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

LiDAR Surveys and Flood Mapping of Nauco Aguada River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 NAUCO AGUADA RIVER

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva Plopenio, and Engr. Ferdinand Bien

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga University (AdNU). AdNU 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 24 river basins in the Bicol Region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Nauco Aguada River Basin

The Nauco Aguada River Basin is under the jurisdiction of three (3) municipalities: Cataingan, Placer and Pio V. Corpuz. The first two (2) towns are classified as second class municipalities while the last town is a fourth class municipality. Based from the 2015 census, Cataingan has a population of 50,327 in its 36 barangays, Placer has 55,826 residents in 35 barangays and Pio V. Corpuz has 23,236 in its 18 barangays.

The main outlet of the basin is the Nauco Aguada River that empties out in the Visayan sea. The mouth of the river is in the town of Placer. The north is bounded by very low hills and the east and west sides of the basin are basically low rolling hills. Majority of the land area in the basin is cultivated; a very small portion is dedicated for fisheries and mangrove. A relatively large area is considered as tree plantation based from the land cover map. The Nauco Aguada river basin is in the southern tip of the island of Masbate and is governed by type IV climate in the modified Corona classification of climate. Rainfall is evenly distributed throughout the year.

According to the 2015 national census of PSA, a total of 7,928 persons are residing within the immediate vicinity of the river, which is distributed among barangays Daanlungsod, Manlut-Od, Poblacion and Taboc in the Municipality of Placer, Province of Masbate. As of December 7, 2014, 88 families in Cataingan, Masbate were affected by Typhoon Ruby as per NDRRMC report (National Disaster Risk Reduction and Management Council, 2014).

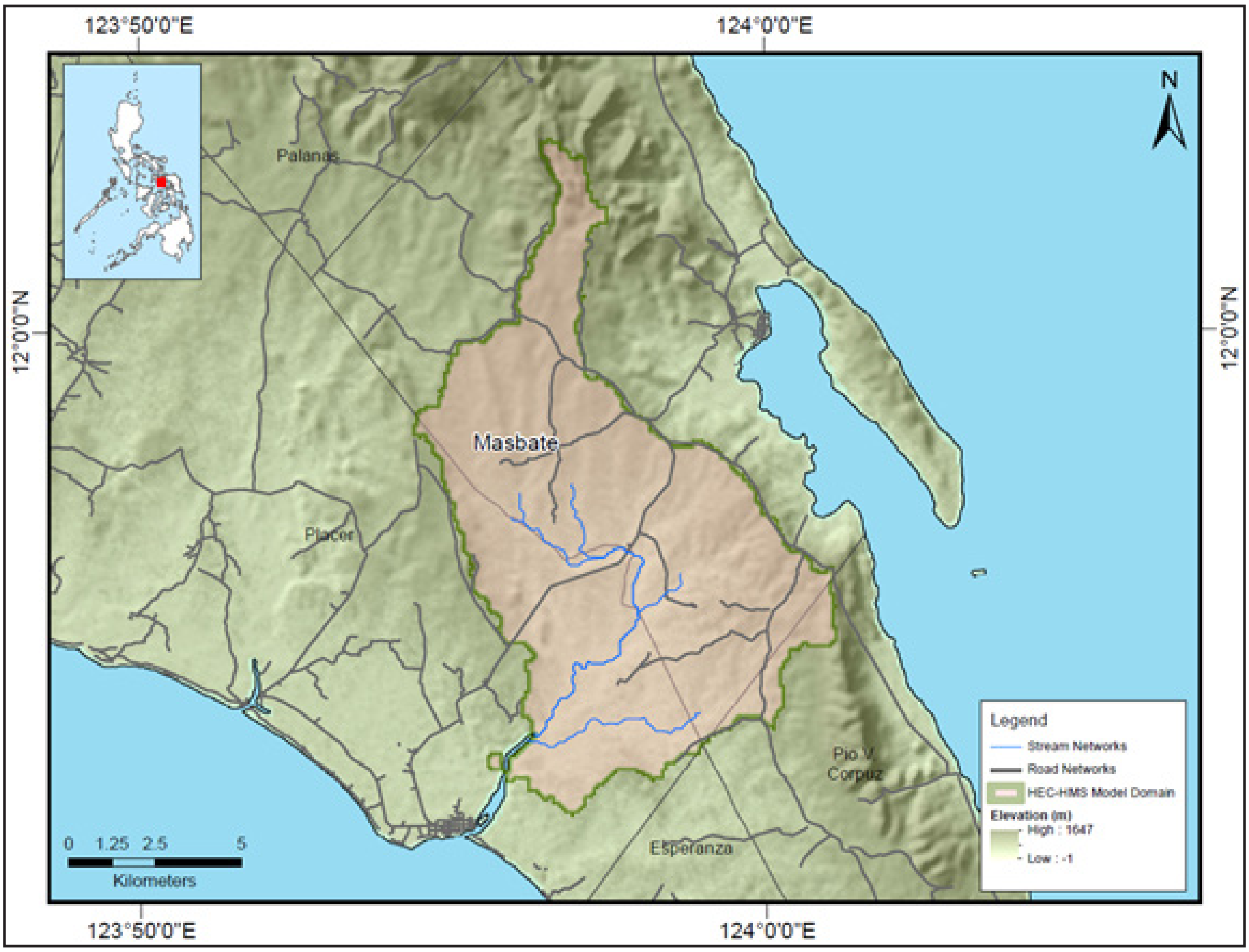

Figure 1. Map of Nauco Aguada River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE NAUCO AGUADA 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

To initiate the LiDAR acquisition survey of the Nauco Aguada floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Nauco Aguada Floodplain in Masbate. These flight missions were planned for 12 lines and ran for at most four (4) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2 shows the flight plan for Nauco Aguada floodplain survey.

Table 1. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK32M	1000	30	50	200	30	130	5
	1200	25	50	200	30	130	5
BLK32L	800	30	50	200	30	130	5
	700	25	50	200	30	130	5
BLK32K	800	30	50	200	30	130	5
	700	25	50	200	30	130	5
	1200	25	50	200	30	130	5

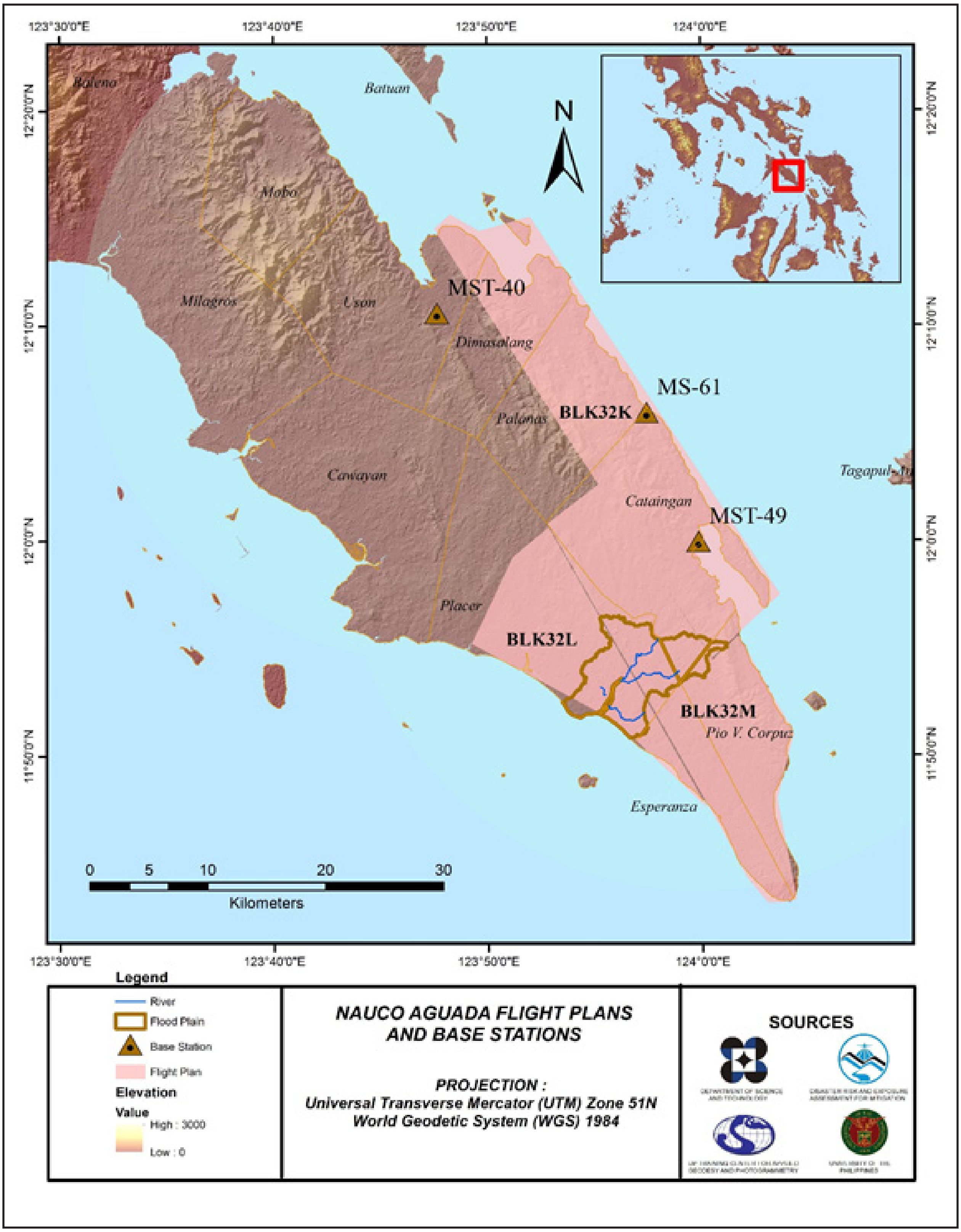


Figure 2. Flight Plan and base stations used for the Nauco Aguada Floodplain survey using Pegasus sensor.

2.2 Ground Base Stations

The field team was able to recover two (2) NAMRIA reference points: MST-40 and MST-49 which are of second (2nd) order accuracy and one (1) NAMRIA benchmark: MS-61 which is of first (1st) order accuracy. The benchmark was used as vertical reference point and was also established as ground control point.

The certifications for the base stations are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from March 25 to April 1, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Nauco Aguada floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Nauco Aguada Floodplain LiDAR Survey. Figure 3 to Figure 5 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 2 and Table 4 show the details about the following NAMRIA control stations and established points. Table 5, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(b)

(a)

Figure 3. GPS set-up over MST-40 (a) as recovered in Buenavista Bridge in Brgy. Buenavista, municipality of Uson, Masbate; and NAMRIA reference point MST-40 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point MST-40 used as base station for the LiDAR acquisition.

Station Name	**MST-40**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 10’ 39.45274” North 123° 47’ 33.62147” East 4.72600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	586266.511 meters 1346708.7 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 10’ 34.84826” North 123° 47’ 38.70589” East 61.65900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	586236.32 meters 1346237.33 meters

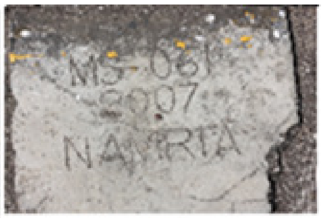
(a) (b)

Figure 4. GPS set-up over MST-49 (a) as recovered in front of the Cataingan Municipal Hall, municipality of Cataingan, Masbate b) NAMRIA reference point MST-49 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MST-49 used as base station for the LiDAR acquisition.

Station Name	MST-49	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 00’ 01.41677” 123° 59’ 46.24265” 21.25500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	608487.281 meters 1327175.1 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 59’ 56.87354” North 123° 59’ 51.34085” East 79.14000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	608449.31 meters 1326710.57 meters

(a)



(b)

Figure 5. GPS set-up over MS-61 (a) as recovered in Nabangig Bridge, Brgy. Nabangig, municipality of Palanas, Masbate; NAMRIA reference point MS-61 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA vertical control point MS-61 used as base station for the LiDAR acquisition with established coordinates.

Station Name	MS-61	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 06’ 1.51238” 123° 57’ 21.24483” 4.74 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 05’ 56.94091” North 123° 57’ 26.33451” East 65.257 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	604178.664 meters 1337699.951 meters

Table 5. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 25, 2014	1263P	1BLK32K084A	MS-61 & MST-49
March 26, 2014	1267P	1BLK32M085A	MS-61 & MST-49
March 31, 2014	1289P	1BLK32K090A	MST-40 & MST-49
April 1, 2014	1291P	1BLK32KL091A	MST-40 & MST-49

2.3 Flight Missions

A total of four (4) missions were conducted to complete the LiDAR data acquisition in Nauco Aguada floodplain, for a total of fourteen hours and fifty seven minutes (14+57) of flying time for RP-C9022 (See Annex 6). All missions were acquired using the Pegasus system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 6, while the actual parameters used during the LiDAR data acquisition are presented in Table 7.

Table 6. Flight missions for the LiDAR data acquisition of the Nauco Aguada Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
March 25, 2014	1263P	133.096	198.221	7.504	190.717	722	3	54
March 26, 2014	1267P	251.862	370.707	40.462	330.245	895	4	29
March 31, 2014	1289P	315.847	172.105	3.396	168.709	321	2	11
April 1, 2014	1291P	315.847	183.804	31.149	152.655	666	4	23
TOTAL		1016.65	924.837	82.511	842.326	2604	14	57

Table 7. Actual parameters used during the LiDAR data acquisition of the Nauco Aguada Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1263P	700	25	50	200	30	130	5
1267P	1000, 1200	30, 25	50	200	30	130	5
1289P	1200	25	50	200	30	130	5
1291P	800, 700	30, 25	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Nauco Aguada floodplain (See Annex 7). It is located in the province of Masbate, with majority of the floodplain situated within the municipalities of Esperanza and Pio V. Corpuz. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 8. Figure 6, on the other hand, shows the actual coverage of the LiDAR acquisition for the Nauco Aguada floodplain.

Table 8. The list of municipalities and cities surveyed of the Nauco Aguada Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Masbate	Cataingan	191.696	9.18	4.79%
	Esperanza	62.754	0.105	0.17%
	Pio V. Corpuz	95.644	3.286	3.44%
	Placer	253.543	53.688	21.18%
TOTAL		603.637	12.571	2.08%

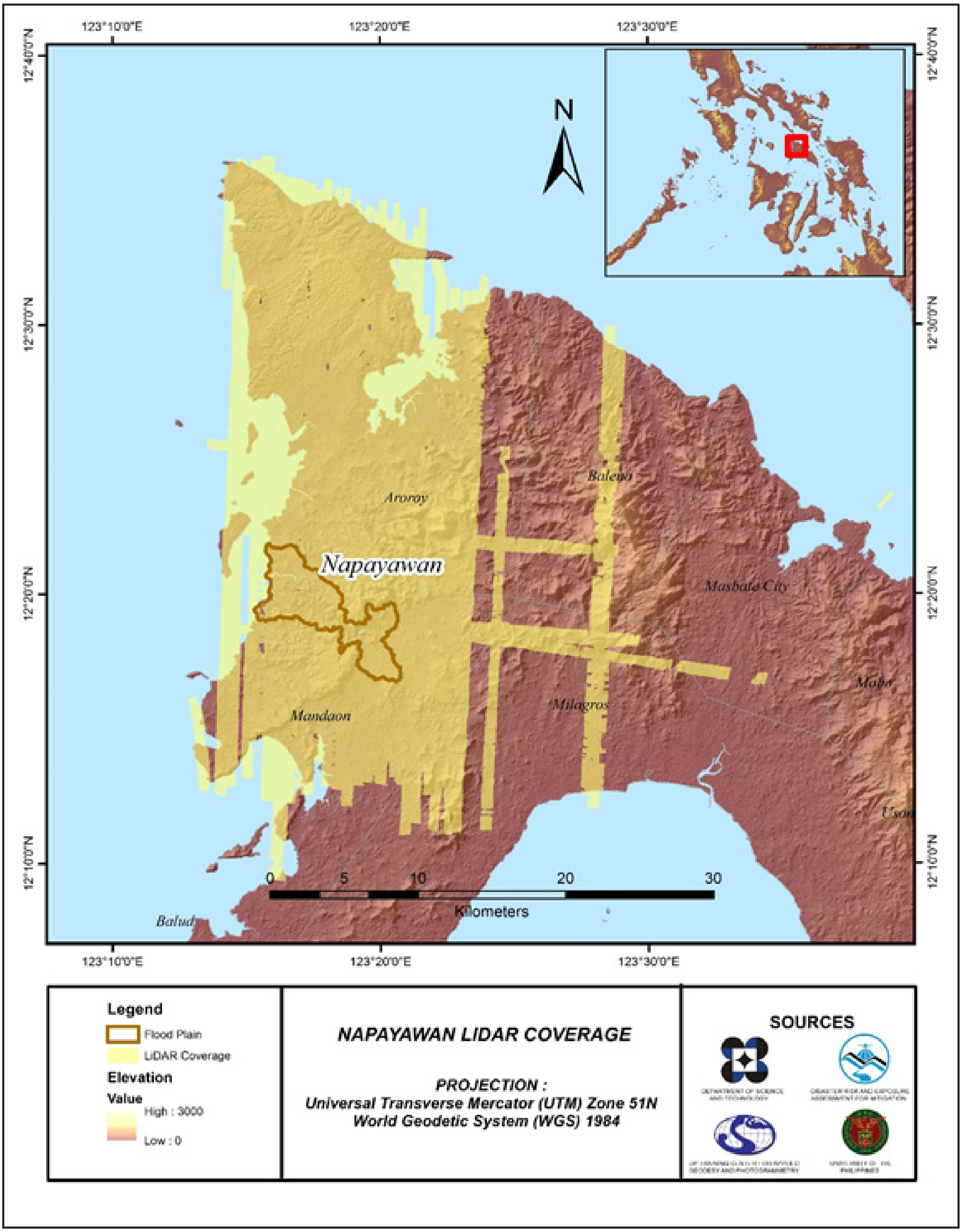


Figure 6. Actual LiDAR survey coverage of the Nauco Aguada Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE NAUCO AGUADA FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

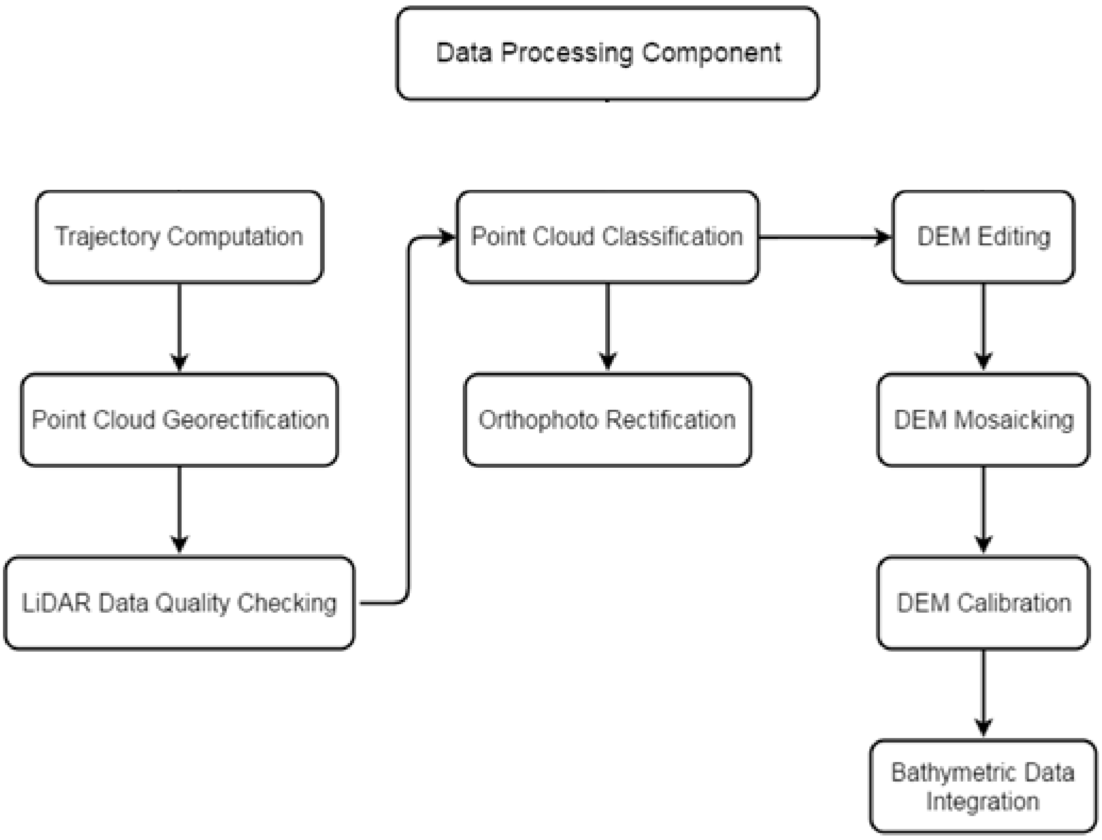

Figure 7. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Nauco Aguada Floodplain can be found in Annex 5. The missions flown during the conduct of the first survey in March 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Masbate.

The Data Acquisition Component (DAC) transferred a total of 106.9 Gigabytes of Range data, 0.87 Gigabytes of POS data, 26.47 Megabytes of GPS base station data, and 173.3 Gigabytes of raw image data to the data server on April 22, 2014 for the first survey and February 6, 2016 for the second survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Nauco Aguada Floodplain was fully transferred on April 23, 2014, as indicated on the Data Transfer Sheets for the Nauco Aguada floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 1291P, one of the Nauco Aguada flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of April 1, 2014 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

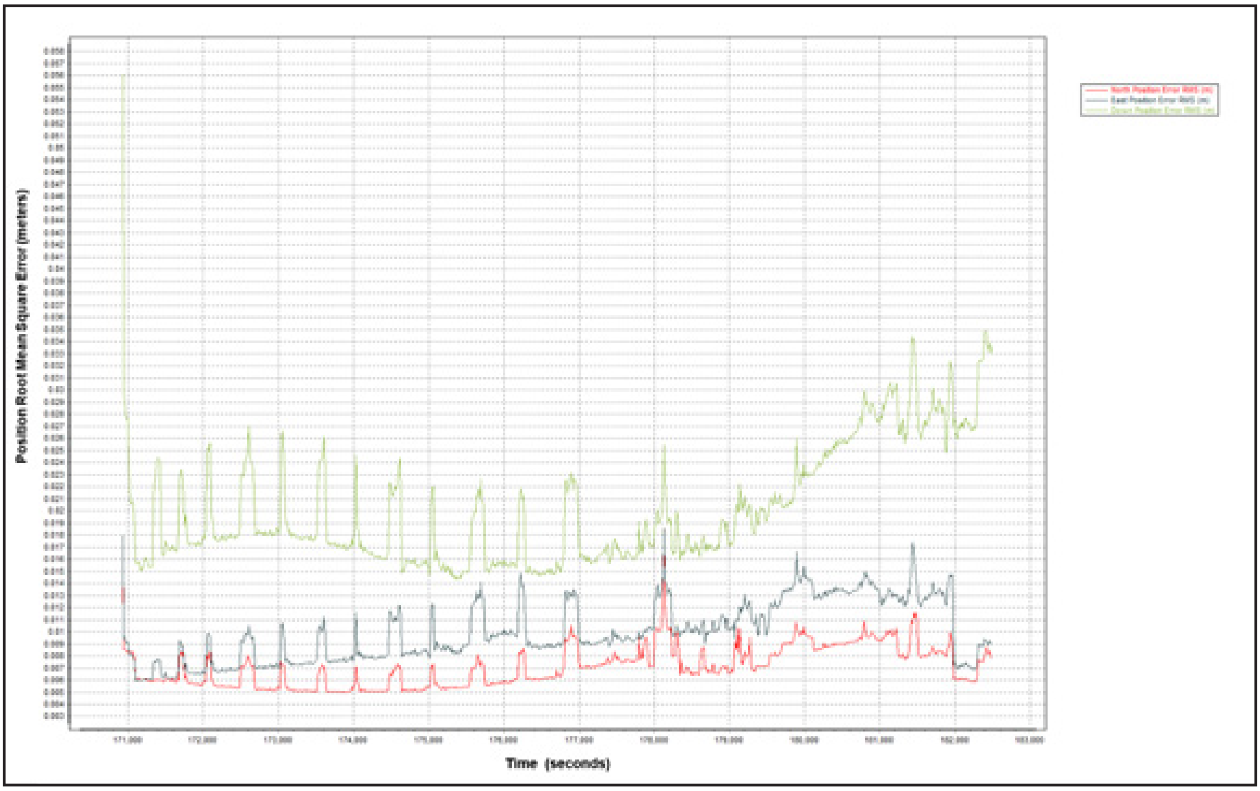

Figure 8. Smoothed Performance Metric Parameters of Nauco Aguada Flight 1291P.

The time of flight was from 171000 seconds to 18300 seconds, which corresponds to morning of April 1, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 0.80 centimeters, the East position RMSE peaks at 1.86 centimeters, the East position RMSE peaks at 1. 85 centimeters, and the Down position RMSE peaks at 3.45 centimeters, which are within the prescribed accuracies described in the methodology.

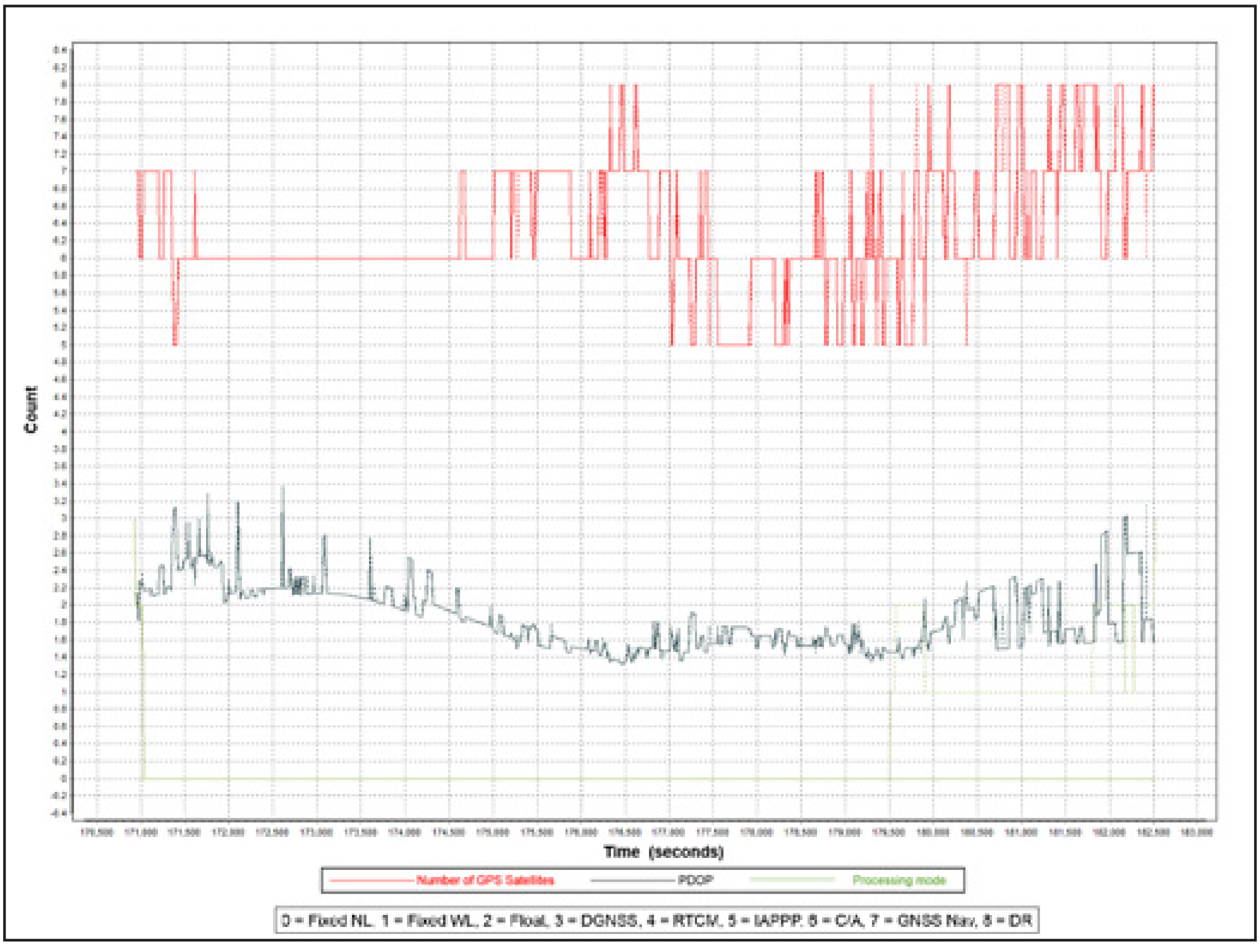

Figure 9. Solution Status Parameters of Nauco Aguada Flight 1291P.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Nauco Aguada Flight 1291P are shown in Figure 9. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 5 and 8, not going lower than 5. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also stayed at the value of 0 for the majority of the survey stayed at the value of 0 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 the POSPAC MMS. Fundamentally, 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 Nauco Aguada flights is shown in Figure 10.

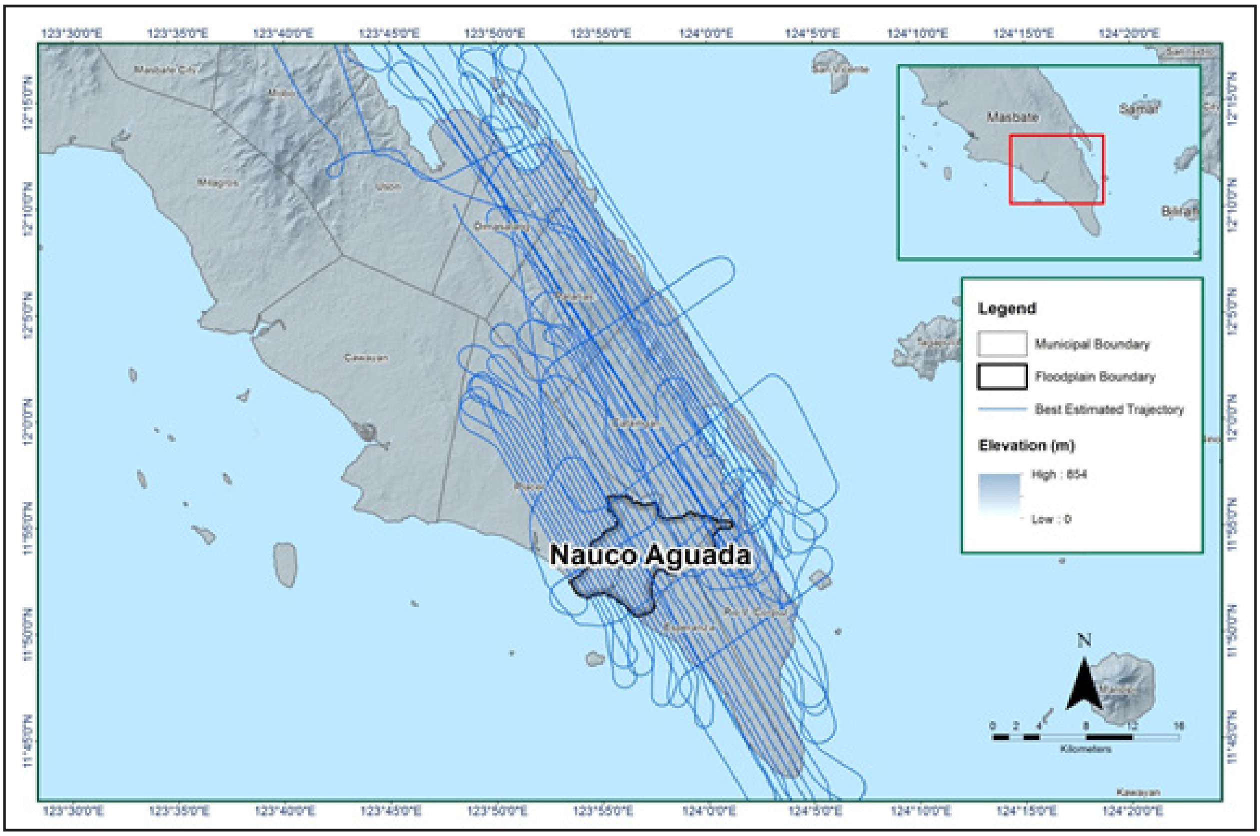

Figure 10. Best Estimated Trajectory of the LiDAR missions conducted over the Nauco Aguada Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 52 flight lines, with each flight line contains two channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Nauco Aguada floodplain are given in Table 9.

Table 9. Self-calibration Results values for Nauco Aguada flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000569
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000997
GPS Position Z-correction stdev)	<0.01meters	0.0021

The optimum accuracy values for all Nauco Aguada flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (Annex 8).

3.5 LiDAR Data Quality Checking

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

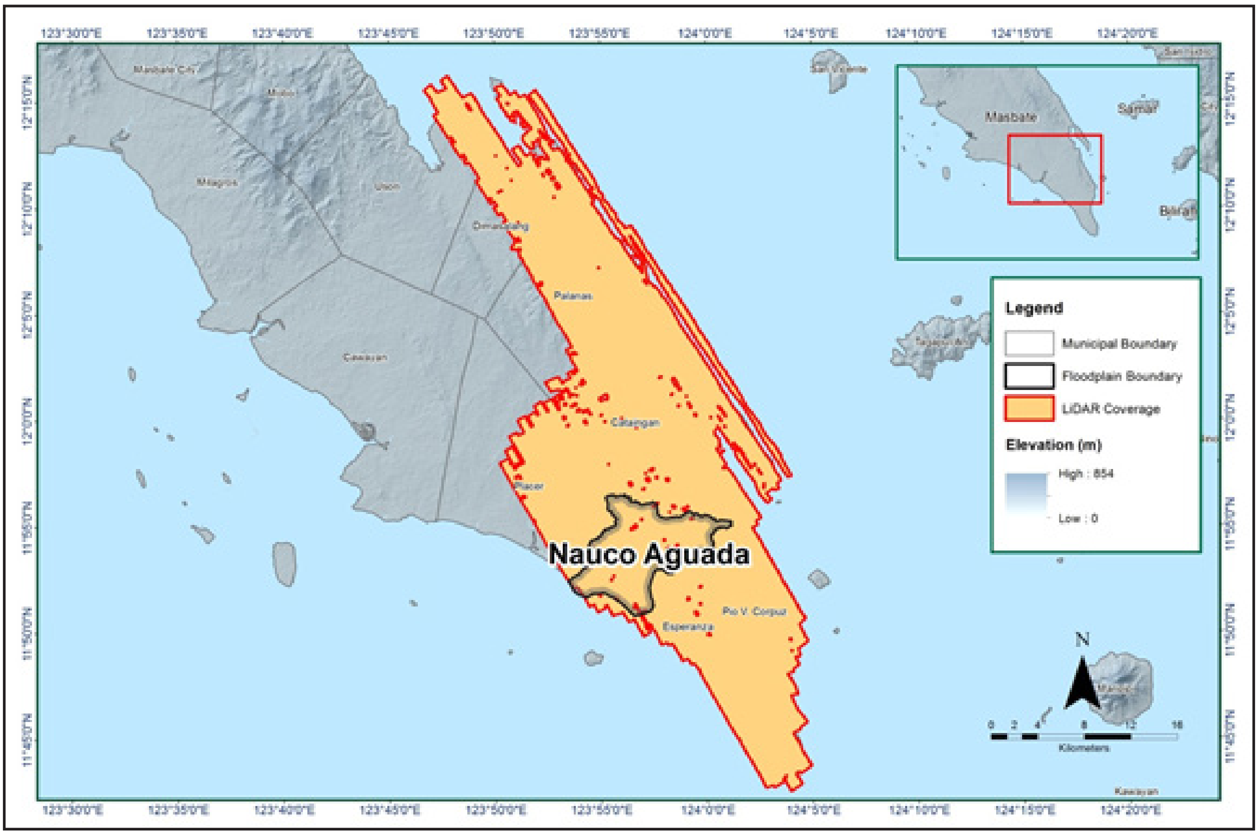

Figure 11. Boundaries of the processed LiDAR data over the Nauco Aguada Floodplain.

A total area of 797.63 square kilometers (sq. kms.) were covered by the Nauco Aguada flight missions as a result of four (4) flight acquisitions, which were grouped and merged into three (3) blocks accordingly, as portrayed in Table 10.

Table 10. List of LiDAR blocks for the Nauco Aguada floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Masbate_Blk32K	1263P	354.41
	1267P	
	1291P	
	1289P	
Masbate_Blk32L	1291P	122.45
Masbate_Blk32M	1267P	320.77
TOTAL		797.63 sq.km

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

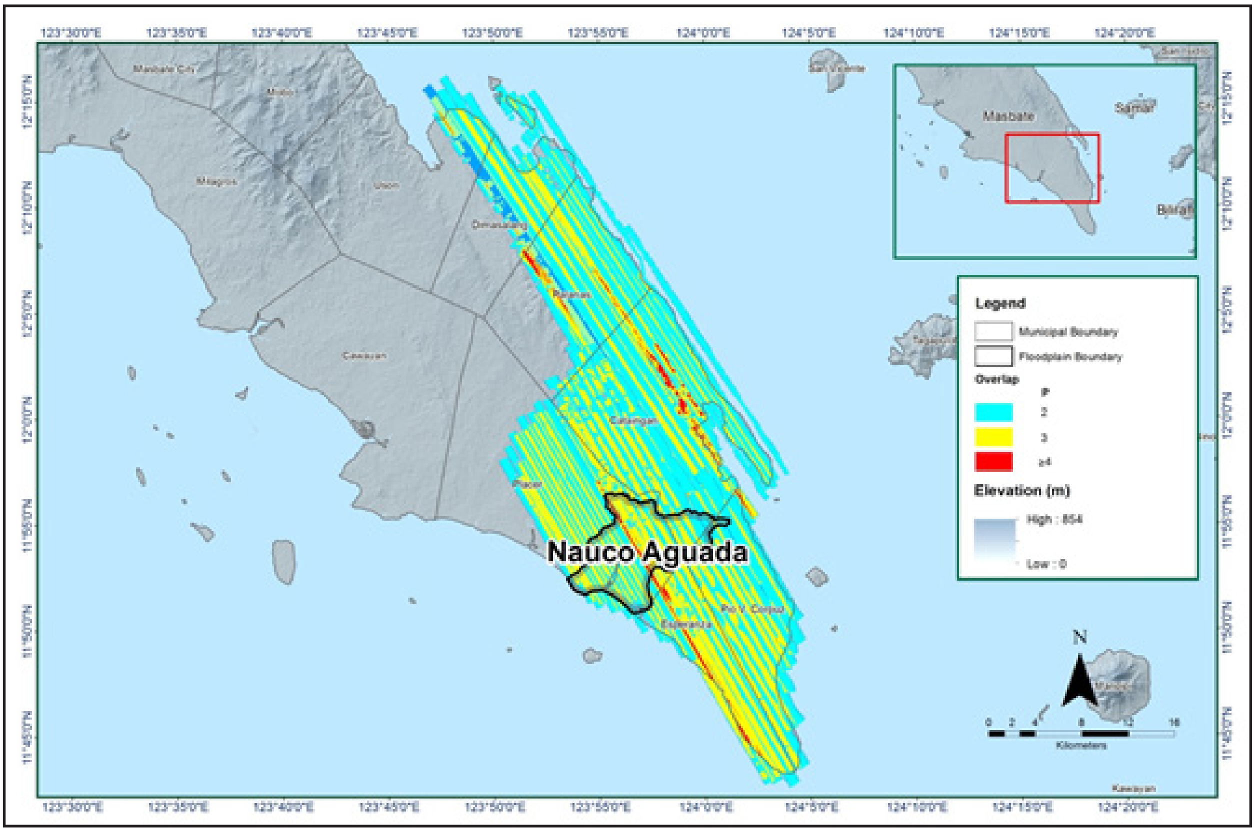

Figure 12. Image of data overlap for Nauco Aguada floodplain.

The overlap statistics per block for the Nauco Aguada floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlap are 37.21% and 52.19% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 13. As seen in the figure below, it was determined that all LiDAR data for the Nauco Aguada Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.66 points per square meter.

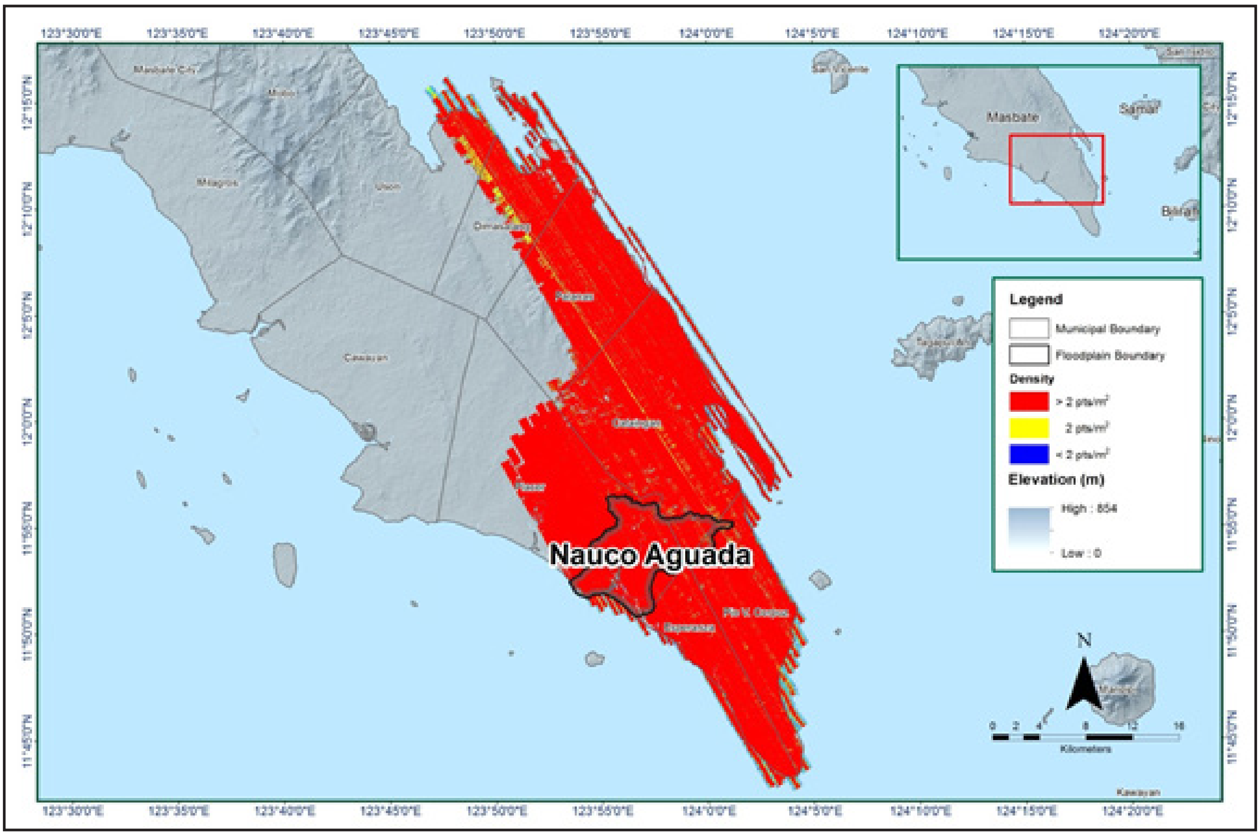

Figure 13. Pulse density map of the merged LiDAR data for Nauco Aguada floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

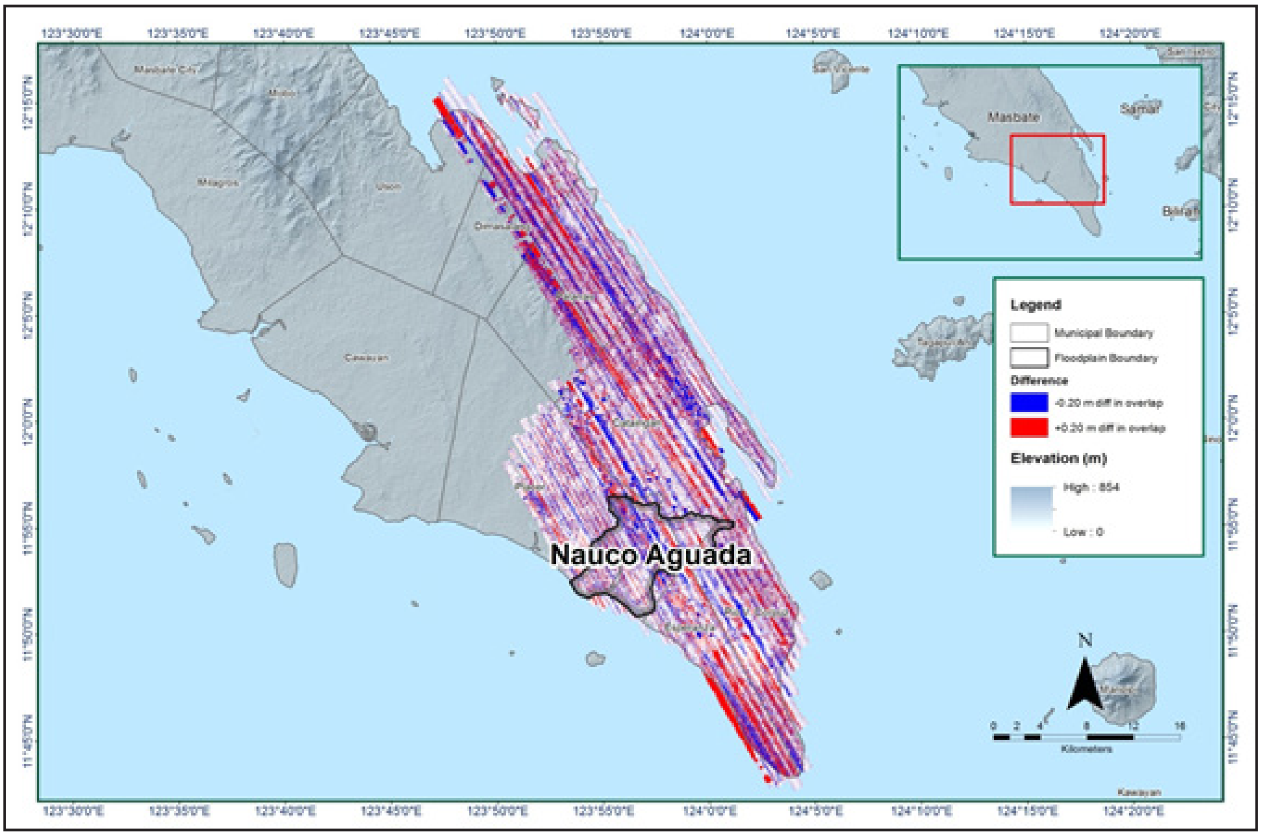

Figure 14. Elevation difference Map between flight lines for the Nauco Aguada Floodplain Survey.

A screen-capture of the processed LAS data from Nauco Aguada flight 1291P loaded in QT Modeler is shown in Figure 14. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed 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 generated satisfactory results. No reprocessing was done for this LiDAR dataset.

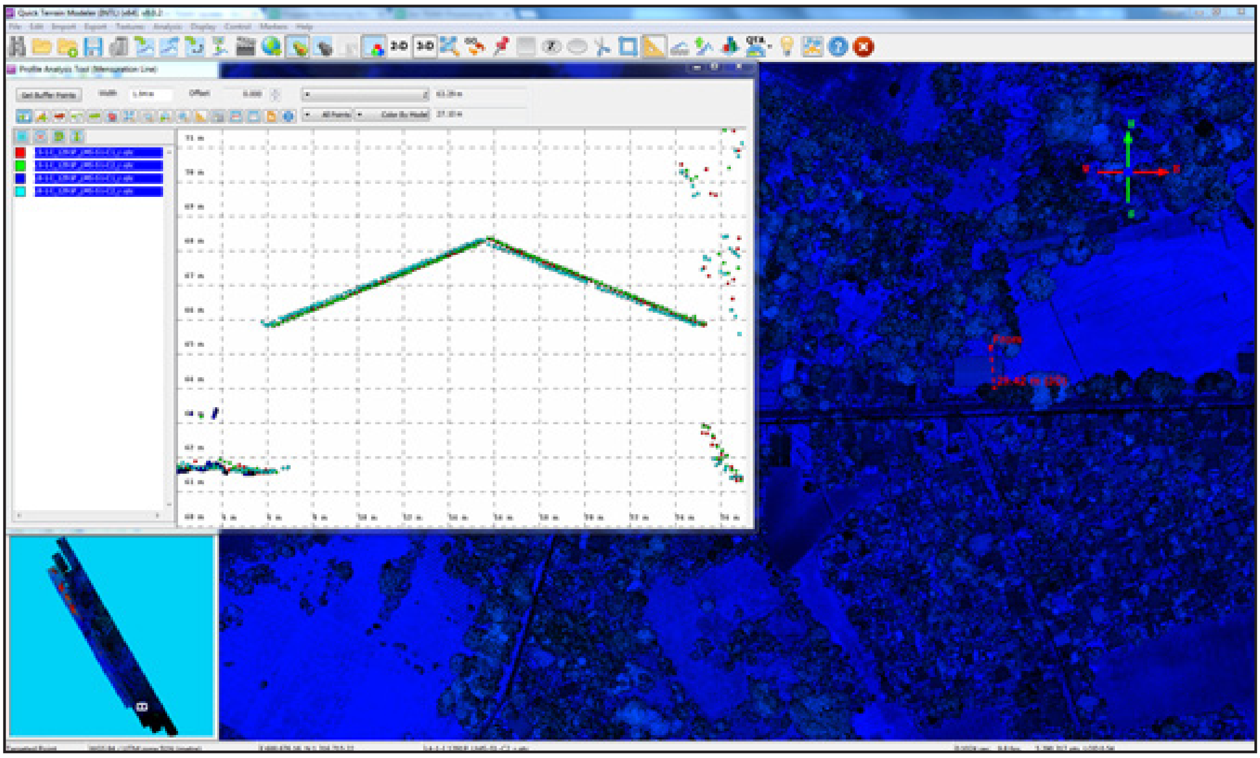

Figure 15. Quality checking for Nauco Aguada flight 1291P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Nauco Aguada classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	973,461,781
Low Vegetation	764,019,420
Medium Vegetation	999,389,436
High Vegetation	698,000,401
Building	10,890,757

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Nauco Aguada floodplain is shown in Figure 16. A total of 1,046 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 11 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 502.98 meters and 46.93 meters respectively.

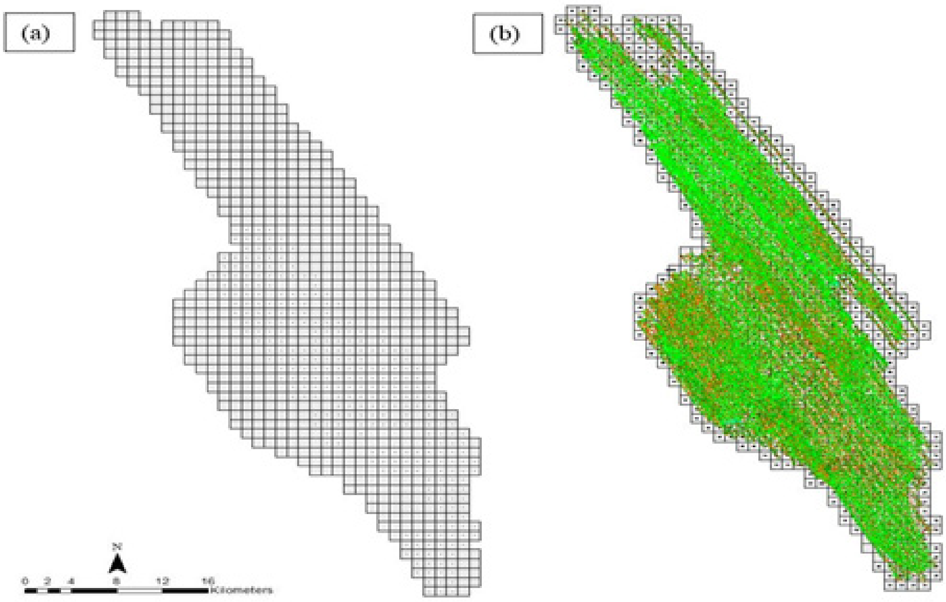

Figure 16. Tiles for Nauco Aguada floodplain (a) and classification results (b) in TerraScan.

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

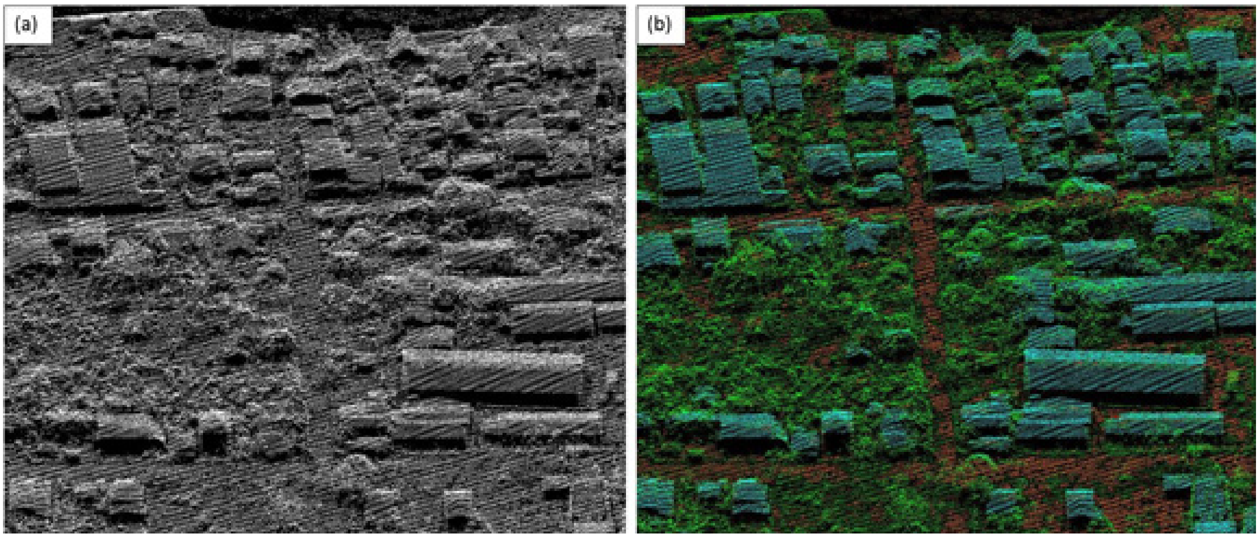

Figure 17. Point cloud before (a) and after (b) classification.

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

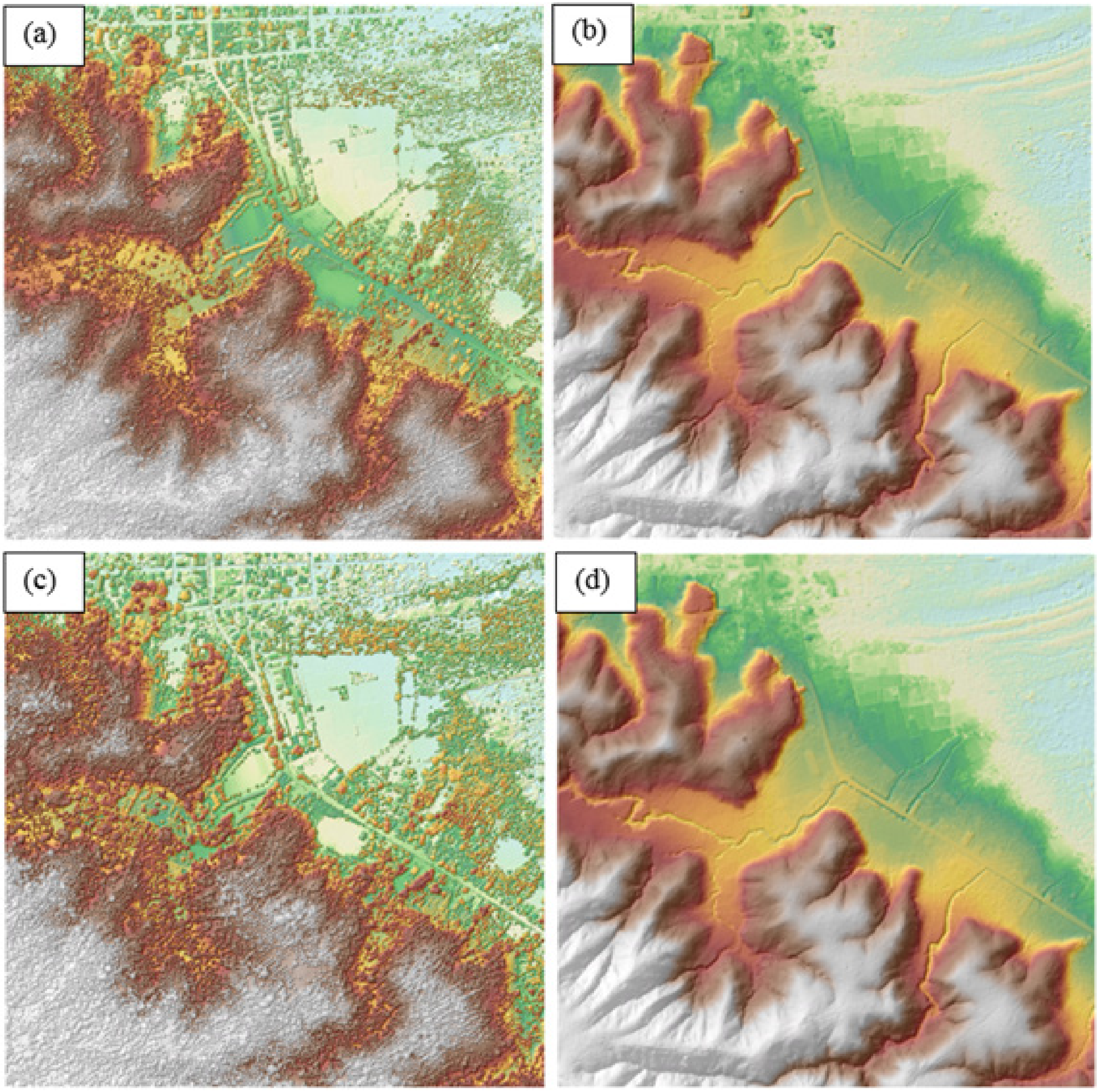

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Nauco Aguada floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 969 1km by 1km tiles area covered by the Nauco Aguada floodplain is shown in Figure 19. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Nauco Aguada floodplain attained a total of 727.82 sq. kms. in orthophotograph coverage comprised of 2,569 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

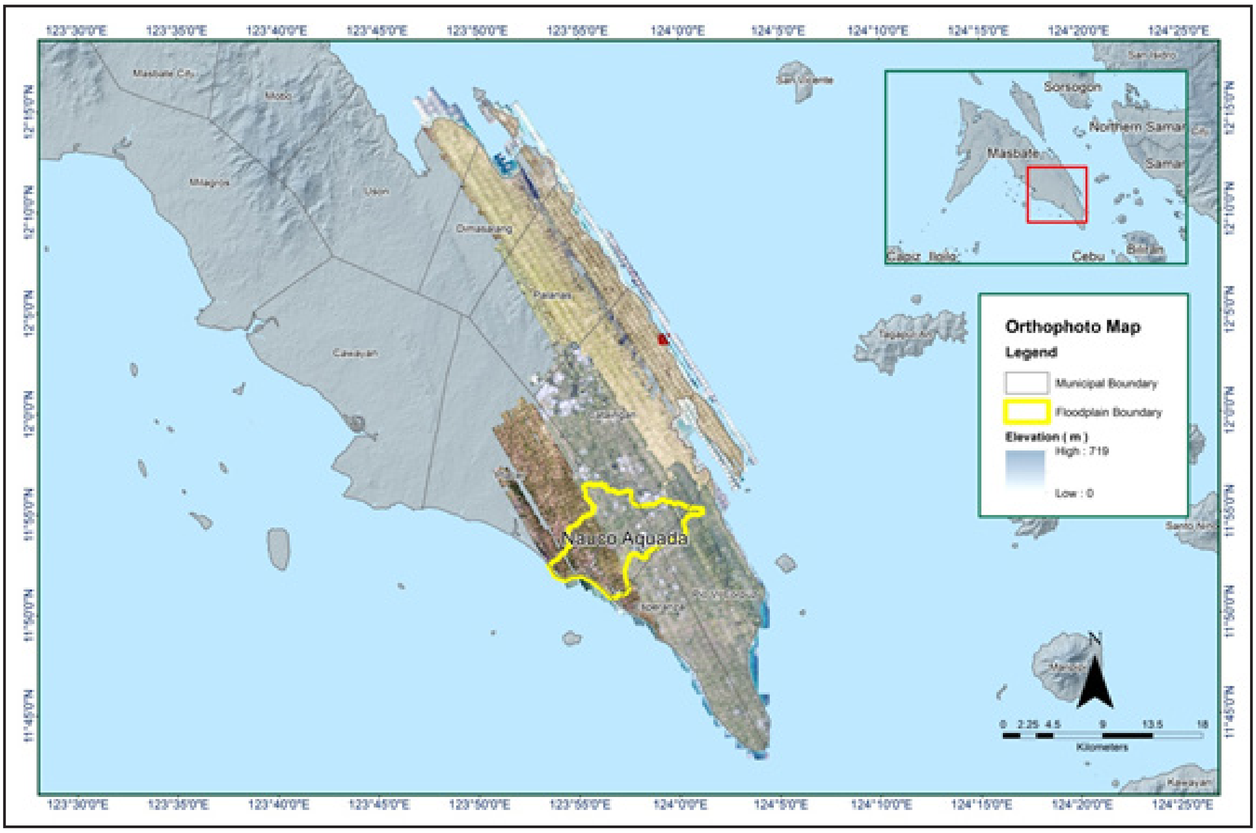

Figure 19. Nauco Aguada Floodplain with the available orthophotographs.

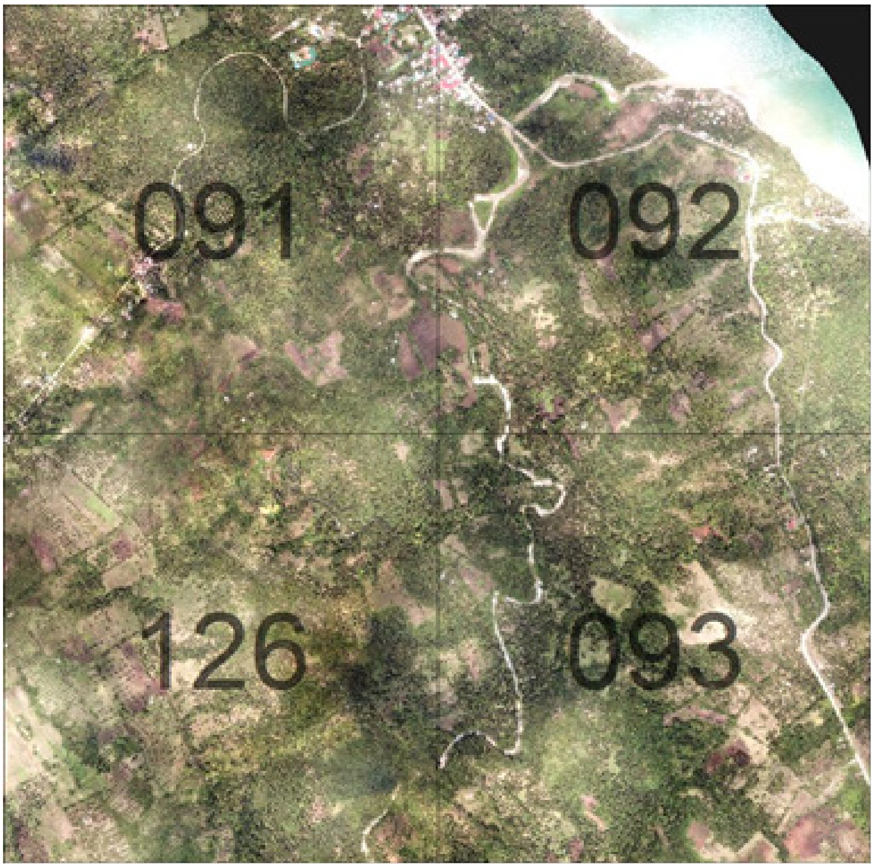

Figure 20. Sample orthophotograph tiles for the Nauco Aguada Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for the Nauco Aguada Floodplain Survey. These blocks are composed of Bagasbas blocks with a total area of 797.63 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Masbate_Blk32M	320.77
Masbate_Blk32L	122.45
Masbate_Blk32K	354.41
TOTAL	797.63 sq.km

Figure 21 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 21a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 21b). Likewise, a paddy field (Figure 21c) was misclassified and removed during the classification process. To complete the surface, the road (Figure 21d) was retrieved and reclassified through manual editing to allow the correct water flow.

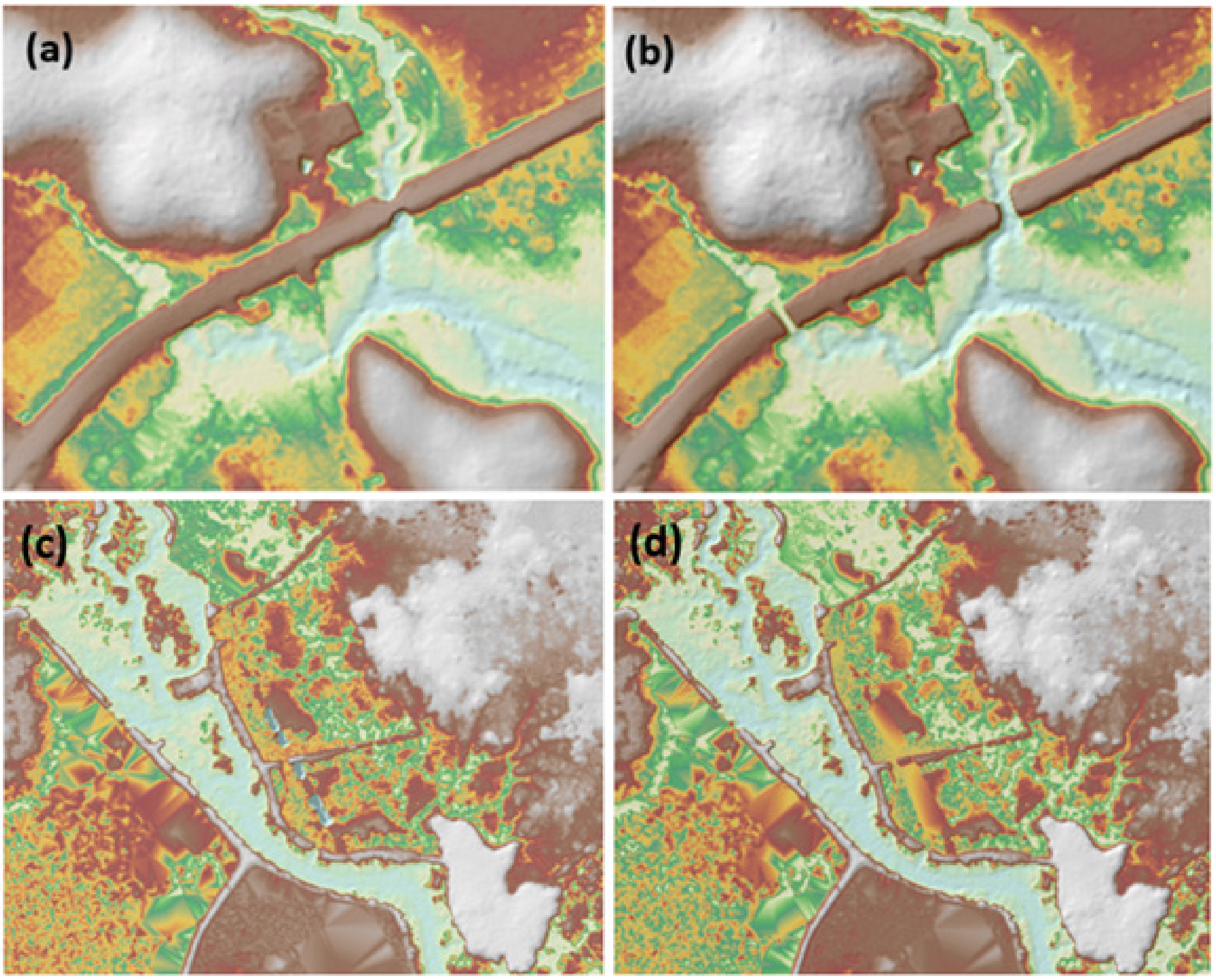

Figure 21. Portions in the DTM of the Nauco Aguada Floodplain – a bridge before (a) and after (b) manual editing; a paddy filed before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Masbate DEM overlapping with the blocks to be mosaicked. Table 13 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Nauco Aguada Floodplain is shown in Figure 22. It can be seen that the entire Nauco Aguada floodplain is 98.50% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 13. Shift values of each LiDAR block of Nauco Aguada Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Masbate_Blk32K	0.00	0.00	2.50
Masbate_Blk32L	0.00	0.00	1.63
Masbate_Blk32M	0.00	0.00	2.78

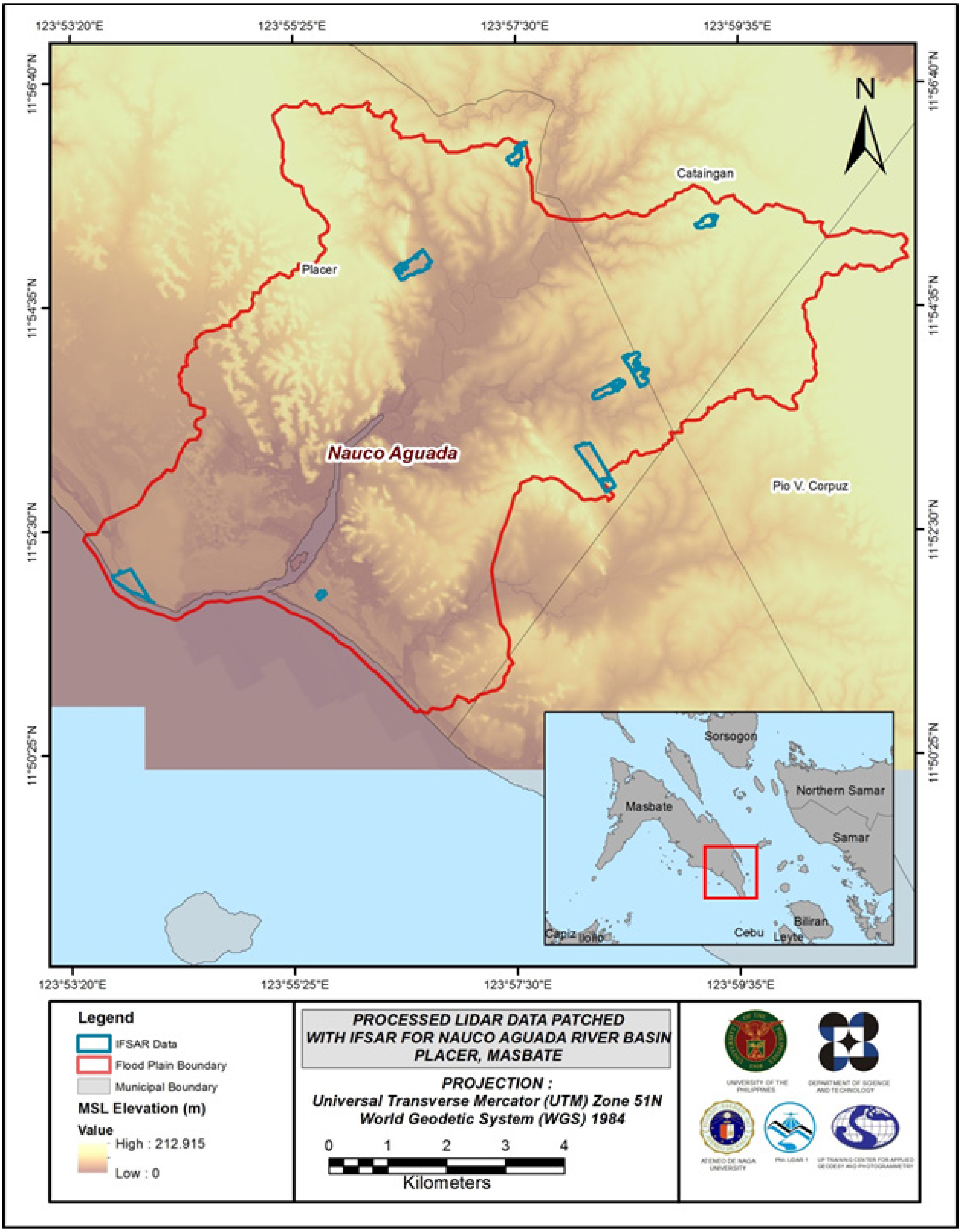

Figure 22. Map of processed LiDAR data for the Nauco Aguada Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Nauco Aguada to collect points with which the LiDAR dataset is validated is shown in Figure 23, with the validation survey points highlighted in green. A total of 2,639 survey points were gathered for the Nauco Aguada floodplain. Random selection of 80% of the survey points, resulting to 2,591 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and the ground survey elevation values is shown in Figure 24. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of the data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 3.22 meters, with a standard deviation of 0.158 meters. The calibration of the Nauco Aguada LiDAR data was accomplished by subtracting the height difference value of 3.22 meters to the Nauco Aguada mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between the Nauco Aguada LiDAR data and the calibration data.

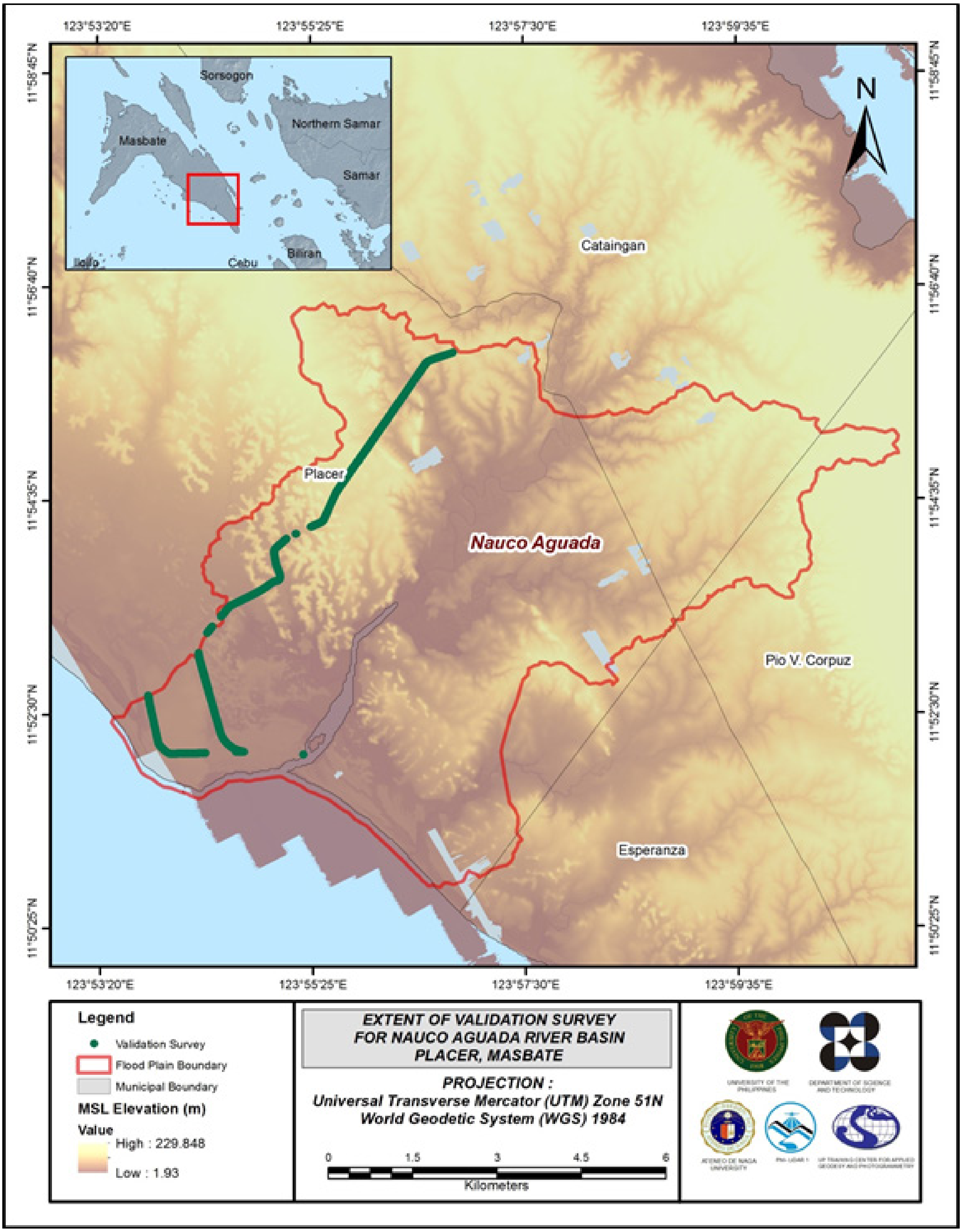

Figure 23. Map of Nauco Aguada Floodplain with validation survey points in green.

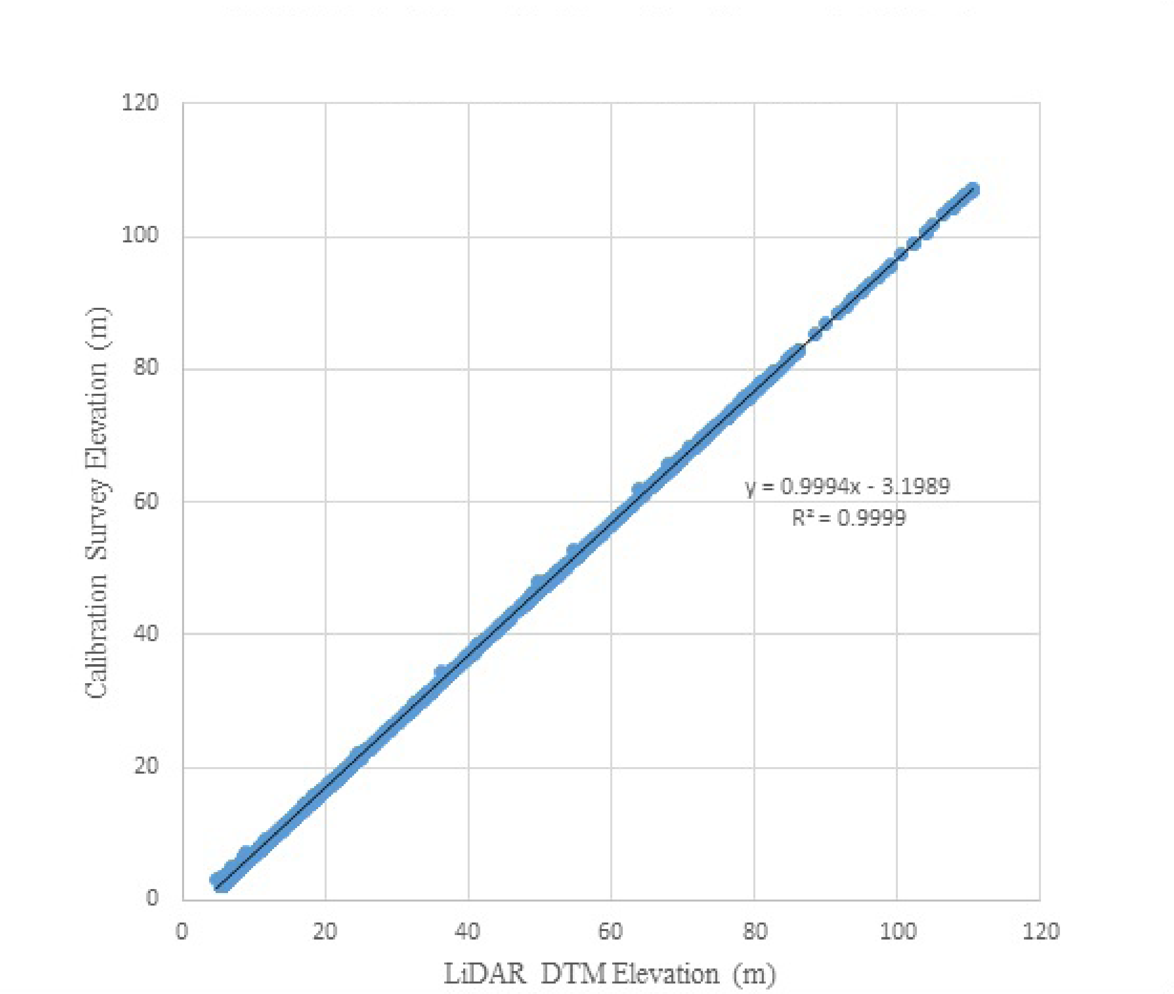

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.22
Standard Deviation	0.16
Average	-3.22
Minimum	-3.53
Maximum	-1.66

The remaining 20% of the total survey points, resulting to 375 points, were used for the validation of calibrated Nauco Aguada DTM. A good correlation between the calibrated mosaicked LiDAR elevation and the ground survey elevation values, which point toward the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 0.09 meters with a standard deviation of 0.06 meters, as shown in Table 15.

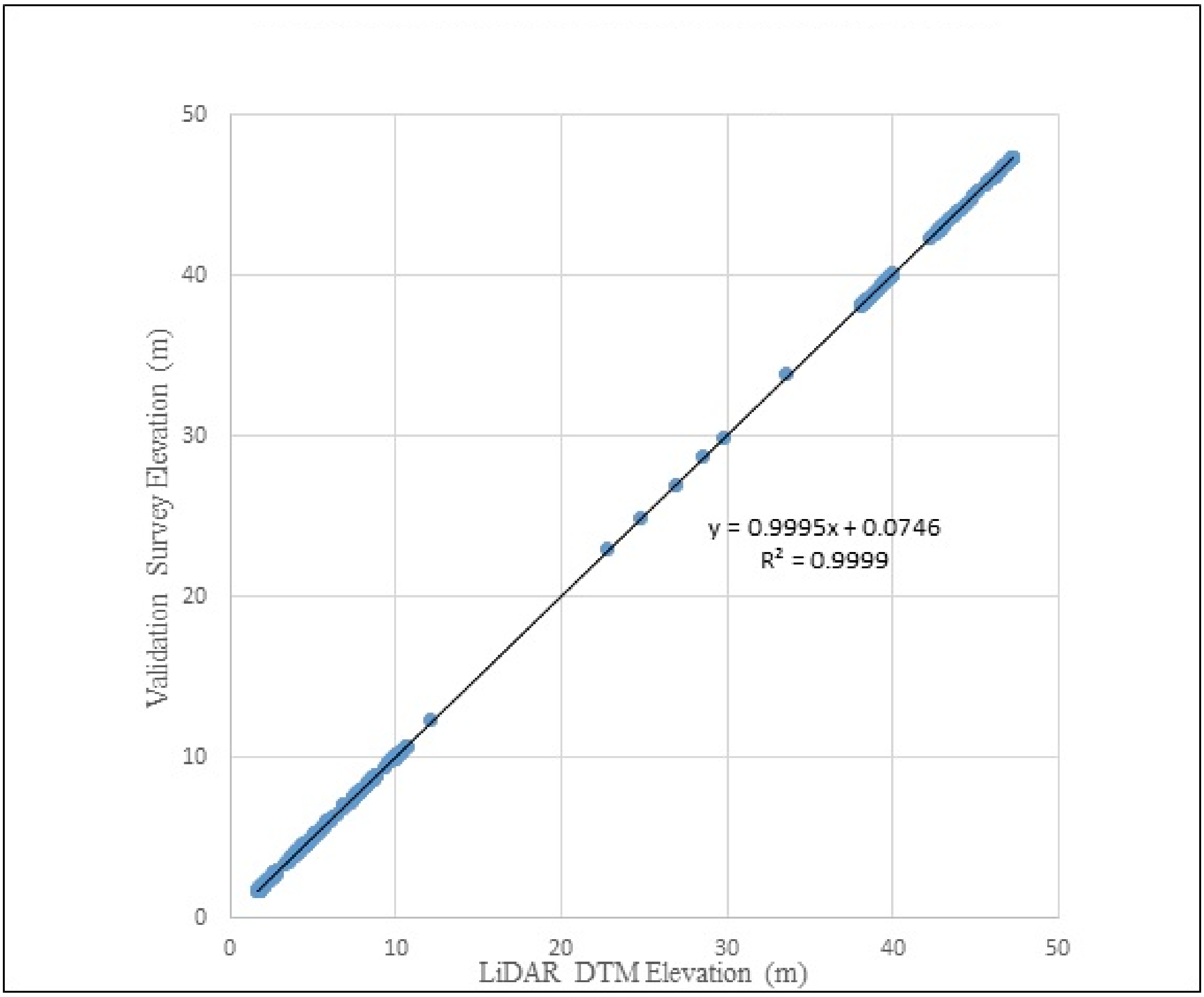

Figure 25. Correlation plot between the validation survey points and the LiDAR data.

Table 15. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.09
Standard Deviation	0.06
Average	-0.07
Minimum	-0.19
Maximum	0.06

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Nauco Aguada with a total of 5,535 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.46 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Nauco Aguada integrated with the processed LiDAR DEM is shown in Figure 26.

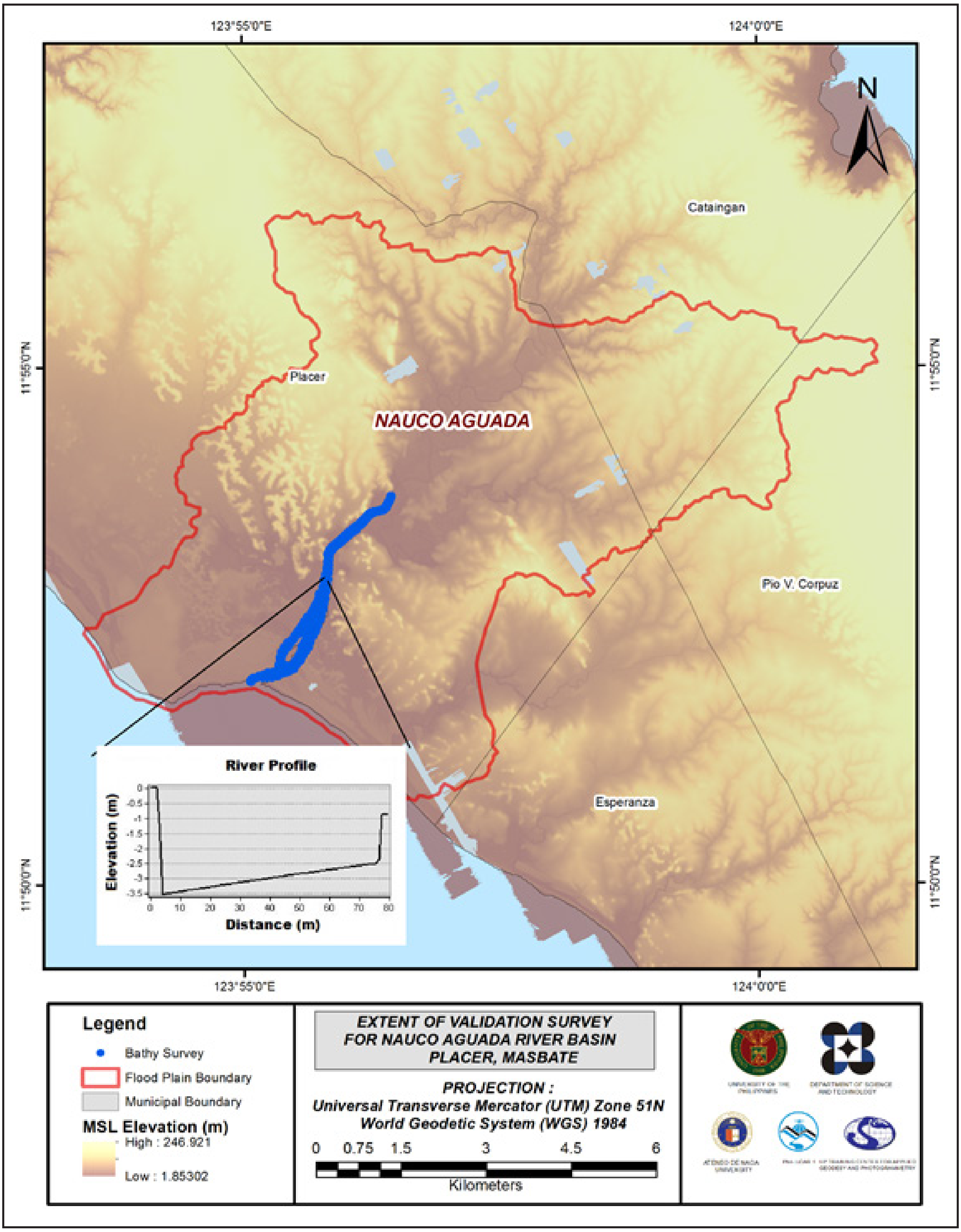

Figure 26. Map of Nauco Aguada floodplain with bathymetric survey points in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Nauco Aguada floodplain, including its 200-m buffer, has a total area of 77.56 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 2,300 building features, were considered for QC. Figure 27 shows the QC blocks for the Nauco Aguada floodplain.

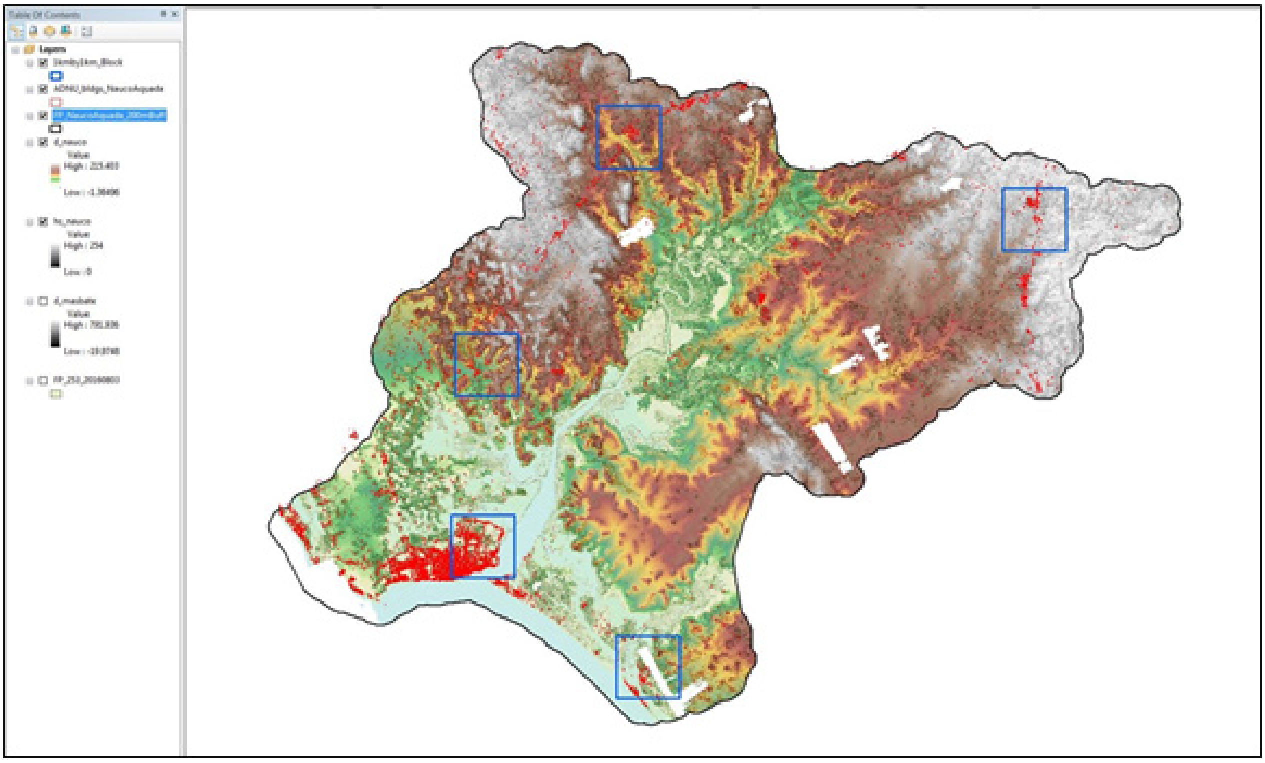

Figure 27. Blocks (in blue) of Nauco Aguada building features that were subjected to QC.

Quality checking of Nauco Aguada building features resulted in the ratings shown in Table 16.

Table 16. Details of the quality checking ratings for the building features extracted for the Nauco Aguada River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Nauco Aguada	99.91	99.96	99.45	PASSED

3.12.2 Height Extraction

Height extraction was done for 8,960 building features in Nauco Aguada floodplain. Of these building features, 310 was filtered out after height extraction, resulting to 8,650 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 12.79 meters.

3.12.3 Feature Attribution

Feature Attribution was done for 8,650 building features in Nauco Aguada Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

Table 17 summarizes the number of building features per type, while Table 18 shows the total length of each road type. Table 19, on the other hand, shows the number of water features extracted per type.

Table 17. Building Features Extracted for Baleno Floodplain.

Facility Type	No. of Features
Residential	8328
School	155
Market	54
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	27
Barangay Hall	15
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	5
Water Supply/Sewerage	0
Religious Institutions	14
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	8
Other Commercial Establishments	42
Total	8,650

Table 18. Total length of extracted roads for Nauco Aguada Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Nauco Aguada	35.53	0	0	12.69	0	48.22

Table 19. Number of extracted water bodies for Nauco Aguada Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Nauco Aguada	1	57	0	0	0	58

A total of 2 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

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

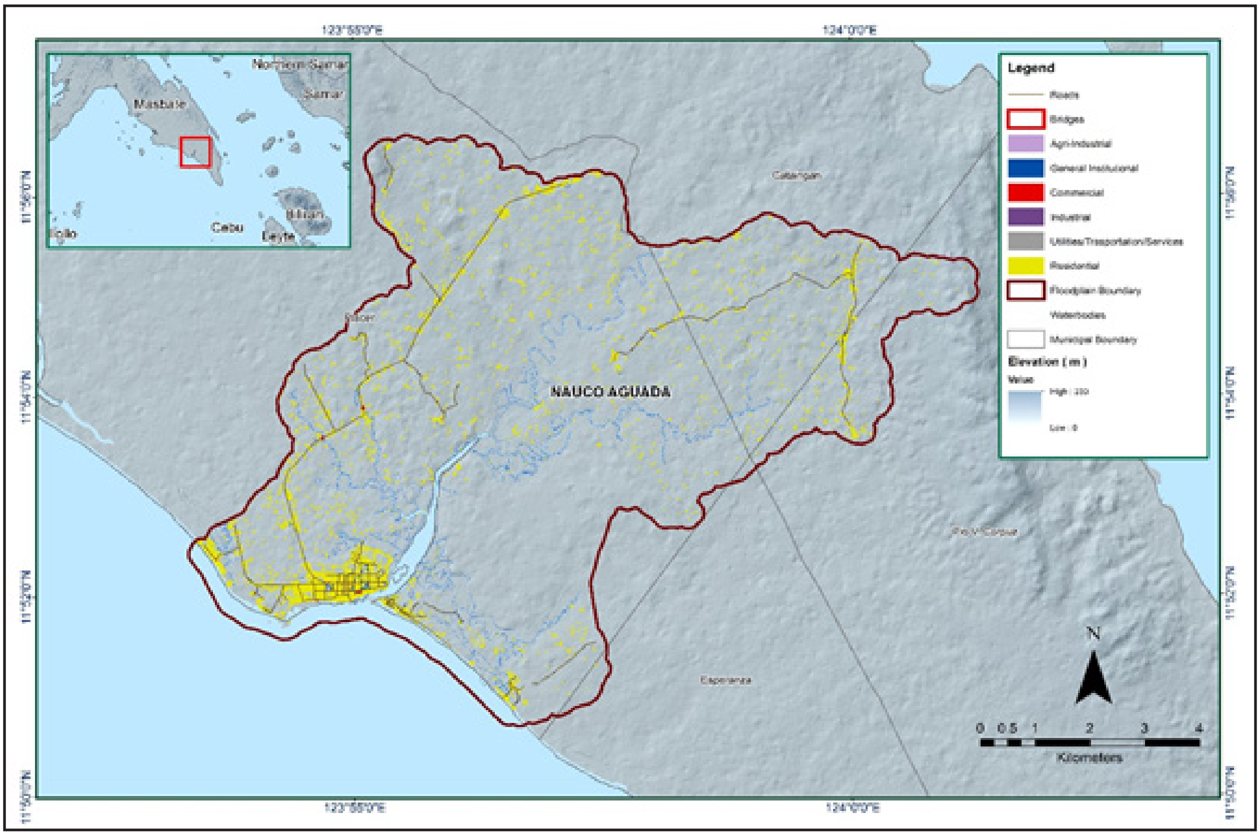

Figure 28. Extracted features of the Nauco Aguada Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, and Vie Marie Paola M. Rivera

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

H.O. Noveloso Surveying (HONS) conducted a field survey in Nauco Aguada River on Jan. 17, 2017, on Feb. 20 to 21, 2017, on Feb. 24, 2017, and on Mar. 13 to 14, 2017 with the following scope: reconnaissance; control survey for the establishment of a control point; and cross-section on the mouth of the river in Brgy. Taboc, Municipality of Placer, Masbate; and bathymetric survey from its upstream in Brgy. Manlut-Od to the mouth of the river located in Brgy. Tubod in Municipality of Placer, Masbate with an approximate length of 4.391 km using a dual frequency Topcon™ GR-5, a Hydrolite™ Single Beam Echo Sounder, and a Sokkia™ Set CX Total Station. Figure 29 illustrates the extent of the Nauco Aguada River Bathymetric Survey.

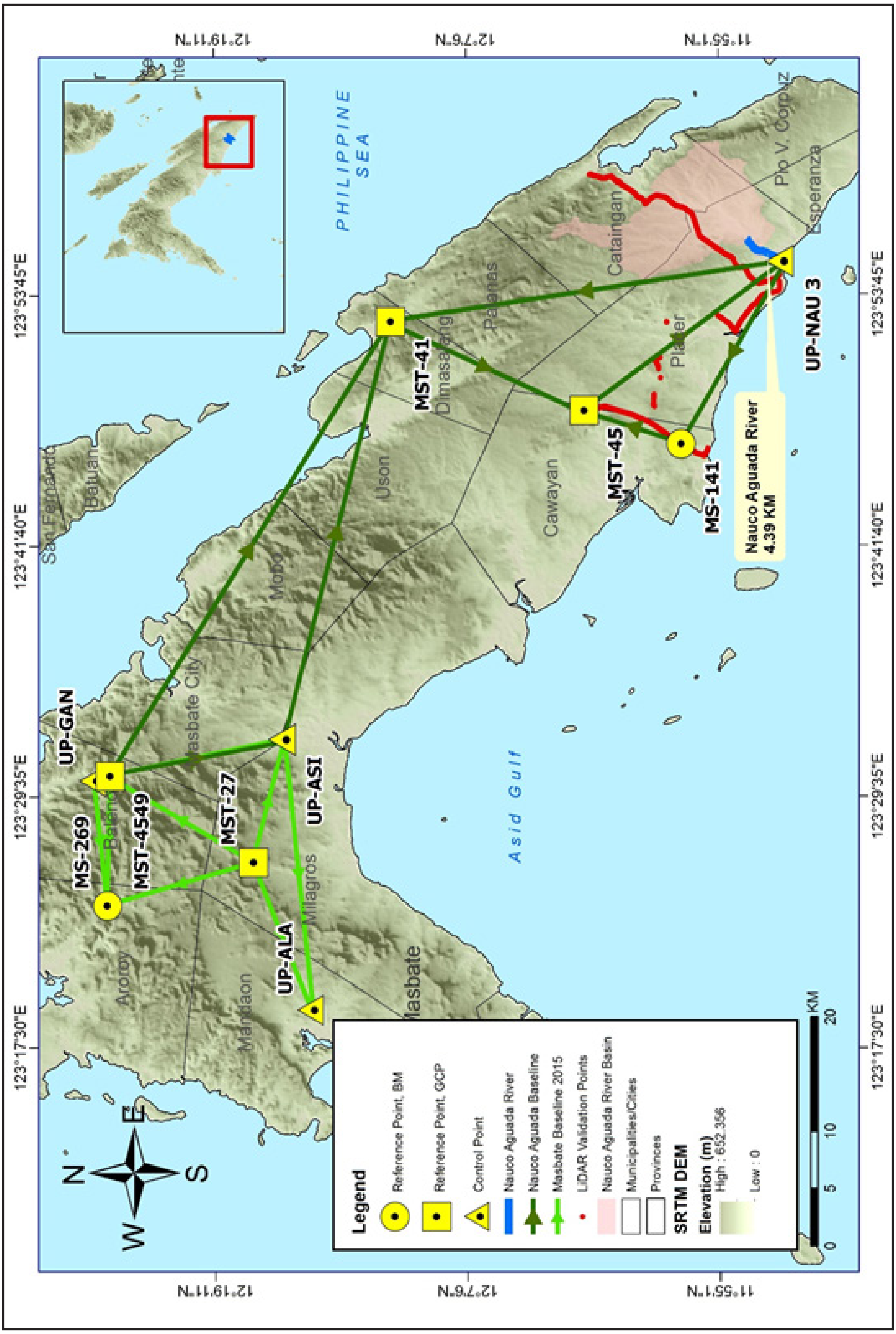

Figure 29. Extent of the bathymetric survey (in blue line) in Nauco Aguada River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Nauco Aguada River Basin is composed of three (3) loops established on January 27 and February 14, 2017 occupying the following reference points: MST-4549, a fixed control from previous field survey in Lanang River located in Brgy. Canjunday, Municipality of Baleno, Masbate; UP-ASI, also a fixed control located in Brgy. Cayabon, Municipality of Milagros, Masbate; and MS-141, a first order BM located in Brgy. San Vicente, Municipality of Cawayan, Masbate.

A GNSS network was established on December 4, 5 and 11, on 2015 for a previous PHIL-LIDAR 1 survey in Lanang River occupying the following reference points: MST-27, a second order GCP in Brgy. Matiporon, Municipality of Milagros, Masbate; and MS-269, a first order BM in Brgy. Luy-A, Municipality of Aroroy, Masbate.

A control point was established namely UP-NAU-3 located near the mouth of the Nauco Aguada River in Brgy, Taboc, Municipality of Placer, Masbate. NAMRIA established control point MST-41 in Brgy. San Vicente, Municipality of Cawayan; and MST-45, in Brgy. Villahermosa, Municipality of Cawayan, Masbate; were also occupied to use as marker during the survey.

Table 20 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 30 shows the GNSS network established in the Nauco Aguada River Survey.

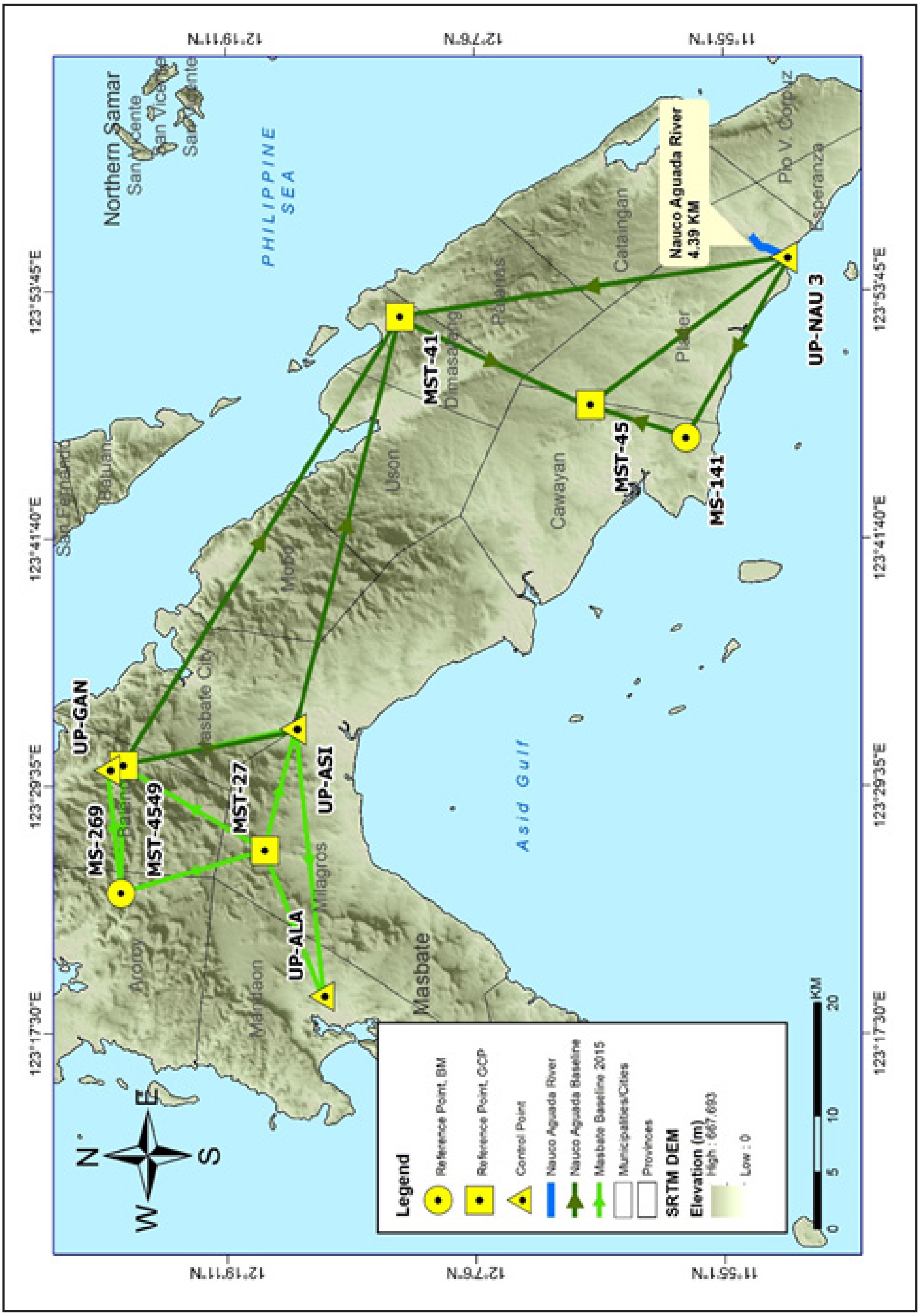

Figure 30. The GNSS Network established in the Nauco Aguada River Survey.

Table 20. References used and control points established in the Nauco Aguada River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey for Lanang River on Dec 4, 5, and 12, 2015						
MST-27	2nd Order GCP	12°17'22.32360"	123°26'26.50548"	109.123	53.606	2007
MS-269	1st Order BM	12°24'21.62817"	123°24'21.39816"	82.132	27.408	2007
Control Survey for Nauco Aguada River on January 27 and February 14, 2017						
MST-4549	Fixed Control	12°24'13.29041"	123°30'36.98735"	76.969	21.829	2013
UP-ASI	Fixed Control	12°15'59.72358"	123°32'20.76940"	66.451	10.476	2007
MS-141	1st Order BM	-	-	-	-	2007
MST-41	Used as Marker	-	-	-	-	2-14-2017
MST-45	Used as Marker	-	-	-	-	1-27-2017
UP-NAU 3	Established	-	-	-	-	1-27-2017

Figure 31 to Figure 36 depict the setup of the GNSS on recovered reference points and established control points in the Nauco Aguada River.

Figure 31. GNSS base set up, Trimble® SPS 985, at MST-4549, located in Brgy. Canjunday, Municipality of Baleno, Masbate.

Figure 32. GNSS receiver setup, Trimble® SPS 985, at UP-ASI, located Brgy. Cayabon, Municipality of Milagros, Masbate.

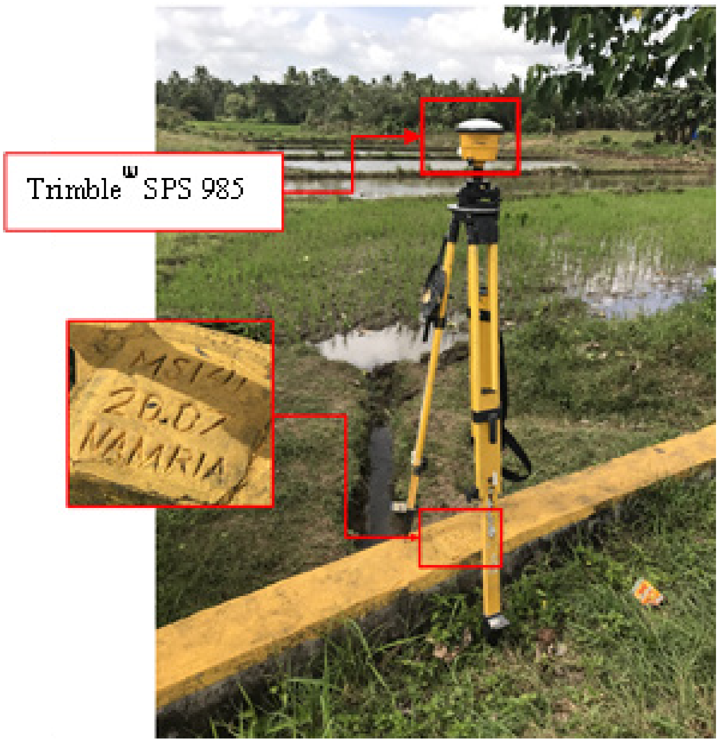

Figure 33. GNSS receiver setup, Trimble® SPS 985, at MS-141, located in Brgy. San Vicente, Municipality of Cawayan, Masbate.

Figure 34. GNSS receiver setup, Trimble® SPS 985, at MST-41, located in Brgy. Gaid, Municipality of Dimasalang, Masbate.

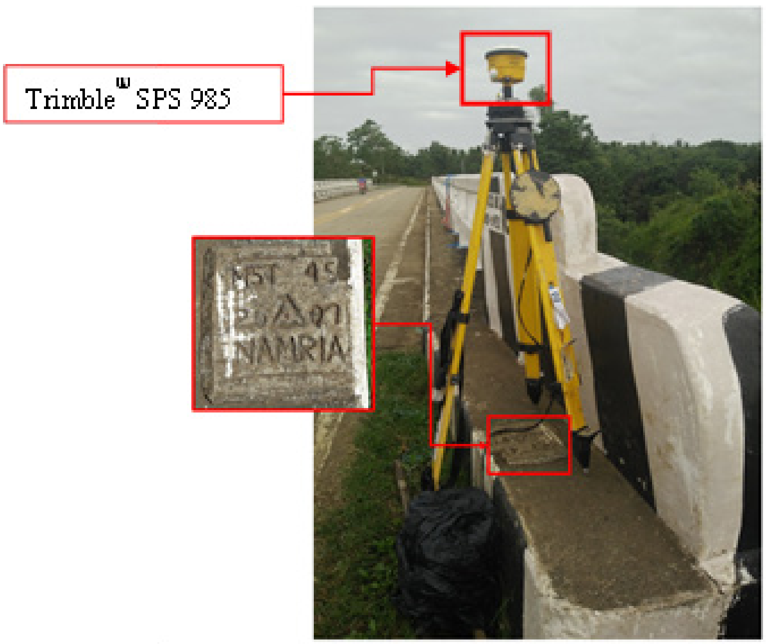

Figure 35. GNSS receiver setup, Trimble® SPS 985, at MST-45, located in Brgy. Villahermosa, Municipality of Cawayan, Masbate.

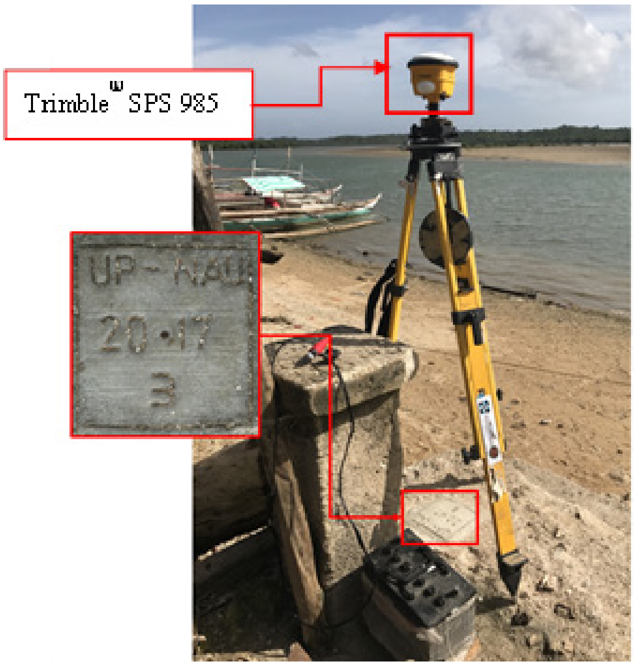

Figure 36. GNSS receiver setup, Trimble® SPS 985, at UP-NAU3, located in Brgy. Taboc, Municipality of Placer, Masbate.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 21 presents the baseline processing results of control points in the Nauco Aguada River Basin, as generated by the TBC software.

Table 21. The Baseline processing report for the Nauco Aguada River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-NAU 3 --- MS-141 (B6)	1-27-2017	Fixed	0.004	0.019	298°53'38"	18166.522	11.403
MS-141 --- MST-45 (B3)	1-27-2017	Fixed	0.004	0.016	18°57'41"	9036.475	2.254
MST-4549 --- UPASI (B8)	1-27-2017	Fixed	0.003	0.014	168°18'59"	15487.632	-10.554
UP-NAU 3 --- MST-41 (B10)	1-27-2017	Fixed	0.003	0.015	351°30'42"	34736.682	4.574
MST-45 --- UP-NAU 3 (B4)	2-14-207	Fixed	0.003	0.014	143°09'49"	21636.574	-13.668
MST-41 --- MST-45 (B11)	2-14-207	Fixed	0.004	0.020	204°41'47"	18750.039	9.089
UP-ASI --- MST-41 (B9)	1-27-2017	Fixed	0.003	0.016	104°48'50"	37813.501	-2.533
MST-4549 --- MST-41 (B7)	1-27-2017	Fixed	0.004	0.019	122°01'41"	46820.813	-13.099

As shown in Table 21, a total of eight (8) baselines were processed with reference points MST-4549 and UP-ASI held fixed for coordinate values; and, MST-4549, MS-ASI, and UP-ASI fixed for elevation values; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 22 to Table 25.

The six (6) control points, MST-4549, MST-41, MST-45, MS-141, UP-ASI, and, UP-NAU-3 were occupied and observed simultaneously to form a GNSS loop. Coordinates of MST-4549 and UP-ASI; and elevation values of MST-4549, MS-141, and UP-ASI were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MS-141	Grid				Fixed
MST-4549	Grid	Fixed	Fixed		Fixed
UP-ASI	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001 (Meter)					

Likewise, 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 23. The fixed controls MST-4549 and UP-ASI have no values for grid errors while MST-4549, MS-141, and UP-ASI have no value for elevation error.

Table 23. Adjusted grid coordinates for the control points used in the Nauco Aguada River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MST-4549	555464.635	?	1371246.784	?	21.829	?	ENe
MST-41	595192.614	0.004	1346499.397	0.004	7.564	0.045	
MST-45	587415.558	0.005	1329444.427	0.004	15.819	0.017	
MS-141	584504.292	0.005	1320892.702	0.005	13.221	?	e
UP-ASI	558628.712	?	1356091.508	?	10.476	?	ENe
UP-NAU 3	600433.760	0.007	1312170.323	0.006	1.747	0.024	

The results of the computation for accuracy are as follows:

a. MST-4549
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. MST-41
Horizontal Accuracy = $\sqrt{((0.4)^2 + (0.4)^2}$
= $\sqrt{(0.16 + 0.16)}$
= 0.57 < 20 cm
Vertical Accuracy = 4.5 cm < 10 cm

c. MST-45
Horizontal Accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64 < 20 cm
Vertical Accuracy = 1.7 cm < 10 cm

d. MS-141
Horizontal Accuracy = $\sqrt{((0.5)^2 + (0.5)^2}$
= $\sqrt{(0.25 + 0.25)}$
= 0.71 < 20 cm
Vertical Accuracy = Fixed

e. UP-ASI
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

f. UP-NAU 3

Horizontal Accuracy	=	$\sqrt{((0.7)^2 + (0.6)^2}$
	=	$\sqrt{(0.49 + 0.36)}$
	=	0.92 < 20 cm
Vertical Accuracy	=	2.4 cm < 10 cm

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

Table 24. Adjusted geodetic coordinates for control points used in the Nauco Aguada River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
MST-4549	N12°24'13.29041"	E123°30'36.98735"	76.969	?	ENe
MST-41	N12°10'44.36122"	E123°52'30.02722"	64.943	0.045	
MST-45	N12°01'29.95768"	E123°48'11.03606"	73.746	0.017	
MS-141	N11°56'51.84368"	E123°46'33.96438"	71.378	?	e
UP-ASI	N12°15'59.72358"	E123°32'20.76940"	66.451	?	ENe
UP-NAU 3	N11°52'06.32015"	E123°55'19.63857"	60.400	0.024	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 24. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Nauco Aguada River GNSS Static Survey are seen in Table 25.

Table 25. The reference and control points utilized in the Nauco Aguada River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey for Lanang River on December 4, 5 and 12, 2015							
MST-27	2nd Order, GCP	12°17'22.32360"	123°26'26.50548"	109.123	1358609.337	547922.386	53.606
MS-269	1st Order, BM	12°24'21.62817"	123°24'21.39816"	82.132	1371483.424	544123.788	27.408
Control Survey for Nauco Aguada River on January 27 and February 14, 2017							
MST-4549	4th order, GCP	12°24'13.29041"	123°30'36.98735"	76.969	1371246.784	555464.635	21.829
MST-41	Used as Marker	12°10'44.36122"	123°52'30.02722"	64.943	1346499.397	595192.614	7.564
MST-45	Used as Marker	12°01'29.95768"	123°48'11.03606"	73.746	1329444.427	587415.558	15.819
MS-141	1st order, BM	11°56'51.84368"	123°46'33.96438"	71.378	1320892.702	584504.292	13.221
UP-ASI	UP established	12°15'59.72358"	123°32'20.76940"	66.451	1356091.508	558628.712	10.476
UP-NAU3	UP established	11°52'06.32015"	123°55'19.63857"	60.4	1312170.323	600433.760	1.747

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

The bridge cross-section and as-built surveys were conducted on February 11, 2017 at the mouth of Nauco Aguada River in Brgy. Taboc, Placer, Masbate as shown in Figure 37. A Topcon™ GR-5 GPS was utilized for this survey.

Figure 37. Cross-section survey at the mouth of Nauco Aguada River.

The cross-sectional line of Nauco Aguada Bridge is about 74 meters with 146 points acquired using the control point UP-NAU-3 as GNSS base station. The cross-section diagram and location map are shown in Figure 38 and Figure 39, respectively.

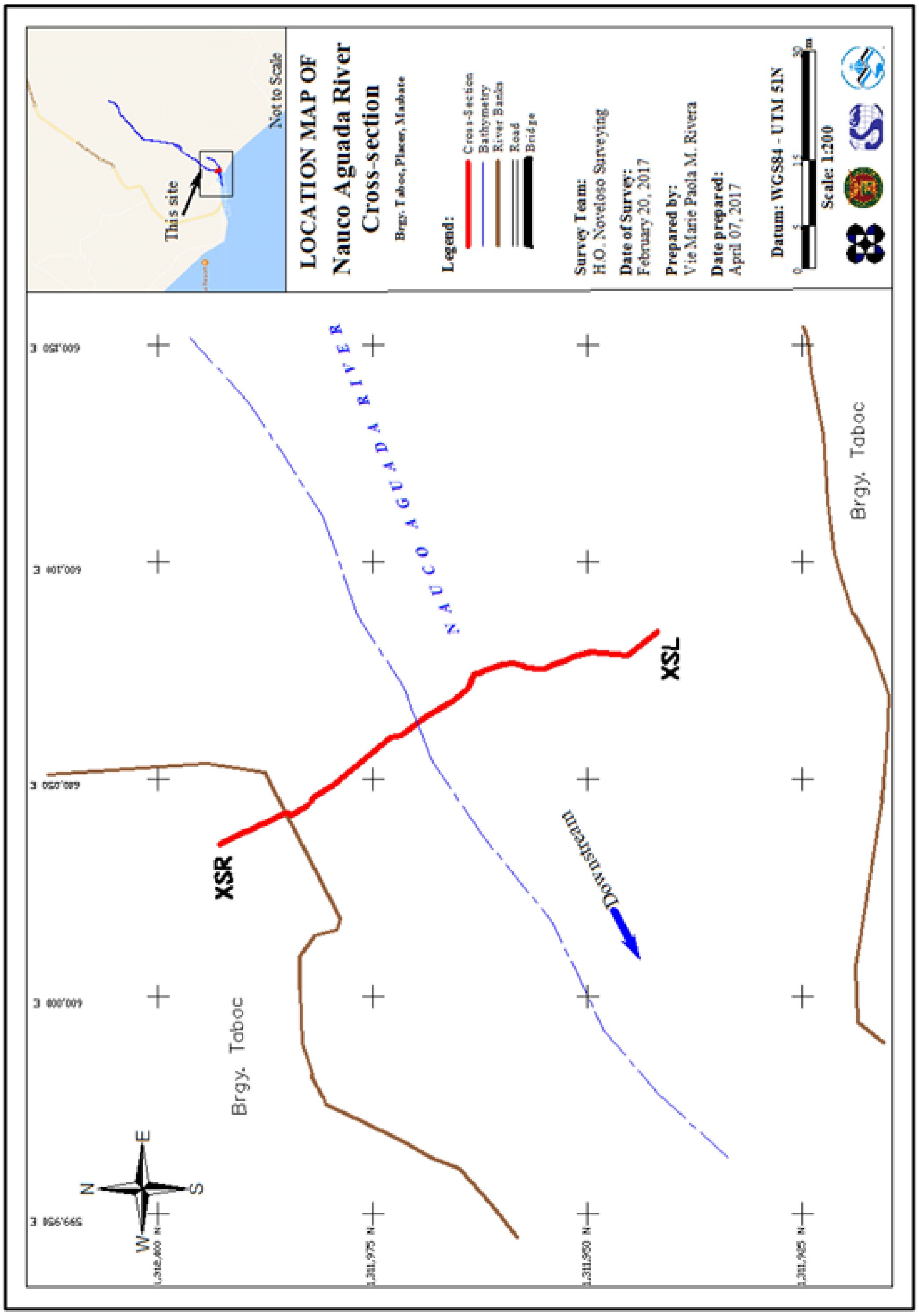

Figure 38. Cancahorao bridge cross-section location map

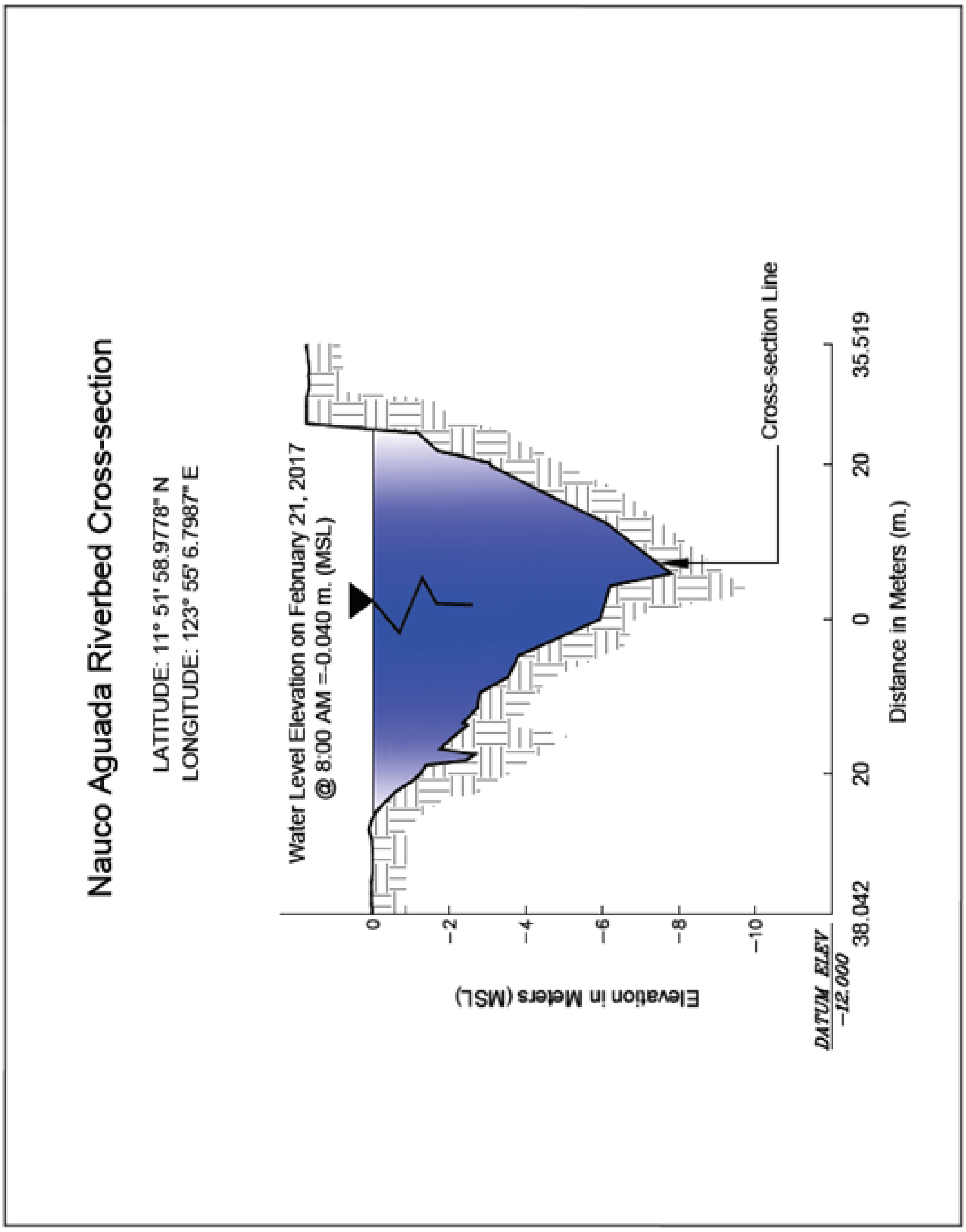

Figure 39. . The Nauco Aguada cross-section survey drawn to scale.

The water surface elevation of Nauco Aguada River was determined by a Topcon™ GR-5 GPS on February 20, 2017 at the pier in Brgy. Taboc, Placer, Masbate with a value of 1.735 m in MSL. This was translated into marking near the pier's bollard as shown in Figure 40. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Nauco Aguada River, the Ateneo de Naga University.

Figure 40. Water level markings along Nauco Aguada River.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by DVBC on January 28, 2017 using a survey grade GNSS Rover receiver, Trimble® SPS 882, which was attached on top of the vehicle as shown in Figure 41. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.902 m and measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-NAU-3 occupied as the GNSS base station in the conduct of the survey.

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

The first day of the validation points acquisition survey ran from Mabuaya Bridge in Brgy. Matiporon, Milagros to Brgy. Poblacion, Aroroy via Baleno in an almost semi-circumferential route. The reference point MST-4549 was utilized during this survey. The second day of this survey also started in Mabuaya Bridge going to Brgy. Poblacion in Aroroy via Mandaon, the opposite side of the circumferential road. It also covered Mandaon Road which started from Brgy. Mabatobato going southwest towards Brgy. Nailaban, both in the Municipality of Mandaon. The reference point MST-27 was used as base station for the last route.

A total of 4,673 points with approximate length of 46.08 km using MST-27 as GNSS base station for the entire extent of validation points acquisition survey, as illustrated in the map in Figure 42.

Figure 42. The extent of the LiDAR ground validation survey (in red) for Nauco Aguada River Basin.

4.7 River Bathymetric Survey

Bathymetric survey was conducted on February 20-21, 2017, February 24, 2017, and March 13-14, 2017 using a dual frequency Topcon™ GR-5 GPS and a Hydrolite™ Single Beam Echo Sounder mounted in a motor boat as shown in Figure 43. The survey started in Brgy. Manlut-Od in the Municipality of Placer, with coordinates 11°53'45.3731"N, 123°56'26.0624"E and ended at the mouth of the river in Brgy. Taboc, Placer, Masbate, with coordinates 11°51' 58.6223"N, 123°55' 05.6055"E.

Figure 43. Set-up of the bathymetric survey in Nauco Aguada River conducted by H.O. Noveloso Surveying.

A manual bathymetric survey was executed on Feb. 20 to 21, 2017, on Feb. 24, 2017, and on Mar. 13, 2017 using a Sokkia™ Set CX Total Station as illustrated in Figure 44. The manual bathymetric survey started in Brgy. Taboc, Placer, Masbate with coordinates 11°52'37.7636"N, 123°55'42.7215"E, traversing down the river and ended at the mouth of the river in Brgy. Taboc, with coordinates 11°52'07.8822"N, 123°55'22.5028"E. The control point UP-NAU-3 is used as GNSS base station all throughout the entire survey.

Figure 44. Set-up of the manual bathymetric survey of H.O. Noveloso Surveying along Nauco Aguada River

Gathering of random points for the checking of the H.O. Noveloso Surveying bathymetric data was performed by DVBC on January 30, 2017 using a survey grade GNSS Rover receiver attached to a boat as seen in Figure 45. A map showing the DVBC bathymetric checking points is illustrated in Figure 46.

Figure 45. Gathering of random bathymetric points along Nauco Aguada River conducted by the DVBC.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2 value of 0.973 for the bathymetric data is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.189 for the bathymetric data was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

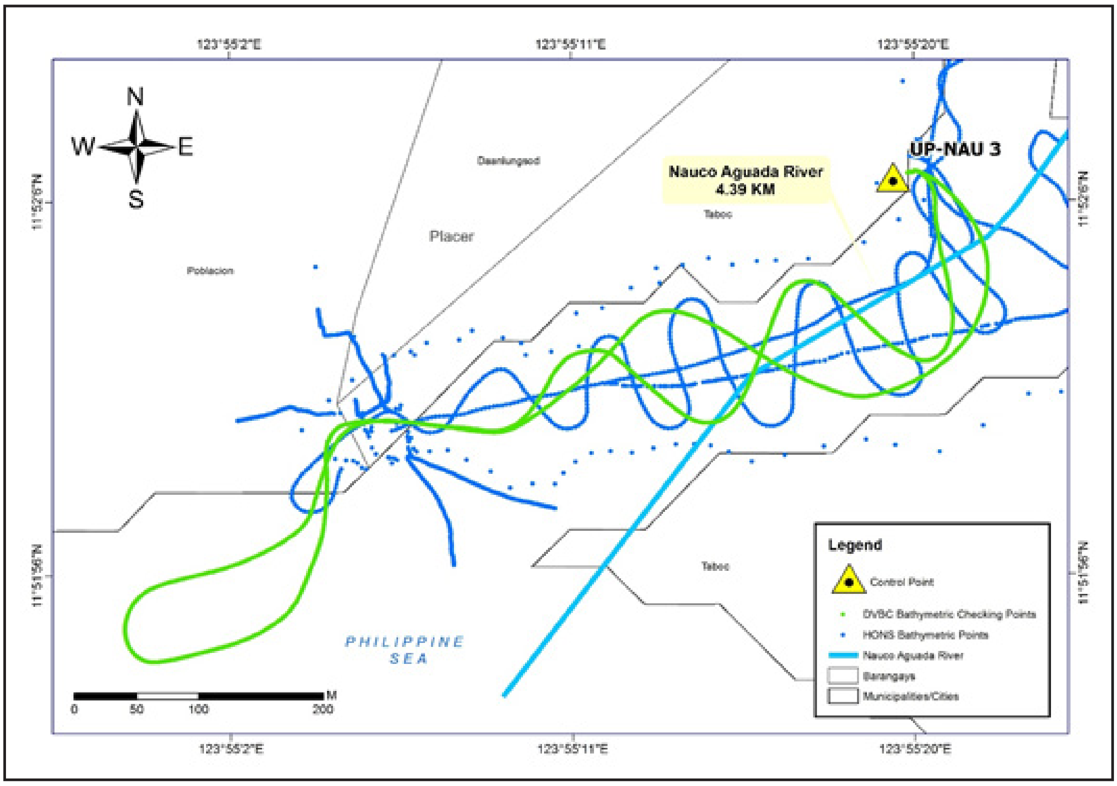

Figure 46. Points used for quality checking gathered by the DBVC along Nauco Aguada River.

The entire bathymetric data coverage for Nauco Aguada River is illustrated in the map in Figure 47. The bathymetric line is approximately 4.39 km in length with 5,715 bathymetric points traversing barangays Daanlungsod, Manlut-Od, Poblacion and Taboc in the Municipality of Placer, Province of Masbate. A CAD diagram was also produced to illustrate the Nauco Aguada riverbed profile as shown in Figure 48. The highest and lowest elevation has a 6.688 m difference. The highest elevation observed was 0.039 m above MSL located in Brgy. Taboc, Placer Municipality, Masbate; while the lowest was -6.649 m below MSL located in Brgy. Poblacion, also in the Municipality of Placer.

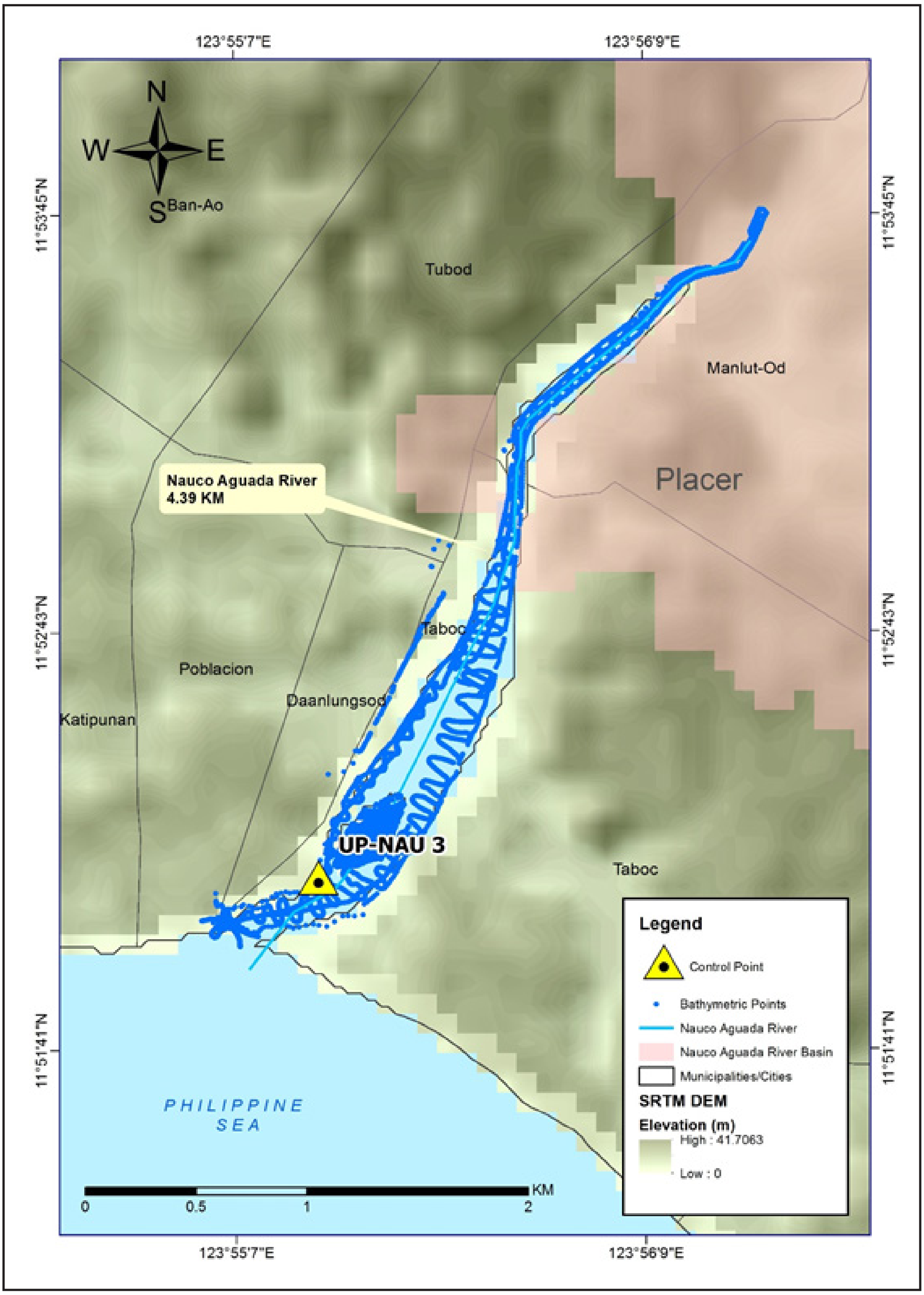

Figure 47. The extent of the Nauco Aguada River Bathymetry Survey.

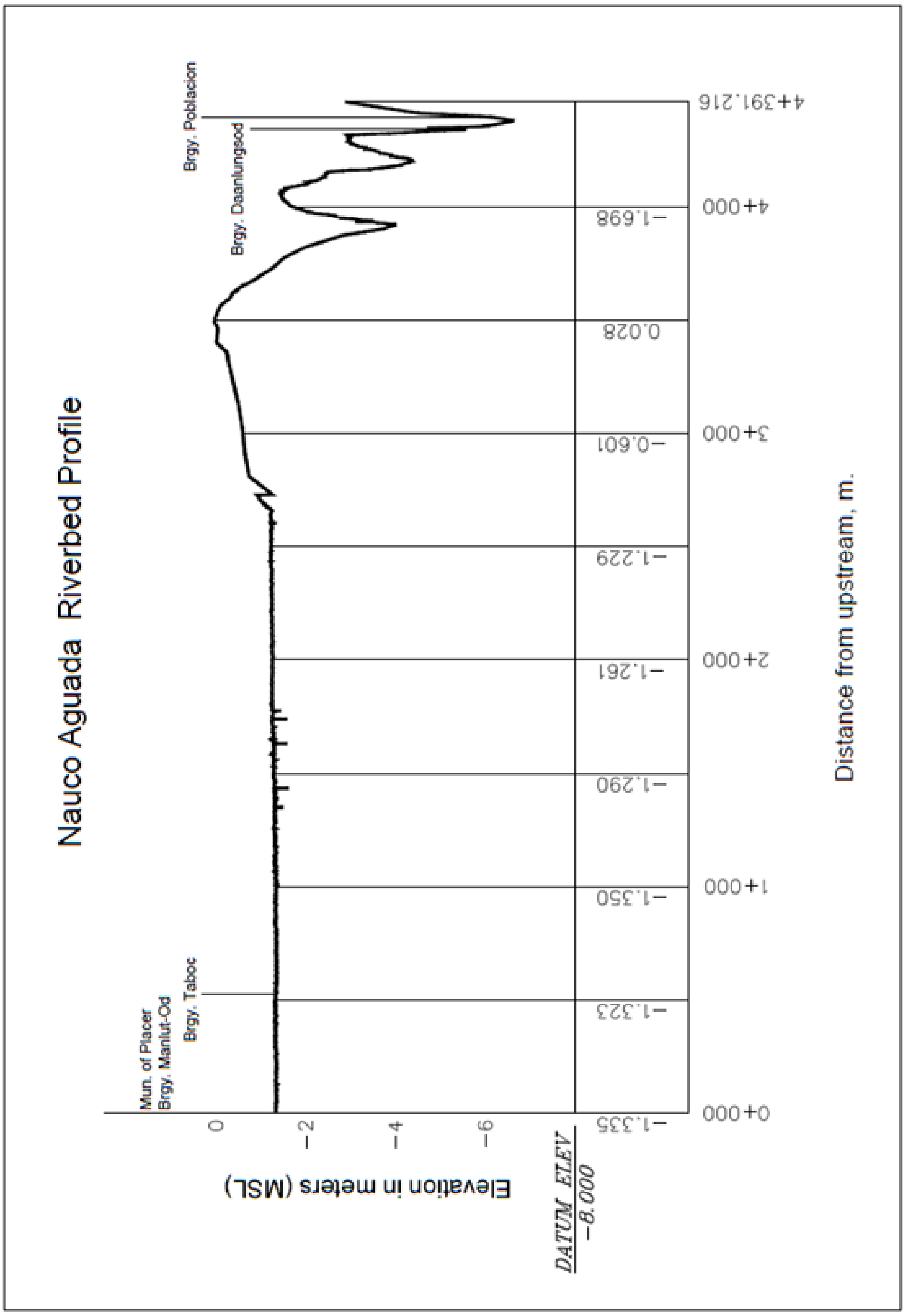

Figure 48. The Nauco Aguada Riverbed Profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute as illustrated in Figure 49. The precipitation data collection started from December 06, 2014 at 12:00 AM to December 09, 2014 at 4:00 PM with a 10-minute recording interval.

The total precipitation for this event in Tagaytay Bridge ARG is 26.6mm. It has a peak rainfall of 5mm on December 08, 2014 at 11:30 AM. The lag time between the peak rainfall and discharge is 14 hours.

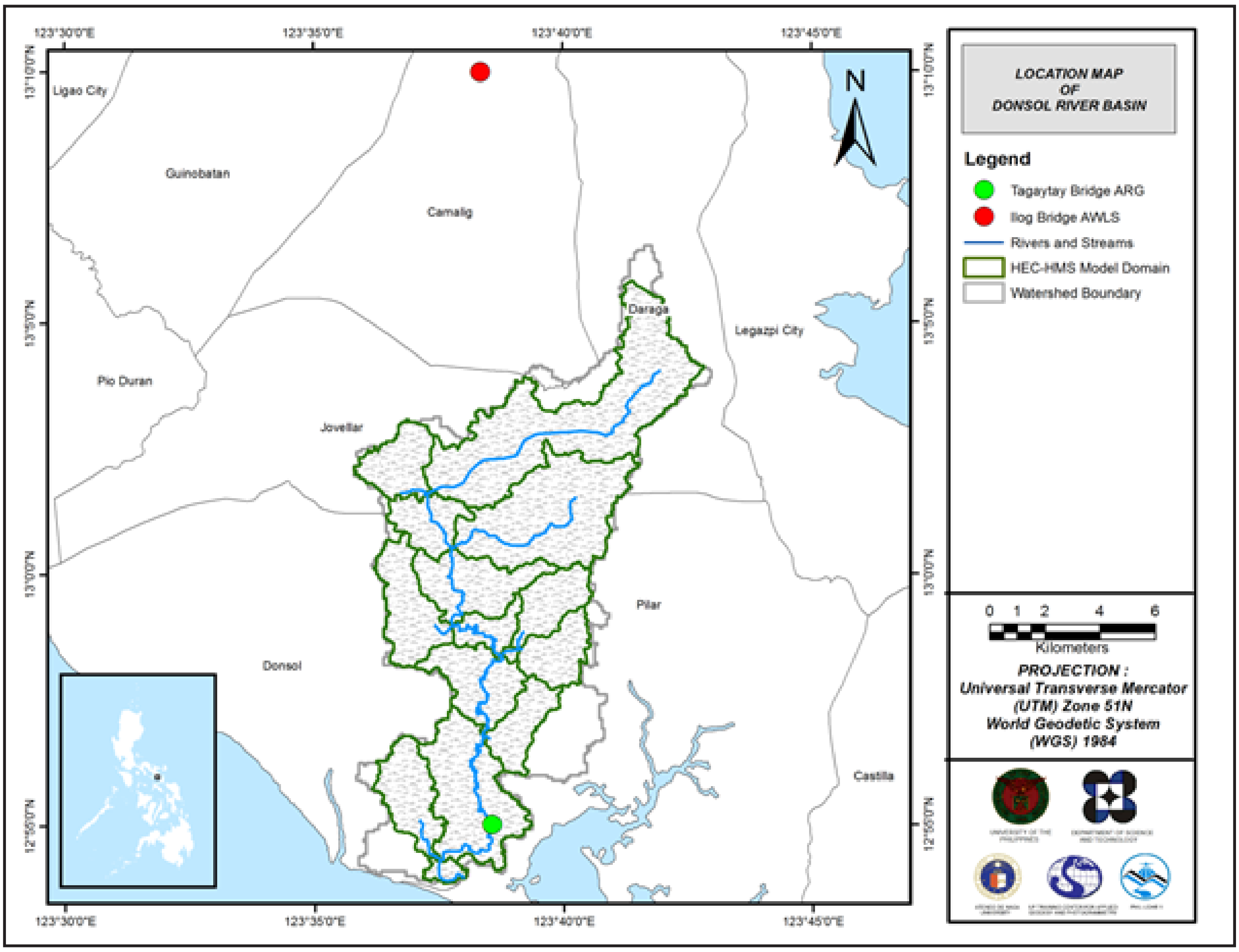

Figure 49. Location Map of the Nauco Aguada HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Nauco Aguada Bridge, Nauco Aguada, Camarines Sur (13°49'14.6"N, 122°47'41.3"E) to establish the relationship between the observed water levels (H) at Nauco Aguada Bridge and outflow (Q) of the watershed at this location.

For Nauco Aguada Bridge, the rating curve is expressed as Q = 18.27e0.3135h as shown in Figure 50.

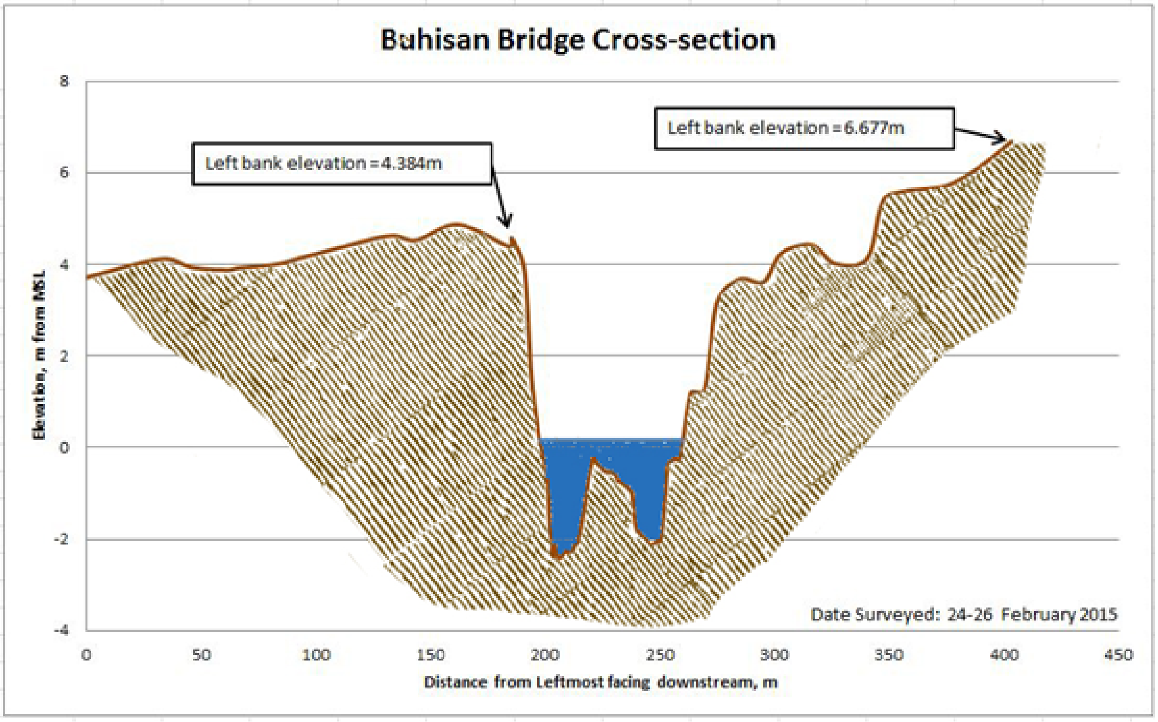

Figure 50. The cross-section plot of the Buhisan Bridge.

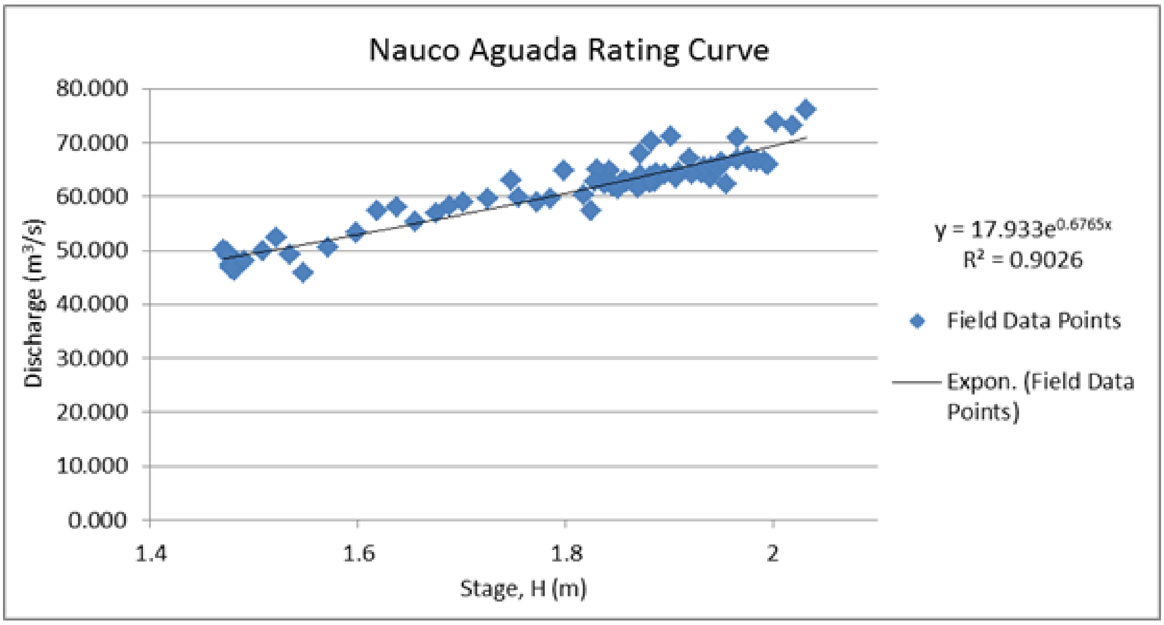

Figure 51. The rating curve of Nauco Aguada Bridge in Nauco Aguada, Masbate.

This rating curve equation was used to compute the river outflow at Nauco Aguada Bridge for the calibration of the HEC-HMS model shown in Figure 49. The total rainfall for this event is 27.8mm and the peak discharge is 51.2 m3/s at 2:30 AM, December 26, 2016.

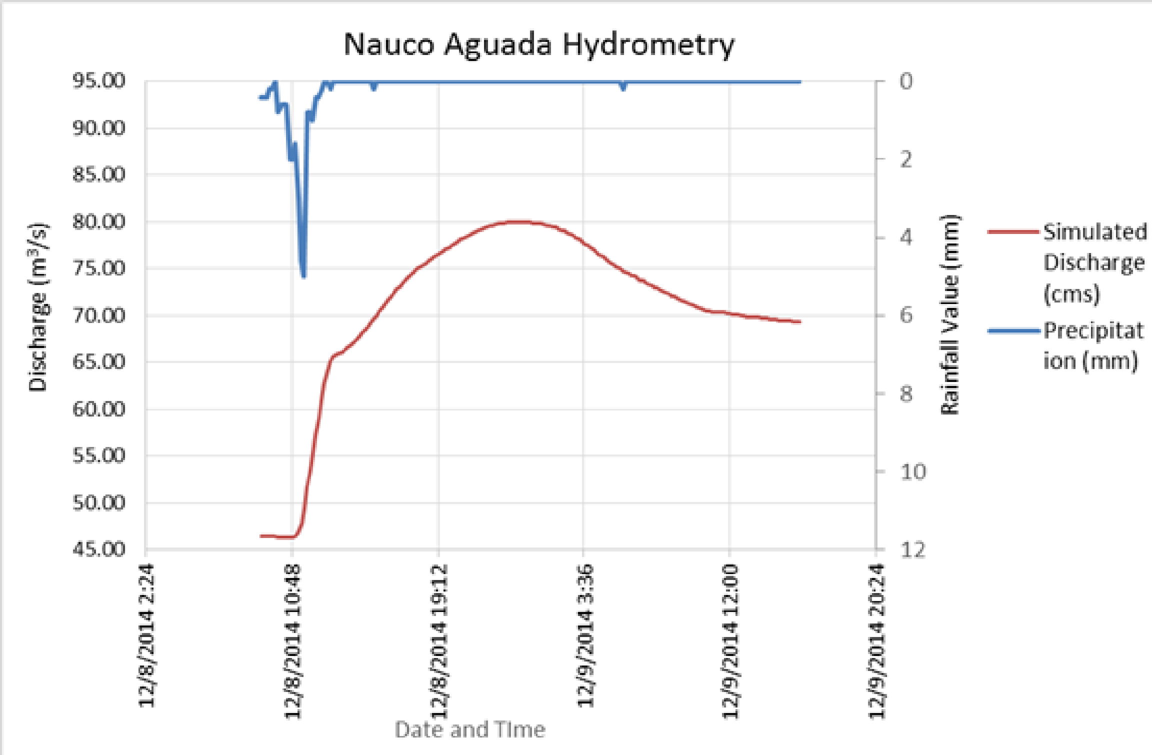

Figure 52. Rainfall and outflow data at the Nauco Aguada Bridge of the Nauco Aguada River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Catarman RIDF (Table 26). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 53). This station was selected based on its proximity to the Nauco Aguada watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 26. RIDF values for the Nauco Aguada River Basin as computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	22.5	34.2	42.4	57.5	80.9	96.4	125.2	156.6	180
5	29.9	45.4	56.2	77	110.3	135.9	183.5	229.5	255.4
10	34.7	52.8	65.4	90	129.7	162	222.1	277.8	305.4
15	37.5	57	70.5	97.3	140.7	176.7	243.9	305.1	333.6
20	39.4	60	74.2	102.4	148.4	187.1	259.1	324.1	353.3
25	40.9	62.2	76.9	106.3	154.3	195	270.9	338.8	368.5
50	45.5	69.2	85.5	118.4	172.6	219.5	307.1	384.1	415.3
100	50	76.1	94	130.5	190.7	243.8	343	429	461.8

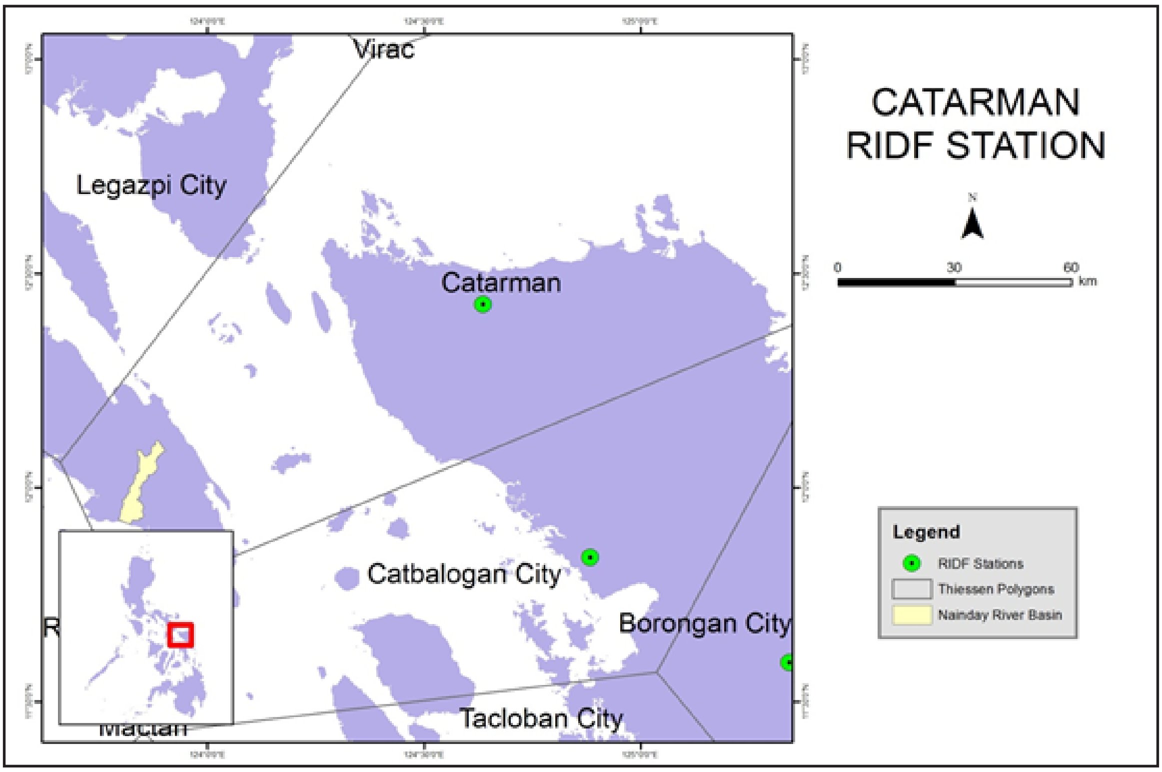

Figure 53. The location of the Catarman RIDF station relative to the Nauco Aguada River Basin.

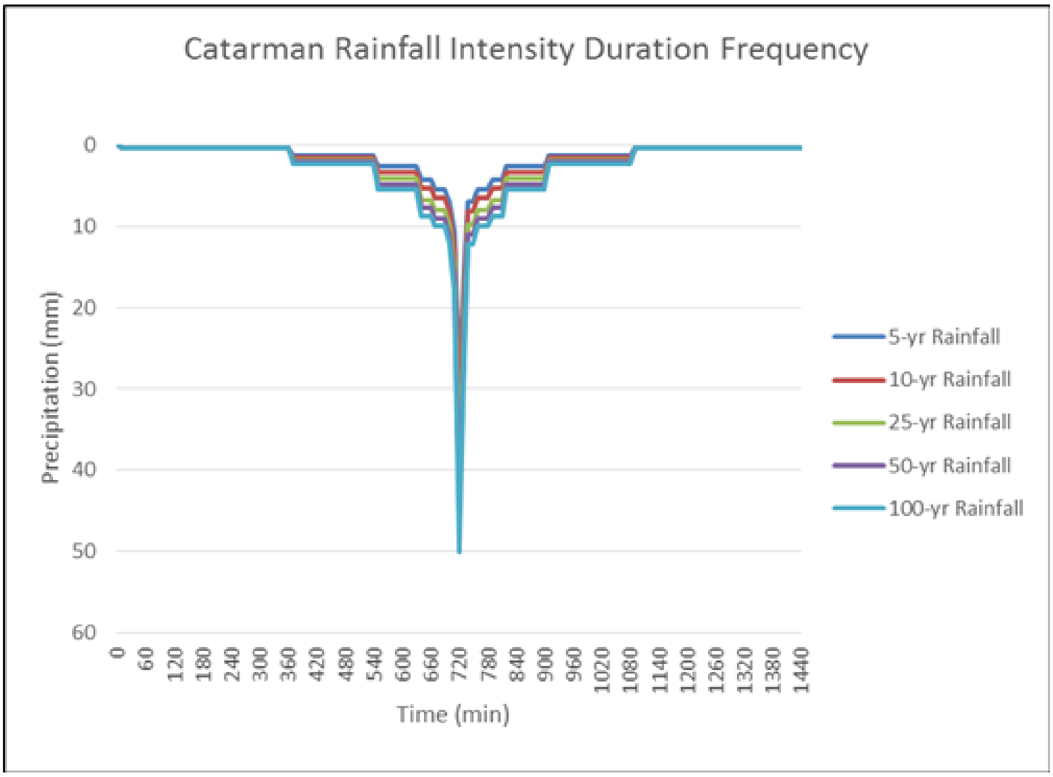

Figure 54. The synthetic storm generated for a 24-hour period rainfall for various return periods.

5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is 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 Nauco Aguada River Basin are shown in Figure 55 and Figure 56, respectively.

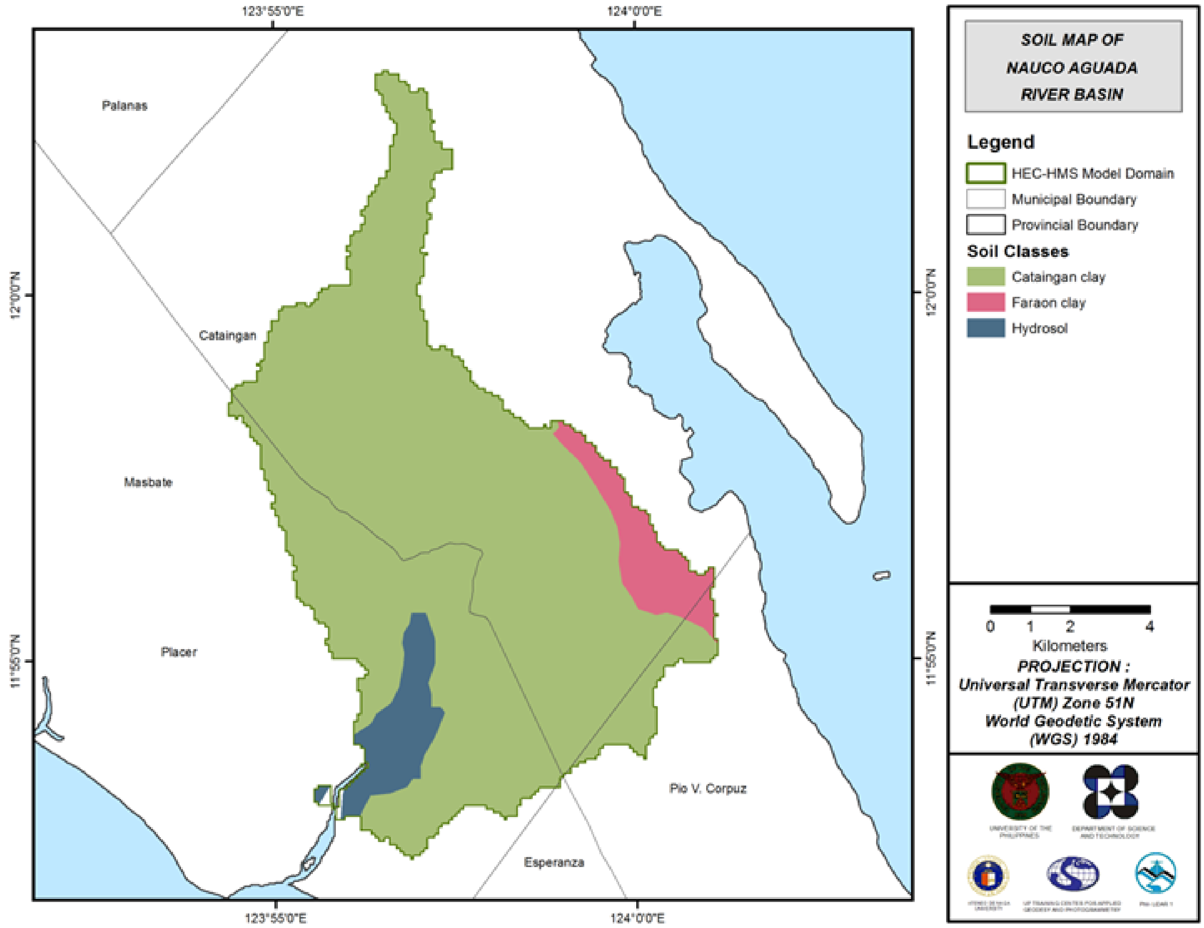

Figure 55. Soil Map of Nauco Aguada River Basin.

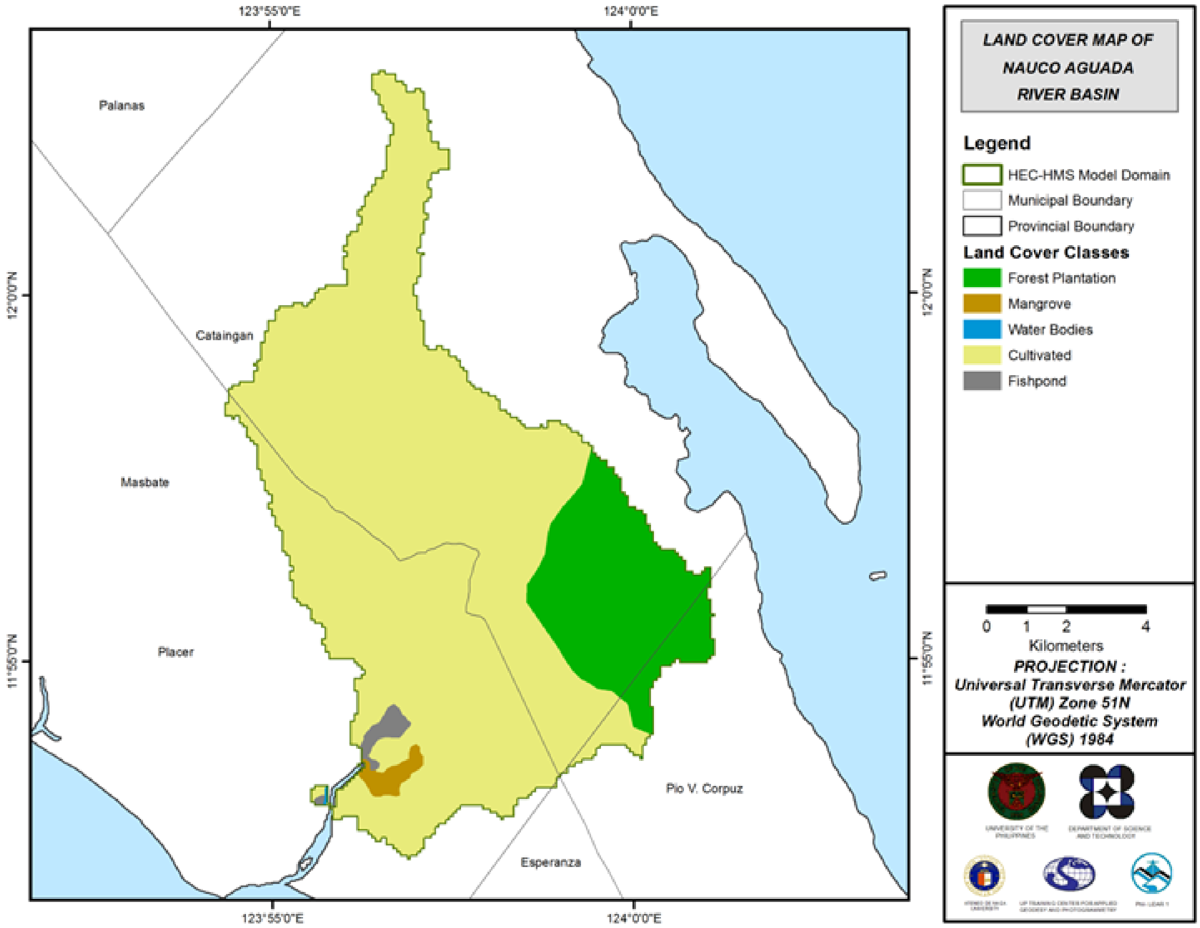

Figure 56. Land Cover Map of Nauco Aguada River Basin.

For Nauco Aguada, three (3) soil classes were identified. These are Cataingan clay, Faraon clay, and hydrosol. Moreover, five (5) land cover classes were identified. These are forest plantation, mangrove, water bodies, fishpond, and cultivated areas.

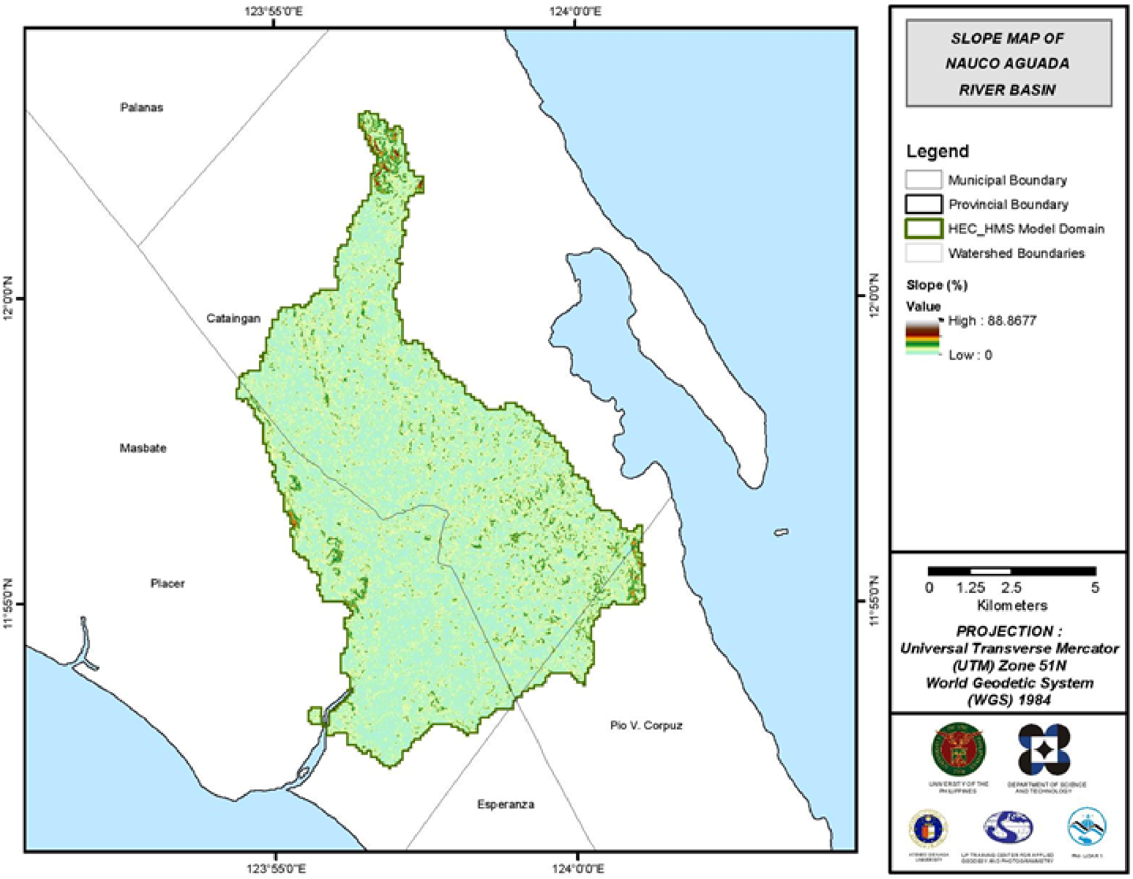

Figure 57. Slope Map of the Nauco Aguada River Basin.

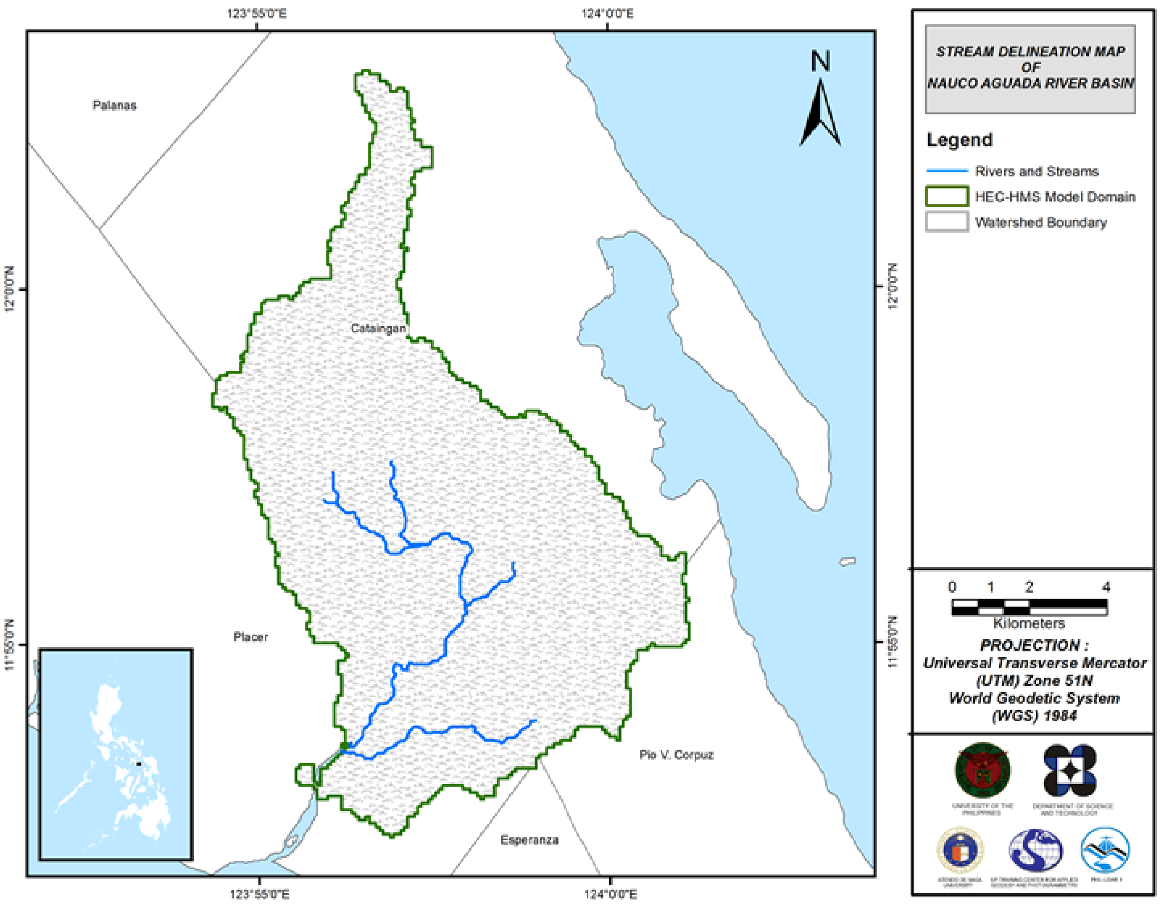

Figure 58. Stream Delineation Map of Nauco Aguada River Basin.

Using the SAR-based DEM, the Nauco Aguada basin was delineated and further divided into subbasins. The model consists of 12 sub basins, 6 reaches, and 6 junctions, as shown in Figure 59. The main outlet is at Nauco Aguada Bridge.

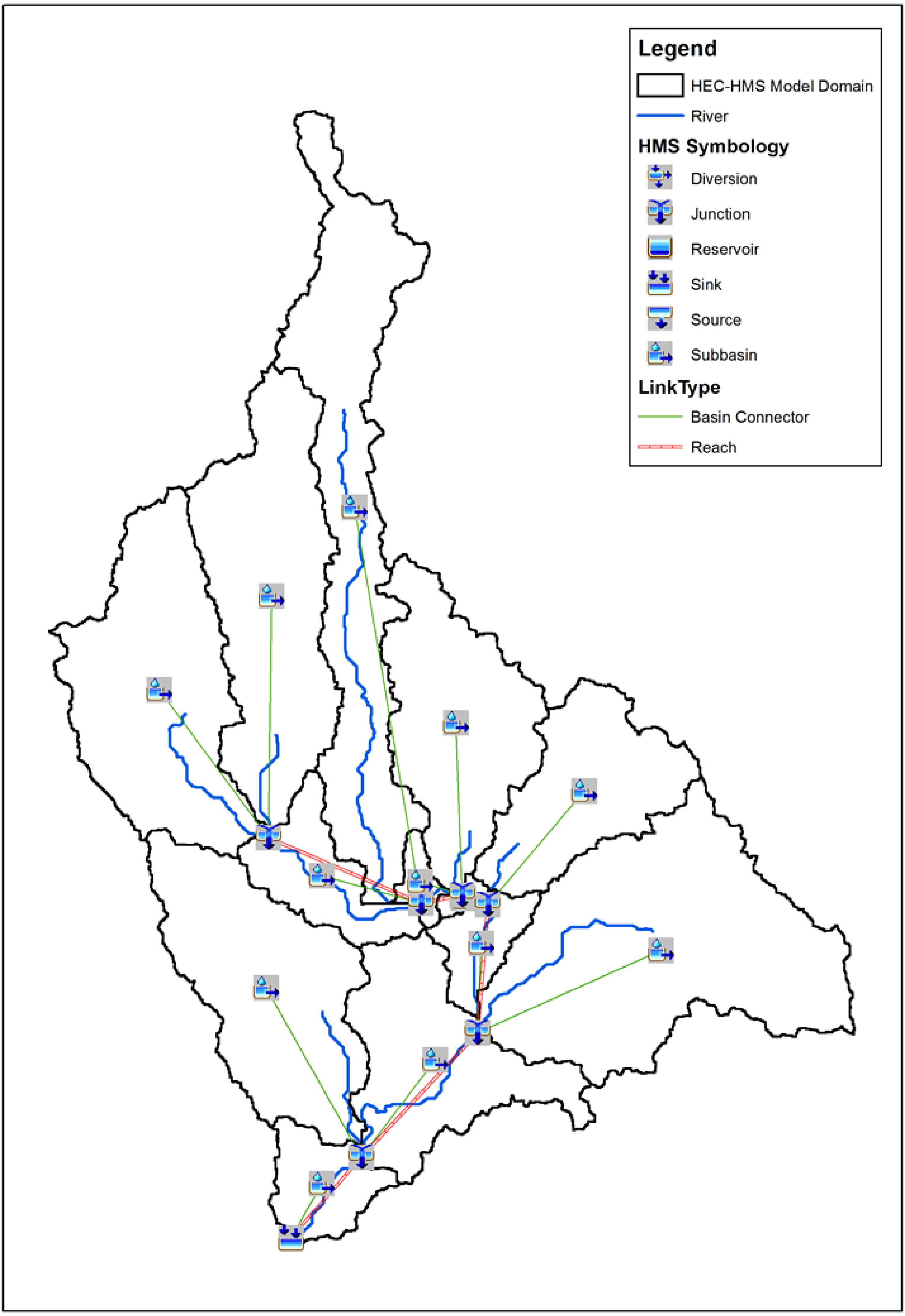

Figure 59. The Nauco Aguada river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

This image is not available for this floodplain.

Figure 60. River cross-section of the Nauco Aguada River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

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

Figure 61. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 7.38956 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Nauco Aguada are in Figure 65, Figure 67, and Figure 69.

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 18,483,300.00 m2. The generated flood depth maps for Nauco Aguada are in Figure 66, Figure 68, and Figure 70.

There is a total of 5,612,454.24.98 m3 of water entering the model. Of this amount, 5,077,846.89 m3 is due to rainfall while 53,460,735.47 m3 is inflow from other areas outside the model. 1,848,957.62 m3 of this water is lost to infiltration and interception, while 2,974,990.80 m3 is stored by the flood plain. The rest, amounting up to 788,466.18 m3, is outflow.

5.6 Results of HMS Calibration

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

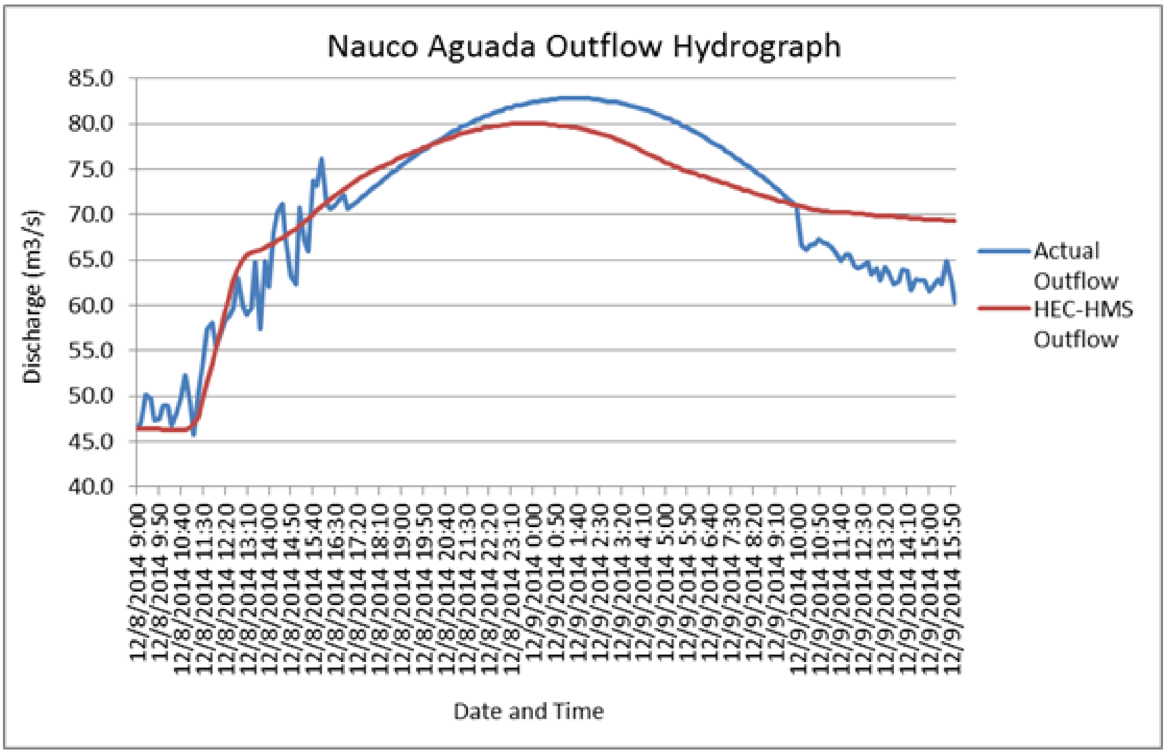

Figure 62. Outflow Hydrograph of Nauco Aguada produced by the HEC-HMS model compared with observed outflow.

Table 27 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of calibrated values for the Nauco Aguada River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001-2
			Curve Number	53-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-0.5
			Storage Coefficient (hr)	0.02-8
	Baseflow	Recession	Recession Constant	0.0004-0.02
			Ratio to Peak	0.01-0.7
Reach	Routing	Muskingum-Cunge	Slope	0.0002-0.008
			Manning's n	0.004-1

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 0.0001mm to 2mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

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 53 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Nauco Aguada, the basin mostly consists of grassland and the soil consists of Alimodian clay loam, Luisiana clay loam, and Faraon clay.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 8 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. For Nauco Aguada, it will take at least 6 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 1 corresponds to the common roughness in Nauco Aguada watershed, which is determined to be mangrove forest with trees with heavy stand that flow into branches (Brunner, 2010).

Table 28. Summary of the Efficiency Test of the Nauco Aguada HMS Model

Accuracy measure	Value
RMSE	2.39
r2	0.82
NSE	0.82
PBIAS	1.05
RSR	0.42

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 2.39 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.82.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.82.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.05.

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 0.42.

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 58) shows the Nauco Aguada outflow using the Catarman Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

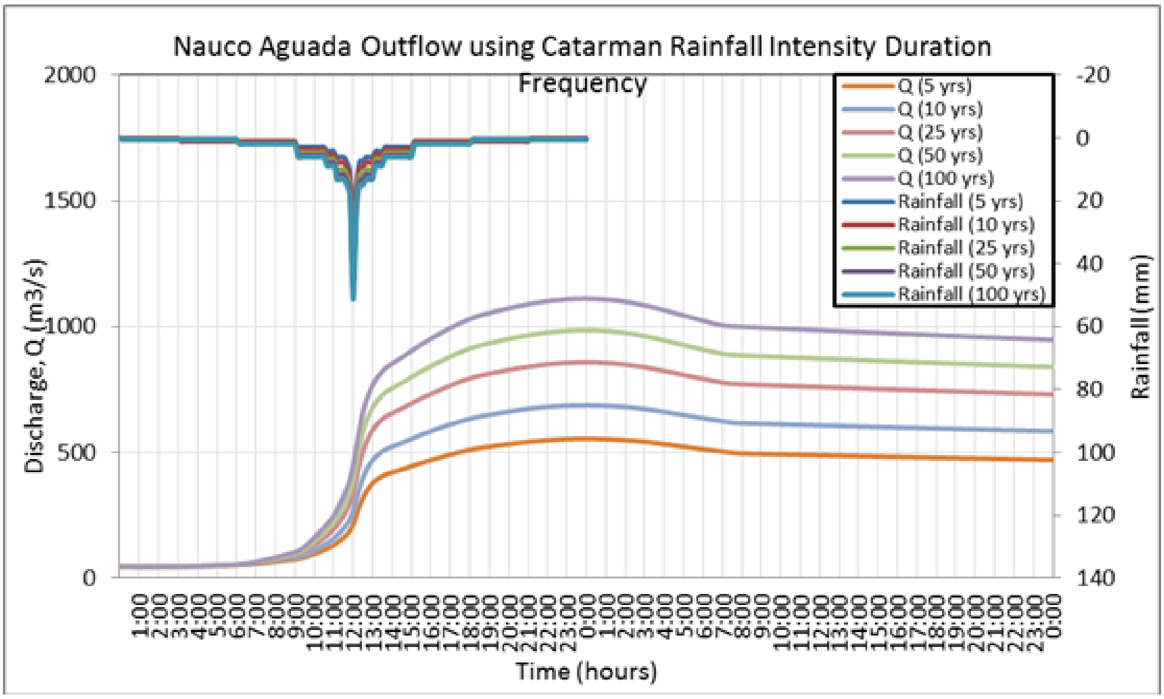

Figure 63. The Outflow hydrograph at the Nauco Aguada Station, generated using the Romblon RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Nauco Aguada discharge using the Catarman Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 29.

Table 29. Outlines the peak values of the Baleno HEC-HMS Model outflow using the Catarman RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	277.54	31.8	657.2	4 hours
10-Year	335.77	38.5	828.3	2 hours
25-Year	409.33	46.9	1070.9	2 hours
50-Year	463.87	53.2	1270.2	2 hours
100-Year	518.02	59.4	1429	1 hour and 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 64 shows a generated sample map of the Nauco Aguada River using the calibrated HMS base flow.

Figure 64. The sample output map of the Nauco Aguada RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 show the 5-, 25-, and 100-year rain return scenarios of the Nauco Aguada flood plain. The flood plain, with an area of 205.73km2, covers four (4) municipalities, namely Cataingan, Esperanza, Pio V. Corpuz, and Placer. Table 30 shows the percentage of area affected by flooding per municipality.

Table 30. Municipalities affected in Nauco Aguada floodplain.

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Cataingan	191.69	26.88	14.02
Esperanza	62.75	15.07	24.02
Pio V. Corpuz	95.64	26	27.18
Placer	253.55	85.99	33.92

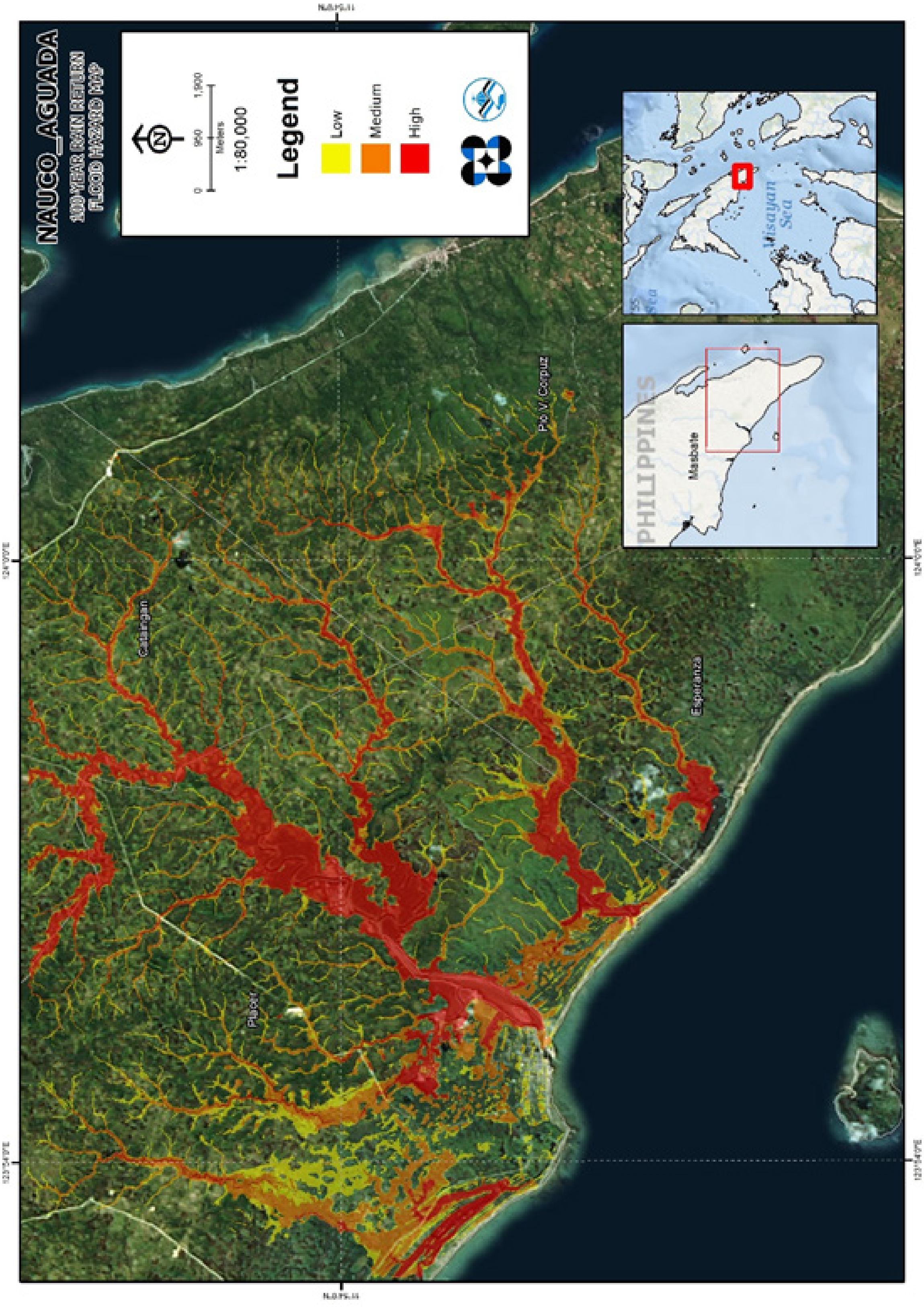

Figure 65. 100-year flood hazard map for the Nauco Aguada flood plain overlaid on Google Earth imagery.

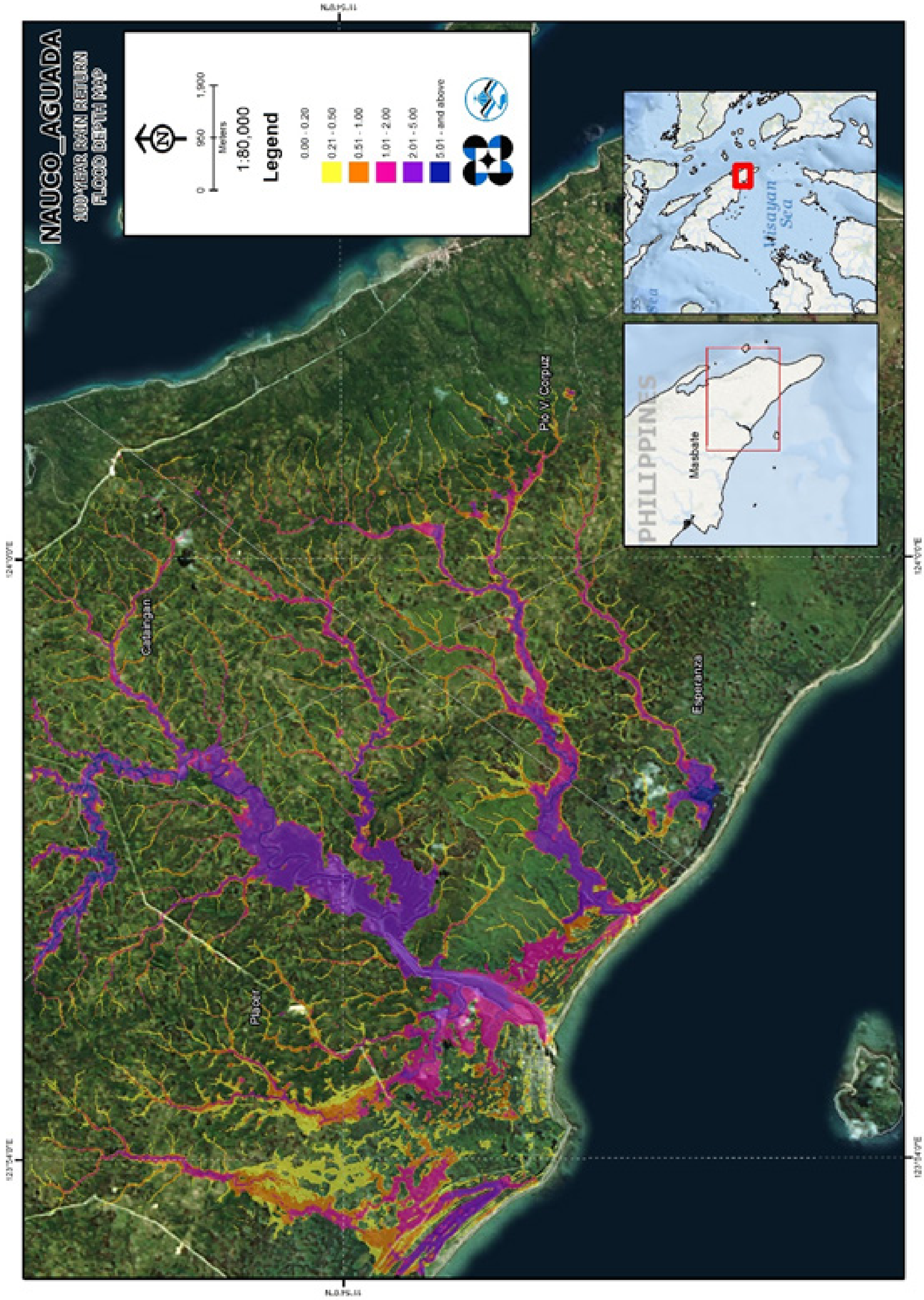

Figure 66. 100-year flow depth map for the Nauco Aguada flood plain overlaid on Google Earth imagery.

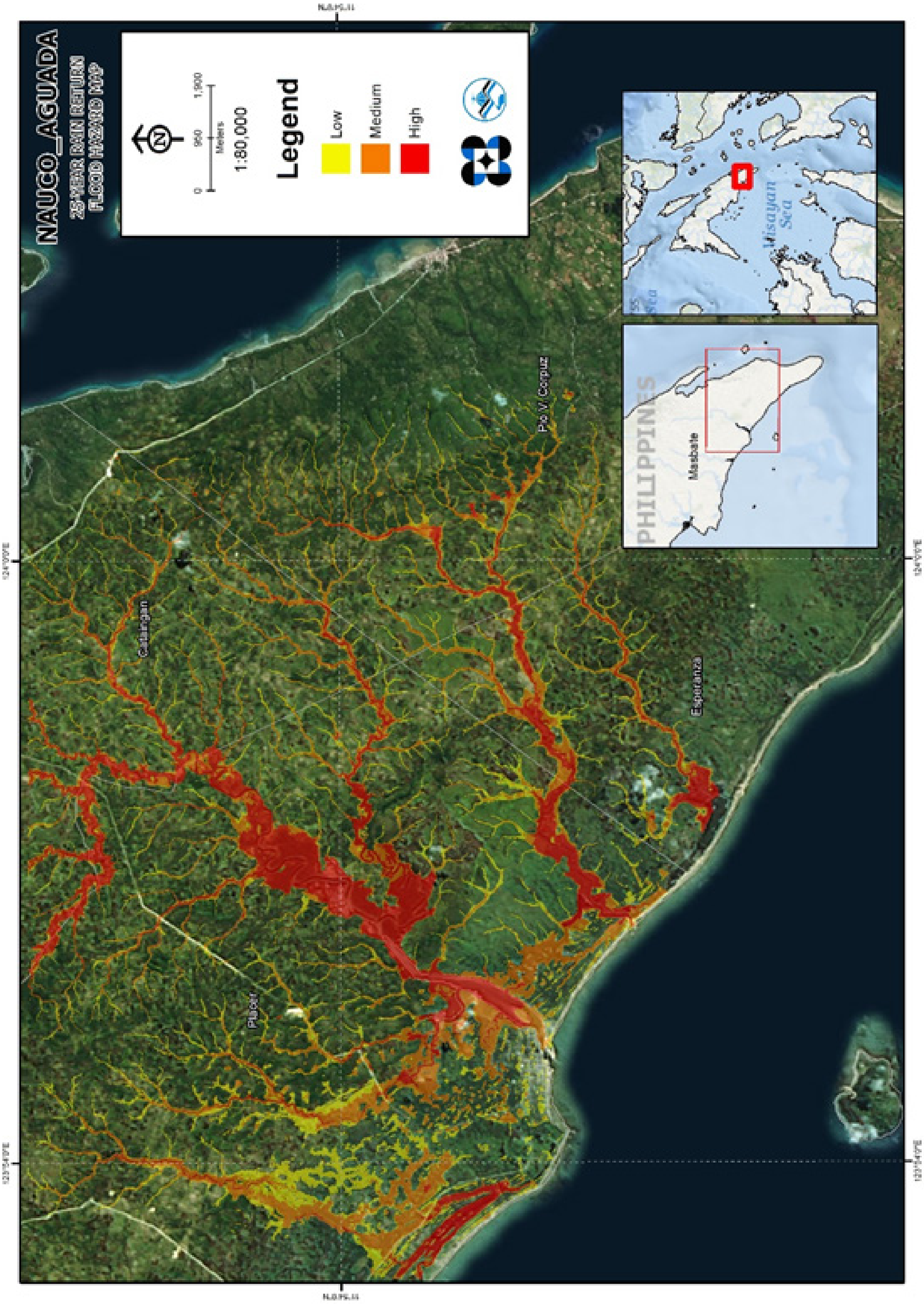

Figure 67. 25-year flood hazard map for the Nauco Aguada flood plain overlaid on Google Earth imagery.

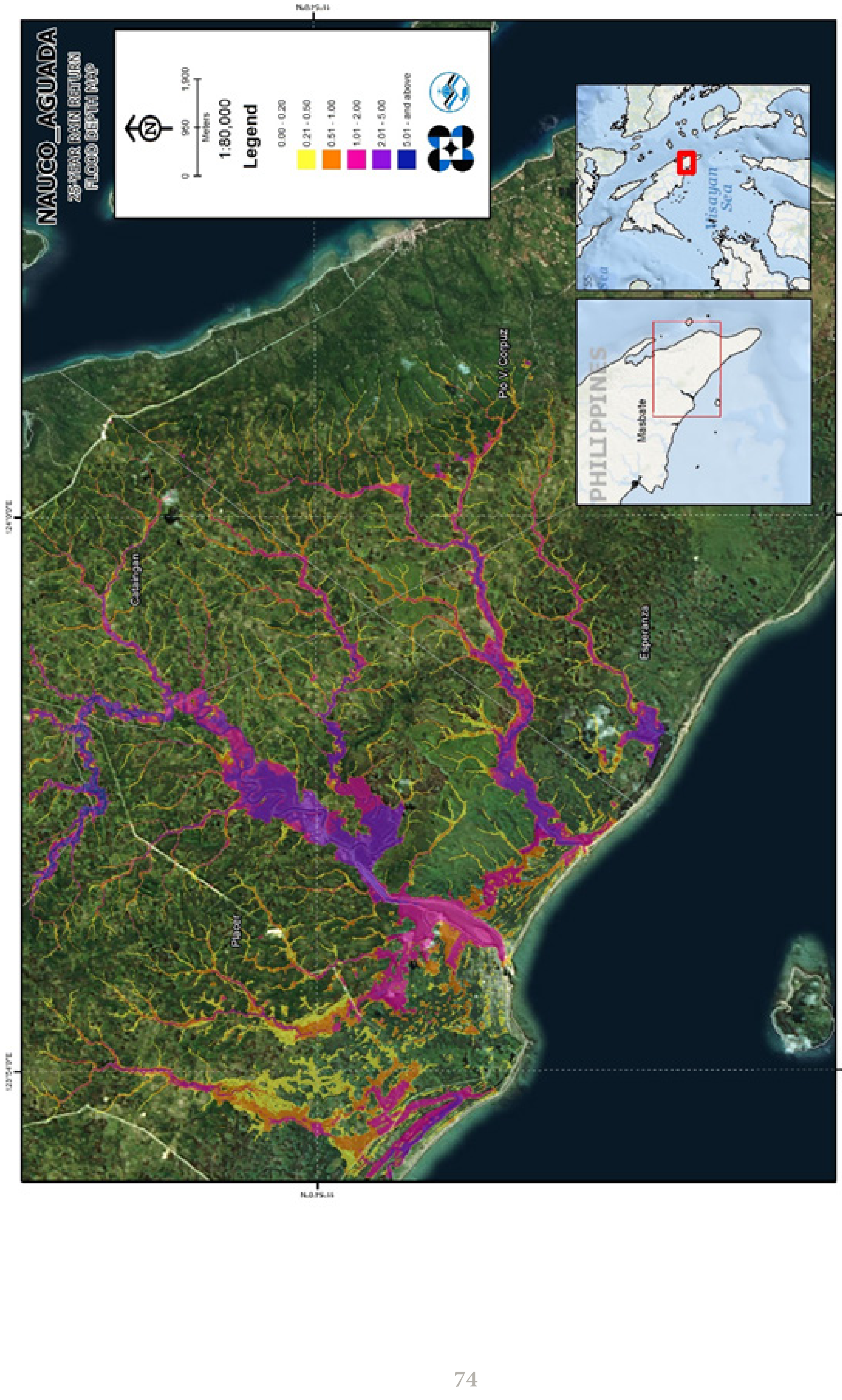

Figure 68. 25-year flow depth map for the Nauco Aguada flood plain overlaid on Google Earth imagery.

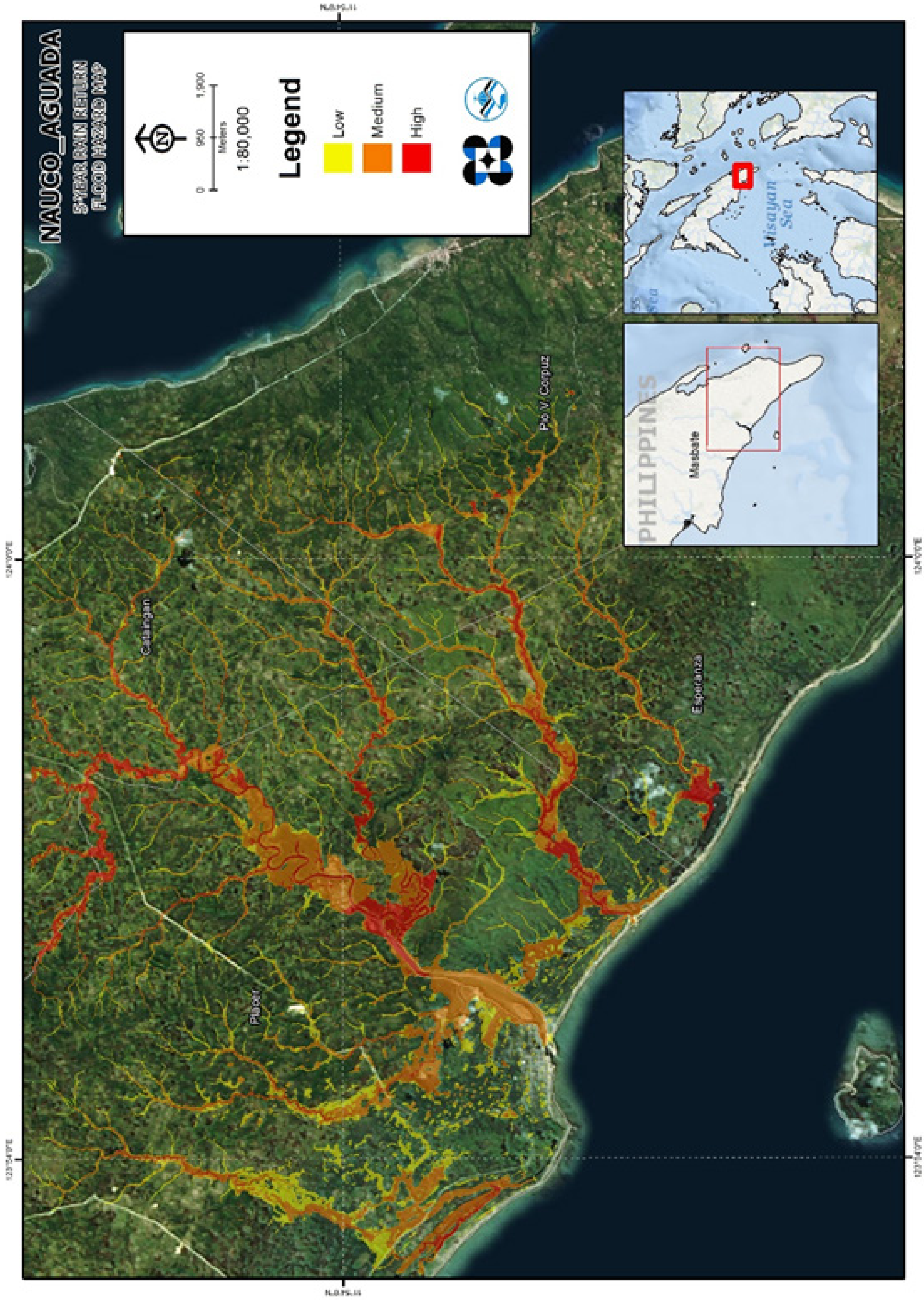

Figure 69. 5-year flood hazard map for the Nauco Aguada flood plain overlaid on Google Earth imagery.

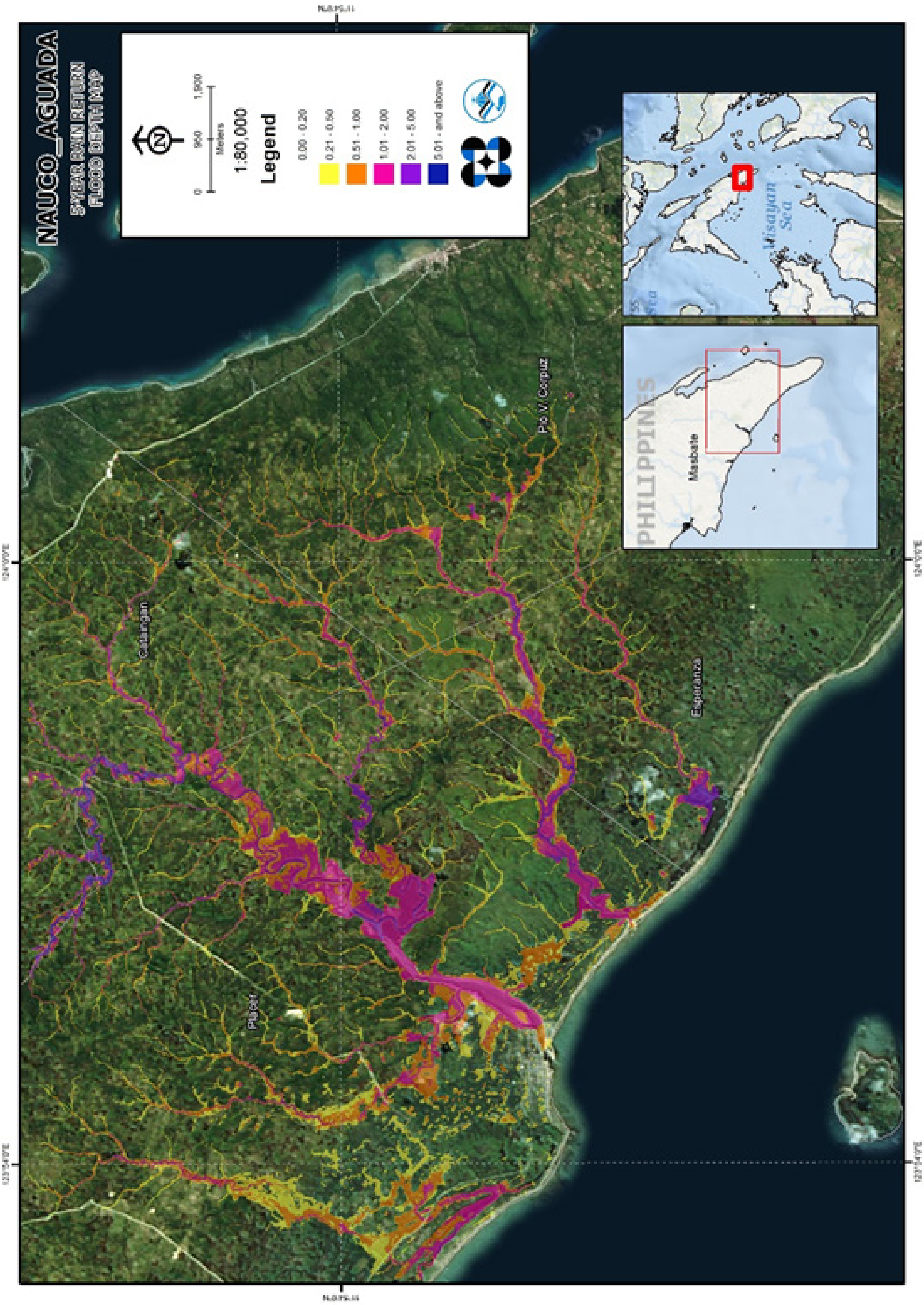

Figure 70. 5-year flow depth map for the Nauco Aguada flood plain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Nauco Aguada River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 33 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 12.22% of the municipality of Cataingan with an area of 191.69 sq. km. will experience flood levels of less than 0.20 meters. 0.62% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.47%, 0.4%, 0.28%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 31 depicts the areas affected in Cataingan in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Cataingan, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Cataingan					
	Badiang	Divisoria	Mintac	Quezon	San Jose	Santo Niño
0.03-0.20	9.65	8.7	0.43	2.41	0.018	2.21
0.21-0.50	0.47	0.46	0.011	0.14	0.00077	0.1
0.51-1.00	0.27	0.45	0.0033	0.12	0.00047	0.066
1.01-2.00	0.18	0.41	0.0016	0.13	0.0012	0.039
2.01-5.00	0.13	0.22	0.0009	0.17	0.0013	0.0065
>5.00	0.0022	0.037	0	0.042	0	0

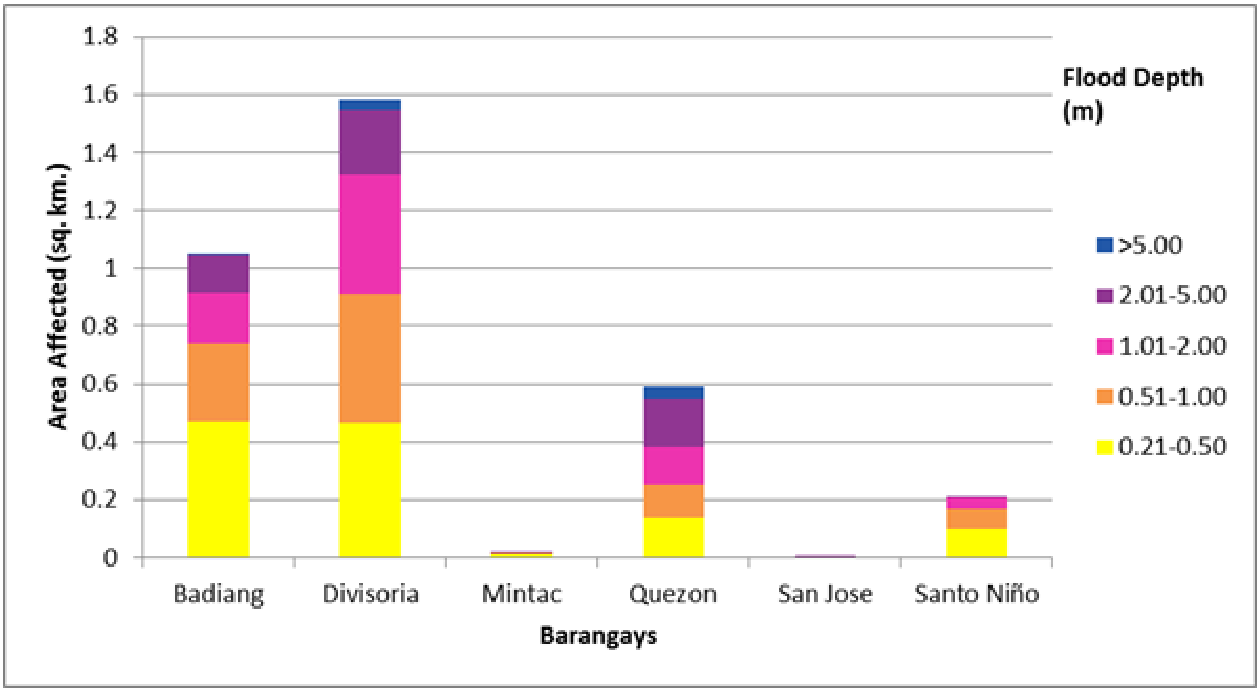

Figure 71. Affected Areas in Cataingan, Masbate during the 5-Year Rainfall Return Period.

For the municipality of Esperanza with an area of 62.75 sq. km., 19.63% will experience flood levels of less than 0.20 meters. 1.38% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.24%, 1.05%, 0.68%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 32 depicts the areas affected in Esperanza in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Esperanza, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Esperanza				
	Baras	Domorog	Guadalupe	Sorosimbajan	Tawad
0.03-0.20	4.11	4.64	1.01	0.44	2.12
0.21-0.50	0.32	0.36	0.048	0.017	0.12
0.51-1.00	0.37	0.25	0.061	0.013	0.079
1.01-2.00	0.33	0.2	0.047	0.0066	0.077
2.01-5.00	0.14	0.28	0.0056	0.0055	0.002
>5.00	0.014	0.0069	0	0	0

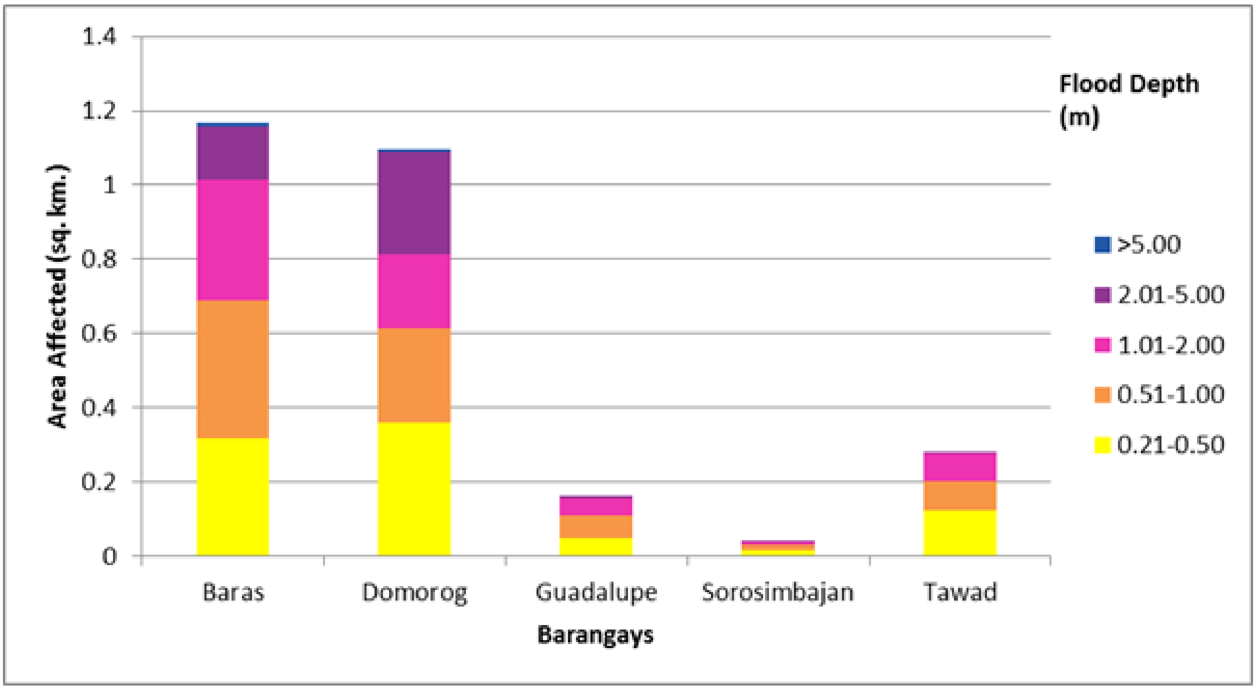

Figure 72. Affected Areas in Esparanza, Masbate during the 5-Year Rainfall Return Period.

For the municipality of Pio V. Corpuz with an area of 95.64 sq. km., 24.47% will experience flood levels of less than 0.20 meters. 1.27% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.89%, 0.5%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 33 depicts the areas affected in Pio V. Corpuz in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Pio V. Corpuz, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Pio V. Corpuz							
	Buenasuerte	Cabangrayan	Guindawahan	Labigan	Lampuyang	Palho	Poblacion	Tubog
0.03-0.20	1.56	4.22	7.78	0.29	5.57	2.87	0.000053	1.12
0.21-0.50	0.048	0.25	0.45	0.0058	0.3	0.12	0	0.043
0.51-1.00	0.0071	0.23	0.32	0	0.21	0.056	0	0.025
1.01-2.00	0	0.24	0.14	0	0.067	0.021	0	0.0043
2.01-5.00	0	0.04	0.013	0	0.0003	0	0	0.0016
>5.00	0	0	0	0	0	0	0	0

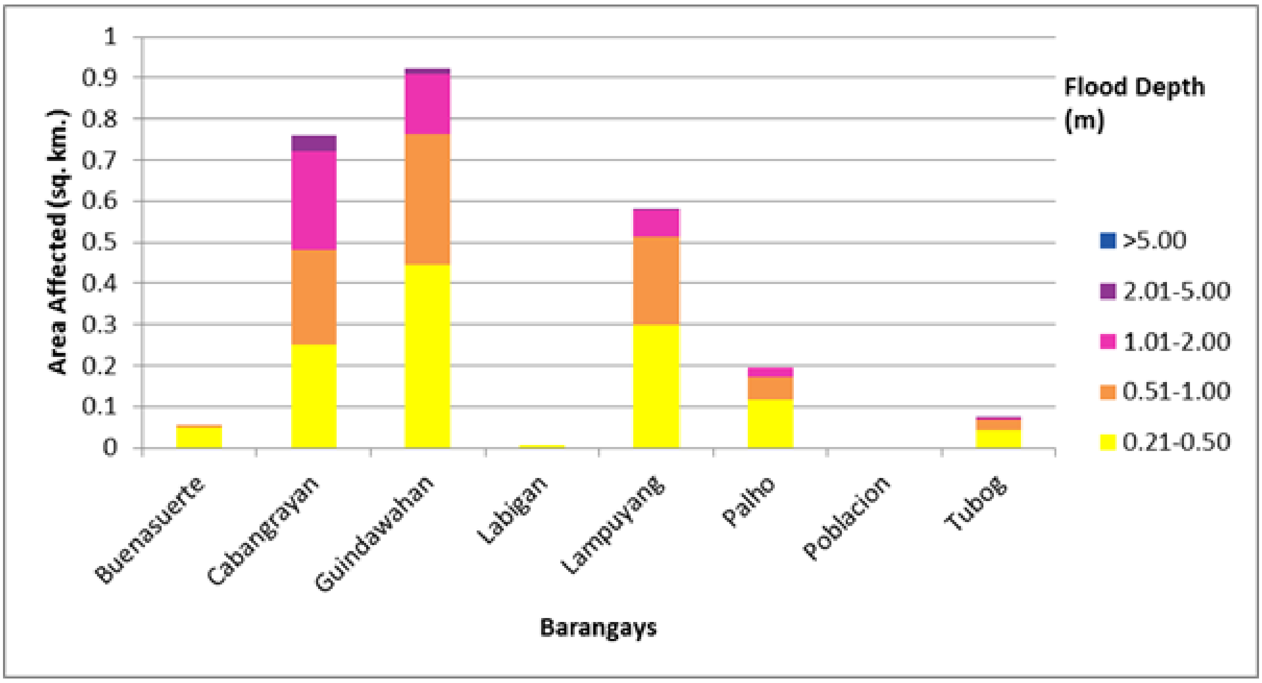

Figure 73. Affected Areas in Pio V. Corpuz, Masbate during the 5-Year Rainfall Return Period.

For the municipality of Placer with an area of 253.55 sq. km., 26.29% will experience flood levels of less than 0.20 meters. 2.75% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.29%, 2.12%, 0.41%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 34 and 35 depict the areas affected in Placer in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Placer, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer									
	Aguada	Ban-Ao	Burabod	Daanlungsod	Daraga	Guinhan-Ayan	Katipunan	Locso-An	Mahayag	Mahayahay
0.03-0.20	5.13	3.56	4.02	0.26	0.027	3.59	1.92	2.65	3.2	1.17
0.21-0.50	0.32	0.6	0.35	0.12	0.0003	0.12	0.33	0.17	0.69	0.065
0.51-1.00	0.14	0.5	0.15	0.13	0	0.051	0.26	0.12	0.24	0.014
1.01-2.00	0.039	0.2	0.055	0.078	0	0.032	0.013	0.055	0.086	0.0009
2.01-5.00	0.0008	0.022	0.0061	0	0	0.021	0	0.0077	0.014	0
>5.00	0	0	0	0	0	0.007	0	0	0	0

Table 35. Affected Areas in Placer, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer									
	Manlut-Od	Matagantang	Naocondiot	Pasiagon	Pili	Poblacion	San Marcos	Taboc	Tubod	Villa Inocencio
0.03-0.20	14.14	7.06	2.43	0.9	0.9	0.97	3.05	5.22	4.82	1.62
0.21-0.50	1	0.34	0.24	0.11	0.1	0.22	0.96	0.8	0.35	0.086
0.51-1.00	1.29	0.32	0.27	0.24	0.036	0.19	0.73	0.67	0.4	0.046
1.01-2.00	2.56	0.31	0.64	0.34	0.00076	0.056	0.11	0.35	0.36	0.11
2.01-5.00	0.52	0.26	0.15	0.022	0	0	0.0005	0.01	0.014	0
>5.00	0.0041	0.12	0.001	0	0	0	0	0	0	0

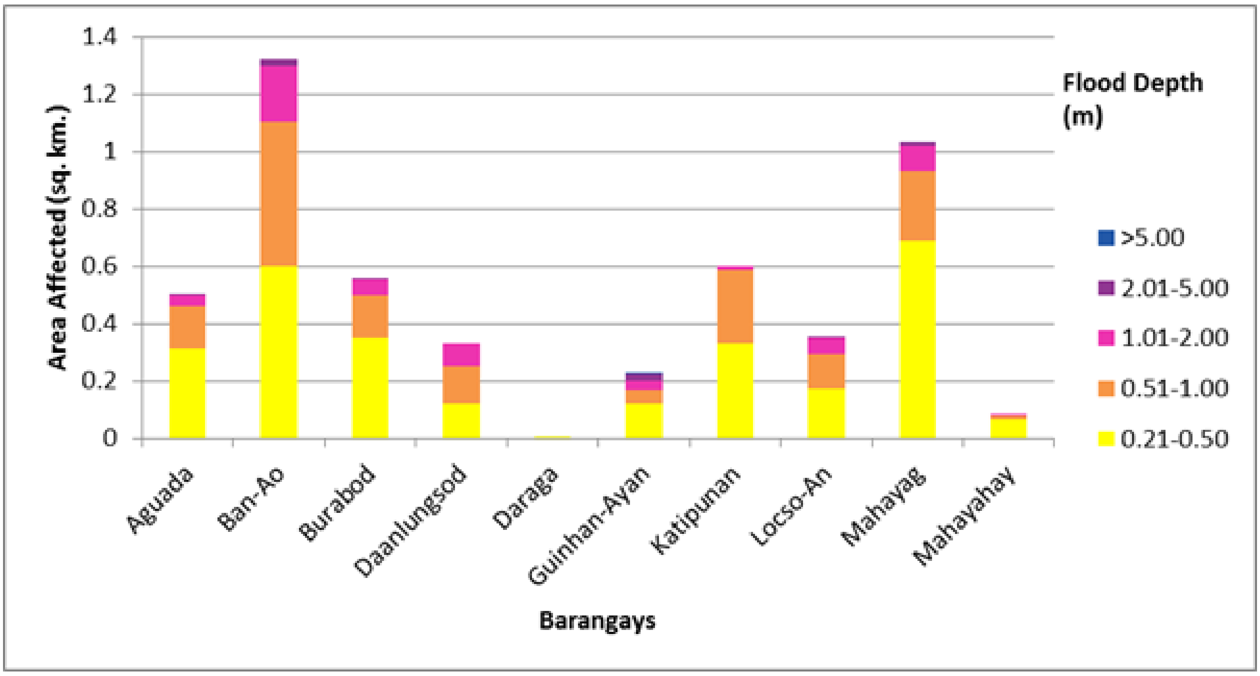

Figure 74. Affected Areas in Placer, Masbate during the 5-Year Rainfall Return Period.

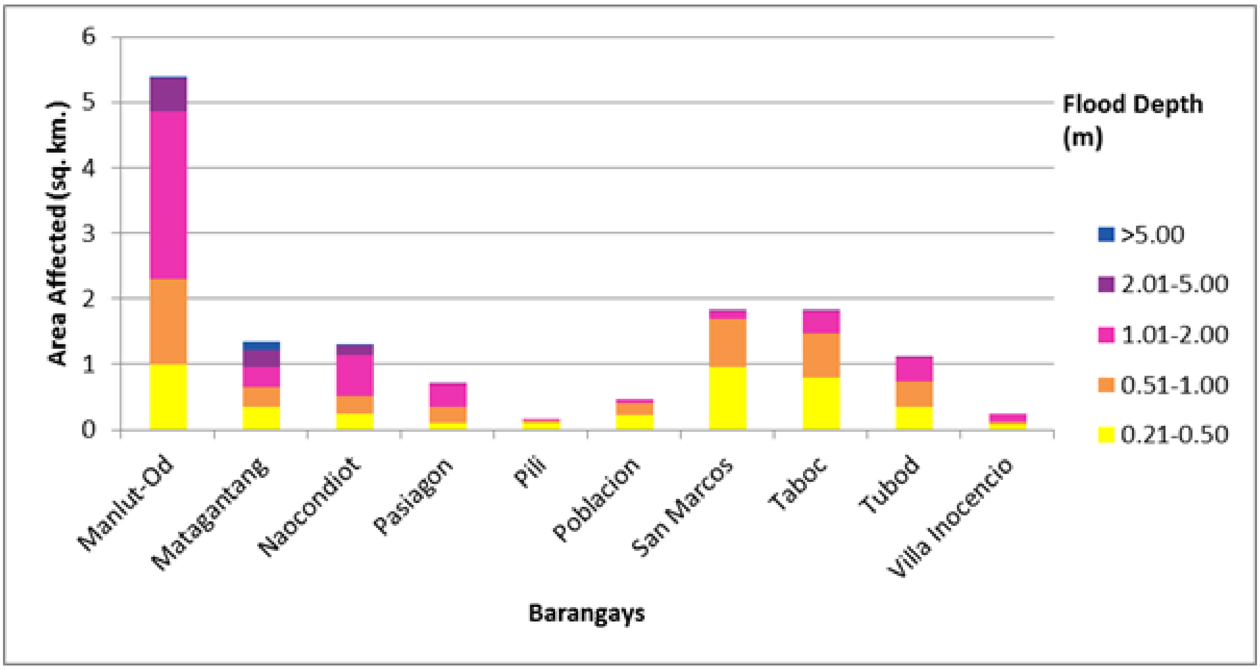

Figure 75. Affected Areas in Placer, Masbate during the 5-Year Rainfall Return Period.

For the 25-year rainfall return period, 11.79% of the municipality of Cataingan with an area of 191.69 sq. km. will experience flood levels of less than 0.20 meters. 0.66% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.53%, 0.55%, 0.43%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 36 depicts the areas affected in Cataingan in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Cataingan, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Cataingan					
	Badiang	Divisoria	Mintac	Quezon	San Jose	Santo Niño
0.03-0.20	9.37	8.41	0.43	2.21	0.011	2.17
0.21-0.50	0.52	0.48	0.014	0.13	0.0016	0.11
0.51-1.00	0.35	0.43	0.0041	0.14	0.0033	0.084
1.01-2.00	0.25	0.55	0.0023	0.19	0.0024	0.052
2.01-5.00	0.2	0.36	0.0011	0.25	0.0022	0.014
>5.00	0.0084	0.065	0	0.082	0.00054	0

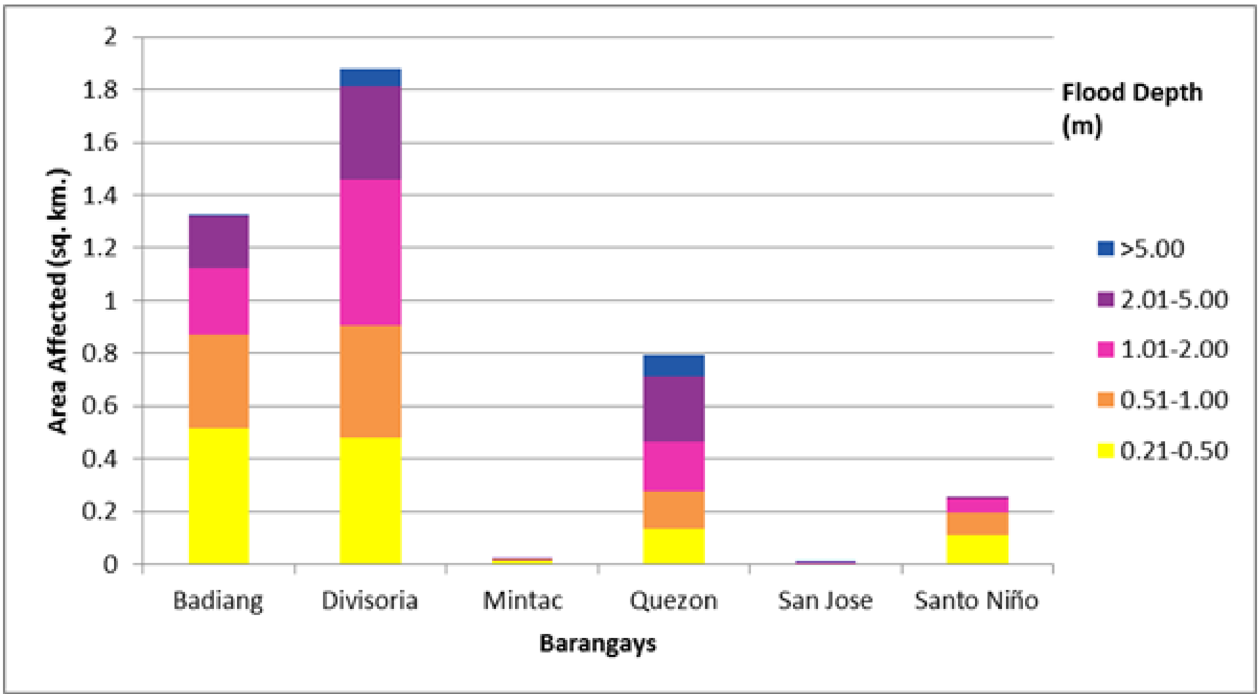

Figure 76. Affected Areas in Cataingan, Masbate during the 25-Year Rainfall Return Period.

For the municipality of Esperanza with an area of 62.75 sq. km., 18.63% will experience flood levels of less than 0.20 meters. 1.37% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.19%, 1.67%, 1.1%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 37 depicts the areas affected in Esperanza in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Esperanza, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Esperanza				
	Baras	Domorog	Guadalupe	Sorosimbajan	Tawad
0.03-0.20	3.88	4.36	0.97	0.42	2.06
0.21-0.50	0.3	0.36	0.052	0.018	0.14
0.51-1.00	0.34	0.26	0.049	0.02	0.083
1.01-2.00	0.51	0.33	0.078	0.018	0.11
2.01-5.00	0.23	0.42	0.017	0.0082	0.013
>5.00	0.023	0.017	0	0	0

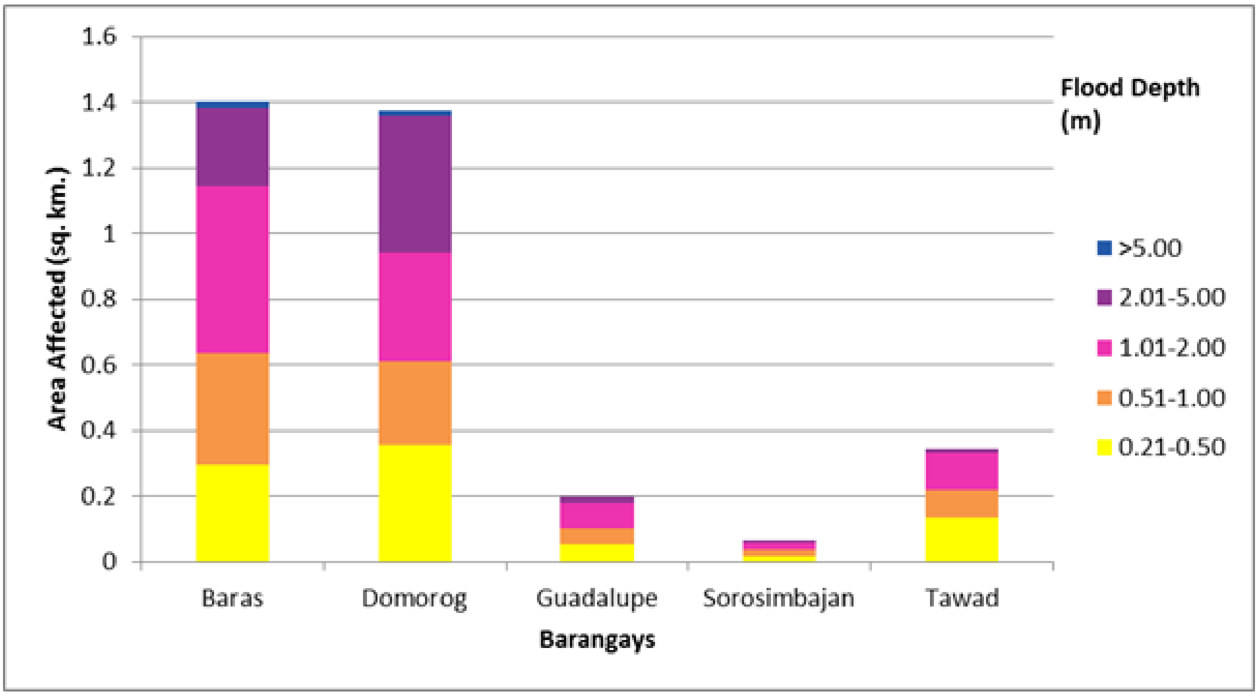

Figure 77. Affected Areas in Esparanza, Masbate during the 25-Year Rainfall Return Period.

For the municipality of Pio V. Corpuz with an area of 95.64 sq. km., 23.9% will experience flood levels of less than 0.20 meters. 1.34% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.02%, 0.73%, 0.2%, and 0.0003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Pio V. Corpuz in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Pio V. Corpuz, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Pio V. Corpuz							
	Buenasuerte	Cabangrayan	Guindawahan	Labigan	Lampuyang	Palho	Poblacion	Tubog
0.03-0.20	1.54	4.06	7.58	0.29	5.47	2.83	0.000053	1.09
0.21-0.50	0.056	0.26	0.46	0.0094	0.31	0.13	0	0.058
0.51-1.00	0.016	0.23	0.38	0.00022	0.25	0.069	0	0.036
1.01-2.00	0.0001	0.29	0.25	0	0.12	0.034	0	0.0076
2.01-5.00	0	0.14	0.034	0	0.0086	0.0029	0	0.0031
>5.00	0	0.00026	0	0	0	0	0	0

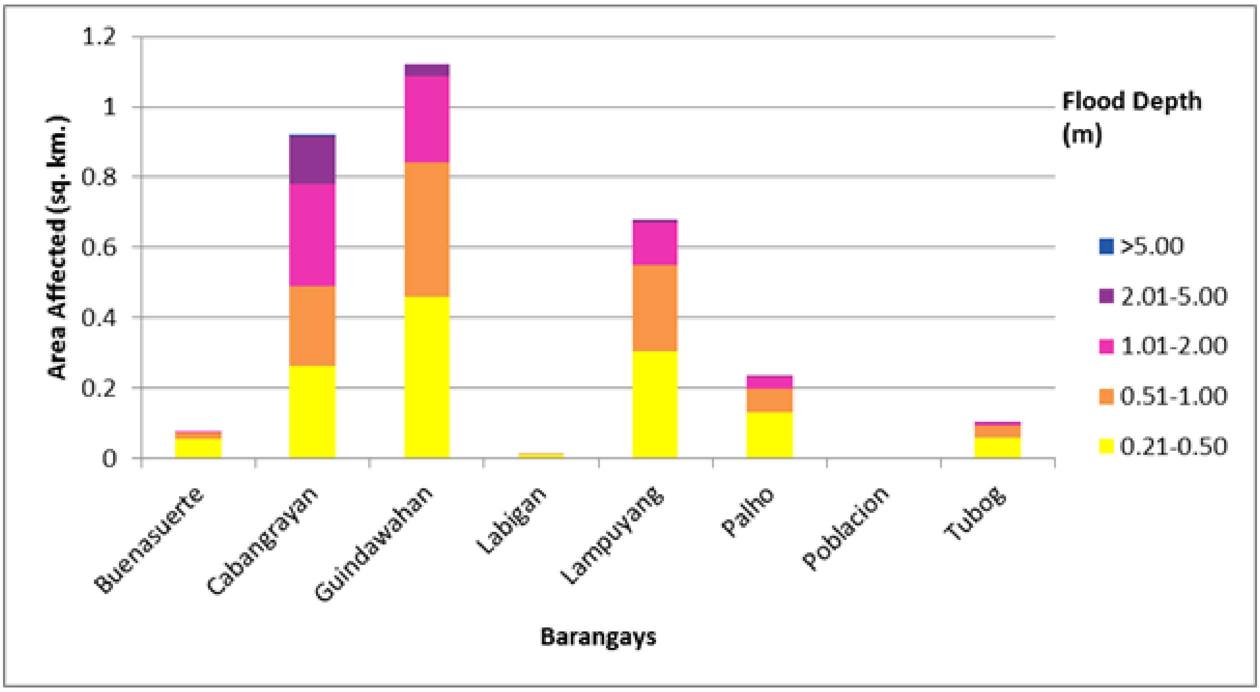

Figure 78. Affected Areas in Pio V. Corpuz, Masbate during the 25-Year Rainfall Return Period.

For the municipality of Placer with an area of 253.55 sq. km., 24.54% will experience flood levels of less than 0.20 meters. 2.85% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.18%, 2.43%, 1.83%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 39 and 40 depict the areas affected in Placer in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Placer, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer									
	Aguada	Ban-Ao	Burabod	Daanlungsod	Daraga	Guinhan-Ayan	Katipunan	Locso-An	Mahayag	Mahayahay
0.03-0.20	5.02	3.24	3.87	0.22	0.025	3.52	1.72	2.58	2.68	1.14
0.21-0.50	0.35	0.64	0.42	0.036	0.0016	0.15	0.32	0.18	0.98	0.086
0.51-1.00	0.19	0.63	0.19	0.14	0	0.065	0.27	0.15	0.39	0.02
1.01-2.00	0.061	0.34	0.08	0.2	0	0.045	0.2	0.091	0.15	0.0029
2.01-5.00	0.0037	0.049	0.013	0.0003	0	0.031	0.00075	0.014	0.029	0
>5.00	0	0	0	0	0	0.013	0	0	0	0

Table 40. Affected Areas in Placer, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer									
	Manlut-Od	Matagantang	Naocondiot	Pasiagon	Pili	Poblacion	San Marcos	Taboc	Tubod	Villa Inocencio
0.03-0.20	13.56	6.71	2.18	0.71	0.83	0.83	2.43	4.79	4.63	1.53
0.21-0.50	1.01	0.35	0.27	0.19	0.12	0.14	0.96	0.55	0.33	0.14
0.51-1.00	0.57	0.31	0.19	0.087	0.084	0.22	0.96	0.73	0.27	0.035
1.01-2.00	1.48	0.39	0.47	0.44	0.0028	0.23	0.49	0.91	0.48	0.11
2.01-5.00	2.89	0.45	0.61	0.19	0	0.0052	0.0032	0.074	0.23	0.043
>5.00	0.018	0.2	0.0054	0	0	0	0	0	0	0

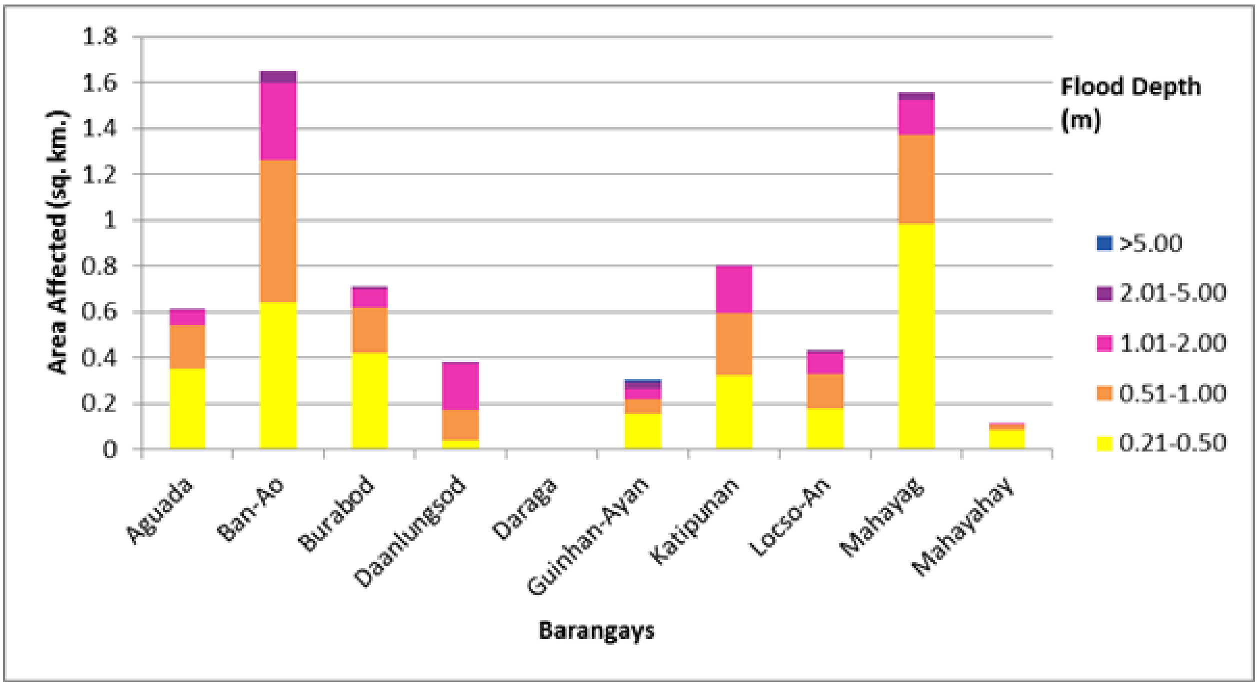

Figure 79. Affected Areas in Placer, Masbate during the 25-Year Rainfall Return Period.

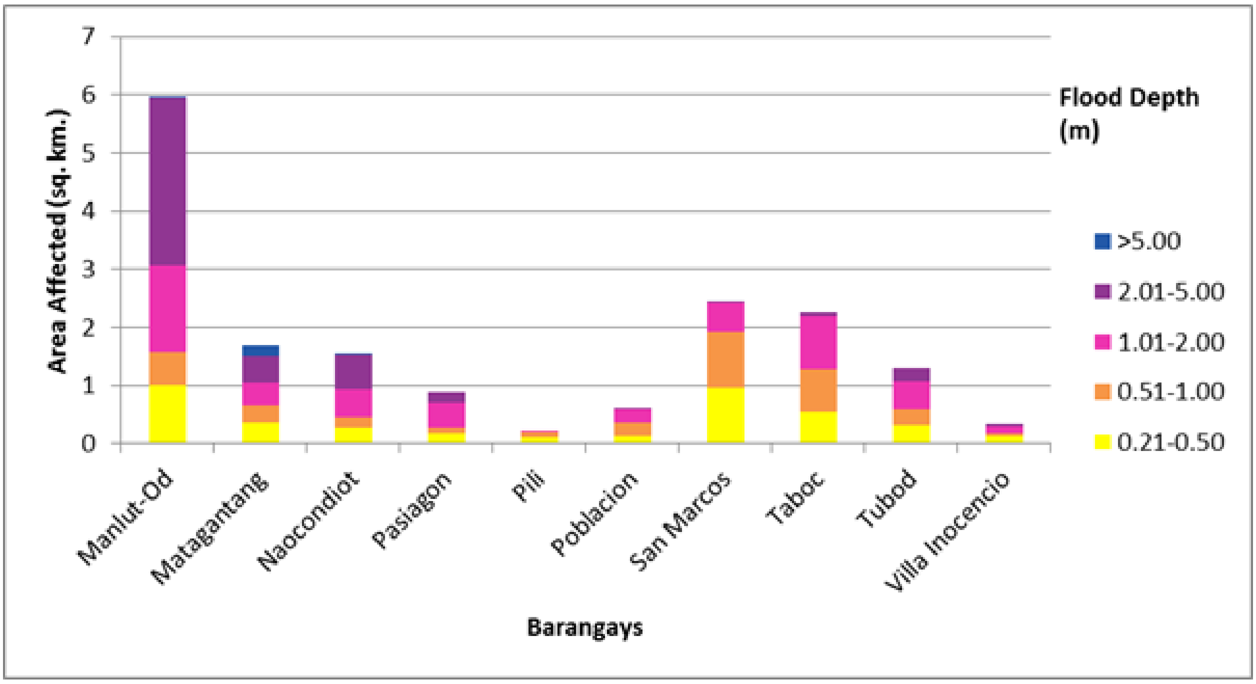

Figure 80. Affected Areas in Placer, Masbate during the 25-Year Rainfall Return Period.

For the 100-year rainfall return period, 11.48% of the municipality of Cataingan with an area of 191.69 sq. km. will experience flood levels of less than 0.20 meters. 0.66% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.57%, 0.61%, 0.57%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 41 depicts the areas affected in Cataingan in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Cataingan, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Cataingan					
	Badiang	Divisoria	Mintac	Quezon	San Jose	Santo Niño
0.03-0.20	9.17	8.22	0.42	2.06	0.0085	2.13
0.21-0.50	0.52	0.48	0.017	0.13	0.0012	0.12
0.51-1.00	0.42	0.42	0.0066	0.15	0.0025	0.088
1.01-2.00	0.31	0.57	0.002	0.22	0.0053	0.067
2.01-5.00	0.25	0.5	0.0017	0.32	0.0029	0.02
>5.00	0.022	0.099	0	0.13	0.00096	0

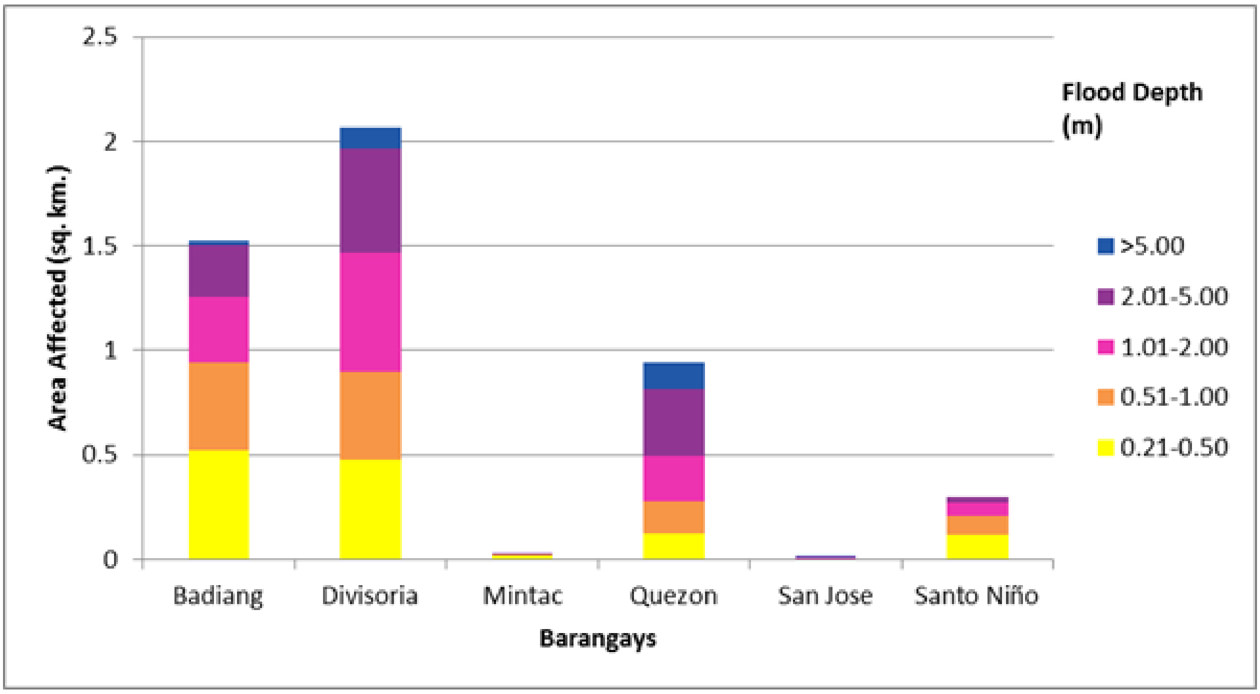

Figure 81. Affected Areas in Cataingan, Masbate during the 100-Year Rainfall Return Period.

For the municipality of Esperanza with an area of 62.75 sq. km., 18% will experience flood levels of less than 0.20 meters. 1.35% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.17%, 1.86%, 1.38%, and 0.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 42 depicts the areas affected in Esperanza in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Esperanza, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Esperanza				
	Baras	Domorog	Guadalupe	Sorosimbajan	Tawad
0.03-0.20	3.74	4.19	0.95	0.4	2.02
0.21-0.50	0.28	0.34	0.057	0.02	0.14
0.51-1.00	0.33	0.25	0.047	0.019	0.091
1.01-2.00	0.55	0.37	0.092	0.027	0.13
2.01-5.00	0.35	0.45	0.027	0.014	0.027
>5.00	0.027	0.14	0	0	0

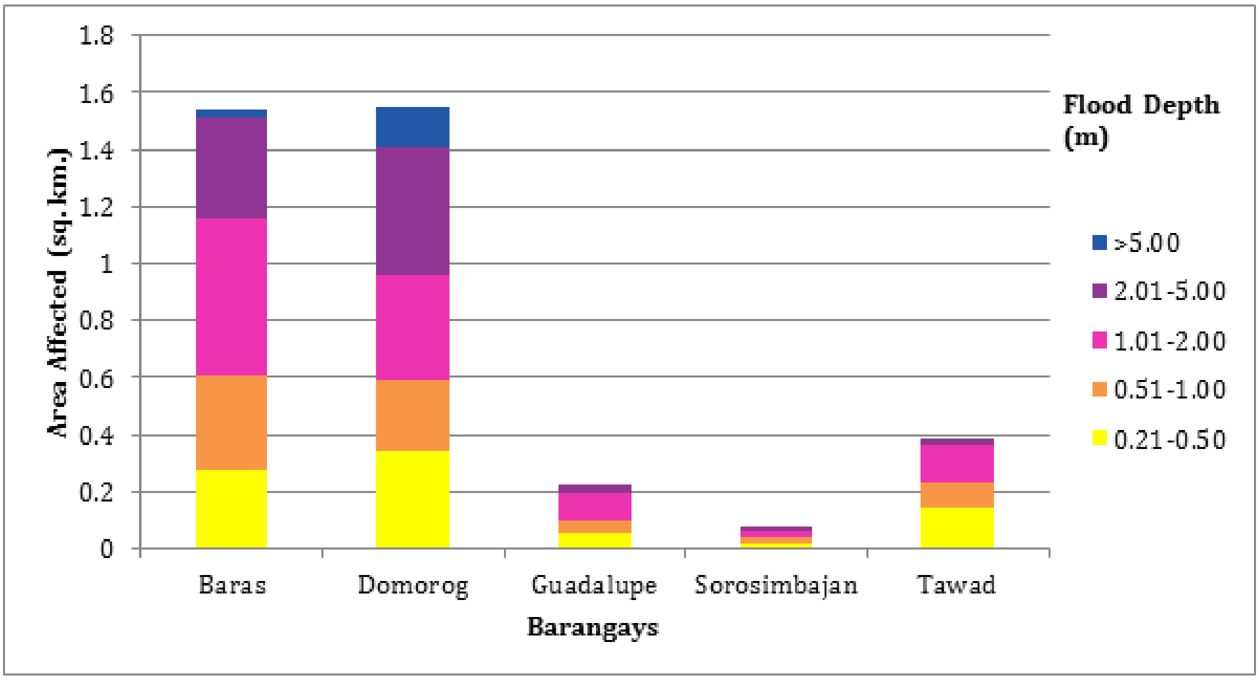

Figure 82. Affected Areas in Esparanza, Masbate during the 100-Year Rainfall Return Period.

For the municipality of Pio V. Corpuz with an area of 95.64 sq. km., 23.5% will experience flood levels of less than 0.20 meters. 1.4% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.1%, 0.86%, 0.32%, and 0.0006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 43 depicts the areas affected in Pio V. Corpuz in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Pio V. Corpuz, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Pio V. Corpuz							
	Buenasuerte	Cabangrayan	Guindawahan	Labigan	Lampuyang	Palho	Poblacion	Tubog
0.03-0.20	1.53	3.95	7.45	0.28	5.39	2.8	0.000053	1.06
0.21-0.50	0.06	0.28	0.47	0.011	0.31	0.14	0	0.065
0.51-1.00	0.023	0.24	0.4	0.0007	0.26	0.079	0	0.047
1.01-2.00	0.00086	0.29	0.32	0	0.16	0.045	0	0.013
2.01-5.00	0	0.22	0.057	0	0.025	0.0052	0	0.0036
>5.00	0	0.00056	0	0	0	0	0	0

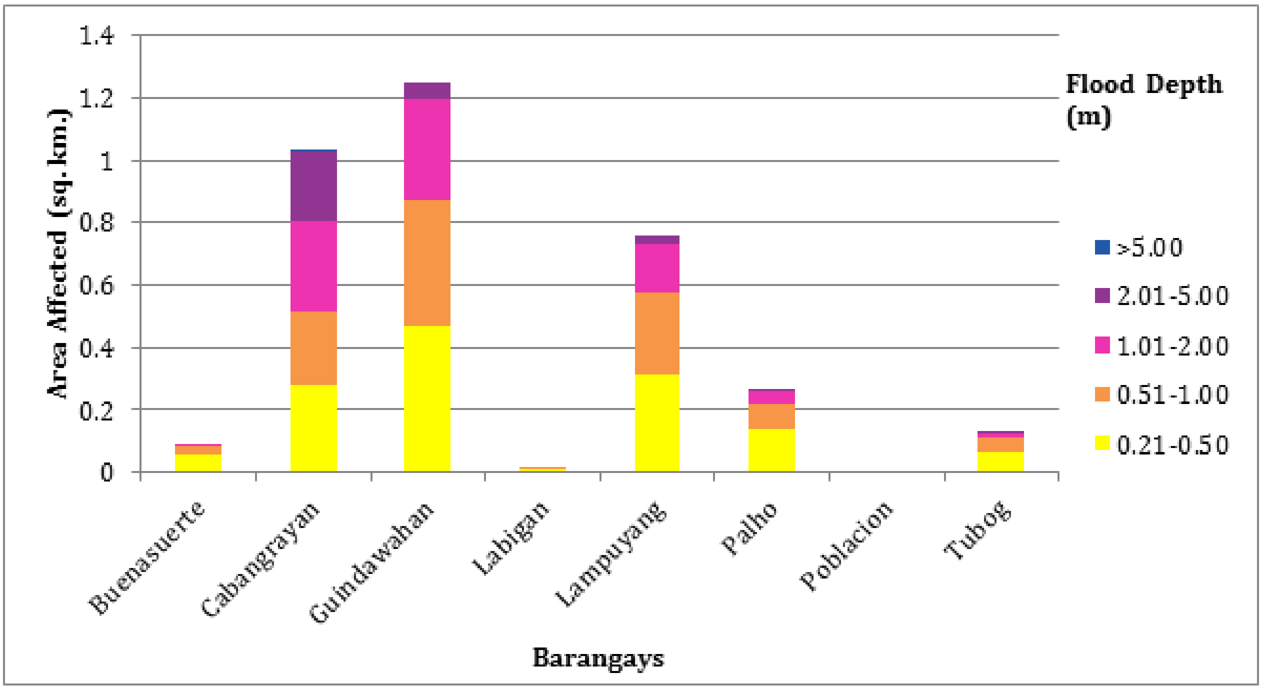

Figure 83. Affected Areas in Pio V. Corpuz, Masbate during the 100-Year Rainfall Return Period.

For the municipality of Placer with an area of 253.55 sq. km., 23.3% will experience flood levels of less than 0.20 meters. 3.03% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.23%, 2.36%, 2.85%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 44 and 45 depicts the areas affected in Placer in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Placer, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer									
	Aguada	Ban-Ao	Burabod	Daanlungsod	Daraga	Guinhan-Ayan	Katipunan	Locso-An	Mahayag	Mahayahay
0.03-0.20	4.93	3.05	3.76	0.19	0.023	3.46	1.58	2.52	2.38	1.12
0.21-0.50	0.38	0.62	0.47	0.041	0.0038	0.17	0.34	0.18	1.13	0.1
0.51-1.00	0.23	0.69	0.23	0.031	0	0.078	0.29	0.17	0.49	0.024
1.01-2.00	0.085	0.43	0.11	0.26	0	0.058	0.31	0.12	0.2	0.0053
2.01-5.00	0.0078	0.094	0.017	0.068	0	0.039	0.0016	0.019	0.038	0
>5.00	0	0	0	0	0	0.017	0	0	0	0

Table 45. Affected Areas in Placer, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer									
	Manlut-Od	Matagantang	Naocondiot	Pasiagon	Pili	Poblacion	San Marcos	Taboc	Tubod	Villa Inocencio
0.03-0.20	13.08	6.45	2.01	0.44	0.78	0.74	2.07	4.56	4.49	1.44
0.21-0.50	1.02	0.36	0.3	0.23	0.15	0.15	0.97	0.52	0.33	0.21
0.51-1.00	0.64	0.3	0.2	0.24	0.1	0.12	0.97	0.53	0.27	0.05
1.01-2.00	0.66	0.38	0.38	0.2	0.0054	0.39	0.82	1.11	0.4	0.077
2.01-5.00	4.04	0.65	0.83	0.49	0	0.039	0.015	0.33	0.46	0.093
>5.00	0.079	0.27	0.014	0	0	0	0	0.0001	0.00000089	0

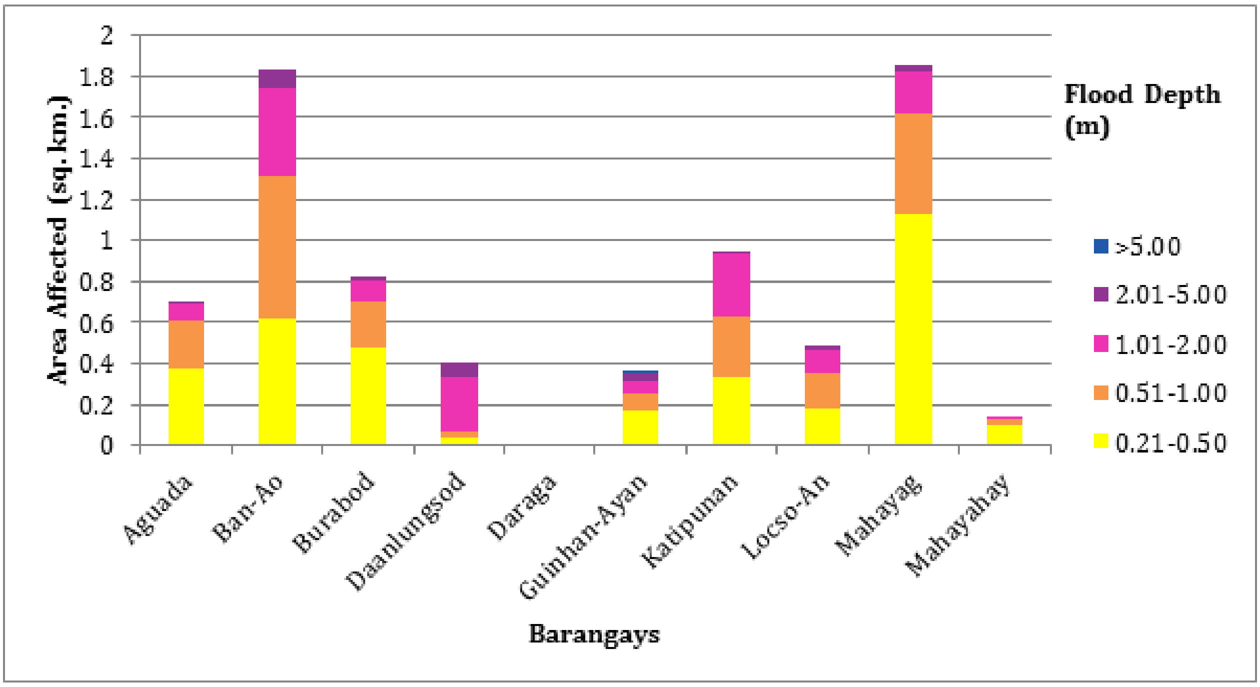

Figure 84. Affected Areas in Placer, Masbate during the 100-Year Rainfall Return Period.

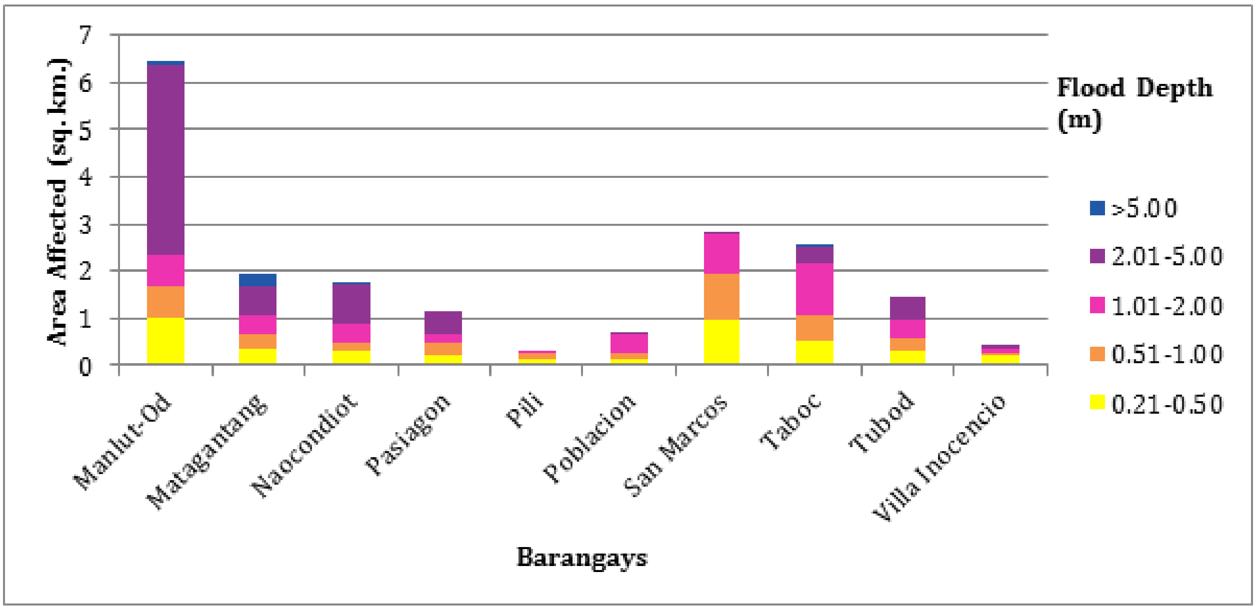

Figure 85. Affected Areas in Placer, Masbate during the 100-Year Rainfall Return Period.

Among the barangays in the municipality of Cataingan, Badiang is projected to have the highest percentage of area that will experience flood levels at 5.58%. Meanwhile, Divisoria posted the second highest percentage of area that may be affected by flood depths at 5.36%.

Among the barangays in the municipality of Esperanza, Domorog is projected to have the highest percentage of area that will experience flood levels at 9.14%. Meanwhile, Baras posted the second highest percentage of area that may be affected by flood depths at 8.42%.

Among the barangays in the municipality of Pio V. Corpuz, Guindawahan is projected to have the highest percentage of area that will experience flood levels of at 9.1%. Meanwhile, Cabangrayan posted the second highest percentage of area that may be affected by flood depths at 5.21%.

Among the barangays in the municipality of Placer, Manlut-Od is projected to have the highest percentage of area that will experience flood levels at 7.7%. Meanwhile, Mataganta posted the second highest percentage of area that may be affected by flood depths at 3.32%.

Moreover, the generated flood hazard maps for the Nauco Aguada flood plain were used to assess the vulnerability of the educational and medical institutions in the flood plain. 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 yr, 25 yr, and 100 yr).

Table 46. Area covered by each warning level with respect to the rainfall scenario.

Warning Level	Area Covered in sq. km.		
	5-year	25-year	100-year
Low	2.08	1.02	1.49
Medium	3.16	3.25	2.84
High	1.21	2.57	3.59

Of the 31 identified Educational Institutions in Nauco Aguada flood plain, 1 was assessed to be exposed to low, 2 to medium, and none to high level flooding during the 5-year scenario. In the 25-year scenario, 3 were assessed to be exposed to low, 2 to medium, and none to high level flooding. In the 100-year scenario, 3 were assessed to be exposed to low, 2 to medium, and none to high level flooding.

Of the 16 identified Medical Institutions in Nauco Aguada flood plain, 2 were assessed to be exposed to low, while none was assessed to be exposed to both medium and high level flooding in the 5-year scenario. In the 25-year scenario, 3 were assessed to be exposed to low, 1 to medium, and none to high level flooding. In the 100-year scenario, 4 were assessed to be exposed to low, 1 to medium, and none to high level flooding.

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 we identified for validation.

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 76.

The flood validation consists of 174 points randomly selected all over the Nauco Aguada flood plain (Figure 86). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.014404. Table 47 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

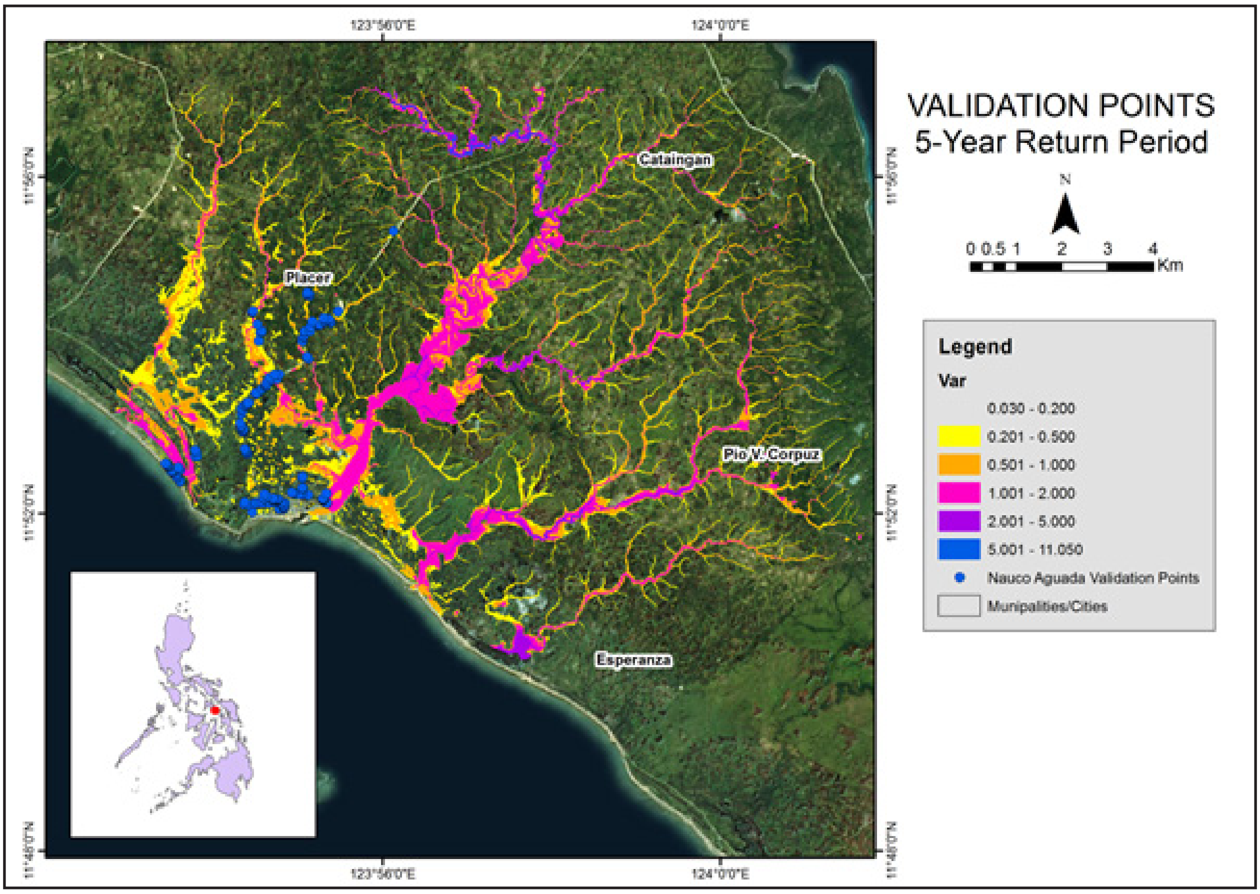

Figure 86. The Validation Points for a 5-year Flood Depth Map of the Nauco Aguada Floodplain.

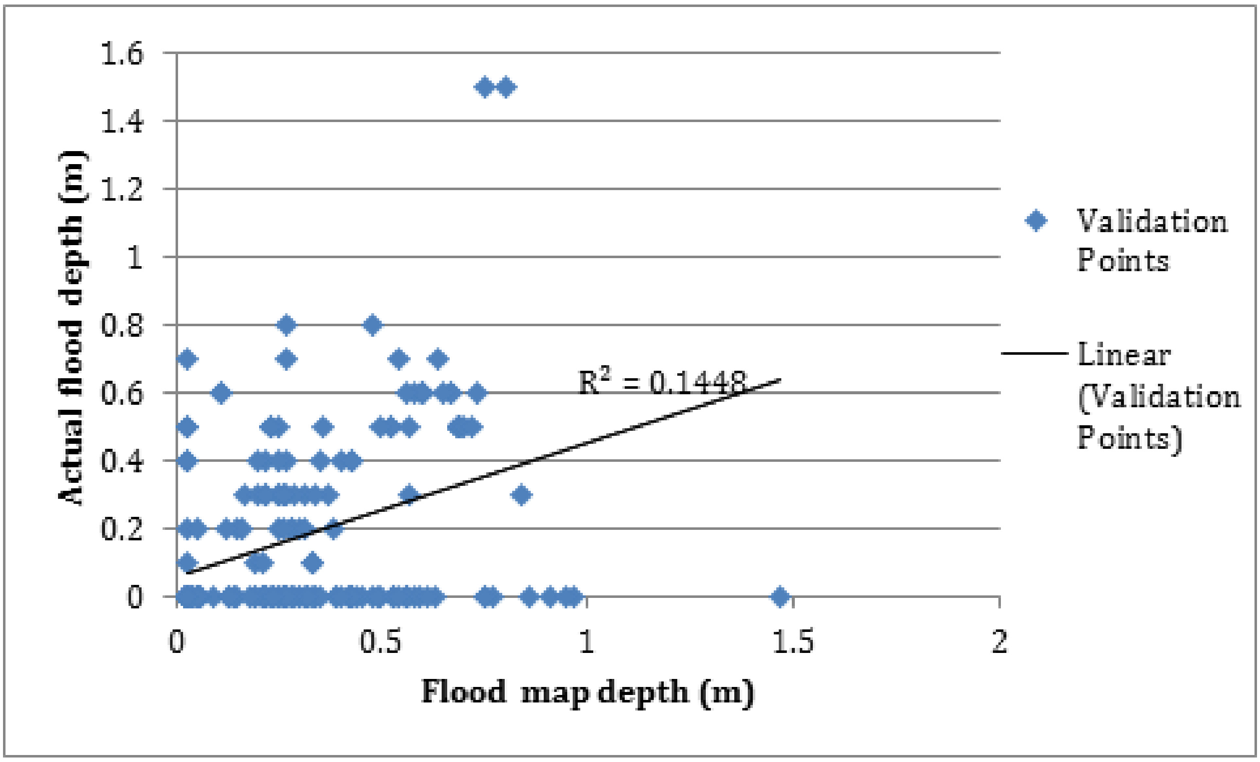

Figure 87. Flood map depth versus actual flood depth.

Table 47. Actual Flood Depth versus Simulated Flood Depth at different levels in Nauco Aguada 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	66	57	18	1	0	0	142
0.21-0.50	7	23	17	0	0	0	47
0.51-1.00	3	3	12	0	0	0	18
1.01-2.00	0	0	2	0	0	0	2
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	76	83	49	1	0	0	209

On the whole, the overall accuracy generated by the flood model is estimated at 48.33%, with 101 points correctly matching the actual flood depths. In addition, there were 83 points estimated one level above and below the correct flood depths, 21 points estimated two levels above and below, and 1 points estimated three or more levels above and below the correct flood depths. A total of 93 points were overestimated while a total of 15 points were underestimated in the modelled flood depths of Nauco Aguada. Table 48 depicts the summary of the accuracy assessment in the Nauco Aguada River Basin survey.

Table 48. The summary of the Accuracy Assessment in the Nauco Aguada River Basin Survey.

BALENO	No. of Points	%
Correct	101	48.33
Overestimated	93	44.50
Underestimated	15	7.18
Total	209	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.

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

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

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

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

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

ANNEXES

ANNEX 1. Technical Specifications of the LIDAR Sensors used in the Nauco Aguada Floodplain Survey

1. PEGASUS SENSOR

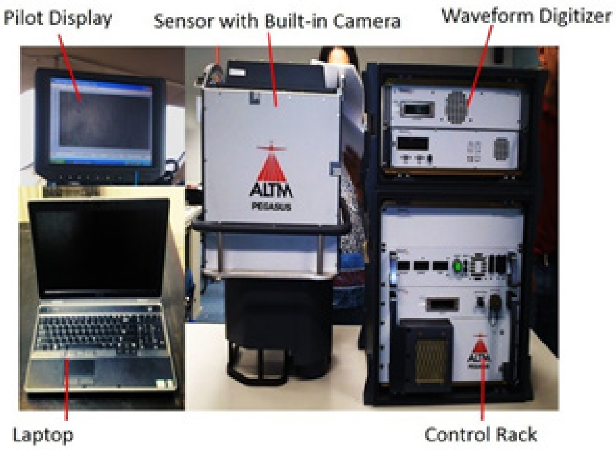


Figure A-1.1. Pegasus Sensor

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)	< 5-35 cm, 1σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (FOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)

Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

ANNEX 2. NAMRIA Certificate of Reference Points Used in the LiDAR Survey

1. MST-40

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-40**
Order: **2nd**

Island: **LUZON**
Municipality: **USON**
Barangay: **BUENAVISTA**

PRS92 Coordinates

Latitude: **12º 10' 39.45274"**	Longitude: **123º 47' 33.62147"**	Ellipsoidal Hgt: **4.72600 m.**

WGS84 Coordinates

Latitude: **12º 10' 34.84826"**	Longitude: **123º 47' 38.70589"**	Ellipsoidal Hgt: **61.65900 m.**

PTM Coordinates

Northing: **1346708.7 m.**	Easting: **586266.511 m.**	Zone: **4**

UTM Coordinates

Northing: **1,346,237.33**	Easting: **586,236.32**	Zone: **51**

Location Description

MST-40
From Masbate City Proper, travel for about 32.6 km. along the Nat'l. Highway going to Uson Town Proper until reaching Brgy. Buenavista. Station is located at the right wing of Buenavista Bridge, 11 m. from the "15 T" signboard. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-40 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-825**

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

9904102014140116

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MST-40

2. MST-49

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-49**
Order: **2nd**

Island: **LUZON**
Municipality: **CATAINGAN**
Barangay: **QUEZON**

PRS92 Coordinates

Latitude: **12° 0' 1.41677"**	Longitude: **123° 59' 46.24265"**	Ellipsoidal Hgt: **21.25500 m.**

WGS84 Coordinates

Latitude: **11° 59' 56.87354"**	Longitude: **123° 59' 51.34085"**	Ellipsoidal Hgt: **79.14000 m.**

PTM Coordinates

Northing: **1327175.1 m.**	Easting: **608487.281 m.**	Zone: **4**

UTM Coordinates

Northing: **1,326,710.57**	Easting: **608,449.31**	Zone: **51**

Location Description

MST-49
From Masbate City Proper, travel for about 74.8 km. along the Nat'l. Highway going to Placer Town Proper to reach Brgy. Quezon, Cataingan Town. Station is located in front (17 m. SE) of Cataingan Mun. Hall, 10 N of the Mun. Trial Court and 15 m. E of the COMELEC Bldg. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-49 2007 NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795949 A**
T.N.:	**2014-826**

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

9904102014140133

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 MST-49

3. MS-61

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MS-61**

Island: **LUZON**	Municipality: **PALANAS**	Barangay: **NABANGIG**
Elevation: **7.0705 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

MS-061

Station is in the Municipality of Palanas, along National Highway leading to town of Cataingan, at Brgy. Nabangig, atop Nabangig Bridge (km 061+156). It is 55m from the Municipality's Boundary Arc. Mark is the head of a 3" copper nail set flush in cement putty with inscription "MS-061 2007 NAMRIA."

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795949 A**
T.N.:	**2014-840**

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

9904102014140622

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3 MS-61

ANNEX 3. Baseline Processing Reports of Control Points used in the LIDAR Survey

1. MS-61

Table A-3.1. MS-61

MS-61 - MST-49 (6:30:34 AM-11:24:24 AM) (S1)

Baseline observation:	MS-61 --- MST-49 (B1)
Processed:	5/13/2014 11:54:33 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.025 m
RMS:	0.009 m
Maximum PDOP:	3.505
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/26/2014 6:30:54 AM (Local: UTC+8hr)
Processing stop time:	3/26/2014 11:24:24 AM (Local: UTC+8hr)
Processing duration:	04:53:30
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	MST-49				
Grid		Local		Global	
Easting	608602.644 m	Latitude	N11°59'56.87354"	Latitude	N11°59'56.87354"
Northing	1326654.175 m	Longitude	E123°59'51.34085"	Longitude	E123°59'51.34085"
Elevation	21.031 m	Height	79.140 m	Height	79.140 m

To:	MS-61				
Grid		Local		Global	
Easting	604178.664 m	Latitude	N12°05'56.94091"	Latitude	N12°05'56.94091"
Northing	1337699.951 m	Longitude	E123°57'26.33451"	Longitude	E123°57'26.33451"
Elevation	7.554 m	Height	65.257 m	Height	65.257 m

Vector					
ΔEasting	-4423.979 m	NS Fwd Azimuth	338°22'53"	ΔX	4935.367 m
ΔNorthing	11045.776 m	Ellipsoid Dist.	11901.865 m	ΔY	524.472 m
ΔElevation	-13.477 m	ΔHeight	-13.883 m	ΔZ	10817.803 m

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME B. HIPOLITO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG MARLON TORRE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	

ANNEX 5. Data Transfer Sheet for Nauco Aguada Floodplain

DATA TRANSFER SHEET
Apr 3, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Mar 19, 2014	1241P	1BLK32E078A	PEGASUS	703MB	2.80MB	8.99MB	281MB	33.3GB	297KB	6.0GB	N/A	5.78MB	121B	825B	82.6KB	N/A	Z:\Airborne_Raw\1241P
Mar 20, 2014	1243P	1BLK32E079A	PEGASUS	1.14GB	2.37MB	6.18MB	169MB	41GB	335KB	21.3GB	N/A	5.45MB	225B	688B	80.3KB	N/A	Z:\Airborne_Raw\1243P
Mar 20, 2014	1245P	1BLK32J079B	PEGASUS	2.33GB	2.22MB	6.76MB	189MB	49.2GB	363KB	22.7GB	N/A	5.45MB	225B	377B	115KB	N/A	Z:\Airborne_Raw\1245P
Mar 21, 2014	1247P	1BLK32J080A	PEGASUS	4.09GB	3.96MB	9.60MB	244MB	55.2GB	426KB	40.8GB	N/A	5.76MB	96B	527B	137KB	N/A	Z:\Airborne_Raw\1247P
Mar 25, 2014	1263P	1BLK32K084A	PEGASUS	2.21GB	2.98MB	8.71MB	217MB	48.9GB	366KB	26.6GB	N/A	4.64MB	92B	936B	136KB	N/A	Z:\Airborne_Raw\1263P
Mar 26, 2014	1267P	1BLK32M085A	PEGASUS	3.67GB	4.25MB	10.8MB	283MB	58.2GB	451KB	36.4GB	N/A	5.94MB	92B	758B	254KB	N/A	Z:\Airborne_Raw\1267P
Mar 27, 2014	1271P	1BLK32H086A	PEGASUS	3.43GB	3.99MB	11.1MB	259MB	74.8GB	585KB	33.8GB	N/A	5.24MB	92B	678B	156KB	N/A	Z:\Airborne_Raw\1271P
Mar 28, 2014	1275P	1BLK32H087A	PEGASUS	2.18GB	2.11MB	6.13MB	164MB	38.4GB	315KB	21.1GB	N/A	6.67MB	93B	350B	145KB	N/A	Z:\Airborne_Raw\1275P
Mar 29, 2014	1281P	1BLK32I088B	PEGASUS	1.45GB	1.58MB	3.74MB	102MB	N/A	N/A	13.8GB	N/A	7.37MB	93B	455B	26.5KB	N/A	Z:\Airborne_Raw\1281P
Mar 31, 2014	1289P	1BLK32K090A	PEGASUS	1.45GB	1.63MB	4.32MB	116MB	22.6GB	162KB	14.1GB	N/A	8.08MB	93B	253B	31.9KB	N/A	Z:\Airborne_Raw\1289P

Received from

Name Faith Joy Sabio
Position
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Nauco Aguada Floodplain - A

DATA TRANSFER SHEET
4/22/2014(MASBATE)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS (mb)	POS (mb)	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/1/2014	1291P	1BLK32KL091A	PEGASUS	2.91	3.36	9.99	256	43.6	332	29.8	NA	7.81	1KB	602	376	NA	Z:\Airborne_Raw\1291P
4/1/2014	1293P	1BLK32HO91B	PEGASUS	1.75	1.46	3.85	115	24.7	213	15.6	NA	7.81	1KB	221	68.5	NA	Z:\Airborne_Raw\1293P
4/2/2014	1295P	1BLK32EO92A	PEGASUS	2.93	3.42	8.9	225	54.2	404	29.2	NA	867KB	1KB	512	137	NA	Z:\Airborne_Raw\1295P
4/3/2014	1299P	1BLK32FG093A	PEGASUS	2.68	3.23	8.65	232	33.4	267	20.8	NA	7.59	1KB	358	113	NA	Z:\Airborne_Raw\1299P
4/3/2014	1301P	1BLK32F093B	PEGASUS	1.95	2.42	5.95	149	44.6	352	19.8	NA	7.59	1KB	538	201	NA	Z:\Airborne_Raw\1301P
4/4/2014	1303P	1BLK32A094A	PEGASUS	2.77	3.48	2.99	218	52.5	404	29.4	NA	6.67	1KB	694	186	NA	Z:\Airborne_Raw\1303P
4/4/2014	1305P	1BLK32A094B	PEGASUS	2.41	2.85	6.88	161	44.3	324	23.3	NA	6.67	1KB	400	2.41	NA	Z:\Airborne_Raw\1305P
4/5/2014	1307P	1BLK32DG095A	PEGASUS	3.84	4.49	4.12	271	67.2	514	37.7	NA	6.49	1KB	523	270	NA	Z:\Airborne_Raw\1307P
4/8/2014	1319P	1BLK32B098A	PEGASUS	3.66	4.32	9.93	254	17.7	526	36.2	NA	4.95	1KB	731	382	NA	Z:\Airborne_Raw\1319P
4/10/2014	1327P	1BLK32D100A	PEGASUS	2.16	2.47	6.99	175	37	277	21.7	NA	5.27	1KB	747	243	NA	Z:\Airborne_Raw\1327P
4/11/2014	1331P	1BLK32B101A	PEGASUS	1.76	1.9	5.09	134	29.8	232	17.8	NA	4.09	1KB	574	316	NA	Z:\Airborne_Raw\1331P

Received from

Name: CARLOS JOSE ... (handwritten)
Position: RA
Signature: [signature] 4/23/14

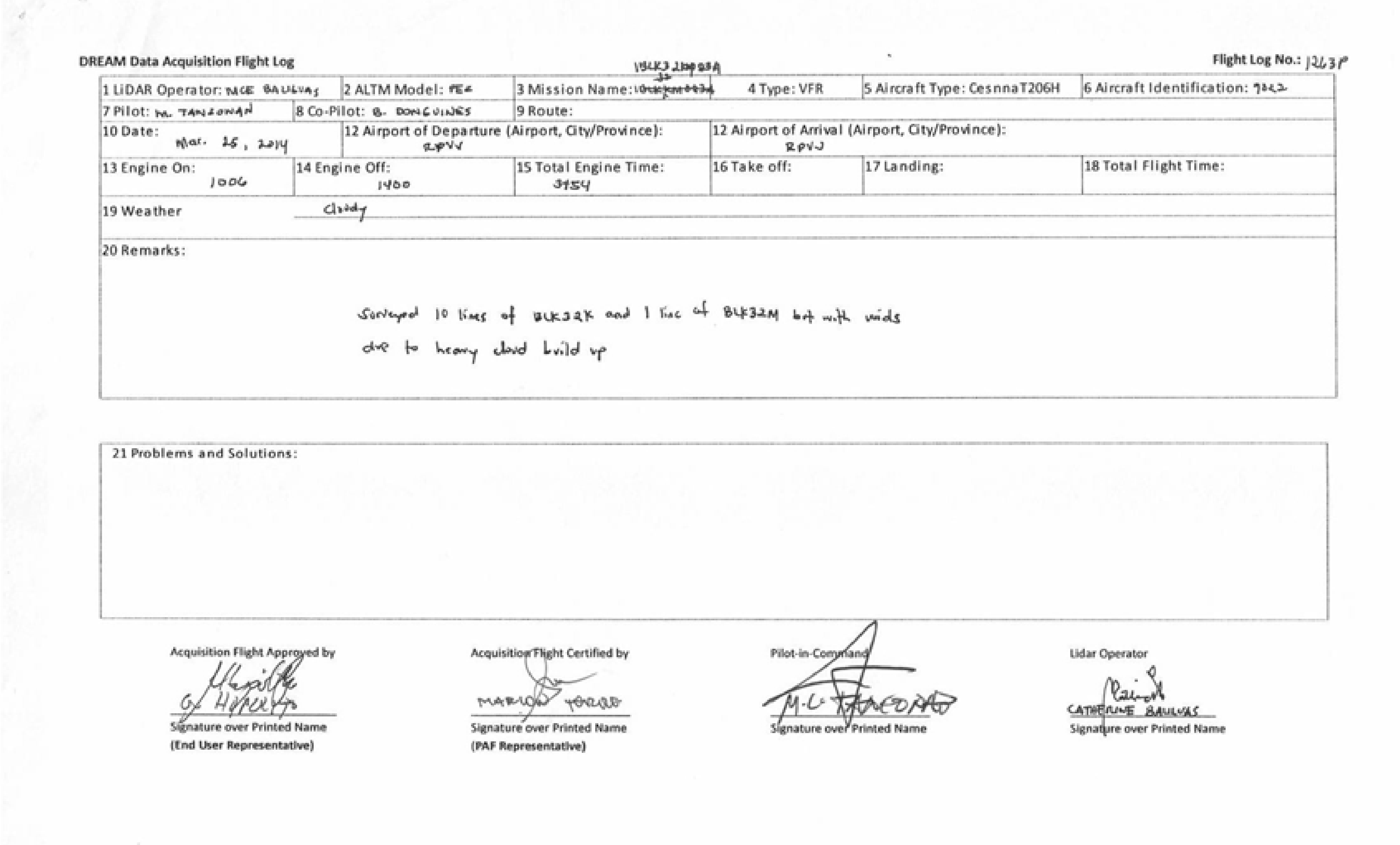
Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature] 4/23/14

Figure A-5.2. Transfer Sheet for Nauco Aguada Floodplain - B

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 1263P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1263P

1 LiDAR Operator: NICE BALUYAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32K085A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route:			
10 Date: Mar. 26, 2014	12 Airport of Departure (Airport, City/Province): RPVV		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1006	14 Engine Off: 1400	15 Total Engine Time: 3454	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 10 lines of BLK32K and 1 line of BLK32M but with voids due to heavy cloud build up

21 Problems and Solutions:

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

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

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

Lidar Operator — CATHERINE BALUYAS — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1263P

2. Flight Log for 1267P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1267P

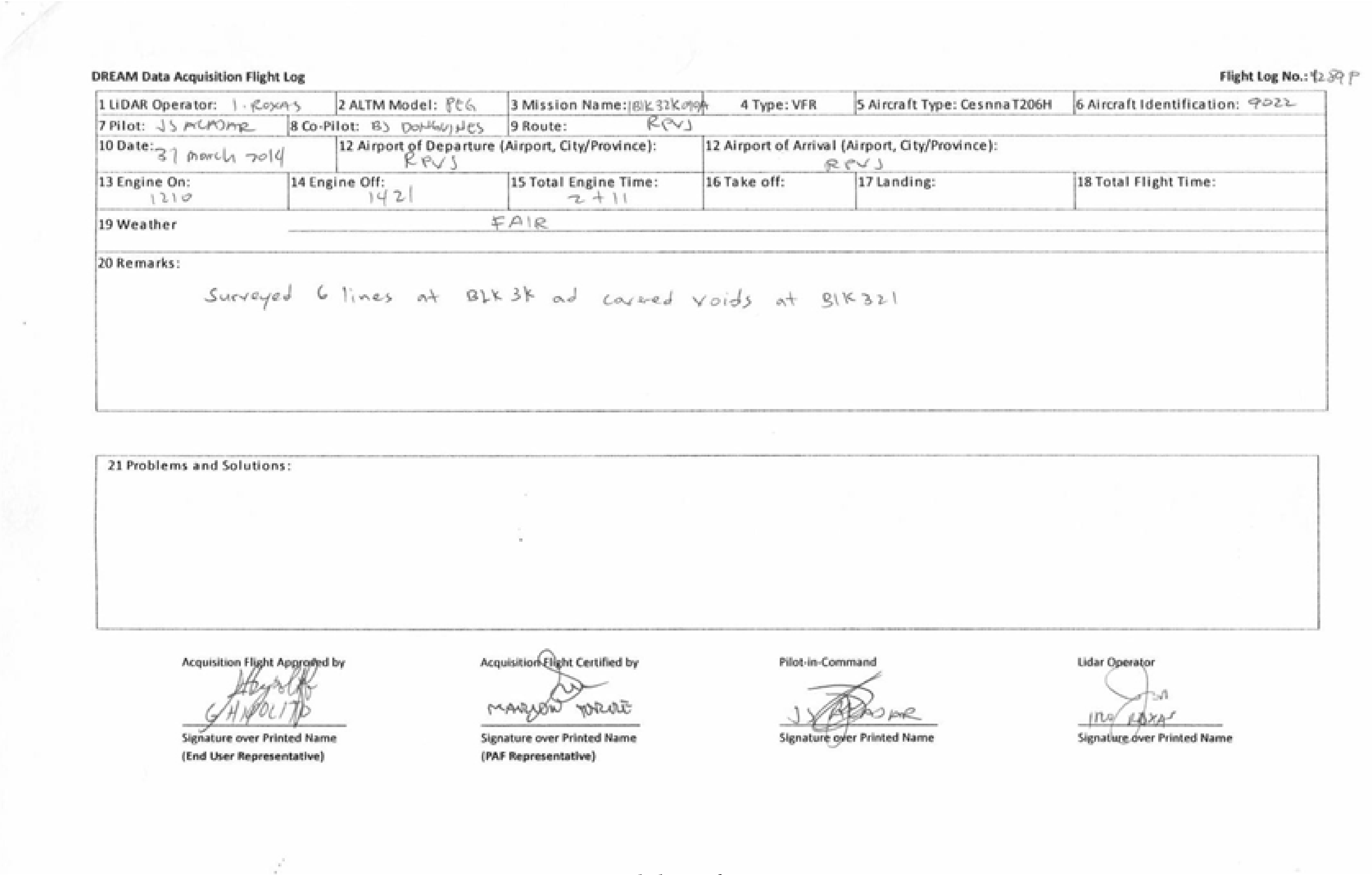
1 LiDAR Operator: I. Roxas	2 ALTM Model: PEG	3 Mission Name: 1BLK32MO85A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: B. Dongvines	9 Route:			
10 Date: Mar. 26, 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0709	14 Engine Off: 1138	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					
20 Remarks: Successful flight No digitizer					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito	Marvin Torres	M. Tangonan	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1267P

3. Flight Log for 1289P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1289P

1 LiDAR Operator: I. Roxas	2 ALTM Model: PEG	3 Mission Name: 1BLK32K090A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JS Alcome	8 Co-Pilot: BJ Dongwines	9 Route: RPVJ			
10 Date: 31 march 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1210	14 Engine Off: 1421	15 Total Engine Time: 2+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	FAIR				

20 Remarks:

Surveyed 6 lines at BLK 3K ad covered voids at BLK321

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1289P

4. Flight Log for 1291P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1291

1 LiDAR Operator: ACE BACULAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32K401A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JS ALAJAR	8 Co-Pilot: RJ DUMAGUINES	9 Route: RPVJ			
10 Date: 1 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0655	14 Engine Off: 1118	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Completed BLK 32L and surveyed 3 lines at BLK 32K an covered gaps at BLK 32I

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C HIPOLITO	MARLON TUNAT	JJ ALAJAR	CATHERINE BALUYAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1291P

ANNEX 7. Flight status reports

MASBATE MISSION
March 25 to April 1, 2014

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1263P	BLK3K	1BLK32K084A	MCE. BALIGUAS	25 MAR 14	Surveyed 10 lines of BLK32K and 2 lines of BLK32M but with voids due to heavy cloud build up; without digitizer
1267P	BLK32M	1BLK32M085A	I. ROXAS	26 MAR 14	Completed BLK32M. Surveyed 1 line at BLK32K and covered voids at BLK32 J AND BLK32I; without digitizer
1289P	BLK32K	1BLK32K090A	I. ROXAS	31 MAR 14	Surveyed 6 lines at BLK32K and covered voids at BLK32I
1291P	BLK32L	1BLK32KL091A	MCE. BALIGUAS	01APR 14	Completed BLK32L and surveyed 3 lines at BLK32K and covered gaps at BLK32I

SWATH PER FLIGHT MISSION

FLIGHT NO. :	1263P
AREA:	BLK32K
MISSION NAME:	1BLK32K084A
PARAMETERS:	Altitude: 700m;
	Scan Frequency: 30Hz;
	Scan Angle: 25deg;
	Overlap: 25%

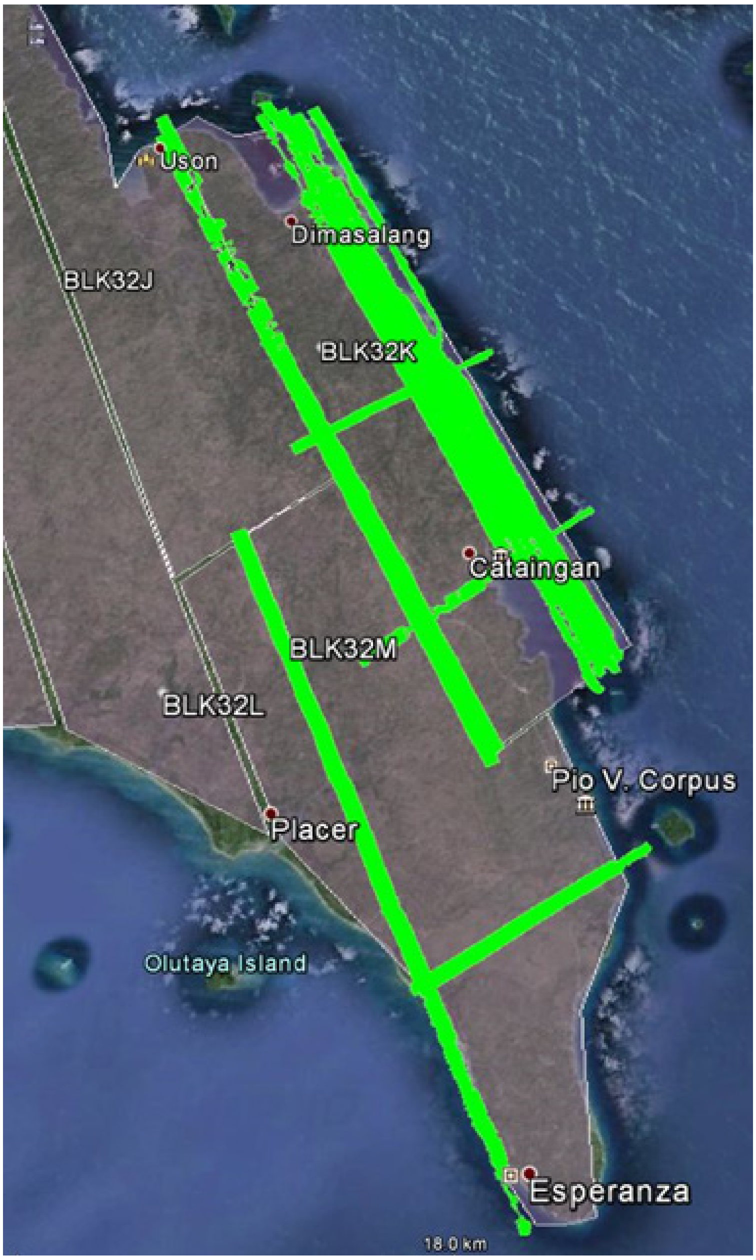


Figure A-7.1. Swath for Flight No. 1263P

FLIGHT NO. :	1267P
AREA:	BLK32M
MISSION NAME:	1BLK32M085A
PARAMETERS:	Altitude: 1000m and 1200m; Scan Frequency: 30Hz; Scan Angle: 25deg; Overlap: 30% and 25%

Figure A-7.2. Swath for Flight No. 1267P

FLIGHT NO. :	1289P
AREA:	BLK32K
MISSION NAME:	1BLK32K090A
PARAMETERS:	Altitude: 1200m;
	Scan Frequency: 30Hz;
	Scan Angle: 25deg;
	Overlap: 25%

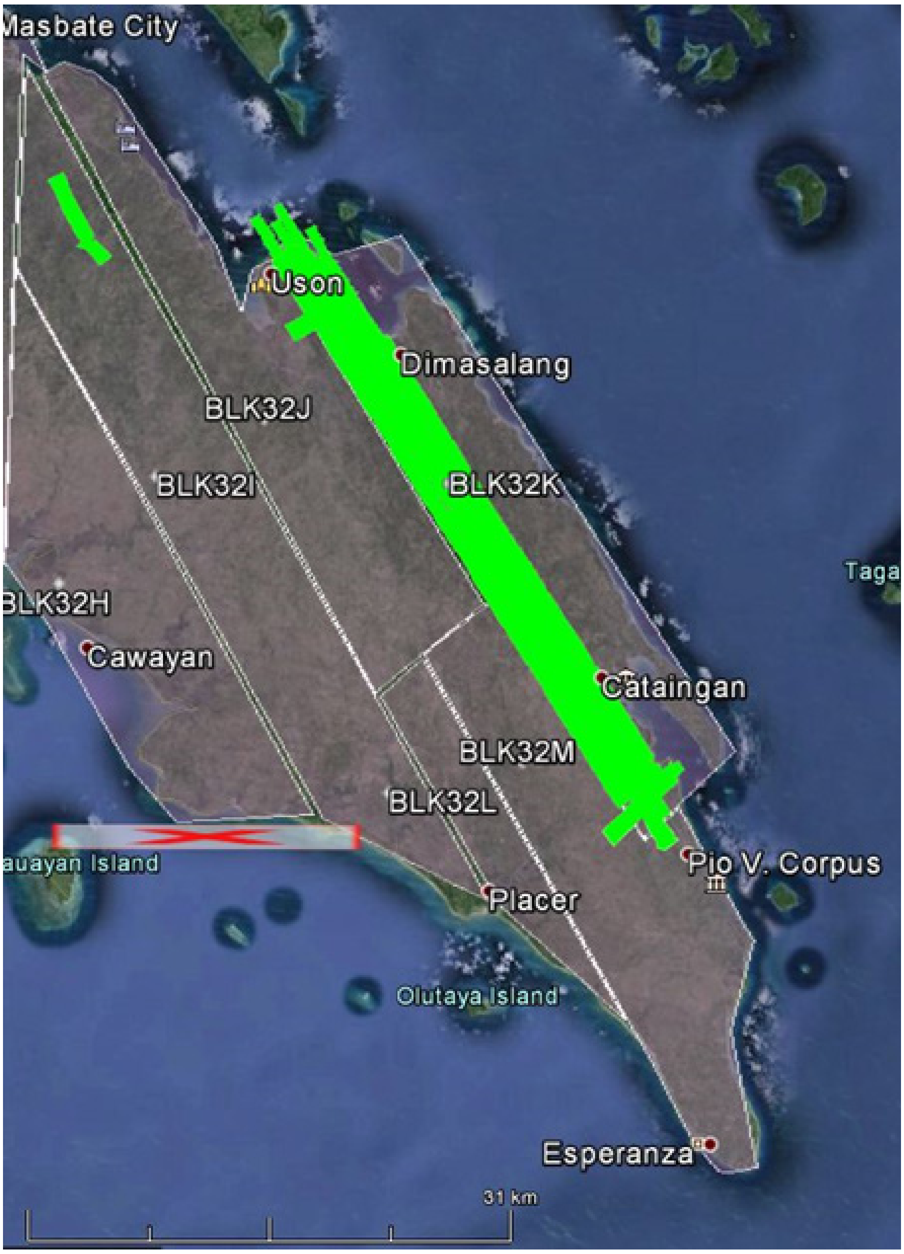


Figure A-7.3. Swath for Flight No. 1327P

FLIGHT NO. :	1291P
AREA:	BLK32K & BLK32L
MISSION NAME:	1BLK32KL091A
PARAMETERS:	Altitude: 800m;
	Scan Frequency: 30Hz;
	Scan Angle: 25deg;
	Overlap: 30%

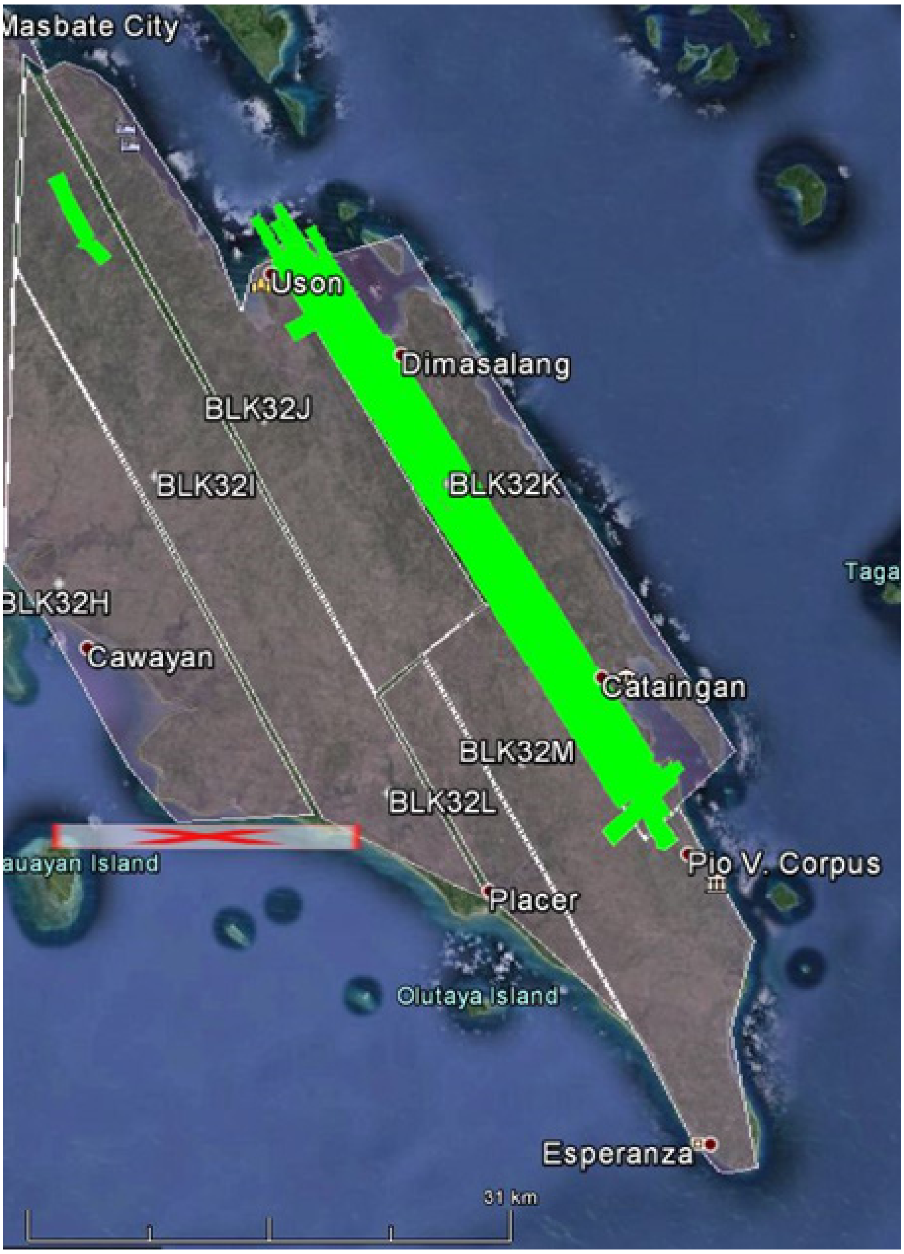


Figure A-7.4. Swath for Flight No. 1291P

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk32D

Flight Area	Masbate
Mission Name	Blk32M
Inclusive Flights	1267P, 1263P
Mission Name	1BLK32M085A, 1BLK32K084A
Range data size	63 GB
Base data size	10.58 MB
POS	500 MB
Image	107.1 GB
Transfer date	April 23 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.86
RMSE for East Position (<4.0 cm)	1.85
RMSE for Down Position (<8.0 cm)	3.45
Boresight correction stdev (<0.001deg)	0.000568
IMU attitude correction stdev (<0.001deg)	0.002429
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	52.19
Ave point cloud density per sq.m. (>2.0)	2.93
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	394
Maximum Height	352.81m
Minimum Height	48.96m
Classification (# of points)	
Ground	361,110,039
Low vegetation	297,792,986
Medium vegetation	362,645,392
High vegetation	175,924,405
Building	2,193,623

Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Irish Cortez, Engr. Merven Natino, Ziarre Mariposa

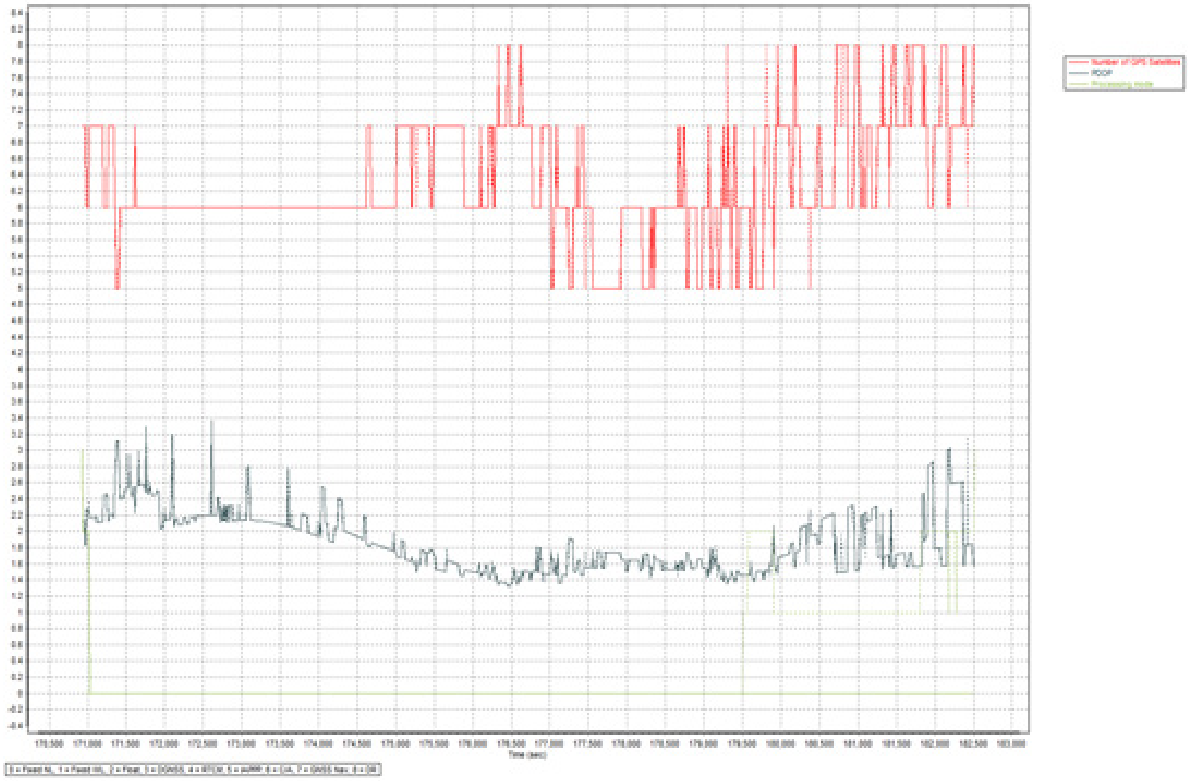


Figure A-8.1. Solution Status

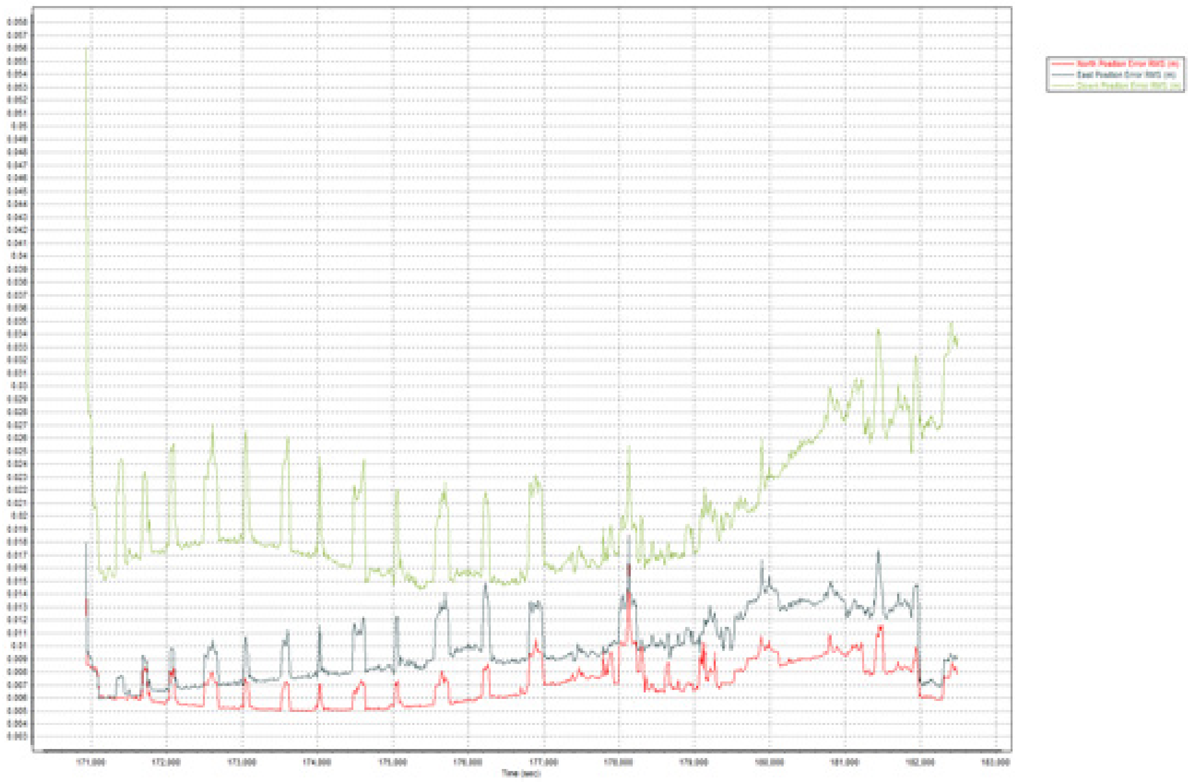


Figure A-8.2. Smoothed Performance Metric Parameters

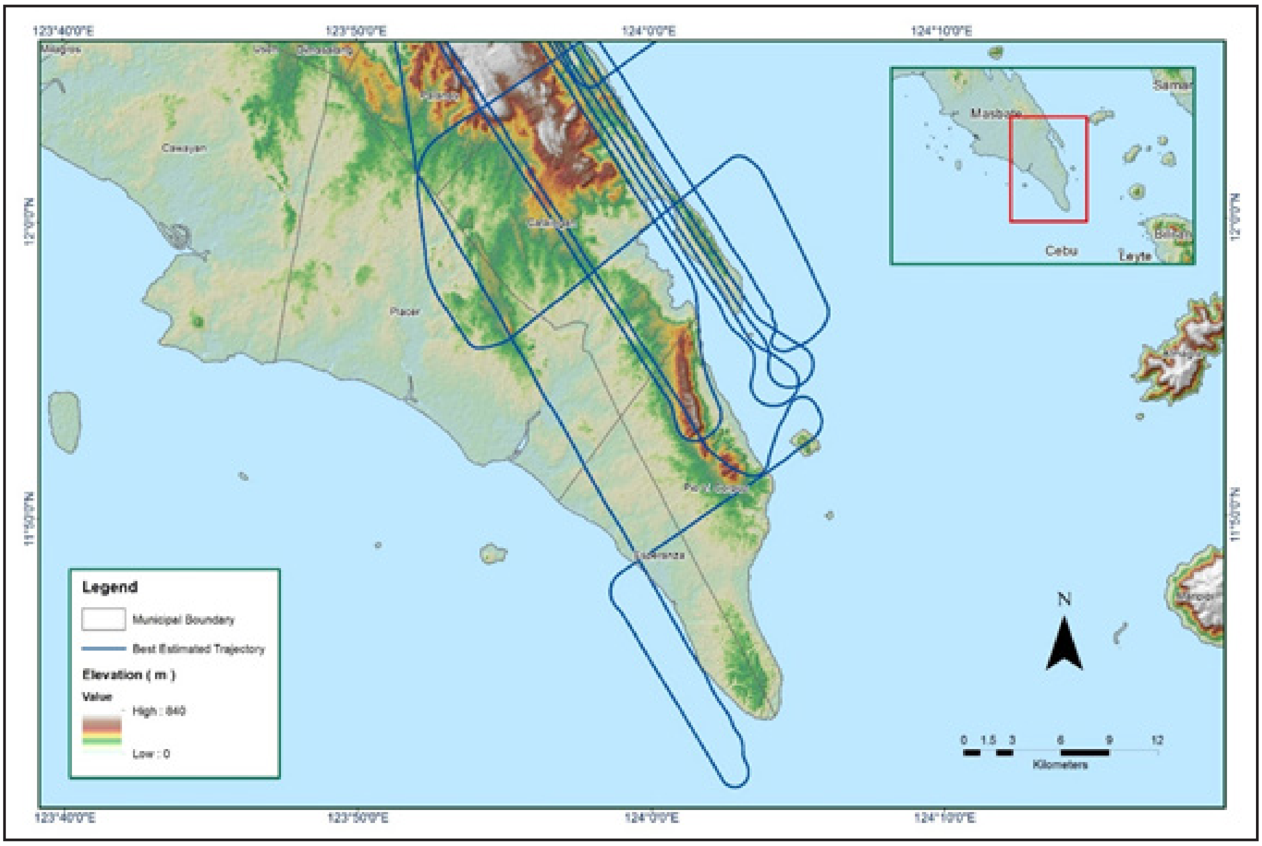


Figure A-8.3. Best Estimated Trajectory

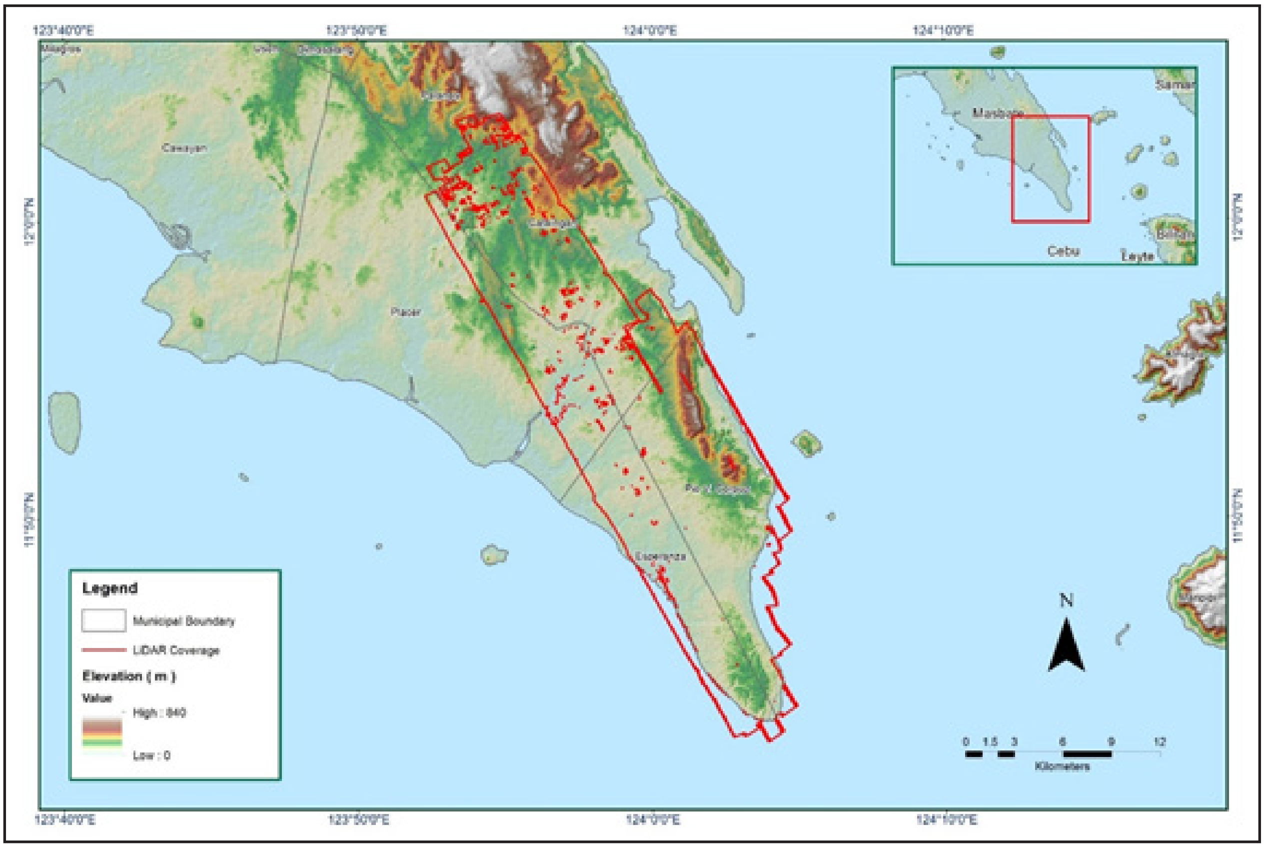


Figure A-8.4. Coverage of LiDAR data

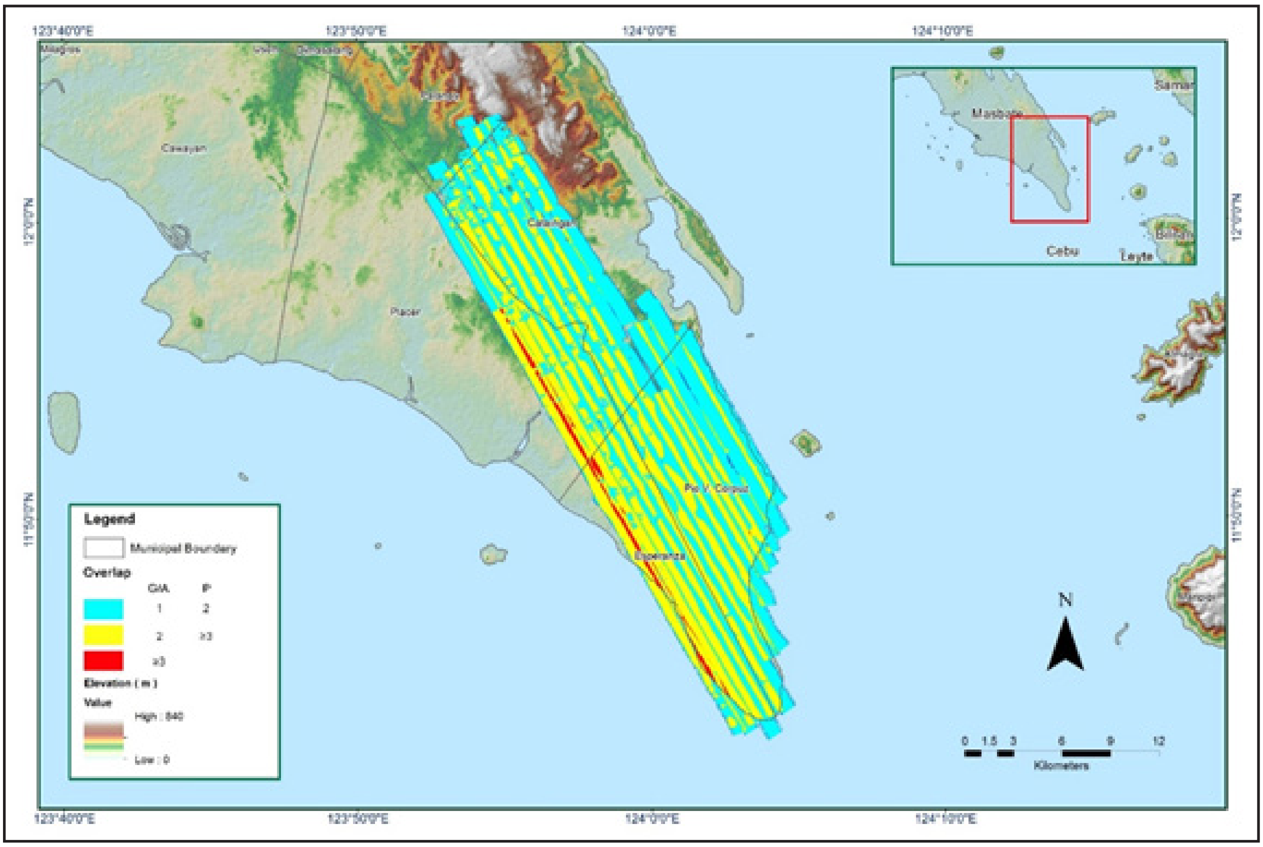


Figure A-8.5. Image of data overlap

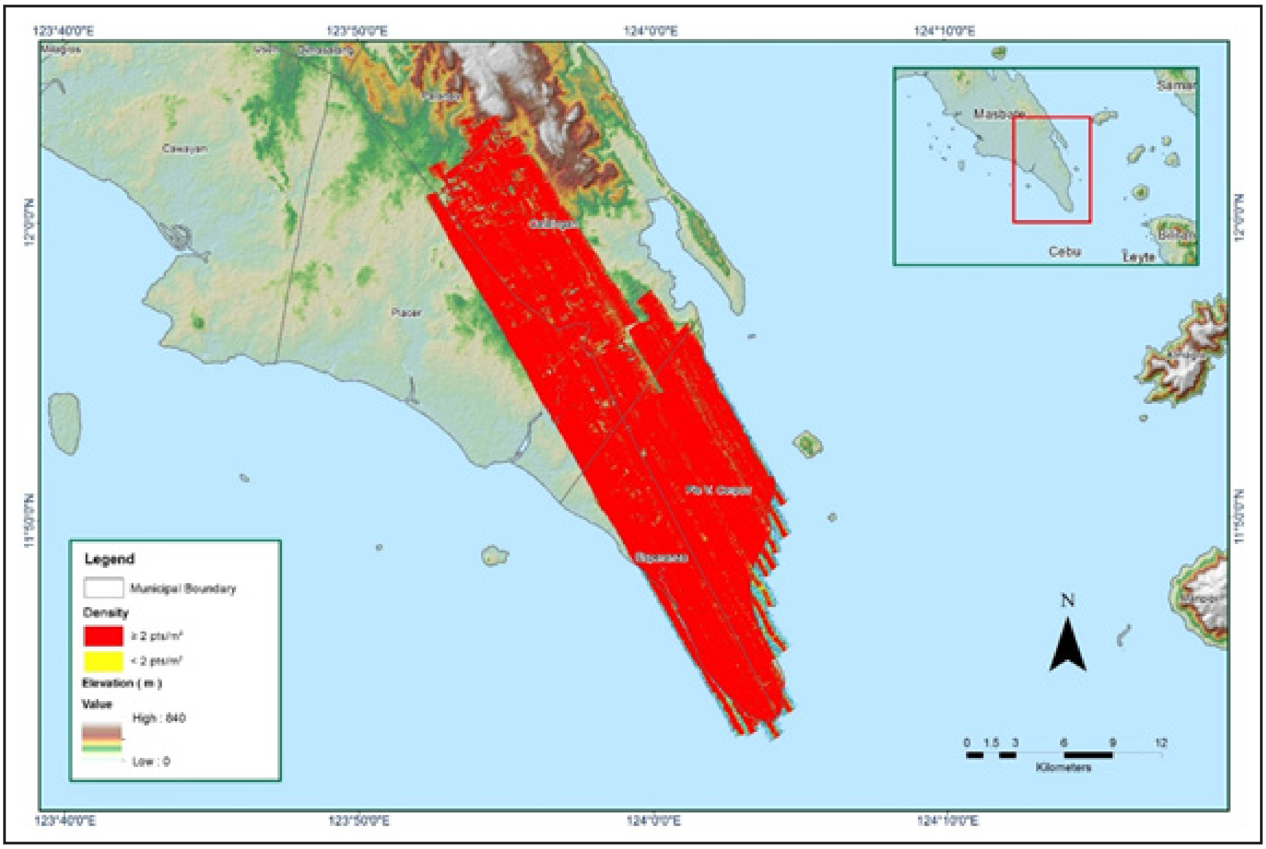


Figure A-8.6. Density map of merged LiDAR data

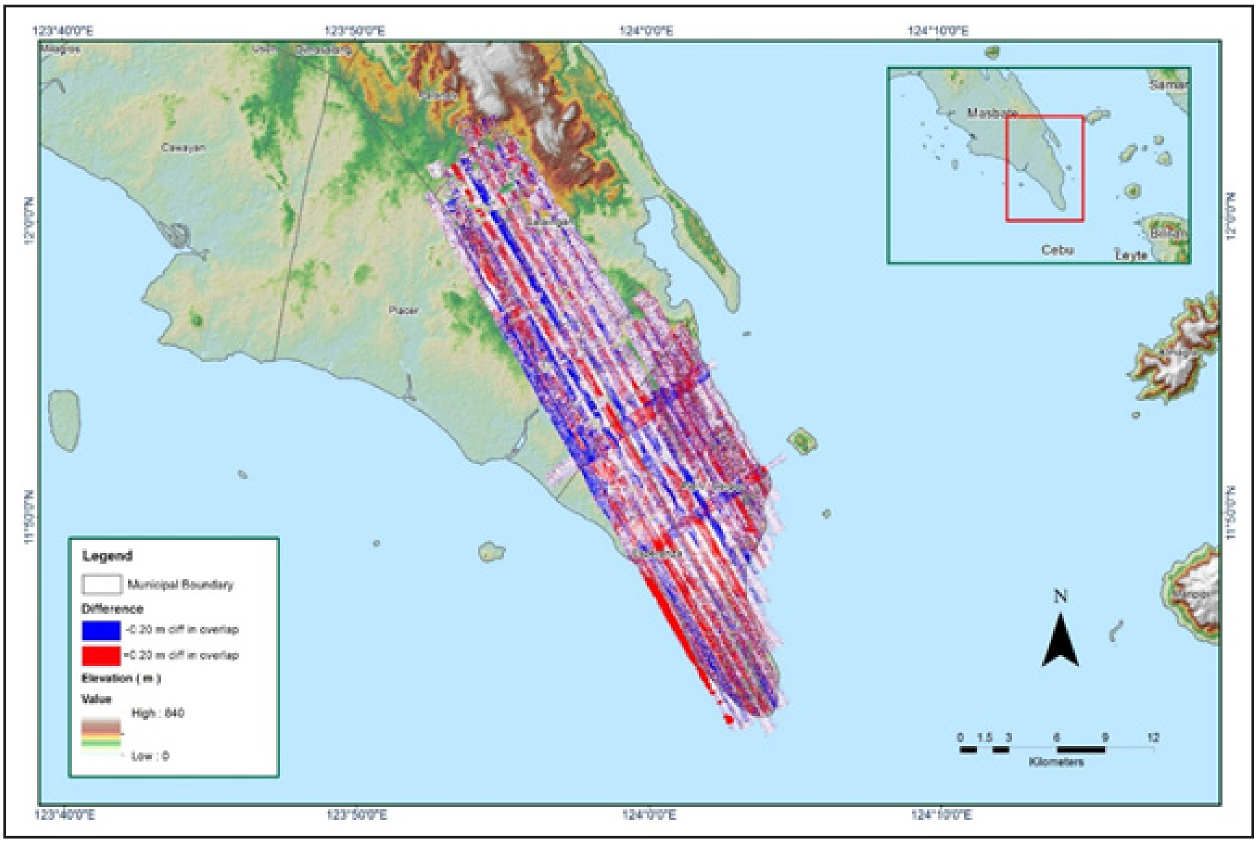


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk32L

Flight Area	Masbate
Mission Name	Blk32L
Inclusive Flights	1291P
Mission Name	1BLK32KL091A
Range data size	29.8 GB
Base data size	7.81 MB
POS	256 MB
Image	4.22 GB
Transfer date	April 23 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.86
RMSE for East Position (<4.0 cm)	1.85
RMSE for Down Position (<8.0 cm)	3.45
Boresight correction stdev (<0.001deg)	0.000568
IMU attitude correction stdev (<0.001deg)	0.002429
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	46.57%
Ave point cloud density per sq.m. (>2.0)	4.28
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	168
Maximum Height	187.1m
Minimum Height	47.37m
Classification (# of points)	
Ground	245,618,687
Low vegetation	177,742,884
Medium vegetation	166,437,529
High vegetation	74,107,542
Building	2,424,545
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Jovy Narisma

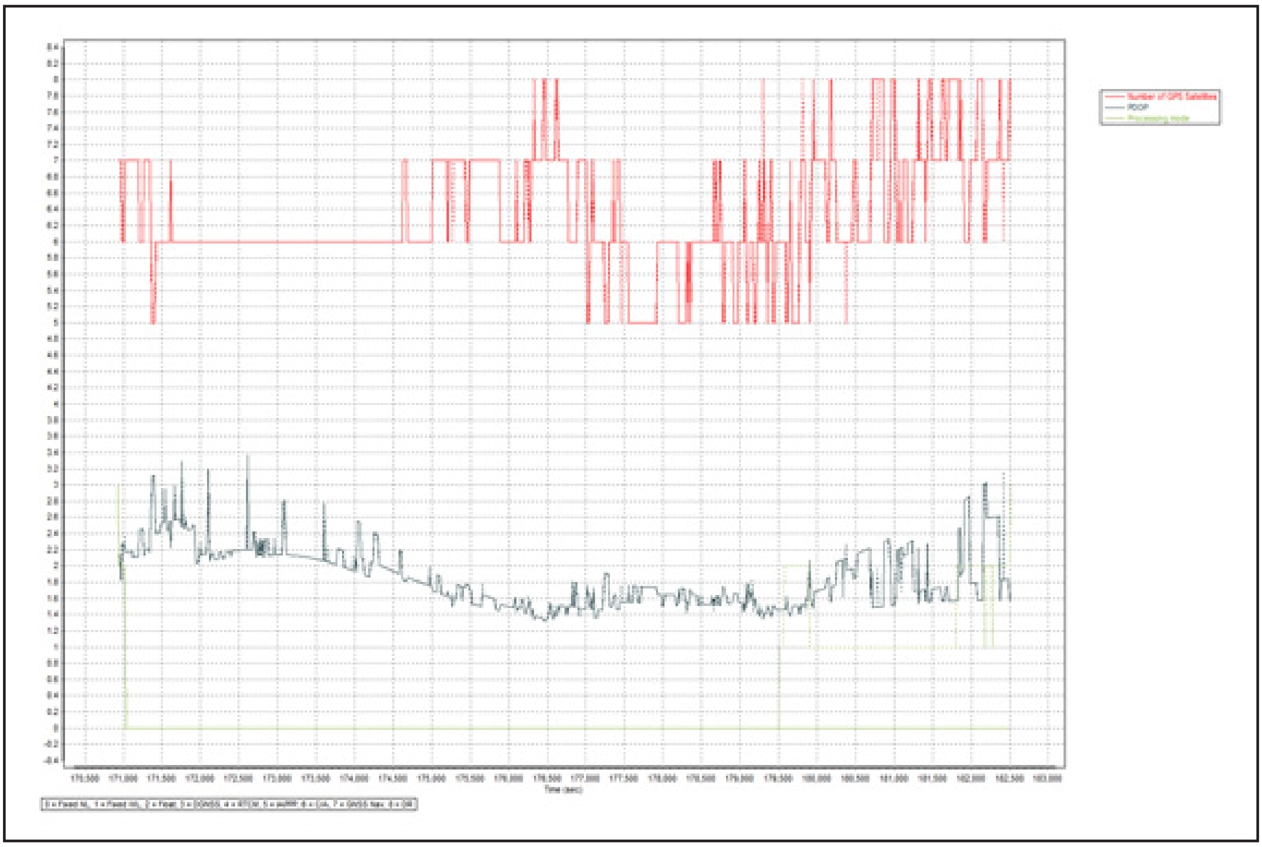


Figure A-8.8. Solution Status

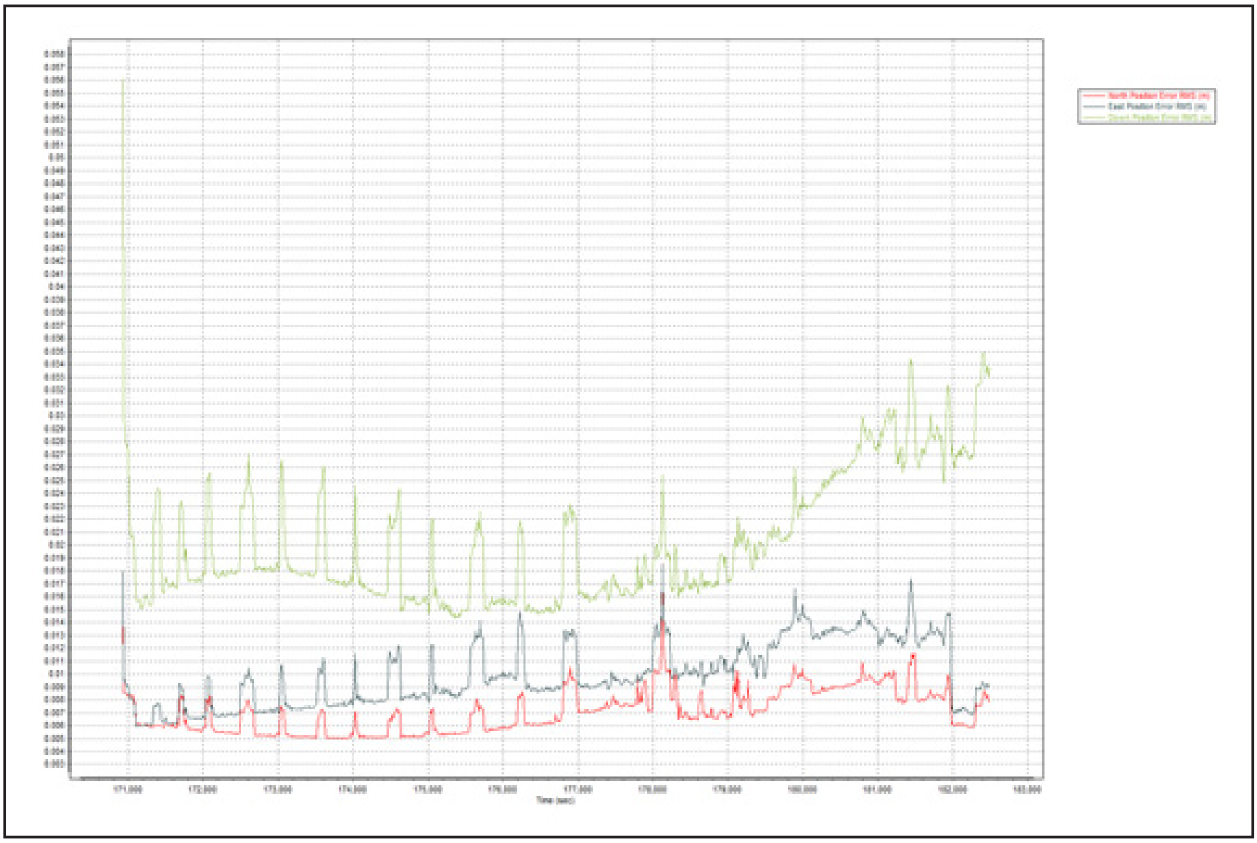


Figure A-8.9. Smoothed Performance Metric Parameters

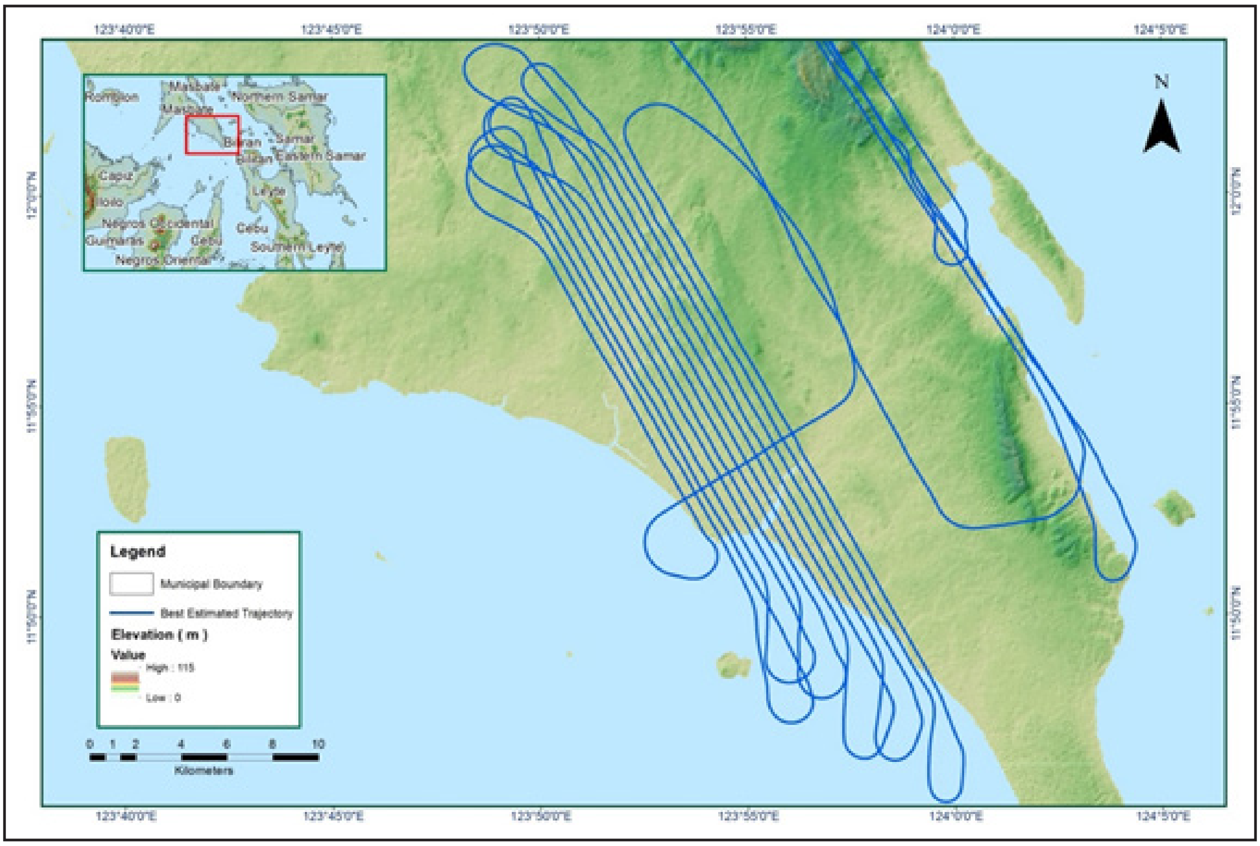


Figure A-8.10. Best Estimated Trajectory

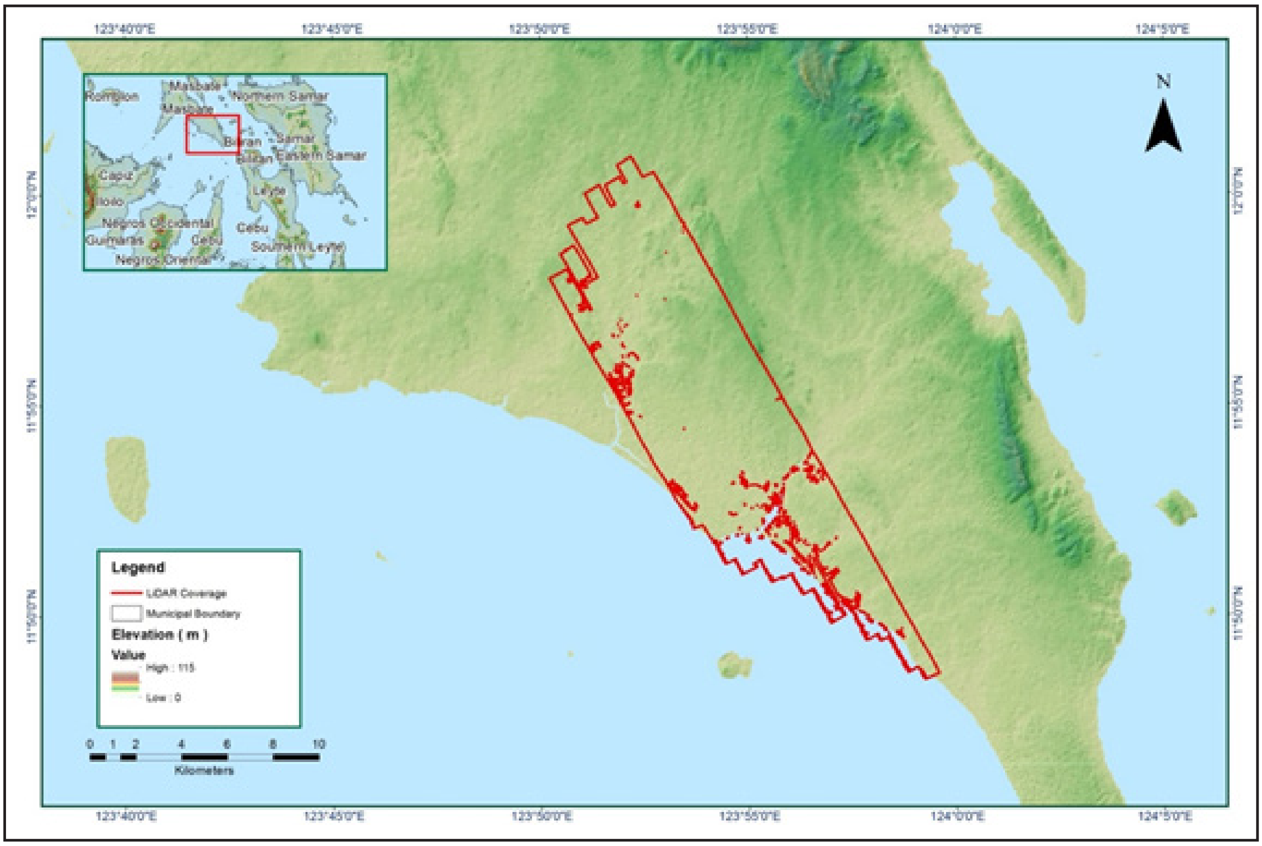


Figure A-8.11. Coverage of LiDAR data

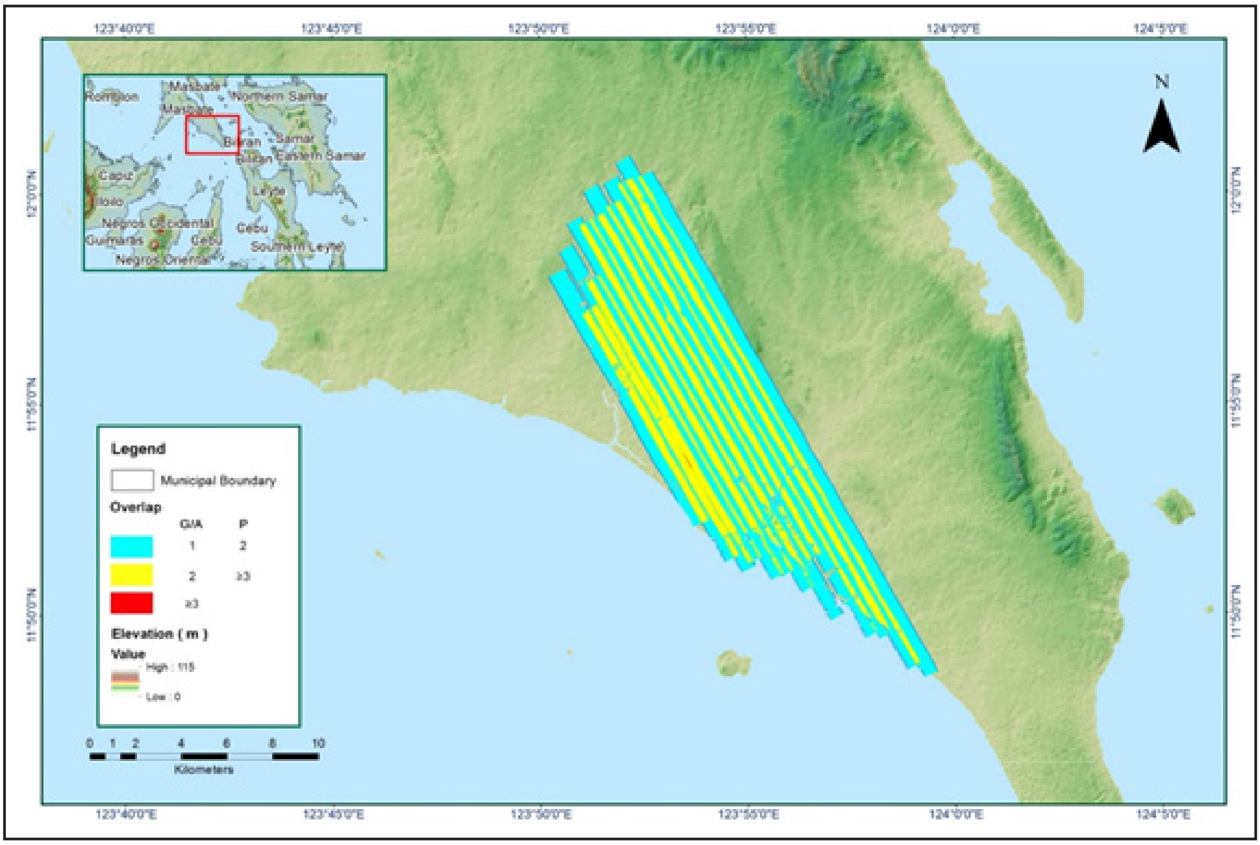


Figure A-8.12. Image of data overlap

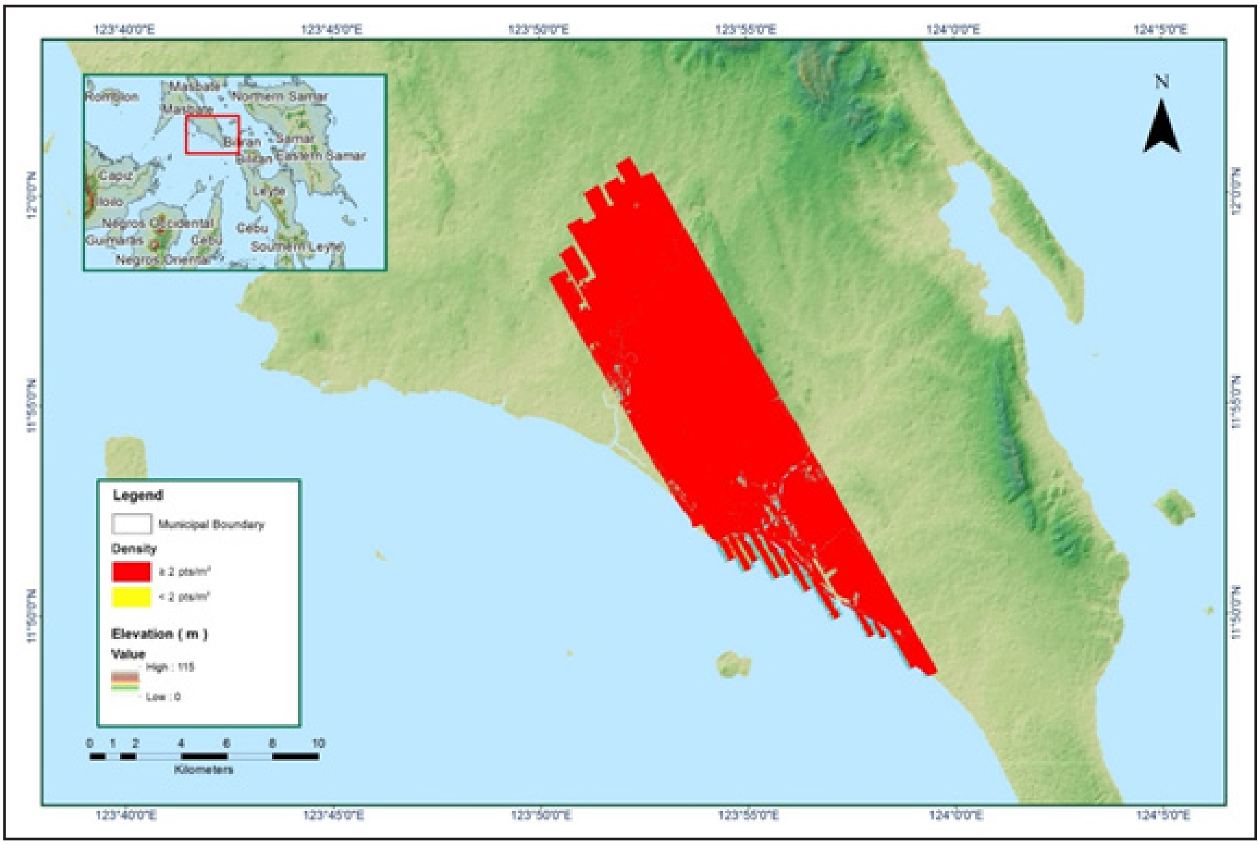


Figure A-8.13. Density map of merged LiDAR data

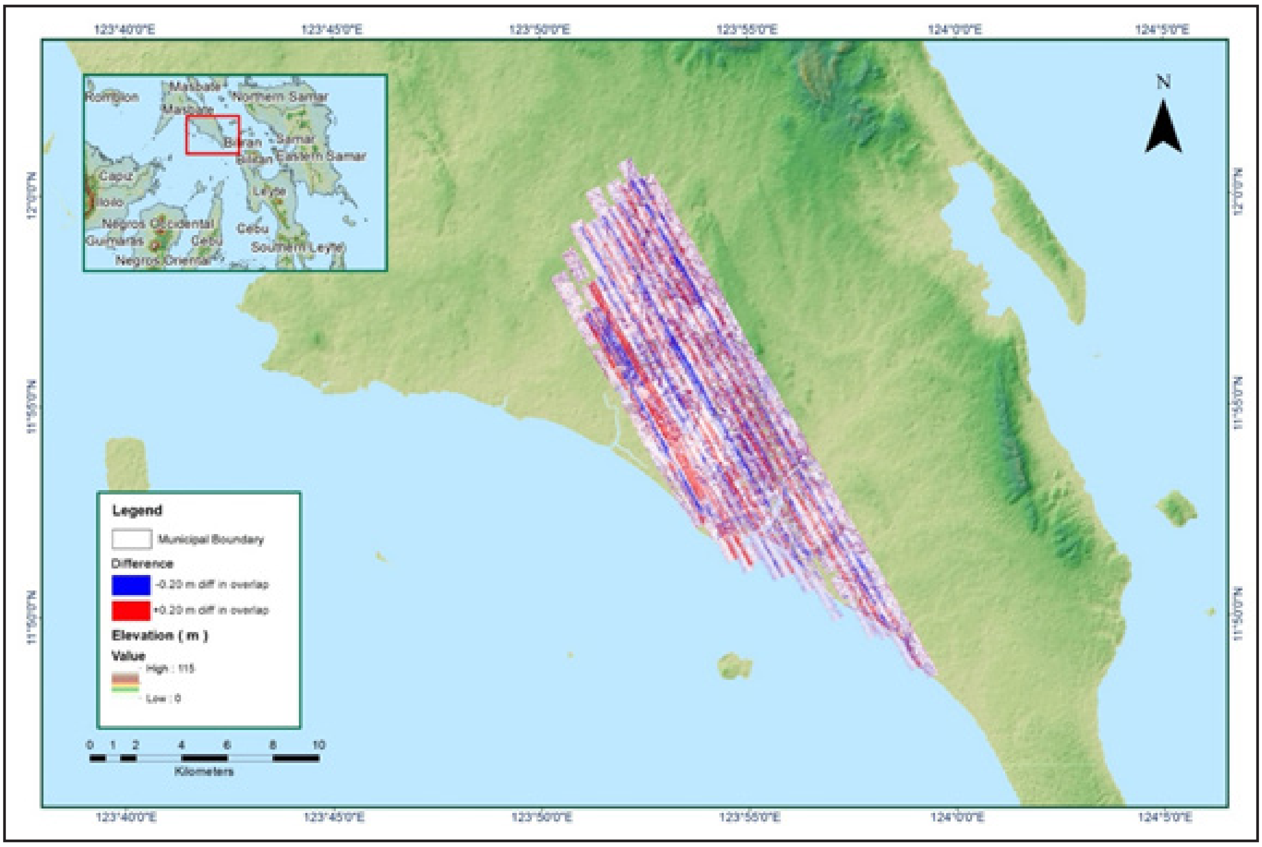


Figure A-8.14. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk32K

Flight Area	Masbate
Mission Name	Blk32K
Inclusive Flights	1263P, 1267P, 1289P, 1291P
Mission Name	1BLK32K084A, 1BLK32M085A, 1BLK32K090A, 1BLK32KL091A
Range data size	106.9 GB
Base data size	26.47 MB
POS	872 MB
Image	133.9 GB
Transfer date	April 23 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.61
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.74
Boresight correction stdev (<0.001deg)	0.000331
IMU attitude correction stdev (<0.001deg)	0.001181
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	37.21%
Ave point cloud density per sq.m. (>2.0)	3.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	484
Maximum Height	502.98 m
Minimum Height	46.93 m
Classification (# of points)	
Ground	366,733,055
Low vegetation	288,483,550
Medium vegetation	470,306,515
High vegetation	447,968,454
Building	6,272,589
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Irish Cortez, Engr. Mark Joshua Salvacion, Engr. Roa Shalemar Redo

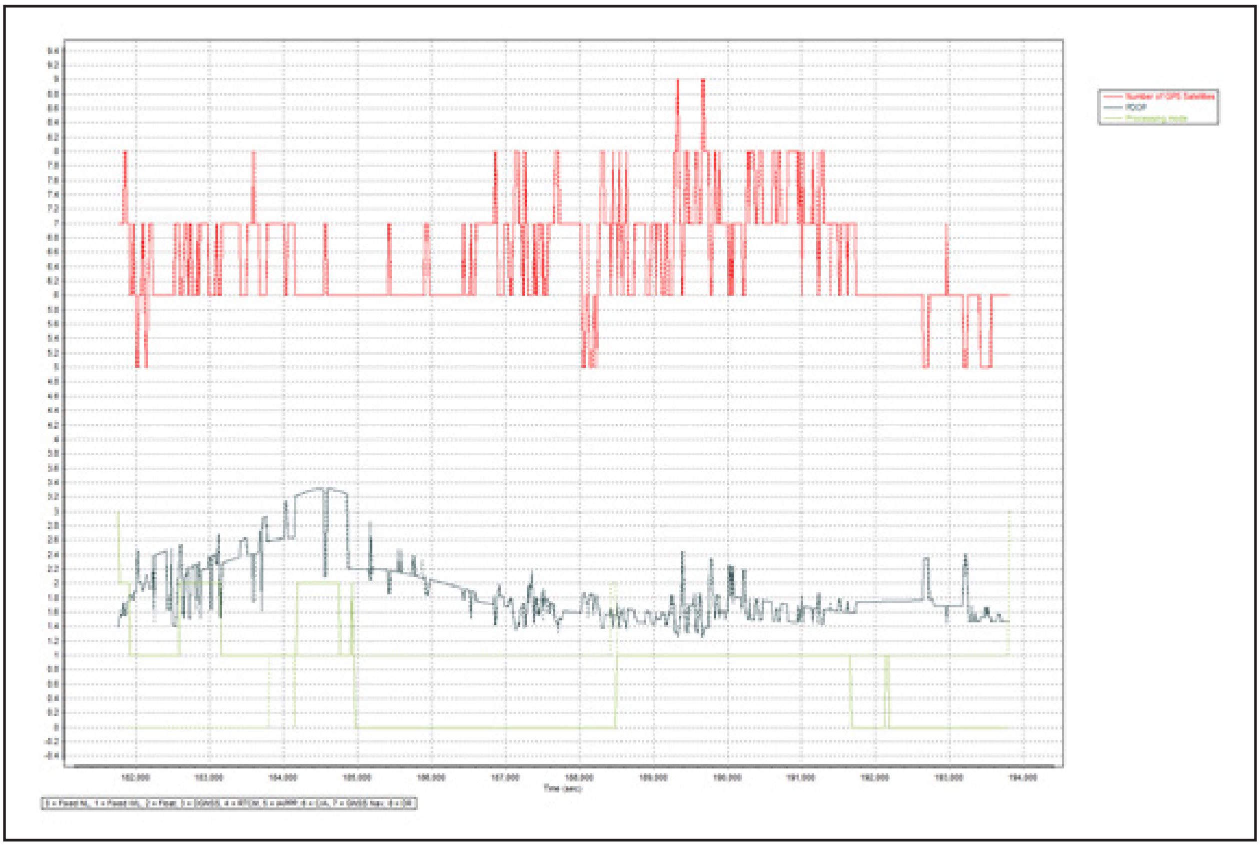


Figure A-8.15. Solution Status

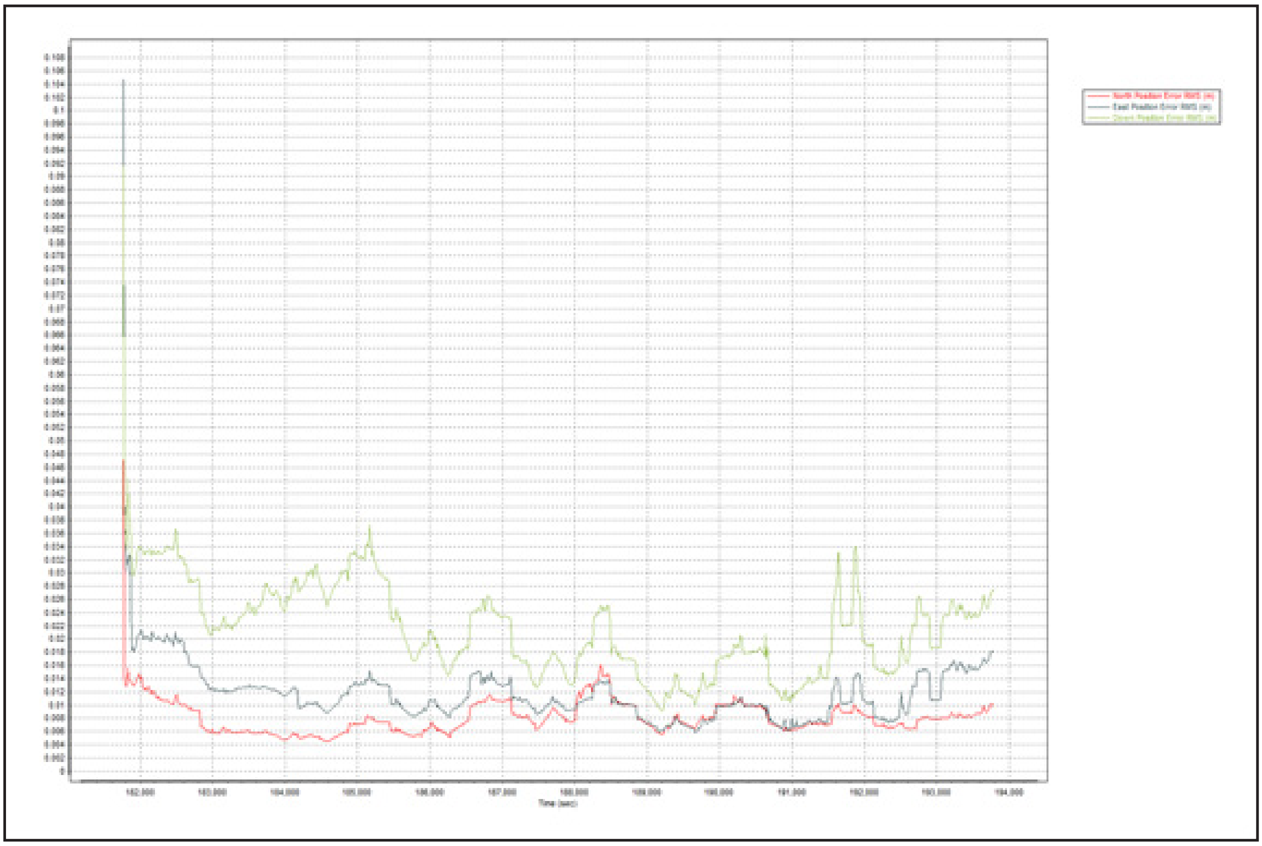


Figure A-8.16. Smoothed Performance Metric Parameters

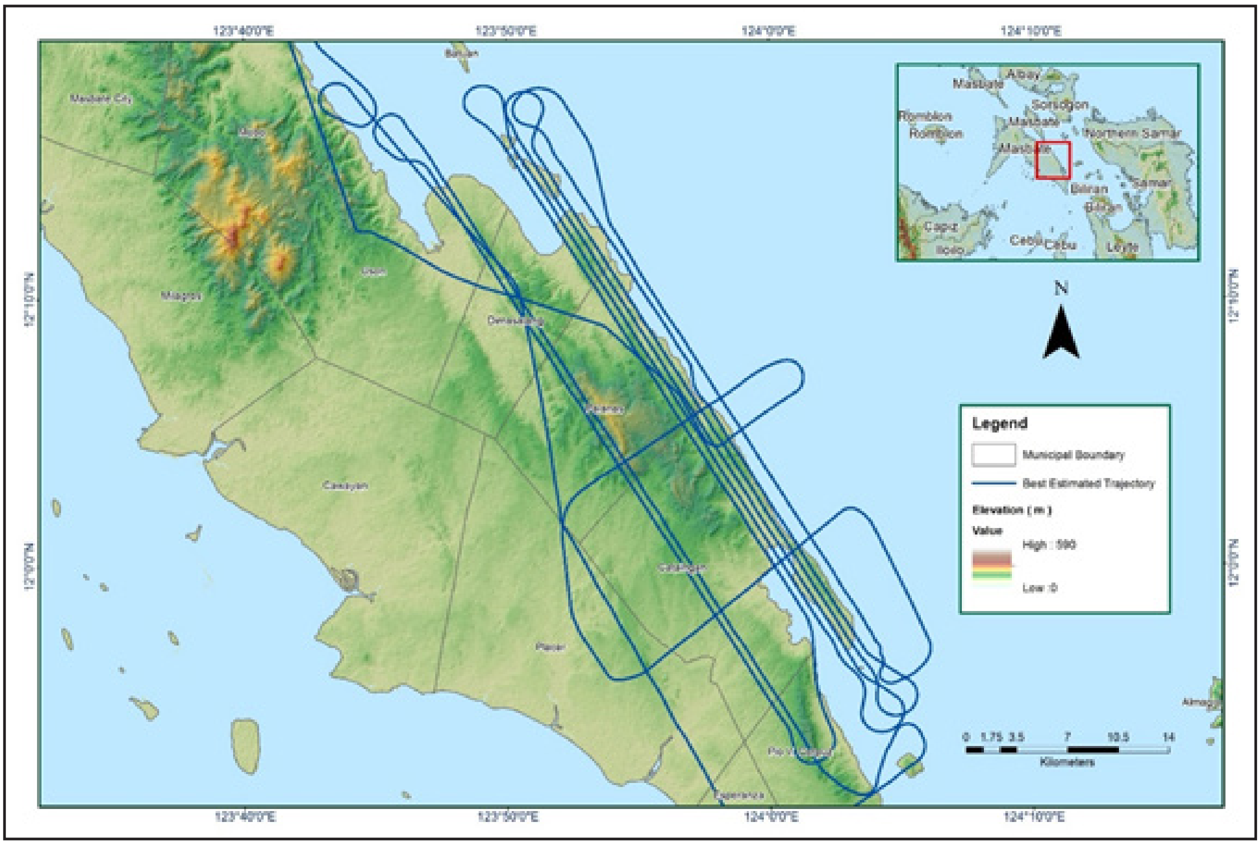


Figure A-8.17. Best Estimated Trajectory

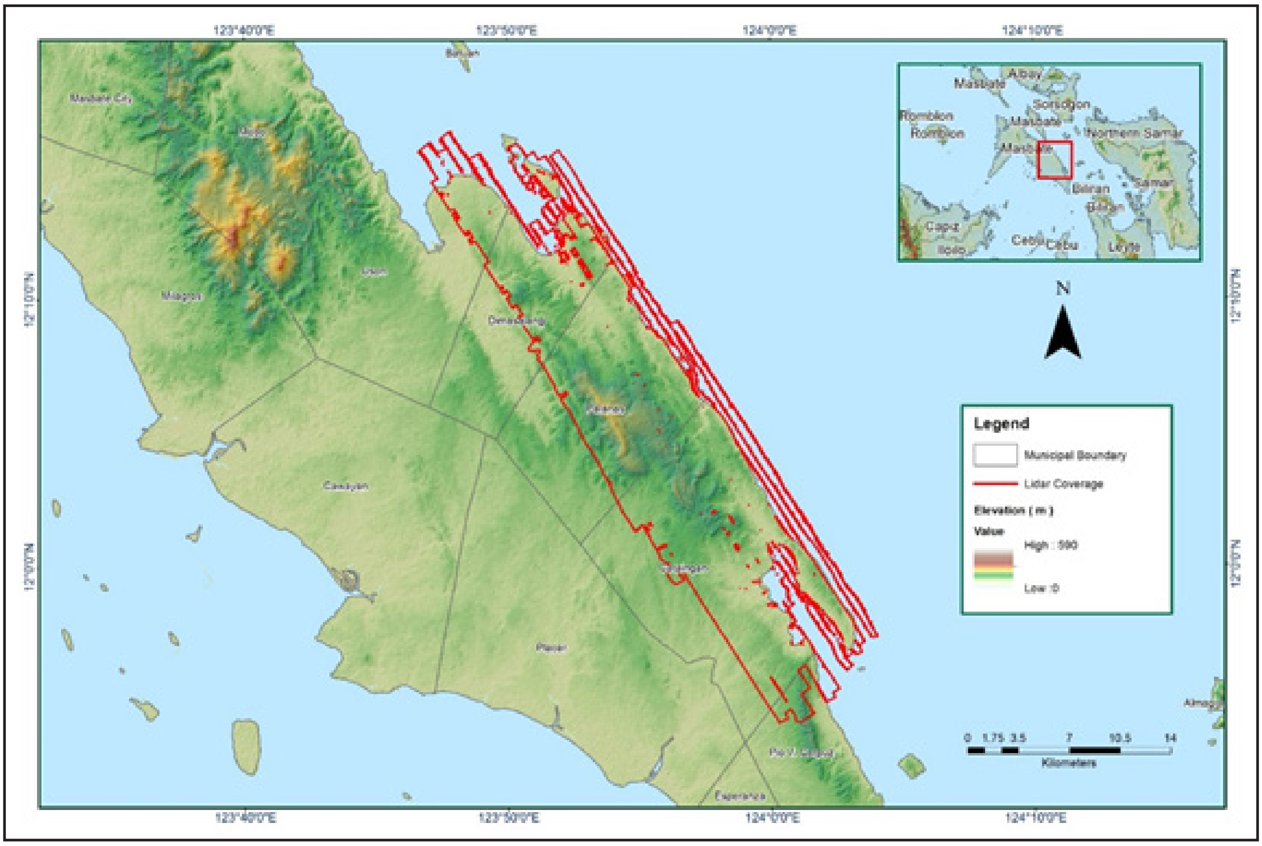


Figure A-8.18. Coverage of LiDAR data

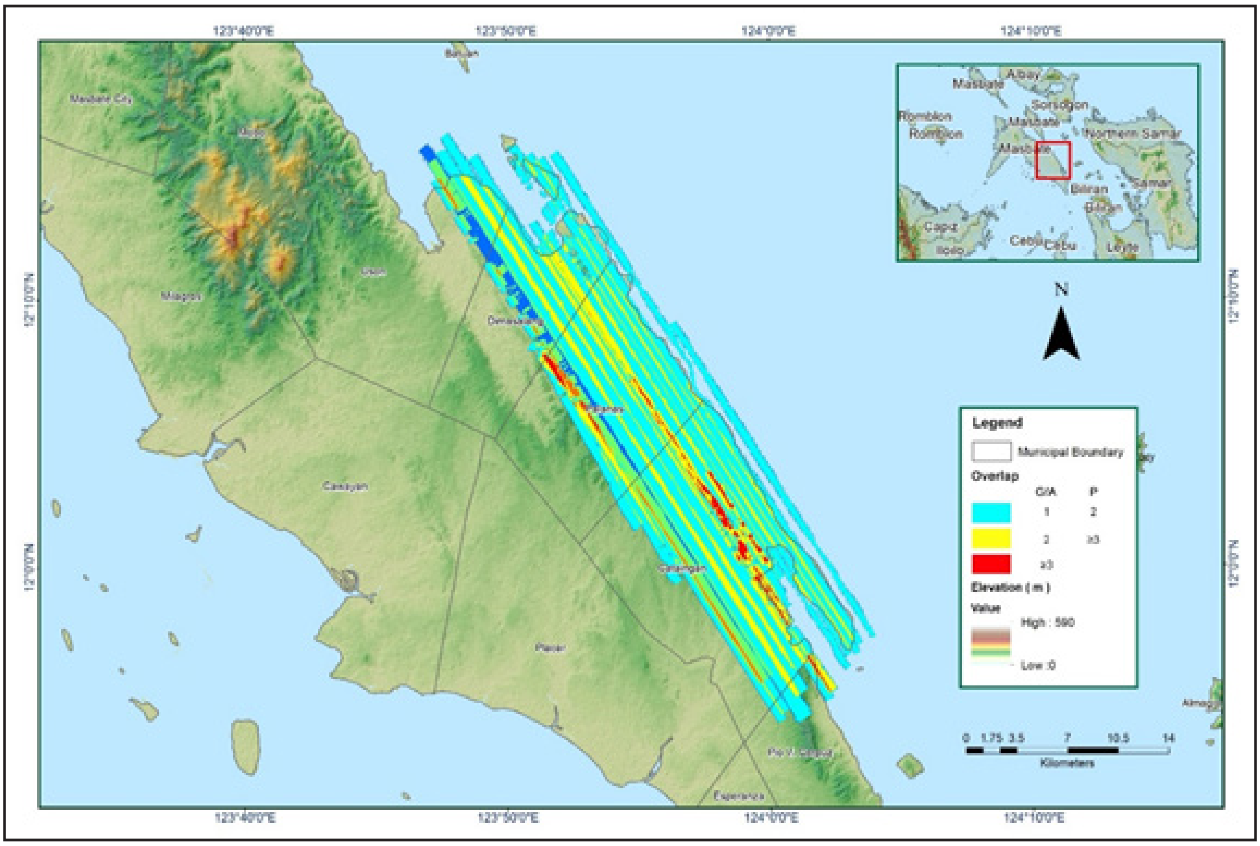


Figure A-8.19. Image of data overlap

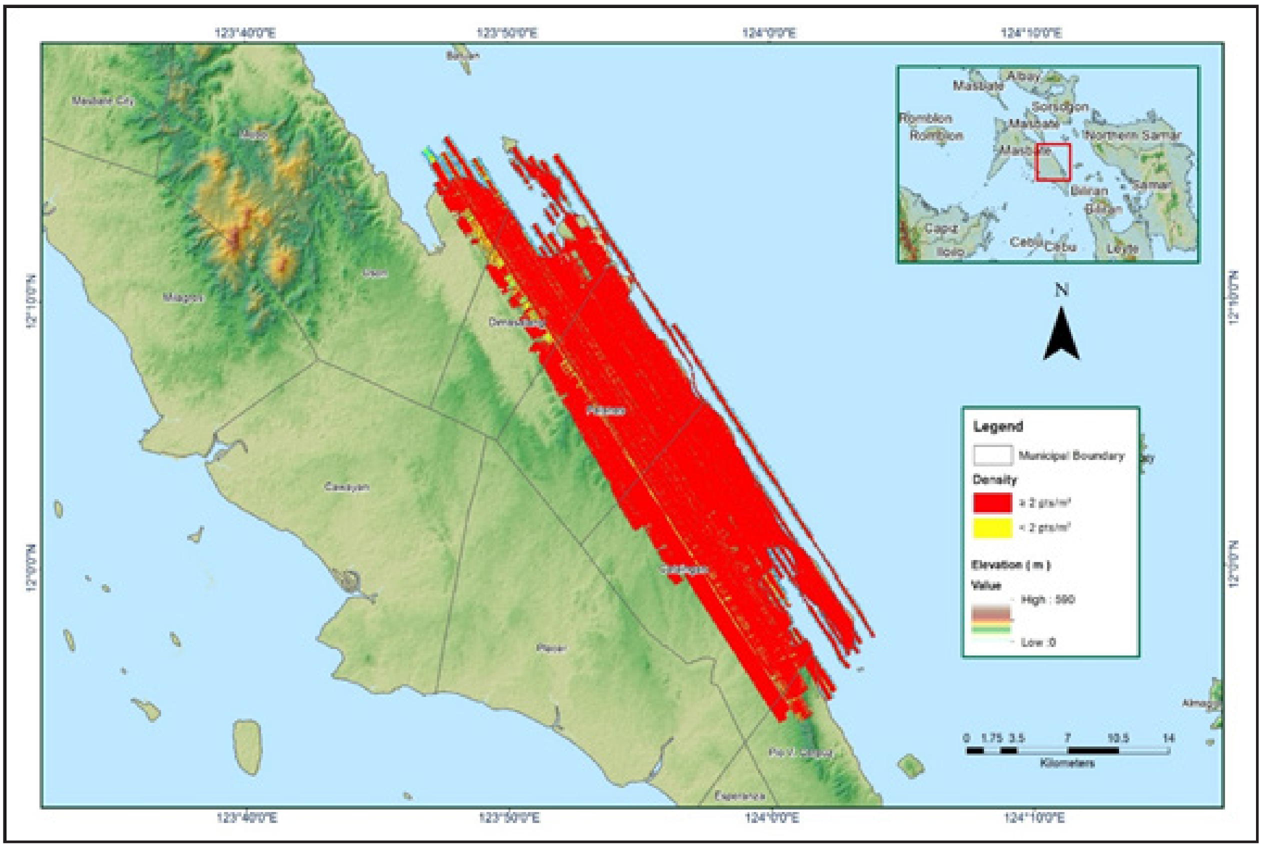


Figure A-8.20. Density map of merged LiDAR data

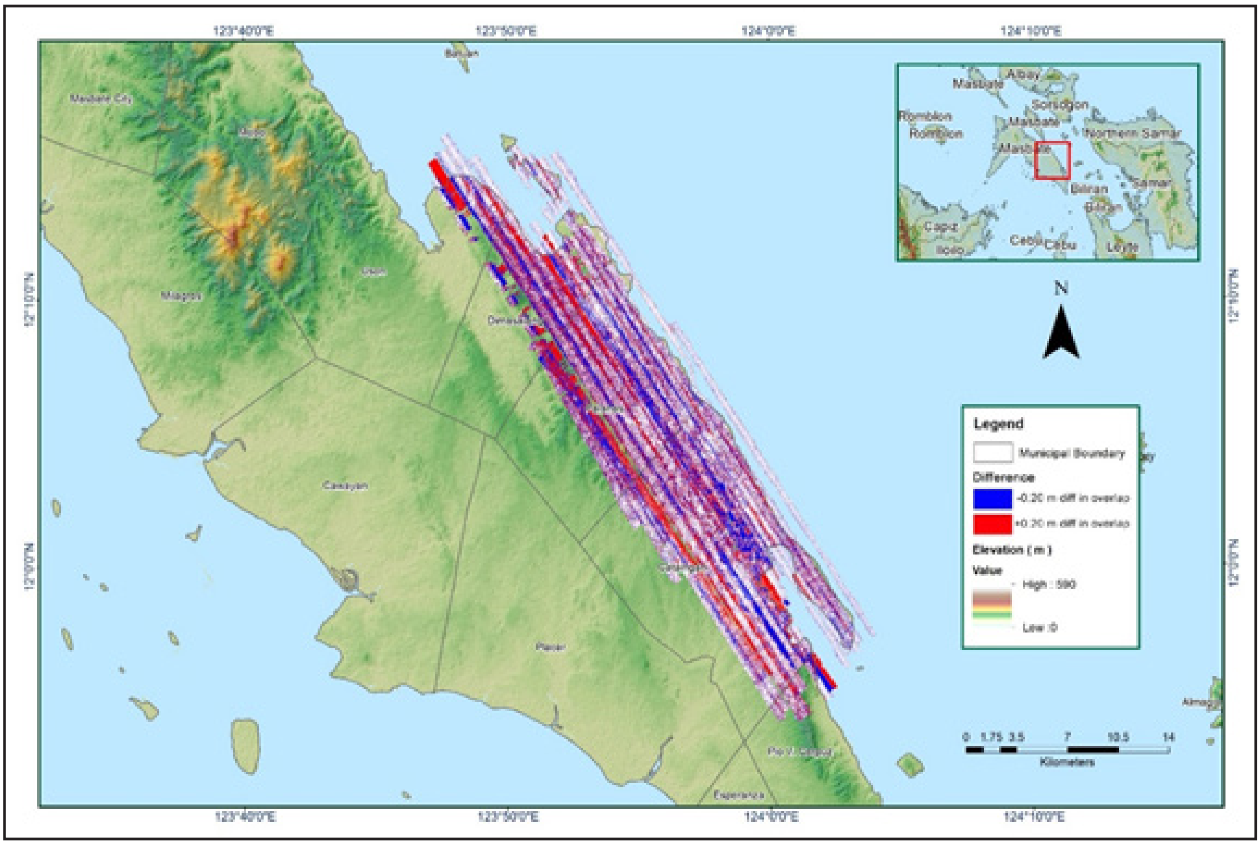


Figure A-8.21. Elevation difference between flight lines

ANNEX 9. Nauco Aguada Model Basin Parameters

Table A-9.1. Nauco Aguada Model Basin Parameters

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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
W180	0.016	83.583	0	0.017	0.60325	Discharge	6.3543	0.00827	Ratio to Peak	0.02471
W190	1.825	77.583	0	0.017	6.82630	Discharge	5.4141	0.00269	Ratio to Peak	0.68206
W200	0.001	97.059	0	0.017	6.86000	Discharge	4.7059	0.00126	Ratio to Peak	0.08055
W210	0.295	92.216	0	0.020	0.01667	Discharge	4.6709	0.00268	Ratio to Peak	0.17986
W220	0.873	98.617	0	0.020	0.08284	Discharge	2.0310	0.00127	Ratio to Peak	0.16416
W230	1.256	60.248	0	0.020	0.62778	Discharge	0.6158	0.00039	Ratio to Peak	0.01112
W240	35.312	99.000	0	0.020	0.50000	Discharge	1.8277	0.00086	Ratio to Peak	0.20000
W250	2.119	99.000	0	0.144	3.07800	Discharge	0.6470	0.00058	Ratio to Peak	0.05915
W260	0.010	69.486	0	0.130	7.63270	Discharge	1.3368	0.00276	Ratio to Peak	0.10406
W270	0.160	60.485	0	0.497	3.90890	Discharge	0.2713	0.00250	Ratio to Peak	0.12716
W280	0.084	97.072	0	0.133	0.06667	Discharge	2.9998	0.00086	Ratio to Peak	0.08462
W290	0.057	99.000	0	0.020	0.06667	Discharge	0.0451	0.00038	Ratio to Peak	0.06767
W300	0.036	53.177	0	0.020	0.05926	Discharge	1.2920	0.00312	Ratio to Peak	0.10000
W310	0.084	99.000	0	0.128	0.05926	Discharge	2.6148	0.00203	Ratio to Peak	0.08463
W320	1.110	96.803	0	0.017	0.06916	Discharge	0.8094	0.00222	Ratio to Peak	0.06084
W330	0.123	97.729	0	0.017	0.06453	Discharge	0.9090	0.00149	Ratio to Peak	0.05994
W340	0.850	66.320	0	0.020	0.14347	Discharge	1.2550	0.02216	Ratio to Peak	0.35655

Annex 10. Nauco Aguada Model Reach Parameters

Table A-10.1. Nauco Aguada Model Reach Parameters

Reach Number	Muskingum-Cunge Channel Routing						
	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	Side slope
R30	Automatic Fixed Interval	2719.0	0.00385	0.43764	Trapezoid	60.9	1
R60	Automatic Fixed Interval	2093.2	0.00694	1.00000	Trapezoid	60.9	1
R80	Automatic Fixed Interval	446.0	0.00847	1.00000	Trapezoid	60.9	1
R90	Automatic Fixed Interval	1081.5	0.00626	1.00000	Trapezoid	60.9	1
R140	Automatic Fixed Interval	1175.3	0.00096	0.00421	Trapezoid	60.9	1
R150	Automatic Fixed Interval	5616.9	0.00021	0.07840	Trapezoid	60.9	1
R160	Automatic Fixed Interval	2677.7	0.00071	0.29037	Trapezoid	60.9	1
R170	Automatic Fixed Interval	3635.8	0.00217	0.65762	Trapezoid	60.9	1

Annex 11. Nauco Aguada Field Validation Points

Table A-11.1. Nauco Aguada Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
93	11.86702176	123.907612	0.04	0	0.04		5-Year
43	11.86757334	123.9132812	0.09	0	0.09		5-Year
45	11.86758515	123.9137087	0.04	0	0.04		5-Year
40	11.86759003	123.9128213	0.03	0	0.03		5-Year
42	11.86760787	123.9129981	0.05	0	0.05		5-Year
41	11.86762979	123.9129743	0.03	0	0.03		5-Year
44	11.8677514	123.9137981	0.06	0	0.06		5-Year
46	11.86797925	123.913816	0.06	0	0.06		5-Year
47	11.86804929	123.9138567	0.03	0	0.03		5-Year
48	11.86811742	123.9138869	0.03	0	0.03		5-Year
49	11.86844254	123.9138875	0.03	0	0.03		5-Year
90	11.86848581	123.9067252	0.22	0.4	-0.18		5-Year
91	11.86852671	123.9067133	0.22	0.3	-0.08		5-Year
88	11.86853136	123.9060135	0.26	0	0.26		5-Year
92	11.86854798	123.9067851	0.25	0.3	-0.05		5-Year
96	11.86877666	123.908873	0.03	0	0.03		5-Year
94	11.86877948	123.90803	0.03	0	0.03		5-Year
95	11.86878045	123.9084124	0.04	0	0.04		5-Year
2	11.8687687	123.9222656	0.8	1.5	-0.7		5-Year
98	11.86881396	123.9094356	0.03	0.2	-0.17	STY Yolanda 2013	5-Year
100	11.86882287	123.9097874	0.03	0	0.03		5-Year
97	11.86882785	123.9091066	0.03	0	0.03		5-Year
101	11.8688337	123.9099256	0.03	0	0.03		5-Year
50	11.86882407	123.9139313	0.03	0	0.03		5-Year
103	11.8688497	123.9105191	0.03	0	0.03		5-Year
102	11.86885537	123.9102891	0.03	0.1	-0.07		5-Year
99	11.86885927	123.9096356	0.03	0	0.03		5-Year
3	11.86882308	123.9222481	0.75	1.5	-0.75		5-Year
105	11.86889411	123.9111584	0.03	0	0.03		5-Year
53	11.86888934	123.9133303	0.03	0	0.03		5-Year
106	11.86891388	123.911537	0.03	0	0.03		5-Year
52	11.86891331	123.9135179	0.03	0	0.03		5-Year
104	11.86892335	123.9108829	0.03	0	0.03		5-Year
51	11.86892691	123.9135691	0.03	0	0.03		5-Year
80	11.86894139	123.9128122	0.03	0	0.03		5-Year
89	11.86896585	123.906117	0.17	0.3	-0.13		5-Year
54	11.86894886	123.9132147	0.03	0	0.03		5-Year
86	11.86934606	123.9124847	0.23	0.5	-0.27		5-Year
78	11.86935759	123.9116078	0.48	0	0.48		5-Year
82	11.86936744	123.9126552	0.25	0.2	0.05		5-Year

85	11.86939982	123.912614	0.28	0.2	0.08		5-Year
9	11.86937349	123.9214818	0.52	0.5	0.02	STY Ruby 2014, STY Yolanda 2013	5-Year
8	11.86938593	123.9214918	0.52	0.5	0.02	STY Yolanda 2013	5-Year
87	11.86945174	123.9124185	0.36	0.5	-0.14	STY Yolanda 2013	5-Year
11	11.86943332	123.9216135	0.69	0.5	0.19	STY Yolanda 2013	5-Year
81	11.86946344	123.9126175	0.28	0.2	0.08		5-Year
75	11.86946552	123.912056	0.22	0	0.22		5-Year
13	11.86943996	123.921574	0.69	0.5	0.19	STY Yolanda 2013	5-Year
12	11.86944	123.9215944	0.69	0.5	0.19	STY Yolanda 2013	5-Year
10	11.86944323	123.9214888	0.57	0.5	0.07	STY Ruby 2014, STY Yolanda 2013	5-Year
79	11.86947663	123.9116204	0.5	0.5	0		5-Year
74	11.8694835	123.9120178	0.22	0	0.22		5-Year
77	11.86948913	123.9118446	0.19	0	0.19		5-Year
20	11.86946938	123.9215429	0.69	0.5	0.19	STY Yolanda 2013	5-Year
76	11.86950825	123.9121171	0.25	0	0.25		5-Year
19	11.86947847	123.921562	0.69	0.5	0.19	STY Yolanda 2013	5-Year
15	11.86948682	123.9215669	0.69	0.5	0.19	STY Yolanda 2013	5-Year
17	11.86948713	123.9215673	0.69	0.5	0.19	STY Yolanda 2013	5-Year
16	11.86948715	123.9215666	0.69	0.5	0.19	STY Yolanda 2013	5-Year
14	11.86948812	123.9215599	0.69	0.5	0.19	STY Yolanda 2013	5-Year
18	11.86948857	123.9215716	0.69	0.5	0.19	STY Yolanda 2013	5-Year
83	11.86953535	123.9126561	0.3	0.2	0.1		5-Year
23	11.86954349	123.9215366	0.58	0.6	-0.02	STY Yolanda 2013	5-Year
84	11.86957923	123.9125932	0.31	0.2	0.11	STY Yolanda 2013	5-Year
72	11.86959281	123.9119104	0.14	0	0.14		5-Year
197	11.86959966	123.9100307	0.42	0	0.42		5-Year
21	11.86957955	123.9215659	0.67	0.6	0.07	STY Yolanda 2013	5-Year
22	11.86957962	123.9215656	0.67	0.6	0.07	STY Yolanda 2013	5-Year
6	11.86959376	123.9214709	0.58	0	0.58		5-Year

26	11.86959944	123.9215492	0.6	0.6	0	STY Yolanda 2013	5-Year
7	11.86960485	123.921464	0.53	0	0.53		5-Year
5	11.86961632	123.9214476	0.32	0	0.32		5-Year
27	11.86962565	123.9215794	0.6	0.6	0	STY Yolanda 2013	5-Year
25	11.8696312	123.9216031	0.6	0.6	0	STY Yolanda 2013	5-Year
24	11.86965153	123.9215891	0.6	0.6	0	STY Yolanda 2013	5-Year
198	11.86970209	123.9102209	0.03	0	0.03		5-Year
196	11.86971141	123.9099507	0.26	0	0.26		5-Year
73	11.86975571	123.9117407	0.3	0	0.3		5-Year
199	11.87013445	123.91048	0.26	0	0.26		5-Year
1	11.87035856	123.9186273	0.05	0	0.05		5-Year
28	11.87046482	123.9174197	0.05	0	0.05		5-Year
195	11.87049995	123.9100186	0.26	0	0.26		5-Year
29	11.87048088	123.9171497	0.26	0	0.26		5-Year
31	11.87048815	123.9161509	0.21	0	0.21		5-Year
30	11.8706022	123.916678	0.15	0.2	-0.05		5-Year
30	11.8706022	123.916678	0.16	0.2	-0.04		5-Year
4	11.87068231	123.9222115	0.03	0.4	-0.37	STY Yolanda 2013	5-Year
32	11.87073646	123.9156354	0.27	0.4	-0.13		5-Year
33	11.87079055	123.9156709	0.35	0.4	-0.05		5-Year
34	11.87090321	123.91535	0.25	0.4	-0.15		5-Year
38	11.8717123	123.9174751	0.28	0	0.28		5-Year
37	11.87176266	123.9176479	0.21	0	0.21		5-Year
39	11.87179869	123.9174811	0.34	0	0.34		5-Year
208	11.87297566	123.8933945	0.15	0	0.15		5-Year
207	11.87322124	123.8932788	0.22	0	0.22		5-Year
206	11.87379776	123.892816	0.13	0	0.13		5-Year
36	11.87377822	123.9174915	0.27	0	0.27		5-Year
205	11.87390702	123.8927278	0.23	0	0.23		5-Year
35	11.8739535	123.917564	0.05	0	0.05		5-Year
204	11.87429658	123.892571	0.21	0	0.21		5-Year
203	11.87441563	123.892398	0.32	0	0.32		5-Year
71	11.87481775	123.8919995	0.32	0	0.32		5-Year
70	11.87481919	123.8919839	0.14	0	0.14		5-Year
69	11.87496033	123.8917979	0.05	0	0.05		5-Year
68	11.87500735	123.8918394	0.27	0	0.27		5-Year
66	11.87513218	123.8915393	0.24	0	0.24		5-Year
67	11.87523482	123.8917248	0.42	0	0.42		5-Year
202	11.87533958	123.8933564	0.91	0	0.91		5-Year
201	11.87560474	123.8931575	0.97	0	0.97		5-Year
200	11.87583723	123.8930309	1.47	0	1.47		5-Year

64	11.8758869	123.8911296	0.56	0	0.56		5-Year
65	11.87601281	123.8911539	0.5	0	0.5		5-Year
63	11.8761736	123.8909542	0.56	0	0.56		5-Year
62	11.87619304	123.8909807	0.56	0	0.56		5-Year
61	11.87636384	123.8907906	0.86	0	0.86		5-Year
60	11.87659795	123.8906931	0.39	0	0.39		5-Year
59	11.87666879	123.8905084	0.45	0	0.45		5-Year
57	11.87801728	123.8962688	0.19	0.1	0.09		5-Year
58	11.8780611	123.8967111	0.33	0.1	0.23		5-Year
194	11.87856261	123.9066106	0.19	0	0.19		5-Year
193	11.87874707	123.9065533	0.34	0	0.34		5-Year
56	11.87884851	123.8965344	0.2	0.4	-0.2	STY Ruby 2014	5-Year
192	11.87885909	123.9063587	0.39	0	0.39		5-Year
191	11.87902118	123.9064765	0.33	0	0.33		5-Year
190	11.87913829	123.9062767	0.38	0.2	0.18		5-Year
55	11.87929101	123.8963695	0.31	0	0.31		5-Year
189	11.87946948	123.9062392	0.53	0	0.53		5-Year
188	11.87947802	123.9061279	0.49	0	0.49		5-Year
187	11.88278274	123.9057668	0.27	0.7	-0.43	STY Yolanda 2013	5-Year
186	11.88286036	123.9056576	0.11	0.6	-0.49		5-Year
185	11.88299862	123.9056142	0.2	0.3	-0.1		5-Year
184	11.88328316	123.9057103	0.25	0.3	-0.05		5-Year
181	11.88330152	123.9056082	0.22	0.3	-0.08		5-Year
182	11.88334243	123.9056932	0.31	0.3	0.01		5-Year
183	11.88338089	123.9058607	0.27	0.3	-0.03		5-Year
180	11.88379281	123.905379	0.03	0.5	-0.47		5-Year
179	11.88391132	123.9053425	0.03	0.5	-0.47		5-Year
178	11.88402064	123.9054005	0.11	0.6	-0.49		5-Year
177	11.8845838	123.9052279	0.03	0	0.03		5-Year
176	11.88645751	123.9055111	0.03	0	0.03		5-Year
175	11.8870339	123.9057421	0.03	0	0.03		5-Year
174	11.88735472	123.9055128	0.03	0	0.03		5-Year
173	11.88796938	123.9060028	0.03	0	0.03		5-Year
172	11.88803199	123.9058414	0.03	0	0.03		5-Year
171	11.88818521	123.9062232	0.03	0	0.03		5-Year
170	11.88822414	123.9065056	0.03	0	0.03		5-Year
169	11.88841734	123.9066976	0.03	0	0.03		5-Year
168	11.88861311	123.9069535	0.03	0.4	-0.37		5-Year
167	11.88865016	123.9067542	0.03	0	0.03		5-Year
166	11.89027243	123.9084947	0.03	0	0.03		5-Year
165	11.89041465	123.9085466	0.03	0	0.03		5-Year
164	11.89052609	123.9082015	0.03	0	0.03		5-Year
163	11.89055579	123.9083818	0.03	0	0.03		5-Year
162	11.89140093	123.9095061	0.03	0	0.03		5-Year

161	11.89172733	123.9101257	0.53	0	0.53		5-Year
159	11.89192857	123.9102887	0.63	0	0.63		5-Year
160	11.8920202	123.9103832	0.77	0	0.77		5-Year
158	11.89211852	123.9104962	0.75	0	0.75		5-Year
157	11.89250622	123.9103271	0.44	0	0.44		5-Year
156	11.892896	123.9106655	0.64	0.7	-0.06	STY Yolanda 2013	5-Year
154	11.89319581	123.9114082	0.59	0	0.59		5-Year
152	11.89336384	123.9124807	0.3	0	0.3		5-Year
155	11.89358882	123.9110817	0.35	0	0.35		5-Year
151	11.89419848	123.9129626	0.7	0.5	0.2		5-Year
153	11.89420229	123.9120401	0.73	0.6	0.13		5-Year
141	11.89727383	123.9187155	0.29	0	0.29		5-Year
140	11.89728978	123.9186791	0.03	0	0.03		5-Year
139	11.89770561	123.9183952	0.03	0	0.03		5-Year
138	11.90074394	123.9174626	0.18	0	0.18		5-Year
150	11.9008514	123.9089133	0.25	0.5	-0.25		5-Year
137	11.90147551	123.9175815	0.72	0.5	0.22		5-Year
136	11.90182521	123.9178684	0.43	0	0.43		5-Year
135	11.90183088	123.9178591	0.43	0	0.43		5-Year
134	11.90187095	123.917841	0.43	0	0.43		5-Year
149	11.90246631	123.909168	0.24	0	0.24		5-Year
148	11.902661	123.9094921	0.25	0	0.25		5-Year
132	11.90267705	123.9179144	0.95	0	0.95		5-Year
133	11.9027169	123.9179334	0.61	0	0.61		5-Year
147	11.90278443	123.9094333	0.32	0	0.32		5-Year
131	11.90282669	123.9190676	0.28	0	0.28		5-Year
130	11.90361162	123.9190746	0.65	0.6	0.05	STY Ruby 2014	5-Year
121	11.90391583	123.9205608	0.48	0.8	-0.32	STY Yolanda 2013	5-Year
120	11.90397104	123.9206291	0.27	0.8	-0.53	STY Yolanda 2013	5-Year
119	11.9040185	123.9209102	0.37	0.3	0.07	STY Yolanda 2013	5-Year
146	11.90413819	123.9086337	0.27	0	0.27		5-Year
118	11.90413315	123.9209236	0.43	0.4	0.03	STY Yolanda 2013	5-Year
113	11.90444566	123.9231274	0.21	0.1	0.11		5-Year
116	11.90457297	123.9219441	0.84	0.3	0.54	STY Yolanda 2013	5-Year
112	11.9046104	123.9230275	0.29	0.3	-0.01		5-Year
129	11.90469557	123.9194613	0.03	0	0.03		5-Year
115	11.90469506	123.9221274	0.4	0	0.4		5-Year
114	11.90491723	123.9221944	0.12	0.2	-0.08	STY Yolanda 2013	5-Year
111	11.90496839	123.9228877	0.54	0	0.54		5-Year

109	11.90502536	123.9224528	0.13	0	0.13		5-Year
110	11.90522625	123.9226471	0.54	0.7	-0.16	STY Yolanda 2013	5-Year
117	11.90537188	123.9217116	0.4	0.4	0	STY Yolanda 2013	5-Year
145	11.90642224	123.9077018	0.57	0.3	0.27		5-Year
144	11.90653104	123.9076053	0.43	0.4	0.03		5-Year
143	11.9066531	123.9076031	0.33	0.1	0.23		5-Year
108	11.90667811	123.924525	0.24	0	0.24		5-Year
142	11.90674077	123.9077936	0.75	0	0.75		5-Year
128	11.90970456	123.9188493	0.34	0.3	0.04	STY Ruby 2014	5-Year
127	11.91002317	123.9183911	0.26	0.3	-0.04	STY Ruby 2014	5-Year
126	11.91002373	123.9183903	0.26	0.3	-0.04	STY Ruby 2014	5-Year
125	11.91006845	123.9187332	0.23	0.5	-0.27	STY Ruby 2014	5-Year
124	11.91018656	123.9188775	0.56	0.6	-0.04	STY Ruby 2014	5-Year
123	11.91029251	123.918664	0.26	0.2	0.06	STY Yolanda 2013	5-Year
122	11.91042914	123.9184451	0.05	0.2	-0.15	STY Yolanda 2013	5-Year
107	11.92252216	123.9354893	0.03	0.7	-0.67		5-Year

ANNEX 12. Educational Institutions affected by flooding in Nauco Aguada Flood Plain

Table A-12.1. Educational Institutions in Masbate affected by flooding in Nauco Aguada Flood Plain

Masbate				
Cataingan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Badiang Daycare Center Placer	Badiang			
Divisoria Daycare Center Placer	Divisoria			
Divisoria Elementary School Placer	Divisoria			
Pio V. Corpuz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Lampuyang Daycare Center Placer	Lampuyang			
Lampuyang Elementary School Placer	Lampuyang			
Placer				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Aguada Daycare Center Placer	Aguada			
Aguada Elementary School Placer	Aguada			
Guinhayaan Elementary School Placer	Aguada			
Ban-Ao Daycare Center Placer	Ban-Ao	Medium	Medium	Medium
Ban-Ao Elementary School Placer	Ban-Ao	Medium	Medium	Medium
Daanglusod Daycare Center Placer	Daanlungsod			
San Ramon Placer Elementary School Placer	Daanlungsod		Low	Low
Guinhayaan Daycare Center Placer	Guinhan-Ayan			
Placer High School Placer	Katipunan			
San Marcos Daycare Center Placer	Katipunan			
Manlutod Daycare Center Placer	Manlut-Od			
Manlutod Elementary School Placer	Manlut-Od			
Matagantang Daycare Center Placer	Matagantang			
Matagantang National High School Placer	Matagantang			
Naocondiot Daycare Center Placer	Naocondiot			
Pasiagon Elementary School Placer	Pasiagon			
Placer Daycare Center Placer	Poblacion			
Placer Integrated School Placer	Poblacion			
Placer National High School Placer	Poblacion			
Rubio Tech college Placer	Poblacion			
San Ramon Placer Elementary School Placer	Poblacion	Low	Low	Low
San Marcos Elementary School Placer	San Marcos			
Taboc Daycare Center Placer	Taboc		Low	Low
Taboc Elementary School Placer	Taboc			
Tubod Daycare Center Placer	Tubod			
Tubod Elementary School Placer	Tubod			

ANNEX 13. Health Institutions affected by flooding in Nauco Aguada Floodplain

Table A-13.1. Health Institutions in Masbate affected by flooding in Nauco Aguada

Masbate				
Cataingan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Badiang Health Center Placer	Badiang			
Divisoria Health Center Placer	Divisoria			
Pio V. Corpuz				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Lampuyang Health Center Placer	Lampuyang			
Placer				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Aguada Health Center	Aguada			
Ban-Ao Health Center Placer	Ban-Ao		Medium	Medium
Guinhayaan Health Center Placer	Guinhan-Ayan			
municipal lying-in Placer	Katipunan	Low	Low	Low
San Marcos Health Center Placer	Katipunan			
Manluot Health Center Placer	Manlut-Od			
Matagantang Health Center Placer	Matagantang			
Naocondiot Health Center Placer	Naocondiot			
Placer Municipal Hospital Placer	Poblacion	Low	Low	Low
Daanglungsod Clinic Placer	Taboc			
Taboc Health Center Placer	Taboc			Low
Tubod Health Center Placer	Tubod			
Villa Inocencio Health Center Placer	Villa Inocencio		Low	Low