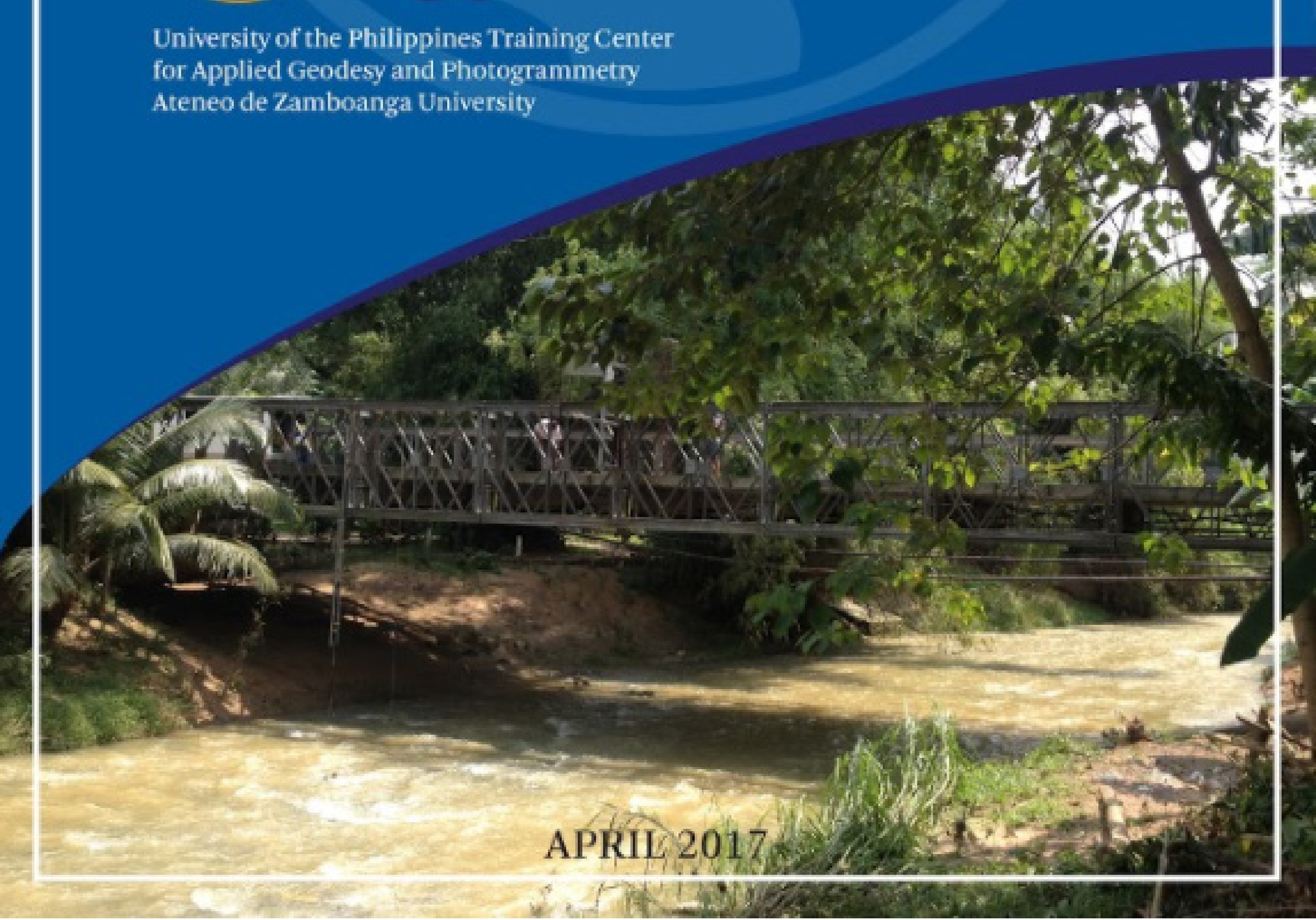
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Manicahan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Zamboanga University



APRIL 2017

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Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid Program and is to be cited as:

E.C. Paringit, M.S. Rodriguez, E. Epino, L.P. Balicanta, C.S. Cruz, L. Acuna, G. Hipolito, G.B. Sinadjan, S.C. Poblete, M.O. Ang, J.D. Fabila, S.D. Samalburo, G. Apat, M.L. Olanda, D.B. Banatin, A.B. Chua, Jr., C. Lubiano, D.M. Bool, E.C. Tong, J.S.Caballero, P.P. dela Cruz, D.T. Lozano, K.B. Borromeo, D.C. Tajora, E. Salvador, R.C. Alberto, C. Atacador, L.R. Taguse, A. Lagmay, C.L. Uichanco, S. Sueno, M. Moises, H. Ines, M. del Rosario, K. Punay, N. Tingin (2017), LiDAR Surveys and Flood Mapping Report of Manicahan River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-124pp

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
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 MANICAHAN RIVER

Enrico C. Paringit, Dr. Eng., Mario Rodriguez, and Emir Epino

1.1 Background of the Phil-LiDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods described 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 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 22 river basins in the Zamboanga Peninsula Region. The university is located in Zamboanga City in the Zamboanga Peninsula.

1.2 Overview of the Manicahan River Basin

Manicahan runs through a 26-kilometer stretch from Bunguiao in the North down to Lapakan, Lamisan and Manicahan in the South. It covers a portion of the heavily forested Pasonanca Watershed. Normally, it has a daily discharge of about 145, 000 cubic meters catering the needs of the abovementioned barangays and even some parts of the neighboring barangays including Victoria, Bolong and Sangali. It has a total catchment area of 70.83 square kilometers

Like other rural rivers, Manicahan is also named after the barangay where it drains. Legend says that the name comes from the word "manikaun" which later became "manikaan" or pronounced in Spanish as, "manicahan". It was believed that when the Spaniards, headed by Governor Cayetano Figueroa, came to the place, the Visayans in the uplands lived by planting crops including peanuts all year round to be bartered with the fishes and other seafoods of the Badjaos in the coastlines. One time, the governor asked the farmers for the name of the place and the farmers, not getting what has been really asked, answered "maningamakaun" or "peanuts for food". And from then on, that phrase became a name and was handed down to generations.

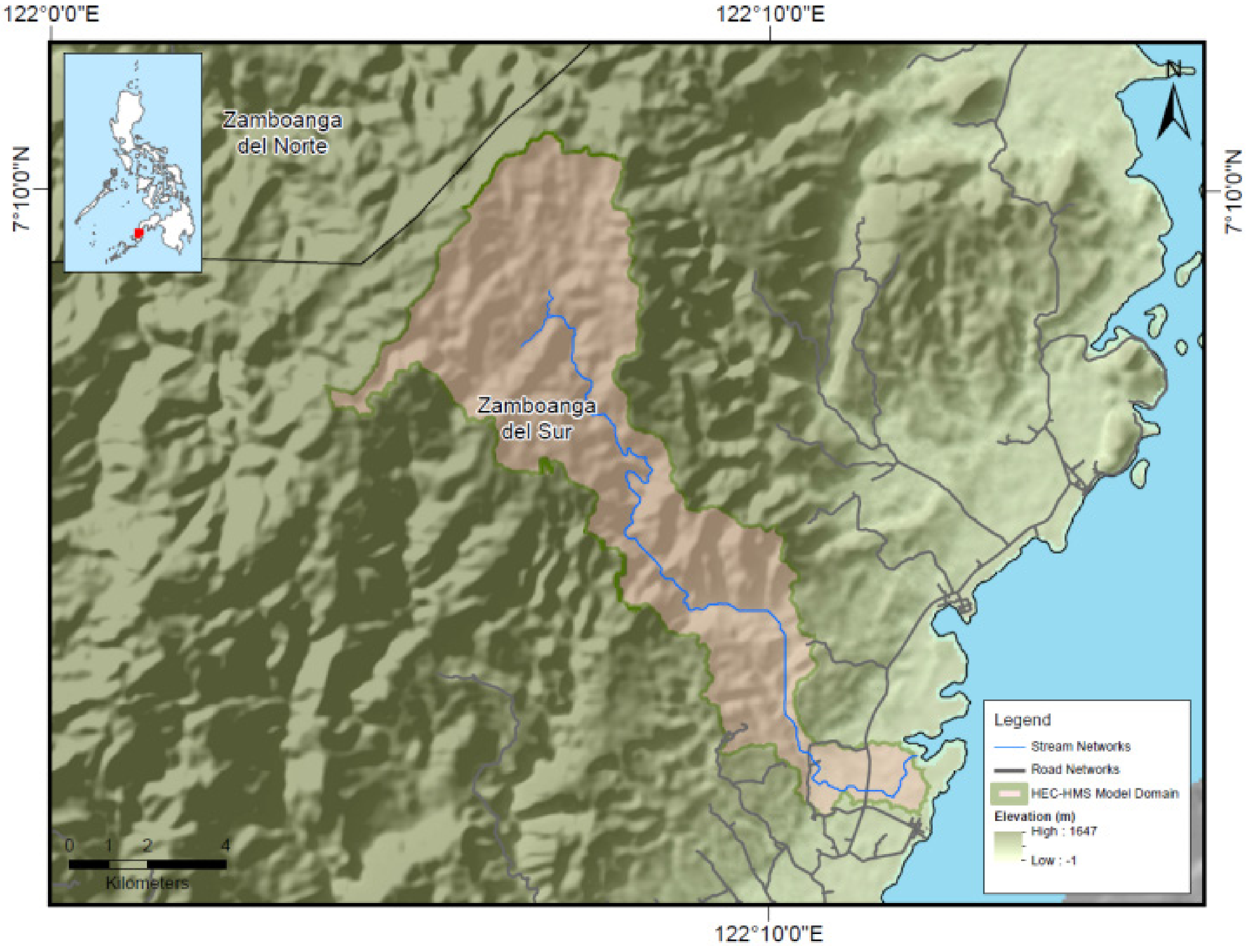

Figure 1. Map of Manicahan River Basin (in brown)

The Manicahan river is also the prime source of irrigation for the farmers in the barangays of Bunguiao, Lapakan, Lamisan, and Manicahan, as well as the neighboring barangays of Victoria, Bolong, and Sangali.

Figure 2. Mini-diversion dam in Manicahan River used for irrigation.

Flood Incidence

According to the geohazard susceptibility assessment conducted by the Environmental Management Bureau of DENR 9, areas along Manicahan has moderate to high susceptibility rate against flooding. Floods pose a threat to the local community especially that these areas are now congested with houses due to decades of influx of transients from Sacol Island.

The most recent flood event in Manicahan was in October of 2015. Some classes were suspended due to heavy rains that according to local weather forecasters were caused by the convergence of cold and humid air currents. In August 2013, 20 families were affected and evacuated to Manicahan Elementary School because of a flood caused by an Intertropical Convergence Zone (ITCZ).

Manicahan has also Automated Rain gauges (ARG) and Water Level Monitoring Systems (WLMS) installed at the Manicahan Spillway (7.03625N, 122.175933E) as part of DOST's nationwide Deployment of Early Warning Systems (DEWS) project.

Hydropower and Recreation

Manicahan River is one of the two rivers in Zamboanga City which have been eyed for potential hydroelectric power project to be implemented by Everhydro Corporation and PhilCarbon. The other river is Ayala located in the west coast of the city. PhilCarbon sought to build a 2.5MW hydropower plant for Manicahan. This proposal has been positively responded by the city council and was enthusiastically approved for further review through the Watershed Management Council (WMC).

Aside from being a potential source of power, Manicahan is also one of the highlights of the newly developed Victoria Adventure Park in Victoria, ZC. Initiated in 2012 by Lacuachero, a group of local adventurous professionals, in partnership with the Zamboanga Adventure Tourism and Eco-recreation Society (ZATERS), this park aims to conserve and promote eco-tourism sites near the river and provide additional income to the local community. Water tubing and other water activities along the river are just some of the major recreation courses that the park offers.

Figure 3. Bamboo rafting along the river is a common water activity for locals

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MANICAHAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuna, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Ms. Sandra C. Poblete

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 Manicahan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Manicahan Floodplain in Zamboanga City. These flight missions were planned for 12 lines and ran for at most four and a half 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 Manicahan 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)
BLK75C	1000, 1100	15	50	200	30	130	5
BLK75D	1000	15	50	200	30	130	5
BLK75E	1000	15	50	200	30	130	5
BLK75FS	1000	15	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

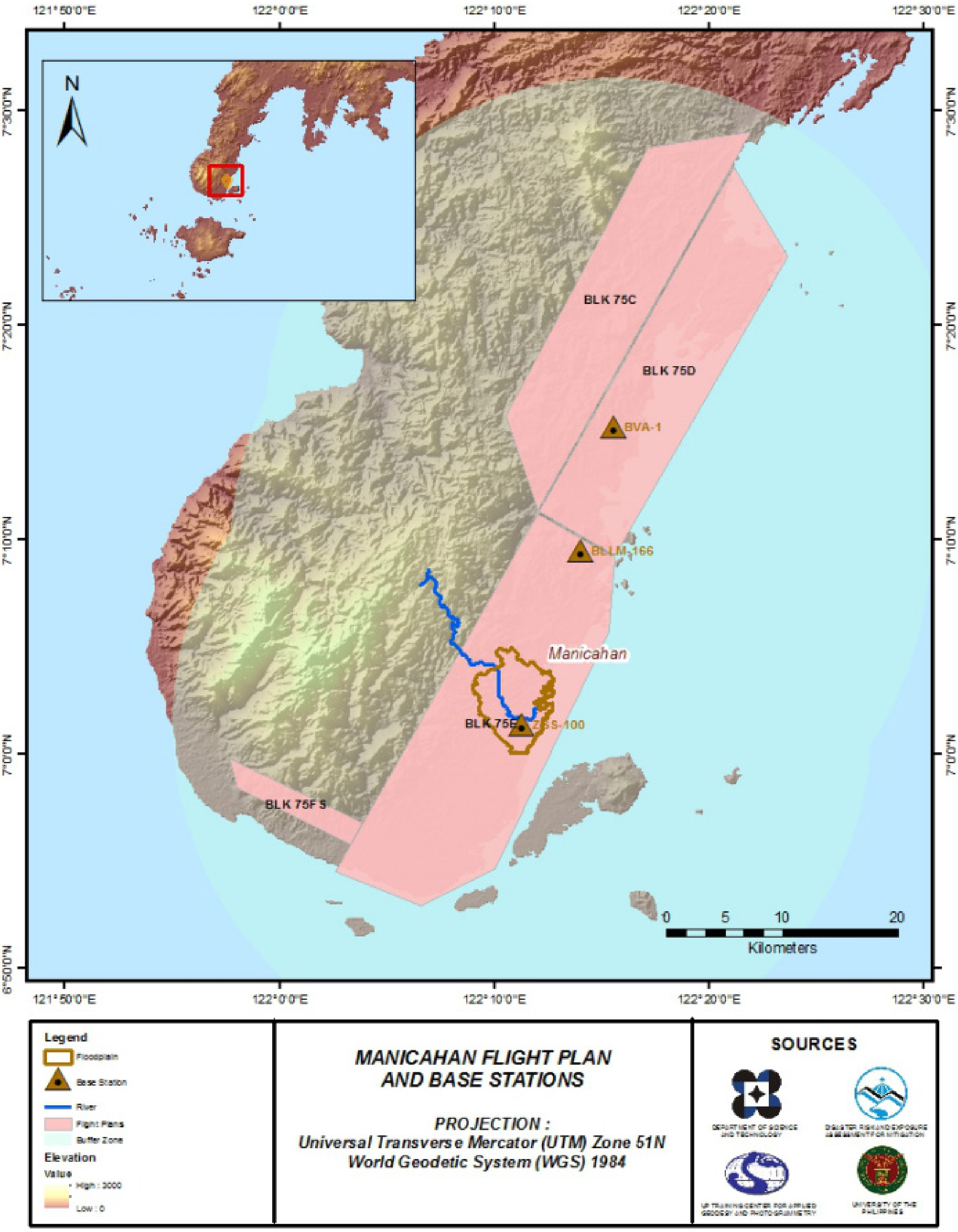

Figure 4. Flight Plan and base stations for Pegasus System used for the Manicahan Floodplain survey.

2.2 Ground Base Stations

The field team was able to recover one (1) NAMRIA ground control point: ZGS-100 which is a second (2nd) order accuracy. The certification 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 February 5 to February 8, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Manicahan floodplain are shown in Figure 4.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Manicahan Floodplain LiDAR Survey. Figure 5 to Figure 6 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 2 to 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.

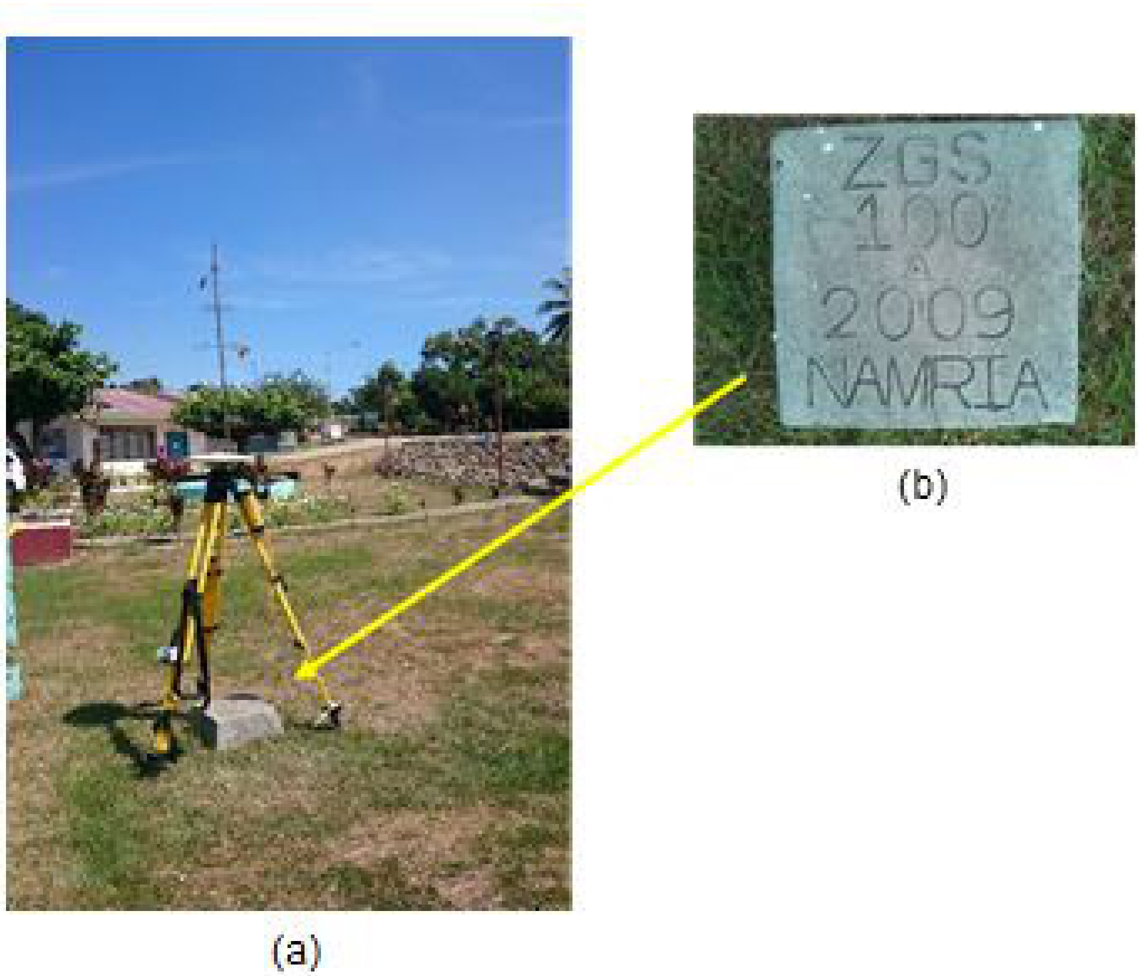

Figure 5. GPS set-up over ZGS-100 in Brgy. Manicahan, Zamboanga City located at the road intersections going to Cagayan de Oro, Butuan City and Iligan City (a) and NAMRIA reference point ZGS-100 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGS-100 used as base station for the LiDAR Acquisition.

Station Name	**ZGS-100**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 1’ 26.72368” North 122° 11’ 12.74401” East 11.27 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	410158.521 meters 776712.542 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 1’ 23.30149” North 122° 11’ 18.30044” East 75.603 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	410189.97 meters 776440.68 meters

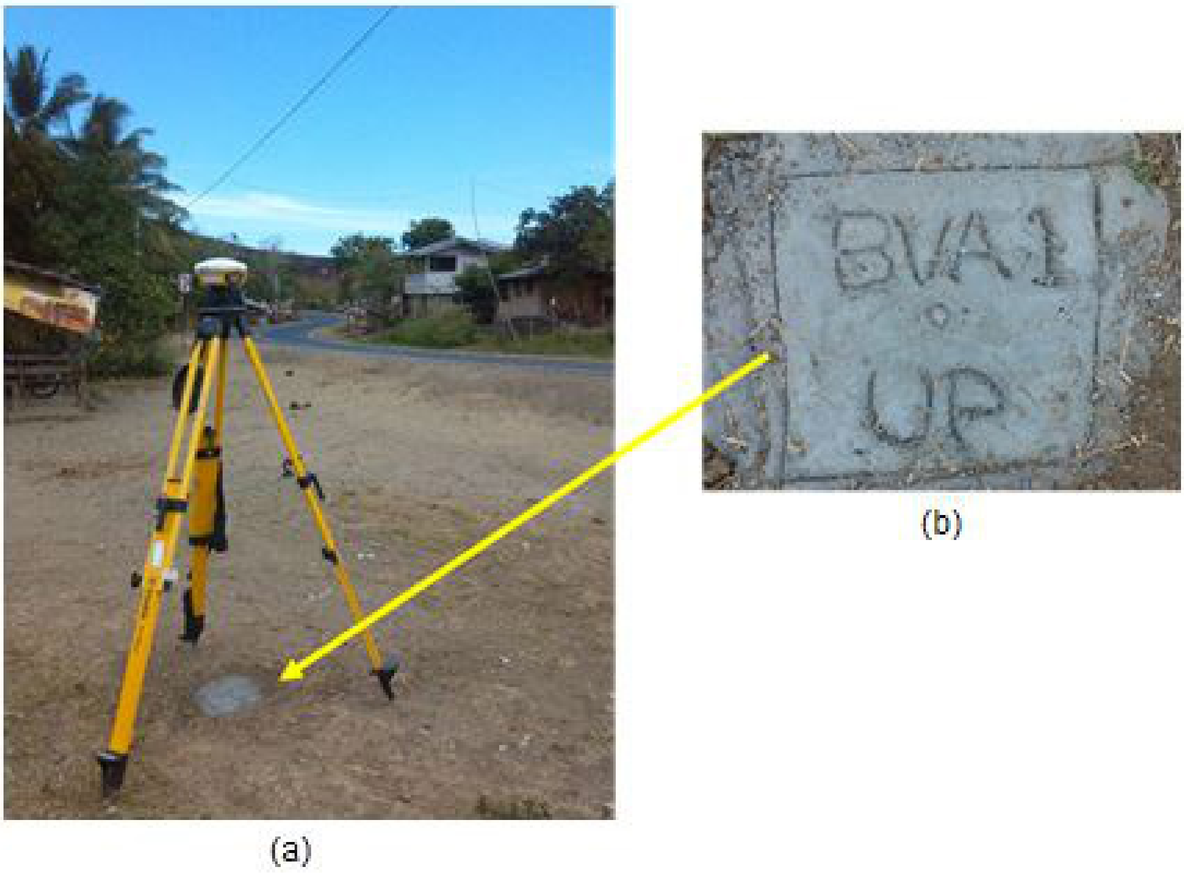

Figure 6. GPS set-up over BVA-1 at Brgy. Buenavista, Zamboanga City (a) and reference point BVA-1 (b) as established by the field team.

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

Station Name	BVA-1	
Order of Accuracy	2nd (established control point)	
Relative Error (Horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 15’ 19.31910” North 122° 15’ 28.78738” East 82.446 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	417,939.856 meters 802,333.522 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 15’ 15.84241” North 122° 15’ 34.32212” East 146.526 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	418,087.142 meters 801,995.112 meters

Table 4. Details of the established control point BLLM-166 used as base station for the LiDAR acquisition.

Station Name	**BVA-1**	
Order of Accuracy	**2nd (established control point)**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 09' 33.60926" North 122° 13' 54.54820" East 124.333 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 09' 30.15553" North 122° 14' 00.09187" East 188.527 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	415179.269 meters 791383.716 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
5 February 2015	2535P	1BLK75E36A	ZGS-100, BLLM-166
8 February 2015	2545P	1BLK75C39A	ZGS-100, BVA-1

2.3 Flight Missions

A total of two (2) missions were conducted to complete the LiDAR data acquisition in Manicahan floodplain, for a total of eight hours and four minutes (8+4) of flying time for[Check total flying hours] 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 Manicahan Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
5 February 2015	2535P	376.00	294.64	43.86	250.78	715	3	53
8 February 2015	2545P	68.50	284.69	9.05	275.64	609	4	11
TOTAL		**444.5**	**579.33**	**52.91**	**526.42**	**1,324**	**8**	**4**

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

Flight Number	**Flying Height (m AGL)**	**Overlap (%)**	**FOV (θ)**	**PRF (khz)**	**Scan Frequency (Hz)**	**Average Speed (kts)**	**Average Turn Time (Minutes)**
2535P	1100	15	50	200	30	130	5
2545P	1000	15	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Manicahan floodplain (See Annex 7). It is located in the province of Zamboanga del Sur, with majority of the floodplain situated within the Zamboanga City. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 8. Figure 5, on the other hand, shows the actual coverage of the LiDAR acquisition for the Manicahan floodplain.

Table 8. List of municipalities and cities surveyed of the Manicahan Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Zamboanga del Sur	Zamboanga City	1461.04	452.63	30.98%
Zamboanga Sibugay	Tungawan	441.86	23.85	5.40%
Total		**1902.9**	**476.48**	**25.04%**

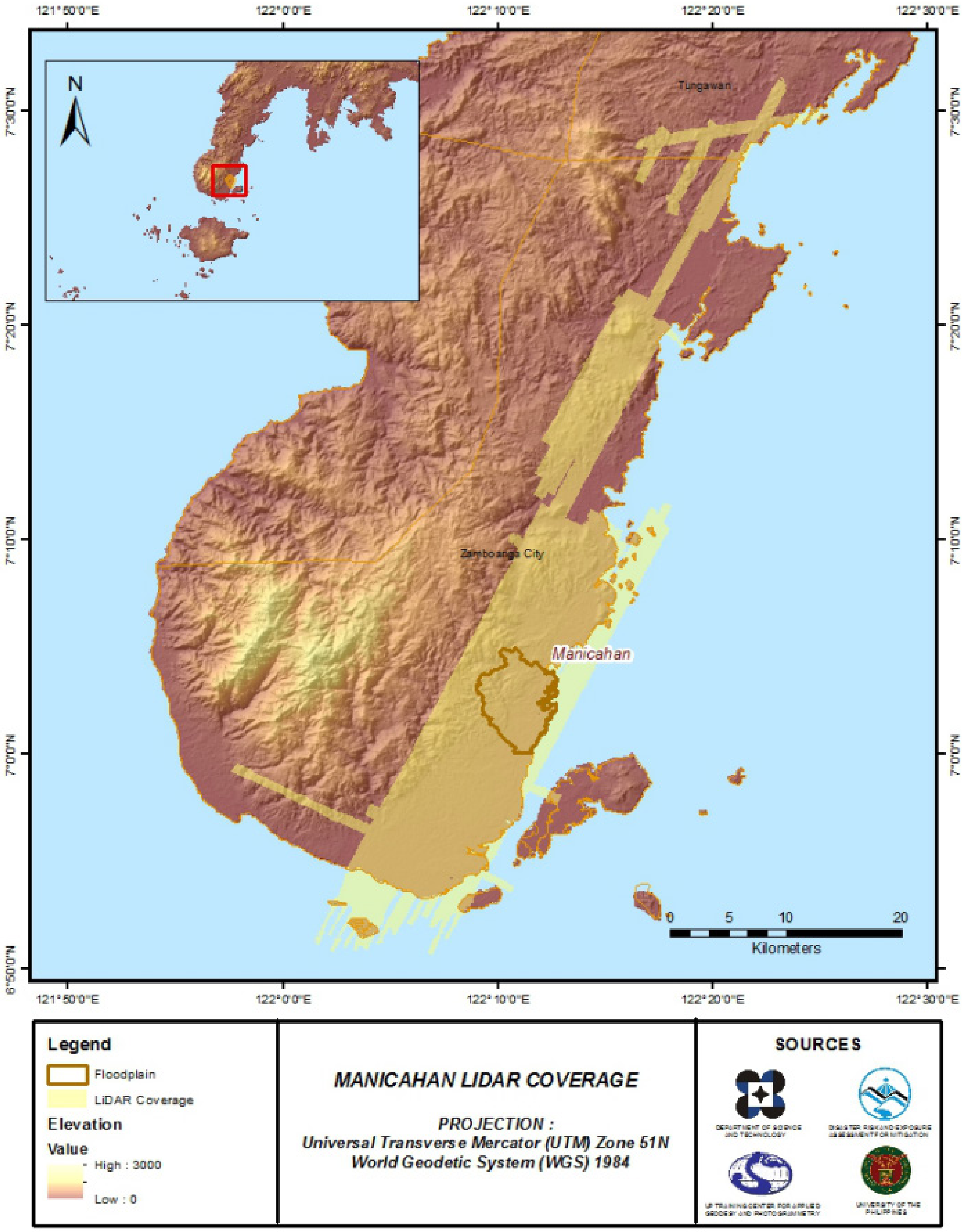

Figure 7. Actual LiDAR survey coverage of the Manicahan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MANICAHAN 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 8.

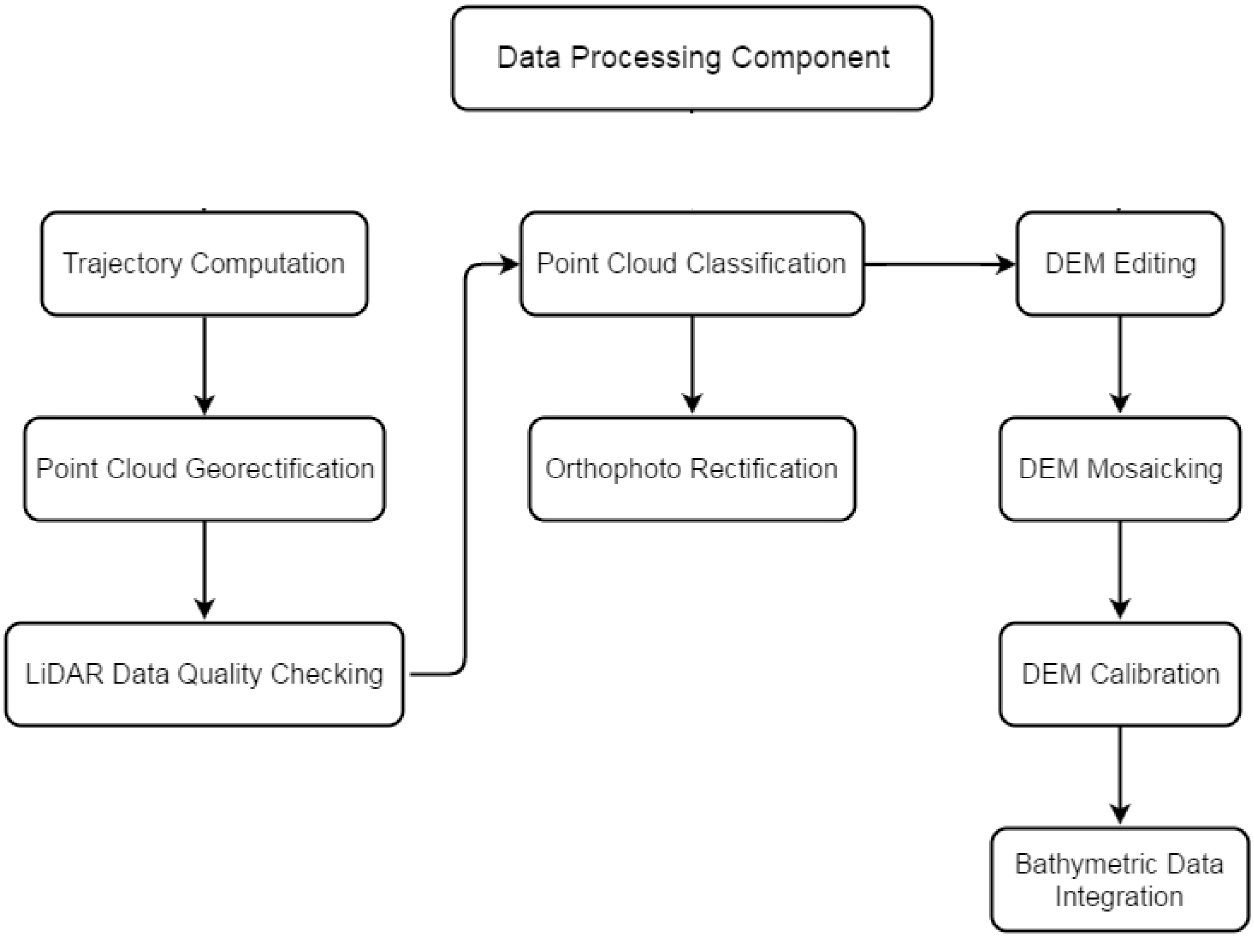


Figure 8. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

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

The Data Acquisition Component (DAC) transferred a total of 56.9 Gigabytes of Range data, 491 Megabytes of POS data, 15.3 Megabytes of GPS base station data, and 85.3 Gigabytes of raw image data to the data server on February 7, 2015 for the survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Manicahan Floodplain was fully transferred on March 13, 2015, as indicated on the Data Transfer Sheets for the Manicahan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 2545P, one of the Manicahan flights, which is the North, East, and Down position RMSE values are shown in Figure 7. 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 February 7, 2015, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

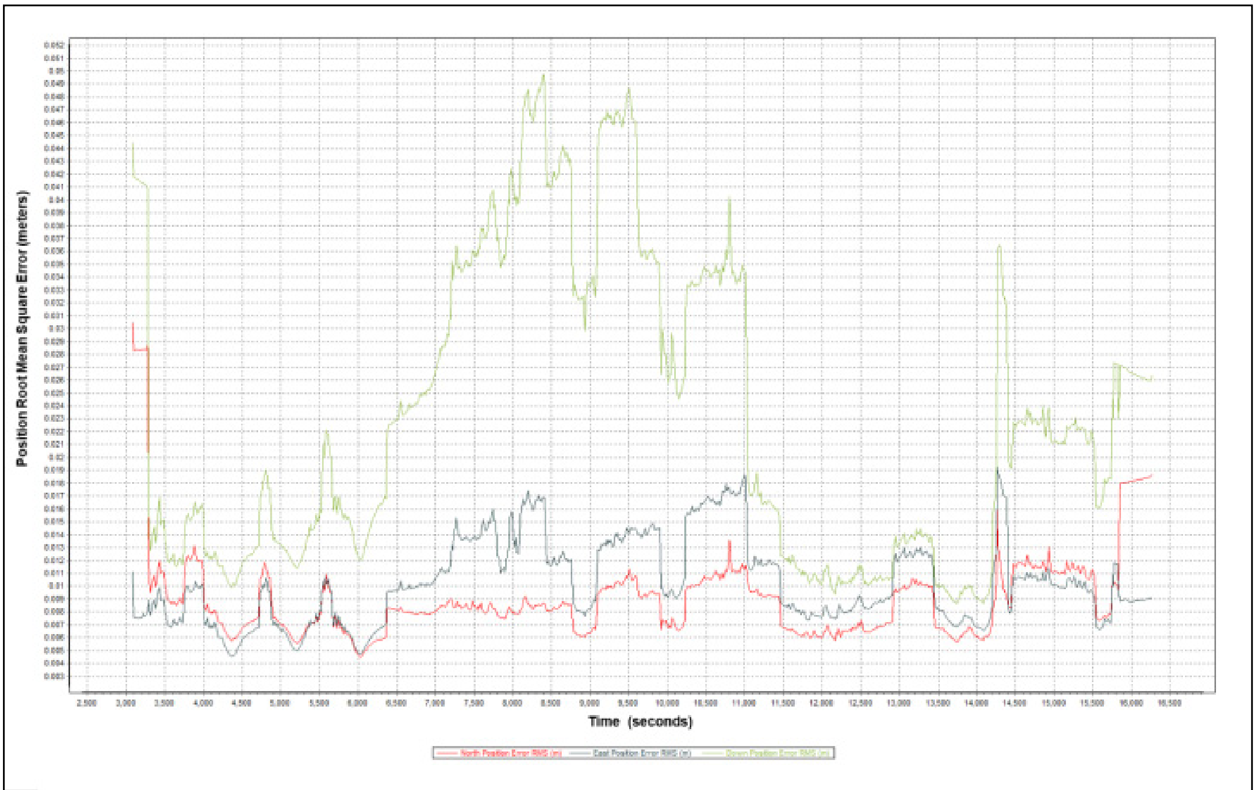


Figure 9. Smoothed Performance Metrics of Manicahan Flight 2545P.

The time of flight was from 3,000 seconds to 16,500 seconds, which corresponds to morning of February 7, 2015. 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 1.80 centimeters, the East position RMSE peaks at 1.90 centimeters, and the Down position RMSE peaks at 5.00 centimeters, which are within the prescribed accuracies described in the methodology.

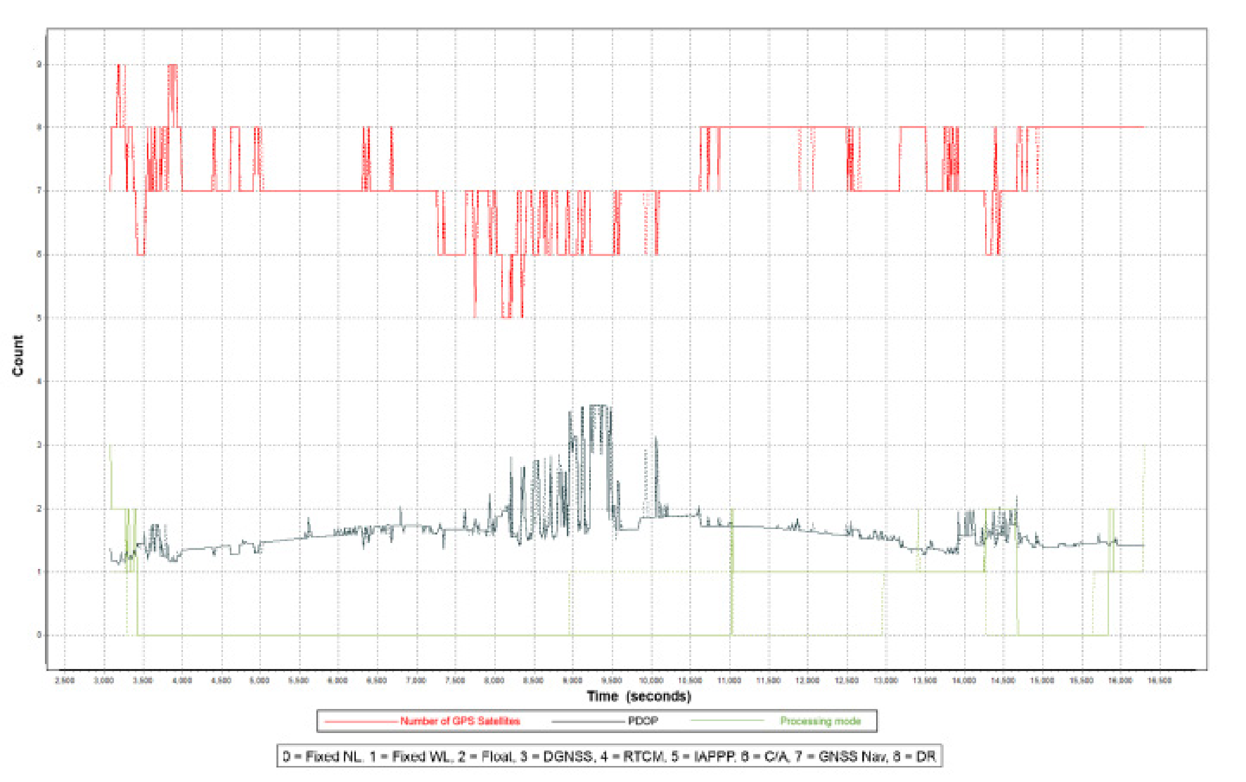


Figure 10. Solution Status Parameters of Manicahan Flight 2545P.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Manicahan Flight 2545P are shown in Figure 10. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the majority of the acquisition were between 6 and 9, not going lower than 6. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also remained at 0 for the majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for 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 Manicahan flights is shown in Figure 11.

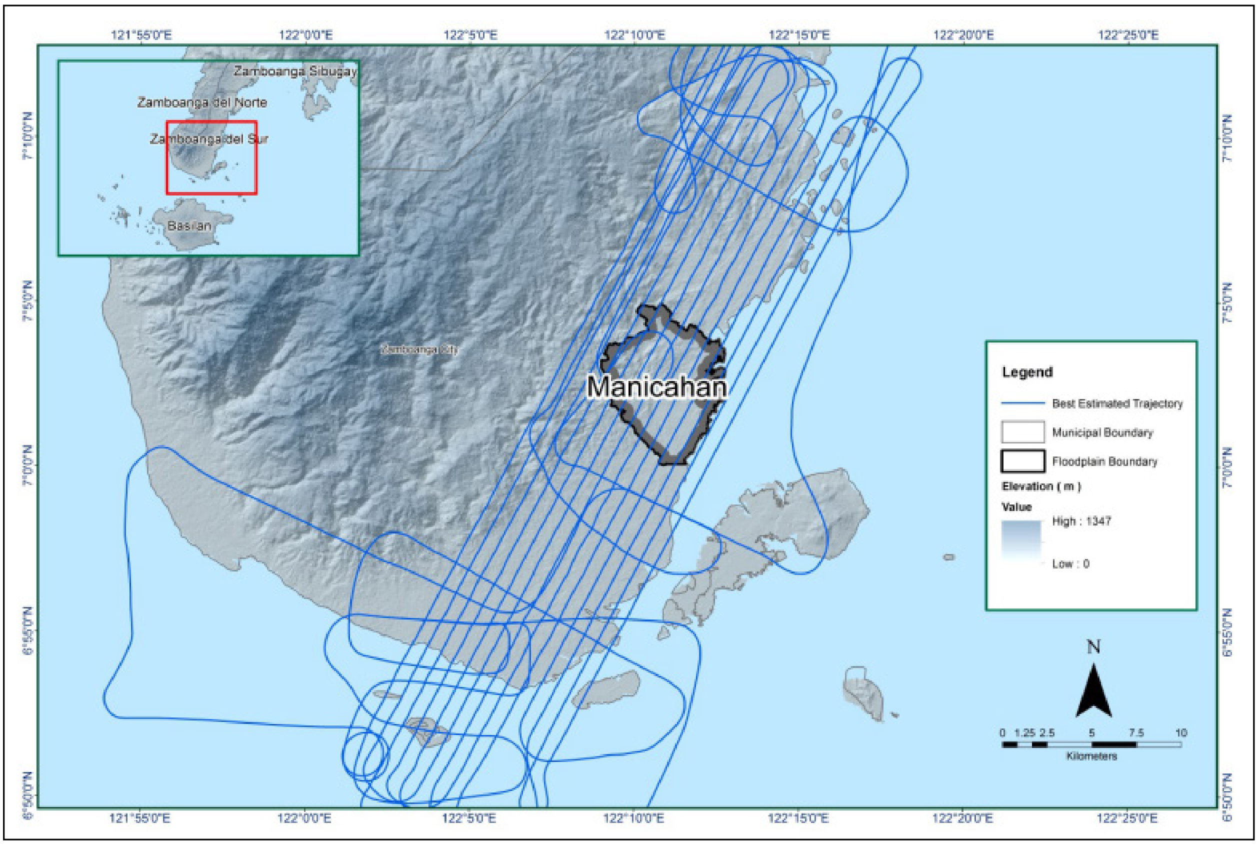


Figure 11. Best estimated trajectory of the LiDAR missions conducted over the Manicahan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 14 flight lines, with each flight line contains two channels, 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 Manicahan floodplain are given in Table 9.

Table 9. Self-calibration Results values for Pinantan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000223
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000915
GPS Position Z-correction stdev	<0.01meters	0.0062

The optimum accuracy values for all Manicahan 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 is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

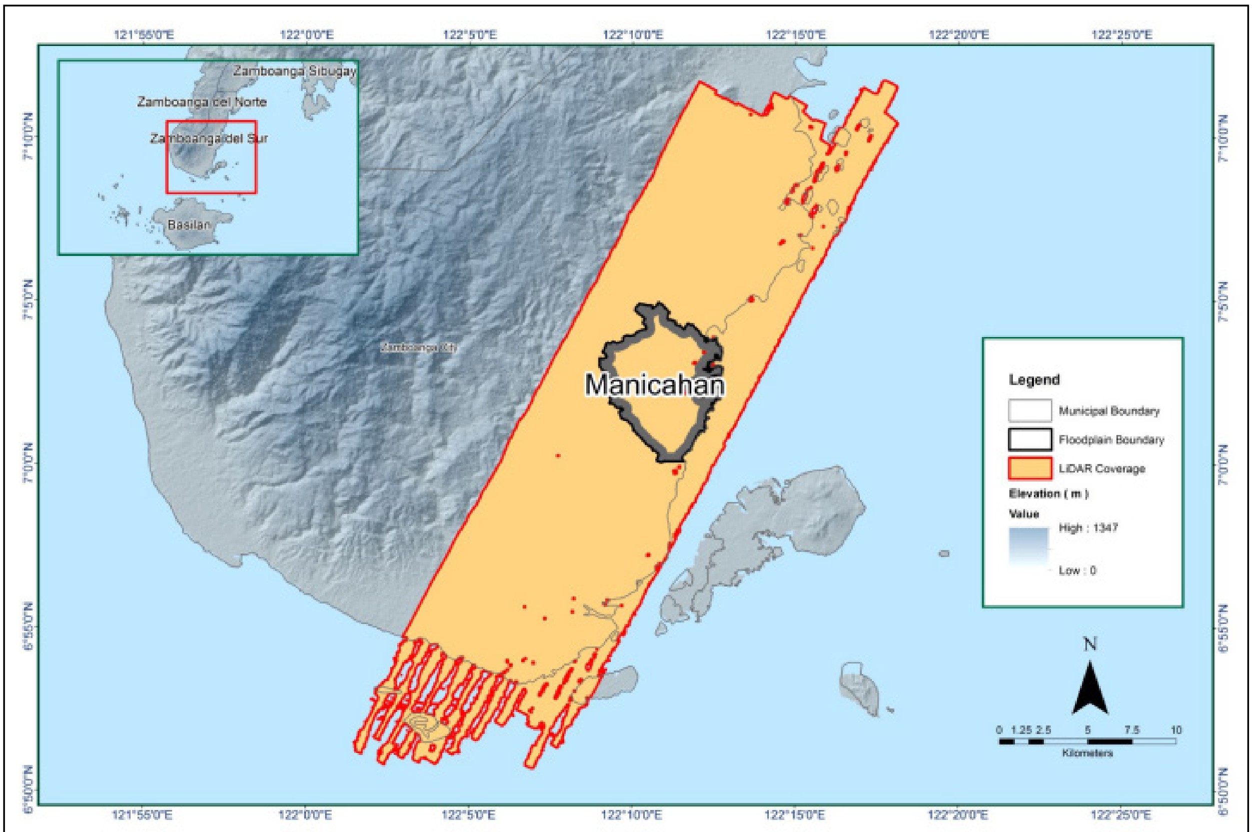


Figure 12. Boundary of the processed LiDAR data on top of the SAR Elevation Data over the Manicahan Floodplain.

A total area of 394.93 square kilometers (sq. kms.) were covered by the Manicahan flight missions as a result of two (2) flight acquisitions, which were grouped and merged into one (1) block as portrayed in Table 10.

Table 10. List of LiDAR blocks for Manicahan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75E	2535P	394.93
	2545P	
TOTAL		**394.93 sq.km.**

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

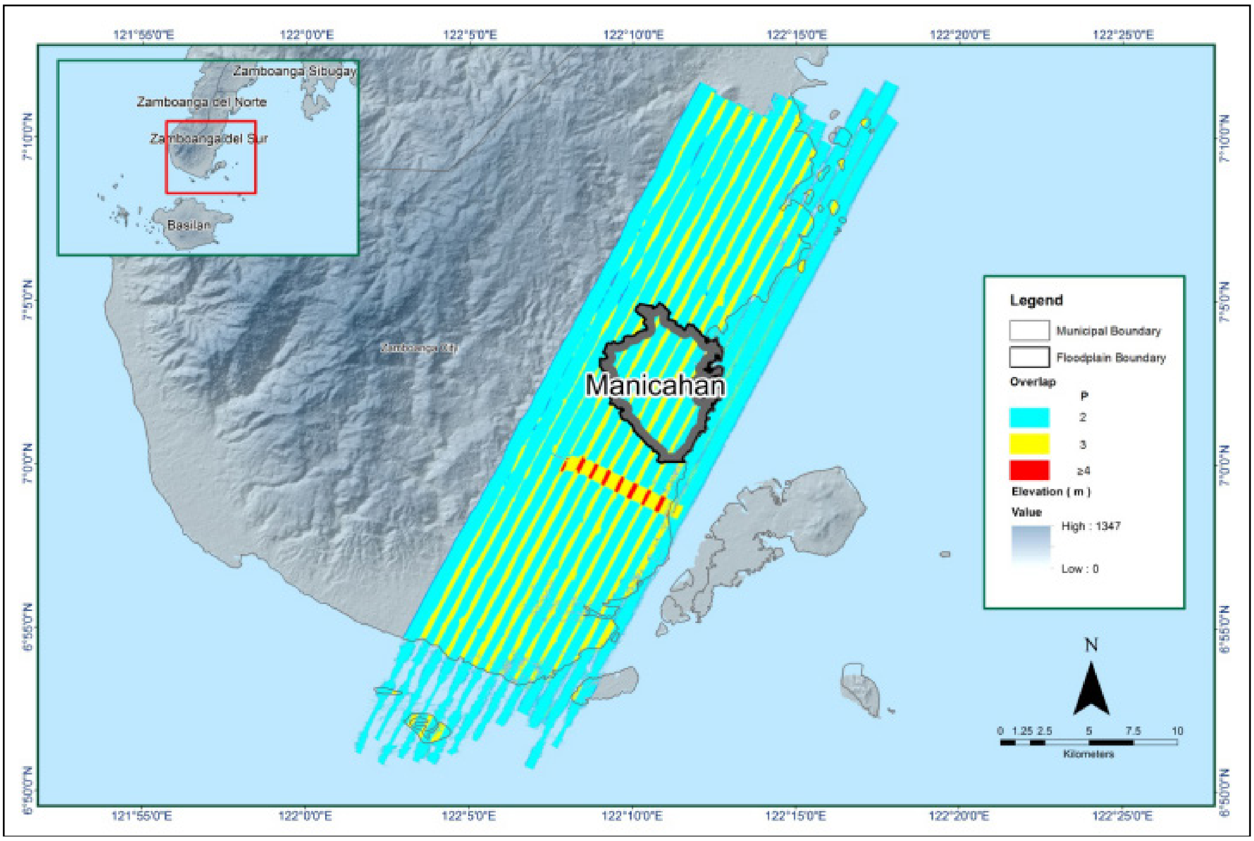


Figure 13. Image of data overlap for Manicahan Floodplain.

The overlap statistics per block for the Manicahan 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 overlaps are 24.50%.

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 14. As seen in the figure below, it was determined that all LiDAR data for the Manicahan Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 2.56 points per square meter.

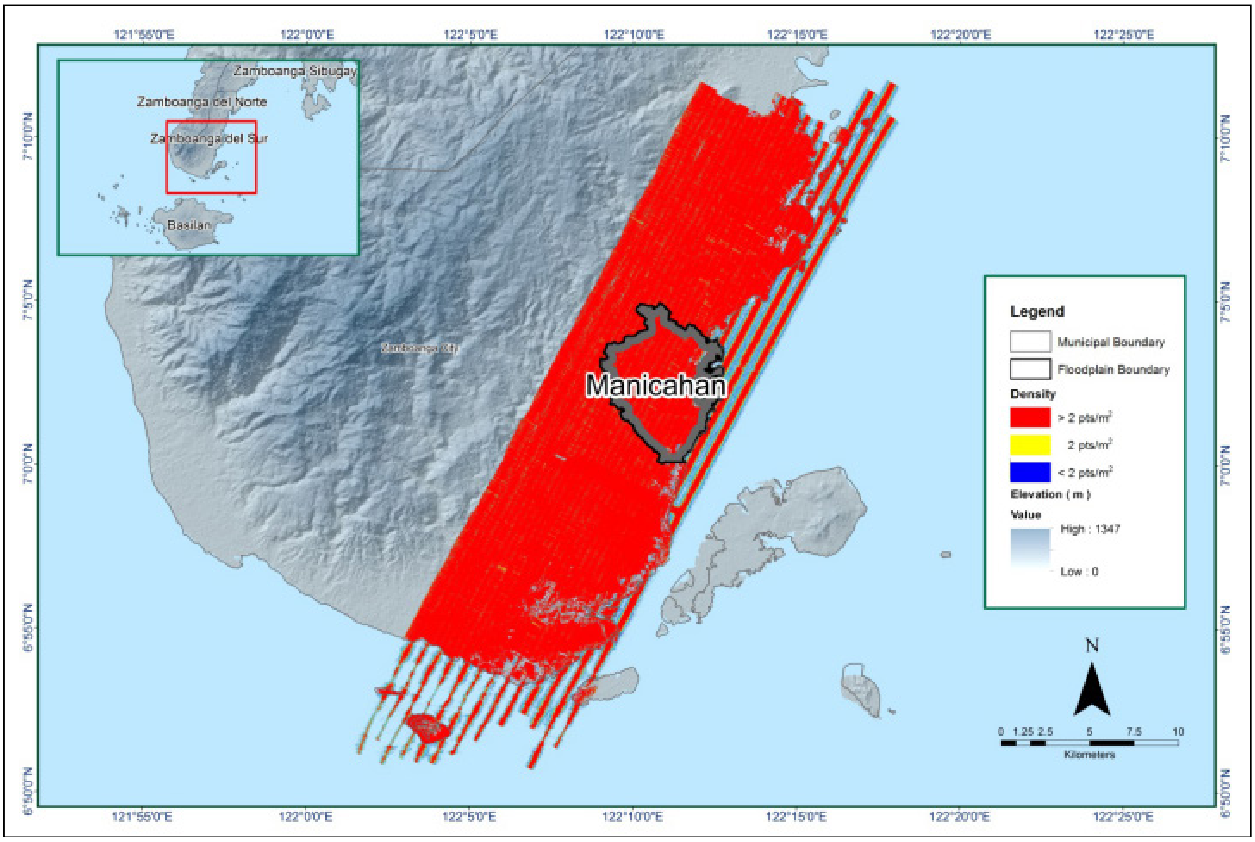


Figure 14. Pulse density map of merged LiDAR data for Manicahan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. 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.

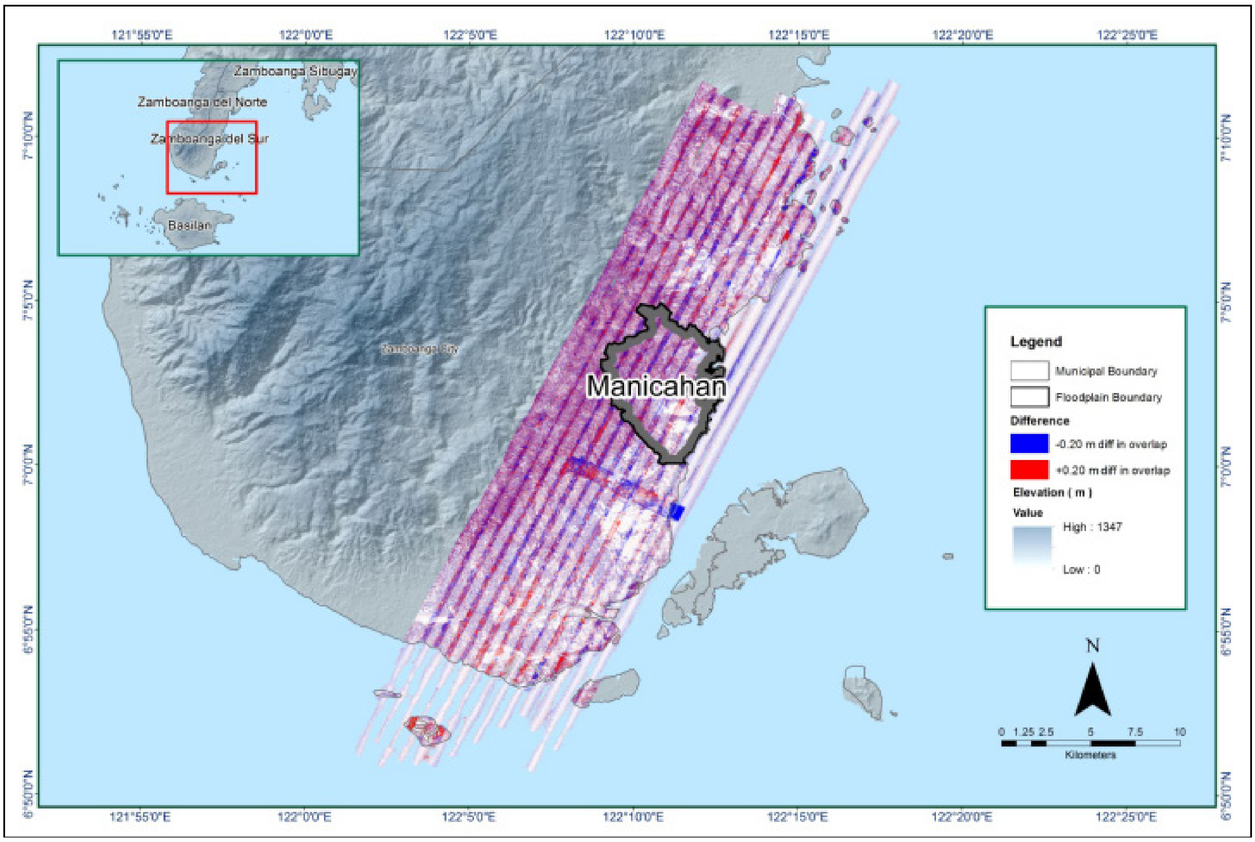


Figure 15. Elevation Difference Map between flight lines for Manicahan Floodplain Survey.

A screen-capture of the processed LAS data from Manicahan flight 2545P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

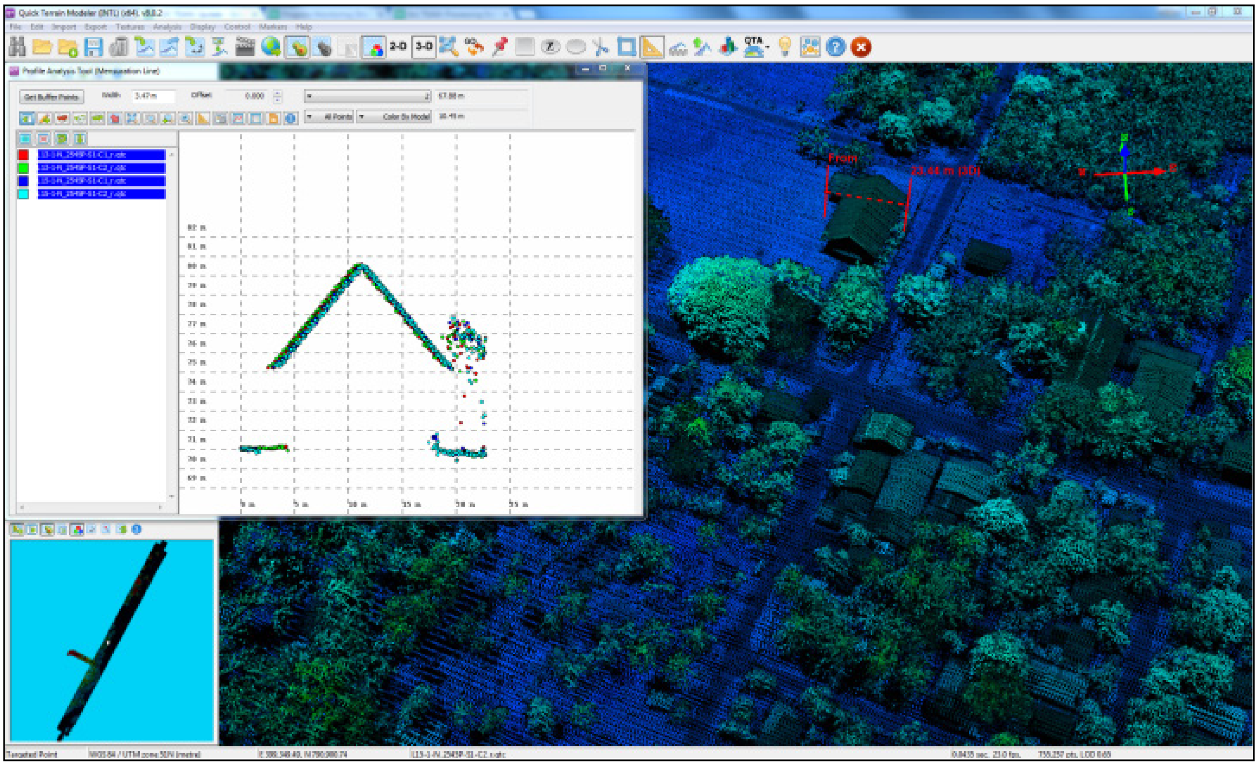


Figure 16. Quality checking for Manicahan flight 2545P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Manicahan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	369,443,876
Low Vegetation	268,989,359
Medium Vegetation	403,829,240
High Vegetation	815,604,498
Building	37,951,116

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Manicahan floodplain is shown in Figure 17. A total of 522 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 498.00 meters and 65.50 meters respectively.

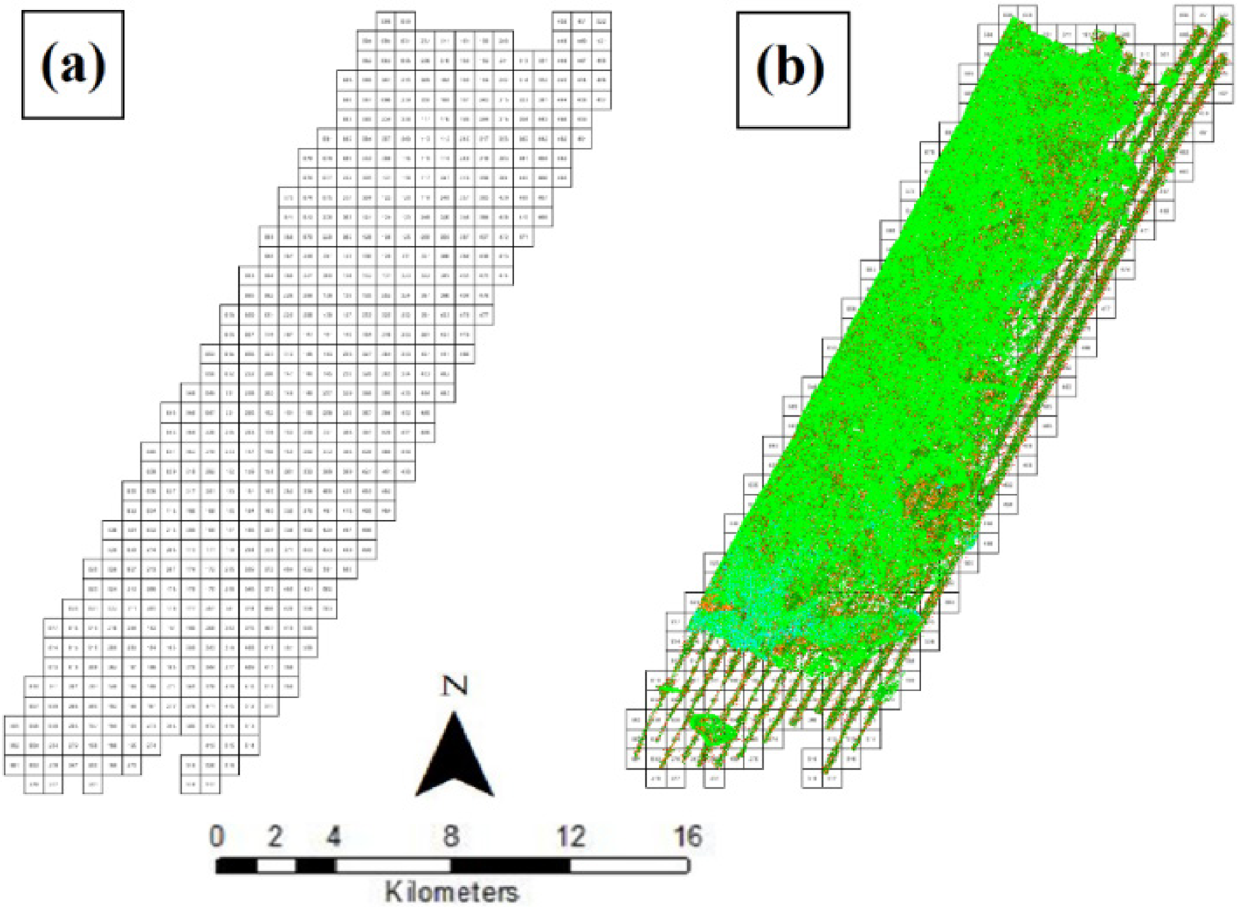


Figure 17. Tiles for Manicahan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are highlighted in orange, while the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

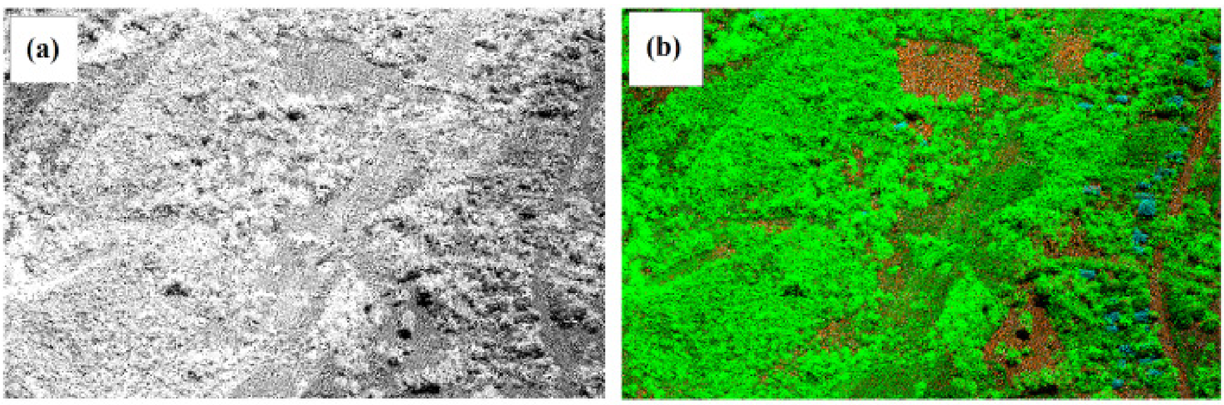


Figure 18. Point cloud before (a) and after (b) classification

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 shown in Figure 19. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

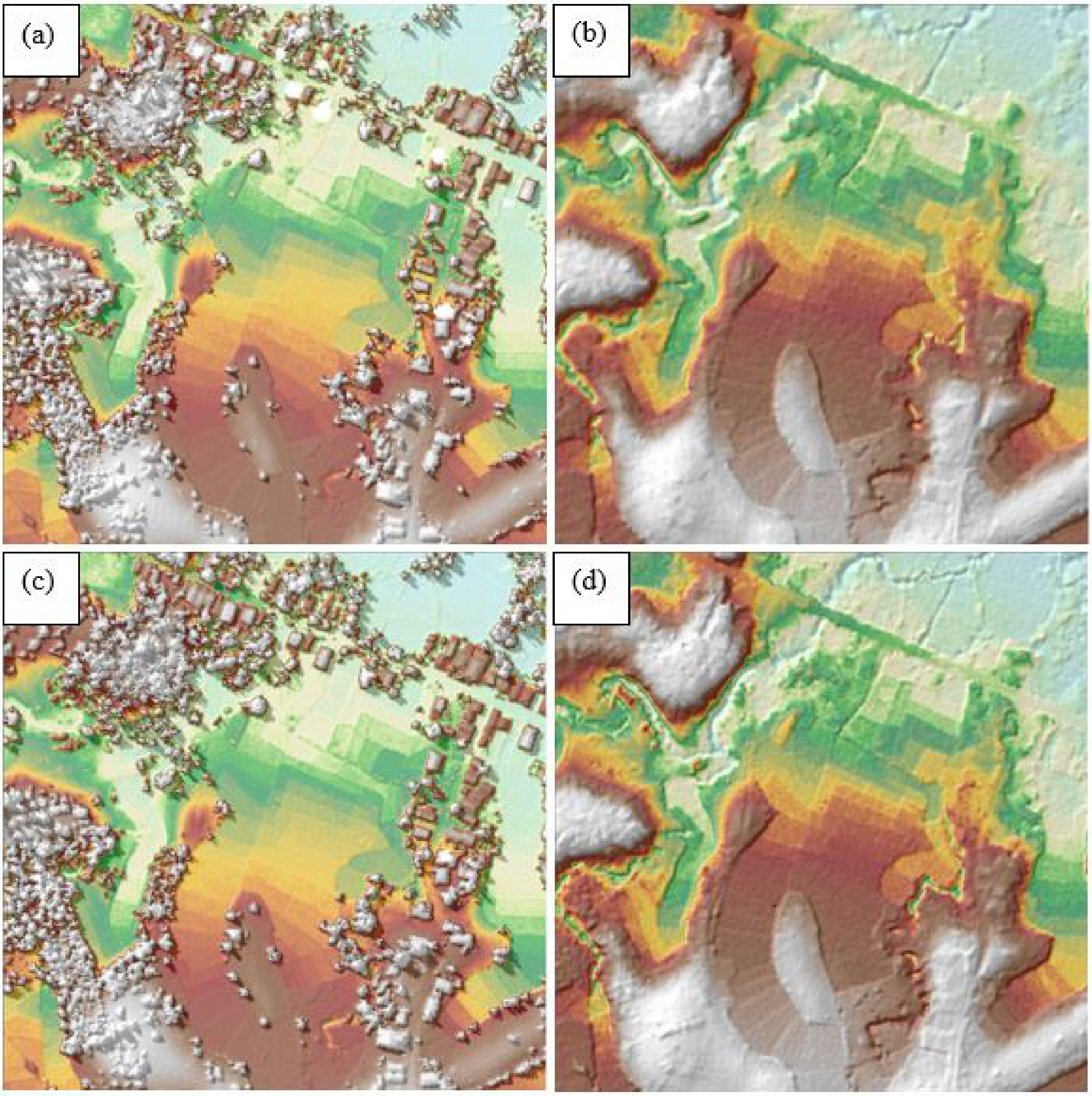


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Manicahan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 520 1km by 1km tiles area covered by the Manicahan floodplain is shown in Figure 20. 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 Manicahan floodplain attained a total of 441.17 sq. kms. in orthophotograph coverage comprised of 1,010 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

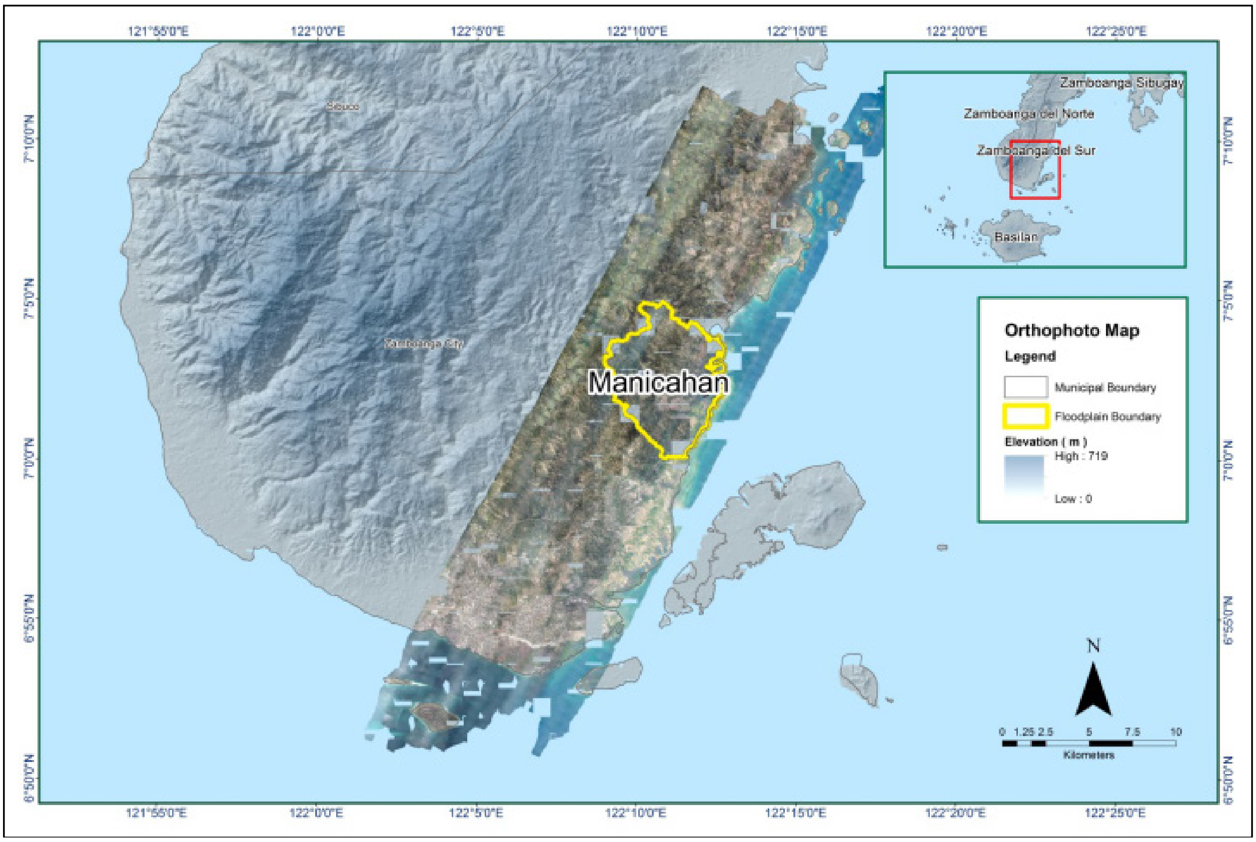


Figure 20. Manicahan Floodplain with available orthophotographs.

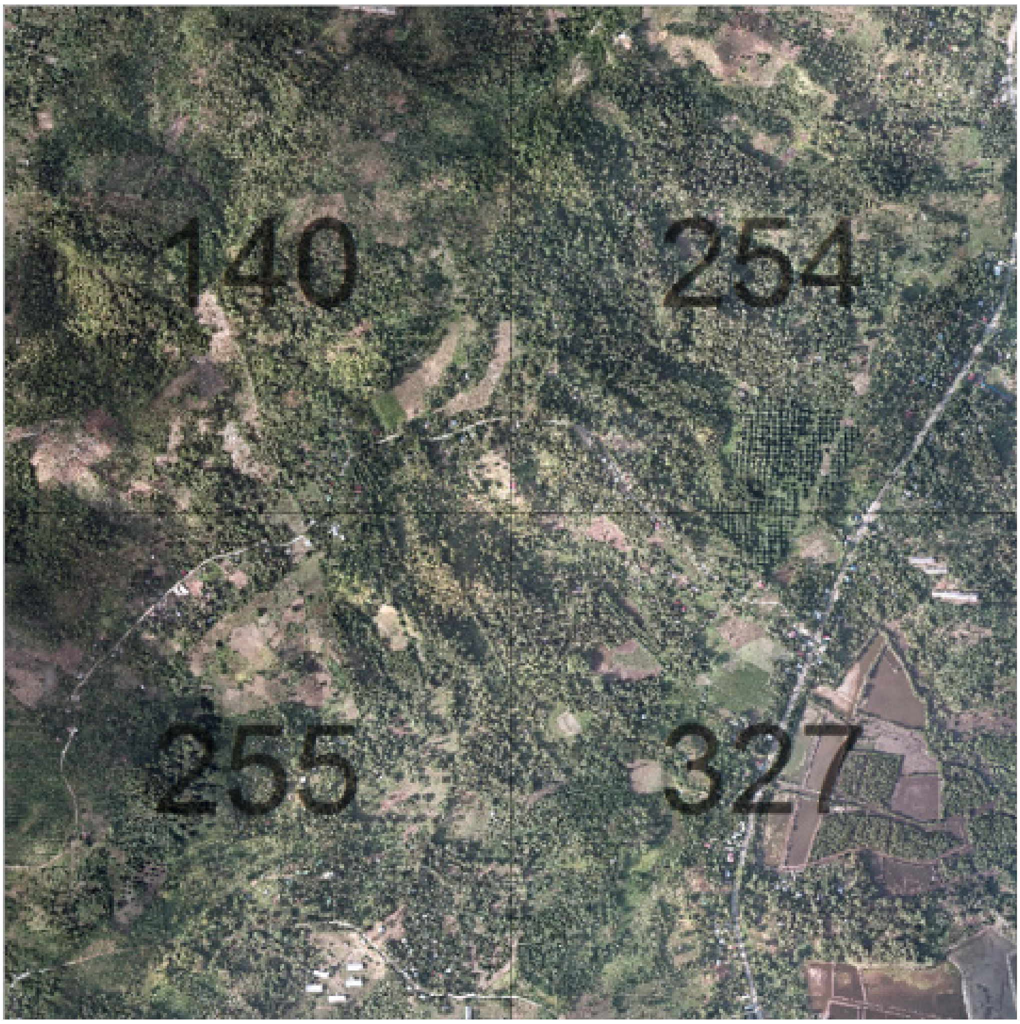


Figure 21. Sample orthophotograph tiles for Manicahan Floodplain.

3.8 DEM Editing and Hydro-Correction

One (1) mission block was processed for the Manicahan Floodplain Survey. This block is Zamboanga_ Blk75E with a total area of 394.93 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)
Zamboanga_Blk75E	394.93
TOTAL	**394.93 sq.km**

Figure 22 shows portions of a DTM before and after manual editing. As evident in the figure, the river embankment (Figure 22a) was misclassified and removed during the classification process and was retrieved and reclassified (Figure 22b) through manual editing to allow the correct water flow. Likewise, the bridge (Figure 22c) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 22d).

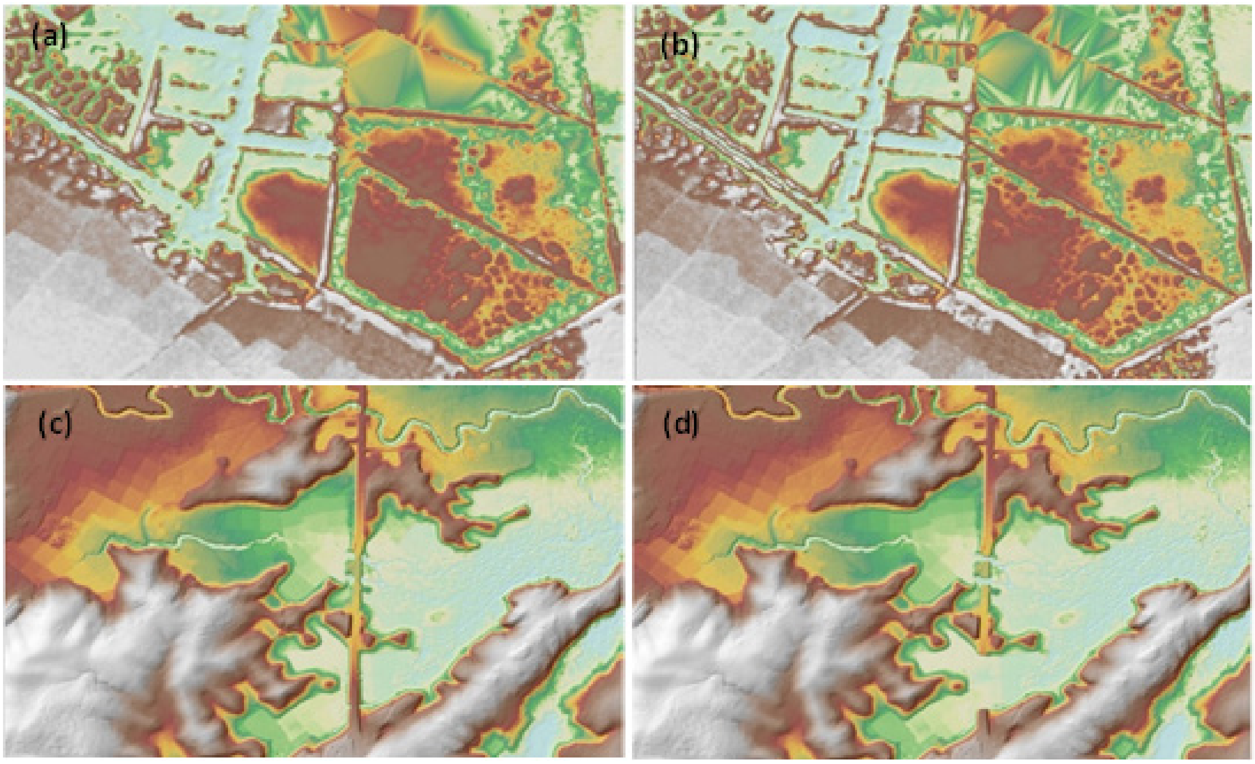


Figure 22. Portions in the DTM of the Manicahan Floodplain – a river enbankment before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Simultaneously mosaicking was done to all the available LiDAR data (Zamboanga_Blk75G, Zamboanga_Blk75F, Zamboanga_Blk75E, Zamboanga_Blk75F_additional, Zamboanga_Blk75D, Zamboanga_Blk75C and Zamboanga_Sacol). Zamboanga_Blk75G was used as the reference block at the start of mosaicking because it is the first available LiDAR data. Table 13 shows the shift values applied to the LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Manicahan Floodplain is shown in Figure 23. It can be seen that the entire Manicahan floodplain is 100% covered by LiDAR data.

Table 13. Shift values of each LiDAR block of Manicahan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_Blk75E	0.00	0.00	0.47

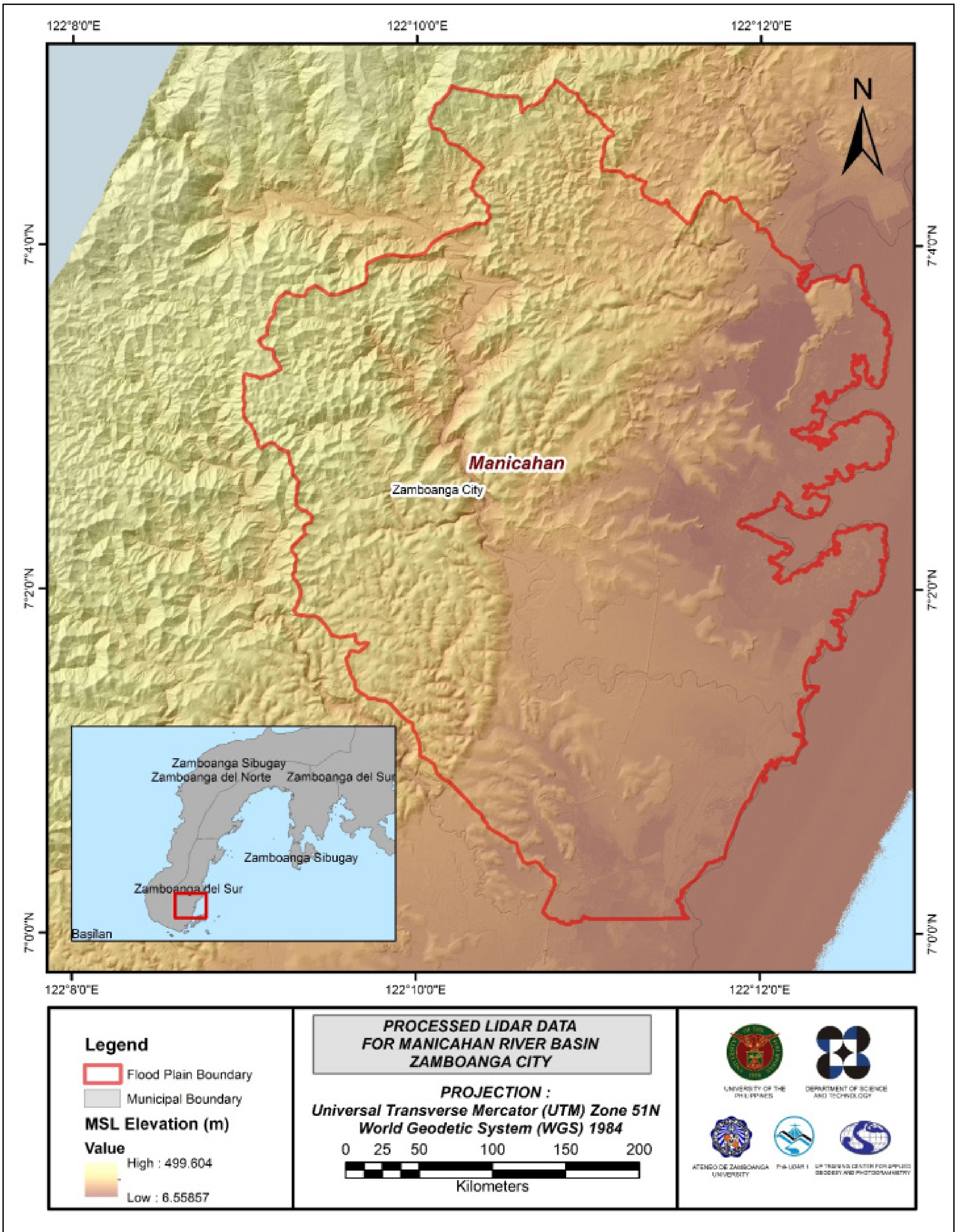


Figure 23. Map of Processed LiDAR Data for Manicahan Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Manicahan to collect points with which the LiDAR dataset is validated is shown in Figure 24, with the validation survey points highlighted in green. Simultaneous mosaicking was done for the Zamboanga LiDAR blocks and the only available data that time was for the Tumaga flood plain. The Manicahan flood plain is included in the set of blocks previously mosaicked, therefore, the Tumaga calibration data and methodology was used. A total of 1,739 survey points were gathered for the Manicahan floodplain. Random selection of 80% of the survey points, resulting to 1,391 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and the ground survey elevation values is shown in Figure 25. 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 8.06 meters, with a standard deviation of 0.07 meters. The calibration of the Manicahan LiDAR data was accomplished by adding the height difference value of 8.06 meters to the Manicahan mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between the Manicahan LiDAR data and the calibration data.

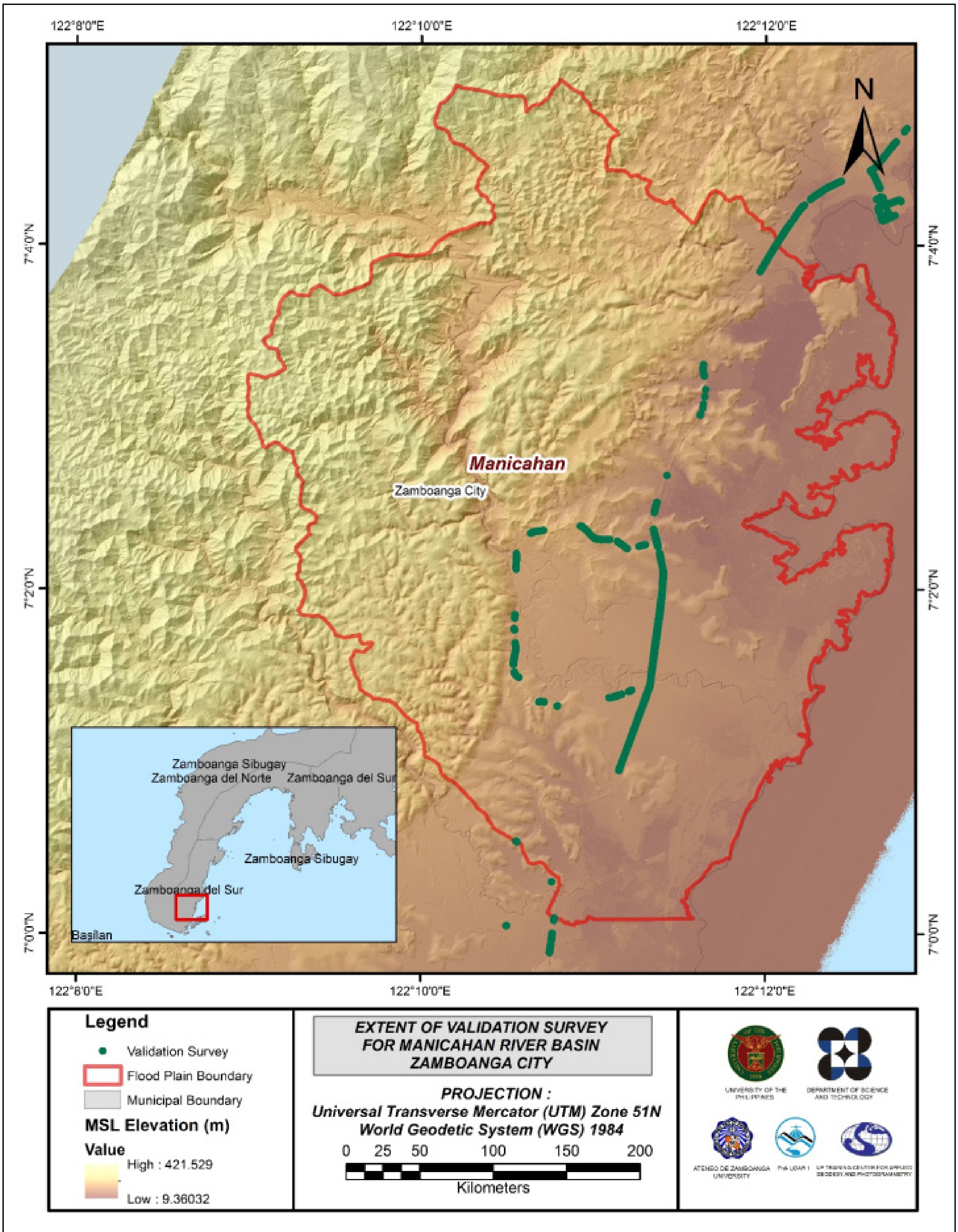


Figure 24. Map of Manicahan Floodplain with validation survey points in green.

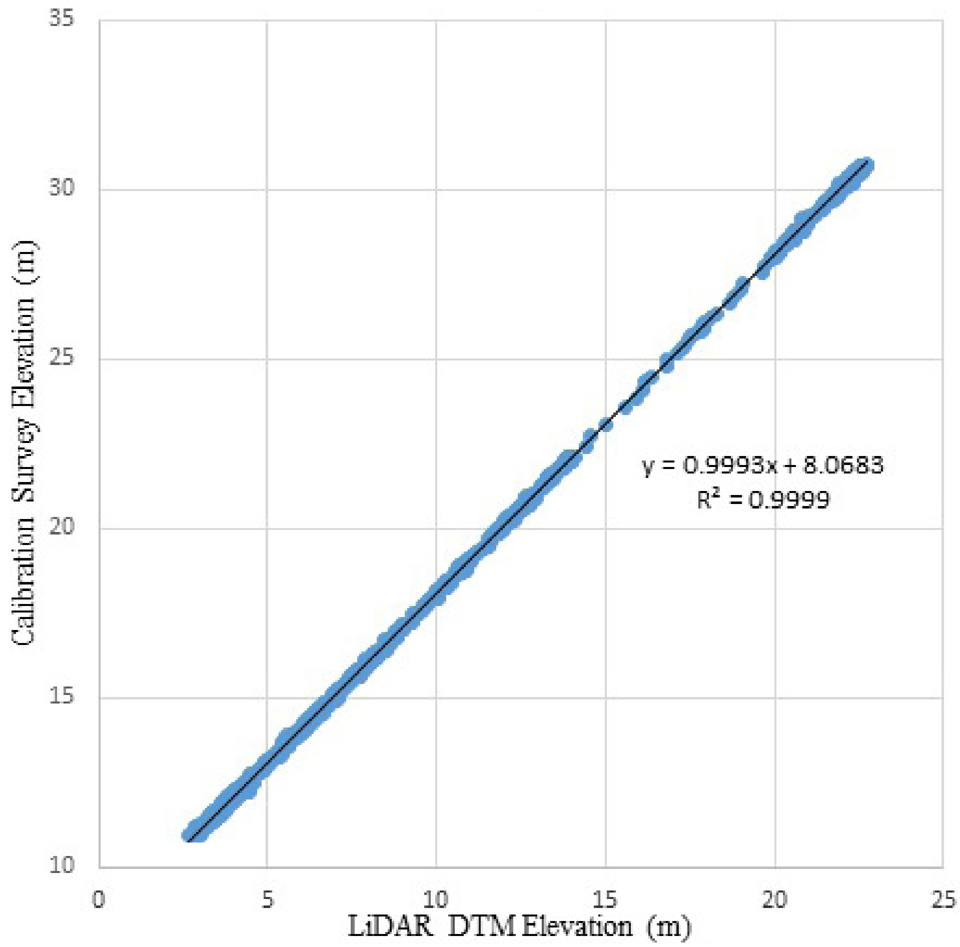


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	8.06
Standard Deviation	0.07
Average	8.06
Minimum	7.91
Maximum	8.20

A total of 1,272 survey points lie within the Manicahan Floodplain; all of which were used to validate the calibrated Manicahan 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 26. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 0.09 meters with a standard deviation of 0.05 meters, as shown in Table 15.

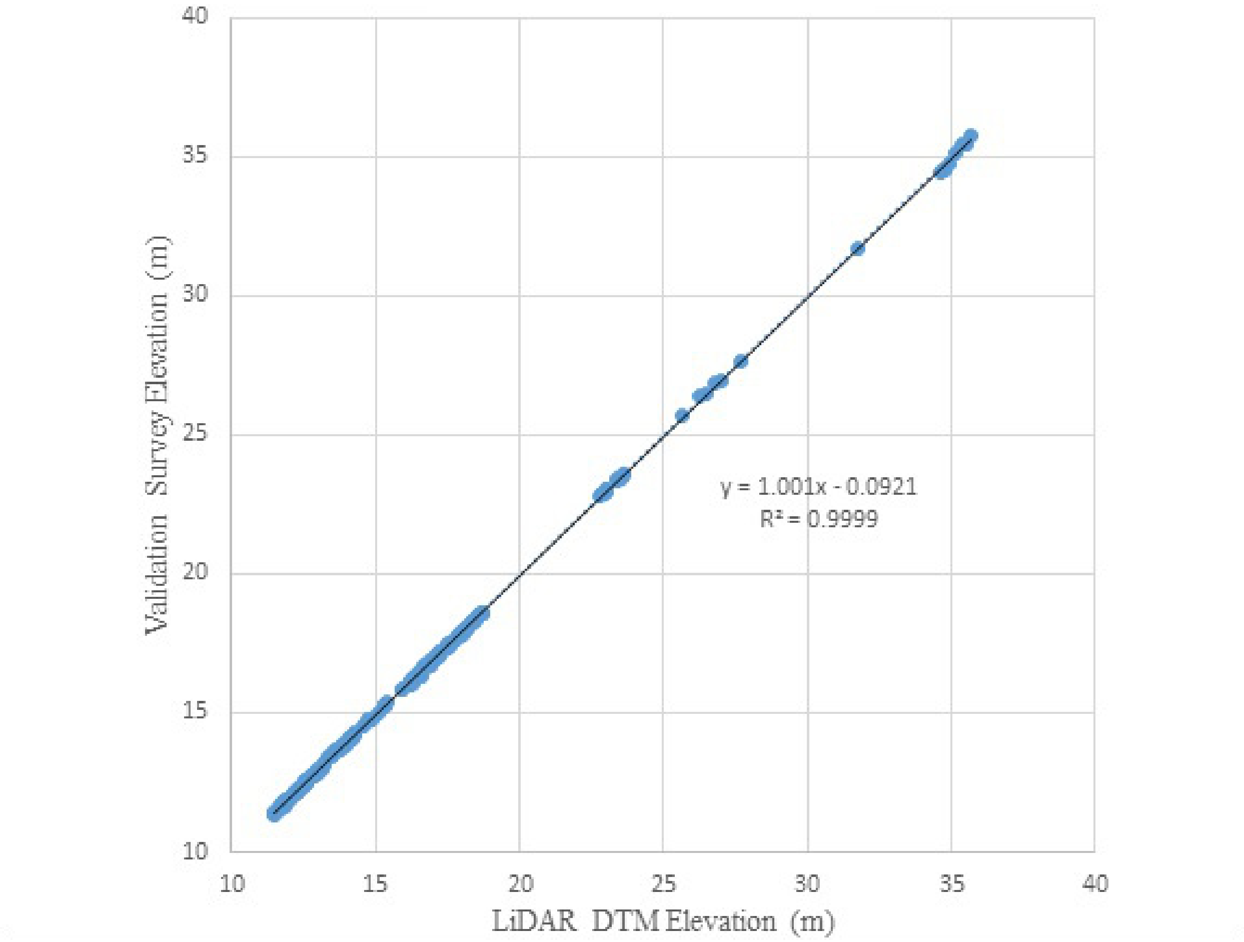


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.09
Standard Deviation	0.05
Average	0.07
Minimum	-0.03
Maximum	0.18

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Manicahan with a total of 1,248 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.19 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Manicahan is shown in Figure 27.

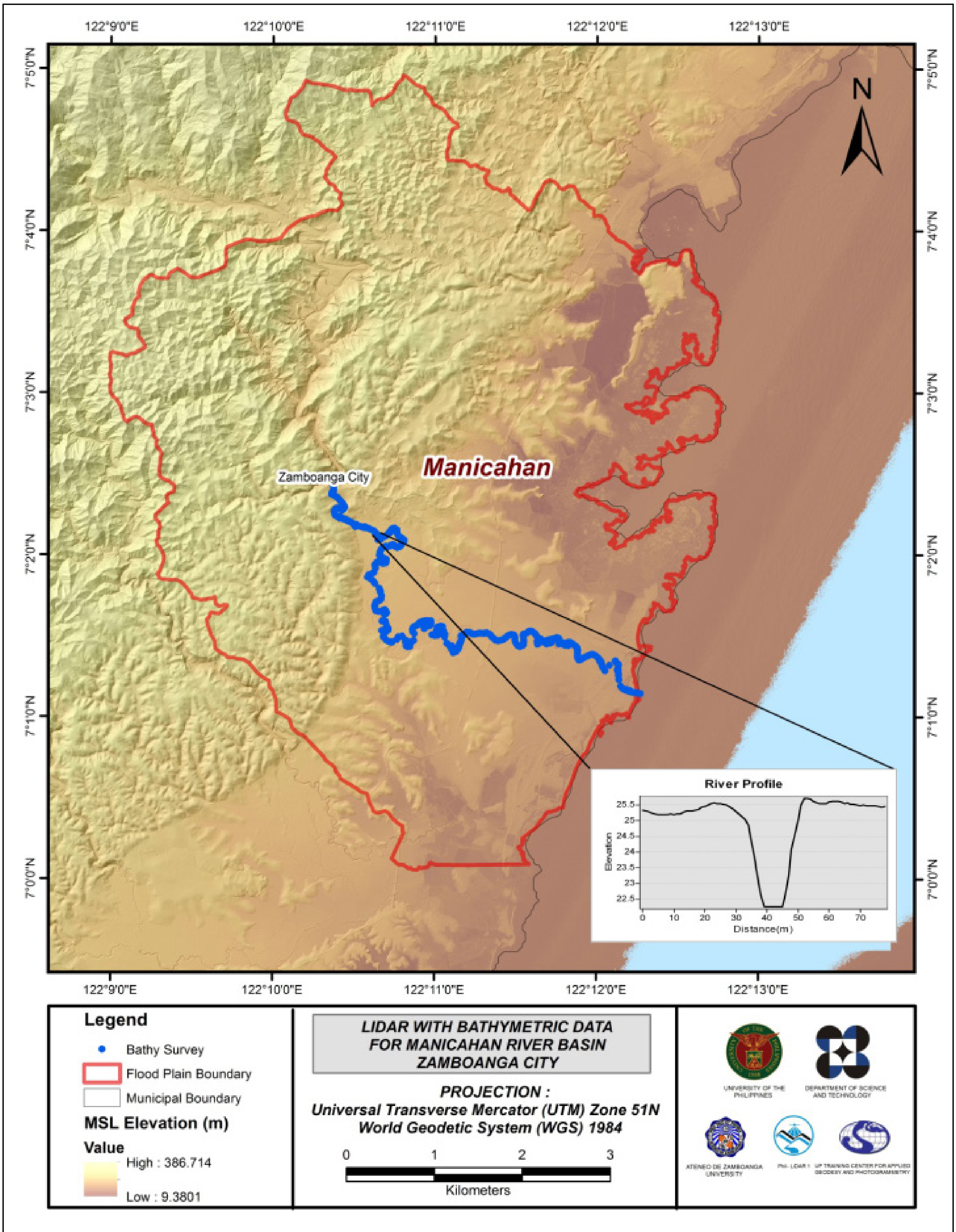


Figure 27. Map of Manicahan Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR 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

Manicahan floodplain, including its 200-m buffer, has a total area of 45.42 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 739 building features, were considered for QC. Figure 28 shows the QC blocks for the Manicahan floodplain.

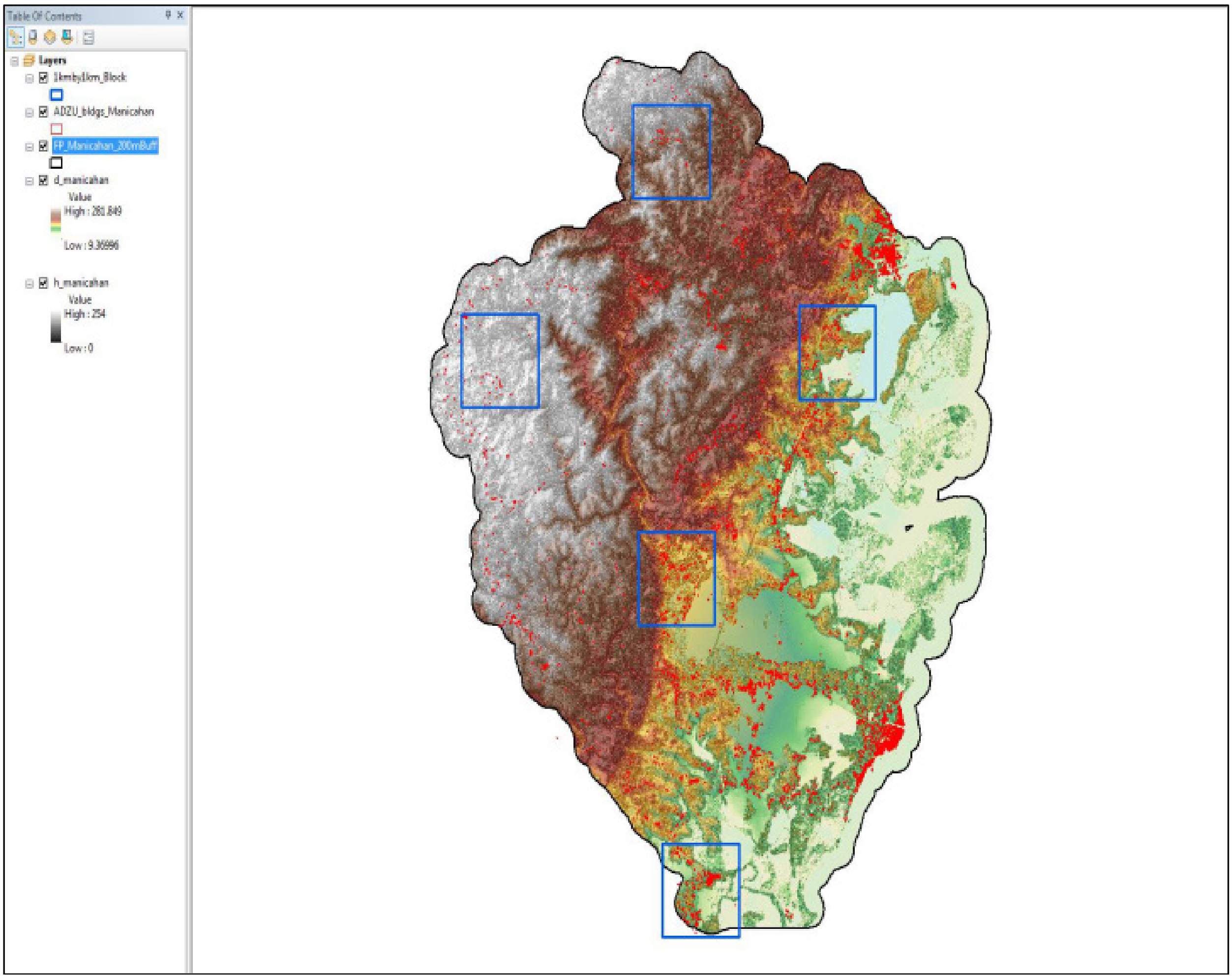


Figure 28. Blocks (in blue) of Manicahan building features that were subjected to QC

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

Table 16. Quality Checking Ratings for Manicahan Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Manicahan	98.79	99.73	98.38	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,878 building features in Manicahan floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,878 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.22 meters.

3.12.3 Feature Attribution

One of the Research Associate of ADZU Phil LiDAR 1 was able to develop GEONYT, an offline web-based application for feature attribution extracted from a LiDAR-based Digital Surface Model and which attribution is conducted by combining automatic data consolidation, geotagging and offline navigation. The app is conveniently integrated in a smart phone/ tablet. The data collected are automatically stored in database and can be viewed as CSV (or excel) and KML (can viewed via google earth). The Geonyt App was the main tool used in all feature attribution activity of the team.

The team, thru the endorsement of the Local Government Units of the Municipality/ City hired a number of enumerators who conducted the house-to-house survey of the features using the GEONYT application. The team provided the enumerators smart tablets where the GEONYT is integrated. The number of days by which the survey was conducted was dependent on the number of features of the flood plain of the riverbasin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the floodplain.

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 Manicahan Floodplain.

Facility Type	No. of Features
Residential	5,564
School	54
Market	43
Agricultural/Agro-Industrial Facilities	13
Medical Institutions	5
Barangay Hall	4
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	2
Transport Terminal	0
Warehouse	10
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	0
Water Supply/Sewerage	5
Religious Institutions	12
Bank	0
Factory	4
Gas Station	0
Fire Station	1
Other Government Offices	1
Other Commercial Establishments	10
N/A	149
Total	**5,878**

Table 18. Number of Extracted Road Networks for Manicahan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Manicahan	2.46	47.31	0.00	9.14	0.00	58.91

Table 19. Number of Extracted Water Bodies for Manicahan Floodplain.

Floodplain	Water Body Type						Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Manicahan	18	0	1	0	99	118	267

A total of 4 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 29 shows the completed Digital Surface Model (DSM) of the Manicahan floodplain overlaid with its ground features.

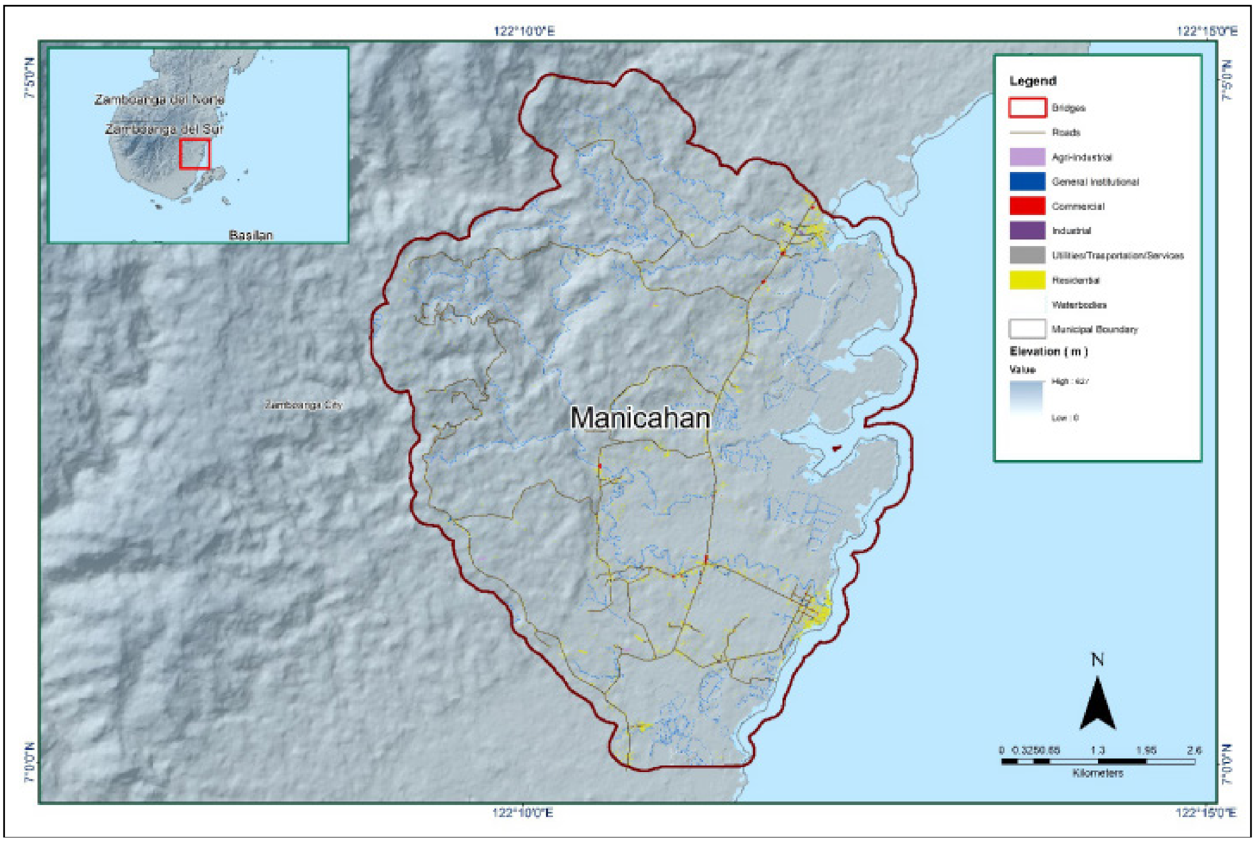


Figure 29. Extracted features for Manicahan Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie Caballero, Patrizcia Mae. P. dela Cruz, Dexter T. Lozano, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto, Cybil Claire Atacador, Engr. Lorenz R. Taguse

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

Ateneo de Zamboanga University (AdZU) conducted a field survey in Manicahan River on September 24, 2015 to October 8, 2015, and January 14-18, 2016 with the following scope of work: reconnaissance; control survey; cross-section, bridge as-built and water level marking in MSL of Manicahan Bridge in Brgy. Cacao, Municipality of Balasan; validation points acquisition of about 11 km covering the survey area; and bathymetric survey from Brgy. Tolosa down to Brgy. Manicahan, Zamboanga City, with an estimated length of 8.468 km using Trimble® SPS 882 GNSS RTK survey technique and open traverse method using total station (Figure 30).

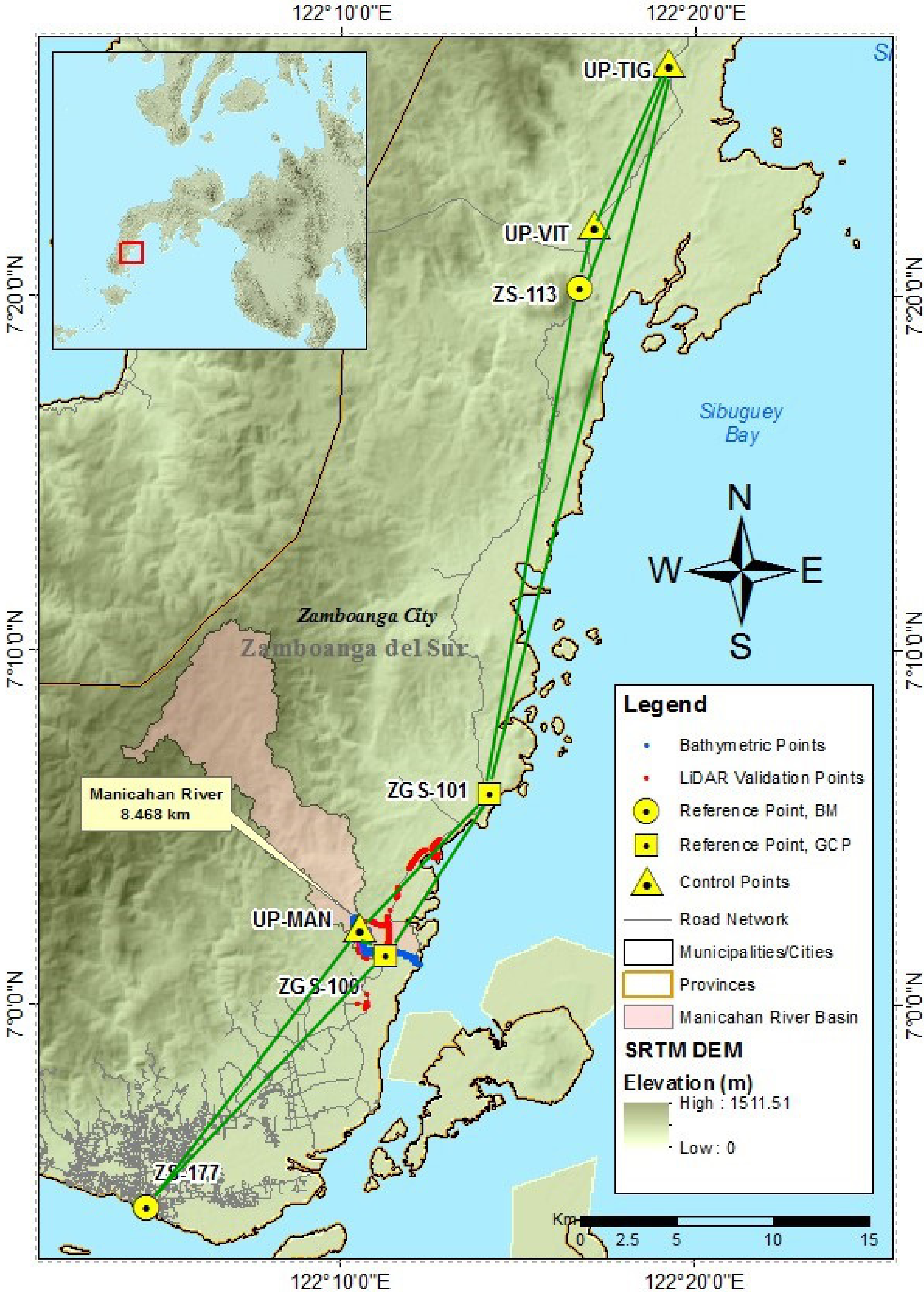


Figure 30. Extent of the bathymetric survey (in blue line) in Manicahan River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Manicahan River survey is composed of four loops established on September 26, 2015, October 3, and October 8, 2015, occupying ZGS-101, a second-order GCP located within the perimeter of Bolong Elementary School; ZS-113, a first order benchmark in Brgy. Tigbalagbag, Zamboanga City; and ZS-177, a first-order benchmark on the back of the central monument at Rizal Park in front of Zamboanga City Hall.

Three control points were also established along the approach of the bridges namely: UP-MAN, situated on Manicahan Steel Bridge in Brgy. Cacap, Zamboanga City; UP-TIG, in Tigbao Bridge in Brgy. Tictapul, Zamboanga City; and UP-VIT in Vitali Bridge in Brgy. Vitali, Zamboanga City. A NAMRIA established control point namely ZGS-100, located in front of Vitali Barangay Hall, was 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 31 shows the GNSS network established in the Manicahan River Survey.

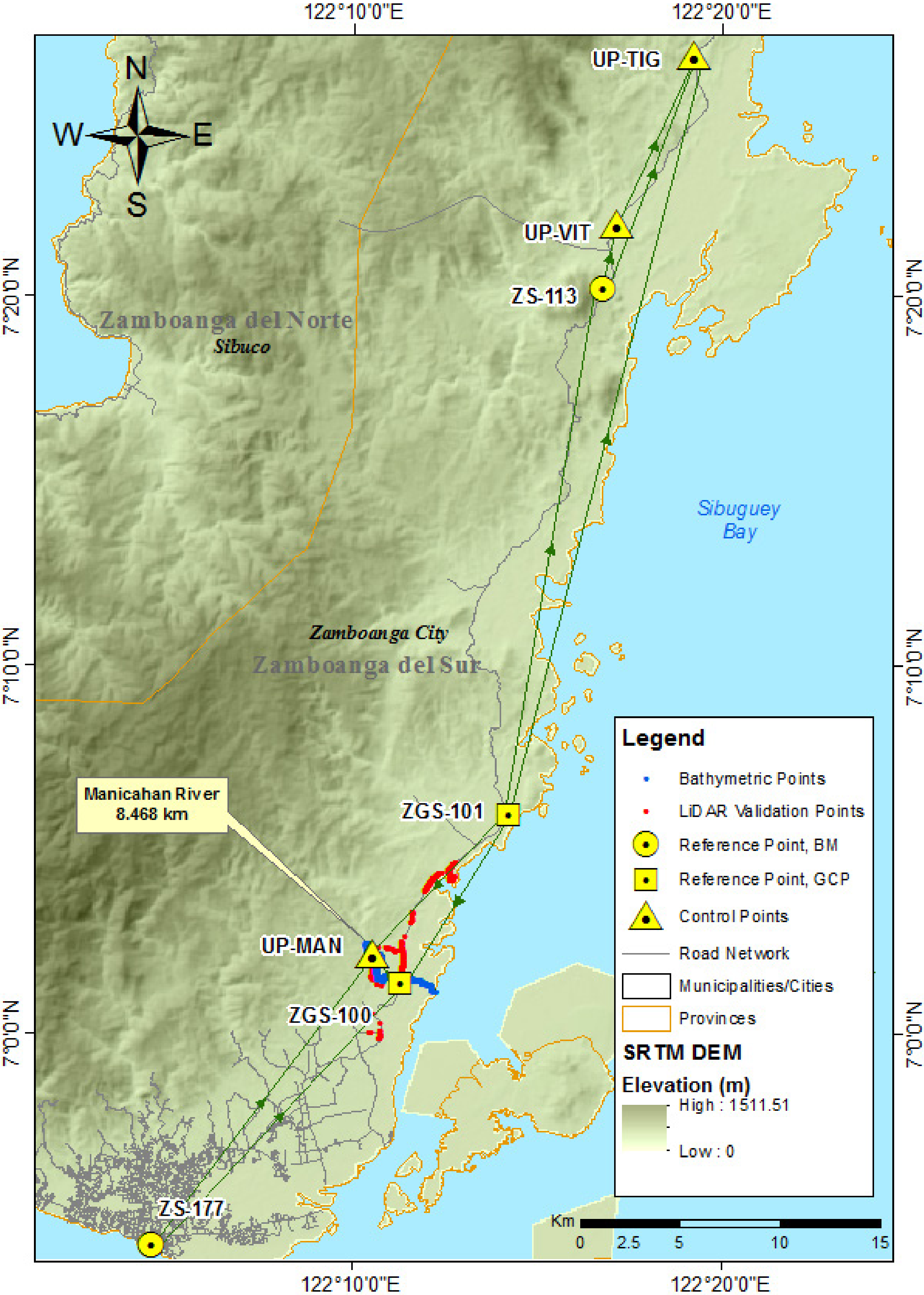


Figure 31. GNSS Network established in the Manicahan River Survey.

Table 20. List of Reference and Control Points occupied for Manicahan River Survey

(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
ZGS-101	2nd Order, GCP	7°05'57.59221"	122°14'13.79610"	80.222	-	2009
ZS-177	1st Order, BM	-	-	80.002	12.311	2007
ZS-113	1st Order, BM	-	-	219.481	151.585	2007
ZGS-100	Used as marker	-	-	-	-	2009
UP-MAN	UP Established	-	-	-	-	October 3, 2015
UP-TIG	UP Established	-	-	-	-	August 1, 2015
UP-VIT	UP Established	-	-	-	-	August 1, 2015

Figure 32 to Figure 38 depict the setup of the GNSS on recovered reference points and established control points in the Manicahan River.

Figure 32. Trimble® SPS 852 set-up at ZGS-101 located at Bolong Elementary School, Brgy. Bolong, Zamboanga City.

Figure 33. Trimble® SPS 852 set-up at ZS-177 located at the stair of Rizal's Park in Brgy. Poblacion, Zamboanga City.

Figure 34. Trimble SPS® 882 set-up at ZGS-100 located at Manicahan Barangay Hall, Zamboanga City.

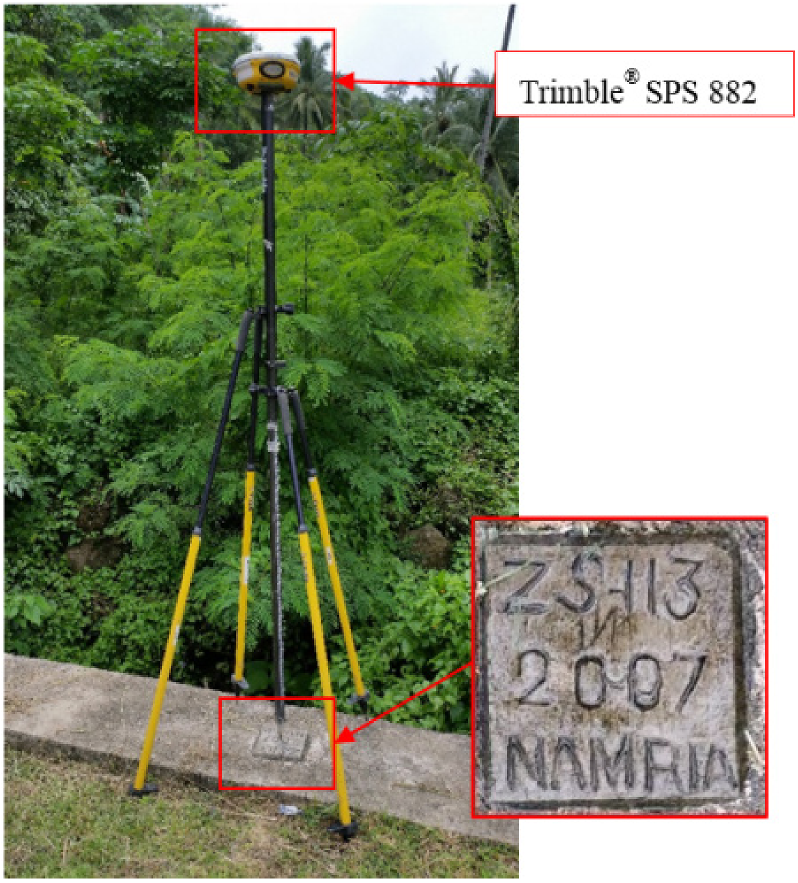


Figure 35. Trimble SPS® 882 set-up at ZS-113 located along Tagasilay-Vitali Road, Brgy. Tigbalabag, Zamboanga City.

Figure 36. Trimble SPS® 852 set-up at UP-MAN located at the approach of Manicahan Steel Bridge in Brgy. Cacap, Zamboanga City.

Figure 37. Trimble SPS® 882 set-up at UP-TIG located at the approach of Tigbao Bridge in Brgy. Tictapul, Zamboanga City.

Figure 38. Trimble® SPS 882 set-up at UP-VIT located at the approach of Vitali Bridge in Brgy. Vitali, Zamboanga City.

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 Manicahan River Basin, as generated by the TBC software.

Table 21. Baseline Processing Summary Report for Manicahan River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZGS101 --- UPTIG	09-26-2015	Fixed	0.003	0.018	13°40'16"	39078.38	9.652
ZGS101 --- ZS113	09-26-2015	Fixed	0.003	0.023	10°06'59"	26671.69	139.258
ZGS101 --- UPVIT	09-26-2015	Fixed	0.003	0.027	10°18'43"	30022.53	6.491
ZGS101 --- UPMAN	10-03-2015	Fixed	0.006	0.026	224°10'56"	9709.698	16.669
ZGS101 --- ZGS100	10-03-2015	Fixed	0.004	0.023	212°35'19"	10000.29	4.51
UPTIG --- ZS113	09-26-2015	Fixed	0.004	0.032	201°14'35"	12567.26	129.543
UPTIG --- UPVIT	09-26-2015	Fixed	0.004	0.029	204°36'51"	9275.764	-3.206
ZS113 --- UPVIT	09-26-2015	Fixed	0.003	0.018	11°52'24"	3352.211	-132.76
ZS177 --- ZGS100	10-08-2015	Fixed	0.007	0.027	223°21'49"	18026.23	-4.678
ZGS100 --- UPMAN	10-08-2015	Fixed	0.005	0.018	316°38'30"	2011.6	12.124
ZGS100 --- UPMAN	10-03-2015	Fixed	0.005	0.023	316°38'33"	2011.599	12.107
ZS177 --- UPMAN	10-08-2015	Fixed	0.011	0.036	37°01'59"	18252.08	16.837

As shown in Table 21, all baselines that formed the GNSS network for the static survey setup acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precision respectively.

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:

<20cm and

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 24.

The control point ZGS-101 was held fixed for the coordinate values, and ZS-177 and ZS-113 were held fixed for the elevation 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)
ZGS101	Global	Fixed	Fixed		
ZS113	Grid				Fixed
ZS177	Grid				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. All fixed control points have no values for grid and elevation errors.

Table 23. Adjusted grid coordinates for the control points used in the Manicahan River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UPMAN	408983.223	0.015	777849.044	0.011	28.988	0.081	
UPTIG	425056.716	0.009	822742.326	0.008	22.012	0.077	
UPVIT	421181.693	0.009	814318.080	0.008	18.825	0.067	
ZGS100	410361.342	0.013	776384.498	0.011	16.872	0.077	
ZGS101	415759.669	?	784798.916	?	12.345	0.064	LL
ZS113	420486.928	0.009	811039.756	0.008	151.585	?	e
ZS177	397965.109	0.025	763304.272	0.017	12.311	?	e

The results of the computation for accuracy are as follows:

a.ZGS-101

horizontal accuracy	=	Fixed
vertical accuracy	=	6.4 cm < 10 cm

b.ZGS-100

horizontal accuracy	=	$\sqrt{((1.30)^2 + (1.10)^2}$
	=	$\sqrt{(1.69 + 1.21)}$
	=	1.70 cm < 20 cm
vertical accuracy	=	7.7 cm < 10 cm

c.ZS-113

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm < 20 cm
vertical accuracy	=	Fixed

d.ZS-177

horizontal accuracy	=	$\sqrt{((2.50)^2 + (1.70)^2}$
	=	$\sqrt{(6.25 + 2.89)}$
	=	3.02 cm < 20 cm
vertical accuracy	=	Fixed

e.UP-MAN

horizontal accuracy	=	$\sqrt{((1.50)^2 + (1.10)^2}$
	=	$\sqrt{(2.25 + 1.21)}$
	=	1.86 cm < 20 cm
vertical accuracy	=	8.10 cm < 10 cm

f.UP-TIG

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm < 20 cm
vertical accuracy	=	7.70 cm < 10 cm

g.UP-VIT

horizontal accuracy	=	$\sqrt{((0.90)^2 + (0.80)^2}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm < 20 cm
vertical accuracy	=	6.70 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 Manicahan River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
UPMAN	N7°02'10.91288"	E122°10'33.30241"	96.857	0.081	
UPTIG	N7°26'33.60615"	E122°19'15.00531"	89.890	0.077	
UPVIT	N7°21'59.09413"	E122°17'09.03227"	86.709	0.067	
ZGS100	N7°01'23.30256"	E122°11'18.30194"	84.730	0.077	
ZGS101	N7°05'57.59221"	E122°14'13.79610"	80.222	0.064	LL
ZS113	N7°20'12.30776"	E122°16'46.54305"	219.481	?	e
ZS177	N6°54'16.64645"	E122°04'35.12376"	80.002	?	e

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 Manicahan River GNSS Static Survey are seen in Table 25.

Table 25. Reference and control points utilized in the Manicahan 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)
ZGS100	2nd Order, GCP	7°01'23.30256"	122°11'18.30194"	84.73	776384.5	410361.3	16.872
ZGS101	2nd Order, GCP	7°05'57.59221"	122°14'13.79610"	80.222	784798.9	415759.7	12.345
ZS177	1st Order, BM	6°54'16.64645"	122°04'35.12376"	80.002	763304.3	397965.1	12.311
ZS113	Used as marker	7°20'12.30776"	122°16'46.54305"	219.481	811039.8	420486.9	151.585
UPMAN	UP Established	7°02'10.91288"	122°10'33.30241"	96.857	777849	408983.2	28.988
UPTIG	UP Established	7°26'33.60615"	122°19'15.00531"	89.89	822742.3	425056.7	22.012
UPVIT	UP Established	7°21'59.09413"	122°17'09.03227"	86.709	814318.1	421181.7	18.825

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

The bridge cross-section and as-built surveys were conducted on October 7, 2015 in Manicahan Bridge, Brgy. Cacao, Municipality of Balasan using the GNSS receiver South® S86T utilizing GNSS RTK survey technique.

The cross-sectional line of Manicahan Bridge is about 121.05 meters with thirty-two (32) points acquired using UP-MAN as GNSS base station. Water surface elevation of the River was determined using total station open traverse technique on January 27, 2016 at 10:30 AM with a value of 23.328 m above MSL. The cross-sectional diagram, location map, and the bridge data form are shown in Figure 37 to Figure 39, respectively.

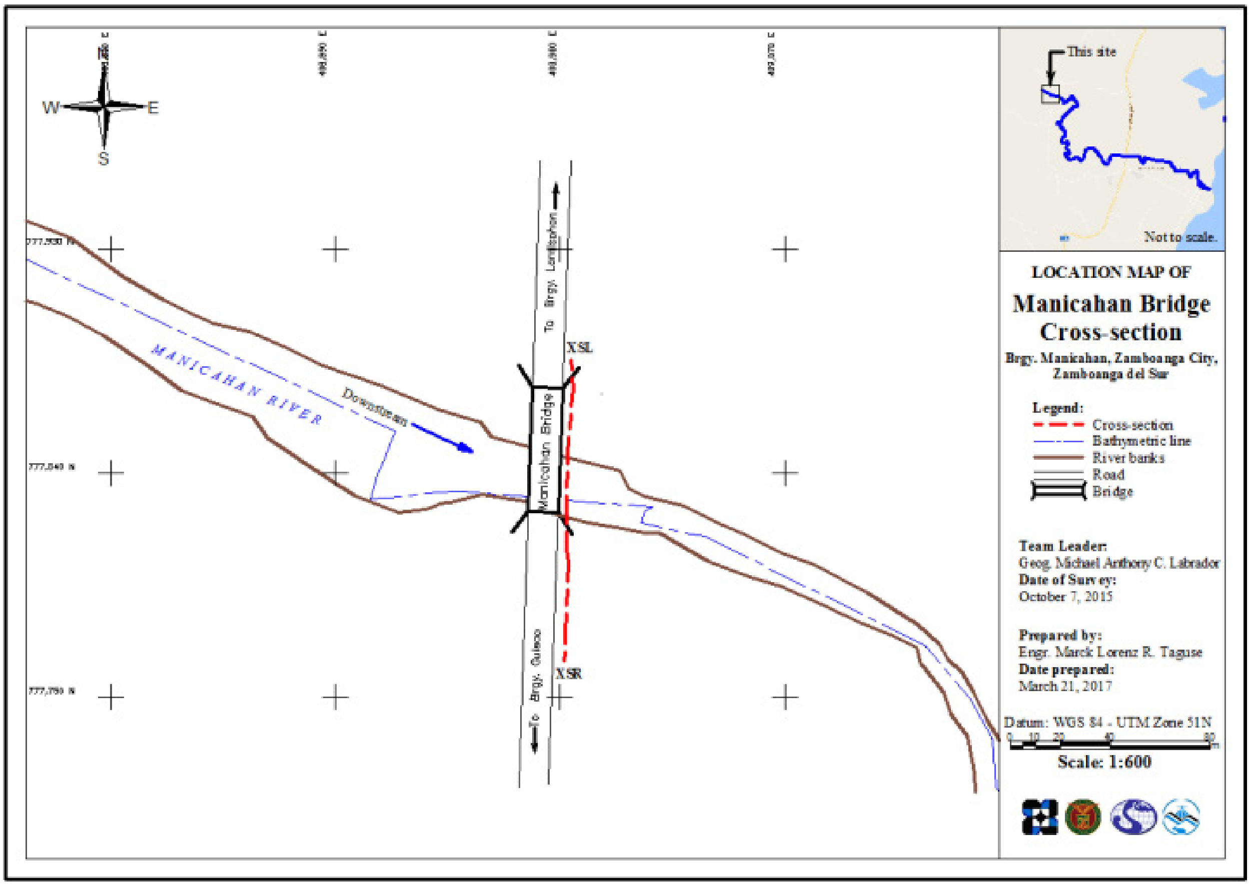


Figure 39. Location map of the Manicahan cross-section survey in Manicahan Bridge.

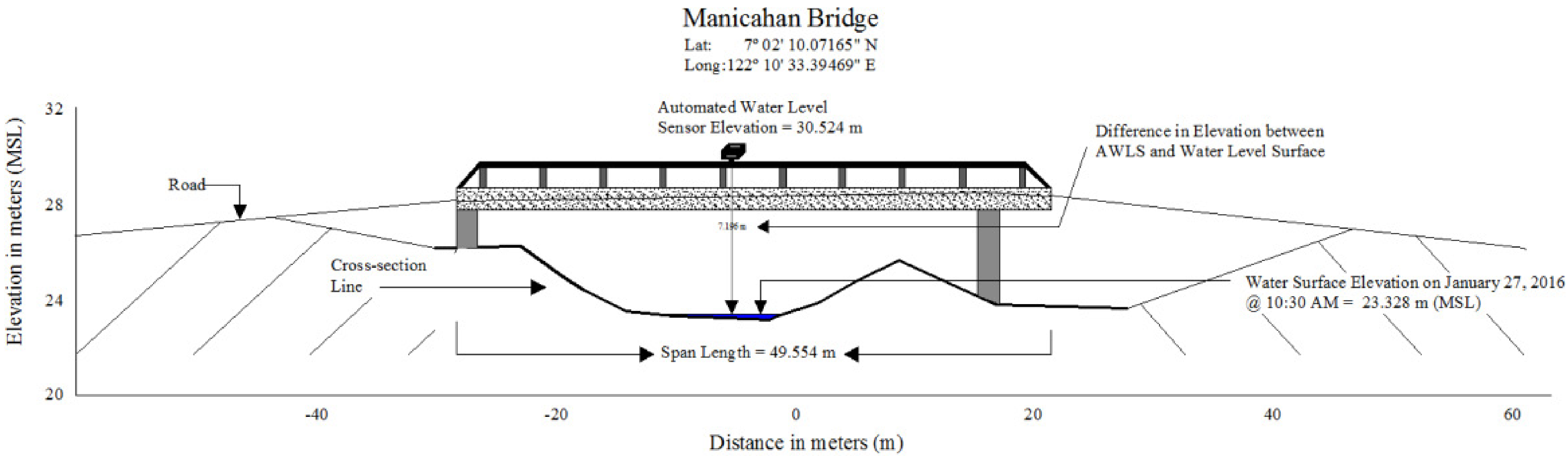


Figure 40. Manicahan cross-section survey in Manicahan Bridge drawn to scale.

Bridge Data Form

Bridge Name: Manicahan Bridge **Date: October 7, 2015**

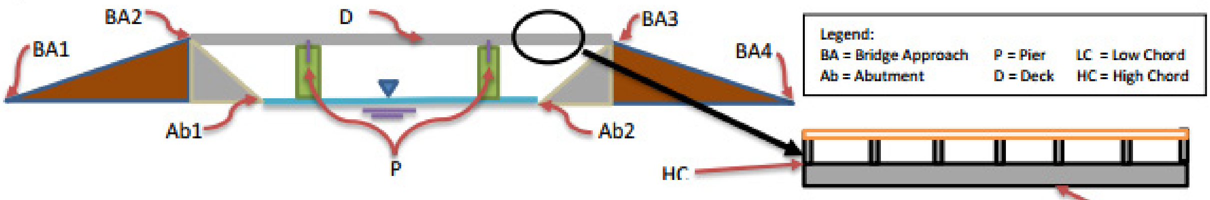
River Name: Manicahan River **Time: 04:00 PM**

Location (Brgy, City,Region): Brgy. Manicahan, Zamboanga City, Zamboanga Peninsula

Survey Team: Michael Anthony Labrador, Precious Annie Lopez, Anthony Abogado, Kim Patrick Tort

Flow condition: low normal ✓ high **Weather Condition:** ✓ fair rainy

Latitude: **Longitude:**



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

Elevation: **Width:** **Span (BA3-BA2): 49.637 m**

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	18.096	BA3	82.071	19.737
BA2	32.434	19.542	BA4	127.354	17.480

Abutment: Is the abutment sloping? Yes ✓No; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Cylindrical Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	79.885	19.887	
Pier 2			

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

Figure 41. Bridge As-built form of Manicahan Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 5 and October 6, 2016 using a survey GNSS rover receiver Trimble® SPS 882 mounted on a pole, which was attached in front of the vehicle as shown in Figure 42. . It was secured with cable ties to ensure that it was horizontally and vertically balanced. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-MAN occupied as the GNSS base stations all throughout the conduct of the survey.

Figure 42. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The GNSS base station was set-up over UP-MAN gathered validation points traversing seven (7) barangays in Zambonaga City. The ground validation line is approximately 11 km in length with 1,451 points.

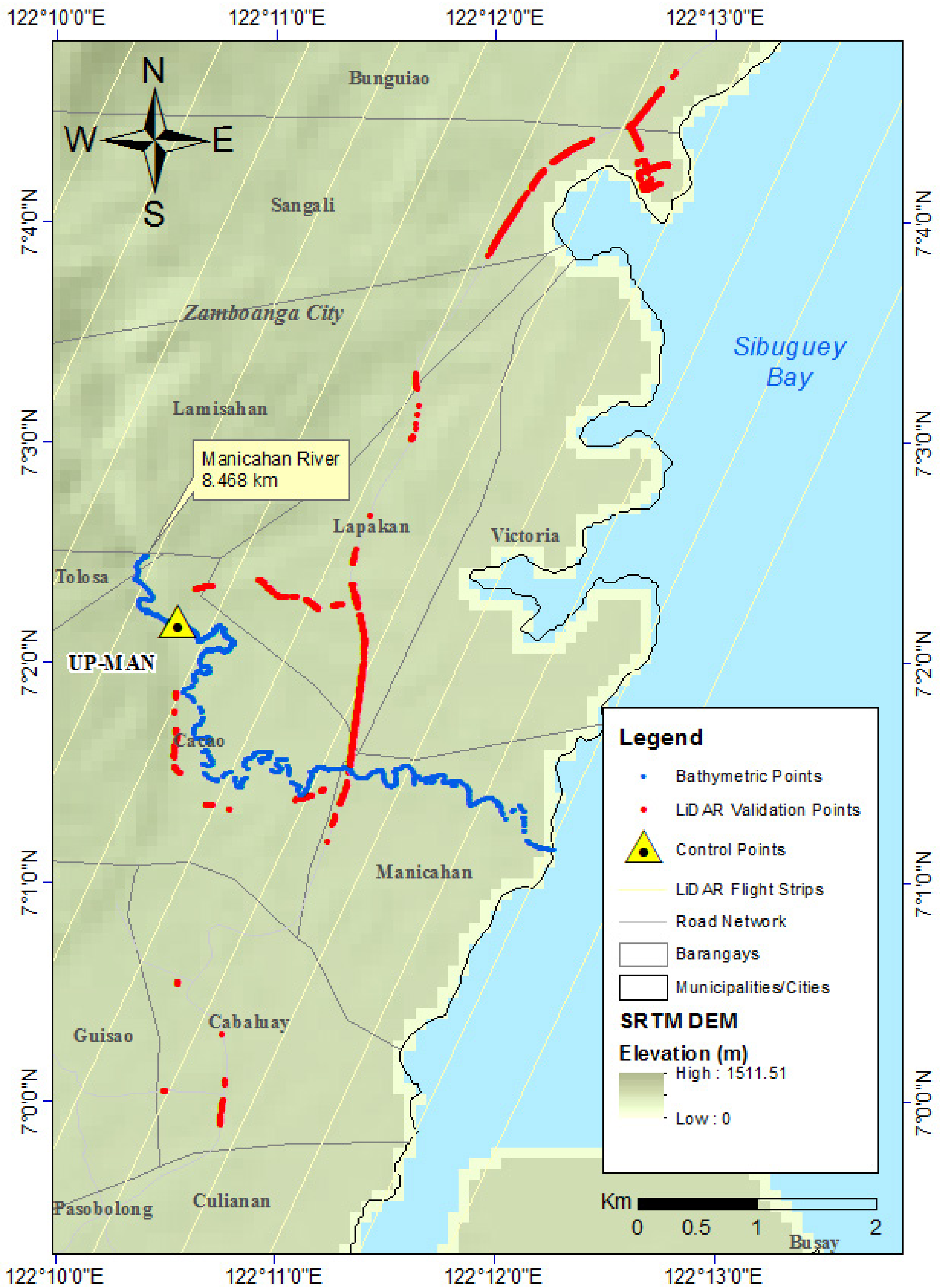


Figure 43. The extent of the LiDAR ground validation survey (in red) for Manicahan River Basin.

4.7 River Bathymetric Survey

Manual bathymetric survey using a Trimble® SPS 882 GNSS PPK technique was executed on October 5, 6, and 7, 2015 starting from the upstream in Brgy. Cacao with coordinates 7°2'10.5797"N 122°10'30.7994"E traversed the river by foot ending in Brgy. Manicahan with coordinates 7°1'8.6329"N 122°12'16.38214"E as shown in Figure 42. The control point UP-MAN was used as GNSS base station for the whole conduct of the survey.

Manual bathymetry resurvey implementing open traverse method using total station was executed on January 22, 23, 25, and 27, 2016 to fill in data from the first survey that did not meet the required accuracy. The survey began from the upstream in Brgy. Caco with coordinates 7°2'28.6951"N 122°10'24.7641"E traversed the river by foot and ended at the mouth of the river in Brgy. Manicahan with coordinates 7°1'18.2597"N 122°12'2.5487"E.

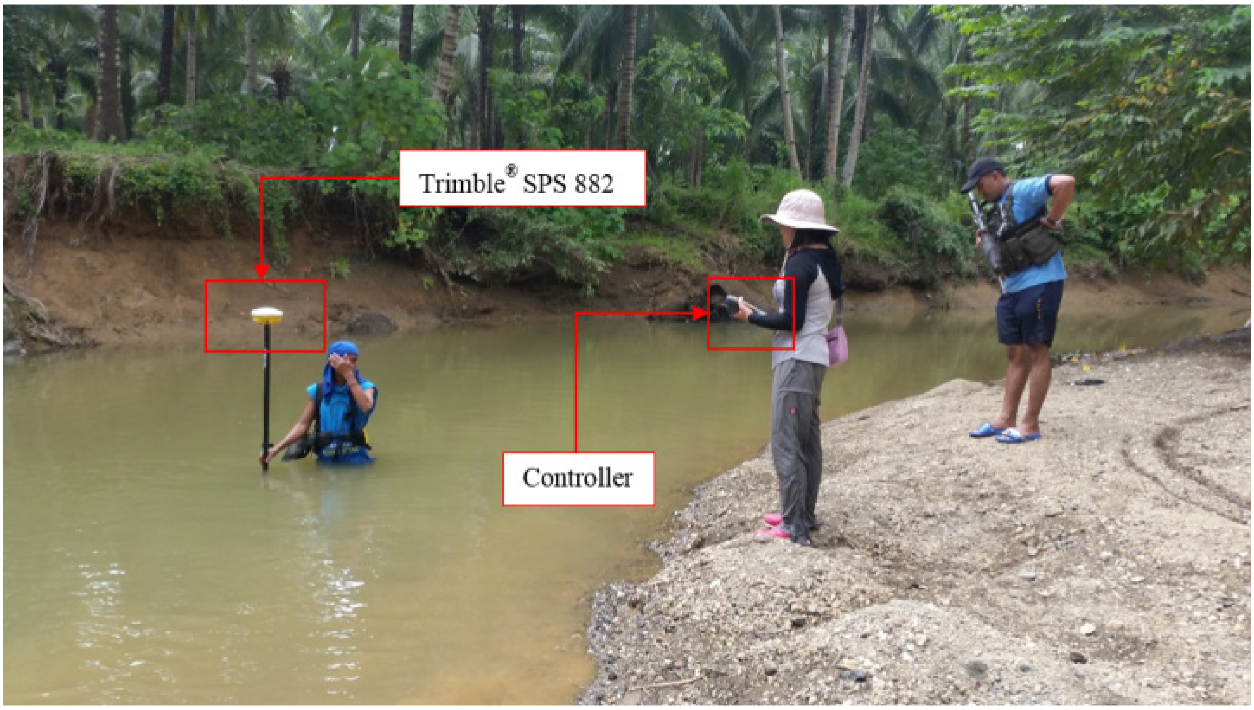


Figure 44. Set up of the bathymetric survey in Manicahan River.

The entire bathymetric data coverage for Manicahan River is illustrated in the map in Figure 45. The bathymetric line is approximately 8.468 km in length with 1,445 bathymetric points acquired using UP-MAN as GNSS base station covering the Manicahan River. A CAD diagram was also produced to illustrate the Manicahan riverbed profile as shown in Figure 46. There is about a 8-m change in elevation observed within the whole extent of the bathymetric data from its upstream in Brgy. Cacao down to the mouth of the river in Brgy. Manicahan, Zamboanga City.

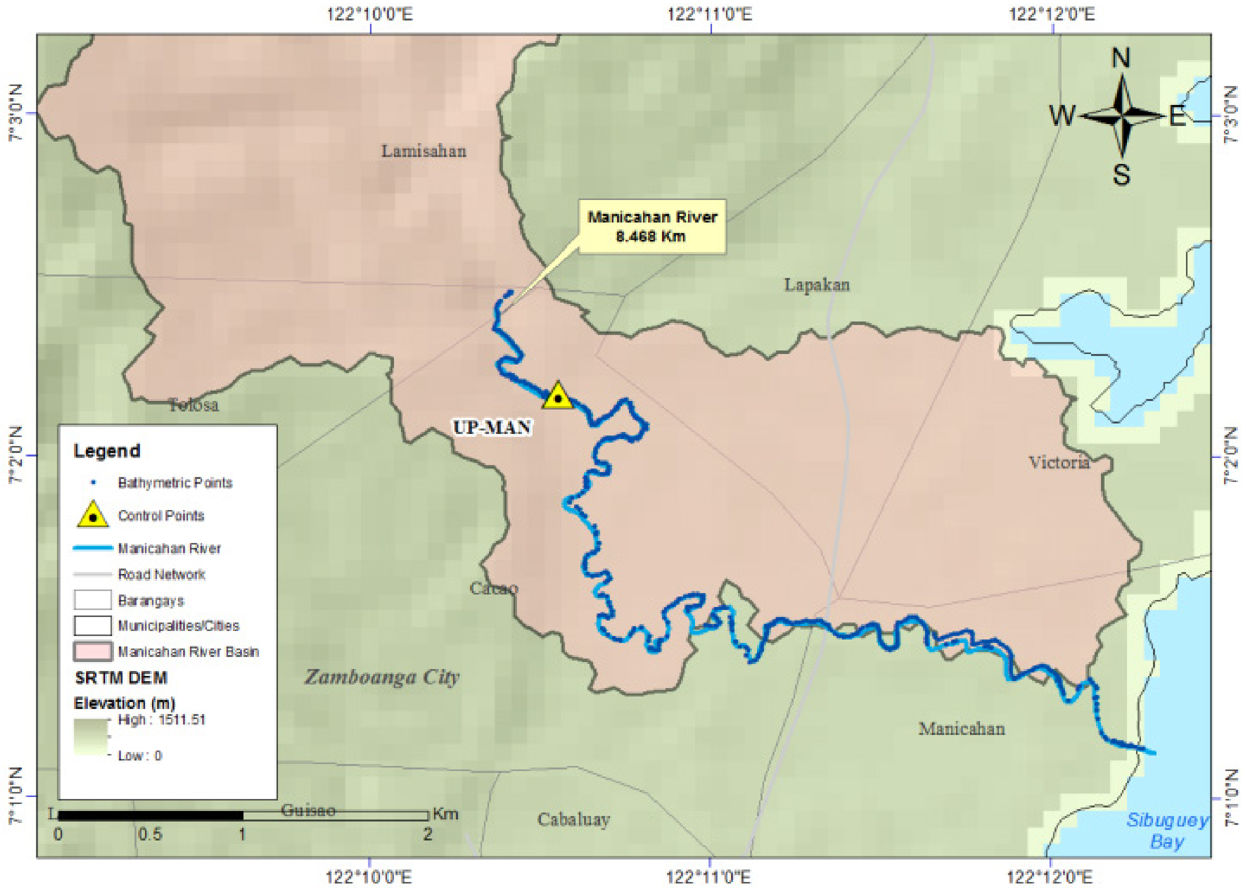


Figure 45. Extent of the Manicahan River Bathymetry Survey and the LiDAR bathymetric data validation points.

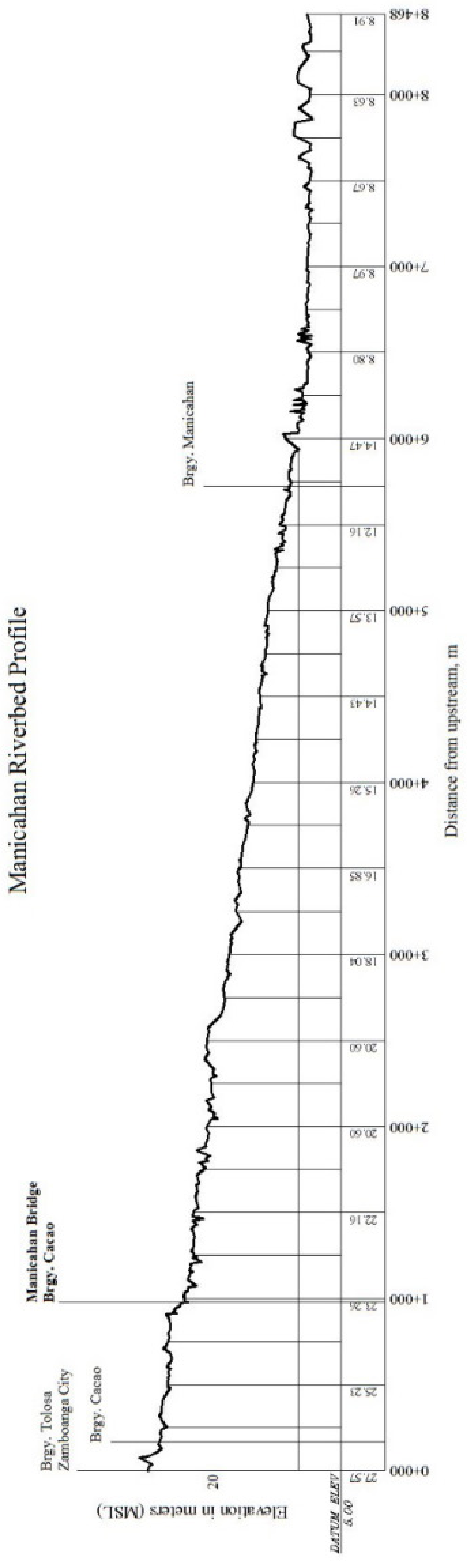


Figure 46. Manicahan riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Alfredo Mahar Francisco A. Lagmay, Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, and Neil R. Tingin

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 data that affect the hydrologic cycle of the Manicahan 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 Silaga 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 47. The precipitation data collection started from November 16, 2014 at 12:00 AM to November 17, 2014 at 11:50 PM.

The total precipitation for this event in Manicahan ARG was 96.4 mm. It has a peak rainfall of 9 mm. on November 16, 2014 at 5:40 in the afternoon. The lag time between the peak rainfall and discharge is 20 minutes.

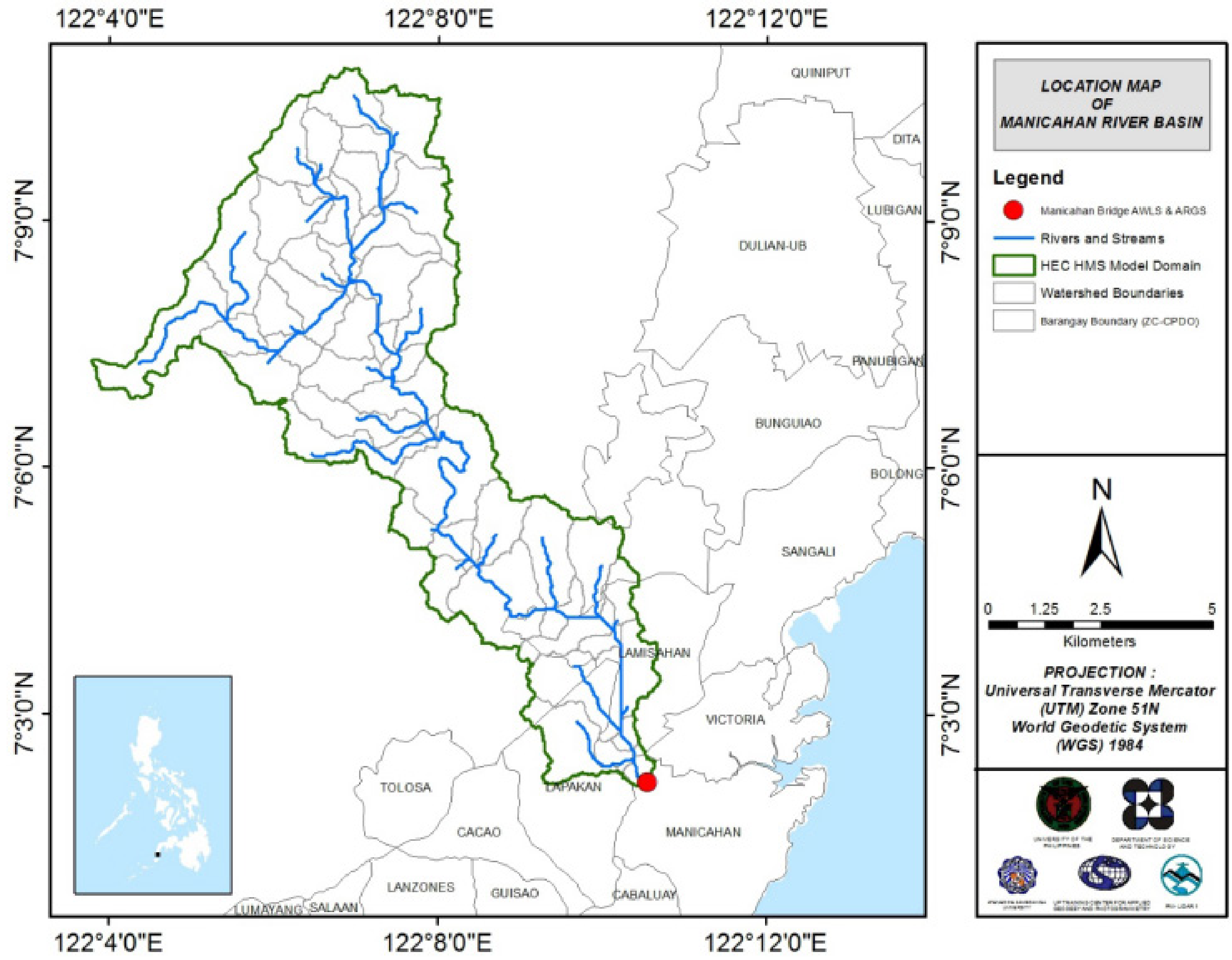


Figure 47. Location map of the Manicahan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Manicahan Spillway at Brgy. Manicahan, Zamboanga City (7° 2' 10.5"N, 122°10' 33.36" E). It gives the relationship between the observed water levels at Manicahan Spillway and outflow of the watershed at this location.

For Manicahan Spillway, the rating curve is expressed as Q = 2E-14e2.0873h as shown in Figure 48.

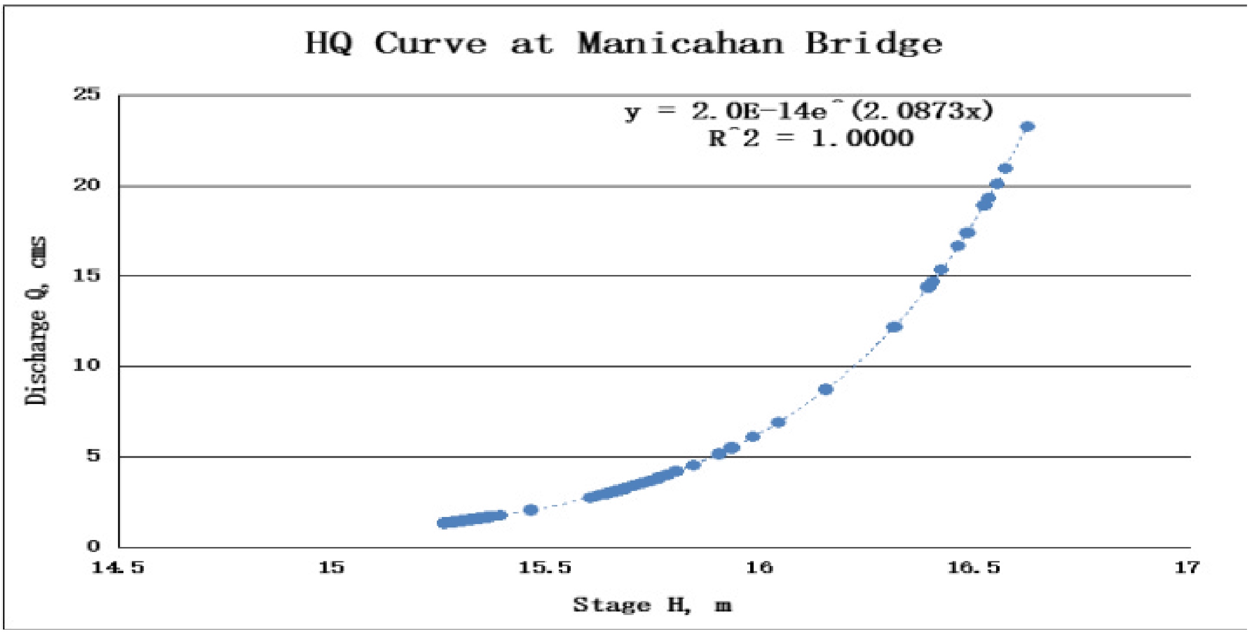


Figure 48. Rating curve at Manicahan Spillway, Salaan, Zamboanga City.

This rating curve equation was used to compute the river outflow at Manicahan Spillway for the calibration of the HEC-HMS model shown in Figure 49. Peak discharge is 23.3 cubic meters per second at 6:00 PM, November 16, 2014.

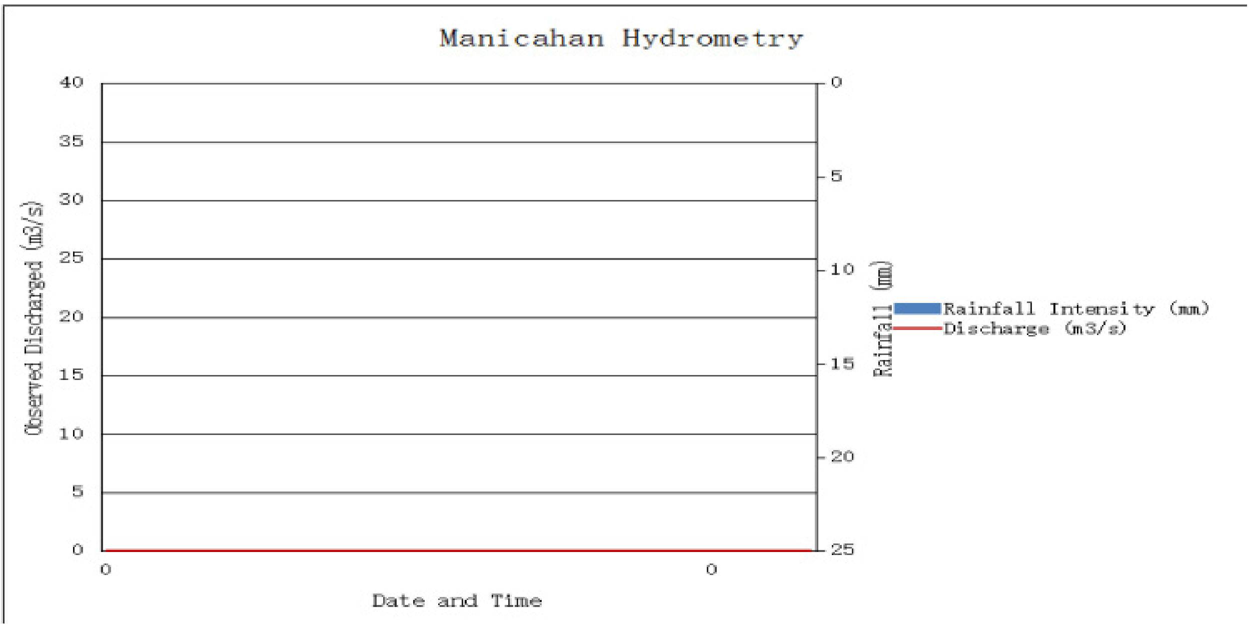


Figure 49. Rainfall at Manicahan ARG and outflow data used for modeling

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Zamboanga City Rain Gauge (Table 32). 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 49). This station was selected based on its proximity to the Manicahan watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 26. RIDF values for the Manicahan River Basin based on average RIDF data of Hinatuan station, 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	15.5	23.3	28.4	36.9	45.6	50.7	60	66.1	77.3
5	21.4	31.6	38.3	50.4	61.2	38.2	82.5	91.5	107.8
10	25.3	37.1	44.8	59.4	71.6	79.8	97.5	108.3	127.9
15	27.5	40.2	48.5	64.4	77.4	86.4	105.9	117.8	139.3
20	29	42.3	51.1	68	81.5	91	111.8	124.4	147.3
25	30.2	44	53.1	70.7	84.7	94.5	116.3	129.5	153.4
50	33.9	49.1	59.2	79.1	94.4	105.4	130.4	145.3	172.3
100	37.5	54.2	65.3	87.4	104	116.2	144.3	161	191.1

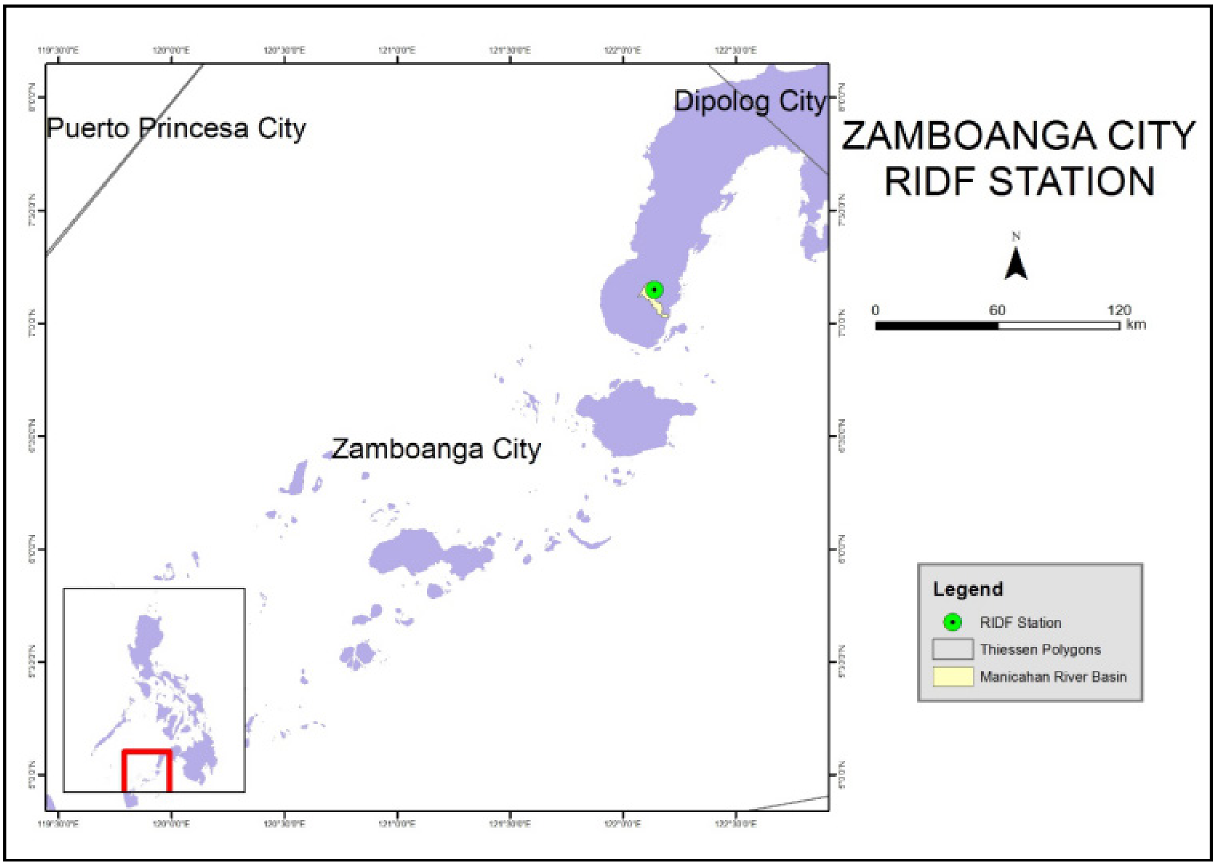


Figure 50. Location of Zamboanga City RIDF station relative to the Manicahan River Basin.

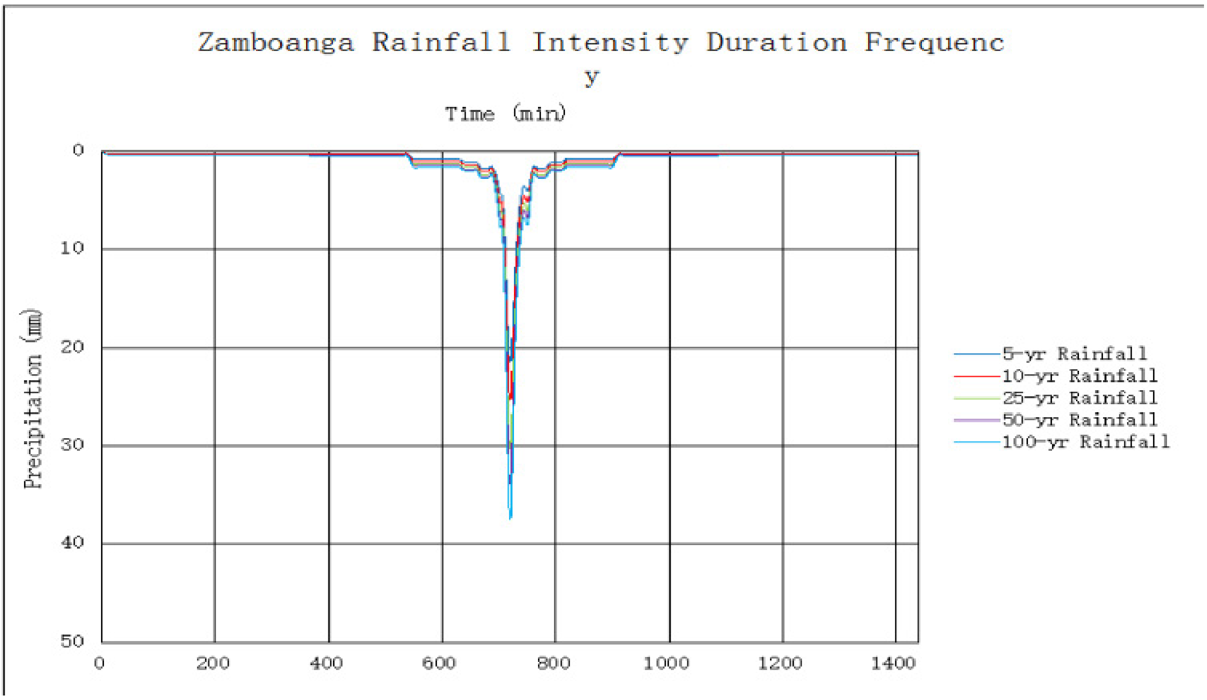


Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was taken before 2004 from the Bureau of Soils under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Pinantan River Basin are shown in Figure 60 and Figure 61, respectively.

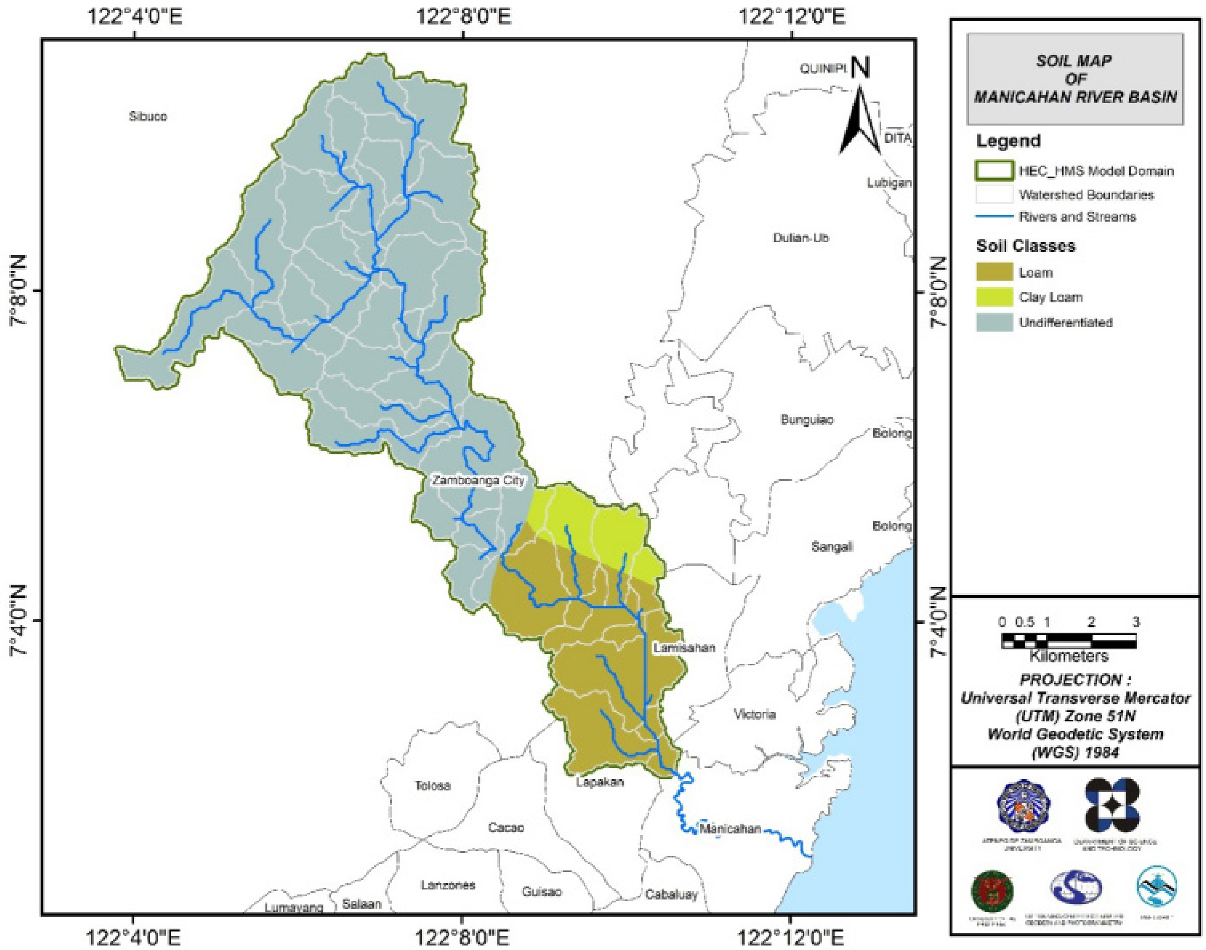


Figure 52. Soil Map of Manicahan River Basin

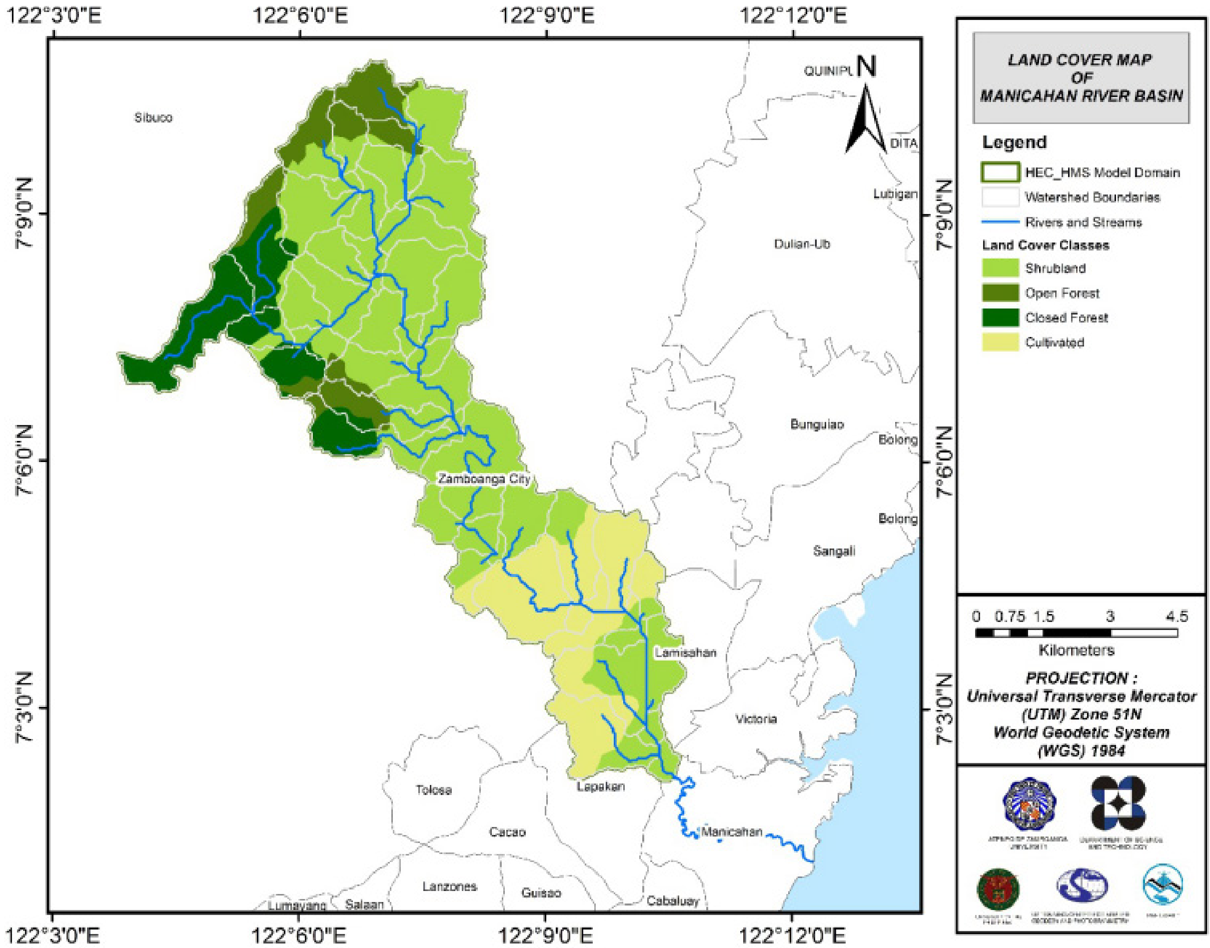


Figure 53. Land Cover Map of Manicahan River Basin (Source: NAMRIA)

For Manicahan, the soil classes identified were clays, hydrosols, silt, silt loam, sandy clay loam and undifferentiated mountain soil. The land cover types identified were mangroves, grassland, cultivated areas, fishponds, built-up areas, brushland and tree plantations.

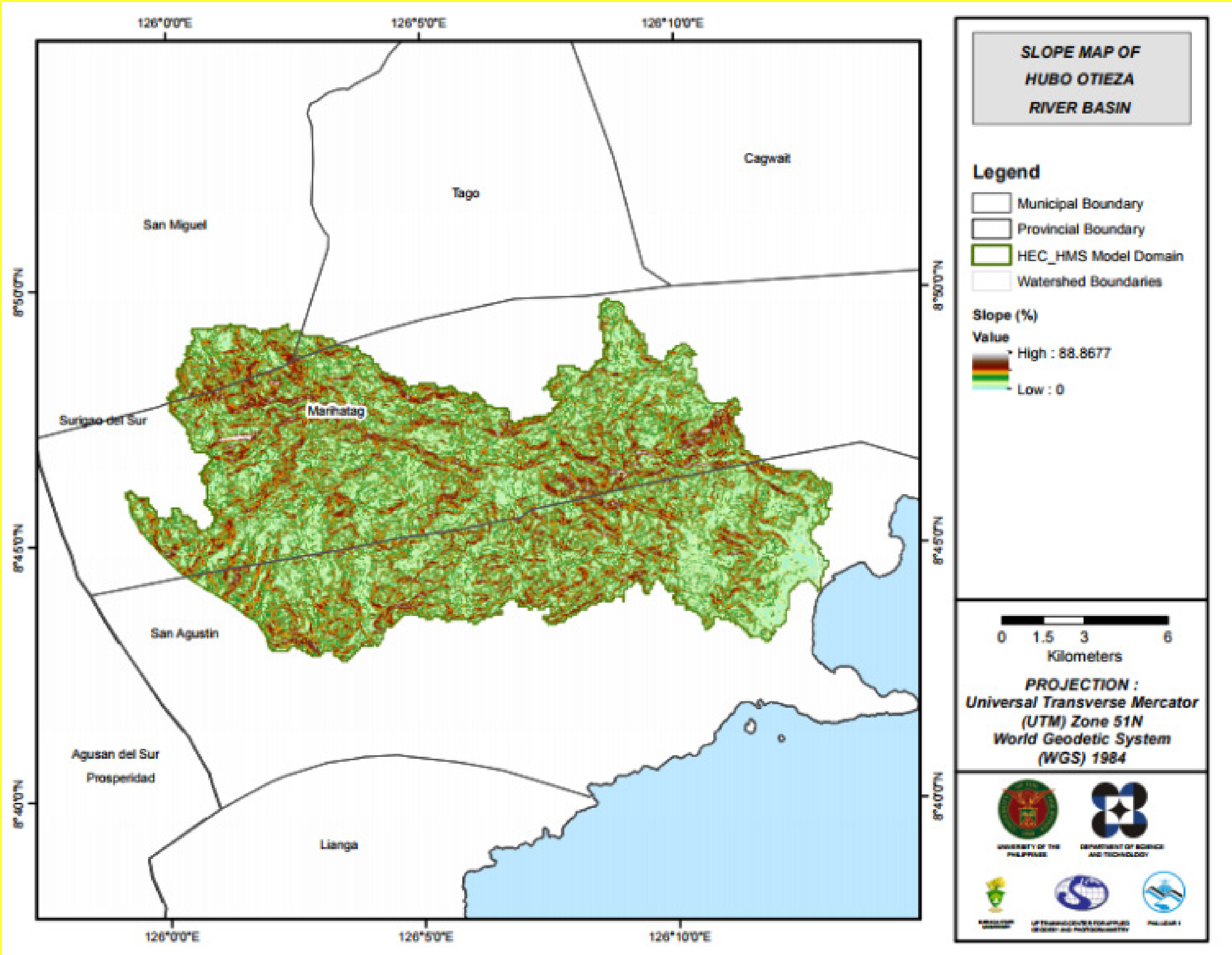


Figure 54. Slope Map of Manicahan River Basin

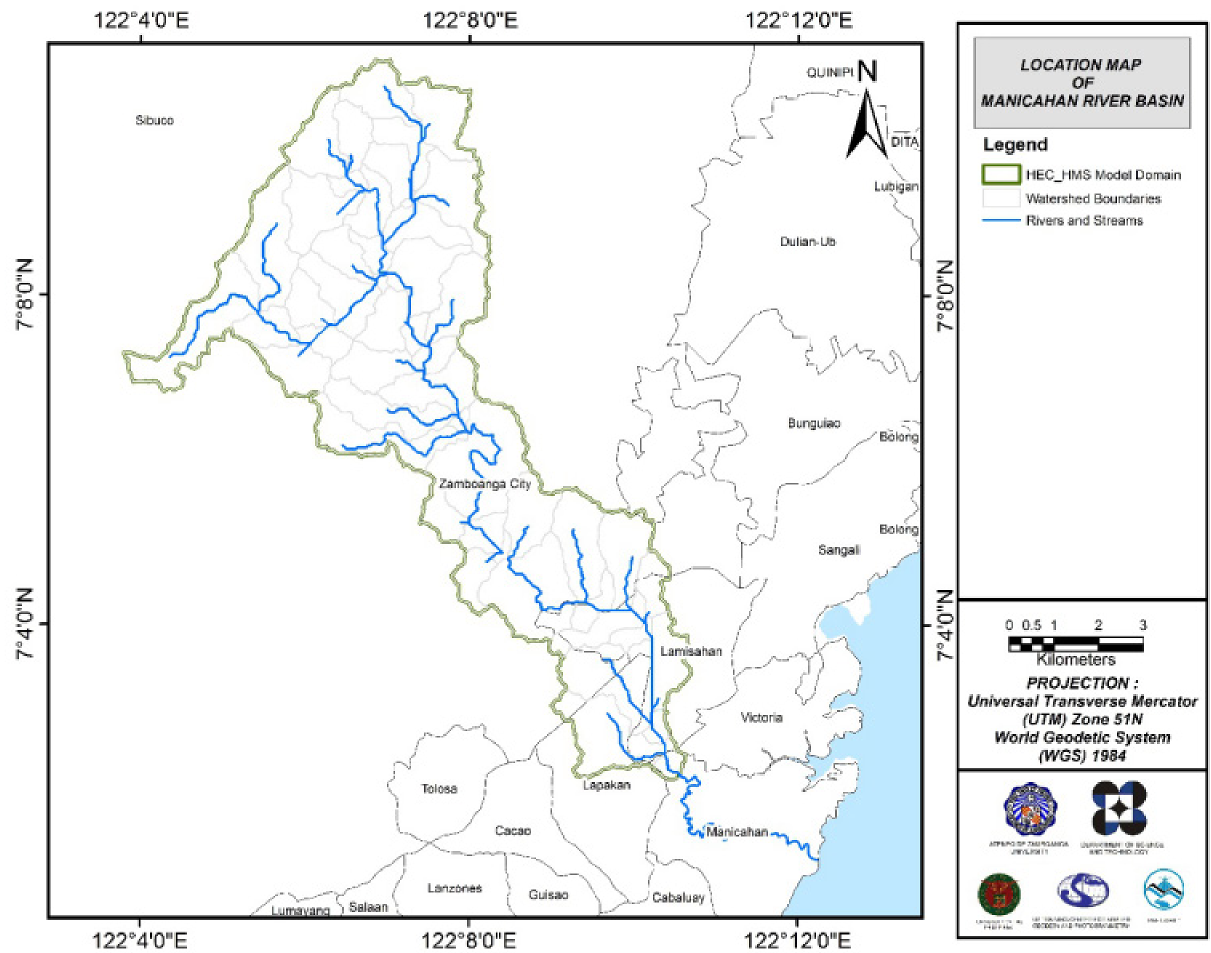


Figure 55. Stream Delineation Map of Manicahan River Basin

Using the SAR-based DEM, the Manicahan basin was delineated and further subdivided into subbasins. The model consists of 51 sub basins, 25 reaches, and 25 junctions as shown in Figure 56. The main outlet is at Manicahan Spillway.

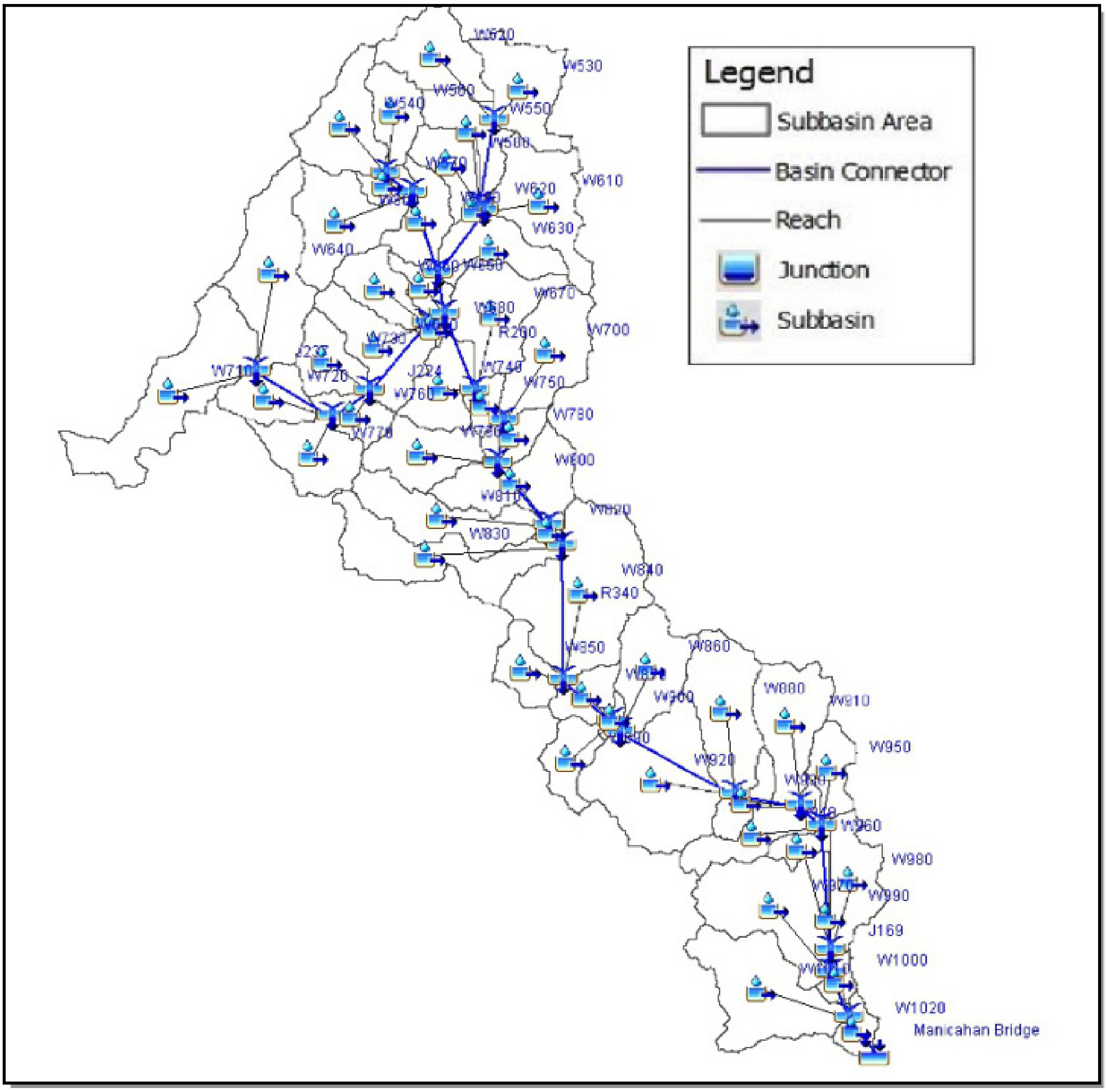


Figure 56. Pinantan River Basin model generated in HEC-HMS

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 (Figure 57).

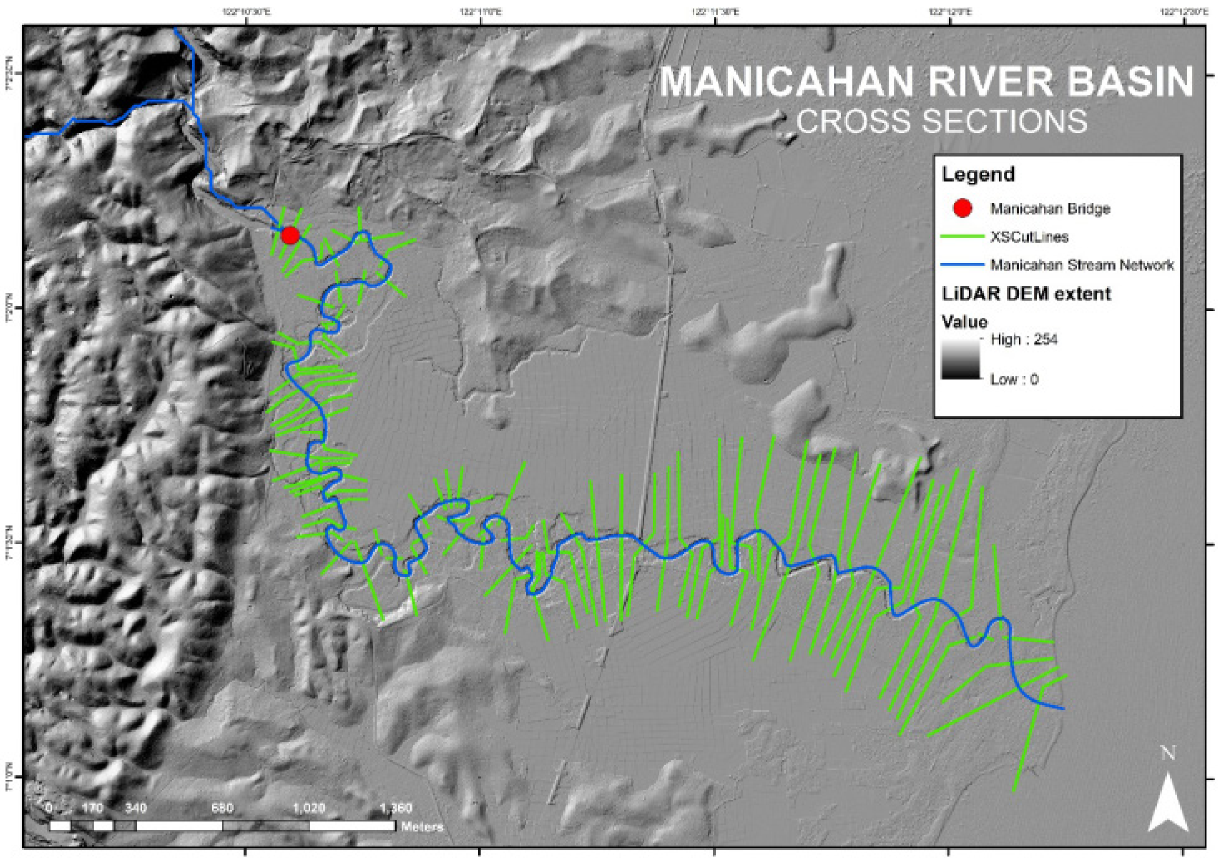


Figure 57. River cross-section of Manicahan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 58. 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 22.20007 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 Manicahan are in Figure 62, 64 and 66.

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 22958400.00 m2. The generated flood depth maps for Manicahan are in Figure 63, 65, and 67.

There is a total of 61783670.89 m3 of water entering the model. Of this amount, 6072171.66 m3 is due to rainfall while 55711499.22 m3 is inflow from other areas outside the model 4363573.50 m3 of this water is lost to infiltration and interception, while 33831397.31 m3 is stored by the flood plain. The rest, amounting up to 23588699.98 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Manicahan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

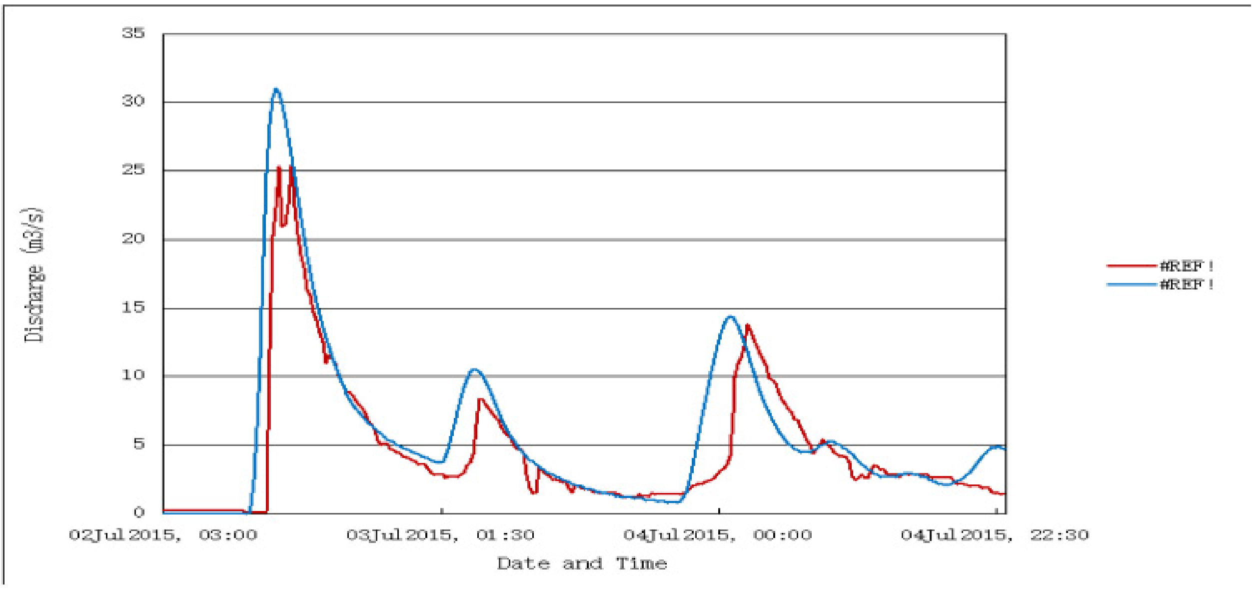


Figure 59. Outflow hydrograph of Manicahan Bridge produced by the HEC-HMS model compared with observed outflow

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

Table 27. Range of calibrated values for the Manicahan River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	16.93 – 110.066
			Curve Number	24 – 43.021
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.018 – 0.48
			Storage Coefficient (hr)	0.018 – 0.63
	Baseflow	Recession	Recession Constant	0.8
			Ratio to Peak	0.1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0039 – 0.068

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 16.93mm to 110.066mm means that there is a considerable 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 range of curve numbers in this area is 24 – 43.021.The magnitude of the outflow hydrograph increases as curve number increases. For Manicahan, the soil classes identified were loam, clay loam and undifferentiated mountain soil. The land cover types identified were shrubland, open and closed canopy forests and cultivated areas.

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 0.018 hours to 0.63 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.8 indicates that the basin is not likely to quickly go back to its original discharge. Ratio to peak of 0.1 indicates a steep receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.15 corresponds to the common roughness in the Manicahan watershed, which is determined to be smooth waterways (Brunner, 2010).

Table 28. Summary of the Efficiency Test of the Manicahan HMS Model

Accuracy measure	Value
RMSE	23.078995
r2	0.8145
NSE	0.59
PBIAS	-24.98
RSR	0.64

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 23.078995 (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 0.8145.

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 0.59.

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 -24.98.

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 0.64.

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

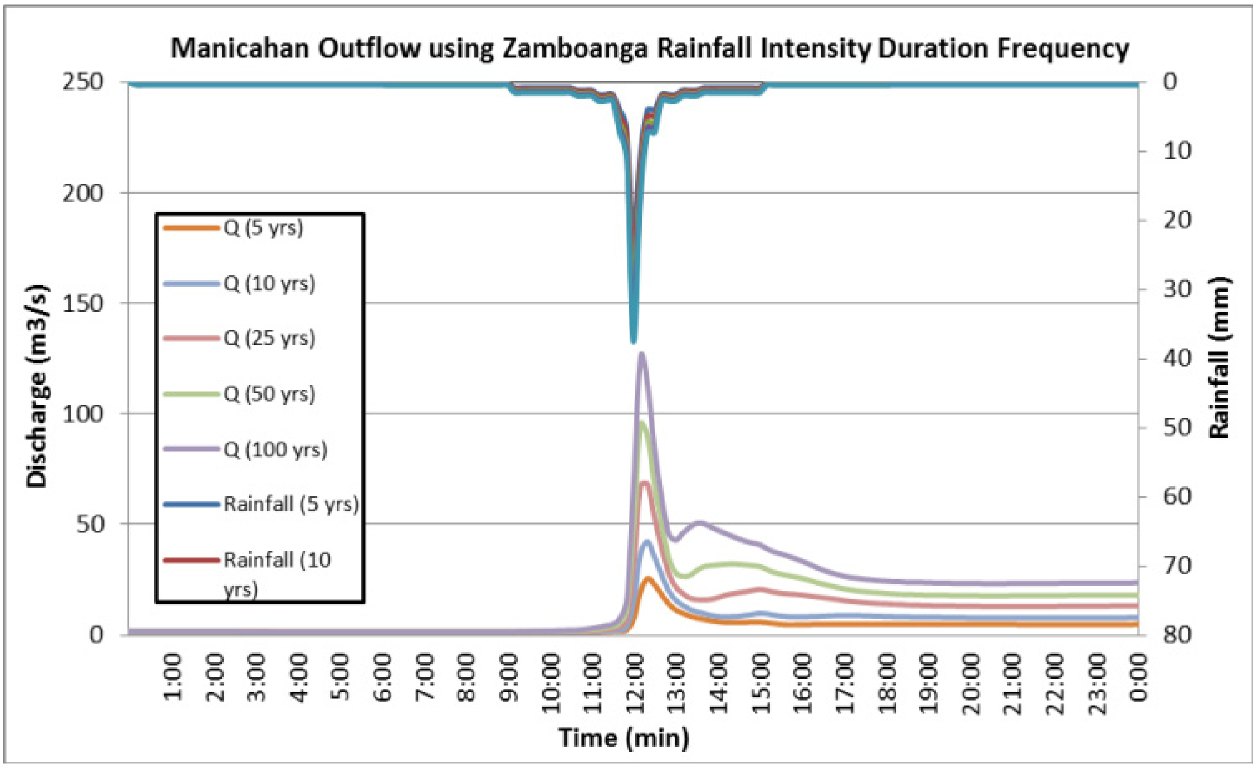


Figure 60. Outflow hydrograph at the Hinatuan Station, generated using the Hinatuan RIDF simulated in HEC-HMS.

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

Table 29. Peak values of the Pinantan HEC-HMS Model outflow using the Zamboanga RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	107.80	21.40	58.80	3 hours and 40 minutes
10-Year	127.90	25.30	78.60	3 hours and 30 minutes
25-Year	153.40	30.20	105.20	3 hours and 20 minutes
50-Year	172.30	33.90	125.80	3 hours and 20 minutes
100-Year	191.10	37.50	146.80	3 hours and 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 61 shows a generated sample map of the Manicahan River using the calibrated HMS base flow.

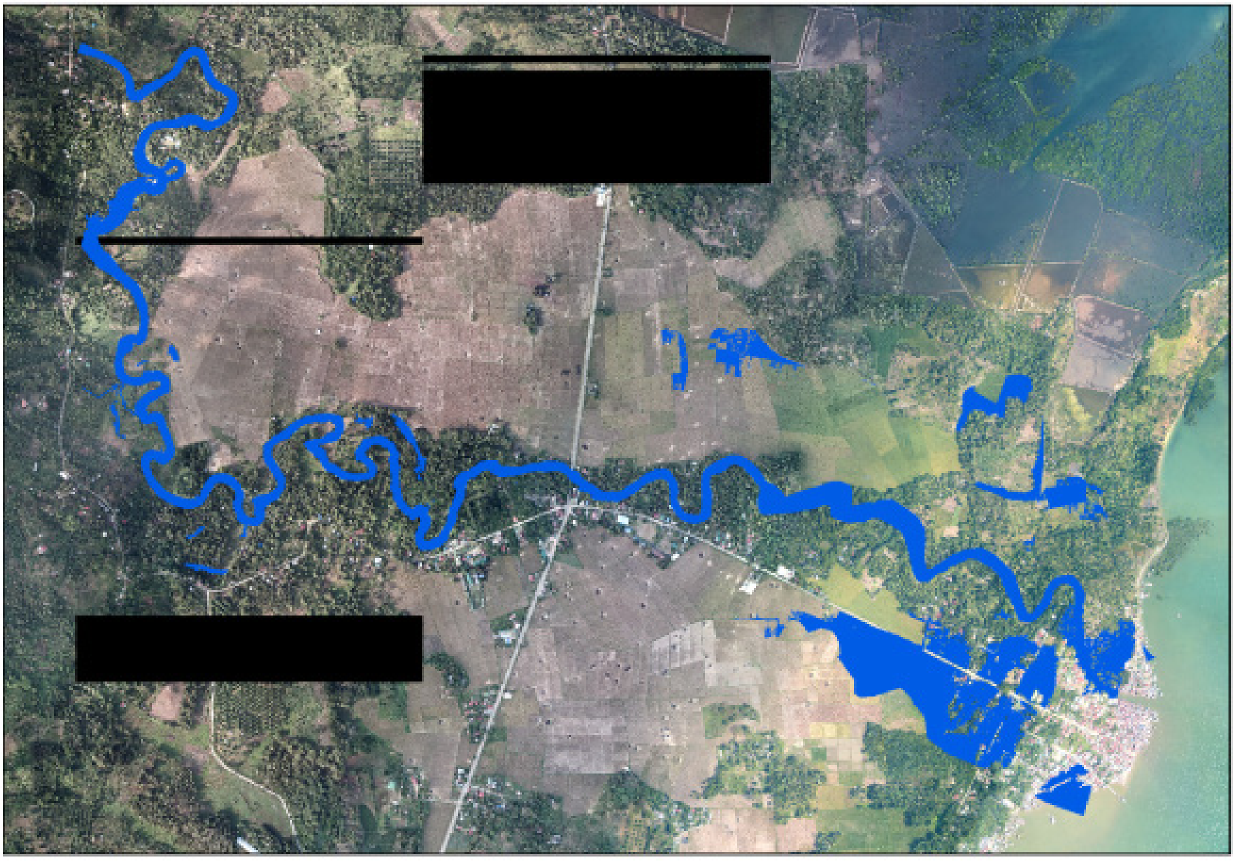


Figure 61. Sample output map of Manicahan RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 62 to Figure 67 shows the 5-, 25-, and 100-year rain return scenarios of the Manicahan floodplain. Table 30 shows the percentage of area affected by flooding in Zamboanga City.

Table 30. Municipalities affected in Manicahan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Zamboanga City	1496.29	40.86	2.73%

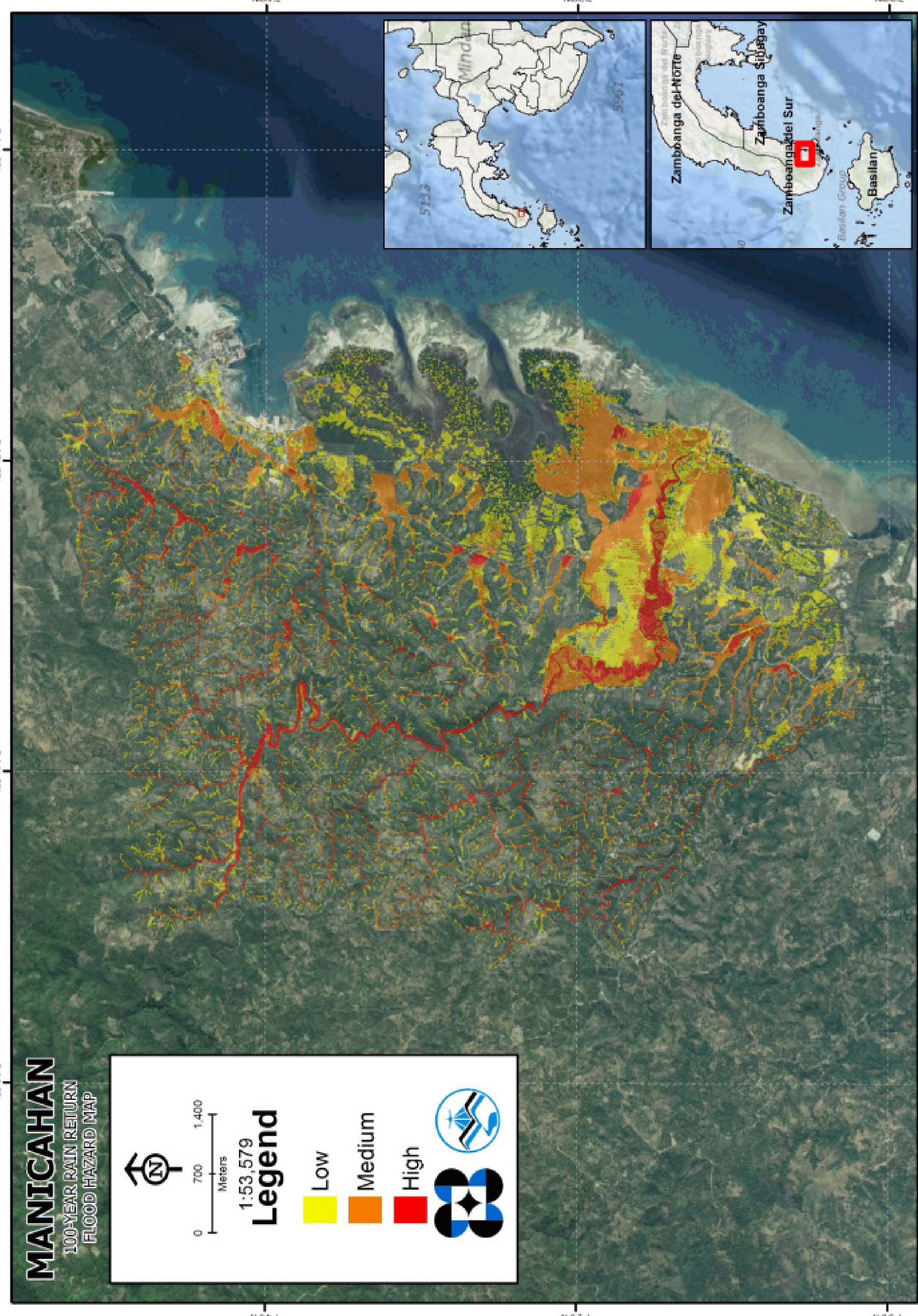


Figure 62. 100-year Flood Hazard Map for Manicahan Floodplain overlaid on Google Earth imagery

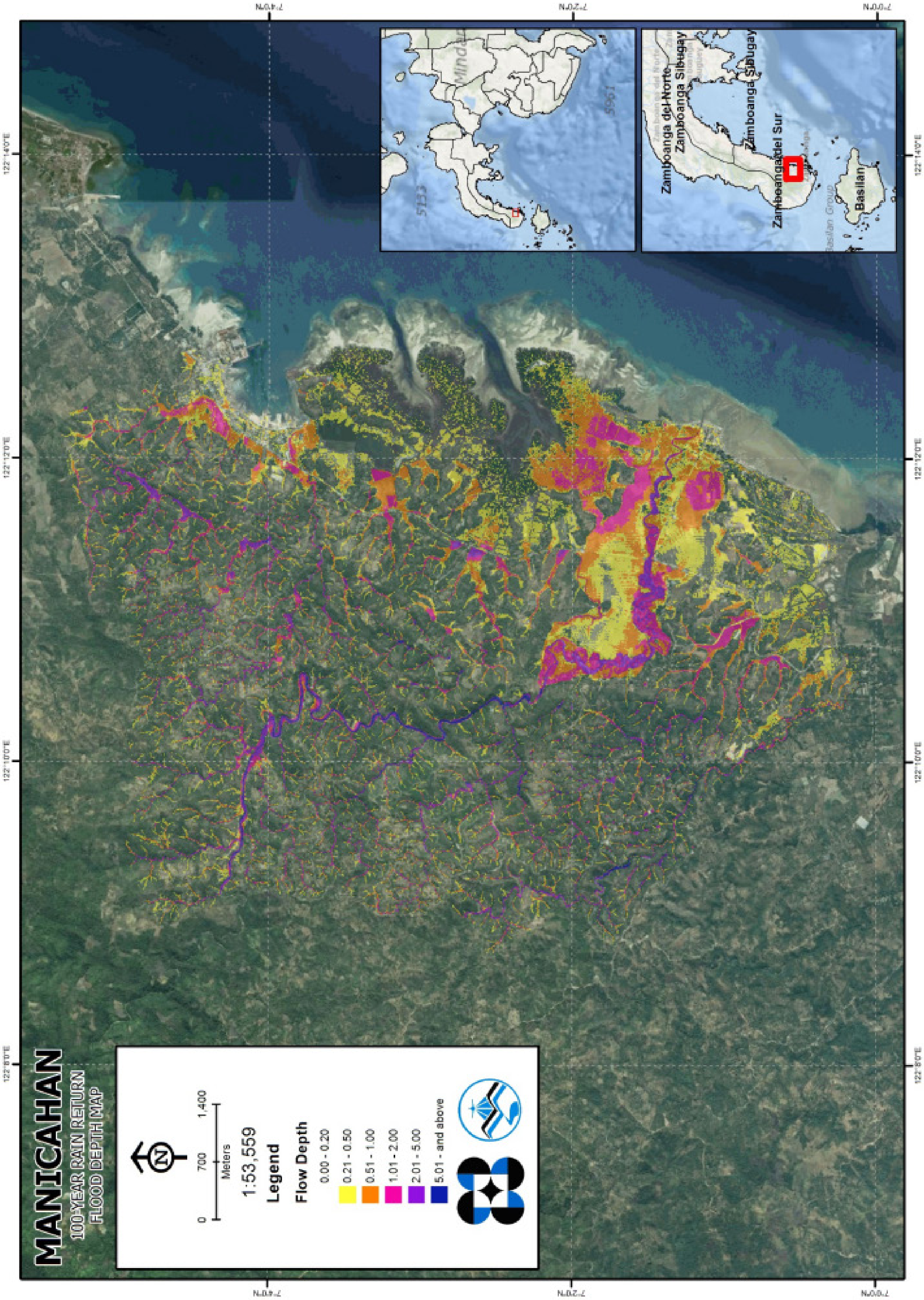


Figure 63. 100-year Flow Depth Map for Manicahan Floodplain overlaid on Google Earth imagery

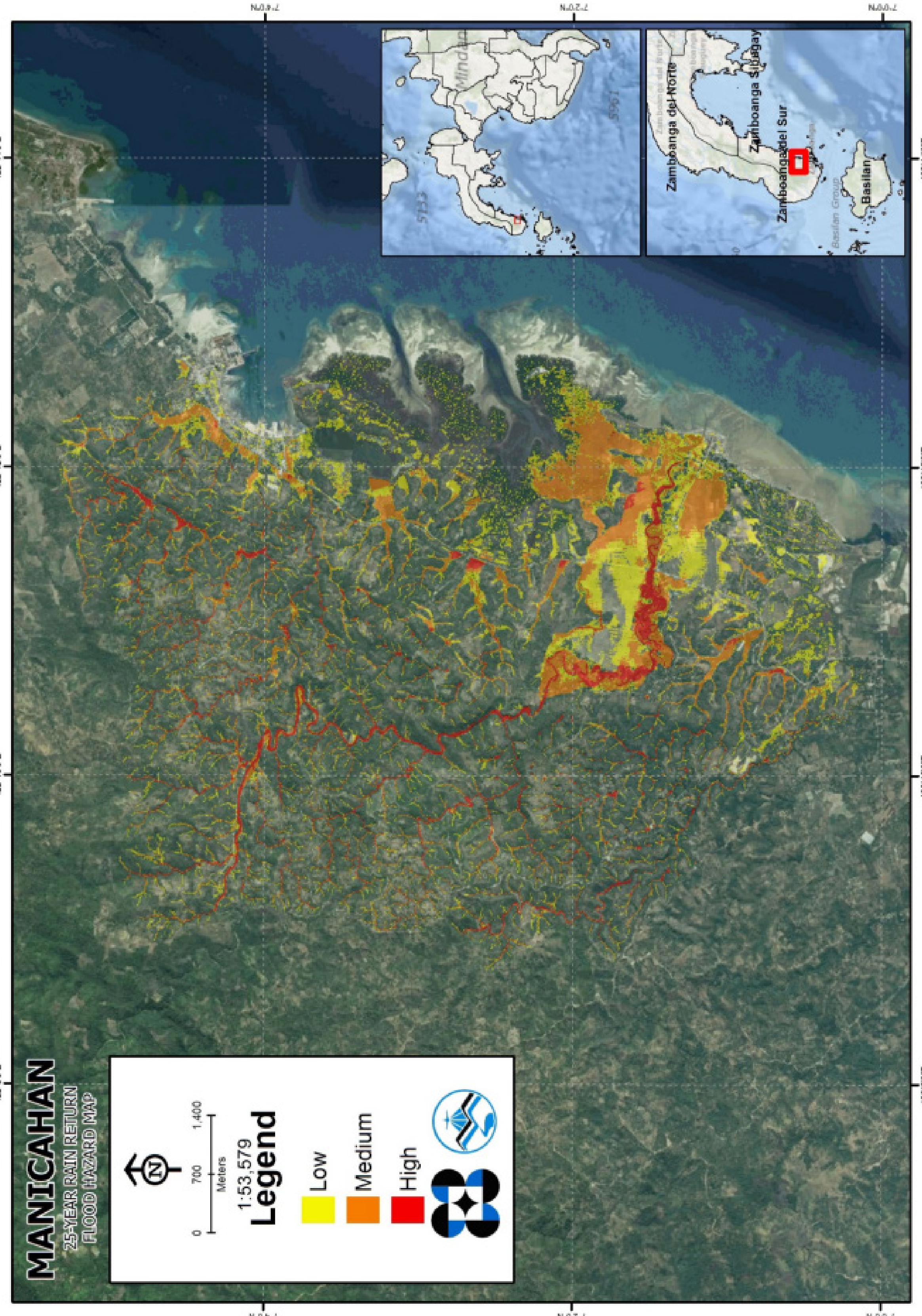


Figure 64. 25-year Flood Hazard Map for Manicahan Floodplain overlaid on Google Earth imagery

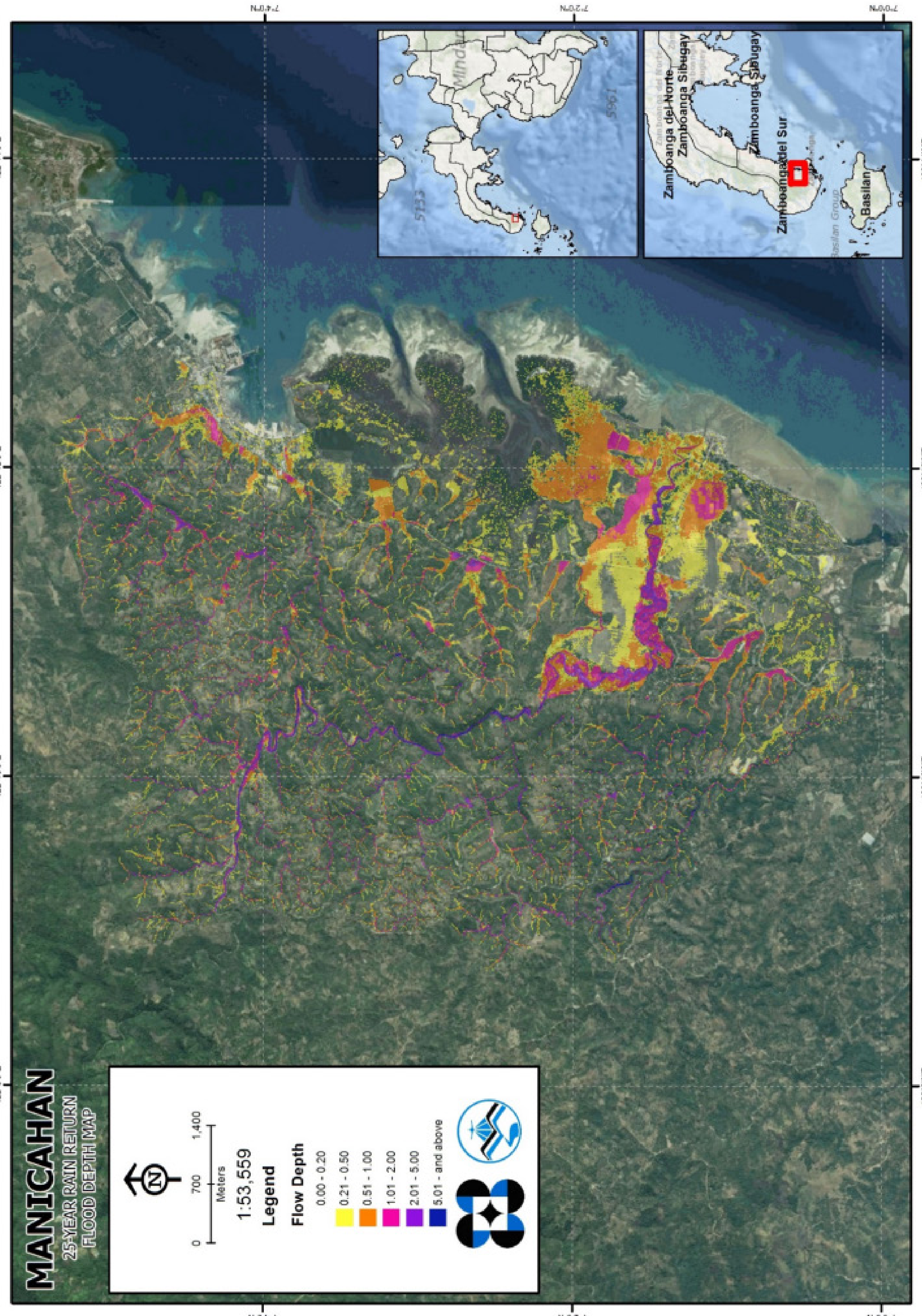


Figure 65. 25-year Flow Depth Map for Manicahan Floodplain overlaid on Google Earth imagery

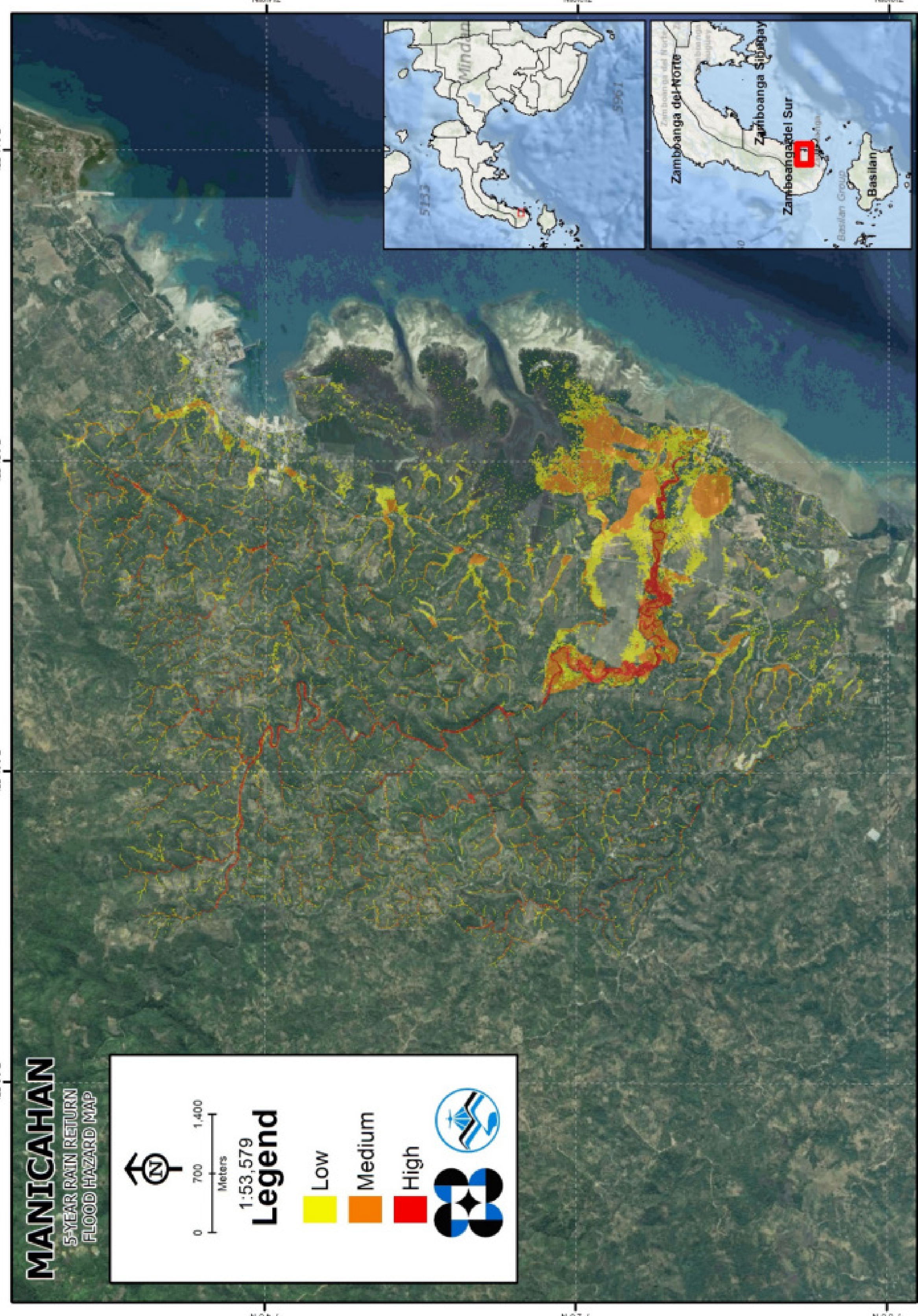


Figure 66. 5-year Flood Hazard Map for Manicahan Floodplain overlaid on Google Earth imagery

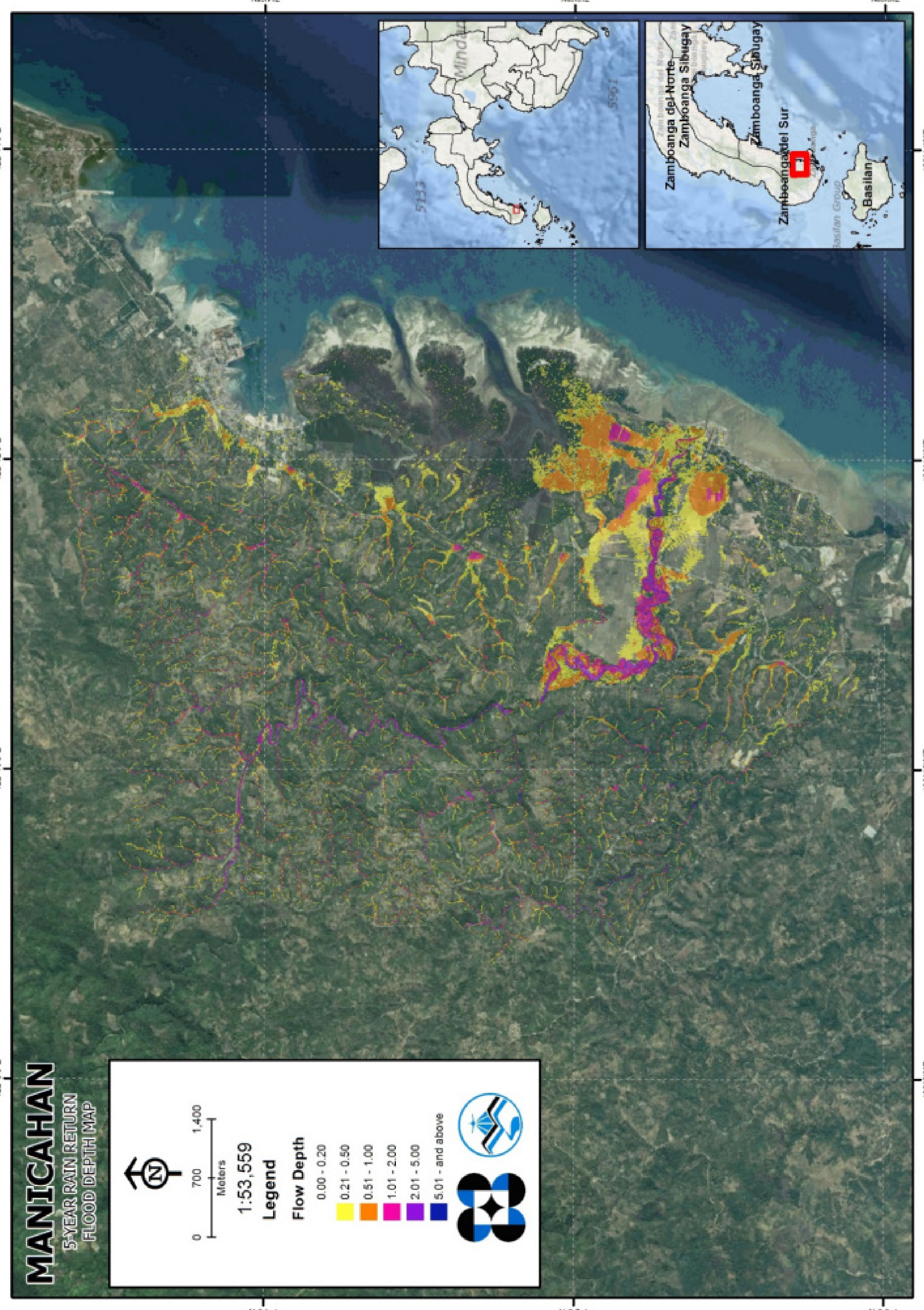


Figure 67. 5-year Flood Depth Map for Manicahan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Manicahan River Basin, grouped accordingly by city/ municipality. For the said basin, 10 barangays in one city are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 2.48% of the Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.02%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Shown in Figure 68 and listed in Table 31 are the affected areas in square kilometers by flood depth per barangay.

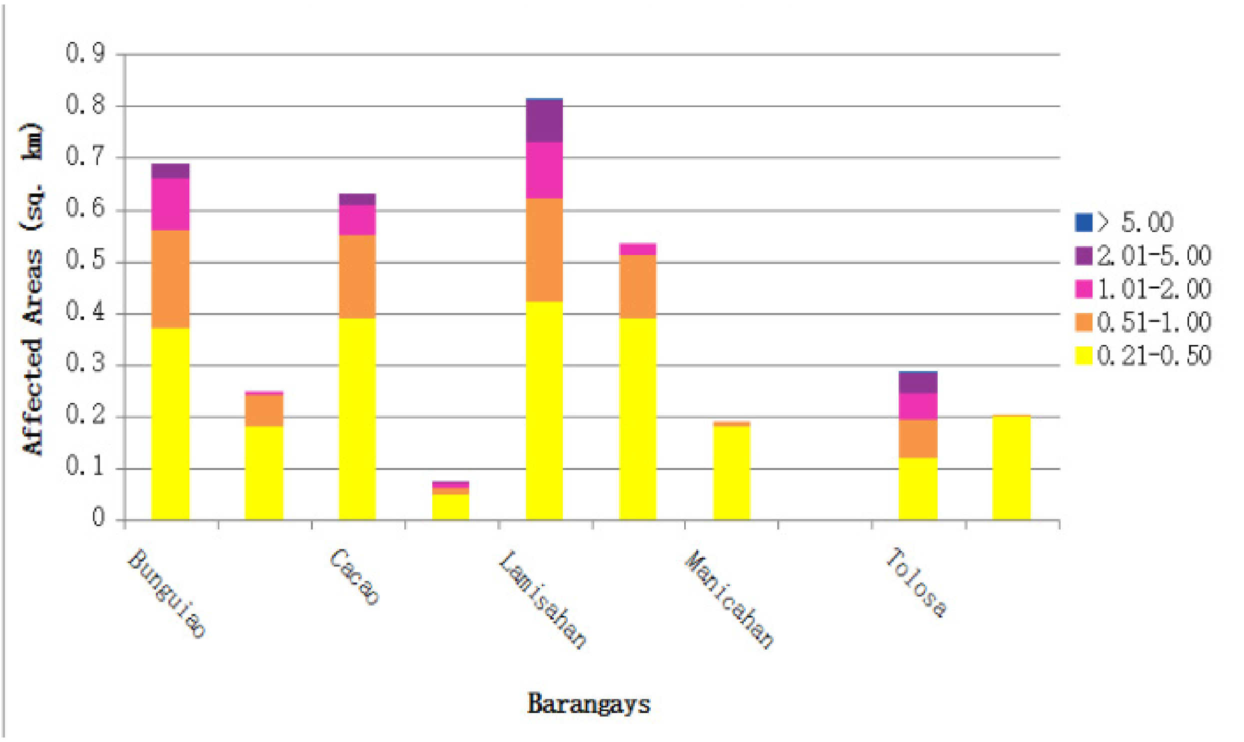


Figure 68. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

Table 31. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)									
	Bunguiao	Cabaluay	Cacao	Guisao	Lamisahan	Lapakan	Manicahan	Sanali	Tolosa	Victoria
0.03-0.20	5.89	1.9	6.23	0.81	7.75	3.52	3.45	0	2.94	4.68
0.21-0.50	0.37	0.18	0.39	0.047	0.42	0.39	0.18	0	0.12	0.2
0.51-1.00	0.19	0.062	0.16	0.015	0.2	0.12	0.01	0	0.073	0.0027
1.01-2.00	0.1	0.0061	0.059	0.0083	0.11	0.025	0	0	0.052	0.0001
2.01-5.00	0.029	0	0.021	0.0028	0.081	0.0001	0	0	0.039	0
> 5.00	0	0	0.0006	0	0.0021	0	0	0	0.0016	0

For the 25-year return period, 2.16% of the Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.07%, 0.04%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Shown in Figure 69 and listed in Table 32 are the affected areas in square kilometers by flood depth per barangay.

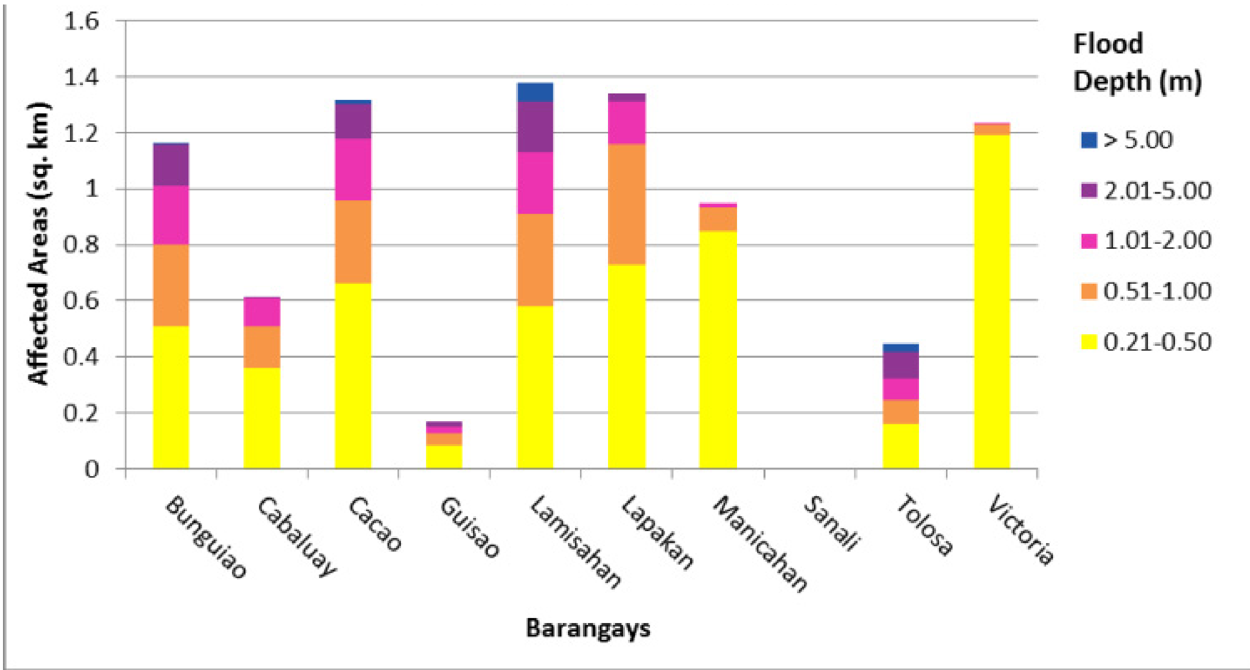


Figure 69. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

Table 32. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)									
	Bunguiao	Cabaluay	Cacao	Guisao	Lamisahan	Lapakan	Manicahan	Sanali	Tolosa	Victoria
0.03-0.20	5.42	1.54	5.54	0.72	7.19	2.73	2.69	0	2.78	3.65
0.21-0.50	0.51	0.36	0.66	0.085	0.58	0.73	0.85	0	0.16	1.19
0.51-1.00	0.29	0.15	0.3	0.043	0.33	0.43	0.086	0	0.086	0.04
1.01-2.00	0.21	0.1	0.22	0.025	0.22	0.15	0.012	0	0.078	0.0006
2.01-5.00	0.15	0.003	0.12	0.017	0.18	0.028	0	0	0.092	0
> 5.00	0.0033	0	0.014	0	0.068	0	0	0	0.032	0

For the 100-year return period, 2.31% of the Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.09%, 0.05%, 0.03%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 are the affected areas in square kilometers by flood depth per barangay.

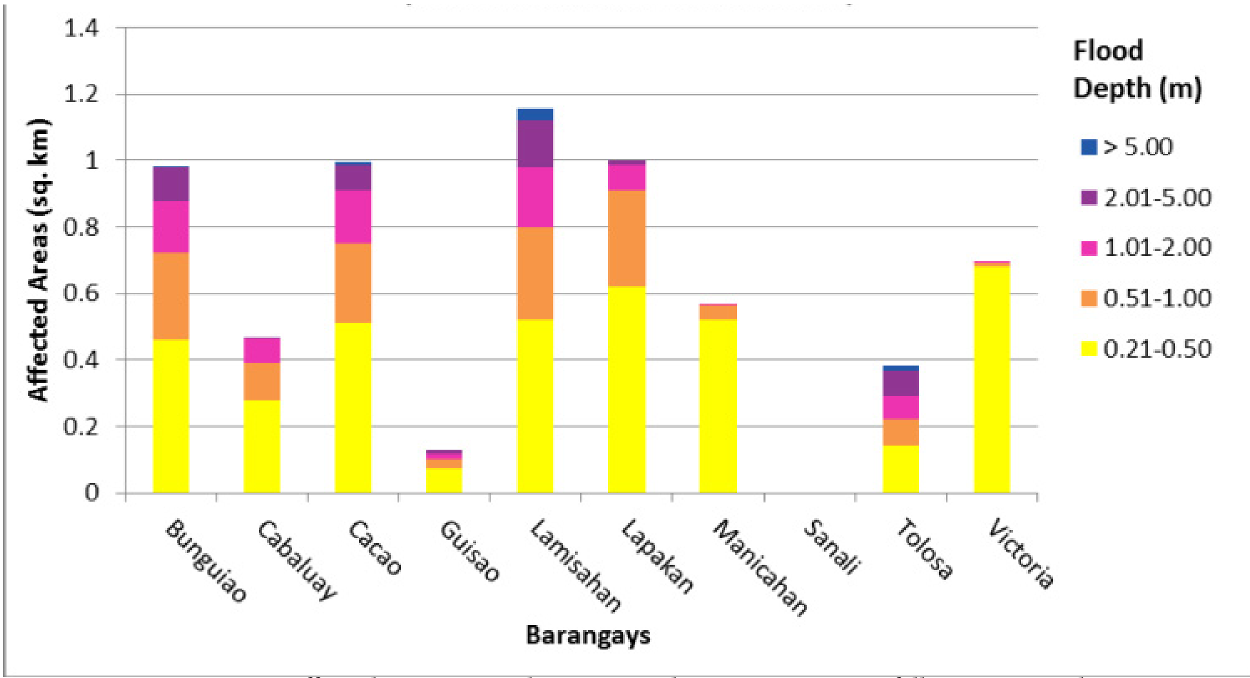


Figure 70. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Table 33. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)									
	Bunguiao	Cabaluay	Cacao	Guisao	Lamisahan	Lapakan	Manicahan	Sanali	Tolosa	Victoria
0.03-0.20	5.42	1.54	5.54	0.72	7.19	2.73	2.69	0	2.78	3.65
0.21-0.50	0.51	0.36	0.66	0.085	0.58	0.73	0.85	0	0.16	1.19
0.51-1.00	0.29	0.15	0.3	0.043	0.33	0.43	0.086	0	0.086	0.04
1.01-2.00	0.21	0.1	0.22	0.025	0.22	0.15	0.012	0	0.078	0.0006
2.01-5.00	0.15	0.003	0.12	0.017	0.18	0.028	0	0	0.092	0
> 5.00	0.0033	0	0.014	0	0.068	0	0	0	0.032	0

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

Table 34. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.05	4.79	6.22
Medium	1.51	2.55	3.22
High	0.49	1.11	1.64
TOTAL	**5.05**	**8.45**	**11.08**

Of the 17 identified education institutions in Manicahan flood plain, two (2) schools were discovered exposed Low-level flooding during a 5-year scenario, while two (2) schools were found exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, the same buildings were found exposed to the same flood hazard levels.

For the 100-year scenario, six (6) schools were discovered exposed Low-level flooding, while three (3) schools were exposed to Medium-level flooding. The educational institutions exposed to flooding are shown in Annex 12.

Apart from this, five (5) identified medical institutions in Manicahan floodplain, none were assessed to be exposed to any flood hazard level in any rainfall scenario. The medical or health institutions exposed to flooding are found in Annex 13.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview of some residents with knowledge of or have had experienced flooding in a particular area. The flood validation data were obtained from September 26 to October 12, 2016.

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 69.

The flood validation consists of 192 points randomly selected all over the Manicahan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.35 m. Table 35 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

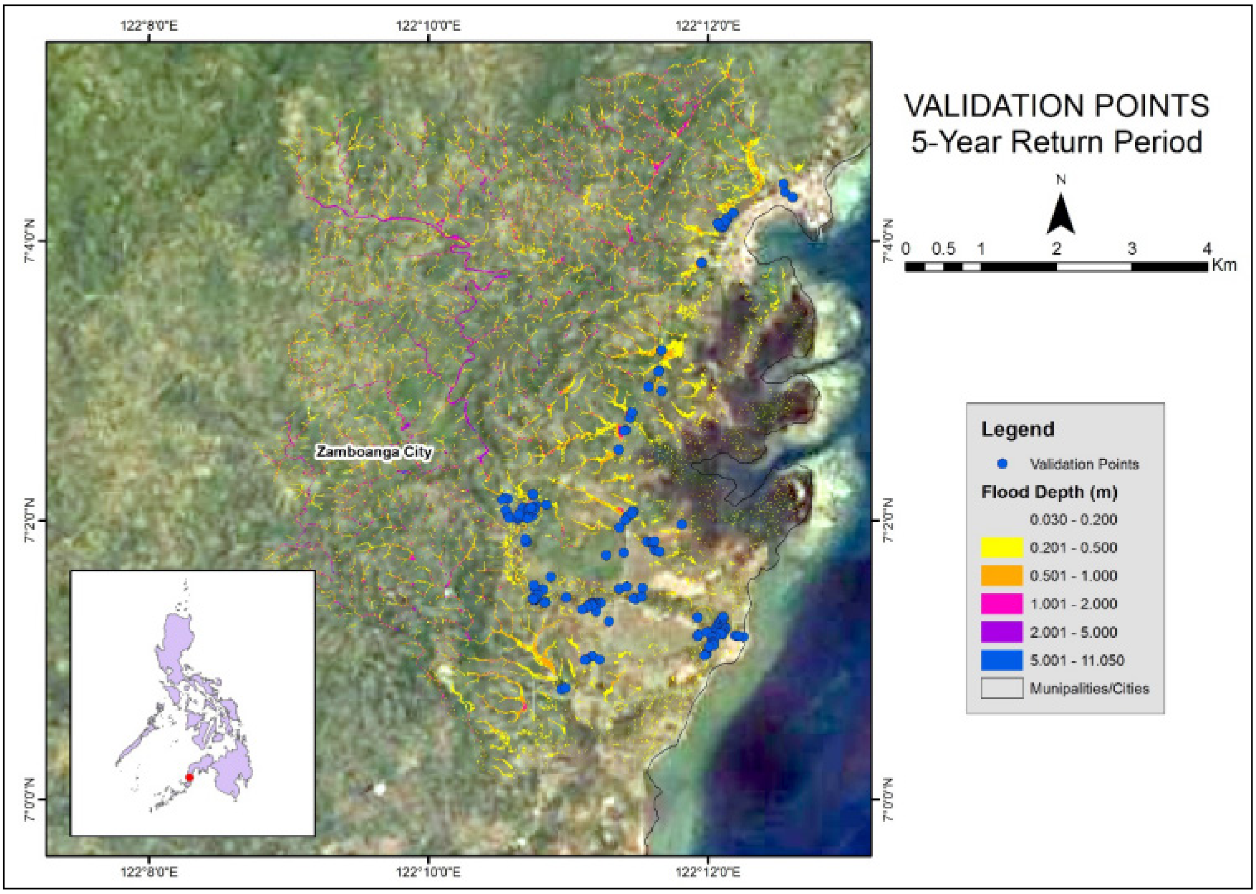


Figure 71. Manicahan flood validation points

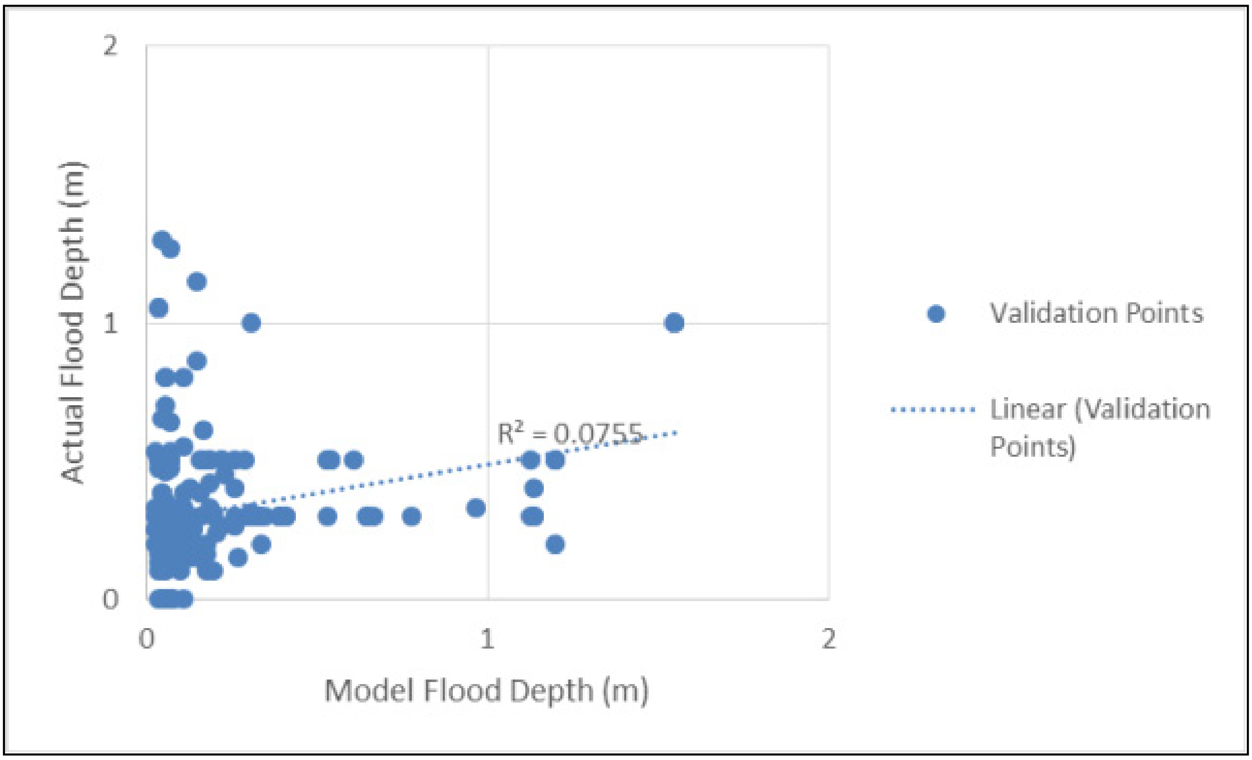


Figure 72. Flood map depth vs. actual flood depth

Table 35. Actual flood vs simulated flood depth at different levels in the Manicahan 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	59	2	0	1	0	0	62
0.21-0.50	66	25	11	8	0	0	110
0.51-1.00	11	1	0	3	0	0	15
1.01-2.00	5	0	0	0	0	0	5
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	141	28	11	12	0	0	192

On the whole, the overall accuracy generated by the flood model is estimated at 43.75% with 84 points correctly matching the actual flood depths. In addition, there were 82 points estimated one level above and below the correct flood depths while there were 19 points and 6 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 83 points were underestimated in the modelled flood depths of Manicahan. Table 36 depicts the summary of the Accuracy Assessment in the Manicahan River Basin Flood Depth Map.

Table 36. Summary of the Accuracy Assessment in the Manicahan River Basin Survey

	No. of Points	%
Correct	84	43.75
Overestimated	25	13.02
Underestimated	83	43.23
Total	**192**	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor Used in the Manicahan LiDAR Data Acquisition Surveys

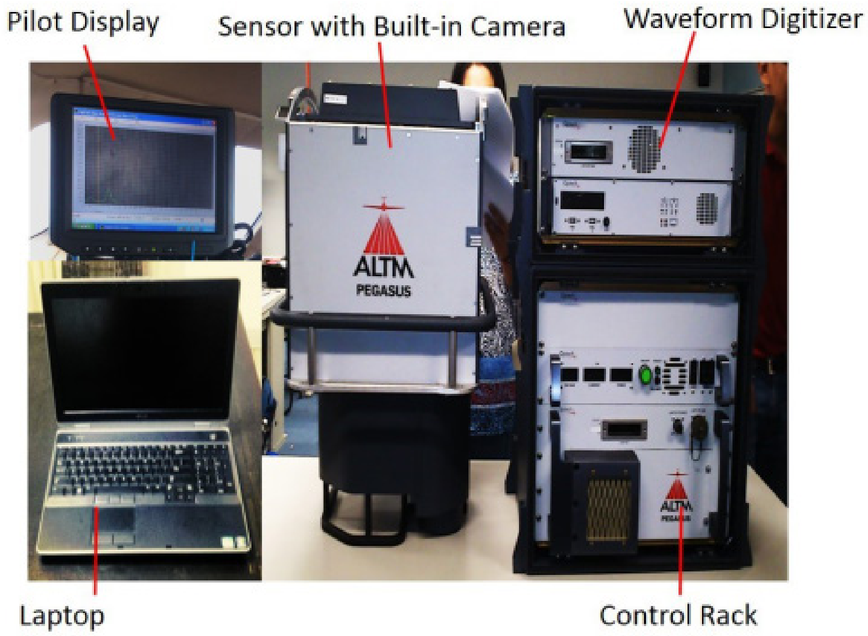


Figure A-1.1. Parameters and Specification of Pegasus Sensor

Table A-1.1. Parameters and Specification of Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);
220-channel dual frequency GPS/ GNSS/Galileo/L-Band receiver	Programmable, 0-75 ˚
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

1. ZGS-100

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

August 29, 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: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-100**
Order: **2nd**

Island: **MINDANAO**	Barangay: **MANICAHAN**		
Municipality: **ZAMBOANGA CITY**	MSL Elevation:		

PRS92 Coordinates

Latitude: **7° 1' 26.72368"**	Longitude: **122° 11' 12.74401"**	Ellipsoidal Hgt: **11.27000 m.**

WGS84 Coordinates

Latitude: **7° 1' 23.30149"**	Longitude: **122° 11' 18.30044"**	Ellipsoidal Hgt: **75.60300 m.**

PTM / PRS92 Coordinates

Northing: **776712.542 m.**	Easting: **410158.521 m.**	Zone: **4**

UTM / PRS92 Coordinates

Northing: **776,440.68**	Easting: **410,189.97**	Zone: **51**

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGS-100, 2009 NAMRIA".Located at Manicahan Barangay Hal 7 meters South from the flag pole 7 meters km post 1916-ZC22

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1902**

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

9 9 0 8 2 9 2 0 1 4 1 5 4 2 2 5

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. ZGS-100

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

1. BLLM-166

Table A-3.1. BLLM-166

Vector Components (Mark to Mark)

From:	ZGS 100				
Grid		Local		Global	
Easting	410189.967 m	Latitude	N7°01'26.72367"	Latitude	N7°01'23.30149"
Northing	776440.678 m	Longitude	E122°11'12.74401"	Longitude	E122°11'18.30044"
Elevation	7.745 m	Height	11.271 m	Height	75.603 m

To:	BLLM166				
Grid		Local		Global	
Easting	415179.269 m	Latitude	N7°09'33.60926"	Latitude	N7°09'30.15553"
Northing	791383.716 m	Longitude	E122°13'54.54820"	Longitude	E122°14'00.09187"
Elevation	120.669 m	Height	124.333 m	Height	188.527 m

Vector					
ΔEasting	4989.302 m	NS Fwd Azimuth	18°21'47"	ΔX	-3276.482 m
ΔNorthing	14943.038 m	Ellipsoid Dist.	15758.784 m	ΔY	-4113.808 m
ΔElevation	112.923 m	ΔHeight	113.062 m	ΔZ	14855.907 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000243854		
Y	-0.0000335461	0.0000552864	
Z	-0.0000068733	0.0000098178	0.0000029948

2. BVA-1

Table A-3.2. BVA-1

Vector Components (Mark to Mark)

From:	ZGS100				
Grid		Local		Global	
Easting	410189.967 m	Latitude	N7°01'26.72367"	Latitude	N7°01'23.30149"
Northing	776440.678 m	Longitude	E122°11'12.74401"	Longitude	E122°11'18.30044"
Elevation	7.745 m	Height	11.271 m	Height	75.603 m

To:	BVA1				
Grid		Local		Global	
Easting	418087.142 m	Latitude	N7°15'19.31910"	Latitude	N7°15'15.84241"
Northing	801995.112 m	Longitude	E122°15'28.78738"	Longitude	E122°15'34.32212"
Elevation	78.652 m	Height	82.446 m	Height	146.526 m

Vector					
ΔEasting	7897.175 m	NS Fwd Azimuth	17°04'19"	ΔX	-4988.546 m
ΔNorthing	25554.433 m	Ellipsoid Dist.	26755.117 m	ΔY	-6818.290 m
ΔElevation	70.906 m	ΔHeight	71.176 m	ΔZ	25386.506 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000123020		
Y	-0.0000172637	0.0000297982	
Z	-0.0000030673	0.0000052949	0.0000017042

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, DR.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader - I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td>Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">LiDAR Operation</td><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUñA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
</table>

FIELD TEAM

<table>
<tr><td rowspan="2">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>JASMINE ALVIAR</td><td>UP-TCAGP</td></tr>
<tr><td>Research Associate (RA)</td><td>ENGR. IRO NIEL ROXAS
KRISTINE JOY ANDAYA</td><td>UP-TCAGP</td></tr>
<tr><td>Ground Survey, Data Download and Transfer</td><td>RA</td><td>RENAN PUNTO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">LiDAR Operation</td><td>Airborne Security</td><td>SSG. RONALD MONTENEGRO</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="2">Pilot</td><td>CAPT. CESAR SHERWIN ALFONSO III</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. JOHN BRYAN DONGUINES</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheet for Manicahan Floodplain

DATA TRANSFER SHEET
02/24/2015(Zamboanga)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Feb-15	2535P	1BLK75E36A	PEGASUS	2.95	2608	12.7	232	43.6	360	30.7	NA	7.53	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2537P	1BLK75C37A	PEGASUS	3.55	1872	13.9	263	52.4	410	35.8	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2539P	1BLK75C37B	PEGASUS	1.37	332	7.98	175	25.2	222	17.6	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
7-Feb-15	2545P	1BLK75C39A	PEGASUS	2.33	473	11.3	259	41.7	305	26.2	NA	7.77	1KB	1KB	70/76	NA	Z:\DAC\RAW DATA
9-Feb-15	2549P	1BLK75A40A	PEGASUS	3.95	2608	10.9	230	32.6	244	22.3	NA	4.37	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
10-Feb-15	2553P	1BLK75S41A	PEGASUS	2.03	566	11.3	256	31.9	247	22.4	NA	6.81	1KB	1KB	89	NA	Z:\DAC\RAW DATA
11-Feb-15	2557P	1BLK75S42A	PEGASUS	1.62	301	10.6	255	34.9	240	20.5	NA	8.47	1KB	1KB	31/88	NA	Z:\DAC\RAW DATA

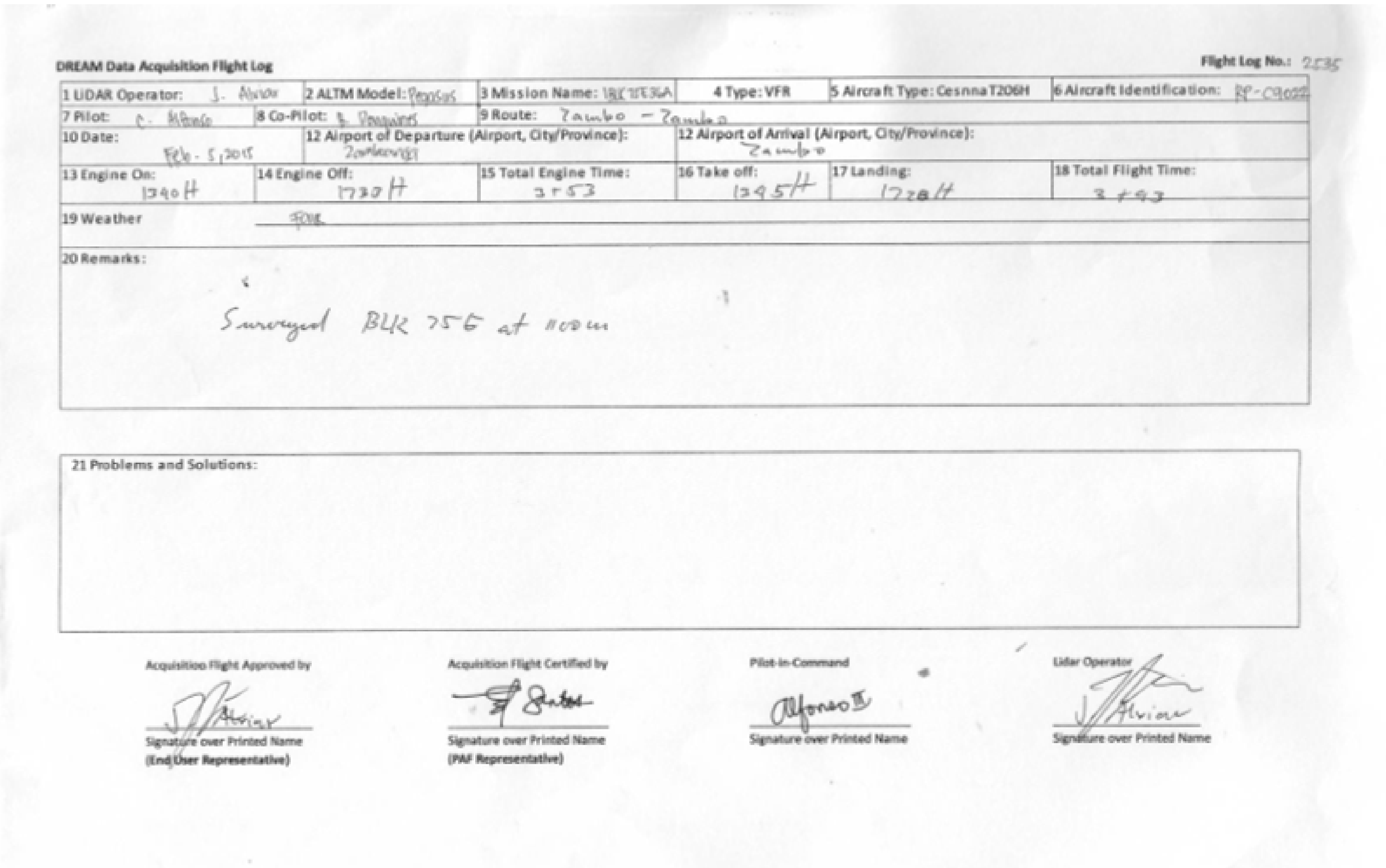
Received from
Name C JOAQUIN
Position
Signature

Received by
Name AC BONGAT
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Manicahan Floodplain

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 2535P


DREAM Data Acquisition Flight Log

Flight Log No.: 2535

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK75E36A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route: Zambo – Zambo			
10 Date: Feb. 5, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zambo		
13 Engine On: 1340H	14 Engine Off: 1730H	15 Total Engine Time: 3+53	16 Take off: 1345H	17 Landing: 1728H	18 Total Flight Time: 3+43
19 Weather: Fair					

20 Remarks:

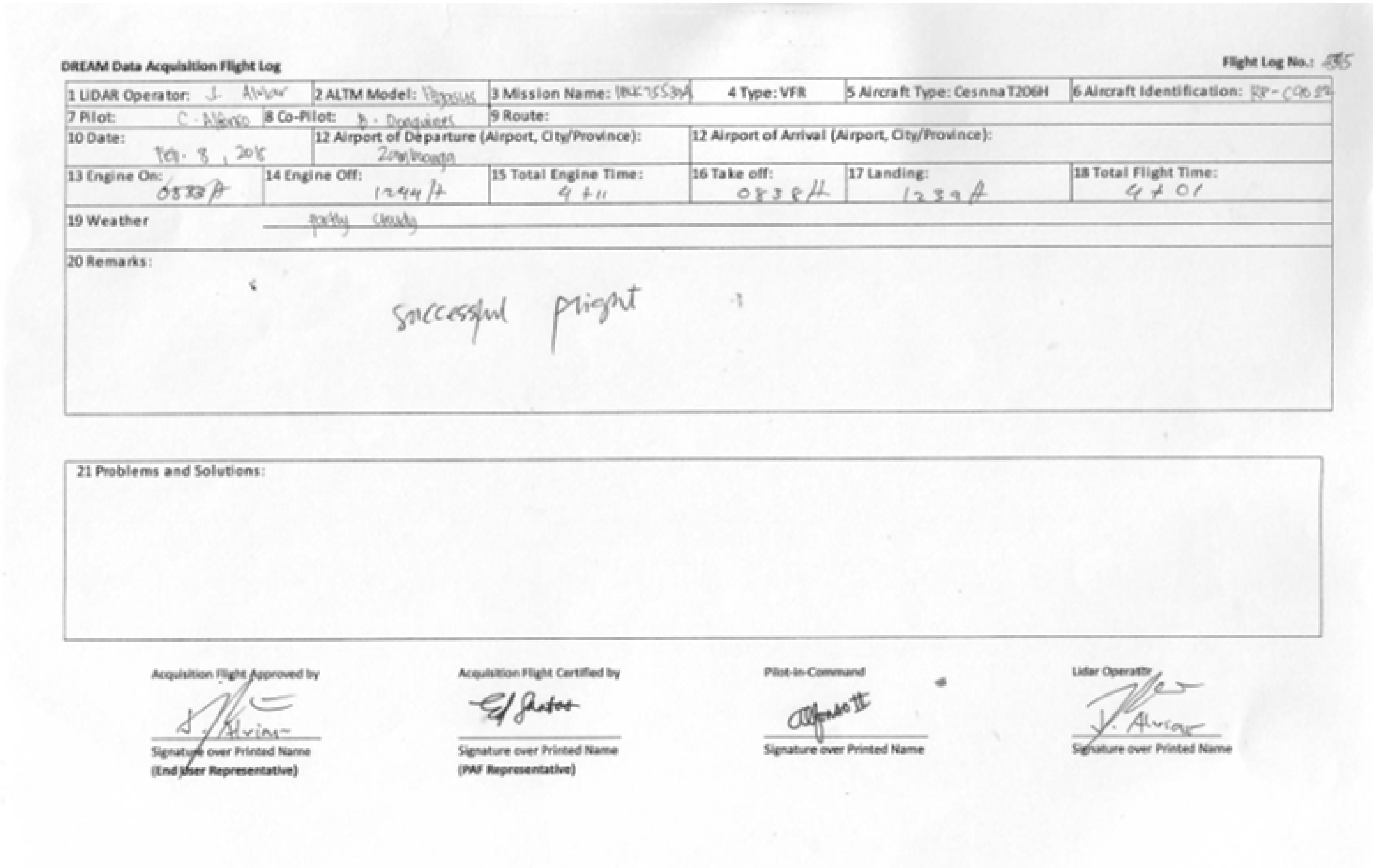
Surveyed BLK 75E at 1100m

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2535P

2. Flight Log for 2545P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 2545

1 LIDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK75S39A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route:			
10 Date: Feb. 8, 2016	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0833H	14 Engine Off: 1244H	15 Total Engine Time: 4+11	16 Take off: 0838H	17 Landing: 1239H	18 Total Flight Time: 4+01
19 Weather: partly cloudy					
20 Remarks: successful flight					

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-6.2. Flight Log for Mission 2545P

Annex 7. Flight Status Reports

Zamboanga City - Zamboanga Sibugay Flights
February 5 to 8, 2015

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2535P	BLK 75E	1BLK75E36A	J. Alviar	February 5, 2015	For completion and some gap filling (terrain)
2545P	BLK 75C, 75D, 75E, 75FS	1BLK75C39A	J. Alviar	February 8, 2015	Abnormal program termination (AVPOS) – AVPOSVIEW terminated – Reopened AVPOS – Still writing

LAS BOUNDARIES PER MISSION FLIGHT

Flight No.:	2535P
Area:	BLK 75E
Mission Name:	1BLK75E36A

Parameters:	
Altitude:	1100 m;
Scan Frequency:	30 Hz;
Scan Angle:	25 deg;
Overlap:	15%

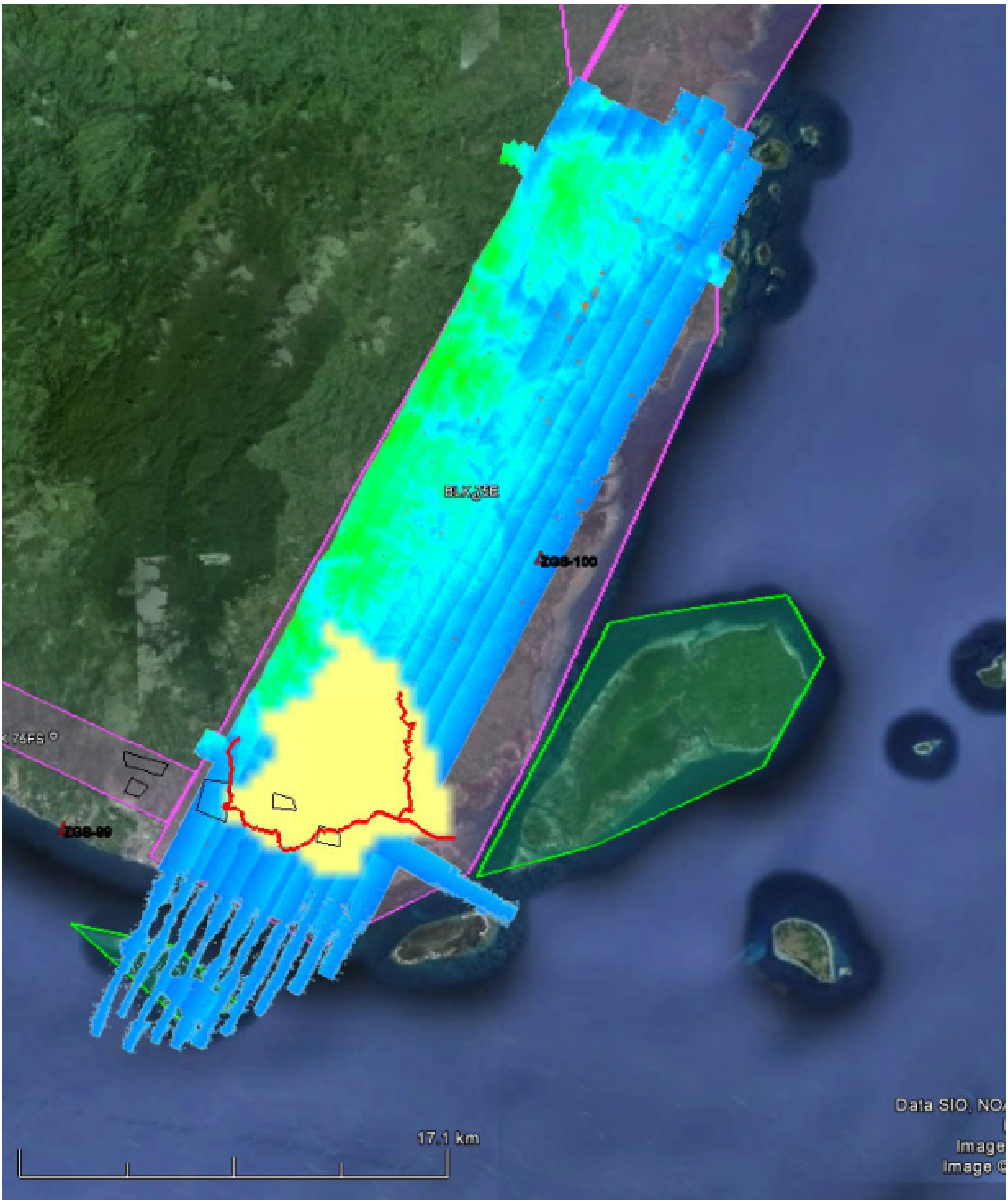


Figure A-7.1. Swath for Flight No. 2535P

Flight No.:	2545P
Area:	BLK 75C, 75D, 75E, 75FS
Mission Name:	1BLK75C39A

Parameters:	
Altitude:	1000 m;
Scan Frequency:	30 Hz;
Scan Angle:	25 deg;
Overlap:	15%

Figure A-7.2. Swath for Flight No. 2545P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk75E

Flight Area	Zamboanga
Mission Name	Blk75E
Inclusive Flights	2535P, 2545P
Mission Name	1BLK75E36A, 1BLK75S39A
Range data size	56.9 GB
Base data size	15.30 MB
POS	491 MB
Image	85.3 GB
Transfer date	February 27 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.08
RMSE for East Position (<4.0 cm)	1.42
RMSE for Down Position (<8.0 cm)	2.94
Boresight correction stdev (<0.001deg)	0.000223
IMU attitude correction stdev (<0.001deg)	0.000328
GPS position stdev (<0.01m)	0.0061
Minimum % overlap (>25)	96.73%
Ave point cloud density per sq.m. (>2.0)	5.11
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	522
Maximum Height	498.00 m
Minimum Height	65.50 m
Classification (# of points)	
Ground	369,443,876
Low vegetation	268,989,359
Medium vegetation	403,829,240
High vegetation	815,604,498
Building	37,951,116
Orthophoto	YES
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Alex John Escobido

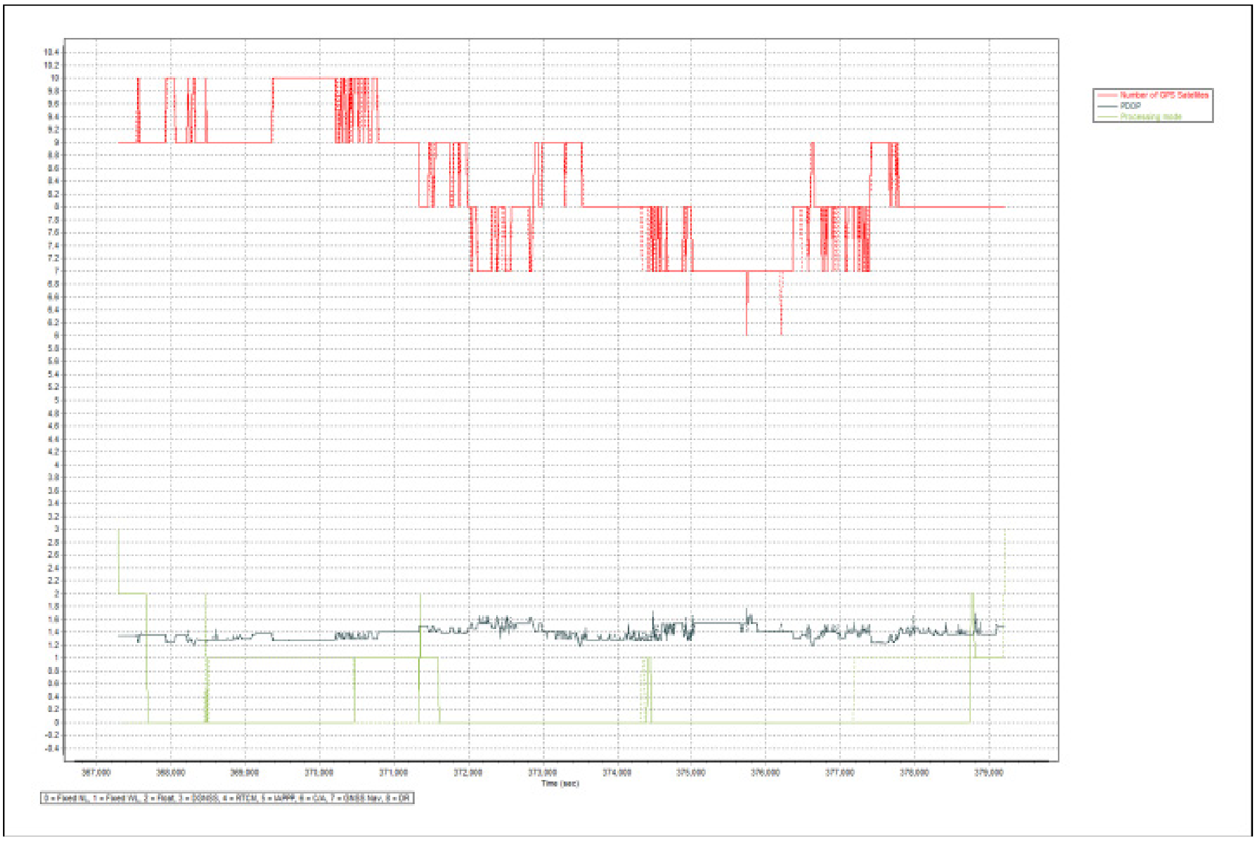


Figure A-8.1. Solution Status

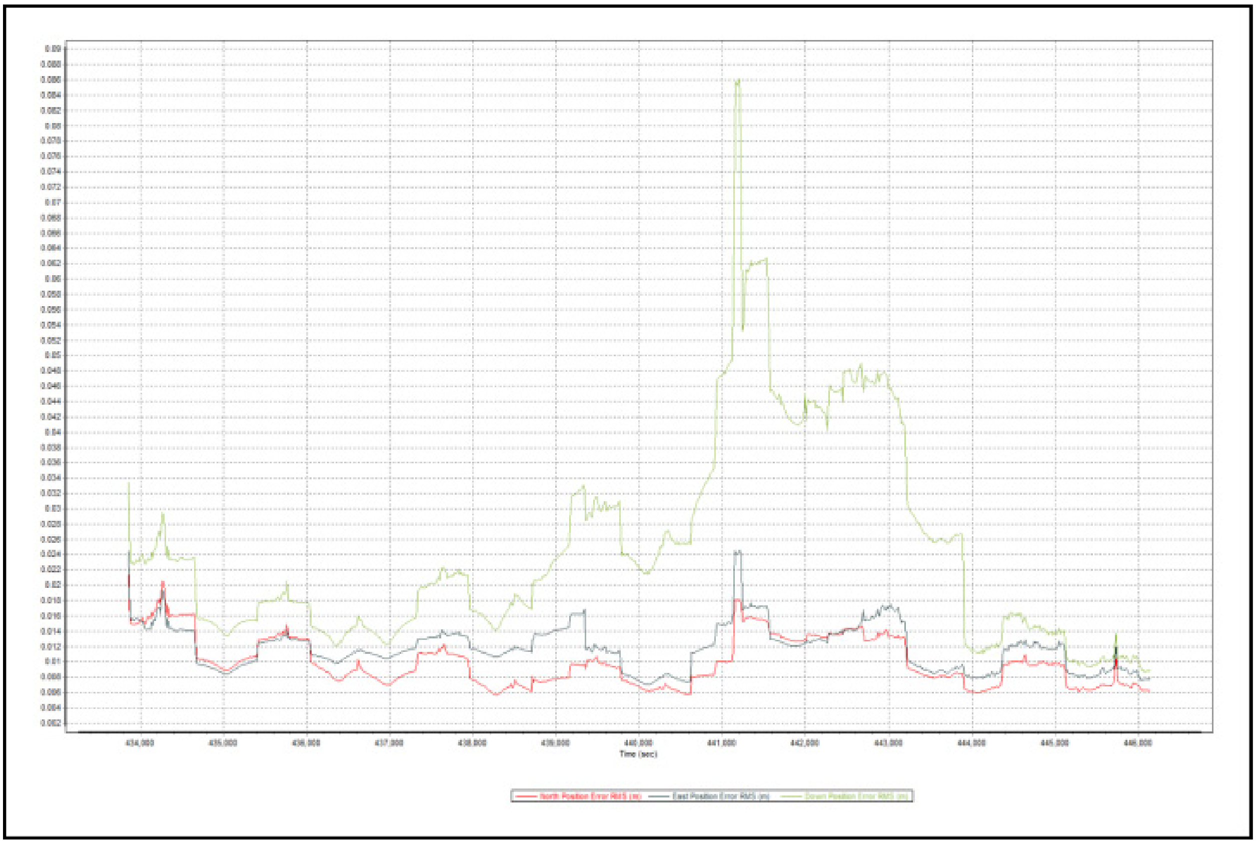


Figure A-8.2. Smoothed Performance Metrics Parameters

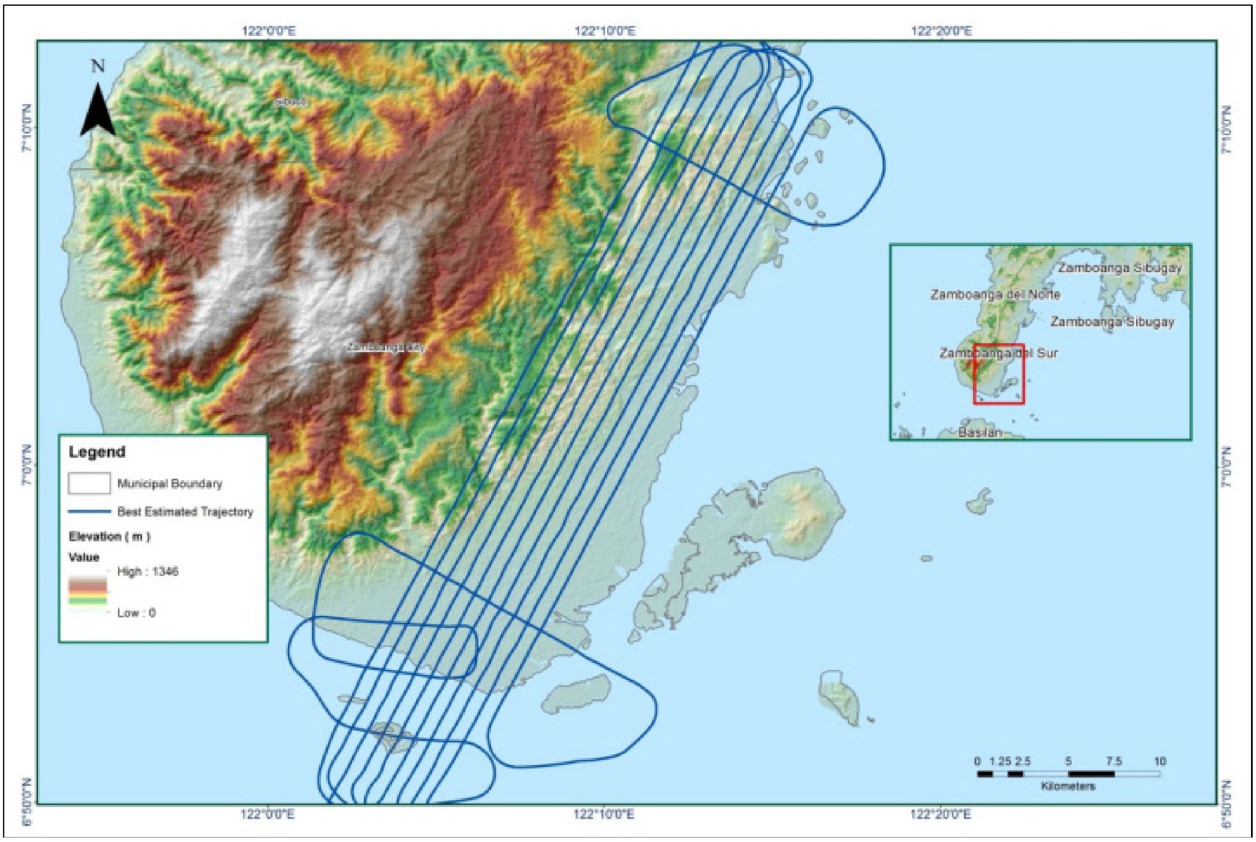


Figure A-8.3. Best Estimated Trajectory

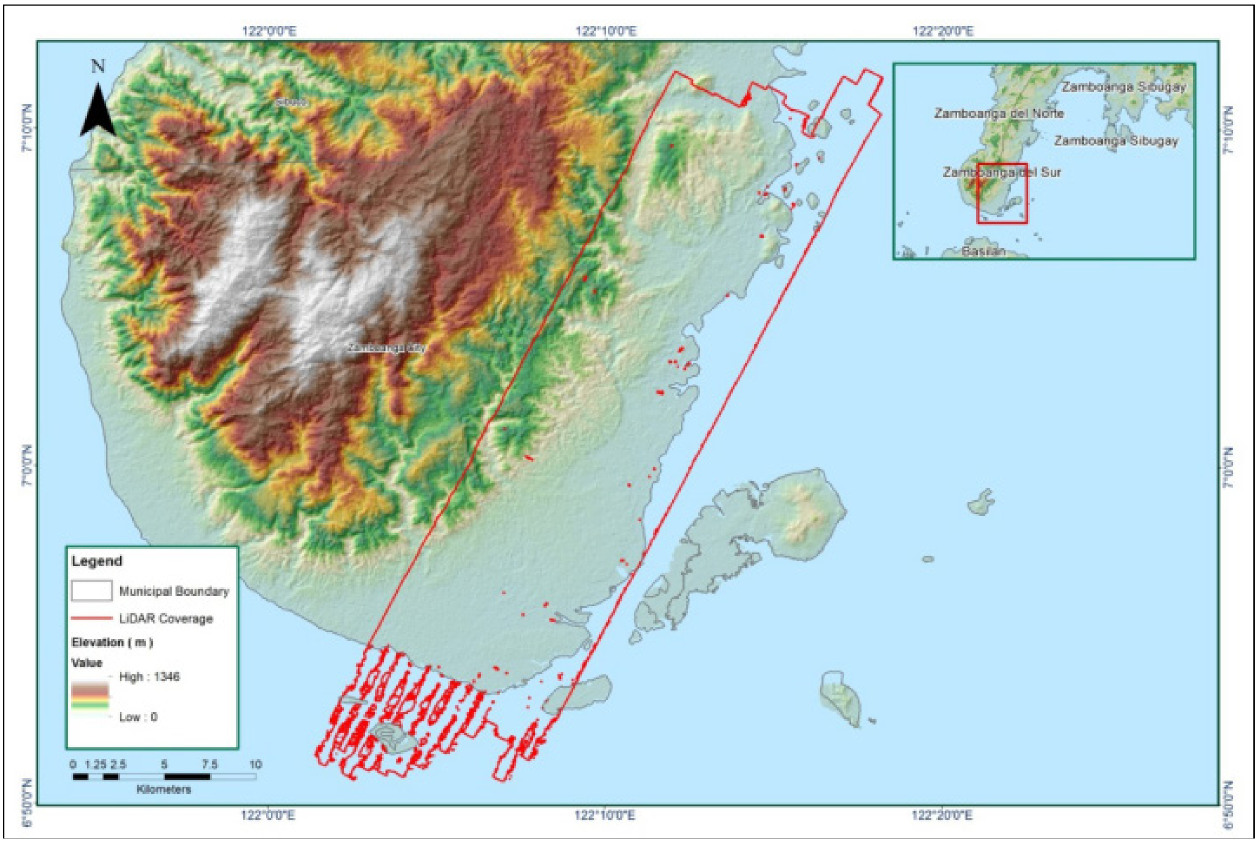


Figure A-8.4. Coverage of LiDAR data

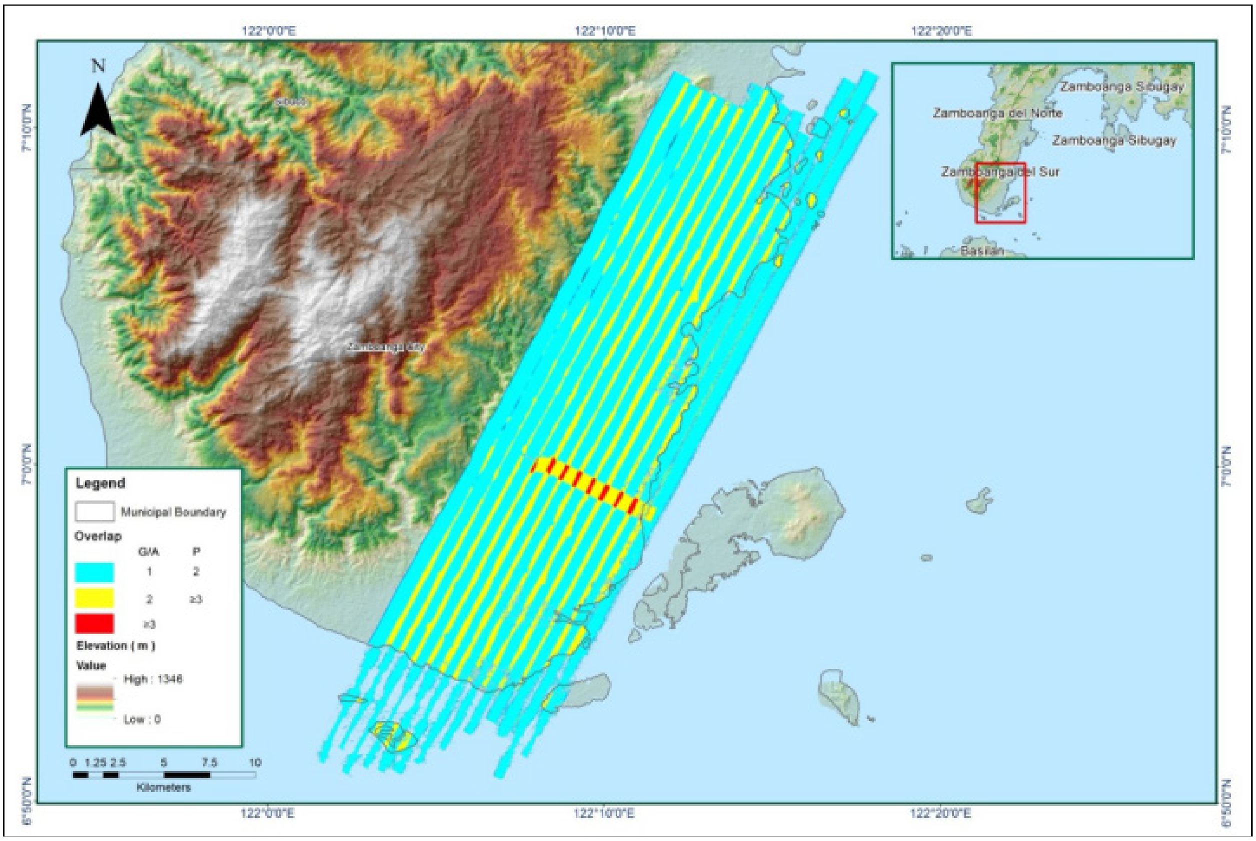


Figure A-8.5. Image of Data Overlap

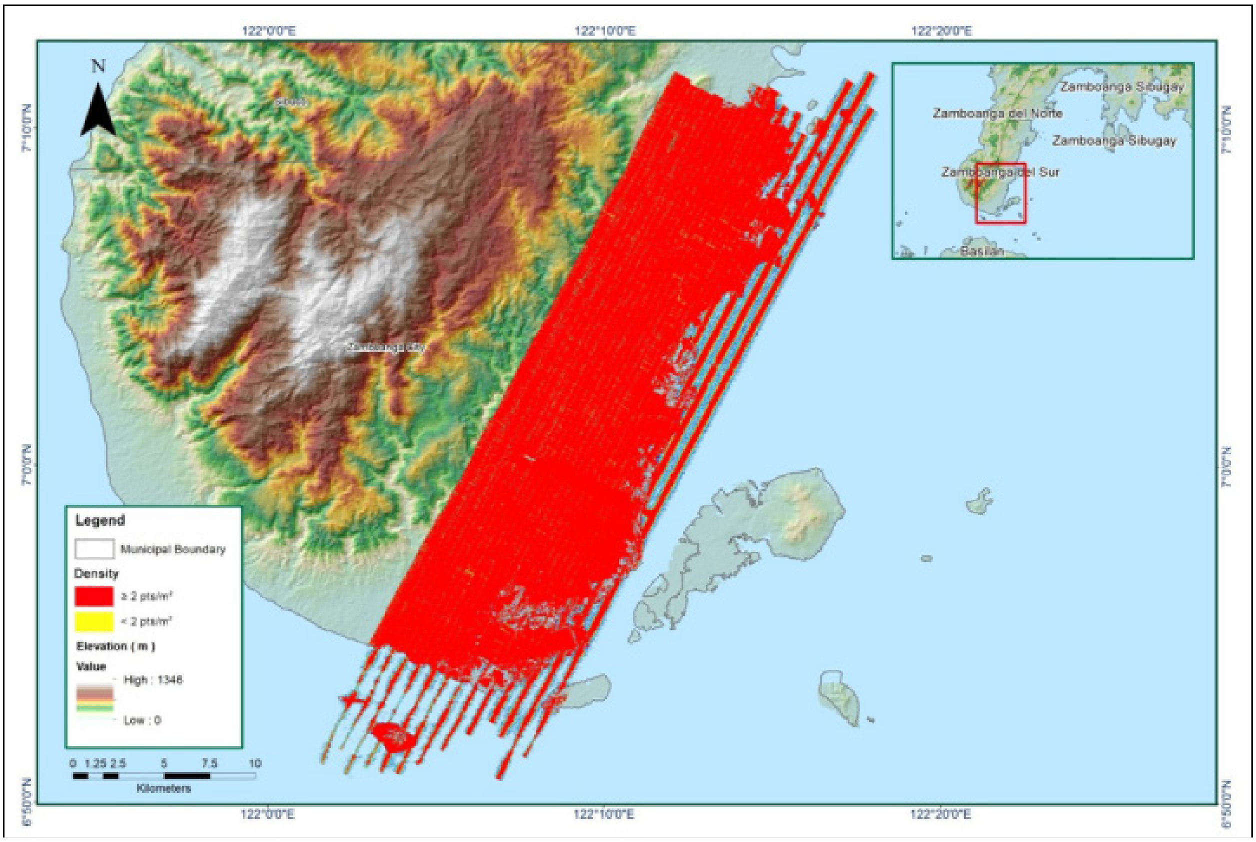


Figure A-8.6. Density map of merged LiDAR data

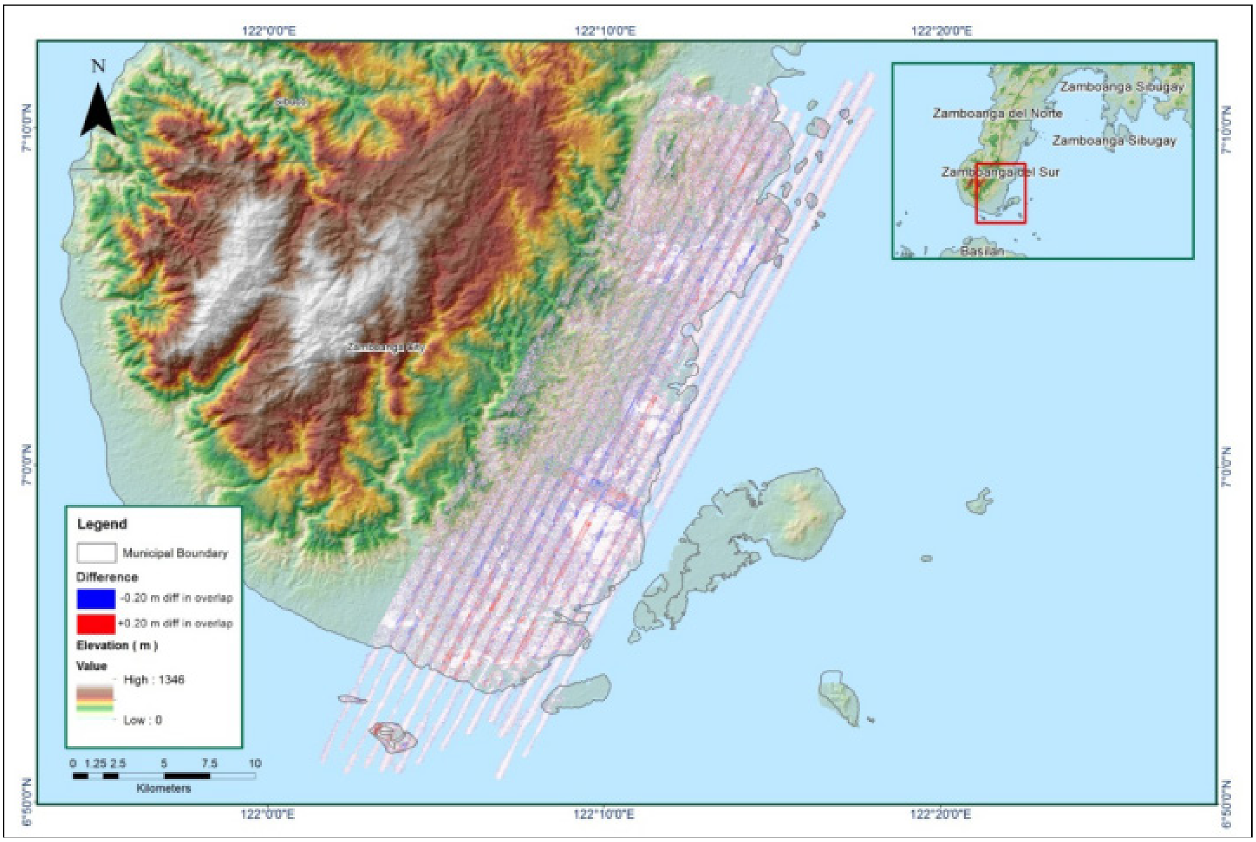


Figure A-8.7. Elevation difference between flight lines

Annex 9. Manicahan Model Basin Parameters

Table A-9.1. Manicahan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W520	66.618	30.2175	0	0.046649	0.0609049	Discharge	0.038417	0.8	Ratio to Peak	0.1
W530	102.054	25.136	0	0.052498	0.0685414	Discharge	0.0421708	0.8	Ratio to Peak	0.1
W540	74.52	29.038	0	0.03851	0.0502787	Discharge	0.0421248	0.8	Ratio to Peak	0.1
W550	78.38	28.491	0	0.039727	0.0518676	Discharge	0.0250679	0.8	Ratio to Peak	0.1
W560	75.94	28.837	0	0.14256	0.18613	Discharge	0.0241633	0.8	Ratio to Peak	0.1
W570	110.066	24	0	0.034963	0.0456477	Discharge	0.0083049	0.8	Ratio to Peak	0.1
W580	106.648	24.4845	0	0.046179	0.0602913	Discharge	0.0244955	0.8	Ratio to Peak	0.1
W590	110.066	24	0	0.036029	0.0470395	Discharge	0.0252468	0.8	Ratio to Peak	0.1
W600	100.08	25.3845	0	0.11887	0.15520	Discharge	0.0489782	0.8	Ratio to Peak	0.1
W610	107.966	24.2975	0	0.093137	0.12160	Discharge	0.050836	0.8	Ratio to Peak	0.1
W620	110.066	24	0	0.01872	0.0244408	Discharge	0.0015715	0.8	Ratio to Peak	0.1
W630	110.066	24	0	0.058392	0.0762366	Discharge	0.0325321	0.8	Ratio to Peak	0.1
W640	75.166	28.793	0	0.059169	0.0772510	Discharge	0.06753	0.8	Ratio to Peak	0.1
W650	110.066	24	0	0.054803	0.0715508	Discharge	0.0127563	0.8	Ratio to Peak	0.1
W660	110.066	24	0	0.059051	0.0770970	Discharge	0.025211	0.8	Ratio to Peak	0.1
W670	110.066	24	0	0.053924	0.0704032	Discharge	0.0472559	0.8	Ratio to Peak	0.1
W680	110.066	24	0	0.027845	0.0363544	Discharge	0.0025732	0.8	Ratio to Peak	0.1
W690	107.684	24.3095	0	0.24424	0.31888	Discharge	0.0414298	0.8	Ratio to Peak	0.1
W700	110.066	24	0	0.058228	0.0760225	Discharge	0.0461137	0.8	Ratio to Peak	0.1
W710	81.026	27.841	0	0.483	0.6306048	Discharge	0.0785078	0.8	Ratio to Peak	0.1
W720	84.326	27.3445	0	0.045609	0.0595471	Discharge	0.0254435	0.8	Ratio to Peak	0.1
W730	102.19	25.0235	0	0.038477	0.0502356	Discharge	0.0243933	0.8	Ratio to Peak	0.1

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W740	110.066	24	0	0.05961	0.0778268	Discharge	0.0288038	0.8	Ratio to Peak	0.1
W750	110.066	24	0	0.028079	0.0366599	Discharge	0.0102137	0.8	Ratio to Peak	0.1
W760	108.748	24.171	0	0.019732	0.0257621	Discharge	0.017131	0.8	Ratio to Peak	0.1
W770	90.102	26.5995	0	0.06592	0.0860652	Discharge	0.0345252	0.8	Ratio to Peak	0.1
W780	110.066	24	0	0.030147	0.0393599	Discharge	0.0142716	0.8	Ratio to Peak	0.1
W790	102.038	25.117	0	0.061058	0.0797173	Discharge	0.0341291	0.8	Ratio to Peak	0.1
W800	109.154	24.1295	0	0.065773	0.0858732	Discharge	0.0449076	0.8	Ratio to Peak	0.1
W810	84.158	27.642	0	0.1394	0.18200	Discharge	0.0459936	0.8	Ratio to Peak	0.1
W820	110.066	24	0	0.05928	0.0773960	Discharge	0.0038202	0.8	Ratio to Peak	0.1
W830	88.744	26.8935	0	0.26427	0.34503	Discharge	0.0577379	0.8	Ratio to Peak	0.1
W840	110.066	24	0	0.069344	0.0905355	Discharge	0.0971106	0.8	Ratio to Peak	0.1
W850	110.066	24	0	0.051187	0.0668297	Discharge	0.0201054	0.8	Ratio to Peak	0.1
W860	92.958	26.95	0	0.031428	0.0410324	Discharge	0.04017	0.8	Ratio to Peak	0.1
W870	110.066	24	0	0.028566	0.0372958	Discharge	0.0181787	0.8	Ratio to Peak	0.1
W880	32.838	37.8955	0	0.026172	0.0341702	Discharge	0.0533325	0.8	Ratio to Peak	0.1
W890	101.83	25.5175	0	0.091611	0.11961	Discharge	0.0205092	0.8	Ratio to Peak	0.1
W900	110.066	24	0	0.017597	0.0183084	Discharge	0.0034625	0.8	Ratio to Peak	0.1
W910	16.9312	43.021	0	0.024839	0.0324298	Discharge	0.0458071	0.8	Ratio to Peak	0.1
W920	45.272	35.9215	0	0.11568	0.15103	Discharge	0.0847581	0.8	Ratio to Peak	0.1
W930	28.656	39	0	0.026756	0.0349326	Discharge	0.0156796	0.8	Ratio to Peak	0.1
W940	28.656	39	0	0.037346	0.0487589	Discharge	0.0284128	0.8	Ratio to Peak	0.1
W950	23.052	41.402	0	0.028232	0.0368597	Discharge	0.0192801	0.8	Ratio to Peak	0.1
W960	64.436	32.4075	0	0.036052	0.0470695	Discharge	0.0099479	0.8	Ratio to Peak	0.1
W970	64.338	32.4255	0	0.051011	0.0666000	Discharge	0.0694082	0.8	Ratio to Peak	0.1
W980	109.928	24.0255	0	0.076476	0.0998471	Discharge	0.0327748	0.8	Ratio to Peak	0.1

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W990	81.764	29.215	0	0.051555	0.0673102	Discharge	.000654167	0.8	Ratio to Peak	0.1
W1000	91.914	27.3445	0	0.017597	0.0229746	Discharge	0.007942	0.8	Ratio to Peak	0.1
W1010	38.022	37.2745	0	0.04332	0.0565586	Discharge	0.0657464	0.8	Ratio to Peak	0.1
W1020	110.066	24	0	0.12668	0.16539	Discharge	0.0100629	0.8	Ratio to Peak	0.1

Annex 10. Manicahan Model Reach Parameters

Table A-10.1. Manicahan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R50	Automatic Fixed Interval	520.12	0.0038453	0.0087308	Trapezoid	20	45
R70	Automatic Fixed Interval	1405.3	0.0149438	0.0085368	Trapezoid	20	45
R80	Automatic Fixed Interval	98.995	0.0101015	0.0039506	Trapezoid	20	45
R110	Automatic Fixed Interval	1636.7	0.0091648	0.0056912	Trapezoid	20	45
R120	Automatic Fixed Interval	1289.9	0.0062018	0.005638	Trapezoid	20	45
R130	Automatic Fixed Interval	959.12	0.0041705	0.0058076	Trapezoid	20	45
R140	Automatic Fixed Interval	303.85	0.0032911	0.06763	Trapezoid	20	45
R180	Automatic Fixed Interval	1518.2	0.001976	0.0303284	Trapezoid	20	45
R200	Automatic Fixed Interval	1604.3	0.0112201	0.0085368	Trapezoid	20	45
R210	Automatic Fixed Interval	1606.4	0.0043576	0.0453844	Trapezoid	20	45
R220	Automatic Fixed Interval	749.12	0.0200236	0.0678304	Trapezoid	20	45
R230	Automatic Fixed Interval	752.55	0.0053153	0.0125492	Trapezoid	20	45
R280	Automatic Fixed Interval	778.70	0.0115577	0.0184472	Trapezoid	20	45
R290	Automatic Fixed Interval	1600.5	0.0049983	0.0188664	Trapezoid	20	45
R310	Automatic Fixed Interval	418.70	0.007165	0.0085368	Trapezoid	20	45
R340	Automatic Fixed Interval	4376.6	0.0070831	0.0059352	Trapezoid	20	45
R350	Automatic Fixed Interval	1056.8	0.0113549	0.0184472	Trapezoid	20	45
R360	Automatic Fixed Interval	203.85	0.0490562	0.0125492	Trapezoid	20	45
R400	Automatic Fixed Interval	2885.9	.000346509	0.0085368	Trapezoid	20	45
R410	Automatic Fixed Interval	1084.6	0.0018441	0.0039506	Trapezoid	20	45
R430	Automatic Fixed Interval	424.26	0.0117851	0.0085368	Trapezoid	20	45
R450	Automatic Fixed Interval	1962.1	0.0076447	0.0085368	Trapezoid	20	45

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R480	Automatic Fixed Interval	354.14	0.0084712	0.0039506	Trapezoid	20	45
R490	Automatic Fixed Interval	1085.7	0.0102168	0.055	Trapezoid	30	1
R510	Automatic Fixed Interval	734.41	0.001	0.0038716	Trapezoid	20	45

Annex 11. Manicahan Field Validation Points

Table A-11.1. Manicahan Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	7.021255	122.188189	0.15	0.86	-0.71		5 -Year
2	7.017118	122.186183	0.04	1.05	-1.01		5 -Year
3	7.016702	122.187019	0.04	1.05	-1.01		5 -Year
4	7.023466	122.187181	0.04	0.5	-0.46		5 -Year
5	7.023357	122.186316	0.17	0.5	-0.33		5 -Year
6	7.023309	122.186434	0.07	1.27	-1.20		5 -Year
7	7.023478	122.186579	0.15	1.15	-1.00		5 -Year
8	7.023477	122.186526	0.31	1	-0.69		5 -Year
9	7.023457	122.186246	0.04	0.25	-0.21		5 -Year
10	7.023496	122.186161	0.05	1.3	-1.25		5 -Year
11	7.023411	122.186106	0.11	0.2	-0.09		5 -Year
12	7.023299	122.186134	0.11	0.55	-0.44		5 -Year
13	7.02313	122.185687	0.03	0.53	-0.50		5 -Year
14	7.022797	122.186668	0.04	0	0.04		5 -Year
15	7.022431	122.186646	0.07	0	0.07		5 -Year
16	7.023122	122.186232	0.06	0	0.06		5 -Year
17	7.022878	122.185519	0.06	0	0.06		5 -Year
18	7.022983	122.185583	0.07	0	0.07		5 -Year
19	7.023582	122.180639	0.06	0.7	-0.64		5 -Year
20	7.023496	122.180521	0.23	0.45	-0.22		5 -Year
21	7.024062	122.17916	0.07	0.64	-0.57		5 -Year
22	7.025053	122.180301	0.04	0.5	-0.46		5 -Year
23	7.025153	122.179509	0.2	0.1	0.10		5 -Year
24	7.025176	122.179306	0.1	0.1	0.00		5 -Year
25	7.025565	122.179234	0.05	0.1	-0.05		5 -Year
26	7.026529	122.181237	0.06	0.1	-0.04		5 -Year
27	7.02411	122.183089	0.03	0.25	-0.22		5 -Year
28	7.022657	122.18502	0.11	0	0.11		5 -Year
29	7.024434	122.179711	0.05	0.65	-0.60		5 -Year
30	7.024034	122.179503	0.07	0.5	-0.43		5 -Year
31	7.023796	122.179293	0.05	0.1	-0.05		5 -Year
32	7.023782	122.179232	0.05	0.1	-0.05		5 -Year
33	7.023852	122.179215	0.13	0.15	-0.02		5 -Year
34	7.023926	122.179178	0.13	0.15	-0.02		5 -Year
35	7.019497	122.203369	0.07	0.5	-0.43		5 -Year
36	7.019558	122.203288	0.06	0.46	-0.40		5 -Year
37	7.019432	122.204211	0.06	0	0.06		5 -Year
38	7.01949	122.203627	0.04	0.1	-0.06		5 -Year
39	7.069243	122.202298	1.13	0.5	0.63	flood	5 -Year
40	7.069963	122.202982	0.22	0.5	-0.28	flood	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	7.068237	122.201731	0.3	0.3	0.00	flood	5 -Year
42	7.06401	122.199214	1.14	0.3	0.84	flood	5 -Year
43	7.07345	122.208964	0.04	0.2	-0.16	flood	5 -Year
44	7.07246	122.209178	0.13	0.4	-0.27	flood	5 -Year
45	7.071816	122.21009	0.05	0.2	-0.15	flood	5 -Year
46	7.044081	122.190172	1.2	0.5	0.70		5 -Year
47	7.045531	122.19071	1.55	1	0.55	flood	5 -Year
48	7.046166	122.190893	0.53	0.5	0.03	flood	5 -Year
49	7.048732	122.194443	0.26	0.5	-0.24	flood	5 -Year
50	7.049214	122.19289	0.61	0.5	0.11	flood	5 -Year
51	7.051055	122.19406	0.39	0.3	0.09	flood	5 -Year
52	7.05124	122.194149	0.67	0.3	0.37	flood	5 -Year
53	7.053584	122.19441	0.54	0.5	0.04	fish pond	5 -Year
54	7.068941	122.201957	0.65	0.3	0.35	flood	5 -Year
55	7.068496	122.201633	0.41	0.3	0.11	flood	5 -Year
56	7.068422	122.201695	0.33	0.3	0.03	flood	5 -Year
57	7.068291	122.201777	0.07	0.3	-0.23	flood	5 -Year
58	7.068461	122.201297	0.39	0.3	0.09	flood	5 -Year
59	7.068276	122.201515	0.33	0.3	0.03		5 -Year
60	7.068364	122.201327	0.2	0.3	-0.10	flood	5 -Year
61	7.068356	122.201314	0.35	0.3	0.05	flood	5 -Year
62	7.068721	122.201162	0.19	0.5	-0.31	flood	5 -Year
63	7.019475	122.198771	0.16	0.38	-0.22		5 -Year
64	7.019672	122.198861	0.07	0.53	-0.46		5 -Year
65	7.020009	122.200064	0.17	0.61	-0.44		5 -Year
66	7.019981	122.199854	0.04	0.47	-0.43		5 -Year
67	7.019724	122.200947	0.19	0.42	-0.23		5 -Year
68	7.020315	122.200949	0.05	0.16	-0.11		5 -Year
69	7.020334	122.200861	0.06	0.16	-0.10		5 -Year
70	7.020469	122.200959	0.05	0.25	-0.20		5 -Year
71	7.020481	122.201309	0.11	0.3	-0.19		5 -Year
72	7.020439	122.201437	0.18	0.16	0.02		5 -Year
73	7.020366	122.201347	0.04	0.13	-0.09		5 -Year
74	7.020391	122.201235	0.13	0.18	-0.05		5 -Year
75	7.020915	122.201209	0.06	0.8	-0.74		5 -Year
76	7.021021	122.201306	0.08	0.14	-0.06		5 -Year
77	7.02114	122.201372	0.1	0.21	-0.11		5 -Year
78	7.02138	122.20157	0.04	0.16	-0.12		5 -Year
79	7.021447	122.201589	0.14	0.25	-0.11		5 -Year
80	7.021647	122.201817	0.04	0.23	-0.19		5 -Year
81	7.021744	122.201781	0.06	0.3	-0.24		5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	7.020728	122.20187	0.17	0.14	0.03		5 -Year
83	7.020586	122.201842	0.07	0.47	-0.40		5 -Year
84	7.020397	122.201979	0.03	0.3	-0.27		5 -Year
85	7.020432	122.20212	0.05	0.16	-0.11		5 -Year
86	7.020161	122.201932	0.09	0.14	-0.05		5 -Year
87	7.019971	122.201783	0.06	0.31	-0.25		5 -Year
88	7.02003	122.201891	0.04	0.31	-0.27		5 -Year
89	7.019825	122.201699	0.13	0.28	-0.15		5 -Year
90	7.01971	122.201692	0.13	0.3	-0.17		5 -Year
91	7.019776	122.20149	0.07	0.33	-0.26		5 -Year
92	7.019357	122.200845	0.05	0.38	-0.33		5 -Year
93	7.017396	122.199804	0.04	0.3	-0.26		5 -Year
94	7.017256	122.199628	0.06	0.33	-0.27		5 -Year
95	7.017186	122.199596	0.07	0.32	-0.25		5 -Year
96	7.019315	122.20049	0.06	0.2	-0.14		5 -Year
97	7.018818	122.200431	0.22	0.26	-0.04		5 -Year
98	7.018873	122.200549	0.13	0.2	-0.07		5 -Year
99	7.018822	122.200682	0.21	0.24	-0.03		5 -Year
100	7.018616	122.20069	0.06	0.2	-0.14		5 -Year
101	7.018397	122.200664	0.07	0.23	-0.16		5 -Year
102	7.018229	122.200141	0.1	0.13	-0.03		5 -Year
103	7.025158	122.189433	0.06	0.25	-0.19		5 -Year
104	7.025381	122.190321	0.07	0.26	-0.19		5 -Year
105	7.023898	122.191366	0.05	0.38	-0.33		5 -Year
106	7.02399	122.191149	0.06	0.35	-0.29		5 -Year
107	7.024209	122.192081	0.11	0.38	-0.27		5 -Year
108	7.025241	122.192176	0.11	0.33	-0.22		5 -Year
109	7.021704	122.198744	0.05	0.14	-0.09		5 -Year
110	7.069978	122.202993	0.22	0.5	-0.28	flood	5 -Year
111	7.069284	122.202277	1.13	0.3	0.83	flood	5 -Year
112	7.068232	122.201725	0.3	0.3	0.00	flood	5 -Year
113	7.064028	122.1992	1.14	0.3	0.84	flood	5 -Year
114	7.073462	122.208962	0.11	0.2	-0.09	flood	5 -Year
115	7.071872	122.210074	0.06	0.2	-0.14	flood	5 -Year
116	7.044087	122.190175	1.2	0.5	0.70	flood	5 -Year
117	7.045533	122.190729	1.55	1	0.55	flood	5 -Year
118	7.046168	122.190927	0.53	0.3	0.23	flood	5 -Year
119	7.051047	122.194063	0.39	0.3	0.09	flood	5 -Year
120	7.05361	122.194449	0.54	0.5	0.04	flood	5 -Year
121	7.048727	122.194458	0.26	0.4	-0.14	flood	5 -Year
122	7.064006	122.199198	1.14	0.4	0.74	floods	5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
123	7.044072	122.1902	1.2	0.2	1.00	flood	5 -Year
124	7.045534	122.190708	1.55	1	0.55	flood	5 -Year
125	7.046177	122.190942	0.53	0.5	0.03	flood	5 -Year
126	7.043989	122.190014	1.14	0.3	0.84	flood	5 -Year
127	7.041739	122.189367	0.1	0.2	-0.10	flood	5 -Year
128	7.068522	122.201631	0.41	0.3	0.11	flood	5 -Year
129	7.068446	122.201392	0.26	0.3	-0.04	flood	5 -Year
130	7.068311	122.201416	0.33	0.3	0.03	flood	5 -Year
131	7.068286	122.20177	0.3	0.3	0.00	flood	5 -Year
132	7.068255	122.201521	0.33	0.3	0.03	flood	5 -Year
133	7.068422	122.2017	0.33	0.3	0.03	flood	5 -Year
134	7.06888	122.202127	0.78	0.3	0.48	flood	5 -Year
135	7.068945	122.201954	0.65	0.3	0.35	flood	5 -Year
136	7.068714	122.201167	0.19	0.5	-0.31	flood	5 -Year
137	7.030728	122.19287	0.06	0	0.06	yolanda	5 -Year
138	7.030789	122.192699	0.06	0	0.06	yolanda	5 -Year
139	7.030724	122.1933	0.05	0	0.05	yolanda	5 -Year
140	7.029744	122.19361	0.07	0	0.07	yolanda	5 -Year
141	7.029626	122.193963	0.06	0	0.06	yolanda	5 -Year
142	7.029539	122.194199	0.05	0	0.05	yoland	5 -Year
143	7.030729	122.193399	0.05	0	0.05	yolanda	5 -Year
144	7.030827	122.19362	0.08	0	0.08	yolanda	5 -Year
145	7.032799	122.196857	0.09	0.12	-0.03	yolanda	5 -Year
146	7.033854	122.190439	0.05	0.24	-0.19	yolanda	5 -Year
147	7.033463	122.190175	0.18	0.1	0.08	yolanda	5 -Year
148	7.034366	122.191006	0.29	0.5	-0.21	yolanda	5 -Year
149	7.034352	122.191088	0.06	0.8	-0.74	yolanda	5 -Year
150	7.034391	122.190981	0.16	0.5	-0.34	yolanda	5 -Year
151	7.034089	122.190943	0.07	0.12	-0.05	yolanda	5 -Year
152	7.033335	122.190149	0.07	0.5	-0.43	yolanda	5 -Year
153	7.03242	122.189465	0.03	0.2	-0.17	yolanda	5 -Year
154	7.029119	122.187831	0.05	0.1	-0.05	yolanda	5 -Year
155	7.029419	122.189953	0.11	0.8	-0.69	yolanda	5 -Year
156	7.035166	122.180699	0.08	0.23	-0.15		5 -Year
157	7.033821	122.179037	0.03	0.25	-0.22	Yolanda	5 -Year
158	7.034022	122.178513	0.03	0.33	-0.30		5 -Year
159	7.03398	122.178649	0.06	0.33	-0.27		5 -Year
160	7.034108	122.178674	0.97	0.33	0.64		5 -Year
161	7.030736	122.178369	0.11	0.28	-0.17		5 -Year
162	7.030753	122.178213	0.06	0.2	-0.14		5 -Year
163	7.030824	122.17822	0.18	0.2	-0.02		5 -Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
164	7.030676	122.178223	0.11	0.2	-0.09		5 -Year
165	7.031057	122.17823	0.09	0.25	-0.16		5 -Year
166	7.033947	122.176156	0.26	0.26	0.00		5 -Year
167	7.034525	122.1759	0.27	0.15	0.12		5 -Year
168	7.033598	122.176288	0.34	0.2	0.14		5 -Year
169	7.035806	122.176155	0.1	0.3	-0.20		5 -Year
170	7.035892	122.175775	0.06	0.3	-0.24		5 -Year
171	7.035728	122.175437	0.12	0.3	-0.18		5 -Year
172	7.036312	122.179127	0.31	0.31	0.00		5 -Year
173	7.036425	122.179118	0.2	0.31	-0.11		5 -Year
174	7.033722	122.178293	0.05	0.33	-0.28		5 -Year
175	7.033779	122.178536	0.1	0.33	-0.23		5 -Year
176	7.033522	122.178451	0.19	0.33	-0.14		5 -Year
177	7.034748	122.177887	0.05	0.3	-0.25		5 -Year
178	7.035018	122.179449	0.07	0.33	-0.26		5 -Year
179	7.035061	122.17945	0.07	0.32	-0.25		5 -Year
180	7.034662	122.178605	0.04	0.2	-0.16		5 -Year
181	7.034745	122.178734	0.06	0.2	-0.14		5 -Year
182	7.034647	122.179341	0.05	0.27	-0.22		5 -Year
183	7.034866	122.179022	0.06	0.29	-0.23		5 -Year
184	7.034791	122.178932	0.05	0.23	-0.18		5 -Year
185	7.033453	122.177319	0.09	0.2	-0.11		5 -Year
186	7.033681	122.177335	0.15	0.2	-0.05		5 -Year
187	7.033775	122.177486	0.04	0.21	-0.17		5 -Year
188	7.033999	122.177464	0.06	0.24	-0.18		5 -Year
189	7.01312	122.182499	0.08	0.3	-0.22	Yolanda	5 -Year
190	7.01329	122.183027	0.16	0.3	-0.14	Yolanda	5 -Year
191	7.016662	122.185443	0.04	0.2	-0.16	Yolanda	5 -Year
192	7.016659	122.185318	0.14	0.2	-0.06	Yolanda	5 -Year

Annex 12. Educational Institutions affected by flooding in Manicahan Floodplain

Table A-12.1. Educational Institutions in Zamboanga City affected by flooding in Manicahan Floodplain

Zamboanga City				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
MANICAHAN SCHOOL	Cacao	None	None	Low
LAPAKAN SCHOOL	Cacao	None	None	None
Manicahan National High School	Cacao	Low	Low	Low
LAMISAHAN SCHOOL	Lapakan	Medium	Medium	Medium
VICTORIA SCHOOL	Lapakan	Low	Low	Medium
Madrasa	Manicahan	None	None	None
Manicahan poblacion elementary shool	Manicahan	None	None	Low
School Madrasa	Manicahan	None	None	None
MNS	Manicahan	None	None	None
MCS	Manicahan	None	None	None
MCN	Manicahan	None	None	None
Manicahan Central school	Manicahan	None	None	Low
Distric office	Manicahan	None	None	None
Manicahan Central school	Manicahan	None	None	Low
SANGALI SCHOOL	Sangali	None	None	Low
LAMISAHAN SCHOOL	Sangali	Medium	Medium	Medium
LAPAKAN SCHOOL	Tolosa	None	None	None

Annex 13. Health Institutions affected by flooding in Manicahan Floodplain

Table A-13.1. Health Institutions in Zamboanga City affected by flooding in Manicahan Floodplain

Zamboanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
LAPAKAN HEALTH CENTER	Cacao	None	None	None
VICTORIA	Lapakan	None	None	None
Health Center	Manicahan	None	None	None
LAMISAHAN	Sangali	None	None	None
LAPAKAN HEALTH CENTER	Tolosa	None	None	None