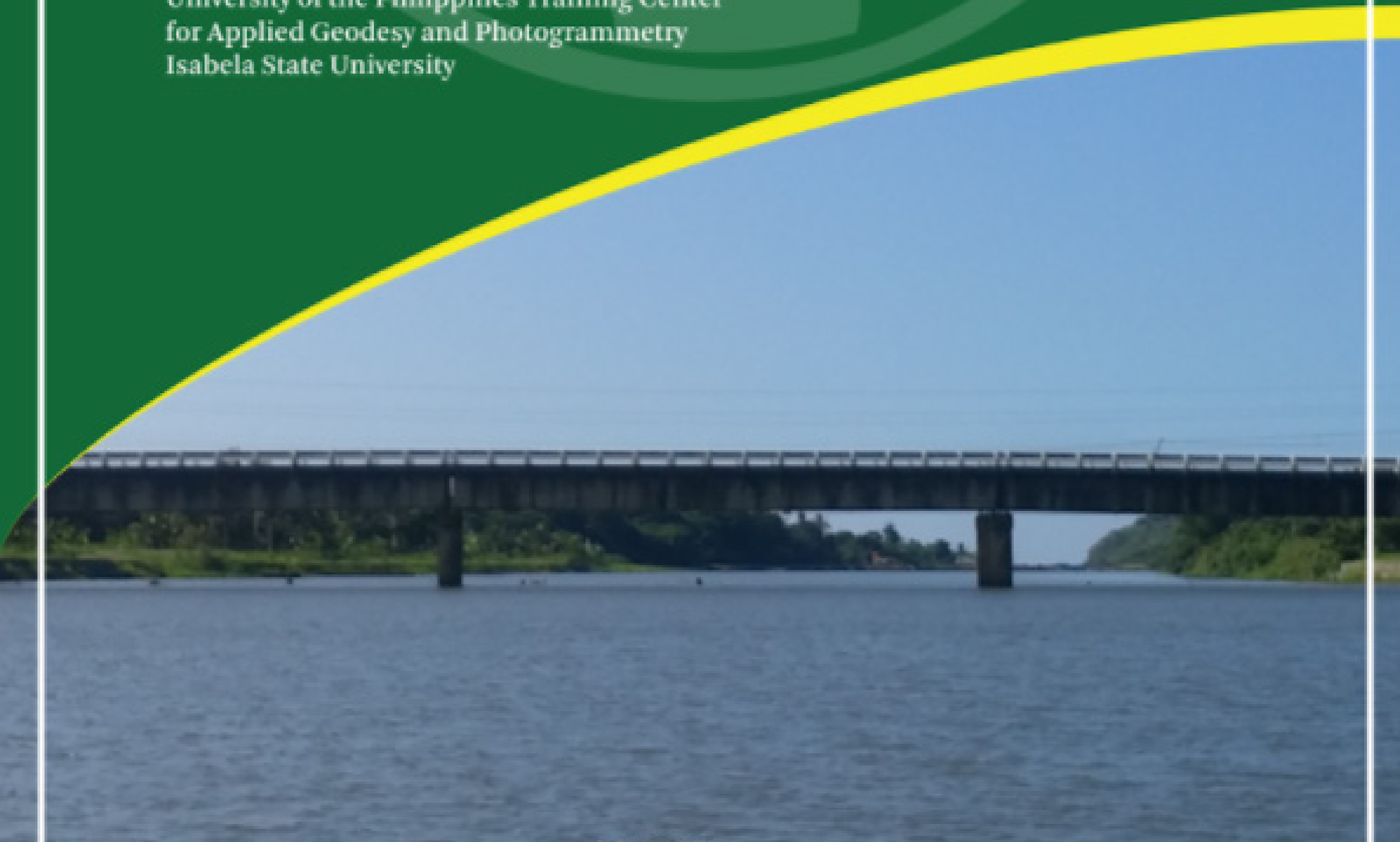
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Cabicungan River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
Isabela State University



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CABICUNGAN RIVER

Enrico C. Paringit, Dr. Eng.,and Dr. Roland Emerito S. Otadoy

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at a 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 a 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 the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Isabela State University (ISU) ISU 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 ten (10) river basins in the Cagayan Region. The university is located in Echague in the province of Isabela.

1.2 Overview of the Cabicungan River Basin

The Cabicungan River Basin (Figure 1) covers six (6) municipalities, namely: Claveria and Sta. Praxedes in the province of Cagayan; Calanasan and Luna in the province of Apayao; and Pagudpud and Adams in the province of Ilocos Norte.. The Department of Environment and Natural Resources (DENR) River Basin Control Office (RBCO) identified the basin to have a drainage area of 244 km2, and an estimated 517 million cubic meters (MCM) in annual run-off (RBCO, 2015). The basin's main stem, the Cabicungan River, is part of the ten (10) river systems in the Cagayan Region. The river traverses a total length of about 36.56 kilometers (km), from the Municipality of Calanasan to the Municipality of Claveria. The river basin is bounded by the Caraballo Mountains, where most of its drainage waters are channeled through.

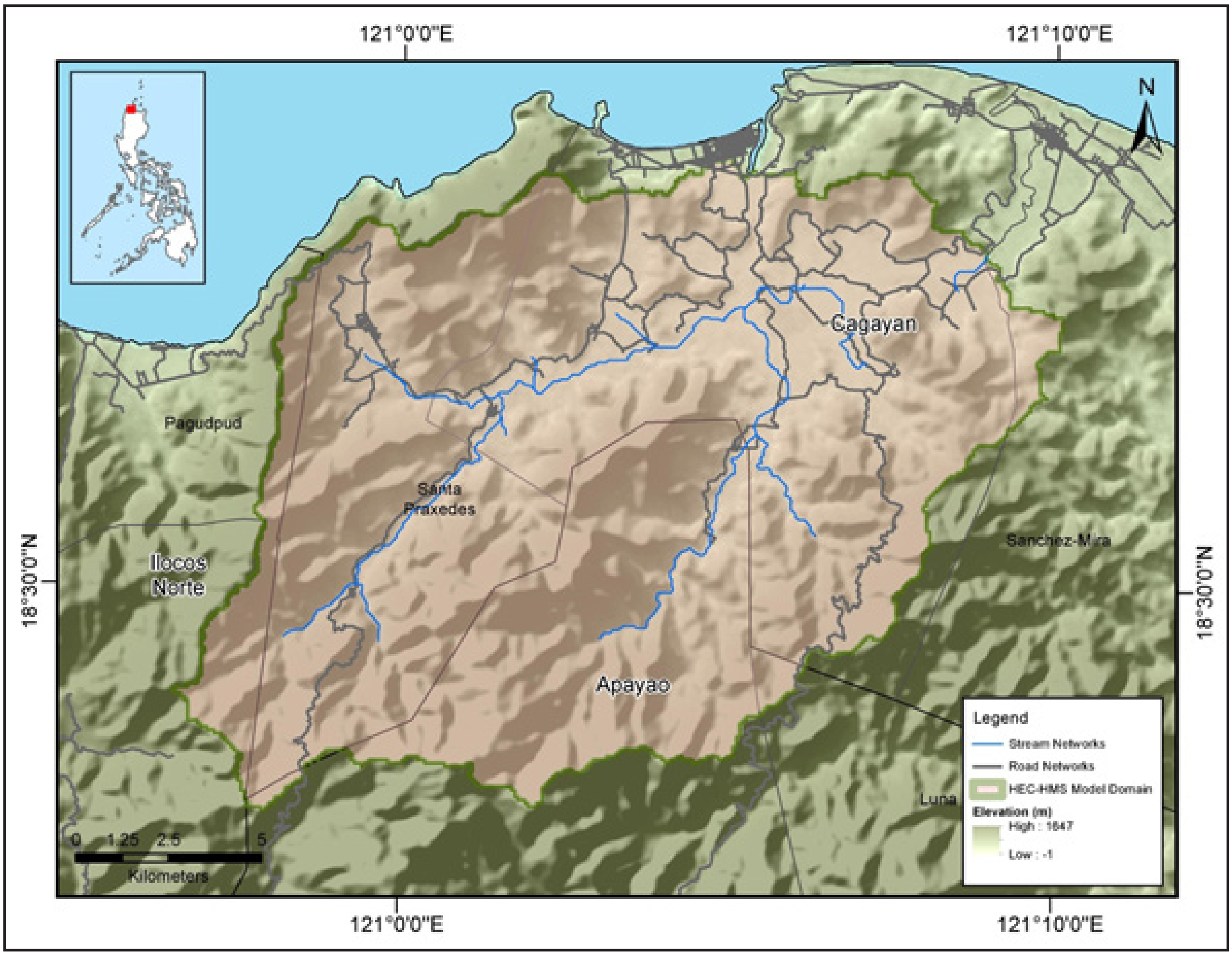


Figure 1. Location map of the Cabicungan River Basin (in brown)

According to the 2015 national census of the National Statistics Office (NSO), the total population of residents within the watershed is 44,822, with 35.54% (or 15,930 persons) living along the Cabicungan River. This community within the immediate vicinity of the river is distributed among the following barangays in the Municipality of Claveria in the province of Cagayan: Bacsay Cataraoan Norte and Sur, Bilibigao, Cadcadir East and West, Capanikian, Centro I, II, III, V, VII, and VIII, Dibalio, Alimoan, Lablabig, Nagsabaran, Pinas, San Antonio, San Vicente, Santa Maria, Tabbugan, Union, and Santa Filomena.

Cagayan is a vast expanse of plains and valleys, bordered by mountains that run from the north to the south both of its eastern and western embankments. Due to its unique topography, the Cagayan province carries three distinct types of climate – Type I, Type II, and Type III. Type I climate prevails in the Municipality of Santa Praxedes and in the western portion of the Municipality of Claveria. This climate type bears two (2) pronounced seasons: wet and dry. The wet season occurs in the months of May to October; and it is dry for the rest of the year. Type III climate is experienced in the eastern part of the Sierra Madre Mountains and in the Babuyan group of islands, where rainfall is evenly distributed throughout the year due to the northeast trade winds. The rest of the province, which consists of the valley floor, has the Type II climate. This climate type is characterized as having no pronounced season. It is relatively wet from May to October, and maximum rain periods are not very pronounced. Under this climate type, the dry season is very brief, lasting only from one to three months in a year.

Claveria, where the mouth of the Cabicungan River is located, is a third-class municipality in the province of Cagayan. It is situated in the northwestern part of the province, along with the Municipality of Sta. Praxedes. Fishing is the primary source of income in the municipality (Lancion and de Guzman, 1995). Claveria is known for its beautiful sceneries and vast natural resources. The municipality's famous attractions include its beaches that offer long stretches of black fine sand, and the Taggat Lagoon, characterized by its preserved, natural charm and fishing boats. The Hatchery for High Value Species of Marine Products operated by the Bureau of Fisheries and Aquatic Resources (BFAR) is located in the area, which is open for public viewing and for educational trips. Also part of Claveria's natural features are mangrove areas of around 45 hectares, mainly comprised of Nypa fruticans (nipa) and Ceriops Tagal (Tangal). The mangroves are found in Barangays Centro IV, Centro V, Centro VI, Centro VII, Pinas, Santa Maria, Dibalio, D. Leaño, Pata West, Pata East, and Magdalena – particularly along the Cabicungan River, the Pata River, and their tributaries. Most of these areas have been converted into settlements, fishponds and agricultural land (e.g., for rice, vegetables, and coconut). About one hectare was eroded into the rivers; and some areas remain uncultivated. Previously, there were about 17.5 hectares of mangrove areas within alienable and disposable lands in Barangay Pata East, but some have already been privately titled and utilized for the establishment of fishponds and rice production. On the other hand, some portions are under the stewardship of the BFAR, maintained for research and production purposes. Furthermore, Claveria and Sta. Praxedes are among the eight (8) municipalities declared as Marine Protected Areas in the province of Cagayan.

Calanasan, where the river stem begins, is a first-class municipality in the province of Apayao that covers the northern tip of the Cordillera Range. In the past, some scientists believed that the environment in this end of the mountain range was unsuitable for Philippine eagles. But recently, the Philippine Eagle Foundation (PEF) and the DENR have confirmed that eagles do thrive in the northern Cordillera Mountains. To preserve the wildlife and endangered species in this area, Eleanor Bulut-Begtang, Apayao congresswoman and former Calanasan mayor of nine years, institutionalized an indigenous method of protecting endangered wildlife in the area, called the "Lapat" Isnag custom. Under the "Lapat" practice, a specific area is established as sacred land – either by the people's selection or after the death of the area's owner or occupant – deeming the area as off-limits from the public.

Lately, Northern Cagayan has been devastated by strong typhoons. Two of the most severe were Typhoon Pepeng (International name, Parma) in October 2009 and Typhoon Ineng (International name, Goni) in August 2015.

Typhoon Pepeng devastated 5,486 barangays in 334 municipalities and 33 cities, in 27 provinces, in Regions I, II, III, V, VI, the Cordillera Administrative Region (CAR), and the National Capital Region (NCR). The number of individuals affected by the storm amounted to 4,478,284 persons (or 954,087 families) per Region. A total of 3,258 families, or 14,892 persons, camped in 54 evacuation centers. Casualties were 465 dead, 207 injured, and 47 missing. Reported deaths in the CAR were mainly caused by landslides; while those in other regions were due to drowning. The typhoon damaged a total of 61,869 houses (6,807 totally and 55,062 partially). The estimated cost of damages to infrastructure and agriculture was PHP 27.297 billion – PHP 6.799 billion to schools and health establishments; PHP 20.495 billion to agriculture; and PHP 0.003 billion to private property. Devastation in agricultural areas of 428,034 hectares incurred losses of 1,052.993 metric tons of crops, including rice, corn, high-value commercial crops, and abaca, as well as irrigation facilities. Damages to 1,531 education facilities (1,280 elementary schools and 251 high schools) in Regions I, II, III, V and CAR totaled PHP 767.45 million.

Typhoon Ineng affected the extreme Northern Luzon region, placing the Batanes Group of Islands and Northern Cagayan, including Calayan and the Babuyan Group of Islands, under Storm Signal No. 3. Typhoon Ineng enhanced the southwest monsoon, bringing heavy monsoon rains in the Ilocos Region, the CAR, NCR, Region IV-A (CALABARZON), and Region IV-B (MIMAROPA). Storm surges, floods, and soil erosions spawned by the typhoon displaced thousands of families, forcing them to seek refuge in different evacuation centers, such as gymnasiums, barangay halls, and schools (http://www.gov.ph/2015/08/25/effects-of-typhoon-ineng-as-of-6-a-m-august-25-2015, 2015). A total of 89,894 families were evacuated in the CAR, and Regions II, III, IV-A, and IV-B. 33 persons were reported dead, 24 were injured, and 7 were reported missing. Damages to infrastructure and agriculture in Regions I, II, III and CAR were estimated at PHP 4.547 billion.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CABICUNGAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Jasmine T. Alviar, and Darryl M. Austria

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

To initiate the LiDAR acquisition survey of the Cabicungan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in the Cagayan and Apayao provinces. These missions were planned for fourteen (14) lines and ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Pegasus LiDAR system was utilized for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 illustrates the flight plans for the Cabicungan floodplain.

Table 1. Flight planning parameters for the Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK1A	850	35	50	200	30	130	5
BLK1B	900	35	50	200	30	130	5

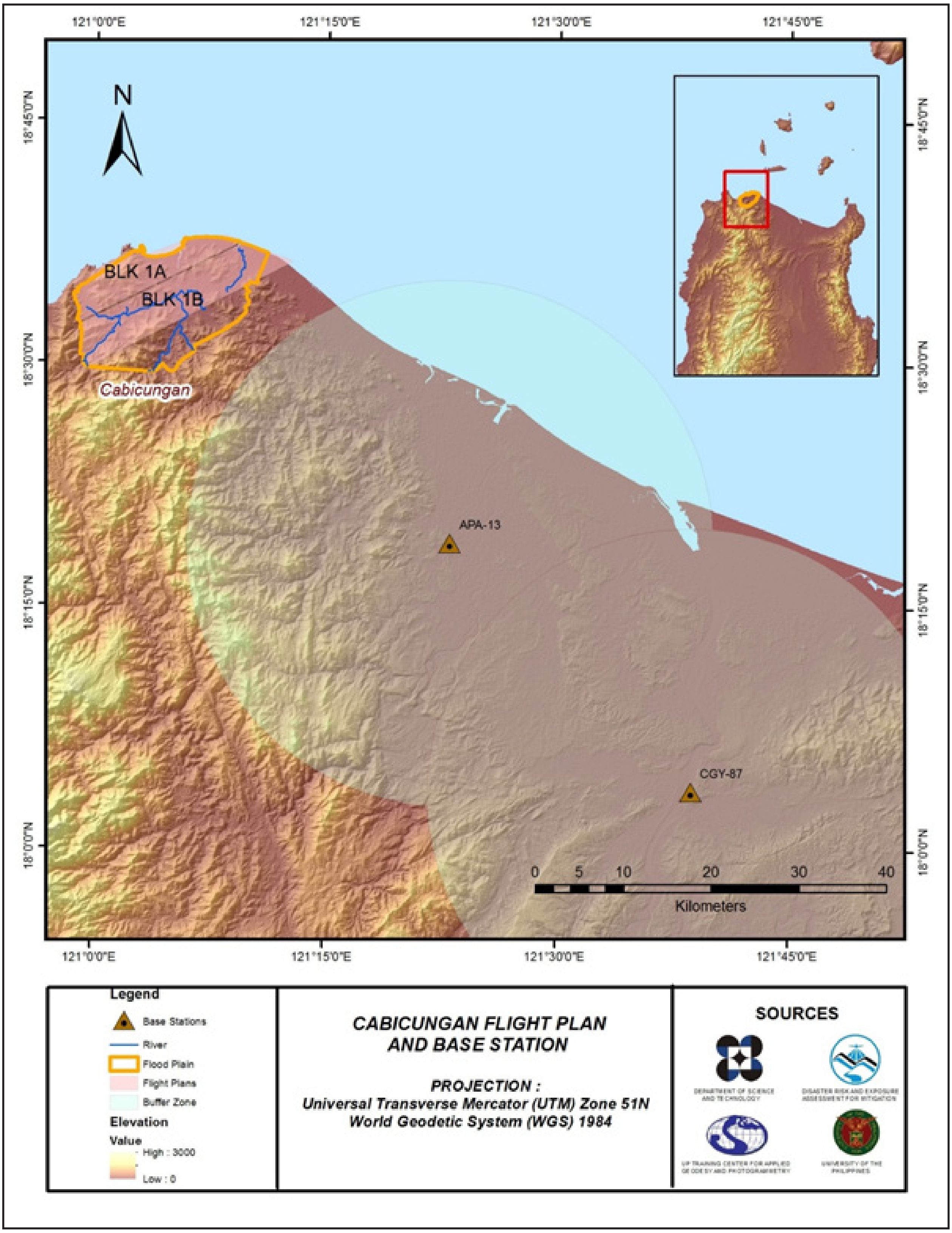


Figure 2. Flight plans and base stations used to cover the Cabicungan floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover two (2) NAMRIA horizontal reference points, APA-13 and CGY-87, which are of second (2nd) order accuracy. The certifications for the NAMRIA reference points are found in Annex 2. These were used as the base stations during the flight operations for the entire duration of the survey, held on November 19-20, 2014. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. The flight plans and locations of base stations used during the aerial LiDAR acquisition in the Cabicungan floodplain are shown in Figure 2. The composition of the full project team is shown in Annex 3.

Figure 3 to Figure 4 exhibit the recovered NAMRIA reference points within the area. Table 2 to Table 3 provide the details about the corresponding NAMRIA control stations. Table 4 lists all of the ground control points occupied during the acquisition, together with the dates of utilization.

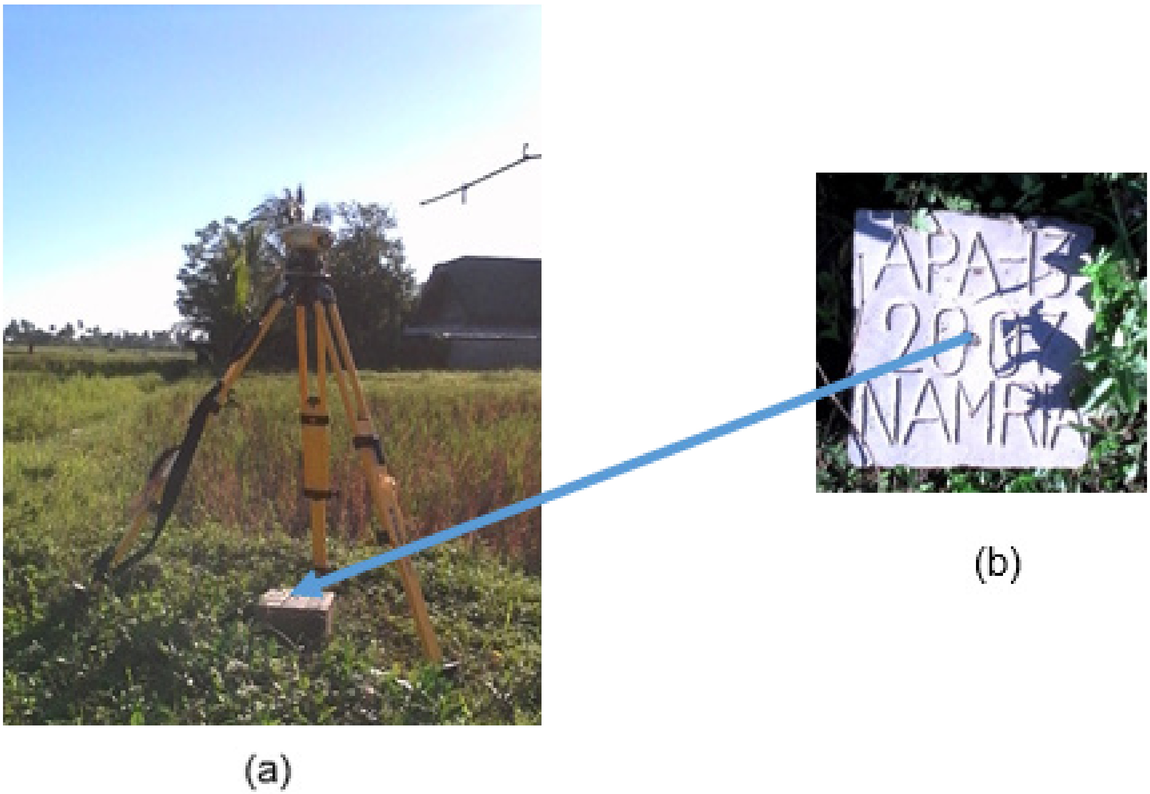
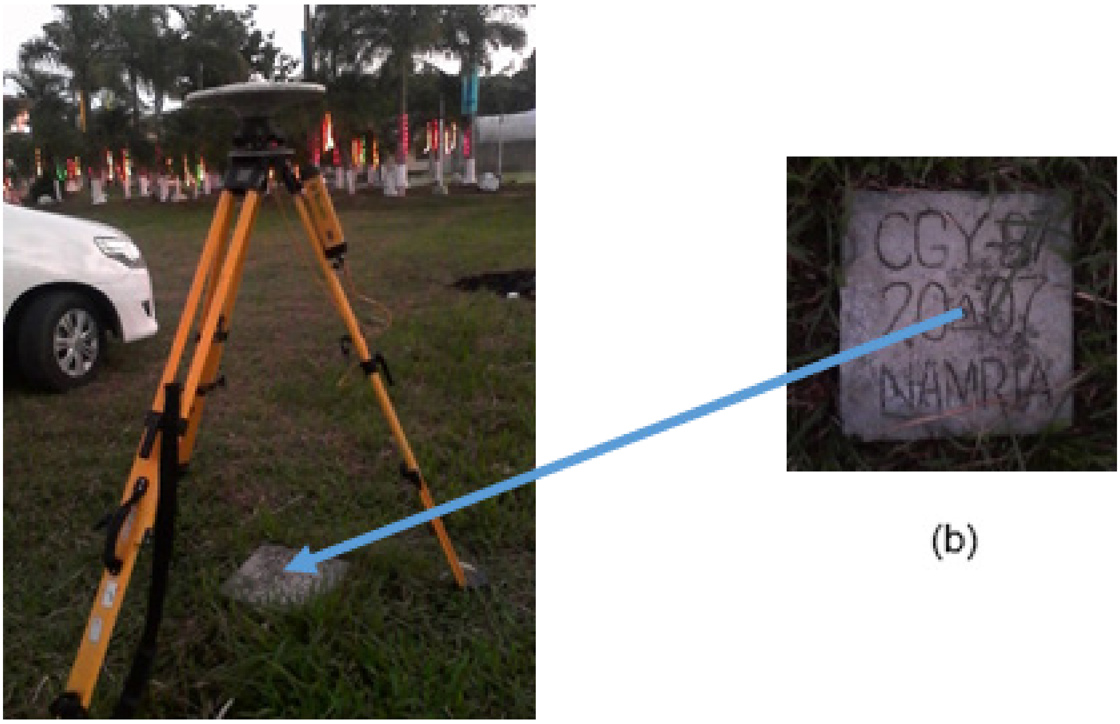


Figure 3. (a) GPS set-up over APA-13, located at the edge of the PCCP, 70 meters northeast of a waiting shed near the barangay hall in Tumog, Municipaity of Luna; and (b) NAMRIA reference point APA-13, as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point APA-13, used as a base station for the LiDAR acquisition

Station Name	APA-13	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18°19'2.39264" North 121°22'58.62210" East 17.98200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	540482.023 meters 2025924.156 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18°18'56.17679" North 121°23'3.20117" East 51.00500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North(UTM 51N PRS 1992)	Easting Northing	329102.89 meters 2025930.60 meters



(b)

(a)

Figure 4. (a) GPS set-up over CGY-87, located on a solar dryer at Barangay Cabayabasan, fronting the barangay hall in the Municipality of Lal-lo; and (b) NAMRIA reference point CGY-87, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point CGY-87, used as a base station for the LiDAR acquisition

Station Name	CGY-87	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 3' 46.30032"North 121° 38' 38.76326"East 37.21200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	568188.029 meters 1997837.978 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 3' 40.15861" North 121° 38' 43.36193" East 71.69600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	356498.94meters 1997546.44meters

Table 4. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 19, 2014	2870P	1BLK21AB323A	APA-13
November 20, 2014	2874P	1BLK21C324A	APA-13 & CGY-87

2.3 Flight Missions

A total of five (5) flight missions were conducted to complete the LiDAR data acquisition in the Cabicungan floodplain, for a total of seven hours and ten minutes (7+10) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. The flight logs of the missions are provided in Annex 5. Table 5 indicates the total area of actual coverage and the corresponding flying hours per mission; and Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for the LiDAR data acquisition in the Cabicungan 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
November 19, 2014	2870P	68.795	227.82	162.64	65.18	-	4	5
November 20, 2014	2874P	109.88	76.59	2.64	73.95	-	3	5
TOTAL		872.2	666.04	67.15	140.35	1368	15	19

Table 6. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2870P	900	30	50	200	30	130	5
2874P	850	30	50	200	30	130	5

2.4 Survey Coverage

The Cabicungan floodplain is located in the provinces of Cagayan, Apayao, and Ilocos Norte, with majority of the floodplain situated within the Municipality of Claveria in Cagayan. The Municipalities of Santa Praxedes, Claveria, and Lasam in Cagayan were mostly covered by the survey. The list of municipalities surveyed, with at least one (1) square kilometer coverage, is outlined in Table 7. The actual coverage of the LiDAR acquisition for the Cabicungan floodplain is presented in Figure 5. See Annex 6 for the flight status reports.

Table 7. List of municipalities and cities surveyed during Loboc floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Apayao	Calanasan	948.15	7.7	0.81
Cagayan	Santa Praxedes	86.19	37.08	43.02
	Claveria	161.25	112.39	69.70
	Sanchez-Mira	205.31	23.84	11.61
	Allacapan	252.24	26.28	10.42
	Lasam	215.36	31.53	14.64
	Lal-lo	760.44	15.82	2.08
Ilocos Norte	Pagudpud	194.15	5.87	3.02
Total		**2,823.09**	**260.51**	**9.23%**

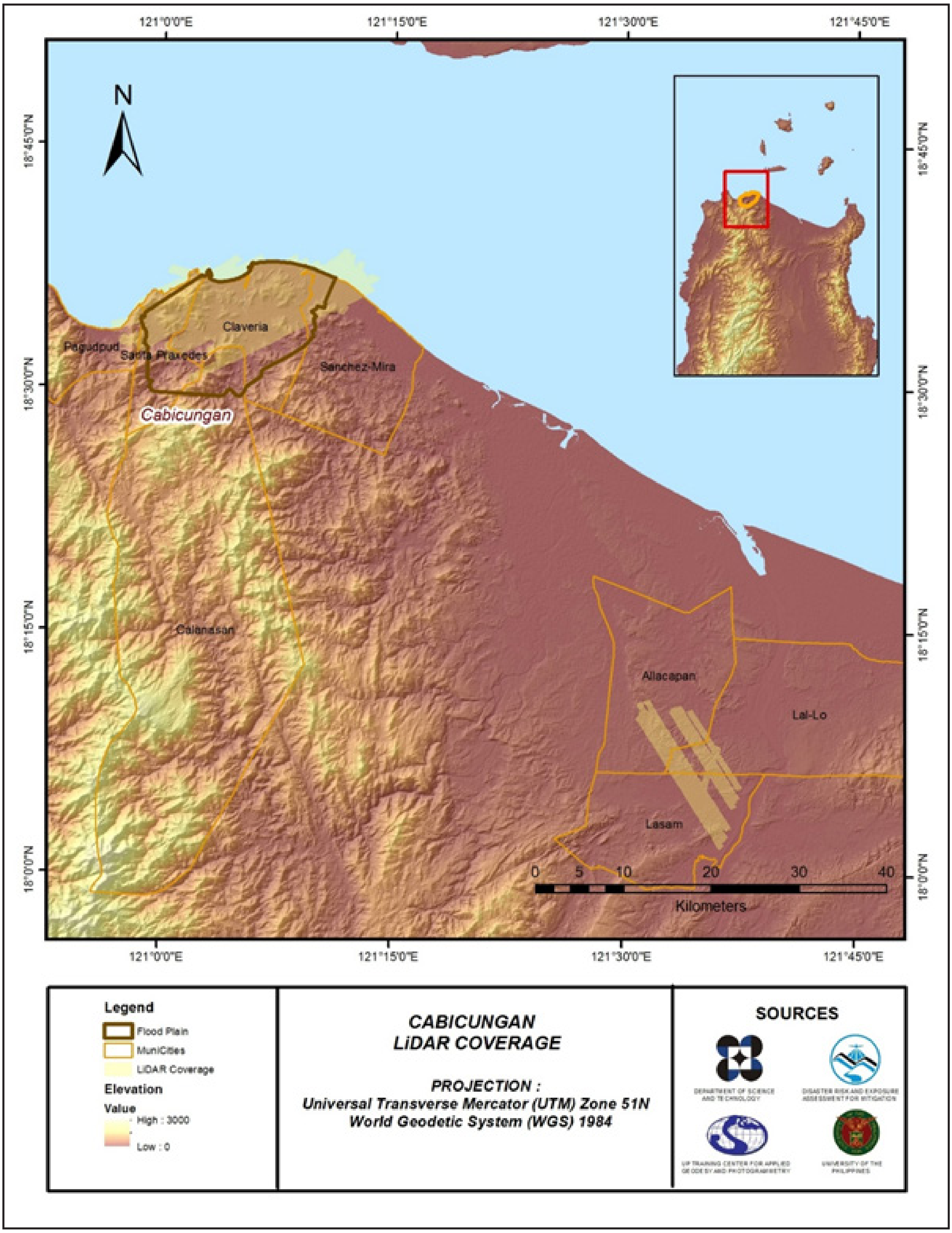


Figure 5. Actual LiDAR survey coverage of the Cabicungan floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE CABICUNGAN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Joida F. Prieto, Engr. Edgardo V. Gubatanga Jr., Engr. Analyn M. Naldo, Engr. Jovelle Anjeanette S. Canlas, Maria Tamsyn C. Malabanan, Engr. Don Matthew B. Banatin, and Engr. Sheila-Maye F. Santillan

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 DAC 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 the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and the vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

Using the elevation of points gathered from 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 (DVBC). 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 accomplished through the help of the georectified point clouds, and the metadata containing the time the image was captured.
These processes are summarized in the diagram in Figure 6.

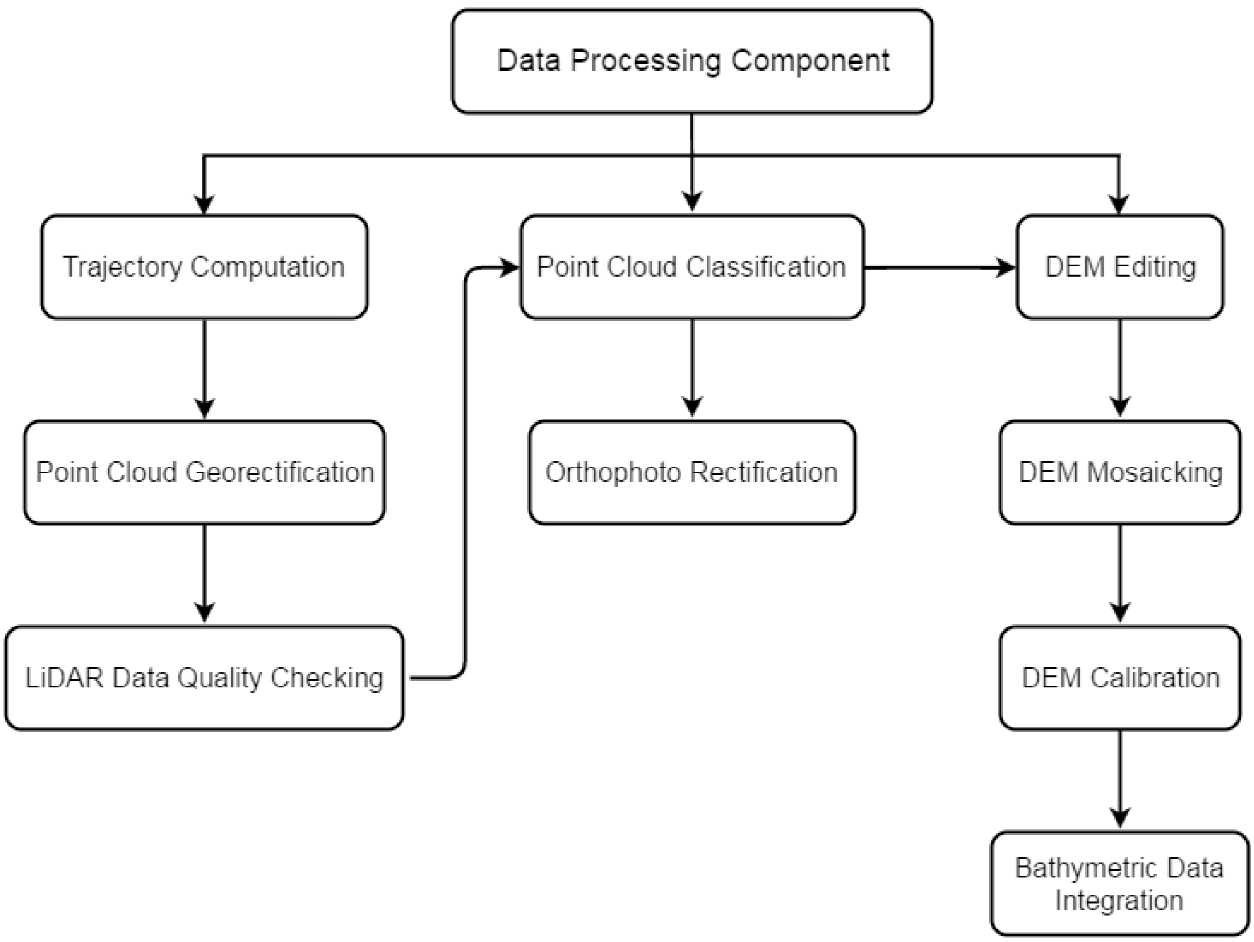


Figure 6. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Cabicungan floodplain can be found in Annex 4. Missions flown during the surveys conducted in November 2015 and January 2017 over Claveria, Cagayan used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The DAC transferred a total of 43.7 Gigabytes of Range data, 0.642 Gigabytes of POS data, 26.81 Megabytes of GPS base station data, and 30.5 Gigabytes of raw image data to the data server on December 2, 2015 for the first survey, and on February 9, 2017 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Cabicungan survey was fully transferred on February 13, 2017, as indicated on the data transfer sheets for the Cabicungan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 2874P, one of the Cabicungan flights, which are the North, East, and Down position RMSE values, are exhibited 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 fell on November 20, 2015 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

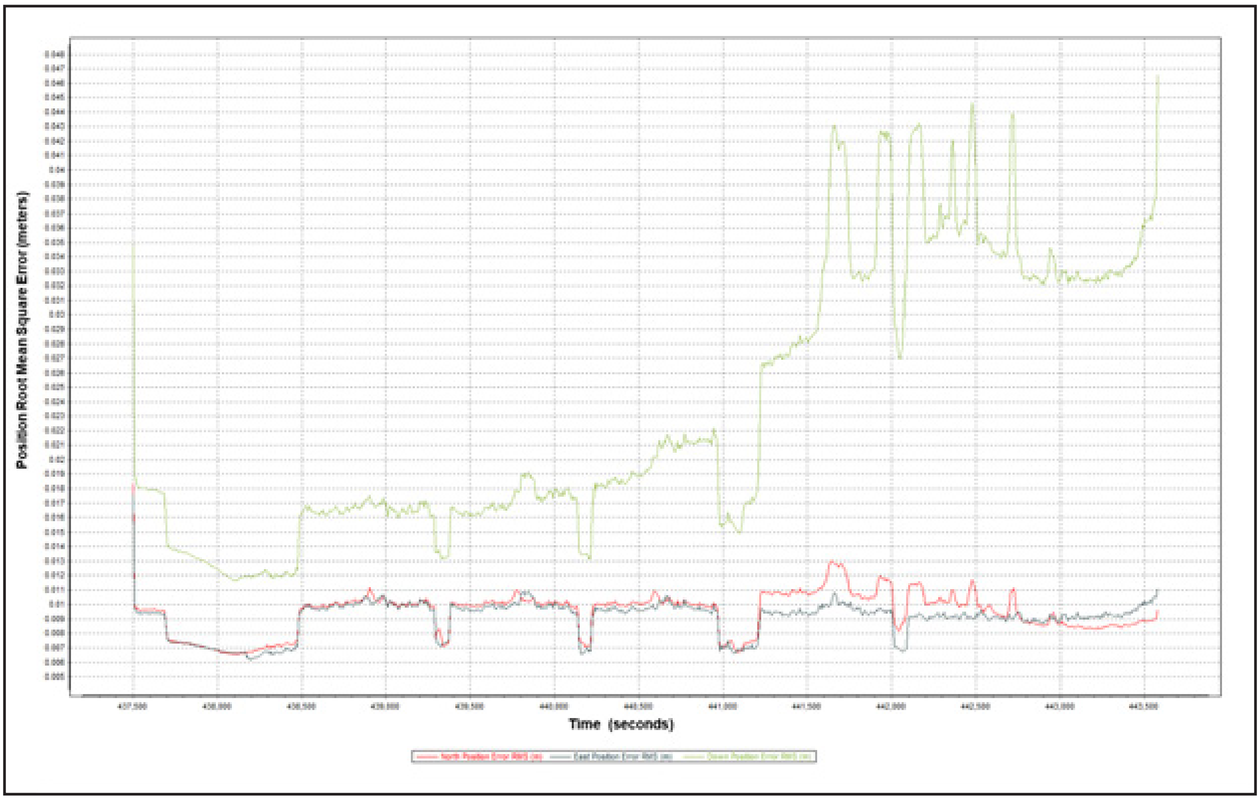


Figure 7. Smoothed Performance Metric Parameters of Cabicungan Flight 2874P

The time of flight was from 437000 seconds to 443500 seconds, which corresponds to the morning of November 20, 2015. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values signifies the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 demonstrates that the North position RMSE peaked at 1.09 centimeters, the East position RMSE peaked at 1. 30 centimeters, and the Down position RMSE peaked at 4.31 centimeters, which are within the prescribed accuracies described in the methodology.

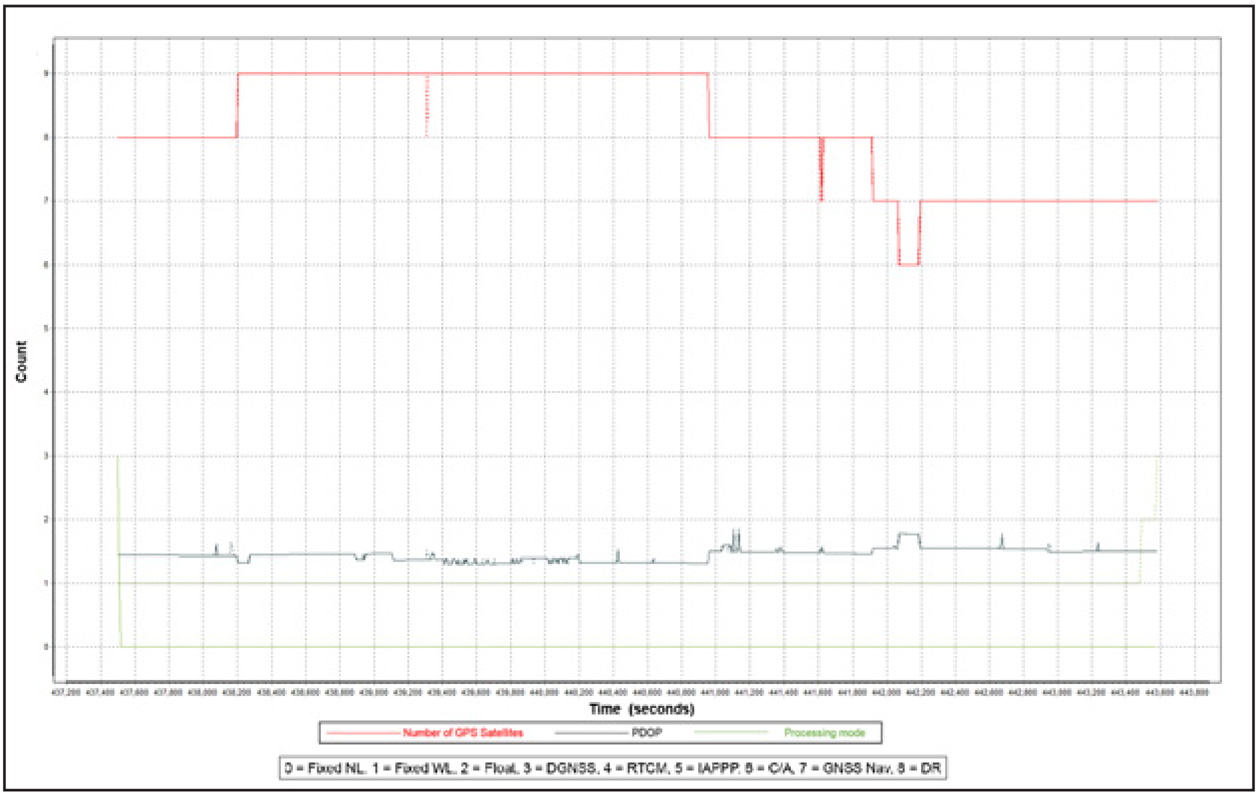


Figure 8. Solution Status Parameters of Cabicungan Flight 2874P

The Solution Status parameters of Flight 2874P, one of the Cabicungan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are illustrated in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value did not go above the value of 2, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. 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 satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Cabicungan flights is presented in Figure 9.

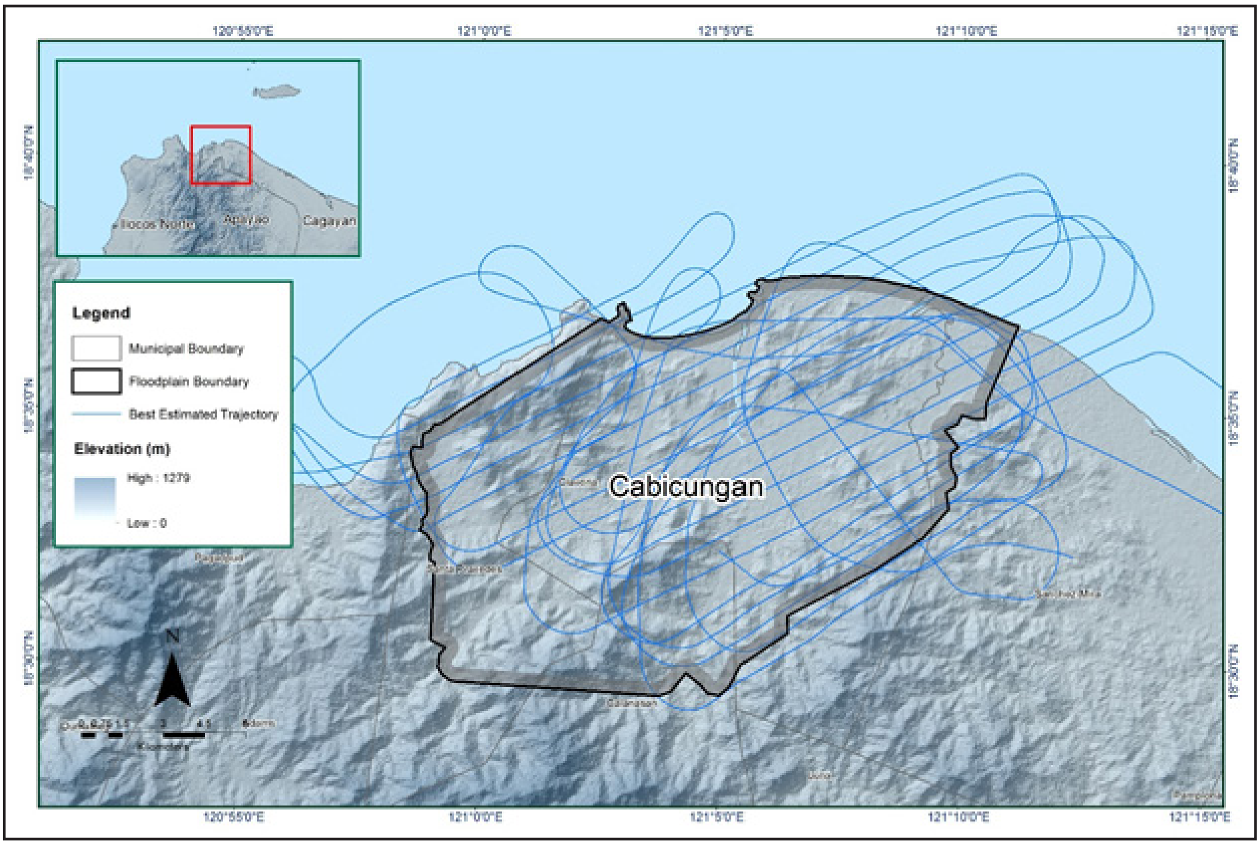


Figure 9. The best estimated trajectory conducted over the Cabicungan floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains thirty-four (34) flight lines, with each flight line containing two (2) channels, since the Pegasus system contains two (2) channels. The summary of the self-calibration results for all flights over the Cabicungan floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 8.

Table 8. Self-calibration results for the Cabicungan flights

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000742
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000718
GPS Position Z-correction stdev)	<0.01meters	0.0062

Optimum accuracy is obtained for all Cabicungan flights, based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for the individual blocks are available in Annex 7: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Cabicungan floodplain are represented in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

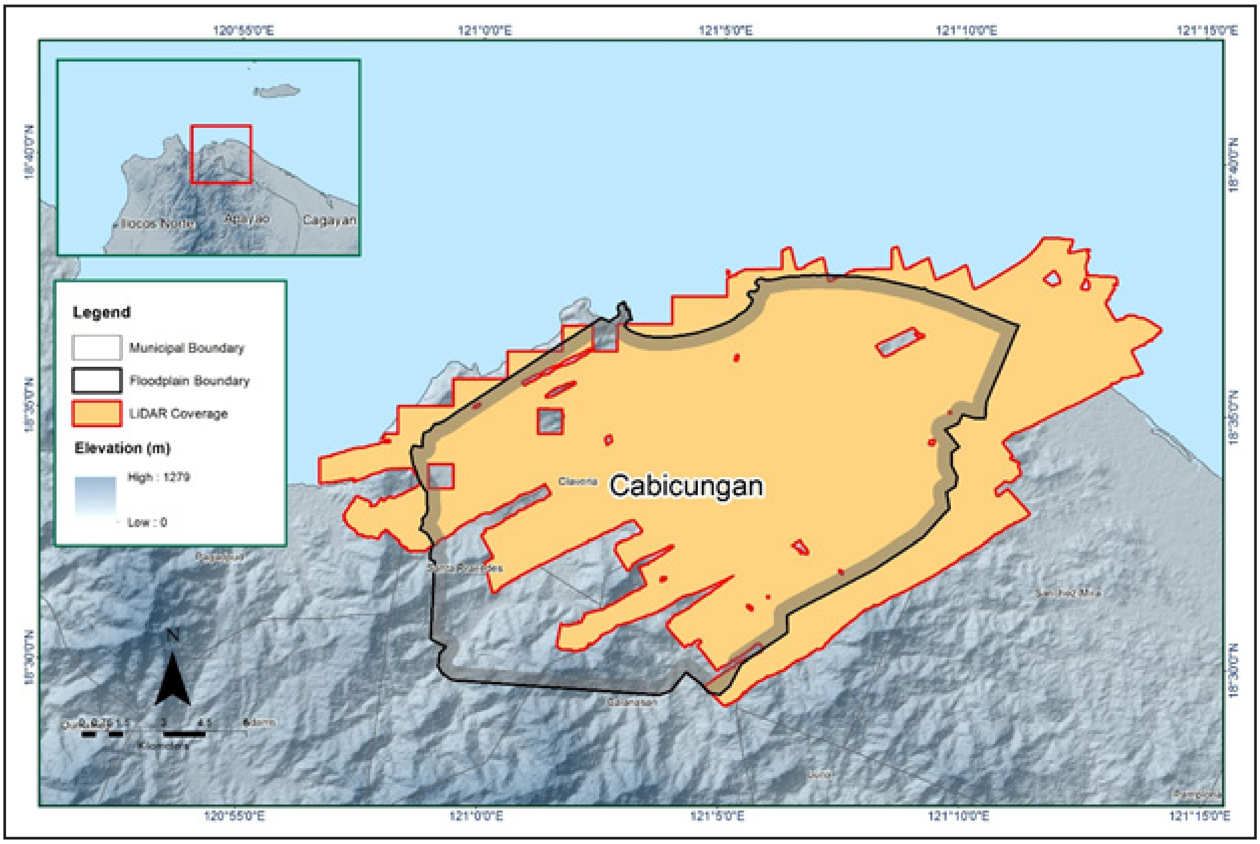


Figure 10. Boundaries of the processed LiDAR data over the Cabicungan floodplain

The total area covered by the Cabicungan missions is 278.43 square kilometers, comprised of four (4) flight acquisitions that were grouped and merged into three (3) blocks, as summarized in Table 9.

Table 9. List of LiDAR blocks for the Cabicungan floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cagayan_reflights_Tugegarao_Blk1A	2870P	94.07
	2874P	
Cagayan_reflights_Tugegarao_Blk1B	2870P	134.01
Cagayan_reflights_Blk1C	23696P	50.35
TOTAL		**278.43 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is depicted in Figure 11. Since the Pegasus system employs two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

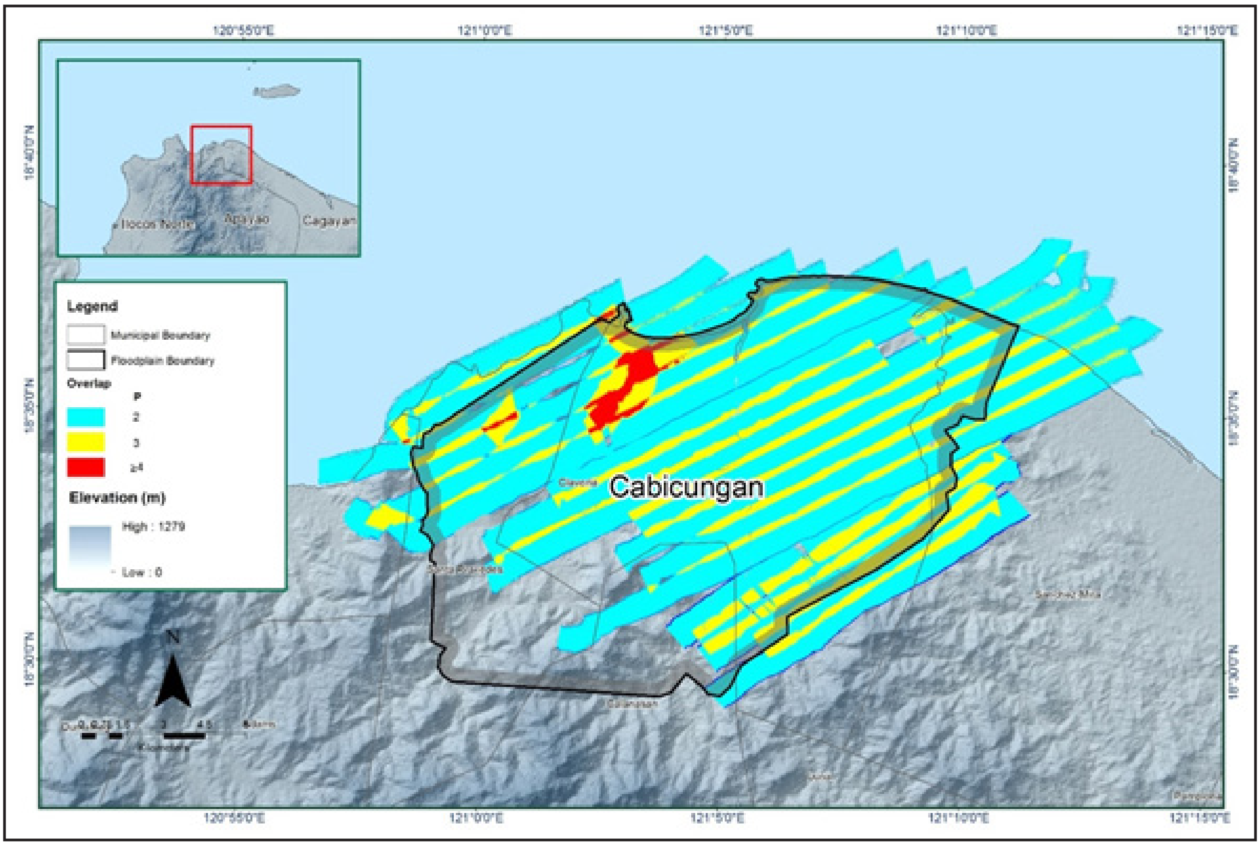


Figure 11. Image of data overlap for the Cabicungan floodplain

The overlap statistics per block for the Cabicungan floodplain can be found in Annex 7. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 23.30% and 39.41%, respectively.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is displayed in Figure 12. It was determined that all LiDAR data for the Cabicungan floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.145 points per square meter.

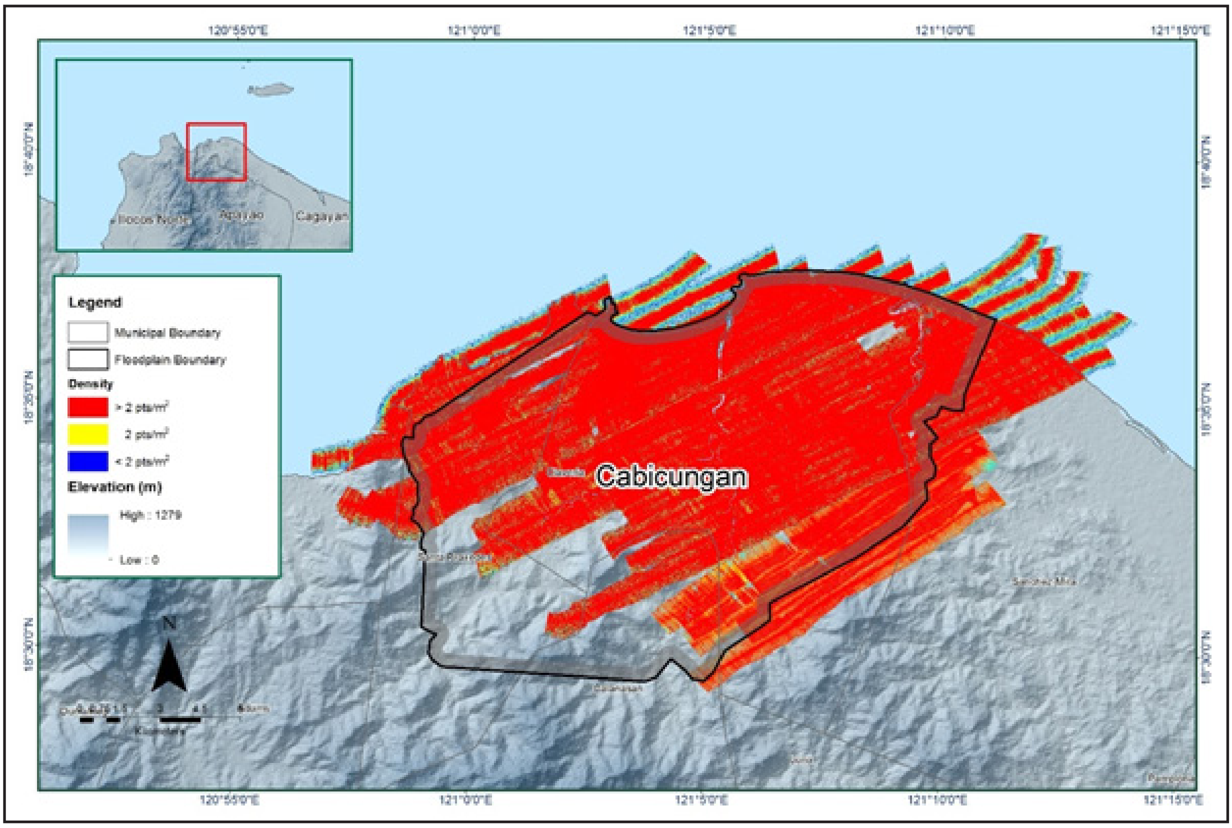


Figure 12. Pulse density map of merged LiDAR data for Cabicungan floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to the 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 meters relative to the elevations of its adjacent flight line. Areas with bright red or bright blue colors were investigated further using the Quick Terrain (QT) Modeler software.

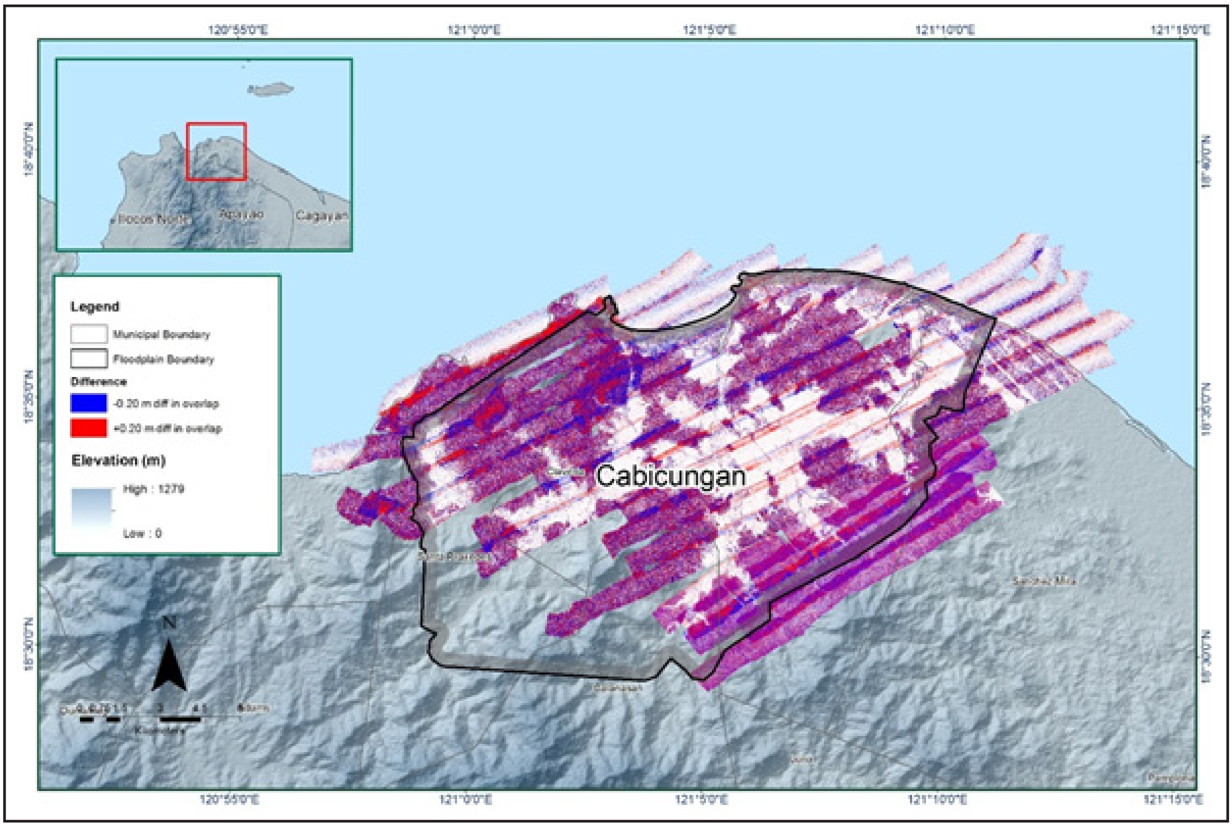


Figure 13. Elevation difference map between flight lines for the Cabicungan floodplain

A screen capture of the processed LAS data from Cabicungan Flight 2874P loaded in the QT Modeler is provided in Figure 14. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

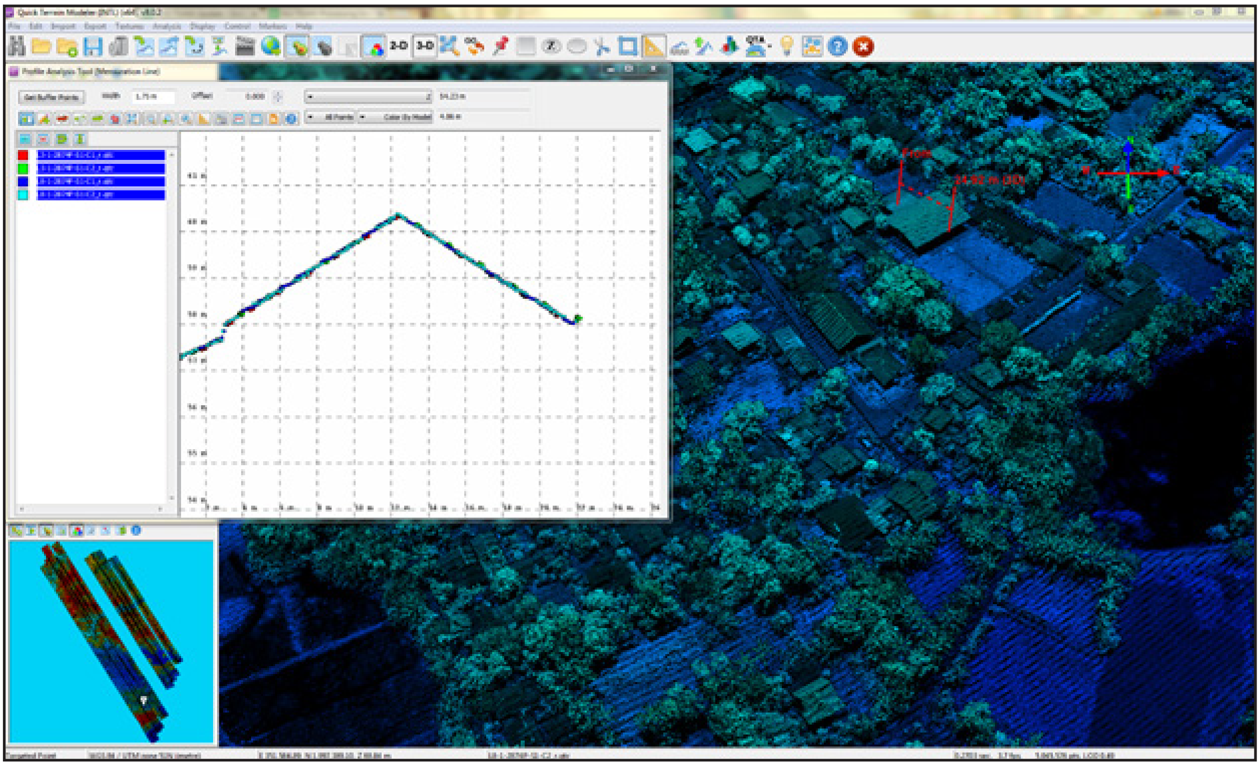


Figure 14. Quality checking for Cabicungan Flight 2874P, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Cabicungan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	217,662,184
Low Vegetation	92,491,017
Medium Vegetation	148,483,287
High Vegetation	620,183,259
Building	5,842,344

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Cabicungan floodplain, are presented in Figure 15. A total of 393 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 10. The point cloud had a maximum and minimum height of 738.86 meters and 39.3 meters, respectively.

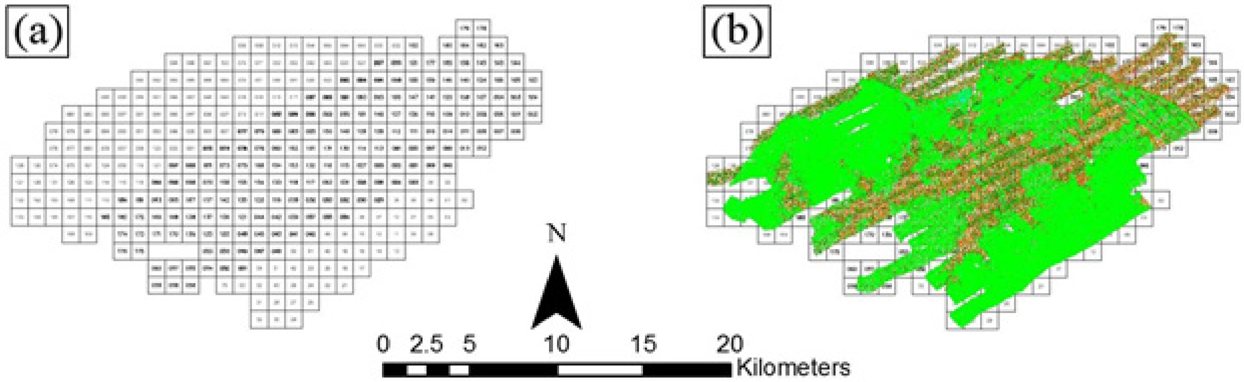


Figure 15. (a) Tiles for Cabicungan floodplain; and (b) classification results in TerraScan

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 is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

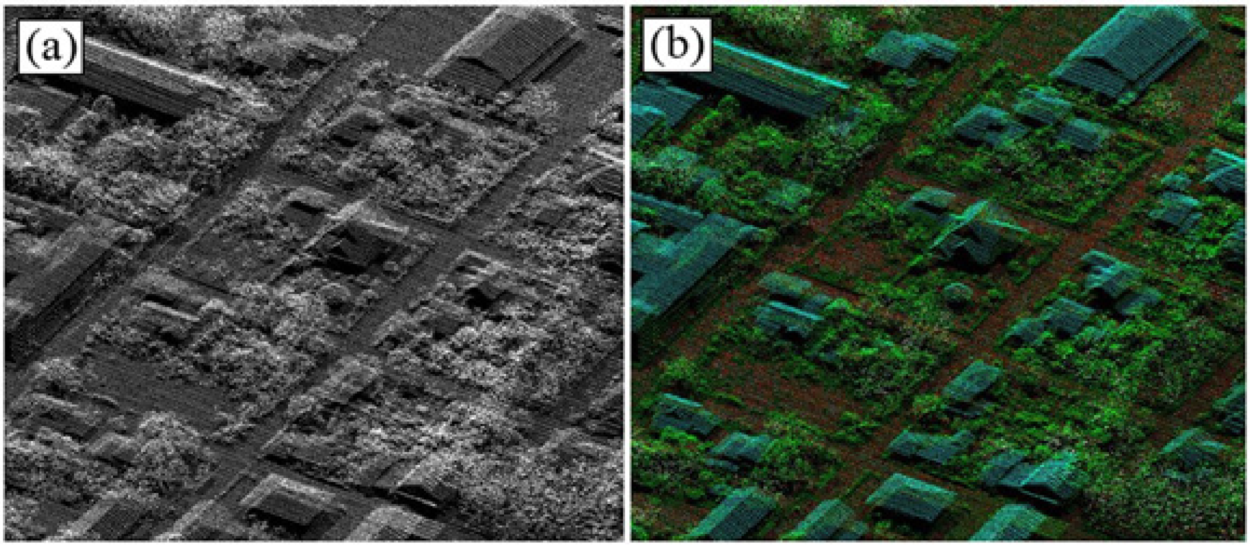


Figure 16. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 17, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

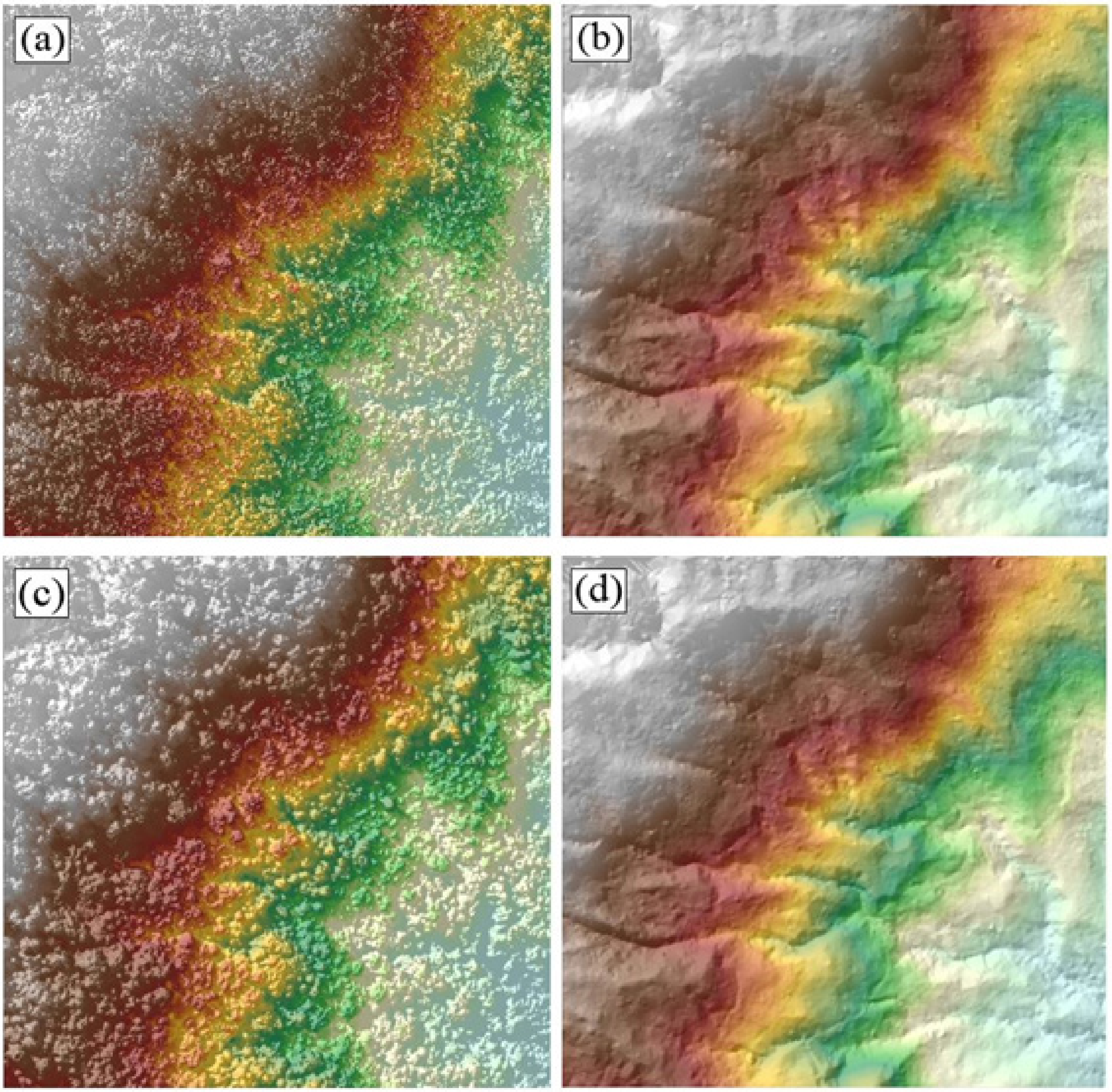


Figure 17. (a) The production of last return DSM and (b) DTM; and (c) first return DSM and (d) secondary DTM in some portion of the Cabicungan floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 264 1km by 1km tiles area covered by the Cabicungan floodplain is presented in Figure 18. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Cabicungan floodplain survey attained a total of 179.65 square kilometers in orthophotographic coverage, comprised of 406 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 19.

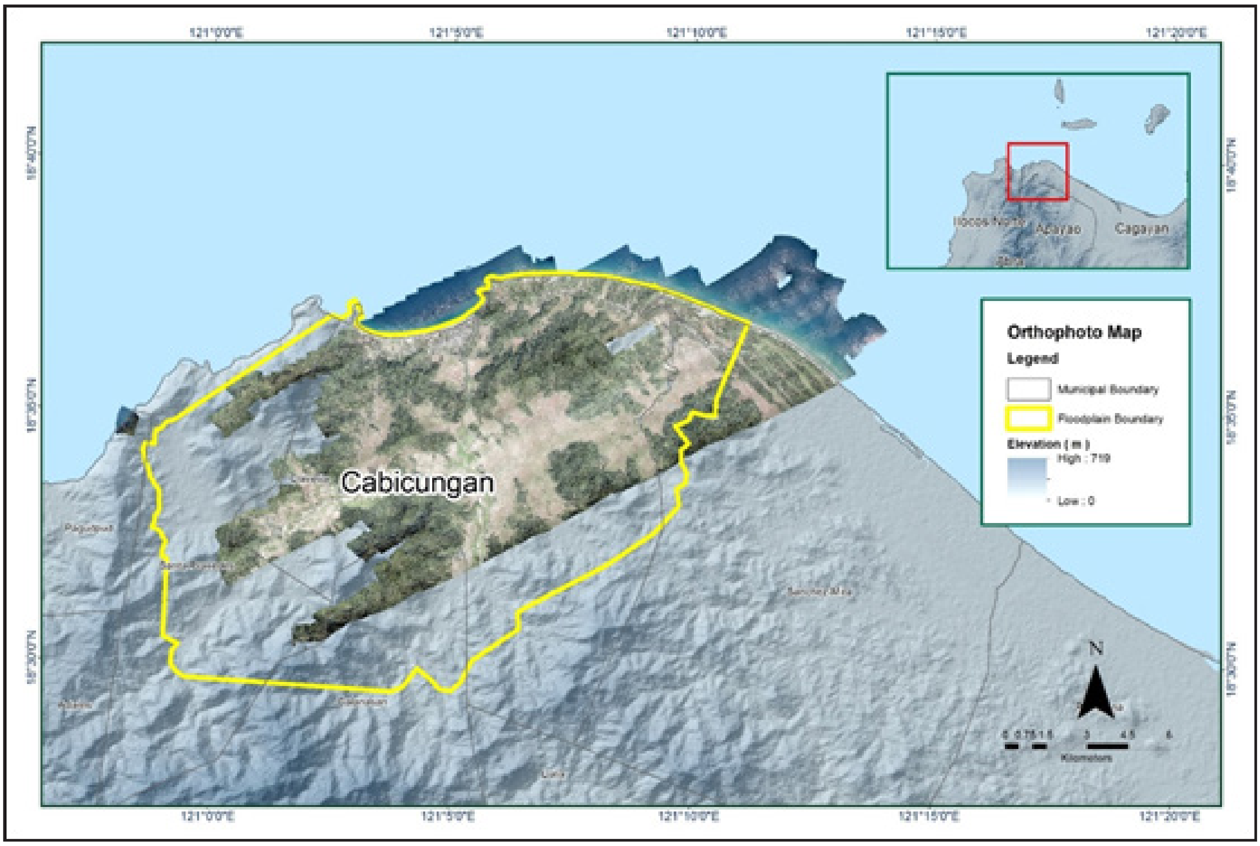


Figure 18. Loboc floodplain with available orthophotographs.

Figure 19. Sample orthophotograph tiles for the Cabicungan floodplain

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for the Cabicungan floodplain. These blocks are composed of Cagayan_reflights_Tugegarao and Cagayan_reflights, with a total area of 278.43 square kilometers. Table 11 specifies the names and corresponding areas of the blocks, in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Cagayan_reflights_Tugegarao_Blk1A	94.07
Cagayan_reflights_Tugegarao_Blk1B	134.01
Cagayan_reflights_Blk1C	50.35
TOTAL	**278.43 sq.km**

Portions of the DTM before and after manual editing are exhibited in Figure 20. A bridge (Figure 20a) was misclassified and removed during the classification process, and had to be interpolated to complete the surface (Figure 20b) in order to allow for the correct flow of water. An interpolated irrigation (Figure 20c) was retrieved (Figure 20d), in order to hydrologically correct the irrigation system. Another case was an interpolated ridge (Figure 20e), which had to be retrieved using object retrieval to achieve the actual surface (Figure 20f). Another example was a building that was still present in the DTM after classification (Figure 20g), and had to be removed through manual editing (Figure 20h).

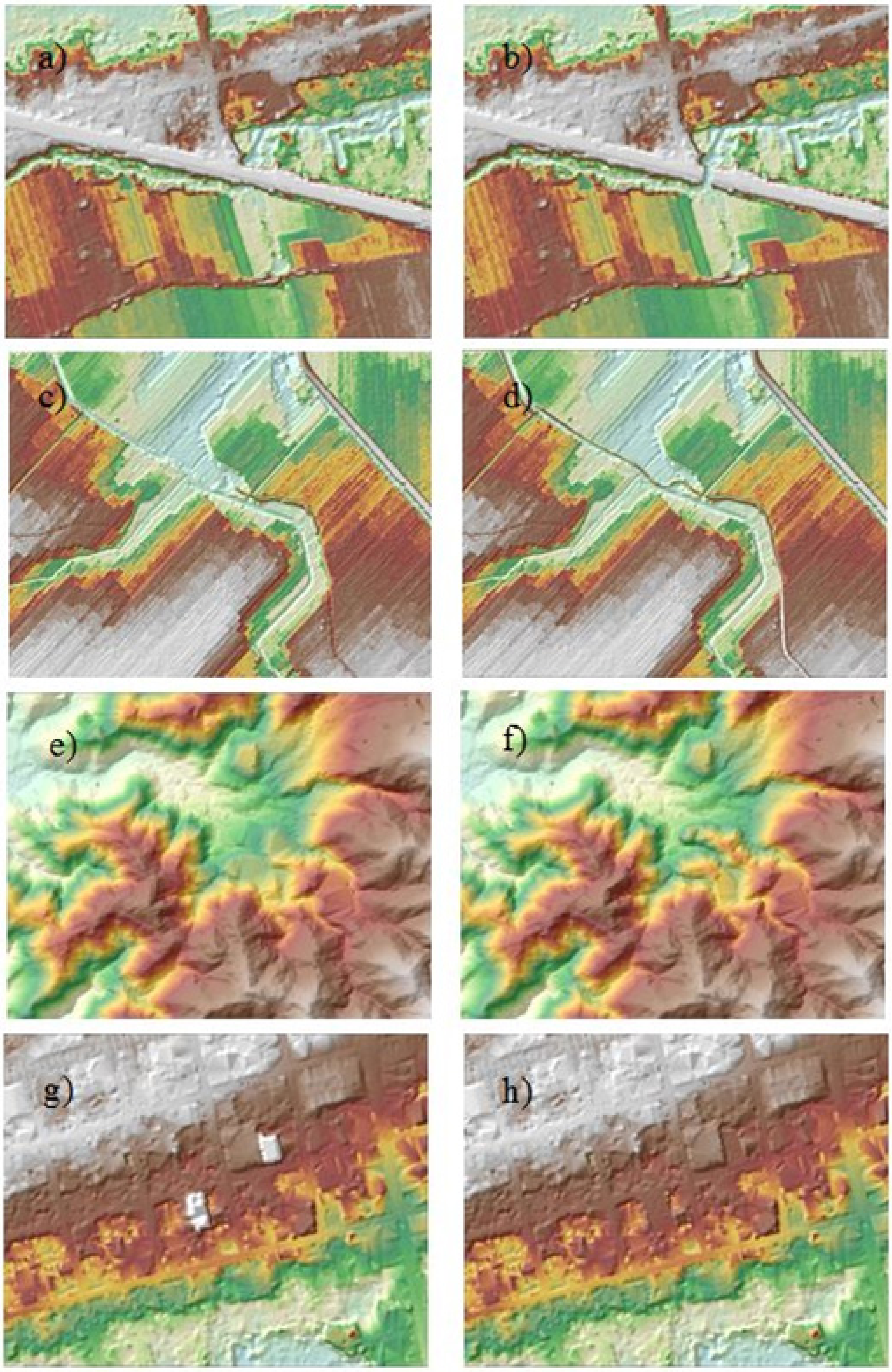


Figure 20. Portions in the DTM of the Cabicungan floodplain – a bridge (a) before and (b) after interpolation; an irrigation (c) before and (d) after object retrieval; interpolated ridge (e) before and (f) after object retrieval; and a building (g) before and (h)

3.9 Mosaicking of Blocks

The Cagayan_reflights_Tuguegarao_Blk1A block was used as the reference block in mosaicking, as it is the closest block to the coast line. Table 12 indicates the shift values applied to each LiDAR block during the mosaicking process.

The mosaicked LiDAR DTM for the Cabicungan floodplain is displayed in Figure 21. The Cabicungan floodplain was 81.00% covered by LiDAR data. Portions without LiDAR data were patched with the available IFSAR data.

Table 12. Shift values of each LiDAR block of the Cabicungan floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Cagayan_reflights_Tuguegarao_Blk1A	0.00	0.00	0.00
Cagayan_reflights_Tuguegarao_Blk1B	-0.45	0.40	0.00
Cagayan_reflights_Blk1C	-0.98	1.06	-3.15

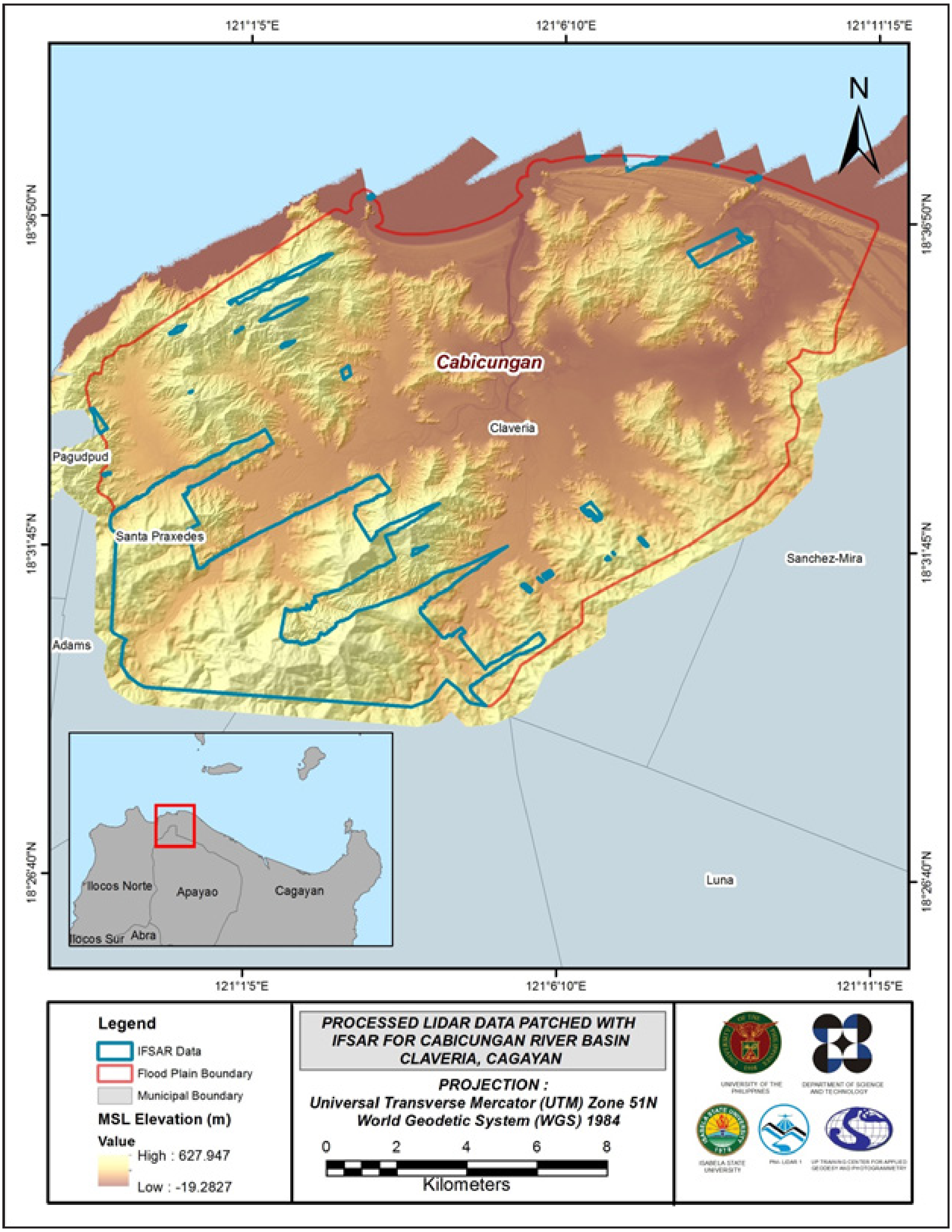


Figure 21. Map of processed LiDAR data for the Cabicungan floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Cabicungan floodplain. The extent of the validation survey performed in Cagayan to collect points with which the LiDAR dataset was validated is illustrated in Figure 22, with the validation survey points highlighted in green. A total of 1,945 survey points were gathered for all of the floodplains within Northern Cagayan, where the Cabicungan floodplain is located. However, the point dataset was not used for the calibration of the LiDAR data for the Cabicungan floodplain; because each LiDAR block was referred to the calibrated Cagayan DEM during the mosaicking process. Thus, the mosaicked DEM of Cabicungan is already considered as a calibrated DEM.

A good correlation between the uncalibrated Cabicungan LiDAR DTM and the ground survey elevation values is reflected in Figure 23. Statistical values were computed from extracted LiDAR values using the selected points, to assess the quality of data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration points is 5.29 meters, with a standard deviation of 0.11 meters. The calibration of the Cabicungan LiDAR data was conducted by subtracting the height difference value, 5.29 meters, from the Cabicungan mosaicked LiDAR data. Table 13 summarizes the statistical values of the compared elevation values between the Cabicungan LiDAR data and the calibration data. These values were also applicable to the Cabicungan DEM.

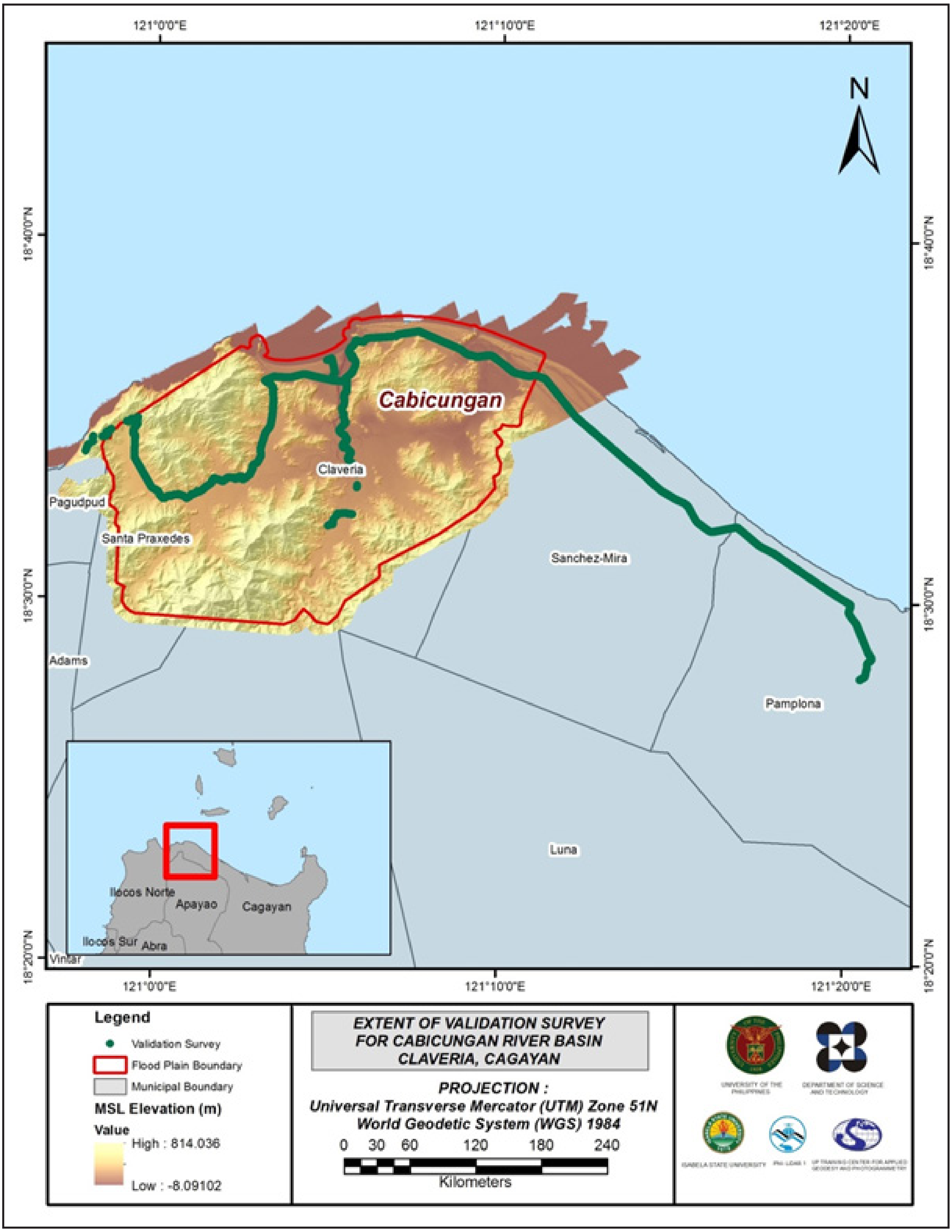


Figure 22. Map of the Cabicungan floodplain, with the validation survey points in green

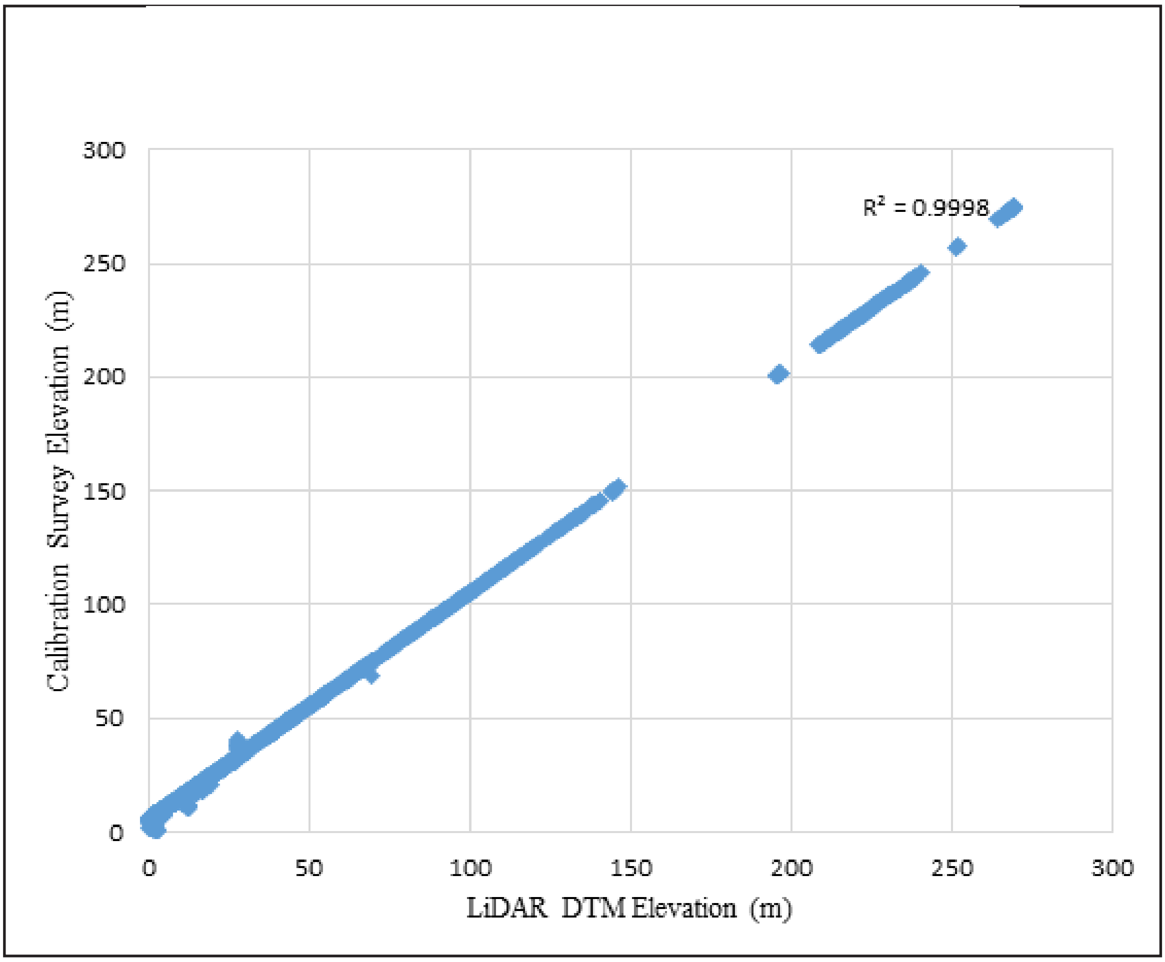


Figure 23. Correlation plot between the calibration survey points and the LiDAR data

Table 13. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	5.29
Standard Deviation	0.11
Average	-5.29
Minimum	-6.25
Maximum	-4.37

The remaining 20% of the total survey points, resulting in 389 points, were used for the validation of the calibrated Cabicungan 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 demonstrated in Figure 24. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.11 meters, with a standard deviation of 0.11 meters, as specified in Table 14.

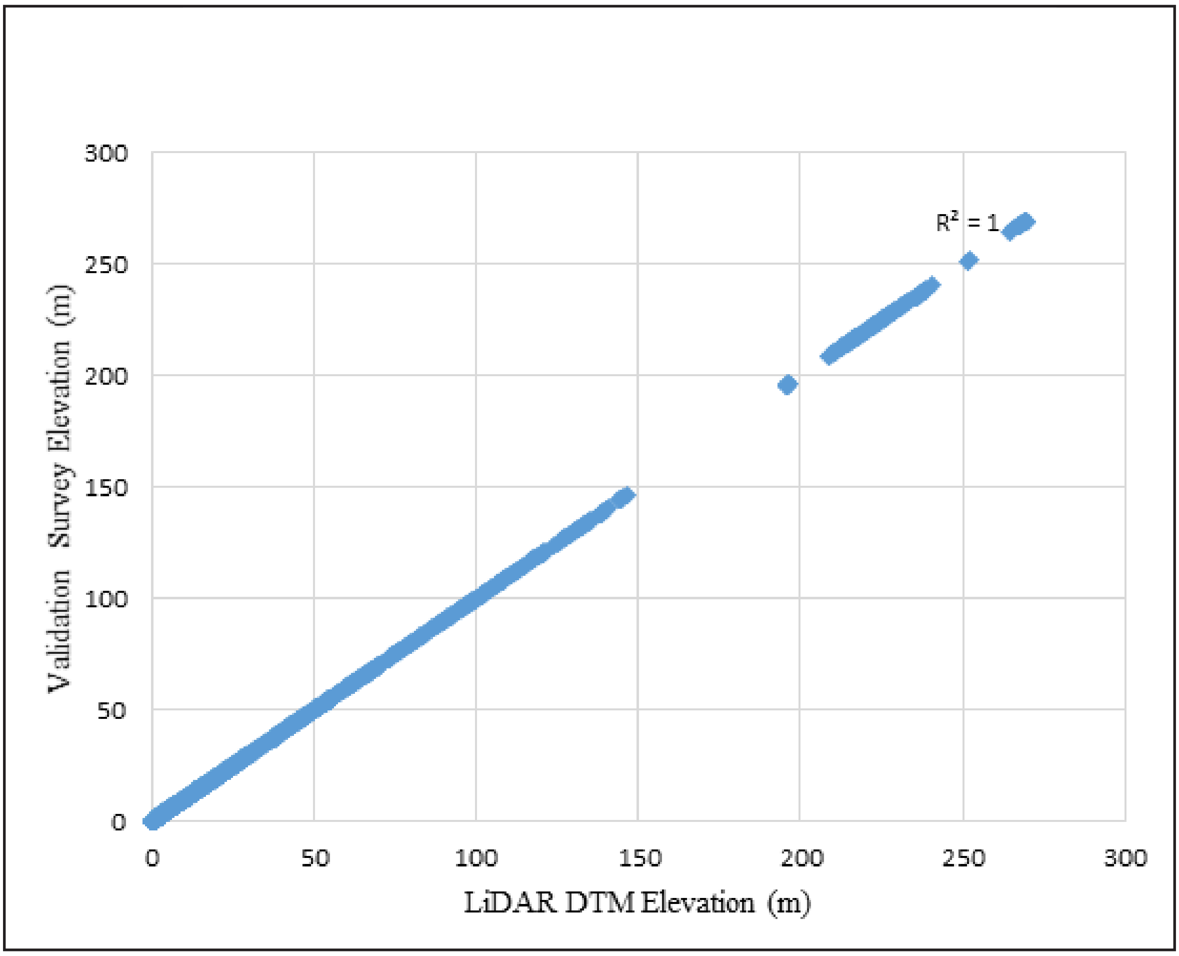


Figure 24. Correlation plot between the validation survey points and the LiDAR data

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.11
Average	0.01
Minimum	-0.27
Maximum	0.54

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, zigzag and centerline data were available for Cabicungan, with 16,071 bathymetric survey points. The resulting raster surface produced was obtained through the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.35 meters. The extent of the bathymetric survey executed by the DVBC in the Cabicungan River, integrated with the processed LiDAR DEM, is shown in Figure 25.

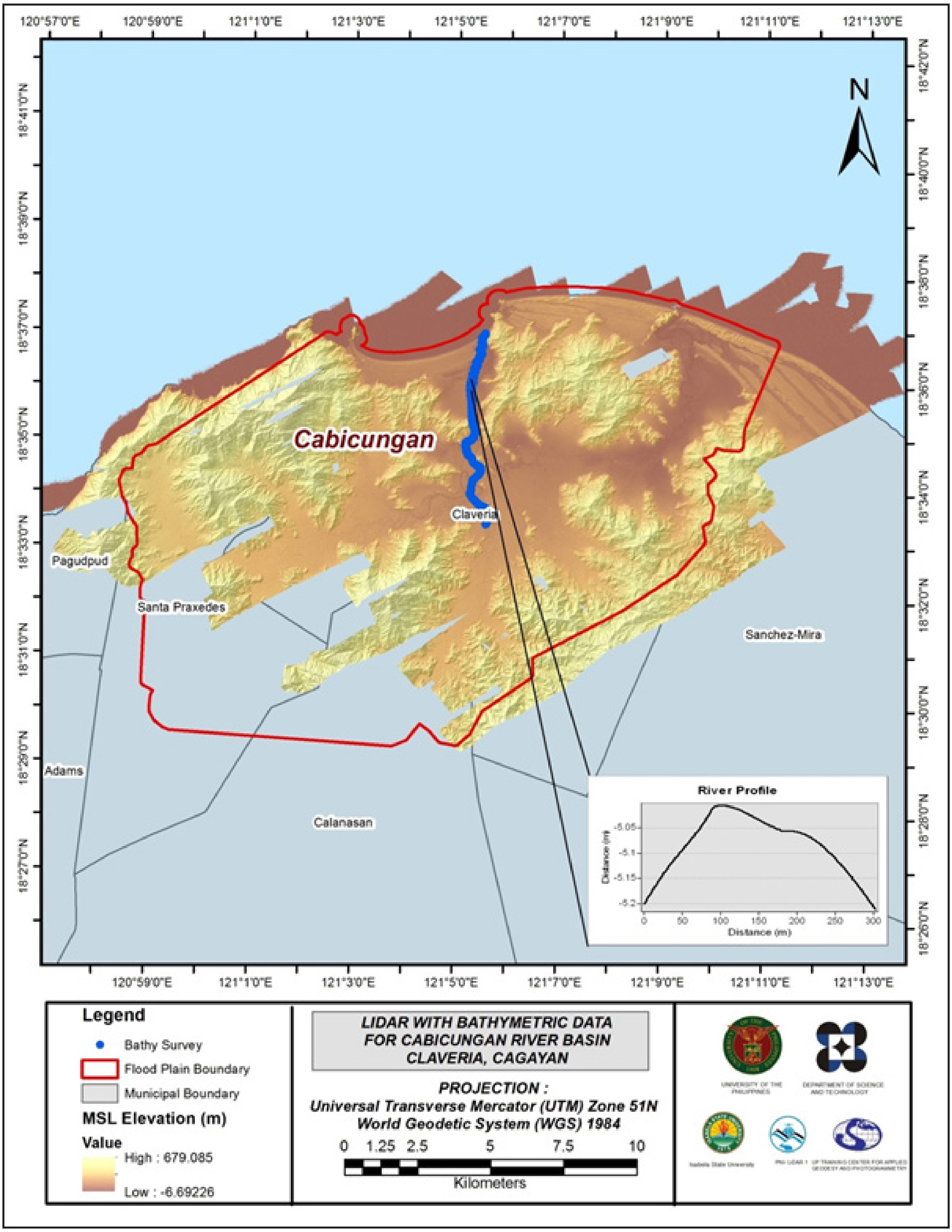


Figure 25. Map of the Cabicungan floodplain, with bathymetric survey points shown in blue

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 a 200-meter buffer zone. Mosaicked LiDAR DEM with a 1-meter 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 – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Cabicungan floodplain, including its 200-meter buffer zone, has a total area of 244.10 square kilometers. Of this area, a total of 7.0 square kilometers, corresponding to a total of 2,986 building features, were considered for quality checking (QC). Figure 26 presents the QC blocks for the Cabicungan floodplain.

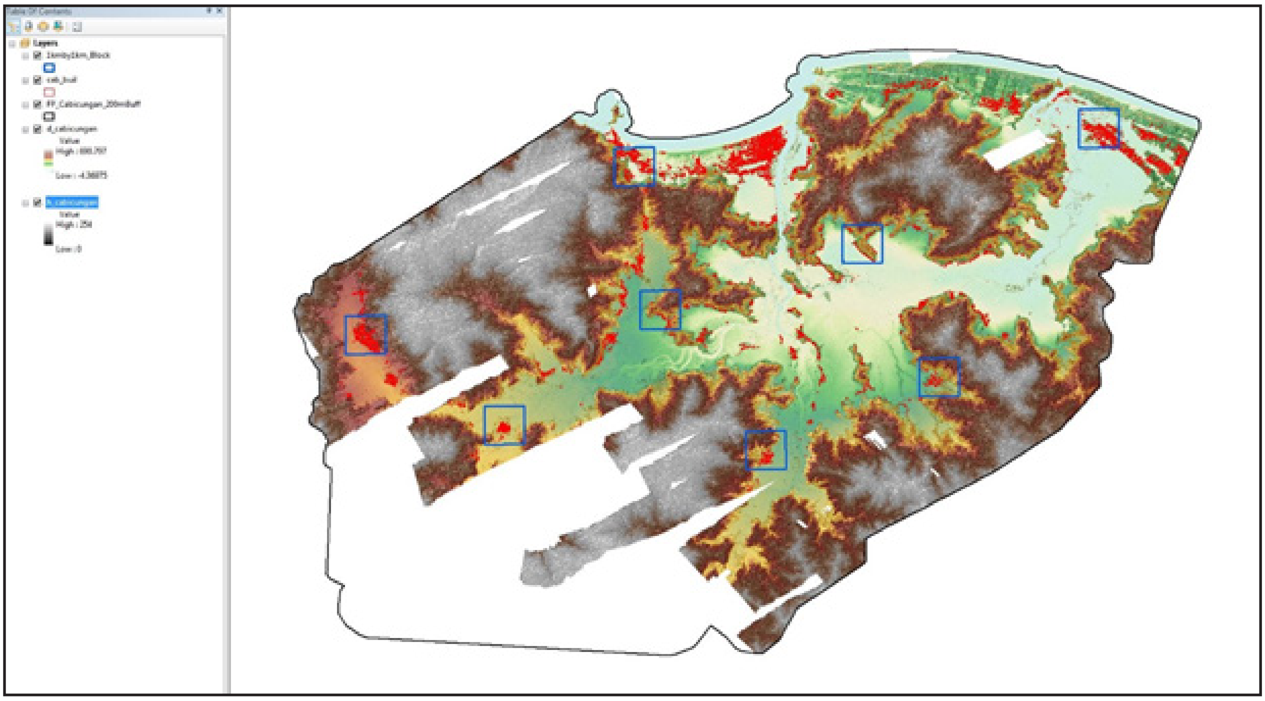


Figure 26. Blocks (in blue) of Cabicungan building features that were subjected to QC

Quality checking of the Cabicungan building features resulted in the ratings given in Table 15.

Table 15. Quality checking ratings for the Cabicungan building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Cabicungan	92.54	99.40	87.08	PASSED

3.12.2 Height Extraction

Height extraction was performed for 14,720 building features in the Cabicungan floodplain. Of these building features, 600 were filtered out after height extraction, resulting in 14,120 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 9.74 meters.

3.12.3 Feature Attribution

The digitized features were identified using participatory mapping. Stakeholders from the local communities, preferably barangay officials, were invited to a forum and were given maps of their respective barangays. They first attributed non-residential buildings; such as, barangay halls, schools, churches, and commercial buildings. All other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was applied to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 16 summarizes the number of building features per type. Table 17 indicates the total length of each road type, and Table 18 provides the number of water features extracted per type.

Table 16. Building features extracted for the Cabicungan floodplain

Facility Type	No. of Features
Residential	13555
School	254
Market	4
Agricultural/Agro-Industrial Facilities	2
Medical Institutions	15
Barangay Hall	45
Military Institution	1
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	3
Transport Terminal	0
Warehouse	2
Power Plant/Substation	0
NGO/CSO Offices	21
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	74
Bank	0
Factory	0
Gas Station	6
Fire Station	0
Other Government Offices	57
Other Commercial Establishments	71
Total	**14,120**

Table 17. Total length of extracted roads for the Cabicungan floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Cabicungan	156.48	34.37	7.90	42.31	0.00	241.07

Table 18. Number of extracted water bodies for the Cabicungan floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cabicungan	24	0	0	0	0	24

A total of thirty-nine (39) 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 27 exhibits the Digital Surface Model (DSM) of the Cabicungan floodplain, overlaid with its ground features.

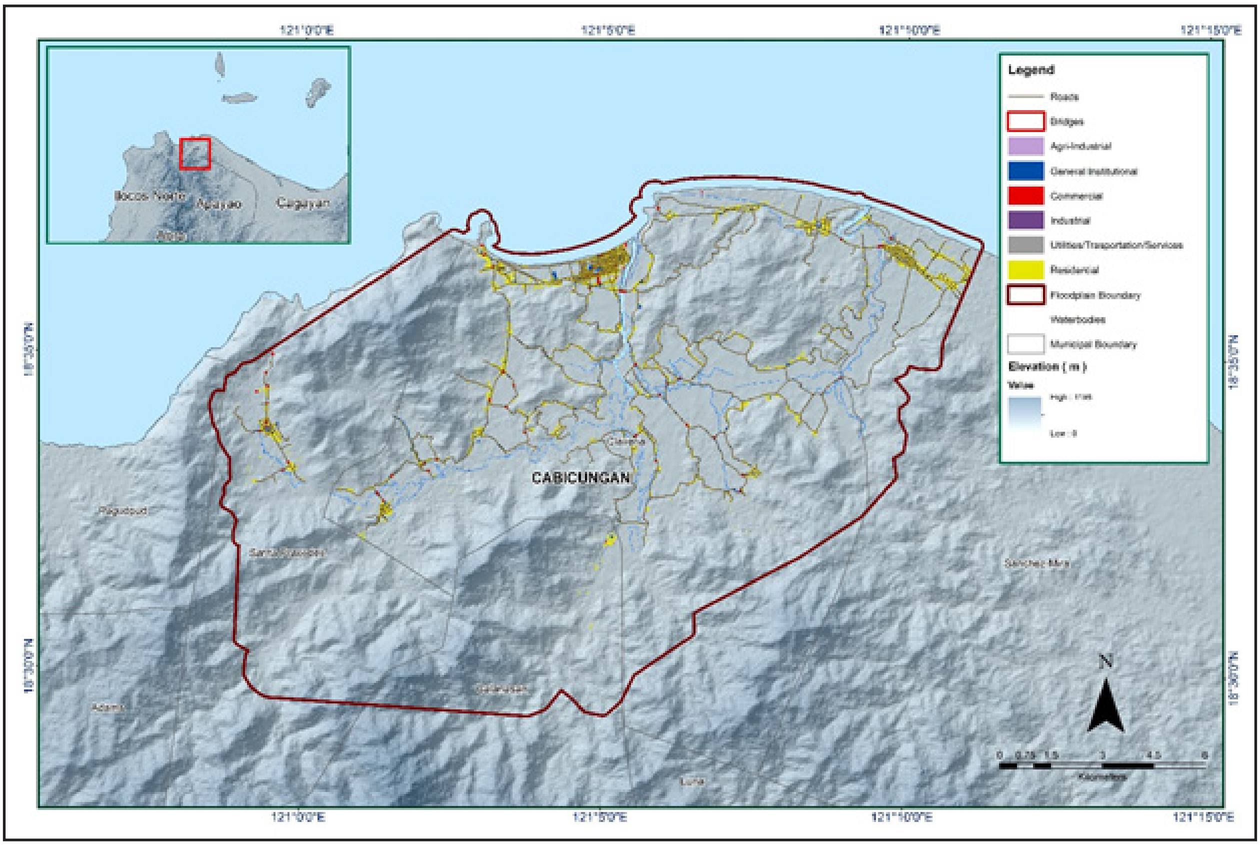


Figure 27. Extracted features for the Cabicungan floodplain

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

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

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Cabicungan River on June 13 – 27, 2016. The scope of work was comprised of: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built survey at the Cabicungan Bridge in Barangay Dibalio, Municipality of Claveria; (iv.) validation points acquisition of about 69 kilometers covering the Cabicungan River Basin area; and (v.) bathymetric survey from the river's upstream in Barangay Bacsay Cataraoan Sur to the mouth of the river in Barangay Camalaggoan, both in the Municipality of Claveria. The bathymetric survey had an approximate length of 7.617 kilometers, using an Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS in PPK survey technique. The scope of the surveys is illustrated in Figure 28.

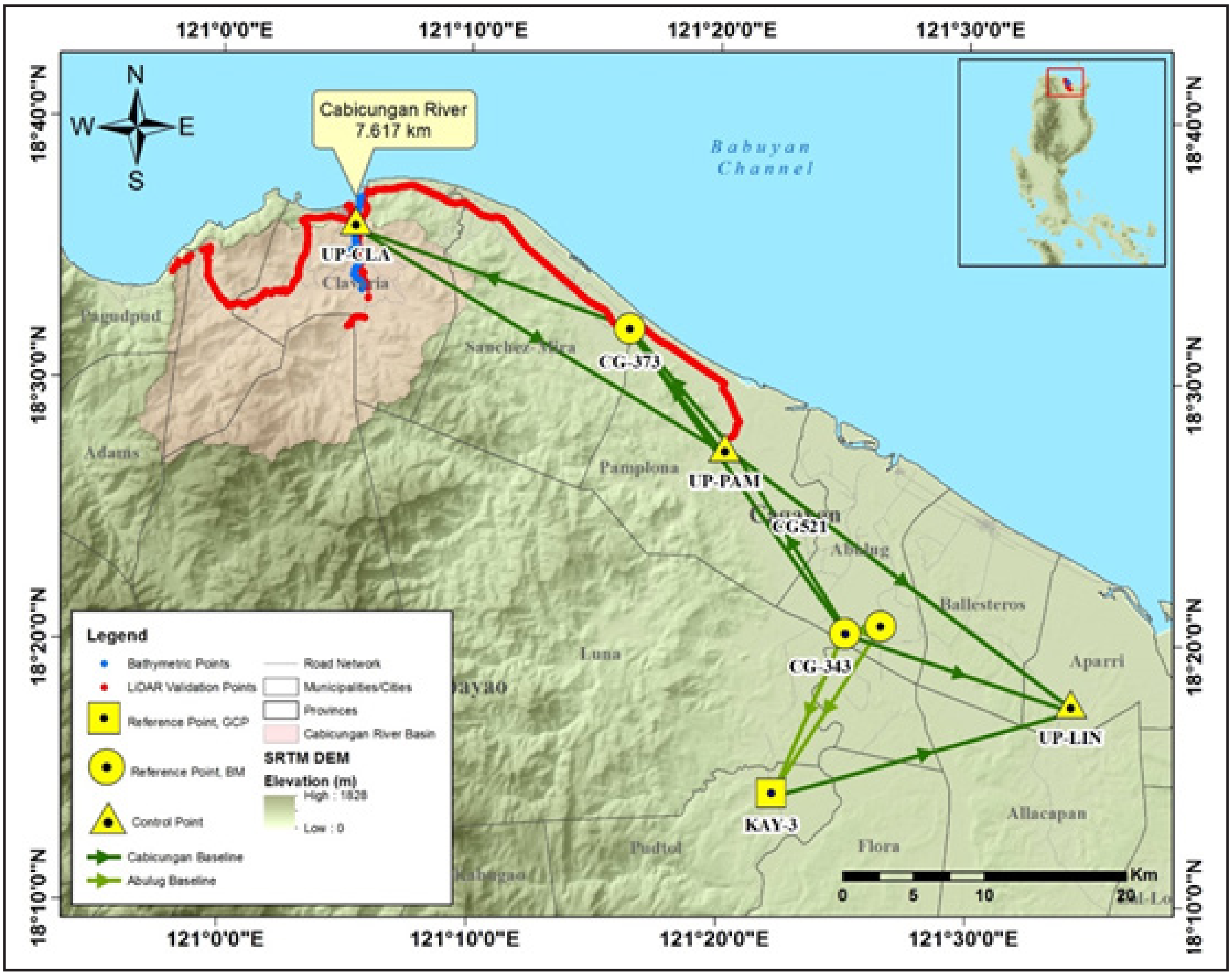


Figure 28. Extent of the bathymetric survey (in blue line) in Cabicungan River and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS network for the Abulug River Survey was established on September 18, 2015, occupying the following control points: (i.) KAY-3, a second-order GCP, in Barangay Imelda, Municipality of Pudtol; and (ii.) CG-343, a first-order BM, in Barangay Libertad, Municipality of Abulug. Both points are in the Cagayan Province.

The GNSS network used for the Cabicungan River Basin is composed of four (4) loops established on June 15-16, 2016, occupying the following reference points: (i.) KAY-3, a second-order GCP from the Abulug River Survey; (ii.) CG-343, a first-order BM, also from the Abulug River Survey; and (iii.) CG-373, a GCP with 95% class accuracy, in Barangay Bangan, Municipality of Sanchez Mira.

Three (3) control points were established along the approach of bridges, namely: (i.) UP-CLA, located at the Cabicungan Bridge in Barangay Dibalio, Municipality of Claveria; (ii.) UP-LIN, at the Linao Bridge in Barangay Bangag-Zingag, Municipality of Aparri; and (iii.) UP-PAM, at the New Pamplona Bridge in Barangay Masi, Municipality of Pamplona.

The summary of the reference and control points and their corresponding locations is provided in Table 19; while the GNSS network established is illustrated in Figure 29.

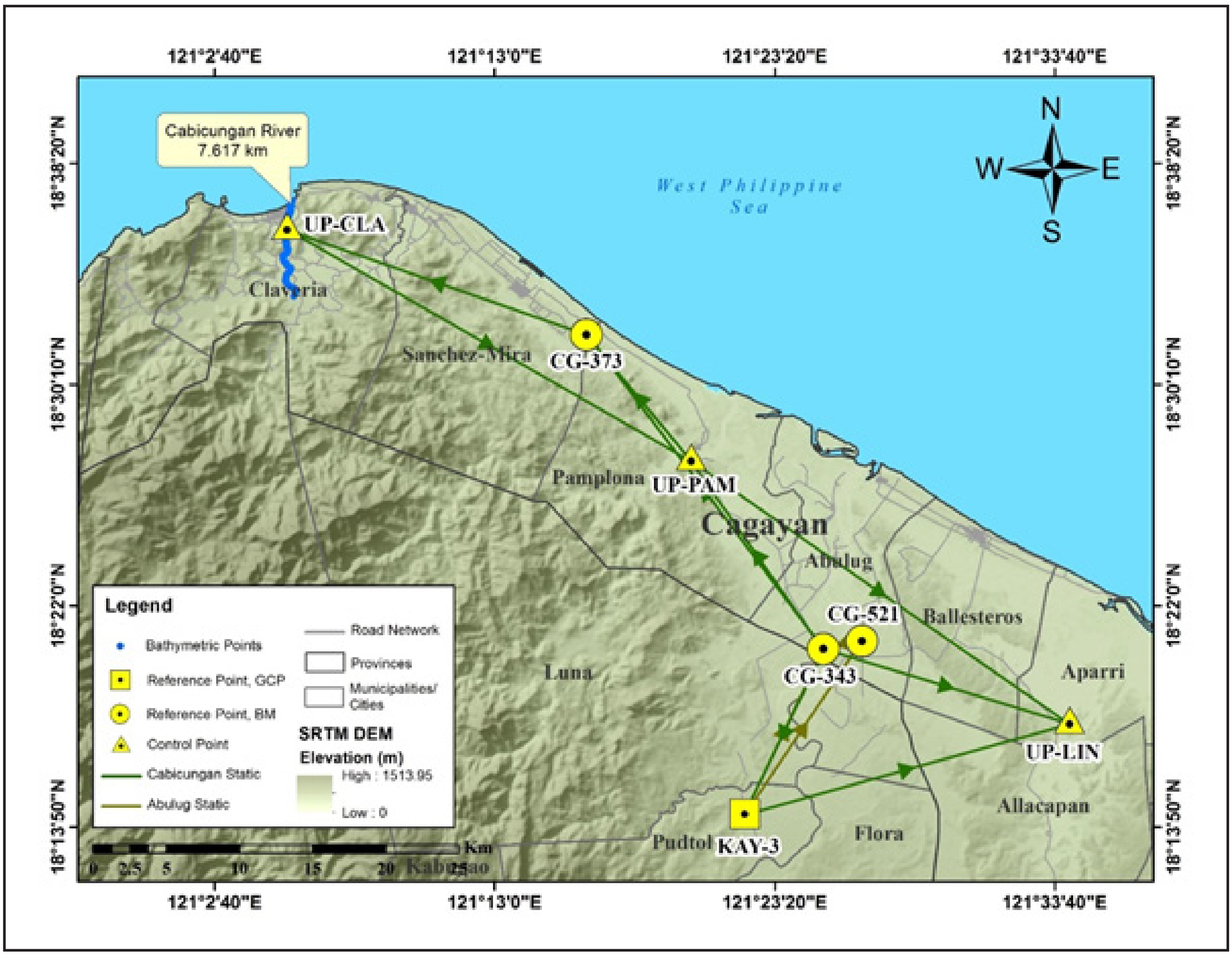


Figure 29. GNSS network covering the Cabicungan River

Table 19. Reference and control points occupied for the Cabicungan River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
Control Survey on September 18, 2015						
KAY-3	2nd order, GCP	18°14'17.68665"N	121°22'13.38974"E	59.230	19.562	1990
CG-343	1st order, BM	18°20'24.45282"N	121°25'08.22638"E	51.980	13.119	2007
CG-521	Used as Marker	18°20'41.57071"N	121°26'33.65512"E	47.372	8.593	2008
Control Survey on June 15 and 16, 2016						
KAY-3	**2nd order, GCP**	**18°14'17.68665"N**	**121°22'13.38974"E**	**59.230**	**19.562**	**1990**
CG-343	**1st order, BM**	**18°20'24.45282"N**	**121°25'08.22638"E**	**51.980**	**13.119**	**2007**
CG-373	**1st order, BM**	**18°32'00.00627"N**	**121°16'23.37638"E**	**40.044**	**3.422**	**2007**
UP-CLA	**UP Established**	-	-	-	-	**06-15-16**
UP-LIN	**UP Established**	-	-	-	-	**06-16-16**
UP-PAM	**UP Established**	-	-	-	-	**06-15-16**

The GNSS set-ups on the recovered reference points and established control points in the Cabicungan River are exhibited in Figure 30 to Figure 35.

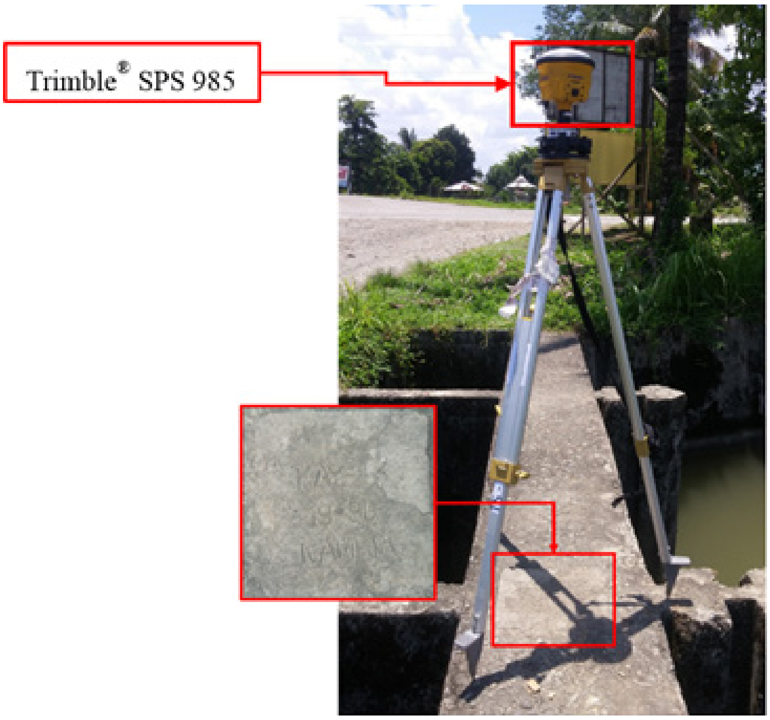


Figure 30. GNSS base set-up, Trimble® SPS 985 at KAY-3, situated on top of a flood gate near the Pudtol Municipal Building in Barangay Imelda, Municipality of Pudtol, Cagayan

Figure 31. Trimble® SPS 882 GNSS receiver setup at BH-503 located inside the campus of Dao Elementary School, Brgy. Dao, Municipality of Dauis, Bohol

Figure 32. GNSS receiver set-up, Trimble® SPS 882 at CG-373, located at the approach of the Bangan Bridge in Barangay Bangan, Municipality of Sanchez Mira, Cagayan

Figure 33. GNSS receiver set-up, Trimble® SPS 852 at UP-CLA, located at the approach of the Cabicungan Bridge in Barangay Dibalio, Municipality of Claveria, Cagayan

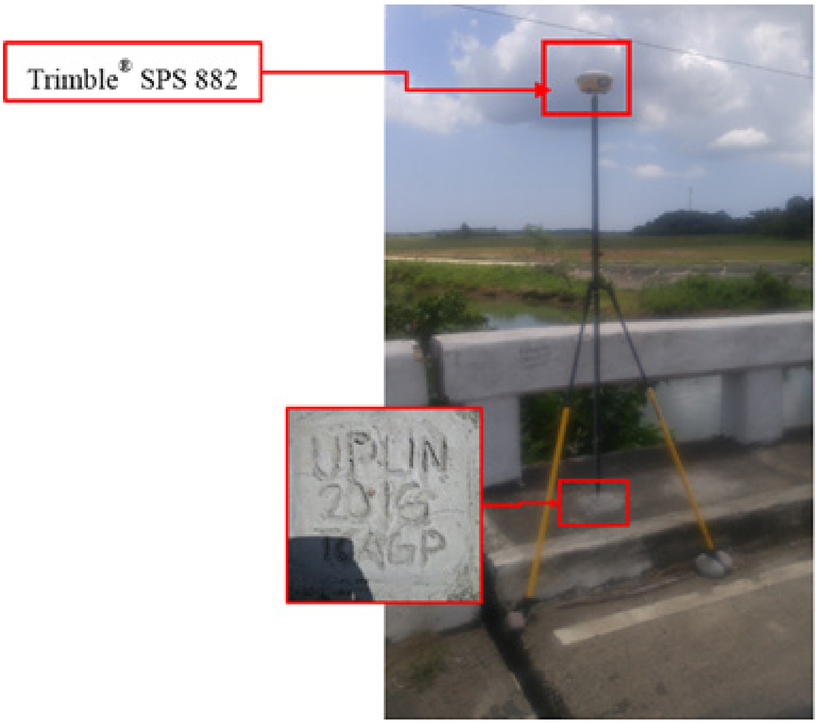


Figure 34. GNSS receiver set-up, Trimble® SPS 882 at UP-LIN, located at the approach of the Linao Bridge in Barangay Bangag-Zingag, Municipality of Aparri, Cagayan

Figure 35. GNSS receiver set-up, Trimble® SPS 985 at UP-PAM, located at the approach of the New Pamplona Bridge in Barangay Masi, Municipality of Pamplona, Cagayan

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the +/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of the control points in the Cabicungan River Basin, generated by the TBC software, are summarized in Table 20.

Table 20. Baseline Processing Summary Report for the Cabicungan River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CG-343 --- UP-LIN	06-16-16	Fixed	0.003	0.011	106°47'38"	16724.001	-8.874
UP-PAM --- CG-343	06-16-16	Fixed	0.004	0.015	326°39'56"	15653.196	-3.143
CG-343 --- KAY-3	06-16-16	Fixed	0.004	0.015	204°29'26"	12390.499	7.221
UP-CLA --- UP-PAM	06-15-16	Fixed	0.003	0.011	120°54'39"	30613.328	6.126
CG-373 --- UP-PAM	06-15-16	Fixed	0.004	0.013	320°43'48"	10734.896	-6.898
UP-CLA --- CG-373	06-15-16	Fixed	0.003	0.012	290°56'38"	20827.307	0.766
UP-PAM --- UP-LIN	06-16-16	Fixed	0.003	0.013	126°01'00"	30439.181	-5.723
UP-LIN --- KAY-3	06-16-16	Fixed	0.003	0.012	73°02'19"	22107.068	-16.071
CG-343 --- CG-373	06-16-16	Fixed	0.003	0.012	324°15'43"	26354.260	-10.043

As reflected in Table 20, a total of nine (9) baselines were processed with reference points KAY-3 and CG-343 held fixed for coordinate and elevation values. CG-373 was also held fixed for elevation values. All of the baselines satisfied 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 centimeters, and z less than 10 centimeters, or in equation form:

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

where:

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

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

The six (6) control points - KAY-3, CG-343, CG-373, UP-CLA, UP-LIN, and UP-PAM – were occupied and observed simultaneously to form a GNSS loop. The coordinates of KAY-3 and CG-343, and the elevation values of both controls and CG-373, were held fixed during the processing of the control points, as conveyed in Table 21. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 21. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
KAY-3	Local	Fixed	Fixed	Fixed	
CG-343	Local	Fixed	Fixed	Fixed	
CG-373	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 outlined in Table 22. The fixed control points KAY-3 and CG-343 did not yield values for grid errors; and both points including CG-373 did not yield values for elevation errors.

Table 22. Adjusted grid coordinates for the control points used in the Cabicungan floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
KAY-3	327699.141	?	2017311.527	?	20.600	?	LLh
CG-343	332932.785	?	2028541.838	?	14.156	?	LLh
CG-373	317727.465	0.015	2050066.562	0.014	3.422	?	e
UP-CLA	298347.481	0.022	2057698.195	0.025	2.999	0.082	
UP-LIN	348899.614	0.009	2023571.535	0.011	6.573	0.079	
UP-PAM	324445.546	0.011	2041693.715	0.009	10.618	0.032	

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

a. KAY-3
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. CG-343
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

c. CG-373
Horizontal Accuracy = $\sqrt{((1.5)^2 + (1.4)^2}$
= $\sqrt{(2.25 + 1.96)}$
= 2.05 < 20 cm
Vertical Accuracy = Fixed

d. UP-CLA
Horizontal Accuracy = $\sqrt{((2.2)^2 + (2.5)^2}$
= $\sqrt{(4.84 + 6.25)}$
= 3.33 < 20 cm
Vertical Accuracy = 8.2 cm < 10 cm

e. UP-LIN
Horizontal Accuracy = $\sqrt{((0.9)^2 + (1.1)^2}$
= $\sqrt{(0.81 + 1.21)}$
= 1.42< 20 cm
Vertical Accuracy = 4.1 cm < 10 cm

f. UP-PAM
Horizontal Accuracy = $\sqrt{((1.1)^2 + (0.9)^2}$
= $\sqrt{(1.21 + 0.81)}$
= 1.42< 20 cm
Vertical Accuracy = 3.2 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the six (6) occupied control points are within the required precision.

Table 23. Adjusted geodetic coordinates for control points used in the Cabicungan River floodplain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
KAY-3	N18°14'17.68665"	E121°22'13.38974"	59.230	?	LLh
CG-343	N18°20'24.45282"	E121°25'08.22638"	51.980	?	LLh
CG-373	N18°32'00.00627"	E121°16'23.37638"	40.044	?	e
UP-CLA	N18°36'01.81879"	E121°05'19.89261"	39.154	0.082	
UP-LIN	N18°17'47.07469"	E121°34'13.39315"	44.429	0.079	
UP-PAM	N18°27'29.74599"	E121°20'15.06060"	47.728	0.032	

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

The computed coordinates of the reference and control points utilized in the Cabicungan River GNSS Static Survey are indicated in Table 24.

Table 24. Reference and control points used in the Cabicungan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on September 18, 2015							
KAY-3	2nd order, GCP	18°14'17.68665"	121°22'13.38974"	59.230	2017311.527	327699.141	19.562
CG-343	1st order, BM	18°20'24.45282"	121°25'08.22638"	51.980	2028541.838	332932.785	13.119
CG-521	Used as Marker	18°20'41.57071"	121°26'33.65512"	47.372	2029046.466	335445.328	8.593
Control Survey on June 15 and 16, 2016							
KAY-3	2nd order, GCP	18°14'17.68665"	121°22'13.38974"	59.230	2017311.527	327699.141	19.562
CG-343	1st order, BM	18°20'24.45282"	121°25'08.22638"	51.980	2028541.838	332932.785	13.119
CG-373	1st order, BM	18°32'00.00627"	121°16'23.37638"	40.044	2050066.562	317727.465	3.422
UP-CLA	UP Established	18°36'01.81879"	121°05'19.89261"	39.154	2057698.195	298347.481	1.961
UP-LIN	UP Established	18°17'47.07469"	121°34'13.39315"	44.429	2023571.535	348899.614	5.535
UP-PAM	UP Established	18°27'29.74599"	121°20'15.06060"	47.728	2041693.715	324445.546	9.580

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

The cross-section and bridge as-built surveys were conducted on June 17 - 18, 2016 at the downstream side of the Cabicungan Bridge in Barangay Dibalio, Municipality of Claveria, Cagayan, as depicted in Figure 36. A survey-grade GNSS receiver, Trimble® SPS 882 in PPK survey technique, was utilized for this survey, as demonstrated in Figure 37.

Figure 36. Cabicungan Bridge, facing downstream

Figure 37. As-built survey of the Cabicungan Bridge

The cross-sectional line surveyed in the Cabicungan Bridge is about 241 meters with one hundred and sixty-nine (169) cross-sectional points, using the control point UP-CLA as the GNSS base station. The location map, cross-section diagram, and the bridge data form are presented in Figure 38 to Figure 40.

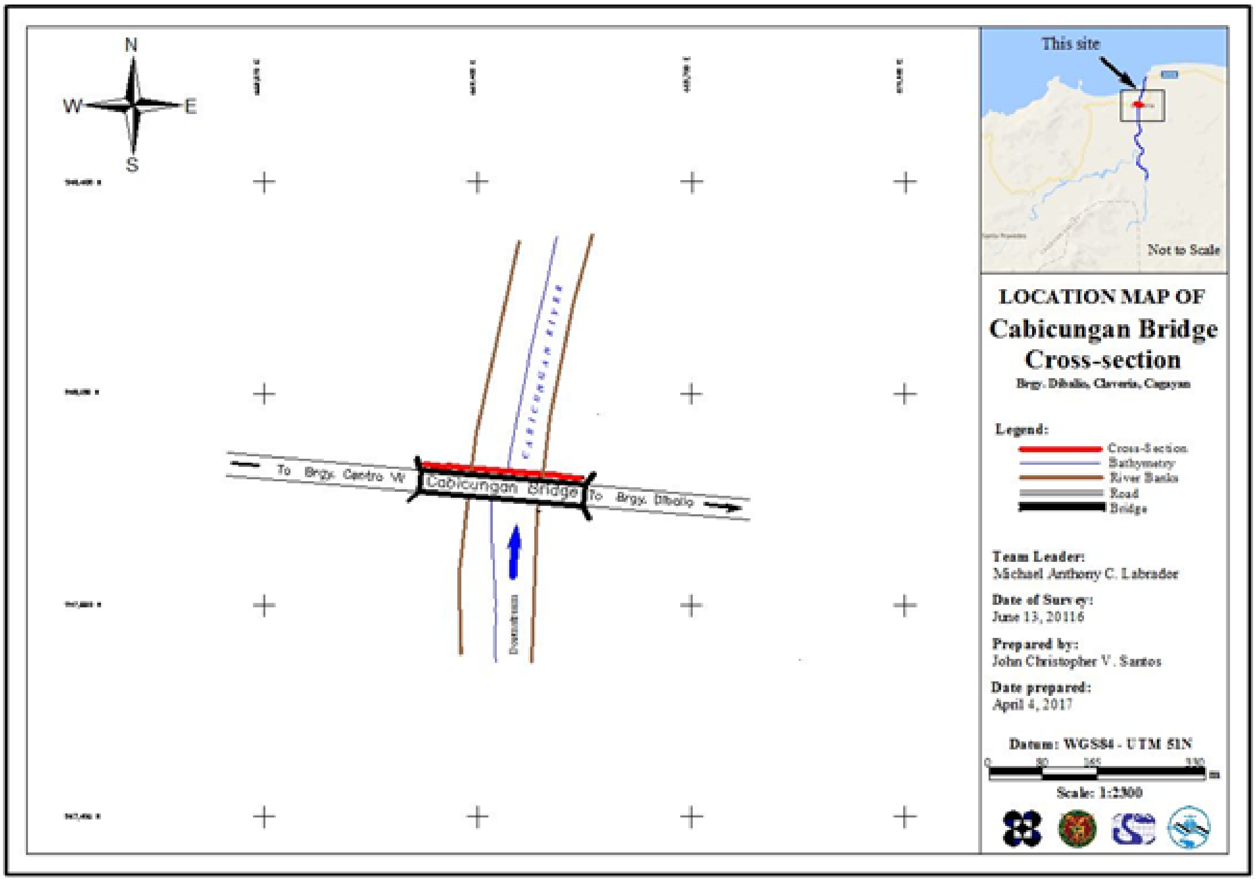


Figure 38. Cabicungan Bridge location map

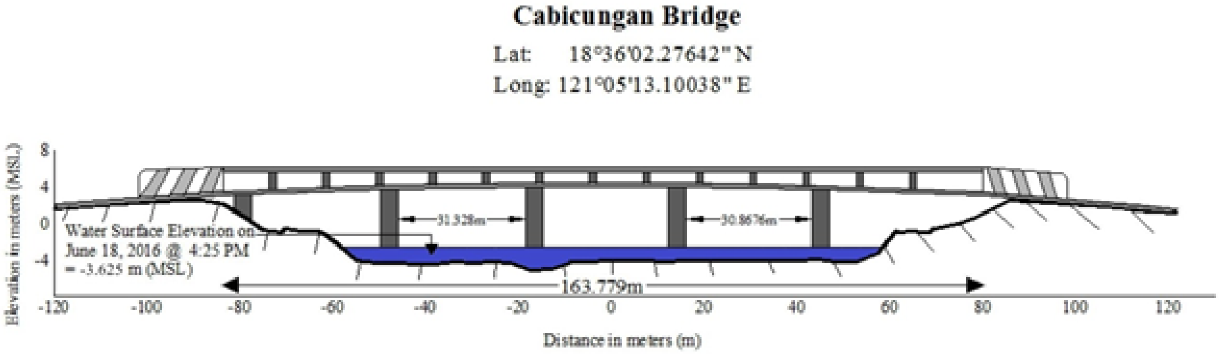


Figure 39. Cabicungan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Cabicungan Bridge **Date:** June 17 & 18, 2016

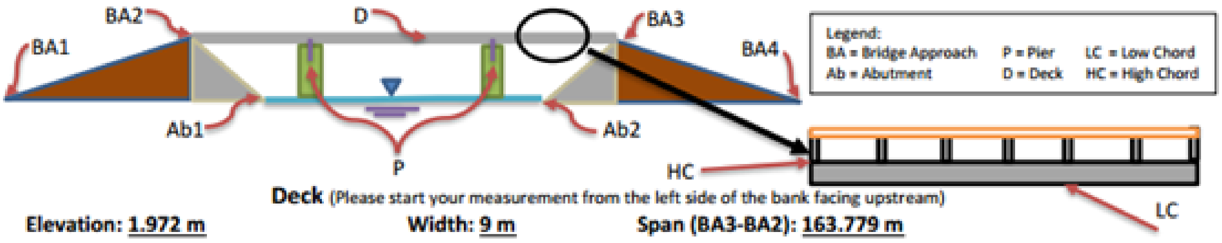
River Name: Cabicungan River **Time:** 4:25 PM

Location (Brgy, City,Region): Brgy. Dibalio, Municipality of Claveria, Cagayan

Survey Team: Romalyn Boado, Lorenz Taguse, Michael Labrador

Flow condition: normal **Weather Condition:** fair

Latitude: 18˚36'2.21210" N **Longitude:** 121˚05'14.38853" E



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

Elevation: 1.972 m **Width:** 9 m **Span (BA3-BA2):** 163.779 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	0.524 m	BA3	200.136 m	1.968 m
BA2	36.357 m	1.972 m	BA4	241.902 m	0.097 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: Cylindrical Number of Piers: 5 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	40.597 m	2.036 m	3.00
Pier 2	71.981 m	2.648 m	3.00
Pier 3	103.317 m	2.940 m	3.00
Pier 4	134.094 m	2.926 m	3.00
Pier 5	164.952 m	2.637 m	3.00

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

Figure 40. Bridge as-built form of the Cabicungan Bridge

The water surface elevation of the Cabicungan River was determined using a survey-grade GNSS receiver, Trimble® SPS 882 in PPK survey technique, on June 18, 2016 at 16:25 hrs. The surface elevation value obtained was 3.65 meters in MSL, as reflected in Figure 39. This was translated into markings on the bridge's deck using the same technique, as displayed in Figure 41. The markings served as a reference for flow data gathering and depth gauge deployment of the ISU Phil-LiDAR 1 team.

Figure 41. Water-level markings on the Cabicungan Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on June 17 - 18, 2016, using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle, as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 1.97 meters and 1.939 meters, measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with UP-CLA occupied as the GNSS base station.

Figure 42. Validation points acquisition survey set-up along the Cabicungan River Basin

The survey started at the Cabicungan Bridge in Barangay Dibalio in the Municipality of Claveria; then headed east, covering the Municipality of Sanchez-Mira, ending in Barangay Centro in the Municipality of Pamplona. The survey then traveled south, encompassing ten (10) barangays in Claveria; and ended in Barangay Santa Filomena in the Municipality of Calanasan. The survey finally headed west, covering fourteen (14) barangays in the Municipality of Pagudpud, which ended in Barangay Pasaleng. The survey gathered a total of 10,490 points with an approximate length of 69 kilometers, using UP-CLA as the GNSS base station for the entire extent of the validation points acquisition survey. This is illustrated in the map in Figure 43.

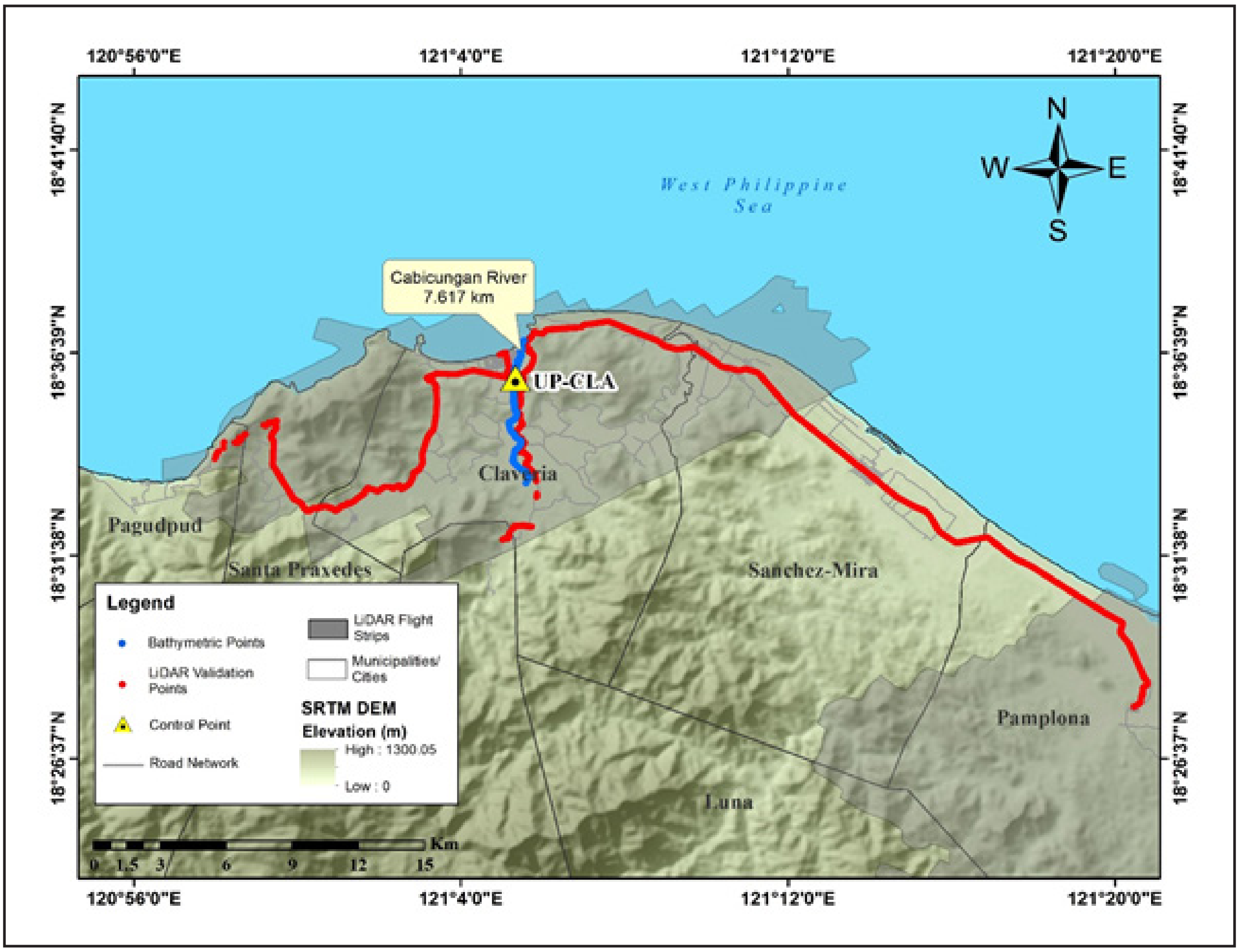


Figure 43. Extent of the LiDAR ground validation survey of Cabicungan River basin

4.7 River Bathymetric Survey

A bathymetric survey was executed on June 17, 2016 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique, set in continuous topo mode, as depicted in Figure 44. The survey started in Barangay San Antonio, with coordinates 18°34'15.57914"N, 121°5'20.30325"E; and ended at the mouth of the river in Barangay Camalaggoan, with coordinates 18°36'57.60717"N, 121°5'32.64657"E. Both points are in the Municipality of Claveria.

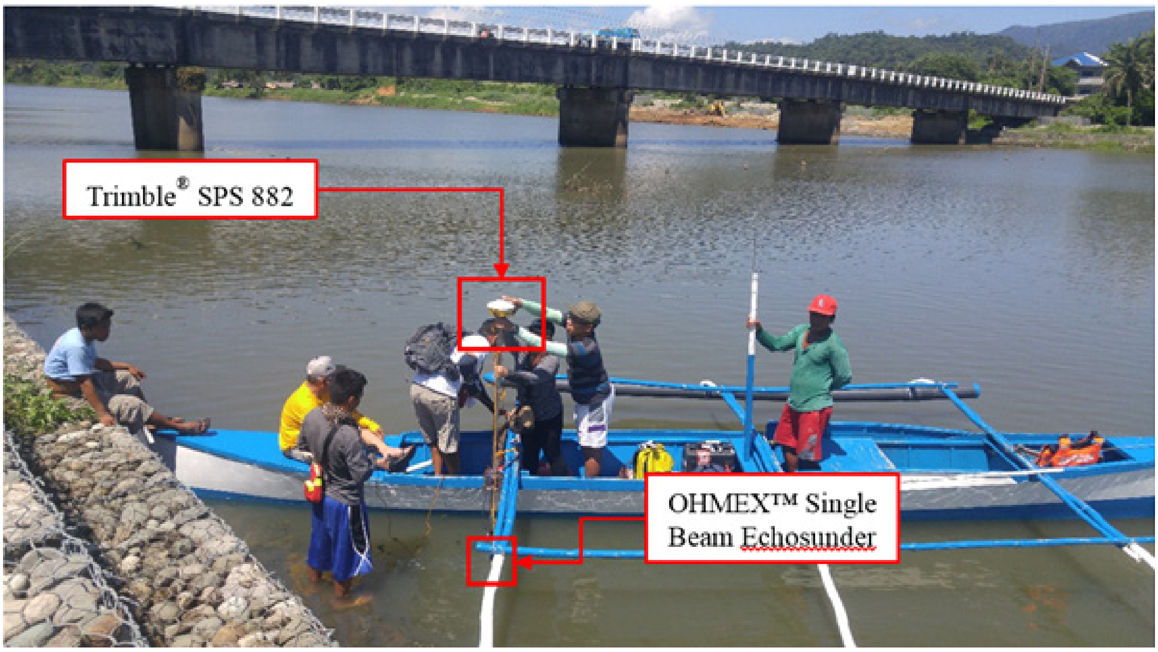


Figure 44. Bathymetric survey using Ohmex™ single beam echo sounder in the Cabicungan River

A manual bathymetric survey was conducted simultaneously with the bathymetric survey, using a Trimble® SPS 882 in GNSS PPK survey technique set in continuous topo mode. The survey started in the upstream portion of the river in Barangay Bacsay Cataraoan in the Municipality of Claveria, with coordinates 18°33'25.78386"N, 121°5'35.77888"E. The surveyors then traversed down by foot, and ended at the starting point of the bathymetric survey by boat. The control point UP-CLA was used as the GNSS base station all throughout the survey.

The bathymetric survey for the Cabicungan River gathered a total of 9,925 points covering 7.617 kilometers of the river, traversing fifteen (15) barangays in the Municipality of Claveia. A CAD drawing was also produced to illustrate the riverbed profile of the Cabicungan River, presented in Figure 46. The profile demonstrates that the highest and lowest elevation had a 14.5-meter difference. The highest elevation observed was 1.084 meters above MSL, located in Barangay Bacsay Cataraoan; while the lowest was -13.423 meters below MSL, located in Barangay Sta. Maria. Both sites are in the Municipality of Claveria. The survey for the remaining 3 kilometers in the upstream part of the river was cut, since the LiDAR data for its riverbed was already available.

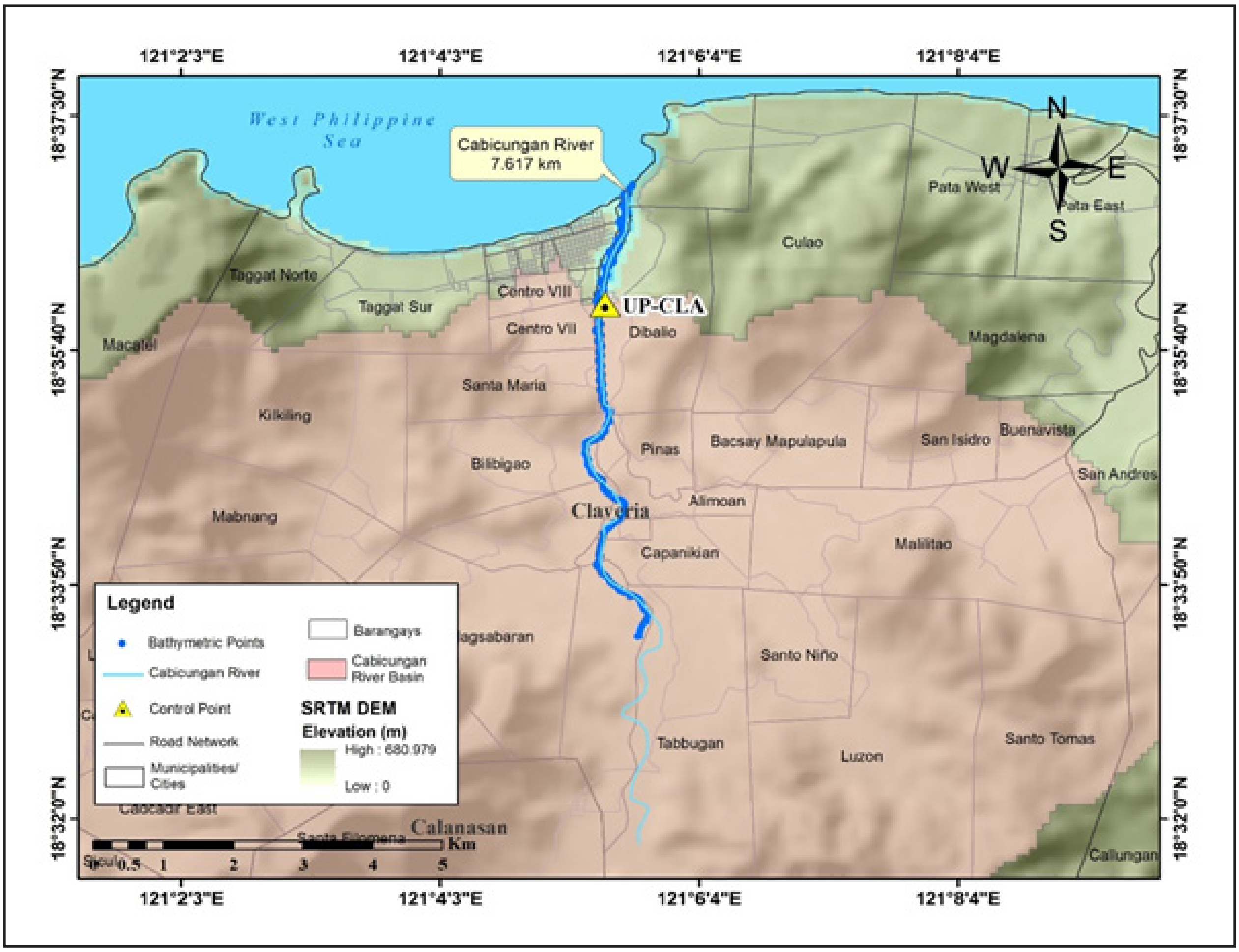


Figure 45. Extent of the bathymetric survey of Cabicungan River

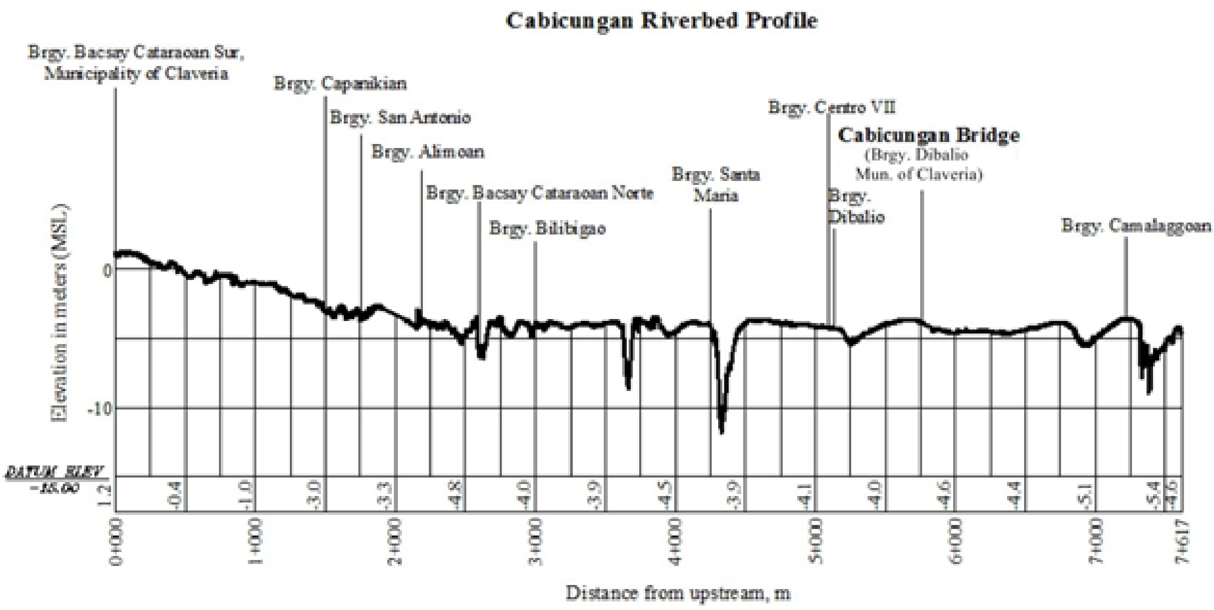


Figure 46. Cabicungan riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

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

5.1.2 Precipitation

Cagayan, including the Cabicungan River Basin, experienced sustained, heavy monsoon rains in the months of January and February 2017. The hydrologic data collection was conducted on January 31, 2017 at 16:50 hrs. until February 2, 2017 at 08:00 hrs. Hydrologic data include the river velocity, water depth, and amount of rain collected from the data logging sensors (i.e., mechanical velocity meter, depth gauge, and rain gauges) in a specific time period. Precipitation data was taken from a portable rain gauge installed by the ISU Phil-LiDAR 1 team, since there is no automatic rain gauge (ARG) within the river basin. The location of the rain gauge is seen in Figure 47.

Total rain from the portable rain gauge was 153.8 millimeters. It peaked at 3.6 millimeters on February 1, 2017 at 17:30 hrs. The lag time between the peak rainfall and discharge was four (4) hours.

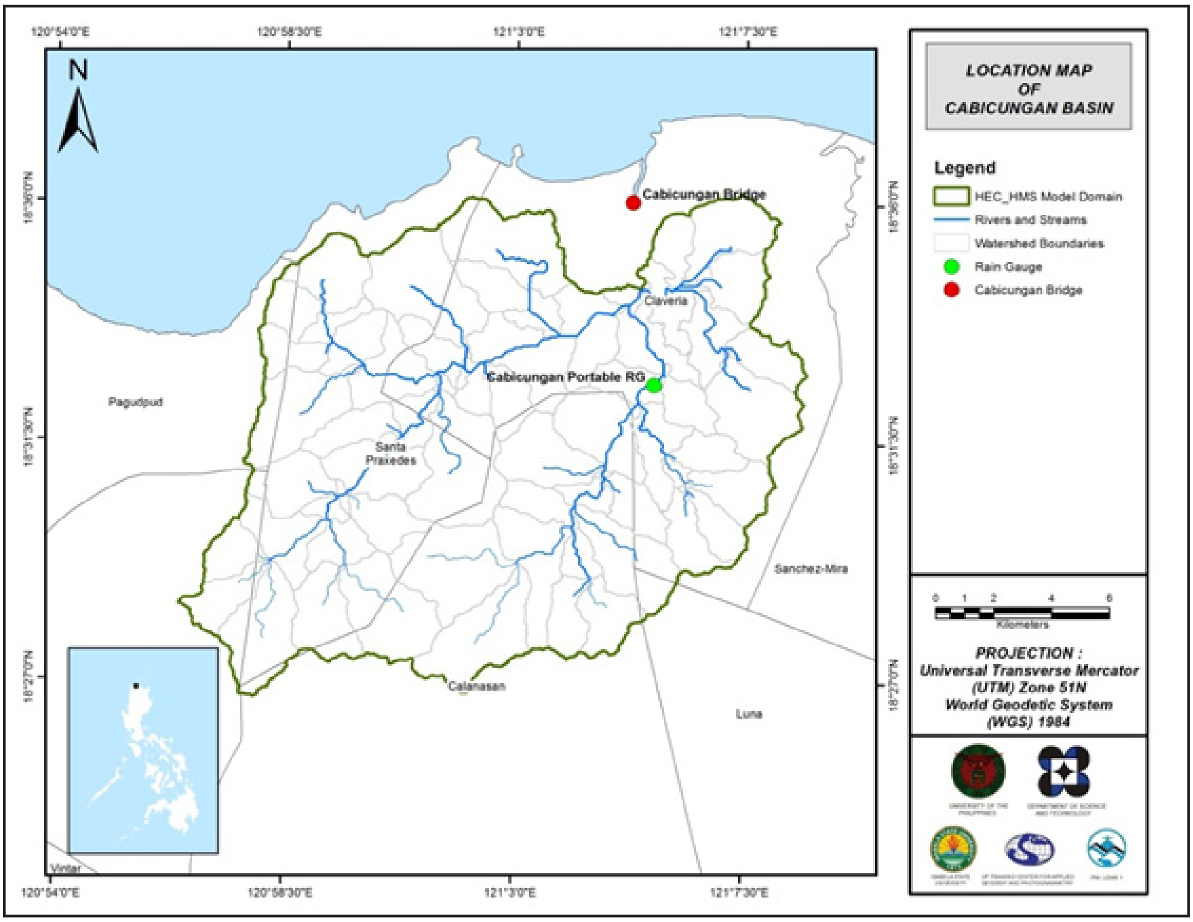


Figure 47. Location map of the Cabicungan HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

The monsoon rains that occurred on January 31, 2017 to February 2, 2017 contributed to a (-)2.349-meter water level rise, with a peak discharge of 206.7 m3/s. This was recorded at 21:30 hrs. on February 1, 2017, with an accumulated rainfall amount of 153.8 millimeters. These hydrologic data represent actual events in the Cabicungan River, and were thus inputted into the hydrologic modeling. The hydrologic measurements were taken from the Cabicungan Bridge in Claveria, Cagayan.

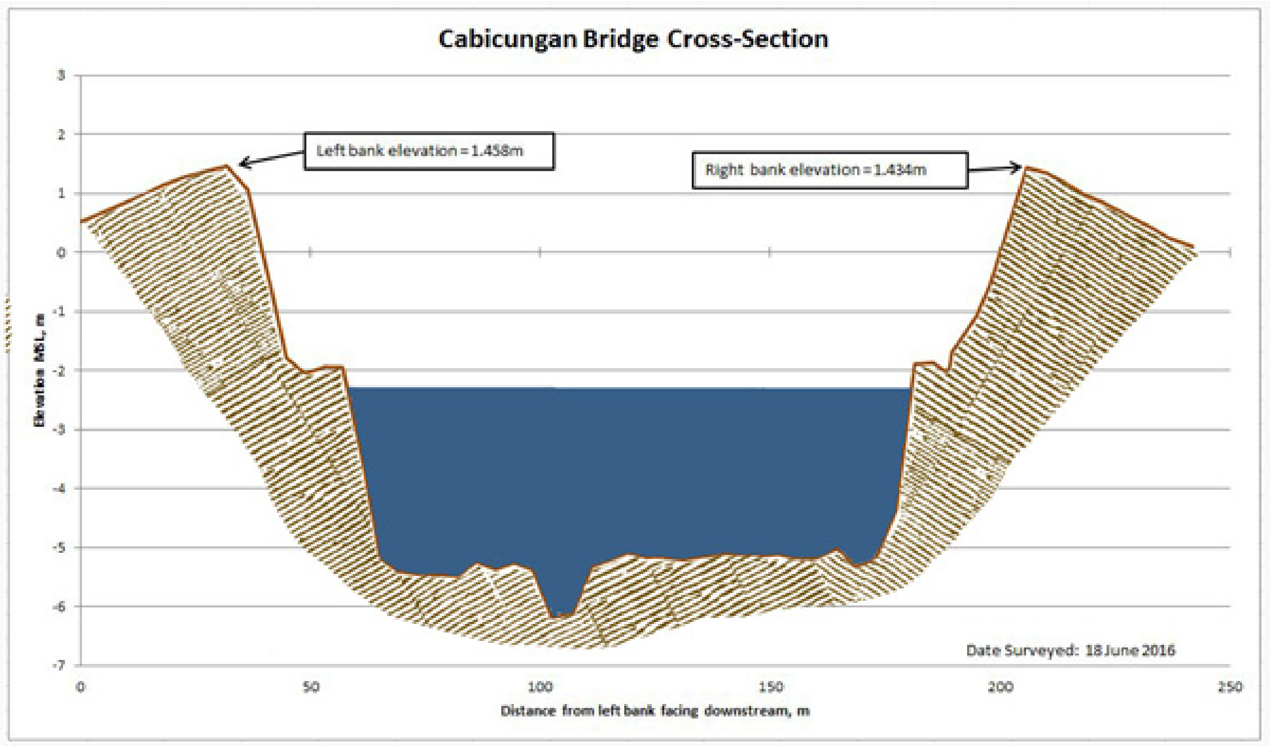


Figure 48. Cross-section plot of the Cabicungan Bridge

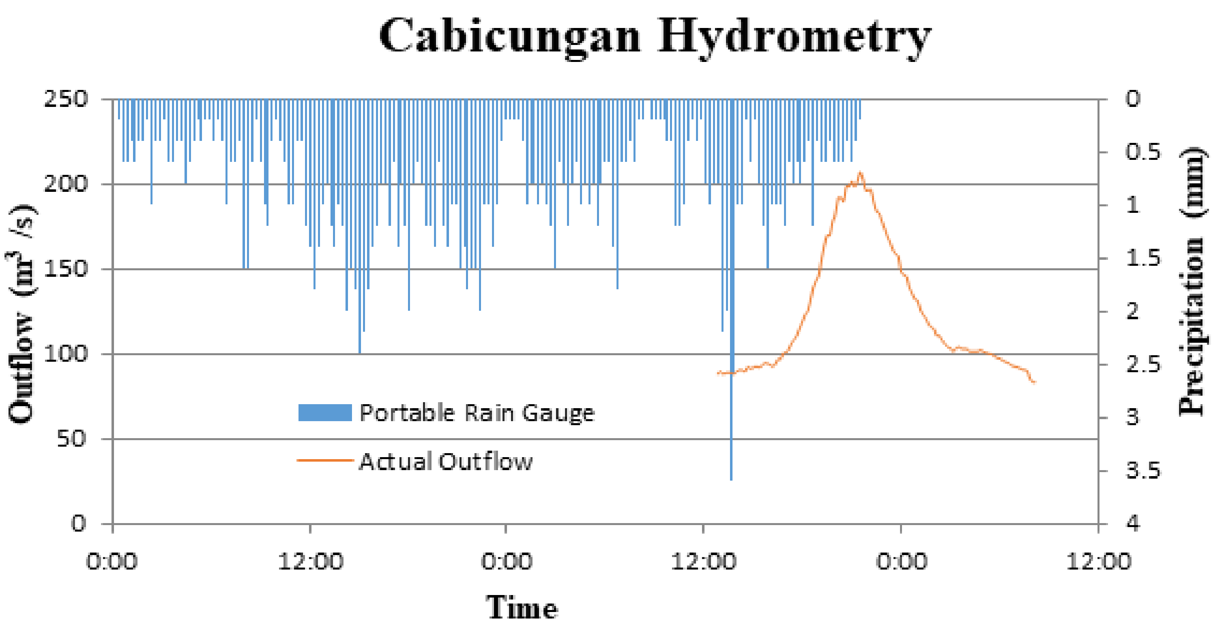


Figure 49. Rainfall and outflow data, which were used for modeling

A rating curve was computed using the prevailing cross-section (Figure 48) at the Cabicungan Bridge to establish the relationship between the observed water levels and the outflow of the watershed at this location. It is expressed in the form of the following equation:

$$Q=anh$$

where,

Q	:	Discharge (m3/s),
h	:	Gauge height (reading from the Cabicungan Bridge depth gauge sensor), and
a and n	:	Constants

The Cabicungan River rating curve measured at the Cabicungan Bridge is expressed as Q = 90903e2.5911x (Figure 50).

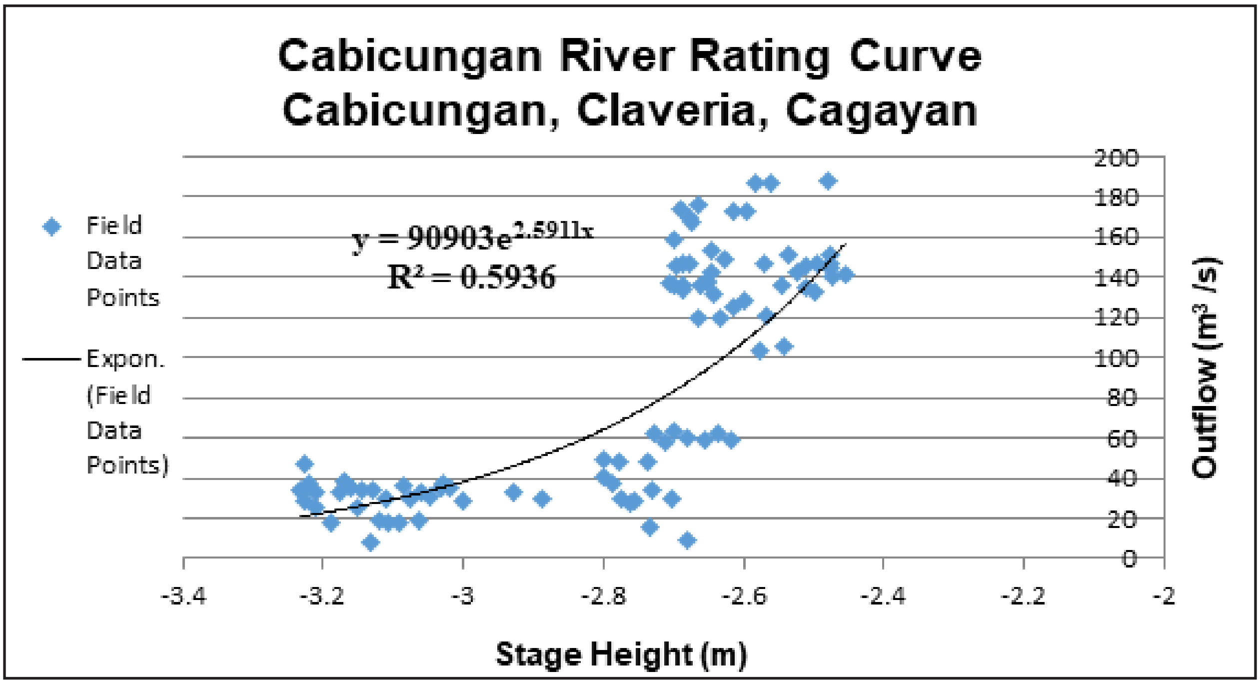


Figure 50. Rating curve at the Cabicungan Bridge, Claveria, Cagayan

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Aparri Rain Gauge (Table 25). This station was selected based on its proximity to the Cabicungan watershed (Figure 51). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 47-year record.

Table 25. RIDF values for the Aparri Rain Gauge, computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	20.1	31.4	39.4	53.3	75.6	92.2	119.4	147.7	167.9
5	28.5	44.9	55.8	78.7	110.4	137	173.6	221.2	252.5
10	34.1	53.8	66.6	95.6	133.4	166.6	209.5	269.9	308.5
15	37.2	58.8	72.7	105.1	146.5	183.4	229.7	297.4	340.2
20	39.4	62.3	77	111.8	155.6	195.1	243.9	316.6	362.3
25	41.1	65	80.3	116.9	162.6	204.1	254.8	331.4	379.3
50	46.3	73.4	90.5	132.7	184.2	231.9	288.4	377.1	431.9
100	51.4	81.7	100.6	148.4	205.6	259.5	321.7	422.4	484

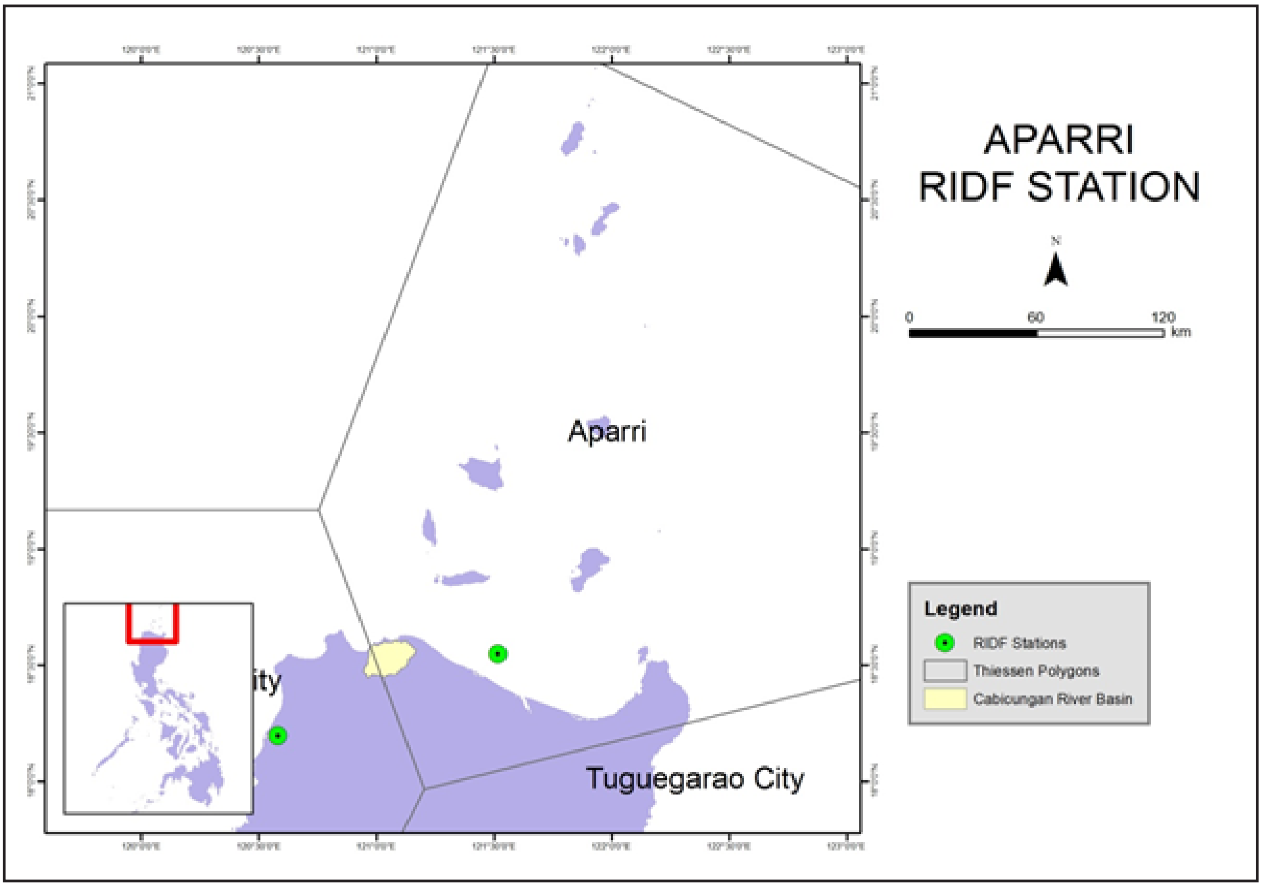


Figure 51. Location of the Aparri RIDF Station, relative to the Cabicungan River Basin

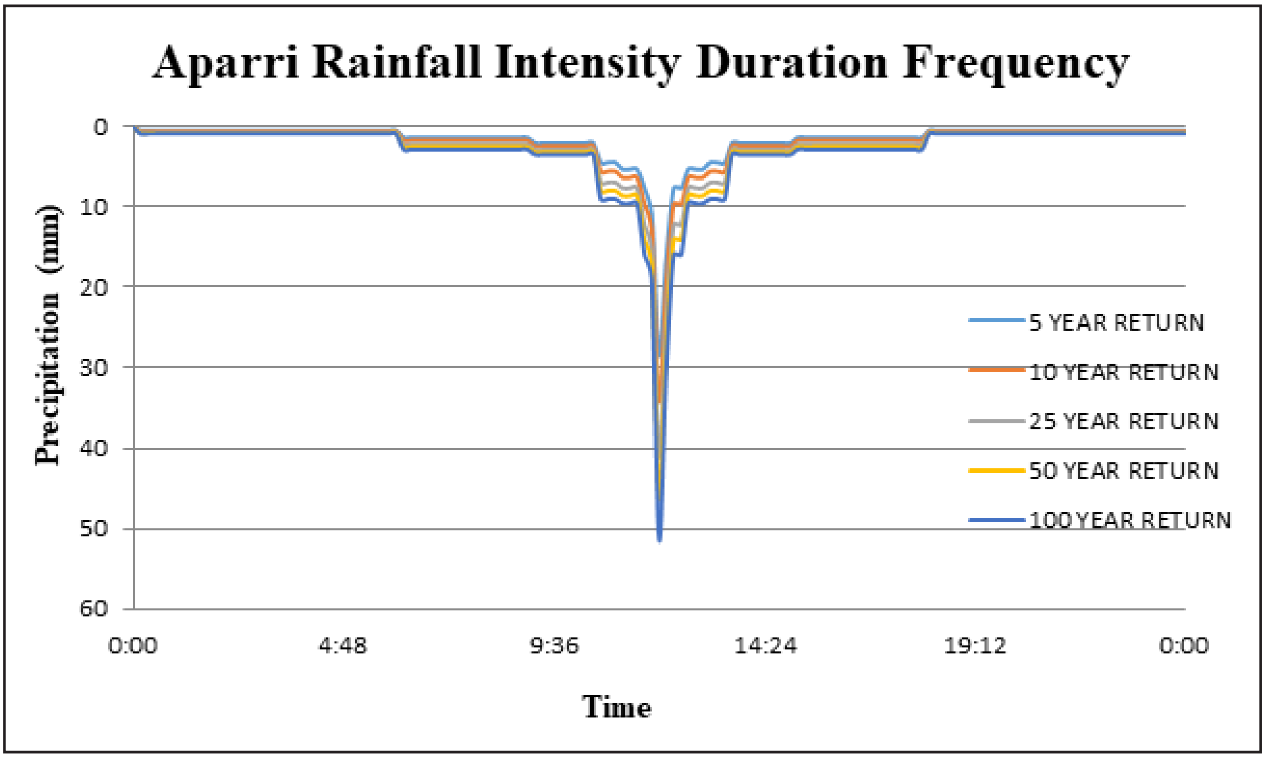


Figure 52. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Cabicungan River Basin are presented in Figures 53 and 54, respectively.

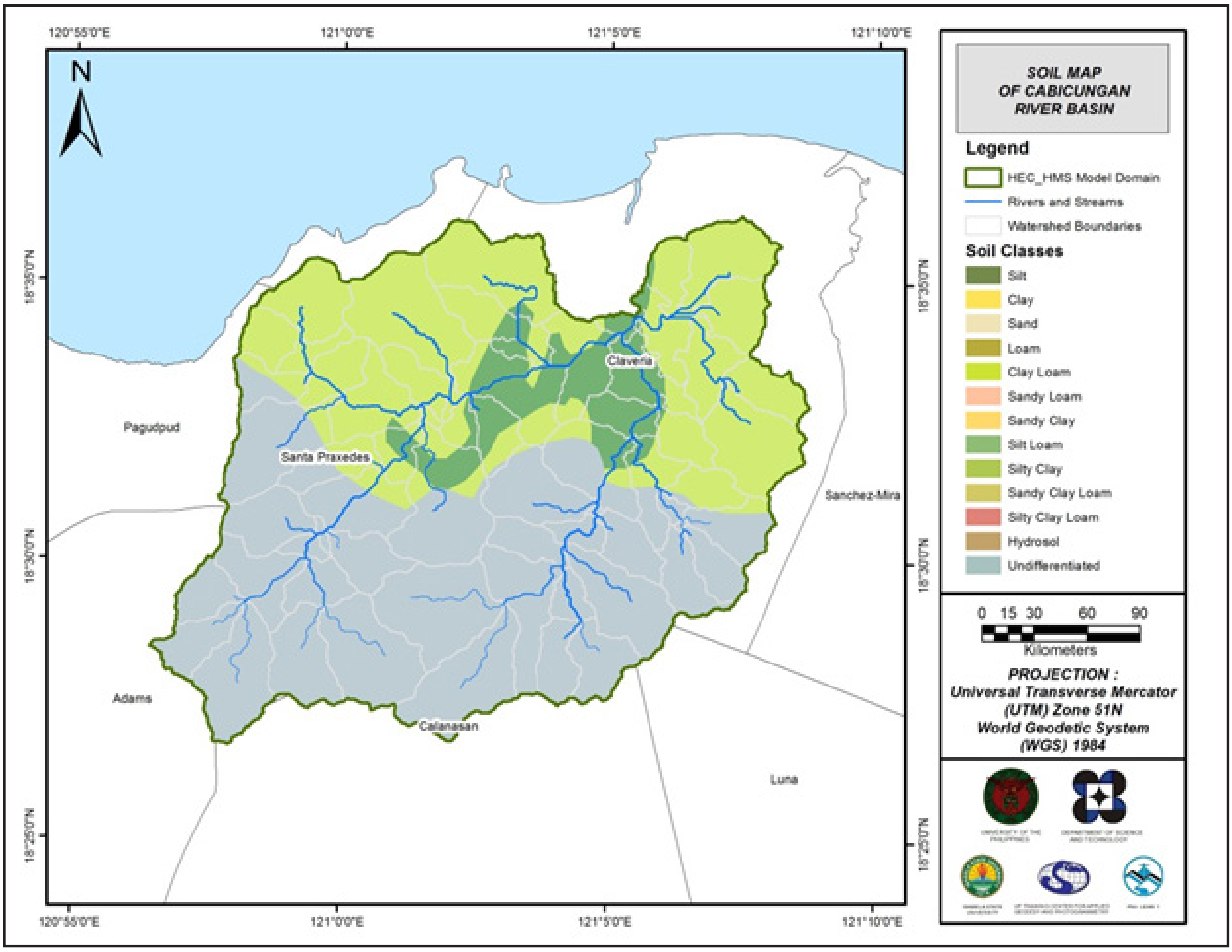


Figure 53. Soil map of the Cabicungan River Basin (Source: DA)

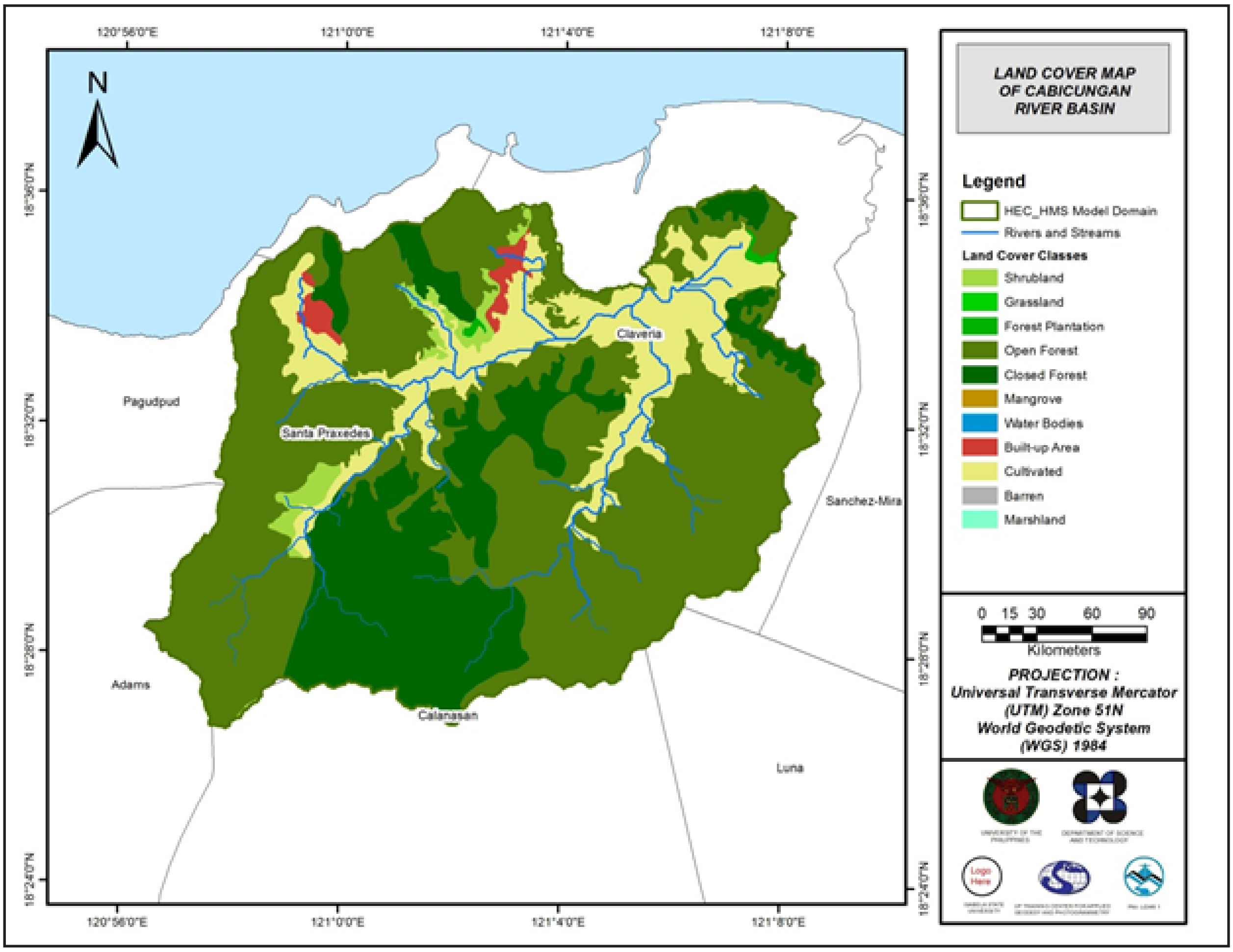


Figure 54. Land cover map of the Cabicungan River Basin (Source: NAMRIA)

Thirteen (13) soil classes were identified in the Cabicungan River Basin. These are silt, clay, sand, loam, clay loam, sandy loam, sandy clay, silt loam, silt clay, sandy clay loam, silty clay loam, hydrosol, and undifferentiated soil. Moreover, eleven (11) land cover classes were identified. These are shrub lands, grasslands, forest plantations, open forests, closed forests, mangroves, water bodies, built-up areas, cultivated land, barren land, and marshlands.

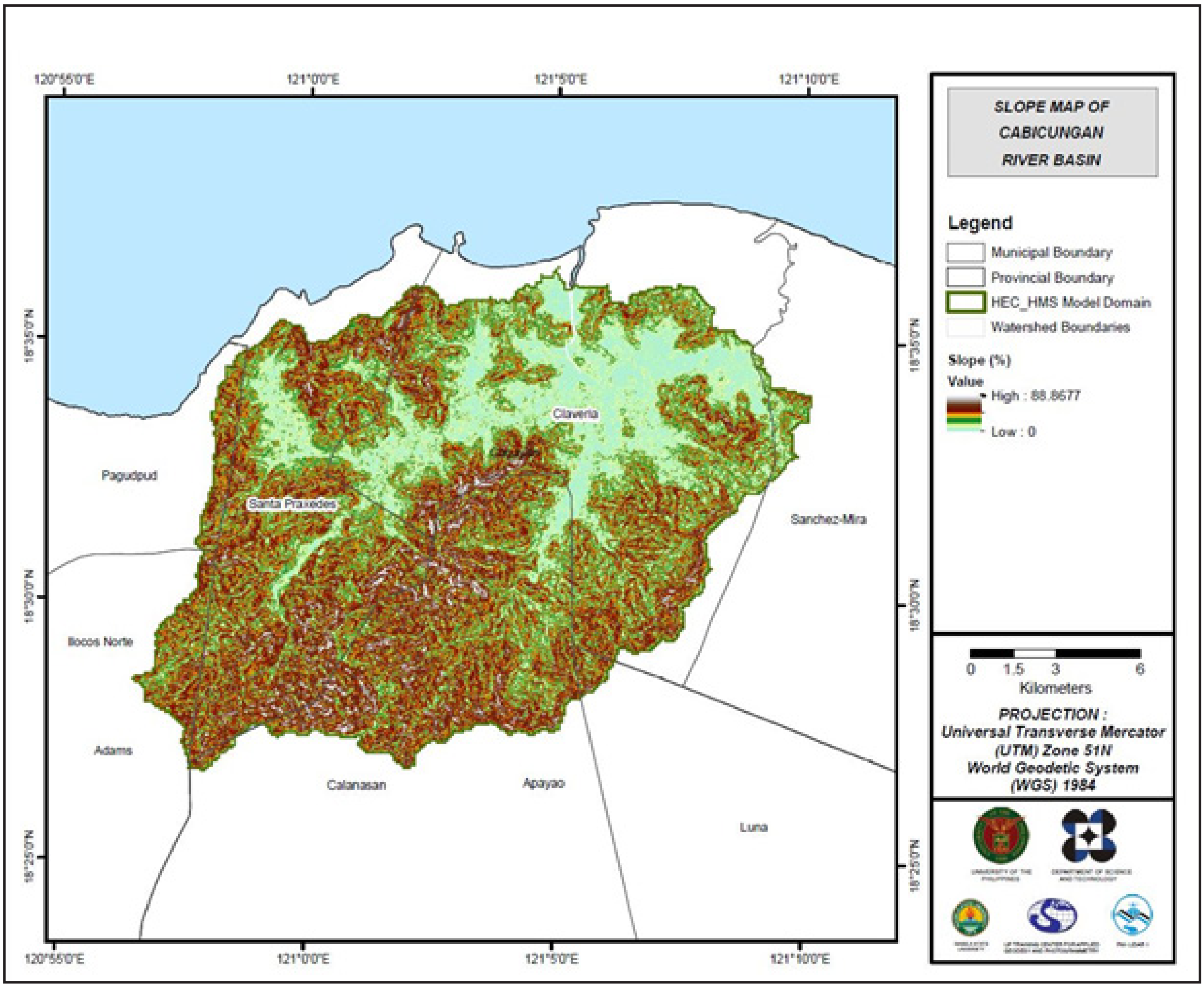


Figure 55. Slope map of the Cabicungan River Basin

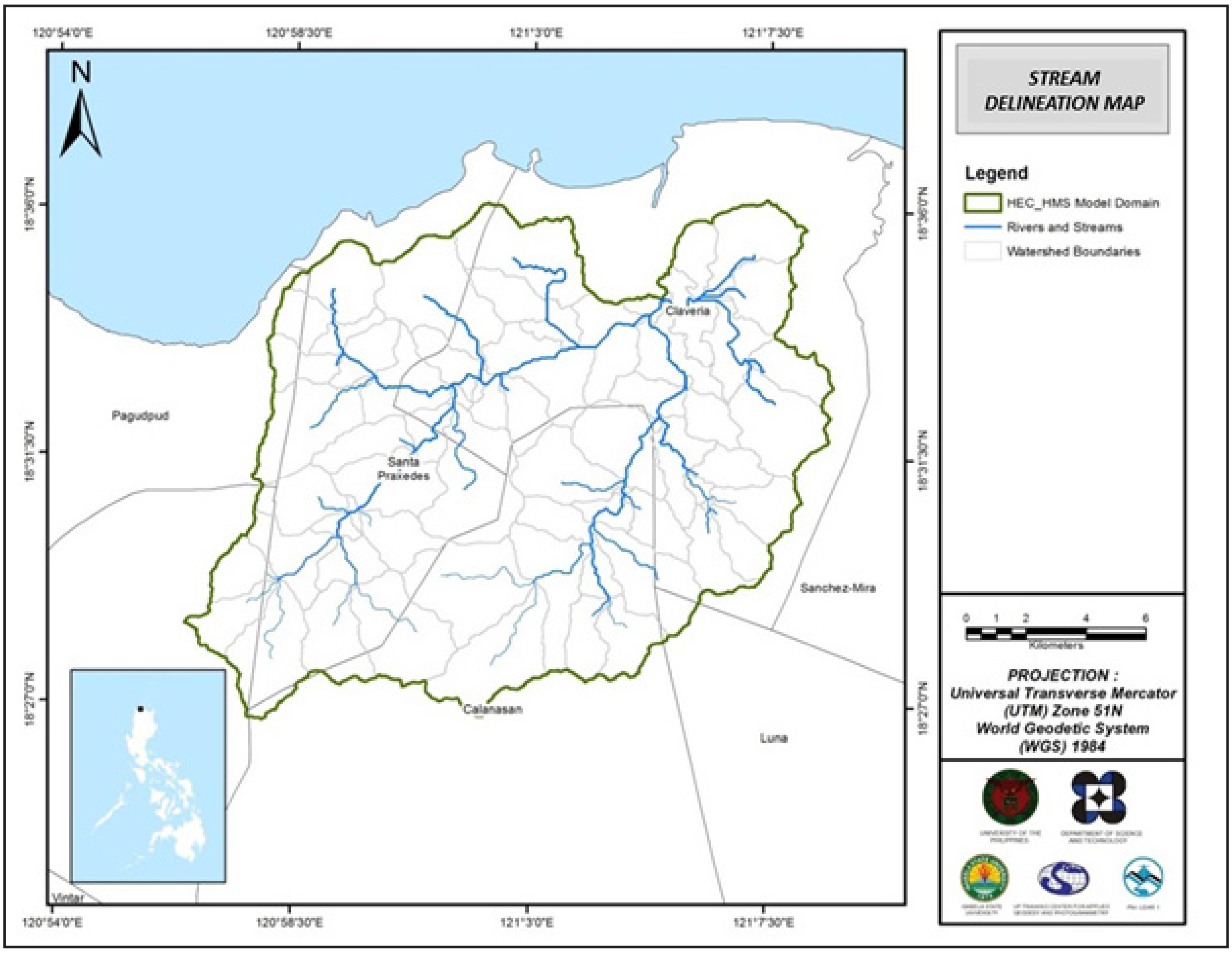


Figure 56. Stream delineation map of the Cabicungan River Basin

A drainage system includes the basin boundaries, sub-basins, and the stream networks. Using ArcMap 10.2 with the HEC-GeoHMS version 10.2 extension, the Cabicungan River centerline and the SAR-DEM with a 10-meter resolution served as primary data, delineating the drainage system of the Cabicungan River Basin. The river centerline was digitized starting from the upstream towards downstream in Google Earth (2014). The default threshold area applied was 140 hectares.

Using the SAR-based DEM, the Cabicungan basin was delineated and further subdivided into sub-basins. The Cabicungan basin model consists of sixty-five (65) sub-basins, thirty-two (32) reaches, and thirty-four (34) junctions. The main outlet is at Outlet 1. This basin model is illustrated in Figure 57. The basins were identified based on the soil and land cover characteristics of the area. Precipitation from the monsoon rainfall event from January 31, 2017 to February 2, 2017 was taken from the installed portable rain gauge. Finally, the model was calibrated using data from the Cabicungan depth gauge sensor. See Annex 9 for the Cabicungan Model Reach Parameters.

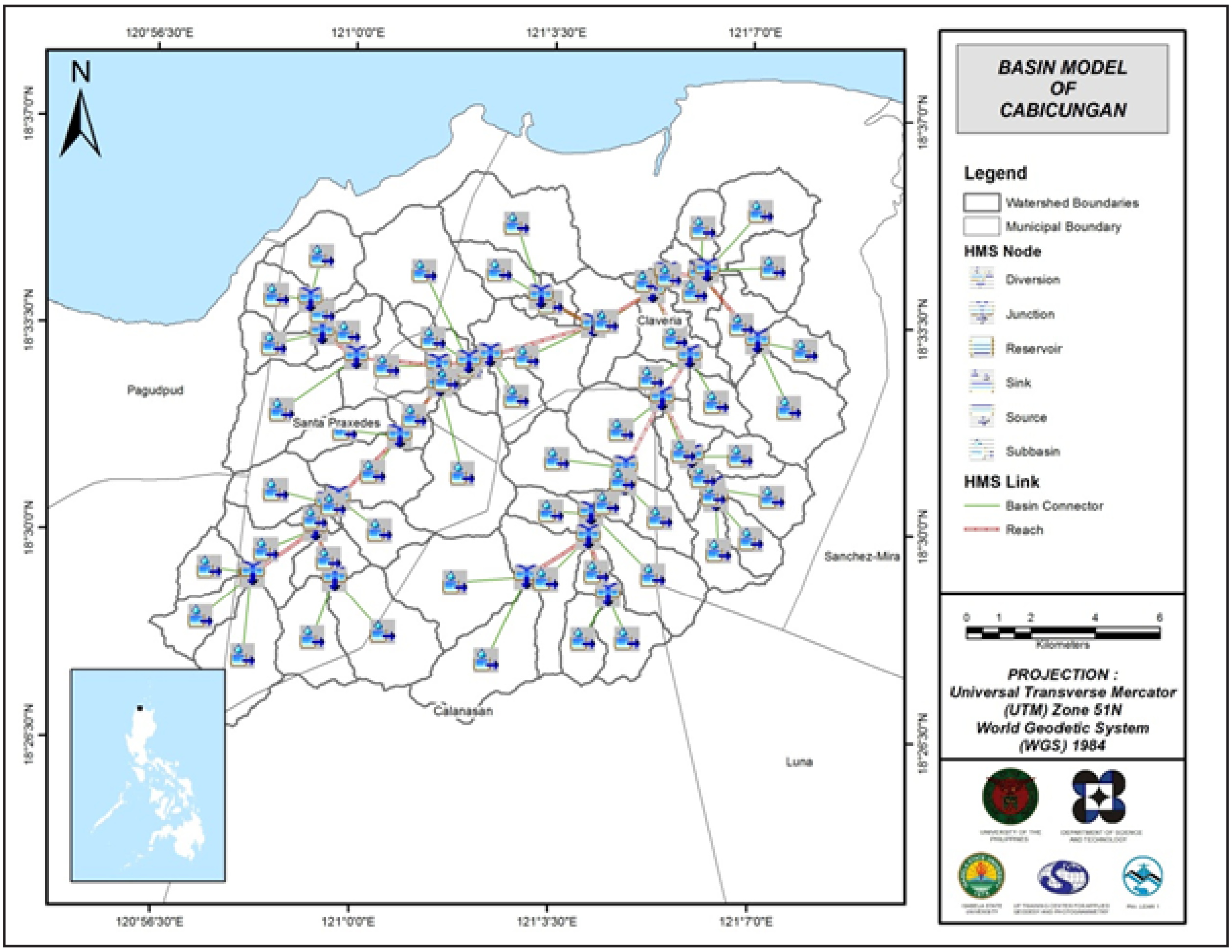


Figure 57. Cabicungan River Basin Model, generated by HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 58).

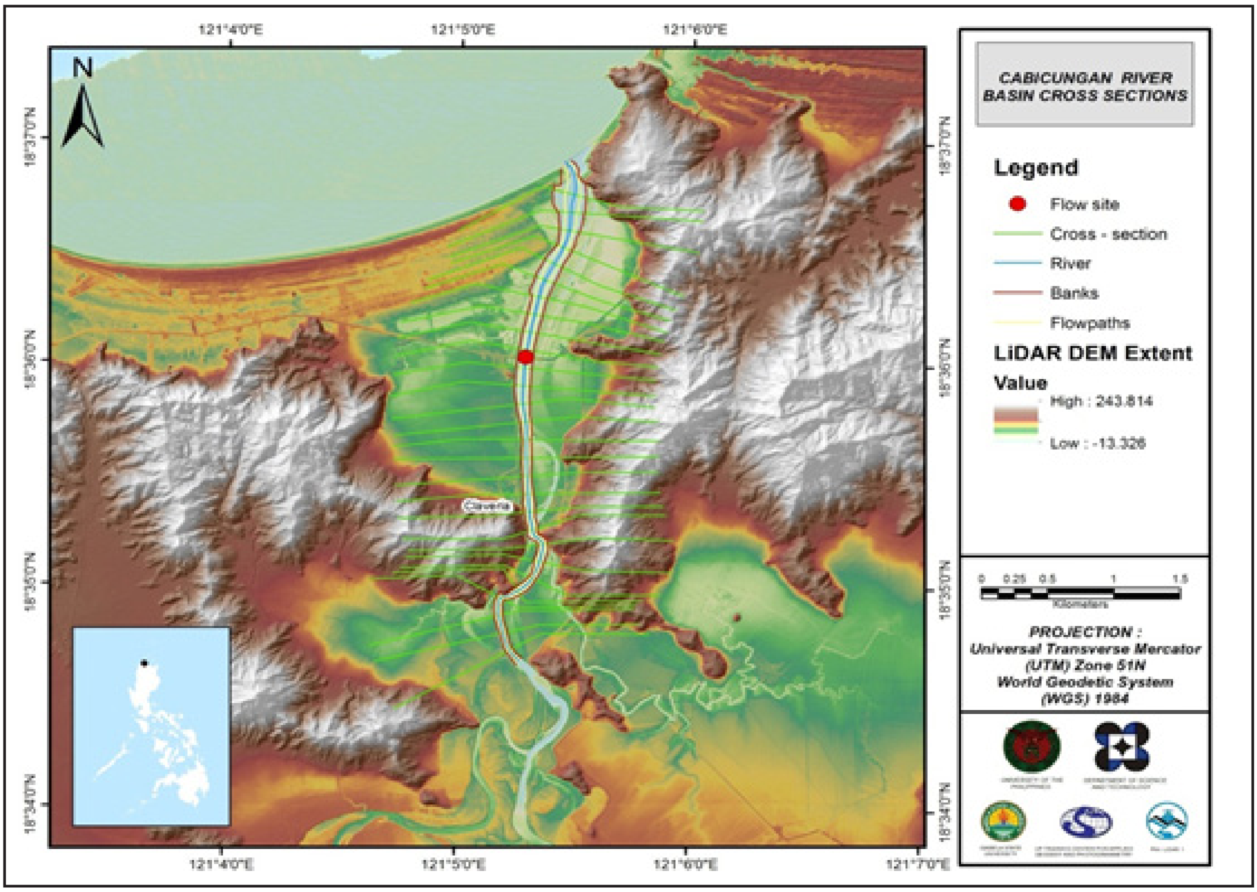


Figure 58. Cabicungan River cross-section, generated using the HEC GeoRAS tool

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 meters by 10 meters in size. Each element as assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y- coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it was determined that the water will generally flow from the southwest side of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively.

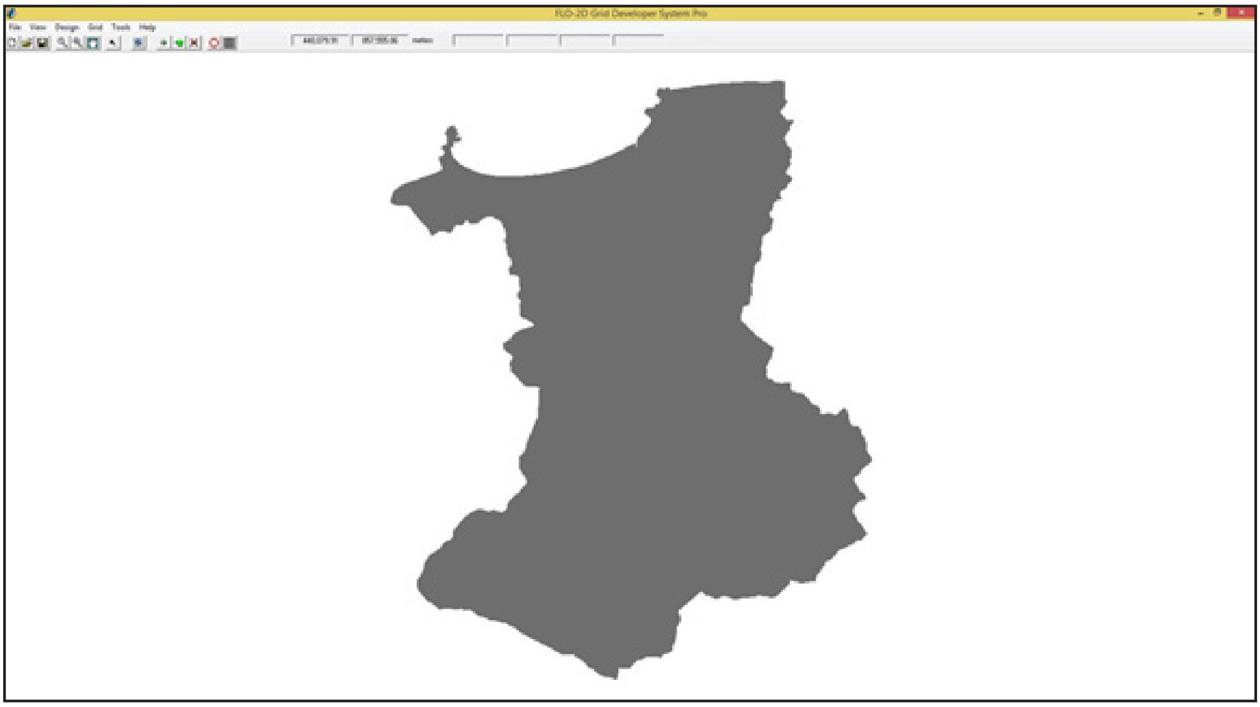


Figure 59. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 206.38159 hours. After the simulation, the FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High generated the flood hazard map. Most of the default values given by the 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 meters; while the minimum vh (product of maximum velocity (v) and maximum depth (h)) was set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically generated a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in the 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 89 723 424.00 m^2.

There as a total of 119 768 593.01 m^3 of water that entered the model. Of this amount, 45 129 083.70 m^3 was due to rainfall, while 74 639 509.30 m^3 was inflow from areas outside the model. 12 611 193.00 m^3 of this water was lost to infiltration and interception, while 19 217 951.59 m^3 was stored by the floodplain. The rest, amounting to up to 87 939 518.90 m^3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Cabicungan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 depicts the comparison between the two discharge data. The Cabicungan Model Basin Parameters are available in Annex 8.

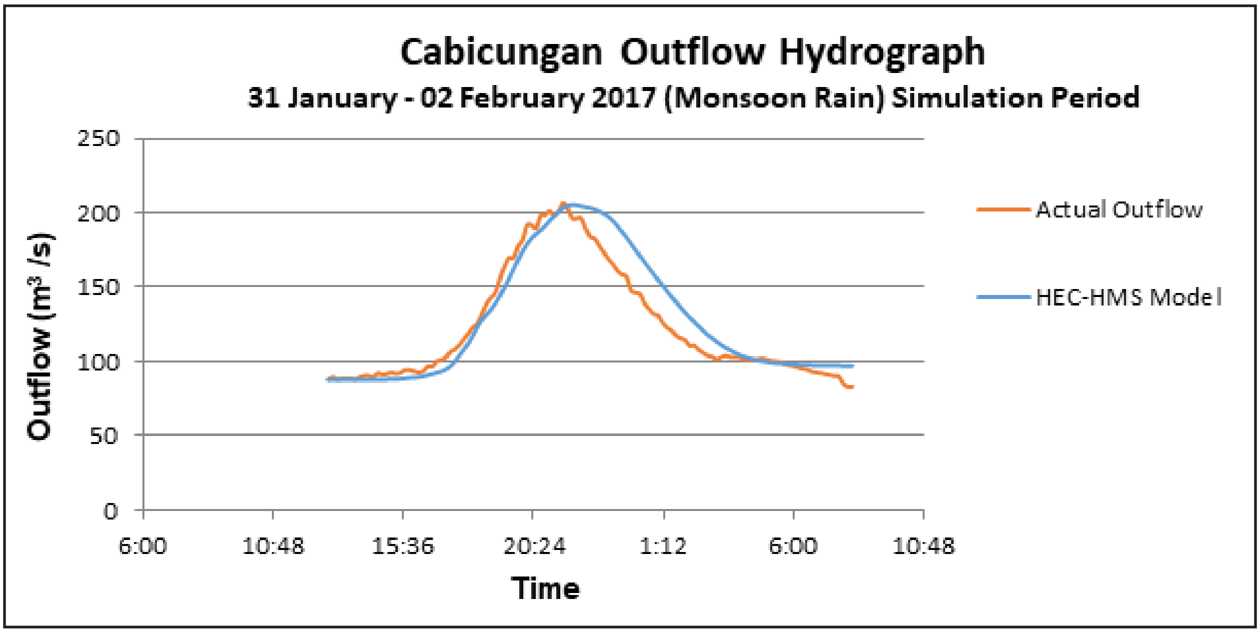


Figure 60. Outflow hydrograph of Cabicungan produced by the HEC-HMS model, compared with observed outflow

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

Table 26. Range of calibrated values for the Cabicungan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.96 – 12.46
			Curve Number	55 - 89
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 0.31
			Storage Coefficient (hr)	0.06 – 1.51
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.3
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. A range of values of 1.96 - 12.46 millimeters for the initial abstraction signifies that there is a minimal amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of the curve number of the Cabicungan River Basin is 55 - 89. The Cabicungan basin mostly consists of open forests, closed land, and cultivated areas; and the soil mostly consists of clay loam, silt loam, and undifferentiated soil.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 1.51 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; while ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 1 indicates that the basin is highly unlikely to quickly revert to its original discharge, and will be higher instead. A ratio to peak of 0.3 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.04 corresponds to the common roughness in the Cabicungan watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 27. Efficiency Test of the Cabicungan HMS Model

Accuracy measure	Value
RMSE	12.9
r^2	0.9139
NSE	0.88
PBIAS	-3.46
RSR	0.34

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 12.9 (m^3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 signifies an almost perfect match of the observed discharge and the resulting discharge from the HEC-HMS model. In the model, the coefficient is 0.9139.
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 0.88.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -3.46.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained an RSR value of 0.34.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph in Figure 61 shows the Cabicungan River outflow using the Aparri RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

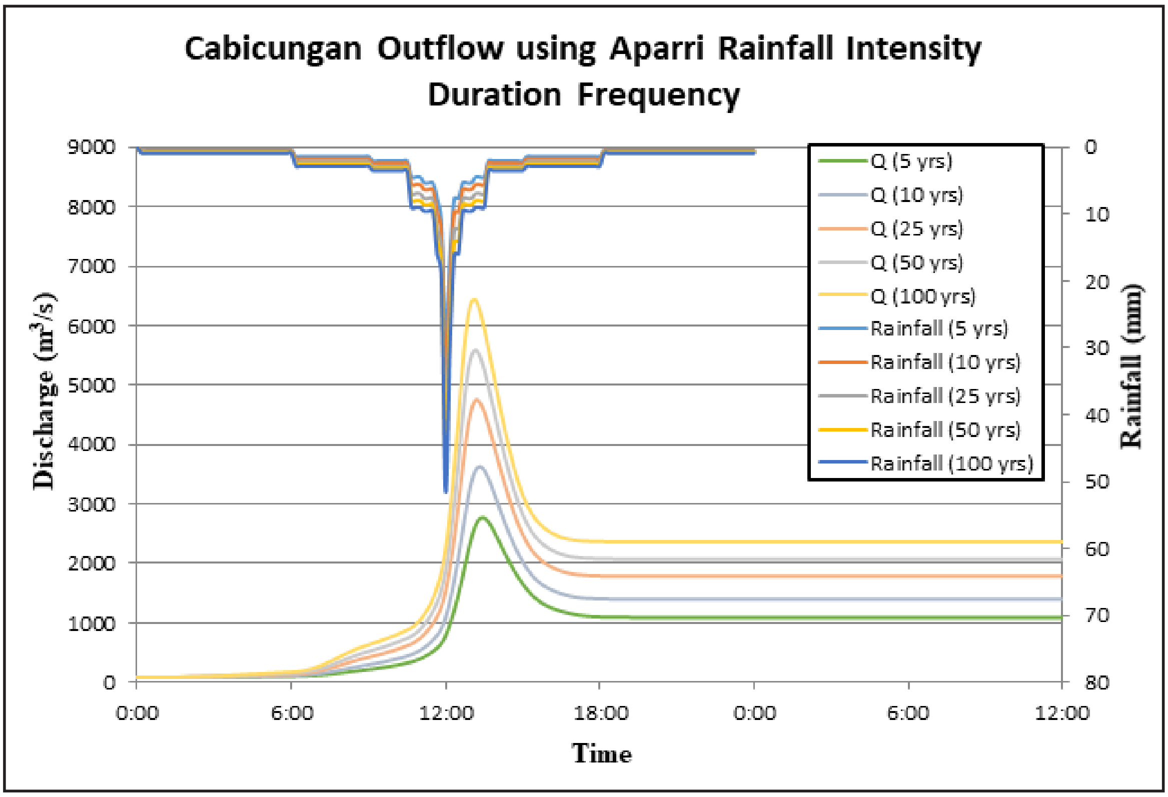


Figure 61. Outflow hydrograph at the Cabicungan Station generated using the Aparri RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Cabicungan discharge using the Aparri RIDF curves in five (5) different return periods is given in Table 28.

Table 28. Peak values of the Cabicungan HEC-HMS Model outflow, using the Aparri RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-year RIDF	252.5	28.5	2755.9	1 hours, 20 minutes
10-year RIDF	308.5	34.1	3628.3	1 hours, 20 minutes
25-year RIDF	379.3	41.1	4747.9	1 hours, 10 minutes
50-year RIDF	431.9	46.3	5591.0	1 hours, 10 minutes
100-year RIDF	484	51.4	6431.0	1 hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the 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 presented. The sample generated map of the Cabicungan River using the calibrated HMS is shown in Figure 62.

Figure 62. Sample output map of the Cabicungan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 63 to Figure 68 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Cabicungan floodplain. The floodplain, with an area of 303.13 square kilometers, covers five (5) municipalities; namely, Calanasan, Claveria, Sanchez-Mira, Santa Praxedes and Pagudpud. Table 29 indicates the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in the Cabicungan floodplain

Municipality	Total Area	Area Flooded	% Flooded
Calanasan	948.15	28.31	3%
Claveria	143.98	161.25	89%
Sanchez-Mira	205.31	23.84	12%
Santa Praxedes	50.89	86.19	59%
Pagudpud	194.15	3.54	2%

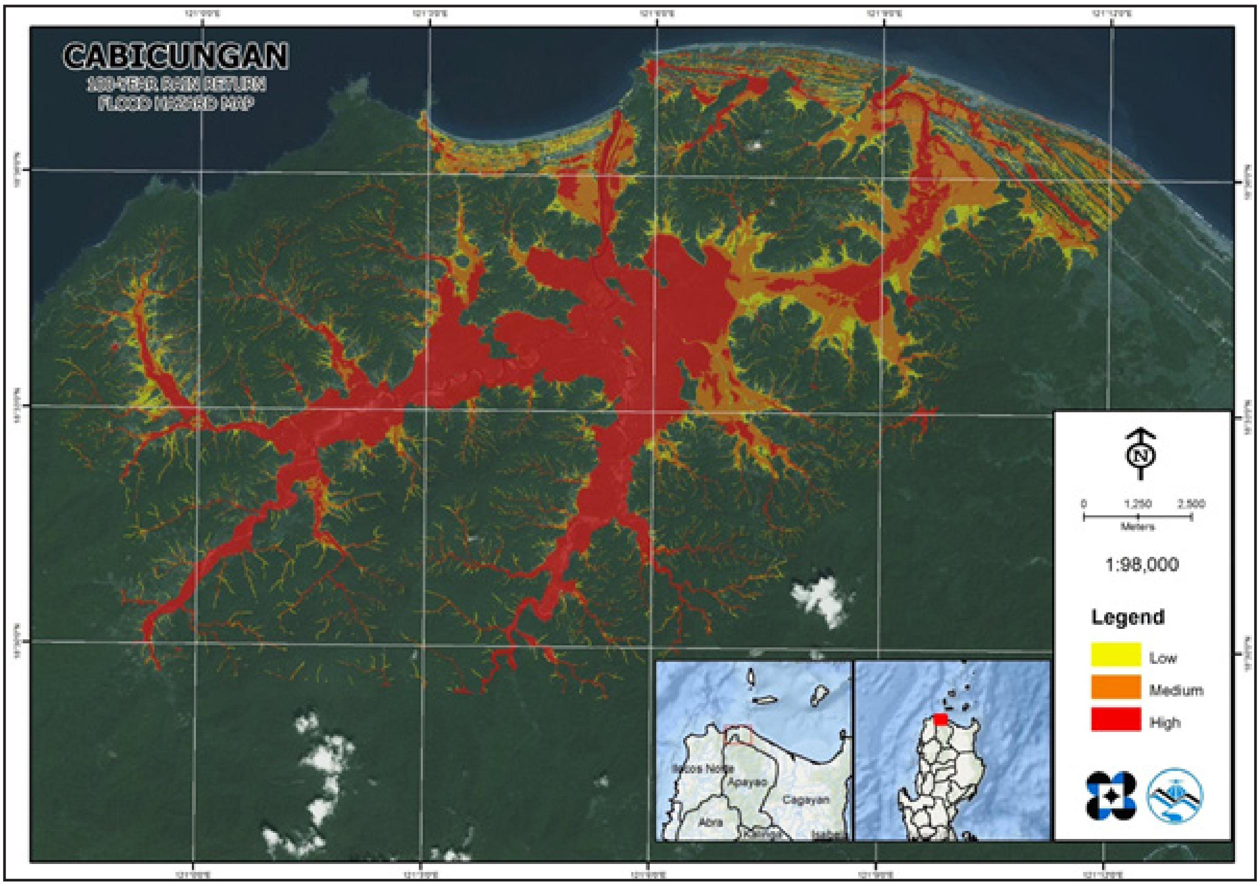


Figure 63. 100-year flood hazard map for the Cabicungan floodplain

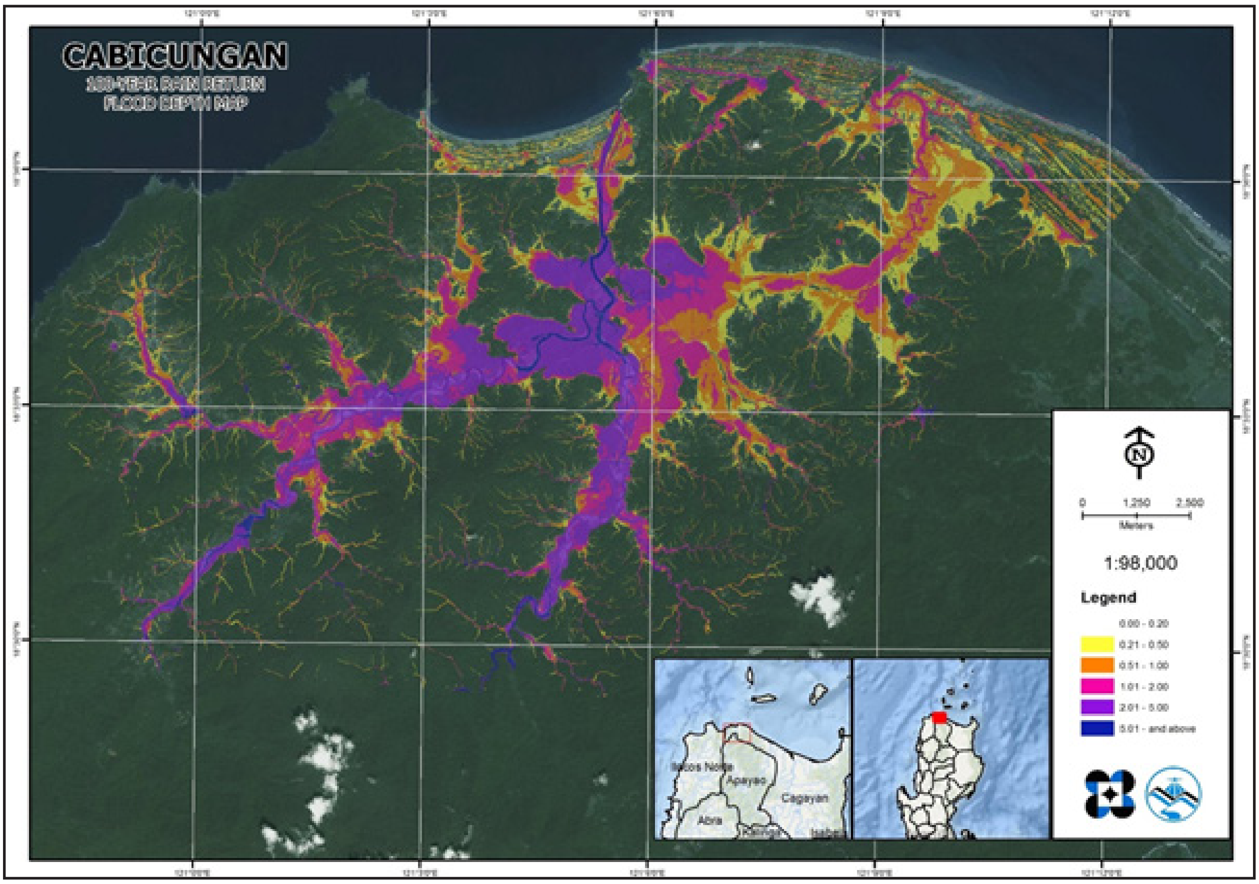


Figure 64. 100-year flow depth map for the Cabicungan floodplain

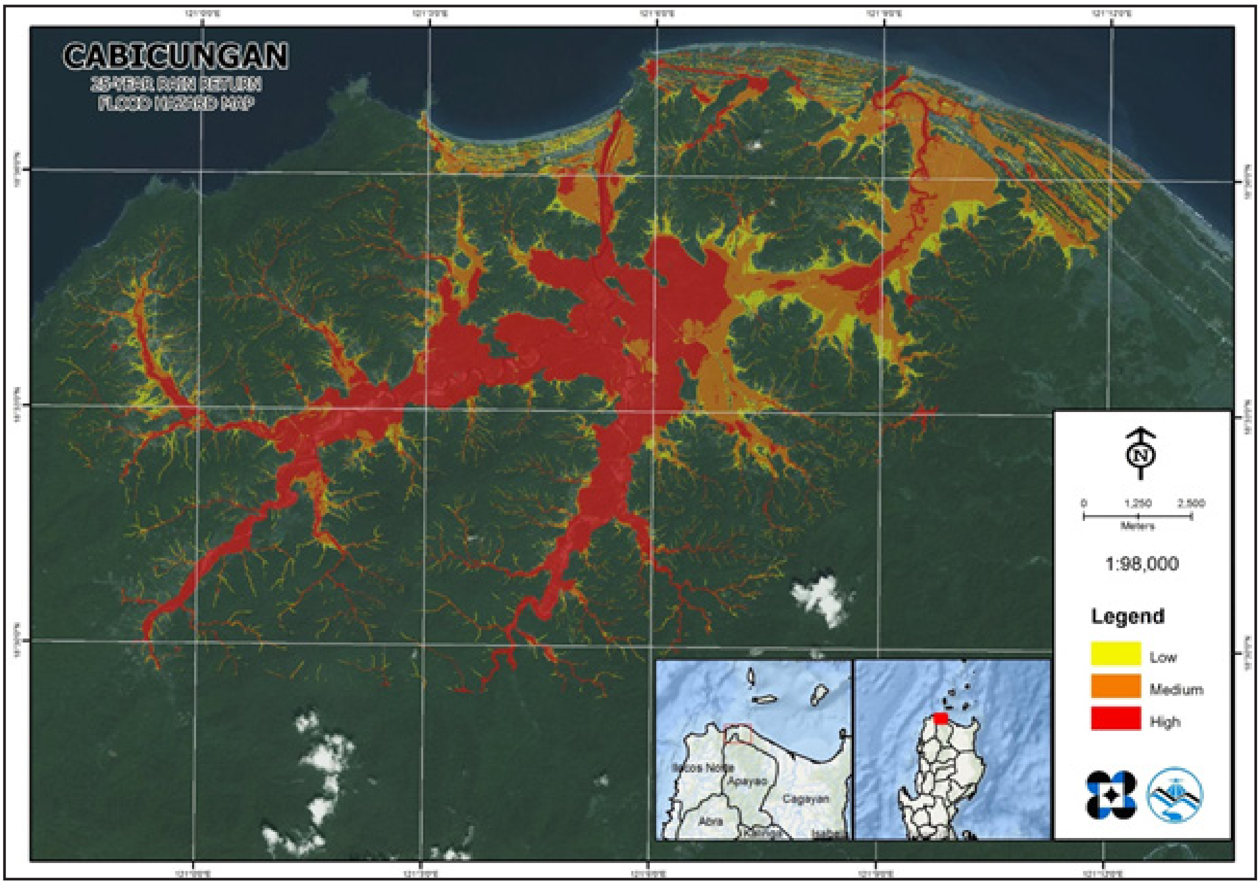


Figure 65. 25-year flood hazard map for the Cabicungan floodplain

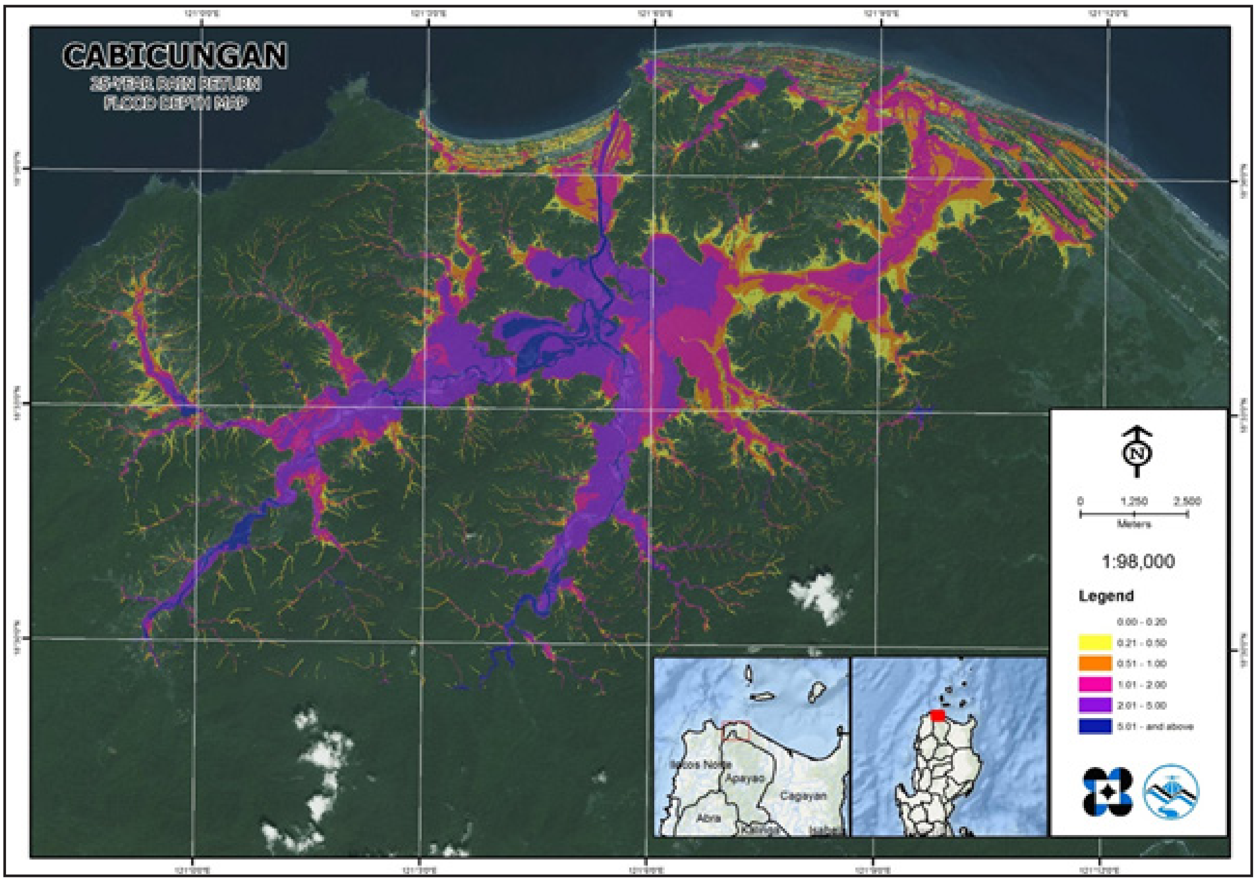


Figure 66. 25-year flow depth map for the Cabicungan floodplain

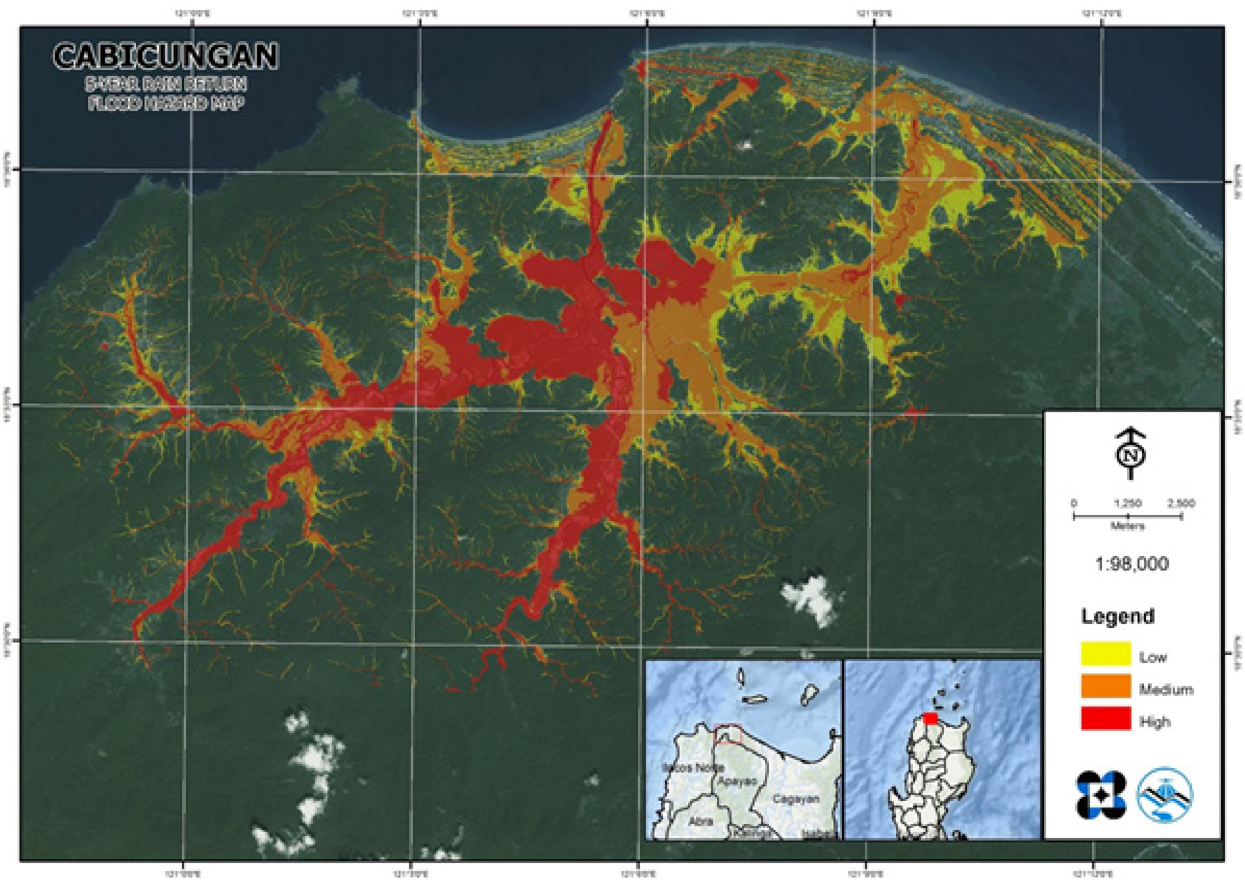


Figure 67. 5-year flood hazard map for the Cabicungan floodplain

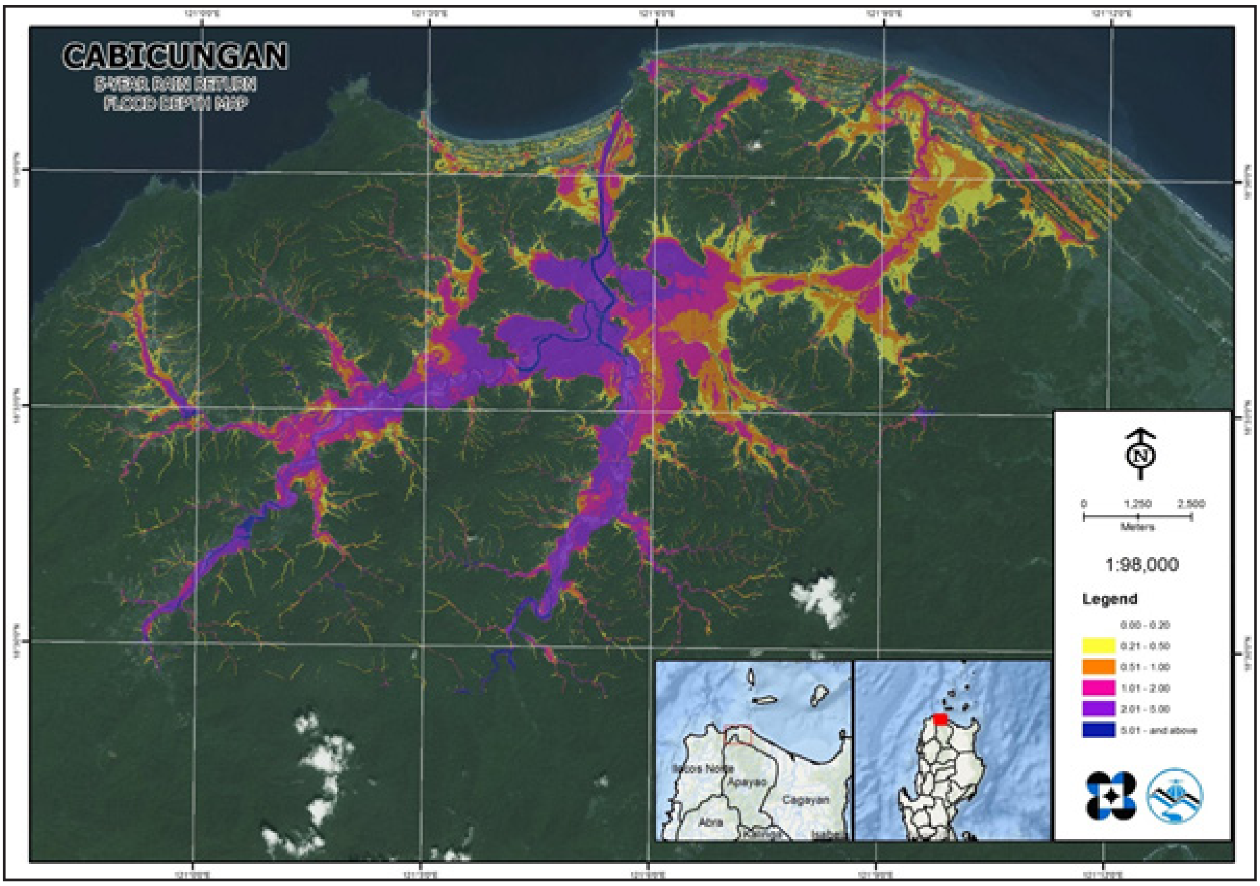


Figure 68. 5-year flow depth map for the Cabicungan floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Cabicungan River Basin, grouped by municipality, are listed below. For the said basin, five (5) municipalities consisting of fifty-nine (59) barangays are expected to experience flooding when subjected to the 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 2.61% of the Municipality of Calanasan, with an area of 948.15 square kilometers, 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. Meanwhile, 0.05%, 0.08%, 0.14%, and 0.03% 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 30 are the affected areas, in square kilometers, by flood depth per barangay.

Table 30. Affected areas in Calanasan, Apayao during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calanasan (in sq. km)
	Santa Filomena
0.03-0.20	24.78
0.21-0.50	0.59
0.51-1.00	0.52
1.01-2.00	0.74
2.01-5.00	1.37
> 5.00	0.3

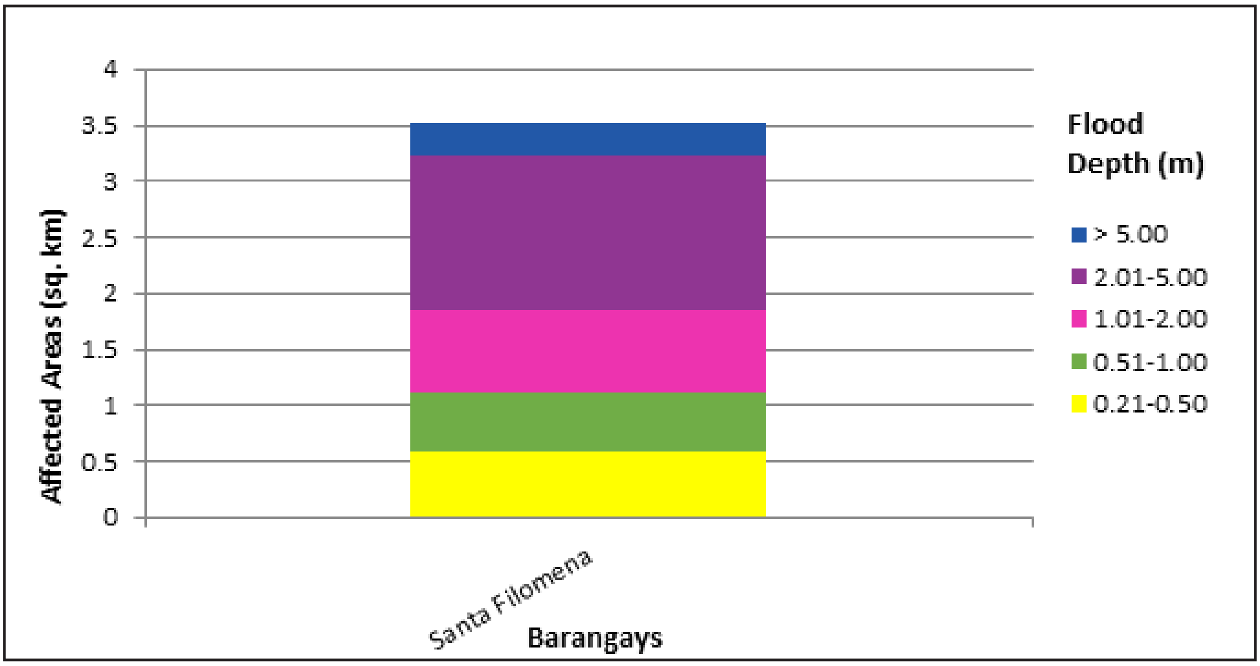


Figure 69. Affected areas in Calanasan, Apayao during a 5-year rainfall return period

For the 5-year return period, 58.40% of the Municipality of Claveria, with an area of 161.25 square kilometers, will experience flood levels of less than 0.20 meters. 6.39% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 7.62%, 8.57%, 7.84%, and 0.44% 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 34 are the affected areas, in square kilometers, by flood depth per barangay.

Table 31. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)										
	Alimoan	Bacsay Cataraoan Norte	Bacsay Cataraoan Sur	Bacsay Mapulapula	Bilibigao	Buenavista	Cadcadir East	Cadcadir West	Camalaggo-an/D Leaño	Capanikian	Centro I
0.03-0.20	0.12	0.81	1.09	0.64	2.01	0.7	3.4	1.12	1.74	0.04	0.11
0.21-0.50	0.0067	0.03	0.12	0.54	0.2	0.15	0.27	0.081	0.11	0.017	0.043
0.51-1.00	0.021	0.033	0.15	0.45	0.14	0.2	0.36	0.23	0.097	0.48	0.012
1.01-2.00	0.25	0.082	0.44	0.71	0.19	0.27	0.41	1.04	0.15	0.89	0.0007
2.01-5.00	0.63	1.04	1.28	0.71	0.85	0.0001	0.31	0.39	0.057	0.35	0
> 5.00	0.066	0.09	0.09	0.00047	0.07	0	0.003	0	0	0.047	0

Table 32. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	Centro II	Centro III	Centro IV	Centro V	Centro VI	Centro VII	Centro VIII	Culao	Dibalio	Kilkiling
0.03-0.20	0.094	0.071	0.14	0.27	0.18	0.34	0.34	8.06	2.72	4.89
0.21-0.50	0.039	0.028	0.015	0.083	0.0085	0.21	0.12	0.53	0.28	0.37
0.51-1.00	0.0083	0.0018	0.0061	0.041	0.0023	0.19	0.17	0.51	0.4	0.48
1.01-2.00	0.000098	0	0.0012	0.0045	0	0.15	0.097	0.5	0.39	0.37
2.01-5.00	0	0	0	0.0016	0	0.011	0.0025	0.11	0.16	0.042
> 5.00	0	0	0	0	0	0.0014	0	0	0.034	0

Table 33. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	Lablabig	Luzon	Mabnang	Magdalena	Malilitao	Nagsabaran	Pata East	Pata West	Pinas	San Antonio
0.03-0.20	1.66	12.96	3.43	5.16	3.63	2.62	1.97	3.08	0.49	0.0068
0.21-0.50	0.11	0.67	0.26	0.56	1.58	0.16	0.56	0.48	0.025	0.00082
0.51-1.00	0.14	0.66	0.29	0.59	1.79	0.096	0.82	0.35	0.024	0.0087
1.01-2.00	0.17	0.37	0.41	0.22	1.11	0.29	0.57	0.19	0.063	0.1
2.01-5.00	0.13	0.072	0.12	0.013	0.043	2.25	0.0097	0.004	0.44	0.059
> 5.00	0.0062	0.0092	0.0003	0	0.0014	0.16	0	0	0.018	0.033

Table 34. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	San Isidro	San Vicente	Santa Maria	Santiago	Santo Niño	Santo Tomas	Tabbugan	Taggat Norte	Taggat Sur	Union
0.03-0.20	1.01	1.79	2.05	0.62	0.88	5.19	8.86	1.89	2.89	5.1
0.21-0.50	0.17	0.084	0.25	0.13	0.38	0.19	0.52	0.11	0.42	0.4
0.51-1.00	0.22	0.051	0.13	0.13	0.9	0.1	0.93	0.074	0.33	0.67
1.01-2.00	0.13	0.22	0.049	0.087	0.55	0.055	1.91	0.063	0.091	1.23
2.01-5.00	0.0001	0.43	0.024	0.0009	0	0.016	1.49	0.0089	0.0016	1.59
> 5.00	0	0.0012	0.044	0	0	0.0004	0.02	0	0	0.018

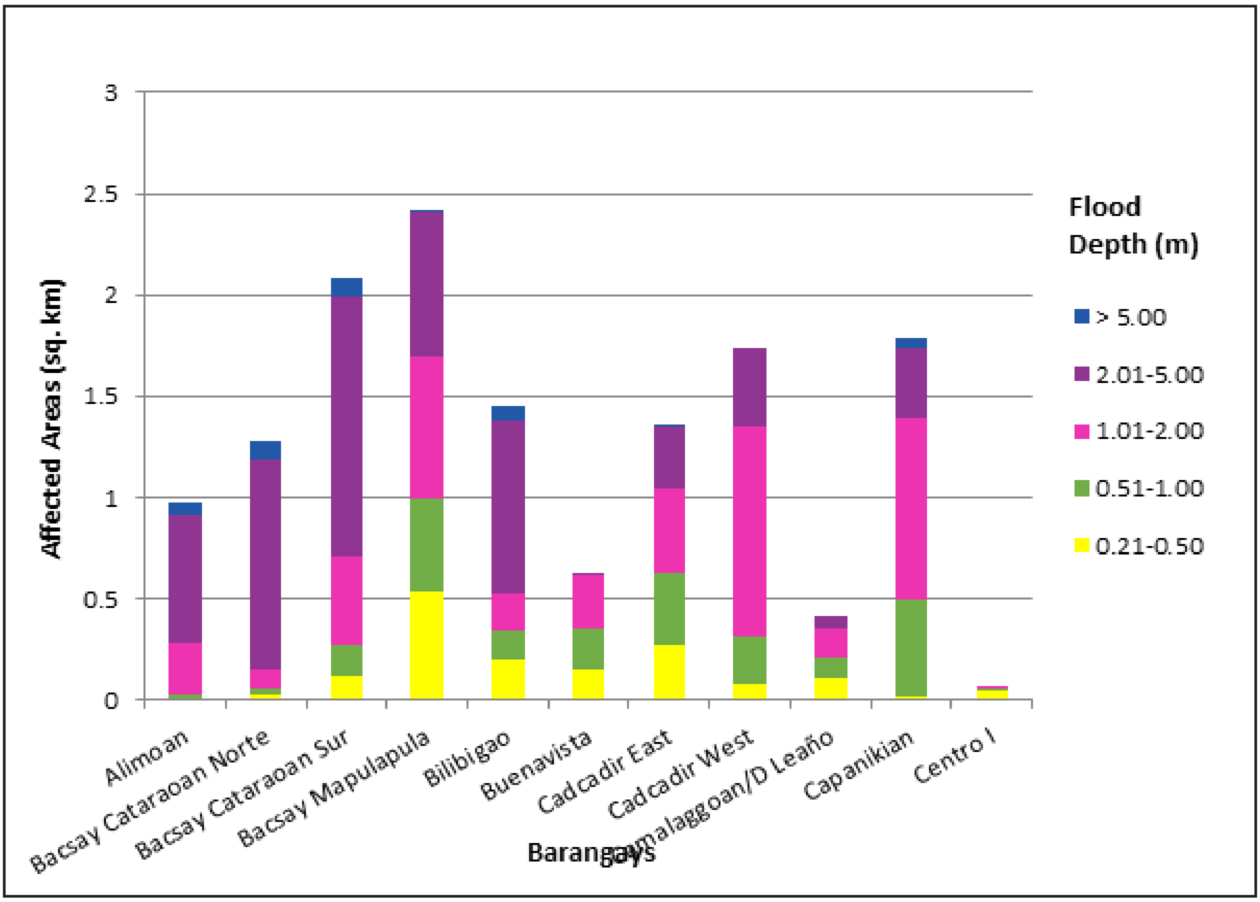


Figure 70. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

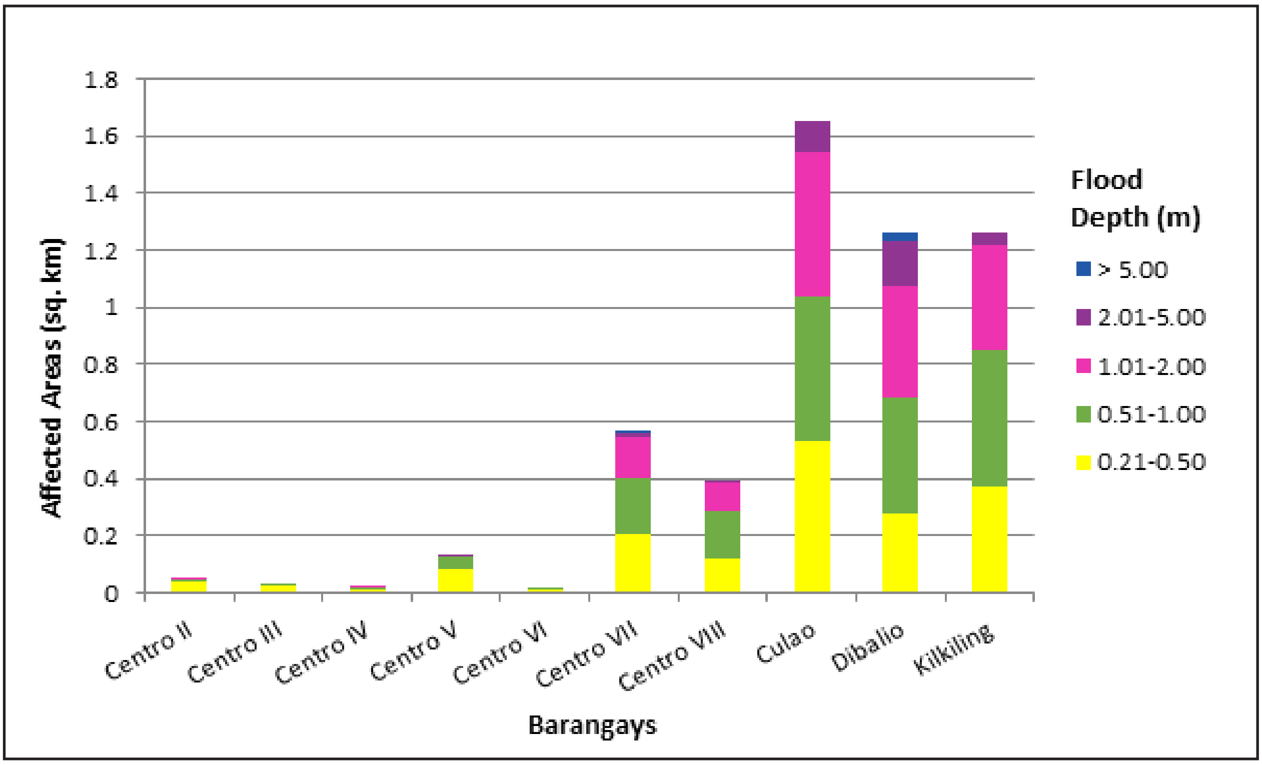


Figure 71. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

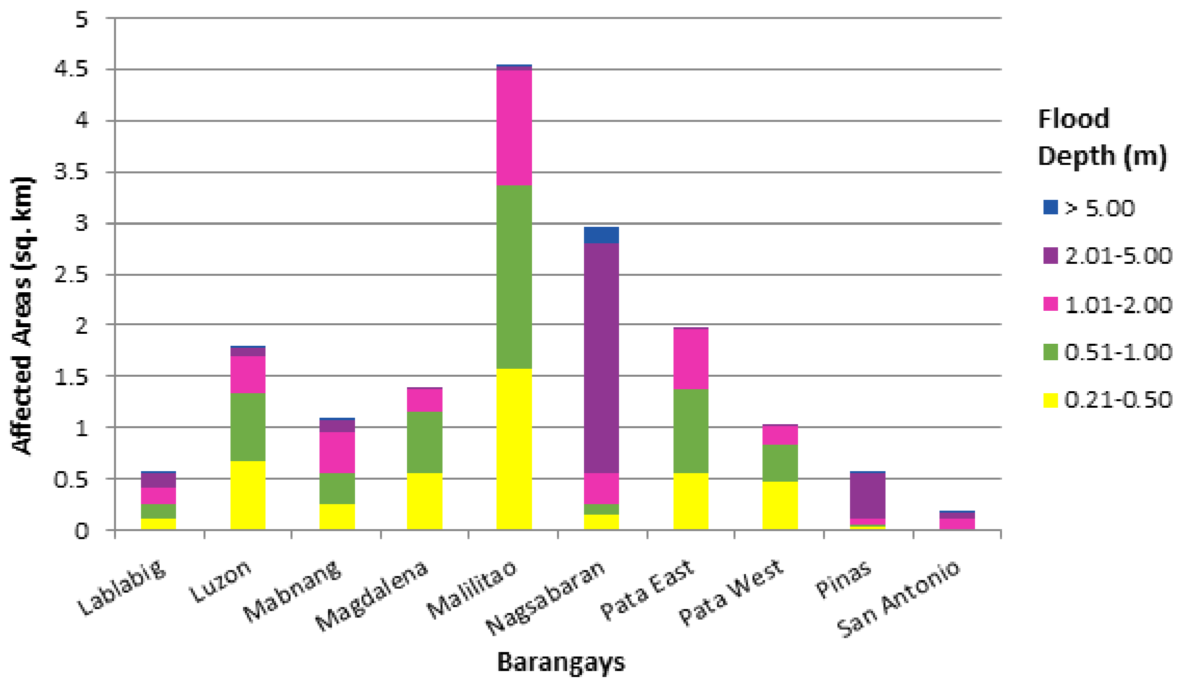


Figure 72. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

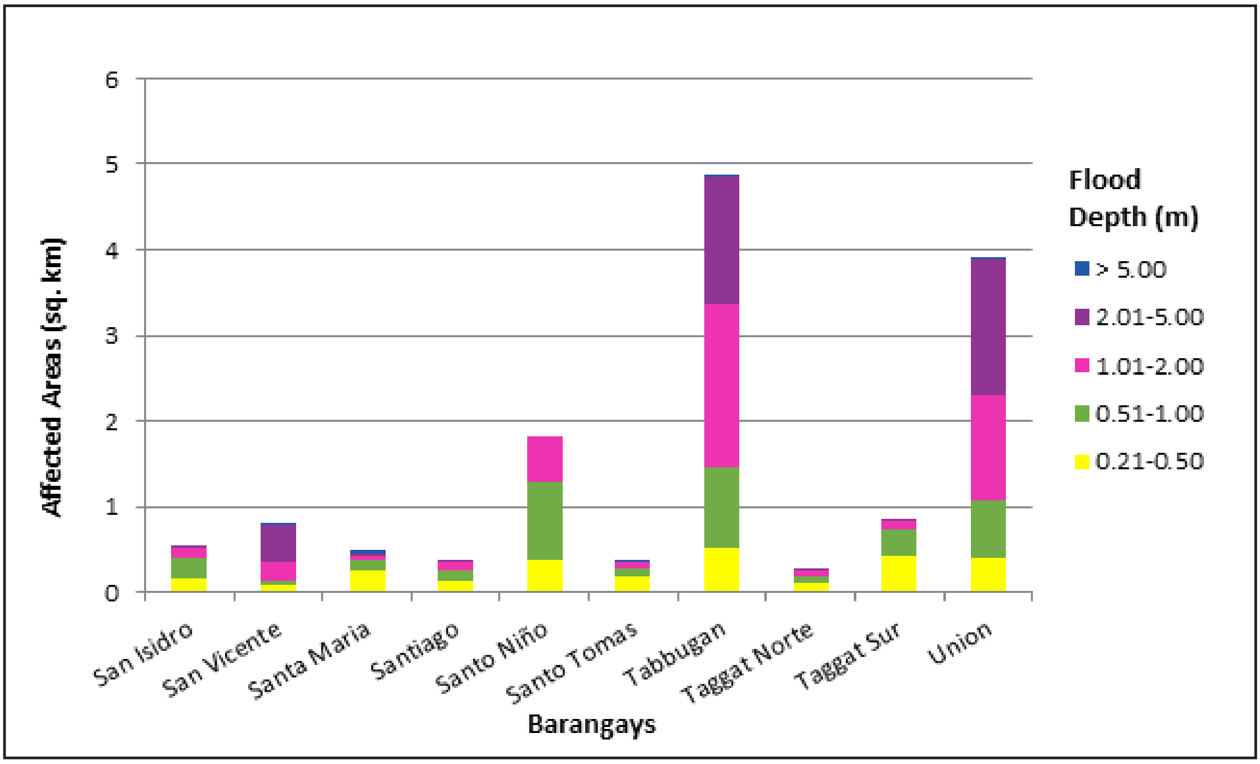


Figure 73. Affected areas in Claveria, Cagayan during a 5-year rainfall return period

For the 5-year return period, 7.60% of the Municipality of Sanchez-Mira, with an area of square kilometers, will experience flood levels of less than 0.20 meters. 1.75% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.69%, 0.49%, 0.06%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected areas in Sanchez-Mira, Cagayan during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sanchez-Mira (in sq. km)					
	Callungan	Magacan	Nagrangtayan	Namuac	San Andres	Tokitok
0.03-0.20	6.94	0.73	1.73	1.45	4.08	0.67
0.21-0.50	1.03	0.21	0.18	0.58	1.52	0.068
0.51-1.00	0.78	0.22	0.19	1.01	1.18	0.092
1.01-2.00	0.18	0.0088	0.14	0.27	0.4	0.017
2.01-5.00	0.06	0.0024	0.0005	0.0046	0.06	0.0027
> 5.00	0.034	0	0	0	0	0

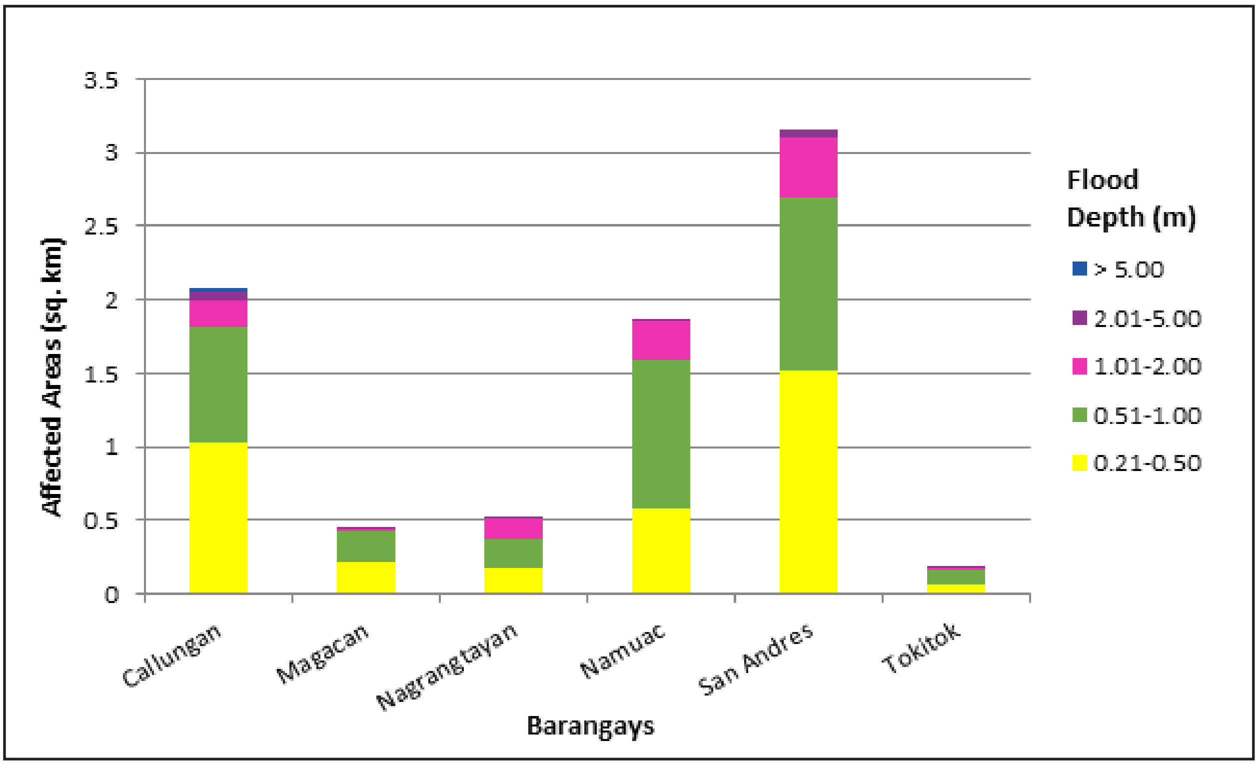


Figure 74. Affected areas in Sanchez-Mira, Cagayan during a 5-year rainfall return period

For the 5-year return period, 51.81% of the Municipality of Santa Praxedes, with an area of 86.19 square kilometers, will experience flood levels of less than 0.20 meters. 2.26% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.57%, 1.37%, 1.71%, and 0.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected areas in Santa Praxedes, Cagayan during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Praxedes (in sq. km)									
	Cadongdongan	Capacuan	Centro I	Centro II	Macatel	Portabaga	Salungsong	San Juan	San Miguel	Sicul
0.03-0.20	4.8	3.83	1.46	1.25	10.91	1.13	7.26	3.51	8.06	2.44
0.21-0.50	0.13	0.45	0.14	0.14	0.31	0.035	0.2	0.23	0.24	0.072
0.51-1.00	0.093	0.35	0.077	0.14	0.16	0.026	0.084	0.18	0.18	0.061
1.01-2.00	0.1	0.28	0.057	0.094	0.1	0.044	0.16	0.065	0.16	0.12
2.01-5.00	0.19	0.24	0.028	0.027	0.058	0.055	0.24	0.013	0.36	0.26
> 5.00	0.028	0.038	0	0	0.016	0.00079	0.014	0	0.082	0.13

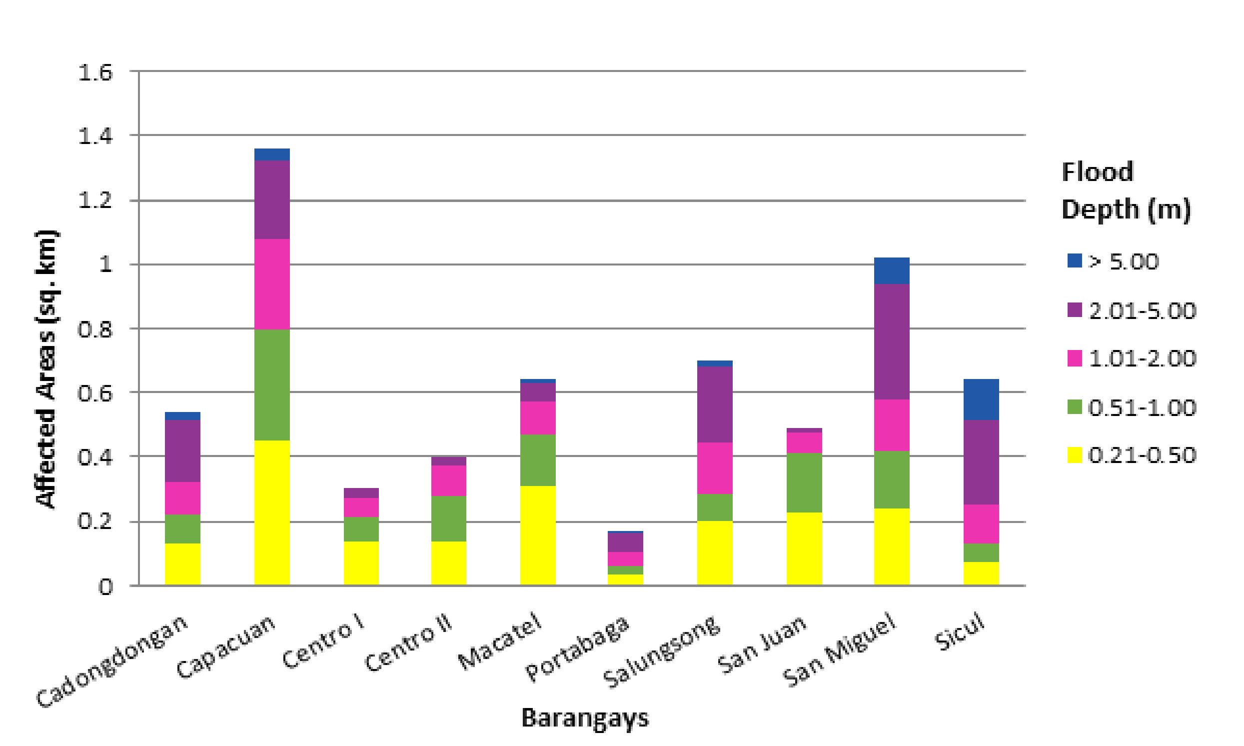


Figure 75. Affected areas in Santa Praxedes, Cagayan during a 5-year rainfall return period

For the 5-year return period, 1.75% of the Municipality of Pagudpud, with an area of 194.15 square kilometers, 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. Meanwhile, 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 37 are the affected areas, in square kilometers, by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pagudpud (in sq. km)
	Pasaleng
0.03-0.20	3.39
0.21-0.50	0.087
0.51-1.00	0.036
1.01-2.00	0.012
2.01-5.00	0.0023
> 5.00	0.0029

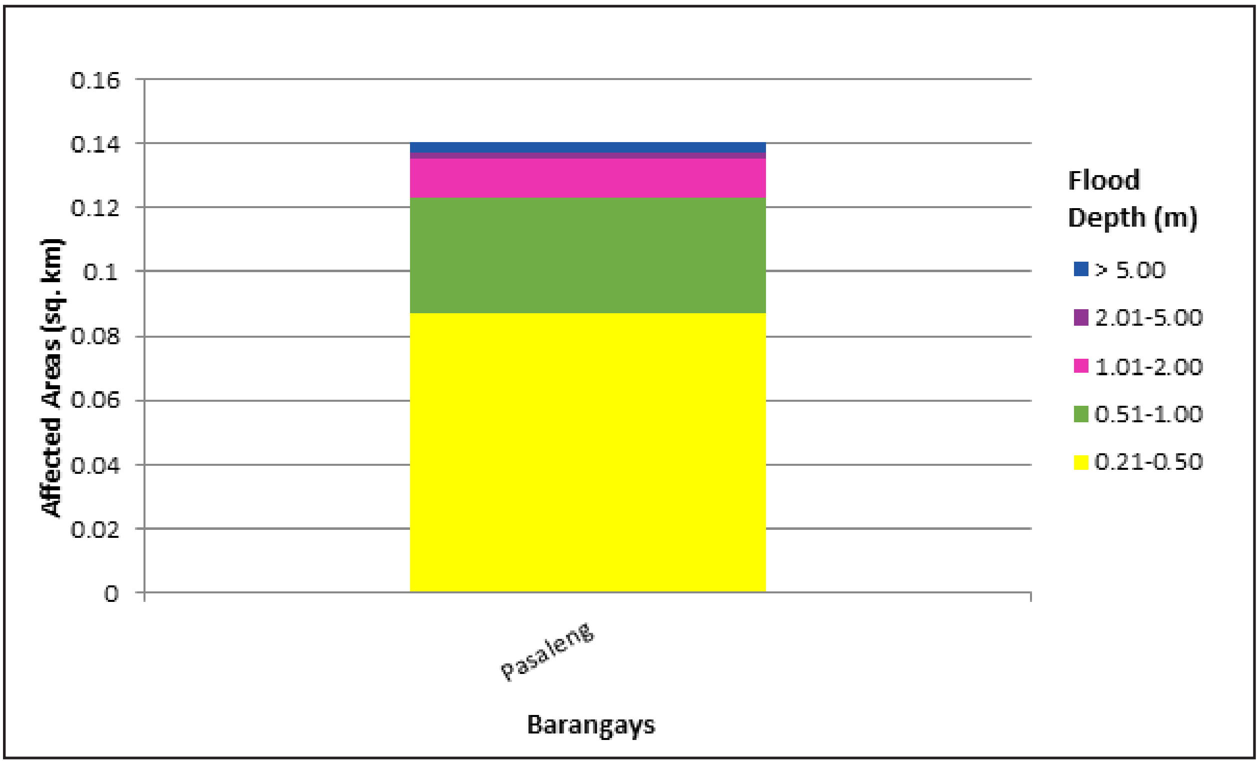


Figure 76. Affected areas in Pagudpud, Ilocos Norte during a 5-year rainfall return period

For the 25-year return period, 2.57% of the Municipality of Calanasan, with an area of 948.15 square kilometers, will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.04%, 0.07%, 0.17%, and 0.07% 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 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Calanasan, Apayao during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calanasan (in sq. km)
	Santa Filomena
0.03-0.20	24.37
0.21-0.50	0.67
0.51-1.00	0.42
1.01-2.00	0.64
2.01-5.00	1.58
> 5.00	0.62

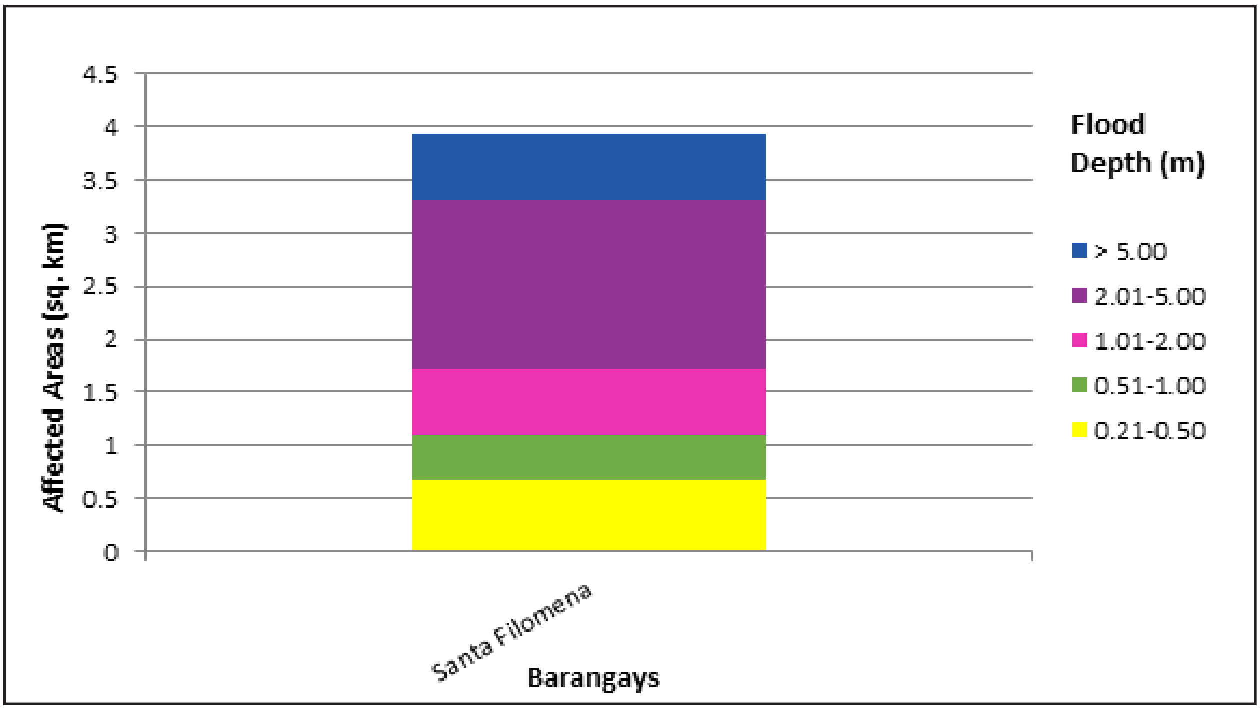


Figure 77. Affected areas in Calanasan, Apayao during a 25-year rainfall return period

For the 25-year return period, 55.64% of the Municipality of Claveria, with an area of 161.25 square kilometers, will experience flood levels of less than 0.20 meters. 5.33% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.01%, 9.88%, 10.97%, and 1.47% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 to 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)										
	Alimoan	Bacsay Cataraoan Norte	Bacsay Cataraoan Sur	Bacsay Map-ulapula	Bilibigao	Buenavista	Cadcadir East	Cadcadir West	Camalaggoan/ D Leaño	Capanikian	Centro I
0.03-0.20	0.11	0.74	1.02	0.53	1.91	0.63	3.31	1.07	1.66	0.028	0.093
0.21-0.50	0.0038	0.027	0.11	0.39	0.17	0.11	0.21	0.082	0.13	0.004	0.051
0.51-1.00	0.0077	0.023	0.077	0.48	0.15	0.15	0.26	0.057	0.11	0.016	0.023
1.01-2.00	0.039	0.057	0.23	0.49	0.16	0.36	0.51	0.73	0.14	0.97	0.0019
2.01-5.00	0.83	0.83	1.55	1.15	0.9	0.064	0.46	0.93	0.13	0.69	0
> 5.00	0.1	0.4	0.18	0.0024	0.17	0	0.017	0.0007	0	0.12	0

Table 40. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	Centro II	Centro III	Centro IV	Centro V	Centro VI	Centro VII	Centro VIII	Culao	Dibalio	Kilkiling
0.03-0.20	0.07	0.061	0.13	0.22	0.17	0.27	0.26	7.77	2.61	4.71
0.21-0.50	0.053	0.032	0.02	0.094	0.01	0.039	0.1	0.54	0.27	0.36
0.51-1.00	0.018	0.0073	0.01	0.065	0.0032	0.26	0.13	0.45	0.27	0.44
1.01-2.00	0.0003	0	0.0018	0.021	0	0.29	0.21	0.65	0.59	0.5
2.01-5.00	0	0	0	0.0022	0	0.039	0.021	0.31	0.2	0.15
> 5.00	0	0	0	0	0	0.0041	0	0	0.042	0.0001

Table 41. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	Lablabig	Luzon	Mabnang	Magdalena	Malilitao	Nagsabaran	Pata East	Pata West	Pinas	San Antonio
0.03-0.20	1.61	12.67	3.32	5	3.15	2.51	1.71	2.82	0.46	0.0048
0.21-0.50	0.084	0.66	0.21	0.43	1.1	0.14	0.34	0.51	0.025	0.0006
0.51-1.00	0.065	0.68	0.24	0.51	1.41	0.091	0.76	0.44	0.021	0.0014
1.01-2.00	0.2	0.58	0.31	0.54	2.05	0.15	1.09	0.3	0.048	0.014
2.01-5.00	0.26	0.13	0.43	0.065	0.45	1.82	0.034	0.032	0.48	0.15
> 5.00	0.0077	0.014	0.0003	0	0.0014	0.87	0	0	0.029	0.042

Table 42. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	San Isidro	San Vicente	Santa Maria	Santiago	Santo Niño	Santo Tomas	Tabbugan	Taggat Norte	Taggat Sur	Union
0.03-0.20	0.92	1.75	1.95	0.58	0.74	5.13	8.62	1.81	2.67	4.92
0.21-0.50	0.17	0.093	0.18	0.099	0.23	0.21	0.43	0.13	0.4	0.35
0.51-1.00	0.13	0.061	0.22	0.11	0.57	0.12	0.39	0.096	0.46	0.31
1.01-2.00	0.31	0.05	0.12	0.17	1.16	0.07	1.61	0.091	0.2	0.92
2.01-5.00	0.0025	0.57	0.031	0.0019	0.0059	0.028	2.57	0.02	0.0036	2.35
> 5.00	0	0.056	0.047	0	0	0.0009	0.12	0	0	0.15

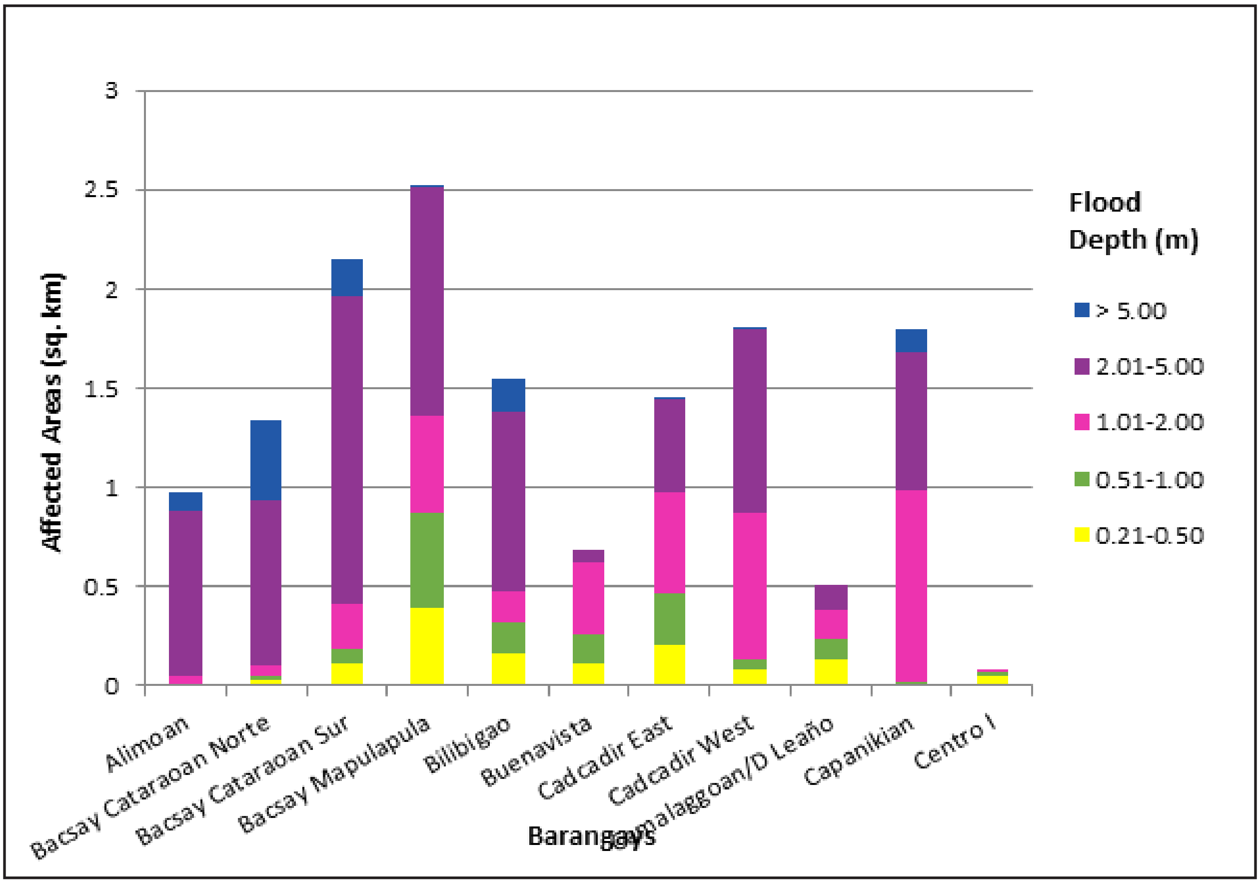


Figure 78. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

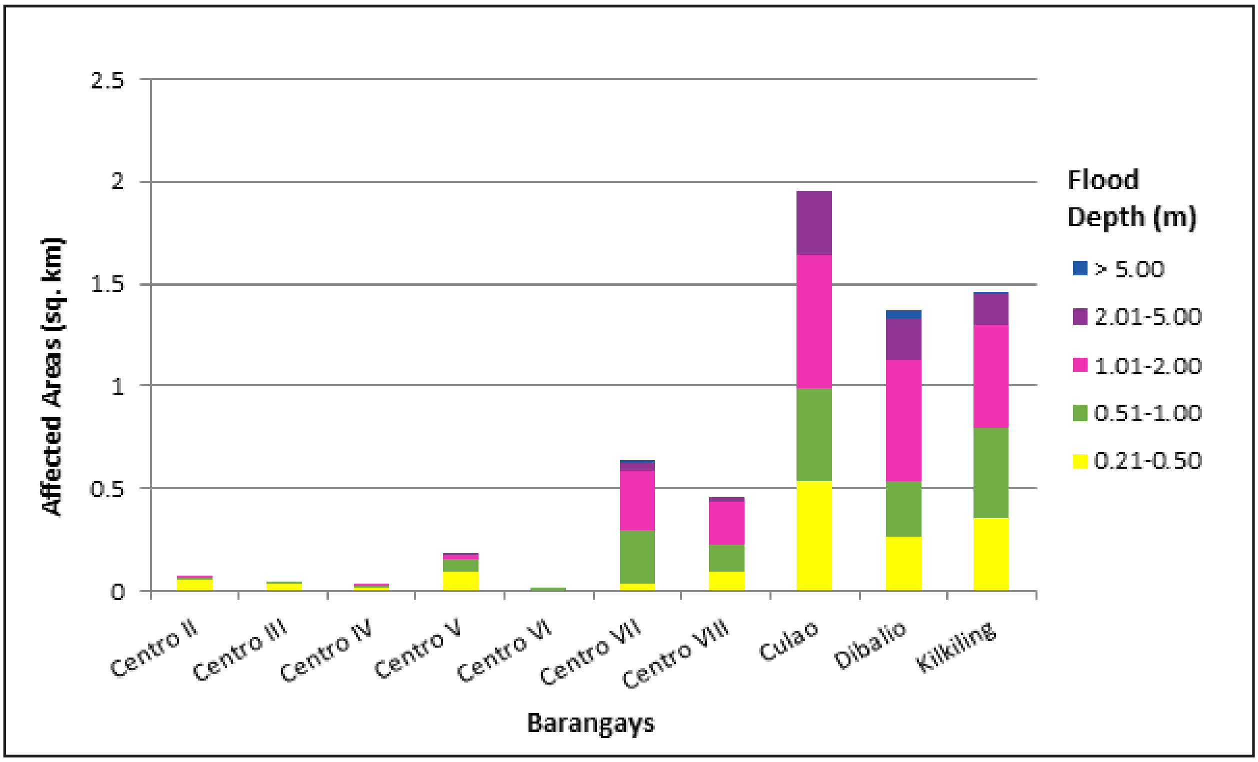


Figure 79. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

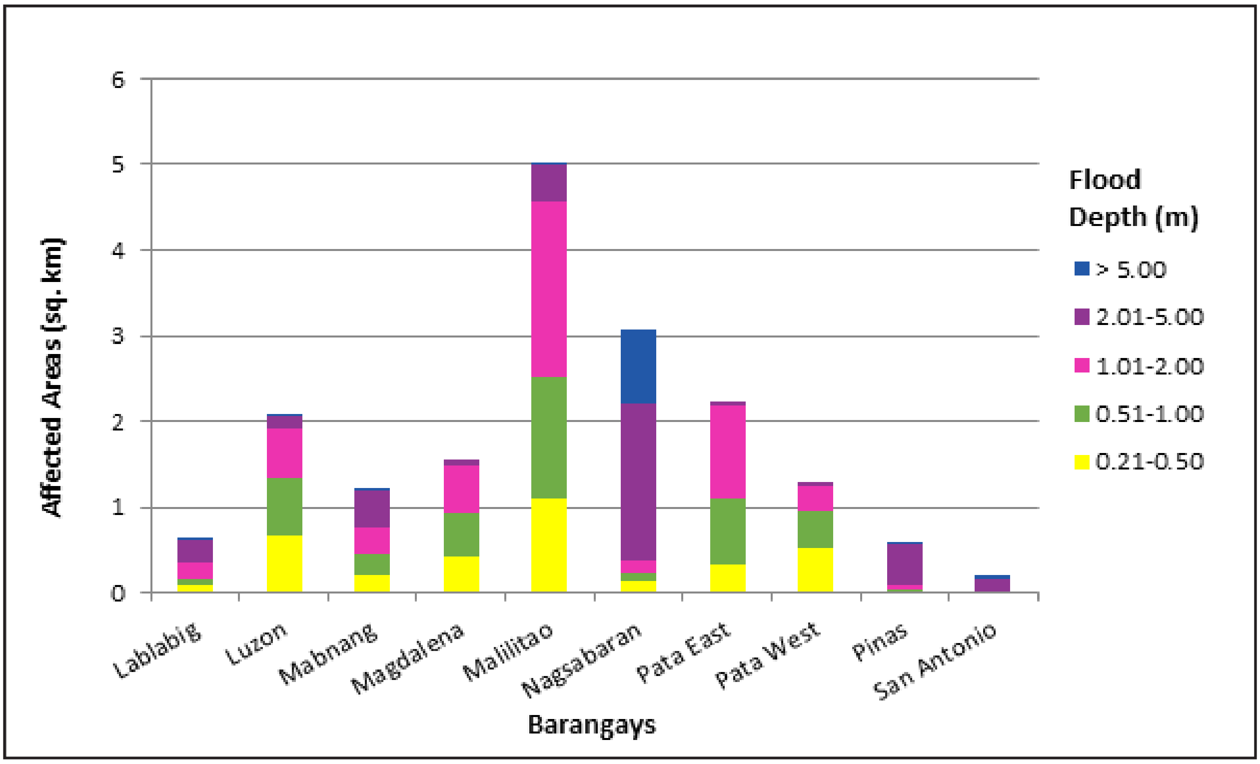


Figure 80. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

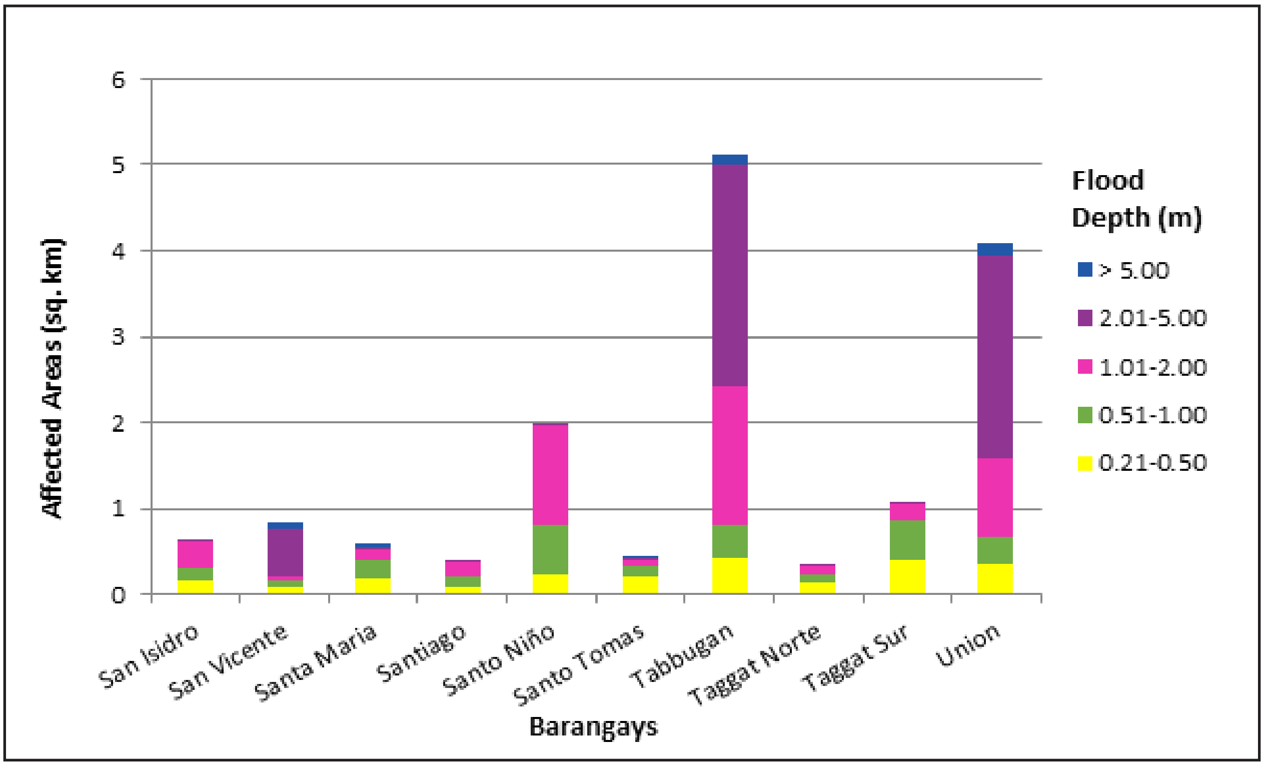


Figure 81. Affected areas in Claveria, Cagayan during a 25-year rainfall return period

For the 25-year return period, 6.97% of the Municipality of Sanchez-Mira, with an area of 205.31 square kilometers, will experience flood levels of less than 0.20 meters. 1.17% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.64%, 1.68%, 0.12%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Sanchez-Mira, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sanchez-Mira (in sq. km)					
	Callungan	Magacan	Nagrangtayan	Namuac	San Andres	Tokitok
0.03-0.20	6.43	0.66	1.65	1.24	3.7	0.63
0.21-0.50	0.97	0.13	0.2	0.17	0.86	0.066
0.51-1.00	0.93	0.24	0.17	0.74	1.22	0.067
1.01-2.00	0.55	0.14	0.22	1.16	1.3	0.077
2.01-5.00	0.07	0.0037	0.0037	0.02	0.15	0.0067
> 5.00	0.07	0	0	0	0	0

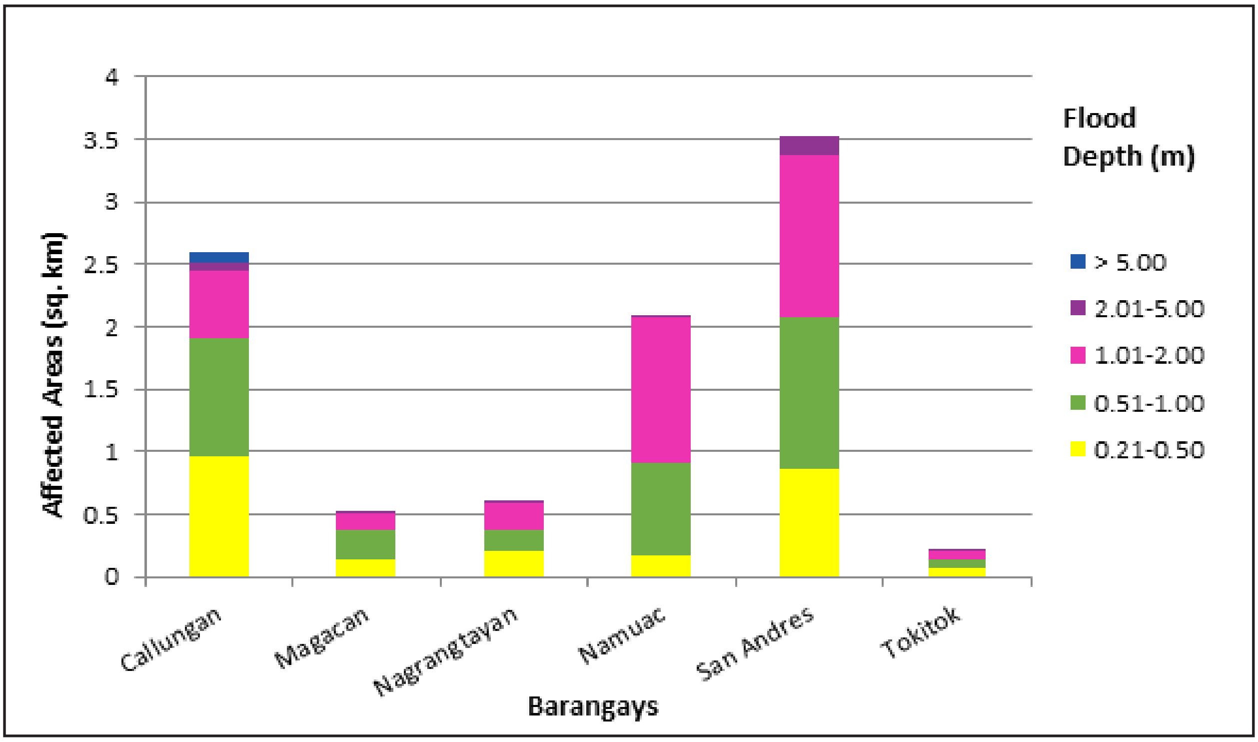


Figure 82. Affected areas in Sanchez-Mira, Cagayan during a 25-year rainfall return period

For the 25-year return period, 50.59% of the Municipality of Santa Praxedes, with an area of 86.19 square kilometers, will experience flood levels of less than 0.20 meters. 2.56% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.64%, 1.53%, 1.86%, and 0.91% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Santa Praxedes, Cagayan during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Praxedes (in sq. km)									
	Cadongdongan	Capacuan	Centro I	Centro II	Macatel	Portabaga	Salungsong	San Juan	San Miguel	Sicul
0.03-0.20	4.72	3.54	1.4	1.16	10.77	1.1	7.14	3.43	7.94	2.4
0.21-0.50	0.14	0.53	0.14	0.16	0.37	0.038	0.25	0.24	0.27	0.068
0.51-1.00	0.095	0.34	0.097	0.14	0.19	0.025	0.099	0.21	0.16	0.057
1.01-2.00	0.11	0.38	0.07	0.13	0.13	0.034	0.084	0.1	0.19	0.088
2.01-5.00	0.18	0.31	0.05	0.057	0.087	0.082	0.31	0.021	0.24	0.27
> 5.00	0.11	0.094	0	0	0.02	0.0073	0.069	0	0.28	0.2

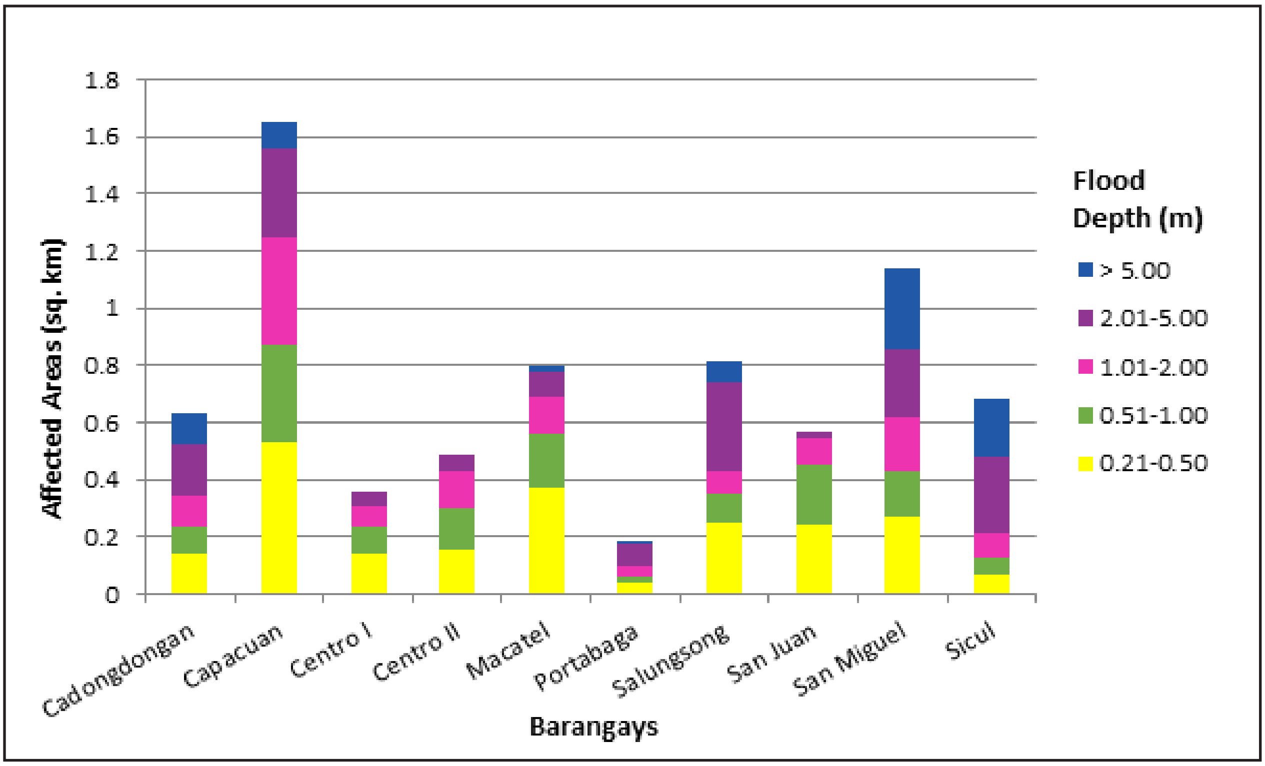


Figure 83. Affected areas in Santa Praxedes, Cagayan during a 25-year rainfall return period

For the 25-year return period, 1.73% of the Municipality of Pagudpud, with an area of 194.15 square kilometers, 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. Meanwhile, 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 45 are the affected areas, in square kilometers, by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pagudpud (in sq. km)
	Pasaleng
0.03-0.20	3.35
0.21-0.50	0.11
0.51-1.00	0.048
1.01-2.00	0.018
2.01-5.00	0.004
> 5.00	0.0036

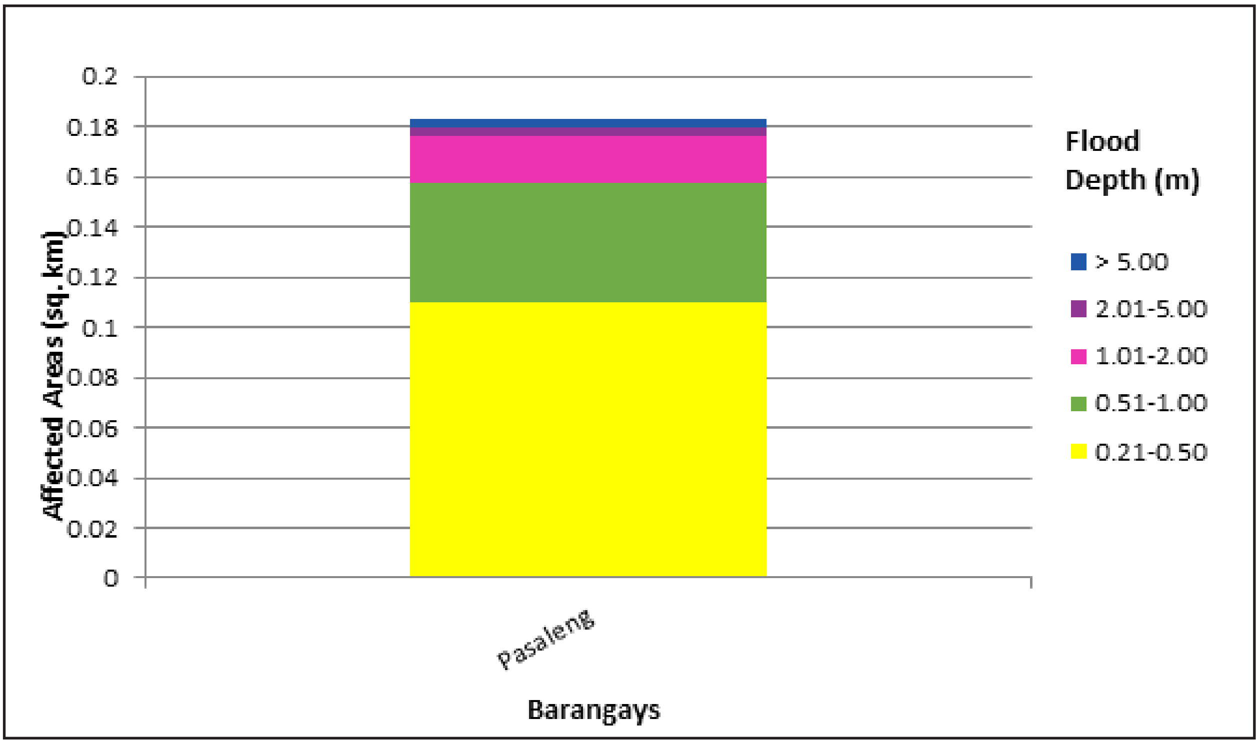


Figure 84. Affected areas in Pagudpud, Ilocos Norte during a 25-year rainfall return period

For the 100-year return period, 2.54% of the Municipality of Calanasan, with an area of 948.15 square kilometers, 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. Meanwhile, 0.05%, 0.05%, 0.18%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Calanasan, Apayao during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calanasan (in sq. km)
	Santa Filomena
0.03-0.20	24.09
0.21-0.50	0.74
0.51-1.00	0.43
1.01-2.00	0.49
2.01-5.00	1.67
> 5.00	0.89

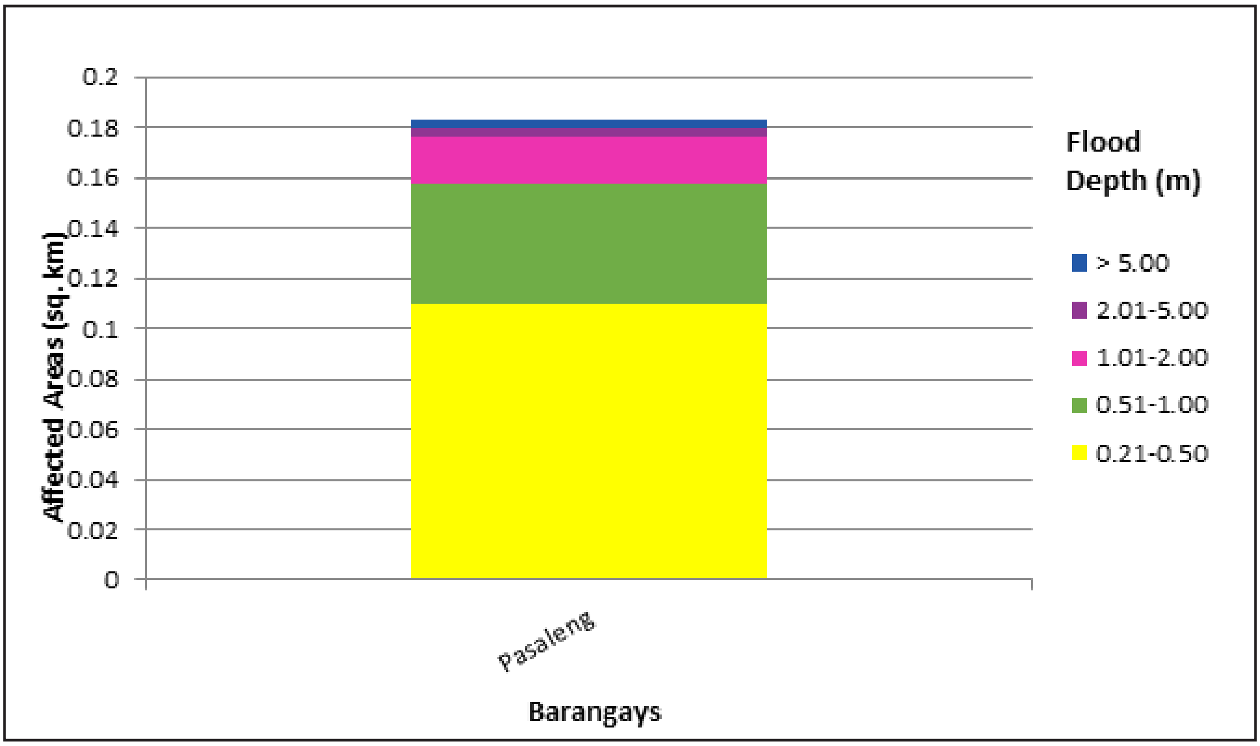


Figure 85. Affected areas in Calanasan, Apayao during a 100-year rainfall return period

For the 100-year return period, 54.10% of the Municipality of Claveria, with an area of 161.25 square kilometers, will experience flood levels of less than 0.20 meters. 4.92% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.30%, 8.77%, 13.22%, and 2.99% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 to 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)										
	Alimoan	Bacsay Cataraoan Norte	Bacsay Cataraoan Sur	Bacsay Mapulapula	Bilibigao	Buenavista	Cadcadir East	Cadcadir West	Camalaggoan/ D Leaño	Capanikian	Centro I
0.03-0.20	0.1	0.7	0.97	0.48	1.85	0.59	3.25	1.04	1.61	0.026	0.08
0.21-0.50	0.0028	0.025	0.11	0.29	0.15	0.099	0.2	0.081	0.13	0.00091	0.054
0.51-1.00	0.0061	0.017	0.069	0.51	0.15	0.1	0.18	0.055	0.12	0.0053	0.032
1.01-2.00	0.019	0.041	0.11	0.49	0.14	0.3	0.45	0.22	0.12	0.19	0.0035
2.01-5.00	0.78	0.49	1.53	1.25	0.76	0.22	0.61	1.46	0.17	1.41	0
> 5.00	0.18	0.81	0.37	0.021	0.41	0	0.049	0.012	0	0.19	0

Table 49. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	Centro II	Centro III	Centro IV	Centro V	Centro VI	Centro VII	Centro VIII	Culao	Dibalio	Kilkiling
0.03-0.20	0.059	0.055	0.13	0.2	0.17	0.26	0.21	7.57	2.54	4.58
0.21-0.50	0.055	0.028	0.023	0.091	0.011	0.037	0.092	0.54	0.25	0.36
0.51-1.00	0.028	0.017	0.012	0.082	0.0038	0.13	0.14	0.45	0.22	0.39
1.01-2.00	0.0004	0.00013	0.0034	0.033	0	0.39	0.25	0.66	0.66	0.55
2.01-5.00	0	0	0	0.0024	0	0.081	0.035	0.49	0.26	0.27
> 5.00	0	0	0	0	0	0.007	0	0	0.056	0.0007

Table 49. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	Lablabig	Luzon	Mabnang	Magdalena	Malilitao	Nagsabaran	Pata East	Pata West	Pinas	San Antonio
0.03-0.20	1.59	12.48	3.26	4.91	2.96	2.44	1.6	2.65	0.45	0.0037
0.21-0.50	0.081	0.65	0.2	0.38	0.87	0.13	0.29	0.5	0.026	0.0005
0.51-1.00	0.054	0.65	0.21	0.47	1.13	0.083	0.51	0.51	0.018	0.00085
1.01-2.00	0.11	0.74	0.23	0.65	2.03	0.12	1.23	0.39	0.039	0.0025
2.01-5.00	0.37	0.2	0.61	0.14	1.17	1.09	0.31	0.056	0.5	0.15
> 5.00	0.02	0.018	0.0003	0	0.0014	1.72	0	0	0.039	0.051

Table 50. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Claveria (in sq. km)									
	San Isidro	San Vicente	Santa Maria	Santiago	Santo Niño	Santo Tomas	Tabbugan	Taggat Norte	Taggat Sur	Union
0.03-0.20	0.88	1.72	1.9	0.55	0.67	5.08	8.49	1.77	2.54	4.82
0.21-0.50	0.16	0.095	0.17	0.099	0.18	0.22	0.41	0.12	0.39	0.33
0.51-1.00	0.094	0.068	0.14	0.087	0.42	0.14	0.35	0.12	0.49	0.28
1.01-2.00	0.36	0.054	0.24	0.22	1.33	0.08	0.72	0.098	0.31	0.56
2.01-5.00	0.041	0.52	0.039	0.0053	0.11	0.04	3.49	0.035	0.0081	2.61
> 5.00	0	0.13	0.048	0	0	0.0012	0.28	0	0	0.4

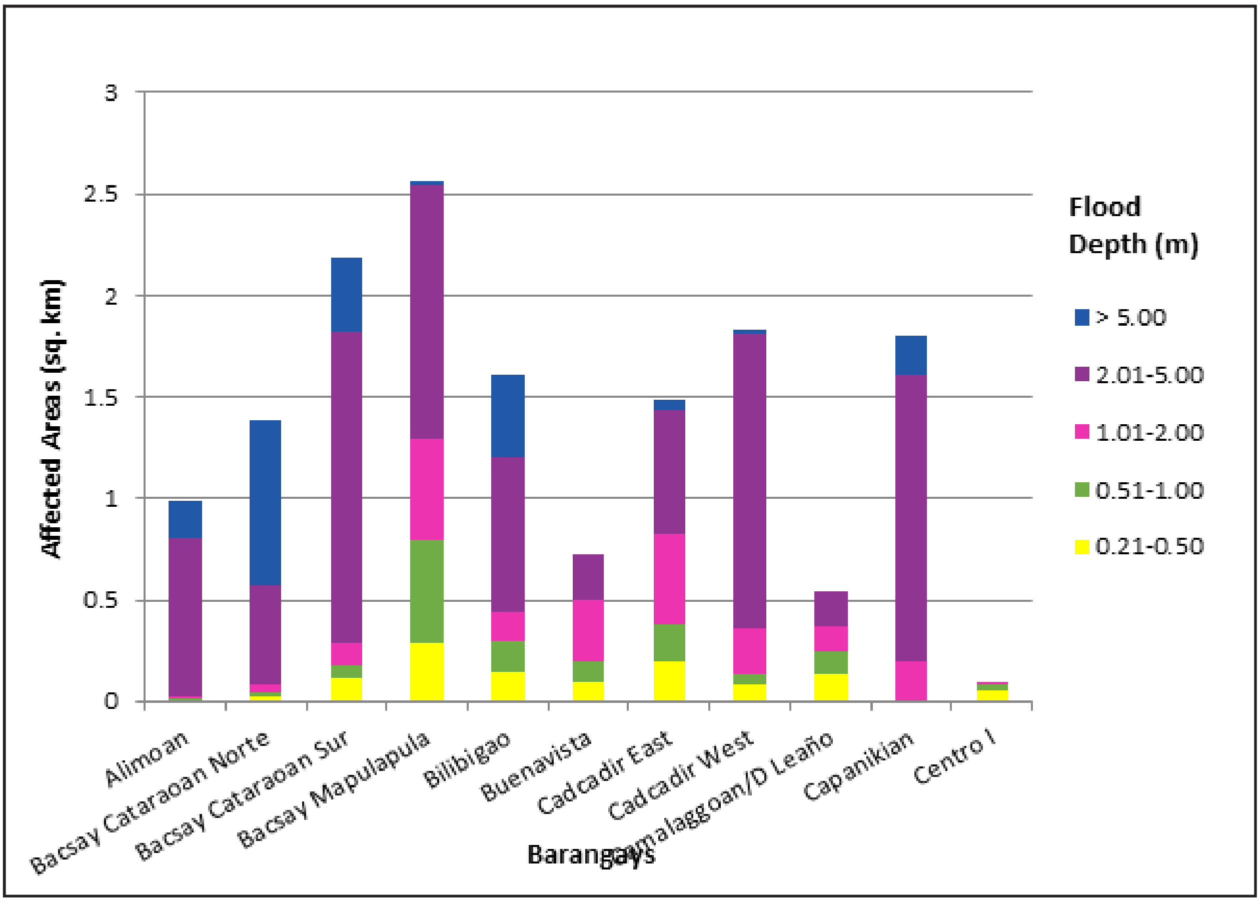


Figure 86. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

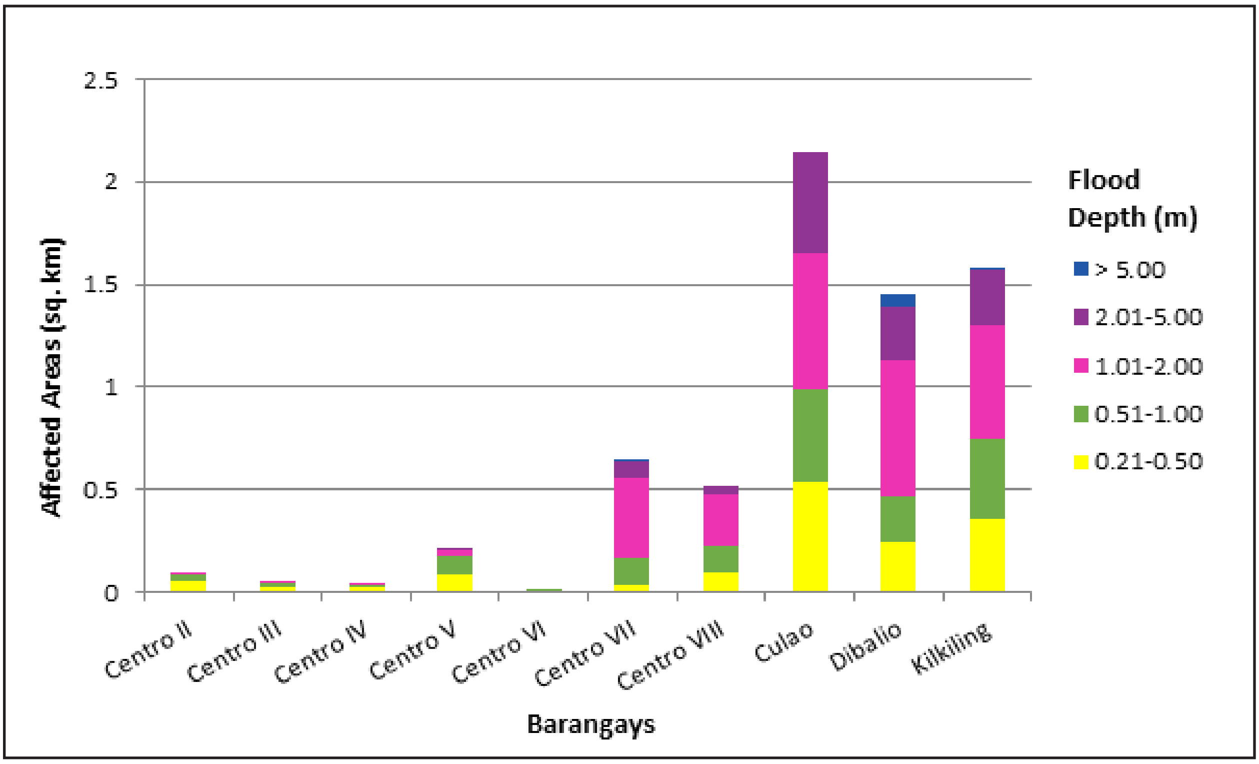


Figure 87. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

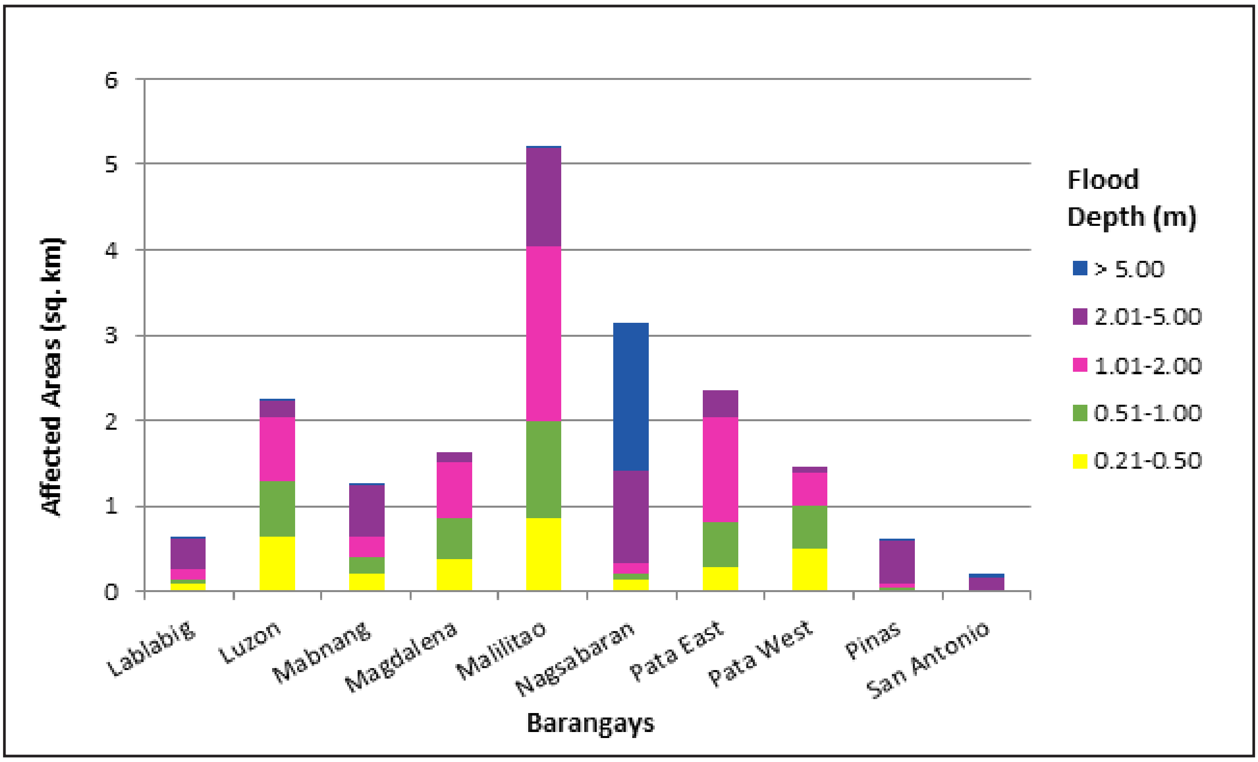


Figure 88. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

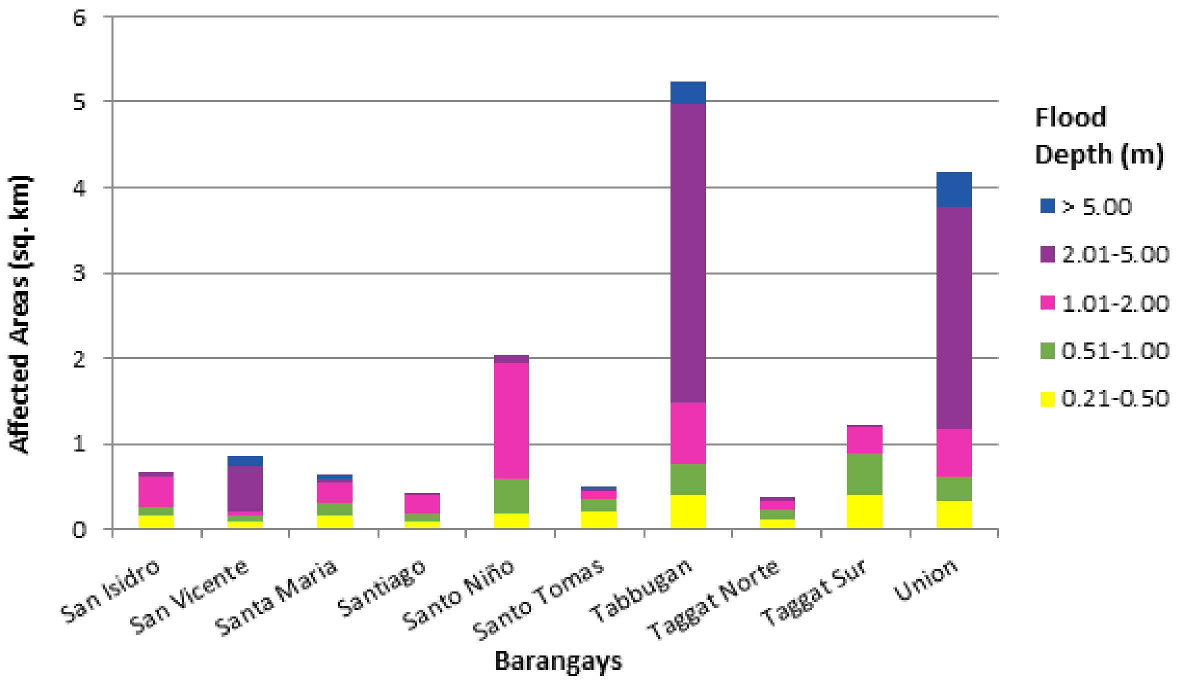


Figure 89. Affected areas in Claveria, Cagayan during a 100-year rainfall return period

For the 100-year return period, 6.66% of the Municipality of Sanchez-Mira, with an area of 205.31 square kilometers, will experience flood levels of less than 0.20 meters. 1.04% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.13%, 2.49%, 0.25%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Sanchez-Mira, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sanchez-Mira (in sq. km)					
	Callungan	Magacan	Nagrangtayan	Namuac	San Andres	Tokitok
0.03-0.20	6.12	0.63	1.6	1.16	3.56	0.6
0.21-0.50	0.95	0.12	0.21	0.13	0.66	0.069
0.51-1.00	0.84	0.13	0.15	0.28	0.85	0.06
1.01-2.00	0.94	0.29	0.27	1.65	1.86	0.11
2.01-5.00	0.075	0.004	0.016	0.1	0.3	0.01
> 5.00	0.095	0.00085	0	0.0001	0	0.00025

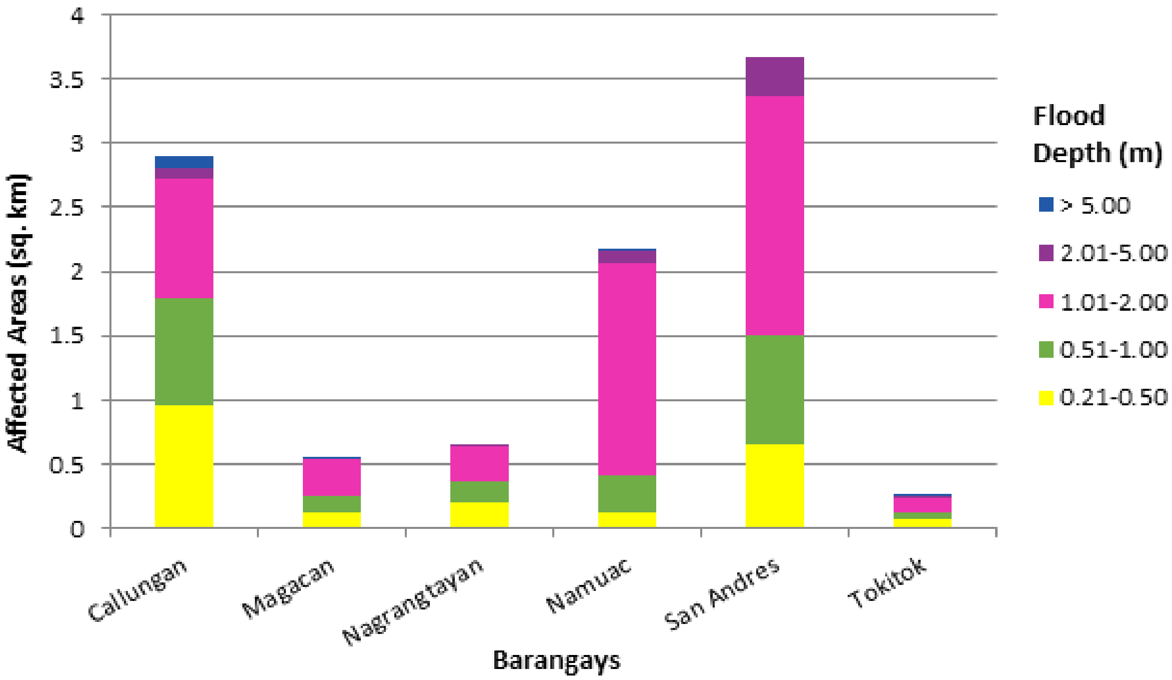


Figure 90. Affected areas in Sanchez-Mira, Cagayan during a 100-year rainfall return period

For the 100-year return period, 49.79% of the Municipality of Santa Praxedes, with an area of 86.19 square kilometers, will experience flood levels of less than 0.20 meters. 2.68% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.66%, 1.66%, 1.91%, and 1.34% 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 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Santa Praxedes, Cagayan during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Praxedes (in sq. km)									
	Cadongdongan	Capacuan	Centro I	Centro II	Macatel	Portabaga	Salungsong	San Juan	San Miguel	Sicul
0.03-0.20	4.67	3.38	1.37	1.11	10.67	1.08	7.05	3.36	7.85	2.37
0.21-0.50	0.14	0.52	0.14	0.17	0.4	0.04	0.29	0.25	0.28	0.076
0.51-1.00	0.098	0.35	0.096	0.12	0.21	0.024	0.11	0.22	0.16	0.046
1.01-2.00	0.1	0.41	0.082	0.16	0.14	0.03	0.086	0.14	0.21	0.077
2.01-5.00	0.16	0.4	0.069	0.078	0.1	0.091	0.25	0.031	0.19	0.28
> 5.00	0.18	0.13	0	0	0.027	0.02	0.17	0	0.39	0.24

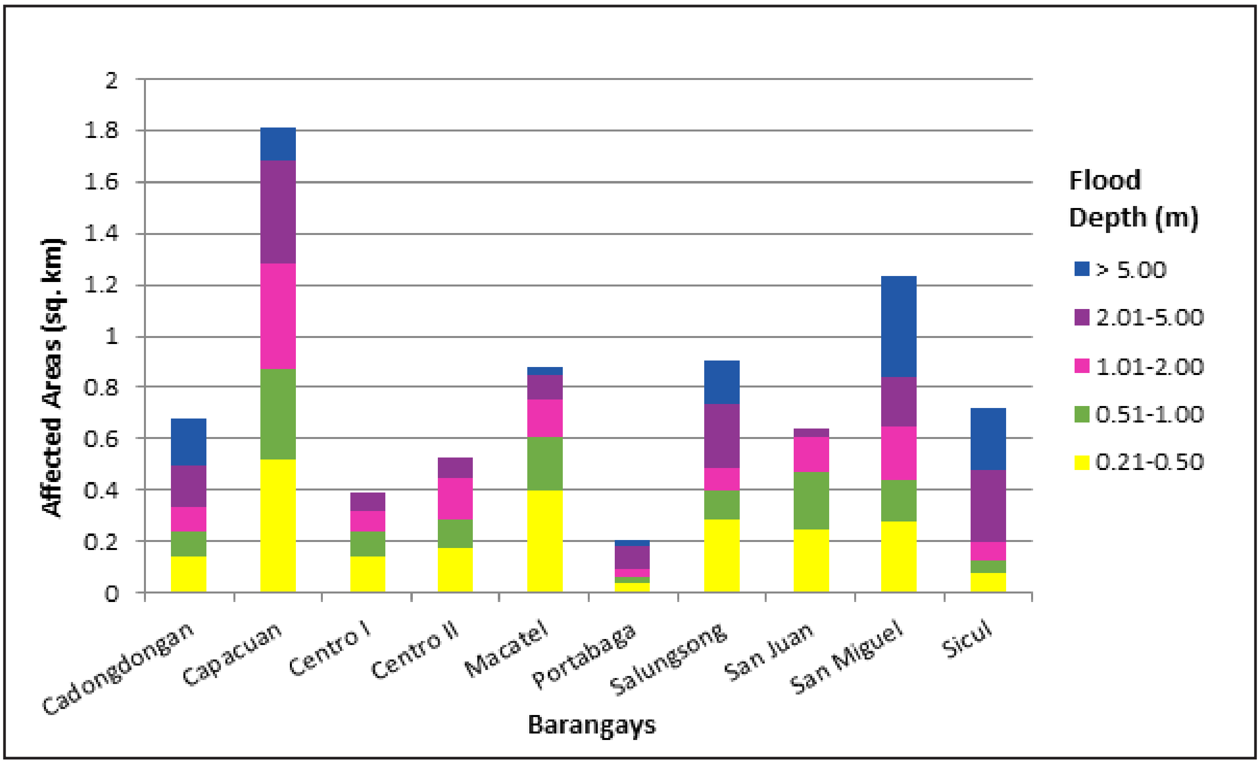


Figure 91. Affected areas in Santa Praxedes, Cagayan during a 100-year rainfall return period

For the 100-year return period, 1.71% of the Municipality of Pagudpud, with an area of 194.15 square kilometers, will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03% 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 53 are the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Pagudpud, Ilocos Norte during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pagudpud (in sq. km)
	Pasaleng
0.03-0.20	3.32
0.21-0.50	0.13
0.51-1.00	0.055
1.01-2.00	0.023
2.01-5.00	0.0057
> 5.00	0.0043

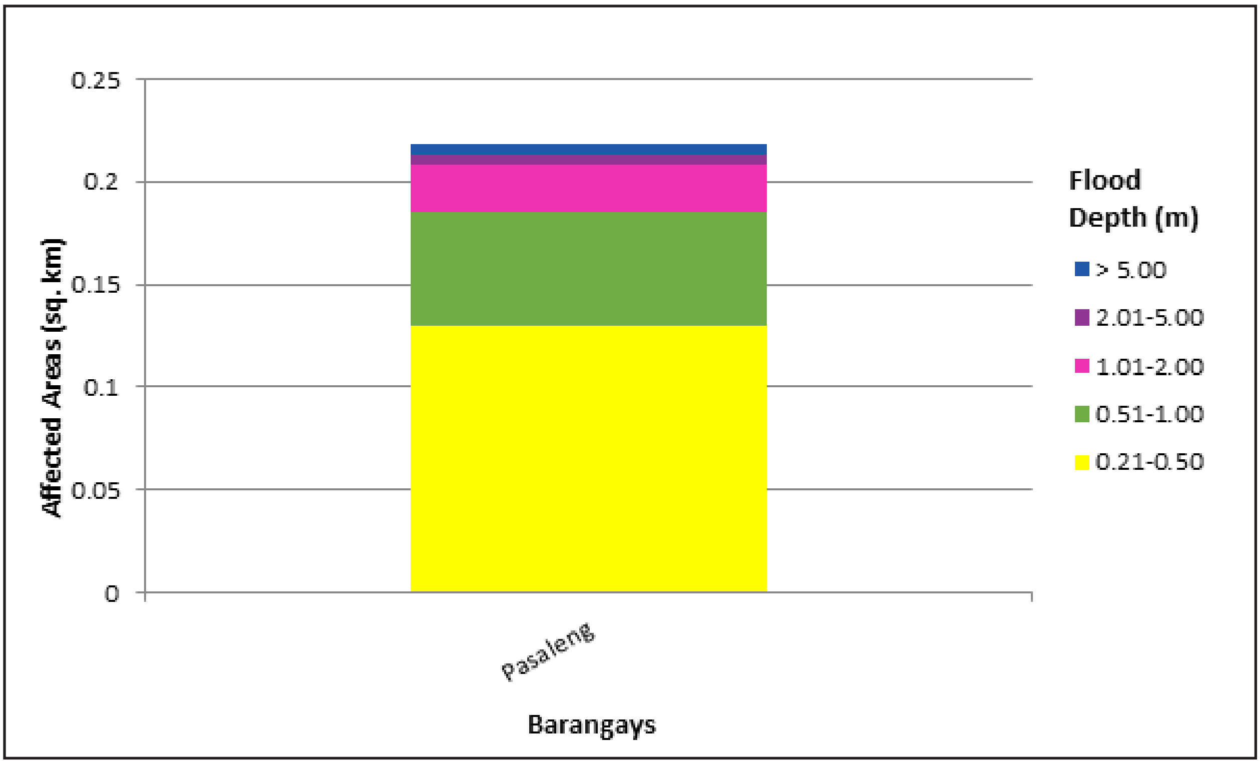


Figure 92. Affected areas in Pagudpud, Ilocos Norte during a 100-year rainfall return period

Barangay Santa Filomena is the only barangay affected in the Municipality of Calanasan in Apayao. The barangay is projected to experience flooding in 2.99% of the area.

Among the barangays in the Municipality of Claveria in Cagayan, Luzon is projected to have the highest percentage of area that will experience flood levels, at 1.55%. Meanwhile, Tabbugan posted the second highest percentage of area that may be affected by flood depths, at 1.45%.

Among the barangays in the Municipality of Sanchez-Mira in Cagayan, Callungan is projected to have the highest percentage of area that will experience flood levels, at 0.95%. Meanwhile, San Andres posted the second highest percentage of area that may be affected by flood depths, at 0.76%.

Among the barangays in the Municipality of Santa Praxedes in Cagayan, Macatel is projected to have the highest percentage of area that will experience flood levels, at 1.22%. Meanwhile, San Miguel posted the second highest percentage of area that may be affected by flood depths, at 0.96%.

Barangay Pasaleng is the only barangay affected in the Municipality of Pagudpud in Ilocos Norte. The barangay is projected to experience flooding in 0.37% of the area.

The generated flood hazard maps for the Cabicungan floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood hazard maps – "Low", "Medium", and "High" – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 10-year).

Table 54. Areas covered by each warning level, with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	16.30	13.58	12.79
Medium	28.53	26.95	24.40
High	24.04	35.56	43.02
TOTAL	68.87	76.09	80.21

Of the fifty-one (51) identified educational institutions in the Cabicungan floodplain, nine (9) were discovered to be exposed to Low-level flooding and six (6) schools were found to be exposed to Medium-level flooding during the 5-year scenario. Five (5) schools were assessed to be exposed to High-level flooding in the same scenario.

For the 25-year scenario, ten (10) schools were discovered to be exposed to Low-level flooding, while eight (8) schools were found to be exposed to Medium-level flooding. In the same scenario, six (6) schools were assessed to be exposed to High-level flooding.

For the 100-year scenario, eleven (11) schools were discovered to be exposed to Low-level flooding, and six (6) schools to Medium-level flooding. Ten (10) schools were projected to be experience High-level flooding in the same scenario.

Of the ten (10) identified medical institutions in the Cabicungan floodplain, one (1) was discovered to be exposed to Medium-level flooding during the 5-year scenario.

For the 25-year scenario, one (1) medical institution was found to be exposed to Low-level flooding, and another one (1) was assessed to be exposed to Medium-level flooding.

For the 100-year scenario, one (1) medical facility was discovered to be exposed to Low-level flooding, and another one (1) to High-level flooding.

The list of educational and health institutions exposed to flooding in the Cabicungan floodplain, are presented in Annex 11 and Annex 12, respectively.

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. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in the river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in the particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 93.

The flood validation consists of two hundred and seventy-four (274) points, randomly selected all over the Cabicungan floodplain. A contingency matrix is presented in Table 55. The validation attained an RMSE value of 1.13. The validation points are found in Annex 10.

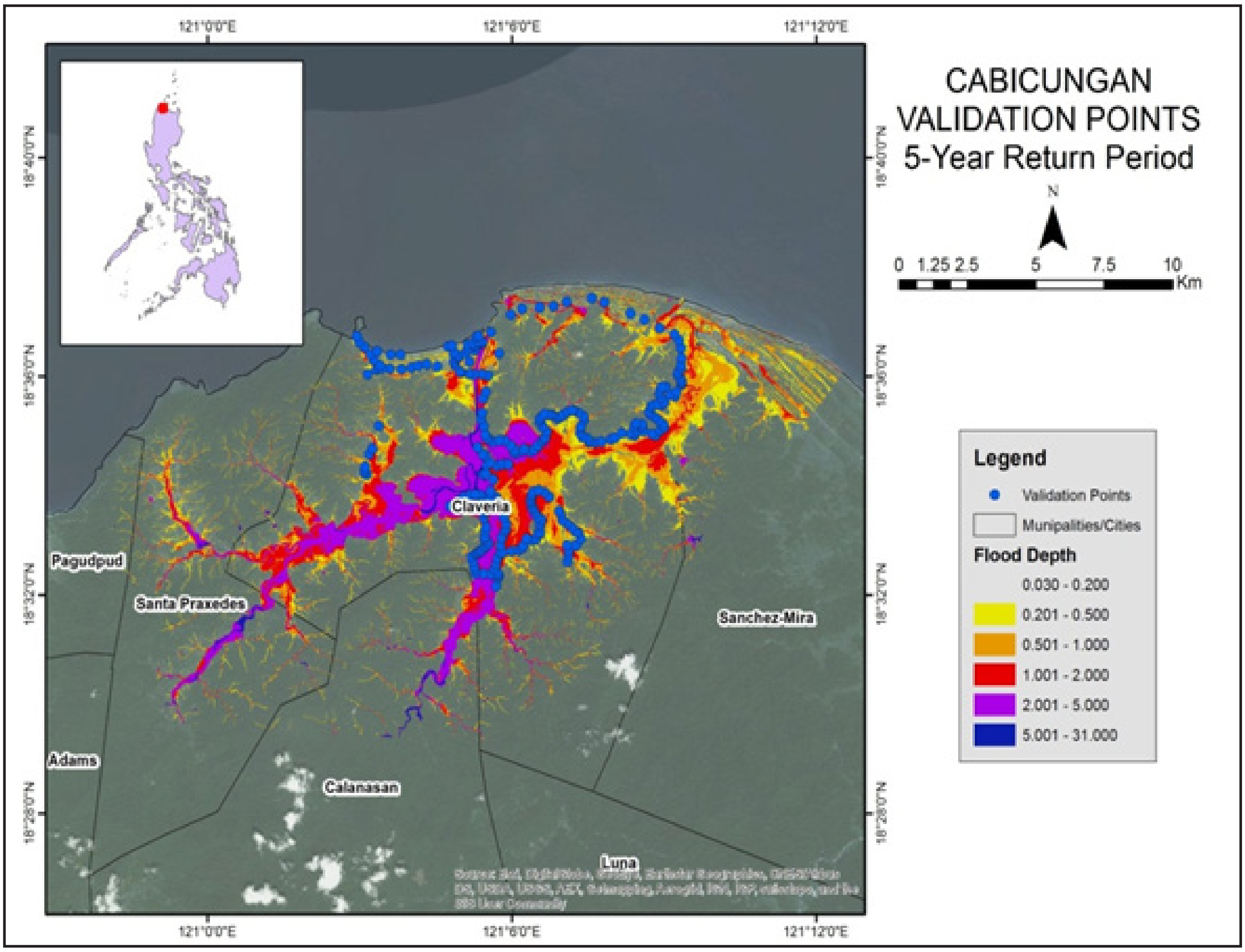


Figure 93. Validation points for the 5-year flood depth map of the Cabicungan floodplain

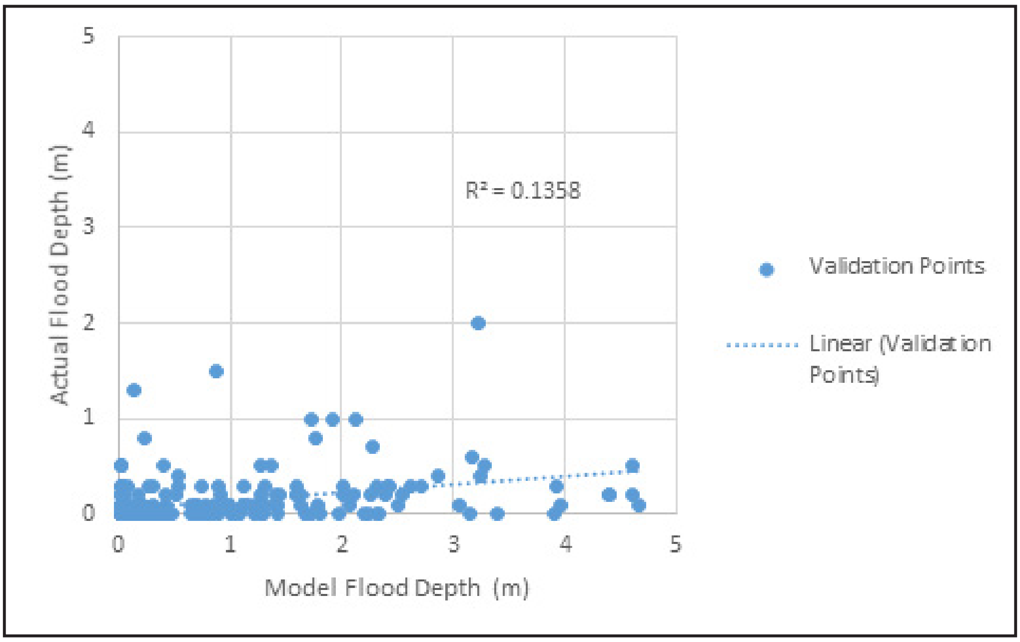


Figure 94. Model flood depth vs. actual flood depth

Table 55. Actual flood depth vs. simulated flood depth in the Cabicungan River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	137	34	15	27	20	0	233
0.21-0.50	8	3	4	5	11	0	31
0.51-1.00	0	1	0	3	3	0	7
1.01-2.00	1	0	1	0	1	0	3
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	146	38	20	35	35	0	274

The overall accuracy generated by the flood model is estimated at 51.09%, with one hundred and forty (140) points correctly matching the actual flood depths. Additionally, there were fifty-one (51) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were twenty-three (23) points and fifty-nine (59) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of eleven (11) points were underestimated in the modeled flood depths of the Cabicungan basin.

Table 56. Summary of the Accuracy Assessment of the Cabicungan model

	No. of Points	%
Correct	140	51.09
Overestimated	123	44.89
Underestimated	11	4.01
Total	274	100.00

REFERENCES

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http://www.ndrrmc.gov.ph

ANNEXES

ANNEX 1. Technical Specifications of the LiDAR Sensors used in the Cabicungan Floodplain Survey

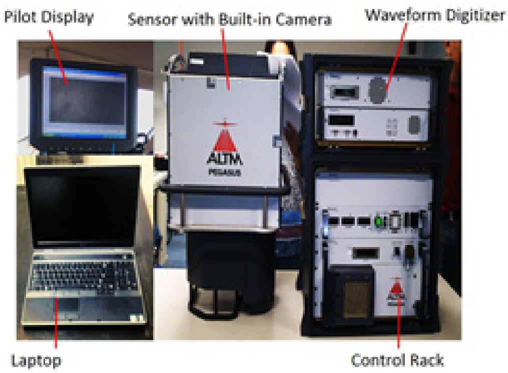


Figure A-1.1. Pegasus Sensor

Table A-1.1. Technical specifications of the Pegasus sensor

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

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

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

1. APA-13

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

December 18, 2013

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: **APAYAO**	
	Station Name: **APA-13**	
Island: **LUZON**	Order: **2nd**	Barangay: **TUMOG**
Municipality: **LUNA**		
	PRS92 Coordinates	
Latitude: **18° 19' 2.39264"**	Longitude: **121° 22' 58.62210"**	Ellipsoidal Hgt: **17.98200 m.**
	WGS84 Coordinates	
Latitude: **18° 18' 56.17679"**	Longitude: **121° 23' 3.20117"**	Ellipsoidal Hgt: **51.00500 m.**
	PTM Coordinates	
Northing: **2025924.156 m.**	Easting: **540482.023 m.**	Zone: **3**
	UTM Coordinates	
Northing: **2,025,930.60**	Easting: **329,102.89**	Zone: **51**

Location Description

APA-13

From the Mun. Hall of Luna, travel towards the direction going to Pudtol. In approx. 15 mins., you will reach the brgy. hall of Tumog in Luna. 30 m fromt he said brgy. hall, an access road is located. This access road will lead you to the brgy. property lot where the station was established. Station is located 8 m from the N edge of the PCCP, and 70 m NE of a waiting shed. Mark is the head of a brass rod with cross cut on top set flushed at the center of a 30 cm x 30 cm x 120 cm concrete monument with inscriptions, "APA-13, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8794962 A**
T.N.: **2013-1593**

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

9 9 1 2 1 8 2 0 1 3 1 3 3 6 4 7

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIF/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-2.1. APA-13

2. CGY-87

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

November 05, 2013

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: **CAGAYAN**	
	Station Name: **CGY-87**	
Island: **LUZON**	Order: **2nd**	Barangay: **CABAYABASAN**
Municipality: **LAL-LO**		
	PRS92 Coordinates	
Latitude: **18° 3' 46.30032"**	Longitude: **121° 38' 38.76326"**	Ellipsoidal Hgt: **37.21200 m.**
	WGS84 Coordinates	
Latitude: **18° 3' 40.15861"**	Longitude: **121° 38' 43.36193"**	Ellipsoidal Hgt: **71.69600 m.**
	PTM Coordinates	
Northing: **1997837.978 m.**	Easting: **568188.029 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,997,546.44**	Easting: **356,498.94**	Zone: **51**

Location Description

CGY-87
Is located on a solar dryer at Brgy. Cabayabasan, fronting the brgy. hall. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-87 2007 NAMRIA".

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**3947129 B**
T.N.:	**2013-1201**

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

9 9 1 1 0 5 2 0 1 3 1 1 0 1 2 2

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

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

Figure A-2.2. CGY-87

ANNEX 3. The LIDAR Survey Team Composition

Table A-3.1. 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 SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	MA. REMEDIOS VILLANUEVA	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERWIN DELOS SANTOS	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JERICO JECIEL	

ANNEX 4. Data Transfer Sheets for the Cabicungan Floodplain Flights

DATA TRANSFER SHEET
cagayan2 12/2/15

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS Output LAS	RAW LAS KML (swath)	LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S) BASE STATION(S)	BASE STATION(S) Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN Actual	FLIGHT PLAN KML	SERVER LOCATION
18-Nov	2866P	1BLK2G322A	pegasus	2.33	na	11.8	266	34.7	258	22.8	na	15.6	1KB	1KB	129	NA	Z:\DAC\RAW DATA
18-Nov	2868P	1BLK2H322B	pegasus	1.87	na	7.94	157	27.7	207	18	na	15.6	1KB	1KB	74	NA	Z:\DAC\RAW DATA
19-Nov	2870P	1BLK21AB323A	pegasus	2.11	na	11.6	255	23.2	211	22.8	na	10.3	1KB	1KB	46	NA	Z:\DAC\RAW DATA
20-Nov	2874P	1BLK21C324A	pegasus	1.22	na	8.12	195	7.3	80	12	na	10.8	1KB	1KB	57/90	NA	Z:\DAC\RAW DATA
21-Nov	2880P	1BLK2HS325A	pegasus	1.76	na	12.2	231	30	240/1	17.7	na	11.4	1KB	1KB	84/76/74	NA	Z:\DAC\RAW DATA

Received from

Name
Position
Signature

Received by

Name AC Borgat 12/4/15
Position
Signature

15-41

Figure A-4.1. Data Transfer Sheet for the Cabicungan Floodplain

ANNEX 5. Flight Logs for the Flight Missions

1. Flight Log for 2870P Mission

Data Acquisition Flight Log

Flight Log No.: 2870P

1 LIDAR Operator: K. QUISADO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK21AB323A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO	8 Co-Pilot: J. JECIEL	9 Route: Tuguegarao - Tuguegarao			
10 Date: NOV 19, 2015	12 Airport of Departure (Airport, City/Province): TUGUEGARAO, CAGAYAN		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO, CAGAYAN		
13 Engine On: 0830H	14 Engine Off: 1235H	15 Total Engine Time: 4+05	16 Take off: 0835H	17 Landing: 1230H	18 Total Flight Time: 3+55
19 Weather	FAIR				

20 Flight Classification

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

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

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

21 Remarks

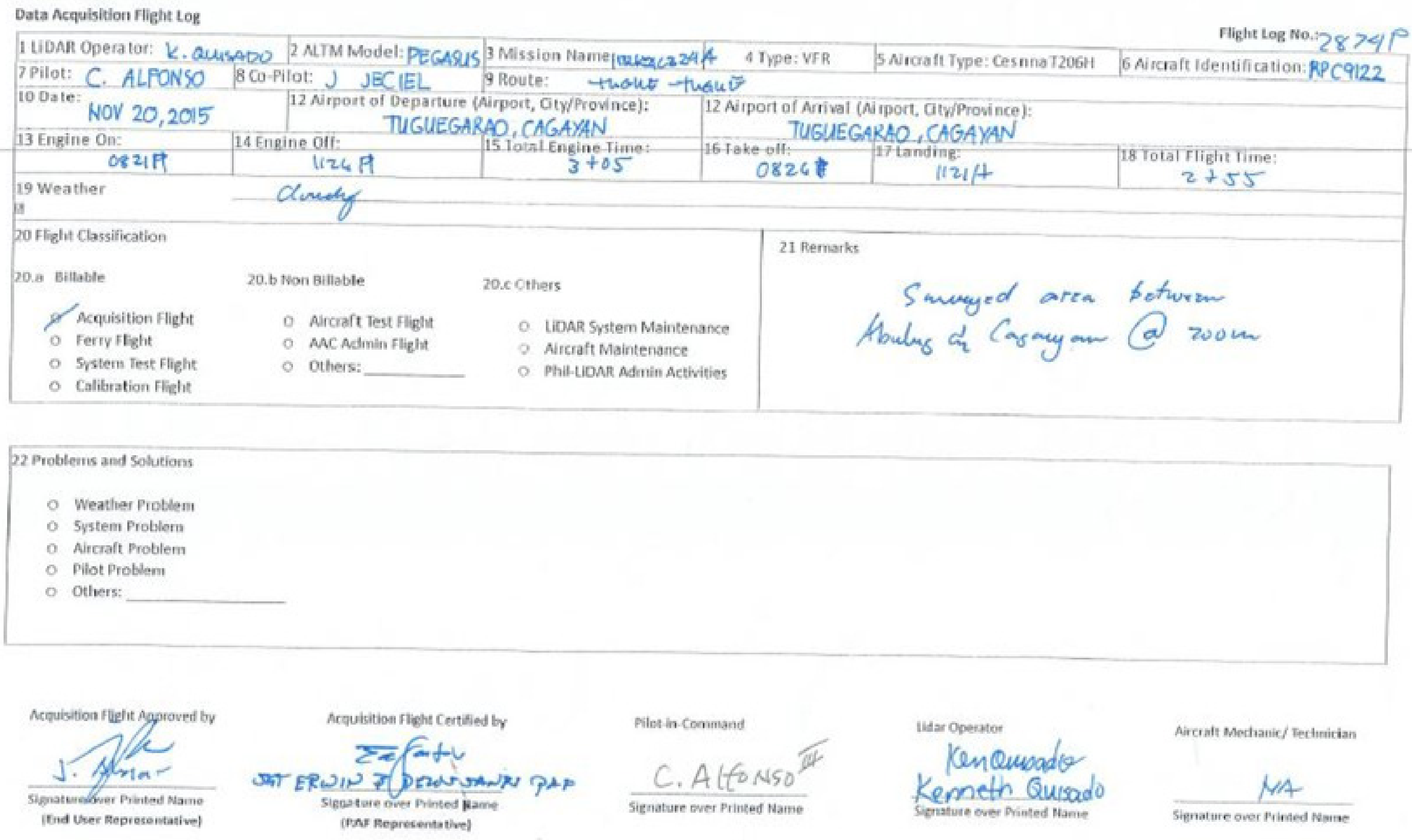
Surveyed BLK 21A&B

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
S. Alfiar	SST ERWIN B DEZASANTU PAF	C. ALFONSO III	Kenneth Quisado	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-5.1. Flight Log for Mission 2870P

2. Flight Log for 2874P Mission



Data Acquisition Flight Log

Flight Log No.: 2874P

1 LiDAR Operator: K. QUISADO	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. ALFONSO	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: NOV 20, 2015	12 Airport of Departure (Airport, City/Province): TUGUEGARAO, CAGAYAN		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO, CAGAYAN		
13 Engine On: 0821H	14 Engine Off: 1124H	15 Total Engine Time: 3+05	16 Take off: 0826H	17 Landing: 1121H	18 Total Flight Time: 2+55
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed area between Abulug & Cagayan @ 700m

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

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

Acquisition Flight Certified by: SGT ERWIN F. DEMANDANTE PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: Kenneth Quisado — Signature over Printed Name

Aircraft Mechanic/ Technician: NA — Signature over Printed Name

Figure A-5.2. Flight Log for Mission 2874P

ANNEX 6. Flight Status Reports

CAGAYAN-APAYAO
(NOVEMBER 18-30, 2015)

Table A-6.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2870P	BLK 21AB CABICUNGAN FP	1BLK21AB323A	K QUISADO	NOV 19	SURVEYED BLK 21AB; 230.90 SQ.KM
2874P	BLK 2HS (ADD'L AREA)	1BLK21C324A	K QUISADO	NOV 20	SURVEYED GAP BETWEEN ABULUG AND CAGAYAN FPS DUE TO HEAVY BUILD UP IN OTHER AREAS; 700M 90.3 SQ.KM

LAS BOUNDARIES PER FLIGHT

Flight No. :	2870P				
Area:	BLK 21AB				
Mission Name:	1BLK21AB323A				
Parameters:	PRF 200	SF	30	FOV	50

LAS/SWATH

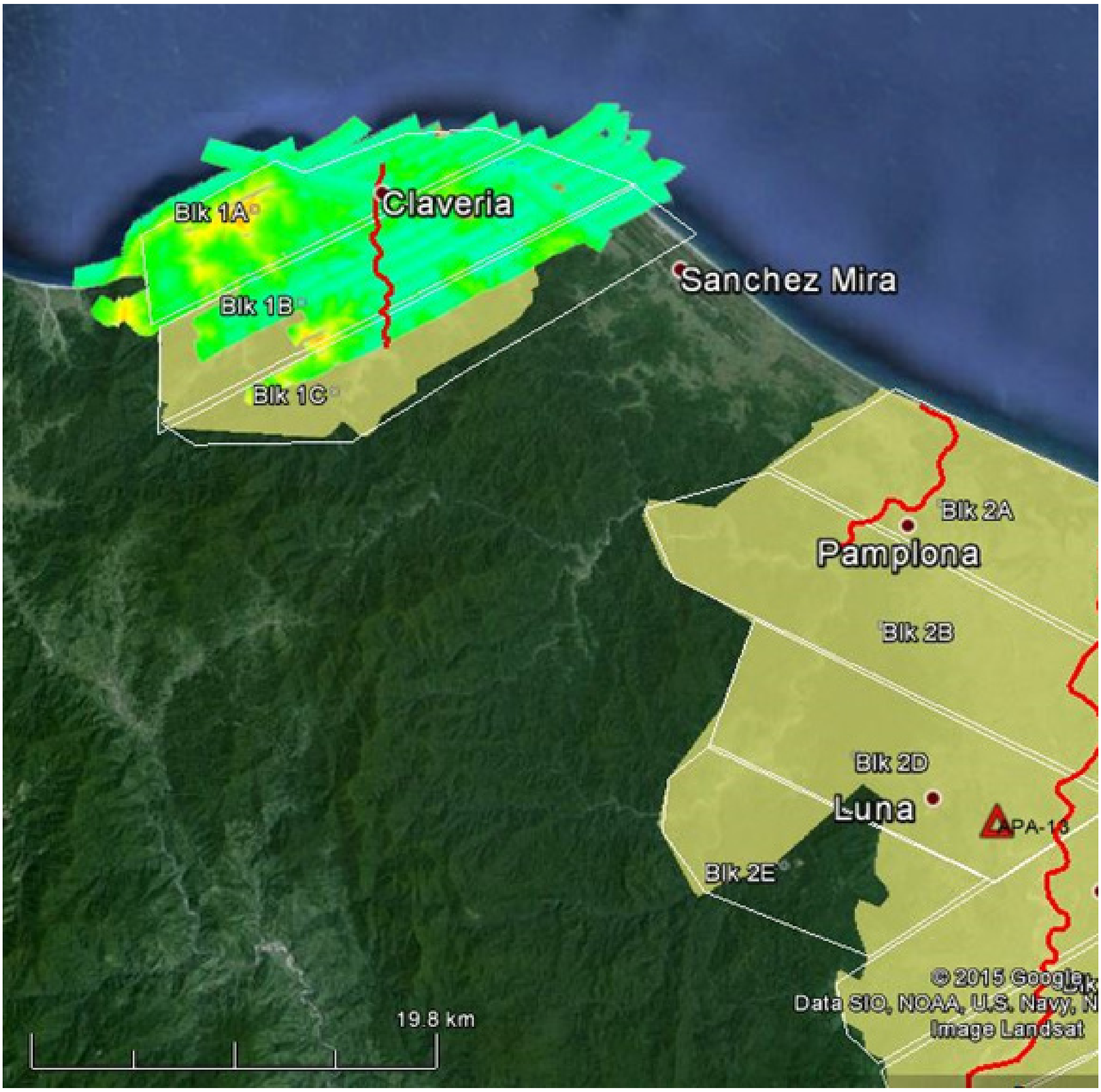


Figure A-6.1. Swath for Flight No. 2870P

Flight No. :	2874P				
Area:	BLK 2HS				
Mission Name:	1BLK21324A				
Parameters:	PRF 200	SF	30	FOV	50

LAS/SWATH

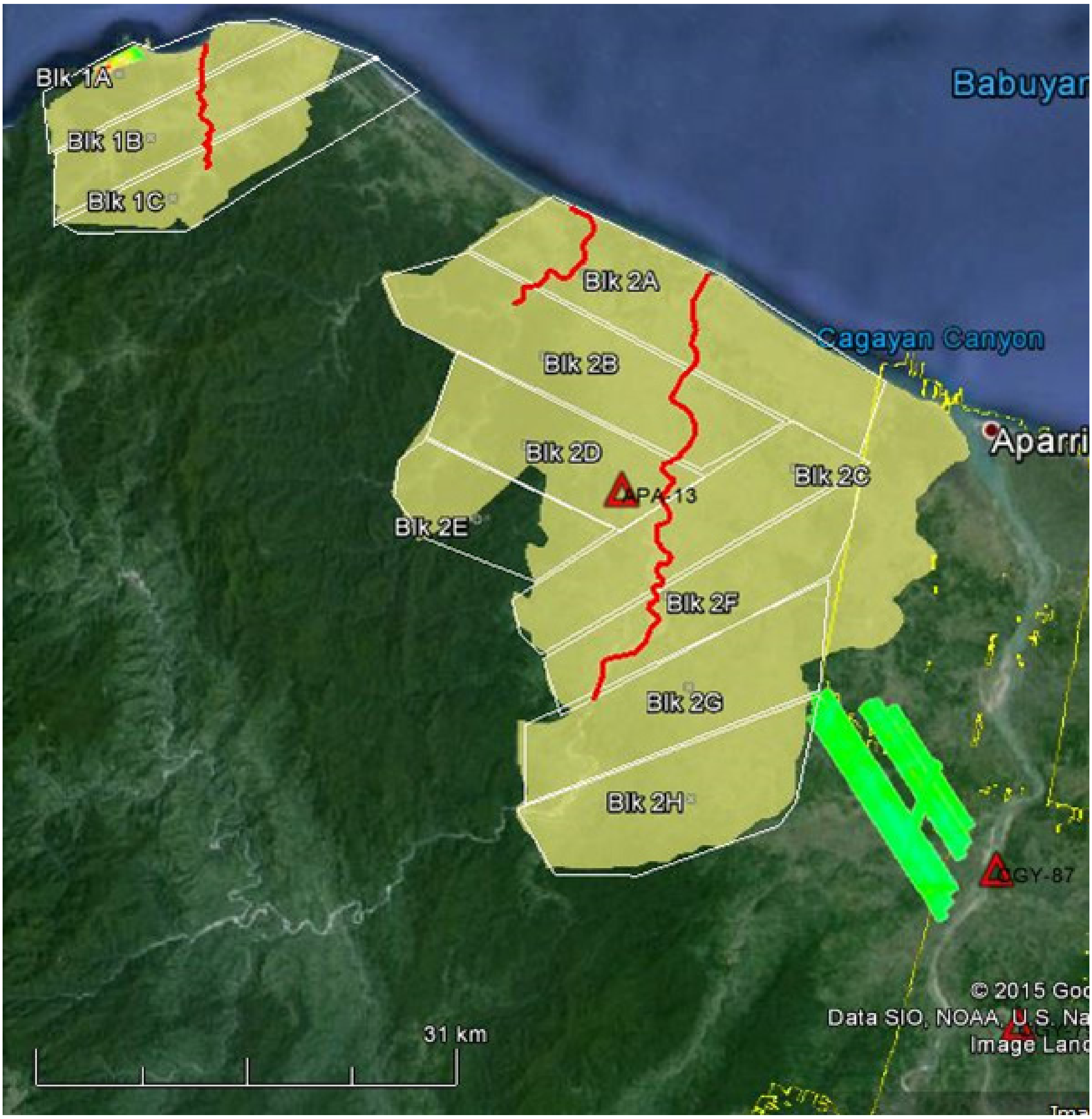


Figure A-6.2. Swath for Flight No. 2874P

ANNEX 8. Mission Summary Reports

Table A-7.1. Mission Summary Report for Mission Blk1A

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk1A
Inclusive Flights	2870P
Range data size	22.8GB
POS	255MB
Image	23.2MB
Transfer date	December 4, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.28
RMSE for East Position (<4.0 cm)	1.12
RMSE for Down Position (<8.0 cm)	4.71
Boresight correction stdev (<0.001deg)	0.000282
IMU attitude correction stdev (<0.001deg)	0.002349
GPS position stdev (<0.01m)	0.0064
Minimum % overlap (>25)	24.73
Ave point cloud density per sq.m. (>2.0)	6.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	133
Maximum Height	739.48 m
Minimum Height	36.03 m
Classification (# of points)	
Ground	60,196,192
Low vegetation	40,626,955
Medium vegetation	71,696,466
High vegetation	432,508,654
Building	6,580,417
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Engr. Melanie Hingpit

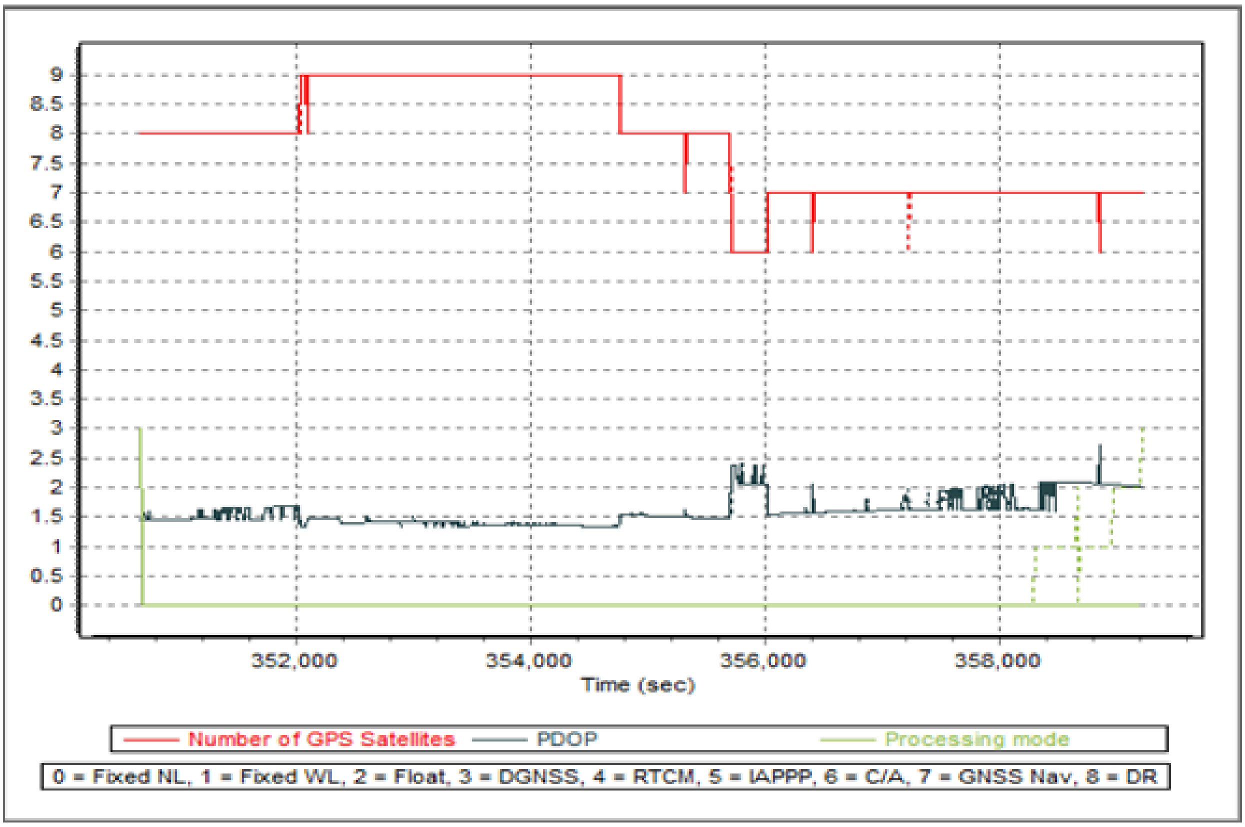


Figure A-7.1. Solution Status

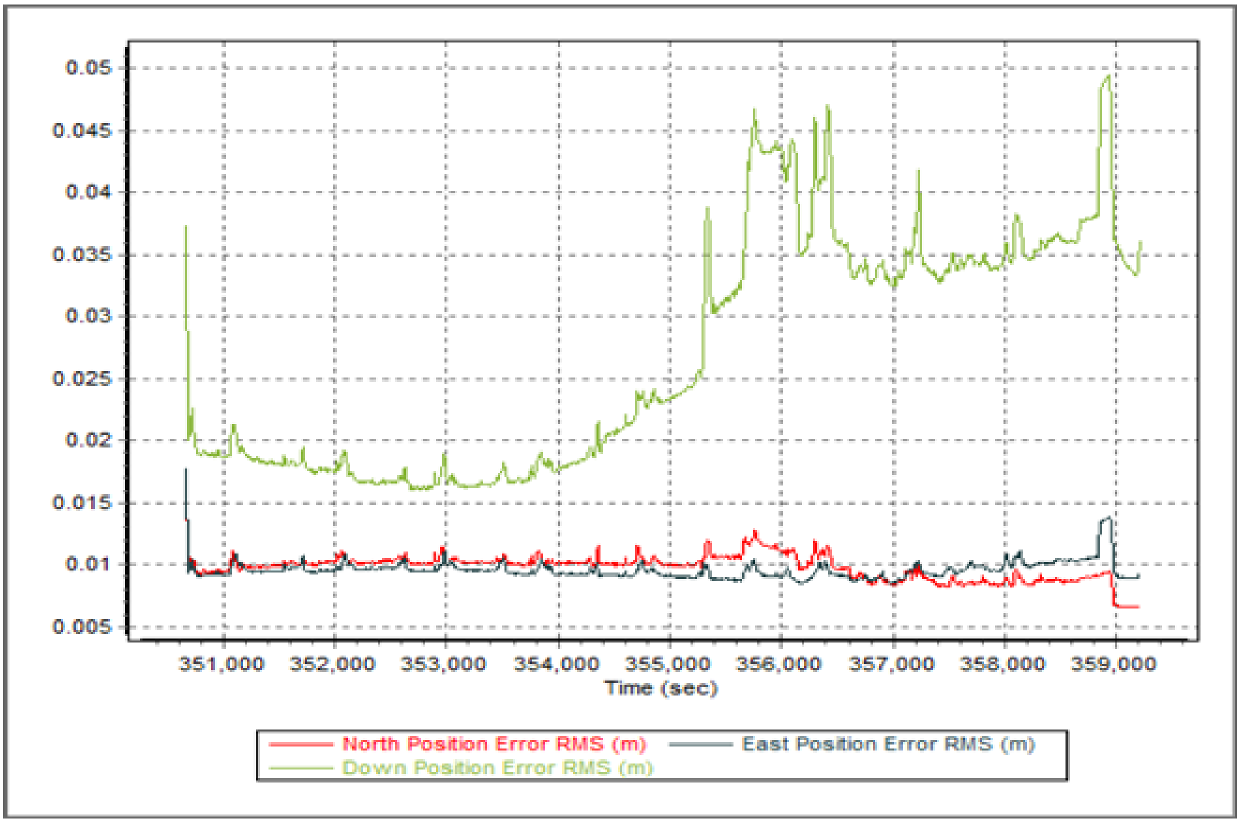


Figure A-7.2. Smoothed Performance Metric Parameters

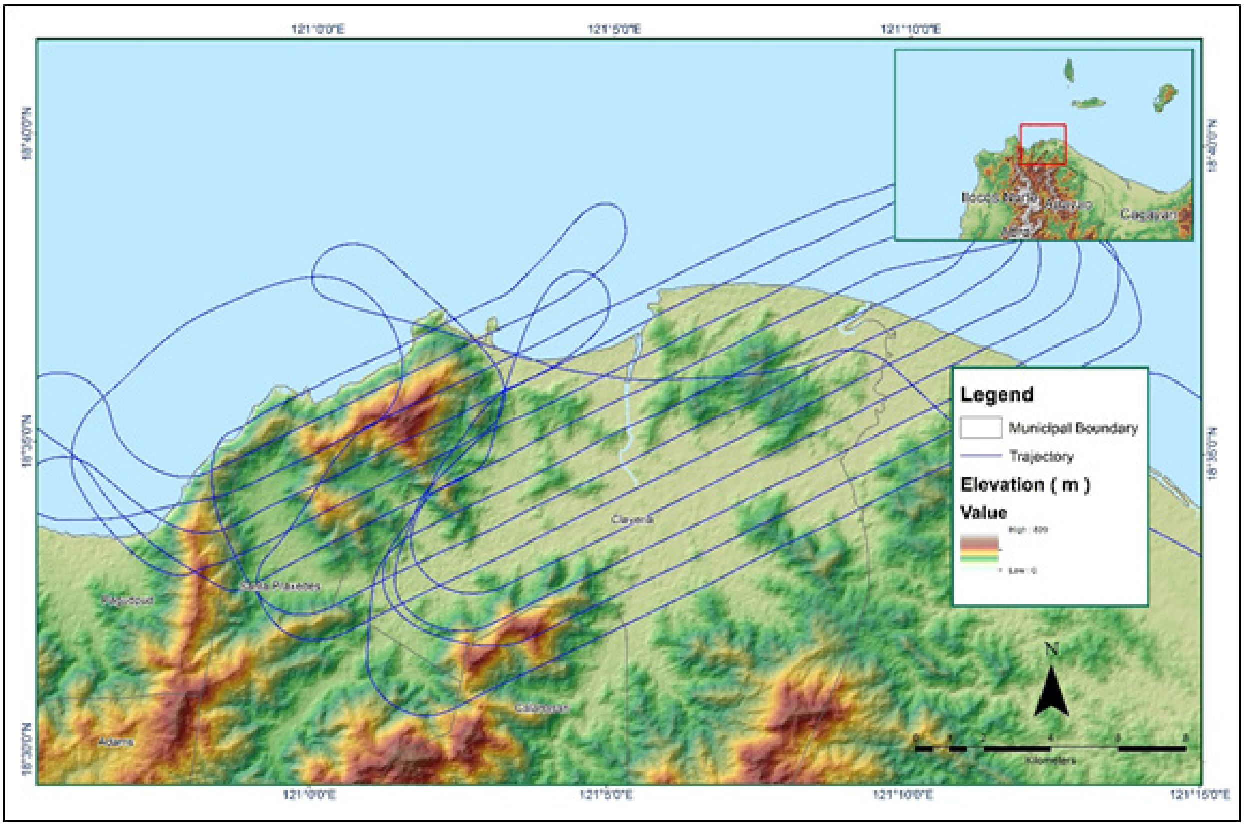


Figure A-7.3. Best Estimated Trajectory

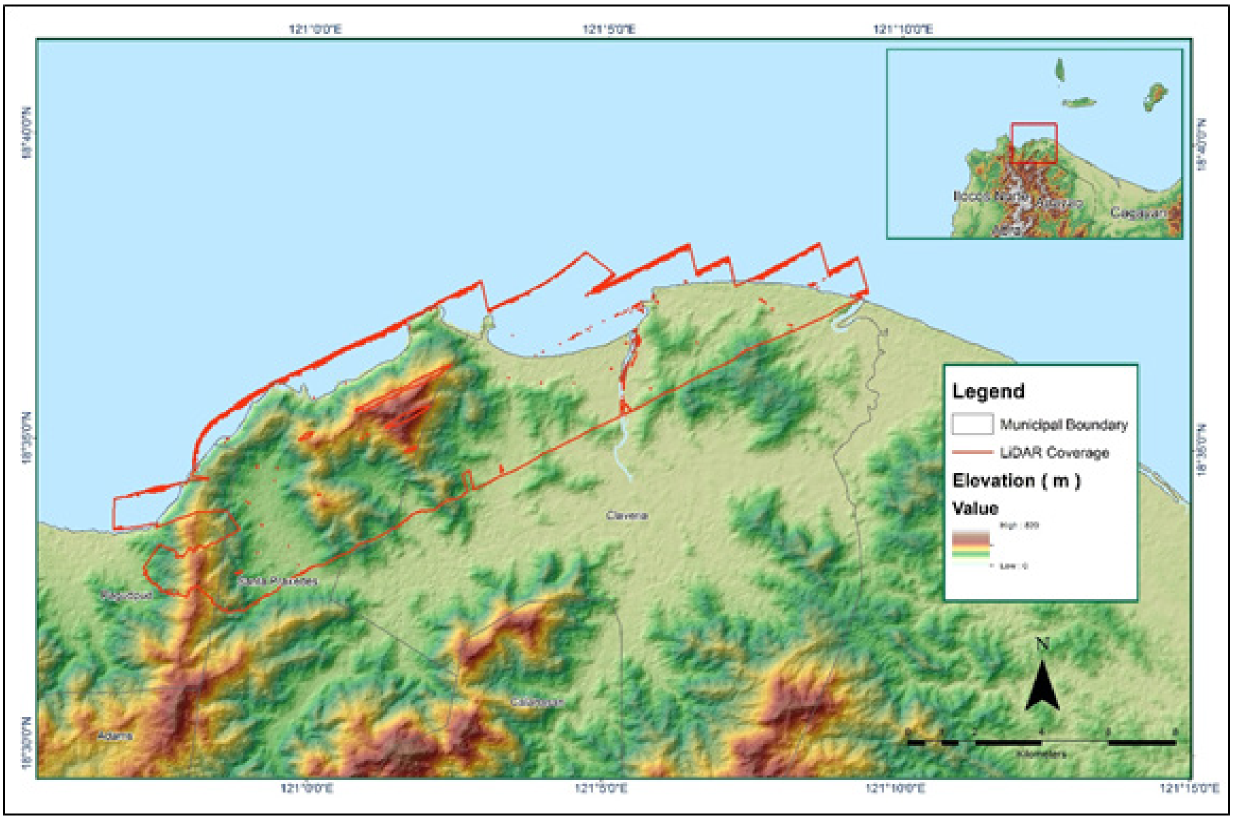


Figure A-7.4. Coverage of LiDAR data

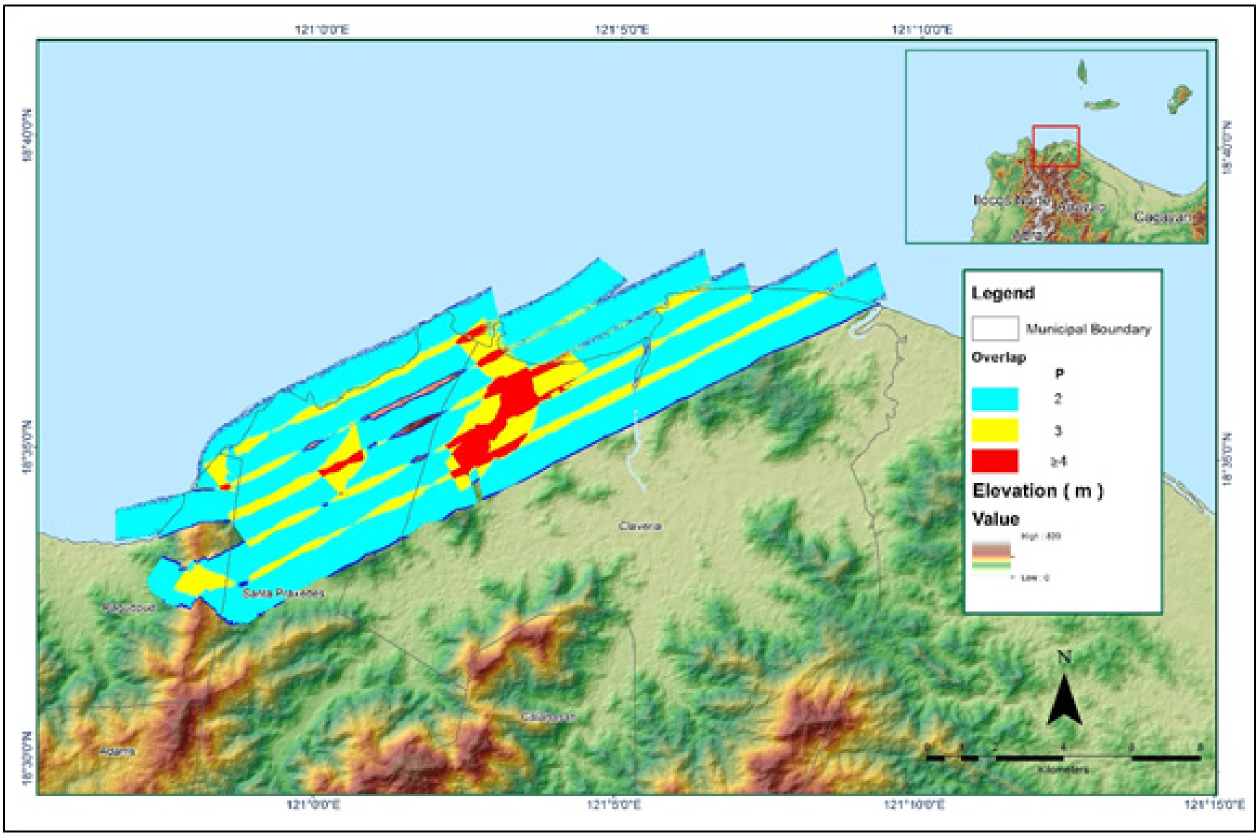


Figure A-7.5. Image of data overlap

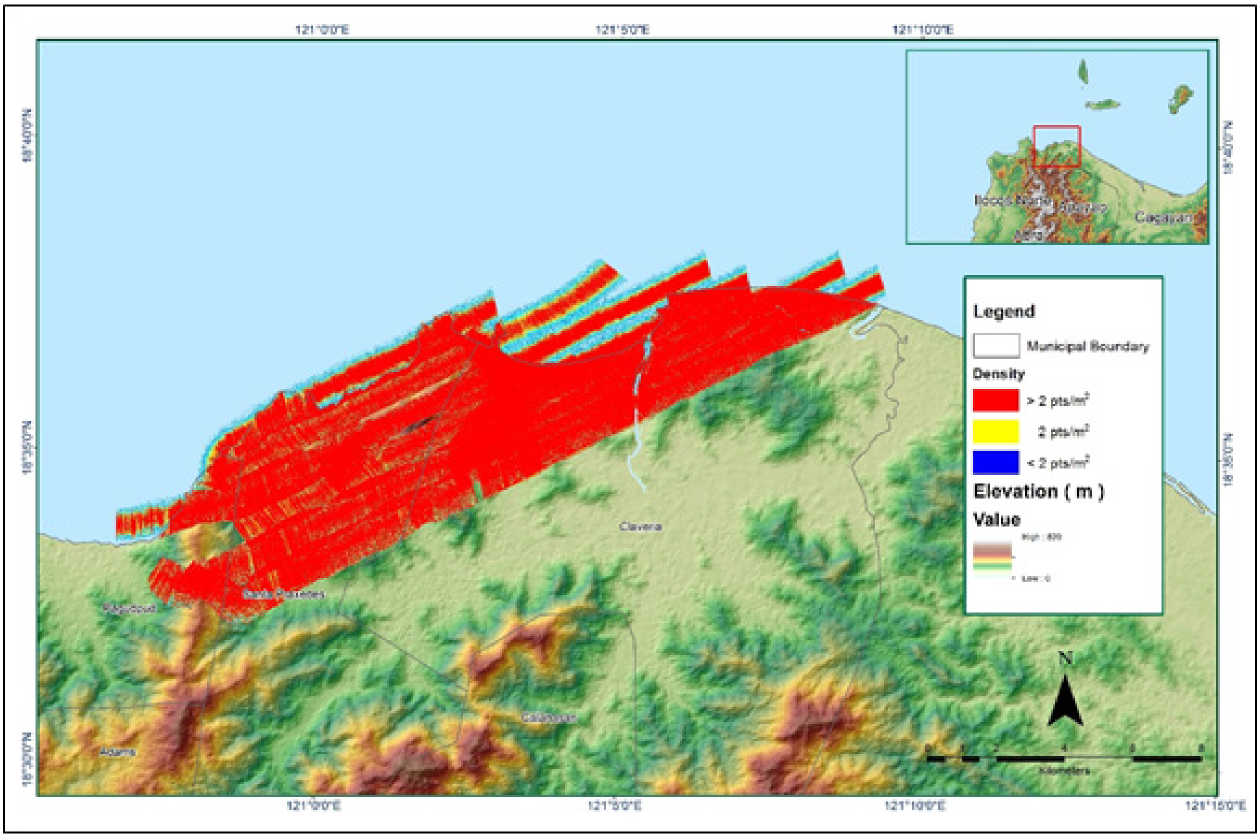


Figure A-7.6. Density map of merged LiDAR data

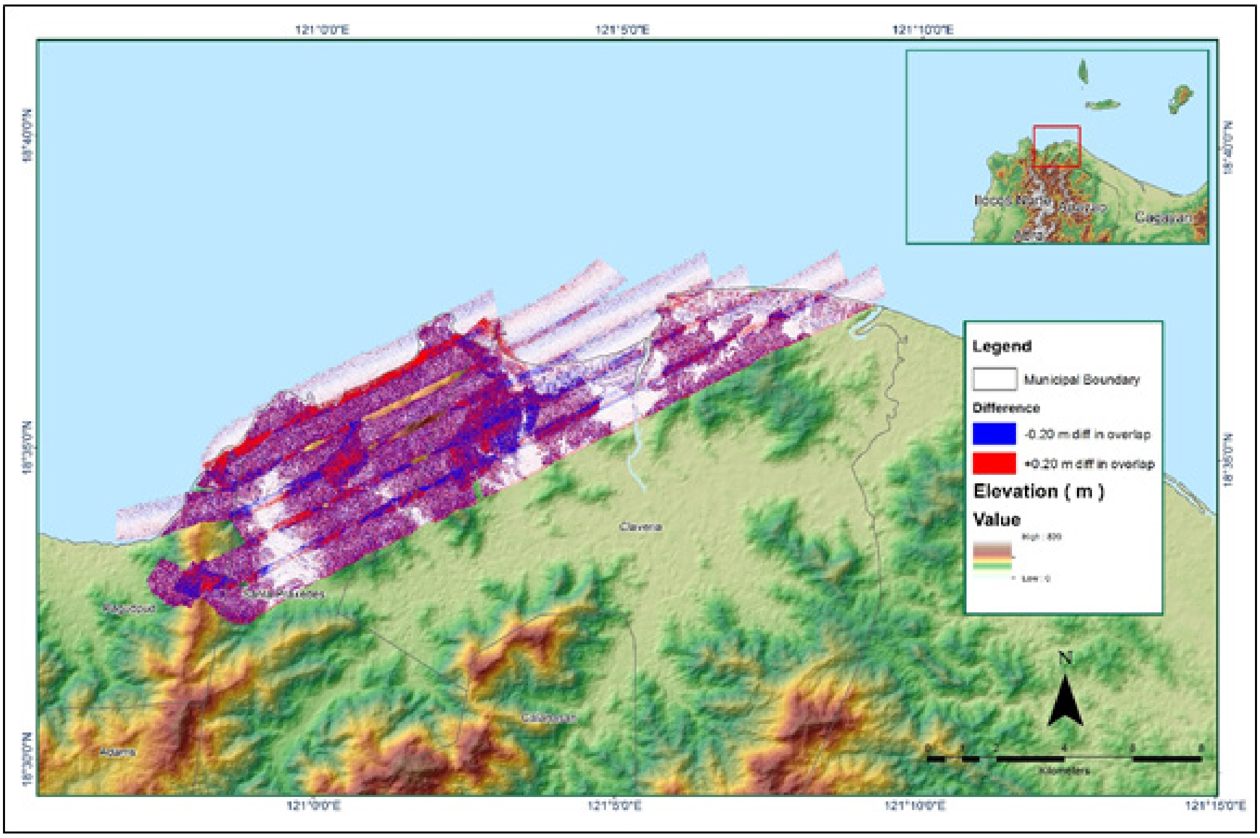


Figure A-7.7. Elevation difference between flight lines

Table A-7.2. Mission Summary Report for Mission Blk1B

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk1B
Inclusive Flights	2870P
Range data size	22.8GB
POS	255MB
Image	23.2MB
Transfer date	December 4, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.28
RMSE for East Position (<4.0 cm)	1.12
RMSE for Down Position (<8.0 cm)	4.71
Boresight correction stdev (<0.001deg)	0.000282
IMU attitude correction stdev (<0.001deg)	0.002349
GPS position stdev (<0.01m)	0.0064
Minimum % overlap (>25)	23.30
Ave point cloud density per sq.m. (>2.0)	4.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	184
Maximum Height	724.87 m
Minimum Height	36.10 m
Classification (# of points)	
Ground	141,902,090
Low vegetation	50,881,395
Medium vegetation	63,256,750
High vegetation	143,550,037
Building	1,619,297
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

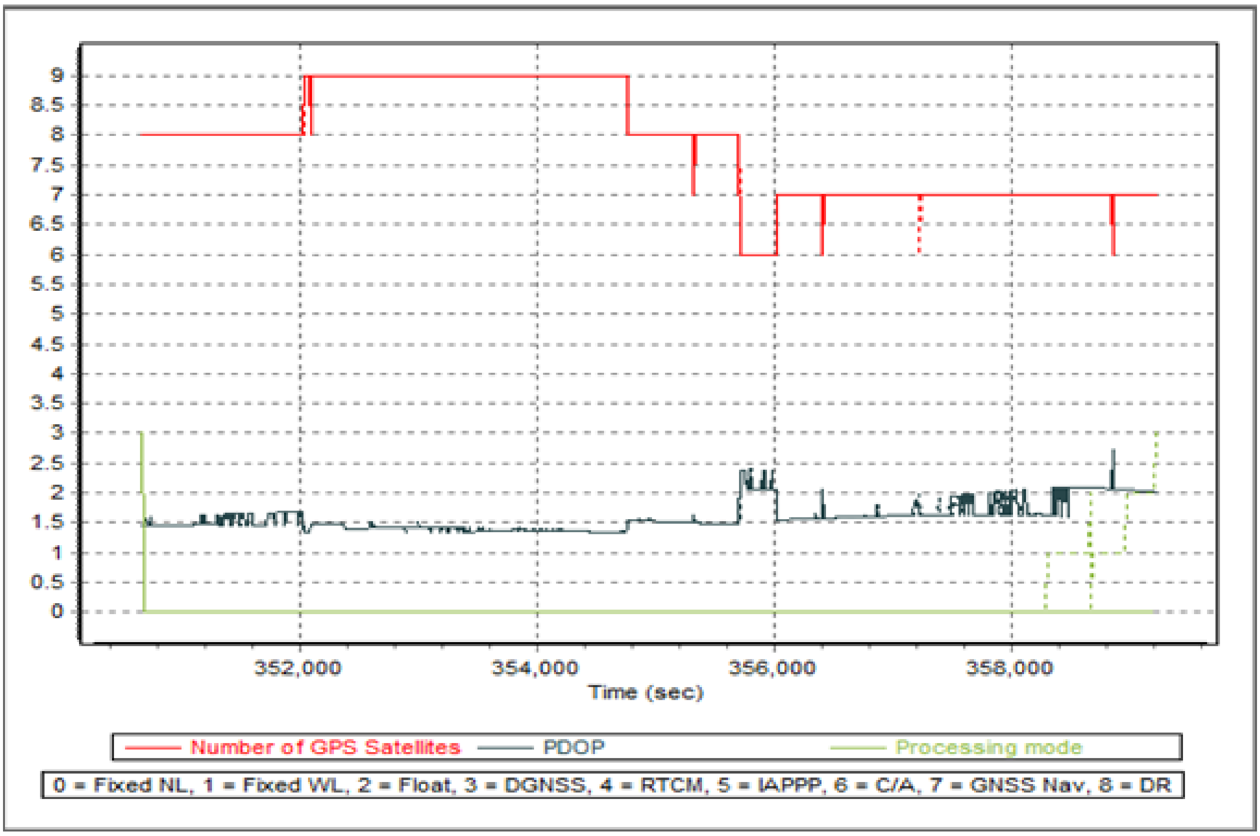


Figure A-7.8. Solution Status

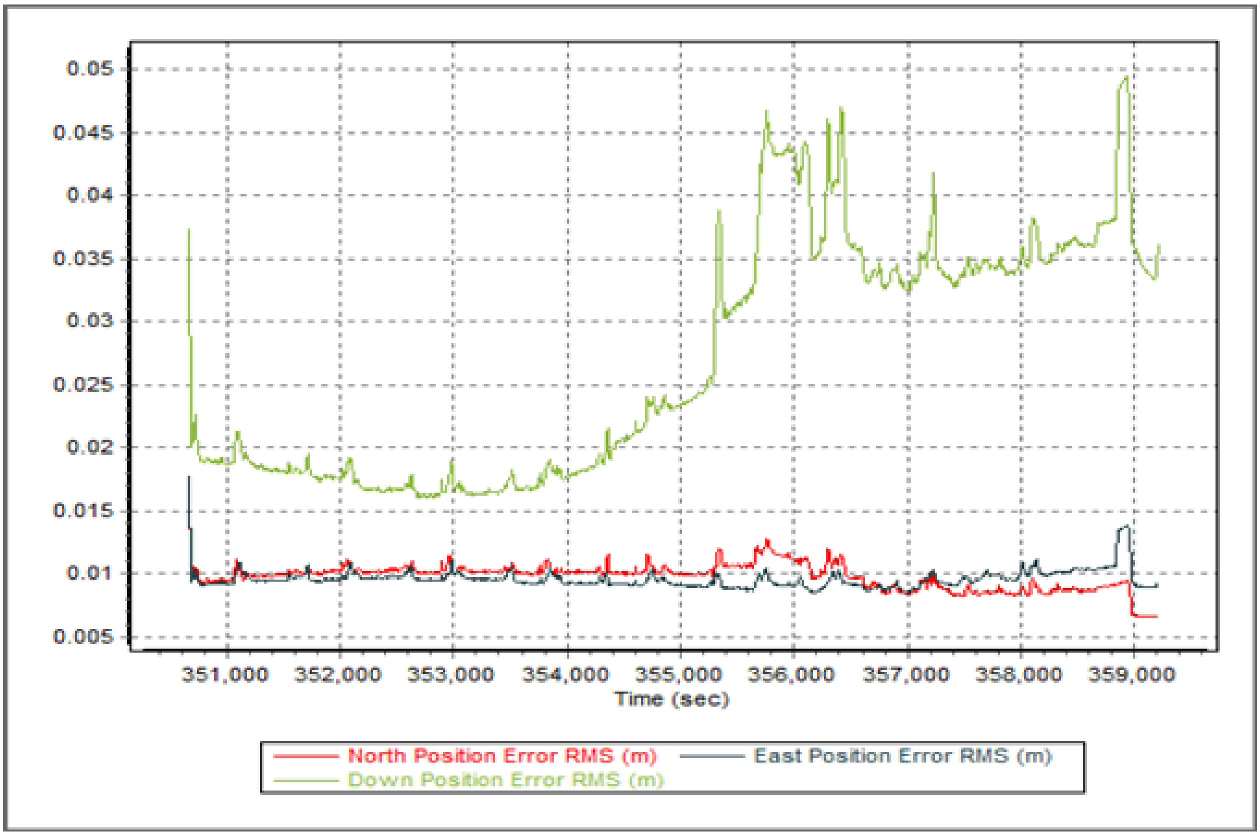


Figure A-7.9. Smoothed Performance Metric Parameters

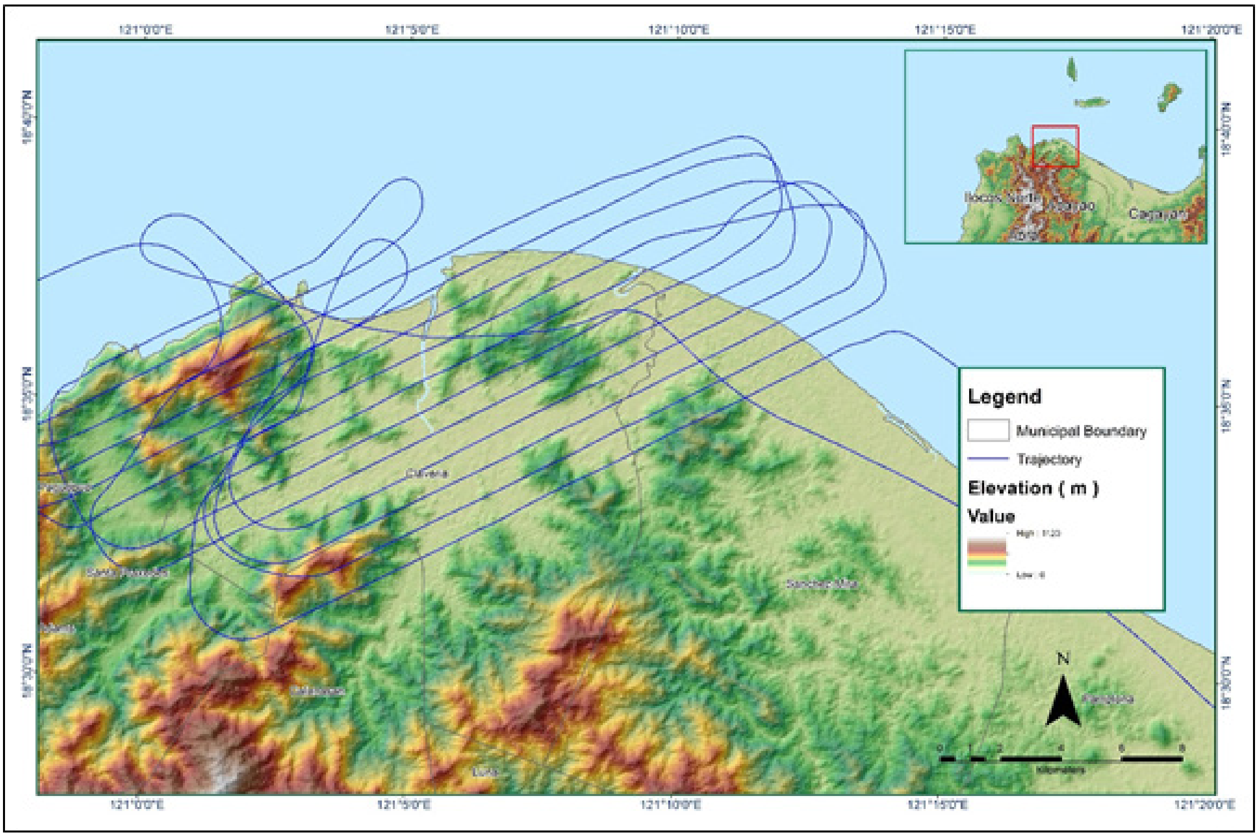


Figure A-7.10. Best Estimated Trajectory

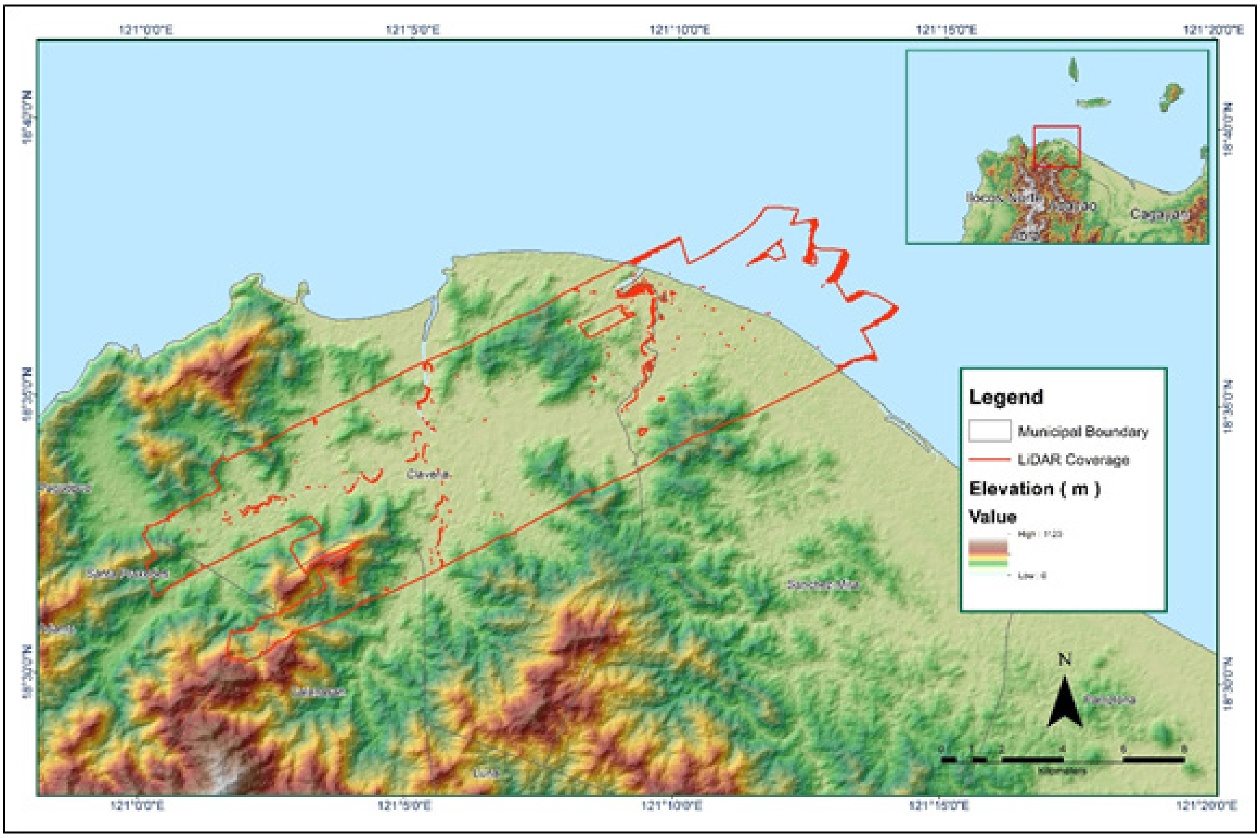


Figure A-7.11. Coverage of LiDAR data

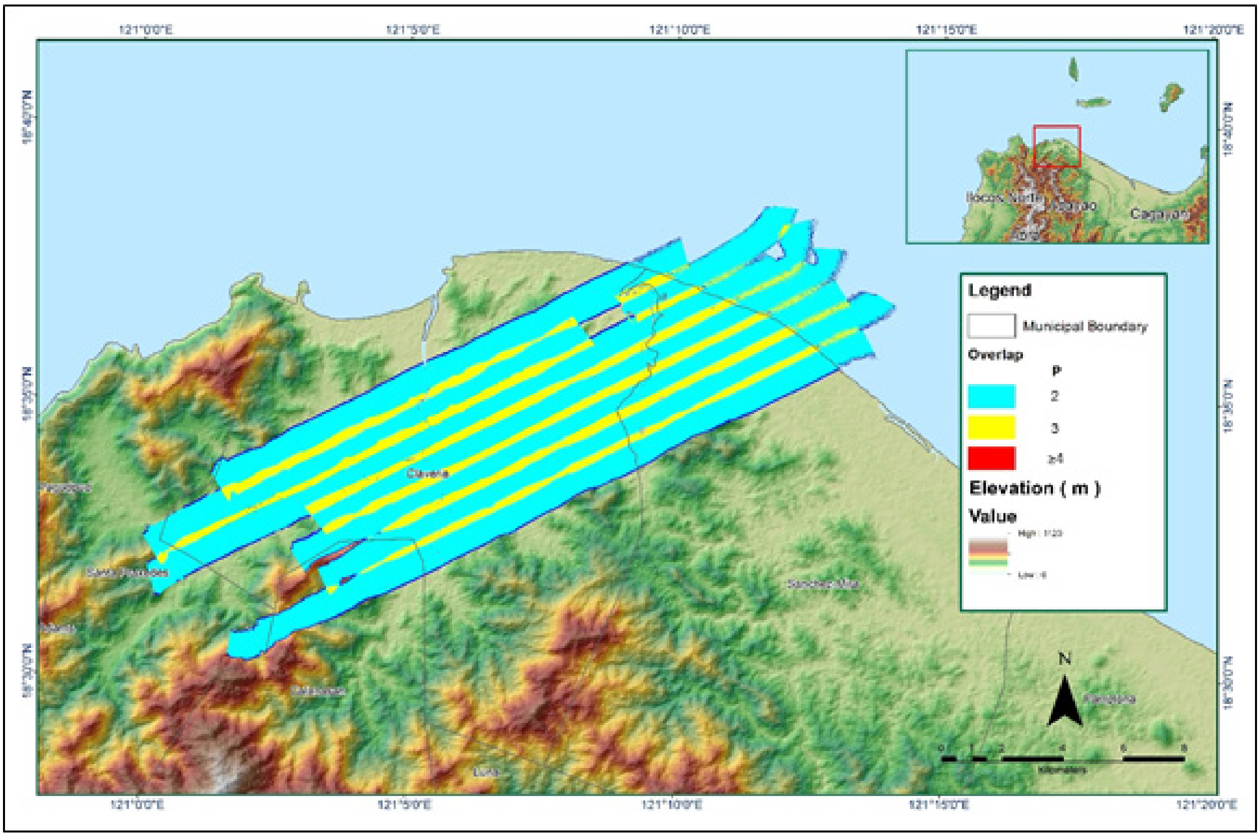


Figure A-7.12. Image of data overlap

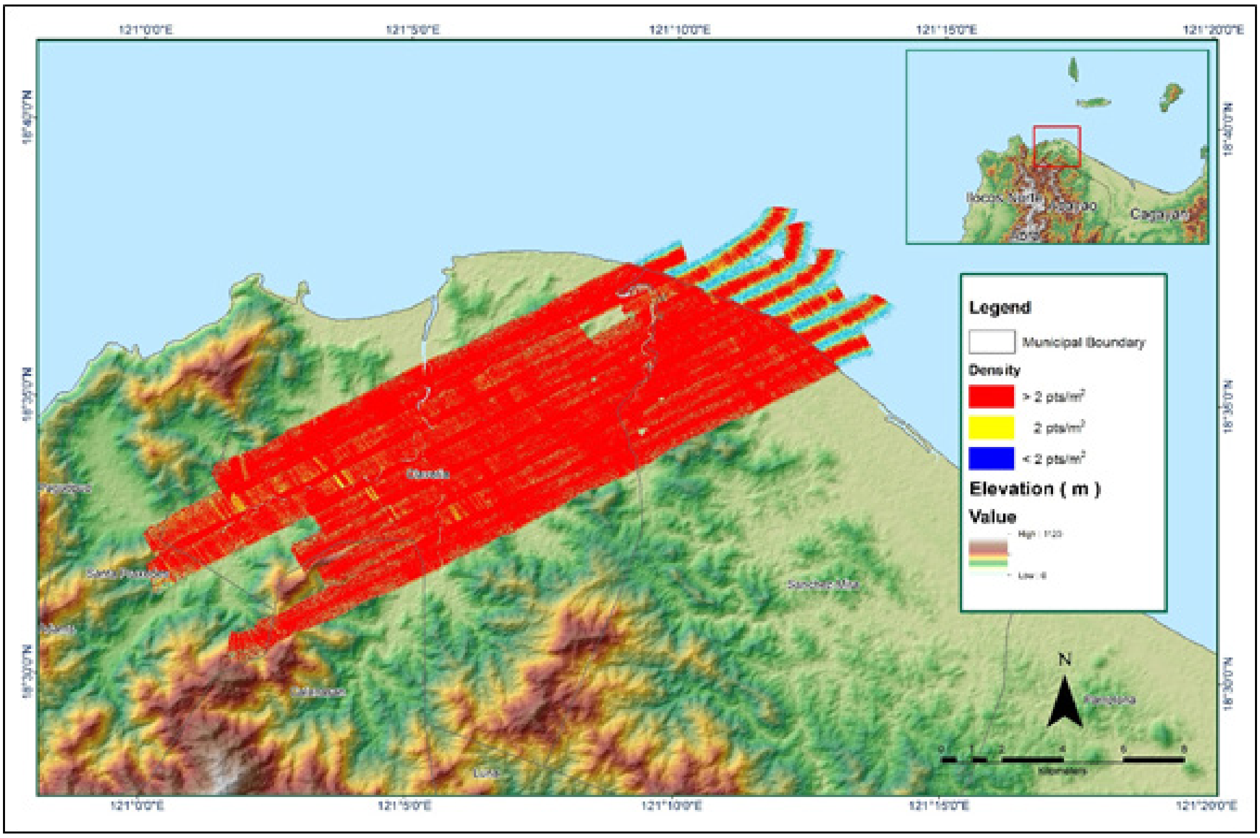


Figure A-7.13. Density map of merged LiDAR data

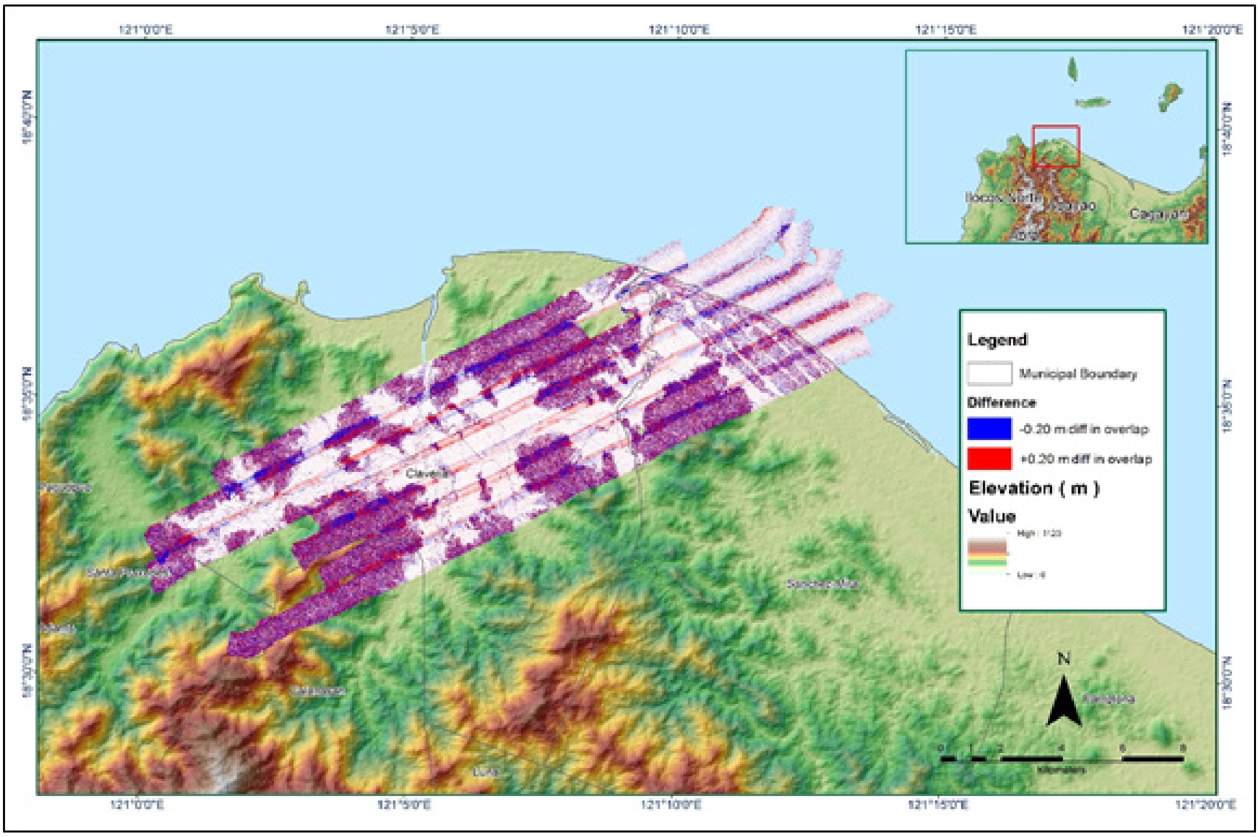


Figure A-7.14. Elevation difference between flight lines

Table A-7.3. Mission Summary Report for Mission Blk1C

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk1C
Inclusive Flights	23696P
Range data size	8.9 GB
Base data size	5.71 MB
POS	192 MB
Image	NA
Transfer date	January 29, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.67
RMSE for East Position (<4.0 cm)	0.83
RMSE for Down Position (<8.0 cm)	1.46
Boresight correction stdev (<0.001deg)	0.000698
IMU attitude correction stdev (<0.001deg)	0.000450
GPS position stdev (<0.01m)	0.0229
Minimum % overlap (>25)	39.41
Ave point cloud density per sq.m. (>2.0)	3.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	76
Maximum Height	635.11 m
Minimum Height	42.30 m
Classification (# of points)	
Ground	24,168,461
Low vegetation	6,297,564
Medium vegetation	29,320,003
High vegetation	321,571,891
Building	1,286,986
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

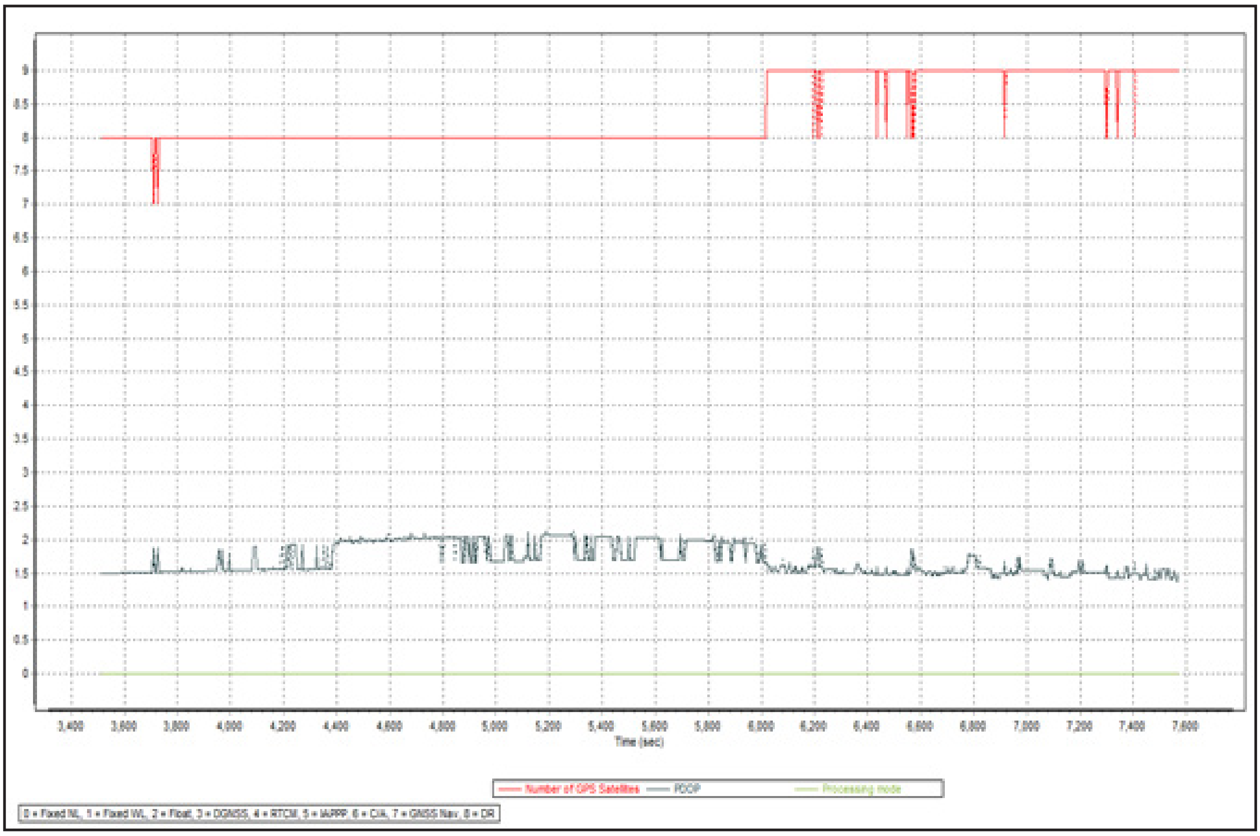


Figure A-7.15. Solution Status

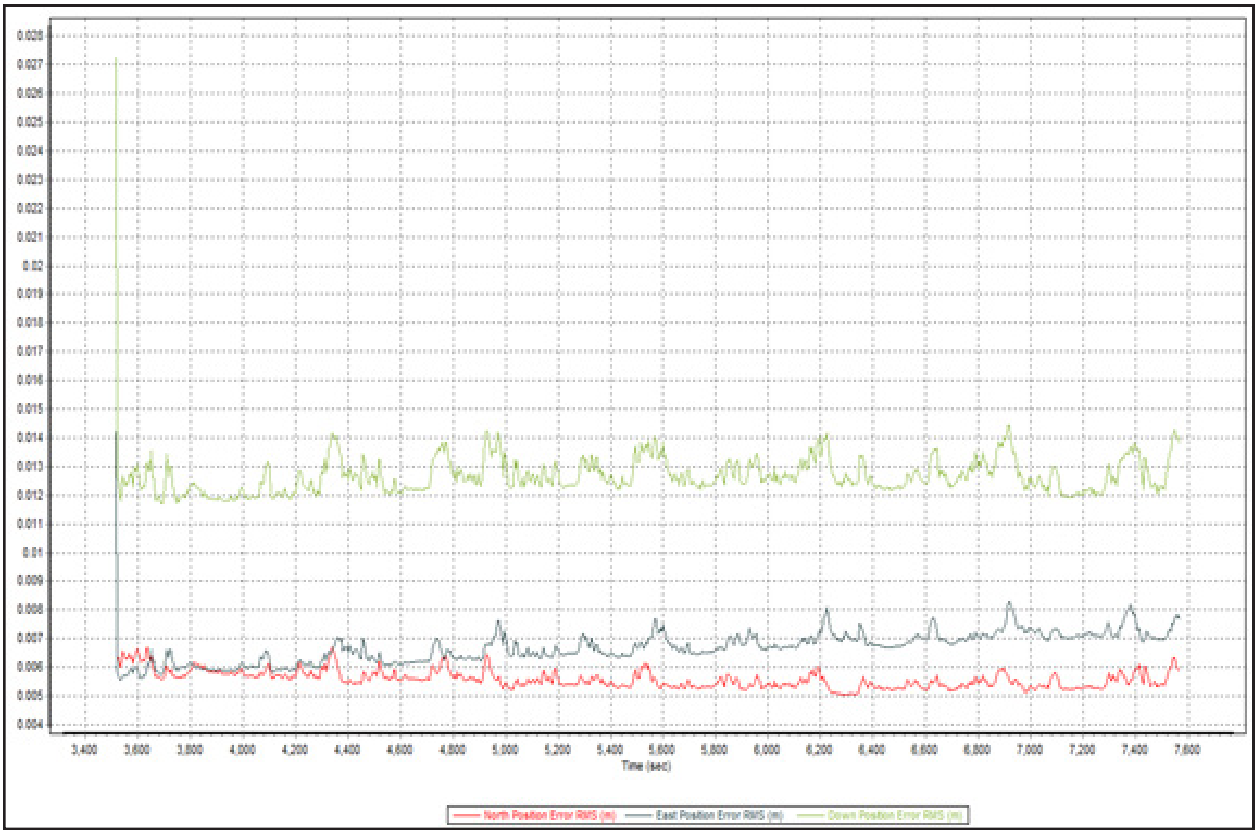


Figure A-7.16. Smoothed Performance Metric Parameters

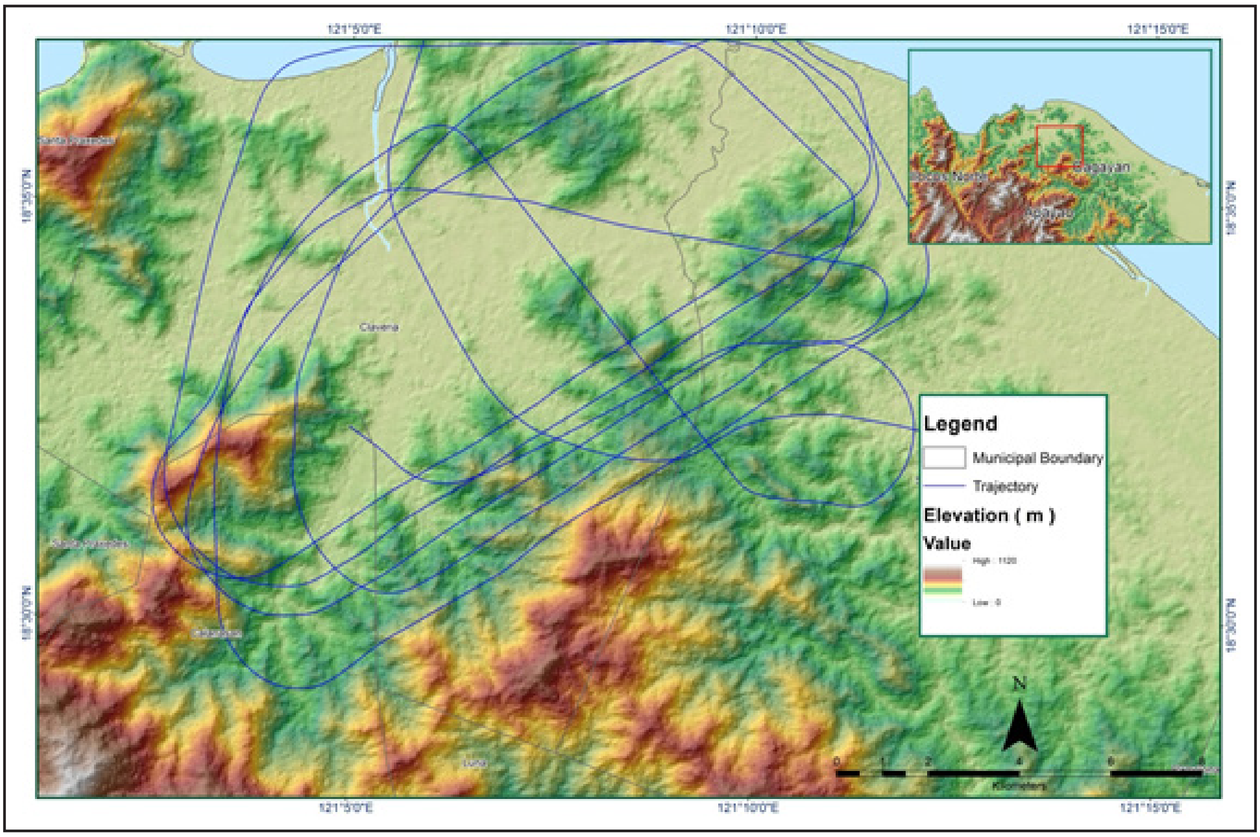


Figure A-7.17. Best Estimated Trajectory

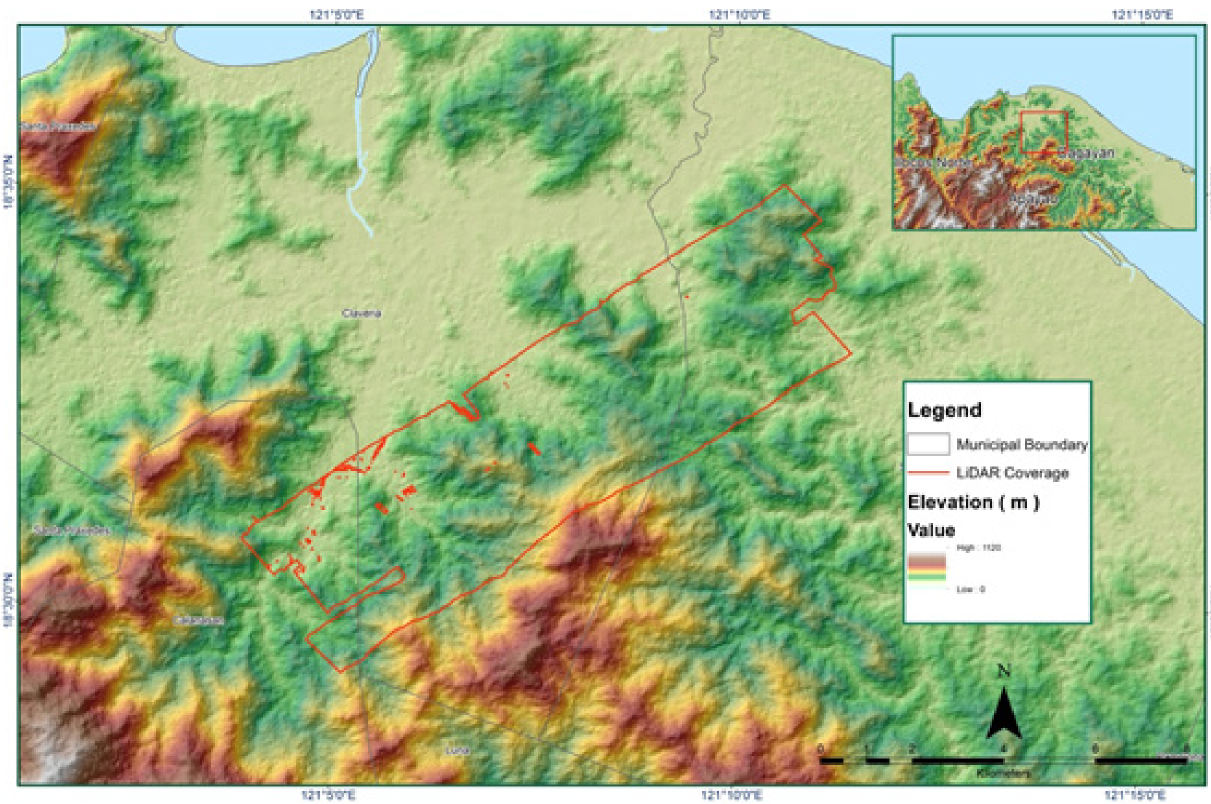


Figure A-7.18. Coverage of LiDAR data

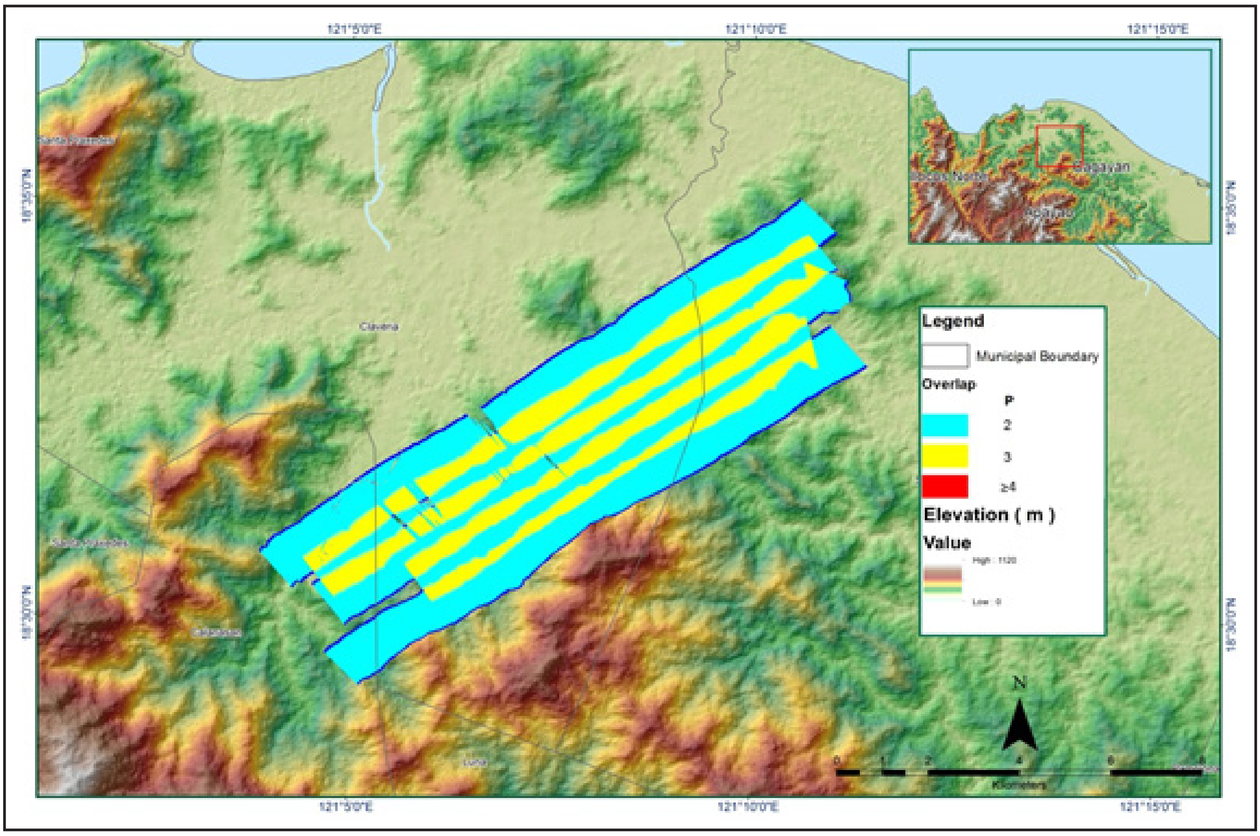


Figure A-7.19. Image of data overlap

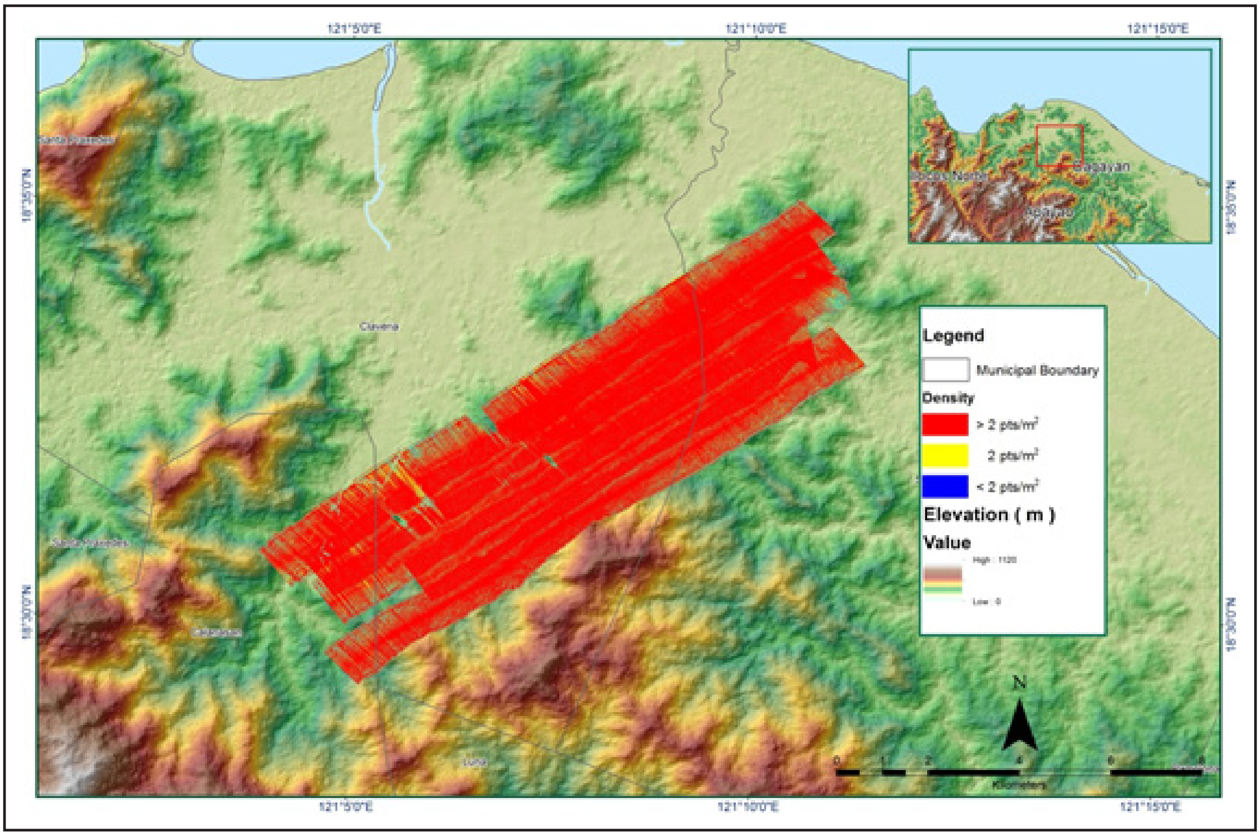


Figure A-7.20. Density map of merged LiDAR data

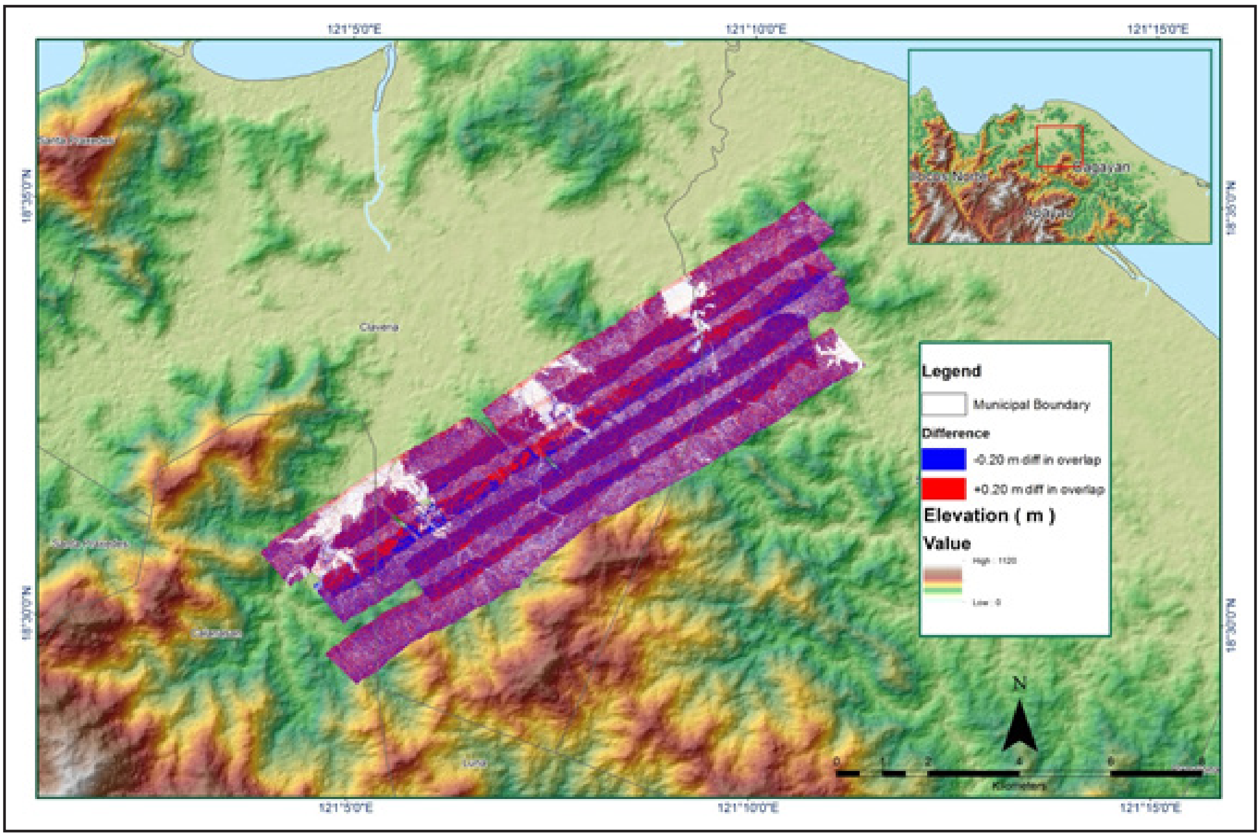


Figure A-7.21. Elevation difference between flight lines

ANNEX 8. Cabicungan Model Basin Parameters

Table A-8.1. Cabicungan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1000	8.5044	64.184	0	0.16839	0.82445	Discharge	2.0256	1	Ratio to Peak	0.3
W1010	4.4715	77	0	0.0912651	0.44683	Discharge	0.92026	1	Ratio to Peak	0.3
W1020	4.4569	77	0	0.0378413	0.18527	Discharge	0.0439339	1	Ratio to Peak	0.3
W1030	10.55	59.093	0	0.2001	0.97968	Discharge	2.0203	1	Ratio to Peak	0.3
W1040	9.9997	60.381	0	0.0851592	0.41694	Discharge	0.21215	1	Ratio to Peak	0.3
W1050	9.3783	61.9052	0	0.13448	0.6584	Discharge	1.0633	1	Ratio to Peak	0.3
W1060	10.16	60	0	0.0322408	0.15785	Discharge	0.0338267	1	Ratio to Peak	0.3
W1070	9.1209	62.559	0	0.13353	0.65377	Discharge	1.3322	1	Ratio to Peak	0.3
W1080	11.077	57.909	0	0.0539083	0.26393	Discharge	0.11639	1	Ratio to Peak	0.3
W1090	12.156	55.629	0	0.14403	0.70516	Discharge	1.1816	1	Ratio to Peak	0.3
W1100	10.643	58.88	0	0.13757	0.67355	Discharge	1.5583	1	Ratio to Peak	0.3
W1110	7.6311	67	0	0.0980367	0.47999	Discharge	0.53405	1	Ratio to Peak	0.3
W1120	10.16	60	0	0.12082	0.59153	Discharge	0.92540	1	Ratio to Peak	0.3
W1130	10.16	60	0	0.15515	0.75964	Discharge	1.1435	1	Ratio to Peak	0.3
W1140	9.4667	61.684	0	0.0757865	0.37105	Discharge	0.31312	1	Ratio to Peak	0.3
W1150	10.382	59.48	0	0.11503	0.56318	Discharge	0.89426	1	Ratio to Peak	0.3
W1160	10.405	59.426	0	0.1767	0.86513	Discharge	1.5692	1	Ratio to Peak	0.3
W1170	10.397	59.446	0	0.0971866	0.47583	Discharge	0.95290	1	Ratio to Peak	0.3
W1180	10.673	58.812	0	0.20377	0.99765	Discharge	2.1896	1	Ratio to Peak	0.3
W1190	10.16	60	0	0.1483	0.72606	Discharge	0.57934	1	Ratio to Peak	0.3
W1200	9.8027	60.856	0	0.22483	1.1008	Discharge	2.3754	1	Ratio to Peak	0.3
W1210	10.16	60	0	0.14373	0.70372	Discharge	0.98186	1	Ratio to Peak	0.3

W1220	12.041	55.862	0	0.30855	1.5107	Discharge	3.3481	1	Ratio to Peak	0.3
W1230	10.16	60	0	0.01667	0.055924	Discharge	0.0041177	1	Ratio to Peak	0.3
W1240	10.16	60	0	0.16136	0.79001	Discharge	1.1712	1	Ratio to Peak	0.3
W1250	10.16	60	0	0.20311	0.99443	Discharge	2.5747	1	Ratio to Peak	0.3
W1260	12.378	55.181	0	0.25728	1.2596	Discharge	2.9367	1	Ratio to Peak	0.3
W1270	11.043	57.985	0	0.15853	0.77617	Discharge	1.8902	1	Ratio to Peak	0.3
W1280	10.16	60	0	0.11562	0.56609	Discharge	1.0462	1	Ratio to Peak	0.3
W1290	12.462	55.0143	0	0.18584	0.90989	Discharge	2.9388	1	Ratio to Peak	0.3
W1300	10.16	60	0	0.13255	0.64894	Discharge	1.3345	1	Ratio to Peak	0.3
W660	3.8325	80	0	0.1458903	0.71428	Discharge	1.9633	1	Ratio to Peak	0.3
W670	3.5609	81	0	0.17667	0.86499	Discharge	3.1037	1	Ratio to Peak	0.3
W680	3.5523	81	0	0.0880879	0.43128	Discharge	1.7568	1	Ratio to Peak	0.3
W690	2.4998	86	0	0.14378	0.70395	Discharge	1.3757	1	Ratio to Peak	0.3
W700	3.8341	80	0	0.10092	0.49411	Discharge	0.92414	1	Ratio to Peak	0.3
W710	2.5244	86	0	0.22529	1.103	Discharge	1.1258	1	Ratio to Peak	0.3
W720	6.7597	69	0	0.0422292	0.20675	Discharge	0.0424025	1	Ratio to Peak	0.3
W730	4.2454	78	0	0.1554	0.76085	Discharge	3.4540	1	Ratio to Peak	0.3
W740	5.9377	72	0	0.0857416	0.41979	Discharge	0.26319	1	Ratio to Peak	0.3
W750	2.5499	86	0	0.1655	0.81028	Discharge	1.3075686	1	Ratio to Peak	0.3
W760	5.3095	74	0	0.154	0.75396	Discharge	1.8275	1	Ratio to Peak	0.3
W770	4.0012	79	0	0.091933	0.4501	Discharge	1.0307	1	Ratio to Peak	0.3
W780	3.3076	82	0	0.1313	0.64283	Discharge	0.61977	1	Ratio to Peak	0.3
W790	3.7532	80	0	0.0647347	0.31694	Discharge	0.93285	1	Ratio to Peak	0.3
W800	2.3711	87	0	0.0590059	0.28889	Discharge	0.52074	1	Ratio to Peak	0.3
W810	4.3903	78	0	0.18731	0.91705	Discharge	1.4197	1	Ratio to Peak	0.3
W820	5.4393	74	0	0.19165	0.93833	Discharge	2.8387	1	Ratio to Peak	0.3
W830	7.0529	68	0	0.1314	0.64335	Discharge	0.94269	1	Ratio to Peak	0.3
W840	2.3973	86	0	0.0823022	0.40295	Discharge	1.0529	1	Ratio to Peak	0.3

W850	3.8021	80	0	0.11676	0.57167	Discharge	2.5994	1	Ratio to Peak	0.3
W860	4.1968	78	0	0.11324	0.55441	Discharge	1.1257	1	Ratio to Peak	0.3
W870	3.6816	81	0	0.0822817	0.40285	Discharge	0.93051	1	Ratio to Peak	0.3
W880	1.9634	89	0	0.0574246	0.28115	Discharge	0.12163	1	Ratio to Peak	0.3
W890	7.0617	68	0	0.0970018	0.47492	Discharge	0.99401	1	Ratio to Peak	0.3
W900	7.6087	67	0	0.13314	0.65185	Discharge	0.89845	1	Ratio to Peak	0.3
W910	3.8581	80	0	0.0874954	0.42838	Discharge	0.91768	1	Ratio to Peak	0.3
W920	8.9474	63.008	0	0.24372	1.1932	Discharge	2.7282	1	Ratio to Peak	0.3
W930	2.008	88	0	0.0397035	0.19439	Discharge	0.11608	1	Ratio to Peak	0.3
W940	3.5332	81	0	0.13134	0.64306	Discharge	1.7271	1	Ratio to Peak	0.3
W950	4.519	77	0	0.10049	0.49198	Discharge	0.75443	1	Ratio to Peak	0.3
W960	7.6465	67	0	0.14542	0.71197	Discharge	2.2657	1	Ratio to Peak	0.3
W970	5.5232	73	0	0.1847	0.90431	Discharge	1.3045	1	Ratio to Peak	0.3
W980	9.1153	62.574	0	0.23174	1.1346	Discharge	3.5628	1	Ratio to Peak	0.3
W990	6.6638	70	0	0.13617	0.6667	Discharge	1.1407	1	Ratio to Peak	0.3

ANNEX 9. Cabicungan Model Reach Parameters

Table A-9.1. Cabicungan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	1998.7	0.001	0.04	Trapezoid	174.073	0.238
R120	Automatic Fixed Interval	2490.1	0.00135	0.04	Trapezoid	174.073	0.238
R130	Automatic Fixed Interval	1216.4	0.00621	0.04	Trapezoid	174.073	0.238
R150	Automatic Fixed Interval	3978.6	0.00224	0.04	Trapezoid	174.073	0.238
R170	Automatic Fixed Interval	3656.2	0.00345	0.04	Trapezoid	174.073	0.238
R180	Automatic Fixed Interval	2845.9	0.00208	0.04	Trapezoid	174.073	0.238
R190	Automatic Fixed Interval	1393.1	0.001	0.04	Trapezoid	174.073	0.238
R210	Automatic Fixed Interval	1213	0.00273	0.04	Trapezoid	174.073	0.238
R220	Automatic Fixed Interval	839.83	0.001	0.04	Trapezoid	174.073	0.238
R250	Automatic Fixed Interval	3319.8	0.00726	0.04	Trapezoid	174.073	0.238
R260	Automatic Fixed Interval	686.98	0.00921	0.04	Trapezoid	174.073	0.238
R280	Automatic Fixed Interval	1892.4	0.00203	0.04	Trapezoid	174.073	0.238
R30	Automatic Fixed Interval	29.142	0.001	0.04	Trapezoid	174.073	0.238
R310	Automatic Fixed Interval	2528.8	0.00955	0.04	Trapezoid	174.073	0.238
R320	Automatic Fixed Interval	2881.2	0.00612	0.04	Trapezoid	174.073	0.238
R340	Automatic Fixed Interval	2823.2	0.00389	0.04	Trapezoid	174.073	0.238
R370	Automatic Fixed Interval	596.27	0.00648	0.04	Trapezoid	174.073	0.238
R380	Automatic Fixed Interval	1417.8	0.03865	0.04	Trapezoid	174.073	0.238
R40	Automatic Fixed Interval	247.99	0.001	0.04	Trapezoid	174.073	0.238
R400	Automatic Fixed Interval	2939.6	0.00545	0.04	Trapezoid	174.073	0.238
R410	Automatic Fixed Interval	413.85	0.07177	0.04	Trapezoid	174.073	0.238
R430	Automatic Fixed Interval	386.27	0.01018	0.04	Trapezoid	174.073	0.238
R460	Automatic Fixed Interval	1948.9	0.01585	0.04	Trapezoid	174.073	0.238

R490	Automatic Fixed Interval	1050.5	0.01472	0.04	Trapezoid	174.073	0.238
R50	Automatic Fixed Interval	1766.8	0.001	0.04	Trapezoid	174.073	0.238
R500	Automatic Fixed Interval	843.55	0.00602	0.04	Trapezoid	174.073	0.238
R520	Automatic Fixed Interval	2662.9	0.04261	0.04	Trapezoid	174.073	0.238
R530	Automatic Fixed Interval	56.569	0.001	0.04	Trapezoid	174.073	0.238
R550	Automatic Fixed Interval	2974.5	0.04227	0.04	Trapezoid	174.073	0.238
R560	Automatic Fixed Interval	1962.7	0.04532	0.04	Trapezoid	174.073	0.238
R580	Automatic Fixed Interval	2128.2	0.02081	0.04	Trapezoid	174.073	0.238
R60	Automatic Fixed Interval	774.97	0.00188	0.04	Trapezoid	174.073	0.238

ANNEX 10. Cabicungan Field Validation Points

Table A-10.1. Cabicungan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Return Period of Event
	Lat	Long					
1	18.53589	121.09489	1.780	0.10	-1.68	TS Pepeng/ October 2009	5 Yr
2	18.53842	121.09546	2.200	0.00	-2.20		5 Yr
3	18.53913	121.09578	0.300	0.10	-0.20	TS Pepeng/ October 2009	5 Yr
4	18.53937	121.09543	2.410	0.30	-2.11	TS Pepeng/ October 2009	5 Yr
5	18.53952	121.09395	2.010	0.30	-1.71	TS Pepeng/ October 2009	5 Yr
6	18.53967	121.09316	4.610	0.20	-4.41	TS Pepeng/ October 2009	5 Yr
7	18.53972	121.09075	2.310	0.30	-2.01	TS Pepeng/ October 2009	5 Yr
8	18.53984	121.08813	0.050	0.10	0.05	TS Pepeng/ October 2009	5 Yr
9	18.54009	121.09534	0.030	0.00	-0.03		5 Yr
10	18.54105	121.08799	0.030	0.00	-0.03		5 Yr
11	18.54123	121.09442	2.240	0.00	-2.24		5 Yr
12	18.54207	121.08758	0.040	0.00	-0.04		5 Yr
13	18.54263	121.09491	0.900	0.00	-0.90		5 Yr
14	18.54336	121.11832	0.320	0.00	-0.32		5 Yr
15	18.54358	121.08710	0.030	0.00	-0.03		5 Yr
16	18.54447	121.09539	2.540	0.20	-2.34	TS Pepeng/ October 2009	5 Yr
17	18.54491	121.08678	0.070	0.00	-0.07		5 Yr
18	18.54501	121.11863	0.030	0.00	-0.03		5 Yr
19	18.54576	121.08819	1.720	0.00	-1.72		5 Yr
20	18.54598	121.08876	2.020	0.20	-1.82	TS Pepeng/ October 2009	5 Yr
21	18.54615	121.09629	1.270	0.20	-1.07	TS Pepeng/ October 2009	5 Yr
22	18.54621	121.09717	1.320	0.10	-1.22	TS Pepeng/ October 2009	5 Yr
23	18.54630	121.08919	2.610	0.30	-2.31	TS Pepeng/ October 2009	5 Yr
24	18.54659	121.08976	0.030	0.00	-0.03		5 Yr
25	18.54661	121.09996	0.780	0.10	-0.68	TS Pepeng/ October 2009	5 Yr
26	18.54664	121.11868	0.240	0.00	-0.24		5 Yr
27	18.54693	121.10218	0.430	0.10	-0.33	TS Pepeng/ October 2009	5 Yr
28	18.54699	121.09035	0.030	0.00	-0.03		5 Yr
29	18.54752	121.10335	0.030	0.00	-0.03		5 Yr

30	18.54785	121.09104	0.070	0.00	-0.07		5 Yr
31	18.54821	121.09172	0.030	0.00	-0.03		5 Yr
32	18.54832	121.12128	0.030	0.00	-0.03		5 Yr
33	18.54836	121.10384	0.220	0.10	-0.12	TS Pepeng/ October 2009	5 Yr
34	18.54844	121.11819	0.800	0.00	-0.80		5 Yr
35	18.54847	121.09625	1.450	0.20	-1.25	TS Pepeng/ October 2009	5 Yr
36	18.54882	121.09234	0.030	0.10	0.07	TS Pepeng/ October 2009	5 Yr
37	18.54961	121.09196	0.140	0.00	-0.14		5 Yr
38	18.54995	121.10665	0.030	0.00	-0.03		5 Yr
39	18.55039	121.10482	0.990	0.10	-0.89	TS Pepeng/ October 2009	5 Yr
40	18.55039	121.10804	0.030	0.00	-0.03		5 Yr
41	18.55040	121.12275	0.030	0.00	-0.03		5 Yr
42	18.55040	121.09112	0.030	0.00	-0.03		5 Yr
43	18.55066	121.09676	2.100	0.20	-1.90	TS Pepeng/ October 2009	5 Yr
44	18.55115	121.09114	0.040	0.00	-0.04		5 Yr
45	18.55195	121.10855	0.030	0.00	-0.03		5 Yr
46	18.55229	121.10940	0.030	0.00	-0.03		5 Yr
47	18.55241	121.12187	0.030	0.00	-0.03		5 Yr
48	18.55252	121.12099	0.030	0.00	-0.03		5 Yr
49	18.55258	121.09767	1.270	0.00	-1.27		5 Yr
50	18.55266	121.09146	0.310	0.00	-0.31		5 Yr
51	18.55345	121.09804	1.300	0.00	-1.30		5 Yr
52	18.55390	121.11977	0.230	0.00	-0.23		5 Yr
53	18.55405	121.09156	0.700	0.10	-0.60	TS Pepeng/ October 2009	5 Yr
54	18.55417	121.10936	0.030	0.00	-0.03		5 Yr
55	18.55487	121.09820	1.210	0.00	-1.21		5 Yr
56	18.55515	121.11804	0.330	0.00	-0.33		5 Yr
57	18.55518	121.10917	0.030	0.00	-0.03		5 Yr
58	18.55612	121.11657	0.030	0.00	-0.03		5 Yr
59	18.55620	121.10988	0.030	0.00	-0.03		5 Yr
60	18.55662	121.09086	0.690	0.10	-0.59	TS Pepeng/ October 2009	5 Yr
61	18.55684	121.09743	1.810	0.00	-1.81		5 Yr
62	18.55700	121.10852	0.050	0.00	-0.05		5 Yr
63	18.55799	121.11608	0.030	0.00	-0.03		5 Yr
64	18.55824	121.09120	1.210	0.10	-1.11	TS Pepeng/ October 2009	5 Yr
65	18.55834	121.10768	0.030	0.00	-0.03		5 Yr
66	18.55881	121.11552	0.030	0.00	-0.03		5 Yr
67	18.55903	121.09188	1.670	0.00	-1.67		5 Yr
68	18.55946	121.10713	0.030	0.00	-0.03		5 Yr

69	18.55968	121.09091	1.400	0.10	-1.30	TS Pepeng/ October 2009	5 Yr
70	18.55984	121.09269	1.400	0.10	-1.30	TS Pepeng/ October 2009	5 Yr
71	18.56015	121.10653	0.030	0.00	-0.03		5 Yr
72	18.56037	121.07975	2.310	0.00	-2.31		5 Yr
73	18.56071	121.09307	2.400	0.20	-2.20	TS Pepeng/ October 2009	5 Yr
74	18.56093	121.09695	0.430	0.20	-0.23	TS Pepeng/ October 2009	5 Yr
75	18.56098	121.08338	2.720	0.30	-2.42	TS Pepeng/ October 2009	5 Yr
76	18.56119	121.08211	3.960	0.10	-3.86	TS Pepeng/ October 2009	5 Yr
77	18.56125	121.08930	3.050	0.10	-2.95	TS Pepeng/ October 2009	5 Yr
78	18.56129	121.10635	0.030	0.00	-0.03		5 Yr
79	18.56149	121.09237	3.160	0.60	-2.56	TS Pepeng/ October 2009	5 Yr
80	18.56174	121.10615	1.130	0.10	-1.03	TS Pepeng/ October 2009	5 Yr
81	18.56244	121.08325	2.870	0.40	-2.47	TS Pepeng/ October 2009	5 Yr
82	18.56251	121.10629	1.640	0.20	-1.44	TS Pepeng/ October 2009	5 Yr
83	18.56281	121.09254	2.270	0.70	-1.57	TS Pepeng/ October 2009	5 Yr
84	18.56284	121.09212	3.230	2.00	-1.23	TS Pepeng/ October 2009	5 Yr
85	18.56295	121.09060	3.280	0.50	-2.78	TS Pepeng/ October 2009	5 Yr
86	18.56298	121.08437	3.240	0.40	-2.84	TS Pepeng/ October 2009	5 Yr
87	18.56304	121.09496	0.270	0.30	0.03	TS Pepeng/ October 2009	5 Yr
88	18.56312	121.11228	0.080	0.10	0.02	TS Pepeng/ October 2009	5 Yr
89	18.56324	121.09300	1.370	0.50	-0.87	TS Pepeng/ October 2009	5 Yr
90	18.56337	121.10651	0.970	0.10	-0.87	TS Pepeng/ October 2009	5 Yr
91	18.56374	121.08826	4.390	0.20	-4.19	TS Pepeng/ October 2009	5 Yr
92	18.56377	121.08645	4.670	0.10	-4.57	TS Pepeng/ October 2009	5 Yr
93	18.56382	121.08891	3.920	0.30	-3.62	TS Pepeng/ October 2009	5 Yr
94	18.56383	121.08942	4.610	0.50	-4.11	TS Pepeng/ October 2009	5 Yr
95	18.56389	121.08810	4.400	0.20	-4.20	TS Pepeng/ October 2009	5 Yr

96	18.56401	121.10660	1.130	0.10	-1.03	TS Pepeng/ October 2009	5 Yr
97	18.56460	121.11085	0.380	0.00	-0.38		5 Yr
98	18.56480	121.10703	0.420	0.00	-0.42		5 Yr
99	18.56484	121.09302	1.300	0.00	-1.30		5 Yr
100	18.56511	121.10879	1.430	0.10	-1.33	TS Pepeng/ October 2009	5 Yr
101	18.56850	121.09395	1.010	0.00	-1.01		5 Yr
102	18.57002	121.09078	0.770	0.00	-0.77		5 Yr
103	18.57010	121.05247	0.030	0.20	0.17	TS Pepeng/ October 2009	5 Yr
104	18.57021	121.09164	0.480	0.00	-0.48		5 Yr
105	18.57063	121.05143	0.540	0.30	-0.24	TS Pepeng/ October 2009	5 Yr
106	18.57149	121.05164	0.290	0.00	-0.29		5 Yr
107	18.57238	121.05188	0.170	0.20	0.03	TS Pepeng/ October 2009	5 Yr
108	18.57271	121.09515	0.030	0.10	0.07	TS Pepeng/ October 2009	5 Yr
109	18.57290	121.09191	3.140	0.00	-3.14		5 Yr
110	18.57308	121.09697	2.070	0.10	-1.97	TS Pepeng/ October 2009	5 Yr
111	18.57316	121.09884	1.630	0.10	-1.53	TS Pepeng/ October 2009	5 Yr
112	18.57362	121.09297	1.430	0.00	-1.43		5 Yr
113	18.57565	121.09145	1.410	0.20	-1.21	TS Pepeng/ October 2009	5 Yr
114	18.57615	121.09045	0.030	0.20	0.17	TS Pepeng/ October 2009	5 Yr
115	18.57625	121.05312	1.130	0.30	-0.83	TS Pepeng/ October 2009	5 Yr
116	18.57652	121.10127	2.430	0.30	-2.13	TS Pepeng/ October 2009	5 Yr
117	18.57666	121.10067	2.250	0.20	-2.05	TS Pepeng/ October 2009	5 Yr
118	18.57712	121.10599	1.310	0.30	-1.01	TS Pepeng/ October 2009	5 Yr
119	18.57717	121.10332	1.600	0.20	-1.40	TS Pepeng/ October 2009	5 Yr
120	18.57758	121.10079	1.590	0.20	-1.39	TS Pepeng/ October 2009	5 Yr
121	18.57763	121.10746	1.720	1.00	-0.72	TS Pepeng/ October 2009	5 Yr
122	18.57767	121.10416	2.330	0.00	-2.33		5 Yr
123	18.57784	121.05420	1.600	0.30	-1.30	TS Pepeng/ October 2009	5 Yr
124	18.57818	121.08886	2.500	0.10	-2.40	TS Pepeng/ October 2009	5 Yr
125	18.57878	121.09969	1.020	0.00	-1.02		5 Yr

126	18.57884	121.10860	1.910	1.00	-0.91	TS Pepeng/ October 2009	5 Yr
127	18.57979	121.12723	0.100	0.00	-0.10		5 Yr
128	18.57988	121.12536	0.030	0.30	0.27	TS Pepeng/ October 2009	5 Yr
129	18.57997	121.12943	0.160	0.00	-0.16		5 Yr
130	18.57997	121.09391	1.980	0.00	-1.98		5 Yr
131	18.57998	121.12536	0.050	0.20	0.15	TS Pepeng/ October 2009	5 Yr
132	18.58012	121.10993	2.130	1.00	-1.13	TS Pepeng/ October 2009	5 Yr
133	18.58029	121.09760	0.650	0.10	-0.55	TS Pepeng/ October 2009	5 Yr
134	18.58035	121.09594	0.710	0.00	-0.71		5 Yr
135	18.58065	121.13243	0.290	0.00	-0.29		5 Yr
136	18.58076	121.11052	1.760	0.80	-0.96	TS Pepeng/ October 2009	5 Yr
137	18.58083	121.09227	0.030	0.00	-0.03		5 Yr
138	18.58103	121.12466	0.050	0.20	0.15	TS Pepeng/ October 2009	5 Yr
139	18.58116	121.13385	0.240	0.00	-0.24		5 Yr
140	18.58117	121.09175	3.390	0.00	-3.39		5 Yr
141	18.58123	121.11102	0.030	0.50	0.47	TS Pepeng/ October 2009	5 Yr
142	18.58148	121.12332	0.030	0.00	-0.03		5 Yr
143	18.58188	121.14719	0.030	0.00	-0.03		5 Yr
144	18.58192	121.14031	0.030	0.00	-0.03		5 Yr
145	18.58214	121.09133	0.030	0.00	-0.03		5 Yr
146	18.58236	121.14608	0.100	0.00	-0.10		5 Yr
147	18.58252	121.13918	0.060	0.00	-0.06		5 Yr
148	18.58258	121.13620	0.380	0.00	-0.38		5 Yr
149	18.58259	121.12244	0.030	0.00	-0.03		5 Yr
150	18.58304	121.14129	0.030	0.00	-0.03		5 Yr
151	18.58313	121.11149	0.850	0.10	-0.75	TS Pepeng/ October 2009	5 Yr
152	18.58326	121.14333	0.030	0.00	-0.03		5 Yr
153	18.58339	121.14878	0.060	0.00	-0.06		5 Yr
154	18.58409	121.12246	0.260	0.00	-0.26		5 Yr
155	18.58438	121.15014	0.030	0.00	-0.03		5 Yr
156	18.58460	121.11018	0.030	0.00	-0.03		5 Yr
157	18.58463	121.14293	0.070	0.00	-0.07		5 Yr
158	18.58472	121.12277	0.250	0.00	-0.25		5 Yr
159	18.58475	121.14030	0.030	0.00	-0.03		5 Yr
160	18.58480	121.05644	0.030	0.00	-0.03		5 Yr
161	18.5848	121.09084	0.060	0.00	-0.06		5 Yr
162	18.58543	121.14977	0.090	0.00	-0.09		5 Yr
163	18.58543	121.14291	0.060	0.00	-0.06		5 Yr

164	18.58563	121.14085	0.030	0.00	-0.03		5 Yr
165	18.58617	121.10911	0.030	0.00	-0.03		5 Yr
166	18.58644	121.14835	0.060	0.00	-0.06		5 Yr
167	18.58664	121.1238	0.300	0.00	-0.30		5 Yr
168	18.58687	121.08993	0.030	0.00	-0.03		5 Yr
169	18.58691	121.10919	0.080	0.00	-0.08		5 Yr
170	18.58721	121.11532	0.220	0.10	-0.12	TS Pepeng/ October 2009	5 Yr
171	18.58746	121.1146	0.030	0.50	0.47	TS Pepeng/ October 2009	5 Yr
172	18.58748	121.14694	0.030	0.00	-0.03		5 Yr
173	18.5875	121.10987	0.060	0.00	-0.06		5 Yr
174	18.58758	121.1162	0.290	0.00	-0.29		5 Yr
175	18.58768	121.12359	0.110	0.00	-0.11		5 Yr
176	18.58807	121.11349	0.110	0.10	-0.01	TS Pepeng/ October 2009	5 Yr
177	18.58815	121.11272	0.030	0.00	-0.03		5 Yr
178	18.58823	121.11692	0.440	0.00	-0.44		5 Yr
179	18.58824	121.112	0.030	0.00	-0.03		5 Yr
180	18.58826	121.14541	0.030	0.00	-0.03		5 Yr
181	18.5884	121.11069	0.110	0.00	-0.11		5 Yr
182	18.58879	121.09043	1.080	0.00	-1.08		5 Yr
183	18.58885	121.12175	0.130	0.00	-0.13		5 Yr
184	18.58906	121.11846	0.370	0.00	-0.37		5 Yr
185	18.58918	121.14513	0.030	0.00	-0.03		5 Yr
186	18.58956	121.12026	1.280	0.50	-0.78	TS Pepeng/ October 2009	5 Yr
187	18.58963	121.11988	0.470	0.00	-0.47		5 Yr
188	18.59052	121.14586	0.650	0.00	-0.65		5 Yr
189	18.59104	121.14638	0.030	0.00	-0.03		5 Yr
190	18.59116	121.14908	0.030	0.00	-0.03		5 Yr
191	18.59128	121.14802	0.030	0.00	-0.03		5 Yr
192	18.592	121.15027	0.030	0.00	-0.03		5 Yr
193	18.59314	121.09071	0.030	0.00	-0.03		5 Yr
194	18.59341	121.14888	0.030	0.00	-0.03		5 Yr
195	18.59381	121.15373	0.030	0.00	-0.03		5 Yr
196	18.59438	121.1521	0.030	0.00	-0.03		5 Yr
197	18.59462	121.14857	0.030	0.00	-0.03		5 Yr
198	18.59521	121.15412	0.030	0.00	-0.03		5 Yr
199	18.59522	121.0915	0.030	0.00	-0.03		5 Yr
200	18.59578	121.14873	0.430	0.00	-0.43		5 Yr
201	18.59662	121.15072	0.030	0.00	-0.03		5 Yr
202	18.59682	121.14942	0.390	0.00	-0.39		5 Yr
203	18.59749	121.15568	0.030	0.10	0.07	TS Pepeng/ October 2009	5 Yr

204	18.5981	121.15584	0.030	0.10	0.07	TS Pepeng/ October 2009	5 Yr
205	18.59839	121.1558	0.040	0.10	0.06	TS Pepeng/ October 2009	5 Yr
206	18.59927	121.15534	0.03	0.00	-0.03		5 Yr
207	18.60013	121.09221	0.53	0.40	-0.13	TS Pepeng/ October 2009	5 Yr
208	18.6004	121.15454	0.14	0.00	-0.14		5 Yr
209	18.60056	121.09025	0.17	0.10	-0.07	TS Pepeng/ October 2009	5 Yr
210	18.60056	121.05274	0.03	0.00	-0.03		5 Yr
211	18.60062	121.08762	3.91	0.00	-3.91		5 Yr
212	18.60073	121.08604	0.03	0.00	-0.03		5 Yr
213	18.60121	121.08332	0.03	0.10	0.07	TS Pepeng/ October 2009	5 Yr
214	18.60122	121.1546	0.03	0.00	-0.03		5 Yr
215	18.60133	121.08303	0.92	0.20	-0.72	TS Pepeng/ October 2009	5 Yr
216	18.60177	121.05546	0.74	0.30	-0.44	TS Pepeng/ October 2009	5 Yr
217	18.60212	121.06383	0.08	0.30	0.22	TS Pepeng/ October 2009	5 Yr
218	18.60222	121.05647	0.03	0.30	0.27	TS Pepeng/ October 2009	5 Yr
219	18.60226	121.05994	0.3	0.30	0	TS Pepeng/ October 2009	5 Yr
220	18.60231	121.15555	0.03	0.00	-0.03		5 Yr
221	18.60236	121.05745	0.06	0.00	-0.06		5 Yr
222	18.60261	121.06706	0.51	0.20	-0.31	TS Pepeng/ October 2009	5 Yr
223	18.60291	121.07561	0.03	0.00	-0.03		5 Yr
224	18.60317	121.06944	0.03	0.30	0.27	TS Pepeng/ October 2009	5 Yr
225	18.60337	121.15559	0.33	0.00	-0.33		5 Yr
226	18.60338	121.05669	0.38	0.00	-0.38		5 Yr
227	18.60339	121.0813	0.03	0.00	-0.03		5 Yr
228	18.60362	121.0721	0.9	0.30	-0.6	TS Pepeng/ October 2009	5 Yr
229	18.60429	121.08627	0.11	0.00	-0.11		5 Yr
230	18.60436	121.08113	0.05	0.00	-0.05		5 Yr
231	18.60483	121.05457	0.03	0.00	-0.03		5 Yr
232	18.6055	121.08135	0.2	0.00	-0.2		5 Yr
233	18.60553	121.15572	0.03	0.00	-0.03		5 Yr
234	18.60583	121.08251	0.03	0.00	-0.03		5 Yr
235	18.60624	121.08247	0.03	0.00	-0.03		5 Yr
236	18.60647	121.06346	0.03	0.00	-0.03		5 Yr
237	18.60651	121.06021	0.03	0.00	-0.03		5 Yr
238	18.60662	121.05358	0.03	0.00	-0.03		5 Yr

239	18.60701	121.09587	0.11	0.00	-0.11		5 Yr
240	18.60705	121.08481	0.03	0.00	-0.03		5 Yr
241	18.6071	121.08112	0.29	0.00	-0.29		5 Yr
242	18.60758	121.05586	0.03	0.00	-0.03		5 Yr
243	18.60793	121.08795	0.03	0.00	-0.03		5 Yr
244	18.60827	121.08552	0.13	0.00	-0.13		5 Yr
245	18.60863	121.15554	0.03	0.00	-0.03		5 Yr
246	18.6089	121.05153	0.24	0.00	-0.24		5 Yr
247	18.60904	121.07909	0.03	0.00	-0.03		5 Yr
248	18.60905	121.08842	0.13	0.00	-0.13		5 Yr
249	18.60933	121.08037	0.03	0.00	-0.03		5 Yr
250	18.60958	121.08767	0.09	0.00	-0.09		5 Yr
251	18.60966	121.08561	0.03	0.00	-0.03		5 Yr
252	18.60999	121.09026	0.23	0.80	0.57	TS Pepeng/ October 2009	5 Yr
253	18.61001	121.08743	0.32	0.00	-0.32		5 Yr
254	18.61026	121.08974	0.41	0.50	0.09	TS Pepeng/ October 2009	5 Yr
255	18.61037	121.04991	0.03	0.00	-0.03		5 Yr
256	18.61044	121.0902	0.87	1.50	0.63	TS Pepeng/ October 2009	5 Yr
257	18.61045	121.09036	0.14	1.30	1.16	TS Pepeng/ October 2009	5 Yr
258	18.61057	121.08898	0.04	0.30	0.26	TS Pepeng/ October 2009	5 Yr
259	18.61095	121.155	0.03	0.00	-0.03		5 Yr
260	18.61208	121.08848	0.03	0.20	0.17	TS Pepeng/ October 2009	5 Yr
261	18.61224	121.04909	0.84	0.00	-0.84		5 Yr
262	18.61233	121.08915	0.03	0.50	0.47	TS Pepeng/ October 2009	5 Yr
263	18.61277	121.15347	0.03	0.00	-0.03		5 Yr
264	18.61335	121.0932	0.03	0.00	-0.03		5 Yr
265	18.61462	121.14865	0.03	0.00	-0.03		5 Yr
266	18.61724	121.14359	0.03	0.00	-0.03		5 Yr
267	18.61878	121.09963	0.08	0.00	-0.08		5 Yr
268	18.61909	121.13896	0.21	0.00	-0.21		5 Yr
269	18.62059	121.10335	0.03	0.00	-0.03		5 Yr
270	18.62101	121.10913	0.35	0.00	-0.35		5 Yr
271	18.62135	121.11368	0.07	0.00	-0.07		5 Yr
272	18.62249	121.13043	0.37	0.00	-0.37		5 Yr
273	18.62261	121.11813	0.03	0.00	-0.03		5 Yr
274	18.6238	121.12627	0.03	0.00	-0.03		5 Yr

ANNEX 11. Educational Institutions Affected by Flooding in Cabicungan Floodplain

Table A-11.1. Educational Institutions Affected by Flooding in the Cabicungan Floodplain – Calanasan, Apayao

Apayao				
Calanasan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
STA FILOMENA ELEMENTARY SCHOOL	Santa Filomena			Low

Table A-11.2. Educational Institutions Affected by Flooding in the Cabicungan Floodplain – Claveria, Cagayan

Cagayan				
Claveria				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BACSAY CATARAOAN ELEMENTARY SCHOOL	Bacsay Cataraoan Norte			
BACSAY CATARAOAN NORTE DAY CARE CENTER	Bacsay Cataraoan Norte			
ALIMOAN ELEMENTARY SCHOOL	Bacsay Mapulapula	High	High	High
SANTIAGO ELEMENTARY SCHOOL	Bacsay Mapulapula			
BILIBIGAO ELEMENTARY SCHOOL	Bilibigao	High	High	High
CADCADIR ELEMENTARY SCHOOL	Cadcadir West	Medium	Medium	High
CLAVERIA CENTRAL SCHOOL	Centro II			Low
ACADEMAY OF ST. JOSEPH	Centro III			
ACADEMY OF ST. JOSEPH	Centro III			
CLAVERIA EAST CENTRAL SCHOOL	Centro V			Low
MALASIN ELEMENTARY SCHOOL	Centro VIII	Low	Medium	Medium
BACSAY MAPULAPULA PRIMARY SCHOOL	Culao		Low	Low
CULAO ELEMENTARY SCHOOL	Culao			
CLAVERIA RURAL VOCATIONAL SCHOOL	Dibalio			
CLAVERIA RURAL VOCATIONAL SCHOOL	Dibalio	Low	Low	Medium
DIBALIO ELEMENTARY SCHOOL	Dibalio			
KILKILING ELEMENTARY SCHOOL	Kilkiling	Low	Medium	Medium
MABNANG PRIMARY SCHOOL	Mabnang	Low	Low	Low
DAY CARE CENTER	Magdalena			
MAGDALENA ELEMENTARY SCHOOL	Magdalena			
CLAVERIA NATIONAL HIGH SCHOOL	Malilitao		Low	Low
MALILITAO ELEMENTARY SCHOOL	Malilitao		Low	Low

STO. TOMAS PRIMARY SCHOOL	Malilitao			
BACSAY CATARAOAN SUR DAY CARE CENTER	Nagsabaran	High	High	High
NAGSABARAN ELEMENTARY SCHOOL	Nagsabaran	High	High	High
SAN VICENTE PRIMARY SCHOOL	Nagsabaran			
PATA ELEMENTARY SCHOOL	Pata West			
ALIMOAN ELEMENTARY SCHOOL	Pinas	High	High	High
PINAS ELEMENTARY SCHOOL	Pinas	Medium	Medium	High
SAN ISIDRRO- BUENAVISTA ELEMENTARY SCHOOL	San Isidro			
STA. MARIA PRIMARY SCHOOL	Santa Maria	Low	Low	Low
DAY CARE CENTER	Santo Niño			
LUZON ELEMENTARY SCHOOL	Santo Niño	Medium	Medium	High
CAPANNIKIAN ELEMENTARY SCHOOL	Tabbugan	Medium	Medium	Medium
TABBUGAN PRIMARY SCHOOL	Tabbugan	Medium	High	High
TAGGAT NORTE ELEMENTARY SCHOOL	Taggat Norte		Low	Low
CLAVERIA SCHOOL OF ARTS & TRADES	Taggat Sur	Low	Low	Medium
TAGGAT SUR ELEMENTARY SCHOOL	Taggat Sur	Low	Medium	Medium
LABLABIG PRIMARY SCHOOL	Union			
UNION ELEMENTARY SCHOOL	Union	Medium	Medium	High

Table A-11.3. Educational Institutions Affected by Flooding in the Cabicungan Floodplain – Sanchez-Mira, Cagayan

Sanchez-Mira				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
NAMUAC-MAGACAN ELEMENTARY SCHOOL	Magacan			
SANCHEZ MIRA NATIONAL HIGH SCHOOL	Nagrangtayan			
MINANGA ELEMENTARY SCHOOL	Namuac			
NAMUAC ACADEMY	Namuac			
TOKITOK ELEMENTARY SCHOOL	Tokitok			

Table A-11.4. Educational Institutions Affected by Flooding in the Cabicungan Floodplain – Santa Praxedes, Cagayan

Santa Praxedes				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
CAPACUAN ELEMENTARY SCHOOL	Capacuan			
SANTA PRAXEDEZ CENTRAL SCHOOL	Centro I			
SANTA PRAXEDEZ NATIONAL HIGH SCHOOL	Centro I	Low	Low	Low
SANTA PRAXEDEZ CENTRAL SCHOOL	Centro II			
SANTA PRAXEDEZ NATIONAL HIGH SCHOOL	Centro II	Low	Low	Low

ANNEX 12. Medical Institutions Affected by Flooding in Cabicungan Floodplain

Table A-12.1. Medical Institutions Affected by Flooding in the Cabicungan Floodplain – Claveria, Cagayan

Cagayan				
Claveria				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
CADCADIR HEALTH STATION	Cadcadir West	Medium	Medium	High
DONATO MEDICAL CLINIC	Centro II			
CLAVERIA INFIRMARY CLINIC	Centro III			
MUNICIPAL HEALTH CENTER	Centro III			
JAVIER PEDIA CLINIC	Centro V			
SAGAYSAY OPTOMETRIC	Centro V			
AGRA CLINIC	Centro VIII		Low	Low
CLAVERIA INFIRMARY CLINIC	Centro VIII			
TAGGAT NORTE HEALTH CENTER	Taggat Norte			

Table A-12.2. Medical Institutions Affected by Flooding in the Cabicungan Floodplain – Sanchez-Mira, Cagayan

Sanchez-Mira				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
NORTHERN CAGAYAN DISTRICT HOSPITAL	San Andres			