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

LiDAR Surveys and Flood Mapping of Batu River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: INTRODUCTION

1.1 Background of the Phil-LiDAR 1 Program

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

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled 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 Zamboanga University (ADZU). ADZU 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 ________ river basins in the ___________________ (LiDAR covered area). The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Batu River Basin

Located at the center of Zamboanga Sibugay Province, the Sibuguey River Basin, the largest river in the Peninsula, has a catchment area of approximately 59.44 km2 with the estimated annual run-off of 719 mcm based on the Flood Modeling Component database. The Sibuguey River Basin encompasses the municipalities of Kabasalan, Siay, Ipil, and Naga with a total population are estimated to 182,403 people according to 2010 census conducted by the NSO.

The Batu River is one of the main tributaries of the Sibuguey River Basin. With a total land area of 59.44 sqkm, the Batu River Basin is one of the several water bodies found in the municipality of Siay, Zamboanga del Norte. The river is connected to a larger stream network comprising of tributaries flowing from Muyo, Labaon, Kipit, Pulidan, Palomac, Gilupan, and Bakalan rivers. The delineated Batu River has an approximate length of 8.14 km traversing the barangays of Laih, Batu, and San Isidro. It travels at around 14.40 kms, and traverses through several barangays in the municipality including Little Baguio, Tigbangan, Tamin, Buayan, Concepcion, and Nazareth on the East, and San Isidro, Batu and Laihon in the west.

The barangays of Batu, Laih, Monching, and Nazareth are the flood prone areas in the vicinity of Batu River reflecting a moderate to high susceptibility to flooding according to the 2012 hazard maps of the Mines and Geosciences Bureau (MGB).

Figure 1. Batu River

The presence of these water bodies played important contribution to the municipality's irrigation system.

With the presence of several water bodies in the municipality, most areas of Siay are prone to flood hazard. According to the maps released by the Mines and Geosciences Bureau (MGB) Region 9, the flood waters may reach up to more than 1 meter in the areas where the 4 rivers are located and especially in the low lying areas. According to the Local Disaster Risk Reduction and Management Office of the municipality, the most significant flooding that happened in Batu River was in 1996, in which the local calamansi and rice farmers were greatly affected.

The municipality of Siay is widely known as the Calamansi Capital of the Peninsula. According to the Philippine Information Agency (PIA) Region 9, an estimated area of 634.4 hectares of land comprises the calamansi farmland, planted by 261 small scale farmers. Calamansi puree, juice, and other calamansi products are traded to the different parts of the country. Aside from this, Siay is known for sand and gravel quarrying, and fishing. It is identified as one of the fish landing centers in the Province of Zamboanga Sibugay.

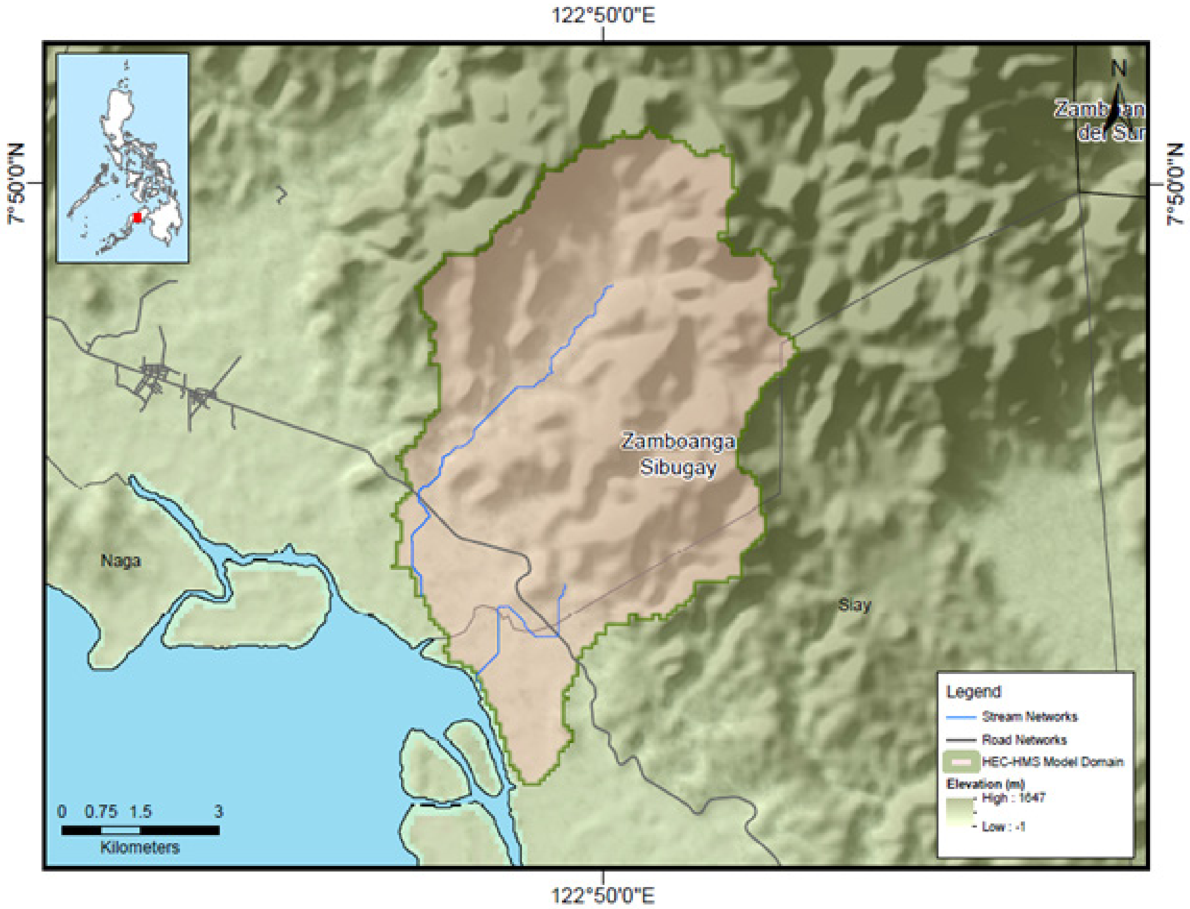

Figure 2. Map of Batu River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN SAN JOSE FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Batu Floodplain in Zamboanga Sibugay. These missions were planned for 12 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 3 shows the flight plan for Batu Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK70A	800,1100,1200	30	50	200	30	130	5
BLK72A	800,1100,1200	30	50	200	30	130	5
BLK73A	800,1200	30	50	200	30	130	5
BLK73B	800,1100,1200	30	50	200	30	130	5

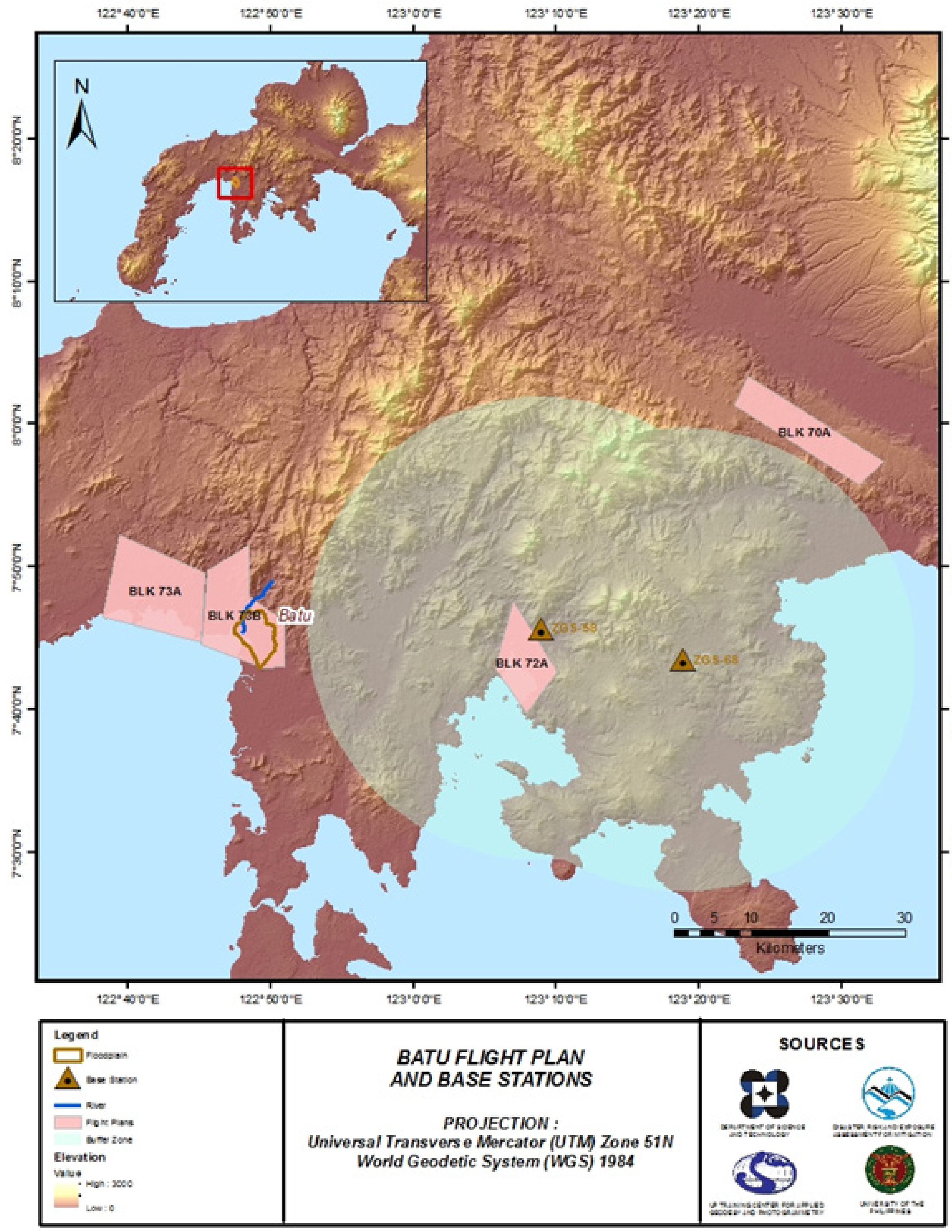
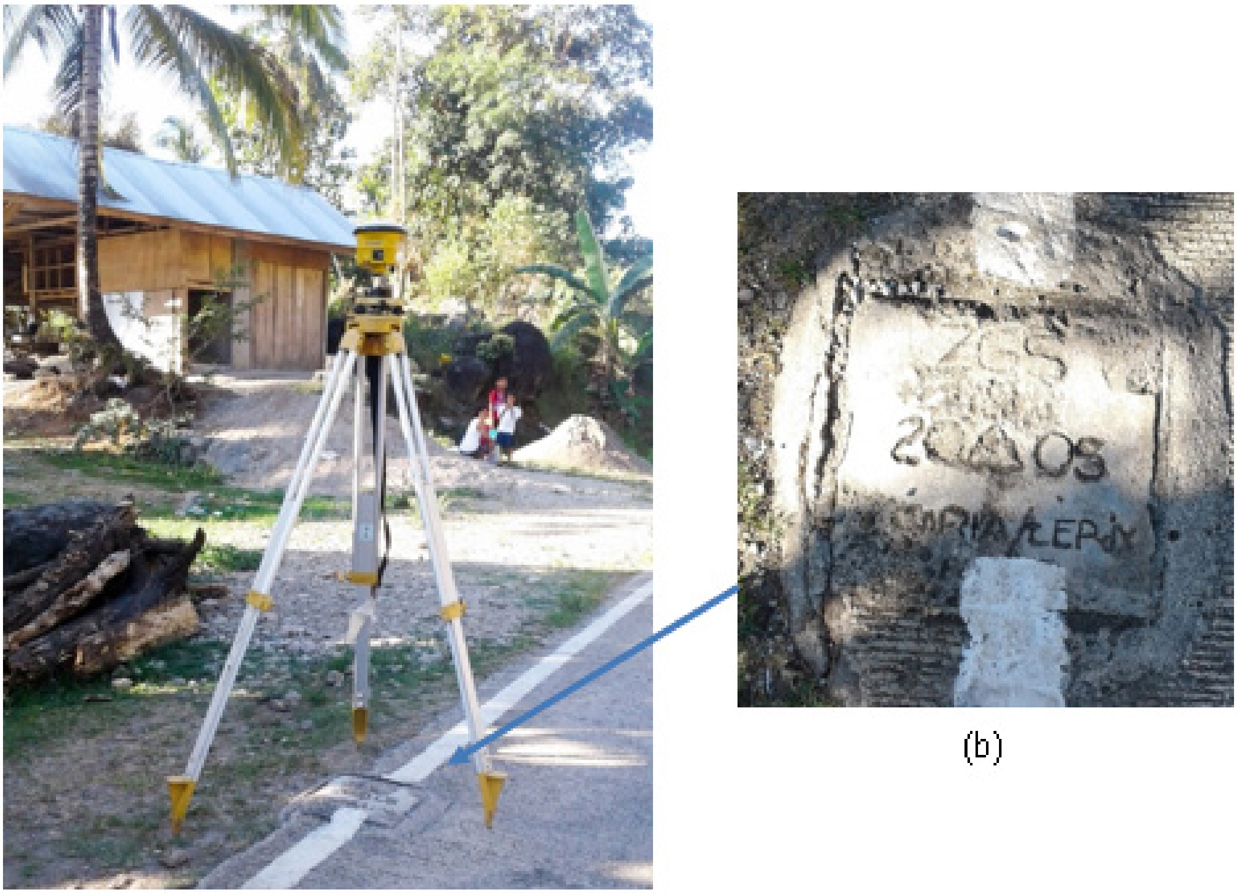


Figure 3. Flight plan and base stations used for Batu Floodplain.

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA ground control points: ZGS-58 and ZGS-68 which areof second (2nd) order accuracy. The certifications for the NAMRIA reference points are found in Annex A-2. These were used as base stations during flight operations for the entire duration of the survey (February 24 - 26, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Batu floodplain are shown in Figure 3.

Figure 4 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 3 present the details about the following NAMRIA control stations, while Table 4 lists all ground control points occupied during the acquisition together with the corresponding dates of utilization.

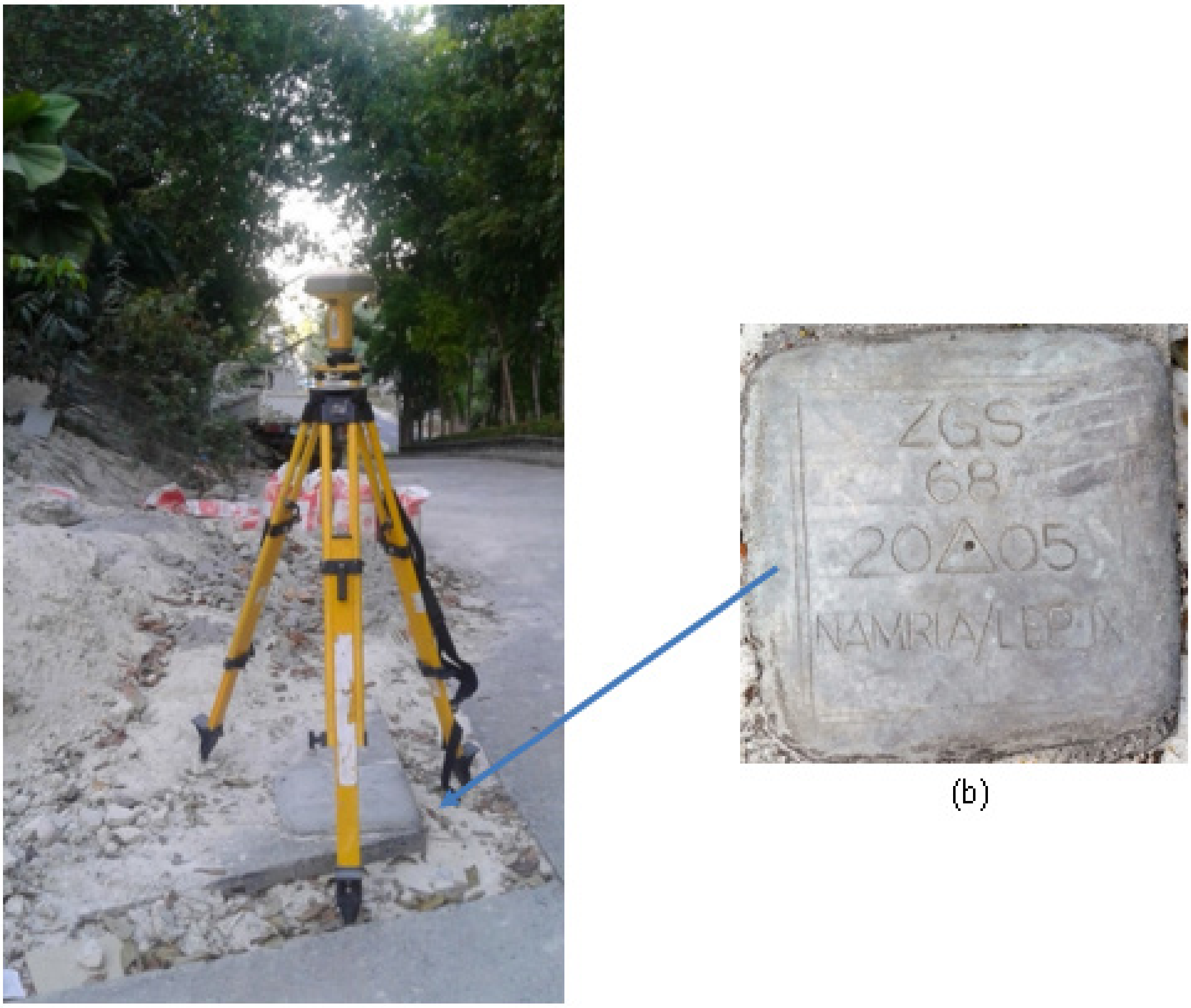


(a) (b)

Figure 4. GPS set-up over ZGS-58 atBrgy. Sicade, Municipality of Kumalarang, Zamboanga del Sur (a) and NAMRIA reference point ZGS-58 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGS-58 used as base station for the LiDAR acquisition.

Station Name	ZGS-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 45’ 44.20587” North 123° 8’ 50.40994” East 31.65 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	516,245.79 meters 857,966.20 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 45’ 40.67639” North 123° 8’ 55.89231” East 96.974 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	516,245.79 meters 857,966.20 meters



(a)

(b)

Figure 5. GPS set-up over ZGS-68atCENRO, Brgy. Poblacion, Municipality of Guipos, Zamboanga del Sur (a) and NAMRIA reference point ZGS-68 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-68 used as base station for the LiDAR acquisition.

Station Name	ZGS-68	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	7° 45’ 44.20587” North 123° 8’ 50.40994” East 31.65 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Longitude	516,245.79 meters 857,966.20 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Ellipsoidal Height	7° 43’ 33.12722” North
Grid Coordinates, Universal Transverse Mercator Zone 51 North	123° 18’ 488.96041” East	516,245.79 meters 857,966.20 meters

Table 4. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 24, 2016	23132P	1BLK73A055A	ZGS-58 & ZGS-68
February 26, 2016	23140P	1BLK73BS057A	ZGS-58 & ZGS-68

2.3 Flight Missions

Two (2) missions were conducted to complete the LiDAR data acquisition in Batu floodplain, for a total of eight hours and forty six minutes (8+46) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

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

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 24, 2016	23132P	228	221.62	2.93	218.69	NA	4	11
February 26, 2016	23140P	369.6	288.69	22.78	265.91	NA	4	35
TOTAL		597.6	510.31	25.71	484.6	NA	8	46

Table 6. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23132P	800,1200	30	50	200	30	130	5
23140P	800,1100, 1200	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Batu Floodplain (See Annex 7). Batu Floodplain is located in the province of Zamboanga Sibugay with majority of the floodplain situated within the municipality of Siay. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Batu floodplain is presented in Figure 6.

Table 7. List of municipalities and cities surveyed during Batu Floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Zamboanga Sibugay	Naga	164.18	86.64	52.77%
	Kabasalan	317.28	95.02	29.95%
	Siay	186.47	32.23	17.29%
	Ipil	130.9	21.04	16.07%
	Titay	176.5	8.68	4.92%
Total 975.33		975.33	243.61	24.98%

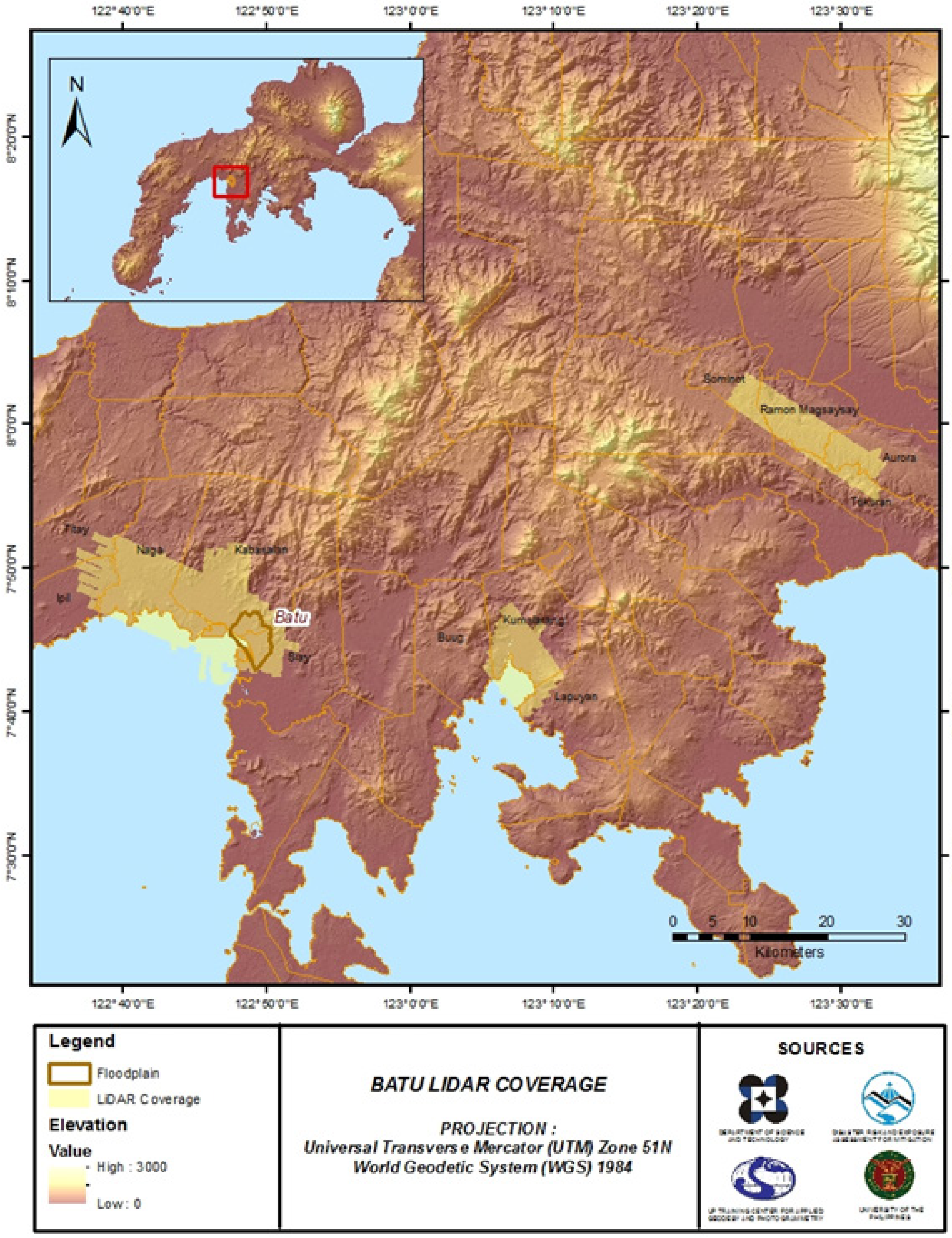


Figure 6. Actual LiDAR survey coverage for Batu Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR BATU 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 were 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 was done to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were 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 were 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 were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.

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

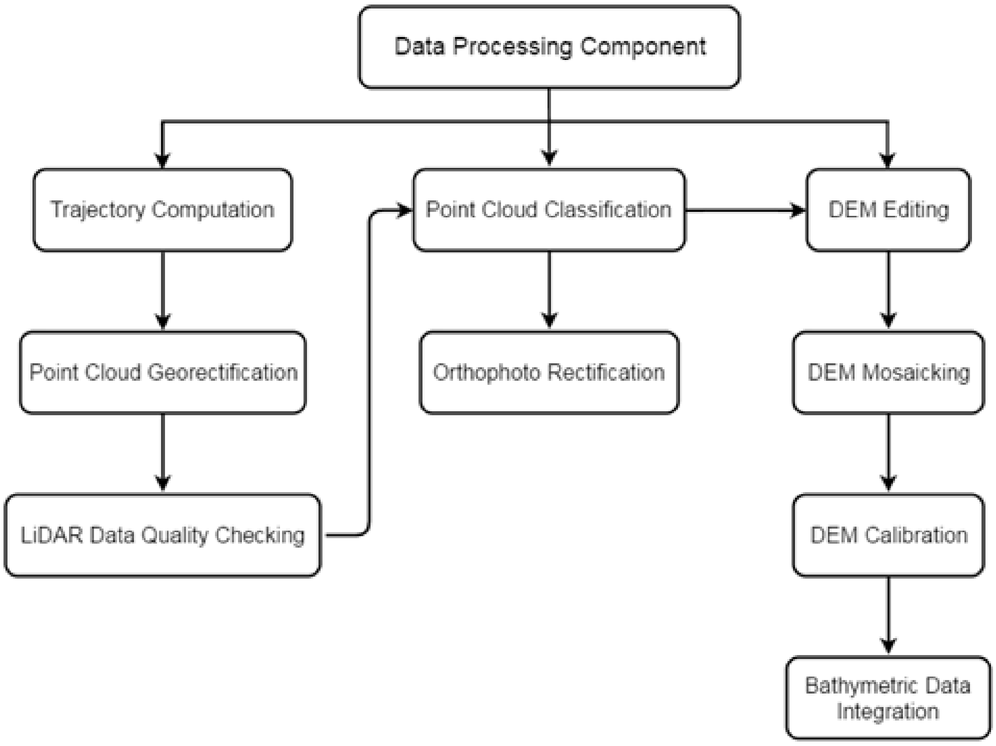


Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Batu floodplain can be found in Annex 5. Missions flown during the survey conducted in February 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.)Pegasus system over Kabasalan and Siay, Zamboanga Sibugay.The Data Acquisition Component (DAC) transferred a total of50.9 Gigabytes of Range data, 571Megabytes of POS data, 115.6 Megabytes of GPS base station data, and 113 Gigabytes of raw image data to the data server on March 7, 2016 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Batu was fully transferred on March 10, 2016, as indicated in the Data Transfer Sheets for Batu Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metricparameters of the computed trajectory for flight 23140P, one of the Batu flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 26, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

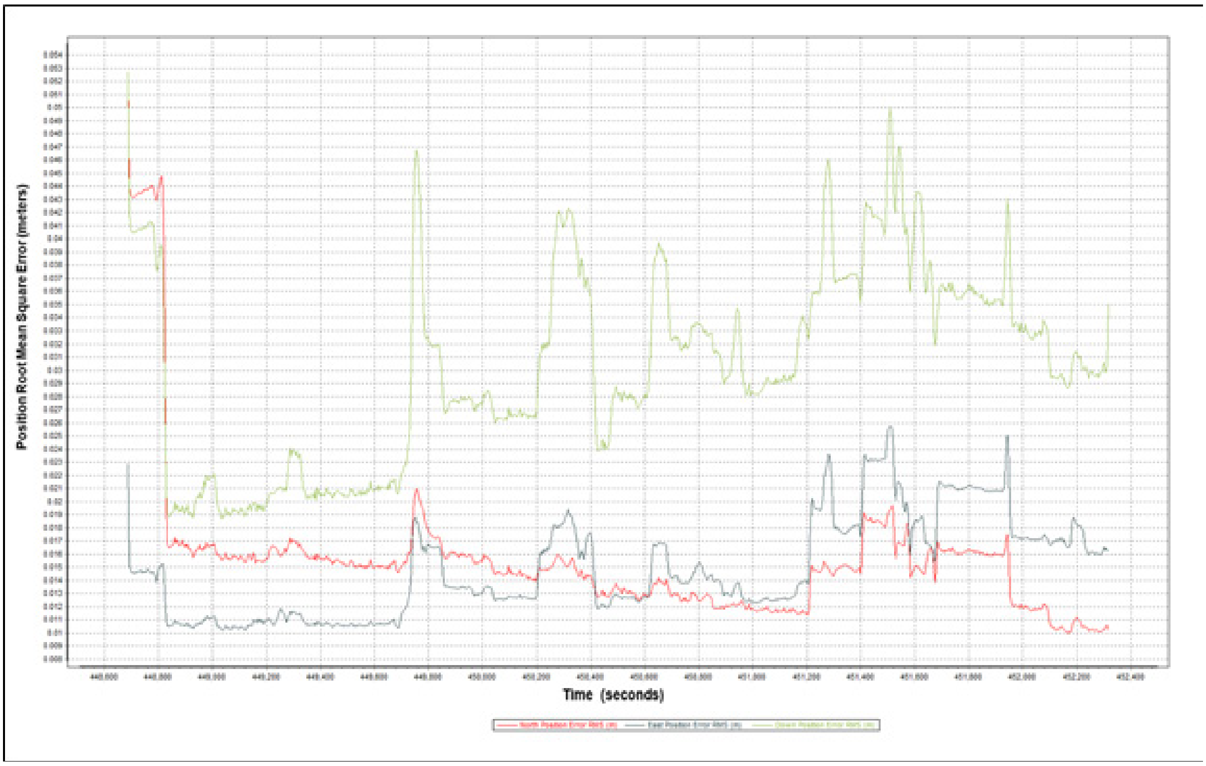


Figure 8. Smoothed Performance Metric Parameters of a Batu Flight 23474P.

The time of flight was from 448600 seconds to 452400 seconds, which corresponds to morning of February 26, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 2.10 centimeters, the East position RMSE peaks at 2.50centimeters, and the Down position RMSE peaks at 4.70centimeters, which are within the prescribed accuracies described in the methodology.

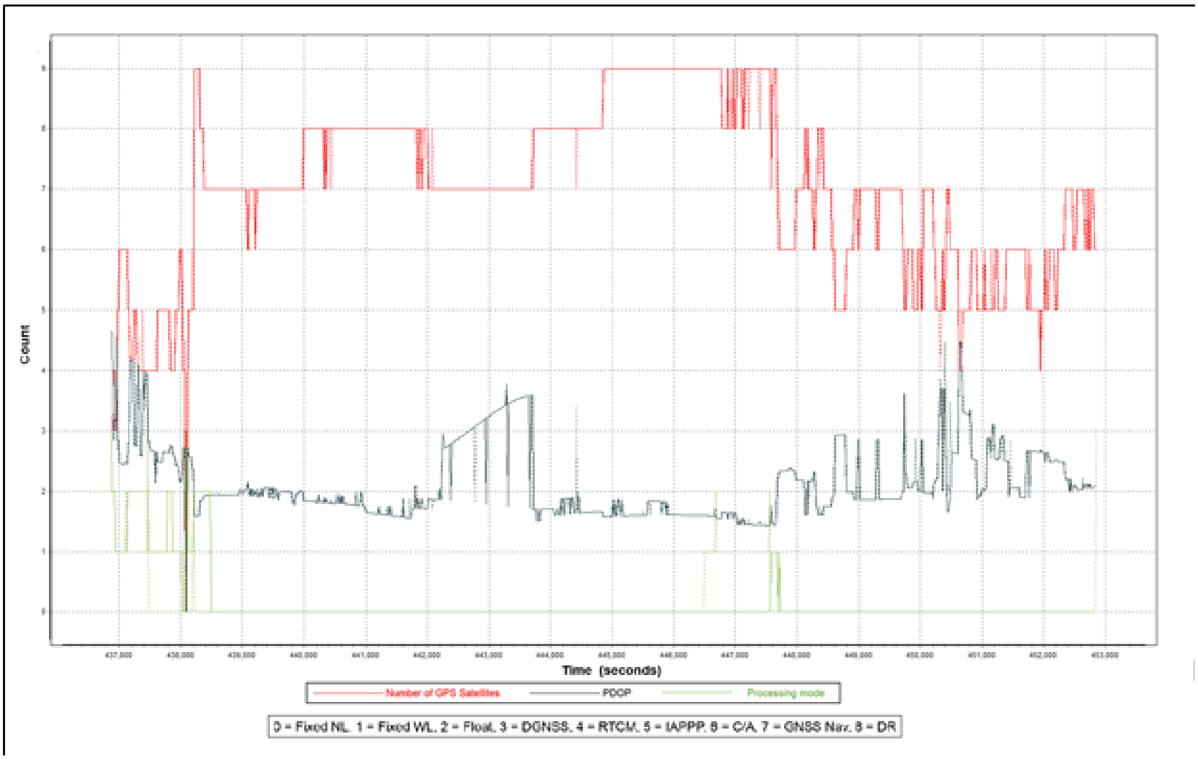


Figure 9. Solution Status Parameters of Batu Flight 23140P.

The Solution Statusparameters of flight 23140P,one of the Batuflights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Batu flights is shown in Figure 10.

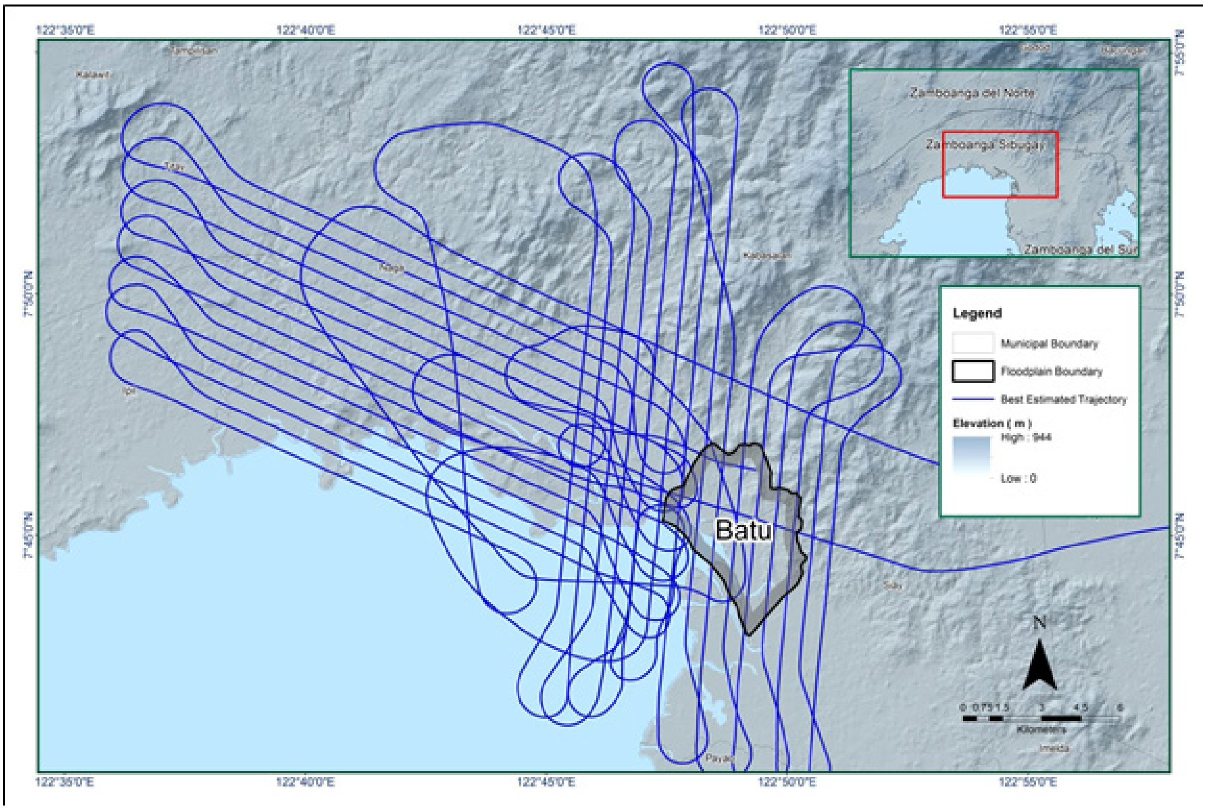


Figure 10. Best Estimated Trajectory of the LiDAR missions conducted over the Batu Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 25flight lines, with each flight line containing one channel, since the Pegasus systemcontainstwo channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Batu Floodplain are given in Table 8.

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

Parameter	Value
Boresight Correction stdev (<0.001degrees)	0.000236
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000494
GPS Position Z-correction stdev (<0.01meters)	0.0013

The optimum accuracy was obtained for all Batu flights based on the computed standard deviationsof the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8.

3.5 LiDAR Data Quality Checking

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

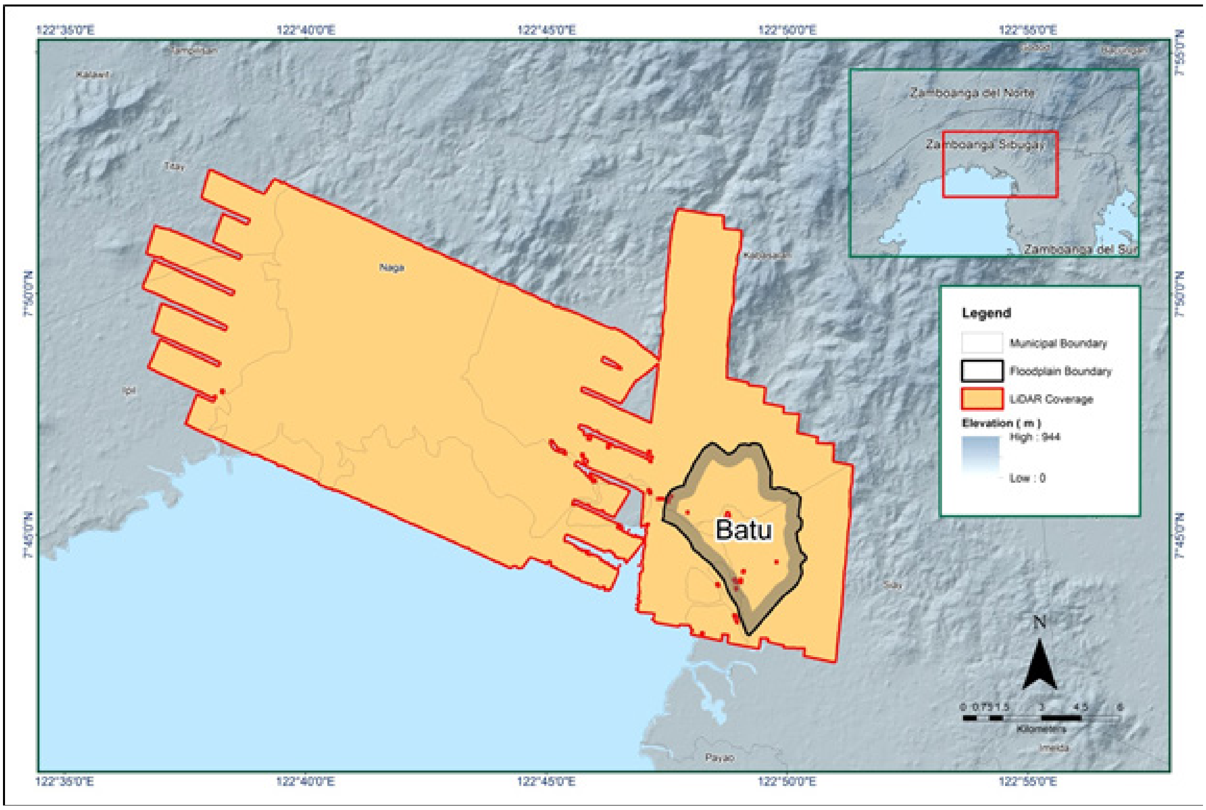


Figure 11. Boundary of the processed LiDAR data over Batu Floodplain

The total area covered by the Batu missions is 270.29 sq.km that is comprised of two (2) flight acquisitions grouped and merged into two (2) blocks as shown in Table B-2.

Table 9. List of LiDAR blocks for Batu Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Pagadian_Blk73A	23132P	184.47
Pagadian_Blk73B	23140P	85.82
TOTAL		270.29sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Pegasus system employ one channel, 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 are expected.

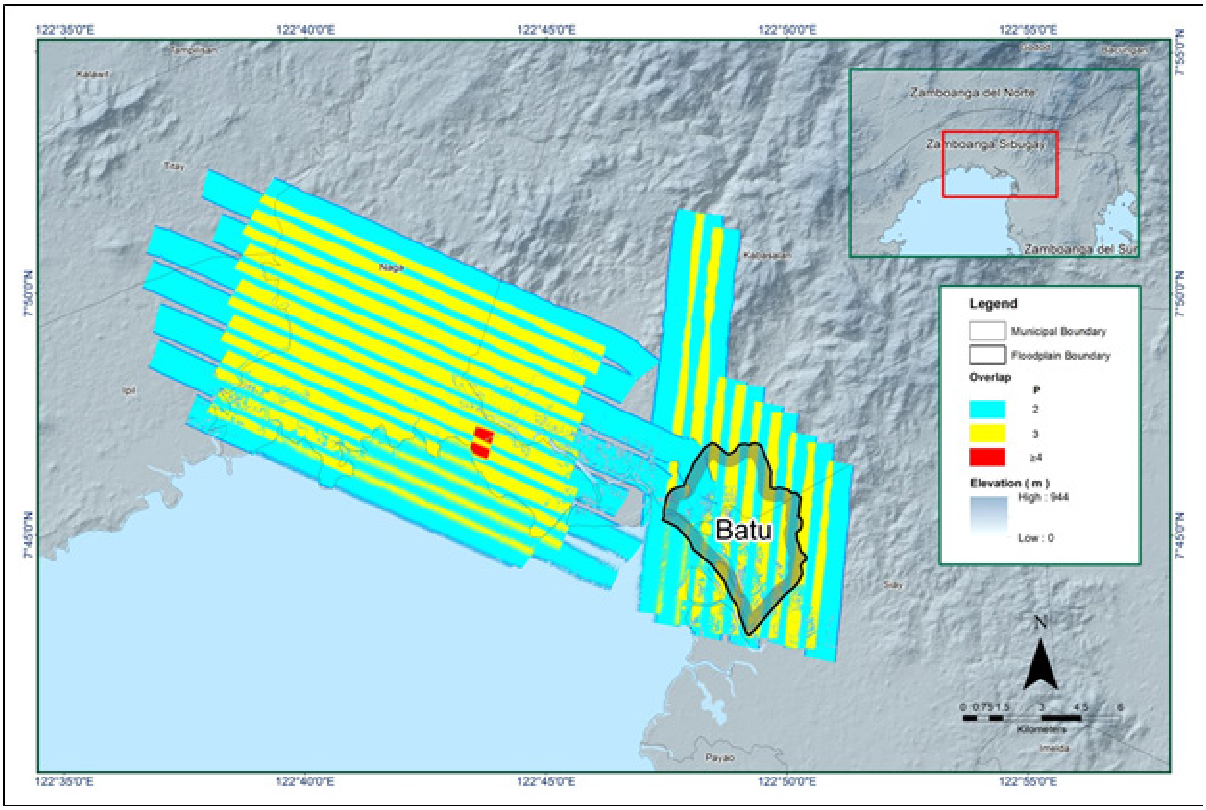


Figure 12. Image of data overlap for Batu Floodplain.

The overlap statistics per block for the Batu Floodplain can be found in Annex 5. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 39.42% and 45.26% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Batu Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.94 points per square meter.

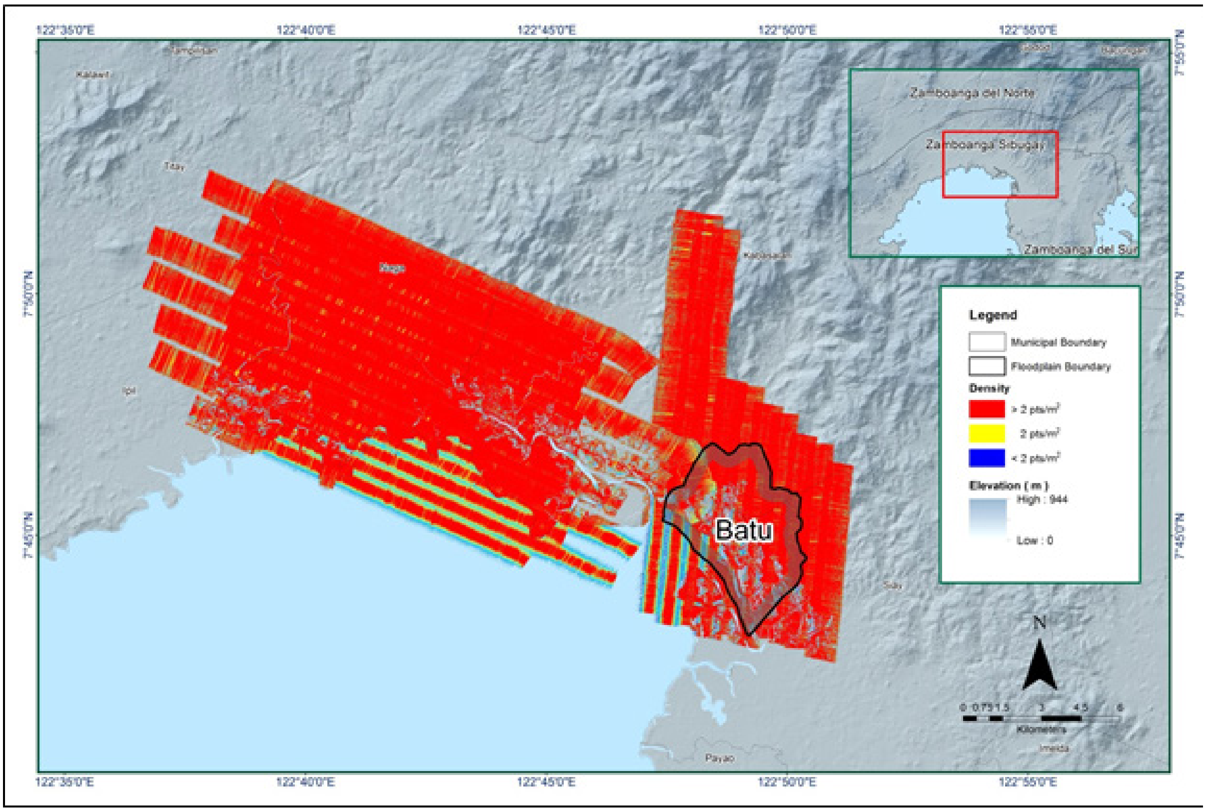


Figure 13. Pulse density map of merged LiDAR data for Batu floodplain.

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

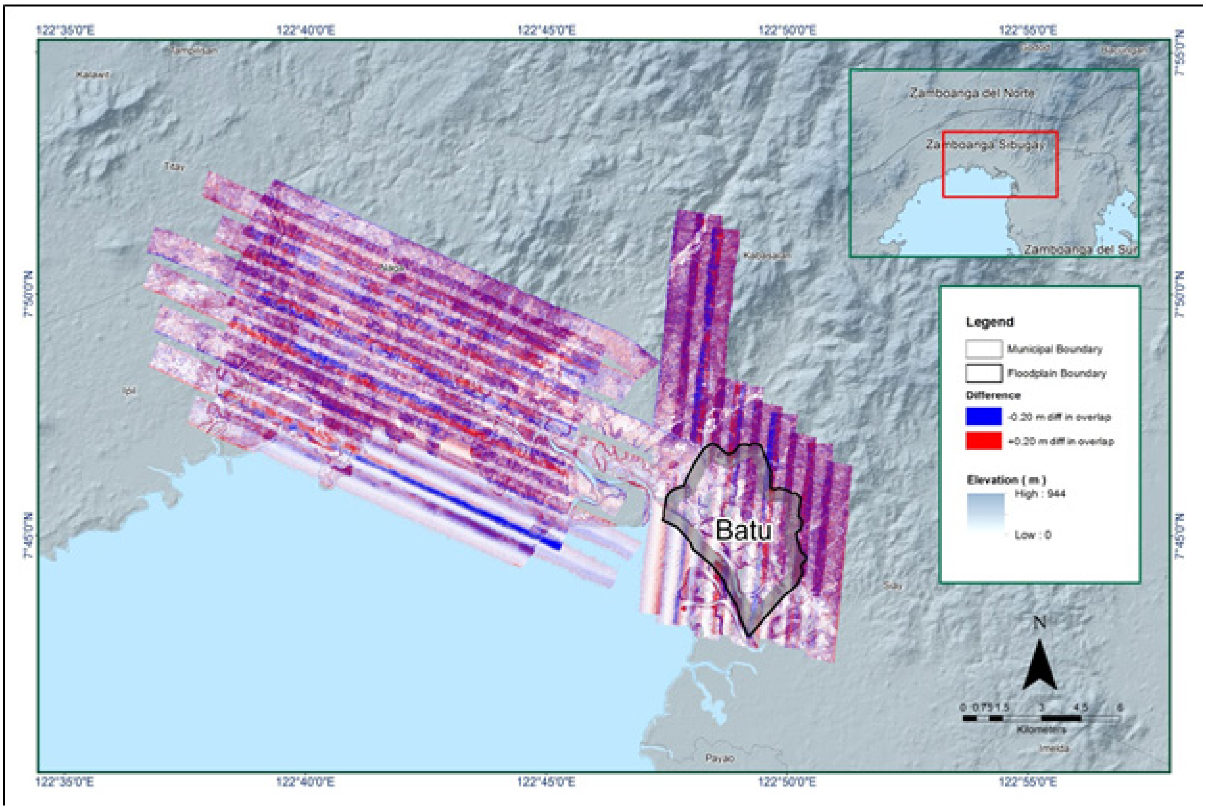


Figure 14. Elevation difference map between flight lines for Batu Floodplain

A screen capture of the processed LAS data from a Batuflight 23140P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

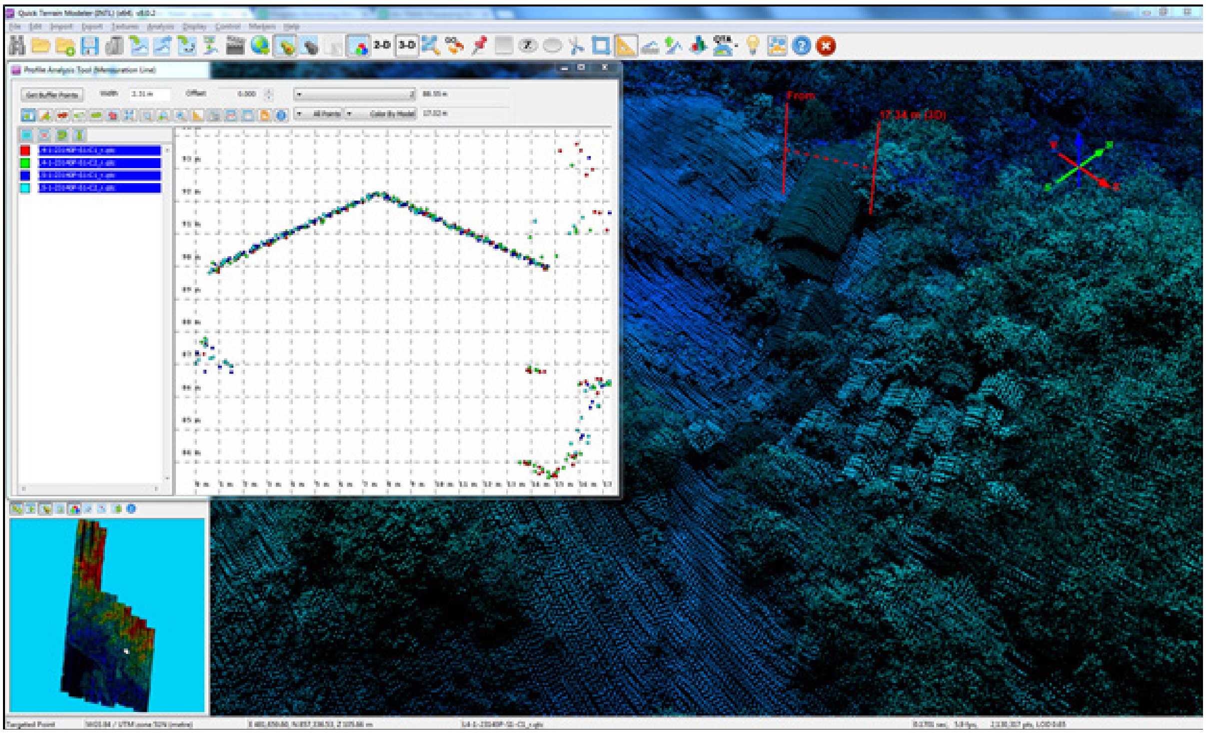


Figure 15. Quality checking for a Batu flight 23140P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Batuclassification results in TerraScan

Pertinent Class	Total Number of Points
Ground	217,756,024
Low Vegetation	180,235,040
Medium Vegetation	284,270,251
High Vegetation	777,109,182
Building	8,159,063

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Batu Floodplain is shown in Figure 16. A total of 351 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 512.68 meters and 58.38 meters respectively.

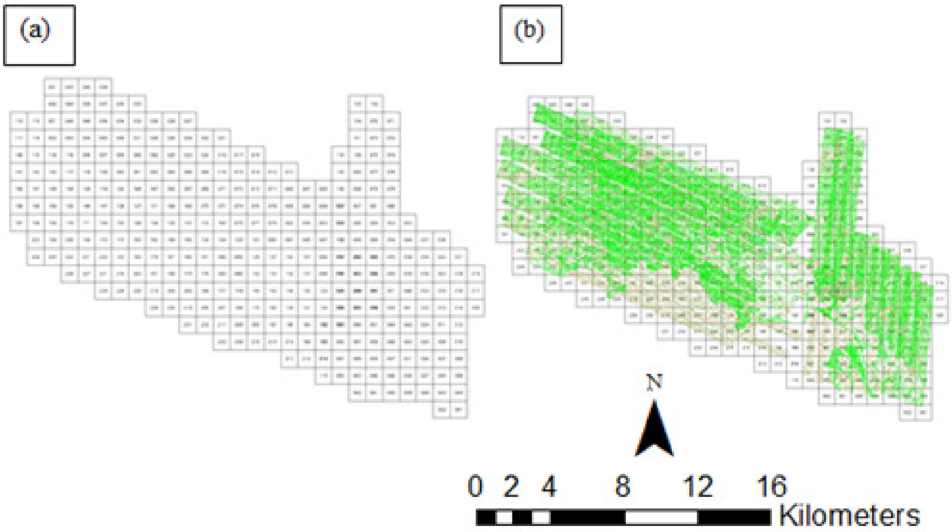


Figure 16. Tiles for Batu Floodplain (a) and classification results (b) in TerraScan.

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

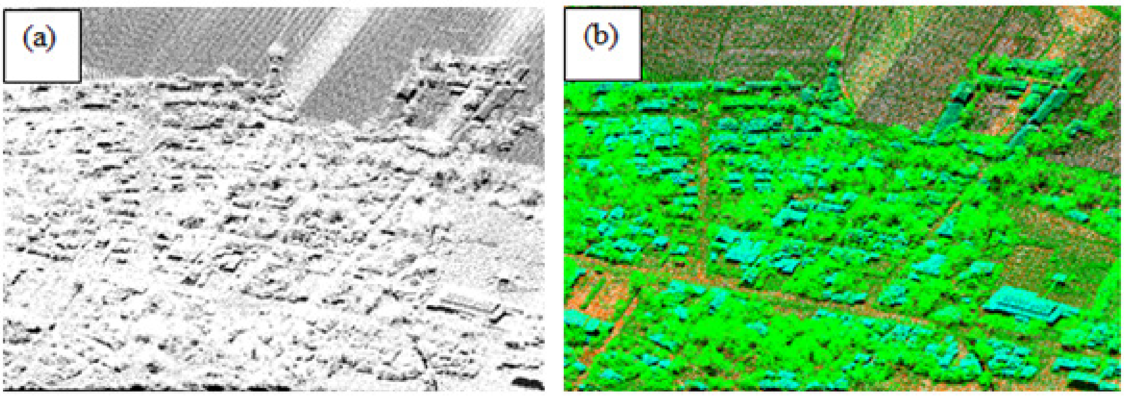


Figure 17. Point cloud before (a) and after (b) classification.

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

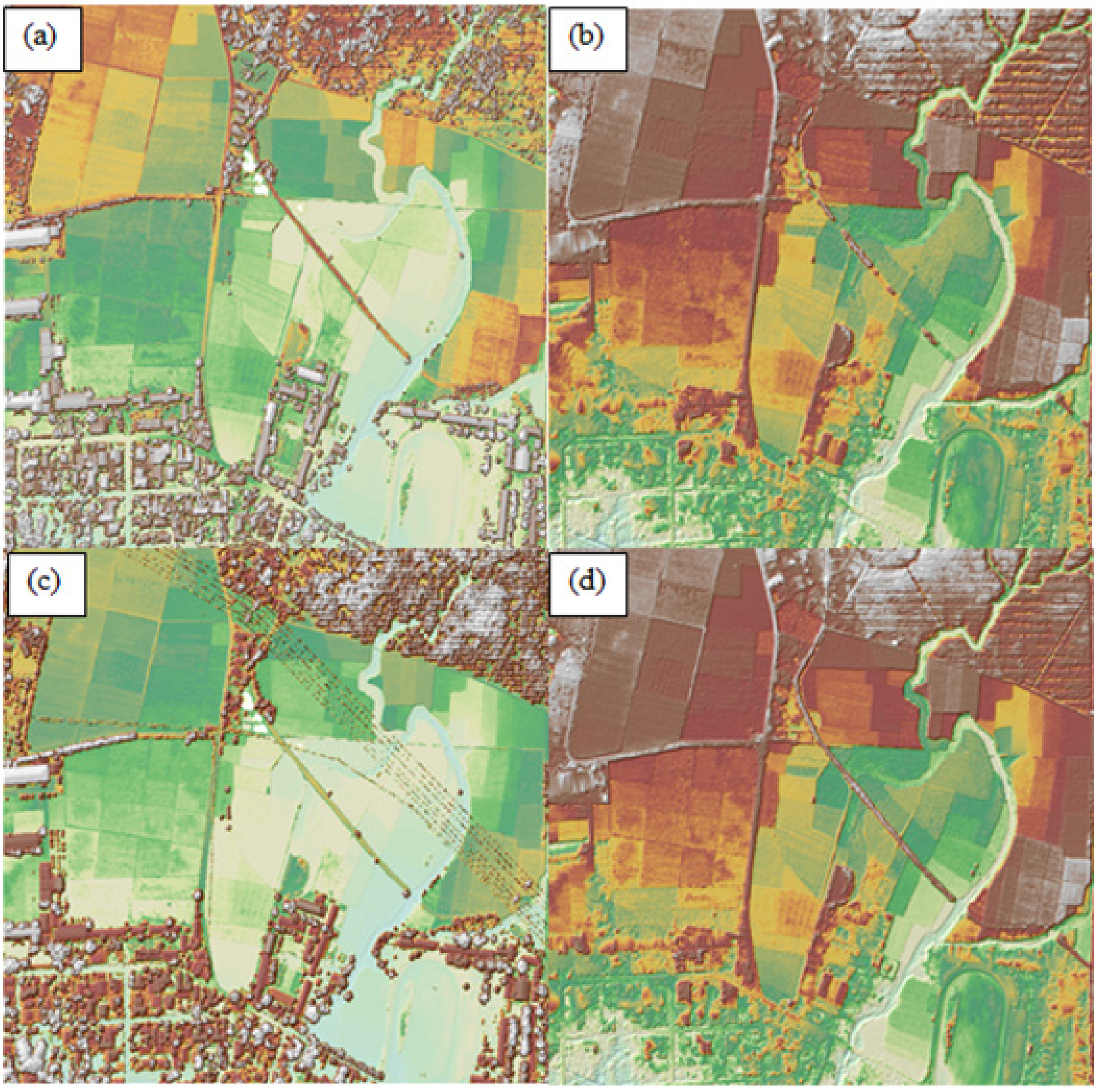


Figure 18. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Batu floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotograps for the Batu floodplain

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Batu Floodplain. These blocks are composed of Pagadian blocks with a total area of 270.29 sq. km. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Pagadian_Blk73A	184.47
Pagadian_Blk73B	85.82
TOTAL	270.29sq.km

Portions of DTM before and after manual editing are shown in Figure 19. The rice field or fishpond embankment (Figure 19a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19b) to allow the correct flow of water. The bridge (Figure 19c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 19d) in order to hydrologically correct the river.

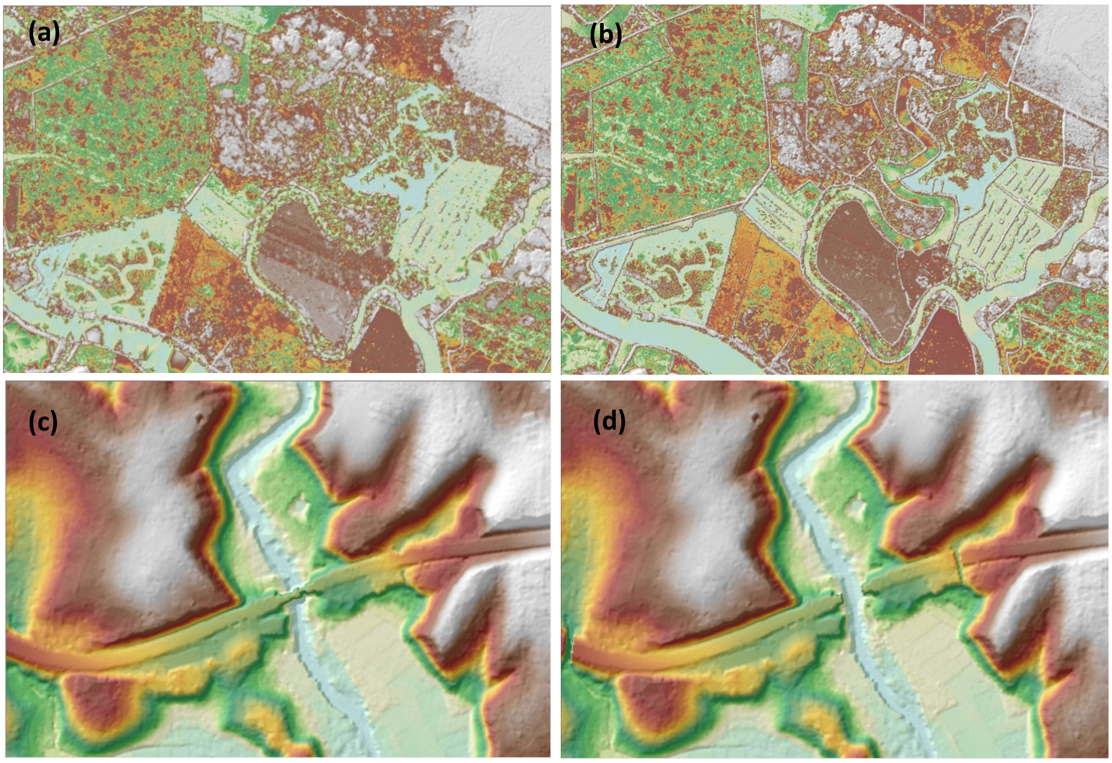


Figure 19. Portions in the DTM of Batu Floodplain – a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after manual editing (d).

3.9 Mosaicking of Blocks

Zamboanga_Blk75A was used as the reference block at the start of mosaicking. After which, Pagadian_ Blk73A and Pagadian_Blk73B were mosaicked to the reference block.

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

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

Mission Blocks	Shift Values (meters)		
	x	y	z
Pagadian_Blk73A	0.40	1.00	9.10
Pagadian_Blk73B	-3.00	1.00	9.30

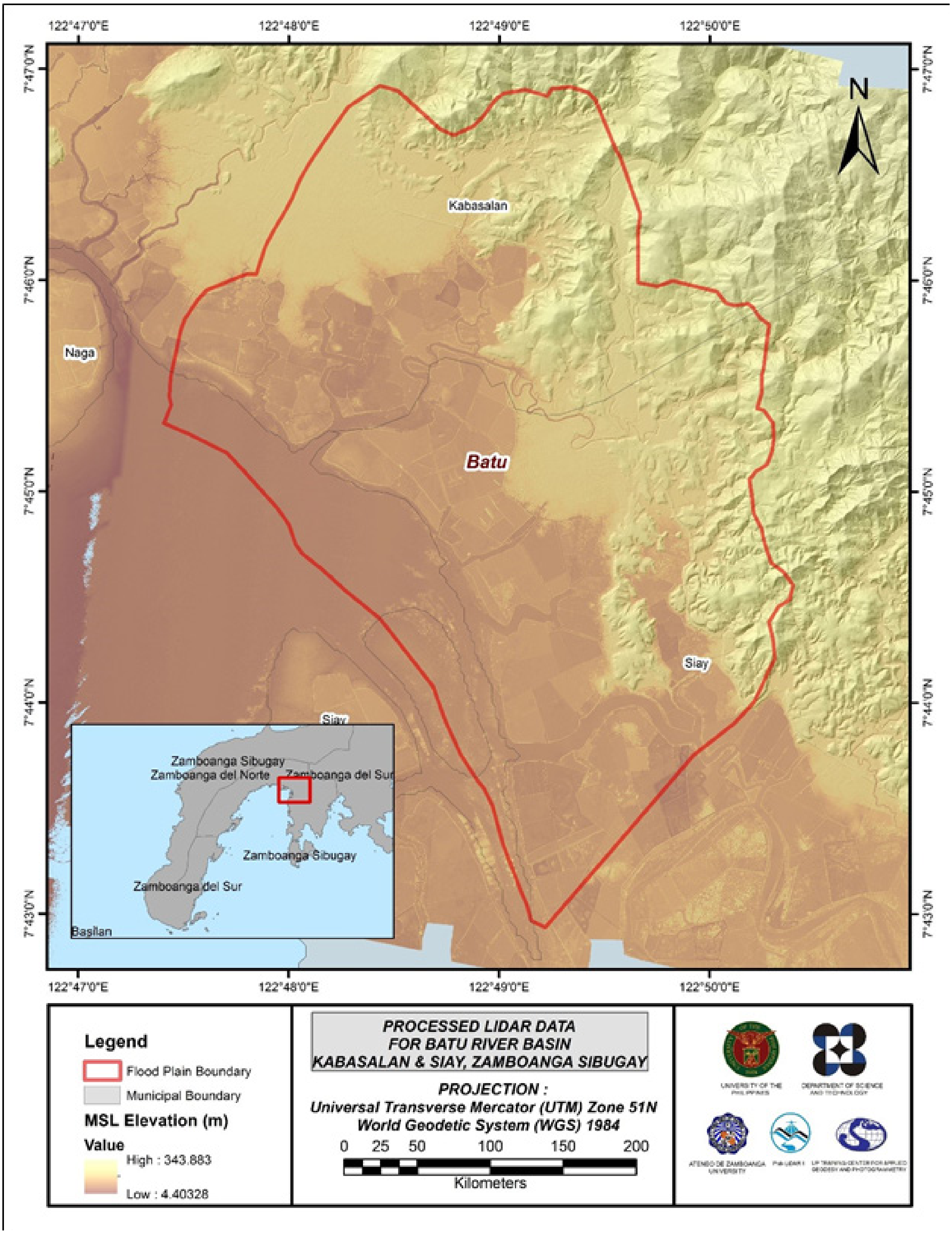


Figure 20. Map of Processed LiDAR Data for Batu Flood Plain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Batu to collect points with which the LiDAR dataset is validated is shown in Figure 21.

Simultaneous mosaicking was done for the Zamboanga_Pagadian LiDAR blocks and the only available data that time was for Sanito. The Batu Floodplain is included in the set of blocks previously mosaicked; therefore, the Sanito calibration data and methodology was used.

A total of 3526 survey points from Sanito data were used for calibration and validation of all the blocks of Zamboanga_Pagadian LiDAR data. Random selection of 80% of the survey points, resulting in 2820 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 9.1 meters with a standard deviation of 0.05 meters. Calibration for Zamboanga_Pagadian LiDAR data was done by adding the height difference value, 9.1 meters, to Zamboanga mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

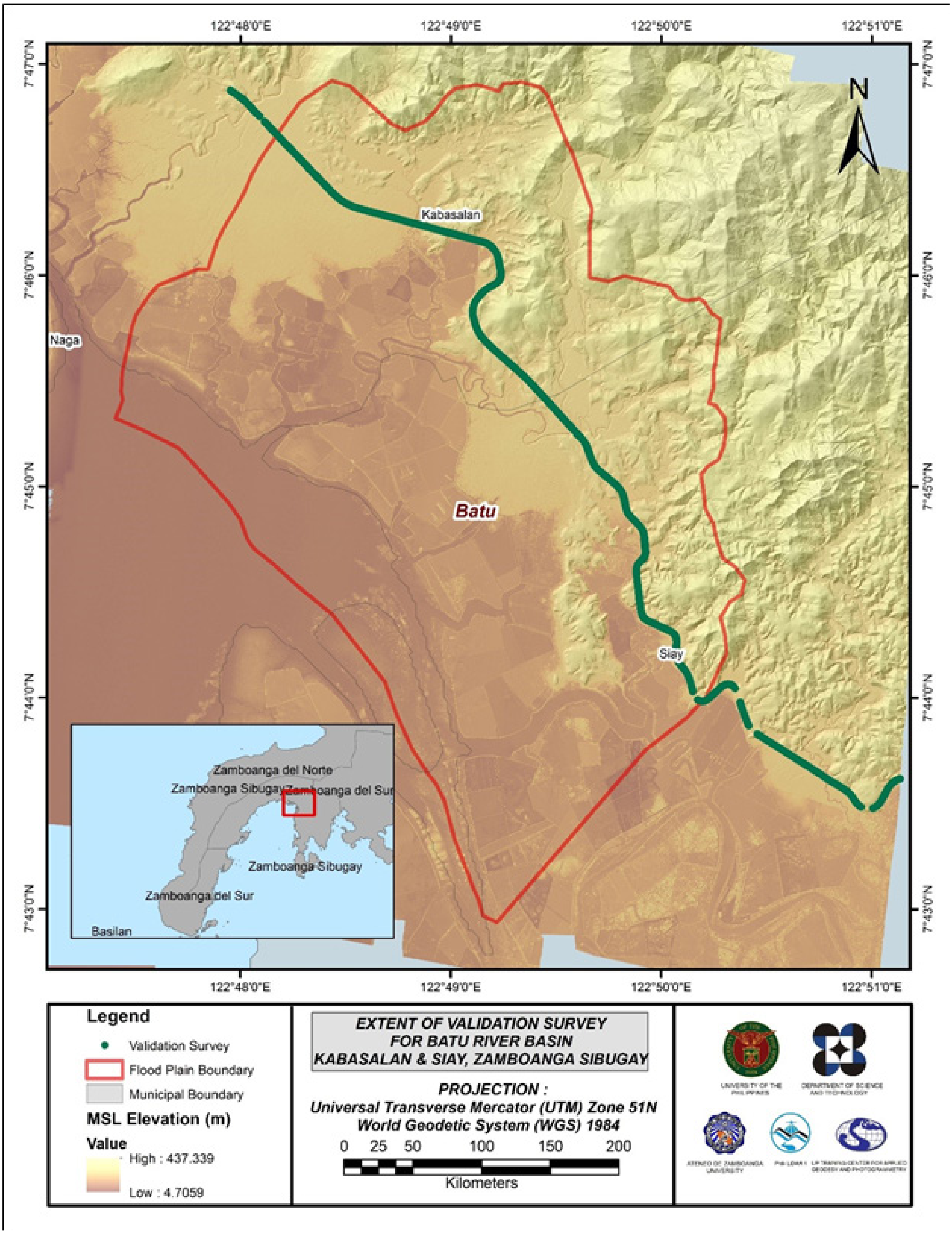


Figure 21. Map of BatuFlood Plain with validation survey points in green.

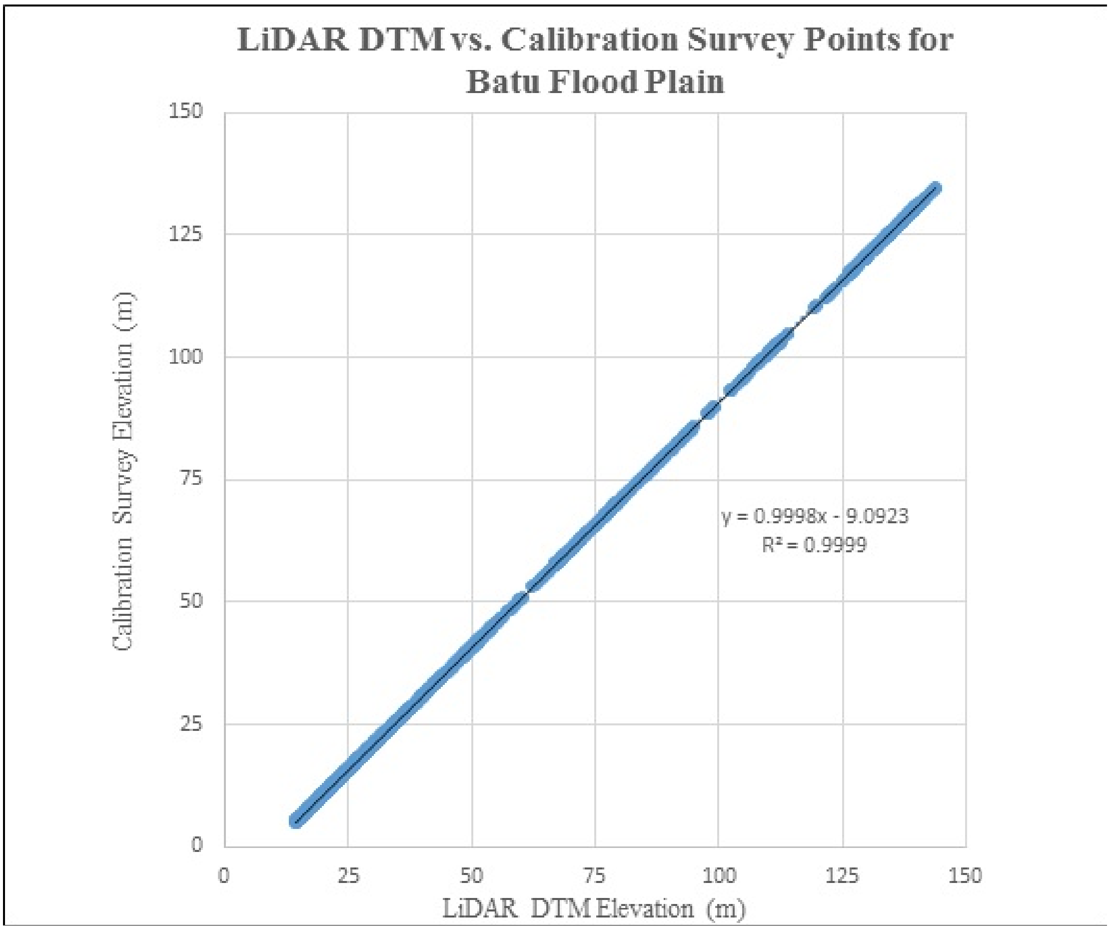


Figure 22. Correlation plot between calibration survey points and LiDAR data

Table 13. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	9.10
Standard Deviation	0.05
Average	9.10
Minimum	8.99
Maximum	9.20

The Batu Floodplain has a total of 1613 survey points and only 20% of the total survey points, resulting in 323 points, were randomly selected and used for the validation of calibrated Batu DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19 meters with a standard deviation of 0.11 meters, as shown in Table 14.

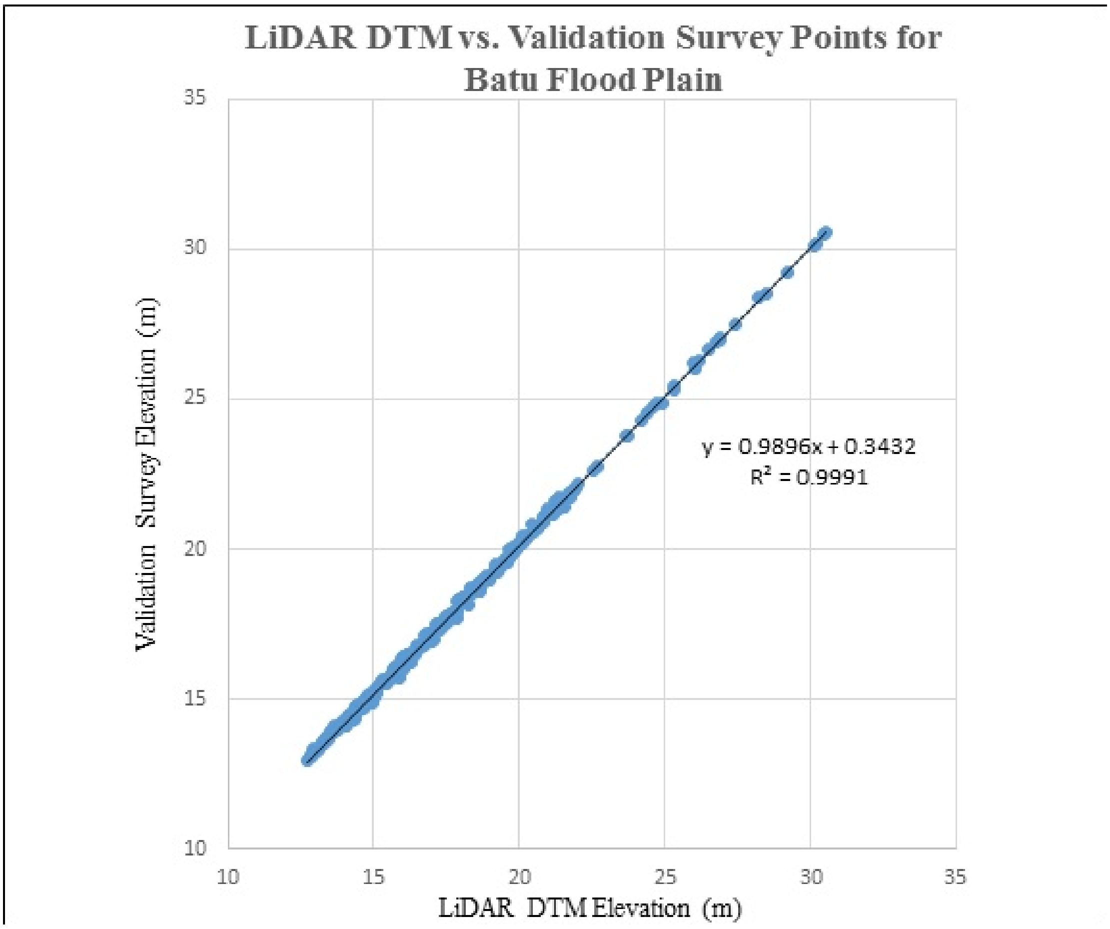


Figure 23. Correlation plot between validation survey points and LiDAR data

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.11
Average	-0.15
Minimum	-0.38

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Batu with 2,354 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 0.38 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Batu integrated with the processed LiDAR DEM is shown in Figure 24.

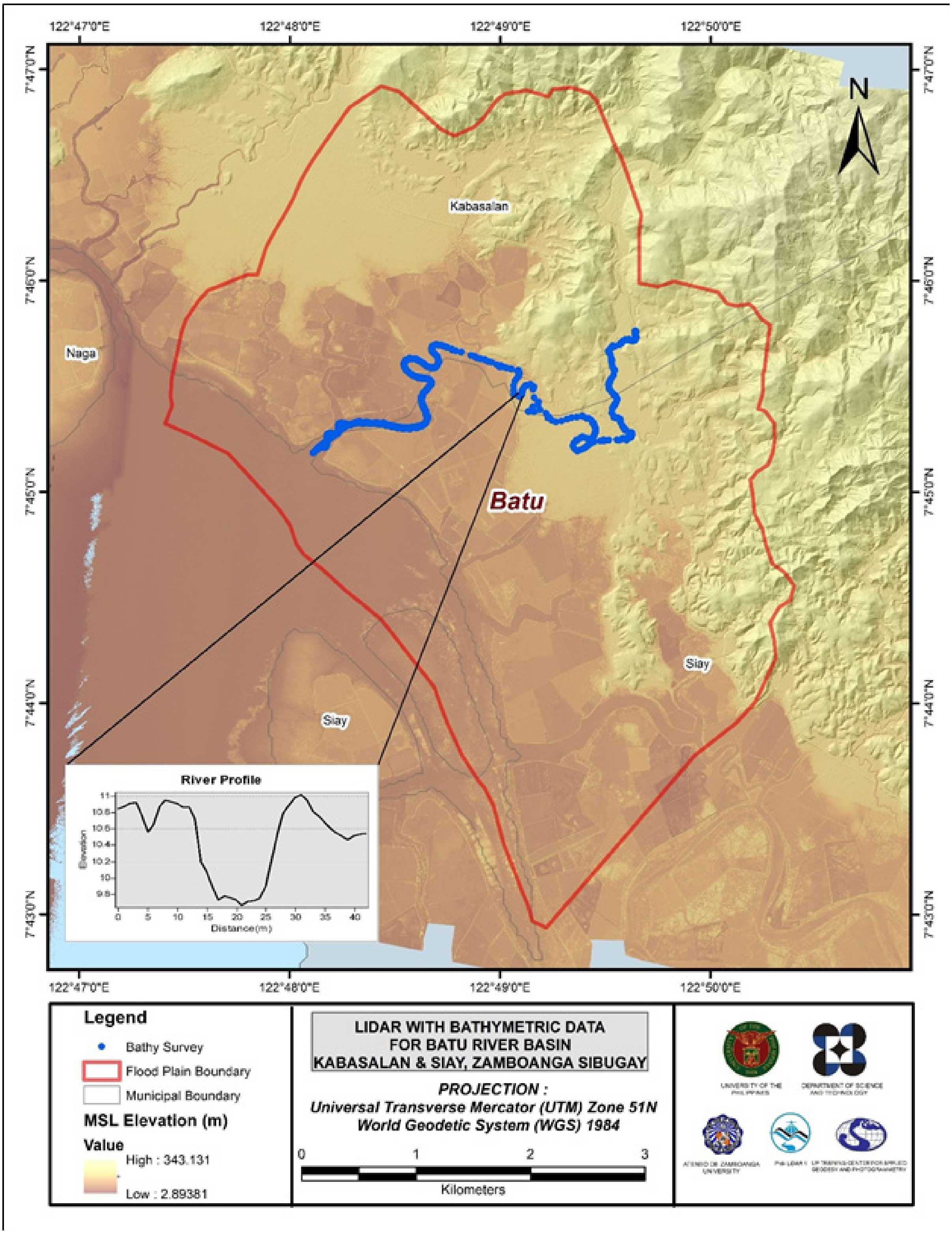


Figure 24. Map of Batu Floodplain with bathymetric survey points shown in blue.

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

3.12.1 Quality Checking of Digitized Features' Boundary

Batu Floodplain, including its 200 m buffer, has a total area of 27.16sq km. For this area, a total of 5.0 sq km, corresponding to a total of 669 building features, are considered for QC. Figure 25 shows the QC blocks for Batu Floodplain.

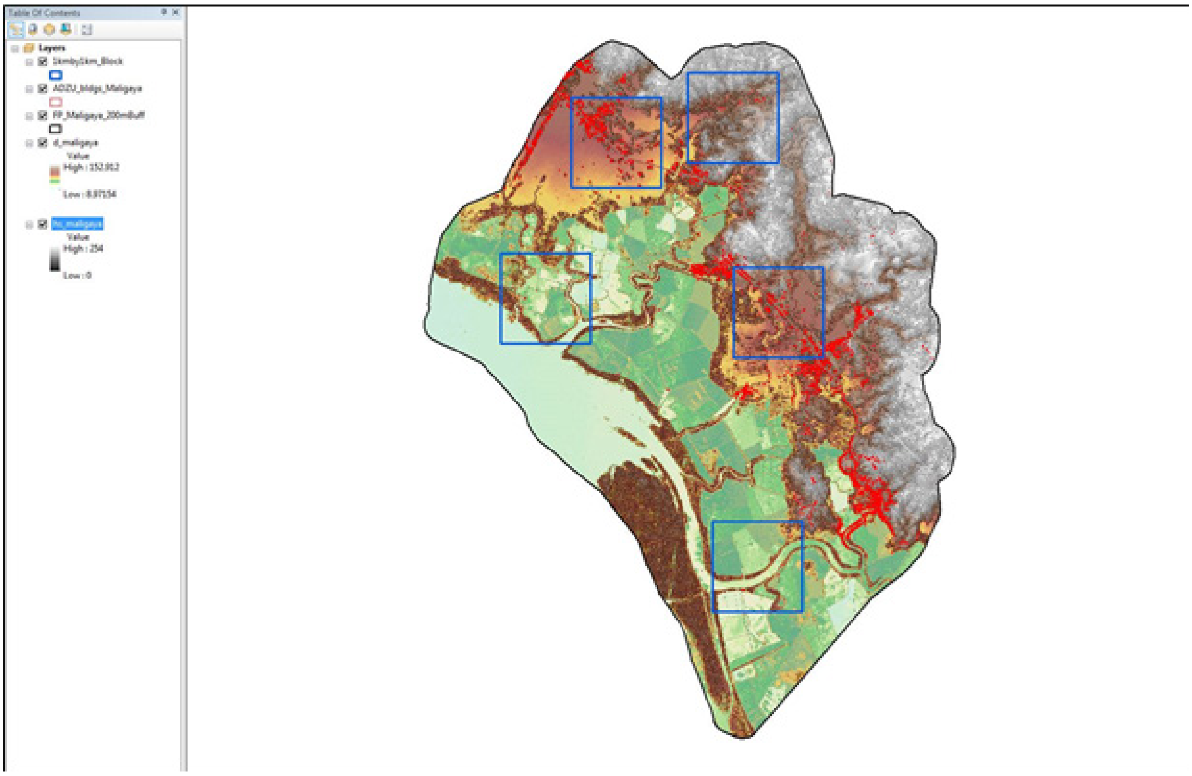


Figure 25. Blocks (in blue) of Batu building features that were subjected in QC.

Quality checking of Batubuilding features resulted in the ratings shown in Table 15.

Table 15. Quality Checking Ratings for Batu Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Batu	95.61	97.76	89.39	PASSED

3.12.2 Height Extraction

Height extraction was done for 3,136 building features in Batu Floodplain. Of these building features, 22 were filtered out after height extraction, resulting in 3,114 buildings with height attributes. The lowest building height is at 2.00 m while the highest building is at 5.33 m.

3.12.3 Feature Attribution

One of the Research Associates 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, through 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 floodplain of the river basin; likewise, the number of enumerators was also dependent on the availability of the tablet and the number of features of the flood plain.

Table 16 summarizes the number of building features per type. On the other hand, Table 17 shows the total length of each road type while Table 18 presents the number of water features extracted per type.

Table 16. Number of Building Features Extracted for Batu Floodplain.

Facility Type	No. of Features
Residential	2966
School	41
Market	22
Agricultural/Agro-Industrial Facilities	12
Medical Institutions	1
Barangay Hall	4
Military Institution	0
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	1
Transport Terminal	4
Warehouse	12
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	0
Water Supply/Sewerage	1
Religious Institutions	13
Bank	1
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	4
Other Commercial Establishments	28
Total	3114

Table 17. Total Length of Extracted Roads for Batu Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Batu	5.62	0.00	0.00	7.71	0.00	13.33

Table 18. Number of Extracted Water Bodies for Batu Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Batu	25	0	1	0	203	229

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

3.12.4 Final Quality Checking of Extracted Features

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

Figure 26 shows the Digital Surface Model (DSM) of Batu Floodplain overlaid with its ground features.

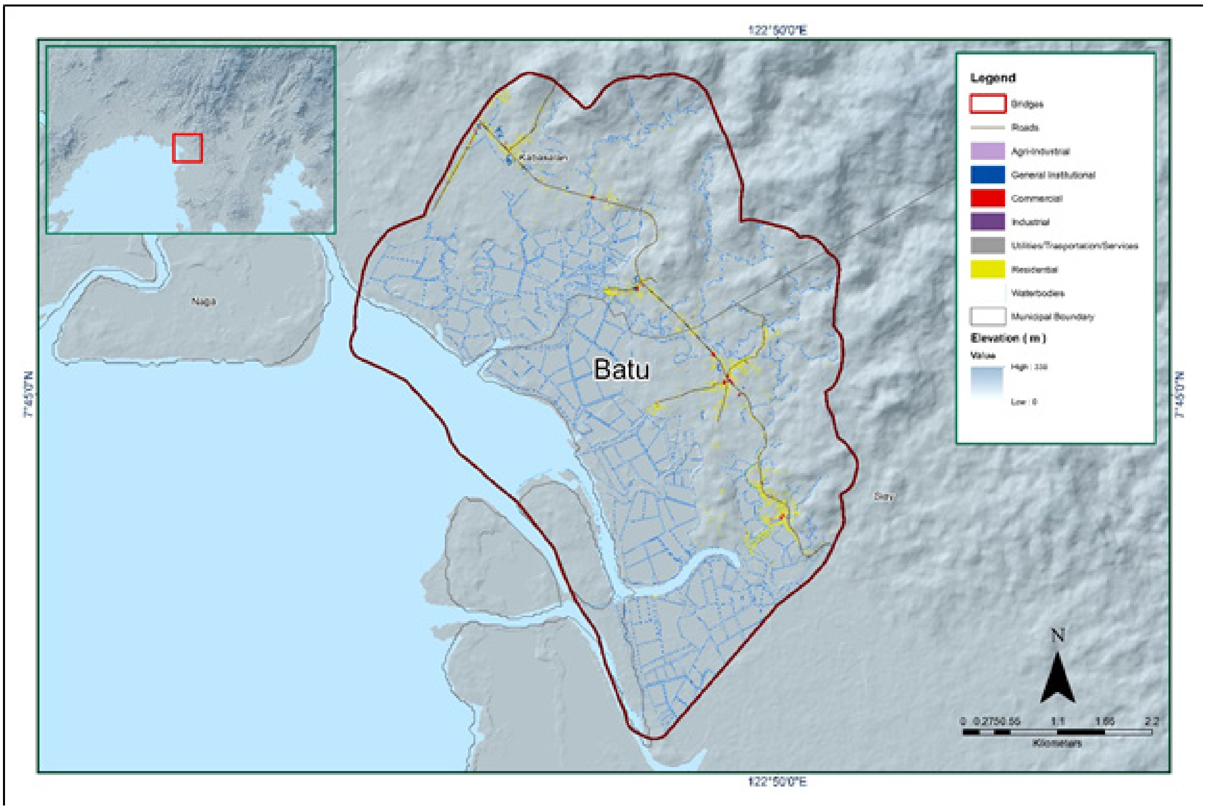


Figure 26. Extracted features for Batu floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T.

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

Fieldwork in Batu River was conducted on July 23 to August 7, 2015with the following objectives: courtesy call to Ateneo de Zamboanga Phil-LiDAR 1, DOST Regional Office 9, Philippine National Police and Municipal Mayor of Siay; static survey for the establishment of control point BAT at the approach of the bridge to be occupied as base station for GNSS surveys; cross-section, bridge as-built and water level markings Batu Bridge with coordinates Lat 7d45’14.71408”N and Long 1221d49’35.99360”E; LiDAR ground validation with estimated length of 24.7 km, and manual bathymetric survey of the river starting from the Batu Bridge then to Brgy. Nazareth down to Brgy. Calapan with a distance of approximately 6.7 km. The entire survey extent is illustrated in Figure 27.

Figure 27. Extent of the bathymetric survey (in blue line) in Batu River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Maligaya River Survey was composed of a single loop established on July 25, 2015 occupying the following reference point: ZSI-36, a second-order GCP in Brgy. Bacalan, Municipality of Ipil; and ZY-56, a first-order BM located in the Pagadian-Zamboanga National Road, Brgy. Sininan, Municipality of Kabasalan.

A UP established control point, BAT, established at the approach of Batu Bridge in Brgy. Batu, Siay, Zamboanga Sibugay was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 19 while the GNSS network established is illustrated in Figure 28.

Table 19. List of references and control points occupied inMaligayaRiver (Zamboanga Sibuguey) survey (Source: NAMRIA and UP-TCAGP)

Control point Name	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid	BM Ortho (m)	Date Established
ZSI-36	2nd Order, GCP	7°48'50.43692"	122°38'25.03291"	94.318	-	2006
ZY-56	1st Order, BM	-	-	74.265	6.187	2007
BAT	UP established	-	-	-	-	7-25-2015

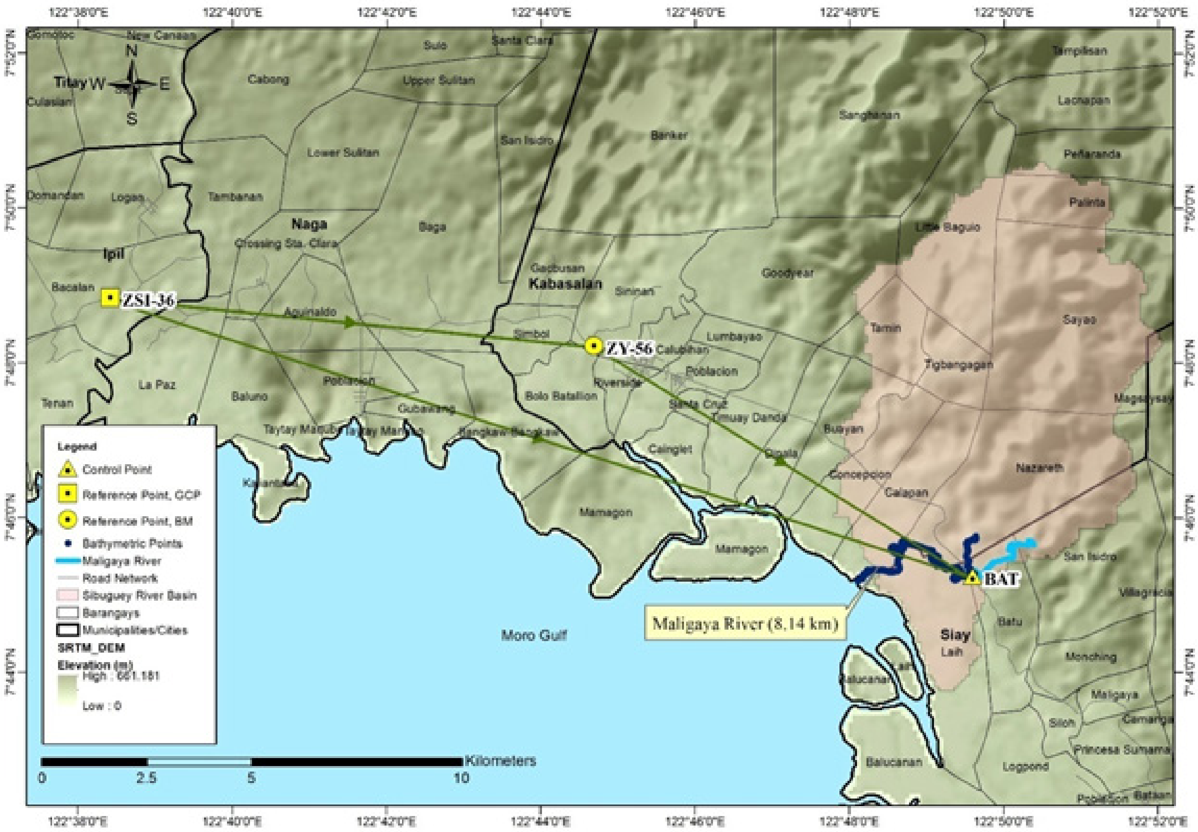


Figure 28. GNSS network covering theMaligayaRiver

The GNSS set up on the recovered reference points, ZSI-36 and ZY-56 are shown in Figure 29 and Figure 30, respectively, while the established control point BAT is shown in Figure 31.

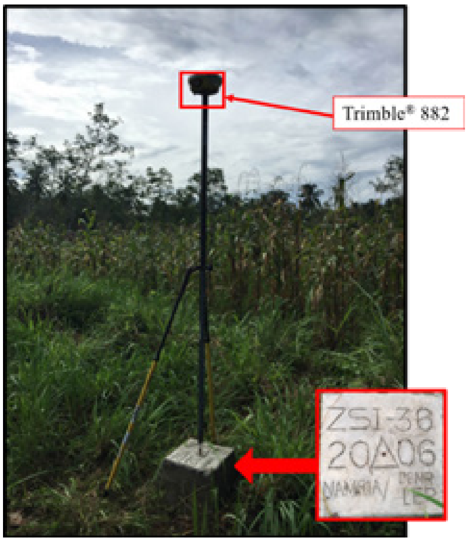


Figure 29. .GNSS receiver, Trimble® SPS 882 setup at reference point ZSI-36, in front of Iglesia Ni Cristo church along the National Highway, Brgy. Bacalan, Municipality of Ipil, Zamboaga Sibugay

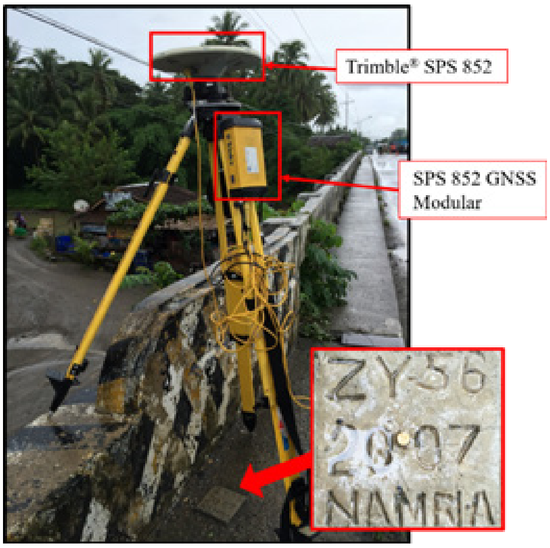


Figure 30. GNSS receiver, Trimble® SPS 852 set up at benchmark ZY-56, along the Pagadian-Zamboanga National Road at the end of Kabasalan Bridge, Brgy. Sininan, Municipality of Kabasalan, Zamboanga Sibugay

Figure 31. GNSS receiver, Trimble® SPS 852 setup at control point BAT, at Batu Bridge in Brgy. Batu, Municipality of Siay, Zamboanga Sibugay along the PAN-Philippine National Highway

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 is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points used in Maligaya River Basin survey is summarized in Table 20, generated by TBC software.

Table 20. Baseline processing report for Batu River control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZSI-36 --- BAT	7-25-2015	Fixed	0.005	0.018	107°51'19"	21599.394	-16.664
ZY-56 --- BAT	7-25-2015	Fixed	0.006	0.036	121°17'34"	10564.198	3.299
ZY-56 --- ZSI-36	7-25-2015	Fixed	0.007	0.025	95°38'06"	11586.285	-20.046
ZSI-36 --- BAT	7-25-2015	Fixed	0.005	0.027	107°51'19"	21599.364	-16.684
ZY-56 --- BAT	7-25-2015	Fixed	0.007	0.027	121°17'34"	10564.225	3.373

Three control points, ZSI-36, ZY-56 and BAT were occupied and observed simultaneously to form a GNSS loop. All 3 baselines acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively as shown in Table 20.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 21 to Table 24 for complete details.

The three control points, ZSI-36, ZY-56 and BAT were occupied and observed simultaneously to form a GNSS loop. Coordinates of ZSI-36; and elevation value of ZY-56 was held fixed during the processing of the control points as presented in Table 21. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 21. Control Point Constraints

Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZSI-36	Local	Fixed	Fixed	
ZY-56	Grid			
Fixed = 0.000001(Meter)				

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 22. The fixed control ZSi-36 has no values for grid errors while ZY-56 has no value for elevation errors.

Table 22. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BAT	480887.313	0.011	857115.876	0.008	9.534	0.078	
ZSI-36	460341.900	?	863753.414	?	26.102	0.080	LL
ZY-56	471866.790	0.013	862606.340	0.009	6.187	?	e

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

ZSI-36
Horizontal accuracy = fixed
Vertical accuracy = 8.0 cm < 10 cm

ZY-56
horizontal accuracy = $\sqrt{((1.3)^2 + (0.9)^2)}$
= $\sqrt{(1.69 + 0.81)}$
= 1.58 < 20 cm
vertical accuracy = fixed

BAT
horizontal accuracy = $\sqrt{((1.1)^2 + (0.8)^2)}$
= $\sqrt{(1.21 + 0.64)}$
= 1.36 cm < 20 cm
vertical accuracy = 7.8 cm < 10 cm

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

Table 23. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
AT	N7°45'14.71408"	E122°49'35.99365"	77.600	0.078	
ZSI-36	N7°48'50.43692"	E122°38'25.03291"	94.318	0.080	LL
ZY-56	N7°48'13.35741"	E122°44'41.37797"	74.265	?	e

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

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

Table 24. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZSI-36	2nd order, GCP	7°48'50.43692"	122°38'25.03291"	94.318	863753.414	460341.900	26.102
ZY-56	1st order, BM	7°48'13.35741"	122°44'41.37797"	74.265	862606.340	471866.790	6.187
BAT	UP Established	7°45'14.71408"	122°49'35.99365"	77.600	857115.876	480887.313	9.534

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

Cross-section and as-built survey were conducted on July 28, 2015 along the downstream side of Batu Bridge in Brgy. Batu, Municipality of Siay using aGNSS receiver, Trimble® SPS 882 in PPK survey technique as shown inFigure 32. Bridge as-built features determination was also performed to get the distance of piers and abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high chord and meter tapes to get its low chord elevation.

Figure 32. Cross-section and bridge as-built survey for Batu Bridge, Brgy. Batu, Zamboanga Sibugay

The cross-sectional line for the Batu Bridge is about 36.60 meters with 49 cross-sectional points gathered using BAT as the GNSS base station. The summary of gathered cross-section, location map, and as-built data for Batu Bridge are shown in Figure 33 to Figure 35, respectively.

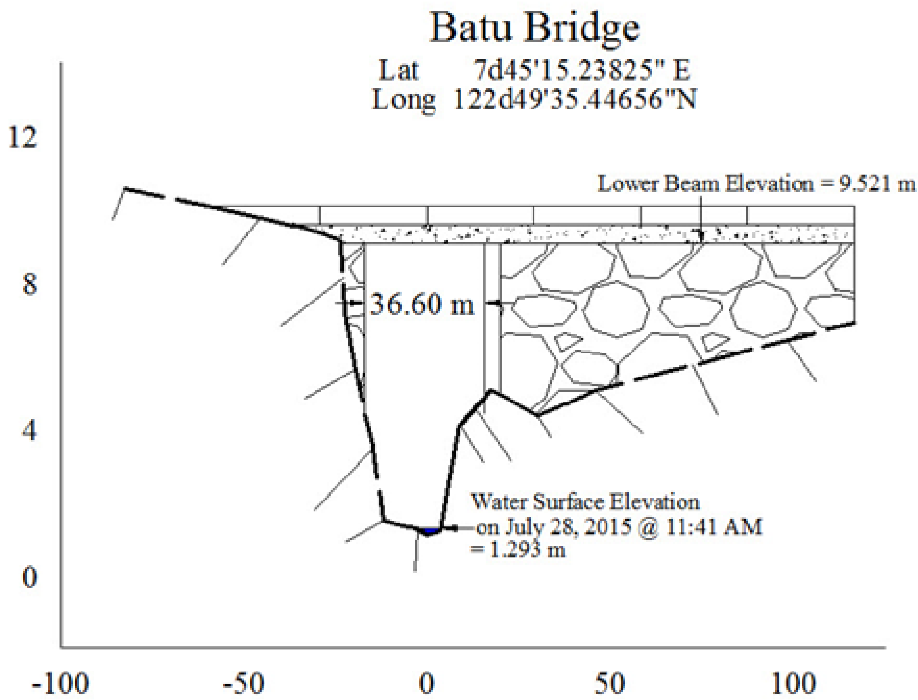


Figure 33. Batu Bridge cross-sectional diagram

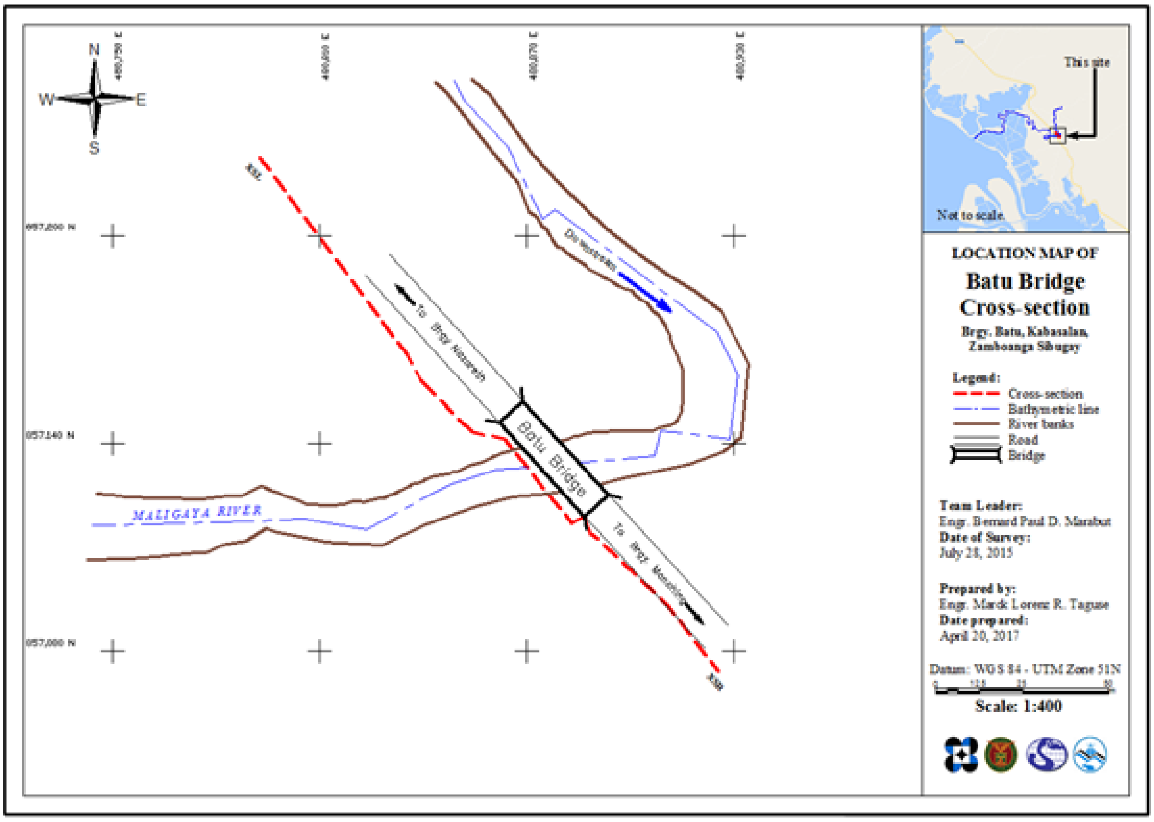


Figure 34. Batu bridge cross-section location map

Bridge Data Form

Bridge Name: Batu Bridge | Date: July 28, 2015

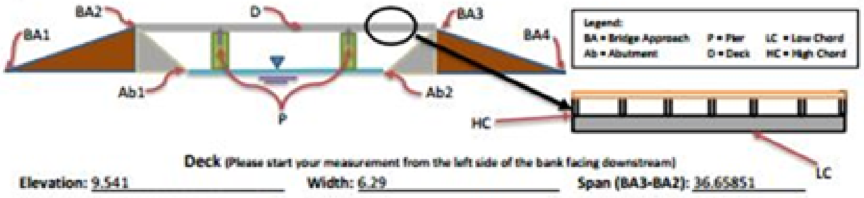
River Name: Maligaya River | Time: 1:42 P.M.

Location (Brgy, City, Region): Barangay Batu, Siay, Zamboanga Sibugay

Survey Team: Team Bernard

Flow condition: low (normal) high | Weather Condition: (fair) rainy

Latitude: 7d45'14.71408" | Longitude: 122d49'35.99360"



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

Elevation: 9.541 | Width: 6.29 | Span (BA3-BA2): 36.65851

	Station	High Chord Elevation	Low Chord Elevation
1		12.323	11.088
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	10.838	BA3	95.785	8.922
BA2	59.12649	9.81	BA4	198.7378	7.182

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

	Station (Distance from BA1)	Elevation
Ab1	60.11179	7.122
Ab2	96.13028	6.424

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

Shape: ______ Number of Piers: 0 Height of column footing: ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 35. Batu Bridge Data Form

Water surface elevation in MSL of Batu River was determined using Trimble® SPS 882 in PPK mode survey on July 28, 2015 at 11:41 A.M. This was translated onto marking the bridge's pier using a digital level. The marked pier shall serve as reference for flow data gathering and depth gauge deployment by AdZU, the accompanying HEI, responsible for Batu River (see Figure 36).

Figure 36. Water level markings on the post of Batu Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on July 28, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached in front of the vehicle as shown in Figure 37. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.293 from the ground up to the bottom of notch of the GNSS Rover receiver.

The survey was conducted using PPK technique on a continuous topography mode, which started from Brgy. Israel, Municipality of Imelda to Brgy. Buayan, Municipality of Kabasalan. A total of 3,653 validation points covering an approximate distance of 24.7km were gathered as shown in Figure 38. The gaps in the validation line as were due to some difficulties in acquiring satellite due to the presence of obstruction such as dense canopy cover of trees along the roads.

Figure 37. Trimble® SPS882 set-up for validation points acquisition survey for Maligaya River

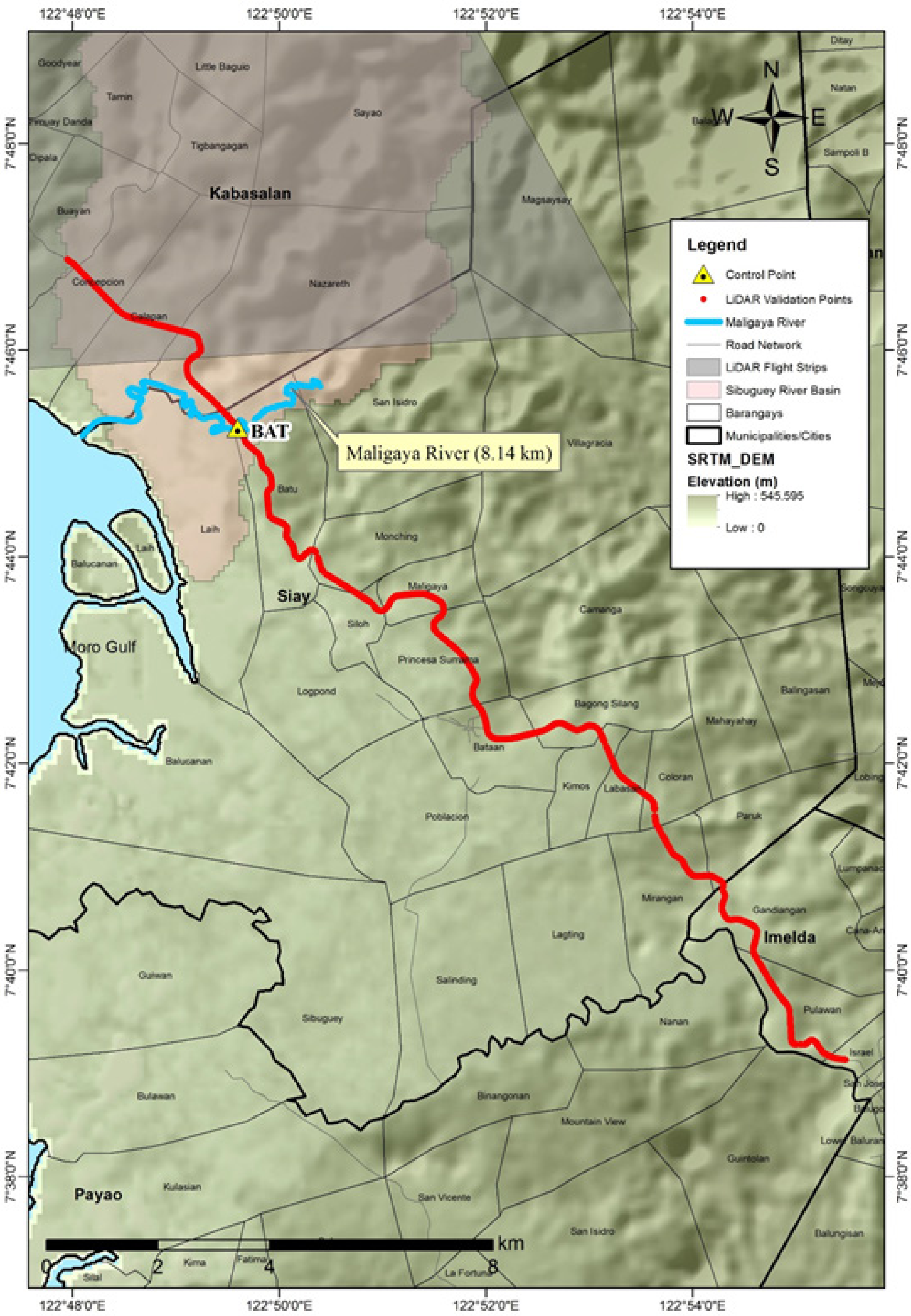


Figure 38. LiDAR ground validation survey coverage for Sibuguey River Basin.

4.7 Bathymetric Survey

Bathymetric survey was conducted on August 04, 2015 using Trimble® SPS 882 in GNSS PPK Survey technique and an OHMEX™ Single beam echosounder mounted on a boat as shown in Figure 39. The survey started in Brgy. Kalapan, Municipality of Kabasalan with coordinates 7°45'41.16264"122°48'44.57890", and ended at the mouth of the river in Bry. Laih, also in Kabasalan with coordinates 7°45'11.04721"122°48'06.63301".

Figure 39. Bathymetric Survey with echosounder in Batu River

Manual bathymetric survey was conducted on July 28, 2015using Trimble® SPS 882 in GNSS PPK Survey technique as shown in Figure 40. The survey began from the upstream part of the river in Brgy. Nazareth, Municipality of Kabasalan with coordinates 7°45'45.66979"122°49'38.45183", traversed the river by foot, and ended at the starting point of bathymetric survey using boat. The control point BAT was used as the GNSS base station all throughout the survey.

Figure 40. Manual Bathymetric survey in Batu River: (a) upstream and (b) downstream.

The entire bathymetric data is 8.14 km with 1,044 bathymetric points covering Batu Bridge to Brgy. Nazareth down to Brgy. Calapan as shown in Figure 42. A CAD drawing was also produced to illustrate the riverbed profile. As shown in Figure 42, an elevation drop of 9 meters in MSL was observed within the distance of approximately 6.7 km. The highest elevation observed was 8.413 m in MSL found 1 km down the Batu Bridge, while the lowest elevation observed was -4.504 m below MSL found 1.5 m from the mouth of the river.

Figure 41. Bathymetric survey of Batu River

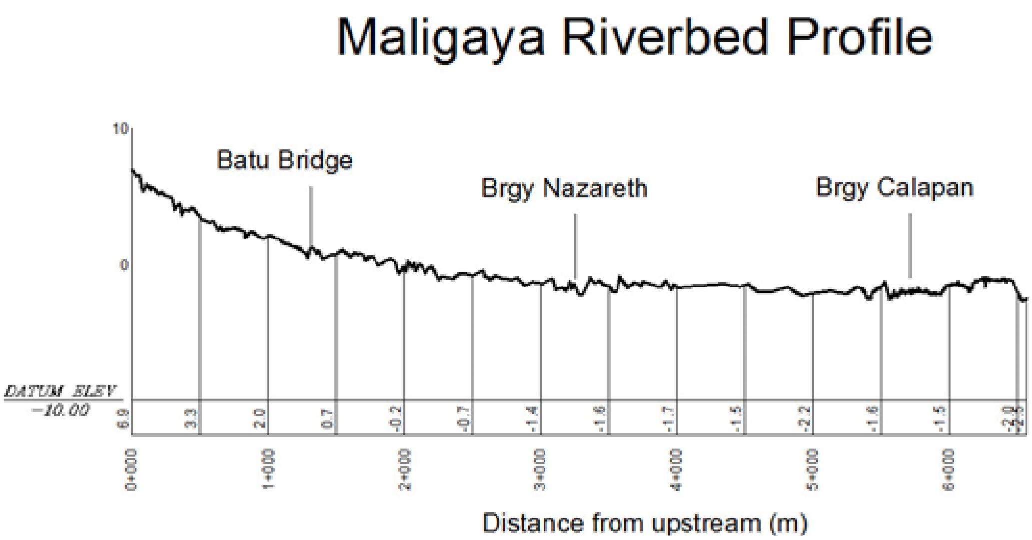


Figure 42. Riverbed profile of Batu River.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the Batu 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 Batu River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. Batu, Siay, Zamboanga Sibugay(7° 45' 15.31" N, 122° 49' 35.76" E). (Figure 43). The precipitation data collection started from October12, 2016 at 12:00 AMto October14, 2016 at 12:00AM with 10 minutes recording interval.

The total precipitation for this event inBrgy. Batu was 24.0 mm. It has a peak rainfall of 4.6 mm. on October12, 2016 at 7:20 AM. The lag time between the peak rainfall and discharge is 7 hours and 10 minutes.

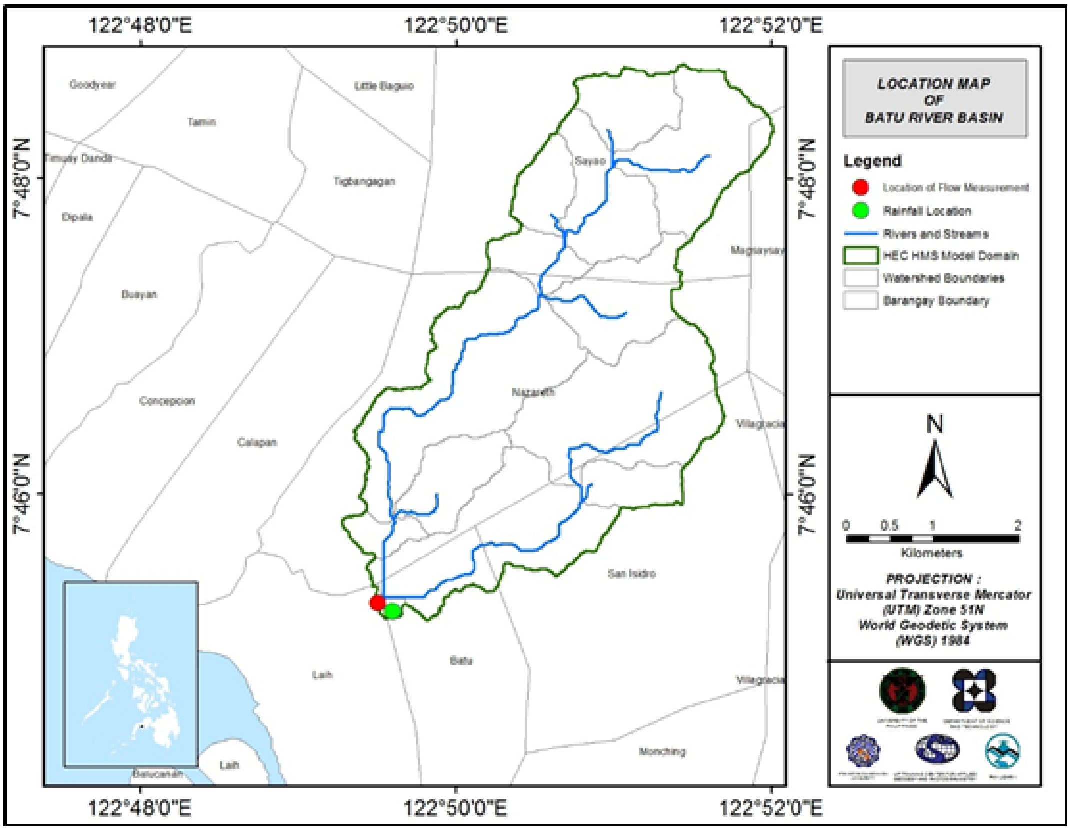


Figure 43. The location map of Batu HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Batu Bridge, Brgy. Batu, Siay, Zamboanga Sibugay(7° 45' 15.45" N, 122° 49' 35.73" E). It gives the relationship between the observed water levels at Batu Bridgeand outflow of the watershed at this location.
For Batu Bridge, the rating curve is expressed as Q = 3E-34e1.0694h as shown in Figure 45.

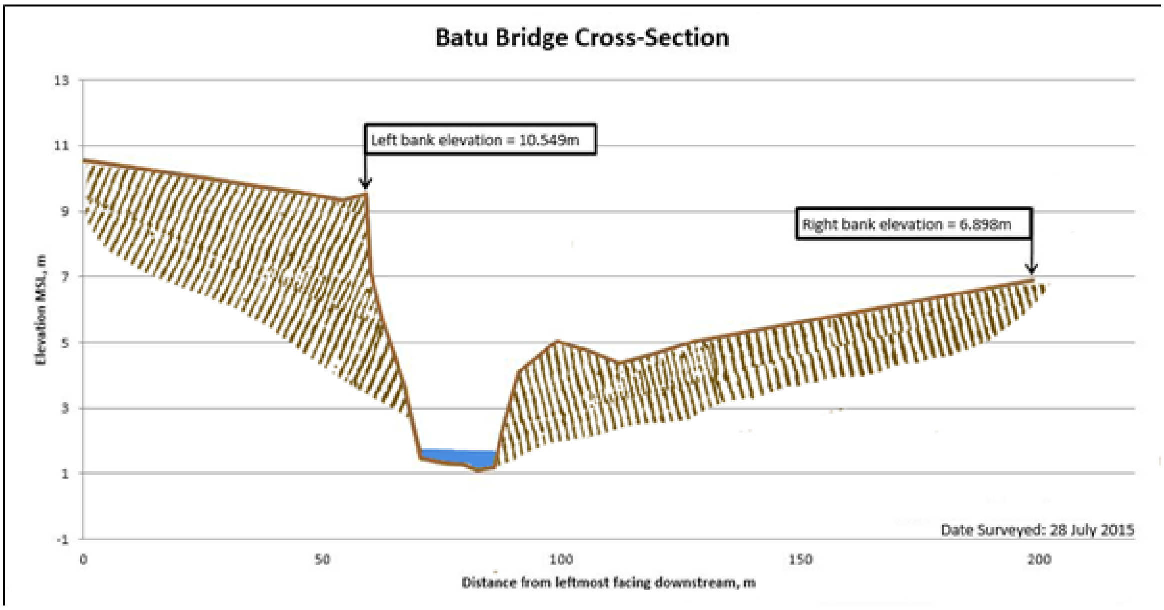


Figure 44. Cross-Section Plot of Batu Bridge

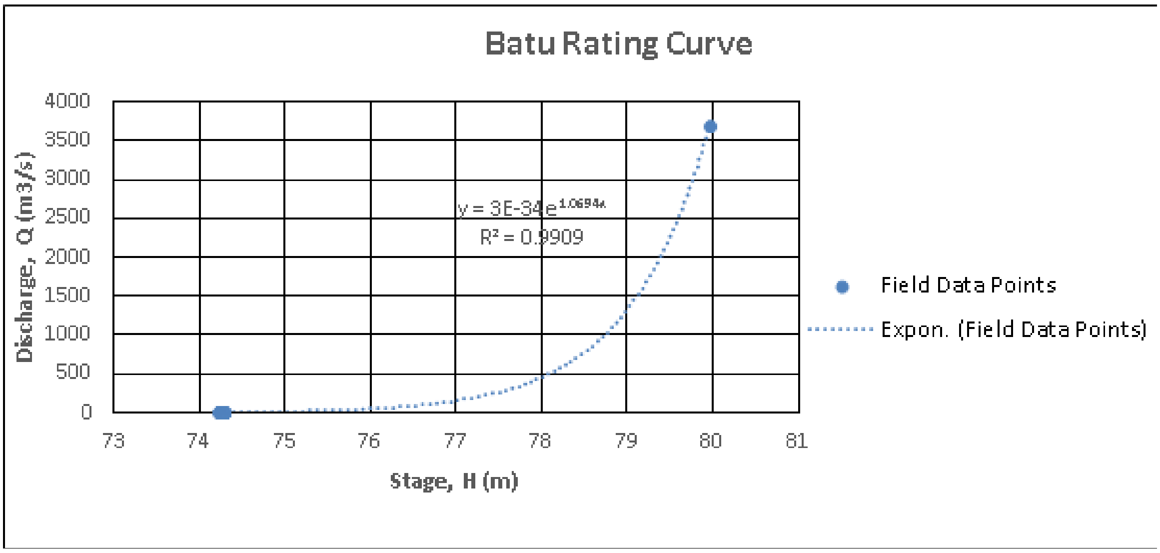


Fig.45Rating Curve at Batu Bridge, Brgy. Batu, Siay, Zamboanga Sibugay

This rating curve equation was used to compute the river outflow at Batu Bridgefor the calibration of the HEC-HMS model shown in Figure 46. Peak discharge is 5.52 cubic meters per second at 2:10 PM, October12, 2016.

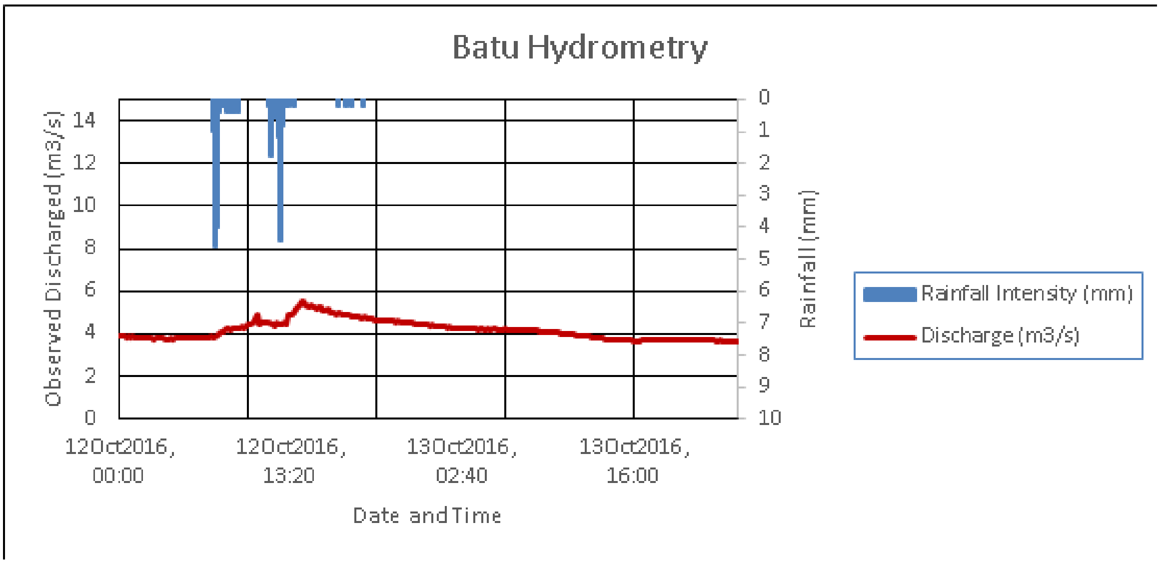


Figure 46. Rainfall and outflow data at Batu Bridge used for modeling

5.2 RIDF Station

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

Table 25. RIDF values for Zamboanga City Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	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

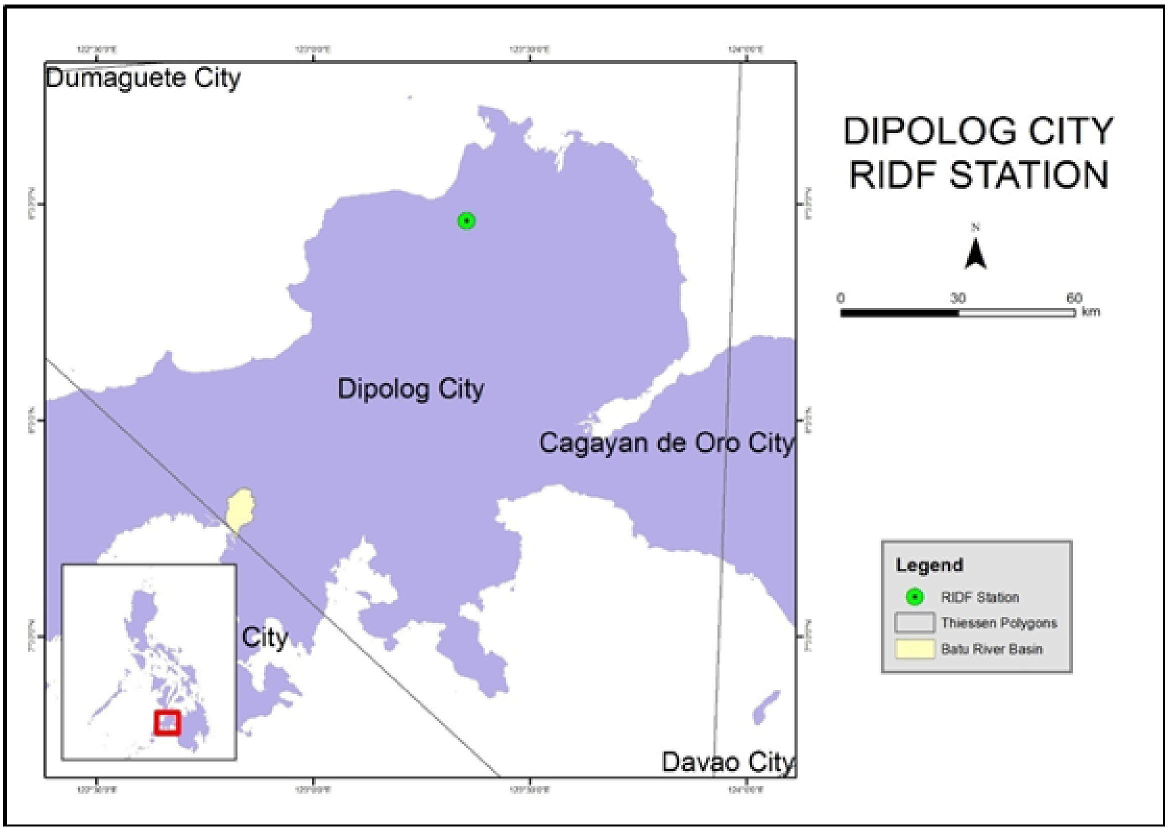


Figure 47. Dipolog City RIDF location relative to Batu River Basin

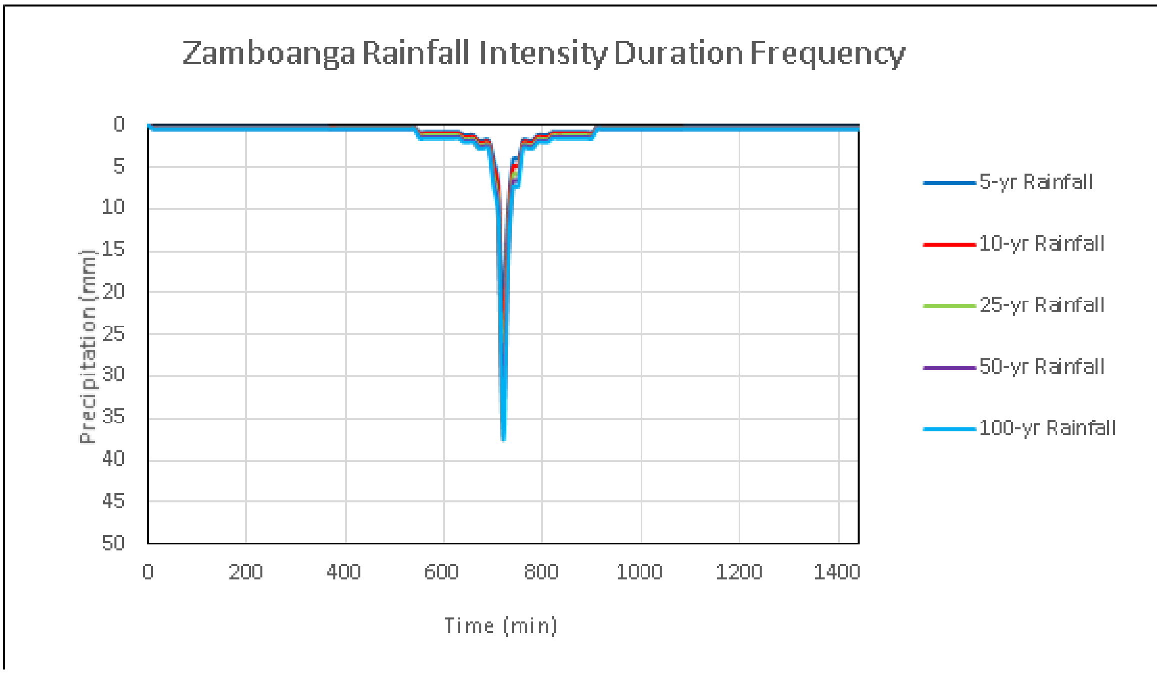


Figure 48. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Batu River Basin are shown in Figure 49 and Figure 50, respectively.

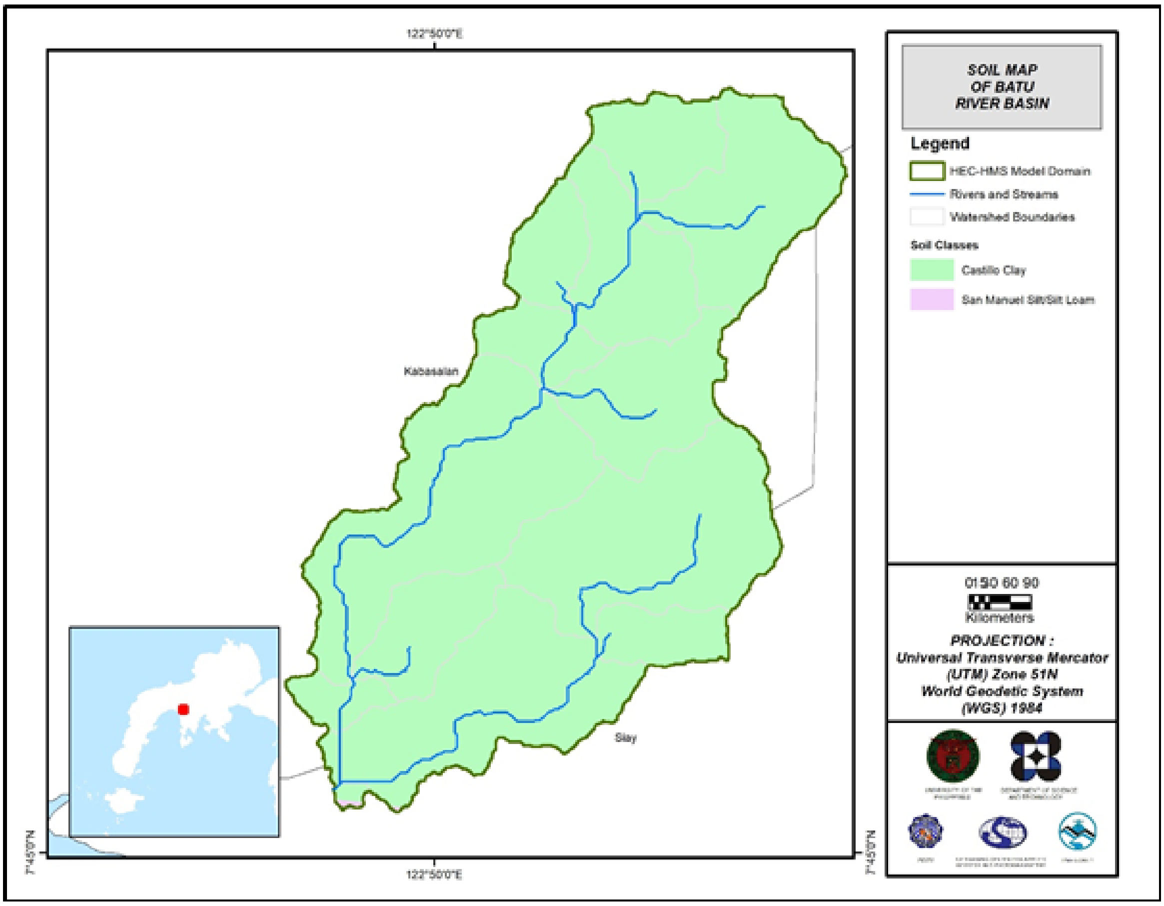


Figure 49. Soil Map of Batu River Basin

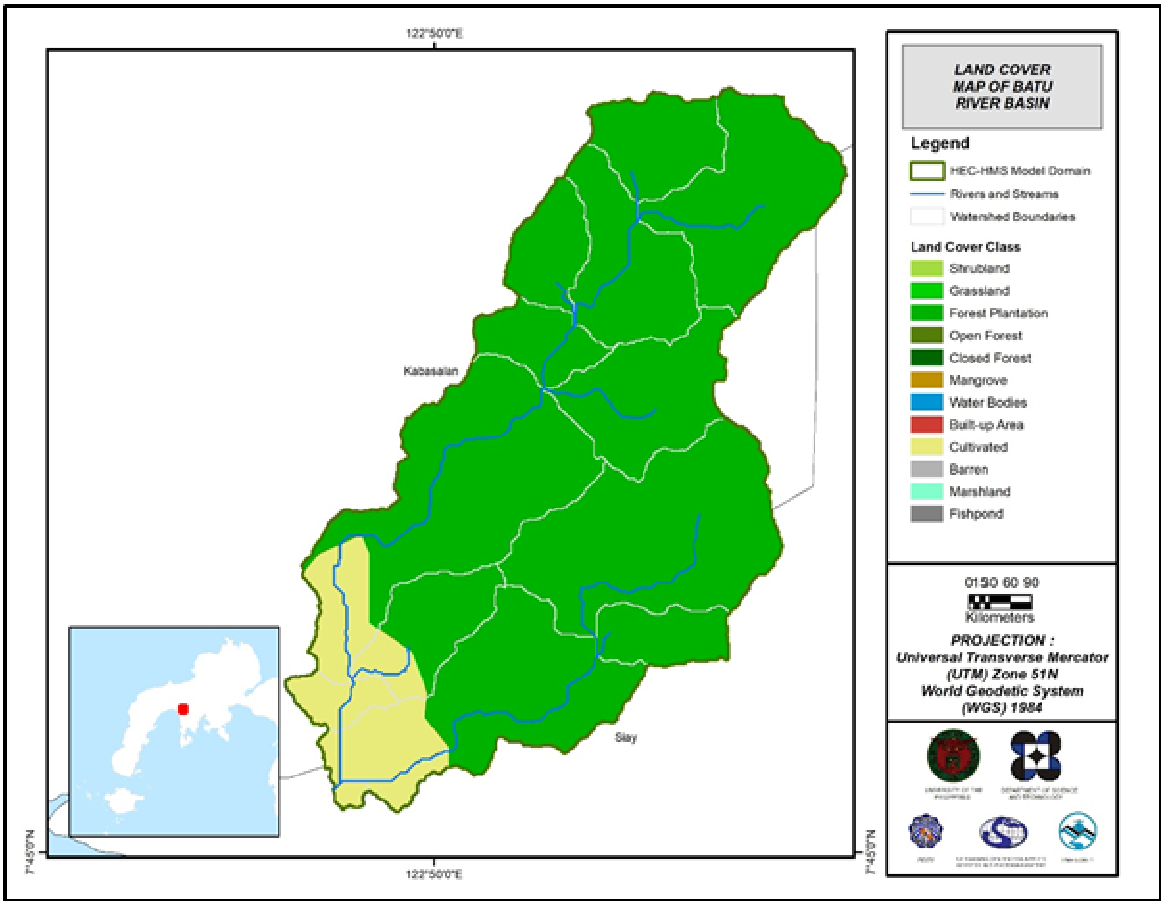


Figure 50. Land Cover Map of Batu River Basin

For Batu, the soil classes identified were clay, silt, and silt loam. The land cover types identified were forest plantations and cultivated areas.

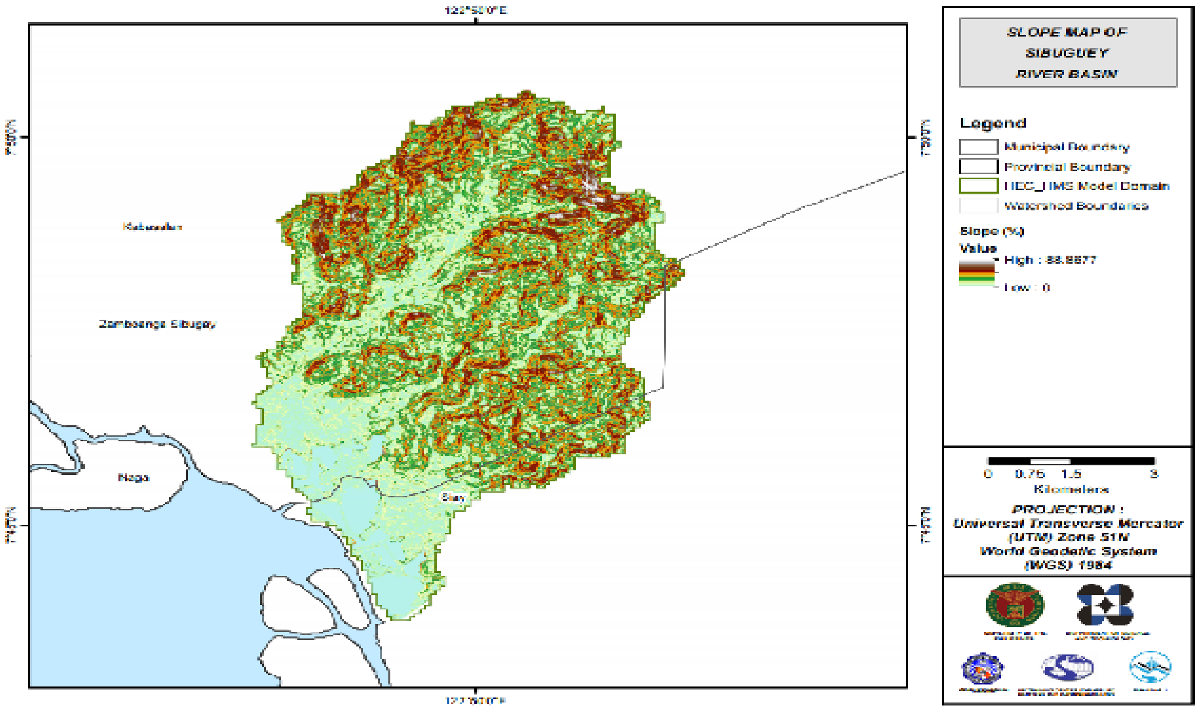


Figure 51. Slope Map of Batu River Basin

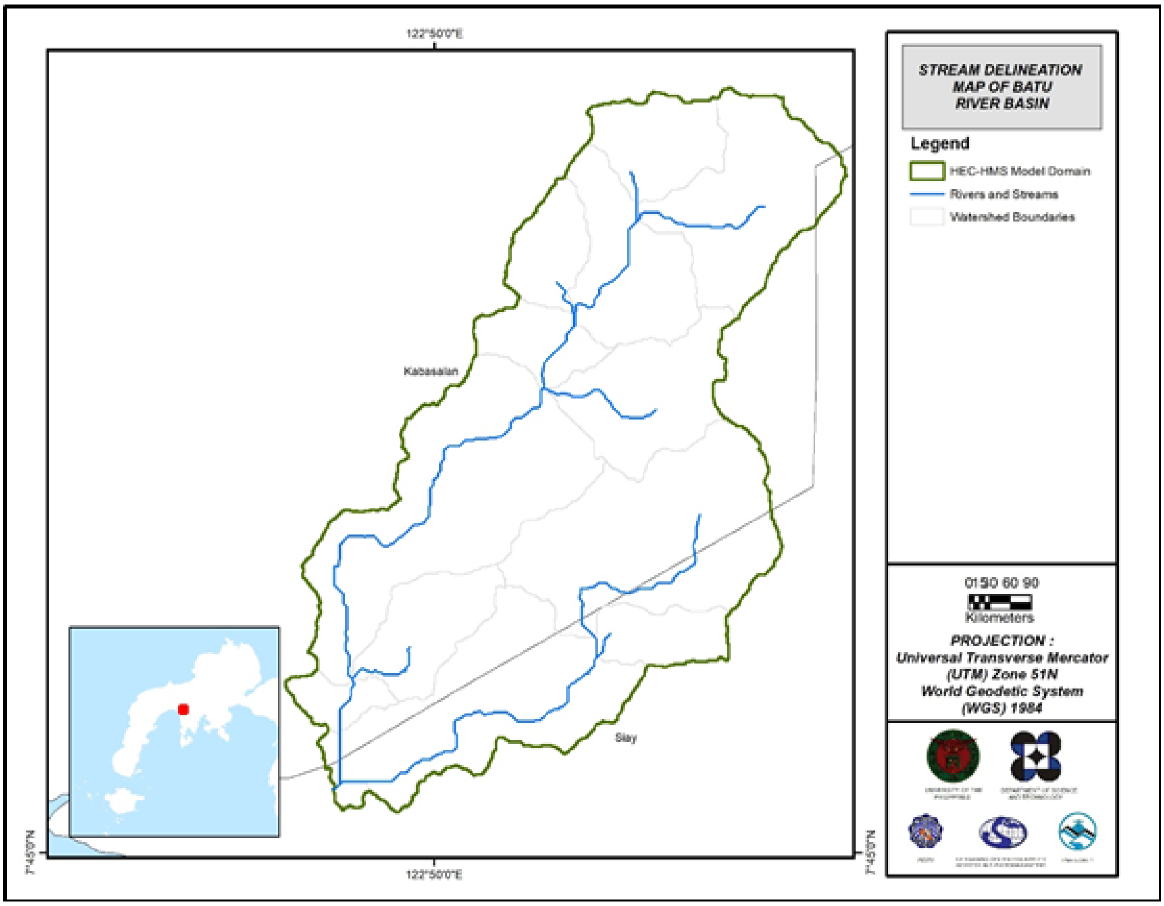


Figure 52. Stream Delineation map of Batu river basin

Using the SAR-based DEM, the Batu basin was delineated and further subdivided into subbasins. The model consists of 13 sub basins, 6 reaches, and 6 junctions as shown in Figure 53 (See Annex 10). The main outlet is at Batu Bridge, Brgy. Batu, Siay, Zamboanga Sibugay.

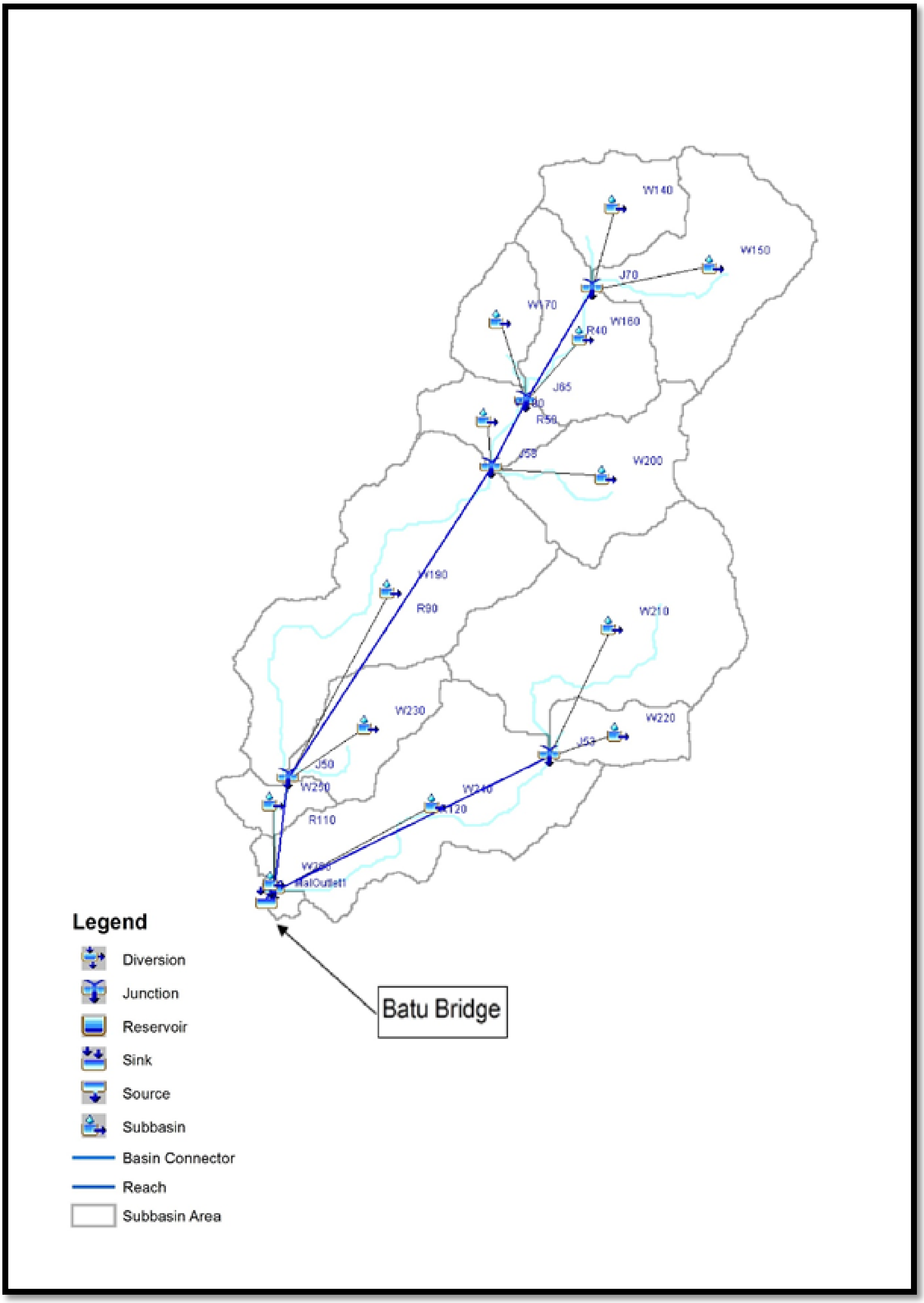


Figure 53. The Batu river basin model generated using HEC-HMS

5.4 Cross-section Data

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 54).

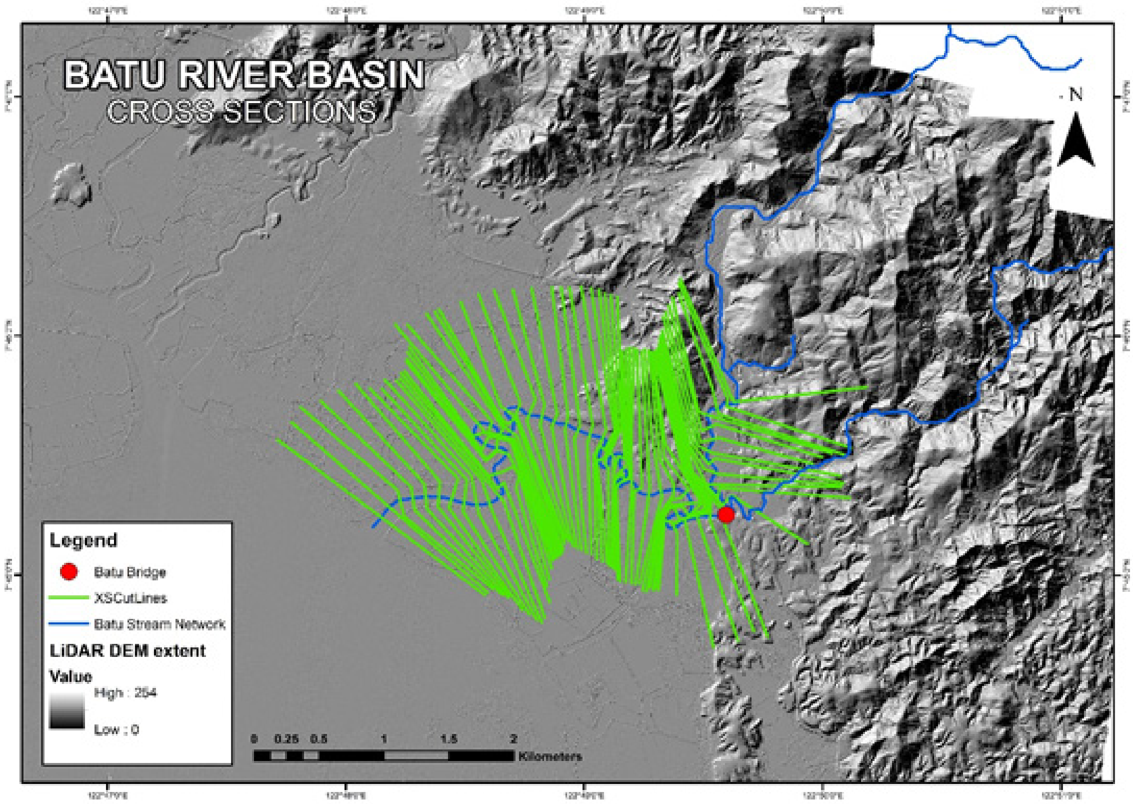


Figure 54. River cross-section of Batu River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were 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 was seen that the water will generally flow from the south of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements, respectively.

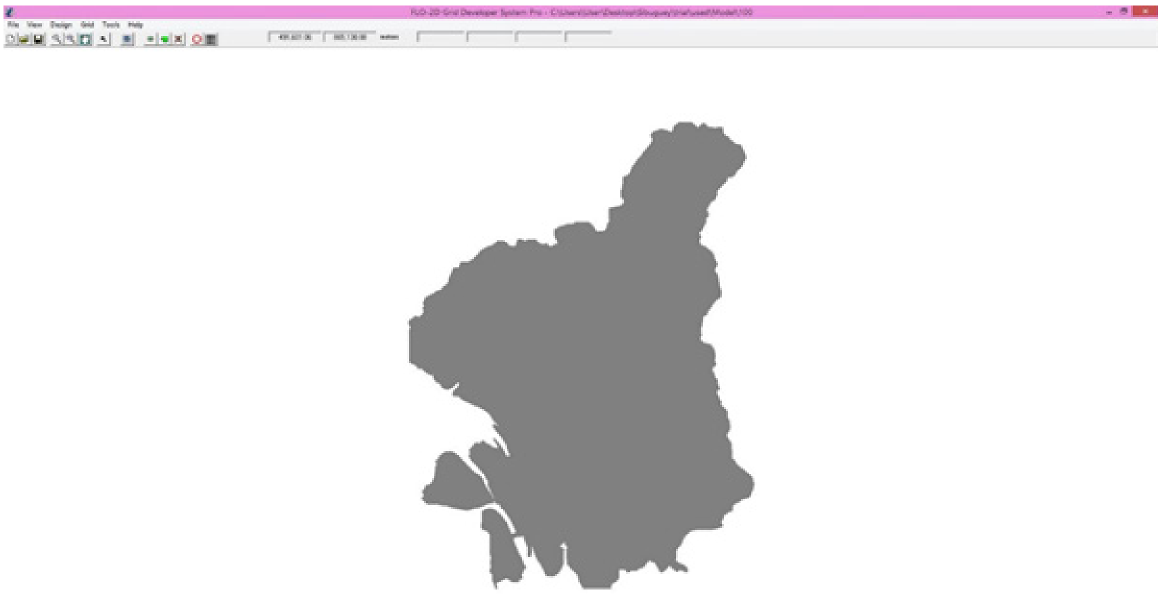


Figure 55. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

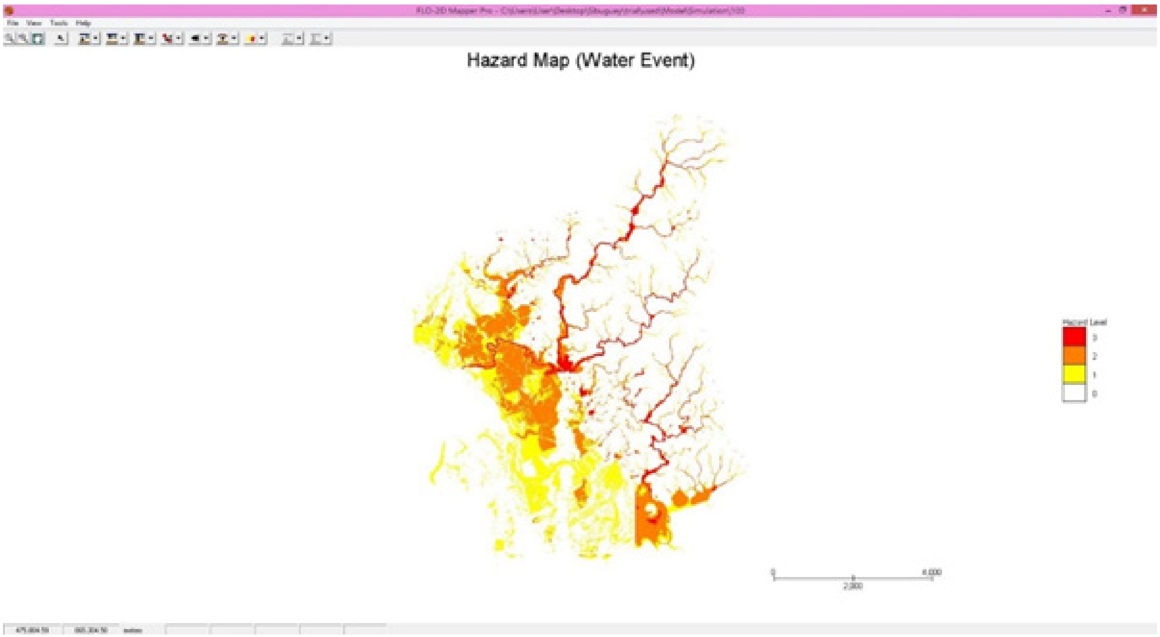


Figure 56. Generated 100-year rain return hazard map from FLO-2D Mapper

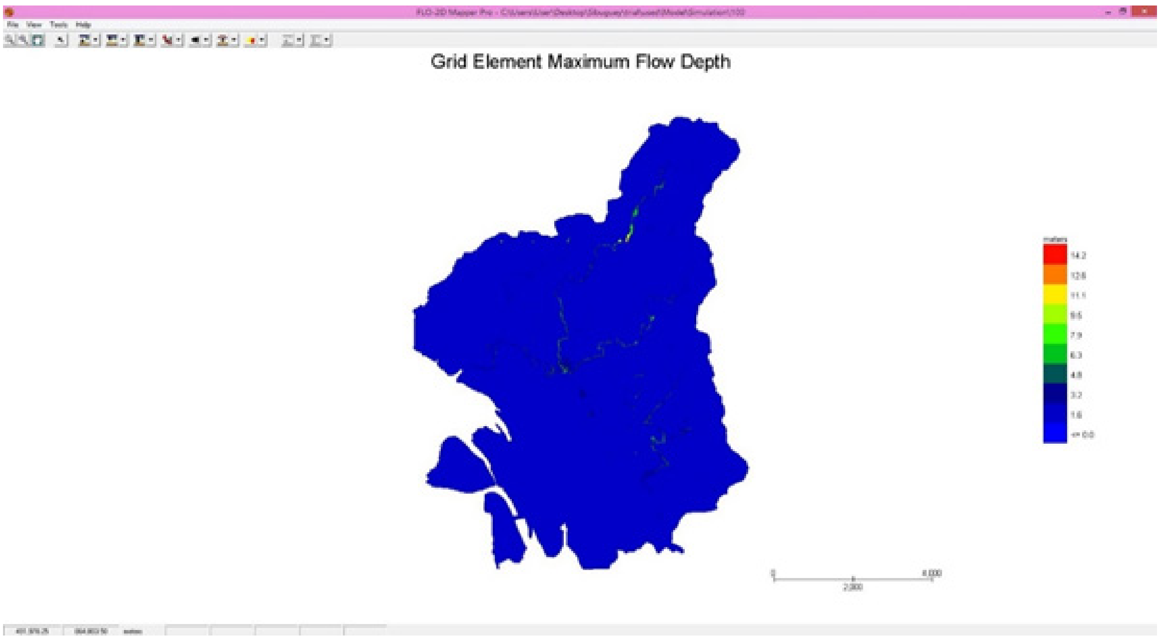


Figure 57. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

After calibrating the Batu HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 58 shows the comparison between the two discharge data.

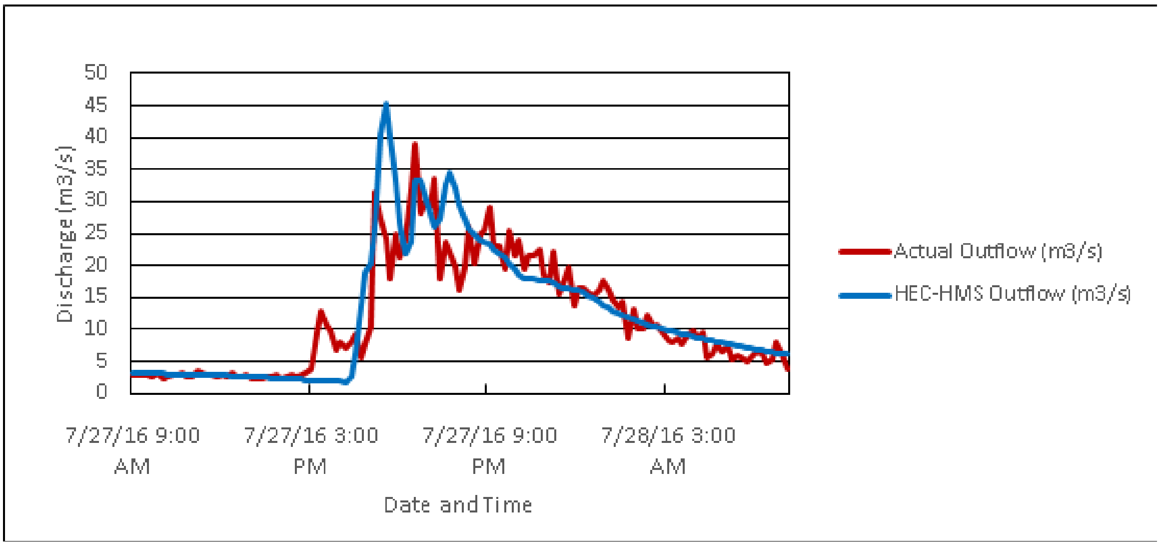


Figure 58. Outflow Hydrograph of Batu produced by the HEC-HMS model compared with observed outflow

The adjusted ranges of values of the parameters used in calibrating the model are enumerated in Table 26.

Table 26. Range of Calibrated Values for Batu

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3.14 – 5.20
			Curve Number	58.1 – 62.3
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.39 – 1.52
			Storage Coefficient (hr)	0.63 – 2.48
	Baseflow	Recession	Recession Constant	0.81
			Ratio to Peak	0.717
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.02

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 3.14mm to 5.20mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 58.1 to 62.3 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Batu, the basin mostly consists of cultivated and tree plantation areas and the soil consists of clay, silty loam, and mountain soil.

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 0.39 hours to 2.48 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 0.81 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.717 indicates a moderate receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.03 corresponds to the common roughness of Philippine watersheds.

Table 27. Summary of the Efficiency Test of Batu HMS Model

RMSE	3.985366
r2	0.9909
NSE	0.734636
PBIAS	-0.21051
RSR	0.515135

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as3.985366 (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 0.9909.

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 0.734636.

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 -0.21051.

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 0.515135.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 59) shows the Batu 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 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.

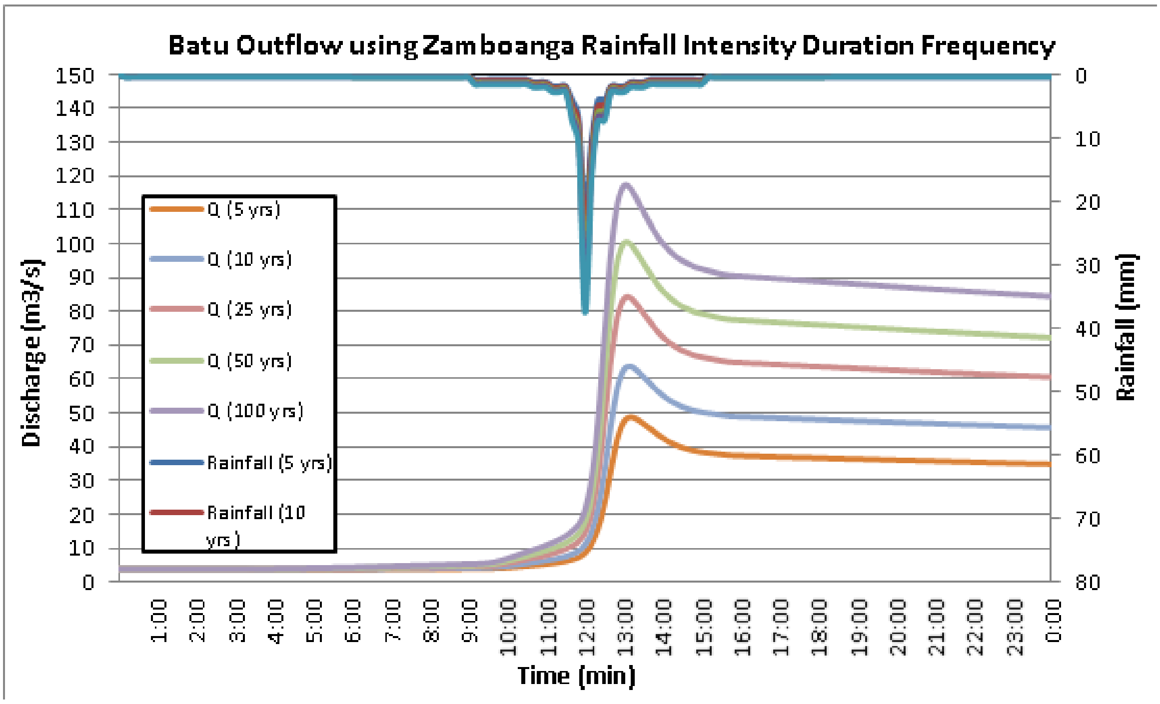


Figure 59. Outflow hydrograph at Batu Bridge Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Batudischarge using the Zamboanga CityRainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 28.

Table 28. Peak values of the Batu HECHMS Model outflow using the Zamboanga City RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	107.8	21.4	48.78	13 hours 10 minutes
10-Year	127.9	25.3	63.80	13 hours 10 minutes
25-Year	153.4	30.2	84.05	13 hours 10 minutes
50-Year	172.3	33.9	100.19	13 hours
100-Year	191.1	37.5	117.17	13 hours

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 was used in determining the flooded areas within the model. The simulated model was an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Batu River using the calibrated HMS base flow is shown in Figure 60.

Figure 60. Sample output of Batu RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 61 to Figure 66 show the 5-, 25-, and 100-year rain return scenarios of the Batu Floodplain.

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

Table 29. Municipalities affected in Batu floodplain

Municipality	Total Area	Area Flooded	% Flooded
Kabasalan	317.277	24.61	8%
Siay	186.46	27.90	14%

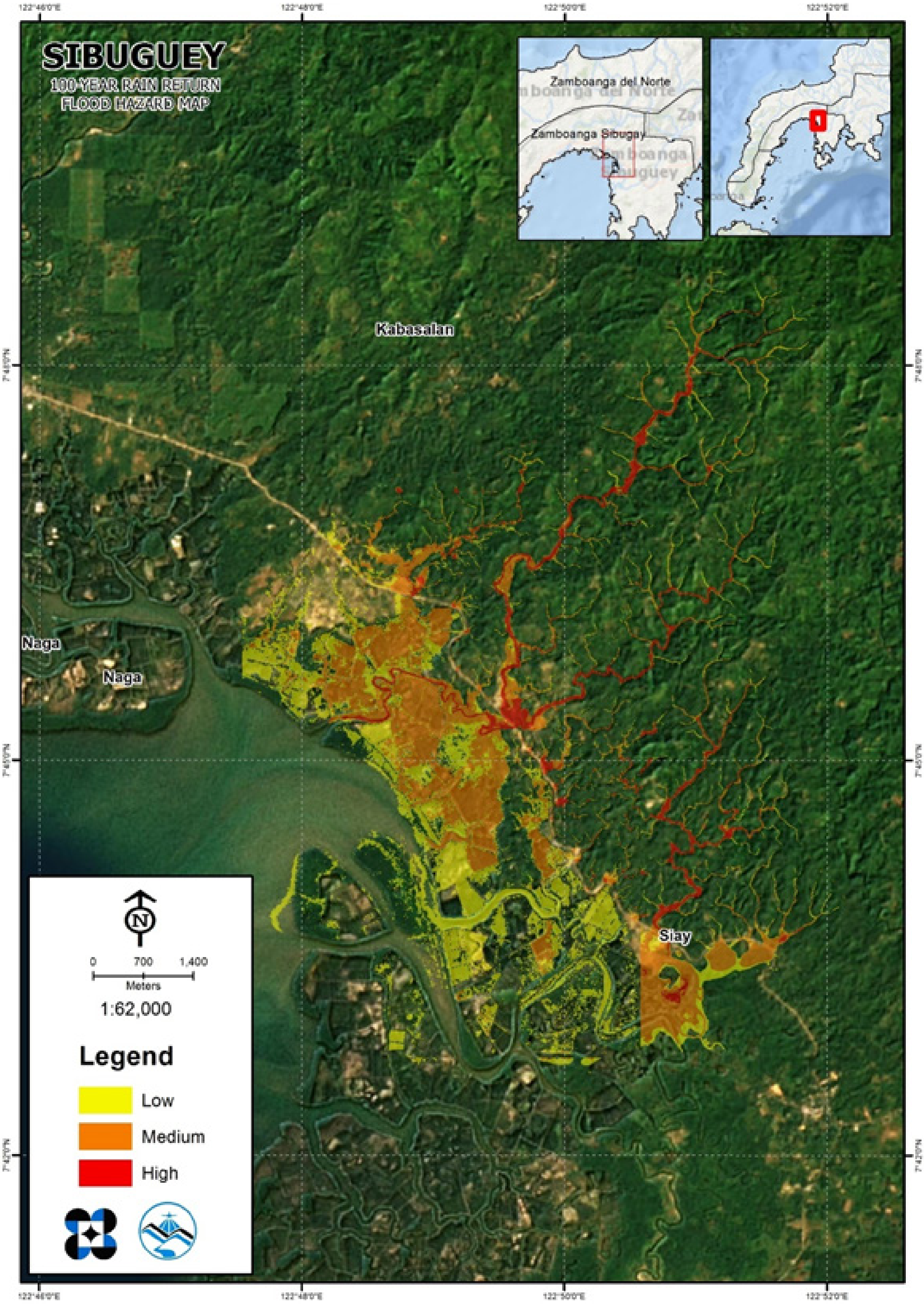


Figure 61. 100-year Flood Hazard Map for Batu Floodplain

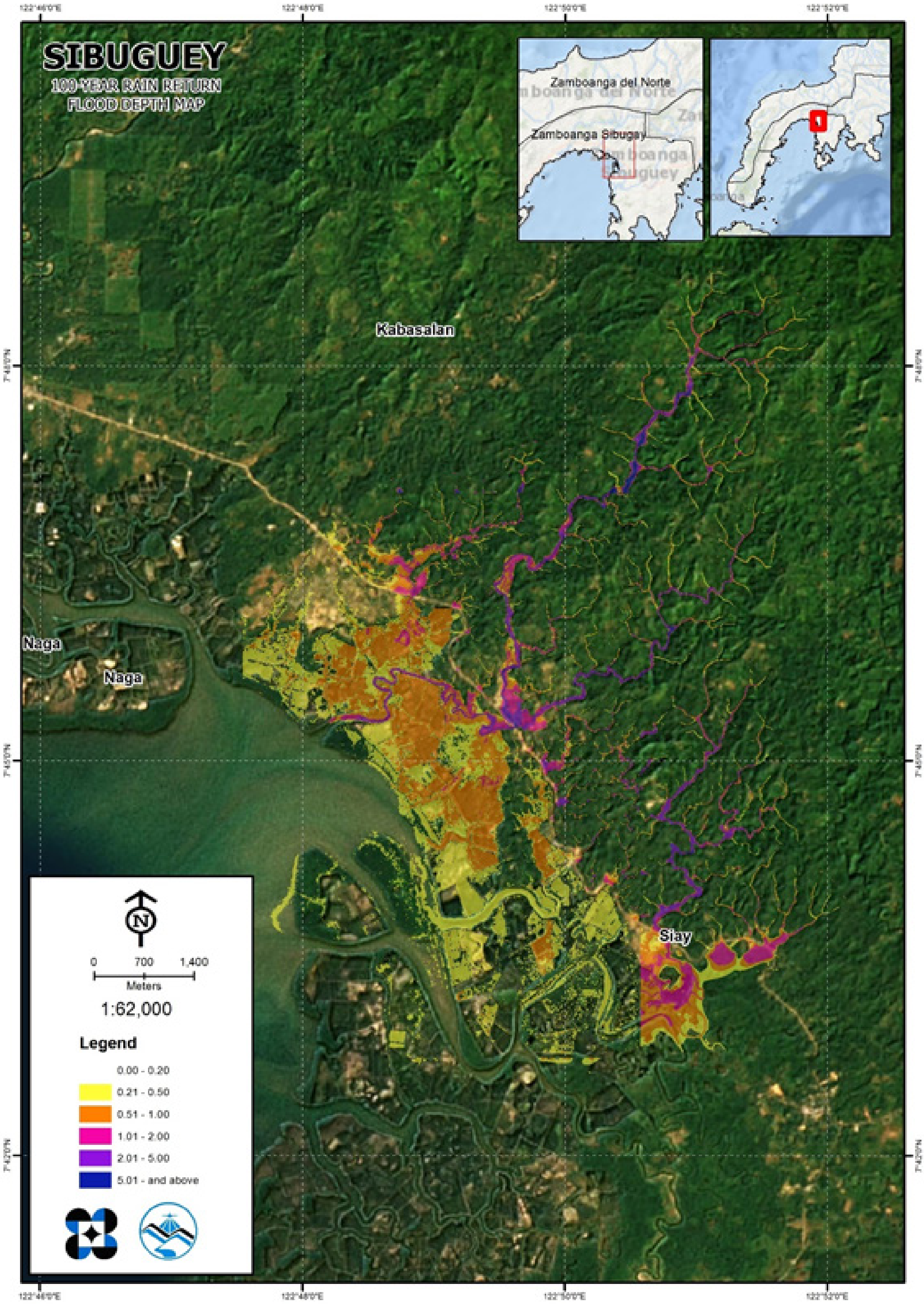


Figure 62. 100-year Flow Depth Map for Batu Floodplain

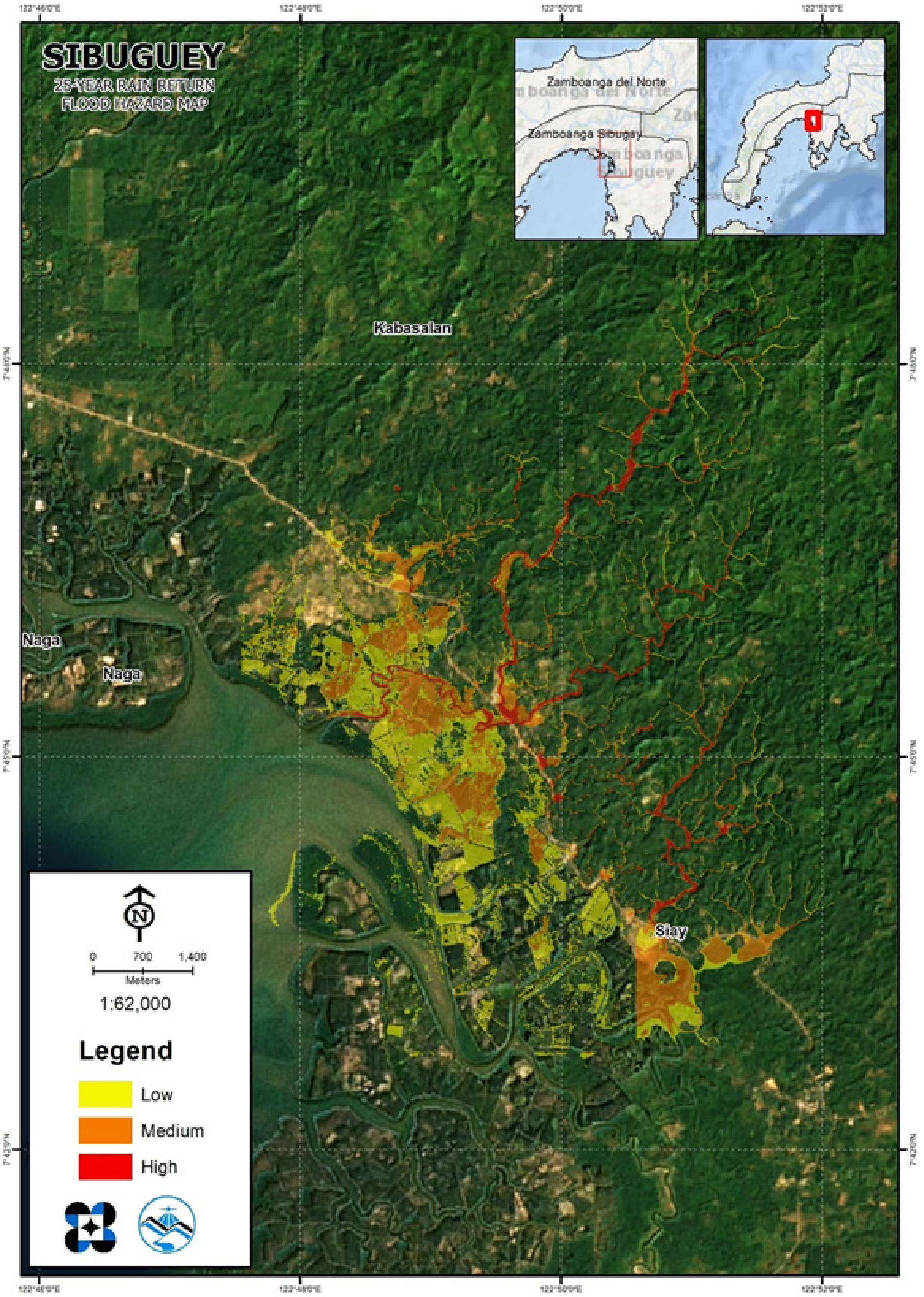


Figure 63. 25-year Flood Hazard Map for Batu Floodplain

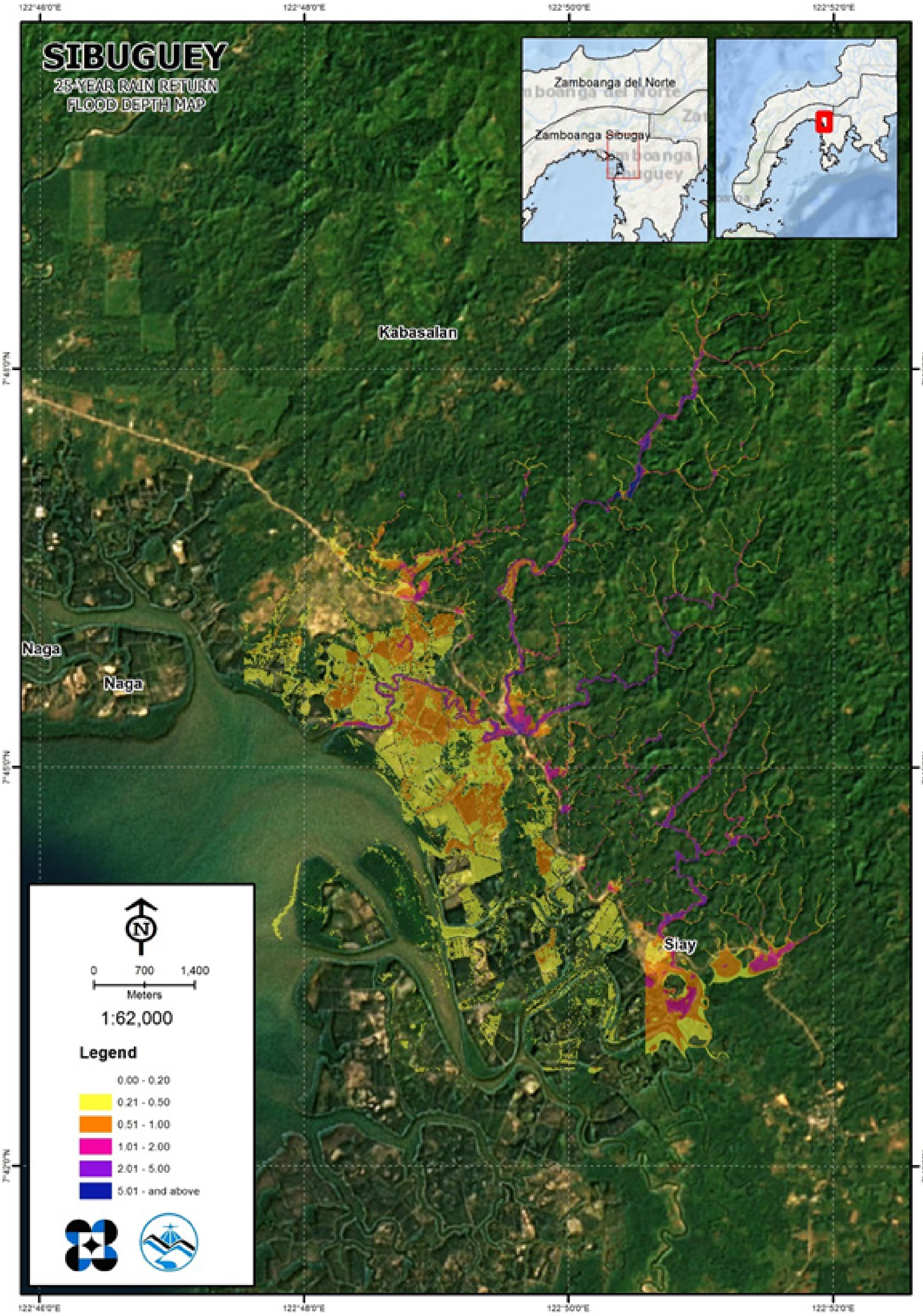


Figure 64. 25-year Flow Depth Map for Batu Floodplain

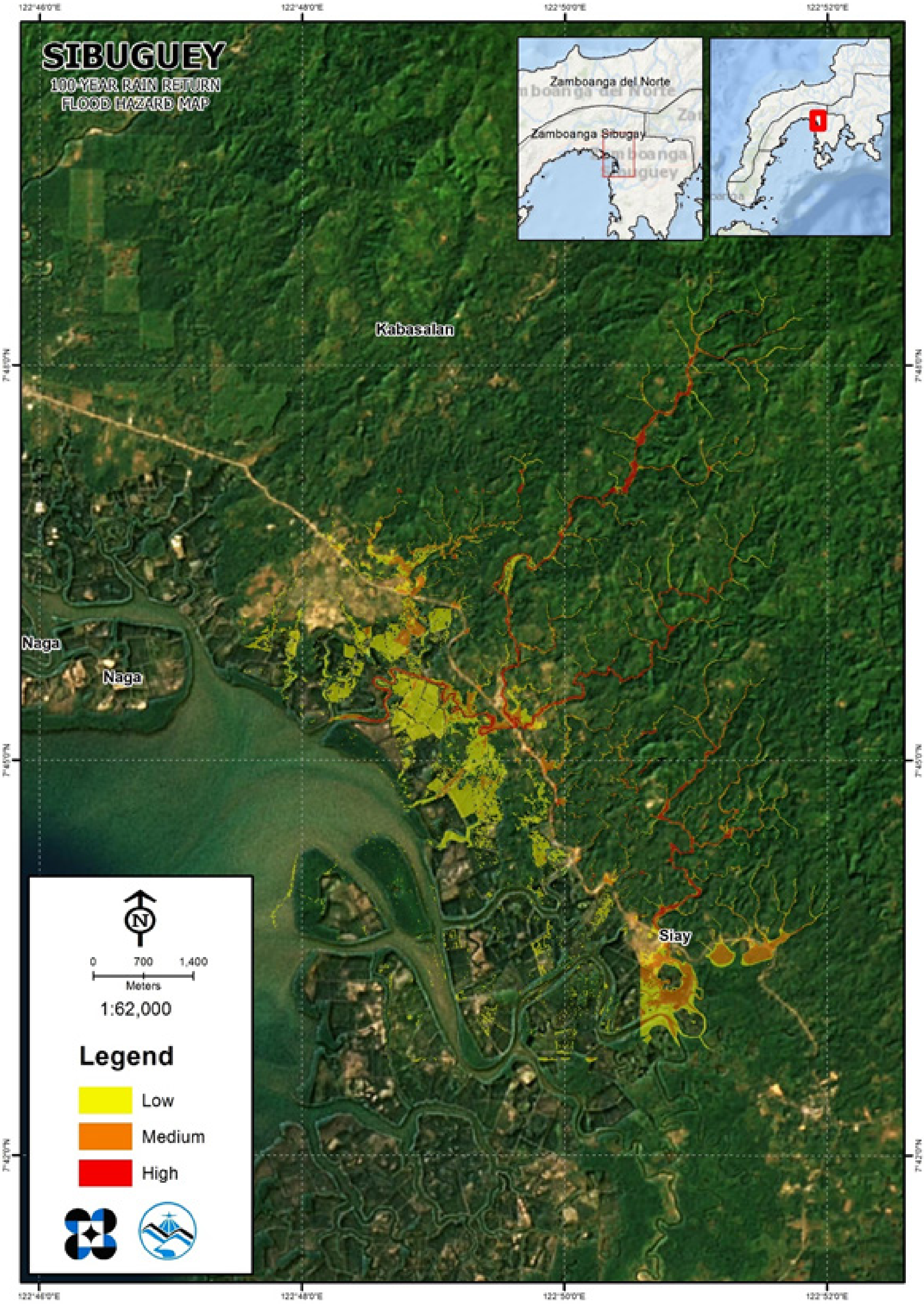


Figure 65. 5-year Flood Hazard Map for Batu Floodplain

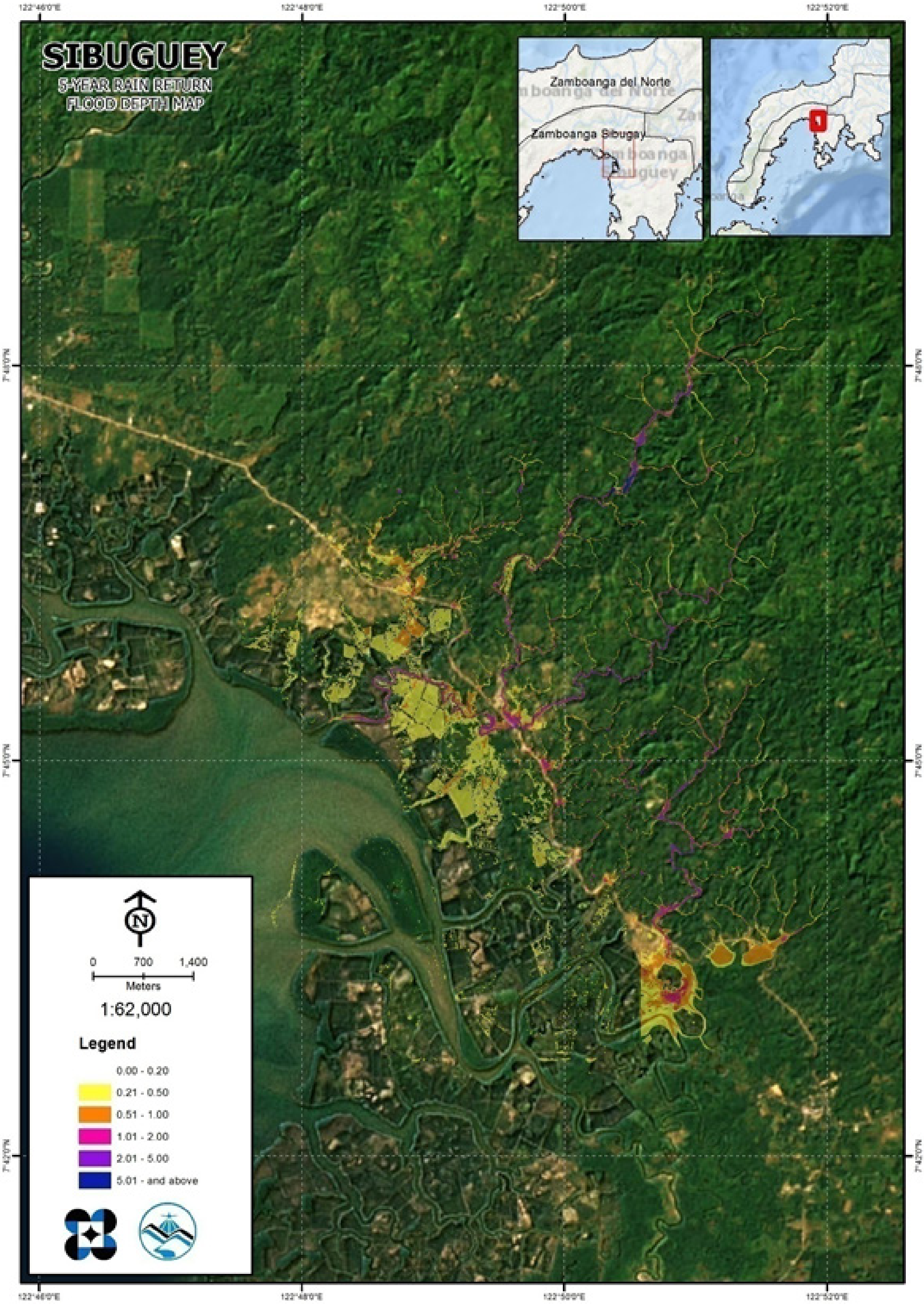


Figure 66. 5-year Flood Depth Map for Batu Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Batu river basin, grouped by municipality, are listed below. For the said basin, 12 barangays in two municipalities are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 6.947% of the municipality of Kabasalan with an area of 317.277 sq. km. will experience flood levels of less 0.20 meters; 0.492% of the area will experience flood levels of 0.21 to 0.50 meters while 0.171%, 0.088%, and 0.053% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 Meters respectively.

Table 30. Affected Areas in Kabasalan, Zamboanga Sibugay during 5-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Kabasalan			
		Calapan	Cancaiyas	Nazareth	Sayao
Affected Area (sq. km.)	0.03-0.20	4.131602	2.519279	10.1392	5.249993
	0.21-0.50	0.696812	0.215867	0.516016	0.130779
	0.51-1.00	0.225233	0.027063	0.217173	0.074277
	1.01-2.00	0.061953	0.0022	0.157193	0.058333
	2.01-5.00	0.020303	0.0019	0.103159	0.042178
	> 5.00	0.0002	0.0001	0.0199	0.015211

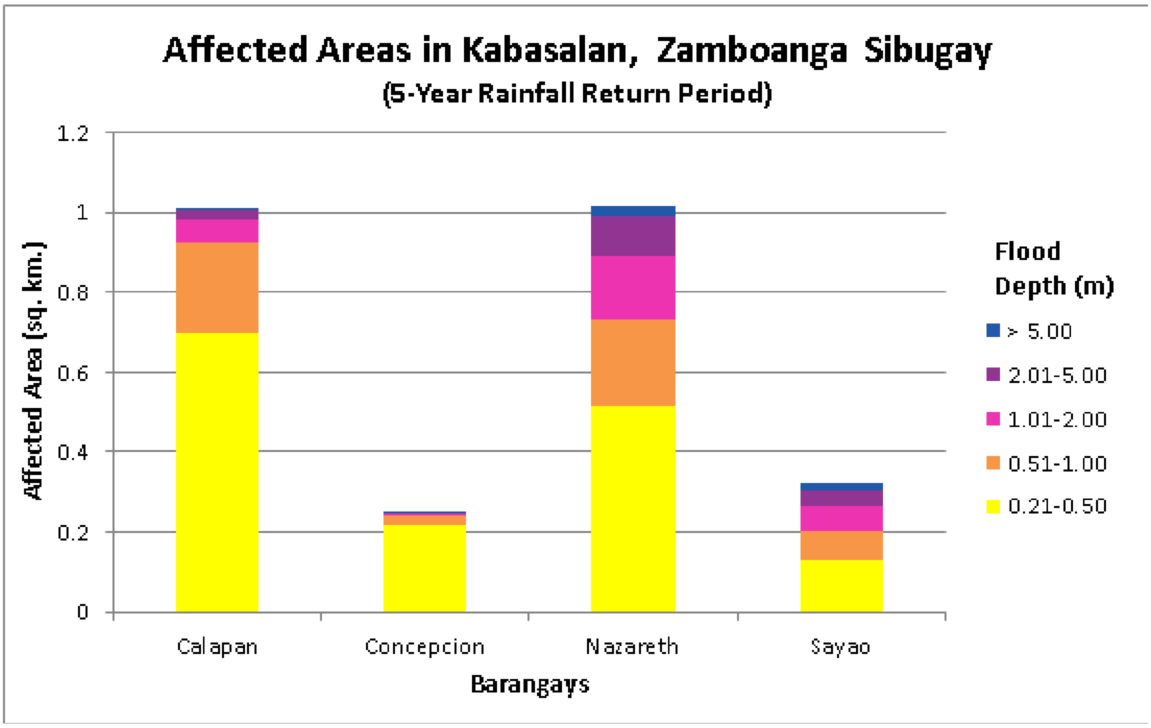


Figure 67. Affected Areas in Basey, Samar during 5-Year Rainfall Return Period

For the municipality of Siay, with an area of 186.469 sq. km., 9.67% will experience flood levels of less 0.20 meters.;1.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.10%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters and 2.01 to 5 meters respectively.

Table 31. Affected Areas in Siay, Zamboanga Sibugay during 5-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Siay			
		Balucanan	Batu	Laih	Logpond
Affected Area (sq. km.)	0.03-0.20	2.350374	3.857458	7.065178	1.666783
	0.21-0.50	0.0524	0.382731	1.383854	0.103149
	0.51-1.00		0.119179	0.108215	0.0017
	1.01-2.00		0.10086	0.039224	
	2.01-5.00		0.052143	0.03753	
	> 5.00		0.0003		

Table 32. Affected Areas in Siay, Zamboanga Sibugay during 5-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Siay			
		Monching	San Isidro	Siloh	Magsaysay
Affected Area (sq. km.)	0.03-0.20	0.404224	2.554019	0.015732	0.118325
	0.21-0.50	0.02815	0.041787	0.00047	
	0.51-1.00	0.011166	0.028294		
	1.01-2.00	0.0037	0.039437		
	2.01-5.00	0.0013	0.042188		
	> 5.00		0.001		

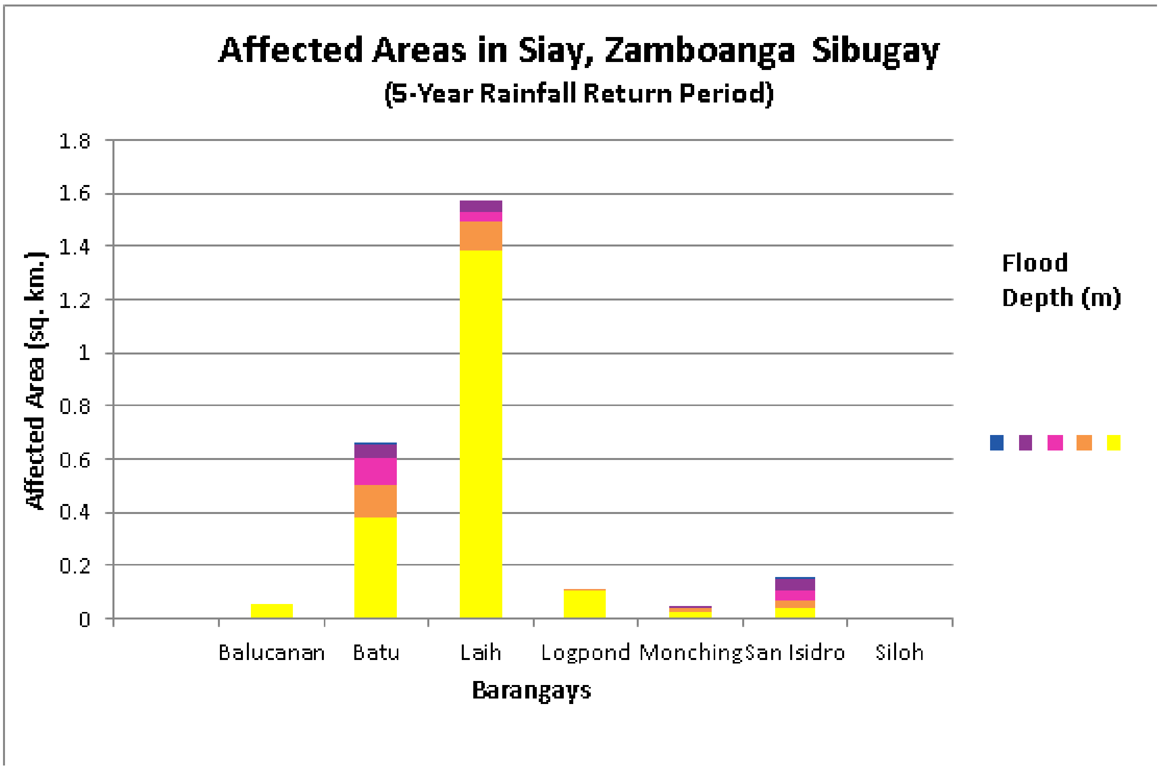


Figure 68. Affected Areas in Siay, Zamboanga Sibugay during 5-Year Rainfall Return Period

For the 25-year return period, 6.424% of the municipality of Kabasalan with an area of 317.277 sq. km. will experience flood levels of less 0.20 meters; 0.695% of the area will experience flood levels of 0.21 to 0.50 meters while 0.395%, 0.140%, 0.090% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 33 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Kabasalan, Zamboanga Sibugay during 25-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Kabasalan				
		Calapan	Concepcion	Nazareth	Sayao	Tigbangagan
Affected Area (sq. km.)	0.03-0.20	3.230099	2.261252	9.712832	5.178495	0.000034
	0.21-0.50	1.097667	0.429486	0.53592	0.143077	
	0.51-1.00	0.628249	0.067071	0.47315	0.085688	
	1.01-2.00	0.151037	0.0056	0.211425	0.074577	
	2.01-5.00	0.028551	0.0022	0.185179	0.068322	
	> 5.00	0.0005	0.0008	0.034131	0.0054	

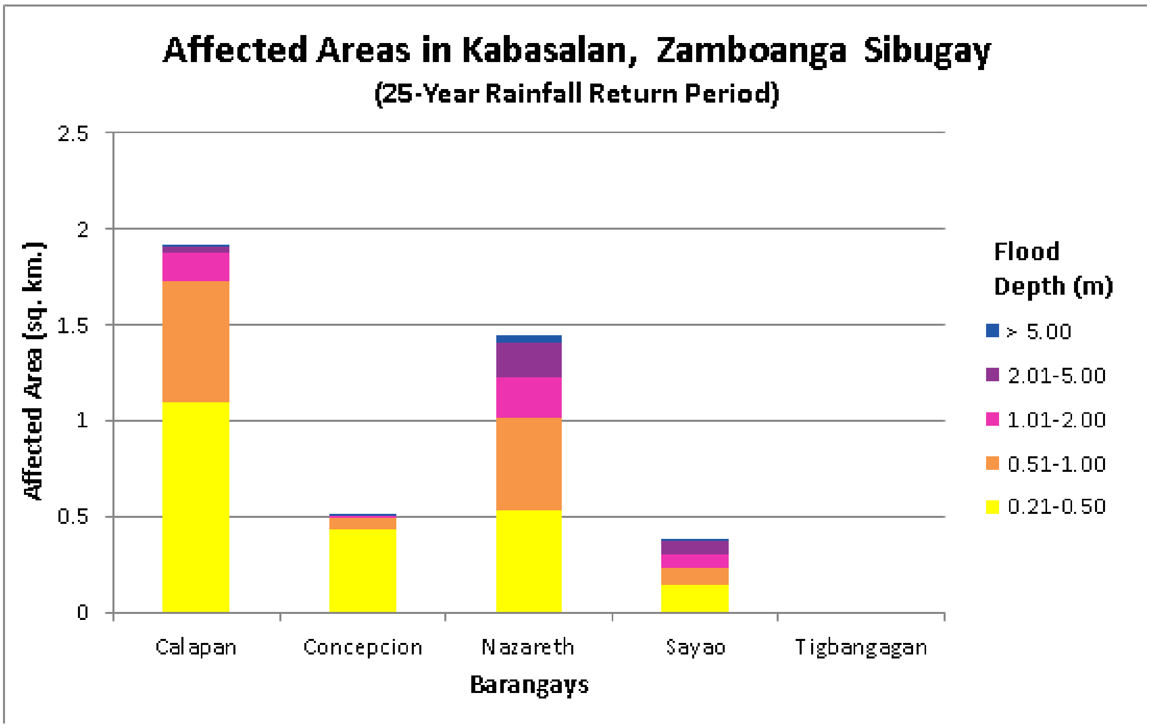


Figure 69. Affected Areas in Kabasalan, Zamboanga Sibugay during 25-Year Rainfall Return Period

For the municipality of Siay, with an area of 186.469 sq. km., 8.030% will experience flood levels of less 0.20 meters. 2.032% of the area will experience flood levels of 0.21 to 0.50 meters while 0.725%, 0.144%, and 0.118% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters and 2.01 to 5 meters respectively.

Table 34. Affected Areas in Siay, Zamboanga Sibugay during 25-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Silay				
		Balucanan	Batu	Laih	Logpond	Monching
Affected Area (sq. km.)	0.03-0.20	2.350374	3.857458	7.065178	1.666783	0.404224
	0.21-0.50	0.0524	0.382731	1.383854	0.103149	0.02815
	0.51-1.00		0.119179	0.108215	0.0017	0.011166
	1.01-2.00		0.10086	0.039224		0.0037
	2.01-5.00		0.052143	0.03753		0.0013
	> 5.00		0.0003			

Table 35. Affected Areas in Siay, Zamboanga Sibugay during 25-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Kabasalan				
		Monching	San Isidro	Siloh	Magsaysay	Tigbangagan
Affected Area (sq. km.)	0.03-0.20	0.404224	2.554019	0.015732	0.118325	0.000034
	0.21-0.50	0.02815	0.041787	0.00047		
	0.51-1.00	0.011166	0.028294			
	1.01-2.00	0.0037	0.039437			
	2.01-5.00	0.0013	0.042188			
	> 5.00		0.001			

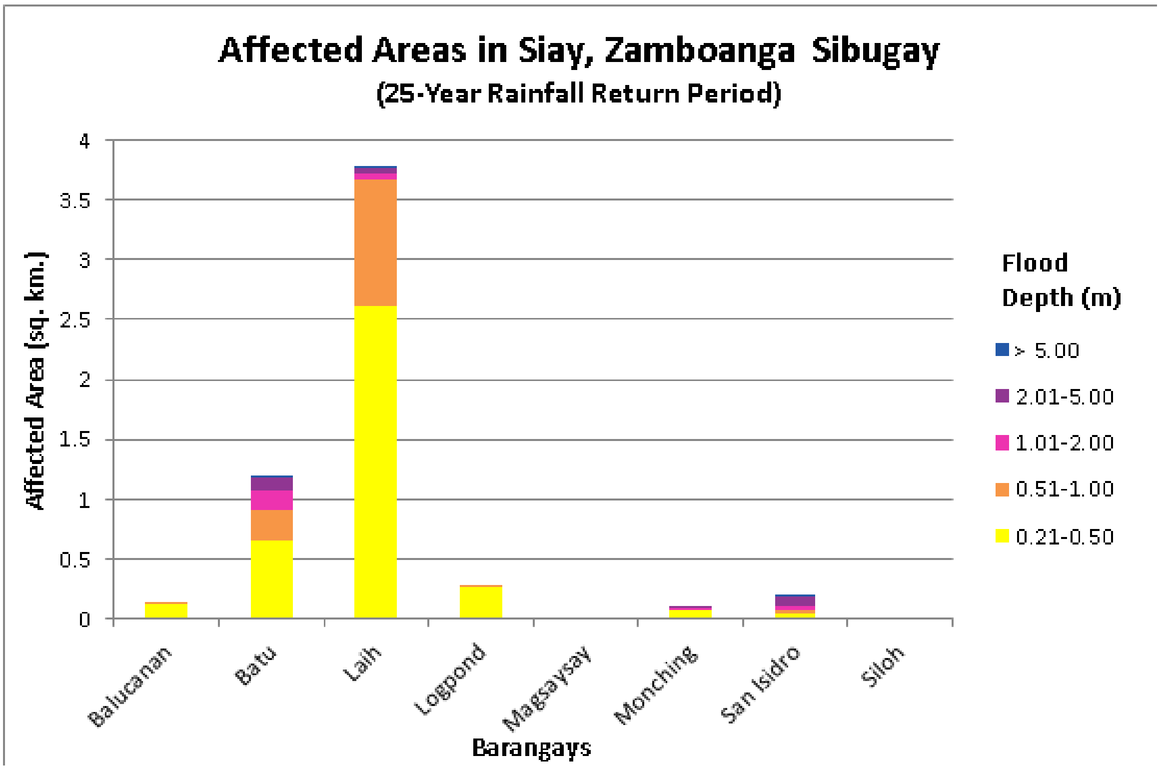


Figure 70. Affected Areas in Siay, Zamboanga Sibugay during 25-Year Rainfall Return Period

For the 100-year return period, 6.178% of the municipality of Kabasalan with an area of 317.277 sq. km. will experience flood levels of less 0.20 meters. 0.653% of the area will experience flood levels of 0.21 to 0.50 meters while 0.590%, 0.206%, 0.109% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Kabasalan, Zamboanga Sibugay during 100-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Kabasalan				
		Calapan	Concepcion	Nazareth	Sayao	Tigbangagan
Affected Area (sq. km.)	0.03-0.20	2.86624	2.07597	9.523974	5.135439	0.000034
	0.21-0.50	0.903228	0.56631	0.450126	0.151632	
	0.51-1.00	1.08925	0.109329	0.582356	0.09245	
	1.01-2.00	0.238148	0.0104	0.323263	0.083342	
	2.01-5.00	0.038236	0.0028	0.226798	0.077485	
	> 5.00	0.001	0.0016	0.04612	0.015211	

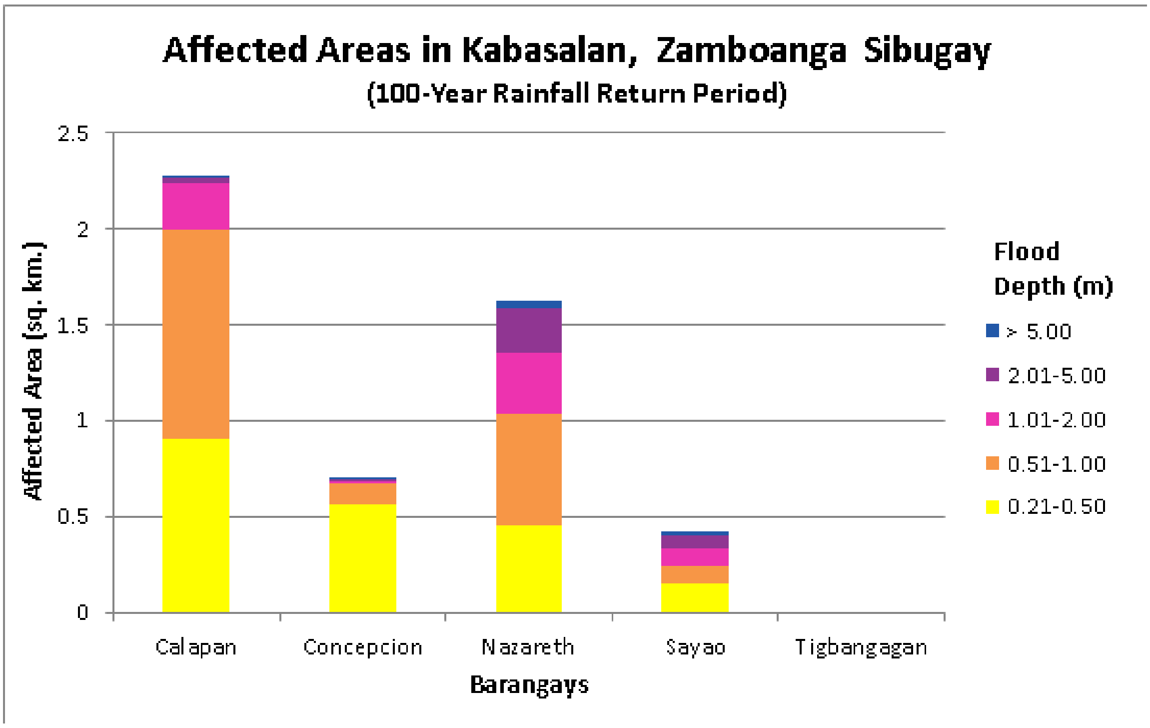


Figure 71. Affected Areas in Kabasalan, Zamboanga Sibugay during 100-Year Rainfall Return Period

For the municipality of Siay, with an area of 186.469 sq. km., 7.09% will experience flood levels of less 0.20 meters. 2.29% of the area will experience flood levels of 0.21 to 0.50 meters while 1.32%, 0.18%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters and 2.01 to 5 meters respectively.

Table 37. Affected Areas in Siay, Zamboanga Sibugay during 100-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Siay			
		Balucanan	Batu	Laih	Logpond
Affected Area (sq. km.)	0.03-0.20	2.86624	2.07597	9.523974	5.135439
	0.21-0.50	0.903228	0.56631	0.450126	0.151632
	0.51-1.00	1.08925	0.109329	0.582356	0.09245
	1.01-2.00	0.238148	0.0104	0.323263	0.083342
	2.01-5.00	0.038236	0.0028	0.226798	0.077485
	> 5.00	0.001	0.0016	0.04612	0.015211

Table 38. Affected Areas in Siay, Zamboanga Sibugay during 100-Year Rainfall Return Period

BATU BASIN		Affected Barangays in Siay			
		Magsaysay	Monching	San Isidro	Siloh
Affected Area (sq. km.)	0.03-0.20	0.118325	0.343403	2.501395	0.006137
	0.21-0.50		0.074447	0.052549	0.010065
	0.51-1.00		0.01584	0.035862	
	1.01-2.00		0.01095	0.032824	
	2.01-5.00		0.0035	0.075095	
	> 5.00		0.0004	0.009	

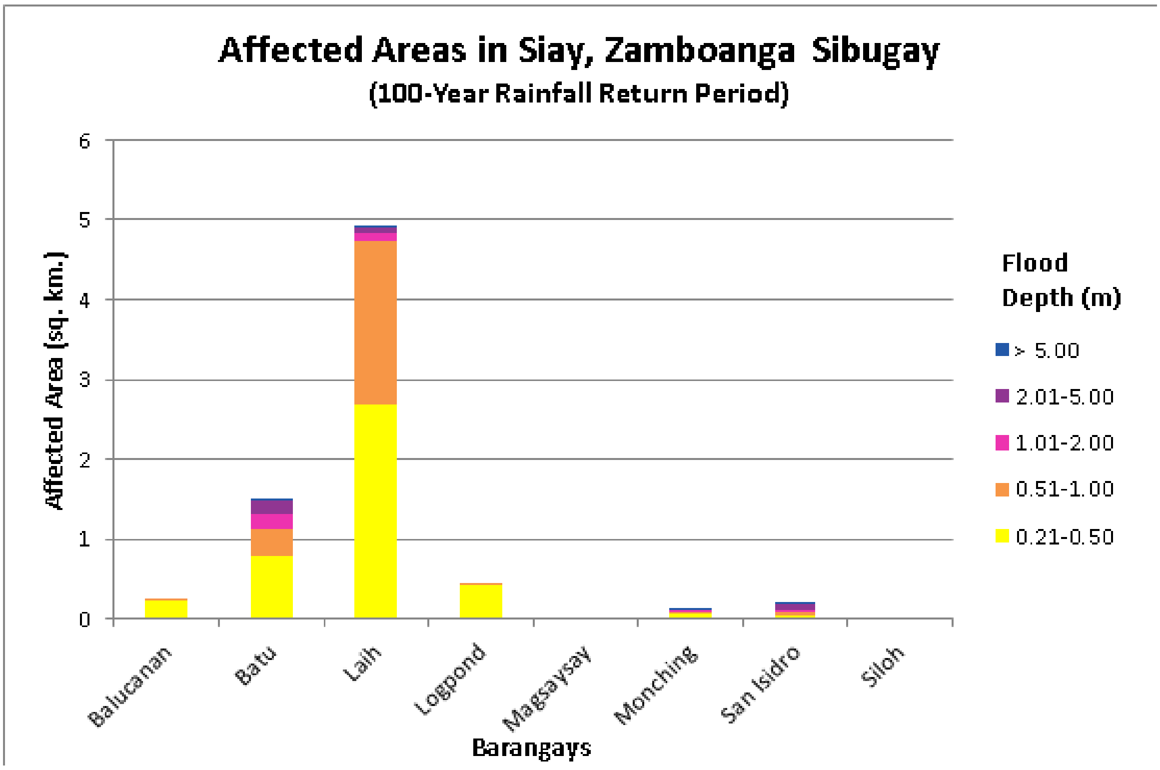


Figure 72. Affected Areas in Siay, Zamboanga Sibugay during 100-Year Rainfall Return Period

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

Table 39. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	3.674798	5.942309	5.701393
Medium	1.0856	3.133147	5.099647
High	1.1176	1.426196	1.680896

Of the 8 identified educational institutions in Batu Floodplain, only the Learning Center in Brgy. Concepcion, Kabasalan was exposed to medium level flooding for all flood hazard scenarios. Buayan Elementary School in the same barangay was assessed to be exposed to low level flooding for all flood hazard scenarios. The sole medical institution identified in the floodplain is the Health Center in Brgy. Nazareth in Kabasalan municipality. It was assessed to be not exposed to any level of flooding for any flood hazard scenario.

5.11 Flood Validation

The flood validation consists of 187 points randomly selected all over the Batu floodplain. It has an RMSE value of 0.47. The validation points are found in Annex 11.

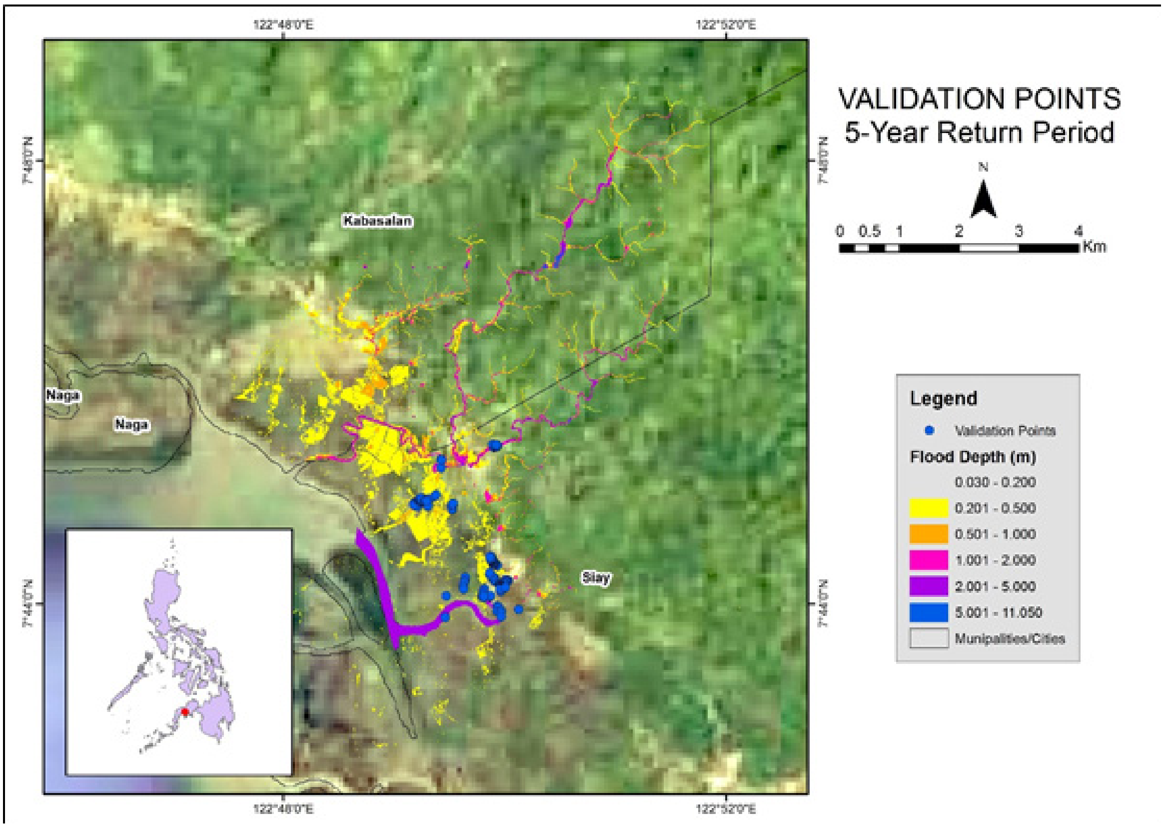


Figure 73. Validation points for 5-year Flood Depth Map of Batu Floodplain

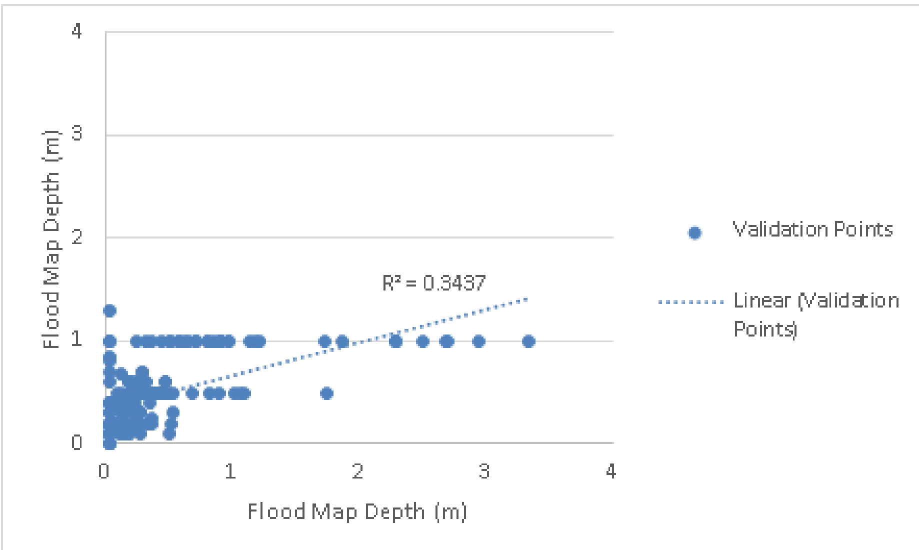


Figure 74. Flood map depth vs actual flood depth

Table 40. Actual Flood Depth vs Simulated Flood Depth in Batu

BATU BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	50	6	2	0	0	0	58
	0.21-0.50	25	43	5	4	0	0	77
	0.51-1.00	11	12	15	5	8	0	51
	1.01-2.00	1	0	0	0	0	0	1
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	87	61	24	4	8	0	187

The overall accuracy generated by the flood model is estimated at 57.75%, with 108 points correctly matching the actual flood depths. In addition, there were 41 points estimated one level above and below the correct flood depths while there were 25 points and 1 point estimated two levels above and below, and three or more levels above and below the correct flood. A total of 30 points were overestimated while a total of 49 points were underestimated in the modelled flood depths of Batu.

Table 41. Summary of Accuracy Assessment in Batu

	No. of Points	%
Correct	108	57.75
Overestimated	30	16.04
Underestimated	49	26.20
Total	187	100.00

REFERENCES

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

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

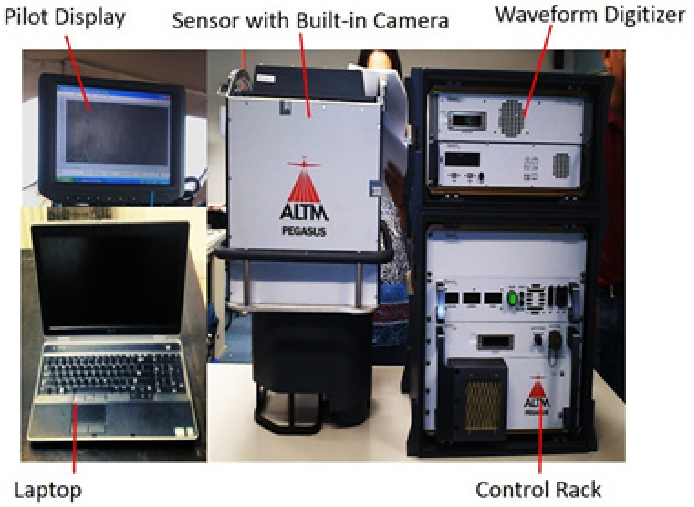
Lagmay A.F., Paringit E.C., et al. 2014. DREAM Flood Modeling Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.
Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.
UP TCAGP 2016, Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM) and Ground Control Points (GCP). Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

LDRRM Office of Siay
Philippine Information Agency- IX
Mines and Geosciences Bureau- IX

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Batu Floodplain Survey



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

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

1. ZGS-58

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

February 24, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **ZAMBOANGA DEL SUR**	
	Station Name: **ZGS-58**	
	Order: **2nd**	
Island: **MINDANAO**	Barangay: **SICADE**	
Municipality: **KUMALARANG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **7° 45' 44.20587"**	Longitude: **123° 8' 50.40994"**	Ellipsoidal Hgt: **31.65000 m.**
	WGS84 Coordinates	
Latitude: **7° 45' 40.67639"**	Longitude: **123° 8' 55.89231"**	Ellipsoidal Hgt: **96.97400 m.**
	PTM / PRS92 Coordinates	
Northing: **858266.608 m.**	Easting: **516251.478 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **857,966.20**	Easting: **516,245.79**	Zone: **51**

Location Description

ZGS-58
Is located about 200 m. NNE of the intersection of the national highway and the road going to Poblacion, Kumalarang. It is about 190 m. NE of the PNP Checkpoint and Collection post, 190 m. NNE of a waiting shed and 400 m. NNE of ZGS-59. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-58 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089868 I**
T.N.: **2016-0411**

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

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

2. ZGS-68

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-68**
Order: **2nd**

Island: **MINDANAO**	Barangay: **POBLACION**		
Municipality: **GUIPOS**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **7° 43' 33.12722"**	Longitude: **123° 18' 48.96041"**	Ellipsoidal Hgt:	**205.94100 m.**
	WGS84 Coordinates		
Latitude: **7° 43' 29.62251"**	Longitude: **123° 18' 54.44472"**	Ellipsoidal Hgt:	**271.74800 m.**
	PTM / PRS92 Coordinates		
Northing: **854250.138 m.**	Easting: **534593.845 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **853,951.14**	Easting: **534,581.74**	Zone:	**51**

Location Description

ZGS-68
Is located on the lot of the CENRO of Guipos. It is on the E end of the S sidewalk along the entrance way of CENRO from the national road, 15 m. E of the said office and 2.5 m. from the centerline of the driveway. Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ZGS-68 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0335**

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

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

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

The Batu River Basin has no Baseline Processing Reports of Control Points used in the LIDAR Survey

Annex 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. KENNETH QUISADO	UP-TCAGP
		ENGR. GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JASMIN DOMINGO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JERICHO JECIEL	AAC

Annex 5. Data Transfer Sheet Batu Floodplain

DATA TRANSFER SHEET
PAGADIAN 3/7/16

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	
02/20/2016	23116P	1BLK76NO051A	Pegasus	2.29 GB	NA	11.9 MB	294 MB	NA	NA	24.4 GB	0 B	63.8 MB	2KB	2KB	148/252/232	NA	Z:\DAC\RAW DATA
02/21/2016	23120P	1BLK69D052A	Pegasus	2.6 GB	NA	12 MB	298 MB	22.5 GB	NA	25.9 GB	0 B	59.6 MB	2KB	1KB	580/100/91/8 2	NA	Z:\DAC\RAW DATA
02/22/2016	23124P	1BLK69AB053A	Pegasus	1.89 GB	NA	11.4 MB	270 MB	NA	NA	21.1 GB	0 B	3.12 MB	1KB	NA	125/108/98/8 7/78/76	NA	Z:\DAC\RAW DATA
02/23/2016	23128P	1BLK70B054A	Pegasus	2.22 GB	NA	12.8 MB	273 MB	311 MB	NA	23.3	0 B	44.4 MB	1KB	NA	92/90/80/73	NA	Z:\DAC\RAW DATA
02/24/2016	23132P	1BLK73A055A	Pegasus	10.3 MB	NA	12.5 MB	266 MB	NA	NA	24.4 GB	0 B	49.7 MB	2KB	1KB	84/84/72/76/5 7	NA	Z:\DAC\RAW DATA
02/26/2016	23140P	1BLK73BS057A	Pegasus	2.47 GB	NA	13.5 MB	305 MB	NA	NA	26.5 GB	0 B	65.9 MB	2KB	1KB	85/83	NA	Z:\DAC\RAW DATA

Received from

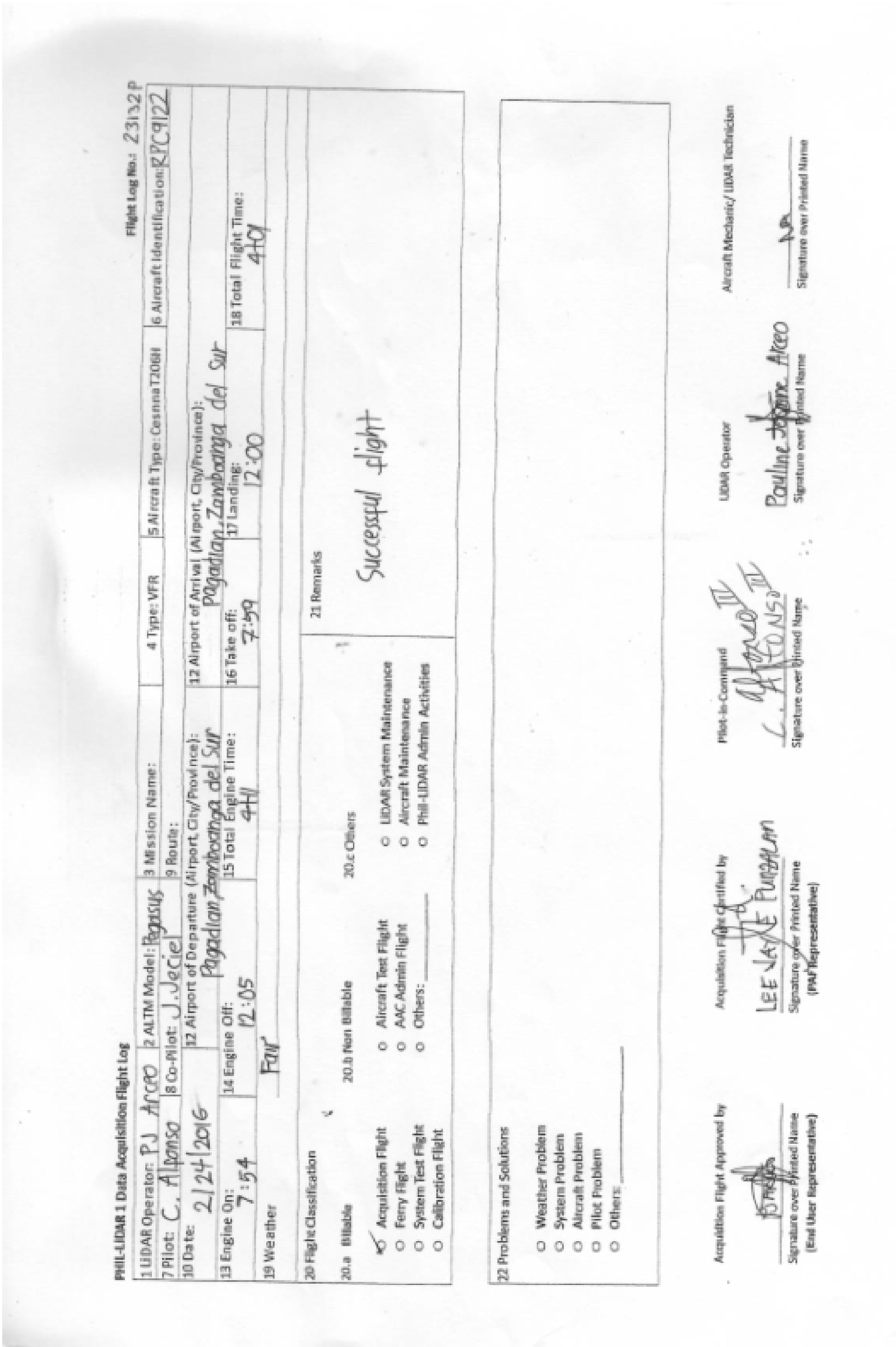
Name R. PUNTO
Position RA
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature] 3/10/16

Annex 6. Flight Logs for the Flight Missions

Flight Log for 1BLK73A055A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23132P

1 LIDAR Operator: PJ Arceo	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/24/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 7:54	14 Engine Off: 12:05	15 Total Engine Time: 4+11	16 Take off: 7:59	17 Landing: 12:00	18 Total Flight Time: 4+01
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ______

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

Acquisition Flight Certified by: LEE JAYE PUNZALAN — Signature over Printed Name (PAF Representative)

Pilot-in-Command: C. ALFONSO IV — Signature over Printed Name

LIDAR Operator: Pauline Joanne Arceo — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: NA — Signature over Printed Name

Flight Log for 1BLK73BS057A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2319OP

1 LiDAR Operator: K Quisado	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: 2/26/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 9:15	14 Engine Off: 13:50	15 Total Engine Time: 4+35	16 Take off: 9:20	17 Landing: 13:45	18 Total Flight Time: 4+25
19 Weather: Fair to Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	LEE J[signature]	C. Alfonso III	Kenneth Quisado	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status Reports

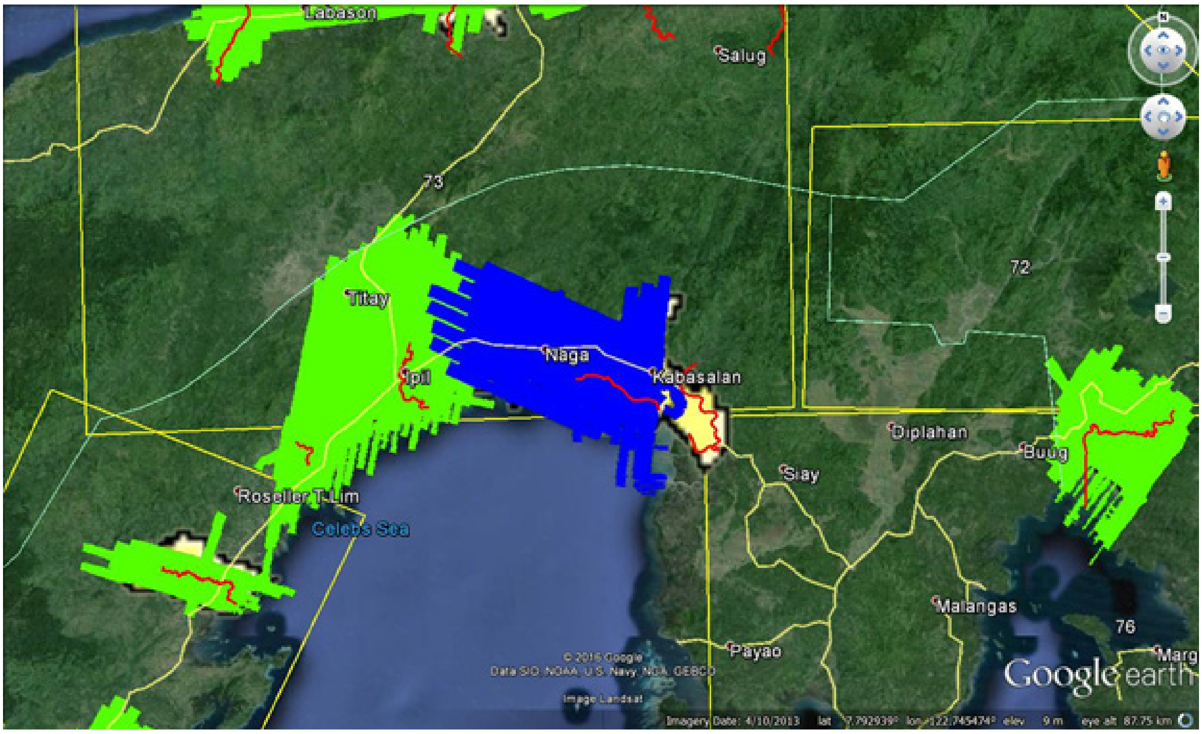
PAGADIAN and DIPOLOG REFLIGHTS
(February 24to February 26, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23132P	BLK 73A, 73B	1BLK73A055A	PJ Arceo	February 24, 2016	Restarted the system several times due to sensor temperature increase. Encountered lost Channel A error. No LAS output. Surveyed floodplains over Zamboanga Sibugay.
23140P	BLK 73B, 72A, 70A	1BLK73BS057A	K. Quisado	February 26, 2016	Encountered lost Channel A. completed BLK 73B and voids over BLK72A and 70A.

LAS BOUNDARIES PER FLIGHT

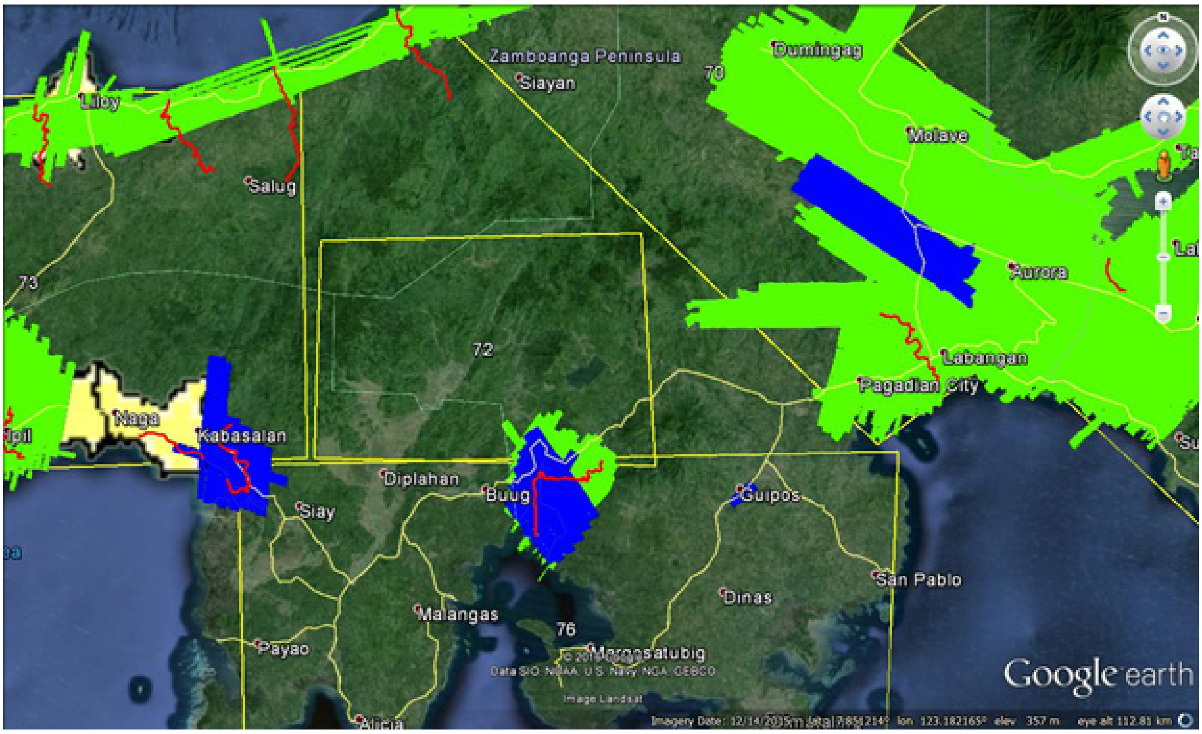
Flight No.: 23132P
Area: BLK 73A, 73B
Mission Name: 1BLK73A055A
Parameters: Altitude: 800/1200 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS



Flight No.: 23140P
Area: BLK 73B, 72A, 70A
Mission Name: 1BLK73BS057A
Parameters: Altitude: 800/1100/1200 m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

LAS



Annex 8. Mission Summary Reports

Flight Area	Pagadian
Mission Name	73A
Inclusive Flights	23132P
Range data size	24.4
POS data size	266
Base data size	49.7
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.3
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000238
IMU attitude correction stdev (<0.001deg)	0.002381
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	45.26
Ave point cloud density per sq.m. (>2.0)	3.04
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	235
Maximum Height	356.21 m
Minimum Height	58.38 m
Classification (# of points)	
Ground	151,535,157
Low vegetation	140,778,106
Medium vegetation	205,446,183
High vegetation	523,304,913
Building	5,697,858
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda

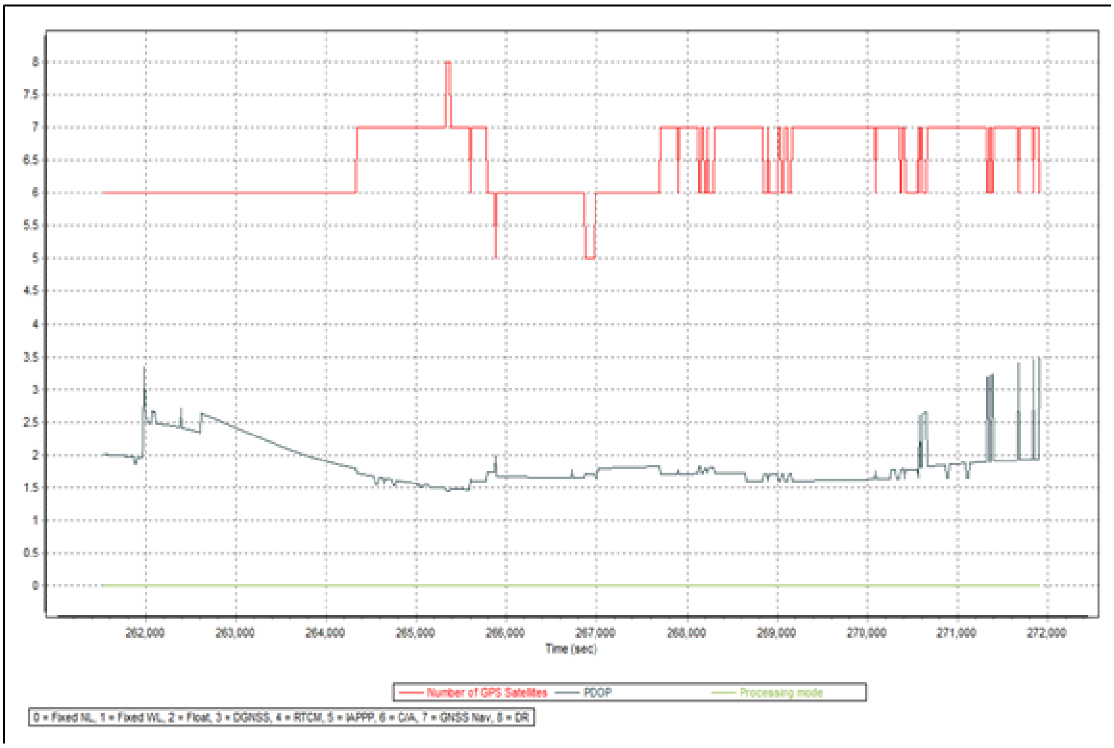


Figure A-8.1 Solution Status

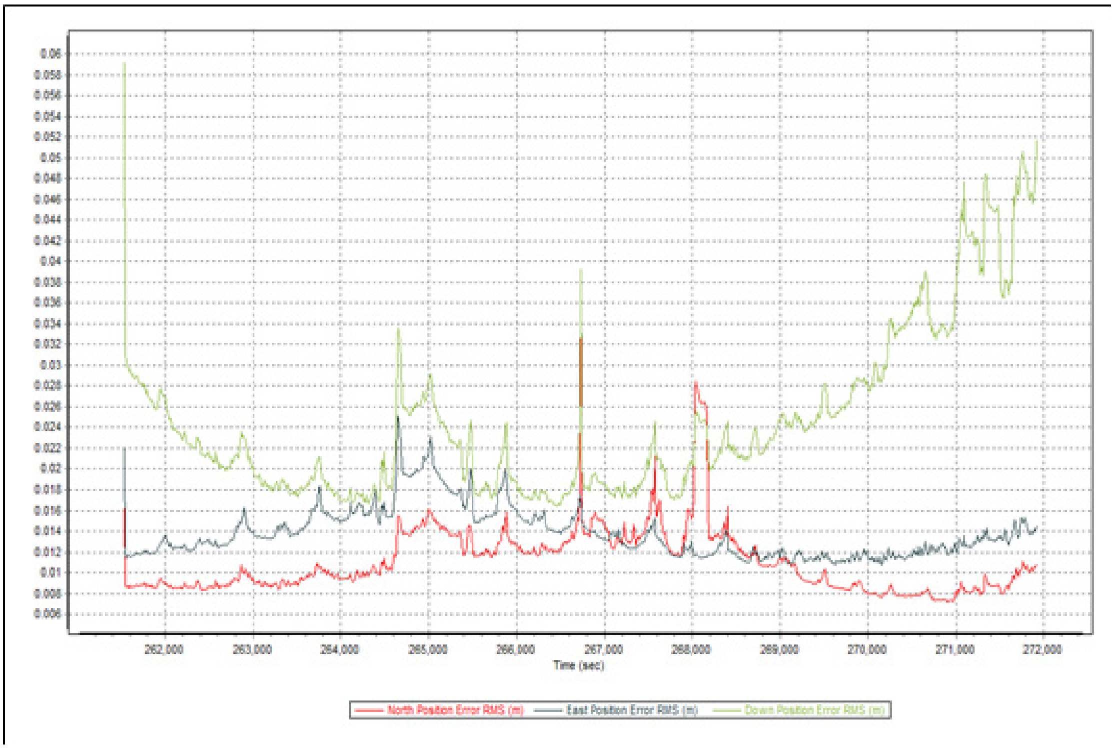


Figure A-8.2 Smoothed Performance Metric Parameters

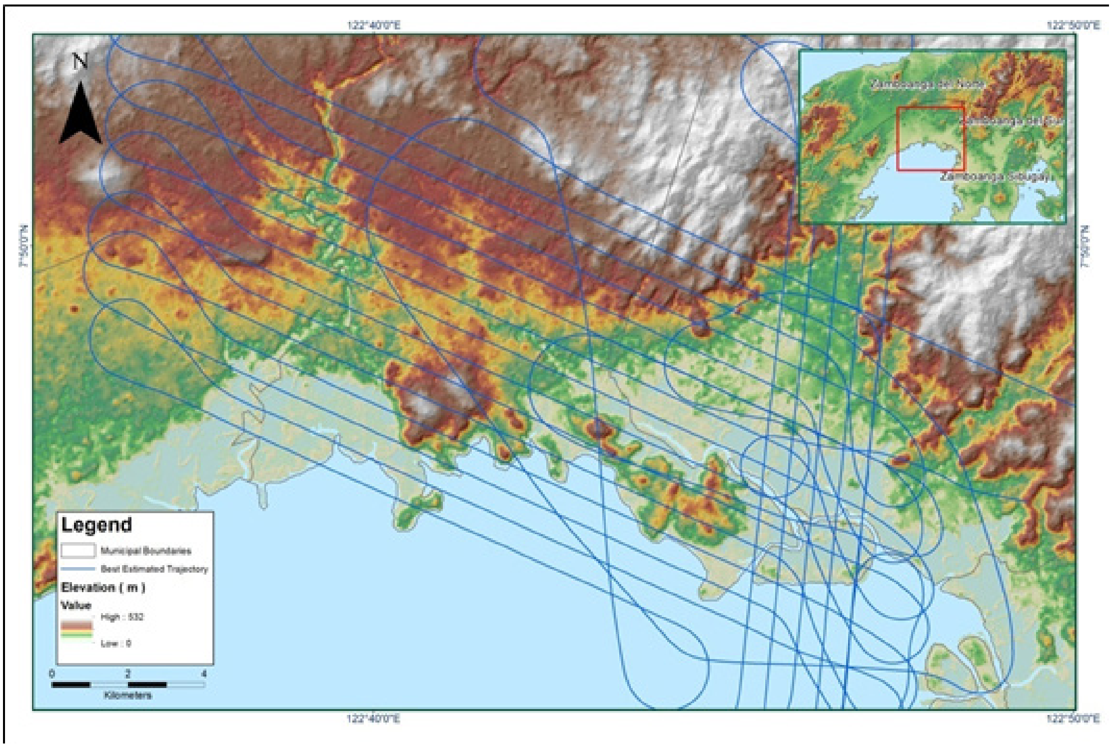


Figure A-8.3 Best Estimated Trajectory

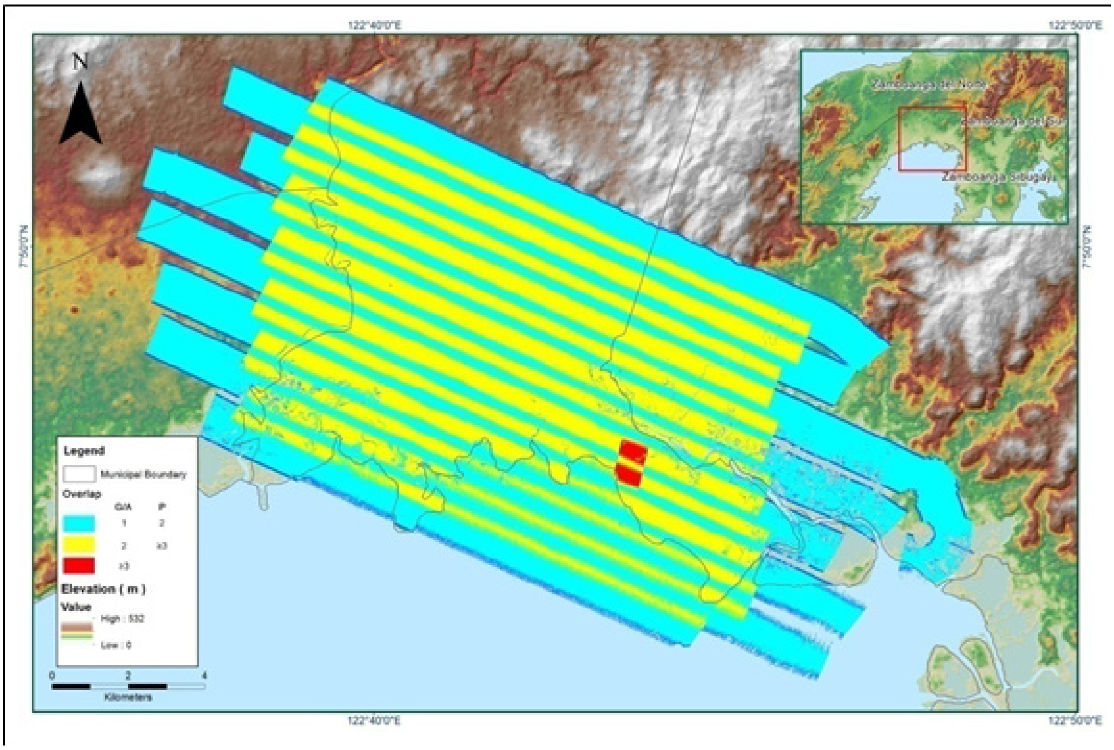


Figure A-8.4 Coverage of LiDAR Data

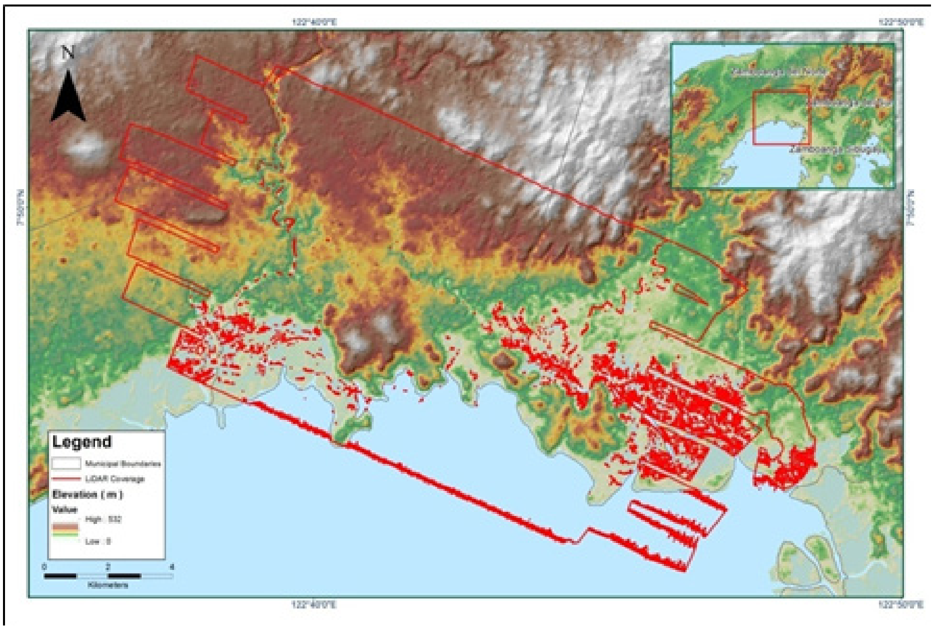


Figure A-8.5 Image of data overlap

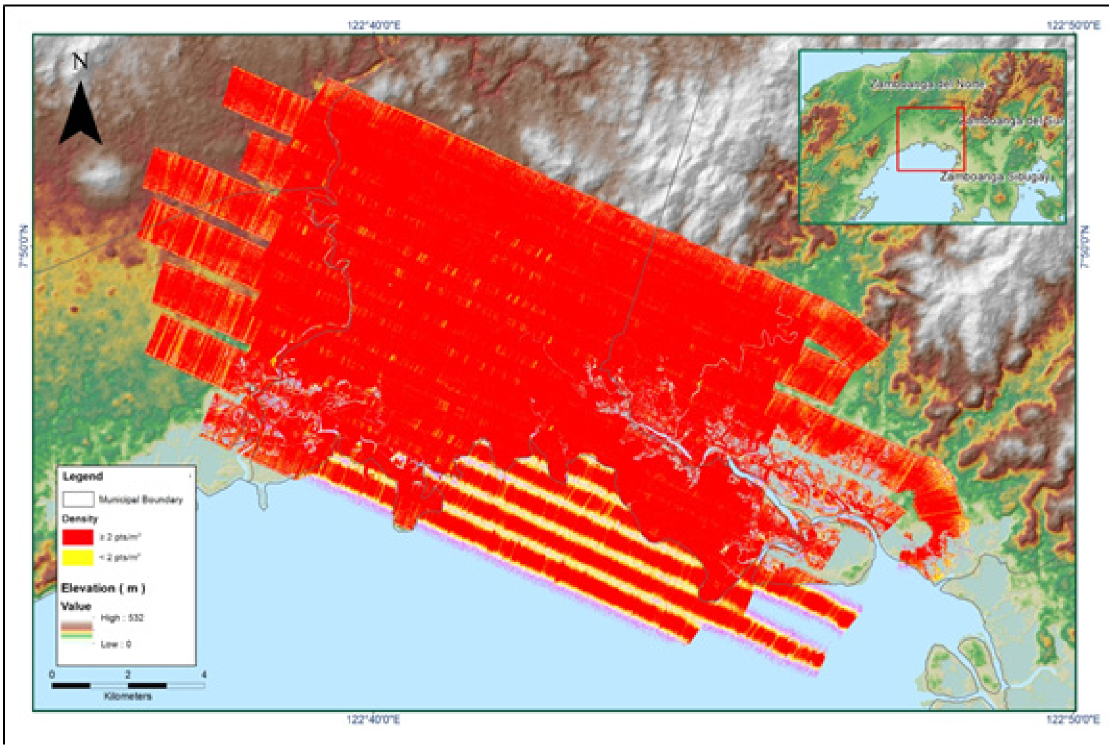


Figure A-8.6 Density map of merged LiDAR data

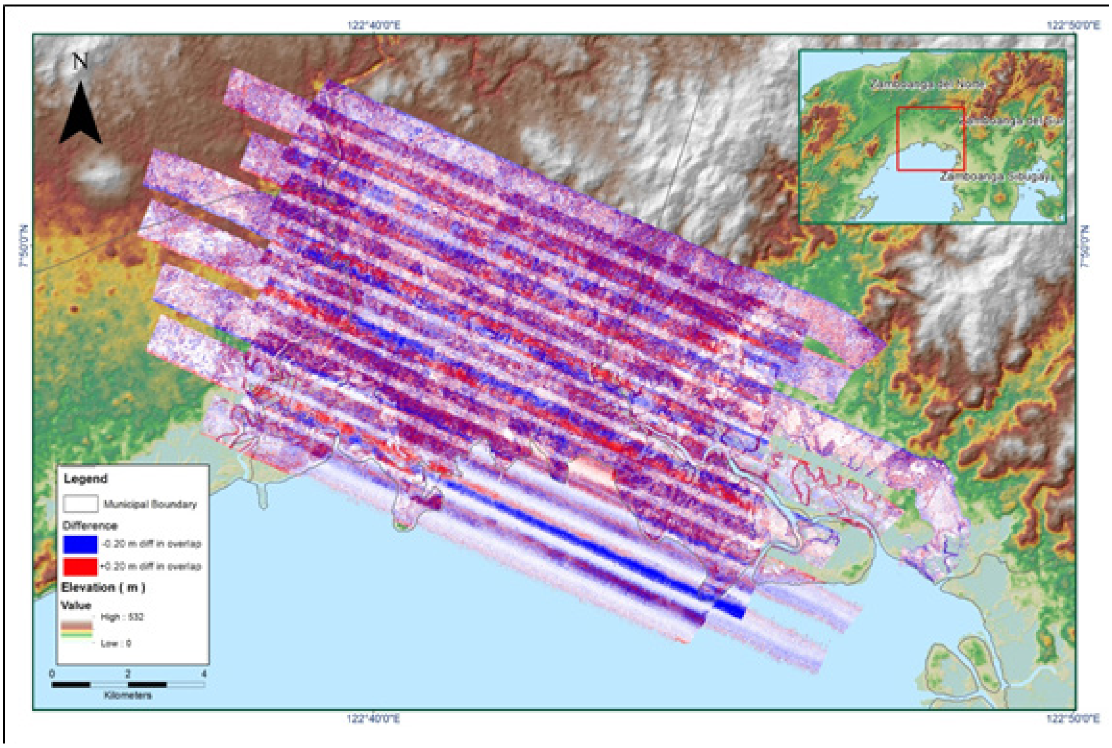


Figure A-8.7 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	73B
Inclusive Flights	23140P
Range data size	26.5
POS data size	305
Base data size	65.9
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	8.4
RMSE for East Position (<4.0 cm)	6.9
RMSE for Down Position (<8.0 cm)	1.6
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.000494
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	39.42
Ave point cloud density per sq.m. (>2.0)	2.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	116
Maximum Height	512.68 m
Minimum Height	66.73 m
Classification (# of points)	
Ground	66,220,867
Low vegetation	39,456,934
Medium vegetation	78,824,068
High vegetation	253,804,269
Building	2,461,205
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Jovelle Canlas, Maria Tamsyn Malabanan

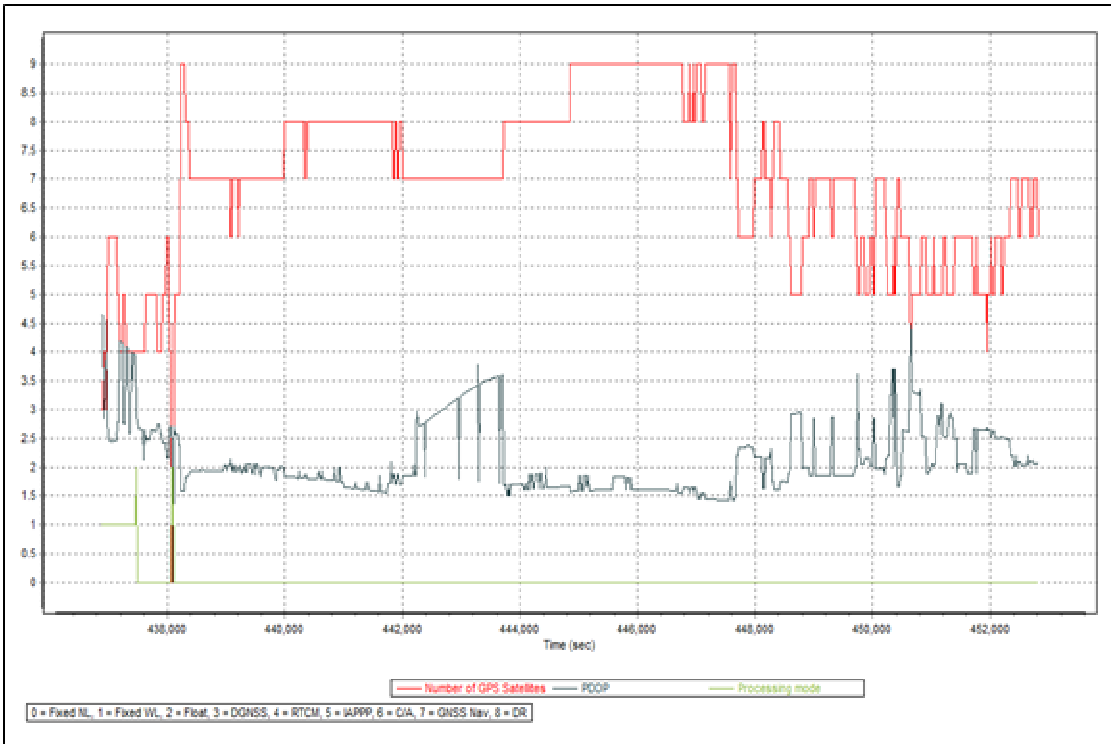


Figure A-8.8 Solution Status

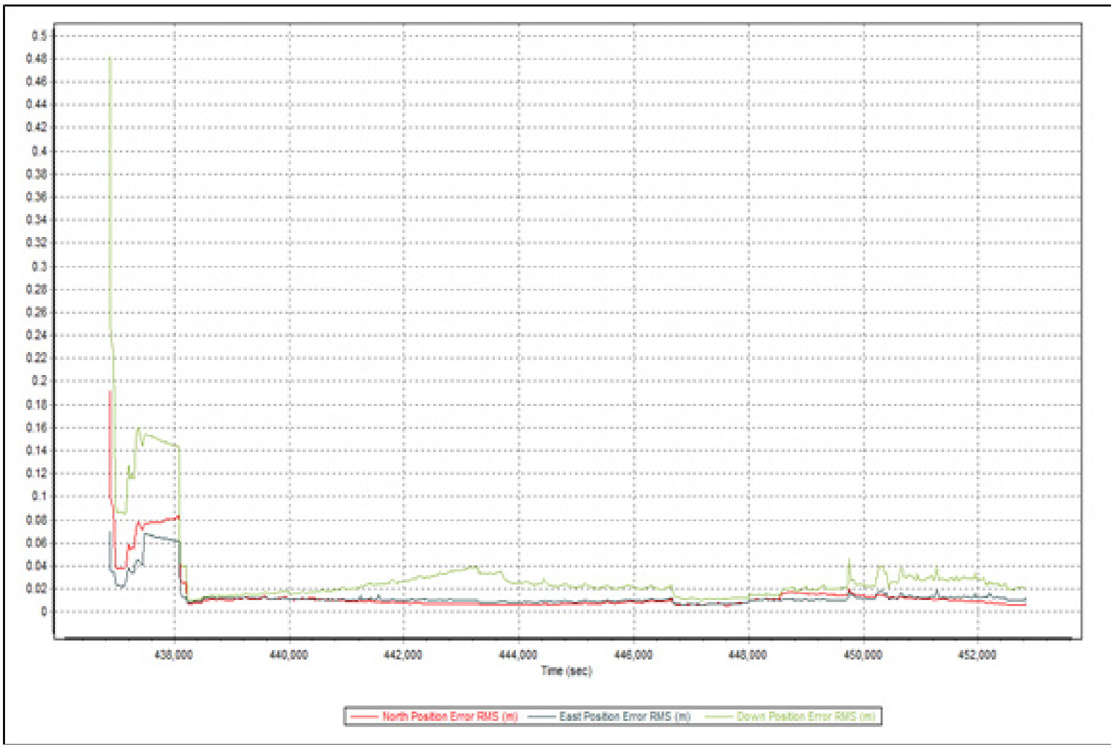


Figure A-8.9 Smoothed Performance Metric Parameters

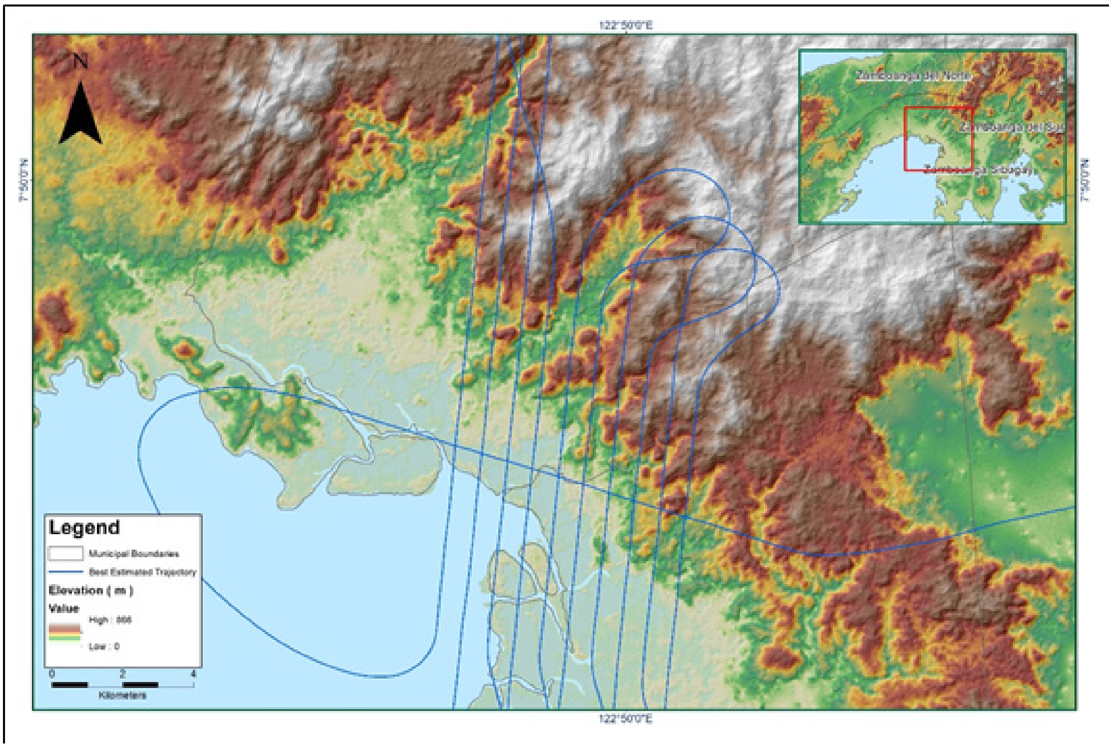


Figure A-8.10 Best Estimated Trajectory

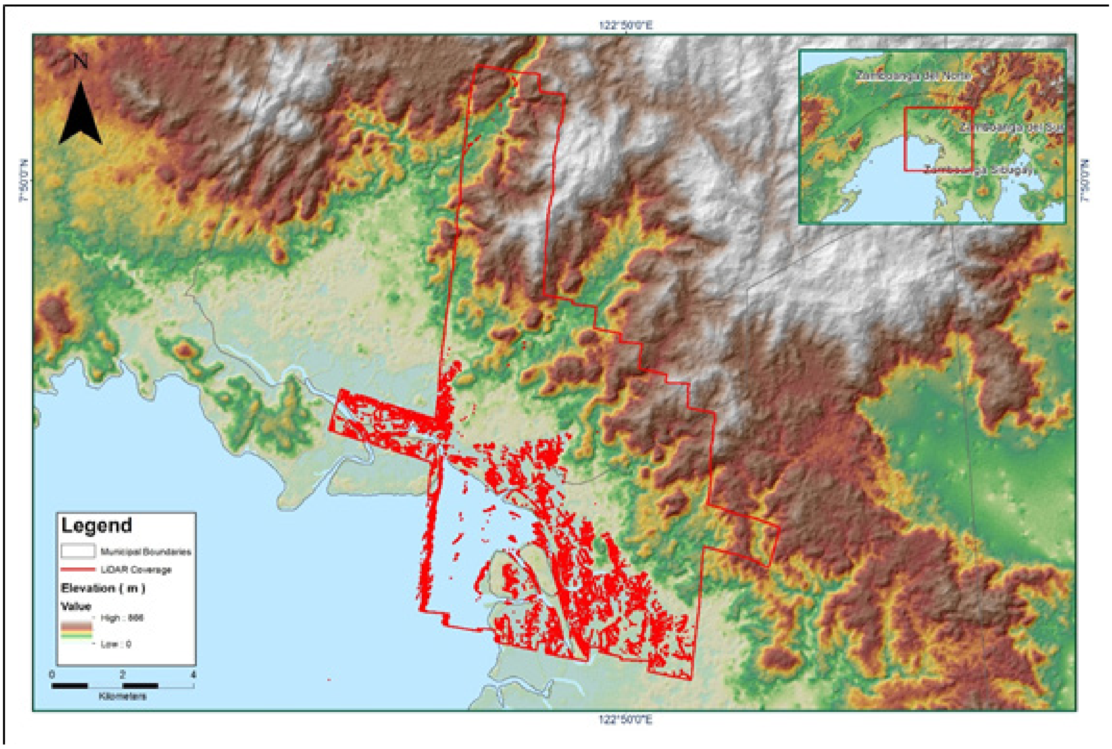


Figure A-8.11 Coverage of LiDAR Data

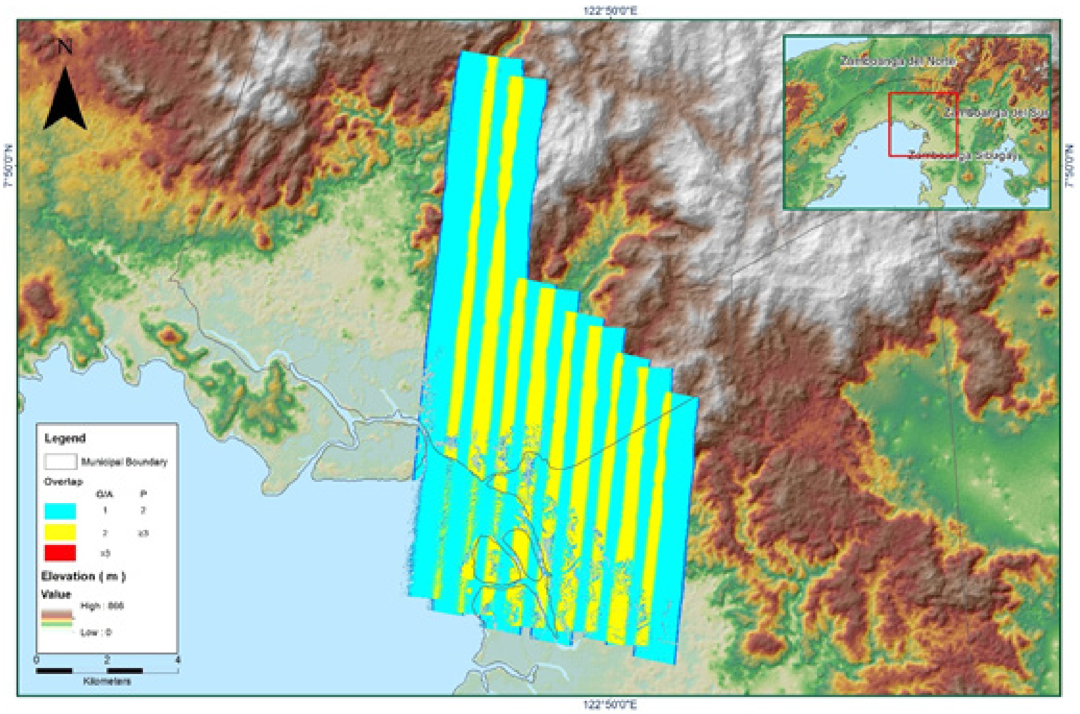


Figure A-8.12 Image of data overlap

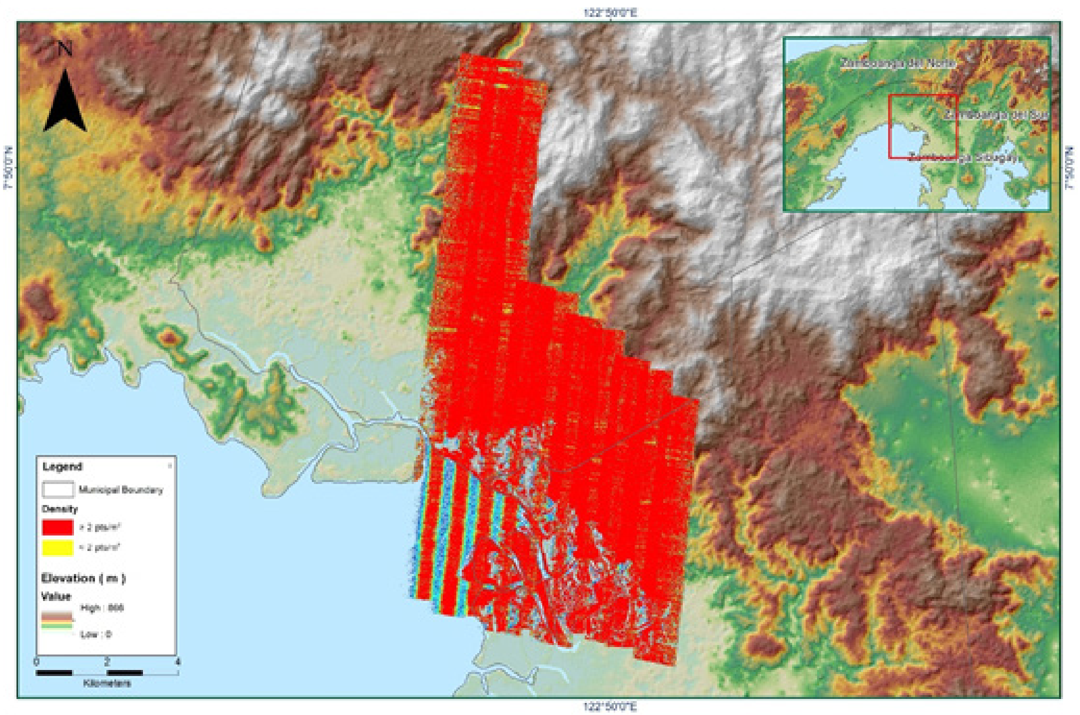


Figure A-8.13 Density map of merged LiDAR data

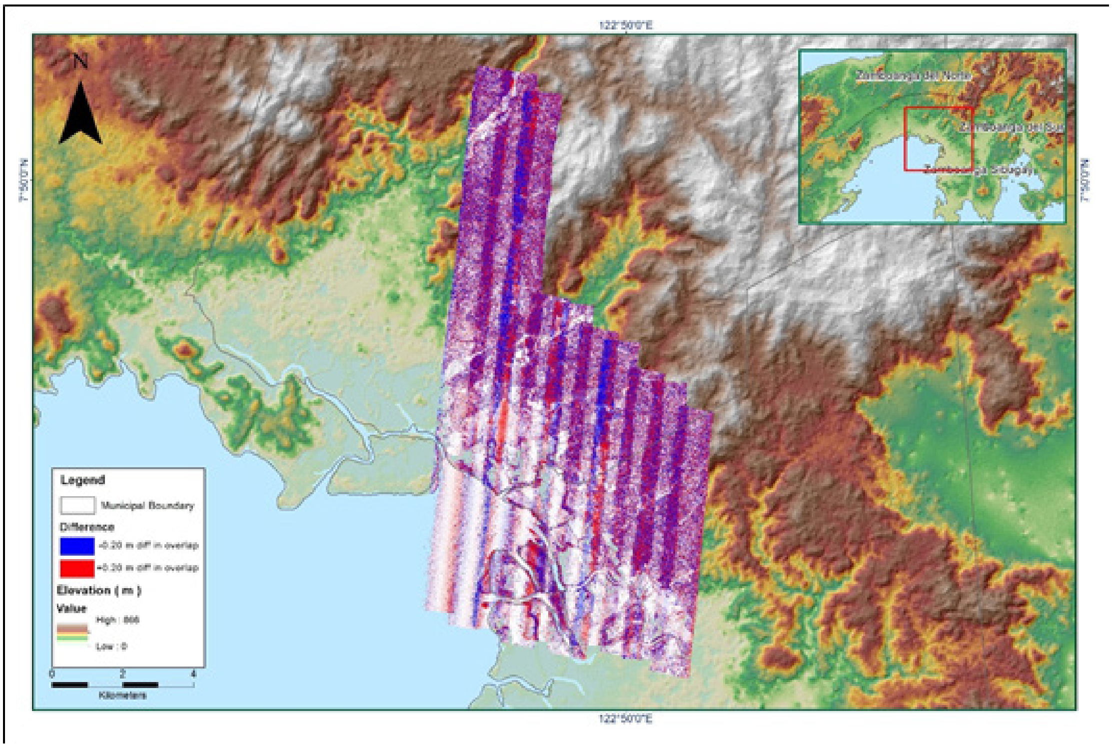


Figure A-8.14 Elevation difference between flight lines

Annex 9. Batu 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
W260	3.2598	62.0382	0.0	0.40133	0.65498	Discharge	0.0264778	0.81	Ratio to Peak	0.717
W250	3.1393	62.3	0.0	0.54797	0.89429	Discharge	0.0720997	0.81	Ratio to Peak	0.717
W240	4.5091	59.4468	0.0	1.2354	2.0161	Discharge	0.56627	0.81	Ratio to Peak	0.717
W230	4.4150	59.6344	0.0	0.56571	0.92323	Discharge	0.20231	0.81	Ratio to Peak	0.717
W220	5.2024	58.1	0.0	0.43184	0.70476	Discharge	0.12787	0.81	Ratio to Peak	0.717
W210	5.2024	58.1	0.0	0.96244	1.5707	Discharge	0.65661	0.81	Ratio to Peak	0.717
W200	5.2024	58.1	0.0	0.75227	1.2277	Discharge	0.30748	0.81	Ratio to Peak	0.717
W190	4.9182	58.6446	0.0	1.5212	2.4826	Discharge	0.76252	0.81	Ratio to Peak	0.717
W180	5.2024	58.1	0.0	0.38747	0.63235	Discharge	0.12827	0.81	Ratio to Peak	0.717
W170	5.2024	58.1	0.0	0.42611	0.69540	Discharge	0.13588	0.81	Ratio to Peak	0.717
W160	5.2024	58.1	0.0	0.62899	1.0265	Discharge	0.29506	0.81	Ratio to Peak	0.717
W150	5.2024	58.1	0.0	0.64104	1.0462	Discharge	0.42353	0.81	Ratio to Peak	0.717
W140	5.2024	58.1	0.0	0.43283	0.70637	Discharge	0.19295	0.81	Ratio to Peak	0.717

Annex 10. Batu Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R40	Automatic Fixed Interval	1314.0	0.0101999	0.02	Trapezoid	30	0.01
R50	Automatic Fixed Interval	696.69	0.0200505	0.02	Trapezoid	30	0.01
R90	Automatic Fixed Interval	4218.1	0.0212603	0.02	Trapezoid	30	0.01
R110	Automatic Fixed Interval	1013.8	0.0068303	0.02	Trapezoid	30	0.01
R120	Automatic Fixed Interval	3151.1	0.0210398	0.02	Trapezoid	30	0.01
R130	Automatic Fixed Interval	85.711	0.0324333	0.02	Trapezoid	30	0.01

Annex 11. Batu Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	7.757272	122.83158	0.86	1	-0.14	Not Defined	5 -Year
2	7.757021	122.83164	2.68	1	1.68	Not Defined	5 -Year
3	7.756911	122.83192	0.5	1	-0.50	Not Defined	5 -Year
4	7.757032	122.83205	0.91	1	-0.09	Not Defined	5 -Year
5	7.756893	122.83168	0.8	1	-0.20	Not Defined	5 -Year
6	7.756837	122.83169	0.8	1	-0.20	Not Defined	5 -Year
7	7.757248	122.83203	2.94	1	1.94	Not Defined	5 -Year
8	7.75717	122.83203	2.29	1	1.29	Not Defined	5 -Year
9	7.748606	122.82062	0.12	0.5	-0.38	Not Defined	5 -Year
10	7.748559	122.82055	0.1	0.5	-0.40	Not Defined	5 -Year
11	7.748549	122.82044	0.38	0.5	-0.12	Not Defined	5 -Year
12	7.748421	122.82047	0.53	0.5	0.03	Not Defined	5 -Year
13	7.747998	122.82021	0.19	0.5	-0.31	Not Defined	5 -Year
14	7.747942	122.82009	0.35	0.5	-0.15	Not Defined	5 -Year
15	7.748706	122.82082	0.2	0.5	-0.30	Not Defined	5 -Year
16	7.734515	122.83057	0.37	0.25	0.12	Not Defined	5 -Year
17	7.734474	122.83047	0.36	0.4	-0.04	Not Defined	5 -Year
18	7.736386	122.82722	0.03	1	-0.97	Not Defined	5 -Year
19	7.73696	122.82739	0.03	1	-0.97	Not Defined	5 -Year
20	7.734455	122.831	0.18	0.4	-0.22	Not Defined	5 -Year
21	7.734389	122.83113	0.17	0.4	-0.23	Not Defined	5 -Year
22	7.734542	122.83117	0.03	0.4	-0.37	Not Defined	5 -Year
23	7.734482	122.82454	0.03	0.85	-0.82	Not Defined	5 -Year

24	7.731278	122.82438	0.13	0.67	-0.54	Not Defined	5 -Year
25	7.734506	122.82993	0.03	0	0.03	Not Defined	5 -Year
26	7.73447	122.82998	0.03	0	0.03	Not Defined	5 -Year
27	7.734367	122.83007	0.03	0	0.03	Not Defined	5 -Year
28	7.734304	122.83011	0.03	0	0.03	Not Defined	5 -Year
29	7.734248	122.83016	0.03	0	0.03	Not Defined	5 -Year
30	7.747977	122.8254	0.23	0.6	-0.37	Not Defined	5 -Year
31	7.748146	122.82553	0.32	0.6	-0.28	Not Defined	5 -Year
32	7.748452	122.82554	0.29	0.7	-0.41	Not Defined	5 -Year
33	7.757079	122.83182	2.7	1	1.70	Not Defined	5 -Year
34	7.757156	122.83194	3.34	1	2.34	Not Defined	5 -Year
35	7.75692	122.83192	0.5	0.5	0.00	Not Defined	5 -Year
36	7.756992	122.83165	2.5	1	1.50	Not Defined	5 -Year
37	7.757171	122.83203	2.29	1	1.29	Not Defined	5 -Year
38	7.75716	122.83209	1.22	1	0.22	Not Defined	5 -Year
39	7.757156	122.8322	1.75	0.5	1.25	Not Defined	5 -Year
40	7.757107	122.83227	1.14	1	0.14	Not Defined	5 -Year
41	7.756909	122.83206	0.72	1	-0.28	Not Defined	5 -Year
42	7.756956	122.83214	0.52	1	-0.48	Not Defined	5 -Year
43	7.749036	122.82081	0.24	0.5	-0.26	Not Defined	5 -Year
44	7.748713	122.82084	0.2	0.5	-0.30	Not Defined	5 -Year
45	7.748585	122.82122	0.27	0.5	-0.23	Not Defined	5 -Year
46	7.748577	122.82129	0.33	0.5	-0.17	Not Defined	5 -Year
47	7.748625	122.82135	0.27	0.5	-0.23	Not Defined	5 -Year

48	7.748562	122.82142	0.29	0.5	-0.21	Not Defined	5 -Year
49	7.749009	122.82116	0.2	0.5	-0.30	Not Defined	5 -Year
50	7.74898	122.82128	0.28	0.5	-0.22	Not Defined	5 -Year
51	7.748837	122.82146	0.3	0.5	-0.20	Not Defined	5 -Year
52	7.748843	122.82162	0.39	0.5	-0.11	Not Defined	5 -Year
53	7.748754	122.82182	0.48	0.5	-0.02	Not Defined	5 -Year
54	7.748014	122.8218	0.28	0.5	-0.22	Not Defined	5 -Year
55	7.749162	122.82081	0.41	0.5	-0.09	Not Defined	5 -Year
56	7.748845	122.82074	0.22	0.5	-0.28	Not Defined	5 -Year
57	7.748934	122.82069	0.27	0.5	-0.23	Not Defined	5 -Year
58	7.749234	122.82088	0.41	0.5	-0.09	Not Defined	5 -Year
59	7.749069	122.82176	0.35	0.5	-0.15	Not Defined	5 -Year
60	7.749498	122.82277	0.37	0.5	-0.13	Not Defined	5 -Year
61	7.749698	122.82297	0.3	0.5	-0.20	Not Defined	5 -Year
62	7.737278	122.8274	0.03	0.8	-0.77	Not Defined	5 -Year
63	7.736683	122.82729	0.03	1.3	-1.27	Not Defined	5 -Year
64	7.736388	122.82722	0.03	1	-0.97	Not Defined	5 -Year
65	7.735859	122.82709	0.03	0.7	-0.67	Not Defined	5 -Year
66	7.735525	122.82714	0.03	0.6	-0.57	Not Defined	5 -Year
67	7.735554	122.83025	0.03	0.2	-0.17	Not Defined	5 -Year
68	7.735231	122.83014	0.03	0.2	-0.17	Not Defined	5 -Year
69	7.734836	122.83014	0.03	0.2	-0.17	Not Defined	5 -Year
70	7.734443	122.8302	0.03	0.2	-0.17	Not Defined	5 -Year
71	7.747472	122.82541	0.26	0.3	-0.04	Not Defined	5 -Year

72	7.747962	122.82543	0.2	0.6	-0.40	Not Defined	5 -Year
73	7.748091	122.82531	0.18	0.6	-0.42	Not Defined	5 -Year
74	7.748156	122.82553	0.48	0.6	-0.12	Not Defined	5 -Year
75	7.736913	122.83344	0.22	0.2	0.02	Not Defined	5 -Year
76	7.736591	122.83209	0.21	0.4	-0.19	Not Defined	5 -Year
77	7.737133	122.83152	0.13	0.3	-0.17	Not Defined	5 -Year
78	7.737254	122.83174	0.13	0.2	-0.07	Not Defined	5 -Year
79	7.737177	122.83179	0.15	0.1	0.05	Not Defined	5 -Year
80	7.736786	122.83177	0.14	0.3	-0.16	Not Defined	5 -Year
81	7.736975	122.83189	0.16	0.3	-0.14	Not Defined	5 -Year
82	7.736699	122.83187	0.15	0.4	-0.25	Not Defined	5 -Year
83	7.736676	122.83208	0.27	0.3	-0.03	Not Defined	5 -Year
84	7.737517	122.83149	0.23	0.4	-0.17	Not Defined	5 -Year
85	7.737693	122.83102	0.54	0.3	0.24	Not Defined	5 -Year
86	7.73802	122.83107	0.34	0.2	0.14	Not Defined	5 -Year
87	7.757277	122.83157	1.19	1	0.19	Not Defined	5 -Year
88	7.757027	122.83208	0.91	1	-0.09	Not Defined	5 -Year
89	7.757168	122.83203	2.29	1	1.29	Not Defined	5 -Year
90	7.757248	122.83204	1.73	1	0.73	Not Defined	5 -Year
91	7.74874	122.82071	0.21	0.5	-0.29	Not Defined	5 -Year
92	7.748732	122.82036	0.42	0.5	-0.08	Not Defined	5 -Year
93	7.748801	122.82028	1.07	0.5	0.57	Not Defined	5 -Year
94	7.748725	122.82018	0.9	0.5	0.40	Not Defined	5 -Year
95	7.748676	122.82015	0.38	0.5	-0.12	Not Defined	5 -Year
96	7.748533	122.82002	0.83	0.5	0.33	Not Defined	5 -Year
97	7.748337	122.81994	0.71	1	-0.29	Not Defined	5 -Year

98	7.748655	122.81992	0.58	1	-0.42	Not Defined	5 -Year
99	7.748569	122.81988	0.33	1	-0.67	Not Defined	5 -Year
100	7.748663	122.81991	0.58	1	-0.42	Not Defined	5 -Year
101	7.748532	122.81979	0.37	1	-0.63	Not Defined	5 -Year
102	7.748383	122.8198	0.44	1	-0.56	Not Defined	5 -Year
103	7.748428	122.81962	0.24	1	-0.76	Not Defined	5 -Year
104	7.748155	122.81972	0.62	1	-0.38	Not Defined	5 -Year
105	7.748821	122.8205	0.66	1	-0.34	Not Defined	5 -Year
106	7.748886	122.82054	0.44	0.5	-0.06	Not Defined	5 -Year
107	7.748914	122.82038	0.98	1	-0.02	Not Defined	5 -Year
108	7.748847	122.82042	0.9	1	-0.10	Not Defined	5 -Year
109	7.748958	122.82043	0.98	1	-0.02	Not Defined	5 -Year
110	7.749066	122.82051	0.68	0.5	0.18	Not Defined	5 -Year
111	7.749015	122.82054	0.39	0.5	-0.11	Not Defined	5 -Year
112	7.74906	122.82058	0.44	0.5	-0.06	Not Defined	5 -Year
113	7.749133	122.82057	0.44	0.5	-0.06	Not Defined	5 -Year
114	7.748939	122.82068	0.27	0.5	-0.23	Not Defined	5 -Year
115	7.748993	122.82082	0.24	0.5	-0.26	Not Defined	5 -Year
116	7.749235	122.82088	0.41	0.5	-0.09	Not Defined	5 -Year
117	7.748954	122.82129	0.25	0.5	-0.25	Not Defined	5 -Year
118	7.748826	122.82146	0.3	0.5	-0.20	Not Defined	5 -Year
119	7.748826	122.82161	0.39	0.5	-0.11	Not Defined	5 -Year
120	7.753741	122.82376	1.87	1	0.87	Not Defined	5 -Year
121	7.755029	122.8238	1.1	0.5	0.60	Not Defined	5 -Year
122	7.754961	122.82382	1.02	0.5	0.52	Not Defined	5 -Year

123	7.732962	122.83222	0.03	0.4	-0.37	Not Defined	5 -Year
124	7.732832	122.83239	0.03	0.4	-0.37	Not Defined	5 -Year
125	7.73222	122.83214	0.03	0.4	-0.37	Not Defined	5 -Year
126	7.732228	122.83279	0.15	0.4	-0.25	Not Defined	5 -Year
127	7.731989	122.83278	0.09	0.4	-0.31	Not Defined	5 -Year
128	7.731374	122.83279	0.07	0.4	-0.33	Not Defined	5 -Year
129	7.732443	122.83544	0.03	0.3	-0.27	Not Defined	5 -Year
130	7.735194	122.83272	0.03	0.4	-0.37	Not Defined	5 -Year
131	7.735359	122.83262	0.03	0.4	-0.37	Not Defined	5 -Year
132	7.747831	122.82537	0.26	0.6	-0.34	Not Defined	5 -Year
133	7.747561	122.82539	0.27	0.3	-0.03	Not Defined	5 -Year
134	7.748094	122.82531	0.18	0.6	-0.42	Not Defined	5 -Year
135	7.748219	122.82552	0.48	0.6	-0.12	Not Defined	5 -Year
136	7.748442	122.82556	0.29	0.7	-0.41	Not Defined	5 -Year
137	7.73683	122.83388	0.24	0.2	0.04	Not Defined	5 -Year
138	7.736731	122.83376	0.11	0.2	-0.09	Not Defined	5 -Year
139	7.736719	122.83366	0.28	0.2	0.08	Not Defined	5 -Year
140	7.736555	122.83372	0.11	0.2	-0.09	Not Defined	5 -Year
141	7.736691	122.83353	0.28	0.3	-0.02	Not Defined	5 -Year
142	7.736684	122.83344	0.28	0.3	-0.02	Not Defined	5 -Year
143	7.736398	122.83333	0.19	0.2	-0.01	Not Defined	5 -Year
144	7.736583	122.83321	0.28	0.1	0.18	Not Defined	5 -Year
145	7.73642	122.83315	0.13	0.1	0.03	Not Defined	5 -Year
146	7.736527	122.83306	0.09	0.2	-0.11	Not Defined	5 -Year
147	7.736433	122.83271	0.13	0.2	-0.07	Not Defined	5 -Year

148	7.736397	122.83263	0.13	0.2	-0.07	Not Defined	5 -Year
149	7.736364	122.83252	0.15	0.2	-0.05	Not Defined	5 -Year
150	7.736264	122.83247	0.16	0.4	-0.24	Not Defined	5 -Year
151	7.73617	122.83255	0.12	0.1	0.02	Not Defined	5 -Year
152	7.736063	122.83258	0.12	0.1	0.02	Not Defined	5 -Year
153	7.736022	122.83261	0.12	0.1	0.02	Not Defined	5 -Year
154	7.735924	122.83266	0.04	0.1	-0.06	Not Defined	5 -Year
155	7.735836	122.83265	0.19	0.1	0.09	Not Defined	5 -Year
156	7.735786	122.83268	0.19	0.1	0.09	Not Defined	5 -Year
157	7.735725	122.83267	0.19	0.1	0.09	Not Defined	5 -Year
158	7.735666	122.8326	0.14	0.1	0.04	Not Defined	5 -Year
159	7.73557	122.83259	0.15	0.1	0.05	Not Defined	5 -Year
160	7.735744	122.83343	0.06	0.2	-0.14	Not Defined	5 -Year
161	7.739112	122.83216	0.03	0.1	-0.07	Not Defined	5 -Year
162	7.739015	122.83219	0.03	0.1	-0.07	Not Defined	5 -Year
163	7.73929	122.83189	0.03	0.1	-0.07	Not Defined	5 -Year
164	7.739193	122.83188	0.03	0.1	-0.07	Not Defined	5 -Year
165	7.739375	122.83187	0.03	0.1	-0.07	Not Defined	5 -Year
166	7.739388	122.83177	0.03	0.1	-0.07	Not Defined	5 -Year
167	7.739609	122.83172	0.03	0.1	-0.07	Not Defined	5 -Year
168	7.73925	122.83161	0.03	0.3	-0.27	Not Defined	5 -Year
169	7.739378	122.83169	0.03	0.1	-0.07	Not Defined	5 -Year
170	7.739335	122.83164	0.03	0.1	-0.07	Not Defined	5 -Year
171	7.7394	122.83157	0.03	0.2	-0.17	Not Defined	5 -Year
172	7.739497	122.83158	0.03	0.2	-0.17	Not Defined	5 -Year

173	7.739521	122.83149	0.03	0.2	-0.17	Not Defined	5 -Year
174	7.739596	122.8316	0.03	0.2	-0.17	Not Defined	5 -Year
175	7.739609	122.83146	0.09	0.2	-0.11	Not Defined	5 -Year
176	7.739762	122.83154	0.03	0.2	-0.17	Not Defined	5 -Year
177	7.739819	122.83127	0.03	0.3	-0.27	Not Defined	5 -Year
178	7.739835	122.83137	0.22	0.3	-0.08	Not Defined	5 -Year
179	7.739864	122.83151	0.03	0.2	-0.17	Not Defined	5 -Year
180	7.739919	122.83148	0.14	0.2	-0.06	Not Defined	5 -Year
181	7.739988	122.83148	0.14	0.2	-0.06	Not Defined	5 -Year
182	7.739962	122.83138	0.51	0.1	0.41	Not Defined	5 -Year
183	7.740042	122.83135	0.52	0.2	0.32	Not Defined	5 -Year
184	7.740013	122.83118	0.37	0.2	0.17	Not Defined	5 -Year
185	7.740328	122.83131	0.06	0.2	-0.14	Not Defined	5 -Year
186	7.740437	122.83121	0.03	0.2	-0.17	Not Defined	5 -Year
187	7.740377	122.83114	0.03	0.1	-0.07	Not Defined	5 -Year

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Annex 12. Educational Institutions affected by flooding in Batu Floodplain

Siay				
Barangay	Buildings	Rainfall Scenario		
		5-year	25-year	100-year
Batu	SDA SCHOOL	None	None	None

Kabasalan				
Barangay	Buildings	Rainfall Scenario		
		5-year	25-year	100-year
Concepcion	Daycare school	None	None	None
Concepcion	F.Ramos National High School	None	None	Low
Concepcion	Buayan elementary school	Medium	Medium	Medium
Concepcion	Learning center	None	None	None
Nazareth	Nazareth es	None	None	None
Nazareth	Day care center	None	None	None
Elementary School	San Vicente			

Annex 13. Health Institutions affected by flooding in Batu Floodplain

Kabasalan				
Barangay	Buildings	Rainfall Scenario		
		5-year	25-year	100-year
Nazareth	Health Center	None	None	None