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

LiDAR Surveys and Flood Mapping of Anibawan River

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

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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 ANIBAWAN RIVER

Enrico C. Paringit, Dr. Eng., Dr. Francis Aldrine Uy, and Engr. Fibor Tan

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the MAPUA Institute of Technology (MIT). MIT is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 26 river basins in the Cavite-Batangas-Rizal-Quezon (CABARZON) Region. The university is located in the City of Manila within Metro Manila in the National Capital Region.

1.2 Overview of the Anibawan River Basin

Situated in the northern tip of Polillo Island, the Anibawan river basin traverses the frequently typhoon-hit municipalities of Burdeos and Panukulan. The DENR River Basin Control Office identified the basin to have a drainage area of 97 km2 and an estimated annual runoff of 155 million cubic meter (MCM) (RBCO, 2015).

Its main stem, the Anibawan River, is among the twenty-four (24) river systems in the CALABARZON Region. According to the 2015 national census of NSO, a total of 6,039 persons are residing within the immediate vicinity of the river distributed among the different barangays, specifically Cabungalunan, Anibawan, Bonifacio, and Carlagan, in the Municipality of Burdeos. The Municipality of Burdeos is fourth income class, and sixty four percent (64%) of its population is engaged in fishing as a means of income, as all of its barangays are coastal (Source: http://mpasupportnetwork.org/files/SOC-2012-2.1-Burdeos-Quezon.pdf).

A few typhoons that have left indelible marks among the residents of these areas are Yoling (1970), Ading (1981), Unsang (1988), Loleng (1998) and Yoyong (2004). Last December 2016, the province of Quezon was one of the provinces hit by Typhoon Nina, internationally known as Nock-Ten. Around forty-one (41) Municipalities were evacuated during the typhoon (Source: http://newsinfo.inquirer.net/856614/10000-evacuated-as-nina-pummels-quezon-province). Given their geographical risks, the residents of these municipalities are highly susceptible to numerous catastrophic events.

The risks of flooding in the Anibawan River Basin call for concrete and immediate solutions. In this regard, the highly accurate collection of LiDAR (Light Detection and Ranging) data to produce digital elevation models (DEMs) and river flow data could be of great help in coming up with detailed hydrological and river hydraulic models. These models are needed in coming up with more reliable flood hazard maps which could help communities in becoming more equipped especially during times of calamities.

Despite the absence of a bridge in the river, numerous people still resides near the river due to their dependence on aquatic resources. However, these residents are exposed to greater risk since heavy rains usually lead to neck-deep flooding in the surrounding communities. These cost the lives and properties of the people. Other sources of living such as farmlands are also destroyed as a result.

Figure 1. Map of Anibawan River Basin (in brown)

Advances in numerical modeling software and recent remote sensing technologies such as Light Detection and Ranging (LiDAR) is needed in addressing these problems. This allows the production of highly accurate digital elevation models (DEMs) of the earth which are necessary in flood modelling to produce high resolution flood hazard maps. The local government units can then use these maps in their land use planning and development, in creating drainage master plans, for disaster preparedness, response, and recovery operations, and many other applications.

CHAPTER 2: LIDAR ACQUISITION IN ANIBAWAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data nearest the delineated priority area for Anibawan floodplain in Quezon Province. These missions were planned for fourteen (14) 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 Pegasus LiDAR system are found in Table 1. Figure 2 shows the flight plan for Anibawan floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR System.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK18Q	1200	30	50	200	30	130	5

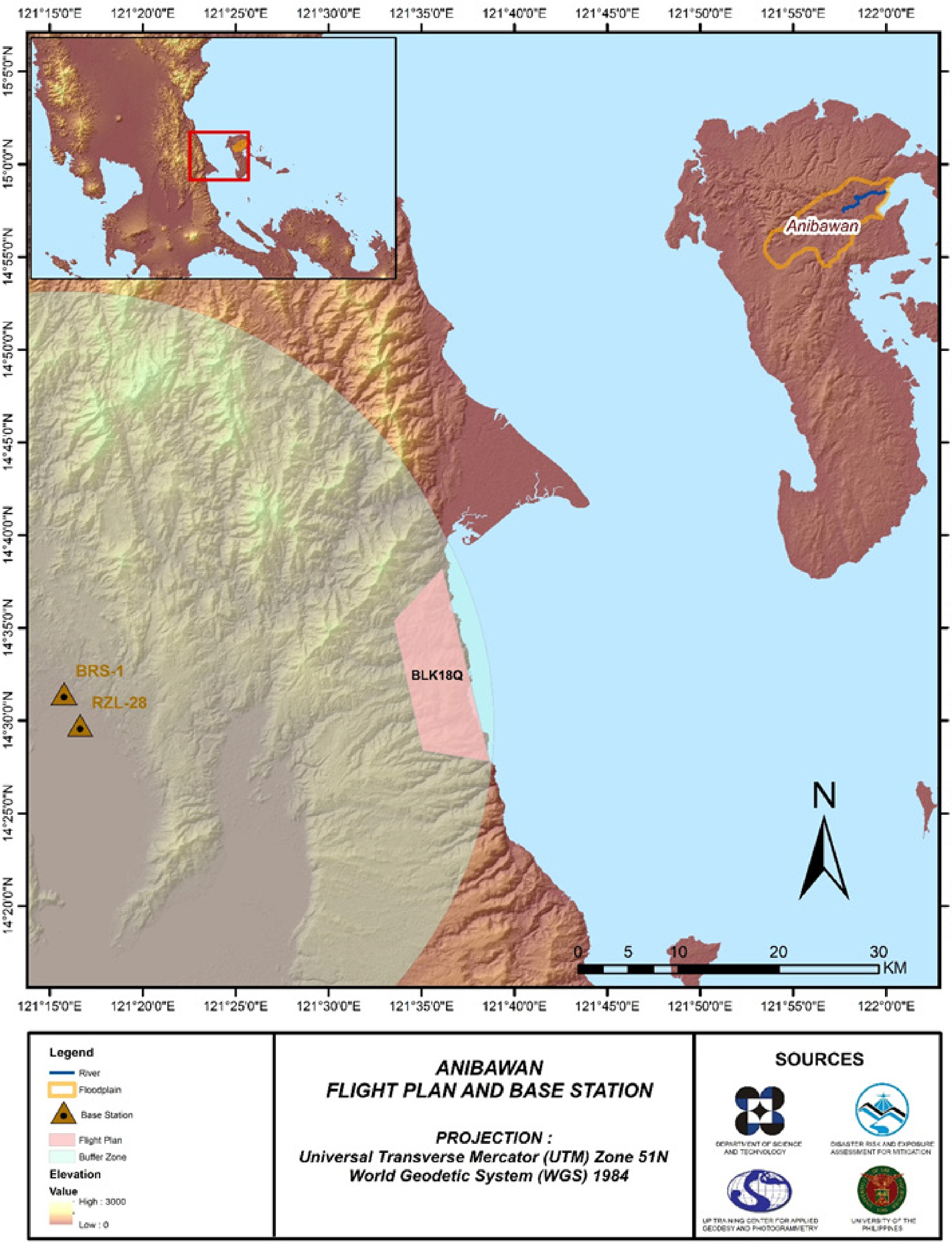

Figure 2. Flight plan and base station for Pegasus System used for Anibawan Floodplain

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point: RZL-28 which is of second (2nd) order accuracy. The project team also established one (1) ground control points BRS-1. The certifications for the base stations are found in Annex 2 while the baseline processing reports for the established point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 21, 2016). Base stations were observed using dual frequency GPS receivers, TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition nearest Anibawan floodplain are shown in Figure 2. The list of team members for LiDAR data acquisition is found in Annex 4.

Figure 2 to Figure 3 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 3 show the details about the NAMRIA control stations while Table 4 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

(a)

Figure 3. GPS set-up over RZL-28 near the lighthouse beside the fishport in Barangay San Isidro, Tanay, Rizal (a) and NAMRIA reference point RZL-28 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point RZL-28 used as base station for the LiDAR Acquisition.

Station Name	RZL-28	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 29’ 49.44078” North 121° 16’ 32.56146” East 5.86600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	529720.085 meters 1603180.963 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°29 ’44.06939” North 121°16’37.46276”East 50.37100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	1,603,302.05 meters 314,172.78 meters

Figure 4. GPS set-up over BRS-1 as established in the rooftop of D' One Resort & Restaurant in Baras, Rizal.

Table 3. Details of the established control point BRS-1 used as base station for the LiDAR Acquisition.

Station Name	**BRS-1**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 31' 32.82507" North 121° 15' 40.79958" East 15.361 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 31'27.44582" North 121° 15' 45.69850" East 59.750 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	312646.981 meters 1606491.077 meters

Table 4. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
21 JUNE 2016	23474P	1BLK18QO173A	BRS-1 and RZL-28

2.3 Flight Missions

One (1) mission was conducted to complete the LiDAR Data Acquisition nearest Anibawan Floodplain, for a total of three hours and seventeen minutes (3+17) of flying time for RP-C9022. The mission was acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for LiDAR data acquisition in Anibawan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
21 June 2016	23474P	121.55	146.82	-	136.66	NA	3	17
TOTAL		121.55	146.82	-	136.66	NA	3	17

Table 6. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23474P	1000	60	50	200	32	130	5

2.4 Survey Coverage

Anibawan floodplain is situated within Quezon Province. The list of municipalities surveyed with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Anibawan floodplain is presented in Figure 5.

Table 7. List of municipalities and cities surveyed in Anibawan Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Quezon	Real	382.11	140.35	36.73%
Total		382.11	140.35	36.73%

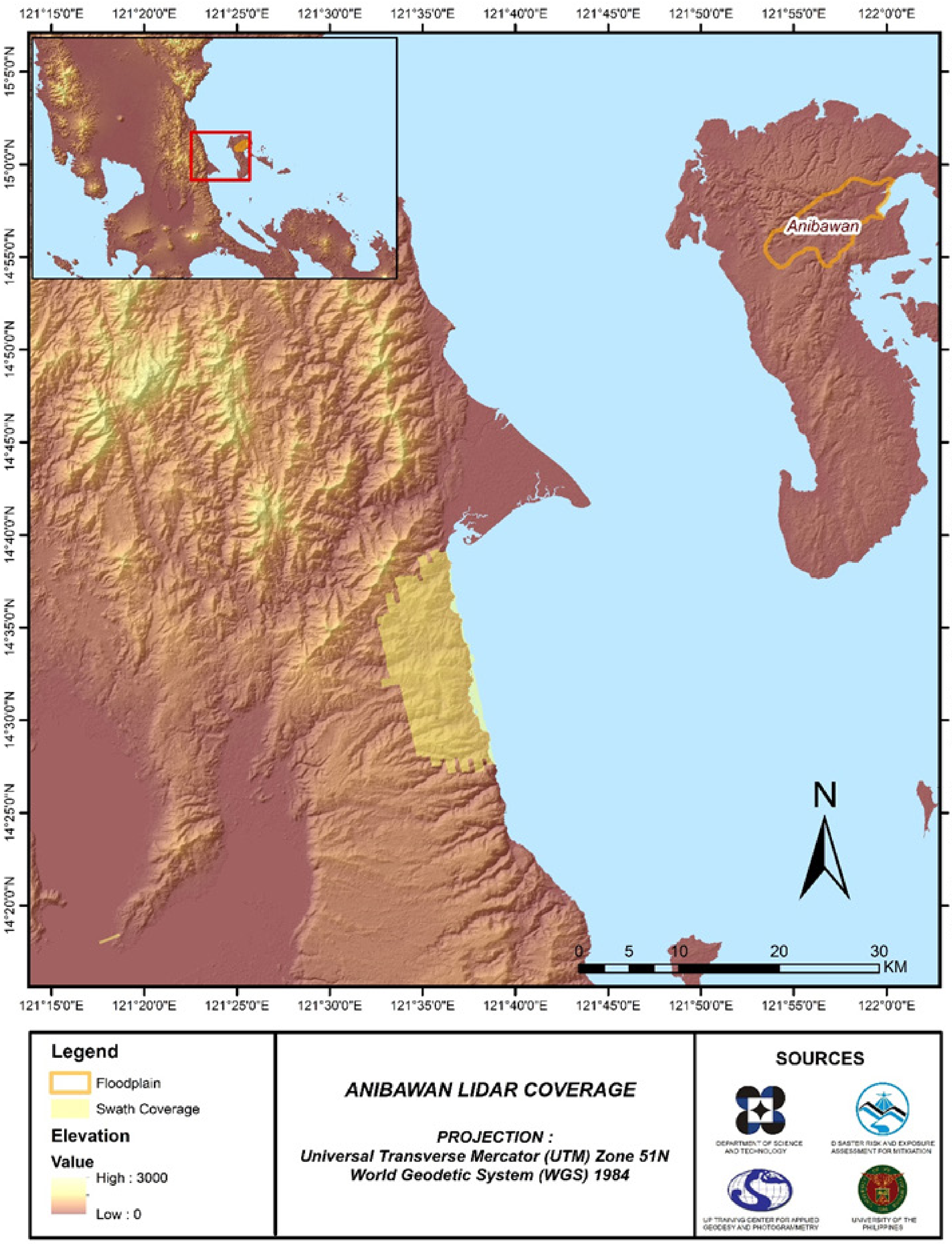

Figure 5. Actual LiDAR survey coverage for Anibawan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR ANIBAWAN 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 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 6.

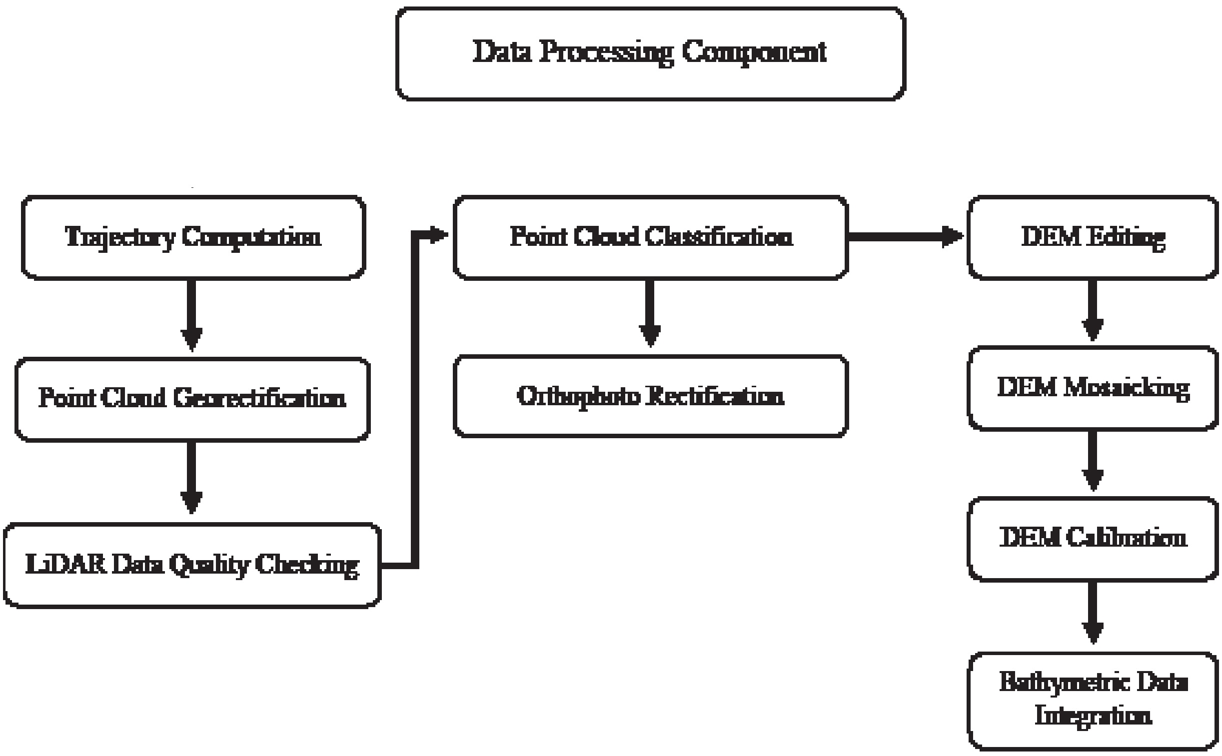


Figure 6. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Anibawan floodplain can be found in Annex 5. Missions flown during the first survey conducted on June 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Burdeos, Quezon.

The Data Acquisition Component (DAC) transferred a total of 12.7 Gigabytes of Range data, 200 Megabytes of POS data, 468 Megabytes of GPS base station data, and 0 Gigabytes of raw image data to the data server on July 13, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Anibawan was fully transferred on July 14, 2016, as indicated on the Data Transfer Sheets for Anibawan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23474P, one of the Anibawan flights, which is the North, East, and Down position RMSE values are shown in Figure 7. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 22, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

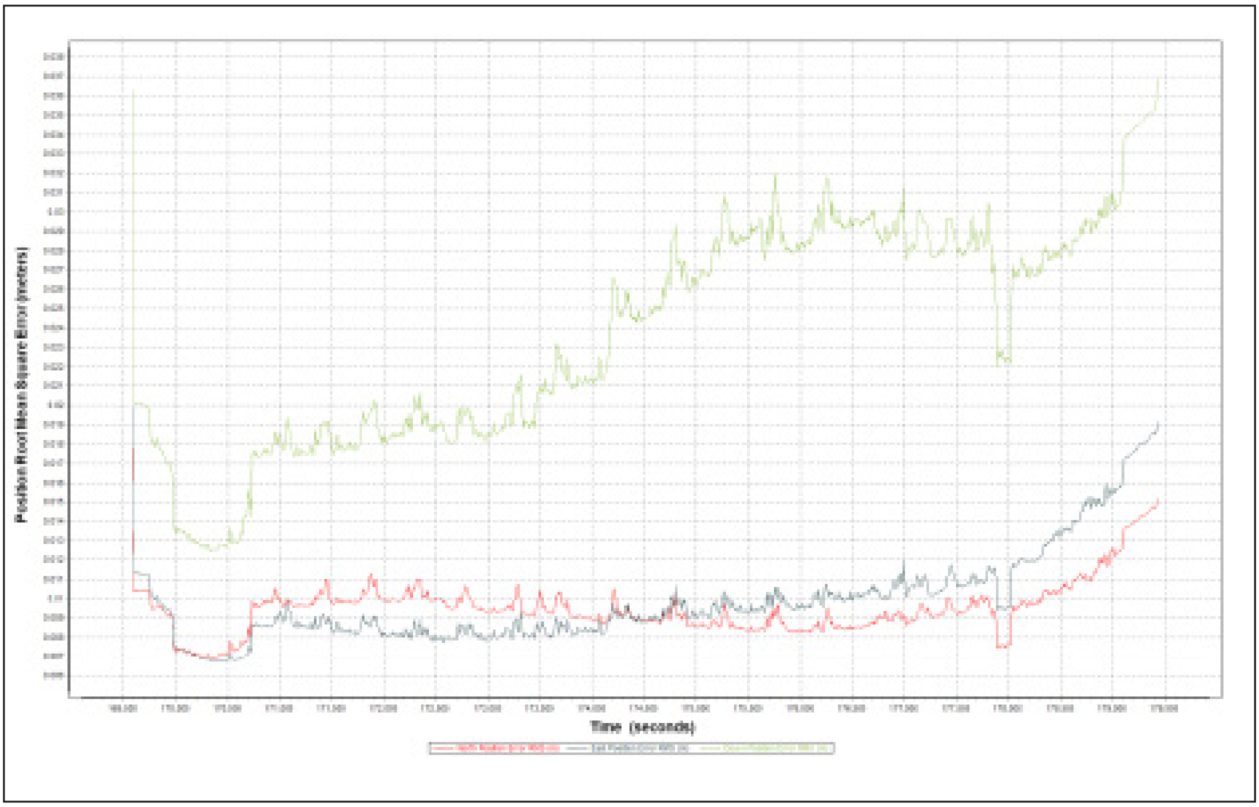


Figure 7. Smoothed Performance Metrics of Anibawan Flight 23474P.

The time of flight was from 169500 seconds to 179500 seconds, which corresponds to afternoon of June 22, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 7 shows that the North position RMSE peaks at 1.30 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 3.20 centimeters, which are within the prescribed accuracies described in the methodology.

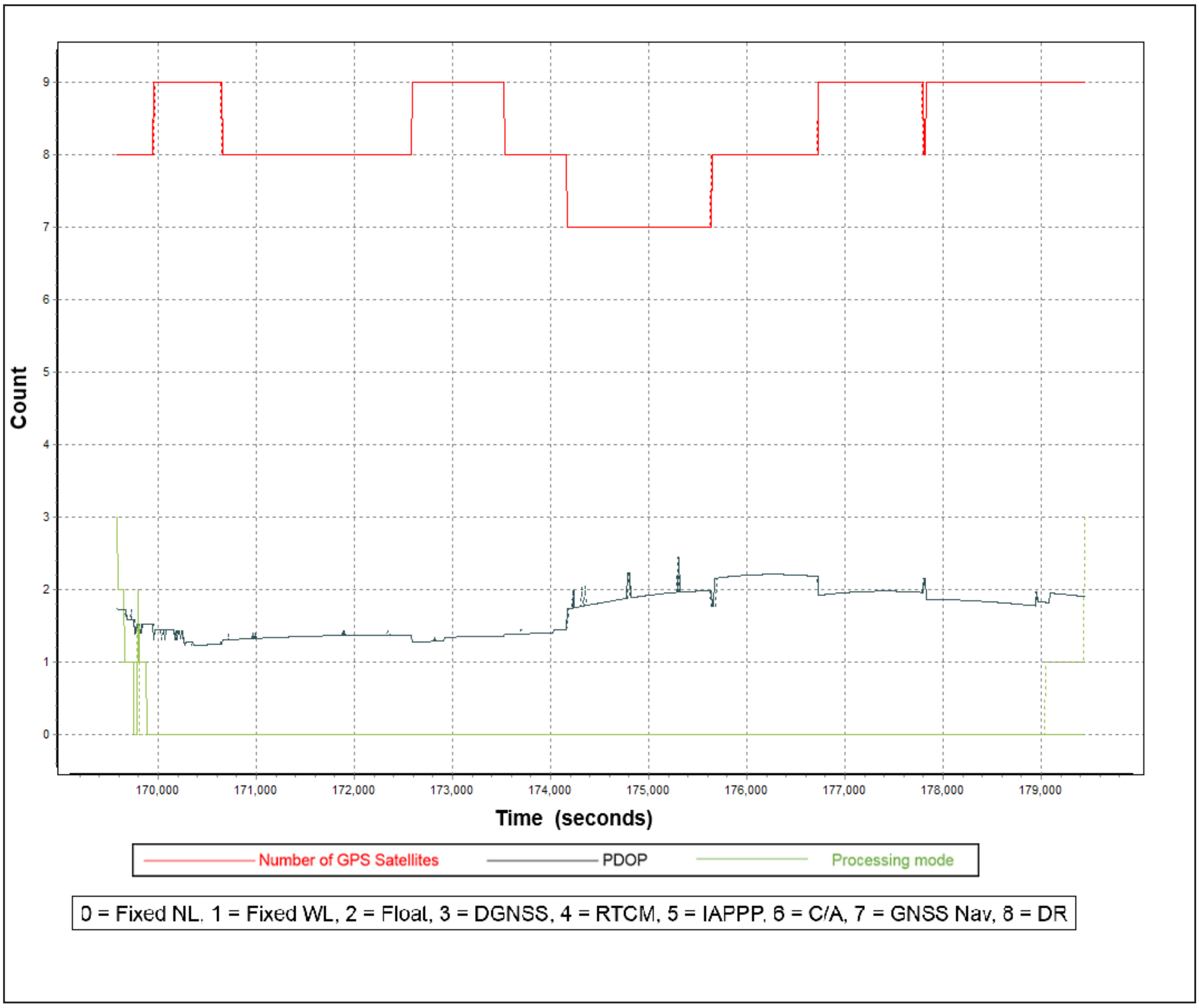


Figure 8. Solution Status Parameters of Anibawan Flight 23474P.

The Solution Status parameters of flight 23474P, one of the Anibawan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 8. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 9. 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 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 Anibawan flights is shown in Figure 9.

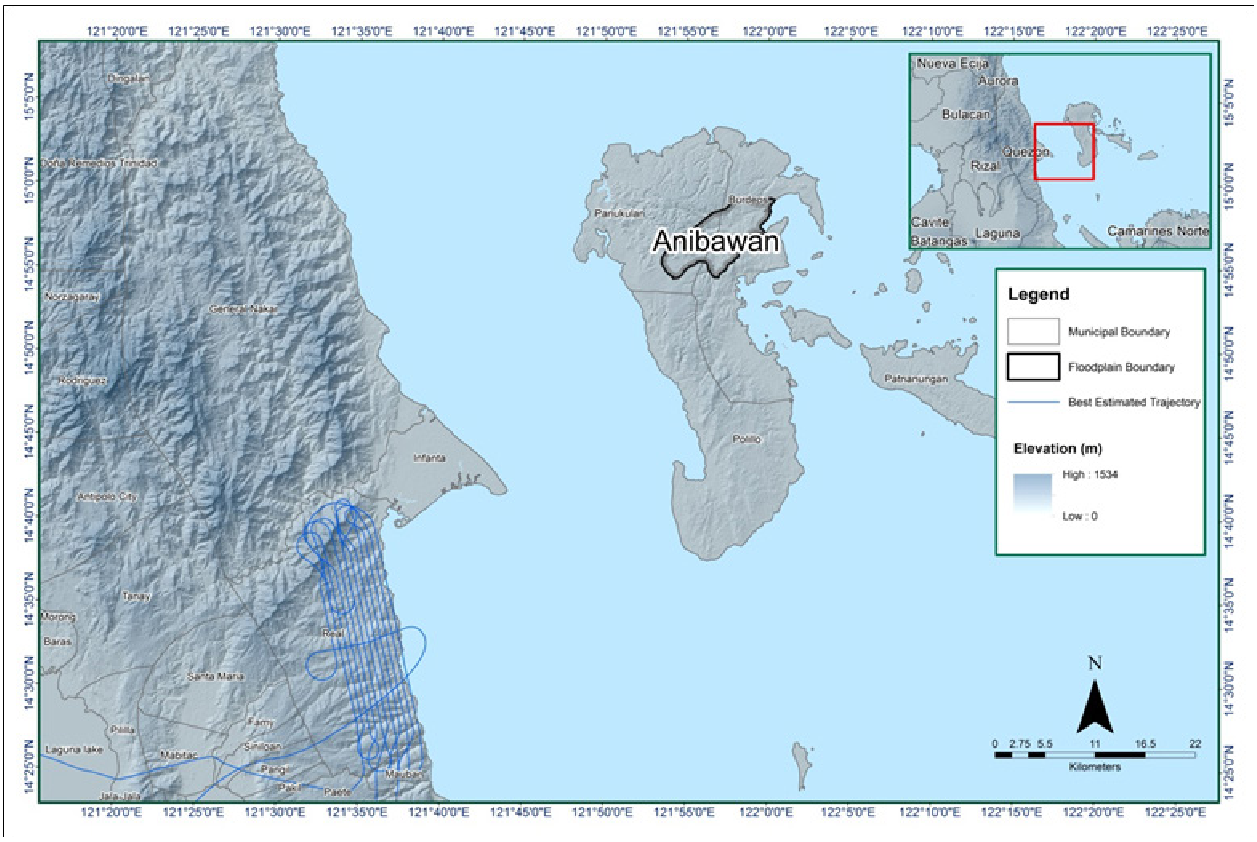


Figure 9. Best Estimated Trajectory for Anibawan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 30 flight lines, with each flight line containing one channel, since the The produced LAS data contains 17 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Anibawan floodplain are given in Table 8.

Table 8. Self-Calibration Results values for Anibawan flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000335
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000935
GPS Position Z-correction stdev	(<0.01meters)	0.0020

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

3.5 LiDAR Data Quality Checking

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

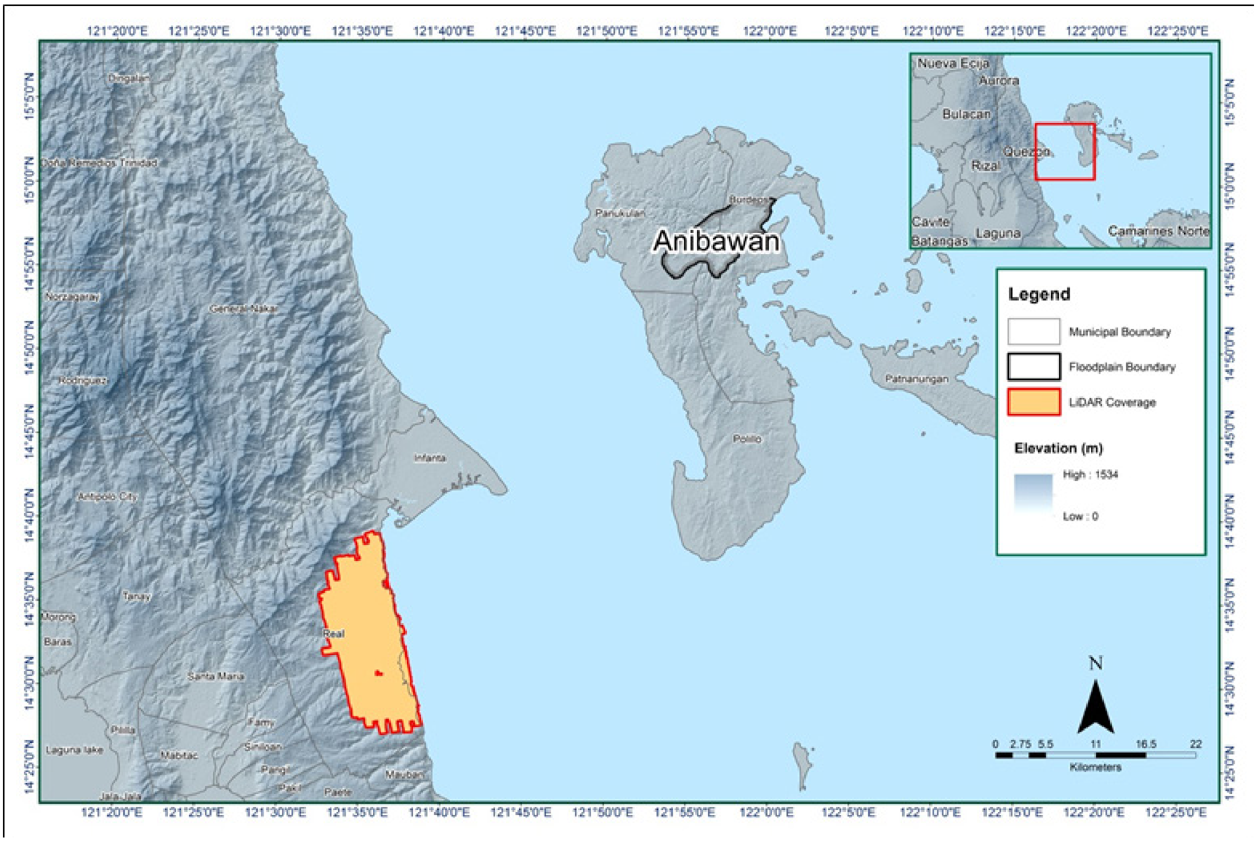


Figure 10. Boundary of the processed LiDAR data over Anibawan Floodplain

The total area covered by the Anibawan missions is 152.06 sq.km that is comprised of one (1) flight acquisition grouped and merged into two (2) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Anibawan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Calabarzon_reflights_Blk18Q	23474P	142.49
Calabarzon_reflights_Blk18Q_supplement	23474P	9.57
TOTAL		152.06 sq.km

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

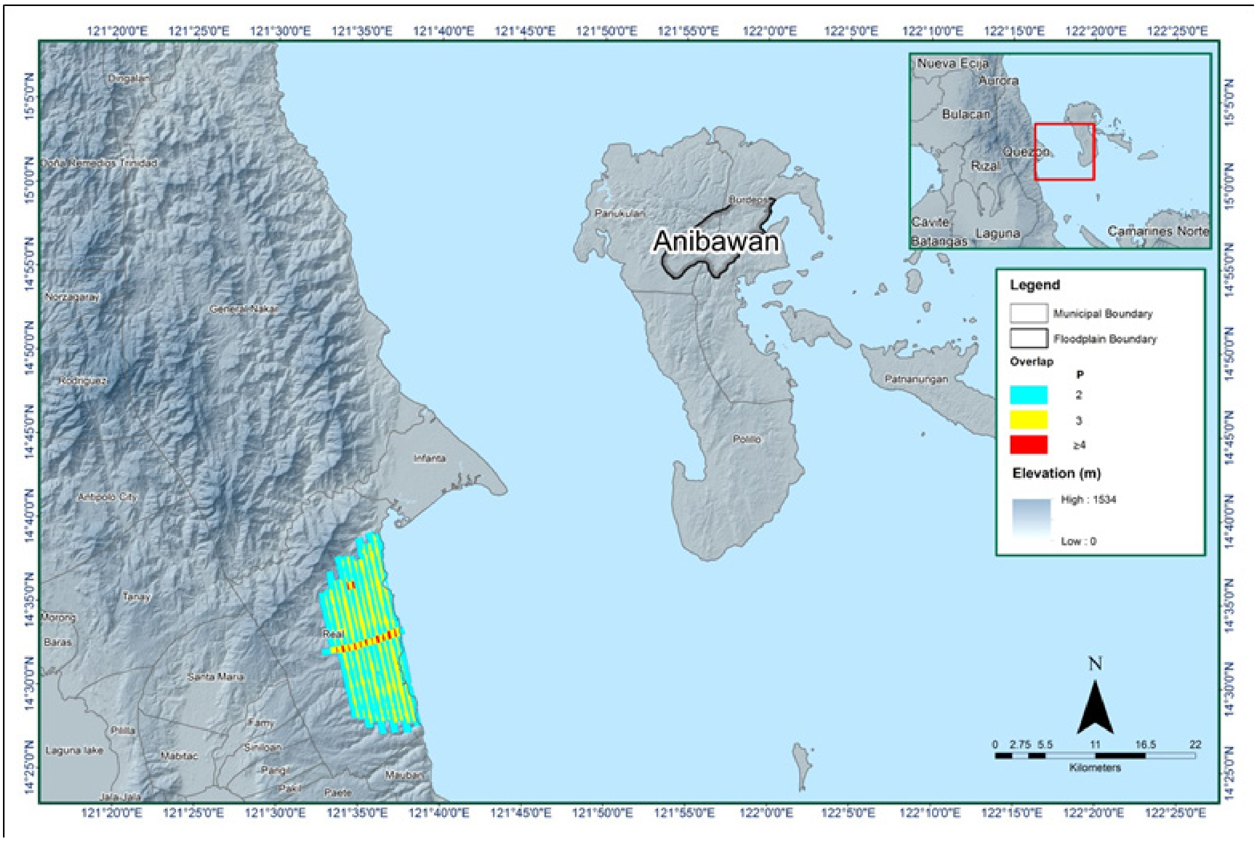


Figure 11. Image of data overlap for Anibawan floodplain.

The overlap statistics per block for the Anibawan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap is 42.49%, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 12. It was determined that all LiDAR data for Anibawan floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.82 points per square meter.

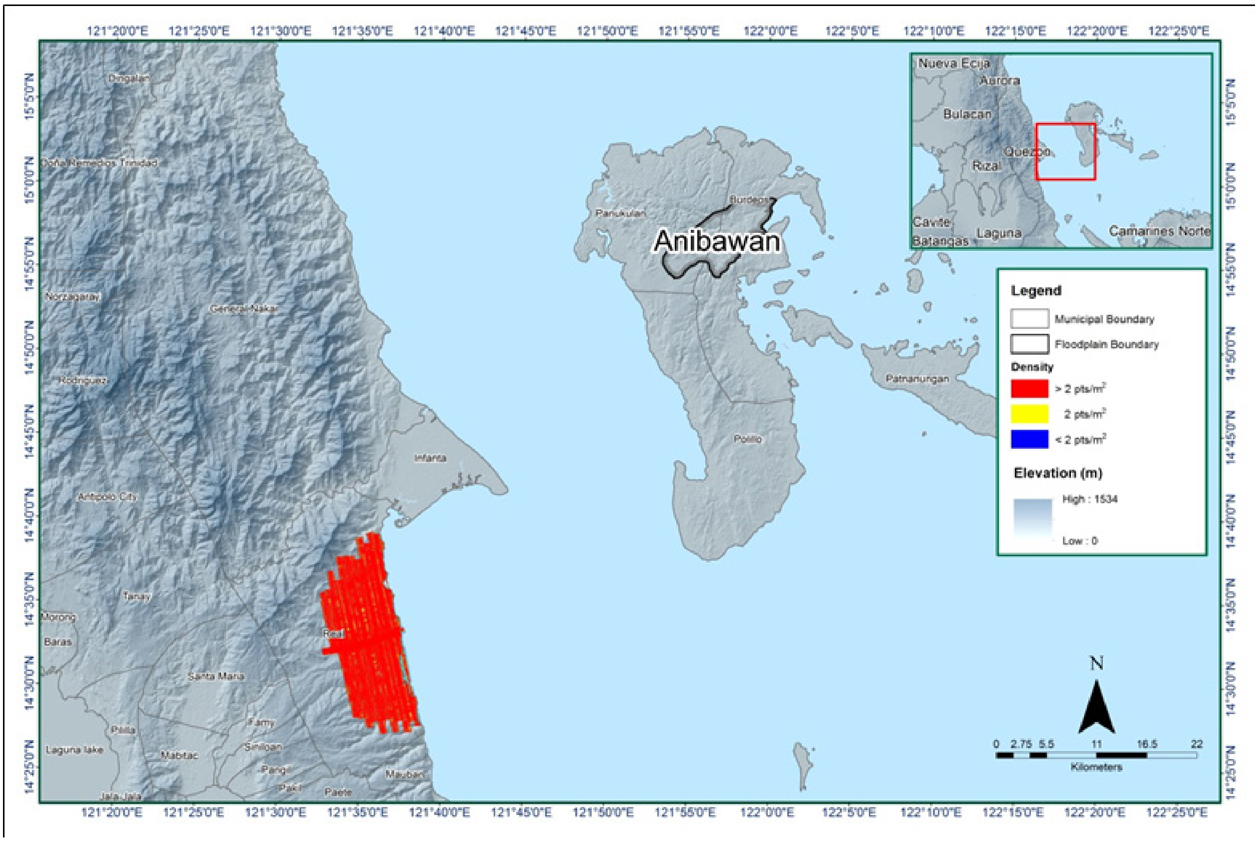


Figure 12. Pulse density map of merged LiDAR data for Anibawan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m 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.

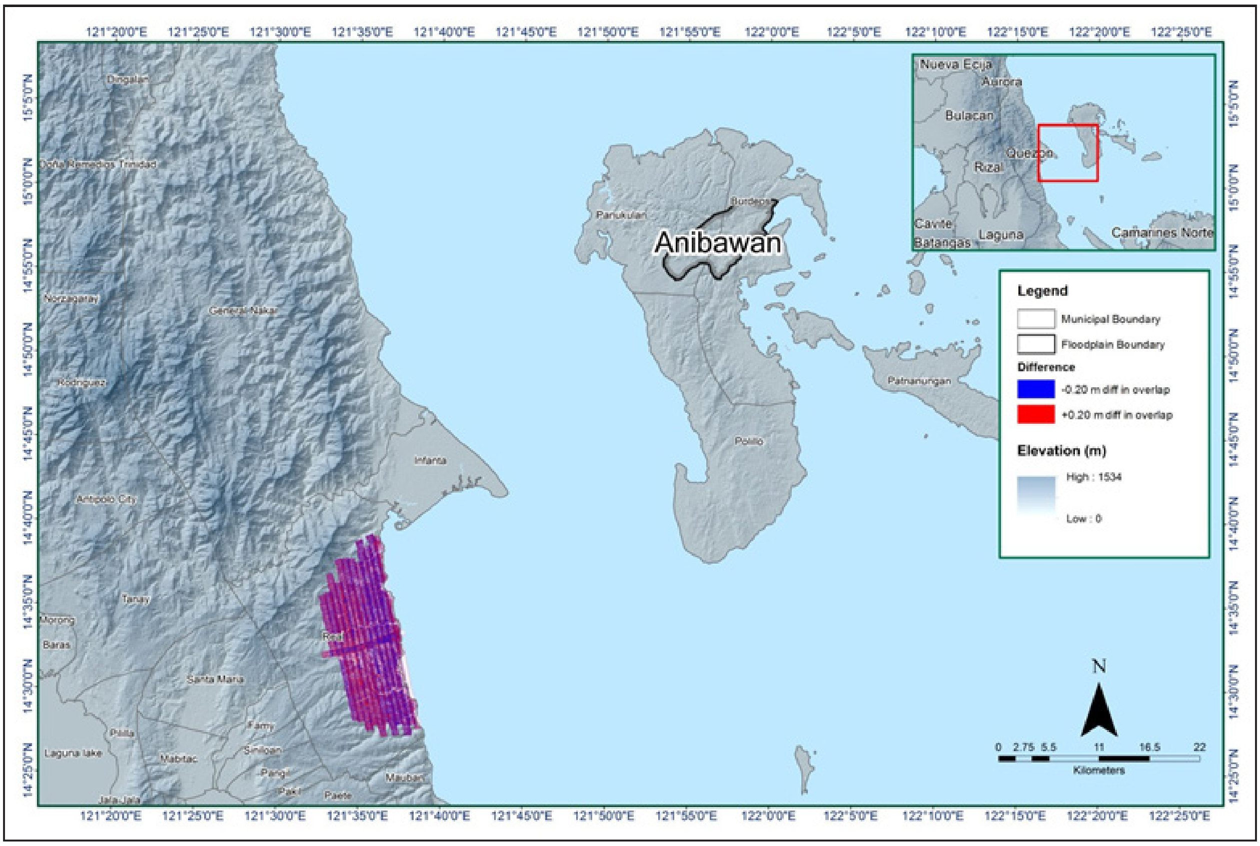


Figure 13. Elevation difference map between flight lines for Anibawan Floodplain.

A screen capture of the processed LAS data from an Anibawan flight 23474P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

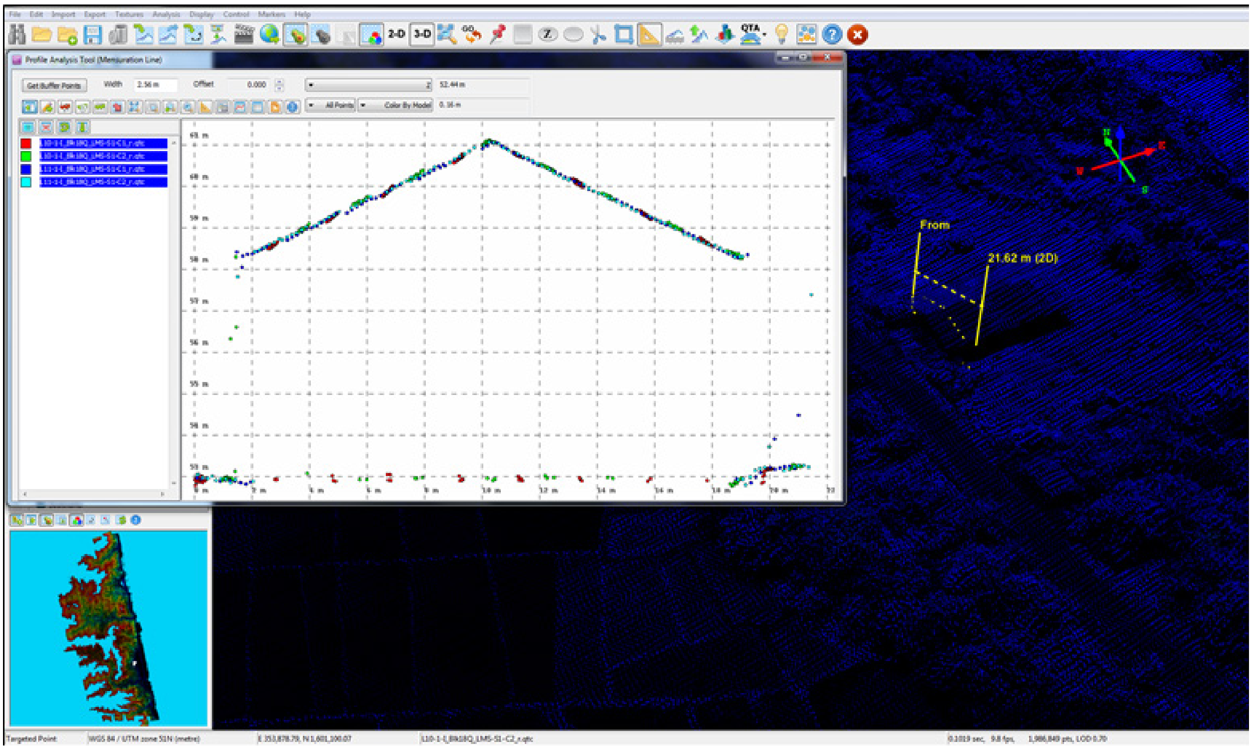


Figure 14. Quality checking for Anibawan flight 23474P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Anibawan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	46,790,724
Low Vegetation	13,952,143
Medium Vegetation	197,708,121
High Vegetation	561,045,147
Building	11,878,643

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block near Anibawan floodplain is shown in Figure 15. A total of 366 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 590.20 meters and 47.79 meters respectively.

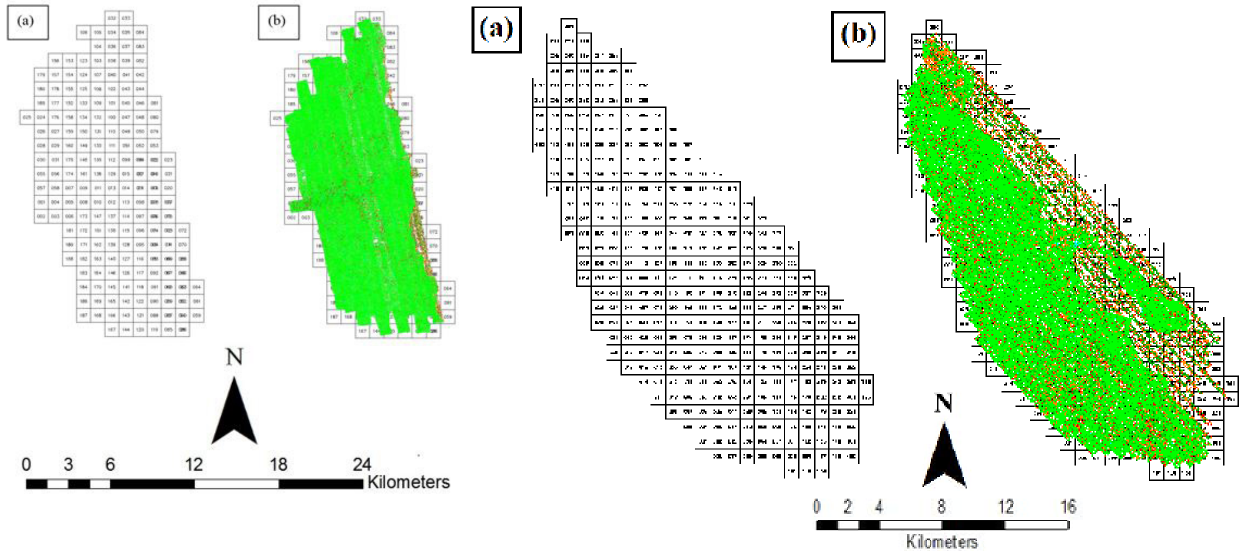


Figure 15. Tiles for Anibawan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 16. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

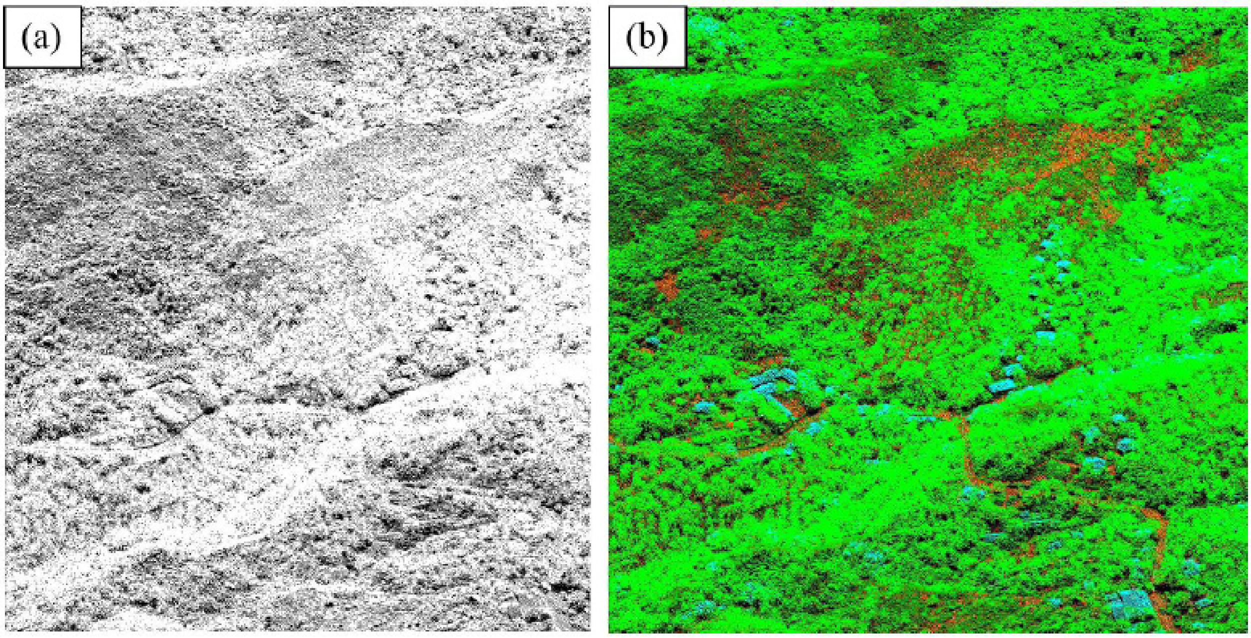


Figure 16. Point cloud before (a) and after (b) classification.

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

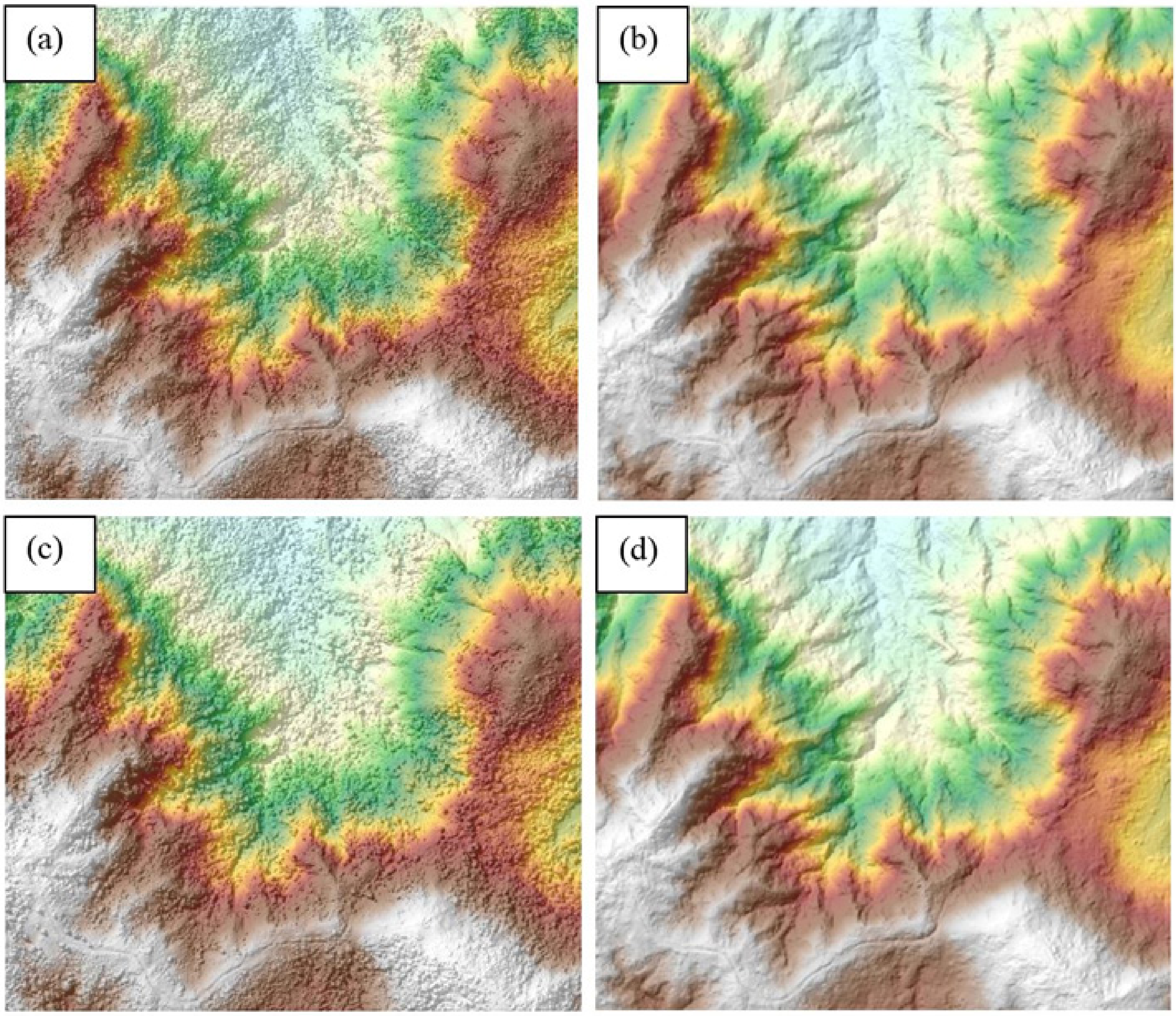


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Anibawan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Anibawan floodplain.

3.8 DEM Editing and Hydro-Correction

Calabarzon_Reflights_Blk18Q and Calabarzon_Reflights_Blk18Q_supplement are the nearby blocks to the Anibawan floodplain. It was processed in order to produce DEMs covering municipalities neighboring the Anibawan floodplain. It has an area of 152.06 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Calabarzon_reflights_Blk18Q	142.49
Calabarzon_reflights_Blk18Q_supplement	9.57
TOTAL	152.06 sq.km

Portions of DTM before and after manual editing are shown in Figure 20. The bridge (Figure 20a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 20b) in order to hydrologically correct the river. The paddy field (Figure 20c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 20d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 20e) and has to be removed through manual editing (Figure 20f).

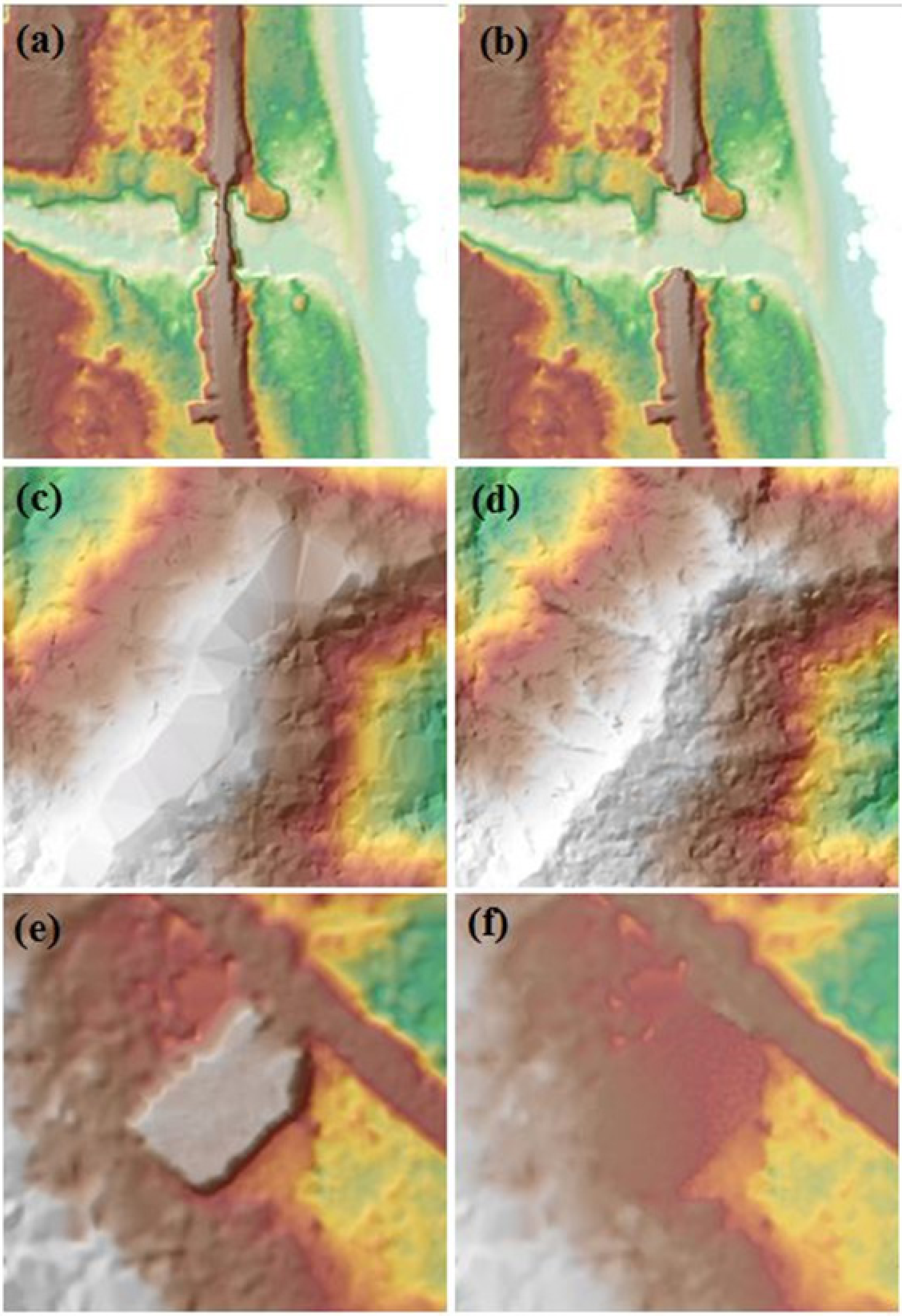


Figure 18. Portions in the DTM of Anibawan Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

The IFSAR data for Anibawan floodplain located in Burdeos, Quezon is mosaicked. This IFSAR data does not overlap the Calabarzon DEM but it has its nearby blocks Calabarzon_Reflights_Blk18Q and Calabarzon_Reflights_Blk18Q_supplement. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

IFSAR data for Anibawan flood plain is shown in Figure 21.

Table 12. Shift Values of each LiDAR Block of Anibawan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
4025-II-1-5,6-10,11-15,16-20,21-25	0.77	1.54	-1.00
4025-III-5,10,15,20,25	0.58	2.00	-1.00
4024-IV-5	-0.04	3.22	-1.00
4024-I-1-5	0.12	1.32	-1.00
4124-IV-1,6,11,16,21	0.90	1.08	-1.00

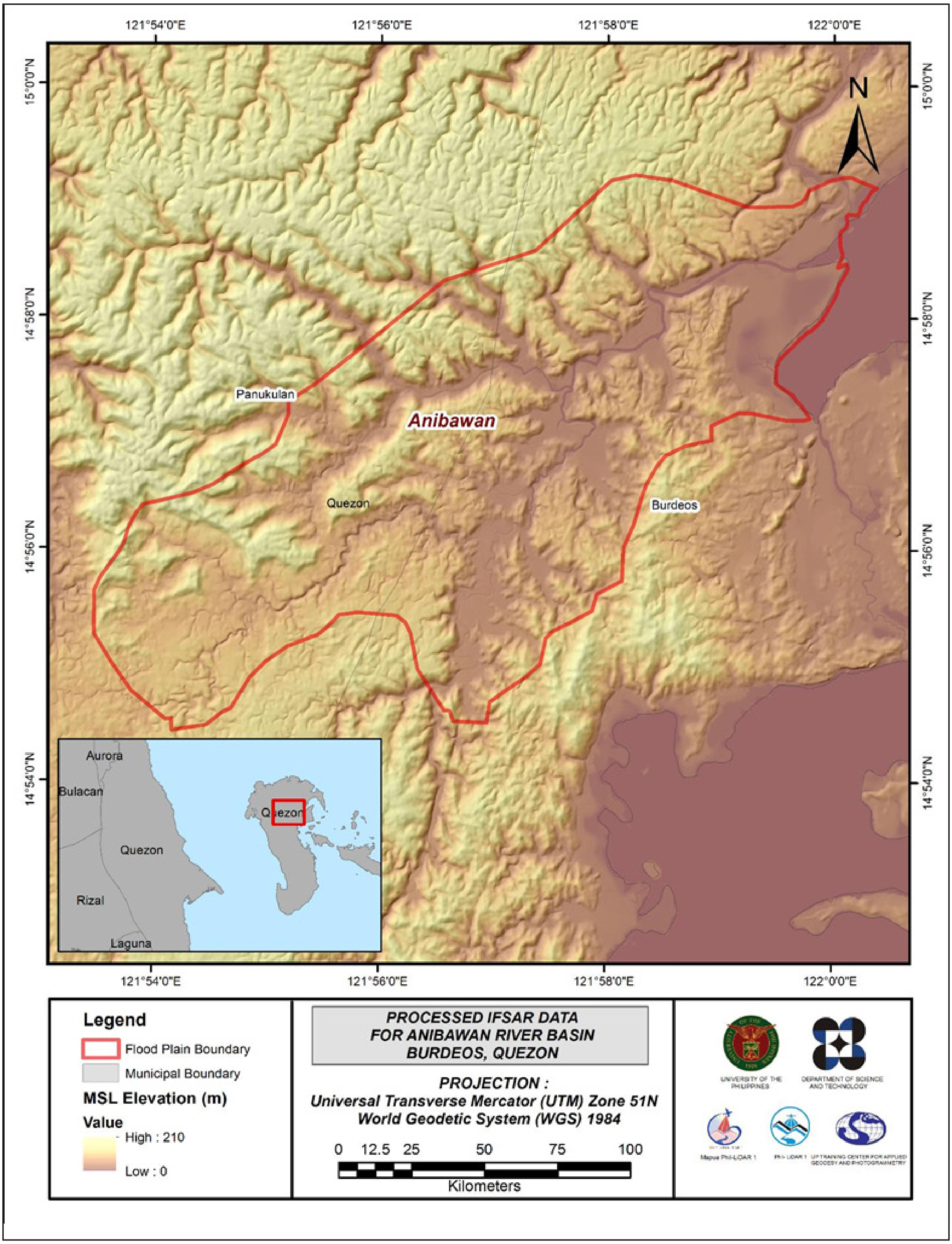


Figure 19. Map of Processed LiDAR Data for Anibawan Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

he extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Anibawan to collect points with which the IFSAR dataset is validated is shown in Figure 20. A total of 670 survey points were used for calibration and validation of Anibawan IFSAR data. Random selection of 80% of the survey points, resulting to 536 points, were used for calibration.

A good correlation between the uncalibrated mosaicked IFSAR elevation values and the ground survey elevation values is shown in Figure 21. Statistical values were computed from extracted IFSAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the IFSAR DTM and calibration elevation values is 0.38 meters with a standard deviation of 0.34 meters. Calibration of Anibawan IFSAR data was done by adding the height difference value, 0.38 meters, to Anibawan mosaicked IFSAR data. Table 13 shows the statistical values of the compared elevation values between IFSAR data and calibration data.

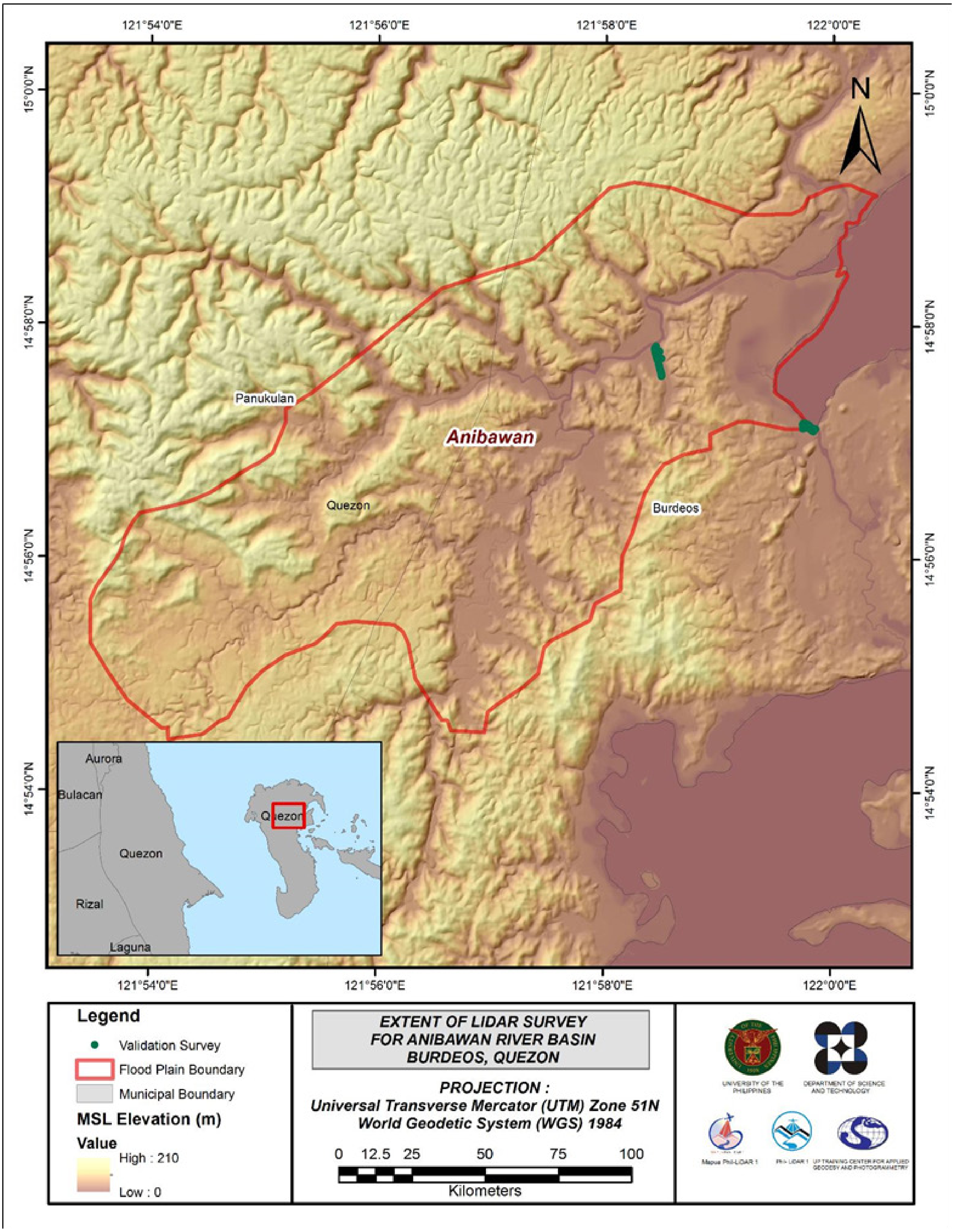


Figure 20. Map of Anibawan Flood Plain with validation survey points in green.

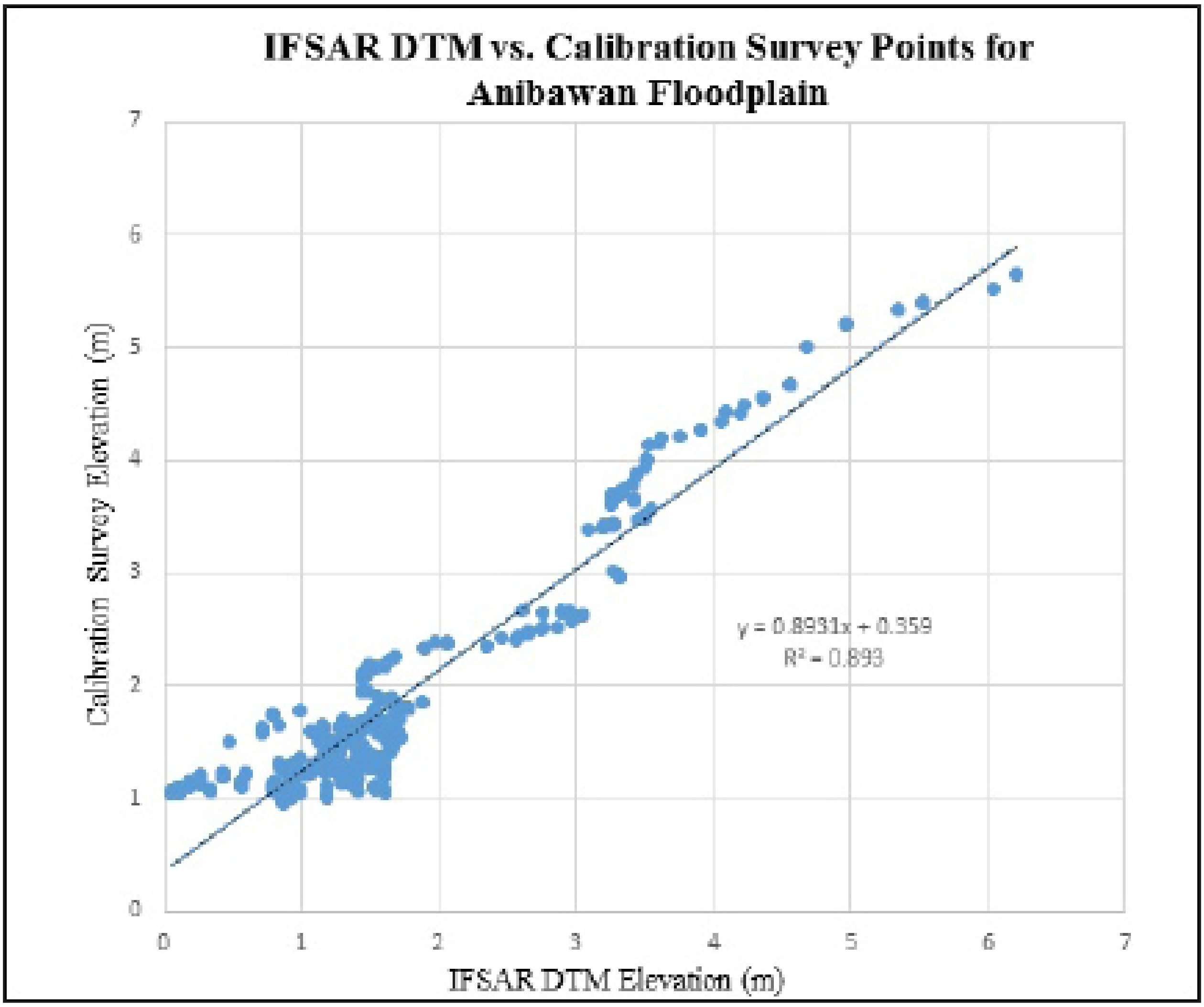


Figure 21. Correlation plot between calibration survey points and IFSAR data.

Table 13. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.38
Standard Deviation	0.34
Average	0.19
Minimum	-0.56
Maximum	1.03

Note: Calibration points lie within the IFSAR data, thus, the Height Difference and Standard Deviation values obtained are still acceptable.

A total of 882 survey points were used for the validation of the calibrated Anibawan DTM. A good correlation between the calibrated mosaicked IFSAR elevation values and the ground survey elevation, which reflects the quality of the IFSAR DTM is shown in Figure 22. The computed RMSE between the calibrated IFSAR DTM and validation elevation values is 0.39 meters with a standard deviation of 0.34 meters, as shown in Table 14.

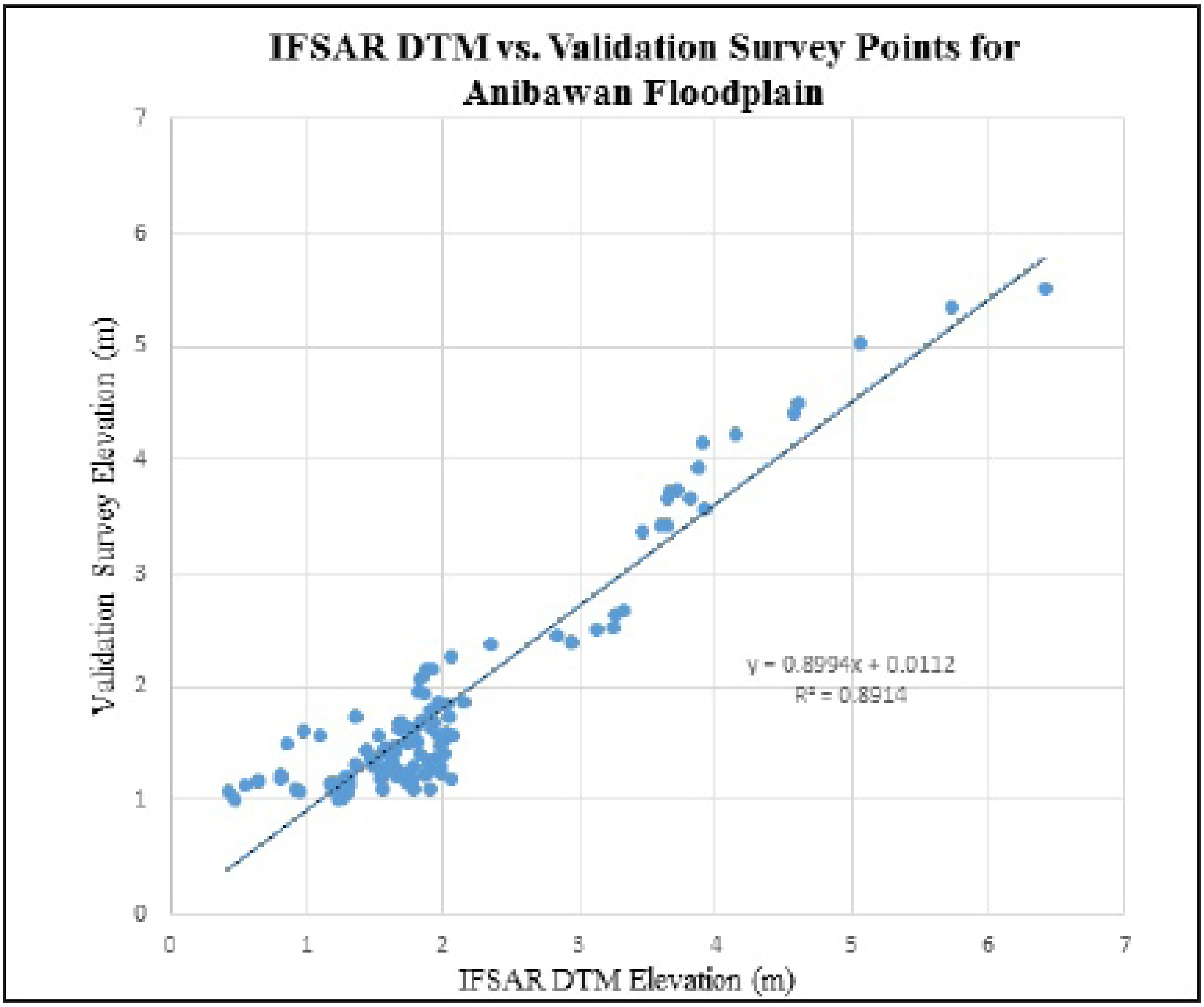


Figure 22. Correlation plot between validation survey points and IFSAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.39
Standard Deviation	0.34
Average	-0.19
Minimum	-0.90
Maximum	0.65

Note: Validation points lie within the IFSAR data, thus, the RMSE and Standard Deviation values obtained are still acceptable.

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Anibawan with 5,711 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation (with barriers) method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.40 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Anibawan integrated with the processed IFSAR DEM is shown in Figure 25.

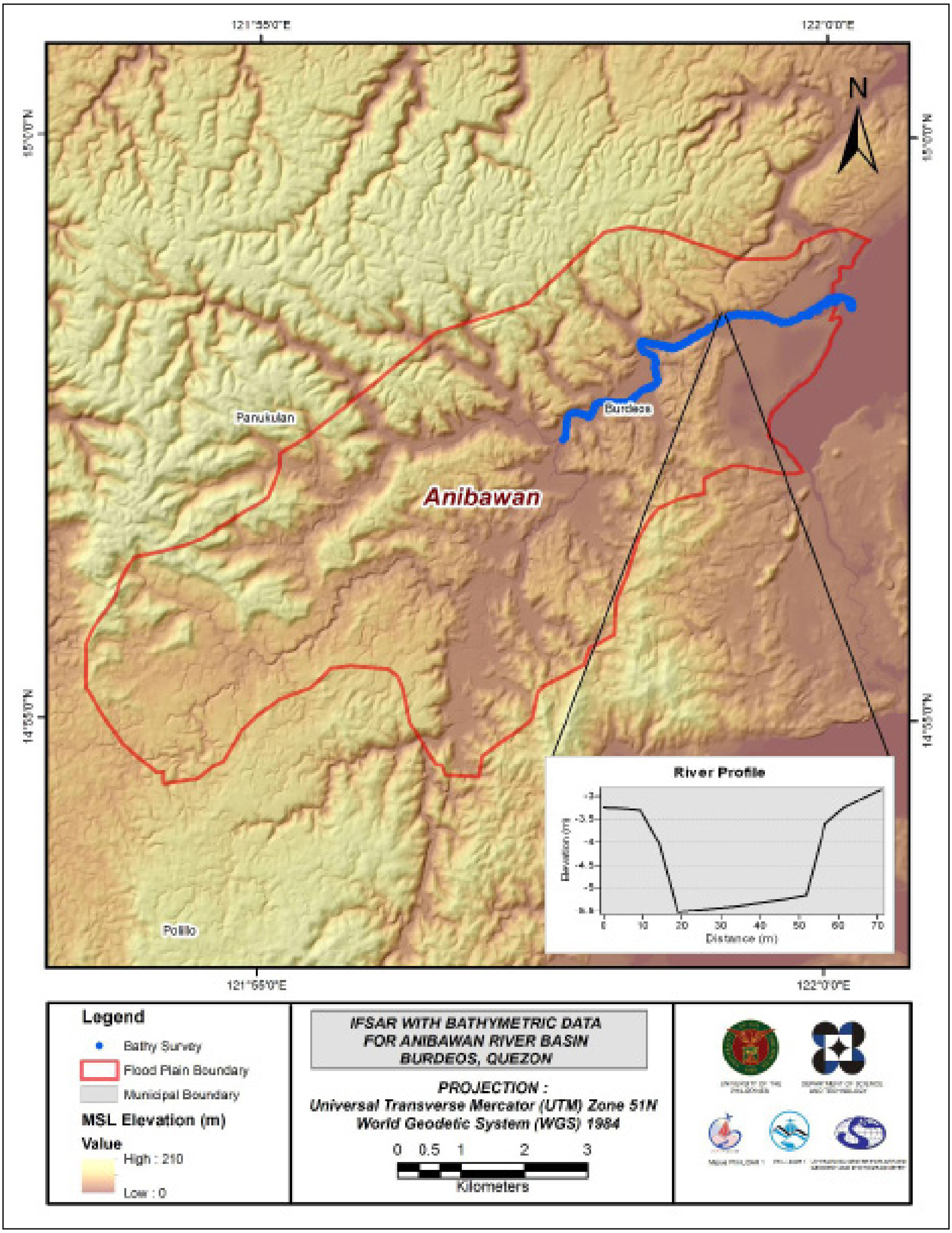


Figure 23. Map of Anibawan Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE ANIBAWAN 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

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Anibawan River on March 6 – 17, 2017 with the following scope of work: reconnaissance; control survey; cross-section survey of selected riverbed in Brgy. Anibawan, Municipality of Burdeos; validation points acquisition of about 925.62 m covering streets in Brgy. Anibawan and Brgy. Cabungalunan, Municipality of Burdeos; and bathymetric survey from its upstream in Brgy. Cabungalunan, Municipality of Burdeos down to the mouth of the river located in the Brgy. Carlagan in the same Municipality, with an approximate length of 6.630 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 28).

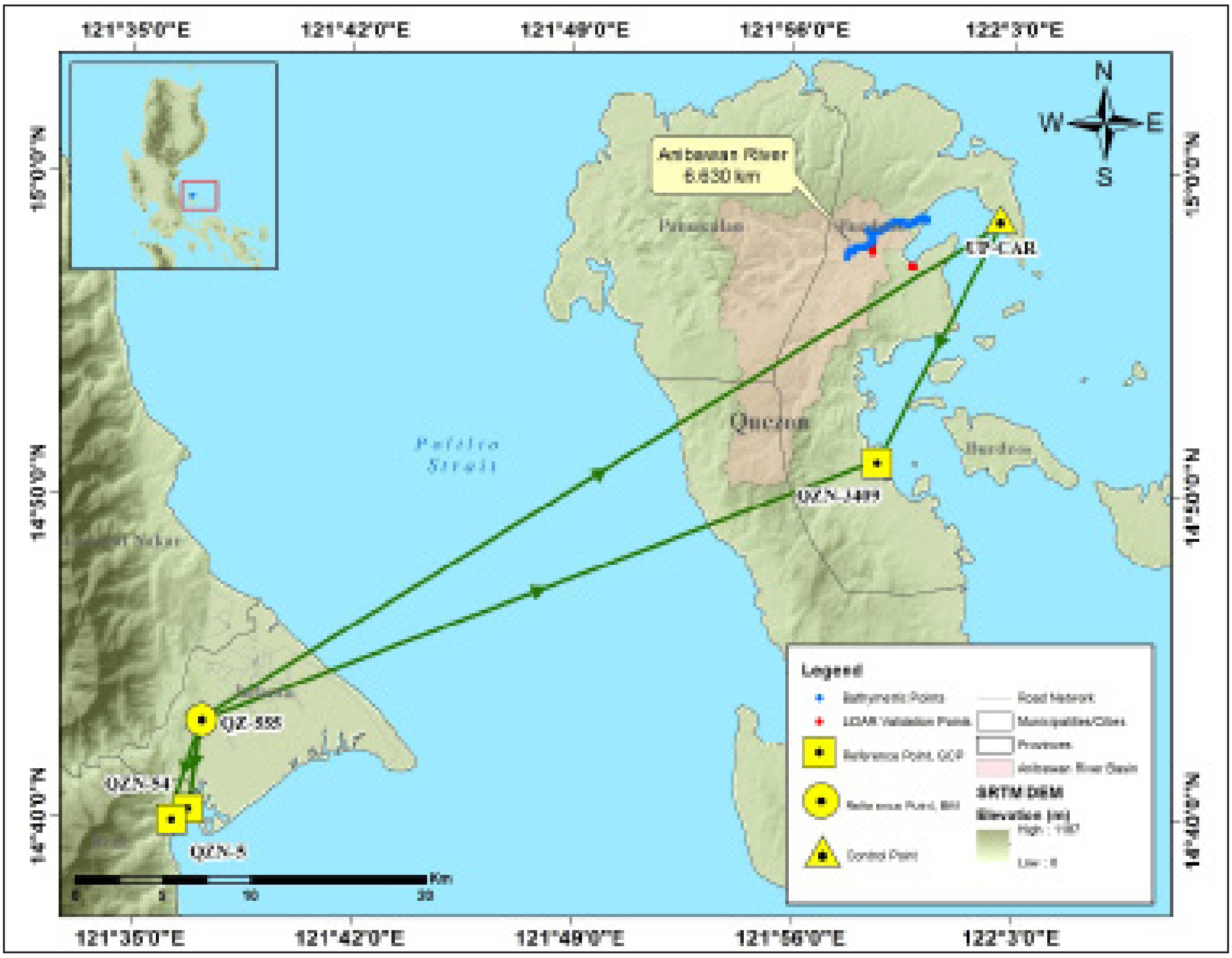


Figure 24. Anibawan River Survey Extent

4.2 Control Survey

The GNSS network used for Anibawan River Basin is composed of two (2) loops established on March 9, 2017 occupying the following reference points: QZN-54, a 2nd order GCP in Brgy. Ungos, Municipality of Real; and, QZ-555, a 1st order BM in Brgy. Gumian, Municipality of Infanta, all in the province of Quezon.

A UP control point, namely UP-CAR was established in Brgy. Carlagan. Municipality of Burdeos, Quezon. NAMRIA established control points, namely: QZN-5, located in Brgy. Poblacion I, Municipality of Real, Quezon; and, QZN-3409, located in Brgy. Poblacion, Municipality of Burdeos, Quezon, were also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 19 while GNSS network established is illustrated in Figure 29.

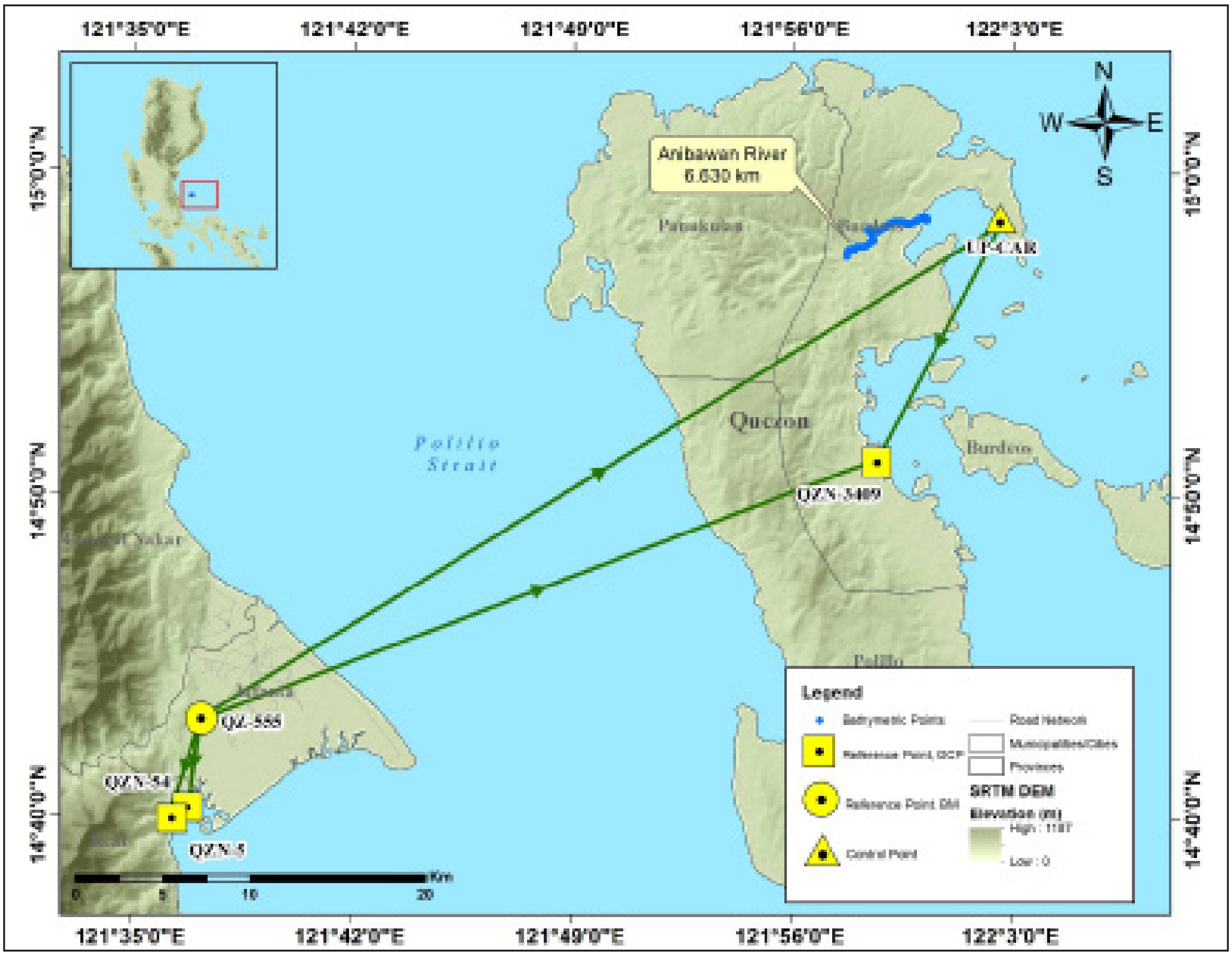


Figure 25. GNSS Network of Anibawan Field Survey

Table 15. List of reference and control points used during the survey in Anibawan River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
QZN-54	2nd order, GCP	14°40'15.00036"	121°36'48.93582"	51.628	-	3-9-2017
QZ-555	1st order, BM	-	-	50.764	4.808	3-9-2017
QZN-5	Used as Marker	-	-	48.022	-	3-9-2017
QZN-3409	Used as Marker	-	-	46.740	-	3-9-2017
UP-CAR	UP established	-	-	44.492	-	3-9-2017

The GNSS set-ups on recovered reference points and established control points in Anibawan River are shown in Figure 26 to Figure 29

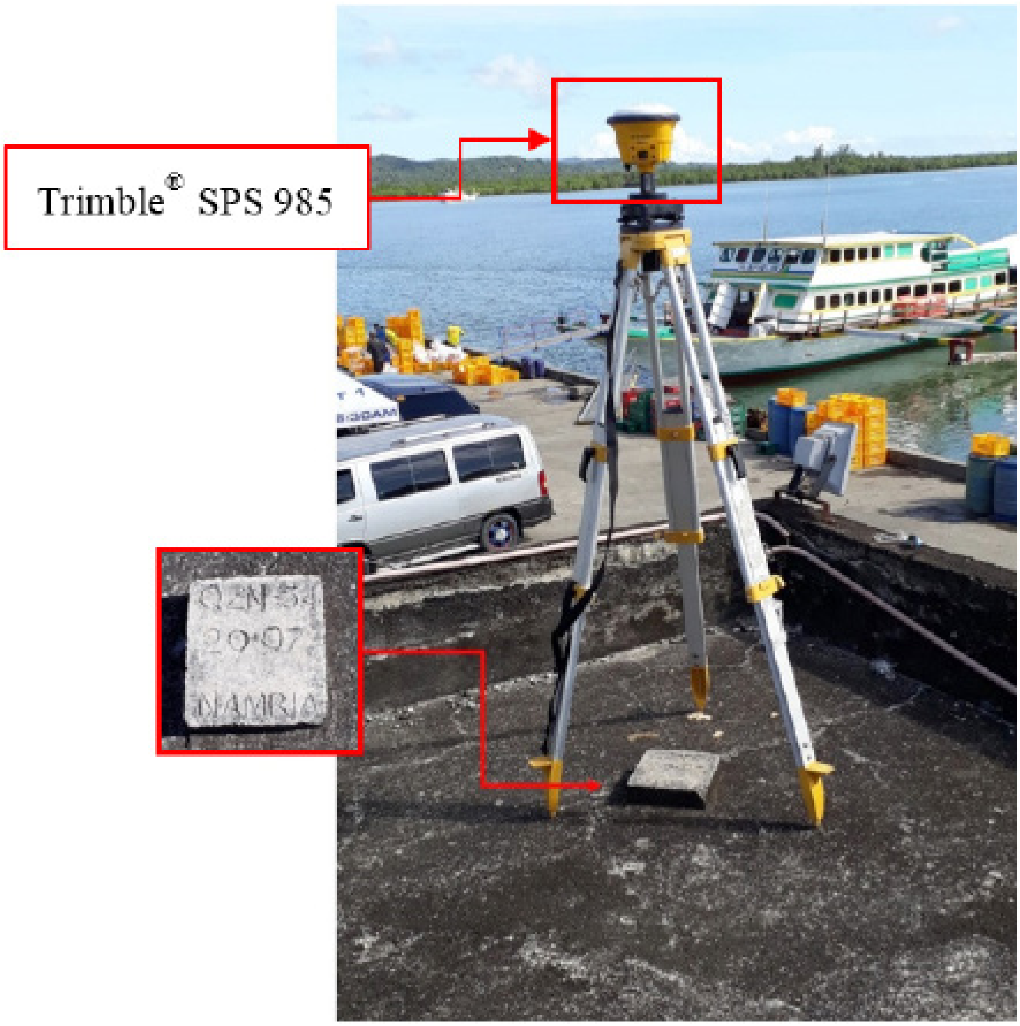


Figure 26. GNSS base set up, Trimble® SPS 985, at QZN-54, located in Brgy. Ungos, Municipality of Real, Quezon

Figure 27. GNSS receiver setup, Trimble® SPS 882, at QZ-555, located in Brgy. Gumian, Municipality of Infanta, Quezon

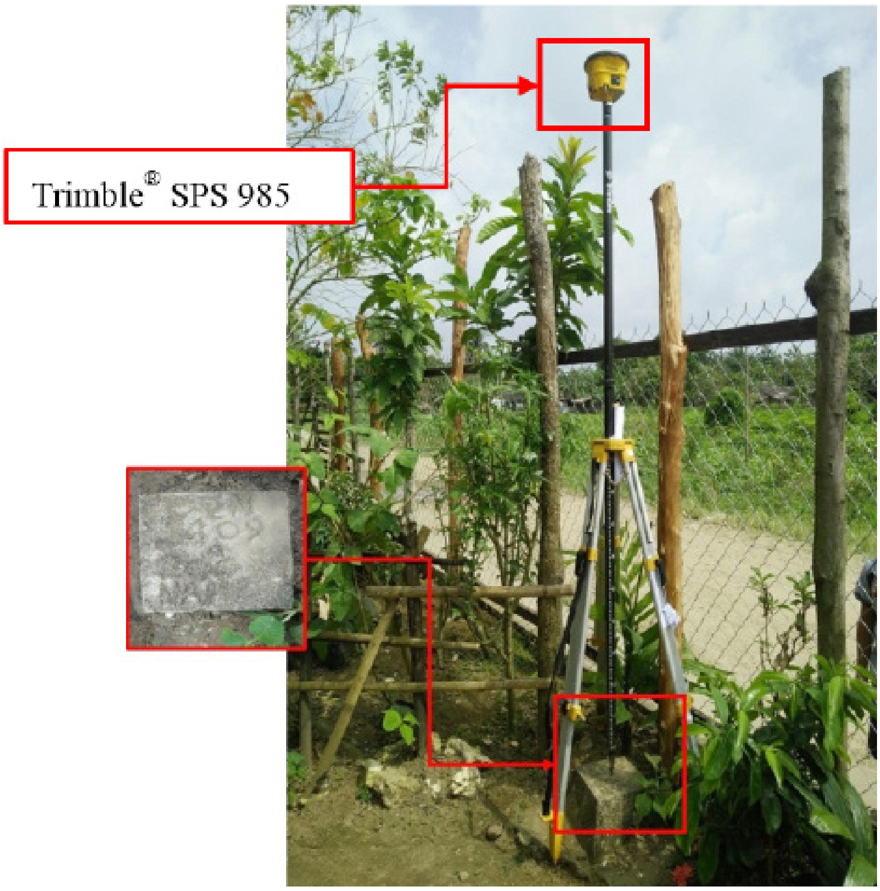


Figure 28. GNSS receiver setup, Trimble® SPS 985, at QZN-3409, located in Brgy. Poblacion, Municipality of Burdeos, Quezon

Figure 29. GNSS receiver setup, Trimble® SPS 882, at UP-CAR, located in Brgy. Carlagan. Municipality of Burdeos, Quezon

4.3 Baseline Processing

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

Table 16. Baseline Processing Report for Anibawan River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
QZ-555 --- QZN-3409 (B4)	03-09-17	Fixed	0.003	0.013	68°53'52"	41234.795	-4.013
QZ-555 --- QZN-3409 (B5)	03-09-17	Fixed	0.004	0.020	68°53'52"	41234.797	-4.025
QZ-555 --- UP-CAR (B8)	03-09-17	Fixed	0.005	0.016	57°36'57"	53778.445	-6.253
QZ-555 --- QZN-5 (B1)	03-09-17	Fixed	0.003	0.013	196°23'31"	5951.739	-2.759
QZ-555 --- QZN-54 (B3)	03-09-17	Fixed	0.003	0.011	188°23'23"	5131.481	0.869
UP-CAR --- QZN-3409 (B7)	03-09-17	Fixed	0.004	0.021	206°33'45"	15589.859	2.242
UP-CAR--- QZN-3409 (B6)	03-09-17	Fixed	0.004	0.023	206°33'45"	15589.854	2.237
QZN-59 --- QZN-54 (B2)	03-09-17	Fixed	0.001	0.002	55°46'11"	1125.868	3.606

As shown in Table 20, a total of eight (8) baselines were processed with reference point QZN-54 held fixed for coordinate values; andQZ-555 fixed for elevation value. 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 22) 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,
yeis the Northing Error, and
zeis the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 21 to Table 23 for the complete details.

The five (5) control points, QZN-54, QZ-555, QZN-5, QZN-3409, and UP-CAR were occupied and observed simultaneously to form a GNSS loop. Coordinates of QZN-54; and elevation value of QZ-555 were held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 17. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
QZN-54	Local	Fixed	Fixed		
QZ-555	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 22. The fixed controls QZN-54 has no value for grid error while QZ-555 has no value for elevation error.

Table 18. Adjusted Grid Coordinates

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
QZN-54	350712.577	?	1622376.741	?	5.630	0.028	LL
QZ-555	351492.188	0.006	1627448.004	0.004	4.808	?	e
QZN-5	349777.954	0.004	1621749.247	0.003	1.998	0.029	
QZN-3409	390044.856	0.008	1642054.474	0.006	2.272	0.032	
UP-CAR	397074.300	0.010	1655965.065	0.007	1.818	0.041	

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

a. QZN-54
horizontal accuracy = Fixed
vertical accuracy = 2.8 cm < 10 cm

b. QZ-555
horizontal accuracy = $\surd((0.6)^2 + (0.4)^2$
= $\surd (0.36 + 0.16)$
= 0.72 < 20 cm
vertical accuracy = Fixed

c. QZN-5
horizontal accuracy = $\surd((0.4)^2 + (0.3)^2$
= $\surd (0.16 + 0.09)$
= 0.5 < 20 cm
vertical accuracy = 2.9 cm < 10 cm

d. QZN-3409
horizontal accuracy = $\surd((0.8)^2 + (0.6)^2$
= $\surd (0.64 + 0.36)$
= 1 < 20 cm
vertical accuracy = 3.2 cm < 10 cm

e. UP-CAR
horizontal accuracy = $\surd((1.0)^2 + (0.7)^2$
= $\surd (1 + 0.49)$
= 1.22 < 20 cm
vertical accuracy = 4.1 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required precision.

Table 19. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
QZ-555	N14°43'00.17333"	E121°37'13.95942"	50.764	?	e
QZN-3409	N14°51'02.20273"	E121°58'40.74969"	46.740	0.032	
QZN-5	N14°39'54.39492"	E121°36'17.82488"	48.022	0.029	
QZN-54	N14°40'15.00036"	E121°36'48.93582"	51.628	0.028	LL
UP-CAR	N14°58'35.92297"	E122°02'33.93892"	44.492	0.041	

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

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

Table 20. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM ZONE 51 N)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	BM Ortho
QZN-54	2nd order, GCP	14°40'15.00036"	121°36'48.93582"	51.628	1622376.741	350712.577	5.630
QZ-555	1st order, BM	14°43'00.17333"	121°37'13.95942"	50.764	1627448.004	351492.188	4.808
QZN-5	Used as Marker	14°39'54.39492"	121°36'17.82488"	48.022	1621749.247	349777.954	1.998
QZN-3409	Used as Marker	14°51'02.20273"	121°58'40.74969"	46.740	1642054.474	390044.856	2.272
UP-CAR	UP established	14°58'35.92297"	122°02'33.93892"	44.492	1655965.065	397074.300	1.818

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

As-built survey was conducted on March 11 and 12, 2017 at the downstream side of the riverbed in Brgy. Anibawan, Municipality of Burdeos, Quezon as shown in Figure 30. A Trimble® SPS 882 GNSS in PPK survey technique and Topcon total station were used as shown in Figure 31.

Figure 30. Riverbed in Anibawan River for Cross-section survey

Figure 31. Total station used in Cross-section survey

The cross-sectional line of Anibawan riverbed is about 97.580 m with 137 cross-sectional points using the control point UP-CAR as the GNSS base station. The location map and cross-section diagram are shown in Figure 32 to Figure 33.

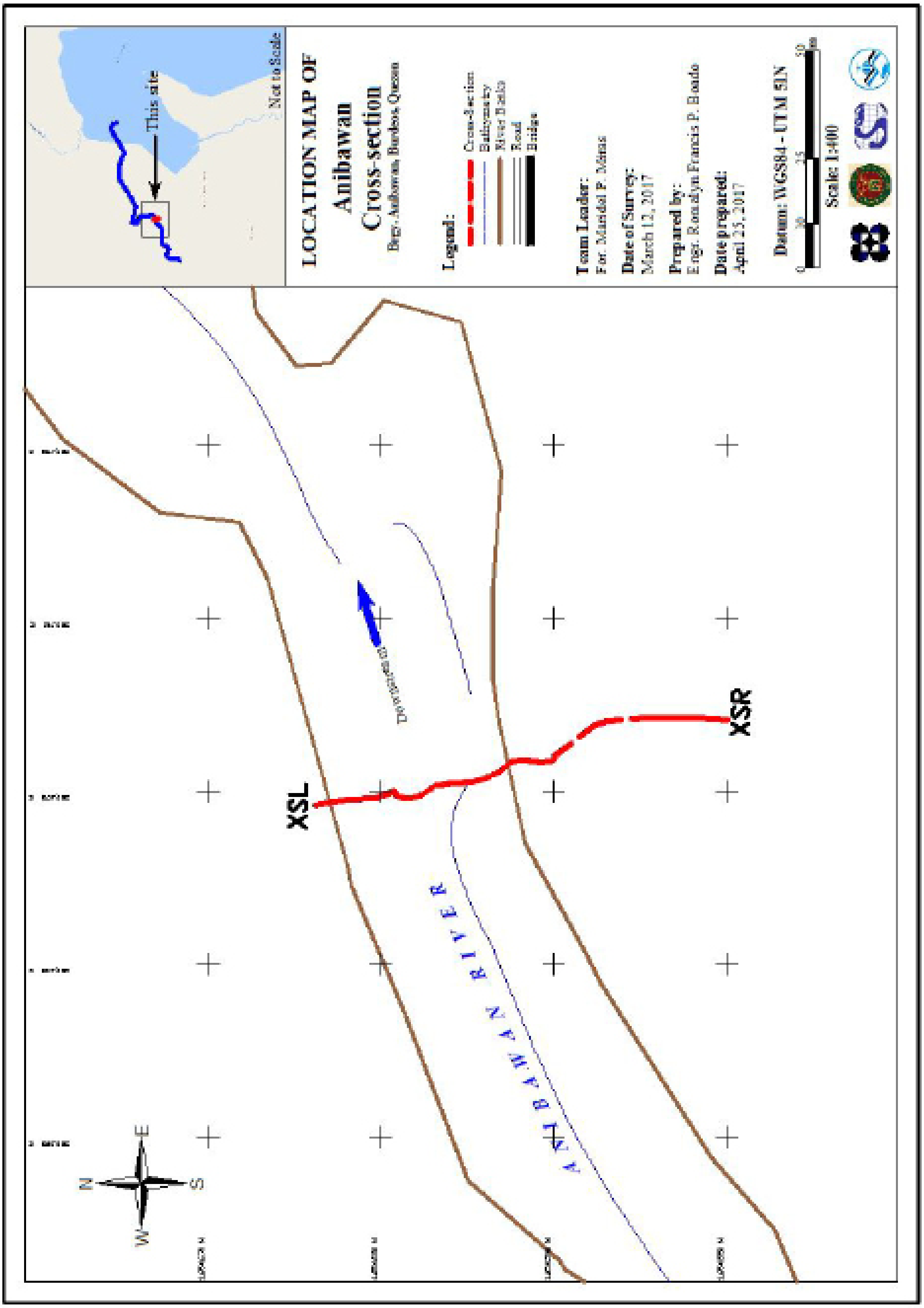


Figure 32. Location map of Anibawan cross-section

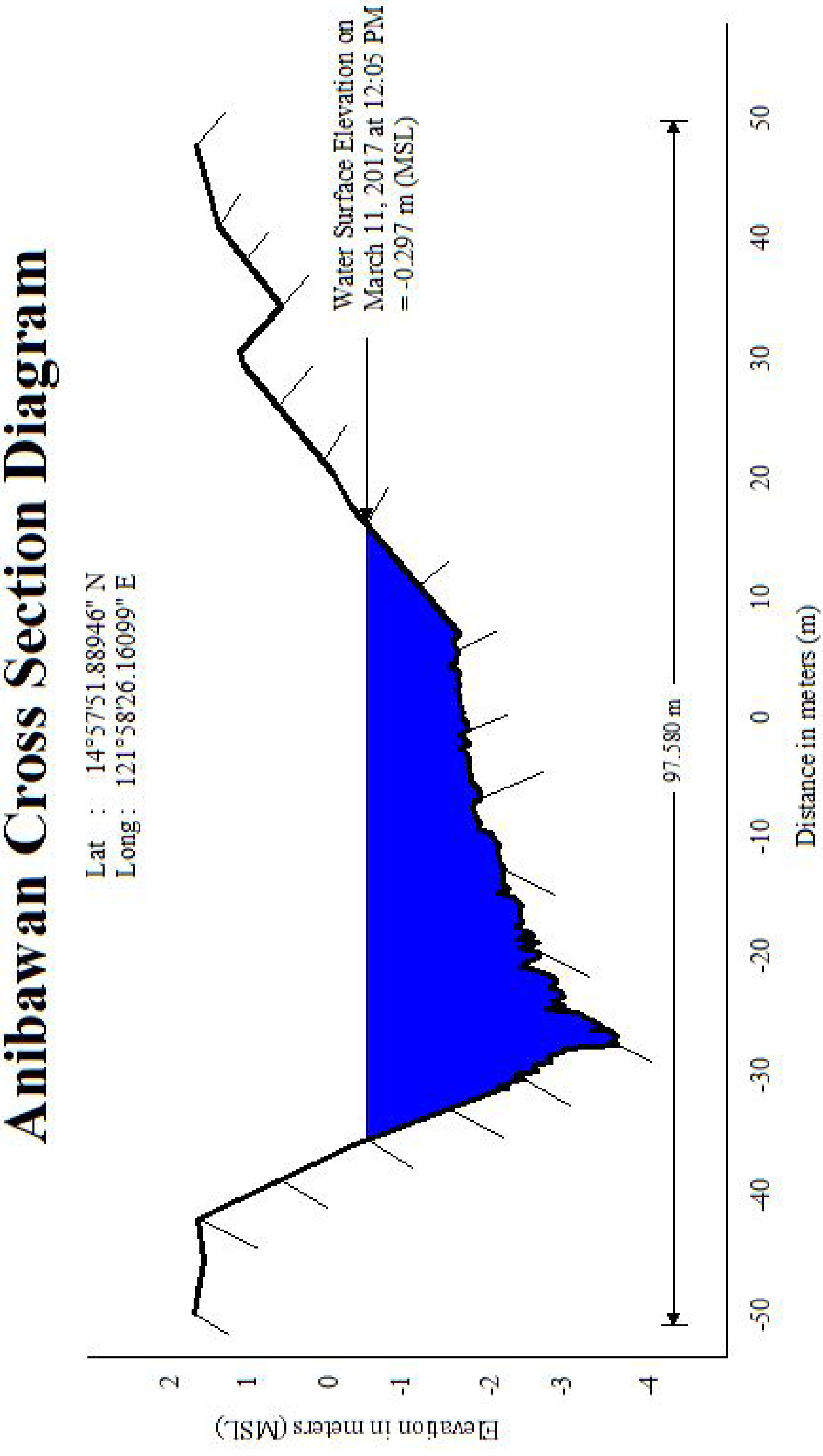


Figure 33. Anibawan Bridge cross-section diagram

Water surface elevation of Anibawan River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on March 11, 2017 at 12:05 PM with a value of -0.297 m in MSL as shown in Figure 33. This was translated into marking on the road pavement using the same technique as shown in Figure 34. This will serve as reference for flow data gathering and depth gauge deployment of the PHIL-LIDAR 1 partner HEI responsible for Anibawan river, the Mapua Institute of Technology.

Figure 34. Water-Level Markings on the pavement in Anibawan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on March 12 and 13, 2017 using a survey-grade GNSS Rover receiver, Trimble® SPS 882. Due to the lack of concrete roads in the Municipality of Burdeos, the survey was conducted in manual GNSS PPK survey technique in continuous topo mode as shown in Figure 35 using UP-CAR as the GNSS base station. The antenna height was 1.680 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver.

Figure 35. Validation points acquisition survey set up along Anibawan River Basin

The conducted survey on March 12, 2017 traversed the streets in Brgy. Anibawan, Municipality of Burdeos, Quezon. The survey continued on March 13, 2017 at the streets of Brgy. Cabungalunan, in the same Municipality. A total of 670 points were gathered with approximate length of 925.62 m, as illustrated in the map in Figure 36.

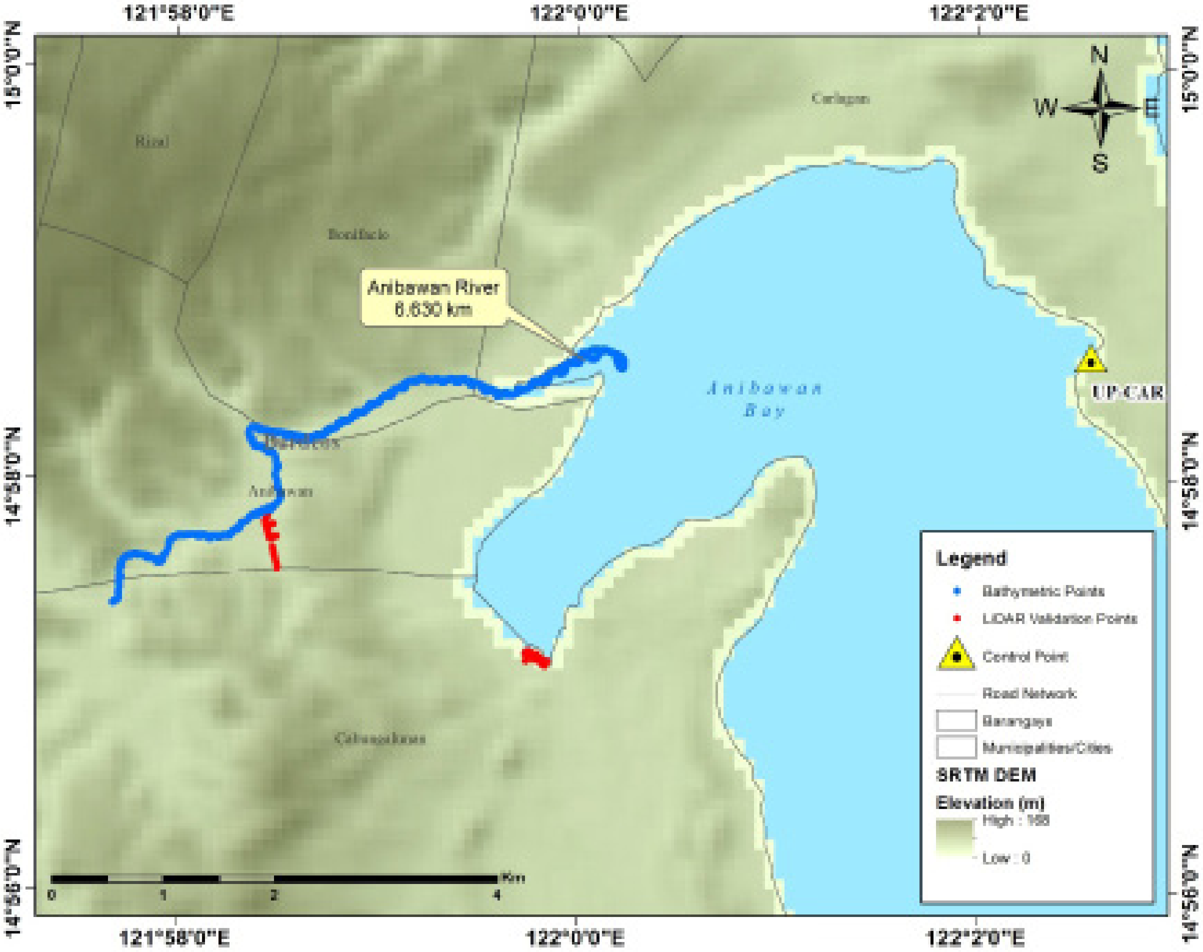


Figure 36. LiDAR validation points acquisition survey for Anibawan River Basin

4.7 Bathymetric Survey

Bathymetric survey was executed on March 12 and 13, 2017 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 37. The survey started in the upstream part of the river in Brgy. Cabungalunan, Municipality of Burdeos with coordinates 14°57’23.67840”N, 121°57’40.62838”E, and ended at the mouth of the river with coordinates 14°58’32.09604”N, 122°00’13.06855”E in Brgy. Carlagan, in the same Municipality. The control point UP-CAR was used as GNSS base station all throughout the entire survey.

Figure 37. Bathymetric survey using Ohmex™ single beam echo sounder in Anibawan River

The bathymetric survey for Anibawan River gathered a total of 14,115 points covering 6.630 km of the river traversing Brgy. Cabungalunan, Municipality of Burdeos, Quezon going downstream as illustrated in the map in (Figure 38).

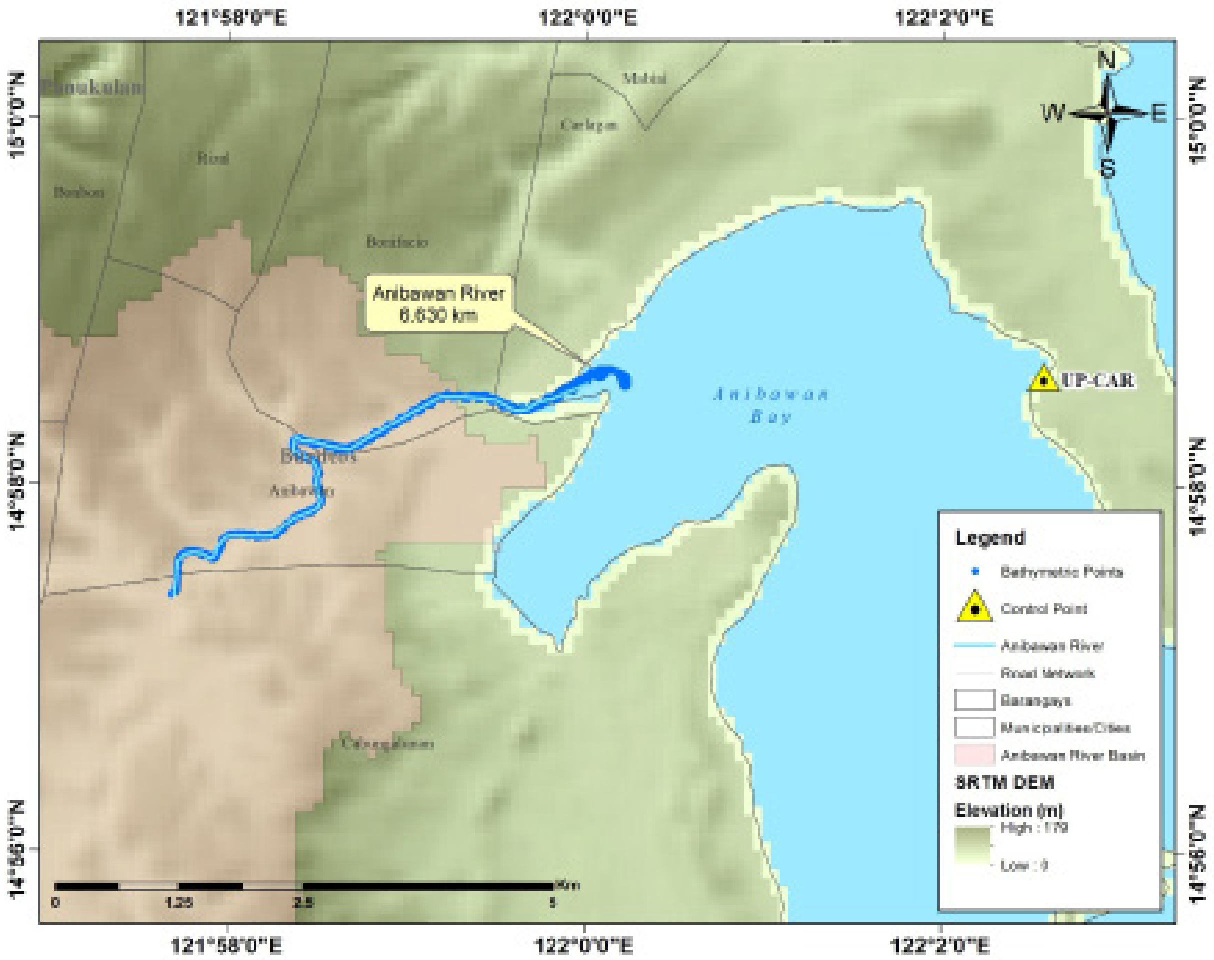


Figure 38. Bathymetric points gathered from Anibawan River

A CAD drawing was also produced to illustrate the riverbed profile of Anibawan River. As shown in Figure 39, the highest and lowest elevation has a 7.56 -m difference for Anibawan River. The highest elevation observed was –0.797 m below MSL located at the middle part of Anibawan river; while the lowest was –6.763 m below MSL located also in the middle portion of the river.

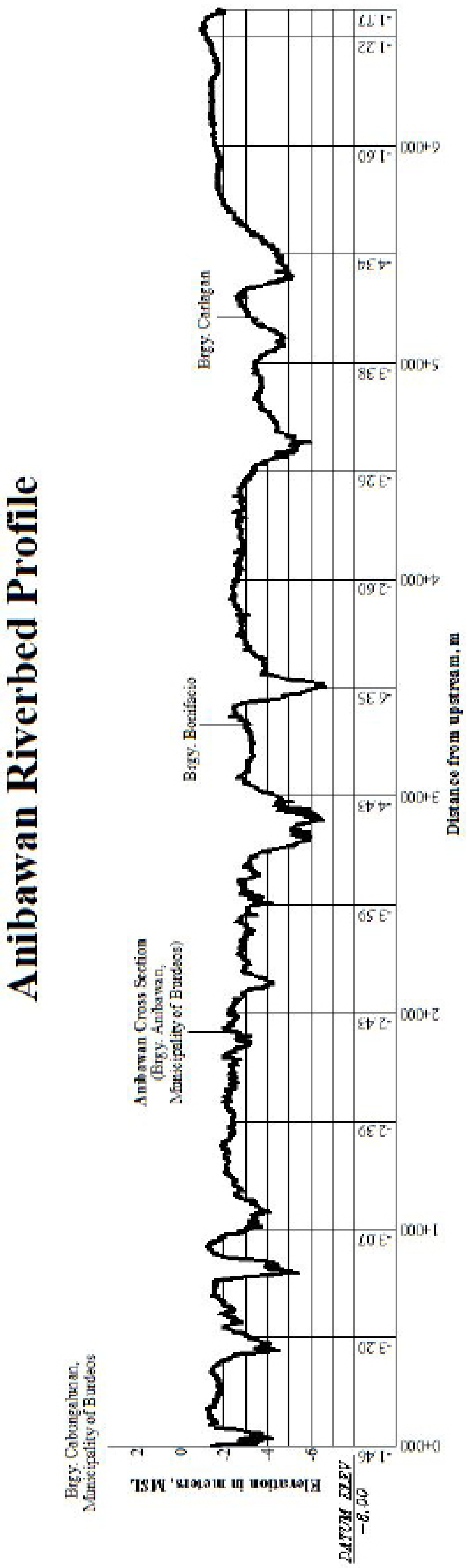


Figure 39. Anibawan riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data used in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge installed by the Mapua Phil-Lidar 1 in Brgy Anibawan Burdeos, Quezon (121°58’27.50”E 14°57’46.25”N). The location of the rain gauge is as shown in Figure 40. The precipitation data collection started from December 15, 2016 18:25 to December 16, 2016 17:55 with a 15-minute recording interval

The Total rain from the automatic rain gauge is 298.2 mm. It peaked to 33.6 mm on December 16, 2016 at 1:25 AM. The lag time between the peak rainfall and discharge is 9 hours and 15 minutes, as shown in Figure 43.

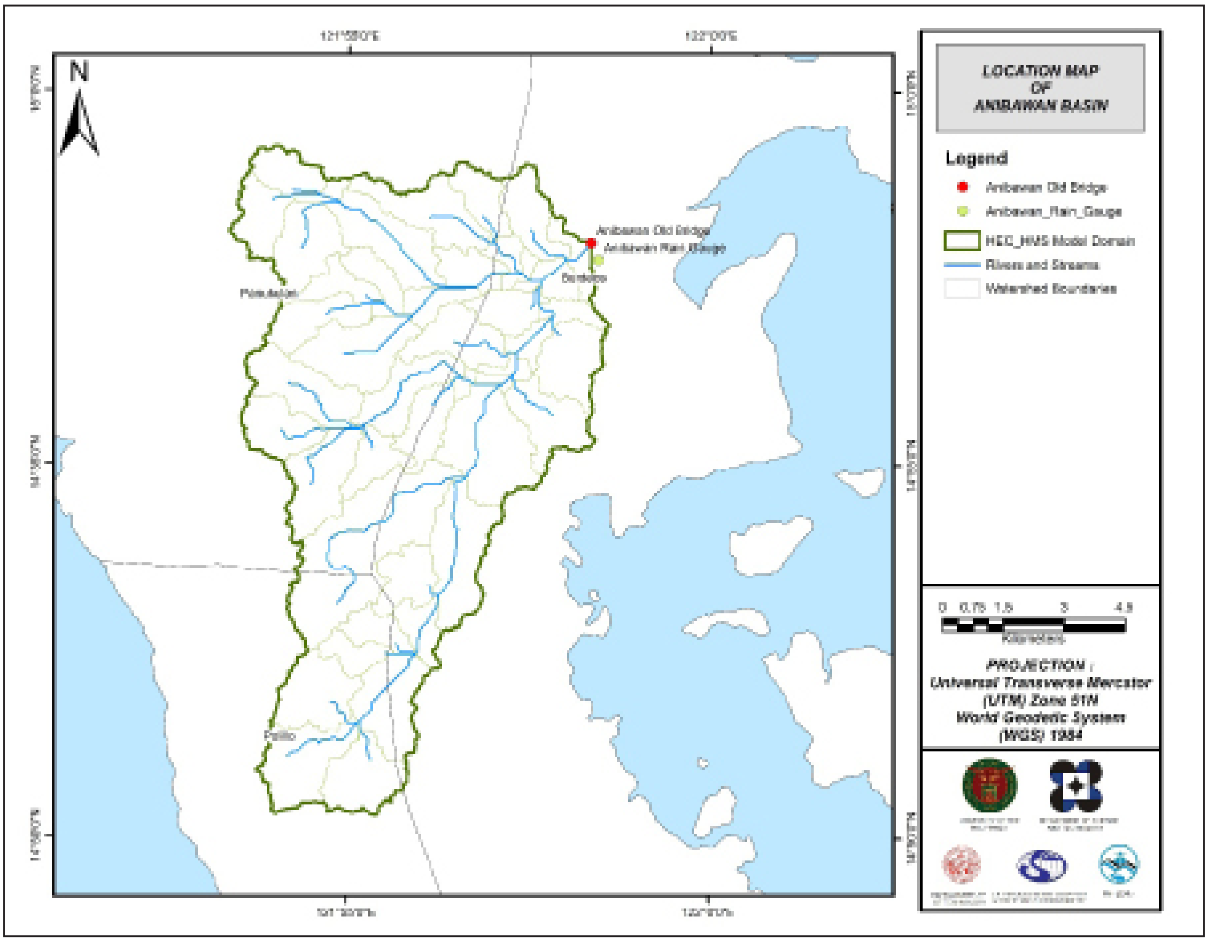


Figure 40. The location map of Anibawan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Old Bridge, Brgy Anibawan Burdeos, Quezon (14°57'51.89"N, 121°58'26.16"E). It gives the relationship between the observed water levels from the Old Bridge using depth gage and outflow of the watershed got using the flow meter at this location.

For the Old Bridge, the rating curve is expressed as Q = 72.708e0.5752x as shown in Figure 42.

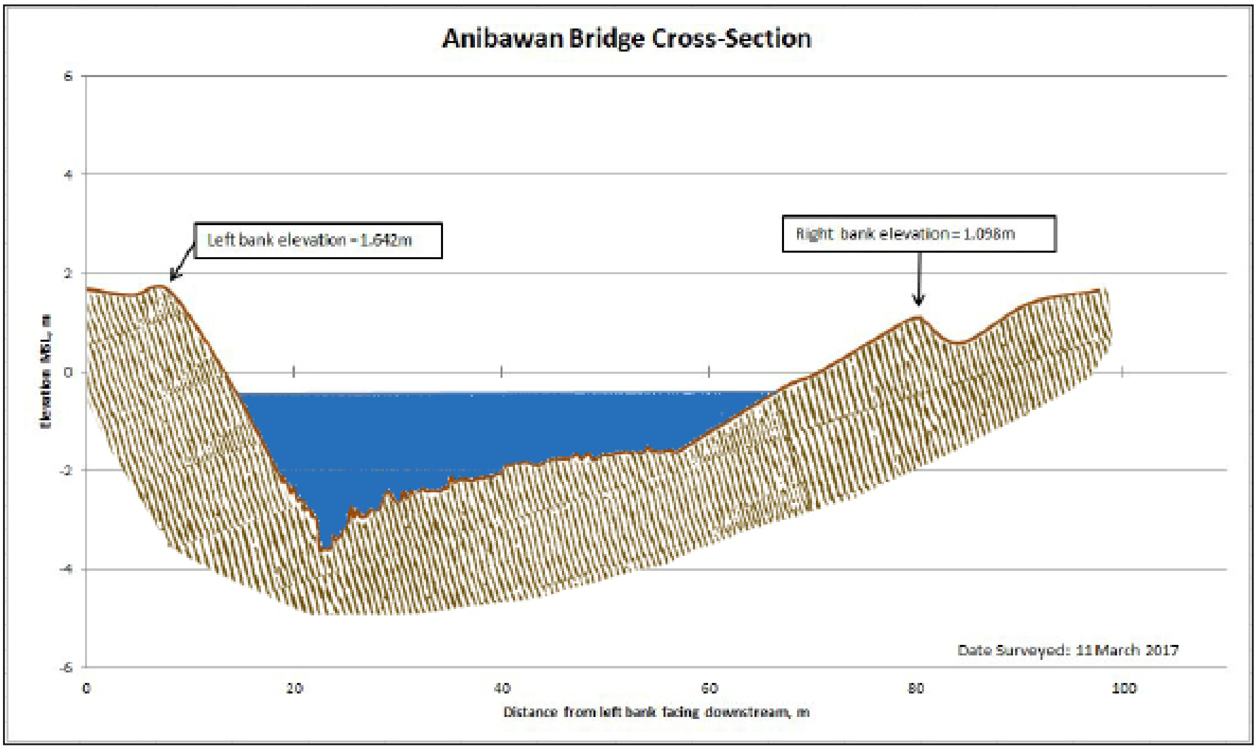


Figure 41. Cross-Section Plot of Talisay (also known as Anibawan) Bridge

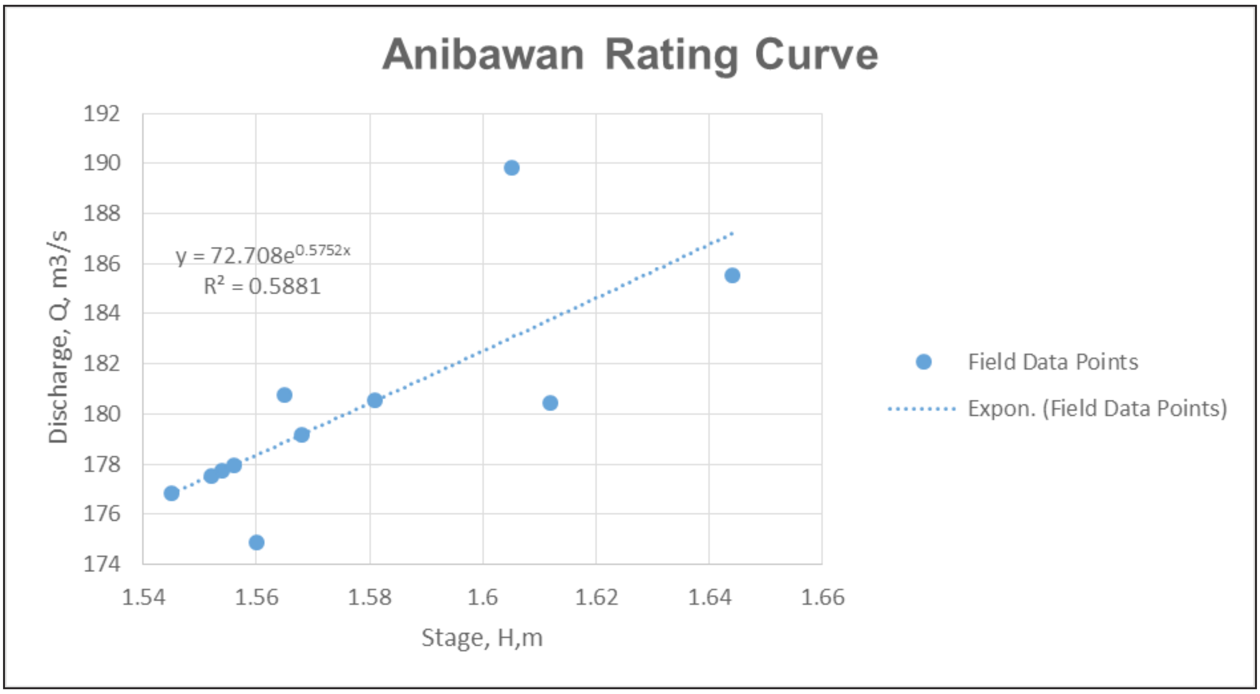


Figure 42. Rating curve at Old Bridge, Brgy Anibawan, Burdeos Quezon

This rating curve equation was used to compute the river outflow at Old Bridge for the calibration of the HEC-HMS model shown in Figure 43. Peak discharge is 290.07 m3 / s at 10:40 AM, Dec 15 2016.

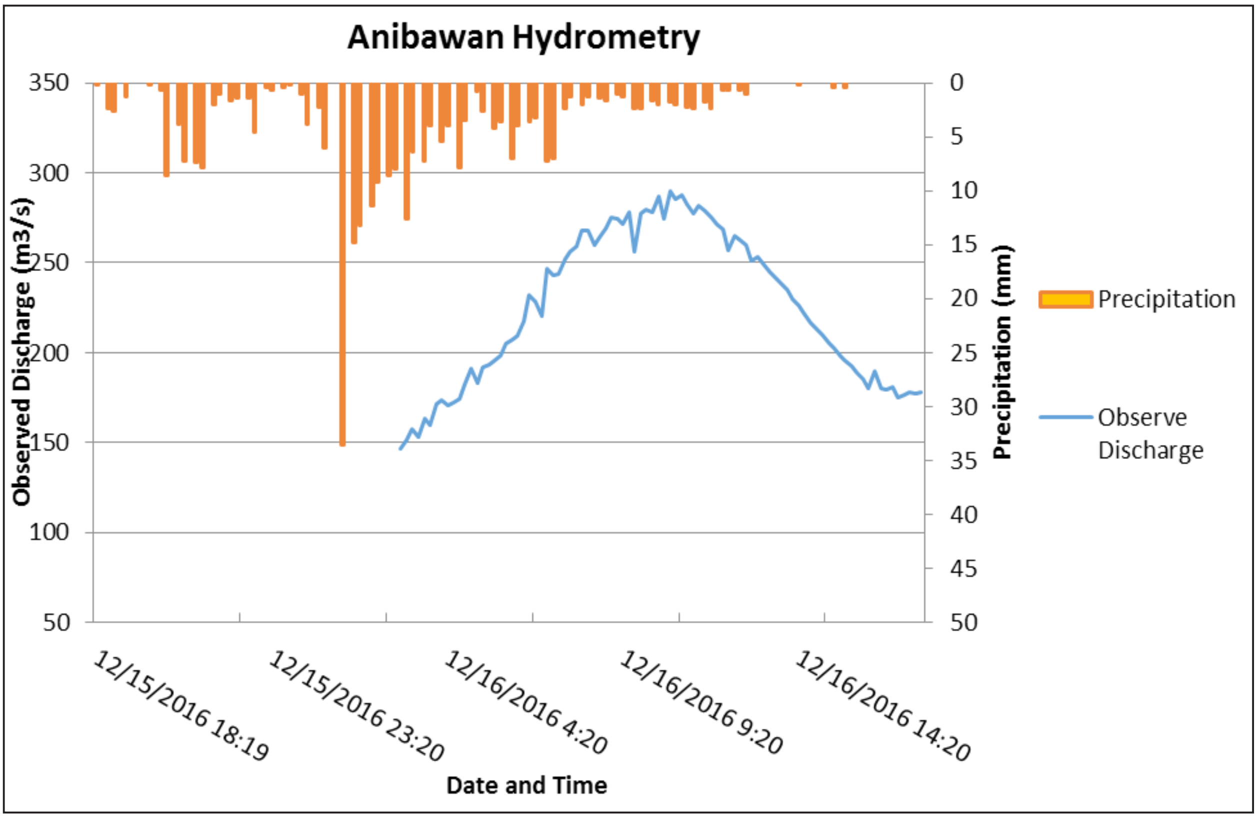


Figure 43. Rainflow and outflow data at Old Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Infanta Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Anibawan watershed. The extreme values for this watershed were computed based on a 40-year record Table 25.

Table 21. RIDF values for Infanta Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	20.4	30.7	39.2	57	79.5	93	121.9	151.2	192.9
5	25.7	38.3	49.3	75.4	112.9	133.1	175.3	212.7	249.6
10	29.2	43.4	56	87.6	135	159.6	210.7	253.4	287.1
15	31.2	46.2	59.8	94.5	147.4	174.5	230.7	276.4	308.2
20	32.6	48.2	62.4	99.4	156.2	185	244.6	292.4	323
25	33.7	49.7	64.4	103.1	162.9	193.1	255.4	304.8	334.4
50	37	54.5	70.7	114.5	183.6	217.9	288.6	343	369.6
100	40.3	59.2	76.9	125.9	204.2	242.6	321.5	380.9	404.4

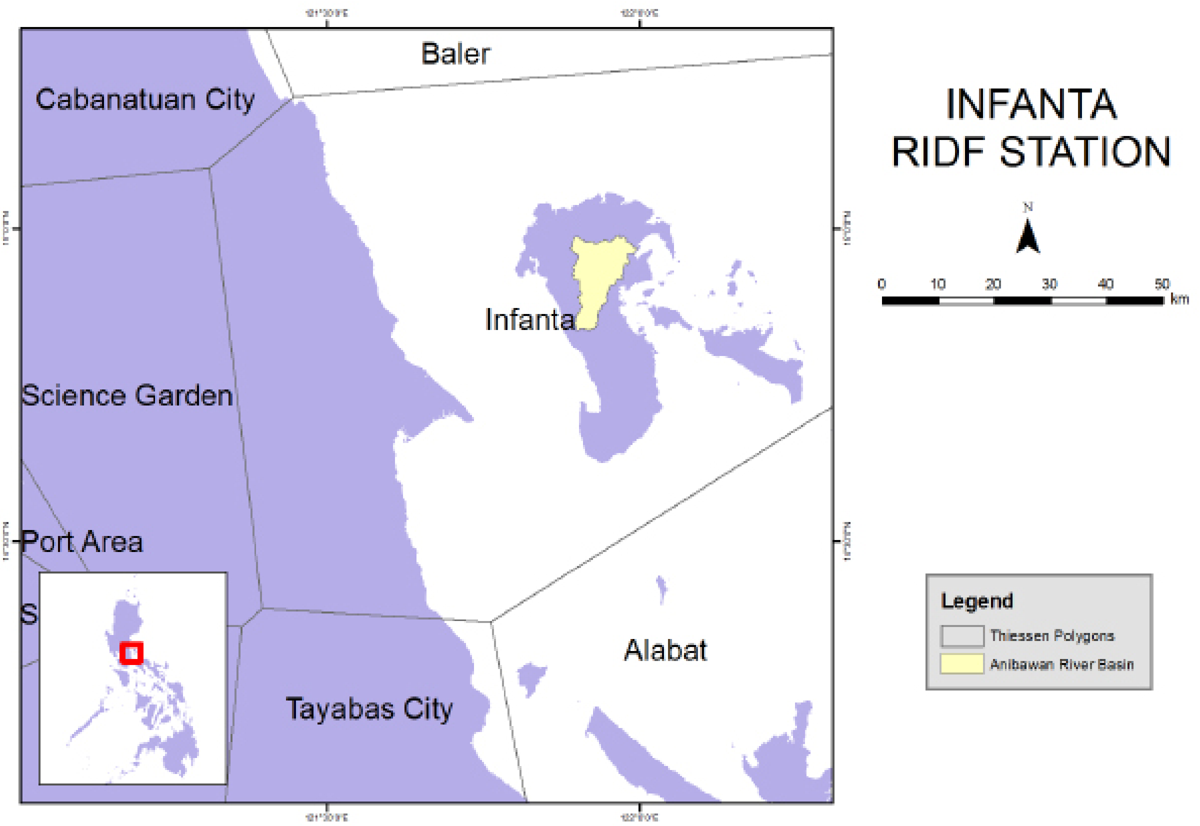


Figure 44. Infanta RIDF location relative to Anibawan River Basin

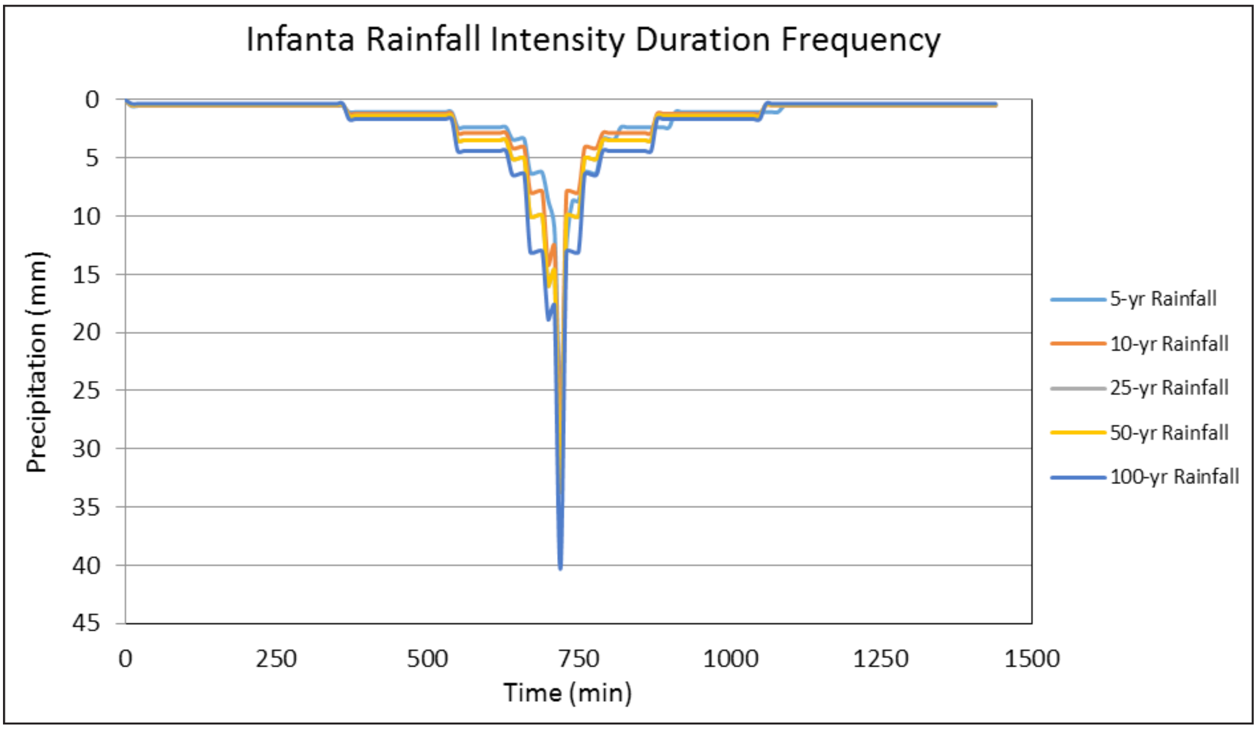


Figure 45. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soil and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Anibawan River Basin are shown in Figure 46 and Figure 47, respectively.

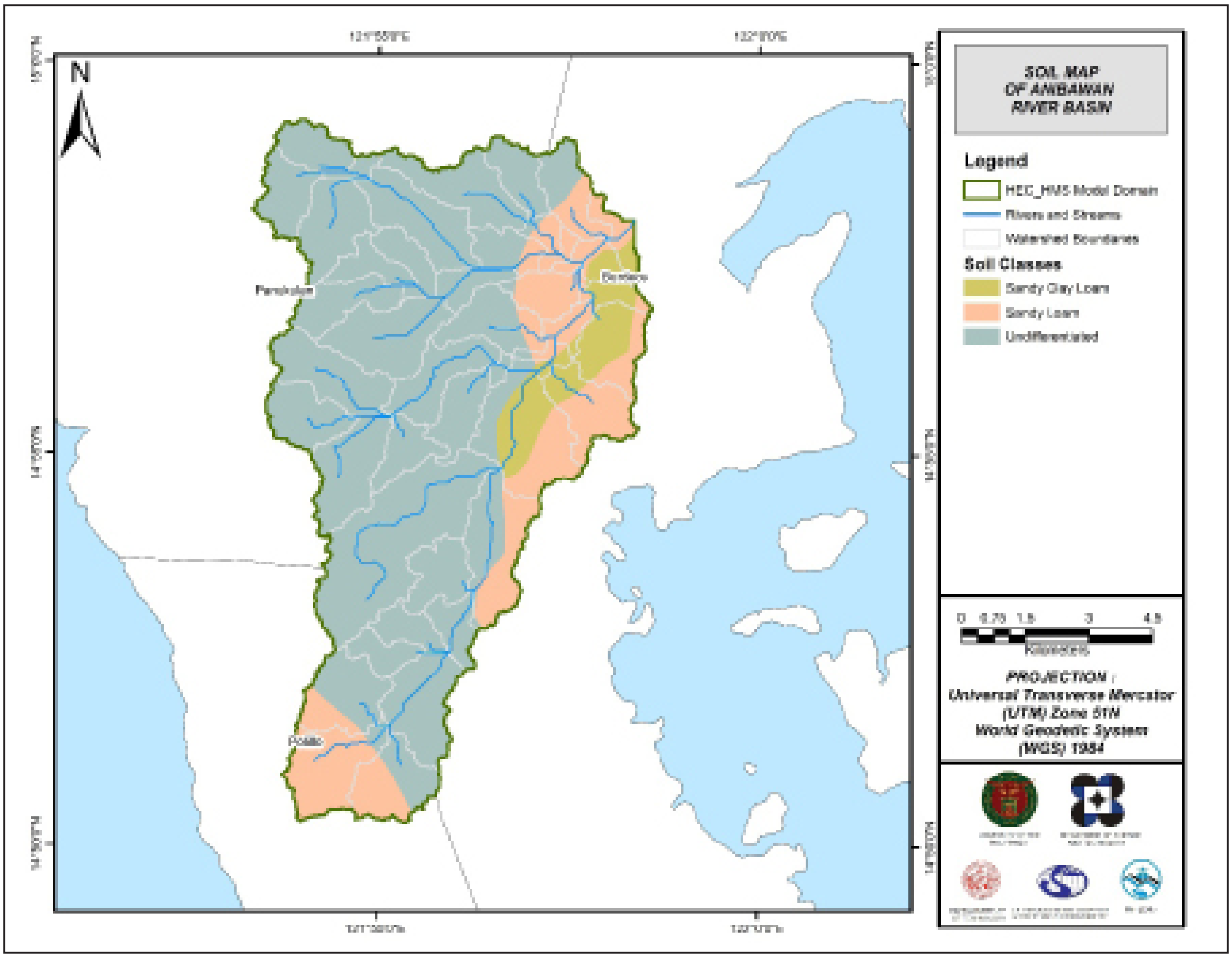


Figure 46. Soil map of the Anibawan River Basin (Source: DA)

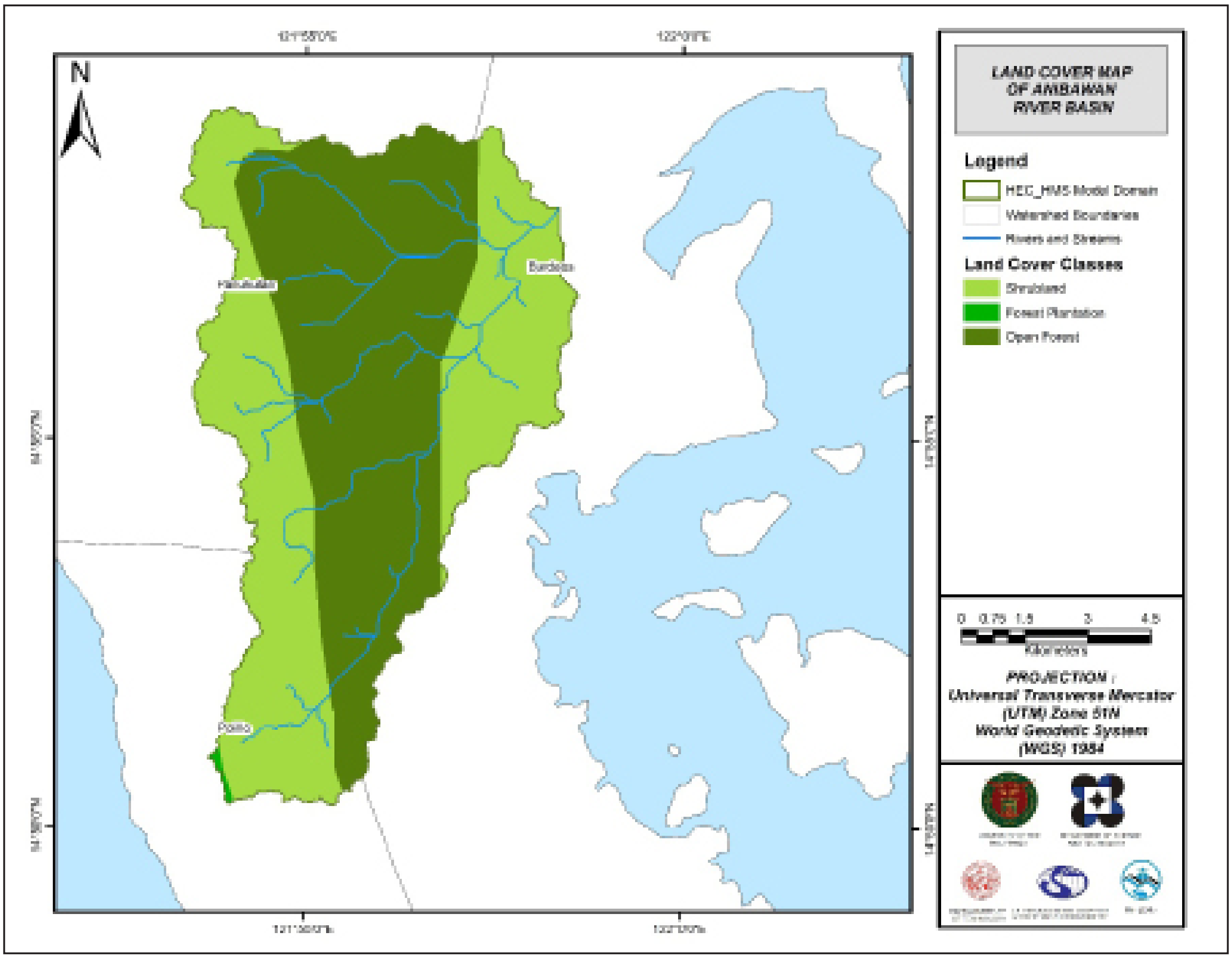


Figure 47. Land cover map of Anibawan River Basin (Source: NAMRIA)

For Anibawan river basin, the three (3) soil classes identified were sandy loam, sandy clay loam, and undifferentiated mountain soil. The three (3) land cover types identified were largely open forest and shrubland, with a small portion of open canopy forests.

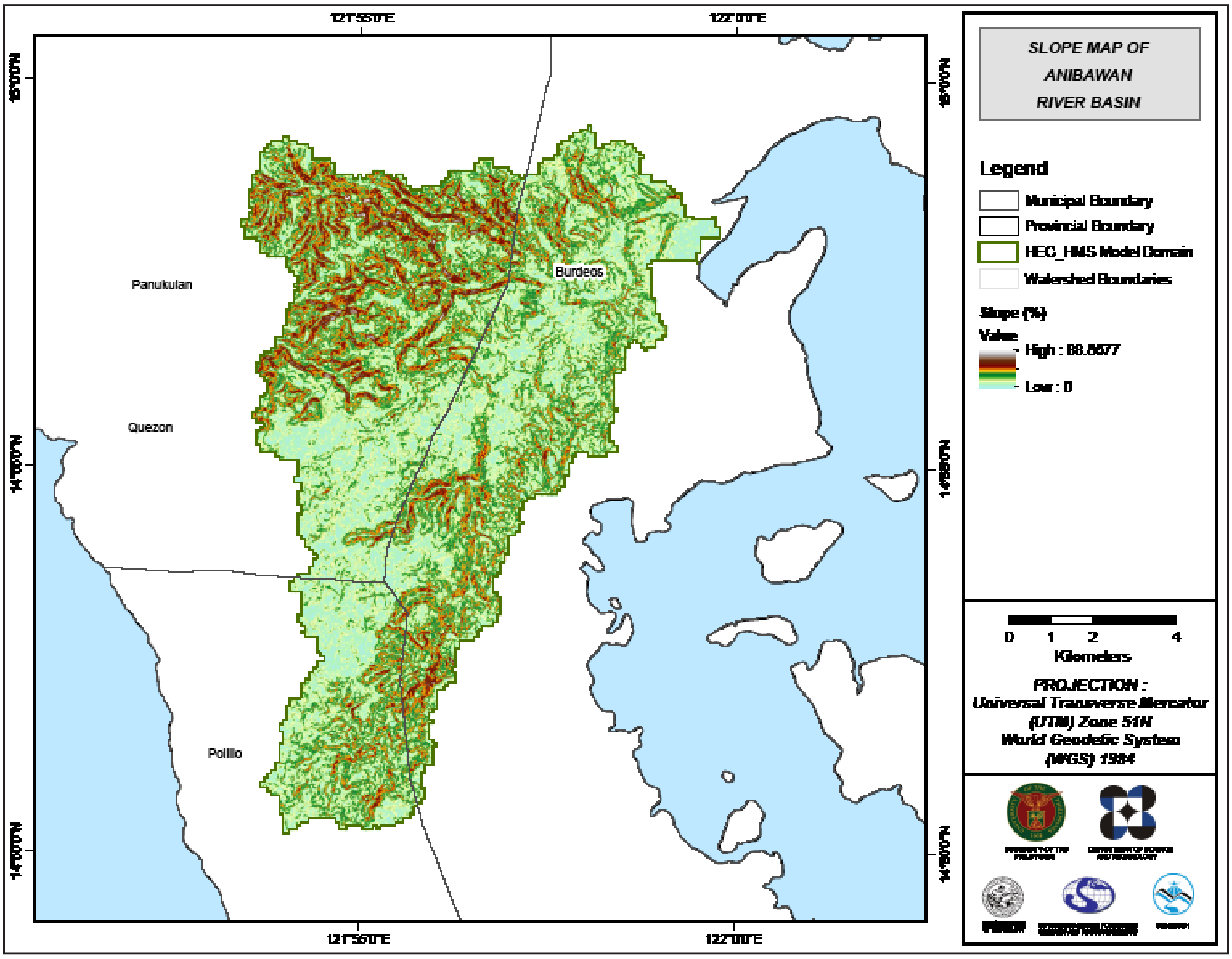


Figure 48. Slope map of Anibawan River Basin

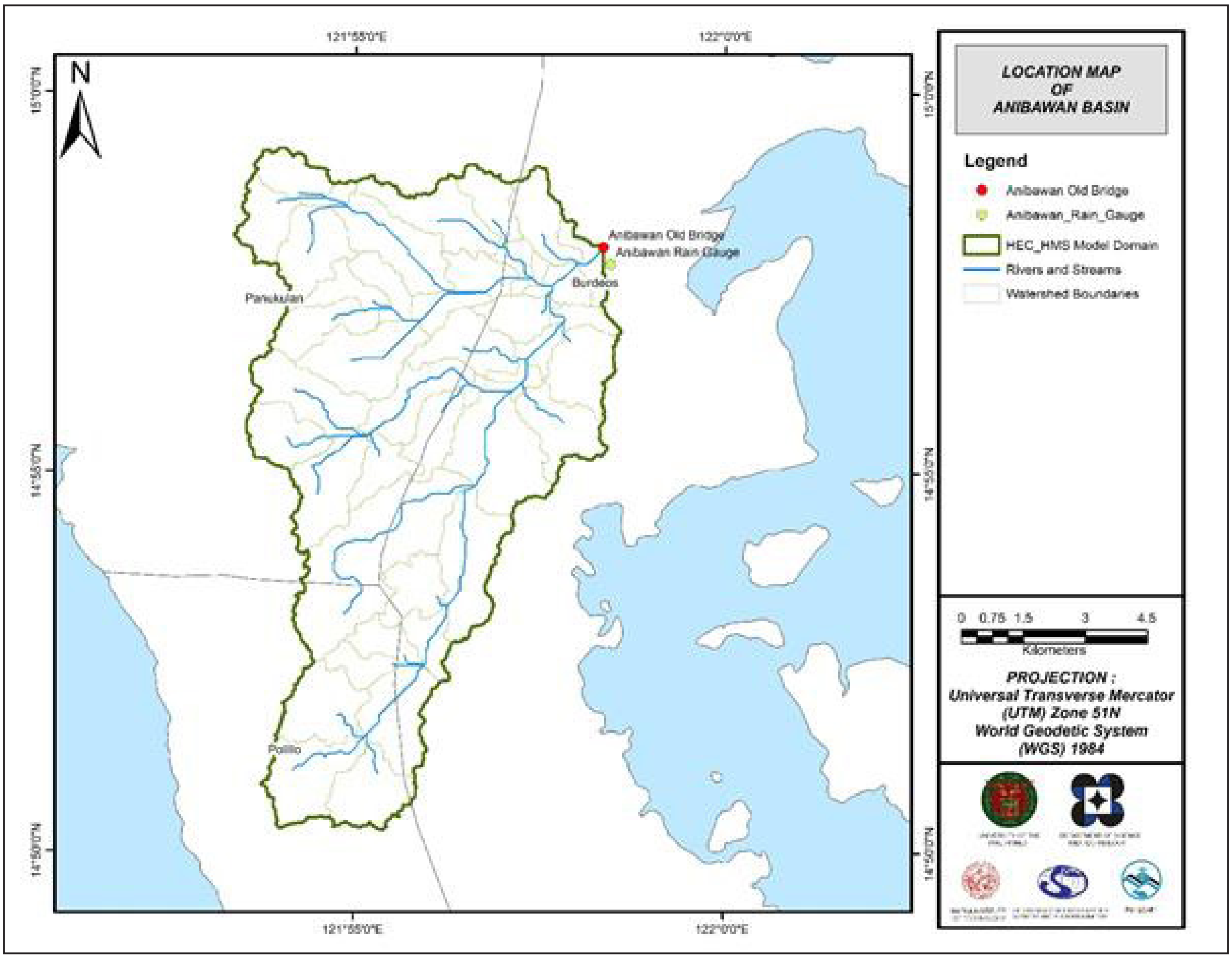


Figure 49. Stream Delineation Map of the Anibawan River Basin

The Anibawan basin model consists of 49 sub-basins, 24 reaches, and 24 junctions. The main outlet is located at the Northwest part of the watershed. This basin model is illustrated in Figure 50. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from manual rain gauge. Finally, it was calibrated using data from the Old Bridge.

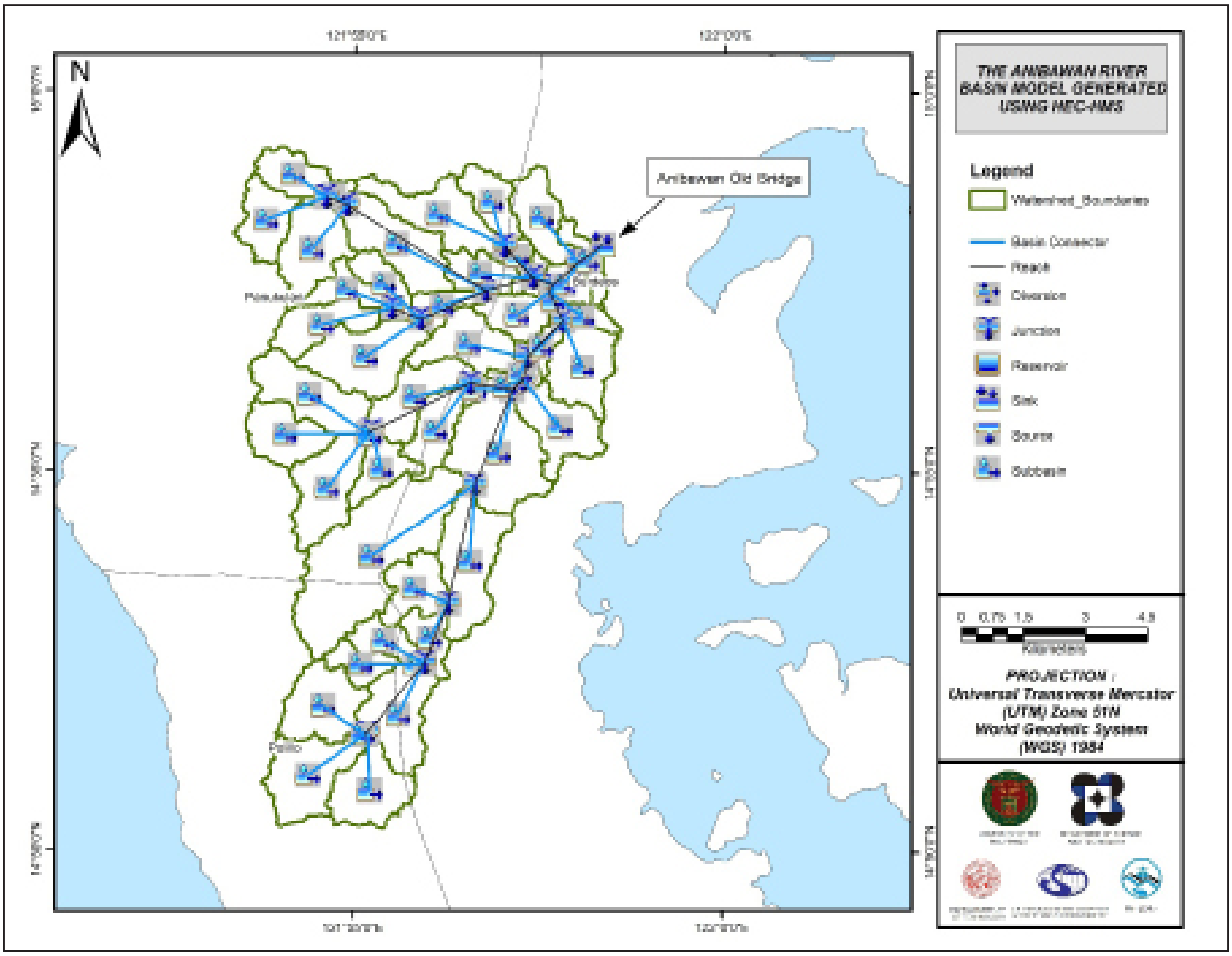


Figure 50. HEC-HMS generated Rosario-Lobo River Basin Model.

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS. This is illustrated in Figure 51.

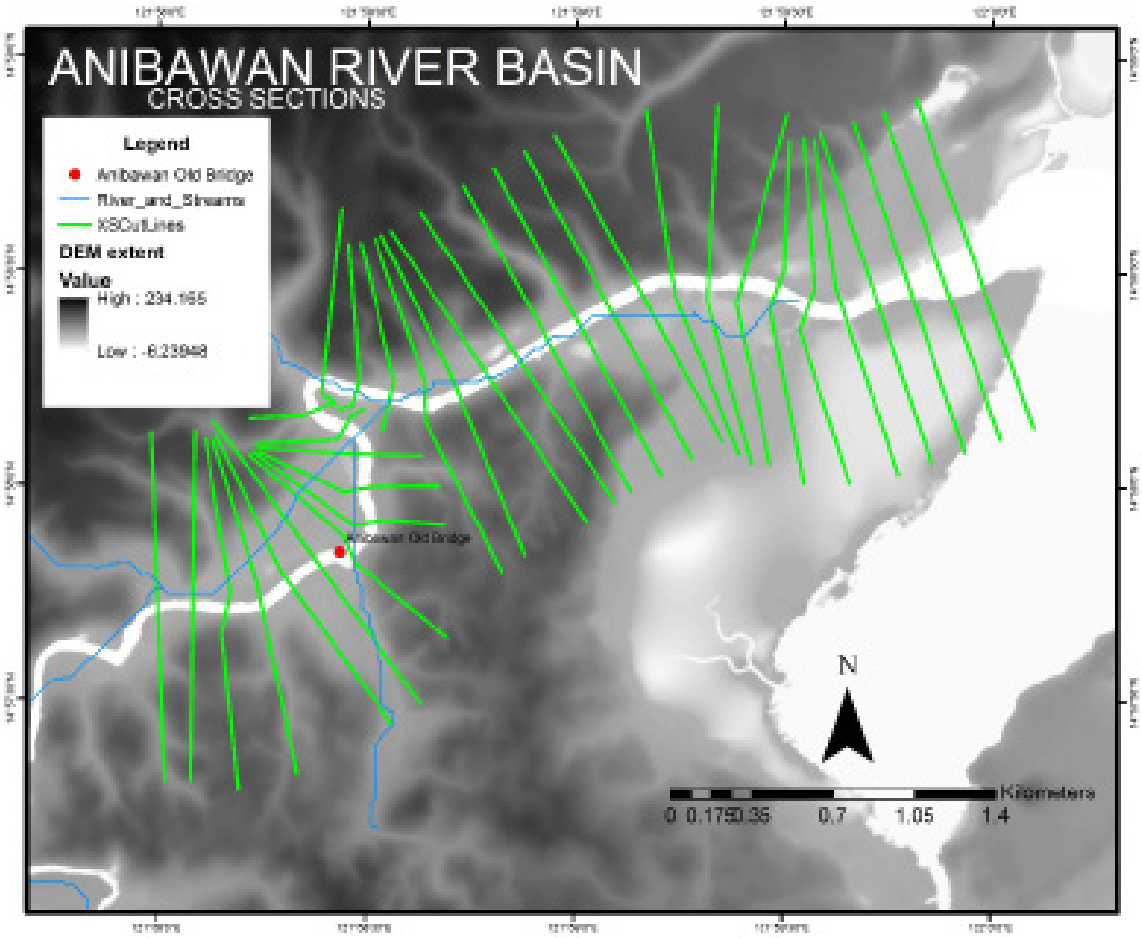


Figure 51. River cross-section of Anibawan River generated through Arcmap HEC GeoRAS tool

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

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

Table 22. Look-up table for Manning's n values (Source: Brunner, 2010)

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

5.5 Flo 2D Model

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

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

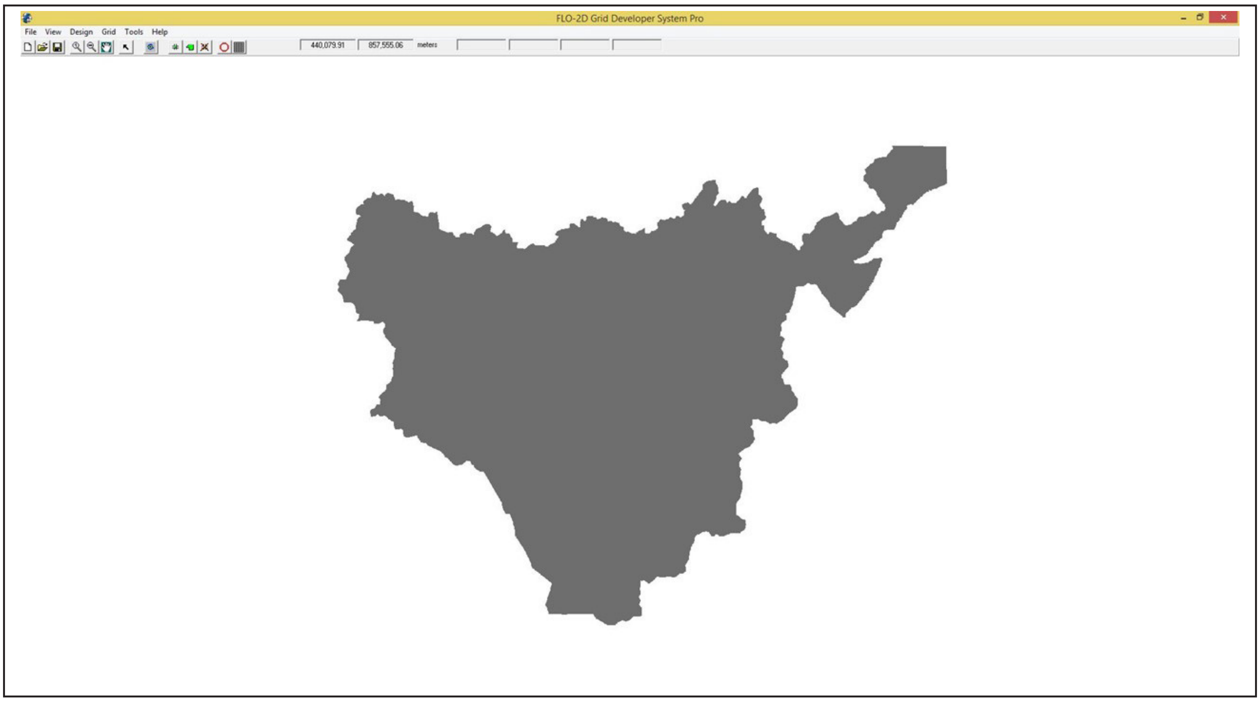


Figure 53. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 90.90137 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.

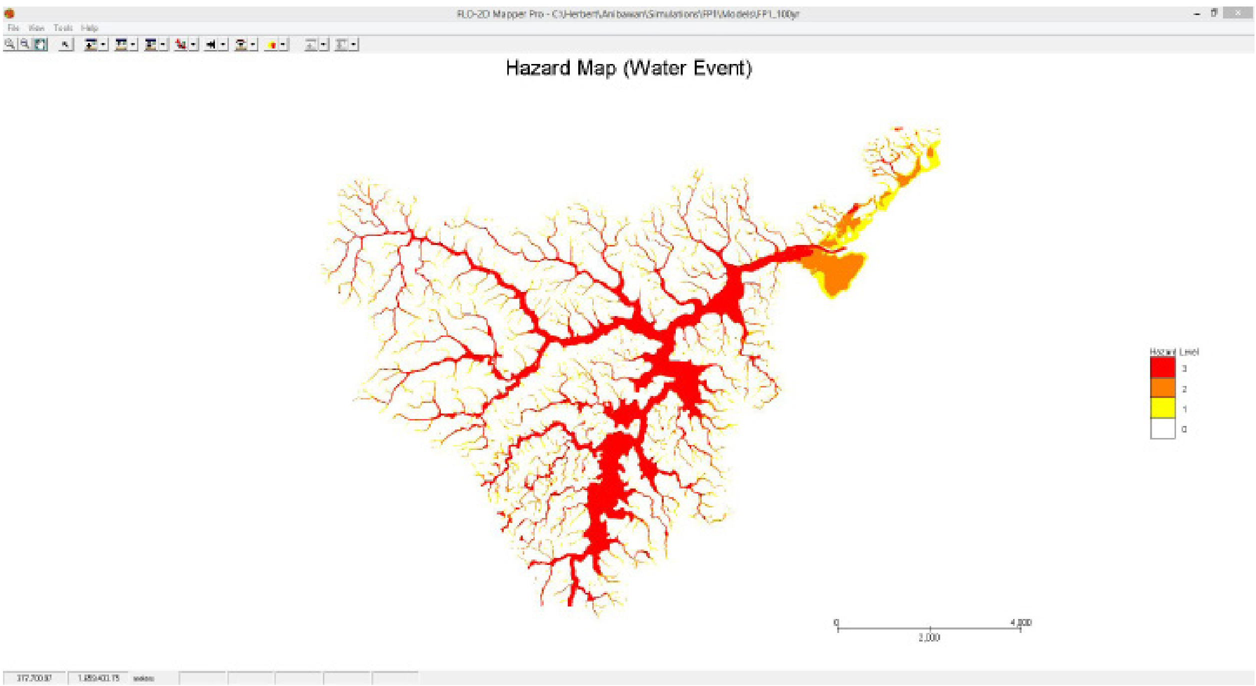


Figure 52. Generated 100-year Rain Return Hazard Map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 67 420 320.00 m2.

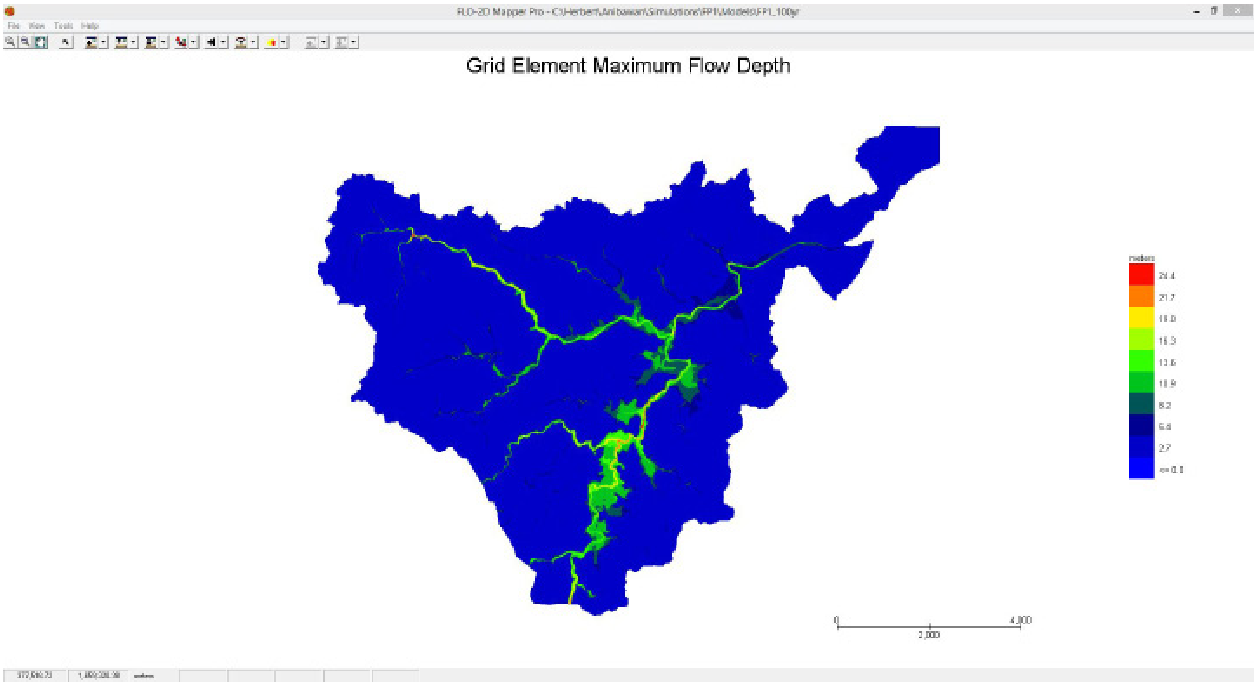


Figure 54. Generated 100-year Rain Return Flow Depth Map from FLO-2D Mapper

There is a total of 62 611 069.15m3 of water entering the model. Of this amount, 41 088 244.83 m3 is due to rainfall while 21 522 824.32 m3 is inflow from other areas outside the model. 6 820 454.00 m3 of this water is lost to infiltration and interception, while 31 415 593.82m3 is stored by the flood plain. The rest, amounting up to 24 375 067.50 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Anibawan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

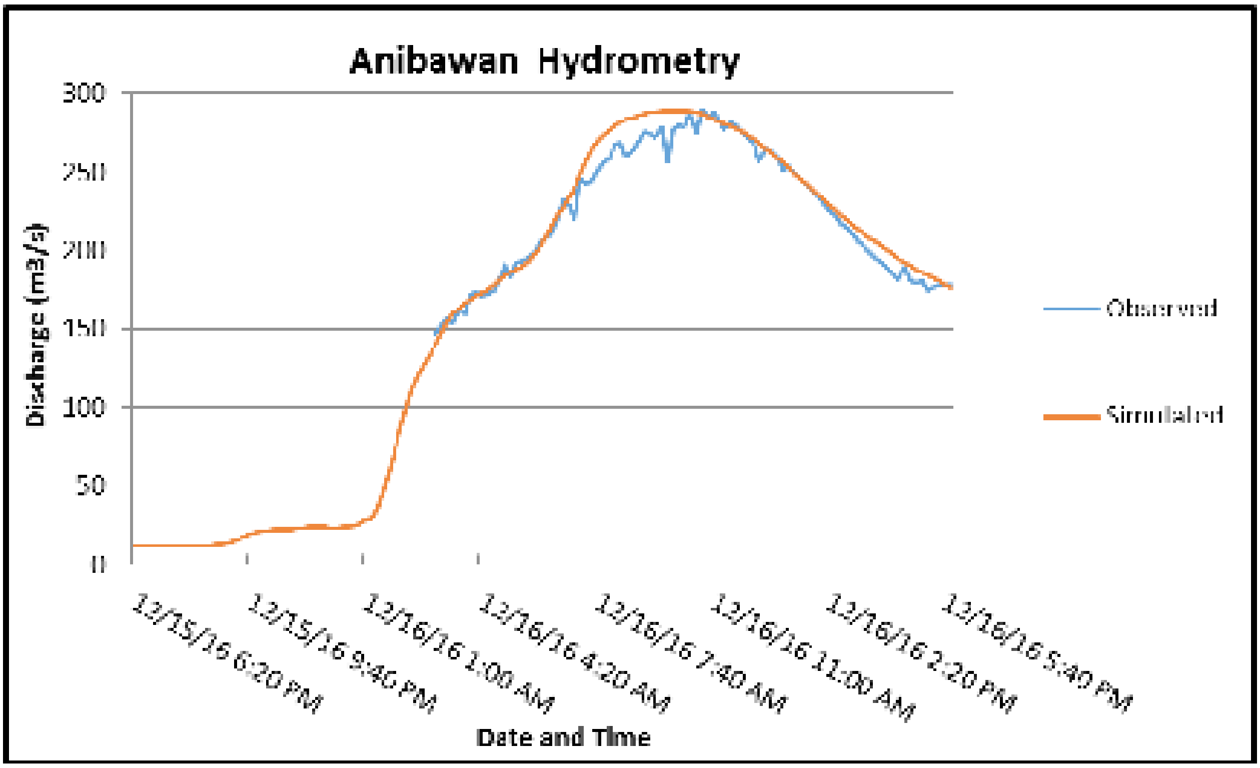


Figure 55. Outflow Hydrograph of Anibawan River produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 23 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 23. Range of Calibrated Values for Anibawan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.62 – 301.66
			Curve Number	35.20 – 87.72
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.024 – 10.78
			Storage Coefficient (hr)	0.029 – 49.29
	Baseflow	Recession	Recession Constant	0.60 – 1
			Ratio to Peak	0.21 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001 - 1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.62mm to 301.66mm means that there is minimal to considerable amount of infiltration or rainfall interception by vegetation, depending on the subbasin.

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 curve numbers for the river's subbasins are from 35.20 to 87.72. For Anibawan, the soil classes identified were sandy loam, sandy clay loam, and undifferentiated mountain soil. The land cover types identified were shrubland, forest plantations and open canopy forests.

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 0.024 hours to 10.78 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. The range of values for the recession constant is from 0.60 to 1. Ratio to peak is from 0.21 to 1. The basin in the modeled events did not quickly go back to its original discharge, as evidenced by the shallower receding limb of the outflow hydrograph.

The Manning's roughness coefficient of 0.0001 – 1 for this basin describes the roughness values of each of the watershed's subbasins. (Brunner, 2010).

Table 24. Summary of the Efficiency Test of Anibawan HMS Model

Accuracy measure	Value
RMSE	9.3
r2	.9724
NSE	.95
PBIAS	-2.35
RSR	.22

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 9.3 (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 .9724.

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 .95.

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 -2.35.

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 0.22.

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 56) shows the Anibawan outflow using the Infanta 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 (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

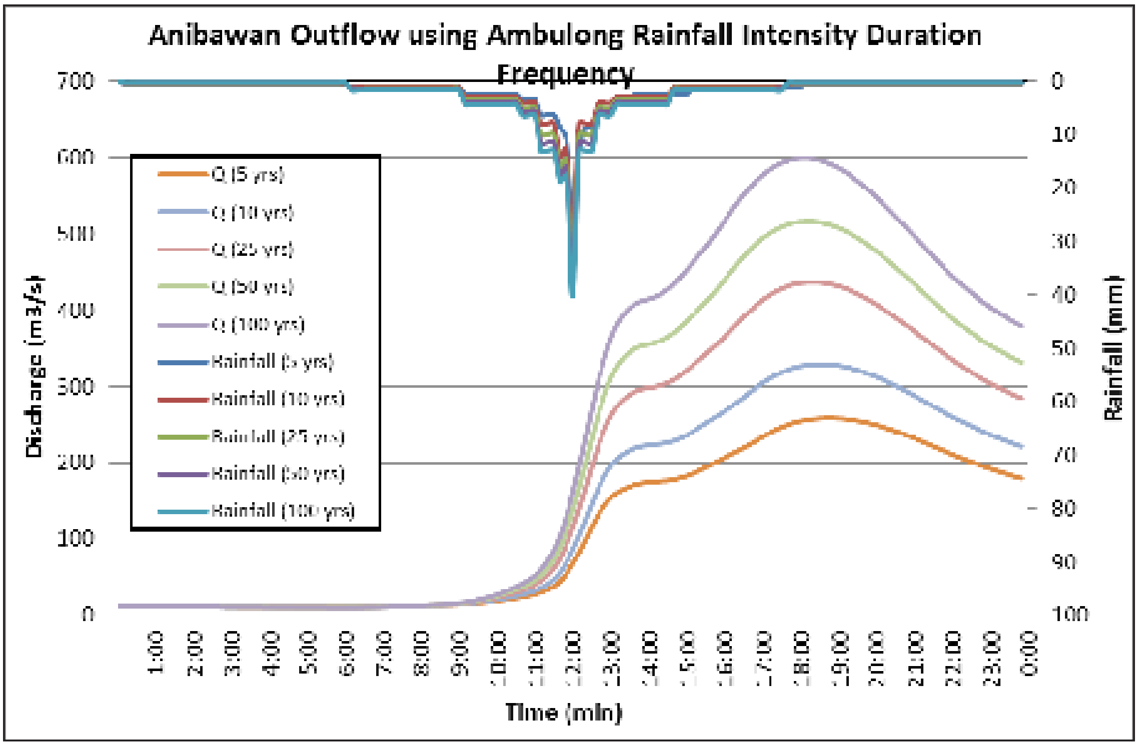


Figure 56. Outflow hydrograph at Anibawan Station generated using Daet RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Anibawan River discharge using the Infanta Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 25.

Table 25. Peak values of the Vigo HECHMS Model outflow using the Daet RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	249.6	25.7	258.6	18 hours and 40 min
10-Year	256.9	29.2	329	18 hours and 10 min
25-Year	296.93	33.7	436.7	18 hours and 20 min
50-Year	326.91	37	516.7	18 hours and 10 min
100-Year	356.38	40.3	598.7	18 hours and 10 min

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of Anibawan River using the calibrated HMS base flow is shown in Figure 57.

Figure 57. Sample output of Anibawan RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 58 to Figure 63 show the 5-, 25-, and 100-year rain return scenarios of the Anibawan floodplain. Table 26 shows the list of municipalities affected by flooding in the Anibawan floodplain.

Table 26. Municipalities affected in Anibawan Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Burdeos	264.89	64.77	24.45%
Panukulan	179.58	46.91	17.71%

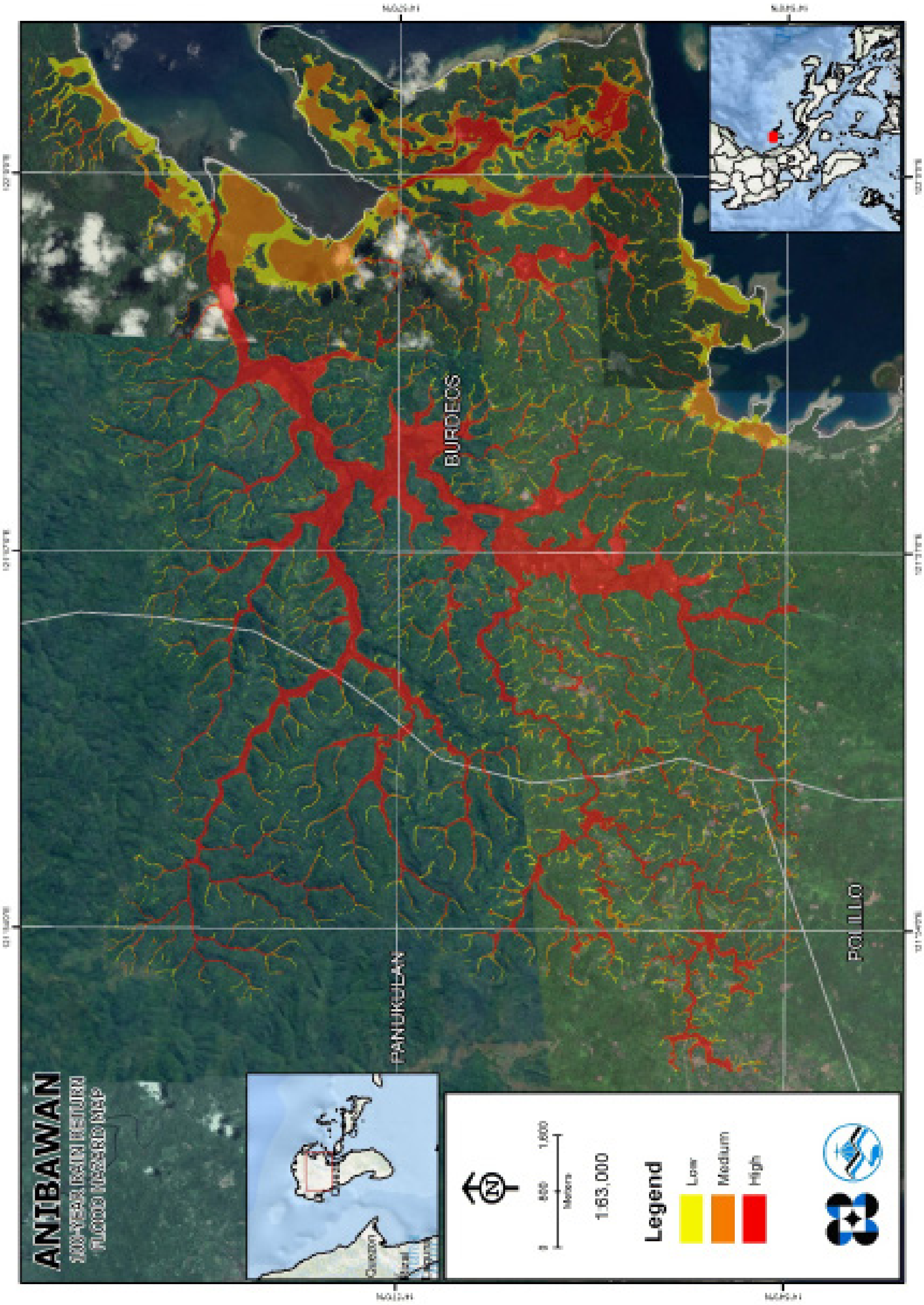


Figure 58. 100-year Flood Hazard Map for Anibawan Floodplain overlaid in Google Earth imagery

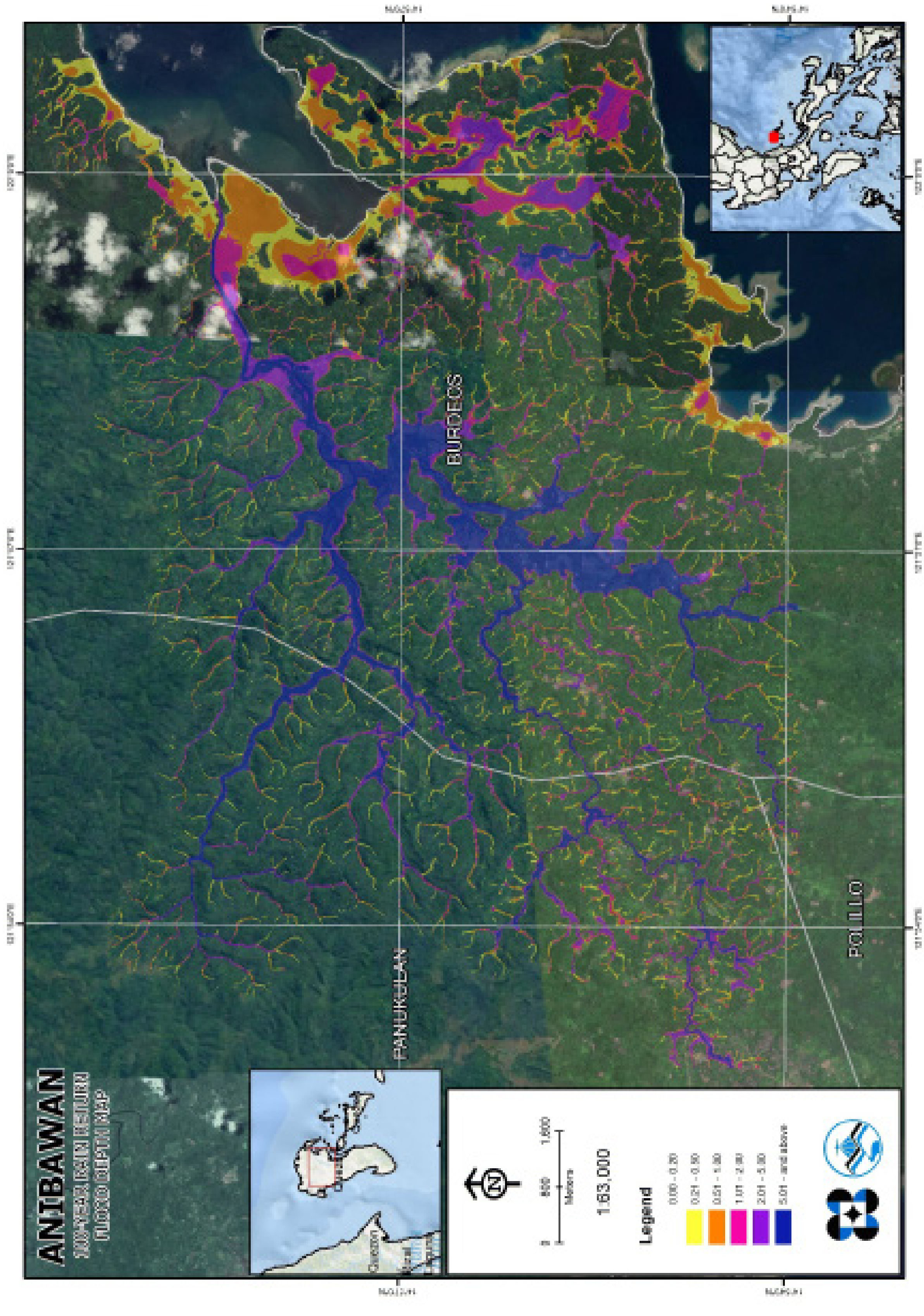


Figure 59. 100-year Flow Depth Map for Anibawan Floodplain overlaid in Google Earth imagery

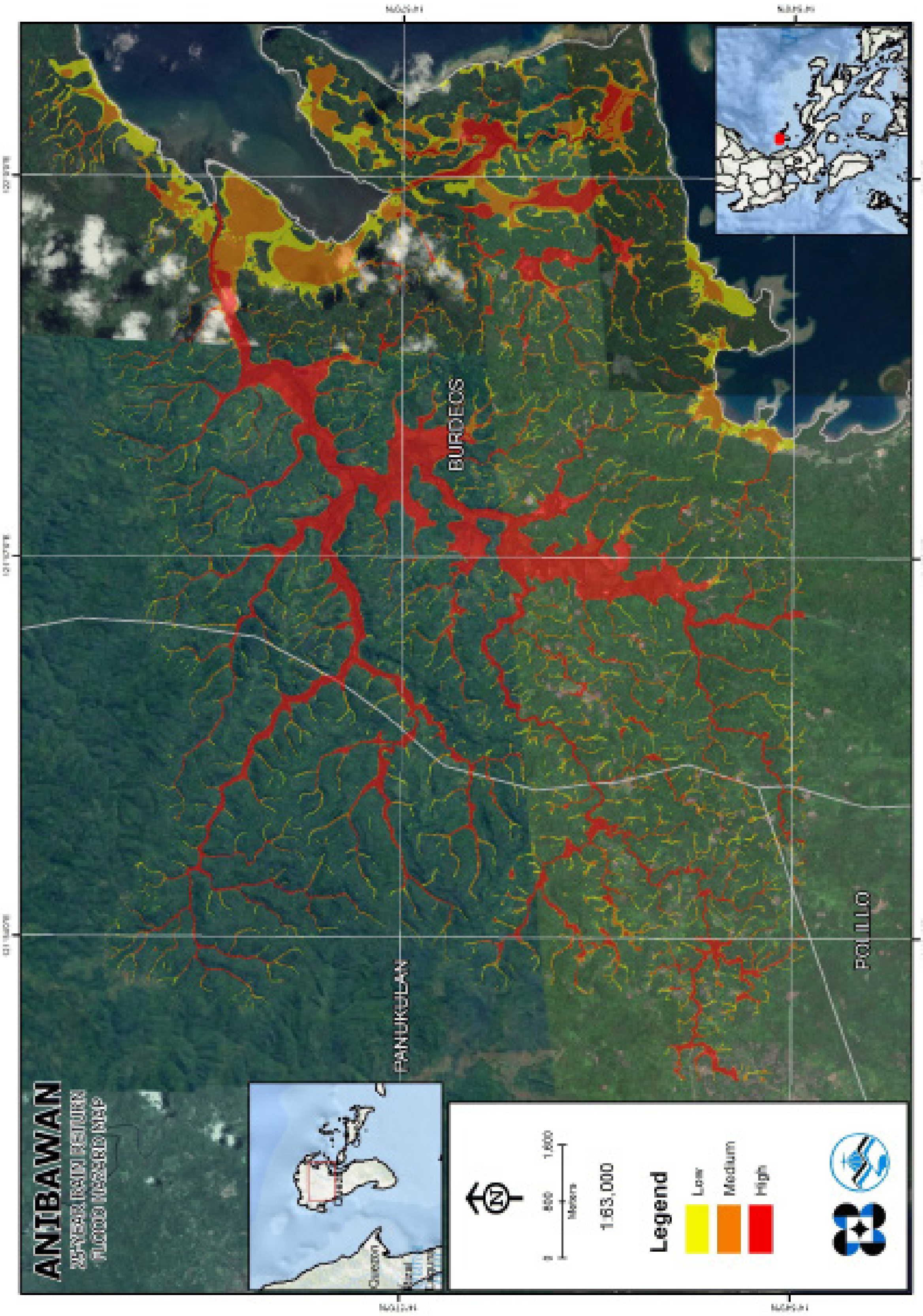


Figure 60. 25-year Flood Hazard Map for Anibawan Floodplain overlaid in Google Earth imagery

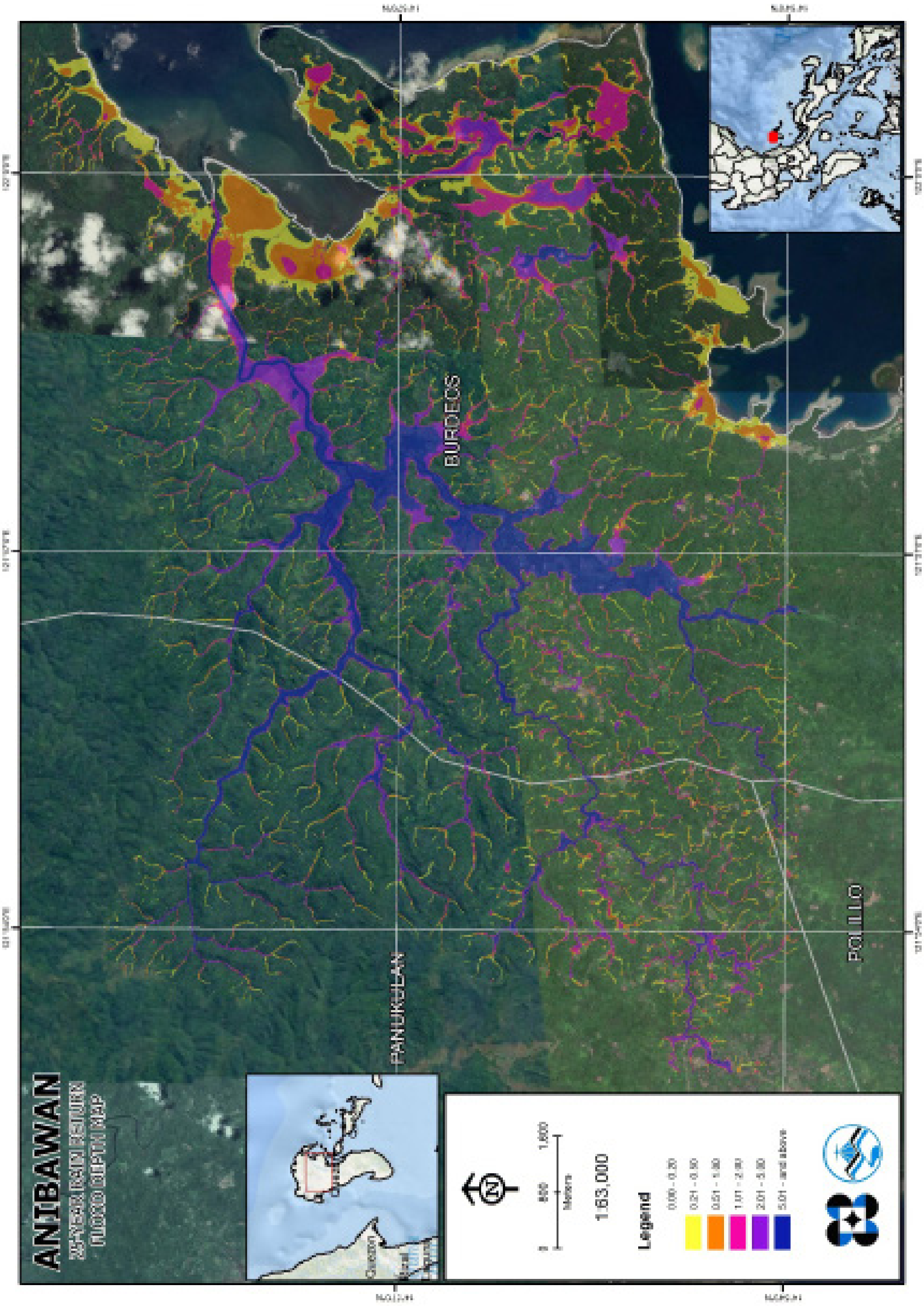


Figure 61. 25-year Flow Depth Map for Anibawan Floodplain overlaid in Google Earth imagery

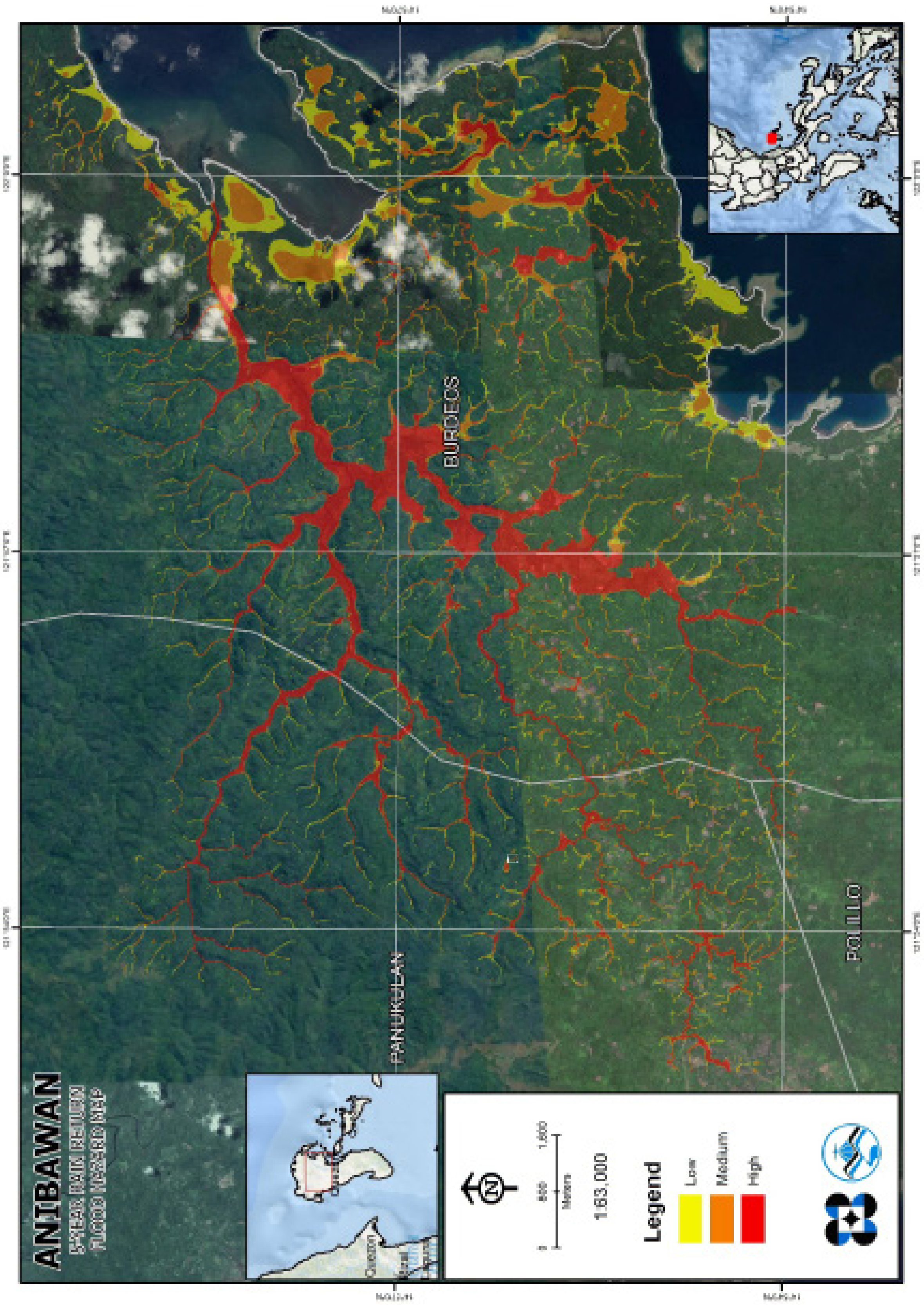


Figure 62. 5-year Flood Hazard Map for Anibawan Floodplain overlaid in Google Earth imagery

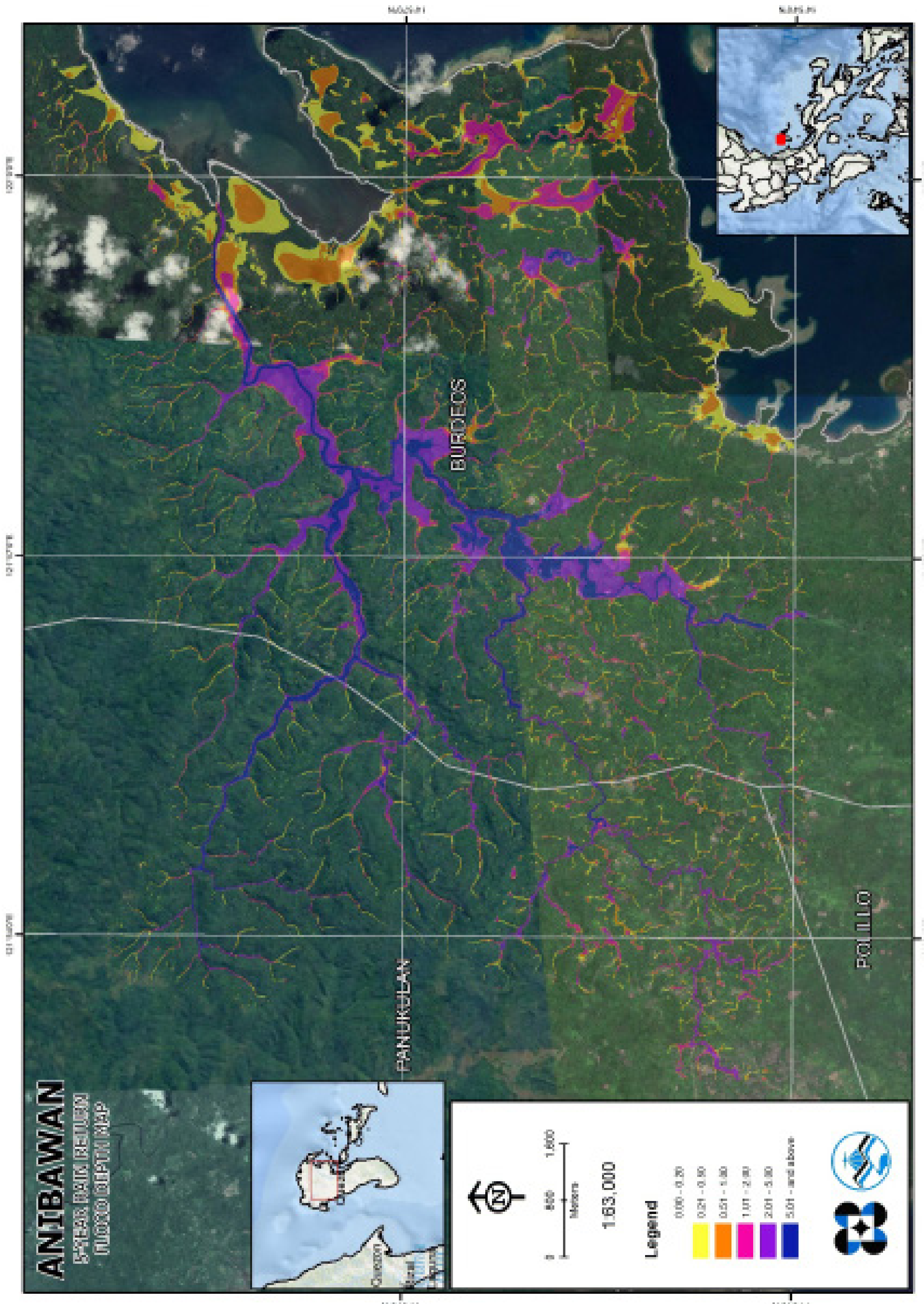


Figure 63. 5-year Flow Depth Map for Anibawan Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Anibawan River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 10 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 15.93% of the municipality of Panukulan with an area of 179.58 sq. km. will experience flood levels of less than 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 0.33%, 0.32%, 0.44%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 27 and shown in Figure 64 are the affected areas in square kilometers by flood depth per barangay.

Table 27. Affected areas in Burdeos, Quezon during a 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Burdeos (in sq. km.)					
	Aluyon	Anibawan	Bonifacio	Cabungalunan	Carlagan	Rizal
0.03-0.20	13.53	6.48	2.76	25.28	2.35	0.39
0.21-0.50	1.06	0.76	0.11	1.8	0.5	0.012
0.51-1.00	0.42	0.64	0.17	1.6	0.14	0.0062
1.01-2.00	0.23	0.21	0.16	1.4	0.05	0.0023
2.01-5.00	0.44	0.77	0.084	1.73	0.021	0
> 5.00	0.14	0.24	0.089	1.18	0.00063	0

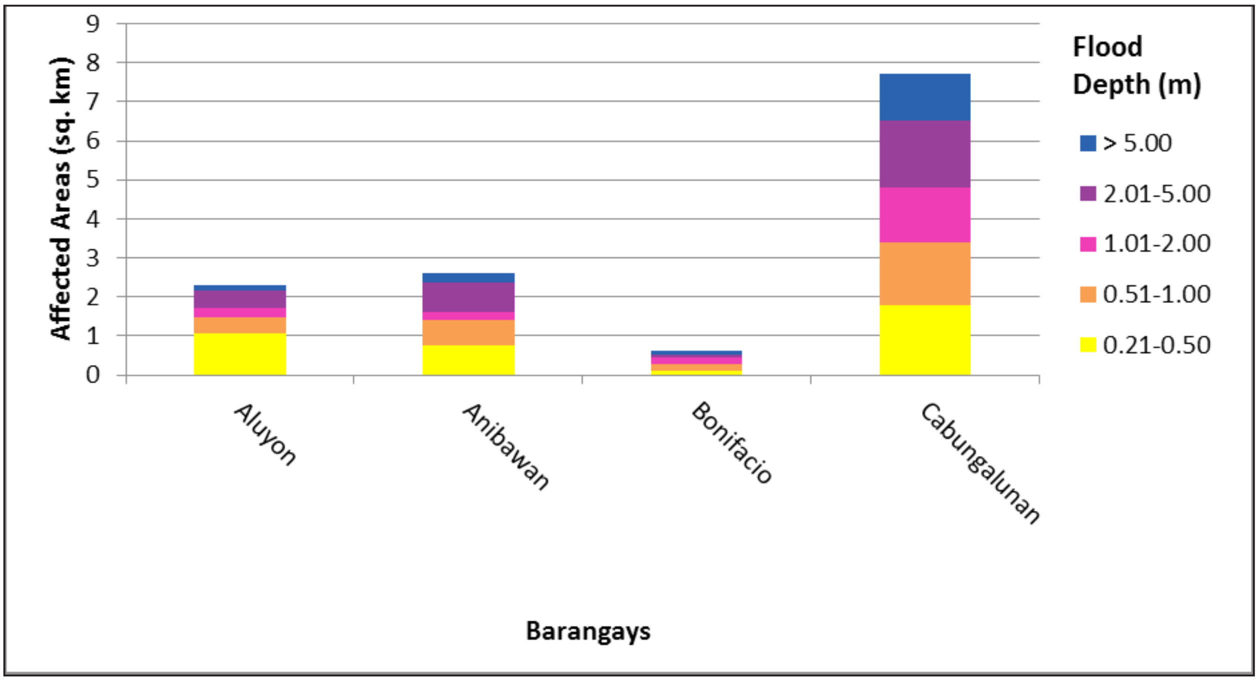


Figure 64. Affected areas in Burdeos, Quezon during a 5-Year Rainfall Return Period.

For the 5-year return period, 15.93% of the municipality of Panukulan with an area of 179.58 sq. km. will experience flood levels of less than 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 0.33%, 0.32%, 0.44%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 28 and shown in Figure 65 are the affected areas in square kilometers by flood depth per barangay.

Table 28. Affected areas in Panukulan, Quezon during a 5-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Panukulan (in sq. km.)			
	Bonbon	Kinalagti	Lipata	Matangkap
0.03-0.20	3.36	0.45	35.88	2.5
0.21-0.50	0.09	0.01	1.13	0.058
0.51-1.00	0.053	0.0059	0.77	0.036
1.01-2.00	0.032	0.0033	0.77	0.031
2.01-5.00	0.026	0.0029	1.1	0.047
> 5.00	0.017	0	0.49	0.038

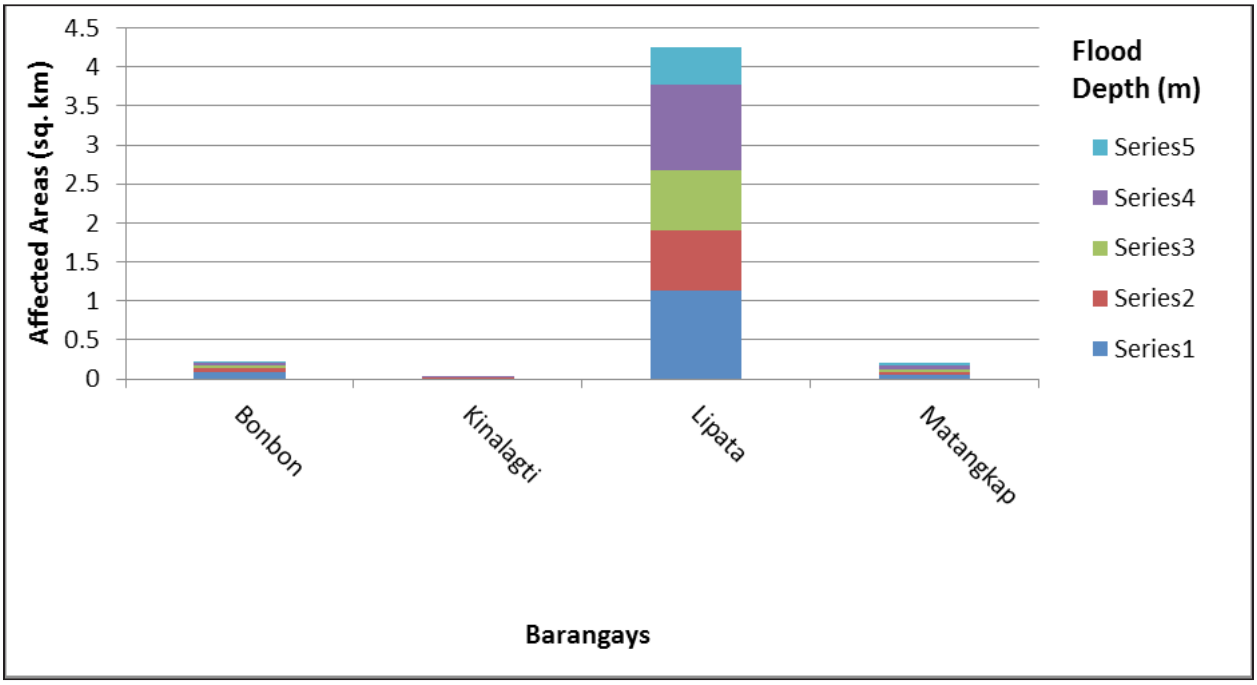


Figure 65. Affected areas in Panukulan, Quezon during a 5-Year Rainfall Return Period.

For the 25-year return period, 17.81% of the municipality of Burdeos with an area of 264.89 sq. km. will experience flood levels of less than 0.20 meters. 1.72% of the area will experience flood levels of 0.21 to 0.50 meters while 1.44%, 1.06%, 1.04%, and 1.38% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 29 and shown in Figure 66 are the affected areas in square kilometers by flood depth per barangay.

Table 29. Affected Areas in Burdeos, Quezon during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Burdeos (in sq. km.)					
	Aluyon	Anibawan	Bonifacio	Cabungalunan	Carlagan	Rizal
0.03-0.20	12.86	5.87	2.68	23.43	1.97	0.38
0.21-0.50	1.1	0.68	0.1	1.98	0.67	0.02
0.51-1.00	0.68	1.02	0.1	1.69	0.31	0.0068
1.01-2.00	0.31	0.31	0.23	1.87	0.088	0.0054
2.01-5.00	0.34	0.71	0.16	1.52	0.027	0.00039
> 5.00	0.55	0.52	0.097	2.49	0.0024	0

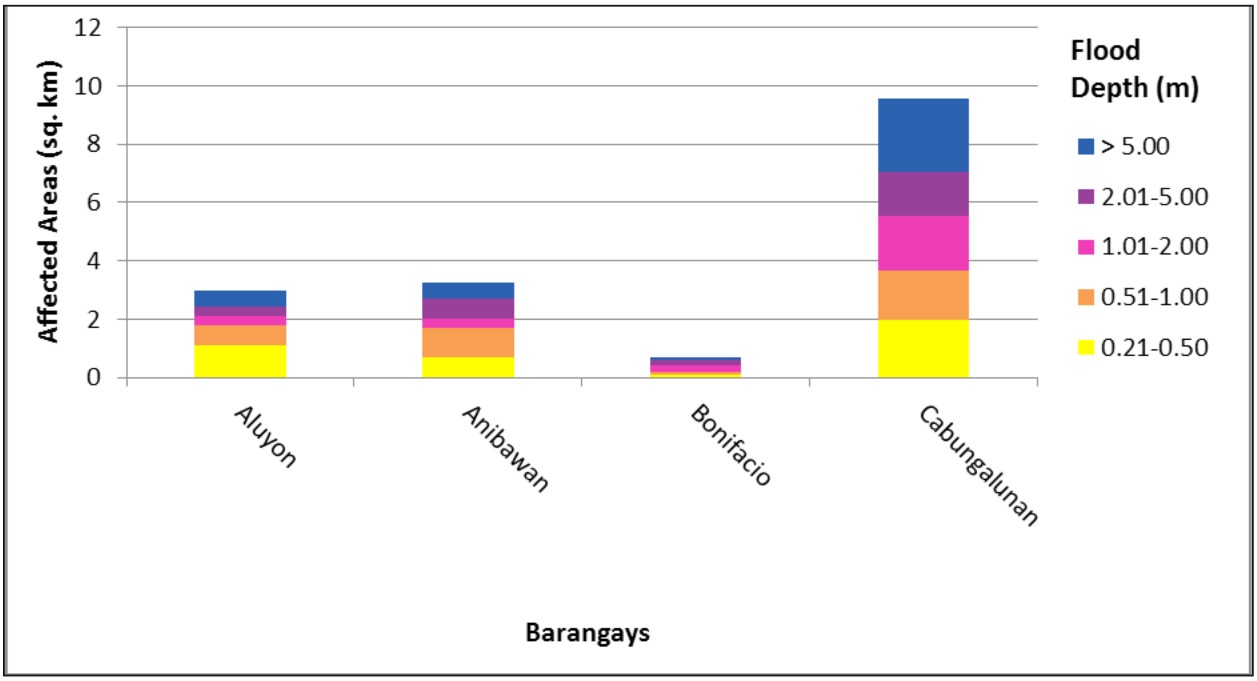


Figure 66. Affected Areas in Burdeos, Quezon during 25-Year Rainfall Return Period

For the 25-year return period, 15.33% of the municipality of Panukulan with an area of 179.58 sq. km. will experience flood levels of less than 0.20 meters. 0.61% of the area will experience flood levels of 0.21 to 0.50 meters while 0.39%, 0.37%, 0.56%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 30 and shown in Figure 67 are the affected areas in square kilometers by flood depth per barangay.

Table 30. Affected Areas in San Francisco, Quezon during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Panukulan (in sq. km.)			
	Bonbon	Kinalagti	Lipata	Matangkap
0.03-0.20	3.28	0.44	34.46	2.43
0.21-0.50	0.11	0.015	1.43	0.069
0.51-1.00	0.07	0.007	0.91	0.049
1.01-2.00	0.046	0.0049	0.89	0.037
2.01-5.00	0.042	0.0051	1.4	0.047
> 5.00	0.034	0.0002	1.06	0.081

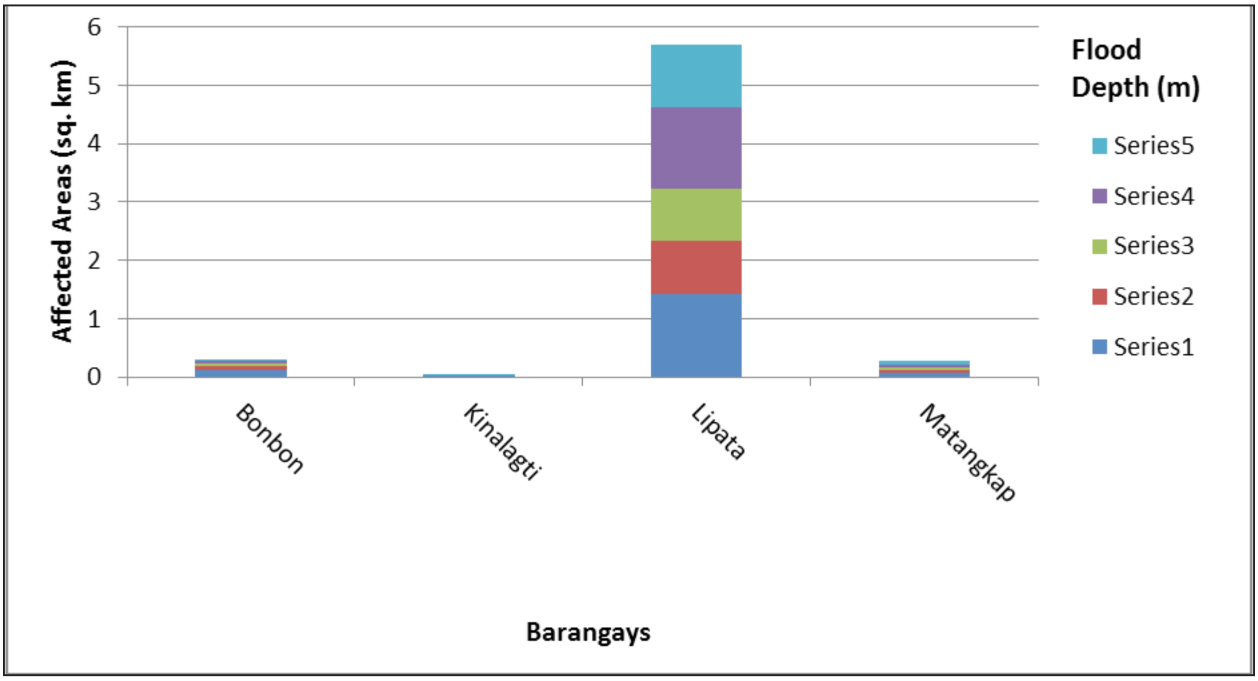


Figure 67. Affected Areas in San Francisco, Quezon during 25-Year Rainfall Return Period

For the 100-year return period, 17.20% of the municipality of Burdeos with an area of 264.89 sq. km. will experience flood levels of less than 0.20 meters. 1.70% of the area will experience flood levels of 0.21 to 0.50 meters while 1.58%, 1.14%, 1.11%, and 1.71% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 31 and shown in Figure 68 are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Burdeos, Quezon during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Burdeos (in sq. km.)					
	Aluyon	Anibawan	Bonifacio	Cabungalunan	Carlagan	Rizal
0.03-0.20	12.86	5.87	2.68	23.43	1.97	0.38
0.21-0.50	1.1	0.68	0.1	1.98	0.67	0.02
0.51-1.00	0.68	1.02	0.1	1.69	0.31	0.0068
1.01-2.00	0.31	0.31	0.23	1.87	0.088	0.0054
2.01-5.00	0.34	0.71	0.16	1.52	0.027	0.00039
> 5.00	0.55	0.52	0.097	2.49	0.0024	0

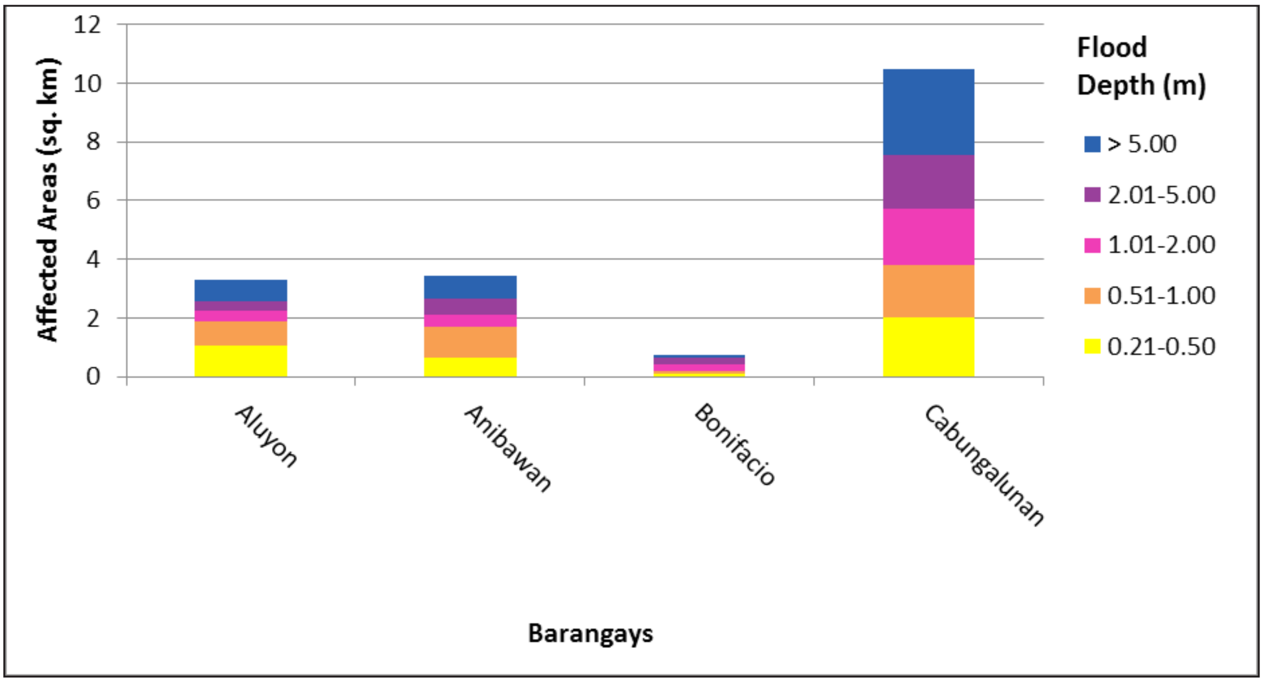


Figure 68. Affected Areas in Burdeos, Quezon during 100-Year Rainfall Return Period

For the 100-year return period, 15.02% of the municipality of Panukulan with an area of 179.58 sq. km. will experience flood levels of less than 0.20 meters. 0.68% of the area will experience flood levels of 0.21 to 0.50 meters while 0.42%, 0.39%, 0.59%, and 0.60% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 32 and shown in Figure 69 are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Panukulan, Quezon during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Panukulan (in sq. km.)			
	Bonbon	Kinalagti	Lipata	Matangkap
0.03-0.20	3.28	0.44	34.46	2.43
0.21-0.50	0.11	0.015	1.43	0.069
0.51-1.00	0.07	0.007	0.91	0.049
1.01-2.00	0.046	0.0049	0.89	0.037
2.01-5.00	0.042	0.0051	1.4	0.047
> 5.00	0.034	0.0002	1.06	0.081

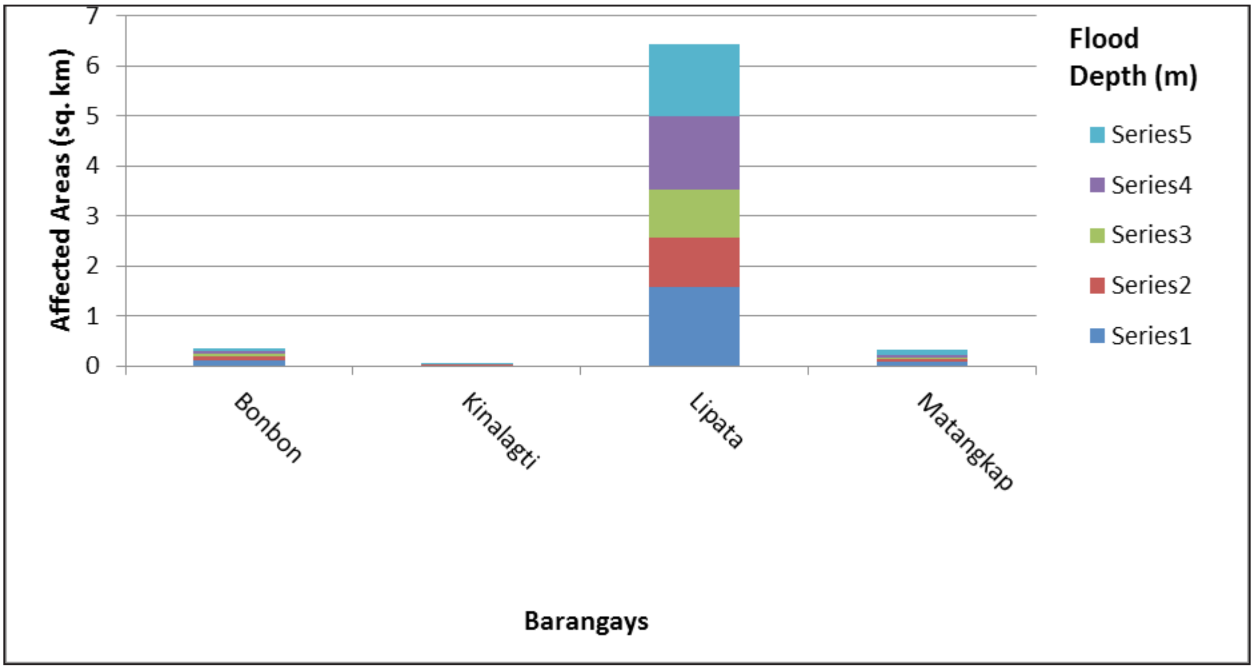


Figure 69. Affected Areas in Panukulan, Quezon during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Anibawan Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps ("Low", "Medium", and "High"), the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-year, 25-year, and 10-year).

Table 33. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	5.56	6.15	6.26
Medium	5.59	7.015	7.59
High	7.81	11.037	12.85
TOTAL	**18.95**	**24.20**	**26.69**

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office, obtaining maps or situation reports about the past flooding events and through interview with some residents who have knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 71.

The flood validation consisted of 180 points randomly selected all over the Anibawan floodplain (Figure 70). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 2.091m. Table 34 shows a contingency matrix of the comparison.

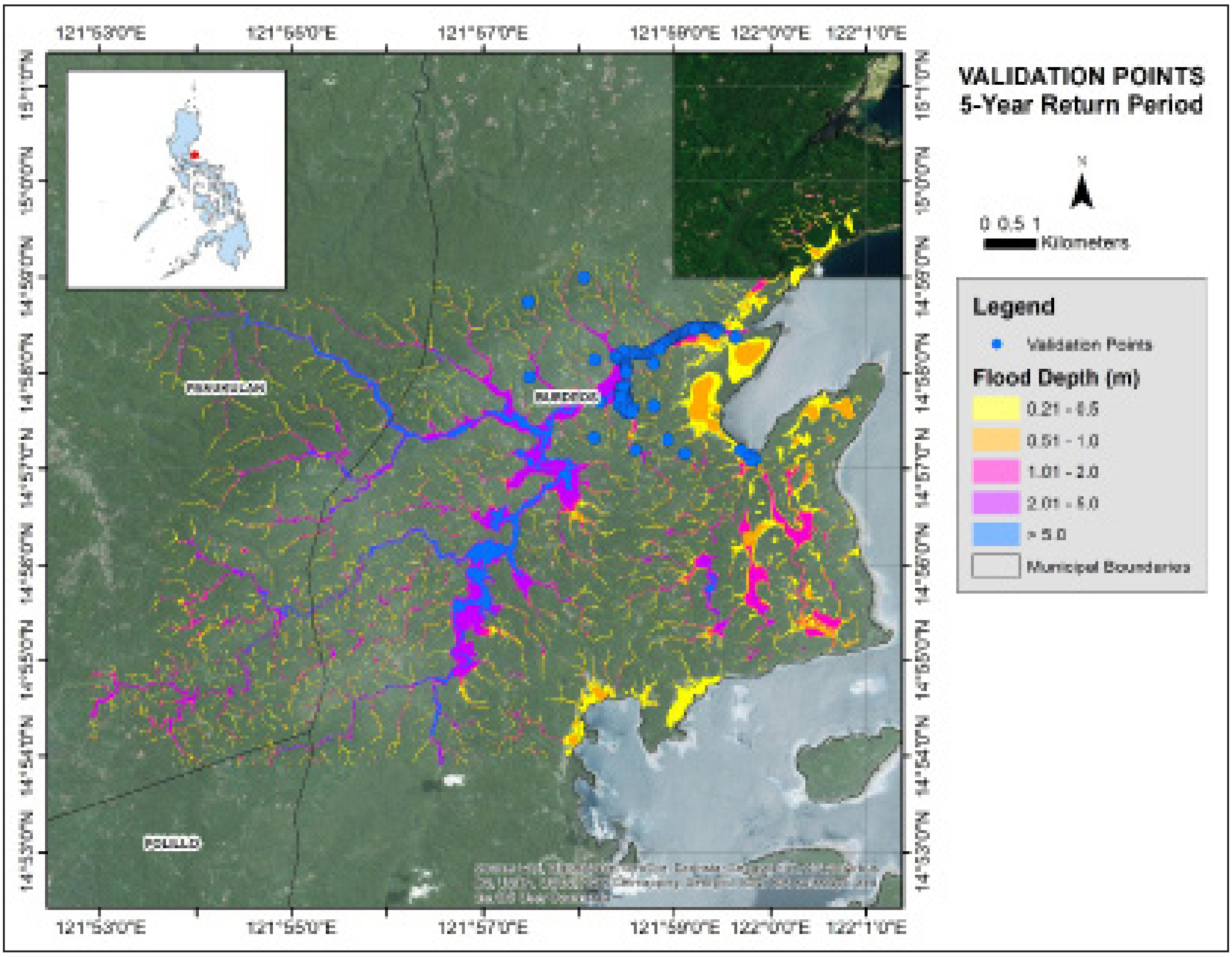


Figure 70. Validation points for 5-year Flood Depth Map of Anibawan Floodplain

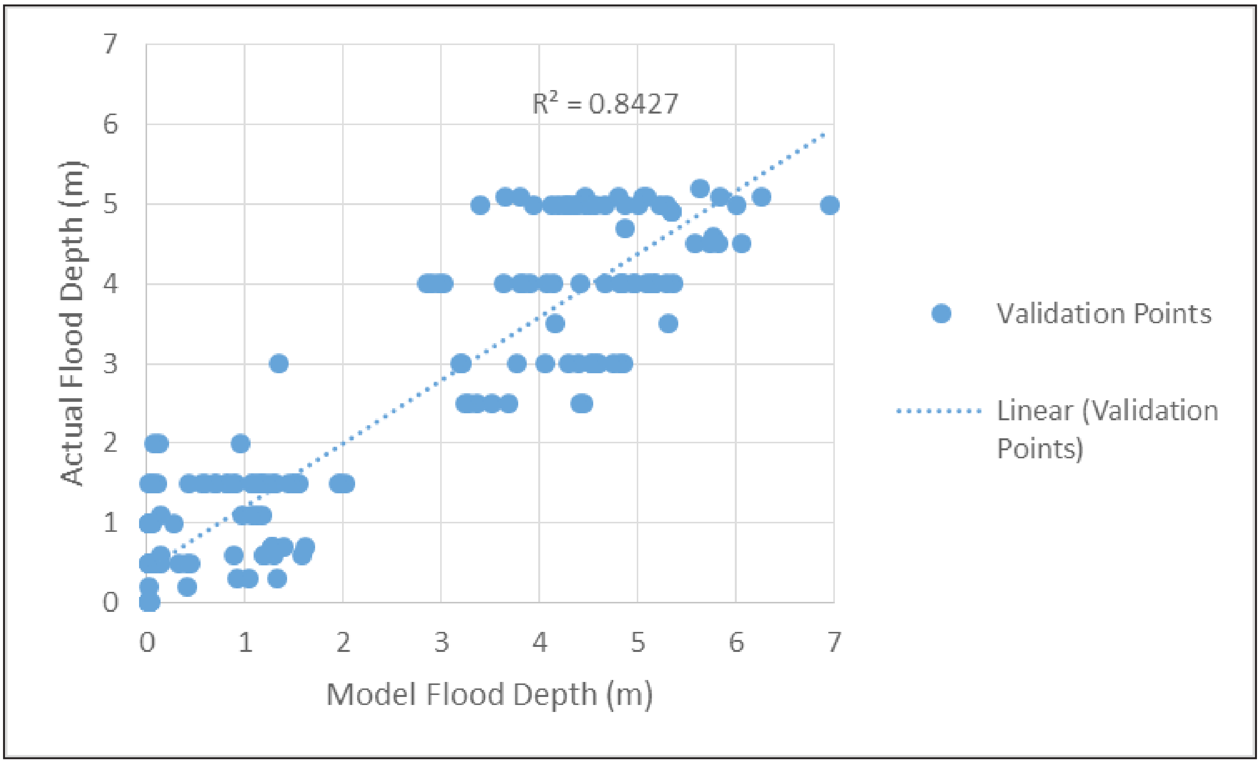


Figure 71. Flood map depth vs. actual flood depth

Table 34. Actual flood vs simulated flood depth at different levels in the Anibawan 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	10	1	0	14	14	0	39
0.21-0.50	1	0	0	0	13	0	14
0.51-1.00	0	0	0	0	15	1	16
1.01-2.00	3	1	1	2	11	1	19
2.01-5.00	1	0	1	6	34	48	90
> 5.00	0	0	0	0	1	1	2
Total	15	2	2	22	88	51	180

The overall accuracy generated by the flood model is estimated at 26.11% with 47 points correctly matching the actual flood depths. In addition, there were 69 points estimated one level above and below the correct flood depths while there were 18 points and 46 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 15 points were underestimated in the modelled flood depths of Anibawan. Table 35 depicts the summary of the Accuracy Assessment in the Anibawan River Basin Survey.

Table 35. Summary of the Accuracy Assessment in the Anibawan River Basin Survey

	No. of Points	%
Correct	47	26.11
Overestimated	118	65.56
Underestimated	15	8.33
Total	180	100.00

REFERENCES

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

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

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

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

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

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

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

Annex 1. Optech Technical Specification of the Pegasus Sensor

1. PEGASUS SENSOR

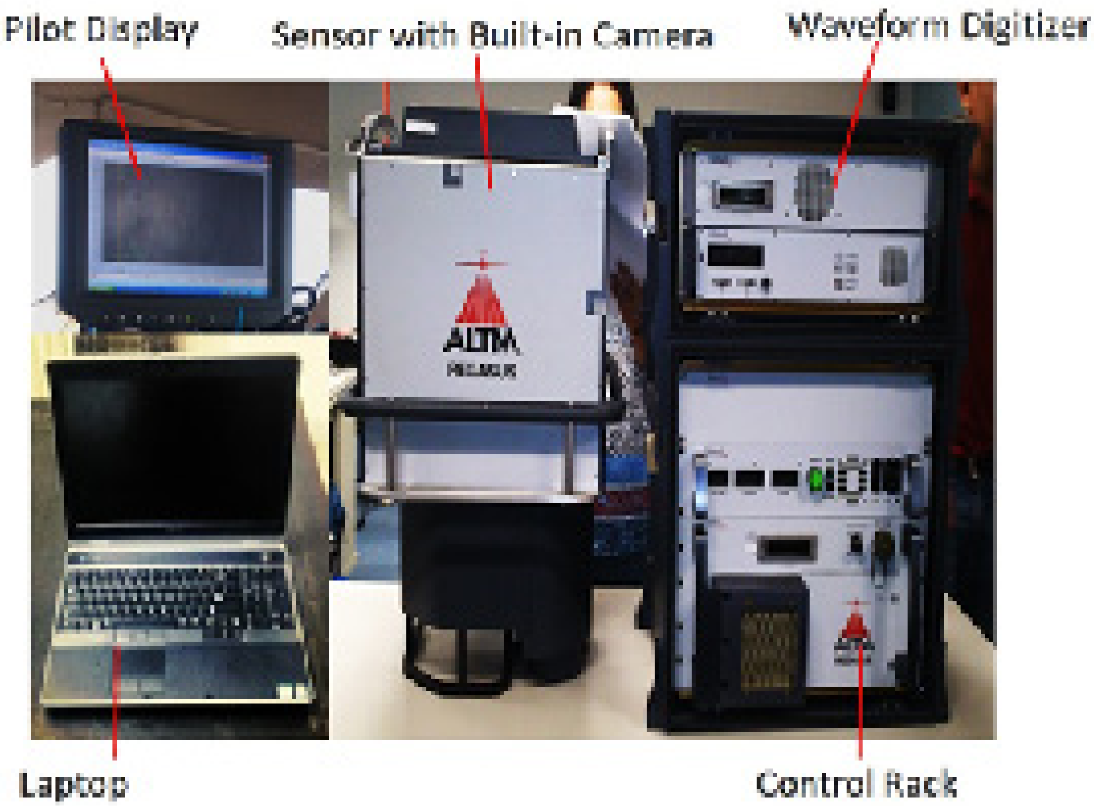


Figure A-1.1 Pegasus Sensor

2. PARAMETERS AND SPECIFICATIONS OF THE PEGASUS SENSOR

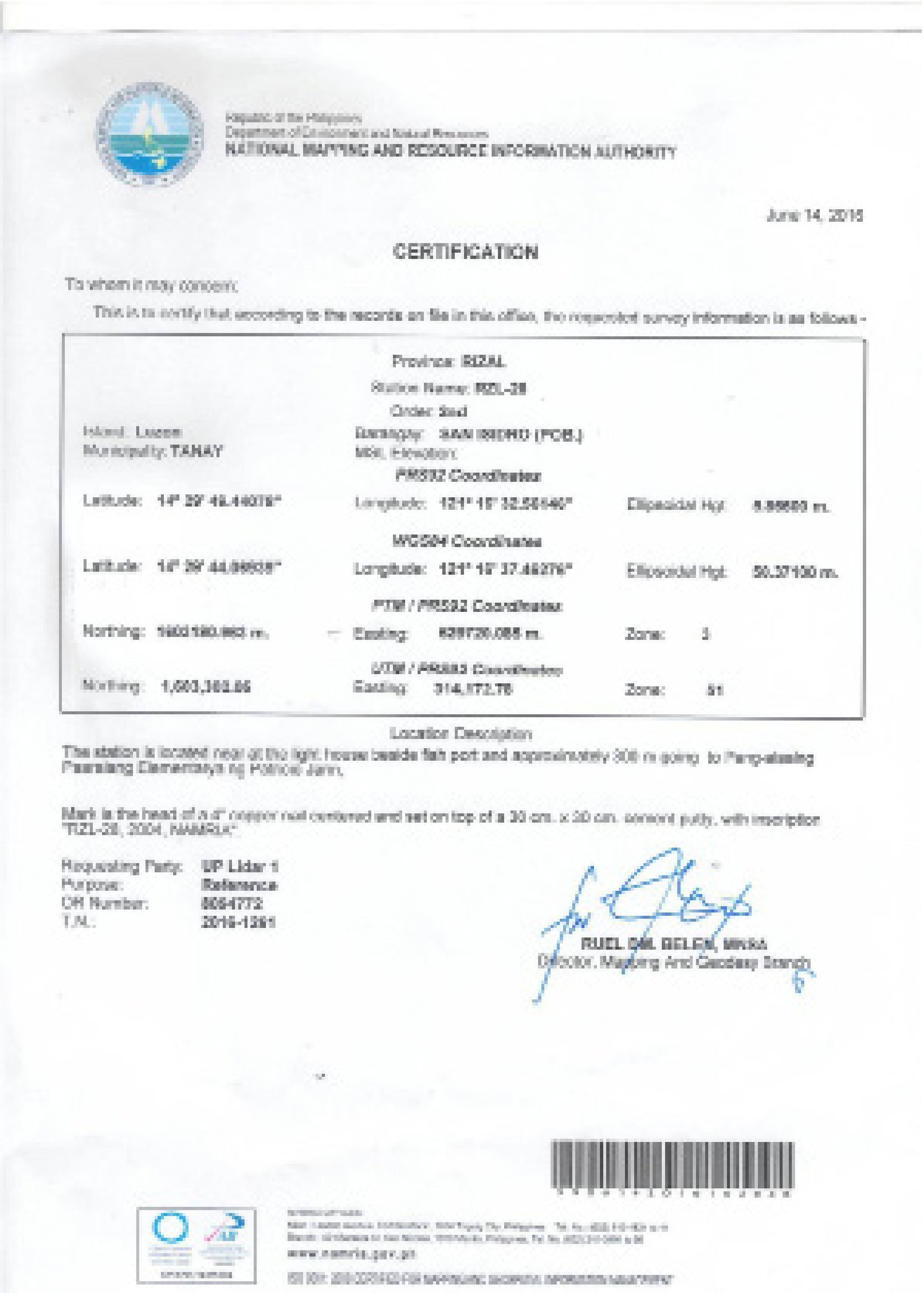
Table A-1.1 Parameters and Specifications of the Pegasus Sensor

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

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. RZL-28



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

June 14, 2016

CERTIFICATION

To whom it may concern:

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

Province: RIZAL

Station Name: RZL-28

Order: 2nd

Island: Luzon
Municipality: TANAY

Barangay: SAN ISIDRO (POB.)
MSL Elevation:

PRS92 Coordinates

Latitude: 14° 29' 49.44078" Longitude: 121° 15' 32.58540" Ellipsoidal Hgt: 5.85500 m.

WGS84 Coordinates

Latitude: 14° 29' 44.86808" Longitude: 121° 15' 37.46276" Ellipsoidal Hgt: 50.37100 m.

PTM / PRS92 Coordinates

Northing: 1603180.860 m. Easting: 528720.085 m. Zone: 3

UTM / PRS92 Coordinates

Northing: 1,603,382.86 Easting: 314,172.78 Zone: 51

Location Description

The station is located near at the light house beside fish port and approximately 300 m going to Pang-alaalang Paaralang Elementarya ng Pililla Jarm.

Mark is the head of a 4" copper nail centered and set on top of a 30 cm. x 30 cm. cement putty, with inscription "RZL-28, 2004, NAMRIA".

Requesting Party: UP Lidar 1
Purpose: Reference
OR Number: 8094772
T.N.: 2016-1261

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

www.namria.gov.ph

Figure A-2.1 RZL-28

Annex 3. Baseline Processing Report of Reference Points Used

BRS-1 - RZL-28 (9 25:08 AM-5:15:34 PM) (S1)

Baseline observation:	BRS-1 --- RZL-28 (B1)
Processed:	6/23/2016 11 42 55 AM
Solution type	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision	0.018 m
RMS:	0.006 m
Maximum PDOP:	4.149
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	6/10/2016 9 25 08 AM (Local UTC+8hr)
Processing stop time:	6/10/2016 5 15 34 PM (Local UTC+8hr)
Processing duration:	07 50 26
Processing interval:	1 second

Vector Components (Mark to Mark)

From	RZL-28				
Grid		Local		Global	
Easting	314172.786 m	Latitude	N14°29'49.44078"	Latitude	N14°29'44.06939"
Northing	1603302.052 m	Longitude	E121°16'32.56145"	Longitude	E121°16'37.46276"
Elevation	4.971 m	Height	5.866 m	Height	50.371 m

To:	BRS-1				
Grid		Local		Global	
Easting	312646.981 m	Latitude	N14°31'32.82507"	Latitude	N14°31'27.44582"
Northing	1606491.077 m	Longitude	E121°15'40.79958"	Longitude	E121°15'45.69850"
Elevation	14.362 m	Height	15.361 m	Height	59.750 m

Vector					
ΔEasting	-1525.805 m	NS Fwd Azimuth	333°59'56"	ΔX	1733.279 m
ΔNorthing	3189.025 m	Ellipsoid Dist.	3535.137 m	ΔY	131.879 m
ΔElevation	9.391 m	ΔHeight	9.496 m	ΔZ	3078.254 m

Figure A-3.1 Baseline Processing Report - A

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA	UP TCAGP
	Research Associate (RA)	ENGR. GRACE SINADJAN	UP TCAGP
	RA	JASMIN DOMINGO	UP TCAGP
Ground Survey, Data Download and Transfer	RA	KRISTINE JOY ANDAYA	UP TCAGP
		FRANK NICOLAS ILEJAY	UP TCAGP
LiDAR Operation	Airborne Security	TSG. CEBU	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORP (AAC)
		CAPT. CAESAR ALFONSO II	AAC
		CAPT. DANTHONY LOGRONIO	AAC
		CAPT. CEDRIC DE ASIS	AAC

Annex 5. Data Transfer Sheet For Anibawan Floodplain

DATA TRANSFER SHEET
CALABARZON 7/13/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	Gnsslmu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S)		SERVER LOCATION
													BASE STATION(S)	Base Info (.txt)	
13-Jun-16	10161L	4BLK18CF 165A	ALS 80	NA	352	134	79.7	4.65	3.89	NA	145	22	649	1KB	Z:\DAC\RAW DATA
13-Jun-16	10162L	4BLK18CF S165B	ALS 80	NA	353	96.5	21.5	8.99	7.55	NA	262	39.5	649	1KB	Z:\DAC\RAW DATA
15-Jun-16	10165L	4BLK18RN 167A	ALS 80	NA	472	130	43.8	12.7	7.2	NA	285	28.7	653	1KB	Z:\DAC\RAW DATA
15-Jun-16	10166L	4BLK18CF 167B	ALS 80	NA	251	102	124	3.42	2.66	NA	79.3	NA	653	1KB	Z:\DAC\RAW DATA
16-Jun-16	10167L	4BLK18R MNS168A	ALS 80	NA	454	134	44	13.8	8.88	NA	320	36.9	316	1KB	Z:\DAC\RAW DATA

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
June 16, 2016	23462P	1BLK18CF S168A	PEGASUS	2.76	NA	10.4	225	NA	NA	25.7	NA	316	1KB	1KB	359/364/268/464/201/203	NA	Z:\DAC\RAW DATA
June 22, 2016	23474P	1BLK18Q1 73A	PEGASUS	1.22	NA	8.87	200	NA	NA	12.7	NA	468	1KB	1KB	268/464/201/203	NA	Z:\DAC\RAW DATA

Received from

Name: R. PANTO
Position: RA
Signature: [signature]

Received by

Name: AC Bongat
Position: SSRS
Signature: [signature] 7/14/16

Figure A-5.1. Data Transfer Sheet for Anibawan Floodplain

Annex 6. Flight Logs

1. Flight Log for 23474P Mission

DREAM Program's Data Acquisition Flight Log — **Flight Log No.:** 23474

1 LIDAR Operator: G. SINADJAN	2 ALTM Model: ALS 80	3 Mission Name: 1BLK18Q0S173A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. TANGONAN	8 Co-Pilot: D. LOGRONIO	9 Route:			
10 Date: June 21, 2016	12 Airport of Departure (Airport, City/Province): RPLL		12 Airport of Arrival (Airport, City/Province): RPLL		
13 Engine On: 0650	14 Engine Off: 1007	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed floodplains in Real, Quezon

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ________________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[signature]	TSg Celebre PAF	M.C. TANGONAN	G. SINADJAN	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for 23474P Mission

Annex 7. Flight Status

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
CALABARZON
(June 22, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23474P	BLK18Q	1BLK18Q173A	G. SINADJAN J. DOMINGO	21 June 2016	Covered 14 lines over Real, Quezon

LAS BOUNDARIES PER FLIGHT

Flight No.:	23474P	
Area:	BLK18Q	
Mission Name:	1BLK18Q173A	
Parameters:	Altitude: 1200 m;	Scan Freq: 32 Hz;
	Scan Angle: 25 deg;	Overlap: 60%

LAS

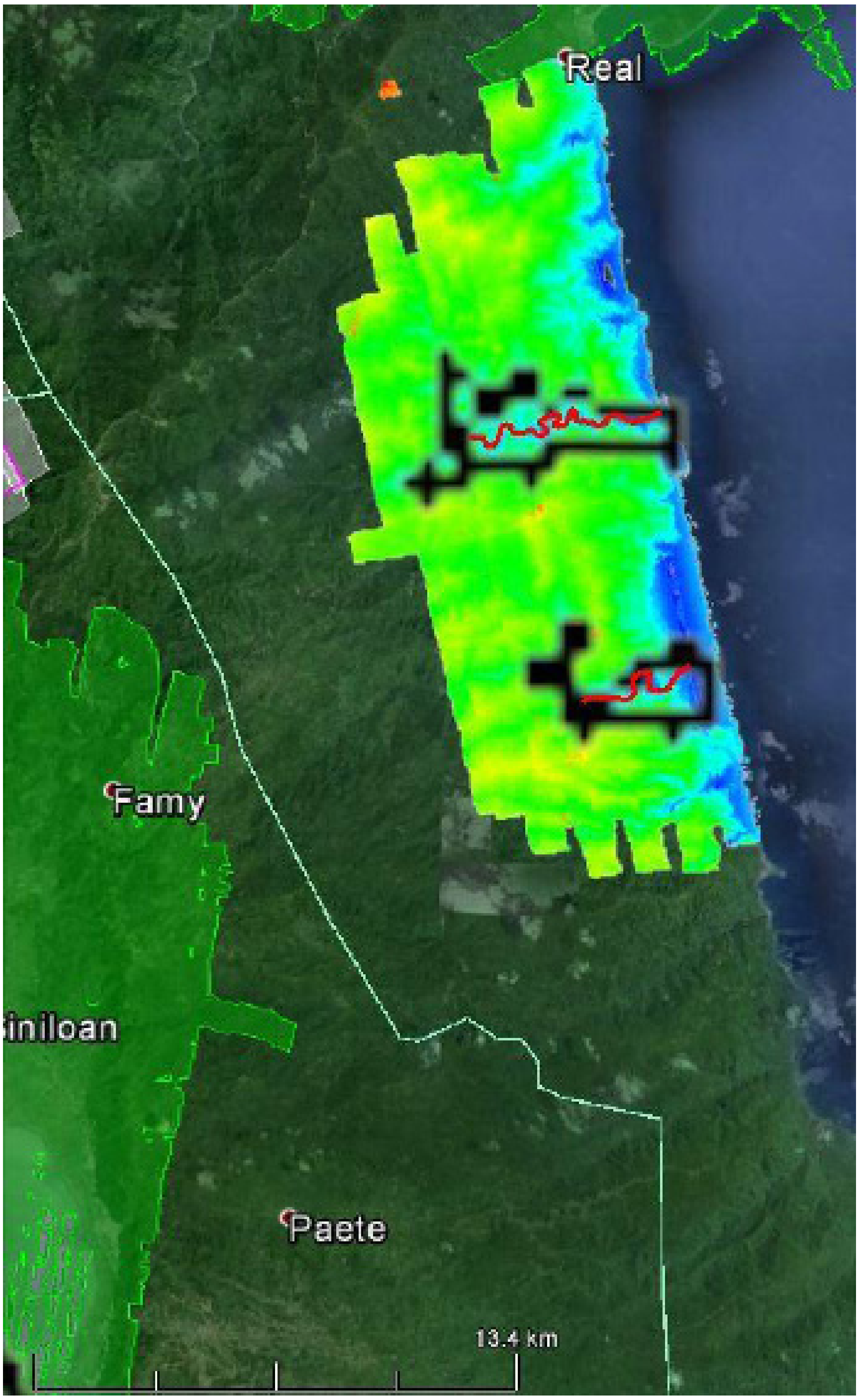


Figure A-7.1. Swath Coverage of Flight No. 23474P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Calabarzon_Reflights_Blk18Q

Flight Area	Davao Oriental
Mission Name	Calabarzon_Reflights_Blk18Q
Inclusive Flights	23474P
Range data size	12.7 GB
POS data size	200 MB
Base data size	468 MB
Image	n/a
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000335
IMU attitude correction stdev (<0.001deg)	0.001170
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	42.49%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	189
Maximum Height	590.20
Minimum Height	47.79
Classification (# of points)	
Ground	41,354,472
Low vegetation	12,086,308
Medium vegetation	90,563,722
High vegetation	527,379,966
Building	10,983,102
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Czarina

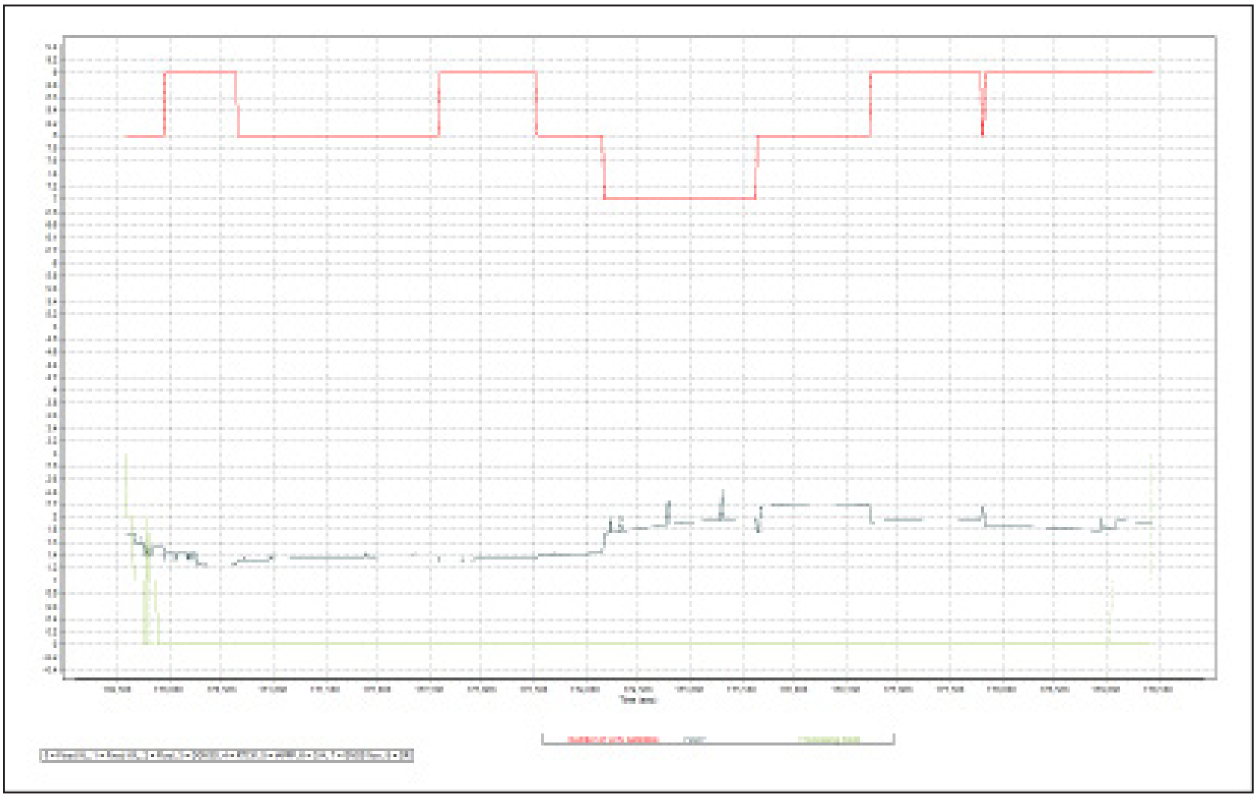


Figure A-8.1. Solution Status

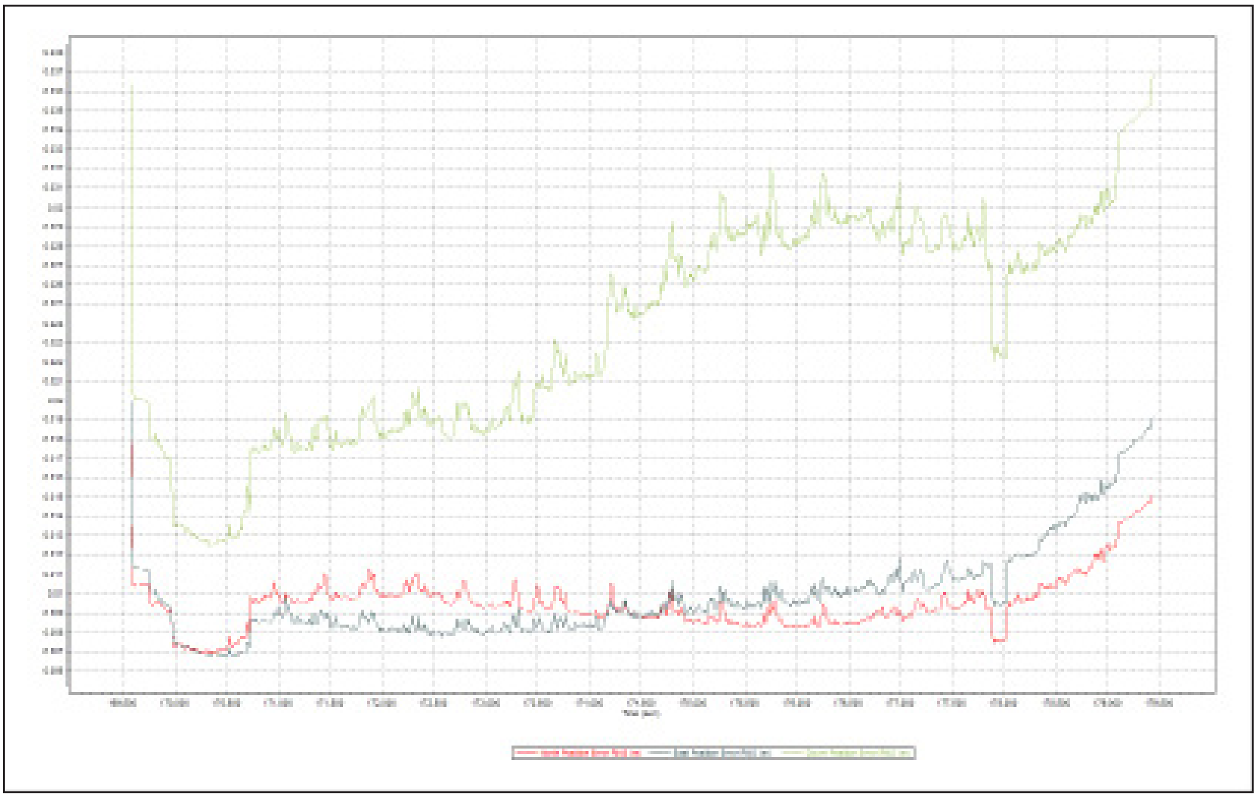


Figure A-8.2. Smoothed Performance Metric Parameters

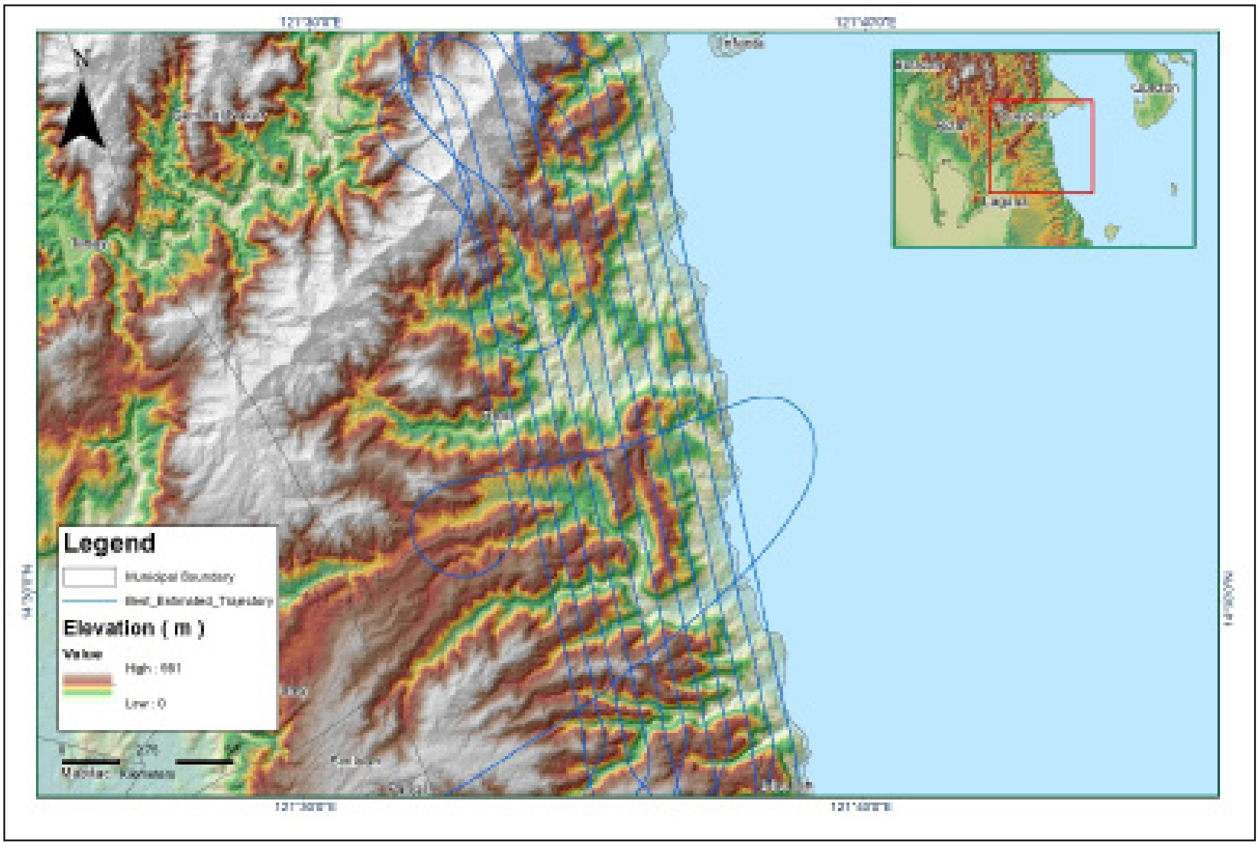


Figure A-8.3. Best Estimated Trajectory

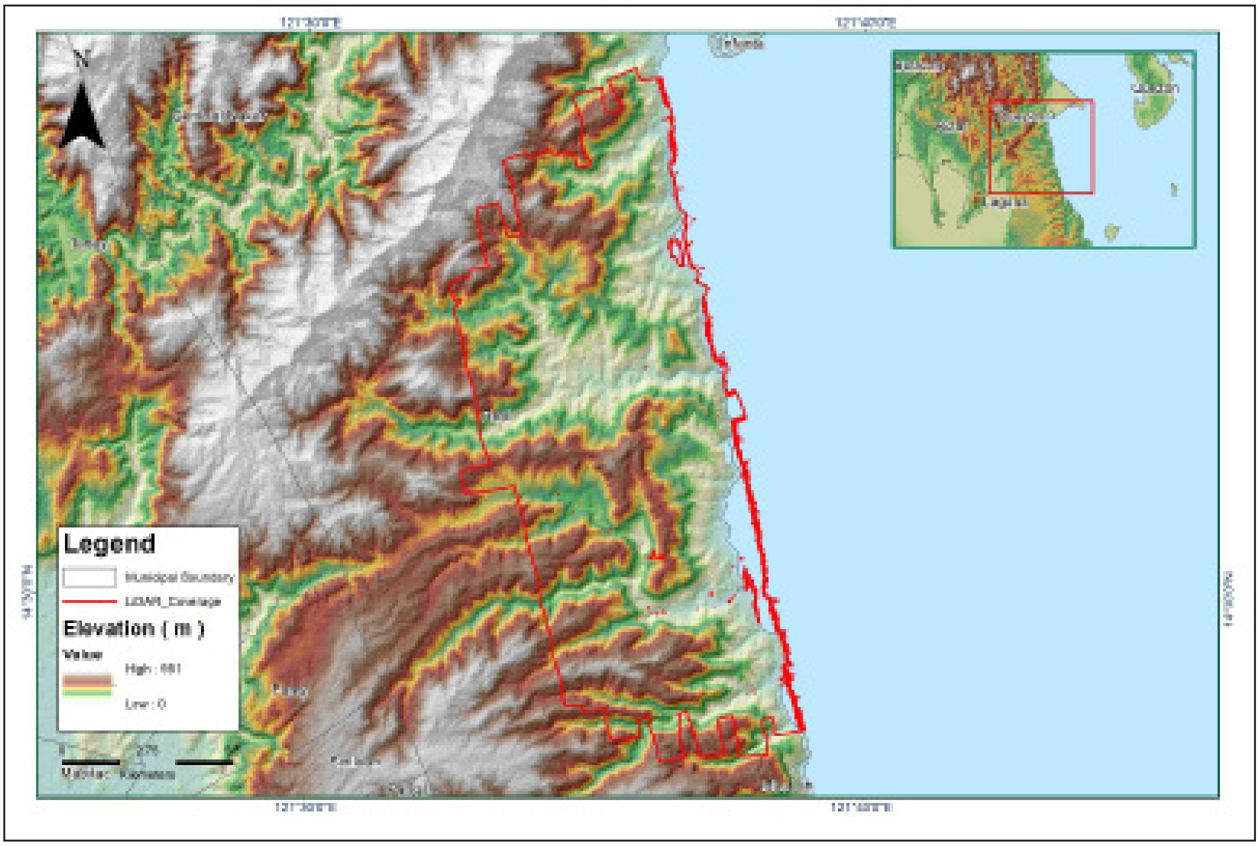


Figure A-8.4. Coverage of LiDAR data

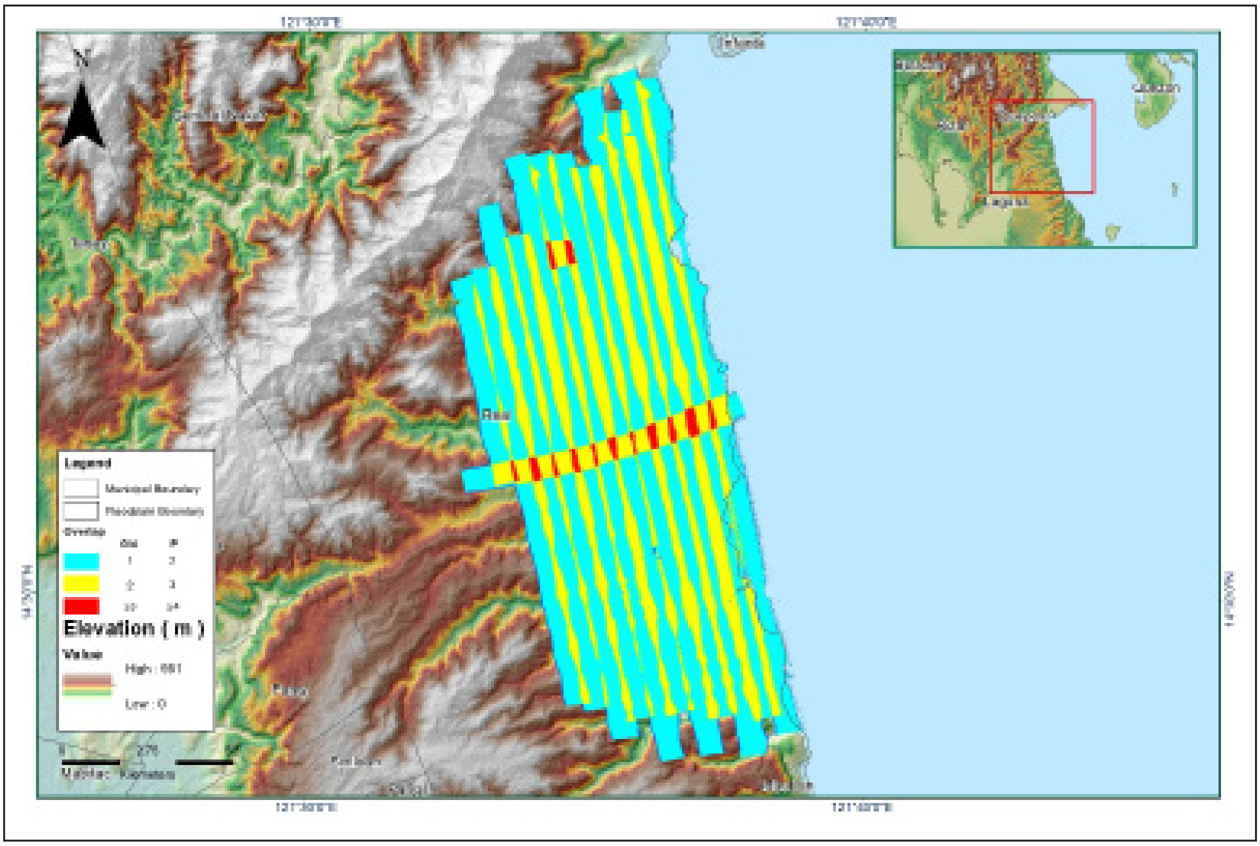


Figure A-8.5. Image of data overlap

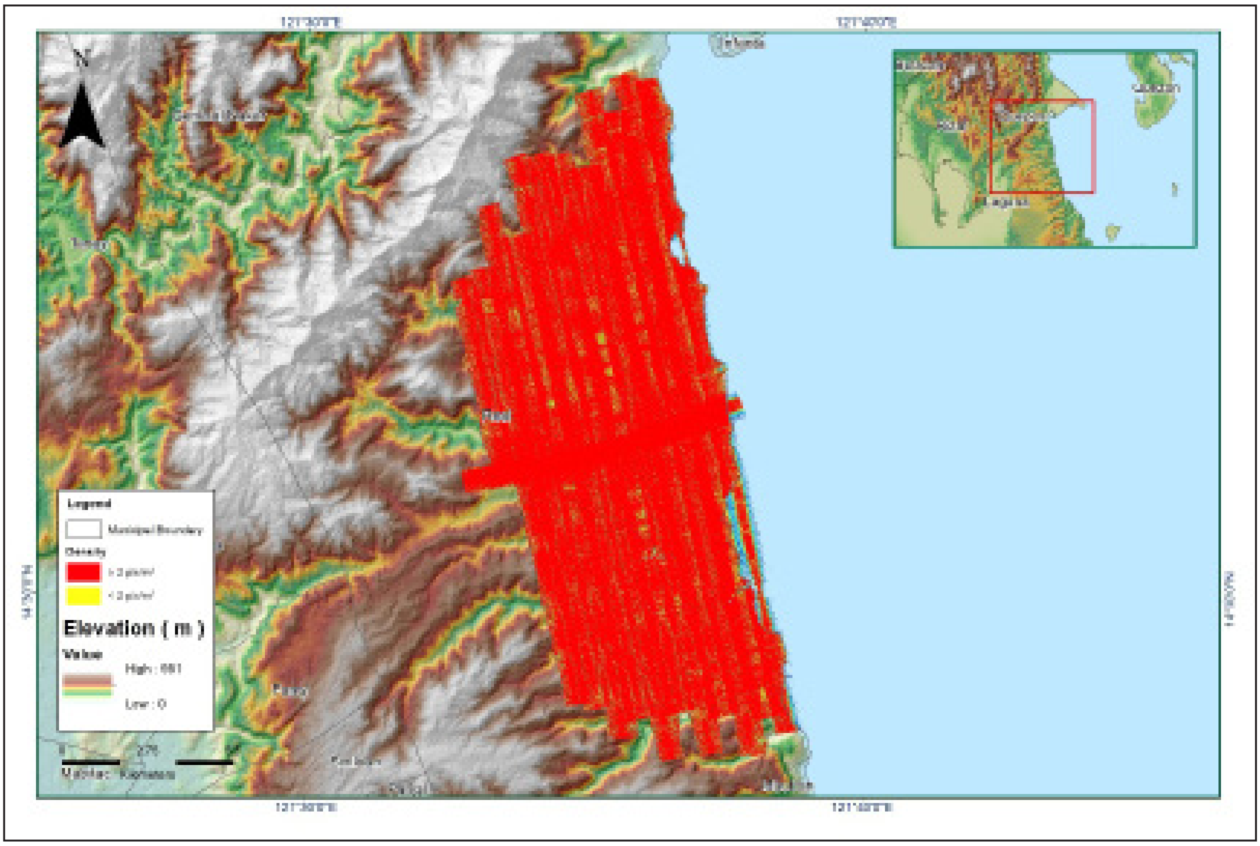


Figure A-8.6. Density map of merged LiDAR data

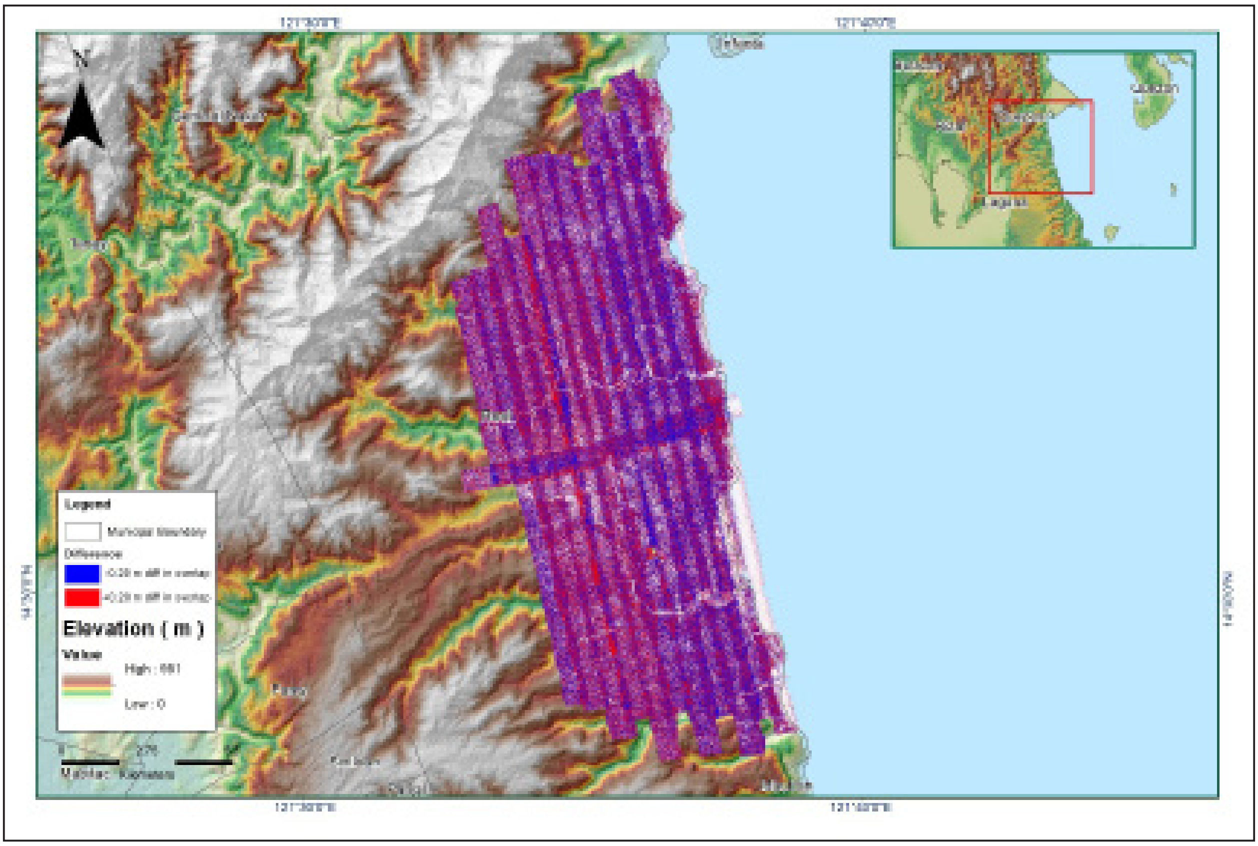


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Calabarzon_Reflights_Blk18Q_Supplement

Flight Area	Davao Oriental
Mission Name	Calabarzon_Reflights_Blk18Q_ Supplement
Inclusive Flights	23474P
Range data size	12.7 GB
POS data size	200 MB
Base data size	468 MB
Image	n/a
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000335
IMU attitude correction stdev (<0.001deg)	0.001170
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	55.48%
Ave point cloud density per sq.m. (>2.0)	2.50
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	26
Maximum Height	350.18 m
Minimum Height	47.79 m
Classification (# of points)	
Ground	5,436,252
Low vegetation	1,865,835
Medium vegetation	7,144,399
High vegetation	33,665,181
Building	895,541
Orthophoto	No
Processed by	

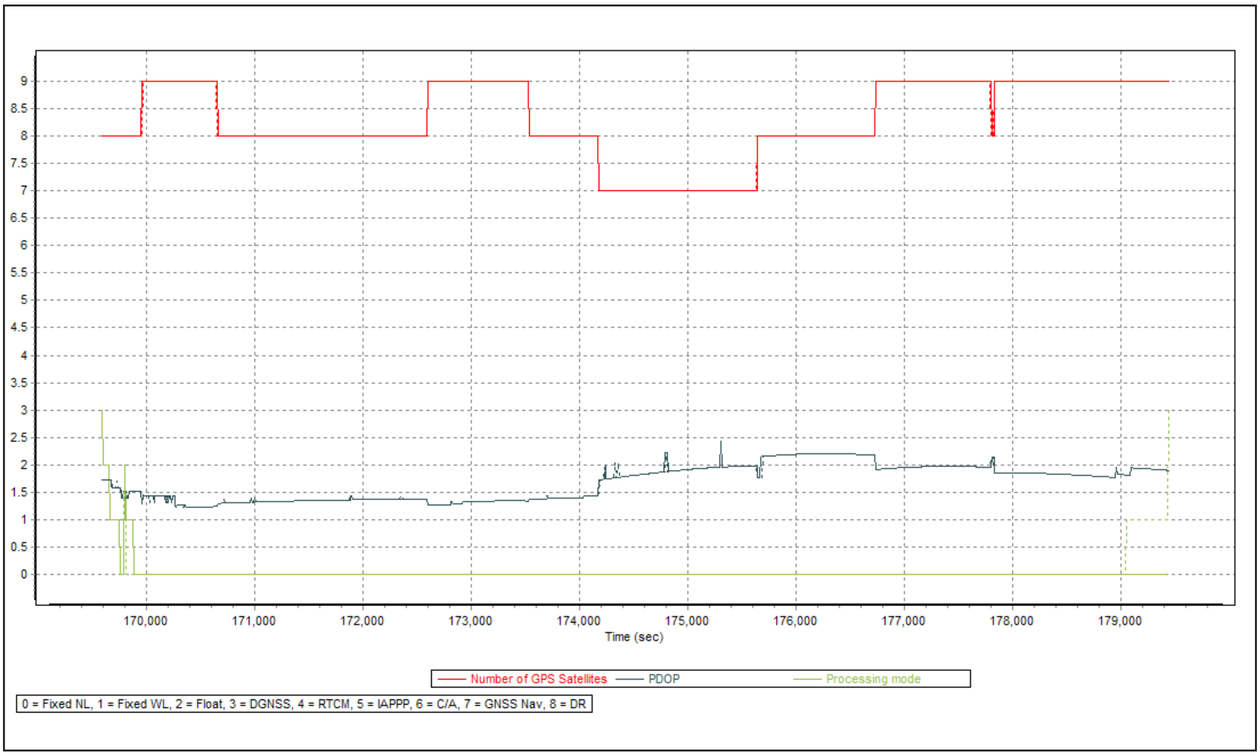


Figure A-8.8. Solution Status

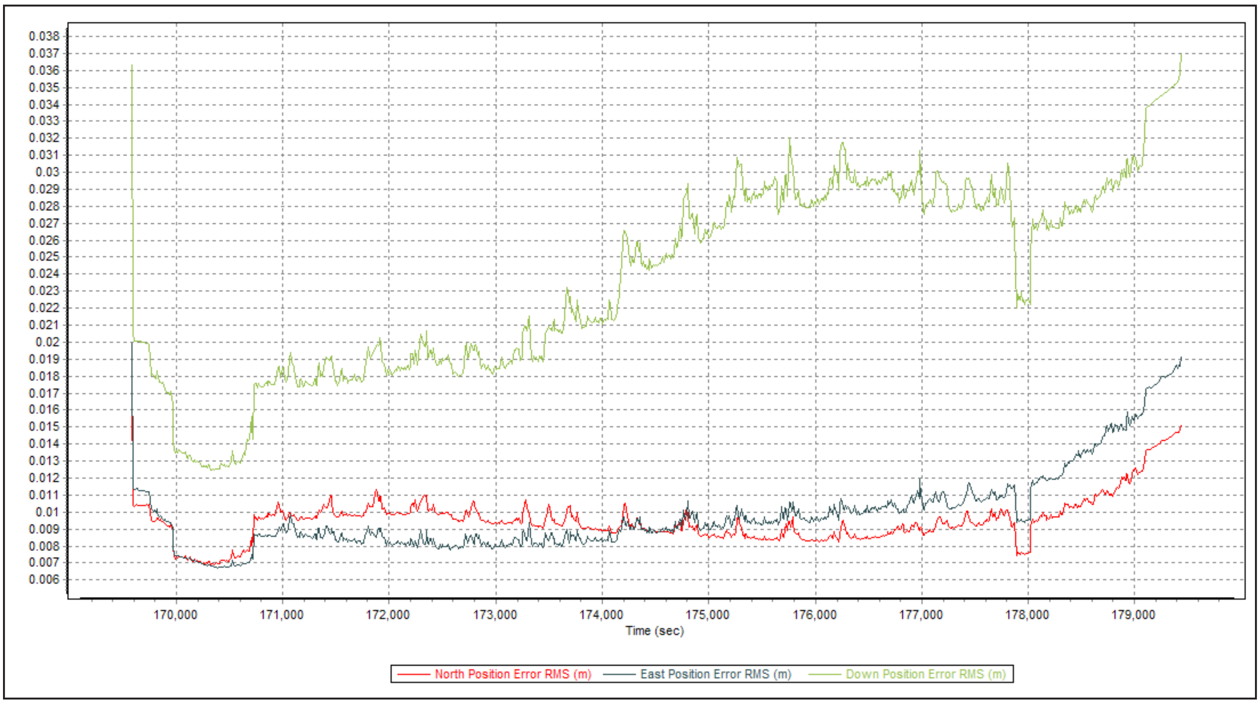


Figure A-8.9. Smoothed Performance Metric Parameters

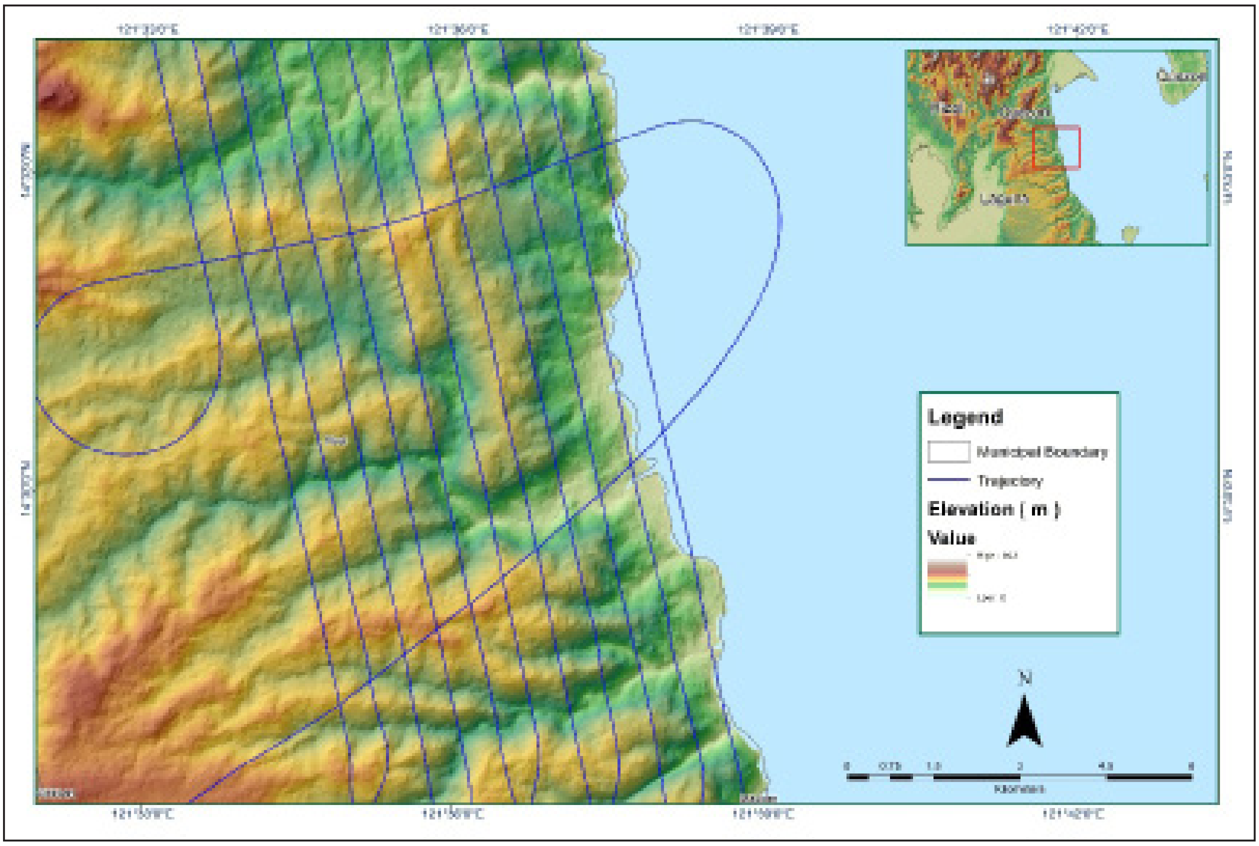


Figure A-8.10. Best Estimated Trajectory

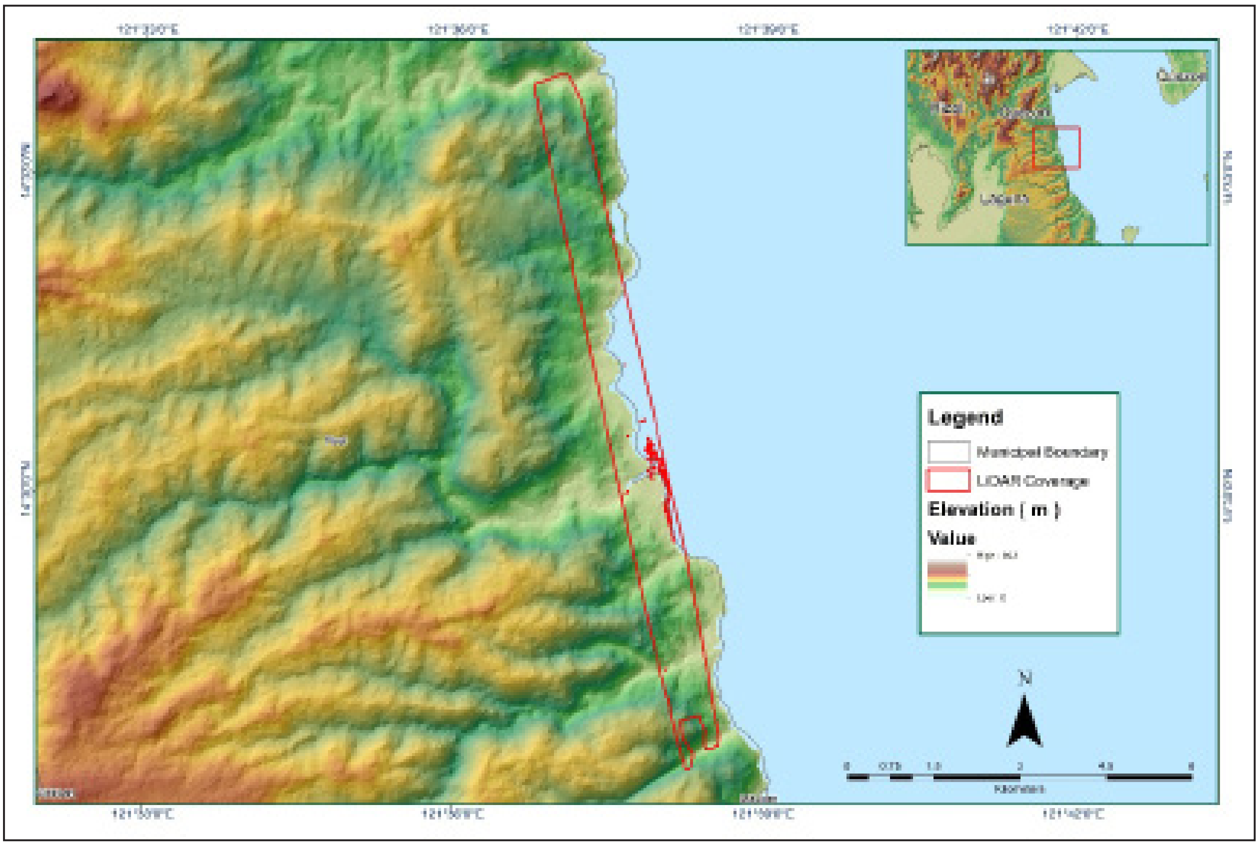


Figure A-8.11. Coverage of LiDAR data

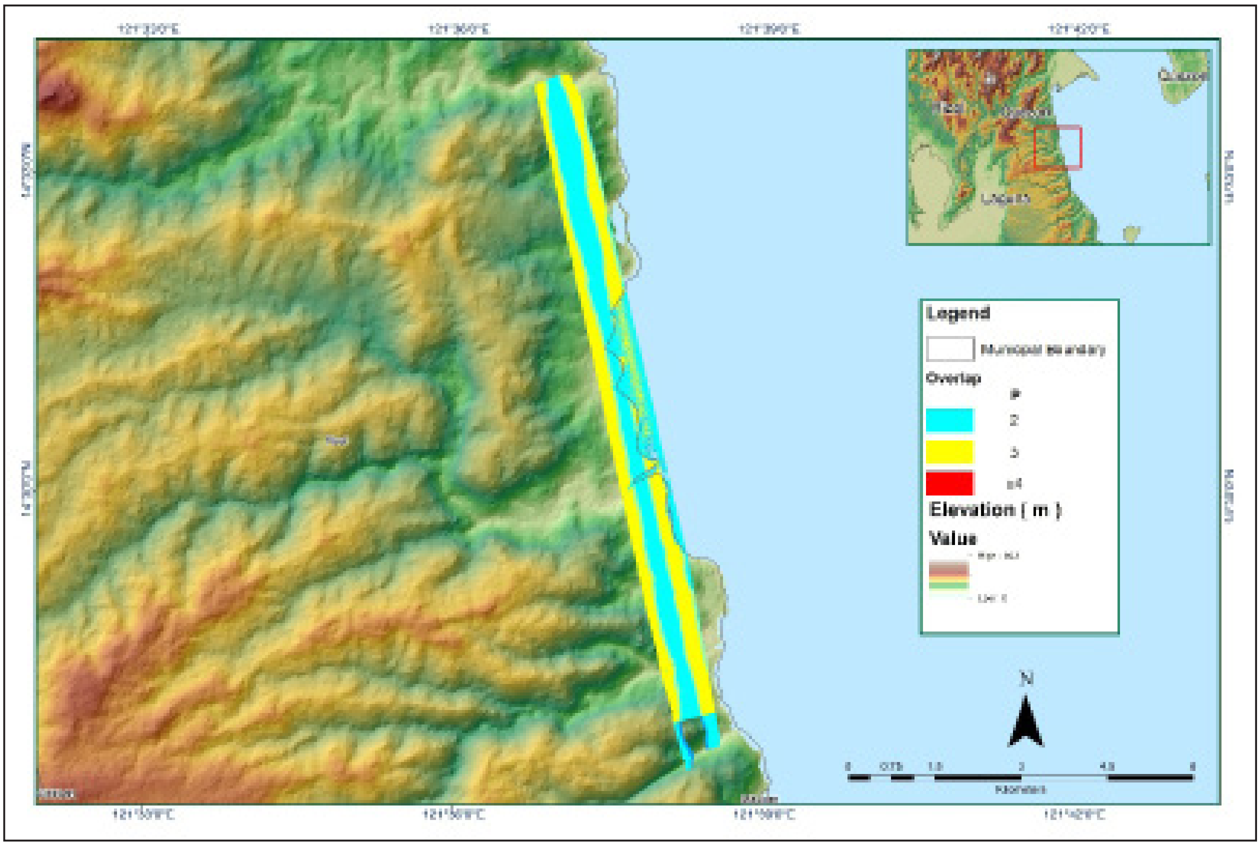


Figure A-8.12. Image of data overlap

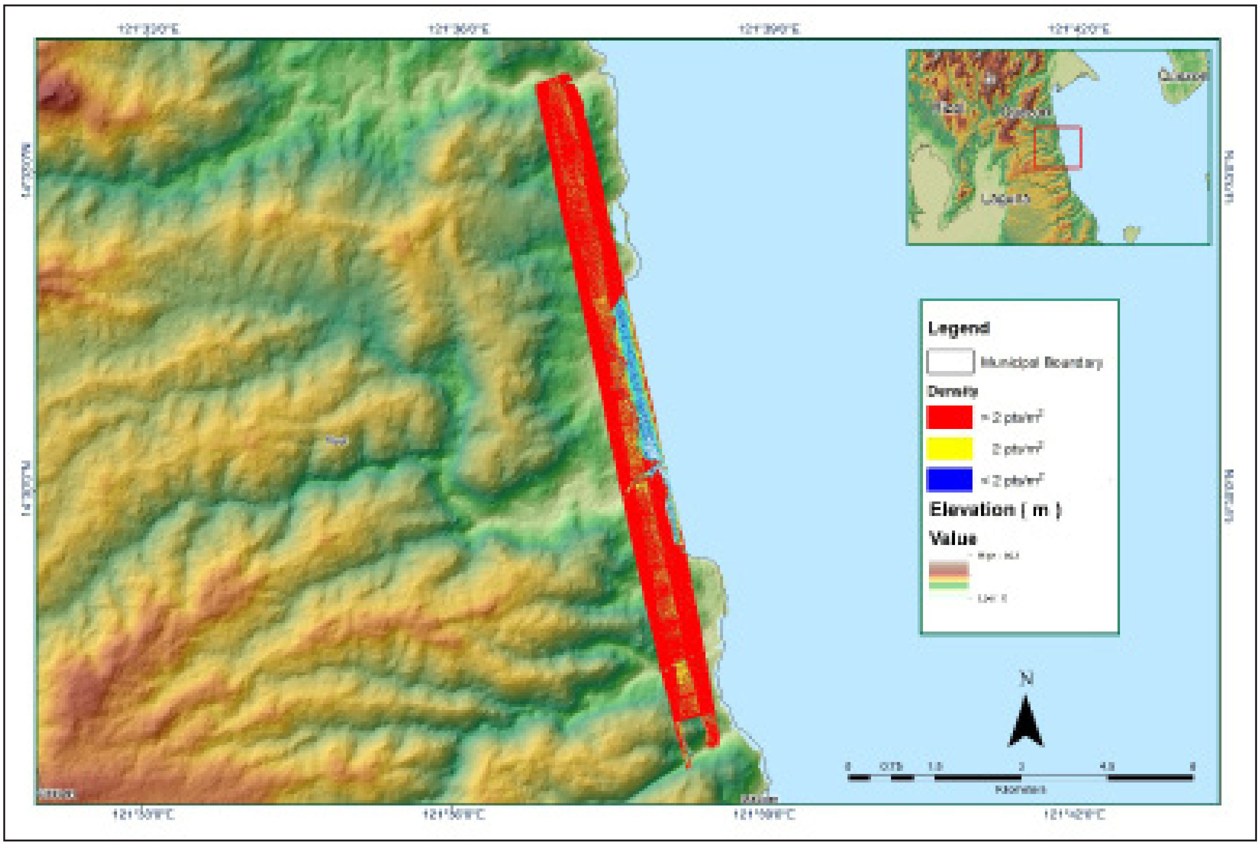


Figure A-8.13. Density map of merged LiDAR data

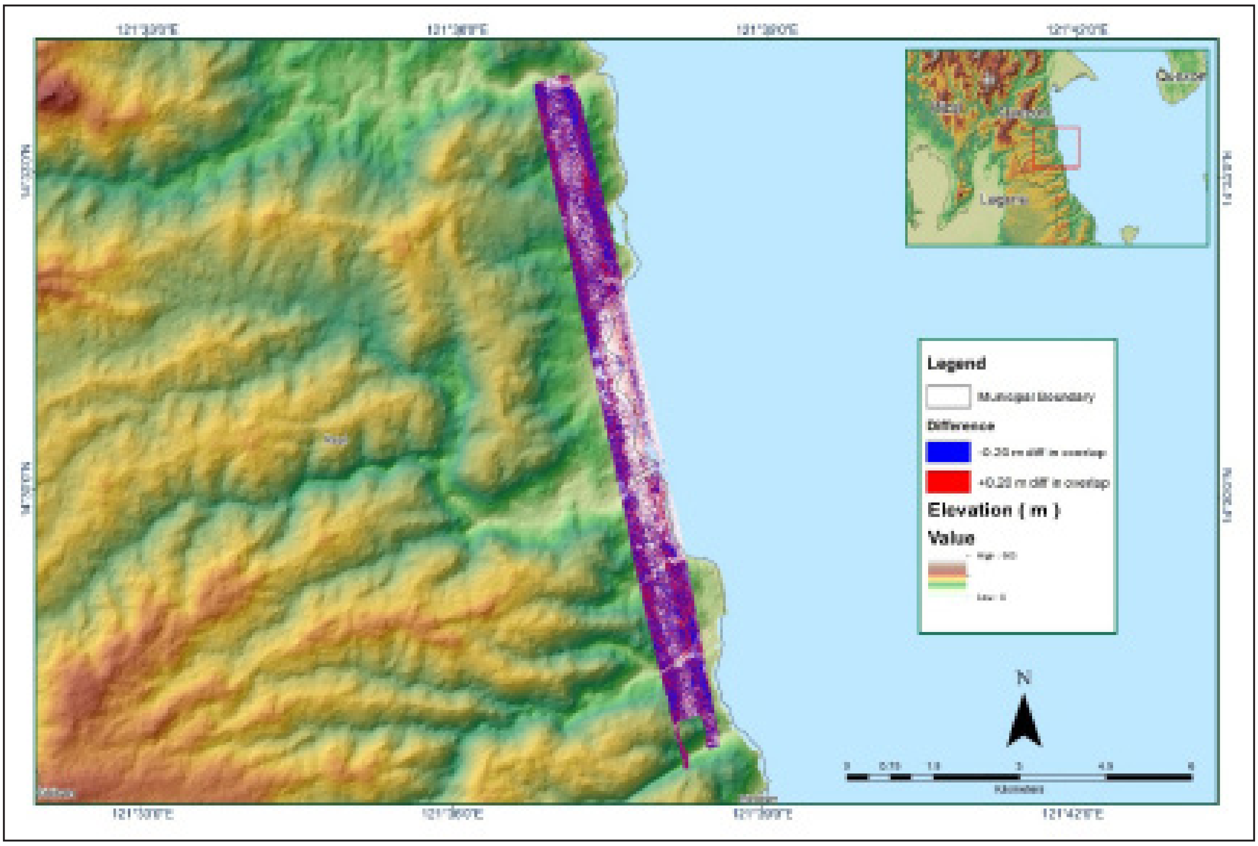


Figure A-8.14. Elevation difference between flight lines

Annex 9. Anibawan Model Basin Parameters

Table A-9.1. Anibawan Model Basin Parameters

Sub-basin	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
W500	13.581	49.173	0	1.7099	0.69993	Discharge	2.00E-01	0.17152	Ratio to Peak	0.44518
W510	20.765	39.514	0	7.9431	2.4235	Discharge	0.24601	0.19637	Ratio to Peak	0.50152
W520	9.1623	37.433	0	4.1675	0.63654	Discharge	5.28E-02	0.17219	Ratio to Peak	1
W530	0.61609	49.556	0	3.0892	5.0985	Discharge	0.36824	0.30594	Ratio to Peak	0.48755
W540	4.2488	49.641	0	0.14742	0.8522	Discharge	0.44552	0.36314	Ratio to Peak	0.45658
W550	9.1623	42.153	0	1.2662	0.2308	Discharge	3.96E-01	0.0777711	Ratio to Peak	1
W560	5.1596	39.471	0	0.15365	0.89703	Discharge	0.20211	0.17608	Ratio to Peak	0.6645
W570	17.404	48.324	0	10.776	1.6552	Discharge	0.12839	0.46595	Ratio to Peak	0.32992
W580	9.9314	58.744	0	1.9991	0.55652	Discharge	0.0759163	0.16806	Ratio to Peak	0.49801
W590	5.7371	37.19	0	0.18171	6.9539	Discharge	0.27161	0.20135	Ratio to Peak	0.47473
W600	9.7922	37.385	0	2.7016	0.65457	Discharge	0.13532	0.24704	Ratio to Peak	0.58329
W610	12.822	40.637	0	0.14809	5.4258	Discharge	0.18359	0.44183	Ratio to Peak	0.5
W620	17.636	46.398	0	0.18978	0.87307	Discharge	0.0512109	0.11432	Ratio to Peak	0.5
W630	23.717	35.37	0	1.5837	0.20259	Discharge	0.008138	0.10096	Ratio to Peak	1
W640	6.3852	51.96	0	1.5027	0.57418	Discharge	0.13852	0.59935	Ratio to Peak	0.78146
W650	17.507	76.187	0	8.6124	3.4309	Discharge	0.1927	0.45377	Ratio to Peak	0.52163
W660	15.88	49.436	0	2.2871	0.93076	Discharge	0.10044	0.36314	Ratio to Peak	0.46741
W670	10.184	48.601	0	0.94797	0.56711	Discharge	0.1574	0.55682	Ratio to Peak	0.54113
W680	20.364	40.778	0	1.1721	12.09	Discharge	0.26797	0.98092	Ratio to Peak	0.61292
W690	4.0704	51.951	0	0.69953	1.1526	Discharge	0.16621	0.37198	Ratio to Peak	0.509
W700	2.1155	45.942	0	1.6483	5.9107	Discharge	0.47032	0.30902	Ratio to Peak	0.21342

Sub-basin	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
W710	13.495	79.235	0	9.7653	2.3924	Discharge	0.0978837	0.46442	Ratio to Peak	0.57643
W720	17.427	40.317	0	1.4794	3.7163	Discharge	0.34006	0.13225	Ratio to Peak	0.44324
W730	3.7023	45.133	0	10.311	1.3403	Discharge	0.32308	0.45284	Ratio to Peak	0.66232
W740	16.158	35.395	0	0.14931	0.70848	Discharge	0.0592094	0.97472	Ratio to Peak	0.47973
W750	4.5754	35.539	0	7.2161	2.8915	Discharge	0.32914	1	Ratio to Peak	0.53054
W760	9.3788	83.753	0	0.14681	0.66291	Discharge	0.0344025	1	Ratio to Peak	0.29528
W770	15.353	48.658	0	8.3696	2.9557	Discharge	0.34055	0.464	Ratio to Peak	0.53349
W780	24.828	53.479	0	2.6818	3.8438	Discharge	0.24197	0.20133	Ratio to Peak	0.32171
W790	8.4592	62.495	0	0.19522	1.4449	Discharge	0.0341744	0.58011	Ratio to Peak	0.49222
W800	39.05	35.314	0	4.0045	2.0696	Discharge	0.4008	0.30456	Ratio to Peak	0.5
W810	4.2708	46.519	0	5.7502	2.7479	Discharge	0.6352	0.46416	Ratio to Peak	0.51533
W820	130.17	35.195	0	1.6688	0.19631	Discharge	0.0029915	0.19753	Ratio to Peak	0.69671
W830	25.169	47.184	0	7.0367	1.1137	Discharge	0.1881	0.69268	Ratio to Peak	0.29389
W840	23.872	49.395	0	5.6996	2.1911	Discharge	0.29056	0.90382	Ratio to Peak	0.50035
W850	190.62	60.642	0	0.0243604	0.0286244	Discharge	2.54E-05	0.19937	Ratio to Peak	0.32786
W860	8.3098	75.422	0	3.9024	49.293	Discharge	0.4079	0.64027	Ratio to Peak	0.76987
W870	2.6131	41.452	0	6.8744	5.4323	Discharge	1.1447	1	Ratio to Peak	0.25044
W880	17.335	41.732	0	8.1063	2.9479	Discharge	0.50787	1	Ratio to Peak	0.77166
W890	22.689	50.532	0	3.305	3.1963	Discharge	0.24609	0.43922	Ratio to Peak	0.21342
W900	10.487	40.604	0	0.22539	0.34583	Discharge	0.16422	0.67641	Ratio to Peak	0.49204
W910	47.654	84.36	0	8.4676	1.2644	Discharge	0.15481	0.28702	Ratio to Peak	0.65594
W920	3.846	77.623	0	7.8137	2.7203	Discharge	0.13862	1	Ratio to Peak	0.58536
W930	301.66	70.56	0	0.1734	0.13585	Discharge	0.0023324	0.12207	Ratio to Peak	0.50586
W940	6.1438	40.408	0	4.4385	3.5716	Discharge	0.41769	0.20486	Ratio to Peak	0.50495

Sub-basin	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
W950	22.051	87.752	0	6.0765	6.2395	Discharge	0.38052	0.9	Ratio to Peak	0.44164
W960	39.818	35.632	0	0.74859	0.30736	Discharge	7.67E-03	0.17631	Ratio to Peak	0.50627
W970	10.798	40.644	0	6.4089	1.9018	Discharge	0.35375	0.0599511	Ratio to Peak	0.21342

Annex 10. Anibawan Model Reach Parameters

Table A-10.1. Anibawan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing								
	Time Step method	Length	Slope	Manning's n	Invert	Shape	Diameter	Width	Side Slope
R100	Automatic Fixed Interval	550.42	0.00413	0.000522757		Trapezoid		55	1
R110	Automatic Fixed Interval	871.25	0.00687	0.0069818		Trapezoid		55	1
R120	Automatic Fixed Interval	4362.9	0.01545	0.0283658		Trapezoid		55	1
R130	Automatic Fixed Interval	1311.5	0.00898	0.0001		Trapezoid		55	1
R140	Automatic Fixed Interval	208.99	0.02386	0.0091074		Trapezoid		55	1
R180	Automatic Fixed Interval	805.98	0.01456	0.0268146		Trapezoid		55	1
R190	Automatic Fixed Interval	1918.5	0.0004	0.000169321		Trapezoid		55	1
R200	Automatic Fixed Interval	985.27	0.00637	0.1906		Trapezoid		55	1
R220	Automatic Fixed Interval	1273.8	0.00037	0.0485138		Trapezoid		55	1
R250	Automatic Fixed Interval	605.56	0.0099	0.0049837		Trapezoid		55	1
R260	Automatic Fixed Interval	1092.1	0.00906	0.0608147		Trapezoid		55	1
R270	Automatic Fixed Interval	359.41	0.00098	1		Trapezoid		55	1
R30	Automatic Fixed Interval	598.7	0.00026	0.019781		Trapezoid		55	1
R300	Automatic Fixed Interval	3542	0.00811	0.36271		Trapezoid		55	1
R320	Automatic Fixed Interval	98.995	0.02816	0.70355		Trapezoid		55	1
R330	Automatic Fixed Interval	14.142	0.06195	0.0620108		Trapezoid		55	1
R360	Automatic Fixed Interval	2778.4	0.00395	0.0493677		Trapezoid		55	1
R380	Automatic Fixed Interval	3397.2	0.00631	0.0148424		Trapezoid		55	1
R420	Automatic Fixed Interval	1696.1	0.01206	0.14729		Trapezoid		55	1
R440	Automatic Fixed Interval	42.426	0.10399	0.0001		Trapezoid		55	1
R450	Automatic Fixed Interval	2233.3	0.00448	0.0943733		Trapezoid		55	1
R470	Automatic Fixed Interval	84.853	0.06039	0.17431		Trapezoid		55	1
R80	Automatic Fixed Interval	842.76	0.0004	0.0048632		Trapezoid		55	1
R90	Automatic Fixed Interval	1210.5	0.01059	0.00011475		Trapezoid		55	1

Annex 11. Anibawan Field Validation Data

Table A-11.1. Anibawan Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	14.96054	121.9747	1.42	0	-1.420	habagat	5-yr return period
2	14.96106	121.9746	1.3	0	-1.300	habagat	5-yr return period
3	14.96122	121.9746	1.45	0	-1.450	habagat	5-yr return period
4	14.96171	121.9744	2.45	0	-2.450	habagat	5-yr return period
5	14.96066	121.9747	1.44	0	-1.440	habagat	5-yr return period
6	14.96044	121.9748	1.18	0	-1.180	habagat	5-yr return period
7	14.96038	121.9748	1.27	0	-1.270	habagat	5-yr return period
8	14.96015	121.9749	1.45	0	-1.450	habagat	5-yr return period
9	14.95982	121.9749	1.13	0	-1.130	habagat	5-yr return period
10	14.96227	121.9742	3.22	0.15	-3.070	habagat	5-yr return period
11	14.9621	121.9743	3.12	0.15	-2.970	habagat	5-yr return period
12	14.96273	121.9746	3.14	0.15	-2.990	habagat	5-yr return period
13	14.96207	121.9743	3.05	0.2	-2.850	habagat	5-yr return period
14	14.96282	121.9746	2.96	0.2	-2.760	habagat	5-yr return period
15	14.96243	121.9742	3.26	0.25	-3.010	habagat	5-yr return period
16	14.96264	121.9745	3.14	0.25	-2.890	habagat	5-yr return period
17	14.96253	121.9742	3.24	0.3	-2.940	habagat	5-yr return period
18	14.96286	121.9747	2.61	0.3	-2.310	habagat	5-yr return period
19	14.96261	121.9745	3.24	0.3	-2.940	habagat	5-yr return period
20	14.96273	121.9744	3.25	0.35	-2.900	habagat	5-yr return period
21	14.96256	121.9744	3.28	0.36	-2.920	habagat	5-yr return period
22	14.96269	121.9744	3.28	0.4	-2.880	habagat	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
23	14.96265	121.9744	3.28	0.4	-2.880	habagat	5-yr return period
24	14.96268	121.9741	3.04	0.5	-2.540	habagat	5-yr return period
25	14.96246	121.9743	3.27	0.5	-2.770	habagat	5-yr return period
26	14.96255	121.9743	3.27	0.51	-2.760	habagat	5-yr return period
27	14.96276	121.9741	2.96	0.6	-2.360	habagat	5-yr return period
28	14.96294	121.974	3.05	0.7	-2.350	habagat	5-yr return period
29	14.96282	121.9745	3.25	0.75	-2.500	habagat	5-yr return period
30	14.96308	121.974	3.15	0.8	-2.350	habagat	5-yr return period
31	14.96317	121.974	3.23	0.8	-2.430	habagat	5-yr return period
32	14.96332	121.974	3.33	0.8	-2.530	habagat	5-yr return period
33	14.96348	121.974	4.09	0.8	-3.290	habagat	5-yr return period
34	14.9637	121.9742	5.69	1.1	-4.590	habagat	5-yr return period
35	14.96352	121.9741	4.53	1.1	-3.430	habagat	5-yr return period
36	14.96361	121.9743	4.82	1.2	-3.620	habagat	5-yr return period
37	14.96298	121.9744	3.41	1.2	-2.210	habagat	5-yr return period
38	14.96291	121.9744	3.32	1.3	-2.020	habagat	5-yr return period
39	14.96318	121.9743	3.75	1.3	-2.450	habagat	5-yr return period
40	14.96336	121.9743	4.09	1.4	-2.690	habagat	5-yr return period
41	14.96304	121.9744	3.54	1.5	-2.040	habagat	5-yr return period
42	14.96348	121.9743	4.65	1.5	-3.150	habagat	5-yr return period
43	14.96339	121.9743	4.63	1.6	-3.030	habagat	5-yr return period
44	14.96362	121.9741	6.22	1	-5.220	habagat	5-yr return period
45	14.9621	121.9749	2.31	0.7	-1.610	yoyong	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
46	14.96223	121.9749	2.45	0.8	-1.650	yoyong	5-yr return period
47	14.95236	121.9967	0.03	1.5	1.470	yoyong	5-yr return period
48	14.96191	121.9743	2.96	2.1	-0.860	yoyong	5-yr return period
49	14.96354	121.9741	4.81	2.1	-2.710	yoyong	5-yr return period
50	14.96339	121.974	3.56	2.2	-1.360	yoyong	5-yr return period
51	14.96263	121.9748	2.5	2.2	-0.300	yoyong	5-yr return period
52	14.96263	121.9748	2.81	2.2	-0.610	yoyong	5-yr return period
53	14.96162	121.9744	2.28	2.2	-0.080	yoyong	5-yr return period
54	14.96248	121.9748	2.62	2.2	-0.420	yoyong	5-yr return period
55	14.96192	121.9751	2.11	2.5	0.390	yoyong	5-yr return period
56	14.96149	121.9745	1.9	2.5	0.600	yoyong	5-yr return period
57	14.96117	121.9746	1.4	2.5	1.100	yoyong	5-yr return period
58	14.96265	121.9748	1.5	2.5	1.000	yoyong	5-yr return period
59	14.96243	121.9749	2.19	2.5	0.310	yoyong	5-yr return period
60	14.96238	121.975	1.3	2.5	1.200	yoyong	5-yr return period
61	14.96321	121.9739	3.24	2.5	-0.740	yoyong	5-yr return period
62	14.96197	121.9751	1.83	2.5	0.670	yoyong	5-yr return period
63	14.96313	121.9739	3.21	2.6	-0.610	yoyong	5-yr return period
64	14.96086	121.9747	1.34	2	0.660	yoyong	5-yr return period
65	14.96258	121.9748	2.6	2	-0.600	yoyong	5-yr return period
66	14.96095	121.9747	1.31	2	0.690	yoyong	5-yr return period
67	14.96205	121.975	2.31	3.5	1.190	habagat	5-yr return period
68	14.96237	121.9742	3.25	3.5	0.250	yoyong	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
69	14.96298	121.9743	3.33	3	-0.330	yoyong	5-yr return period
70	14.96302	121.9743	3.46	3	-0.460	yoyong	5-yr return period
71	14.96229	121.9742	3.21	3	-0.210	yoyong	5-yr return period
72	14.96109	121.9744	1.84	3	1.160	yoyong	5-yr return period
73	14.96361	121.9742	4.81	3	-1.810	yoyong	5-yr return period
74	14.96429	121.9743	4.3	4	-0.300	habagat	5-yr return period
75	14.96416	121.9742	7.85	4	-3.850	habagat	5-yr return period
76	14.96446	121.9746	3.28	4.6	1.320	habagat	5-yr return period
77	14.97439	121.9909	5.03	5	-0.030	habagat	5-yr return period
78	14.97447	121.9904	5.39	5	-0.390	habagat	5-yr return period
79	14.97451	121.99	5.47	5	-0.470	habagat	5-yr return period
80	14.97452	121.9898	5.43	5	-0.430	habagat	5-yr return period
81	14.97453	121.9893	5.84	5	-0.840	habagat	5-yr return period
82	14.97455	121.9889	6.3	5	-1.300	habagat	5-yr return period
83	14.97457	121.9886	6.57	5	-1.570	habagat	5-yr return period
84	14.9746	121.9882	6.92	5	-1.920	habagat	5-yr return period
85	14.97463	121.9878	7.49	5	-2.490	habagat	5-yr return period
86	14.97466	121.9874	6.96	5	-1.960	habagat	5-yr return period
87	14.97466	121.9871	6.58	5	-1.580	habagat	5-yr return period
88	14.9746	121.9867	6.38	5	-1.380	habagat	5-yr return period
89	14.97449	121.9863	5.63	5	-0.630	habagat	5-yr return period
90	14.97435	121.986	5.47	5	-0.470	habagat	5-yr return period
91	14.97419	121.9856	5.53	5	-0.530	habagat	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
92	14.974	121.9853	5.5	5	-0.500	habagat	5-yr return period
93	14.97381	121.9849	5.25	5	-0.250	habagat	5-yr return period
94	14.97362	121.9845	5.13	5	-0.130	habagat	5-yr return period
95	14.97343	121.9842	4.35	5	0.650	habagat	5-yr return period
96	14.97328	121.9839	5.11	5	-0.110	habagat	5-yr return period
97	14.97311	121.9836	5.19	5	-0.190	habagat	5-yr return period
98	14.97299	121.9834	5.26	5	-0.260	habagat	5-yr return period
99	14.9729	121.9832	5.33	5	-0.330	habagat	5-yr return period
100	14.97274	121.9829	3.86	5	1.140	habagat	5-yr return period
101	14.9726	121.9827	5.47	5	-0.470	habagat	5-yr return period
102	14.9725	121.9825	5.46	5	-0.460	habagat	5-yr return period
103	14.97233	121.9822	5.35	5	-0.350	habagat	5-yr return period
104	14.97216	121.9819	5.44	5	-0.440	habagat	5-yr return period
105	14.97205	121.9817	5.46	5	-0.460	habagat	5-yr return period
106	14.97183	121.9813	5.7	5	-0.700	habagat	5-yr return period
107	14.97161	121.9809	4.06	5	0.940	habagat	5-yr return period
108	14.97136	121.9805	3.72	5	1.280	habagat	5-yr return period
109	14.97109	121.9801	4.34	5	0.660	habagat	5-yr return period
110	14.97091	121.9798	6.34	5	-1.340	habagat	5-yr return period
111	14.97074	121.9795	6.59	5	-1.590	habagat	5-yr return period
112	14.97056	121.9791	7.17	5	-2.170	habagat	5-yr return period
113	14.97032	121.9787	7.37	5	-2.370	habagat	5-yr return period
114	14.97011	121.9781	5	5	0.000	habagat	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
115	14.97003	121.9778	2.31	5	2.690	habagat	5-yr return period
116	14.97003	121.9774	2.27	5	2.730	habagat	5-yr return period
117	14.97007	121.9771	2.58	5	2.420	habagat	5-yr return period
118	14.97012	121.9767	2.51	5	2.490	habagat	5-yr return period
119	14.97018	121.9764	3.04	5	1.960	habagat	5-yr return period
120	14.97023	121.976	3.55	5	1.450	habagat	5-yr return period
121	14.97026	121.9757	8.29	5	-3.290	habagat	5-yr return period
122	14.97041	121.9747	8.47	5	-3.470	habagat	5-yr return period
123	14.97048	121.9744	6.41	5	-1.410	habagat	5-yr return period
124	14.96961	121.973	6.24	5	-1.240	habagat	5-yr return period
125	14.96941	121.9733	5.29	5	-0.290	habagat	5-yr return period
126	14.96467	121.9749	4.09	5	0.910	habagat	5-yr return period
127	14.96911	121.9737	9.38	5	-4.380	habagat	5-yr return period
128	14.96856	121.9746	8.89	5	-3.890	habagat	5-yr return period
129	14.96831	121.9748	9.36	5	-4.360	habagat	5-yr return period
130	14.96803	121.9749	8.69	5	-3.690	habagat	5-yr return period
131	14.96773	121.9749	8.41	5	-3.410	habagat	5-yr return period
132	14.96744	121.9749	8.61	5	-3.610	habagat	5-yr return period
133	14.96716	121.9749	8.63	5	-3.630	habagat	5-yr return period
134	14.96686	121.9749	8.84	5	-3.840	habagat	5-yr return period
135	14.96455	121.9747	3.9	5	1.100	habagat	5-yr return period
136	14.9515	121.9974	0.11	0.2	0.090	habagat	5-yr return period
137	14.95143	121.9966	0.22	2	1.780	habagat	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
138	14.95262	121.9957	0.42	0.2	-0.220	habagat	5-yr return period
139	14.95331	121.9949	0.15	0.3	0.150	habagat	5-yr return period
140	14.95261	121.9852	0.03	0	-0.030	habagat	5-yr return period
141	14.95512	121.9821	0.03	0	-0.030	habagat	5-yr return period
142	14.95326	121.9766	0.03	0	-0.030	habagat	5-yr return period
143	14.95544	121.9693	0.03	0	-0.030	habagat	5-yr return period
144	14.96092	121.9797	0.03	0	-0.030	habagat	5-yr return period
145	14.96163	121.9703	4.89	2.5	-2.390	habagat	5-yr return period
146	14.96836	121.9796	0.03	2.6	2.570	habagat	5-yr return period
147	14.97086	121.9807	1.44	0	-1.440	habagat	5-yr return period
148	14.97424	121.9869	0.98	2.2	1.220	habagat	5-yr return period
149	14.97369	121.9904	0.61	2	1.390	habagat	5-yr return period
150	14.97283	121.994	0.03	2	1.970	habagat	5-yr return period
151	14.96898	121.9694	0.03	1.5	1.470	habagat	5-yr return period
152	14.96606	121.9582	0.03	0	-0.030	habagat	5-yr return period
153	14.9833	121.9676	0.03	0	-0.030	habagat	5-yr return period
154	14.97904	121.9579	0.03	0	-0.030	habagat	5-yr return period
155	14.96279	121.9743	3.23	0	-3.230	habagat	5-yr return period
156	14.96266	121.9742	3.2	0.6	-2.600	habagat	5-yr return period
157	14.9629	121.9746	2.93	0.3	-2.630	habagat	5-yr return period
158	14.96171	121.9748	1.61	0.1	-1.510	habagat	5-yr return period
159	14.96178	121.9745	2.05	0.1	-1.950	habagat	5-yr return period
160	14.96149	121.974	2.77	0.2	-2.570	habagat	5-yr return period

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
161	14.95992	121.9749	1.19	0.2	-0.990	habagat	5-yr return period
162	14.96052	121.9744	2.1	0.2	-1.900	habagat	5-yr return period
163	14.96105	121.9737	2.76	0.2	-2.560	habagat	5-yr return period
164	14.96141	121.9736	3.1	0.2	-2.900	habagat	5-yr return period
165	14.96295	121.9739	3.06	0.7	-2.360	habagat	5-yr return period
166	14.96289	121.9742	3.11	0.7	-2.410	habagat	5-yr return period
167	14.96313	121.9743	3.67	0.8	-2.870	habagat	5-yr return period
168	14.96231	121.9745	3	0.21	-2.790	habagat	5-yr return period
169	14.9619	121.9745	2.62	0.1	-2.520	habagat	5-yr return period
170	14.96197	121.9747	2.01	0.1	-1.910	habagat	5-yr return period
171	14.96146	121.9747	1.59	0.1	-1.490	habagat	5-yr return period
172	14.96048	121.975	1.46	0.1	-1.360	habagat	5-yr return period
173	14.96417	121.9741	3.59	5.9	2.310	habagat	5-yr return period
174	14.96398	121.9741	7.52	2.678	-4.842	habagat	5-yr return period
175	14.96431	121.974	2.8	1.282	-1.518	habagat	5-yr return period
176	14.96409	121.9741	7.84	6	-1.840	habagat	5-yr return period
177	14.96415	121.9745	8.64	4	-4.640	habagat	5-yr return period
178	14.96239	121.9741	3.19	0.7	-2.490	habagat	5-yr return period
179	14.96048	121.9761	0.04	0	-0.040	habagat	5-yr return period
180	14.95981	121.9758	1.4	0	-1.400	habagat	5-yr return period
			RMSE	2.090739			