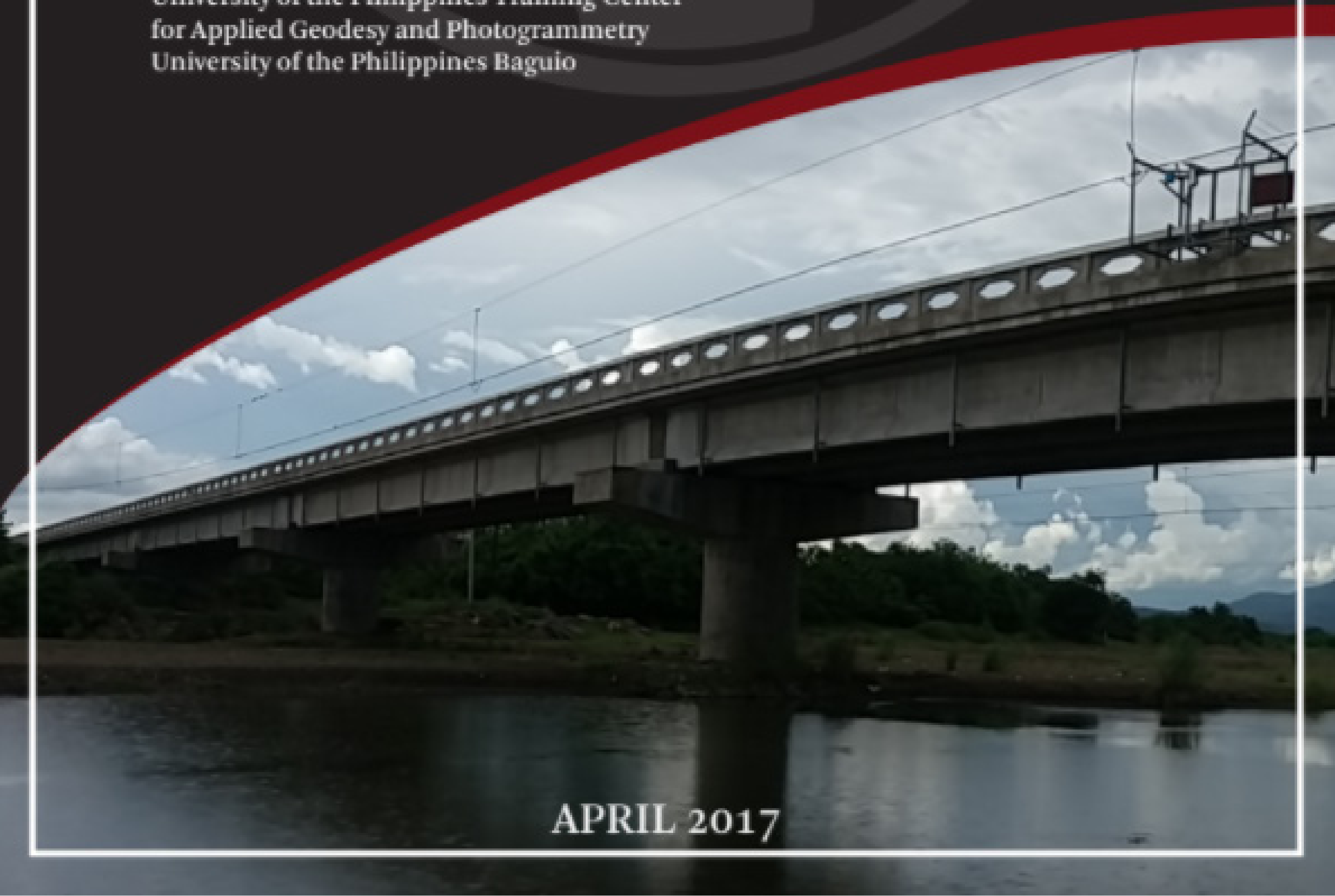
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Buaya River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BUAYA RIVER

Enrico C. Paringit, Dr. Eng. and Chelo S. Pascua, Ph.D.

1.1 Background of the Phil-LIDAR 1 Program

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

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)

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

1.2 Overview of the Buaya River Basin

Malbog River Basin covers the municipalities of Castilla and some portions of Pilar in the province of Sorsogon. The DENR River Basin Control Office identified the basin to have a drainage area of 2224 km2 and an estimated annual runoff of 330 million cubic meter (MCM) (RBCO, 2015).

Its main stem, Malbog River, is part of the twenty four (24) river systems in Bicol Region. According to the 2015 national census of the National Statistics Office, a total of 10,147persons distributed among eight (8) barangays are residing within the immediate vicinity of the river. These barangays are as follows: Sogoy and Loreto from the municipality of Castilla and Sacnagnan, Malbog, Ginablan, Calpi, Pineda, and Binanuahan from the municipality of Pilar. The municipalities of Pilar and Castilla are mainly agricultural. Around 80 percent of the total land area of Castilla is devoted to crop production, 60 percent of which consists of coconut trees. (http://lgucastilla.wixsite.com/castillasorsogon/plan, 2017). The economic growth of the municipality of Pilar relies mainly on agriculture with coconut as a major product, being the major supplier of copra to the coconut oil milling industry in Bicol. Among the coastal residents of Pilar, fishing has been their main source of income. (http://pilar-sorsogon.weebly.com/about-pilar.html, 2017).

Recent flooding that occurred in this area was caused by Typhoon Glenda, internationally known as Rammasun, last July 2014. Water pumps and rice farms in the villages were massively destroyed while a total of 6,529 houses were totally damaged. (http://bicoltoday.com/2014/07/19/glenda-destroyed-6529-houses-in-sorsogon-city/,2017).

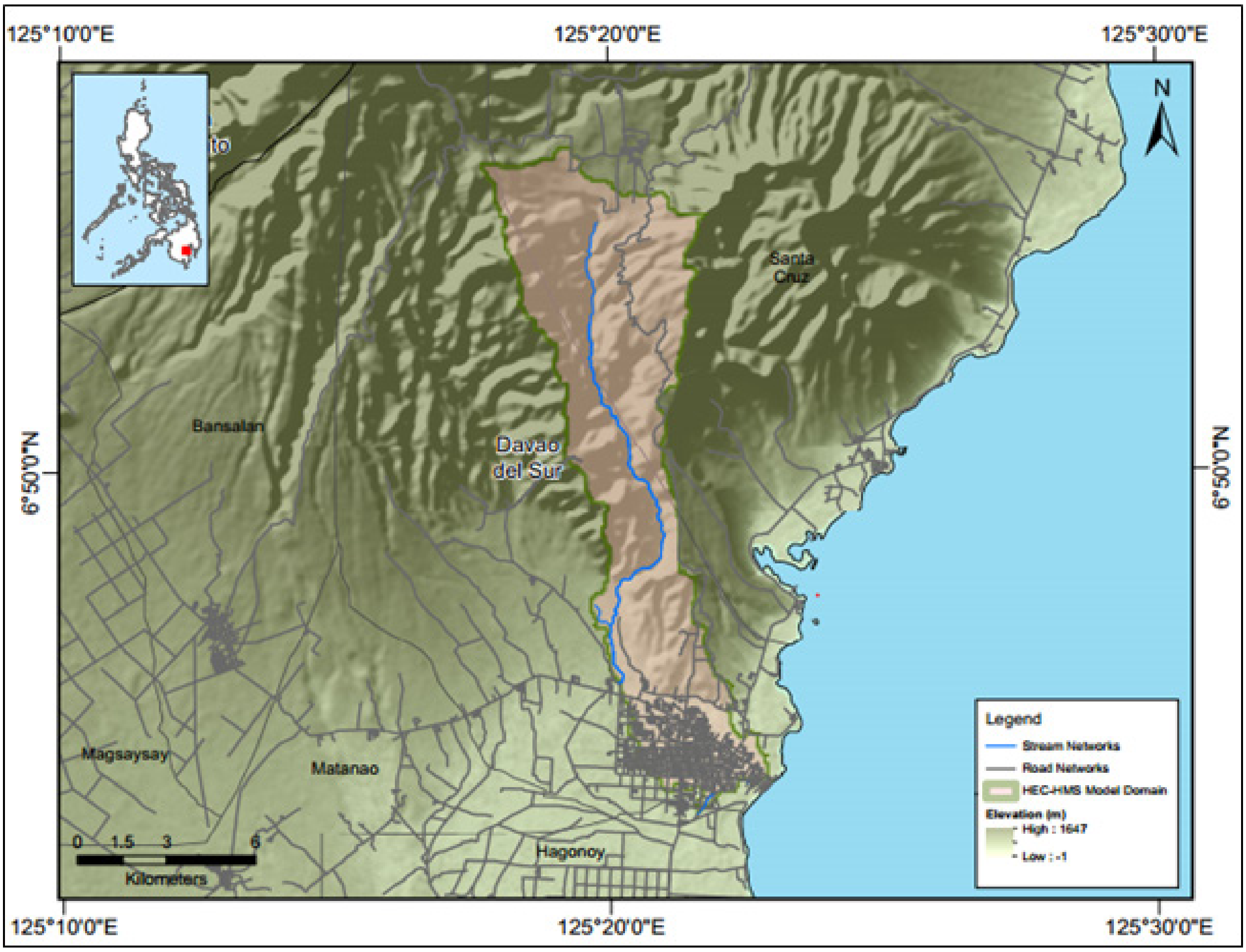


Figure 1. Map of the Buaya River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BUAYA FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Jasmine T. Alviar, Engr. Brylle Adam G. De Castro

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Buaya Floodplain in Abra, Ilocos Norte, Ilocos Sur and La Union Provinces. These missions were planned for 8 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR systems are found in Table 1 and Table 2. Figure 2 shows the flight plan for Buaya floodplain.

Table 1. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK27A	1000	25	40	100	50	130	5

Table 2. Flight planning parameters for Pegasus LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK27B	1200	30	50	200	30	130	5
BLK27AB	1200	30	50	200	30	130	5

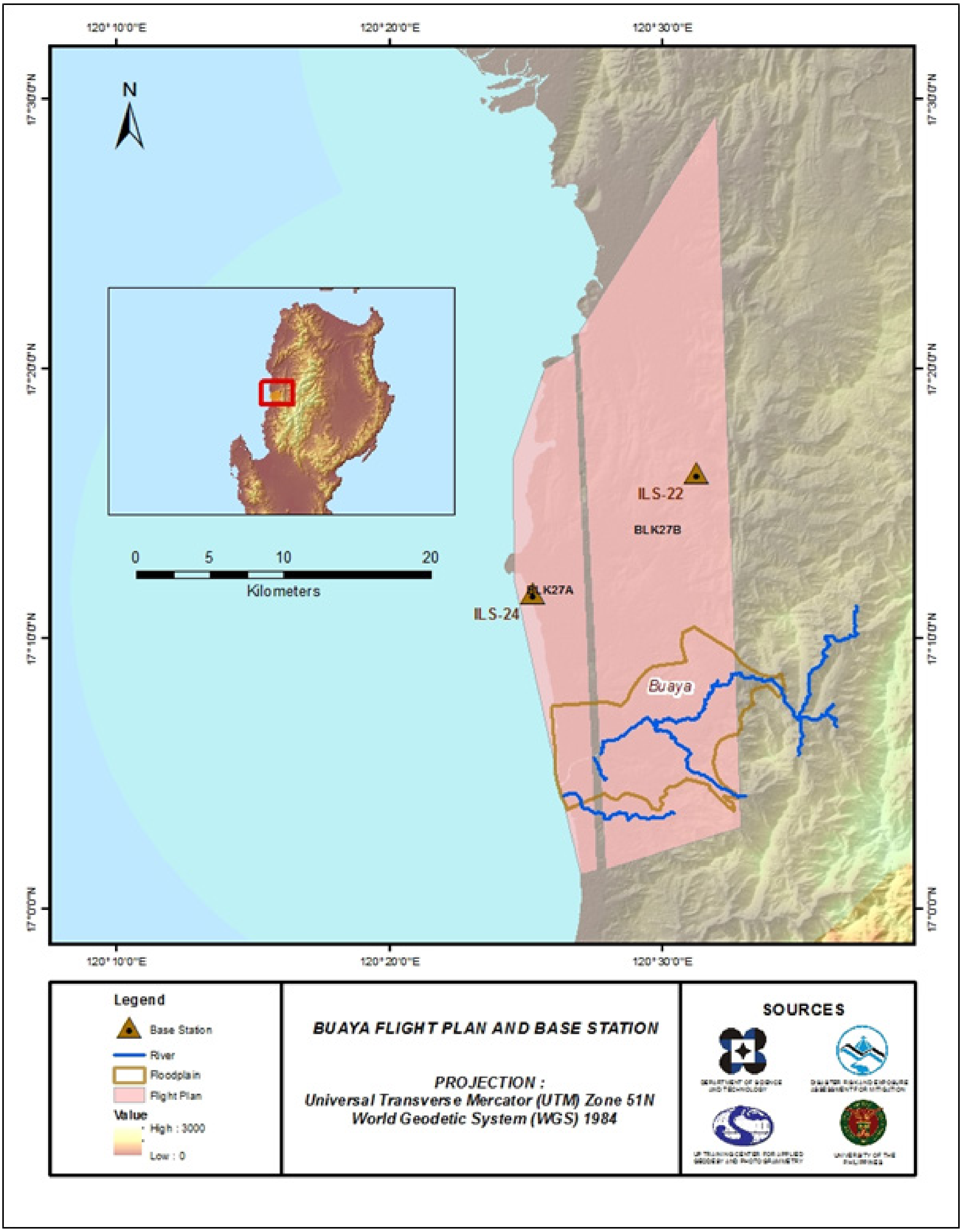
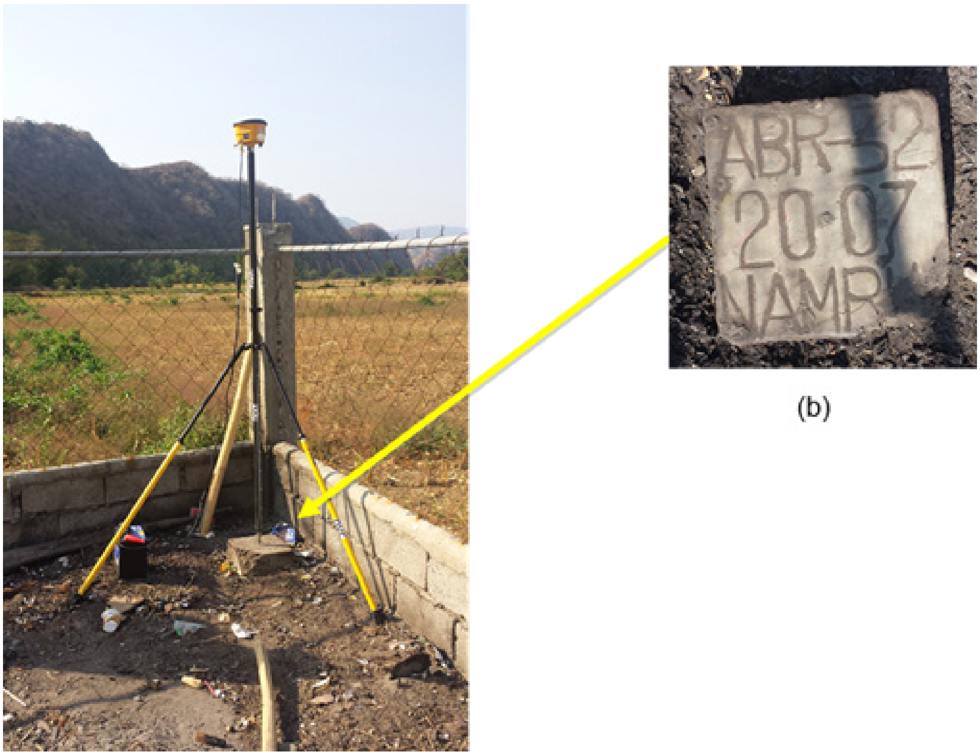


Figure 2. Flight plan and base stations used for Buaya Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA horizontal ground control points of second (2nd) order accuracy, ABR-32, ILS-22 and ILS-24. The certification for the base station is found in ANNEX 2. These were used as base stations during flight operations for the entire duration of the survey (February 18 – March 21, 2014) especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 985 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Buaya floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 5 show the details about the following NAMRIA control stations and established points while Table 5 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.



(b)

(a)

Figure 3. GPS set-up over ABR-32 inside the Barangay Hall Compound of Barangay Suyo, Pidigan Abra (a) and NAMRIA reference point ABR-32 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ABR-32 used as base station for the LiDAR Acquisition.

Station Name	**ABR-32**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°33’49.34656” North 120°33’25.07659” East 39.322 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	452,967.729 meters 1,942,534.242 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°33’43.229” North 120°33’29.72282” East 72.814 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	240,677.03 meters 1,943,468.54 meters

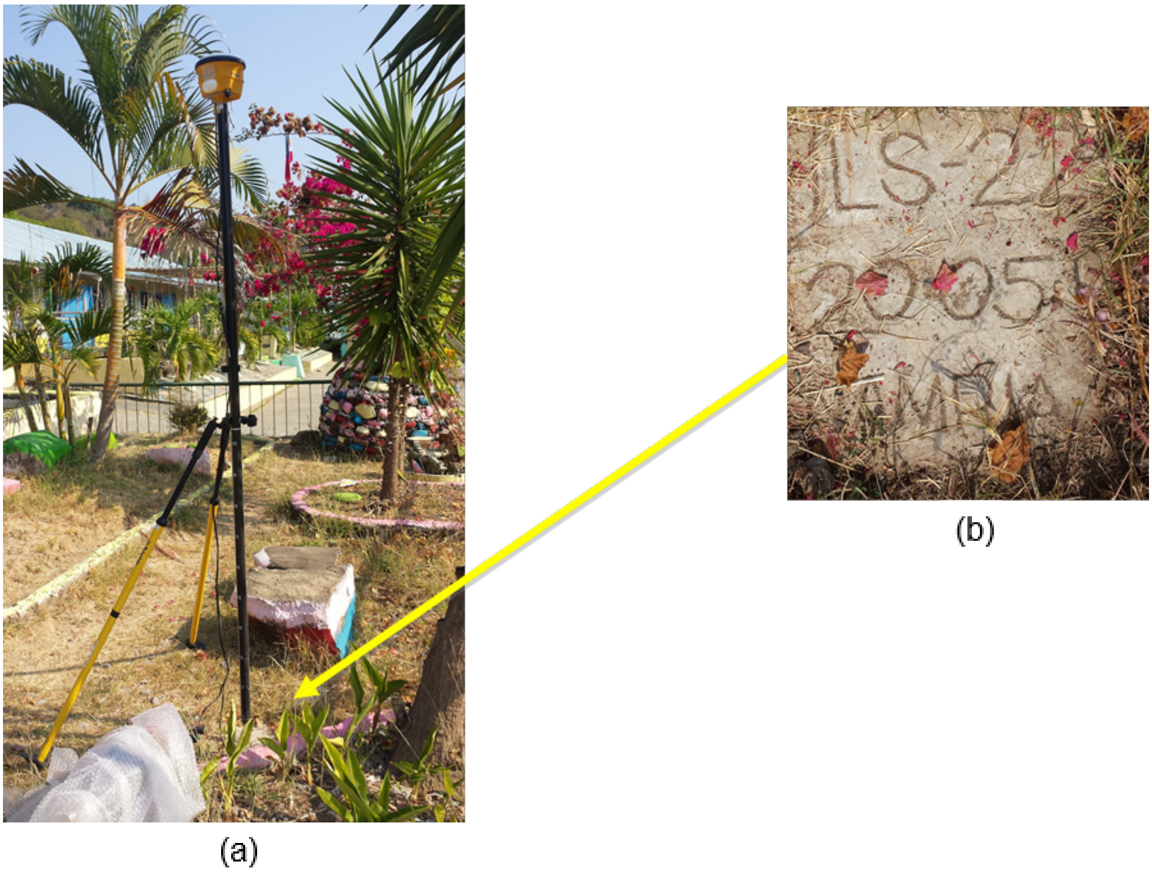


Figure 4. GPS set-up over ILS-22 inside Lidlidda North Central School in Lidlidda, Ilocos Sur (a) and NAMRIA reference point ILS-22 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ILS-22 used as base station for the LiDAR Acquisition.

Station Name	**ILS-22**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°16’13.59403” North 120°31’8.89179” East 55.312 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	448,870.206 meters 1,910,089 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°16’7.53708” North 120°31’13.56269” East 89.647 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	236, 238.44 meters 1,911,053.54 meters

(a) (b)

Figure 5. GPS set-up over ILS-24 beside the University of Northern Philippines Annex in Barangay Darapidap, Ilocos Sur (a) and NAMRIA reference point ILS-24 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ILS-24 used as base station for the LiDAR Acquisition.

Station Name	ILS-24	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°11'46.25613" North 120°25'8.83897" East 12.287 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Latitude Longitude Ellipsoidal Height	438,210.77 meters 1,901,900.937 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°11'40.20757" North 120°25'13.51659" East 46.616 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	225,489.39 meters 1,902,971.42 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
4-Mar-16	1179	1BLK27B063A	ILS-22 and ILS-24
8-Mar-14	1195	1BLK27ABS067A	ILS-22
10-Mar-14	7119	2BLK27A069B	ABR-32 and ILS-22

2.3 Flight Missions

Three (3) missions were conducted to complete the LiDAR data acquisition in Buaya floodplain, for a total of ten hours and forty nine minutes (10+49) of flying time for RP-C9322 and RP-C9022. All missions were acquired using the Gemini and Pegasus LiDAR systems. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Buaya floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
2-Mar-14	1179	381.54	343.64	58.58	285.06	645	4	15
8-Mar-14	1195	321.95	139.75	24.45	115.3	257	2	17
10-Mar-14	7119	114.98	235.93	24.25	211.68	-	4	17
TOTAL		818.47	719.32	107.28	612.04	902	10	49

Table 8. Actual parameters used during LiDAR data acquisition.

Flight Number	**Flying Height (m AGL)**	**Overlap (%)**	**FOV (θ)**	**PRF (khz)**	**Scan Frequency (Hz)**	**Average Speed (kts)**	**Average Turn Time (Minutes)**
1179	1200	30	50	200	30	130	5
1195	1200	30	50	200	30	130	5
7119	1000	25	40	100	50	130	5

2.4 Survey Coverage

Buaya Floodplain is located in the provinces of Abra, Ilocos Norte, Ilocos Sur and La Union with majority of the floodplain situated within the municipalities of San Esteban, Santiago and Santa Lucia and City of Candon. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Buaya floodplain is presented in Figure 6.

Table 9. List of municipalities and cities surveyed during Buaya floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Ilocos Sur	San Esteban	17.27	17.27	100%
	Candon City	80.18	80.08	100%
	Santiago	65.57	65.25	100%
	Santa Lucia	43.88	43.43	99%
	Banayoyo	23.23	22.49	97%
	Santa Maria	52.32	49.62	95%
	Galimuyod	32.81	27.84	85%
	Santa Cruz	105.95	88.28	83%
	Burgos	49.60	40.49	82%
	Lidlidda	39.48	24.05	61%
	Narvacan	97.18	46.70	48%
	Salcedo	69.23	31.57	46%
	Nagbukel	36.46	10.01	27%
	Suyo	148.52	10.96	7%
	San Emilio	138.02	1.85	1%
	Sigay	98.45	1.19	1%
	TOTAL	1098.15	561.08	51.09%

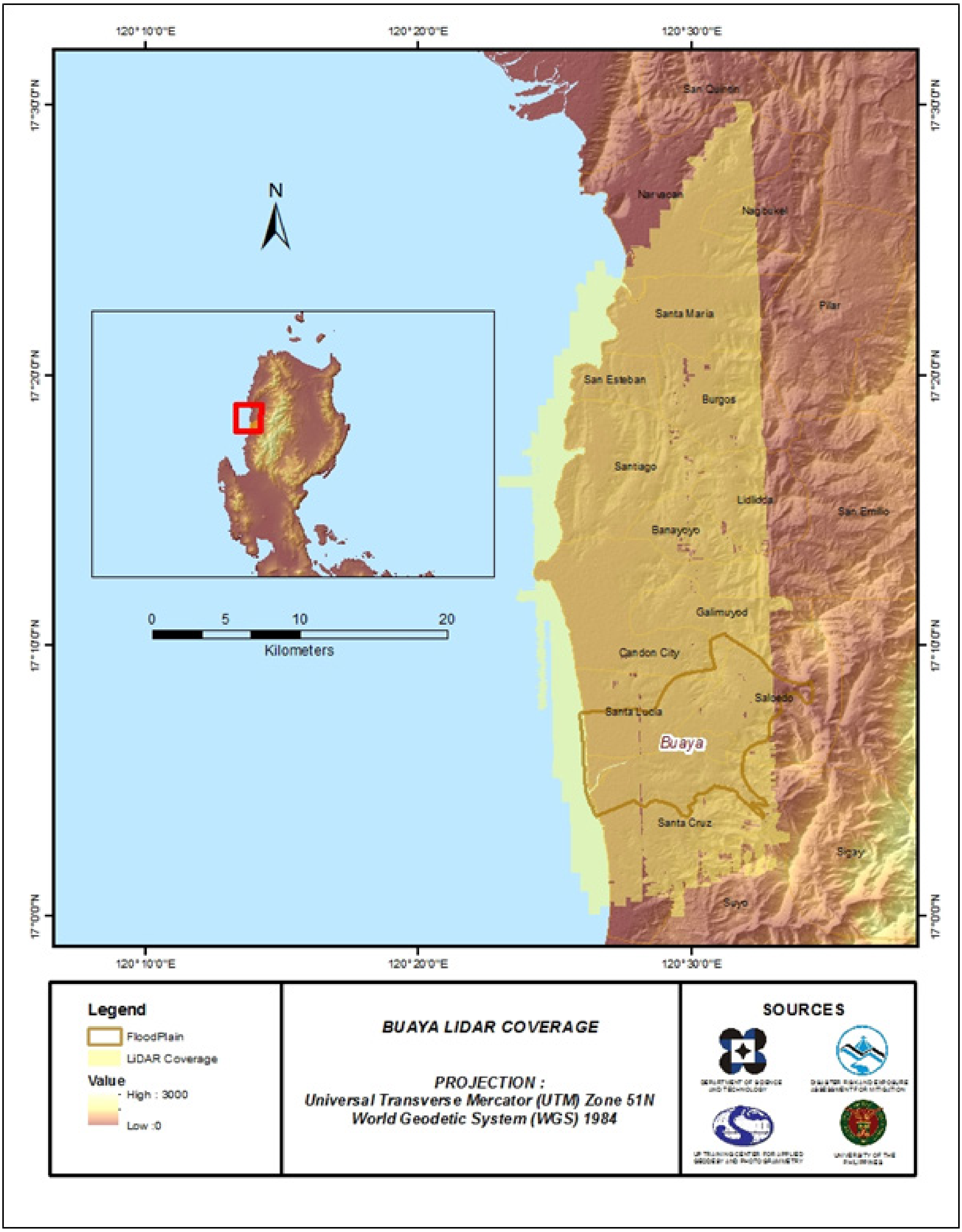


Figure 6. Actual LiDAR survey coverage for Buaya floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BUAYA FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

Using the elevation of points gathered in the field, the LiDAR-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.

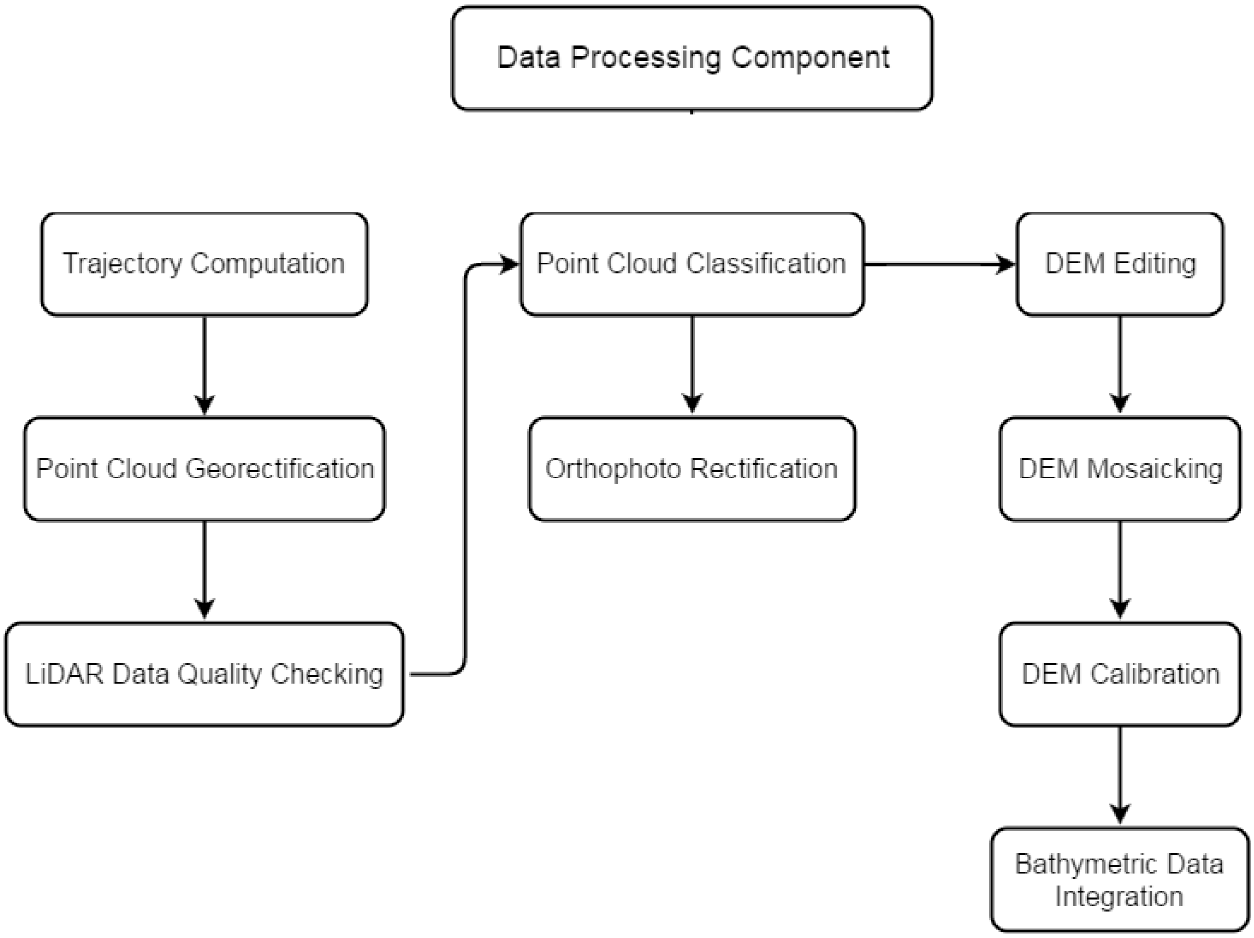


Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Buaya floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the survey conducted on March 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over the province of Ilocos Sur.

The Data Acquisition Component (DAC) transferred a total of 69.3 Gigabytes of Range data, 0.623 Gigabytes of POS data, and 22.0 Megabytes of GPS base station data to the data server on March 17, 2014 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Buaya was fully transferred on April 22, 2014, as indicated on the Data Transfer Sheets for Buaya floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 7119G, one of the Buaya 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 March 10, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

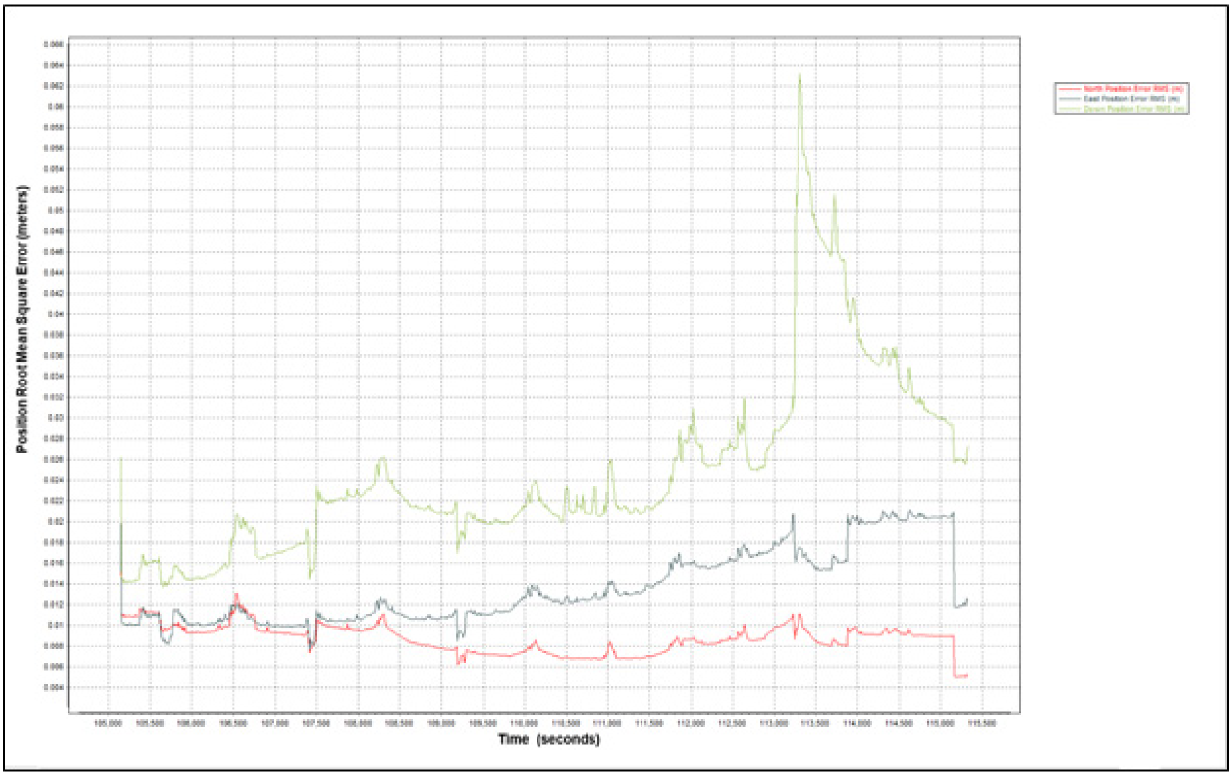


Figure 8. Smoothed Performance Metric Parameters of a Buaya Flight 7119G.

The time of flight was from 105000 seconds to 115500 seconds, which corresponds to afternoon of March 10, 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 1.40 centimeters, the East position RMSE peaks at 2.20 centimeters, and the Down position RMSE peaks at 6.20 centimeters, which are within the prescribed accuracies described in the methodology.

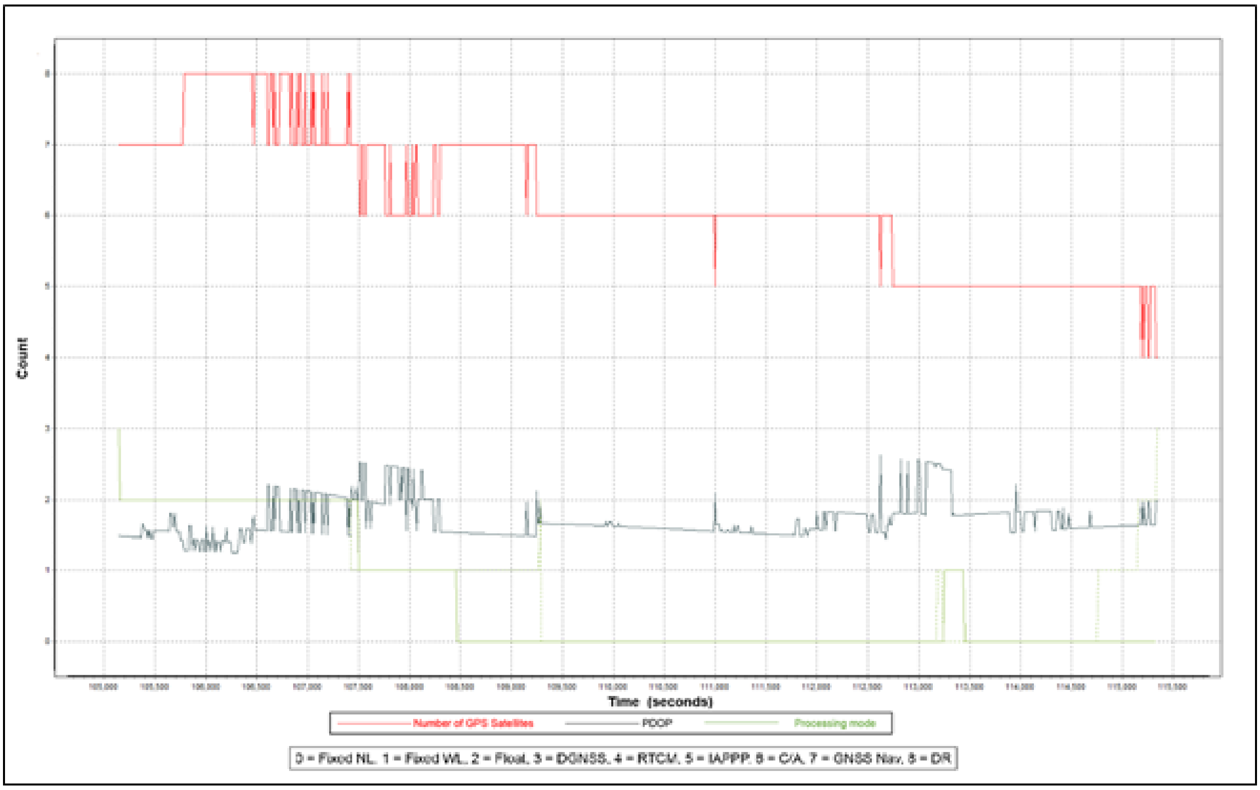


Figure 9. Solution Status Parameters of Buaya Flight 7119G.

The Solution Status parameters of flight 7119G, one of the Buaya 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 majority of the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 and 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Buaya flights is shown in Figure 10.

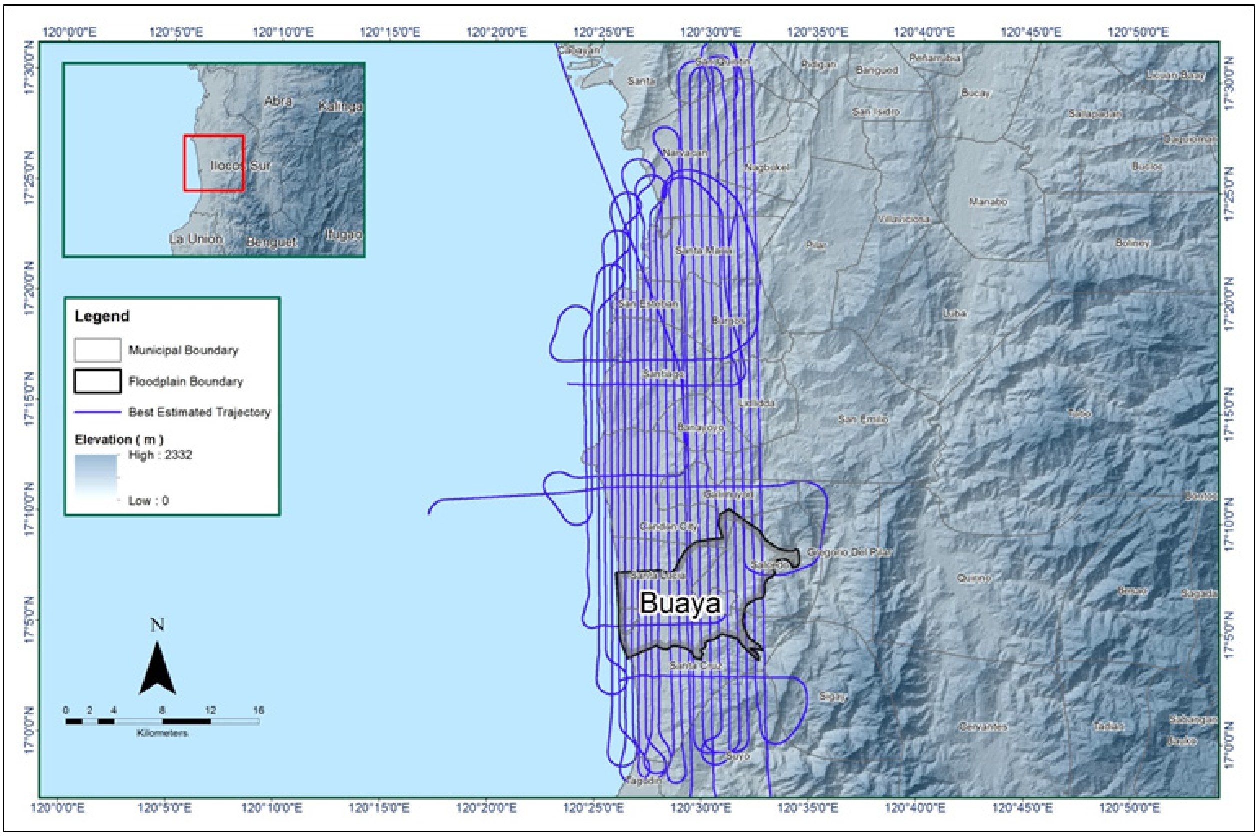


Figure 10. Best Estimated Trajectory of the LiDAR missions conducted over the Buaya Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 35 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Buaya floodplain are given in Table 10.

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

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000236
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000884
GPS Position Z-correction stdev)	<0.01meters	0.0075

The optimum accuracy is obtained for all Buaya 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 Data Quality Checking

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

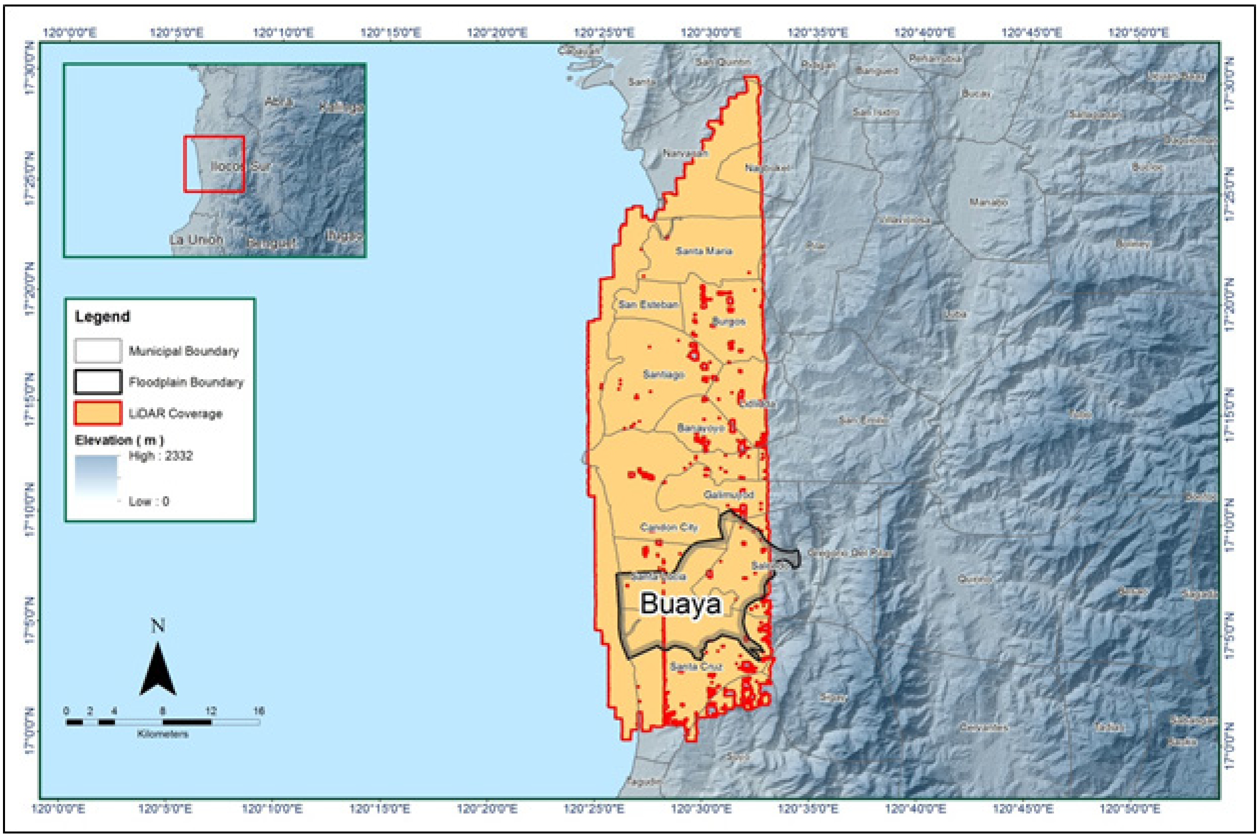


Figure 11. Boundary of the processed LiDAR data over Buaya Floodplain.

The total area covered by the Buaya missions is 639.96 sq.km that is comprised of three (3) flight acquisitions grouped and merged into two (2) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Buaya floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Ilocos_Blk27A	7119G	227.64
Ilocos_Blk2BCD	1179G	412.32
	1195G	
TOTAL		639.96 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

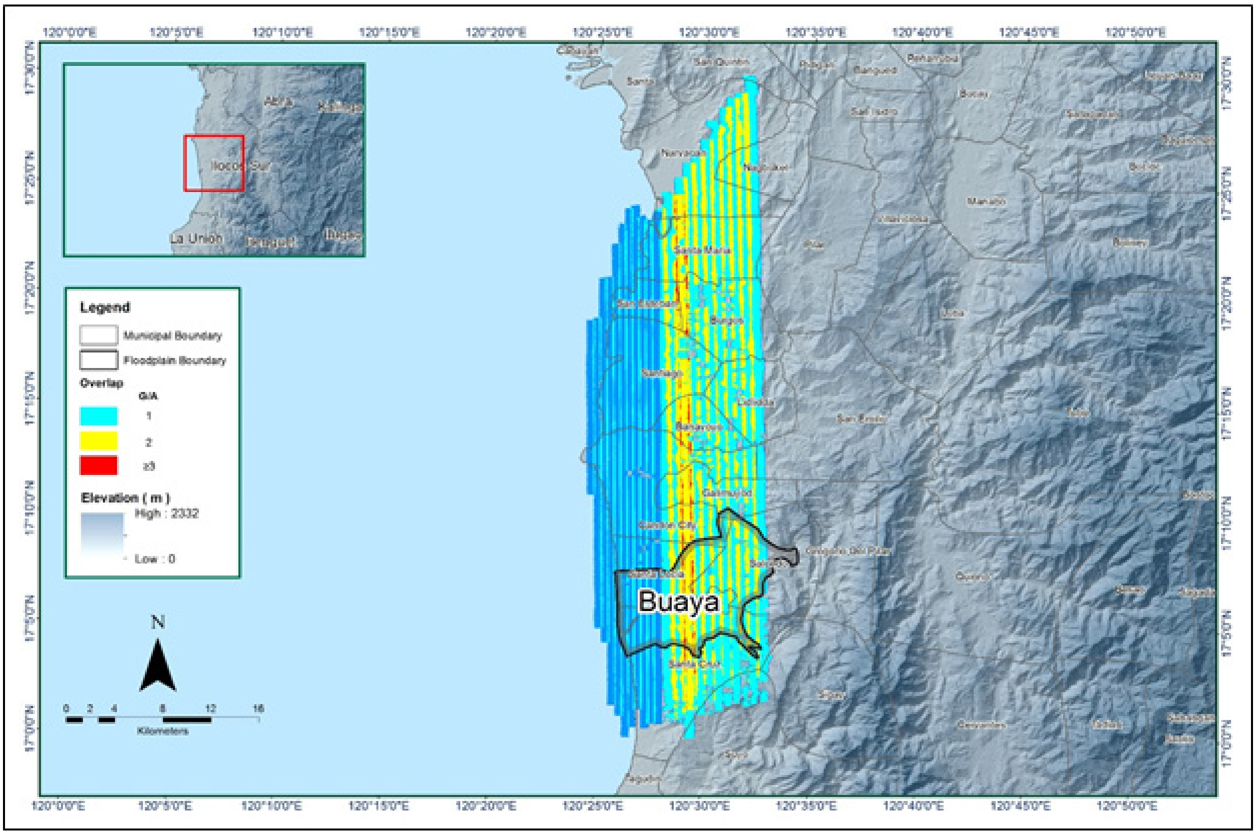


Figure 12. Image of data overlap for Buaya floodplain.

The overlap statistics per block for the Buaya 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 27.26% and 45.11% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Buaya floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.5 points per square meter.

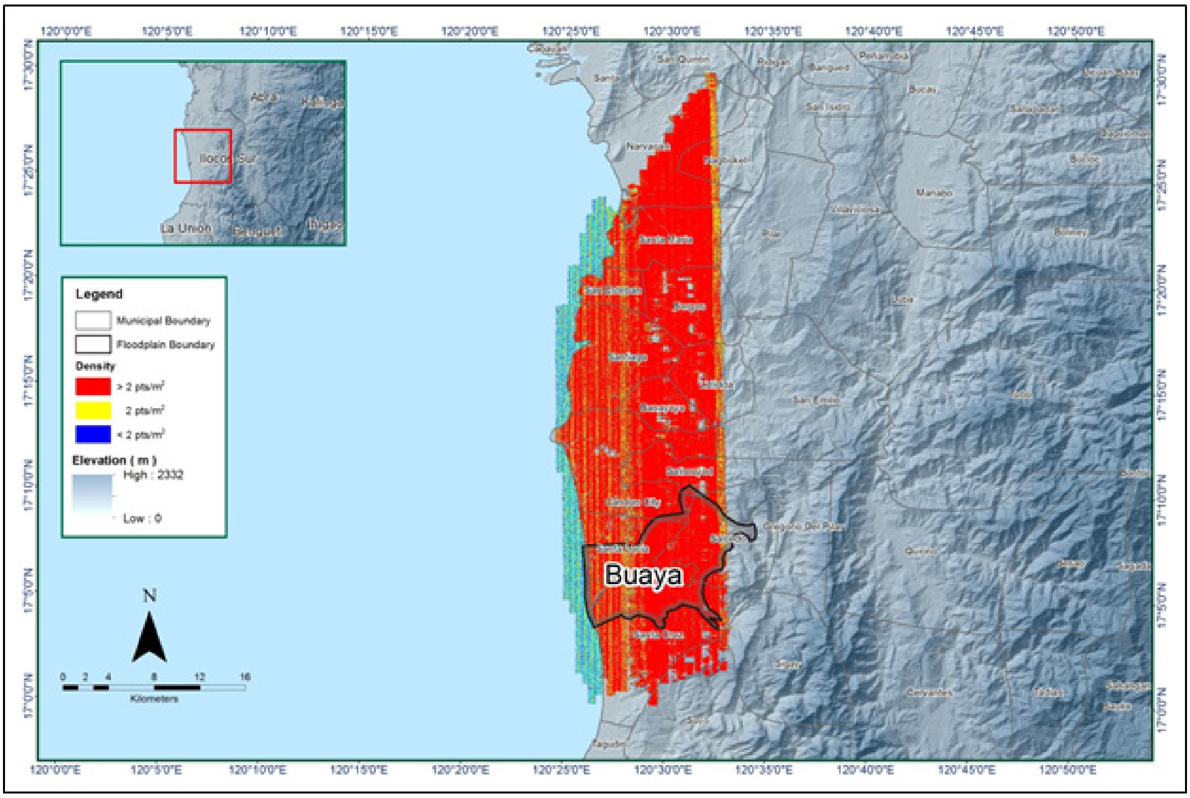


Figure 13. Pulse density map of merged LiDAR data for Buaya floodplain.

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.

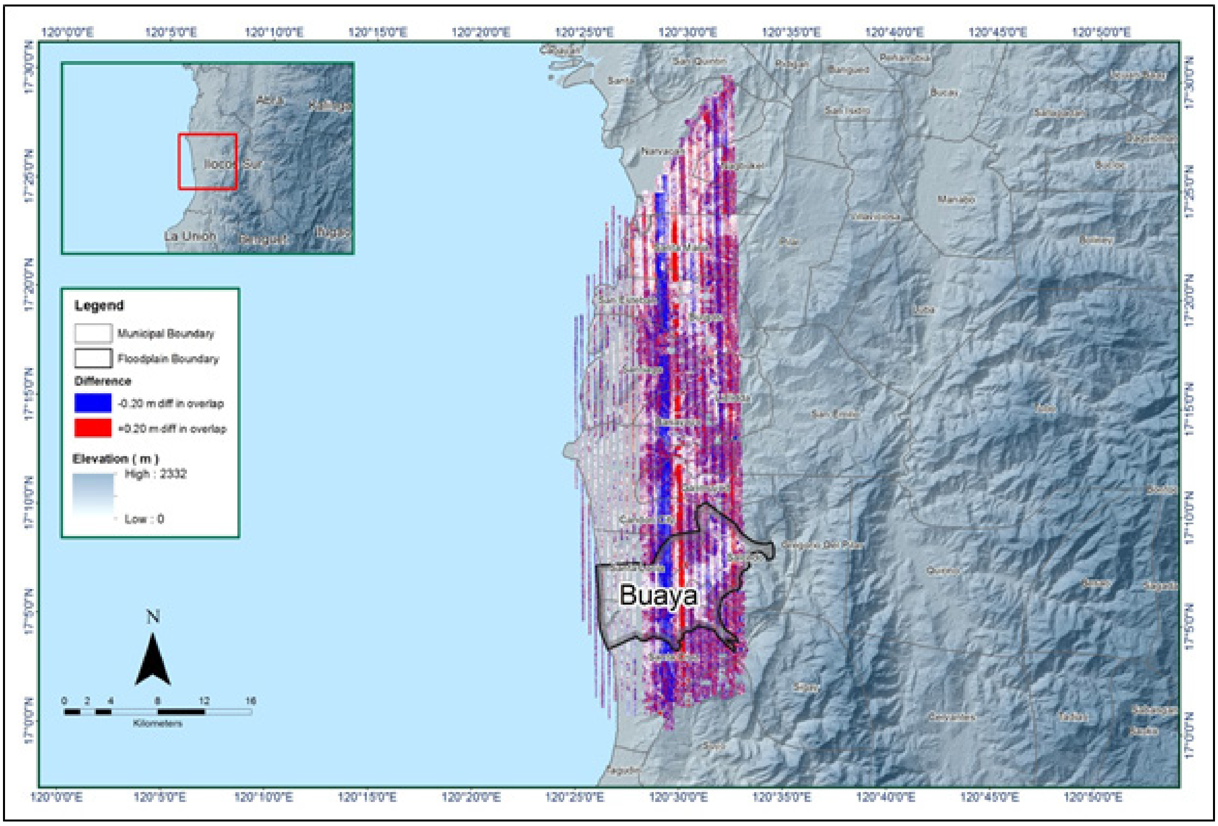


Figure 14. Elevation difference map between flight lines for Buaya floodplain.

A screen capture of the processed LAS data from a Buaya flight 7119G 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.

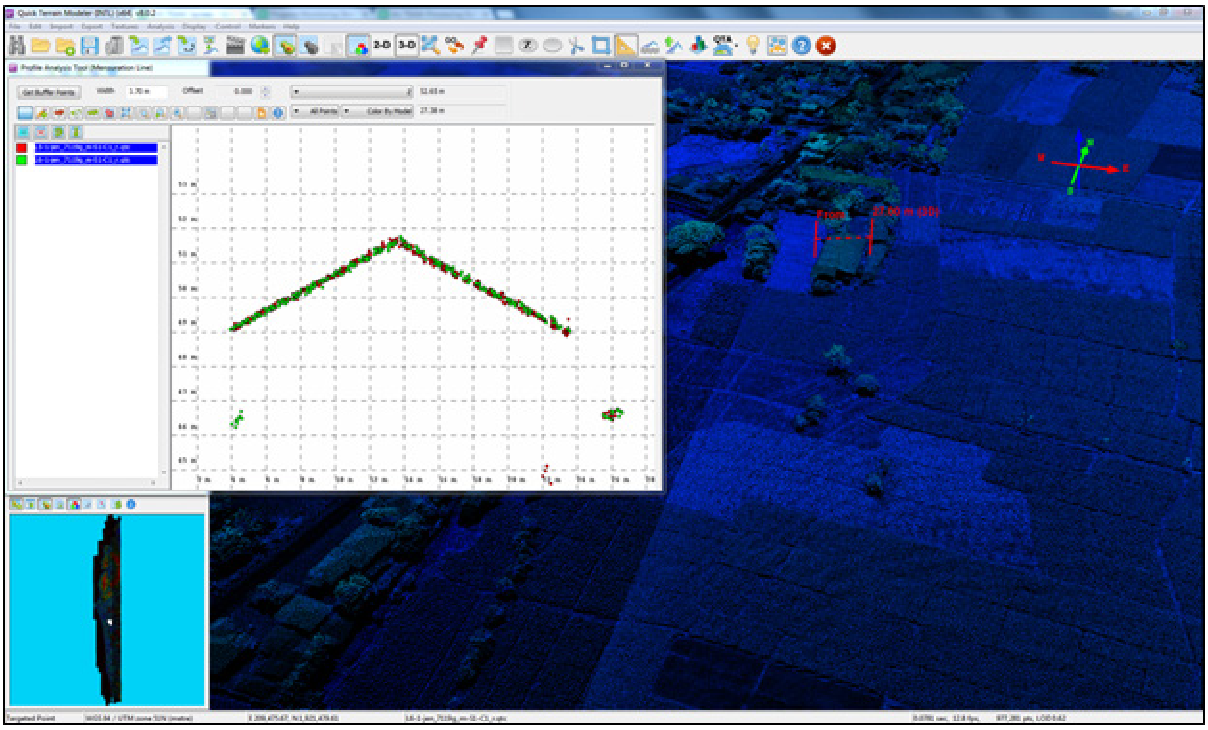


Figure 15. Quality checking for a Buaya flight 7119G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Buaya classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	361,617,188
Low Vegetation	310,111,106
Medium Vegetation	346,148,668
High Vegetation	669,338,834
Building	27,106,907

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Buaya floodplain is shown in Figure 16. A total of 744 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 859.24 meters and 37.49 meters respectively.

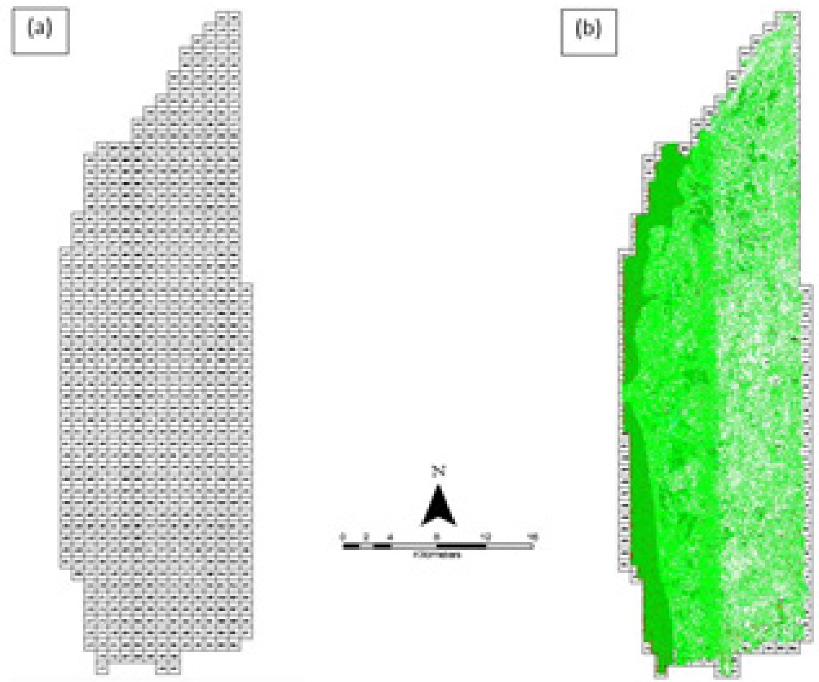


Figure 16. Tiles for Buaya floodplain (a) and classification results (b) in TerraScan.

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.

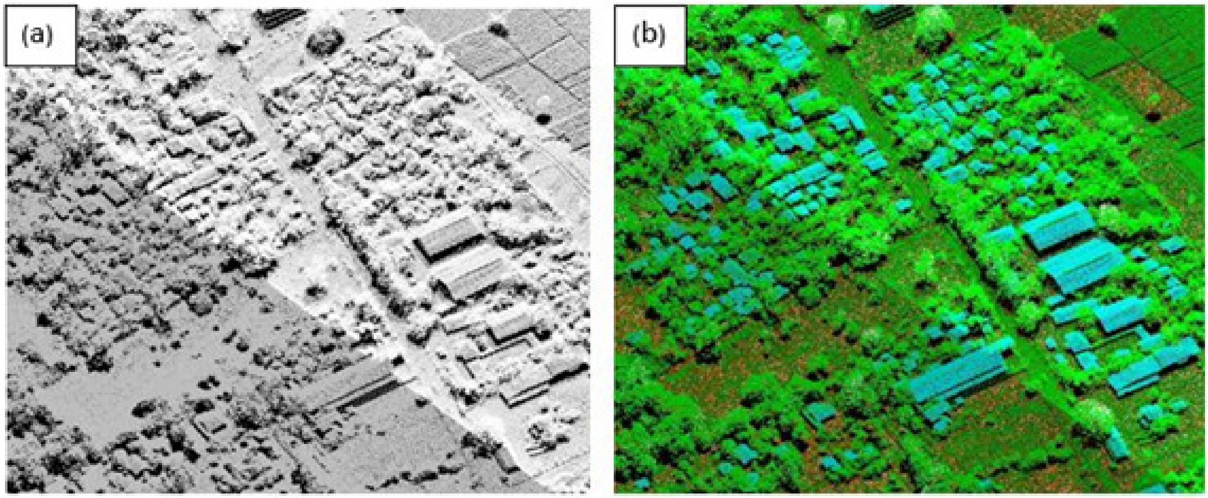


Figure 17. Point cloud before (a) and after (b) classification.

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.

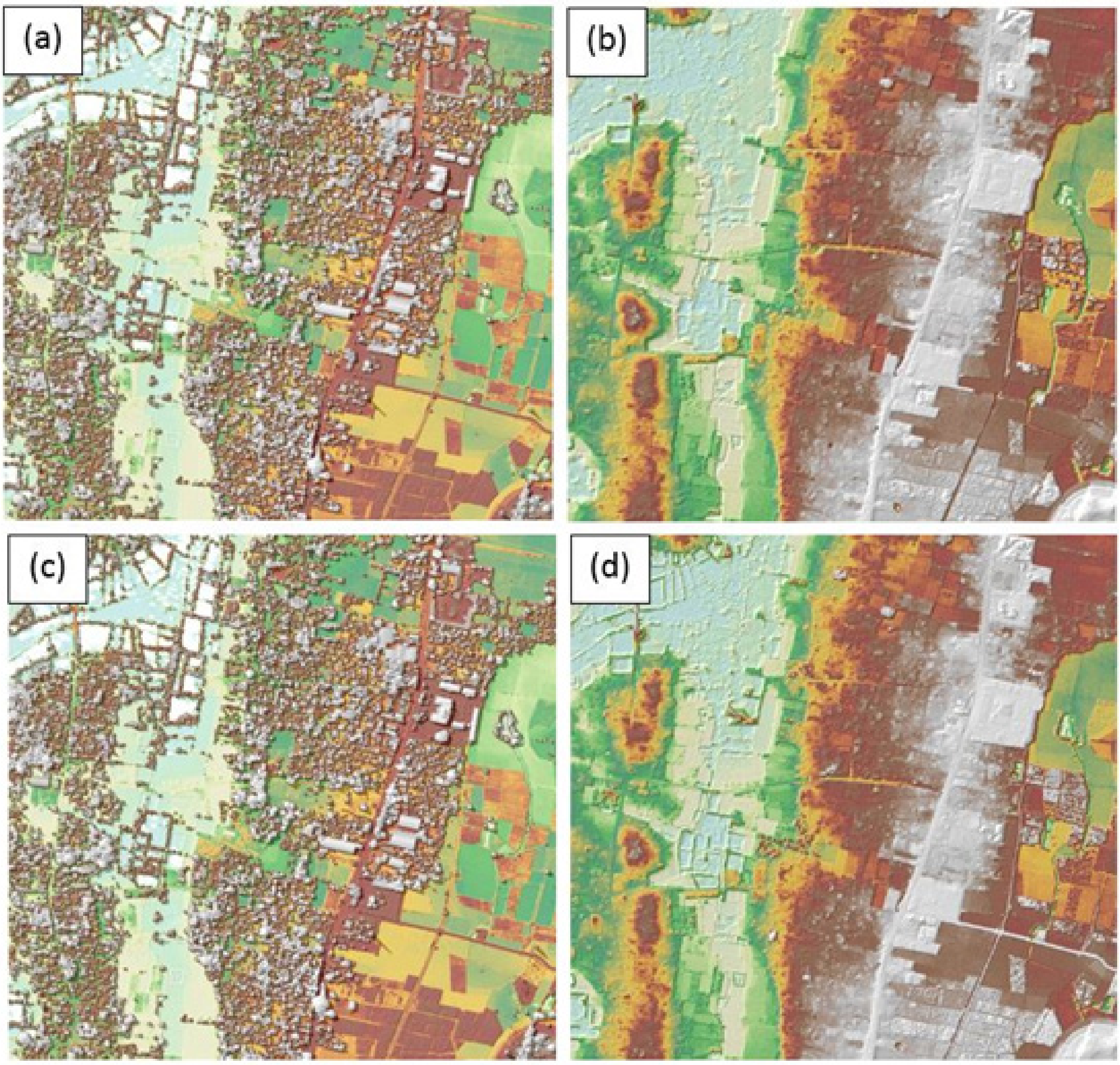


Figure 18. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Buaya floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 485 1km by 1km tiles area covered by Buaya 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 Buaya floodplain survey attaind a total of 378.53 sq.km in orthophotogaph coverage comprised of 756 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

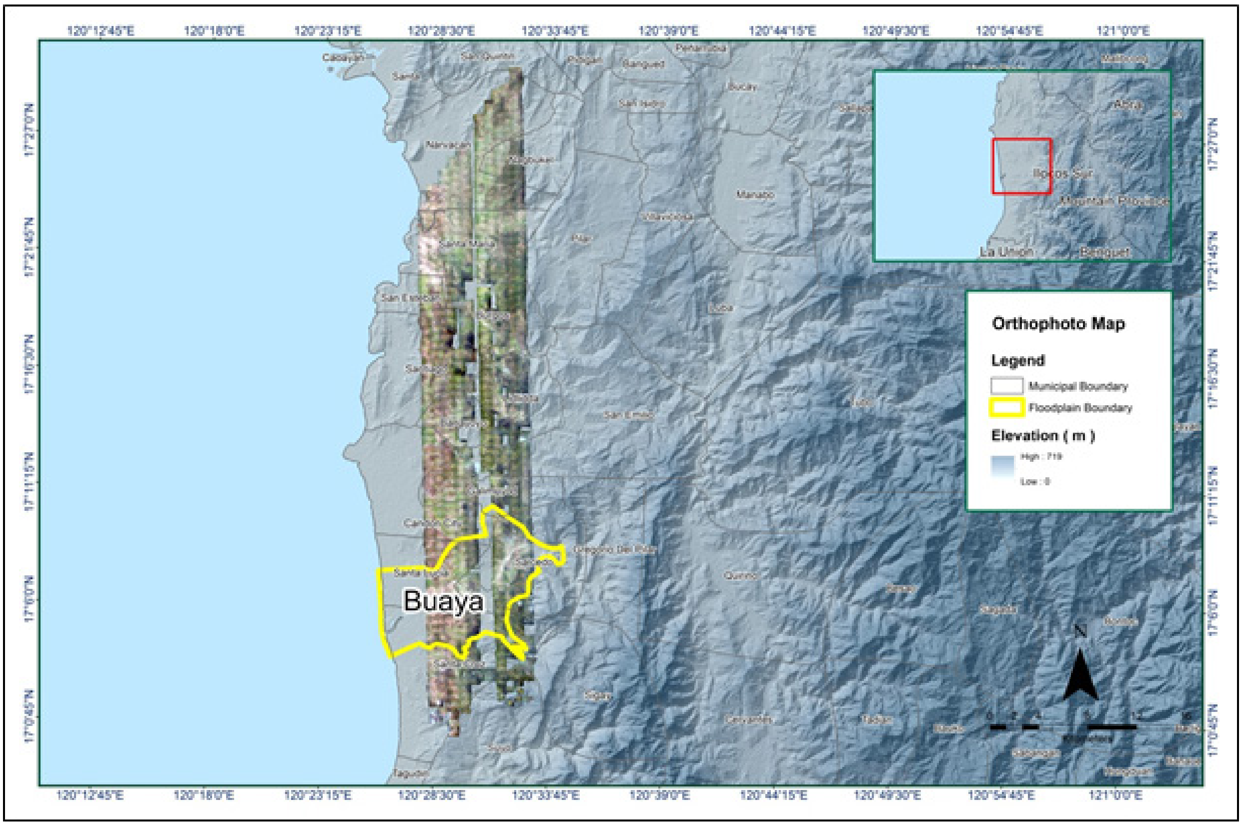


Figure 19. Buaya floodplain with available orthophotographs.

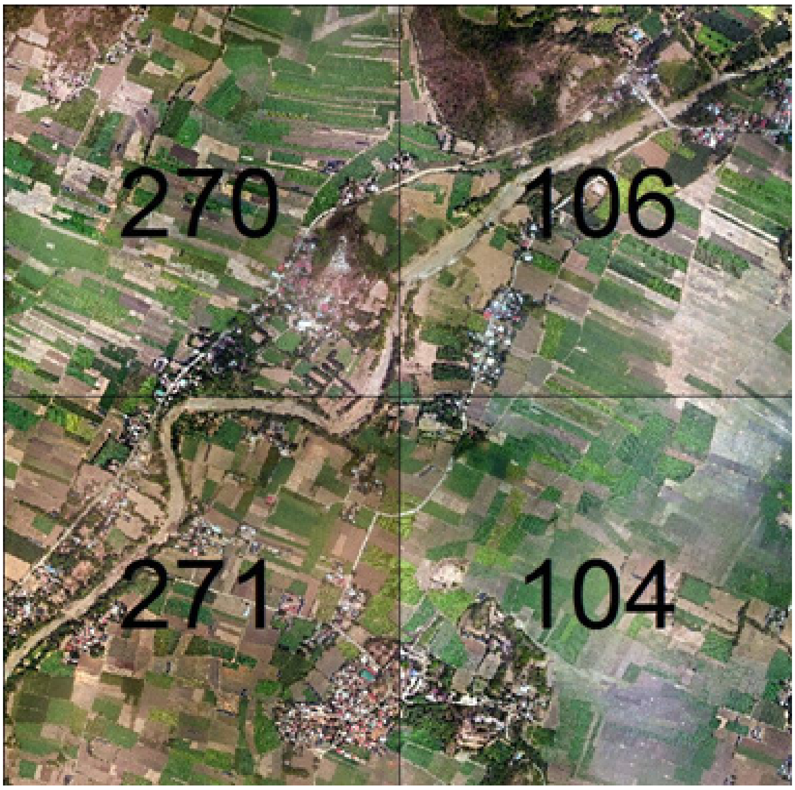


Figure 20. Sample orthophotograph tiles for Buaya floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Buaya flood plain. These blocks are composed of Ilocos blocks with a total area of 639.96 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Ilocos_Blk27A	227.64
Ilocos_Blk27BCD	412.32
TOTAL	639.96 sq.km

Portions of DTM before and after manual editing are shown in Figure 21. The river embankment (Figure 21a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21b) to allow the correct flow of water. The bridge (Figure 21c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21d) in order to hydrologically correct the river. 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).

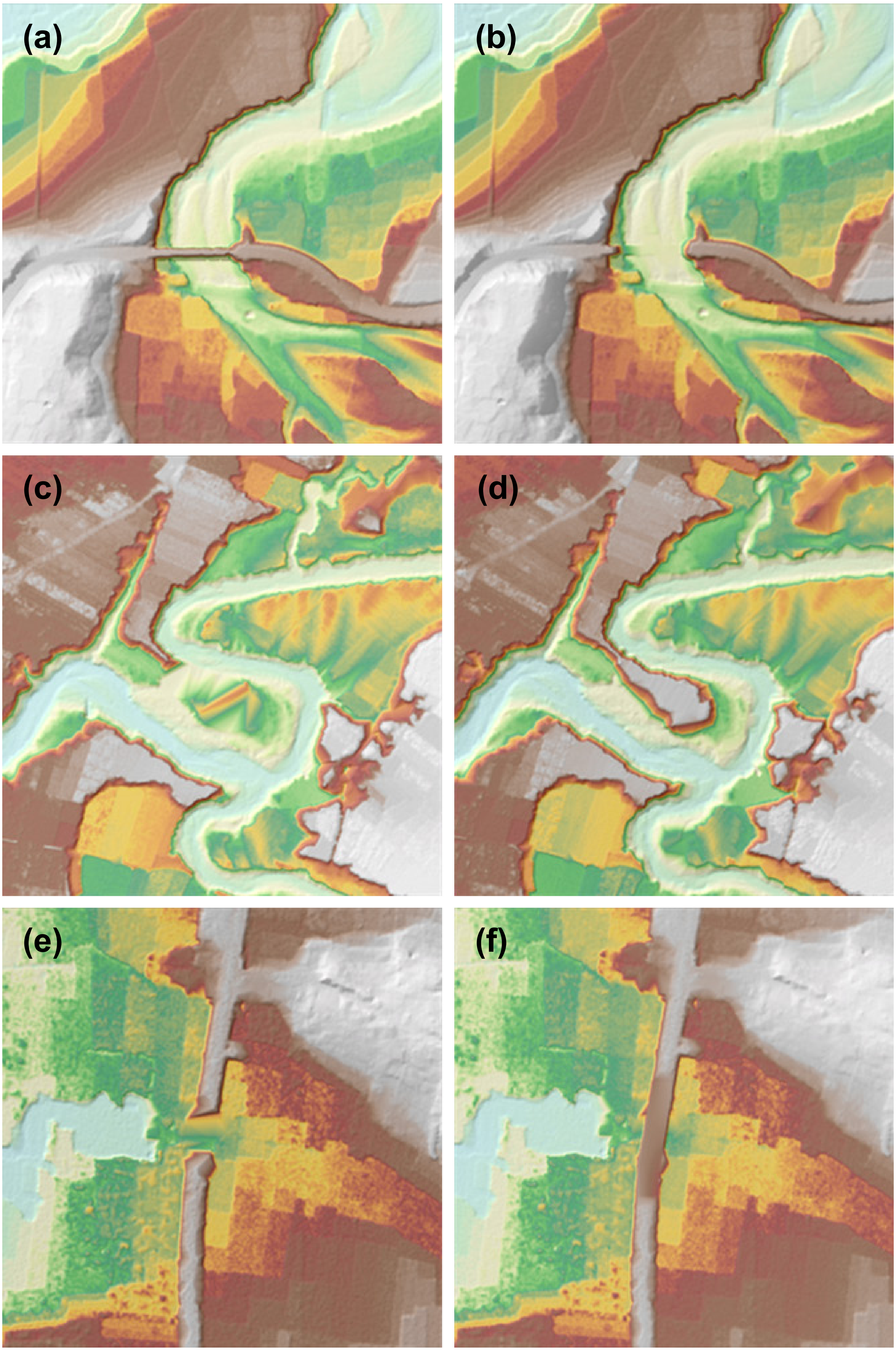


Figure 21. Portions in the DTM of Buaya floodplain – a bridge before (a) and after (b) manual editing; a terrain before (c) and after (d) data retrieval; and a road before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

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

Mosaicked LiDAR DTM for Buaya floodplain is shown in Figure 20. It can be seen that the entire Buaya floodplain is 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Buaya floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Ilocos_Blk27A	0.75	3.17	2.40
Ilocos_Blk27BCD	2.00	2.08	0.30

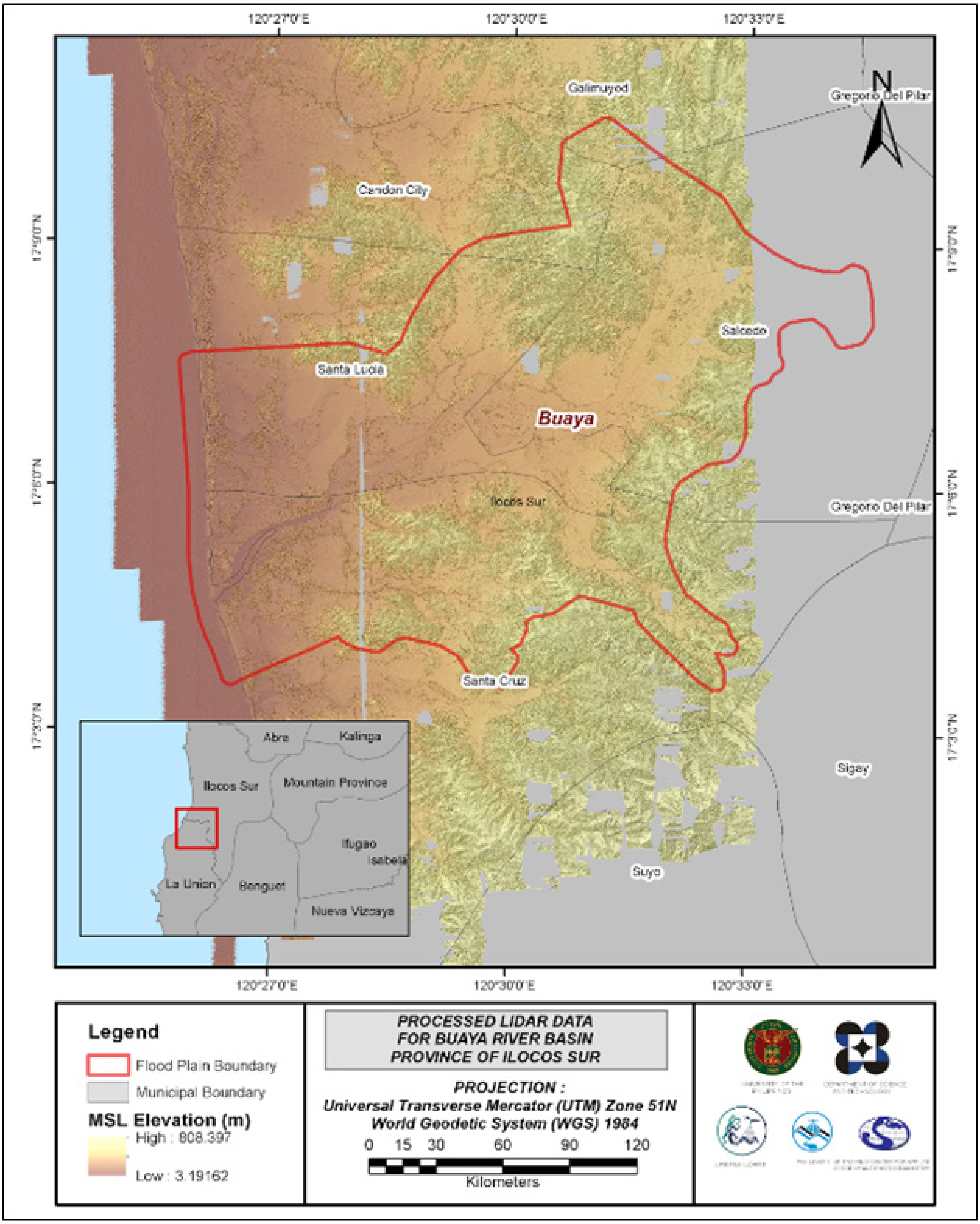


Figure 22. Map of Processed LiDAR Data for Buaya Floodplain.

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 Buaya to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 1960 survey points were used for calibration and validation of Buaya LiDAR data. Random selection of 80% of the survey points, resulting to 1571 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 24. 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 3.48 meters with a standard deviation of 0.13 meters. Calibration of Buaya LiDAR data was done by subtracting the height difference value, 3.48 meters, to Buaya mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

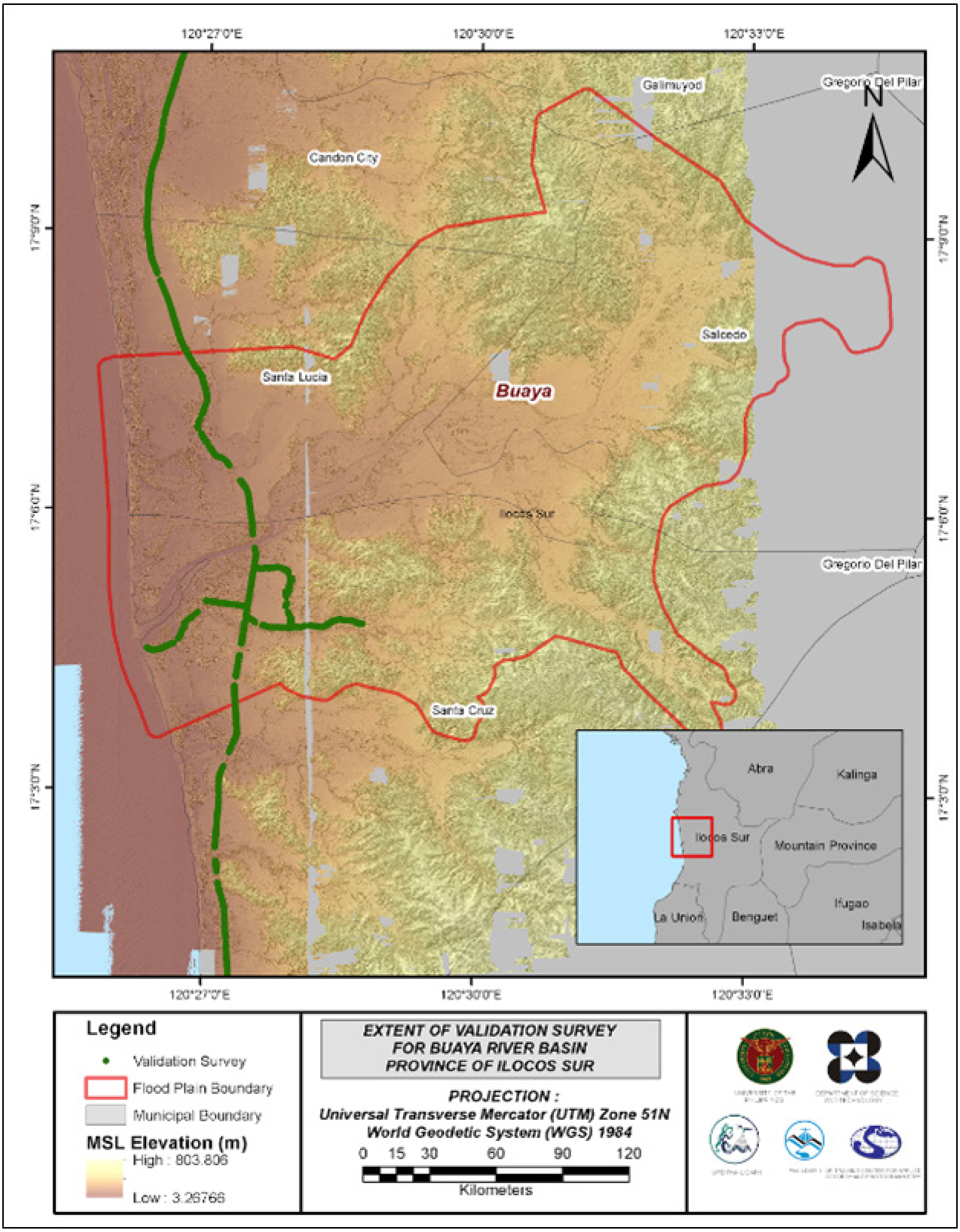


Figure 23. Map of Buaya Flood Plain with validation survey points in green.

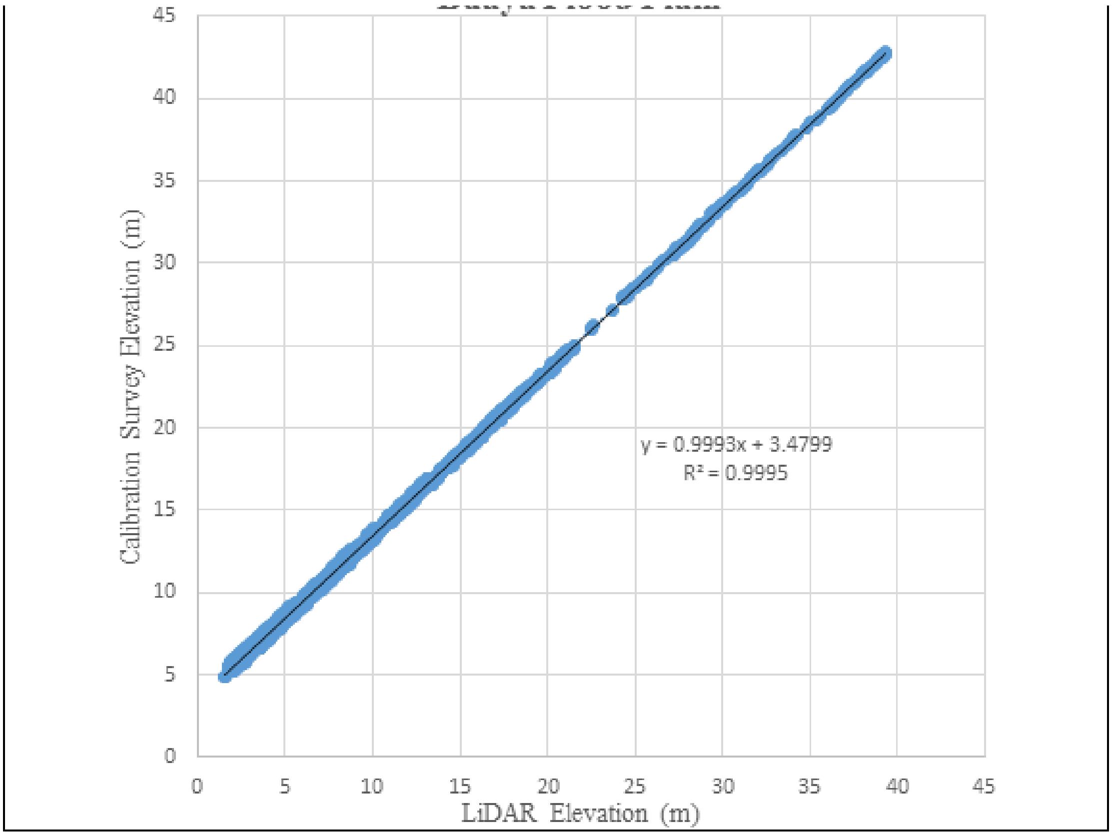


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.48
Standard Deviation	0.13
Average	-3.47
Minimum	-3.74
Maximum	-3.21

The remaining 20% of the total survey points, resulting to 135 points, were used for the validation of calibrated Buaya 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 0.18 meters with a standard deviation of 0.06 meters, as shown in Table 16.

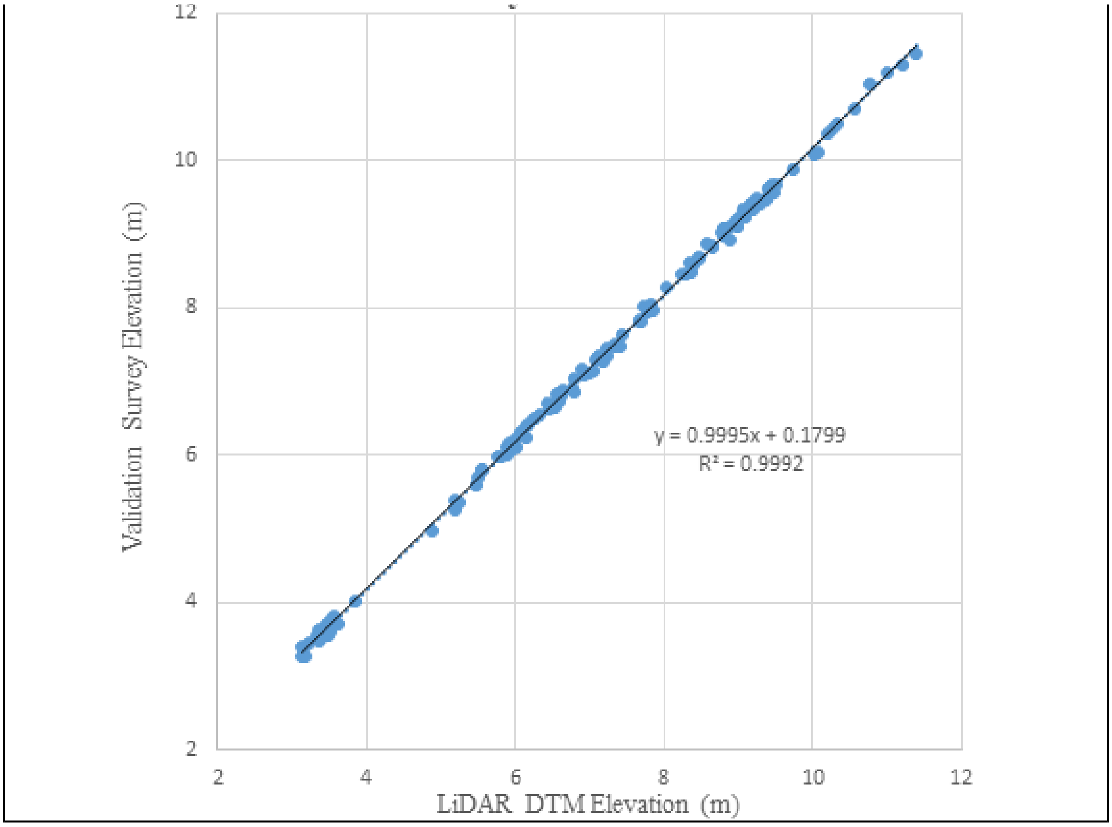


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.06
Average	-0.17
Minimum	-0.29
Maximum	-0.04

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Buaya with 3476 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 0.8 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Buaya integrated with the processed LiDAR DEM is shown in Figure 26.

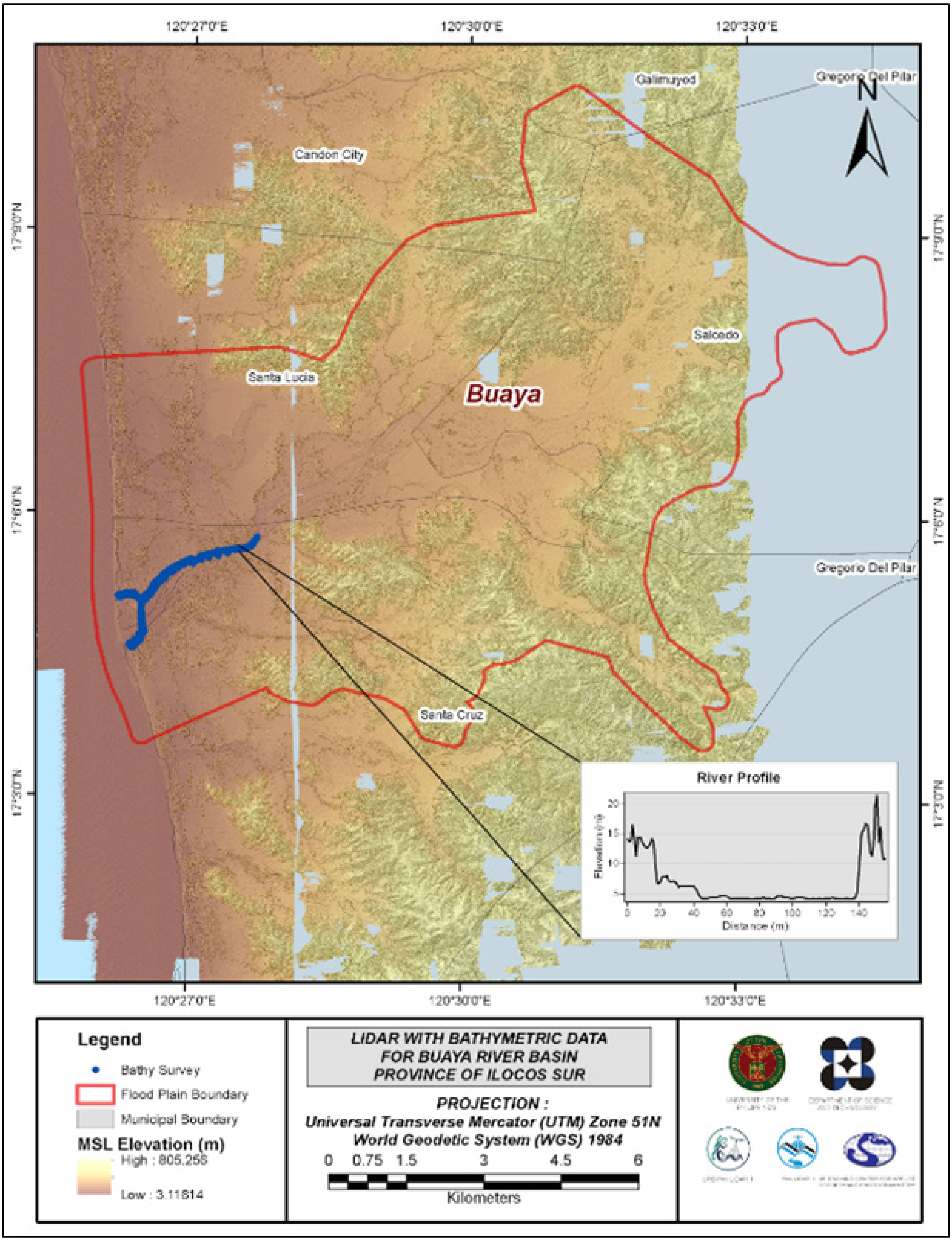


Figure 26. Map of Buaya Flood Plain with bathymetric survey points shown in blue.

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 of Digitized Features' Boundary

Buaya floodplain, including its 200 m buffer, has a total area of 110.27 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 191 building features, are considered for QC. Figure 27 shows the QC blocks for Buaya floodplain.

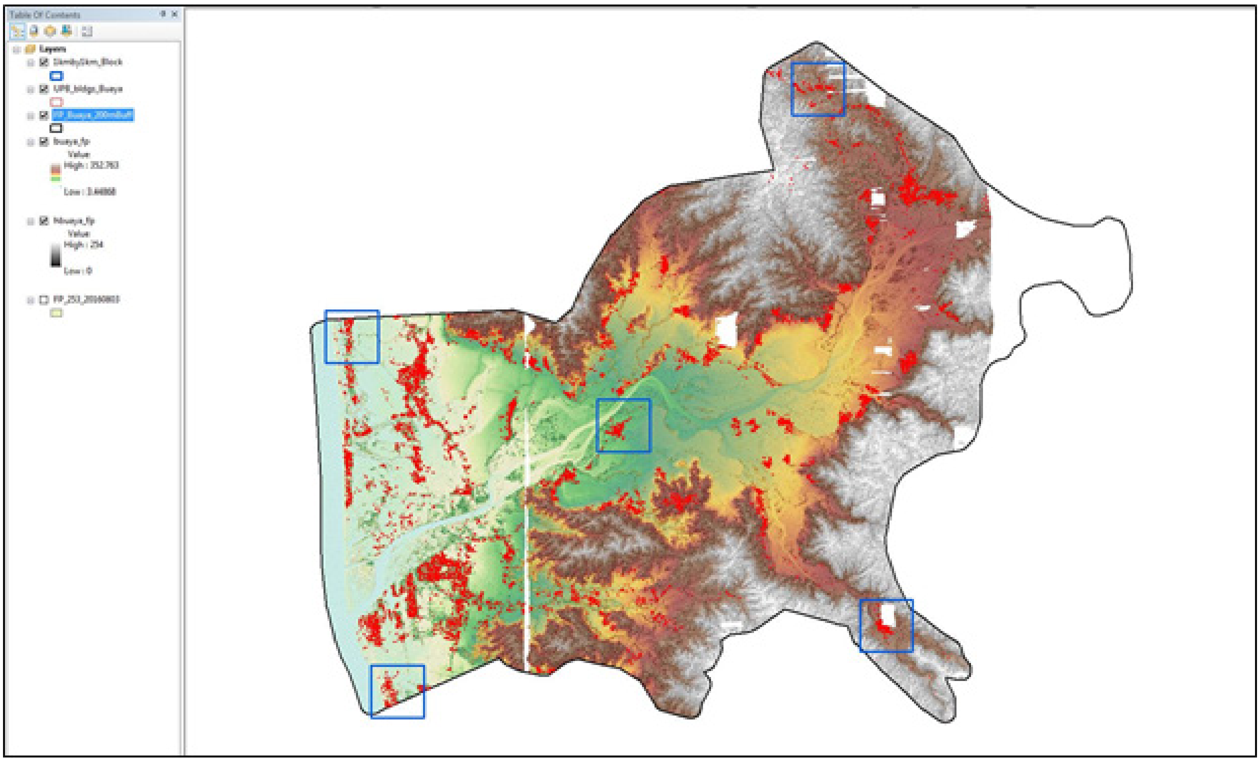


Figure 27. Blocks (in blue) of Buaya building features that were subjected to QC.

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

Table 17. Quality Checking Ratings for Buaya Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Buaya	100.00	100.00	98.76	PASSED

3.12.2 Height Extraction

Height extraction was done for 13,536 building features in Buaya floodplain. Of these building features, 178 buildings were filtered out after height extraction, resulting to 13,358 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 14.23 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 18 summarizes the number of building features per type. On the other hand, Table B-10 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 18. Number of Building Features Extracted for Buaya Floodplain.

Facility Type	No. of Features
Residential	12,933
School	229
Market	3
Agricultural/Agro-Industrial Facilities	3
Medical Institutions	4
Barangay Hall	18
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	19
Power Plant/Substation	0
NGO/CSO Offices	3
Police Station	3
Water Supply/Sewerage	0
Religious Institutions	30
Bank	1
Factory	0
Gas Station	8
Fire Station	0
Other Government Offices	12
Other Commercial Establishments	87
Total	13,358

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Buaya	69.12	37.59	7.68	31.92	0.00	146.31

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

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

A total of 31 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 Buaya floodplain overlaid with its ground features.

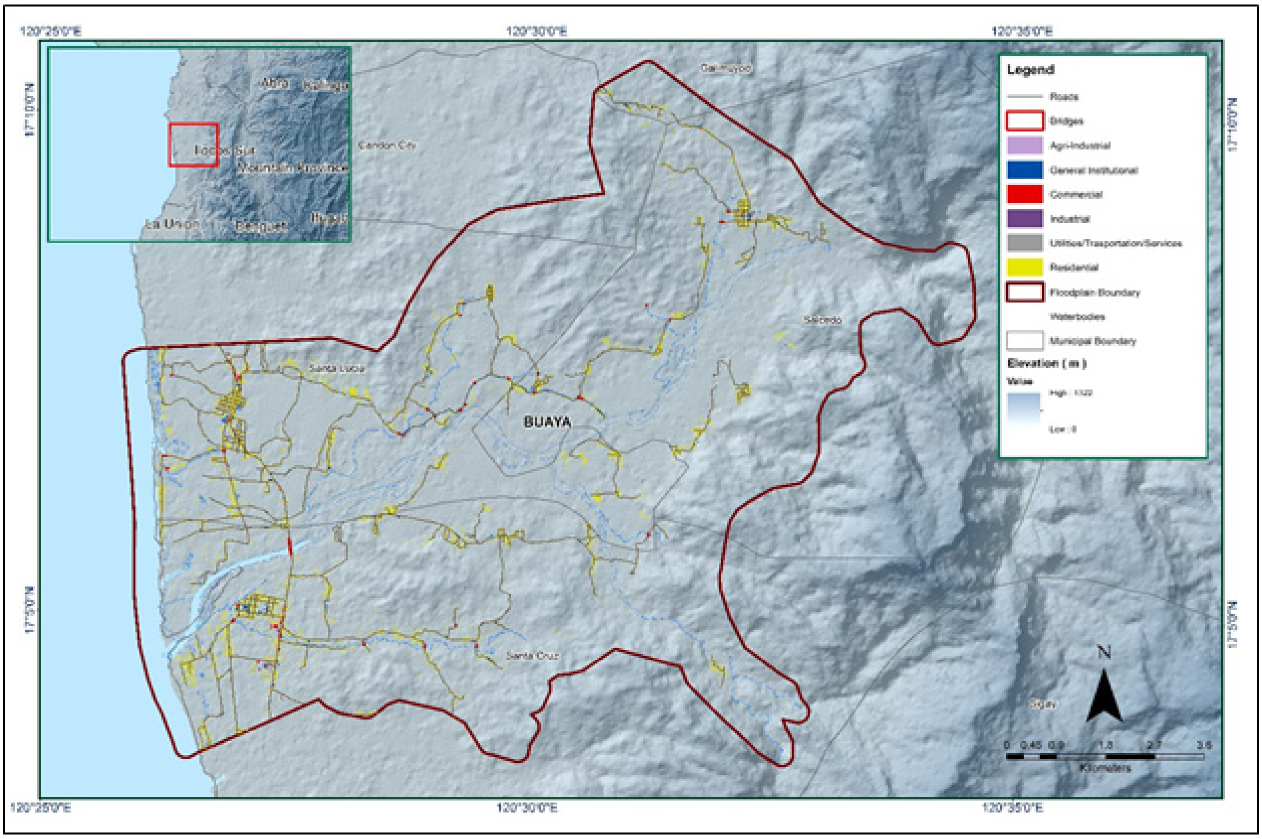


Figure 28. Extracted features for Buaya floodplain.

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

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

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

4.1 Summary of Activities

Buaya River Basin covers majority of five (5) municipalities of Ilocos Sur namely: Santa Lucia, Salcedo, Santa Cruz, Sigay and Gregorio Del Pilar; and minor portions of Galimuyod, Quirino, Suyo and Gandon City; all in Ilocos Sur. The DENR River Basin Control Office identified the basin to have a drainage area of 169 km2 and an estimated 413 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Buaya River, is part of the 13 river systems under the PHIL-LiDAR 1 partner HEI, UP Baguio. There is a total of 4,393 persons residing in the immediate vicinity of the river according to the 2010 National Census which are distributed among the five (5) barangays in Municipality of Santa Cruz namely, Quinsoriano, Saoat, Villa Hermosa, Las-Ud, and Pilar. Agriculture products such as rice, corn, root crops, tobacco, and cotton, is the primary source of economic activity in the province (Official Website of the Province of Ilocos Sur, 2013, retrieved from http://www.ilocossur.gov.ph/). Ilocos Region suffered major damages from Typhoon "Ineng", internationally known as Goni, on August 2014, reaching P246 million damages in agriculture, multi-million worth of road constructions, and isolated 730 families in the midst of the typhoon. The PDRRMC and other concerned government offices had a difficult time responding to rescues and conducting relief services due to damaged roads and bridges (Ibid).

In line with this, DVBC conducted a field survey in Buaya River on June 9 – 23, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Santa Cruz Bridge in Brgy. Quinsoriano, Municipality of Santa Cruz; validation points acquisition of about 78.68 km covering the Buaya River Basin area; and bathymetric survey from its upstream in Brgy. Quinsoriano in the Municipality of Santa Cruz to the mouth of the river located in Brgy. Pilar and Brgy. Villa Hermosa in the same Municipality, with an approximate length of 4.331 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 29).

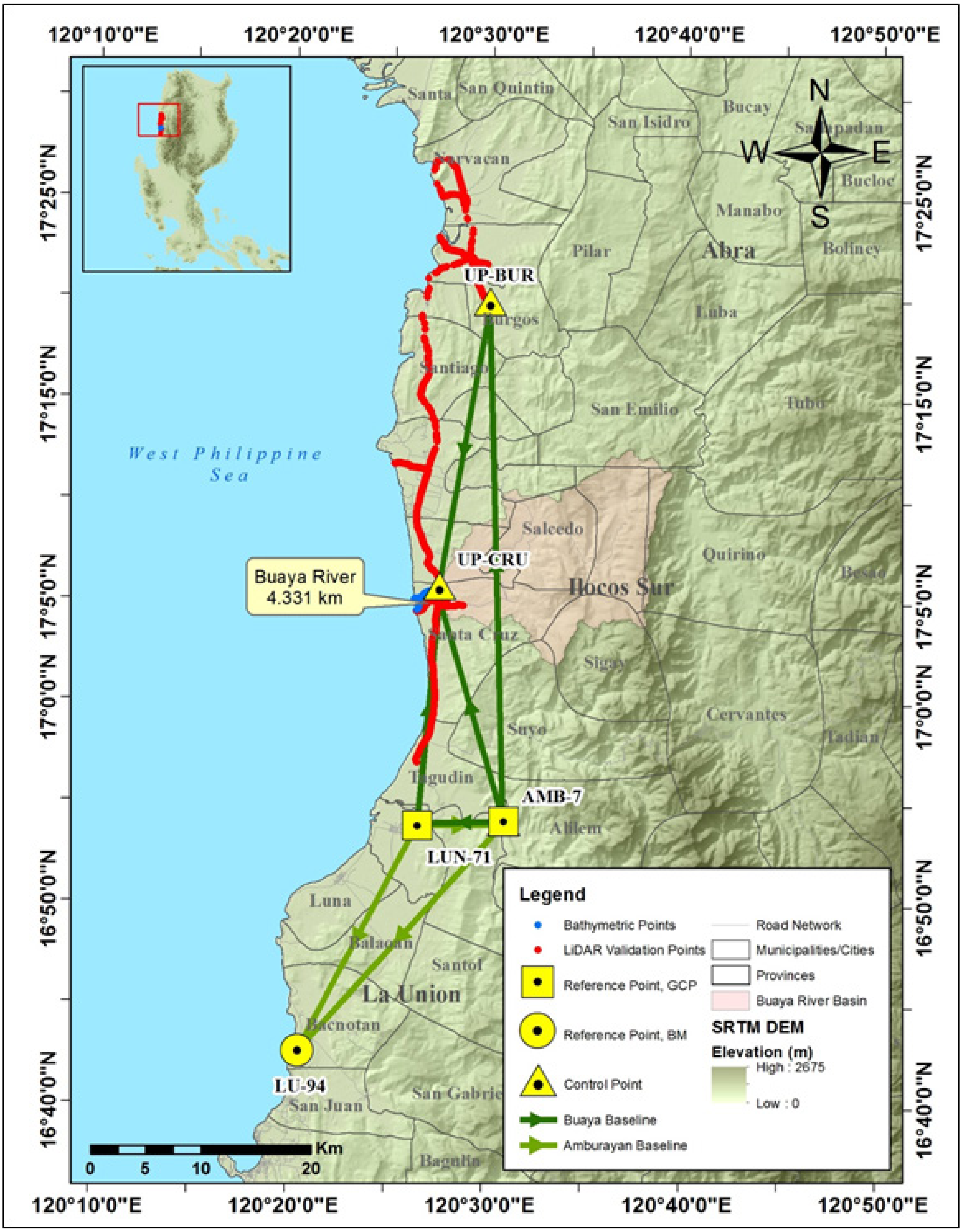


Figure 29. Extent of the bathymetric survey (in blue line) in Buaya River
and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS network from Amburayan River Survey was established on May 7, 2016 occupying the control 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.

The GNSS network used for Buaya River Basin is composed of two (2) loops established on June 10, 2016 occupying the following reference points: LUN-71, a second-order GCP from Amburayan Survey; and AMB-7, a NAMRIA established control point with fixed value of elevation, located at the approach of Alilem Bridge, in Brgy. Kiat, Municipality of Alilem, Ilocos Sur, from Amburayan Survey.

Two (2) control points were established along the approach of bridges namely: UP-BUR, located at Burgos Bridge in Brgy. Poblacion Norte, Municipality of Burgos; and UP-CRU, at Sta. Cruz Bridge, in Brgy Quinsoriano, Municipality of Santa Cruz.

The summary of reference and control points and its location is summarized in Table 21 while the GNSS network established is illustrated in Figure 30.

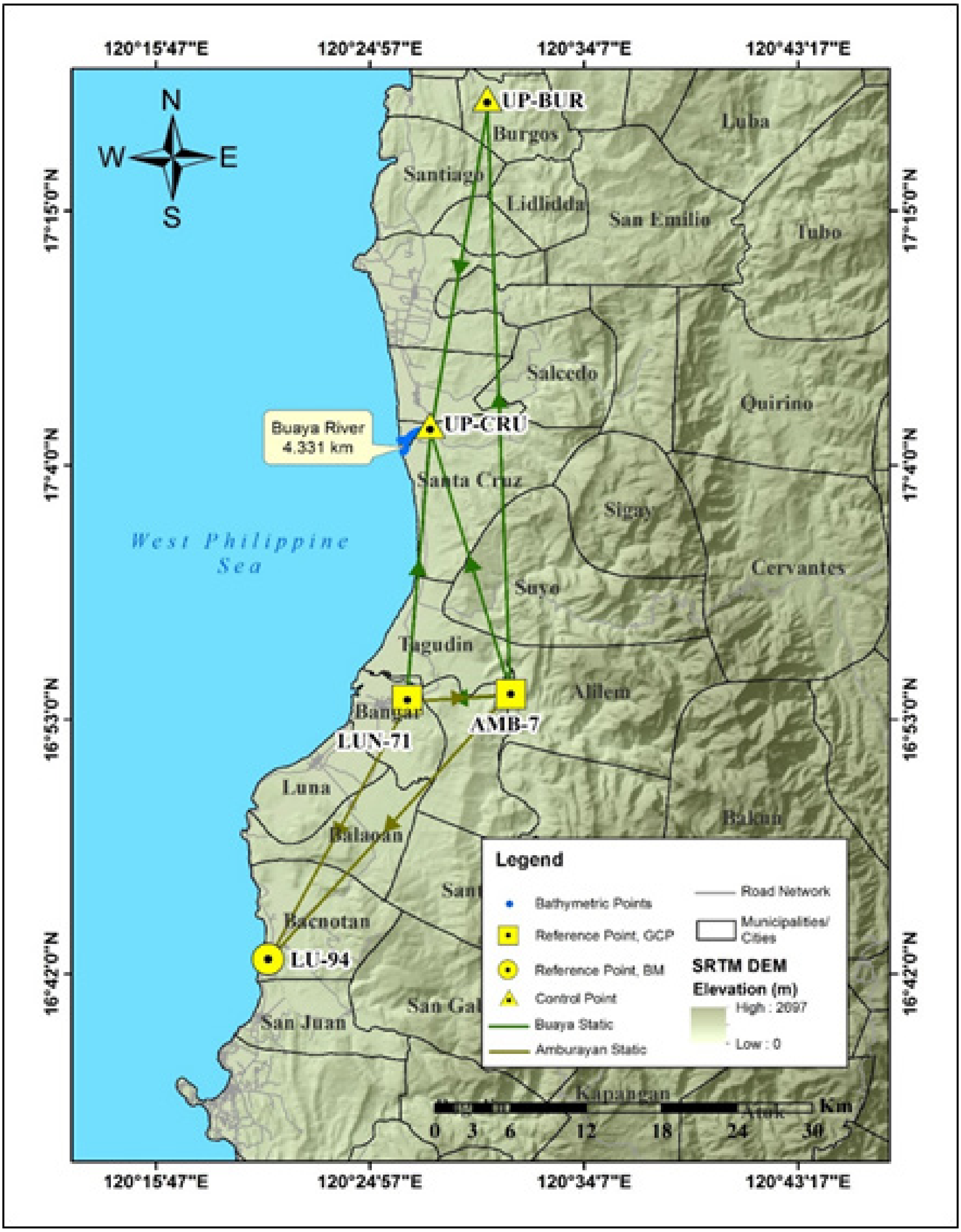


Figure 30. The GNSS Network established in the Buaya River Survey.

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
Control Survey on May 7, 2016						
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	12.794	2007
LU-94	1st order, BM	16°42'38.41914"N	120°20'35.13397"E	46.965	7.349	2007
AMB-7	Used as Marker	16°54'6.54124"N	120°30'58.32790"E	86.879	46.253	2010
Control Survey on June 10, 2016						
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	12.794	2007
AMB-7	Fixed Control	16°54'6.54124"N	120°30'58.32790"E	86.879	46.253	2010
UP-BUR	UP Established	-	-	-	-	2016
UP-CRU	UP Established	-	-	-	-	2016

The GNSS set-ups on recovered reference points and established control points in Buaya River are shown in Figure 31 to Figure 34.

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

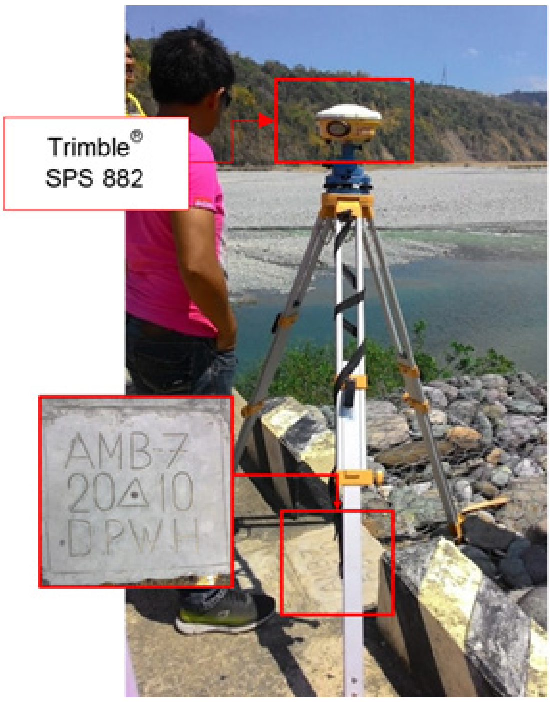


Figure 32. GNSS receiver setup, Trimble® SPS 882, at AMB-7, located at the approach of Alilem Bridge, in Brgy. Kiat, Municipality of Alilem, Ilocos Sur

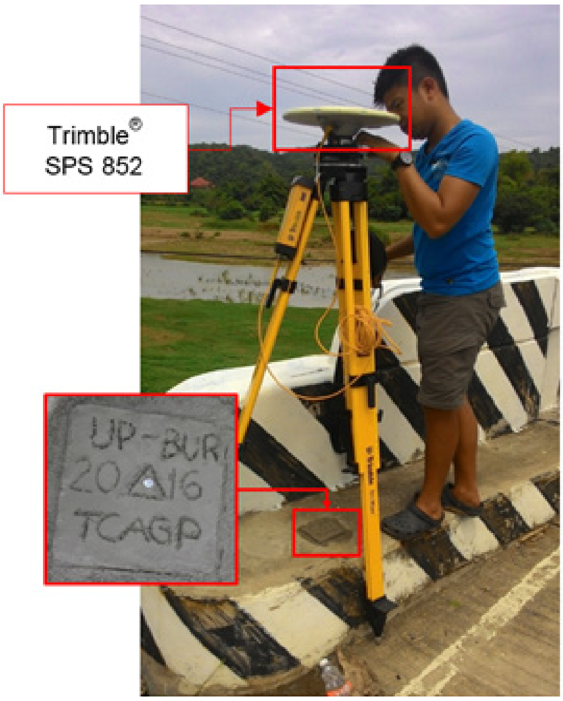


Figure 33. GNSS receiver setup, Trimble® SPS 852, at UP-BUR, located at the approach of Burgos Bridge, in Brgy. Poblacion Norte, Municipality of Burgos, Ilocos Sur

Figure 34. GNSS receiver setup, Trimble® SPS 882, at UP-CRU, located at the approach of Santa Cruz Bridge, in Brgy. Quinsoriano, Municipality of Santa Cruz, 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 Buaya River Basin is summarized in Table 22 generated by TBC software.

Table 22. The Baseline processing report for the Buaya River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-BUR --- AMB-7	06-10-2016	Fixed	0.004	0.013	357°51'02"	47547.951	-33.725
UP-BUR --- UP-CRU	06-10-2016	Fixed	0.004	0.014	189°25'31"	26406.856	-4.843
AMB-7 --- LUN-71	06-10-2016	Fixed	0.004	0.012	266°39'44"	7872.513	-34.551
AMB-7 --- UP-CRU	06-10-2016	Fixed	0.005	0.017	344°06'39"	22317.155	-38.497
LUN-71 --- UP-CRU	06-10-2016	Fixed	0.005	0.018	4°32'26"	21992.529	-3.979

As shown Table 22 a total of five (5) baselines were processed with reference points LUN-71 and AMB-7 held fixed for grid and elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates table 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:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 26 for complete details.

The four (4) control points, LUN-71, AMB-7, UP-BUR and UP-CRU were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of both LUN-71 and AMB-7 from Amburayan Survey were held fixed during the processing of the control points as presented in Table 23 Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LUN-71	Local	Fixed	Fixed	Fixed	
AMB-7	Local	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control point LUN-71 and AMB-7 have no values for grid and elevation errors.

Table 24. Adjusted grid coordinates for the control points used in the Buaya River flood plain survey.

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	?	LLh
AMB-7	235409.911	?	1870361.711	?	46.253	?	LLh
UP-BUR	234232.833	0.043	1917917.546	0.055	14.873	0.042	
UP-CRU	229569.844	0.021	1891912.463	0.026	9.383	0.041	

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

a. LUN-71
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. AMB-7
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

c. UP-BUR
Horizontal Accuracy = $\sqrt{((4.3)^2 + (5.5)^2}$
= $\sqrt{(18.49 + 30.25)}$
= 6.98 cm < 20 cm
Vertical Accuracy = 4.2 cm < 10 cm

d. UP-CRU
Horizontal Accuracy = $\sqrt{((2.1)^2 + (2.6)^2}$
= $\sqrt{(4.41 + 6.76)}$
= 3.34 cm < 20 cm
Vertical Accuracy = 4.1 cm < 10 cm

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

Table 25. Adjusted geodetic coordinates for control points used in the Buaya River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
LUN-71	N16°53'51.58283"	E120°26'32.77383"	52.356	?	LLh
AMB-7	N16°54'06.54124"	E120°30'58.32790"	86.879	?	LLh
UP-BUR	N17°19'52.14111"	E120°29'57.93445"	53.174	0.042	
UP-CRU	N17°05'44.74025"	E120°27'31.66275"	48.353	0.041	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. The reference and control points utilized in the Buaya River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N			
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)	Date Established
Control Survey on May 7, 2016								
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	1870002.301	227541.709	12.794	2007
LU-94	1st order, BM	16°42'38.41914"N	120°20'35.13397"E	46.965	1849438.439	216674.512	7.349	2007
AMB-7	Used as Marker	16°54'06.54124"N	120°30'58.32790"E	86.879	1870361.711	235409.911	46.253	2010
Control Survey on June 10, 2016								
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	1870002.301	227541.709	12.794	2007
AMB-7	Fixed Control	16°54'06.54124"N	120°30'58.32790"E	86.879	1870361.711	235409.911	46.253	2010
UP-BUR	UP Established	17°19'52.14111"N	120°29'57.93445"E	53.174	1917917.546	234232.833	14.873	2016
UP-CRU	UP Established	17°05'44.74025"N	120°27'31.66275"E	48.353	1891912.463	229569.844	9.383	2016

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

Cross-section and as-built survey were conducted on June 12, 2016 at the downstream side of Sta. Cruz Bridge in Brgy. Quinsoriano, Municipality of Santa Cruz, Ilocos Sur as shown in Figure 35. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey as shown in Figure 36.

Figure 35.Buaya Bridge facing upstream

Figure 36. As-Built Survey of Santa Cruz Bridge

The cross-sectional line of Santa Cruz Bridge is about 565 m with eighty-four (84) cross-sectional points using the control point UP-CRU as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 37 to Figure 39.

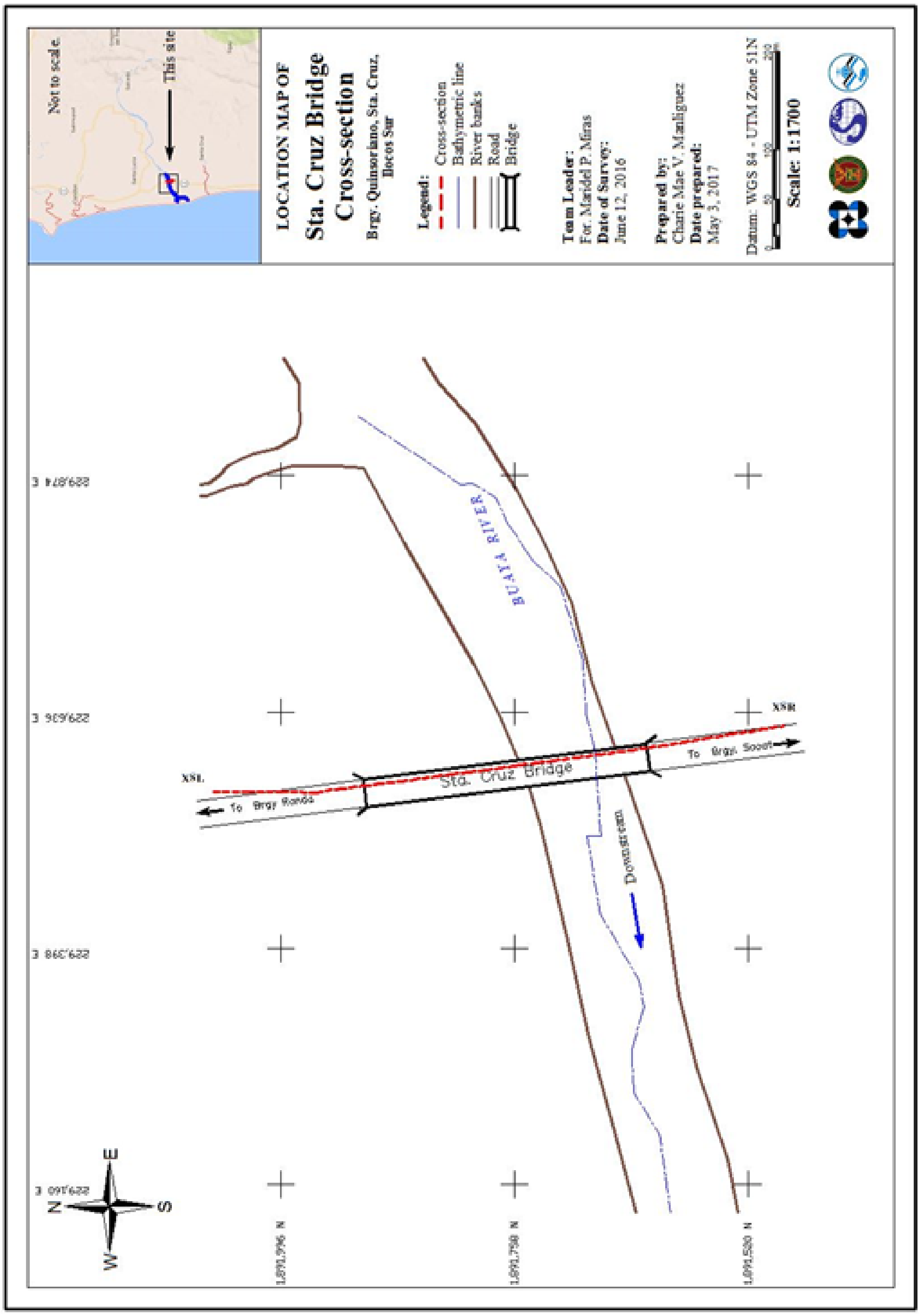


Figure 37. Sta. Cruz Bridge cross-section location map

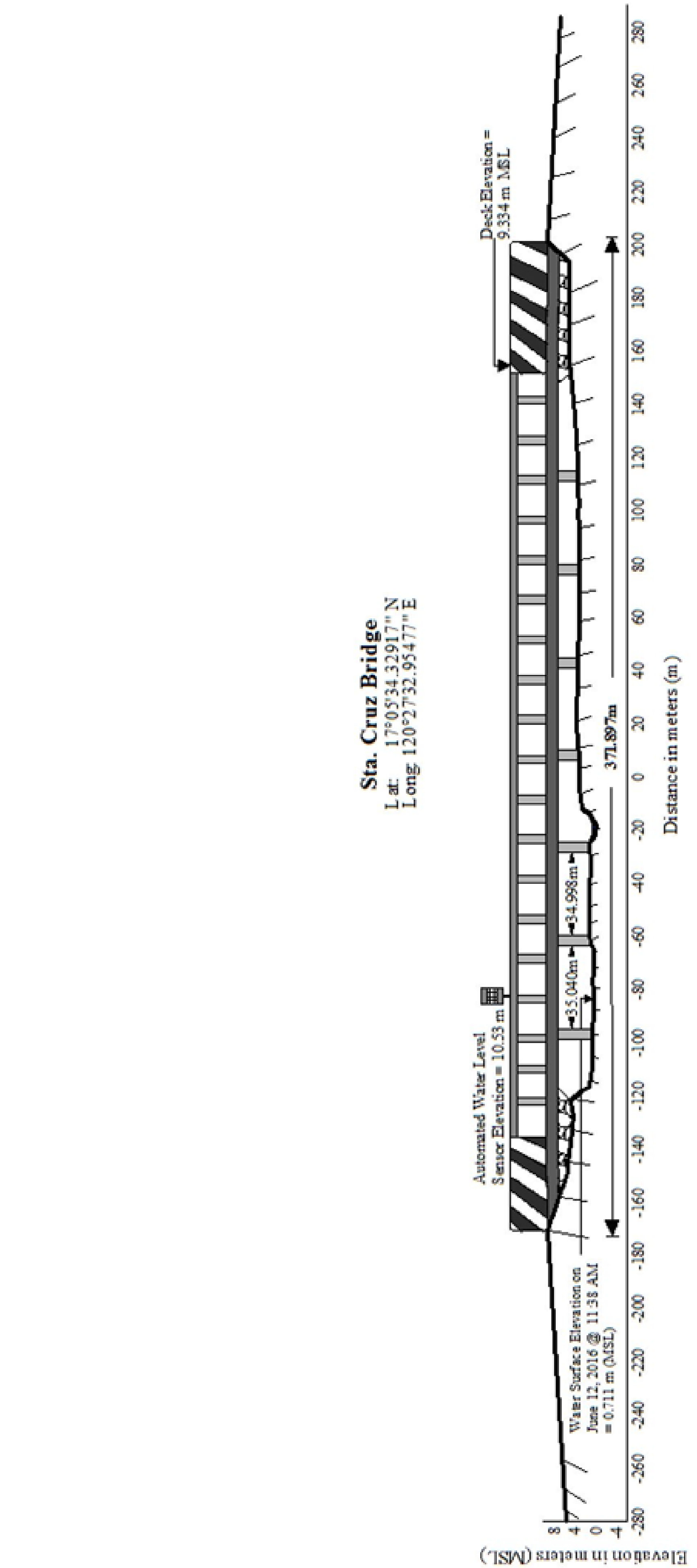


Figure 38. Santa Cruz Bridge cross-section diagram

Bridge Data Form

Bridge Name: Santa Cruz Bridge **Date:** June 12, 2016

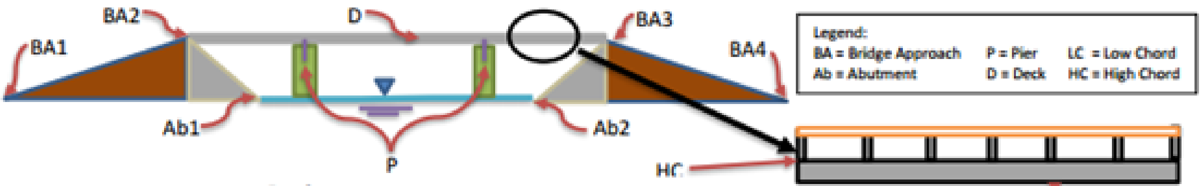
River Name: Buaya River **Time:** 10:26 AM

Location (Brgy, City,Region): Brgy. Quinsoriano, Municipality of Santa Cruz, Ilocos Sur

Survey Team: Maridel Miras, Caren Ordoña

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

Latitude: 17°05'34.32917" N **Longitude:** 120°27'32.95477" E



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

Elevation: 8.973 m **Width:** 9.69 m **Span (BA3-BA2):** 286.871 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	8.973 m	BA3	322.227m	9.334 m
BA2	35.356 m	9.366 m	BA4	371.897 m	9.002 m

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

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

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

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

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	74.149 m	9.334 m	3.00
Pier 2	109.189 m	9.320 m	3.00
Pier 3	144.187 m	9.362 m	3.00
Pier 4	179.004 m	9.369 m	3.00
Pier 5	213.592 m	9.356 m	3.00
Pier 6	248.623 m	9.362 m	3.00
Pier 7	283.635 m	9.331 m	3.00

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

Figure 39. Bridge as-built form of Santa Cruz Bridge

Water surface elevation of Buaya River was determined a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on June 12, 2016 at 11:38 AM with a value of 0.711 m in MSL as shown in Figure 38. This was translated into marking on the bridge's deck using the same technique with a value of 9.377 m in MSL. This will serve as reference for flow data gathering and depth gauge deployment of UPB for Buaya River.

Figure 40. Water-level markings on the deck of Santa Cruz Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on June 12 and 16, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown in Fi. It wure 41as secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 2.090 m and 2.025 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-CRU occupied as the GNSS base stations in the conduct of the survey.

Figure 41. The validation point acquisition survey setup using a GNSS receiver fixed in a van along the Buaya River Basin

The survey started from Brgy. Borono in the Municipality of Tagudin, going north covering seven (7) Municipalities of Ilocos Sur namely: Santa Lucia, Santiago, San Esteban, Burgos, Santa Maria and Narvacan; and Candon City. The survey gathered a total of 9,969 points with approximate length of 78.68 km using UP-CRU as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 42.

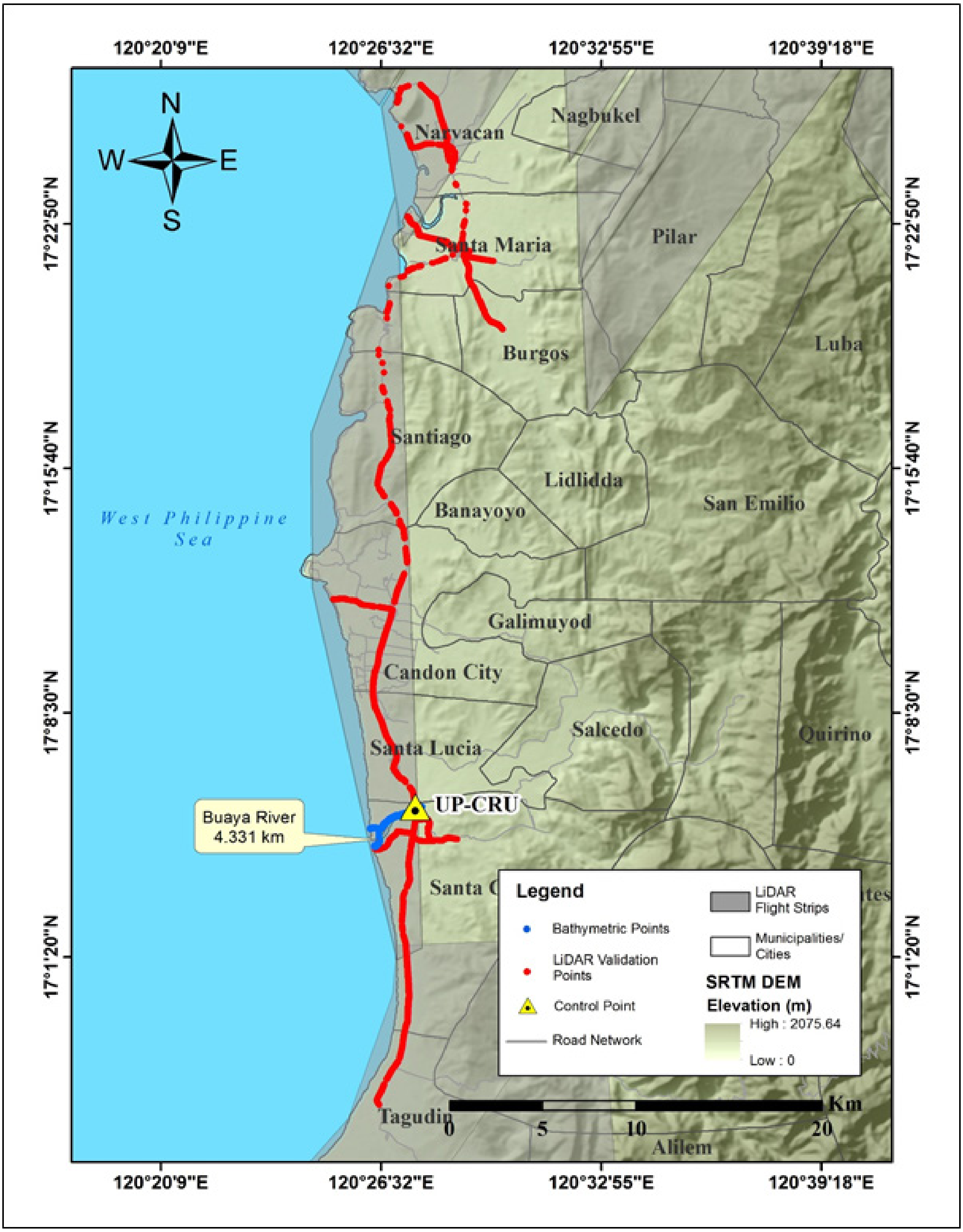


Figure 42. Validation point acquisition survey of Buaya River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on June 14, 2016 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 43. The survey started from in Brgy. Villa Hermosa, Municipality of Santa Cruz, with coordinates 17°5'30.12262"N, 120°26'59.90222"E, and ended at two different mouths of the river: in Brgy. Pilar with coordinates 17°4'34.72341"N, 120°26'21.36624"E; and in Brgy. Villa Hermosa with coordinates 17°5'6.76064"N,

Figure 43. Bathymetric survey using Ohmex™ single beam echo sounder in Buaya River

Manual bathymetric survey, on the other hand, was conducted simultaneously on the same day using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as shown in Figure 44. The survey started from the upstream of the river in Brgy. Quinsoriano, Municipality of Santa Cruz, with coordinates 17°5'45.03500"N, 120°27'43.96187"E, traversed down by foot, and ended at the starting point of bathymetric survey by boat. The control point UP-CRU was used as the GNSS base station all throughout the entire survey.

Figure 44. Manual bathymetric survey in Buaya River

The bathymetric survey for Buaya River gathered a total of 3,604 points covering 4.331 km of the river traversing Barangays Villa Hermosa, Las-ud, Pilar and Quinsoriano in Municipality of Santa Cruz. A CAD drawing was also produced to illustrate the riverbed profile of Buaya River. As shown in Figure 46 and Figure 47, the highest and lowest elevation has a 5-m difference. The highest elevation observed was 1.083 m above MSL located in Brgy. Quinsoriano, while the lowest was -4.416 m below MSL located in Brgy. Pilar, both in Municipality of Santa Cruz. The survey for the remaining 13 km upstream of the river was cut because LiDAR data for its riverbed is already available.

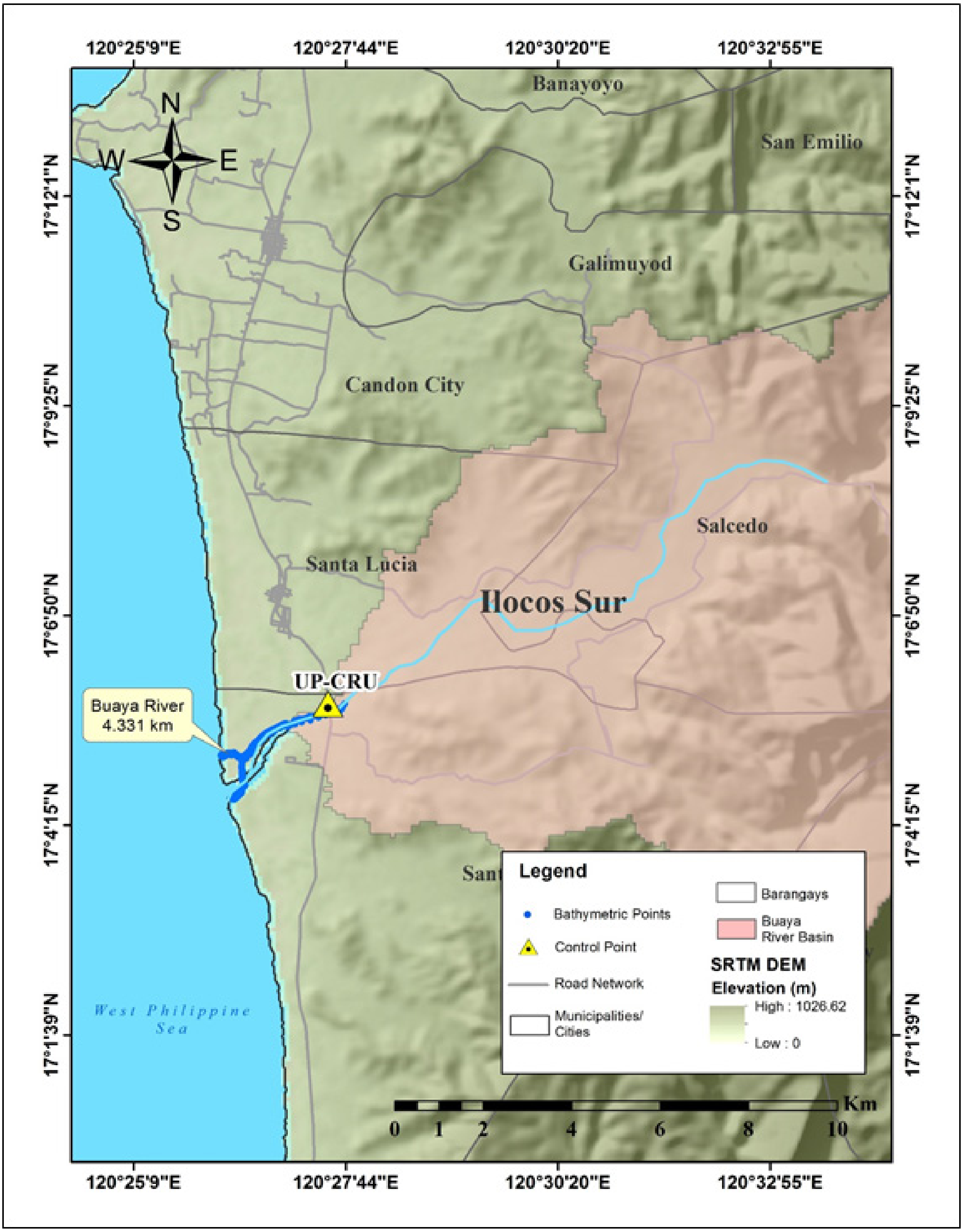


Figure 45. Extent of the bathymetric survey (in blue line) in Buaya River

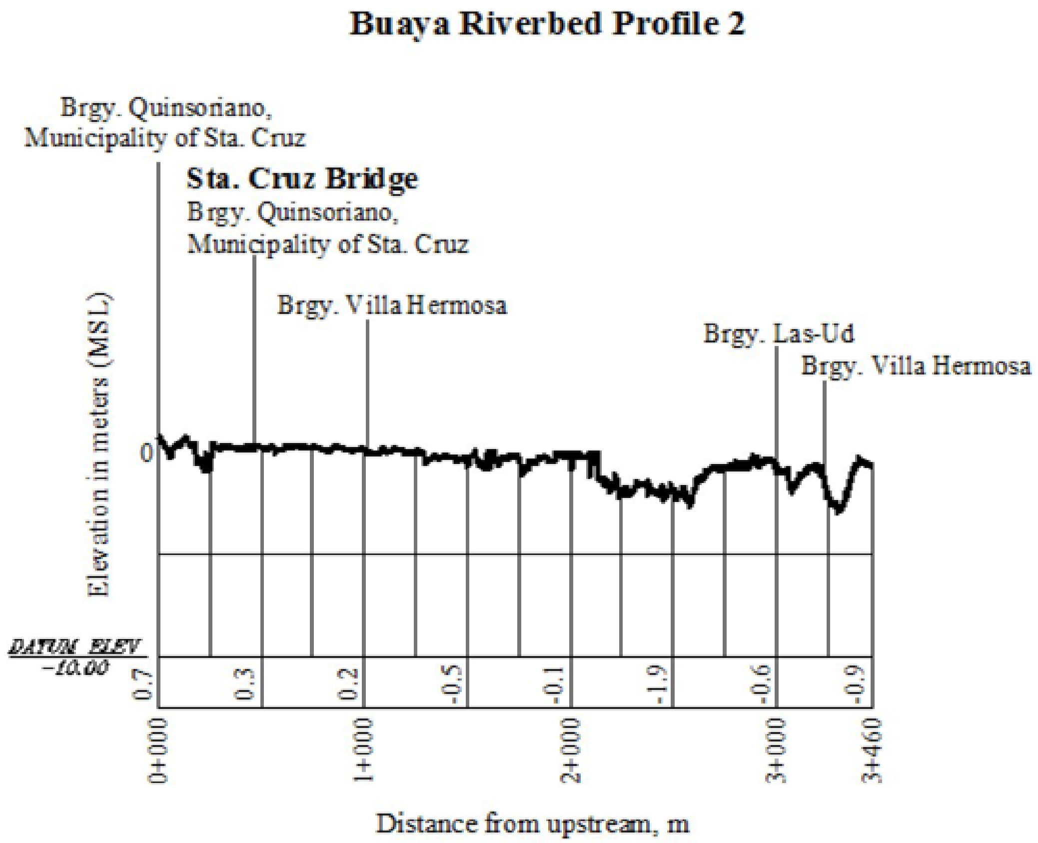


Figure 46. Buaya Riverbed Profile, right mouth facing downstream

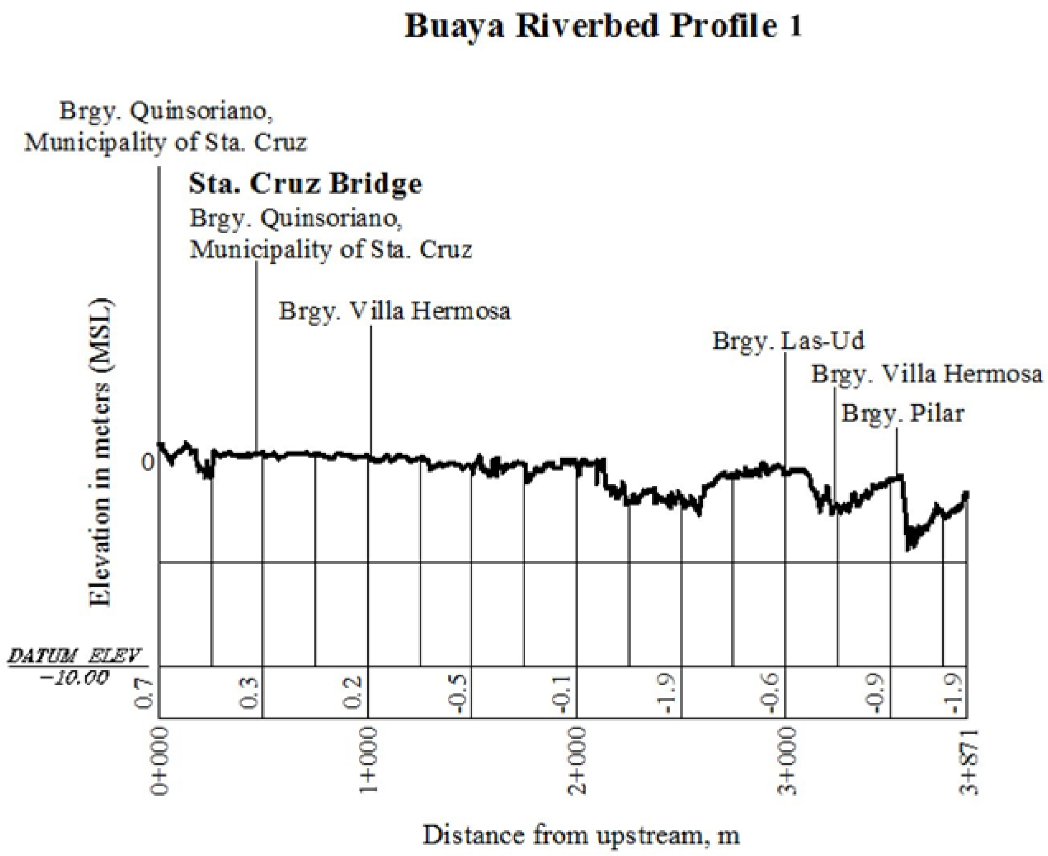


Figure 47. Buaya Riverbed Profile, left mouth facing downstream

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Buaya river were monitored, collected and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the Poblacion Sur ARG (17°8’53.41” N, 120°36’35.68” E), located in Gregorio del Pilar, Ilocos Sur, as shown in Figure 48. The precipitation data collection started from August 15, 2016 at 12:00 PM to August 16, 2016 at 5:30 PM with a 15-minute recording interval.

The total precipitation for this event in Poblacion Sur ARG was 219 mm. It has a peak rainfall of 20 mm. on August 15, 2016 at 9:30 PM. The lag time between the peak rainfall and discharge is 2 hours.

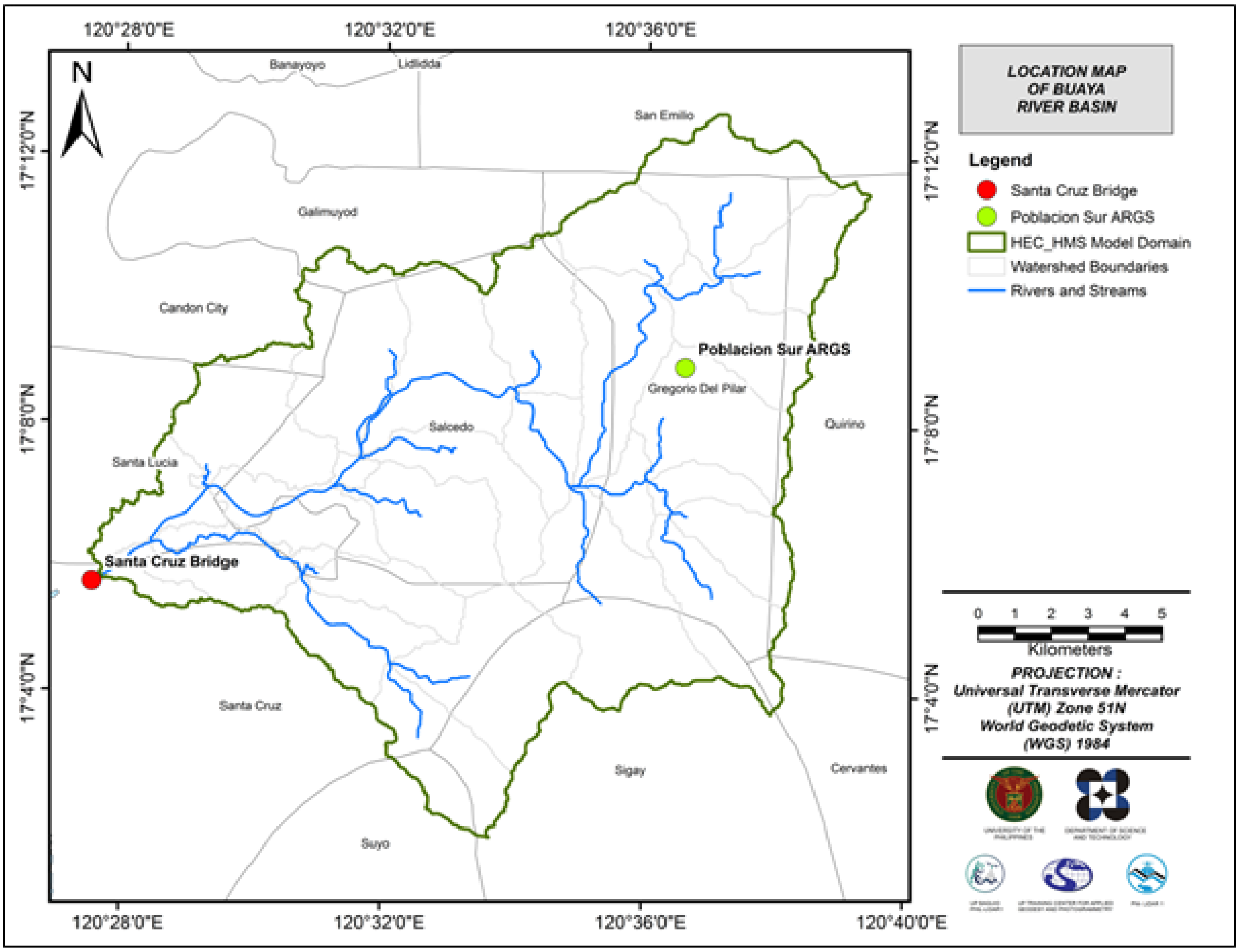


Figure 48. The location map of Buaya HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at the same location, at Sta. Cruz Bridge or Quinsoriano Bridge, Brgy. Quinsoriano, Santa Cruz, Ilocos Sur (17°5'37.28" N, 120°27'32.47" E). It gives the relationship between the observed water level from the Sta. Cruz or Quinsoriano Bridge Automated Water Level Sensor (AWLS) and outflow of the watershed at this location.

For Sta. Cruz or Quinsoriano Bridge, the rating curve is expressed as Q = 3.2179e1.0493h as shown in Figure 50.

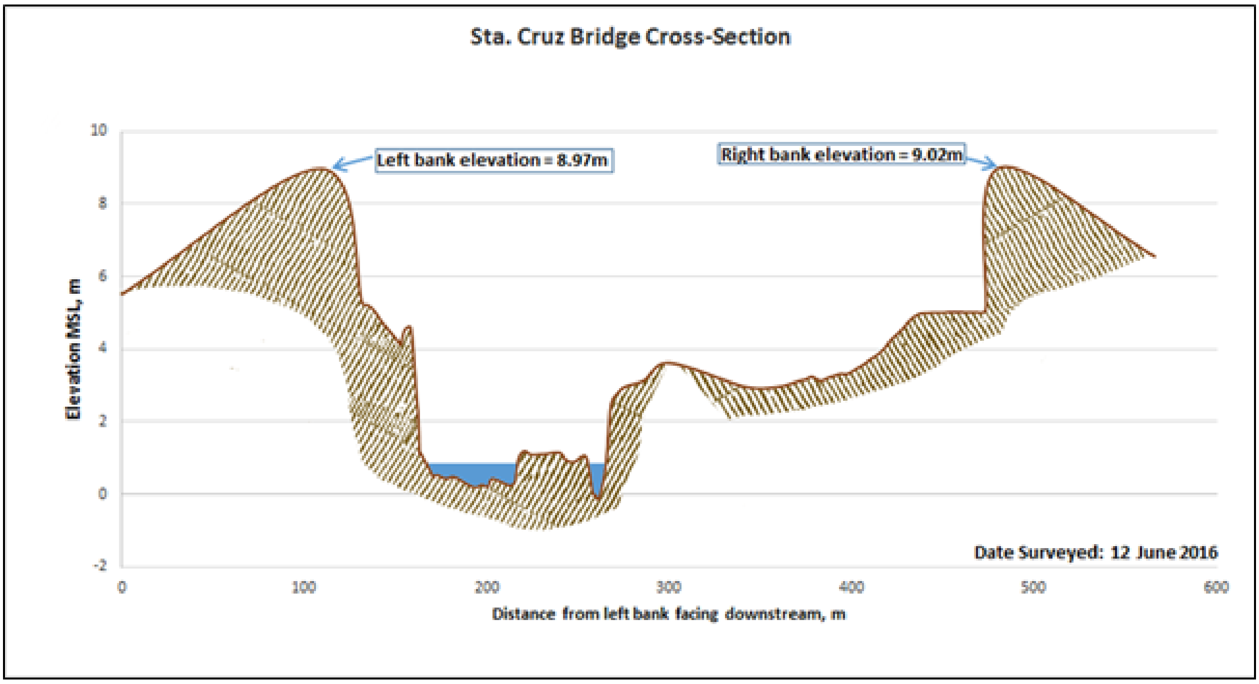


Figure 49.Cross-Section Plot of Sta. Cruz Bridge

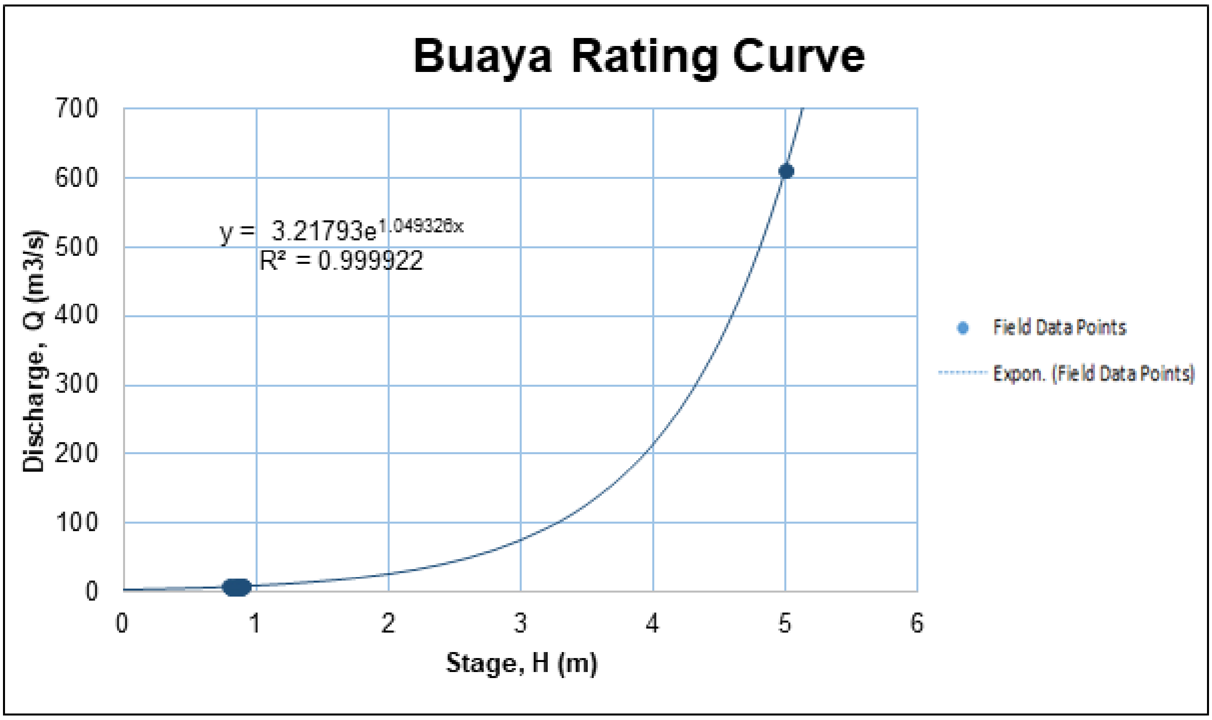


Figure 50. Rating Curve at Sta. Cruz Bridge, Santa Cruz, Ilocos Sur

The rating curve equation was used to compute for the river outflow at Sta. Cruz Bridge for the calibration of the HEC-HMS model for Buaya, as shown in Figure 51. The total rainfall for this event is 219 mm and the peak discharge is 117.54 m3/s at 11:30 PM of August 15. 2016.

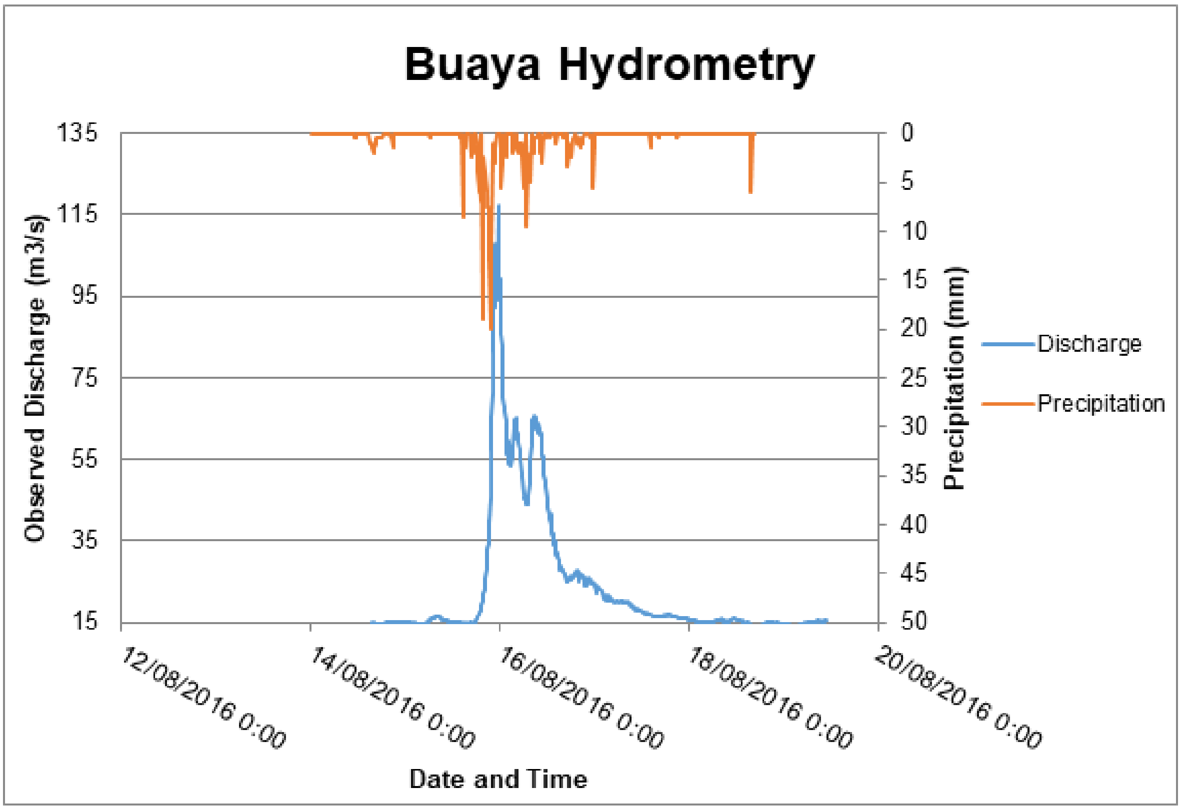


Figure 51. Rainfall and outflow data at Sta. Cruz Bridge used for modeling.

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 Buaya watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 27. 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

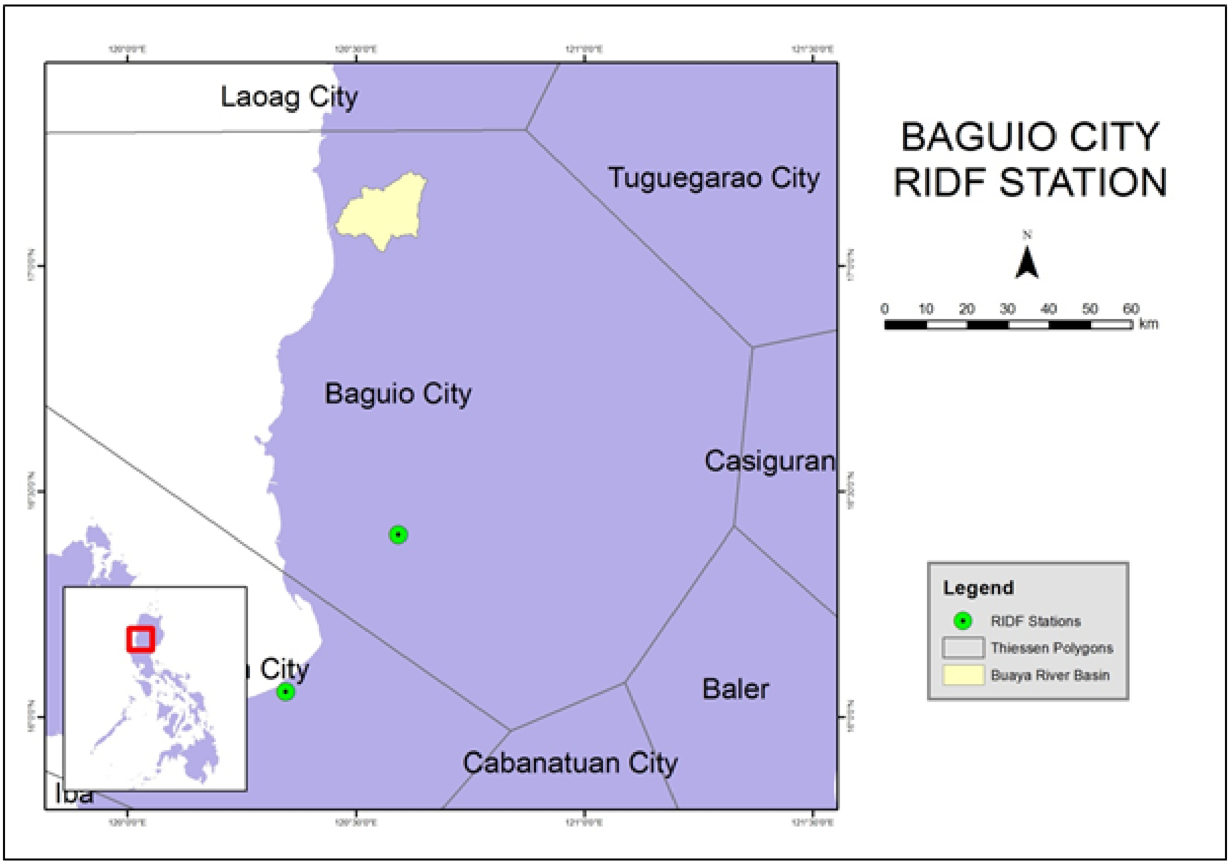


Figure 52. Location of Baguio RIDF Station relative to Buaya River Basin

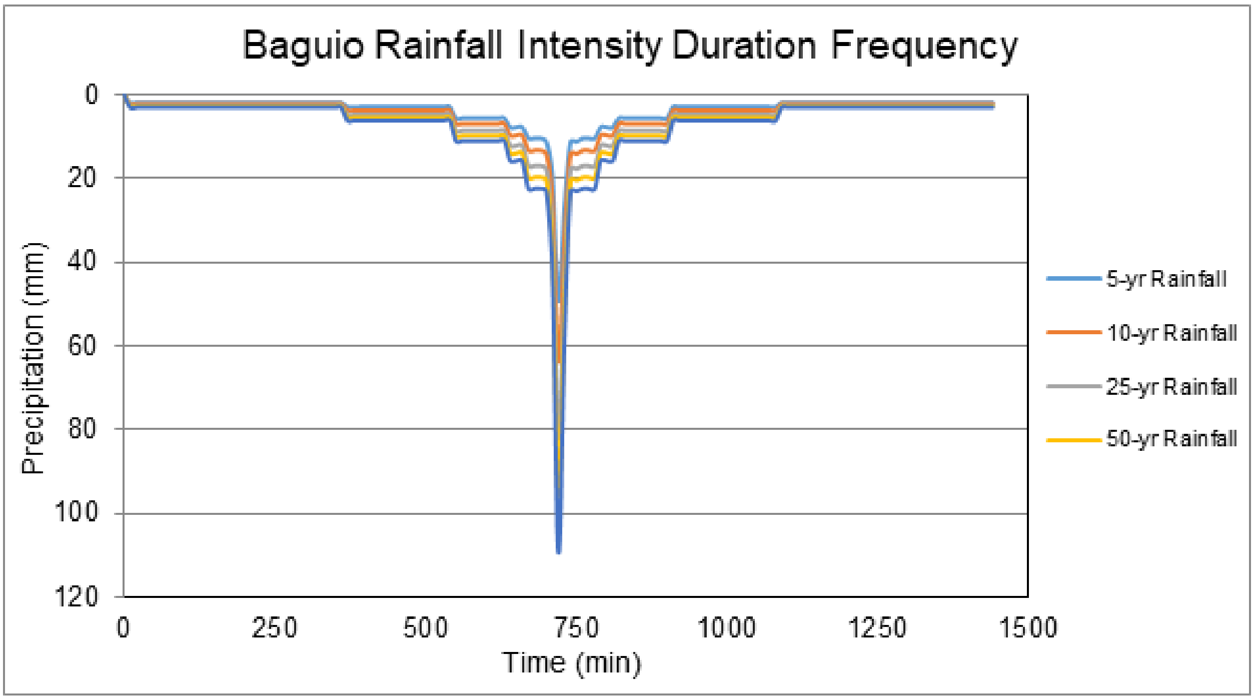


Figure 53. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was taken before 2004 by the Bureau of Soils and Water Management (BSWM), under the Department of Agriculture (DA). The land cover dataset file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Musi-Musi River Basin are shown in Figures 54 and 55, respectively.

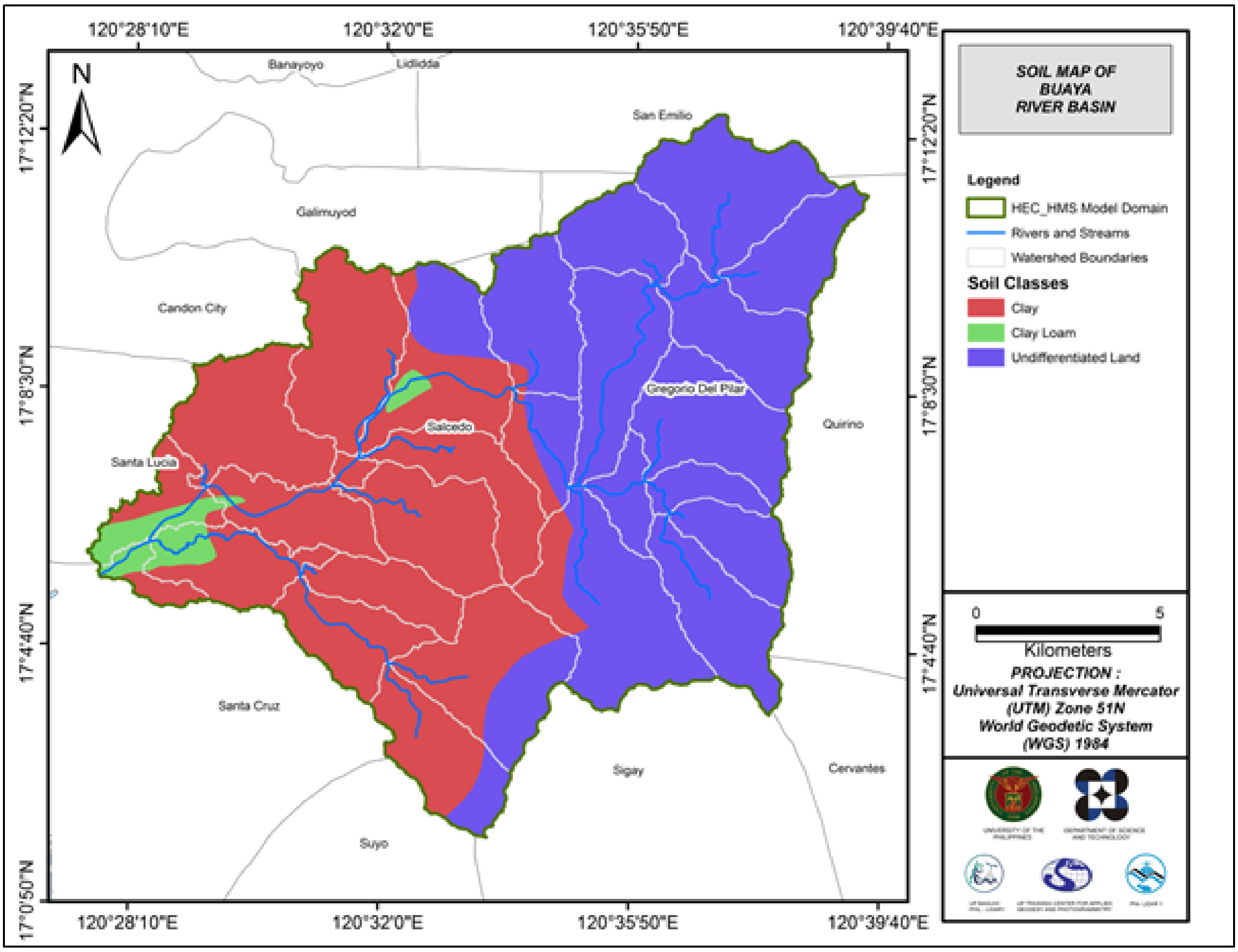


Figure 54. Soil Map of Buaya River Basin (Source: NAMRIA)

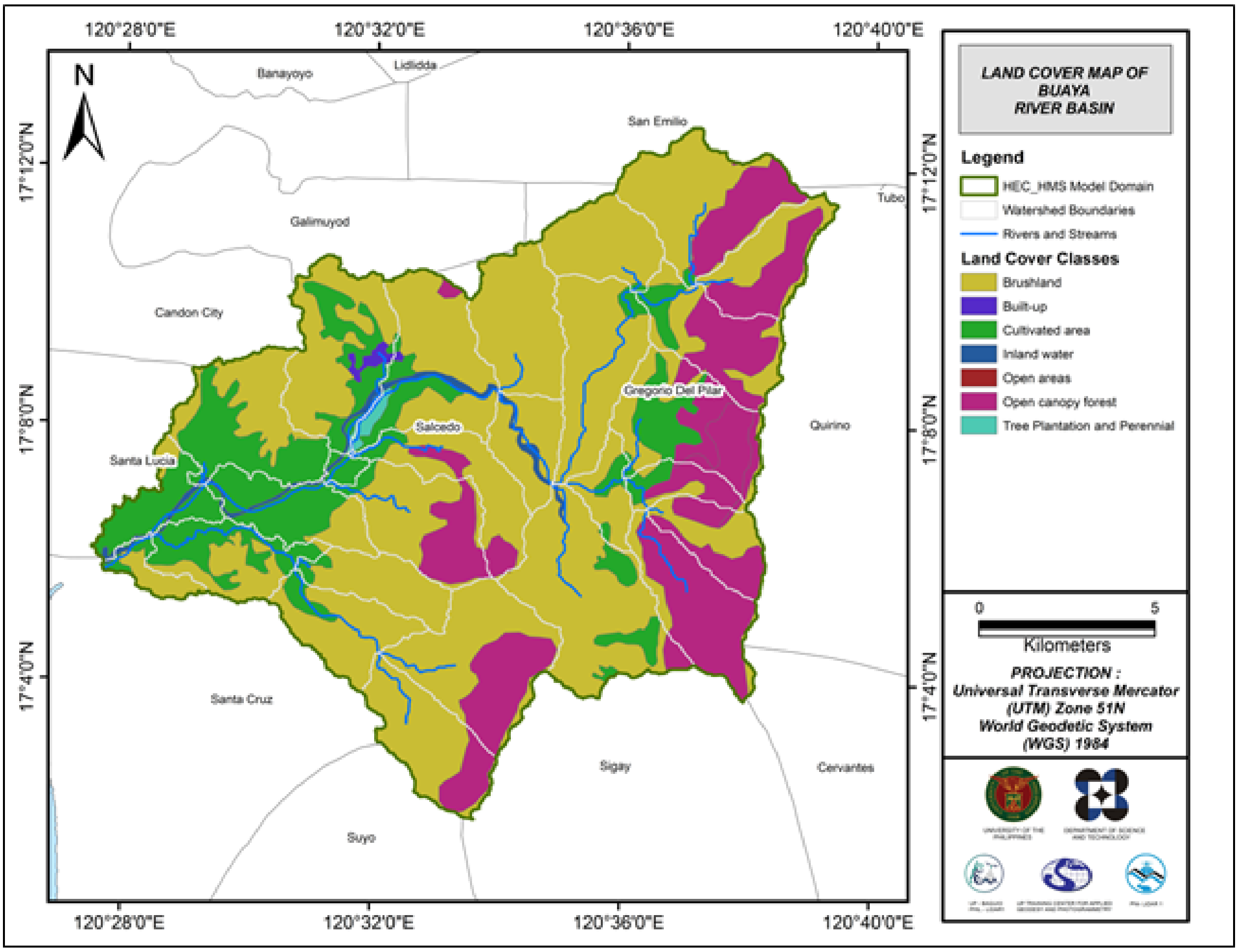


Figure 55. Land Cover Map of Buaya River Basin (Source: NAMRIA)

For Buaya, three soil classes were identified. These are clay, clay 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.

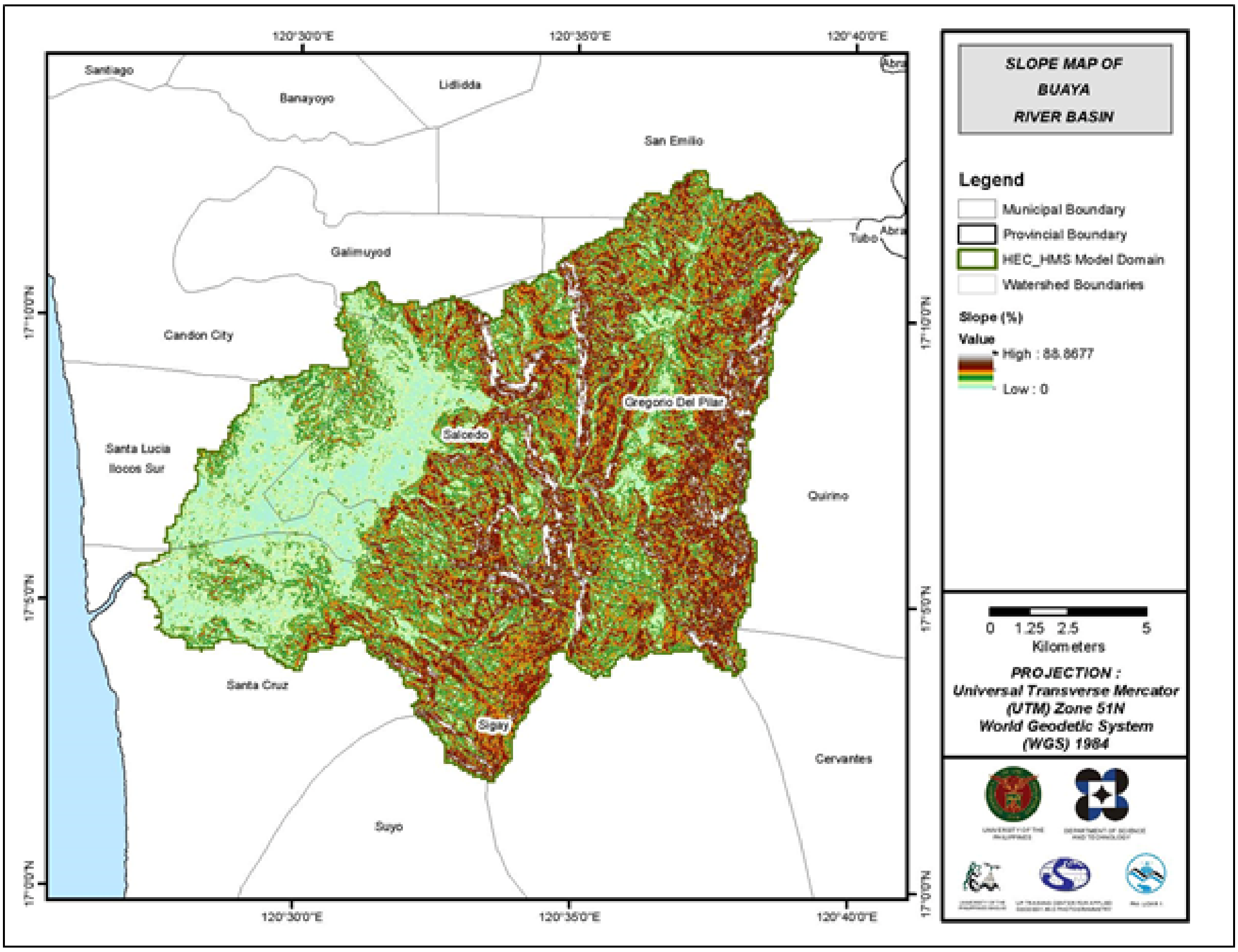


Figure 56. Slope Map of Buaya River Basin

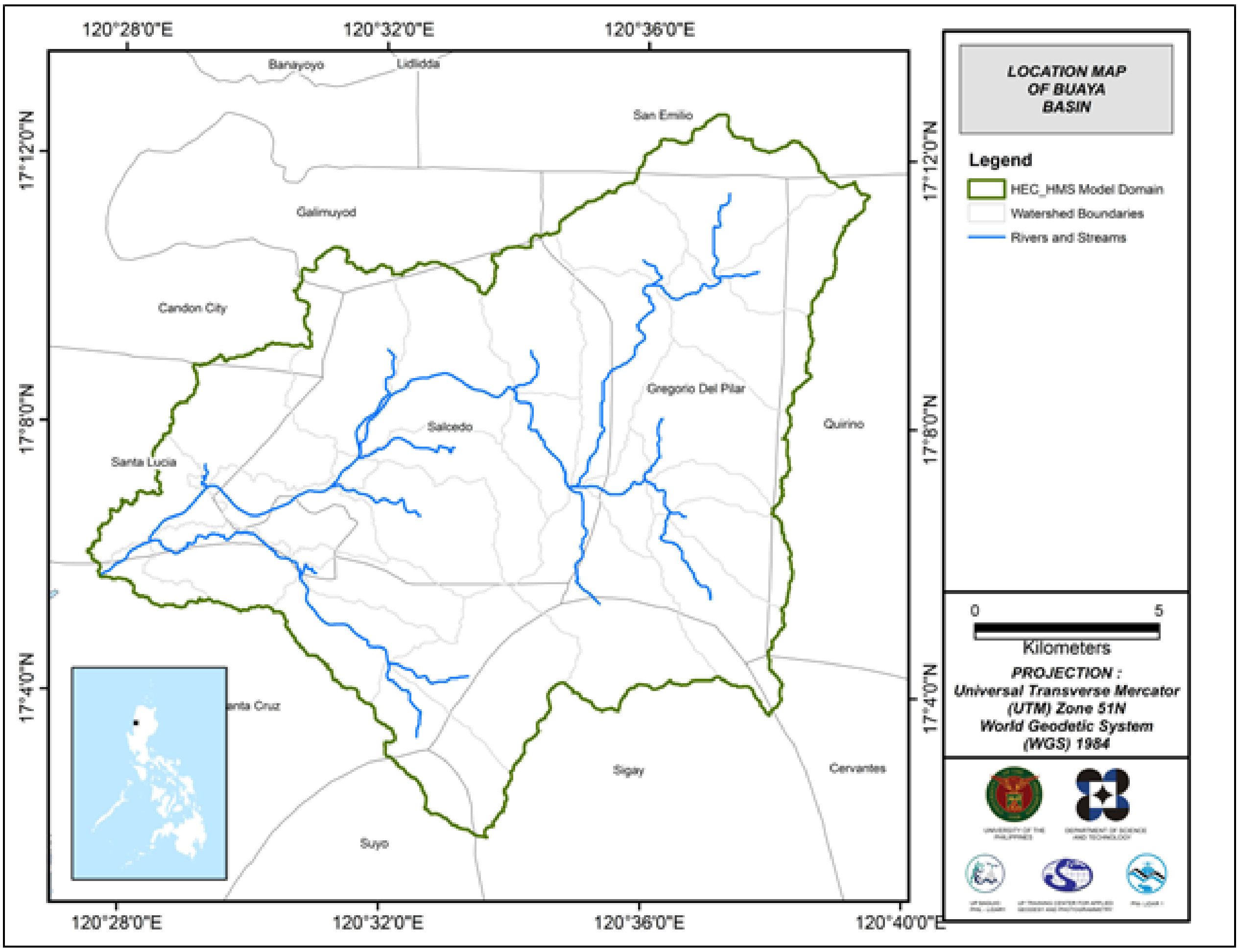


Figure 57. Stream Delineation Map of Buaya River Basin

Using the SAR-based DEM, the Buaya basin was delineated and further subdivided into subbasins. The model consists of 29 sub basins, 14 reaches, and 15 junctions, as shown in Figure 58. The main outlet is 91.

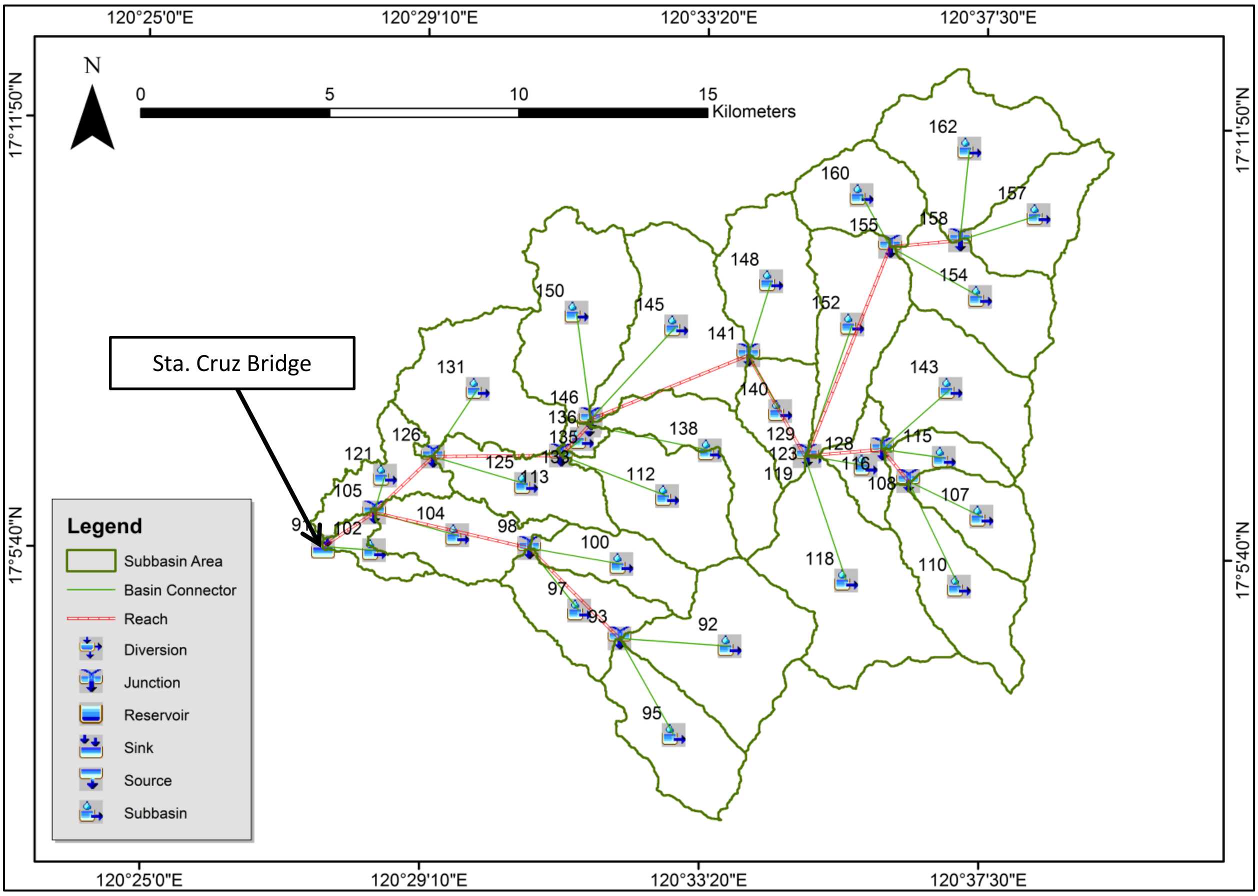


Figure 58. The Buaya river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

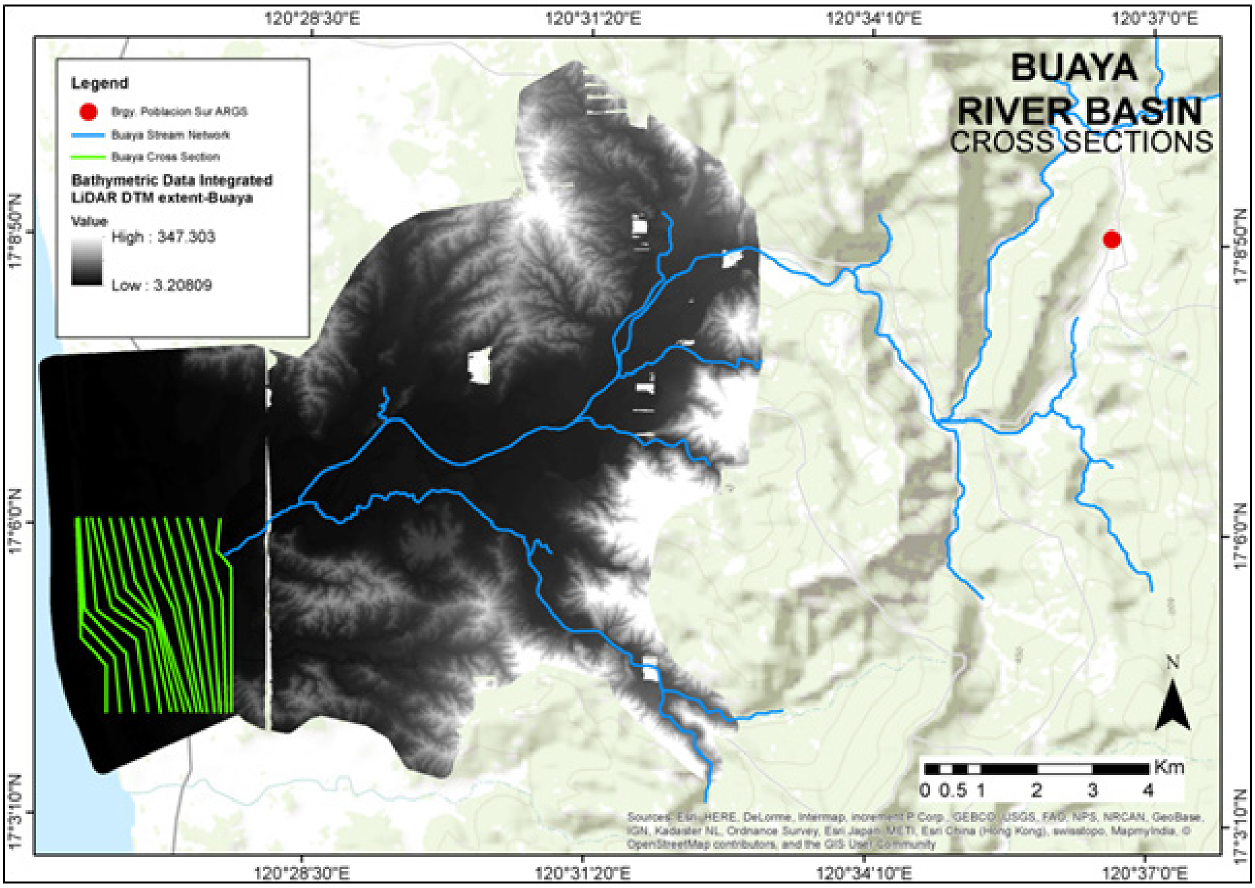


Figure 59. River cross-section of Buaya River generated through Arcmap HEC GeoRAS tool

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 east of the model to the west, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

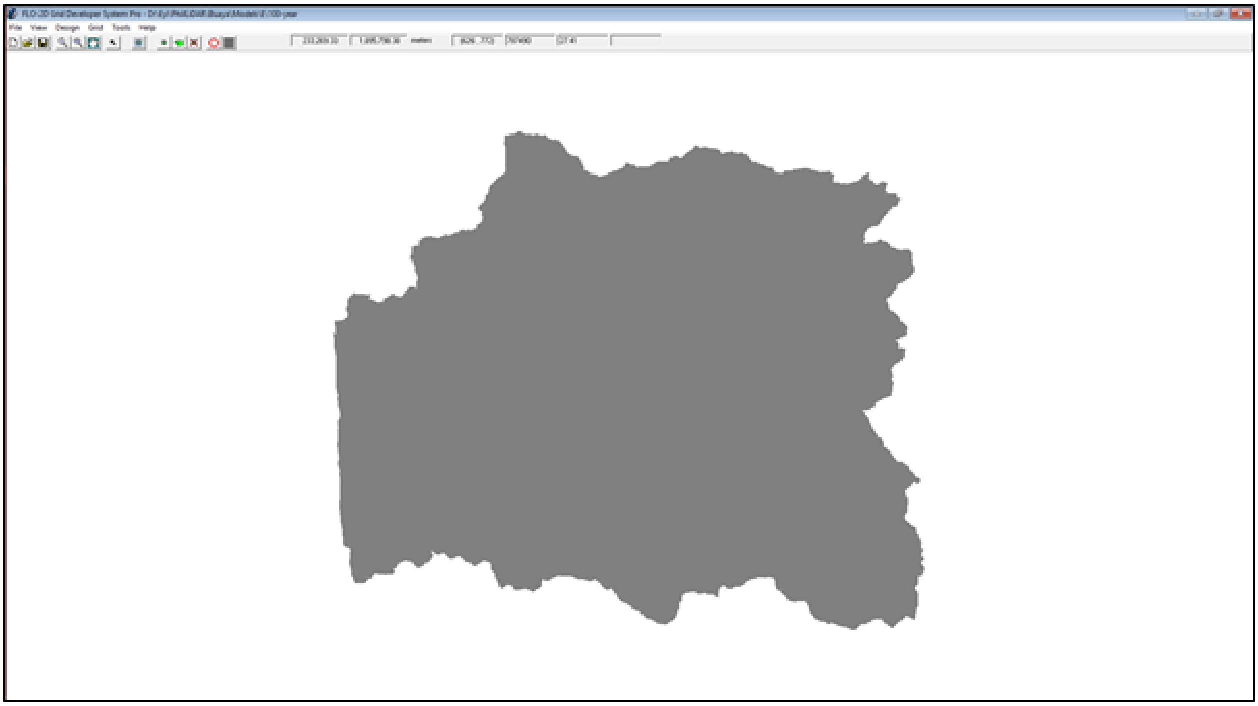


Figure 60. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 49.71 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Buaya are in Figures 64, 66, and 68.

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 95,682,048.00 m2. The generated flood depth maps for Buaya are in Figures 65, 67, and 69.

There is a total of 169,651,883.60 m3 of water entering the model, of which 68,843,586.23 m3 is due to rainfall and 100,808,297.37 m3 is inflow from basins upstream. 16,391,495.00 m3 of this water is lost to infiltration and interception, while 27,280,953.19 m3 is stored by the flood plain. The rest, amounting up to 125,979,428.08 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Buaya HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data. (See Annex 9).

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

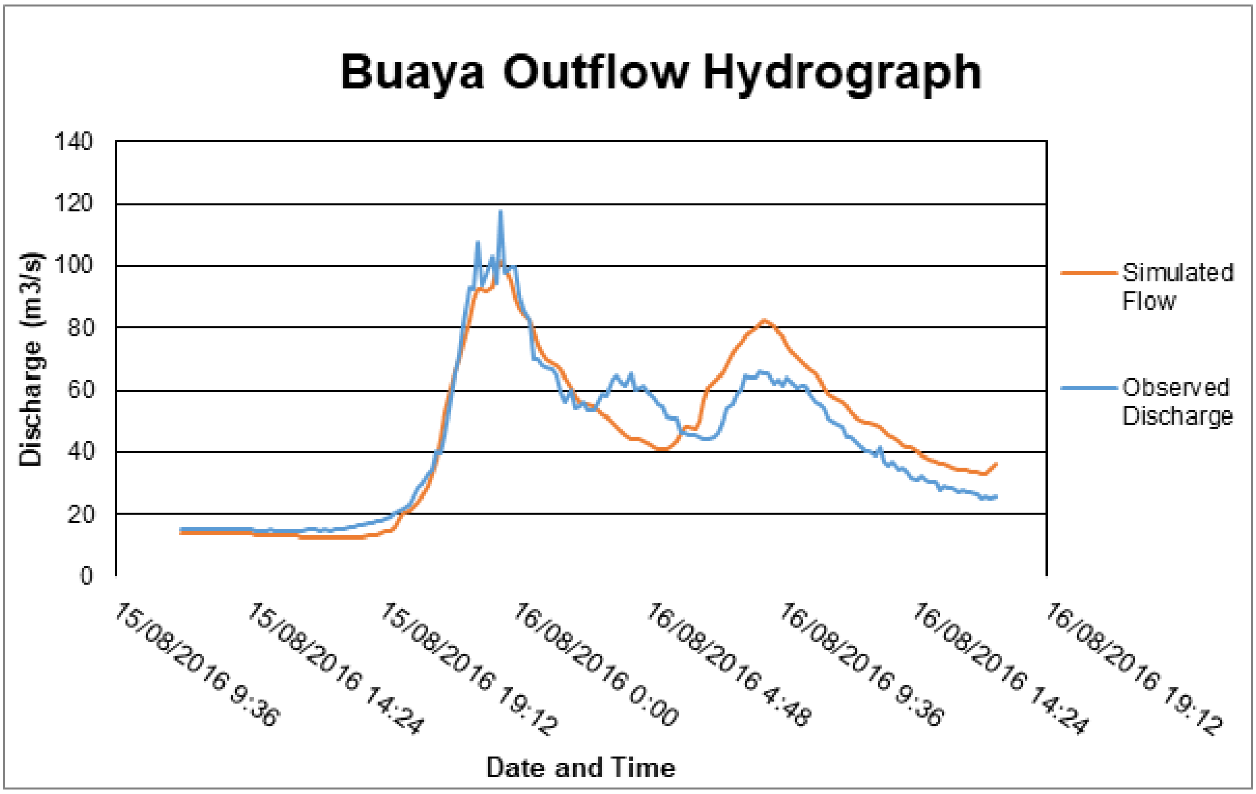


Figure 61. Outflow Hydrograph of Buaya produced by the HEC-HMS model compared with observed outflow

Table 28. Range of Calibrated Values for Buaya River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	1.44 – 267.09
			Curve Number	35.02 – 57.53
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.0976 – 15.73
			Storage Coefficient (hr)	0.064 – 50.23
	Baseflow	Recession	Recession Constant	0.00001
			Ratio to Peak	0.00015
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.011 – 0.46

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 1.44 mm to 267.09 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 Buaya, the basin consists mainly of brushlands 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 0.064 hours to 50.23 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant which is 0.00001 indicates that the basin is highly likely to quickly go back to its original discharge. Ratio to peak which is 0.00015 indicates a much steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Buaya river basin reaches' Manning's coefficients range from 0.011 to 0.46, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Buaya HMS Model

Accuracy measure	Value
RMSE	8.5
r2	0.8996
NSE	0.88
PBIAS	-3.67
RSR	0.35

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 8.5 m3/s.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8996.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.88.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -3.67.

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 0.35.

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 62) shows the Buaya 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.

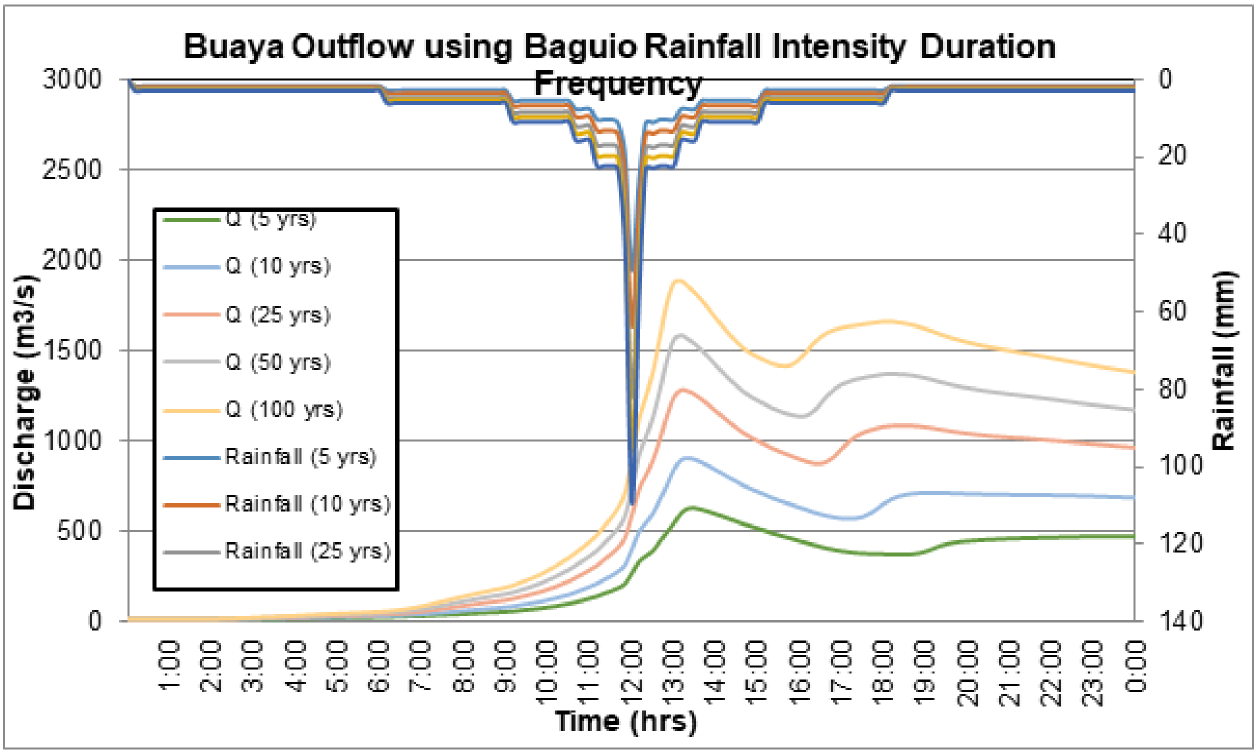


Figure 62. Outflow hydrograph at Buaya Station generated using the Baguio RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Buaya discharge using the Baguio Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Buaya 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	629.2	1 hour 30 minutes
10-Year	701.7	63.8	905.1	1 hour 20 minutes
25-Year	876.1	82.1	1281.9	1 hour 10 minutes
50-Year	1005.5	95.8	1584.9	1 hour 10 minutes
100-Year	1134	109.3	1885.7	1 hour 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining 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 Buaya River using the calibrated HMS base flow is shown in Figure 63.

Figure 63. Sample output of Buaya 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 Buaya floodplain are shown in Figures 64 to 69. The floodplain, with an area of 96.87 sq. km., covers four municipalities. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Buaya floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Ilocos Sur	Candon City	80.18	2.42	3.02%
Ilocos Sur	Salcedo	69.23	20.03	28.93%
Ilocos Sur	Santa Cruz	105.96	38.64	36.47%
Ilocos Sur	Santa Lucia	43.88	35.20	80.22%

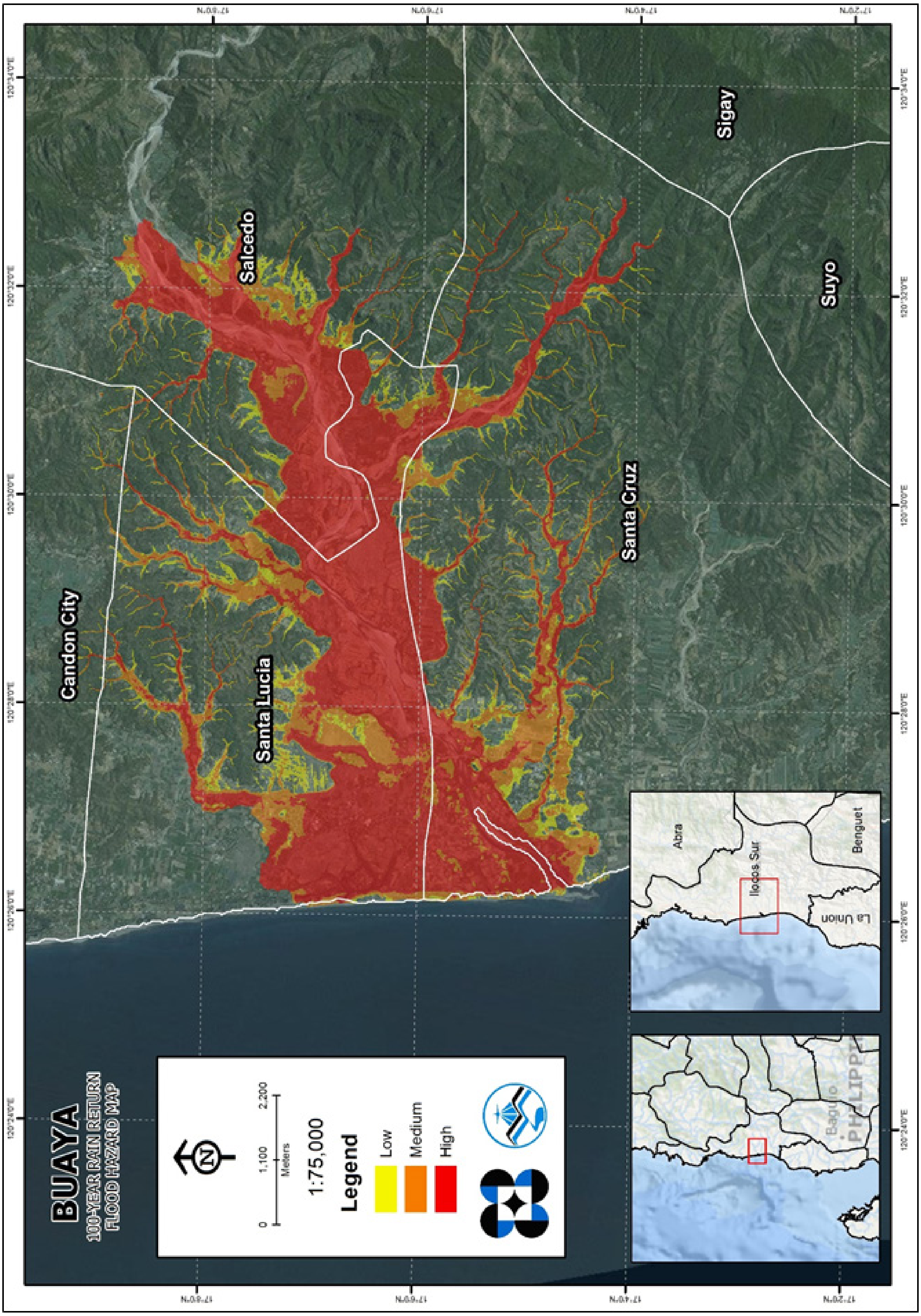


Figure 64. 100-year Flood Hazard Map for Buaya Floodplain overlaid on Google Earth imagery

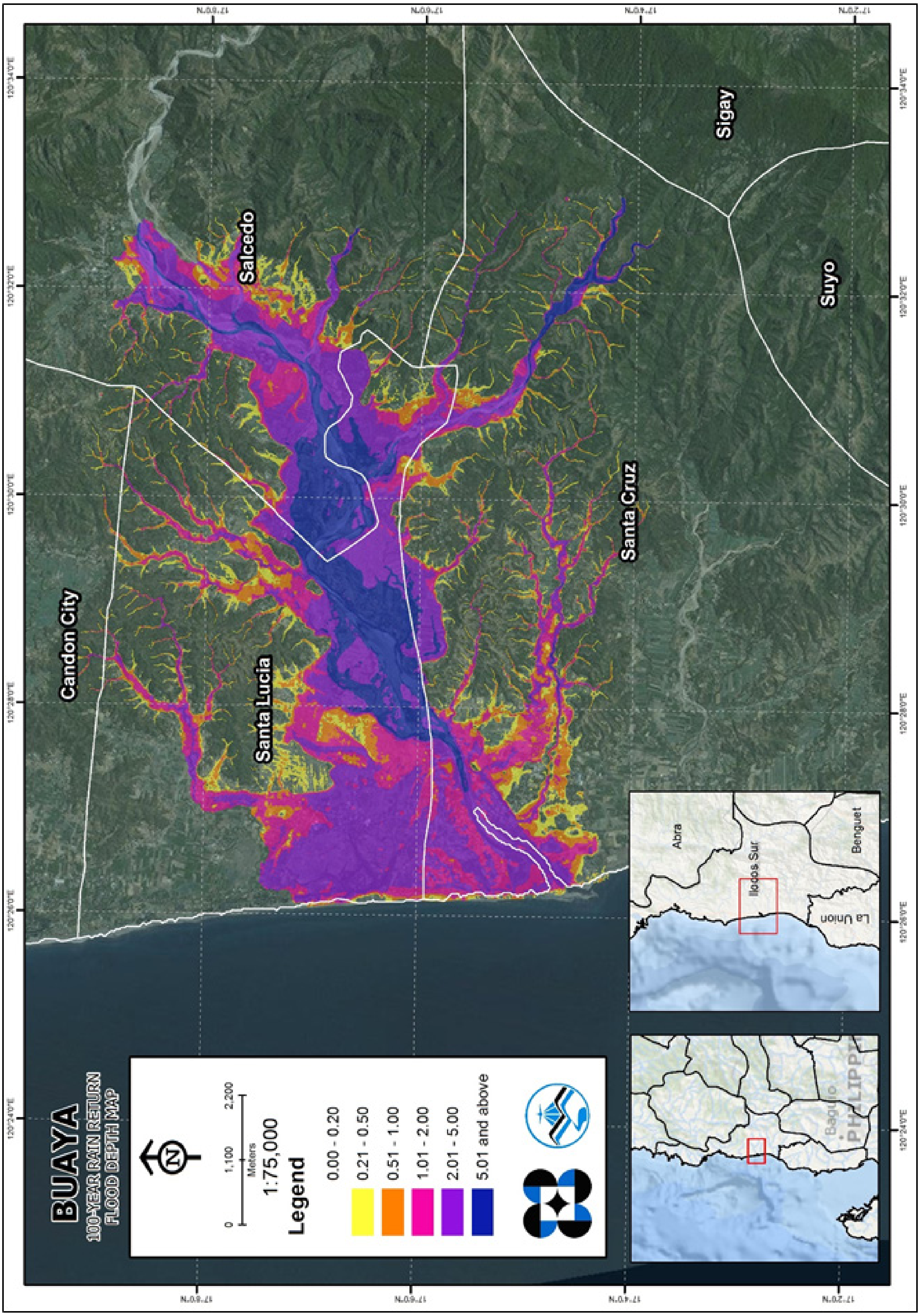


Figure 65. 100-year Flow Depth Map for Buaya Floodplain overlaid on Google Earth imagery

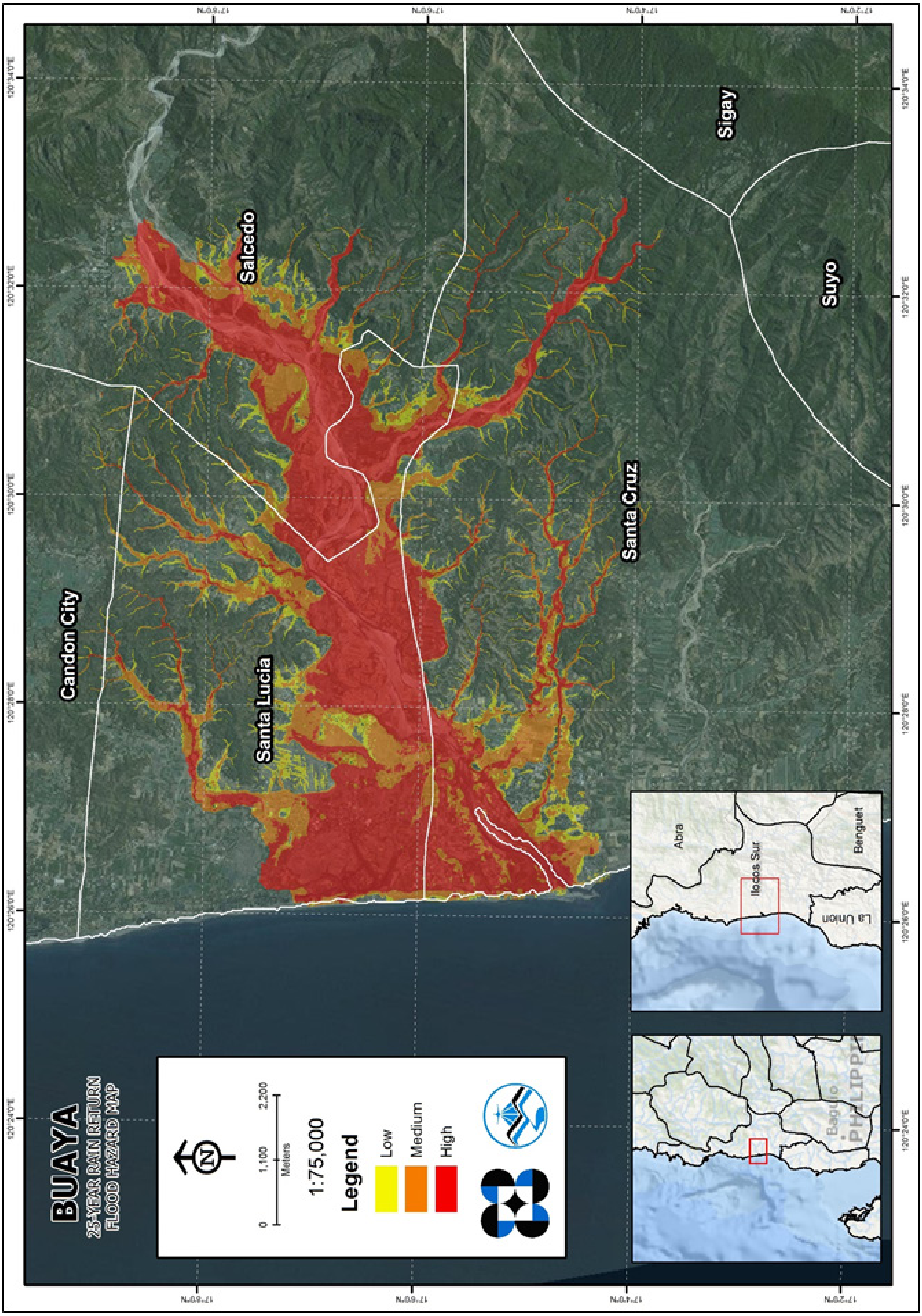


Figure 66. 25-year Flood Hazard Map for Buaya Floodplain overlaid on Google Earth imagery

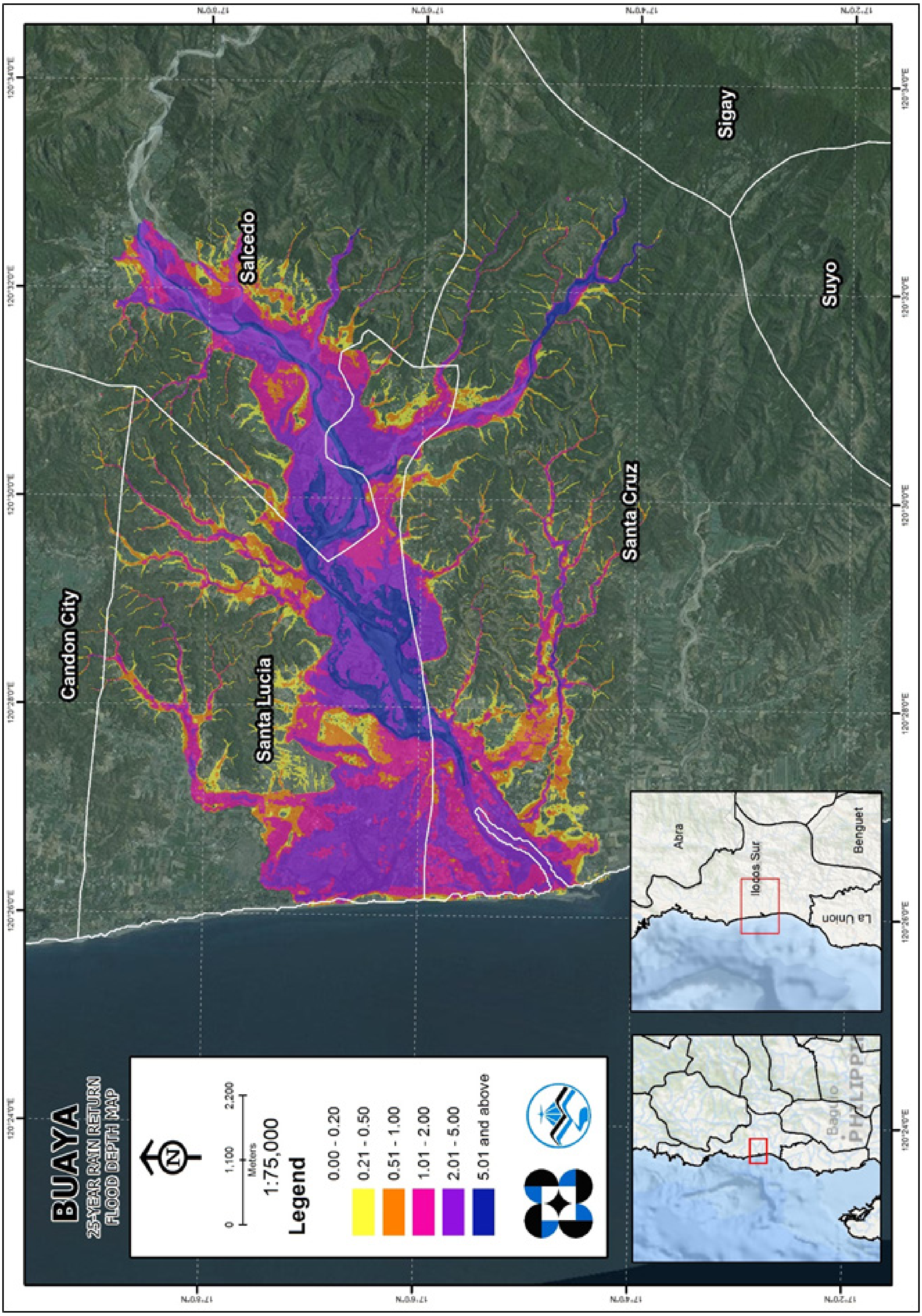


Figure 67. 25-year Flow Depth Map for Buaya Floodplain overlaid on Google Earth imagery

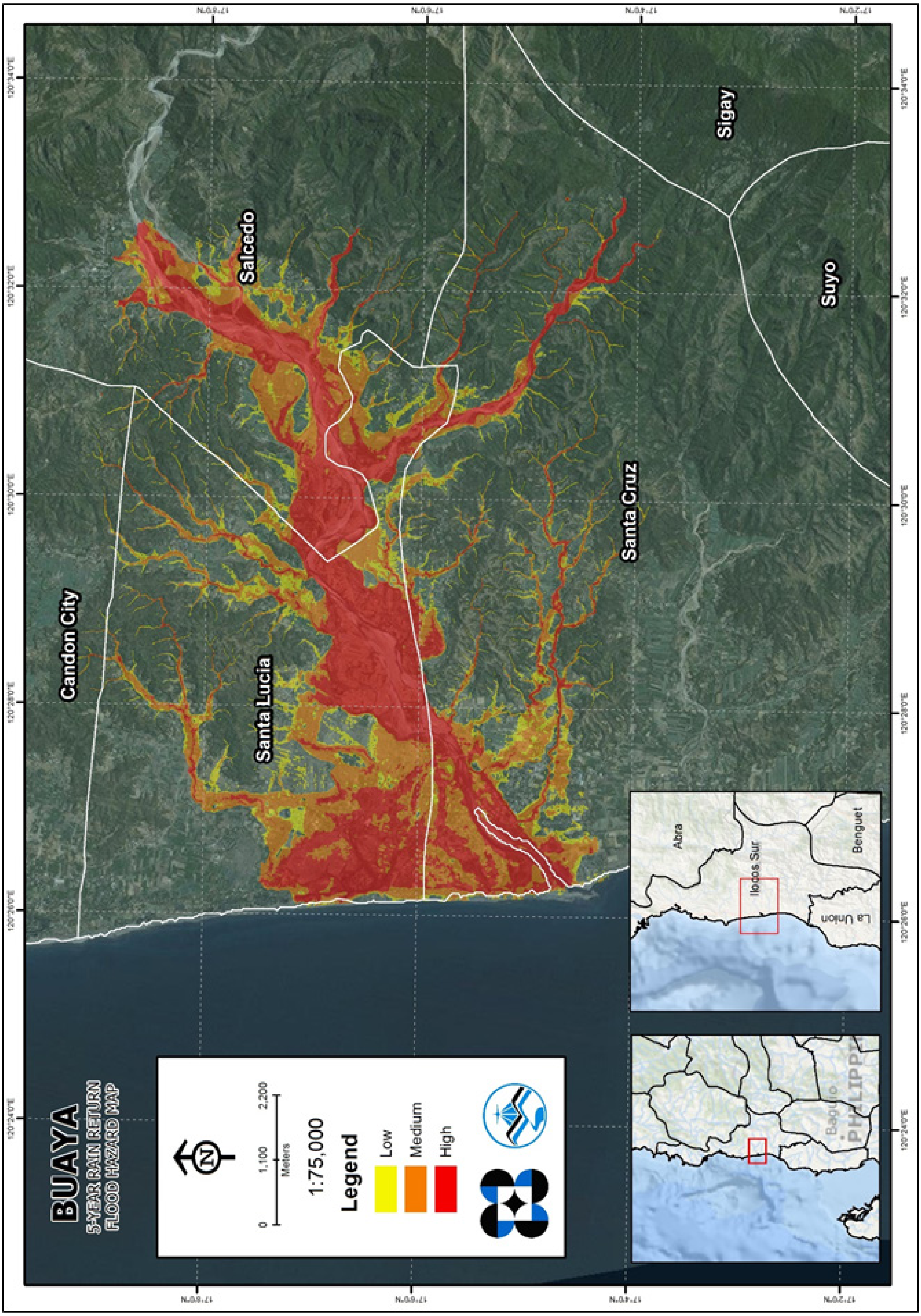


Figure 68. 5-year Flood Hazard Map for Buaya Floodplain overlaid on Google Earth imagery

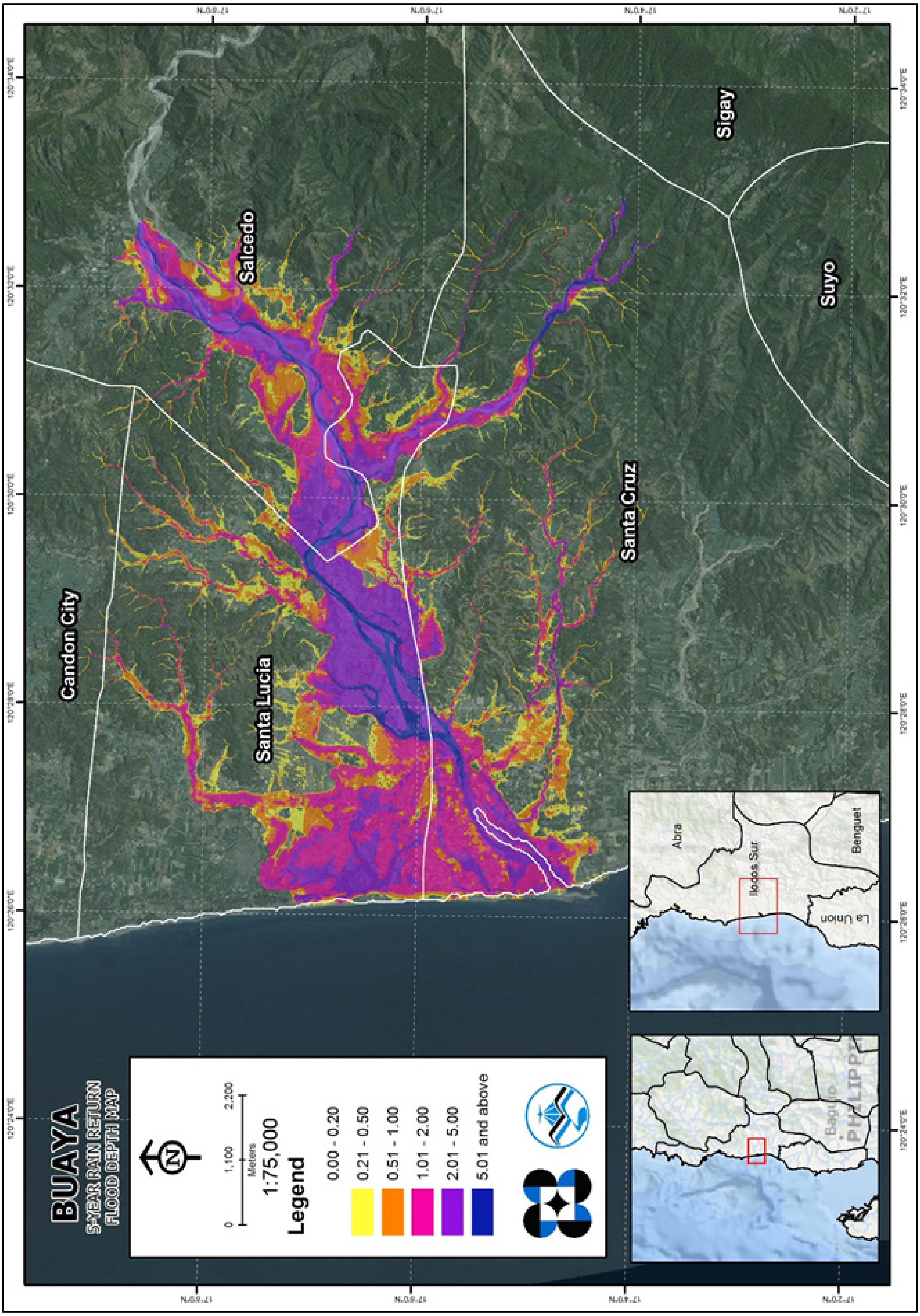


Figure 69. 5-year Flood Depth Map for Buaya Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Buaya river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 76 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 2.86% of the municipality of Candon City with an area of 80.175 sq. km. will experience flood levels of less than 0.20 meters. 0.09% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay. (See Annex 12 and Annex 13)

Table 32. Affected Areas in Candon City, Ilocos Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Candon City (in sq. km)			
	Allangigan Primero	Cubcubboot	Palacapac	Parioc Primero
0.03-0.20	0.67	0.39	1.08	0.15
0.21-0.50	0.02	0.0095	0.039	0.0032
0.51-1.00	0.013	0.0007	0.021	0.0027
1.01-2.00	0.0048	0.0008	0.0055	0.0005
2.01-5.00	0.0015	0.0002	0.0003	0
> 5.00	0	0	0	0

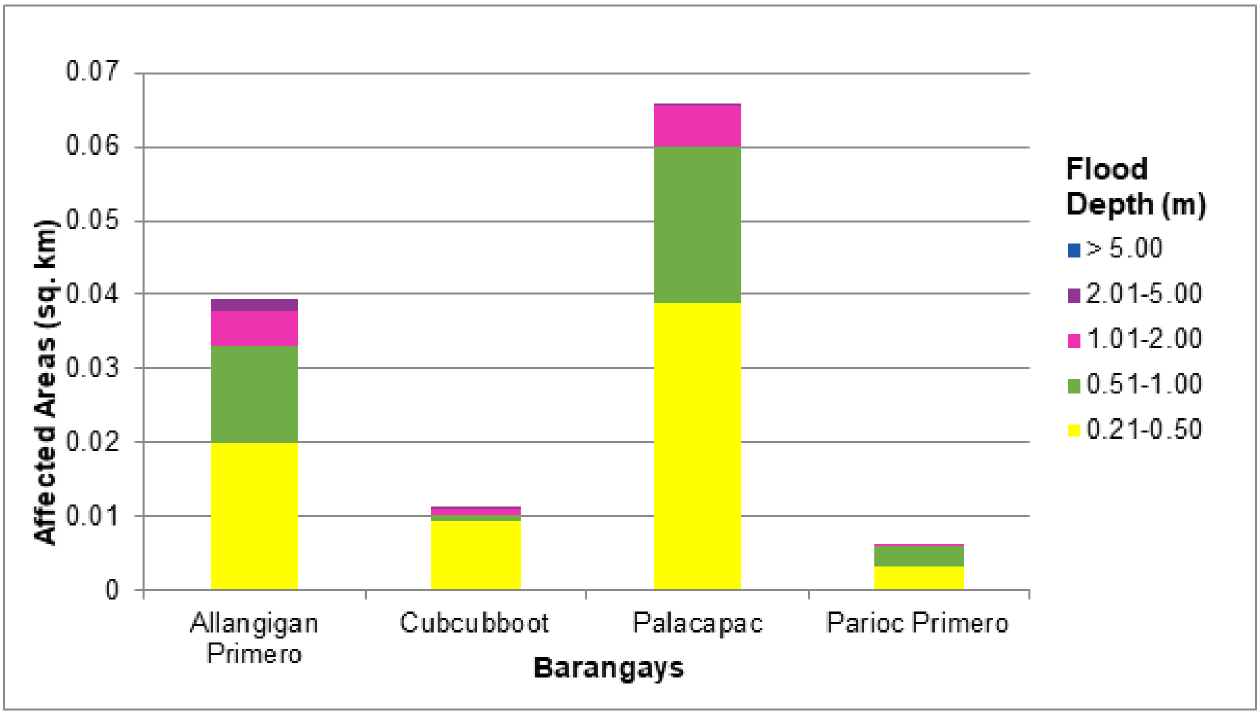


Figure 70. Affected Areas in Candon City, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 15.89% of the municipality of Salcedo with an area of 69.23 sq. km. will experience flood levels of less than 0.20 meters. 1.84% of the area will experience flood levels of 0.21 to 0.50 meters while 2.37%, 3.60%, 4.47%, and 0.75% 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 Salcedo, Ilocos Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Salcedo (in sq. km)						
	Atabay	Balidbid	Baluarte	Culiong	Dinaratan	Kaliwakiw	Lucbuban
0.03-0.20	0.64	0.018	0.39	0.039	2.64	1.05	0.67
0.21-0.50	0.087	0.035	0.0079	0.013	0.18	0.052	0.14
0.51-1.00	0.13	0.079	0.0042	0.042	0.11	0.037	0.13
1.01-2.00	0.26	0.22	0.0002	0.1	0.2	0.018	0.13
2.01-5.00	0.42	0.12	0	1.09	0.093	0.0064	0.049
> 5.00	0.083	0.036	0	0.23	0.0036	0	0

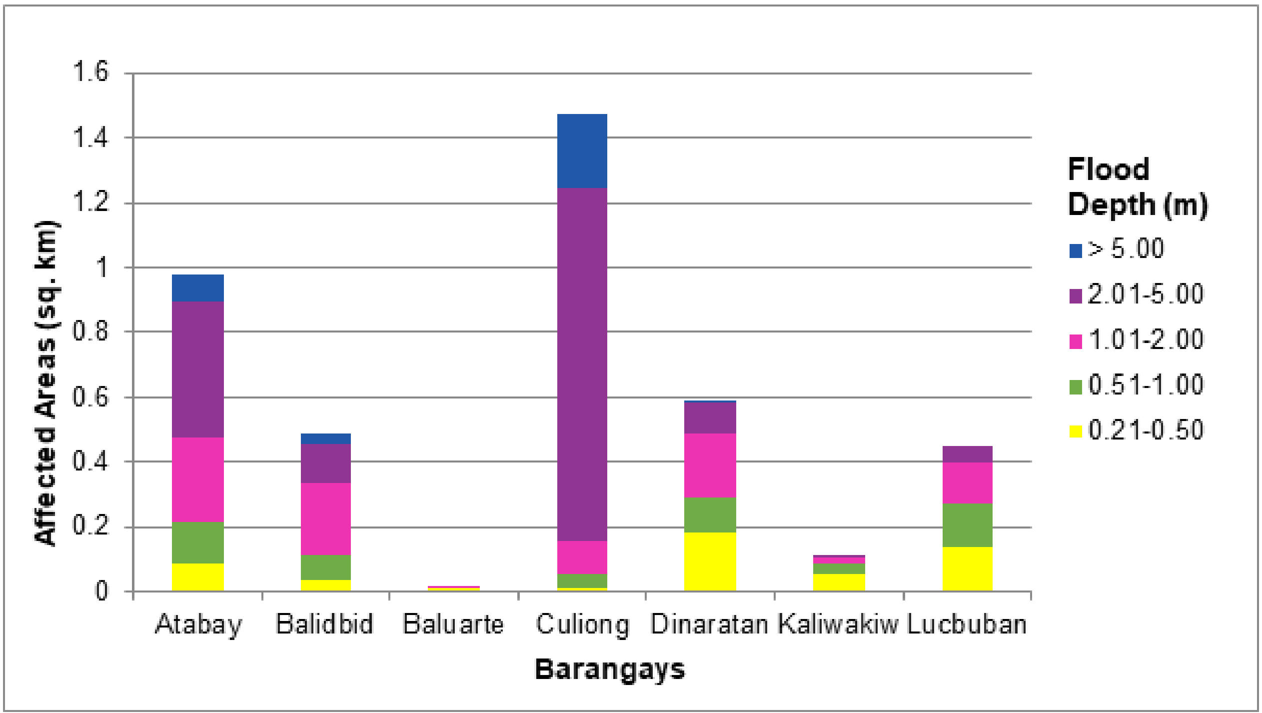


Figure 71. Affected Areas in Salcedo, Ilocos Sur during 5-Year Rainfall Return Period

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Salcedo (in sq. km)					
	Maligcong	Pias	Poblacion Norte	Poblacion Sur	San Tiburcio	Sorioan
0.03-0.20	1.87	0.44	0.052	0.12	0.94	2.13
0.21-0.50	0.079	0.13	0.007	0.063	0.17	0.31
0.51-1.00	0.05	0.46	0.00018	0.13	0.15	0.32
1.01-2.00	0.051	0.6	0.00014	0.23	0.46	0.22
2.01-5.00	0.0053	0.49	0.0017	0.29	0.29	0.24
> 5.00	0	0.096	0	0.038	0.0008	0.03

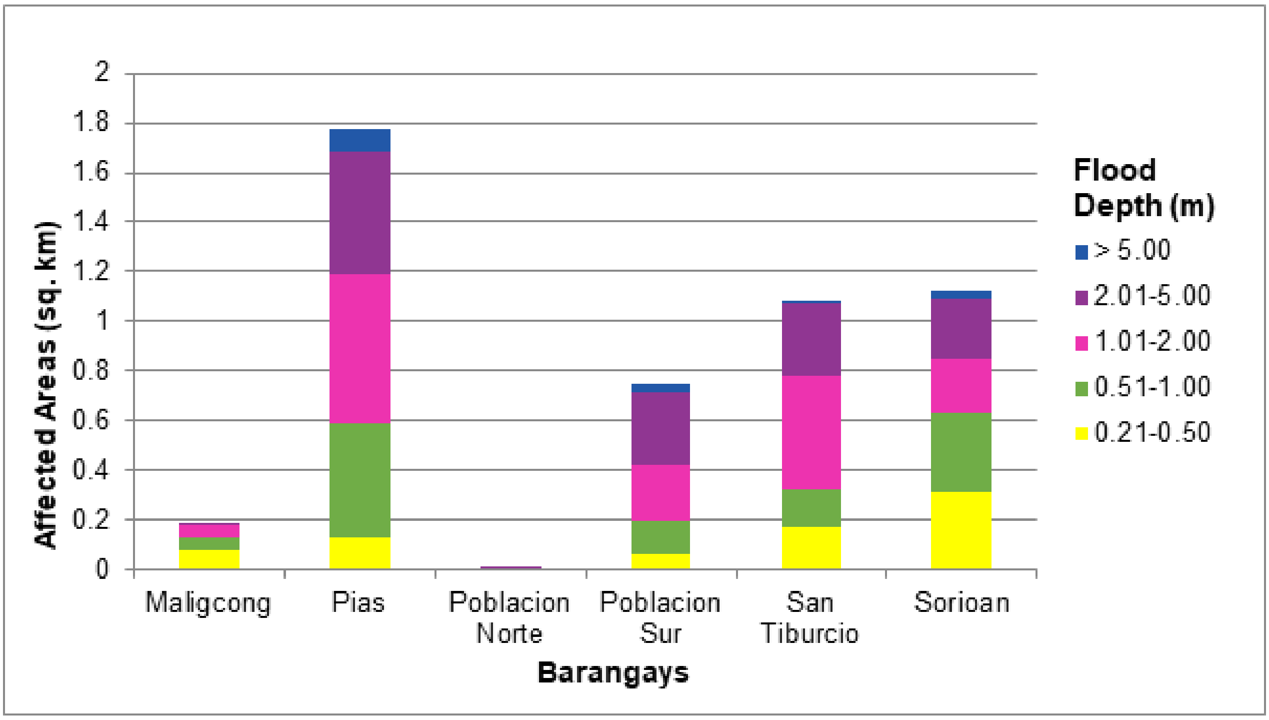


Figure 72. Affected Areas in Salcedo, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 26.03% of the municipality of Santa Cruz with an area of 105.955 sq. km. will experience flood levels of less than 0.20 meters. 2.27% of the area will experience flood levels of 0.21 to 0.50 meters while 2.26%, 3.49%, 2.08%, and 0.31% 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 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)								
	Bacsayan	Banay	Besalan	Bugbuga	Calaoaan	Camanggaan	Coscosnong	Daligan	Gabor Norte
0.03-0.20	0.8	1.07	1.54	3.93	1.87	1.02	4.61	0.26	0.69
0.21-0.50	0.033	0.087	0.1	0.15	0.15	0.063	0.21	0.0099	0.053
0.51-1.00	0.03	0.069	0.083	0.057	0.14	0.037	0.11	0.0008	0.049
1.01-2.00	0.031	0.13	0.088	0.044	0.14	0.026	0.15	0	0.015
2.01-5.00	0.0044	0.11	0.011	0.082	0.078	0.0042	0.26	0	0.0048
> 5.00	0	0	0	0.052	0.0048	0	0.11	0	0

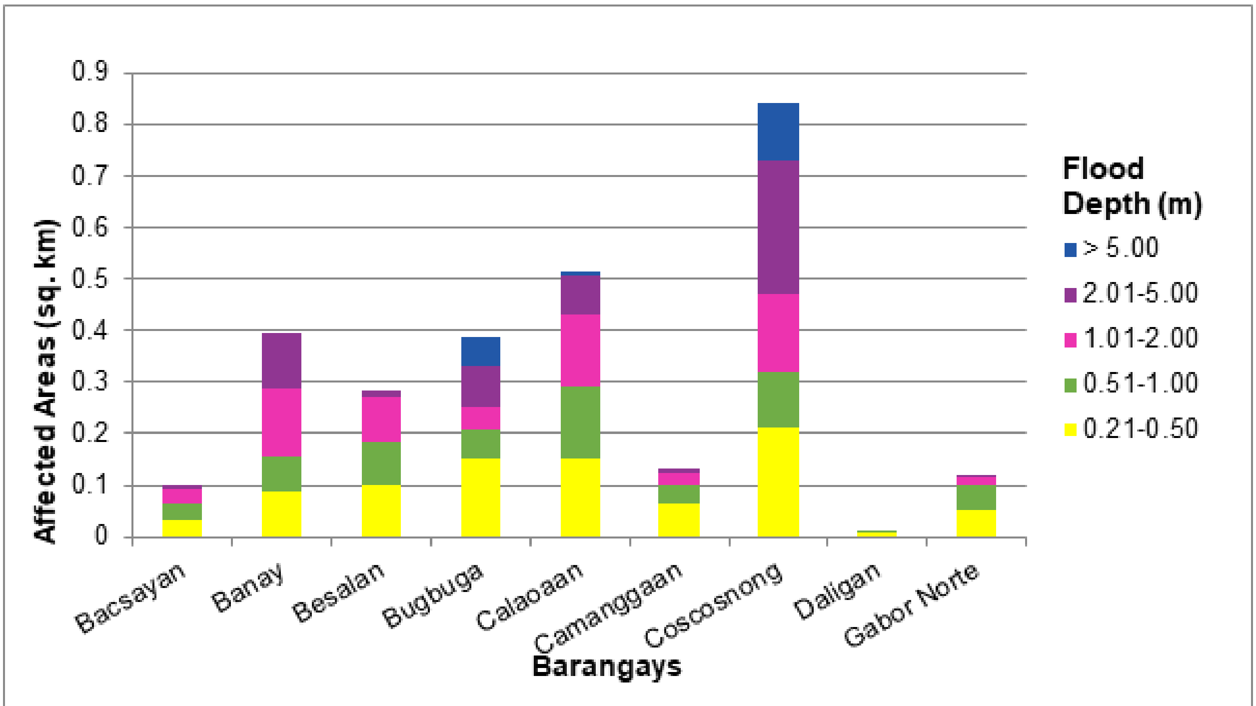


Figure 73. Affected Areas in Santa Cruz, Ilocos Sur during 5-Year Rainfall Return Period

Table 36. 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)								
	Lantag	Las-Ud	Padaoil	Pilar	Poblacion Este	Poblacion Norte	Poblacion Sur	Poblacion Weste	Quinfermin
0.03-0.20	1.08	0.00084	1.74	0.27	0.12	0.057	0.077	0.071	0.96
0.21-0.50	0.32	0.00091	0.068	0.099	0.0007	0.027	0.011	0.019	0.037
0.51-1.00	0.26	0.0044	0.032	0.15	0	0.0083	0.0067	0.034	0.042
1.01-2.00	0.097	0.11	0.035	0.095	0	0.0061	0.0026	0.012	0.027
2.01-5.00	0.071	0.055	0.05	0.058	0	0.000052	0.0012	0.0076	0.0014
> 5.00	0.0029	0	0	0	0	0	0	0	0

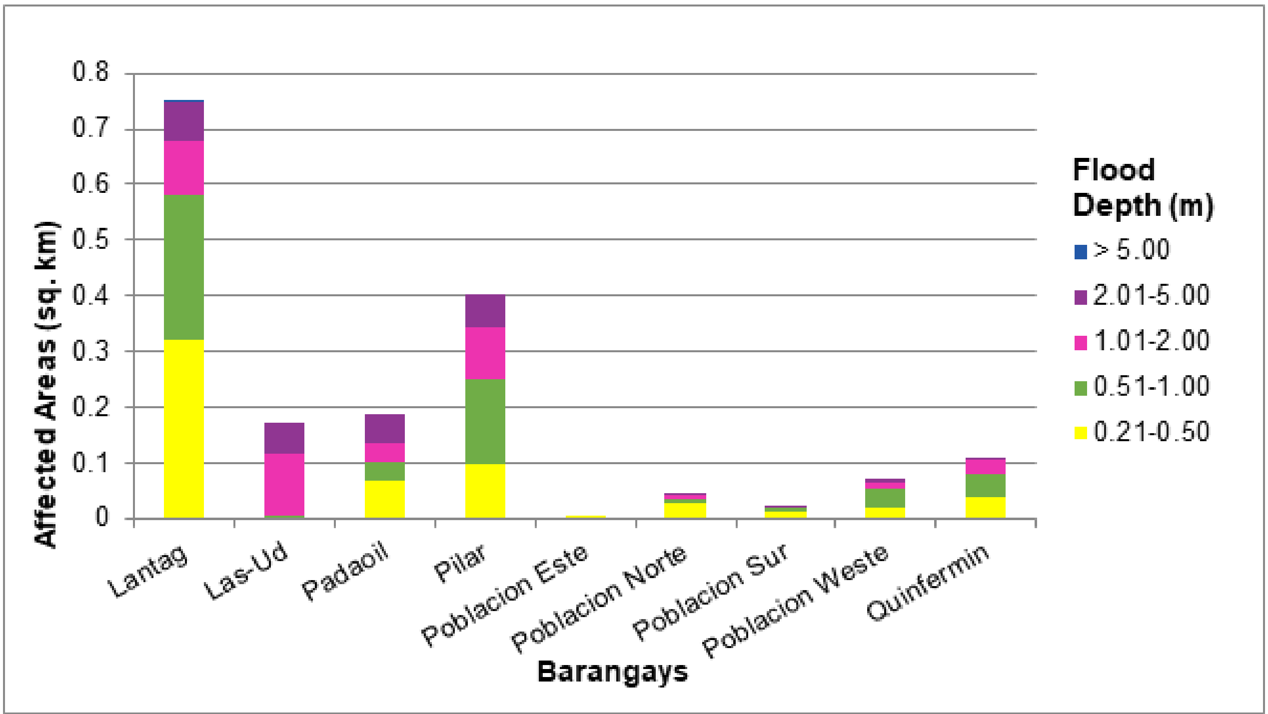


Figure 74. Affected Areas in Santa Cruz, Ilocos Sur during 5-Year Rainfall Return Period

Table 37. 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)							
	Quinsoriano	San Jose	Saoat	Sidaoen	Suyo	Tampugo	Villa Hermosa	Villa Laurencia
0.03-0.20	0.61	1.1	0.34	0.14	0.3	0.76	0.12	4.04
0.21-0.50	0.11	0.12	0.16	0.051	0.13	0.055	0.1	0.24
0.51-1.00	0.15	0.075	0.28	0.14	0.048	0.071	0.36	0.16
1.01-2.00	0.37	0.0011	0.24	0.018	0.013	0.2	1.72	0.13
2.01-5.00	0.31	0	0.032	0.00036	0.0079	0.18	0.84	0.038
> 5.00	0.15	0	0.0077	0	0	0	0	0.000002

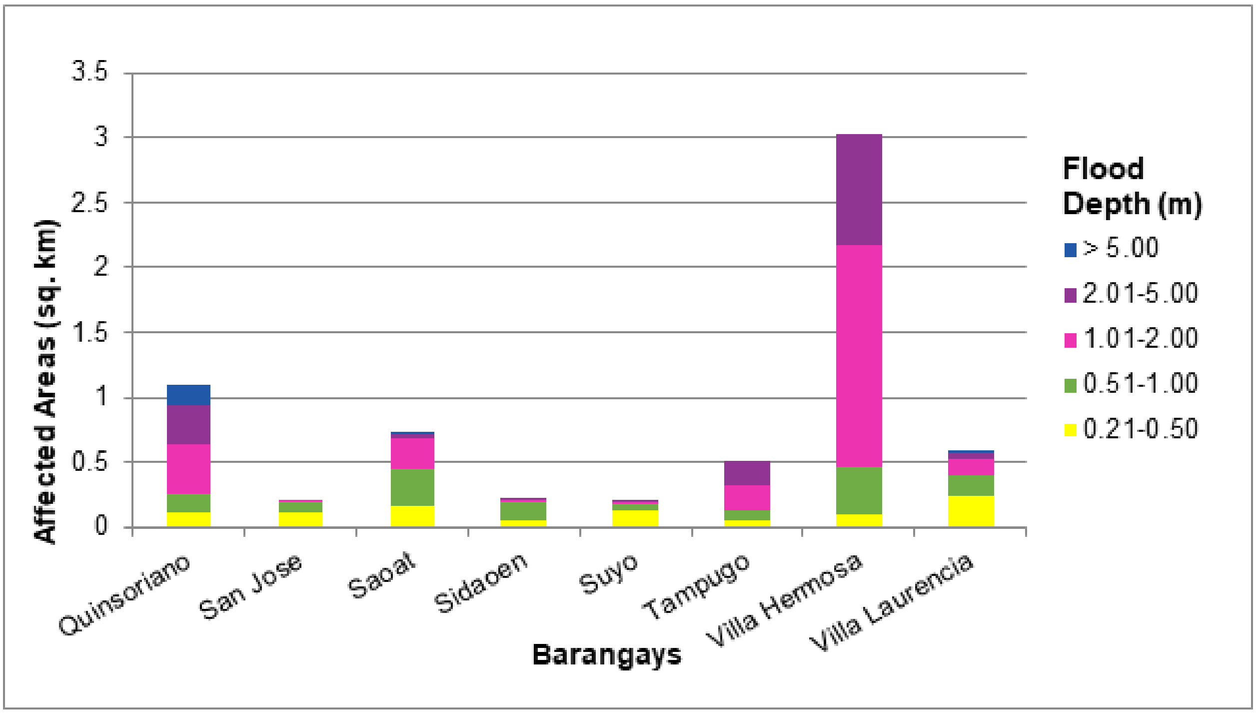


Figure 75. Affected Areas in Santa Cruz, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 38.07% of the municipality of Santa Lucia with an area of 43.877 sq. km. will experience flood levels of less than 0.20 meters. 6.46% of the area will experience flood levels of 0.21 to 0.50 meters while 8.36%, 12.72%, 12.20%, and 2.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Alincaoeg	Angkileng	Arangin	Ayusan	Banbanaba	Bani	Bao-As	Barangobong	Buliclic	Burgos	Cabaritan
0.03-0.20	1.57	0.15	0.72	0.037	1.3	0.26	0.054	0.26	1.66	0	0.2
0.21-0.50	0.097	0.031	0.13	0.053	0.1	0.095	0.0068	0.15	0.074	0	0.19
0.51-1.00	0.13	0.16	0.17	0.096	0.061	0.058	0.0087	0.19	0.057	0.022	0.31
1.01-2.00	0.079	0.26	0.085	0.24	0.028	0.15	0.039	0.054	0.021	0.24	0.17
2.01-5.00	0.0011	0.011	0.000056	0.043	0.0024	0.36	0.29	0	0.0002	0.023	1.05
> 5.00	0	0	0	0	0	0.017	0	0	0	0	0.17

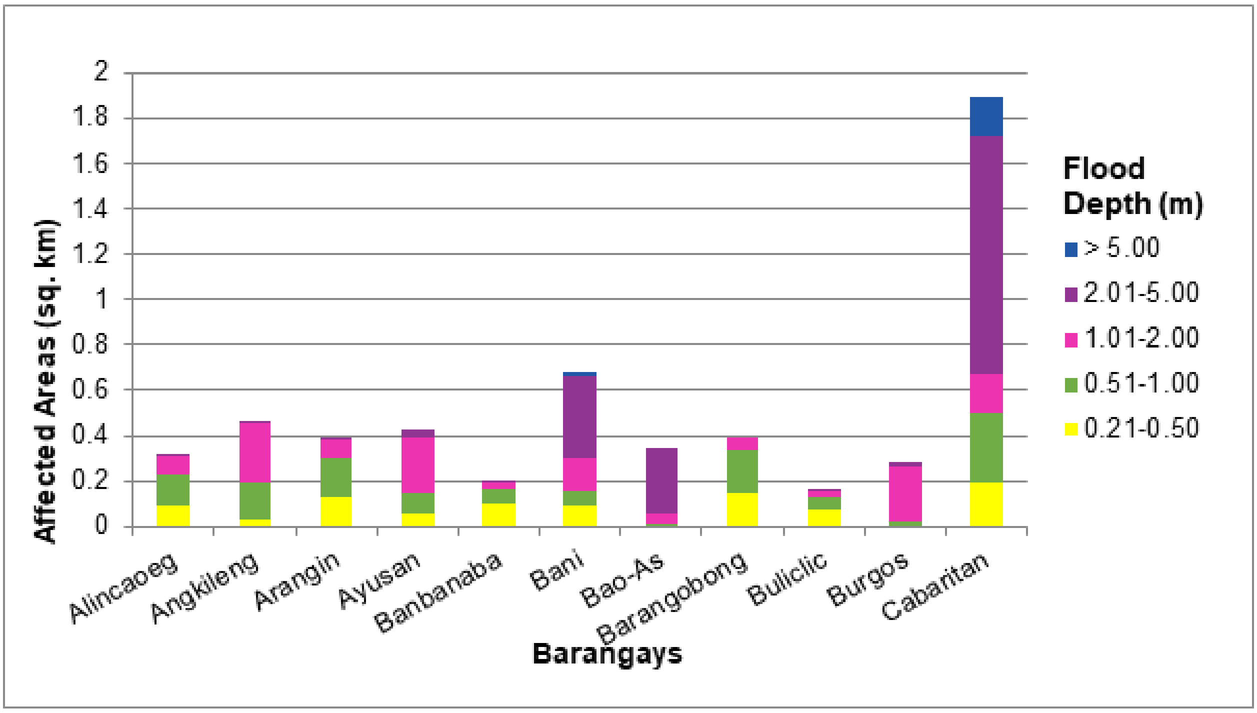


Figure 76. Affected Areas in Santa Lucia, Ilocos Sur during 5-Year Rainfall Return Period

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Catayagan	Conconig East	Conconig West	Damacuag	Luba	Lubong	Nagrebcan	Nagtablaan	Namatican	Nangalisan	Palali Norte
0.03-0.20	0.014	1.07	1.19	0.44	0	0.15	0	0.29	0.43	0.023	1.6
0.21-0.50	0.025	0.21	0.19	0.18	0	0.0028	0	0.083	0.042	0.018	0.18
0.51-1.00	0.025	0.18	0.13	0.2	0.0005	0	0.0029	0.13	0.078	0.055	0.21
1.01-2.00	0.014	0.12	0.11	0.23	0.04	0	0.29	0.096	0.11	0.36	0.14
2.01-5.00	0	0.054	0.0083	1.27	0.0016	0	0.23	0.18	0.6	0.19	0.0055
> 5.00	0	0.00007	0	0.63	0	0	0	0.11	0.075	0	0

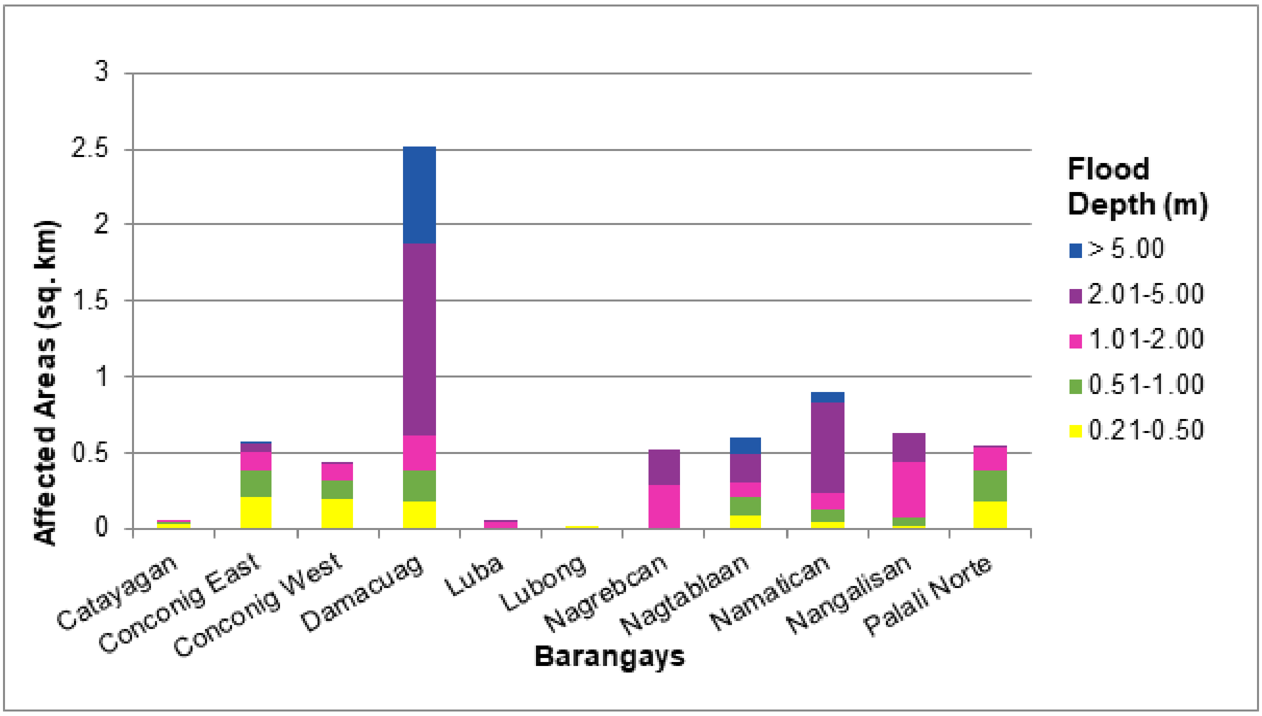


Figure 77. Affected Areas in Santa Lucia, Ilocos Sur during 5-Year Rainfall Return Period

Table 40. Affected Areas in Santa Lucia, Ilocos Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Palali Sur	Paoc Norte	Paoc Sur	Paratong	Pila East	Pila West	Quinabalayangan	Ronda	San Juan	San Pedro	Sapang
0.03-0.20	0.61	0.16	0.42	0.012	1.08	0.26	0.00077	0.0099	0.042	1.15	1.54
0.21-0.50	0.25	0.057	0.14	0.01	0.11	0.091	0.0027	0.065	0.031	0.13	0.092
0.51-1.00	0.17	0.15	0.17	0.04	0.15	0.11	0.025	0.29	0.14	0.087	0.063
1.01-2.00	0.11	0.26	0.25	0.36	0.14	0.16	0.19	0.87	0.31	0.011	0.042
2.01-5.00	0.013	0.16	0.12	0.21	0.0013	0.0077	0.22	0.16	0.14	0	0.0028
> 5.00	0	0.029	0	0	0	0	0	0.0026	0	0	0

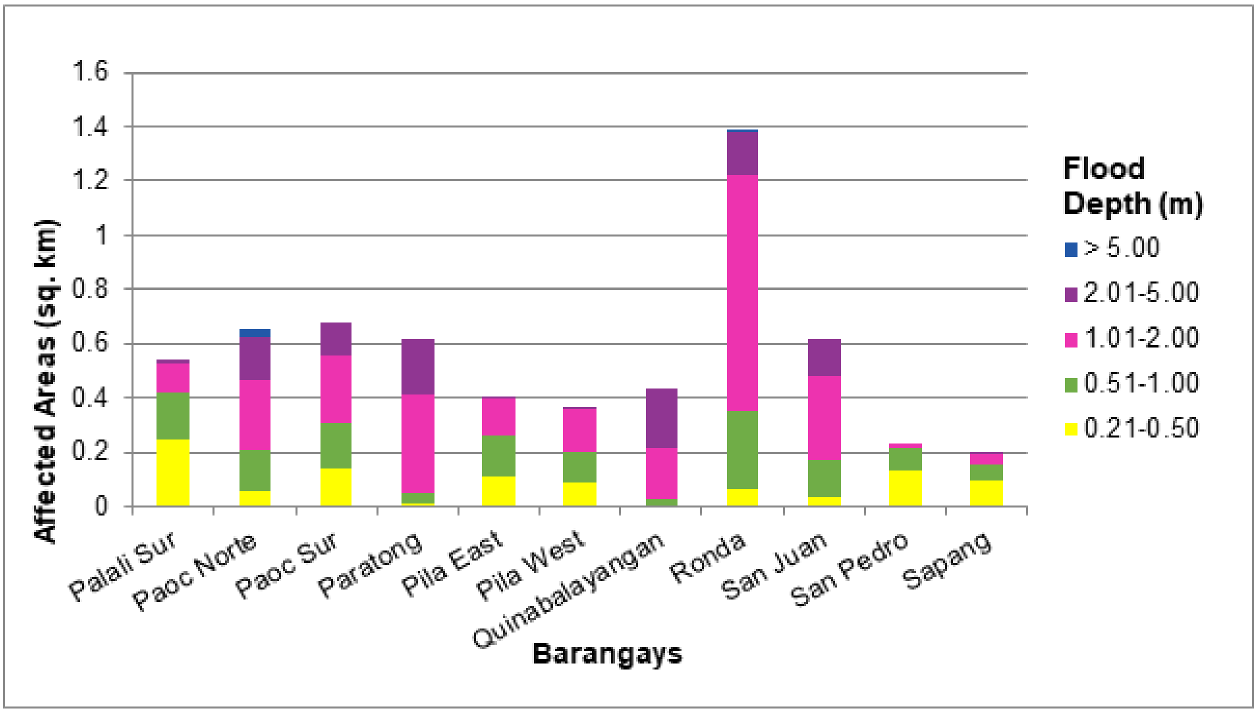


Figure 78. Affected Areas in Santa Lucia, Ilocos Sur during 5-Year Rainfall Return Period

For the 25-year return period, 2.79% of the municipality of Candon City with an area of 80.175 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%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Candon City, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Candon City (in sq. km)			
	Allangigan Primero	Cubcubboot	Palacapac	Parioc Primero
0.03-0.20	0.65	0.38	1.06	0.15
0.21-0.50	0.027	0.015	0.047	0.0042
0.51-1.00	0.016	0.0025	0.031	0.0026
1.01-2.00	0.0074	0.0008	0.011	0.0019
2.01-5.00	0.004	0.0003	0.0014	0
> 5.00	0	0	0	0

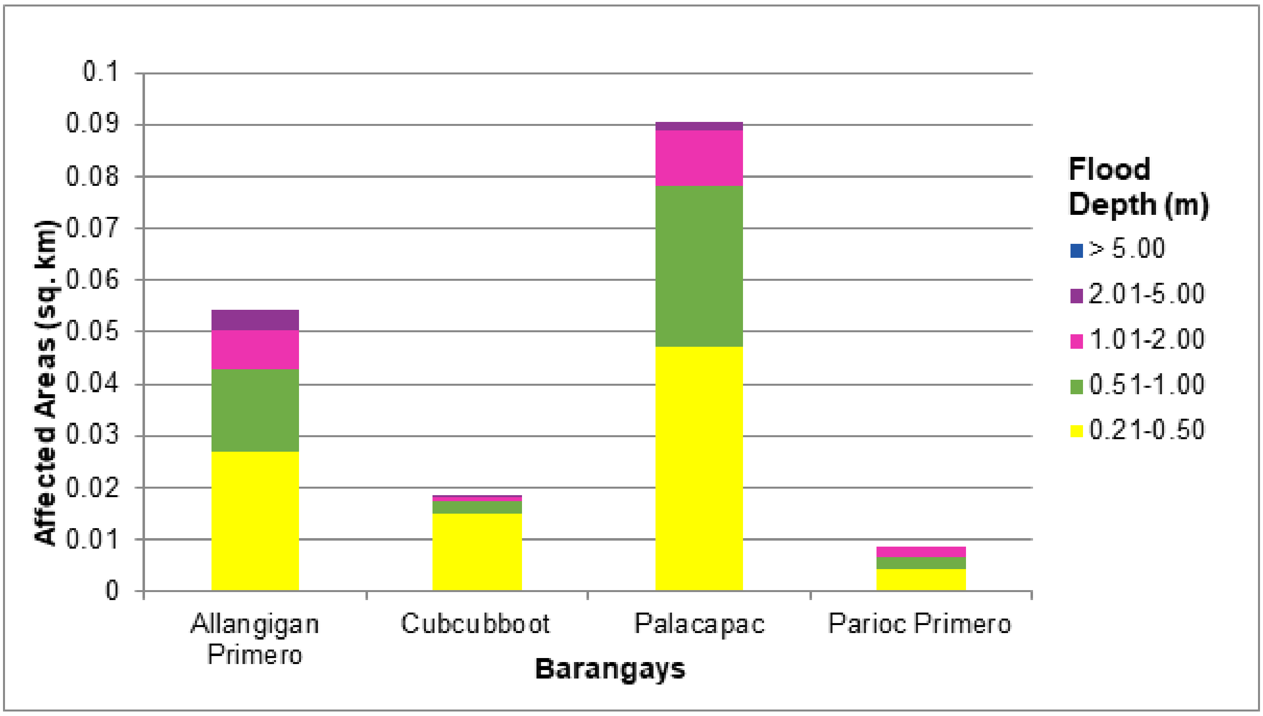


Figure 79. Affected Areas in Candon City, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 14.34% of the municipality of Salcedo with an area of 69.23 sq. km. will experience flood levels of less than 0.20 meters. 1.59% of the area will experience flood levels of 0.21 to 0.50 meters while 1.89%, 3.25%, 6.08%, and 1.75% 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 Salcedo, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Salcedo (in sq. km)						
	Atabay	Balidbid	Baluarte	Culiong	Dinaratan	Kaliwakiw	Lucbuban
0.03-0.20	0.6	0.008	0.38	0	2.56	1.01	0.58
0.21-0.50	0.047	0.013	0.0097	0.0024	0.16	0.061	0.12
0.51-1.00	0.091	0.055	0.0063	0.015	0.15	0.046	0.14
1.01-2.00	0.2	0.17	0.0011	0.076	0.17	0.033	0.18
2.01-5.00	0.57	0.23	0	0.74	0.19	0.014	0.094
> 5.00	0.11	0.04	0	0.68	0.0056	0	0

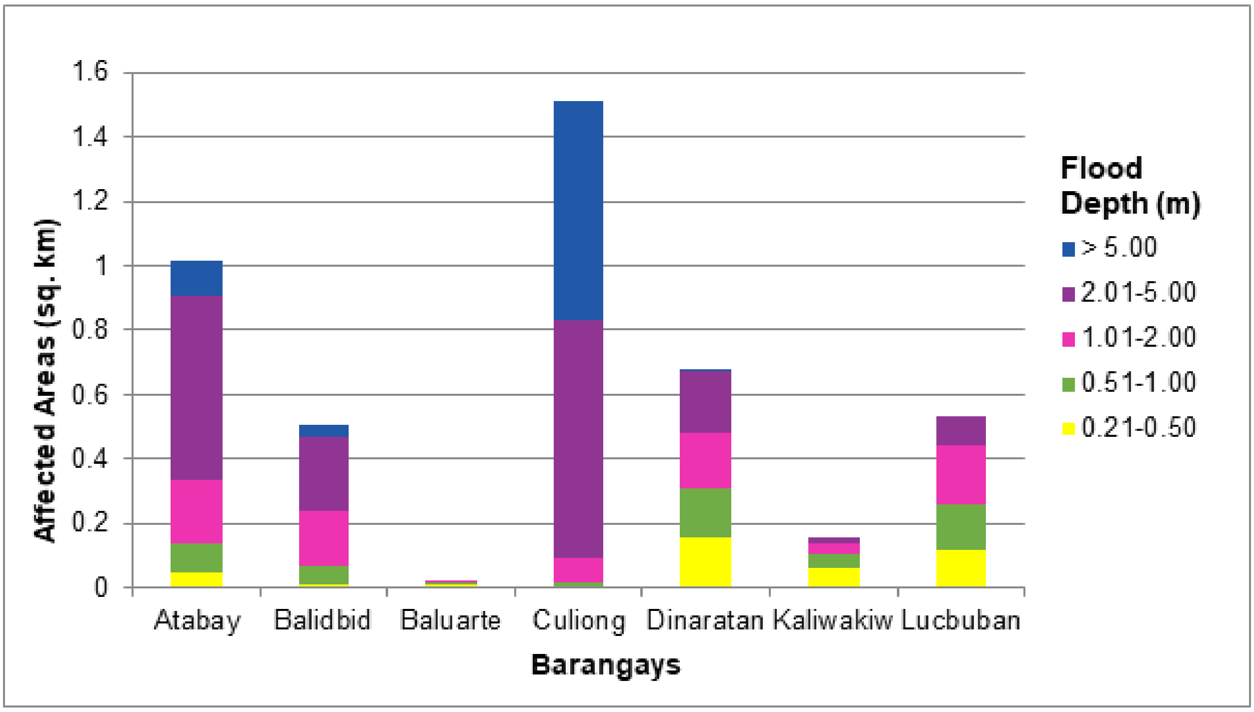


Figure 80. Affected Areas in Salcedo, Ilocos Sur during 25-Year Rainfall Return Period

Table 43. Affected Areas in Salcedo, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Salcedo (in sq. km)					
	Maligcong	Pias	Poblacion Norte	Poblacion Sur	San Tiburcio	Sorioan
0.03-0.20	1.82	0.28	0.025	0.073	0.73	1.86
0.21-0.50	0.094	0.085	0.027	0.043	0.12	0.32
0.51-1.00	0.054	0.22	0.0061	0.066	0.14	0.32
1.01-2.00	0.057	0.63	0.00024	0.23	0.16	0.34
2.01-5.00	0.03	0.82	0.0018	0.41	0.75	0.36
> 5.00	0	0.17	0	0.05	0.11	0.048

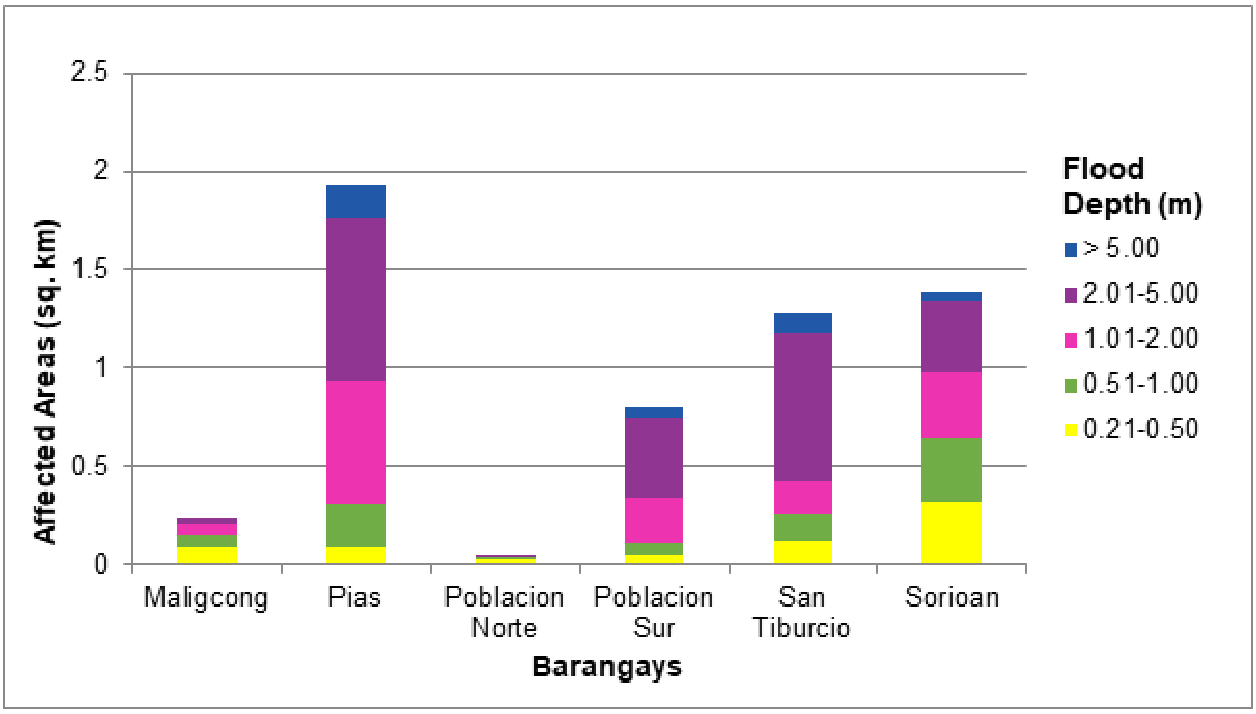


Figure 81. Affected Areas in Salcedo, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 24.29% of the municipality of Santa Cruz with an area of 105.955 sq. km. will experience flood levels of less than 0.20 meters. 2.28% of the area will experience flood levels of 0.21 to 0.50 meters while 2.36%, 3.57%, 3.43%, and 0.52% 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 44. 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)								
	Bacsayan	Banay	Besalan	Bugbuga	Calaoaan	Camanggaan	Coscosnong	Daligan	Gabor Norte
0.03-0.20	0.78	1	1.33	3.82	1.73	0.98	4.4	0.26	0.65
0.21-0.50	0.036	0.089	0.11	0.18	0.16	0.067	0.28	0.014	0.057
0.51-1.00	0.031	0.077	0.075	0.073	0.16	0.055	0.15	0.0029	0.052
1.01-2.00	0.039	0.13	0.14	0.049	0.19	0.04	0.15	0.00006	0.04
2.01-5.00	0.016	0.16	0.16	0.097	0.13	0.013	0.28	0	0.0081
> 5.00	0	0.00034	0.0026	0.1	0.01	0	0.2	0	0

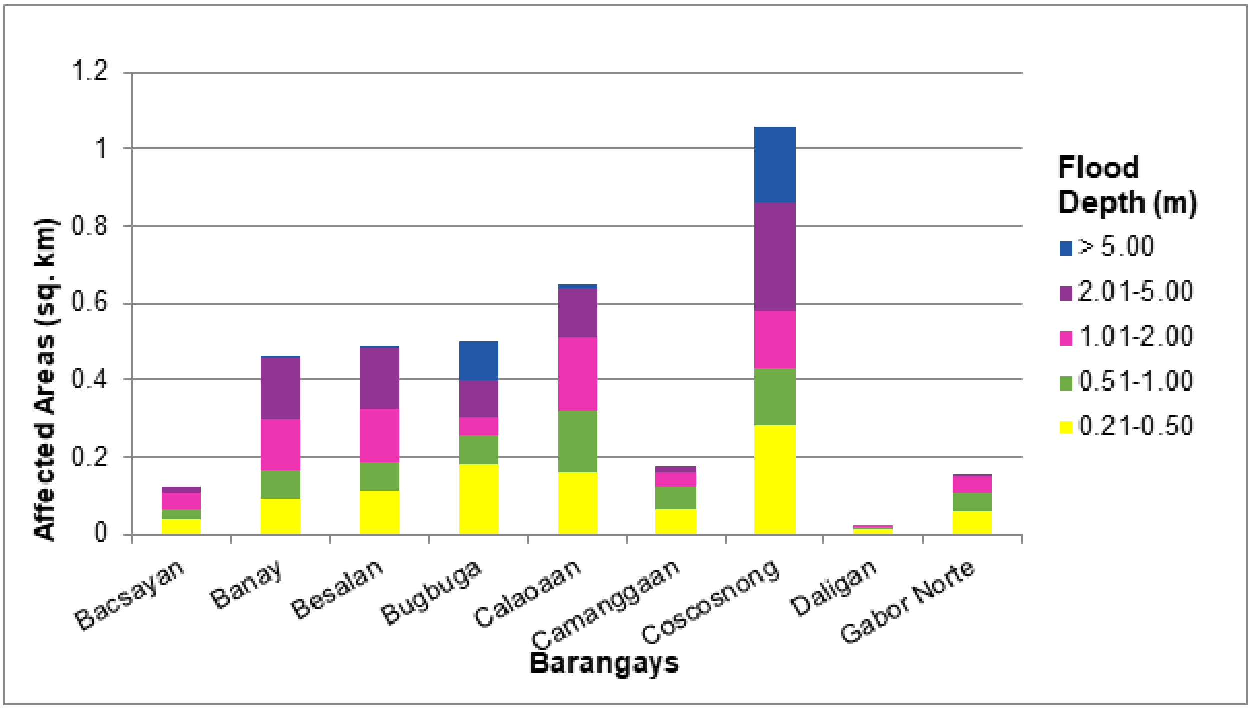


Figure 82. Affected Areas in Santa Cruz, Ilocos Sur during 25-Year Rainfall Return Period

Table 45. 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)								
	Lantag	Las-Ud	Padaoil	Pilar	Poblacion Este	Poblacion Norte	Poblacion Sur	Poblacion Weste	Quinfermin
0.03-0.20	0.88	0.00038	1.69	0.2	0.12	0.021	0.069	0.061	0.93
0.21-0.50	0.25	0.00071	0.076	0.11	0.0023	0.031	0.014	0.016	0.041
0.51-1.00	0.4	0.0021	0.046	0.14	0	0.038	0.011	0.035	0.04
1.01-2.00	0.19	0.1	0.033	0.14	0	0.0099	0.0035	0.021	0.05
2.01-5.00	0.1	0.073	0.078	0.077	0	0.00023	0.0013	0.0095	0.007
> 5.00	0.0071	0	0.0035	0	0	0	0	0	0

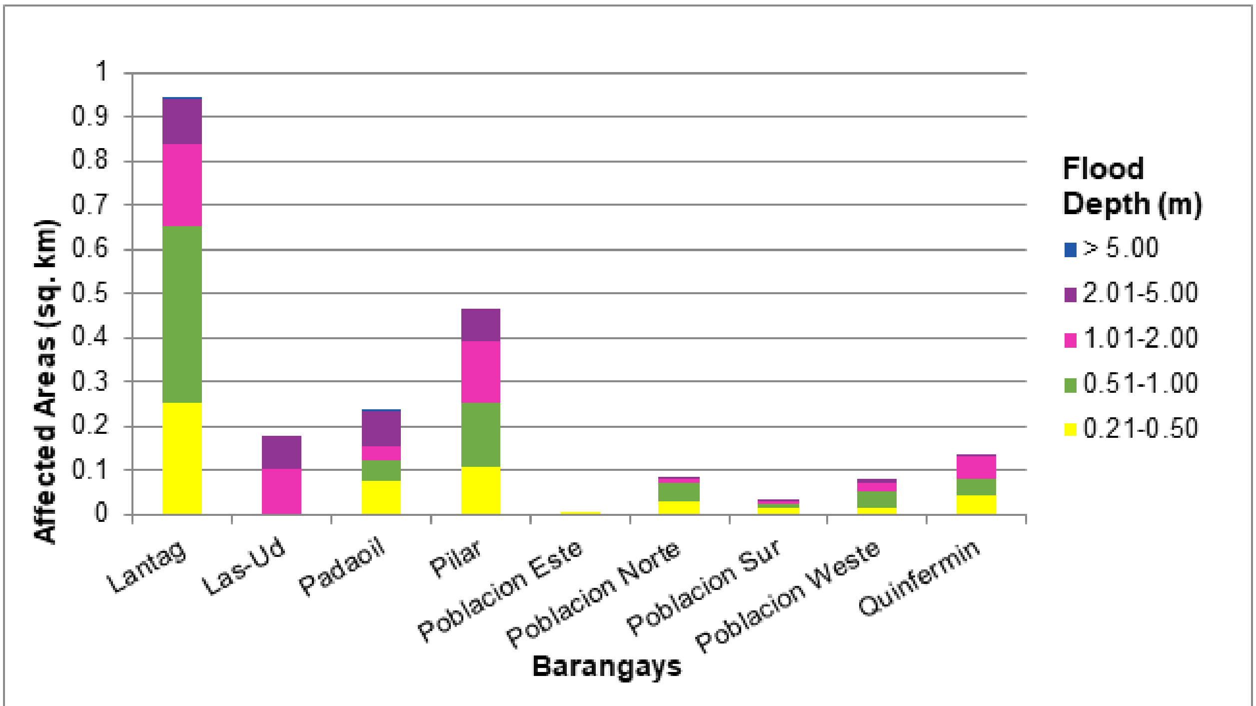


Figure 83. Affected Areas in Santa Cruz, Ilocos Sur during 25-Year Rainfall Return Period

Table 46. 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)							
	Quinsoriano	San Jose	Saoat	Sidaoen	Suyo	Tampugo	Villa Hermosa	Villa Laurencia
0.03-0.20	0.55	1.05	0.26	0.13	0.25	0.65	0.062	3.86
0.21-0.50	0.098	0.1	0.08	0.05	0.16	0.033	0.085	0.28
0.51-1.00	0.15	0.13	0.27	0.15	0.057	0.02	0.15	0.19
1.01-2.00	0.37	0.019	0.38	0.021	0.016	0.053	1.41	0.19
2.01-5.00	0.37	0	0.061	0.00029	0.0092	0.45	1.44	0.094
> 5.00	0.17	0	0.0094	0	0	0.053	0	0.00011

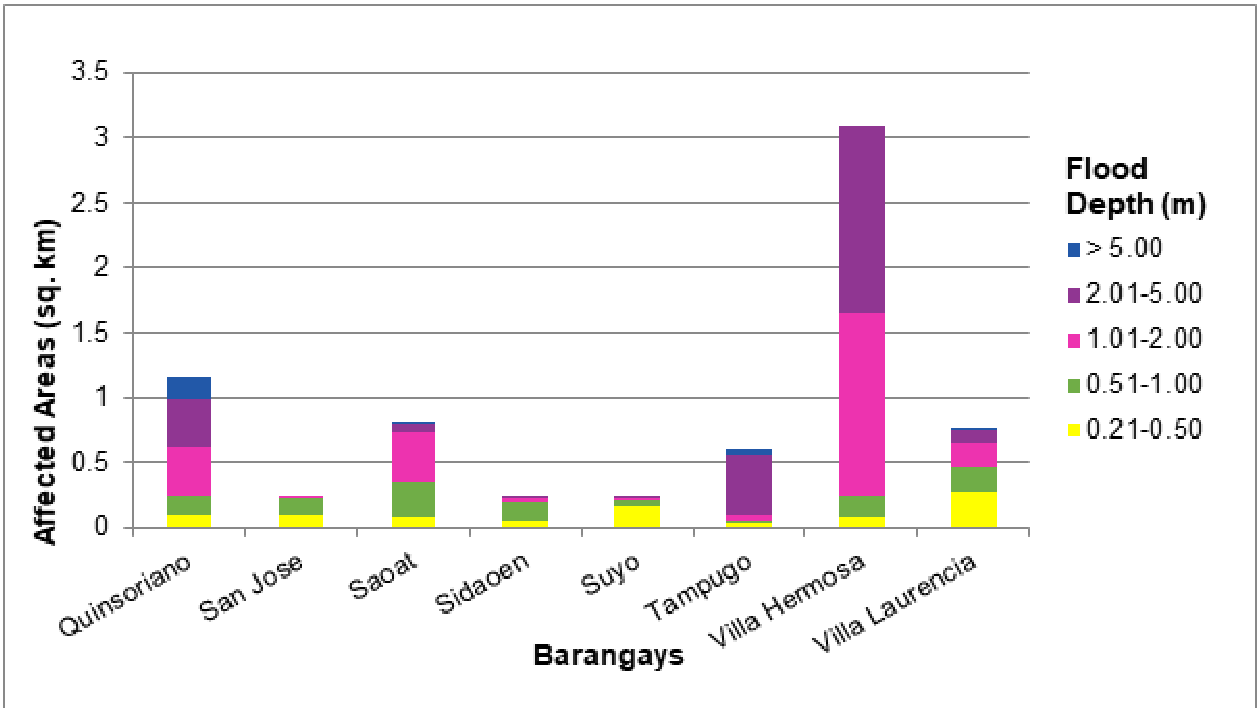


Figure 84. Affected Areas in Santa Cruz, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 32.84% of the municipality of Santa Lucia with an area of 43.877 sq. km. will experience flood levels of less than 0.20 meters. 5.15% of the area will experience flood levels of 0.21 to 0.50 meters while 6.38%, 12.36%, 17.77%, and 5.78% 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 Santa Lucia, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Alincaoeg	Angkileng	Arangin	Ayusan	Banbanaba	Bani	Bao-As	Barangobong	Buliclic	Burgos	Cabaritan
0.03-0.20	1.48	0.12	0.66	0.0066	1.25	0.081	0.044	0.2	1.61	0	0.015
0.21-0.50	0.12	0.033	0.086	0.01	0.1	0.03	0.0091	0.1	0.078	0	0.0022
0.51-1.00	0.12	0.0098	0.079	0.06	0.09	0.08	0.011	0.21	0.064	0	0.027
1.01-2.00	0.14	0.25	0.24	0.25	0.046	0.21	0.018	0.16	0.049	0.068	0.46
2.01-5.00	0.022	0.21	0.044	0.15	0.0085	0.44	0.32	0	0.0025	0.21	0.76
> 5.00	0	0	0	0	0	0.099	0	0	0	0	0.84

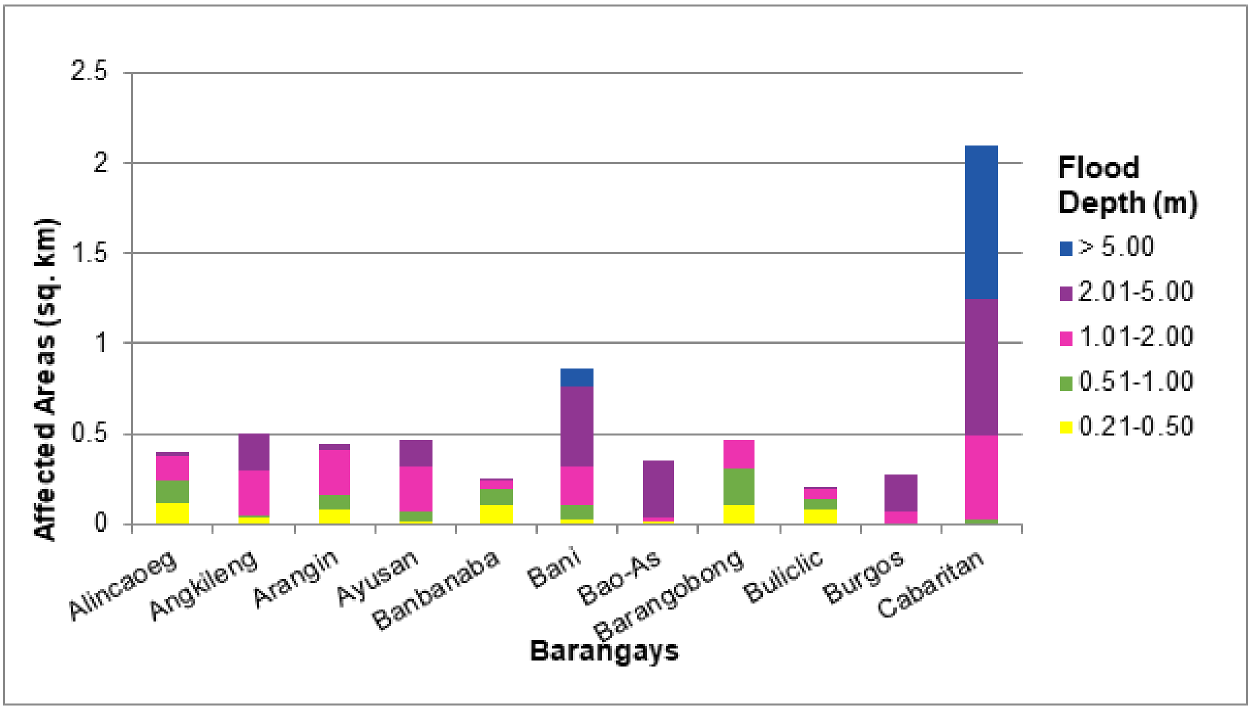


Figure 85. Affected Areas in Santa Lucia, Ilocos Sur during 25-Year Rainfall Return Period

Table 48. Affected Areas in Santa Lucia, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Catayagan	Conconig East	Conconig West	Damacuag	Luba	Lubong	Nagrebcan	Nagtablaan	Namatican	Nangalisan	Palali Norte
0.03-0.20	0.0051	0.95	1.07	0.054	0	0.15	0	0.21	0.38	0.014	1.48
0.21-0.50	0.0073	0.21	0.24	0.2	0	0.0036	0	0.026	0.035	0.011	0.16
0.51-1.00	0.039	0.13	0.08	0.37	0	0.0003	0	0.11	0.022	0.041	0.23
1.01-2.00	0.026	0.22	0.19	0.31	0.027	0	0.028	0.14	0.054	0.17	0.25
2.01-5.00	0.00014	0.12	0.052	0.96	0.015	0	0.5	0.19	0.6	0.42	0.025
> 5.00	0	0.00012	0	1.05	0	0	0	0.21	0.24	0	0

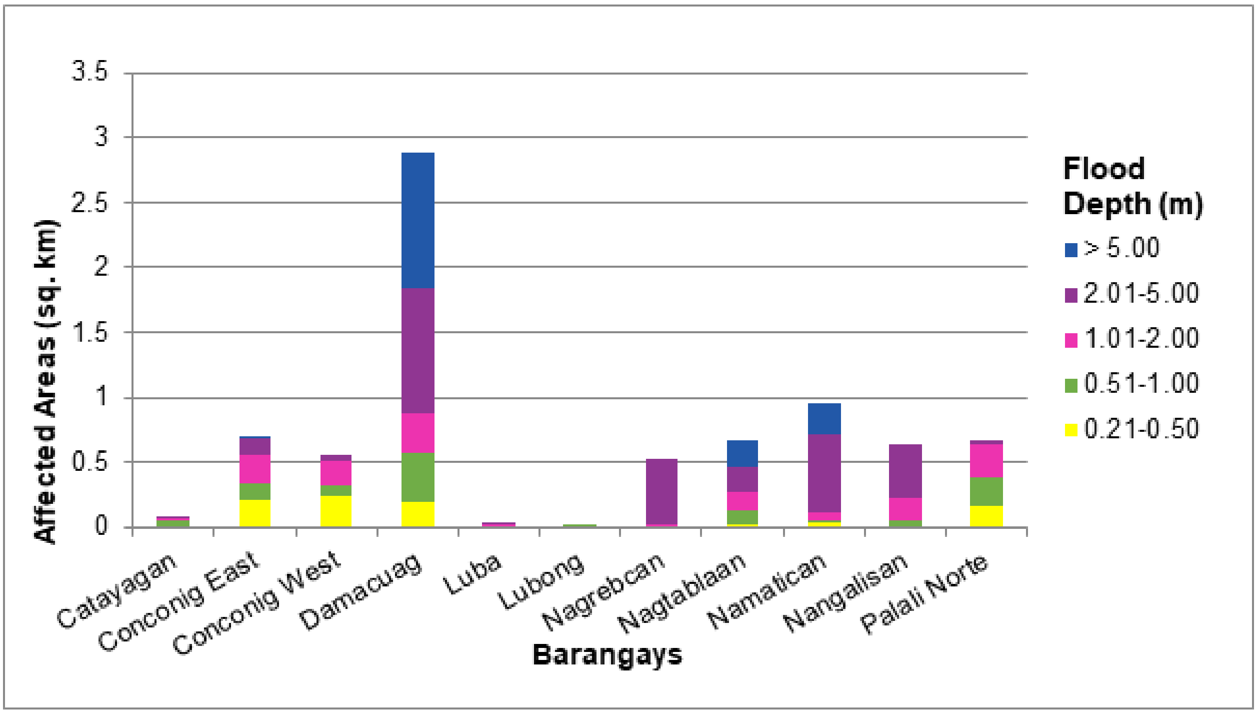


Figure 86. Affected Areas in Santa Lucia, Ilocos Sur during 25-Year Rainfall Return Period

Table 49. Affected Areas in Santa Lucia, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Palali Sur	Paoc Norte	Paoc Sur	Paratong	Pila East	Pila West	Quinabalayangan	Ronda	San Juan	San Pedro	Sapang
0.03-0.20	0.5	0.05	0.3	0.0063	1	0.21	0	0.000018	0.0019	1.09	1.47
0.21-0.50	0.19	0.033	0.15	0.0024	0.092	0.082	0.00093	0.0054	0.013	0.13	0.1
0.51-1.00	0.25	0.053	0.12	0.015	0.13	0.077	0.012	0.12	0.035	0.13	0.085
1.01-2.00	0.17	0.073	0.29	0.14	0.21	0.21	0.078	0.65	0.2	0.033	0.062
2.01-5.00	0.045	0.51	0.25	0.47	0.035	0.041	0.35	0.62	0.41	0.0024	0.015
> 5.00	0	0.094	0	0	0	0	0	0.0026	0	0	0

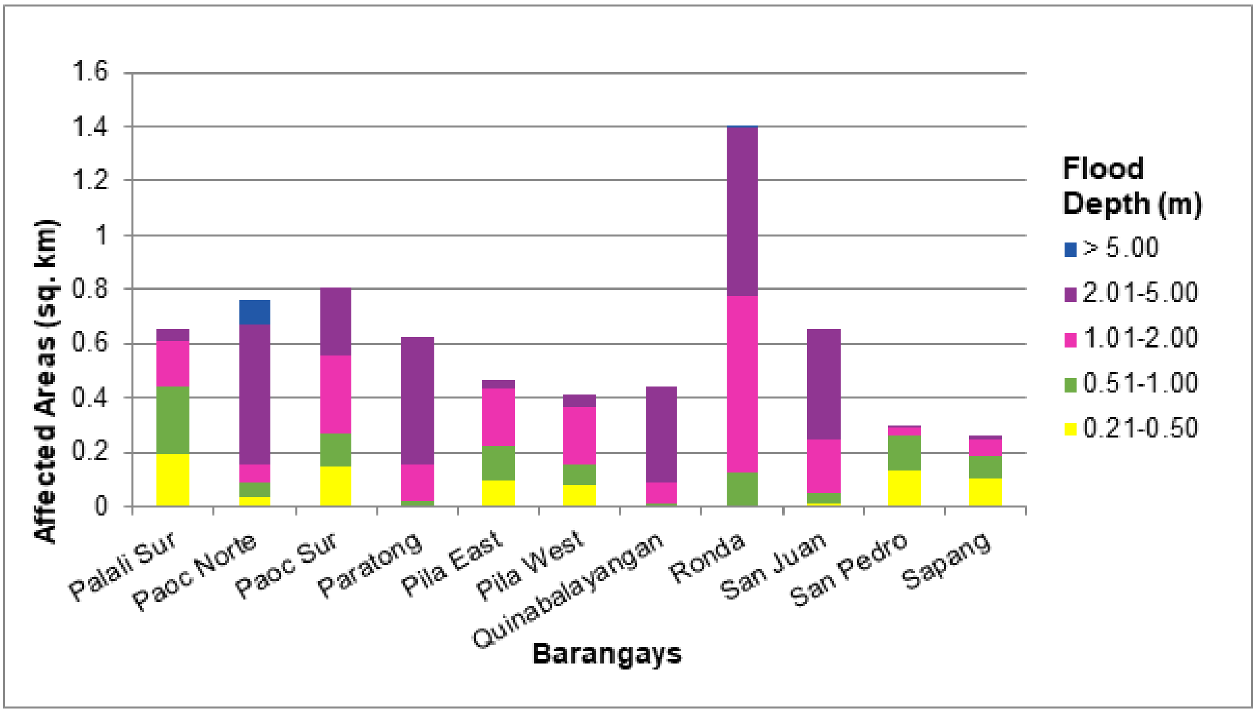


Figure 87. Affected Areas in Santa Lucia, Ilocos Sur during 25-Year Rainfall Return Period

For the 100-year return period, 2.76% of the municipality of Candon City with an area of 80.175 sq. km. will experience flood levels of less than 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.04%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Candon City, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Candon City (in sq. km)			
	Allangigan Primero	Cubcubboot	Palacapac	Parioc Primero
0.03-0.20	0.64	0.38	1.04	0.15
0.21-0.50	0.03	0.018	0.054	0.0056
0.51-1.00	0.016	0.0047	0.034	0.0032
1.01-2.00	0.011	0.0007	0.016	0.0021
2.01-5.00	0.0055	0.0004	0.0032	0
> 5.00	0	0	0	0

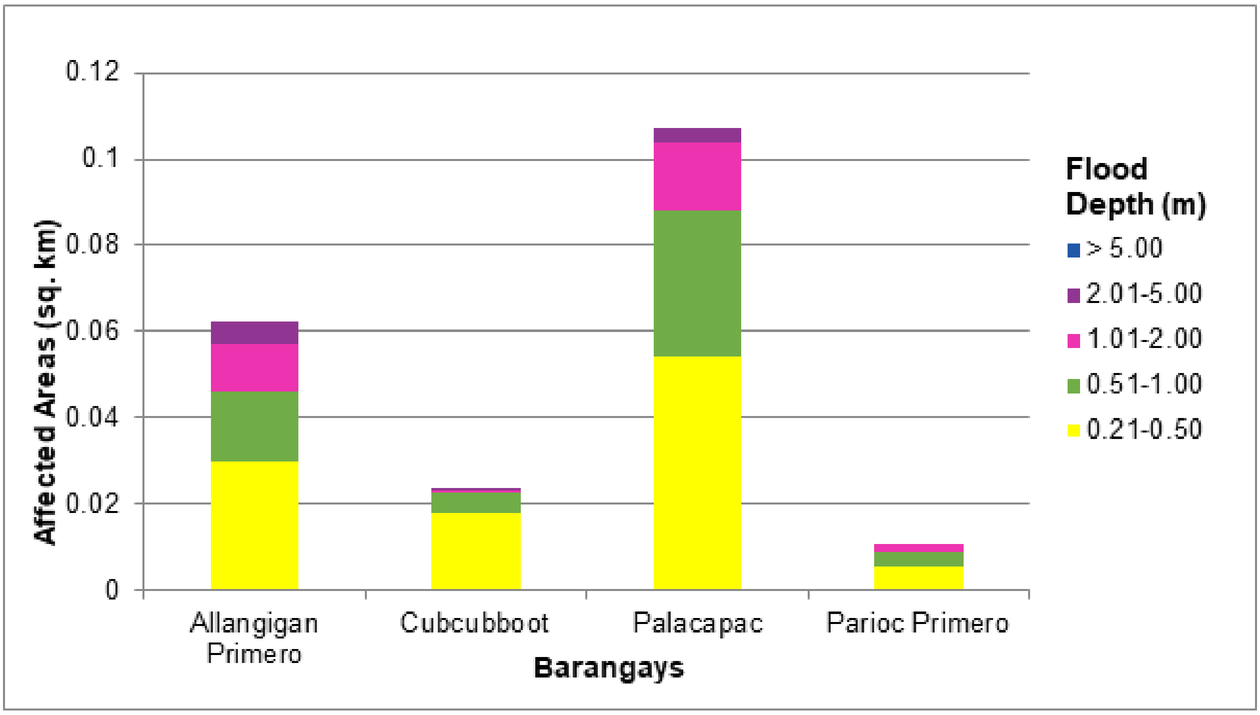


Figure 88. Affected Areas in Candon City, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 13.61% of the municipality of Salcedo with an area of 69.23 sq. km. will experience flood levels of less than 0.20 meters. 1.60% of the area will experience flood levels of 0.21 to 0.50 meters while 1.42%, 2.77%, 5.90%, and 3.67% 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 51. Affected Areas in Salcedo, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Salcedo (in sq. km)						
	Atabay	Balidbid	Baluarte	Culiong	Dinaratan	Kaliwakiw	Lucbuban
0.03-0.20	0.57	0.0043	0.38	0	2.5	0.99	0.53
0.21-0.50	0.051	0.009	0.012	0	0.16	0.065	0.14
0.51-1.00	0.058	0.049	0.0057	0	0.15	0.048	0.12
1.01-2.00	0.16	0.12	0.0035	0.021	0.12	0.044	0.2
2.01-5.00	0.63	0.29	0	0.24	0.29	0.022	0.13
> 5.00	0.15	0.046	0	1.25	0.013	0	0.0016

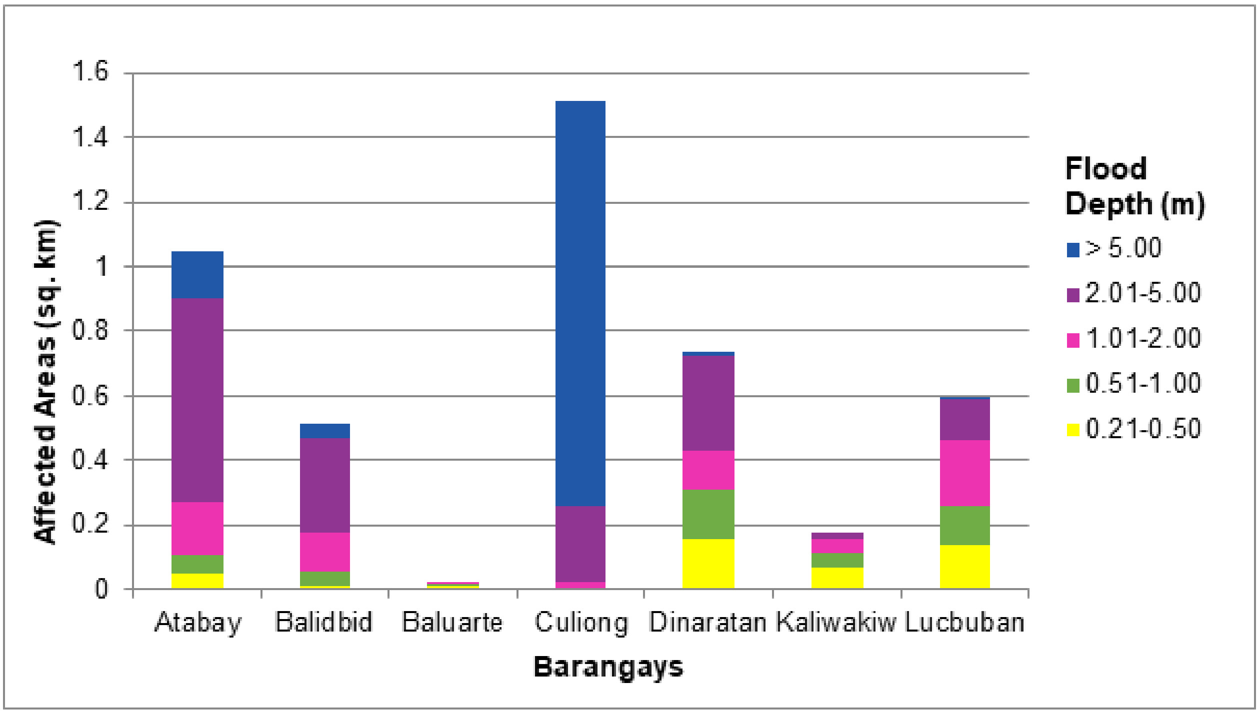


Figure 89. Affected Areas in Salcedo, Ilocos Sur during 100-Year Rainfall Return Period

Table 52. Affected Areas in Salcedo, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Salcedo (in sq. km)					
	Maligcong	Pias	Poblacion Norte	Poblacion Sur	San Tiburcio	Sorioan
0.03-0.20	1.79	0.25	0.016	0.055	0.65	1.69
0.21-0.50	0.11	0.044	0.031	0.036	0.098	0.35
0.51-1.00	0.057	0.05	0.011	0.046	0.1	0.29
1.01-2.00	0.058	0.54	0.00057	0.15	0.13	0.37
2.01-5.00	0.049	0.97	0.0018	0.5	0.49	0.47
> 5.00	0	0.36	0	0.087	0.56	0.072

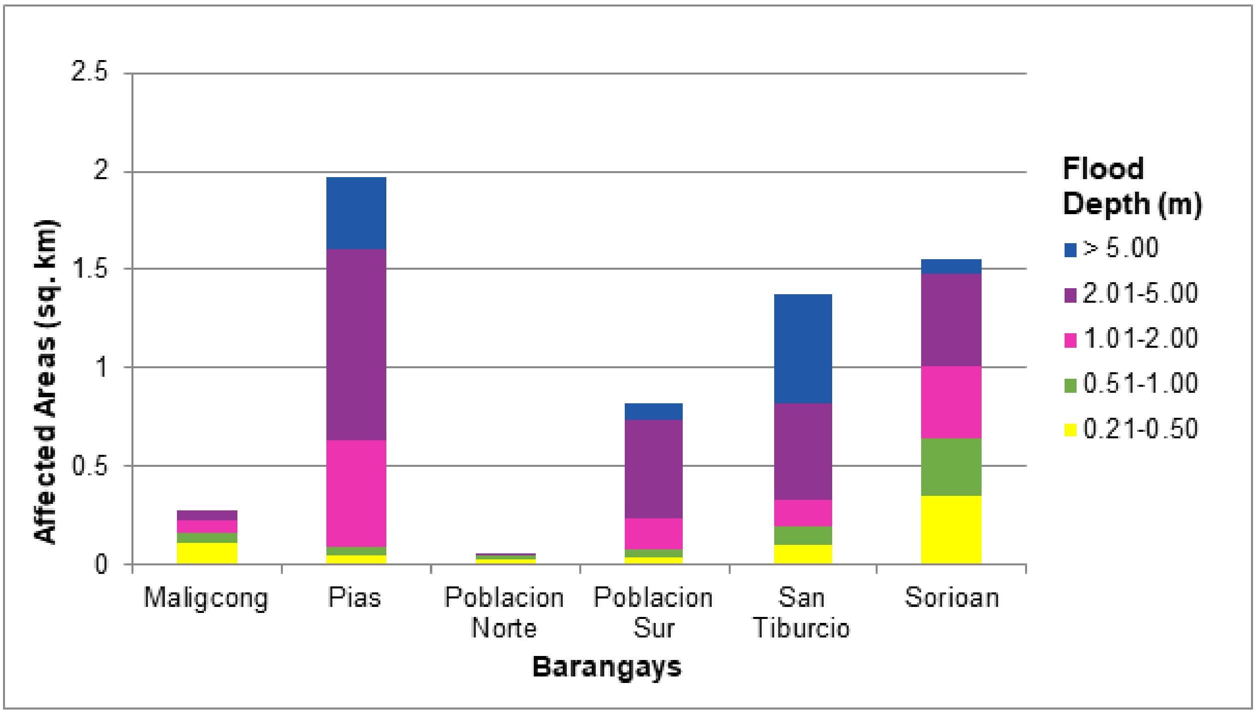


Figure 90. Affected Areas in Salcedo, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 23.26% of the municipality of Santa Cruz with an area of 105.955 sq. km. will experience flood levels of less than 0.20 meters. 2.27% of the area will experience flood levels of 0.21 to 0.50 meters while 2.30%, 3.64%, 4.18%, and 0.82% 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 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)								
	Bacsayan	Banay	Besalan	Bugbuga	Calaoaan	Camanggaan	Coscosnong	Daligan	Gabor Norte
0.03-0.20	0.76	0.92	1.25	3.73	1.64	0.94	4.29	0.25	0.64
0.21-0.50	0.04	0.11	0.098	0.2	0.14	0.059	0.25	0.015	0.063
0.51-1.00	0.03	0.093	0.063	0.086	0.17	0.053	0.2	0.0052	0.052
1.01-2.00	0.044	0.12	0.1	0.054	0.23	0.067	0.15	0.00013	0.051
2.01-5.00	0.026	0.22	0.26	0.098	0.18	0.029	0.29	0	0.011
> 5.00	0	0.0051	0.048	0.15	0.015	0	0.27	0	0

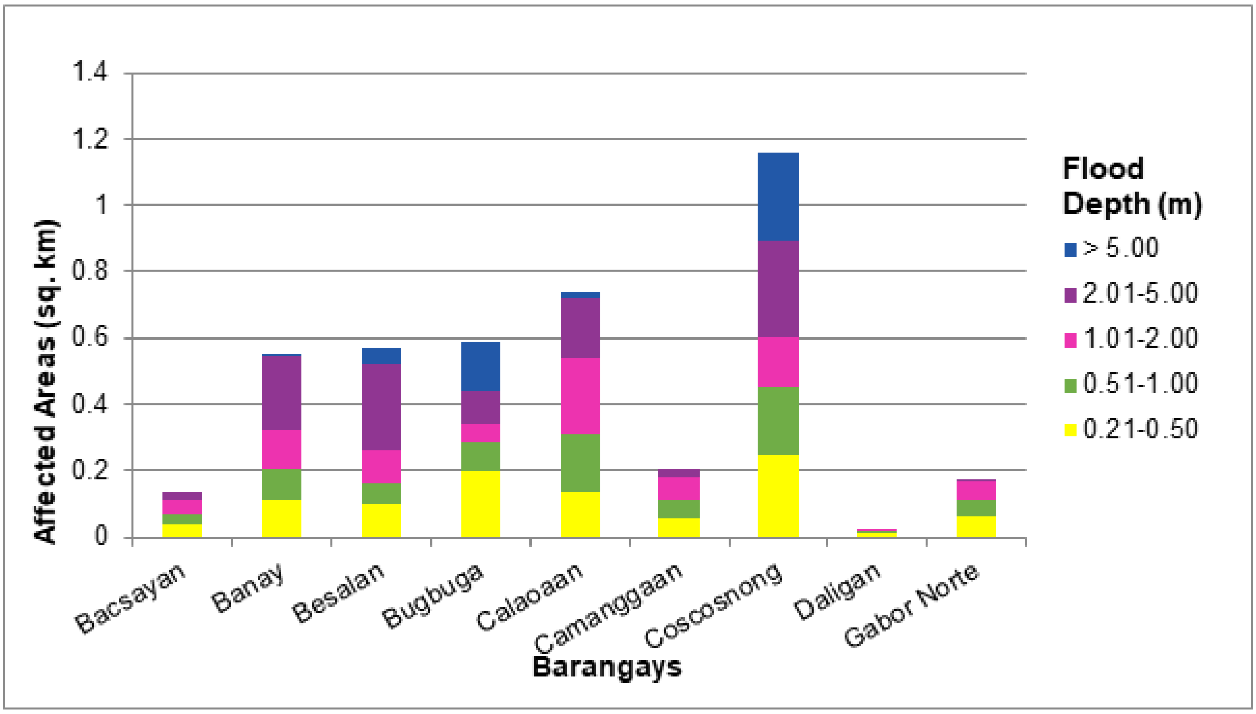


Figure 91. Affected Areas in Santa Cruz, Ilocos Sur during 100-Year Rainfall Return Period

Table 54. 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)								
	Lantag	Las-Ud	Padaoil	Pilar	Poblacion Este	Poblacion Norte	Poblacion Sur	Poblacion Weste	Quinfermin
0.03-0.20	0.79	0.00034	1.66	0.17	0.1	0	0.066	0.052	0.91
0.21-0.50	0.22	0.0004	0.082	0.1	0.019	0.024	0.013	0.019	0.045
0.51-1.00	0.37	0.0017	0.05	0.14	0.000038	0.051	0.013	0.036	0.036
1.01-2.00	0.32	0.082	0.036	0.18	0	0.023	0.0043	0.026	0.059
2.01-5.00	0.13	0.092	0.085	0.085	0	0.00055	0.0018	0.011	0.017
> 5.00	0.0095	0	0.015	0	0	0	0	0	0

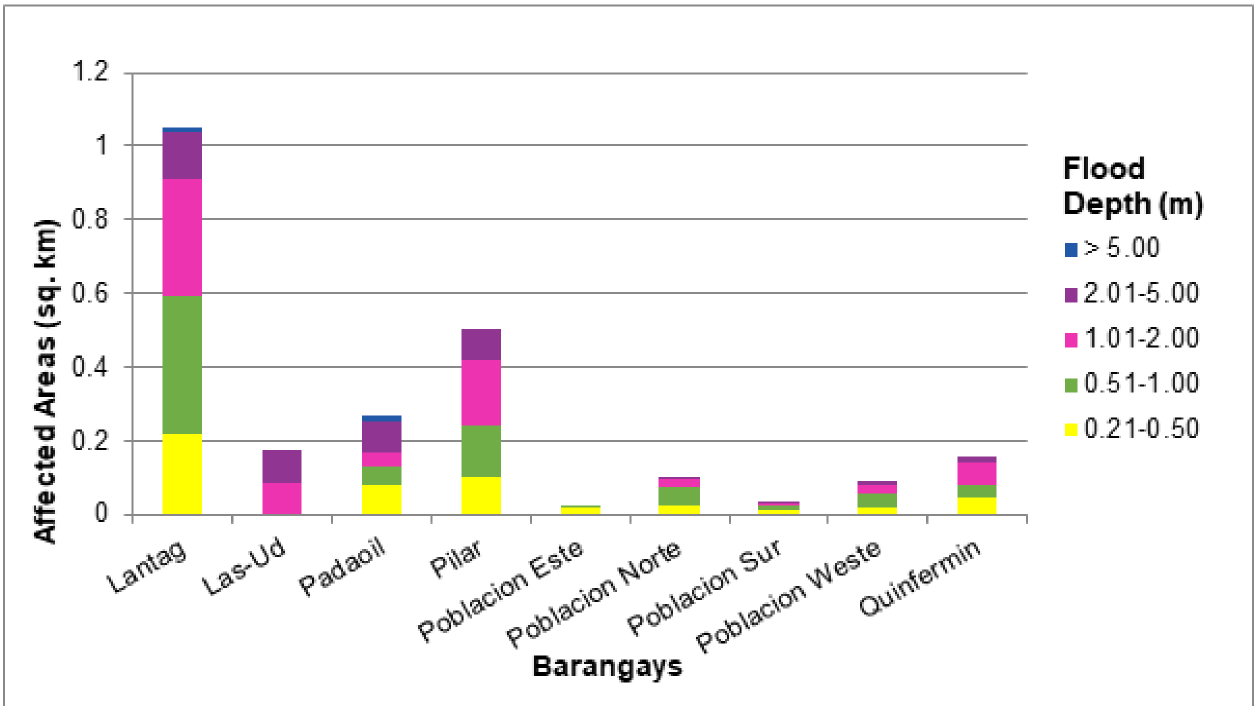


Figure 92. Affected Areas in Santa Cruz, Ilocos Sur during 100-Year Rainfall Return Period

Table 55. 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)							
	Quinsoriano	San Jose	Saoat	Sidaoen	Suyo	Tampugo	Villa Hermosa	Villa Laurencia
0.03-0.20	0.51	1.01	0.2	0.12	0.22	0.63	0.039	3.75
0.21-0.50	0.089	0.083	0.09	0.053	0.18	0.033	0.088	0.29
0.51-1.00	0.13	0.13	0.15	0.15	0.074	0.02	0.12	0.21
1.01-2.00	0.33	0.078	0.48	0.029	0.018	0.037	1.13	0.21
2.01-5.00	0.44	0.0018	0.12	0.00039	0.0099	0.41	1.76	0.15
> 5.00	0.2	0	0.011	0	0	0.14	0.0016	0.00074

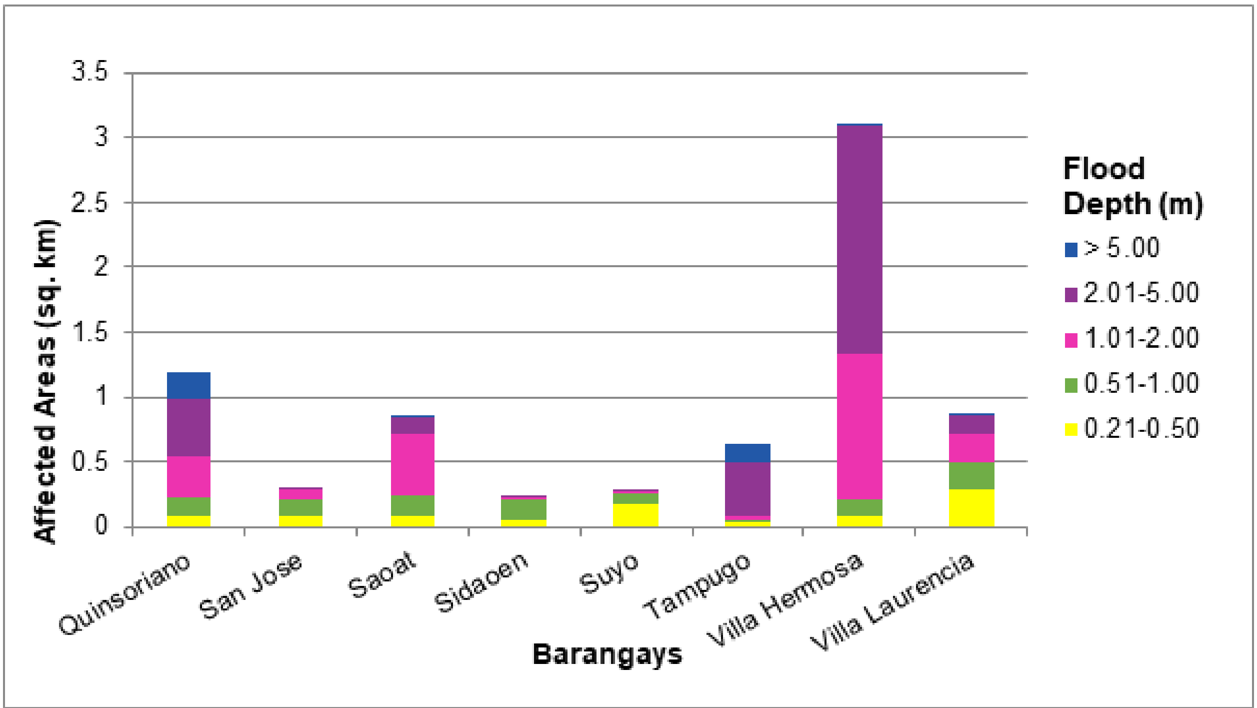


Figure 93. Affected Areas in Santa Cruz, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 30.85% of the municipality of Santa Lucia with an area of 43.877 sq. km. will experience flood levels of less than 0.20 meters. 4.61% of the area will experience flood levels of 0.21 to 0.50 meters while 5.21%, 10.59%, 20.26%, and 8.76% 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 56. Affected Areas in Santa Lucia, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Alincaoeg	Angkileng	Arangin	Ayusan	Banbanaba	Bani	Bao-As	Barangobong	Buliclic	Burgos	Cabaritan
0.03-0.20	1.43	0.1	0.6	0.0017	1.22	0.03	0.039	0.16	1.59	0	0.013
0.21-0.50	0.13	0.045	0.1	0.0054	0.1	0.014	0.011	0.11	0.082	0	0.00032
0.51-1.00	0.098	0.0093	0.045	0.025	0.1	0.037	0.011	0.13	0.066	0	0.0005
1.01-2.00	0.18	0.13	0.036	0.23	0.059	0.12	0.016	0.26	0.064	0.013	0.02
2.01-5.00	0.045	0.33	0.32	0.21	0.016	0.43	0.32	0.0063	0.007	0.27	0.81
> 5.00	0	0	0	0	0	0.31	0	0	0	0	1.25

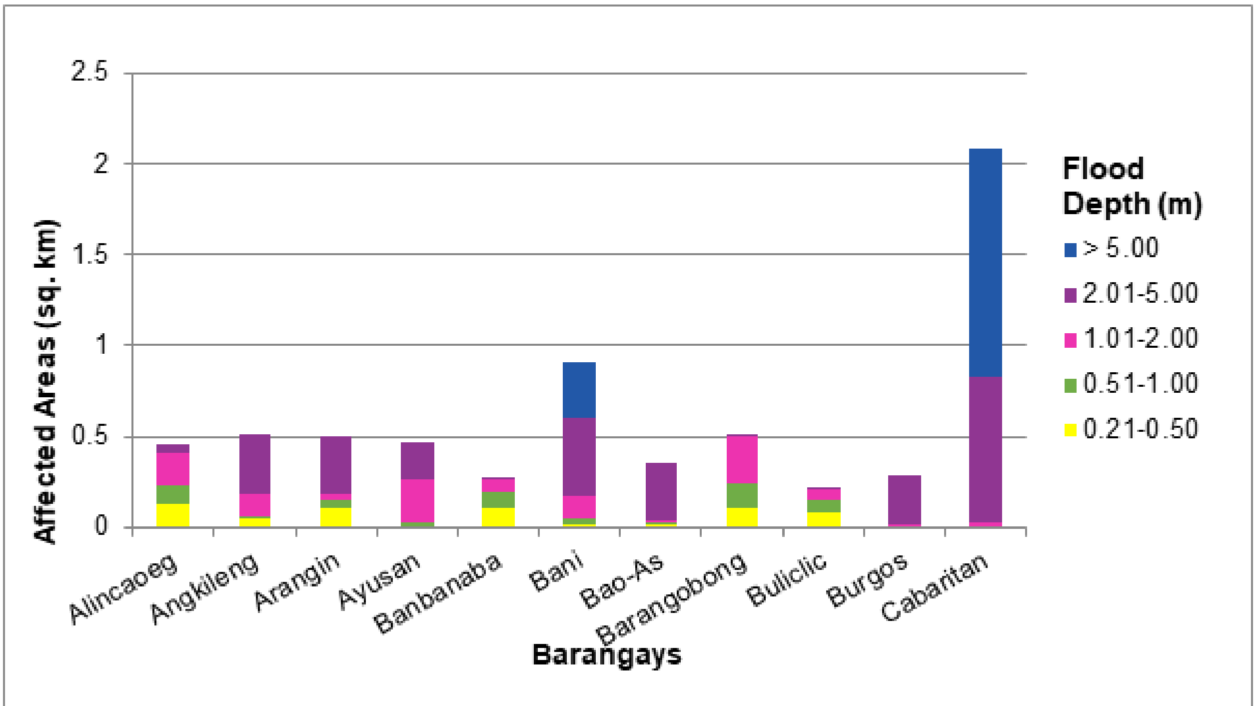


Figure 94. Affected Areas in Santa Lucia, Ilocos Sur during 100-Year Rainfall Return Period

Table 57. Affected Areas in Santa Lucia, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Catayagan	Conconig East	Conconig West	Damacuag	Luba	Lubong	Nagrebcan	Nagtablaan	Namatican	Nangalisan	Palali Norte
0.03-0.20	0.0013	0.9	0.99	0.019	0	0.15	0	0.19	0.36	0.011	1.39
0.21-0.50	0.0046	0.21	0.27	0.13	0	0.0034	0	0.013	0.035	0.011	0.17
0.51-1.00	0.028	0.14	0.089	0.35	0	0.00097	0	0.052	0.02	0.035	0.21
1.01-2.00	0.035	0.24	0.18	0.39	0.01	0	0.003	0.17	0.043	0.13	0.3
2.01-5.00	0.0077	0.15	0.096	0.82	0.032	0	0.53	0.18	0.45	0.46	0.061
> 5.00	0	0.00016	0	1.25	0	0	0	0.29	0.43	0	0

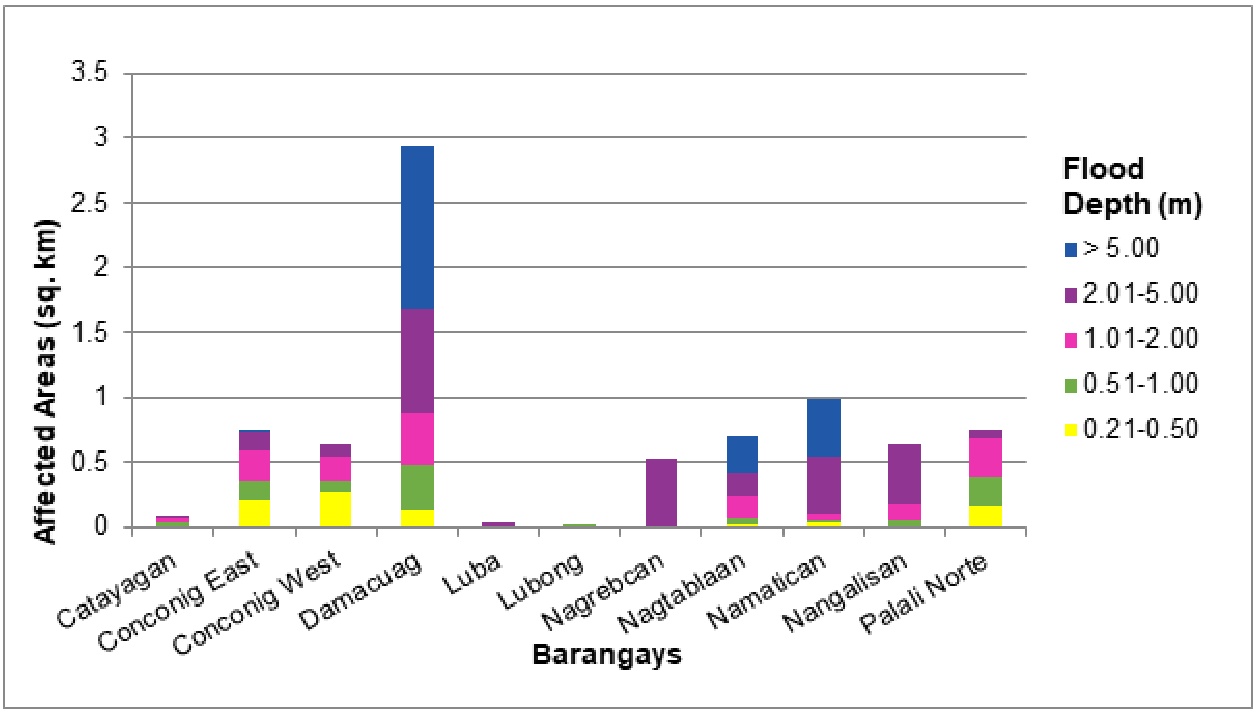


Figure 95. Affected Areas in Santa Lucia, Ilocos Sur during 100-Year Rainfall Return Period

Table 58. Affected Areas in Santa Lucia, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangay in Santa Lucia (in sq. km)										
	Palali Sur	Paoc Norte	Paoc Sur	Paratong	Pila East	Pila West	Quinabalayangan	Ronda	San Juan	San Pedro	Sapang
0.03-0.20	0.45	0.015	0.26	0.0056	0.97	0.19	0	0	0	1.01	1.44
0.21-0.50	0.14	0.0033	0.069	0.0016	0.077	0.072	0.00053	0.00037	0.0033	0.11	0.1
0.51-1.00	0.22	0.0073	0.14	0.0098	0.12	0.062	0.0062	0.045	0.026	0.11	0.093
1.01-2.00	0.26	0.067	0.29	0.085	0.21	0.2	0.056	0.61	0.084	0.079	0.076
2.01-5.00	0.094	0.41	0.35	0.52	0.096	0.099	0.38	0.74	0.55	0.072	0.026
> 5.00	0	0.31	0.00012	0	0	0	0	0.003	0	0	0

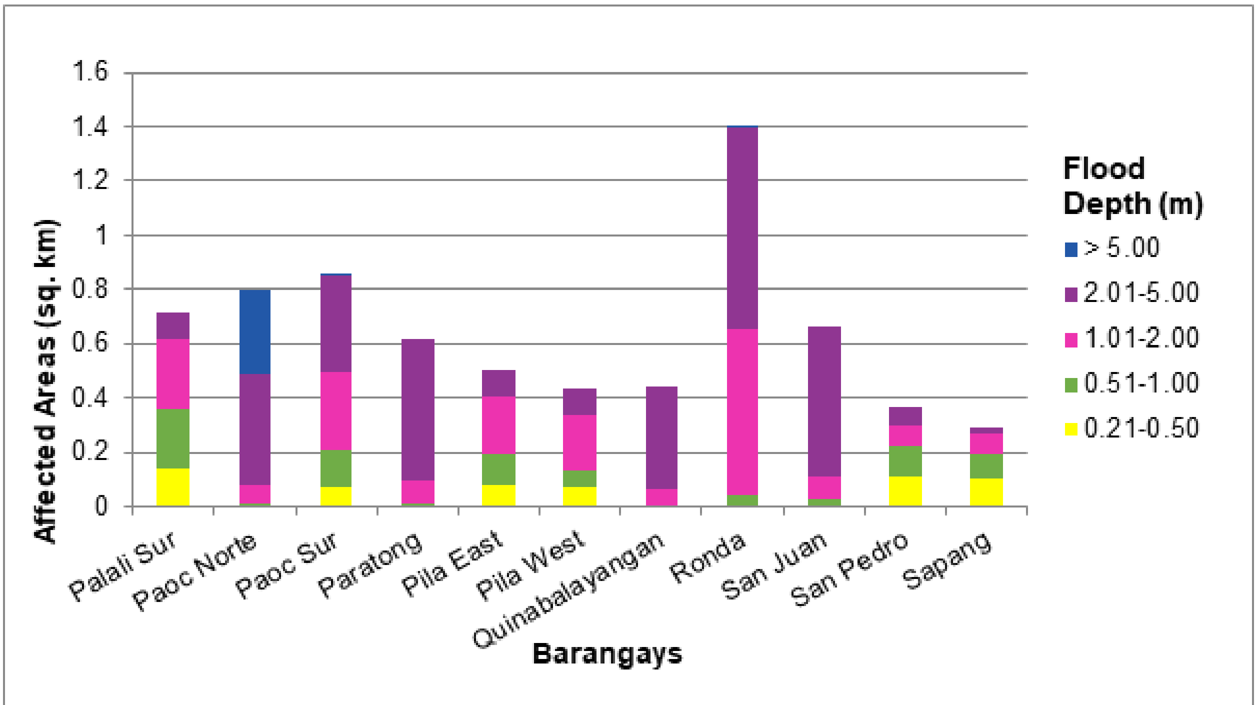


Figure 96. Affected Areas in Santa Lucia, Ilocos Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Candon City in Ilocos Sur, Palacapac is projected to have the highest percentage of area that will experience flood levels at 1.43%. Meanwhile, Allangigan Primero posted the second highest percentage of area that may be affected by flood depths at 0.88%.

Among the barangays in the municipality of Salcedo in Ilocos Sur, Sorioan is projected to have the highest percentage of area that will experience flood levels at 4.69%. Meanwhile, Dinaratan posted the second highest percentage of area that may be affected by flood depths at 4.66%.

Among the barangays in the municipality of Santa Cruz in Ilocos Sur, Coscosnong is projected to have the highest percentage of area that will experience flood levels at 5.14%. Meanwhile, Villa Laurencia posted the second highest percentage of area that may be affected by flood depths at 4.35%.

Among the barangays in the municipality of Santa Lucia in Ilocos Sur, Damacuag is projected to have the highest percentage of area that will experience flood levels at 6.72%. Meanwhile, Palali Norte posted the second highest percentage of area that may be affected by flood depths at 4.87%.

Moreover, the generated flood hazard maps for the Buaya 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 59. 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	6.74	6.01	5.75
Medium	14.27	12.47	10.96
High	18.46	26.26	30.54
TOTAL	39.47	44.74	47.25

Of the 41 identified educational institutions in the Buaya floodplain, five schools were assessed to be highly prone to flooding as they are exposed to the High level flooding for all three rainfall scenarios. These are the Brgy. Cabaritan Day Care Center and Cabaritan Private School in Brgy. Cabaritan, Daycare in Brgy. Nagrebacan, Quinsoriano Private School in Brgy. Ronda, and Sta. Lucia Caltex Filling Station in Brgy. San Juan. Four 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 Buaya floodplain.

Four medical institutions were identified in the Buaya floodplain. Dr. Antonio L. Valle Sr. Memorial Health Center in Brgy. Villa Hermosa was found to be relatively prone to flooding, having Medium level flooding in the 5-year return period and High level flooding in the other two rainfall scenarios. See Annex 13 for a detailed enumeration of hospitals and clinics in the Buaya floodplain.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering 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.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and improve on the results of the flood map.

The flood validation survey was conducted in January 2017. The flood validation consists of 326 points randomly selected all over the Buaya flood plain. It has an RMSE value of 1.05. The validation points are found in Annex 11.

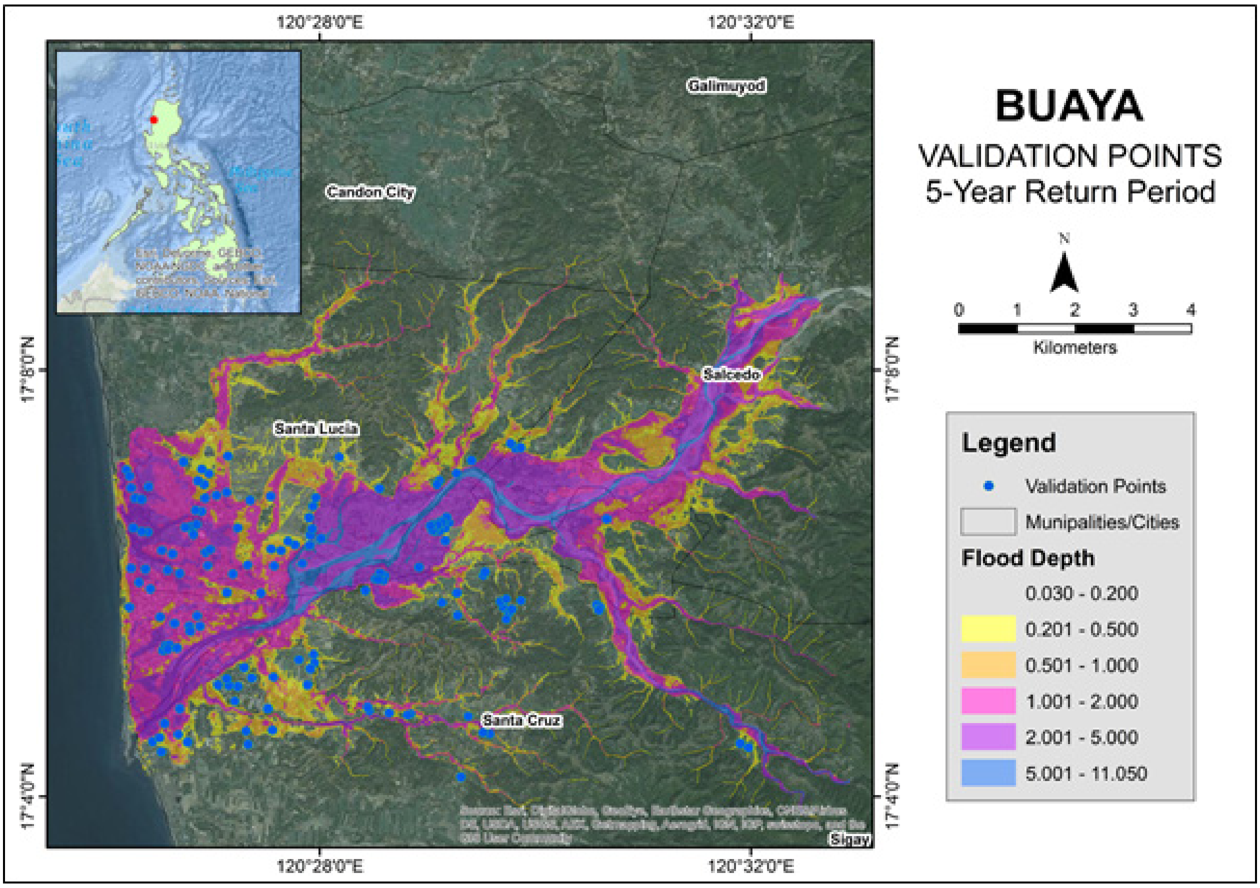


Figure 97. Flood Validation Points for Buaya River Basin

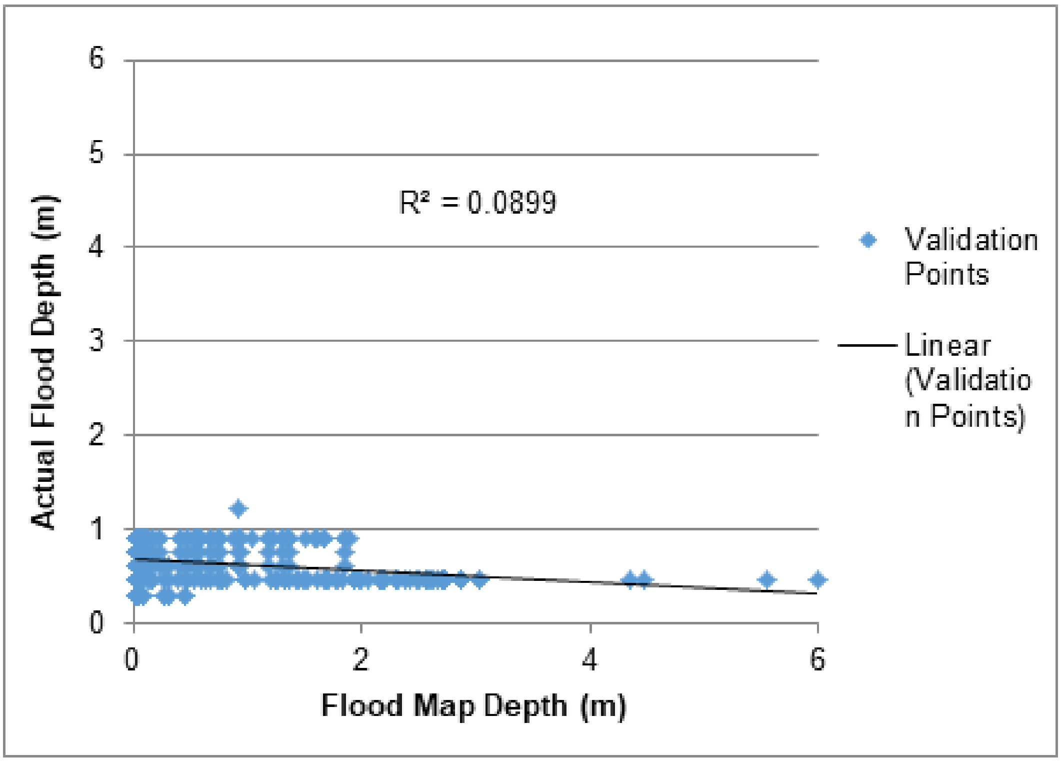


Figure 98. Flood Map Depth vs Actual Flood Depth for Buaya

Table 60. Actual flood vs simulated flood depth at differnent levels in the Buaya River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	0	0	0	0	0	0	0
0.21-0.50	39	12	11	29	35	2	128
0.51-1.00	117	15	40	25	0	0	197
1.01-2.00	0	0	1	0	0	0	1
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	156	27	52	54	35	2	326

The overall accuracy generated by the flood model is estimated at 15.95%, with 52 points correctly matching the actual flood depths. In addition, there were 91 points estimated one level above and below the correct flood depths while there were 146 points and 37 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 102 points were overestimated while a total of 172 points were underestimated in the modelled flood depths of Buaya.

Table 61. Summary of Accuracy Assessment in Buaya

	No. of Points	%
Correct	52	15.95
Overestimated	102	31.29
Underestimated	172	52.76
Total	326	100

REFERENCES

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

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

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

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

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

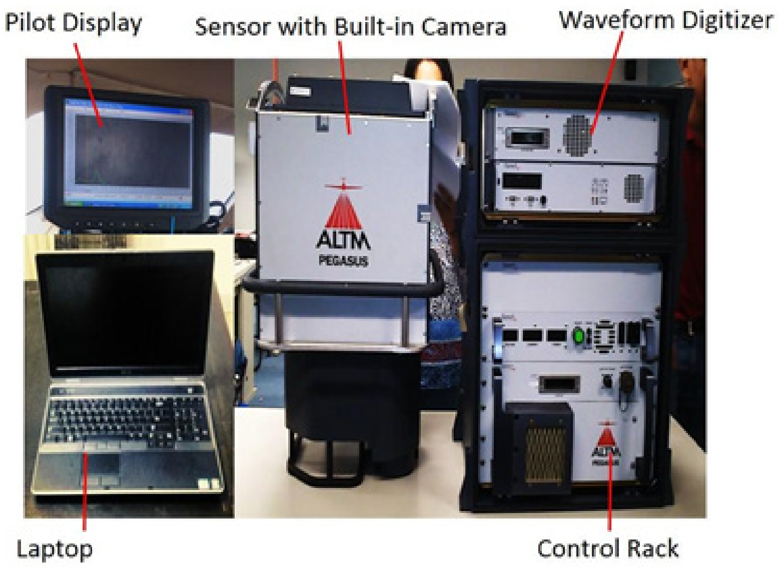
UP TCAGP 2016. Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM) and Ground Control Points (GCP). Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry

ANNEXES

ANNEX 1. Optech Technical Specification of the Gemini Sensor, and Pegasus Sensor

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

Parameters and Specification of Gemini Sensor



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

Parameters and Specification of Pegasus Sensor

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

1. ABR-32

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: **ABRA**
Station Name: **ABR-32**
Order: **2nd**

Island: **LUZON**
Municipality: **PIDIGAN**
Barangay: **SUYO (MALIDONG)**

PRS92 Coordinates

Latitude:	17° 33' 49.34656"	Longitude:	120° 33' 25.07659"	Ellipsoidal Hgt:	39.32200 m.

WGS84 Coordinates

Latitude:	17° 33' 43.22900"	Longitude:	120° 33' 29.72282"	Ellipsoidal Hgt:	72.81400 m.

PTM Coordinates

Northing:	1942534.242 m.	Easting:	452967.729 m.	Zone:	3

UTM Coordinates

Northing:	1,943,468.54	Easting:	240,677.03	Zone:	51

Location Description

ABR-32

From Bangued, travel towards Ilocos Sur for about 8 km. Turn right at the intersection road and continue travel for about 3.6 km, until reaching the Barangay Hall of Suyo. The station is located about 15 m NE of the stage. Mark is the head of a brass rod with cross cut on top flushed at the center of a 30 cm x 30 cm x 120 cm concrete monument with inscriptions, "ABR-32, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-443**

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

9903042014160036

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. ILS-22

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: **ILOCOS SUR**
Station Name: **ILS-22**
Order: **2nd**

Island: **LUZON**		Barangay: **POBLACION NORTE**
Municipality: **LIDLIDDA**		
	PRS92 Coordinates	
Latitude: **17° 16' 13.59403"**	Longitude: **120° 31' 8.89179"**	Ellipsoidal Hgt: **55.31200 m.**
	WGS84 Coordinates	
Latitude: **17° 16' 7.53708"**	Longitude: **120° 31' 13.56269"**	Ellipsoidal Hgt: **89.64700 m.**
	PTM Coordinates	
Northing: **1910089.724 m.**	Easting: **448870.206 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,911,053.54**	Easting: **236,238.44**	Zone: **51**

Location Description

ILS-22

From Candon City, travel N along the national highway for about 6 km. then turn E at the junction and travel for about 8 km. until reaching the Lidlidda Public Market. Turn NW and travel for about 4 km. to reach the North Central School. It is located inside the school compound on the science park near the NE corner of the concrete stage. It is 1.5 m. NNW of the E corner of the concrete stage and 0.8 m. NNE of the NE side of the stage.

Mark is the head of a 4 in. copper nail, centered on a concrete block 30 cm. x 30 cm. and 10 cm. above the ground surface, with inscriptions "ILS-22, 2005, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-440**

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

99030420141155611

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. ILS-24

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: **ILOCOS SUR**
Station Name: **ILS-24**
Order: **2nd**

Island: **LUZON**
Municipality: **CANDON CITY**
Barangay: **DARAPIDAP**

		PRS92 Coordinates			
Latitude:	**17° 11' 46.25613"**	Longitude:	**120° 25' 8.83897"**	Ellipsoidal Hgt:	**12.28700 m.**
		WGS84 Coordinates			
Latitude:	**17° 11' 40.20757"**	Longitude:	**120° 25' 13.51659"**	Ellipsoidal Hgt:	**46.61600 m.**
		PTM Coordinates			
Northing:	**1901900.937 m.**	Easting:	**438210.77 m.**	Zone:	**3**
		UTM Coordinates			
Northing:	**1,902,971.42**	Easting:	**225,489.39**	Zone:	**51**

Location Description

ILS-24

From the national highway of Candon City proper going to Vigan City, turn left on the road fronted by Jollibee. Continue traveling this road passing through the City Wet Market and University of Northern Philippines (UNP) Annex on the left side until reaching its end, which is a "T" intersection. Take the road to the left passing through Darapidap Beach Resort until reaching the E gate of Ilocos Sur Polytechnic State College (ISPSC). It is located on the right side of the concrete road, approx. 10 m. SSE of the campus' E gate, about 75 m. S of the main entrance. It is also about 15 m. ESE of the campus' concrete water tank.

Mark is the head of an umbrella type G.I. roofing nail embedded and centered on a 30 cm. x 30 cm. concrete monument protruding by about 5 cm., with inscriptions "CANDON-1, 2004, PRS-92, FNSP-LMS-DENR".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-441**

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

9 9 0 3 0 4 2 0 1 4 1 3 3 6 5 8

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

CP/4701/12/09/814

ANNEX 3. Baseline Processing Reports of Reference Points Used

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1 Data Acquisition Component Leader	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		AUBREY MATIRA-PAGADOR	
	Research Associate (RA)	MA. VERLINA E. TONGA	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	
		FAITH JOY SABLE	
		RENAN PUNTO	
Ground Survey, Data Download and Transfer		IRO NIEL ROXAS	UP-TCAGP
		KENNETH QUISADO	
LiDAR Operation	Airborne Security	SSG. DIOSCORO SOBERANO	PHILIPPINE AIR FORCE (PAF)
		SSG. OLIVER SACLOT	
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR SHERWIN ALFONSO III	
		CAPT. BRYAN DONGUINES	
		CAPT. MARK LAWRENCE TANGONAN	

ANNEX 5. Data Transfer Sheet for Buaya Floodplain

(CLA 4/1/2014)

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	220MB	N/A	N/A	19.8	N/A	6.5	1KB	459B	35	NA	X:\Airborne_Raw\1151P
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\1153P
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\1155P
2/26/2014	1157P	1BLK10B057B	PEGASUS	1.85GB	NA	6.62MB	129MB	25.6GB	220KB	17.4	N/A	6.95	1KB	485B	45	N/A	X:\Airborne_Raw\1157P
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\1159P
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\1161P
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\1163P
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\1165P
3/1/2014	1167P	1BLK10H060A	PEGASUS	831MB	NA	7.42MB	170MB	17.5GB	146KB	8.66	N/A	6.64	1KB	318B	20	N/A	X:\Airborne_Raw\1167P
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\1169P
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\1171P
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\1173P
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\1175P
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\1177P
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\1179P
Mar 5, 2014	1183P	1BLK12AC064A	PEGASUS	1.5GB	NA	10.3MB	206MB	35.6GB	304KB	22.5GB	N/A	5.94	1KB	1KB	42/36/33/4234	N/A	X:\Airborne_Raw\1183P
Mar 5, 2014	1185P	1BLK10D064B	PEGASUS	1.18GB	NA	5.85MB	151MB	16.4GB	142KB	11.7GB	N/A	5.94	1KB	1KB	n/a	N/A	X:\Airborne_Raw\1185P
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\1187P
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\1189P
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\1195P
Mar 8, 2014	1197P	1BLK10CGS067B	PEGASUS	714MB	NA	4.95MB	112MB	14.5GB	131KB	8.10GB	N/A	1.44MB	9KB	1KB	27	N/A	X:\Airborne_Raw\1197P

Received from
Name CHRIS JOAQUIN
Position RA
Signature [signature]

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature [signature]

DATA TRANSFER SHEET
3/19/2014(ILOCOS BATCH 2)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/ CASI	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Mar 3, 2014	7104GC	2BLK06E062A & 2BLK06A062A	GEMINI	NA	68.1KB	429KB	206MB	NA	NA	19.3GB	NA	12.3MB	1KB	1KB	6/174/10/5/38KB	8KB	Z:\Airborne_Raw\7104GC
Mar 3, 2014	7105GC	2BLK06AS062B & 2BLK06C062B	GEMINI	NA	302KB	493KB	254MB	NA	NA	23.3GB	NA	12.6MB	1KB	1KB	6/206/6/208/67KB	11KB	Z:\Airborne_Raw\7105GC
Mar 4, 2014	7107GC	2BLK07C063B	GEMINI	NA	59.1KB	306KB	187MB	NA	NA	15GB	NA	3.84MB	1KB	1KB	132KB	192KB	Z:\Airborne_Raw\7107GC
Mar 5, 2014	7108GC	2BLK07C063B	GEMINI	NA	106KB	636KB	266MB	NA	NA	29.2GB	NA	11MB	1KB	1KB	266KB	10/10KB	Z:\Airborne_Raw\7108GC
Mar 7, 2014	7112GC	2BLK06G066A & 2BLK06DS066A	GEMINI	NA	286KB	451KB	247MB	NA	NA	18.5GB	NA	11.4MB	1KB	1KB	197/64KB	17KB	Z:\Airborne_Raw\7112GC
Mar 8, 2014	7114GC	2BLK07CS067A & 2BLK06G067A	GEMINI	NA	88.4KB	436KB	264MB	NA	NA	19.3GB	NA	8.45MB	1KB	1KB	7/5/304KB	7/5KB	Z:\Airborne_Raw\7114GC
Mar 9, 2014	7116GC	2BLK07B068A	GEMINI	NA	306KB	476KB	257MB	NA	NA	19.4GB	NA	10.8MB	1KB	1KB	5/209/51/5/209KB	9KB	Z:\Airborne_Raw\7116GC
Mar 10, 2014	7118GC	2BLK07D069A & 2BLK07G069A	GEMINI	NA	332KB	483KB	259MB	NA	NA	18.7GB	NA	14.5MB	1KB	1KB	6/228/346/10/5/228KB	10KB	Z:\Airborne_Raw\7118GC
MAR 10\	7119GC	2BLK27A069B	GEMINI	NA	321KB	520KB	253MB	NA	NA	24.6GB	NA	14.7MB	1KB	1KB	5/48/5/221/51KB	NA	Z:\Airborne_Raw\7119GC
Mar 11, 2014	7120GC	2BLK06F070A & 2BLK07A070A	GEMINI	NA	67.4KB	506KB	251MB	NA	NA	16GB	NA	11.2MB	1KB	1KB	10/26/219KB	16KB	Z:\Airborne_Raw\7120GC
Mar 11, 2014	7121GC	2BLK07GS070B & 2BLK07AS070B	GEMINI	NA	216KB	319KB	217MB	NA	NA	12.7GB	NA	10.6MB	1KB	1KB	149/6KB	10KB	Z:\Airborne_Raw\7121GC
Mar 12, 2014	7122GC	2BLK07E071A & 2BLK07F071A	GEMINI	NA	74.4KB	399KB	228MB	NA	NA	14.5GB	NA	8.36MB	1KB	1KB	399/7/399/6KB	9KB	Z:\Airborne_Raw\7122GC

Received from

Name CHRIS VOADUFIW
Position RA
Signature [signature] 04/21/14

Received by

Name JOIDA F PRIETO
Position SSRS
Signature [signature] 4/22/14

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 1179P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1179P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK27B 063A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 4, 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: 0851	14 Engine Off: 1306	15 Total Engine Time: 4+15	16 Take off:	17 Landing:	18 Total Flight Time: 4+05
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 PACLOT	M. J. TANGONAN	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 1195P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1195P

1 LiDAR Operator: F. SABLE	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. Dongwines	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: 10 + 05	14 Engine Off: 12 + 24	15 Total Engine Time: 2 + 19	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	Antonio Punto
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 7119G Mission

DREAM Data Acquisition Flight Log 2BLK27A069B **Flight Log No.:** 7119

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 7322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-10-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 1219H	14 Engine Off: 1634H	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Mission completed w/ voids due to clouds					

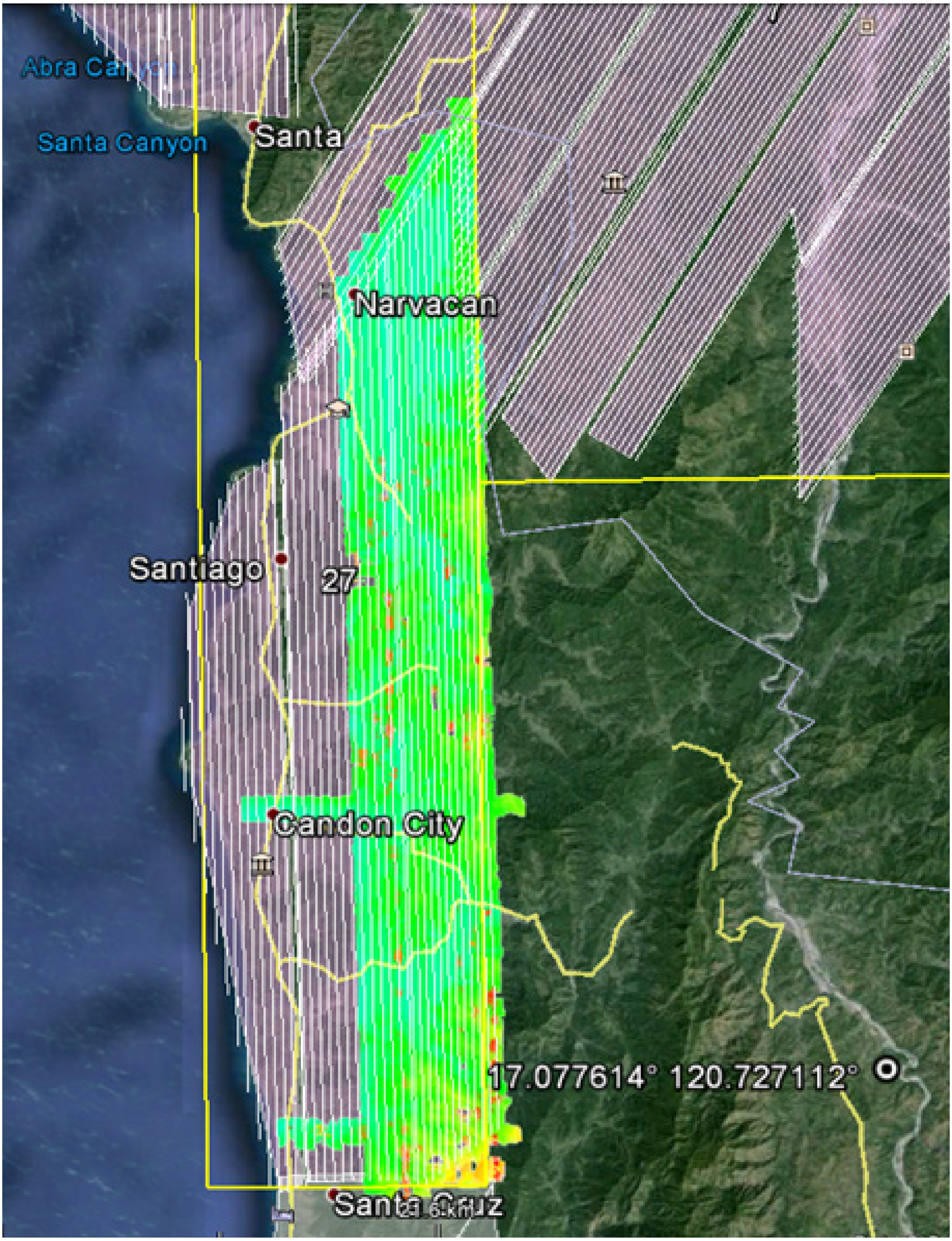
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	Sgt Diosdado Sobretodo PAF	R. Samar II	CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

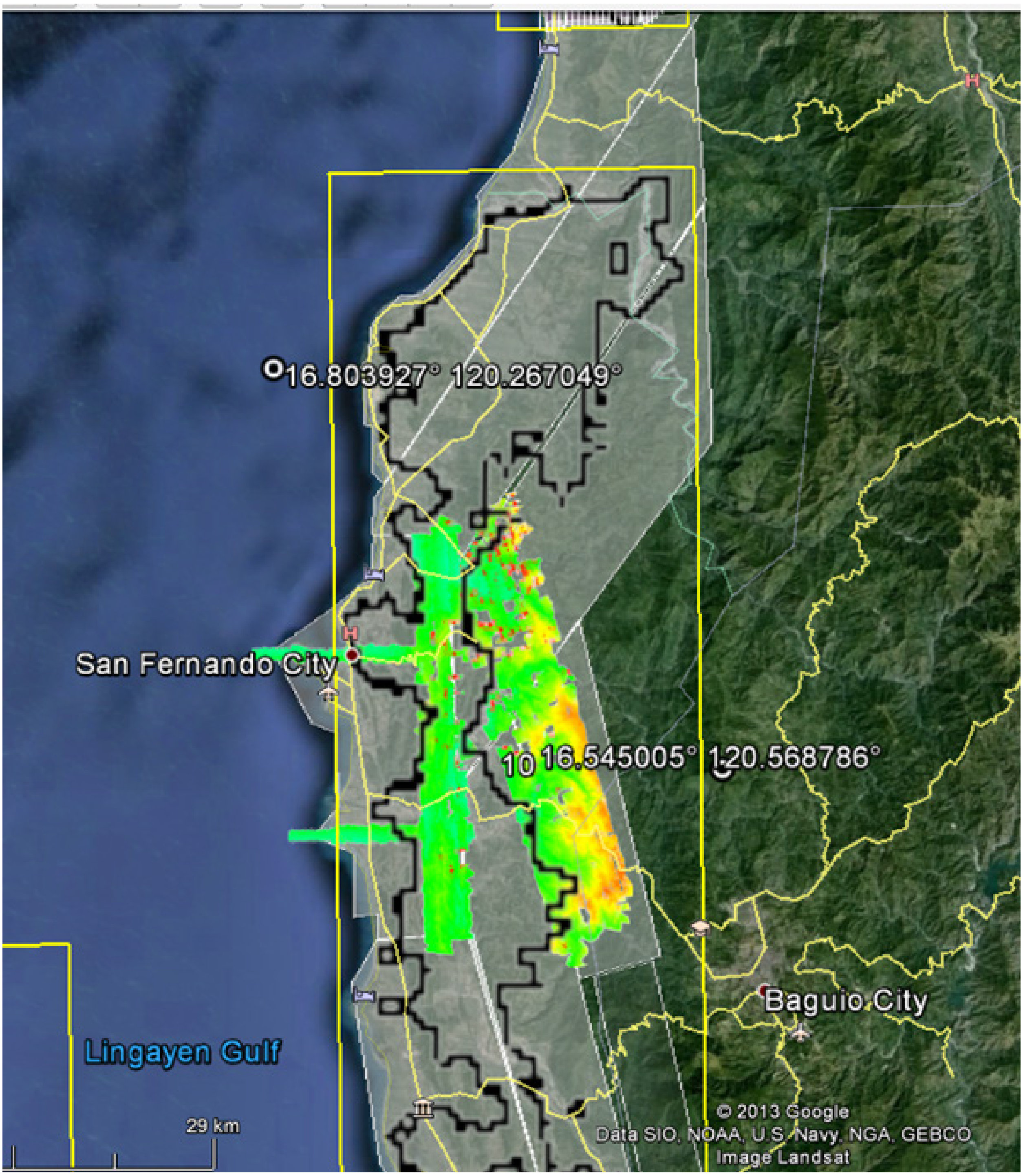
ANNEX 7. Flight status reports

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1179 P	BLK 27B	1BLK27B063A	R. PUNTO	4-Mar-14	Surveyed Ilocos Sur Block (Narvacan-Candon City)
1195 P	BLK 27A & BLK27B	1BLK27ABS067A	F. SABLE	8-Mar-14	Mission Complete
7119 G	BLK27A	2BLK27A069B	MCE BALIGUAS	10-Mar-14	Mission completed with voids due to clouds

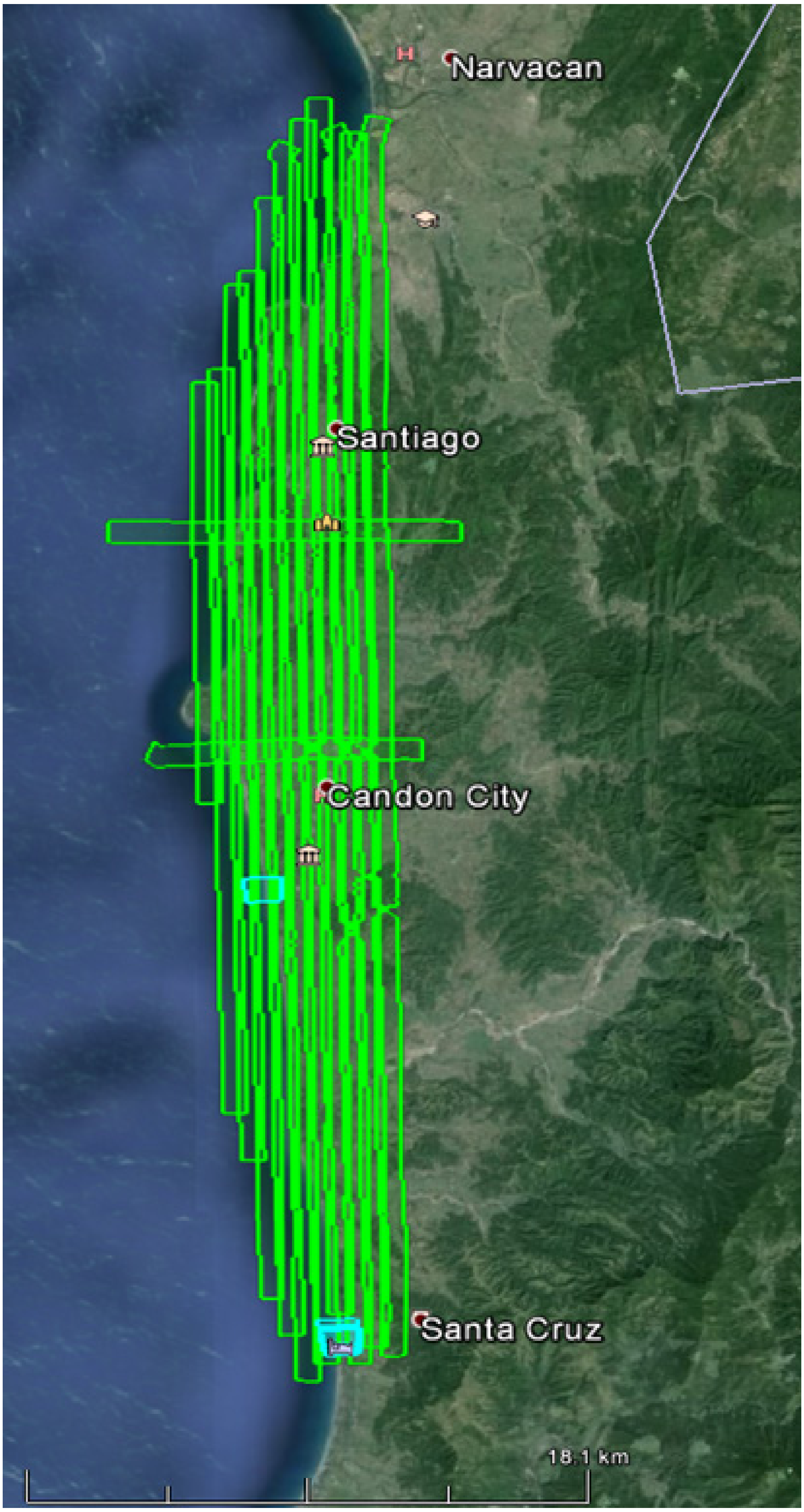
Flight No.:	1179P
Area:	27B
Mission Name:	1BLK27B063A
Parameters:	Altitude: 1200m; Scan Frequency: 30; FOV: 50 %



Flight No.:	1195P
Area:	BLK27A & BLK27B
Mission Name:	1BLK27ABS067A
Parameters:	Altitude: 1200m; Scan Frequency: 30; FOV: 50 %

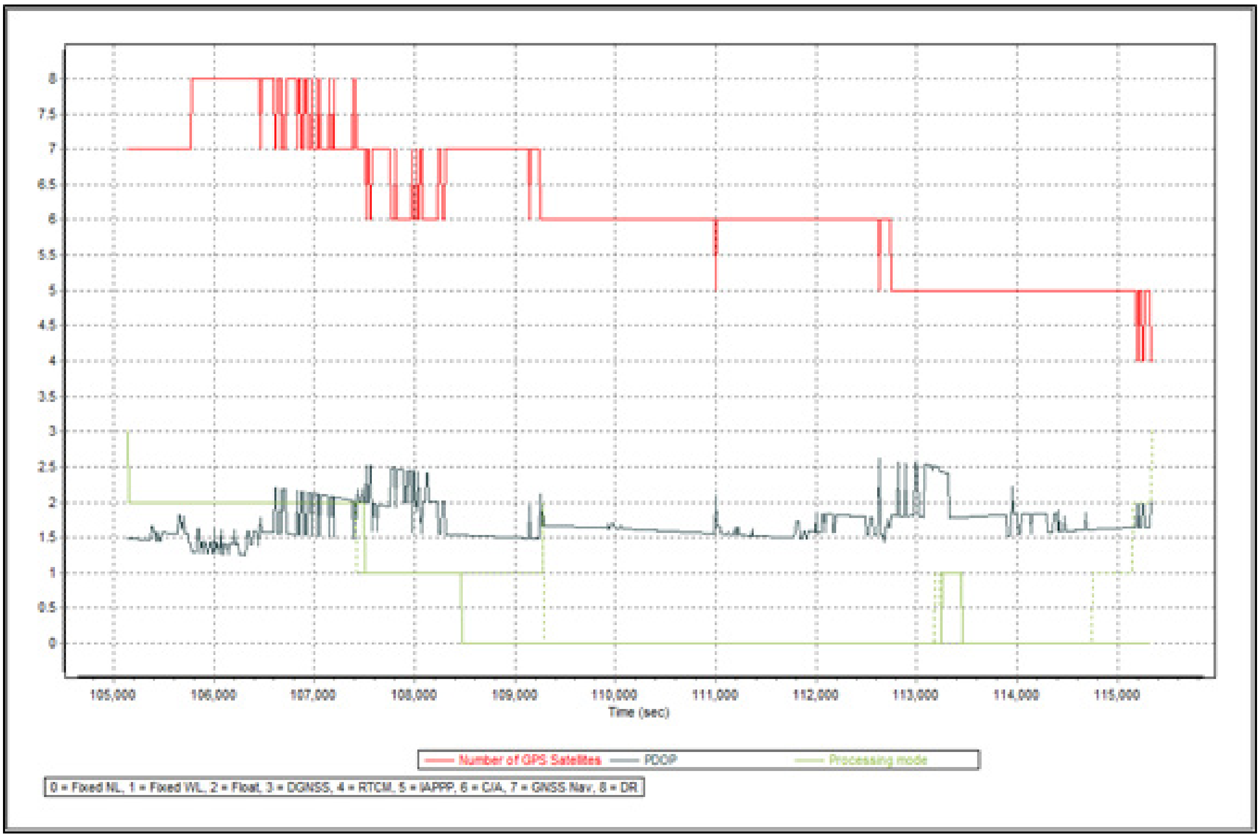


Flight No. :	7119 G
Area:	BLK27
Mission Name:	2BLK27A069B
Parameters:	Altitude: 1000 m; Scan Frequency: 50; FOV: 40%

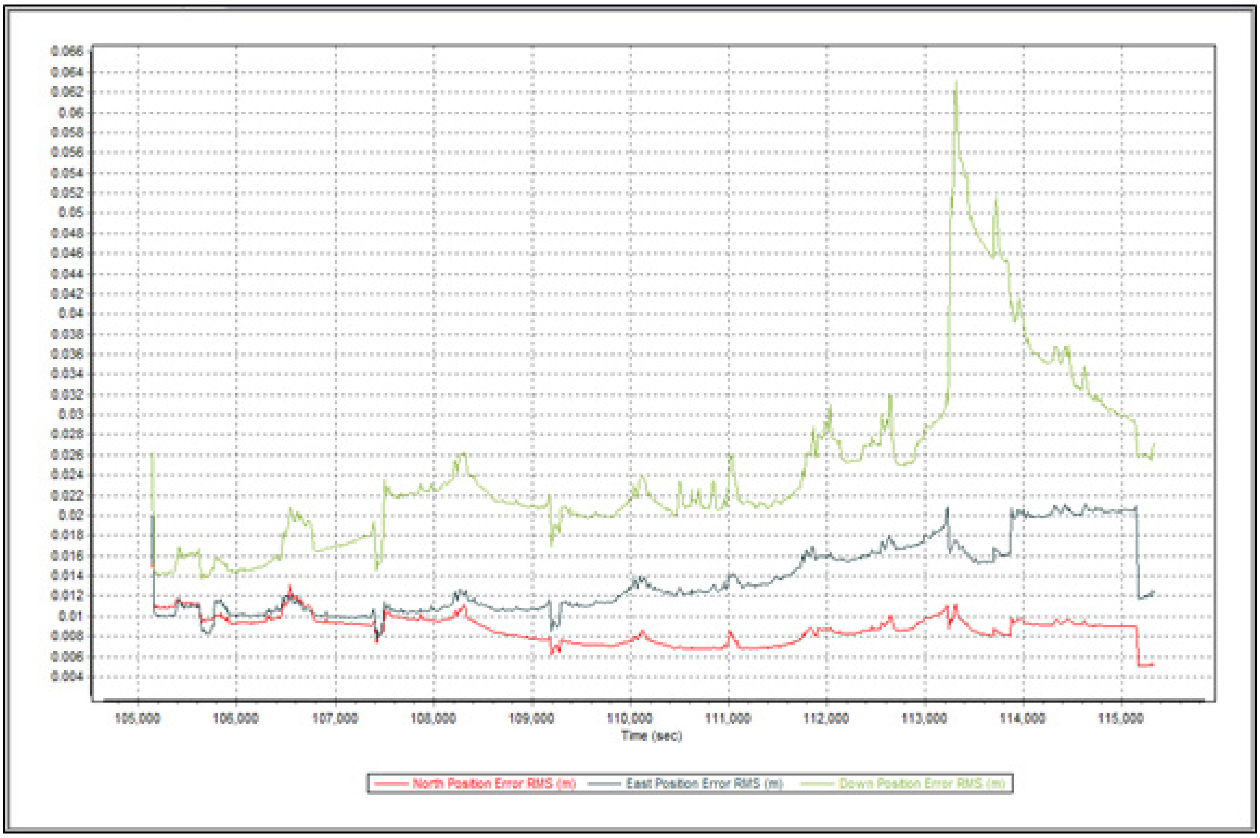


ANNEX 8. Mission Summary Reports

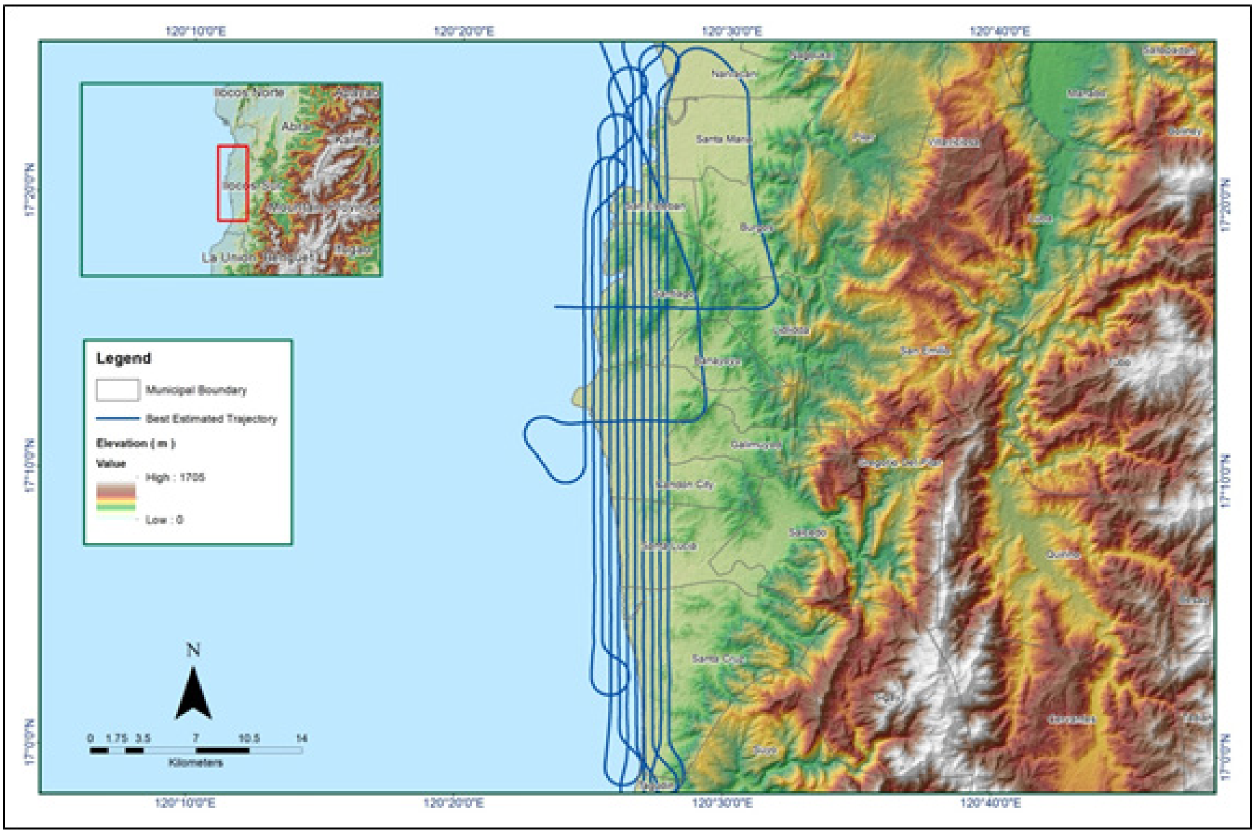
Flight Area	Ilocos
Mission Name	Blk27A
Inclusive Flights	7119G
Range data size	24.6 GB
POS data size	14.7 MB
Base data size	253 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	6.3
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.003340
GPS position stdev (<0.01m)	0.0112
Minimum % overlap (>25)	27.26%
Ave point cloud density per sq.m. (>2.0)	2.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	277
Maximum Height	327.77m
Minimum Height	37.49m
Classification (# of points)	
Ground	93,269,184
Low vegetation	93,660,205
Medium vegetation	129,697,767
High vegetation	133,575,832
Building	8,860,833
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Mark Joshua Salvacion, Jovy Narisma



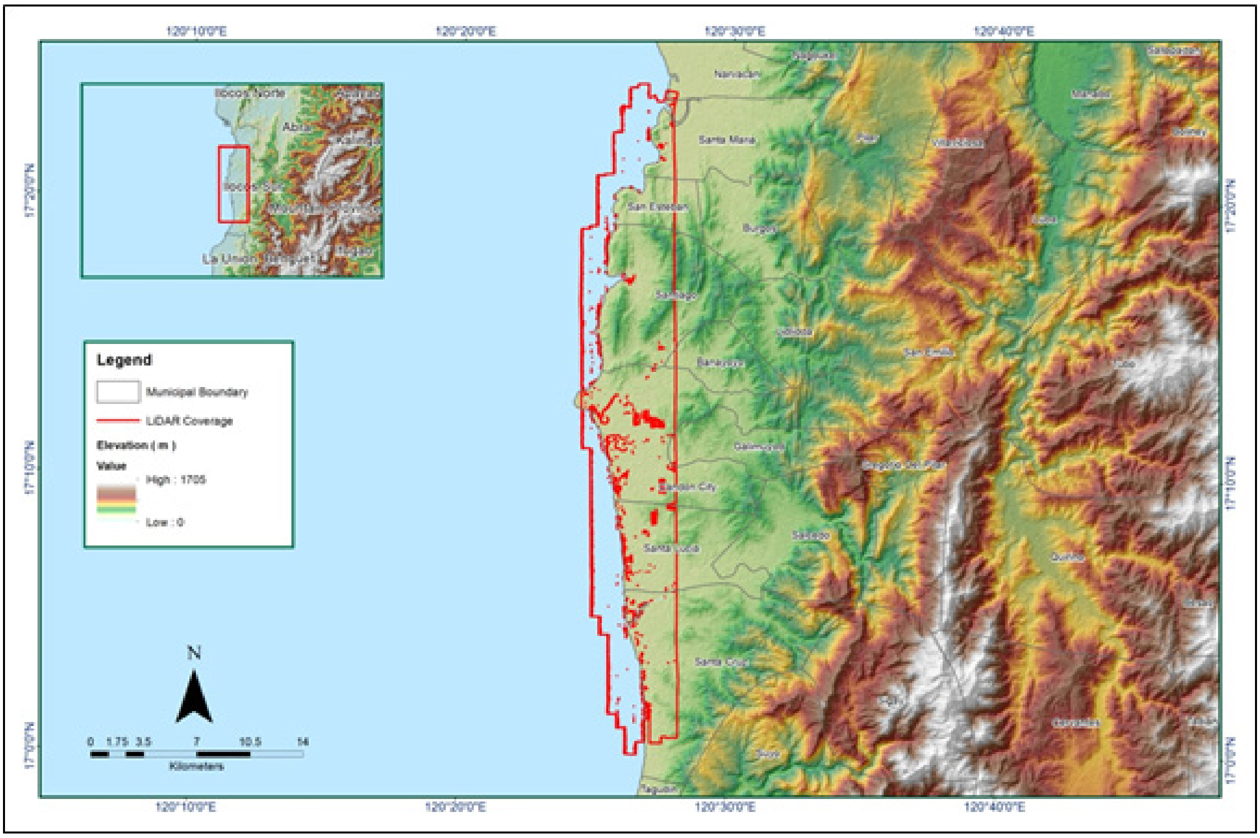
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR Data

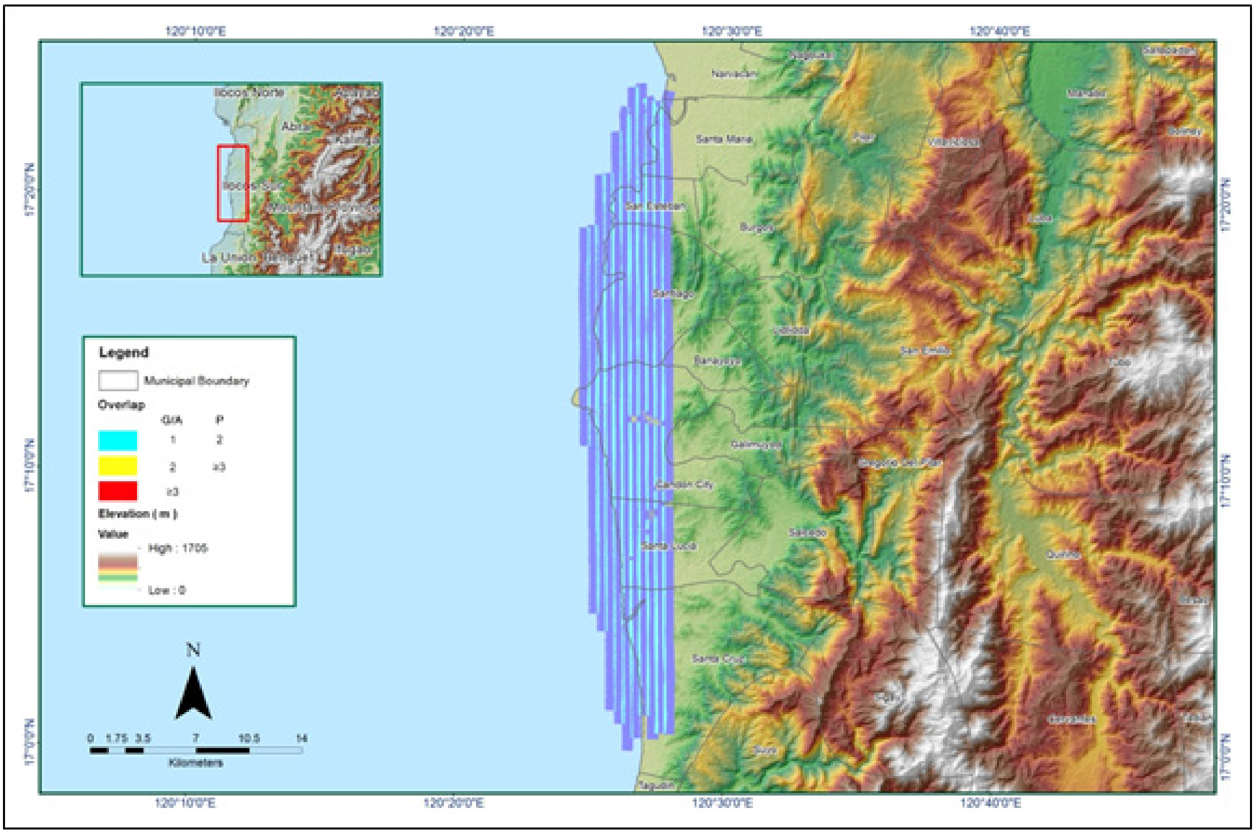
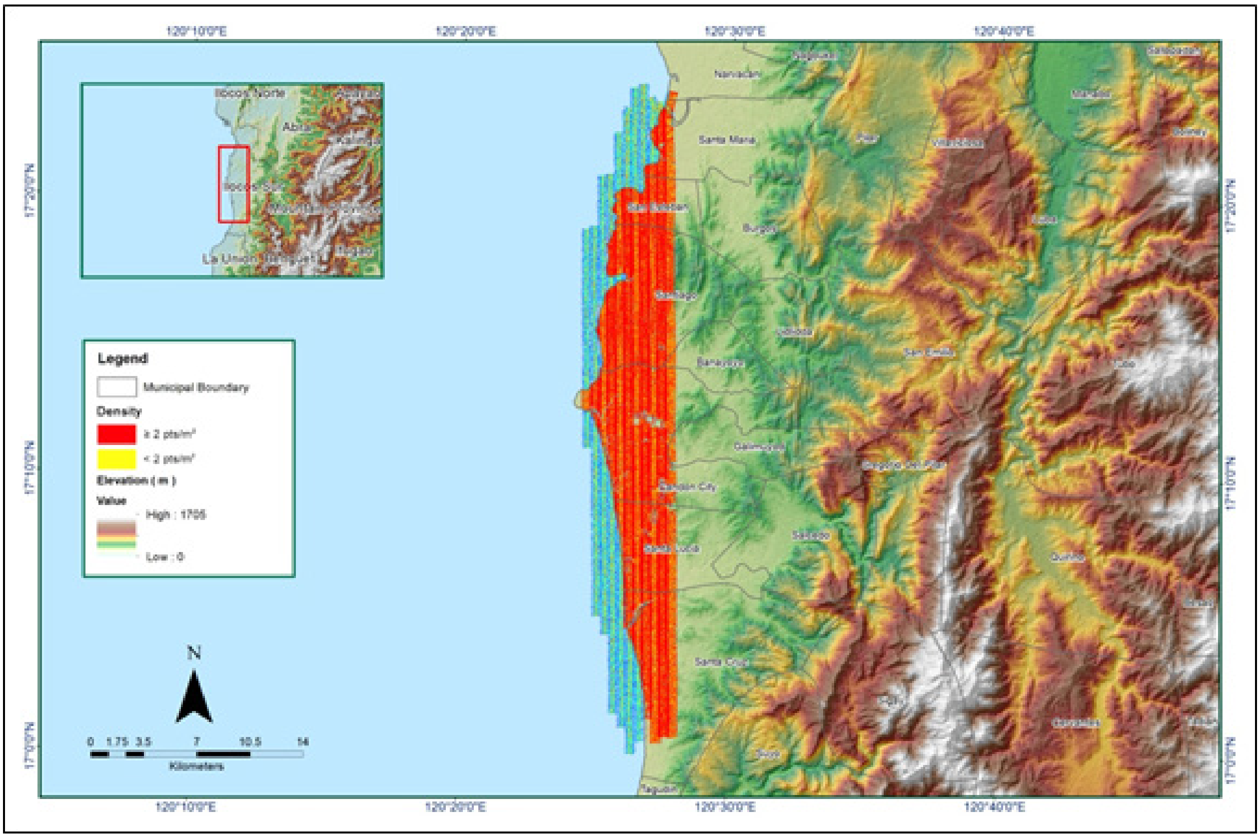
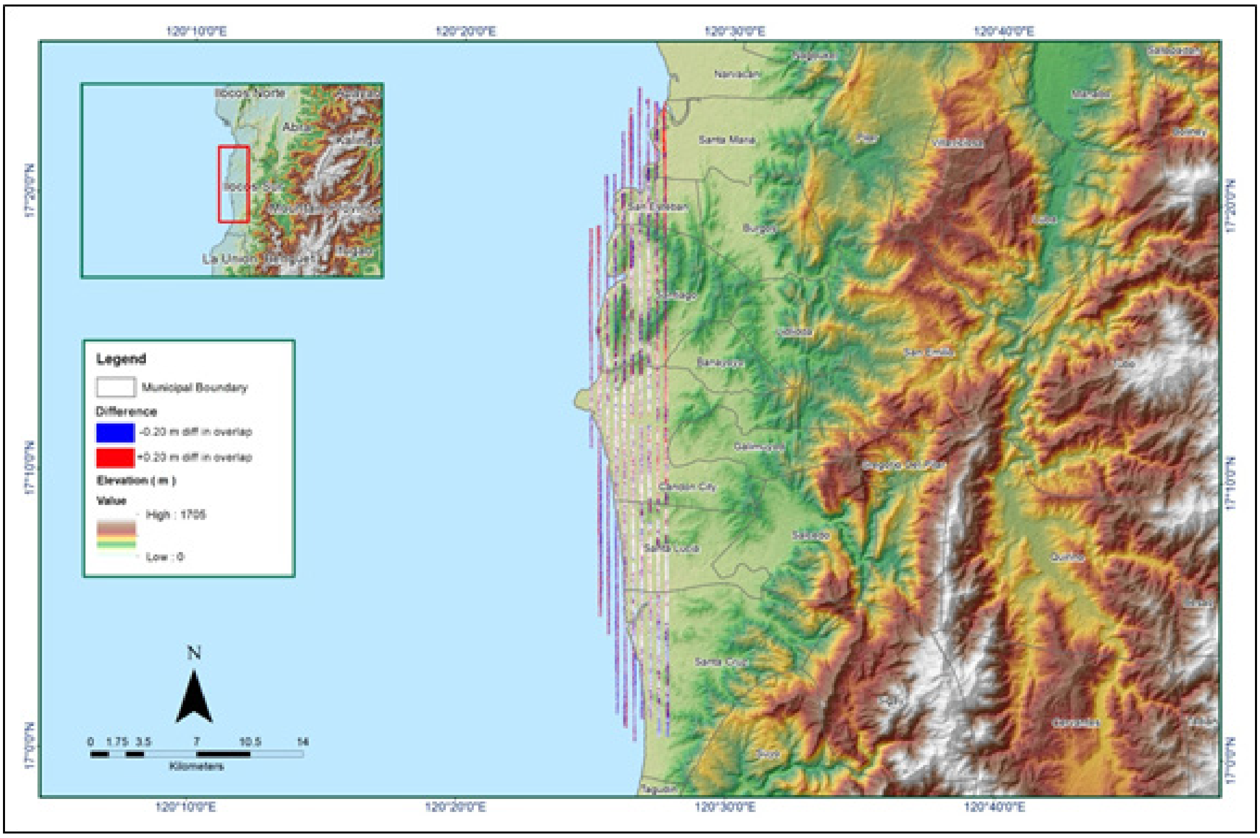


Image of Data Overlap

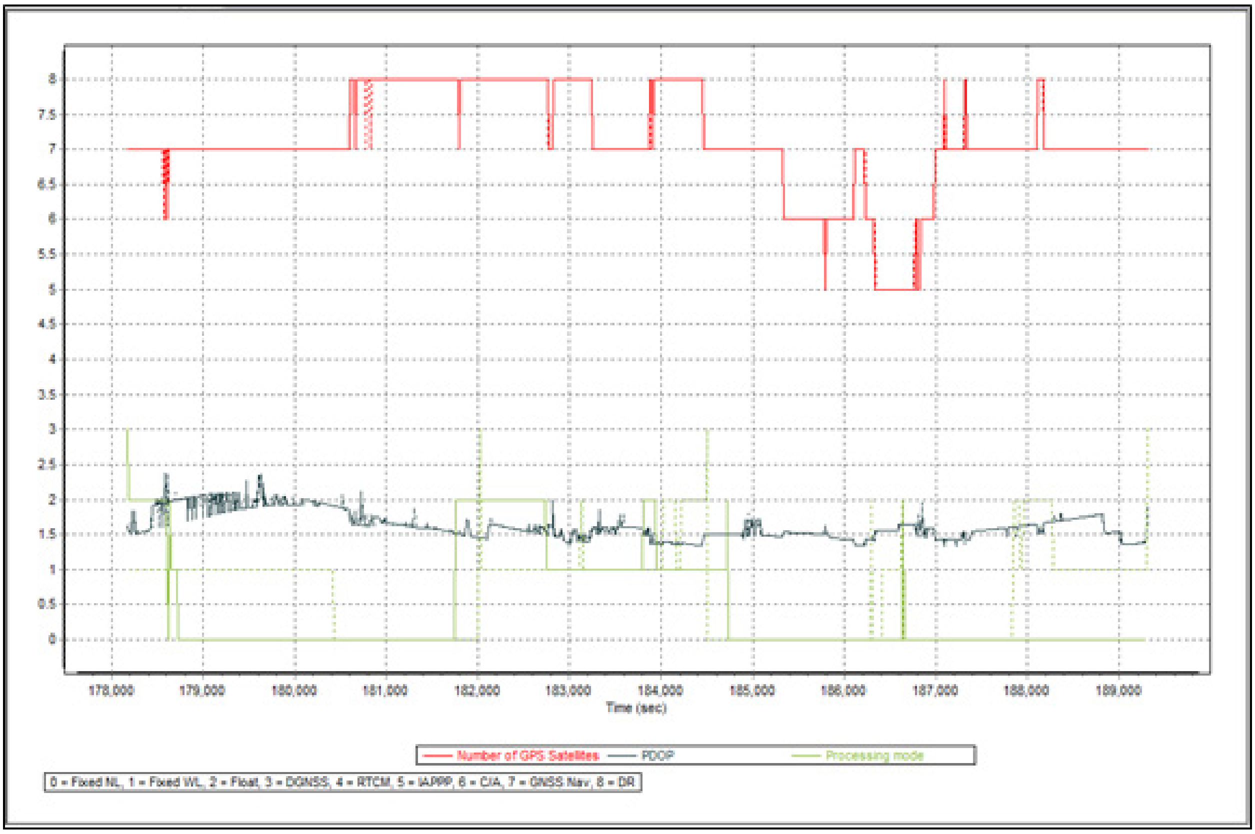


Density map of merged LiDAR data

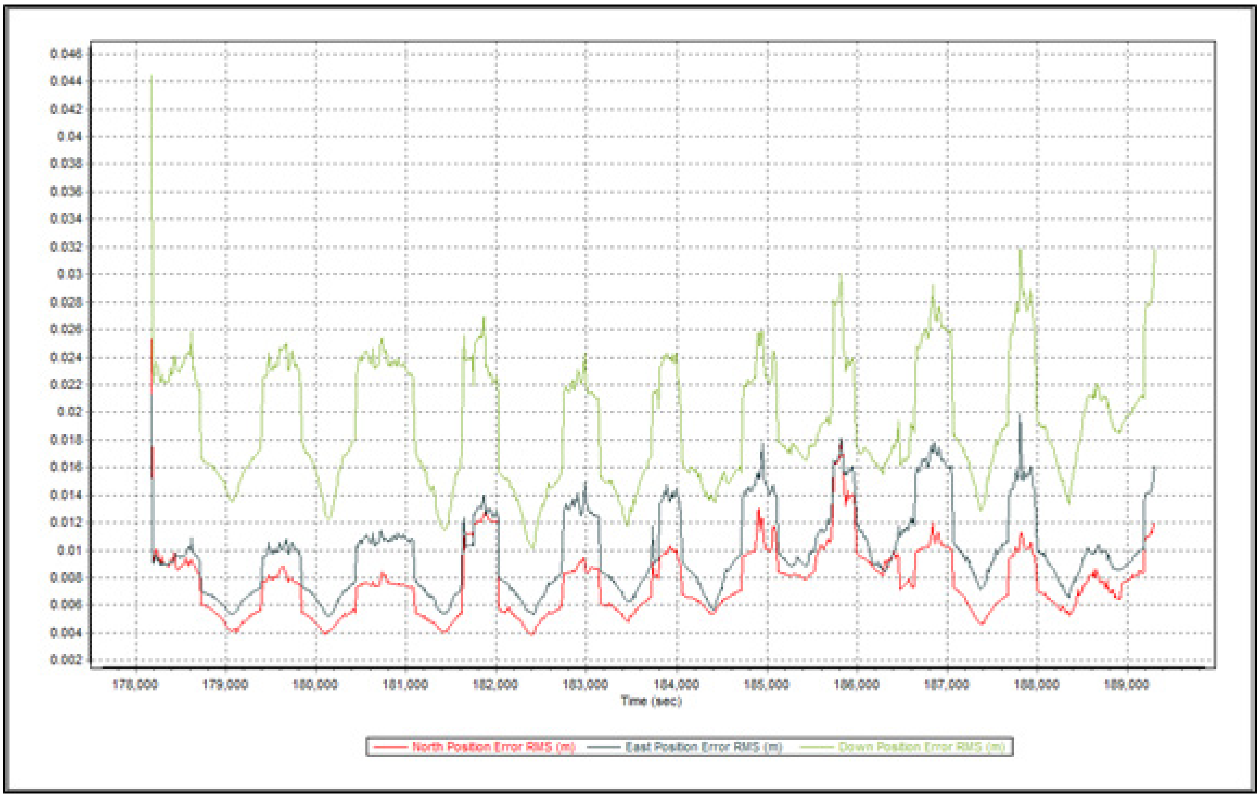


Elevation difference between flight lines

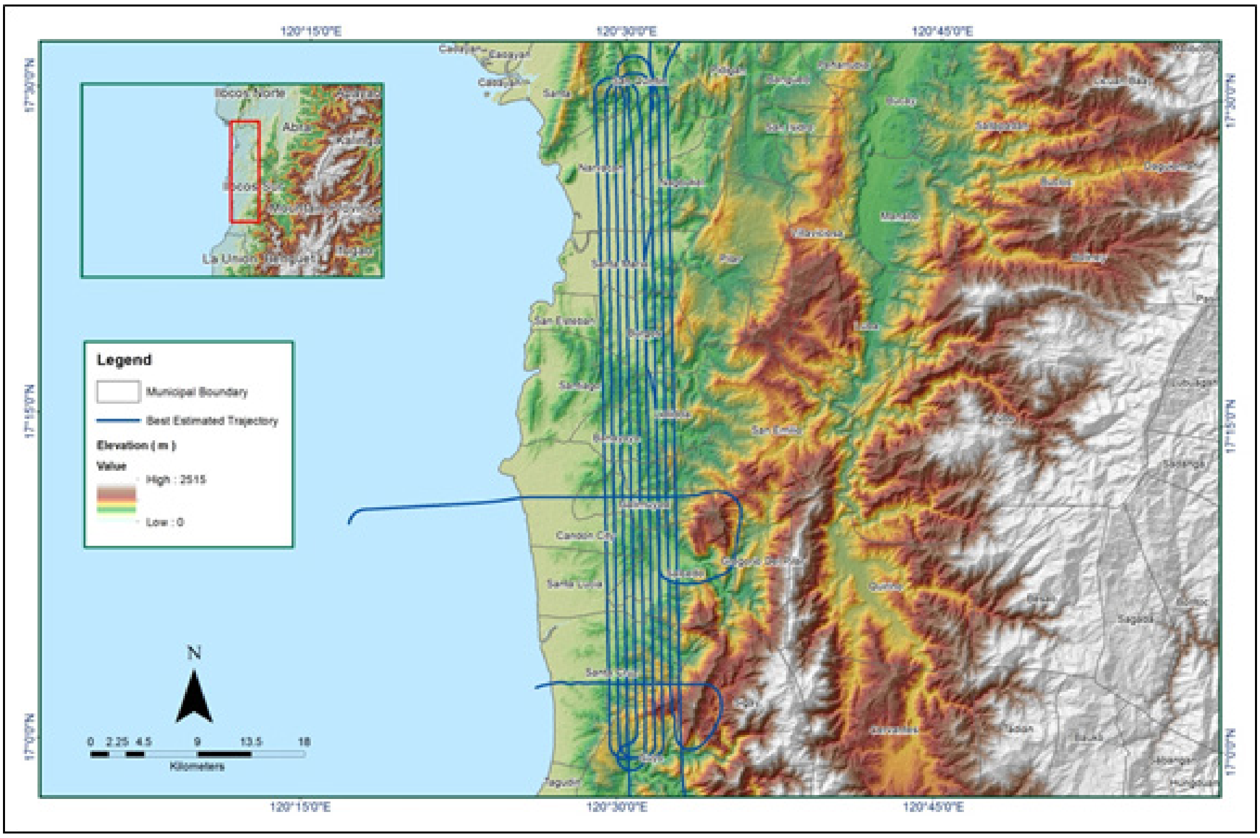
Flight Area	**Ilocos**
Mission Name	Blk27BCD
Inclusive Flights	1179P, 1195P
Range data size	44.7 GB
POS data size	5.86 MB
Base data size	370 MB
Image	55.4 GB
Transfer date	March 7, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000733
IMU attitude correction stdev (<0.001deg)	0.005568
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	45.11%
Ave point cloud density per sq.m. (>2.0)	2.53
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	497
Maximum Height	859.24m
Minimum Height	39.94m
Classification (# of points)	
Ground	268,348,004
Low vegetation	216,450,901
Medium vegetation	216,450,901
High vegetation	535,763,002
Building	18,246,074
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Engr. Jeffrey Delica



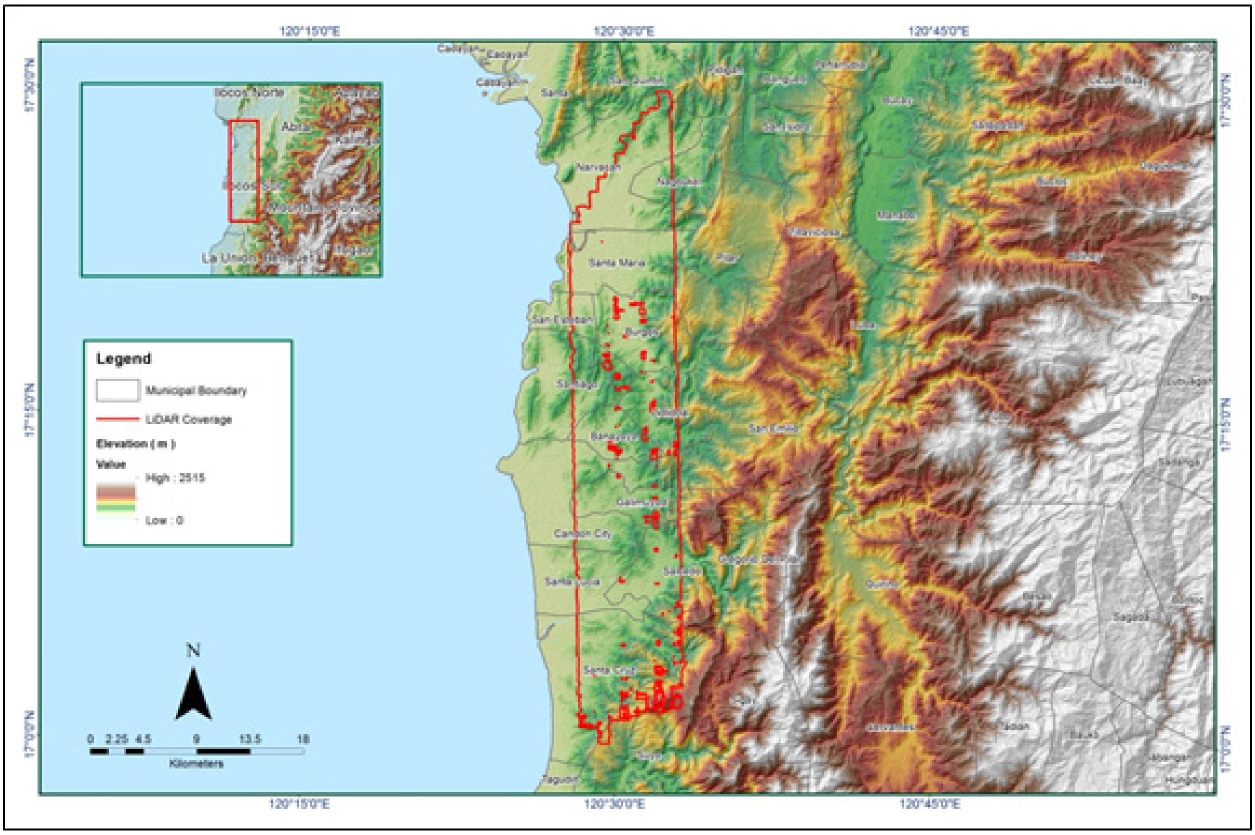
Solution Status Parameters



Smoothed Performance Metrics Parameters



Best Estimated Trajectory



Coverage of LiDAR data

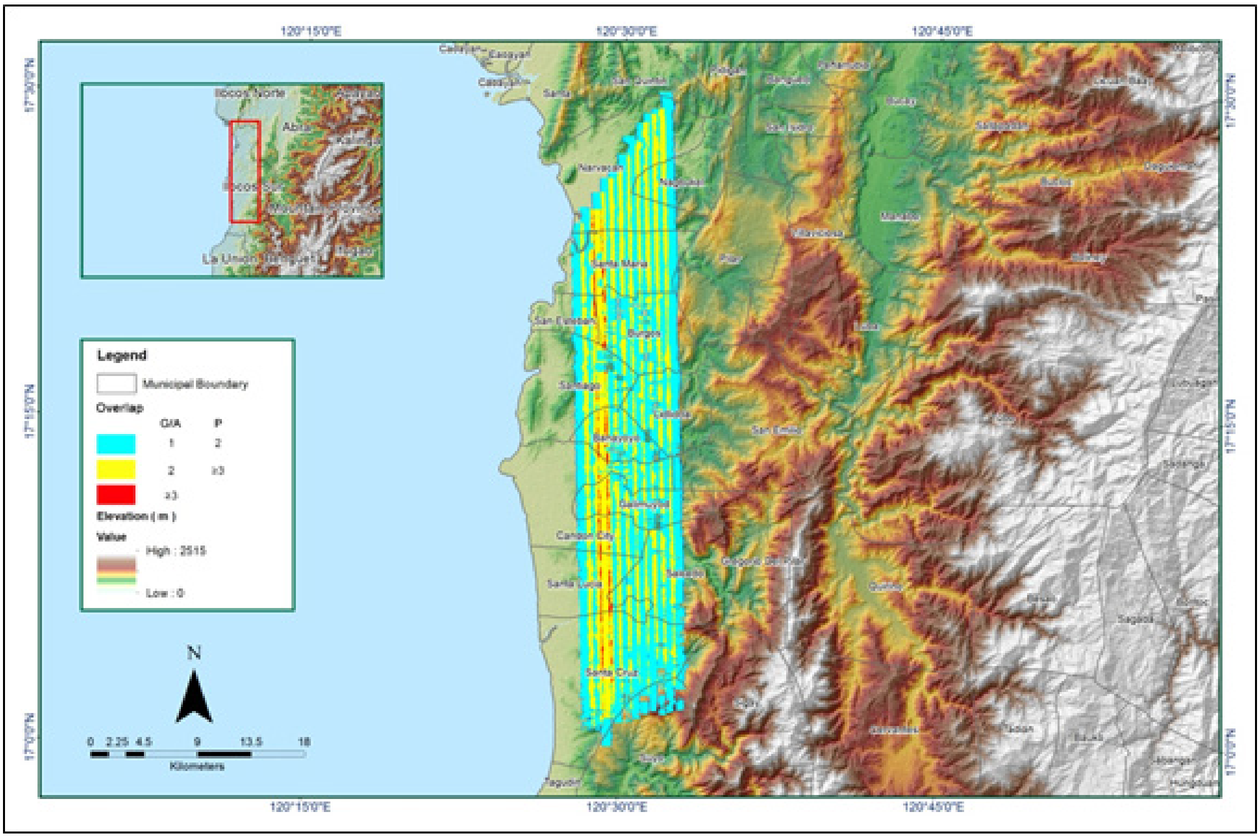
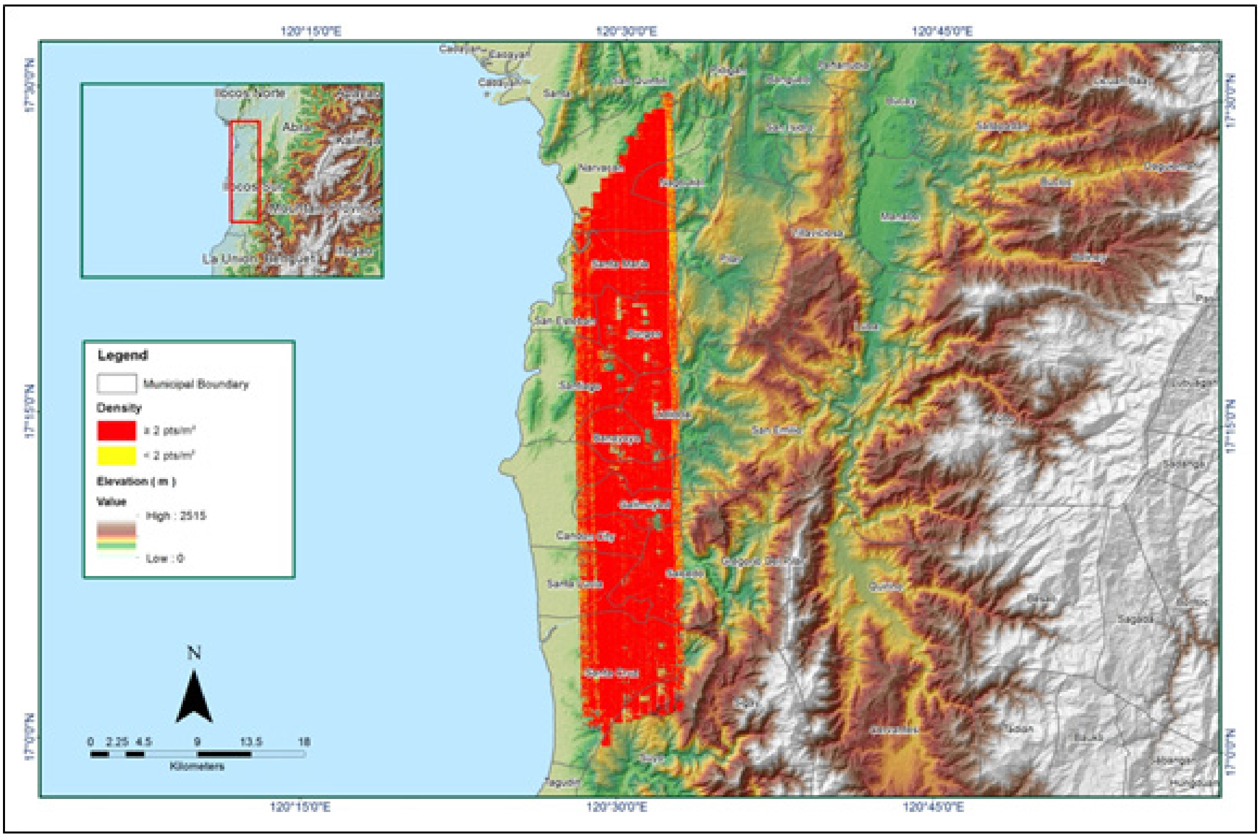
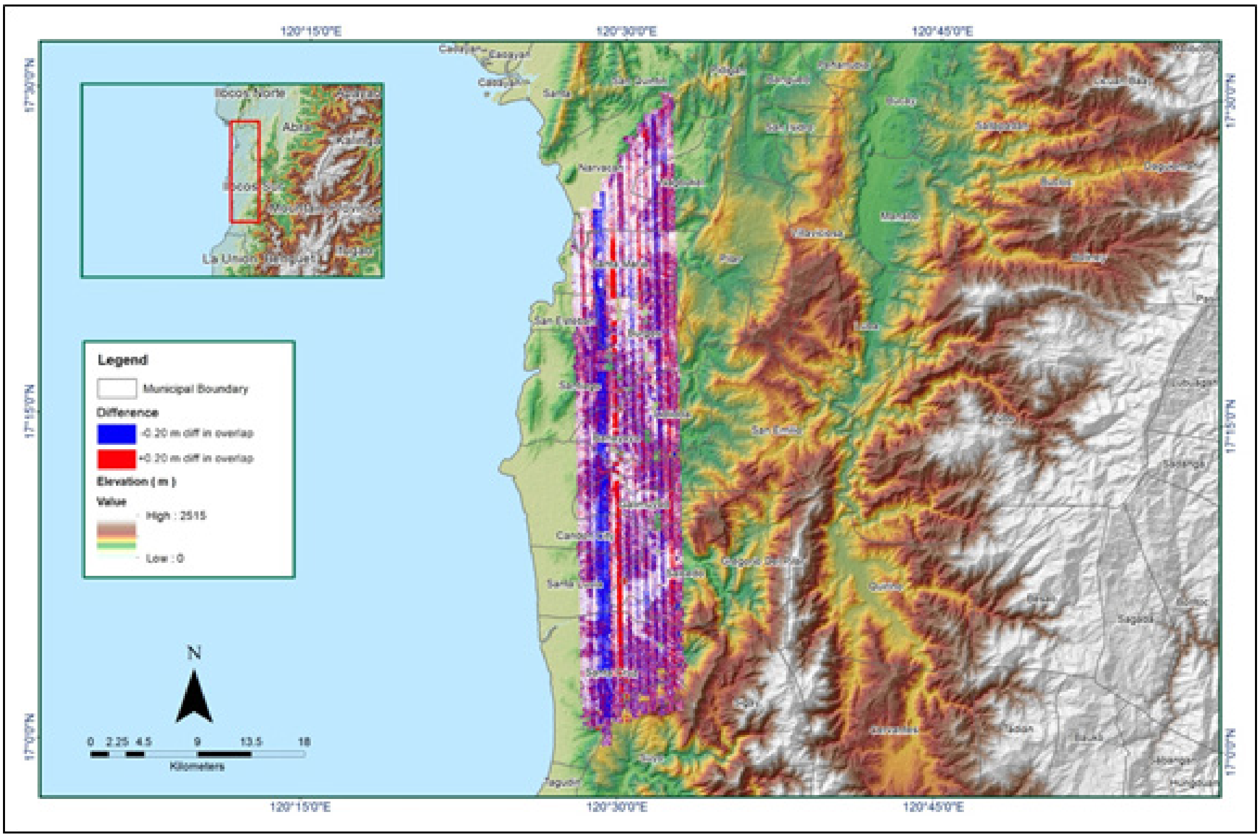


Image of Data Overlap



Density map of merged LiDAR data



Elevation difference between flight lines

ANNEX 9. Buaya Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W300	242.74	52.647	0	1.8871	9.0588	Discharge	7.0373	0.00001	Ratio to Peak	0.000151
W310	267.09	52.764	0	2.6992	5.899	Discharge	0.23949	0.00001	Ratio to Peak	0.000151
W320	215.66	52.764	0	6.7382	9.6525	Discharge	1.2935	0.00001	Ratio to Peak	0.000151
W330	80.148	35.235	0	5.9582	29.256	Discharge	0.72191	0.00001	Ratio to Peak	0.000151
W340	99.126	35.176	0	14.527	47.185	Discharge	0.26132	0.00001	Ratio to Peak	0.000151
W350	52.627	35.281	0	15.73	81.399	Discharge	0.29875	0.00001	Ratio to Peak	0.000151
W360	266.98	51.709	0	2.3518	11.418	Discharge	0.21896	0.00001	Ratio to Peak	0.000151
W370	17.51	35.255	0	0.82674	7.6775	Discharge	0.19861	0.00001	Ratio to Peak	0.000151
W380	248.5	36.534	0	1.579	17.462	Discharge	0.41489	0.00001	Ratio to Peak	0.000151
W390	165.88	35.02	0	5.367	18.406	Discharge	0.1213	0.00001	Ratio to Peak	0.000151
W400	10.259	35.242	0	0.22014	12.17	Discharge	0.17904	0.00001	Ratio to Peak	0.000151
W410	30.36	35.351	0	0.097578	0.064135	Discharge	0.00114	0.00001	Ratio to Peak	0.000151
W420	1.4417	35.284	0	0.72968	0.63881	Discharge	0.014204	0.00001	Ratio to Peak	0.000151
W430	10.206	35.097	0	0.51998	1.8803	Discharge	0.18578	0.00001	Ratio to Peak	0.000151
W440	103.31	35.166	0	2.2639	9.0184	Discharge	0.11872	0.00001	Ratio to Peak	0.000151
W450	4.189	35.309	0	0.69265	0.64354	Discharge	0.11511	0.00001	Ratio to Peak	0.000151

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W460	147.9	40.436	0	0.30498	3.2245	Discharge	0.001055	0.00001	Ratio to Peak	0.000151
W470	20.286	57.527	0	0.277	0.9286	Discharge	0.08138	0.00001	Ratio to Peak	0.000151
W480	156.87	49.582	0	3.0843	50.23	Discharge	0.60328	0.00001	Ratio to Peak	0.000151
W490	30.991	35.045	0	5.6817	17.723	Discharge	0.1699	0.00001	Ratio to Peak	0.000151
W500	14.335	35.323	0	0.75613	13.157	Discharge	0.15983	0.00001	Ratio to Peak	0.000151
W510	130.11	52.838	0	4.6657	14.161	Discharge	0.327	0.00001	Ratio to Peak	0.000151
W520	189.58	35.674	0	0.95144	4.5801	Discharge	0.30303	0.00001	Ratio to Peak	0.000151
W530	18.876	47.56	0	27.774	16.77	Discharge	0.054678	0.00001	Ratio to Peak	0.000151
W540	83.81	35.179	0	0.21925	0.16522	Discharge	0.12751	0.00001	Ratio to Peak	0.000151
W550	22.958	35.176	0	0.30088	19.281	Discharge	0.060465	0.00001	Ratio to Peak	0.000151
W560	16.013	35.176	0	0.22023	12.649	Discharge	0.11262	0.00001	Ratio to Peak	0.000151
W570	117.39	35.291	0	12.144	11.041	Discharge	0.20458	0.00001	Ratio to Peak	0.000151
W580	6.0869	35.146	0	0.4901	1.3461	Discharge	0.31431	0.00001	Ratio to Peak	0.000151

ANNEX 10. Buaya Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	1131.7	0.003635	0.06804	Trapezoid	167	1
R120	Automatic Fixed Interval	7315.2	0.013514	0.088101	Trapezoid	60.7	1
R130	Automatic Fixed Interval	3647.8	0.012341	0.31294	Trapezoid	99.4	1
R140	Automatic Fixed Interval	64.142	0.006111	0.43884	Trapezoid	98.1	1
R160	Automatic Fixed Interval	2355.8	0.015963	0.45959	Trapezoid	58.3	1
R170	Automatic Fixed Interval	1360.5	0.017717	0.90002	Trapezoid	40	1
R180	Automatic Fixed Interval	4135.9	0.00406	0.027183	Trapezoid	135	1
R210	Automatic Fixed Interval	2315.3	0.002387	0.060476	Trapezoid	179.4	1
R220	Automatic Fixed Interval	1768.8	0.0001	0.46404	Trapezoid	97	1
R230	Automatic Fixed Interval	5763	0.005026	0.03497	Trapezoid	104.9	1
R270	Automatic Fixed Interval	4046.2	0.011109	0.059803	Trapezoid	69.8	1
R40	Automatic Fixed Interval	2489.4	0.017323	0.18602	Trapezoid	47.1	1
R70	Automatic Fixed Interval	6004.4	0.007672	0.13589	Trapezoid	100.8	1
R80	Automatic Fixed Interval	190.71	0.016294	0.011177	Trapezoid	132	1

ANNEX 11. Buaya Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	17.111266	120.448366	1.77	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
2	17.095869	120.50985	0.1	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
3	17.086702	120.465211	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
4	17.08809	120.46345	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
5	17.08809	120.46345	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
6	17.08809	120.46345	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
7	17.08809	120.46345	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
8	17.079796	120.477425	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
9	17.079796	120.477425	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
10	17.079796	120.477425	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
11	17.079796	120.477425	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
12	17.080134	120.474338	0.03	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
13	17.095869	120.50985	0.1	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
14	17.080134	120.474338	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
15	17.080134	120.474338	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
16	17.080134	120.474338	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
17	17.080473	120.458643	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
18	17.080473	120.458643	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
19	17.080473	120.458643	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
20	17.080473	120.458643	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
21	17.084163	120.464776	0.32	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
22	17.084163	120.464776	0.32	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
23	17.084163	120.464776	0.32	0.3048	0.093	Karen/ August 18-21, 2008	5-Year

24	17.108198	120.446969	1.93	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
25	17.084163	120.464776	0.32	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
26	17.088954	120.465706	0.95	0.762	0.581	Karen/ August 18-21, 2008	5-Year
27	17.088954	120.465706	0.95	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
28	17.088954	120.465706	0.95	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
29	17.088954	120.465706	0.95	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
30	17.085249	120.45616	0.12	0.762	0.581	Karen/ August 18-21, 2008	5-Year
31	17.085249	120.45616	0.12	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
32	17.085249	120.45616	0.12	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
33	17.085249	120.45616	0.12	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
34	17.089557	120.442433	1.3	0.762	0.581	Karen/ August 18-21, 2008	5-Year
35	17.10804	120.440087	3.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
36	17.089557	120.442433	1.3	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
37	17.089557	120.442433	1.3	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
38	17.089557	120.442433	1.3	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
39	17.104638	120.44389	1.7	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
40	17.104882	120.449012	1.25	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
41	17.105309	120.449689	1.33	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
42	17.108951	120.446732	1.93	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
43	17.107654	120.447125	1.83	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
44	17.108785	120.445852	1.8	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
45	17.109256	120.447648	2.3	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
46	17.108124	120.439145	3.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
47	17.119226	120.49013	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
48	17.115765	120.48489	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year

49	17.109503	120.486638	2.87	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
50	17.110329	120.486278	2.42	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
51	17.116102	120.485202	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
52	17.121152	120.496969	0.06	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
53	17.108153	120.484428	2.5	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
54	17.117233	120.487824	1.94	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
55	17.121196	120.497788	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
56	17.121893	120.496214	0.06	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
57	17.108701	120.437823	2.19	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
58	17.110289	120.465033	0.14	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
59	17.109264	120.484263	2.72	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
60	17.109264	120.484263	2.72	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
61	17.109264	120.484263	2.72	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
62	17.109264	120.484263	2.72	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
63	17.109264	120.484263	2.72	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
64	17.109502	120.485543	2.71	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
65	17.108566	120.48398	2.63	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
66	17.10965	120.485269	2.71	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
67	17.108663	120.48448	2.61	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
68	17.11991	120.452469	0.6	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
69	17.108611	120.485981	2.33	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
70	17.119751	120.469674	0.12	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
71	17.099146	120.440446	1.52	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
72	17.100178	120.438688	2.17	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
73	17.102084	120.443142	2	0.4572	0.209	Mario/ September 18-22, 2014	5-Year

74	17.102238	120.439703	2.05	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
75	17.102406	120.437464	1.2	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
76	17.102797	120.449326	1.33	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
77	17.105184	120.44225	1.37	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
78	17.110083	120.511049	1.93	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
79	17.076514	120.492951	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
80	17.073724	120.442192	0.07	0.762	0.581	Karen/ August 18-21, 2008	5-Year
81	17.073724	120.442192	0.07	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
82	17.073724	120.442192	0.07	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
83	17.073724	120.442192	0.07	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
84	17.075249	120.446233	0.28	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
85	17.075249	120.446233	0.28	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
86	17.075249	120.446233	0.28	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
87	17.075249	120.446233	0.28	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
88	17.075327	120.440806	0.45	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
89	17.075327	120.440806	0.45	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
90	17.076514	120.492951	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
91	17.075327	120.440806	0.45	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
92	17.075327	120.440806	0.45	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
93	17.075902	120.441891	0.73	0.762	0.581	Karen/ August 18-21, 2008	5-Year
94	17.075902	120.441891	0.73	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
95	17.075902	120.441891	0.73	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
96	17.075902	120.441891	0.73	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
97	17.076417	120.444804	0.76	0.762	0.581	Karen/ August 18-21, 2008	5-Year
98	17.076417	120.444804	0.76	0.9144	0.836	Karen/ August 18-21, 2008	5-Year

99	17.076417	120.444804	0.76	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
100	17.076417	120.444804	0.76	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
101	17.076514	120.492951	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
102	17.083919	120.454007	0.1	0.762	0.581	Karen/ August 18-21, 2008	5-Year
103	17.083919	120.454007	0.1	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
104	17.083919	120.454007	0.1	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
105	17.083919	120.454007	0.1	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
106	17.086886	120.454971	0.09	0.762	0.581	Karen/ August 18-21, 2008	5-Year
107	17.086886	120.454971	0.09	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
108	17.086886	120.454971	0.09	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
109	17.086886	120.454971	0.09	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
110	17.08162	120.453525	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
111	17.08162	120.453525	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
112	17.11301	120.455909	1.24	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
113	17.076514	120.492951	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
114	17.08162	120.453525	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
115	17.08162	120.453525	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
116	17.084125	120.450941	0.05	0.762	0.581	Karen/ August 18-21, 2008	5-Year
117	17.084125	120.450941	0.05	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
118	17.084125	120.450941	0.05	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
119	17.084125	120.450941	0.05	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
120	17.113357	120.438119	1.44	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
121	17.117788	120.43677	0.48	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
122	17.113156	120.439106	1.71	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
123	17.116752	120.437255	1.69	0.4572	0.209	Mario/ September 18-22, 2014	5-Year

124	17.079651	120.480756	0.48	0.762	0.581	Karen/ August 18-21, 2008	5-Year
125	17.114964	120.437468	1.42	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
126	17.115142	120.440186	2.3	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
127	17.069787	120.488514	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
128	17.069787	120.488514	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
129	17.069787	120.488514	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
130	17.069787	120.488514	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
131	17.093337	120.446497	1.18	0.762	0.581	Karen/ August 18-21, 2008	5-Year
132	17.093337	120.446497	1.18	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
133	17.093337	120.446497	1.18	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
134	17.093337	120.446497	1.18	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
135	17.079651	120.480756	0.48	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
136	17.090313	120.442794	1.58	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
137	17.087575	120.465862	0.16	0.762	0.581	Karen/ August 18-21, 2008	5-Year
138	17.087575	120.465862	0.16	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
139	17.087575	120.465862	0.16	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
140	17.087575	120.465862	0.16	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
141	17.0841	120.452636	0.08	0.762	0.581	Karen/ August 18-21, 2008	5-Year
142	17.0841	120.452636	0.08	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
143	17.0841	120.452636	0.08	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
144	17.0841	120.452636	0.08	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
145	17.085139	120.452285	0.08	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
146	17.079651	120.480756	0.48	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
147	17.098499	120.457562	1.51	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
148	17.0986	120.452318	0.64	0.4572	0.209	Mario/ September 18-22, 2014	5-Year

149	17.101501	120.453237	1.49	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
150	17.101591	120.444996	1.6	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
151	17.102755	120.459617	1.27	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
152	17.102918	120.455514	0.53	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
153	17.105378	120.459159	0.74	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
154	17.095867	120.495598	0.06	0.762	0.581	Karen/ August 18-21, 2008	5-Year
155	17.095867	120.495598	0.06	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
156	17.095867	120.495598	0.06	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
157	17.079651	120.480756	0.48	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
158	17.095867	120.495598	0.06	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
159	17.096699	120.509525	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
160	17.096699	120.509525	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
161	17.096699	120.509525	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
162	17.096699	120.509525	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
163	17.096312	120.495062	0.06	0.762	0.581	Karen/ August 18-21, 2008	5-Year
164	17.096312	120.495062	0.06	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
165	17.096312	120.495062	0.06	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
166	17.096312	120.495062	0.06	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
167	17.095409	120.495952	0.03	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
168	17.095032	120.487956	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
169	17.095409	120.495952	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
170	17.095409	120.495952	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
171	17.095409	120.495952	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
172	17.097444	120.495256	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
173	17.097444	120.495256	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year

174	17.097444	120.495256	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
175	17.097444	120.495256	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
176	17.097203	120.494628	0.05	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
177	17.097203	120.494628	0.05	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
178	17.097203	120.494628	0.05	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
179	17.095032	120.487956	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
180	17.097203	120.494628	0.05	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
181	17.097357	120.497779	0.05	0.762	0.581	Karen/ August 18-21, 2008	5-Year
182	17.097357	120.497779	0.05	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
183	17.097357	120.497779	0.05	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
184	17.097357	120.497779	0.05	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
185	17.09762	120.495527	0.03	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
186	17.09762	120.495527	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
187	17.09762	120.495527	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
188	17.09762	120.495527	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
189	17.108705	120.453982	1.69	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
190	17.095032	120.487956	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
191	17.085402	120.459502	1.37	0.762	0.581	Karen/ August 18-21, 2008	5-Year
192	17.085402	120.459502	1.37	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
193	17.085402	120.459502	1.37	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
194	17.085402	120.459502	1.37	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
195	17.076973	120.455241	0.68	0.762	0.581	Karen/ August 18-21, 2008	5-Year
196	17.076973	120.455241	0.68	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
197	17.076973	120.455241	0.68	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
198	17.076973	120.455241	0.68	0.6096	0.372	Mario/ September 18-22, 2014	5-Year

199	17.076973	120.455241	0.68	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
200	17.076973	120.455241	0.68	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
201	17.095032	120.487956	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
202	17.07712	120.459353	0.58	0.762	0.581	Karen/ August 18-21, 2008	5-Year
203	17.07712	120.459353	0.58	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
204	17.07712	120.459353	0.58	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
205	17.07712	120.459353	0.58	0.6096	0.372	Mario/ September 18-22, 2014	5-Year
206	17.07712	120.459353	0.58	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
207	17.07712	120.459353	0.58	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
208	17.074883	120.455585	0.53	0.762	0.581	Karen/ August 18-21, 2008	5-Year
209	17.074883	120.455585	0.53	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
210	17.074883	120.455585	0.53	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
211	17.074883	120.455585	0.53	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
212	17.101286	120.49197	0.04	0.762	0.581	Karen/ August 18-21, 2008	5-Year
213	17.098915	120.473735	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
214	17.098915	120.473735	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
215	17.098915	120.473735	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
216	17.098915	120.473735	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
217	17.078154	120.442674	1.67	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
218	17.080433	120.445021	1.9	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
219	17.09043	120.443395	1.51	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
220	17.08973	120.44318	0.88	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
221	17.089912	120.444619	0.91	0.762	0.581	Karen/ August 18-21, 2008	5-Year
222	17.089912	120.444619	0.91	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
223	17.113769	120.45068	0.75	0.4572	0.209	Mario/ September 18-22, 2014	5-Year

224	17.101286	120.49197	0.04	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
225	17.089912	120.444619	0.91	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
226	17.089912	120.444619	0.91	0.6096	0.372	Mario/ September 18-22, 2014	5-Year
227	17.089912	120.444619	0.91	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
228	17.089912	120.444619	0.91	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
229	17.089912	120.444619	0.91	1.2192	1.486	Mario/ September 18-22, 2014	5-Year
230	17.094788	120.441992	1.23	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
231	17.09332	120.448149	1.05	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
232	17.09256	120.446633	1.34	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
233	17.094959	120.447708	1.6	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
234	17.093769	120.444205	1.68	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
235	17.101286	120.49197	0.04	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
236	17.09629	120.437239	0.59	0.9144	0.836	Mario/ September 18-22, 2014	5-Year
237	17.076731	120.491903	0.04	0.762	0.581	Karen/ August 18-21, 2008	5-Year
238	17.076731	120.491903	0.04	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
239	17.076731	120.491903	0.04	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
240	17.076731	120.491903	0.04	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
241	17.079262	120.489628	0.03	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
242	17.101286	120.49197	0.04	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
243	17.079262	120.489628	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
244	17.079262	120.489628	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
245	17.079262	120.489628	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
246	17.096304	120.510052	0.09	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
247	17.096304	120.510052	0.09	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
248	17.096304	120.510052	0.09	0.3048	0.093	Karen/ August 18-21, 2008	5-Year

249	17.096304	120.510052	0.09	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
250	17.095968	120.496366	0.03	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
251	17.095968	120.496366	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
252	17.095968	120.496366	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
253	17.097047	120.485583	0.03	0.4572	0.209	Karen/ August 18-21, 2008	5-Year
254	17.095968	120.496366	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
255	17.097047	120.485583	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
256	17.097047	120.485583	0.03	0.3048	0.093	Karen/ August 18-21, 2008	5-Year
257	17.097047	120.485583	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
258	17.098527	120.487891	1.85	0.762	0.581	Karen/ August 18-21, 2008	5-Year
259	17.098527	120.487891	1.85	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
260	17.098527	120.487891	1.85	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
261	17.114263	120.45228	1.98	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
262	17.098527	120.487891	1.85	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
263	17.101823	120.492244	0.04	0.762	0.581	Karen/ August 18-21, 2008	5-Year
264	17.101823	120.492244	0.04	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
265	17.101823	120.492244	0.04	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
266	17.101823	120.492244	0.04	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
267	17.074402	120.532978	0.55	0.762	0.581	Karen/ August 18-21, 2008	5-Year
268	17.074402	120.532978	0.55	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
269	17.074402	120.532978	0.55	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
270	17.074402	120.532978	0.55	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
271	17.111436	120.447459	1.68	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
272	17.115484	120.448805	0.78	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
273	17.116065	120.447828	0.99	0.4572	0.209	Mario/ September 18-22, 2014	5-Year

274	17.113352	120.448934	1.93	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
275	17.10108	120.476128	2.57	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
276	17.10254	120.482022	4.35	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
277	17.101176	120.476727	2.87	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
278	17.108209	120.485225	2.39	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
279	17.106712	120.486066	2.18	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
280	17.108607	120.484662	2.59	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
281	17.109538	120.485556	2.56	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
282	17.112085	120.465618	0.05	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
283	17.11716	120.449553	0.67	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
284	17.112085	120.465618	0.05	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
285	17.109147	120.484904	2.72	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
286	17.115441	120.484826	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
287	17.114838	120.475927	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
288	17.079471	120.480237	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
289	17.079471	120.480237	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
290	17.079471	120.480237	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
291	17.079471	120.480237	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
292	17.094424	120.495511	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
293	17.094424	120.495511	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
294	17.119023	120.445577	1.06	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
295	17.094424	120.495511	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
296	17.094424	120.495511	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
297	17.075033	120.531694	0.24	0.762	0.581	Karen/ August 18-21, 2008	5-Year
298	17.075033	120.531694	0.24	0.9144	0.836	Karen/ August 18-21, 2008	5-Year

299	17.075033	120.531694	0.24	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
300	17.075033	120.531694	0.24	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
301	17.100751	120.475253	2.48	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
302	17.107571	120.46519	0.03	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
303	17.100515	120.476509	2.2	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
304	17.101611	120.475989	2.15	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
305	17.095869	120.50985	0.1	0.762	0.581	Karen/ August 18-21, 2008	5-Year
306	17.10857	120.465478	0.16	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
307	17.103146	120.463983	4.47	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
308	17.105158	120.460678	0.98	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
309	17.108349	120.484061	2.67	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
310	17.100643	120.475758	2.16	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
311	17.105997	120.465082	5.54	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
312	17.106045	120.462828	0.82	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
313	17.106629	120.461751	0.39	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
314	17.107027	120.466874	5.99	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
315	17.109024	120.483774	2.87	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
316	17.095869	120.50985	0.1	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
317	17.117882	120.448432	0.48	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
318	17.113422	120.466058	0.17	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
319	17.113621	120.459097	0.77	0.4572	0.209	Mario/ September 18-22, 2014	5-Year
320	17.080672	120.474059	0.42	0.762	0.581	Karen/ August 18-21, 2008	5-Year
321	17.080672	120.474059	0.42	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
322	17.080672	120.474059	0.42	0.6096	0.372	Karen/ August 18-21, 2008	5-Year
323	17.080672	120.474059	0.42	0.9144	0.836	Karen/ August 18-21, 2008	5-Year

324	17.086702	120.465211	0.03	0.762	0.581	Karen/ August 18-21, 2008	5-Year
325	17.086702	120.465211	0.03	0.9144	0.836	Karen/ August 18-21, 2008	5-Year
326	17.086702	120.465211	0.03	0.6096	0.372	Karen/ August 18-21, 2008	5-Year

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ANNEX 12. Educational Institutions Affected by flooding in Buaya Flood Plain

Ilocos Sur				
Salcedo				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
PAOC ES	Atabay			
ARANGIN-DINARATAN ES	Dinaratan			
DINARATAN NATIONAL HIGH SCHOOL	Dinaratan			
DAY CARE CENTER	Kaliwakiw			
LUCBUBAN PS	Lucbuban	Low	Low	Medium
PIAS ES	Pias			
CULIONG ES	San Tiburcio	Low	Low	Low
NAGTABLAAN ES	San Tiburcio		Medium	High
NAGTABLAAN HS	San Tiburcio			Medium
SORIANO ES	Sorioan			Low
Santa Cruz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BANAY PS	Banay			
SAN JOSE ES	Besalan			
BOGUIBOG ES	Bugbuga			Low
SAN JOSE ES	Camanggaan			
ST. JOSEPH THE WORKER PARISH & SAN JOSE HS	Camanggaan			
LANTAG ES	Lantag			Low
PILAR ES	Pilar	Medium	Medium	Medium
P.R. PIMENTEL MEMORIAL ACADEMY	Poblacion Este			
SANTA CRUZ CENTRAL SCHOOL	Poblacion Este			
STA. CRUZ INSTITUTE	Poblacion Este			
STA. CRUZ INSTITUTE	Poblacion Weste			
BESALAN ES	Tampugo	Medium	High	High
VILLA HERMOSA ES	Villa Hermosa	Medium	Medium	High

Salcedo				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
STA. LUCIA NORTH CS	Angkileng	Medium	Medium	High
STA. LUCIA SOUTH CS	Angkileng	Medium	High	High
STA. LUCIA SOUTH CS	Ayusan	Medium	High	High
ANTERO P. HERMOSURA ES	Bao-As			
STA. LUCIA ACADEMY	Barangobong		Low	Low
STA. LUCIA NORTH CS	Barangobong	Low	Medium	Medium
BRGY. CABARITAN DAY CARE CENTER	Cabaritan	High	High	High
CABARITAN PS	Cabaritan	High	High	High
CONCONIG PS	Conconig East			
DAMACUAG ES	Damacuag	Low	Medium	Medium
DAYCARE	Nagrebcan	High	High	High
BULICLIC PS	Palali Norte			
PALALI ES	Palali Sur			
PALALI NHS	Palali Sur	Low	Low	Low
PARATONG DAY CARE	Paratong	Low	Medium	Medium
QUINSORIANO PS	Ronda	High	High	High
RONDA PS	Ronda	Medium	High	High
STA. LUCIA CALTEX FILLING STATION	San Juan	High	High	High

ANNEX 13. Health Institutions affected by flooding in Buaya Floodplain

Ilocos Sur				
Santa Cruz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
DR. ANTONIO L. VALLESR. MEMORIAL HEALTH CENTER	Poblacion Weste	Low	Medium	Medium
ST. MARTIN DE PORRES HOSPITAL	Saoat			
DR. ANTONIO L. VALLESR. MEMORIAL HEALTH CENTER	Villa Hermosa	Medium	High	High
Santa Cruz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
ILOCOS SUR DISTRICT HOSPITAL STA. LUCIA	Ronda	Low	Medium	Medium