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

LiDAR Surveys and Flood Mapping of Quiaoit River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
UPB	University of the Philippines Baguio
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 QUIAOIT RIVER

Enrico C. Paringit, Dr. Eng. and Dr. Chelo Pascua

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).

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

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled *Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods* (Paringit et al., 2017).

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Baguio (UPB). UPB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 12 river basins in the Ilocos Region. The university is located in Baguio City in the province of Benguet.

1.2 Overview of the Quiaoit River Basin

Quiaoit River Basin covers the Municipalities of Paoay, Currimao and Sarrat, and the City of Batac in the province of Ilocos Norte. The DENR River Basin Control Office identified the basin to have a drainage area of 188 sq km and an estimated 460 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Quiaoit River, is part of the 12 river systems in Ilocos. According to the 2010 national census of NSO, a total of 13,868 people are residing within the immediate vicinity of the river distributed among twenty (20) barangays in the municipalities of Paoay and Currimao, and the city of Batac. The water supply in Quiaoit River is considered for domestic water use and irrigation for a thousand people in the town especially to farmers (Ilocos Agriculuture Resources Research and Development Consortium, 2014) Last August 2014, Quiaoit River overflowed due to torrential rain brought by “Habagat” that made bridges along major roads impassable.

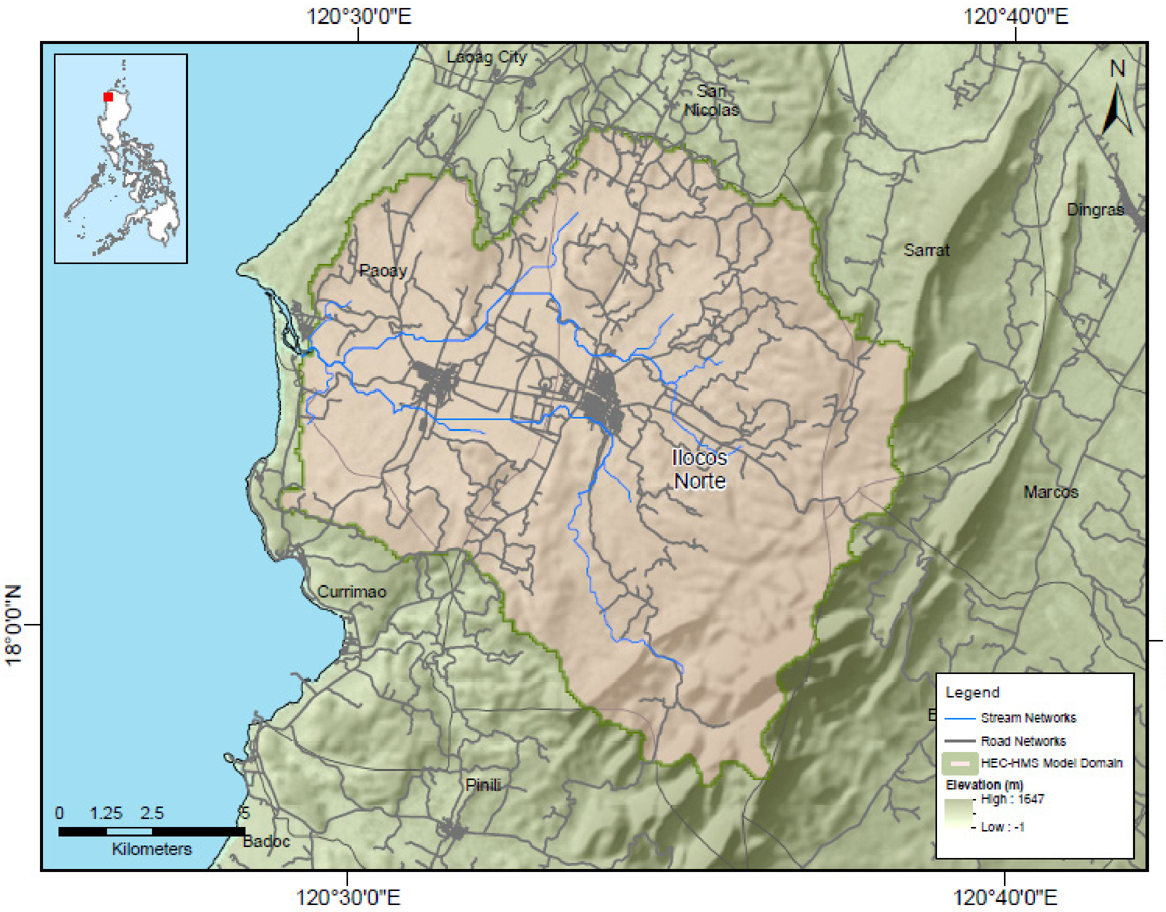

Figure 1. Map of the Quiaoit River Basin

CHAPTER 2: LIDAR ACQUISITION IN QUIAOIT 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 Quiaoit Floodplain in Ilocos Norte. These missions were planned for 14 lines and ran for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plan for Quiaoit Floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Fre-quency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK05F	1000	30	40	100	50	120	5
BLK05G	1000	25,30	40	100	40,50	120	5
BLK05H	1000	45	40	125	50	120	5
BLK05I	1000	45	40	100	50	120	5

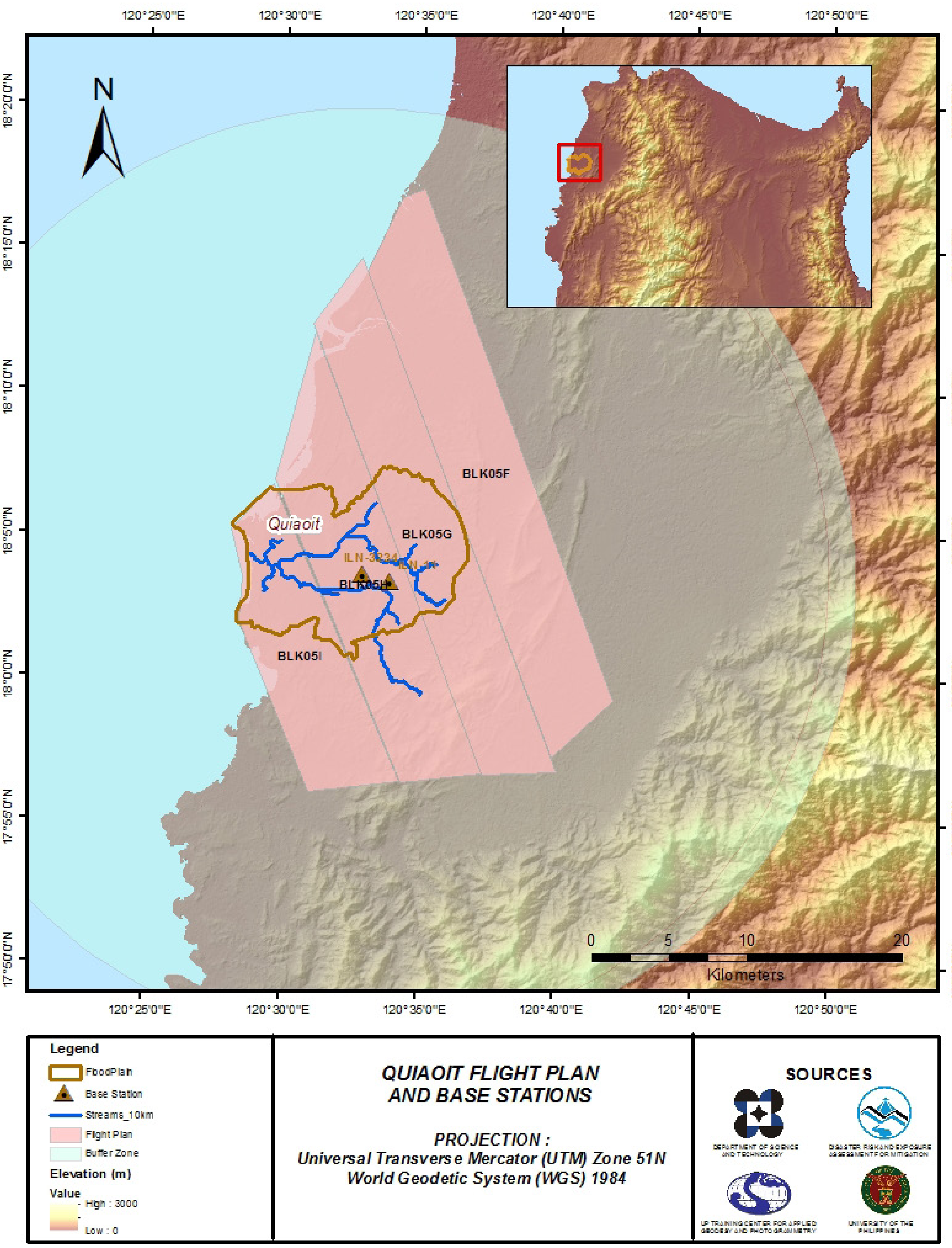
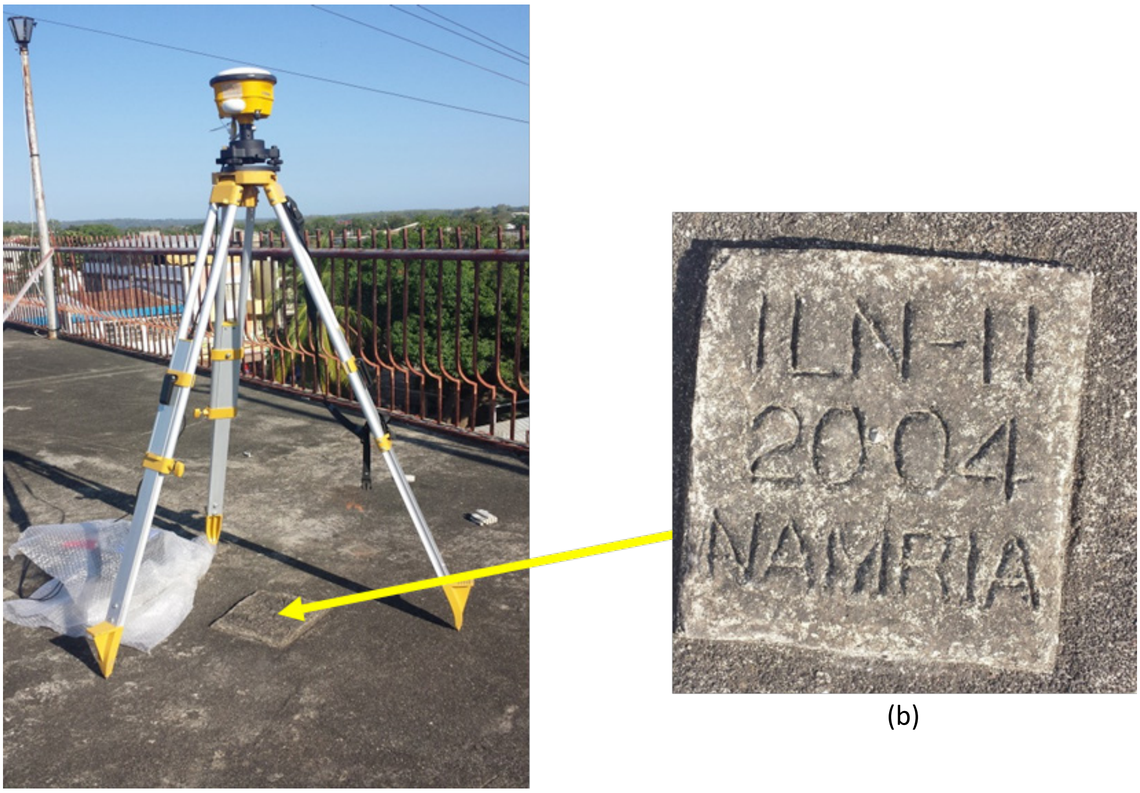


Figure 2. Flight plan and base stations used for Quiaoit Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points ILN-11, which is of second (2nd)-order accuracy and ILN-3234, which is of fourth (4th)-order accuracy. The certifications for the NAMRIA reference points are found in ANNEX 2. These points were used as base stations during flight operations for the entire duration of the survey (February 21–23, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS R8 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Quiaoit Floodplain are shown in Figure 2.

Figure 3 to Figure 4 show the recovered NAMRIA reference points within the area. Table 2 and Table 3 present the details about the following NAMRIA control stations and establish points, while Table 4 lists all ground control points occupied during the acquisition with the corresponding dates of utilization.



(a) (b)

Figure 3. GPS set-up over ILN-11 located on the rooftop of Batac Municipal Hall Building in Batac Ilocos Norte (a) and NAMRIA reference point ILN-11 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point ILN-11 used as base station for the LiDAR acquisition

Station Name	ILN-11	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	18°3’26.86785” North
	Longitude	120°33’49.91547” East
	Ellipsoidal Height	42.96000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	453,827.436 meters
	Northing	1,997,176.225 meters

Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18°3'20.64522" North 120°33'54.52048" East 74.87400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	242,121.13 meters 1,998,122.81 meters

(a) (b)

Figure 4. GPS set-up over ILN-3234 located in front of the Administration Building of Mariano Marcos Memorial University in Batac, Ilocos Norte (a) and NAMRIA reference point Iln-3234 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ILN-3234 used as base station for the LiDAR acquisition

Station Name	ILN-3234	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18°3'41.82025" North 120°32'3.1072" East 22.632 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	240510.416 meters 1998532.959 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18°3'35.59528" North 120°32'54.91553" East 54.492 meters

Table 4. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 21, 2014	7085G	2BLK05G052A	ILN-11 and ILN-3234
February 22, 2014	7086G	2BLK05H053A	ILN-11 and ILN-3234
February 22, 2014	7087G	2BLK05GS053B & 2BLK05F053B	ILN-11 and ILN-3234
February 23, 2014	7089G	2BLK05I054B	ILN-11 and ILN-3234

2.3 Flight Missions

Four (4) missions were conducted to complete LiDAR data acquisition in Quiaoit Floodplain, for a total of fourteen hours and seventeen minutes (14+37) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR systems. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition in Quiaoit 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
21-Feb-14	7085G	147	129.54	19.75	109.78	NA	2	59
22-Feb-14	7086G	124	176.08	61.47	114.61	NA	3	53
22-Feb-14	7087G	269	253.85	26.19	227.66	NA	4	17
23-Feb-14	7089G	117	142.39	46.73	95.66	NA	3	29
TOTAL		657	701.86	154.14	547.71	NA	14	37

Table 6. 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)
7085G	1000	25	40	100	40	120	5
7086G	1000	45	40	125	50	120	5
7087G	1000	30	40	100	50	120	5
7089G	1000	45	40	100	50	120	5

2.4 Survey Coverage

Quiaoit Floodplain is located in the province of Ilocos Norte, with majority of the floodplain situated within the city of Batac and municipality of Paoay. Paoay and Batac are completely covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in 7. The actual coverage of the LiDAR acquisition for Silaga Floodplain is presented in Figure 5.

Table 7. List of municipalities and cities surveyed during Quiaoit Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Ilocos Norte	Paoay	71.62	71.62	100%
	Batac City	134.62	134.46	100%
	San Nicolas	40.23	39.95	99%
	Currimao	32.97	31.04	94%
	Banna	89.62	77.74	87%
	Pinili	63.18	52.59	83%
	Laoag City	114.36	82.73	72%
	Sarrat	92.25	38.69	42%
	Marcos	73.57	12.01	16%
	Bacarra	47.1	5.65	12%
	Badoc	77.07	5.68	7%
	Nueva Era	619	10.36	2%
	Total	1,455.59	562.52	38.65%

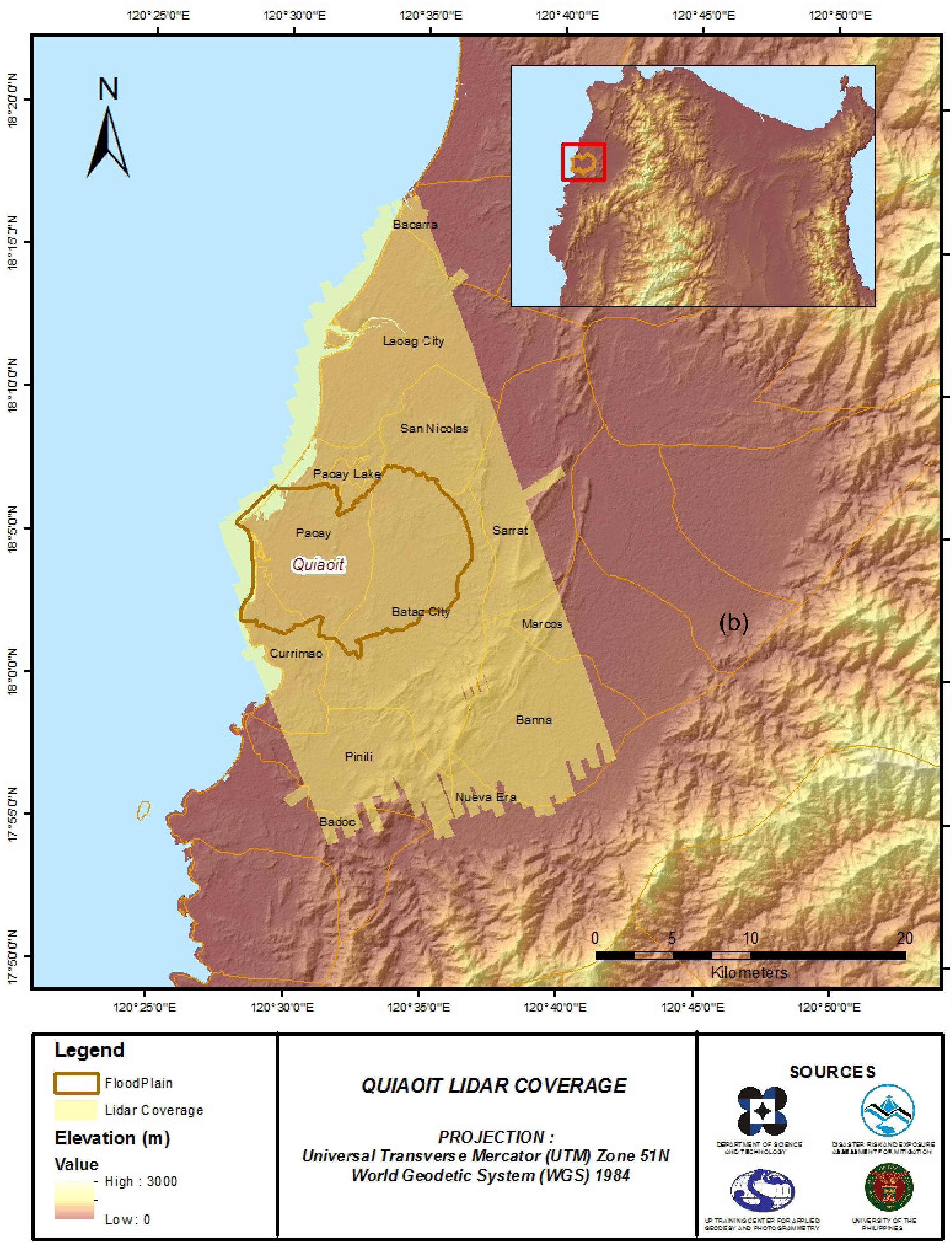


Figure 5. Actual LiDAR survey coverage for Quiaoit Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR QUIAOIT FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 6.

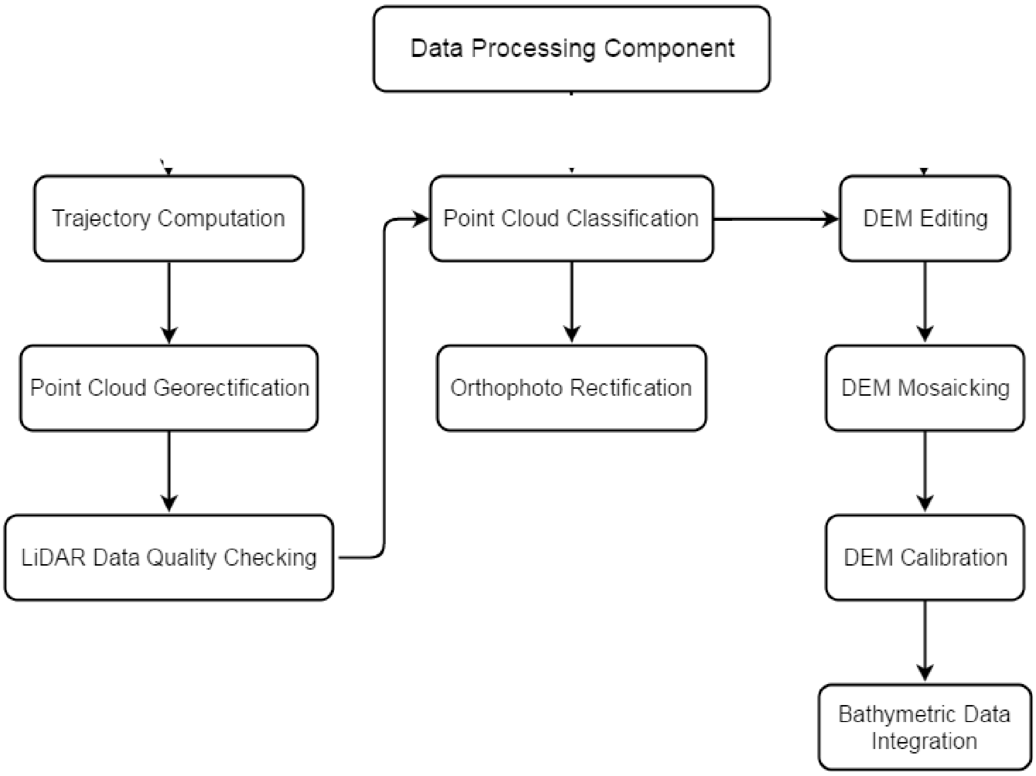


Figure 6. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Quiaoit Floodplain can be found in ANNEX 5. Missions flown for all the survey conducted used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Ilocos. The Data Acquisition Component (DAC) transferred a total of 82.6 Gigabytes of Range data, 0.83 Gigabytes of POS data, and 47.50 Megabytes of GPS base station data to the data server on February 21, 2014 for the first survey and February 23, 2014 for the last survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Quiaoit was fully transferred on April 25, 2014 as indicated on the data transfer sheets for Quiaoit Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7089G, one of the Quiaoit flights, which are the North, East, and Down position RMSE values, are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 23, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

Figure 7. Smoothed Performance Metrics of Quiaoit Flight 7089G

The time of flight was from 23500 seconds to 33500 seconds, which corresponds to afternoon of February 23, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the time that the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaks at 2.40 centimeters, the East position RMSE peaks at 3.80 centimeters, and the Down position RMSE peaks at 6.40 centimeters, which are within the prescribed accuracies described in the methodology.

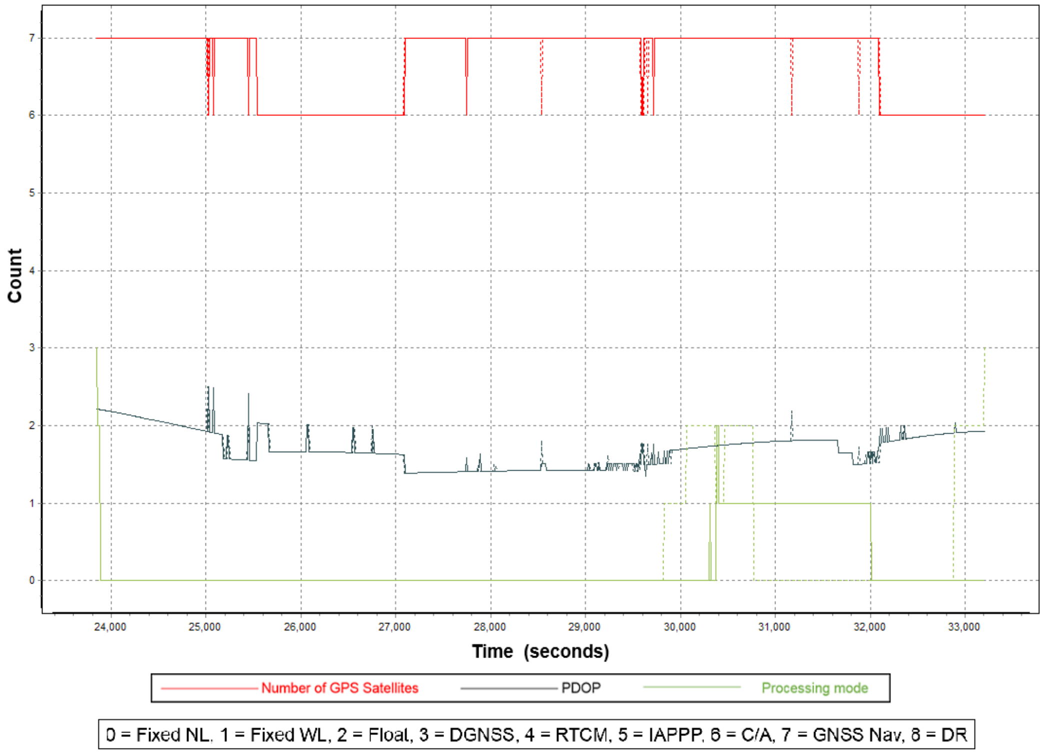


Figure 8. Solution Status parameters of Quiaoit Flight 7089G

The Solution Status parameters of flight 7089G, one of the Quiaoit flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go below 6. Majority of the time, the number of satellites tracked was between 6 and 7. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 or 2 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 Quiaoit flights is shown in Figure 9.

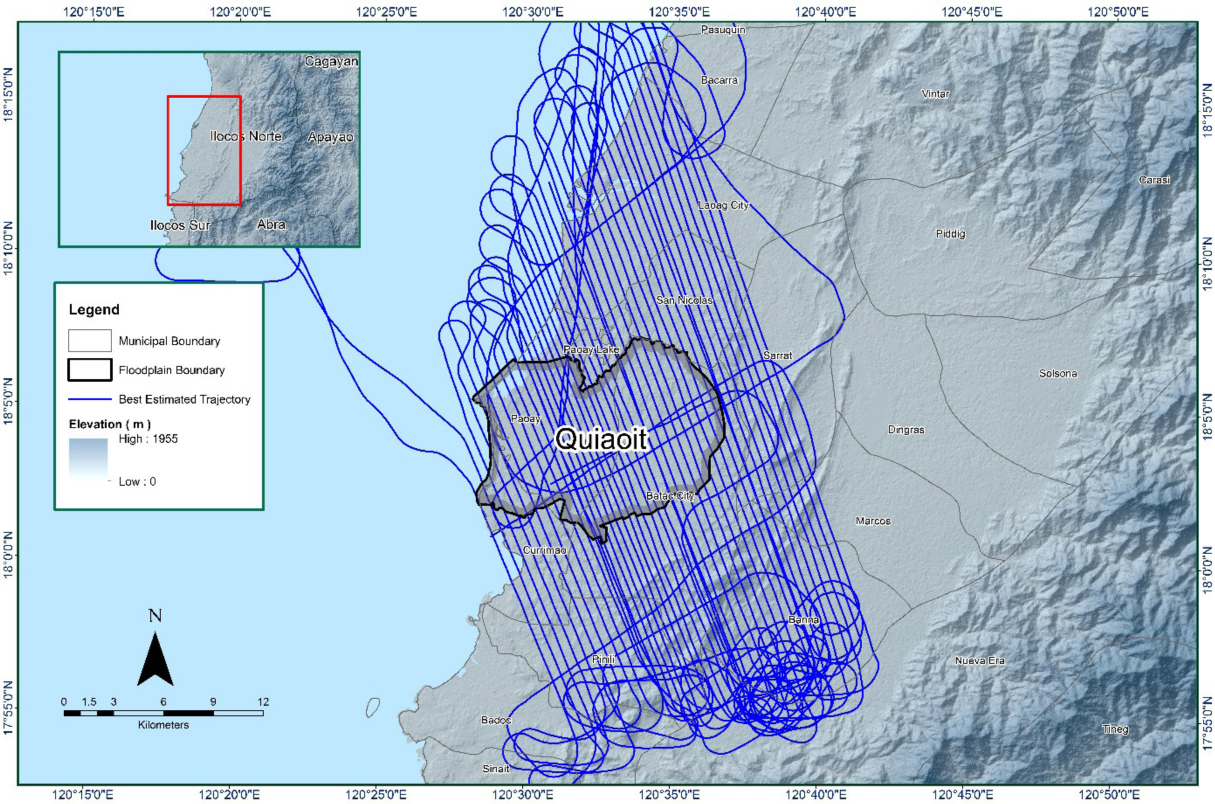


Figure 9. Best estimated trajectory of LiDAR missions conducted over Quiaoit Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 54 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Quiaoit Floodplain are given in Table 8.

Table 8. Self-calibration results values for Quiaoit flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000236
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000595
GPS Position Z-correction stdev	(<0.01meters)	0.0076

The optimum accuracy is obtained for all Quiaoit 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.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Quiaoit Floodplain is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

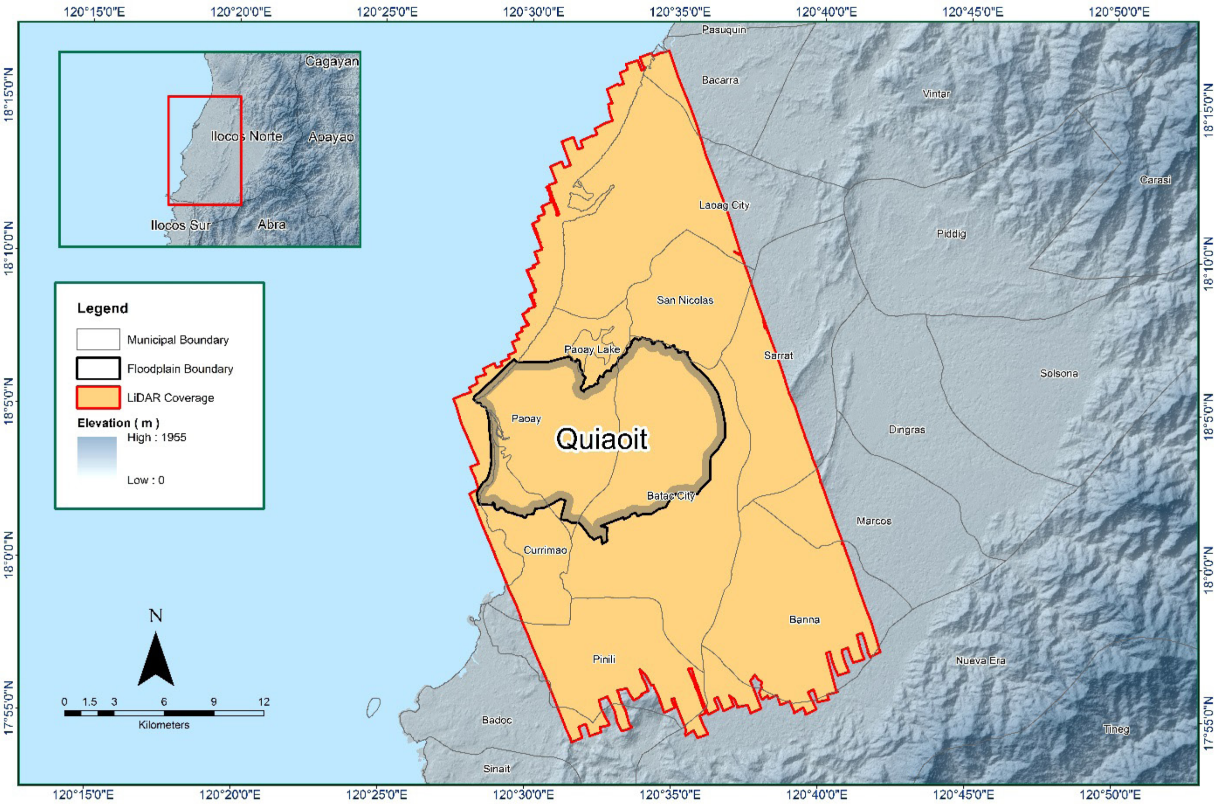


Figure 10. Boundary of the processed LiDAR data over Quiaoit Floodplain

The total area covered by the Quiaoit missions is 662.77 sq km comprised of four (4) flight acquisitions grouped and merged into five (5) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Quiaoit Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
Ilocos_Blk05EF_additional	7087G	163.18
Ilocos_Blk05FG_additional	7087G	78.82
Ilocos_Blk05G	7085G	120.64
Ilocos_Blk05H	7086G	167.17
Ilocos_Blk05I	7089G	132.97
TOTAL		662.77 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 11. Since the Gemini system employs one channel, an average value of 1 (blue) would be expected for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

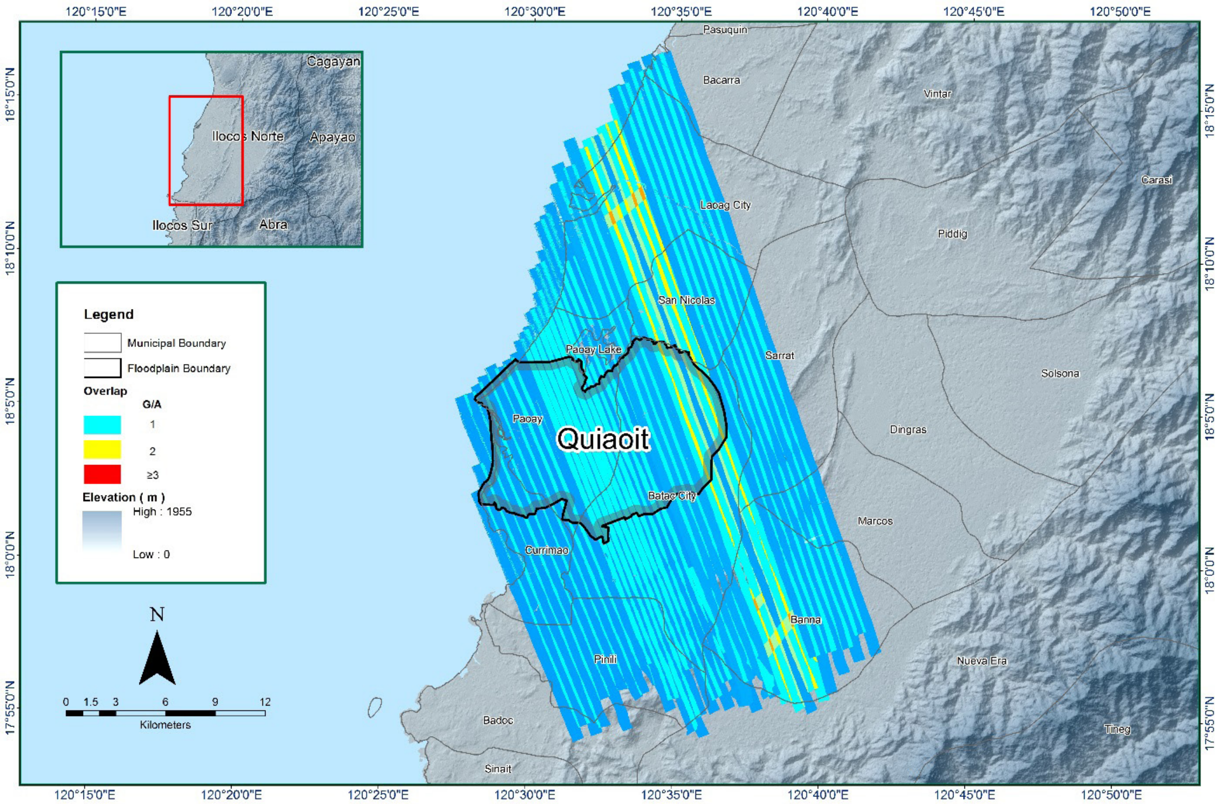


Figure 11. Image of data overlap for Quiaoit Floodplain.

The overlap statistics per block for the Quiaoit 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 32.82% and 84.28%, 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 12. It was determined that all LiDAR data for Quiaoit Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.74 points per square meter.

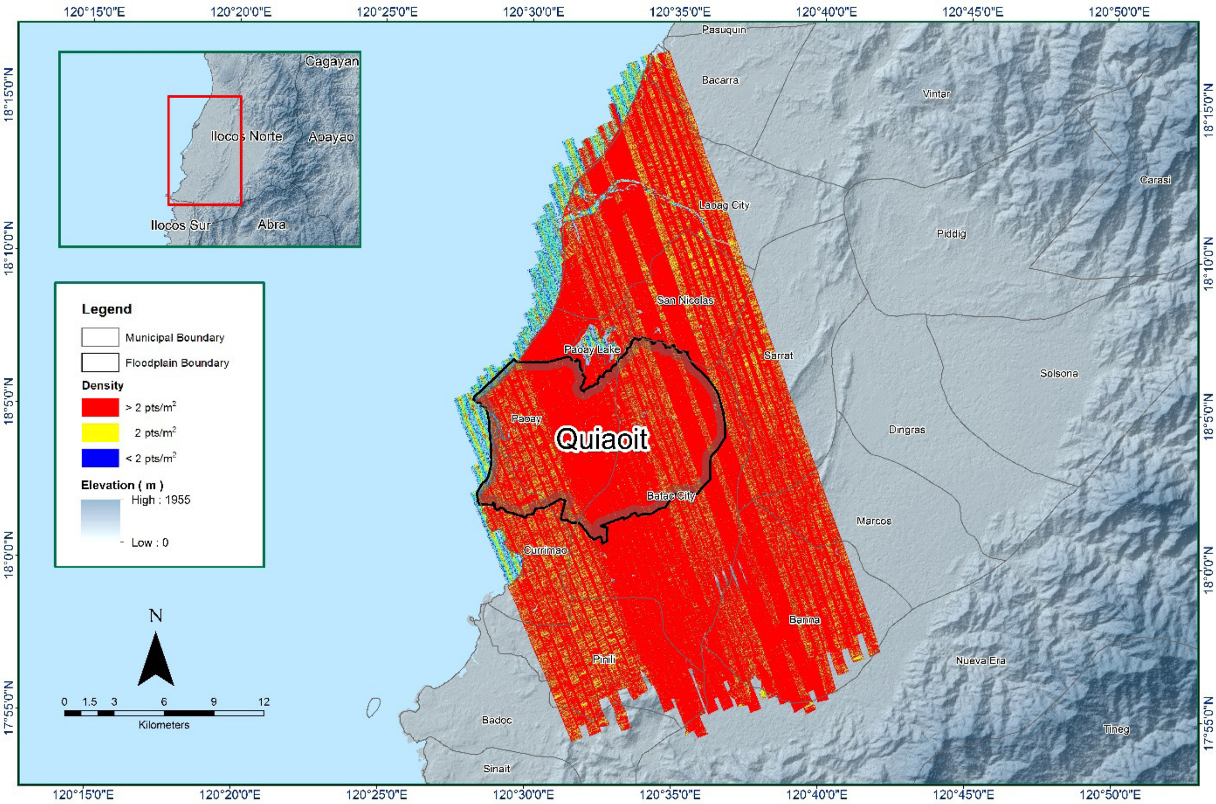


Figure 12. Pulse density map of merged LiDAR data for Quiaoit Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. 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 0.20 m 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 0.20 m 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.

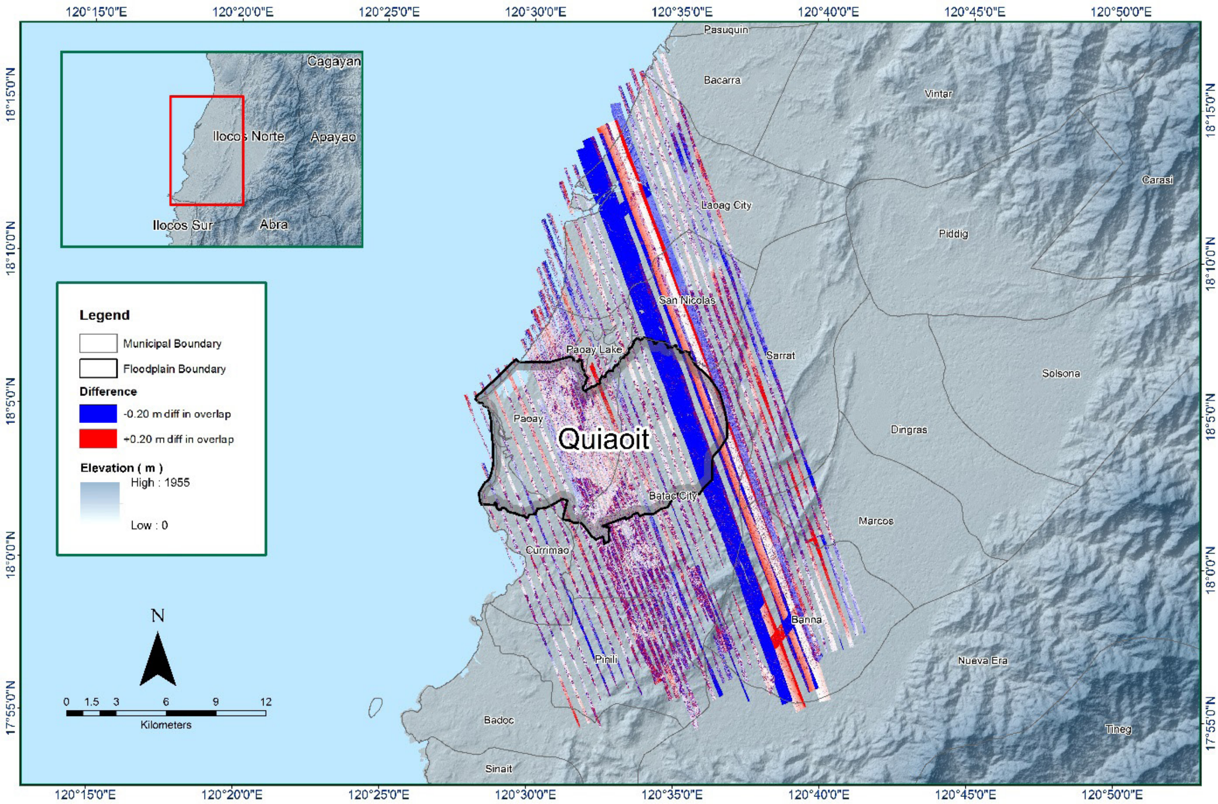


Figure 13. Elevation difference map between flight lines for Quiaoit Floodplain.

A screen capture of the processed LAS data from a Quiaoit flight 7089G loaded in QT Modeler is shown in Figure 14. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

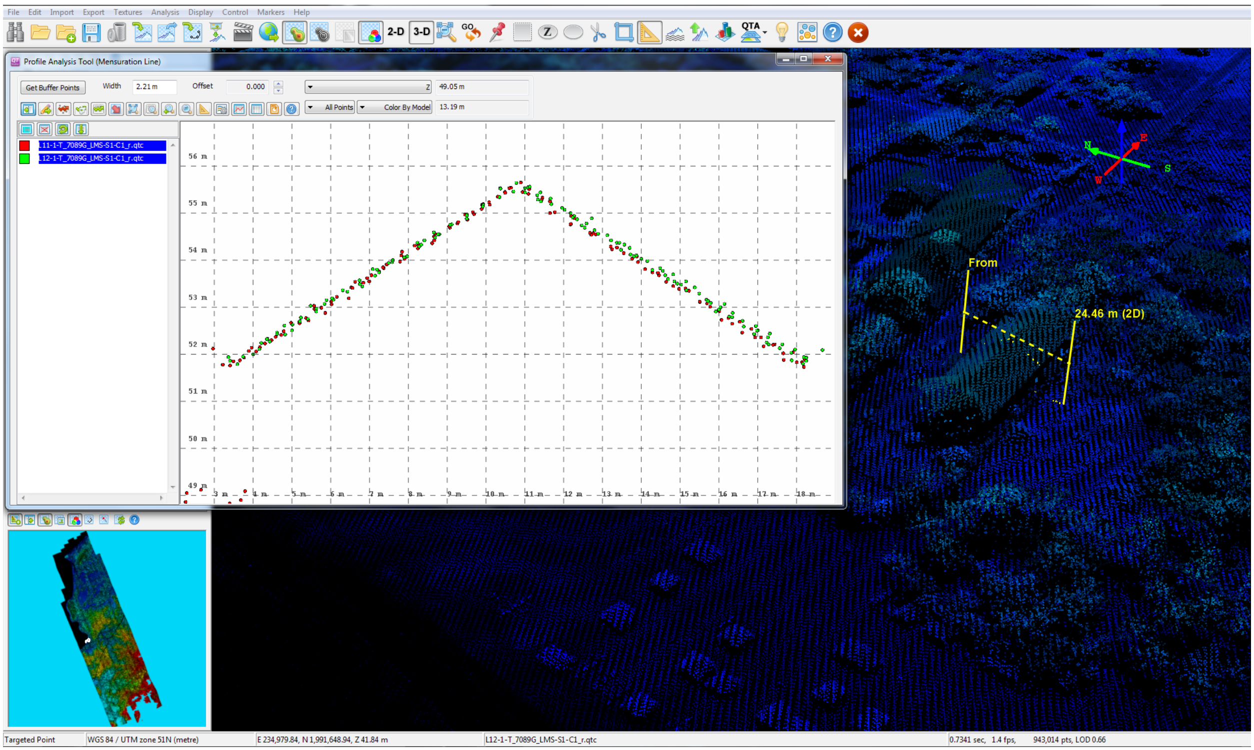


Figure 14. Quality checking for a Quiaoit flight 7089G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Quiaoit classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	301,578,176
Low Vegetation	332,658,557
Medium Vegetation	568,219,415
High Vegetation	781,653,878
Building	21,950,452

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Quiaoit Floodplain is shown in Figure 15. A total of 930 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 589.13 meters and 38.82 meters, respectively.

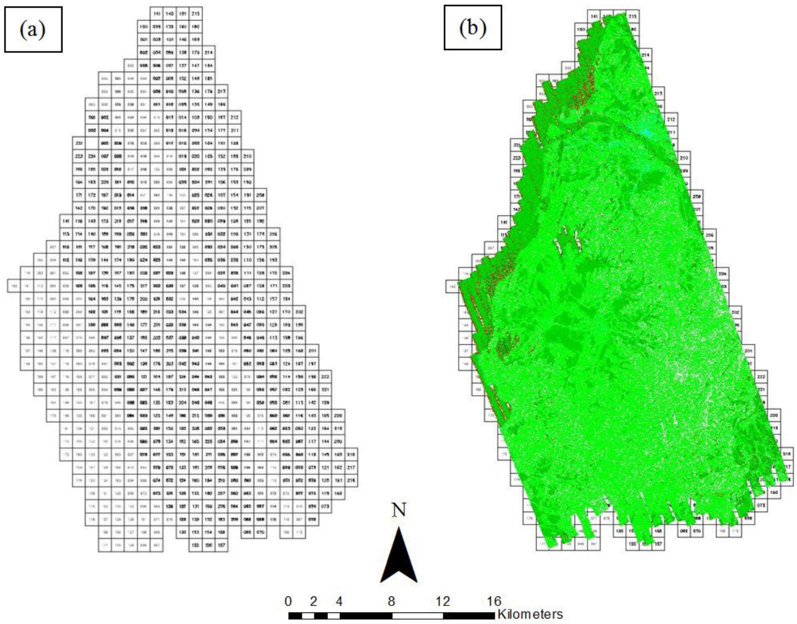


Figure 15. Tiles for Quiaoit Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 16. 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.

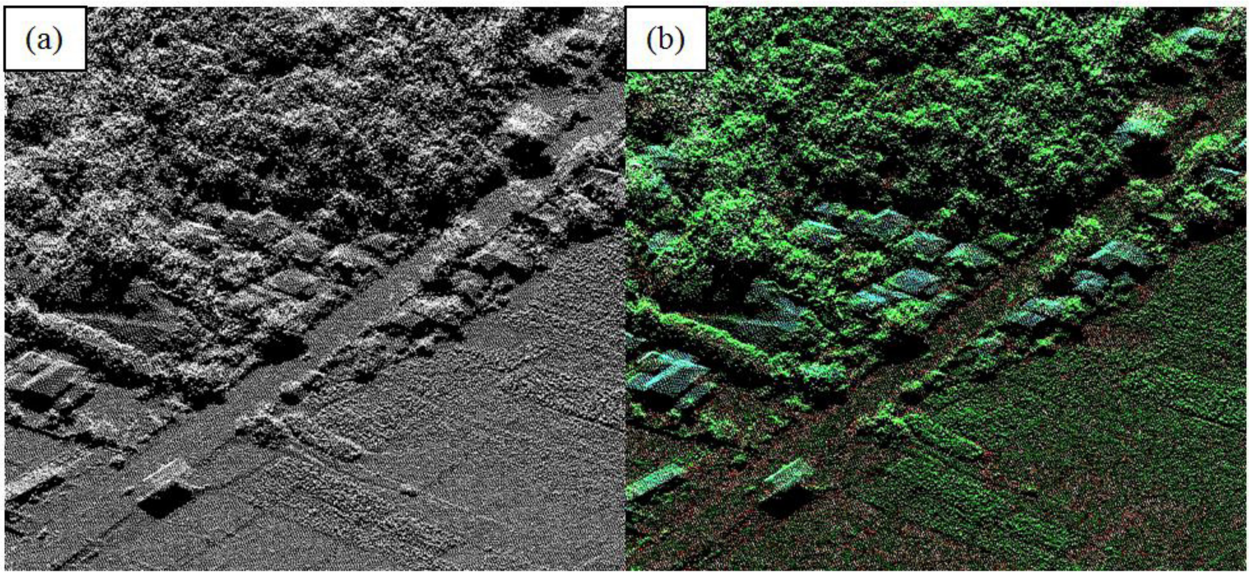


Figure 16. Point cloud before (a) and after (b) classification

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

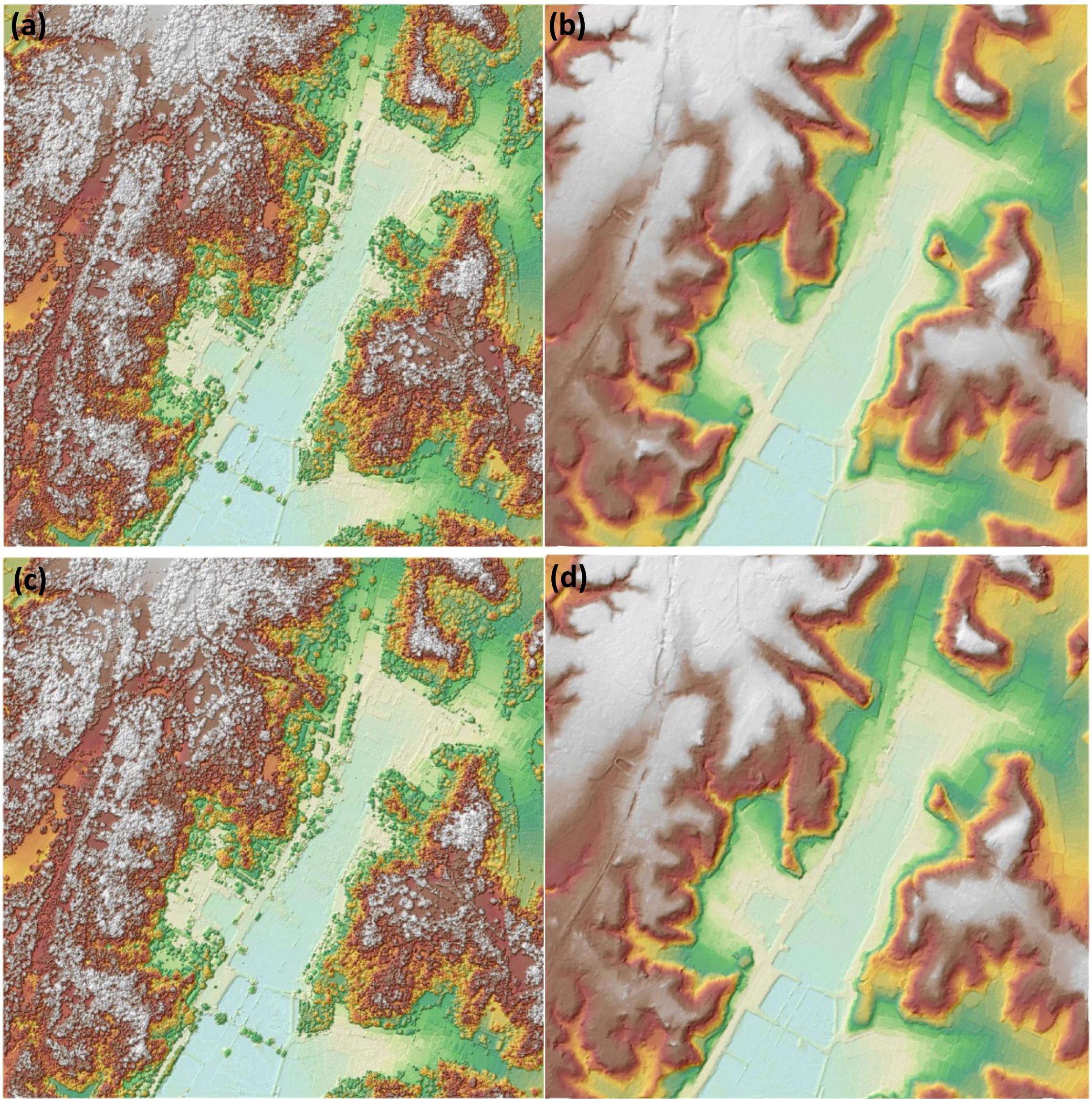


Figure 17. The production of last return DSM (a) and DTM (b); first return DSM (c) and secondary DTM (d) in some portion of Quiaoit Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Quiaoit Floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Quiaoit Floodplain. These blocks were composed of Ilocos blocks with a total area of 662.77 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq km)
Ilocos_Blk05EF_additional	163.18
Ilocos_Blk05FG_additional	78.82
Ilocos_Blk05G	120.64
Ilocos_Blk05H	167.17
Ilocos_Blk05I	132.97
TOTAL	662.77 sq km

Portions of DTM before and after manual editing are shown in Figure 18. The bridge (Figure 18a) was considered to be an impedance to the flow of water along the river and had to be removed (Figure 18b) in order to hydrologically correct the river. The terrain (Figure 18c) had been misclassified and removed during classification process and had to be retrieved (Figure 18d) to complete the surface. Another example is an embankment that was removed in the DTM after classification (Figure 18e) and had to be retrieved (Figure 18f) to allow the correct flow of water.

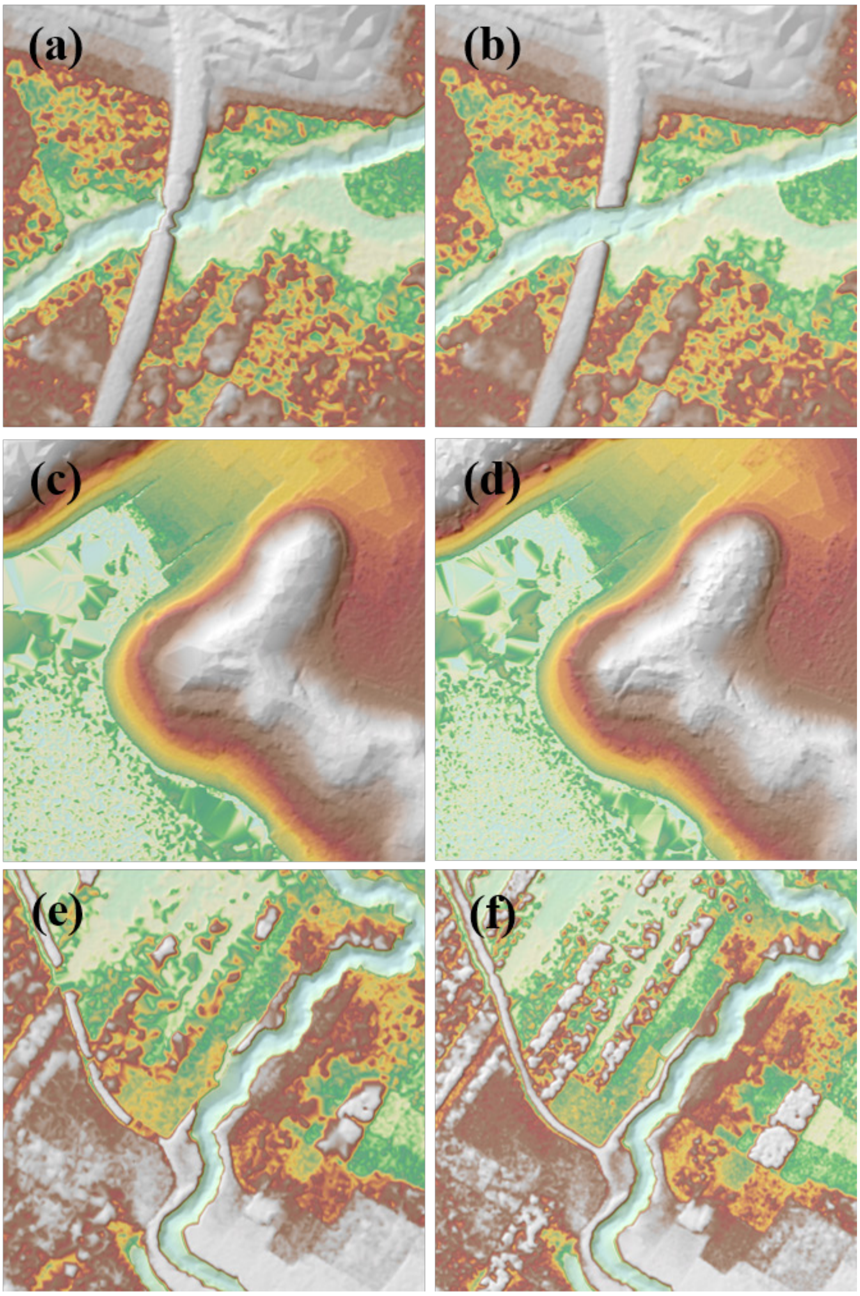


Figure 18. Portions in the DTM of Quiaoit Floodplain—a bridge before (a) and after (b) manual editing; a terrain before (c) and after (d) data retrieval; and an embankment before (e) and after (f) manual editing

3.9 Mosaicking of Blocks

Ilocos_Blk5A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy.

Mosaicked LiDAR DTM for Quiaoit Floodplain is shown in Figure 19. It can be seen that the entire Quiaoit Floodplain is 99.98% covered by LiDAR data.

Table 12. Shift values of each LiDAR Block of Quiaoit Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Ilocos_Blk05EF_additional	-1.20	1.40	-0.30
Ilocos_Blk05FG_additional	0.30	-4.75	-0.62
Ilocos_Blk05G	-1.00	1.50	-0.25
Ilocos_Blk05H	1.10	-4.90	0.00
Ilocos_Blk05I	0.11	-3.90	0.00

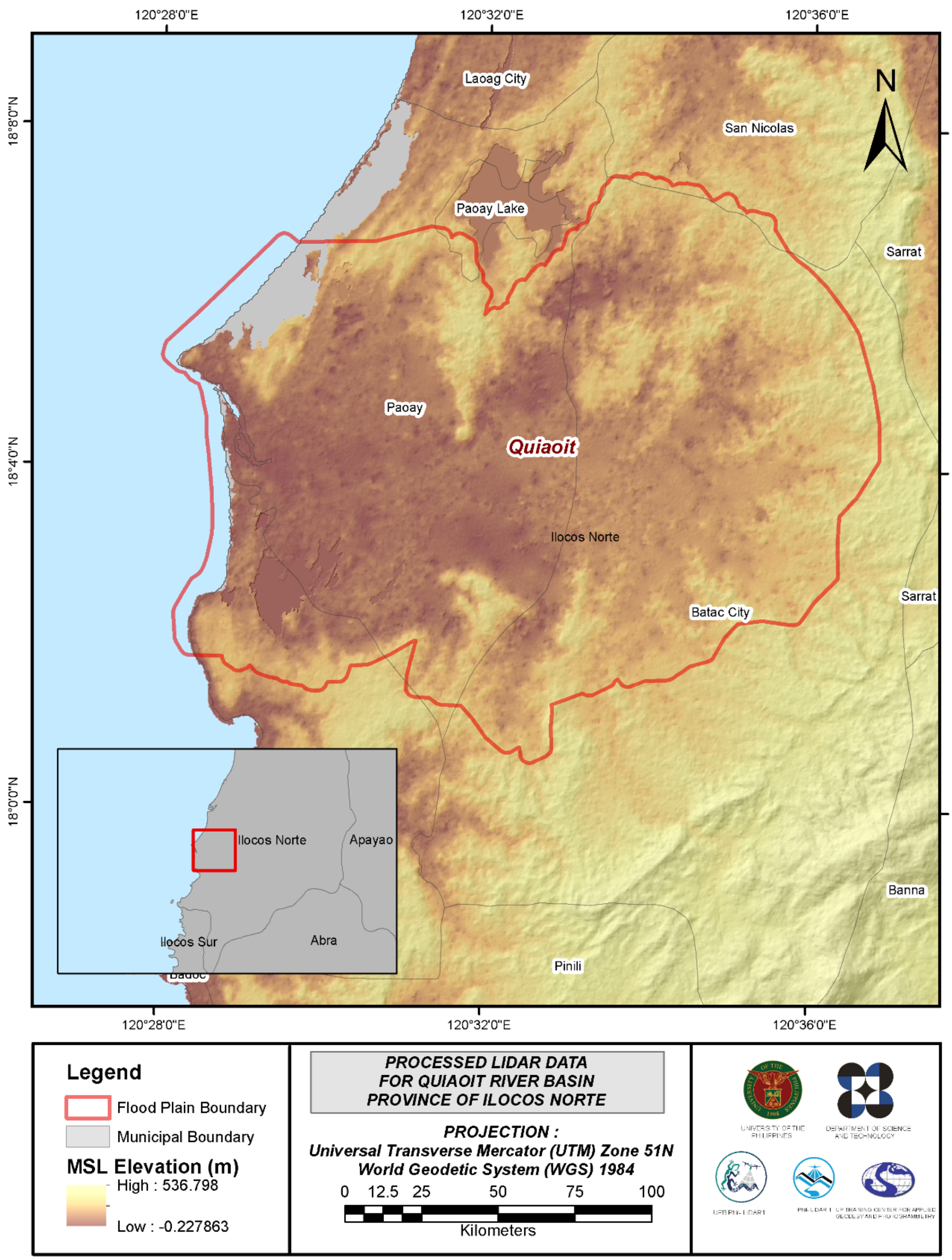


Figure 19. Map of processed LiDAR Data for Quiaoit Floodplain

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 Quiaoit to collect points with which the LiDAR dataset is validated is shown in Figure 20. A total of 7,440 survey points were used for calibration and validation of Quiaoit LiDAR data. Eighty percent of the survey points, resulting in 5,952 points, were randomly selected and used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 21. 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 elevation values is 5.62 meters with a standard deviation of 0.20 meters. Calibration of Quiaoit LiDAR data was done by adding the height difference value, 5.62 meters, to Quiaoit mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

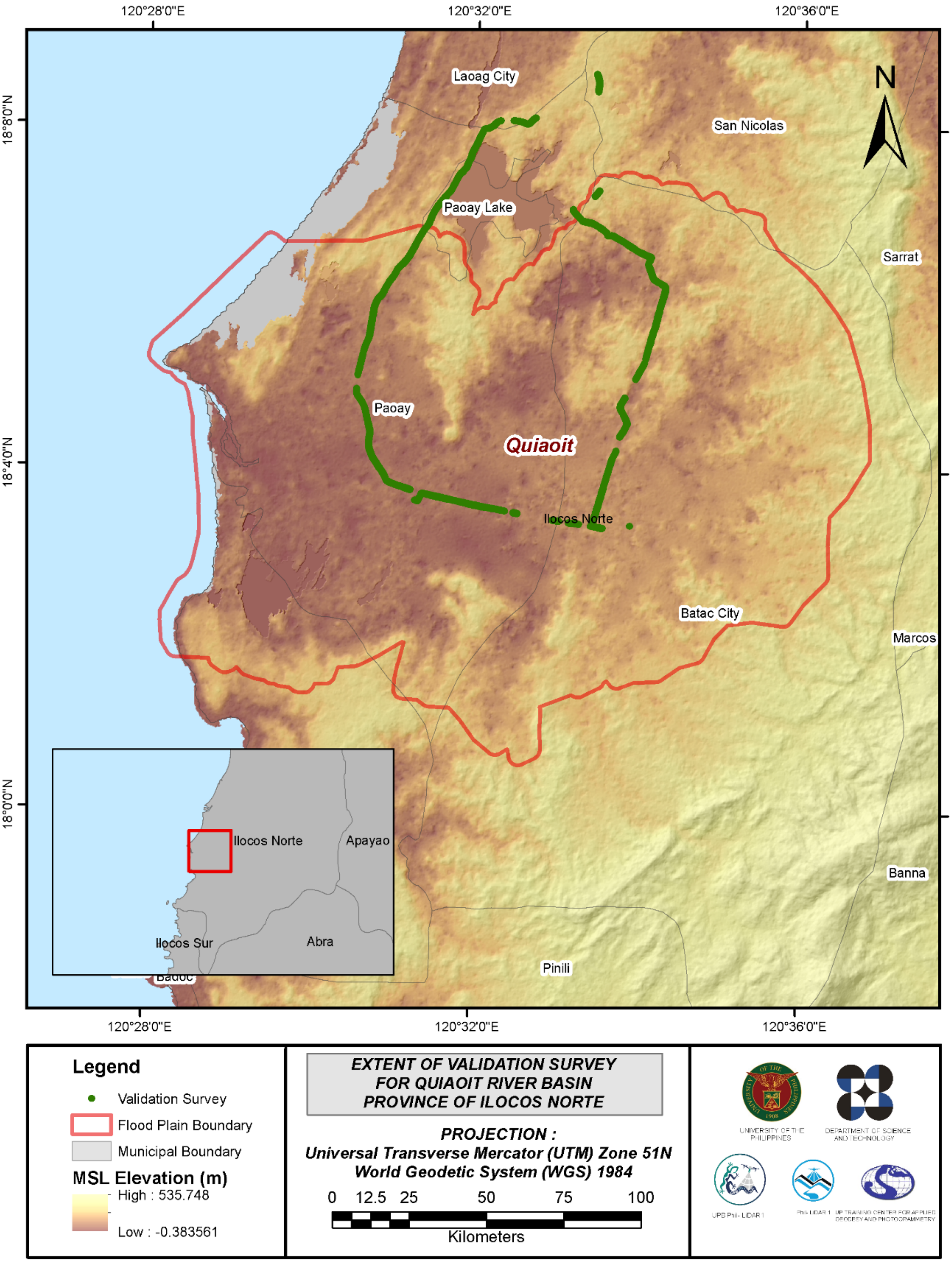


Figure 20. Map of Quiaoit Floodplain with validation survey points in green

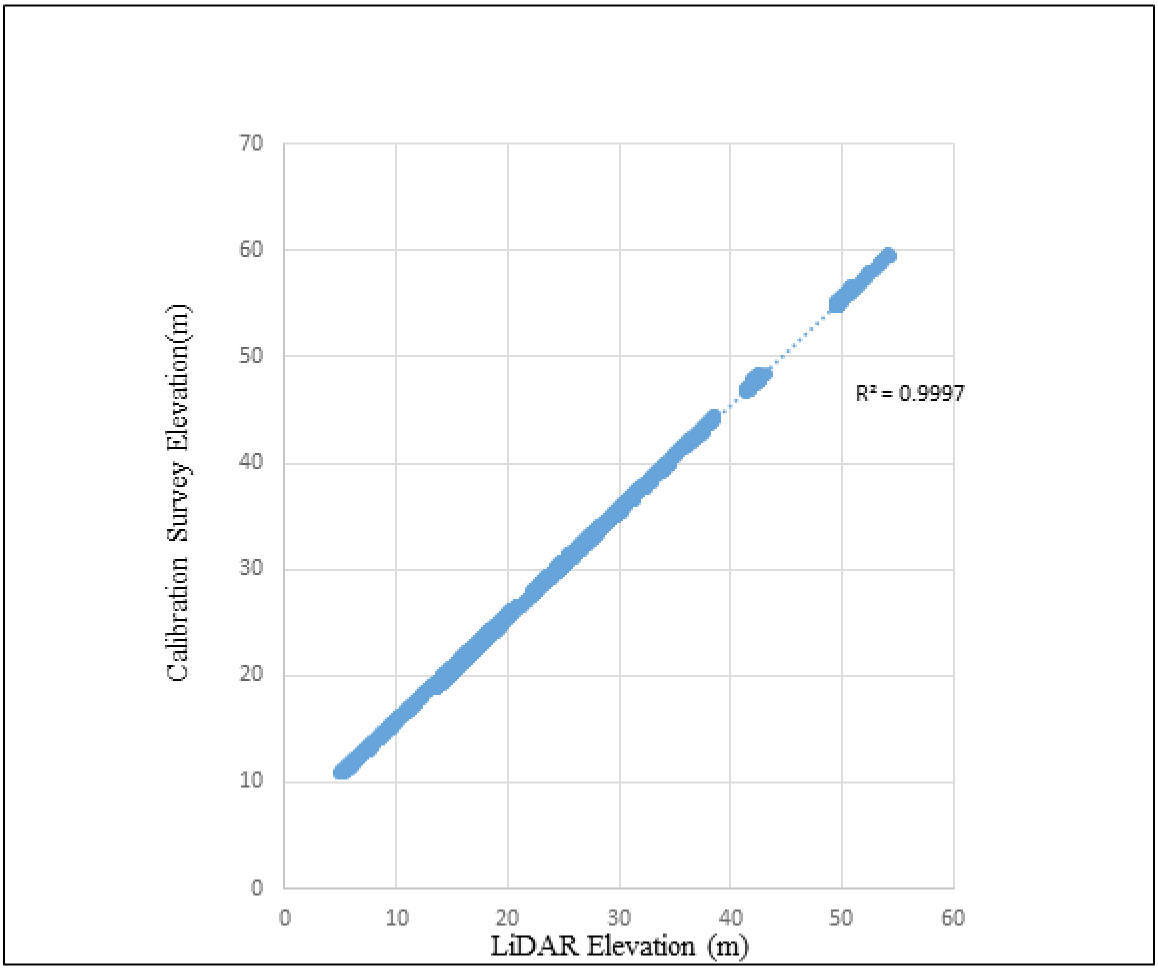


Figure 21. Correlation plot between calibration survey points and LiDAR data

Table 13. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	5.62
Standard Deviation	0.20
Average	-5.62
Minimum	-6.01
Maximum	-5.21

The remaining 20% of the total survey points, resulting in 1,488 points, were used for the validation of calibrated Quiaoit 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 22. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.23 meters with a standard deviation of 0.23 meters, as shown in Table 14.

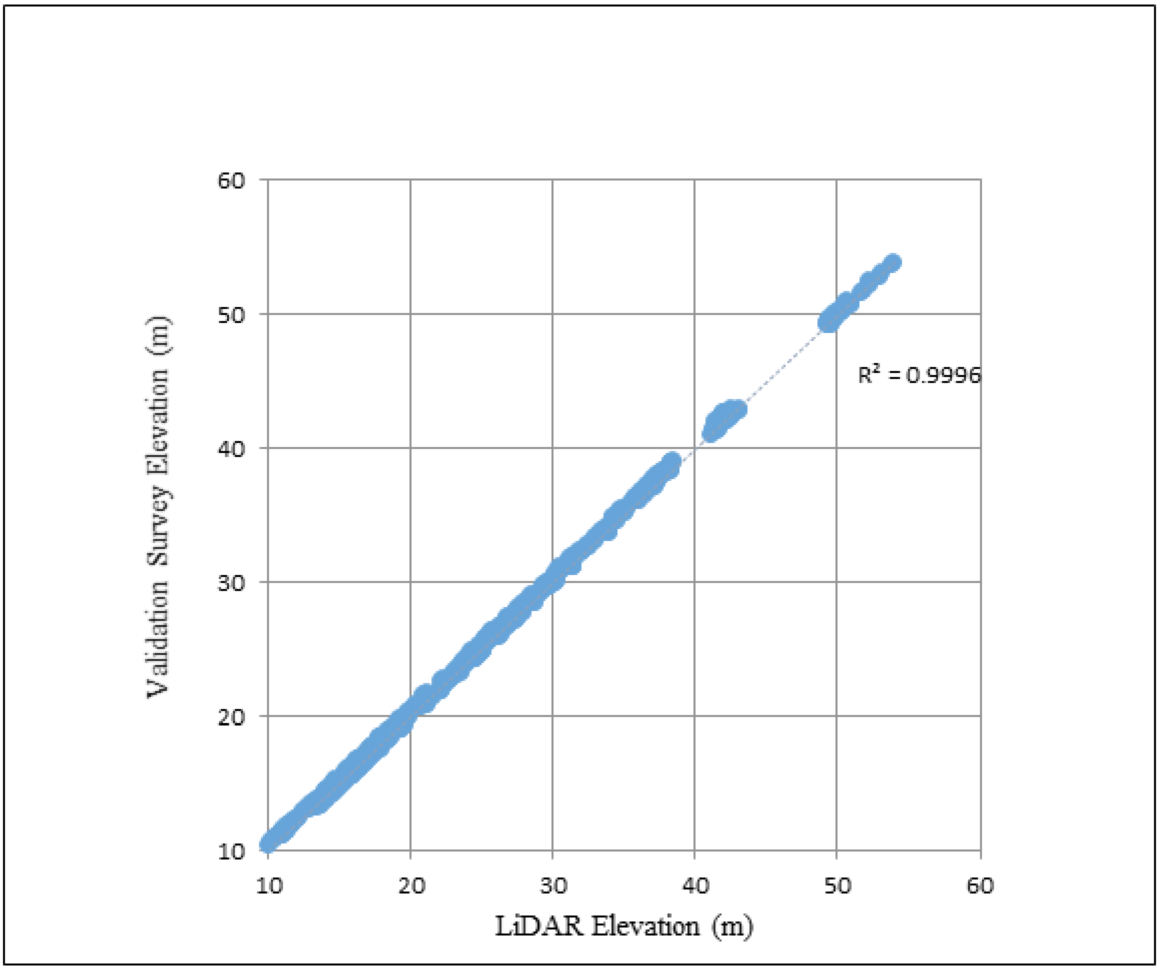


Figure 22. Correlation plot between validation survey points and LiDAR data

Table 14. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.23
Standard Deviation	0.23
Average	-0.01
Minimum	-0.45
Maximum	0.48

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Quiaoit with 2,115 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface was represented by the computed RMSE value of 0.38 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Quiaoit integrated with the processed LiDAR DEM is shown in Figure 23.

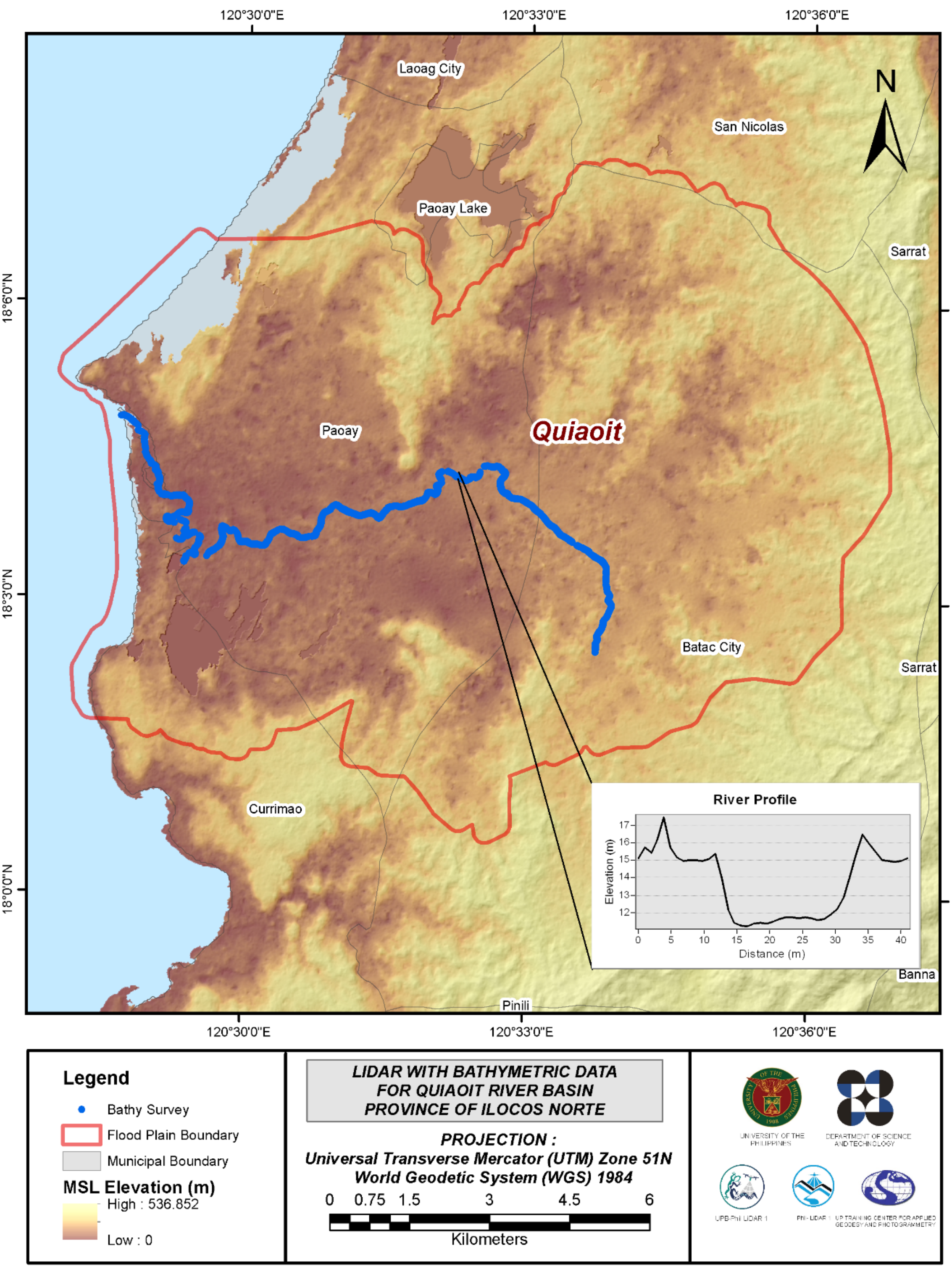


Figure 23. Map of Quiaoit Floodplain with bathymetric survey points shown in blue

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

Quiaoit Floodplain, including its 200 m buffer, has a total area of 125.17 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,356 building features, are considered for QC. Figure 24 shows the QC blocks for Quiaoit Floodplain.

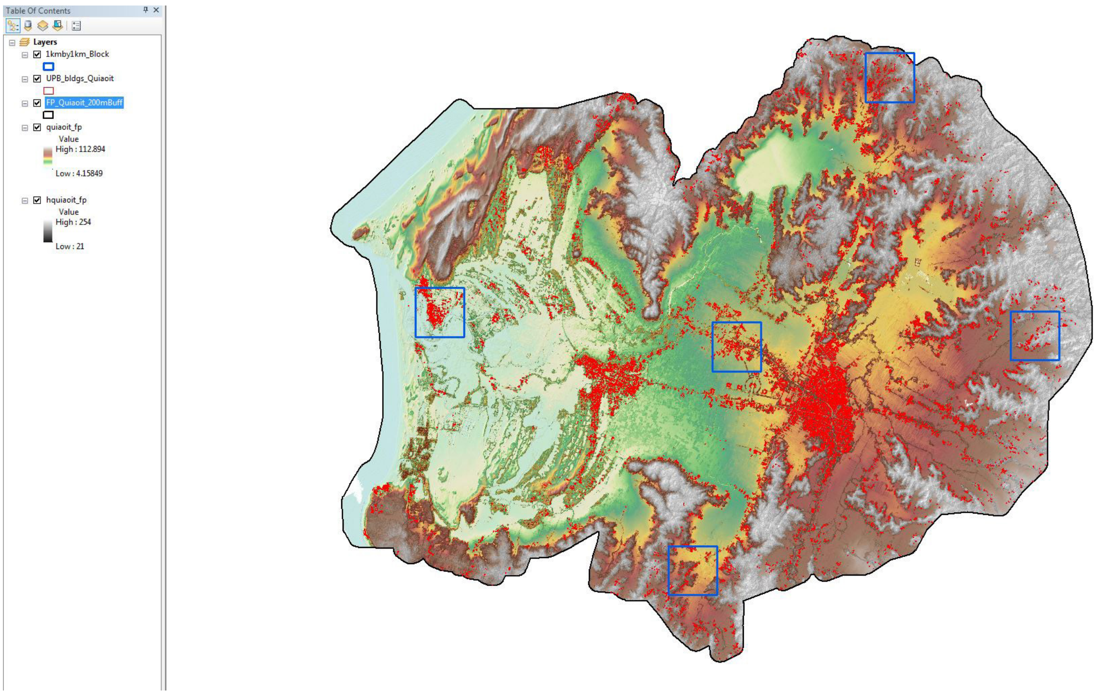


Figure 24. Blocks of Quiaoit building features subjected to QC

Quality checking of Quiaoit building features resulted in the ratings shown in Table 15.

Table 15. Quality checking ratings for Quiaoit building features

Floodplain	Completeness	Correctness	Quality	Remarks
Quiaoit	99.78	99.63	95.50	PASSED

3.12.2 Height Extraction

Height extraction was done for 16,038 building features in Quiaoit Floodplain. Of these building features, 193 buildings were filtered out after height extraction, resulting in 15,845 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 12.39 m.

3.12.3 Feature Attribution

Data collected from various sources which included OpenStreetMap and Google Maps/Earth were used in the attribution of building features. Areas without available data were subjected for field attribution using ESRI's Collector App. The app can be accessed offline and data collected can be synced to ArcGIS Online when WiFi or mobile data is available.

Table 16 summarizes the number of building features per type. On the other hand, Table 17 shows the total length of each road type, while Table 18 presents the number of water features extracted per type.

Table 16. Building features extracted for Quiaoit Floodplain

Facility Type	No. of Features
Residential	15,256
School	212
Market	17
Agricultural/Agro-Industrial Facilities	12
Medical Institutions	21
Barangay Hall	3
Military Institution	1
Sports Center/Gymnasium/Covered Court	9
Telecommunication Facilities	1
Transport Terminal	2
Warehouse	6
Power Plant/Substation	0
NGO/CSO Offices	8
Police Station	2
Water Supply/Sewerage	1
Religious Institutions	24
Bank	6
Factory	0
Gas Station	10
Fire Station	0
Other Government Offices	16
Other Commercial Establishments	238
Total	15,845

Table 17. Total length of extracted roads for Quiaoit Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Quiaoit	247.82	30.09	25.22	32.37	0.00	335.50

Table 18. Number of extracted water bodies for Quiaoit Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Quiaoit	8	88	0	0	0	96

A total of 21 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 25 shows the Digital Surface Model (DSM) of Quiaoit Floodplain overlaid with its ground features.

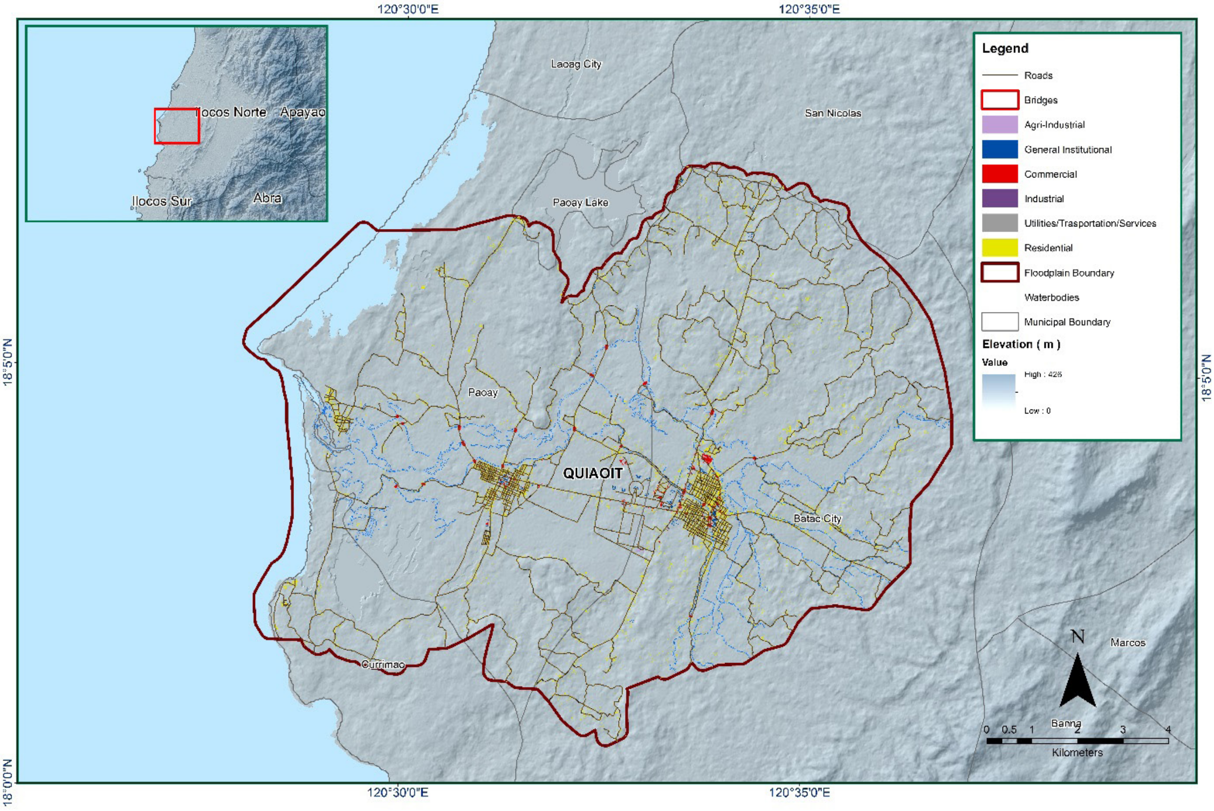


Figure 25. Extracted features for Quiaoit Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE QUIAOIT 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 Quiaoit River on April 28 to May 12, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built surveys at Quiaoit Bridges 1 and 2; validation points data acquisition of about 27 km for the areas traversing the Quiaoit River Basin; and bathymetric survey from Brgy. Camguidan, Batac City down to Brgy. Masintoc, Municipality of Paoay, with an estimated length of 17.842 km using Ohmex™ single-beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 26).

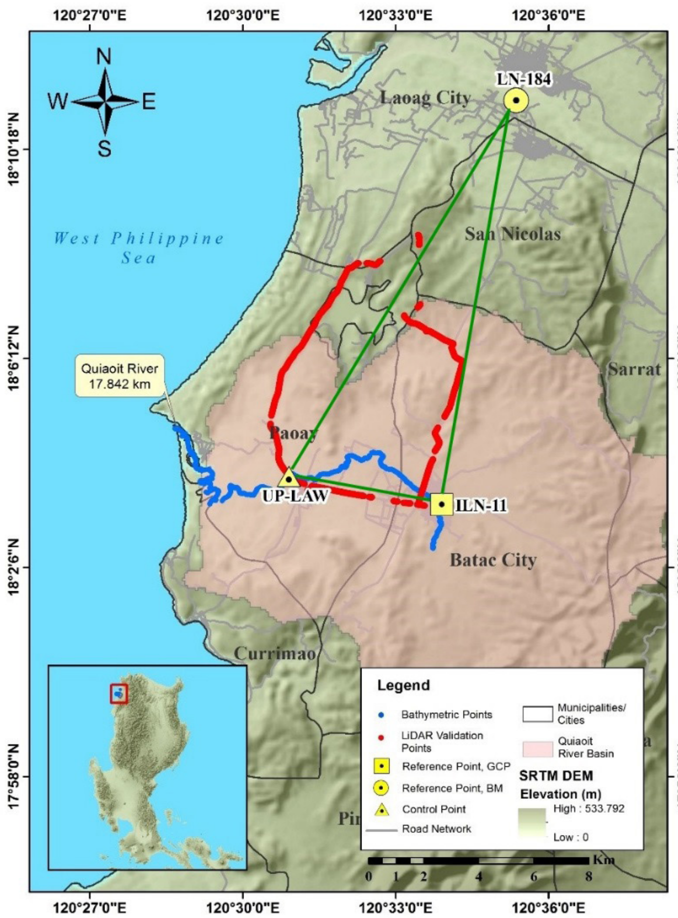


Figure 26. Extent of the bathymetric survey (in blue) in Quiaoit River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Quiaoit River Basin is composed of single loop established on April 29, 2016 occupying the following reference points: ILN-11, a second-order GCP in Brgy. Ricarte Poblacion, Batac City; and LN-184, a first-order BM in Brgy. Nangalisan East, Laoag City.

An additional control point was established in the area, UP-LAW, in Brgy. San Roque, Batac City.

The summary of reference and control points and their location is summarized in Table 19 while the GNSS network established is illustrated in Figure 27.

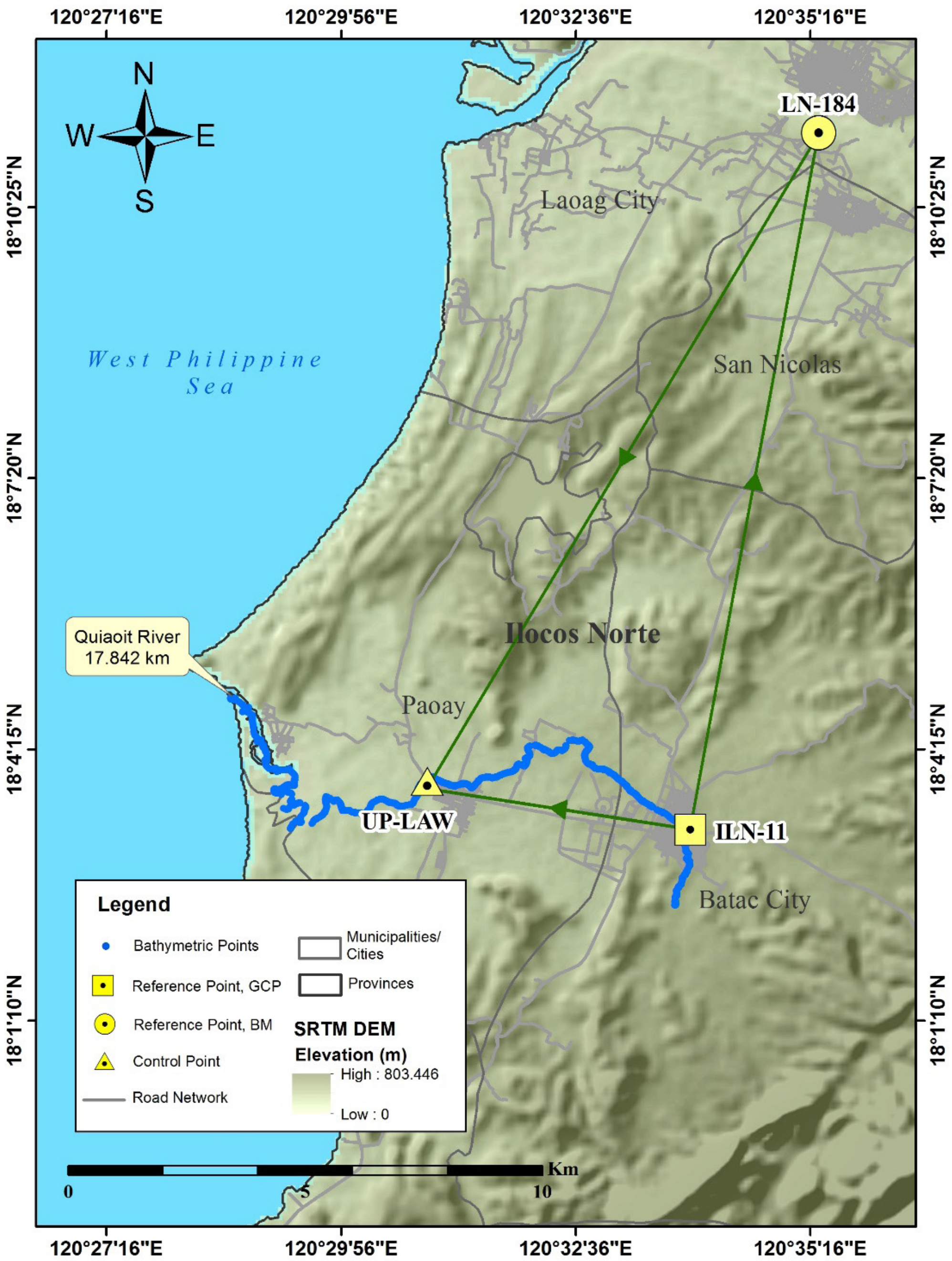


Figure 27. GNSS network covering Quiaoit River

Table 19. List of reference and control points occupied for Quiaoit 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
ILN-11	2nd order, GCP	18°03'20.64552"N	120°33'54.52048"E	69.532	-	2004
LN-184	1st order, BM	-	-	49.220	12.678	2007
UP-LAW	Used as Marker	-	-	-	-	4-29-2016

The GNSS set-ups on recovered reference points and established control points in Quiaoit River are shown in Figure 28 to Figure 30.

Figure 28. GNSS base set-up, Trimble® SPS 852, at ILN-11, located on the roof top of Batac City Hall in Brgy. San Roque, Batac City, Ilocos Sur

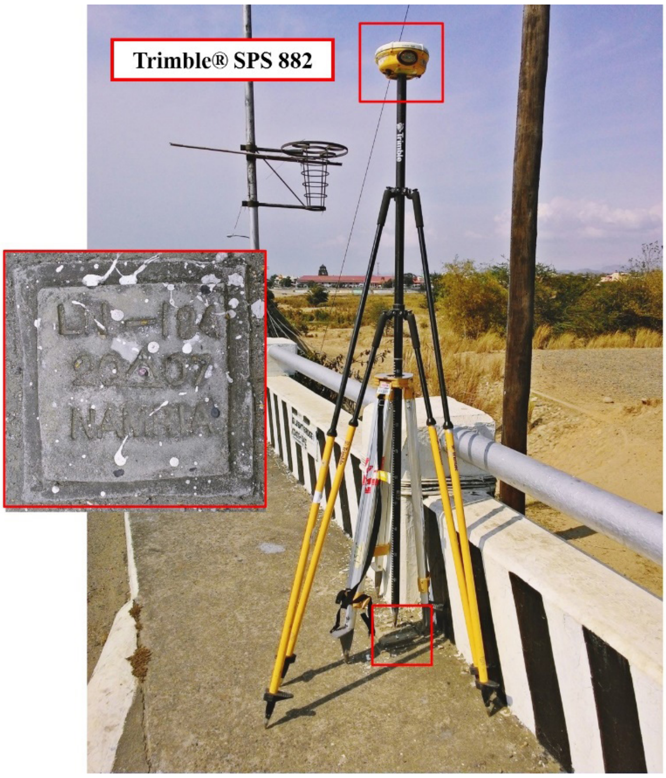


Figure 29. GNSS receiver set-up, Trimble® SPS 882, at LN-184, located at the approach of Laoag Bridge along Manila-North Road, Brgy. Nangalisan East, Laoag City, Ilocos Norte

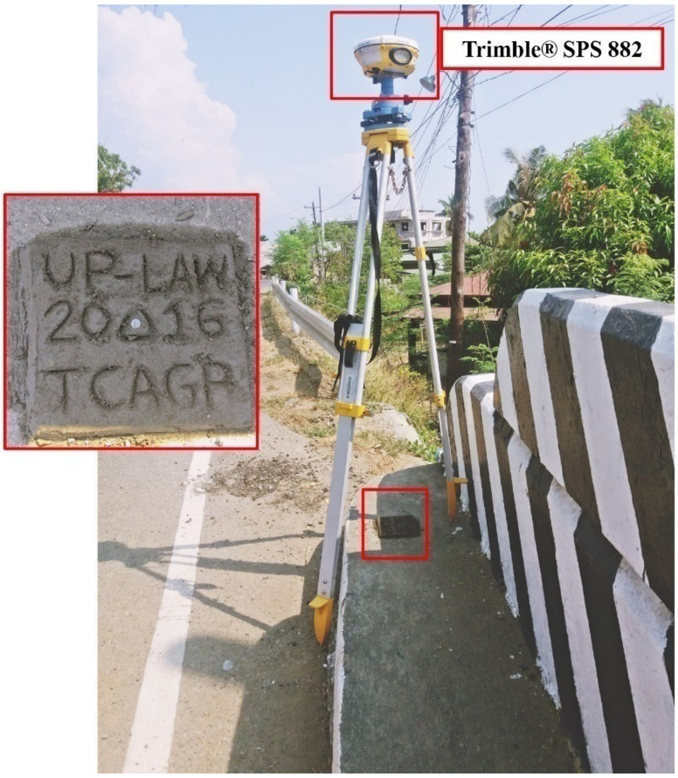


Figure 30. GNSS receiver set-up, Trimble® SPS 882, at UP-LAW, located at the approach of Lawa Bridge along Marcos Avenue in Brgy. San Roque, Batac City, Ilocos Norte

4.3 Baseline Processing

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

Table 20. Baseline processing summary report for Quiaoit River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
ILN-11 --- LN-184	4-29-2016	Fixed	0.008	0.021	9°57’44”	14828.96
ILN-11 --- UP-LAW	4-29-2016	Fixed	0.003	0.01	280°50’14”	5390.828
LN-184 --- UP-LAW	4-29-2016	Fixed	0.009	0.025	210°02’54”	15700.88

As shown in Table 20, a total of three (3) baselines were processed with reference points ILN-11 and LN-184 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates table of the TBC-generated Network Adjustment Report, it 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:

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 21 to Table 24 for complete details.

The three (3) control points, ILN-11, LN-184, and UP-LAW, were occupied and observed simultaneously to form a GNSS loop. Coordinates of ILN-11 and elevation value of LN-184 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points were be computed.

Table 21. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ILN-11	Local	Fixed	Fixed		
LN-184	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 22. The fixed control point ILN-11 has no values for grid errors; and LN-184 for elevation error.

Table 22. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ILN-11	242257.819	?	1998049.985	?	32.680	0.026	LL
LM-184	245017.274	0.007	2012626.163	0.004	12.678	?	e
UP-LAW	236974.637	0.003	1999133.738	0.003	8.822	0.027	

With the mentioned equation, for horizontal and for the vertical, the computation for the accuracy are as follows:

ILN-11

horizontal accuracy = Fixed

vertical accuracy = 2.60 cm < 10 cm

LN-184

horizontal accuracy = $\sqrt{((0.70)^2 + (0.40)^2}$

= $\sqrt{(0.49+ 0.16)}$

= 0.81 cm < 20 cm

vertical accuracy = Fixed

UP-LAW

horizontal accuracy = $\sqrt{((0.30)^2 + (0.30)^2}$

= $\sqrt{(0.09 + 0.09)}$

= 0.42 < 20 cm

vertical accuracy = 2.70 cm < 10 cm

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

Table 23. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Con-straint
ILN-11	N18°03’20.64552”	E120°33’54.52048”	69.532	0.026	LL
LM-184	N18°11’15.68957”	E120°35’21.81791”	49.220	?	e
UP-LAW	N18°03’53.58954”	E120°30’54.47361”	45.357	0.027	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

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

Table 24. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ILN-11	2nd order, GCP	18°03’20.64552”	120°33’54.52048”	69.532	1998049.985	242257.819	32.680
LN-184	1st order, BM	18°11’15.68957”	120°35’21.81791”	49.220	2012626.163	245017.274	12.678
UP-LAW	UP Established	18°03’53.58954”	120°30’54.47361”	45.357	1999133.738	236974.637	8.822

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

Cross-section and as-built survey were conducted on May 4, 2016 at the downstream side of Quiaoit Bridges 1 and 2 in Brgy. Valdez Poblacion, Batac City using a survey-grade GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 31.

Figure 31. Downstream side of a) Quiaoit Bridge 1 and b) Quiaoit Bridge 2

The cross-sectional line for the Quiaoit Bridge 1 is about 36 m with 17 cross-sectional points while Quiaoit Bridge 2 is about 38 m with 23 cross-sectional points. Both surveys utilized ILN-11 as the GNSS base station. The location maps, cross-section diagrams, and bridge data forms are shown in Figure 32 to Figure 37.

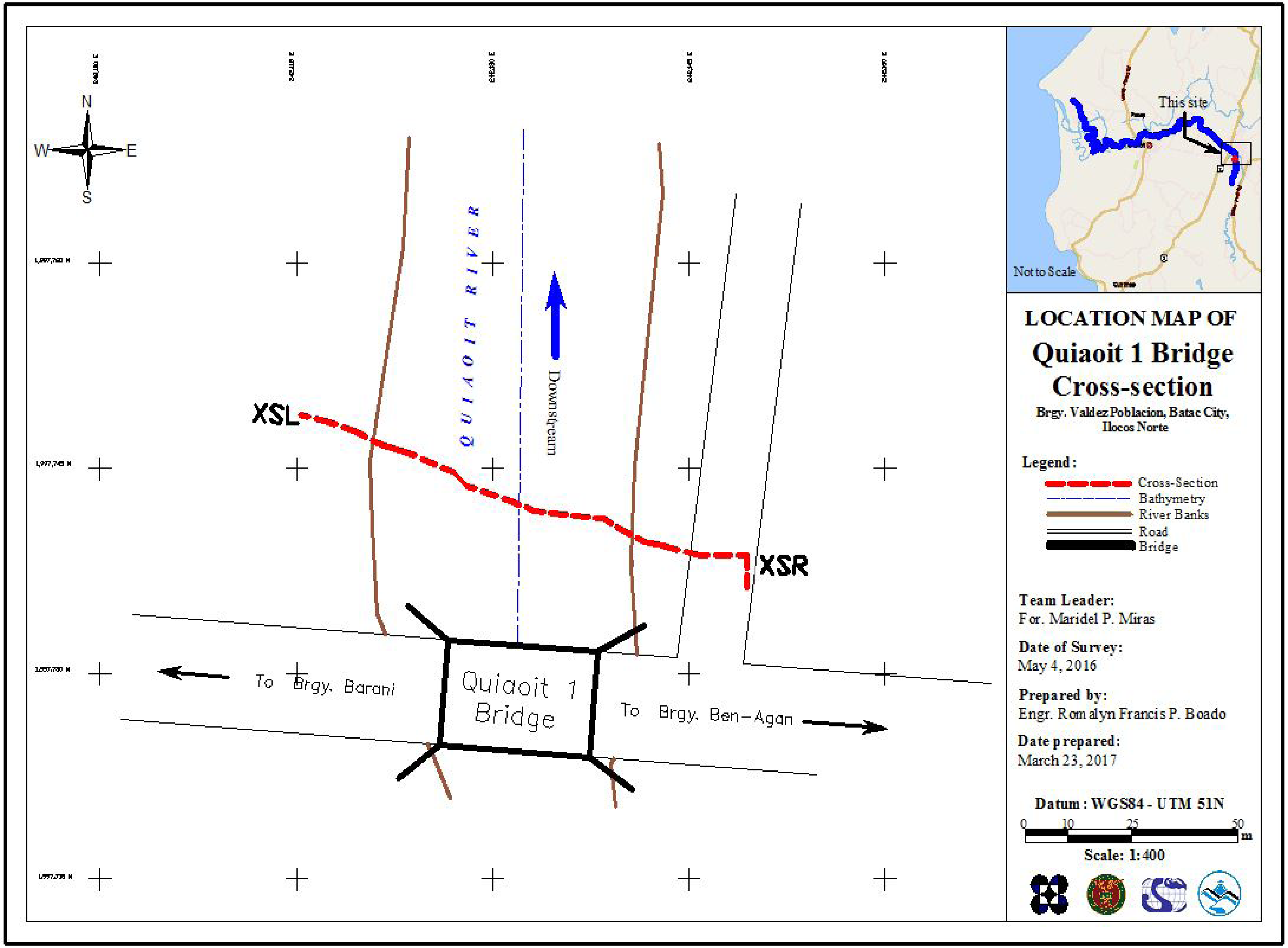


Figure 32. Quiaoit bridge 1 cross-section location map

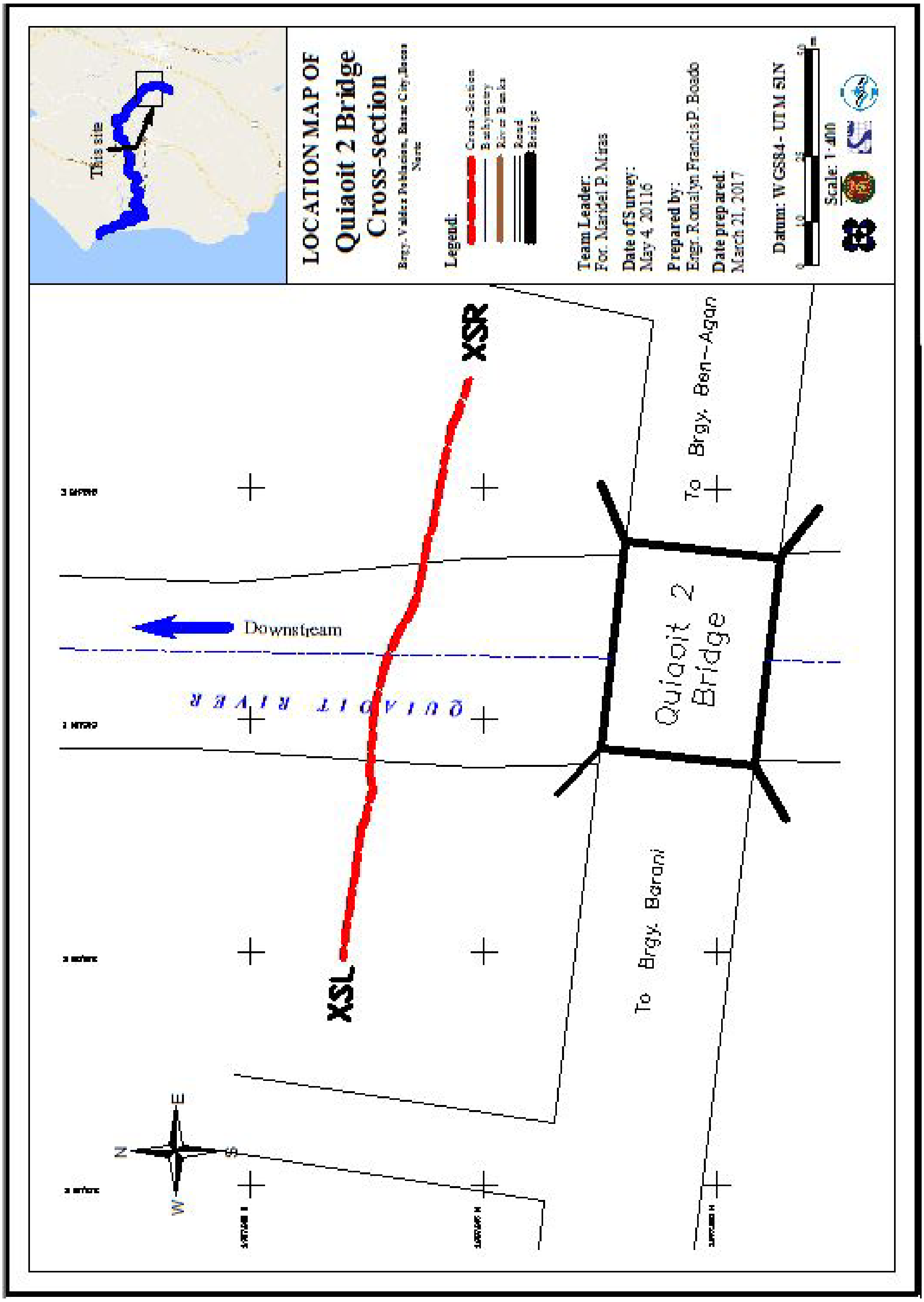


Figure 33. Quiaoit bridge 2 cross-section location map

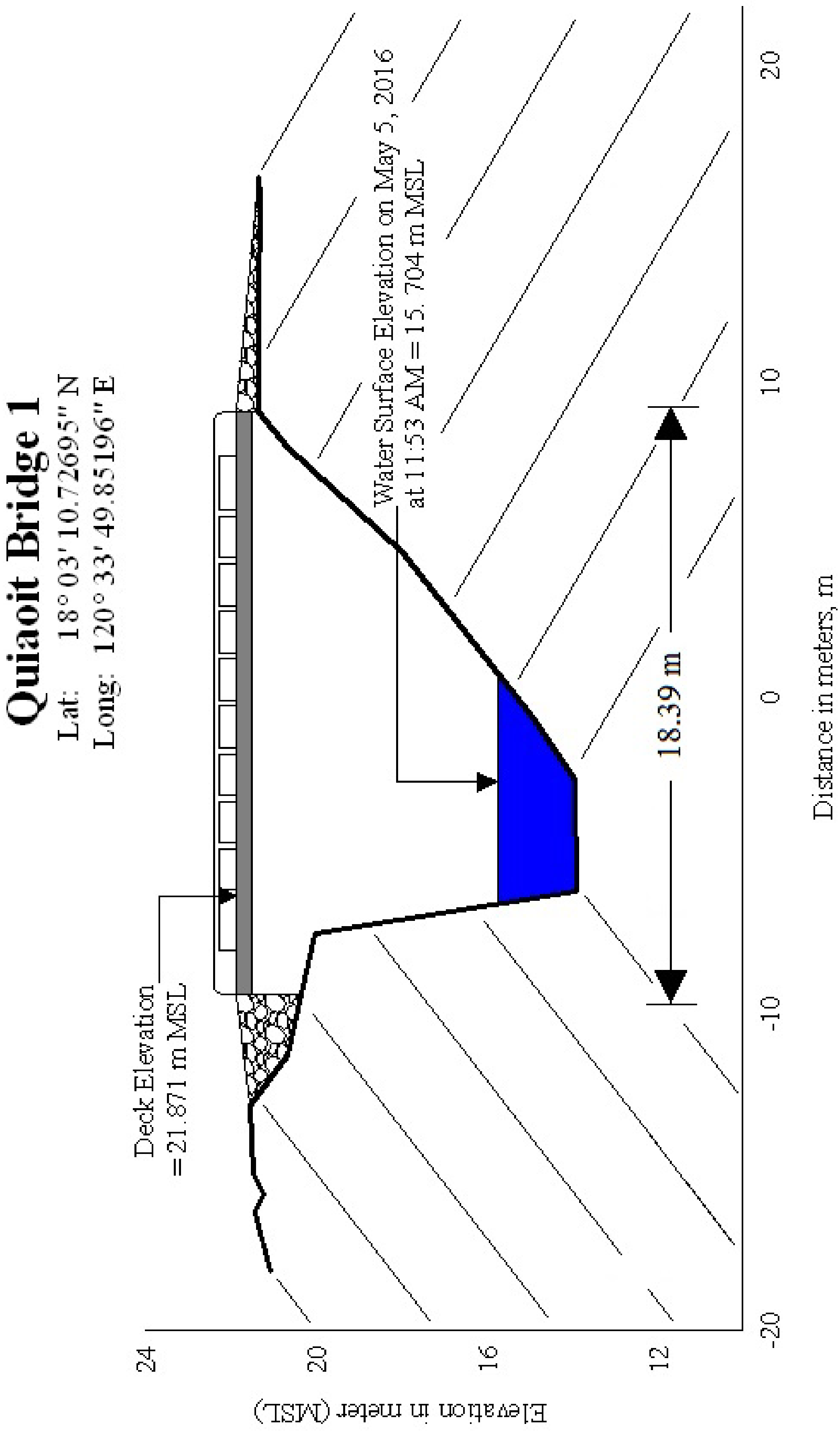


Figure 34. Quiaoit Bridge 1 cross-section diagram

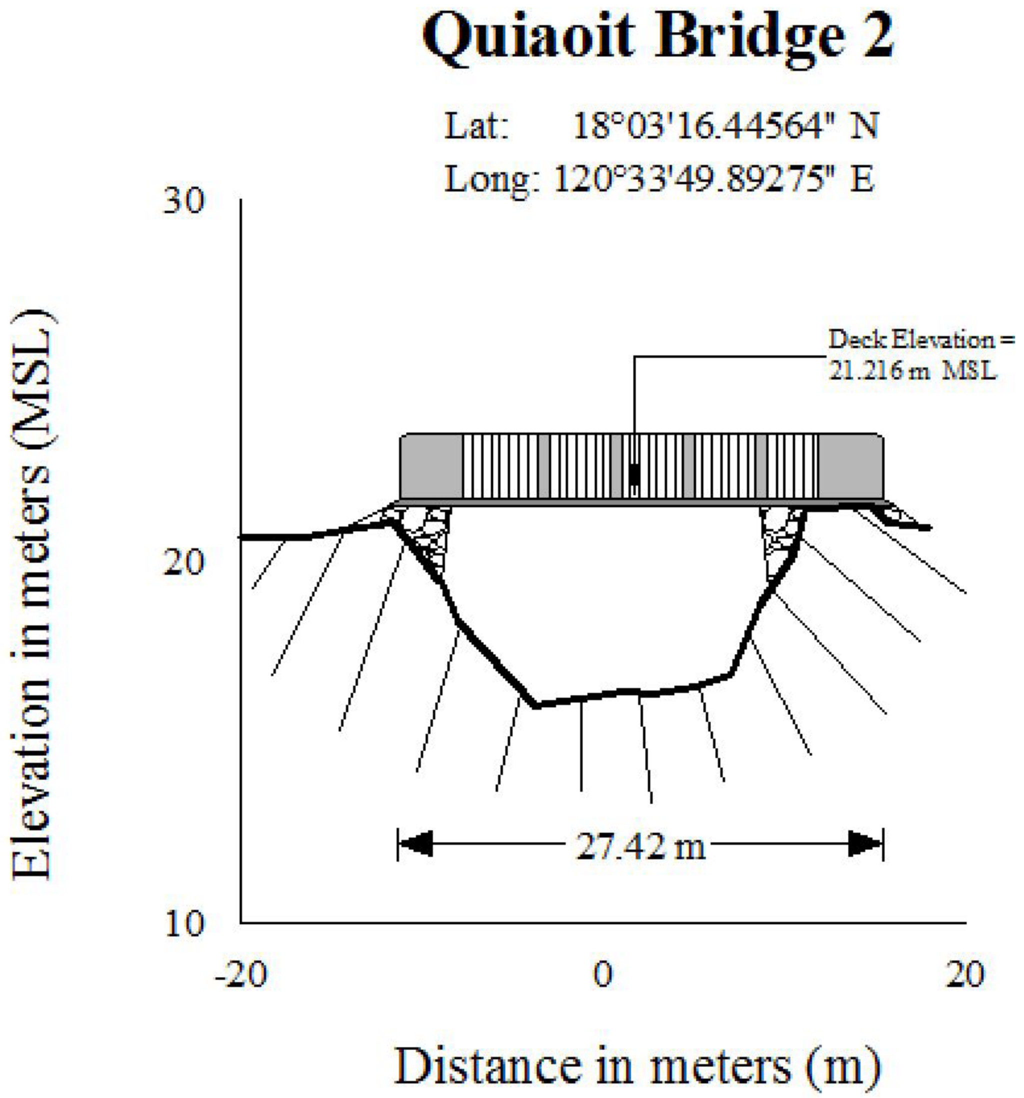
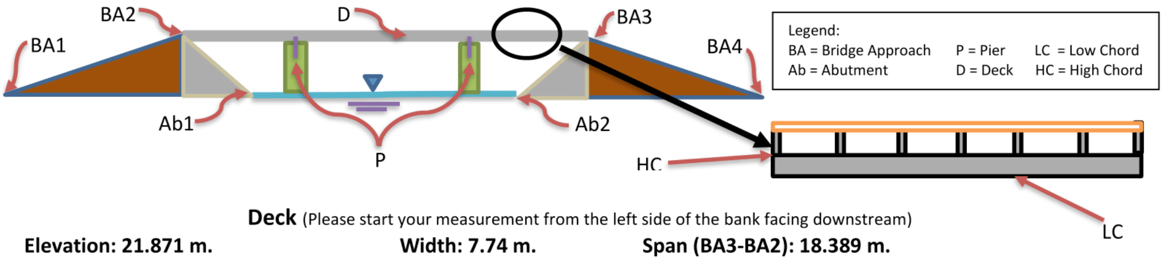


Figure 35. Quiaoit Bridge 2 cross-section diagram

Bridge Data Form

Bridge Name: Quiaoit Bridge 1	**Date: May 4, 2016**
River Name: Quiaoit River	**Time: 1:00 PM**
Location: Brgy. Valdez Poblacion, Batac City, Ilocos Norte	
Survey Team: Maridel Miras, Rodel Alberto, Caren Ordoña	
Flow condition: low ✓ normal high	**Weather Condition:** ✓ fair rainy
Latitude: 18°03'10.79651"N	**Longitude: 120°33'49.81219"E**



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

Elevation: 21.871 m. **Width: 7.74 m.** **Span (BA3-BA2): 18.389 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	n/a	n/a	n/a
2			
3			
4			
5			

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	21.210	BA3	28.920	21.958
BA2	10.530	21.871	BA4	36.366	21.354

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

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

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

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

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	n/a	n/a	n/a
Pier 2	n/a	n/a	n/a
Pier 3	n/a	n/a	n/a
Pier 4	n/a	n/a	n/a

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 36. Bridge as-built form of Quiaoit Bridge 1

Bridge Data Form

Bridge Name: Quiaoit Bridge 2 **Date: May 4, 2016**

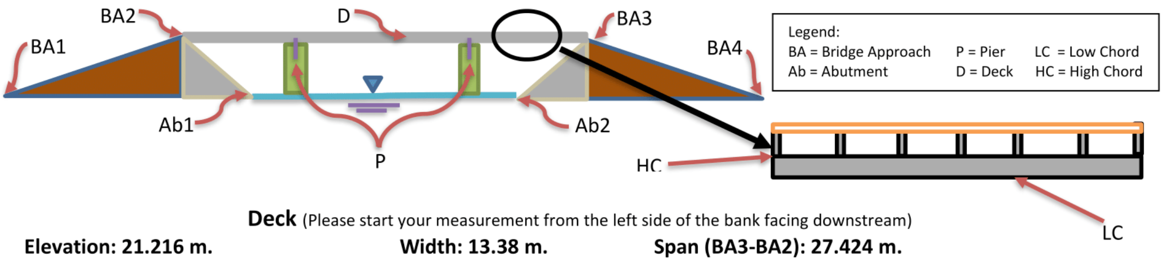
River Name: Quiaoit River **Time: 11:59 AM**

Location: Brgy. Valdez Poblacion, Batac City, Ilocos Norte

Survey Team: Maridel Miras, Rodel Alberto, Caren Ordoña

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

Latitude: 18°03'16.48827"N **Longitude: 120°33'49.71068"E**



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

Elevation: 21.216 m. **Width: 13.38 m.** **Span (BA3-BA2): 27.424 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	n/a	n/a	n/a
2			
3			
4			
5			

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	20.614	BA3	35.824	21.145
BA2	8.400	21.216	BA4	38.037	20.916

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

	Station (Distance from BA1)	Elevation
Ab1	12.048	18.279
Ab2	27.111	16.816

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

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

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	n/a	n/a	n/a
Pier 2	n/a	n/a	n/a
Pier 3	n/a	n/a	n/a
Pier 4	n/a	n/a	n/a

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 37. Bridge as-built form of Quiaoit Bridge 2

Water surface elevation of Quiaoit River, as shown in Figure 38, was determined on May 5, 2016 at 11:53 AM with a value of 15.704 m in MSL. This was marked on the bridge's railings that will serve as reference for flow data gathering and depth gauge deployment of UPB for Quiaoit River.

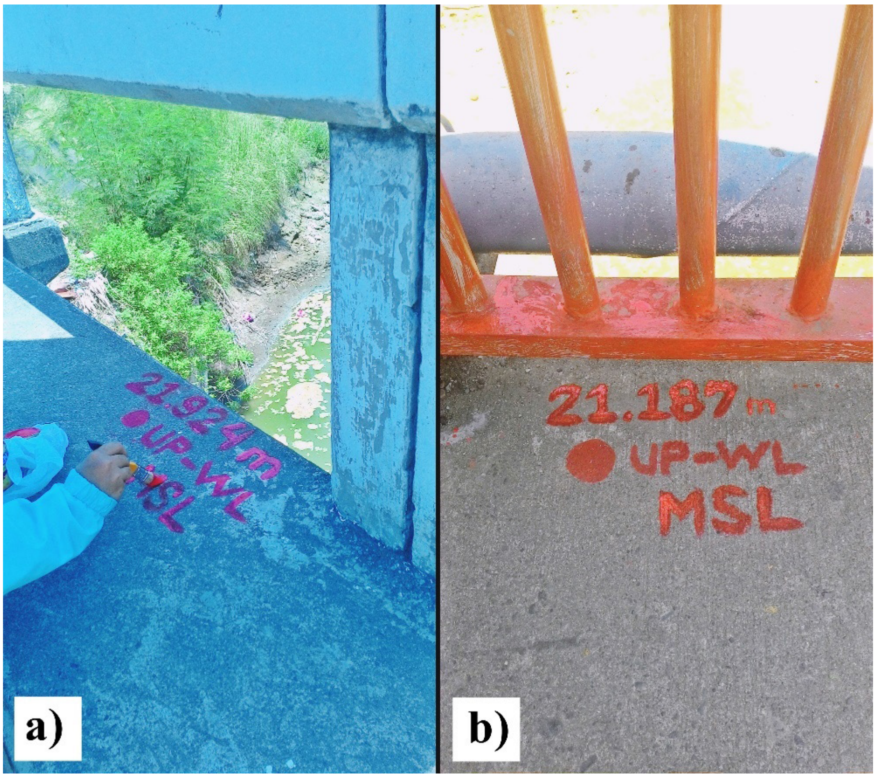


Figure 38. Water-level markings on the bridge of a) Quiaoit Bridge 1 and b) Quiaoit Bridge 2

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on May 1, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown in Figure 39. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.968 m 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 ILN-11 occupied as the GNSS base stations in the conduct of the survey.

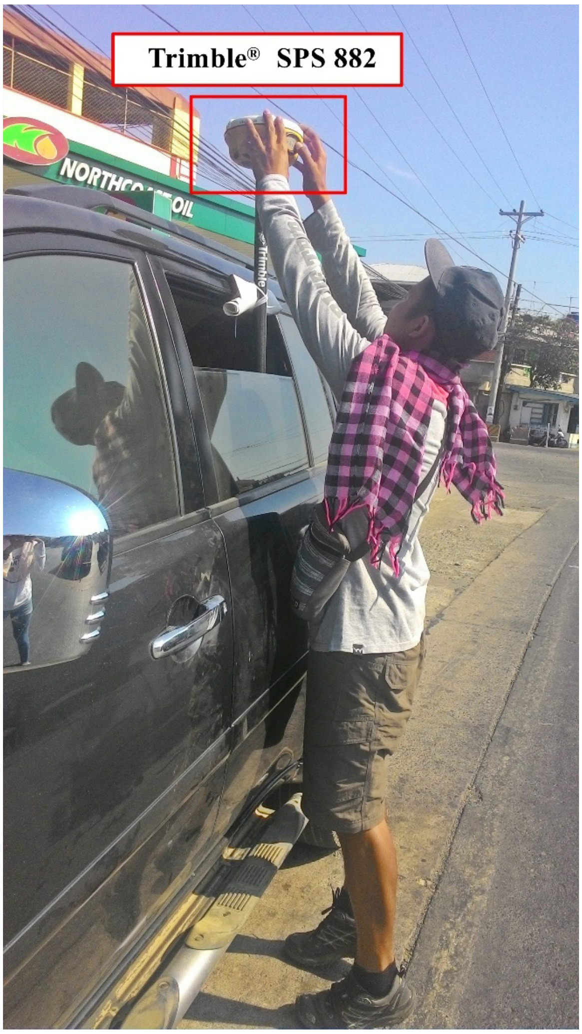


Figure 39. Validation points acquisition survey set up along Quiaoit River Basin

The survey started from Brgy. Nangunuday in the municipality of Paoay, going south towards Brgy. San Roque, also in Paoay via Currimao-Paoay-Suba-Balacao Road. Then, it went east towards Brgy. Caunayan, Batac City via Marcos Avenue before going north towards Brgy. Sta. Asuncion, Municipality of San Nicolas via Manila-North Road. The survey gathered 7,438 points with an approximate length of 26.696 km using ILN-11 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 40.

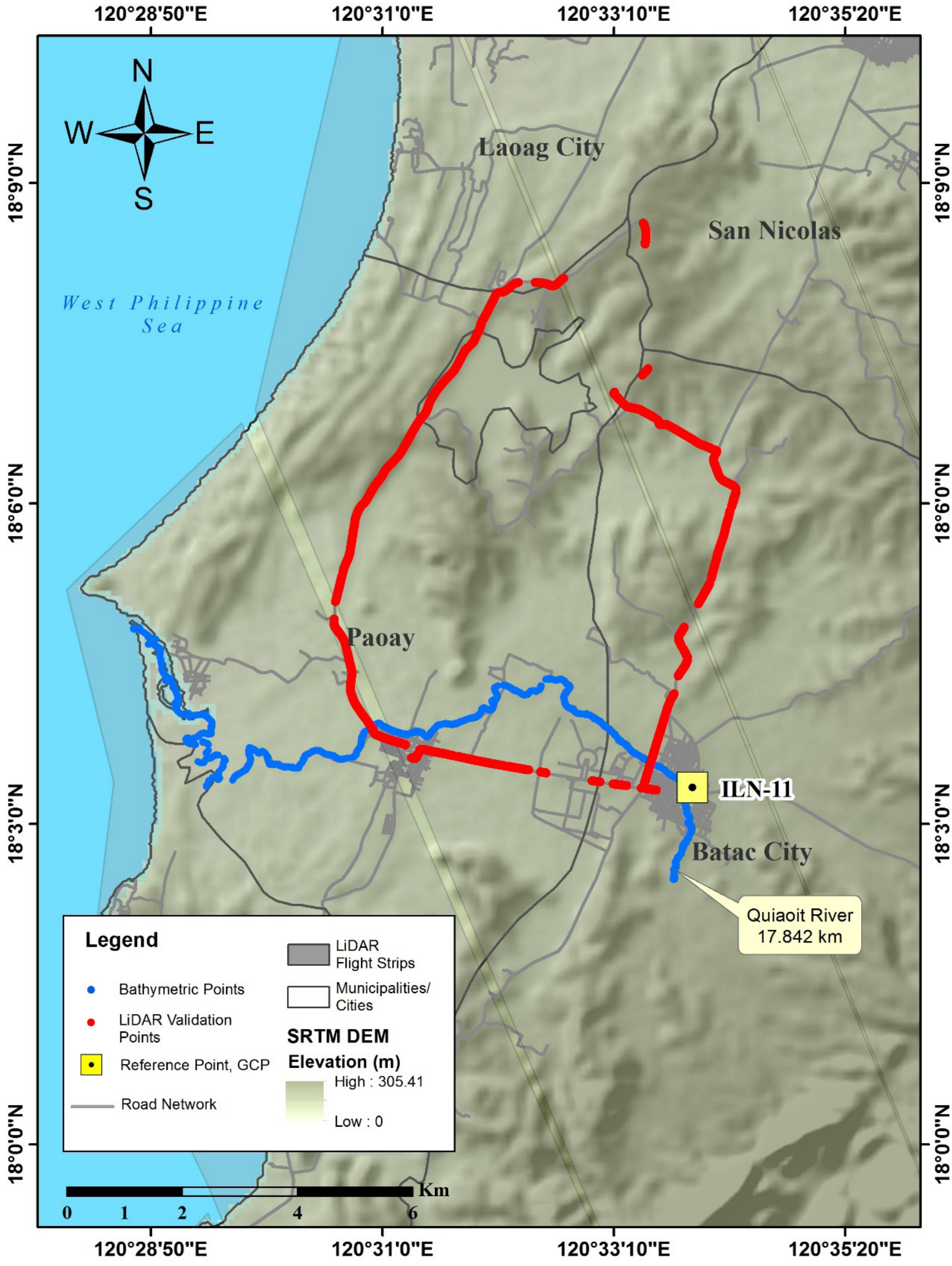


Figure 40. Validation point acquisition survey of Quiaoit River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on April 30, and May 2 to 4, 2016 using Trimble® SPS 882 in GNSS PPK survey technique and South GPS S86-T in GNSS RTK survey technique in continuous topo mode as illustrated in Figure 41. The survey started from the upstream in Brgy. Camguidan, Batac City, with coordinates 18°2'28.98562"N, 120°33'43.90235"E, traversed down by foot and ended at the mouth of the river in Brgy. Masintoc, Municipality of Paoay, with coordinates 18°4'49.69637"N, 120°28'40.47656"E. The control points ILN-11, LN-184, and UP-LAW were used as GNSS base stations.

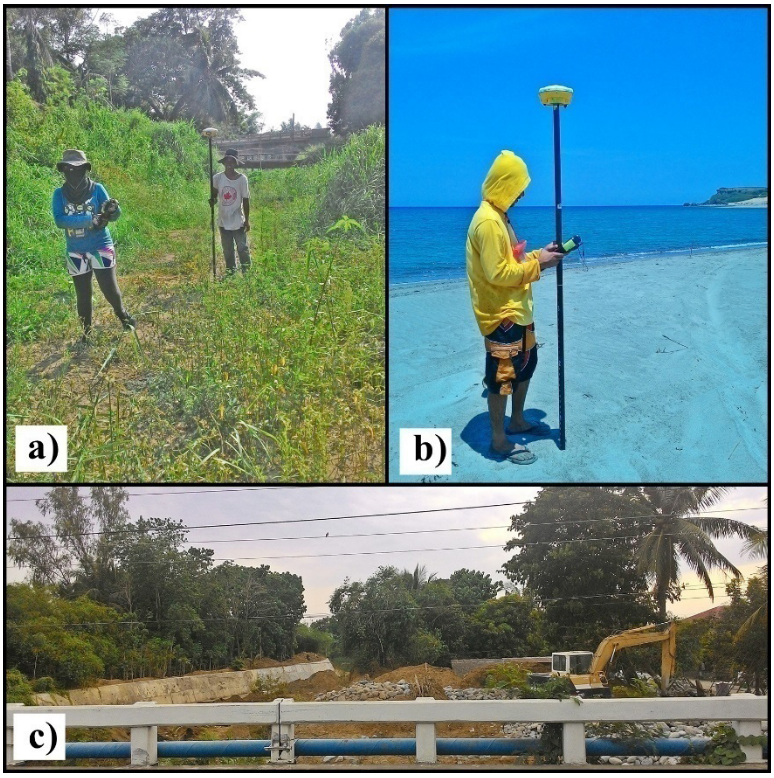


Figure 41. Bathymetric survey set-up in Quiaoit River

The bathymetric survey for Quiaoit River gathered a total of 4,764 points covering 17.842 km of the river traversing 20 barangays in the municipalities of Paoay and Currimao, and city of Batac. A CAD drawing was also produced to illustrate the riverbed profile of Quiaoit River. As shown in Figure 43, the highest and lowest elevations have a 27-m difference. The highest elevation observed was 21.612 m above MSL located in Brgy. Camguidan, Batac City while the lowest was 5.652 m below MSL located in Brgy. Cabuyog, Municipality of Paoay.

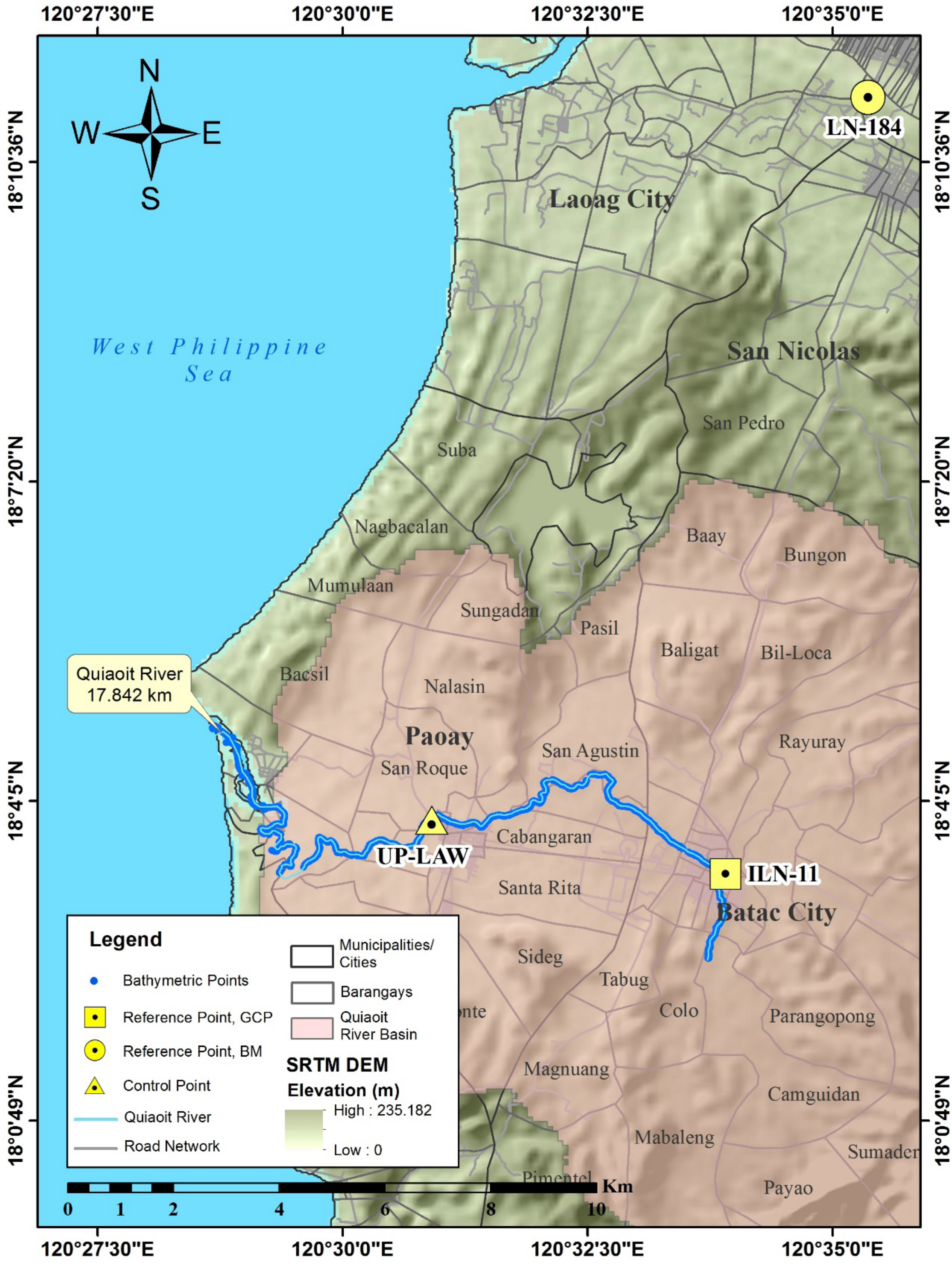


Figure 42. Bathymetric survey of Quiaoit River

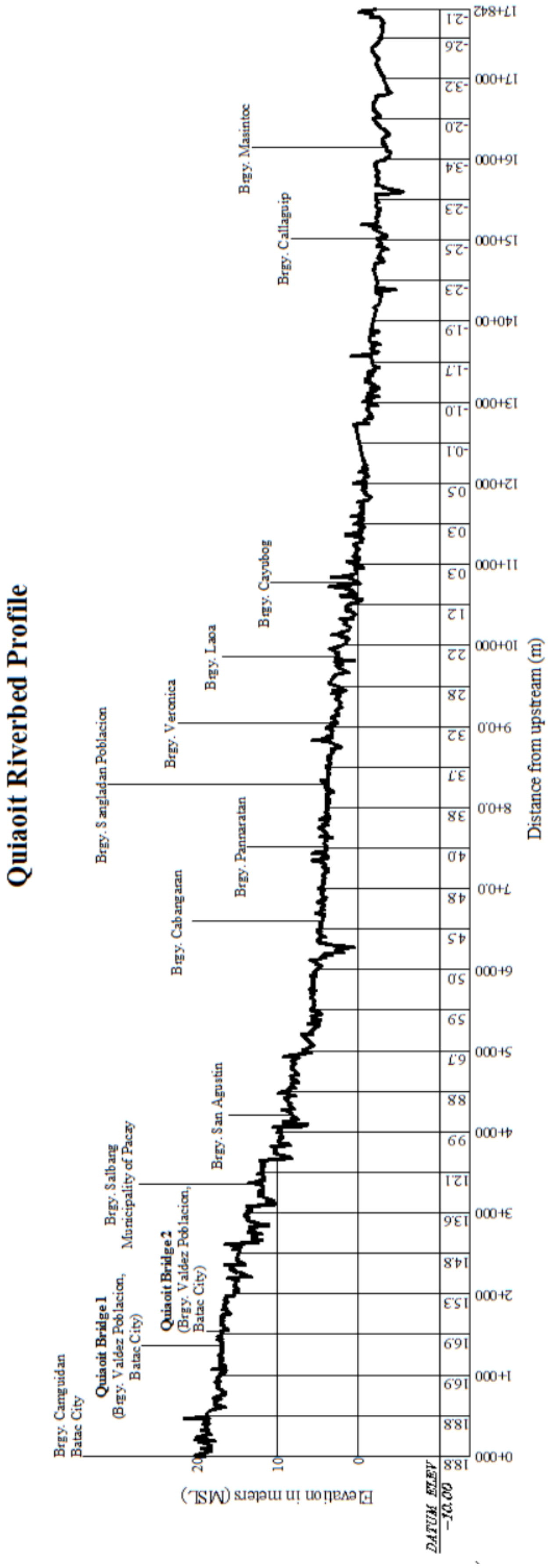


Figure 43. Quiaoit riverbed profile

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, Hannah Aventurado

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the PhilRice Batac-FMON1 ARG (18°3’16.55” N, 120°32’49.49” E), located in Batac, Ilocos Norte, as shown in Figure 44. The precipitation data collection started on July 31, 2016 at 12:00 AM and ended on August 2, 2016 at 12:00 PM with a 15-minute recording interval.

The total precipitation for this event in PhilRice Batac-FMON1 ARG was 22.8 mm. It has a peak rainfall of 5.6 mm on July 31, 2016 at 3:00 PM. The lag time between the peak rainfall and discharge is 6 hours and 50 minutes.

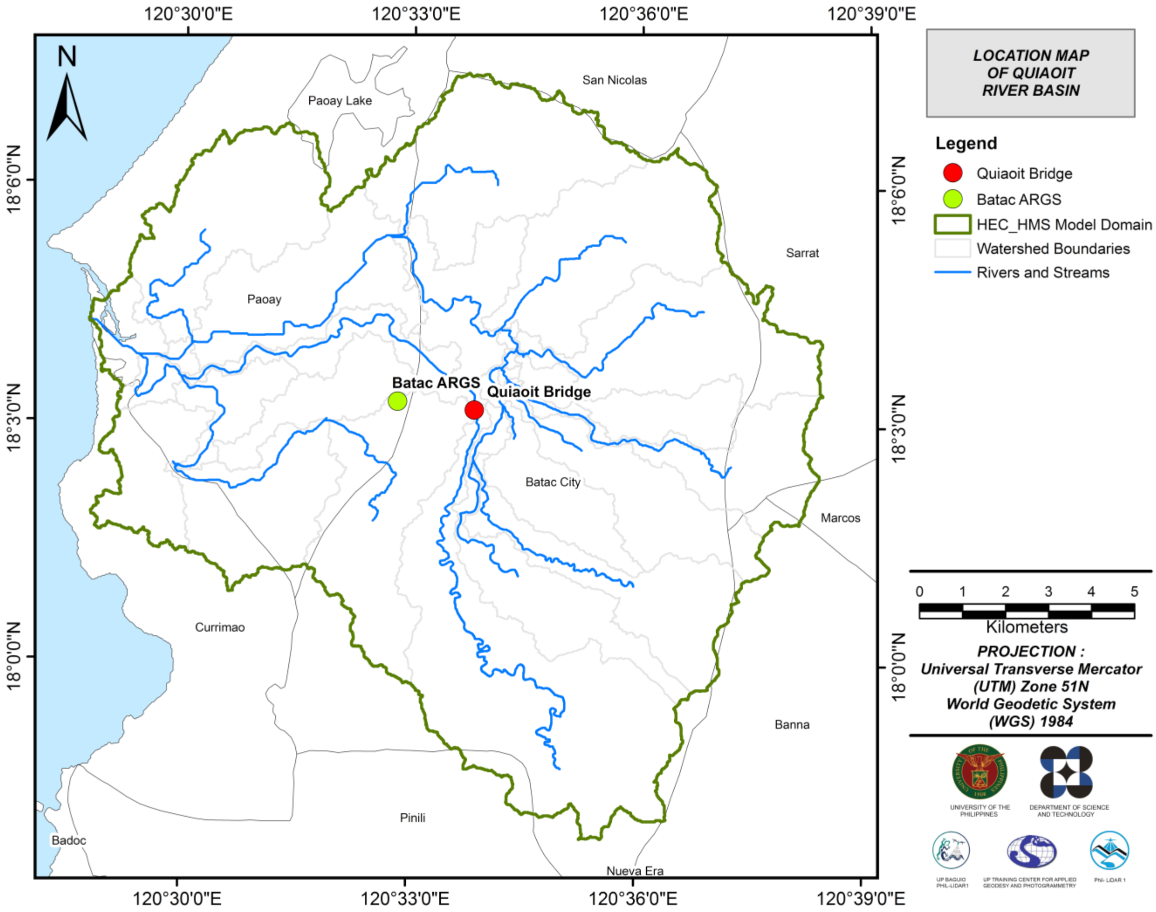


Figure 44. Location map of Quiaoit HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Quiaoit Bridge, Batac, Ilocos Norte (18°3’10.33” N, 120°33’50.57” E). It gives the relationship between the observed water level from the Quiaoit Bridge and outflow of the watershed at this location.

For Quiaoit Bridge, the rating curve is expressed as $Q = 2.8834E\text{-}03e^{0.463x}$ as shown in Figure 46.

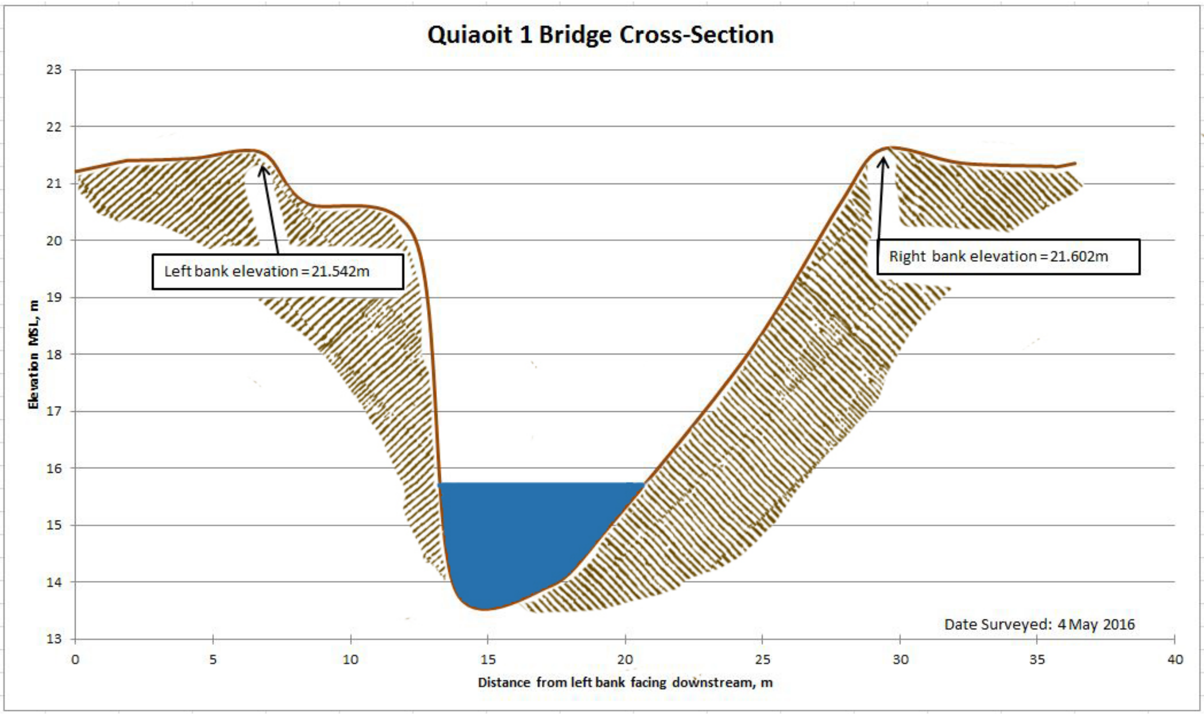


Figure 45. Cross-section plot of Quiaoit Bridge

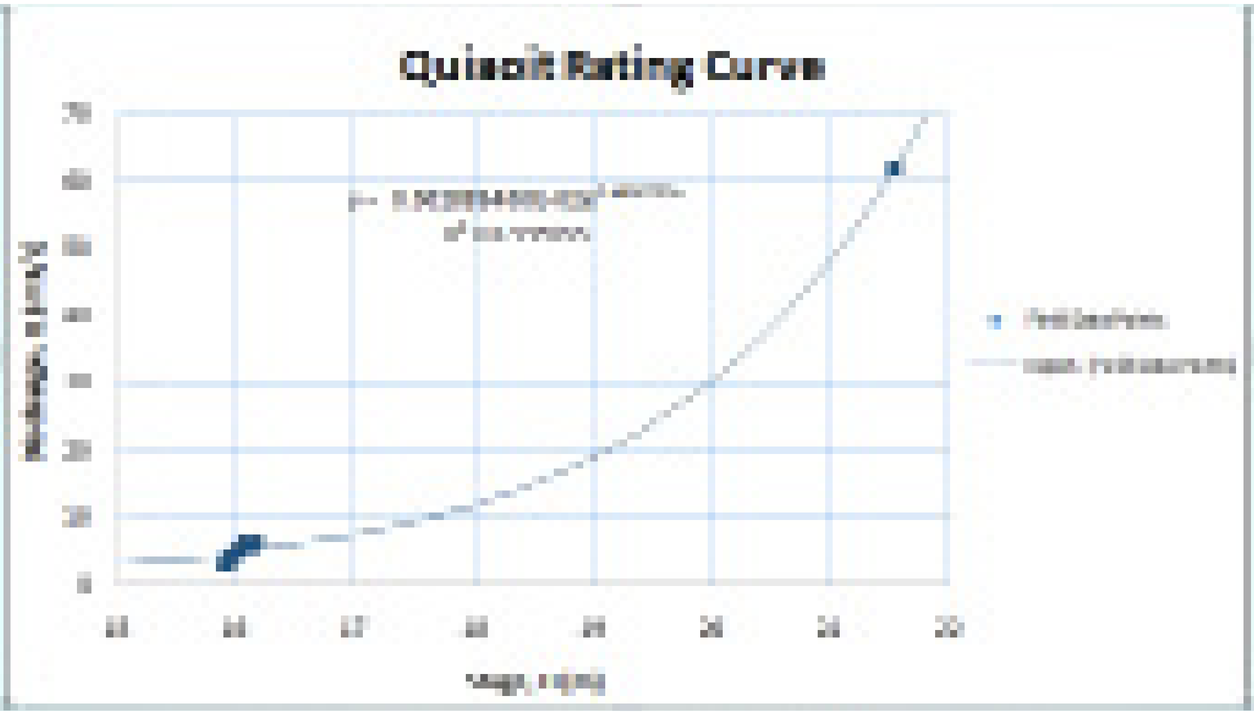


Figure 46. Rating curve at Quiaoit Bridge, Batac, Ilocos Norte

The rating curve equation was used to compute for the river outflow at Quiaoit Bridge for the calibration of the HEC-HMS model for Quiaoit, as shown in Figure 47. The total rainfall for this event is 22.8 mm and the peak discharge is 9.67 m^3/s at 9:50 PM of July 31, 2016.

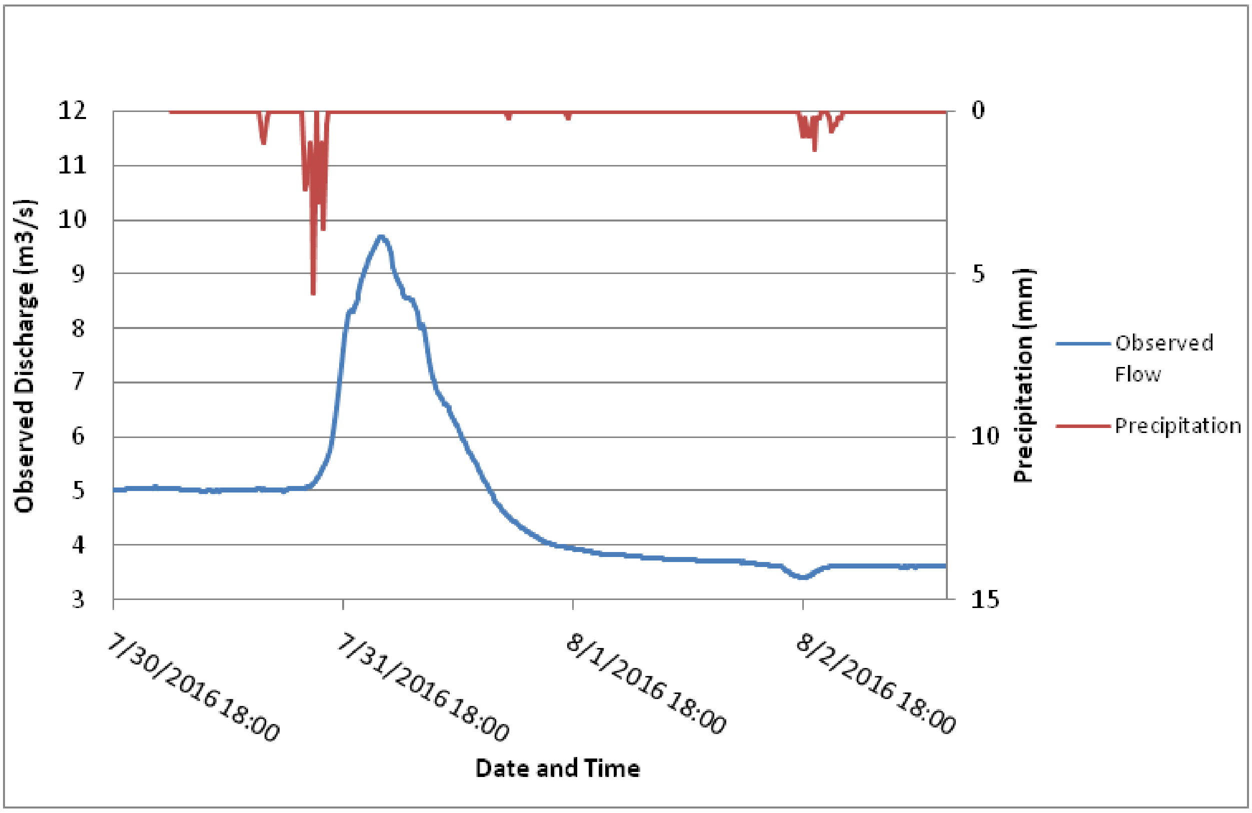


Figure 47. Rainfall and outflow data at Quiaoit Bridge used for modeling

5.2 RIDF Station

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

Table 25. RIDF values for Laoag 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	22.7	35.4	45.7	62.5	89	110.9	148.5	187.8	232.8
5	31.4	48	61.5	87.1	124.6	157.8	211.7	266.3	331.7
10	37.2	56.3	71.9	103.5	148.2	189	253.6	318.3	397.1
15	40.5	61	77.8	112.7	161.6	206.5	277.2	347.7	434
20	42.8	64.3	81.9	119.1	170.9	218.8	293.7	368.2	459.9
25	44.5	66.8	85.1	124.1	178.1	228.3	306.4	384.1	479.8
50	50	74.6	94.8	139.4	200.2	257.4	345.7	432.8	541.1
100	55.3	82.4	104.5	154.6	222.2	286.4	384.6	481.2	602

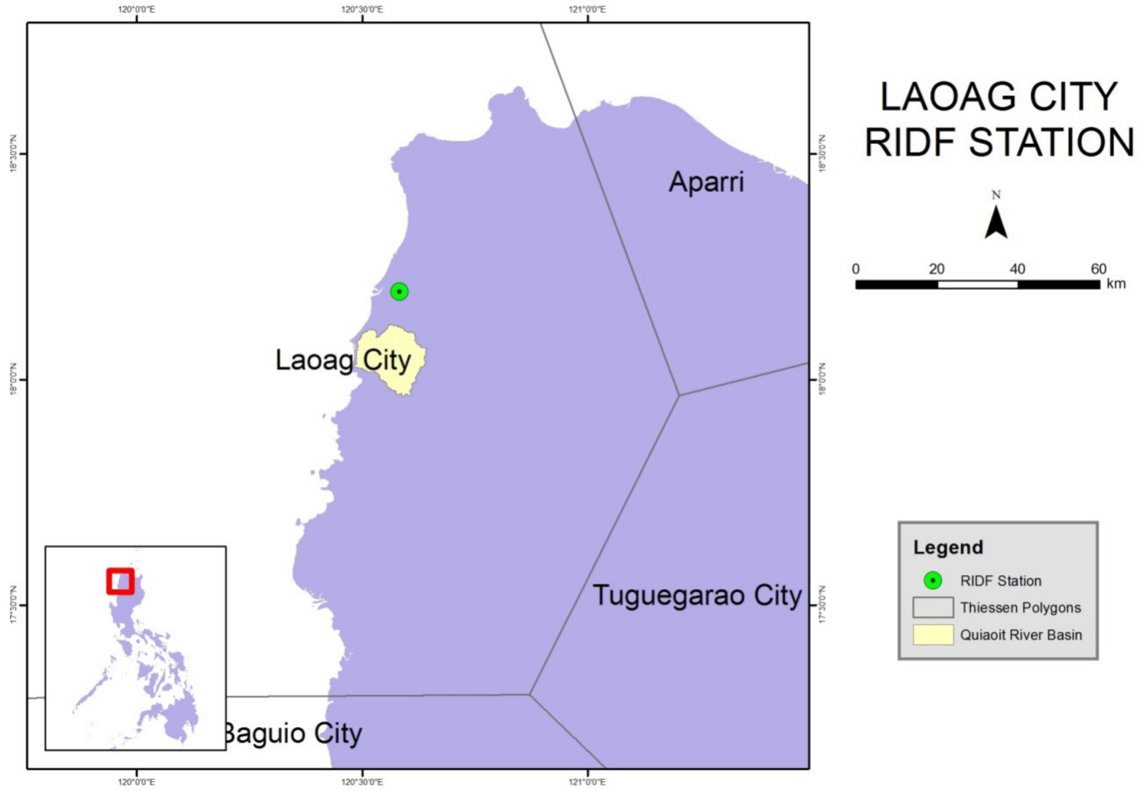


Figure 48. Location of Laoag RIDF Station relative to Quiaoit River Basin

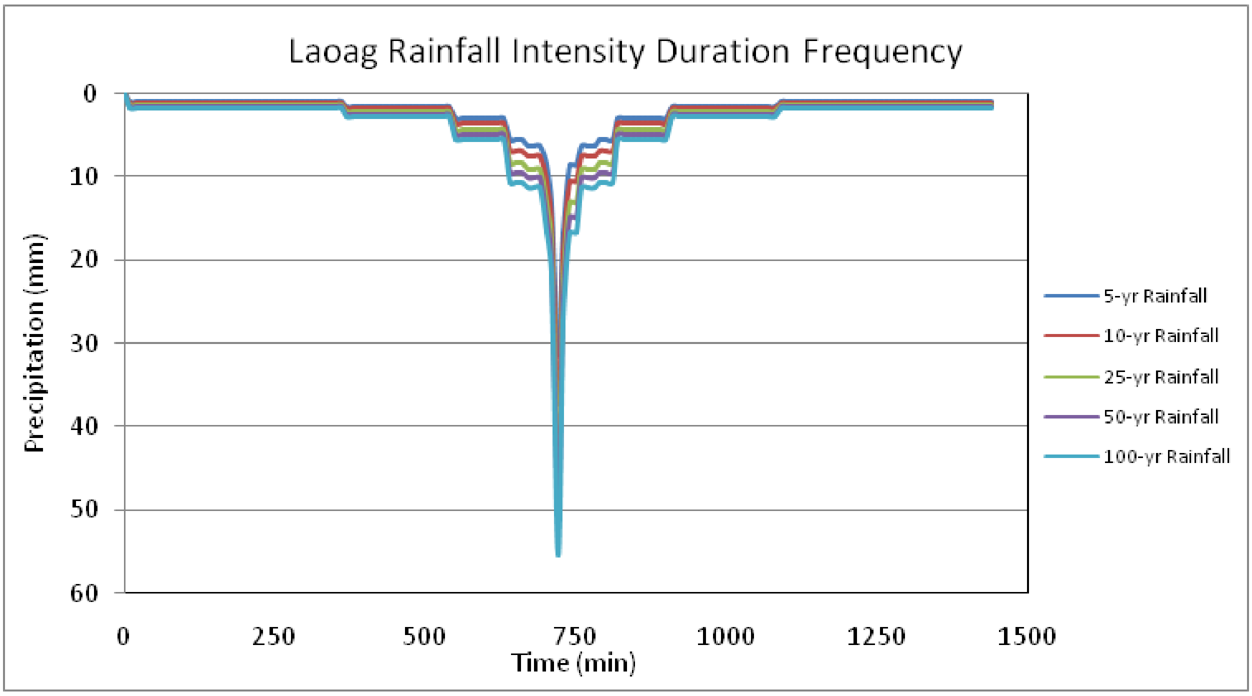


Figure 49. Synthetic storm generated for a 24-hour period rainfall for various return period

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset was taken from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover maps of the Quiaoit River Basin are shown in Figure 50 and Figure 51, respectively.

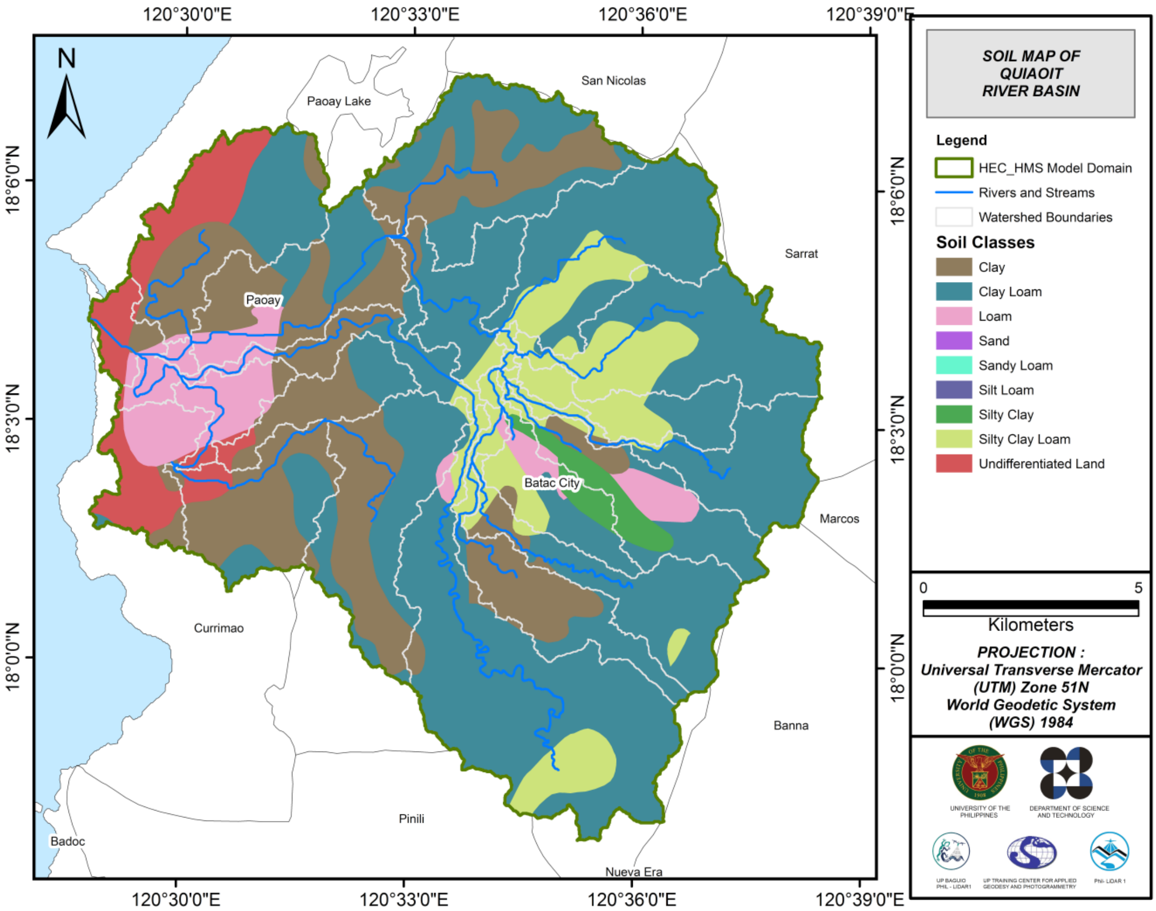


Figure 50. Soil map of Quiaoit River Basin

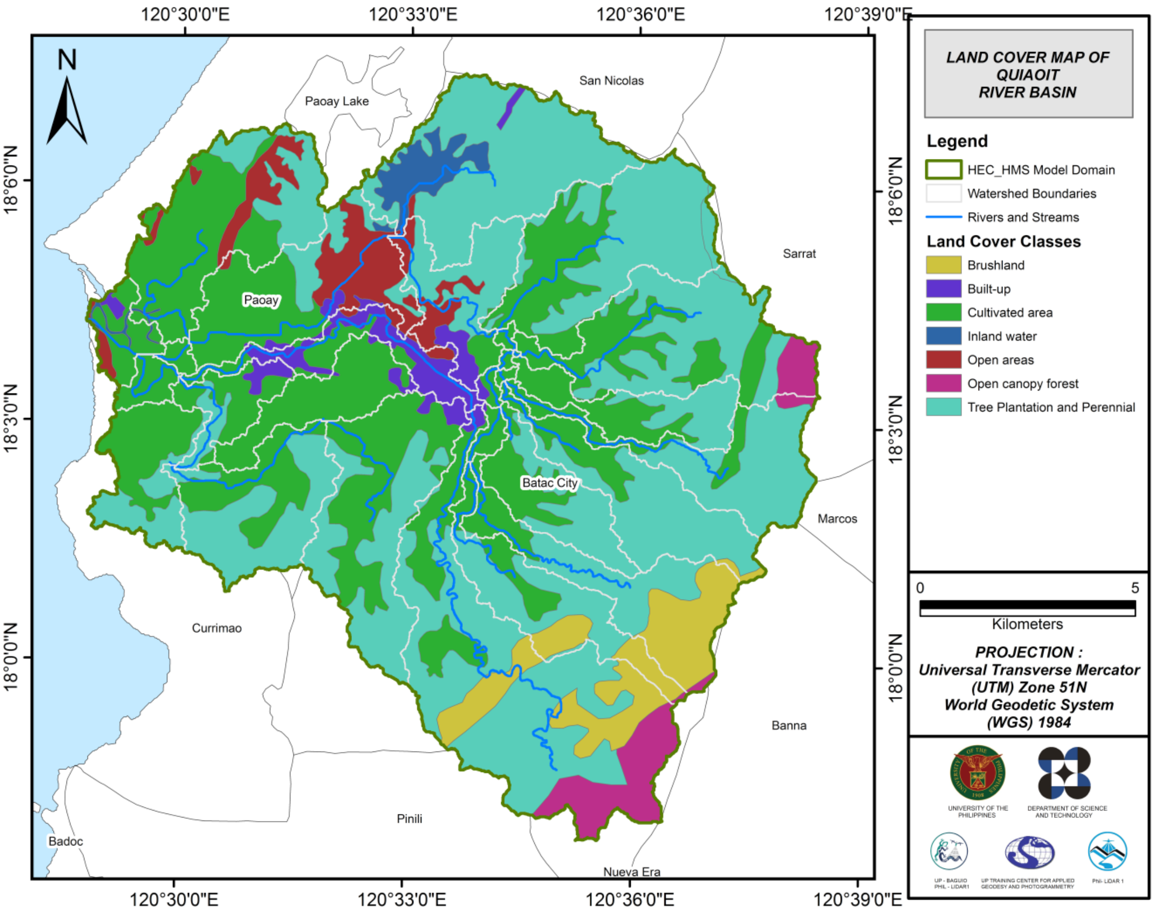


Figure 51. Land cover map of Quiaoit River Basin

For Quiaoit, nine soil classes were identified. These are clay, clay loam, loam, sand, sandy loam, silt loam, silty clay, silty clay loam, and undifferentiated land. Moreover, seven land cover classes were identified, namely brushlands, built-up areas, cultivated areas, inland water, open areas, open canopy forests, and tree plantations.

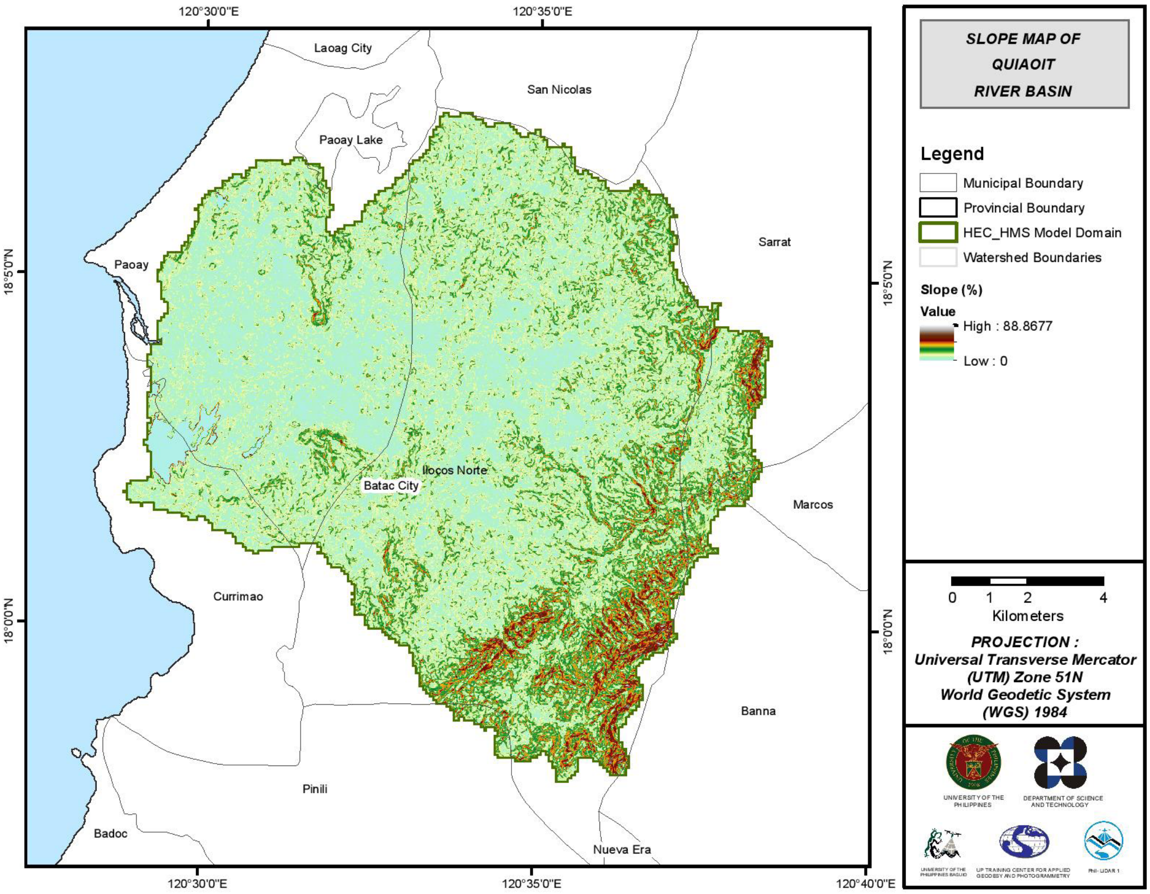


Figure 52. Slope map of Quiaoit River Basin

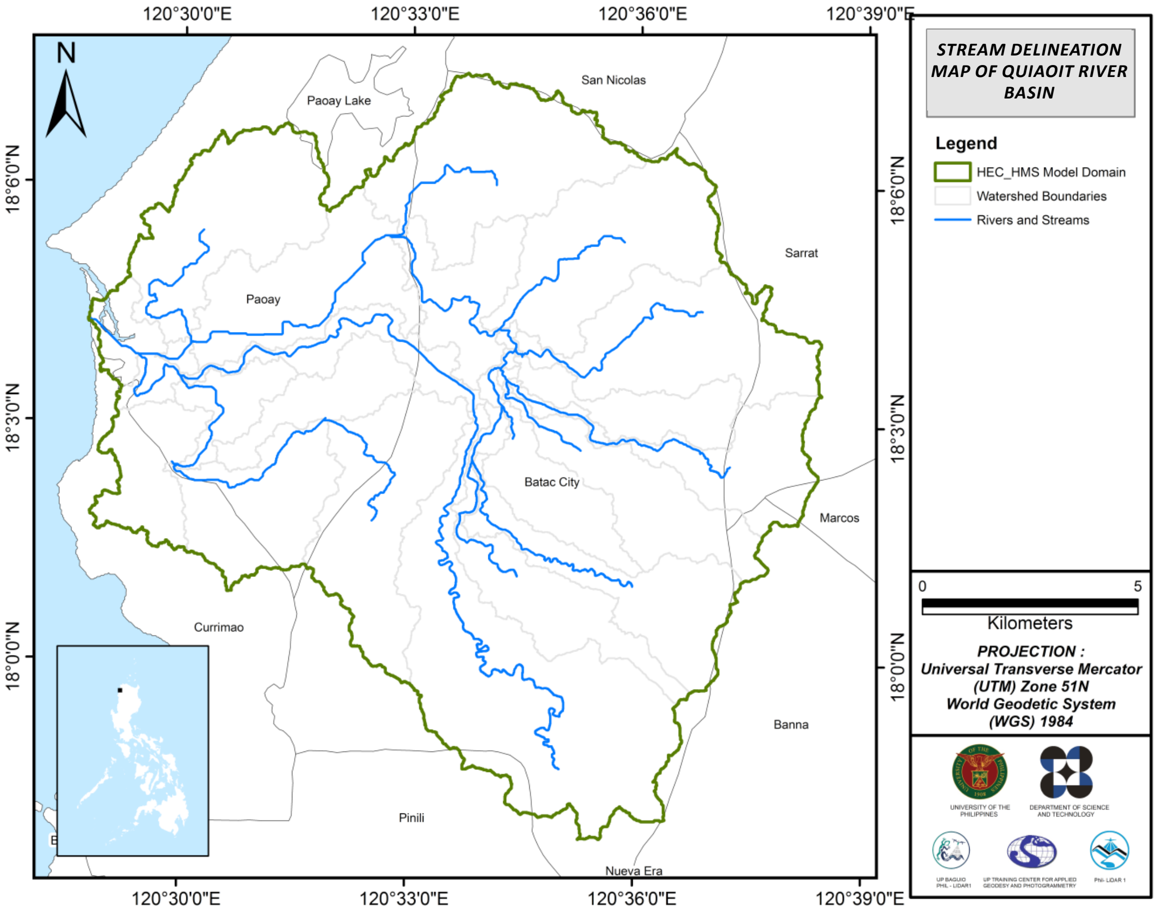


Figure 53. Stream delineation map of Quiaoit River Basin

Using the SAR-based DEM, the Quiaoit Basin was delineated and further subdivided into subbasins. The model consists of 16 subbasins, 8 reaches, and 8 junctions, as shown in Figure 54. The main outlet is labeled as 93.

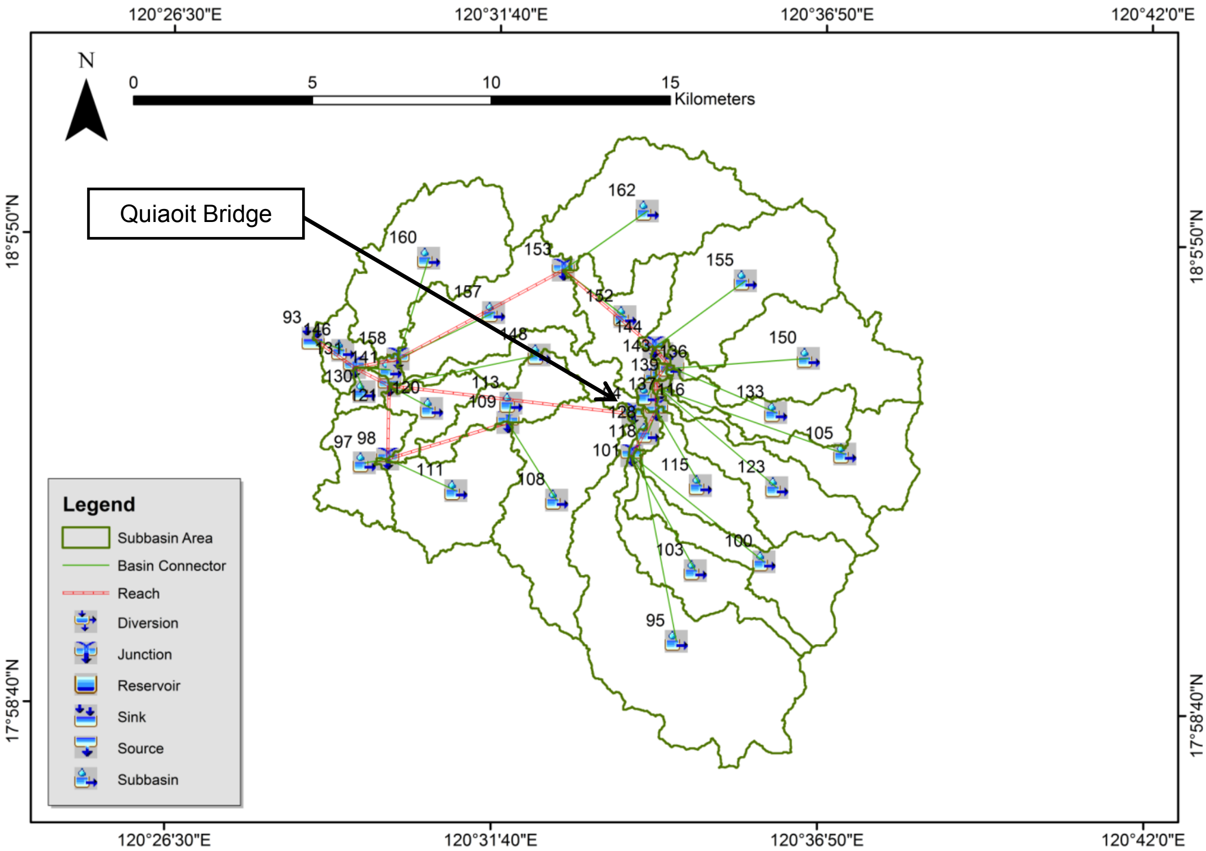


Figure 54. The Quiaoit River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

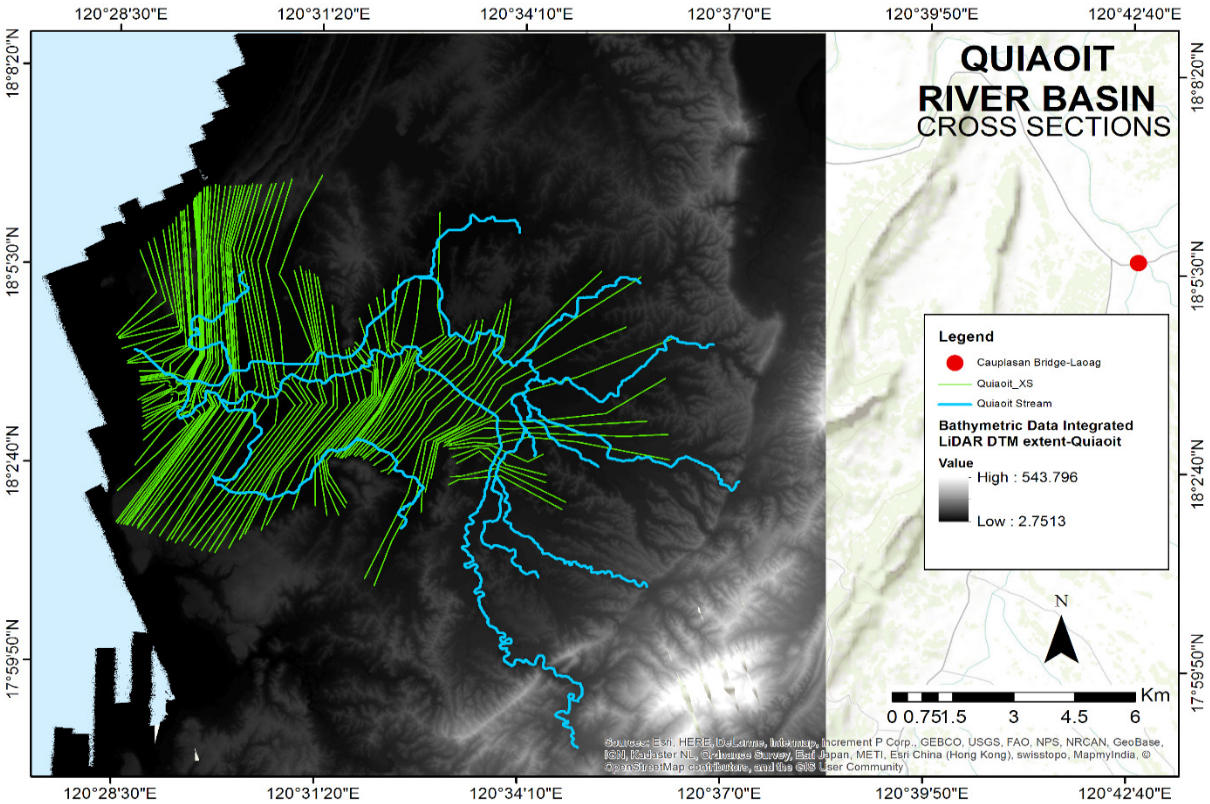


Figure 55. River cross-section of Quiaoit River generated through Arcmap HEC GeoRAS tool

5.5 FLO-2D Model

The automated modeling 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 was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinates of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were 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 southeast of the model to the northwest, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements, respectively.

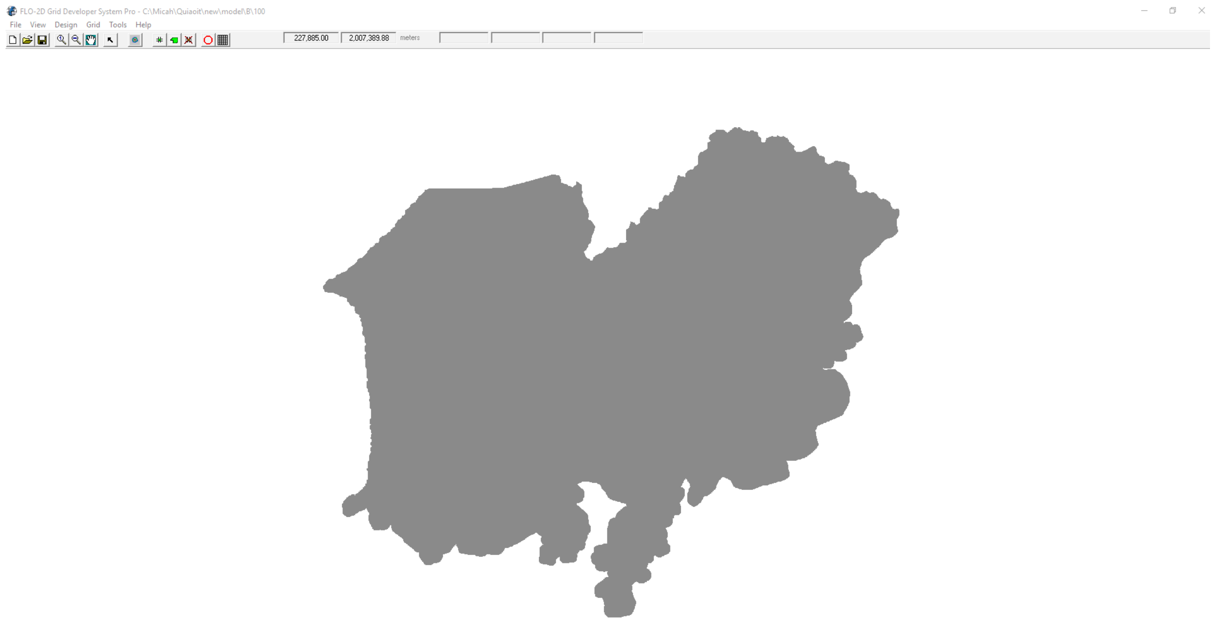


Figure 56. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 75.41016 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that showed 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 created the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) was set at 0 m^2/s. The generated hazard maps for Quiaoit are found in Figure 60, Figure 62, and Figure 64.

The creation of a flood hazard map from the model also automatically created a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in FLO-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts cover a maximum land area of 95,834,800.00 m^2. The generated flood depth maps for Quiaoit are found in Figure 61, Figure 63, and Figure 65.

There is a total of 83,108,921.62 m^3 of water entering the model. Of this amount, 49,642,588.88 m^3 is due to rainfall while 33,466,332.73 m^3 is inflow from other areas outside the model. About 15,713,015.00 m^3 of this water is lost to infiltration and interception, while 55 198 496.58 m^3 is stored by the floodplain. The rest, amounting up to 12 197 365.45 m^3, is outflow.

5.6 Results of HMS Calibration

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

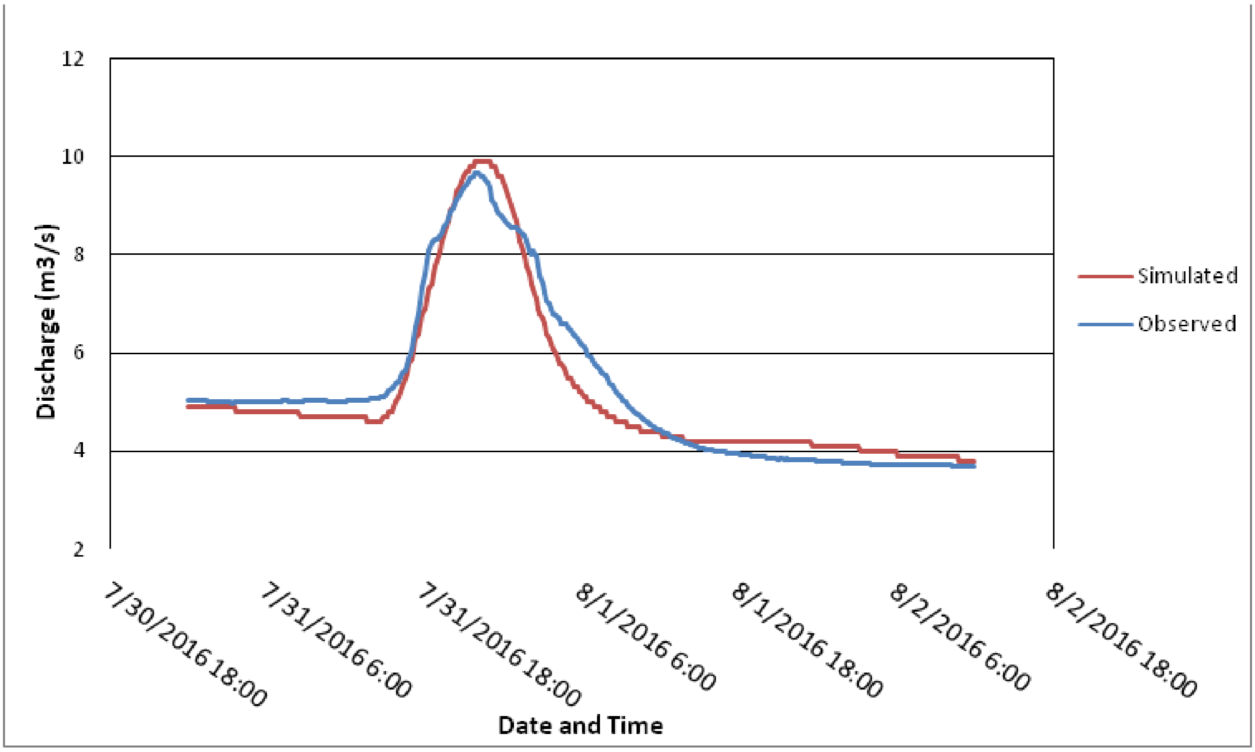


Figure 57. Outflow hydrograph of Quiaoit produced by the HEC-HMS model compared with observed outflow

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

Table 26. Range of calibrated values for Quiaoit

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	0.91 – 4.05
			Curve Number	72.96 - 98.91
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.41 - 12.23
			Storage Coefficient (hr)	0.16 - 4.69
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.0001 - 0.00015
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001 - 0.087

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.91 mm to 4.05 mm means that there is a small initial fraction of the storm depth after which runoff begins, increasing the river outflow.

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. A range from 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Quiaoit, the basin consists mainly of cultivated areas, tree plantations, and perennials, and the soil consists of mostly clay loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.16 hours to 12.23 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. Meanwhile, ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant value of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Values of ratio to peak within the range of 0.0001–0.00015 indicate a much steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Quiaoit River Basin is determined to be cultivated with mature field crops, with reaches having Manning's coefficient of 0.04 (Brunner, 2010).

Table 27. Summary of the efficiency test of Quiaoit HMS Model

Accuracy Measure	Value
RMSE	0.4
r2	0.9518
NSE	0.94
PBIAS	1.56
RSR	0.24

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.4 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A value 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 0.9518.

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 0.94.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.56.

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 0.24.

5.7 Calculated Outflow Hydrographys and Discharge Values for Different Rainfall Return Periods

5.7.1 Hydrograph Using the Rainfall Runoff Model

The summary graph (Figure 58) shows the Quiaoit outflow using the Laoag RIDF curves in five different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

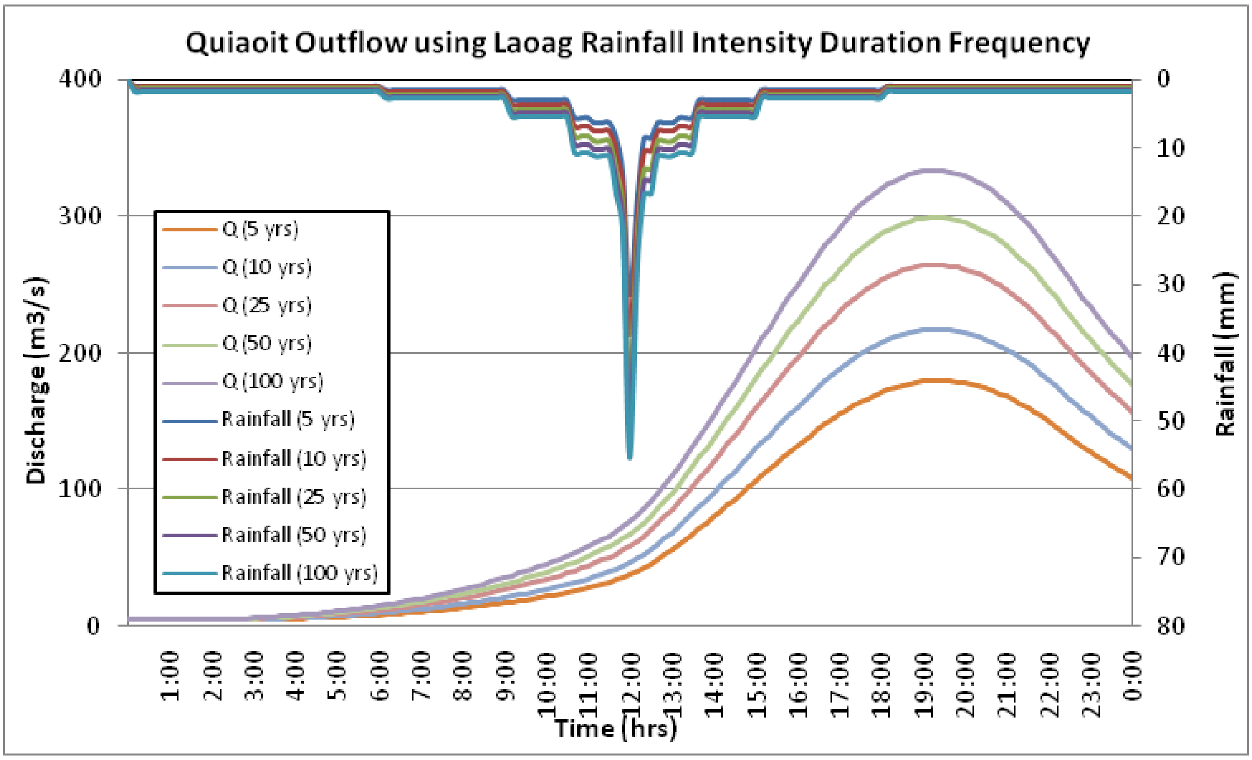


Figure 58. Outflow hydrograph at Quiaoit Station generated using the Laoag RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Quiaoit discharge using the Laoag RIDF curves in five different return periods is shown in Table 28.

Table 28. Peak values of the Quiaoit HEC-HMS Model outflow using the Laoag RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3/s)	Time to Peak
5-Year	331.7	31.4	179.7	7 hours, 20 minutes
10-Year	397.1	37.2	217.2	7 hours, 20 minutes
25-Year	479.8	44.5	264.4	7 hours, 20 minutes
50-Year	541.1	50	299.2	7 hours, 20 minutes
100-Year	602	55.3	333.8	7 hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section for each time step per 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 is shown. The sample generated map of Quiaoit River using the calibrated HMS base flow is shown in Figure 59.

Figure 59. Sample output of Quiaoit RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. The 5-, 25-, and 100-year rain return scenarios of the Quiaoit Floodplain are shown in Figure 60 to Figure 65. The floodplain, with an area of 195.205 sq km, covers nine municipalities. Table 29 shows the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in Quiaoit Floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Ilocos Norte	Banna	89.6193	1.44915	1.62%
Ilocos Norte	Batac City	134.621	118.822	88.26%
Ilocos Norte	Currimao	32.9651	8.77761	26.63%
Ilocos Norte	Marcos	73.5738	0.53616	0.73%
Ilocos Norte	Paoay Lake	3.63878	0.13585	3.73%
Ilocos Norte	Paoay	71.6164	56.6408	79.09%
Ilocos Norte	Pinili	63.1835	1.15383	1.83%
Ilocos Norte	San Nicolas	40.2254	0.12837	0.32%
Ilocos Norte	Sarrat	92.2471	7.2581	7.87%

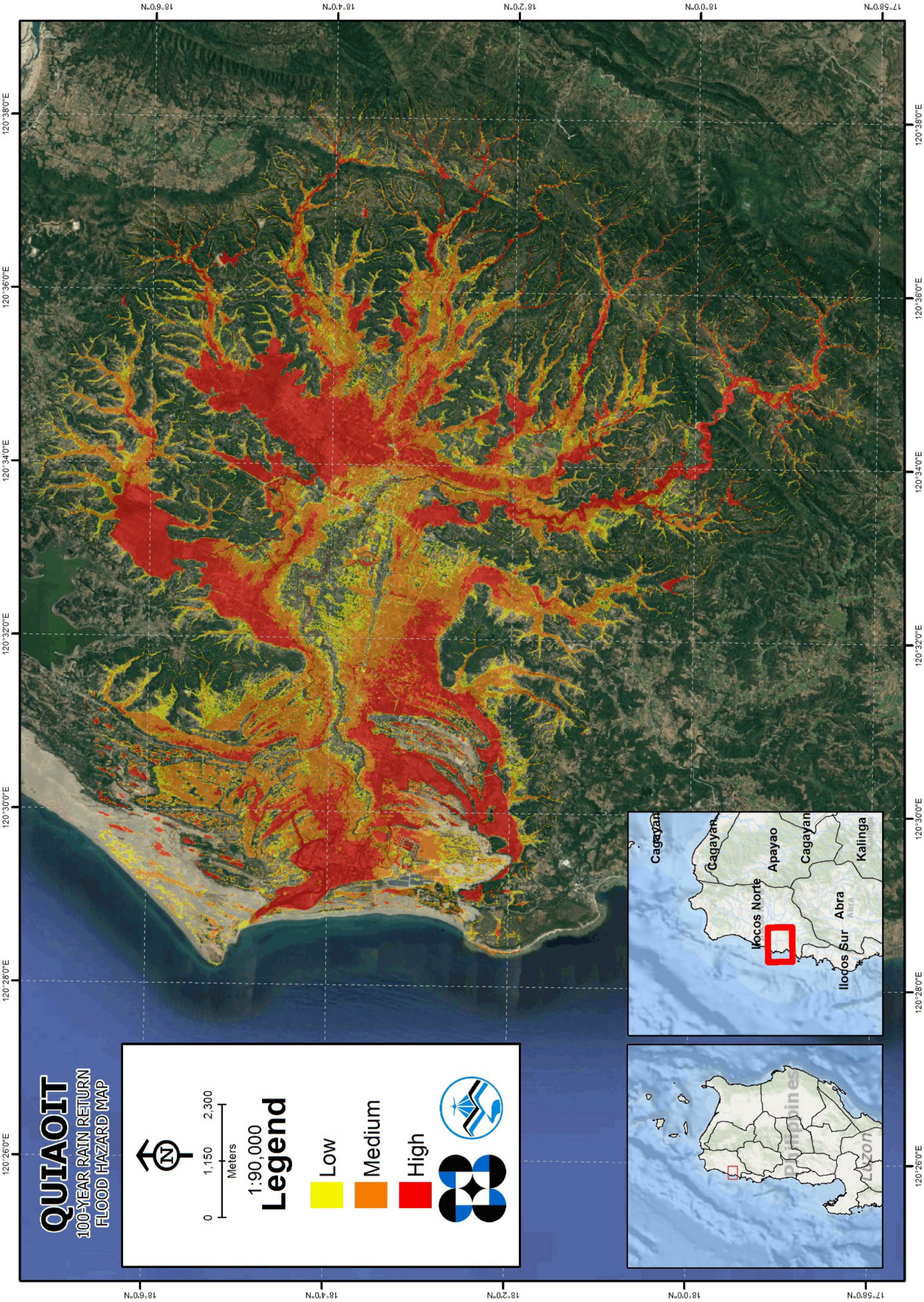


Figure 60. 100-year flood hazard map for Quiaoit Floodplain overlaid on Google Earth imagery

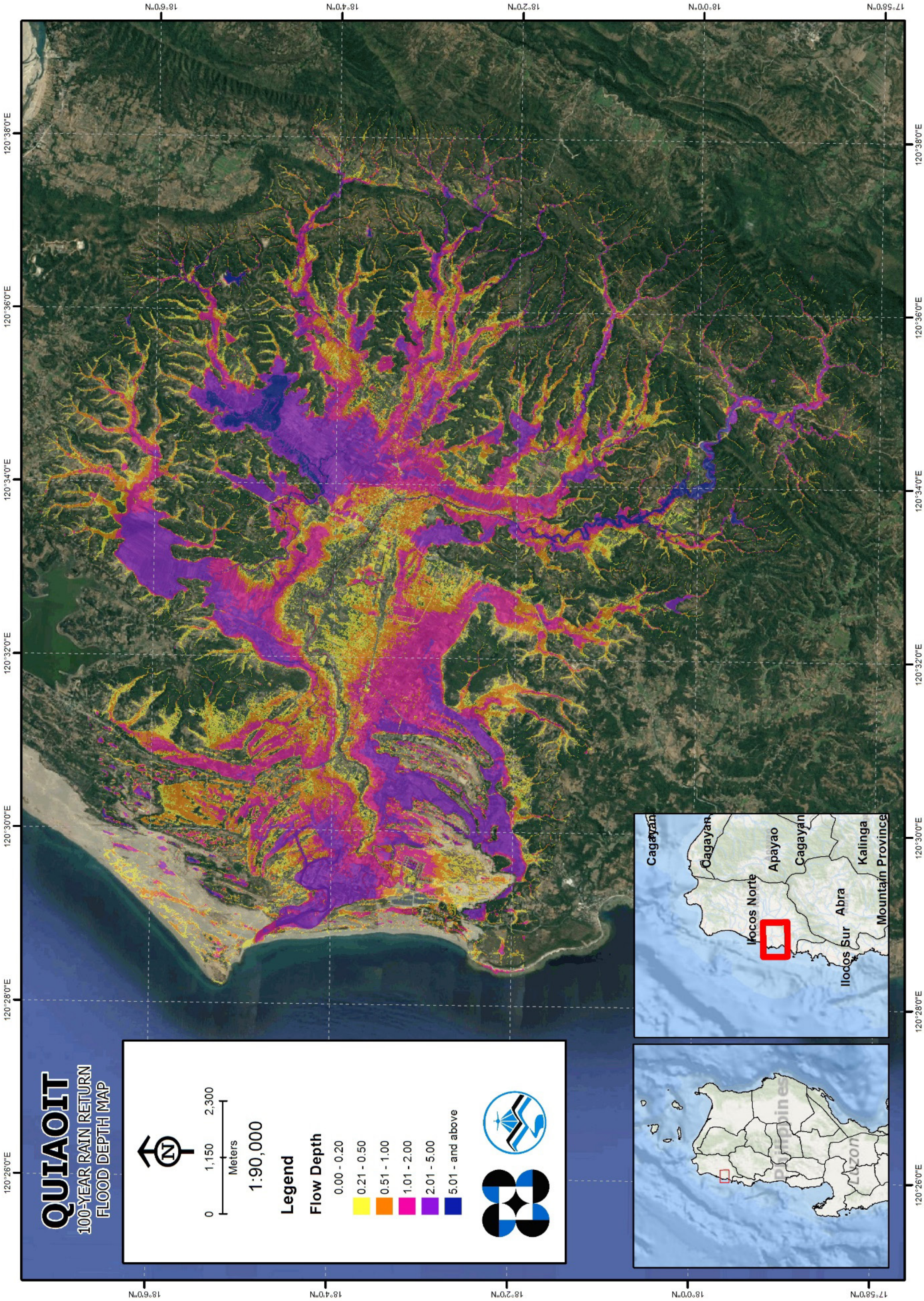


Figure 61. 100-year flow depth map for Quiaoit Floodplain overlaid on Google Earth imagery

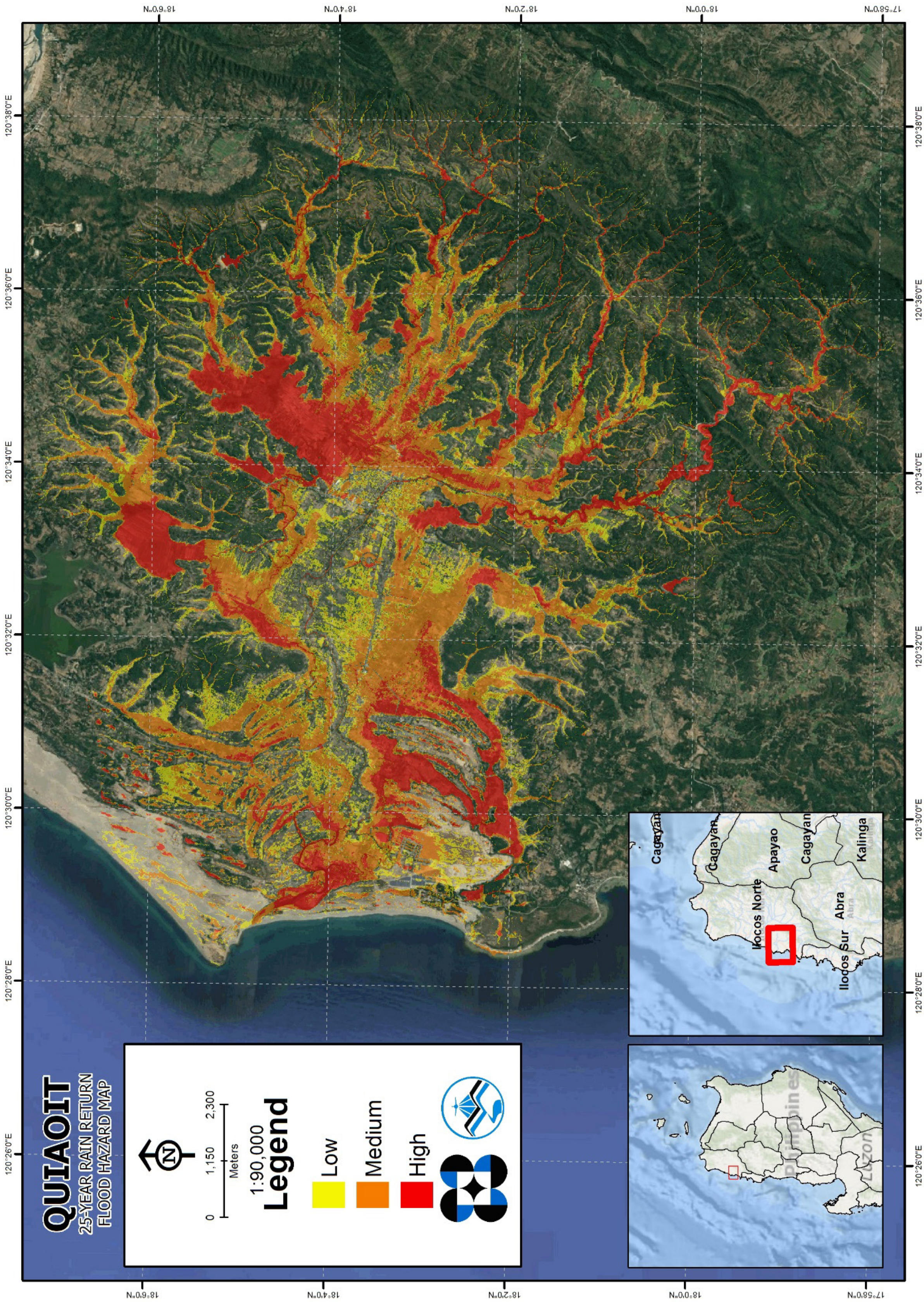


Figure 62. 25-year flood hazard map for Quiaoit Floodplain overlaid on Google Earth imagery

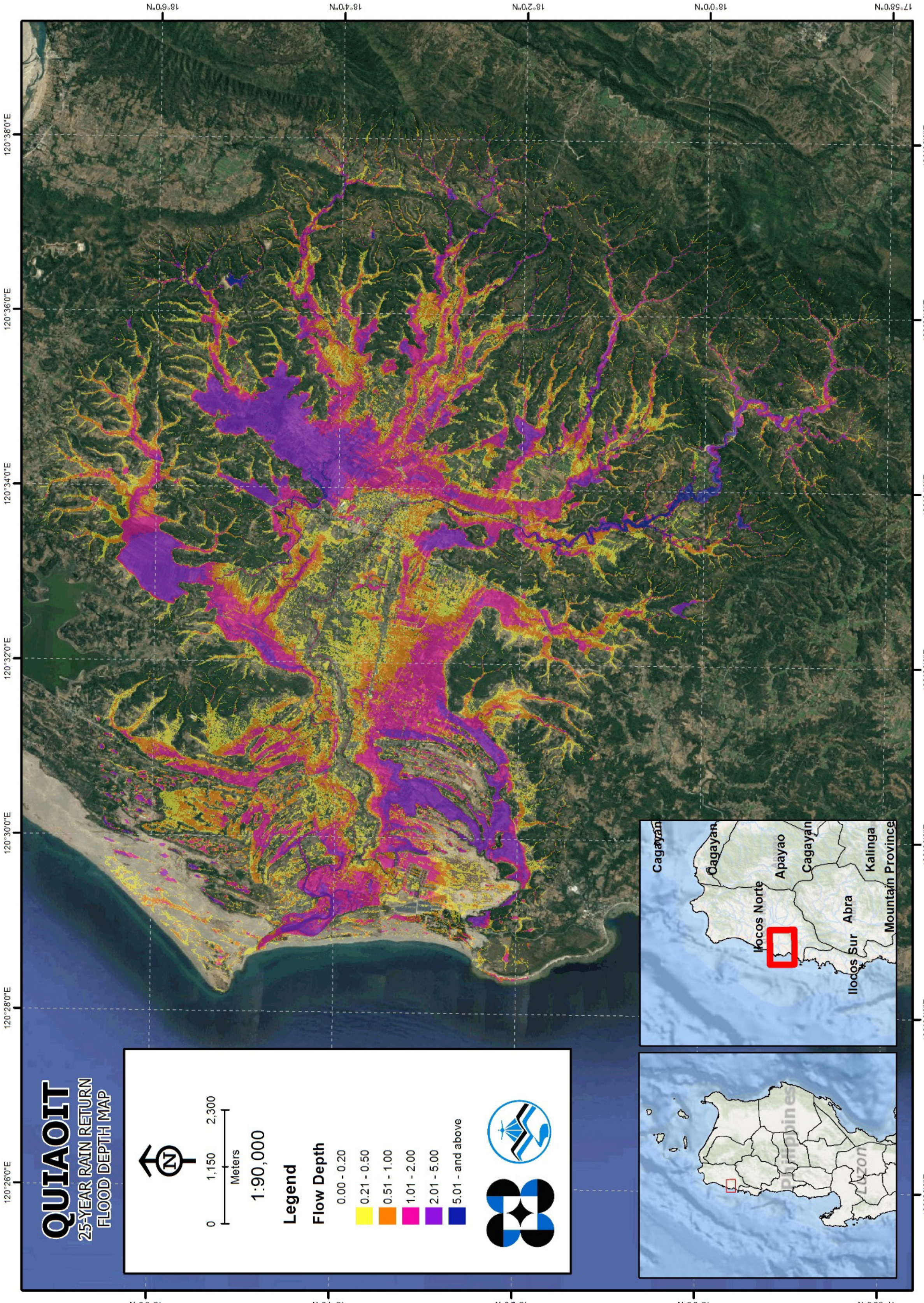


Figure 63. 25-year flow depth map for Quiaoit Floodplain overlaid on Google Earth imagery

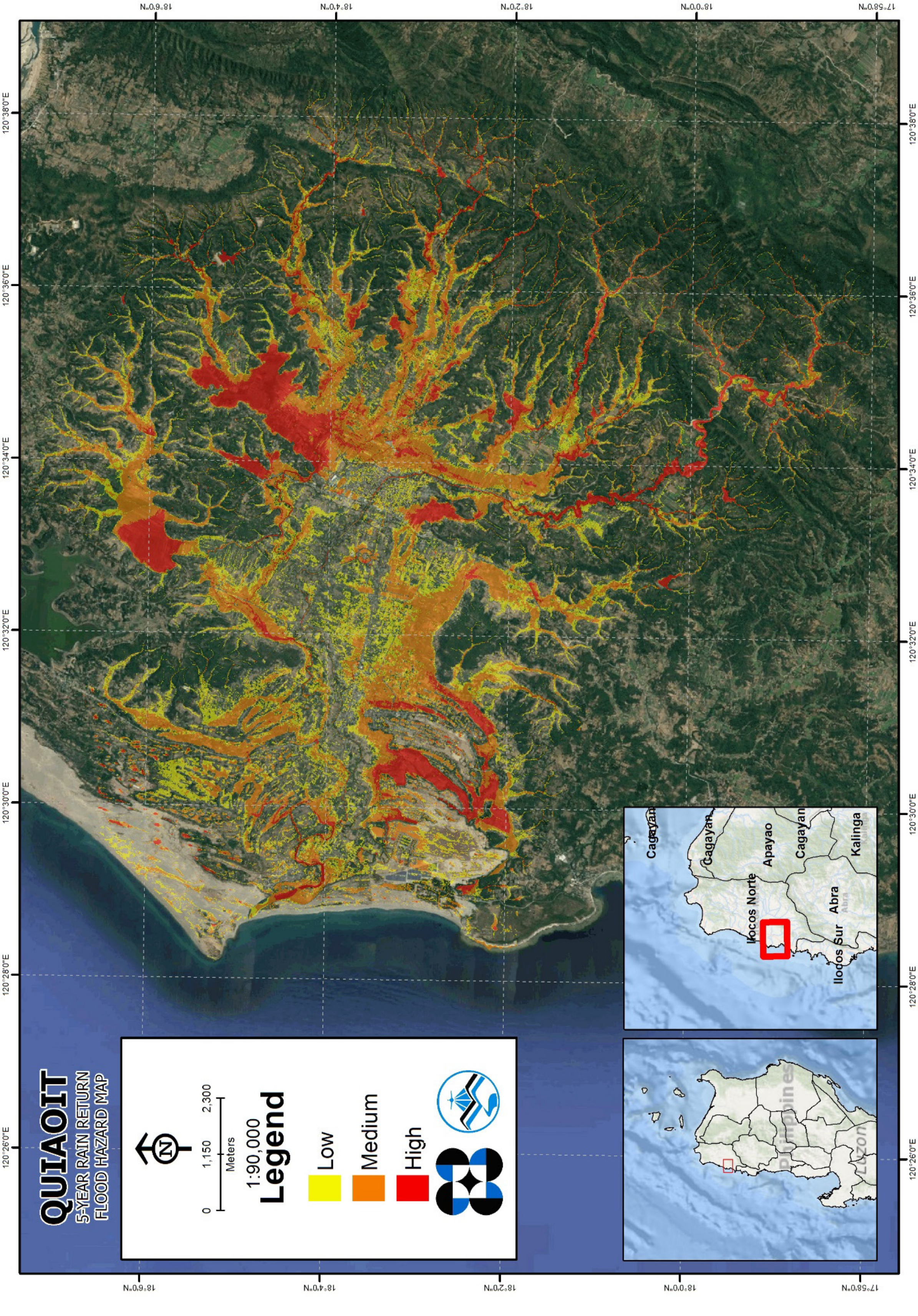


Figure 64. 5-year flood hazard map for Quiaoit Floodplain overlaid on Google Earth imagery

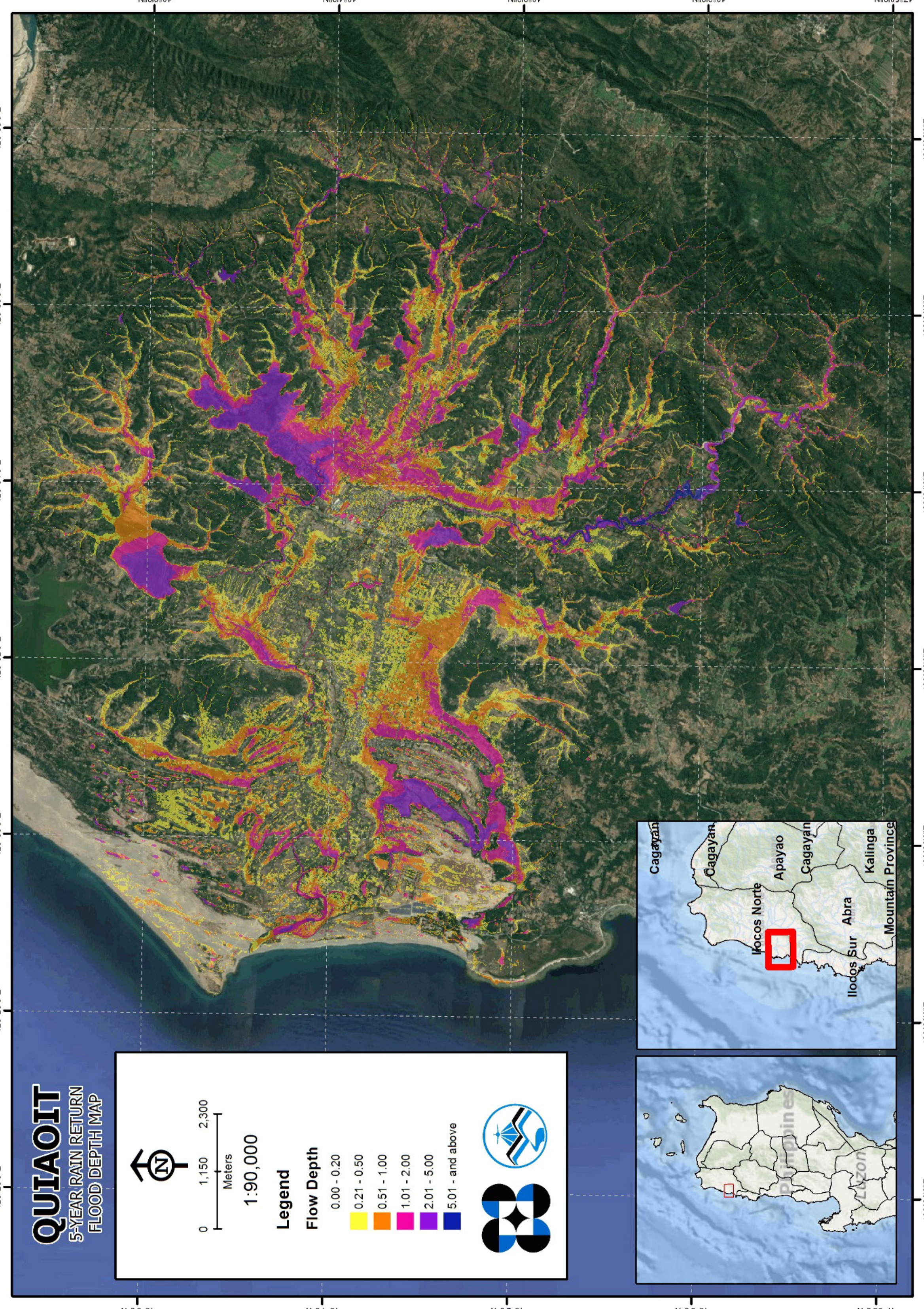


Figure 65. 5-year flow depth map for Quiaoit Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Quiaoit River Basin, grouped by municipality, are listed below. For the said basin, nine (9) municipalities consisting of 90 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 1.53% of the municipality of Banna with an area of 89.62 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 0.02%, 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 30 are the affected areas in square kilometers by flood depth per barangay.

Table 30. Affected areas in Banna, Ilocos Norte during a 5-year rainfall return period

Affected area (sq.km.) By flood depth (in m.)	Area of affected barangays in Banna (in sq. km)		
	Barbarangay	Bomitog	Nagpatayan
0-0.20	1.32	0.0029	0.045
0.21-0.50	0.043	0.000001	0.000014
0.51-1.00	0.022	0	0.000029
1.01-2.00	0.009	0	0
2.01-5.00	0.0049	0	0
> 5.00	0	0	0

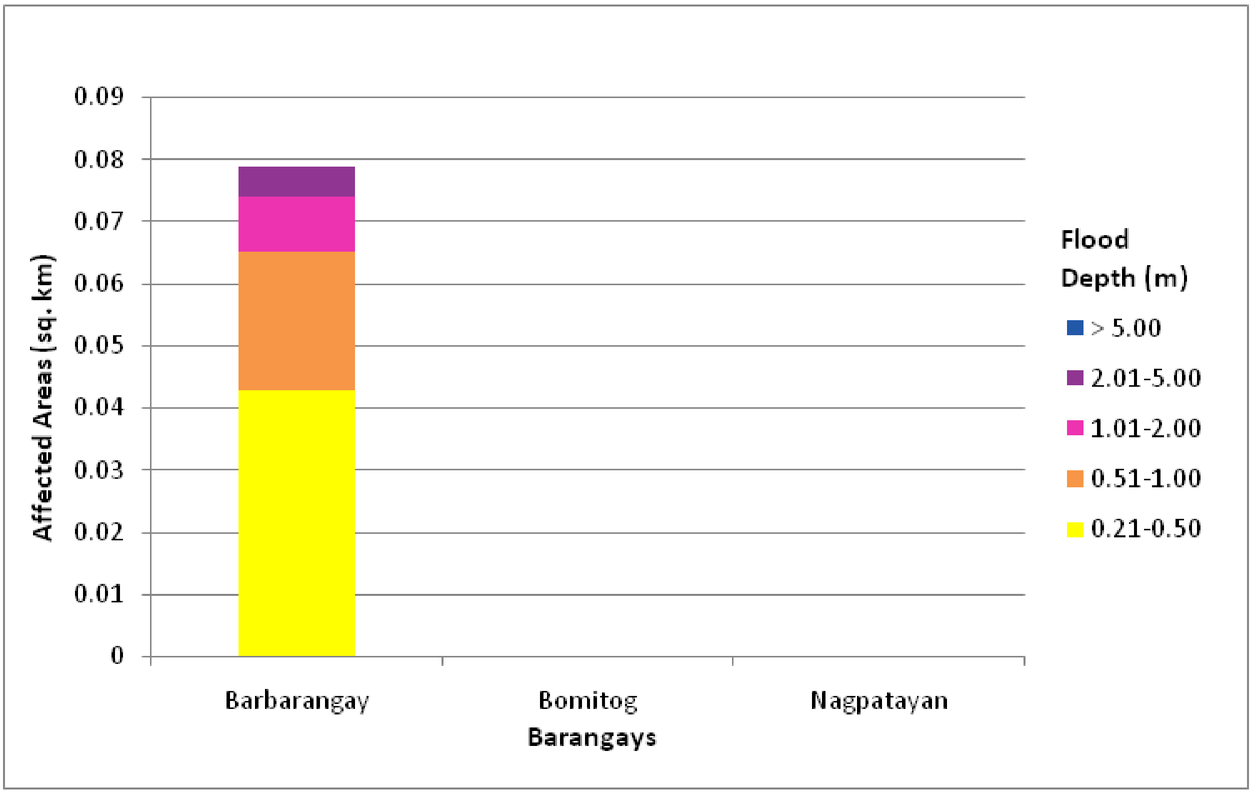


Figure 66. Affected areas in Banna, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 64.50% of the municipality of Batac City with an area of 134.62 sq km will experience flood levels of less than 0.20 meters; 7.84% of the area will experience flood levels of 0.21 to 0.50 meters; while 7.18%, 5.99%, 2.53%, and 0.22% 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 31 to Table 34 are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

Affected area (sq km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Ablan Poblacion	Acosta Poblacion	Aglipay	Baay	Baligat	Baoa East	Baoa West	Barani	Ben-Agan	Bil-Loca	Biningan
0-0.20	0.12	0.17	0.12	2.6	2.8	1.11	1.59	0.13	0.014	3.53	0.85
0.21-0.50	0.02	0.082	0.047	0.45	0.35	0.12	0.51	0.046	0.034	0.41	0.043
0.51-1.00	0.0023	0.074	0.0038	0.32	0.44	0.12	0.48	0.018	0.17	0.26	0.043
1.01-2.00	0.00041	0.082	0	0.15	0.41	0.076	0.29	0.0061	0.17	0.39	0.052
2.01-5.00	0	0.004	0	0.049	0.71	0.042	0.045	0.0011	0.0019	0.43	0.014
> 5.00	0	0	0	0.0001	0	0.0003	0	0	0	0.023	0

Table 32. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

Affected area (sq km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Bungon	Callaguip	Camandingan	Camguidan	Cangrunaan	Capacuan	Caunayan	Colo	Dariwdiw	Lacub	Mabaleng
0-0.20	3.68	0.12	2.33	3.21	0.5	5.56	0.091	2.02	3.13	0.11	7.01
0.21-0.50	0.42	0.039	0.15	0.7	0.21	0.43	0.033	0.38	0.51	0.059	0.58
0.51-1.00	0.27	0.011	0.12	0.78	0.54	0.34	0.0026	0.34	0.53	0.02	0.27
1.01-2.00	0.086	0.0049	0.05	0.65	0.62	0.16	0.0002	0.19	0.82	0.043	0.21
2.01-5.00	0.0084	0	0.018	0.12	0.015	0.035	0	0.091	0.28	0.0046	0.21
> 5.00	0	0	0.0001	0	0	0.0006	0	0.012	0.0002	0	0.12

Table 33. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

Affected area (sq km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Magnuang	Maipalig	Nagbacalan	Naguirangan	Palongpong	Palpalicong	Parangopong	Payao	Pimentel	Quiling Norte	Quiling Sur
0-0.20	2.29	4.78	3.11	0.4	2.1	0.15	3.58	5.25	1.67	0.86	0.96
0.21-0.50	0.59	0.13	0.15	0.25	0.31	0.061	0.48	0.32	0.14	0.18	0.29
0.51-1.00	0.43	0.084	0.1	0.37	0.3	0.1	0.35	0.15	0.096	0.3	0.22
1.01-2.00	0.11	0.09	0.073	0.38	0.2	0.13	0.26	0.15	0.038	0.36	0.053
2.01-5.00	0.0078	0.018	0.074	0.02	0.039	0.0071	0.12	0.22	0.046	0.062	0.0015
> 5.00	0	0	0.0041	0	0	0	0	0.13	0	0.0054	0

Table 34. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

Affected area (sq km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)									
	Quiom	Rayuray	Ricarte Poblacion	San Julian	San Mateo	San Pedro	Suabit	Sumader	Tabug	Valdez Poblacion
0-0.20	3.26	1.54	0.044	0.15	3.69	2.78	0.038	8.07	1.26	0.087
0.21-0.50	0.17	0.29	0.024	0.019	0.66	0.22	0.041	0.34	0.23	0.052
0.51-1.00	0.15	0.5	0.047	0.0067	0.65	0.1	0.028	0.25	0.25	0.015
1.01-2.00	0.15	0.75	0.0097	0.0014	0.42	0.018	0.038	0.18	0.17	0.0037
2.01-5.00	0.11	0.44	0.0001	0.0001	0.094	0.0077	0.0057	0.041	0.0017	0
> 5.00	0.004	0	0	0	0	0	0	0.0003	0	0

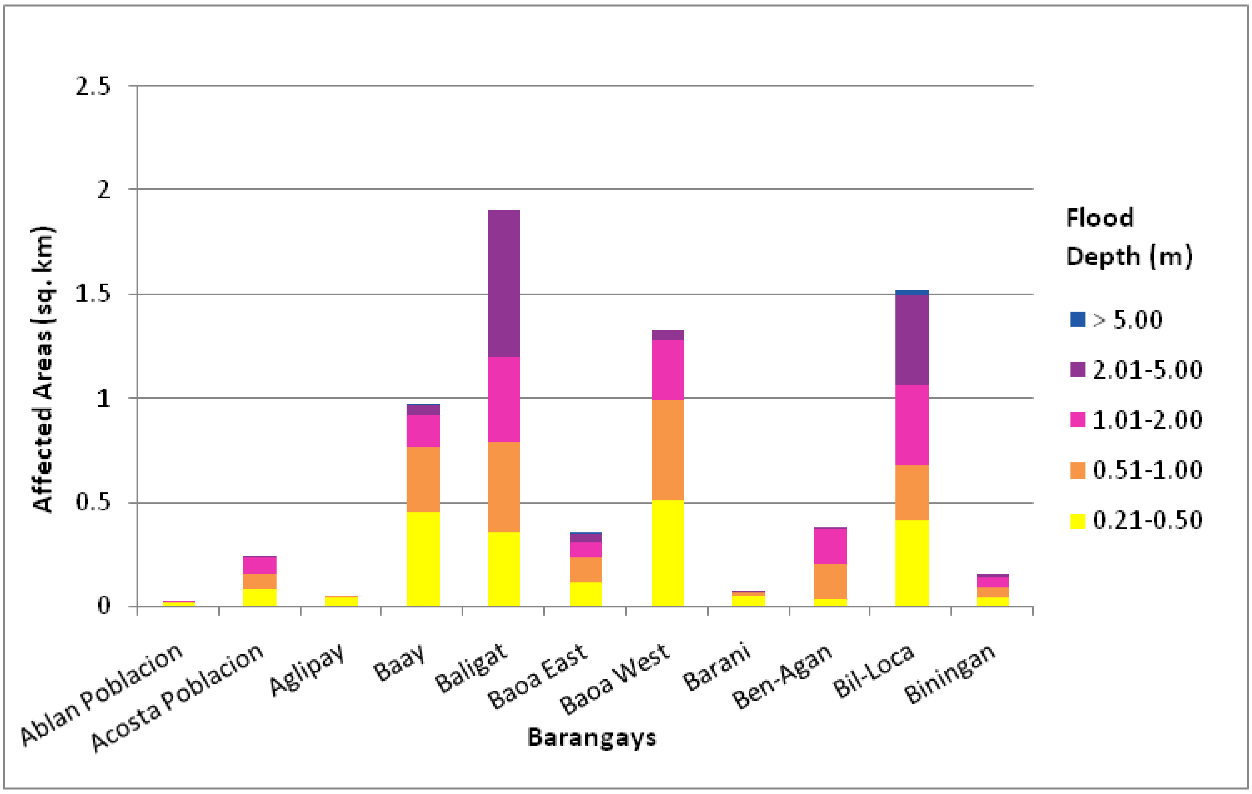


Figure 67. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

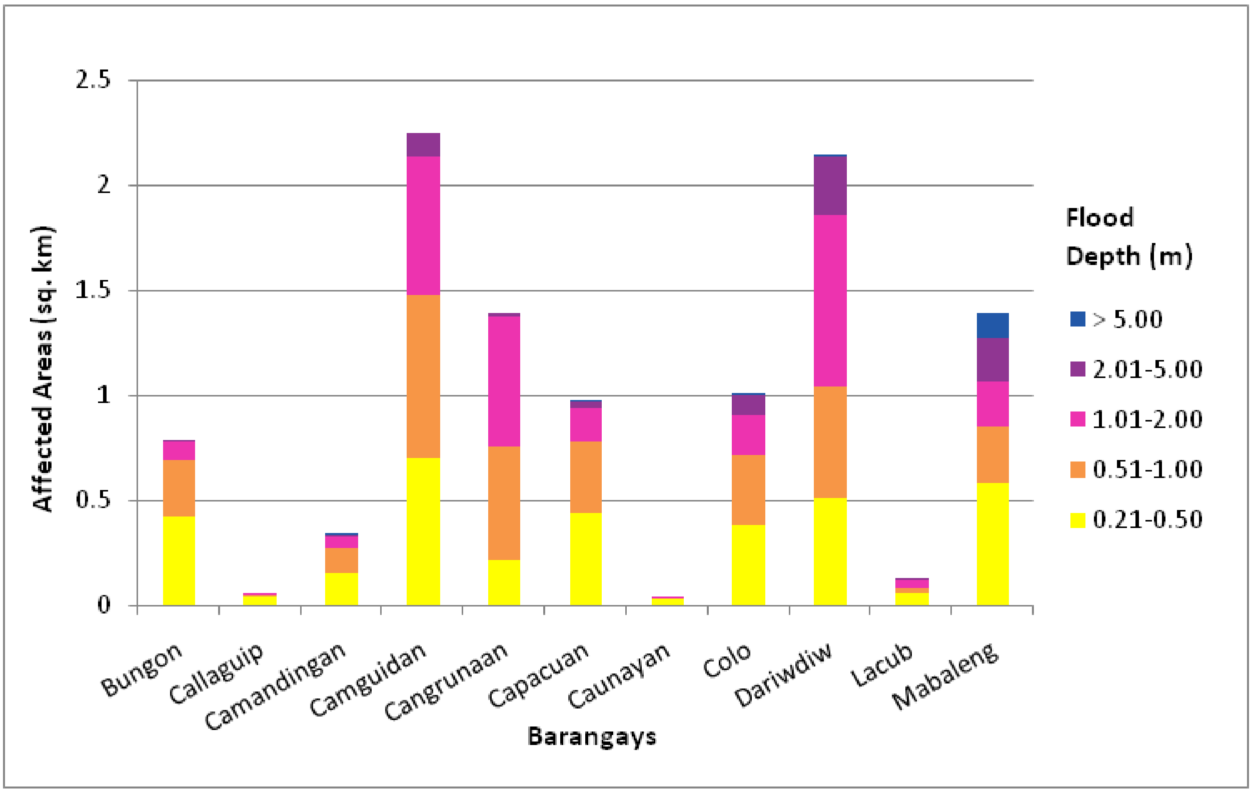


Figure 68. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

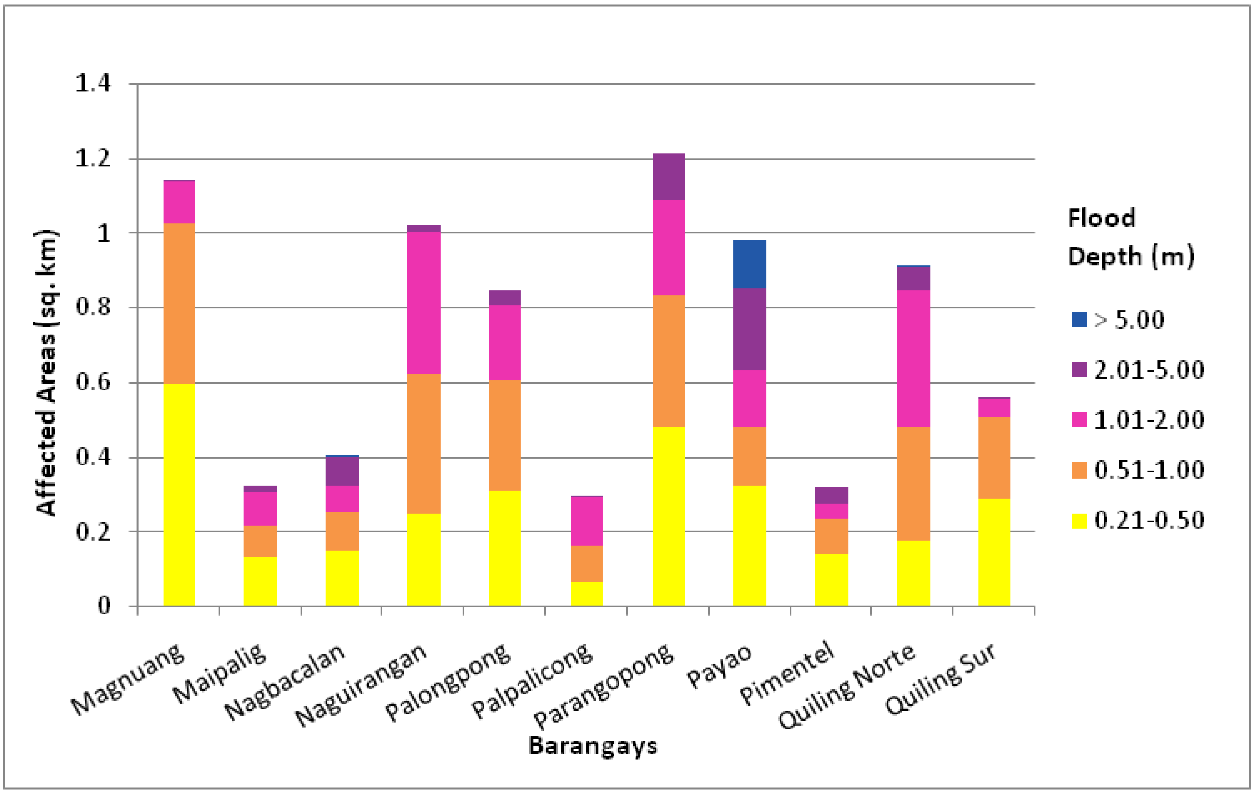


Figure 69. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

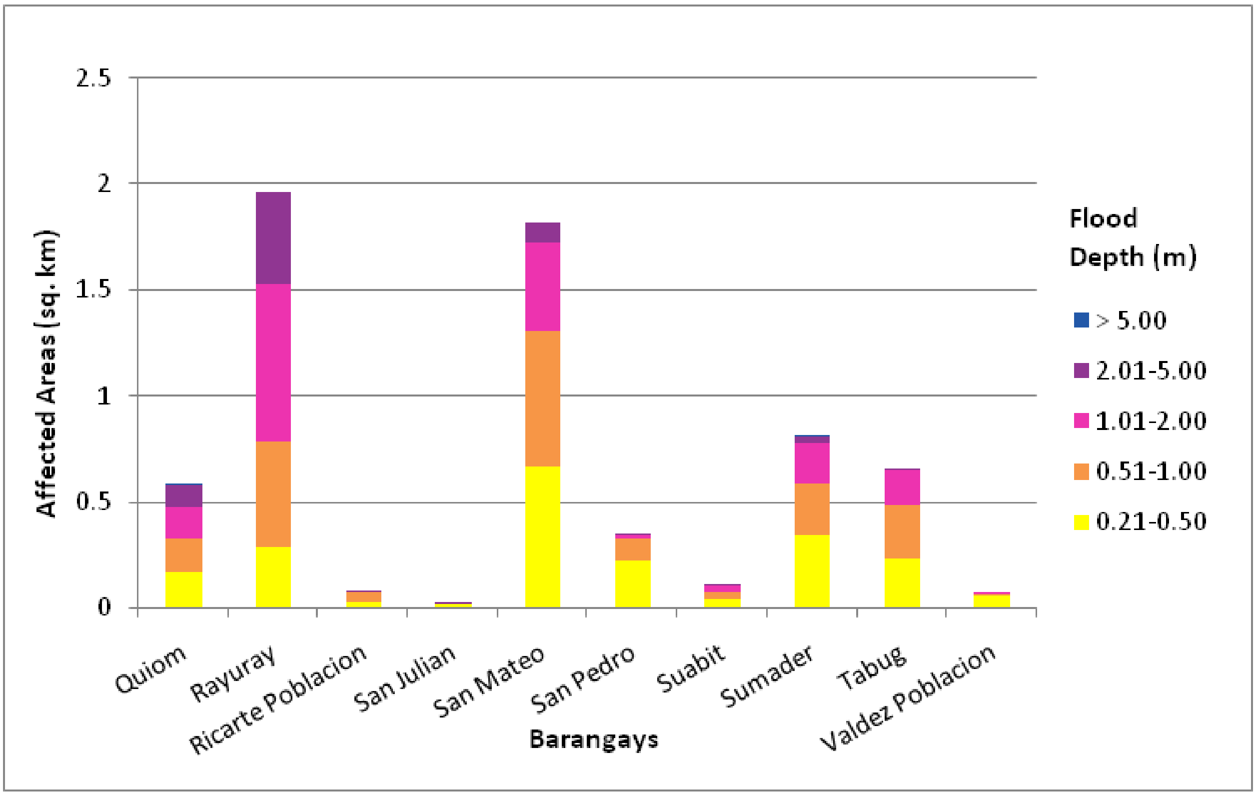


Figure 70. Affected areas in Batac City, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 20.35% of the municipality of Currimao with an area of 32.965 sq km will experience flood levels of less than 0.20 meters; 2.76% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.53%, 1.51%, and 0.47% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 35 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Currimao, Ilocos Norte during a 5-year rainfall return period

Affected area (sq km.) By flood depth (in m.)	Area of affected barangays in Currimao (in sq. km)						
	Bimmanga	Lang-Ayan-Baramban	Paguludan-Salindeg	Pangil	Poblacion I	Santa Cruz	Tapao-Tigue
0-0.20	1.23	0.36	1.15	0.96	0.088	0.051	2.87
0.21-0.50	0.28	0.028	0.19	0.083	0.0047	0.00037	0.32
0.51-1.00	0.056	0.0057	0.16	0.042	0.0028	0	0.24
1.01-2.00	0.044	0.0029	0.029	0.019	0.0041	0	0.4
2.01-5.00	0.026	0.0001	0.0011	0	0.0002	0	0.13
> 5.00	0	0	0	0	0	0	0

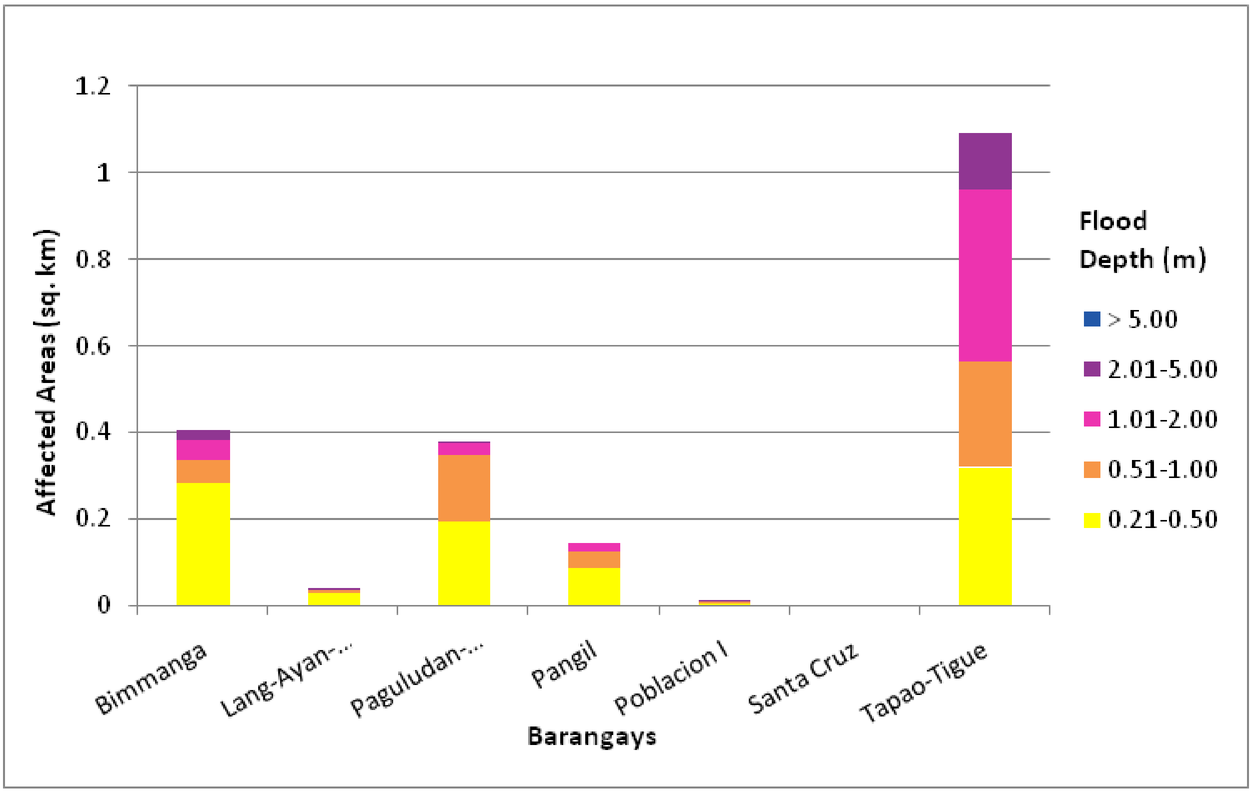


Figure 71. Affected areas in Currimao, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 0.69% of the municipality of Marcos with an area of 73.57 sq km will experience flood levels of less than 0.20 meters; 0.02% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected areas in Marcos, Ilocos Norte during a 5-year rainfall return period

Affected area (sq km.) By flood depth (in m.)	Area of affected barangay in Marcos (in sq. km)
	Fortuna
0-0.20	0.51
0.21-0.50	0.016
0.51-1.00	0.0078
1.01-2.00	0.0058
2.01-5.00	0.0012
> 5.00	0

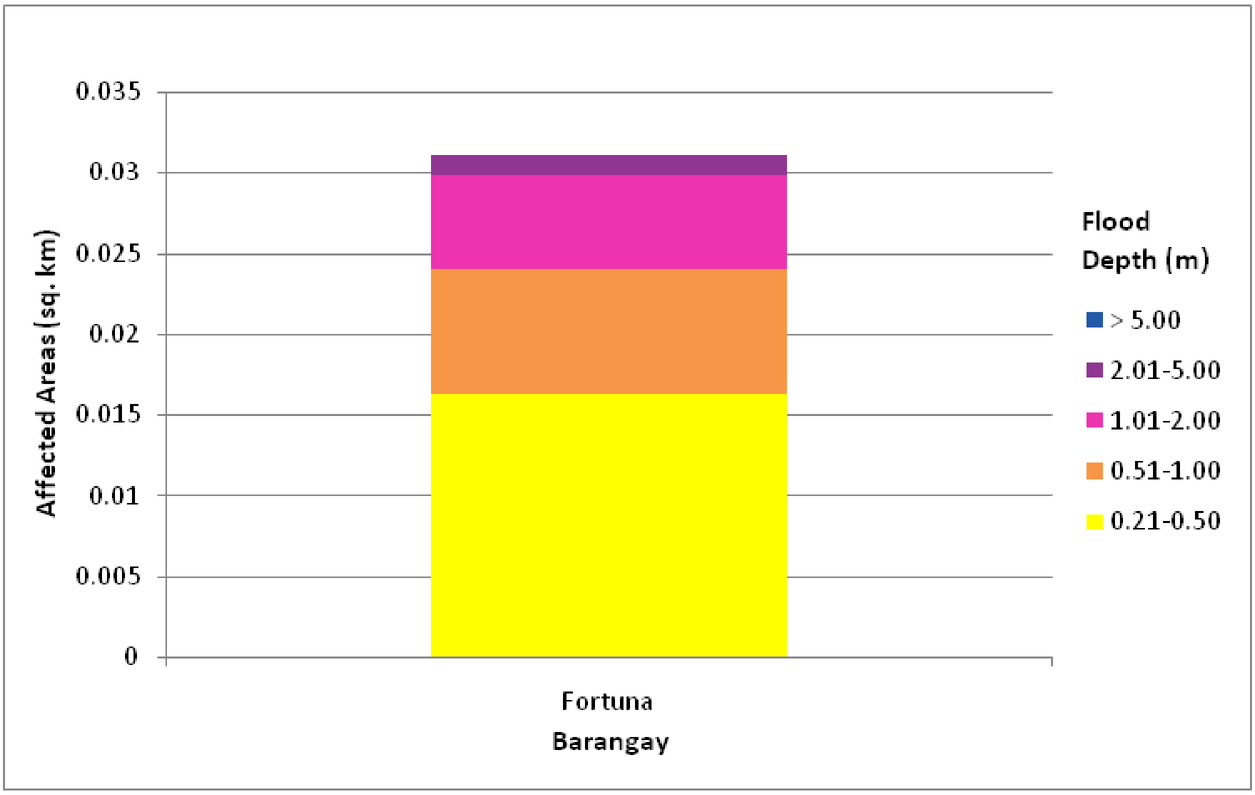


Figure 72. Affected areas in Marcos, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 46.77% of the municipality of Paoay with an area of 71.62 sq km will experience flood levels of less than 0.20 meters; 12.05% of the area will experience flood levels of 0.21 to 0.50 meters; while 11.01%, 6.72%, 2.53% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 37 to Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Paoay, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)									
	Bacsil	Cabagoan	Cabangaran	Callaguip	Cayubog	Dolores	Laoa	Masintoc	Monte	Mumulaan
0-0.20	4.76	0.012	0.92	0.23	1.04	0.073	0.33	1.74	3.13	1.95
0.21-0.50	1.03	0.019	0.67	0.047	0.4	0.033	0.12	0.28	0.47	0.18
0.51-1.00	0.55	0.056	0.25	0.098	0.34	0.0076	0.15	0.16	0.31	0.11
1.01-2.00	0.23	0.012	0.059	0.098	0.15	0	0.04	0.085	0.46	0.079
2.01-5.00	0.043	0.00031	0.0033	0.018	0.021	0	0.0018	0.015	0.033	0.038
> 5.00	0.0019	0	0	0	0	0	0	0	0	0.00078

Table 38. Affected areas in Paoay, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)									
	Nagbacalan	Nalasin	Oaig-Upay-Abulao	Pambaran	Pannaratan	Paratong	Pasil	Salbang	San Agustin	San Blas
0-0.20	0.68	3.3	0.96	0.41	0.22	1.77	1.32	1.09	1.14	0.15
0.21-0.50	0.037	0.83	0.26	0.11	0.078	0.31	0.09	0.24	0.46	0.089
0.51-1.00	0.031	0.64	0.33	0.17	0.064	0.31	0.045	0.032	0.71	0.13
1.01-2.00	0.026	0.15	0.34	0.31	0.044	0.29	0.15	0.02	1.08	0.04
2.01-5.00	0.0095	0.01	0.068	0.36	0.00053	0.44	0.42	0.0003	0.28	0.0065
> 5.00	0	0	0	0	0	0	0	0	0.0001	0

Table 39. Affected areas in Paoay, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)								
	San Juan	San Pedro	San Roque	Sangladan Poblacion	Santa Rita	Sideg	Sungadan	Surgui	Veronica
0-0.20	0.26	0.053	1.54	0.078	1.04	2.44	1.36	1.17	0.34
0.21-0.50	0.027	0.027	0.83	0.015	1.06	0.38	0.28	0.16	0.11
0.51-1.00	0.029	0.027	0.82	0.0022	1.59	0.56	0.16	0.055	0.15
1.01-2.00	0.019	0.015	0.29	0	0.36	0.31	0.02	0.062	0.079
2.01-5.00	0.0007	0.0009	0.0056	0	0.014	0.018	0	0.0091	0.0029
> 5.00	0	0	0	0	0	0	0	0	0

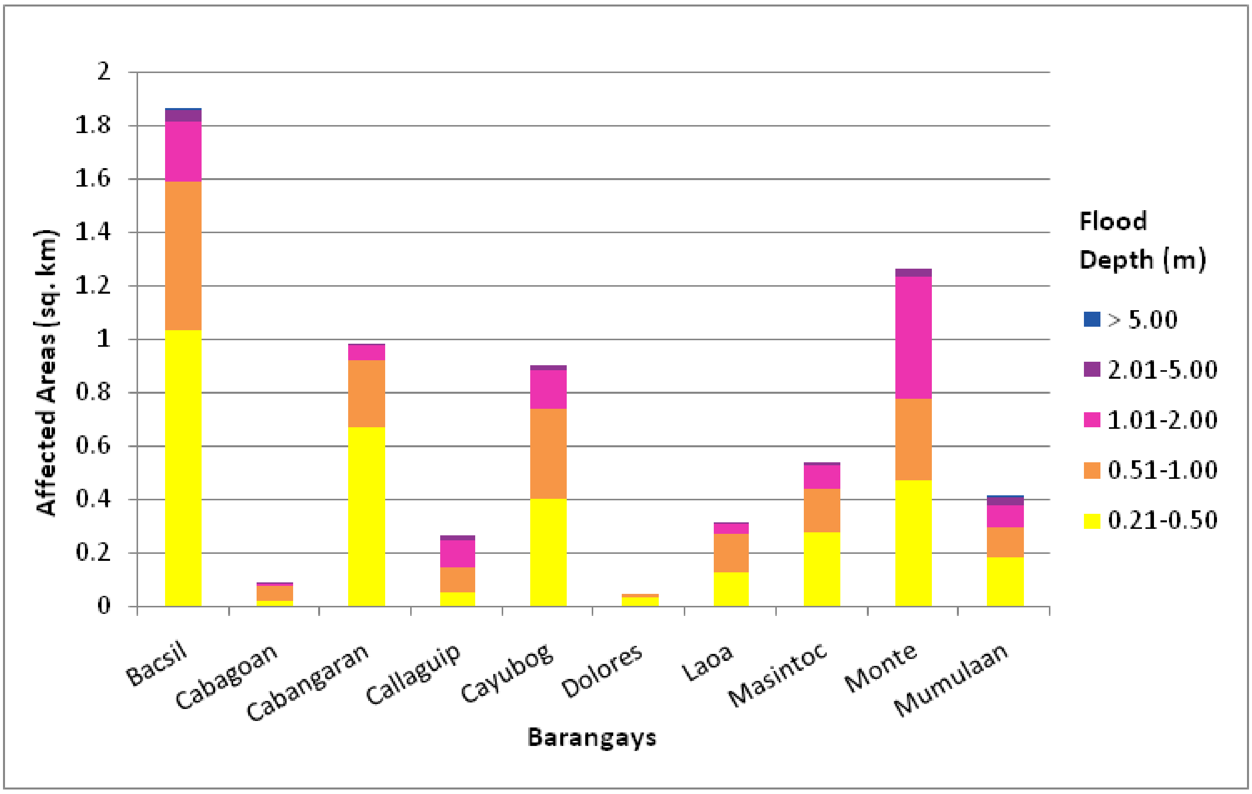


Figure 73. Affected areas in Paoay, Ilocos Norte during a 5-year rainfall return period

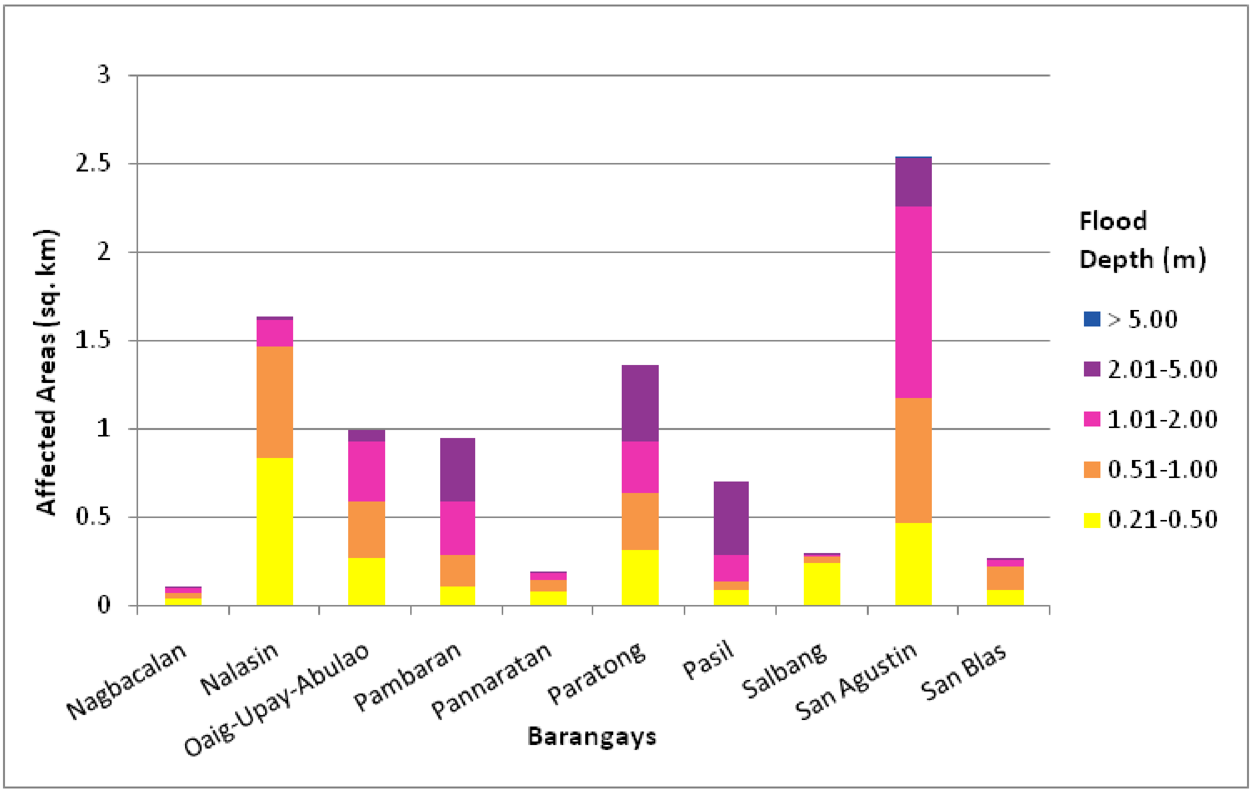


Figure 74. Affected areas in Paoay, Ilocos Norte during a 5-year rainfall return period

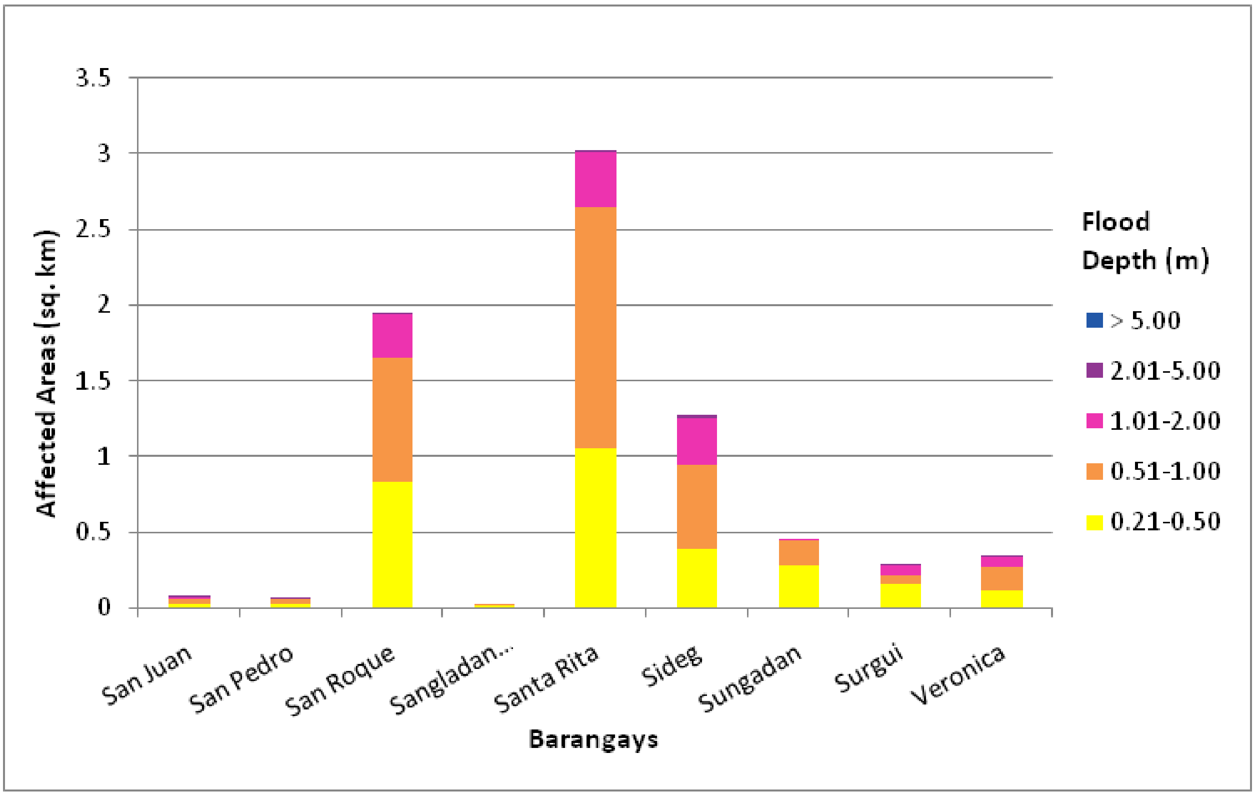


Figure 75. Affected areas in Paoay, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 3.68% of the municipality of Paoay Lake with an area of 3.64 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 0.01% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Paoay Lake, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Paoay Lake (in sq. km)
	Paoay Lake
0-0.20	0.13
0.21-0.50	0.0013
0.51-1.00	0.00045
1.01-2.00	0.00014
2.01-5.00	0
> 5.00	0

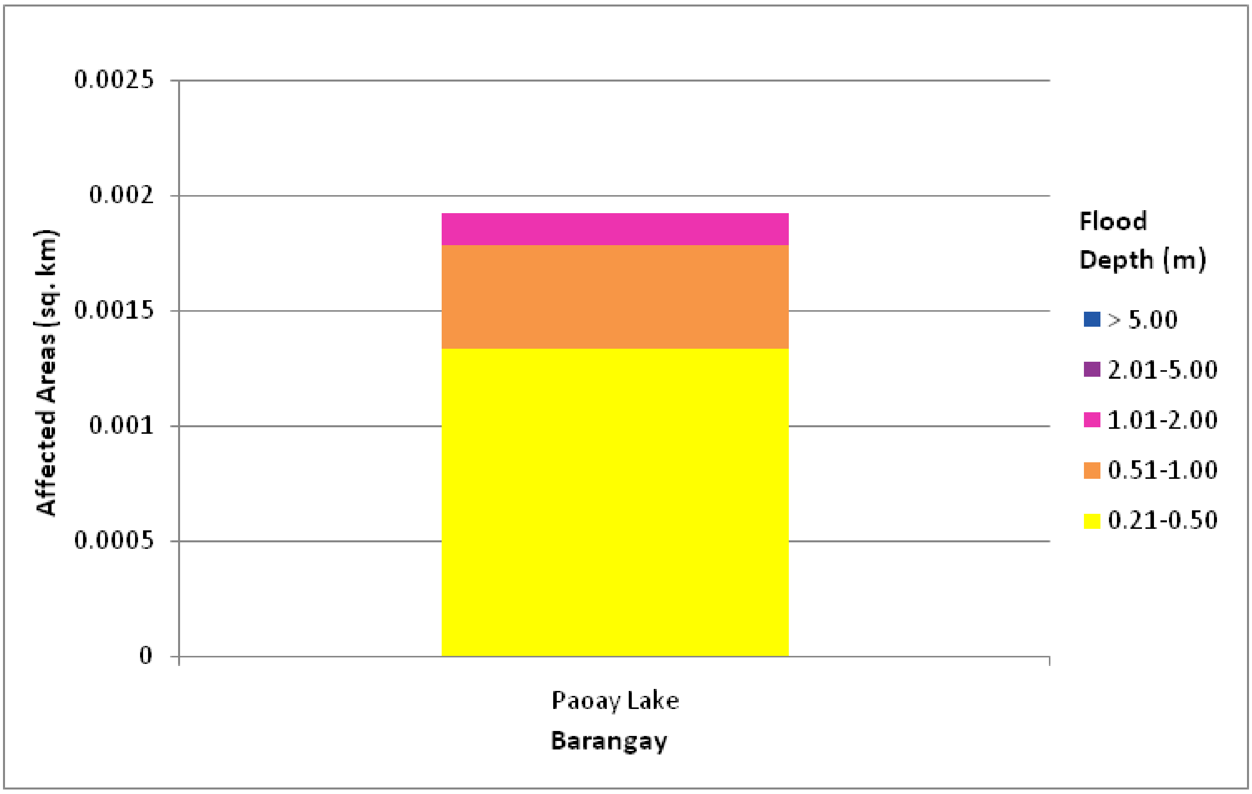


Figure 76. Affected areas in Paoay Lake, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 1.69% of the municipality of Pinili with an area of 63.18 sq km will experience flood levels of less than 0.20 meters; 0.08% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.04%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected areas in Pinili, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Pinili (in sq. km)
	Buanga
0-0.20	1.07
0.21-0.50	0.049
0.51-1.00	0.027
1.01-2.00	0.0073
2.01-5.00	0.0028
> 5.00	0.0001

Figure 77. Affected areas in Pinili, Ilocos Norte during a 5-year rainfall return period

For the 5-year return period, 0.31% of the municipality of San Nicolas with an area of 40.225 sq km will experience flood levels of less than 0.20 meters. Listed in Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in San Nicolas, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in San Nicolas (in sq. km)		
	San Agustin	San Pablo	San Pedro
0-0.20	0.079	0.028	0.02
0.21-0.50	0.001	0.00069	0.00019
0.51-1.00	0.00015	0.000067	0.00019
1.01-2.00	0	0.000002	0.00013
2.01-5.00	0	0	0
> 5.00	0	0	0

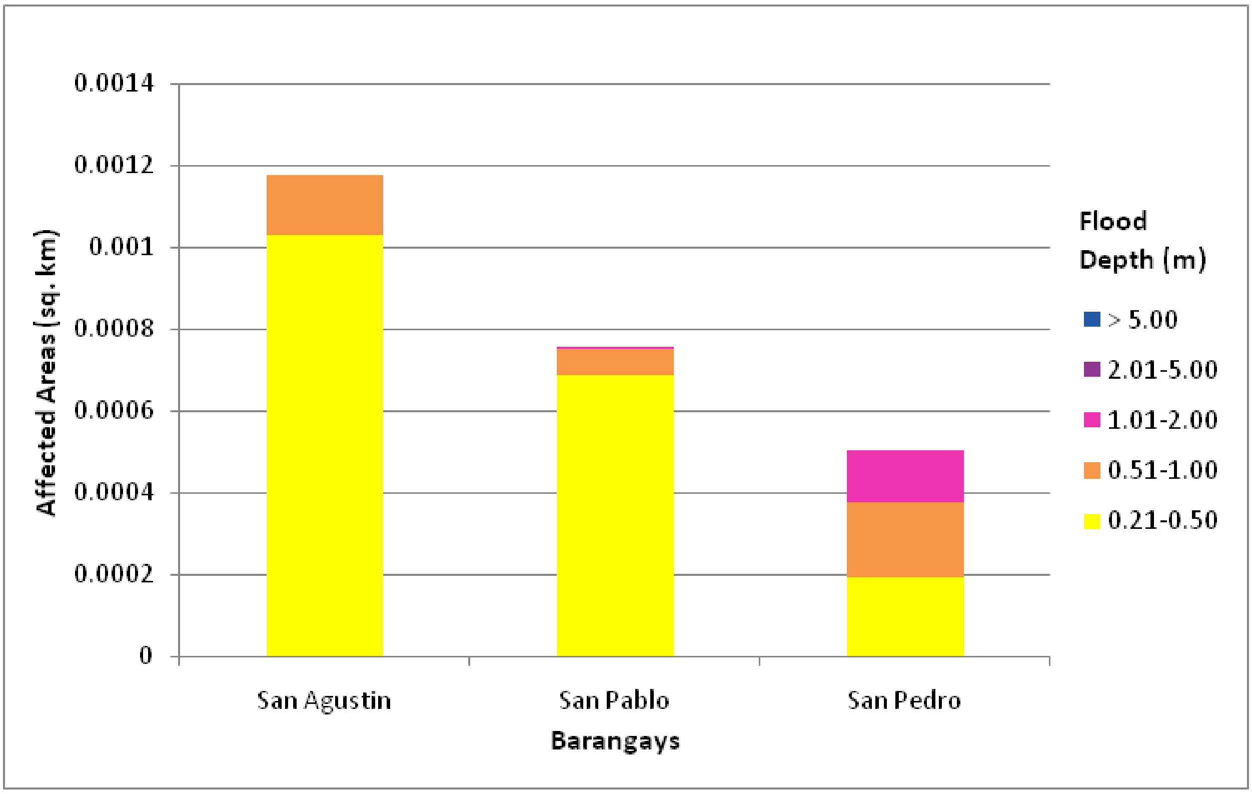


Figure 78. Affected Areas in San Nicolas, Ilocos Norte during 5-Year Rainfall Return Period

For the 5-year return period, 7.10% of the municipality of Sarrat with an area of 92.25 sq km will experience flood levels of less than 0.20 meters; 0.33% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.21%, 0.15%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in Sarrat, Ilocos Norte during a 5-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Sarrat (in sq. km)	
	San Bernabe	San Pedro
0-0.20	0.0031	6.55
0.21-0.50	0	0.3
0.51-1.00	0.000019	0.2
1.01-2.00	0	0.14
2.01-5.00	0	0.07
> 5.00	0	0.003

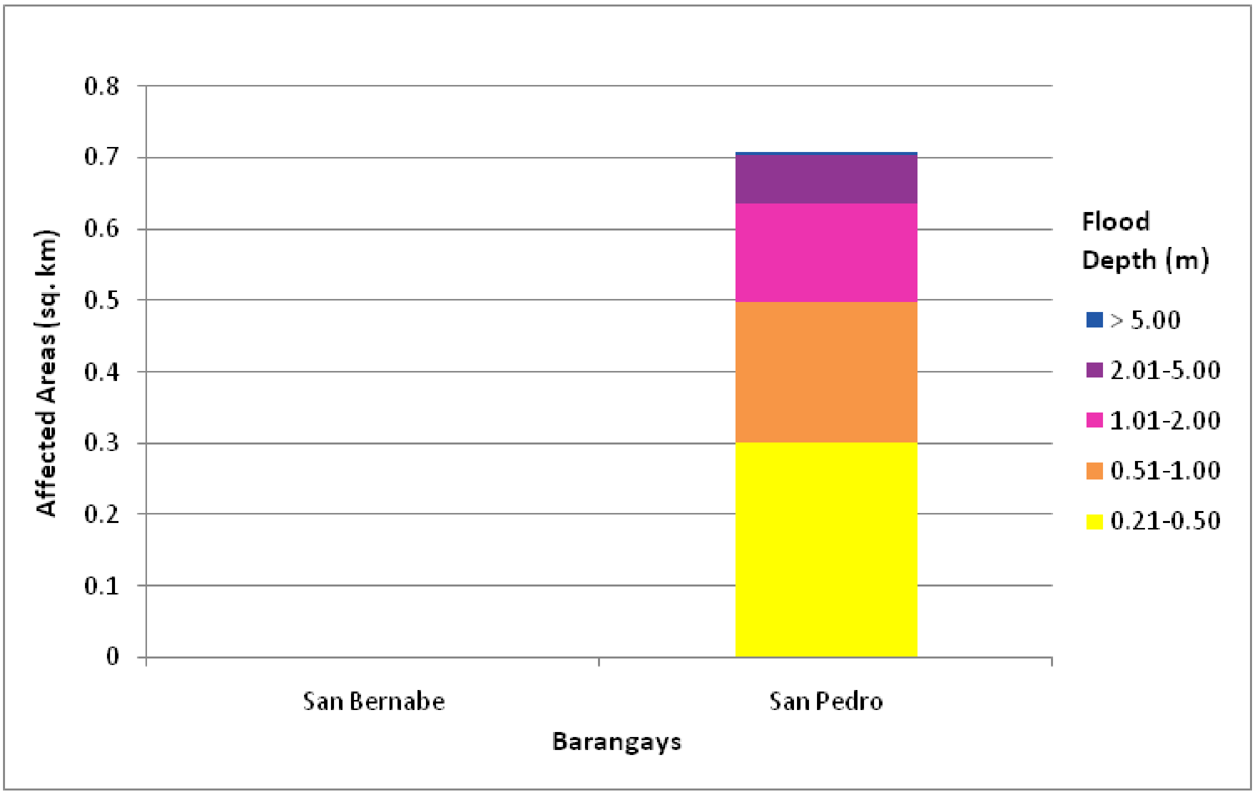


Figure 79. Affected areas in Sarrat, Ilocos Norte during a 5-year rainfall return period

For the 25-year return period, 1.51% of the municipality of Banna with an area of 89.62 sq km will experience flood levels of less than 0.20 meters; 0.06% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.03%, 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in Banna, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Banna (in sq. km)		
	Barbarangay	Bomitog	Nagpatayan
0-0.20	1.31	0.0029	0.045
0.21-0.50	0.05	0.000001	0.000038
0.51-1.00	0.027	0	0.000029
1.01-2.00	0.013	0	0
2.01-5.00	0.006	0	0
> 5.00	0.0001	0	0

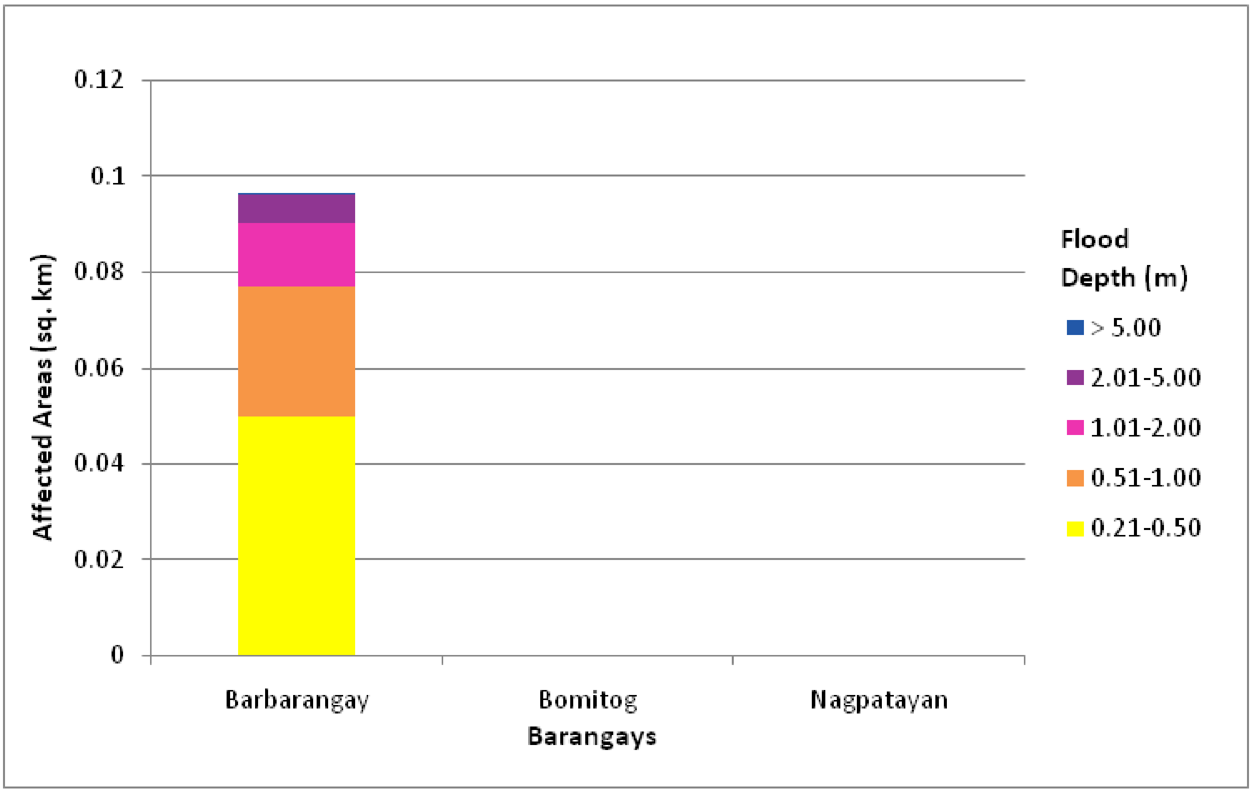


Figure 80. Affected areas in Banna, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 60.18% of the municipality of Batac City with an area of 134.62 sq km will experience flood levels of less than 0.20 meters; 7.36% of the area will experience flood levels of 0.21 to 0.50 meters; while 7.38%, 8.17%, 4.77%, and 0.40% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 to Table 48 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Ablan Poblacion	Acosta Poblacion	Aglipay	Baay	Baligat	Baoa East	Baoa West	Barani	Ben-Agan	Bil-Loca	Biningan
0-0.20	0.1	0.09	0.092	2.4	2.57	1.04	1.4	0.054	0.006	3.31	0.83
0.21-0.50	0.037	0.096	0.034	0.41	0.26	0.098	0.39	0.059	0.0076	0.39	0.041
0.51-1.00	0.0025	0.083	0.044	0.38	0.29	0.13	0.56	0.063	0.1	0.3	0.043
1.01-2.00	0.001	0.1	0.0012	0.19	0.43	0.13	0.46	0.02	0.25	0.41	0.059
2.01-5.00	0	0.036	0	0.19	1.15	0.06	0.1	0.0015	0.029	0.61	0.032
> 5.00	0	0	0	0.0001	0.0036	0.0011	0	0	0	0.029	0

Table 46. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Bungon	Callaguip	Camandingan	Camguidan	Cangrunaan	Capacuan	Caunayan	Colo	Dariwdiw	Lacub	Mabaleng
0-0.20	3.53	0.083	2.26	2.81	0.37	5.39	0.061	1.7	2.84	0.057	6.63
0.21-0.50	0.41	0.064	0.18	0.63	0.12	0.42	0.053	0.32	0.45	0.069	0.65
0.51-1.00	0.35	0.023	0.13	0.75	0.33	0.42	0.012	0.4	0.44	0.045	0.42
1.01-2.00	0.16	0.0089	0.08	1.04	0.94	0.24	0.0005	0.4	0.78	0.047	0.27
2.01-5.00	0.012	0	0.024	0.22	0.13	0.066	0	0.18	0.77	0.019	0.26
> 5.00	0.0004	0	0.0002	0.001	0	0.0007	0	0.021	0.0023	0	0.17

Table 47. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Magnuang	Maipalig	Nagbacalan	Naguirangan	Palongpong	Palpalicong	Parangopong	Payao	Pimentel	Quiling Norte	Quiling Sur
0-0.20	2.13	4.71	3.03	0.26	1.9	0.1	3.37	5.06	1.6	0.71	0.64
0.21-0.50	0.51	0.16	0.17	0.17	0.33	0.051	0.46	0.33	0.15	0.12	0.32
0.51-1.00	0.57	0.09	0.12	0.36	0.3	0.08	0.42	0.19	0.11	0.18	0.27
1.01-2.00	0.22	0.1	0.094	0.53	0.32	0.18	0.33	0.16	0.064	0.51	0.26
2.01-5.00	0.016	0.043	0.059	0.11	0.081	0.032	0.2	0.25	0.061	0.23	0.026
> 5.00	0	0	0.041	0	0	0	0	0.24	0	0.0082	0

Table 48. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)									
	Quiom	Rayuray	Ricarte Poblacion	San Julian	San Mateo	San Pedro	Suabit	Sumader	Tabug	Valdez Poblacion
0-0.20	3.17	1.31	0.034	0.14	3.38	2.71	0.014	7.91	1.15	0.058
0.21-0.50	0.18	0.2	0.018	0.027	0.61	0.22	0.03	0.38	0.24	0.055
0.51-1.00	0.15	0.31	0.041	0.0091	0.71	0.15	0.042	0.27	0.2	0.034
1.01-2.00	0.18	0.72	0.031	0.0027	0.64	0.036	0.045	0.24	0.32	0.0098
2.01-5.00	0.15	0.97	0.0003	0.0001	0.17	0.007	0.02	0.084	0.015	0
> 5.00	0.025	0	0	0	0	0.0042	0	0.0008	0	0

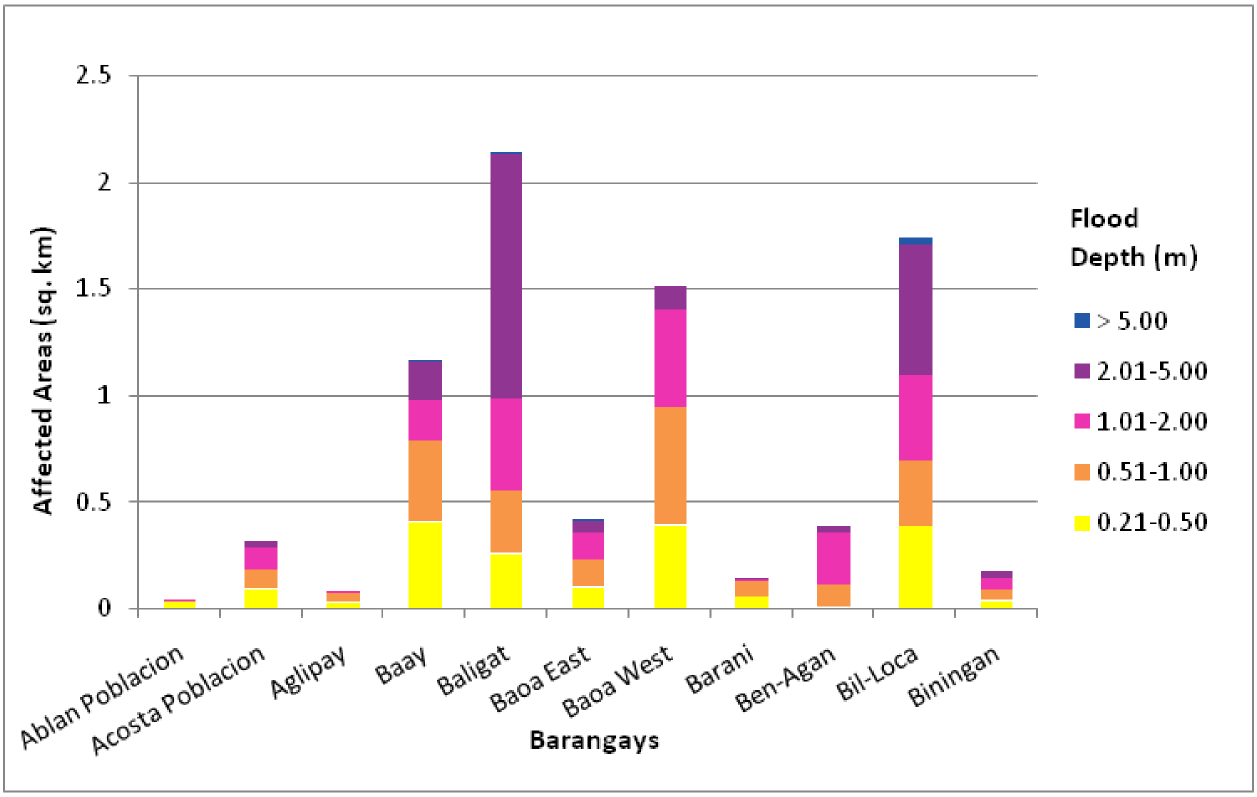


Figure 81. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

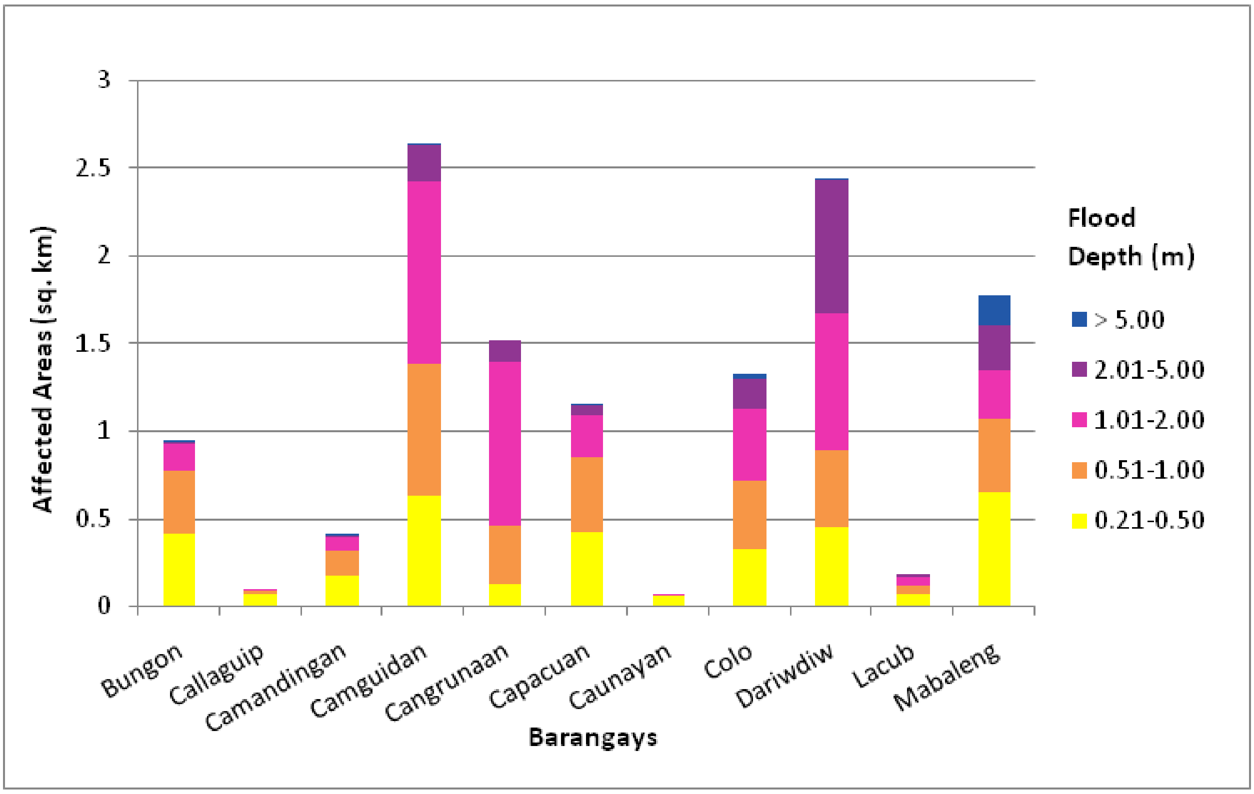


Figure 82. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

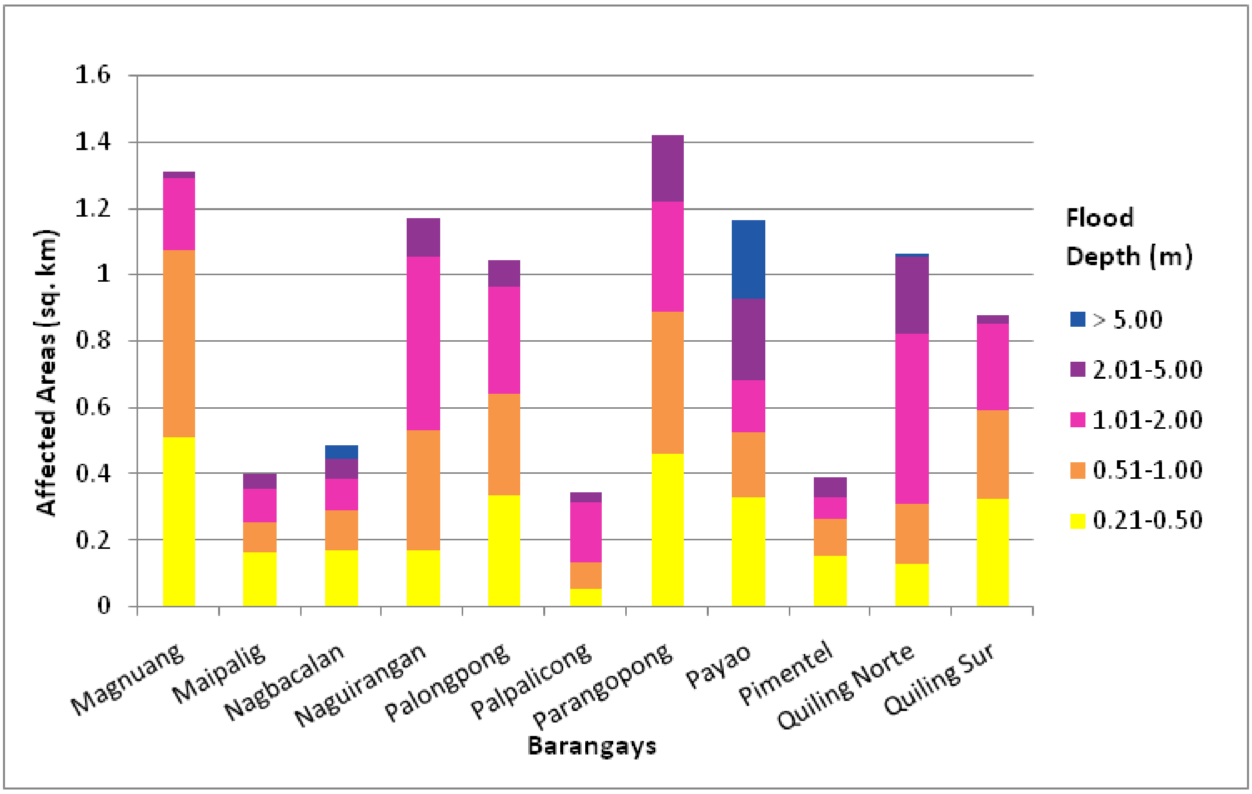


Figure 83. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

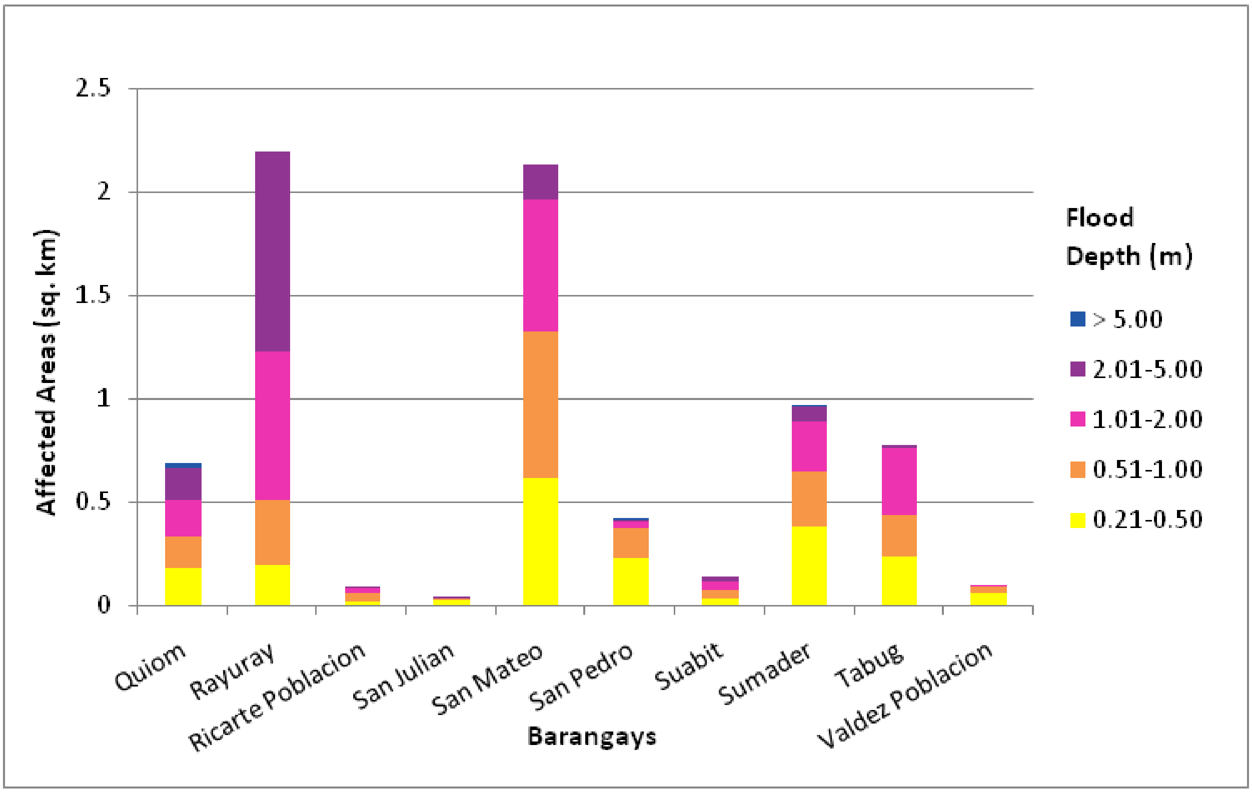


Figure 84. Affected areas in Batac City, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 18.51% of the municipality of Currimao with an area of 32.965 sq km will experience flood levels of less than 0.20 meters; 3.32% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.74%, 1.44%, and 1.62% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 49 are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected areas in Currimao, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Currimao (in sq. km)						
	Bimmanga	Lang-Ayan-Baramban	Paguludan-Salindeg	Pangil	Poblacion I	Santa Cruz	Tapao-Tigue
0-0.20	1.05	0.35	0.98	0.91	0.087	0.05	2.67
0.21-0.50	0.38	0.039	0.23	0.1	0.0047	0.00093	0.33
0.51-1.00	0.1	0.0089	0.21	0.053	0.0032	0	0.2
1.01-2.00	0.054	0.0035	0.1	0.027	0.0052	0	0.28
2.01-5.00	0.056	0.0001	0.0086	0.0025	0.0005	0	0.47
> 5.00	0	0	0	0	0	0	0

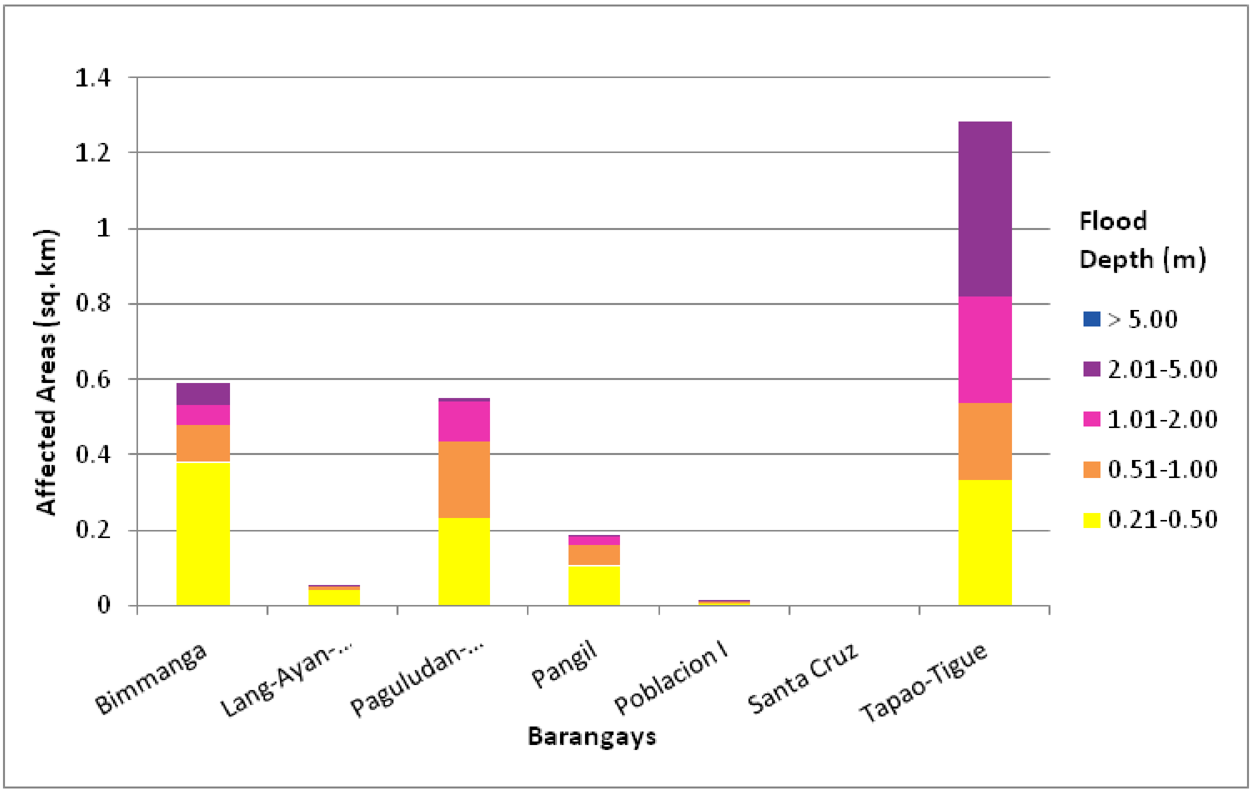


Figure 85. Affected areas in Currimao, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 0.68% of the municipality of Marcos with an area of 73.57 sq km will experience flood levels of less than 0.20 meters; 0.02% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 50 are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected areas in Marcos, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Marcos (in sq. km)
	Fortuna
0-0.20	0.5
0.21-0.50	0.017
0.51-1.00	0.0099
1.01-2.00	0.007
2.01-5.00	0.0021
> 5.00	0

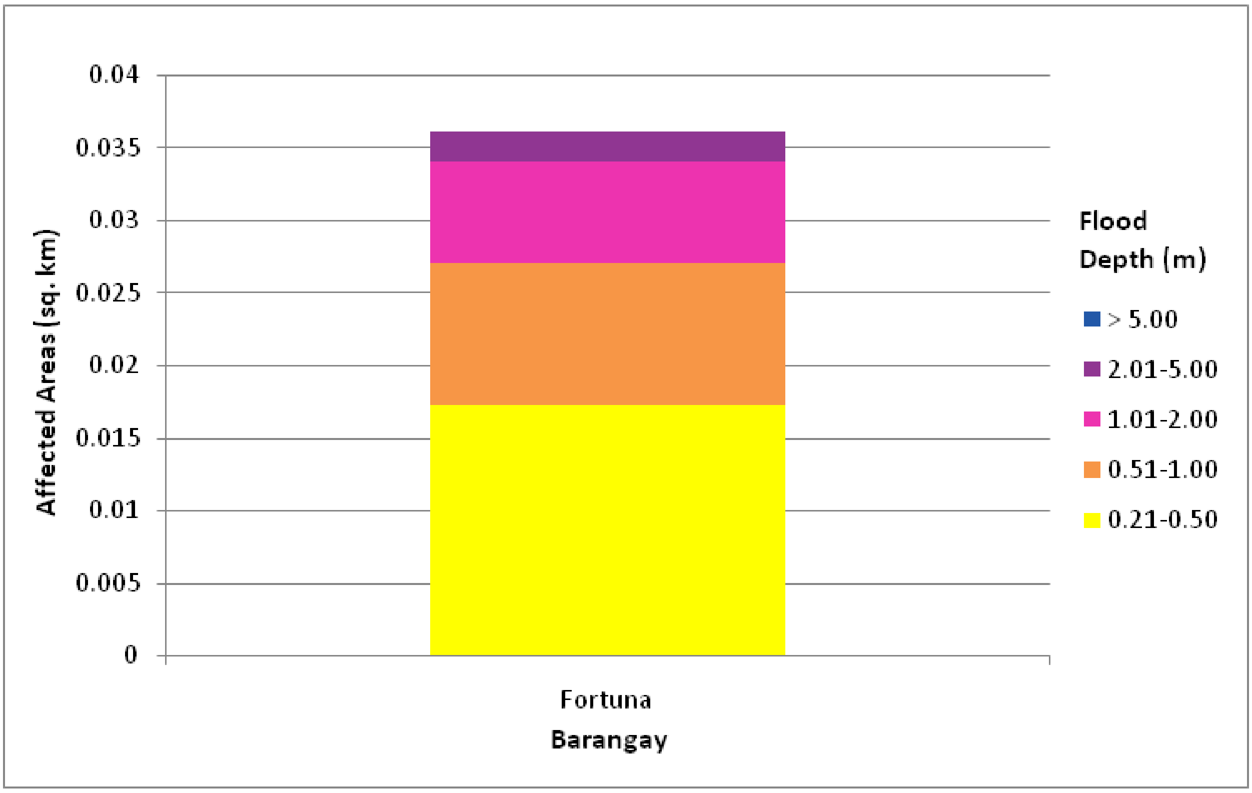


Figure 86. Affected areas in Marcos, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 36.96% of the municipality of Paoay with an area of 71.62 sq km will experience flood levels of less than 0.20 meters; 9.94% of the area will experience flood levels of 0.21 to 0.50 meters; while 11.44%, 13.13%, 7.57%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 to Table 53 are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected areas in Paoay, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)									
	Bacsil	Cabagoan	Cabangaran	Callaguip	Cayubog	Dolores	Laoa	Masintoc	Monte	Mumulaan
0-0.20	4.17	0.0007	0.55	0.17	0.29	0.025	0.14	1.57	2.88	1.83
0.21-0.50	0.96	0.0037	0.75	0.026	0.14	0.032	0.083	0.28	0.46	0.2
0.51-1.00	0.89	0.019	0.48	0.019	0.34	0.045	0.19	0.21	0.38	0.14
1.01-2.00	0.48	0.073	0.13	0.068	0.78	0.012	0.22	0.12	0.31	0.12
2.01-5.00	0.11	0.0038	0.0048	0.21	0.39	0	0.015	0.099	0.36	0.069
> 5.00	0.008	0	0	0.000073	0	0	0	0	0	0.0039

Table 52. Affected areas in Paoay, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)									
	Nagbacalan	Nalasin	Oaig-Upay-Abulao	Pambaran	Pannaratan	Paratong	Pasil	Salbang	San Agustin	San Blas
0-0.20	0.64	2.93	0.41	0.24	0.11	1.43	1.2	0.97	0.55	0.064
0.21-0.50	0.045	0.82	0.27	0.065	0.085	0.27	0.1	0.33	0.27	0.048
0.51-1.00	0.035	0.71	0.31	0.14	0.1	0.34	0.041	0.058	0.43	0.15
1.01-2.00	0.031	0.45	0.46	0.31	0.099	0.44	0.08	0.025	1.13	0.14
2.01-5.00	0.024	0.017	0.51	0.61	0.0065	0.65	0.58	0.0035	1.27	0.012
> 5.00	0	0	0	0	0	0	0.012	0	0.017	0

Table 53. Affected areas in Paoay, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)								
	San Juan	San Pedro	San Roque	Sangladan Poblacion	Santa Rita	Sideg	Sungadan	Surgui	Veronica
0-0.20	0.23	0.016	0.84	0.049	0.49	2.22	1.25	1.05	0.15
0.21-0.50	0.035	0.016	0.45	0.034	0.48	0.32	0.29	0.19	0.063
0.51-1.00	0.029	0.039	1.07	0.0097	1.16	0.47	0.2	0.075	0.11
1.01-2.00	0.036	0.045	1.08	0.0026	1.8	0.54	0.071	0.07	0.28
2.01-5.00	0.0095	0.0066	0.048	0	0.13	0.15	0	0.068	0.086
> 5.00	0	0	0	0	0	0	0	0	0

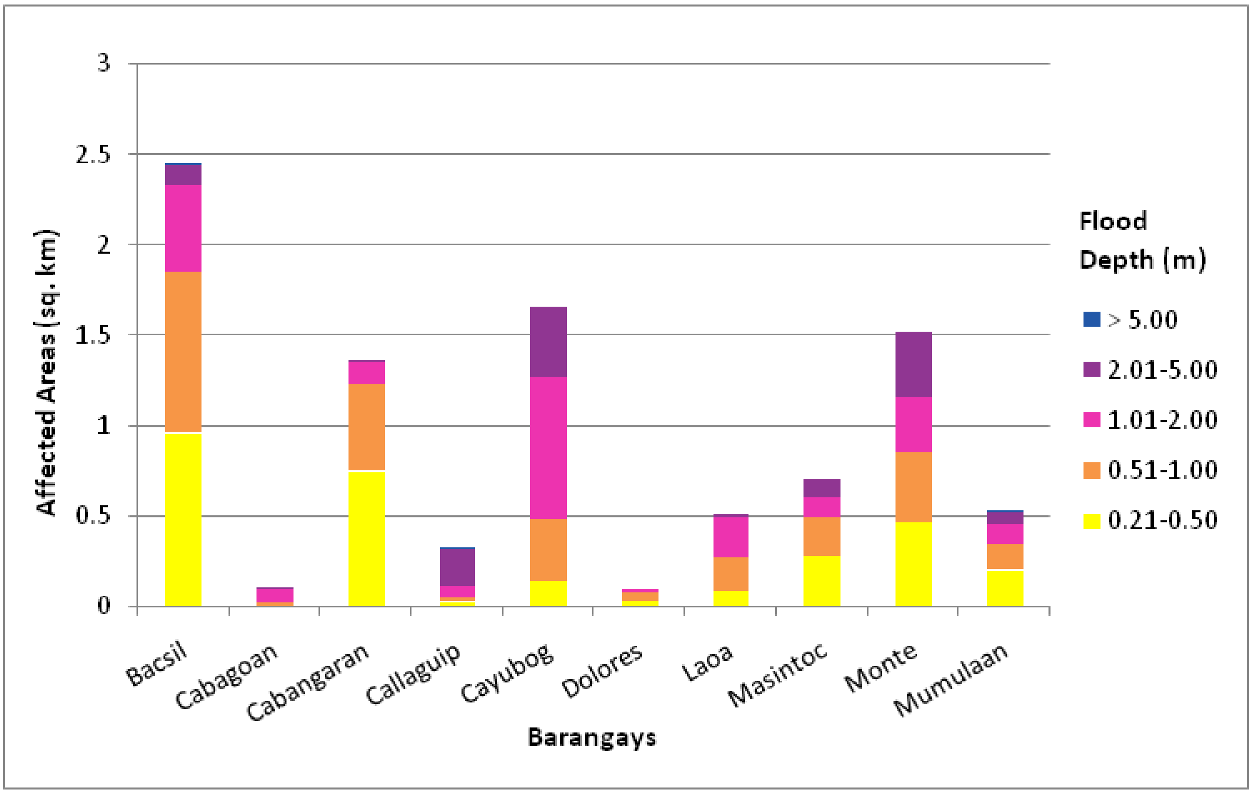


Figure 87. Affected areas in Paoay, Ilocos Norte during a 25-year rainfall return period

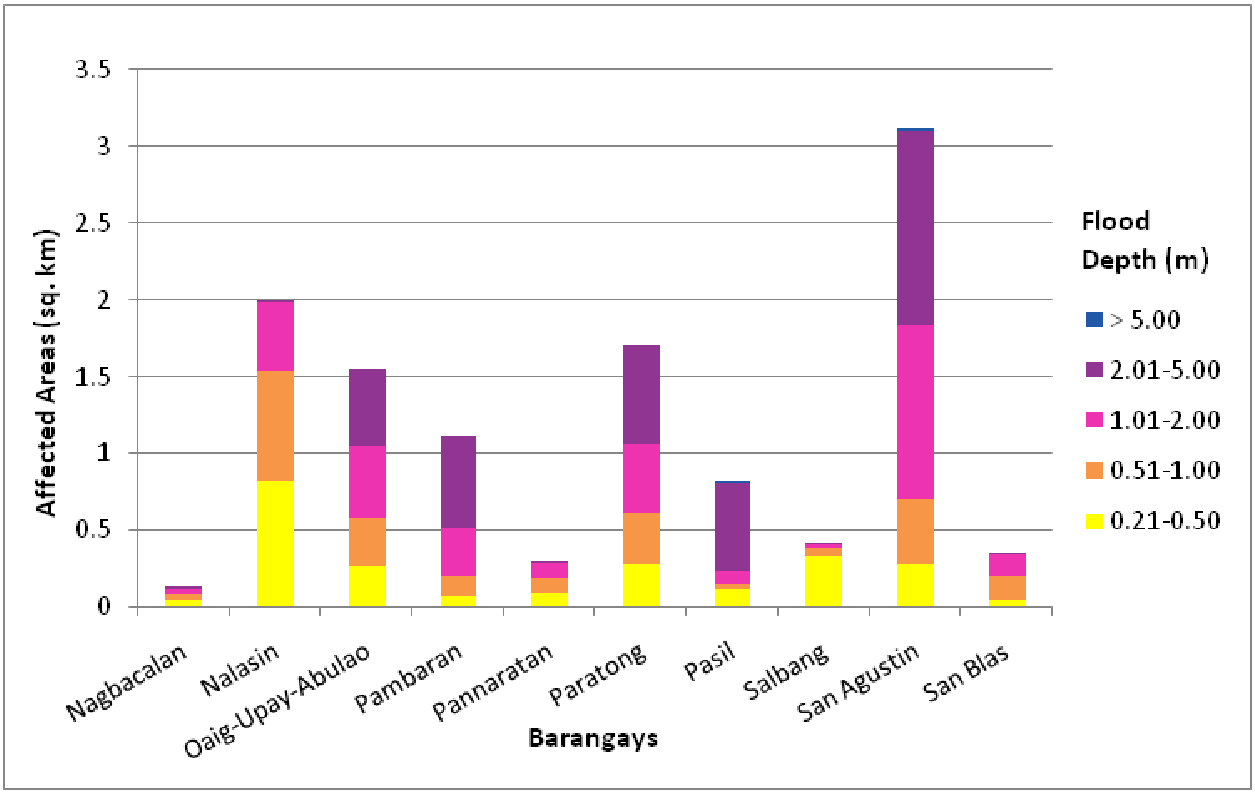


Figure 88. Affected areas in Paoay, Ilocos Norte during a 25-year rainfall return period

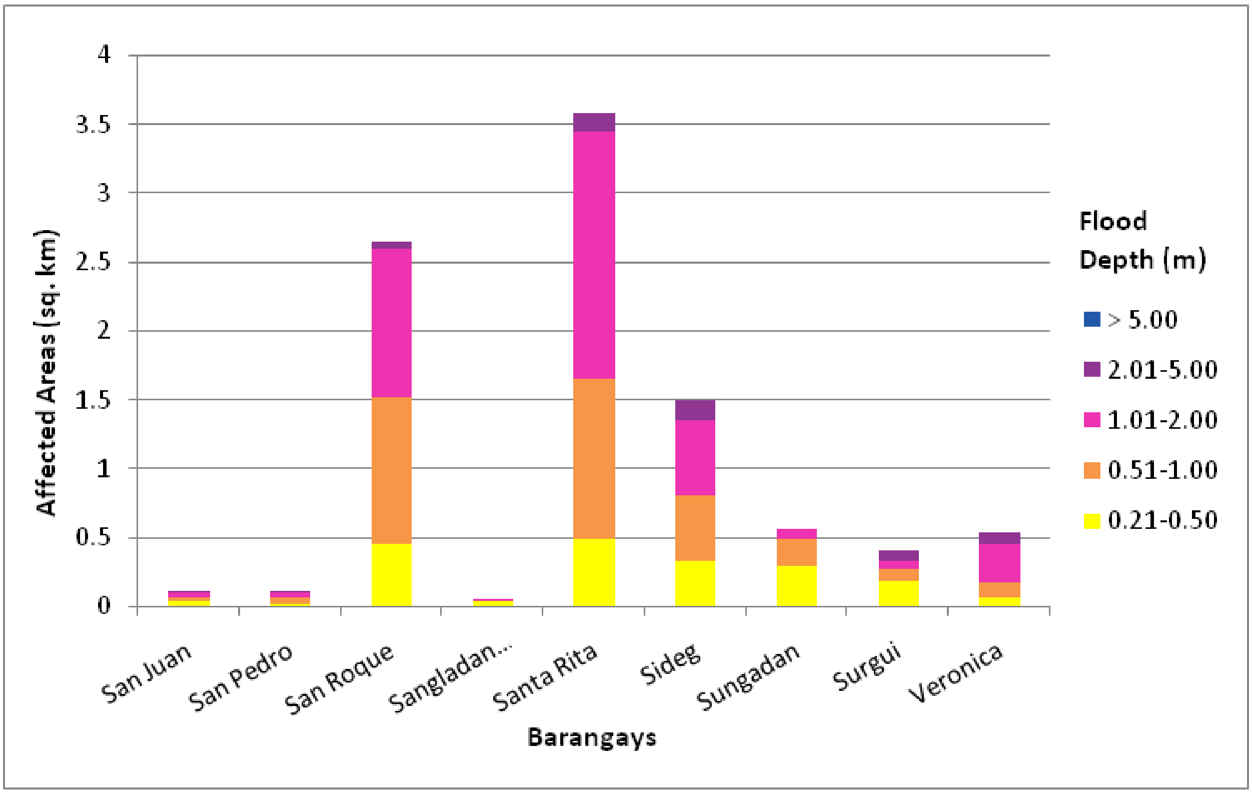


Figure 89. Affected areas in Paoay, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 3.63% of the municipality of Paoay Lake with an area of 3.64 sq km will experience flood levels of less than 0.20 meters; 0.08% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.01% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 54 are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected areas in Paoay Lake, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Paoay Lake (in sq. km)
	Paoay Lake
0-0.20	0.13
0.21-0.50	0.003
0.51-1.00	0.00038
1.01-2.00	0.0002
2.01-5.00	0
> 5.00	0

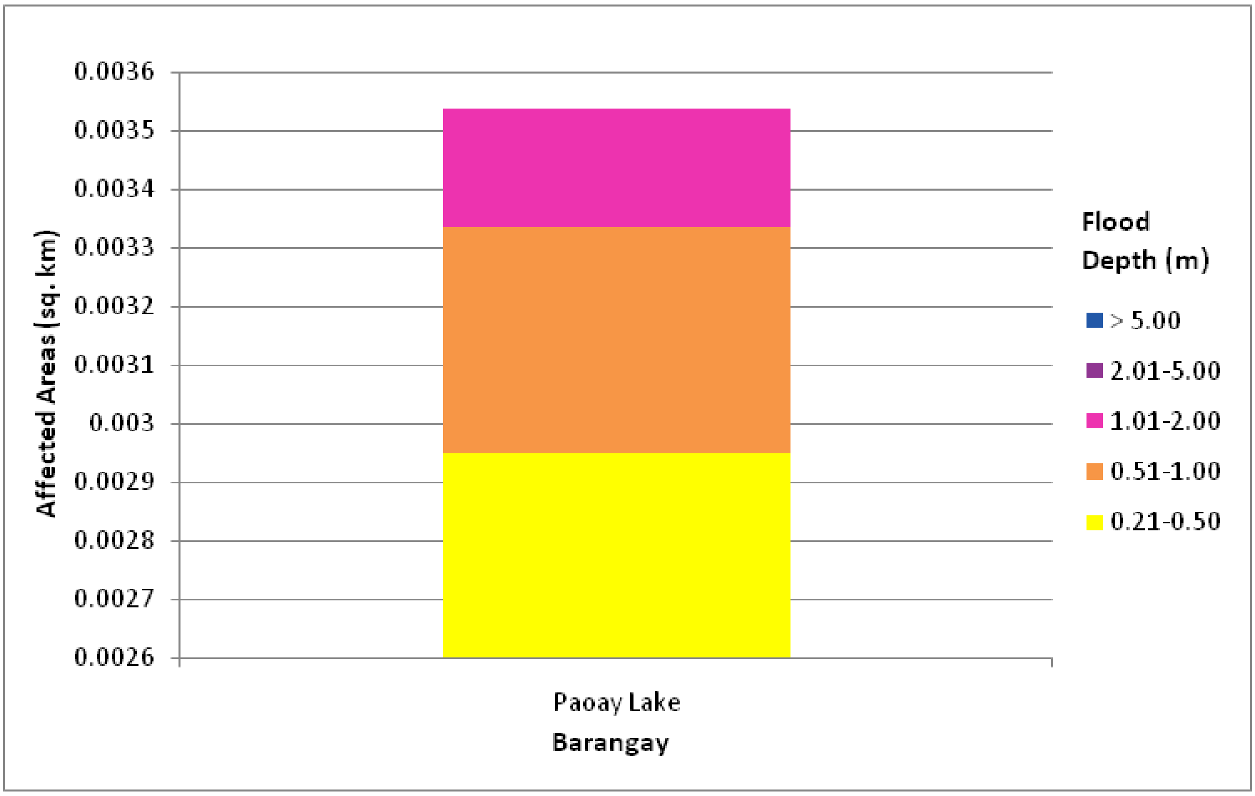


Figure 90. Affected areas in Paoay Lake, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 1.66% of the municipality of Pinili with an area of 63.18 sq km will experience flood levels of less than 0.20 meters; 0.08% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.05%, 0.02%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected areas in Pinili, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Pinili (in sq. km)
	Buanga
0-0.20	1.05
0.21-0.50	0.052
0.51-1.00	0.033
1.01-2.00	0.013
2.01-5.00	0.0037
> 5.00	0.0002

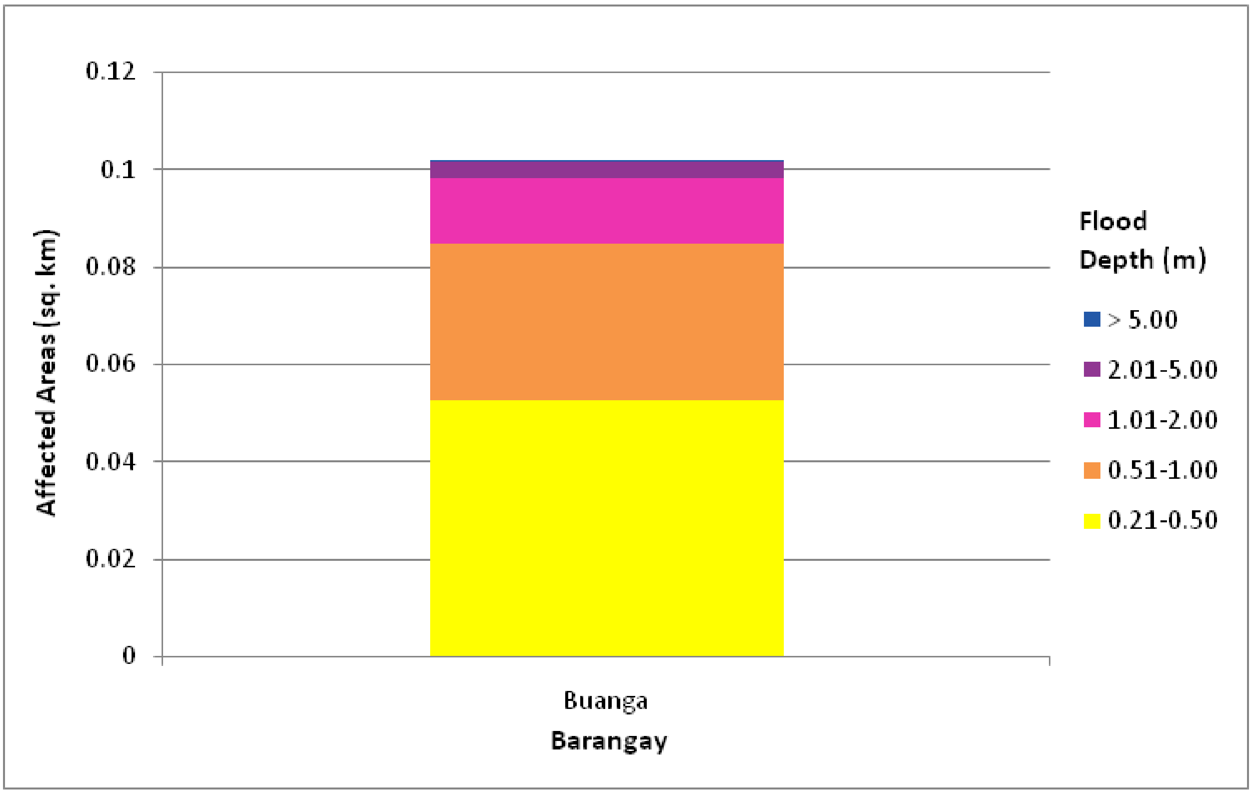


Figure 91. Affected areas in Pinili, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 0.31% of the municipality of San Nicolas with an area of 40.225 sq km will experience flood levels of less than 0.20 meters; while 0.01% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 56 are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected areas in San Nicolas, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in San Nicolas (in sq. km)		
	San Agustin	San Pablo	San Pedro
0-0.20	0.077	0.028	0.019
0.21-0.50	0.002	0.00075	0.00016
0.51-1.00	0.00018	0.00015	0.00033
1.01-2.00	0	0.000022	0.00016
2.01-5.00	0	0	0
> 5.00	0	0	0

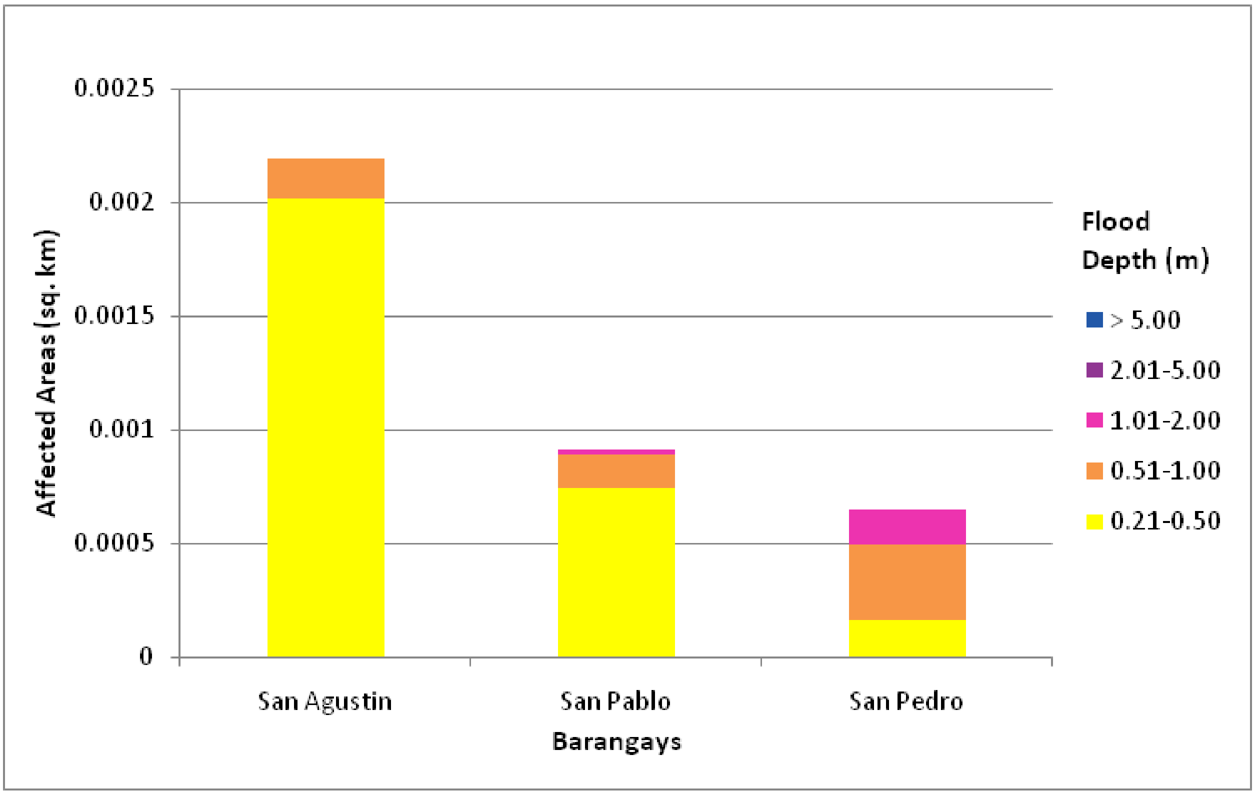


Figure 92. Affected areas in San Nicolas, Ilocos Norte during a 25-year rainfall return period

For the 25-year return period, 6.95% of the municipality of Sarrat with an area of 92.25 sq km will experience flood levels of less than 0.20 meters; 0.36% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.25%, 0.18%, 0.11%, 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 57 are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected areas in Sarrat, Ilocos Norte during a 25-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Sarrat (in sq. km)	
	San Bernabe	San Pedro
0-0.20	0.0031	6.41
0.21-0.50	0	0.33
0.51-1.00	0.000019	0.23
1.01-2.00	0	0.17
2.01-5.00	0	0.1
> 5.00	0	0.0075

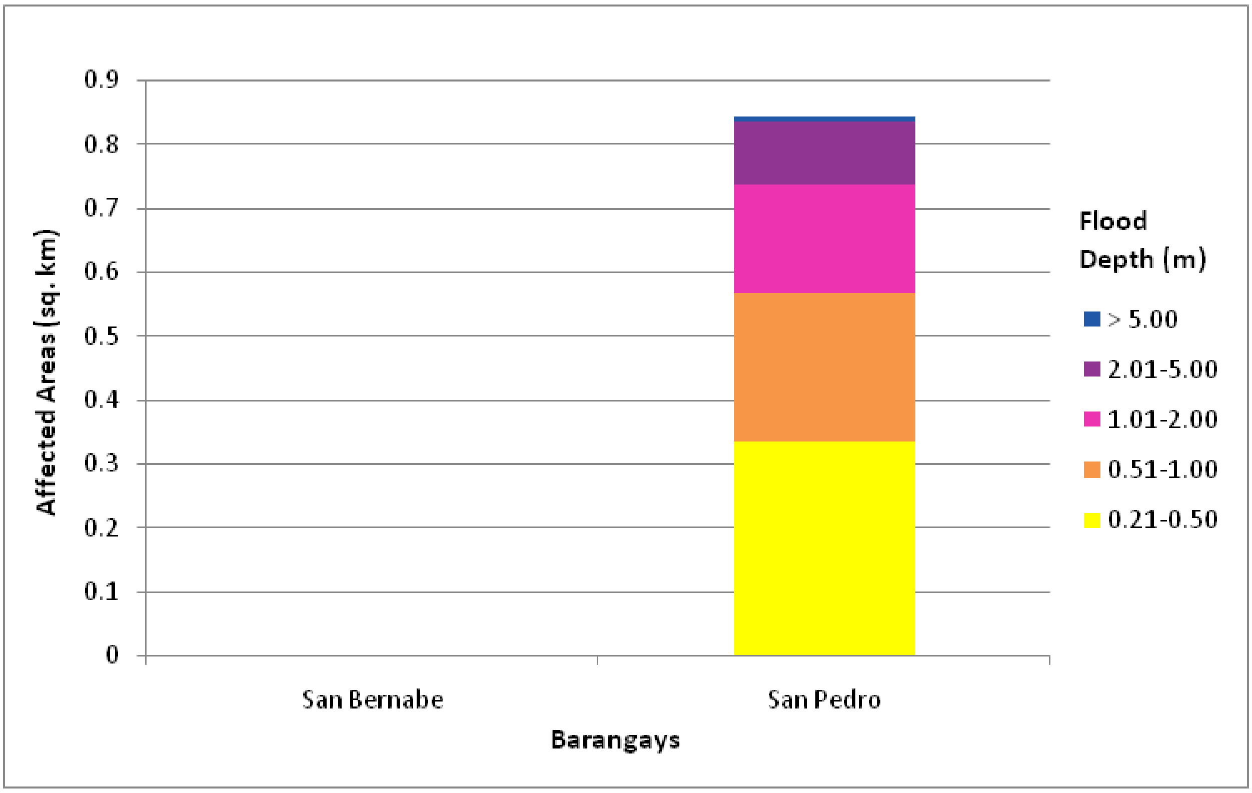


Figure 93. Affected areas in Sarrat, Ilocos Norte during a 25-year rainfall return period

For the 100-year return period, 1.49% of the municipality of Banna with an area of 89.62 sq km will experience flood levels of less than 0.20 meters; 0.06% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.03%, 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, respectively. Listed in Table 58 are the affected areas in square kilometers by flood depth per barangay.

Table 58. Affected areas in Banna, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Banna (in sq. km)		
	Barbarangay	Bomitog	Nagpatayan
0-0.20	1.29	0.0029	0.044
0.21-0.50	0.056	0.000001	0.00013
0.51-1.00	0.031	0	0.000029
1.01-2.00	0.016	0	0
2.01-5.00	0.0071	0	0
> 5.00	0.0001	0	0

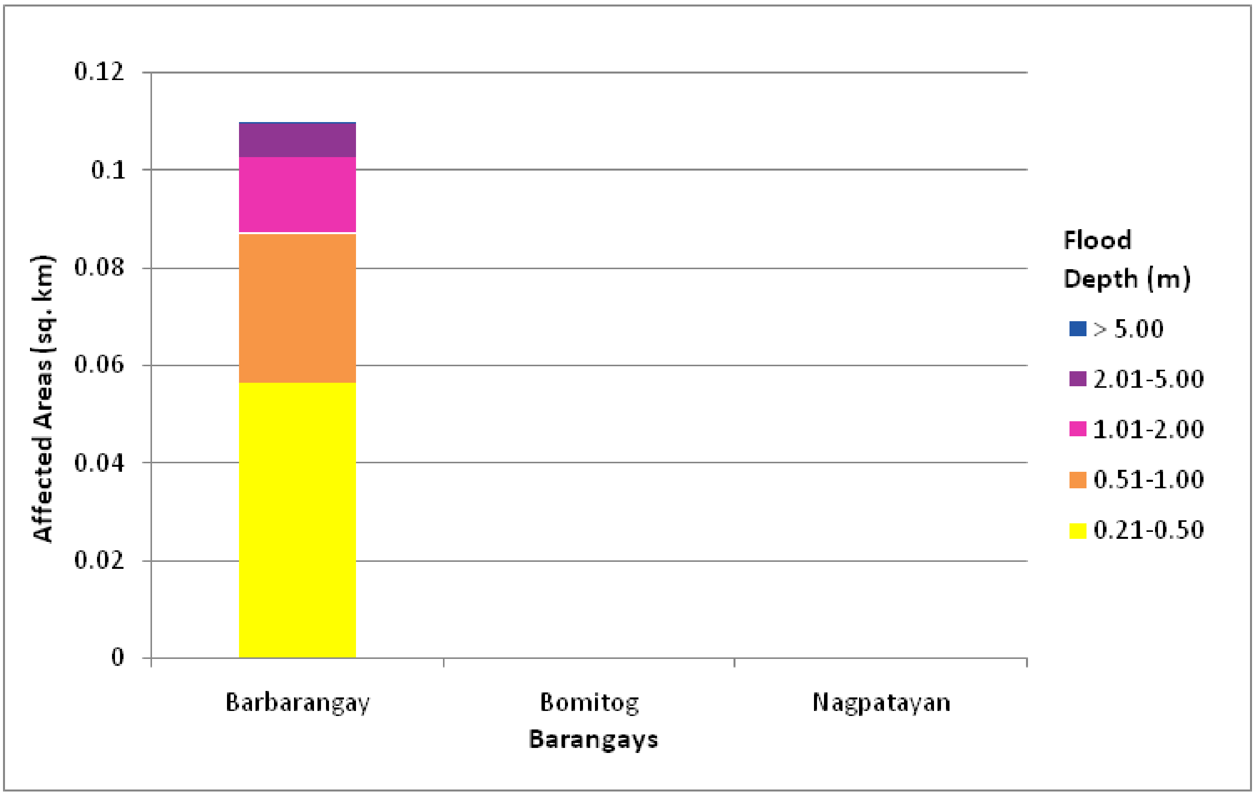


Figure 94. Affected areas in Banna, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 57.88% of the municipality of Batac City with an area of 134.62 sq km will experience flood levels of less than 0.20 meters; 6.95% of the area will experience flood levels of 0.21 to 0.50 meters; while 7.43%, 8.90%, 6.26%, and 0.85% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 59 to Table 62 are the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Ablan Poblacion	Acosta Poblacion	Aglipay	Baay	Baligat	Baoa East	Baoa West	Barani	Ben-Agan	Bil-Loca	Biningan
0-0.20	0.076	0.059	0.085	2.3	2.47	1.01	1.32	0.042	0.0032	3.18	0.81
0.21-0.50	0.06	0.075	0.018	0.36	0.24	0.092	0.31	0.029	0.0046	0.4	0.041
0.51-1.00	0.0046	0.11	0.064	0.42	0.26	0.13	0.56	0.097	0.036	0.3	0.044
1.01-2.00	0.0021	0.1	0.004	0.22	0.33	0.15	0.56	0.028	0.29	0.4	0.057
2.01-5.00	0	0.059	0	0.26	0.96	0.075	0.15	0.0026	0.06	0.73	0.048
> 5.00	0	0	0	0.0078	0.45	0.0021	0.0002	0	0	0.034	0

Table 60. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Bungon	Callaguip	Camandingan	Camguidan	Cangrunaan	Capacuan	Caunayan	Colo	Dariwdiw	Lacub	Mabaleng
0-0.20	3.44	0.064	2.22	2.6	0.33	5.29	0.032	1.6	2.69	0.043	6.36
0.21-0.50	0.41	0.065	0.18	0.57	0.077	0.42	0.063	0.22	0.43	0.042	0.66
0.51-1.00	0.38	0.037	0.15	0.76	0.23	0.44	0.032	0.4	0.39	0.079	0.47
1.01-2.00	0.22	0.013	0.099	1.17	0.92	0.3	0.0008	0.5	0.69	0.034	0.39
2.01-5.00	0.015	0	0.028	0.35	0.33	0.089	0	0.27	1.08	0.039	0.31
> 5.00	0.0024	0	0.0004	0.0023	0	0.0009	0	0.029	0.0047	0	0.2

Table 61. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)										
	Magnuang	Maipalig	Nagbacalan	Naguirangan	Palongpong	Palpalicong	Parangopong	Payao	Pimentel	Quiling Norte	Quiling Sur
0-0.20	2.04	4.66	2.98	0.21	1.75	0.081	3.26	4.94	1.56	0.64	0.48
0.21-0.50	0.45	0.19	0.18	0.12	0.37	0.047	0.43	0.34	0.16	0.084	0.33
0.51-1.00	0.62	0.093	0.13	0.31	0.31	0.073	0.46	0.21	0.12	0.13	0.28
1.01-2.00	0.3	0.1	0.11	0.57	0.39	0.19	0.37	0.16	0.08	0.48	0.3
2.01-5.00	0.022	0.063	0.062	0.21	0.13	0.054	0.27	0.26	0.068	0.42	0.13
> 5.00	0	0.0002	0.048	0	0	0	0.0001	0.31	0	0.011	0

Table 62. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Batac City (in sq. km)									
	Quiom	Rayuray	Ricarte Poblacion	San Julian	San Mateo	San Pedro	Suabit	Sumader	Tabug	Valdez Poblacion
0-0.20	3.11	1.2	0.023	0.12	3.21	2.67	0.01	7.81	1.08	0.038
0.21-0.50	0.18	0.17	0.02	0.037	0.56	0.22	0.02	0.39	0.25	0.049
0.51-1.00	0.15	0.2	0.033	0.012	0.73	0.18	0.044	0.28	0.16	0.053
1.01-2.00	0.2	0.66	0.047	0.0048	0.76	0.049	0.045	0.27	0.39	0.015
2.01-5.00	0.18	1.26	0.0004	0.0001	0.24	0.0077	0.031	0.12	0.041	0.0006
> 5.00	0.033	0	0	0	0.00013	0.0062	0	0.0013	0	0

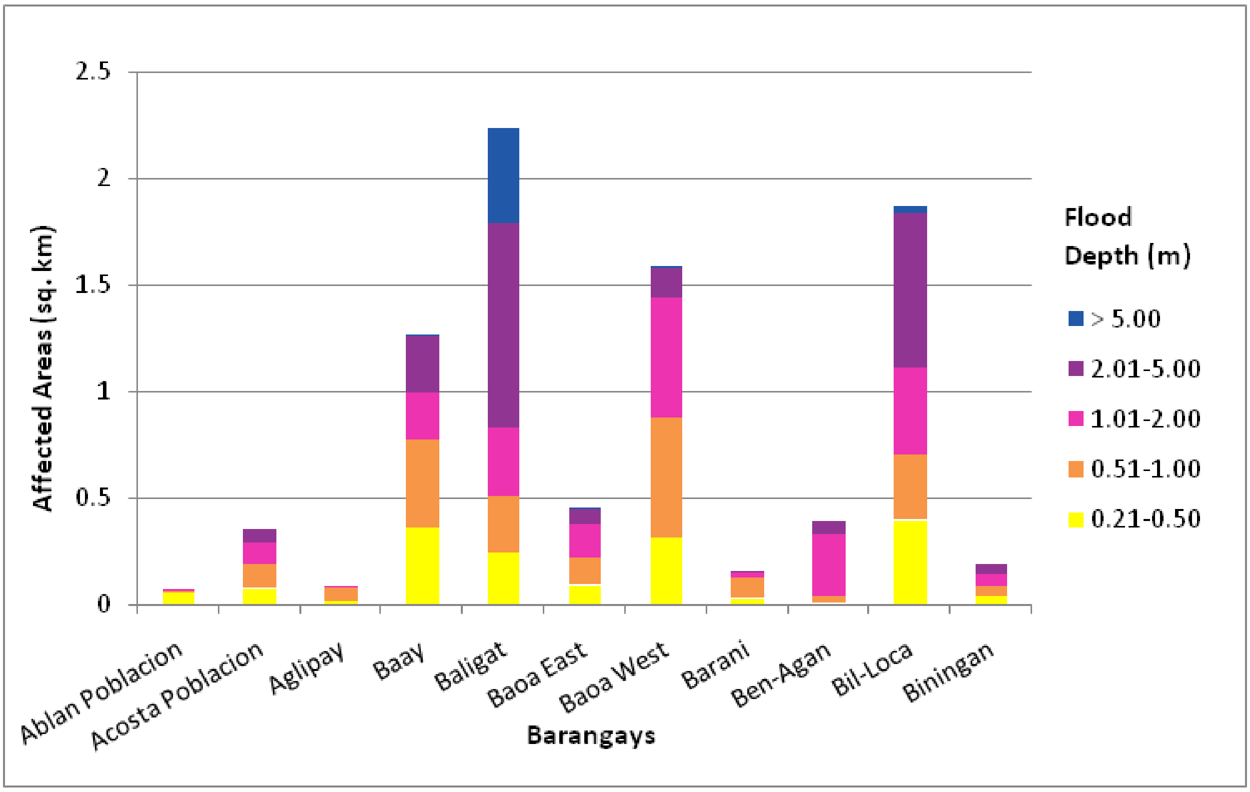


Figure 95. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

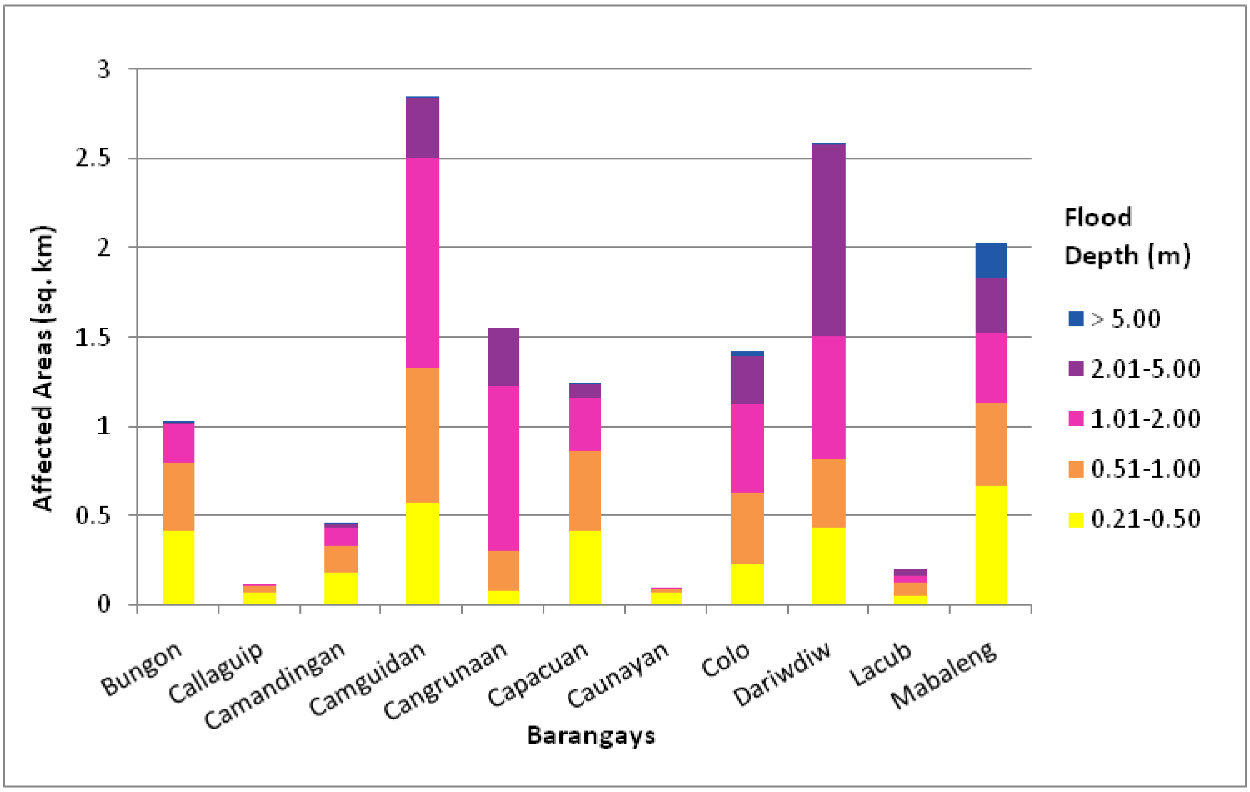


Figure 96. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

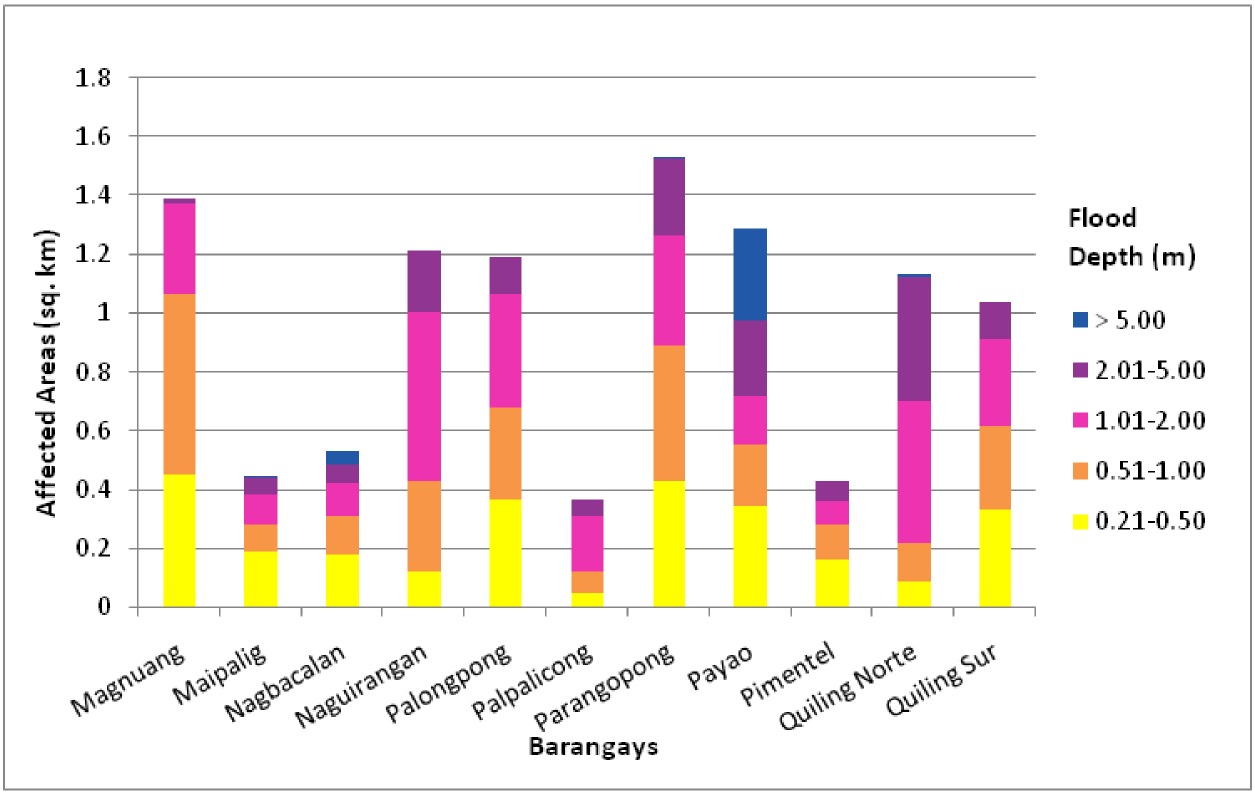


Figure 97. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

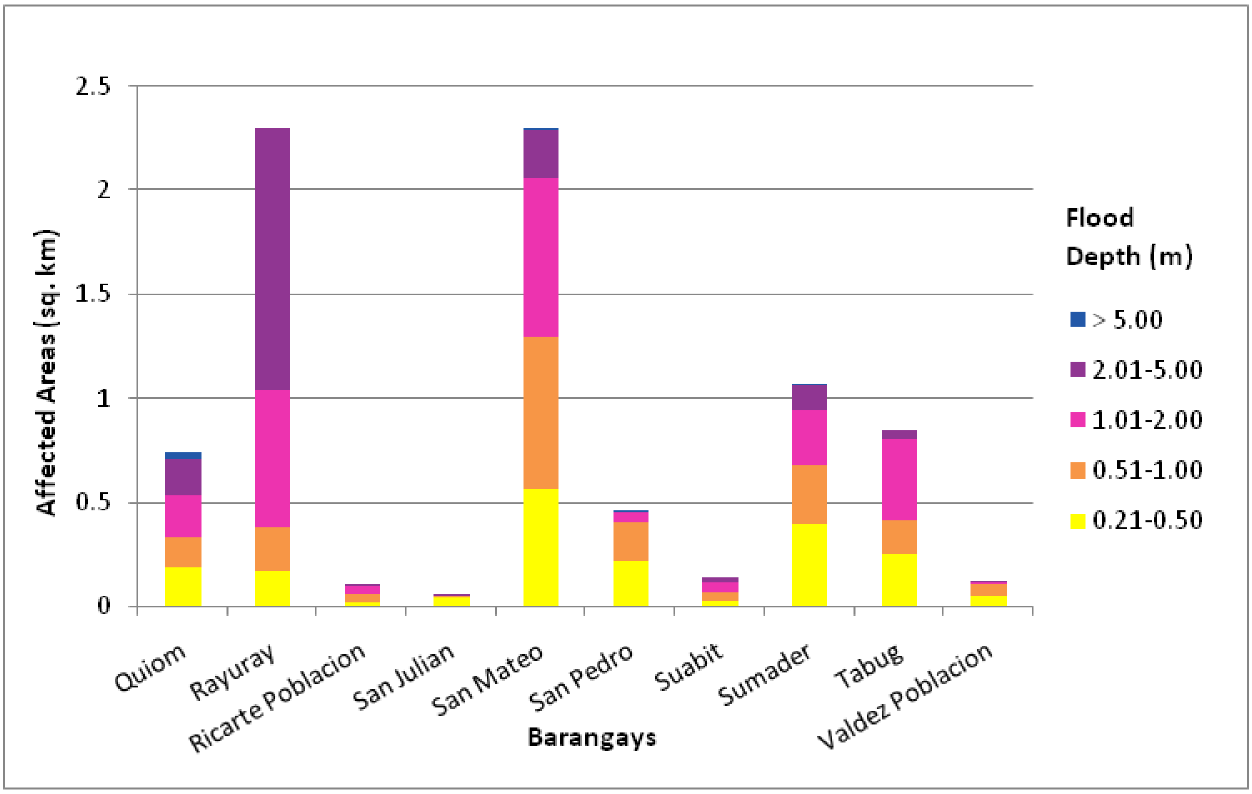


Figure 98. Affected areas in Batac City, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 17.33% of the municipality of Currimao with an area of 32.965 sq km will experience flood levels of less than 0.20 meters; 3.23% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.23%, 1.63%, and 2.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 63 are the affected areas in square kilometers by flood depth per barangay

Table 63. Affected areas in Currimao, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Currimao (in sq. km)						
	Bimmanga	Lang-Ayan-Baramban	Paguludan-Salindeg	Pangil	Poblacion I	Santa Cruz	Tapao-Tigue
0-0.20	0.92	0.34	0.87	0.88	0.085	0.05	2.56
0.21-0.50	0.37	0.045	0.17	0.12	0.0051	0.0011	0.35
0.51-1.00	0.2	0.0099	0.23	0.059	0.004	0	0.23
1.01-2.00	0.068	0.0046	0.23	0.035	0.0055	0	0.19
2.01-5.00	0.072	0.00011	0.025	0.0036	0.0006	0	0.63
> 5.00	0	0	0	0	0	0	0

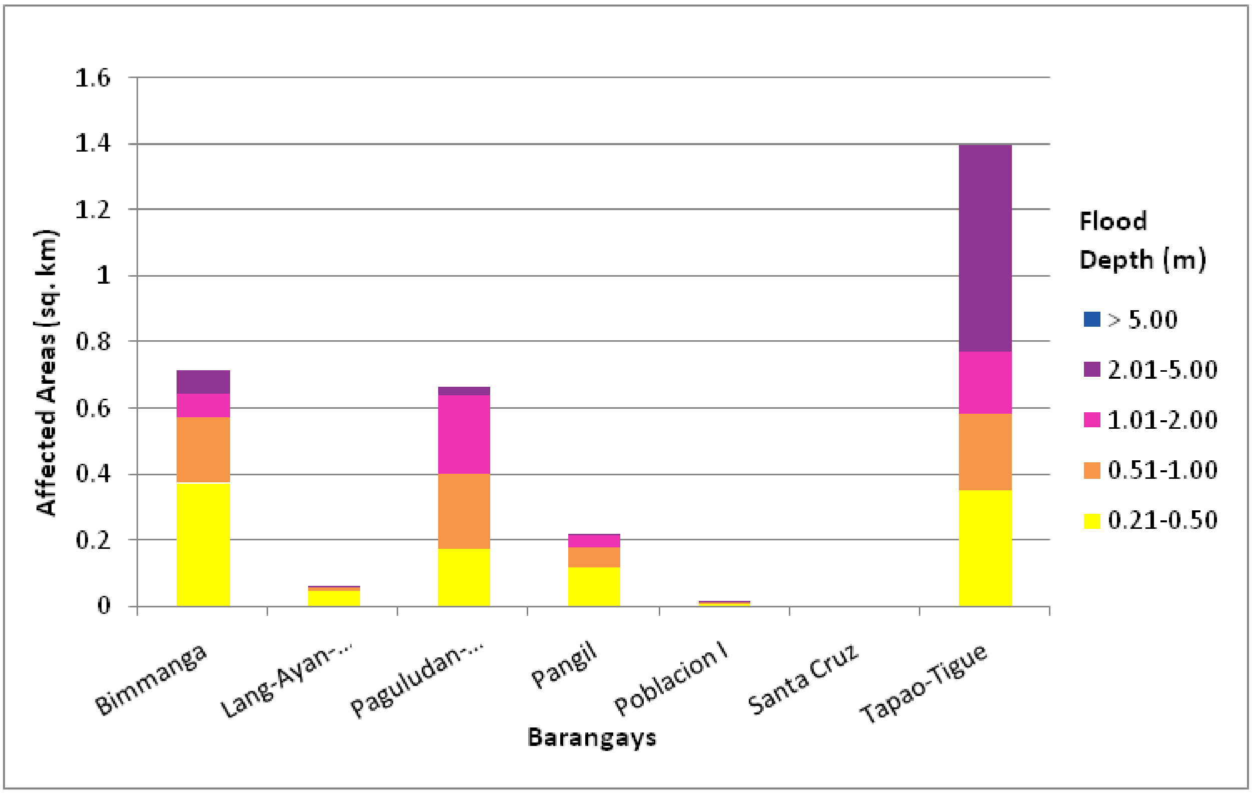


Figure 99. Affected areas in Currimao, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 0.68% of the municipality of Marcos with an area of 73.57 sq km will experience flood levels of less than 0.20 meters; 0.02% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.02% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 64 are the affected areas in square kilometers by flood depth per barangay.

Table 64. Affected areas in Marcos, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Marcos (in sq. km)
	Fortuna
0-0.20	0.5
0.21-0.50	0.017
0.51-1.00	0.012
1.01-2.00	0.0076
2.01-5.00	0.0026
> 5.00	0

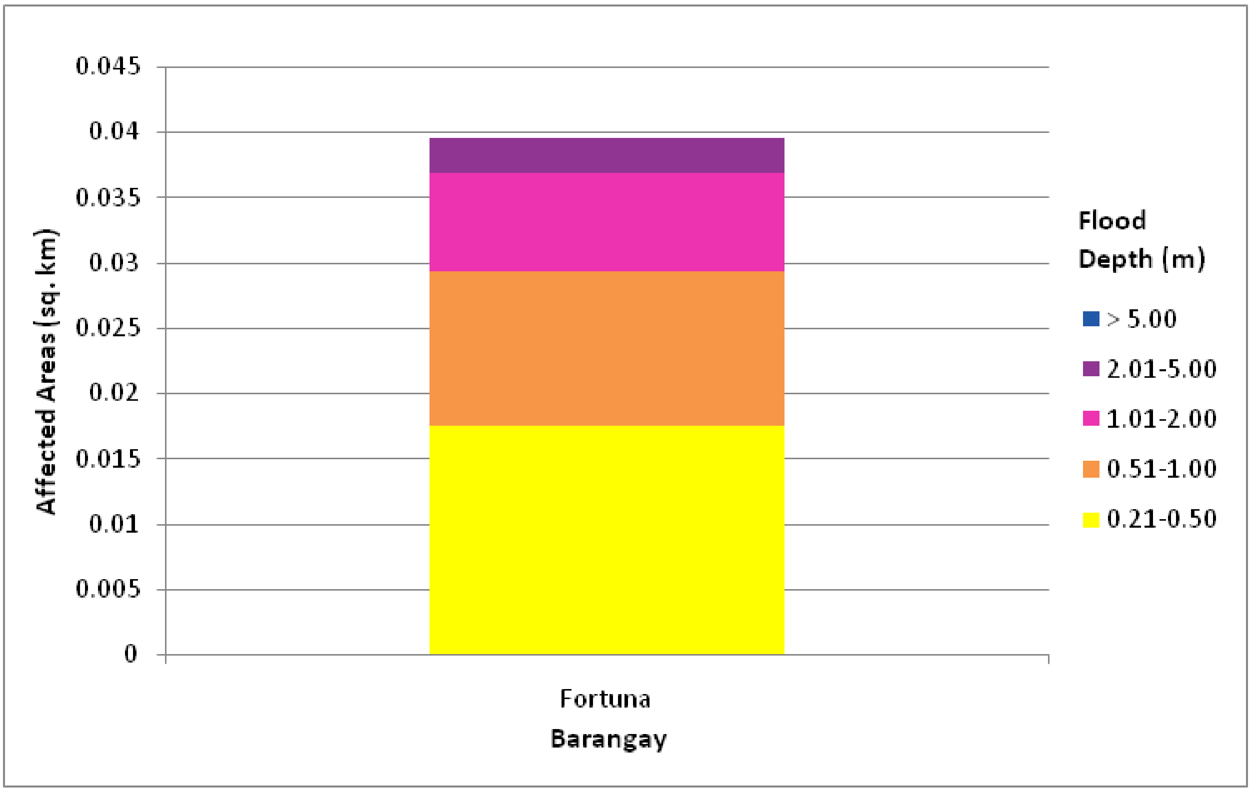


Figure 100. Affected areas in Marcos, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 31.87% of the municipality of Paoay with an area of 71.62 sq km will experience flood levels of less than 0.20 meters; 8.05% of the area will experience flood levels of 0.21 to 0.50 meters; while 10.32%, 15.85%, 12.43%, and 0.57% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 65 to Table 67 are the affected areas in square kilometers by flood depth per barangay.

Table 65. Affected areas in Paoay, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)									
	Bacsil	Cabagoan	Cabangaran	Callaguip	Cayubog	Dolores	Laoa	Masintoc	Monte	Mumulaan
0-0.20	3.78	0	0.32	0.14	0.17	0.0064	0.027	1.42	2.71	1.76
0.21-0.50	0.83	0.0005	0.55	0.034	0.063	0.014	0.031	0.3	0.45	0.21
0.51-1.00	1.09	0.0077	0.7	0.019	0.14	0.051	0.076	0.25	0.44	0.16
1.01-2.00	0.65	0.081	0.32	0.028	0.5	0.042	0.33	0.15	0.31	0.13
2.01-5.00	0.25	0.011	0.012	0.26	1.07	0	0.17	0.16	0.48	0.095
> 5.00	0.019	0	0	0.0029	0.0002	0	0	0	0	0.0081

Table 66. Affected areas in Paoay, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)									
	Nagbacalan	Nalasin	Oaig-Upay-Abulao	Pambaran	Pannaratan	Paratong	Pasil	Salbang	San Agustin	San Blas
0-0.20	0.62	2.74	0.042	0.17	0.043	1.17	1.15	0.8	0.25	0.038
0.21-0.50	0.05	0.78	0.076	0.044	0.049	0.21	0.11	0.34	0.18	0.025
0.51-1.00	0.038	0.71	0.3	0.098	0.12	0.39	0.039	0.2	0.37	0.1
1.01-2.00	0.037	0.67	0.61	0.31	0.16	0.53	0.074	0.025	0.86	0.22
2.01-5.00	0.032	0.024	0.93	0.73	0.03	0.84	0.31	0.0086	1.98	0.025
> 5.00	0.00061	0.0001	0.001	0	0	0	0.34	0	0.029	0

Table 67. Affected areas in Paoay, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Paoay (in sq. km)								
	San Juan	San Pedro	San Roque	Sangladan Poblacion	Santa Rita	Sideg	Sungadan	Surgui	Veronica
0-0.20	0.19	0.0083	0.52	0.017	0.35	2.11	1.2	0.99	0.083
0.21-0.50	0.046	0.0027	0.23	0.013	0.28	0.29	0.31	0.2	0.049
0.51-1.00	0.032	0.019	0.57	0.046	0.76	0.35	0.19	0.075	0.055
1.01-2.00	0.043	0.065	1.72	0.019	2.36	0.67	0.11	0.083	0.23
2.01-5.00	0.026	0.028	0.45	0.00059	0.31	0.29	0.00026	0.11	0.26
> 5.00	0	0	0	0	0	0	0	0	0

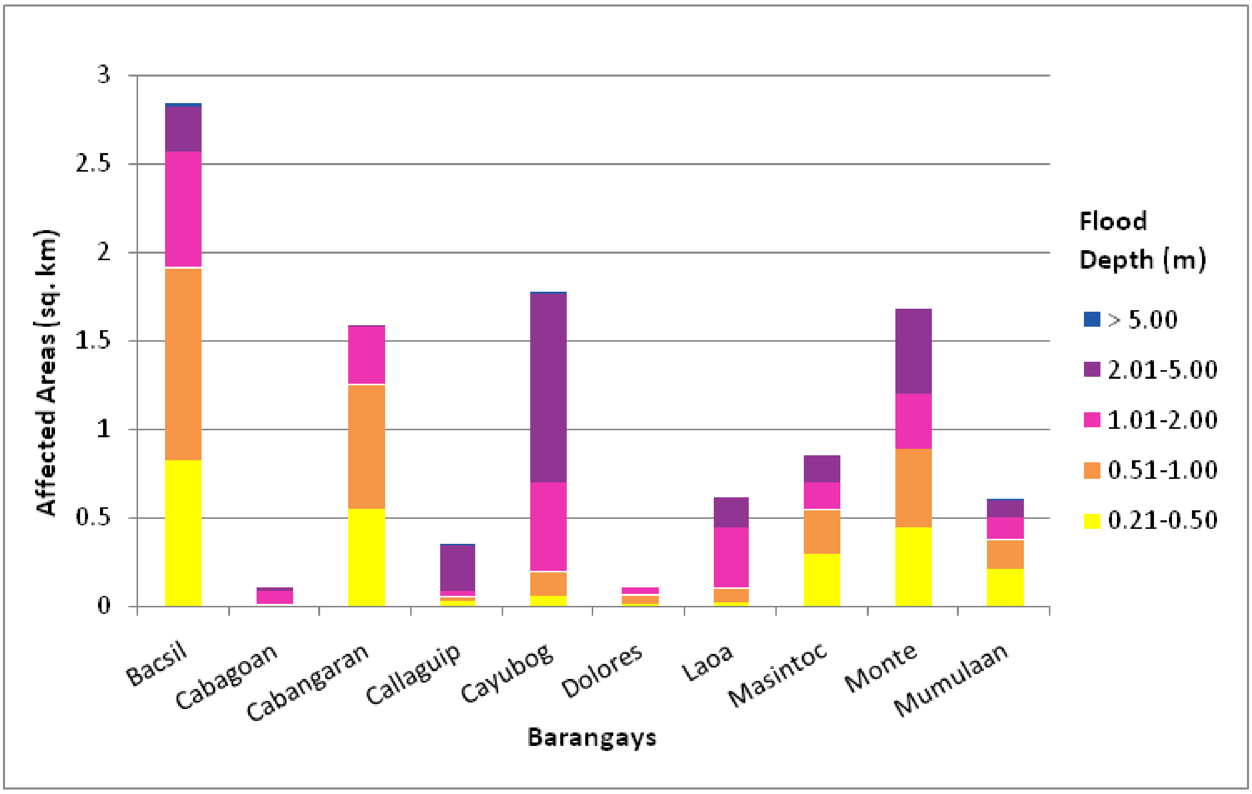


Figure 101. Affected areas in Paoay, Ilocos Norte during a 100-year rainfall return period

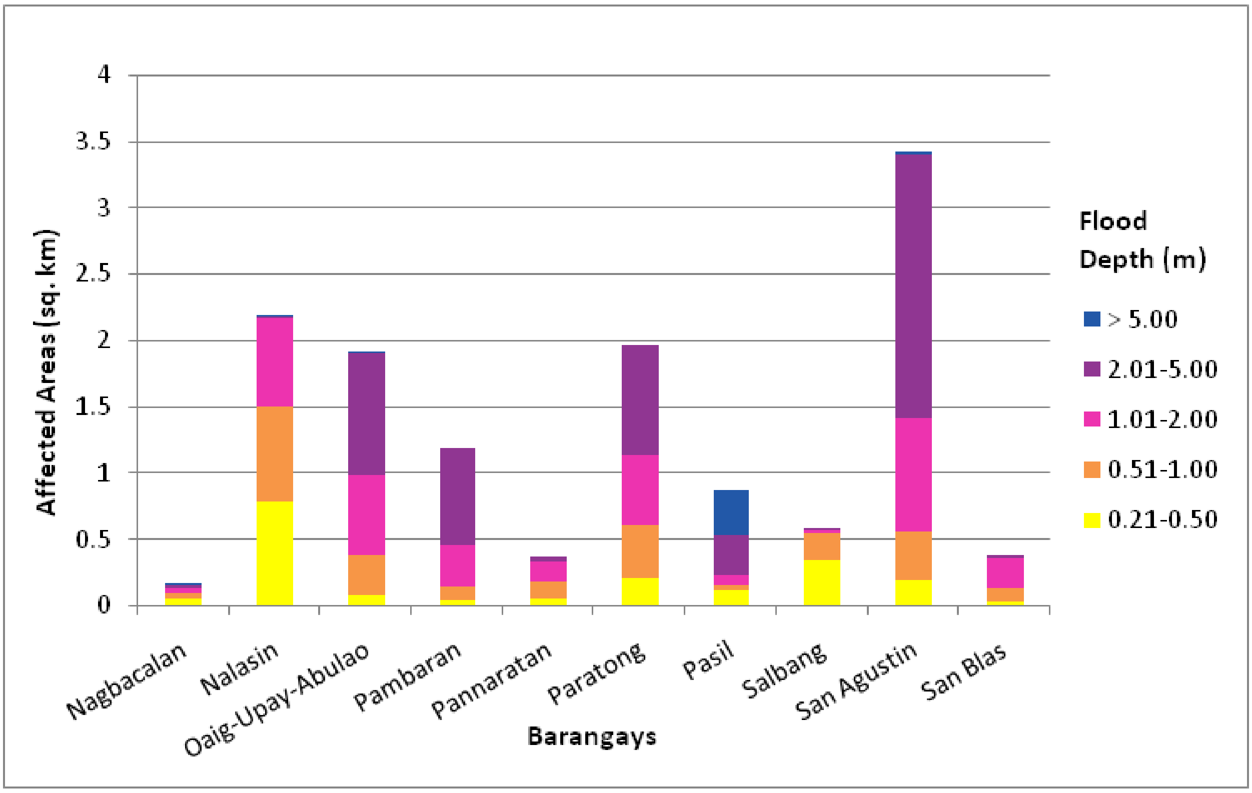


Figure 102. Affected areas in Paoay, Ilocos Norte during a 100-year rainfall return period

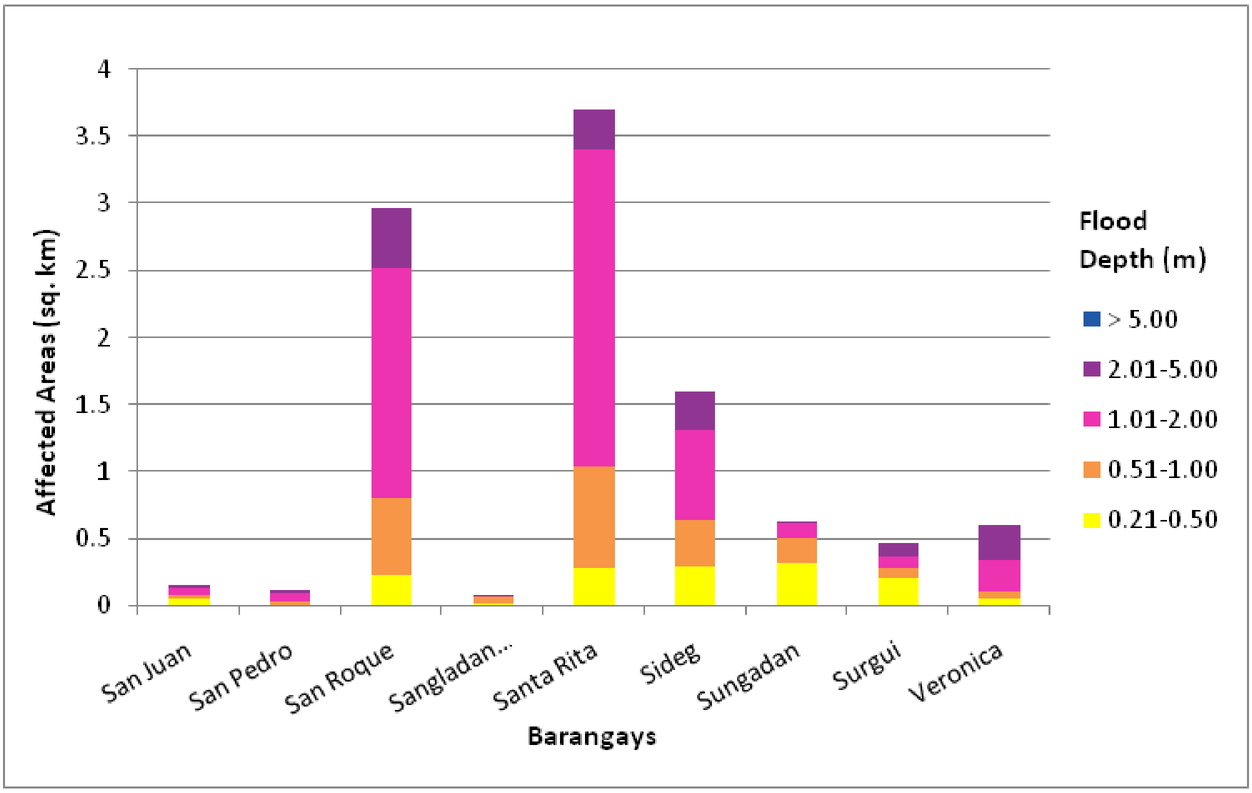


Figure 103. Affected areas in Paoay, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 3.61% of the municipality of Paoay Lake with an area of 3.64 sq km will experience flood levels of less than 0.20 meters; 0.10% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.01% and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, respectively. Listed in Table 68 are the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected areas in Paoay Lake, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Paoay Lake (in sq. km)
	Paoay Lake
0-0.20	0.13
0.21-0.50	0.0038
0.51-1.00	0.00038
1.01-2.00	0.00022
2.01-5.00	0
> 5.00	0

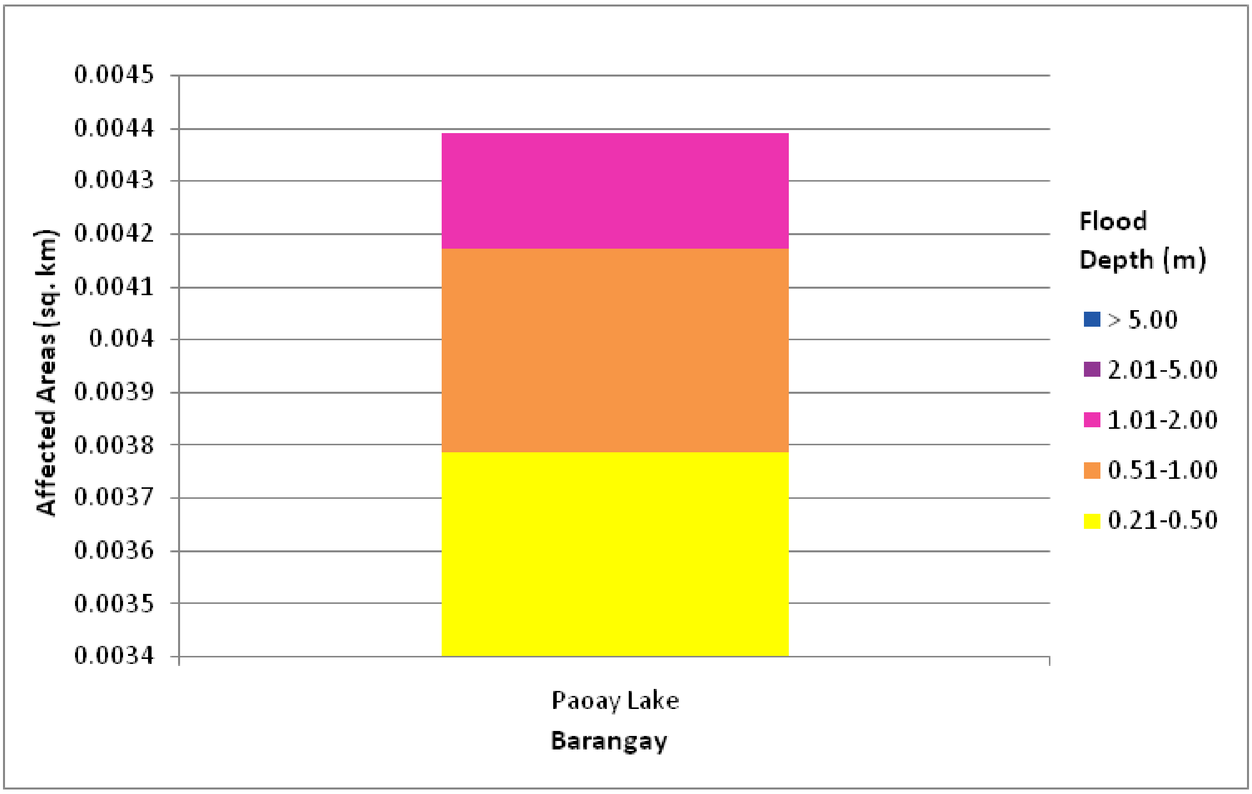


Figure 104. Affected areas in Paoay Lake, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 1.65% of the municipality of Pinili with an area of 63.18 sq km will experience flood levels of less than 0.20 meters; 0.09% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.06%, 0.03%, 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, respectively. Listed in Table 69 are the affected areas in square kilometers by flood depth per barangay.

Table 69. Affected areas in Pinili, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangay in Pinili (in sq. km)
	Buanga
0-0.20	1.04
0.21-0.50	0.054
0.51-1.00	0.036
1.01-2.00	0.016
2.01-5.00	0.0047
> 5.00	0.0003

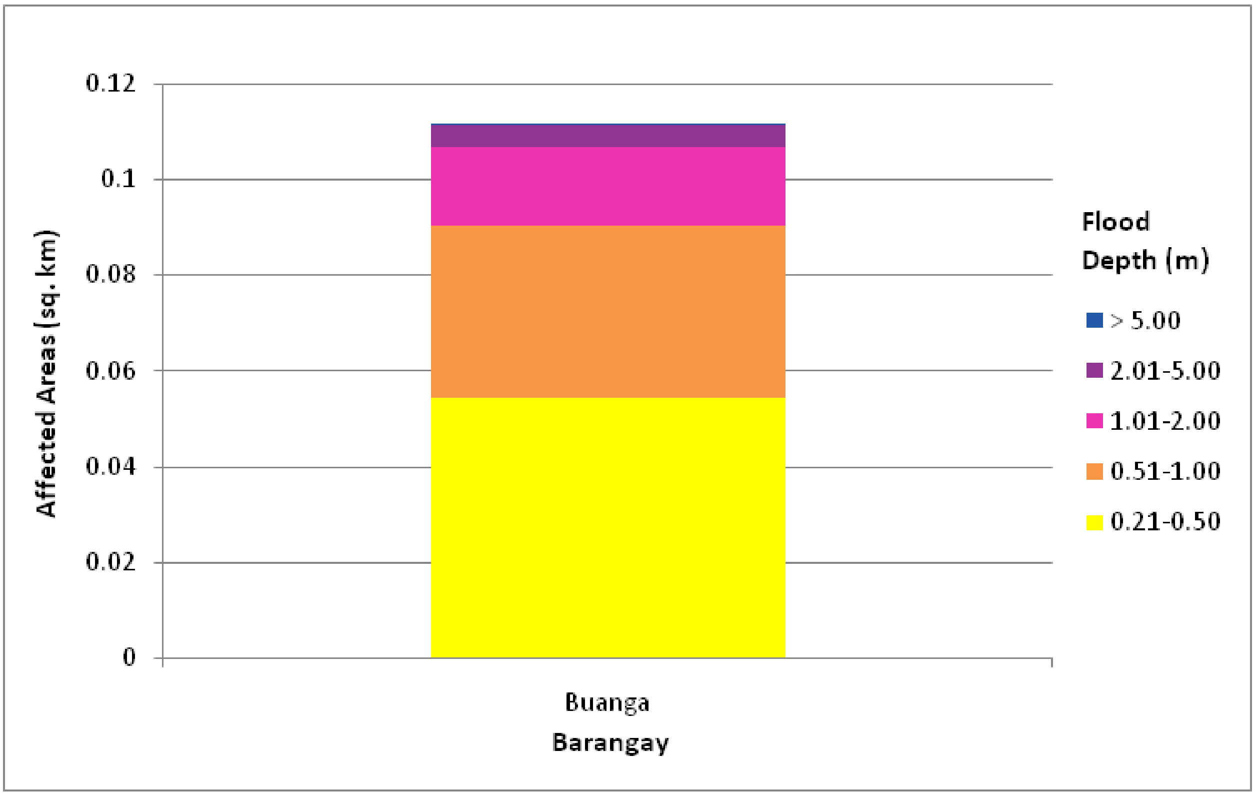


Figure 105. Affected areas in Pinili, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 0.31% of the municipality of San Nicolas with an area of 40.225 sq km will experience flood levels of less than 0.20 meters; while 0.01% of the area will experience flood levels of 0.21 to 0.50 meters. Listed in Table 70 are the affected areas in square kilometers by flood depth per barangay.

Table 70. Affected areas in San Nicolas, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in San Nicolas (in sq. km)		
	San Agustin	San Pablo	San Pedro
0-0.20	0.077	0.028	0.019
0.21-0.50	0.0029	0.00097	0.00021
0.51-1.00	0.00013	0.00015	0.00033
1.01-2.00	0.000047	0.000022	0.00016
2.01-5.00	0	0	0
> 5.00	0	0	0

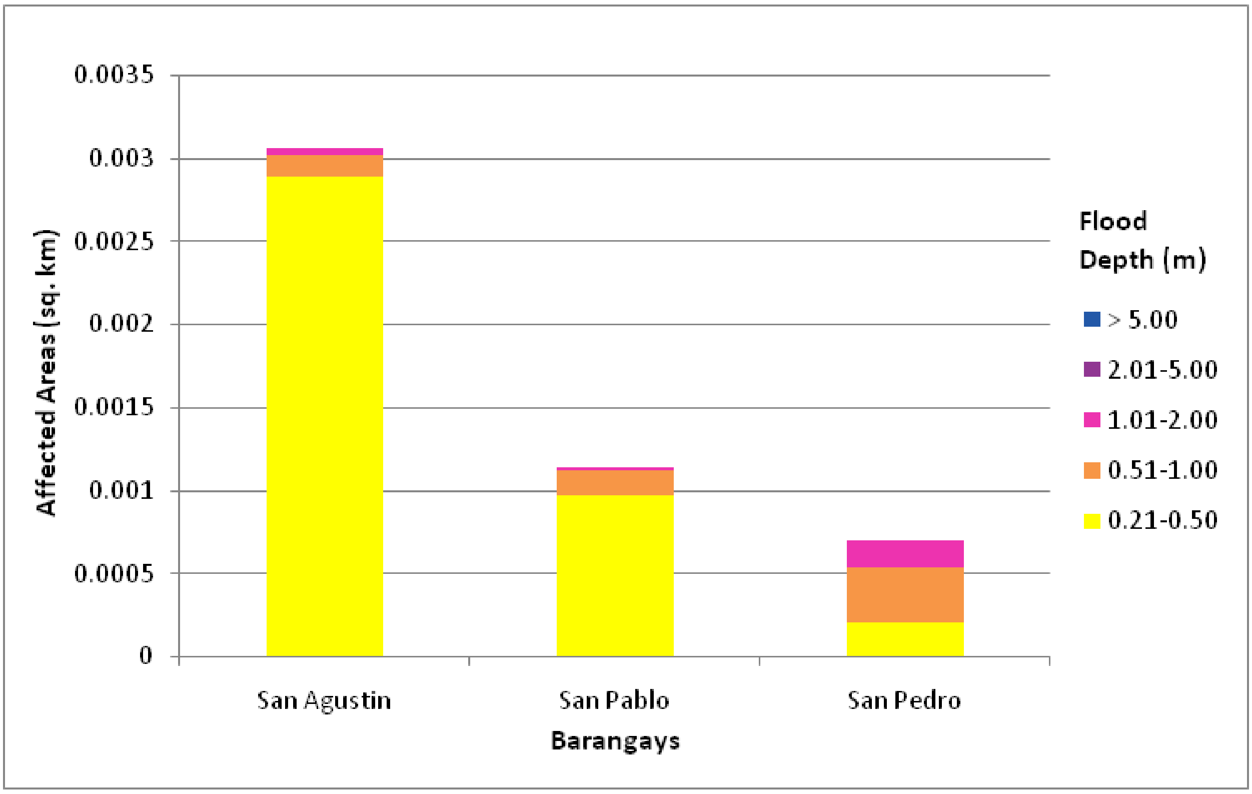


Figure 106. Affected areas in San Nicolas, Ilocos Norte during a 100-year rainfall return period

For the 100-year return period, 6.86% of the municipality of Sarrat with an area of 92.25 sq km will experience flood levels of less than 0.20 meters; 0.38% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.27%, 0.21%, 0.13%, 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 71 are the affected areas in square kilometers by flood depth per barangay.

Table 71. Affected areas in Sarrat, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) By flood depth (in m.)	Area of affected barangays in Sarrat (in sq. km)	
	San Bernabe	San Pedro
0-0.20	0.0031	6.32
0.21-0.50	0	0.35
0.51-1.00	0.000019	0.25
1.01-2.00	0	0.2
2.01-5.00	0	0.12
> 5.00	0	0.011

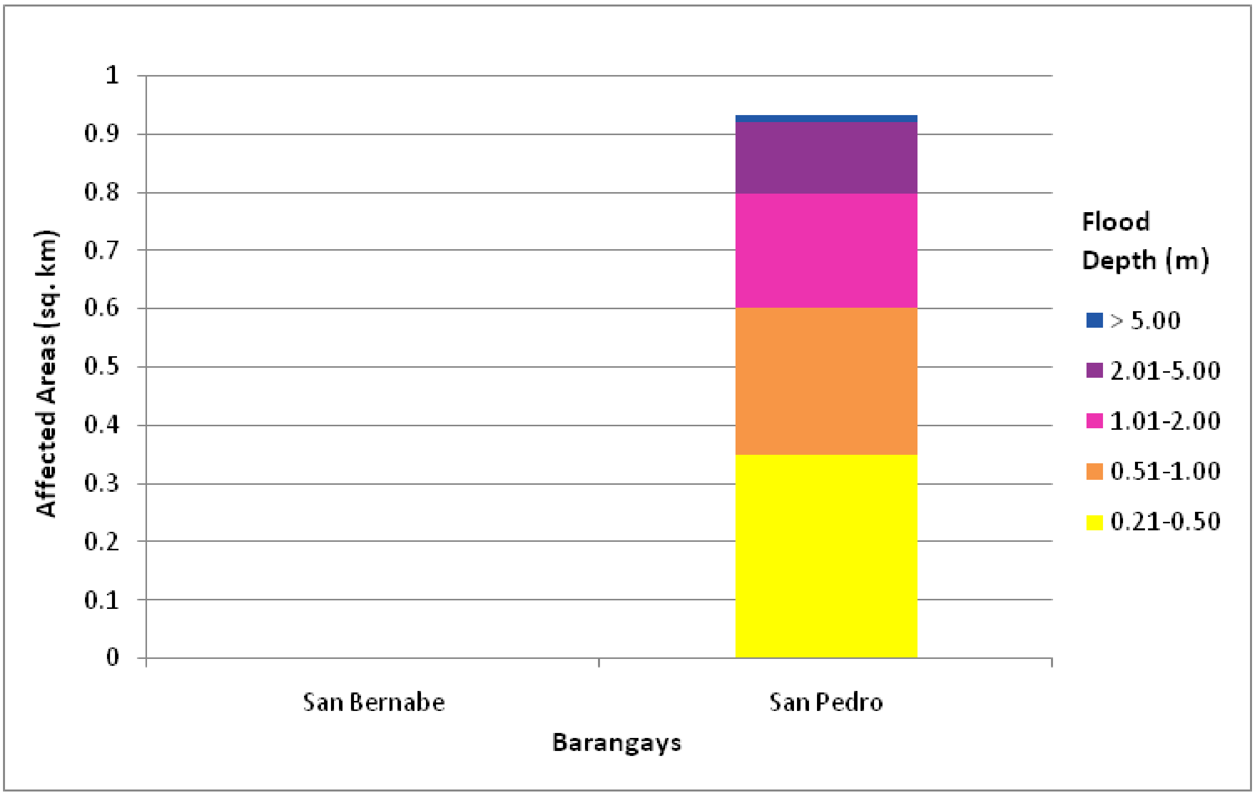


Figure 107. Affected areas in Sarrat, Ilocos Norte during a 100-year rainfall return period

Among the barangays in the municipality of Banna in Ilocos Norte, Barbarangay is projected to have the highest percentage of area that will experience flood levels at 1.56%. Meanwhile, Nagpatayan posted the second highest percentage of area that may be affected by flood depths at 0.05%.

Among the barangays in the municipality of Batac City in Ilocos Norte, Sumader is projected to have the highest percentage of area that will experience flood levels at 6.60%. Meanwhile, Mabaleng posted the second highest percentage of area that may be affected by flood depths at 6.24%.

Among the barangays in the municipality of Currimao in Ilocos Norte, Tapao-Tigue is projected to have the highest percentage of area that will experience flood levels at 12.01%. Meanwhile, Bimmanga posted the second highest percentage of area that may be affected by flood depths at 4.96%.

Brgy. Fortuna is the only barangay affected in the municipality of Marcos in Ilocos Norte. The barangay is projected to experience flood in 0.73% of the municipality.

Among the barangays in the municipality of Paoay in Ilocos Norte, Bacsil is projected to have the highest percentage of area that will experience flood levels at 9.25%. Meanwhile, Nalasin posted the second highest percentage of area that may be affected by flood depths at 6.88%.

Brgy. Paoay Lake is the only barangay affected in the municipality of Paoay Lake in Ilocos Norte. The barangay is projected to experience flood in 3.73% of the municipality.

Brgy. Buanga is the only barangay affected in the municipality of Pinili in Ilocos Norte. The barangay is projected to experience flood in 1.83% of the municipality.

Among the barangays in the municipality of San Nicolas in Ilocos Norte, San Agustin is projected to have the highest percentage of area that will experience flood levels at 0.20%. Meanwhile, San Pablo posted the second highest percentage of area that may be affected by flood depths at 0.07%.

Among the barangays in the municipality of Sarrat in Ilocos Norte, San Pedro is projected to have the highest percentage of area that will experience flood levels at 7.86%. Meanwhile, San Bernabe posted the second highest percentage of area that may be affected by flood depths at 0.00%.

Moreover, the generated flood hazard maps for the Quiaoit Floodplain were used to assess the vulnerability of the educational and health institutions in the floodplain. Using the flood depth units of PAGASA 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 100-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	20.52	18.54	16.60
Medium	27.13	31.74	31.87
High	10.75	21.76	30.82
TOTAL	58.4	72.04	79.29

Of the 80 identified educational institutions in the Quiaoit Floodplain, Colo-Mabaleng Elementary School in Brgy. Colo was assessed to be exposed to high-level flooding for all three rainfall scenarios. Two other institutions were found to be susceptible to flooding, experiencing medium-level flooding in the 5-year return period, and high-level flooding in the 25- and 100-year rainfall scenarios. These are the Maranatha Christian Academy in Brgy. Acosta Poblacion and Paoay East Central Elementary School in Brgy. Santa Rita. Annex 12 shows the detailed enumeration of schools exposed to flooding in the Quiaoit Floodplain.

Ten medical institutions were identified in the Quiaoit Floodplain. Gaoat General Hospital in Brgy. Palpalicong and Batac Maternal and Child Health Care Unit in Brgy. Suabit were found to be relatively prone to flooding, having low-level flooding in the 5-year rain return period and medium-level flooding in the 25- and 100-year scenarios. Annex 13 shows the detailed enumeration of hospitals, clinics, and other health institutions in the Quiaoit Floodplain.

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 by going to a local DRRM office to obtain maps or situation reports about the past flooding events or by interviewing some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed.

The flood validation survey was conducted in December 2016. The flood validation consists of 287 points randomly selected all over the Quiaoit Floodplain. It has an RMSE value of 0.97.

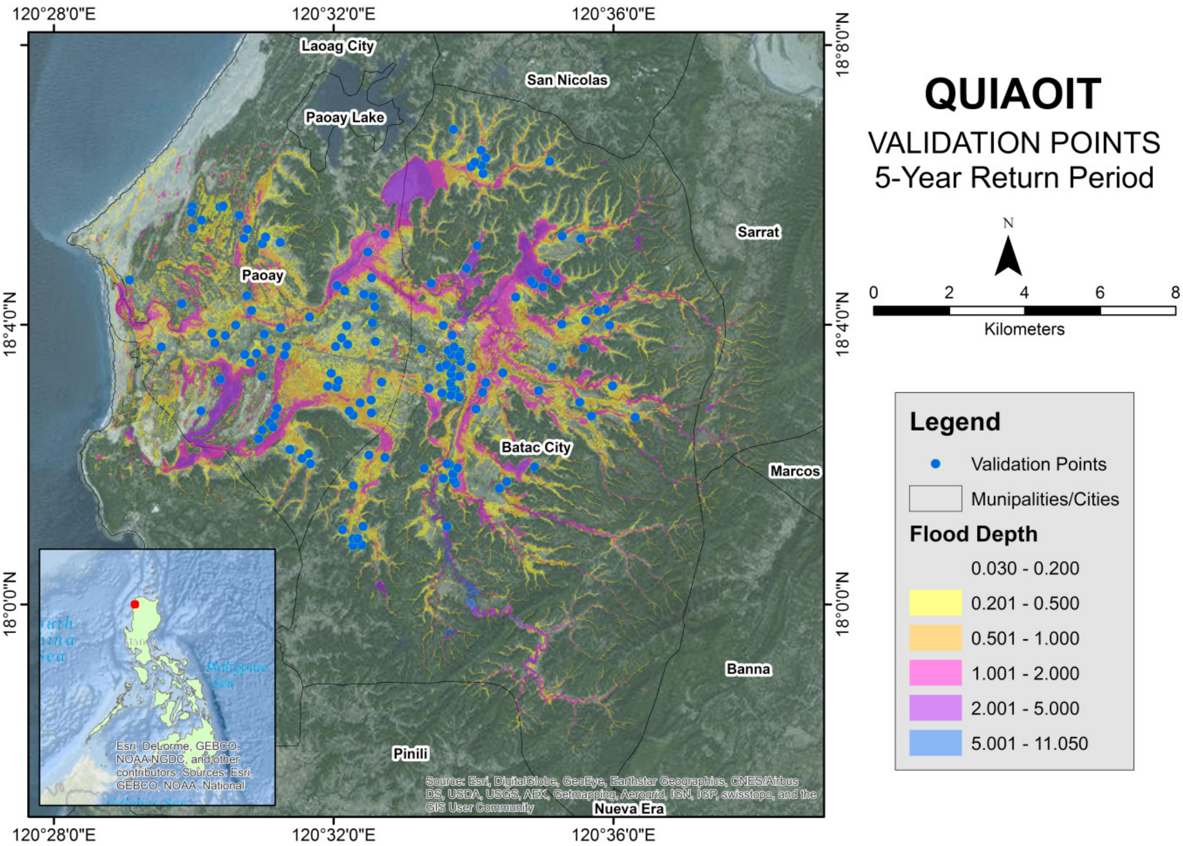


Figure 108. Flood validation points for Quiaoit River Basin

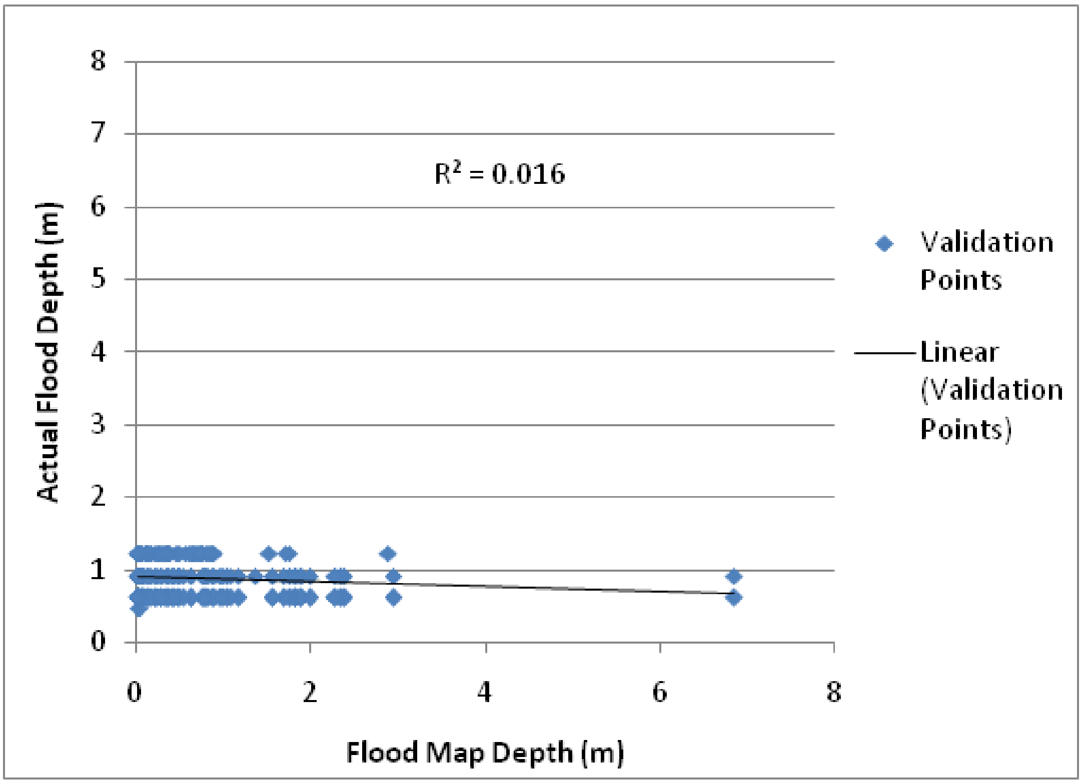


Figure 109. Flood map depth vs. actual flood depth for Quiaoit

Table 73. Actual flood depth vs. simulated flood depth in Quiaoit

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	0	0	0	0	0	0	0
0.21-0.50	2	0	0	0	0	0	2
0.51-1.00	79	39	36	44	16	2	216
1.01-2.00	28	19	18	3	1	0	69
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	109	58	54	47	17	2	287

The overall accuracy generated by the flood model is estimated at 13.59%, with 39 points correctly matching the actual flood depths. In addition, there were 104 points estimated one level above and below the correct flood depths, while there were 114 points and 30 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 63 points were overestimated while a total of 185 points were underestimated in the modelled flood depths of Quiaoit.

Table 74. Summary of accuracy assessment in Quiaoit River Basin Survey

	No. of Points	%
Correct	39	**13.59**
Overestimated	63	21.95
Underestimated	185	64.46
Total	287	100

REFERENCES

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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.O., Sarmiento, C. 2017. *Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods*. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

ANNEXES

Annex 1. OPTECH Technical Specification of the Gemini Sensor

Table A-1.1. Parameters and Specifications of Gemini Sensor

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

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

1. ILN-11

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ILOCOS NORTE**
Station Name: **ILN-11**
Order: **2nd**

Island: **LUZON**
Municipality: **BATAC**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **18° 3' 26.86785"** Longitude: **120° 33' 49.91547"** Ellipsoidal Hgt: **42.96000 m.**

WGS84 Coordinates

Latitude: **18° 3' 20.64552"** Longitude: **120° 33' 54.52048"** Ellipsoidal Hgt: **74.87400 m.**

PTM Coordinates

Northing: **1997176.225 m.** Easting: **453827.436 m.** Zone: **3**

UTM Coordinates

Northing: **1,998,122.81** Easting: **242,121.13** Zone: **51**

Location Description

ILN-11
Is situated on the rooftop of Batac Municipal Bldg. It is located near the E end corner of the upper rooftop, about 15 m. E of a small antenna tower. It is about 1.9 m. and 2.8 m. perpendicular distance from the N and E edge of the rooftop, respectively. Mark is the head of a 3" copper nail centered and embedded on top of a 22 cm. x 22 cm. cement putty set flushed on the cemented rooftop, with inscriptions "ILN-11, 2004, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795394 A**
T.N.: **2014-352**

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

99021920141140833

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

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

Figure A-2.1. ILN-11

2. ILN-3234

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ILOCOS NORTE**
Station Name: **ILN-3234**
Order: **4th**

Island: **LUZON**		Barangay: **QUILING SUR**
Municipality: **BATAC**		
	PRS92 Coordinates	
Latitude: **18° 3' 41.82025"**	Longitude: **120° 32' 50.31072"**	Ellipsoidal Hgt: **22.63200 m.**
	WGS84 Coordinates	
Latitude: **18° 3' 35.59528"**	Longitude: **120° 32' 54.91553"**	Ellipsoidal Hgt: **54.49200 m.**
	PTM Coordinates	
Northing: **1997640.111 m.**	Easting: **452075.694 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,998,605.86**	Easting: **240,373.73**	Zone: **51**

Location Description

ILN-3234
Is located at Brgy. Quiling, Mun. of Batac, inside the Mariano Marcos Memorial State University. It is situated about 50 m. S of the admin. bldg. and 10 m. NW of the Mariano Marcos monument. Mark is the head of a 4 in. copper nail centered and embedded on a 20 cm. x 20 cm. concrete monument, with inscriptions "ILN-3234 2007 NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795394 A**
T.N.: **2014-351**

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

9902192014140752

CIP/4701/12/09/814

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

Figure A-2.2. ILN-11

Annex 3. Baseline Processing Reports of Reference Points Used in the LiDAR Survey

There are no baseline processing reports for Quiaoit Floodplain.

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI S. SARMIENTO	UP-TCAGP
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	ENGR. LOVELYN ASUNCION	UP TCAGP
		LOVELY GRACIA ACUNA	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY PAGADOR	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
	RA	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG DIOSCORO SOBERANO	PILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. RAUL CZ SAMAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR SHERWIN ALFONSO III	AAC

Annex 5. Data Transfer Sheet for Quiaoit Floodplain

DATA TRANSFER SHEET [illegible]
4/25/2014(Albay sorsogon)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/ CASI	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
2/21/2014	7085G	2BLK05G052A	GEMINI	NA	180	330	158	N/A	N/A	13.9	N/A	11.6	200	639	44.8	6.91	Z:\Airborne_Raw\7085G
2/22/2014	7086G	2BLK05H053A	GEMINI	NA	81	522	227	N/A	N/A	27.5	N/A	12.9	179	327	408	8.7	Z:\Airborne_Raw\7086G
2/22/2014	7087G	2BLK05GS+F053B	GEMINI	NA	98.3	601	247	N/A	N/A	26.2	N/A	12.3	179	586	366	12.2	Z:\Airborne_Raw\7087G
2/23/2014	7088G	2BLK05FS+E054A	GEMINI	NA	77.2	467	211	N/A	N/A	21.2	N/A	11.2	163	749	201	12.1	Z:\Airborne_Raw\7088G
2/23/2014	7089G	2BLK05I054B	GEMINI	NA	191	349	199	N/A	N/A	15	N/A	10.7	163	372	263	9.53	Z:\Airborne_Raw\7089GG

Received from

Name CHRIS [illegible]

Position FA

Signature [signature]

Received by

Name JOIDA F. PRIETO

Position SSRS

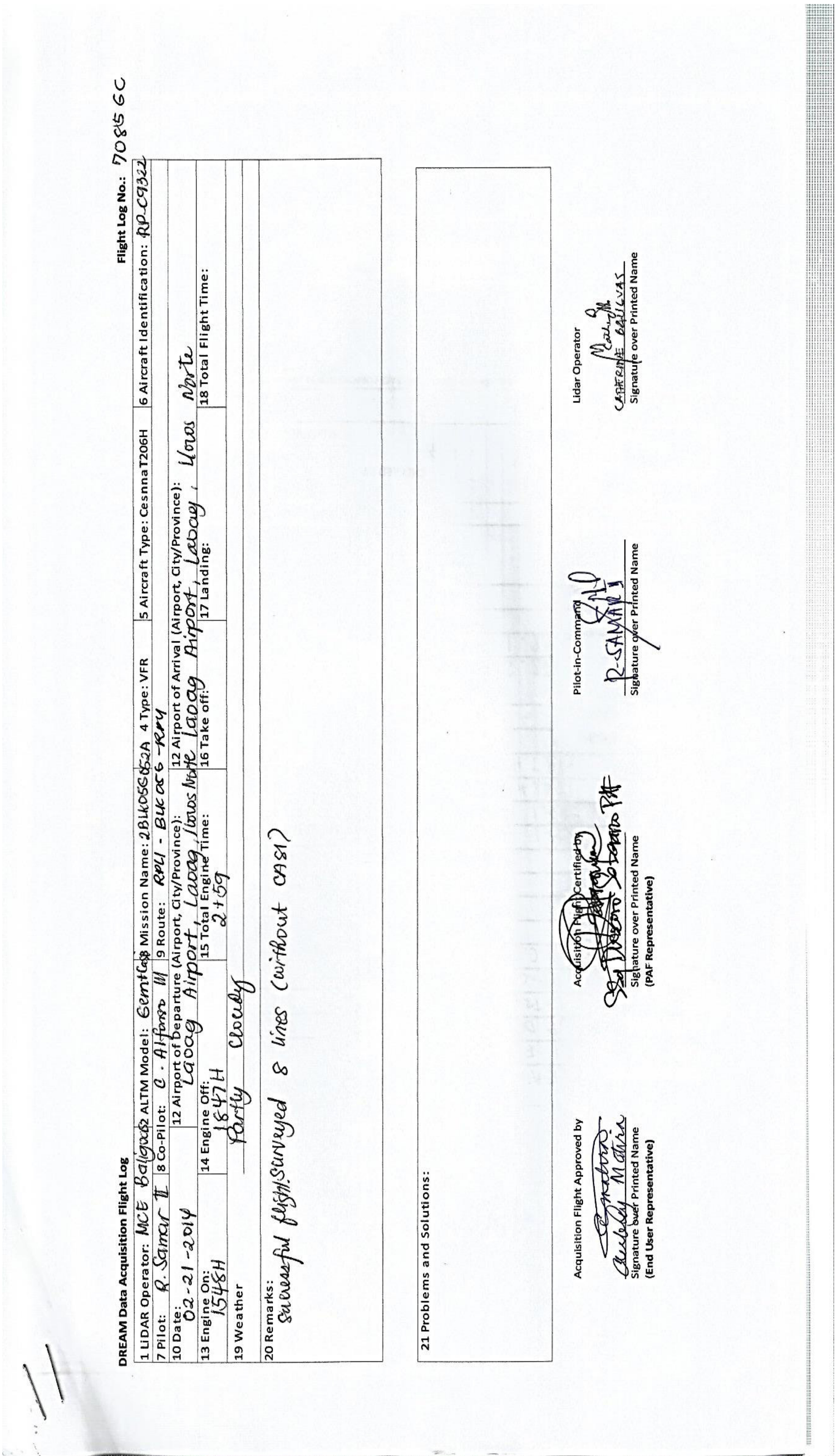
Signature [signature]

04/25/14

Figure A-5.1. Data Transfer Sheet

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 2BLK05G052A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7085GC

1 LIDAR Operator: MCE Balgua	2 ALTM Model: Gemini	3 Mission Name: 2BLK05G052A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route: RPLI - BLK05G - RPLI			
10 Date: 02-21-2014	12 Airport of Departure (Airport, City/Province): Laoag Airport, Laoag, Ilocos Norte		12 Airport of Arrival (Airport, City/Province): Laoag Airport, Laoag, Ilocos Norte		
13 Engine On: 1548H	14 Engine Off: 1847H	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly Cloudy				

20 Remarks: Successful flight, surveyed 8 lines (without CASI)

21 Problems and Solutions:

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

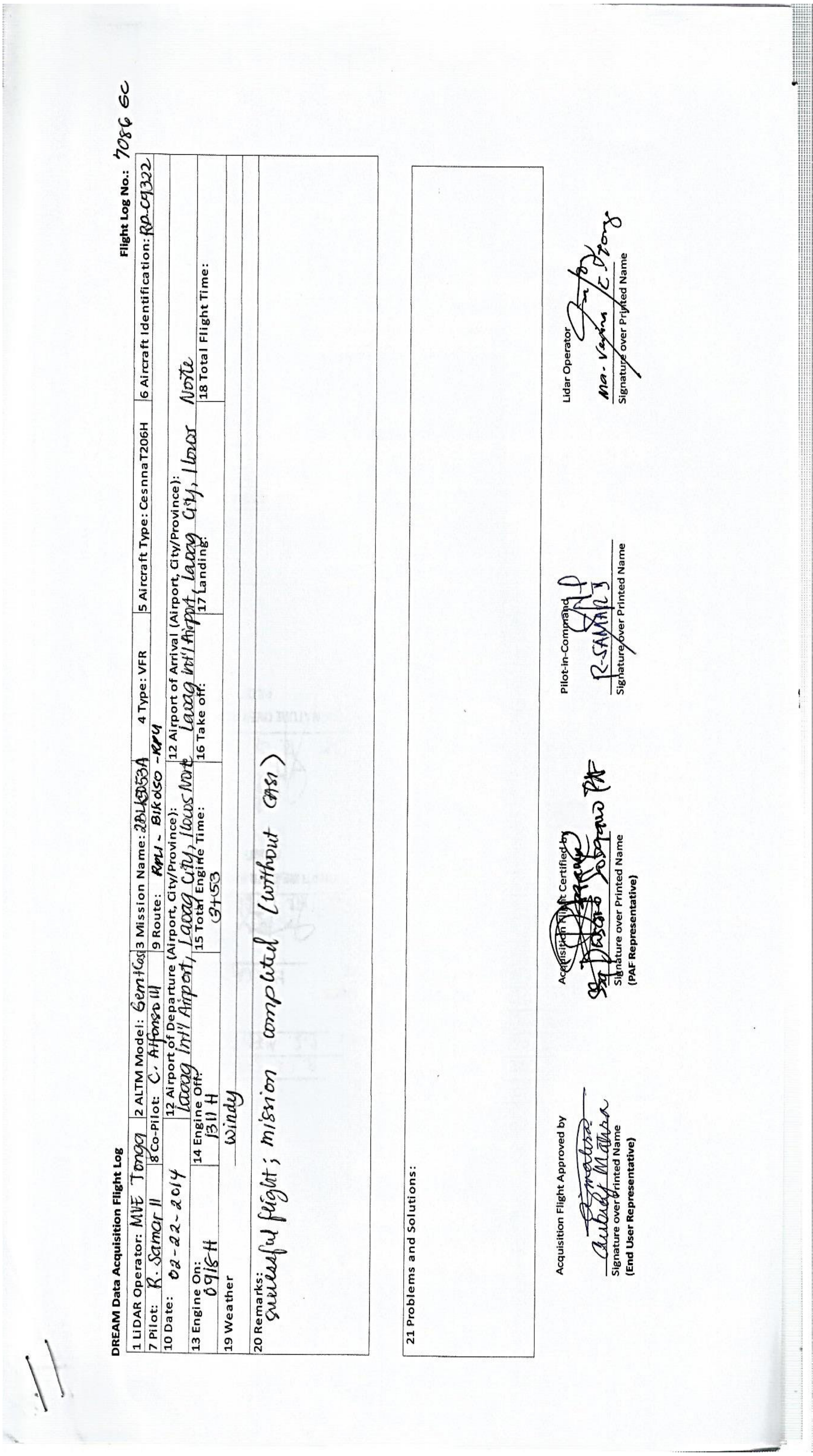
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — R. SAMAR II — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2BLK05G052A

2. Flight Log for 2BLK05H053A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7086 GC

1 LiDAR Operator: MVE Tongga	2 ALTM Model: Gemini	3 Mission Name: 2BLK05H053A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route: RPLI - Bikoso - RPLI			
10 Date: 02-22-2014	12 Airport of Departure (Airport, City/Province): Laoag Int'l Airport, Laoag City, Ilocos Norte		12 Airport of Arrival (Airport, City/Province): Laoag Int'l Airport, Laoag City, Ilocos Norte		
13 Engine On: 0918 H	14 Engine Off: 1311 H	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Windy					
20 Remarks: Successful flight; mission completed (without CASI)					

21 Problems and Solutions:

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

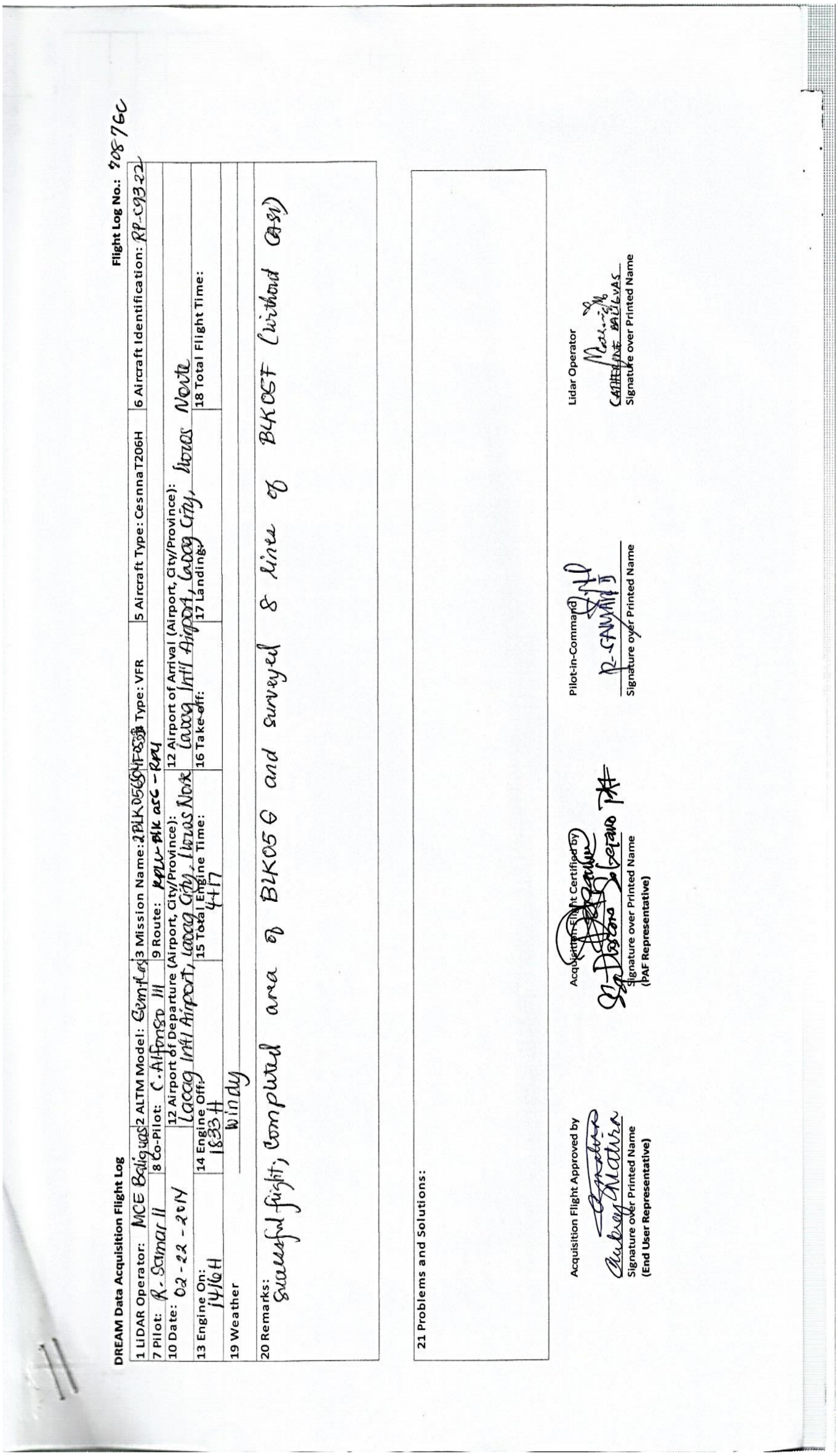
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

Pilot-in-Command: R. Samar II — Signature over Printed Name

Lidar Operator: Ma. Verlina E. Tonga — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 2BLK05H053A

3 Flight Log for 2BLK05GS053B & 2BLK05F053B Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7087GC

1 LiDAR Operator: MCE Baliguas	2 ALTM Model: Gemini	3 Mission Name: 2BLK05GSF053B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route: Laoag - Blk 05G - Laoag			
10 Date: 02-22-2014	12 Airport of Departure (Airport, City/Province): Laoag Int'l Airport, Laoag City, Ilocos Norte		12 Airport of Arrival (Airport, City/Province): Laoag Int'l Airport, Laoag City, Ilocos Norte		
13 Engine On: 1416H	14 Engine Off: 1833H	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: windy					

20 Remarks: successful flight; computed area of BLK05G and surveyed 8 lines of BLK05F (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by: Aubrey Matira — Signature over Printed Name (End User Representative)

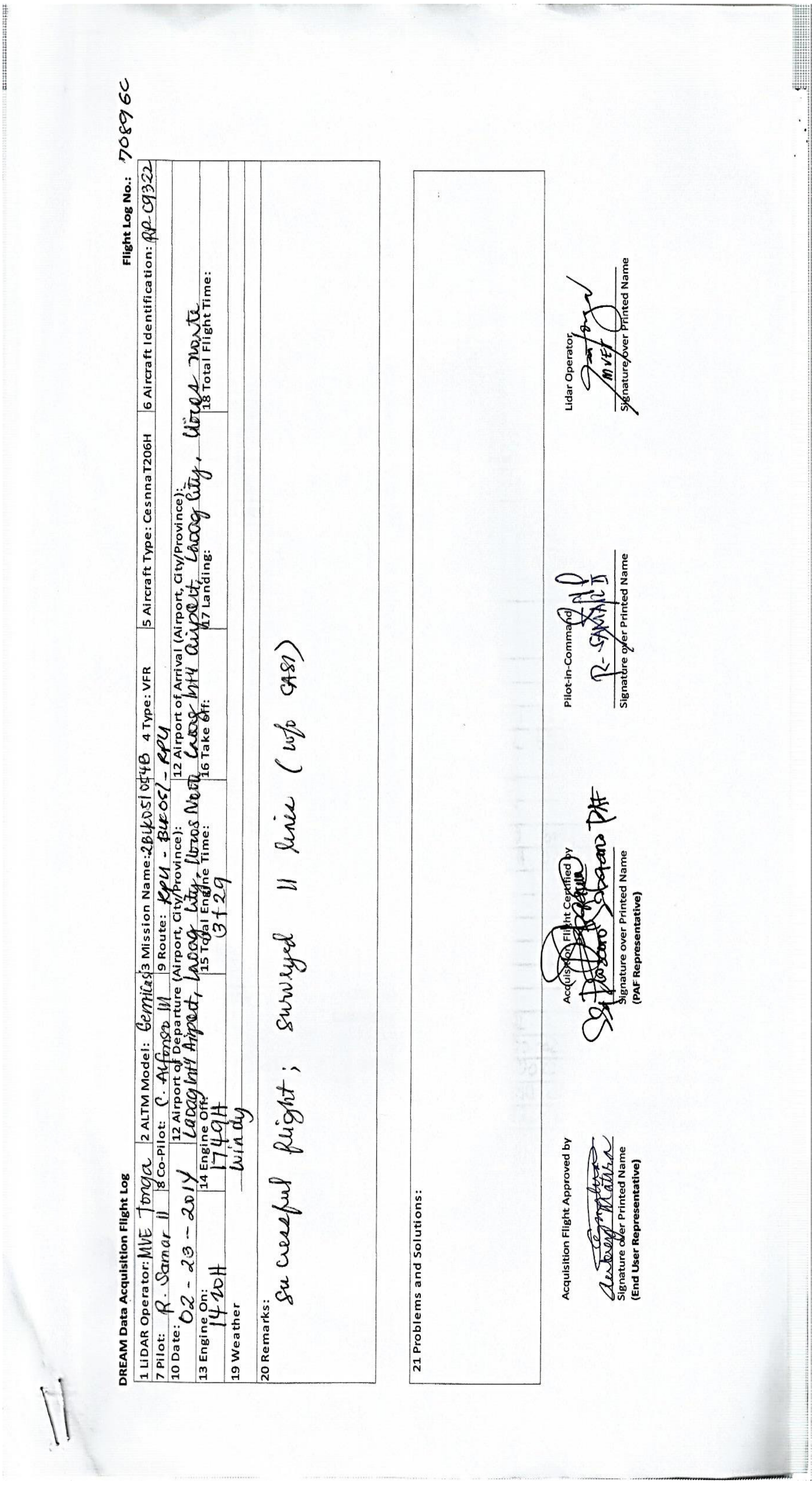
Acquisition Flight Certified by: Sgt. Dioscoro Soberano PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: R. Samar II — Signature over Printed Name

Lidar Operator: Catherine Baliguas — Signature over Printed Name

Figure A-6.3. Flight Log for Missions 2BLK05GS053B and 2BLK05F053B

4. Flight Log for 2BLK05I054B Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 70896C

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK05I054B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route: RPLI - BLK05I - RPLI			
10 Date: 02-23-2014	12 Airport of Departure (Airport, City/Province): Laoag Int'l Airport, Laoag City, Ilocos Norte		12 Airport of Arrival (Airport, City/Province): Laoag Int'l Airport, Laoag City, Ilocos Norte		
13 Engine On: 1420H	14 Engine Off: 1749H	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Windy					

20 Remarks:

Successful flight; surveyed 11 lines (w/o CASI)

21 Problems and Solutions:

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

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

Pilot-in-Command: R. Samar II — Signature over Printed Name

Lidar Operator: MVE Tonga — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2BLK05I054B

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Reports

FLIGHT STATUS REPORT ILOCOS NORTE, ILOCOS SUR and ABRA					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7085	BLK05	2BLK05G052A	MCE BALIGU-AS	21 FEB 14	Surveyed 8 line (without CASI)
7086	BLK05	2BLK05H053A	MVE TONGA	22 FEB 14	Mission completed (without CASI)
7087	BLK05	2BLK05GS053B & 2BLK05F053B	MCE BALIGU-AS	22 FEB 14	Completed area of BLK05G and surveyed 8 lines at BLK05F (without CASI)
7089	BLK05	2BLK05I054B	MVE TONGA	23 FEB 14	Surveyed 11 lines (without CASI)

Swath Coverage for Mission 2BLK05G052A

Flight No. :	7085 G
Area:	BLK05
Mission Name:	2BLK05G052A
Parameters:	Altitude: 1000m ; Scan Frequency: 40Hz ; Scan angle: 20deg; Overlap: 25%

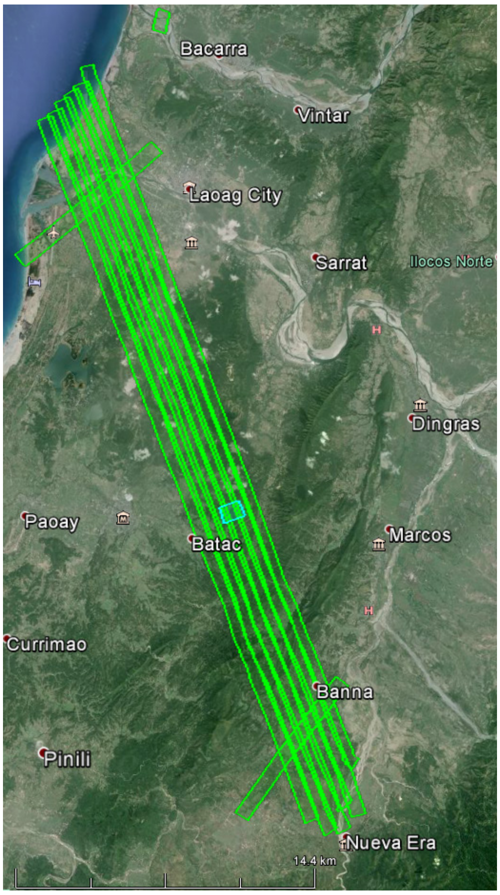


Figure A-7.1. Swath for Flight No. 7085 G

Swath Coverage for Mission 2BLK05H053A

Flight No. :	7086 G
Area:	BLK05
Mission Name:	2BLK05H053A
Parameters:	Altitude: 1000m; Scan Frequency: 50Hz ; Scan angle: 20deg; Overlap: 45%

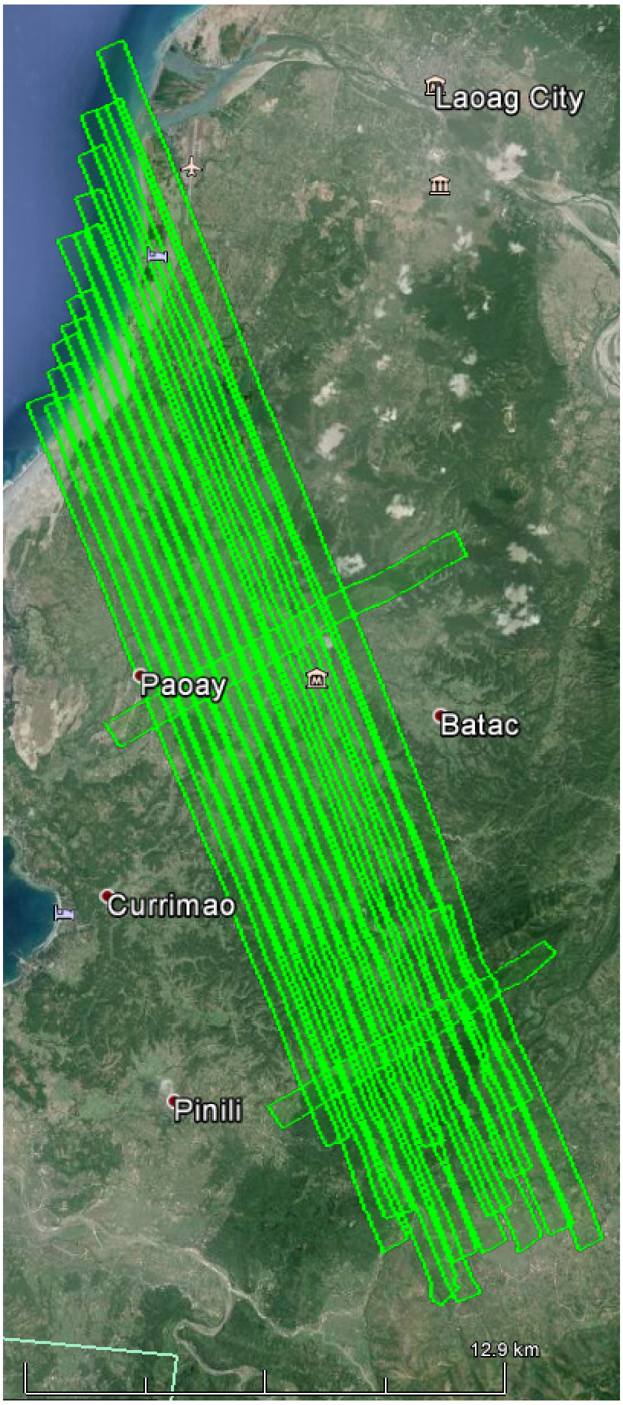


Figure A-7.2. Swath for Flight No. 7086 G

Swath Coverage for Mission 2BLK05GS053B & 2BLK05F053B

Flight No. :	7087 G
Area:	BLK05
Mission Name:	2BLK05GS053B & 2BLK05F053B
Parameters:	Altitude: 1000m; Scan Frequency: 50Hz; Scan angle: 20deg; Overlap: 30%

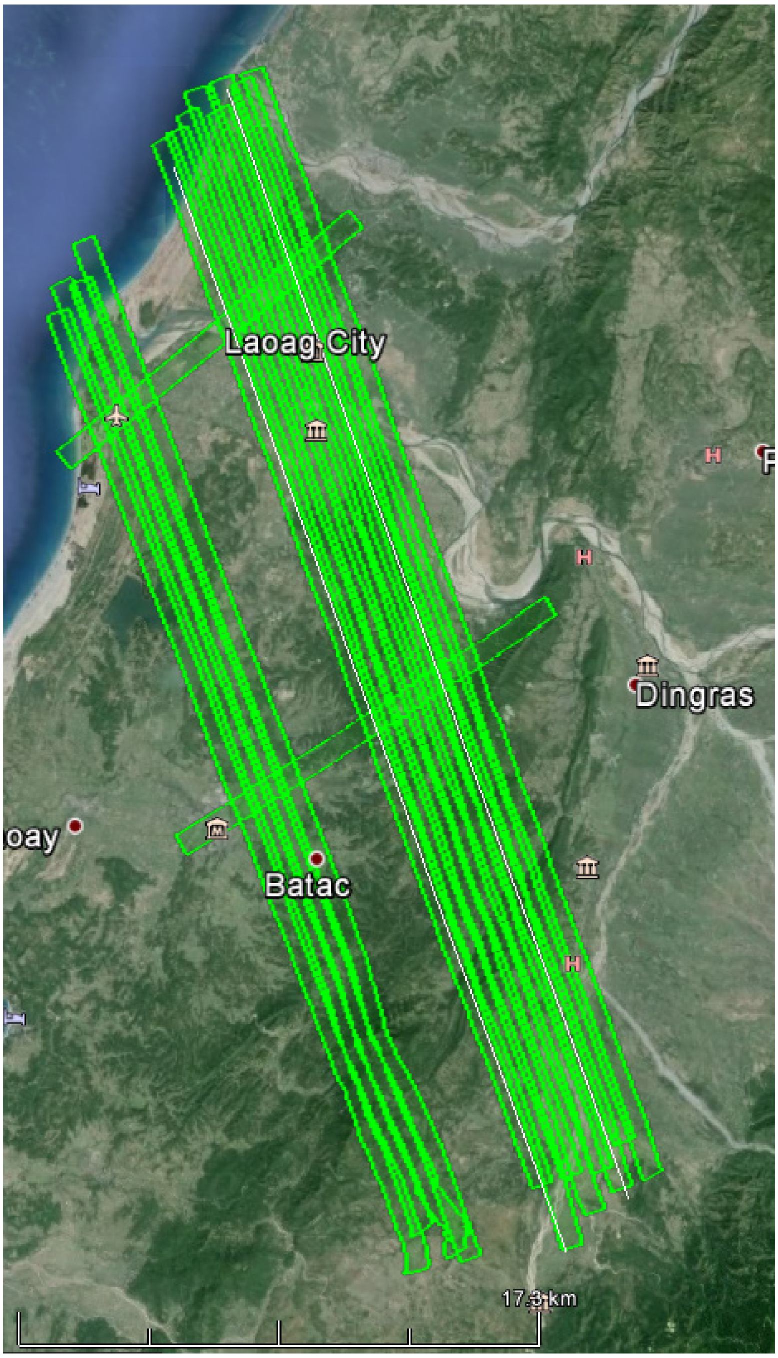


Figure A-7.3. Swath for Flight No. 7087 G

Swath Coverage for Mission 2BLK05I054B

Flight No. :	7089 G
Area:	BLK05
Mission Name:	2BLK05I054B
Parameters:	Altitude: 1000m; Scan Frequency: 50Hz; Scan angle: 20deg; Overlap: 45%

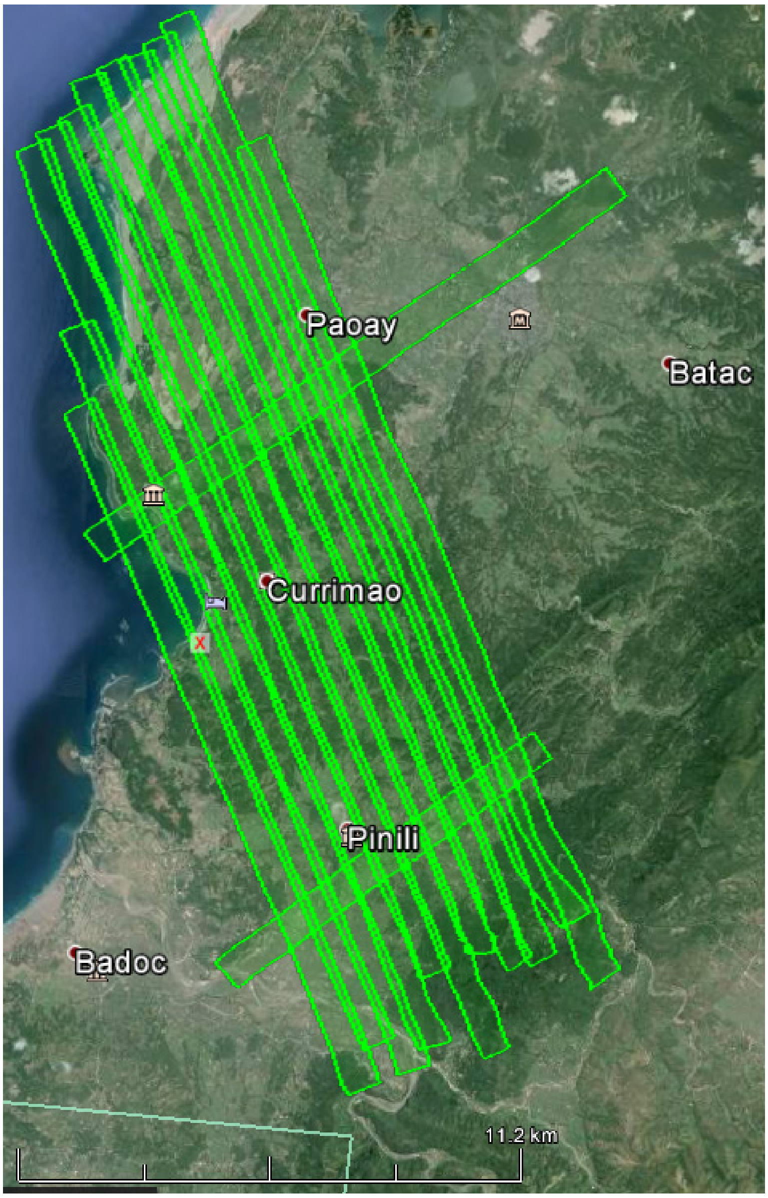


Figure A-7.4. Swath for Flight No. 7089 G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk5EF additional

Flight Area	Ilocos
Mission Name	Blk5EF additional
Inclusive Flights	7087G
Range data size	26.2 GB
POS	247 MB
Image	N/A
Base Station	12.3 MB
Transfer date	March 3, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.6
RMSE for East Position (<4.0 cm)	7.7
RMSE for Down Position (<8.0 cm)	8.4
Boresight correction stdev (<0.001deg)	0.000353
IMU attitude correction stdev (<0.001deg)	0.001157
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	32.82%
Ave point cloud density per sq.m. (>2.0)	3.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	222
Maximum Height	466.06 m
Minimum Height	39.20 m
Classification (# of points)	
Ground	83,228,672
Low vegetation	90,581,648
Medium vegetation	104,895,186
High vegetation	167,061,020
Building	8,465,630
Orthophoto	No
Processed by	Victoria Maria Rejuso, Aljon Rie Araneta, Engr. Ma. Ailyn Olanda

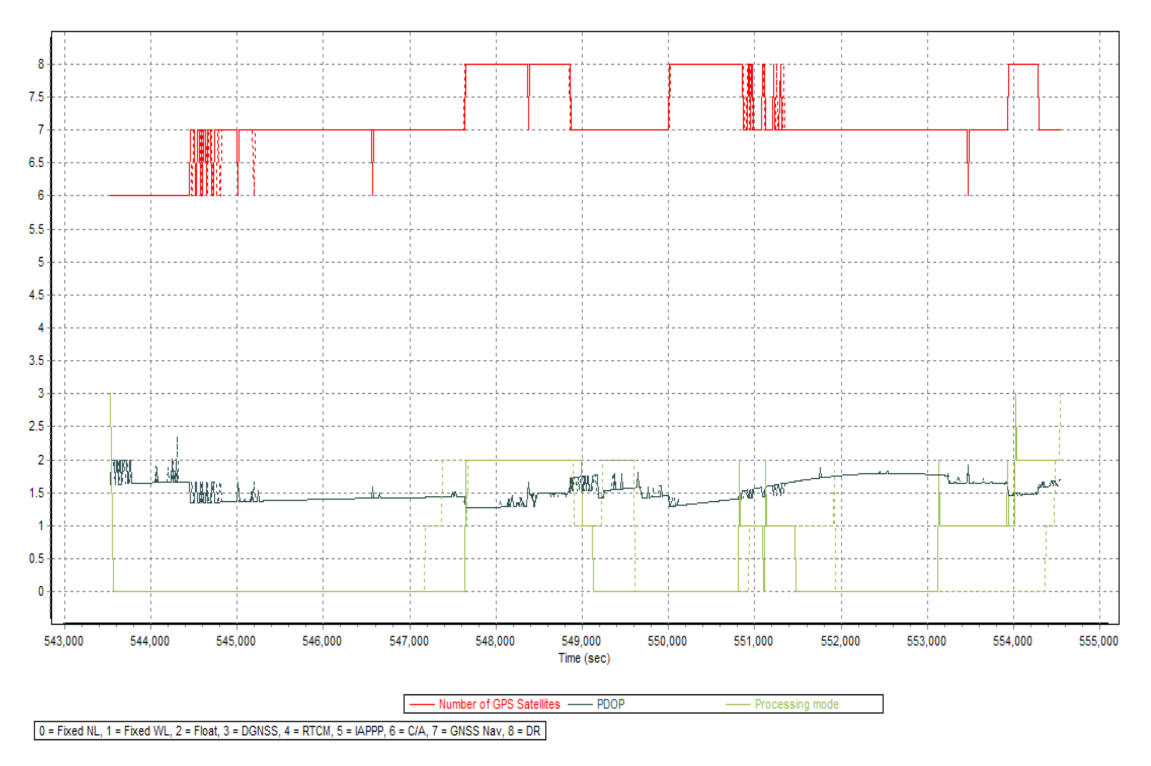


Figure A-8.1. Solution Status

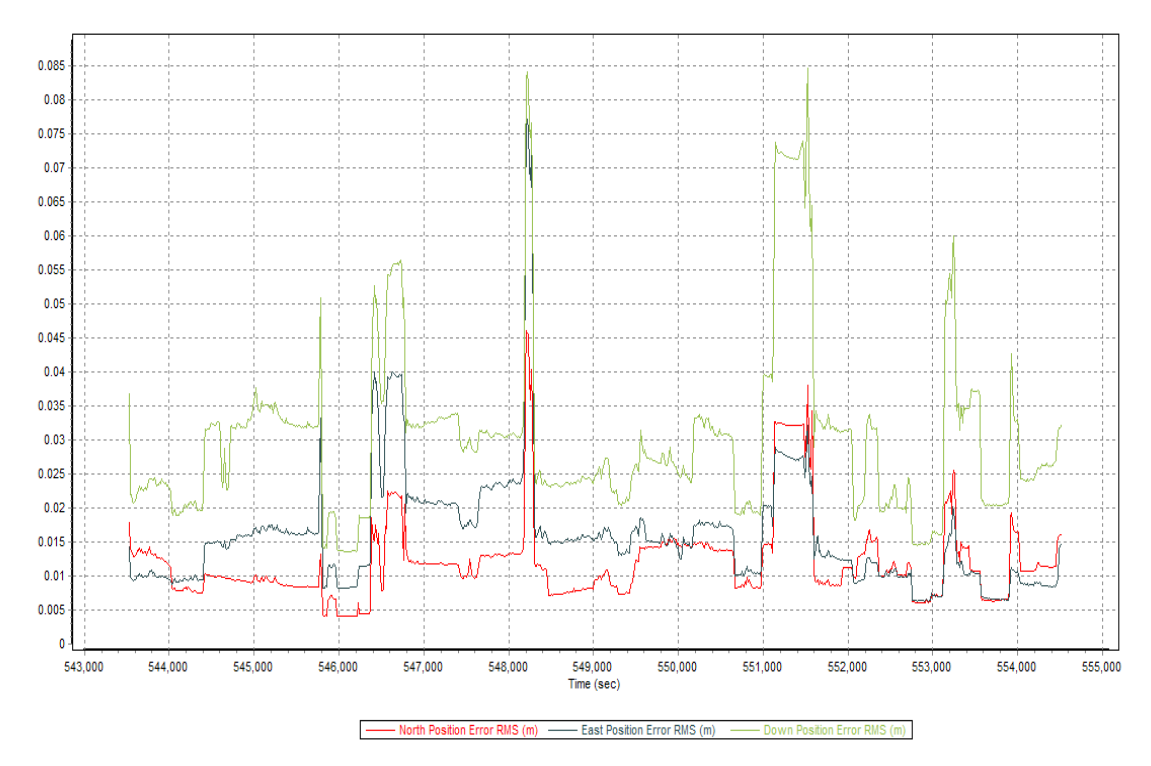


Figure A-8.2. Smoothed Performance Metrics Parameters

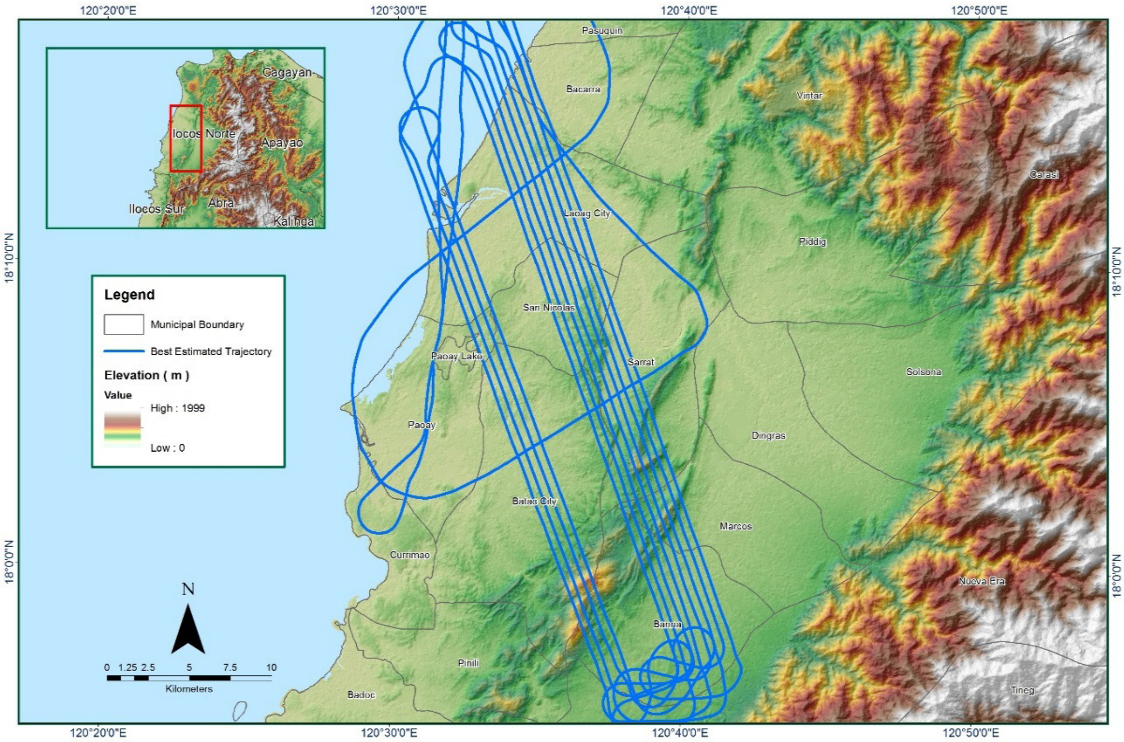


Figure A-8.3. Best Estimated Trajectory

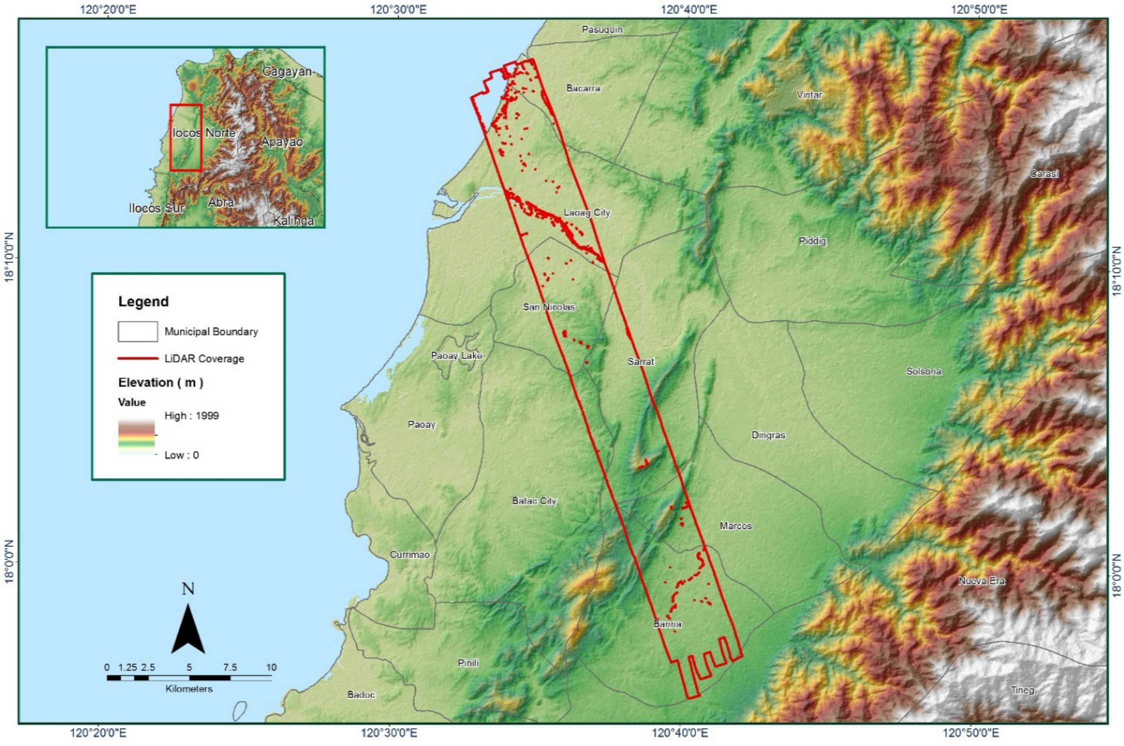


Figure A-8.4. Coverage of LiDAR data

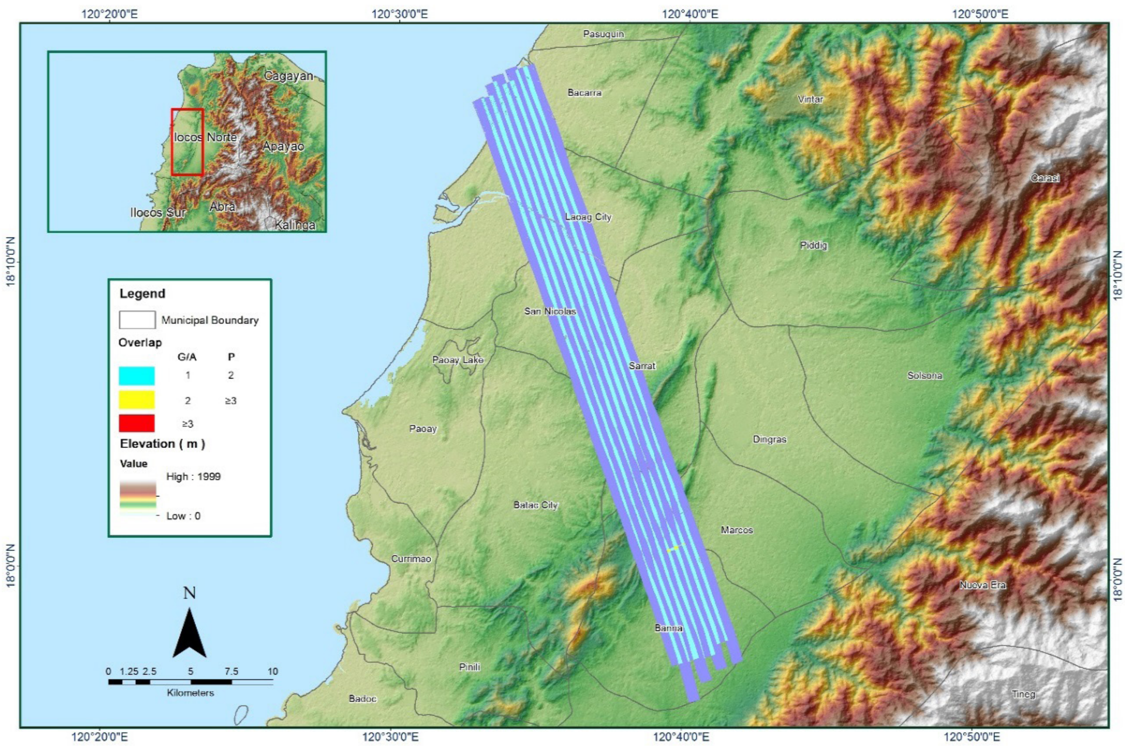


Figure A-8.5. Image of data overlap

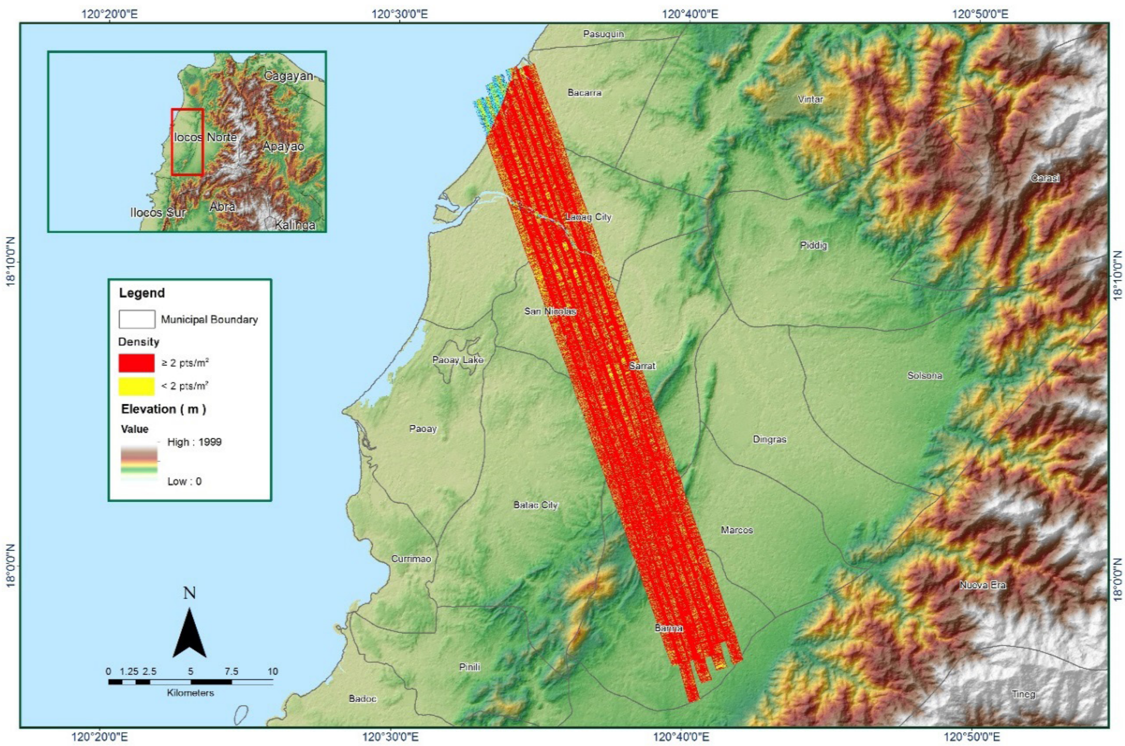


Figure A-8.6. Density map of merged LiDAR data

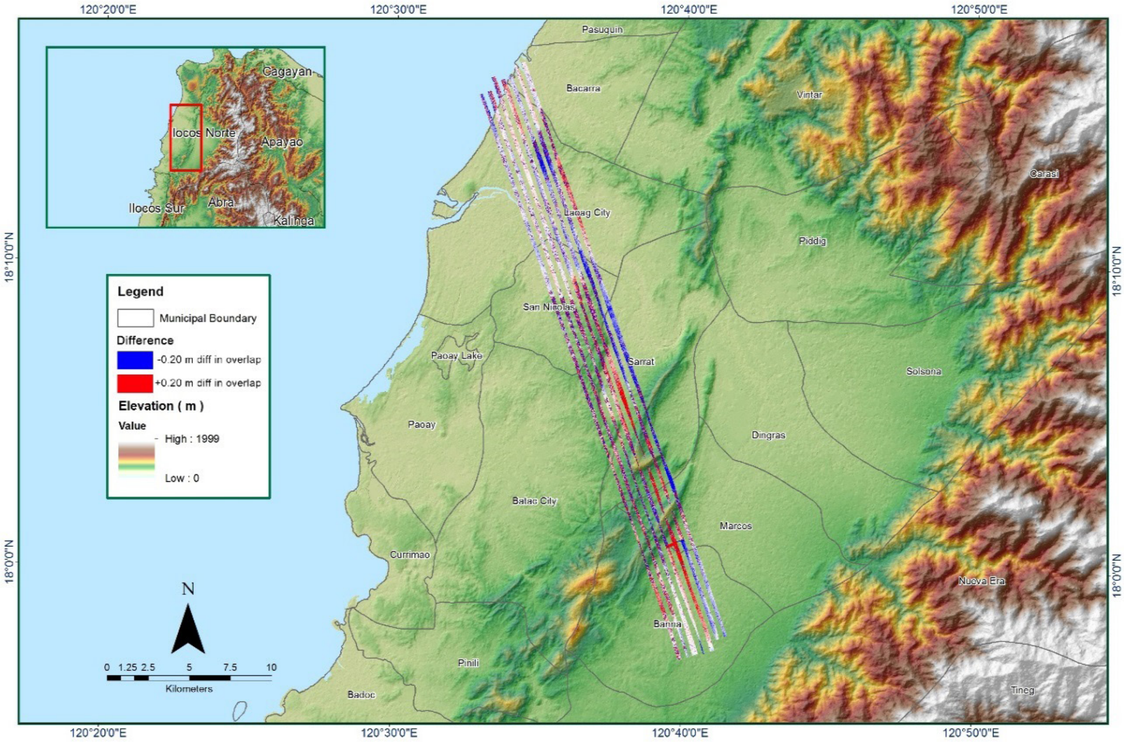


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk05FG_additional

Flight Area	Ilocos
Mission Name	Blk05FG_additional
Inclusive Flights	7087G
Range data size	26.2GB
POS	247MB
Image	N/A
Base Station	12.3 MB
Transfer date	April 25, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.9
RMSE for East Position (<4.0 cm)	5.2
RMSE for Down Position (<8.0 cm)	9.6
Boresight correction stdev (<0.001deg)	0.000323
IMU attitude correction stdev (<0.001deg)	0.000528
GPS position stdev (<0.01m)	0.0111
Minimum % overlap (>25)	21.67%
Ave point cloud density per sq.m. (>2.0)	2.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	131
Maximum Height	39.50 m
Minimum Height	589.13 m
Classification (# of points)	
Ground	35,485,459
Low vegetation	36,495,875
Medium vegetation	46,829,856
High vegetation	80,548,539
Building	2,331,876
Orthophoto	No
Processed by	Victoria Maria Rejuso, Engr. Antonio Chua Jr., Engr. Melissa Fernandez

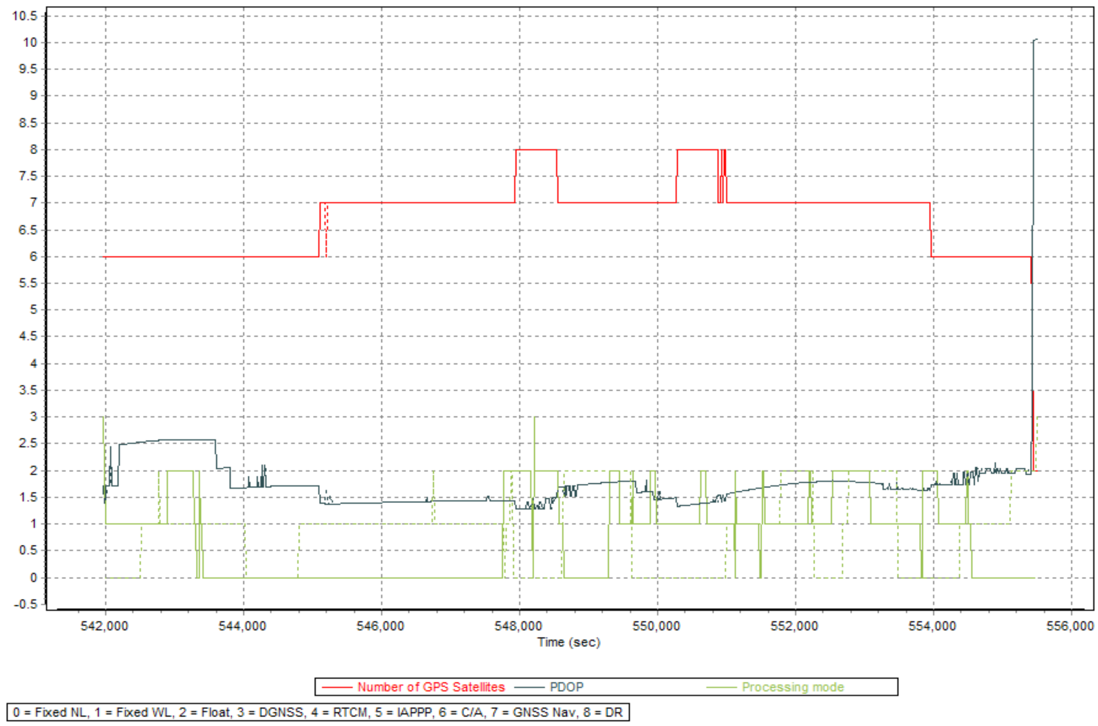


Figure A-8.8. Solution Status

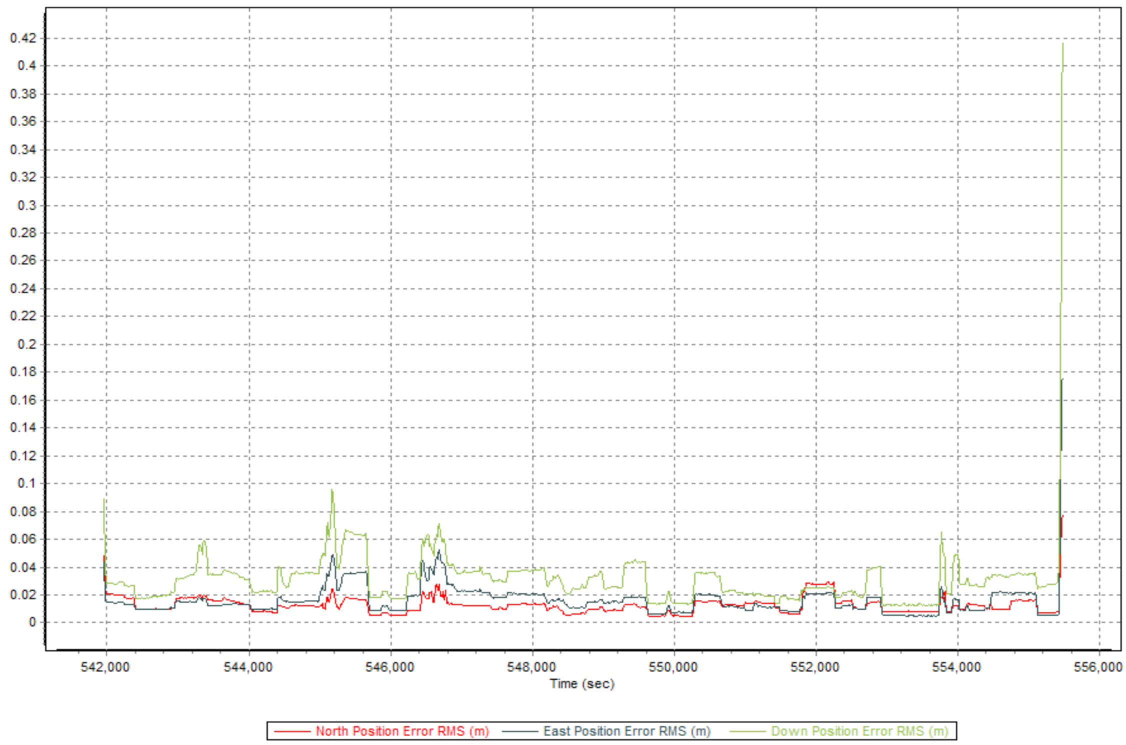


Figure A-8.9. Smoothed Performance Metrics Parameters

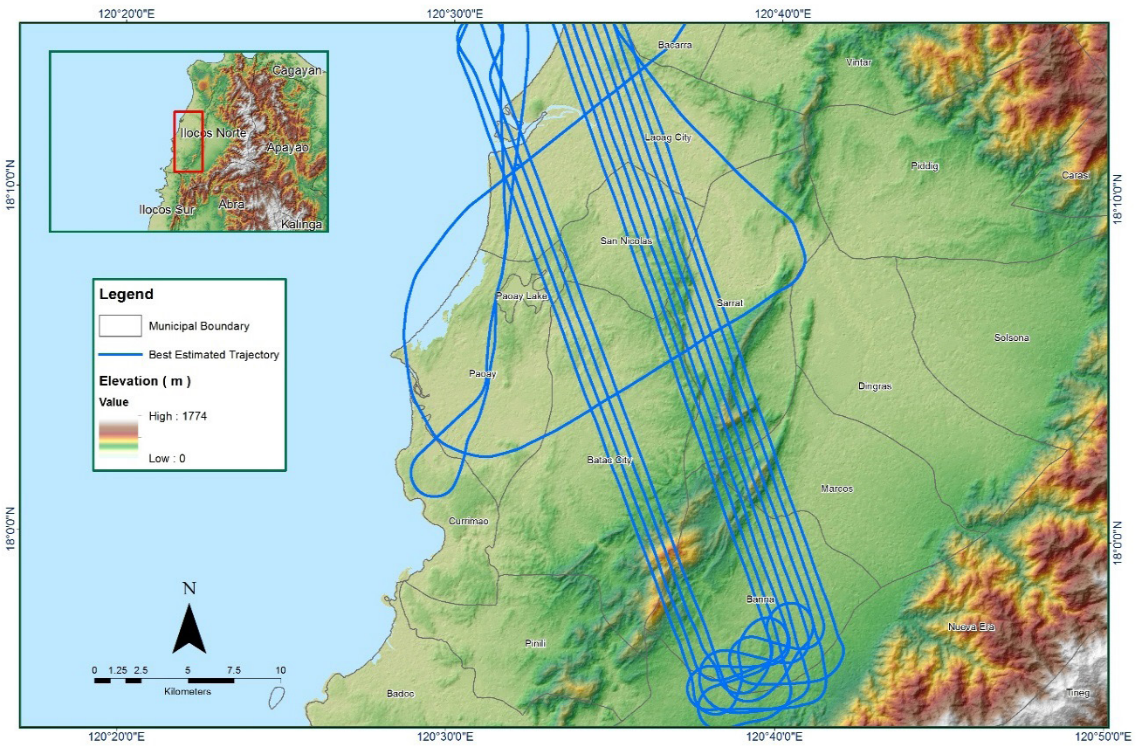


Figure A-8.10. Best Estimated Trajectory

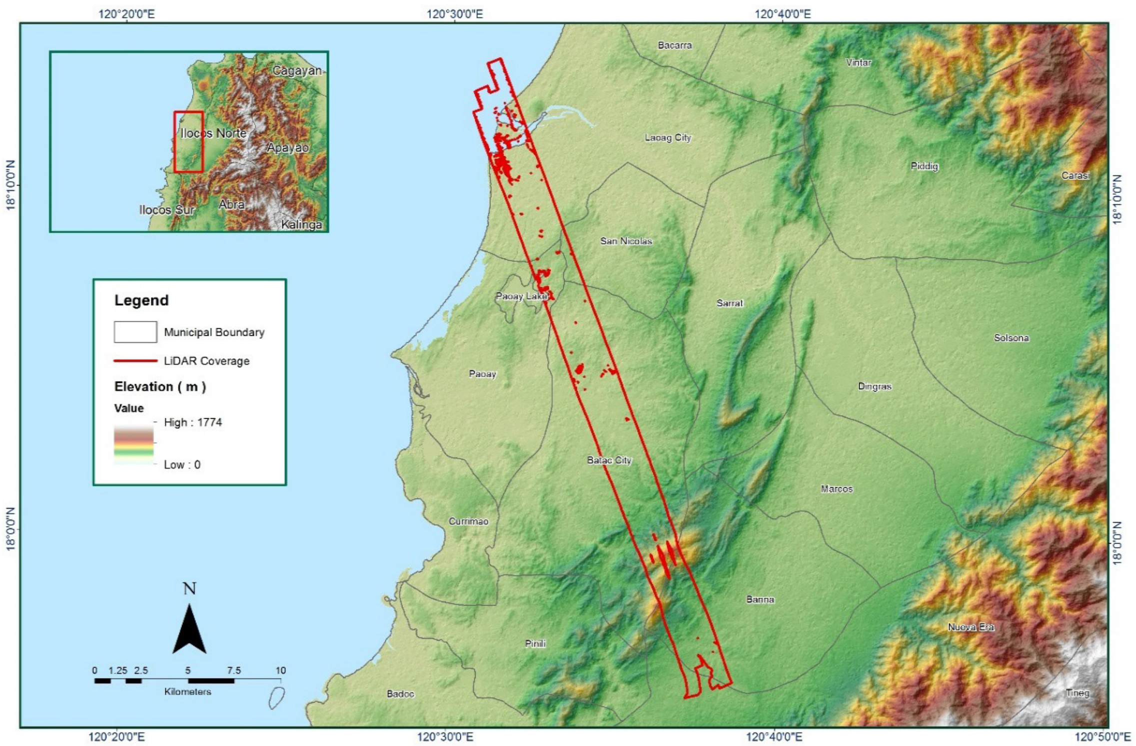


Figure A-8.11. Coverage of LiDAR data

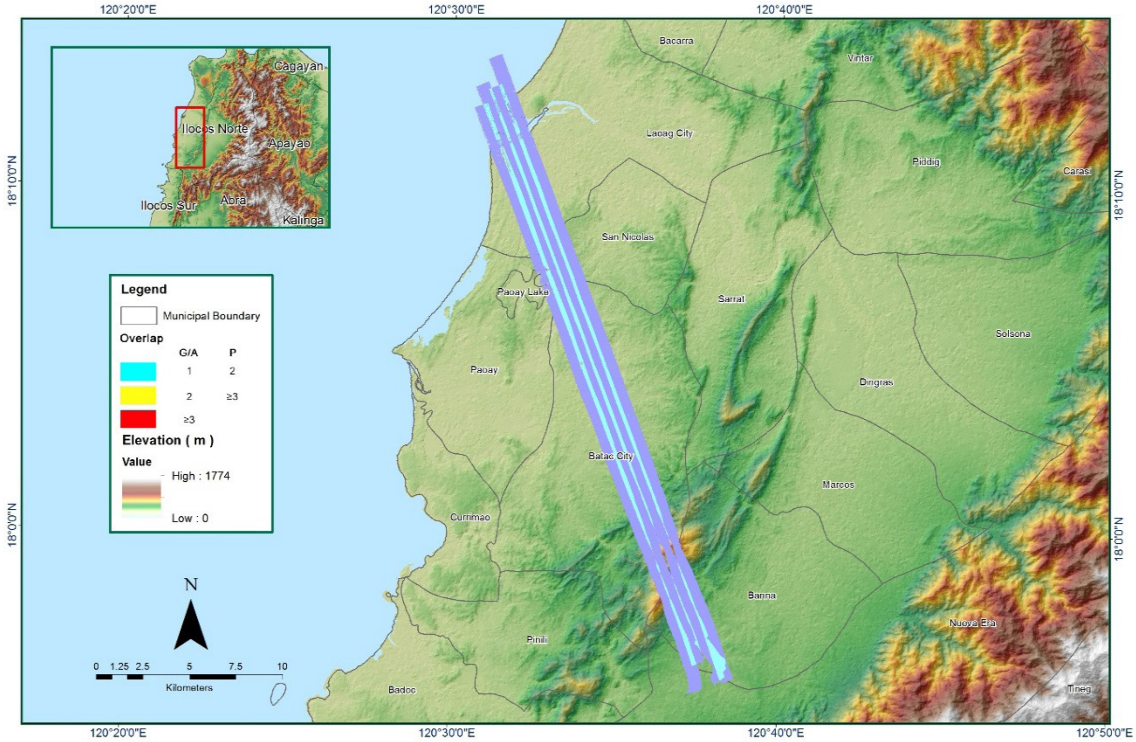


Figure A-8.12. Image of data overlap

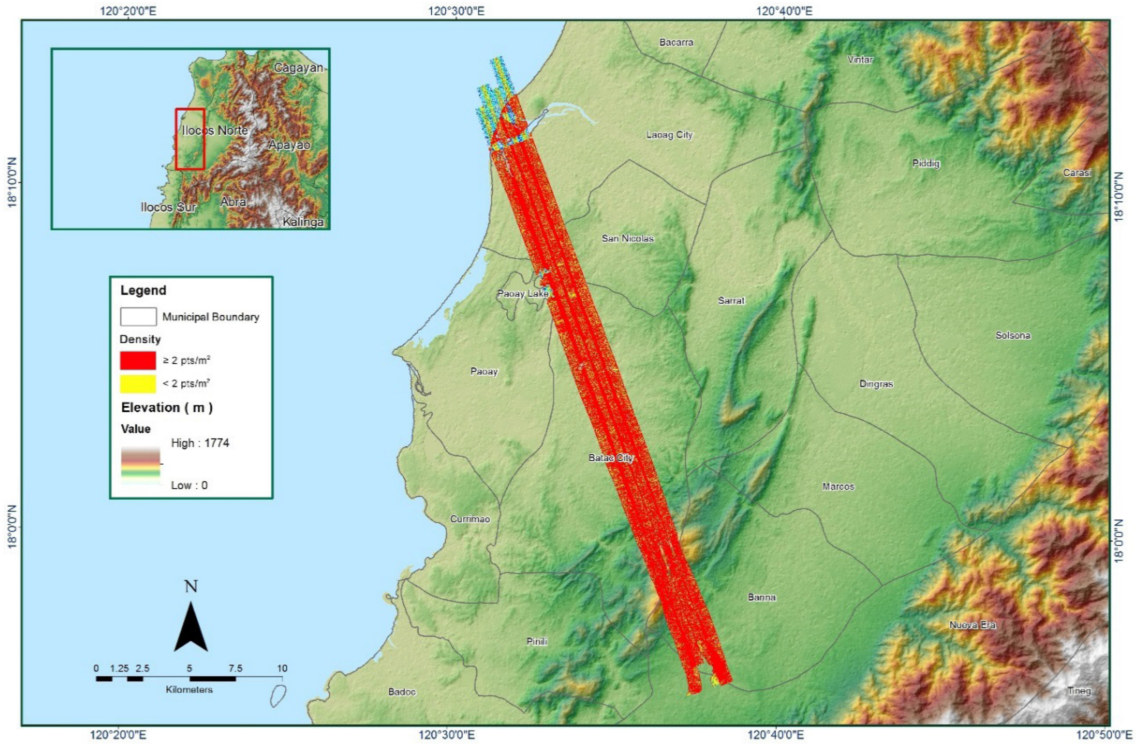


Figure A-8.13. Density map of merged LiDAR data

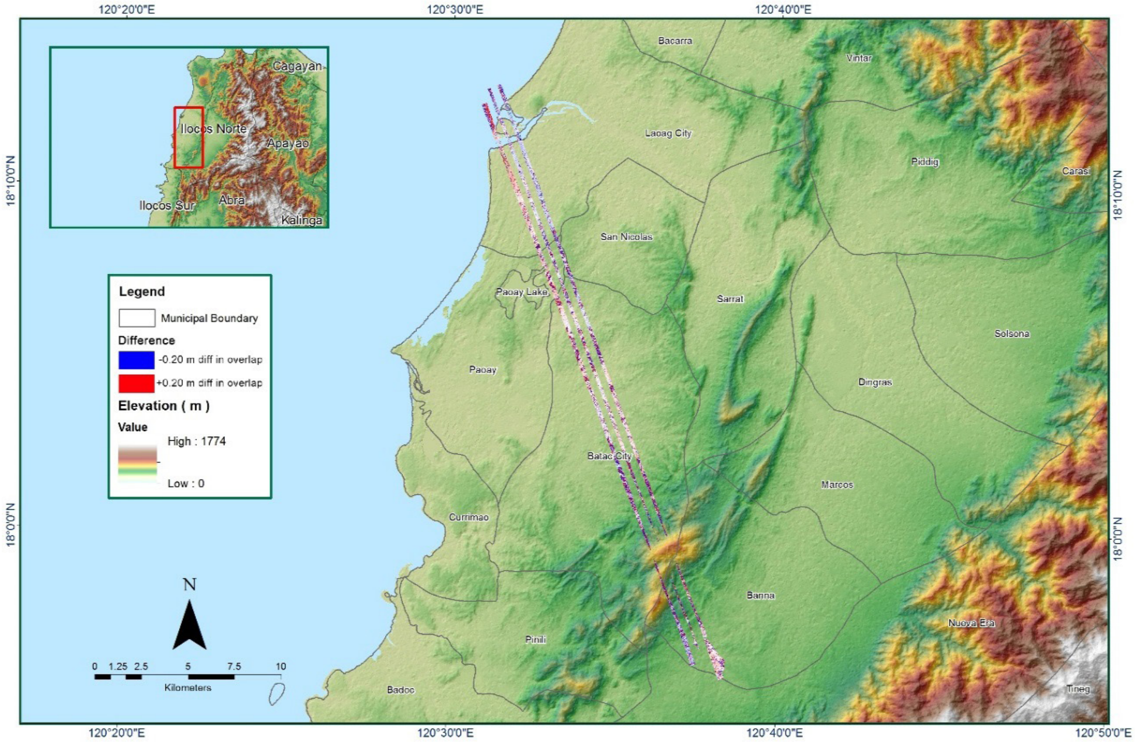


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk05_G

Flight Area	Oriental Mindoro
Mission Name	Blk05_G
Inclusive Flights	7085G
Range data size	13.9 GB
POS	158 MB
Image	N/A
Base Station	11.6 MB
Transfer date	April 25, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.1
RMSE for East Position (<4.0 cm)	3.7
RMSE for Down Position (<8.0 cm)	9.2
Boresight correction stdev (<0.001deg)	0.000673
IMU attitude correction stdev (<0.001deg)	0.000756
GPS position stdev (<0.01m)	0.0112
Minimum % overlap (>25)	84.28%
Ave point cloud density per sq.m. (>2.0)	5.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	176
Maximum Height	537.85 m
Minimum Height	38.95 m
Classification (# of points)	
Ground	62,450,922
Low vegetation	62,751,467
Medium vegetation	74,301,334
High vegetation	133,270,609
Building	3,941,158
Orthophoto	No
Processed by	Victoria Rejuso, Engr. Antonio Chua Jr., Engr. Gladys Mae Apat

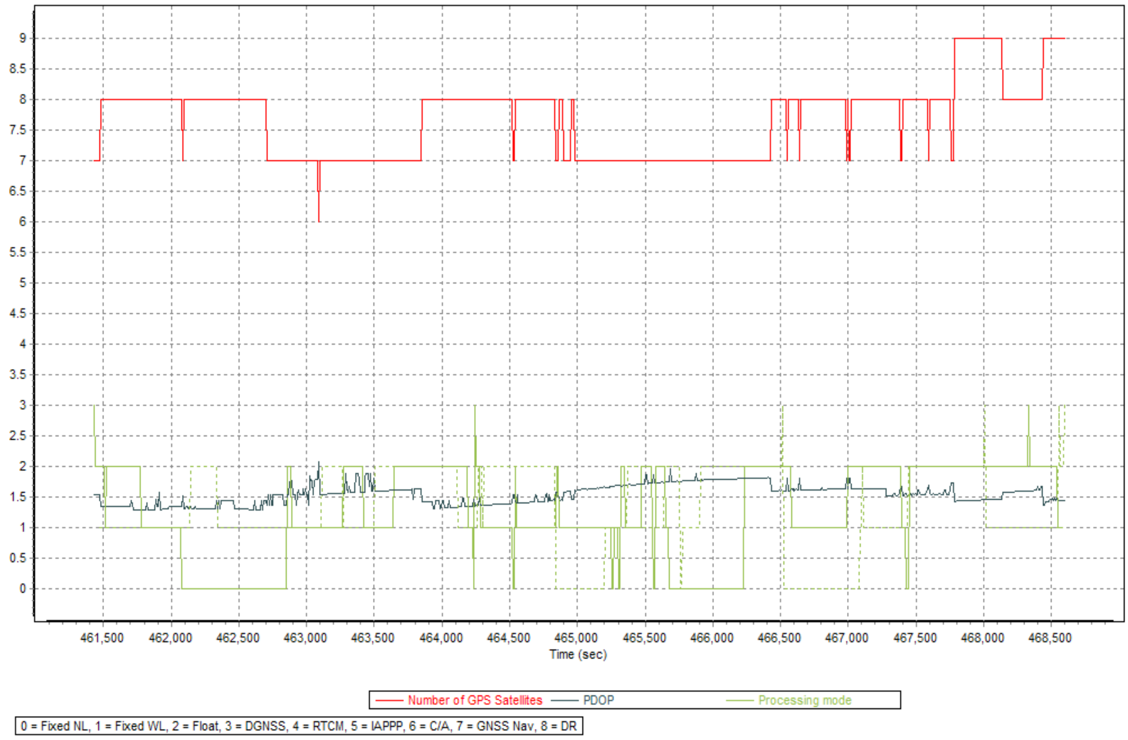


Figure A-8.15. Solution Status

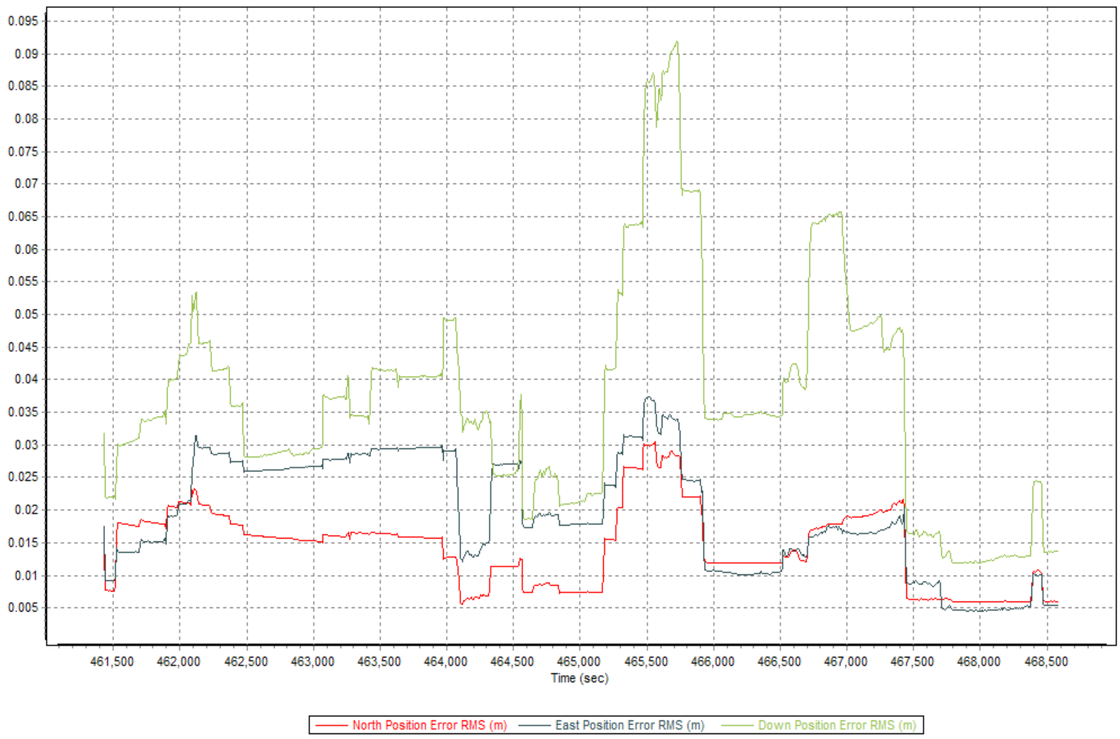


Figure A-8.16. Smoothed Performance Metrics Parameters

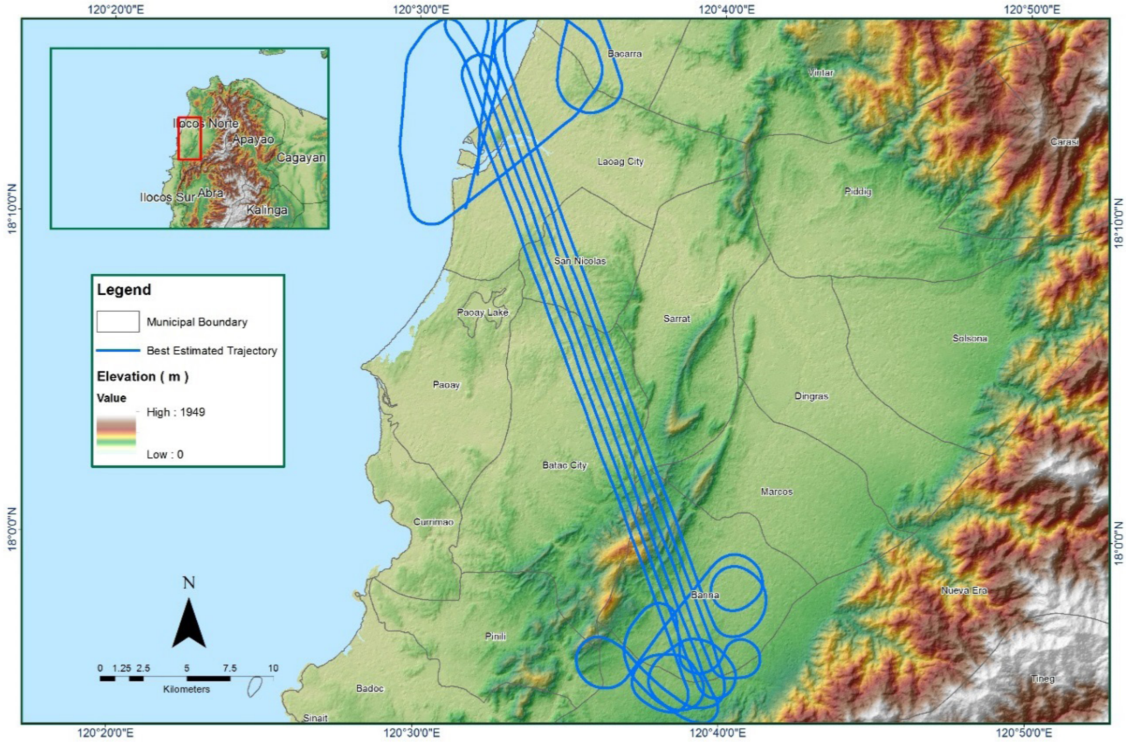


Figure A-8.17. Best Estimated Trajectory

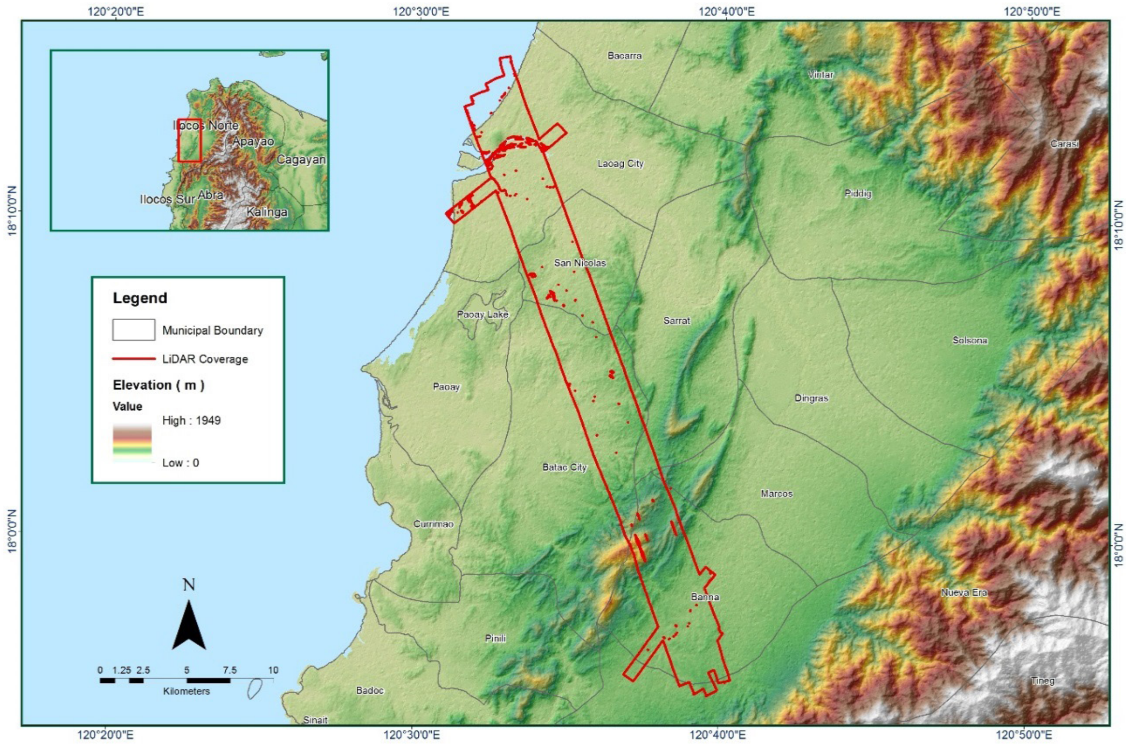


Figure A-8.18. Coverage of LiDAR data

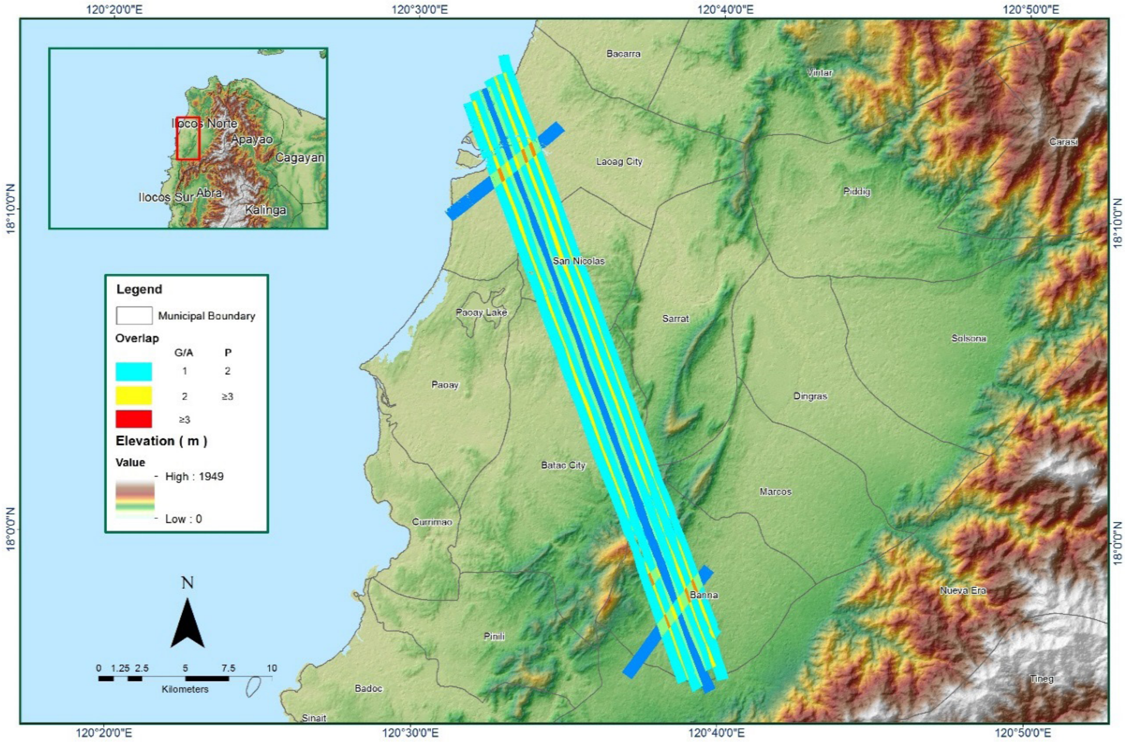


Figure A-8.19. Image of data overlap

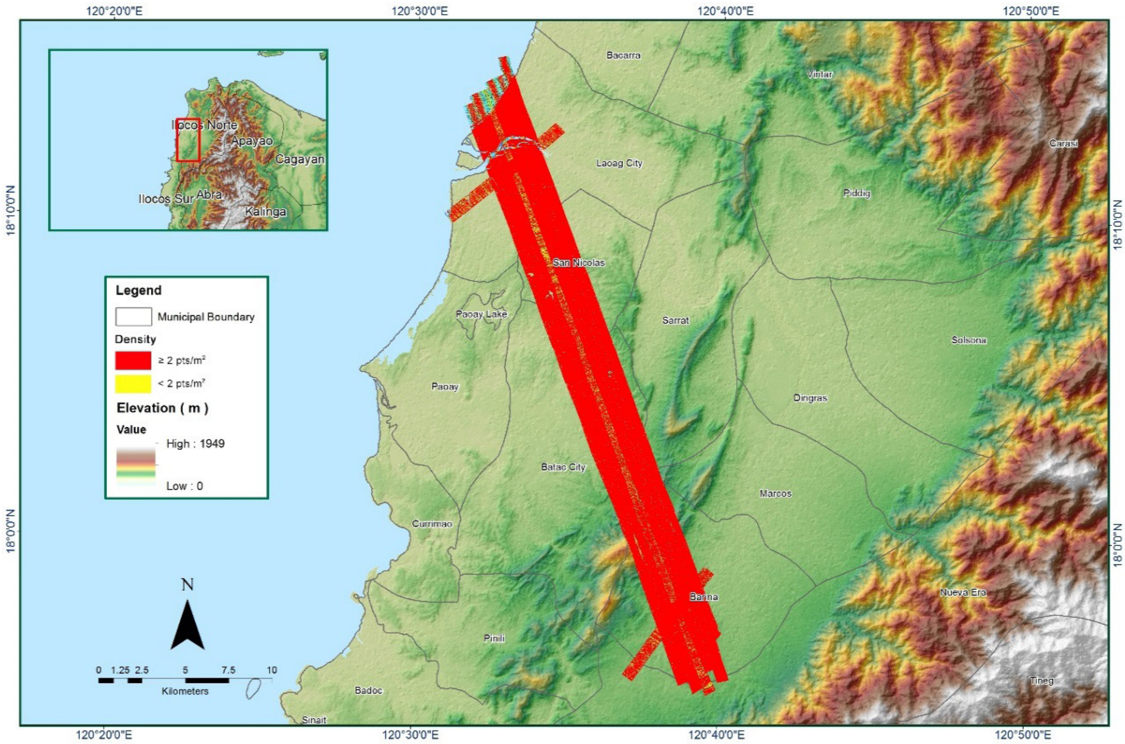


Figure A-8.20. Density map of merged LiDAR data

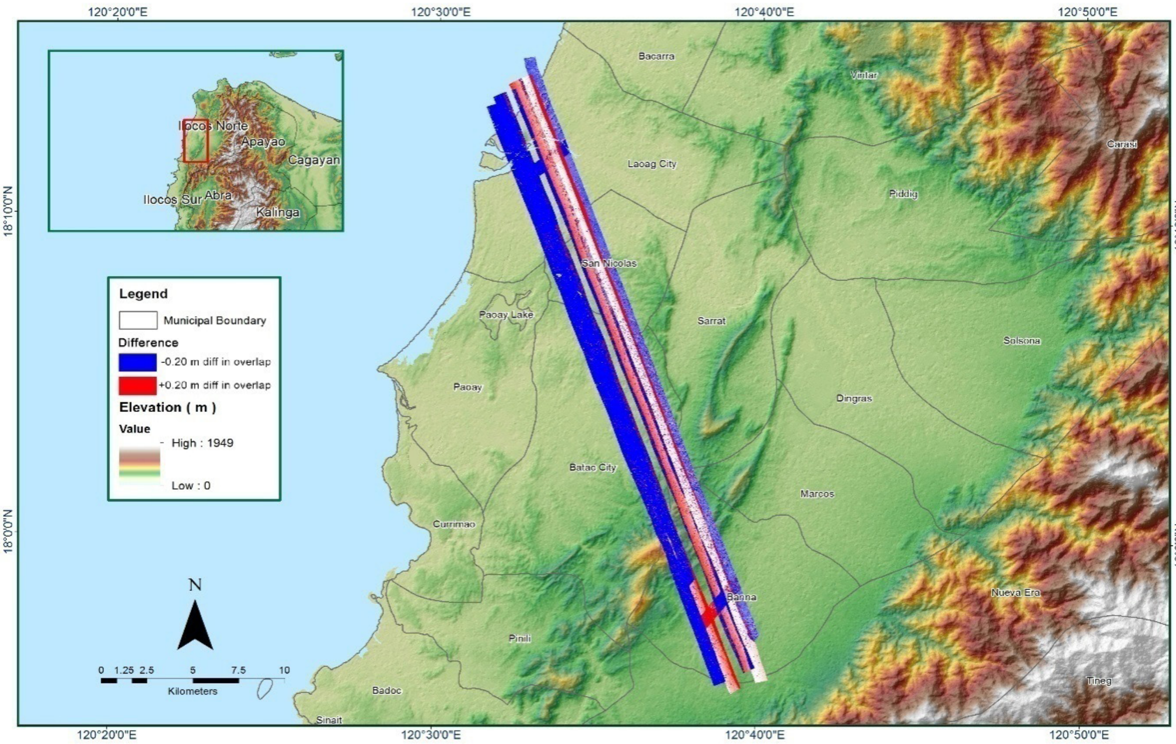


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk05_H

Flight Area	Ilocos
Mission Name	Blk05_H
Inclusive Flights	7086G
Range data size	27.5GB
POS	227MB
Image	N/A
Base Station	12.9 MB
Transfer date	April 25, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.6
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.002460
GPS position stdev (<0.01m)	0.0085
Minimum % overlap (>25)	50.03%
Ave point cloud density per sq.m. (>2.0)	4.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	225
Maximum Height	588.11 m
Minimum Height	38.82 m
Classification (# of points)	
Ground	60,695,013
Low vegetation	81,084,657
Medium vegetation	267,249,514
High vegetation	270,673,899
Building	3,887,059
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Charmaine Cruz, Ryan James Nicholai Dizon

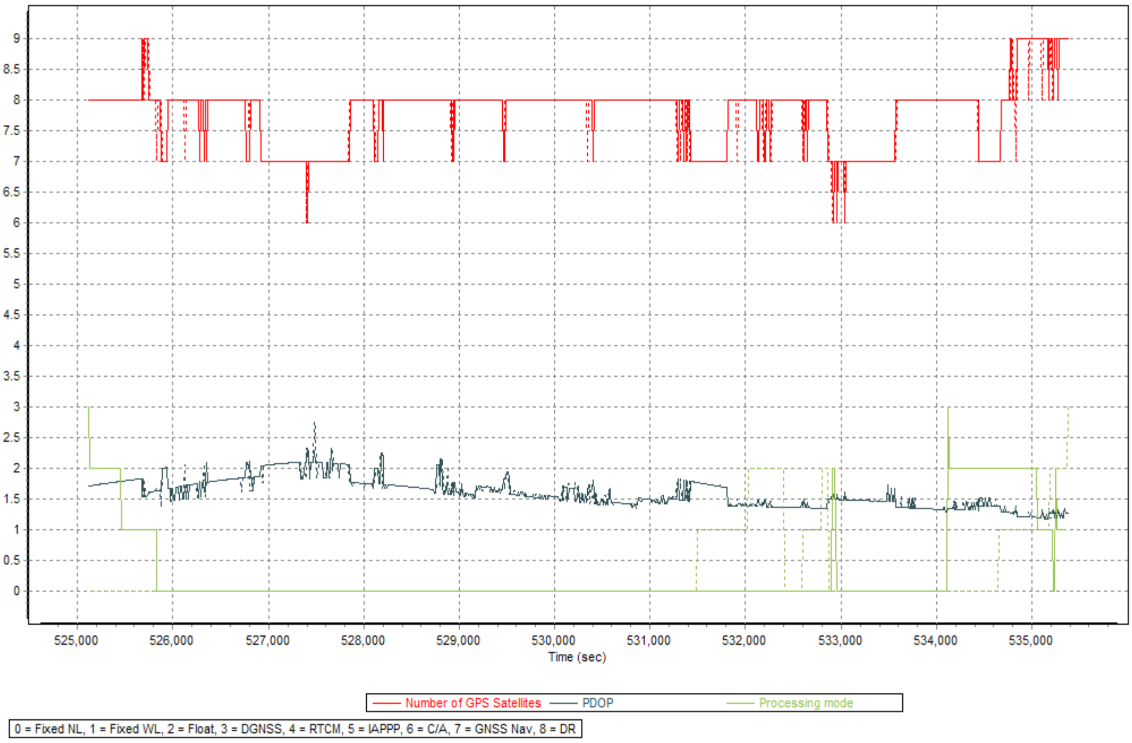


Figure A-8.22. Solution Status

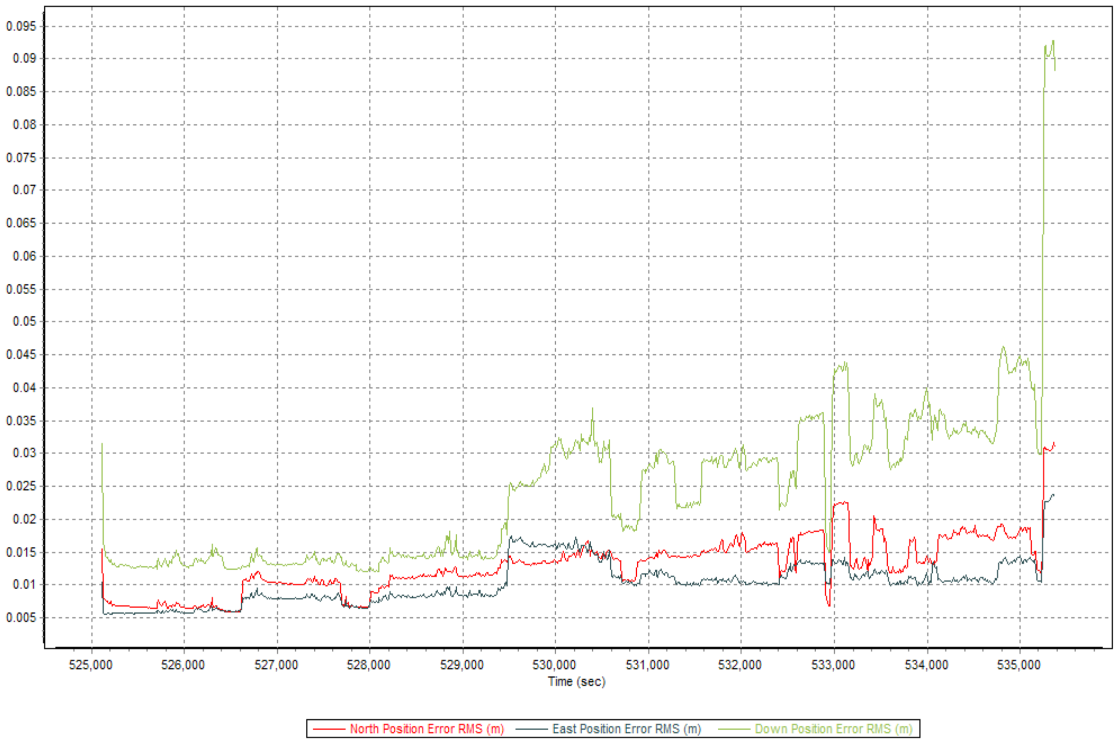


Figure A-8.23. Smoothed Performance Metrics Parameters

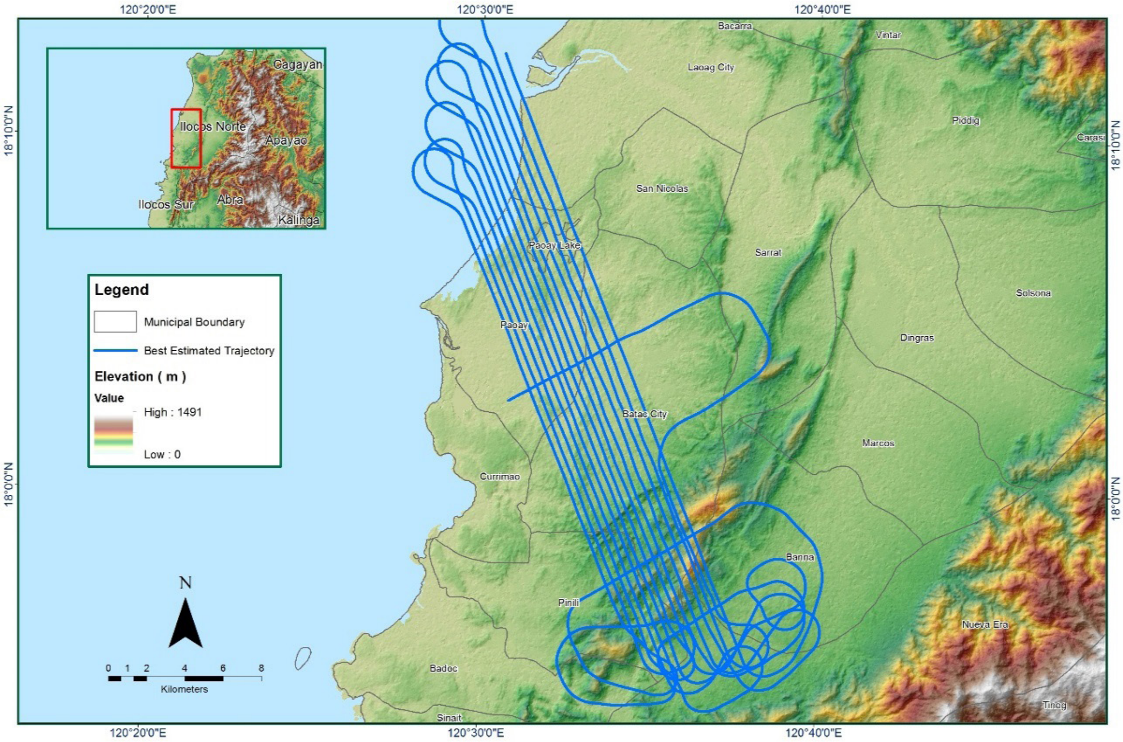


Figure A-8.24. Best Estimated Trajectory

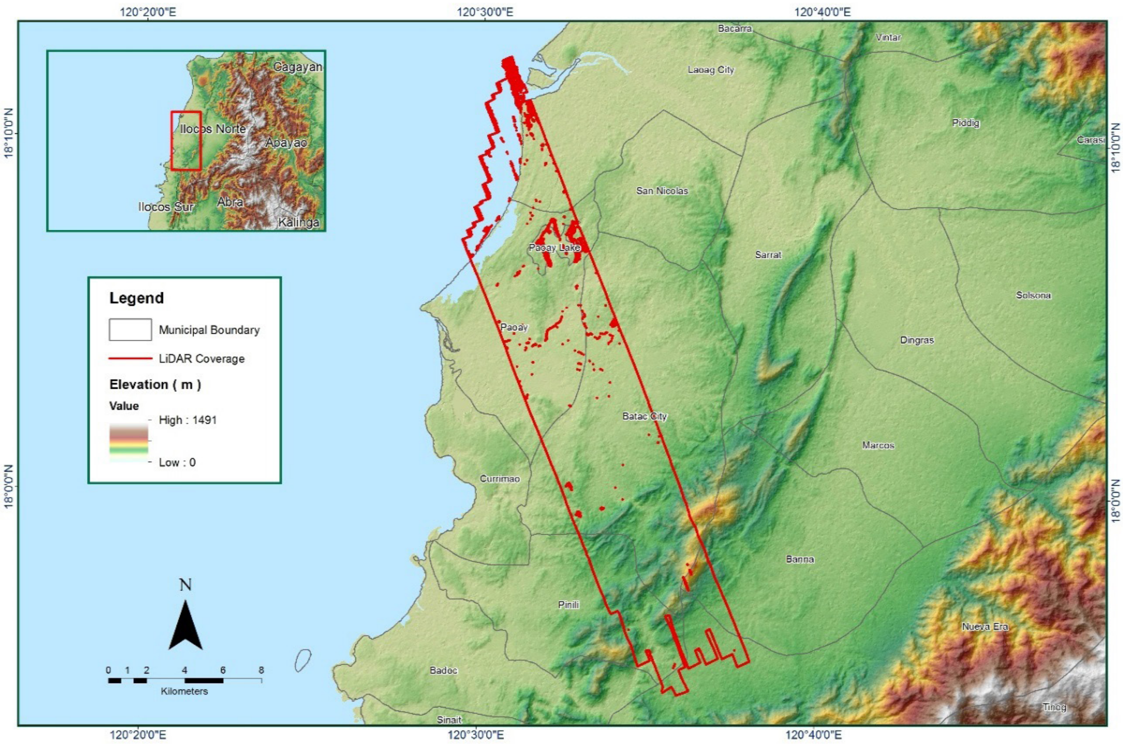


Figure A-8.25. Coverage of LiDAR data

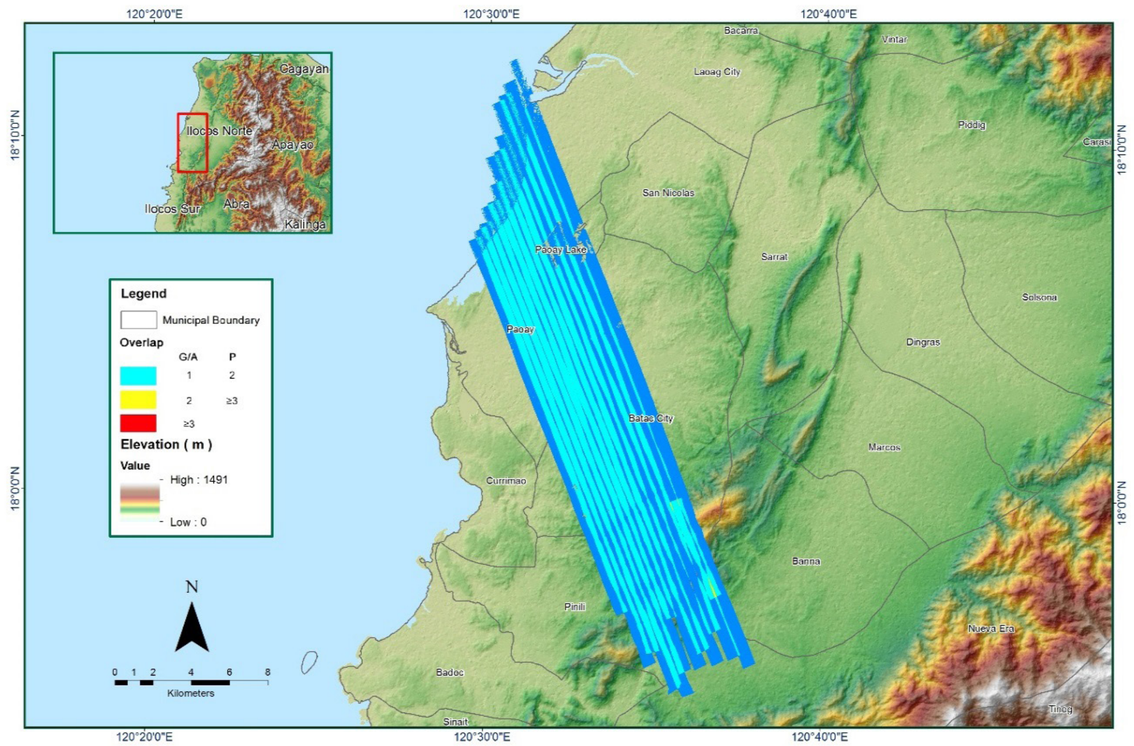


Figure A-8.26. Image of data overlap

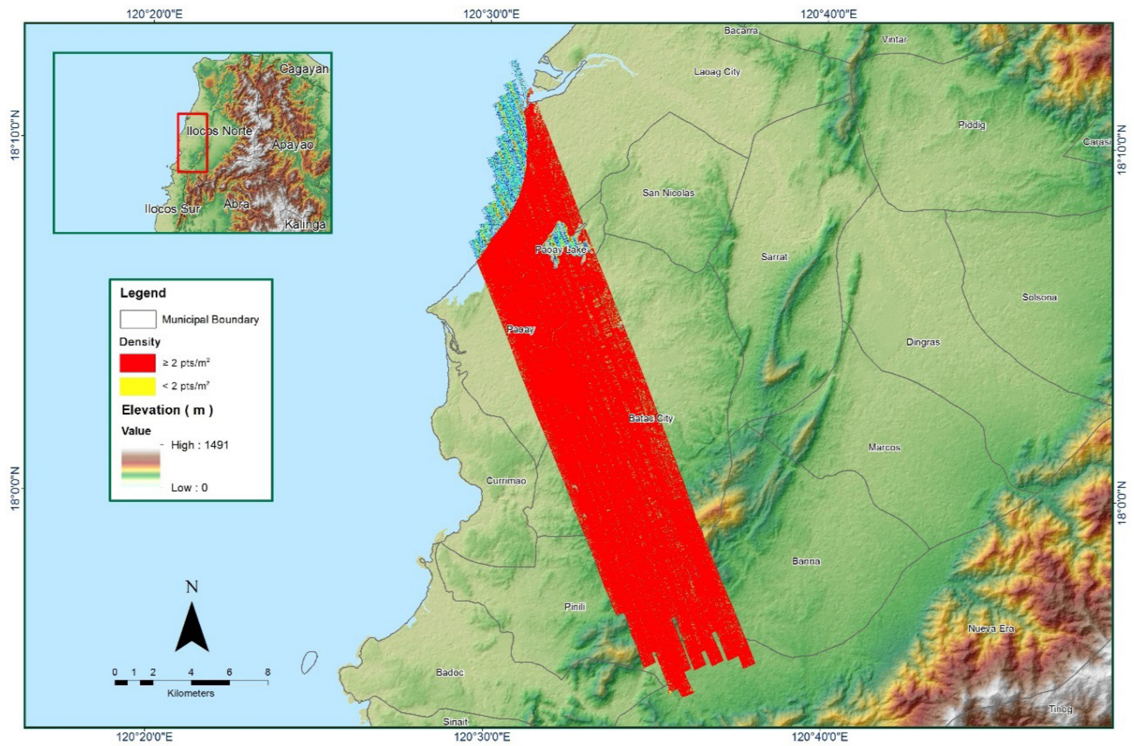


Figure A-8.27. Density map of merged LiDAR data

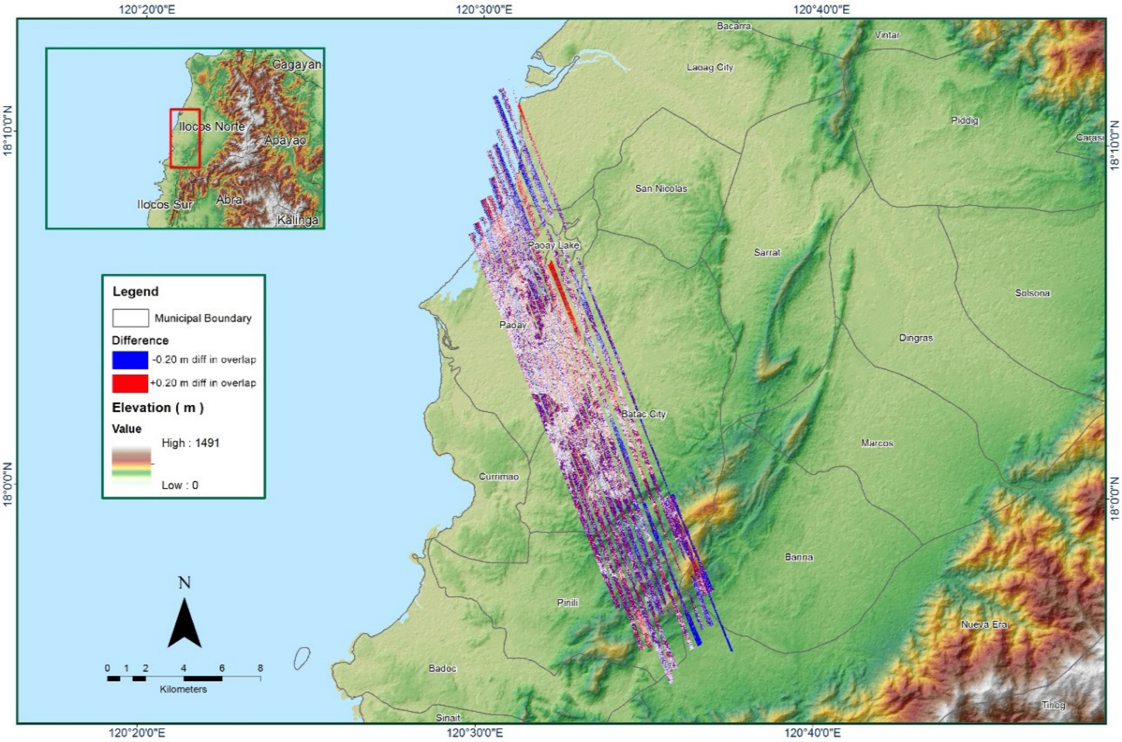


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk05_I

Flight Area	Ilocos
Mission Name	Blk05_I
Inclusive Flights	7089G
Range data size	15GB
POS	199MB
Image	N/A
Base Station	10.7 MB
Transfer date	April 25, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.4
RMSE for East Position (<4.0 cm)	3.8
RMSE for Down Position (<8.0 cm)	6.3
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.000595
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	23.97%
Ave point cloud density per sq.m. (>2.0)	2.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	176
Maximum Height	430.63 m
Minimum Height	39.72 m
Classification (# of points)	
Ground	59,718,110
Low vegetation	61,744,910
Medium vegetation	74,943,525
High vegetation	130,099,811
Building	3,324,729
Orthophoto	No
Processed by	Victoria Rejuso, Engr. Melanie Hingpit, Ryan James Nicholai Dizon

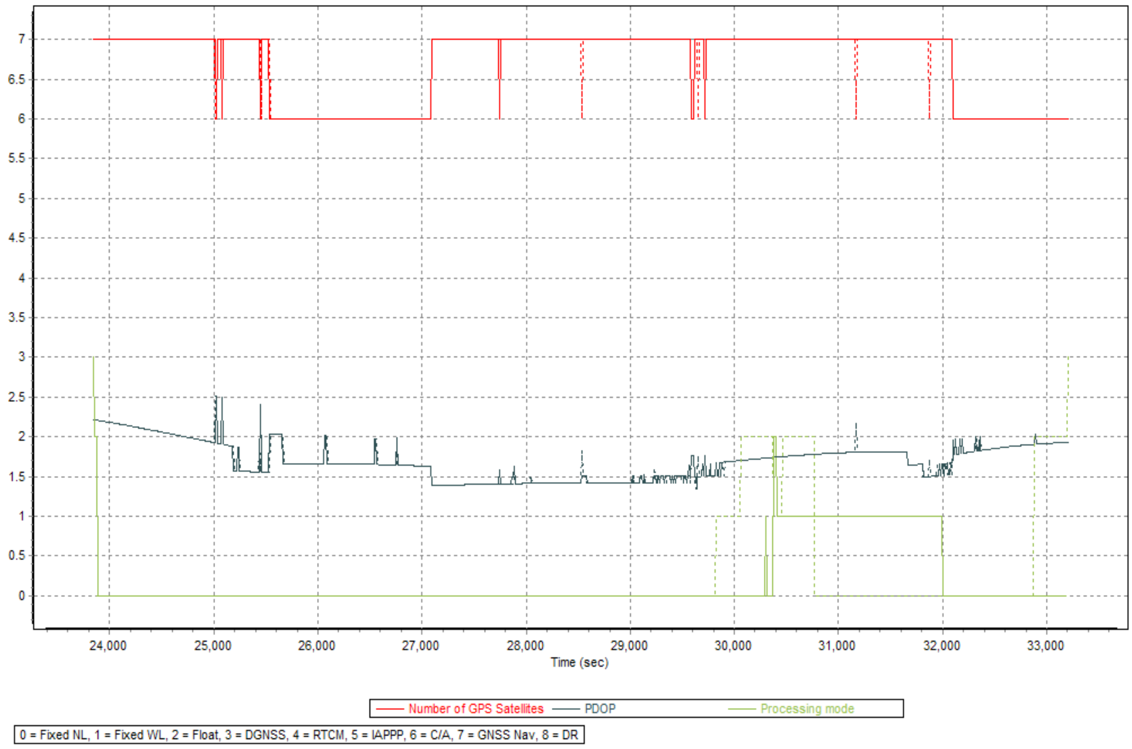


Figure A-8.29. Solution Status

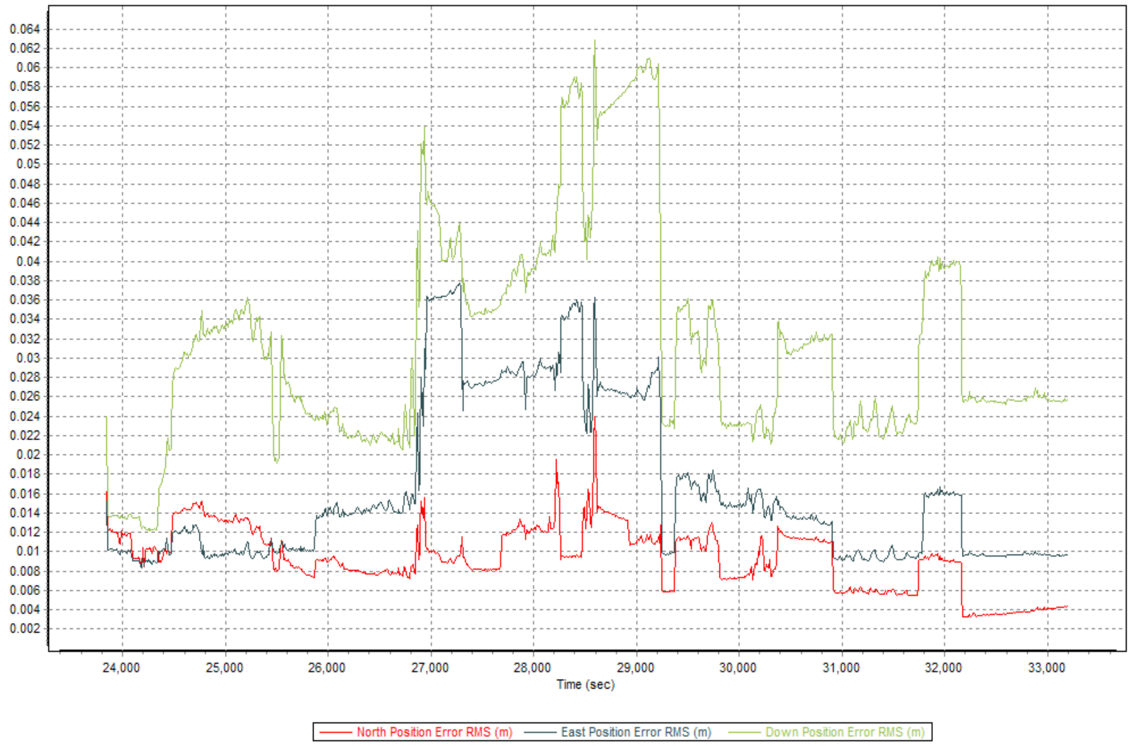


Figure A-8.30. Smoothed Performance Metrics Parameters

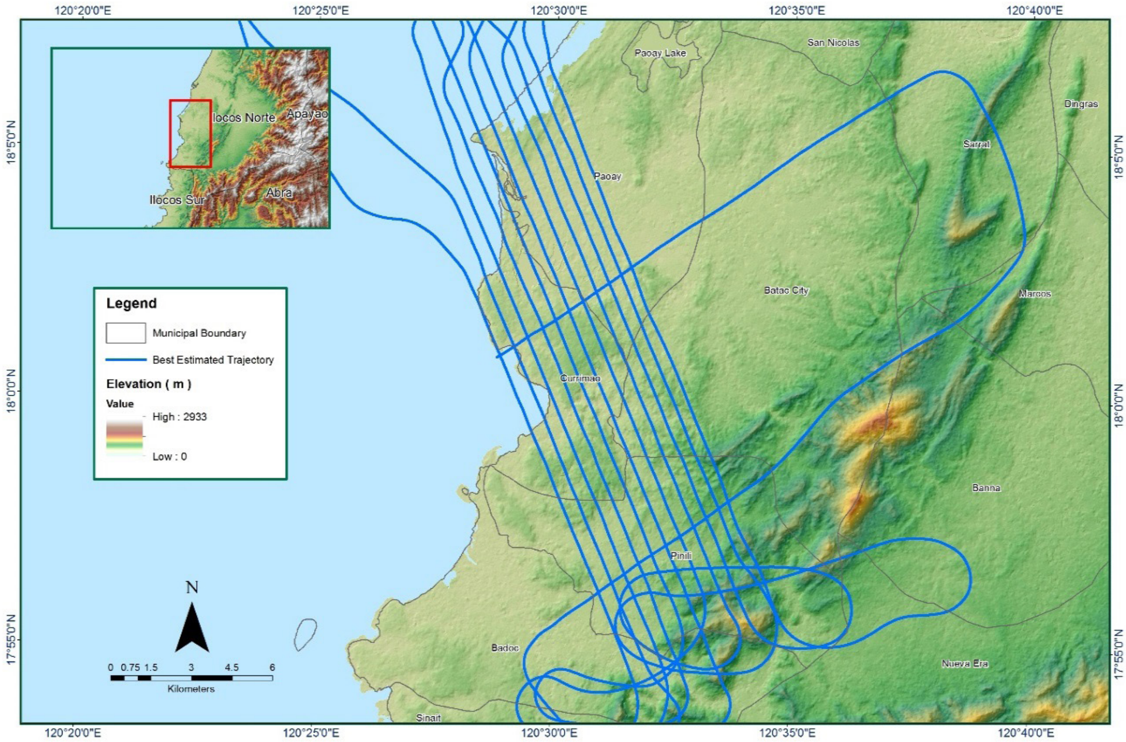


Figure A-8.31. Best Estimated Trajectory

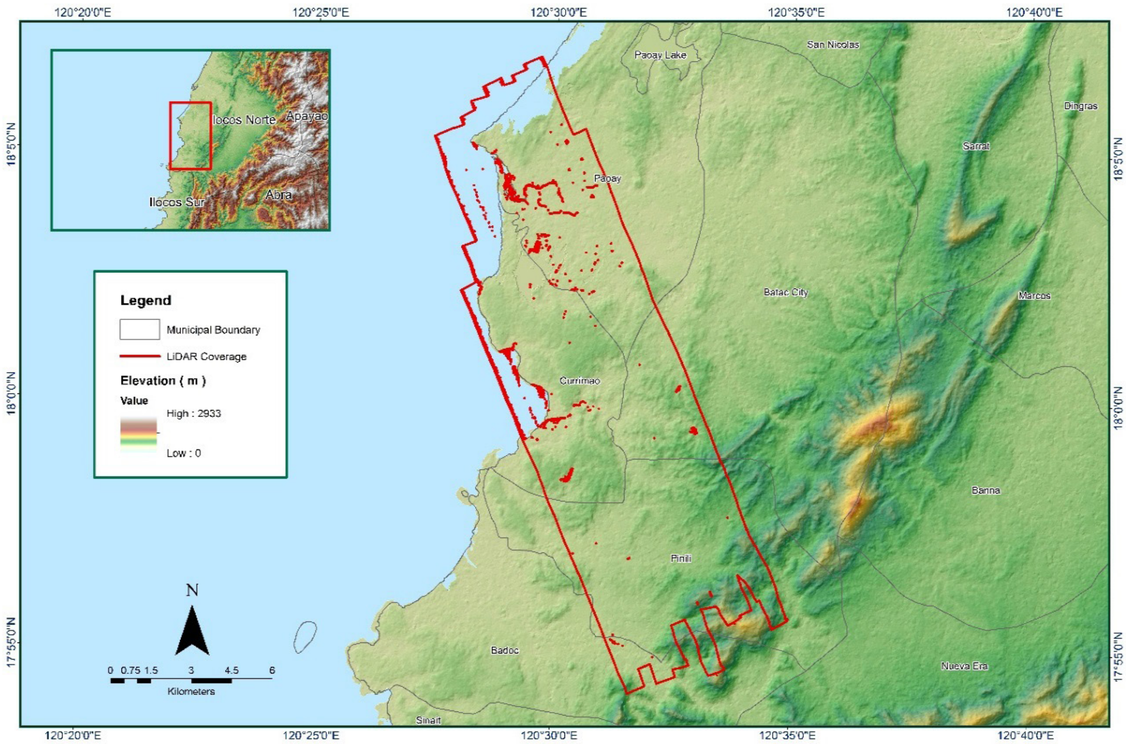


Figure A-8.32. Coverage of LiDAR data

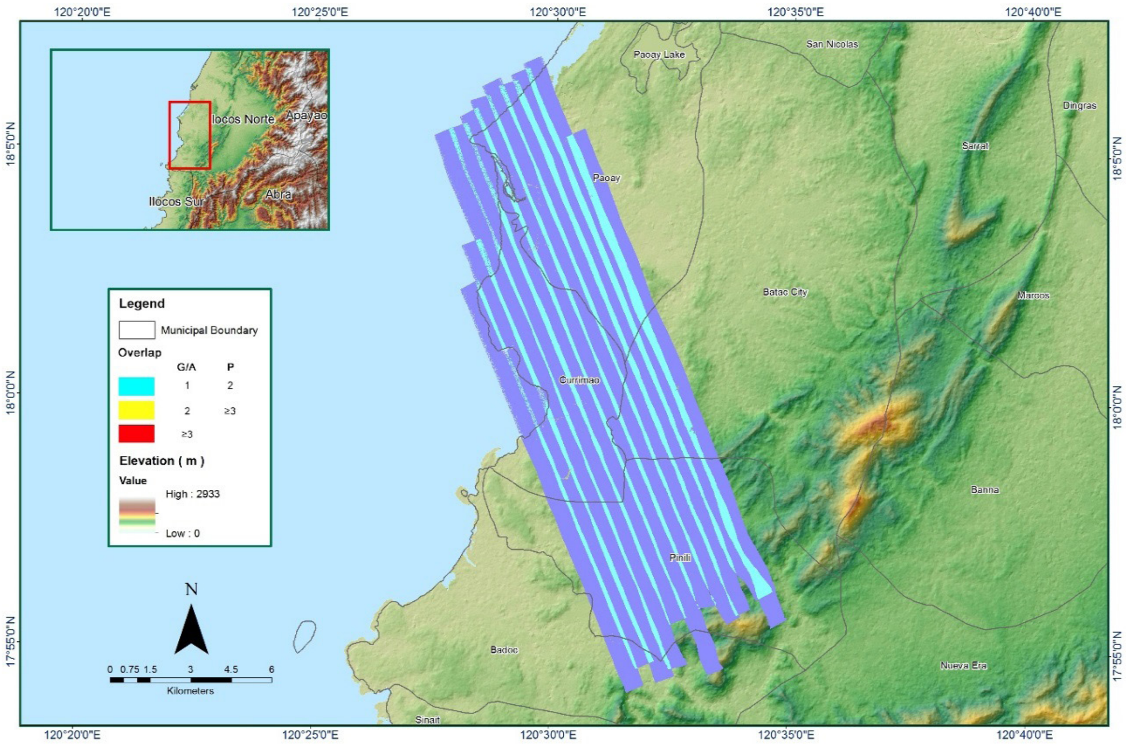


Figure A-8.33. Image of data overlap

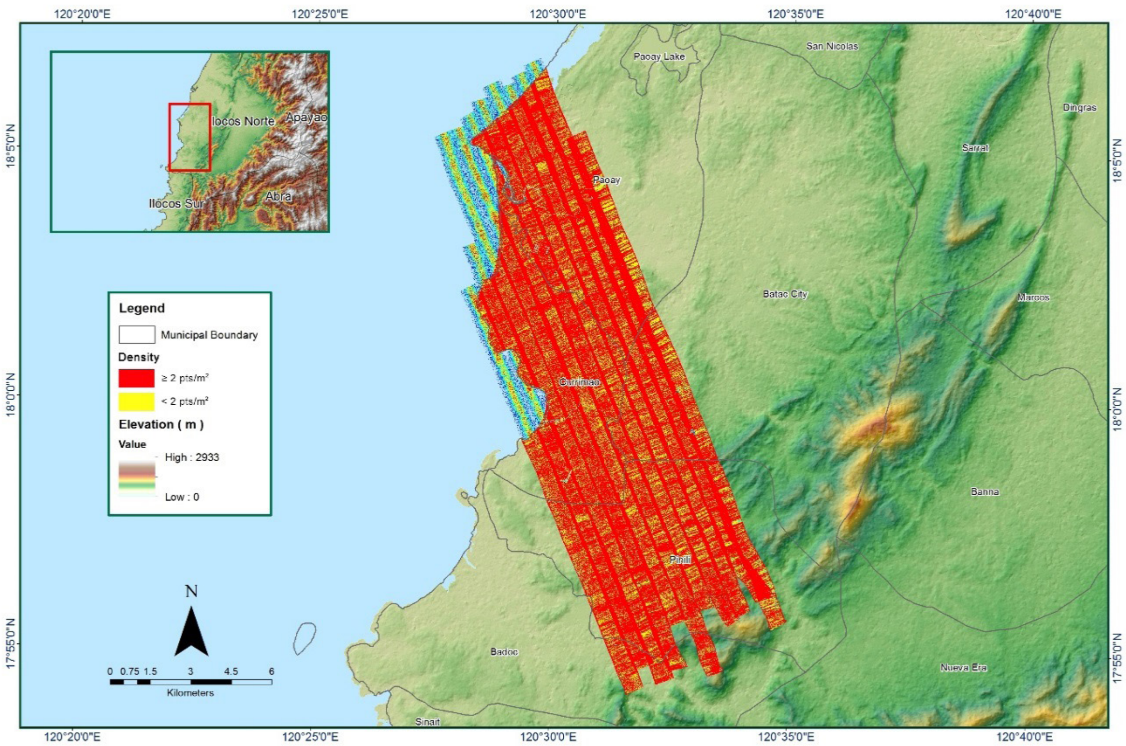


Figure A-8.34. Density map of merged LiDAR data

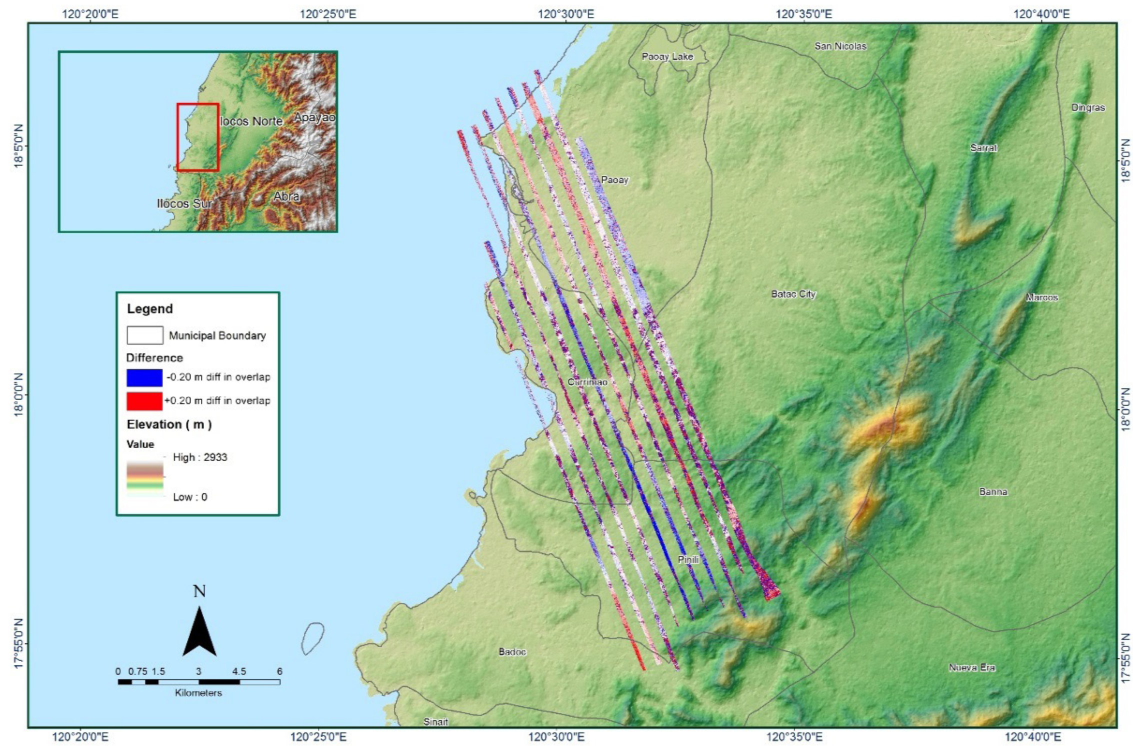


Figure A-8.35. Elevation difference between flight lines

Annex 9. Quiaoit Model Basin Parameters

Table A-9.1. Quiaoit 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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W280	2.1198	90.83776	0	5.94328	2.6050032	Discharge	2.7751	0.9	Ratio to Peak	0.0001
W290	3.4712	83.2471	0	8.5442	3.2768729	Discharge	2.4162	0.9	Ratio to Peak	0.0001
W300	2.0851	91.05082	0	9.80994	3.762444	Discharge	2.0634	0.9	Ratio to Peak	0.0001
W310	2.2569	90.0046	0	5.45874	2.0935586	Discharge	2.5443	0.9	Ratio to Peak	0.0001
W320	2.052	91.2554	0	8.90512	3.415349	Discharge	1.2006	0.9	Ratio to Peak	0.0001
W330	2.235	90.1371	0	4.26594	1.6360841	Discharge	2.4925	0.9	Ratio to Peak	0.0001
W350	4.0475	80.38192	0	3.39752	4.690553	Discharge	0.45038	0.9	Ratio to Peak	0.0001
W360	1.9116	92.13202	0	1.27834	1.3030374	Discharge	0.0414134	0.9	Ratio to Peak	0.0001
W370	3.5232	82.97998	0	2.42032	0.4902758	Discharge	0.088514	0.9	Ratio to Peak	0.0001
W380	1.5697	94.34	0	0.414246	0.9282735	Discharge	0.0041954	0.9	Ratio to Peak	0.0001
W390	1.5697	94.34	0	1.9768	0.15887	Discharge	0.0273355	0.9	Ratio to Peak	0.0001
W400	2.025	91.42288	0	4.91134	0.7581476	Discharge	0.93578	0.9	Ratio to Peak	0.0001
W410	3.7267	81.95178	0	4.86738	1.8835908	Discharge	0.2259	0.9	Ratio to Peak	0.0001
W420	0.91064	98.90754	0	1.8536	1.8667131	Discharge	0.0730562	0.9	Ratio to Peak	0.0001
W430	1.5697	94.34	0	1.85094	0.7109032	Discharge	0.0269812	0.9	Ratio to Peak	0.0001
W440	2.8806	86.40272	0	4.16864	0.7098504	Discharge	1.5589	0.9	Ratio to Peak	0.0001

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 (cms)	Recession Constant	Threshold Type	Ratio to Peak
W450	4.0047	80.58862	0	9.03504	1.5987426	Discharge	0.62842	0.9	Ratio to Peak	0.0001
W460	1.4077	95.42332	0	2.38084	3.465028	Discharge	0.12262	0.9	Ratio to Peak	0.0001
W470	2.3616	89.38026	0	4.62056	0.9131066	Discharge	1.0296	0.9	Ratio to Peak	0.0001
W480	1.902	92.1935	0	6.19052	1.7720927	Discharge	0.94675	0.9	Ratio to Peak	0.0001
W490	2.6188	87.8793	0	4.88642	2.3741956	Discharge	1.7122	0.9	Ratio to Peak	0.0001
W500	2.0139	91.49178	0	6.3826	1.8740498	Discharge	2.4650405	0.9	Ratio to Peak	0.0001
W510	2.3248	89.59862	0	4.43926	2.4478587	Discharge	1.5197	0.9	Ratio to Peak	0.0001
W520	2.6374	87.77224	0	3.78462	1.7025421	Discharge	1.3591	0.9	Ratio to Peak	0.0001
W530	2.9973	85.7593	0	3.7821	1.4514822	Discharge	1.6867	0.9	Ratio to Peak	0.0001
W540	5.7504	72.96298	0	3.72624	1.4504952	Discharge	1.0699	0.9	Ratio to Peak	0.0001
W560	1.3061	96.1155	0	12.22998	1.4290773	Discharge	0.84975	0.9	Ratio to Peak	0.0001
W570	2.6508	86.805	0	9.8249	3.0203	Discharge	4.9227	0.90395	Ratio to Peak	0.00015

Annex 10. Quiaoit Model Reach Parameters

Table A-10.1. Quiaoit Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	1448.1	0.003454	0.04	Trapezoid	23.4	1
R110	Automatic Fixed Interval	727.4	0.00107	0.04	Trapezoid	22.4	1
R130	Automatic Fixed Interval	352.13	0.001	0.04	Trapezoid	24.4	1
R140	Automatic Fixed Interval	2863.9	0.002394	0.04	Trapezoid	19	1
R150	Automatic Fixed Interval	1248.8	0.000458	0.04	Trapezoid	19.4	1
R190	Automatic Fixed Interval	1667.8	0.000469	0.04	Trapezoid	17.7	1
R210	Automatic Fixed Interval	3607.5	0.000458	0.04	Trapezoid	23.1	1
R230	Automatic Fixed Interval	4821.4	0.001234	0.04	Trapezoid	27	1
R270	Automatic Fixed Interval	9996.9	0.001159	0.04	Trapezoid	27.6	1
R30	Automatic Fixed Interval	5501.9	0.002086	0.04	Trapezoid	41.4	1
R50	Automatic Fixed Interval	6523.3	0.000595	0.04	Trapezoid	23.4	1
R60	Automatic Fixed Interval	799.41	0.003177	0.04	Trapezoid	23.8	1
R70	Automatic Fixed Interval	1512.9	0.000103	0.04	Trapezoid	56	1
R80	Automatic Fixed Interval	213.14	0.012559	0.04	Trapezoid	15.5	1

Annex 11. Quiaoit Field Validation Points

Table A-11.1. Quiaoi Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	18.014104	120.537966	0.062	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
2	18.033609	120.560309	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
3	18.050412	120.559134	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
4	18.050623	120.568833	1.833	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
5	18.050623	120.568833	1.833	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
6	18.050623	120.568833	1.833	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
7	18.050623	120.568833	1.833	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
8	18.051011	120.582177	1.178	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
9	18.051011	120.582177	1.178	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
10	18.051011	120.582177	1.178	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
11	18.051011	120.582177	1.178	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
12	18.051575	120.555996	1.561	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
13	18.01422	120.540065	0.44	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
14	18.051575	120.555996	1.561	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
15	18.051831	120.534041	0.701	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
16	18.052091	120.531939	0.862	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
17	18.052926	120.569551	1.82	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
18	18.052926	120.569551	1.82	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
19	18.052926	120.569551	1.82	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
20	18.052926	120.569551	1.82	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
21	18.053053	120.544748	0.457	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
22	18.053369	120.534461	0.358	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
23	18.053734	120.506296	2.894	1.2192	1.486	Mario/ September 18-22, 2014	5- Year

24	18.01422	120.540065	0.44	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
25	18.054418	120.516262	0.031	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
26	18.055146	120.532753	0.399	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
27	18.055265	120.573603	0.624	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
28	18.055265	120.573603	0.624	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
29	18.055265	120.573603	0.624	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
30	18.055265	120.573603	0.624	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
31	18.056568	120.558741	0.031	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
32	18.056568	120.558741	0.031	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
33	18.051177	120.562356	0.102	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
34	18.056568	120.558741	0.031	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
35	18.056568	120.558741	0.031	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
36	18.056597	120.566125	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
37	18.056597	120.566125	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
38	18.057622	120.513497	0.578	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
39	18.057947	120.563635	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
40	18.057947	120.563635	0.03	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
41	18.057947	120.563635	0.03	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
42	18.057947	120.563635	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
43	18.059574	120.561376	0.062	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
44	18.051177	120.562356	0.102	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
45	18.060267	120.563454	0.213	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
46	18.060629	120.560648	0.495	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
47	18.059272	120.563219	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
48	18.059483	120.521602	0.756	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
49	18.059591	120.512167	0.032	1.2192	1.486	Mario/ September 18-22, 2014	5- Year

50	18.059858	120.514945	0.646	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
51	18.056618	120.585426	0.031	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
52	18.056618	120.585426	0.031	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
53	18.060774	120.518415	0.189	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
54	18.060974	120.554285	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
55	18.051704	120.561506	0.24	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
56	18.060974	120.554285	0.03	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
57	18.060974	120.554285	0.03	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
58	18.060974	120.554285	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
59	18.061137	120.592826	0.869	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
60	18.061137	120.592826	0.869	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
61	18.06143	120.562018	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
62	18.06143	120.562018	0.03	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
63	18.06143	120.562018	0.03	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
64	18.06143	120.562018	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
65	18.061434	120.492275	0.119	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
66	18.051704	120.561506	0.24	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
67	18.06154	120.533813	0.486	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
68	18.061548	120.522078	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
69	18.062025	120.536647	0.226	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
70	18.062334	120.505027	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
71	18.062741	120.543264	0.107	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
72	18.063613	120.535233	0.242	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
73	18.064167	120.507521	0.901	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
74	18.064215	120.561537	1.894	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
75	18.064215	120.561537	1.894	0.6096	0.372	Mario/ September 18-22, 2014	5- Year

76	18.064215	120.561537	1.894	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
77	18.052804	120.561147	0.061	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
78	18.064215	120.561537	1.894	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
79	18.064215	120.561537	1.894	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
80	18.064215	120.561537	1.894	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
81	18.064502	120.516775	0.155	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
82	18.0647	120.504356	0.646	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
83	18.065978	120.520669	0.63	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
84	18.066477	120.536417	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
85	18.066627	120.510005	0.713	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
86	18.066865	120.587676	0.491	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
87	18.066865	120.587676	0.491	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
88	18.052804	120.561147	0.061	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
89	18.066865	120.587676	0.491	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
90	18.066865	120.587676	0.491	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
91	18.067197	120.542582	0.131	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
92	18.067743	120.593411	0.293	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
93	18.067743	120.593411	0.293	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
94	18.067743	120.593411	0.293	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
95	18.067743	120.593411	0.293	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
96	18.068548	120.527593	0.742	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
97	18.07102	120.543142	0.308	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
98	18.030107	120.559447	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
99	18.070098	120.513753	0.876	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
100	18.070399	120.598028	0.354	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
101	18.070399	120.598028	0.354	0.6096	0.372	Mario/ September 18-22, 2014	5- Year

102	18.070399	120.598028	0.354	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
103	18.070399	120.598028	0.354	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
104	18.06662	120.599074	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
105	18.06662	120.599074	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
106	18.071716	120.497125	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
107	18.073293	120.576697	0.767	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
108	18.073293	120.576697	0.767	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
109	18.014104	120.537966	0.062	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
110	18.030107	120.559447	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
111	18.073293	120.576697	0.767	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
112	18.073293	120.576697	0.767	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
113	18.073677	120.512668	0.141	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
114	18.075724	120.583179	1.758	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
115	18.075724	120.583179	1.758	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
116	18.075724	120.583179	1.758	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
117	18.075724	120.583179	1.758	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
118	18.076063	120.534153	1.759	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
119	18.076442	120.58107	1.686	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
120	18.076442	120.58107	1.686	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
121	18.054278	120.561939	0.221	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
122	18.076442	120.58107	1.686	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
123	18.076442	120.58107	1.686	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
124	18.066531	120.559409	0.338	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
125	18.076593	120.556545	0.031	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
126	18.07715	120.580311	1.992	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
127	18.07715	120.580311	1.992	0.6096	0.372	Mario/ September 18-22, 2014	5- Year

128	18.07715	120.580311	1.992	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
129	18.07715	120.580311	1.992	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
130	18.07751	120.586153	2.385	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
131	18.07751	120.586153	2.385	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
132	18.054278	120.561939	0.221	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
133	18.07751	120.586153	2.385	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
134	18.07751	120.586153	2.385	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
135	18.069933	120.596421	1.078	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
136	18.069933	120.596421	1.078	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
137	18.077897	120.542362	0.5	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
138	18.079063	120.584258	2.352	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
139	18.079063	120.584258	2.352	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
140	18.079063	120.584258	2.352	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
141	18.079063	120.584258	2.352	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
142	18.080183	120.564978	2.95	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
143	18.054445	120.563342	0.056	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
144	18.080183	120.564978	2.95	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
145	18.080183	120.564978	2.95	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
146	18.080183	120.564978	2.95	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
147	18.077417	120.484705	0.066	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
148	18.084043	120.541462	1.708	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
149	18.085592	120.567527	2.283	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
150	18.085592	120.567527	2.283	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
151	18.085592	120.567527	2.283	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
152	18.085592	120.567527	2.283	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
153	18.086032	120.516307	0.828	1.2192	1.486	Mario/ September 18-22, 2014	5- Year

154	18.054445	120.563342	0.056	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
155	18.086331	120.520583	0.039	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
156	18.087295	120.511972	0.683	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
157	18.087842	120.587763	1.559	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
158	18.087842	120.587763	1.559	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
159	18.087842	120.587763	1.559	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
160	18.087842	120.587763	1.559	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
161	18.074792	120.535968	0.176	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
162	18.088325	120.5456	1.527	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
163	18.089485	120.51278	0.802	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
164	18.089701	120.499699	0.044	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
165	18.055017	120.561304	0.282	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
166	18.091649	120.501833	0.347	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
167	18.087264	120.592226	0.032	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
168	18.087264	120.592226	0.032	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
169	18.094765	120.506237	0.263	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
170	18.095013	120.506983	0.351	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
171	18.073474	120.54273	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
172	18.108287	120.568463	0.801	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
173	18.108287	120.568463	0.801	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
174	18.108287	120.568463	0.801	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
175	18.108287	120.568463	0.801	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
176	18.055017	120.561304	0.282	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
177	18.07402	120.540549	0.137	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
178	18.102744	120.568939	0.065	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
179	18.102744	120.568939	0.065	0.6096	0.372	Mario/ September 18-22, 2014	5- Year

180	18.102744	120.568939	0.065	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
181	18.102744	120.568939	0.065	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
182	18.106475	120.569604	0.031	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
183	18.104428	120.566067	0.093	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
184	18.104428	120.566067	0.093	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
185	18.104428	120.566067	0.093	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
186	18.104428	120.566067	0.093	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
187	18.056393	120.561441	0.226	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
188	18.104699	120.568607	0.407	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
189	18.104699	120.568607	0.407	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
190	18.104699	120.568607	0.407	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
191	18.104699	120.568607	0.407	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
192	18.105443	120.566953	0.367	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
193	18.105443	120.566953	0.367	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
194	18.105443	120.566953	0.367	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
195	18.105443	120.566953	0.367	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
196	18.094871	120.499619	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
197	18.093527	120.499431	0.03	0.4572	0.209	10/04/2009	5- Year
198	18.056393	120.561441	0.226	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
199	18.093527	120.499431	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
200	18.105655	120.584798	0.128	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
201	18.105655	120.584798	0.128	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
202	18.105655	120.584798	0.128	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
203	18.105655	120.584798	0.128	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
204	18.113263	120.561822	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
205	18.113263	120.561822	0.03	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
206	18.113263	120.561822	0.03	0.9144	0.836	Mario/ September 18-22, 2014	5- Year

207	18.113263	120.561822	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
208	18.092795	120.510843	0.051	0.4572	0.209	10/04/2009	5- Year
209	18.057154	120.560181	0.15	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
210	18.092795	120.510843	0.051	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
211	18.087603	120.517118	0.376	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
212	18.087603	120.517118	0.376	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
213	18.017866	120.535452	0.031	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
214	18.057154	120.560181	0.15	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
215	18.029332	120.574566	0.63	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
216	18.029332	120.574566	0.63	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
217	18.027707	120.57281	0.031	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
218	18.027707	120.57281	0.031	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
219	18.028902	120.562381	0.885	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
220	18.028902	120.562381	0.885	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
221	18.029643	120.561902	0.961	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
222	18.029643	120.561902	0.961	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
223	18.031164	120.561725	0.514	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
224	18.017866	120.535452	0.031	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
225	18.031164	120.561725	0.514	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
226	18.032582	120.562861	1	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
227	18.032582	120.562861	1	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
228	18.033484	120.560913	0.031	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
229	18.033484	120.560913	0.031	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
230	18.01866	120.560336	6.854	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
231	18.01866	120.560336	6.854	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
232	18.018681	120.540315	1.039	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
233	18.018681	120.540315	1.039	0.9144	0.836	Mina/ November 24-27, 2007	5- Year

234	18.015722	120.537989	0.06	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
235	18.028344	120.538023	1.043	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
236	18.028344	120.538023	1.043	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
237	18.044987	120.594725	0.544	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
238	18.044987	120.594725	0.544	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
239	18.039527	120.515442	0.065	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
240	18.032528	120.554877	0.032	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
241	18.032528	120.554877	0.032	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
242	18.032841	120.581162	1.371	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
243	18.032841	120.581162	1.371	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
244	18.015722	120.537989	0.06	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
245	18.0336	120.527793	0.273	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
246	18.034864	120.525789	0.293	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
247	18.03507	120.545552	0.825	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
248	18.03507	120.545552	0.825	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
249	18.035638	120.541737	0.898	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
250	18.035638	120.541737	0.898	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
251	18.03596	120.527385	0.608	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
252	18.041639	120.516348	0.031	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
253	18.036978	120.522912	0.378	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
254	18.043454	120.518121	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
255	18.015765	120.539081	0.143	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
256	18.042317	120.518887	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
257	18.046844	120.519872	0.03	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
258	18.045034	120.519352	0.346	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
259	18.044624	120.605162	0.179	0.6096	0.372	Mina/ November 24-27, 2007	5- Year

260	18.044624	120.605162	0.179	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
261	18.045142	120.537957	0.757	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
262	18.045686	120.54235	0.343	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
263	18.046134	120.537044	0.752	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
264	18.046176	120.501713	0.032	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
265	18.046644	120.567213	0.78	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
266	18.015765	120.539081	0.143	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
267	18.046644	120.567213	0.78	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
268	18.046644	120.567213	0.78	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
269	18.046644	120.567213	0.78	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
270	18.048103	120.539639	0.852	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
271	18.048272	120.591967	0.977	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
272	18.048272	120.591967	0.977	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
273	18.052164	120.599814	0.438	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
274	18.052164	120.599814	0.438	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
275	18.048767	120.54226	0.334	1.2192	1.486	Mario/ September 18-22, 2014	5- Year
276	18.049436	120.563295	0.293	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
277	18.033609	120.560309	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
278	18.049436	120.563295	0.293	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
279	18.049436	120.563295	0.293	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
280	18.049436	120.563295	0.293	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
281	18.04989	120.561264	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year
282	18.04989	120.561264	0.03	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
283	18.04989	120.561264	0.03	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
284	18.04989	120.561264	0.03	0.9144	0.836	Mina/ November 24-27, 2007	5- Year
285	18.050412	120.559134	0.03	0.6096	0.372	Mina/ November 24-27, 2007	5- Year

286	18.050412	120.559134	0.03	0.6096	0.372	Mario/ September 18-22, 2014	5- Year
287	18.050412	120.559134	0.03	0.9144	0.836	Mario/ September 18-22, 2014	5- Year
				RMSE	0.971637		

Annex 12. Educational Institutions Affected by Flooding in Quiaoit Floodplain

Table A-12.1. Educational Institutions in Batac City, Ilocos Norte Affected by Flooding in Quiaoit Floodplain

Ilocos Norte				
Batac City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
EUREKA HIGH SCHOOL	Ablan Poblacion	Low	Low	Low
BATAC NATIONAL HIGH SCHOOL	Acosta Poblacion		Low	Low
BATAC NATIONAL HIGH SCHOOL	Acosta Poblacion		Low	Low
CATALINO ACOSTA MEMORIAL ELEMENTARY SCHOOL	Acosta Poblacion	Low	Medium	Medium
MARANATHA CHRISTIAN ACADEMY	Acosta Poblacion	Medium	High	High
BAAY ELEMENTARY SCHOOL	Baay			
BALIGAT ELEMENTARY SCHOOL	Baligat			
BIL-LOCA ELEMENTARY SCHOOL	Baligat	Low	Low	Low
BIL-LOCA ELEMENTARY SCHOOL	Bil-Loca		Low	Low
DARIWDIW ELEMENTARY SCHOOL	Bil-Loca			
DARIWDIW ELEMENTARY SCHOOL	Bil-Loca			
BATAC NATIONAL HIGH SCHOOL	Bungon			
NAGUIRANGAN-CAPACUAN ELEMENTARY SCHOOL	Capacuan			
EXECUTIVE GUEST HOUSE	Caunayan		Low	Low
MMSU SCIENCE ELEMENTARY	Caunayan		Low	Low
UNIVERSITY MANSION	Caunayan			
COLO-MABALENG ELEMENTARY SCHOOL	Colo	High	High	High
NAGBACALAN ELEMENTARY SCHOOL	Dariwdiw			
BENIGNO MACADAEG MEM. ES	Palongpong			
CARPENTRY VISUAL ARTS	Quiling Sur			
COLLEGE OF BUSINESS ECONOMICS AND ACCOUNTANCY	Quiling Sur	Low	Low	Low
COLLEGE OF BUSINESS ECONOMICS AND ACCOUNTANCY	Quiling Sur			Low
LABORATORY HIGH SCHOOL	Quiling Sur		Low	Low
MARIANO MARCOS STATE UNIVERSITY	Quiling Sur	Low	Low	Medium
MMSU	Quiling Sur			Low
MMSU COLLEGE OF AGRICULTURE AND FORESTRY	Quiling Sur			
MMSU COLLEGE OF LAW	Quiling Sur			
MMSU GUARDHOUSE	Quiling Sur			Low
MMSU LAGOON	Quiling Sur			Low
MMSU SCIENCE ELEMENTARY	Quiling Sur	Low	Low	Medium
MMSU SWIMMING POOL	Quiling Sur			
MMSU-CAFSD	Quiling Sur		Low	Low

RAYURAY ELEMENTARY SCHOOL	Rayuray			
BATAC JUNIOR COLLEGE	Ricarte Poblacion	Low	Medium	Medium
BATAC JUNIOR COLLEGE	Ricarte Poblacion	Low	Medium	Medium
CARPENTRY VISUAL ARTS	San Julian			
DEPARTMENT OF PHYSICAL THERAPY	San Julian			
MARIANO MARCOS STATE UNIVERSITY	San Julian			
MMSU NATIONAL TRAINING CENTER	San Julian			
NURSING ARTS LABORATORY	San Julian			
SAN MATEO ELEMENTARY SCHOOL	San Mateo			
HILARIO VALDEZ MEM. ELEM. SCHOOL	Suabit	Low	Medium	Medium
HILARIO VALDEZ MEMORIAL ELEMENTARY SCHOOL	Suabit	Medium	Medium	Medium
TABUG ELEMENTARY SCHOOL	Tabug	Low	Low	Low
BATAC JUNIOR COLLEGE	Valdez Poblacion	Low	Medium	Medium
ICA	Valdez Poblacion			Low
IMMACULATE CONCEPCION ACADEMY	Valdez Poblacion	Low	Medium	Medium
MARIANO MARCOS MEMORIAL ELEMENTARY SCHOOL	Valdez Poblacion		Low	Medium
MARIANO MARCOS MEMORIAL ELEMENTARY SCHOOL	Valdez Poblacion		Low	Medium
MMMES	Valdez Poblacion	Low	Medium	Medium

Table A-12.2. Educational Institutions in Currimao, Ilocos Norte Affected by Flooding in Quiaoit Floodplain

Currimao				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BIMMAGA ELEMENTARY SCHOOL	Bimmanga			
BIMMAGA, CURRIMAO DAY CARE CENTER	Bimmanga	Low	Low	Low
MONTE PS	Tapao-Tigue			

Table A-12.3. Educational Institutions in Paoay, Ilocos Norte Affected by Flooding in Quiaoit Floodplain

Paoay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BACSIL PRIMARY SCHOOL	Bacsil			
CONTINUING EDUCATION AND TRAINING CENTER	Cabangaran			
MARIANO MARCOS STATE UNIVERSITY	Cabangaran			
MMSU COLLEGE OF ARTS AND SCIENCES	Cabangaran			
MMSU COLLEGE OF ENGINEERING	Cabangaran	Low	Medium	Medium
MMSU LIBRARY	Cabangaran	Low	Low	Low

MMSU-CAFSD	Cabangaran			
MMSU-COE	Cabangaran	Low	Medium	Medium
SALBANG ELEMENTARY SCHOOL	Cabangaran		Low	Medium
PAGULUDAN PS	Cayubog	Low	Medium	High
MARIANO MARCOS STATE UNIVERSITY - COLLEGE OF INDUSTRIAL TECHNOLOGY	Dolores	Low	Medium	Medium
PAOAY CENTRAL ELEMENTARY SCHOOL	Dolores		Medium	Medium
PAOAY NATIONAL HIGH SCHOOL	Dolores		Medium	Medium
PAOAY NATIONAL HIGHSCHOOL	Dolores		Medium	Medium
MUMULAAN PRIMARY SCHOOL	Mumulaan		Low	Low
NALASIN ELEMENTARY SCHOOL	Nalasin			Medium
MALAGUIP INTEGRATED SCHOOL	Oaig-Upay-Abulao		Low	Medium
PASIL ELEMENTARY SCHOOL	Pasil			
CONTINUING EDUCATION AND TRAINING CENTER	Salbang			
CONTINUING EDUCATION AND TRAINING CENTER - MINI TEATRO	Salbang			
MMSU LIBRARY	Salbang		Low	Low
QUILING ELEMENTARY SCHOOL	Salbang			
NALASIN ELEMENTARY SCHOOL	San Roque		Low	Medium
EVANGELISTA ELEMENTARY SCHOOL	Santa Rita			
PAOAY EAST CENTRAL ELEMENTARY SCHOOL	Santa Rita	Medium	High	High
PAOAY NATIONAL HIGH SCHOOL	Santa Rita			
PAOAY NATIONAL HIGH SCHOOL	Santa Rita			

Annex 13. Health Institutions Affected in Quiaoit Floodplain

Table A-13.1. Health Institutions in Batac City, Ilocos Norte Affected by Flooding in Quiaoit Floodplain

Ilocos Norte				
Batac City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
MARIANO MARCOS MEMORIAL MEDICAL CENTER	Callaguip			
GAOAT GENERAL HOSPITAL	Palpalicong	Low	Medium	Medium
MMSU CLINIC	Quiling Sur			Low
MARIANO MARCOS MEMORIAL MEDICAL CENTER	San Julian	Low	Low	Low
MARIANO MARCOS MEMORIAL MEDICAL CENTER	San Julian			
MARIANO MARCOS MEMORIAL MEDICAL HOSPITAL	San Julian			
BATAC MATERNAL AND CHILD HEALTH CARE UNIT	Suabit	Low	Medium	Medium
BATAC MUNICIPAL HEALTH OFFICE	Suabit		Medium	Medium
NORTHMED CLINIC	Valdez Poblacion			

Table A-13.2. Health Institutions in Currimao, Ilocos Norte Affected by Flooding in Quiaoit Floodplain

Currimao				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BIMMANGA HEALTH CENTER	Bimmanga	Low	Low	Low