Ilaya	Health Station	None	None	None