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

LiDAR Surveys and Flood Mapping of Amburayan River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND AMBURAYAN RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The 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 University of the Philippines Baguio (UPB). UPB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 12 river basins in the Ilocos Region and the Cordillera Administrative Region. The university is located in Baguio City in the province of Benguet.

1.2 Overview of the Amburayan River Basin

Amburayan River Basin covers five (5) municipalities in Benguet, four (4) municipalities in La Union, and five (5) municipalities in Ilocos Sur. The DENR River Basin Control Office identified the basin to have a drainage area of 1,386 km^2 and an estimated 3,389 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Amburayan River, is part of the river systems in Ilocos Region. According to the 2010 national census of NSO, a total of 22,768 people is residing within the immediate vicinity of the river which is distributed among twenty one (21) barangays in the Municipalities of Tagudin and Alilem, in Ilocos Sur; and Municipalities of Bangar and Sudipen, in La Union. Municipalities surrounding the river primarily depends on agriculture (i.e. rice and crop production) as their source of income. Most of the lands are irrigated by the river while certain portions are dependent on rain (https://sites.google.com/site/bluefirr/history/existing-land-use, 2013). The most recent flood event in the area which even made some road, like Bangar-Luna Road, unpassable was on July, 2015 brought by Typhoon Egay.

LiDAR or Light Detection and Ranging, a remote sensing technology used to examine the earth's surface, is used to create high resolution maps for the purpose of flood hazard mapping. Flood hazard mapping defines those coastal areas which are at risk of flooding under extreme conditions. With the adverse effects of flooding, the government has implemented the Phil-LiDAR1 project to mitigate the impacts of flooding in the country and to provide accurate flood hazard and risk data to guide the community for appropriate actions. Through flood hazard maps, one can easily identify the flood inundation of an area. This project is very beneficial to the community as this will bring knowledge and awareness of the things to do to prepare for disasters like flooding. The flood hazard maps incorporate data for river flows, storm tides, hydrologic and hydraulic analyses and rainfall and topographic surveys. Moreover, through the identification of the areas being flooded, engineers can also compute for the flood flows and design a drainage system to lessen the impact of flooding in the community. This also helps for the economic expansion in an area for locations not prone to flooding, as it will encourage more investors for development projects and businesses in different sectors, including the agricultural and non-agricultural sectors.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE AMBURAYAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Amburayan floodplain in La Union. These missions were planned for sixteen (16) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 1 shows the flight plans and base stations used for Amburayan floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
10A	1200	30	50	200	30	130	5
10B	1000/1200	30	50	200	30	130	5
10C	1200 / 1500 / 1800	30	50	200	30	130	5
10D	1200 / 1500	30	50	200	30	130	5
10G	1500	30	50	200	30	130	5

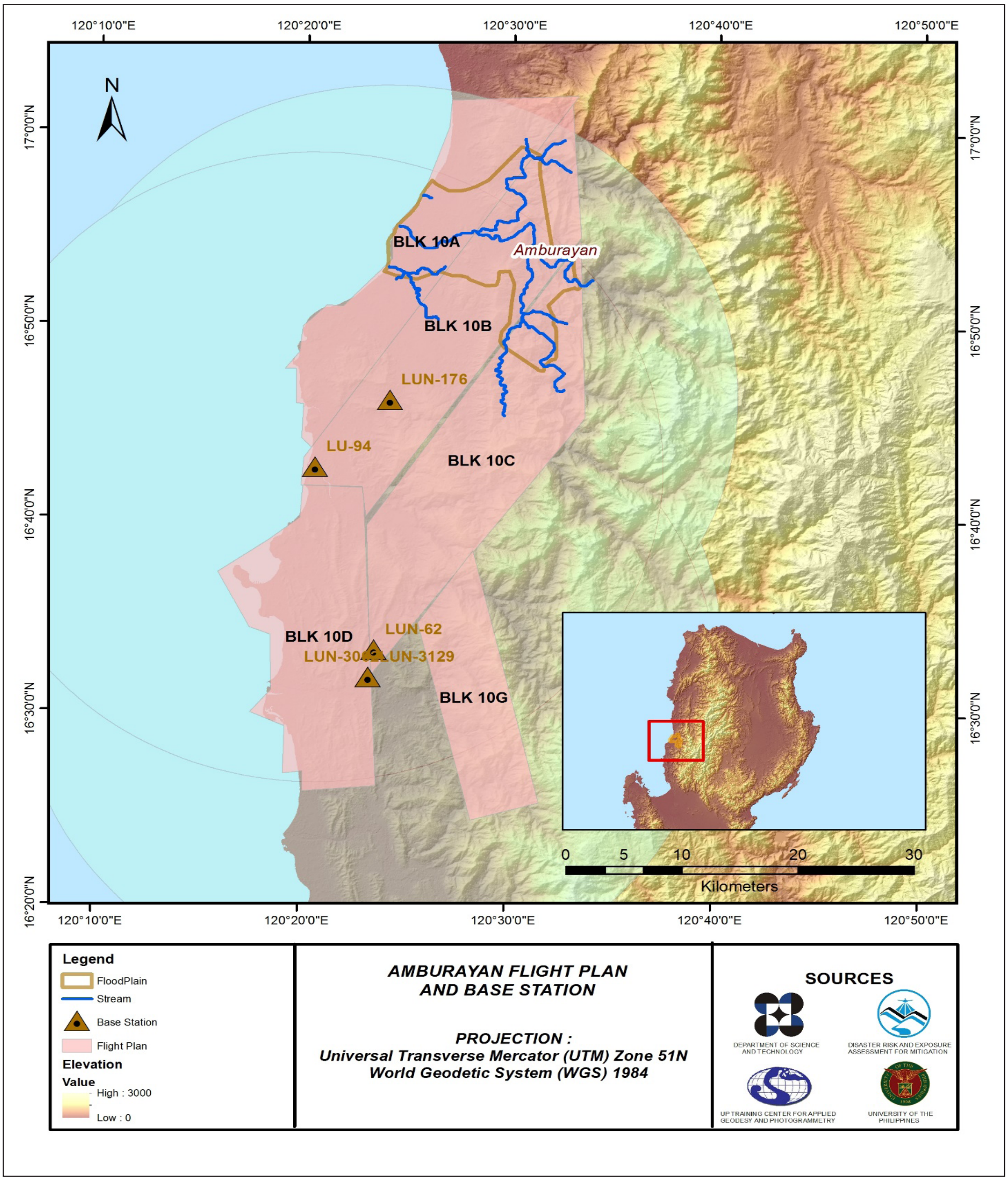

Figure 1. Flight plans and base stations used for Amburayan floodplain.

2.2 Ground Base Stations

The project team was able to two (2) NAMRIA control stations (LUN-62 and LUN-176) with second (2nd) order accuracy, two (2) (LUN-3062 and LUN-3129) with fourth (4th) order accuracy and Benchmark (BM LU-94) with first (1st) order accuracy. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing report is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 25 – March 8, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Amburayan floodplain are shown in Figure 1.

Figure 2 to Figure 5 show the recovered NAMRIA reference points within the area, in addition Table 2 to Table 6 show the details about the following NAMRIA control stations and established points, Table 7 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

Figure 2. a) GPS set-up over LUN-62 as recovered 15 m S from the first access ladder of the river control and about 100 m N from the end, it is also situated 300 m S of a hanging bridge. b) NAMRIA reference point LUN-62 as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point LUN-62 used as base station for the LiDAR acquisition.

Station Name	LUN-62	
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	16° 33' 19.98115" 120° 23' 28.76004" 33.18400 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	435034.926 m 1831016.667 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 33' 14.07106" 120° 23' 33.49149" 69.44500 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	221592.72 m 1832084.35 m

Figure 3. a) GPS set-up over LUN-176 recovered near a corner of a farm dike, about 15 m SE of the well and about 20 m SW of the nearest house. b) NAMRIA reference point LUN-176 as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point LUN-176 used as base station for the LiDAR acquisition.

Station Name	LUN-176	
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	16° 46’ 14.35394” 120° 24’ 5.41918” 35.63300 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	436193.115 m 1854816.574 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 46’ 8.39718” 120° 24’ 10.13252” 71.25300 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	222990.04 m 1855884.50 m

Figure 4. a) GPS set-up over LUN-3062 recovered at the top of a dike, approximately 100 m north of Philippine Central College of Arts Sciences & Technology and 80 m north of Naguilian emission testing center in Brgy. Natividad, Naguilian, La Union. b) NAMRIA reference point LUN-3062 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point LUN-3062 used as base station for the LiDAR acquisition.

Station Name	LUN-3062	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16° 31’ 55.00993” 120° 23’ 12.50504” 25.32100 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	434545.028 m 1828406.255 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 31’ 49.10470” 120° 23’ 17.23850” 61.64400 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	221076.59 m 1829477.48 m

Figure 5. a) GPS set-up over LUN-3129 recovered beside the National Road about 50 meters northeast of the nearest house. b) NAMRIA reference point LUN-3129 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point LUN-3129 used as base station for the LiDAR acquisition.

Station Name	LUN-3129	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16° 31’ 55.00993” 120° 23’ 12.50504” 25.32100 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	434545.028 m 1828406.255 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 31’ 49.10470” 120° 23’ 17.23850” 61.64400 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	221076.59 m 1829477.48 m

Table 6. Details of the recovered NAMRIA reference point LU-94 with proces used as base station for the LiDAR acquisition.

Station Name	LU-94	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	16°42' 38.64674"
	Longitude	120°20'35.05091"
	Ellipsoidal Height	49.582 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	21672.143 m
	Northing	1849445.472 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	16°42' 38.64674"
	Longitude	120°20'35.05091"
	Ellipsoidal Height	49.582 m

Table 7. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 25, 2014	1151P	1BLK10A056A	LUN-176 and LUN-3129
February 25, 2014	1153P	1BLK10AS056B	LUN-176 and LUN-3129
February 26, 2014	1155P	1BLK10C057A	LUN-176 and LU-94
February 27, 2014	1157P	1BLK10B057B	LUN-176 and LUN-94
March 2, 2014	1171P	1BLK10CDS061A	LUN-62 and LUN-3062
March 3, 2014	1175P	1BLK10BS062A	LUN-176 and LUN-3129
March 3, 2014	1177P	1BLK10CS062B	LUN-176 and LUN-3129
March 8, 2014	1197P	1BLK10GCS067B	LUN-62 and LUN-3062

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR data acquisition in Amburayan Floodplain, for a total of twenty four hours and fifty eight minutes (24+58) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Amburayan 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
February 25, 2014	1151P	223.74	284.52	71.7	212.82	NA	3	53
February 25, 2014	1153P	223.74	92.67	30.2	62.47	NA	1	55
February 26, 2014	1155P	298.49	251.57	33.98	217.59	574	3	41
February 27, 2014	1157P	283.36	151.43	39.39	112.04	454	2	29
March 2, 2014	1171P	551.6	201.6	0	201.6	334	3	25
March 3, 2014	1175P	283.36	323.08	79.64	243.44	675	3	35
March 3, 2014	1177P	298.49	276.14	14.32	261.82	501	2	53
March 8, 2014	1197P	434.41	110.17	0	110.17	257	2	59
TOTAL		2597.19	1691.18	269.23	1421.95	2795	24	58

Table 9. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (Hz)	Scan Frequency (kHz)	Average Speed (kts)	Average Turn Time (Minutes)
1151P	1200	30	50	200	30	130	5
1153P	1200	30	50	200	30	130	5
1155P	1200	30	50	200	30	130	5
1157P	1200	30	50	200	30	130	5
1171P	1500	30	50	200	30	130	5
1175P	1200	30	50	200	30	130	5
1177P	1800	30	50	200	30	130	5
1197P	1500	30	50	200	30	130	5

2.4 Survey Coverage

Amburayan floodplain is located in the province of La Union and Ilocos Sur with majority of the floodplain situated within the municipalities of Tagudin and Supiden. Municipalities of Santol, San Gabriel, Bacnotan, Suyo, Sudipen, San Fernando City and Balaoan are mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Amburayan floodplain is presented in Figure 6.

Table 10. List of municipalities and cities surveyed during Amburayan floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Benguet	Sablan	90.22	8.70	10%
	Tuba	322.02	3.32	1%
Ilocos Sur	Tagudin	54.35	54.35	100%
	Suyo	148.52	77.27	52%
	Sugpon	180.28	49.62	28%
	Alilem	132.18	34.23	26%
	Santa Cruz	105.95	25.19	24%
La Union	Bacnotan	80.67	80.67	100%
	Balaoan	60.96	60.96	100%
	Bangar	45.12	45.12	100%
	Luna	50.66	50.65	100%
	Sudipen	75.75	75.55	100%
	Santol	97.97	94.69	97%
	San Juan	53.44	35.11	66%
	San Gabriel	154.19	88.91	58%
	San Fernando City	121.05	63.10	52%
	Burgos	51.92	26.28	51%
	Bagulin	77.97	33.35	43%
	Naguilian	86.39	30.77	36%
	Bauang	85.26	7.50	9%
	Aringay	95.65	6.94	7%
	Total	2,170.52	952.28	43.87%

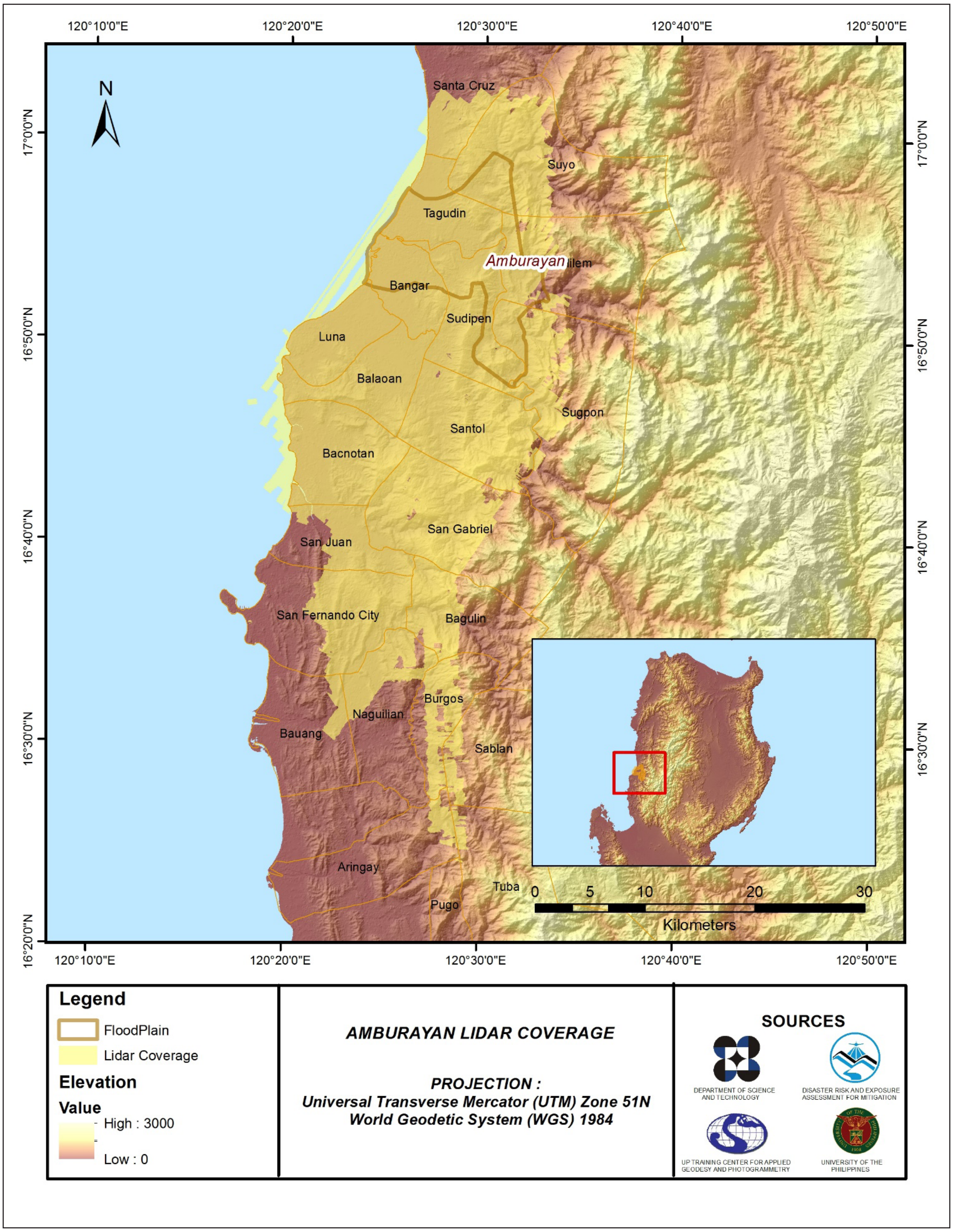

Figure 6. Actual LiDAR survey coverage for Amburayan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE AMBURAYAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

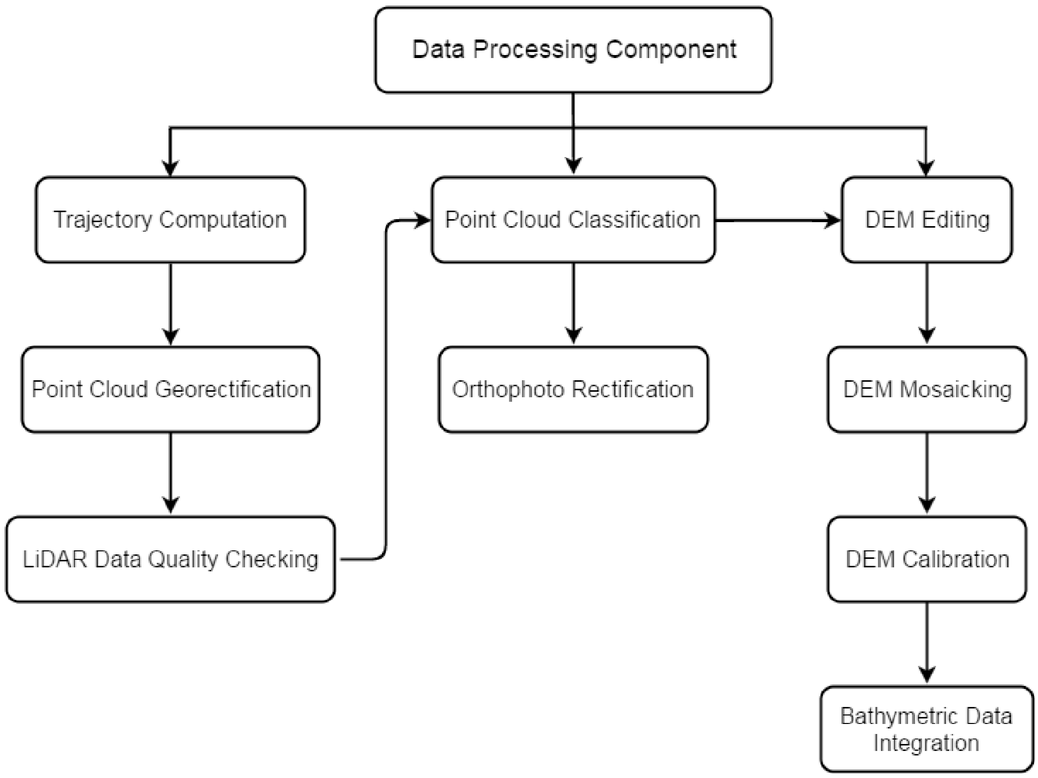

Figure 7. Schematic Diagram for Data Pre-Processing Component.

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

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

These processes are summarized in the flowchart shown in Figure 7.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Amburayan floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over the province of La Union. The Data Acquisition Component (DAC) transferred a total of 137.58 Gigabytes of Range data, 1.3515 Gigabytes of POS data, 48.91 Megabytes of GPS base station data, and 167.30 Gigabytes of raw image data to the data server on March 17, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Amburayan was fully transferred on March 17, 2014 as indicated on the Data Transfer Sheets for Amburayan floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metric* parameters of the computed trajectory for flight 1155P, one of the Amburayan flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 23, 2014 00:00 AM. The y-axis is the RMSE value for that particular position.

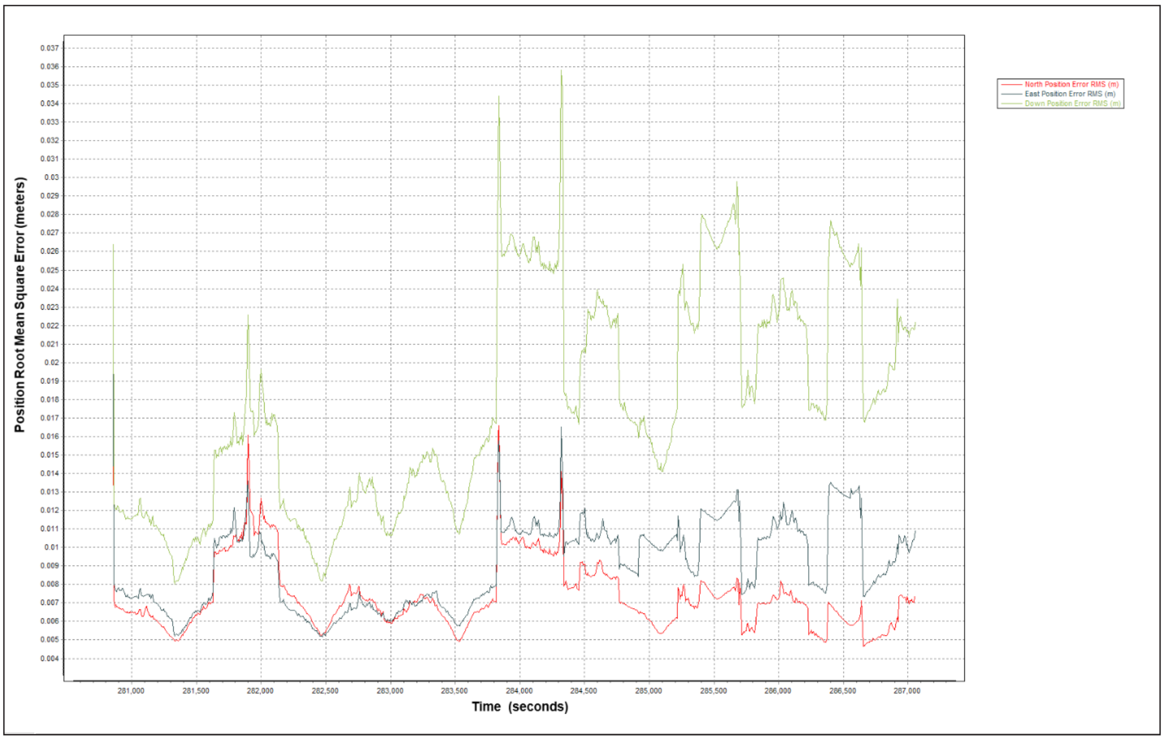

Figure 8. Smoothed Performance Metric Parameters of Amburayan Flight 1155P.

The time of flight was from 280,850 seconds to 287,000 seconds, which corresponds to morning of February 26, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.66 centimeters, the East position RMSE peaks at 1.65 centimeters, and the Down position RMSE peaks at 3.58 centimeters, which are within the prescribed accuracies described in the methodology.

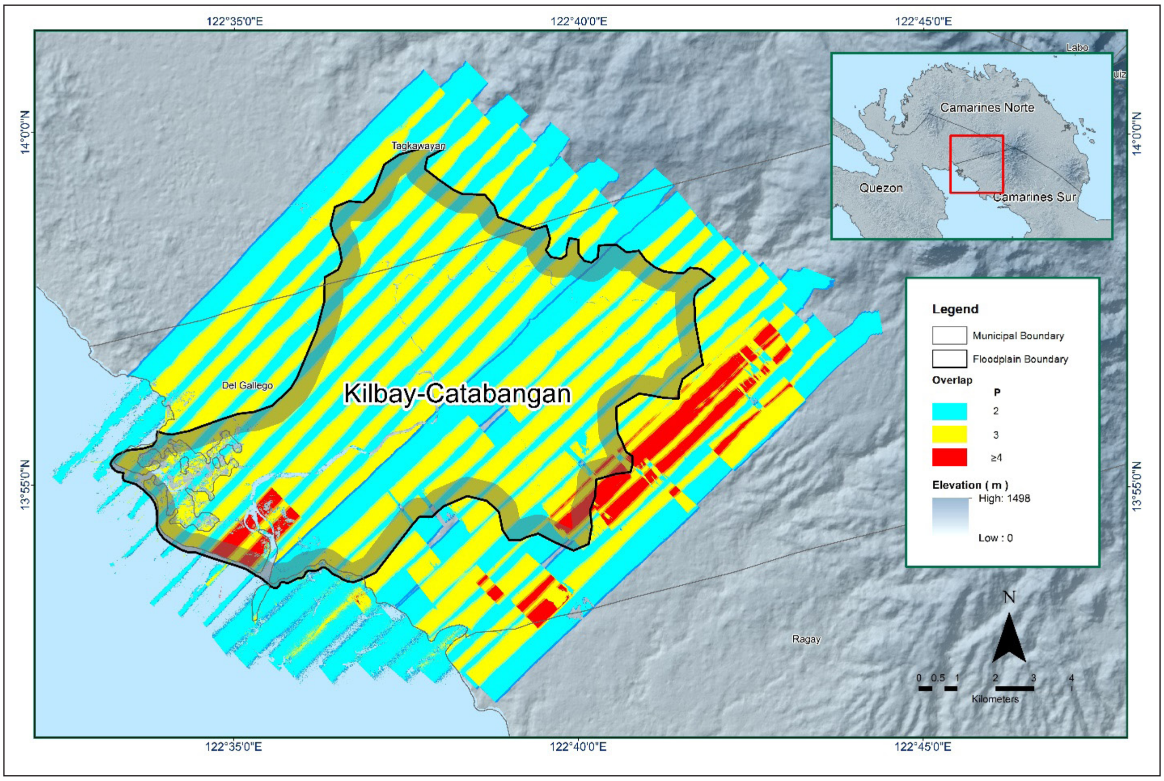

Figure 9. Solution Status Parameters of Amburayan Flight 1155P.

The S*olution Status* parameters of flight 1155P, one of the Amburayan flights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down below 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which still indicates optimal GPS geometry. The processing mode stayed at the value of 0 for almost the entire survey time with some peaks up to 1 attributed to the turn performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Amburayan flights is shown in Figure 10.

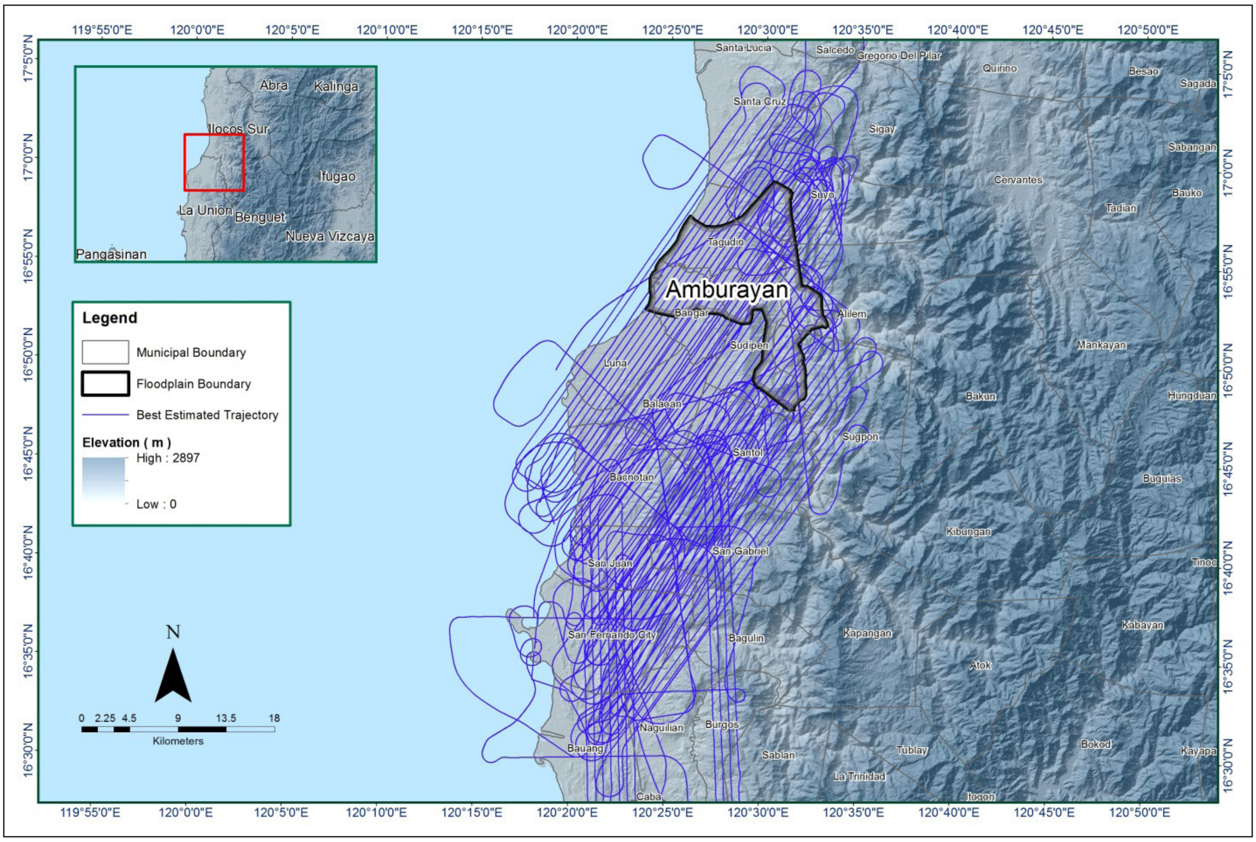

Figure 10. Best Estimated Trajectory for Amburayan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 126 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Amburayan floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Amburayan flights.

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000398
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000953
GPS Position Z-correction stdev (<0.01meters)	0.0096

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

3.5 LiDAR Quality Checking

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

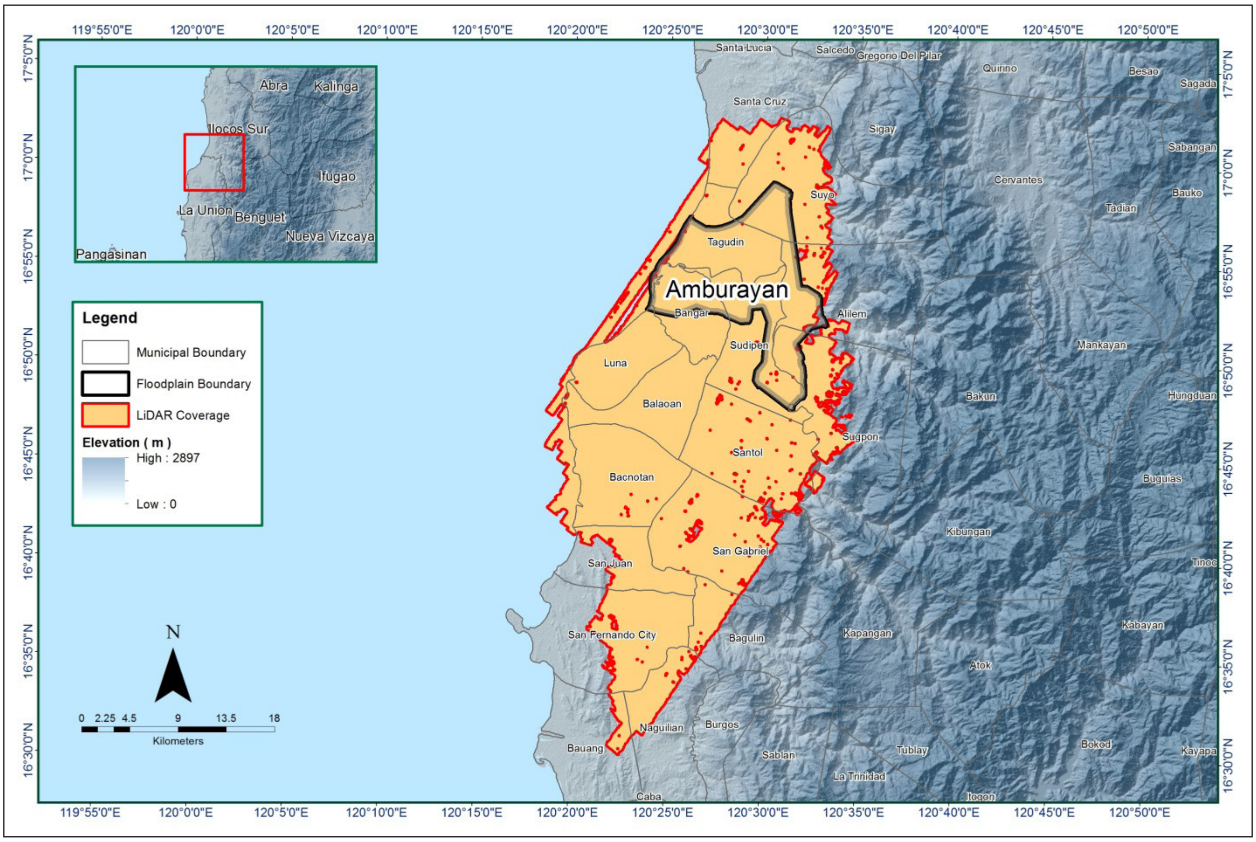

Figure 11. Figure 11. Boundary of the processed LiDAR data over Amburayan Floodplain.

The total area covered by the Amburayan missions is 1,361.84 sq.km that is comprised of eight (8) flight acquisitions grouped and merged into four (4) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Amburayan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
LaUnion_Blk10A	1151P	280.58
LaUnion_Blk10B	1153P	379.73
	1157P	
	1175P	
LaUnion_Blk10C	1155P	399.93
	1171P	
	1177P	
	1197P	
LaUnion_Blk10C_additional	1177P	301.60
TOTAL		1,361.84

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

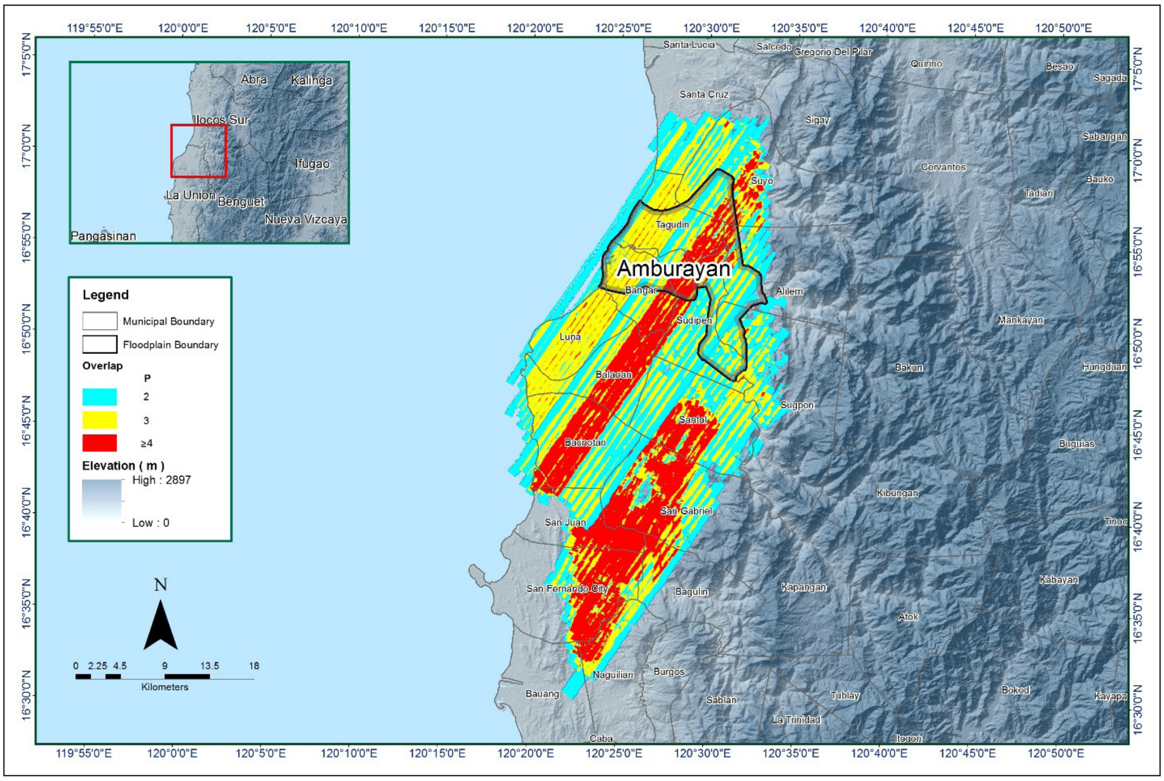

Figure 12. Image of data overlap for Amburayan floodplain.

The overlap statistics per block for the Amburayan floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 35.05% and 64.34% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Amburayan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.23 points per square meter.

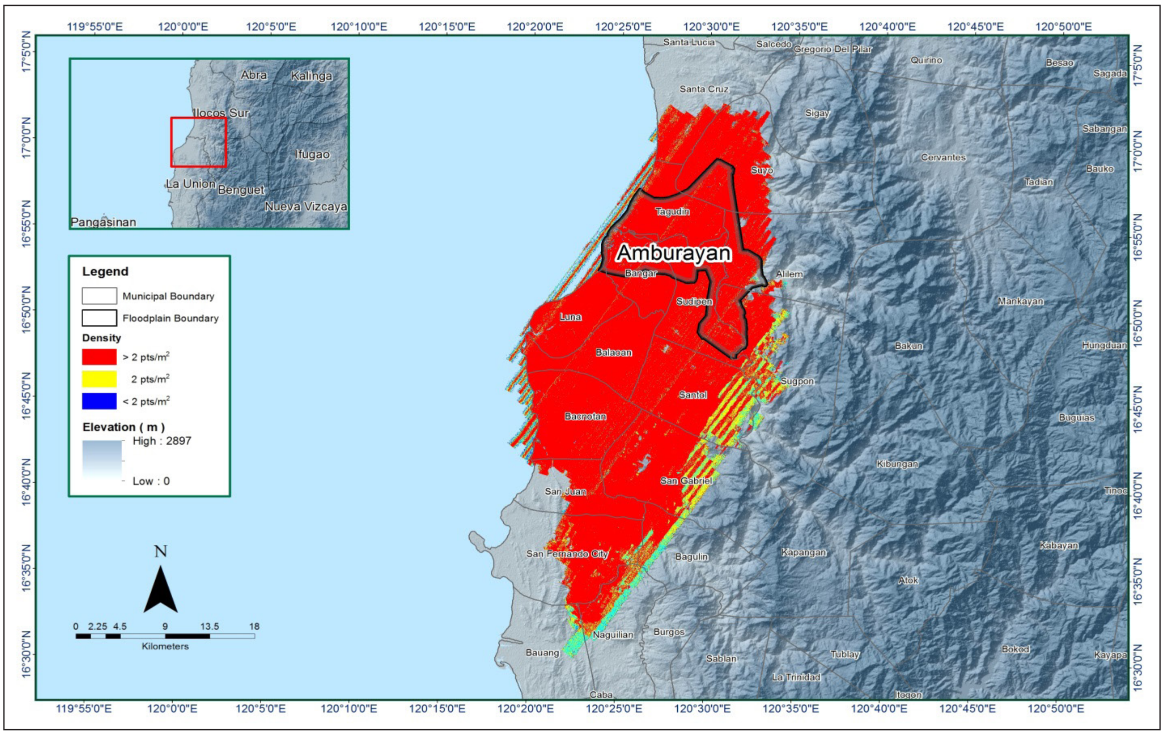

Figure 13. Density map of merged LiDAR data for Amburayan floodplain.

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

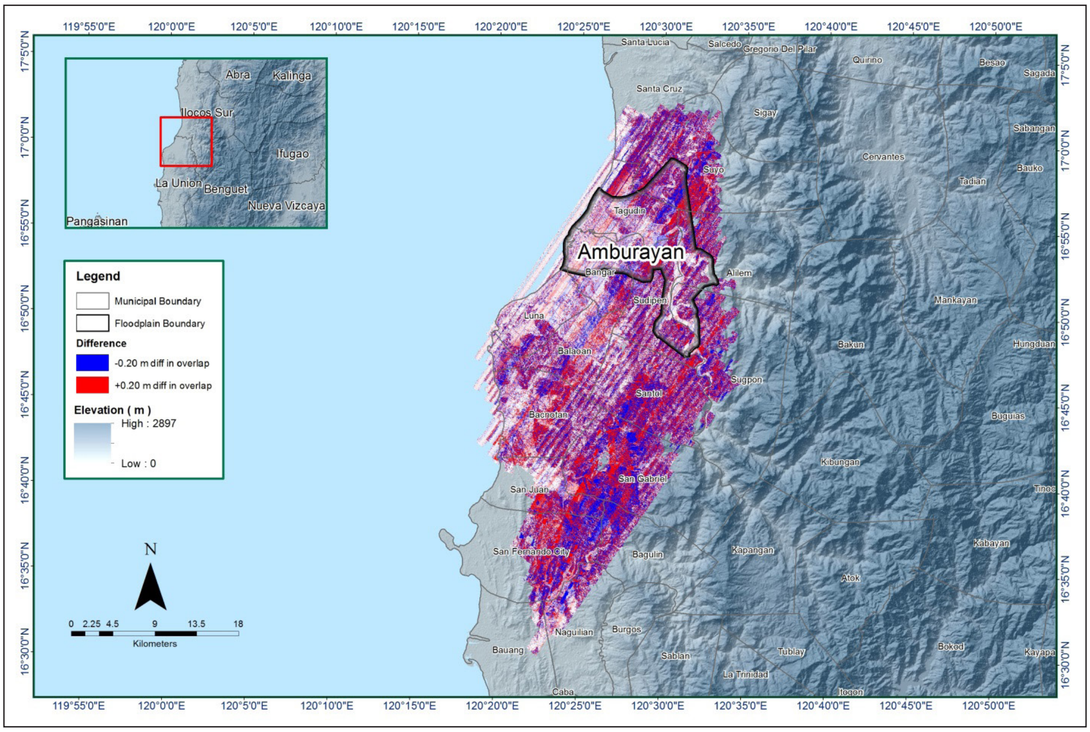

Figure 14. Elevation difference map between flight lines for Amburayan floodplain.

A screen capture of the processed LAS data from an Amburayan flight 1155P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

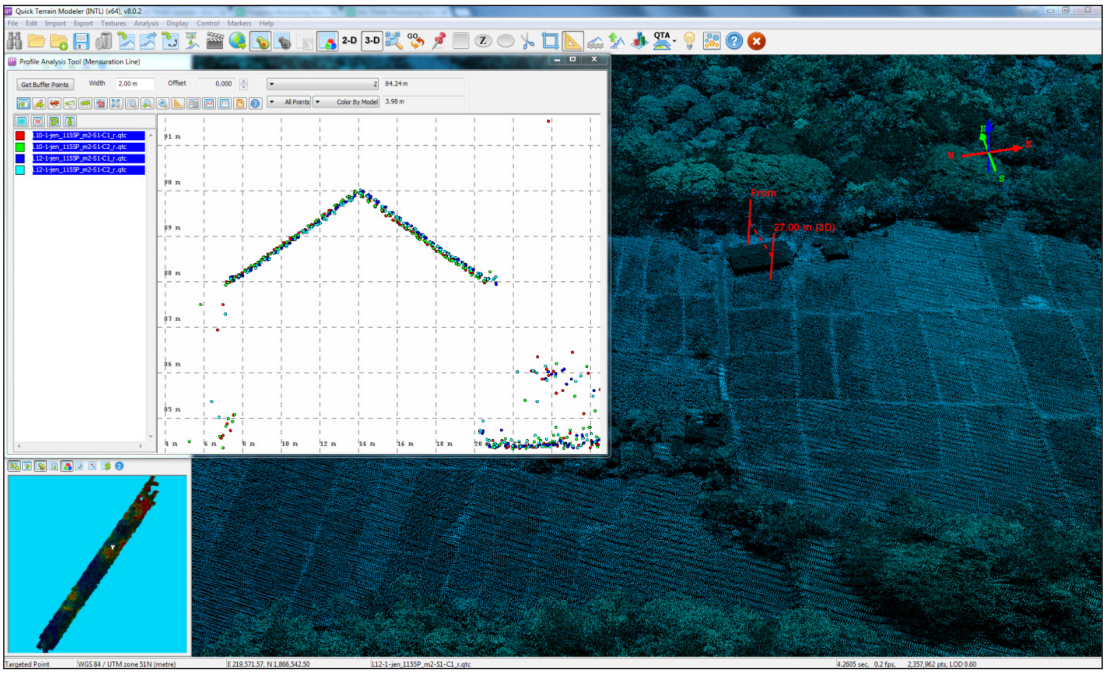

Figure 15. Quality checking for a Amburayan flight 1155P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Amburayan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,115,450,324
Low Vegetation	988,568,721
Medium Vegetation	1,812,497,388
High Vegetation	2,070,413,150
Building	93,860,270

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Amburayan floodplain is shown in Figure 16. A total of 1,714 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 1,038.87 meters and 40.04 meters respectively.

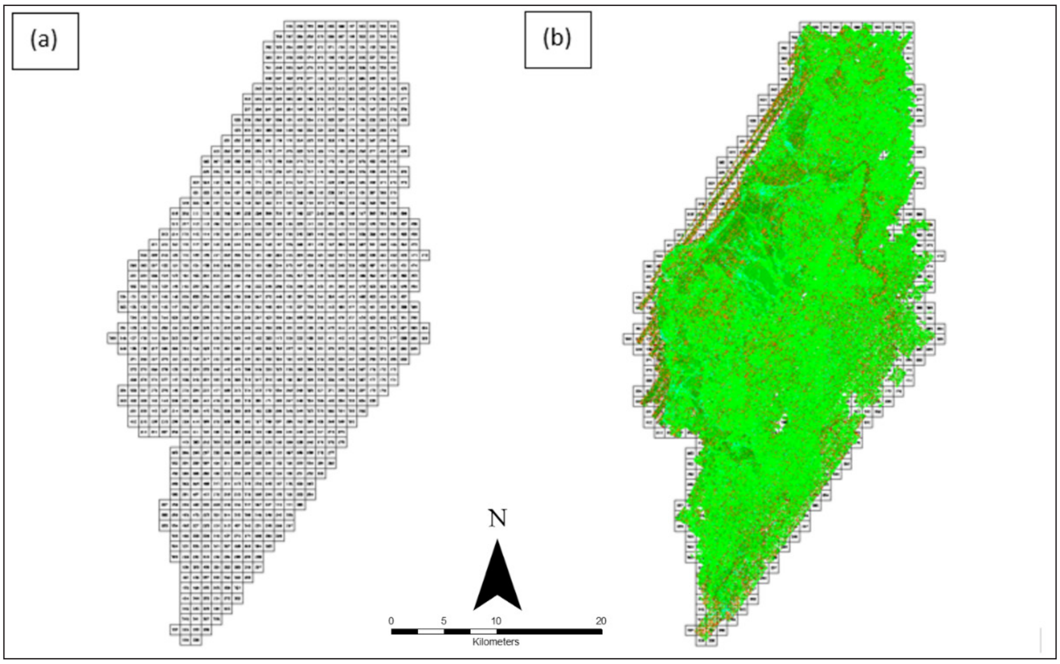

Figure 16. Tiles for Amburayan floodplain (a) and classification results (b) in TerraScan.

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

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

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

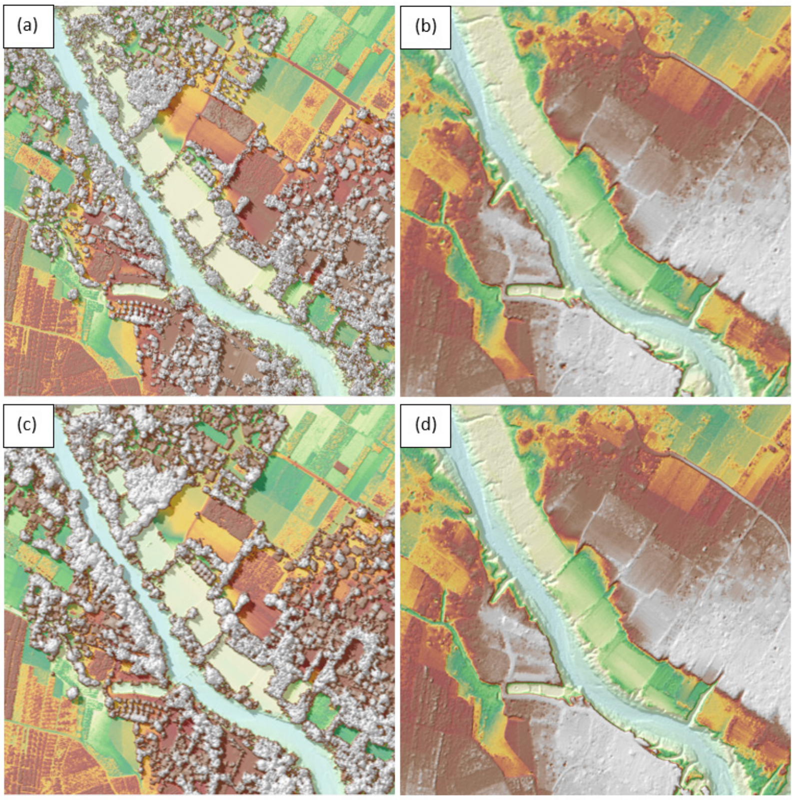

Figure 18. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Amburayan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,163 1km by 1km tiles area covered by Amburayan floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Amburayan floodplain has a total of 583.92 sq.km orthophotogaph coverage comprised of 2,451 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

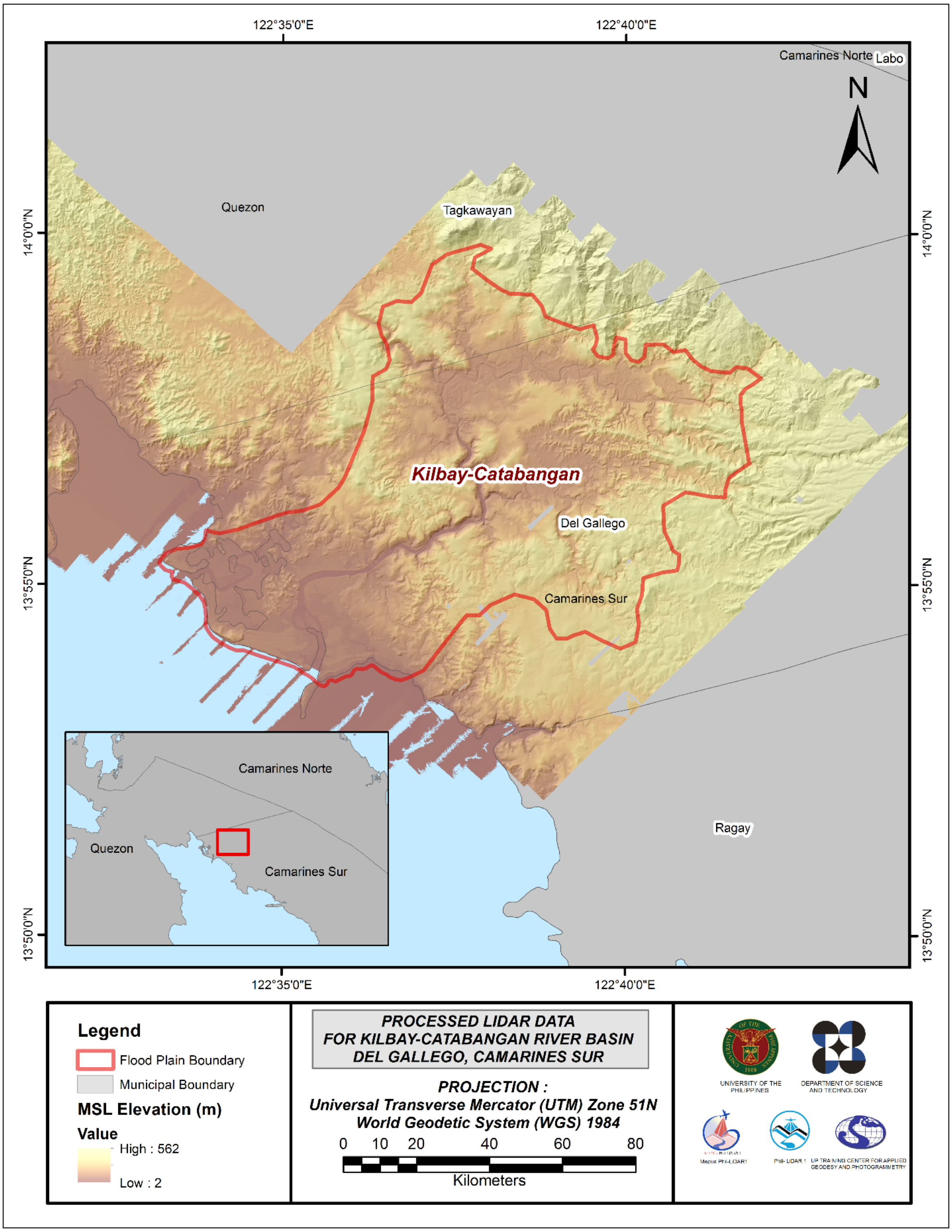

Figure 19. Amburayan floodplain with available orthophotographs.

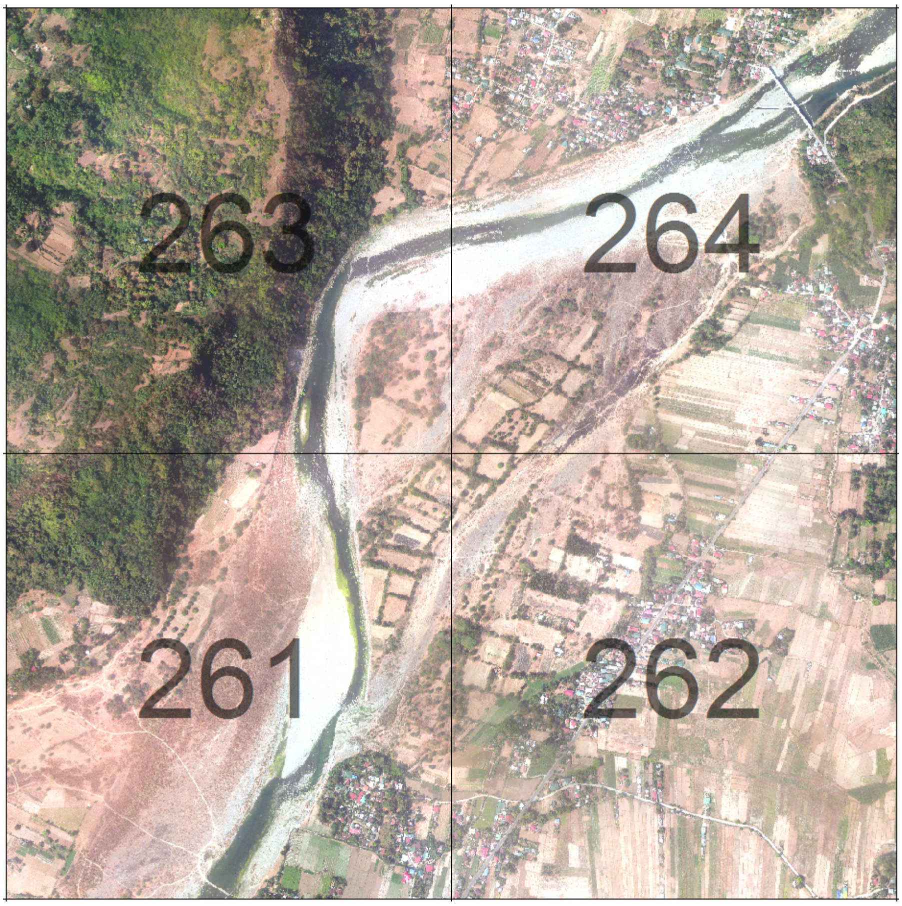

Figure 20. Sample orthophotograph tiles for Amburayan floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Amburayan flood plain. These blocks are composed of La Union blocks with a total area of 1,361.84 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km)
LaUnion_Blk10A	280.58
LaUnion_Blk10B	379.73
LaUnion_Blk10C	399.93
LaUnion_Blk10C_additional	301.60
TOTAL	1,361.84

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is considered to be an impedance to the flow of water along the river and had to be removed (Figure 21b) in order to hydrologically correct the river. The paddy field (Figure 21c) with a no data area had to be filled to complete the surface (Figure 21d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 21e) and has to be removed through manual editing (Figure 21f).

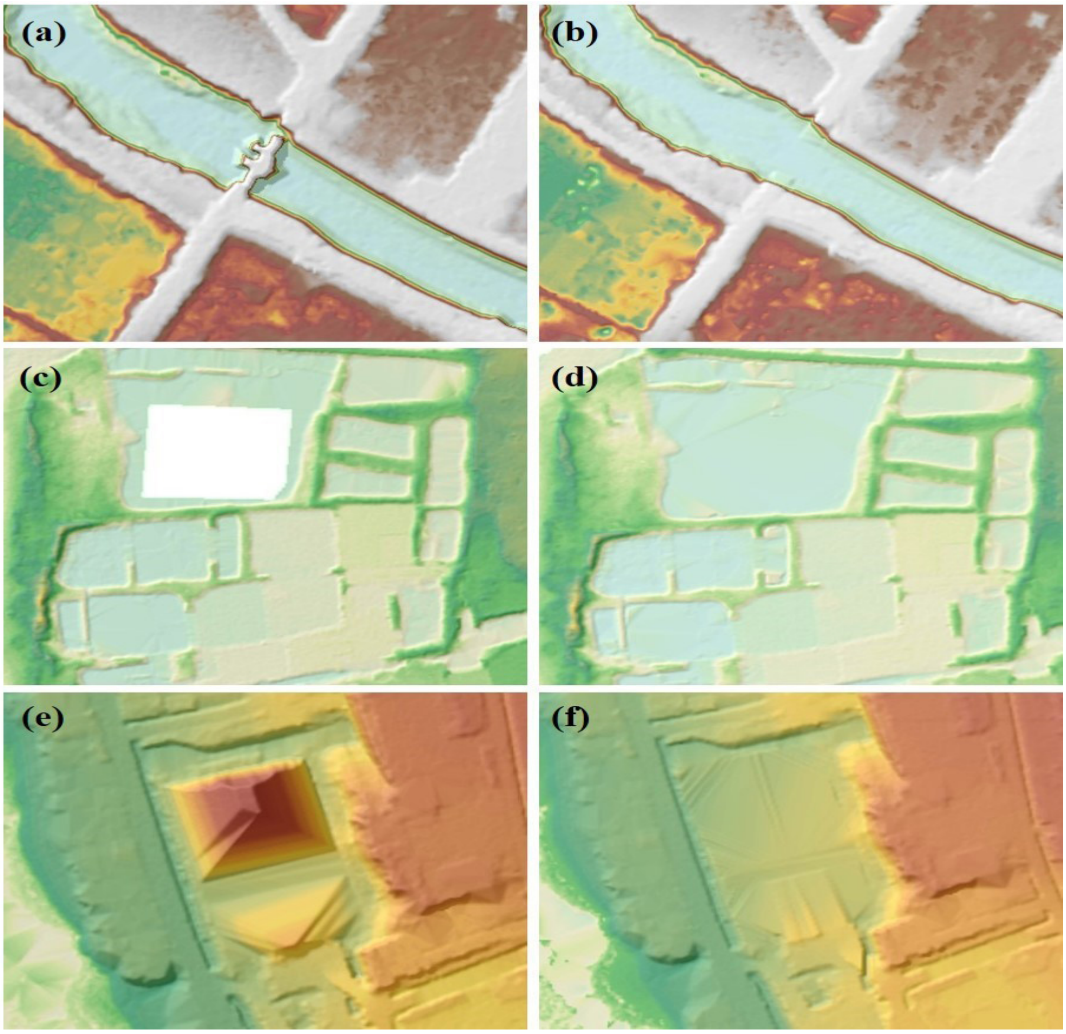

Figure 21. Portions in the DTM of Amburayan floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) manual editing; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

LaUnion_Blk10A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Amburayan floodplain is shown in Figure 22. It can be seen that the entire Amburayan floodplain is 97.87% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Amburayan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
LaUnion_Blk10A	0.00	0.00	0.00
LaUnion_Blk10B	0.00	0.00	0.00
LaUnion_Blk10C	0.00	0.00	0.00
LaUnion_Blk10C_additional	0.00	0.00	0.00

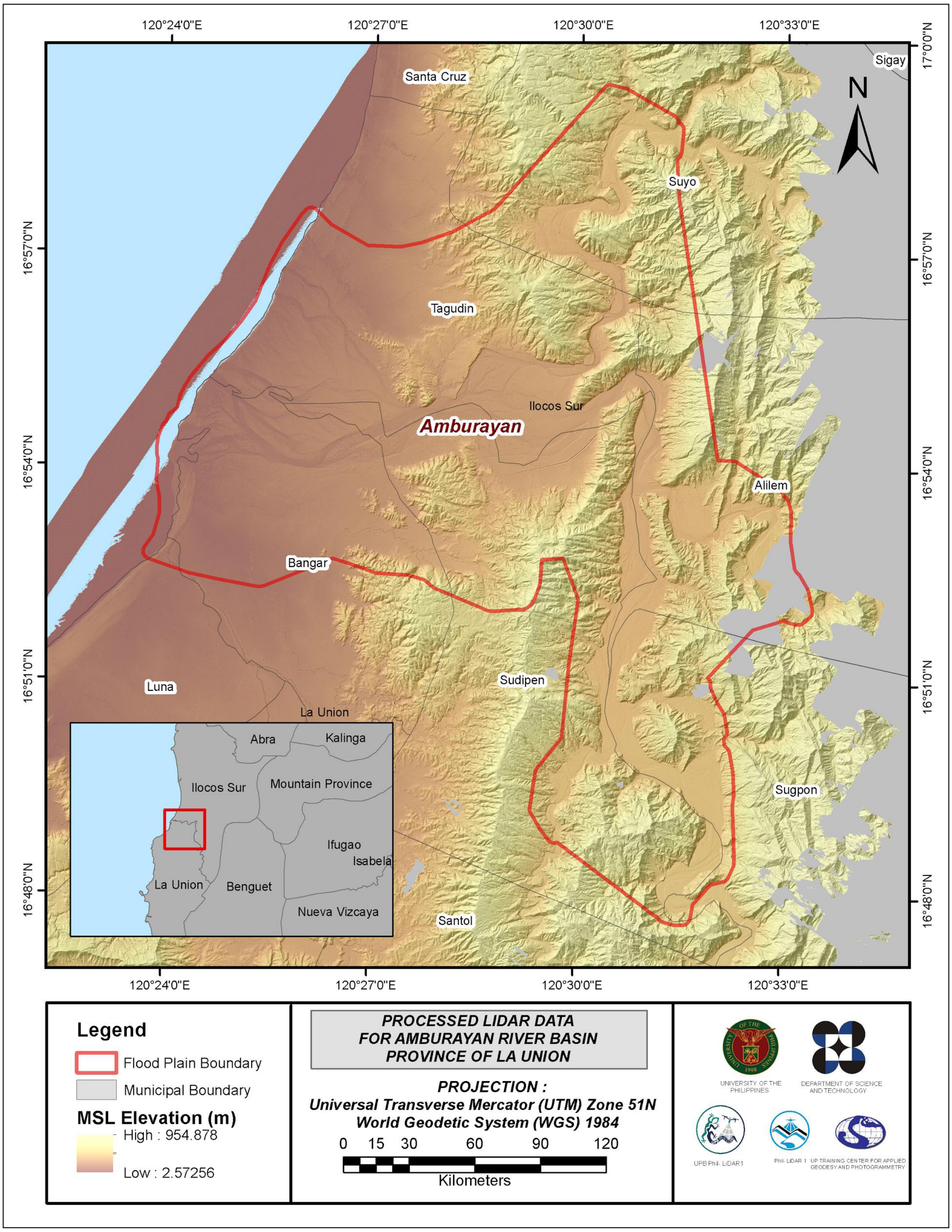

Figure 22. Map of Processed LiDAR Data for Amburayan Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Amburayan to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 4,957 survey points were used for calibration and validation of Amburayan LiDAR data. Random selection of 80% of the survey points, resulting to 4,957 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 3.22 meters with a standard deviation of 0.09 meters.

Calibration of Amburayan LiDAR data was done by adding the height difference value, 3.22 meters, to Amburayan mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

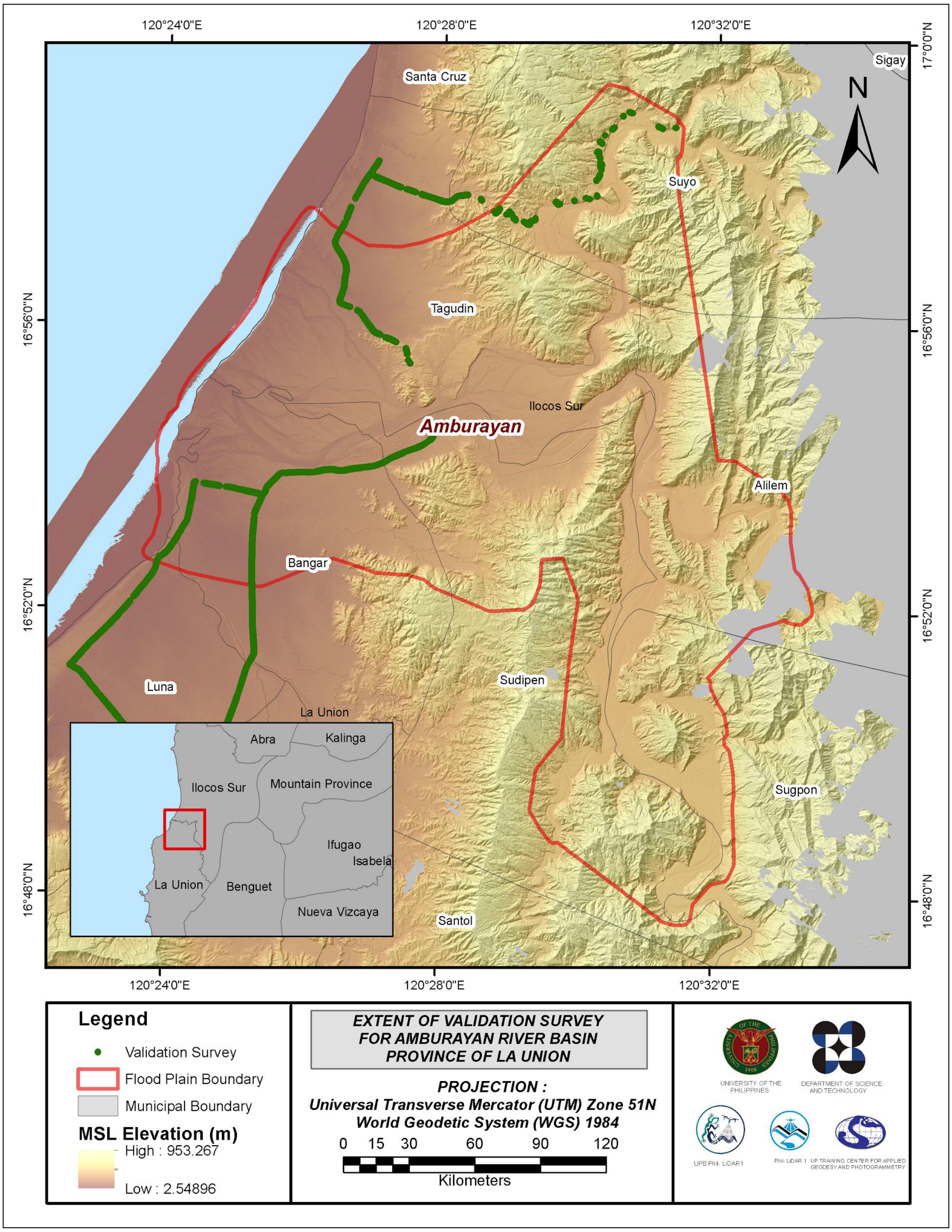

Figure 23. Map of Amburayan Flood Plain with validation survey points in green.

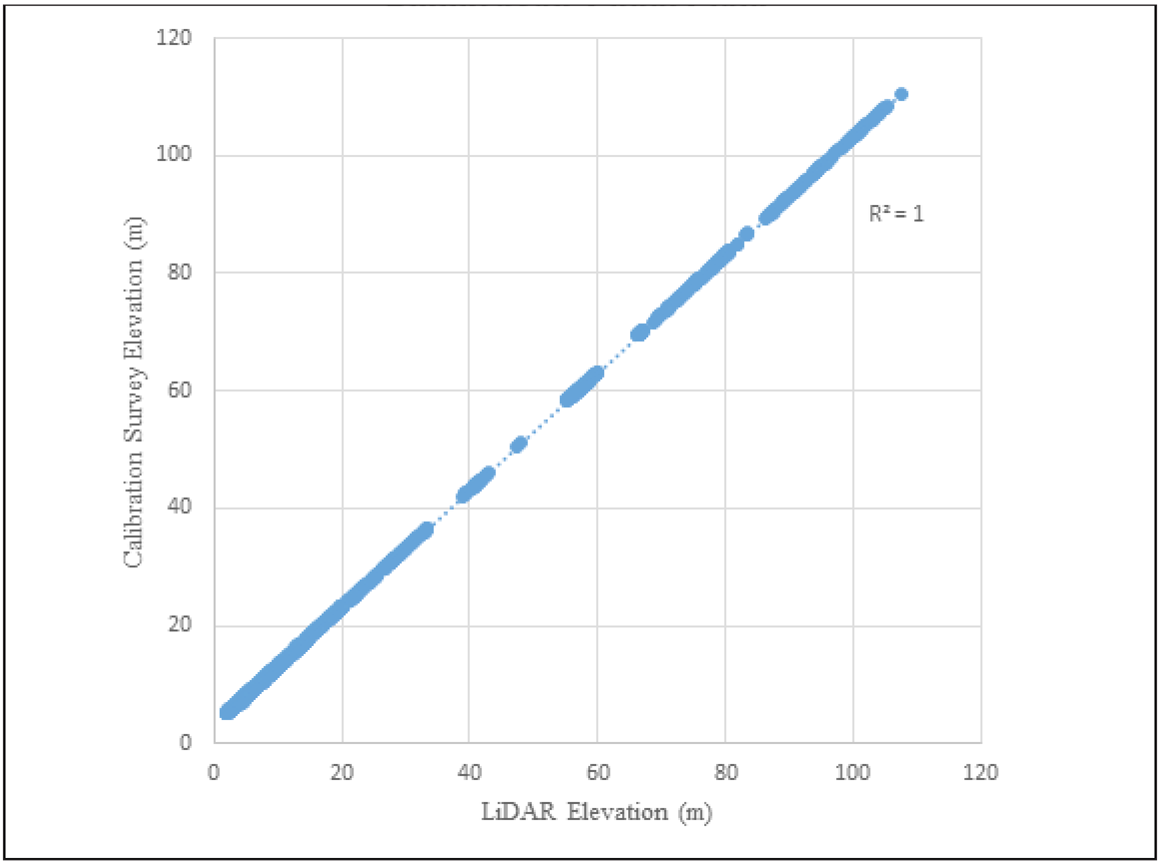

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.22
Standard Deviation	0.09
Average	-3.21
Minimum	-3.40
Maximum	-3.03

The remaining 20% of the total survey points, resulting to 365 points, were used for the validation of calibrated Amburayan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.06 meters, as shown in Table 17.

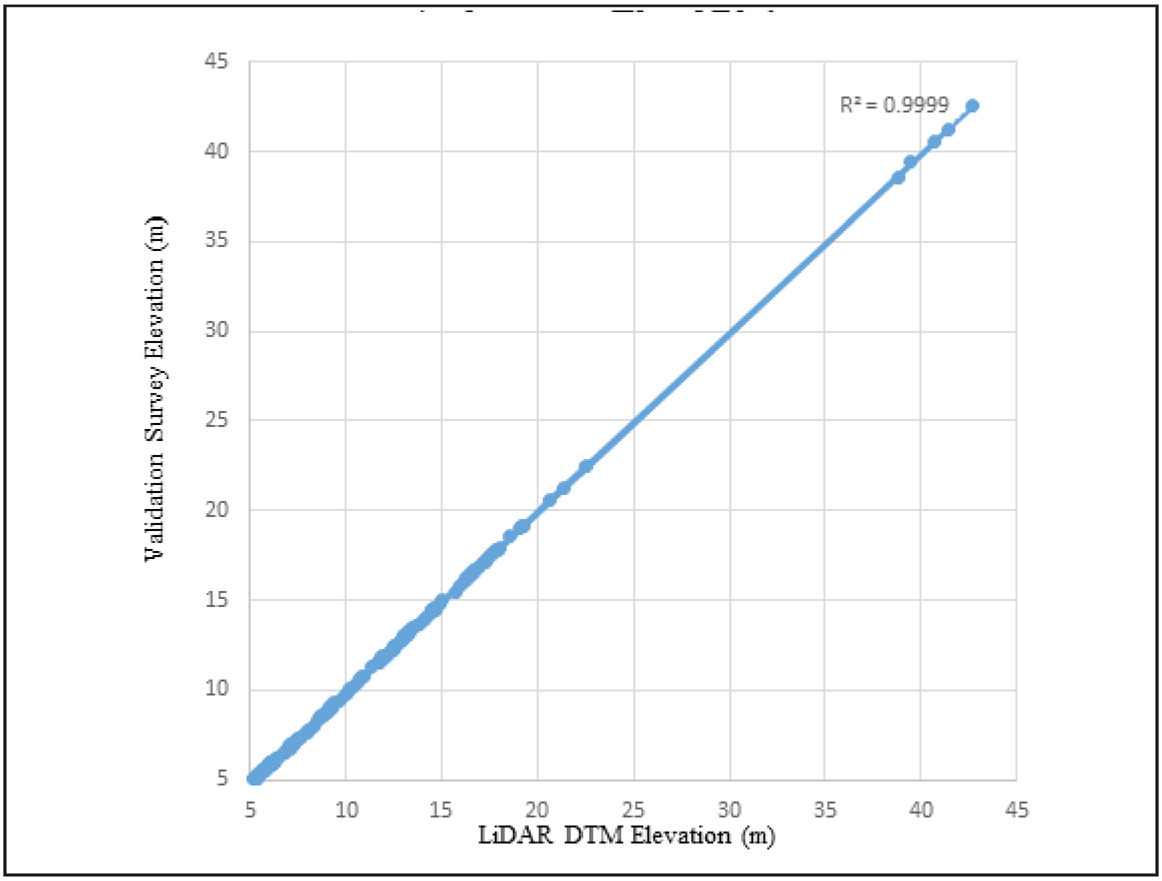

Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.06
Average	0.15
Minimum	0.02
Maximum	0.30

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Amburayan with 39,949 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.03 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Amburayan integrated with the processed LiDAR DEM is shown in Figure 26.

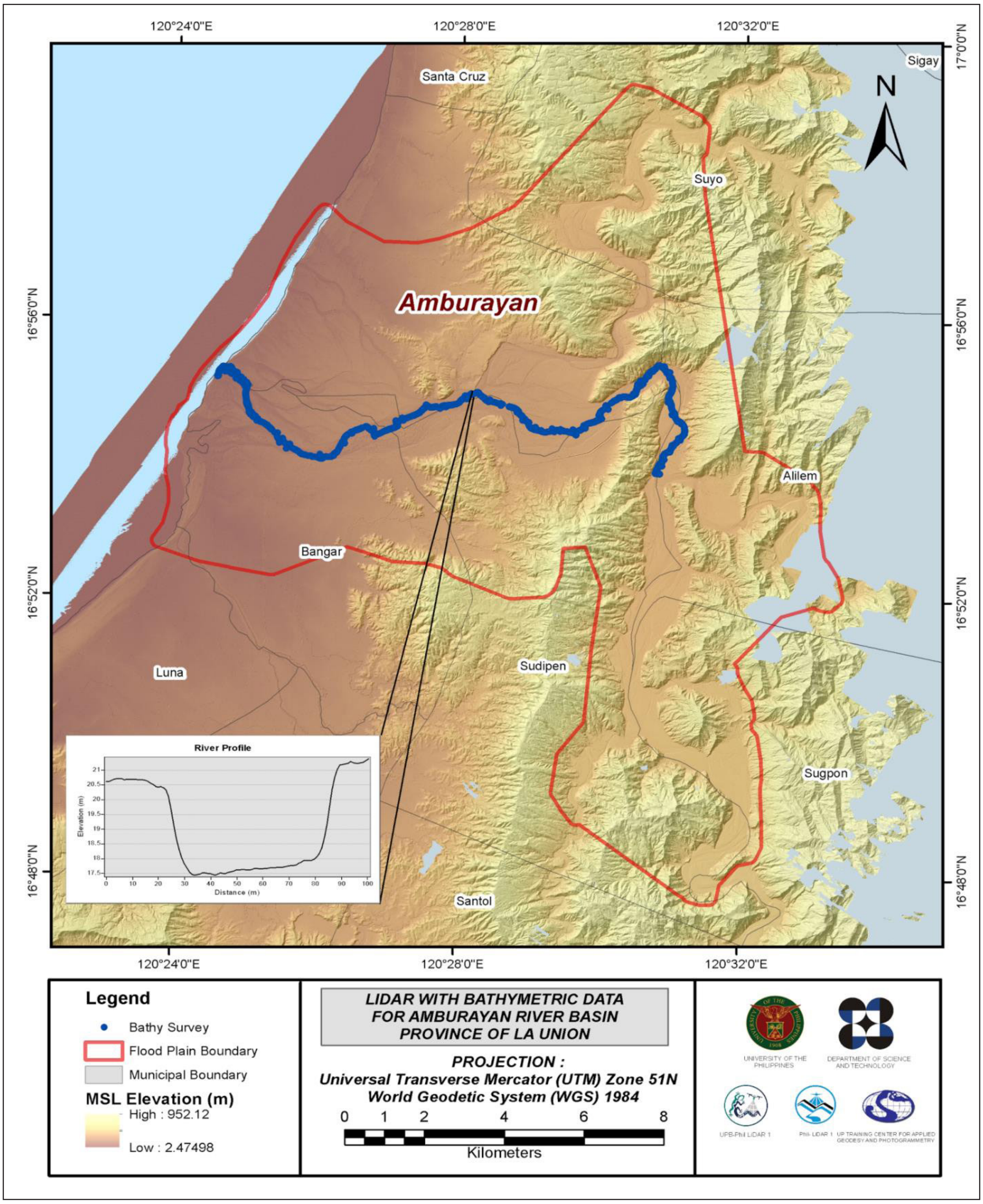

Figure 26. Map of Amburayan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Amburayan floodplain, including its 200 m buffer, has a total area of 161.15 sq km. For this area, a total of 5.00 sq km, corresponding to a total of 1,950 building features, are considered for QC. Figure 27 shows the QC blocks for Amburayan floodplain.

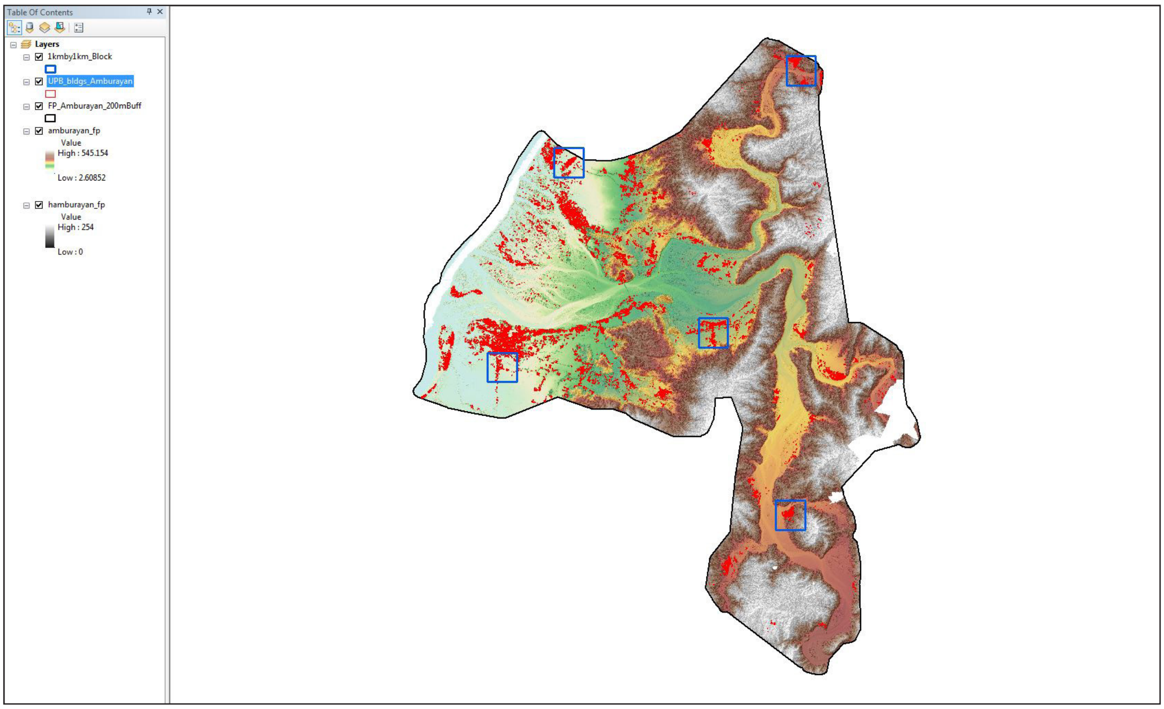

Figure 27. QC blocks for Amburayan building features.

Quality checking of Amburayan building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Amburayan Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Amburayan	99.90	100.00	99.28	PASSED

3.12.2 Height Extraction

Height extraction was done for 20,774 building features in Amburayan floodplain. Of these building features, 719 was filtered out after height extraction, resulting to 20,055 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 11.87 m.

3.12.3 Feature Attribution

Data collected from various sources which includes OpenStreetMap and Google Maps/Earth were used in the attribution of building features. Areas where there is no available data were subjected for field attribution using ESRI's Collector App. The app can be accessed offline and data collected can be synced to ArcGIS Online when WiFi or mobile data is available.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Number of Building Features Extracted for Amburayan Floodplain.

Facility Type	No. of Features
Residential	19,509
School	234
Market	5
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	8
Barangay Hall	30
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	0
Power Plant/Substation	2
NGO/CSO Offices	1
Police Station	2
Water Supply/Sewerage	2
Religious Institutions	21
Bank	3
Factory	0
Gas Station	13
Fire Station	2
Other Government Offices	5
Other Commercial Establishments	196
Total	**20,055**

Table 20. Total Length of Extracted Roads for Amburayan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Amburayan	12.19	3.81	0	14.70	0.00	30.70

Table 21. Number of Extracted Water Bodies for Amburayan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Amburayan	1	0	0	0	0	**1**

A total of 3 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

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

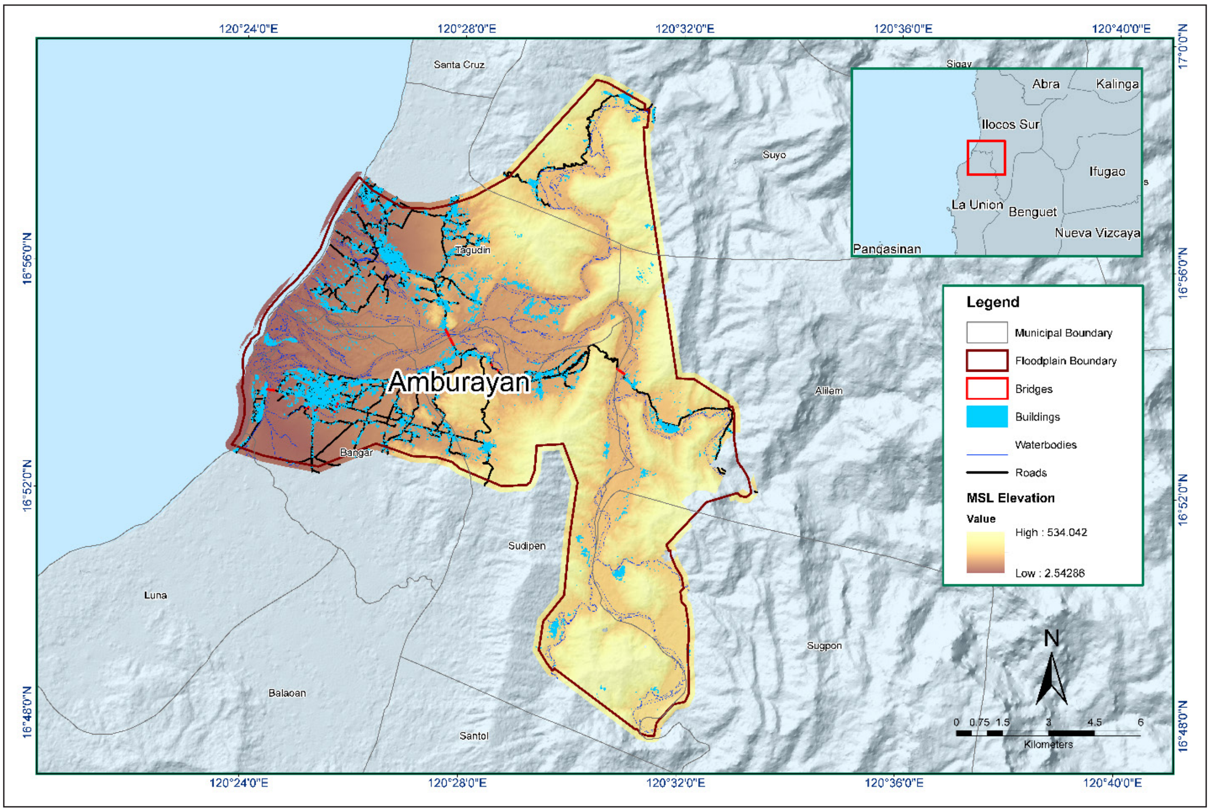

Figure 28. Extracted features for Amburayan floodplain

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Amburayan River on April 28 to May 12, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built surveys at Amburayan Bridge; validation points data acquisition of about 44 km for the areas traversing the Amburayan River Basin; and bathymetric survey from Brgy. Namaltugan, Municipality of Sudipen down to Brgy. Pudoc West, Municipality of Tagudin, La Union; and Brgy. Mindoro, Municipality of Bangar, Ilocos Sur, with an estimated length of 18.839 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 29).

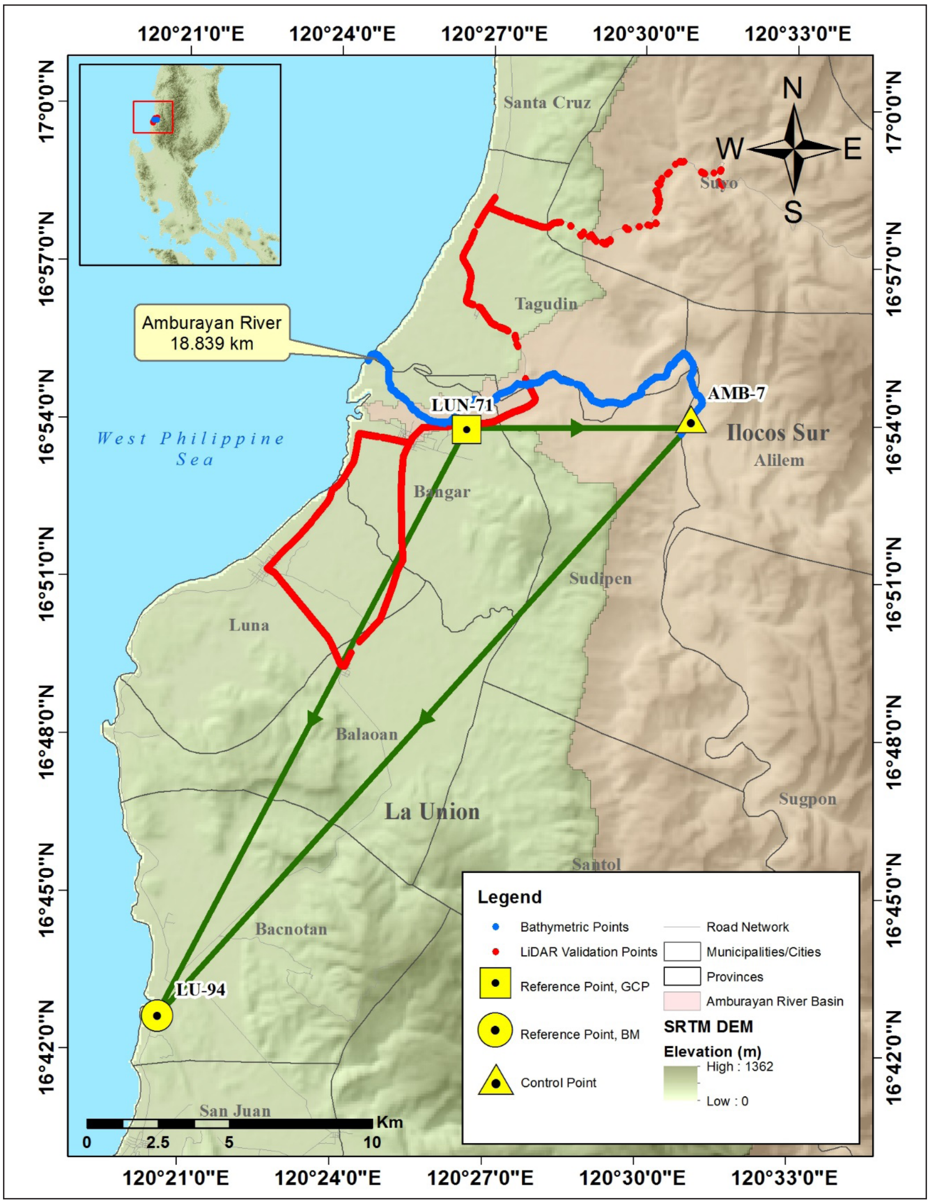


Figure 29. Amburayan River Survey Extent.

4.2 Control Survey

The GNSS network used for Amburayan River Basin is composed of single loop established on May 7, 2016 occupying the following reference points: LUN-71, a second-order GCP, in Brgy. Gen. Prim West, Municipality of Bangar; and LU-94, a first-order BM, in Brgy. Nagsimbaanan, Muncipality of Bacnotan; both in La Union Province.

A NAMRIA established control point namely AMB-1 located at the approach of Alilem Bridge, in Brgy. Kiat, Municipality of Alilem, Ilocos Sur, was also occupied to use as marker.

The summary of reference and control points and its location is summarized in Table 22 while the GNSS network established is illustrated in Figure 30.

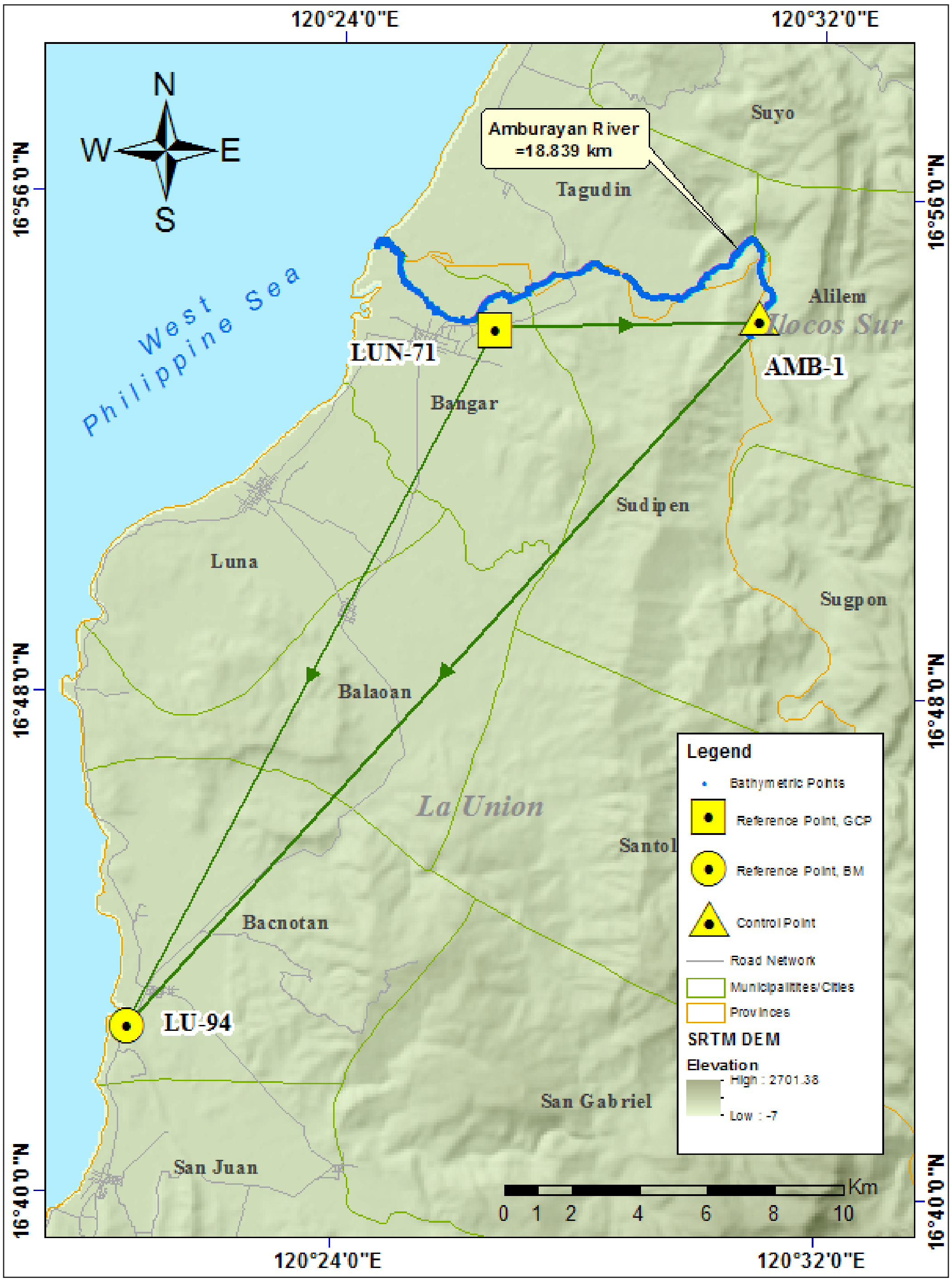


Figure 30. GNSS Network covering Amburayan River.

Table 22. List of Reference and Control Points occupied for Amburayan River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	-	2007
LU-94	1st order, BM	-	-	46.965	7.349	2010
AMB-7	Used as Marker	-	-	-	-	2010

The GNSS set-ups on recovered reference points and established control points in Amburayan River are shown in Figure 31 to Figure 33.

Figure 31. GNSS base set up, Trimble® SPS 852, at LUN-71, situated beside an irrigation canal at the right intersection of the barangay roads in Brgy. General Prim West, Municipality of Sudipen, La Union.

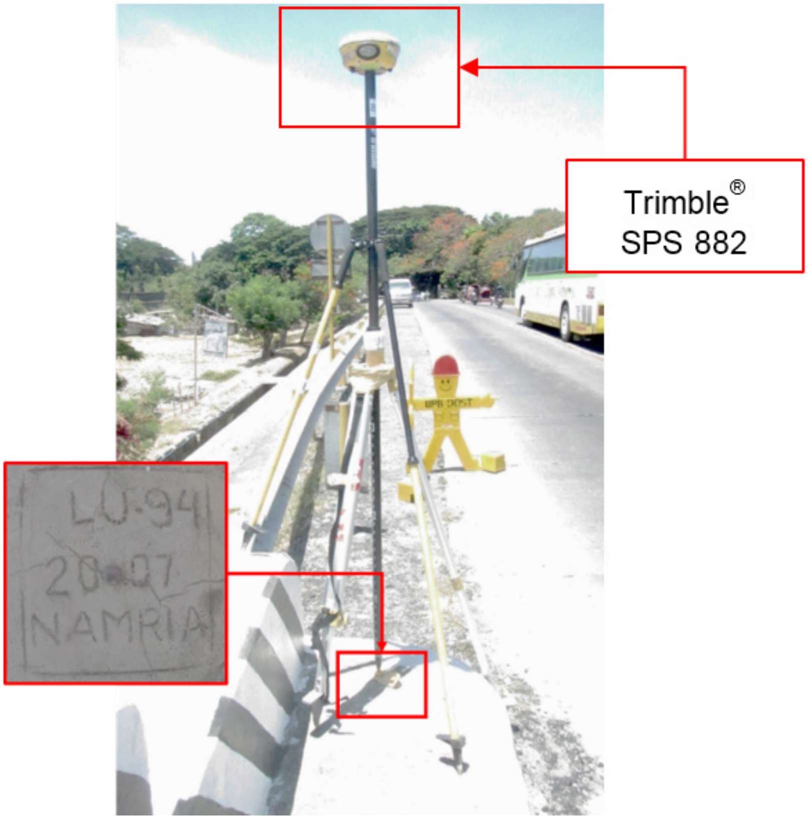


Figure 32. GNSS receiver set up, Trimble® SPS 882, at LU-94, located at the approach of Baroro Bridge in Brgy. Nagsimabaanan, Municipality of Bacnotan, La Union.

Figure 33. GNSS receiver setup, Trimble® SPS 882, at AMB-7, located at the approach of Alilem Bridge in Brgy. Kiat, Municipality of Alilem, Ilocos Sur.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Amburayan River Basin is summarized in Table 23 generated by TBC software.

Table 23. Baseline Processing Summary Report for Amburayan River Survey.

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
AMB-7 --- LU-94	5-7-2016	Fixed	0.006	0.021	221°07'26"	28070.731
LUN-71 --- LU-94	5-7-2016	Fixed	0.007	0.28	207°06'53"	23245.821
LUN-71 --- AMB-7	5-7-2016	Fixed	0.003	0.011	86°38'26"	7872.535

As shown Table 23 a total of three (3) baselines were processed with reference points LUN-71 and LU-94 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 24 to Table 27 for complete details.

The three (3) control points, LUN-71, LU-94, and AMB-7, were occupied and observed simultaneously to form a GNSS loop. Coordinates of LUN-71 and elevation value of LU-94 were held fixed during the processing of the control points as presented in Table 24 Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LUN-71	Local	Fixed	Fixed		
LU-94	Grid				Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. The fixed control point LUN-71 has no values for grid errors; and LU-94, for elevation error.

Table 25. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LU-71	227541.709	?	1870002.301	?	12.794	0.052	LL
LU-94	216674.512	0.009	1849438.439	0.006	7.349	?	e
AMB-7	235409.911	0.005	1870361.711	0.004	46.253	0.052	

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

a. LUN-71

horizontal accuracy = Fixed
vertical accuracy = 5.20 cm < 10 cm

b. LU-94

horizontal accuracy = $\sqrt{((0.90)^2 + (0.60)^2}$
= $\sqrt{(0.81+ 0.36)}$
= 1.08 cm < 20 cm
vertical accuracy = Fixed

c. AMB-7

horizontal accuracy = $\sqrt{((0.50)^2 + (0.40)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64 < 20 cm
vertical accuracy = 5.2 cm < 10 cm

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

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
LUN-71	N16°53'51.58283"	E120°26'32.77383"	52.356	0.052	LL
LU-94	N16°42'38.41914"	E120°20'35.13397"	46.965	?	e
AMB-7	N16°54'06.54124"	E120°30'58.32790"	86.879	0.052	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 27. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing |(m)	Easting (m)	BM Ortho (m)
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	1870002.301	227541.709	12.794
LU-94	1st order, BM	16°42'38.4194"N	120°20'35.13397"E	46.965	1849438.439	216674.512	7.349
AMB-7	Used as Marker	16°54'06.54124"N	120°30'58.32790"E	86.879	1870361.711	235409.911	46.253

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

Cross-section and as-built survey were conducted on May 7, 2016 at the downstream side of Amburayan Bridge in Brgy. Ipet, Municipality of Sudipen, La Union using a survey grade GNSS receiver Trimble® SPS 882 i PPK survey technique as shown in Figure 34B.

Figure 34. A) Amburayan Bridge facing downstream, and its B) Cross-section As-built survey.

The cross-sectional line of Amburayan Bridge is about 802 m with six hundred and ninety (690) cross-sectional points acquried using the control point LUN-71 as the GNSS base station. The cross-section diagram, planimetric map and the bridge data form are shown in Figure 35 to Figure 37, respectively.

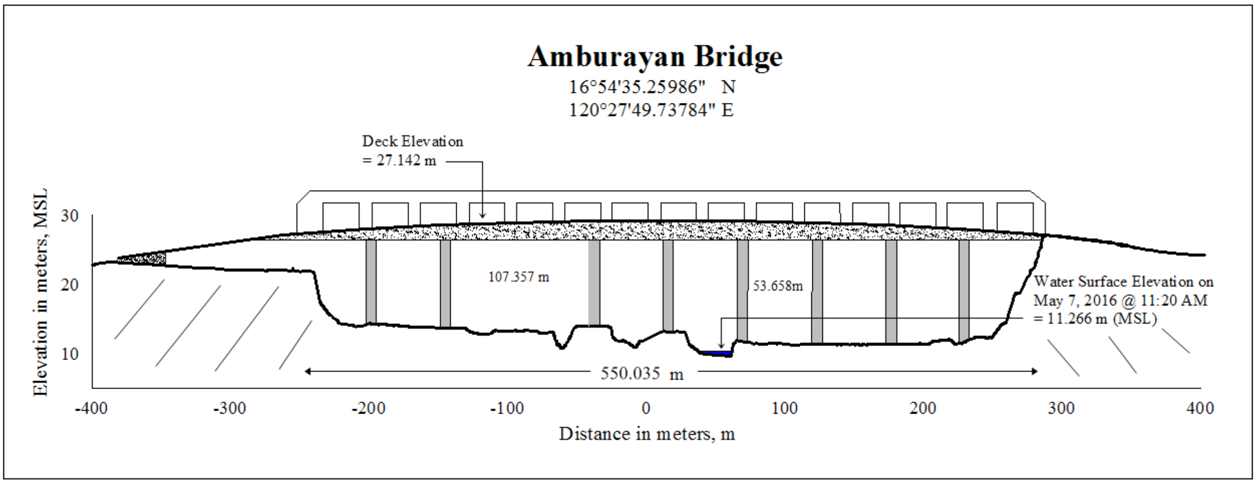


Figure 35. Amburayan Bridge cross-section diagram.

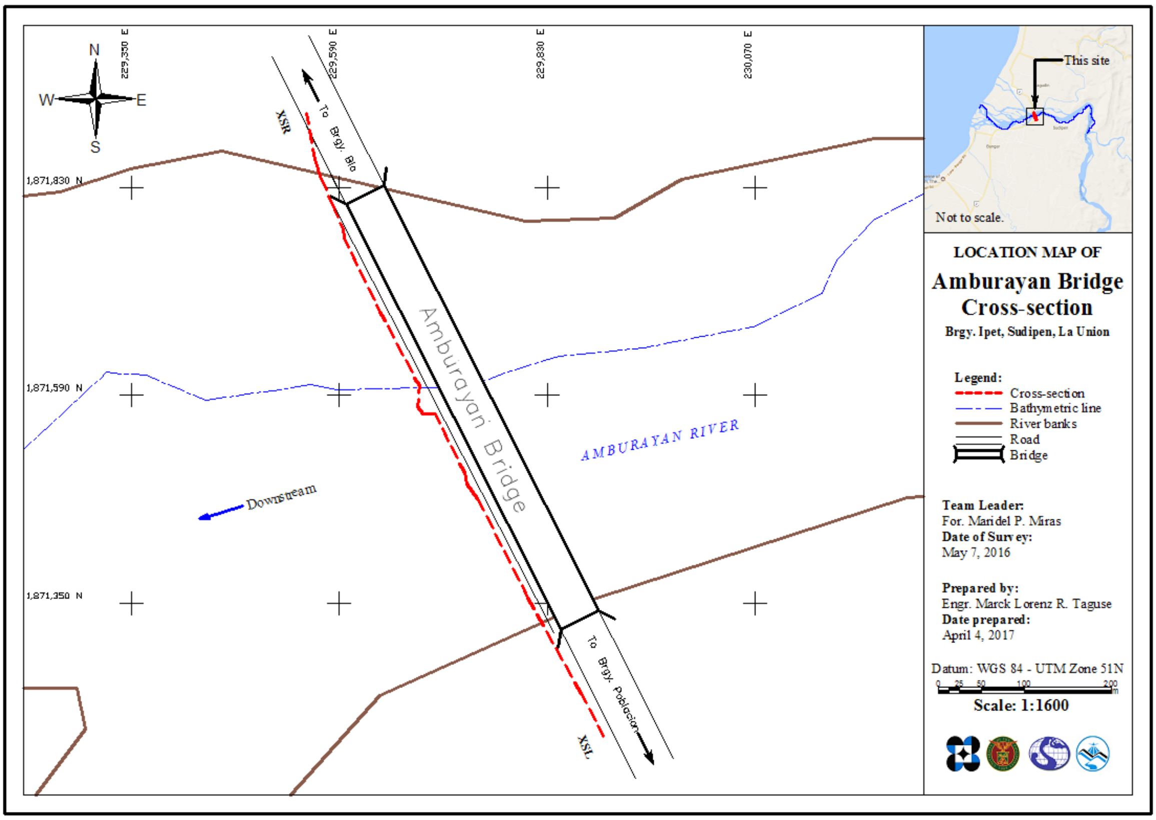


Figure 36. Amburayan Bridge Planimetric map.

Bridge Data Form

Bridge Name: Amburayan Bridge | Date: May 7, 2016

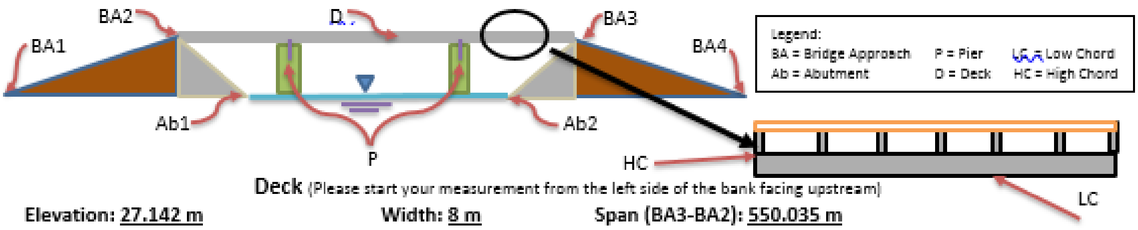
River Name: Amburayan River | Time: 11:20 AM

Location (Brgy, City,Region): Brgy. Ipet, Municipality of Sudipen

Survey Team: Maridel Miras, Rodel Alberto, Caren Ordoña

Flow condition: normal | Weather Condition: fair

Latitude: 16°54'35.25986" N | Longitude: 120°27'49.73784" E



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

Elevation: 27.142 m | Width: 8 m | Span (BA3-BA2): 550.035 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	23.723 m	BA3	668.646 m	27.095 m
BA2	118.611 m	27.142 m	BA4	727.992 m	25.602 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: Oval Number of Piers: 8 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	179.150 m	28.013 m	Not available
Pier 2	232.550 m	28.539 m	Not available
Pier 3	339.915 m	29.123 m	Not available
Pier 4	393.208 m	29.163 m	Not available
Pier 5	446.980 m	29.072 m	Not available
Pier 6	500.640 m	28.877 m	Not available
Pier 7	554.109 m	28.500 m	Not available
Pier 8	606.912 m	27.999 m	Not available

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

Figure 37. Bridge as-built form of Amburayan Bridge.

Water surface elevation of Amburayan River was determined on May 7, 2016 at 11:20 AM with a value of 11.266 m in MSL as shown in Figure 35. This was translated into marking on the bridge's deck that will serve as reference for flow data gathering and depth gauge deployment of UPB for Amburayan River as shown in Figure 38.

Figure 38. Water-level markings on the deck of Amburayan Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on May 8, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown in Figure 39. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 2.045 m and 2.268 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique set to continuous topo mode was utilized in the conduct of the survey.

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

The survey started from Brgy. Central West in the Municipality of Bangar, going south covering Municipalities of Luna and Balaoan. Then, it went north towards upper barangays of Bangar and Municipalities of Tagudin and ended in Brgy. Urzadan, in Municipality of Suyo, Ilocos Sur. The survey gathered a total of 6,758 points with an approximate length of 44.33 km using LUN-71 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 40.

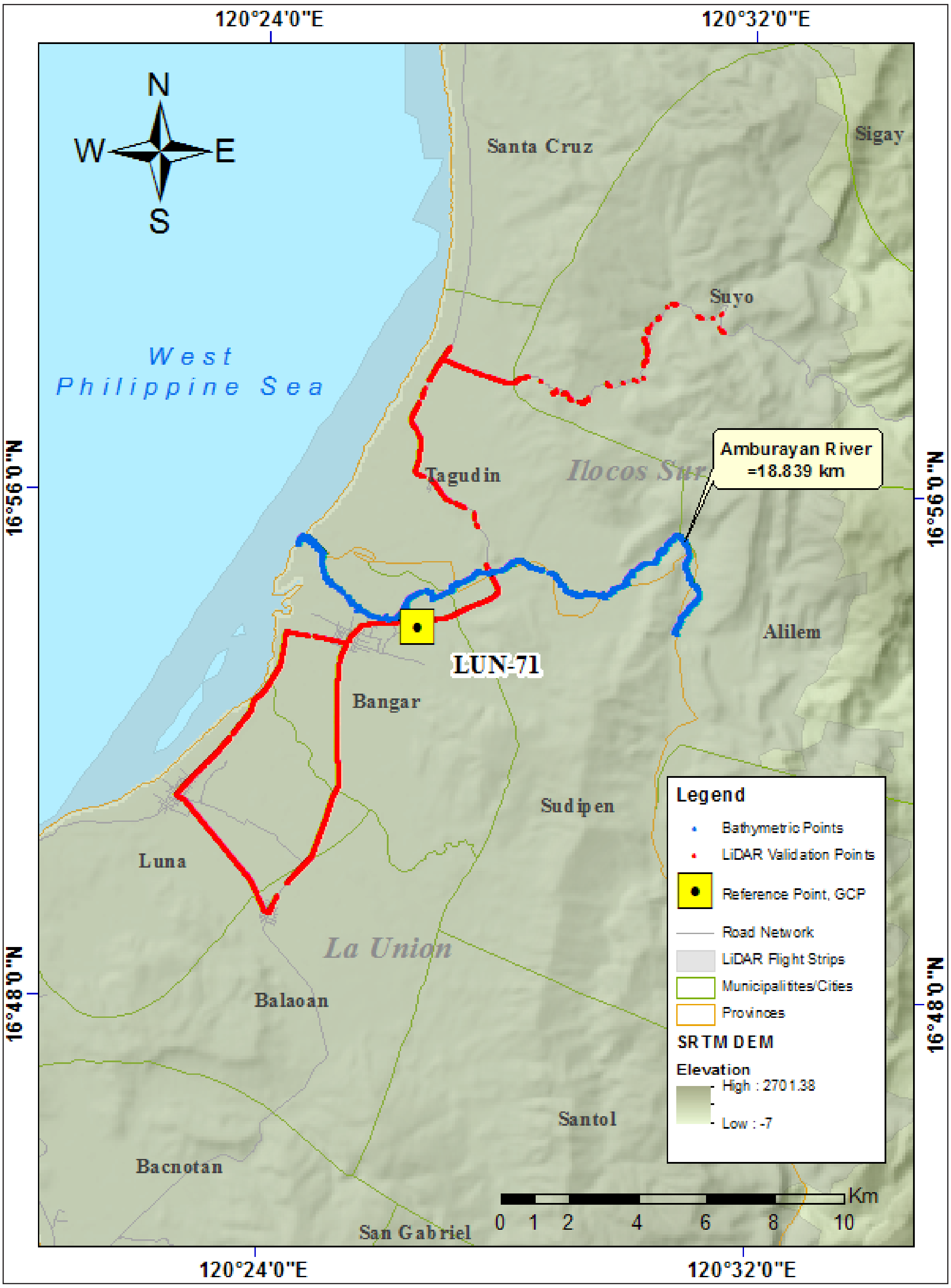


Figure 40. Validation point acquisition survey of Amburayan River basin.

4.7 River Bathymetric Survey

Manual bathymetric survey was executed on May 10 and 11, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 41. The survey started from the upstream in Brgy. Namaltugan, Municipality of Sudipen, with coordinates 16°53›49.49486»N, 120°30›46.72955»E, traversed down by foot and ended in Brgy. Mindoro, Municipality of Bangar, with coordinates 16°54›31.29321»N, 120°25›9.28033»E.

Figure 41. Bathymetric survey set-up in Amburayan River

On June 13, 2016, bathymetric survey was done using Ohmex™ single beam Echosounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode. The survey started from the end point of manual bathymetry and ended at the mouth of the river in Brgy. Mindoro, Municipality of Bangar, with coordinates 16°55›13.44191»N, 120°24›36.29810»E. The control point LUN-71 was used as the GNSS base station all throughout the entire survey.

The bathymetric survey for Amburayan River gathered a total of 40,825 points covering 18.839 km of the river traversing Municipalities of Tagudin and Alilem in the Provicne of Ilocos Sur; and Municipalities of Bangar and Sudipen in the Province of La Union as shown in Figure 42. A CAD drawing was also produced to illustrate the riverbed profile of Amburayan River. Figure 43. The highest and lowest elevation has a 40-m difference. The highest elevation observed was 35.946 m above MSL located in Brgy. Namaltugan, Municipality of Sudipen while the lowest was -4.621 m below MSL located in Brgy. Maria Cristina West, Municipality of Bangar, both in La Union as shown in Figure 43 and Figure 44. The survey for the remaining 24 km upstream of the river was cut because LiDAR data for its riverbed is already available.

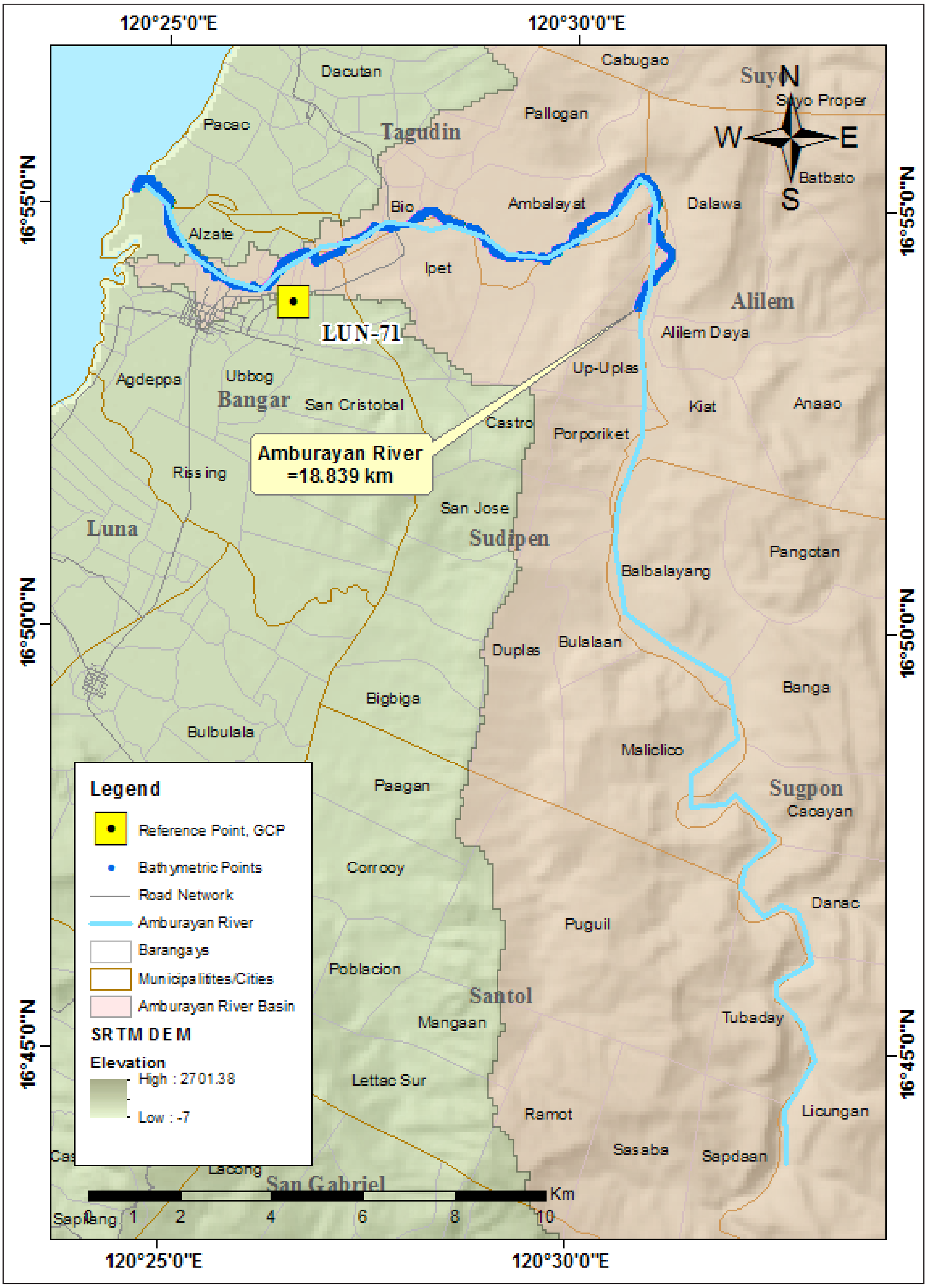


Figure 42. Bathymetric survey of Amburayan River.

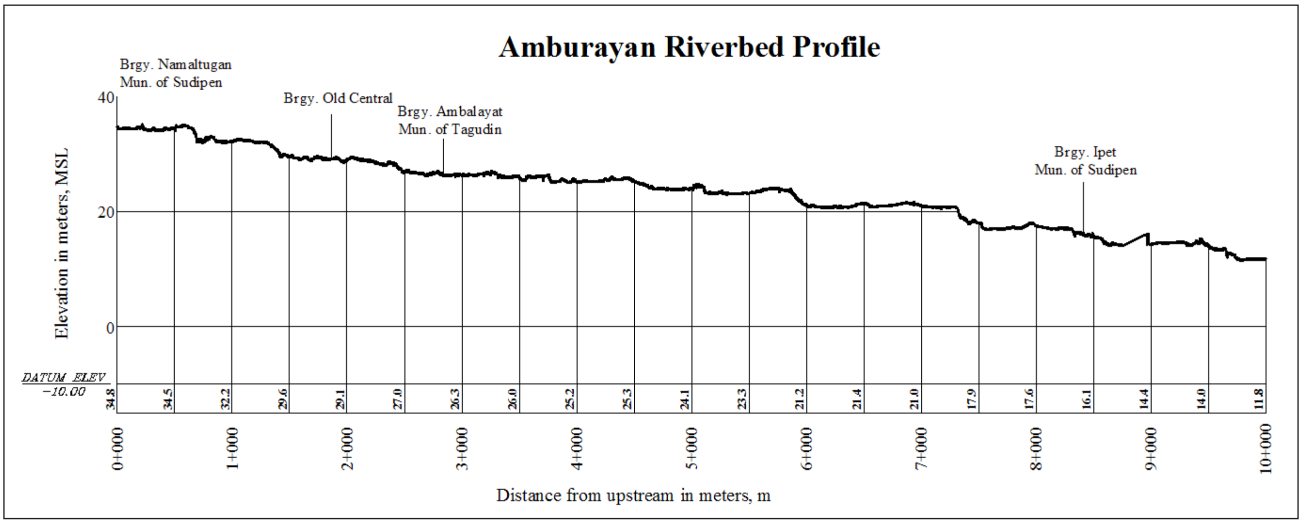


Figure 43. Amburayan Riverbed Profile, upstream part.

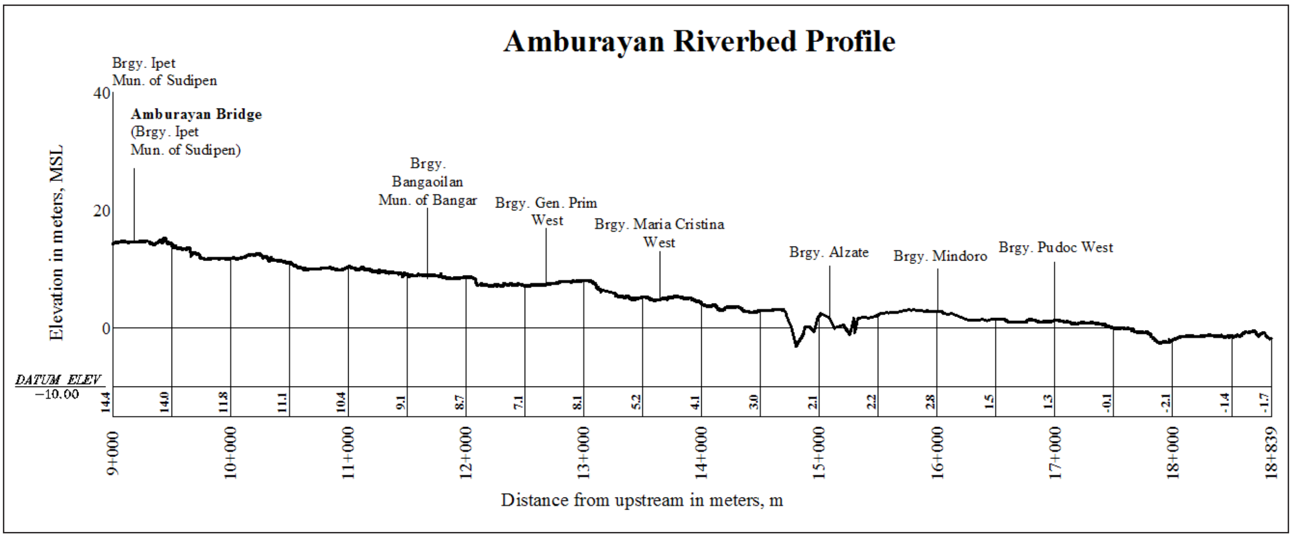


Figure 44. Amburayan Riverbed Profile, downstream part.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

The methods applied in this chapter were based on the DREAM methods manual (Ang, 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

Components and data that affect the hydrologic cycle of the river basin were monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the Ana-Ao Bridge ARG (16°52’26.6” N, 120°32’55.5” E), located in Alilem, Ilocos Sur, as shown in Figure 45. The precipitation data collection started from October 17, 2015 at 11:00 AM to October 23, 2015 at 12:00 PM with a 10-minute recording interval.

The total precipitation for this event in Sablan ARG was 295 mm. It has a peak rainfall of 7.8 mm. on October 20, 2015 at 1:00 AM. The lag time between the peak rainfall and discharge is 4 hours.

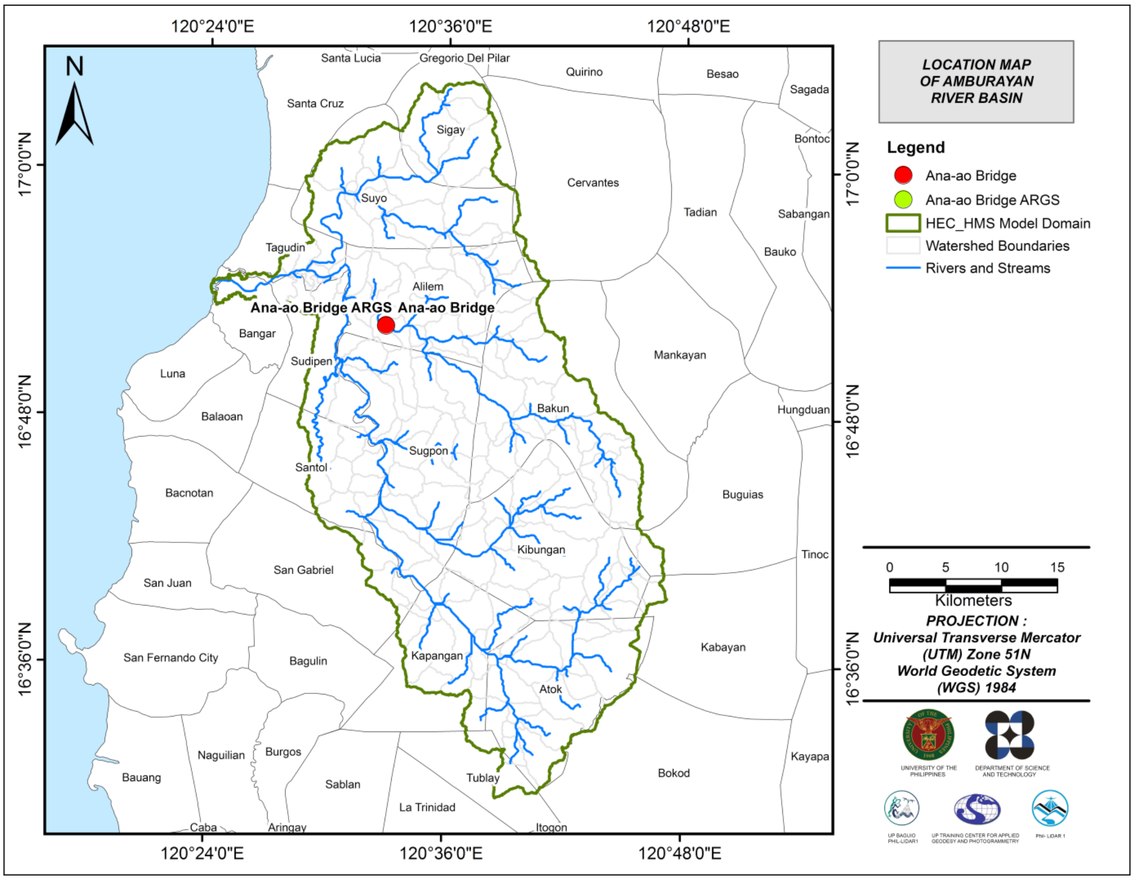


Figure 45. The location map of Amburayan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Amburayan Bridge, Sudipen, La Union (16°54'36" N, 120°27'50.4" E). It gives the relationship between the observed water level from Amburayan Bridge/Brgy. Bio Bridge and outflow of the watershed at this location.

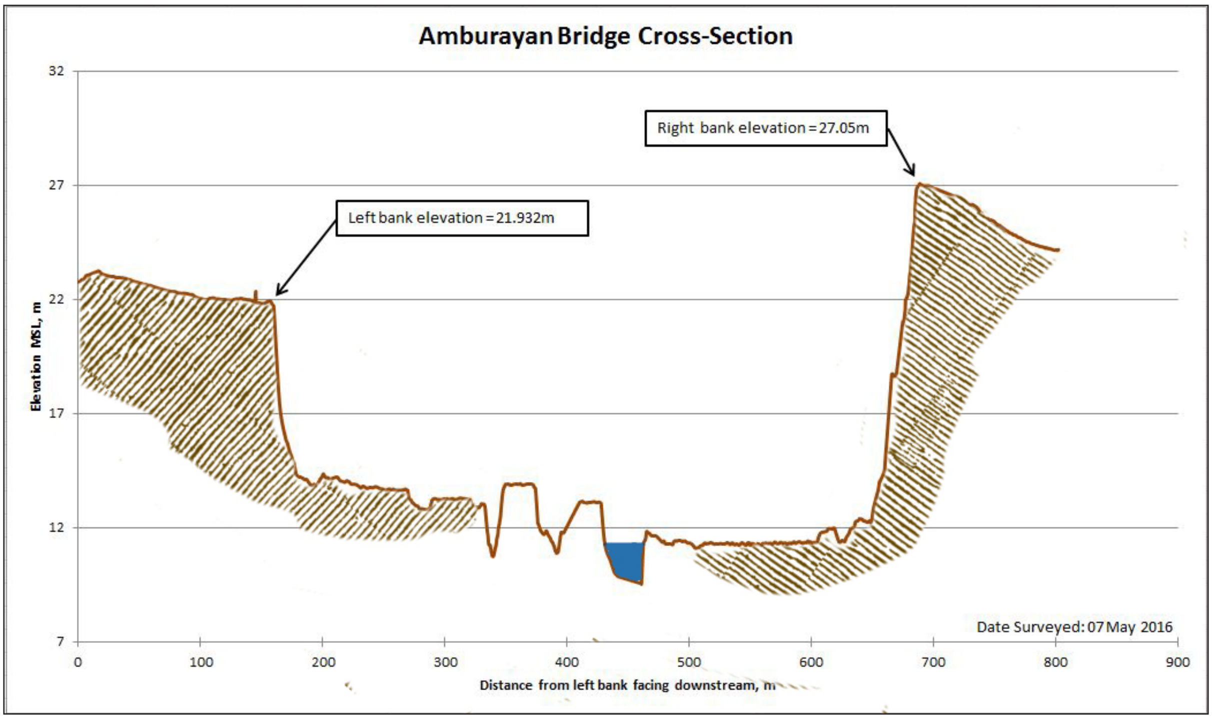


Figure 46. Cross-Section Plot of Amburayan Bridge.

For Amburayan Bridge, the rating curve is expressed as $Q = 0.0411e^{0.6121x}$ as shown in Figure 47.

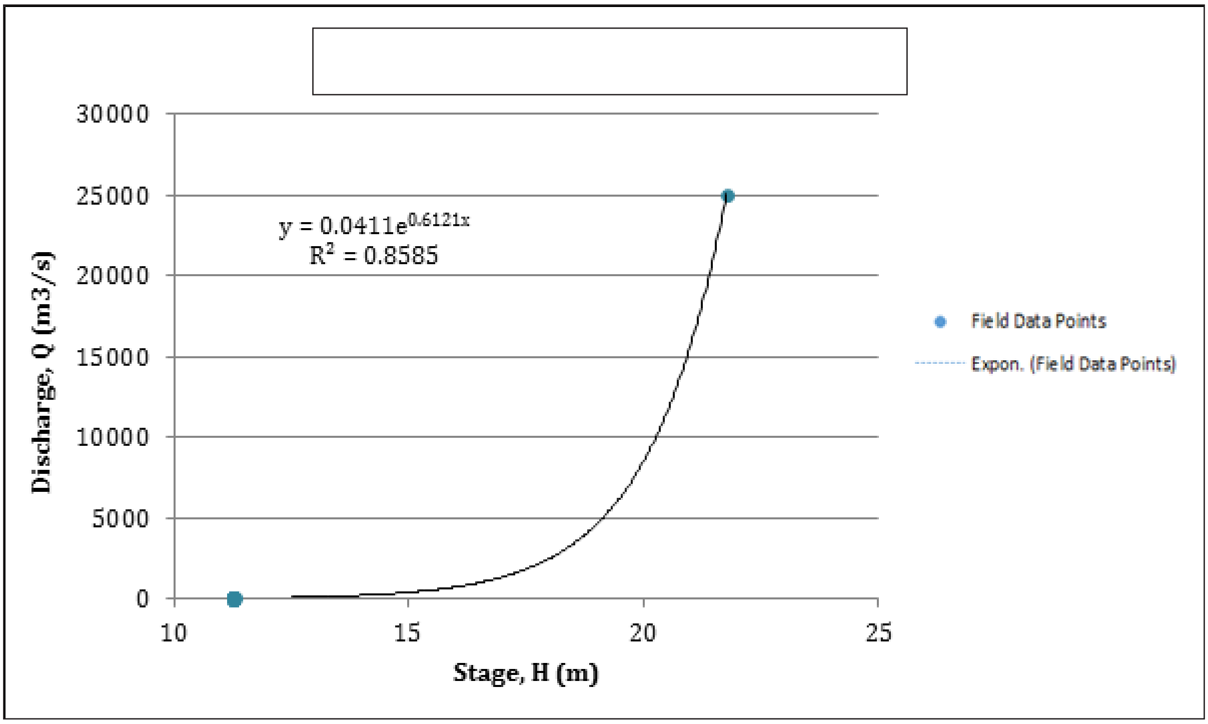


Figure 47. Rating Curve at Amburayan Bridge, Sudipen, La Union.

The rating curve equation was used to compute for the river outflow at Amburayan Bridge for the calibration of the HEC-HMS model for Amburayan, as shown in Figure 48. The total rainfall for this event is 295 mm and the peak discharge is 1239.85 m^3/s at 5:00 AM of October 20, 2015.

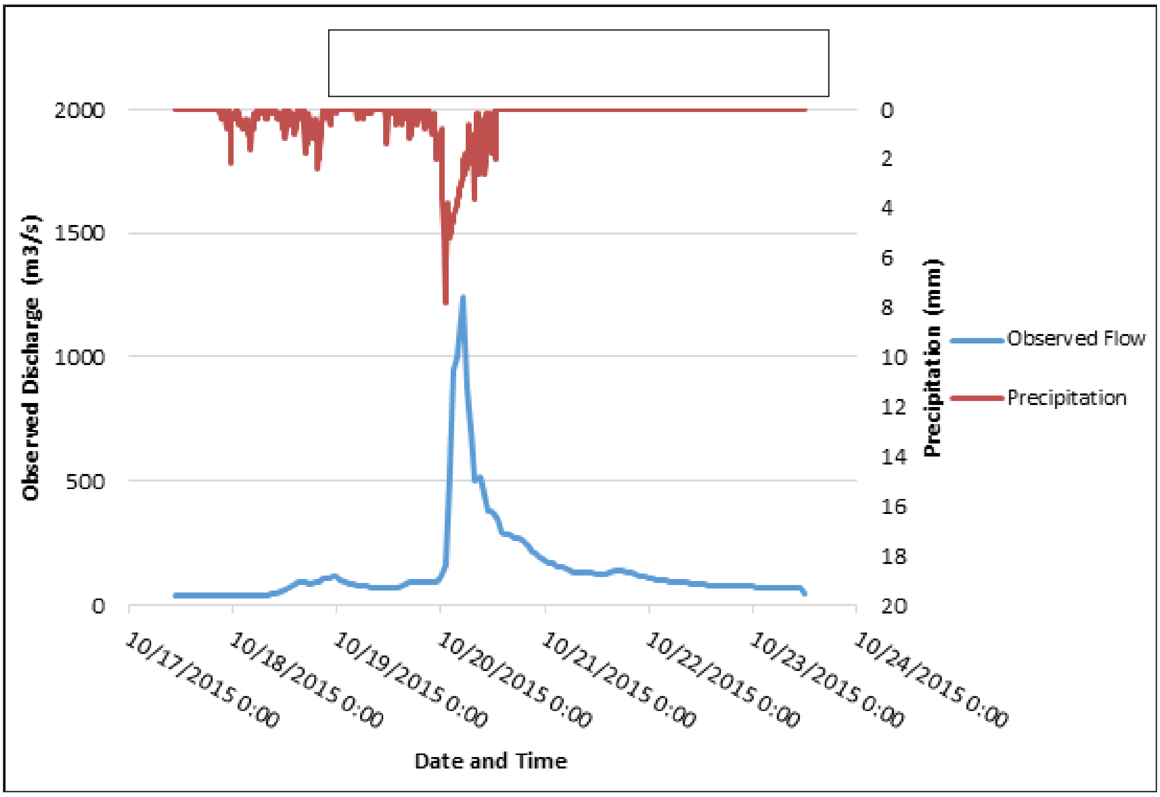


Figure 48. Rainfall and outflow data at Amburayan Bridge used for modeling.

5.2 RIDF Station

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

Table 28. RIDF values for Baguio 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	27.4	41.6	51.9	72.5	108	136.3	199.5	258.6	355.1
5	49.3	75.2	94.2	127.7	189.7	235.7	334.8	436.9	563.6
10	63.8	97.5	122.1	164.3	243.8	301.5	424.3	555	701.7
15	72	110	137.9	184.9	274.4	338.6	474.8	621.6	779.6
20	77.7	118.8	149	199.3	295.7	364.6	510.2	668.2	834.1
25	82.1	125.6	157.5	210.5	312.2	384.6	537.5	704.1	876.1
50	95.8	146.4	183.7	244.7	362.9	446.3	621.4	814.8	1005.5
100	109.3	167.1	209.7	278.7	413.2	507.5	704.7	924.7	1134

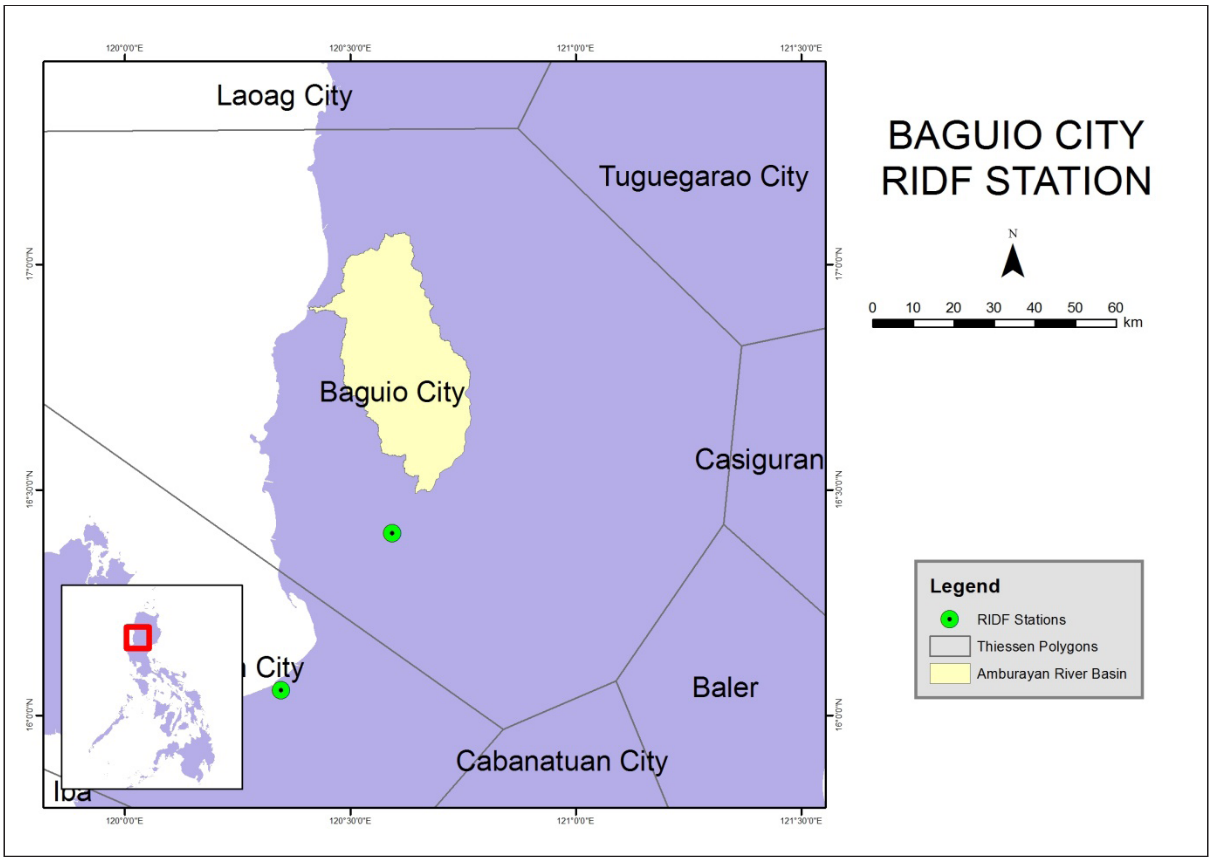


Figure 49. Location of Baguio RIDF Station relative to Amburayan River Basin.

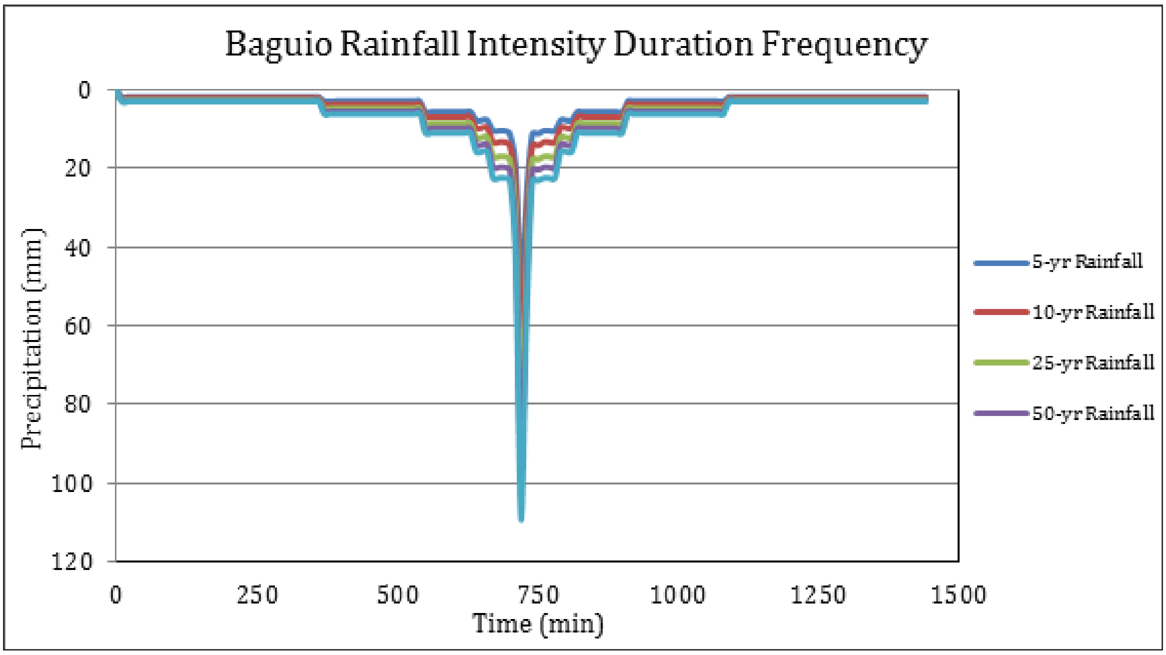


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Amburayan River Basin are shown in Figures 51 and 52, respectively.

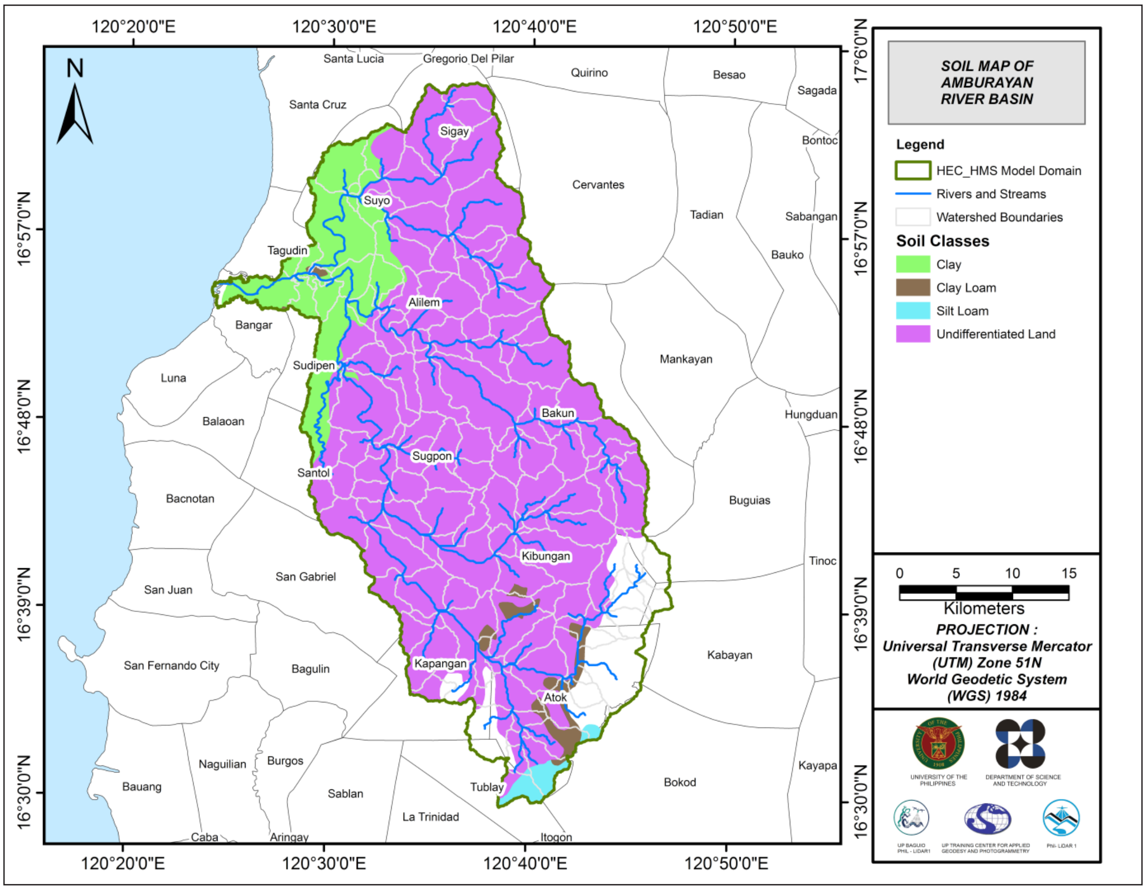


Figure 51. Soil Map of Amburayan River Basin.

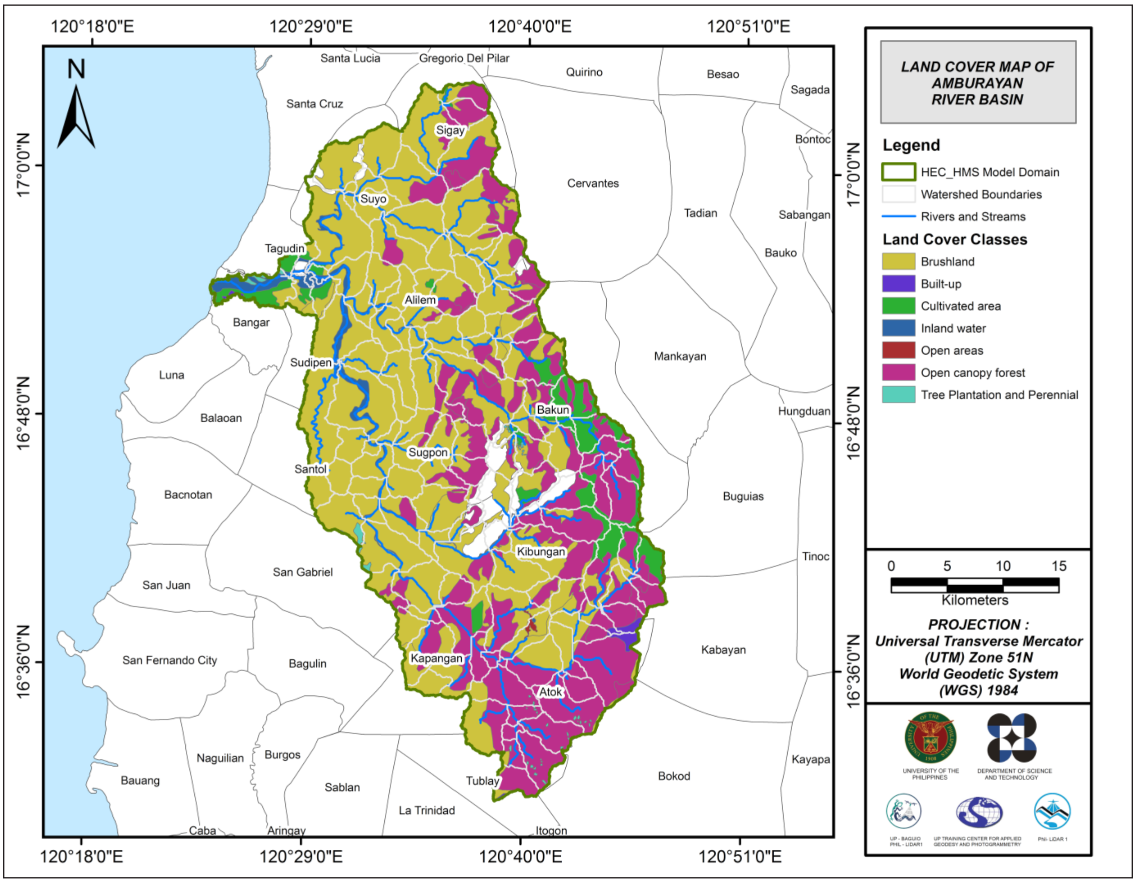


Figure 52. Land Cover Map of Amburayan River Basin.

For Amburayan, four soil classes were identified. These are clay, clay loam, silt loam and undifferentiated land. Moreover, seven land cover classes were identified. These are brushlands, built-up areas, cultivated areas, inland water, open areas, open canopy forests, and tree plantations.

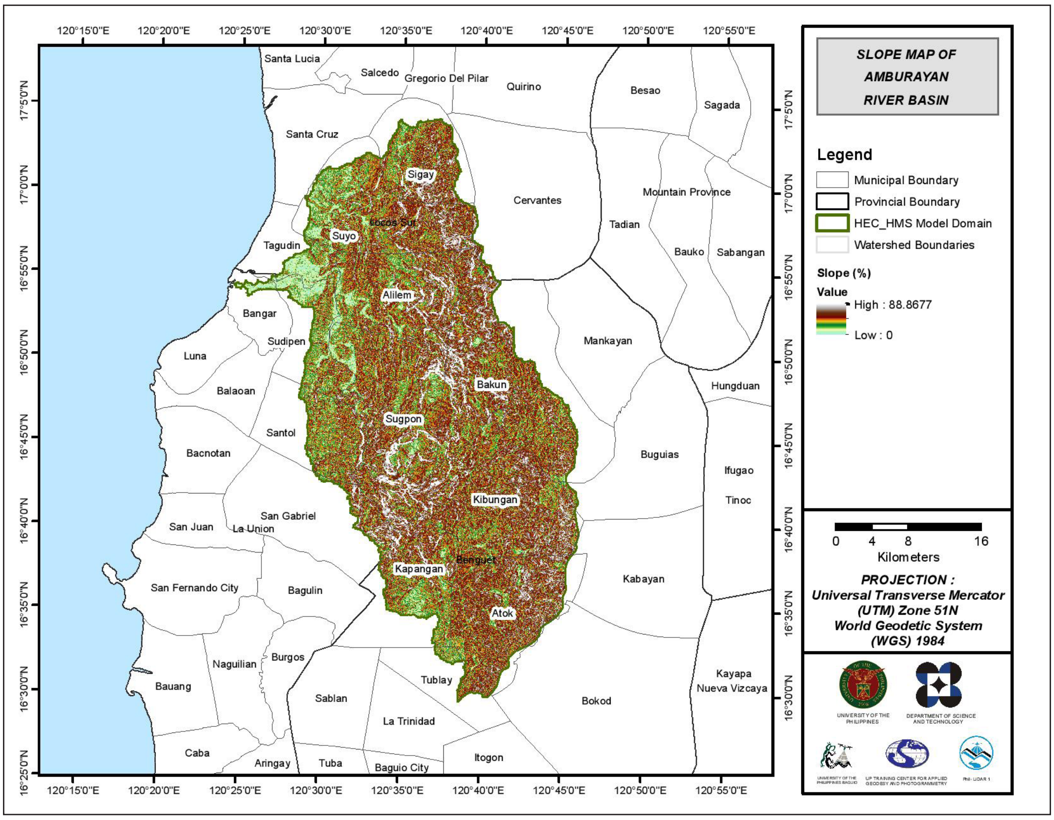


Figure 53. Slope Map of Amburayan River Basin

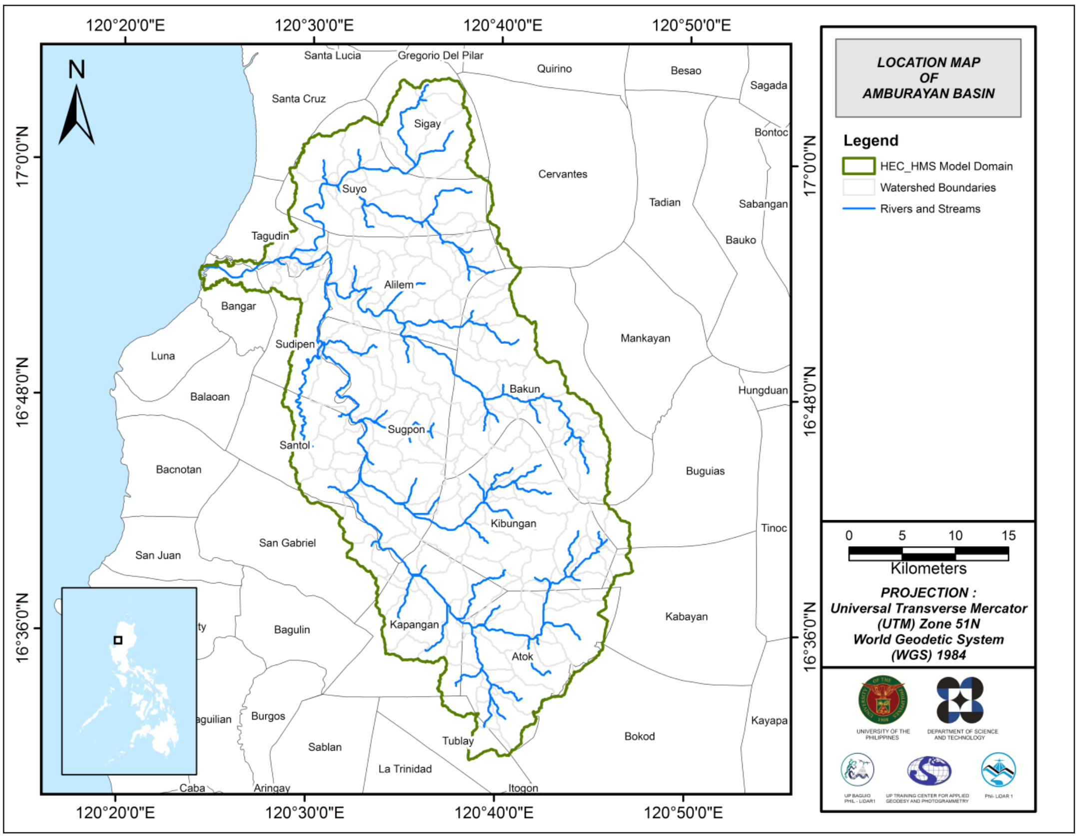


Figure 54. Stream Delineation Map of Amburayan River Basin.

Using the SAR-based DEM, the Amburayan basin was delineated and further subdivided into subbasins. The model consists of 146 sub basins, 146 reaches, and 76 junctions, as shown in Figure 55. The main outlet is 469.

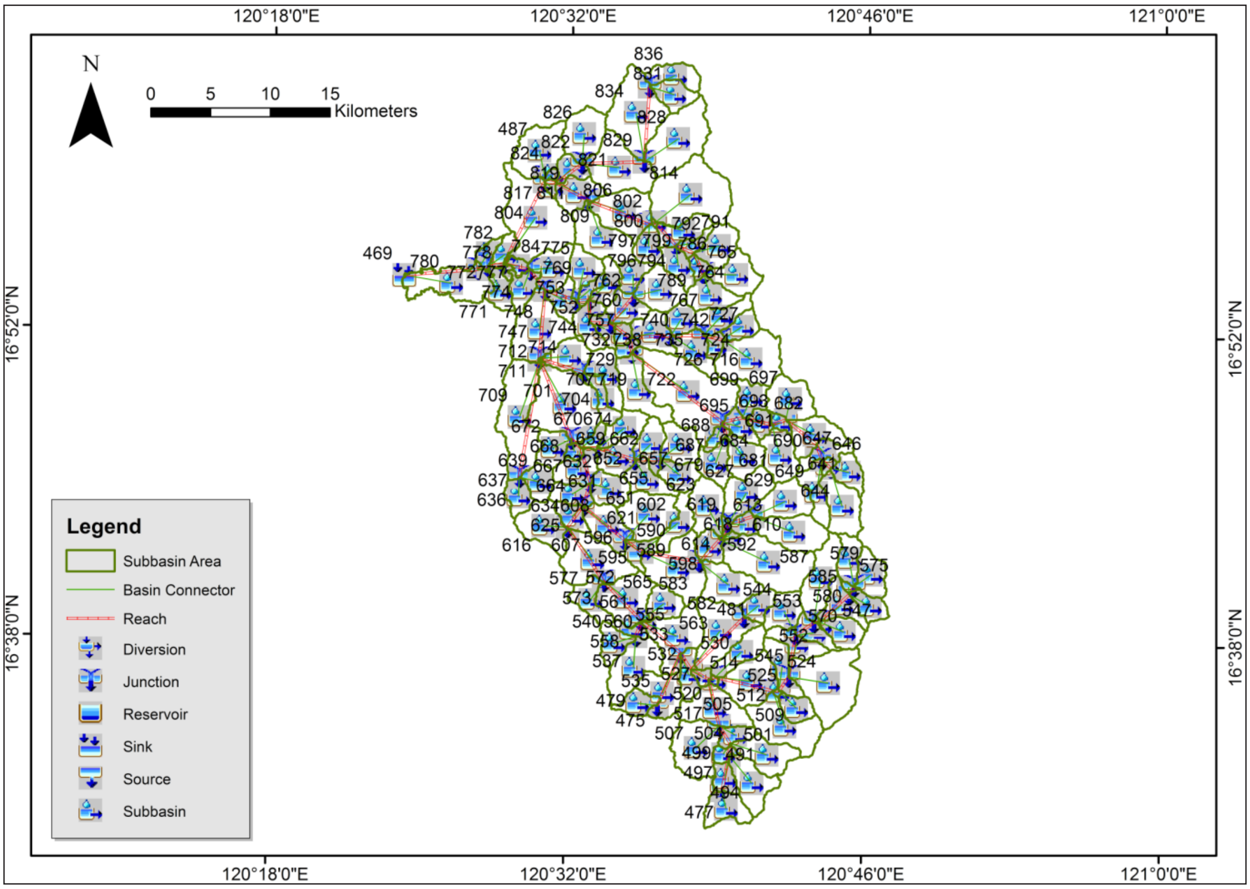


Figure 55. The Amburayan river basin model generated using HEC-HMS

5.4 Cross-section Data

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

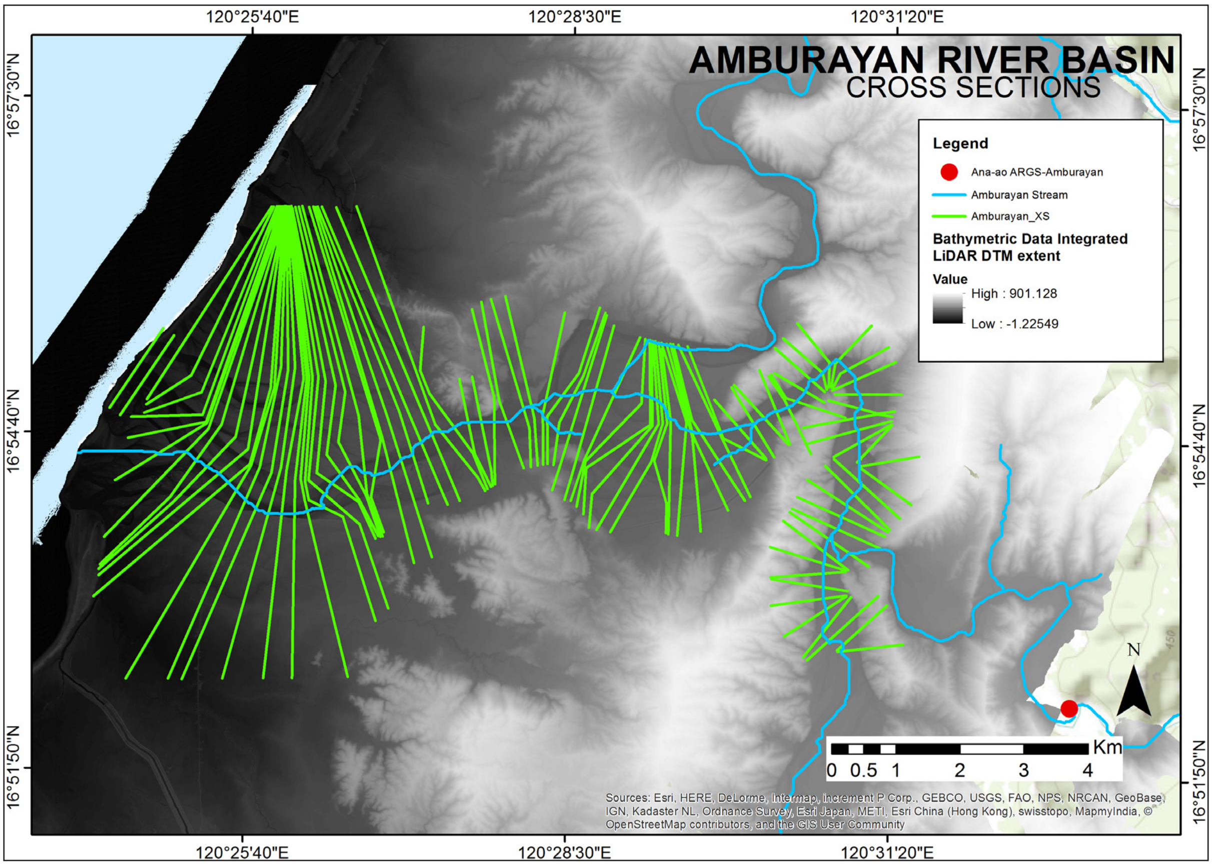


Figure 56. River cross-section of Amburayan River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the south of the model to the northwest, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

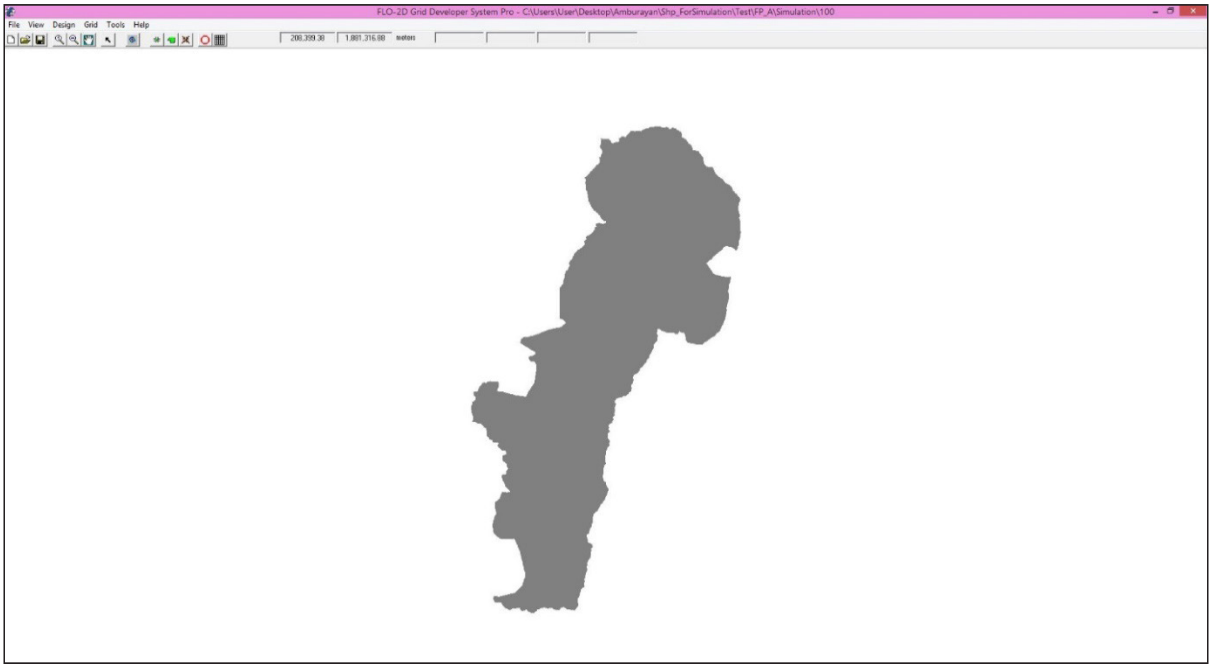


Figure 57. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 44.69 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s. The generated hazard maps for Amburayan are in Figures __, __, and __.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 68,866,656.00 m^2. The generated flood depth maps for Amburayan are in Figures __, __, and __.

There is a total of 24,676,494.27 m^3 of water entering the model, of which 24,507,668.93 m^3 is due to rainfall and 168,825.35 m^3 is inflow from basins upstream. 6,450,876.00 m^3 of this water is lost to infiltration and interception, while 3,622,213.98 m^3 is stored by the flood plain. The rest, amounting up to 14,603,410.79 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Amburayan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 58 shows the comparison between the two discharge data.

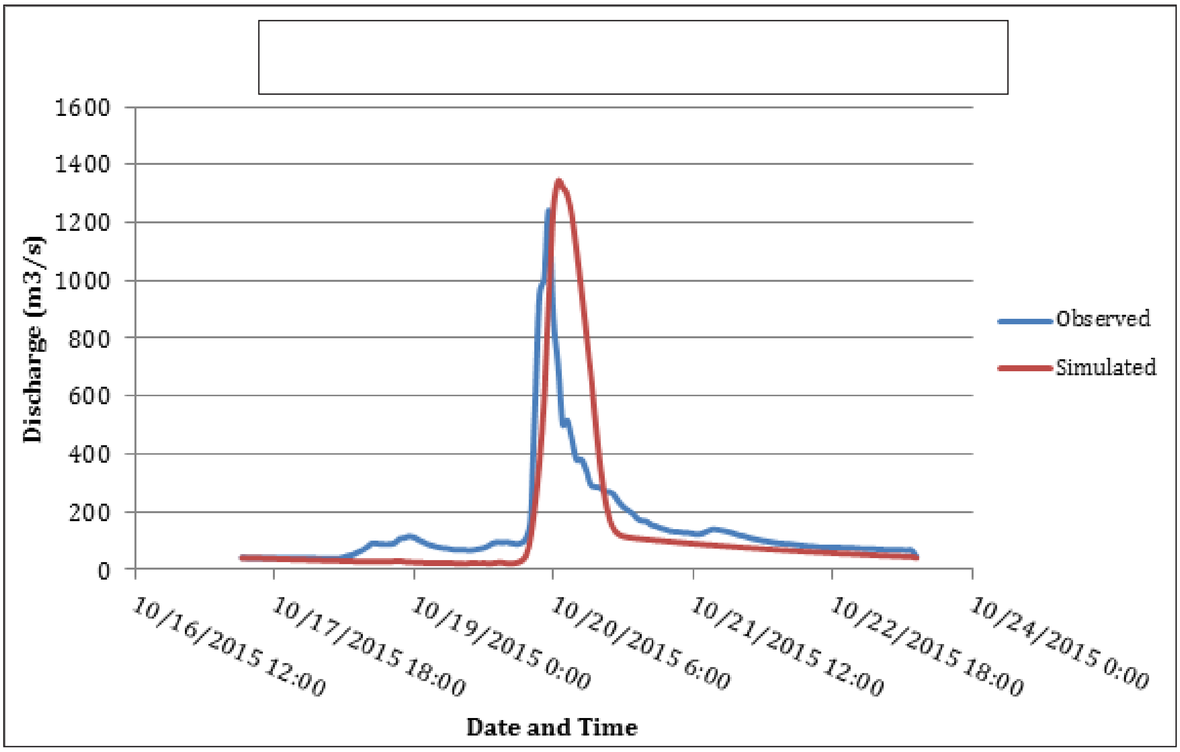


Figure 58. Outflow Hydrograph of Amburayan produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for Amburayan.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	1.92 – 206.37
			Curve Number	35 – 44.55
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.0167 – 0.6178
			Storage Coefficient (hr)	0.0167 – 0.63
	Baseflow	Recession	Recession Constant	0.8
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.01

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 1.92 mm to 206.37 mm means that there is an average initial fraction of the storm depth after which runoff begins.

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 curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Amburayan, the basin consists mainly of brushlands and open canopy forests and the soil consists of mostly undifferentiated land and clay.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.0167 hours to 0.63 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant equal to 0.8 indicate that the basin is unlikely to quickly go back to its original discharge. Ratio to peak of 0.2 indicate a much steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Amburayan river basin reaches' Manning's coefficient is 0.01, showing that the catchment is filled smooth surfaces, making runoff flow faster into the streams.

Table 30. Summary of the Efficiency Test of Amburayan HMS Model

RMSE	179
r^2	0.5907
NSE	0.02
PBIAS	3.5
RSR	0.99

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 179 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.5907.

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 0.02.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 3.50.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.99.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 59) shows the Amburayan outflow using the Baguio Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

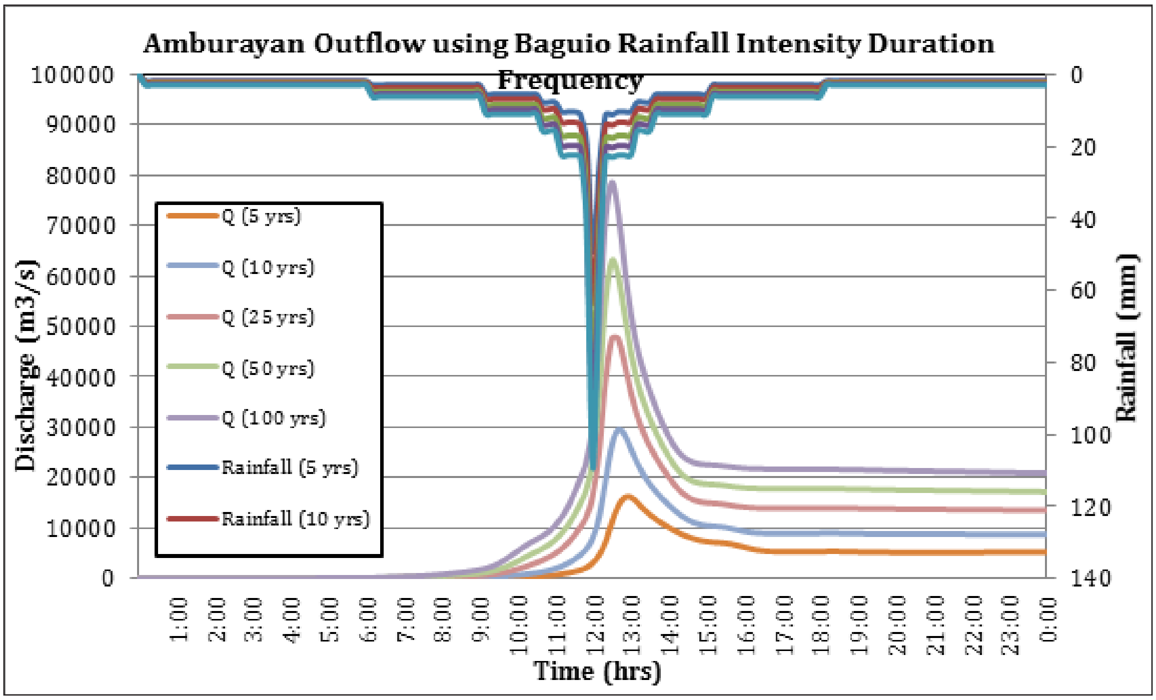


Figure 59. Outflow hydrograph at Amburayan Station generated using the Baguio RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Amburayan discharge using the Baguio Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Amburayan HEC-HMS Model outflow using the Baguio RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	563.85	49.3	16140.3	1 hour
10-Year	701.7	63.8	29519	40 minutes
25-Year	876.1	82.1	47595.5	40 minutes
50-Year	1005.5	95.8	63059.4	30 minutes
100-Year	1134	109.3	78619.3	30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Amburayan River using the calibrated HMS base flow is shown in Figure 60.

Figure 60. Sample output of Amburayan RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Amburayan floodplain are shown in Figures 61 to 66. The floodplain, with an area of 187.2 sq. km., covers 9 municipalities from two provinces. Table 32 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Amburayan floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Ilocos Sur	Alilem	132.18	6.80	5.14%
Ilocos Sur	Santa Cruz	105.96	0.08	0.07%
Ilocos Sur	Suyo	148.52	21.33	14.36%
Ilocos Sur	Tagudin	54.35	52.53	96.66%
La Union	Balaoan	60.96	10.34	16.96%
La Union	Bangar	45.12	45.08	99.90%
La Union	Luna	50.66	8.70	17.17%
La Union	Santol	97.97	3.53	3.61%
La Union	Sudipen	75.75	38.21	50.44%

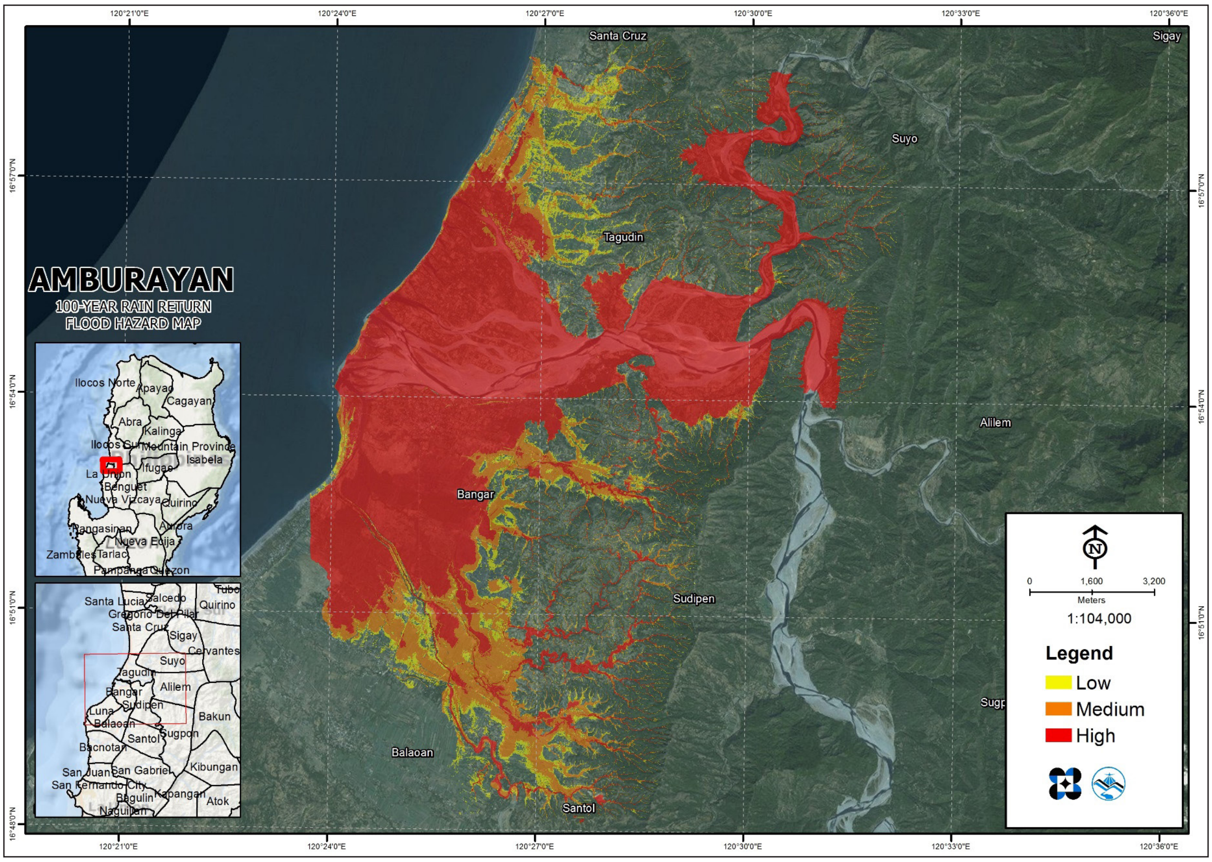


Figure 61. 100-year Flood Hazard Map for Amburayan Floodplain overlaid on Google Earth imagery

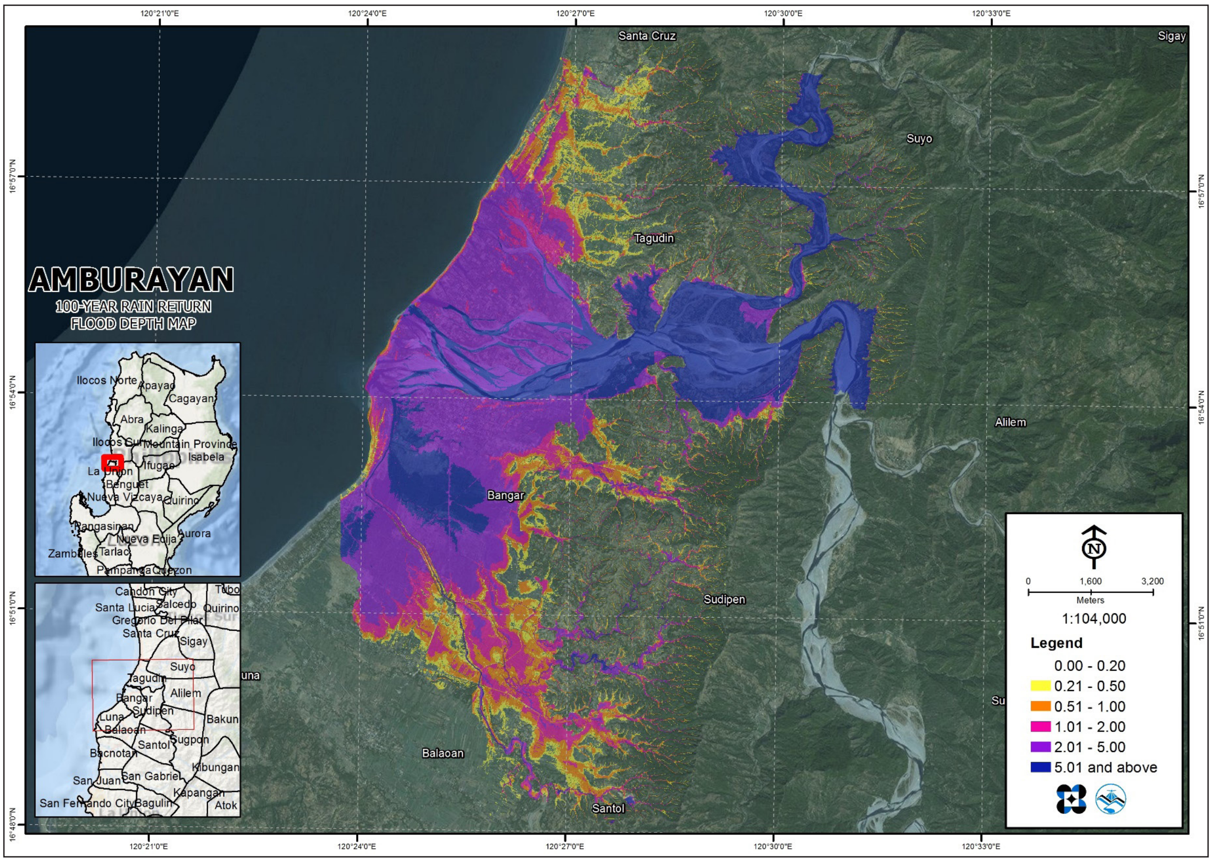


Figure 62. 100-year Flow Depth Map for Amburayan Floodplain overlaid on Google Earth imagery.

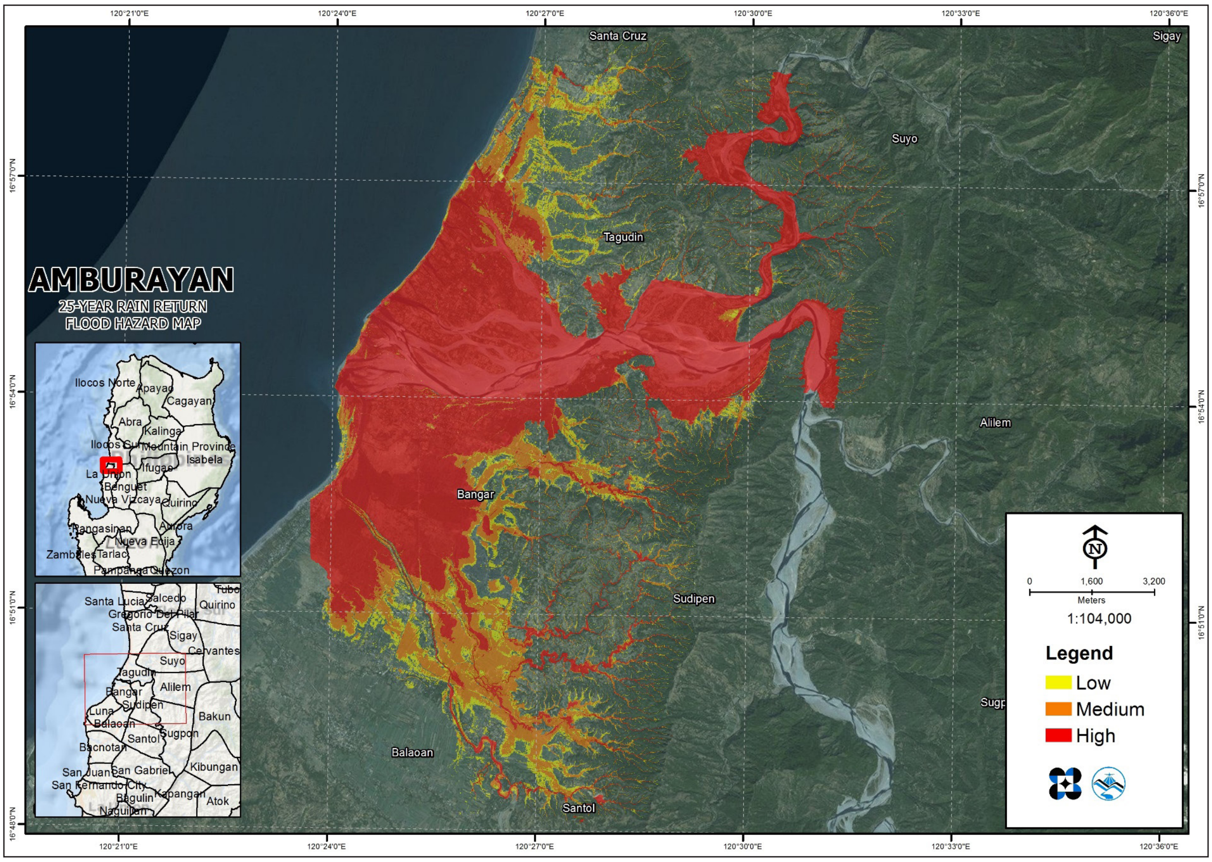


Figure 63. 25-year Flood Hazard Map for Amburayan Floodplain overlaid on Google Earth imagery.

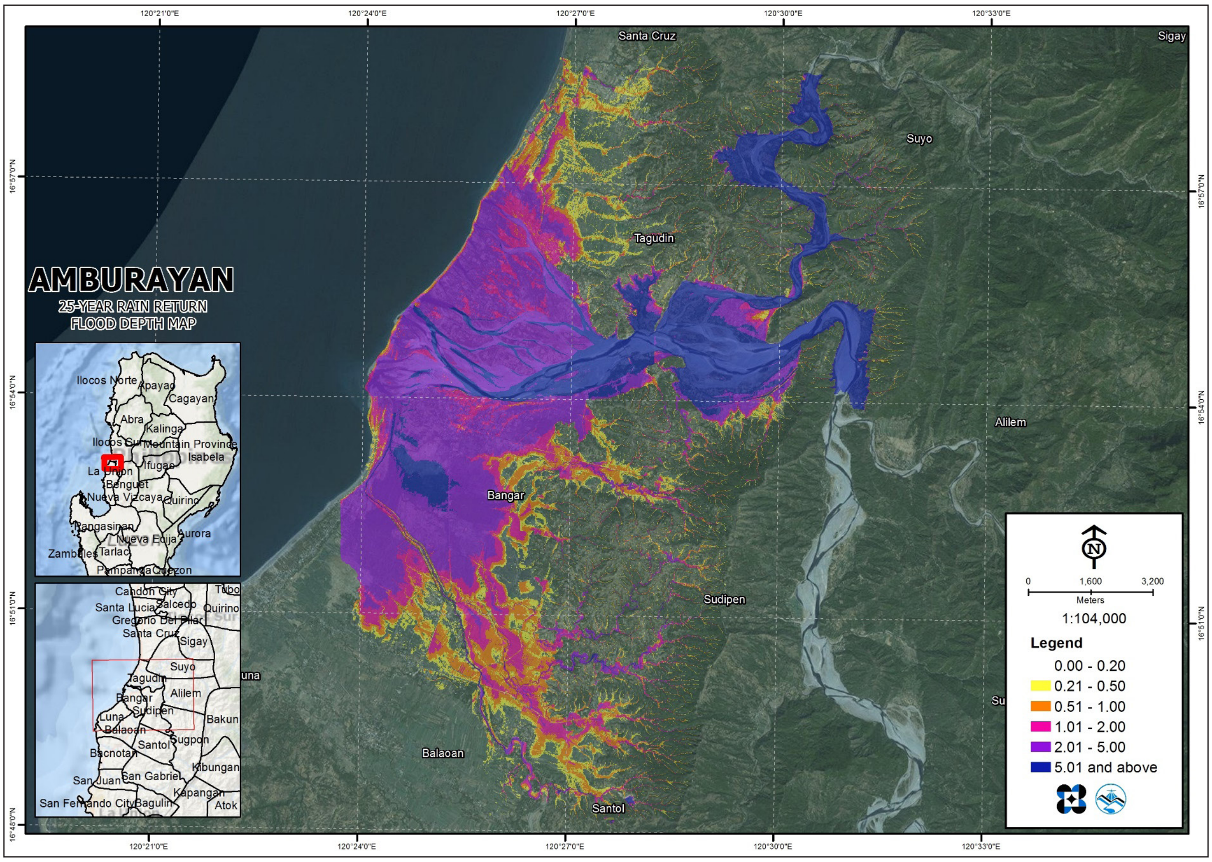


Figure 64. 25-year Flow Depth Map for Amburayan Floodplain overlaid on Google Earth imagery

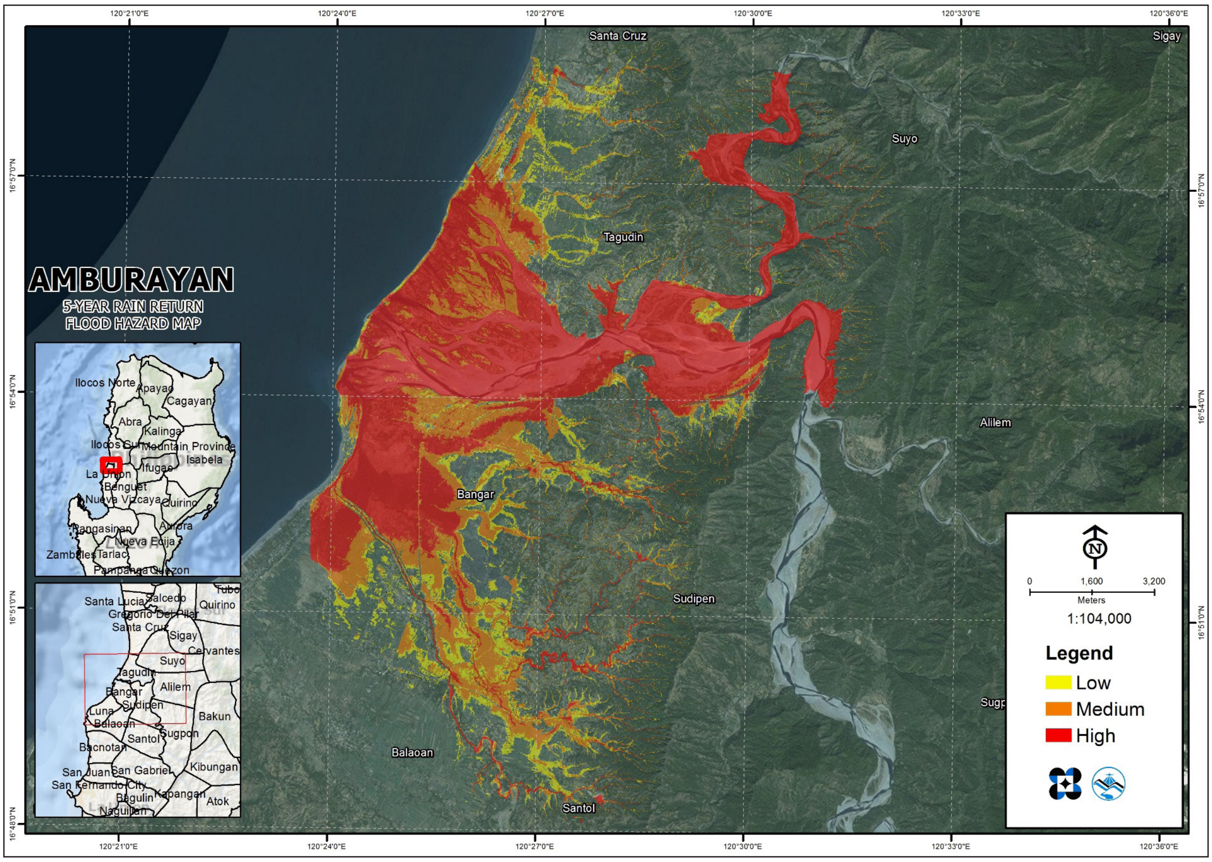


Figure 65. 5-year Flood Hazard Map for Amburayan Floodplain overlaid on Google Earth imagery.

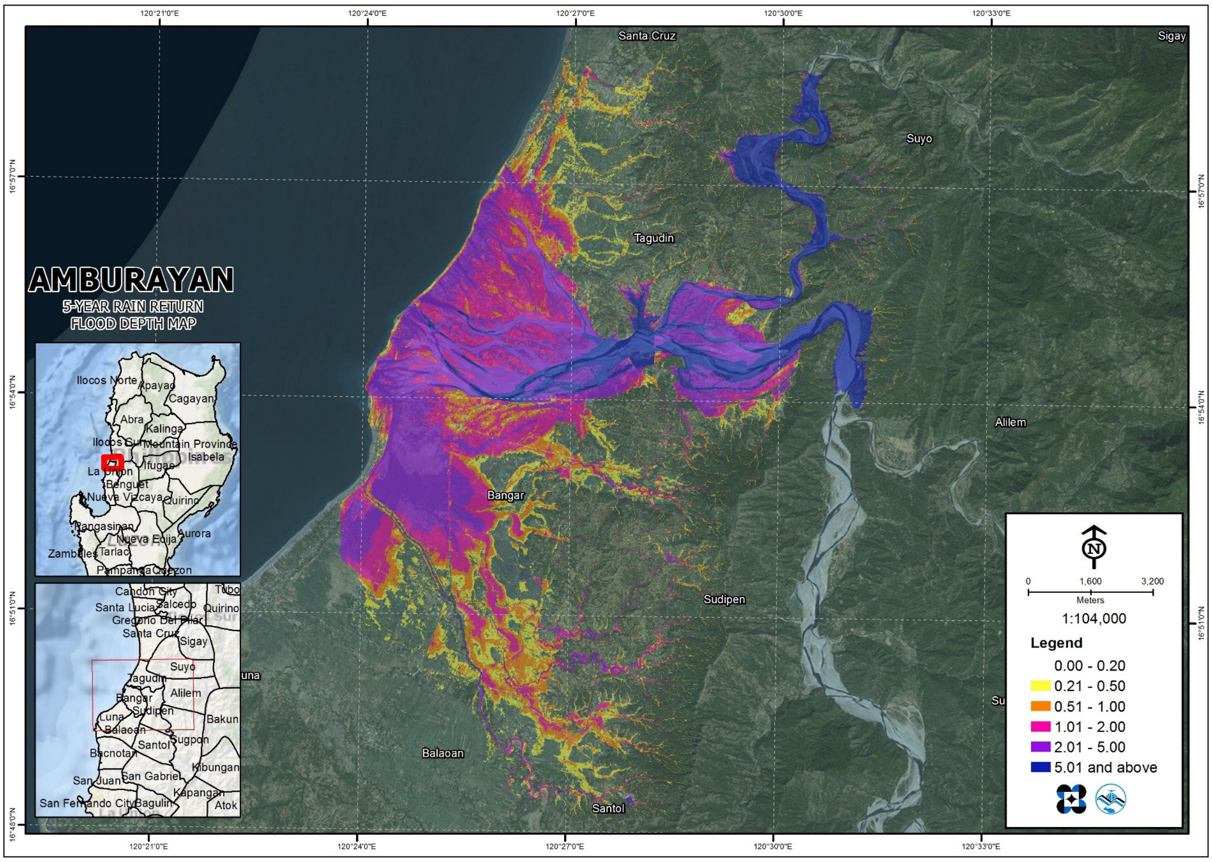


Figure 66. 5-year Flood Depth Map for Amburayan Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Amburayan river basin, grouped by municipality, are listed below. For the said basin, two provinces with 9 municipalities consisting of 130 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 4.04% of the municipality of Alilem with an area of 132.176 sq. km. will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.03%, 0.05%, and 0.85% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Alilem, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Alilem (in sq. km)	
	Dalawa	Kiat
0.03-0.20	5.31	0.03
0.21-0.50	0.16	0.00083
0.51-1.00	0.072	0.0011
1.01-2.00	0.04	0.002
2.01-5.00	0.051	0.0086
> 5.00	0.61	0.52

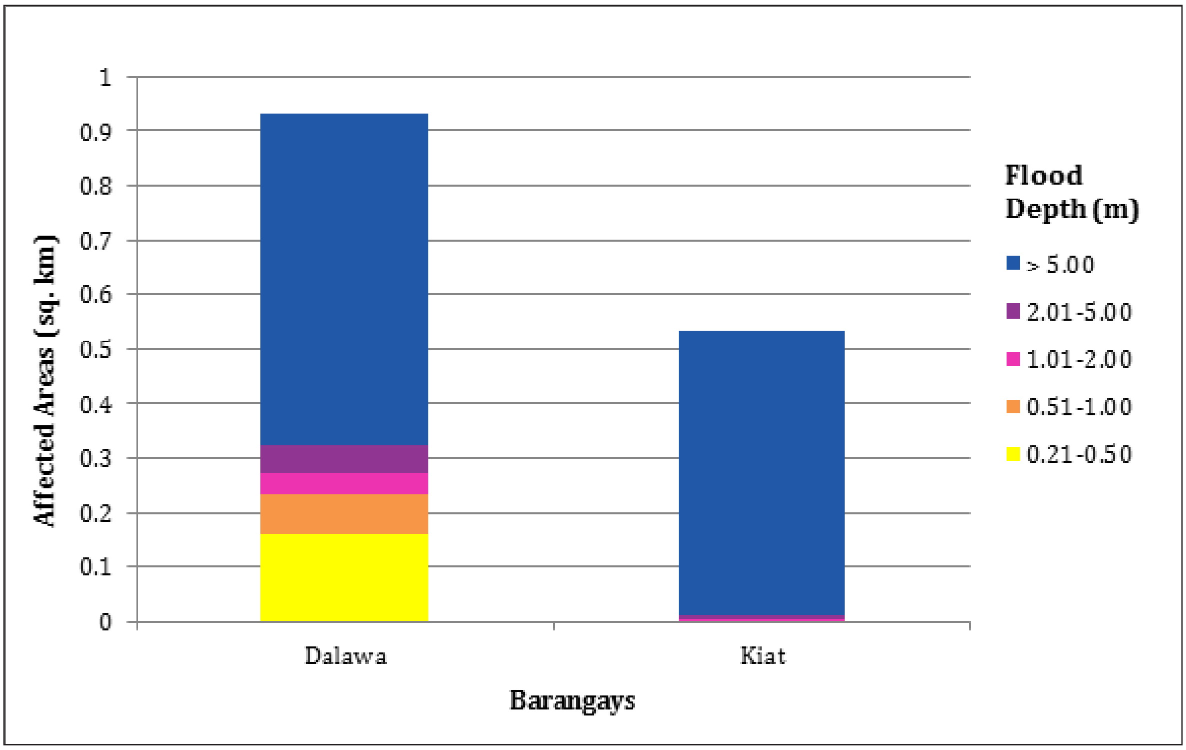


Figure 67. Affected Areas in Alilem, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 0.07% of the municipality of Santa Cruz with an area of 105.955 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Santa Cruz, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Cruz (in sq. km)
	Gabor Sur
0.03-0.20	0.074
0.21-0.50	0.001
0.51-1.00	0.0003
1.01-2.00	0.0004
2.01-5.00	0.0001
> 5.00	0

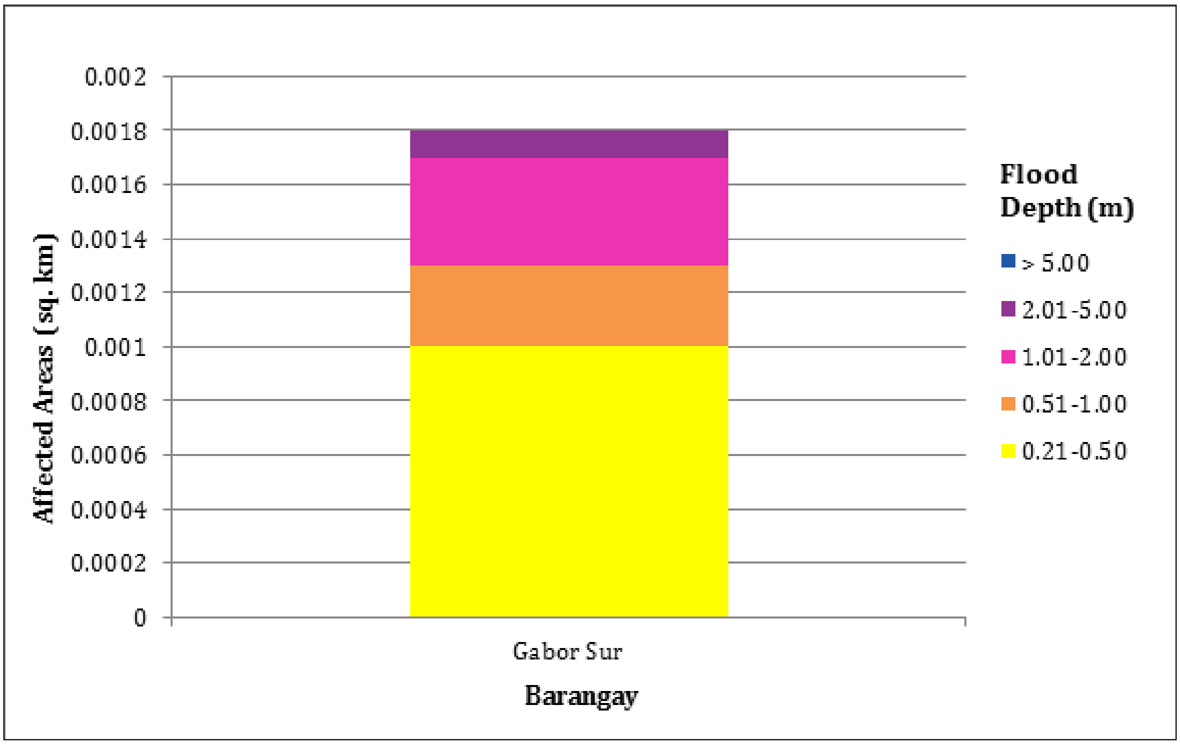


Figure 68. Affected Areas in Santa Cruz, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 11.55% of the municipality of Suyo with an area of 148.52 sq. km. will experience flood levels of less than 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.15%, 0.18%, and 1.99% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Suyo, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Suyo (in sq. km)				
	Baringcucurong	Cabugao	Poblacion	Suyo Proper	Urzadan
0.03-0.20	4.21	8.08	0.89	3.32	0.65
0.21-0.50	0.12	0.24	0.024	0.086	0.018
0.51-1.00	0.062	0.15	0.015	0.046	0.0075
1.01-2.00	0.042	0.13	0.011	0.032	0.0034
2.01-5.00	0.013	0.21	0.012	0.027	0.0013
> 5.00	0	2.81	0.14	0.0047	0

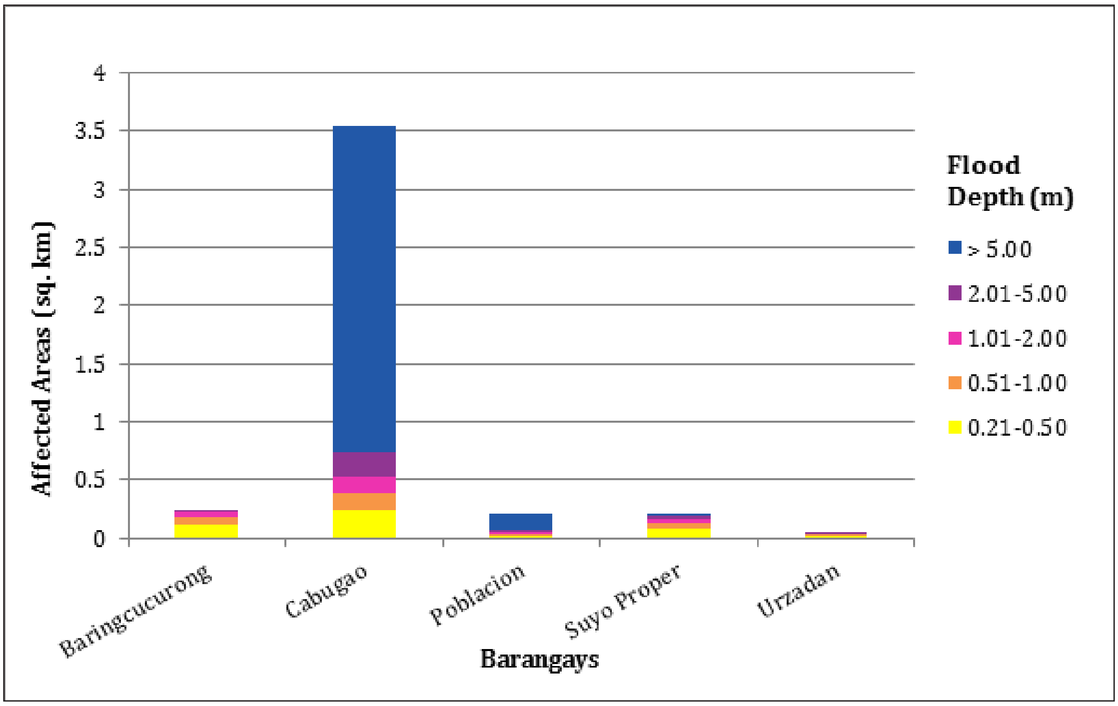


Figure 69. Affected Areas in Suyo, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 49.72% of the municipality of Tagudin with an area of 54.35 sq. km. will experience flood levels of less than 0.20 meters. 6.36% of the area will experience flood levels of 0.21 to 0.50 meters while 5.01%, 11.65%, 15.06%, and 8.91% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)											
	Ag-Aguman	Ambalayat	Baracbac	Bario-An	Baritao	Bimmanga	Bio	Bitalag	Borono	Bucao East	Bucao West	Cabaroan
0.03-0.20	0.4	2.87	1.29	0.78	0.0002	0.1	0.27	1.23	0.85	0.43	0.16	0.25
0.21-0.50	0.023	0.24	0.2	0.046	0.0026	0.076	0.0044	0.2	0.28	0.013	0.012	0.011
0.51-1.00	0.0088	0.17	0.05	0.031	0.15	0.18	0.0061	0.054	0.13	0.0079	0.021	0.013
1.01-2.00	0.017	0.36	0.012	0.03	1.02	0.2	0.014	0.016	0.015	0.016	0.27	0.028
2.01-5.00	0.27	2.5	0.0036	0.0041	0.45	0.067	0.032	0.0017	0	0.3	0.34	0.083
> 5.00	0.097	2.47	0	0	0.0038	0	0.37	0	0	0.42	0.033	0.13

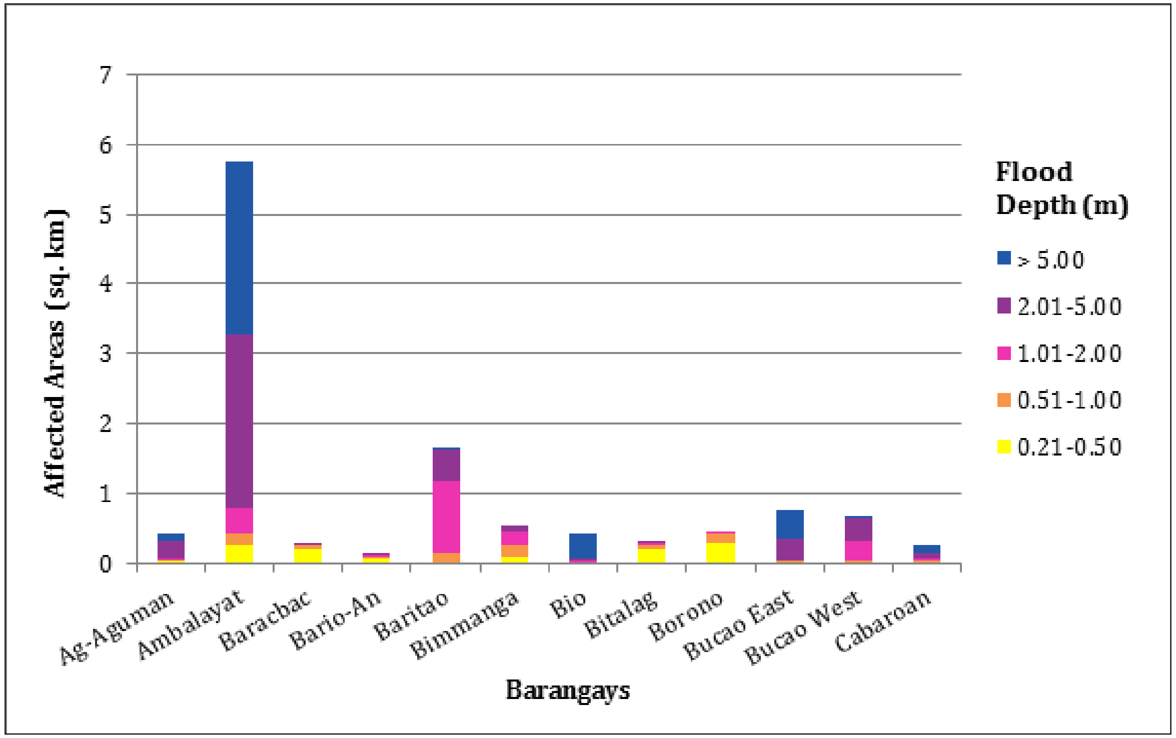


Figure 70. Figure 70. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Table 37. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Cabugbugan	Cabulanglangan	Dacutan	Dardarat	Del Pilar	Farola	Gabur	Garitan	Jardin	Lacong
0.03-0.20	2.38	1.08	1.06	0.37	0.012	0.31	0.56	1.17	0.0002	0.53
0.21-0.50	0.08	0.067	0.34	0.12	0.011	0.17	0.034	0.062	0.0021	0.016
0.51-1.00	0.043	0.032	0.18	0.084	0.036	0.11	0.012	0.013	0.029	0.0028
1.01-2.00	0.018	0.017	0.13	0.068	0.14	0.0059	0.0094	0.0055	0.12	0.0036
2.01-5.00	0.005	0.0085	0.017	0.0004	0.031	0.001	0.0004	0.0006	0.14	0.0016
> 5.00	0	0.015	0	0	0	0	0	0	0.0037	0

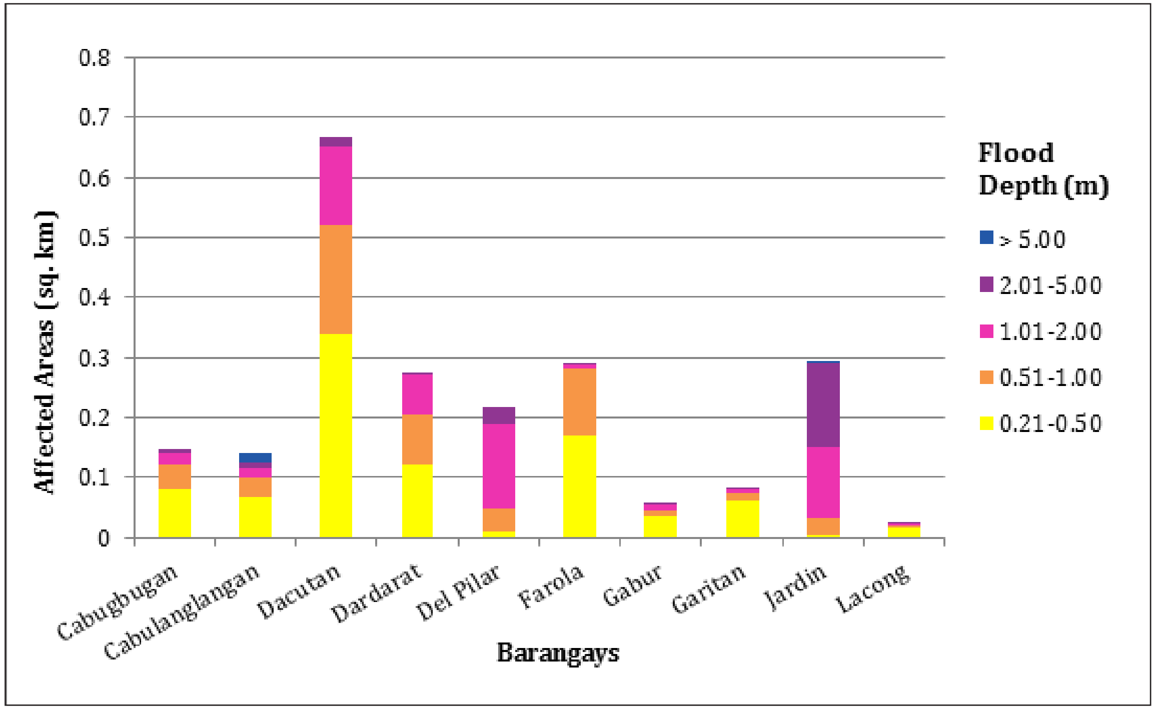


Figure 71. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Table 38. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Lantag	Las-Ud	Libtong	Lubnac	Magsaysay	Malacañang	Pacac	Pallogan	Pudoc East	Pudoc West
0.03-0.20	0.027	0.0053	0.63	1.31	0.23	0.54	0.0093	4.74	0	0.011
0.21-0.50	0.0074	0.011	0.24	0.27	0.094	0.15	0.013	0.17	0.0005	0.029
0.51-1.00	0.035	0.074	0.2	0.05	0.055	0.017	0.1	0.1	0.046	0.044
1.01-2.00	0.41	0.18	0.044	0.0041	0.007	0.0013	0.64	0.11	0.6	0.48
2.01-5.00	0.35	0.1	0.00015	0	0	0	0.89	0.28	0.34	0.88
> 5.00	0.027	0	0	0	0	0	0	0.9	0.05	0.036

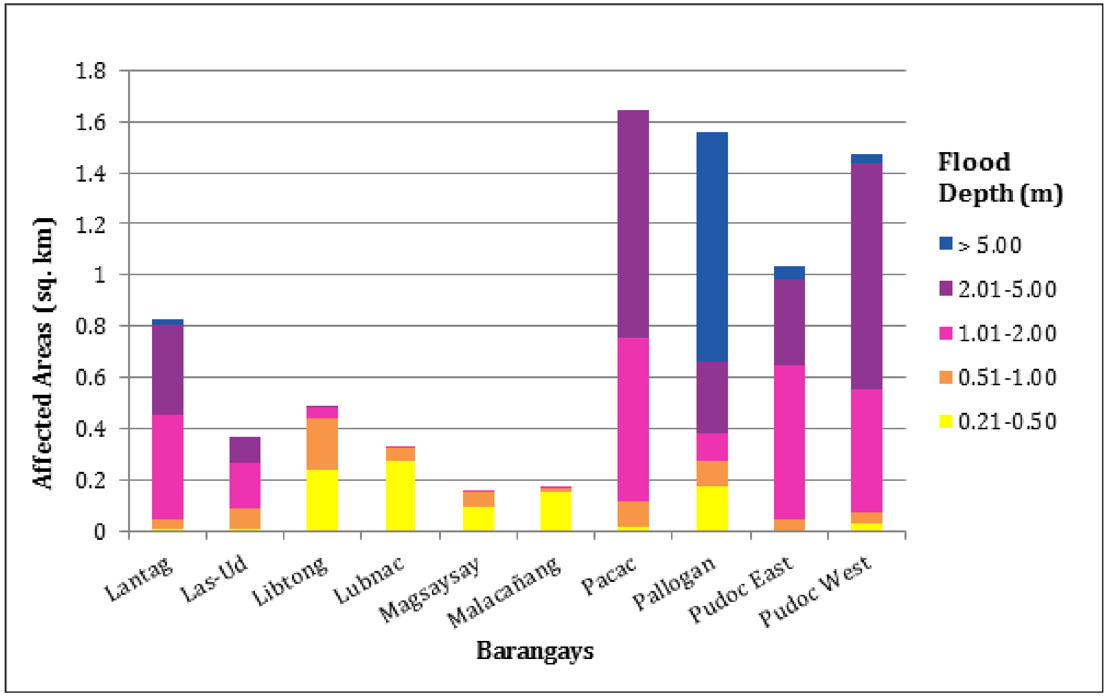


Figure 72. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Table 39. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Pula	Quirino	Ranget	Rizal	Salvacion	San Miguel	Sawat	Tallaoen	Tampugo	Tarangotong
0.03-0.20	0.098	0.075	1.27	0.12	0.12	0.36	0.0051	0.8	0.55	0.022
0.21-0.50	0.0034	0.043	0.063	0.0077	0.0083	0.017	0.013	0.21	0.053	0.044
0.51-1.00	0.0083	0.2	0.019	0.0068	0.042	0.0028	0.089	0.06	0.029	0.18
1.01-2.00	0.014	0.075	0.012	0.0048	0.2	0.00062	0.37	0.0021	0.039	0.62
2.01-5.00	0.13	0.0036	0.0025	0.0042	0.16	0	0.33	0.0002	0.019	0.44
> 5.00	0.27	0.00018	0.0002	0	0.014	0	0	0	0	0

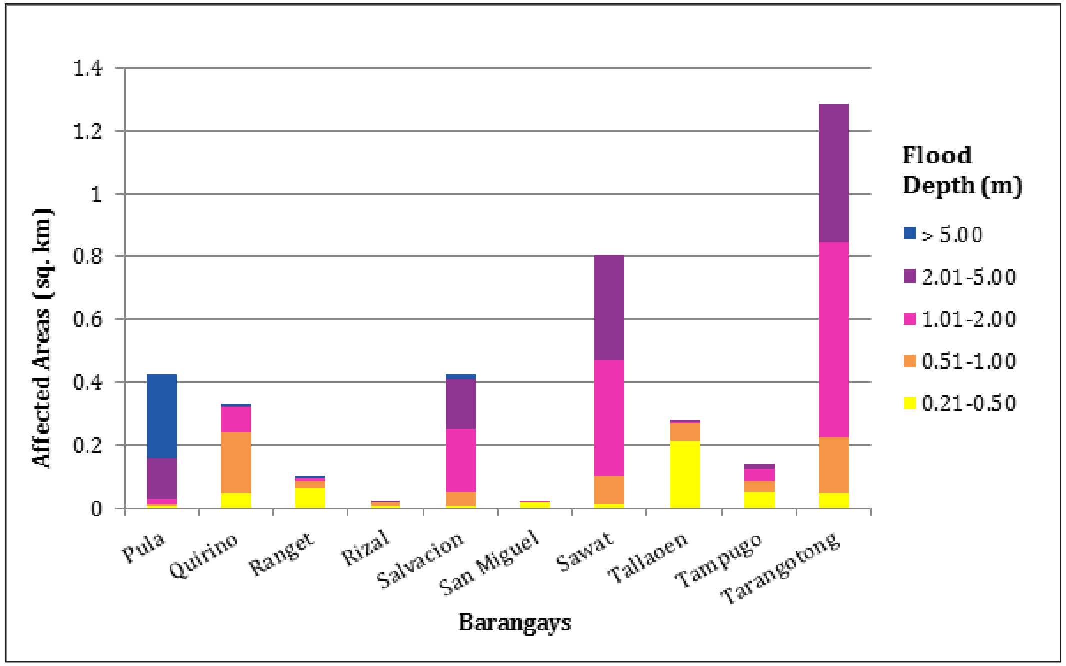


Figure 73. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 10.53% of the municipality of Balaoan with an area of 60.96 sq. km. will experience flood levels of less than 0.20 meters. 2.55% of the area will experience flood levels of 0.21 to 0.50 meters while 2.30%, 1.00%, 0.54%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Balaoan, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balaoan (in sq. km)						
	Baracbac Este	Baracbac Oeste	Bet-Ang	Bulbulala	Butubut Norte	Butubut Oeste	Calliat
0.03-0.20	0.53	0.83	0.26	0.6	0.59	0.27	0.63
0.21-0.50	0.17	0.13	0.067	0.012	0.041	0.0043	0.086
0.51-1.00	0.095	0.043	0.0085	0.0043	0.033	0.00036	0.083
1.01-2.00	0.064	0.012	0.00032	0.0078	0.031	0	0.018
2.01-5.00	0.046	0.052	0.0013	0.0083	0.03	0	0.014
> 5.00	0.000099	0.0035	0.0012	0	0	0	0

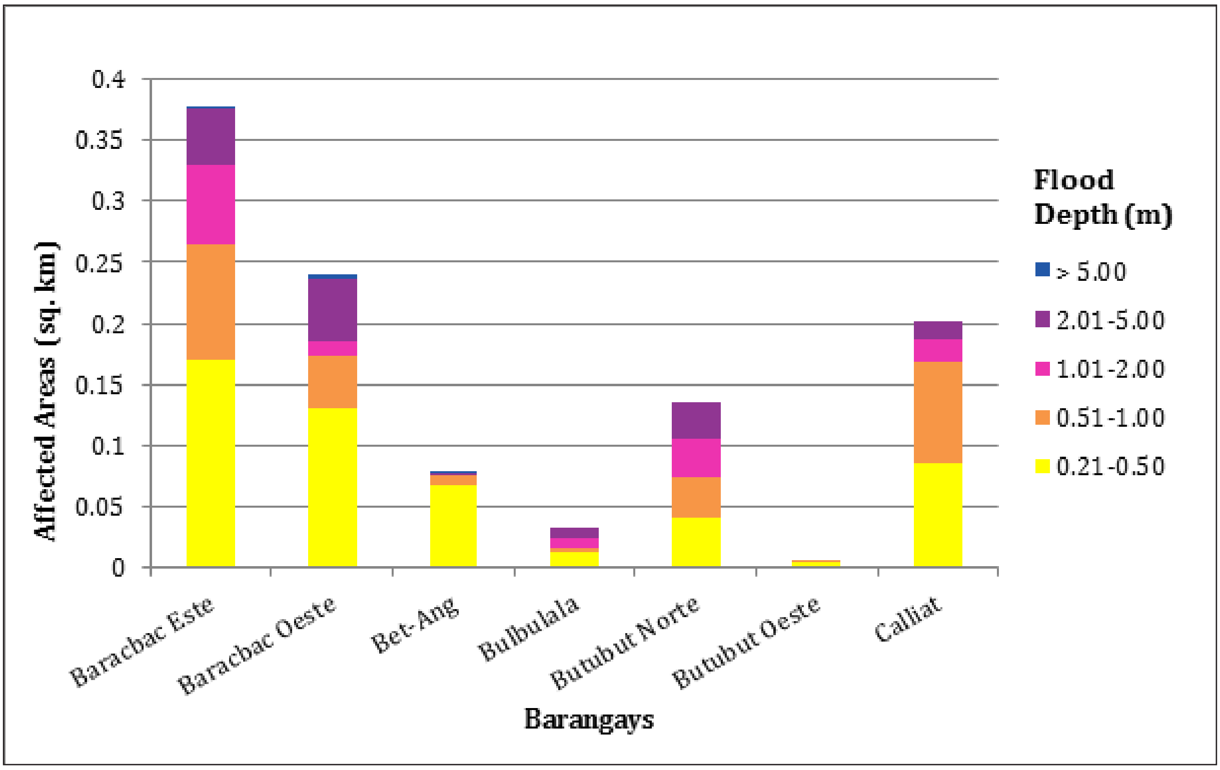


Figure 74. Affected Areas in Tagudin, Ilocos Sur during 5-Year Rainfall Return Period.

Table 41. Affected Areas in Balaoan, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balaoan (in sq. km)						
	Napaset	Pantar Norte	Pantar Sur	Sablut	Sinapangan Norte	Sinapangan Sur	Tallipugo
0.03-0.20	0.14	0.11	0.49	0.21	0.52	1.01	0.23
0.21-0.50	0.08	0.017	0.067	0.11	0.17	0.059	0.54
0.51-1.00	0.019	0.0032	0.01	0.034	0.32	0.12	0.63
1.01-2.00	0	0.0003	0.011	0.0059	0.15	0.049	0.26
2.01-5.00	0	0	0.0084	0.01	0.015	0.096	0.05
> 5.00	0	0	0	0.0056	0	0.0073	0.013

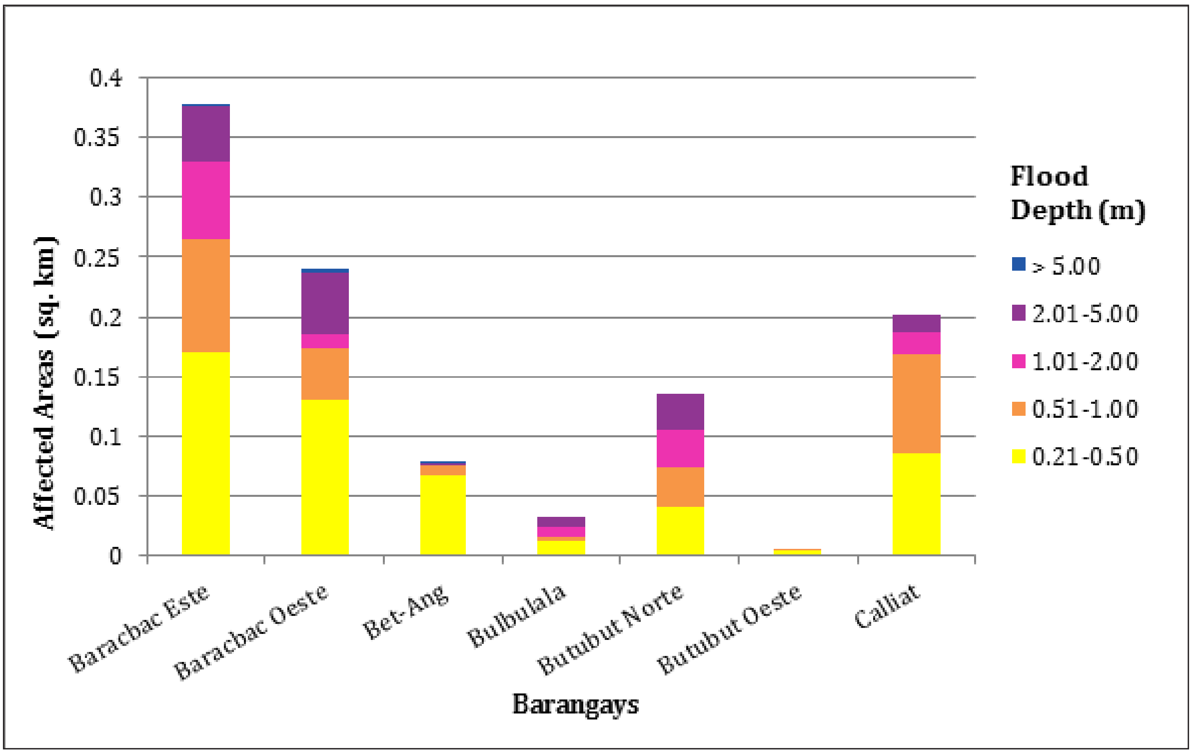


Figure 75. Affected Areas in Balaoan, La Union during 5-Year Rainfall Return Period.

For the 5-year return period, 35.58% of the municipality of Bangar with an area of 45.12 sq. km. will experience flood levels of less than 0.20 meters. 8.39% of the area will experience flood levels of 0.21 to 0.50 meters while 10.99%, 17.07%, 25.47%, and 2.49% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Bangar, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Agdeppa	Alzate	Bangaoilan East	Bangaoilan West	Barraca	Cadapli	Caggao	Central East No. 1	Central East No. 2	Central West No. 1	Central West No. 2
0.03-0.20	0.046	0	0.53	0.14	0.006	0.34	0.0033	0	0	0	0.012
0.21-0.50	0.037	0	0.12	0.067	0.026	0.22	0.012	0	0.00036	0.00027	0.0099
0.51-1.00	0.06	0.0077	0.11	0.1	0.13	0.32	0.073	0.0002	0.0067	0.0066	0.025
1.01-2.00	0.23	0.5	0.34	0.27	0.21	0.09	0.25	0.04	0.027	0.033	0.02
2.01-5.00	2.88	0.83	0.19	0.22	0.33	0.023	0.42	0.0084	0	0.015	0
> 5.00	0	0.096	0.12	0.25	0	0.00073	0.0023	0	0	0	0

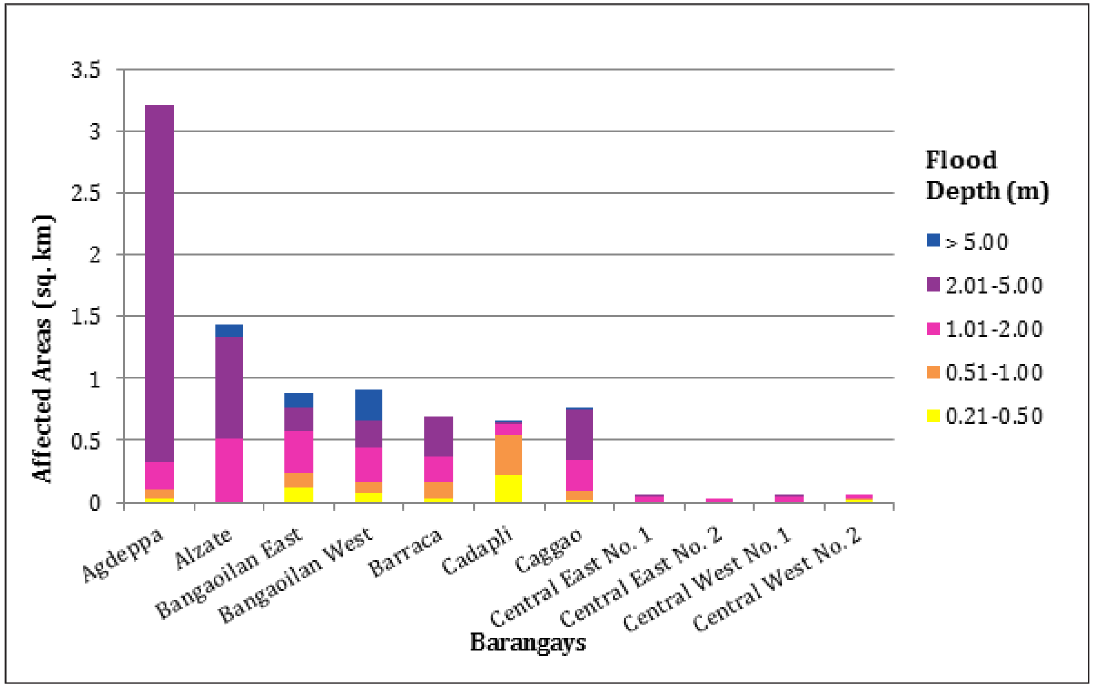


Figure 76. Affected Areas in Bangar, La Union during 5-Year Rainfall Return Period.

Table 43. Affected Areas in Bangar, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Central West No. 3	Consuegra	General Prim East	General Prim West	General Terrero	Luzong Norte	Luzong Sur	Maria Cristina East	Maria Cristina West	Mindoro	Nagsabaran
0.03-0.20	0	0.01	0.011	0.014	0.0091	3.24	3.05	0.016	0.0077	0.012	0
0.21-0.50	0.0003	0.024	0.015	0.011	0.03	0.33	0.16	0.022	0.032	0.042	0
0.51-1.00	0.009	0.099	0.059	0.061	0.16	0.35	0.097	0.11	0.16	0.1	0.0012
1.01-2.00	0.05	0.25	0.19	0.26	0.071	0.29	0.089	0.2	0.17	0.52	0.054
2.01-5.00	0	0.58	0.16	0.59	0.21	0.066	0.093	0.0038	0.021	1.55	0.33
> 5.00	0	0.099	0.11	0.22	0.041	0.0003	0.0011	0.0047	0.11	0.054	0

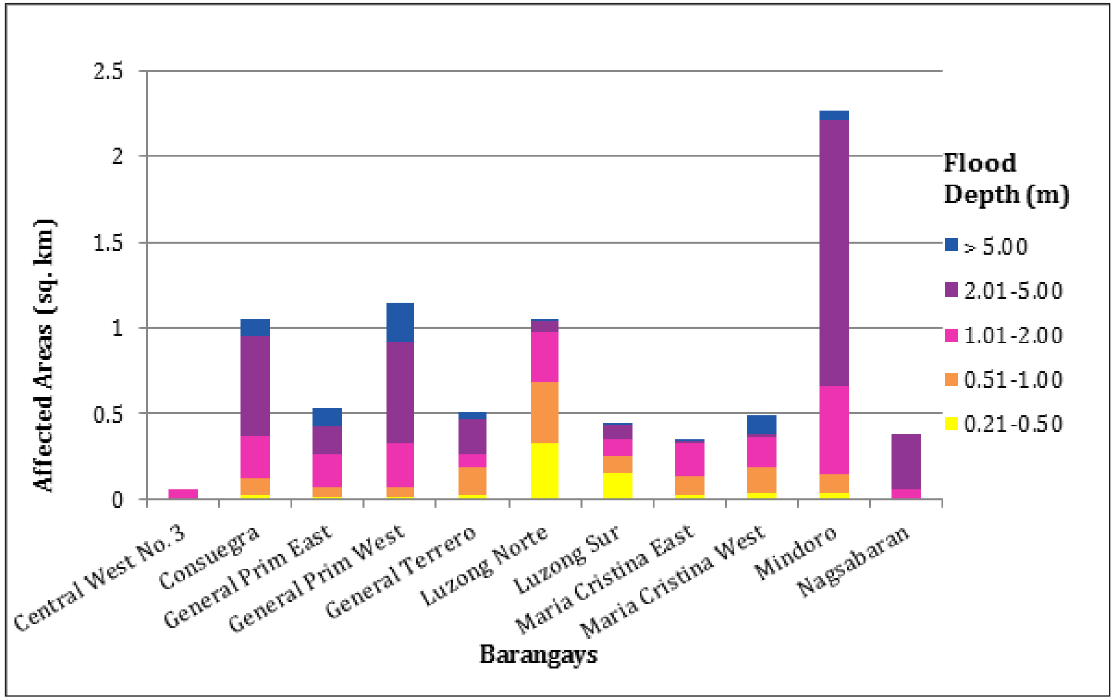


Figure 77. Affected Areas in Bangar, La Union during 5-Year Rainfall Return Period.

Table 44. Affected Areas in Bangar, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Paratong No. 3	Paratong No. 4	Paratong Norte	Quintarong	Reyna Regente	Rissing	San Blas	San Cristobal	Sinapangan Norte	Sinapangan Sur	Ubbog
0.03-0.20	0.1	0.15	0.037	0	0.0005	1.02	0.021	2.74	2.36	1.23	0.95
0.21-0.50	0.027	0.016	0.023	0	0.0029	0.54	0.059	0.48	0.37	0.71	0.4
0.51-1.00	0.03	0.0074	0.065	0.0018	0.038	0.76	0.12	0.3	0.23	0.96	0.4
1.01-2.00	0.019	0.037	0.15	0.023	0.21	1.34	0.52	0.14	0.14	0.45	0.52
2.01-5.00	0.15	0.2	0.3	0.27	0.081	0.75	0.91	0.081	0.05	0.18	0.00089
> 5.00	0	0	0	0	0	0.0033	0	0.0016	0.001	0.0075	0

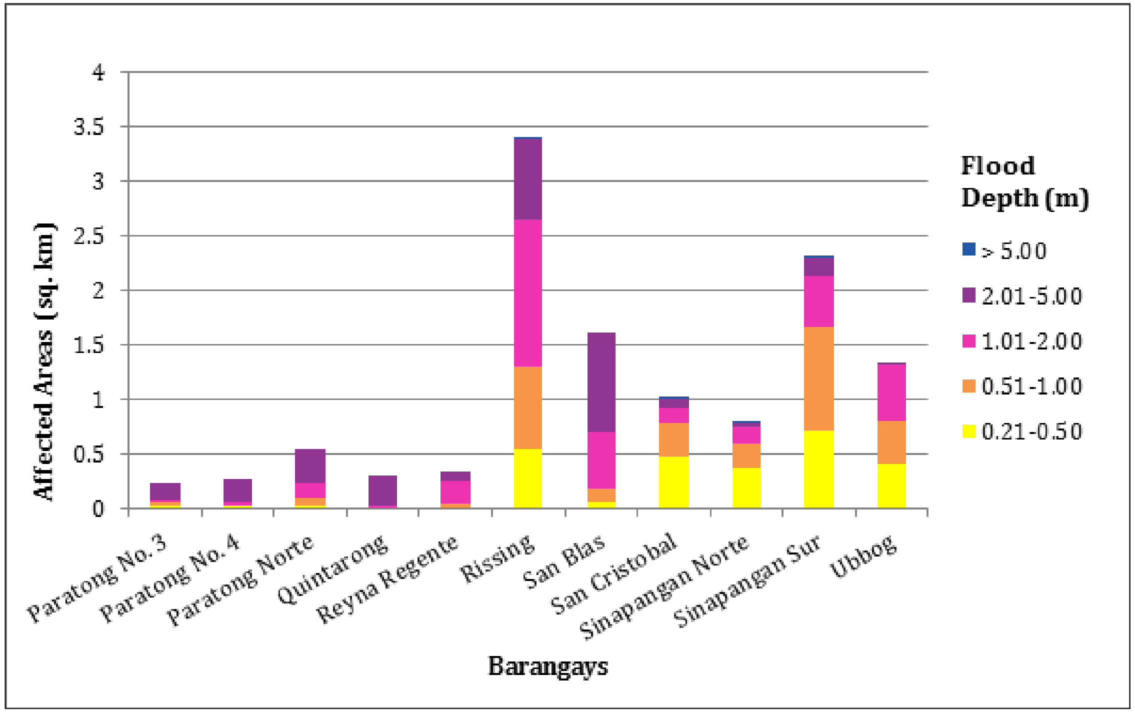


Figure 78. Affected Areas in Bangar, La Union during 5-Year Rainfall Return Period.

For the 5-year return period, 8.27% of the municipality of Luna with an area of 50.66 sq. km. will experience flood levels of less than 0.20 meters. 1.91% of the area will experience flood levels of 0.21 to 0.50 meters while 1.66%, 2.88%, 2.46%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Luna, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km)								
	Barangobong	Cantoria No. 1	Cantoria No. 2	Cantoria No. 3	Cantoria No. 4	Napaset	Oaqui No. 1	Oaqui No. 2	Oaqui No. 3
0.03-0.20	0.3	0.41	0.039	0.23	0.29	0.092	0.5	0.33	0.14
0.21-0.50	0.083	0.038	0.0002	0.01	0.066	0.0077	0.078	0.055	0.022
0.51-1.00	0.012	0.0034	0	0.0001	0.059	0.00096	0.00071	0.0001	0.052
1.01-2.00	0	0	0	0	0.002	0.00021	0	0	0.013
2.01-5.00	0	0	0	0	0	0.0011	0	0	0
> 5.00	0	0	0	0	0	0.00092	0	0	0

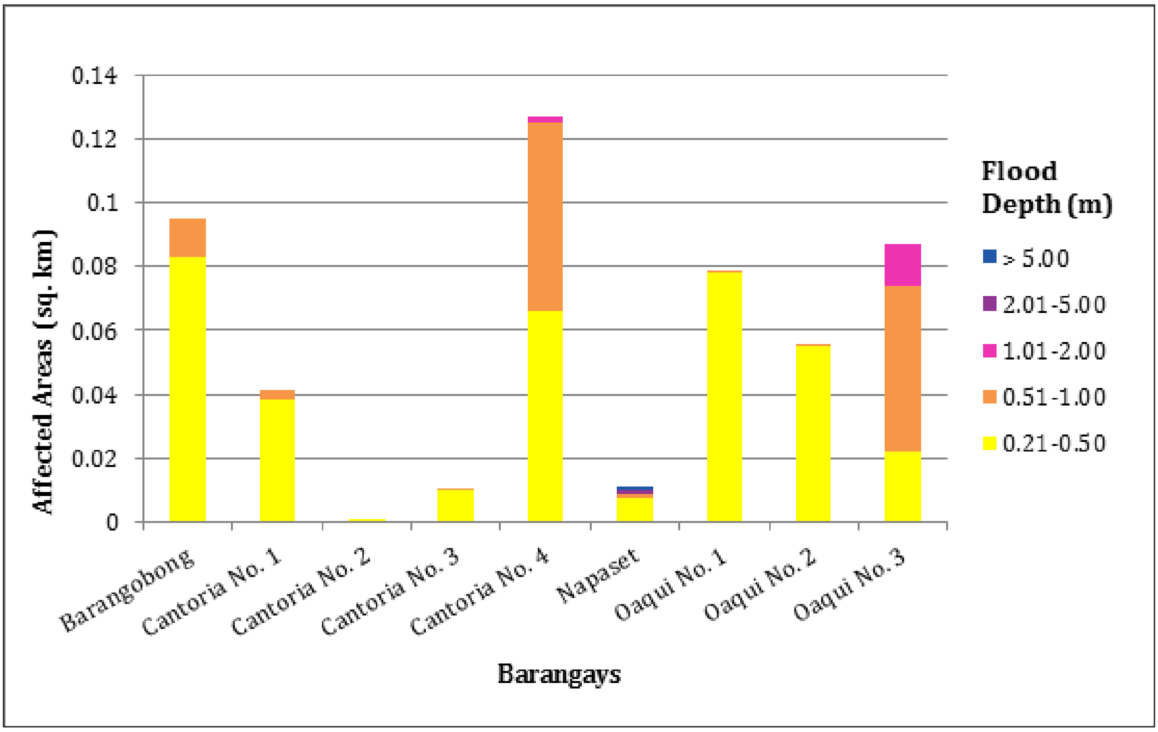


Figure 79. Affected Areas in Luna, La Union during 5-Year Rainfall Return Period.

Table 46. Affected Areas in Luna, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km)								
	Oaqui No. 4	Rimos No. 1	Rimos No. 2	Rimos No. 3	Rimos No. 4	Rimos No. 5	Rissing	Santo Domingo Norte	Suyo
0.03-0.20	0.1	0.026	0.002	0.16	0.19	0.34	0.38	0.0016	0.66
0.21-0.50	0.06	0.021	0.0029	0.068	0.1	0.098	0.066	0.0001	0.19
0.51-1.00	0.027	0.065	0.035	0.12	0.14	0.14	0.12	0	0.066
1.01-2.00	0	0.013	0.25	0.26	0.28	0.5	0.14	0	0.000095
2.01-5.00	0	0.0027	0.15	0.28	0.4	0.39	0.02	0	0
> 5.00	0	0	0	0	0	0	0.011	0	0

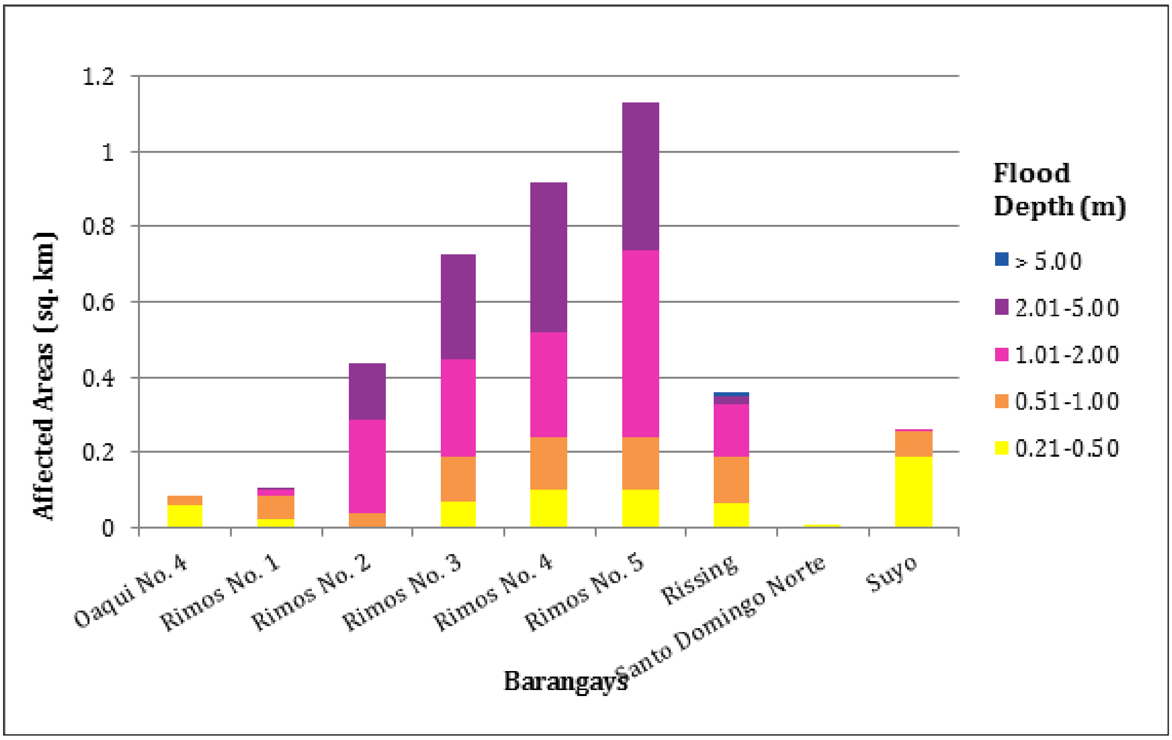


Figure 80. Affected Areas in Luna, La Union during 5-Year Rainfall Return Period.

For the 5-year return period, 2.82% of the municipality of Santol with an area of 97.97 sq. km. will experience flood levels of less than 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.07%, 0.06%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Santol, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santol (in sq. km)
	Paagan
0.03-0.20	2.76
0.21-0.50	0.44
0.51-1.00	0.16
1.01-2.00	0.071
2.01-5.00	0.06
> 5.00	0.034

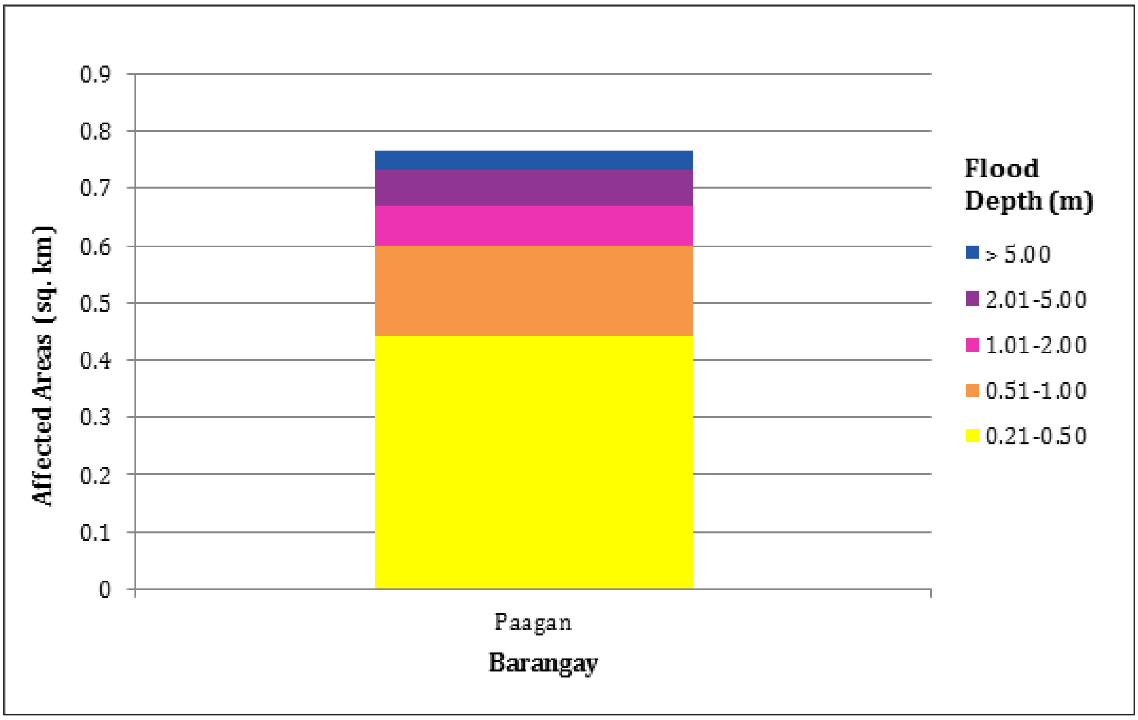


Figure 81. Affected Areas in Santol, La Union during 5-Year Rainfall Return Period.

For the 5-year return period, 36.44% of the municipality of Sudipen with an area of 75.745 sq. km. will experience flood levels of less than 0.20 meters. 2.82% of the area will experience flood levels of 0.21 to 0.50 meters while 2.09%, 2.35%, 3.75%, and 3.00% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Sudipen, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sudipen (in sq. km)						
	Bigbiga	Castro	Duplas	Ilocano	Ipet	Namaltugan	Old Central
0.03-0.20	3.79	2.26	0.11	1.81	2.43	0.15	3.7
0.21-0.50	0.49	0.11	0.00056	0.15	0.14	0.002	0.3
0.51-1.00	0.43	0.052	0.0005	0.14	0.14	0.0015	0.19
1.01-2.00	0.16	0.028	0.0004	0.19	0.51	0.0011	0.36
2.01-5.00	0.016	0.012	0.0002	0.29	1.39	0.0032	0.39
> 5.00	0.0003	0.00025	0	0.00036	1.13	0.1	0.61

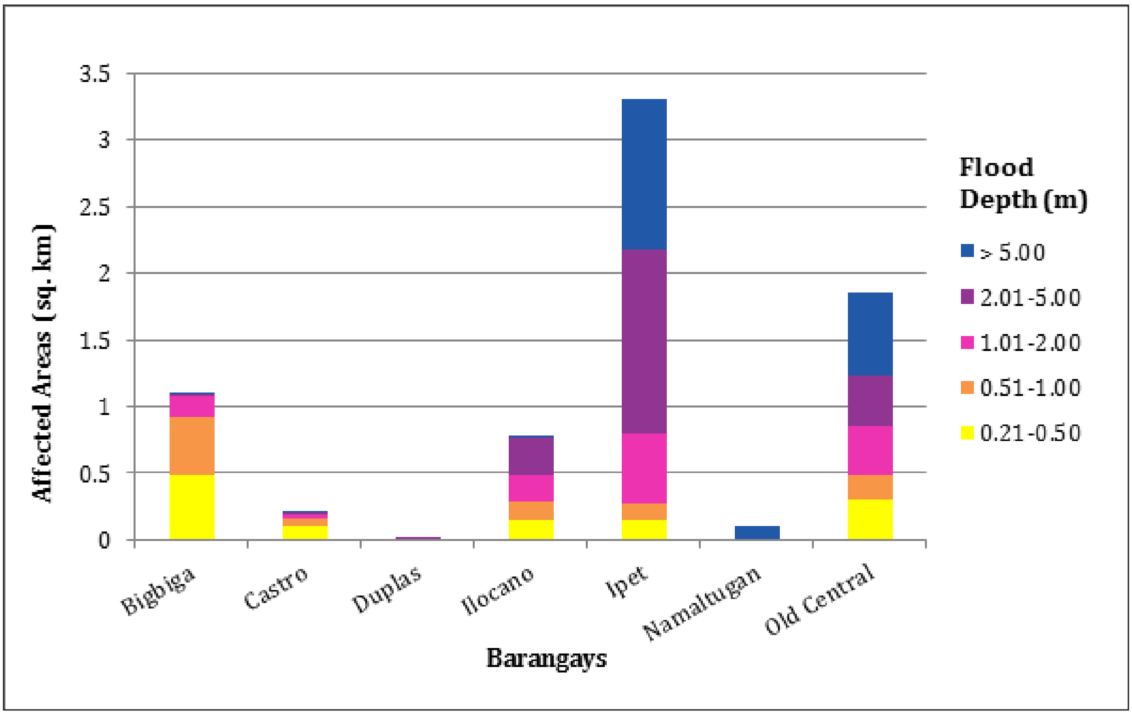


Figure 82. Affected Areas in Sudipen, La Union during 5-Year Rainfall Return Period.

Table 49. Affected Areas in Sudipen, La Union during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sudipen (in sq. km)						
	Poblacion	San Francisco Norte	San Francisco Sur	San Jose	Sengngat	Turod	Up-Uplas
0.03-0.20	0.83	3.39	2.76	3.55	1.6	1.13	0.089
0.21-0.50	0.072	0.16	0.25	0.18	0.18	0.1	0.0005
0.51-1.00	0.048	0.11	0.19	0.13	0.12	0.034	0.00039
1.01-2.00	0.091	0.1	0.13	0.082	0.11	0.019	0.00066
2.01-5.00	0.52	0.062	0.06	0.062	0.036	0.0024	0.00037
> 5.00	0.42	0.0029	0.0004	0.004	0.00045	0	0.000024

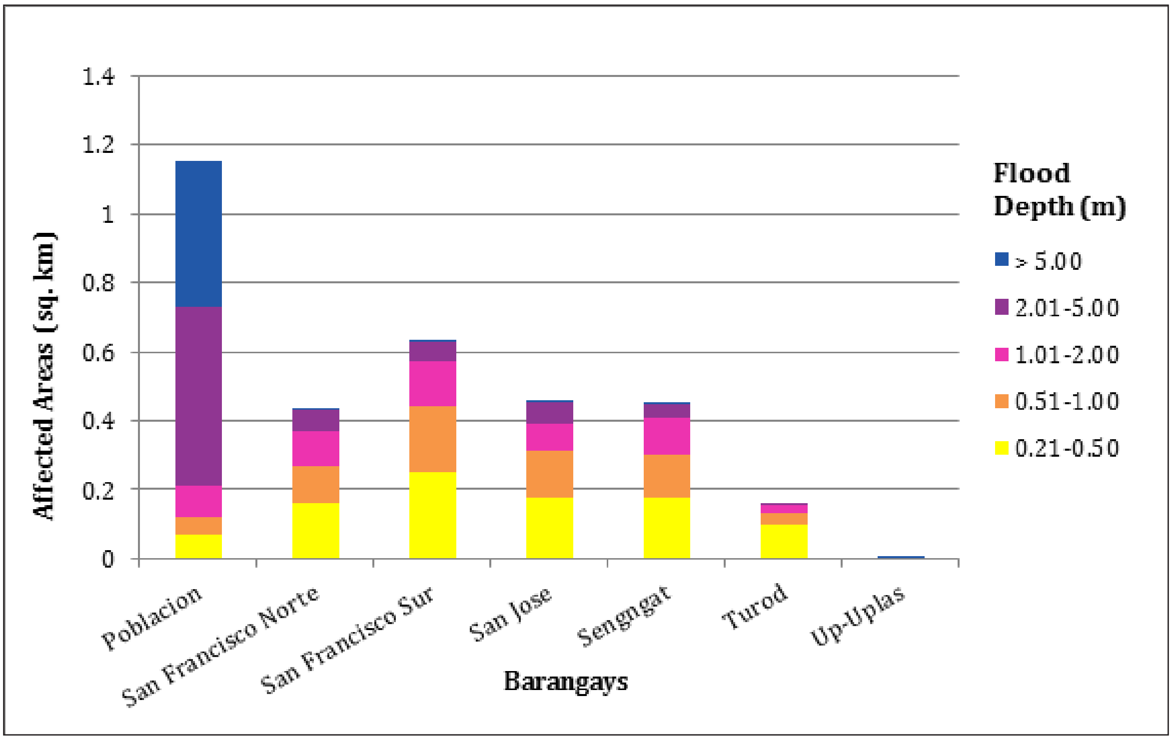


Figure 83. Affected Areas in Sudipen, La Union during 5-Year Rainfall Return Period.

For the 25-year return period, 3.85% of the municipality of Alilem with an area of 132.176 sq. km. will experience flood levels of less than 0.20 meters. 0.14% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.04%, 0.05%, and 1.00% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Alilem, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Alilem (in sq. km)	
	Dalawa	Kiat
0.03-0.20	5.08	0.0036
0.21-0.50	0.19	0.0005
0.51-1.00	0.096	0.0012
1.01-2.00	0.05	0.0015
2.01-5.00	0.058	0.0038
> 5.00	0.77	0.55

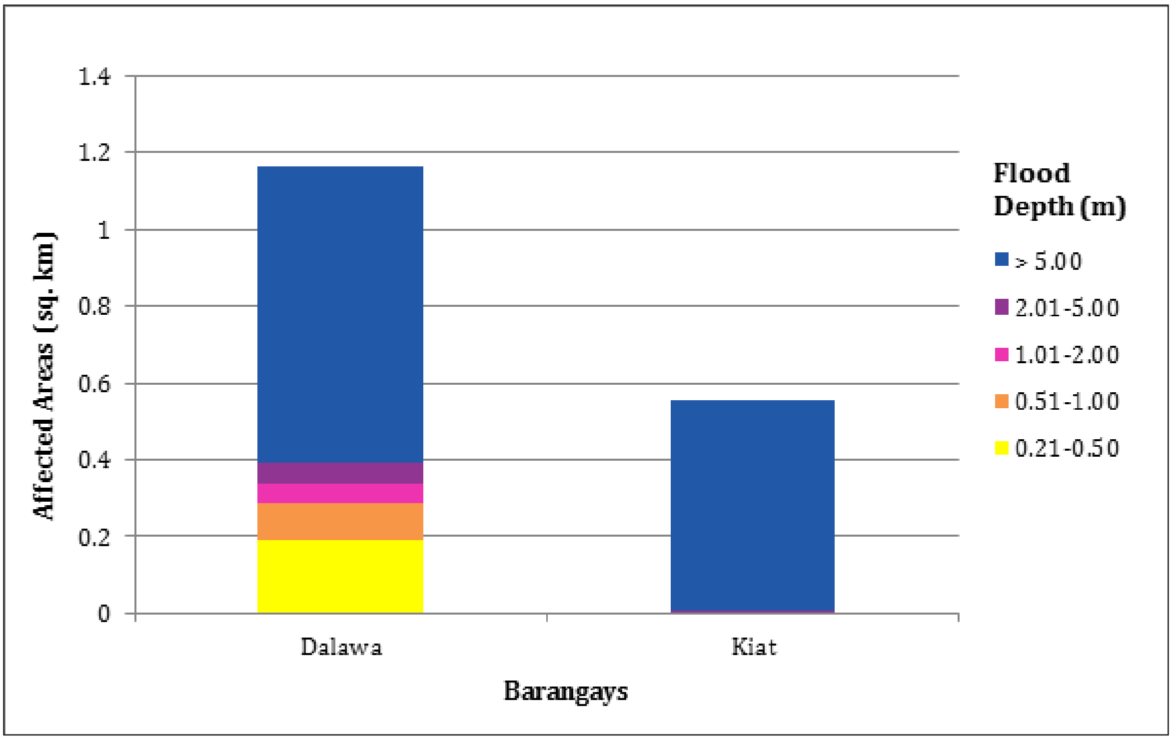


Figure 84. Affected Areas in Alilem, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 0.07% of the municipality of Santa Cruz with an area of 105.955 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected Areas in Santa Cruz, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Cruz (in sq. km)
	Gabor Sur
0.03-0.20	0.074
0.21-0.50	0.00092
0.51-1.00	0.0007
1.01-2.00	0.0005
2.01-5.00	0.0001
> 5.00	0

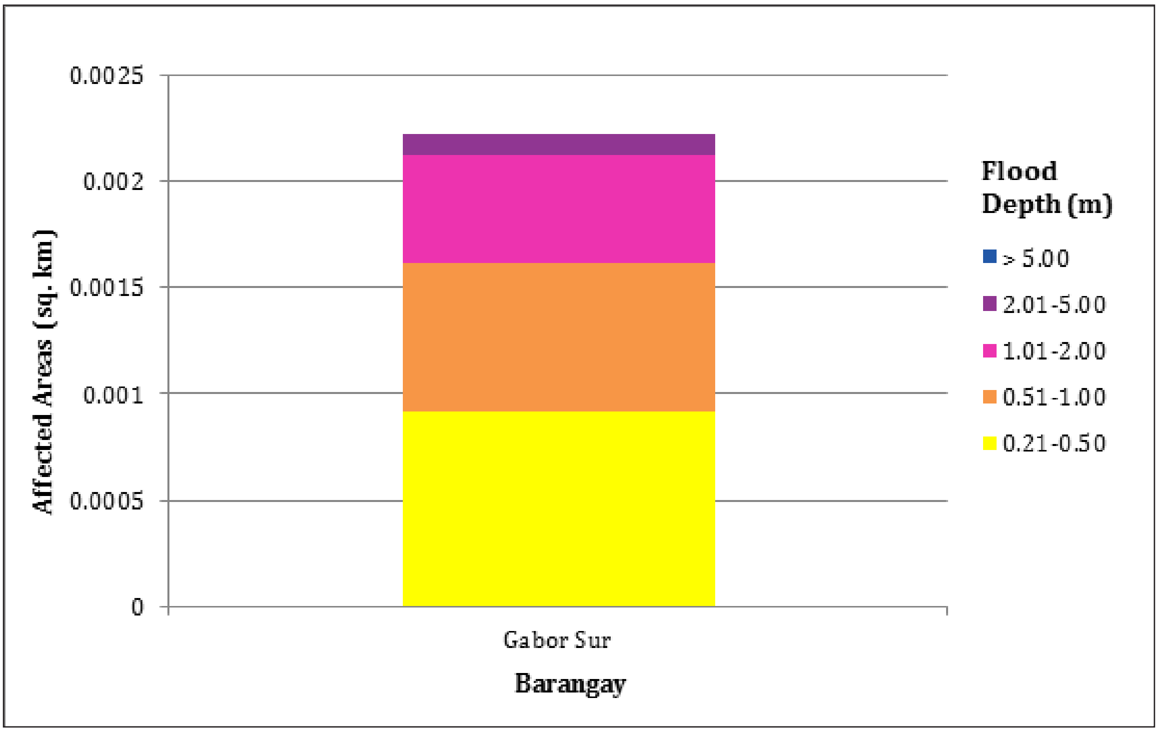


Figure 85. Affected Areas in Santa Cruz, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 11.12% of the municipality of Suyo with an area of 148.52 sq. km. will experience flood levels of less than 0.20 meters. 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.21%, 0.17%, 0.18%, and 2.32% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay

Table 52. Affected Areas in Suyo, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Suyo (in sq. km)				
	Baringcucurong	Cabugao	Poblacion	Suyo Proper	Urzadan
0.03-0.20	4.14	7.6	0.86	3.27	0.64
0.21-0.50	0.14	0.26	0.026	0.1	0.023
0.51-1.00	0.079	0.15	0.022	0.055	0.0089
1.01-2.00	0.061	0.13	0.011	0.041	0.0058
2.01-5.00	0.02	0.2	0.014	0.036	0.0014
> 5.00	0	3.27	0.16	0.009	0

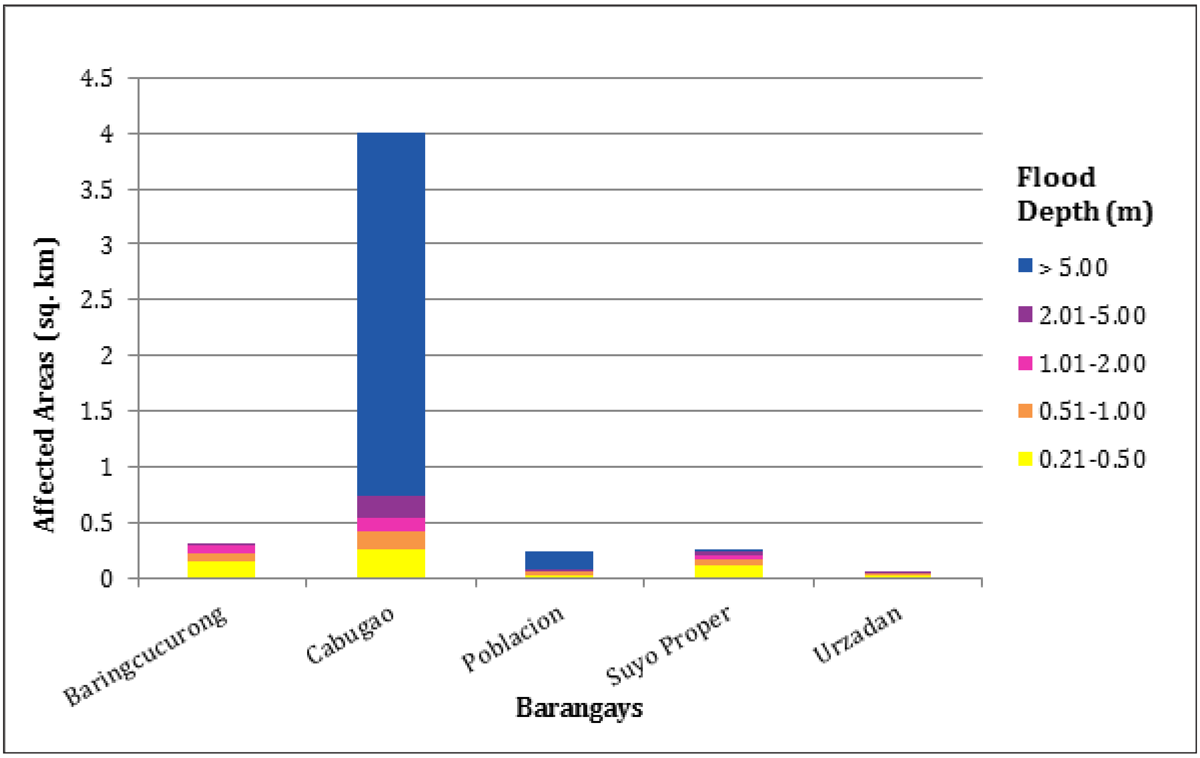


Figure 86. Affected Areas in Suyo, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 44.00% of the municipality of Tagudin with an area of 54.35 sq. km. will experience flood levels of less than 0.20 meters. 6.79% of the area will experience flood levels of 0.21 to 0.50 meters while 4.56%, 7.41%, 17.65%, and 16.21% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)											
	Ag-Aguman	Ambalayat	Baracbac	Bario-An	Baritao	Bimmanga	Bio	Bitalag	Borono	Bucao East	Bucao West	Cabaroan
0.03-0.20	0.26	2.46	1.15	0.75	0	0.035	0.23	1.09	0.68	0.4	0.12	0.12
0.21-0.50	0.025	0.11	0.29	0.059	0	0.053	0.0057	0.28	0.34	0.016	0.013	0.0063
0.51-1.00	0.015	0.099	0.088	0.038	0.0002	0.13	0.0036	0.099	0.22	0.009	0.018	0.011
1.01-2.00	0.034	0.21	0.019	0.038	0.31	0.28	0.0085	0.023	0.035	0.018	0.03	0.021
2.01-5.00	0.071	0.75	0.006	0.0096	1.27	0.12	0.021	0.0026	0.0001	0.17	0.53	0.067
> 5.00	0.42	4.96	0.0001	0	0.047	0	0.43	0	0	0.57	0.12	0.29

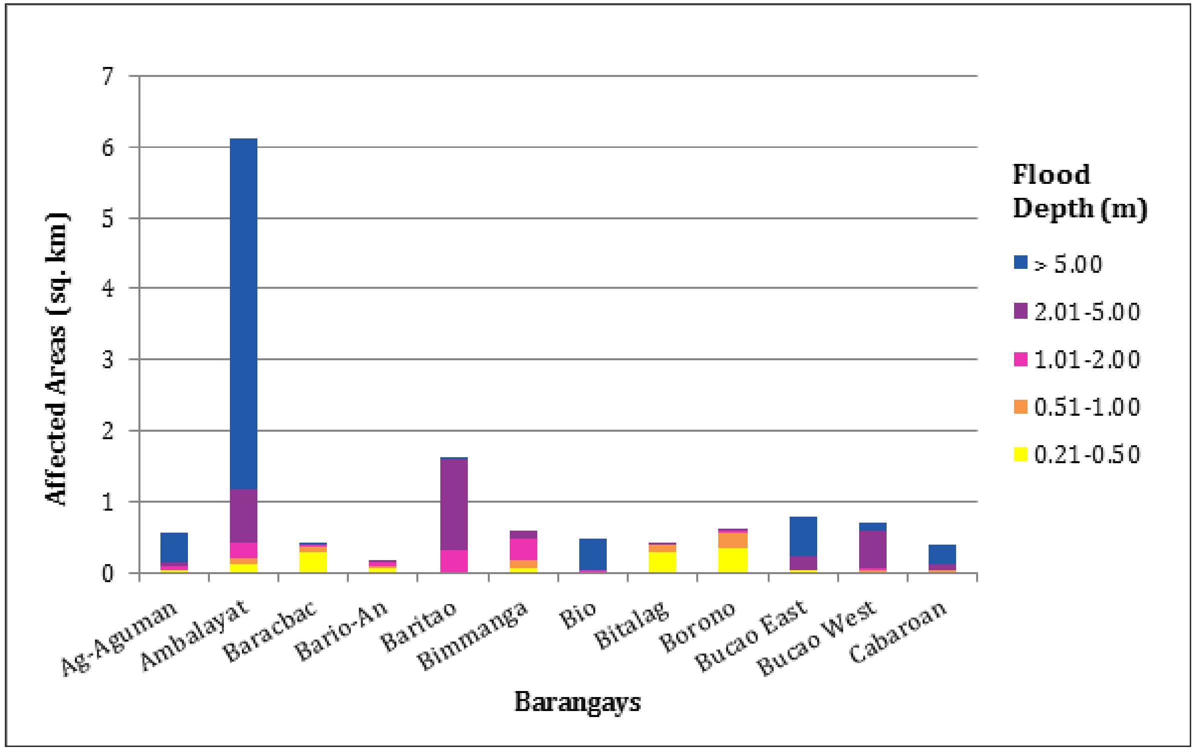


Figure 87. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Table 54. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Cabugbugan	Cabulanglangan	Dacutan	Dardarat	Del Pilar	Farola	Gabur	Garitan	Jardin	Lacong
0.03-0.20	2.35	0.97	0.85	0.2	0.00092	0.2	0.54	1.13	0	0.47
0.21-0.50	0.087	0.062	0.38	0.16	0.0076	0.1	0.054	0.095	0	0.02
0.51-1.00	0.053	0.038	0.19	0.13	0.017	0.23	0.01	0.017	0.0019	0.01
1.01-2.00	0.033	0.035	0.25	0.12	0.099	0.059	0.015	0.0082	0.083	0.013
2.01-5.00	0.0073	0.063	0.046	0.031	0.1	0.0033	0.0012	0.001	0.21	0.023
> 5.00	0.0001	0.051	0	0	0	0	0	0	0.0069	0.015

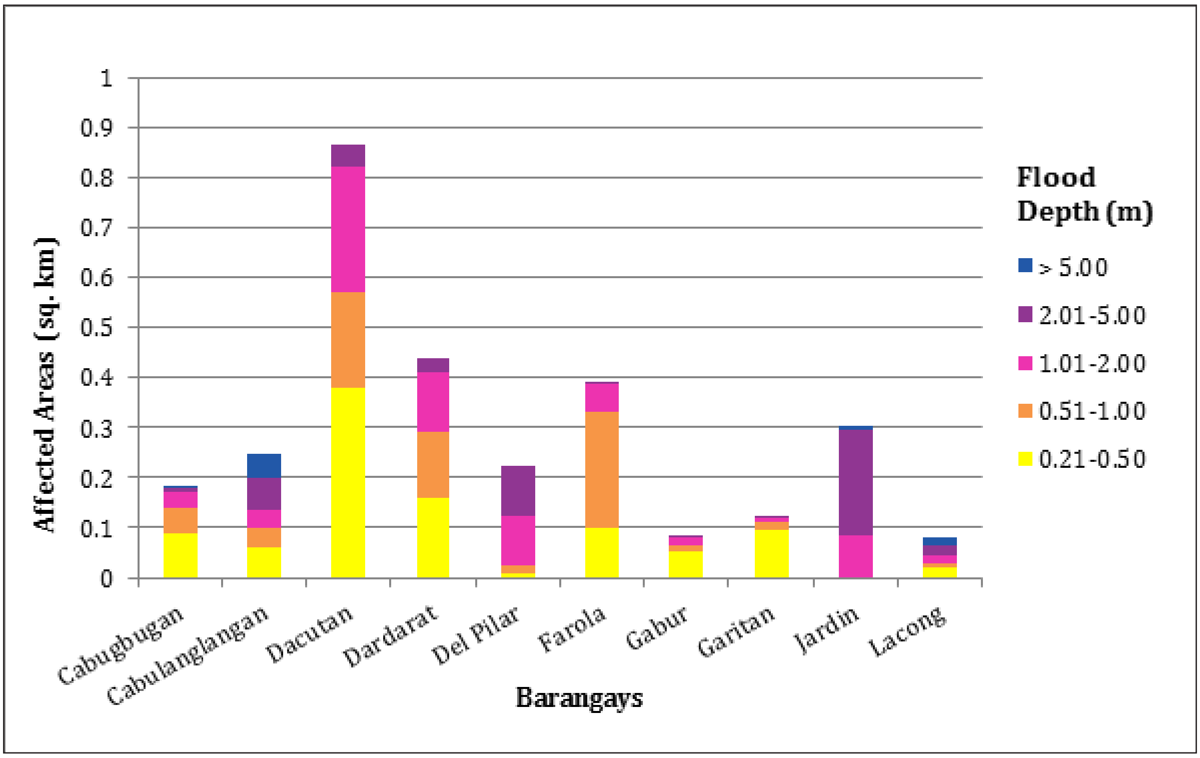


Figure 88. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Table 55. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Lantag	Las-Ud	Libtong	Lubnac	Magsaysay	Malacañang	Pacac	Pallogan	Pudoc East	Pudoc West
0.03-0.20	0.024	0.0024	0.48	1.17	0.16	0.47	0.0079	4.54	0	0.0058
0.21-0.50	0.002	0.0013	0.19	0.32	0.082	0.2	0.0027	0.19	0	0.0042
0.51-1.00	0.0094	0.012	0.24	0.14	0.075	0.037	0.036	0.11	0	0.042
1.01-2.00	0.13	0.18	0.19	0.0099	0.072	0.0028	0.22	0.087	0.091	0.12
2.01-5.00	0.62	0.18	0.0022	0	0	0	1.39	0.22	0.82	1.2
> 5.00	0.06	0	0	0	0	0	0.0017	1.17	0.12	0.098

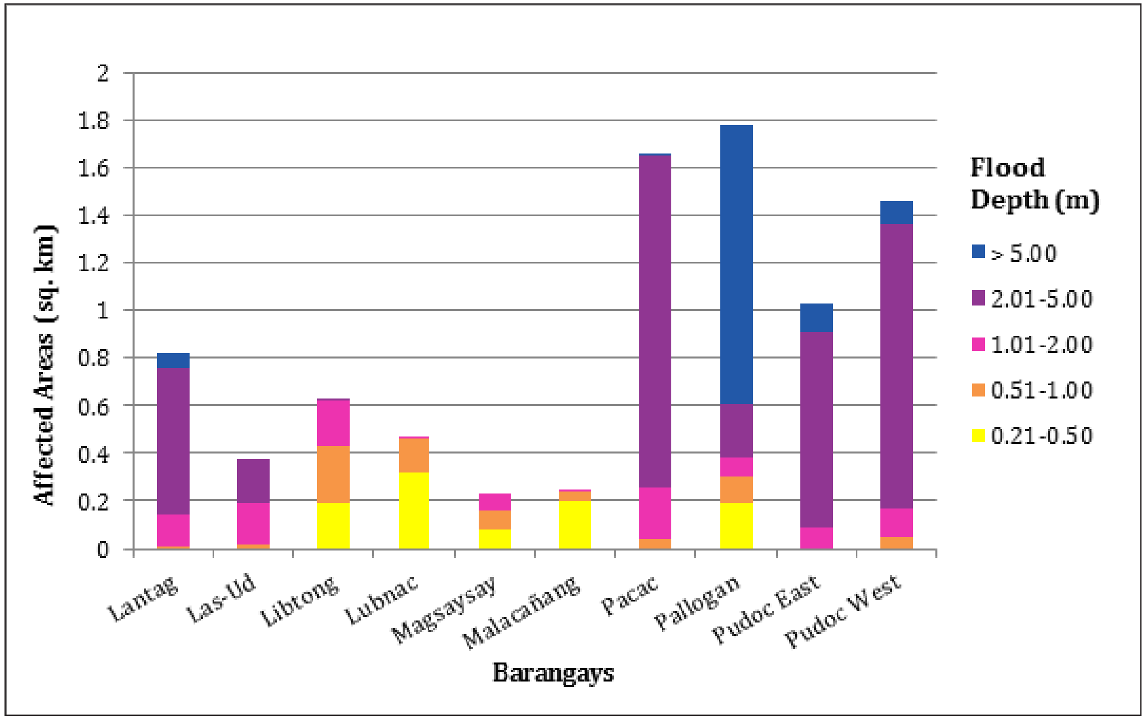


Figure 89. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Table 56. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Pula	Quirino	Ranget	Rizal	Salvacion	San Miguel	Sawat	Tallaoen	Tampugo	Tarangotong
0.03-0.20	0.034	0.056	1.21	0.11	0.1	0.35	0	0.67	0.51	0.0092
0.21-0.50	0.0002	0.015	0.11	0.0064	0.0045	0.02	0.0088	0.28	0.065	0.024
0.51-1.00	0.00058	0.059	0.02	0.0056	0.008	0.0061	0.023	0.11	0.044	0.073
1.01-2.00	0.015	0.26	0.018	0.009	0.071	0.001	0.28	0.011	0.038	0.48
2.01-5.00	0.052	0.008	0.0043	0.0099	0.34	0.0001	0.49	0.0002	0.035	0.72
> 5.00	0.43	0.00028	0.0003	0	0.021	0	0	0	0	0

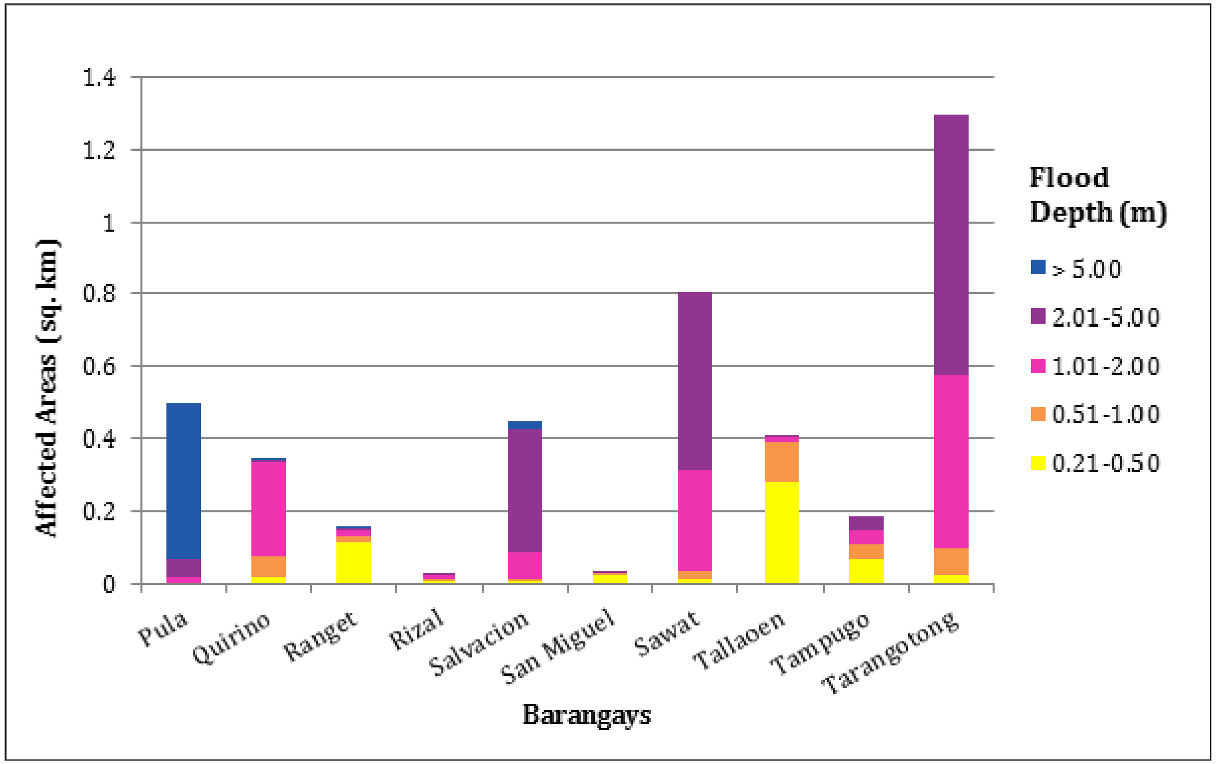


Figure 90. Affected Areas in Tagudin, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 8.62% of the municipality of Balaoan with an area of 60.96 sq. km. will experience flood levels of less than 0.20 meters. 2.23% of the area will experience flood levels of 0.21 to 0.50 meters while 3.08%, 2.12%, 0.75%, and 0.14% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Balaoan, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balaoan (in sq. km)						
	Baracbac Este	Baracbac Oeste	Bet-Ang	Bulbulala	Butubut Norte	Butubut Oeste	Calliat
0.03-0.20	0.38	0.59	0.15	0.57	0.52	0.26	0.51
0.21-0.50	0.12	0.26	0.12	0.038	0.059	0.0094	0.12
0.51-1.00	0.19	0.13	0.059	0.0051	0.047	0.00062	0.091
1.01-2.00	0.11	0.028	0.00086	0.0082	0.053	0.000007	0.085
2.01-5.00	0.081	0.044	0.0011	0.011	0.042	0	0.019
> 5.00	0.01	0.019	0.0014	0	0	0	0.0001

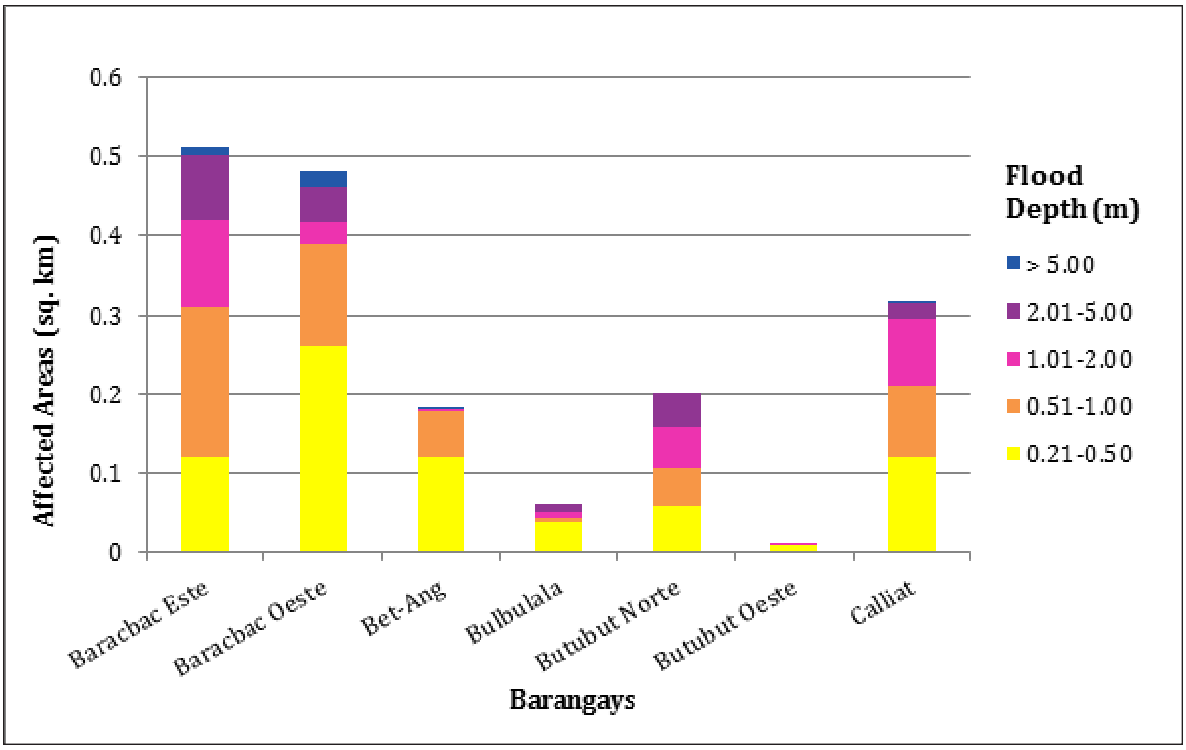


Figure 91. Affected Areas in Balaoan, La Union during 25-Year Rainfall Return Period.

Table 58. Affected Areas in Balaoan, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balaoan (in sq. km)						
	Napaset	Pantar Norte	Pantar Sur	Sablut	Sinapangan Norte	Sinapangan Sur	Tallipugo
0.03-0.20	0.089	0.093	0.44	0.13	0.46	0.98	0.082
0.21-0.50	0.061	0.034	0.1	0.085	0.098	0.054	0.2
0.51-1.00	0.081	0.0045	0.018	0.12	0.25	0.11	0.77
1.01-2.00	0.0086	0.0011	0.015	0.018	0.32	0.065	0.58
2.01-5.00	0	0	0.014	0.01	0.036	0.11	0.087
> 5.00	0	0	0.0023	0.0065	0	0.03	0.015

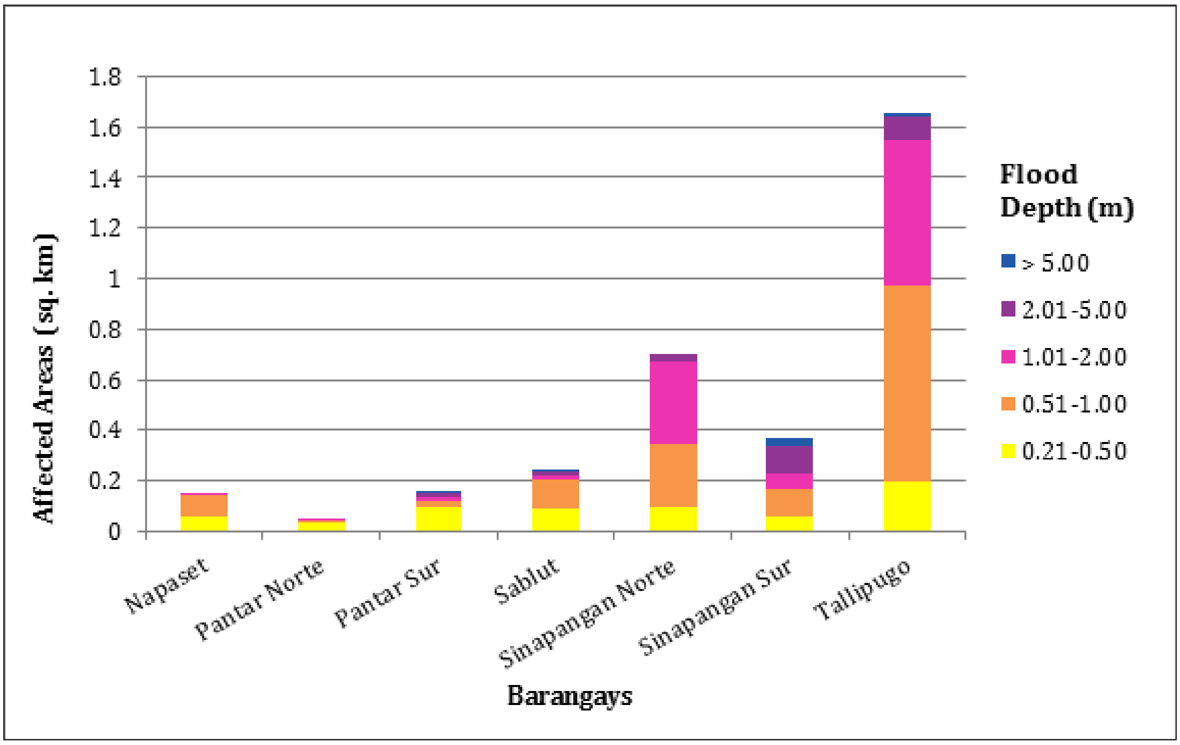


Figure 92. Affected Areas in Balaoan, La Union during 25-Year Rainfall Return Period.

For the 25-year return period, 28.40% of the municipality of Bangar with an area of 45.12 sq. km. will experience flood levels of less than 0.20 meters. 5.54% of the area will experience flood levels of 0.21 to 0.50 meters while 8.30%, 10.82%, 38.81%, and 8.03% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected Areas in Bangar, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Agdeppa	Alzate	Bangaoilan East	Bangaoilan West	Barraca	Cadapli	Caggao	Central East No. 1	Central East No. 2	Central West No. 1	Central West No. 2
0.03-0.20	0.0032	0	0.47	0.1	0	0.26	0	0	0	0	0.0004
0.21-0.50	0.0034	0	0.083	0.031	0	0.14	0.0002	0	0	0	0.0008
0.51-1.00	0.011	0	0.062	0.051	0.0015	0.31	0.0019	0	0	0	0.0042
1.01-2.00	0.073	0.016	0.11	0.11	0.068	0.25	0.063	0	0.0038	0.00036	0.027
2.01-5.00	1.98	1.15	0.49	0.43	0.61	0.029	0.64	0.049	0.03	0.055	0.034
> 5.00	1.18	0.27	0.19	0.35	0.011	0.0024	0.046	0	0	0	0

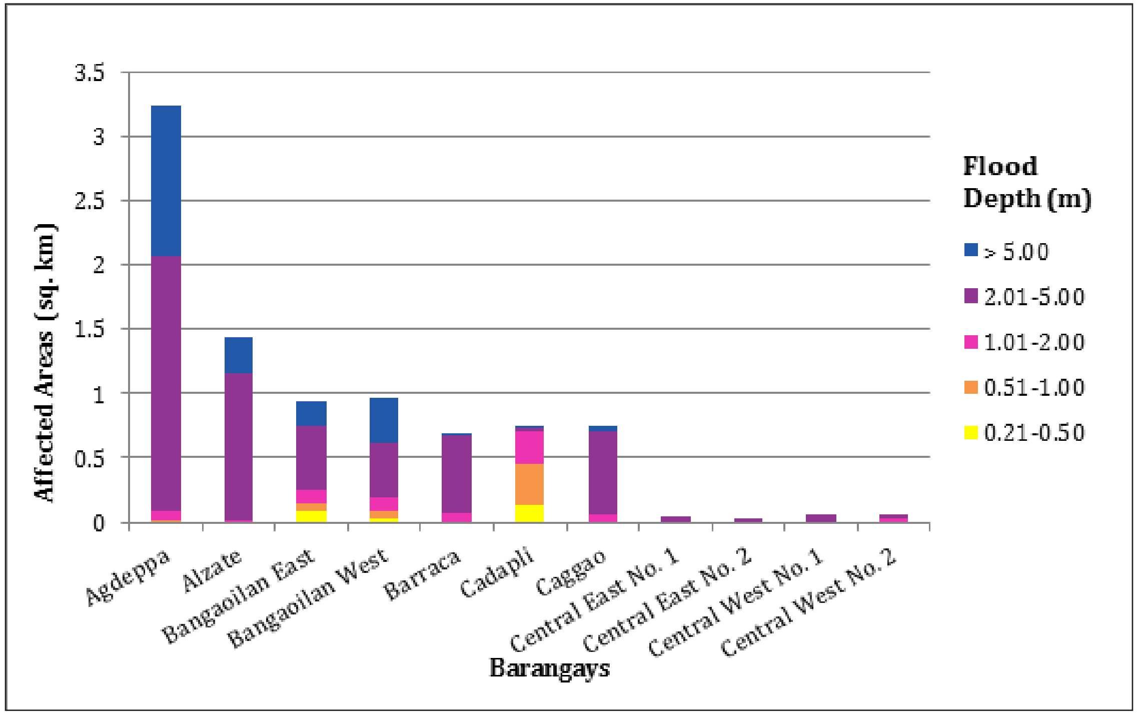


Figure 93. Affected Areas in Bangar, La Union during 25-Year Rainfall Return Period.

Table 60. Affected Areas in Bangar, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Central West No. 3	Consuegra	General Prim East	General Prim West	General Terrero	Luzong Norte	Luzong Sur	Maria Cristina East	Maria Cristina West	Mindoro	Nagsabaran
0.03-0.20	0	0	0	0	0.0039	2.99	2.77	0	0	0.0002	0
0.21-0.50	0	0.001	0	0	0.0004	0.3	0.23	0.0007	0.0004	0.0098	0
0.51-1.00	0	0.0029	0.0016	0.0071	0.0026	0.32	0.15	0.0066	0.0027	0.051	0
1.01-2.00	0.005	0.12	0.04	0.025	0.15	0.39	0.13	0.054	0.11	0.19	0
2.01-5.00	0.054	0.73	0.36	0.77	0.22	0.27	0.2	0.29	0.26	1.79	0.32
> 5.00	0	0.2	0.15	0.35	0.14	0.0007	0.0097	0.0054	0.13	0.24	0.063

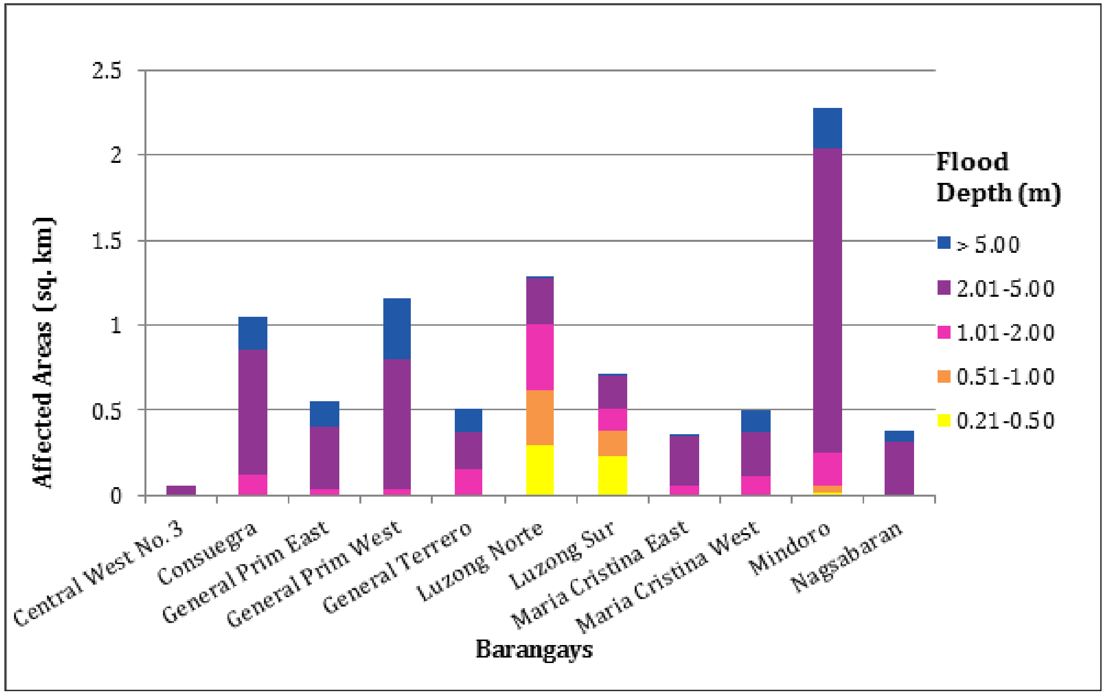


Figure 94. Affected Areas in Bangar, La Union during 25-Year Rainfall Return Period.

Table 61. Affected Areas in Bangar, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Paratong No. 3	Paratong No. 4	Paratong Norte	Quintarong	Reyna Regente	Rissing	San Blas	San Cristobal	Sinapangan Norte	Sinapangan Sur	Ubbog
0.03-0.20	0.017	0.059	0.01	0	0	0.27	0	2.44	2.13	1.05	0.24
0.21-0.50	0.024	0.037	0.0092	0	0	0.26	0	0.44	0.35	0.39	0.19
0.51-1.00	0.034	0.034	0.029	0	0.0002	0.45	0.0022	0.51	0.35	0.98	0.37
1.01-2.00	0.083	0.039	0.11	0.0029	0.015	0.87	0.037	0.24	0.22	0.82	0.51
2.01-5.00	0.13	0.23	0.37	0.28	0.32	2.54	1.47	0.11	0.088	0.25	0.96
> 5.00	0.05	0.014	0.049	0.0091	0	0.0038	0.12	0.0037	0.0074	0.027	0

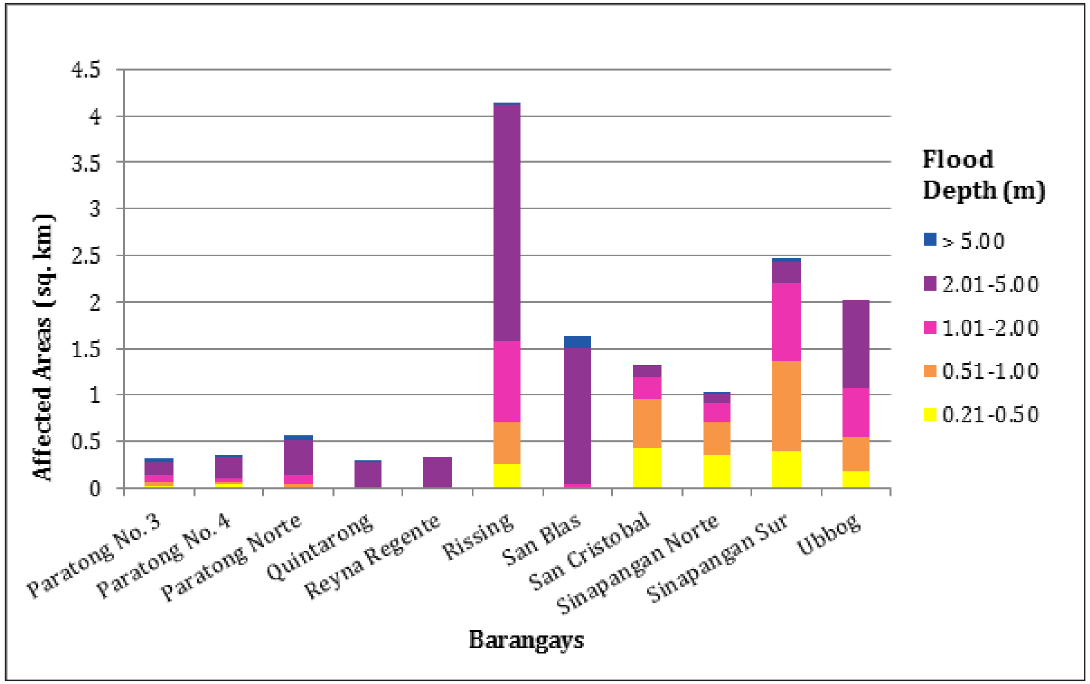


Figure 95. Affected Areas in Bangar, La Union during 25-Year Rainfall Return Period.

For the 25-year return period, 3.79% of the municipality of Luna with an area of 50.66 sq. km. will experience flood levels of less than 0.20 meters. 1.70% of the area will experience flood levels of 0.21 to 0.50 meters while 1.78%, 2.75%, 7.08%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 62. Affected Areas in Luna, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km)								
	Barangobong	Cantoria No. 1	Cantoria No. 2	Cantoria No. 3	Cantoria No. 4	Napaset	Oaqui No. 1	Oaqui No. 2	Oaqui No. 3
0.03-0.20	0.049	0.25	0.039	0.22	0.21	0.084	0.32	0.2	0.028
0.21-0.50	0.042	0.089	0.0003	0.018	0.071	0.011	0.16	0.1	0.077
0.51-1.00	0.061	0.078	0	0.0001	0.085	0.0053	0.097	0.077	0.084
1.01-2.00	0.16	0.035	0	0	0.048	0.00059	0.0022	0.0014	0.038
2.01-5.00	0.083	0	0	0	0	0.0012	0	0	0
> 5.00	0	0	0	0	0	0.00092	0	0	0

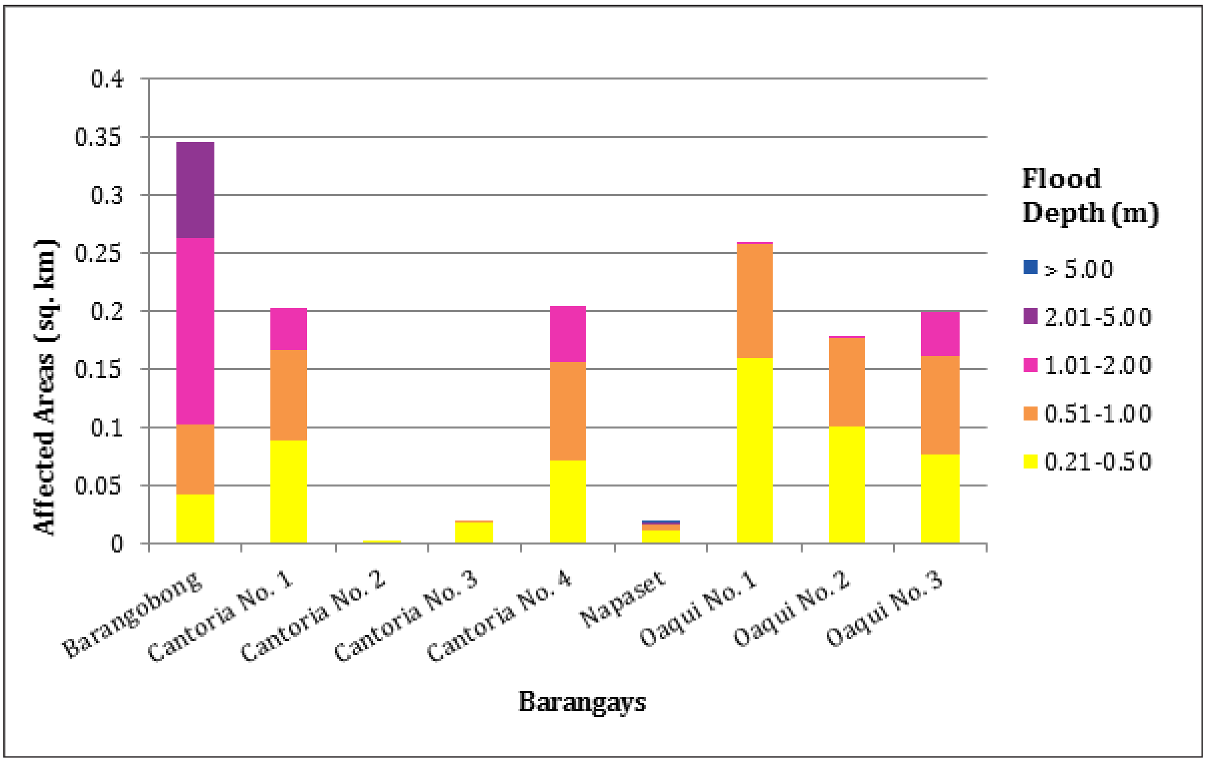


Figure 96. Affected Areas in Luna, La Union during 25-Year Rainfall Return Period.

Table 63. Affected Areas in Luna, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km)								
	Oa qui No. 4	Rimos No. 1	Rimos No. 2	Rimos No. 3	Rimos No. 4	Rimos No. 5	Rissing	Santo Domingo Norte	Suyo
0.03-0.20	0.04	0	0	0.0078	0.0026	0.11	0.28	0	0.082
0.21-0.50	0.054	0.000064	0	0.018	0.0059	0.01	0.12	0.00006	0.086
0.51-1.00	0.086	0.0029	0	0.035	0.044	0.022	0.065	0.00012	0.16
1.01-2.00	0.012	0.021	0.0013	0.11	0.17	0.18	0.2	0.0016	0.41
2.01-5.00	0	0.1	0.44	0.71	0.89	1.13	0.062	0	0.17
> 5.00	0	0	0	0	0	0.014	0.013	0	0

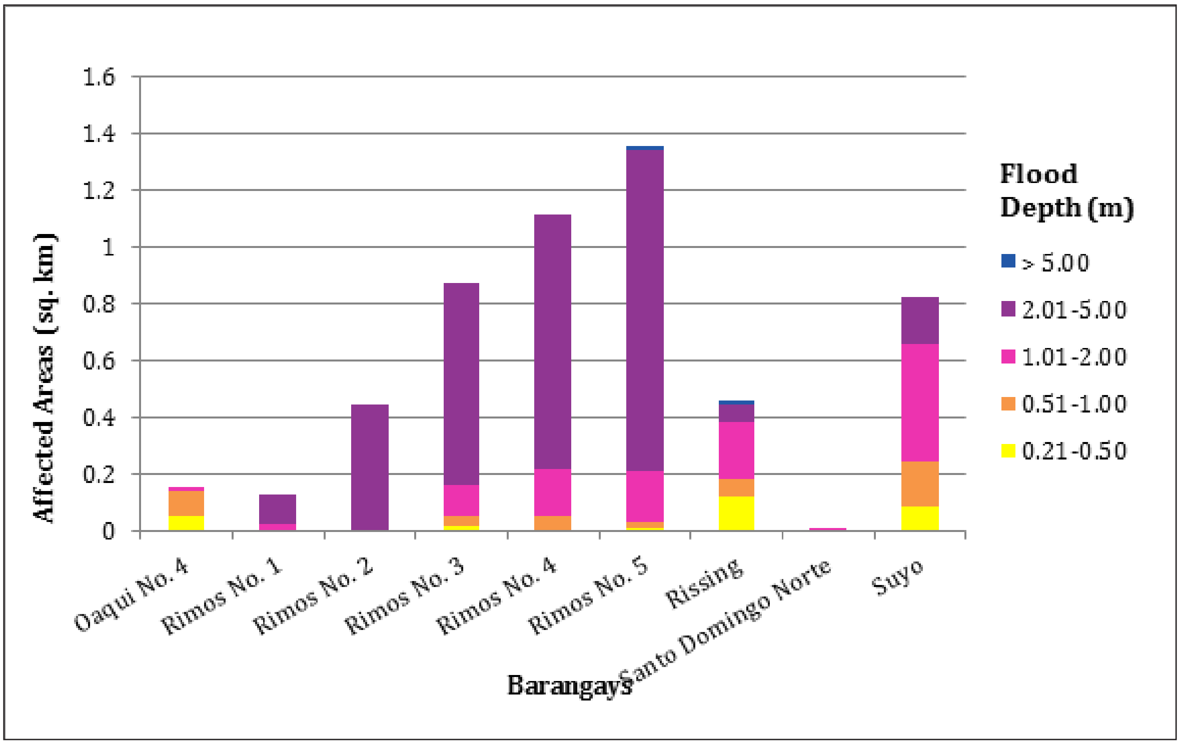


Figure 97. Affected Areas in Luna, La Union during 25-Year Rainfall Return Period.

For the 5-year return period, 2.82% of the municipality of Santol with an area of 97.97 sq. km. will experience flood levels of less than 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.07%, 0.06%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 64. Affected Areas in Santol, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santol (in sq. km)
	Paagan
0.03-0.20	2.45
0.21-0.50	0.48
0.51-1.00	0.38
1.01-2.00	0.1
2.01-5.00	0.079
> 5.00	0.042

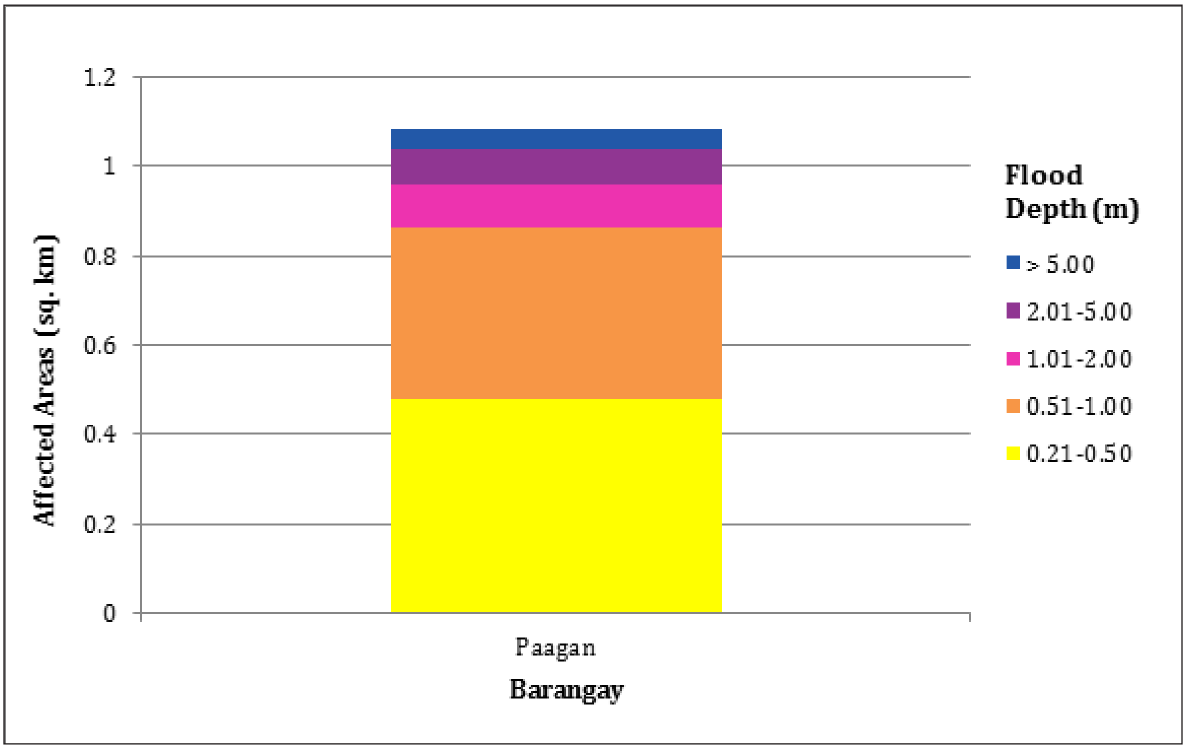


Figure 98. Affected Areas in Santol, La Union during 25-Year Rainfall Return Period.

For the 25-year return period, 34.47% of the municipality of Sudipen with an area of 75.745 sq. km. will experience flood levels of less than 0.20 meters. 2.69% of the area will experience flood levels of 0.21 to 0.50 meters while 2.28%, 1.86%, 3.85%, and 5.29% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 65. Affected Areas in Sudipen, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sudipen (in sq. km)						
	Bigbiga	Castro	Duplas	Ilocano	Ipet	Namaltugan	Old Central
0.03-0.20	3.58	2.2	0.11	1.59	2.28	0.14	3.4
0.21-0.50	0.4	0.13	0.00056	0.14	0.1	0.001	0.3
0.51-1.00	0.53	0.071	0.0003	0.1	0.096	0.0015	0.16
1.01-2.00	0.33	0.038	0.0004	0.12	0.14	0.0017	0.15
2.01-5.00	0.038	0.021	0.0004	0.33	1.4	0.0039	0.49
> 5.00	0.0005	0.00035	0	0.3	1.71	0.11	1.05

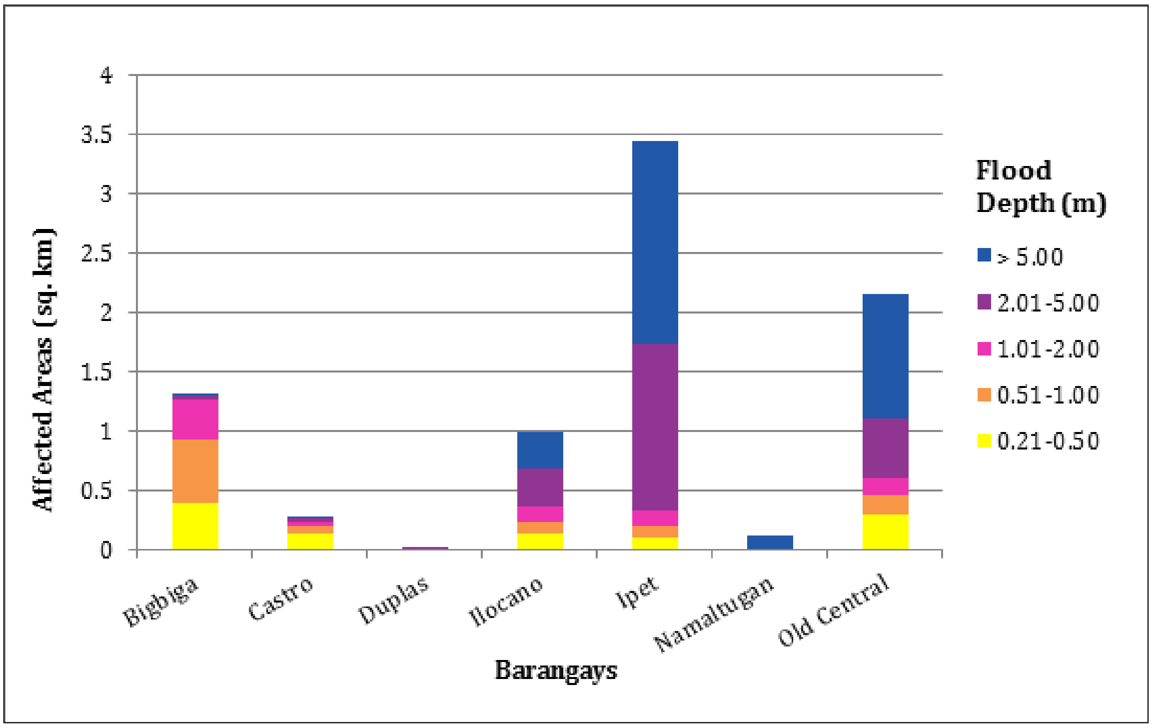


Figure 99. Affected Areas in Sudipen, La Union during 25-Year Rainfall Return Period.

Table 66. Affected Areas in Sudipen, La Union during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sudipen (in sq. km)						
	Poblacion	San Francisco Norte	San Francisco Sur	San Jose	Sengngat	Turod	Up-Uplas
0.03-0.20	0.77	3.29	2.65	3.45	1.47	1.09	0.088
0.21-0.50	0.075	0.17	0.22	0.19	0.2	0.11	0.0006
0.51-1.00	0.058	0.12	0.23	0.15	0.15	0.056	0.00049
1.01-2.00	0.034	0.13	0.19	0.11	0.14	0.027	0.0007
2.01-5.00	0.24	0.11	0.11	0.091	0.077	0.0041	0.00053
> 5.00	0.81	0.01	0.0035	0.012	0.00075	0	0.000024

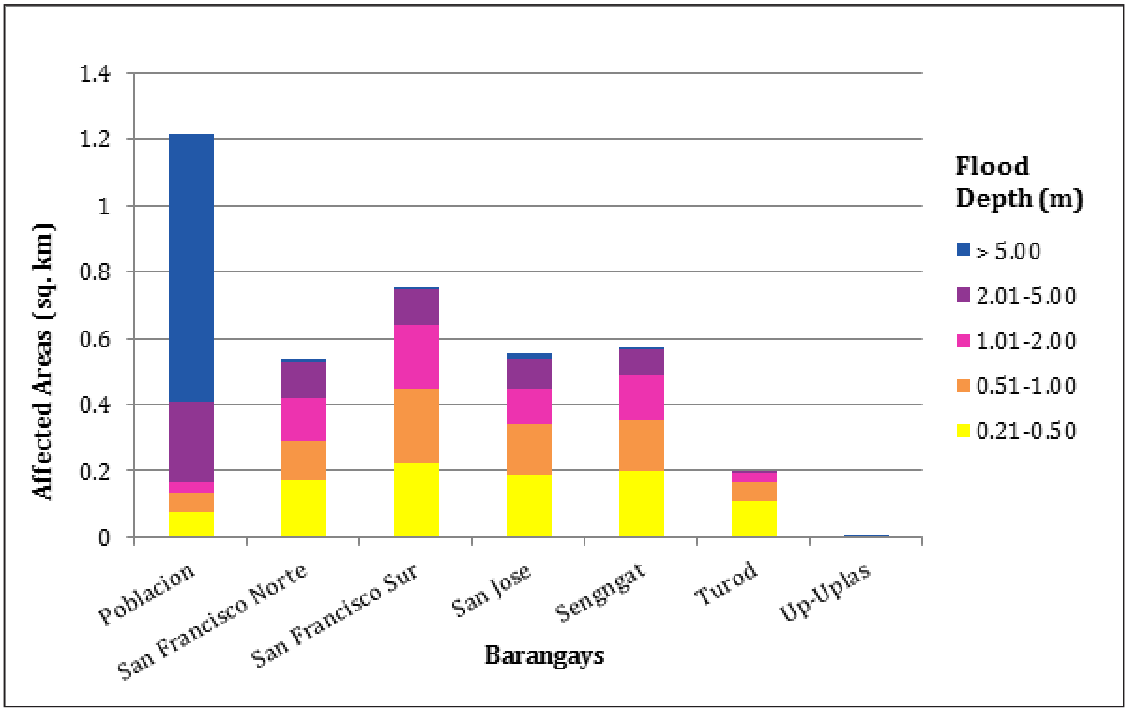


Figure 100. Affected Areas in Sudipen, La Union during 25-Year Rainfall Return Period.

For the 100-year return period, 3.73% of the municipality of Alilem with an area of 132.176 sq. km. will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.04%, 0.05%, and 1.09% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 67. Affected Areas in Alilem, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Alilem (in sq. km)	
	Dalawa	Kiat
0.03-0.20	4.93	0.00052
0.21-0.50	0.21	0.00027
0.51-1.00	0.1	0.0002
1.01-2.00	0.054	0
2.01-5.00	0.061	0.00084
> 5.00	0.88	0.56

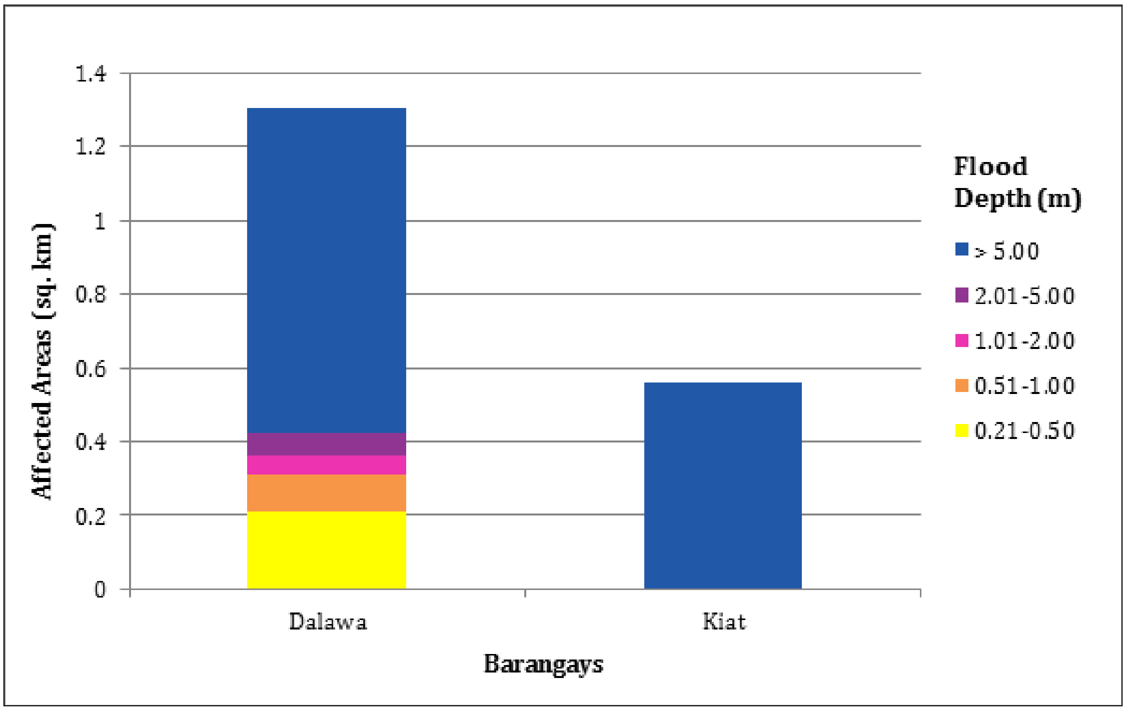


Figure 101. Affected Areas in Alilem, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 0.07% of the municipality of Santa Cruz with an area of 105.955 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected Areas in Santa Cruz, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Cruz (in sq. km)
	Gabor Sur
0.03-0.20	0.074
0.21-0.50	0.00082
0.51-1.00	0.0004
1.01-2.00	0.001
2.01-5.00	0.0001
> 5.00	0

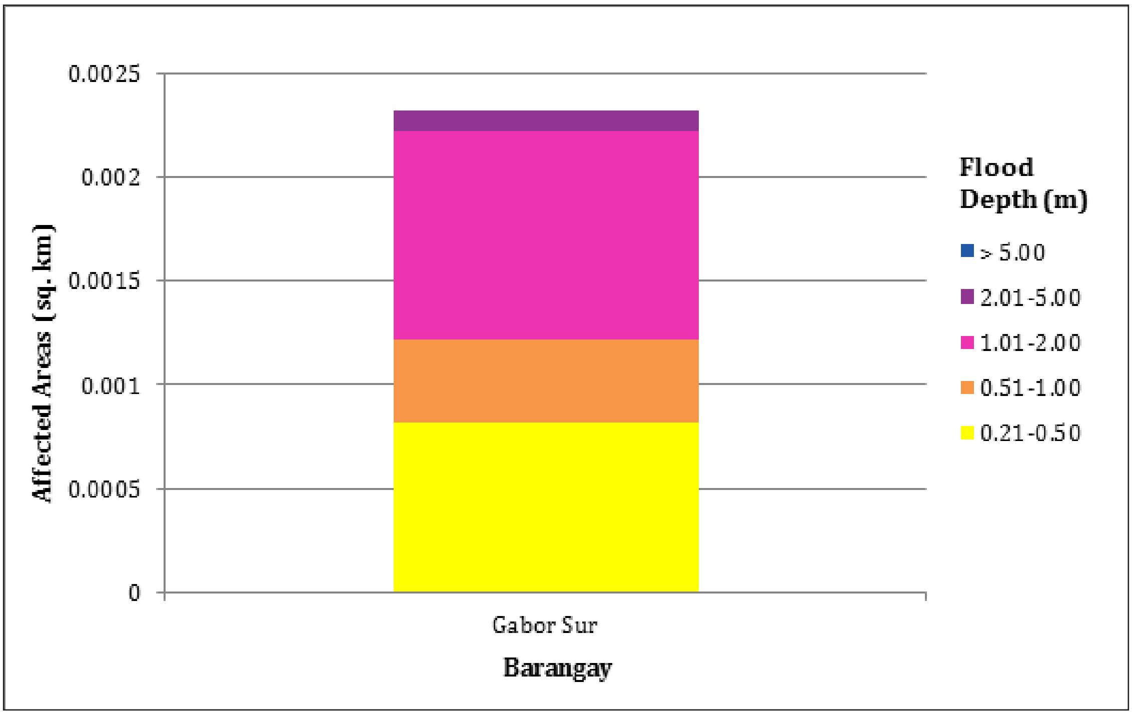


Figure 102. Figure 102. Affected Areas in Santa Cruz, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 10.85% of the municipality of Suyo with an area of 148.52 sq. km. will experience flood levels of less than 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.23%, 0.19%, 0.20%, and 2.51% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 69. Affected Areas in Suyo, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Suyo (in sq. km)				
	Baringcucurong	Cabugao	Poblacion	Suyo Proper	Urzadan
0.03-0.20	4.1	7.31	0.84	3.23	0.63
0.21-0.50	0.15	0.26	0.024	0.12	0.024
0.51-1.00	0.09	0.16	0.019	0.061	0.012
1.01-2.00	0.071	0.14	0.014	0.045	0.0065
2.01-5.00	0.025	0.21	0.011	0.043	0.0018
> 5.00	0	3.54	0.17	0.013	0

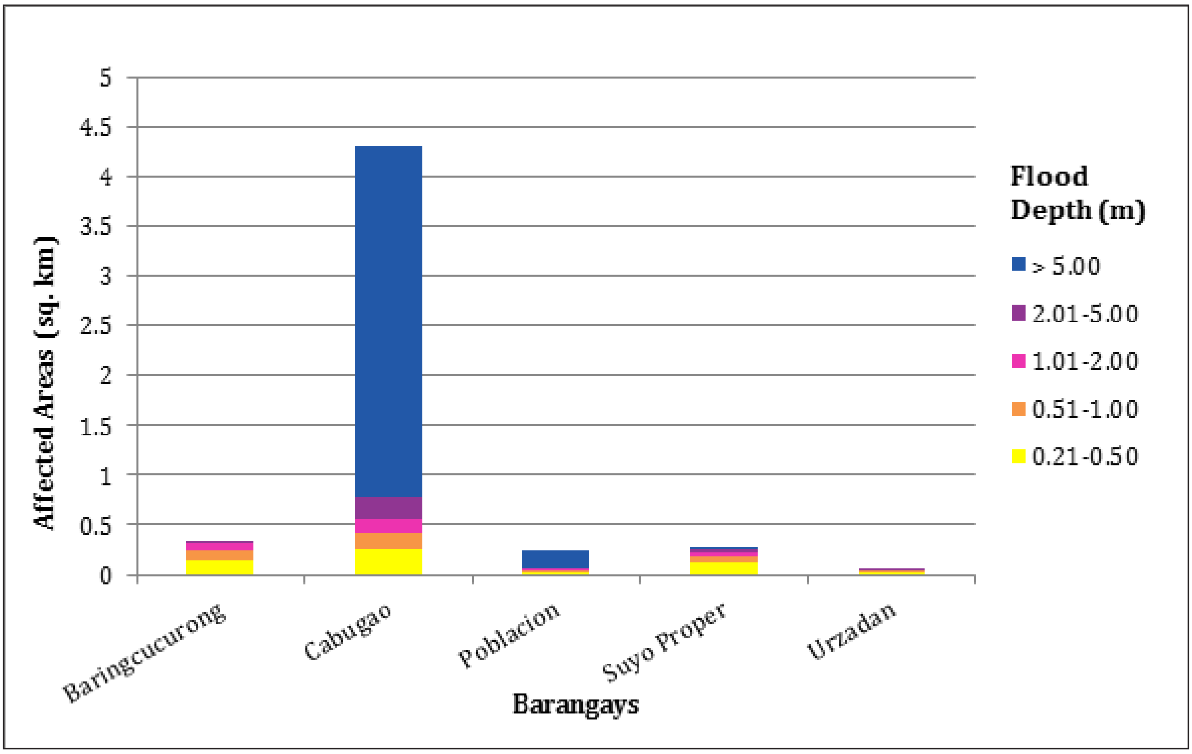


Figure 103. Affected Areas in Suyo, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 41.15% of the municipality of Tagudin with an area of 54.35 sq. km. will experience flood levels of less than 0.20 meters. 7.24% of the area will experience flood levels of 0.21 to 0.50 meters while 4.83%, 6.04%, 18.88%, and 18.55% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 mAeters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 70. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)											
	Ag-Aguman	Ambalayat	Baracbac	Bario-An	Baritao	Bimmanga	Bio	Bitalag	Borono	Bucao East	Bucao West	Cabaroan
0.03-0.20	0.21	2.34	1.08	0.72	0	0.017	0.21	1	0.58	0.4	0.11	0.087
0.21-0.50	0.028	0.09	0.33	0.071	0	0.037	0.0062	0.33	0.35	0.016	0.0092	0.0049
0.51-1.00	0.016	0.041	0.11	0.044	0.0001	0.1	0.0037	0.13	0.29	0.0087	0.017	0.0069
1.01-2.00	0.027	0.044	0.025	0.041	0.063	0.31	0.0094	0.028	0.06	0.017	0.03	0.017
2.01-5.00	0.086	0.4	0.0067	0.015	1.49	0.16	0.025	0.0035	0.00076	0.14	0.51	0.062
> 5.00	0.46	5.68	0.0001	0	0.074	0	0.44	0	0	0.61	0.15	0.33

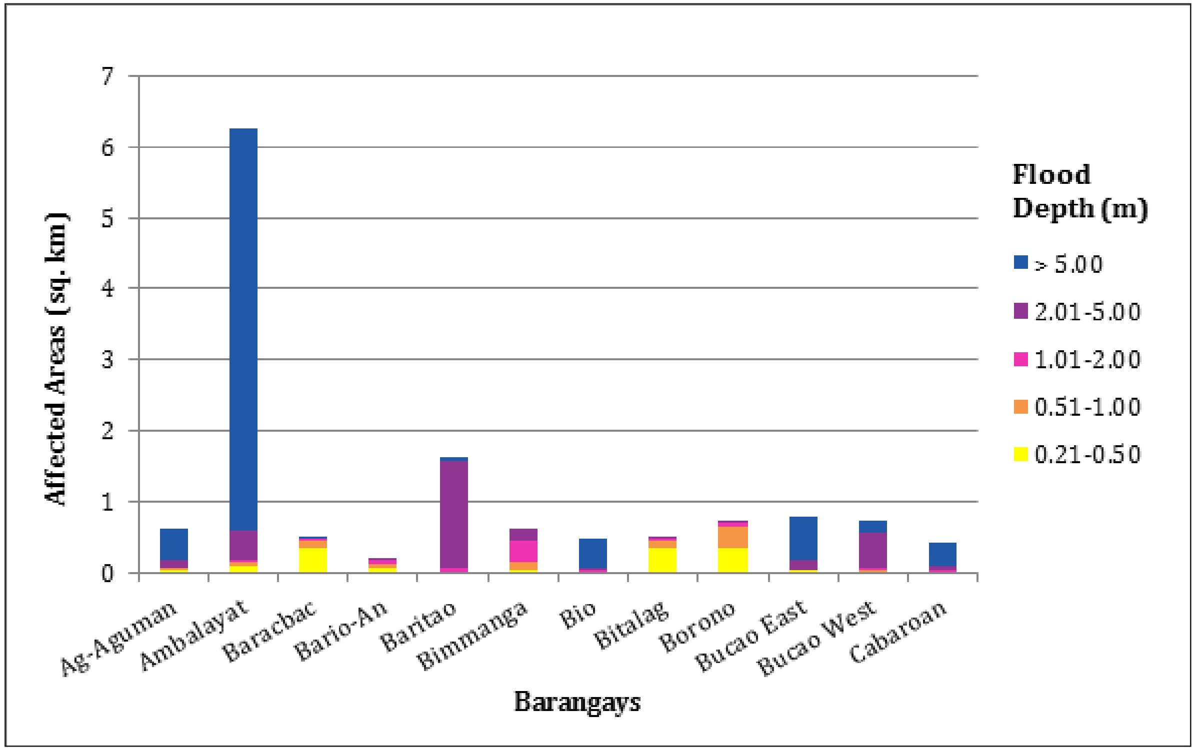


Figure 104. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Table 71. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Cabugbugan	Cabulanglangan	Dacutan	Dardarat	Del Pilar	Farola	Gabur	Garitan	Jardin	Lacong
0.03-0.20	2.32	0.92	0.71	0.12	0.0001	0.14	0.51	1.1	0	0.44
0.21-0.50	0.096	0.06	0.4	0.16	0.00079	0.091	0.077	0.11	0	0.025
0.51-1.00	0.059	0.048	0.22	0.17	0.013	0.23	0.011	0.022	0.0002	0.012
1.01-2.00	0.04	0.039	0.3	0.15	0.051	0.12	0.017	0.0097	0.053	0.015
2.01-5.00	0.01	0.078	0.093	0.042	0.16	0.0036	0.0018	0.0014	0.24	0.035
> 5.00	0.0001	0.079	0	0	0	0	0	0	0.009	0.025

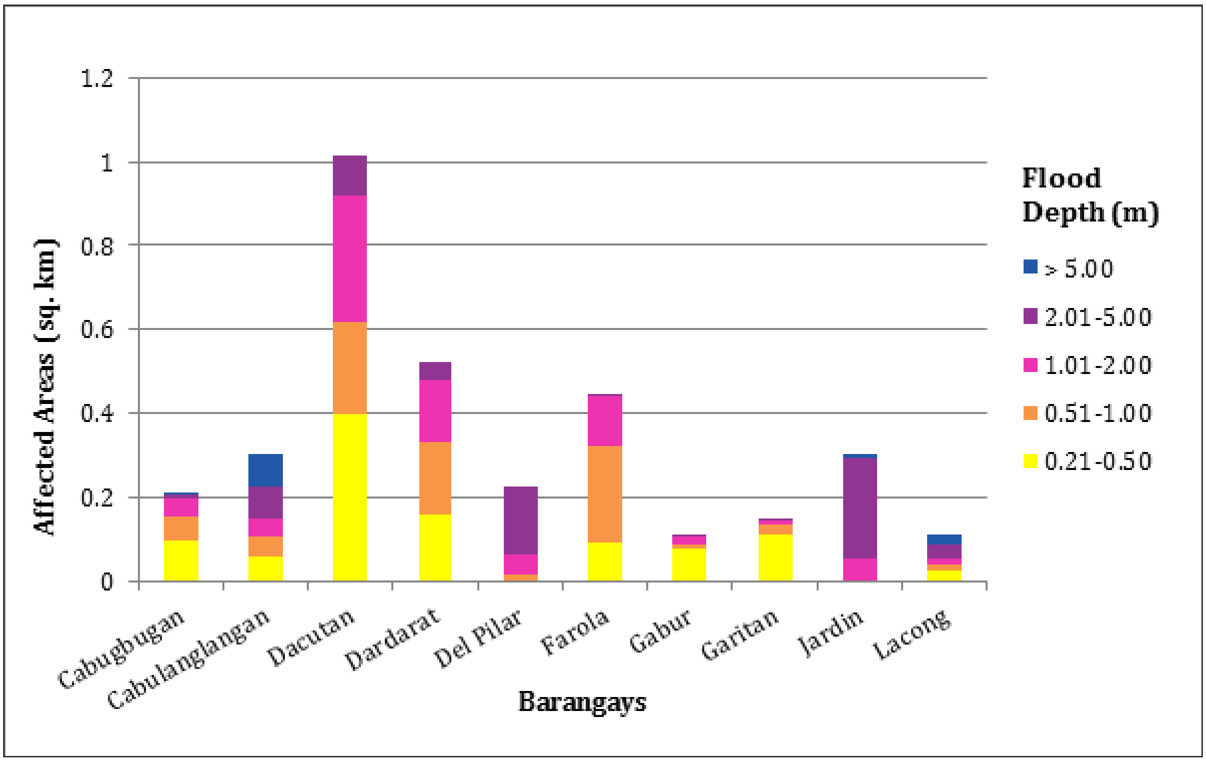


Figure 105. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Table 72. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Lantag	Las-Ud	Libtong	Lubnac	Magsaysay	Malacañang	Pacac	Pallogan	Pudoc East	Pudoc West
0.03-0.20	0.023	0.0017	0.38	1.07	0.12	0.43	0.0079	4.42	0	0.0056
0.21-0.50	0.00063	0.001	0.21	0.35	0.082	0.22	0.0011	0.19	0	0.0011
0.51-1.00	0.0044	0.0039	0.24	0.2	0.067	0.052	0.025	0.11	0	0.034
1.01-2.00	0.042	0.13	0.28	0.019	0.11	0.0034	0.09	0.1	0.019	0.058
2.01-5.00	0.7	0.24	0.0044	0.0001	0.0073	0	1.53	0.15	0.85	1.23
> 5.00	0.08	0.00003	0	0	0	0	0.0051	1.34	0.16	0.15

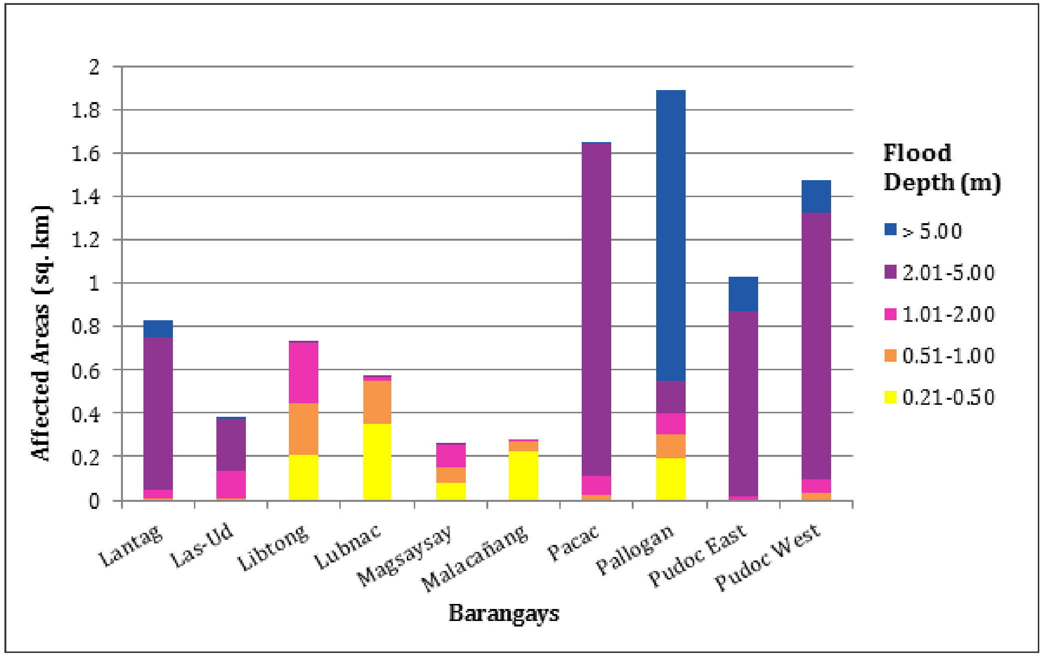


Figure 106. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Table 73. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagudin (in sq. km)									
	Pula	Quirino	Ranget	Rizal	Salvacion	San Miguel	Sawat	Tallaoen	Tampugo	Tarangotong
0.03-0.20	0.032	0.048	1.18	0.11	0.096	0.35	0	0.6	0.47	0.0064
0.21-0.50	0.0008	0.012	0.13	0.0071	0.0036	0.024	0.0045	0.31	0.081	0.015
0.51-1.00	0.0005	0.029	0.025	0.0035	0.0062	0.0081	0.017	0.14	0.054	0.054
1.01-2.00	0.00043	0.29	0.02	0.013	0.024	0.0013	0.2	0.024	0.042	0.35
2.01-5.00	0.037	0.027	0.0057	0.011	0.39	0.00049	0.59	0.0002	0.042	0.88
> 5.00	0.46	0.00028	0.0003	0	0.027	0	0.0018	0	0	0.0017

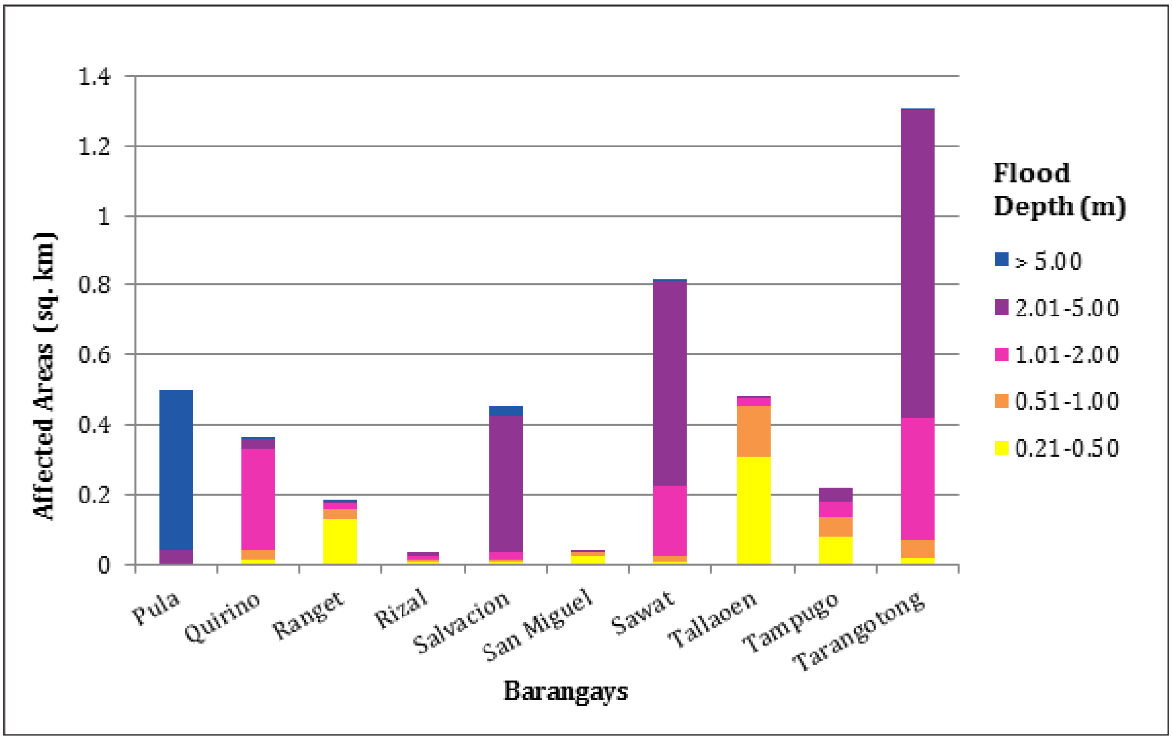


Figure 107. Affected Areas in Tagudin, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 7.58% of the municipality of Balaoan with an area of 60.96 sq. km. will experience flood levels of less than 0.20 meters. 2.14% of the area will experience flood levels of 0.21 to 0.50 meters while 2.97%, 3.07%, 0.99%, and 0.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 74. Affected Areas in Balaoan, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balaoan (in sq. km)						
	Baracbac Este	Baracbac Oeste	Bet-Ang	Bulbulala	Butubut Norte	Butubut Oeste	Calliat
0.03-0.20	0.3	0.47	0.1	0.54	0.49	0.26	0.42
0.21-0.50	0.11	0.24	0.13	0.067	0.061	0.013	0.14
0.51-1.00	0.2	0.24	0.09	0.0071	0.05	0.00062	0.12
1.01-2.00	0.17	0.059	0.007	0.008	0.068	0.00011	0.12
2.01-5.00	0.1	0.043	0.0012	0.012	0.051	0	0.024
> 5.00	0.021	0.023	0.0014	0	0.0007	0	0.00083

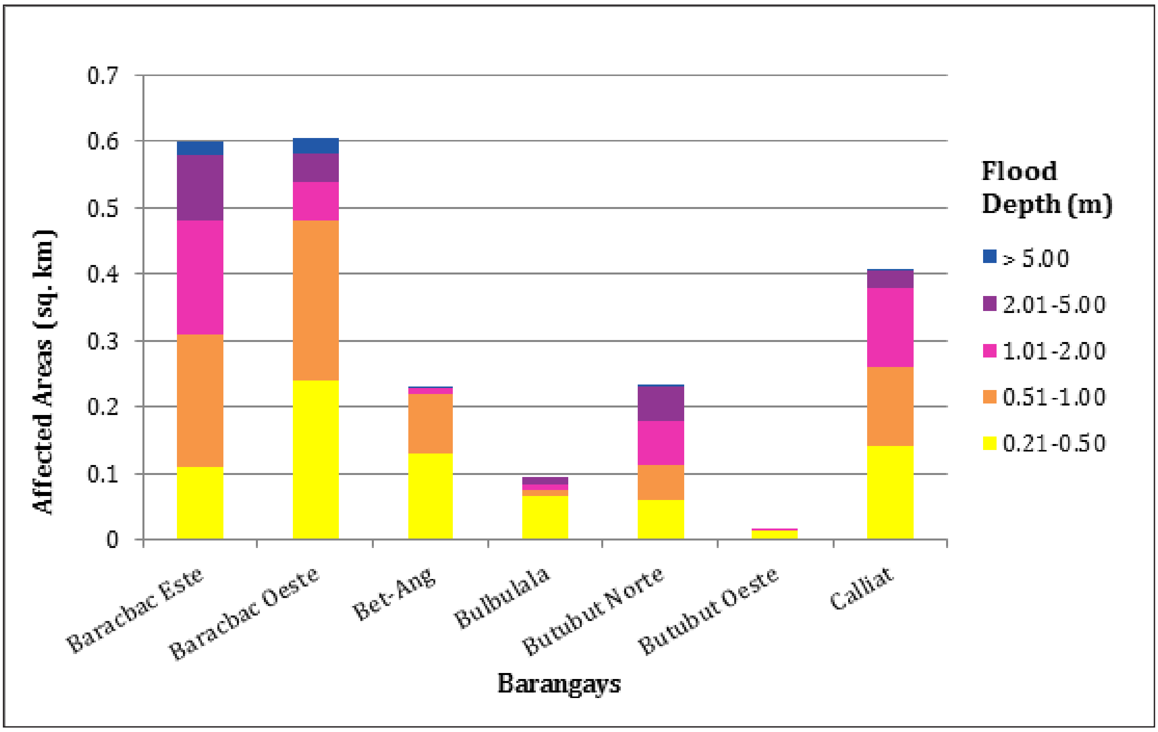


Figure 108. Affected Areas in Balaoan, La Union during 100-Year Rainfall Return Period.

Table 75. Affected Areas in Balaoan, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balaoan (in sq. km)						
	Napaset	Pantar Norte	Pantar Sur	Sablut	Sinapangan Norte	Sinapangan Sur	Tallipugo
0.03-0.20	0.073	0.079	0.37	0.093	0.43	0.96	0.033
0.21-0.50	0.046	0.045	0.14	0.069	0.068	0.054	0.12
0.51-1.00	0.087	0.0071	0.047	0.14	0.19	0.09	0.54
1.01-2.00	0.034	0.0018	0.015	0.055	0.4	0.095	0.84
2.01-5.00	0	0	0.016	0.01	0.074	0.095	0.18
> 5.00	0	0	0.003	0.007	0	0.059	0.016

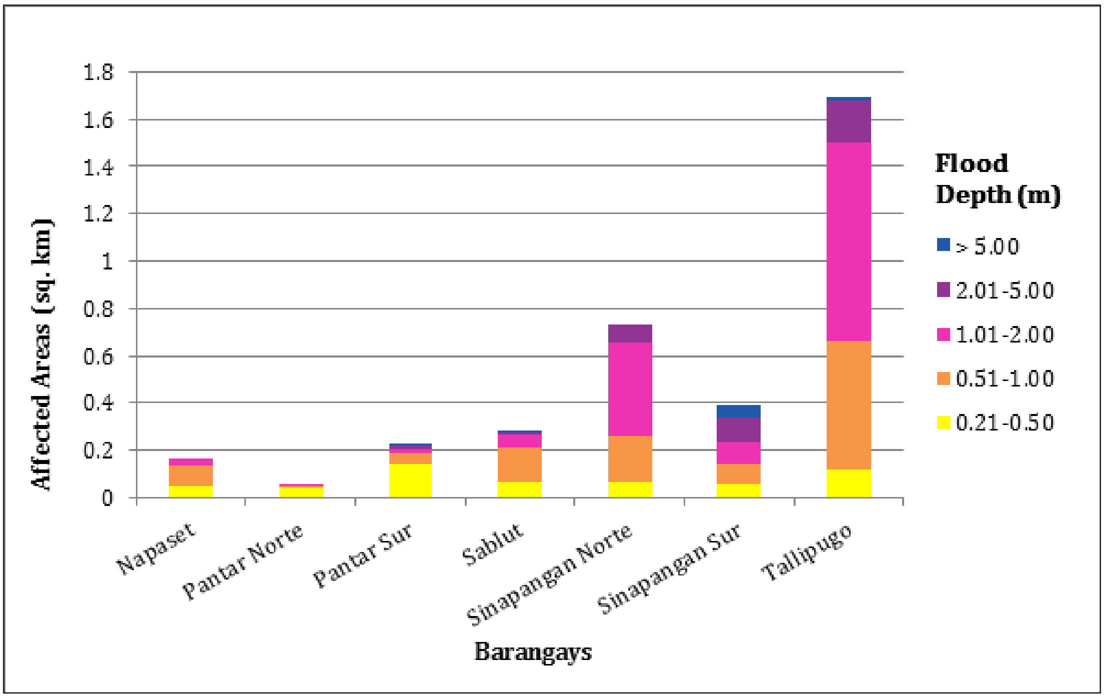


Figure 109. Affected Areas in Balaoan, La Union during 100-Year Rainfall Return Period.

For the 100-year return period, 25.91% of the municipality of Bangar with an area of 45.12 sq. km. will experience flood levels of less than 0.20 meters. 4.52% of the area will experience flood levels of 0.21 to 0.50 meters while 7.43%, 9.12%, 36.99%, and 15.99% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 76. Affected Areas in Bangar, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Agdeppa	Alzate	Bangaoilan East	Bangaoilan West	Barraca	Cadapli	Caggao	Central East No. 1	Central East No. 2	Central West No. 1	Central West No. 2
0.03-0.20	0.00062	0	0.44	0.089	0	0.23	0	0	0	0	0
0.21-0.50	0.00068	0	0.055	0.022	0	0.11	0	0	0	0	0.0001
0.51-1.00	0.0016	0	0.086	0.048	0	0.27	0.0003	0	0	0	0.0003
1.01-2.00	0.017	0.0002	0.074	0.094	0.005	0.34	0.0065	0	0	0	0.0066
2.01-5.00	1.09	1.05	0.55	0.46	0.59	0.037	0.64	0.049	0.034	0.055	0.06
> 5.00	2.15	0.39	0.2	0.36	0.099	0.0031	0.1	0	0	0.00022	0

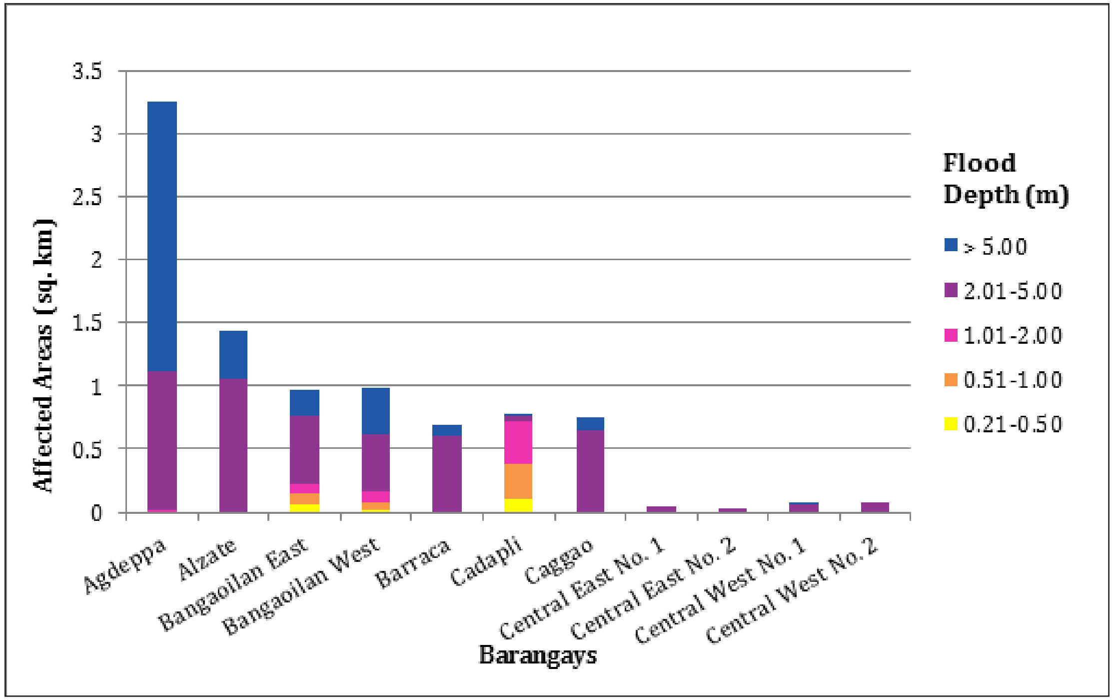


Figure 110. Affected Areas in Bangar, La Union during 100-Year Rainfall Return Period.

Table 77. Affected Areas in Bangar, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Central West No. 3	Consuegra	General Prim East	General Prim West	General Terrero	Luzong Norte	Luzong Sur	Maria Cristina East	Maria Cristina West	Mindoro	Nagsabaran
0.03-0.20	0	0	0	0	0.0033	2.89	2.6	0	0	0	0
0.21-0.50	0	0	0	0	0.0004	0.27	0.23	0	0	0.0005	0
0.51-1.00	0	0.0012	0.0001	0.0001	0.0012	0.28	0.17	0.0019	0.00068	0.042	0
1.01-2.00	0	0.033	0.018	0.015	0.012	0.31	0.17	0.017	0.03	0.11	0
2.01-5.00	0.059	0.77	0.36	0.74	0.34	0.42	0.23	0.33	0.34	1.78	0.15
> 5.00	0	0.25	0.17	0.4	0.17	0.1	0.093	0.0054	0.13	0.35	0.23

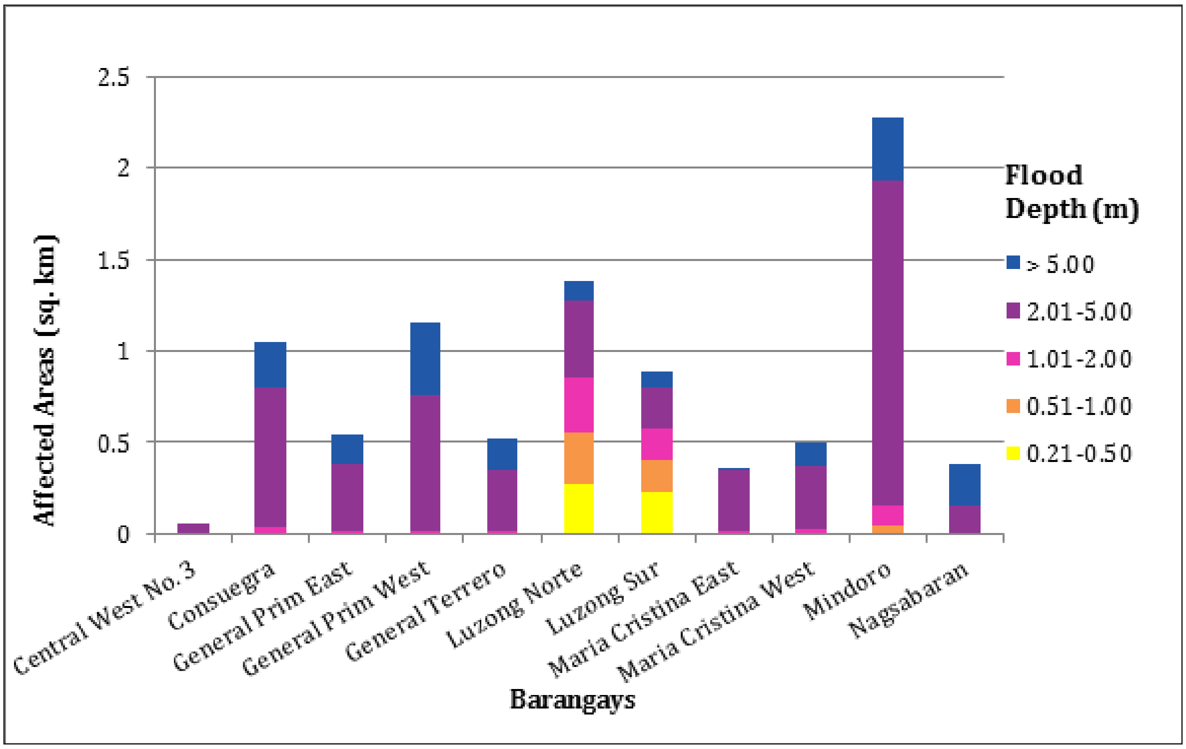


Figure 111. Affected Areas in Bangar, La Union during 100-Year Rainfall Return Period.

Table 78. Affected Areas in Bangar, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangar (in sq. km)										
	Paratong No. 3	Paratong No. 4	Paratong Norte	Quintarong	Reyna Regente	Rissing	San Blas	San Cristobal	Sinapangan Norte	Sinapangan Sur	Ubbog
0.03-0.20	0.0018	0.0069	0.0054	0	0	0.097	0	2.28	1.97	1	0.078
0.21-0.50	0.013	0.045	0.0042	0	0	0.13	0	0.42	0.35	0.29	0.1
0.51-1.00	0.033	0.047	0.018	0	0	0.28	0	0.52	0.42	0.89	0.24
1.01-2.00	0.08	0.054	0.07	0.0001	0.0005	0.67	0.00028	0.37	0.27	0.99	0.35
2.01-5.00	0.094	0.2	0.33	0.22	0.33	2.78	0.65	0.15	0.12	0.31	1.37
> 5.00	0.11	0.057	0.15	0.076	0.0001	0.44	0.97	0.0077	0.014	0.058	0.13

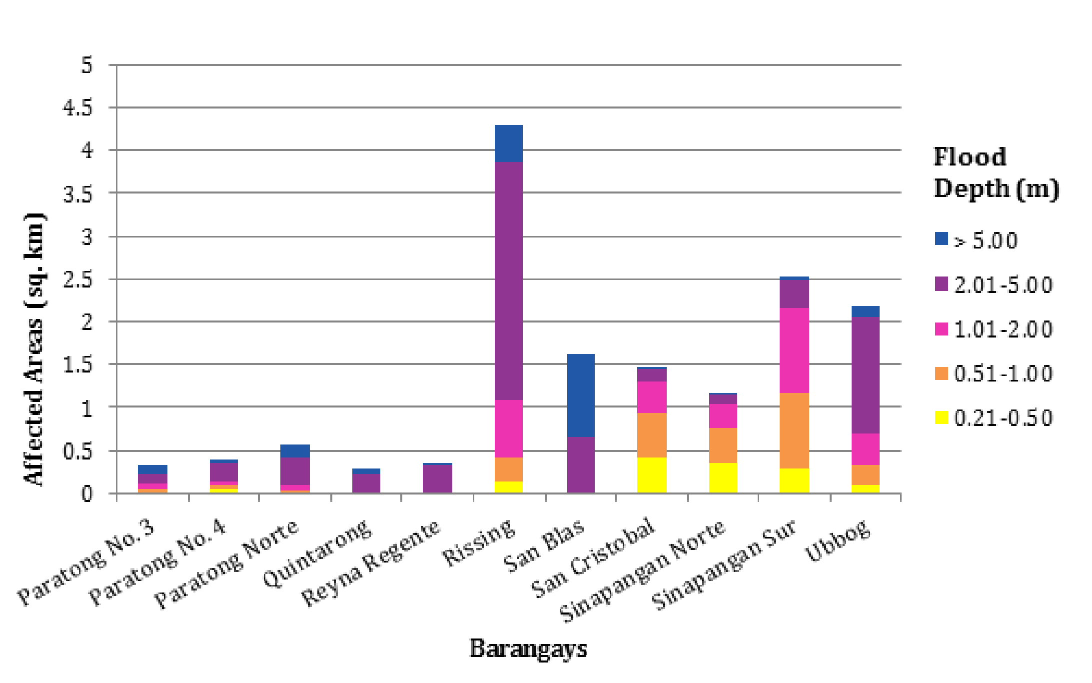


Figure 112. Affected Areas in Bangar, La Union during 100-Year Rainfall Return Period.

For the 100-year return period, 1.92% of the municipality of Luna with an area of 50.66 sq. km. will experience flood levels of less than 0.20 meters. 1.33% of the area will experience flood levels of 0.21 to 0.50 meters while 1.86%, 2.91%, 7.91%, and 1.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 79. Affected Areas in Luna, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km)								
	Barangobong	Cantoria No. 1	Cantoria No. 2	Cantoria No. 3	Cantoria No. 4	Napaset	Oaqui No. 1	Oaqui No. 2	Oaqui No. 3
0.03-0.20	0	0.13	0.039	0.22	0.16	0.045	0.086	0.085	0.0065
0.21-0.50	0.0009	0.073	0.0003	0.023	0.077	0.042	0.11	0.045	0.03
0.51-1.00	0.034	0.078	0	0.0002	0.083	0.012	0.18	0.15	0.11
1.01-2.00	0.13	0.15	0	0	0.088	0.0018	0.2	0.11	0.081
2.01-5.00	0.23	0.023	0	0	0	0.0012	0.0002	0	0
> 5.00	0	0	0	0	0	0.001	0	0	0

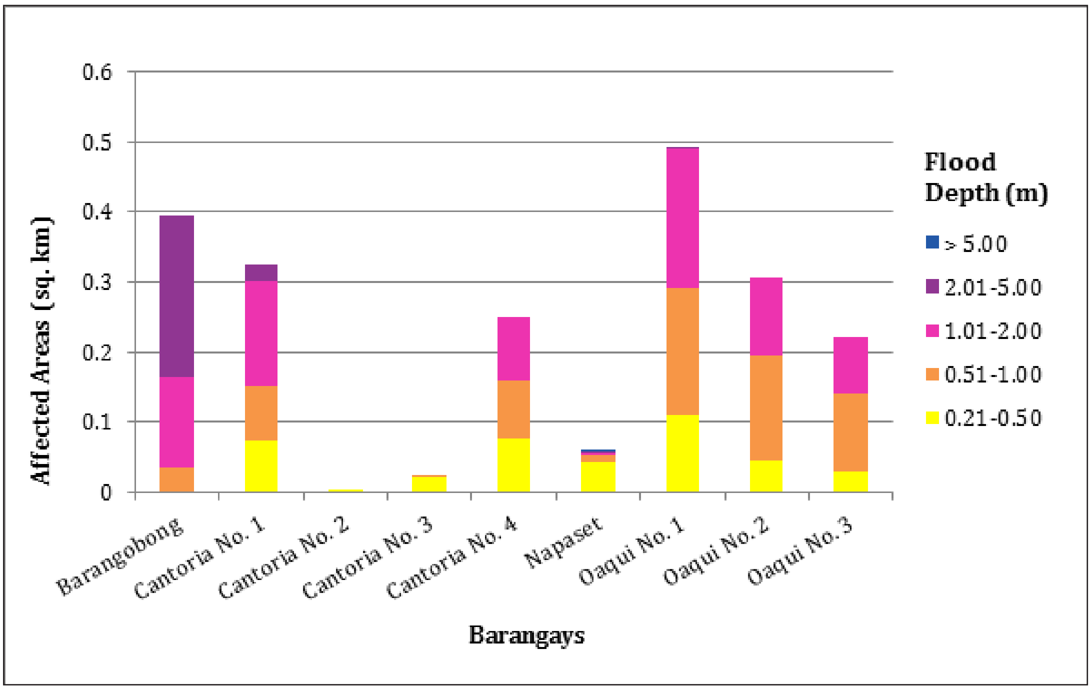


Figure 113. Affected Areas in Luna, La Union during 100-Year Rainfall Return Period.

Table 80. Affected Areas in Luna, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km)								
	Oaqui No. 4	Rimos No. 1	Rimos No. 2	Rimos No. 3	Rimos No. 4	Rimos No. 5	Rissing	Santo Domingo Norte	Suyo
0.03-0.20	0.0053	0	0	0.0012	0.000003	0.065	0.12	0	0.0088
0.21-0.50	0.043	0	0	0.00017	0.00096	0.032	0.18	0	0.018
0.51-1.00	0.1	0	0	0.0044	0.0016	0.016	0.13	0	0.044
1.01-2.00	0.041	0.0044	0	0.062	0.088	0.039	0.18	0.00066	0.3
2.01-5.00	0	0.12	0.36	0.64	0.77	1.21	0.11	0.0011	0.54
> 5.00	0	0.000064	0.084	0.17	0.25	0.1	0.014	0	0

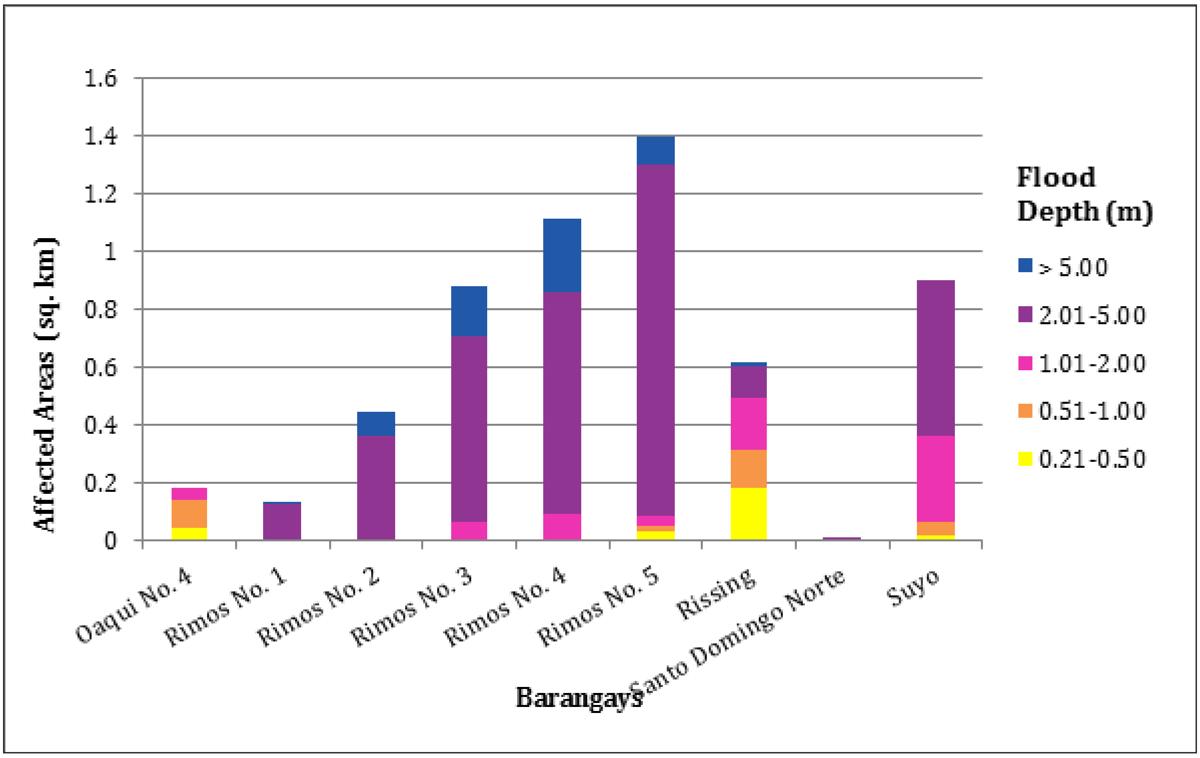


Figure 114. Affected Areas in Luna, La Union during 100-Year Rainfall Return Period.

For the 100-year return period, 2.37% of the municipality of Santol with an area of 97.97 sq. km. will experience flood levels of less than 0.20 meters. 0.42% of the area will experience flood levels of 0.21 to 0.50 meters while 0.53%, 0.15%, 0.09%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 81. Affected Areas in Santol, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santol (in sq. km)
	Paagan
0.03-0.20	2.32
0.21-0.50	0.41
0.51-1.00	0.52
1.01-2.00	0.15
2.01-5.00	0.091
> 5.00	0.047

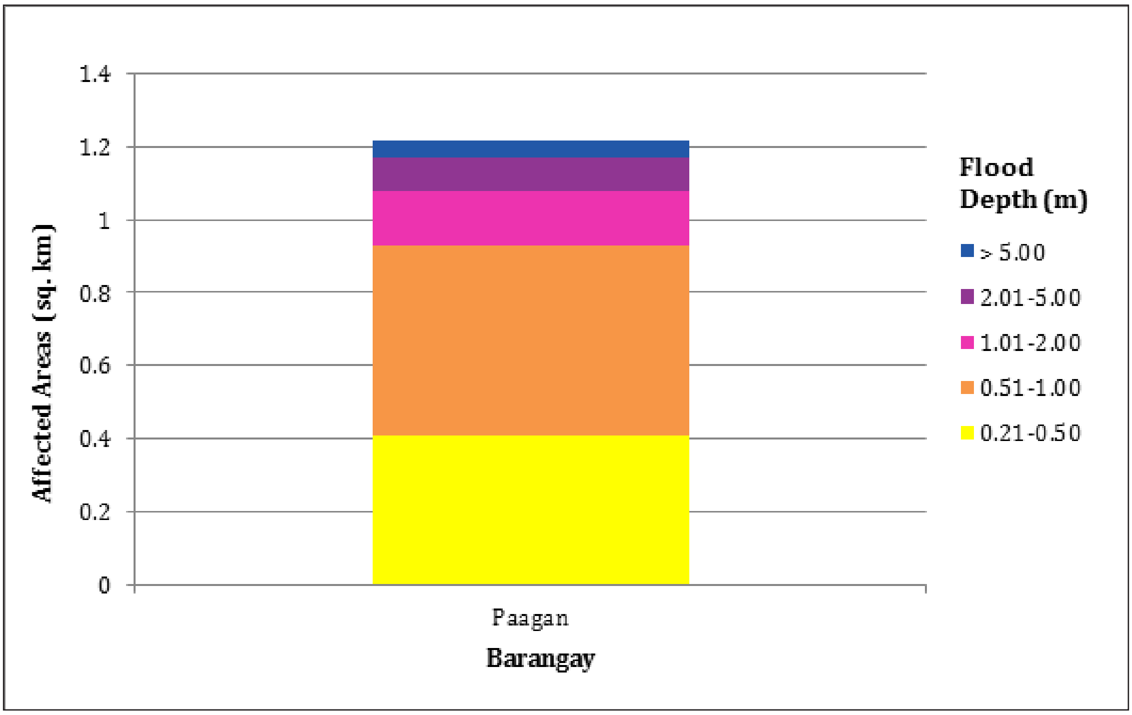


Figure 115. Affected Areas in Santol, La Union during 100-Year Rainfall Return Period.

For the 100-year return period, 33.36% of the municipality of Sudipen with an area of 75.745 sq. km. 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 while 2.27%, 2.03%, 3.22%, and 6.99% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 82. Affected Areas in Sudipen, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sudipen (in sq. km)						
	Bigbiga	Castro	Duplas	Ilocano	Ipet	Namaltugan	Old Central
0.03-0.20	3.46	2.16	0.11	1.49	2.2	0.12	3.2
0.21-0.50	0.4	0.14	0.00062	0.12	0.093	0.0011	0.23
0.51-1.00	0.5	0.081	0.0004	0.093	0.079	0.002	0.13
1.01-2.00	0.45	0.046	0.0004	0.1	0.12	0.0021	0.11
2.01-5.00	0.069	0.028	0.0004	0.18	1.25	0.0053	0.28
> 5.00	0.0006	0.00075	0	0.59	1.98	0.12	1.6

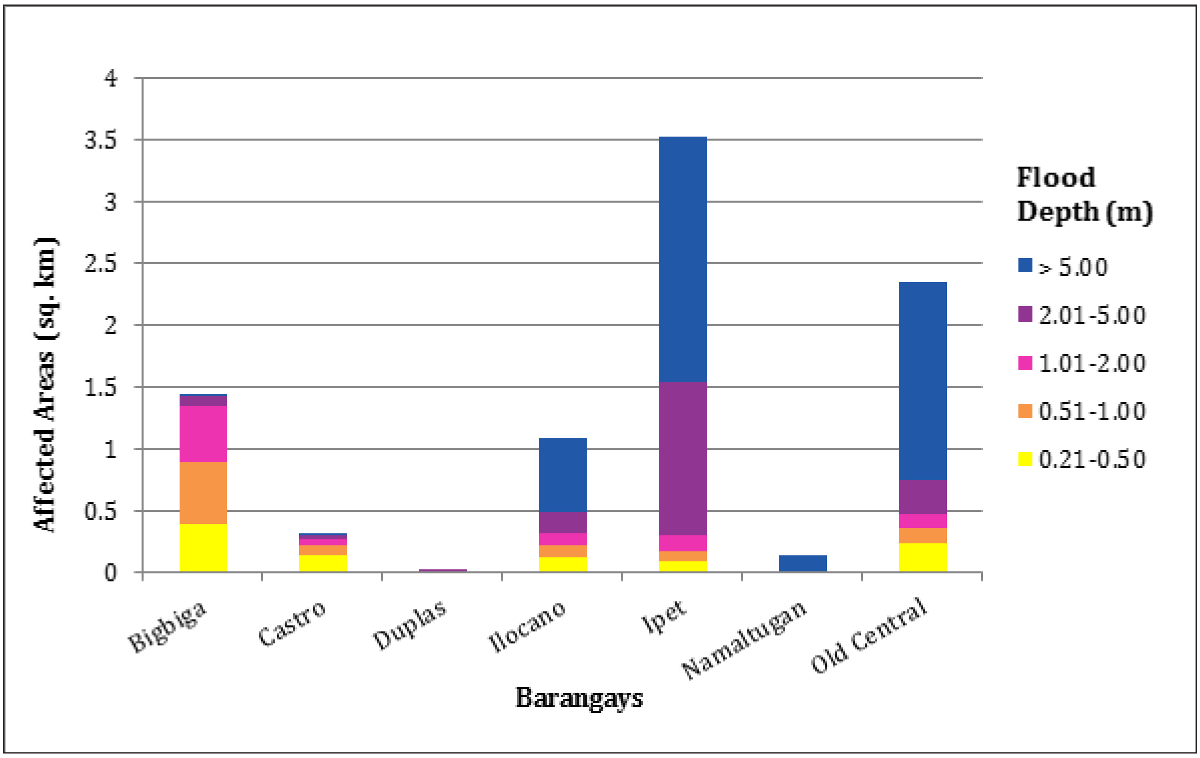


Figure 116. Affected Areas in Sudipen, La Union during 100-Year Rainfall Return Period.

Table 83. Affected Areas in Sudipen, La Union during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sudipen (in sq. km)						
	Poblacion	San Francisco Norte	San Francisco Sur	San Jose	Sengngat	Turod	Up-Uplas
0.03-0.20	0.74	3.24	2.59	3.4	1.4	1.07	0.088
0.21-0.50	0.075	0.17	0.2	0.2	0.2	0.11	0.0007
0.51-1.00	0.063	0.13	0.24	0.16	0.16	0.08	0.0003
1.01-2.00	0.038	0.13	0.21	0.13	0.17	0.03	0.00079
2.01-5.00	0.099	0.14	0.16	0.11	0.11	0.0058	0.00063
> 5.00	0.96	0.018	0.0095	0.018	0.0011	0	0.000024

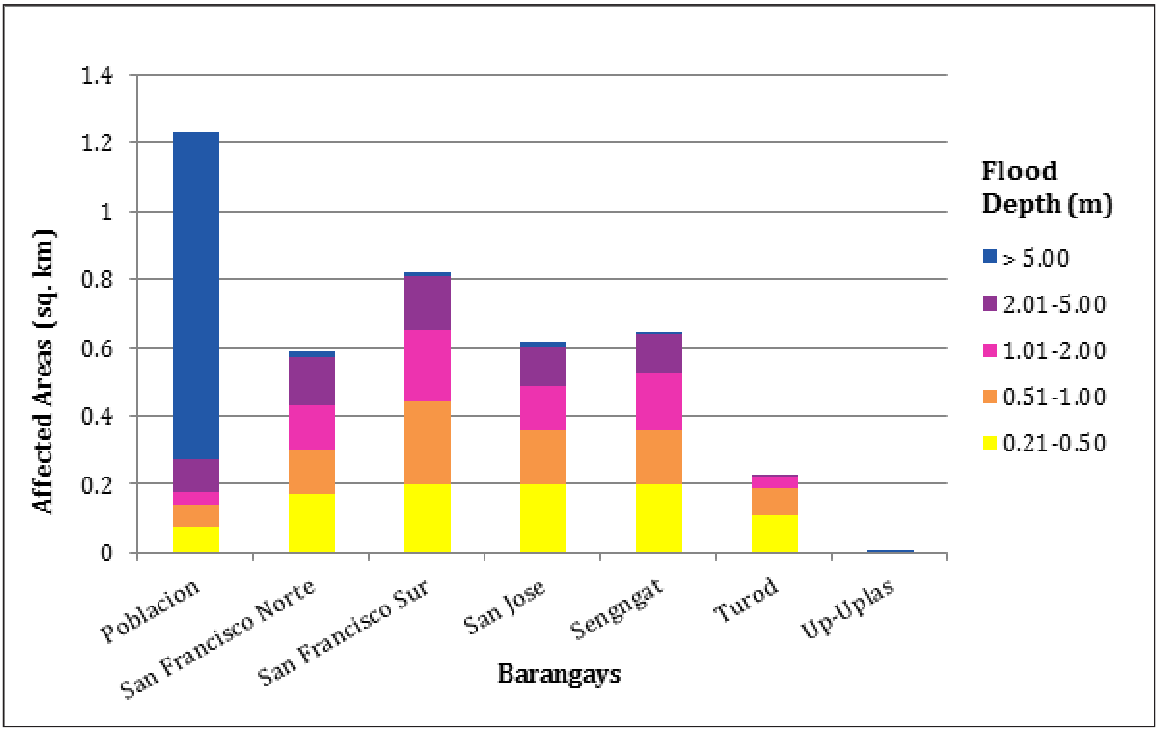


Figure 117. Affected Areas in Sudipen, La Union during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Alilem in Ilocos Sur, Dalawa is projected to have the highest percentage of area that will experience flood levels at 4.72%. Meanwhile, Kiat posted the second highest percentage of area that may be affected by flood depths at 0.43%.

Brgy. Gabor Sur is the only barangay affected in the municipality of Santa Cruz in Ilocos Sur. The barangay is projected to experience flood in 0.07% of the municipality.

Among the barangays in the municipality of Suyo in Ilocos Sur, Cabugao is projected to have the highest percentage of area that will experience flood levels at 7.82%. Meanwhile, Baringcucurong posted the second highest percentage of area that may be affected by flood depths at 2.99%.

Among the barangays in the municipality of Tagudin in Ilocos Sur, Ambalayat is projected to have the highest percentage of area that will experience flood levels at 15.84%. Meanwhile, Pallogan posted the second highest percentage of area that may be affected by flood depths at 11.59%.

Among the barangays in the municipality of Balaoan in La Union, Tallipugo is projected to have the highest percentage of area that will experience flood levels at 2.83%. Meanwhile, Sinapangan Sur posted the second highest percentage of area that may be affected by flood depths at 2.20%.

Among the barangays in the municipality of Bangar in La Union, Rissing is projected to have the highest percentage of area that will experience flood levels at 9.78%. Meanwhile, Luzong Norte posted the second highest percentage of area that may be affected by flood depths at 9.48%.

Among the barangays in the municipality of Luna in La Union, Rimos No. 5 is projected to have the highest percentage of area that will experience flood levels at 2.90%. Meanwhile, Rimos No. 4 posted the second highest percentage of area that may be affected by flood depths at 2.19%.

Brgy. Paagan is the only barangay affected in the municipality of Santol in La Union. The barangay is projected to experience flood in 3.60% of the municipality.

Among the barangays in the municipality of Sudipen in La Union, Ipet is projected to have the highest percentage of area that will experience flood levels at 7.58%. Meanwhile, Old Central posted the second highest percentage of area that may be affected by flood depths at 7.33%.

Moreover, the generated flood hazard maps for the Amburayan Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

Table 84. Area covered by each warning level with respect to the rainfall scenario.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	13.01	11.59	10.95
Medium	21.50	18.49	18.71
High	46.68	63.52	69.74
TOTAL	81.19	93.6	99.4

Of the 78 identified educational institutions in the Amburayan floodplain, 19 schools were assessed to be highly prone to flooding as they are exposed to the High level flooding for all three rainfall scenarios. 22 other institutions were found to be also susceptible to flooding, experiencing Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios. See Annex 12 for a detailed enumeration of schools in the Amburayan floodplain.

10 medical institutions were identified in the Amburayan floodplain. Tagudin Medical Diagnostic Center in Brgy. Las-Ud was found to be highly prone to flooding, having High level flooding in all three rainfall scenarios. See Annex 13 for a detailed enumeration of hospitals and clinics in the Amburayan floodplain.

5.11 Flood Validation

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

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

The validation personnel will then go to the specified points identified in a river basin and will gather data regarding the actual flood level in each location. Data gathering can be done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation survey was conducted in January 2017. The flood validation consists of 326 points randomly selected all over the Amburayan flood plain. It has an RMSE value of 1.38.

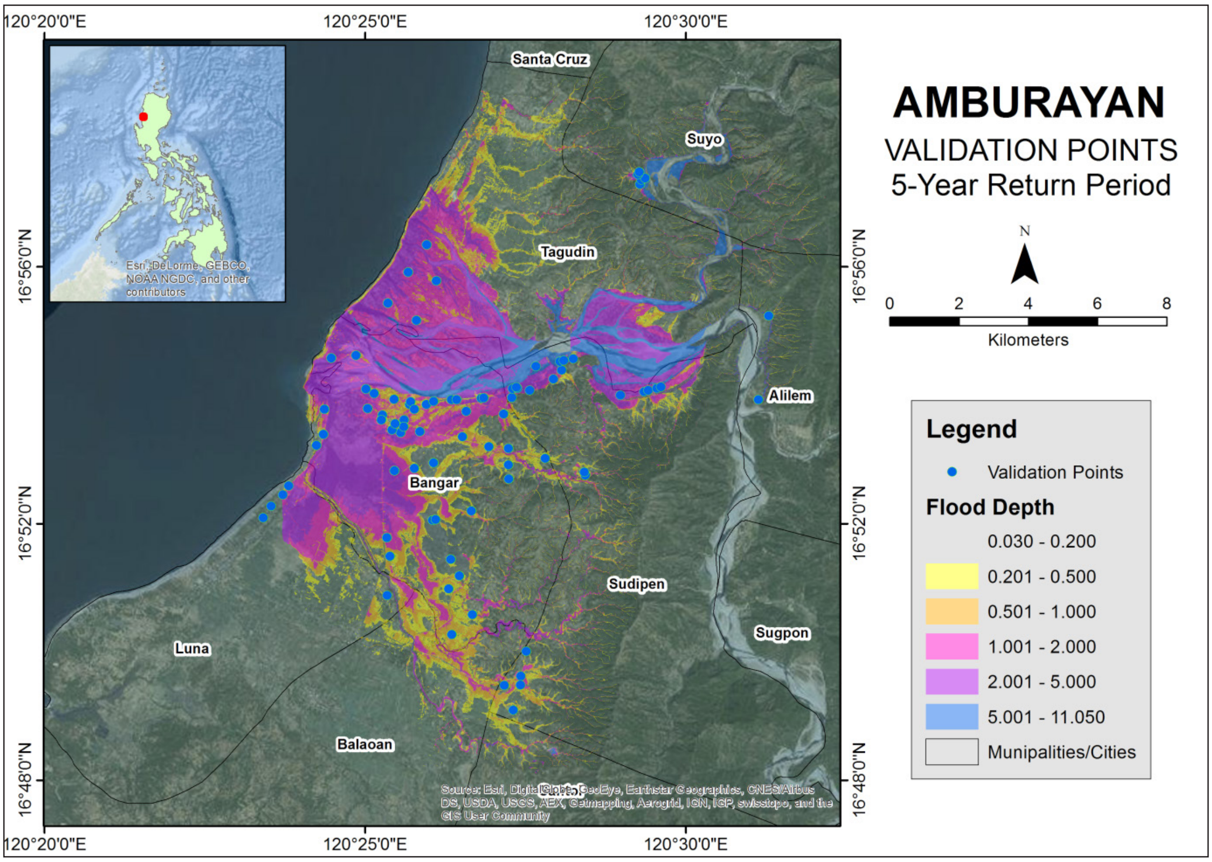


Figure 118. Flood Validation Points for Amburayan River Basin.

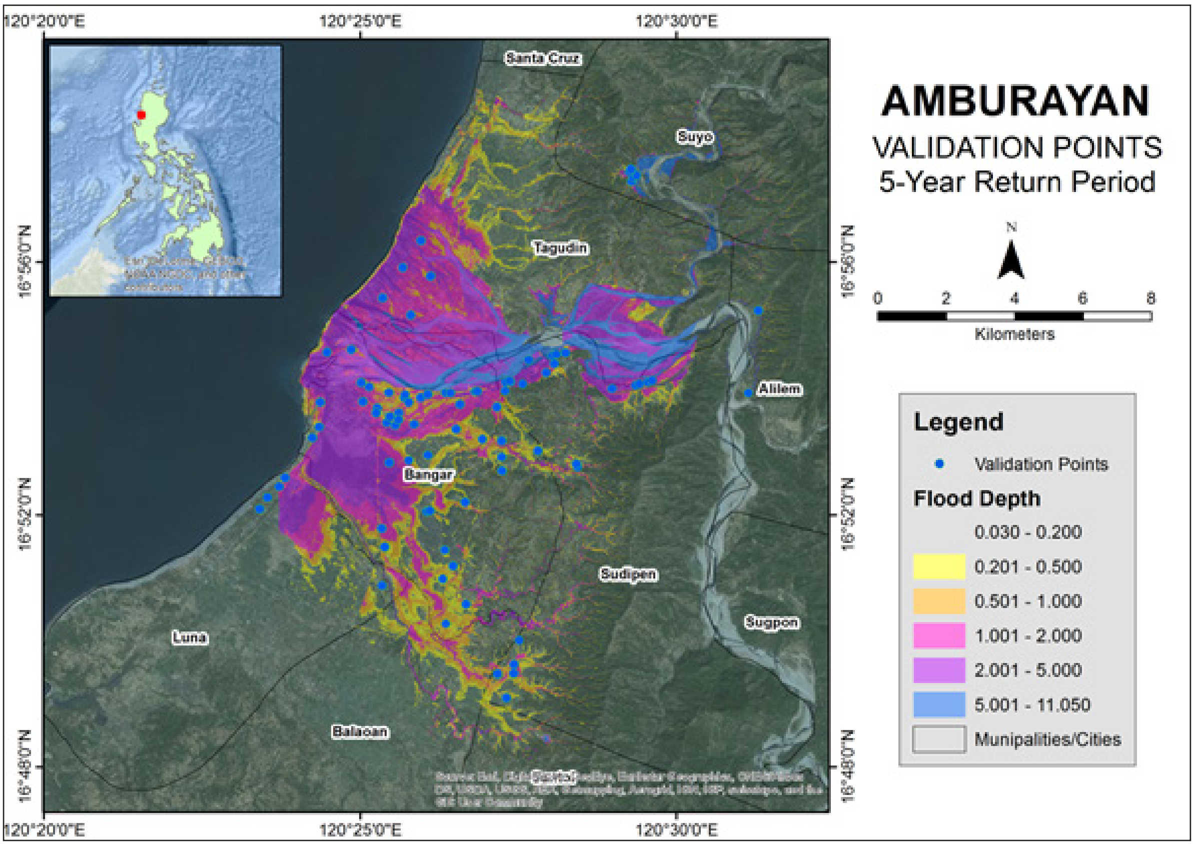


Figure 119. Flood Map Depth vs Actual Flood Depth for Amburayan.

Table 85. Table 85. Actual Flood Depth vs Simulated Flood Depth in Amburayan.

AMBURAYAN BASIN		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
Actual Flood Depth (m)	0-0.20	18	1	2	0	0	0	21
	0.21-0.50	10	16	27	21	1	1	76
	0.51-1.00	19	14	71	47	2	6	159
	1.01-2.00	8	4	18	30	8	2	70
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	55	35	118	98	11	9	326

The overall accuracy generated by the flood model is estimated at 41.41%, with 135 points correctly matching the actual flood depths. In addition, there were 125 points estimated one level above and below the correct flood depths while there were 50 points and 16 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 118 points were overestimated while a total of 73 points were underestimated in the modelled flood depths of Amburayan.

Table 86. Summary of Accuracy Assessment in Amburayan.

	No. of Points	%
Correct	135	**41.41**
Overestimated	118	36.20
Underestimated	73	22.39
Total	326	100

REFERENCES

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

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

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

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

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

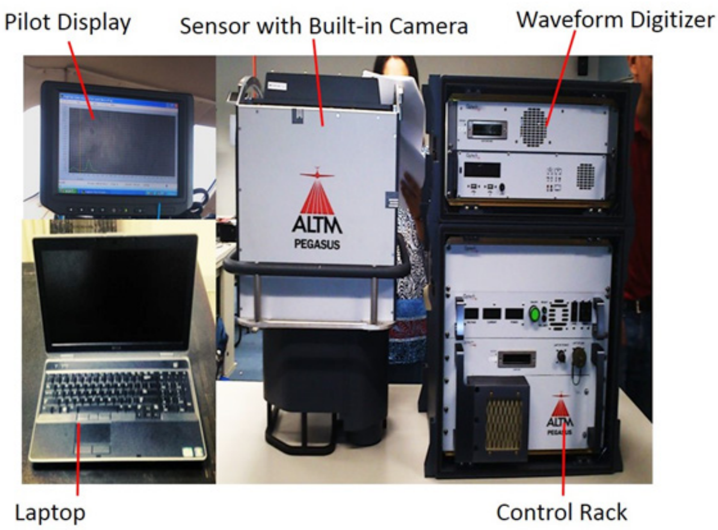
Sarmiento C., Paringit E.C., et al. 2014. *DREAM Data Acquisition Component Manual*. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

ANNEX 1. TECHNICAL SPECIFICATION OF THE SENSOR

1. Pegasus



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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20˚

4 Target size ≥ laser footprint5 Dependent on system configuration

ANNEX 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. LUN-62

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LA UNION**
Station Name: **LUN-62**
Order: **2nd**

Island: **LUZON**
Municipality: **NAGUILIAN**
Barangay: **BARAOAS NORTE**

	PRS92 Coordinates	
Latitude: **16° 33' 19.98115"**	Longitude: **120° 23' 28.76004"**	Ellipsoidal Hgt: **33.18400 m.**
	WGS84 Coordinates	
Latitude: **16° 33' 14.07106"**	Longitude: **120° 23' 33.49149"**	Ellipsoidal Hgt: **69.44500 m.**
	PTM Coordinates	
Northing: **1831016.667 m.**	Easting: **435034.926 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,832,084.35**	Easting: **221,592.72**	Zone: **51**

Location Description

LUN-62
From Naguilian Town Hall, travel N to Brgy. Baraoas Norte until reaching the rough road and the river control. Station is located 15 m. S from the first access ladder of the river control and about 100 m. N from the end. It is also situated 300 m. S of a hanging bridge. Mark is the head of a 4 in. copper nail centered and embedded in a 0.3 m. x 0.3 m. cement putty, with inscriptions "LUN-62 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-451**

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

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

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

2. LUN-176

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LA UNION**
Station Name: **LUN-176**
Order: **2nd**

Island: **LUZON**
Municipality: **BALAOAN**
Barangay: **BUNGOL**

	PRS92 Coordinates	
Latitude: **16° 46' 14.35394"**	Longitude: **120° 24' 5.41918"**	Ellipsoidal Hgt: **35.63300 m.**
	WGS84 Coordinates	
Latitude: **16° 46' 8.39718"**	Longitude: **120° 24' 10.13252"**	Ellipsoidal Hgt: **71.25300 m.**
	PTM Coordinates	
Northing: **1854816.574 m.**	Easting: **436193.115 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,855,884.60**	Easting: **222,990.04**	Zone: **51**

Location Description

LUN-176 (FNSP-DENR)

From Candon City, Ilocos Sur, travel S to the province of La Union passing through Balaoan town proper until reaching Km. Post No. 292 on the left side of the highway. Travel more for about 300 m. until reaching a concrete waiting shed on the right side of the highway, before reaching a highway curve and the road leading to Magic Star Fireworks Factory. Beside the concrete shed is a trail, follow this trail until reaching a house with an artesian well beside a series of Coconut trees. It is located on a corner of a farm dike, about 15 m. SE of the well and about 20 m. SW of the nearest house.

Mark is the head of a 3 in. concrete nail embedded and centered on a 30 cm. x 30 cm. concrete monument protruding by about 5 cm., with inscriptions "LUN-176, 2004, PRS-92, FNSP-DENR-I".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-453**

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

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

3. LUN-3062

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LA UNION**
Station Name: **LUN-3062**
Order: **4th**

Island: **LUZON**
Municipality: **NAGUILIAN**
Barangay: **NATIVIDAD (POB.)**

PRS92 Coordinates

Latitude: **16° 31' 55.00993"**	Longitude: **120° 23' 12.50504"**	Ellipsoidal Hgt: **25.32100 m.**

WGS84 Coordinates

Latitude: **16° 31' 49.10470"**	Longitude: **120° 23' 17.23850"**	Ellipsoidal Hgt: **61.64400 m.**

PTM Coordinates

Northing: **1828406.255 m.**	Easting: **434545.028 m.**	Zone: **3**

UTM Coordinates

Northing: **1,829,477.48**	Easting: **221,076.59**	Zone: **51**

Location Description

LUN-3062

Is located at barangay Natividad, Naguilian, La Union. The station is erected at the top of a dike. It is approximately 100 m north of Philippine Central College of Arts Science & Technology and 80 m north of Naguilian emission testing center.
Mark in the head of a 3 inches concrete nail embedded and centered on a 30 cm x 30 cm x 100 cm standard concrete monument protruding by about 20 cm, with the inscription LUN-3062 PRS-92 DENR-FNSP R-1.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-455**

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

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

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

4. LUN-3129

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LA UNION**
Station Name: **LUN-3129 (BLLM-9)**
Order: **4th**

Island: **LUZON**
Municipality: **BALAOAN**
Barangay: **BUNGOL**

PRS92 Coordinates		
Latitude: **16° 46' 13.75662"**	Longitude: **120° 24' 16.12821"**	Ellipsoidal Hgt: **37.03000 m.**
WGS84 Coordinates		
Latitude: **16° 46' 7.80013"**	Longitude: **120° 24' 20.84154"**	Ellipsoidal Hgt: **72.65800 m.**
PTM Coordinates		
Northing: **1854797.26 m.**	Easting: **436510.212 m.**	Zone: **3**
UTM Coordinates		
Northing: **1,855,862.08**	Easting: **223,307.10**	Zone: **51**

Location Description

LUN-3129 (BLLM-9)

The station is located of National road about 50 meters northeast of the house of Engr. Whitney Valdez.

Station mark is the head of a 3" concrete nail embedded and centered on a 30cm. x 30cm. x 100 cm. standard concrete monument protruding about 20cm. with inscription "LUN-3129 (BLLM-9); 2008; DENR/LMS I."

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-456**

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

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

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

5. LU-94

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LA UNION**
Station Name: **LU-94**

Island: **LUZON**	Municipality: **BACNOTAN**	Barangay: **BARORO**
Elevation: **7.3488 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LU-94
Station is located in Brgy. Baroro, Bacnotan, La Union along the national highway set on the S edge of Baroro bridge, 4 m SE of the centerline of the national highway, 30 m SE of Baroro national memorial monument.

Mark is the head of a 4" copper nail set on a drilled hole and cemented flushed on top of a 10 cm x 10 cm cement putty with inscription LU-94 2007 NAMRIA.

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-449**

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

9903042014160555

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

ANNEX 3. BASELINE PROCESSING REPORT

Vector Components (Mark to Mark)

From:	LUN-176				
Grid		Local		Global	
Easting	223129.137 m	Latitude	N16°46'08.61931"	Latitude	N16°46'08.61931"
Northing	1855819.084 m	Longitude	E120°24'10.06092"	Longitude	E120°24'10.06092"
Elevation	31.168 m	Height	70.997 m	Height	70.997 m

To:	LU-94				
Grid		Local		Global	
Easting	216672.143 m	Latitude	N16°42'38.64674"	Latitude	N16°42'38.64674"
Northing	1849445.472 m	Longitude	E120°20'35.05091"	Longitude	E120°20'35.05091"
Elevation	9.967 m	Height	49.582 m	Height	49.582 m

Vector					
ΔEasting	-6456.994 m	NS Fwd Azimuth	224°37'26"	ΔX	4564.890 m
ΔNorthing	-6373.612 m	Ellipsoid Dist.	9067.628 m	ΔY	4806.440 m
ΔElevation	-21.201 m	ΔHeight	-21.415 m	ΔZ	-6187.390 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000159225		
Y	-0.0000194629	0.0000365086	
Z	-0.0000081542	0.0000147591	0.0000075754

ANNEX 4. THE SURVEY TEAM

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
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUNA	UP-TCAGP
	Research Associate (RA)	RENAN PUNTO	UP-TCAGP
	RA	FAITH JOY SABLE	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. OLIVER SACLOT	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK LAWRENCE TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

ANNEX 5. DATA TRANSFER SHEET FOR BARORO FLOODPLAIN FLIGHTS

(LA UNION)

DATA TRANSFER SHEET
Mar 17, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2/25/2014	1151P	1BLK10A056A	PEGASUS	3.03GB	NA	12.3MB	229MB	N/A	N/A	19.8	N/A	6.5	1KB	459B	35	NA	X:\Airborne_Raw\151P
2/25/2014	1153P	1BLK10AS056B	PEGASUS	836MB	NA	3.57MB	84.5MB	N/A	N/A	8.02	N/A	6.51	1KB	244B	38	N/A	X:\Airborne_Raw\153P
2/26/2014	1155P	1BLK10C057A	PEGASUS	2.64GB	NA	11MB	220MB	33.1GB	289KB	26.4	N/A	6.95	1KB	610B	44	N/A	X:\Airborne_Raw\155P
2/26/2014	1157P	1BLK10B057B	PEGASUS	1.85GB	NA	6.62MB	129MB	25.6GB	229KB	17.4	N/A	6.95	1KB	485B	45	N/A	X:\Airborne_Raw\157P
2/27/2014	1159P	1BLK10GD058A	PEGASUS	2.76GB	NA	11.4MB	221MB	4.7GB	148KB	27.9	N/A	6.55	1KB	669B	29	N/A	X:\Airborne_Raw\159P
2/27/2014	1161P	1BLK10DS058B	PEGASUS	1.28GB	NA	7.08MB	152MB	22.3GB	186KB	15.6	N/A	6.55	1KB	474B	50	N/A	X:\Airborne_Raw\161P
2/28/2014	1163P	1BLK10F059A	PEGASUS	3.42GB	NA	12MB	216MB	53.2GB	416KB	31.7	N/A	6.05	1KB	328B	31	N/A	X:\Airborne_Raw\163P
2/28/2014	1165P	1BLK10E059B	PEGASUS	1.41GB	NA	7.12MB	143MB	25.6GB	208KB	16.7	N/A	6.05	1KB	502B	n/a	N/A	X:\Airborne_Raw\165P
3/1/2014	1167P	1BLK10H060A	PEGASUS	831MB	NA	7.42MB	170MB	17.5GB	145KB	8.66	N/A	6.64	1KB	318B	20	N/A	X:\Airborne_Raw\167P
3/1/2014	1169P	1BLK10ES060B	PEGASUS	2.05GB	NA	7.17MB	133MB	28.6GB	224KB	19.1	N/A	6.64	1KB	304B	45	N/A	X:\Airborne_Raw\169P
3/2/2014	1171P	1BLK10CDS061A	PEGASUS	1.72GB	NA	9.73MB	206MB	21GB	170KB	17	N/A	7.08	1KB	310B	32	N/A	X:\Airborne_Raw\171P
3/2/2014	1173P	1BLK10DS061B	PEGASUS	1.52GB	NA	5.95MB	116MB	20.3GB	169KB	14.5	N/A	7.08	1KB	481B	50	N/A	X:\Airborne_Raw\173P
3/3/2014	1175P	1BLK10BS062A	PEGASUS	3.14GB	NA	11.8MB	214MB	43.1GB	341KB	29.5	N/A	6.74	1KB	305B	38	N/A	X:\Airborne_Raw\175P
3/3/2014	1177P	1BLK10CS062B	PEGASUS	1.18GB	NA	8.31MB	157MB	30GB	254KB	11.3	N/A	6.74	1KB	741B	42	N/A	X:\Airborne_Raw\177P
Mar 4, 2014	1179P	1BLK27B063A	PEGASUS	3.54GB	NA	14MB	260MB	39.3GB	361KB	34.5	N/A	5.86	1KB	1KB	38	N/A	X:\Airborne_Raw\179P
Mar 5, 2014	1183P	1BLK12AC064A	PEGASUS	1.5GB	NA	10.3MB	206MB	35.6GB	304KB	22.5GB	N/A	5.94	1KB	1KB	42/38/33/4234	N/A	X:\Airborne_Raw\183P
Mar 5, 2014	1185P	1BLK10D064B	PEGASUS	1.18GB	NA	5.86MB	151MB	16.4GB	142KB	11.7GB	N/A	5.94	1KB	1KB	n/a	N/A	X:\Airborne_Raw\185P
Mar 6, 2014	1187P	1BLK12DS065A	PEGASUS	2.34GB	NA	11MB	212MB	35.3GB	302KB	24.4GB	N/A	6.62	1KB	1KB	36	N/A	X:\Airborne_Raw\187P
Mar 6, 2014	1189P	1BLK12CS065B	PEGASUS	2.06GB	NA	8.08MB	151MB	37.7GB	332KB	19.7GB	N/A	6.62	1KB	1KB	42	N/A	X:\Airborne_Raw\189P
Mar 8, 2014	1195P	1BLK27ABS067A	PEGASUS	915MB	NA	4.91MB	110MB	16.1GB	130KB	10.2GB	N/A	From Ilocos	1KB	1KB	36	N/A	X:\Airborne_Raw\195P
Mar 8, 2014	1197P	1BLK10CGS067B	PEGASUS	714MB	NA	4.95MB	112MB	14.5GB	131KB	8.16GB	N/A	1.44MB	1KB	1KB	27	N/A	X:\Airborne_Raw\197P

Received from
Name CHRIS JOAQUIN
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature

ANNEX 6. FLIGHT LOGS

1. Flight Log for 1151P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1151P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK1DA056A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION AREA			
10 Date: FEB. 25, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0912	14 Engine Off: ~~1605~~ 1305	15 Total Engine Time: 3 + 53	16 Take off:	17 Landing:	18 Total Flight Time: 3 + 43
19 Weather	cloudy				

20 Remarks: SUCCESSFUL FLIGHT

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	OLIVER SACLOT	M.C TANGONAN	REGINO PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

2. Flight Log for 1153P Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1153P

1 LiDAR Operator: F. SAGUE	2 ALTM Model: PEG	3 Mission Name: 1BLK10AS056B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION			
10 Date: FEB. 25, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0912	14 Engine Off: 1805	15 Total Engine Time: 1+53	16 Take off:	17 Landing:	18 Total Flight Time: 1+45
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	OLIVER BACLOT	M.C TANGONAN	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1155P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1155P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK10CS57A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION			
10 Date: FEB. 26, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0901	14 Engine Off: 1242	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time: 3+31
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	OLIVER SPELOT	M. C. TANGONAN	RENATO PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

4. Flight Log for 1157P Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1157P

1 LiDAR Operator: F. SABLE	2 ALTM Model: PEG	3 Mission Name: 1BLK10B057B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. AGAWIN	9 Route: LA UNION			
10 Date: FEB. 26, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 1333	14 Engine Off: 1602	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time: 2+19
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

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

Pilot-in-Command
M. L TANGONAN
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

5. Flight Log for 1171P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1171P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK1OCDS061A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: N. ADAWIN	9 Route: LA UNION			
10 Date: MAR. 2, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0912	14 Engine Off: 1241	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time: 3+29
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	OLIVER BACLOT	M. I. TANGONAN	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

6. Flight Log for 1175P Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1175P

1 LiDAR Operator: K. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK10BS062A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 3, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0903	14 Engine Off: 1238	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time: 3+25
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	OLIVER PACIOT	M. L. TANGONAN	K. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

7. Flight Log for 1177P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1177P

1 LiDAR Operator: F. SABLE	2 ALTM Model: PEG	3 Mission Name: 1BLK10CS062B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 3, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 815	14 Engine Off: 1108	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time: 2+43
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

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

Pilot-in-Command
M.C. TANGONAN
Signature over Printed Name

Lidar Operator
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

8. Flight Log for 1197P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1197P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route:			
10 Date: MAR. 8, 2014	12 Airport of Departure (Airport, City/Province): LA UNION		12 Airport of Arrival (Airport, City/Province): LA UNION		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 2 + 59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION SUCCESSFUL					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	MARLON TORRE	M.L. TANGONAN	PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

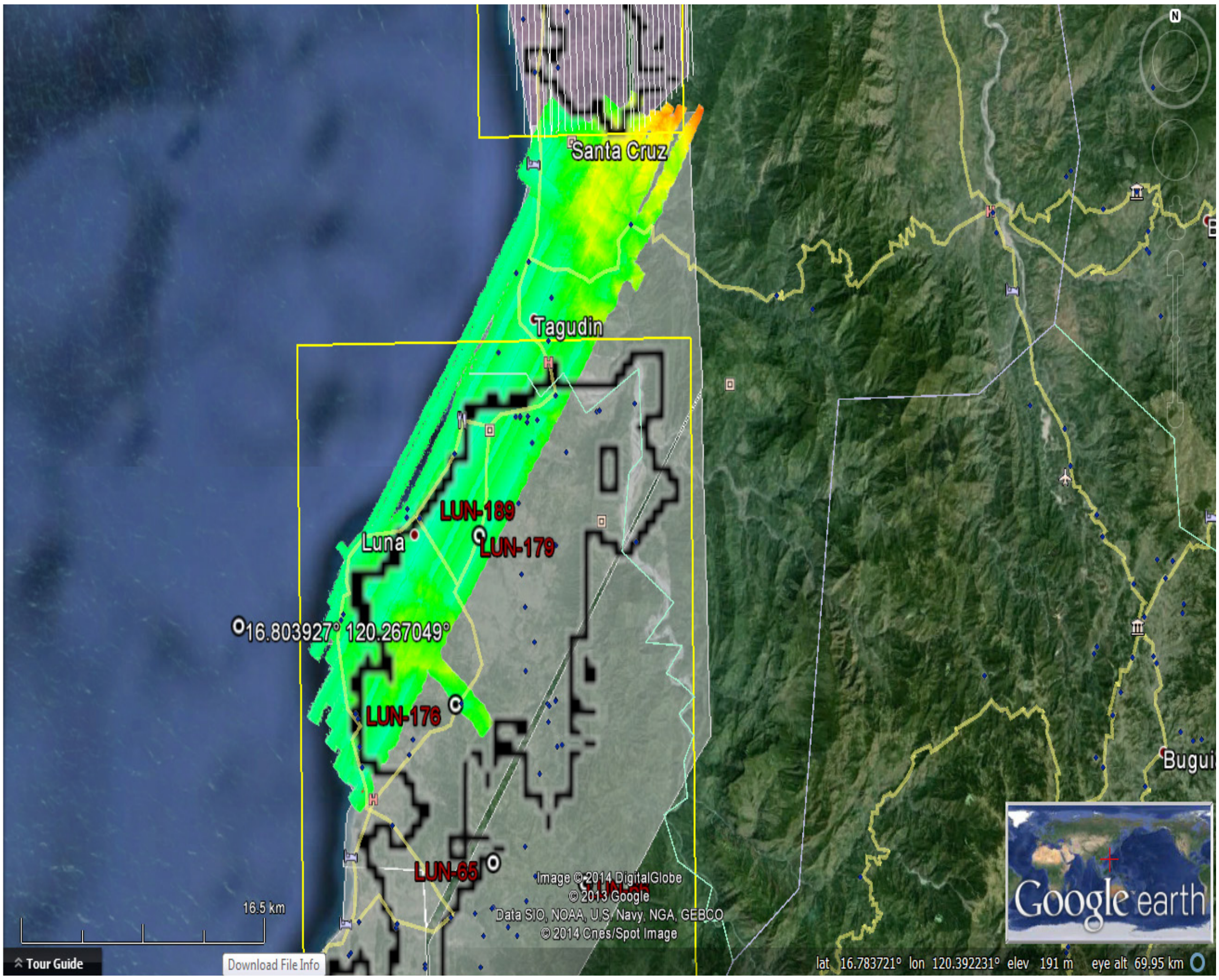
ANNEX 7. FLIGHT STATUS REPORT

La Union (February 25 to March 8, 2014)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1151P	BLOCK 10A	1BLK10A056A	R. PUNTO	February 25, 2014	Finish the survey with voids due to eye safety, laser sets off; renamed from 1149P
1153P	BLOCK 10A	1BLK10AS056B	F. SABLE	February 25, 2014	Survey voids of Block10A and 1 line Blk10B; renamed from 1151P
1155P	BLOCK 10C	1BLK10C057A	R. PUNTO	February 26, 2014	Survey Block 10C with data voids due to eye safety, laser sets off; renamed from 1153P
1157P	BLOCK 10B	1BLK10B057B	F. SABLE	PEGASUS	February 26, 2014
1171P	BLOCK 10D & BLOCK 10C	1BLK10CDS061A	R. PUNTO	March 2, 2014	Supplementary flight to cover voids for Block10D & Block10C; renamed from 1169P
1175P	BLOCK 10B	1BLK10BS062A	R. PUNTO	March 3, 2014	Supplementary flight to complete Block 10B; renamed from 1173P
1177P	BLOCK 10C	1BLK10CS062B	F. SABLE	March 3, 2014	Supplementary flight to cover voids in Block 10C; renamed from 1175P
1197P	BLOCK 10G,10C	1BLK10GCS067B	R.PUNTO	March 8, 2014	Mission Complete

LAS BOUNDARIES PER FLIGHT

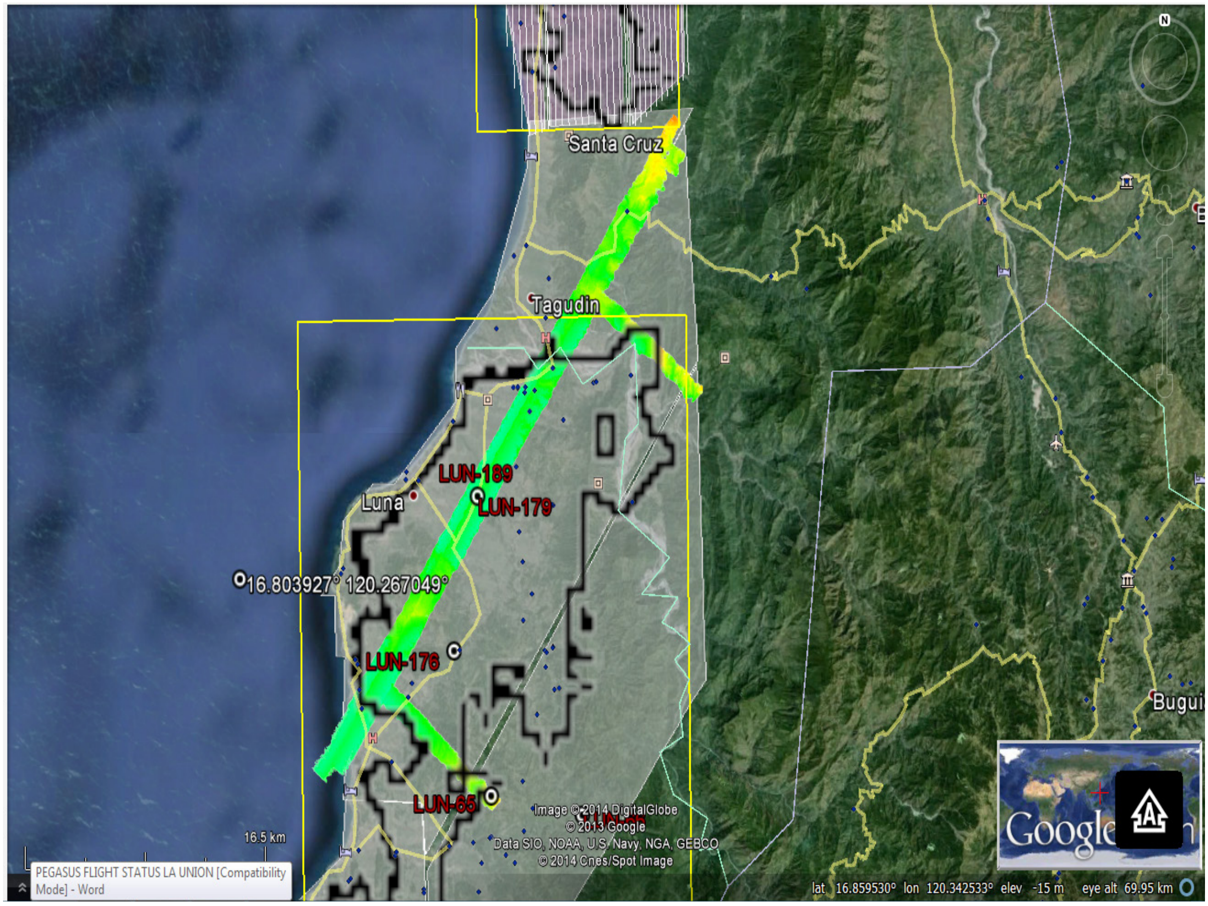
Flight No. : 1151P
Area: BLK 10A
Mission Name: 1BLK10A056A
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



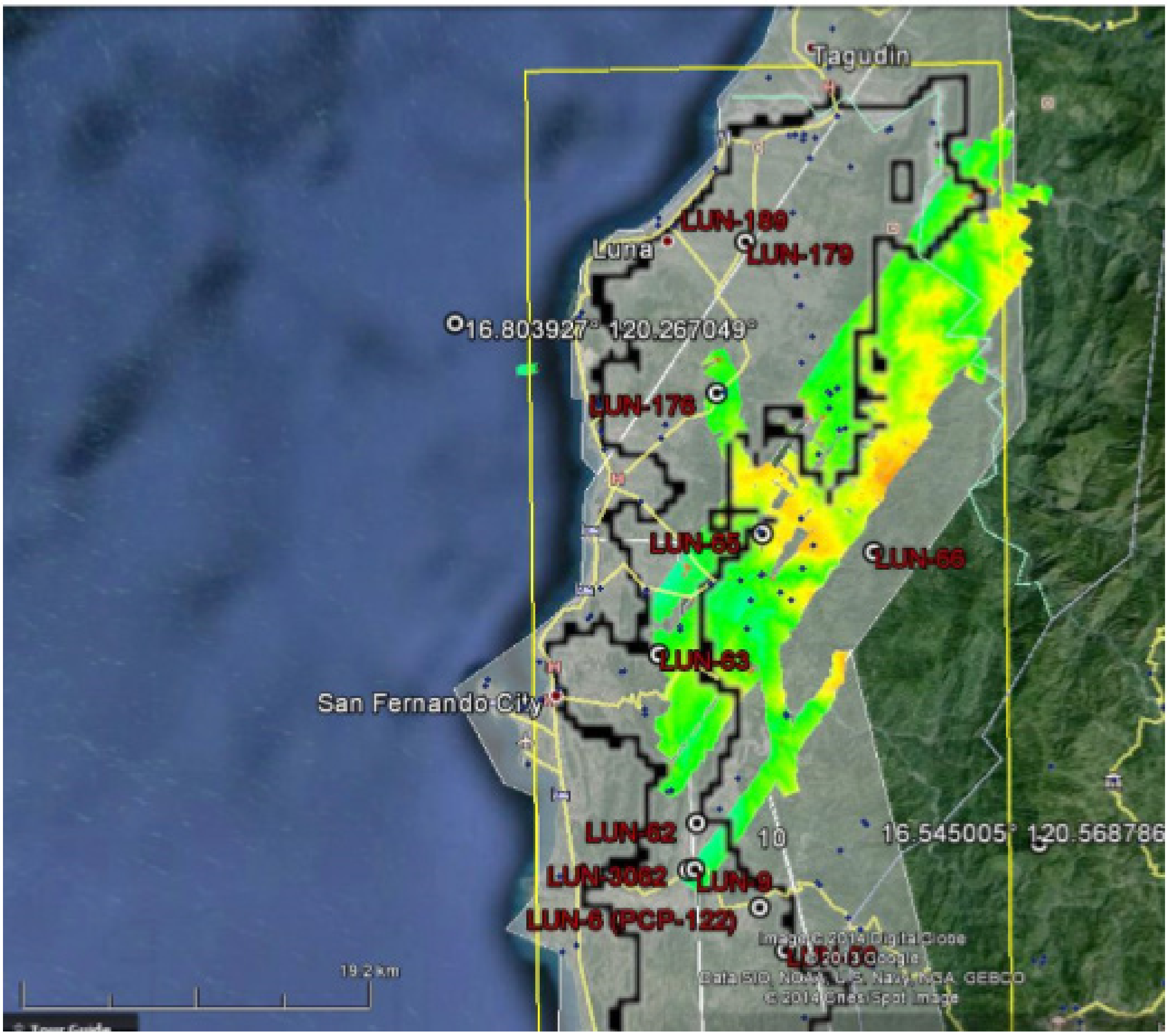
Flight No. : 1153P
Area: BLK 10A
Mission Name: 1BLK10BAS056B
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



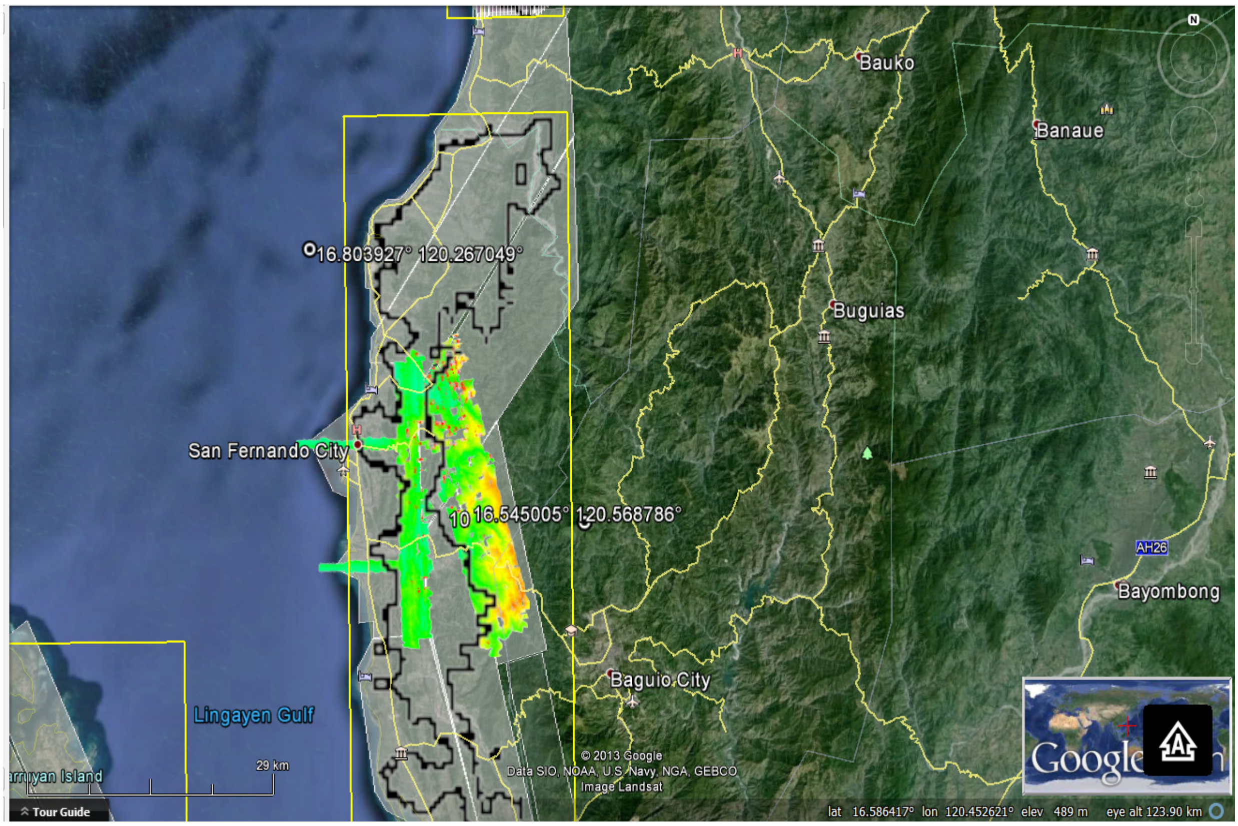
Flight No. : 1155P
Area: BLK 10C
Mission Name: 1BLK10C057A
Parameters: Altitude: 1200 m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



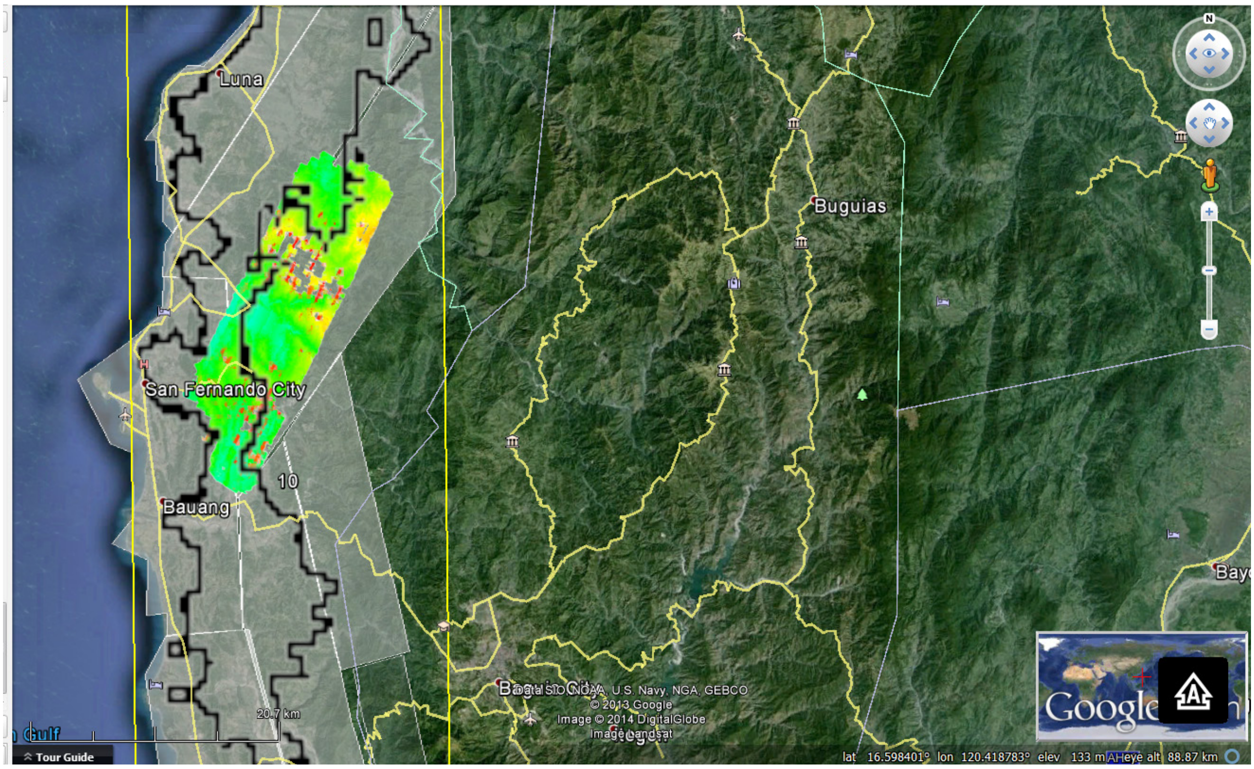
Flight No. : 1157P
Area: BLK 10B
Mission Name: 1BLK10B057B
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25 degrees; Overlap: 30%

LAS



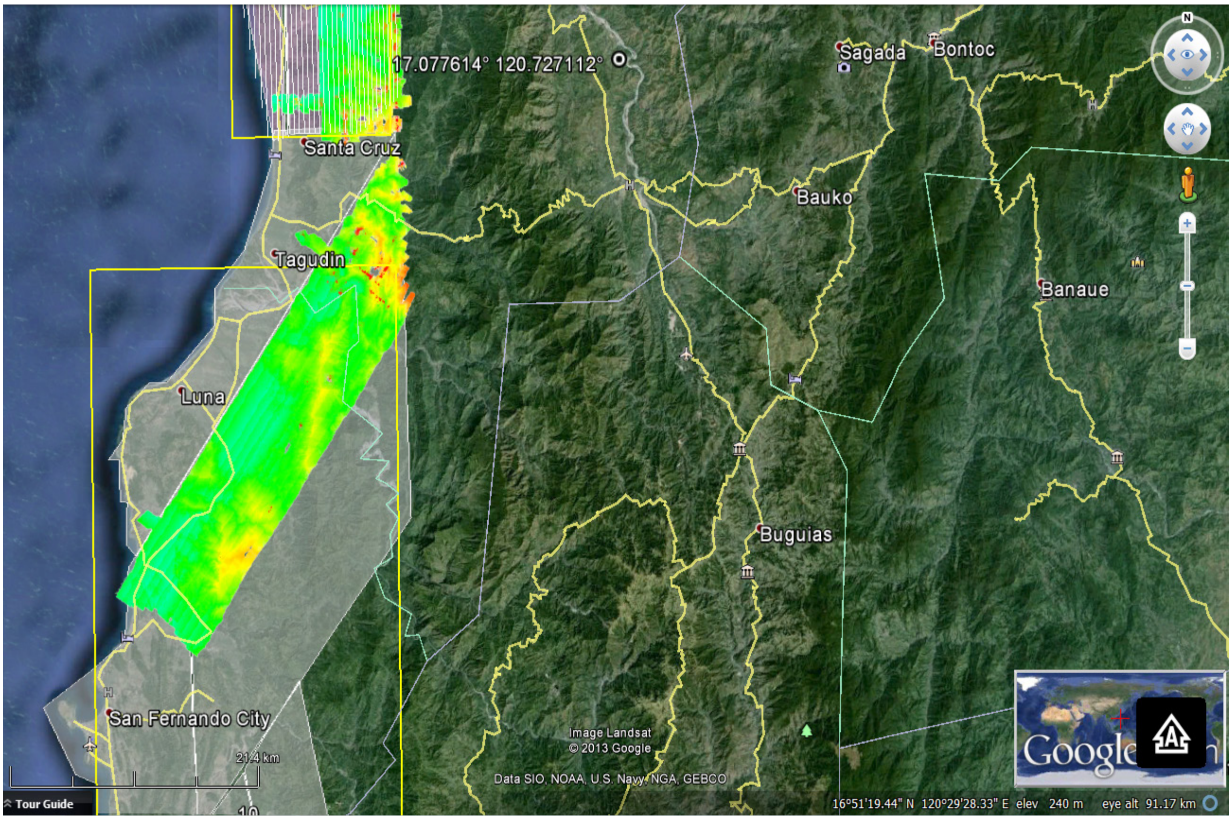
Flight No. : 1171P
Area: BLK 10C and BLK 10D
Mission Name: 1BLK10CDS061A
Parameters: Altitude: 1500m; Scan Frequency: 30Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



Flight No. : 1175P
Area: BLK 10B
Mission Name: 1BLK10BS062A
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



Flight No. : 1177P

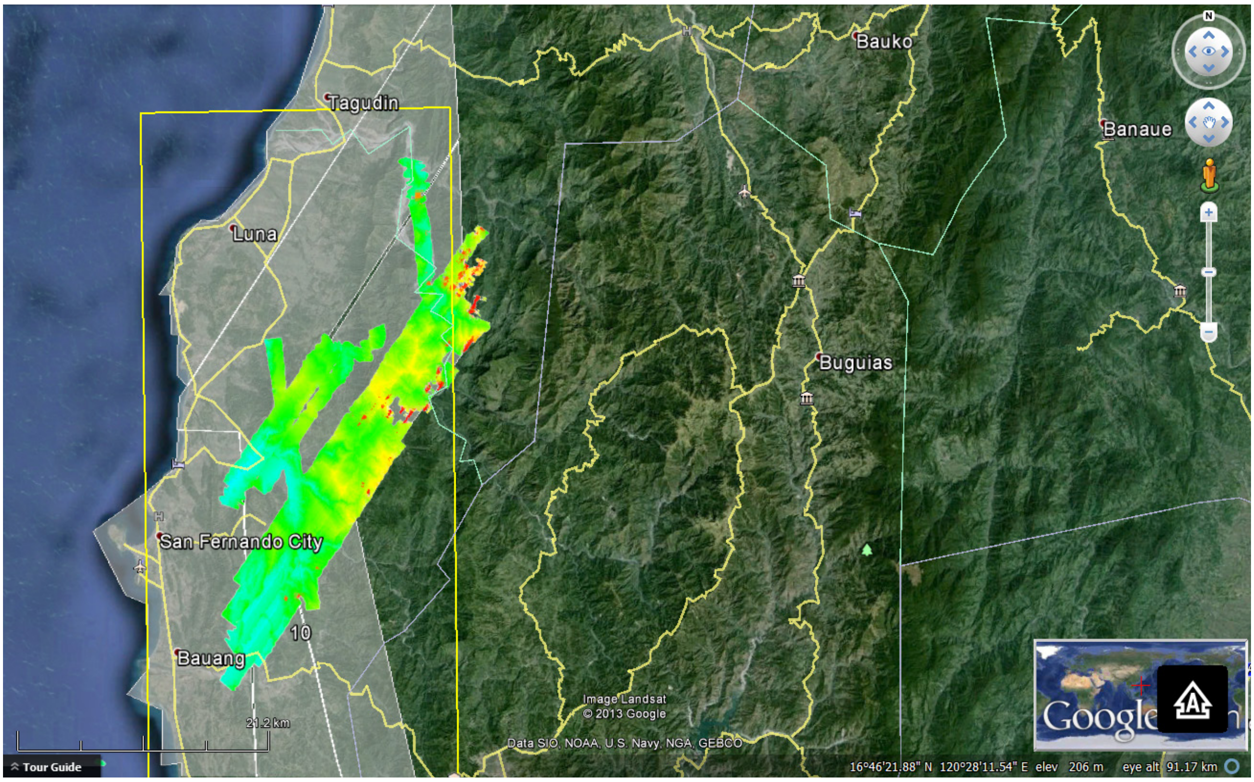
Area: BLK 10C

Mission Name: 1BLK10CS062B

Parameters: Altitude: 1800m; Scan Frequency: 30Hz;

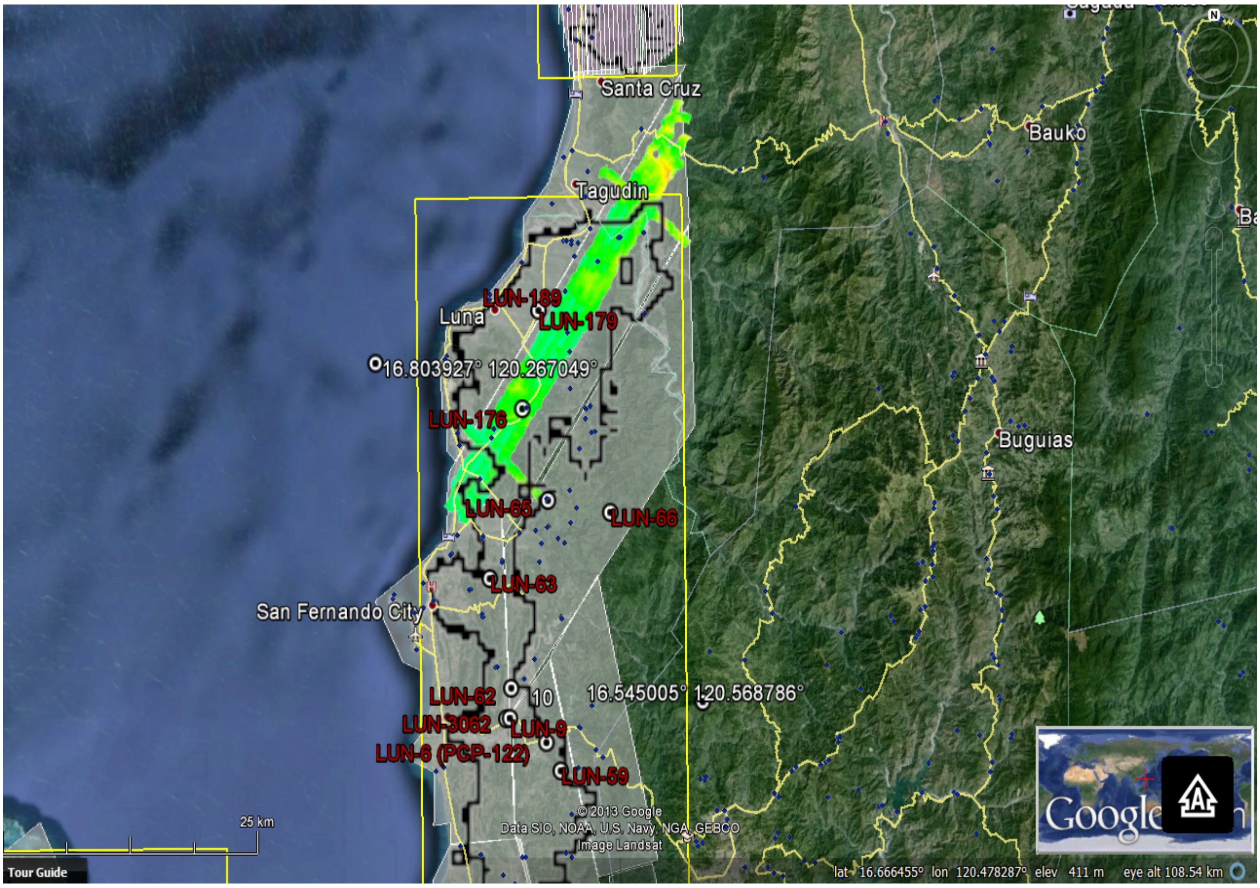
Scan Angle: 25 deg; Overlap: 30%

LAS



Flight No. : 1197P
Area: BLK 10G and 10C
Mission Name: 1BLK10GCS067B
Parameters: Altitude: 1500m; Scan Frequency: 30Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



ANNEX 8. MISSION SUMMARY REPORT

Flight Area	La Union
Mission Name	**Blk10A**
Inclusive Flights	1151P
Range data size	19.8 GB
POS	229 MB
Image	n/a
Transfer date	February 25, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.6
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	8.3
Boresight correction stdev (<0.001deg)	0.000566
IMU attitude correction stdev (<0.001deg)	0.004107
GPS position stdev (<0.01m)	0.0104
Minimum % overlap (>25)	64.34%
Ave point cloud density per sq.m. (>2.0)	2.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	363
Maximum Height	872.34
Minimum Height	40.04
Classification (# of points)	
Ground	251,566,818
Low vegetation	258,692,292
Medium vegetation	271,117,698
High vegetation	270,170,604
Building	19,016,823
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Ma. Celina Rosete, Engr. Roa Shalemar Redo

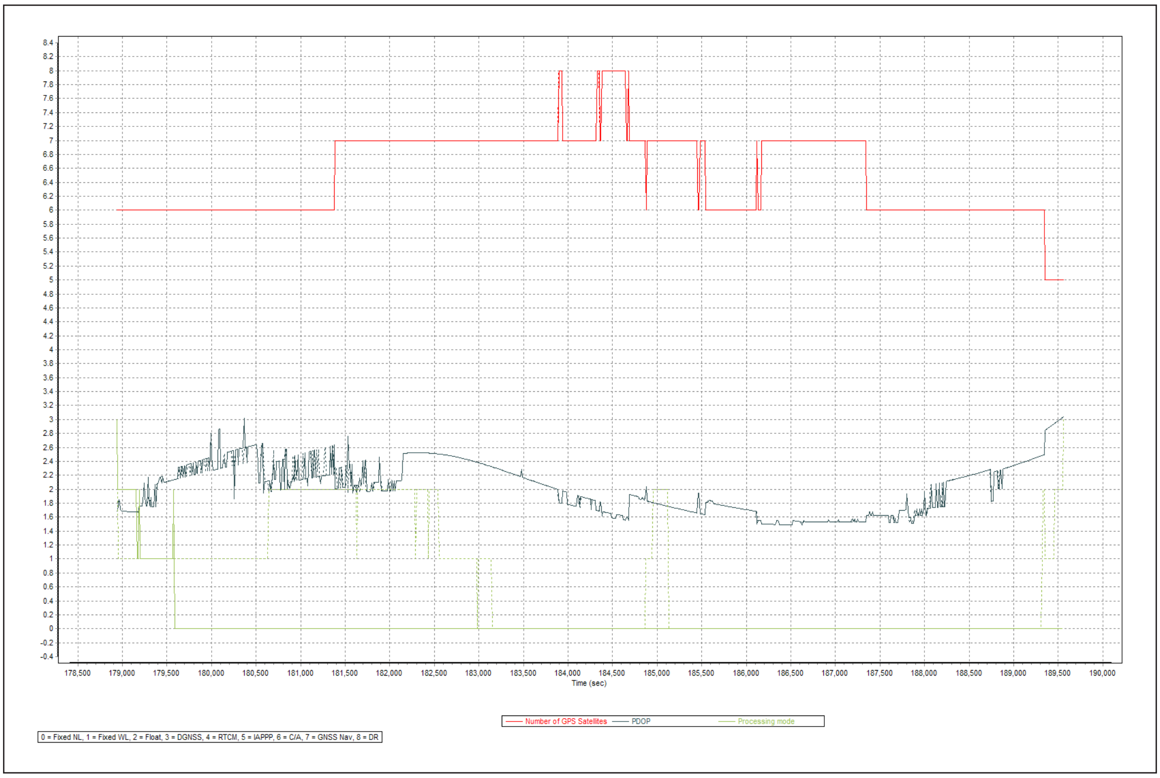


Figure 1.1.1 Solution Status

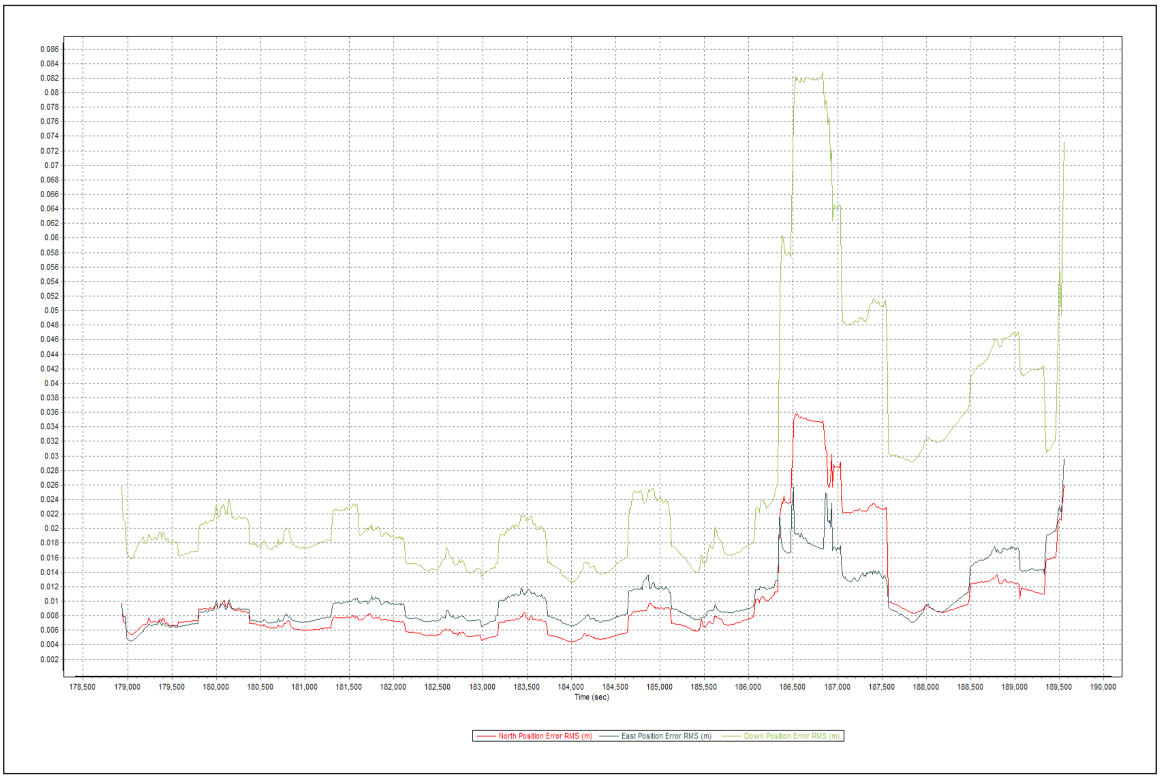


Figure 1.1.2 Smoothed Performance Metric Parameter

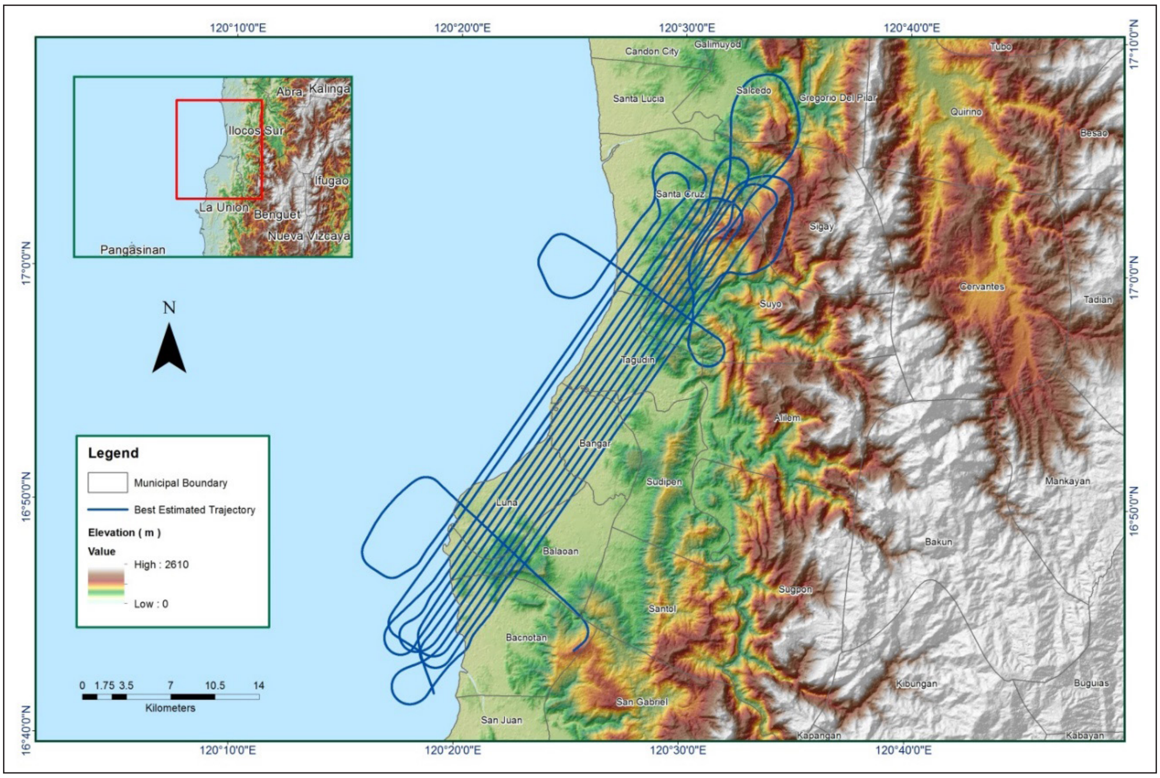


Figure 1.1.3 Best Estimated Trajectory

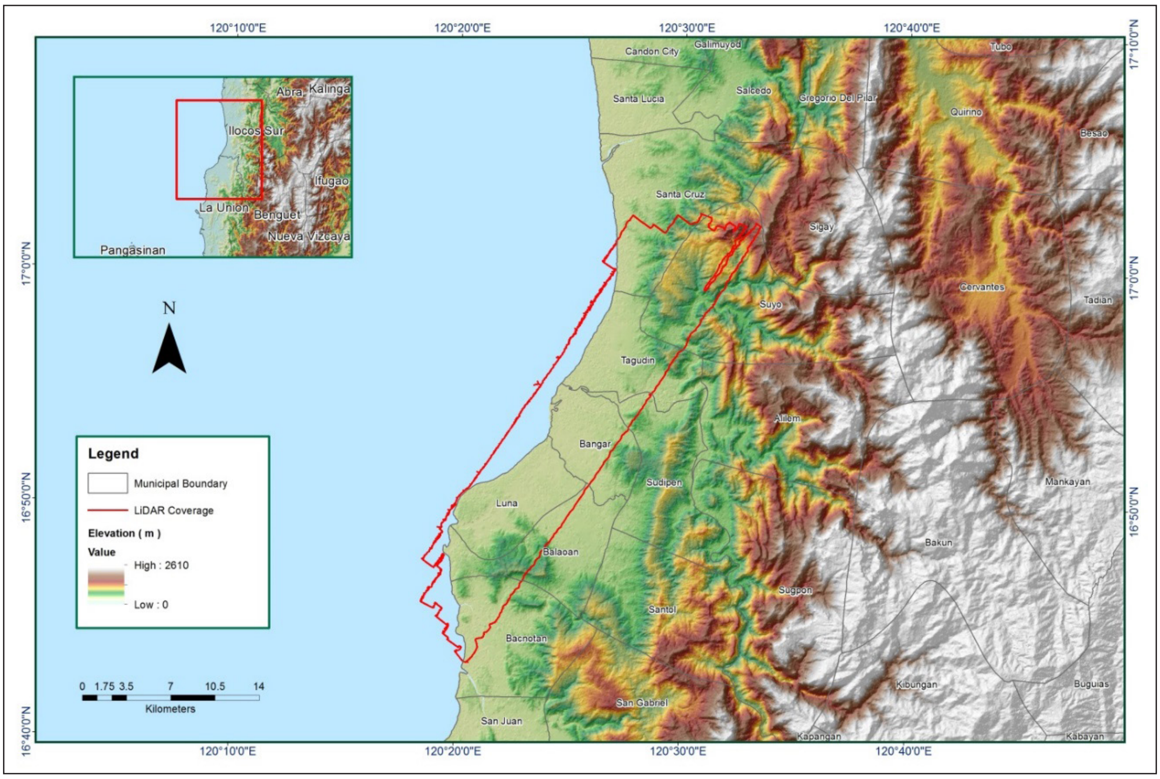


Figure 1.1.4 Coverage of LIDAR data

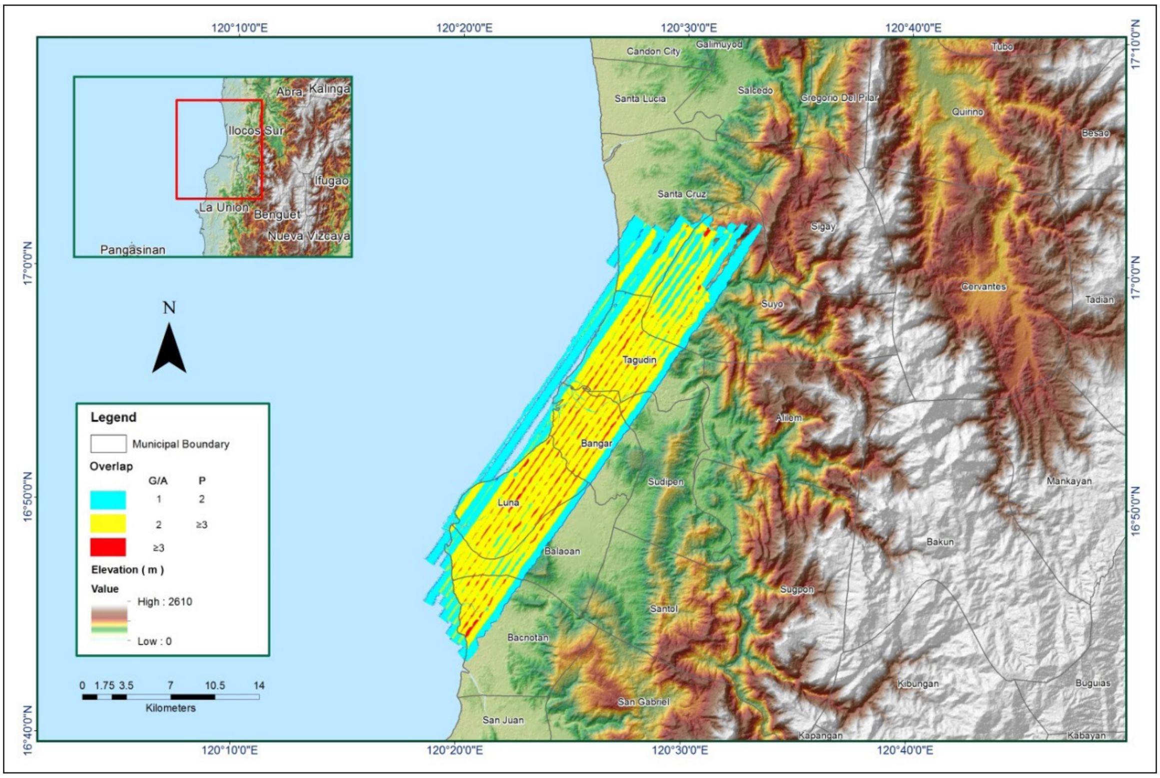


Figure 1.1.5 Image of Data Overlap

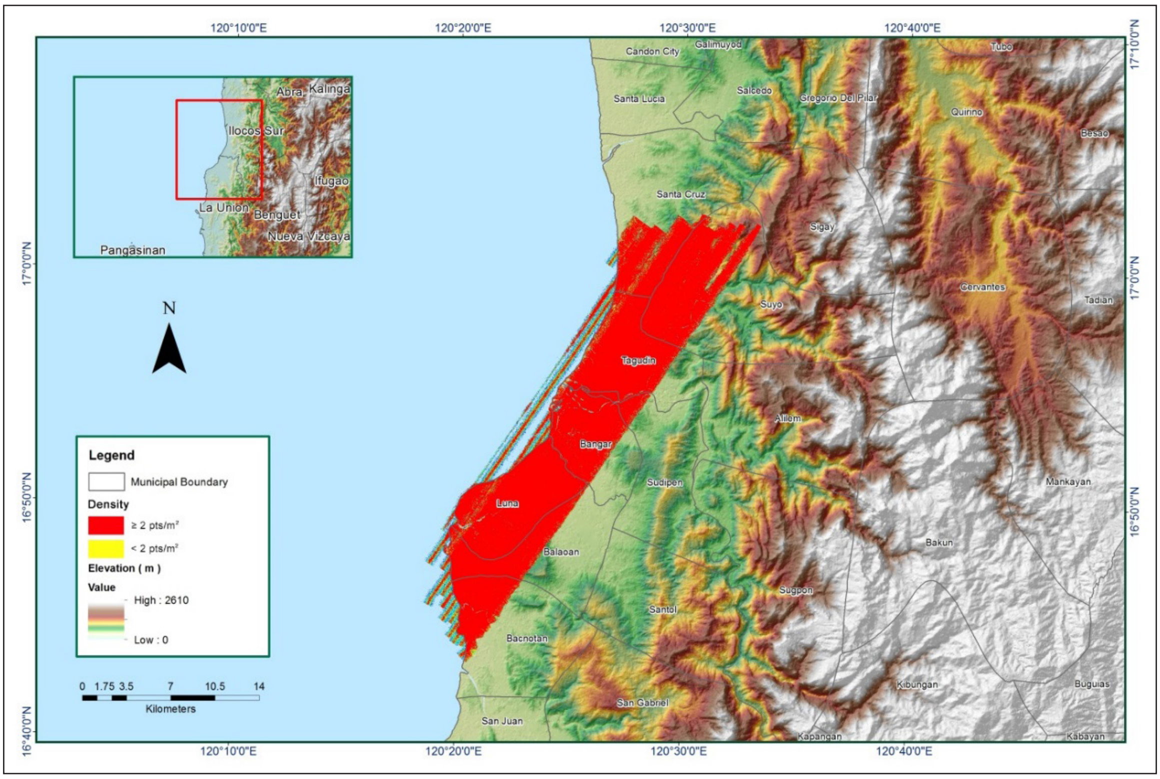


Figure 1.1.6 Density map of merged LIDAR data

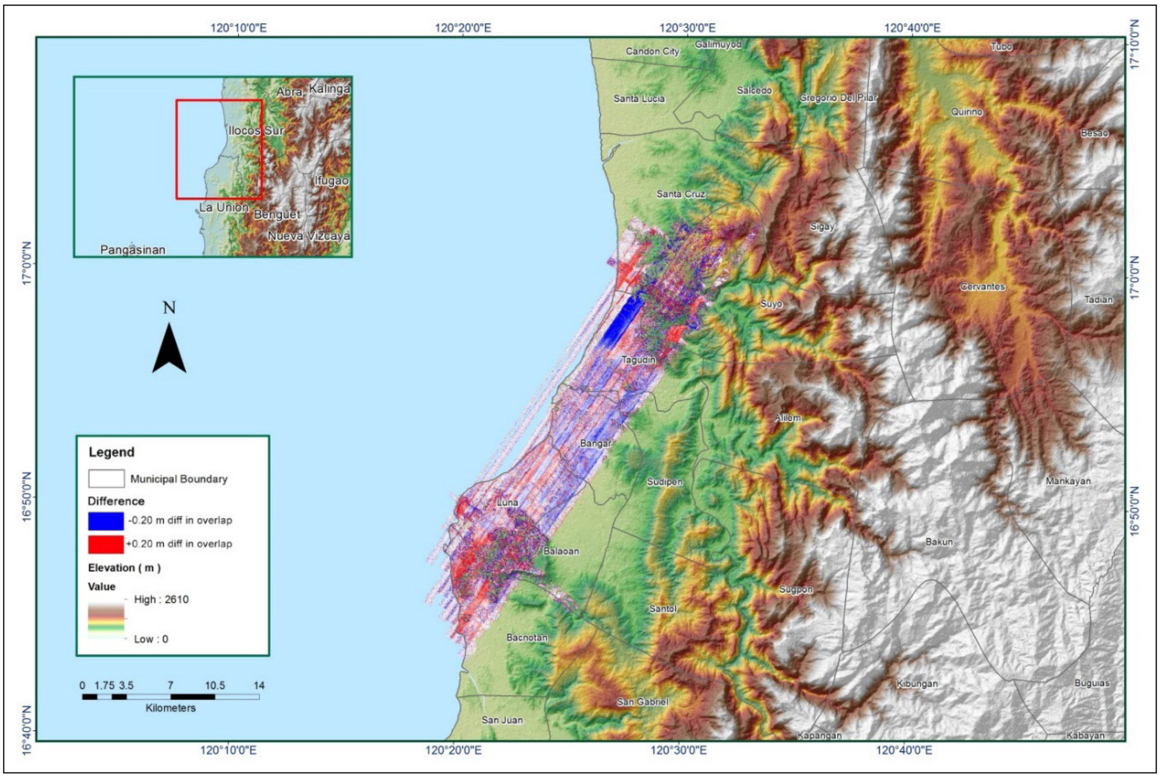


Figure 1.1.7 Elevation difference between flight lines

Flight Area	La Union
Mission Name	**Blk10B**
Inclusive Flights	1153P, 1157P, 1175P
Range data size	54.92 GB
POS	114MB
Image	68.7 GB
Transfer date	March 03, 2014
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)	1.66
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	3.58
Boresight correction stdev (<0.001deg)	0.00027
IMU attitude correction stdev (<0.001deg)	0.0028
GPS position stdev (<0.01m)	0.0065
Minimum % overlap (>25)	61.20%
Ave point cloud density per sq.m. (>2.0)	4.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	455
Maximum Height	967.51
Minimum Height	42.13
Classification (# of points)	
Ground	384,680,895
Low vegetation	361,413,391
Medium vegetation	639,589,607
High vegetation	674,742,918
Building	37,030,506
Orthophoto	Yes
Processed by:	Engr. Jennifer Saguran, Engr. Charmaine Cruz, Jovy Narisma

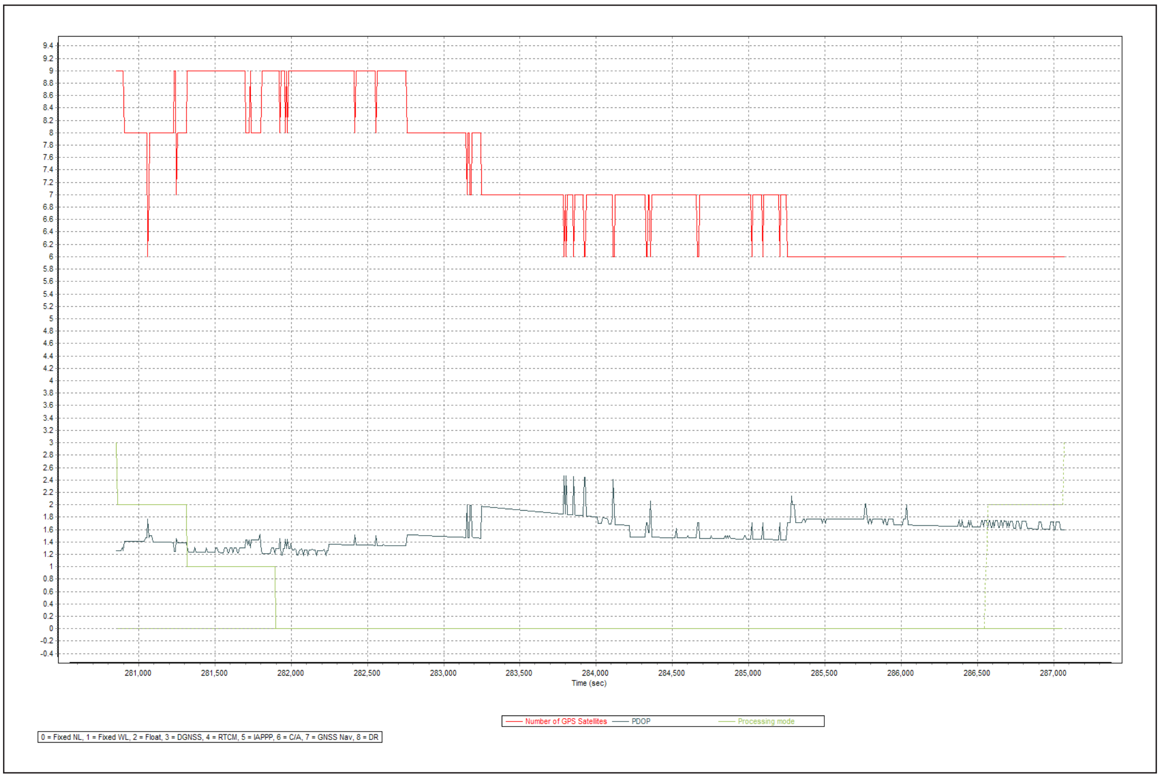


Figure 1.2.1 Solution Status

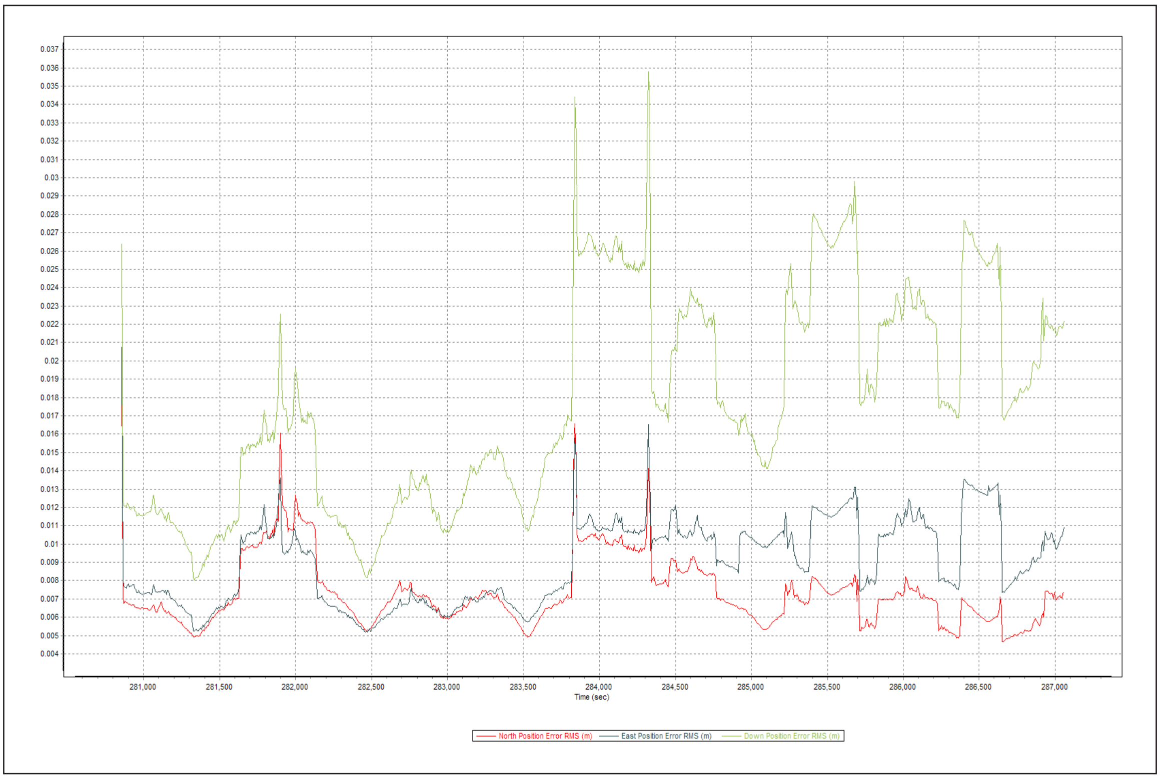


Figure 1.2.2 Smoothed Performance Metric Parameter

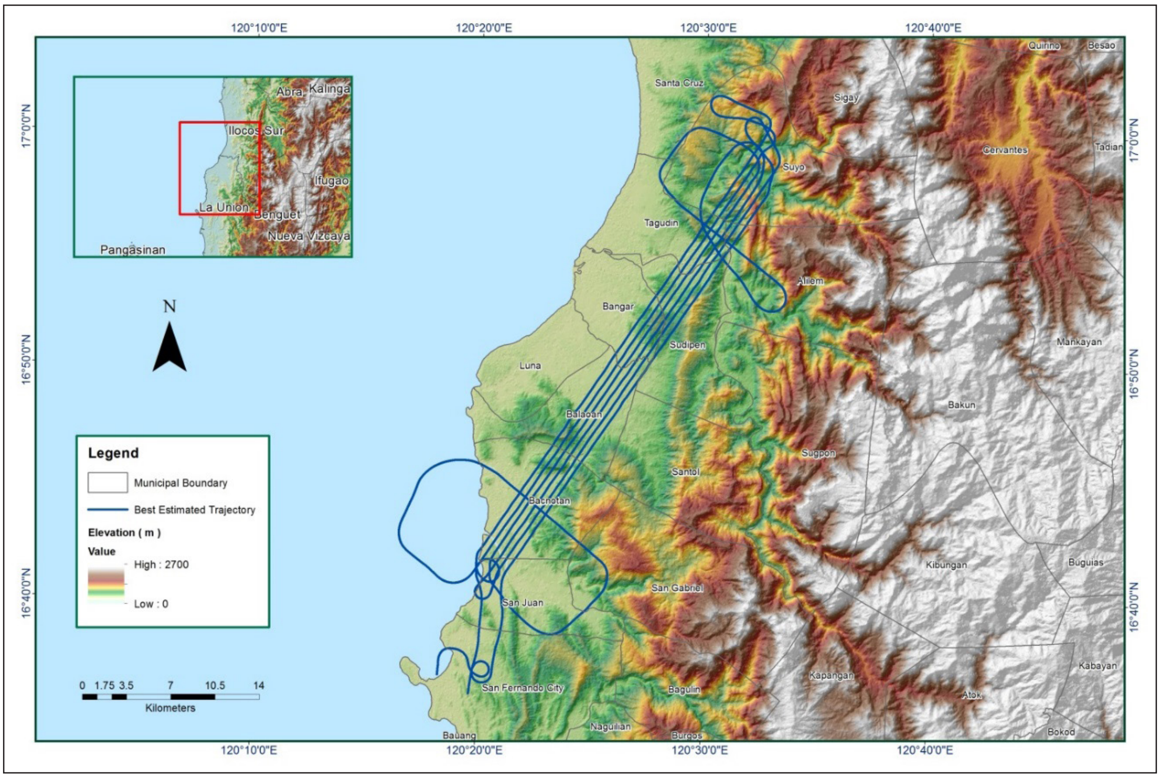


Figure 1.2.3 Best Estimated Trajectory

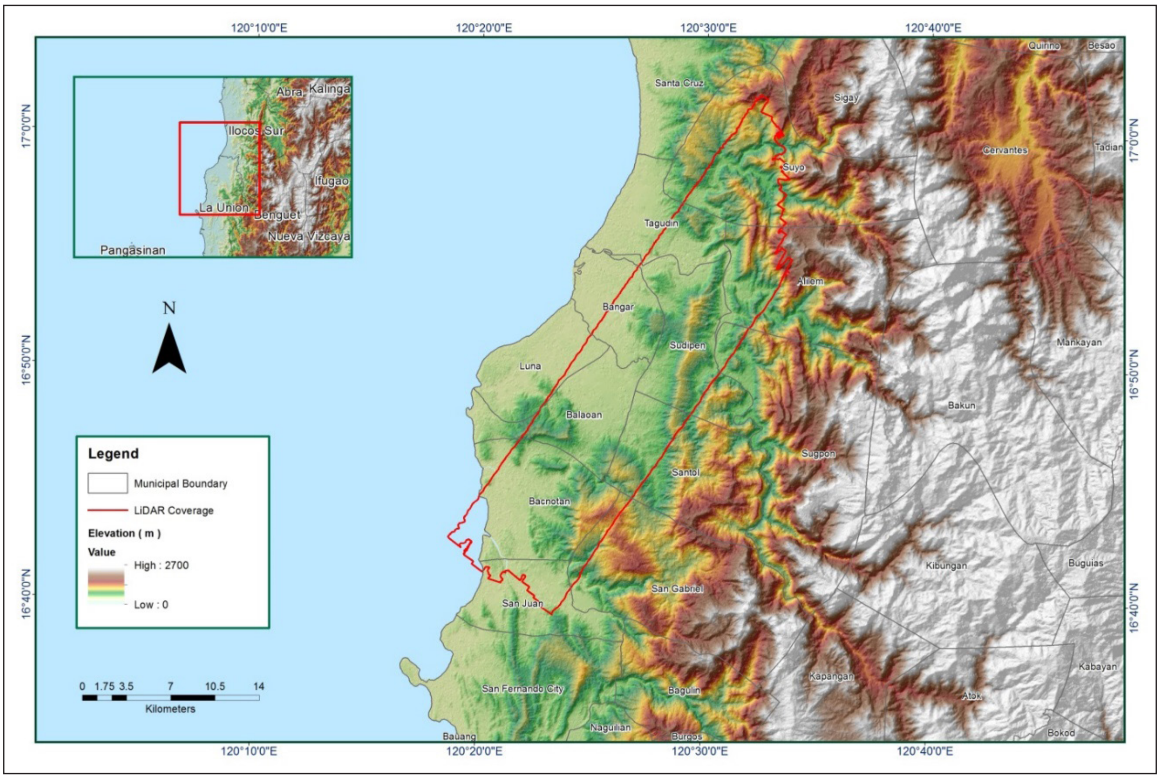


Figure 1.2.4 Coverage of LIDAR data

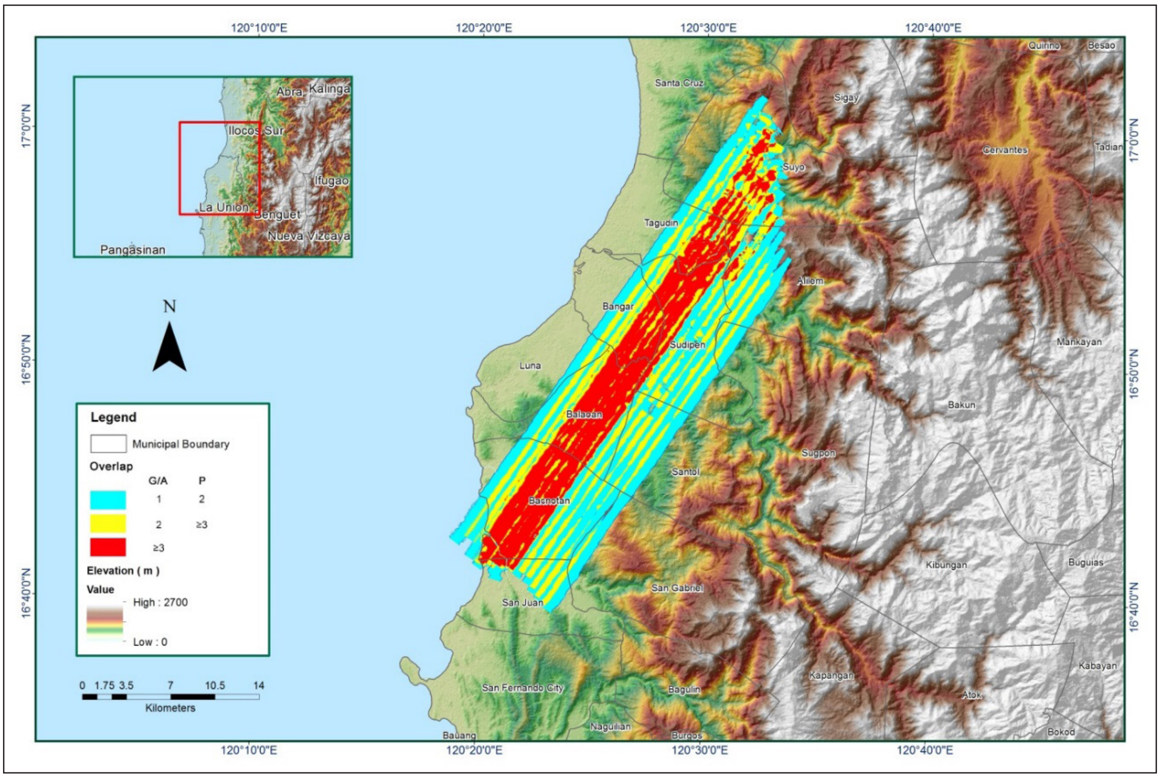


Figure 1.2.5 Image of Data Overlap

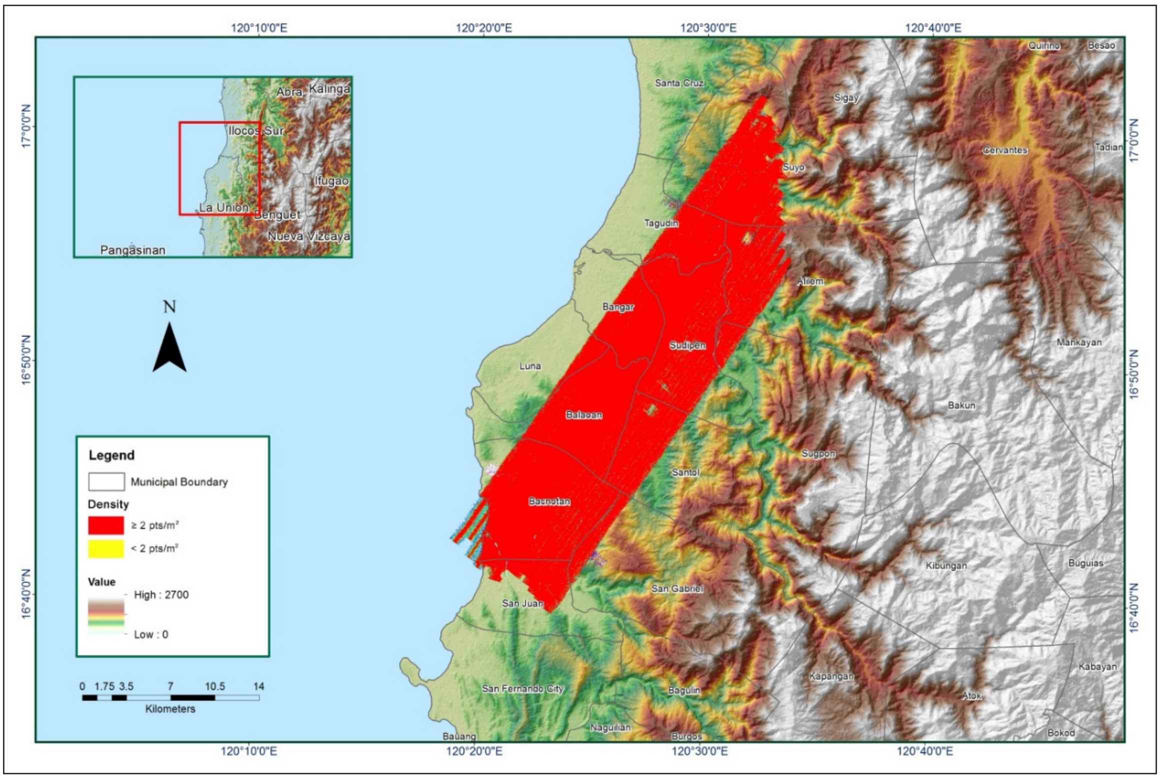


Figure 1.2.6 Density map of merged LIDAR data

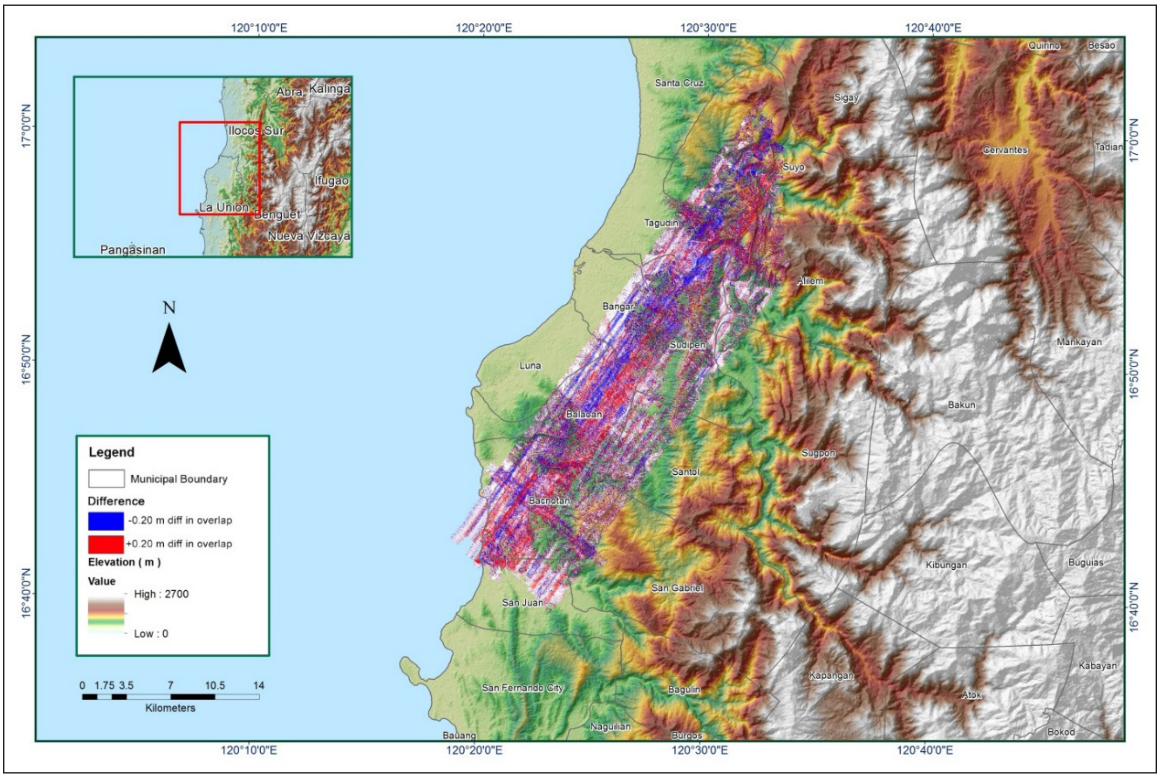


Figure 1.2.7 Elevation difference between flight lines

Flight Area	La Union
Mission Name	Blk10C
Inclusive Flights	1155P, 1171P, 1177P, 1197P
Range data size	62.86 GB
POS	695 MB
Image	98.6 GB
Transfer date	March 08, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.62
RMSE for East Position (<4.0 cm)	4.3
RMSE for Down Position (<8.0 cm)	6.55
Boresight correction stdev (<0.001deg)	0.000398
IMU attitude correction stdev (<0.001deg)	0.017218
GPS position stdev (<0.01m)	0.0267
Minimum % overlap (>25)	35.05%

Ave point cloud density per sq.m. (>2.0)	3.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	505
Maximum Height	1038.87
Minimum Height	45.5
Classification (# of points)	
Ground	270,659,389
Low vegetation	232,081,137
Medium vegetation	638,506,120
High vegetation	737,644,888
Building	23,046,935
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. Jeffrey Delica

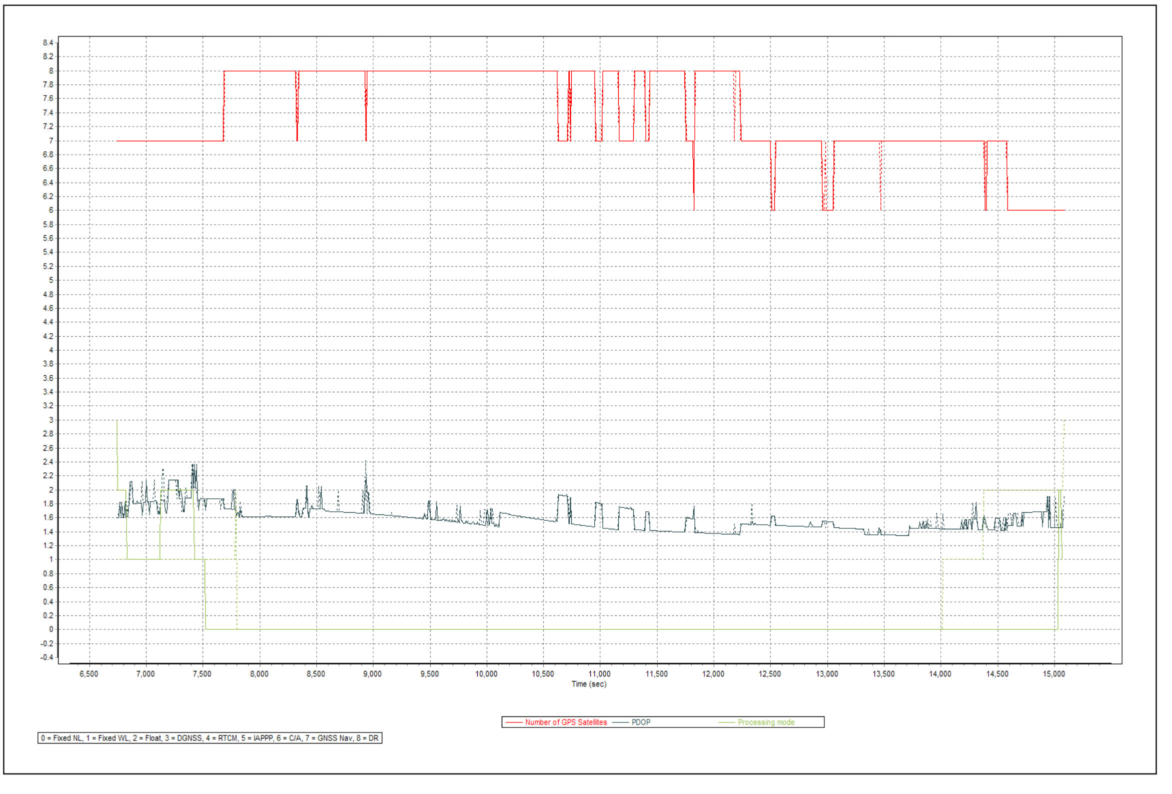


Figure 1.3.1 Solution Status

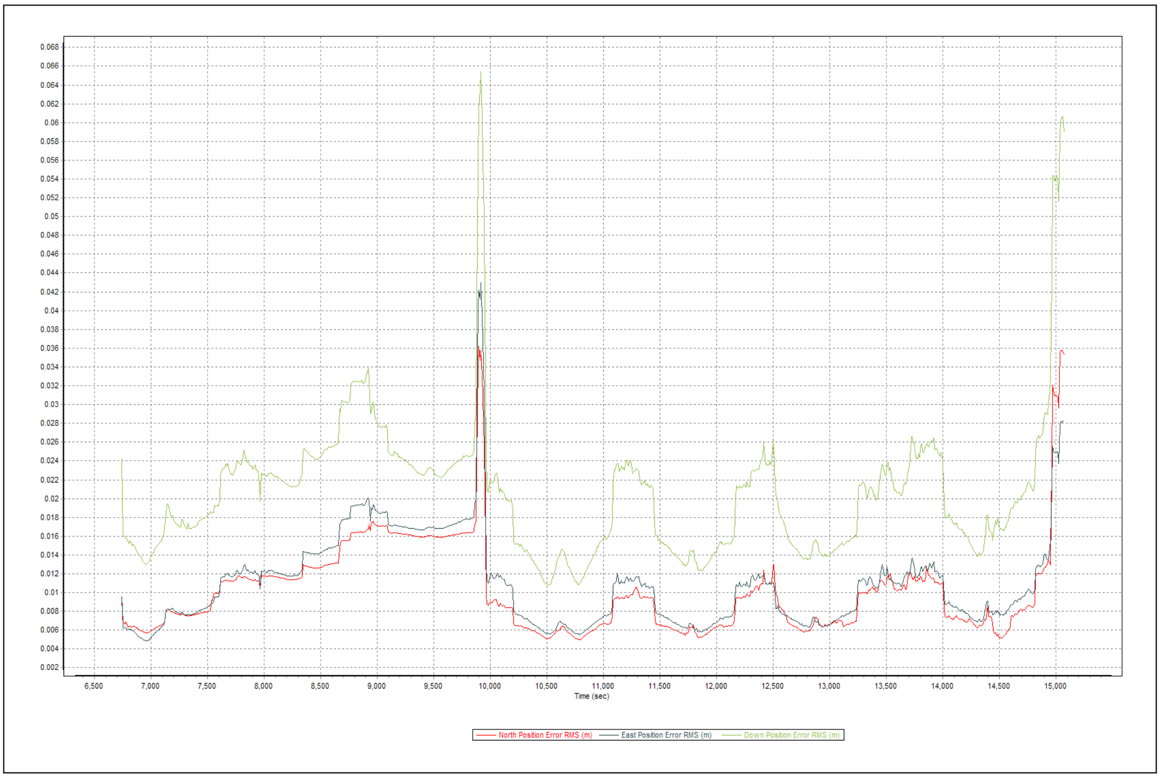


Figure 1.3.2 Smoothed Performance Metric Parameters

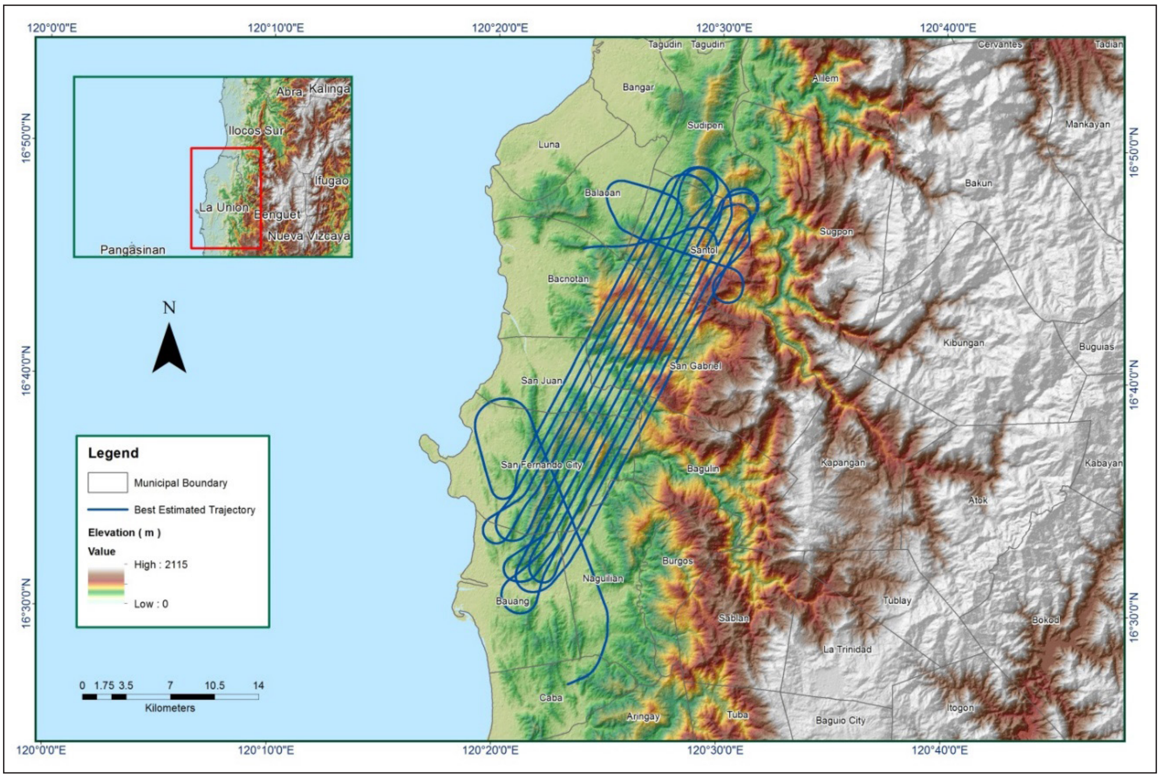


Figure 1.3.3 Best Estimated Trajectory

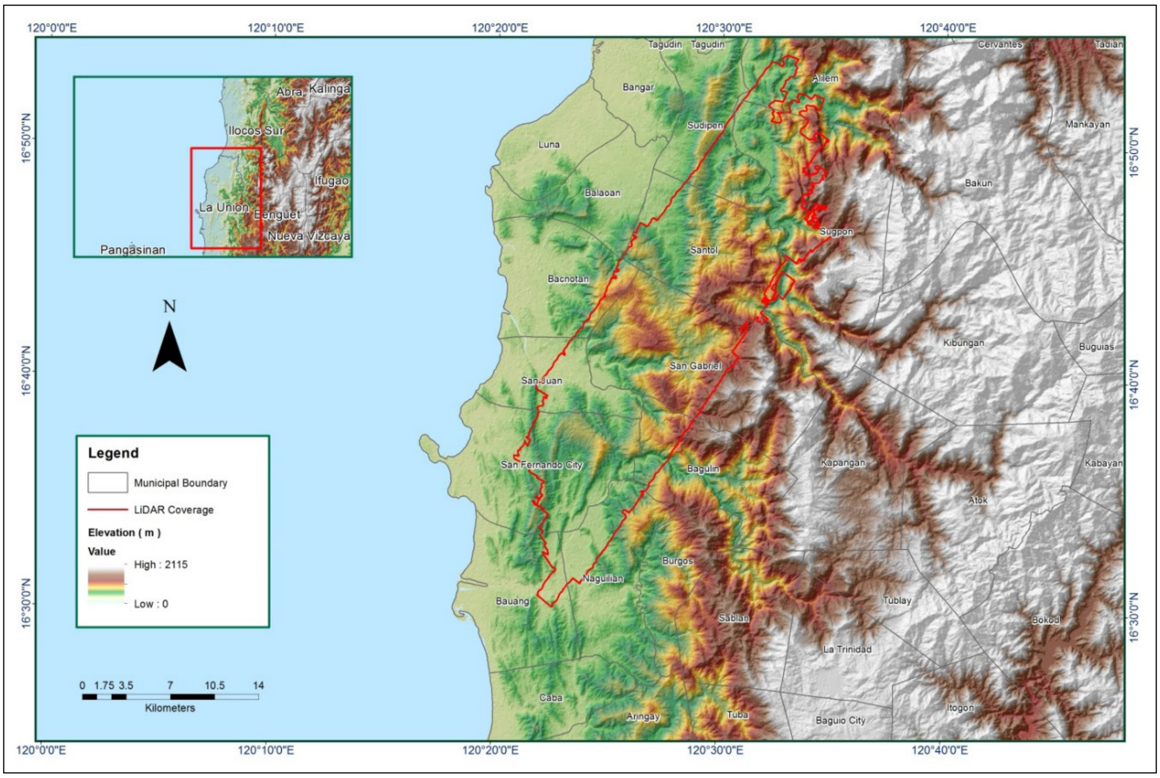


Figure 1.3.4 Coverage of LIDAR data

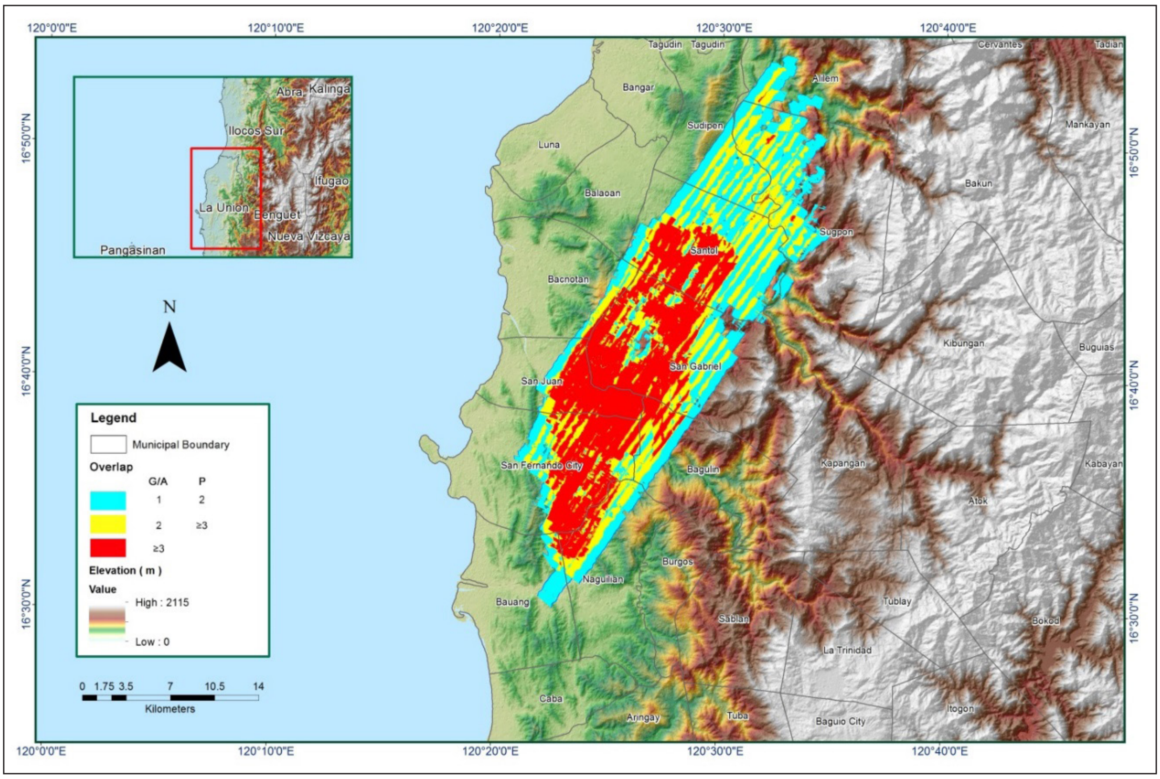


Figure 1.3.5 Image of Data Overlap

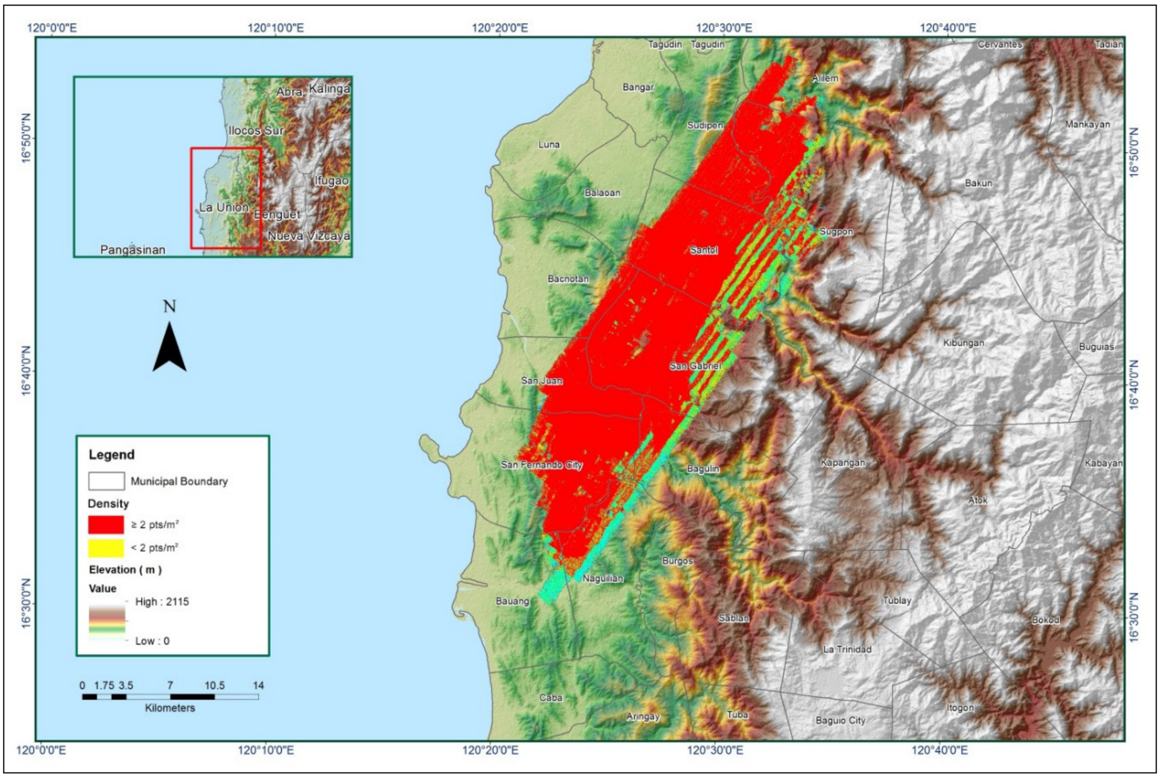


Figure 1.3.6 Density map of merged LIDAR data

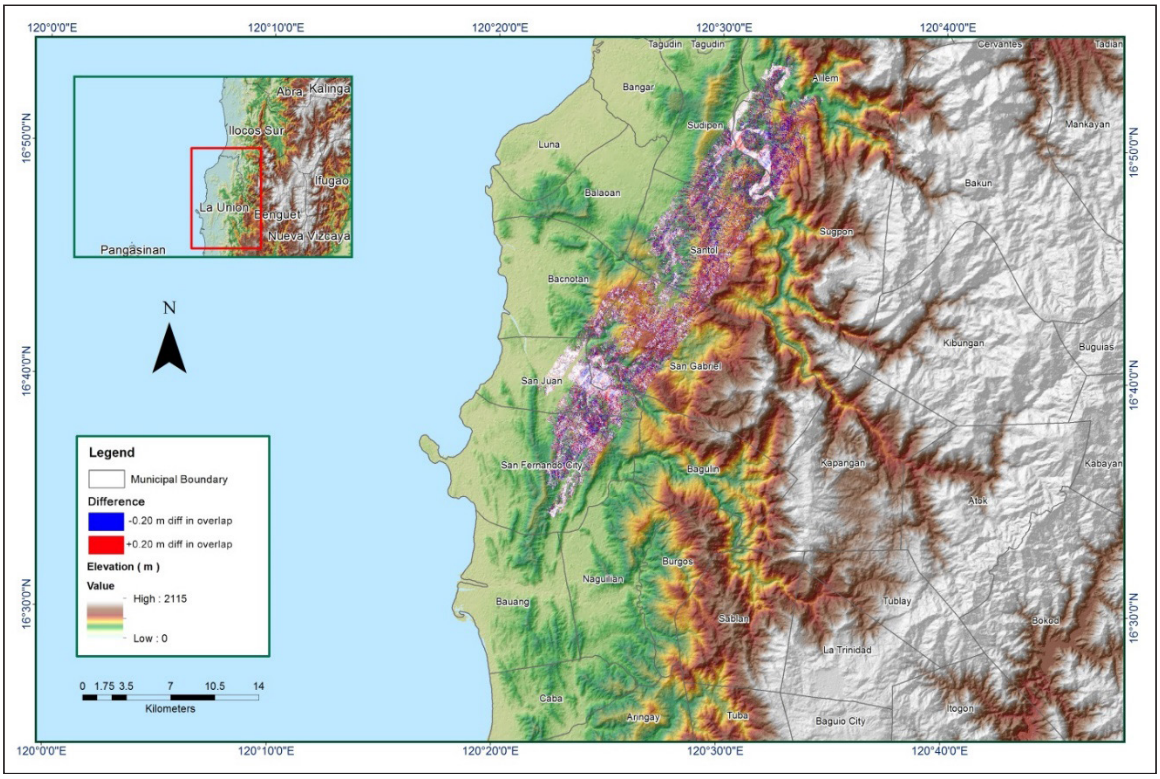


Figure 1.3.7 Elevation difference between flight lines

Flight Area	La Union
Mission Name	**Blk10C_additional**
Inclusive Flights	1177P
Range data size	11.3 GB
POS	157 MB
Image	30 GB
Transfer date	March 08, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.24
RMSE for East Position (<4.0 cm)	1.48
RMSE for Down Position (<8.0 cm)	2.74
Boresight correction stdev (<0.001deg)	0.000398
IMU attitude correction stdev (<0.001deg)	0.022977
GPS position stdev (<0.01m)	0.007
Minimum % overlap (>25)	52.15%
Ave point cloud density per sq.m. (>2.0)	2.44
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	391
Maximum Height	1,038.57
Minimum Height	42.19
Classification (# of points)	
Ground	208,543,222
Low vegetation	136,381,901
Medium vegetation	263,283,963
High vegetation	387,854,740
Building	14,766,006
Orthophoto	
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga, Jr., Engr. Ma. Ailyn Olanda

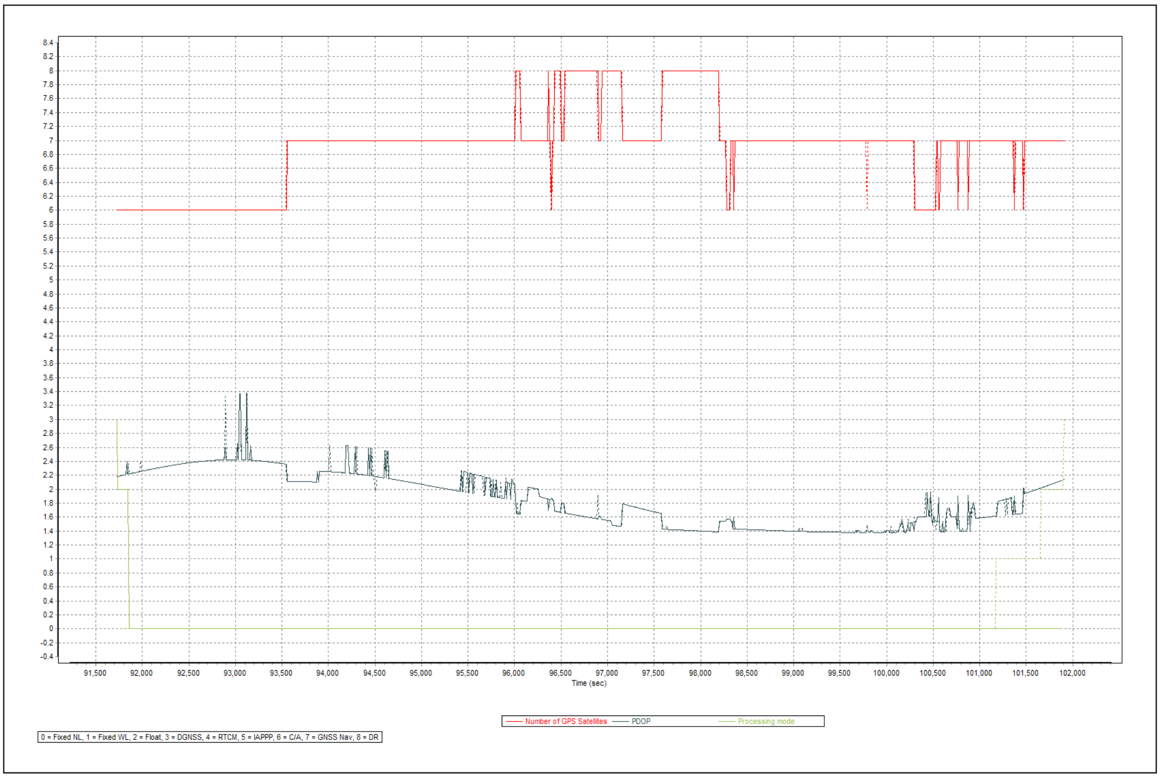


Figure 1.4.1 Solution Status

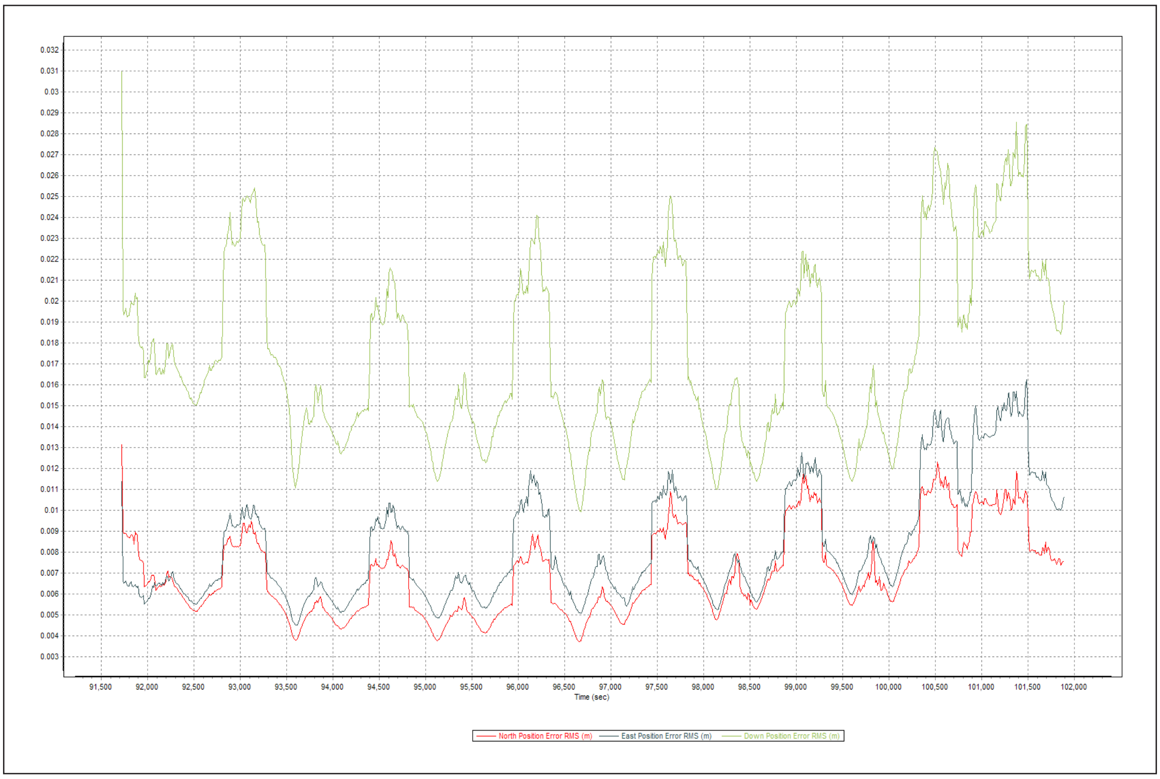


Figure 1.4.2 Smoothed Performance Metric Parameter

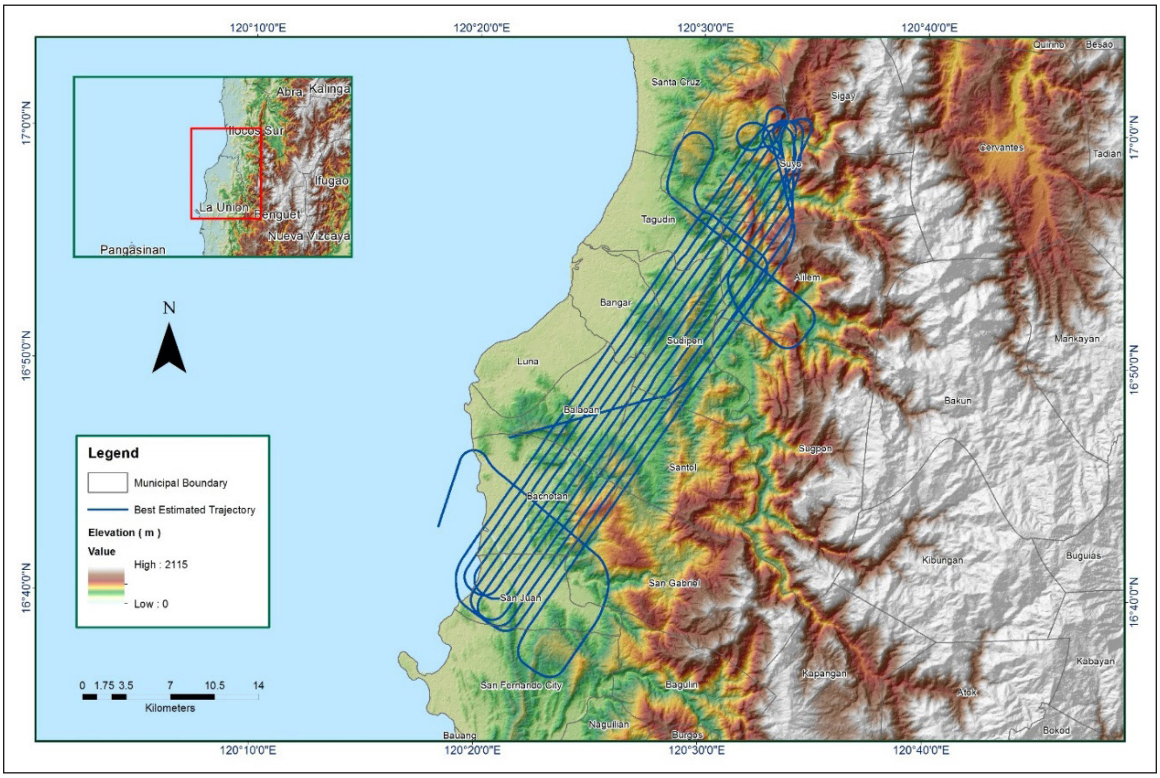


Figure 1.4.3 Best Estimated Trajectory

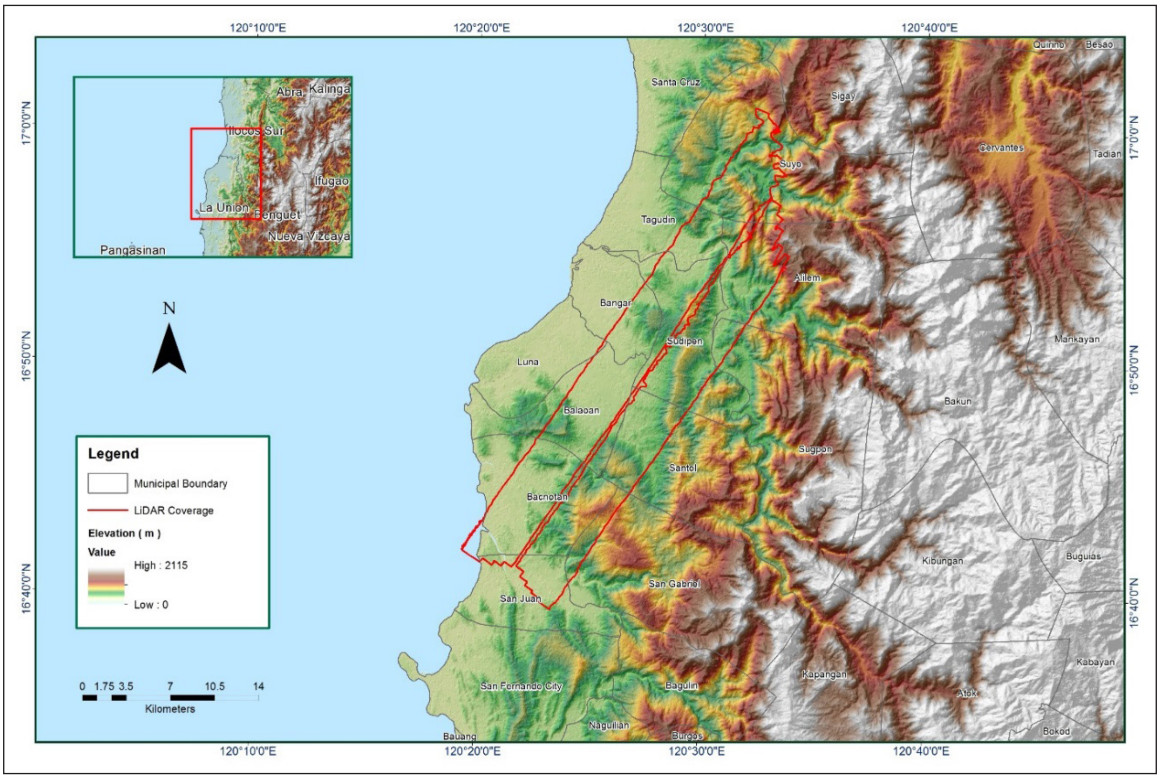


Figure 1.4.4 Coverage of LIDAR data

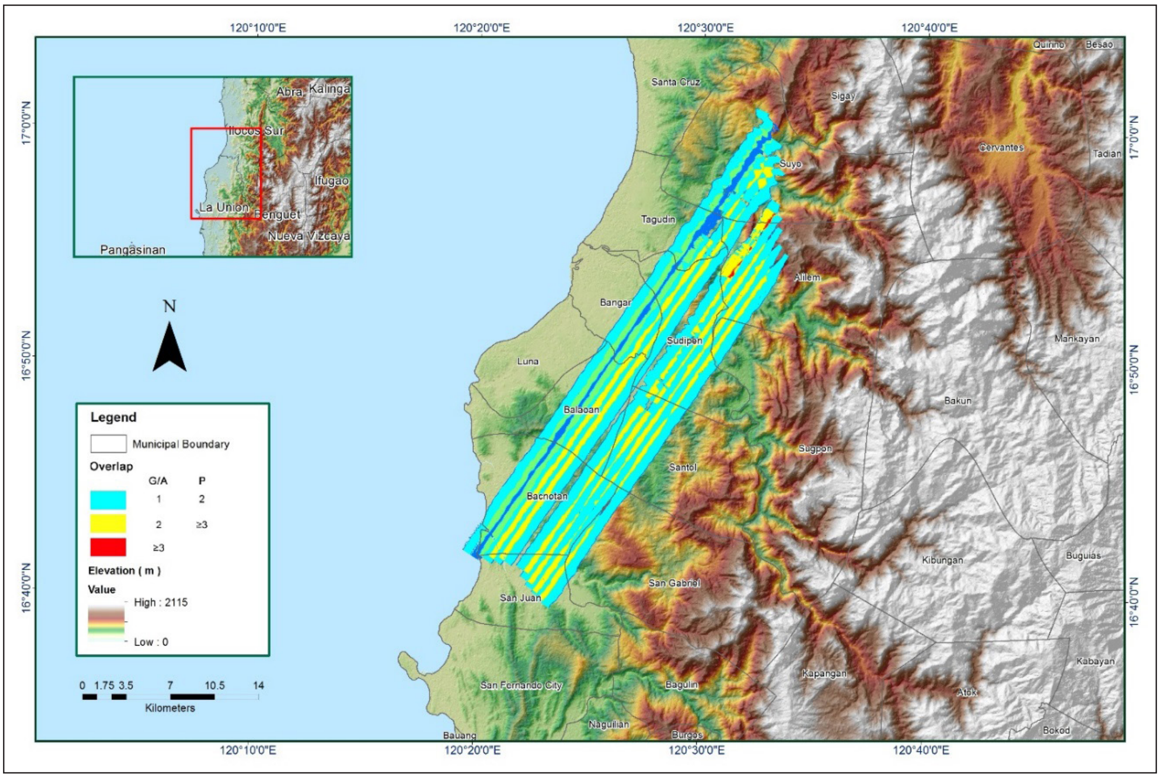


Figure 1.4.5 Image of Data Overlap

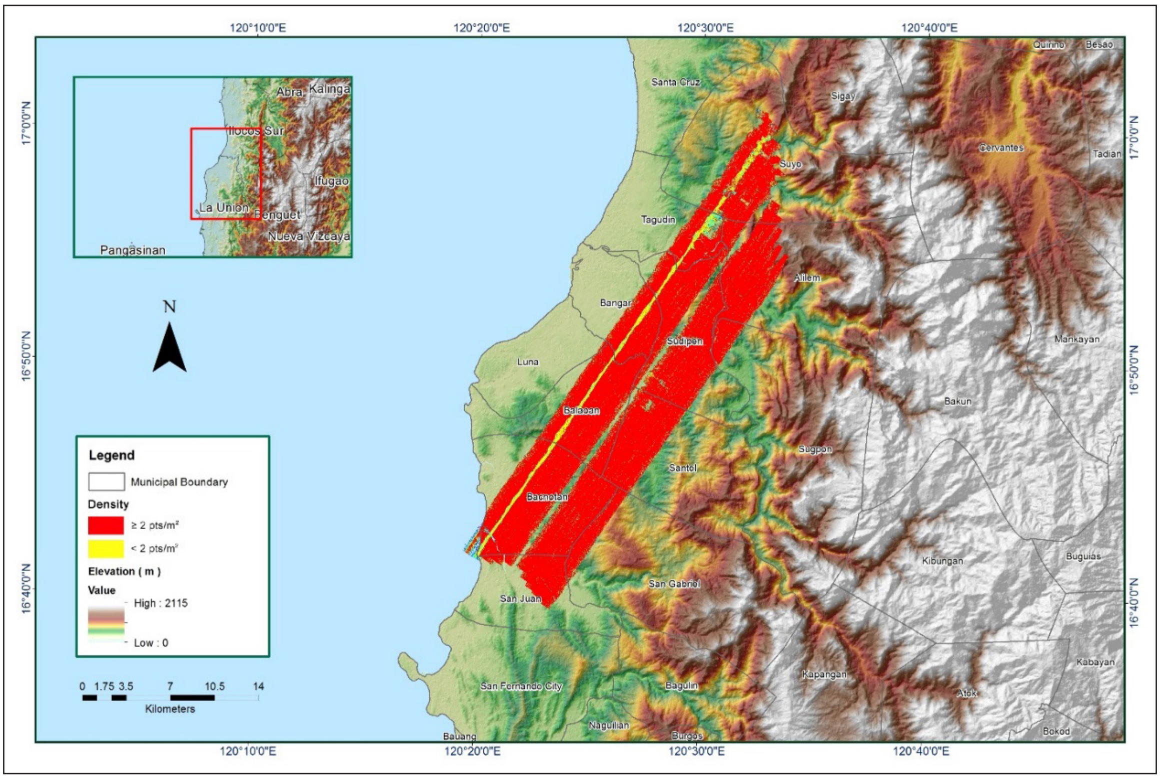


Figure 1.4.6 Density map of merged LIDAR data

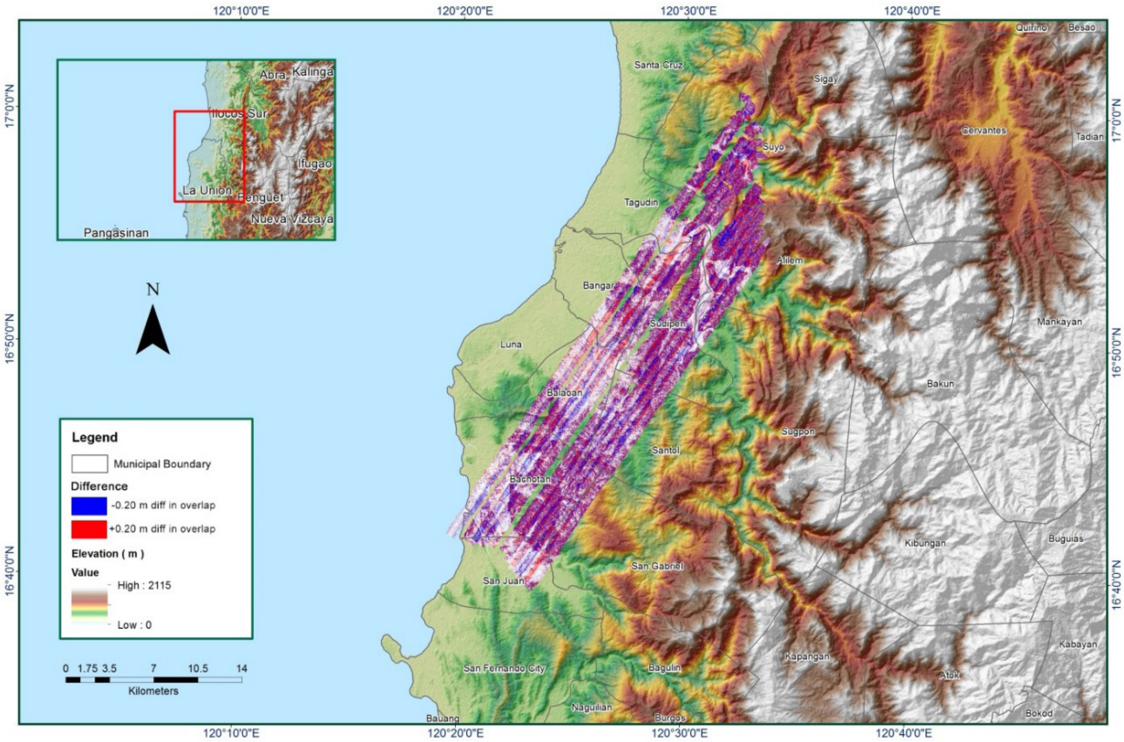


Figure 1.4.7 Elevation difference between flight lines

ANNEX 9. Amburayan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1400	145.2105	35	0	0.175416	0.178925	Discharge	0.21901	0.8	Ratio to Peak	0.2
W1410	189.45	35	0	0.468216	0.47758	Discharge	0.75077	0.8	Ratio to Peak	0.2
W1420	131.145	35	0	0.120424	0.12283	Discharge	0.21641	0.8	Ratio to Peak	0.2
W1430	159.675	35	0	0.249248	0.25423	Discharge	0.70211	0.8	Ratio to Peak	0.2
W1440	149.7435	35	0	0.185864	0.18958	Discharge	0.40411	0.8	Ratio to Peak	0.2
W1460	181.53	35	0	0.255368	0.050525	Discharge	0.60937	0.8	Ratio to Peak	0.2
W1470	121.0365	35	0	0.128528	0.26048	Discharge	0.14073	0.8	Ratio to Peak	0.2
W1480	60.7575	37.53041	0	0.0464224	0.131095	Discharge	0.036043	0.8	Ratio to Peak	0.2
W1490	174.975	35	0	0.29668	0.0473505	Discharge	0.92712	0.8	Ratio to Peak	0.2
W1500	122.616	35	0	0.193816	0.302615	Discharge	0.27353	0.8	Ratio to Peak	0.2
W1510	128.475	35	0	0.229792	0.197695	Discharge	0.4682	0.8	Ratio to Peak	0.2
W1520	203.34	35	0	0.25612	0.23439	Discharge	0.49437	0.8	Ratio to Peak	0.2
W1530	62.7585	37.23341	0	0.511952	0.26124	Discharge	0.98201	0.8	Ratio to Peak	0.2
W1540	206.37	35	0	0.0535328	0.5222	Discharge	0.007471	0.8	Ratio to Peak	0.2
W1550	196.05	35	0	0.172144	0.054605	Discharge	0.24253	0.8	Ratio to Peak	0.2
W1560	206.37	35	0	0.159752	0.175585	Discharge	0.18913	0.8	Ratio to Peak	0.2
W1570	205.425	35	0	0.137104	0.16295	Discharge	0.19846	0.8	Ratio to Peak	0.2
W1580	199.5	35	0	0.119808	0.13985	Discharge	0.096873	0.8	Ratio to Peak	0.2
W1590	206.37	35	0	0.103832	0.122205	Discharge	0.074213	0.8	Ratio to Peak	0.2
W1600	181.695	35	0	0.158272	0.105905	Discharge	0.28178	0.8	Ratio to Peak	0.2
W1610	55.818	38.28281	0	0.141288	0.16144	Discharge	0.30624	0.8	Ratio to Peak	0.2
W1620	36.8295	41.48051	0	0.09168	0.144115	Discharge	0.14414	0.8	Ratio to Peak	0.2
W1640	20.4945	44.55	0	0.091504	0.09351	Discharge	0.062584	0.8	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1650	31.1805	42.53783	0	0.114464	0.3673	Discharge	0.19144	0.8	Ratio to Peak	0.2
W1660	44.3835	40.14648	0	0.143184	0.093335	Discharge	0.17988	0.8	Ratio to Peak	0.2
W1670	70.224	36.16767	0	0.12328	0.116755	Discharge	0.24725	0.8	Ratio to Peak	0.2
W1680	190.11	35	0	0.136616	0.14605	Discharge	0.27399	0.8	Ratio to Peak	0.2
W1690	157.32	35	0	0.154976	0.125745	Discharge	0.3302	0.8	Ratio to Peak	0.2
W1700	195.645	35	0	0.143088	0.13935	Discharge	0.16644	0.8	Ratio to Peak	0.2
W1710	163.68	35	0	0.139576	0.15807	Discharge	0.37248	0.8	Ratio to Peak	0.2
W1720	196.185	35	0	0.144176	0.14595	Discharge	0.22329	0.8	Ratio to Peak	0.2
W1730	192.42	35	0	0.157392	0.14237	Discharge	0.18774	0.8	Ratio to Peak	0.2
W1740	159.96	35	0	0.11984	0.147065	Discharge	0.082986	0.8	Ratio to Peak	0.2
W1750	77.721	35.15639	0	0.14224	0.160535	Discharge	0.18396	0.8	Ratio to Peak	0.2
W1760	76.635	35.29944	0	0.266896	0.122235	Discharge	0.65001	0.8	Ratio to Peak	0.2
W1780	178.59	35	0	0.158832	0.14509	Discharge	0.25949	0.8	Ratio to Peak	0.2
W1790	195.795	35	0	0.10696	0.272235	Discharge	0.17533	0.8	Ratio to Peak	0.2
W1800	203.025	35	0	0.21152	0.251555	Discharge	0.29727	0.8	Ratio to Peak	0.2
W1810	167.94	35	0	0.145544	0.162005	Discharge	0.27463	0.8	Ratio to Peak	0.2
W1820	180.21	35	0	0.154136	0.1091	Discharge	0.080037	0.8	Ratio to Peak	0.2
W1830	200.235	35	0	0.098584	0.21575	Discharge	0.062172	0.8	Ratio to Peak	0.2
W1840	185.52	35	0	0.084936	0.148455	Discharge	0.081862	0.8	Ratio to Peak	0.2
W1850	157.41	35	0	0.101744	0.157215	Discharge	0.1649	0.8	Ratio to Peak	0.2
W1860	163.905	35	0	0.359576	0.100555	Discharge	1.1879	0.8	Ratio to Peak	0.2
W1870	183.96	35	0	0.24172	0.086635	Discharge	0.41651	0.8	Ratio to Peak	0.2
W1880	138.7305	35	0	0.176064	0.10378	Discharge	0.63299	0.8	Ratio to Peak	0.2
W1890	200.01	35	0	0.278984	0.36677	Discharge	0.26768	0.8	Ratio to Peak	0.2
W1900	1.9242	44.55	0	0.01667	0.24655	Discharge	0.000708	0.8	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W1910	108.525	35	0	0.617744	0.179585	Discharge	0.81924	0.8	Ratio to Peak	0.2
W1920	206.37	35	0	0.251384	0.28456	Discharge	0.29119	0.8	Ratio to Peak	0.2
W1930	206.37	35	0	0.207056	0.01667	Discharge	0.16352	0.8	Ratio to Peak	0.2
W1940	139.836	35	0	0.422656	0.6301	Discharge	0.90777	0.8	Ratio to Peak	0.2
W1950	150.315	35	0	0.123216	0.256415	Discharge	0.20145	0.8	Ratio to Peak	0.2
W1960	73.725	35.68851	0	0.101528	0.211195	Discharge	0.37756	0.8	Ratio to Peak	0.2
W1970	172.68	35	0	0.133312	0.43111	Discharge	0.15457	0.8	Ratio to Peak	0.2
W1980	55.503	38.33181	0	0.04212	0.12568	Discharge	0.061558	0.8	Ratio to Peak	0.2
W2000	152.115	35	0	0.088512	0.103555	Discharge	0.0738	0.8	Ratio to Peak	0.2
W2010	113.6805	35	0	0.09076	0.135975	Discharge	0.11854	0.8	Ratio to Peak	0.2
W2020	169.53	35	0	0.209904	0.042962	Discharge	0.34107	0.8	Ratio to Peak	0.2
W2030	150.195	35	0	0.148008	0.155795	Discharge	0.24315	0.8	Ratio to Peak	0.2
W2040	143.367	35	0	0.164072	0.09028	Discharge	0.27658	0.8	Ratio to Peak	0.2
W2050	192.33	35	0	0.196296	0.09257	Discharge	0.23516	0.8	Ratio to Peak	0.2
W2060	206.37	35	0	0.18332	0.214105	Discharge	0.21916	0.8	Ratio to Peak	0.2
W2070	206.37	35	0	0.120128	0.15097	Discharge	0.077848	0.8	Ratio to Peak	0.2
W2080	146.1795	35	0	0.087824	0.16735	Discharge	0.054899	0.8	Ratio to Peak	0.2
W2090	174.84	35	0	0.210568	0.20022	Discharge	0.25917	0.8	Ratio to Peak	0.2
W2100	188.43	35	0	0.151536	0.186985	Discharge	0.25105	0.8	Ratio to Peak	0.2
W2110	201.27	35	0	0.157248	0.12253	Discharge	0.25574	0.8	Ratio to Peak	0.2
W2120	160.74	35	0	0.130736	0.08958	Discharge	0.29562	0.8	Ratio to Peak	0.2
W2130	150.555	35	0	0.121544	0.214785	Discharge	0.22031	0.8	Ratio to Peak	0.2
W2140	178.5	35	0	0.166352	0.15457	Discharge	0.24289	0.8	Ratio to Peak	0.2
W2150	104.766	35	0	0.163704	0.16039	Discharge	0.24433	0.8	Ratio to Peak	0.2
W2160	127.0005	35	0	0.0752816	0.133355	Discharge	0.039807	0.8	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W2170	121.0575	35	0	0.182464	0.123975	Discharge	0.39586	0.8	Ratio to Peak	0.2
W2180	110.0895	35	0	0.122688	0.16968	Discharge	0.193	0.8	Ratio to Peak	0.2
W2190	206.37	35	0	0.186048	0.16698	Discharge	0.19729	0.8	Ratio to Peak	0.2
W2200	206.37	35	0	0.177288	0.076785	Discharge	0.17251	0.8	Ratio to Peak	0.2
W2210	194.175	35	0	0.190576	0.186115	Discharge	0.18432	0.8	Ratio to Peak	0.2
W2220	198.915	35	0	0.161104	0.125145	Discharge	0.25119	0.8	Ratio to Peak	0.2
W2230	115.5585	35	0	0.16932	0.18977	Discharge	0.38234	0.8	Ratio to Peak	0.2
W2240	134.2935	35	0	0.185416	0.18083	Discharge	0.38338	0.8	Ratio to Peak	0.2
W2250	193.86	35	0	0.2206	0.19439	Discharge	0.15404	0.8	Ratio to Peak	0.2
W2260	157.545	35	0	0.168936	0.164325	Discharge	0.36663	0.8	Ratio to Peak	0.2
W2270	195.225	35	0	0.20984	0.17271	Discharge	0.4963	0.8	Ratio to Peak	0.2
W2280	128.3865	35	0	0.105488	0.189125	Discharge	0.1036	0.8	Ratio to Peak	0.2
W2290	199.26	35	0	0.199928	0.225015	Discharge	0.39382	0.8	Ratio to Peak	0.2
W2300	121.893	35	0	0.0580928	0.172315	Discharge	0.028529	0.8	Ratio to Peak	0.2
W2310	121.7955	35	0	0.17256	0.21404	Discharge	0.45615	0.8	Ratio to Peak	0.2
W2320	187.2	35	0	0.258016	0.1076	Discharge	0.61798	0.8	Ratio to Peak	0.2
W2330	175.395	35	0	0.187488	0.203925	Discharge	0.3514	0.8	Ratio to Peak	0.2
W2340	161.265	35	0	0.229952	0.059255	Discharge	0.22788	0.8	Ratio to Peak	0.2
W2350	125.3625	35	0	0.0547856	0.17601	Discharge	0.020945	0.8	Ratio to Peak	0.2
W2360	137.928	35	0	0.107608	0.263175	Discharge	0.17431	0.8	Ratio to Peak	0.2
W2370	206.265	35	0	0.128856	0.19124	Discharge	0.14032	0.8	Ratio to Peak	0.2
W2380	161.4	35	0	0.265608	0.23455	Discharge	0.81297	0.8	Ratio to Peak	0.2
W2390	168.69	35	0	0.255448	0.05588	Discharge	0.6341	0.8	Ratio to Peak	0.2
W2400	105.6105	35	0	0.213272	0.109765	Discharge	0.4442	0.8	Ratio to Peak	0.2
W2410	100.6815	35	0	0.147768	0.131435	Discharge	0.21574	0.8	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W2420	182.76	35	0	0.224888	0.27092	Discharge	0.41146	0.8	Ratio to Peak	0.2
W2430	75.1215	35.50041	0	0.092232	0.26056	Discharge	0.25788	0.8	Ratio to Peak	0.2
W2440	181.905	35	0	0.146304	0.217535	Discharge	0.22254	0.8	Ratio to Peak	0.2
W2450	197.115	35	0	0.0540952	0.15072	Discharge	0.025794	0.8	Ratio to Peak	0.2
W2460	192.6	35	0	0.195176	0.229385	Discharge	0.48385	0.8	Ratio to Peak	0.2
W2470	127.548	35	0	0.126856	0.094075	Discharge	0.16523	0.8	Ratio to Peak	0.2
W2480	151.035	35	0	0.14792	0.14923	Discharge	0.25811	0.8	Ratio to Peak	0.2
W2490	166.35	35	0	0.154928	0.055175	Discharge	0.22283	0.8	Ratio to Peak	0.2
W2510	206.37	35	0	0.052268	0.19908	Discharge	0.004561	0.8	Ratio to Peak	0.2
W2520	177.375	35	0	0.098704	0.129395	Discharge	0.082405	0.8	Ratio to Peak	0.2
W2530	128.985	35	0	0.221152	0.15088	Discharge	0.53223	0.8	Ratio to Peak	0.2
W2540	176.595	35	0	0.0422776	0.15803	Discharge	0.003703	0.8	Ratio to Peak	0.2
W2550	145.0635	35	0	0.144288	0.281285	Discharge	0.16342	0.8	Ratio to Peak	0.2
W2560	112.3635	35	0	0.098792	0.053315	Discharge	0.22698	0.8	Ratio to Peak	0.2
W2570	181.77	35	0	0.183448	0.10068	Discharge	0.25356	0.8	Ratio to Peak	0.2
W2580	131.574	35	0	0.18112	0.22558	Discharge	0.23376	0.8	Ratio to Peak	0.2
W2590	191.805	35	0	0.142648	0.0431235	Discharge	0.197926	0.8	Ratio to Peak	0.2
W2600	172.05	35	0	0.234288	0.147175	Discharge	0.48885	0.8	Ratio to Peak	0.2
W2620	108.552	35	0	0.1412	0.100765	Discharge	0.17691	0.8	Ratio to Peak	0.2
W2630	167.385	35	0	0.216168	0.18712	Discharge	0.27794	0.8	Ratio to Peak	0.2
W2640	127.0005	35	0	0.099568	0.18474	Discharge	0.057159	0.8	Ratio to Peak	0.2
W2650	110.19	35	0	0.195688	0.145505	Discharge	0.83831	0.8	Ratio to Peak	0.2
W2660	156.06	35	0	0.183088	0.238975	Discharge	0.23987	0.8	Ratio to Peak	0.2
W2670	127.0005	35	0	0.050388	0.304615	Discharge	0.016845	0.8	Ratio to Peak	0.2
W2680	131.736	35	0	0.199184	0.144025	Discharge	0.45176	0.8	Ratio to Peak	0.2

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W2690	159.48	35	0	0.224976	0.22049	Discharge	0.48071	0.8	Ratio to Peak	0.2
W2700	130.0965	35	0	0.0411936	0.101555	Discharge	0.010891	0.8	Ratio to Peak	0.2
W2710	117.5055	35	0	0.114504	0.199605	Discharge	0.17247	0.8	Ratio to Peak	0.2
W2720	176.265	35	0	0.37932	0.18675	Discharge	0.51031	0.8	Ratio to Peak	0.2
W2730	112.614	35	0	0.112696	0.051395	Discharge	0.12941	0.8	Ratio to Peak	0.2
W2740	105.8085	35	0	0.195336	0.20317	Discharge	0.54411	0.8	Ratio to Peak	0.2
W2750	127.0005	35	0	0.0784384	0.229475	Discharge	0.067521	0.8	Ratio to Peak	0.2
W2770	120.825	35	0	0.197872	0.0420175	Discharge	0.36536	0.8	Ratio to Peak	0.2
W2780	84.453	35	0	0.168856	0.116795	Discharge	0.35779	0.8	Ratio to Peak	0.2
W2800	21.2835	44.52525	0	0.360096	0.386905	Discharge	0.53725	0.8	Ratio to Peak	0.2
W2810	36.258	41.58495	0	0.125192	0.114955	Discharge	0.095999	0.8	Ratio to Peak	0.2
W2850	70.4595	36.135	0	0.0495344	0.19924	Discharge	0.029679	0.8	Ratio to Peak	0.2
W2860	68.43	36.41814	0	0.147584	0.080005	Discharge	0.49247	0.8	Ratio to Peak	0.2
W2900	183.915	35	0	0.246624	0.171015	Discharge	0.23324	0.8	Ratio to Peak	0.2
W2910	181.215	35	0	0.122224	0.201825	Discharge	0.11854	0.8	Ratio to Peak	0.2
W2950	68.1435	36.45873	0	0.152744	0.17223	Discharge	0.33463	0.8	Ratio to Peak	0.2
W2960	101.9325	35	0	0.13012	0.127695	Discharge	0.17833	0.8	Ratio to Peak	0.2
W3000	132.9945	35	0	0.275768	0.150535	Discharge	0.5825	0.8	Ratio to Peak	0.2
W3010	159.225	35	0	0.135048	0.124665	Discharge	0.16569	0.8	Ratio to Peak	0.2
W3050	170.925	35	0	0.298648	0.13272	Discharge	0.32973	0.8	Ratio to Peak	0.2
W3060	205.53	35	0	0.173256	0.137745	Discharge	0.16615	0.8	Ratio to Peak	0.2
W3100	140.4645	35	0	0.167664	0.176725	Discharge	0.13697	0.8	Ratio to Peak	0.2
W3110	145.1505	35	0	0.133128	0.13579	Discharge	0.26355	0.8	Ratio to Peak	0.2

ANNEX 10. Amburayan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	3752.9	0.009565	0.01	Trapezoid	154	1
R1000	Automatic Fixed Interval	6251.3	0.010653	0.01	Trapezoid	74	1
R1050	Automatic Fixed Interval	926.69	0.10019	0.01	Trapezoid	57	1
R1070	Automatic Fixed Interval	5226.5	0.028836	0.01	Trapezoid	63.2	1
R1090	Automatic Fixed Interval	141.42	0.043036	0.01	Trapezoid	66.1	1
R1100	Automatic Fixed Interval	3886.9	0.10888	0.01	Trapezoid	22.3	1
R1120	Automatic Fixed Interval	490.71	0.12969	0.01	Trapezoid	38.9	1
R1150	Automatic Fixed Interval	2238.7	0.038125	0.01	Trapezoid	149.6	1
R1160	Automatic Fixed Interval	1478.8	0.11765	0.01	Trapezoid	44	1
R1180	Automatic Fixed Interval	4566.8	0.026731	0.01	Trapezoid	73.4	1
R1190	Automatic Fixed Interval	1730.4	0.000847	0.01	Trapezoid	116	1
R120	Automatic Fixed Interval	6604.7	0.022949	0.01	Trapezoid	77.5	1
R1200	Automatic Fixed Interval	8720.2	0.082154	0.01	Trapezoid	42	1
R1220	Automatic Fixed Interval	3781	0.017205	0.01	Trapezoid	47	1
R1240	Automatic Fixed Interval	1877.5	0.030195	0.01	Trapezoid	104	1
R1250	Automatic Fixed Interval	661.13	0.00821	0.01	Trapezoid	80.1	1
R1260	Automatic Fixed Interval	5543	0.020216	0.01	Trapezoid	84.9	1
R1270	Automatic Fixed Interval	1766.8	0.078122	0.01	Trapezoid	46.4	1
R1280	Automatic Fixed Interval	577.7	0.055509	0.01	Trapezoid	45.8	1
R130	Automatic Fixed Interval	576.27	0.004327	0.01	Trapezoid	48.3	1
R1310	Automatic Fixed Interval	5804.8	0.05243	0.01	Trapezoid	31	1
R1320	Automatic Fixed Interval	4480.9	0.035483	0.01	Trapezoid	36.3	1
R1340	Automatic Fixed Interval	1909.1	0.013661	0.01	Trapezoid	59.5	1
R1360	Automatic Fixed Interval	1140.1	0.10994	0.01	Trapezoid	57.9	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1390	Automatic Fixed Interval	3530.2	0.035615	0.01	Trapezoid	56.3	1
R160	Automatic Fixed Interval	2891.6	0.041836	0.01	Trapezoid	46.2	1
R180	Automatic Fixed Interval	1779.9	0.066692	0.01	Trapezoid	43.6	1
R200	Automatic Fixed Interval	14008	0.002722	0.01	Trapezoid	203	1
R210	Automatic Fixed Interval	1453.3	0.016089	0.01	Trapezoid	241	1
R230	Automatic Fixed Interval	2678.9	0.001831	0.01	Trapezoid	277	1
R240	Automatic Fixed Interval	2108.9	0.078148	0.01	Trapezoid	33.5	1
R270	Automatic Fixed Interval	7579.2	0.001116	0.01	Trapezoid	33.6	1
R2820	Automatic Fixed Interval	945.27	0.004573	0.01	Trapezoid	536	1
R290	Automatic Fixed Interval	4999.4	0.001155	0.01	Trapezoid	503	1
R2920	Automatic Fixed Interval	2376.6	0.014524	0.01	Trapezoid	99.1	1
R2970	Automatic Fixed Interval	1718.5	0.046537	0.01	Trapezoid	34.5	1
R30	Automatic Fixed Interval	9072.8	0.031174	0.01	Trapezoid	47.9	1
R340	Automatic Fixed Interval	1210.5	0.002243	0.01	Trapezoid	116	1
R350	Automatic Fixed Interval	4796.5	0.006886	0.01	Trapezoid	172	1
R360	Automatic Fixed Interval	3219.3	0.043524	0.01	Trapezoid	31.9	1
R370	Automatic Fixed Interval	3151.6	0.00566	0.01	Trapezoid	45.9	1
R400	Automatic Fixed Interval	2432.4	0.003747	0.01	Trapezoid	97	1
R410	Automatic Fixed Interval	1812.5	0.088375	0.01	Trapezoid	63.3	1
R430	Automatic Fixed Interval	4081.6	0.046845	0.01	Trapezoid	52.6	1
R440	Automatic Fixed Interval	3285.3	0.056017	0.01	Trapezoid	44.8	1
R450	Automatic Fixed Interval	1828.9	0.014747	0.01	Trapezoid	75.7	1
R460	Automatic Fixed Interval	7378.5	0.006027	0.01	Trapezoid	496	1
R470	Automatic Fixed Interval	134.85	0.089839	0.01	Trapezoid	95	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R490	Automatic Fixed Interval	5041.1	0.017517	0.01	Trapezoid	52	1
R550	Automatic Fixed Interval	11044	0.060988	0.01	Trapezoid	62.9	1
R560	Automatic Fixed Interval	1927.8	0.063262	0.01	Trapezoid	37.4	1
R570	Automatic Fixed Interval	1408.1	0.082319	0.01	Trapezoid	26.2	1
R580	Automatic Fixed Interval	2888.7	0.06452	0.01	Trapezoid	25	1
R590	Automatic Fixed Interval	1223.3	0.11626	0.01	Trapezoid	62	1
R60	Automatic Fixed Interval	6111.9	0.026709	0.01	Trapezoid	75.5	1
R600	Automatic Fixed Interval	11359	0.003518	0.01	Trapezoid	567	1
R620	Automatic Fixed Interval	1646.8	0.039633	0.01	Trapezoid	63.5	1
R660	Automatic Fixed Interval	1584.7	0.003457	0.01	Trapezoid	279	1
R690	Automatic Fixed Interval	3151.3	0.087182	0.01	Trapezoid	49.4	1
R70	Automatic Fixed Interval	389.71	0.021723	0.01	Trapezoid	25.5	1
R700	Automatic Fixed Interval	3672.5	0.094099	0.01	Trapezoid	49.1	1
R710	Automatic Fixed Interval	4146.2	0.00642	0.01	Trapezoid	29	1
R730	Automatic Fixed Interval	1369.8	0.034996	0.01	Trapezoid	33.6	1
R770	Automatic Fixed Interval	15836	0.013927	0.01	Trapezoid	35	1
R80	Automatic Fixed Interval	1033.8	0.002352	0.01	Trapezoid	119	1
R800	Automatic Fixed Interval	4266.3	0.009474	0.01	Trapezoid	195	1
R820	Automatic Fixed Interval	2186.8	0.019012	0.01	Trapezoid	174	1
R860	Automatic Fixed Interval	2528.9	0.055025	0.01	Trapezoid	28.9	1
R870	Automatic Fixed Interval	2480.1	0.005941	0.01	Trapezoid	115	1
R90	Automatic Fixed Interval	3030.9	0.019747	0.01	Trapezoid	74.8	1
R910	Automatic Fixed Interval	1210.5	0.007436	0.01	Trapezoid	50.8	1
R920	Automatic Fixed Interval	382.84	0.083881	0.01	Trapezoid	31	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R930	Automatic Fixed Interval	5119.8	0.039925	0.01	Trapezoid	96.2	1
R950	Automatic Fixed Interval	1963.8	0.089898	0.01	Trapezoid	48.4	1
R970	Automatic Fixed Interval	2698.9	0.040062	0.01	Trapezoid	45	1
R990	Automatic Fixed Interval	5730.6	0.024823	0.01	Trapezoid	56.1	1

ANNEX 11. Amburayan Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
1	16.893575	120.420878	1.150	1.219	0.005	Nina/ September 19-23, 2008	5-Year
2	16.895093	120.452601	0.530	0.457	0.005	Egay/ July 4-8, 2015	5-Year
3	16.892631	120.424425	1.090	0.305	0.617	Pepeng/ October 2-5, 2009	5-Year
4	16.892631	120.424425	1.090	0.457	0.400	Egay/ July 4-8, 2015	5-Year
5	16.893586	120.426728	1.480	1.219	0.068	Nina/ September 19-23, 2008	5-Year
6	16.893586	120.426728	1.480	0.610	0.758	Mario/ September 18-22, 2014	5-Year
7	16.893586	120.426728	1.480	0.914	0.320	Mario/ September 18-22, 2014	5-Year
8	16.893586	120.426728	1.480	0.457	1.046	Egay/ July 4-8, 2015	5-Year
9	16.893586	120.426728	1.480	0.914	0.320	Pepeng/ October 2-5, 2009	5-Year
10	16.893586	120.426728	1.480	1.067	0.171	Pepeng/ October 2-5, 2009	5-Year
11	16.897627	120.428236	0.570	1.219	0.421	Nina/ September 19-23, 2008	5-Year
12	16.897627	120.428236	0.570	0.305	0.070	Mario/ September 18-22, 2014	5-Year
13	16.895093	120.452601	0.530	0.914	0.148	Nina/ September 19-23, 2008	5-Year
14	16.897627	120.428236	0.570	0.457	0.013	Egay/ July 4-8, 2015	5-Year
15	16.897627	120.428236	0.570	0.914	0.119	Pepeng/ October 2-5, 2009	5-Year
16	16.897627	120.428236	0.570	1.219	0.421	Pepeng/ October 2-5, 2009	5-Year
17	16.898351	120.428458	0.580	1.219	0.409	Nina/ September 19-23, 2008	5-Year
18	16.898351	120.428458	0.380	0.305	0.006	Nina/ September 19-23, 2008	5-Year
19	16.898351	120.428458	0.380	0.457	0.006	Nina/ September 19-23, 2008	5-Year
20	16.898351	120.428458	0.380	0.914	0.286	Nina/ September 19-23, 2008	5-Year
21	16.898351	120.428458	0.380	1.219	0.704	Nina/ September 19-23, 2008	5-Year
22	16.898832	120.518801	0.760	0.305	0.207	Ineng/ August 20-23, 2015	5-Year
23	16.898832	120.518801	0.760	0.610	0.023	Mario/ September 18-22, 2014	5-Year
24	16.895093	120.452601	0.530	1.067	0.288	Pepeng/ October 2-5, 2009	5-Year
25	16.920643	120.521431	8.650	0.305	69.642	Ineng/ August 20-23, 2015	5-Year
26	16.920643	120.521431	8.650	0.610	64.648	Ineng/ August 20-23, 2015	5-Year
27	16.895837	120.442921	1.700	1.219	0.231	Nina/ September 19-23, 2008	5-Year
28	16.895837	120.442921	1.700	0.610	1.189	Mario/ September 18-22, 2014	5-Year
29	16.895837	120.442921	1.700	0.914	0.617	Mario/ September 18-22, 2014	5-Year
30	16.895837	120.442921	1.700	0.457	1.545	Egay/ July 4-8, 2015	5-Year
31	16.895837	120.442921	1.700	0.914	0.617	Pepeng/ October 2-5, 2009	5-Year
32	16.895837	120.442921	1.700	1.067	0.401	Pepeng/ October 2-5, 2009	5-Year
33	16.898843	120.439051	0.850	1.219	0.136	Nina/ September 19-23, 2008	5-Year
34	16.898843	120.439051	0.850	0.610	0.058	Mario/ September 18-22, 2014	5-Year
35	16.899237	120.446788	1.600	1.219	0.145	Nina/ September 19-23, 2008	5-Year
36	16.898843	120.439051	0.850	0.914	0.004	Mario/ September 18-22, 2014	5-Year
37	16.898843	120.439051	0.850	0.457	0.154	Egay/ July 4-8, 2015	5-Year
38	16.898843	120.439051	0.850	0.914	0.004	Pepeng/ October 2-5, 2009	5-Year
39	16.898843	120.439051	0.850	1.219	0.136	Pepeng/ October 2-5, 2009	5-Year
40	16.898871	120.440447	1.320	1.219	0.010	Nina/ September 19-23, 2008	5-Year
41	16.898871	120.440447	1.320	0.610	0.505	Nina/ September 19-23, 2008	5-Year
42	16.898871	120.440447	1.320	0.610	0.505	Nina/ September 19-23, 2008	5-Year
43	16.898871	120.440447	1.320	0.457	0.744	Nina/ September 19-23, 2008	5-Year
44	16.898871	120.440447	1.320	0.914	0.165	Nina/ September 19-23, 2008	5-Year
45	16.898871	120.440447	1.320	1.219	0.010	Nina/ September 19-23, 2008	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
46	16.899237	120.446788	1.600	0.610	0.981	Mario/ September 18-22, 2014	5-Year
47	16.898942	120.424179	0.820	1.219	0.159	Nina/ September 19-23, 2008	5-Year
48	16.898942	120.424179	0.770	0.610	0.026	Mario/ September 18-22, 2014	5-Year
49	16.898942	120.424179	0.770	0.914	0.021	Mario/ September 18-22, 2014	5-Year
50	16.898942	120.424179	0.770	0.457	0.098	Egay/ July 4-8, 2015	5-Year
51	16.898942	120.424179	0.770	0.914	0.021	Mario/ September 18-22, 2014	5-Year
52	16.898942	120.424179	0.770	1.219	0.202	Pepeng/ October 2-5, 2009	5-Year
53	16.899989	120.48293	2.560	1.219	1.798	Karen/ August 18-21, 2008	5-Year
54	16.900876	120.489089	1.150	1.219	0.005	Karen/ August 18-21, 2008	5-Year
55	16.901246	120.490163	0.950	1.219	0.072	Karen/ August 18-21, 2008	5-Year
56	16.904236	120.465557	0.970	1.067	0.009	Karen/ August 18-21, 2008	5-Year
57	16.899237	120.446788	1.600	0.914	0.470	Mario/ September 18-22, 2014	5-Year
58	16.906496	120.467662	0.620	1.219	0.359	Karen/ August 18-21, 2008	5-Year
59	16.908756	120.467249	6.420	1.219	27.048	Karen/ August 18-21, 2008	5-Year
60	16.909055	120.468199	7.810	1.219	43.439	Karen/ August 18-21, 2008	5-Year
61	16.909488	120.470683	0.770	0.610	0.026	Nina/ September 19-23, 2008	5-Year
62	16.869987	120.44427	0.420	0.914	0.244	Nina/ September 19-23, 2008	5-Year
63	16.869987	120.44427	0.420	0.610	0.036	Mario/ September 18-22, 2014	5-Year
64	16.869987	120.44427	0.420	0.914	0.244	Mario/ September 18-22, 2014	5-Year
65	16.869987	120.44427	0.420	0.457	0.001	Egay/ July 4-8, 2015	5-Year
66	16.869987	120.44427	0.420	0.914	0.244	Pepeng/ October 2-5, 2009	5-Year
67	16.869987	120.44427	0.420	0.610	0.036	Pepeng/ October 2-5, 2009	5-Year
68	16.899237	120.446788	1.600	0.457	1.306	Egay/ July 4-8, 2015	5-Year
69	16.867537	120.434189	0.030	0.152	0.015	Nina/ September 19-23, 2008	5-Year
70	16.867537	120.434189	0.030	0.610	0.336	Nina/ September 19-23, 2008	5-Year
71	16.867537	120.434189	0.030	0.914	0.78	Mario/ September 18-22, 2014	5-Year
72	16.867537	120.434189	0.030	0.457	0.182	Nina/ September 19-23, 2008	5-Year
73	16.867537	120.434189	0.030	0.152	0.015	Nina/ September 19-23, 2008	5-Year
74	16.867537	120.434189	0.030	0.152	0.015	Nina/ September 19-23, 2008	5-Year
75	16.867722	120.434966	0.030	0.152	0.015	Pepeng/ October 2-5, 2009	5-Year
76	16.867722	120.434966	0.030	0.610	0.336	Mario/ September 18-22, 2014	5-Year
77	16.867722	120.434966	0.030	0.914	0.782	Pepeng/ October 2-5, 2009	5-Year
78	16.867722	120.434966	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
79	16.899237	120.446788	1.600	0.914	0.470	Pepeng/ October 2-5, 2009	5-Year
80	16.867722	120.434966	0.030	0.152	0.015	Nina/ September 19-23, 2008	5-Year
81	16.867722	120.434966	0.030	0.152	0.015	Pepeng/ October 2-5, 2009	5-Year
82	16.896398	120.429418	0.870	0.914	0.002	Nina/ September 19-23, 2008	5-Year
83	16.896398	120.429418	0.870	0.610	0.068	Mario/ September 18-22, 2014	5-Year
84	16.896398	120.429418	0.870	0.914	0.002	Nina/ September 19-23, 2008	5-Year
85	16.896398	120.429418	0.870	0.457	0.170	Nina/ September 19-23, 2008	5-Year
86	16.896398	120.429418	0.870	0.914	0.002	Mario/ September 18-22, 2014	5-Year
87	16.896398	120.429418	0.870	0.610	0.068	Nina/ September 19-23, 2008	5-Year
88	16.89757	120.432534	1.090	0.914	0.031	Mario/ September 18-22, 2014	5-Year
89	16.89757	120.432534	1.090	0.610	0.231	Mario/ September 18-22, 2014	5-Year
90	16.899237	120.446788	1.600	1.219	0.145	Pepeng/ October 2-5, 2009	5-Year
91	16.89757	120.432534	1.090	0.914	0.031	Mario/ September 18-22, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
92	16.89757	120.432534	1.090	0.457	0.400	Pepeng/ October 2-5, 2009	5-Year
93	16.89757	120.432534	1.090	0.914	0.031	Pepeng/ October 2-5, 2009	5-Year
94	16.89757	120.432534	1.090	0.610	0.231	Pepeng/ October 2-5, 2009	5-Year
95	16.898415	120.434443	0.760	0.914	0.024	Nina/ September 19-23, 2008	5-Year
96	16.898415	120.434443	0.760	0.610	0.023	Ineng/ August 20-23, 2015	5-Year
97	16.898415	120.434443	0.760	0.914	0.024	Mario/ September 18-22, 2014	5-Year
98	16.898415	120.434443	0.760	0.457	0.092	Egay/ July 4-8, 2015	5-Year
99	16.898415	120.434443	0.760	0.914	0.024	Pepeng/ October 2-5, 2009	5-Year
100	16.898415	120.434443	0.760	0.610	0.023	Pepeng/ October 2-5, 2009	5-Year
101	16.899269	120.447494	1.560	1.219	0.116	Pepeng/ October 2-5, 2009	5-Year
102	16.90968	120.407828	0.480	1.219	0.546	Nina/ September 19-23, 2008	5-Year
103	16.90968	120.407828	0.080	0.305	0.051	Mario/ September 18-22, 2014	5-Year
104	16.90968	120.407828	0.080	0.457	0.142	Egay/ July 4-8, 2015	5-Year
105	16.90968	120.407828	0.080	0.914	0.696	Pepeng/ October 2-5, 2009	5-Year
106	16.90968	120.407828	0.080	1.219	1.298	Pepeng/ October 2-5, 2009	5-Year
107	16.910373	120.414275	0.830	1.219	0.151	Nina/ September 19-23, 2008	5-Year
108	16.910373	120.414275	0.830	0.610	0.049	Mario/ September 18-22, 2014	5-Year
109	16.910373	120.414275	0.830	0.914	0.007	Mario/ September 18-22, 2014	5-Year
110	16.910373	120.414275	0.830	0.457	0.139	Egay/ July 4-8, 2015	5-Year
111	16.910373	120.414275	0.830	0.914	0.007	Pepeng/ October 2-5, 2009	5-Year
112	16.893575	120.420878	0.080	0.610	0.280	Mario/ September 18-22, 2014	5-Year
113	16.899269	120.447494	1.560	0.610	0.903	Pepeng/ October 2-5, 2009	5-Year
114	16.910373	120.414275	0.830	1.219	0.151	Pepeng/ October 2-5, 2009	5-Year
115	16.901836	120.492391	1.460	1.219	0.058	Karen/ August 18-21, 2008	5-Year
116	16.902175	120.493459	2.020	1.219	0.641	Karen/ August 18-21, 2008	5-Year
117	16.931918	120.427812	1.980	0.305	2.806	Ineng/ August 20-23, 2015	5-Year
118	16.931918	120.427812	1.980	0.610	1.878	Ineng/ August 20-23, 2015	5-Year
119	16.889875	120.405845	0.520	0.457	0.004	Nina/ September 19-23, 2008	5-Year
120	16.889875	120.405845	0.520	0.610	0.008	Mario/ September 18-22, 2014	5-Year
121	16.889875	120.405845	0.520	0.914	0.156	Mario/ September 18-22, 2014	5-Year
122	16.889875	120.405845	0.520	0.457	0.004	Egay/ July 4-8, 2015	5-Year
123	16.889875	120.405845	0.520	0.305	0.046	Pepeng/ October 2-5, 2009	5-Year
124	16.899269	120.447494	1.560	0.914	0.417	Pepeng/ October 2-5, 2009	5-Year
125	16.889875	120.405845	0.520	0.457	0.004	Pepeng/ October 2-5, 2009	5-Year
126	16.887014	120.40401	0.180	1.219	1.080	Nina/ September 19-23, 2008	5-Year
127	16.887014	120.40401	0.180	0.610	0.185	Mario/ September 18-22, 2014	5-Year
128	16.887014	120.40401	0.180	0.914	0.539	Mario/ September 18-22, 2014	5-Year
129	16.887014	120.40401	0.180	0.457	0.077	Egay/ July 4-8, 2015	5-Year
130	16.887014	120.40401	0.180	0.914	0.539	Pepeng/ October 2-5, 2009	5-Year
131	16.887014	120.40401	0.180	1.067	0.786	Pepeng/ October 2-5, 2009	5-Year
132	16.896332	120.406088	0.930	1.219	0.084	Nina/ September 19-23, 2008	5-Year
133	16.896332	120.406088	0.930	0.610	0.103	Mario/ September 18-22, 2014	5-Year
134	16.896332	120.406088	0.930	0.914	0.000	Mario/ September 18-22, 2014	5-Year
135	16.899269	120.447494	1.560	0.457	1.216	Pepeng/ October 2-5, 2009	5-Year
136	16.896332	120.406088	0.930	0.457	0.224	Egay/ July 4-8, 2015	5-Year
137	16.896332	120.406088	0.930	0.914	0.000	Pepeng/ October 2-5, 2009	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
138	16.896332	120.406088	0.930	1.067	0.019	Pepeng/ October 2-5, 2009	5-Year
139	16.899376	120.45478	0.030	0.152	0.015	Nina/ September 19-23, 2008	5-Year
140	16.901267	120.459437	2.110	1.219	0.794	Karen/ August 18-21, 2008	5-Year
141	16.901747	120.454949	3.480	1.219	5.111	Karen/ August 18-21, 2008	5-Year
142	16.901832	120.456147	3.590	1.219	5.621	Karen/ August 18-21, 2008	5-Year
143	16.902068	120.455896	3.480	1.219	5.111	Karen/ August 18-21, 2008	5-Year
144	16.907492	120.460997	4.770	1.219	12.608	Karen/ August 18-21, 2008	5-Year
145	16.919428	120.429971	1.560	0.305	1.576	Ineng/ August 20-23, 2015	5-Year
146	16.899269	120.447494	1.560	0.914	0.417	Pepeng/ October 2-5, 2009	5-Year
147	16.919428	120.429971	1.560	0.610	0.903	Ineng/ August 20-23, 2015	5-Year
148	16.923927	120.422571	1.300	0.305	0.990	Ineng/ August 20-23, 2015	5-Year
149	16.923927	120.422571	1.300	0.610	0.477	Ineng/ August 20-23, 2015	5-Year
150	16.890579	120.430873	1.960	1.219	0.549	Nina/ September 19-23, 2008	5-Year
151	16.890579	120.430873	1.960	0.610	1.824	Mario/ September 18-22, 2014	5-Year
152	16.890579	120.430873	1.960	0.914	1.093	Mario/ September 18-22, 2014	5-Year
153	16.890579	120.430873	1.960	0.457	2.258	Egay/ July 4-8, 2015	5-Year
154	16.890579	120.430873	1.960	0.914	1.093	Pepeng/ October 2-5, 2009	5-Year
155	16.890579	120.430873	1.960	1.067	0.798	Pepeng/ October 2-5, 2009	5-Year
156	16.86819	120.390192	0.030	1.219	1.414	Mario/ September 18-22, 2014	5-Year
157	16.899269	120.447494	1.560	1.219	0.116	Nina/ September 19-23, 2008	5-Year
158	16.871183	120.392293	0.420	1.219	0.639	Mario/ September 18-22, 2014	5-Year
159	16.874163	120.395259	1.170	1.219	0.002	Mario/ September 18-22, 2014	5-Year
160	16.876445	120.396851	1.550	1.219	0.109	Mario/ September 18-22, 2014	5-Year
161	16.848025	120.422403	0.030	1.067	1.075	Mario/ September 18-22, 2014	5-Year
162	16.858217	120.423129	0.360	0.457	0.009	Nina/ September 19-23, 2008	5-Year
163	16.858217	120.423129	0.360	0.610	0.062	Nina/ September 19-23, 2008	5-Year
164	16.858217	120.423129	0.360	0.914	0.307	Nina/ September 19-23, 2008	5-Year
165	16.858217	120.423129	0.360	0.457	0.009	Nina/ September 19-23, 2008	5-Year
166	16.858217	120.423129	0.360	0.914	0.307	Nina/ September 19-23, 2008	5-Year
167	16.858217	120.423129	0.360	0.457	0.009	Nina/ September 19-23, 2008	5-Year
168	16.929667	120.435171	0.590	0.305	0.081	Ineng/ August 20-23, 2015	5-Year
169	16.863028	120.422294	1.360	1.219	0.020	Nina/ September 19-23, 2008	5-Year
170	16.863028	120.422294	1.360	0.610	0.563	Mario/ September 18-22, 2014	5-Year
171	16.863028	120.422294	1.360	0.914	0.199	Mario/ September 18-22, 2014	5-Year
172	16.863028	120.422294	1.360	0.457	0.815	Egay/ July 4-8, 2015	5-Year
173	16.863028	120.422294	1.360	0.914	0.199	Pepeng/ October 2-5, 2009	5-Year
174	16.863028	120.422294	1.360	1.067	0.086	Pepeng/ October 2-5, 2009	5-Year
175	16.880408	120.424228	2.580	1.219	1.852	Nina/ September 19-23, 2008	5-Year
176	16.880408	120.424228	0.240	0.305	0.004	Mario/ September 18-22, 2014	5-Year
177	16.880408	120.424228	0.240	0.457	0.047	Nina/ September 19-23, 2008	5-Year
178	16.880408	120.424228	0.240	0.914	0.455	Nina/ September 19-23, 2008	5-Year
179	16.929667	120.435171	0.590	0.610	0.000	Ineng/ August 20-23, 2015	5-Year
180	16.880408	120.424228	0.240	1.219	0.959	Pepeng/ October 2-5, 2009	5-Year
181	16.878232	120.453925	0.030	0.152	0.015	Karen/ August 18-21, 2008	5-Year
182	16.878232	120.453925	0.870	0.610	0.068	Nina/ September 19-23, 2008	5-Year
183	16.878232	120.453925	0.870	0.914	0.002	Nina/ September 19-23, 2008	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
184	16.878232	120.453925	0.870	0.457	0.170	Egay/ July 4-8, 2015	5-Year
185	16.878232	120.453925	0.870	0.152	0.515	Pepeng/ October 2-5, 2009	5-Year
186	16.878232	120.453925	0.870	0.152	0.515	Pepeng/ October 2-5, 2009	5-Year
187	16.881894	120.453837	0.080	0.457	0.142	Egay/ July 4-8, 2015	5-Year
188	16.881894	120.453837	0.630	0.610	0.000	Nina/ September 19-23, 2008	5-Year
189	16.881894	120.453837	0.630	0.914	0.081	Nina/ September 19-23, 2008	5-Year
190	16.894826	120.421115	0.030	1.219	1.414	Nina/ September 19-23, 2008	5-Year
191	16.881894	120.453837	0.630	0.457	0.030	Nina/ September 19-23, 2008	5-Year
192	16.881894	120.453837	0.630	0.305	0.106	Nina/ September 19-23, 2008	5-Year
193	16.881894	120.453837	0.630	0.457	0.030	Nina/ September 19-23, 2008	5-Year
194	16.82707	120.457052	0.030	0.152	0.015	Karen/ August 18-21, 2008	5-Year
195	16.833544	120.458516	0.030	0.152	0.015	Karen/ August 18-21, 2008	5-Year
196	16.939081	120.432689	1.070	0.305	0.586	Ineng/ August 20-23, 2015	5-Year
197	16.939081	120.432689	1.070	0.610	0.212	Ineng/ August 20-23, 2015	5-Year
198	16.879281	120.473799	0.030	0.152	0.015	Karen/ August 18-21, 2008	5-Year
199	16.880076	120.473558	0.030	0.305	0.076	Karen/ August 18-21, 2008	5-Year
200	16.853102	120.441135	0.240	0.457	0.047	Egay/ July 4-8, 2015	5-Year
201	16.894826	120.421115	0.030	0.610	0.336	Mario/ September 18-22, 2014	5-Year
202	16.853102	120.441135	0.240	0.610	0.137	Nina/ September 19-23, 2008	5-Year
203	16.853102	120.441135	0.240	0.914	0.455	Pepeng/ October 2-5, 2009	5-Year
204	16.853102	120.441135	0.240	0.457	0.047	Nina/ September 19-23, 2008	5-Year
205	16.853102	120.441135	0.240	0.305	0.004	Nina/ September 19-23, 2008	5-Year
206	16.853102	120.441135	0.240	0.457	0.047	Nina/ September 19-23, 2008	5-Year
207	16.857433	120.438893	0.380	0.457	0.006	Nina/ September 19-23, 2008	5-Year
208	16.857433	120.438893	0.380	0.610	0.053	Nina/ September 19-23, 2008	5-Year
209	16.857433	120.438893	0.380	0.914	0.286	Nina/ September 19-23, 2008	5-Year
210	16.857433	120.438893	0.380	0.457	0.006	Nina/ September 19-23, 2008	5-Year
211	16.857433	120.438893	0.380	0.305	0.006	Nina/ September 19-23, 2008	5-Year
212	16.894826	120.421115	0.030	0.914	0.782	Mario/ September 18-22, 2014	5-Year
213	16.857433	120.438893	0.380	0.457	0.006	Nina/ September 19-23, 2008	5-Year
214	16.837908	120.439136	0.870	0.914	0.002	Nina/ September 19-23, 2008	5-Year
215	16.837908	120.439136	0.870	0.610	0.068	Nina/ September 19-23, 2008	5-Year
216	16.837908	120.439136	0.870	0.914	0.002	Nina/ September 19-23, 2008	5-Year
217	16.837908	120.439136	0.870	0.457	0.170	Nina/ September 19-23, 2008	5-Year
218	16.837908	120.439136	0.870	0.914	0.002	Nina/ September 19-23, 2008	5-Year
219	16.837908	120.439136	0.870	0.610	0.068	Nina/ September 19-23, 2008	5-Year
220	16.843079	120.444522	0.530	0.914	0.148	Pepeng/ October 2-5, 2009	5-Year
221	16.843079	120.444522	0.530	0.610	0.006	Nina/ September 19-23, 2008	5-Year
222	16.843079	120.444522	0.530	0.914	0.148	Nina/ September 19-23, 2008	5-Year
223	16.893575	120.420878	0.080	0.914	0.696	Mario/ September 18-22, 2014	5-Year
224	16.894826	120.421115	0.030	0.457	0.182	Egay/ July 4-8, 2015	5-Year
225	16.843079	120.444522	0.530	0.457	0.005	Egay/ July 4-8, 2015	5-Year
226	16.843079	120.444522	0.530	0.914	0.148	Pepeng/ October 2-5, 2009	5-Year
227	16.843079	120.444522	0.530	0.610	0.006	Pepeng/ October 2-5, 2009	5-Year
228	16.849698	120.438357	0.630	0.914	0.081	Nina/ September 19-23, 2008	5-Year
229	16.849698	120.438357	0.630	0.610	0.000	Nina/ September 19-23, 2008	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
230	16.849698	120.438357	0.630	0.914	0.081	Nina/ September 19-23, 2008	5-Year
231	16.849698	120.438357	0.630	0.457	0.030	Nina/ September 19-23, 2008	5-Year
232	16.849698	120.438357	0.630	0.914	0.081	Nina/ September 19-23, 2008	5-Year
233	16.849698	120.438357	0.630	0.610	0.000	Nina/ September 19-23, 2008	5-Year
234	16.881002	120.42945	0.770	0.914	0.021	Nina/ September 19-23, 2008	5-Year
235	16.894826	120.421115	0.030	0.914	0.782	Nina/ September 19-23, 2008	5-Year
236	16.881002	120.42945	0.770	0.610	0.026	Nina/ September 19-23, 2008	5-Year
237	16.881002	120.42945	0.770	0.914	0.021	Nina/ September 19-23, 2008	5-Year
238	16.881002	120.42945	0.770	0.457	0.098	Nina/ September 19-23, 2008	5-Year
239	16.881002	120.42945	0.770	0.914	0.021	Pepeng/ October 2-5, 2009	5-Year
240	16.881002	120.42945	0.770	0.610	0.026	Nina/ September 19-23, 2008	5-Year
241	16.882439	120.43447	0.080	0.152	0.005	Nina/ September 19-23, 2008	5-Year
242	16.882439	120.43447	0.080	0.610	0.280	Mario/ September 18-22, 2014	5-Year
243	16.882439	120.43447	0.080	0.914	0.696	Pepeng/ October 2-5, 2009	5-Year
244	16.882439	120.43447	0.080	0.152	0.005	Egay/ July 4-8, 2015	5-Year
245	16.882439	120.43447	0.080	0.152	0.005	Pepeng/ October 2-5, 2009	5-Year
246	16.894826	120.421115	0.030	1.219	1.414	Pepeng/ October 2-5, 2009	5-Year
247	16.882439	120.43447	0.080	0.152	0.005	Pepeng/ October 2-5, 2009	5-Year
248	16.889187	120.441924	0.770	0.914	0.021	Pepeng/ October 2-5, 2009	5-Year
249	16.889187	120.441924	0.770	0.610	0.026	Nina/ September 19-23, 2008	5-Year
250	16.889187	120.441924	0.770	0.914	0.021	Nina/ September 19-23, 2008	5-Year
251	16.889187	120.441924	0.770	0.457	0.098	Nina/ September 19-23, 2008	5-Year
252	16.889187	120.441924	0.770	0.914	0.021	Nina/ September 19-23, 2008	5-Year
253	16.889187	120.441924	0.770	0.610	0.026	Karen/ August 18-21, 2008	5-Year
254	16.896562	120.417319	1.790	1.219	0.326	Nina/ September 19-23, 2008	5-Year
255	16.896562	120.417319	1.790	0.610	1.393	Mario/ September 18-22, 2014	5-Year
256	16.896562	120.417319	1.790	0.914	0.767	Mario/ September 18-22, 2014	5-Year
257	16.896562	120.417319	1.790	0.457	1.776	Egay/ July 4-8, 2015	5-Year
258	16.896562	120.417319	1.790	0.914	0.767	Pepeng/ October 2-5, 2009	5-Year
259	16.896562	120.417319	1.790	1.067	0.523	Pepeng/ October 2-5, 2009	5-Year
260	16.81824	120.455085	0.060	0.914	0.730	Mario/ September 18-22, 2014	5-Year
261	16.893575	120.420878	0.080	0.457	0.142	Nina/ September 19-23, 2008	5-Year
262	16.824661	120.452799	0.770	1.067	0.088	Pepeng/ October 2-5, 2009	5-Year
263	16.824807	120.456978	0.780	0.914	0.018	Karen/ August 18-21, 2008	5-Year
264	16.954716	120.488059	1.000	0.305	0.483	Mario/ September 18-22, 2014	5-Year
265	16.954716	120.488059	1.000	0.610	0.152	Mario/ September 18-22, 2014	5-Year
266	16.954716	120.488059	1.000	0.914	0.007	Mario/ September 18-22, 2014	5-Year
267	16.955932	120.488397	8.530	0.914	57.997	Mario/ September 18-22, 2014	5-Year
268	16.956386	120.489377	9.720	0.610	82.999	Mario/ September 18-22, 2014	5-Year
269	16.956386	120.489377	9.720	0.914	77.539	Mario/ September 18-22, 2014	5-Year
270	16.957308	120.487473	3.020	0.305	7.372	Mario/ September 18-22, 2014	5-Year
271	16.957308	120.487473	3.020	0.610	5.810	Mario/ September 18-22, 2014	5-Year
272	16.893575	120.420878	0.080	0.914	0.696	Mario/ September 18-22, 2014	5-Year
273	16.957308	120.487473	3.020	0.914	4.434	Mario/ September 18-22, 2014	5-Year
274	16.957957	120.487837	5.720	0.610	26.116	Mario/ September 18-22, 2014	5-Year
275	16.957957	120.487837	5.720	0.914	23.094	Mario/ September 18-22, 2014	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
276	16.883609	120.463374	0.270	0.152	0.014	Karen/ August 18-21, 2008	5-Year
277	16.886231	120.453846	0.060	0.152	0.009	Nina/ September 19-23, 2008	5-Year
278	16.886231	120.453846	0.060	0.610	0.302	Mario/ September 18-22, 2014	5-Year
279	16.886231	120.453846	0.060	0.914	0.730	Karen/ August 18-21, 2008	5-Year
280	16.886231	120.453846	0.060	0.457	0.158	Egay/ July 4-8, 2015	5-Year
281	16.886231	120.453846	0.060	0.152	0.009	Pepeng/ October 2-5, 2009	5-Year
282	16.886231	120.453846	0.060	0.152	0.009	Pepeng/ October 2-5, 2009	5-Year
283	16.893575	120.420878	0.080	1.219	1.298	Pepeng/ October 2-5, 2009	5-Year
284	16.886664	120.448777	0.530	0.914	0.148	Mario/ September 18-22, 2014	5-Year
285	16.886664	120.448777	0.530	0.610	0.006	Mario/ September 18-22, 2014	5-Year
286	16.886664	120.448777	0.530	0.914	0.148	Mario/ September 18-22, 2014	5-Year
287	16.886664	120.448777	0.530	0.457	0.005	Nina/ September 19-23, 2008	5-Year
288	16.886664	120.448777	0.530	0.914	0.148	Nina/ September 19-23, 2008	5-Year
289	16.886664	120.448777	0.530	0.610	0.006	Nina/ September 19-23, 2008	5-Year
290	16.900465	120.41898	1.400	1.219	0.033	Nina/ September 19-23, 2008	5-Year
291	16.900465	120.41898	1.400	0.610	0.625	Mario/ September 18-22, 2014	5-Year
292	16.900465	120.41898	1.400	0.914	0.236	Mario/ September 18-22, 2014	5-Year
293	16.900465	120.41898	1.400	0.457	0.889	Egay/ July 4-8, 2015	5-Year
294	16.895093	120.452601	0.620	1.219	0.359	Nina/ September 19-23, 2008	5-Year
295	16.900465	120.41898	1.400	0.914	0.236	Pepeng/ October 2-5, 2009	5-Year
296	16.900465	120.41898	1.400	1.219	0.033	Pepeng/ October 2-5, 2009	5-Year
297	16.901592	120.416845	1.560	1.219	0.116	Pepeng/ October 2-5, 2009	5-Year
298	16.901592	120.416845	0.770	0.610	0.026	Mario/ September 18-22, 2014	5-Year
299	16.901592	120.416845	0.770	0.914	0.021	Nina/ September 19-23, 2008	5-Year
300	16.901592	120.416845	0.770	0.457	0.098	Egay/ July 4-8, 2015	5-Year
301	16.901592	120.416845	0.770	0.914	0.021	Nina/ September 19-23, 2008	5-Year
302	16.901592	120.416845	0.770	1.067	0.088	Karen/ August 18-21, 2008	5-Year
303	16.890264	120.425839	1.680	1.219	0.212	Nina/ September 19-23, 2008	5-Year
304	16.890264	120.425839	1.680	0.610	1.146	Mario/ September 18-22, 2014	5-Year
305	16.895093	120.452601	0.530	0.610	0.006	Mario/ September 18-22, 2014	5-Year
306	16.890264	120.425839	1.680	0.914	0.586	Mario/ September 18-22, 2014	5-Year
307	16.890264	120.425839	1.680	0.457	1.495	Egay/ July 4-8, 2015	5-Year
308	16.890264	120.425839	1.680	0.914	0.586	Pepeng/ October 2-5, 2009	5-Year
309	16.890264	120.425839	1.680	1.067	0.376	Pepeng/ October 2-5, 2009	5-Year
310	16.891806	120.42668	1.230	1.219	0.000	Nina/ September 19-23, 2008	5-Year
311	16.891806	120.42668	1.230	0.610	0.385	Mario/ September 18-22, 2014	5-Year
312	16.891806	120.42668	1.230	0.914	0.100	Mario/ September 18-22, 2014	5-Year
313	16.891806	120.42668	1.230	0.457	0.597	Egay/ July 4-8, 2015	5-Year
314	16.891806	120.42668	1.230	0.914	0.100	Pepeng/ October 2-5, 2009	5-Year
315	16.891806	120.42668	1.230	1.067	0.027	Pepeng/ October 2-5, 2009	5-Year
316	16.895093	120.452601	0.530	0.914	0.148	Nina/ September 19-23, 2008	5-Year
317	16.890983	120.423678	1.690	1.219	0.222	Nina/ September 19-23, 2008	5-Year
318	16.890983	120.423678	1.690	0.610	1.167	Mario/ September 18-22, 2014	5-Year
319	16.890983	120.423678	1.690	0.914	0.602	Mario/ September 18-22, 2014	5-Year
320	16.890983	120.423678	1.690	0.457	1.520	Egay/ July 4-8, 2015	5-Year
321	16.890983	120.423678	1.690	0.914	0.602	Pepeng/ October 2-5, 2009	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Lon					
322	16.890983	120.423678	1.690	1.067	0.388	Pepeng/ October 2-5, 2009	5-Year
323	16.892631	120.424425	1.090	0.305	0.617	Nina/ September 19-23, 2008	5-Year
324	16.892631	120.424425	1.090	0.610	0.231	Mario/ September 18-22, 2014	5-Year
325	16.892631	120.424425	1.090	0.914	0.031	Nina/ September 19-23, 2008	5-Year
326	16.892631	120.424425	1.090	0.457	0.400	Egay/ July 4-8, 2015	5-Year
				RMSE	1.37709		

ANNEX 12. Educational Institutions Affected in Amburayan Flood Plain

Ilocos Sur				
Alilem				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ALILEM CENTRAL SCHOOL	Alilem Daya			
ALILEM NHS (ALILEM DAYA HS)	Alilem Daya			
DALAWA ELEMENTARY SCHOOL	Dalawa	High	High	High
PALASIPAS ES	Dalawa			
AGUIWAS PS	Kiat			
GUILONG PS	Kiat	High	High	High
KIAT ES	Kiat			
Tagudin				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
AG-AGUMAN ELEM. SCHOOL	Ag-Aguman			
AMBALAYAT HIGH SCHOOL	Ambalayat	High	High	High
AMBALAYAT IS	Ambalayat	High	High	High
BARACBAC COMM. SCH.	Ambalayat	Medium	High	High
OLD SUDIPEN NHS	Ambalayat	High	High	High
DACUTAN DAY CARE CENTER	Bimmanga	Medium	High	High
DAY CARE CENTER	Bimmanga	Medium	Medium	Medium
TALLAOEN ELEMENTARY SCHOOL	Bimmanga		Low	Low
BIO ES	Cabaroan			
CABULANGLANGAN ES	Cabulanglangan		High	High
TALLAOEN ELEMENTARY SCHOOL	Dardarat		Low	Low
AIRTOP COMPUTER SCHOOL	Del Pilar	Medium	Medium	High
SAN PEDRO COMMUNITY SCHOOL	Farola	Low	Medium	Medium
CAMPUS MATE GEN. MERCHANDISE	Las-Ud	Medium	Medium	High
ILOCOS SUR POLYTHECNIC STATE COLLEGE	Las-Ud	Medium	Medium	High
ISPSC	Las-Ud	Medium	High	High
TAGUDIN NHS	Las-Ud	Medium	High	High
TNHS	Las-Ud	Medium	High	High
PALLOGAN ES	Pallogan	Low	Medium	High
PUDOC EAST ELEMENTARY SCHOOL	Pudoc East	High	High	High
PUDOC WEST INTEGRATED SCHOOL	Pudoc West	High	High	High
ADVENTIST SCHOOL	Quirino			
MAGSAYSAY DAY CARE CENTER	Quirino	High	High	High
SAINT AUGUSTINE SCHOOL	Quirino	Medium	Medium	High
ST. AUGUSTINE CHURCH	Quirino	Medium	Medium	Medium
ST. AUGUSTINE SCHOOL	Quirino	Medium	Medium	High
TAGUDIN CENTRAL SCHOOL	Quirino		Low	Medium

TAGUDIN ELEMENTARY SCHOOL	Quirino			
UCCP CHRIST-GIFTED ACADEMY INC.	Quirino	Low	Medium	Medium
UCCP CHRIST-GIFTED INC.	Quirino	Medium	Medium	Medium
SAN MIGUEL ES	Salvacion	Medium	High	High

La Union				
Bangar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DO	Agdeppa	Medium	High	High
BANGAOILAN ES	Bangaoilan West	High	High	High
BANGAR CES	Barraca	Medium	High	High
BANGAR ELEMENTARY SCHOOL	Barraca	Medium	High	High
CAGGAO ES	Barraca	Medium	High	High
DAYCARE CENTER	Barraca	High	High	High
TER-CON ELEMENTARY SCHOOL	Barraca	Medium	High	High
CADAPLI ELEMENTARY SCHOOL	Cadapli	Medium	Medium	Medium
DONA F. LACSAMANA VDA DE ORTEGA MNHS - CASA CRISTO ANNEX	Cadapli	Medium	Medium	Medium
SENG-NGAT ELEMENTARY SCHOOL	Cadapli			
CAGGAO ES	Caggao	High	High	High
ST. CHRISTOPHER ACADEMY	Central West No. 2	Medium	High	High
RUS ES	Central West No. 3	Medium	High	High
PUDOC ES	Consuegra	High	High	High
GENERAL PRIM ELEMENTARY SCHOOL	General Prim West	Low	High	High
DAY CARE CENTER	General Terrero	Medium	High	High
TER-CON ELEMENTARY SCHOOL	General Terrero	Medium	High	High
ALJAY'S STORE0	Maria Cristina West	Medium	High	High
GEN. PRIM DAY CARE CENTER	Maria Cristina West	Medium	High	High
MARIA CRISTINA ELEMENTARY SCHOOL	Maria Cristina West	Medium	High	High
REGIONAL SCIENCE HS, LA UNION	Maria Cristina West	Medium	High	High
MINDORO INTEGRATED SCHOOL	Mindoro	High	High	High
AG-NA ELEM.SCHOOL	Nagsabaran	High	High	High
PARATONG ES	Paratong No. 3	High	High	High
PARATONG DAY CARE	Paratong No. 4		Medium	Medium
PARATONG ES	Paratong Norte	Medium	High	High
MA. CRISTINA ES	Reyna Regente	Medium	High	High
RUS ES	Reyna Regente	Medium	High	High

DO	San Blas	High	High	High
SENG-NGAT ELEMENTARY SCHOOL	San Cristobal		Low	Low
Sudipen				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
DUPLAS ES	Duplas			
MALICLICO ES	Duplas			
OLD SUDIPEN ES	Ilocano	High	High	High
OLD SUDIPEN NHS	Ilocano	High	High	High
SUDIPEN VOC'L SCH.	Ipet		Low	High
SUDIPEN CENTRAL SCHOOL	Poblacion	High	High	High
CASTRO ES	Sengngat	Low	Low	Low
SENGNGAT ES	Sengngat	Low	Low	Medium
PORPORIKET ES	Up-Uplas			
UP-UPLAS ES	Up-Uplas			

ANNEX 13. Medical Institutions Affected in Amburayan Flood Plain

Ilocos Sur				
Tagudin				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
TALLAOEN HEALTH CENTER	Bimmanga	Low	Low	Medium
TALLAOEN HEALTH CENTER	Dardarat	Low	Low	Medium
ST. THERESE CHILDREN'S CLINIC	Las-Ud	Medium	Medium	Medium
TAGUDIN MEDICAL DIAGNOSTIC CENTER	Las-Ud	High	High	High
ATIGA MATERNITY AND DIAGNOSTIC CENTER	Quirino		Low	Medium
DENTAL CLINIC	Quirino	Medium	Medium	High
ST. THERESE CHILDREN'S CLINIC	Quirino	Medium	Medium	High
GRANADA OPTICAL CLINIC	Rizal			

La Union				
Bangar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ARTINEZ STORE	Central West No. 2	Medium	High	High
RURAL HEALTH UNIT	Maria Cristina West	Low	Medium	High