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

LiDAR Surveys and Flood Mapping of Patawag River

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

APRIL 2017

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

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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

Mr. Mario S. Rodriguez and Enrico C Paringit, Dr. Eng.

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 Libertad River Basin

The Patawag River Basin covers four (4) municipalities in Zamboanga del Norte, namely the municipalities of Kalawit, Labson, Liloy, and Tampilisan. It has a total watershed area of 181.73 sq. km. According to the DENR River Basin Control Office (RBCO, 2015), the Patawag River Basin has a drainage area of 177 sq. km. and an estimated 133 cubic meter (MCM) annual run-off.

Its main stem, Patawag River, is part of the eighteen (18) river systems under the PHIL-LIDAR 1 Program partner HEI, Ateneo de Zamboanga University. Serving as the political boundary between two municipalities, the Patawag River is located in between the municipalities of Labason and Liloy.

As reported by the Provincial Government of Zamboanga del Norte, the municipalities of Tampilisan, Kalawit and Liloy, where the Patawag River Basin is located, are part of the top 8 municipalities in the province where most rubbers were planted and where trading of rubber is one of the major economic activities.

Based on the Expanded Vulnerability and Suitability Assessment Map for Rubber generated by the province, the municipality of Tampilisan has a total of 7.326 hectares, existing for rubber plants, while the municipality of Kalawit has a total of 5.227 hectares.

Meanwhile, according to the 2015 national census of PSA, a total of 2,480 persons are residing in Brgy. Patawag in the Municipality of Bacungan, which is within the immediate vicinity of the river. The economy of the province Zamboanga del Norte largely rests on agriculture particularly fishing, and mineral extraction (Source: http://www.islandsproperties.com/places/zambonor.htm).

According to history, the name of the river came from the Cebuano word “Tawag” which means “to call”. When the bridge wasn’t built yet, the people from either side of the river used to call for a boat for them to be able to cross, as they would not dare cross on their own as it was known that the river was infested with crocodiles. Thus, both sides of the river were called “Patawag”. To lessen the confusion, the localities have labeled Patawag-Labason for the Labason-side of the river and Patawag-Liloy on the other side.

Figure 1. Patawag River

As Pawatag River is the main channel of the river basin, the amount of water that flows down to the river is enormous. Though the waters of the river do not usually overflow from the riverbanks, the riverside and nearby areas of the river are still susceptible to flooding. This was indicated in the Geo-hazard Maps generated by the Mines and Geosciences Bureau (MGB), in which they have pointed out that the flooding in the area could reach to more than 1 meter in height.

This was exemplified in 2013 when the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of the Municipality of Labason have recorded a flooding incidence caused by a continuous rain in the upstream area of the river.

Just recently, on February 1, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Patawag River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Mindanao as per NDRRMC report (Source: www.ndrrmc.gov.ph/attachments/article/3/ADVISORY_GFA_No.06-REGII,_No.05-REG_III,_No.01-REG_IX,_No.02-REG_X,_No.02-REG_XI,_No.02-CARAGA,_No.05-CAR,_No.01-ARMM.pdf)

Figure 2. Up-streams of Patawag River hours after rain event

Sources:
Municipal DRRM Plan- MDRRMO Labason
Mines and Geosciences Bureau
Provincial Commodities Investment Plan- LGU of Zamboanga del Norte

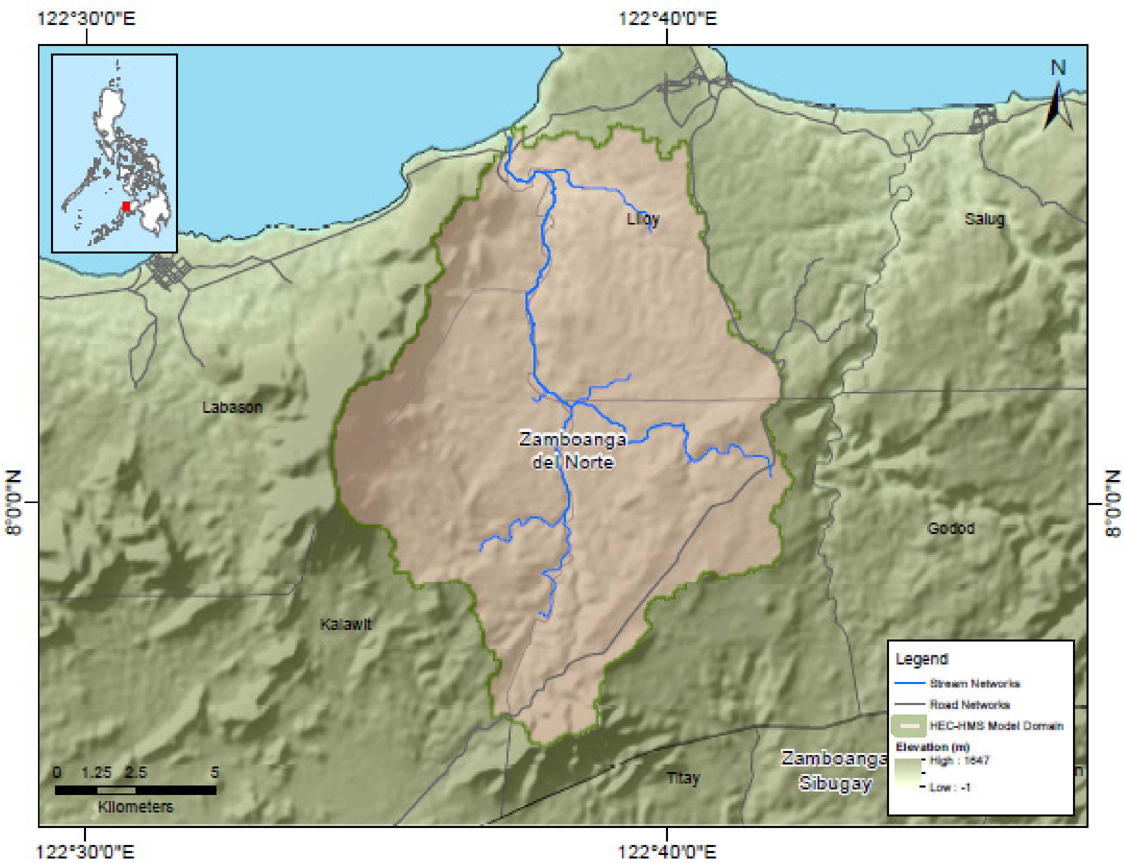

Figure 3. Map of Patawag River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN PATAWAG FLOODPLAIN

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

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Patawag floodplain in Zamboanga del Norte. 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 4 shows the flight plans for Patawag 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)
BLK73A	750, 850, 1000	20, 30	50	200	30	130	5
BLK73D	600, 700, 800, 1000, 1100, 1200	30	50	200	30	130	5
BLK73E	600, 700, 800, 1000, 1100, 1200	30	50	200	30	130	5
BLK73F	700, 800, 1000, 1100, 1200	30	50	200	30	130	5

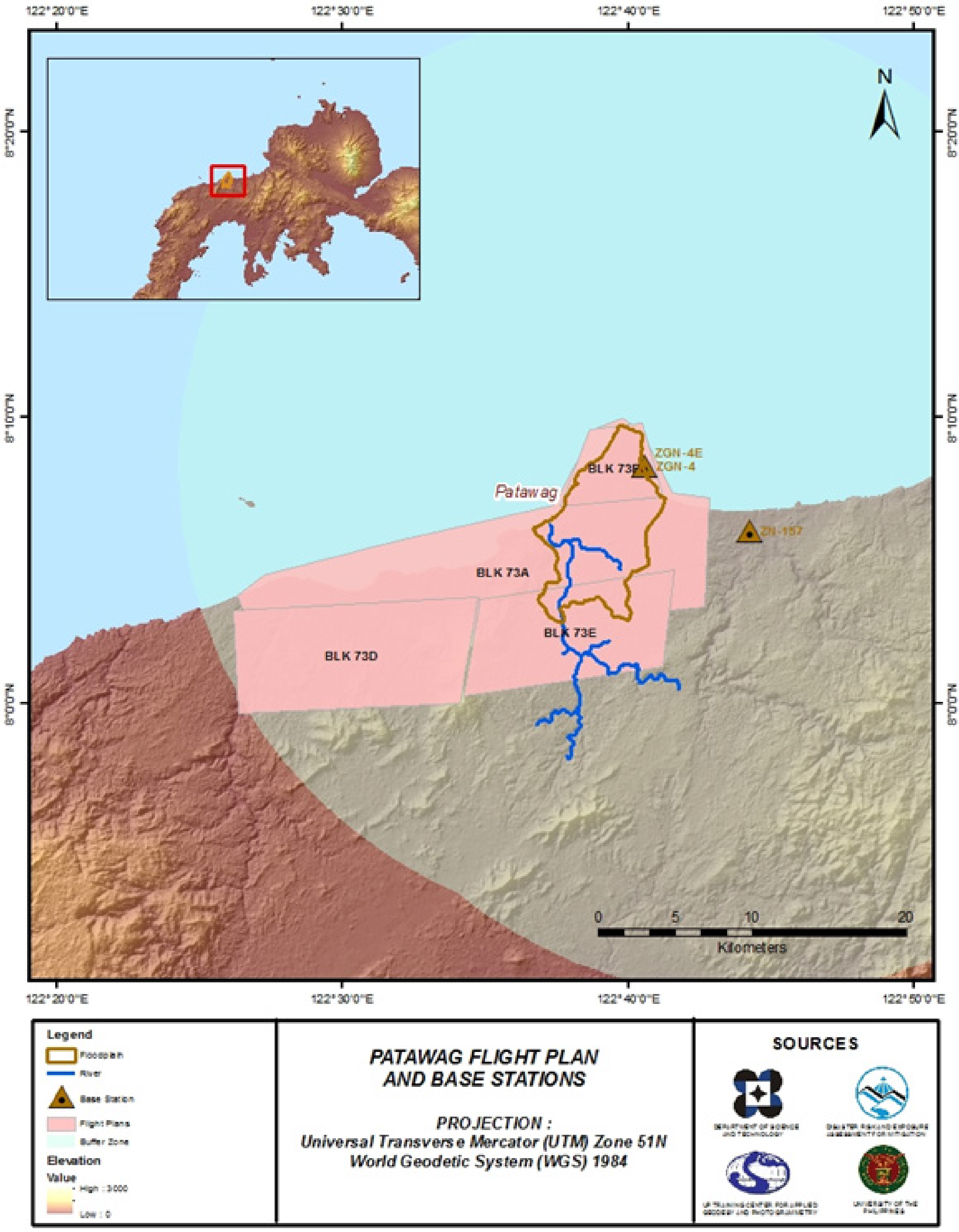

Figure 4. Flight plan and base stations used for Patawag Floodplain.

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point, ZGN-4, which is of first (1st) order accuracy. The project team also recovered one (1) NAMRIA benchmark, ZN-157 and established one (1) ground control point, ZGN-4E.The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing reports for the benchmark and established control pointare found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (November 6 - 11, 2014 and November 26 - 28, 2016). Base stations were observed using dual frequency GPS receivers:TRIMBLE SPS 852, TRIMBLE SPS 882 and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Patawag Floodplain are shown in Figure 4.

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

Figure 5. GPS set-up over ZGN-4 at Barangay Lamao, Liloy, Zamboanga del Norte (a) and NAMRIA reference point ZGN-4 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ZGN-4 used as base station for the LiDAR acquisition.

Station Name	NGW-87	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 8' 20.40827" North 122° 40' 28.89097" East 3.848 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	464,150.413 meters 899,937.404 meter
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 8' 16.73719" North 122° 40' 34.34251" East 67.3513 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	516210.93 meters 1143192.99 meters

Table 3. Details of the recovered NAMRIA vertical control point ZN-157 used as base station for the LiDAR acquisition with established coordinates.

Station Name	ZN-157	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 6’ 5.34724” North 122° 44’ 9.71575” East 7.394 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 6’ 1.69150” North 122° 44’ 15.17027” East 71.024 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	471,084.95 meters 895,414.31 meters

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

Station Name	ZGN-4E	
Order of Accuracy	2nd (established point)	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 8' 16.81854" North 122° 40' 34.48473" East 67.351 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 8' 16.81854" North 122° 40' 34.48473" East 67.351 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	464,334.47 meters 899,568.85 meters

Table 5. Ground Control Points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 6, 2014	2169P	1BLK73A310A	ZGN-4, ZN-157
November 10, 2014	2185P	1BLK73A314A	ZGN-4, ZGN-4E
November 11, 2014	2189P	1BLK73A315A	ZGN-4, ZN-157
November 26, 2016	23582P	1BLK73DE331A	ZGN-4, ZN-157
November 28, 2016	23590P	1BLK73DEF333A	ZGN-4, ZN-157

2.3 Flight Missions

Five (5) missions were conducted to complete the LiDAR data acquisition in Patawag Floodplain, for a total of twenty-one hours and two minutes (21+2) of flying time for RP-9122. The missions were acquired using the Pegasus LiDAR system. Table 6 shows the total area of actual coverage and the corresponding flying hours of the mission while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for LiDAR data acquisition in Patawag floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
November 6, 2014	2169P	223.6	170.41	36.98	133.43	559	4	5
November 10, 2014	2185P	223.6	83.00	23.56	59.44	611	4	30
November 11, 2014	2189P	223.6	79.52	33.73	45.79	950	3	53
November 26, 2016	**23582P**	178.01	181.39	9.06	172.33	NA	4	23
November 28, 2016	**23590P**	202.03	130.22	21.51	108.71	NA	4	11
TOTAL		1,050.84	644.54	124.84	519.7	2,120	21	2

Table 7. 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)
2169P	750	30	50	200	30	130	5
2185P	750, 850,1000	20	50	200	30	130	5
2189P	750, 850, 1000	20	50	200	30	130	5
23582P	600, 700, 800, 1000, 1100, 1200	30	50	200	30	130	5
23590P	700, 800, 1000, 1100, 1200	30	50	200	30	130	5

2.4 Survey Coverage

Patawag floodplain is located along the province of Zamboanga del Norte, with majority of the floodplain situated within the municipality ofLiloy.Municipalities of Liloy and Labason are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 8. The actual coverage of the LiDAR acquisition for Patawag floodplain is presented in Figure 6.

Table 8. List of municipalities and cities surveyed during Patawag floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Zamboanga del Norte	Liloy	123.94	112.56	90.82%
	Labason	179.14	152.91	85.35%
	Tampilisan	103.05	11.57	11.23%
	Kalawit	**329.51**	**27.96**	**8.48%**
	Gutalac	**449.87**	**27.17**	**6.04%**
Total		1185.51	332.17	28.02%

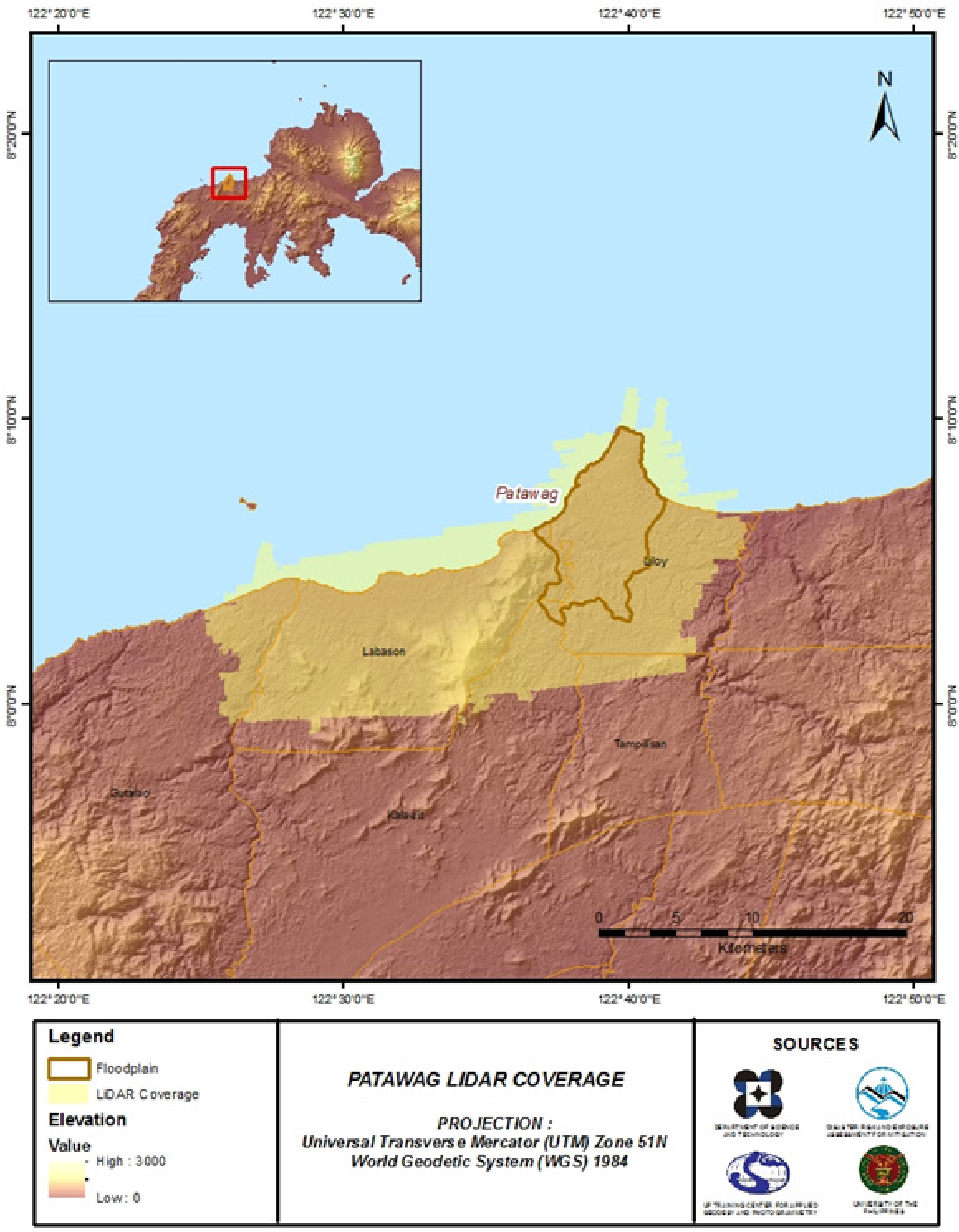

Figure 6. Actual LiDAR survey coverage for Patawag Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR PATAWAG FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Ma. Ailyn L. Olanda , Engr. Don Matthew B. Banatin, Engr. Erica Erin E. Elazegui, Engr. Christy Lubiano , Deane Leonard M. Bool, Eriasha Loryn C. Tong

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.

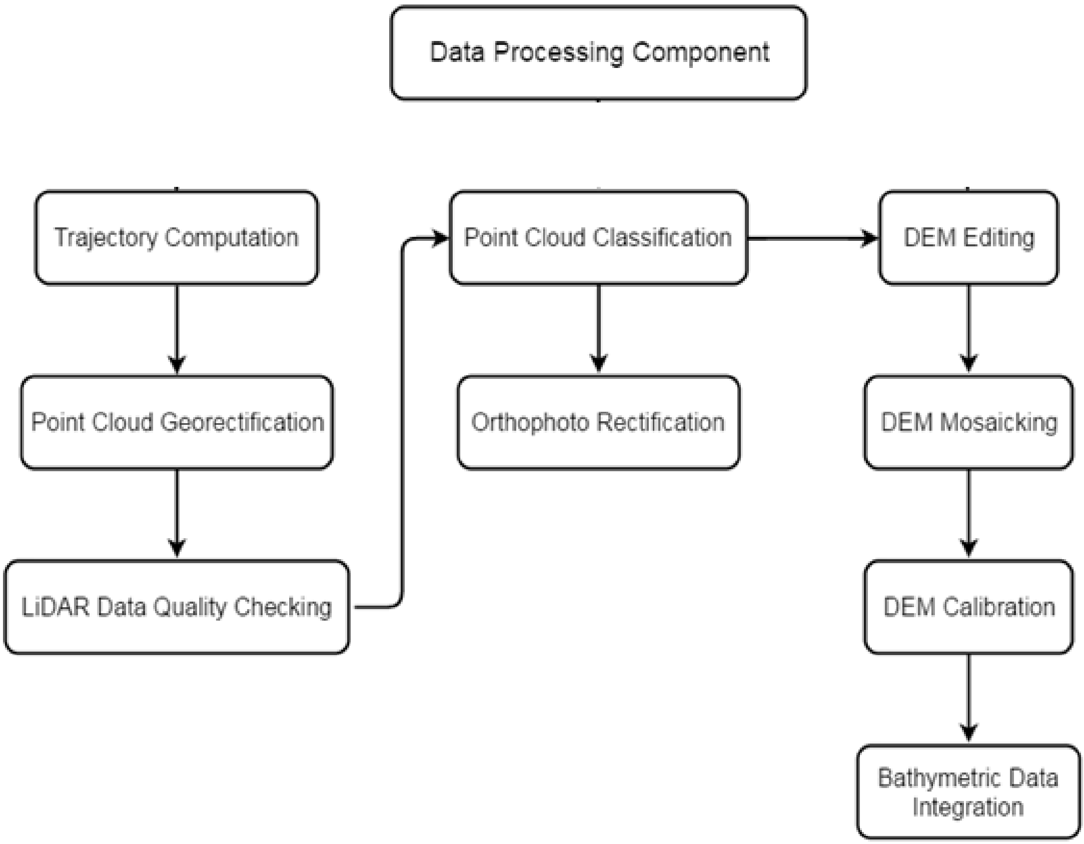

Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Patawag Floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown over Liloy, Zamboanga del Norte during the first and second surveys conducted on November 2014 and December 2016, respectively, used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. The Data Acquisition Component (DAC) transferred a total of 98.9 Gigabytes of Range data, 1.196 Gigabytes of POS data, 274.6 Megabytes of GPS base station data, and 120.6 Gigabytes of raw image data to the data server on December 9, 2014 for the first survey and on November 28, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Patawag was fully transferred on November 28, 2016, as indicated in the Data Transfer Sheets for Patawag Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23590P, one of the Patawag 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 November 28, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

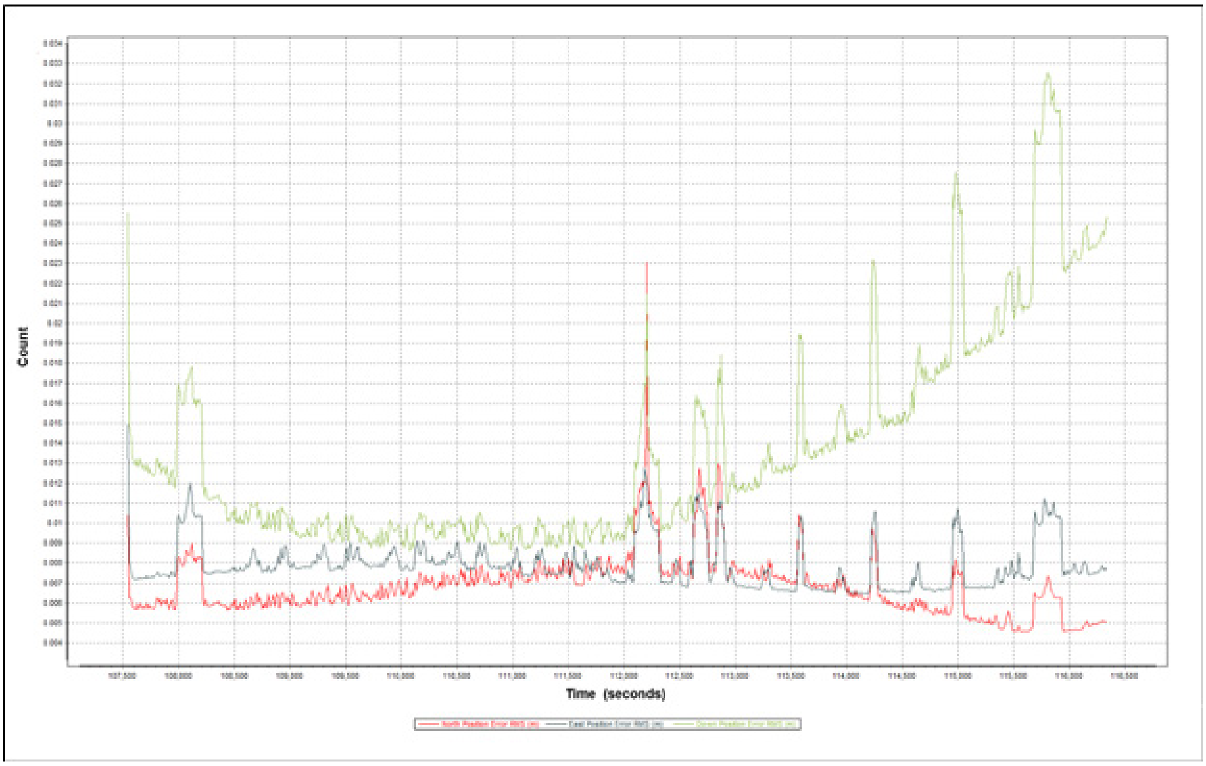

Figure 8. Smoothed Performance Metrics of a Patawag Flight 23590P.

The time of flight was from 107500 seconds to 116500 seconds, which corresponds to afternoon of November 28, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 2.30 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 3.25 centimeters, which are within the prescribed accuracies described in the methodology.

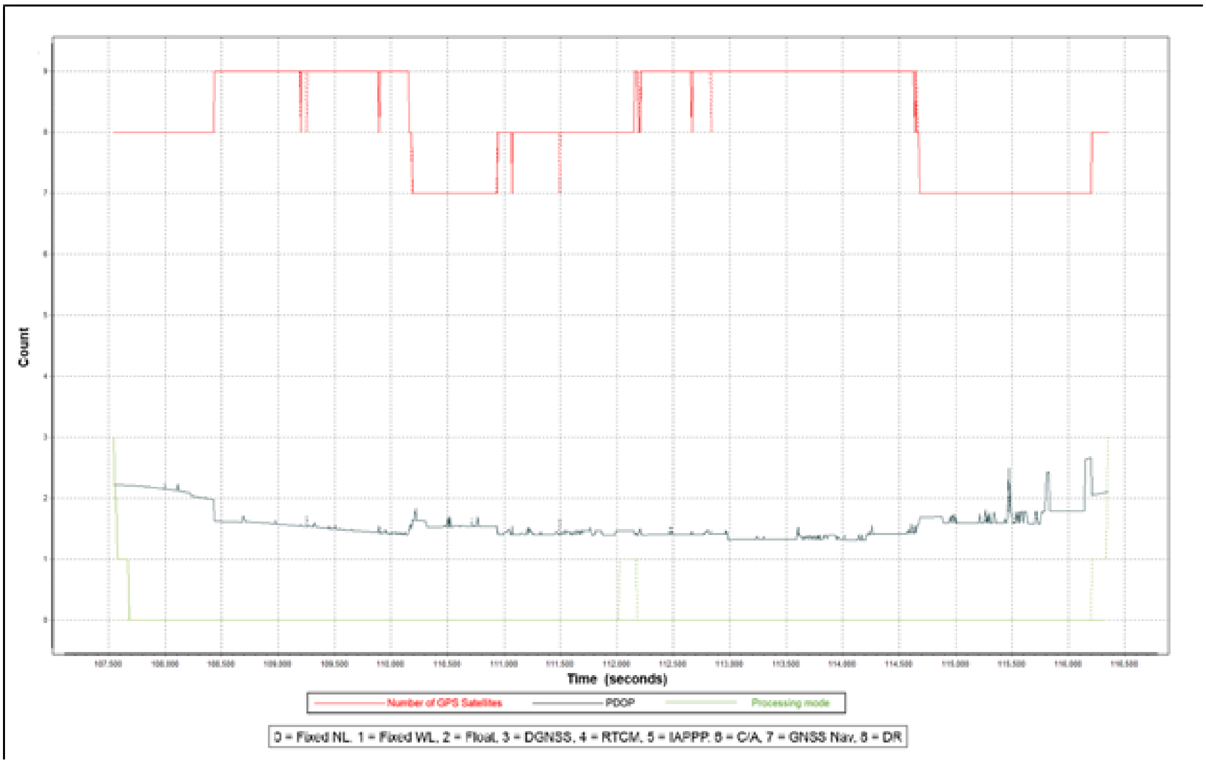

Figure 9. Solution Status Parameters of Patawag Flight 23590P.

The Solution Status parameters of flight 23590P, one of the Patawag flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), 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 7. Most of the time, the number of satellites tracked was between 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 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 Patawag flights is shown in Figure 10.

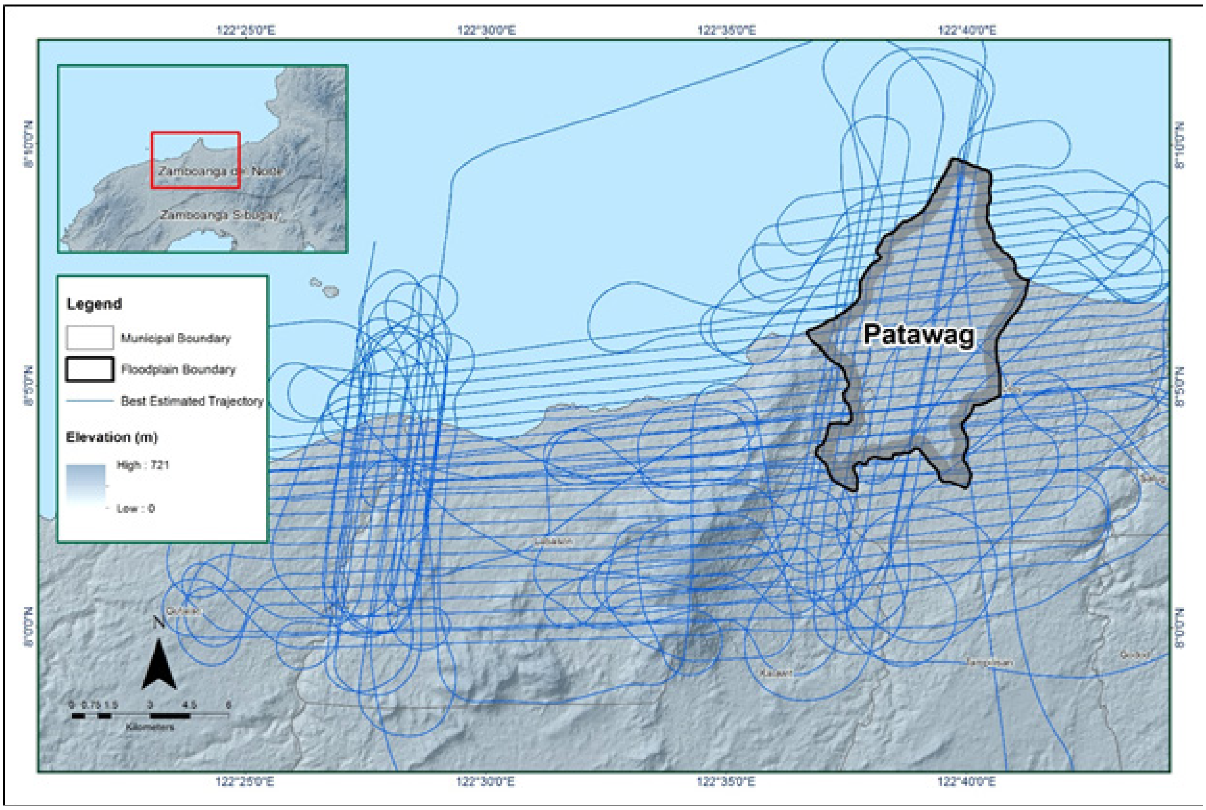

Figure 10. Best estimated trajectory for Patawag Floodplain.Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 148 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Patawag Floodplain are indicated in Table 9.

Table 9. Self-Calibration Results values for Patawag flights.

Parameter	Value
Boresight Correction stdev (<0.001degrees)	0.000281
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000760
GPS Position Z-correction stdev (<0.01meters)	0.0058

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

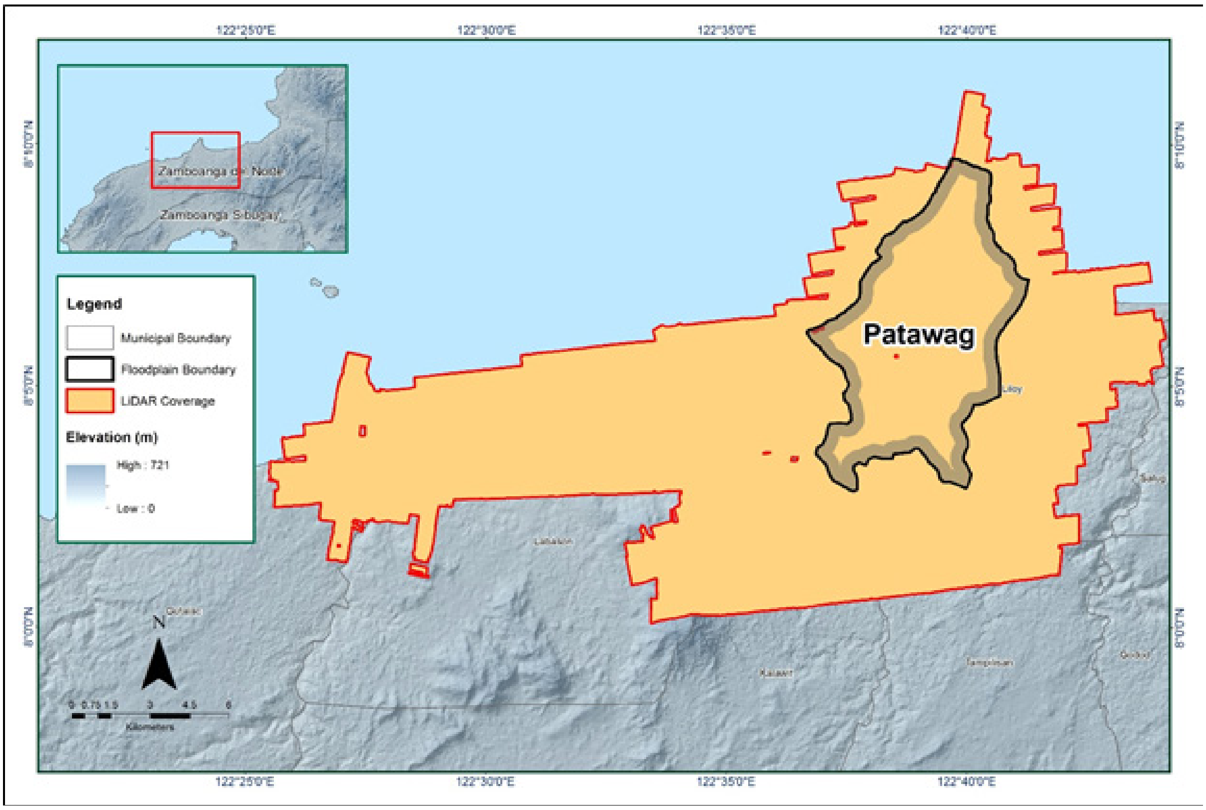

Figure 11. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Patawag Floodplain.

The total area covered by the Patawag missions is 372.56 sq.km comprised of five (5) flight acquisitions grouped and merged into three (3) blocks as shown in Table 10.

Table 10. List of LiDAR blocks for Patawag floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Dipolog_Blk73A	2169P	199.65
	2185P	
	2189P	
Dipolog_reflights_Blk73A_additional	23590P	126.39
Dipolog_reflights_Blk73A_supplement	23582P	46.52
TOTAL		**372.56 sq. km.**

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

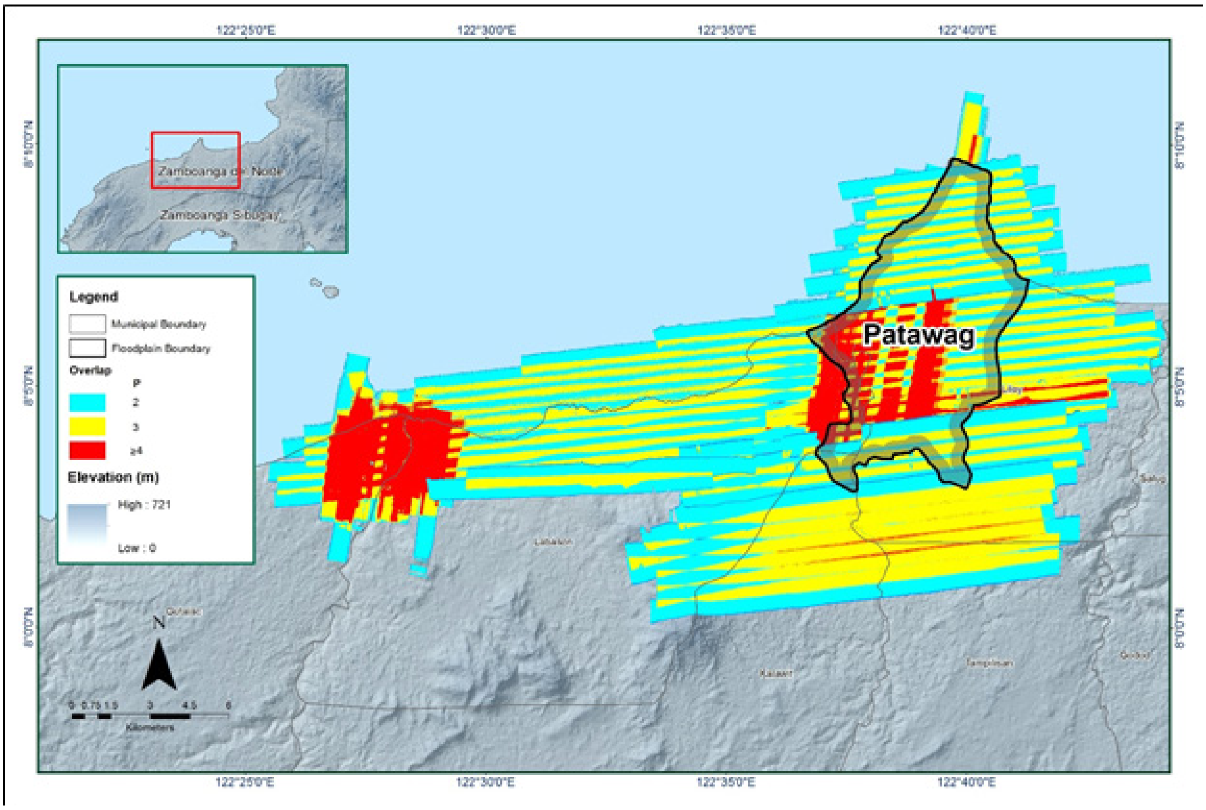

Figure 12. Image of data overlap for Patawag Floodplain.

The overlap statistics per block for the Patawag floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 41.33% and 59.36% 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 Patawag floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.69 points per square meter.

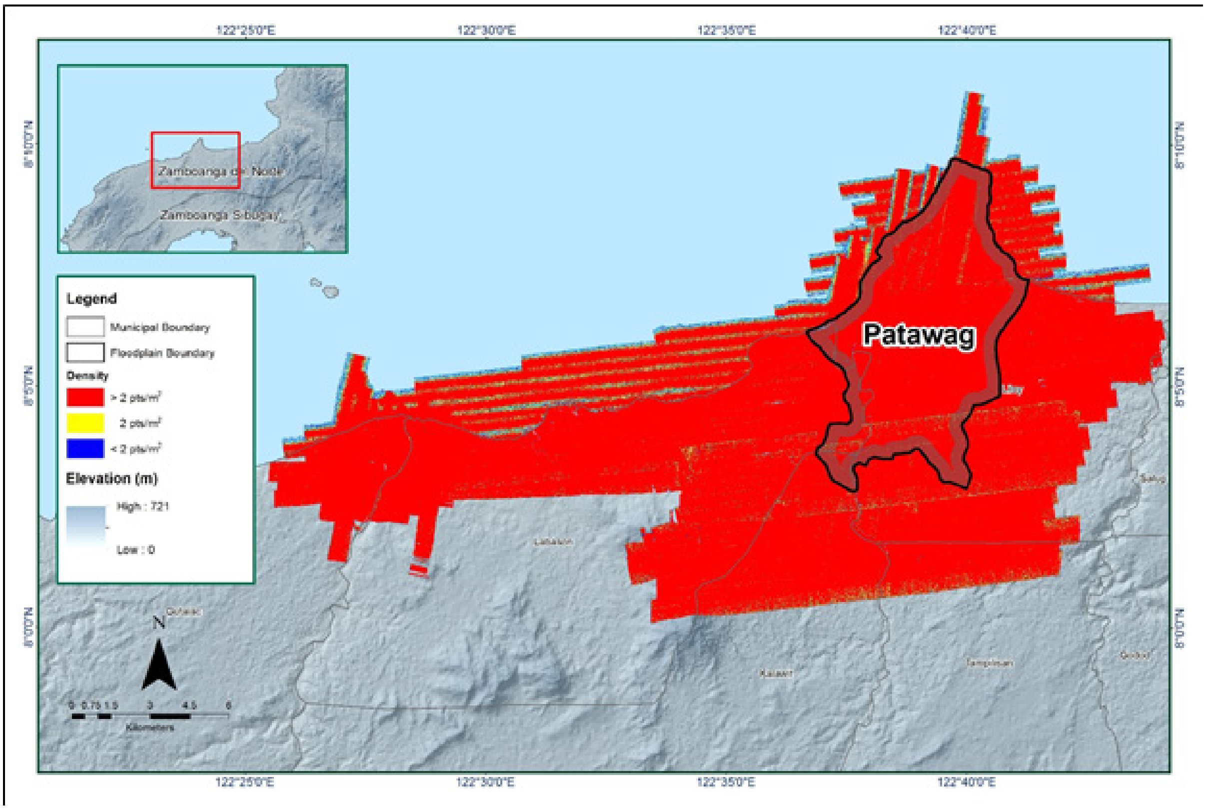

Figure 13. Pulse density map of merged LiDAR data for Patawag floodplain.

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.

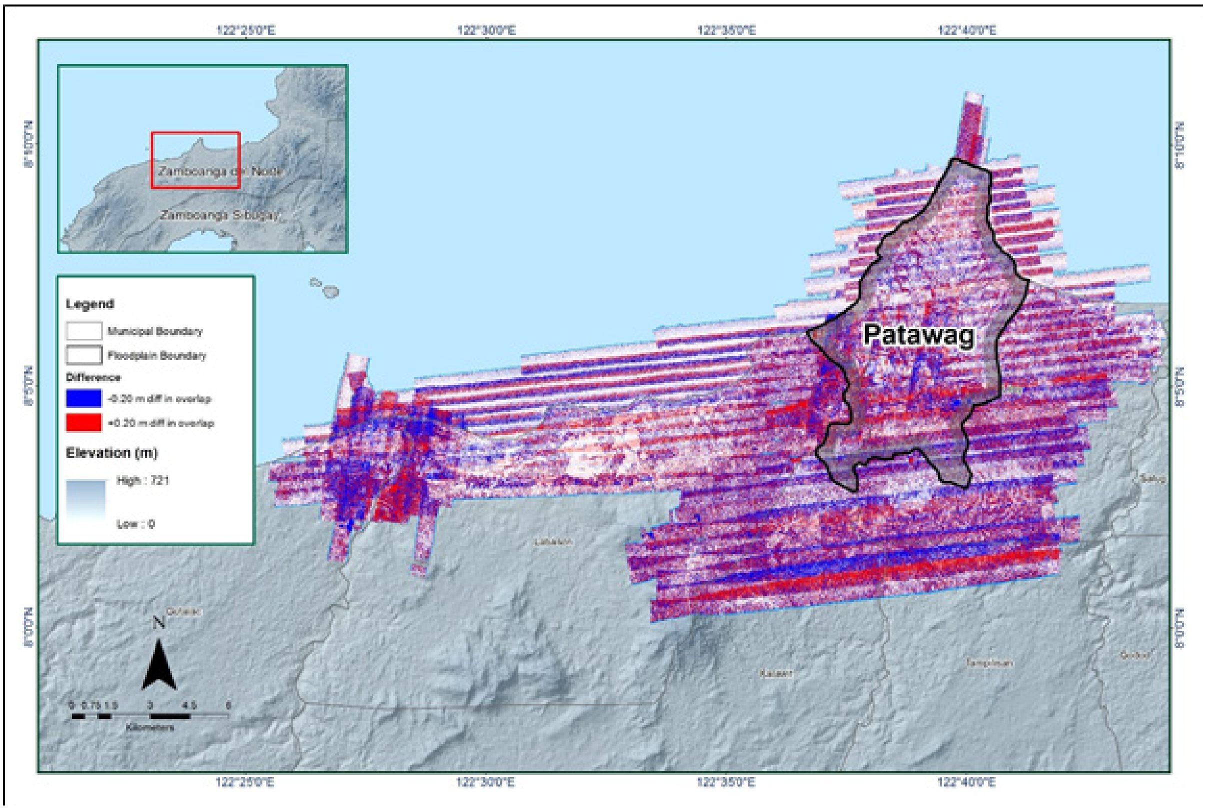

Figure 14. Elevation difference map between flight lines for Patawag floodplain.

A screen capture of the processed LAS data from a Patawag flight 23590P 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 yellow 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.

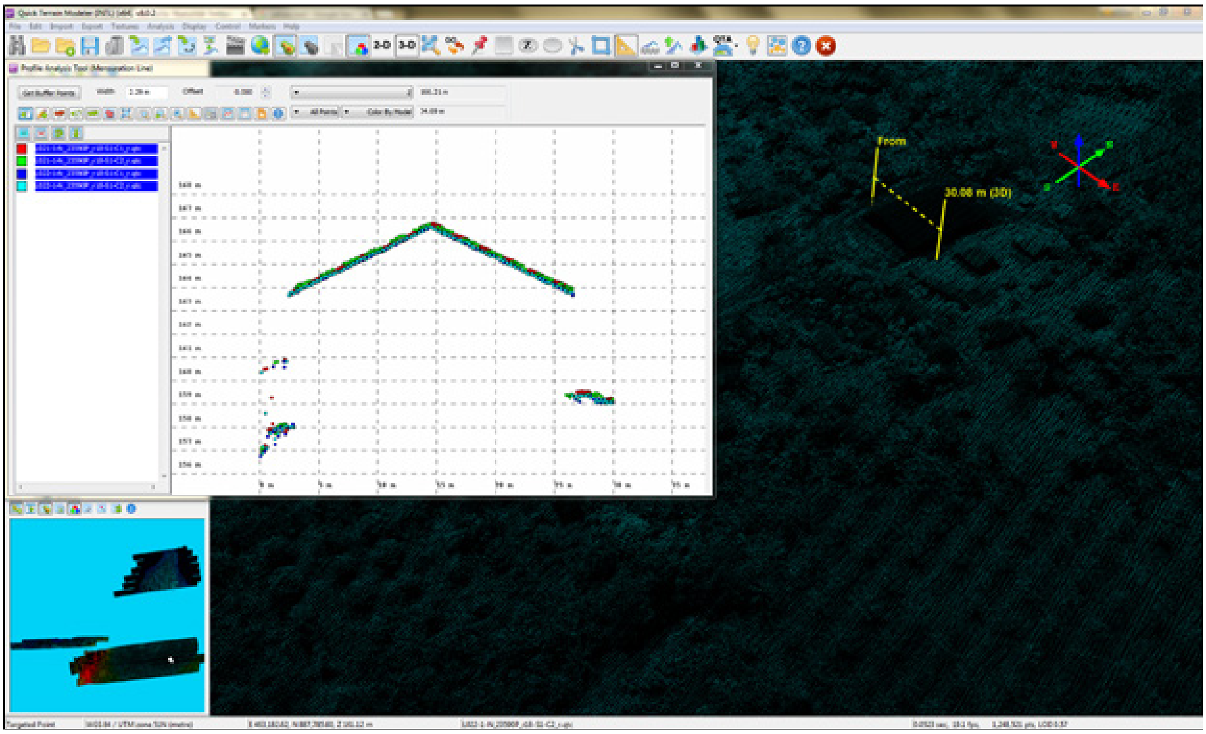

Figure 15. Quality checking for Patawag flight 23590P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Patawag classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	316,257,459
Low Vegetation	393,916,474
Medium Vegetation	547,399,563
High Vegetation	356,827,606
Building	11,617,652

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Patawag Floodplain is shown in Figure 16. A total of 281 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 62.42 meters and 432.78 meters, respectively.

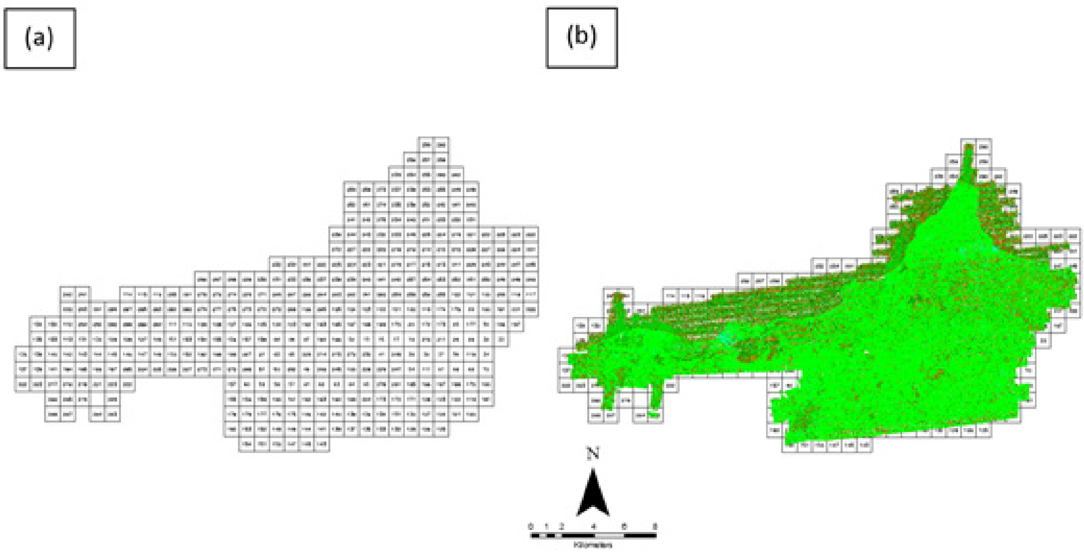

Figure 16. Tiles for Patawag floodplain (a) and classification results (b) in TerraScan.

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.

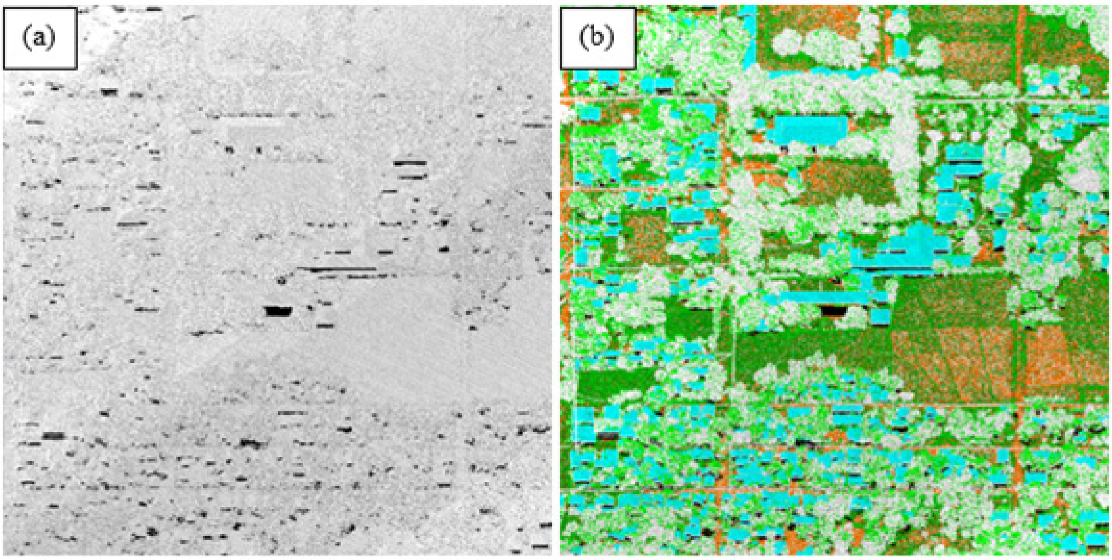

Figure 17. Point cloud before (a) and after (b) classification.

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.

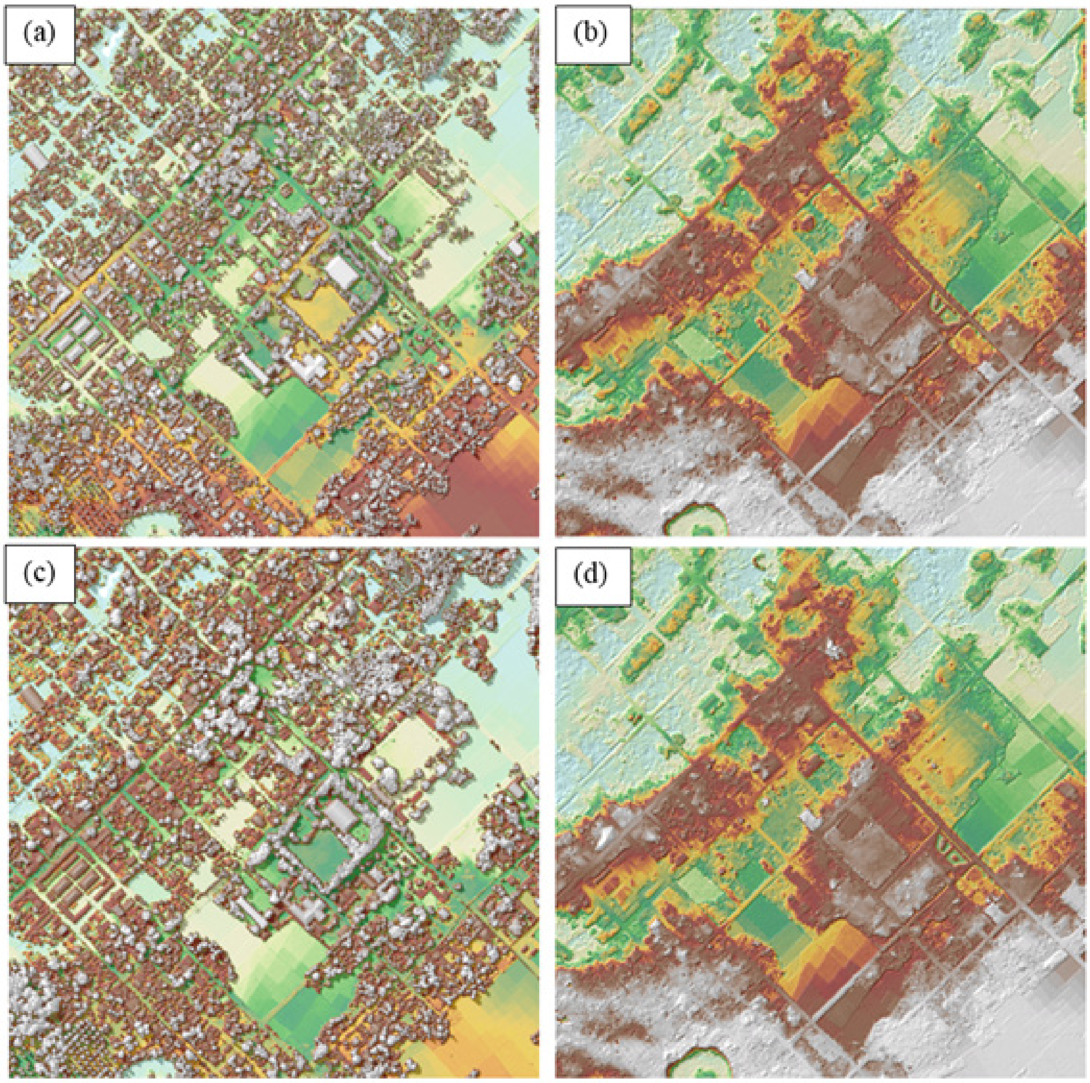

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Patawag Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophographs for the Patawag floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Patawag Floodplain. These blocks are composed of Dipolog and Dipolog_reflights blocks with a total area of 372.56square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
Dipolog_Blk73A	199.65
Dipolog_reflights_Blk73A_additional	126.39
Dipolog_reflights_Blk73A_supplement	46.52
TOTAL	372.56 sq. km.

Portions of DTM before and after manual editing are shown in Figure 19. The portion of the mountain (Figure 19a) has been 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.

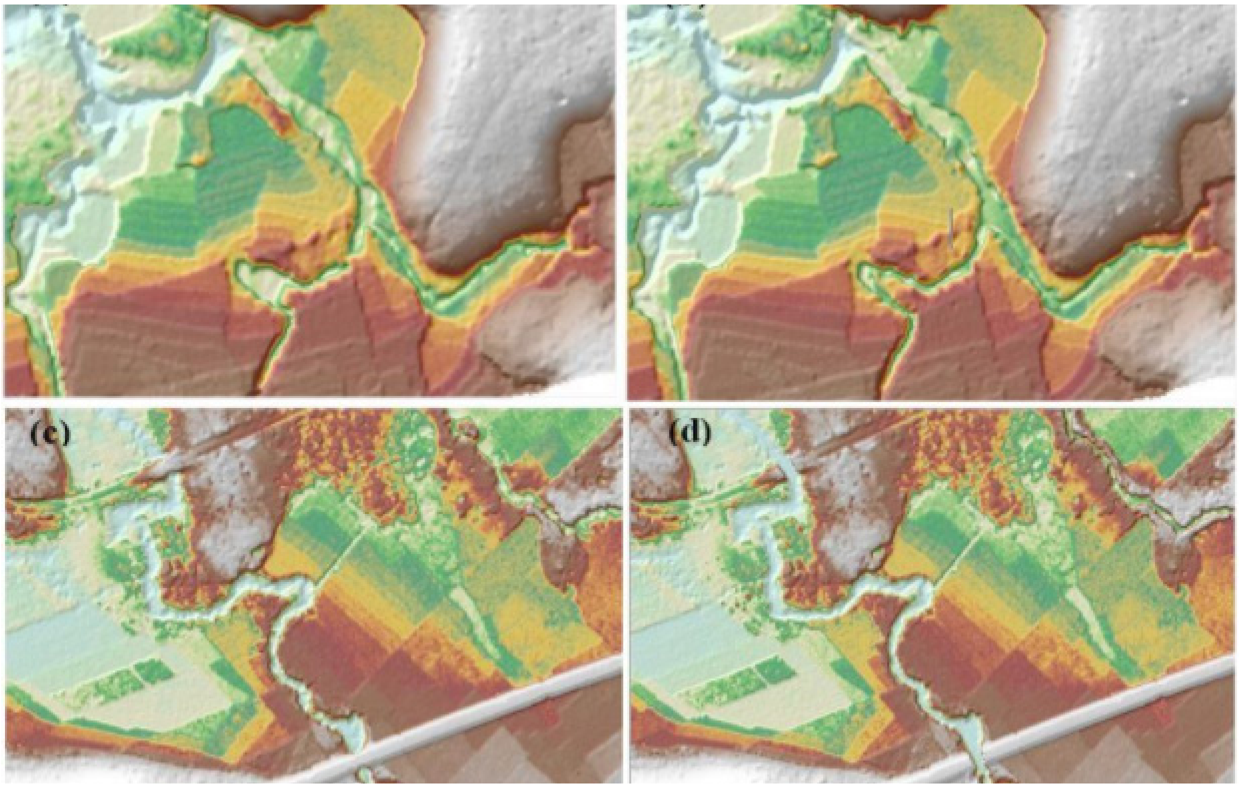

Figure 19. Portions in the DTM of Patawag Floodplain– a cut portion of the mountain before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Dipolog_Blk73B was used as the reference block at the start of mosaicking because it was the first available data at that time. Table 13 shows the shift values applied to each LiDAR block during mosaicking.

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

Table 13. Shift Values of each LiDAR Block of Patawag floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dipolog_Blk73A	0.00	0.00	0.43
Dipolog_Blk73A_additional	0.00	0.00	0.38
Dipolog_reflights_Blk73A_supplement	0.00	0.00	0.58
Dipolog_reflights_Blk73A_ additional(Upper)	0.85	0.39	0.58
Dipolog_reflights_Blk73A_ additional(Lower)	0.26	0.52	0.49

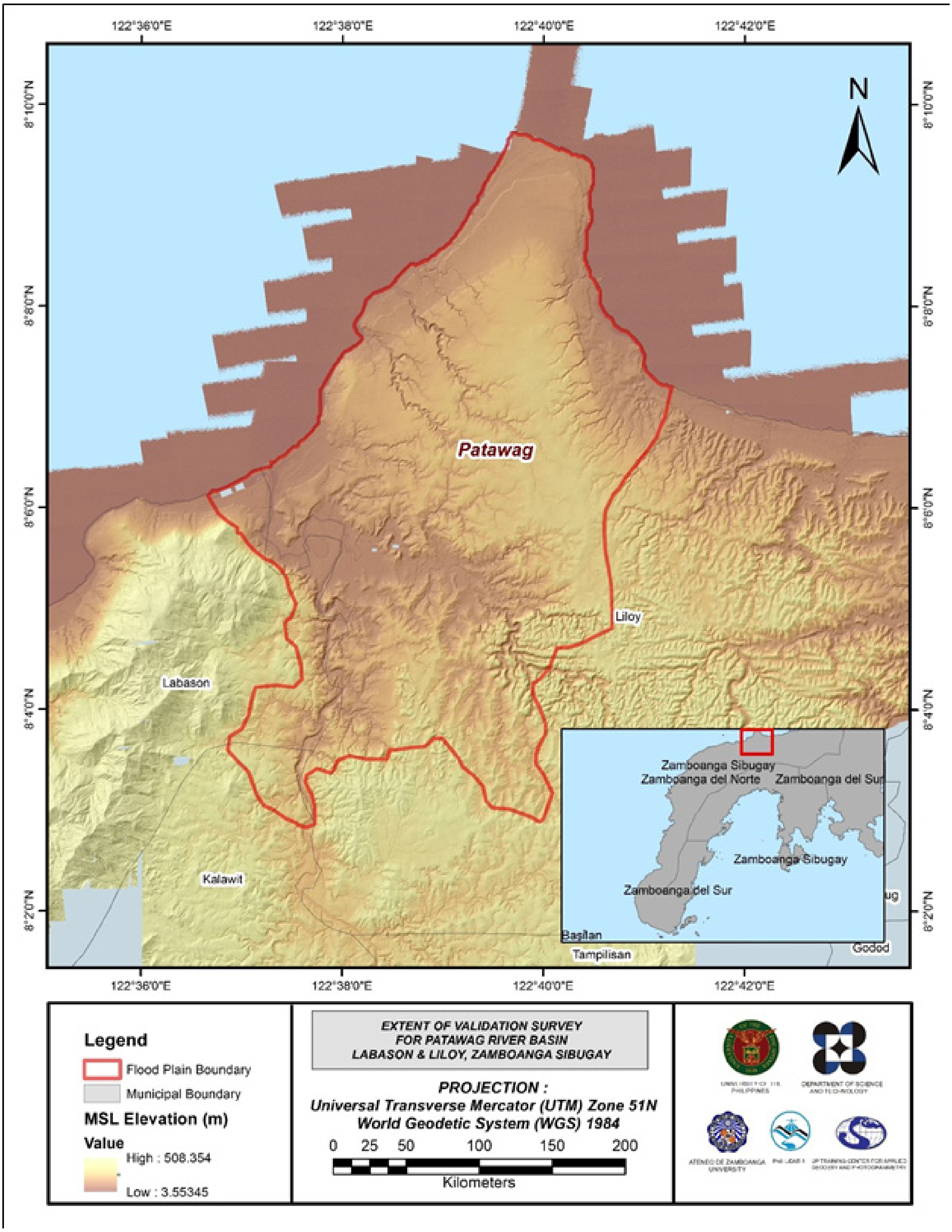

Figure 20. Map of Processed LiDAR Data for Patawag Floodplain.

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 Patawag to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 12,287 survey points were gathered for all the flood plains within the provinces of Zamboanga del Norte and Misamis Occidental wherein the Patawag floodplain is located. Random selection of 80% of the survey points, resulting to 9,830 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and 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 points is 4.25 meters with a standard deviation of 0.15 meters. Calibration of the LiDAR data was done by adding the height difference value, 4.25 meters, to the mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

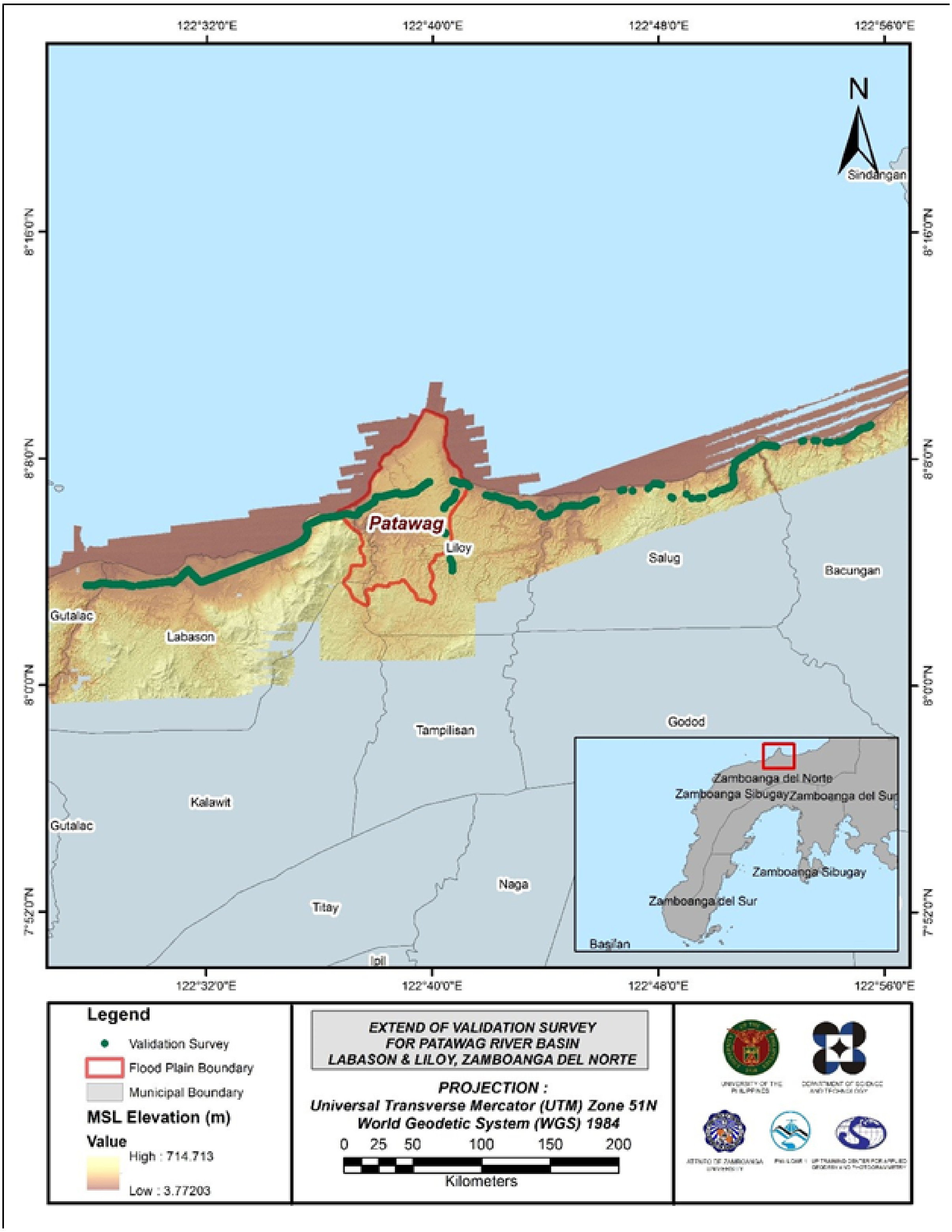

Figure 21. Map of Patawag Floodplain with validation survey points in green.

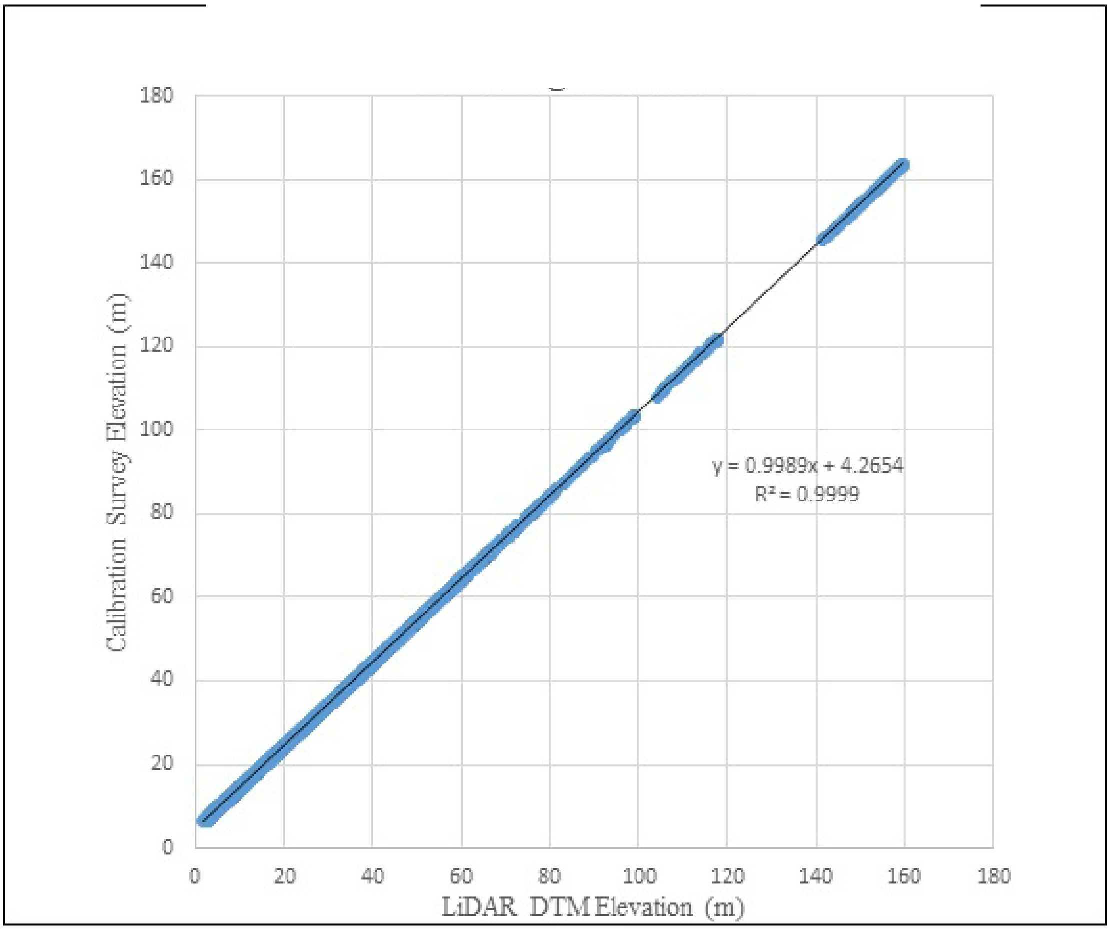

Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	4.25
Standard Deviation	0.15
Average	4.25
Minimum	3.90
Maximum	4.60

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 233 points, were used for the validation of calibrated Patawag 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 0.18 meters with a standard deviation of 0.17 meters, as shown in Table 15.

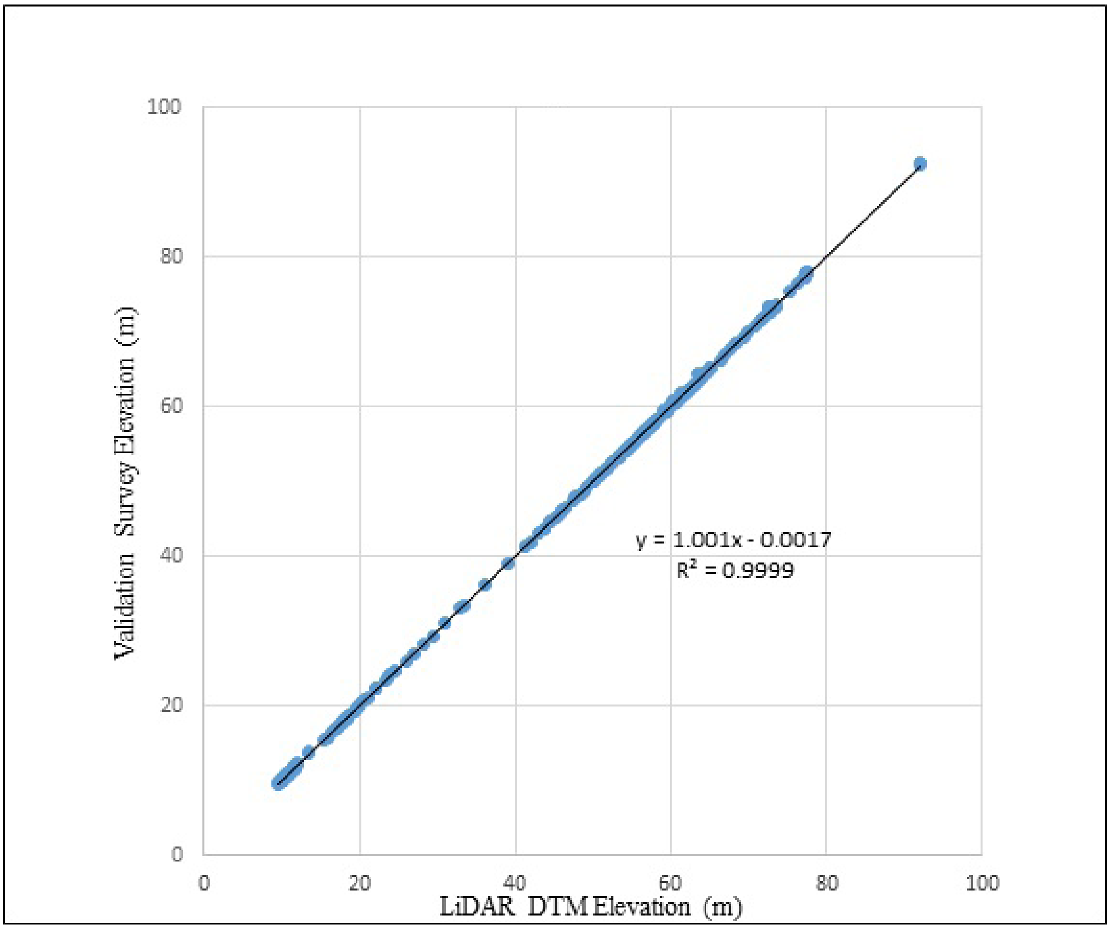

Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.18
Standard Deviation	0.17
Average	0.04
Minimum	-0.30
Maximum	0.39

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross section data was available for Patawag with 13,504 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation and Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.47 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Patawag integrated with the processed LiDAR DEM is shown in Figure 24.`

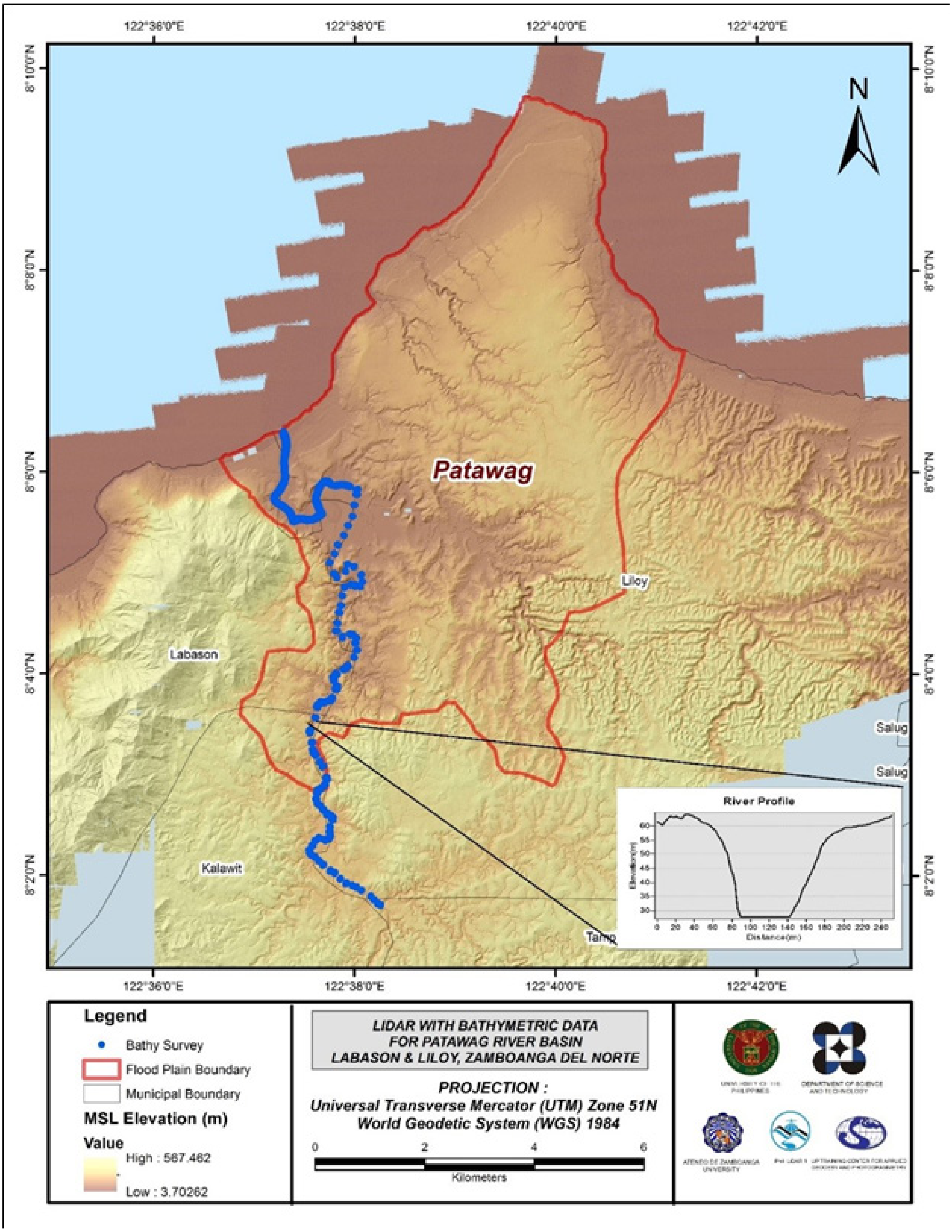

Figure 24. Map of Patawag Floodplain with bathymetric survey points shown in blue.

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 (QC) of Digitized Features' Boundary

Patawag floodplain, including its 200 m buffer, has a total area of 66.48 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1936 building features, are considered for QC. Figure 25 shows the QC blocks for Patawag Floodplain.

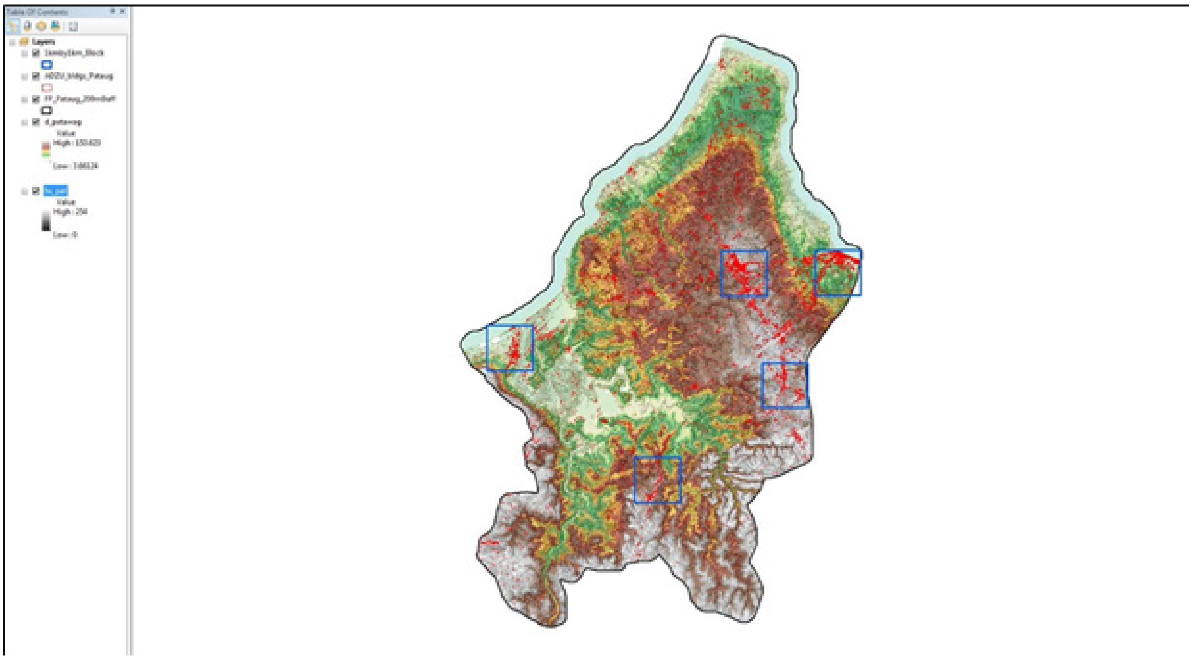

Figure 25. Blocks (in blue) for Patawag building features subjected to QC.

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

Table 16. Quality Checking Ratings for Patawag Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Patawag	99.43	99.90	93.39	PASSED

3.12.2 Height Extraction

Height extraction was done for 7,538 building features in Patawag Floodplain. Of these building features, none was filtered out after height extraction, resulting to 7,538 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.76 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 flood plain of the riverbasin; likewise, the number of enumerators was also dependent on the availability of the tablet and the number of features of the flood plain.

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

Table 17. Building Features Extracted for Patawag Floodplain.

Facility Type	No. of Features
Residential	6,995
School	55
Market	103
Agricultural/Agro-Industrial Facilities	237
Medical Institutions	6
Barangay Hall	17
Military Institution	2
Sports Center/Gymnasium/Covered Court	6
Telecommunication Facilities	2
Transport Terminal	2
Warehouse	31
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	1
Water Supply/Sewerage	1
Religious Institutions	42
Bank	2
Factory	0
Gas Station	6
Fire Station	1
Other Government Offices	3
Other Commercial Establishments	26
Total	**7,538**

Table 18. Total Length of Extracted Roads for Patawag Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Patawag	4.21	69.72	0.00	19.72	0.00	93.65

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

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Patawag	70	0	1	0	0	71

A total of 3 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.

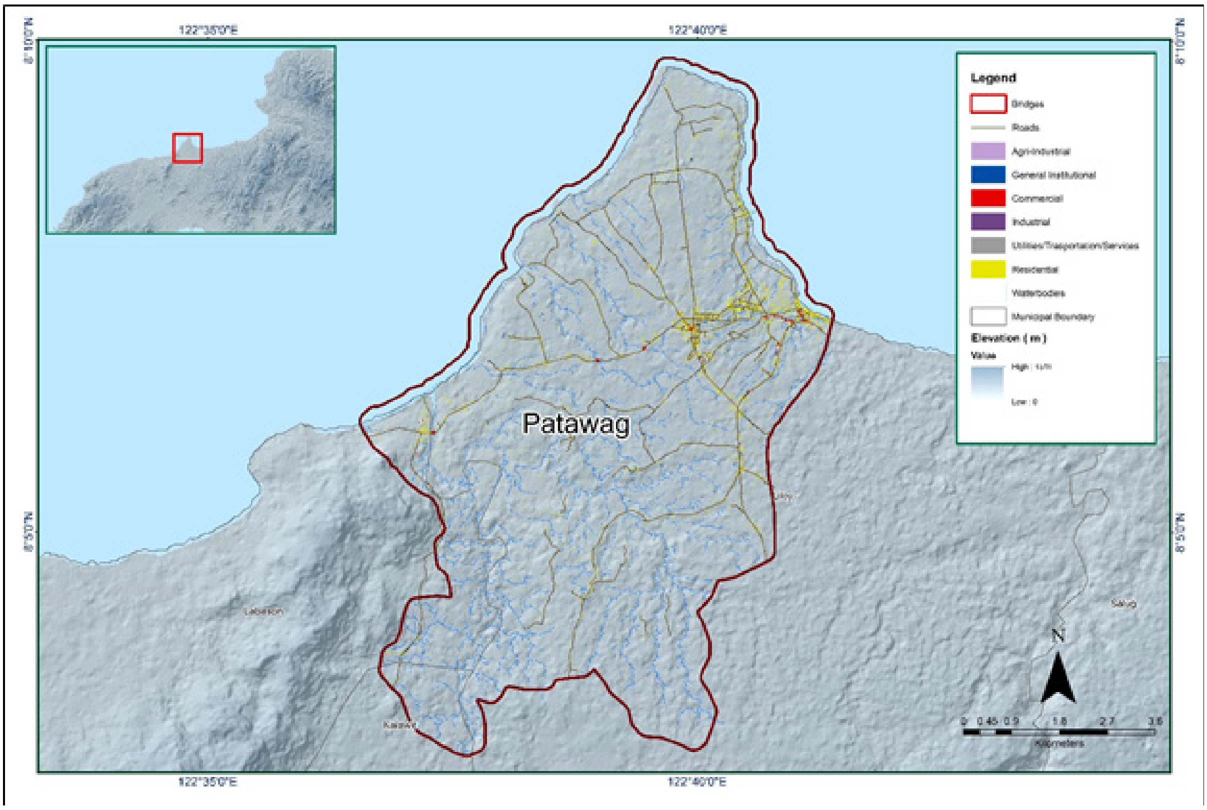

Figure 26 shows the Digital Surface Model (DSM) of Patawag Floodplain overlaid with its ground features.

CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE LIBERTAD RIVER BASIN

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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).

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Libertad River on January 16, 2016 to February 10, 2016 with the following scope: reconnaissance; control survey; cross-section and as-built survey at Barangay Cangabo, Libertad, Negros Oriental; validation points acquisition of about 24.175 km; and bathymetric survey from Brgy. Cangabo down to Brgy. Poblacion, both in the Municipality of Libertad with approximate length of 8.023 km. The entire survey extent is illustrated in Figure 29.

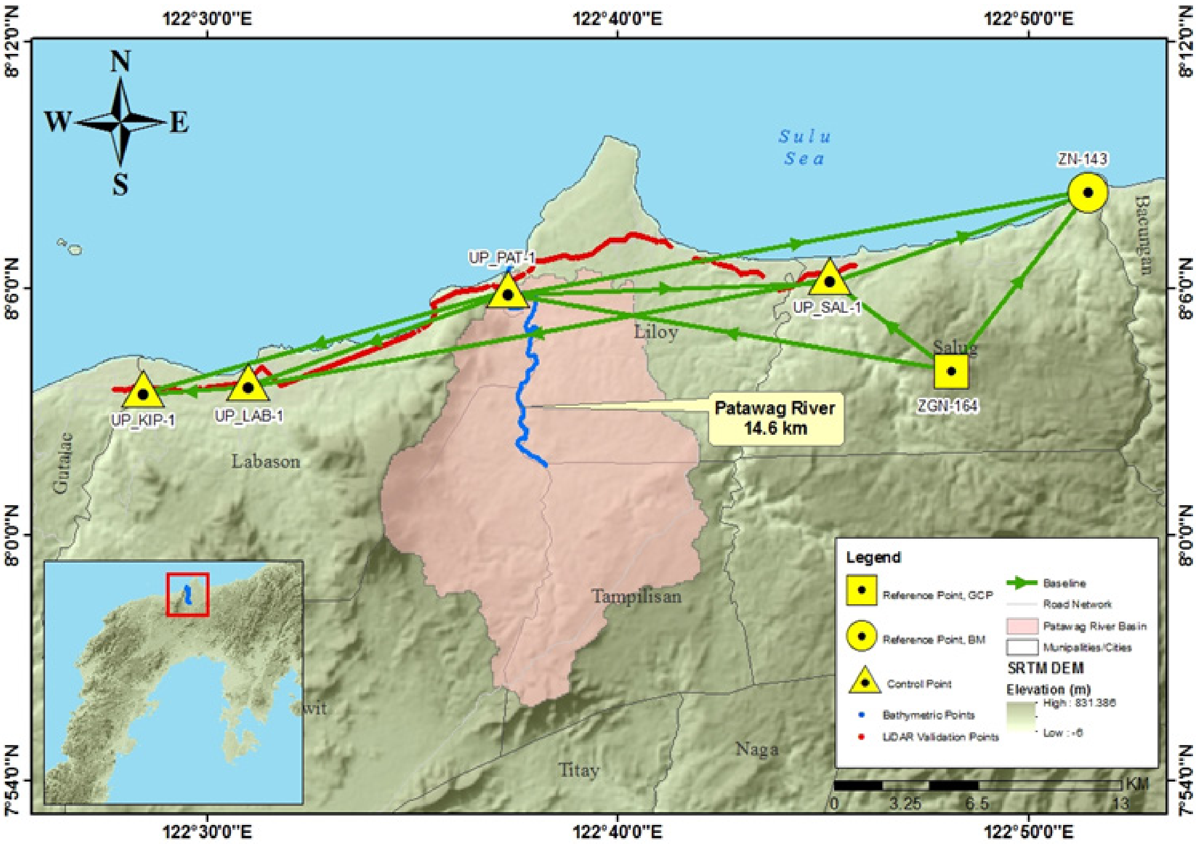


Figure 27. Patawag River Survey Extent

4.2 Control Survey

The GNSS network used for Patawag River is composed of five (5) loops established on August 24, 2016 occupying the following occupying the following reference points: ZGN-164, a second-order GCP, situated inside the barangay hall compound beside basketball court in Brgy. Caracol, Salug, Province of Zamboanga del Norte; and ZN-143, a first-order BM, located at Brgy.Ramon Magsaysay, Salug, Province of Zamboanga del Norte.

Four (4) control points established in the area by ABSD: UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, UP_LAB-1 inat Labason Bridge in Brgy. Antonio, Municipality of Labason, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, and UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac. The summary of reference and control points and its location is summarized in Tables 20 and 21 while GNSS network established is illustrated in Figure 28.

Table 20. List of reference and control points used during the survey in Patawag River (First Network)
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
UP_KIP-1	Established	8°03'35.83524"N	122°28'26.48383"E	78.022	12.435	08-24-16
UP_LAB-1	Established	8°03'44.29109"N	122°30'59.74333"E	75.708	9.889	08-24-16
UP_PAT-1	Established	8°06'00.79142"N	122°37'19.54470" E	76.488	10.835	08-24-16
UP_SAL-1	Established	8°06'20.46964"N	122°45'09.85390"E	76.124	10.080	08-24-16

Table 21. List of reference and control points used during the survey in Patawag River (Second Network)
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
ZGN-164	2nd Order GCP	8°03'58.80475"N	E122°48'08.60698"E	296.130	229.325	2004
ZN-143	1st Order BM	8°08'21.39646"N	22°51'28.86114"E	77.323	11.526	2009
UP_PAT-1	Established	8°06'00.79142"N	122°37'19.54470"E	76.488	10.835	08-24-16
UP_SAL-1	Established	8°06'20.46964"N	122°45'09.85390"E	76.124	10.080	08-24-16

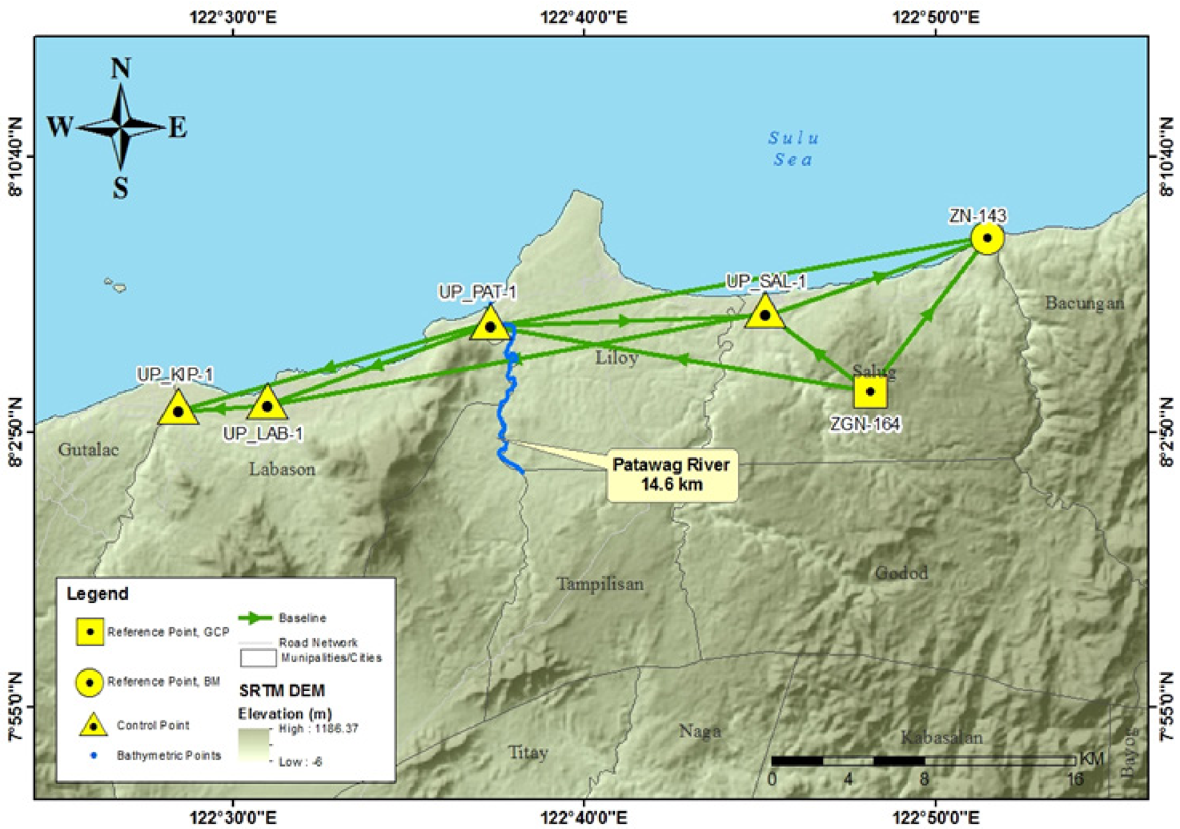


Figure 28. Patawag River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Patawag River are shown from Figure 29 to Figure 34.

Figure 29. GNSS rover, Trimble® SPS 882, ZGN-164, situated inside the barangay hall compound beside basketball court in Brgy. Caracol, Salug, Province of Zamboanga del Norte.

Figure 30. GNSS rover, Trimble® SPS 882, at ZN-143, an established control point, located at the right side walk going to Brgy. Rizon direction of Polandok Bridge in Brgy.Ramon Magsaysay, Salug, Province of Zamboanga del Norte

Figure 31. UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, Province of Zamboanga del Norte

Figure 32. GNSS receiver set up, Trimble® SPS 882, at UP_LAB-1 at Labason Bridge in Brgy. Antonio, Municipality of Labason, Province of Zamboanga del Norte

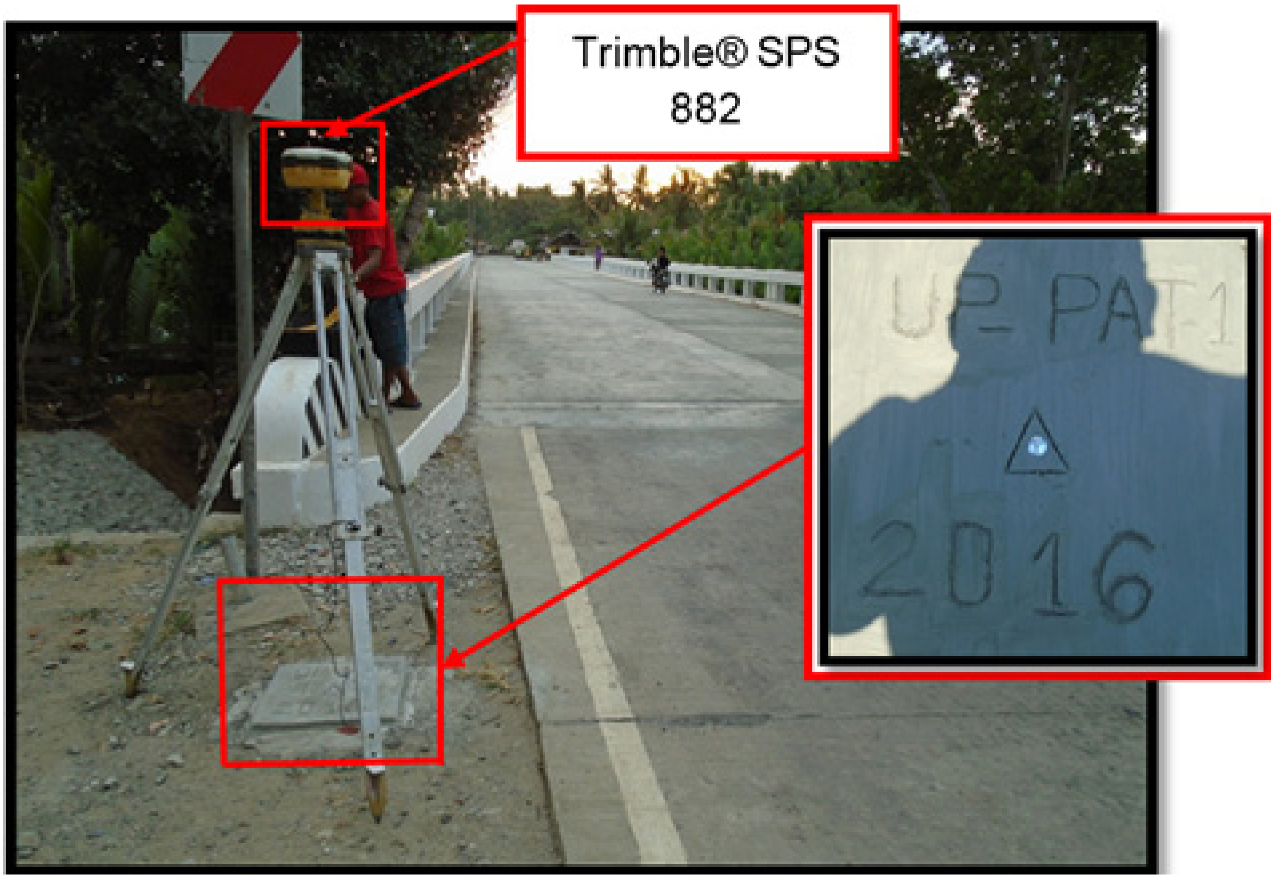


Figure33.GNSS receiver set up, Trimble® SPS 882, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, Province of Zamboanga del Norte

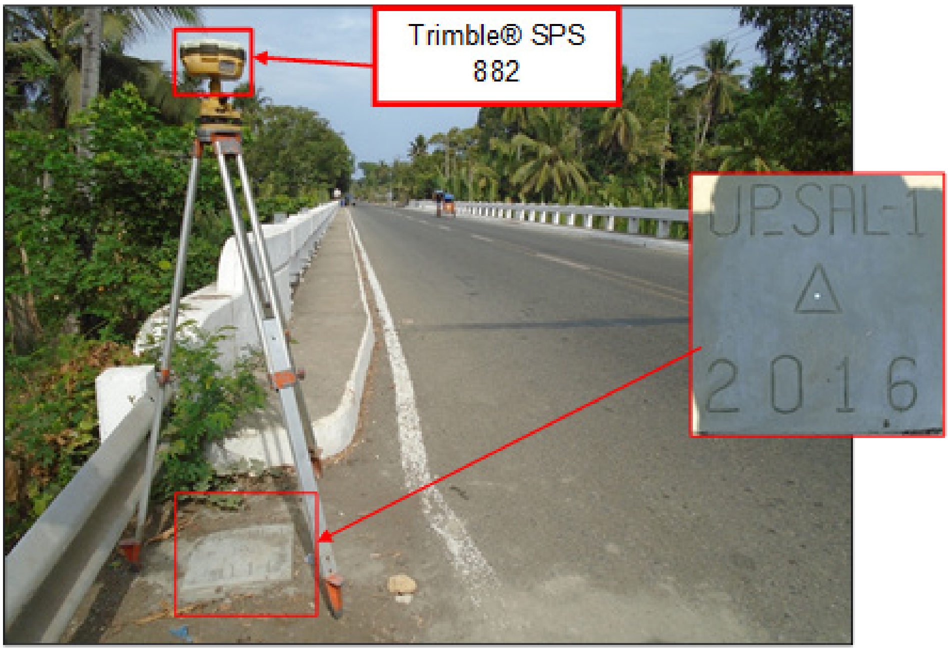


Figure 34. GNSS receiver set up, Trimble® SPS 882, UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac, Province of Zamboanga del Norte

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Patawag River Basin is summarized in Tables 22 and 23 generated by TBC software.

Table 22. Baseline Processing Report for Patawag River Static Survey (First Network)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_KIP-1 --- UP_PAT-1	8-27-2016	Fixed	0.006	0.035	254°44'54"	16917.407	1.523
UP_LAB-1 --- UP_SAL-1	8-27-2016	Fixed	0.005	0.054	259°34'18"	26466.198	-0.410
UP_LAB-1 --- UP_KIP-1	8-27-2016	Fixed	0.006	0.033	266°50'03"	4699.763	2.326
UP_SAL-1 --- UPPAT1	8-27-2016	Fixed	0.006	0.040	87°35'11"	14411.370	-0.290
UP_LAB-1 --- UP_PAT-1	8-27-2016	Fixed	0.013	0.081	250°10'37"	12361.399	-0.729

As shown in Table 22, a total of five (5) baselines were processed with coordinate and ellipsoidal height values of UP_PAT-1 and UP_SAL-1 held fixed. All of them passed the required accuracy.

Table 23. Baseline Processing Report for Patawag River Static Survey (Second Network)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_PAT-1 --- ZGN-164	8-27-2016	Fixed	0.006	0.029	280°41'32"	20222.545	-219.677
ZGN-164 --- UP_SAL-1	8-27-2016	Fixed	0.004	0.030	308°29'46"	6992.329	-219.983
ZGN-164 --- ZN-143	8-27-2016	Fixed	0.005	0.021	37°13'49"	10132.429	-218.798
UP_PAT-1 --- UP_SAL-1	8-27-2016	Fixed	0.009	0.047	87°35'12"	14411.385	-0.393
UP_PAT-1 --- ZN-143	8-27-2016	Fixed	0.008	0.042	80°33'03"	26357.443	0.785
UP_SAL-1 --- ZN-143	8-27-2016	Fixed	0.006	0.035	72°14'19"	12183.132	1.211

As shown in Table 23 a total of six (6) baselines were processed with coordinate and ellipsoidal height values of ZGN-164 and ZN-143 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown from Table 24 to Table 26 for the complete details. Refer to Annex A for the computation for the accuracy of ABSD.

The four (4) control points, UP_KIP-1, UP_LAB-1, UP_PAT-1, UP_SAL-1 were occupied and observed simultaneously to form a GNSS loop. For the second network, the four (4) control points ZGN-164, ZN-143, UP_PAT-1, and UP_SAL-1. The coordinates and ellipsoidal height of UP_PAT-1 and UP_SAL-1, and ZGN-164 and ZN-143 were held fixed during the processing of the control points as presented in Tables 24 and 25. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 24. Control Point Constraints (First Network)

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
UP_PAT-1	Local	Fixed	Fixed	Fixed	
UP_SAL-1	Local	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Table 25. Control Point Constraints (Second Network)

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGN-164	Local	Fixed	Fixed		
ZN-143	Grid				Fixed
Fixed = 0.000001(Meter)					

The lists of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network are indicated in Tables 26 and 27. All fixed control points have no values for grid errors and elevation error.

Table 26. Adjusted Grid Coordinated (First Network)

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UP_KIP-1	442045.506	0.011	890963.192	0.011	12.435	0.053	
UP_LAB-1	446736.710	0.011	891217.077	0.011	9.889	0.058	
UP_PAT-1	458365.200	?	895396.684	?	10.835	?	LLh
UP_SAL-1	472758.821	?	895989.921	?	10.080	?	LLh

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

aUP_KIP-1
horizontal accuracy = √((0.1)^2 + (1.1)^2
= √ (0.01 + 1.21)
= 1.10 < 20 cm
vertical accuracy = 5.3 < 10 cm

UP_LAB-1
horizontal accuracy = √((0.1)^2 + (1.1)^2
= √ (0.01 + 1.21)
= 1.10 < 20 cm
vertical accuracy = 5.8 < 10 cm

UP_PAT-1
horizontal accuracy = Fixed
vertical accuracy = Fixed

UP_SAL-1
horizontal accuracy = Fixed
vertical accuracy = Fixed

Table 27. Adjusted Grid Coordinated

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ZGN-164	478227.123	?	891636.530	?	229.325	0.040	LL
ZN-143	484358.928	0.006	899697.912	0.006	11.526	?	e
UP_PAT-1	458365.200	0.007	895396.684	0.006	10.835	0.054	
UP_SAL-1	472758.821	0.006	895989.921	0.006	10.080	0.051	

ZGN-164
horizontal accuracy = Fixed
vertical accuracy = Fixed

ZN-143
horizontal accuracy = Fixed
vertical accuracy = Fixed

UP_PAT-1
horizontal accuracy = $\sqrt{((0.7)^2 + (0.6)^2}$
= $\sqrt{(0.49 + 0.36)}$
= $0.85 < 20$ cm
vertical accuracy = $5.4 < 10$ cm

UP_SAL-1
horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$
= $\sqrt{(0.36 + 0.25)}$
= $0.61 < 20$ cm
vertical accuracy = $5.1 < 10$ cm

Following the given formula, the horizontal and vertical accuracy result of the six (6) occupied control points are within the required precision.

Table 28. Adjusted Geodetic Coordinates (First Network)

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
UP_KIP-1	8°03'35.83524" N	122°28'26.48383"E	78.022	0.053	
UP_LAB-1	8°03'44.29109" N	122°30'59.74333"E	75.708	0.058	
UP_PAT-1	8°06'00.79142" N	122°37'19.54470" E	76.488	?	LLh
UP_SAL-1	8°06'20.46964"N	122°45'09.85390"E	76.124	?	LLh

Table 29. Adjusted Geodetic Coordinates (Second Network)

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
ZGN-164	8°03'58.80475" N	122°48'08.60698" E	296.130	0.040	LL
ZN-143	8°08'21.39646" N	122°51'28.86114" E	77.323	?	e
UP_PAT-1	8°06'00.79142" N	122°37'19.54470" E	76.488	0.054	
UP_SAL-1	8°06'20.46964" N	122°45'09.85390" E	76.124	0.051	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Tables 28 and 29. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summaries of reference control points used are indicated in Tables 30 and 31.

Table 30. Reference and control points used and its location (First Network)
(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)
UP_KIP-1	Established	8°03'35.83524"N	122°28'26.48383"E	78.022	890963.192	442045.506	12.435
UP_LAB-1	Established	8°03'44.29109"N	122°30'59.74333"E	75.708	891217.077	446736.710	9.889
UP_PAT-1	Established	8°06'00.79142"N	122°37'19.54470" E	76.488	895396.684	458365.200	10.835
UP_SAL-1	Established	8°06'20.46964"N	122°45'09.85390"E	76.124	895989.921	472758.821	10.080

Table 31. Reference and control points used and its location (Second Network)
(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)
ZGN-164	2nd Order GCP	8°03’58.80475”N	122°48’08.60698”E	296.130	891636.530	478227.123	229.325
ZN-143	1st Order BM	8°08’21.39646”N	122°51’28.86114”E	77.323	899697.912	484358.928	11.526
UP_PAT-1	Established	8°06’00.79142”N	122°37’19.54470E	76.488	895396.684	458365.200	10.835
UP_SAL-1	Established	8°06’20.46964”N	122°45’09.85390”E	76.124	895989.921	472758.821	10.080

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

Cross-section and as-built surveys were conducted on April 4, 2016 at the upstream side of Patawag Bridge in Brgy. Patawag, Municipality of Liloy, Province of Zamboanga Del Norte as shown in Figure 35. A Nikon® Total Station was utilized for this survey as shown in Figure 36.

Figure 35. Patawag Bridge facing downstream

Figure 36. As-built survey of Patawag Bridge

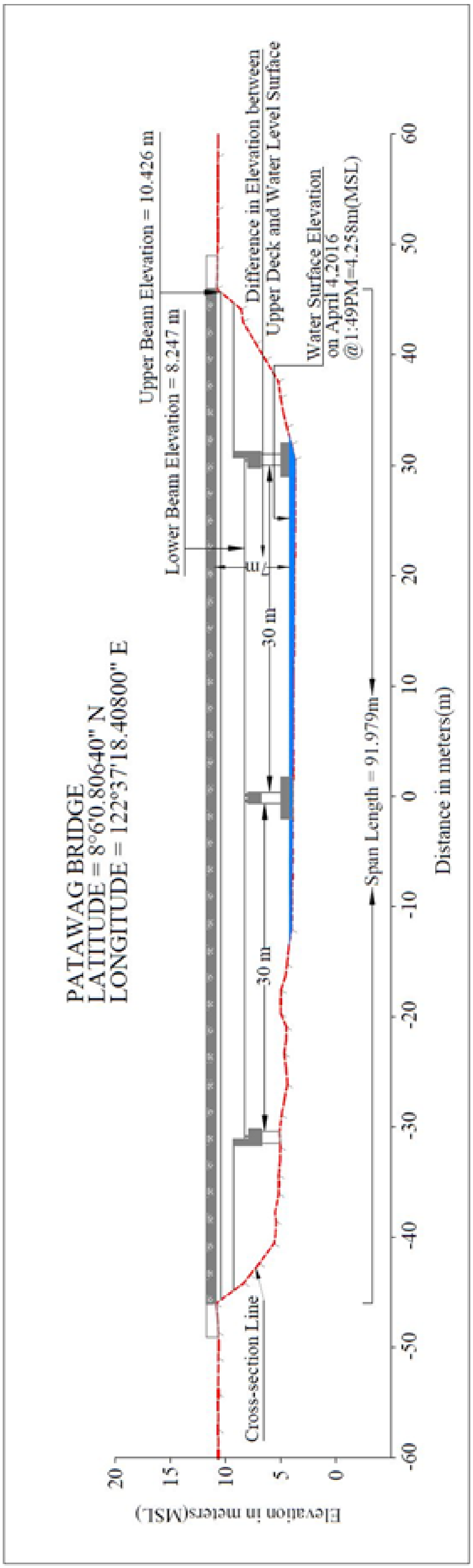


Figure 37. Patawag Bridge Cross-section Diagram

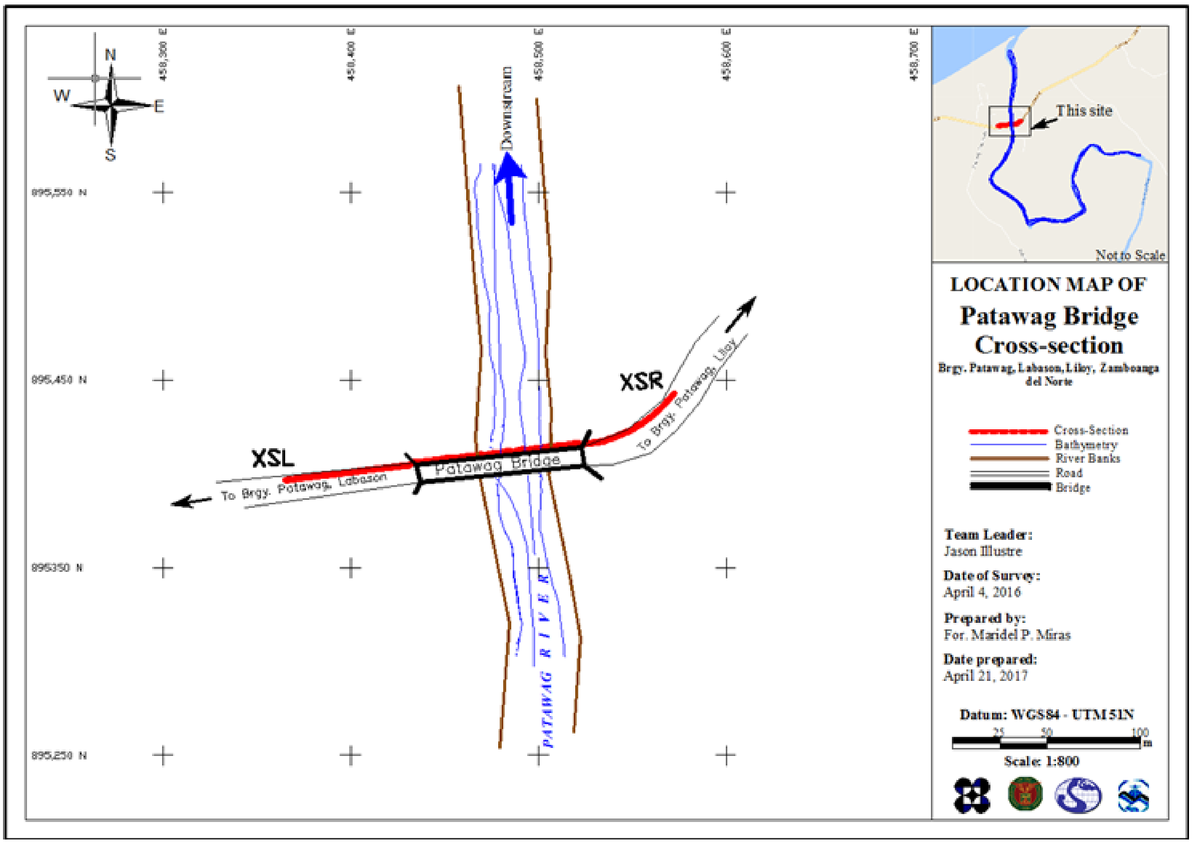


Figure 38. Patawag Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Patawag Bridge

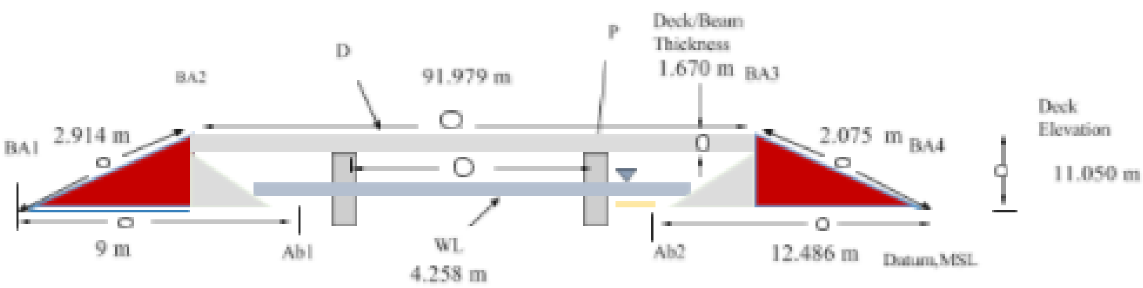
River Name: Patawag River
Location (Brgy,City,Region): Brgy. Patawag, Liloy, Zamboanga Del Norte

Survey Team: Jayson Ilustre, Ryan Artenio (Local Aide)
Date and Time: April 4, 2016, 1:49 P.M.

Flow Condition: low normal high

Weather Condition: fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	2.914 m	
2. BA2-BA3	91.979 m	
3. BA3-BA4	2.075 m	
4. BA1-Ab1	9 m	
5. Ab2-BA4	12.486 m	
6. Deck/beam thickness	1.670 m	
7. Deck elevation	11.050 m	

Note: Observer should be facing downstream

Figure 39. Patawag Bridge Data Sheet

Water surface elevation of Patawag River was determined by a Nikon® Total Station on April 4, 2016 at 1:49 PM at Patawag Bridge area with a value of 4.258 m in MSL as shown in Figure 37. This was translated into marking on the bridge's pier as shown in Figure 40. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Patawag River, the Ateneo de Zamboanga University.

Figure 40. Water-level markings on Patawag Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 24, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 41. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.278 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with ZN-143 occupied as the GNSS base station in the conduct of the survey.

Figure 41. Validation points acquisition survey set-up for Patawag River

The survey started from Brgy. La Libertad, Municipality of Gutalac, Zamboanga del Norte going west along national high way covering six (19) barangays in four (4) municipalities, namely, the municipalities of Gutalac, Labason, Liloy and Salug, and ending in Brgy. Poblacion, Municipality of Salug, Zamboanga del Norte. The survey gathered a total of 6,266 points with approximate length of 36.9 km using UP_PAT-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 42.

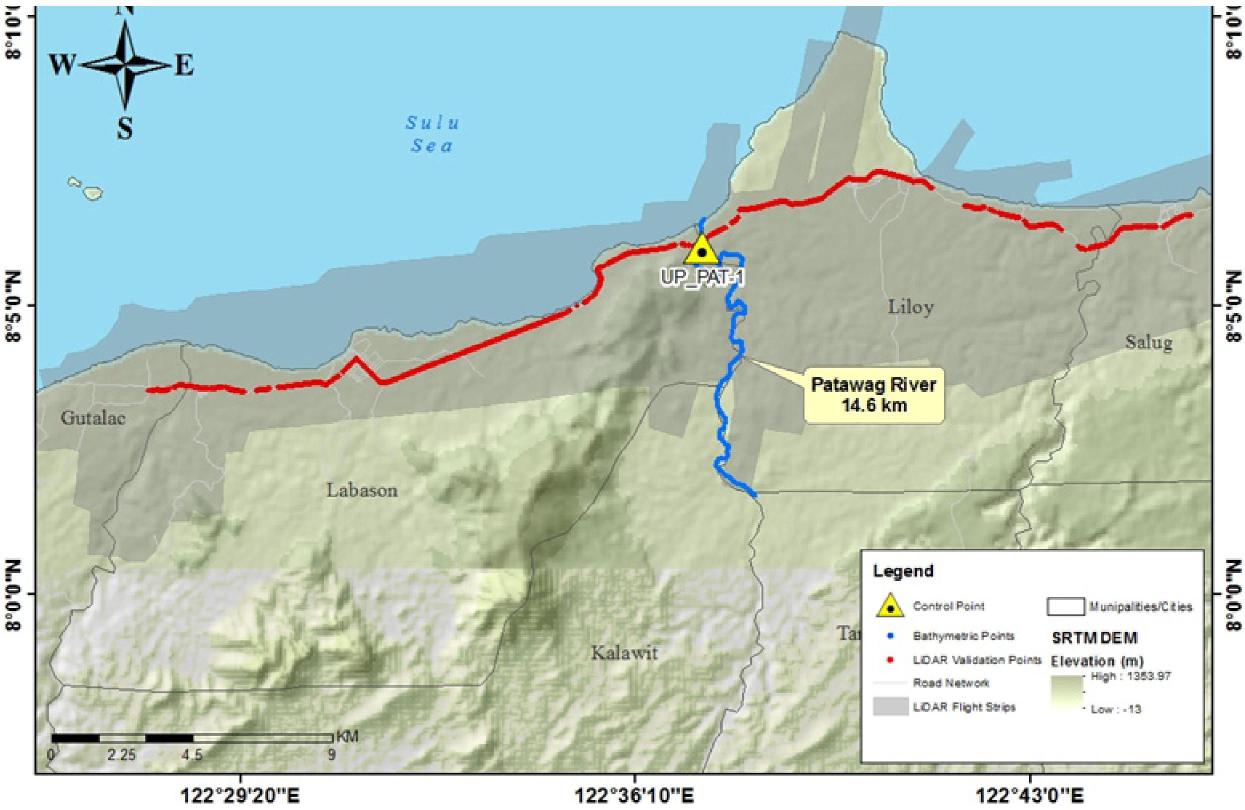


Figure 42. Validation points acquisition covering the Patawag River Basin Area

4.7 River Bathymetric Survey

Bathymetric survey was executed on April 4-7, 2016 at Patawag River using a Nikon® Total Station as illustrated in Figure 43. The survey started from the mouth of the river at Brgy. Patawag, Liloy, Zamboanga del Norte with coordinates 8°5'49.17637"N, 122°38'0.77403"E and ended in Brgy. Malila T, Tampilisan, Zamboanga del Norte, with coordinates 8°1'41.98319"N, 122°738'15.55759"E. The control points AB-1 and AB-2 were used as GNSS base stations all throughout the entire survey.

Figure 43. Cross-section survey at Patawag River using Hi-Target™Total Station

The bathymetric survey for Patawag River gathered a total of 2,493 points covering 16.48 km of the river traversing Brgy. Patawag in the Municipality of Liloy toBrgy. Malila-T in the Municipality of Tampilisan. A CAD drawing was also produced to illustrate the riverbed profile of Patawag River. As shown in Figure 46, the highest and lowest elevation has a 22-m difference. The highest elevation observed was 53.0 m above MSL located in Brgy. Malila T in the Municipality of Tampilisan while the lowest was -13.271 m below MSL located in Brgy. Patawag in the Municipality of Liloy.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 21-31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. A map showing the DVC bathymetric checking points is shown in Figure 45.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.95was obtained was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

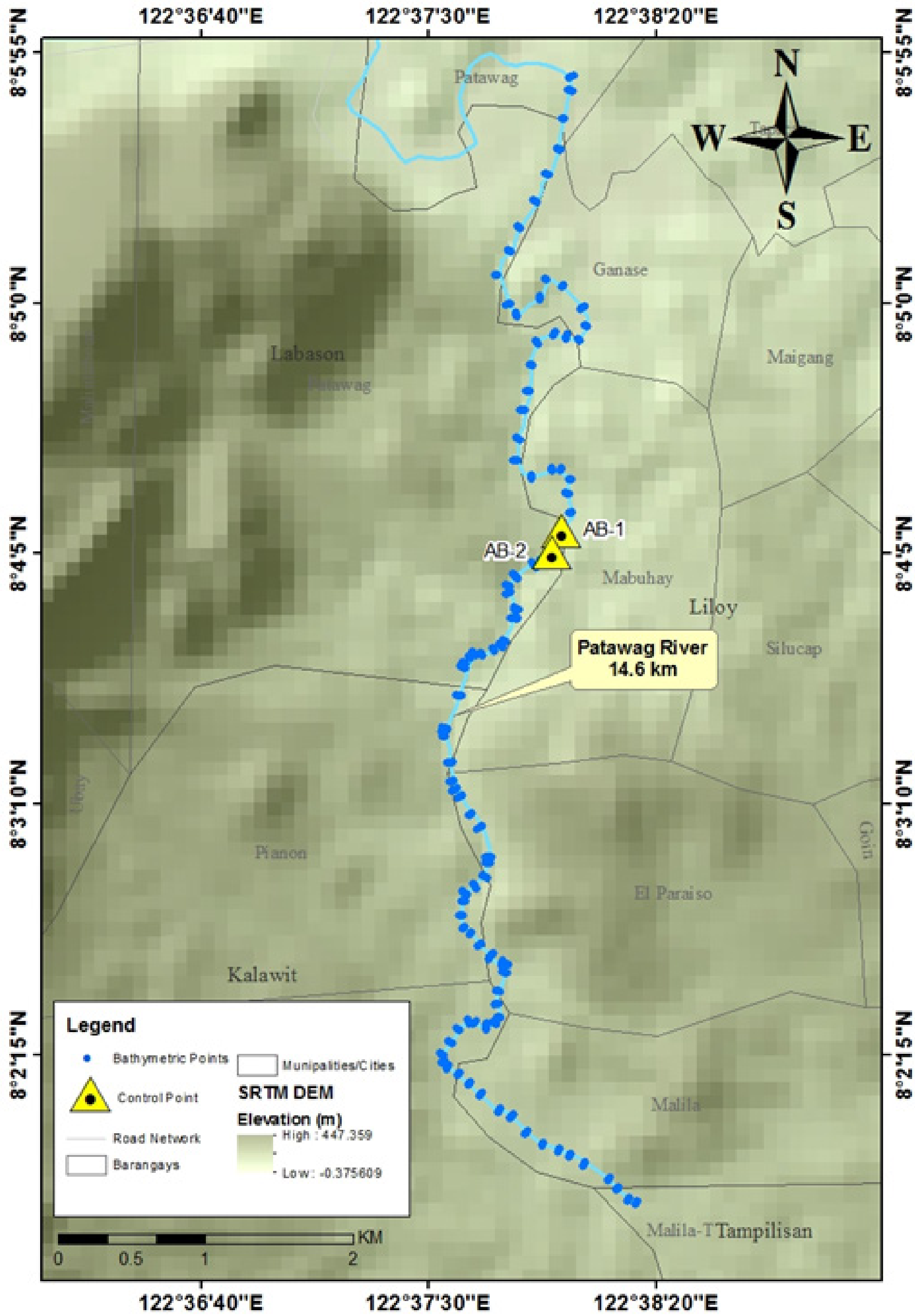


Figure 44. Bathymetric survey of Patawag River

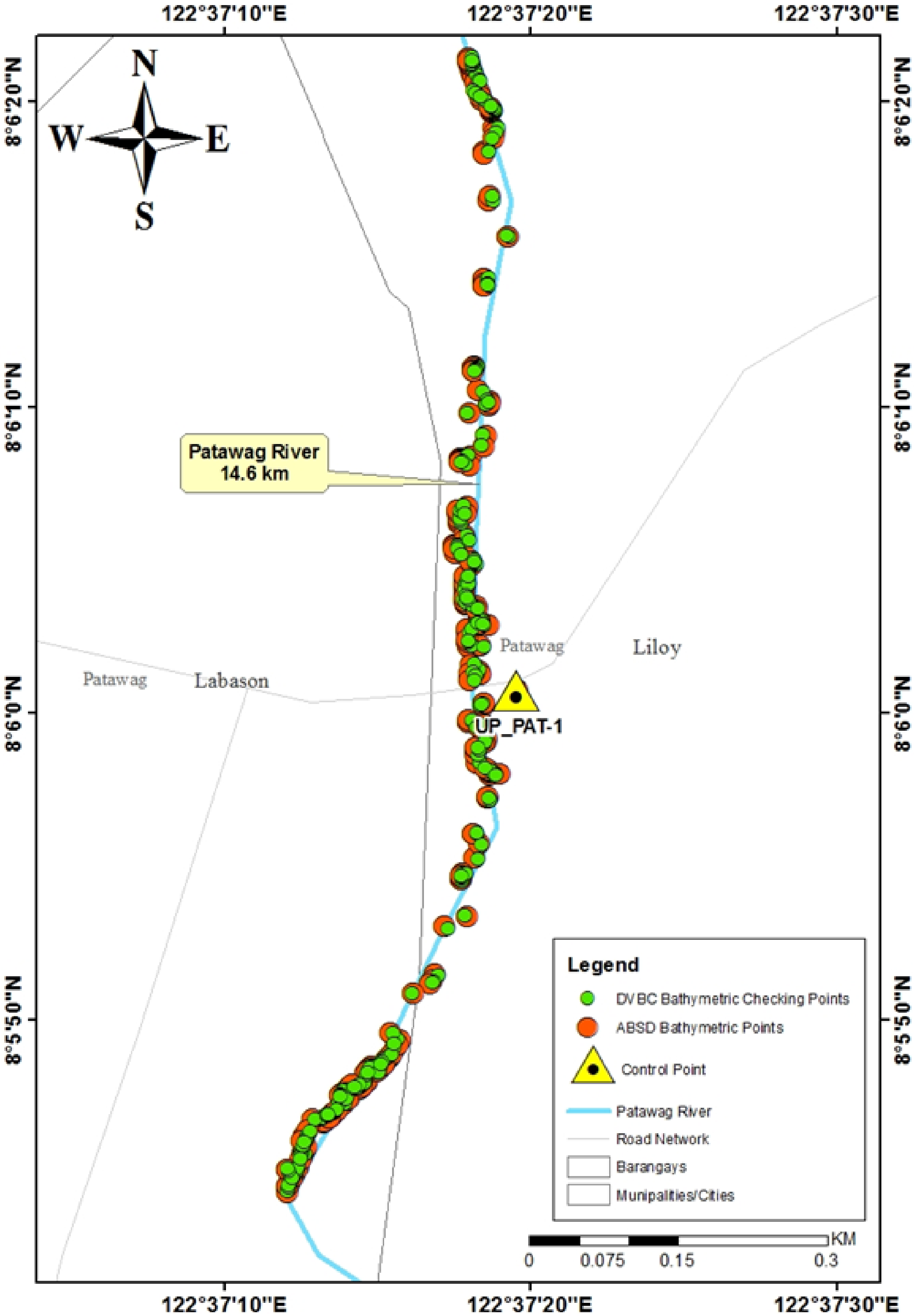


Figure 45. Quality checking points gathered along Patawag River by DVBC

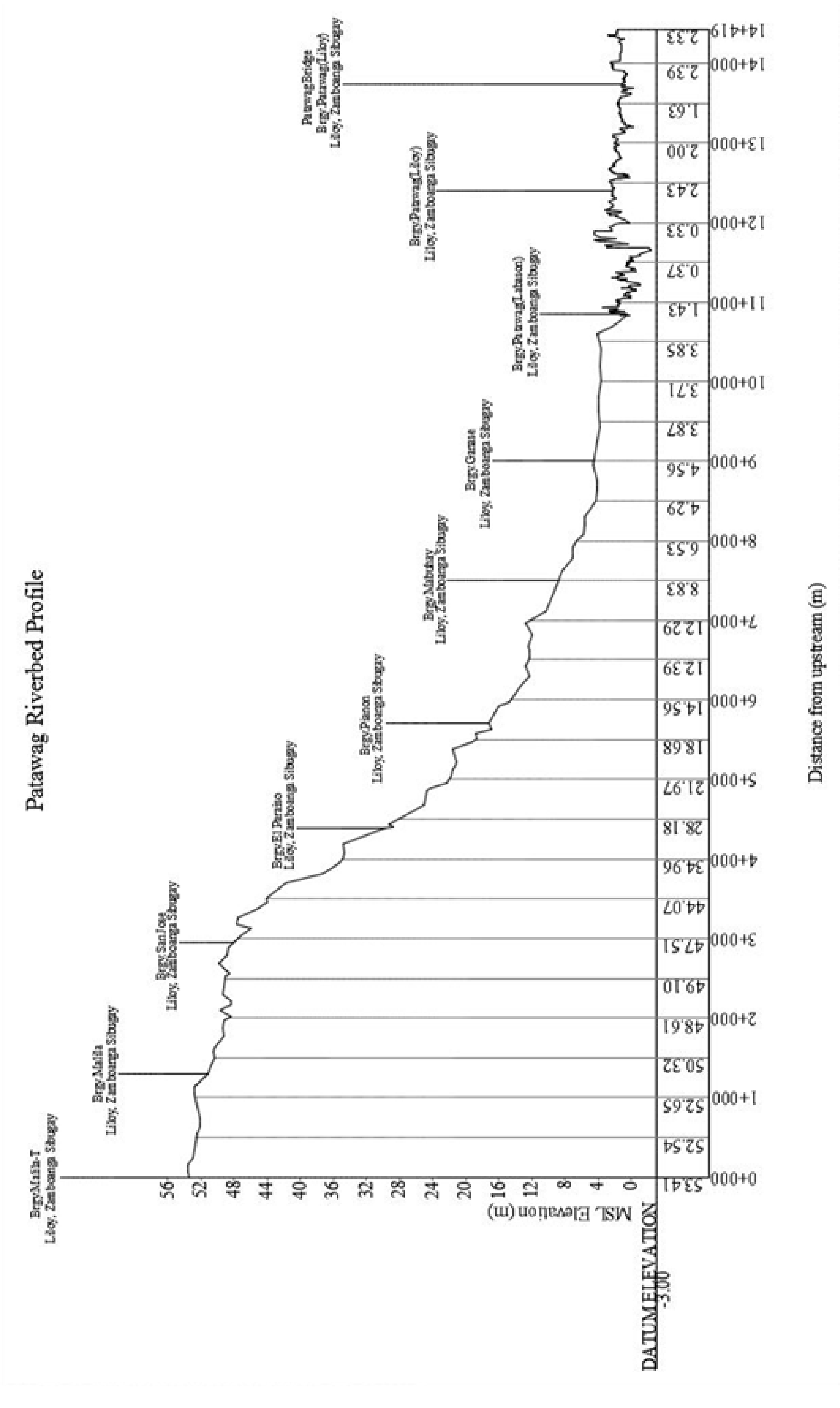


Figure 46. Patawag Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. Malila, Liloy, Zamboanga del Norte (8° 1' 49.41" N, 122° 38' 19.24" E). (Figure 47). The precipitation data collection started from June 28, 2016 at 12:39AM to June 29, 2016 at 12:29AM with 10 minutes recording interval.

The total precipitation for this event in Brgy. Malila was 33.4 mm. It has a peak rainfall of 7.8 mm. on June 28, 2016 at 4:29 PM. The lag time between the peak rainfall and discharge is 3 hours and 20 minutes.

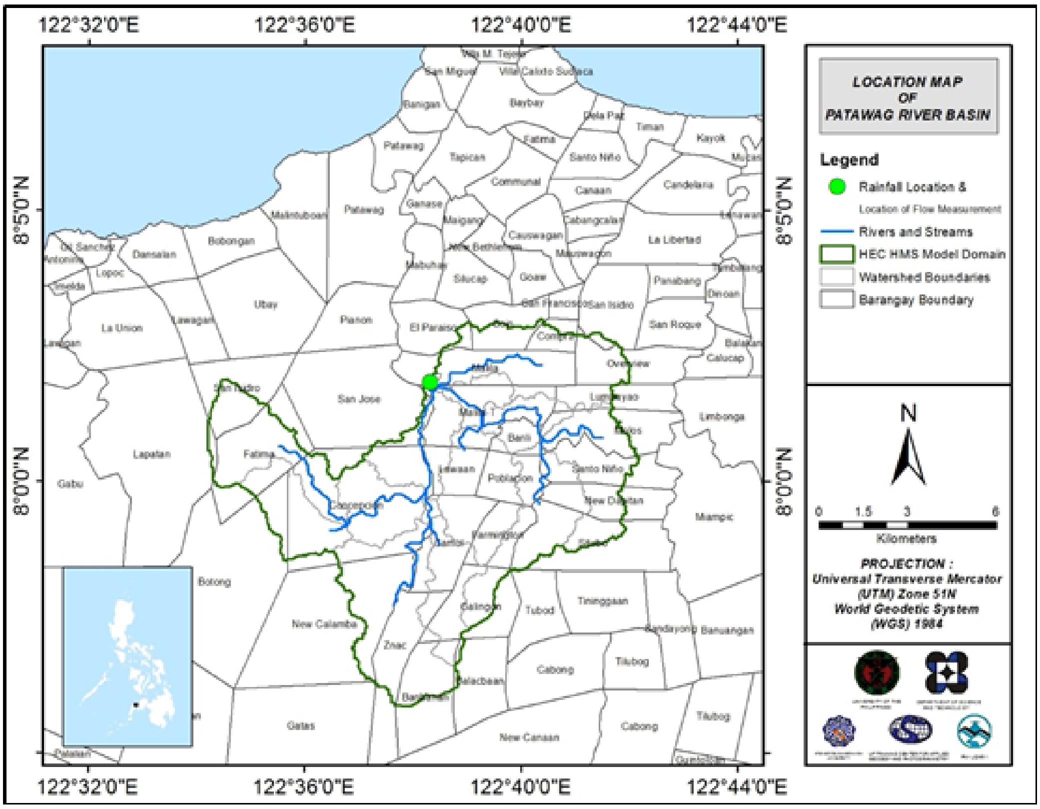


Figure 47. The location map of Patawag HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at a Spillway in Brgy. El Paraiso, Liloy, Zamboanga del Norte(8° 1' 43.8" N, 122° 38' 13.7" E). It gives the relationship between the observed water levels at Brgy. El Paraiso and outflow of the watershed at this location.
For Brgy. El Paraiso, the rating curve is expressed as Q = 4E-106e2.0442h as shown in Figure 49.

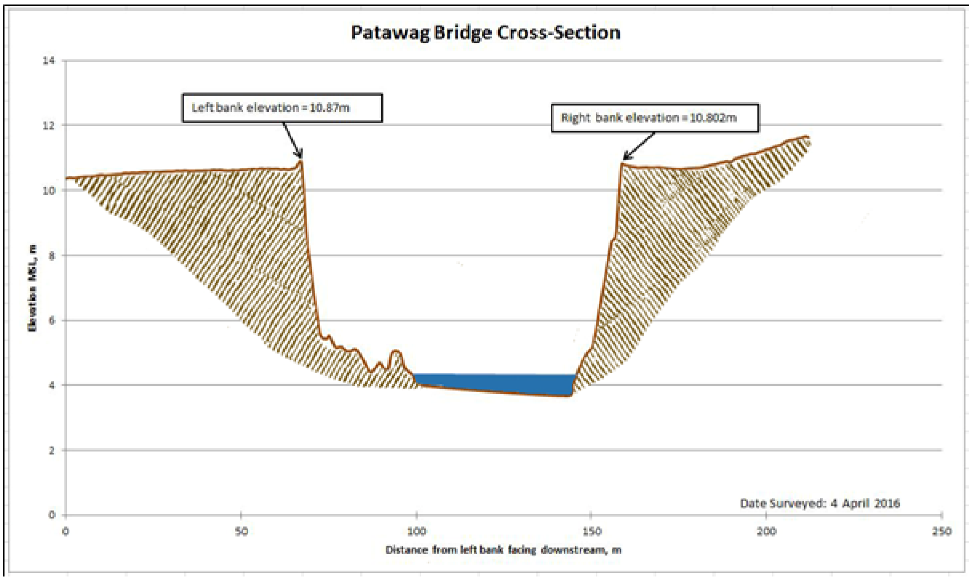


Figure 48. Cross-Section Plot of Spillway, Brgy. El Paraiso, Liloy, Zamboanga del Norte

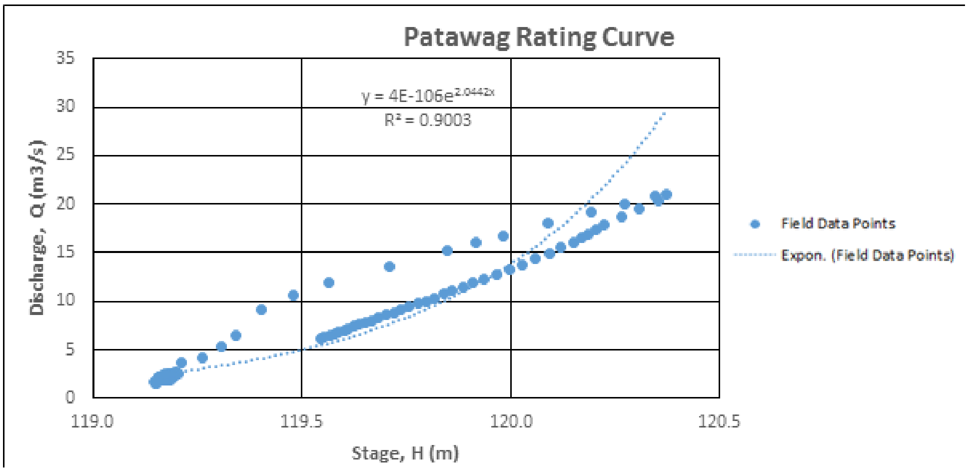


Figure49.Rating Curve at Spillway, Brgy. El Paraiso, Liloy, Zamboanga del Norte

This rating curve equation was used to compute the river outflow at Spillway, Brgy. El Paraiso for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 20.95 cubic meters per second at 7:09 PM, June 28, 2016.

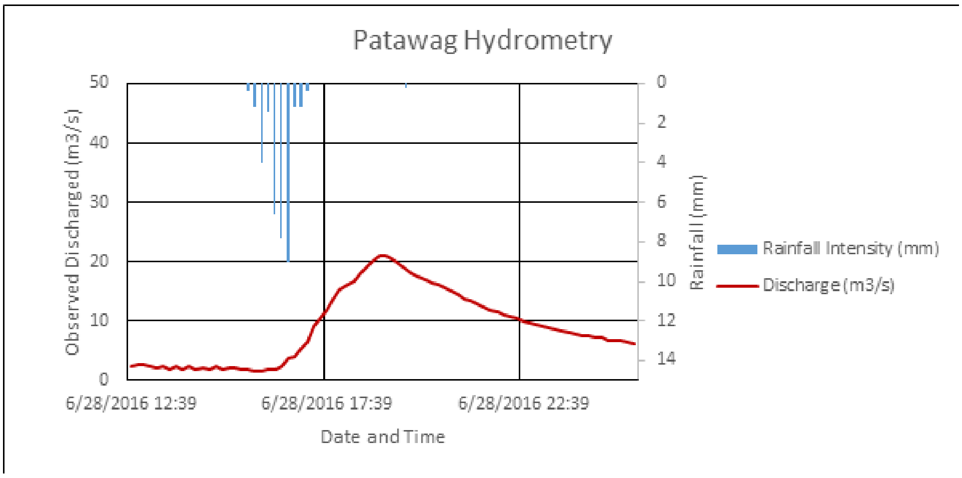


Figure50. Rainfall and outflow data at Spillway, Brgy. El Paraiso used for modeling

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 was chosen based on its proximity to the Patawag watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 32. 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

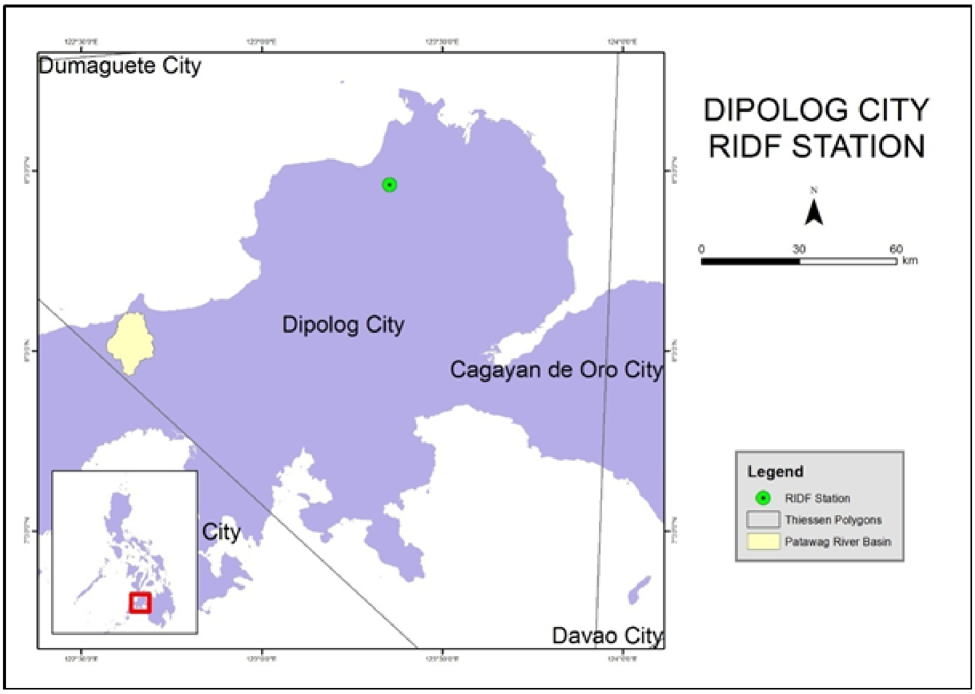


Figure 51. Dipolog City RIDF location relative to Patawag River Basin

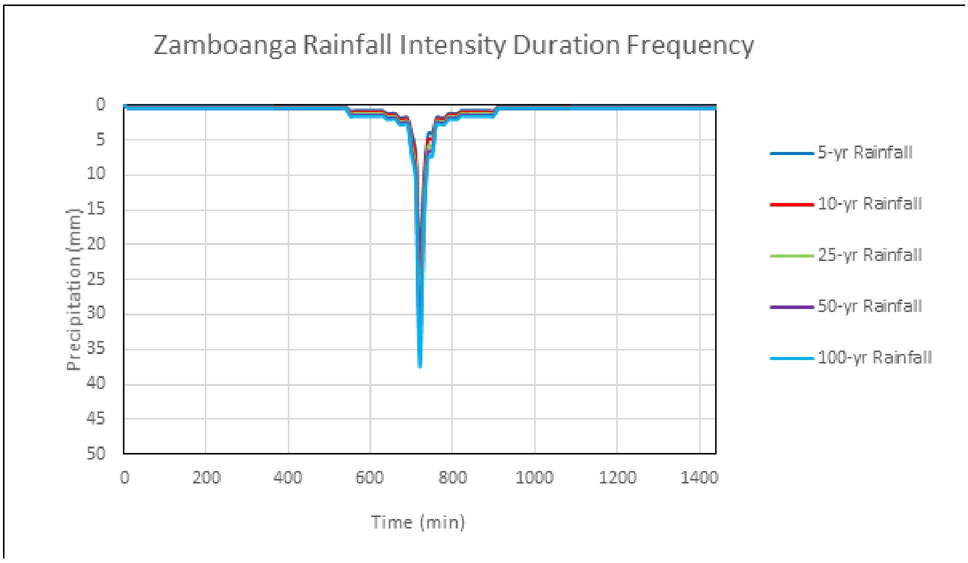


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Patawag River Basin are shown in Figures 53 and 54, respectively.

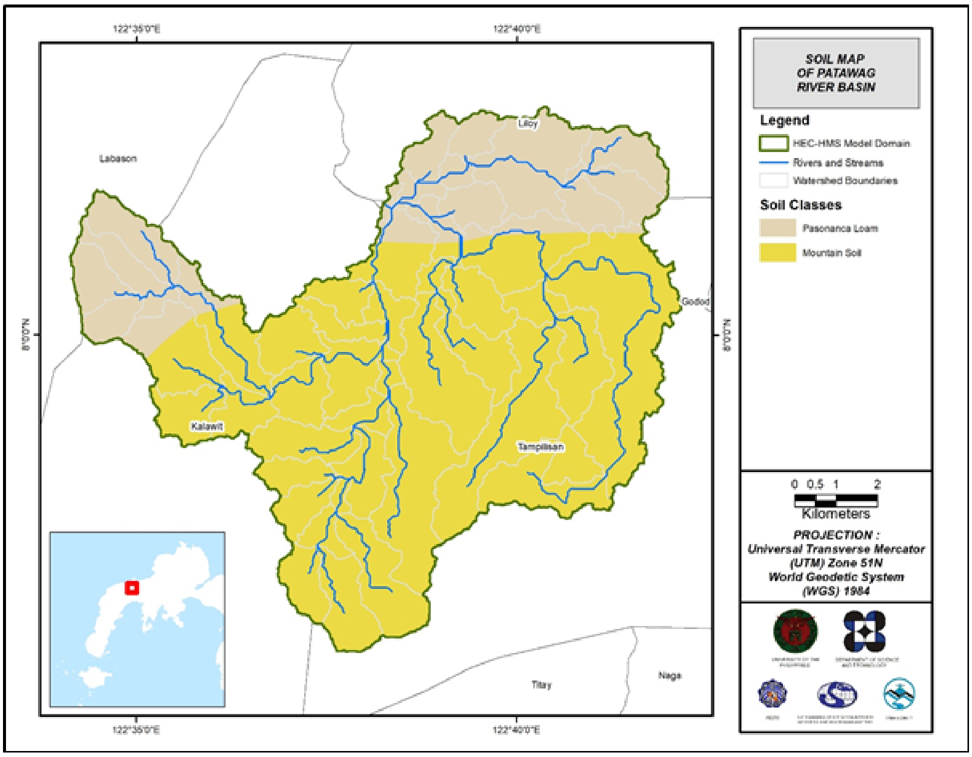


Figure 53. Soil Map of Patawag River Basin

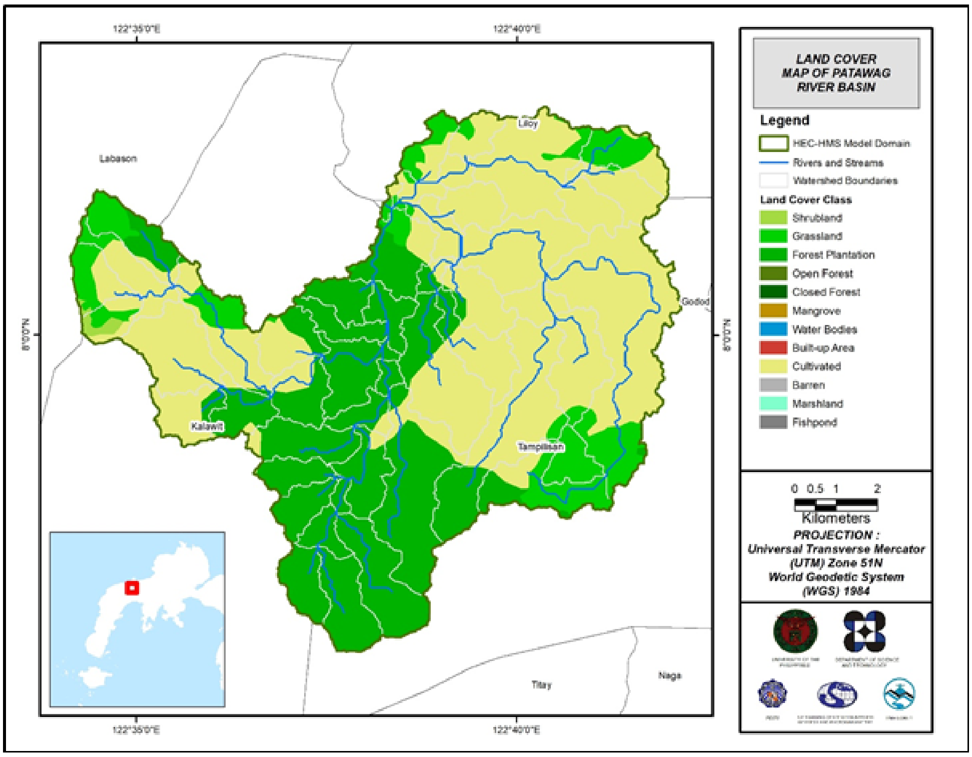


Figure 54. Land Cover Map of Patawag River Basin

For Patawag, the soil classes identified were loam and undifferentiated mountain soil. The land cover types identified were cultivated areas, grassland, shrubland, open canopy forests and forest plantations.

Figure 55. [insert Slope Map]

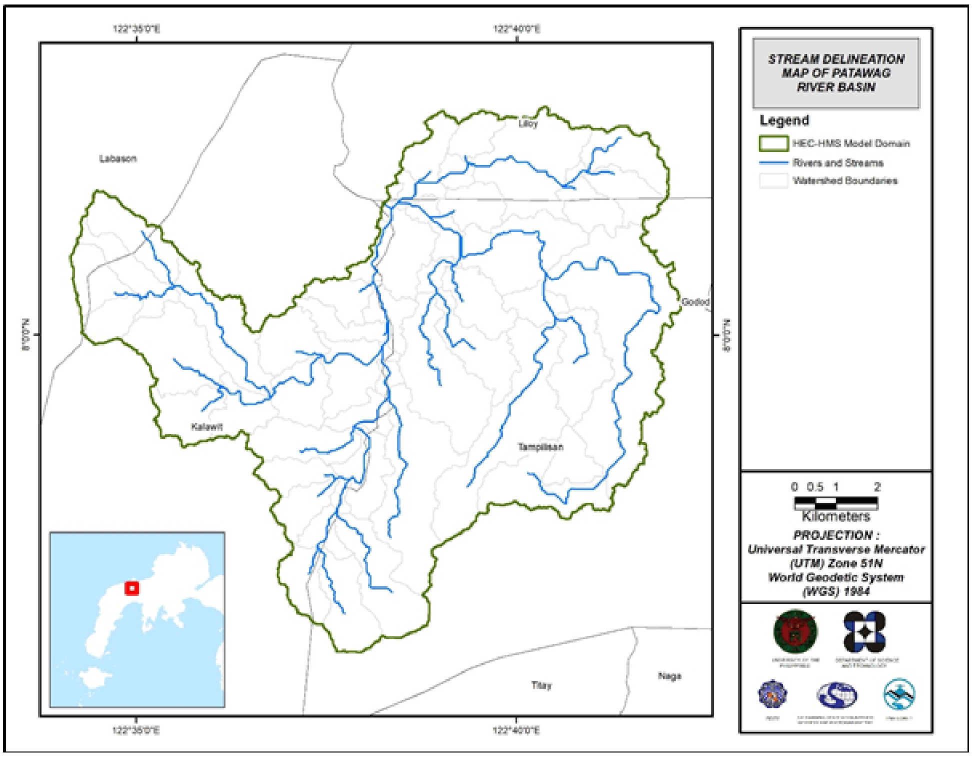


Figure 56. Stream delineation map of Patawag river basin

Using the SAR-based DEM, the Patawag basin was delineated and further subdivided into subbasins. The model consists of 55 sub basins, 27 reaches, and 27 junctions as shown in Figure 57. The main outlet is at Spillway, Brgy. El Paraiso, Liloy, Zamboanga del Norte.

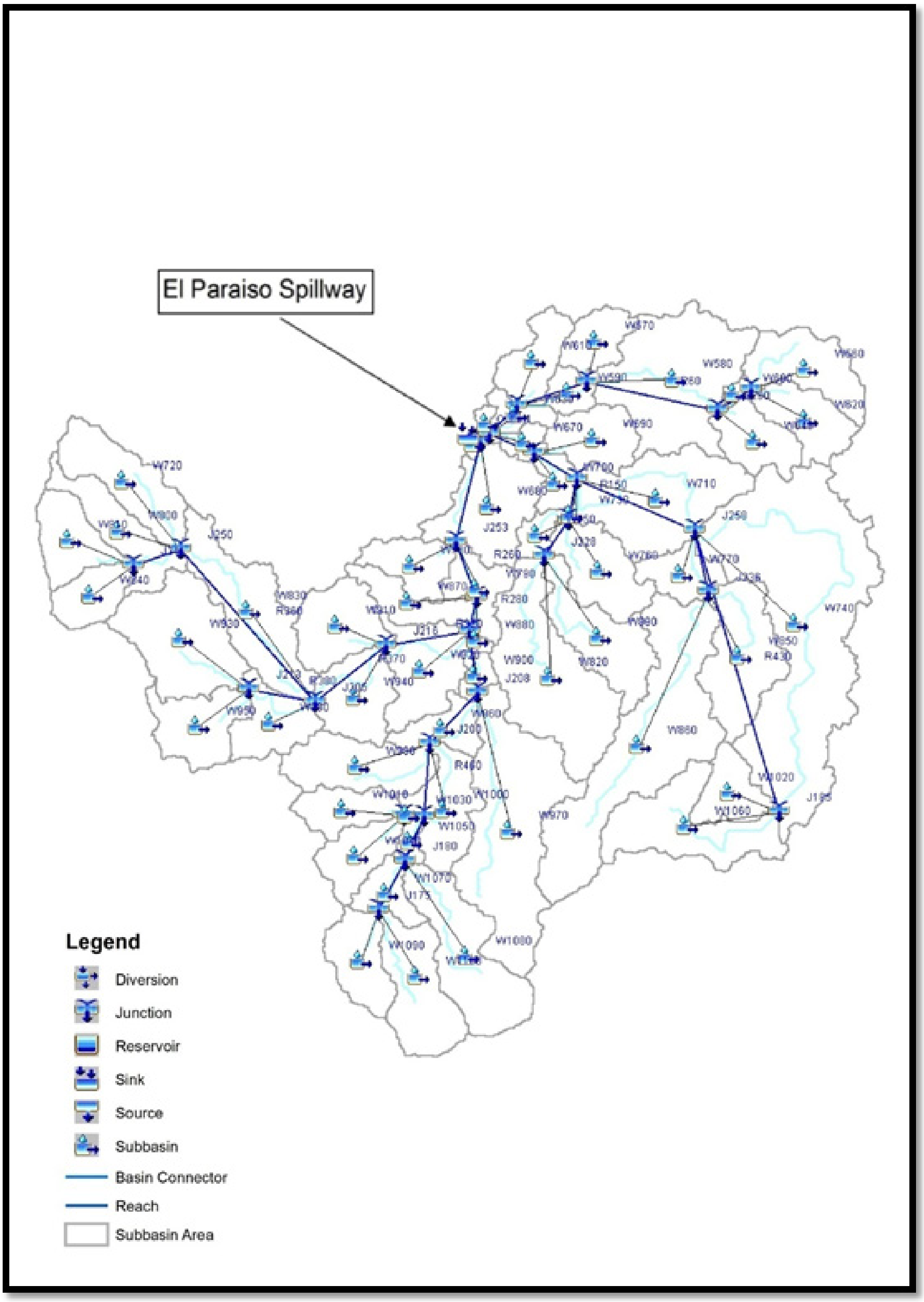


Figure 57. caption

5.4 Cross-section Data

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

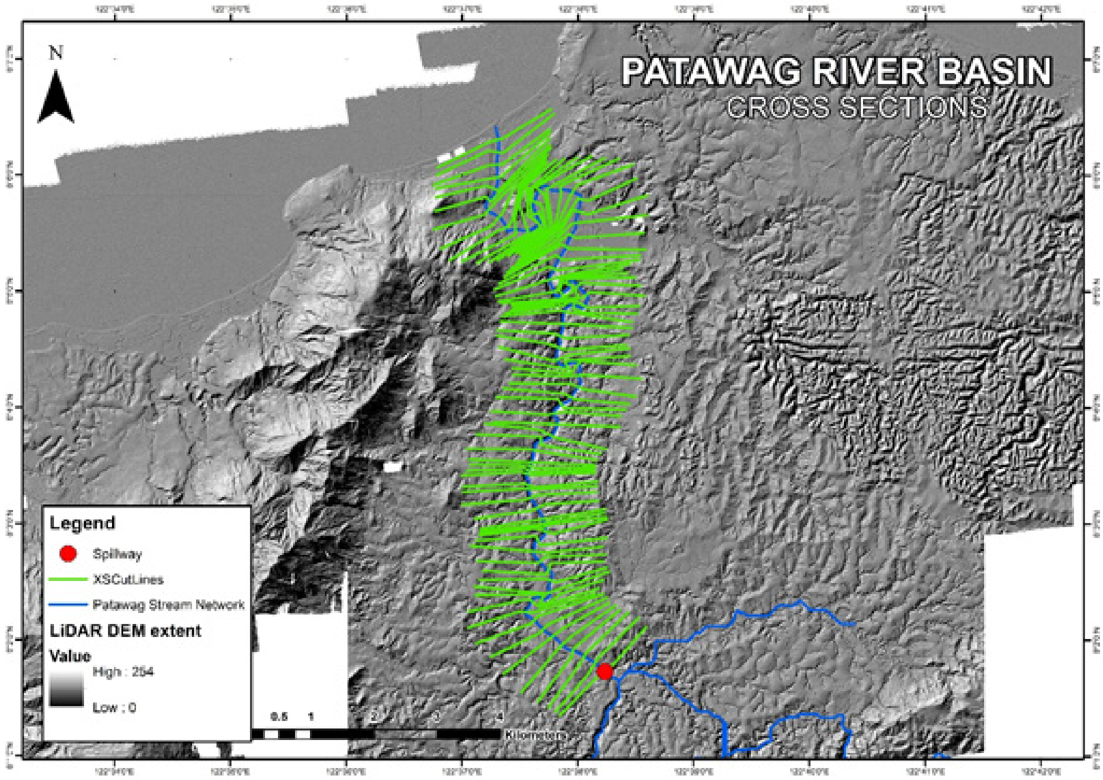


Figure 58. River cross-section of Patawag River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modelling 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 modelling 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 is seen that the water will generally flow from the south of the model to the north, following the main channel. As such, boundary elements northwest of the model were assigned as outflow elements.

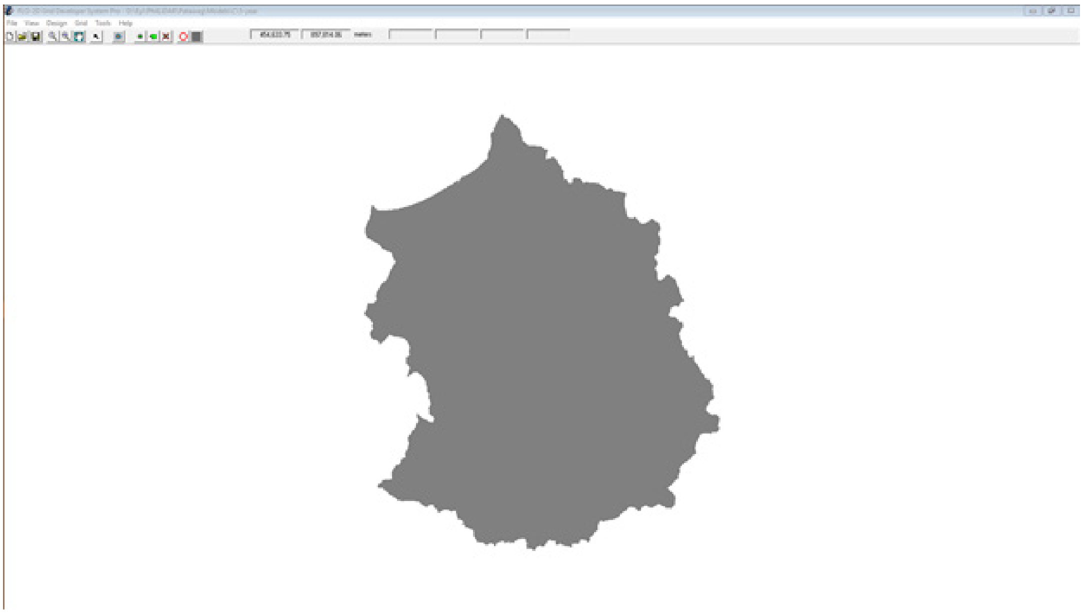


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 13.04 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

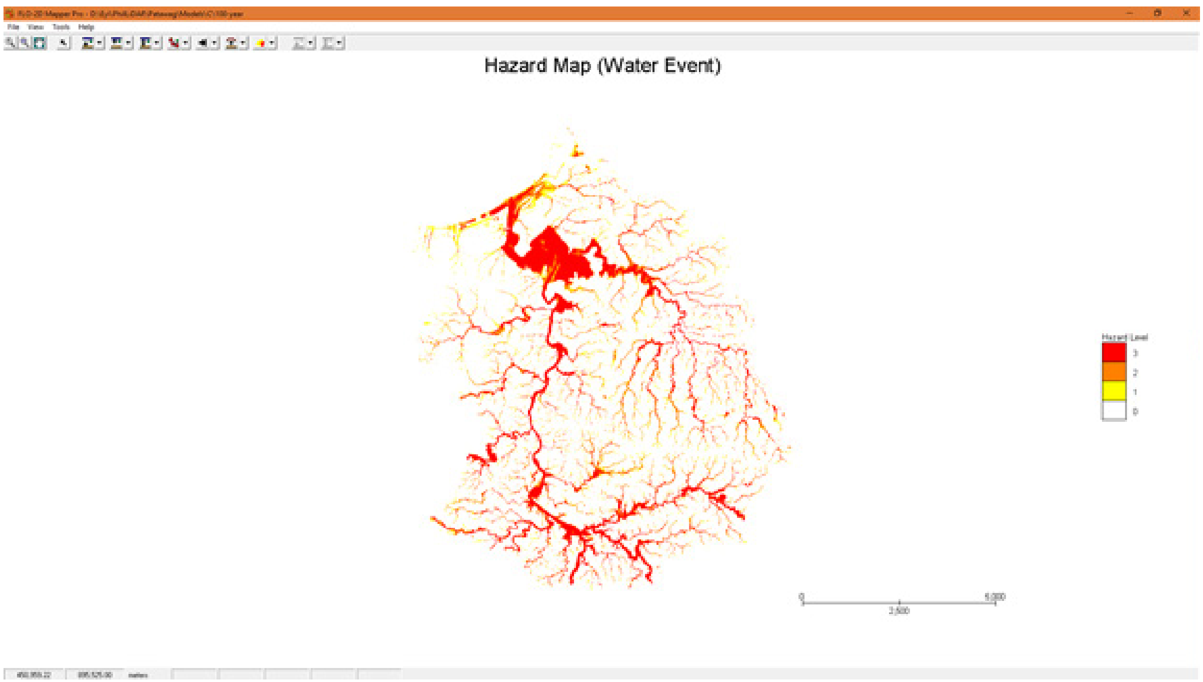


Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically created a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts cover a maximum land area of 36,541,900.00 m2.

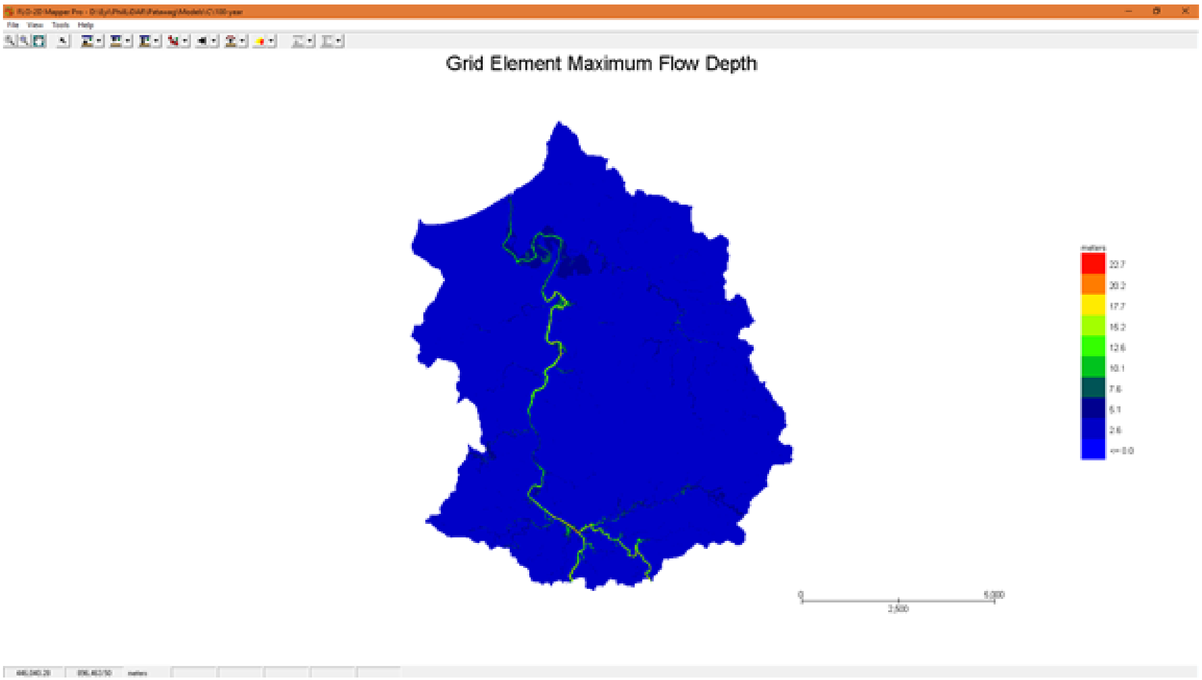


Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 7,561,098.38 m3 of water entering the model, the entirety of which is due to rainfall. 1,750,284.88 m3 of this water is lost to infiltration and interception, while 1,739,479.36m3 is stored by the flood plain. The rest, amounting up to 4,071,332.84 m3,is outflow.

5.6 Results of HMS Calibration

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

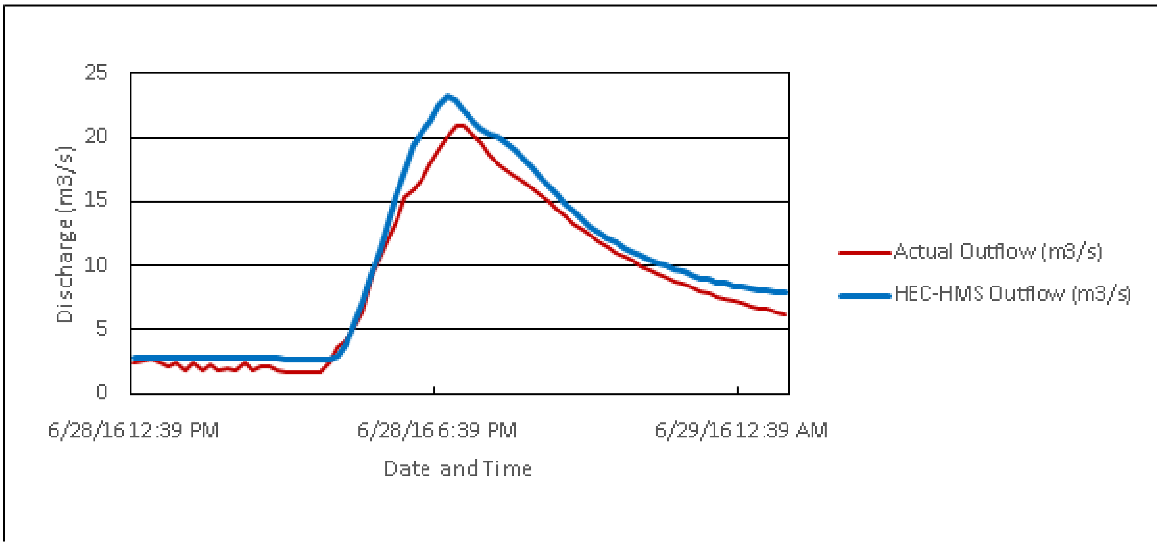


Figure 62. Outflow Hydrograph of Patawag produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of Calibrated Values for Patawag

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	9.55 – 39.26
			Curve Number	55.59 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.25 – 3.18
			Storage Coefficient (hr)	0.55 – 7.41
	Baseflow	Recession	Recession Constant	0.47
			Ratio to Peak	0.02
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04
				2.90-25.29

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 9.55mm to 39.26mm means that there is a considerable amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. For Patawag, the soil classes identified were loam and undifferentiated mountain soil. The land cover types identified were cultivated areas, grassland, shrubland, open canopy forests and forest plantations.

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 0.25 hours to 3.18 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 0.47 indicates that the basin is moderately likely to go back to its original discharge. Ratio to peak of 0.02 indicates a steep receding limb of the outflow hydrograph.

Table 34. Summary of the Efficiency Test of Patawag HMS Model

Accuracy measure	Value
RMSE	12.25847
r2	0.9003
NSE	0.948106
PBIAS	-4.19524
RSR	0.227804

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 12.25847 (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 0.9003.

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 0.948106.

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 -4.19524.

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 0.227804.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) shows the Patawag outflow using the Zamboanga City RIDF curves 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.

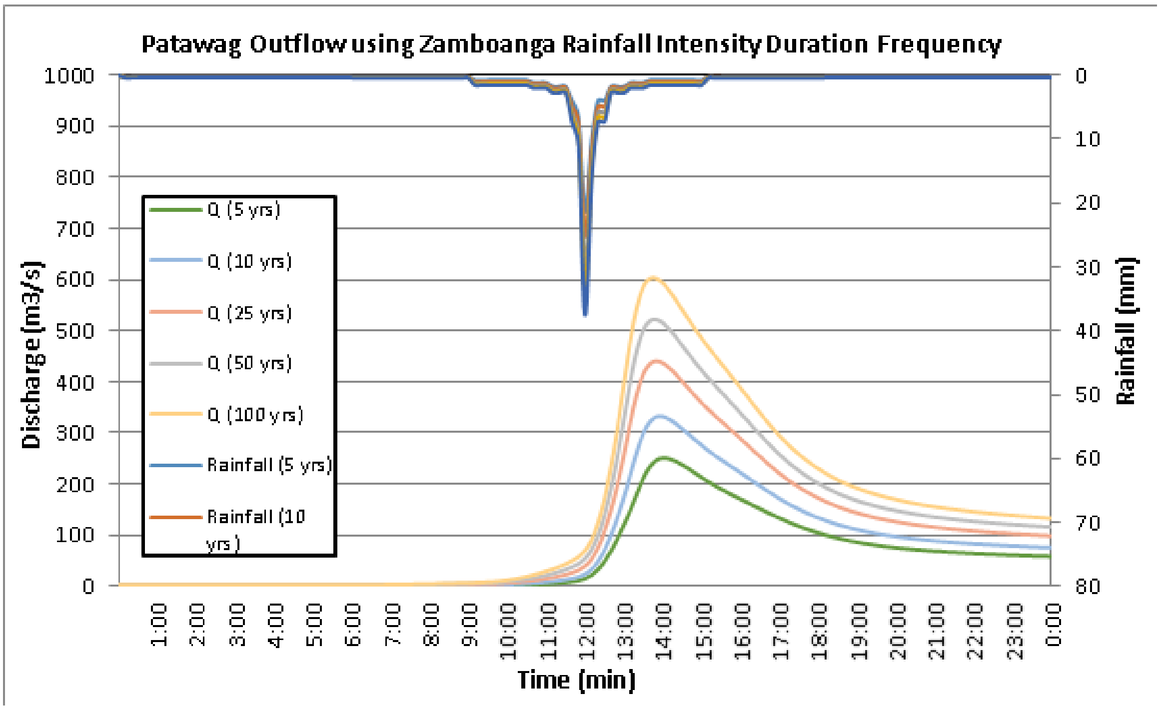


Figure 63. Outflow hydrograph at Patawag Bridge Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Patawag discharge using the Zamboanga City RIDF curves in five different return periods is shown in Table 35.

Table 35. Peak values of the Patawag 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	251	14 hours
10-Year	127.9	25.3	332.2	14 hours
25-Year	153.4	30.2	440.8	13 hours, 50 minutes
50-Year	172.3	33.9	521.9	13 hours, 50 minutes
100-Year	191.1	37.5	602.4	13 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

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

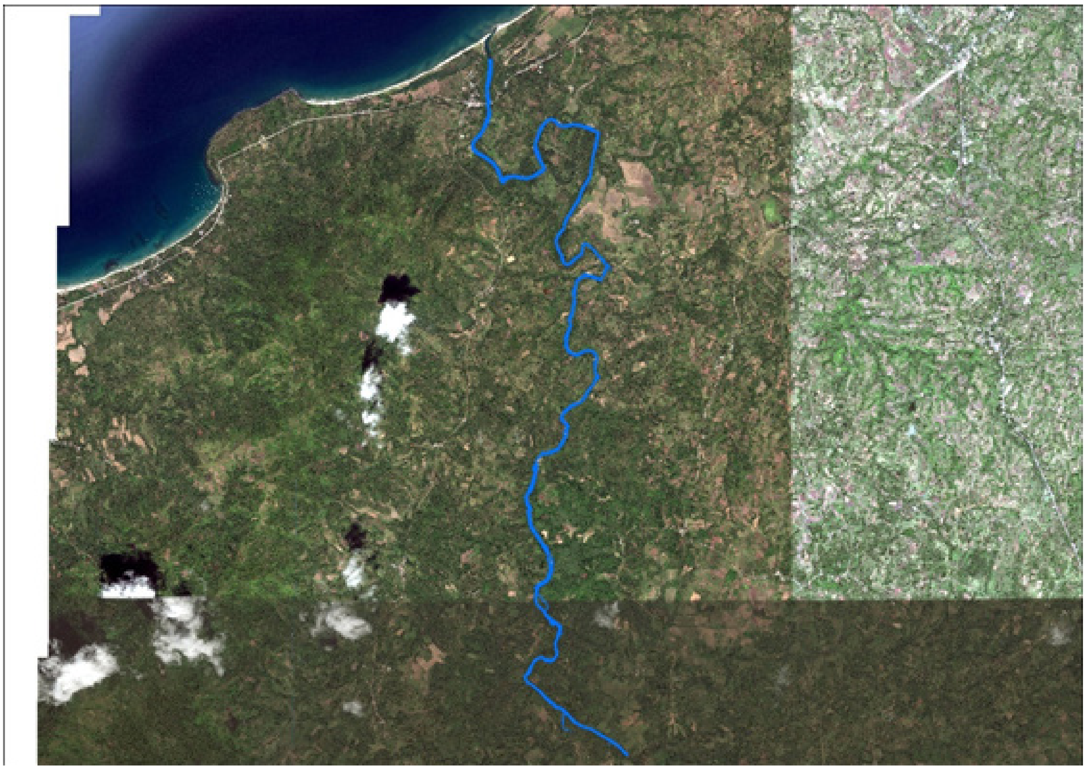


Figure 64. Sample output of Patawag RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 65 to Figure 70 show the 100-, 25-, and 5-year rain return scenarios of the Patawag floodplain.

The generated flood hazard maps for the Patawag 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 (100 yr, 25 yr, and 5 yr).

Table 36. Municipalities affected in Patawag Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Liloy	122.49	88.03	72%
Kalawit	248.64	16.21	7%
Labason	159.43	15.22	10%
Tampilisan	144.44	5.02	3%

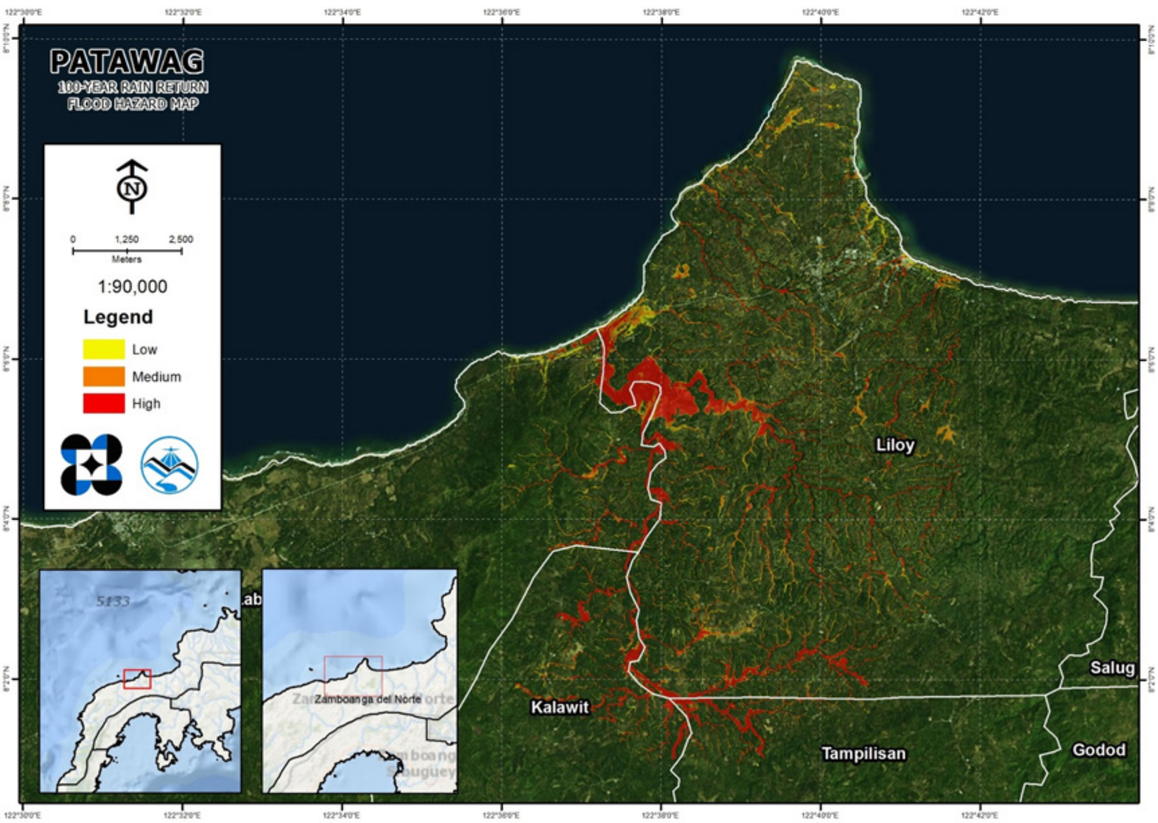


Figure 65. 100-year Flood Hazard Map for Patawag Floodplain

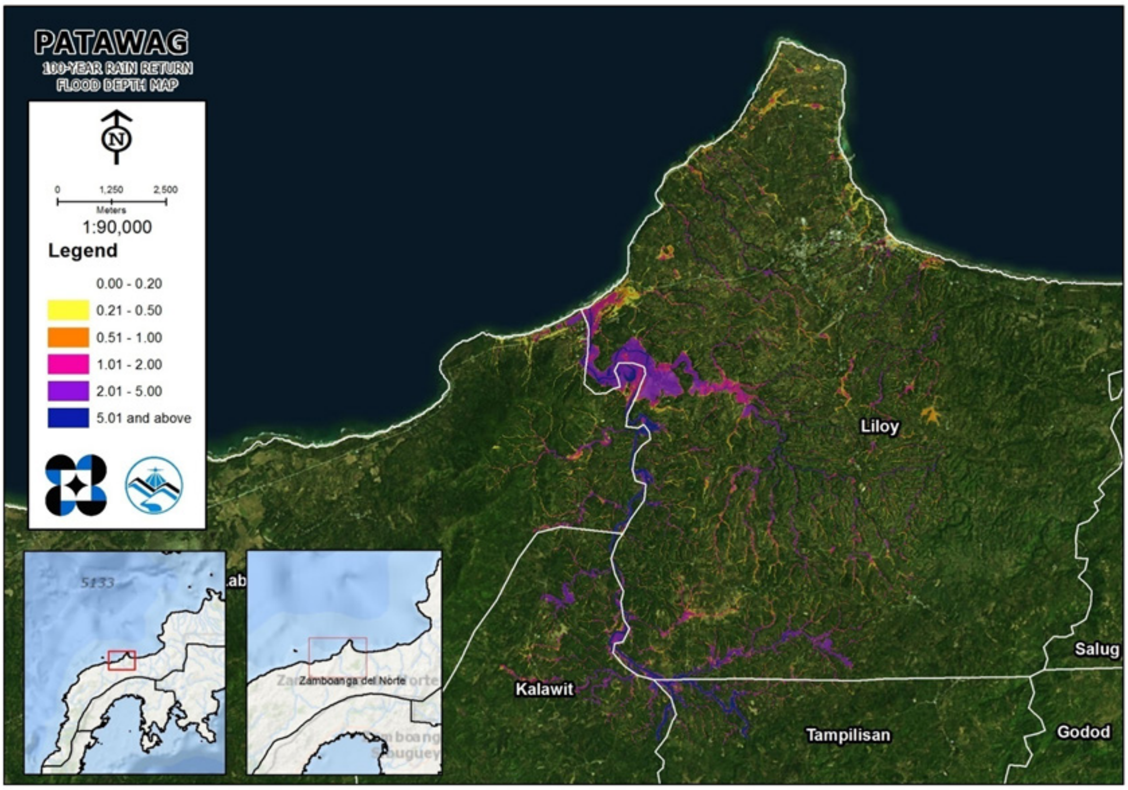


Figure 66. 100-year Flow Depth Map for Patawag Floodplain

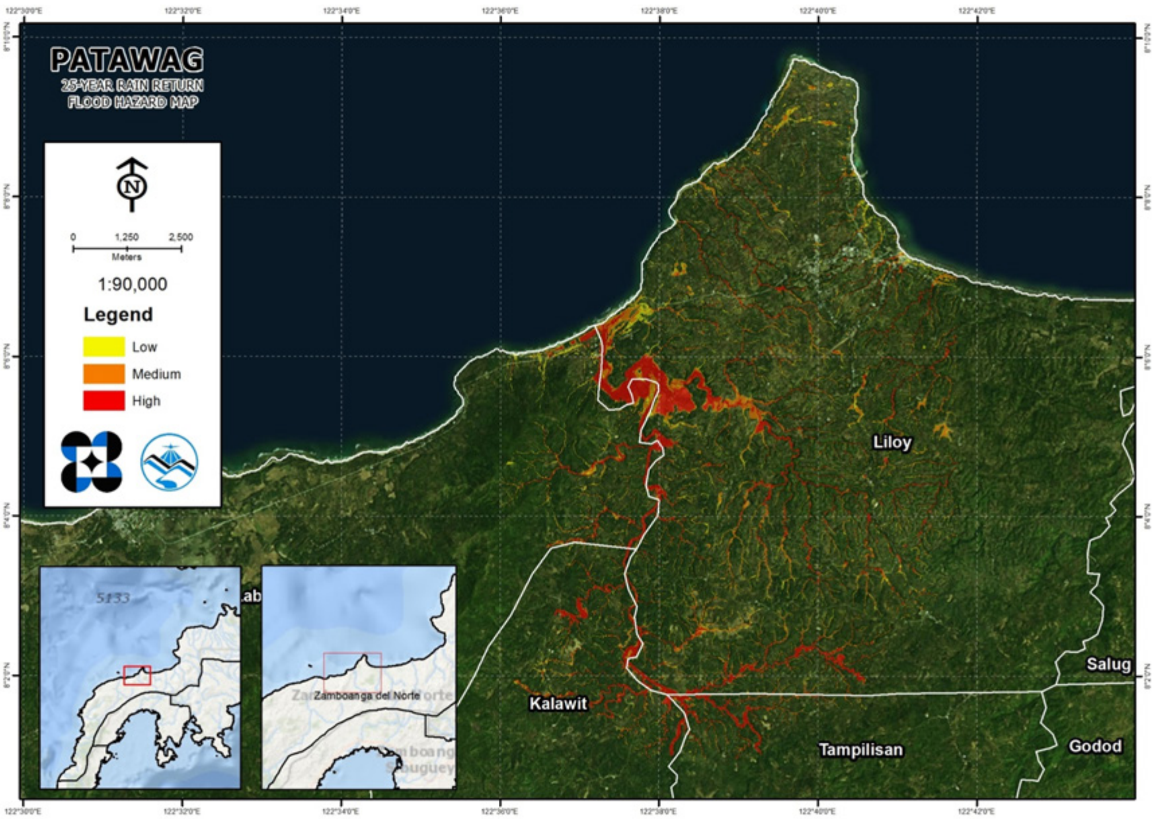


Figure 67. 25-year Flood Hazard Map for Patawag Floodplain

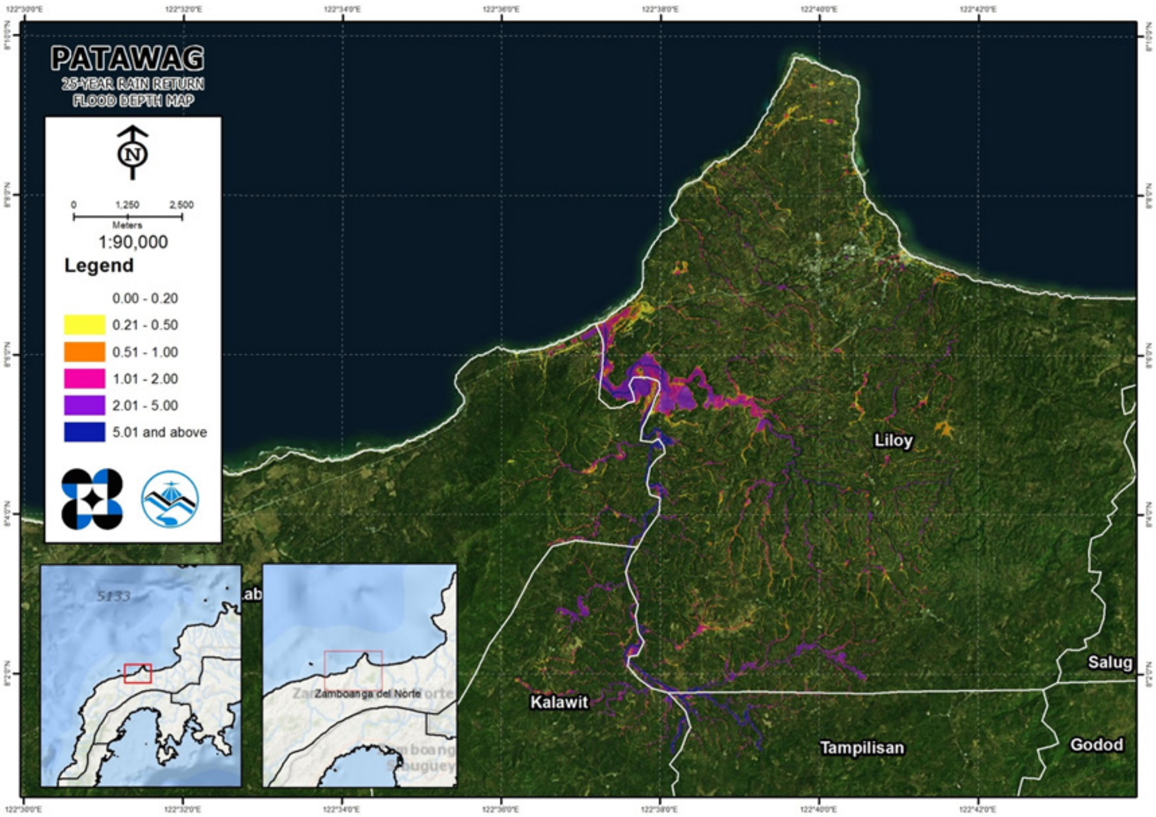


Figure 68. 25-year Flow Depth Map for Patawag Floodplain

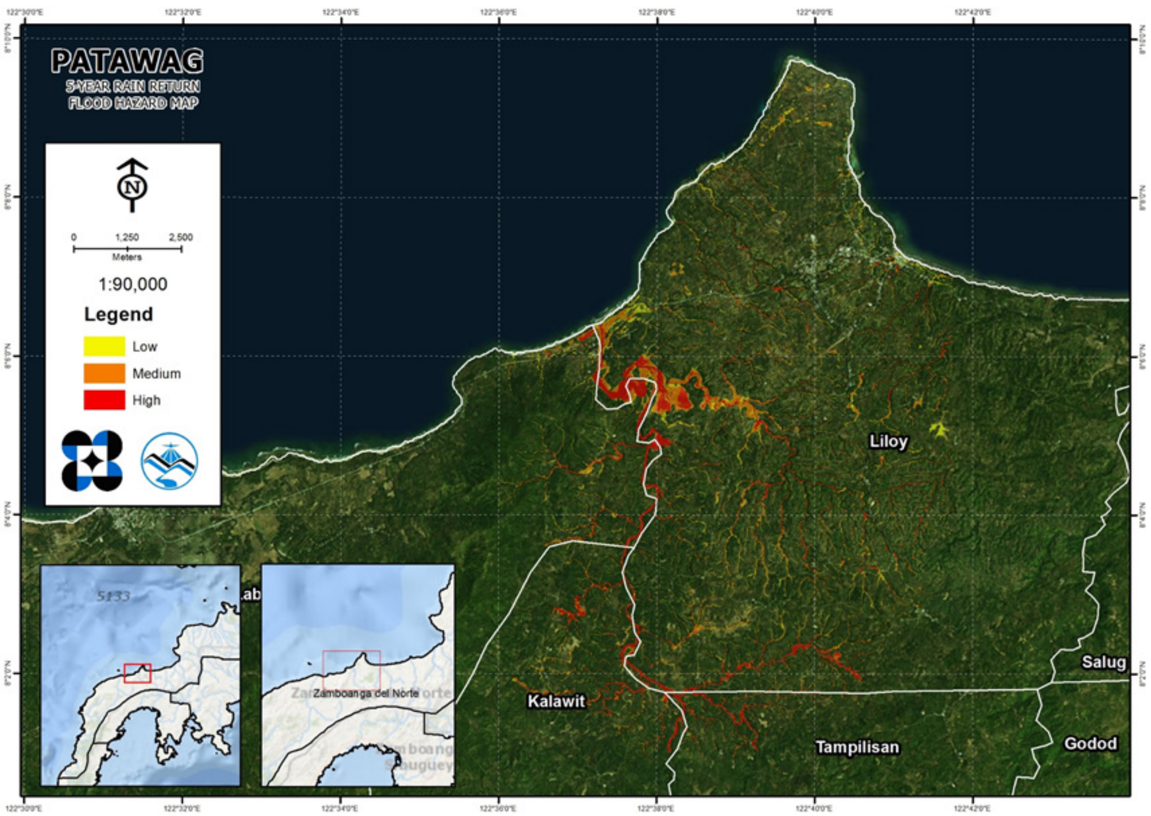


Figure 69. 5-year Flood Hazard Map for Patawag Floodplain

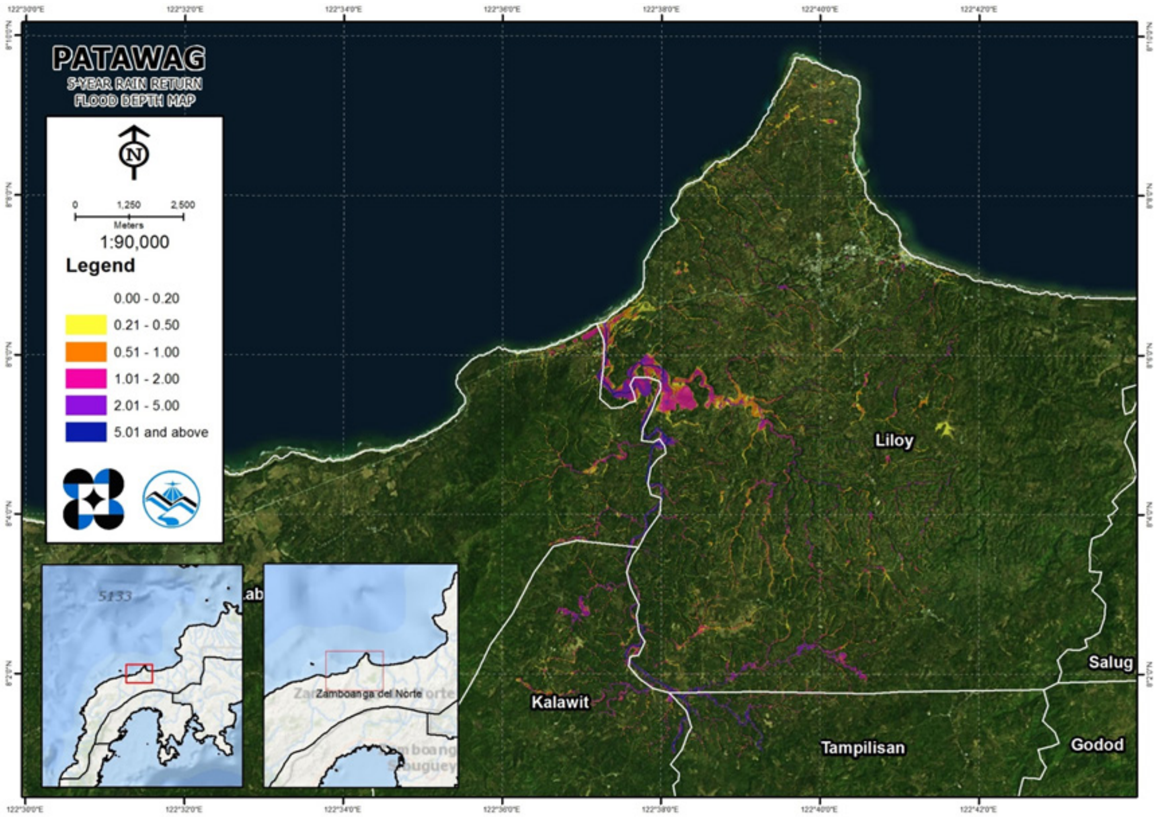


Figure 70. 5-year Flood Depth Map for Patawag Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Salug river basin, grouped by municipality, are listed below. For the said basin, 11 barangays in two municipalities are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 67.76% of the municipality of Liloy with an area of 122.4937 sq. km. will experience flood levels of less than 0.20 meters; 2.09% of the area will experience flood levels of 0.21 to 0.50 meters while 1.72%, 1.68%, 0.86%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Liloy, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)									
		Banigan	Baybay	Cabangcalan	Canaan	Causwagan	Communal	Compra	Dela Paz	El Paraiso	Fatima
Affected Area (sq. km.)	1	2.63	6.93	1.77	1.84	3.83	4.02	1.52	0.98	3.74	1.44
	2	0.098	0.16	0.086	0.05	0.081	0.14	0.028	0.054	0.11	0.023
	3	0.046	0.11	0.027	0.06	0.062	0.19	0.024	0.026	0.1	0.021
	4	0.02	0.094	0.028	0.021	0.056	0.11	0.018	0.018	0.085	0.016
	5	0.0032	0.053	0.0048	0.0046	0.041	0.052	0.0027	0.0071	0.033	0.005
	6	0	0.0001	0	0	0.0013	0.0006	0	0	0.011	0

For the municipality of Jimalalud, with an area of 154.7 sq. km., 1.65% will experience flood levels of less 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters while 0.034%, 0.027%, 0.026%, and 0.006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Liloy, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)										
		Goaw	Goin	La Libertad	Lamao	Mabuhay	Maigang	Malila	Mauswagon	New Bethlehem	Overview	Patawag
Affected Area (sq. km.)	1	2.278191	3.633608	0.395048	1.475041	2.990706	1.812184	6.185689	1.252911	1.859628	1.355291	2.413398
	2	0.060514	0.109285	0.00495	0.037295	0.081228	0.048601	0.148288	0.026611	0.037302	0.074635	0.219519
	3	0.050763	0.077717	0.005319	0.0148	0.048377	0.036137	0.14932	0.020378	0.043804	0.03994	0.235099
	4	0.051207	0.042223	0.005659	0.006305	0.055433	0.022988	0.225638	0.021935	0.058996	0.018252	0.294908
	5	0.023249	0.00418	0.006986	0.0037	0.040976	0.007814	0.247908	0.020129	0.043285	0.0003	0.198696
	6	0	0	0	0	0.019451	0.0001	0.058297	0.0001	0	0	0.098036

Table 39. Affected Areas in Liloy, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)									
		Punta	San Francisco	San Isidro	San Miguel	Santa Cruz	Santo Niño	Silucap	Tapican	Villa Calixto Sudiaca	Villa M. Tejero
Affected Area (sq. km.)	1	2.676511	0.976524	1.921319	2.663262	1.300076	2.775829	3.48598	4.367635	2.178786	2.142044
	2	0.085238	0.029017	0.043606	0.084582	0.04031	0.053067	0.118855	0.178777	0.082638	0.051691
	3	0.033314	0.024134	0.0295	0.052878	0.0125	0.049189	0.10859	0.244014	0.028747	0.029593
	4	0.0105	0.027394	0.0229	0.032478	0.0053	0.050229	0.05275	0.280912	0.0116	0.021595
	5	0.0007	0.0092	0.008828	0.007678	0.0003	0.02331	0.007005	0.08921	0.003734	0.0104
	6	0	0	0	0	0.019451	0.0001	0.058297	0.0001	0	0

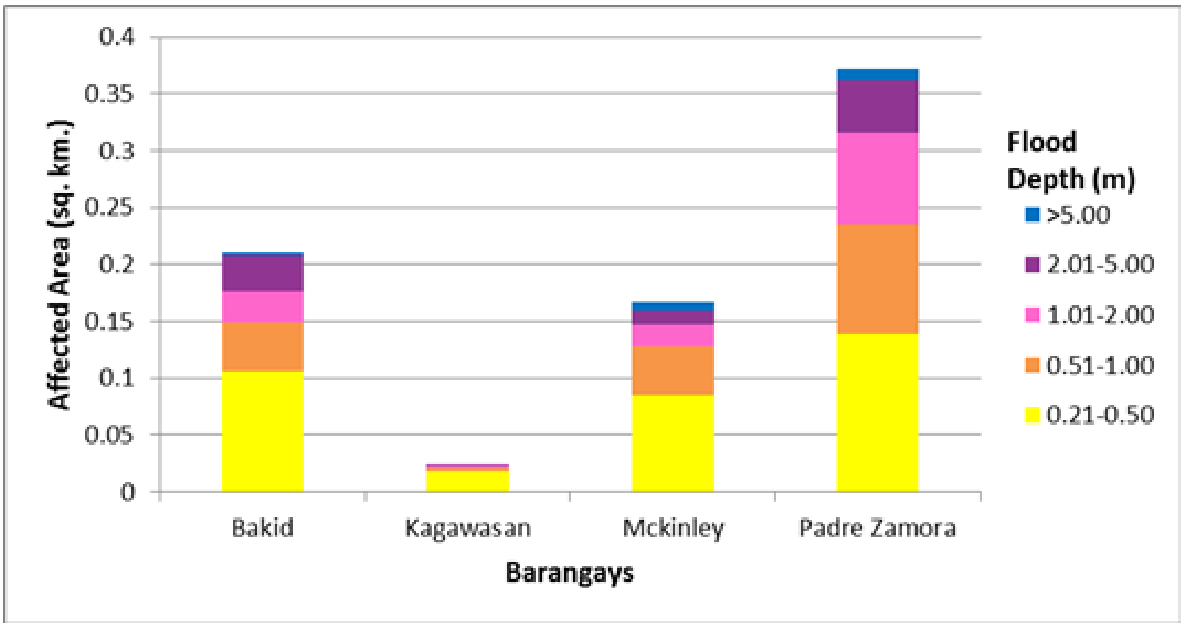


Figure 71. Affected Areas in Liloy, Zamboanga del Norte during 5-Year Rainfall Return Period.

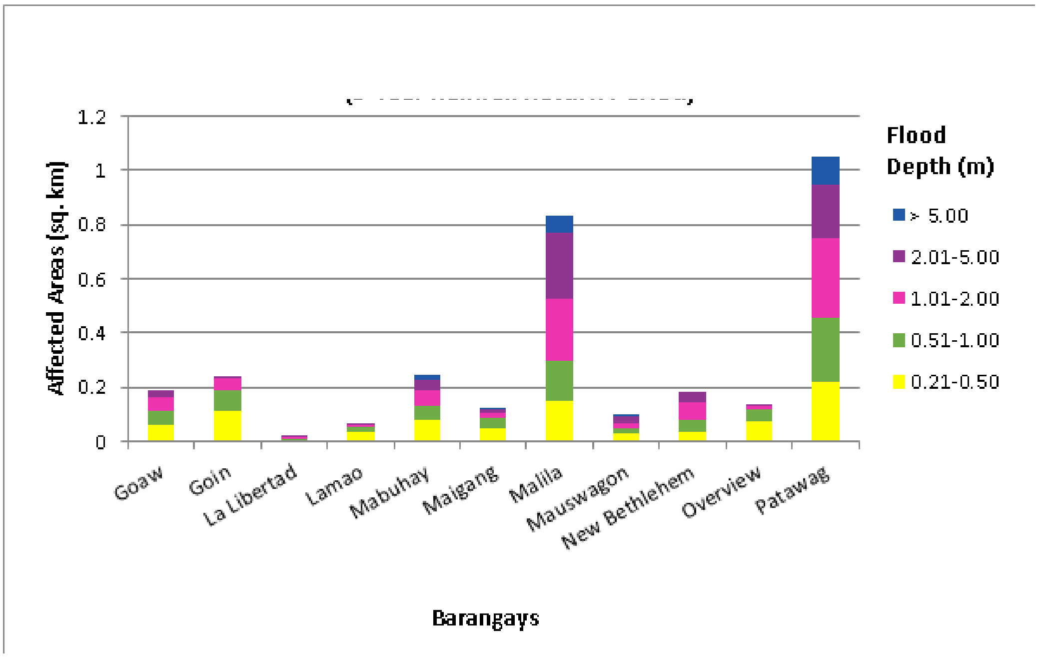


Figure 72. Affected Areas in Liloy, Zamboanga del Norte during 5-Year Rainfall Return Period

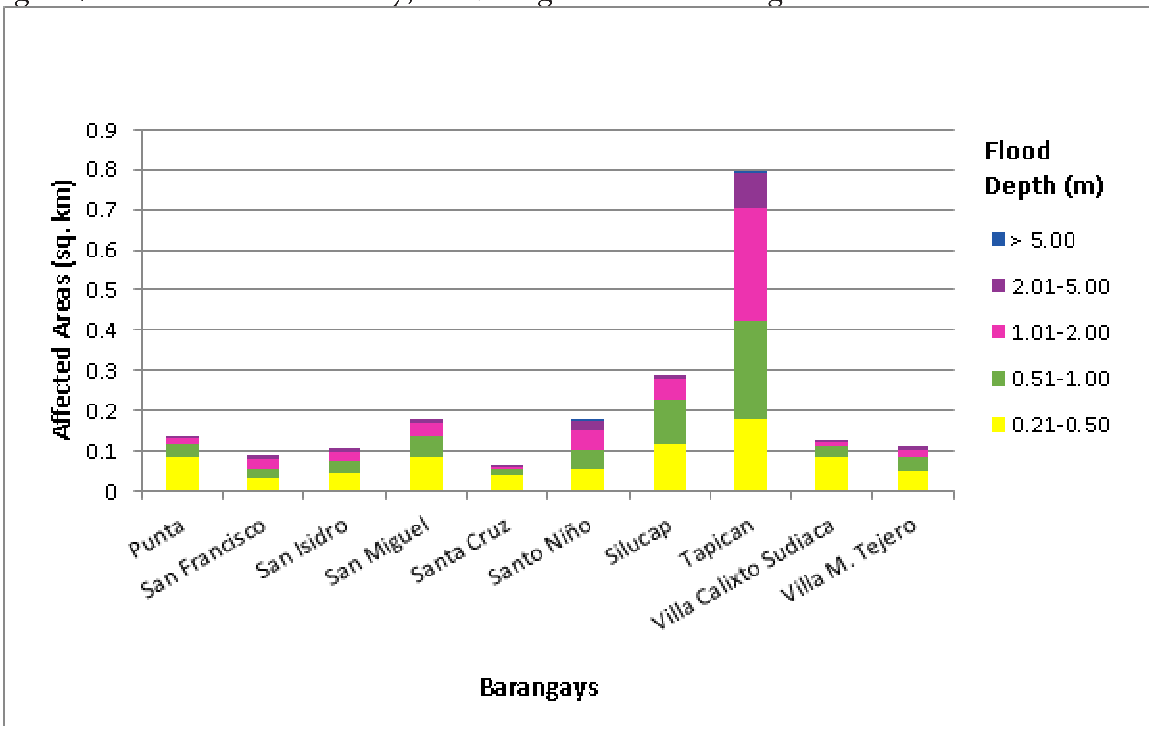


Figure 73. Affected Areas in Liloy, Zamboanga del Norte during 5-Year Rainfall Return Period

For the 5-year return period, 5.79% of the municipality of Kalawit with an area of 248.6416 sq. km. will experience flood levels of less than 0.20 meters;. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, 0.19%, 0.12%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Kalawit, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Kalawit (in sq. km.)		
		Fatima	Pianon	San Jose
Affected Area (sq. km.)	1	0.0013	4.84	9.55
	2	0	0.17	0.31
	3	0	0.16	0.32
	4	0	0.18	0.3
	5	0	0.12	0.18
	6	0	0.0068	0.062

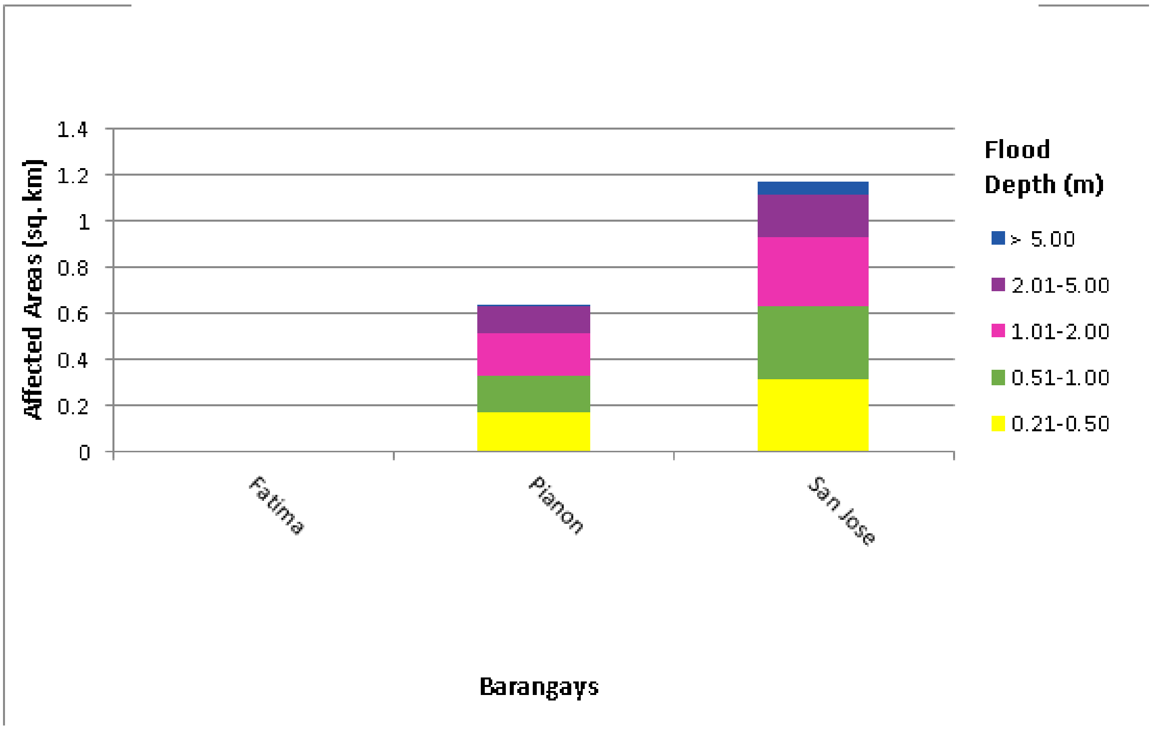


Figure 74. Affected Areas in Kalawit, Zamboanga del Norte during 5-Year Rainfall Return Period

For the 25-year return period, 65.96% of the municipality of Liloy with an area of 122.4937 sq. km. will experience flood levels of less than 0.20 meters;. 2.23% of the area will experience flood levels of 0.21 to 0.50 meters while 1.89%, 2.08%, 1.85%, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in tables are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Labason, Zamboanga del Norte during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Labason (in sq. km.)		
		Malintuboan	Patawag	Ubay
Affected Area (sq. km.)	1	2.91	10.16	0.75
	2	0.052	0.35	0.02
	3	0.025	0.23	0.01
	4	0.0064	0.34	0.002
	5	0.0015	0.25	0
	6	0	0.13	0

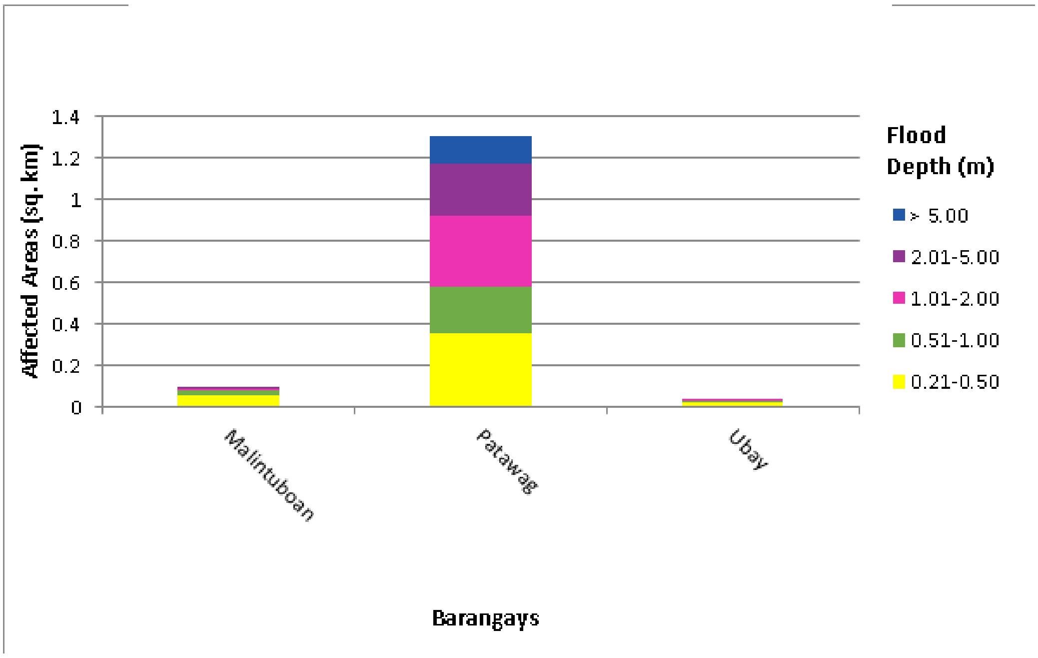


Figure 75. Affected Areas in Labason, Zamboanga del Norte during 5-Year Rainfall Return Period

For the 25-year return period, 65.96% of the municipality of Liloy with an area of 122.4937 sq. km. will experience flood levels of less than 0.20 meters; 2.23% of the area will experience flood levels of 0.21 to 0.50 meters while 1.89%, 2.08%, 1.85%, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in tables are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Liloy, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)										
		Banigan	Baybay	Cabangcalan	Canaan	Causwagan	Communal	Compra	Dela Paz	El Paraiso	Fatima	Ganase
Affected Area (sq. km.)	1	2.55	6.8	1.74	1.8	3.75	3.91	1.5	0.94	3.64	1.42	1.29
	2	0.13	0.18	0.051	0.055	0.094	0.13	0.031	0.058	0.13	0.031	0.068
	3	0.072	0.14	0.08	0.06	0.069	0.13	0.028	0.052	0.12	0.023	0.069
	4	0.04	0.13	0.041	0.051	0.072	0.23	0.027	0.026	0.12	0.022	0.091
	5	0.006	0.094	0.011	0.013	0.074	0.11	0.0054	0.016	0.064	0.0088	0.24
	6	0	0.0005	0	0	0.0051	0.0039	0	0	0.012	0	0.083

Table 43. Affected Areas in Liloy, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)										
		Goaw	Goin	La Libertad	Lamao	Mabuhay	Maigang	Malila	Mauswagon	New Bethlehem	Overview	Patawag
Affected Area (sq. km.)	1	2.234907	3.577706	0.38868	1.453252	2.908448	1.774817	5.958741	1.227616	1.817185	1.323396	2.158189
	2	0.060887	0.113024	0.006749	0.040179	0.093017	0.054822	0.156621	0.030304	0.035768	0.078231	0.1717
	3	0.054423	0.101729	0.005405	0.027005	0.06209	0.044483	0.160489	0.028271	0.042233	0.053347	0.222309
	4	0.06143	0.059175	0.006705	0.012105	0.065584	0.033104	0.219944	0.022121	0.05996	0.032369	0.348218
	5	0.052276	0.015379	0.009694	0.0046	0.070616	0.019696	0.408028	0.030082	0.085453	0.001076	0.449354
	6	0	0	0.000729	0	0.036418	0.0009	0.111316	0.003671	0.002417	0	0.109885

Table 44. Affected Areas in Liloy, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)									
		Punta	San Francisco	San Isidro	San Miguel	Santa Cruz	Santo Niño	Silucap	Tapican	Villa Calixto Sudiaca	Villa M. Tejero
Affected Area (sq. km.)	1	2.605307	0.951489	1.882398	2.609616	1.27395	2.718748	3.417174	4.254721	2.09698	2.103146
	2	0.124043	0.030295	0.058327	0.080333	0.059542	0.067695	0.120822	0.131054	0.126037	0.065088
	3	0.0561	0.027179	0.037234	0.066971	0.016394	0.050777	0.12257	0.149557	0.055707	0.036881
	4	0.019114	0.036219	0.031601	0.057599	0.0082	0.068845	0.092313	0.347284	0.019647	0.032107
	5	0.0017	0.021086	0.016592	0.026359	0.0004	0.044958	0.02008	0.272629	0.007134	0.018
	6	0	0	0	0	0	0.0009	0.000222	0.005804	0	0.0001

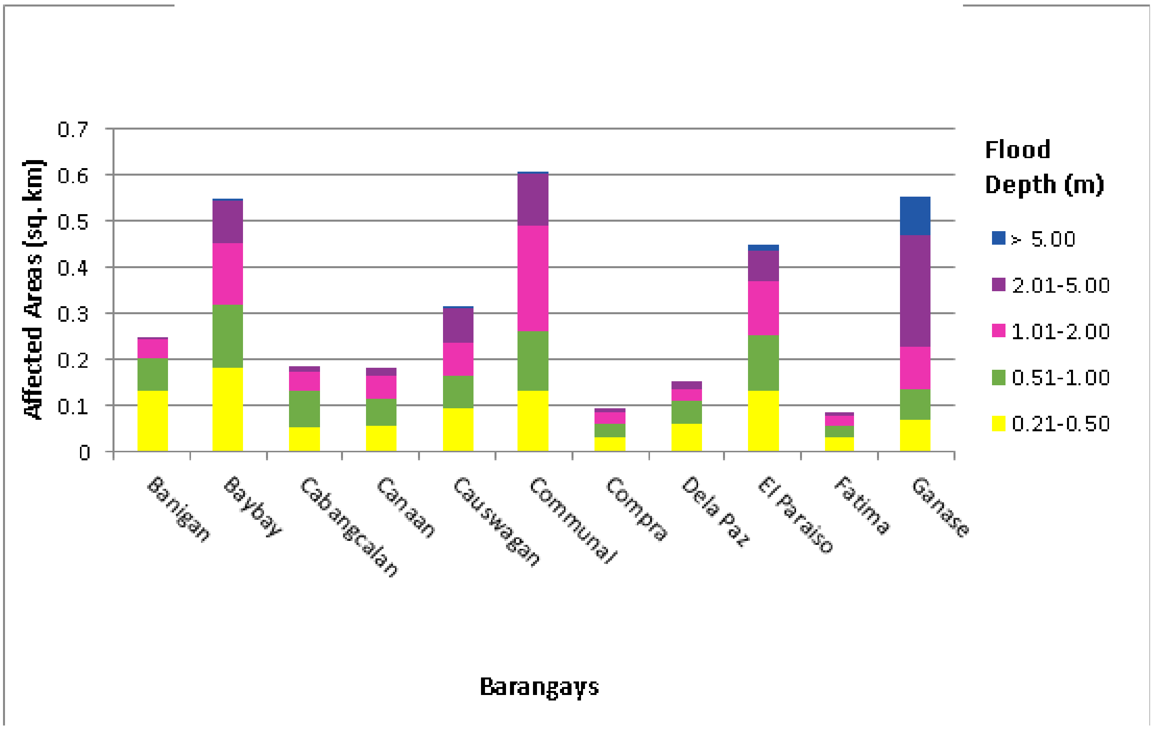


Figure 76. Affected Areas in Liloy, Zamboanga del Norte during 25-Year Rainfall Return Period

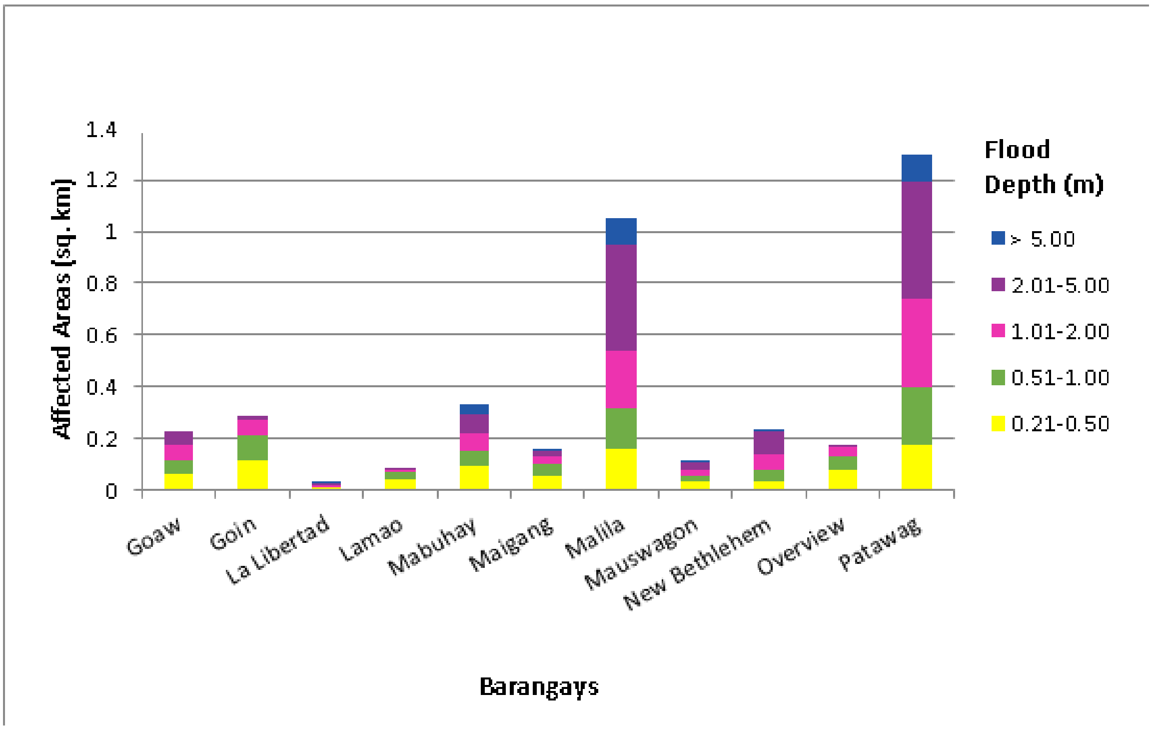


Figure 77. Affected Areas in Liloy, Zamboanga del Norte during 25-Year Rainfall Return Period

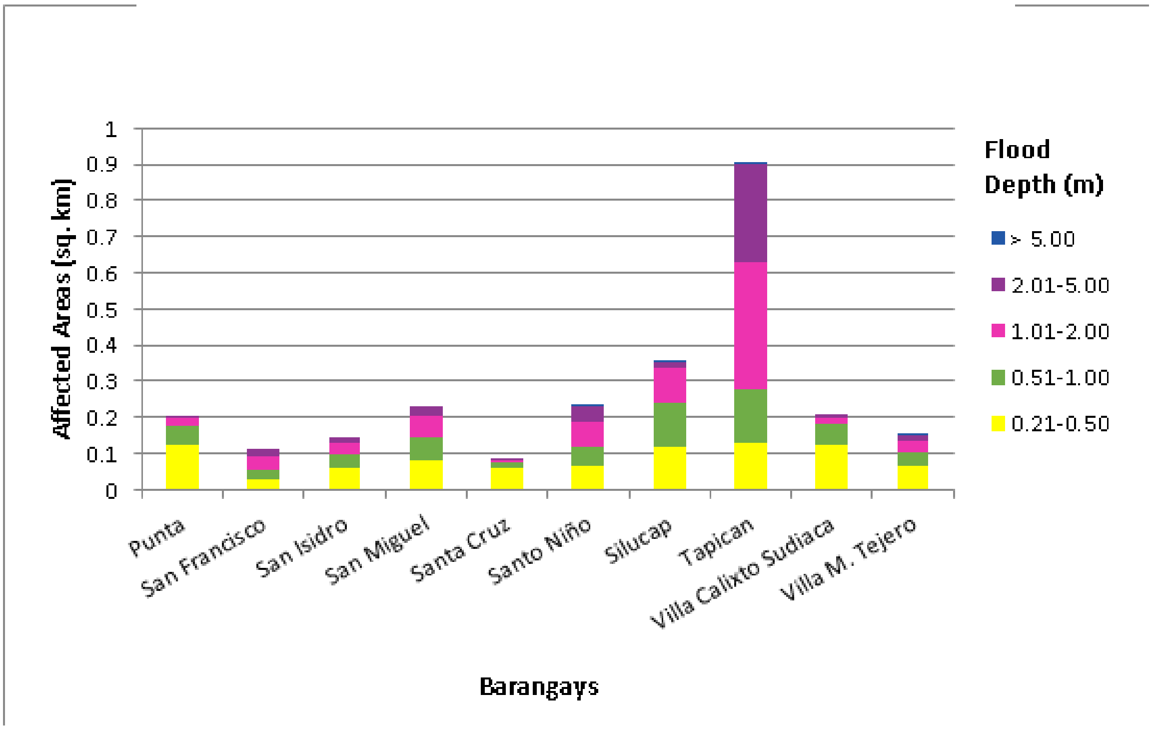


Figure 78. Affected Areas in Liloy, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 25-Year return period, 5.63% of the municipality of Kalawit with an area of 248.6416 sq. km. will experience flood levels of less than 0.20 meters; 0.20% of the area will experience flood levels of 0.21 to 0.50 meters while 0.20%, 0.22%, 0.21%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Kalawit, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Kalawit (in sq. km.)		
		Fatima	Pianon	San Jose
Affected Area (sq. km.)	1	0.0013	4.72	9.27
	2	0	0.17	0.33
	3	0	0.17	0.32
	4	0	0.18	0.37
	5	0	0.21	0.32
	6	0	0.03	0.12

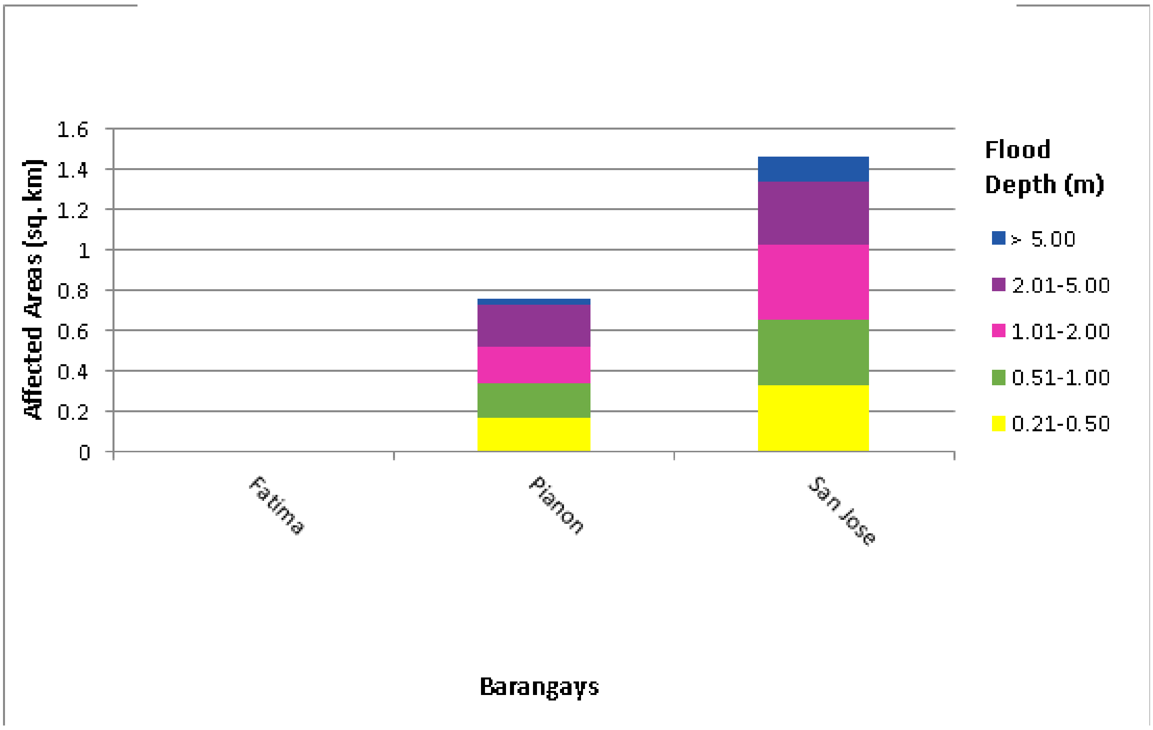


Figure 79. Affected Areas in Kalawit, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 25-Year return period, 14.04% of the municipality of Labason with an area of 159.4316 sq. km. will experience flood levels of less than 0.20 meters; 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.26%, 0.33%, 0.31%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Labason, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Labason (in sq. km.)		
		Malintuboan	Patawag	Ubay
Affected Area (sq. km.)	1	2.87	9.83	0.74
	2	0.08	0.42	0.025
	3	0.031	0.28	0.013
	4	0.011	0.31	0.0033
	5	0.0021	0.44	0
	6	0	0.18	0

Figure 80. Affected Areas in Labason, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 25-Year return period, 5.10% of the municipality of Tampilisan with an area of 144.4397 sq. km. will experience flood levels of less than 0.20 meters; 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.09%, 0.11%, 0.17%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Tampilisan, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Tampilisan (in sq. km.)		
		Barili	Lumbayao	Malila-T
Affected Area (sq. km.)	1	0.51	1.34	5.23
	2	0.012	0.028	0.13
	3	0.014	0.013	0.13
	4	0.0084	0.0082	0.17
	5	0.0033	0.0034	0.3
	6	0.006	0	0.27

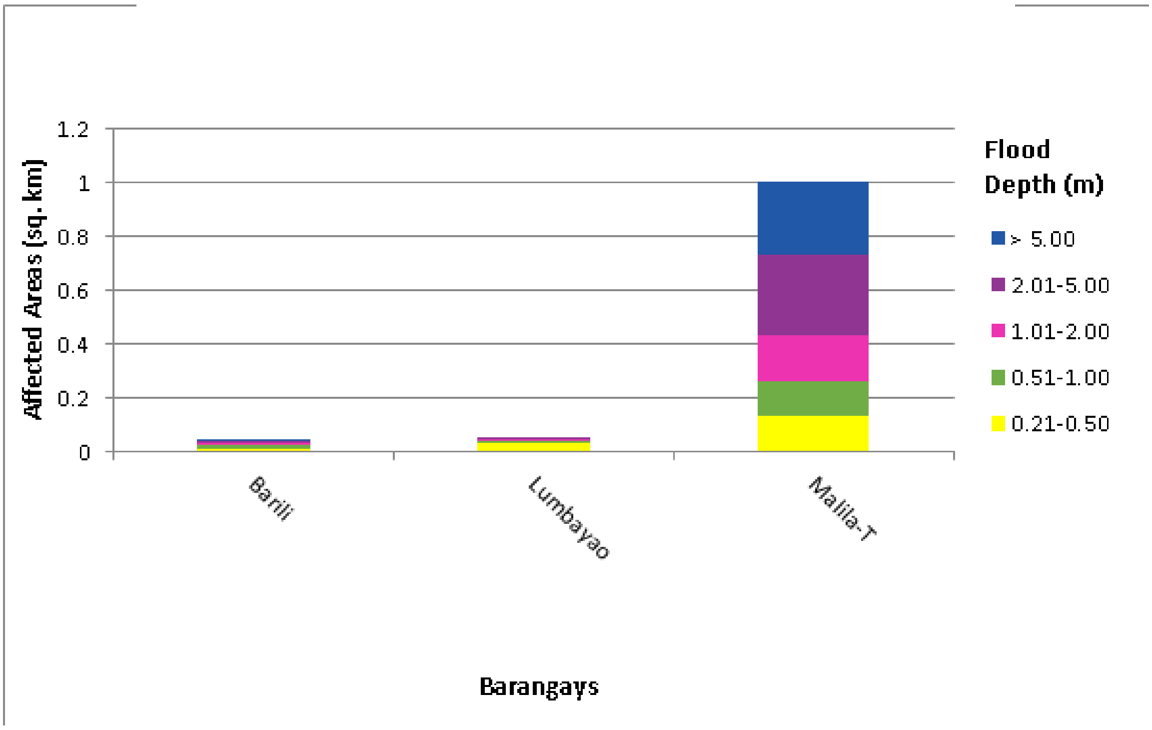


Figure 81. Affected Areas in Tampilisan, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 25-Year return period, 5.10% of the municipality of Tampilisan with an area of 144.4397 sq. km. will experience flood levels of less than 0.20 meters; 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.09%, 0.11%, 0.17%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Tampilisan, Zamboanga del Norte during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Tampilisan (in sq. km.)		
		Barili	Lumbayao	Malila-T
Affected Area (sq. km.)	1	0.52	1.35	5.49
	2	0.012	0.023	0.11
	3	0.013	0.0096	0.11
	4	0.0057	0.0069	0.15
	5	0.0031	0.0012	0.24
	6	0.0027	0	0.13

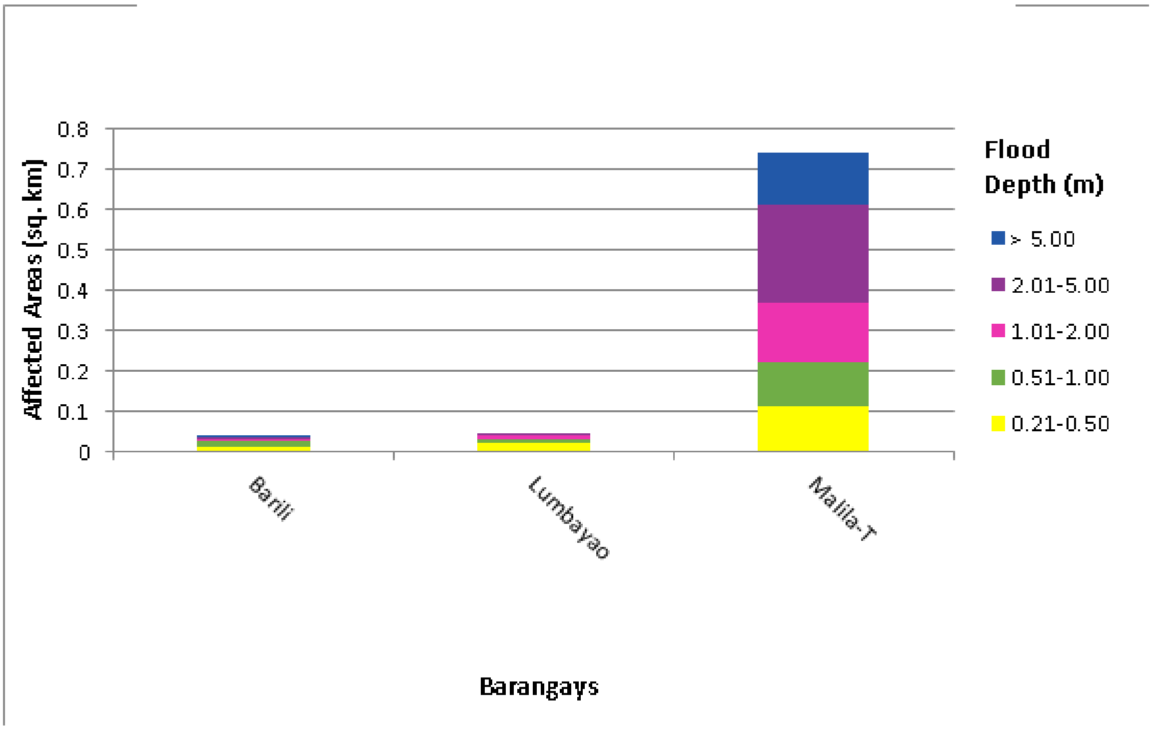


Figure 82. Affected Areas in Tampilisan, Zamboanga del Norte during 25-Year Rainfall Return Period

For the 100-year return period, 64.76% of the municipality of Liloy with an area of 122.4937 sq. km. will experience flood levels of less than 0.20 meters; 2.39% of the area will experience flood levels of 0.21 to 0.50 meters while 1.95%, 2.18%, 2.51%, and 0.49% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the tables are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Liloy, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)										
		Banigan	Baybay	Cabangcalan	Canaan	Causwagan	Communal	Compra	Dela Paz	El Paraiso	Fatima	Ganase
Affected Area (sq. km.)	1	2.49	6.71	1.71	1.77	3.71	3.85	1.49	0.9	3.56	1.41	1.22
	2	0.15	0.21	0.052	0.057	0.1	0.13	0.033	0.066	0.14	0.035	0.052
	3	0.094	0.15	0.092	0.053	0.073	0.12	0.027	0.059	0.12	0.025	0.066
	4	0.054	0.14	0.038	0.066	0.074	0.25	0.032	0.037	0.14	0.026	0.095
	5	0.0094	0.13	0.025	0.027	0.096	0.15	0.0096	0.021	0.078	0.011	0.3
	6	0	0.002	0.0001	0	0.013	0.01	0	0.0004	0.032	0.0001	0.1

Table 50. Affected Areas in Liloy, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)										
		Goaw	Goin	La Libertad	Lamao	Mabuhay	Maigang	Malila	Mauswagon	New Bethlehem	Overview	Patawag
Affected Area (sq. km.)	1	2.204436	3.541911	0.382188	1.435731	2.857095	1.757572	5.746984	1.210418	1.791569	1.30509	2.063271
	2	0.063851	0.117758	0.008699	0.0477	0.090905	0.054684	0.167998	0.034023	0.037202	0.076792	0.169898
	3	0.053448	0.107636	0.007001	0.030405	0.069161	0.048857	0.178539	0.030238	0.039974	0.064146	0.167036
	4	0.070522	0.071942	0.00752	0.017005	0.061776	0.038983	0.239796	0.02503	0.058276	0.039016	0.301211
	5	0.071567	0.027767	0.010139	0.0063	0.085077	0.026127	0.49891	0.03517	0.10597	0.003376	0.614703
	6	0.0001	0	0.002416	0	0.072157	0.0016	0.182912	0.007184	0.010025	0	0.143537

Table 51. Affected Areas in Liloy, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Liloy (in sq. km.)									
		Punta	San Francisco	San Isidro	San Miguel	Santa Cruz	Santo Niño	Silucap	Tapican	Villa Calixto Sudiaca	Villa M. Tejero
Affected Area (sq. km.)	1	2.541866	0.936581	1.857733	2.56998	1.251855	2.687728	3.3784	4.195465	2.038283	2.068456
	2	0.152511	0.028856	0.063082	0.088337	0.074519	0.067206	0.125805	0.134299	0.15691	0.078871
	3	0.081473	0.027139	0.044587	0.063419	0.021213	0.057998	0.119931	0.115779	0.071474	0.046089
	4	0.028014	0.042325	0.037762	0.073119	0.0102	0.071857	0.119785	0.267036	0.029904	0.036307
	5	0.0024	0.031067	0.022988	0.046022	0.0007	0.064134	0.028847	0.434566	0.008934	0.0253
	6	0	0.0003	0	0	0	0.003	0.000413	0.013904	0	0.0003

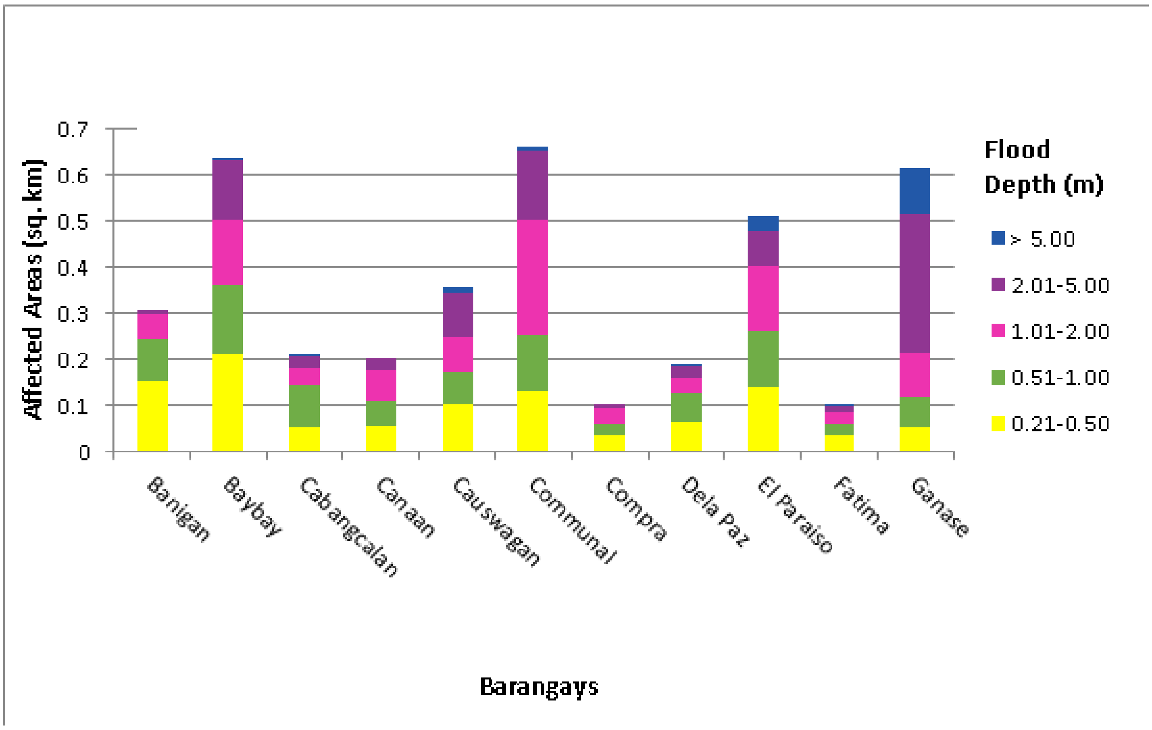


Figure 83. Affected Areas in Liloy, Zamboanga del Norte during 100-Year Rainfall Return Period

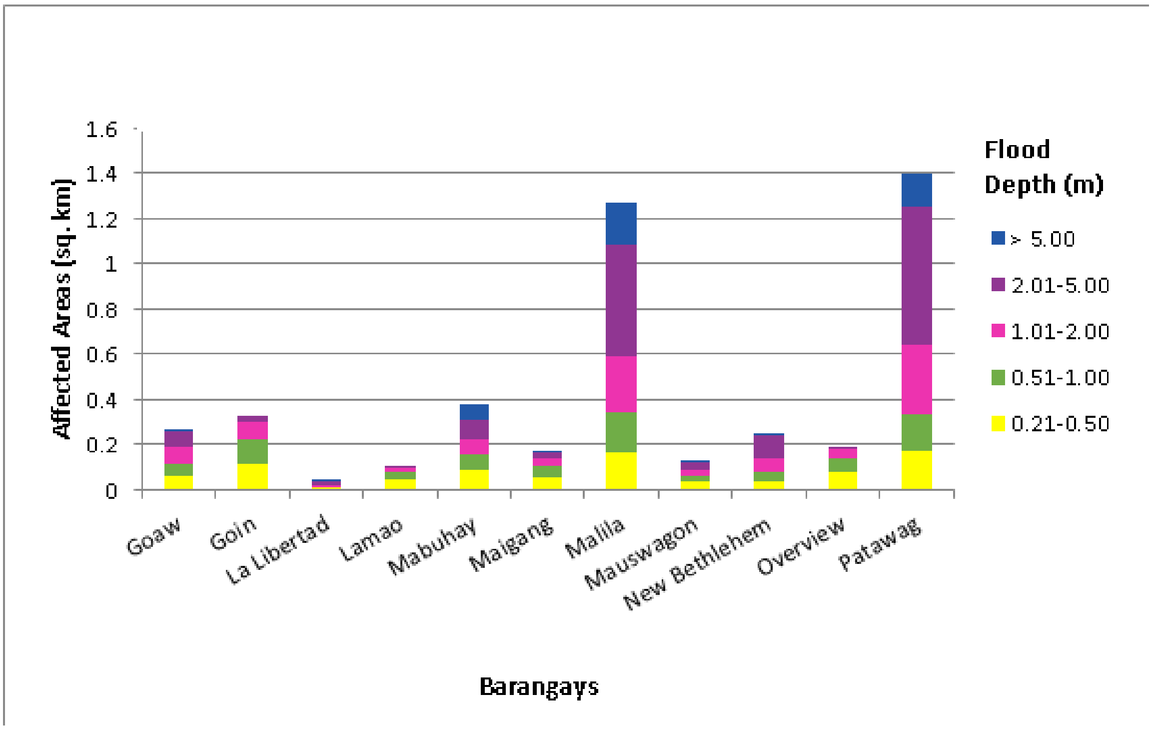


Figure 84. Affected Areas in Liloy, Zamboanga del Norte during 100-Year Rainfall Return Period

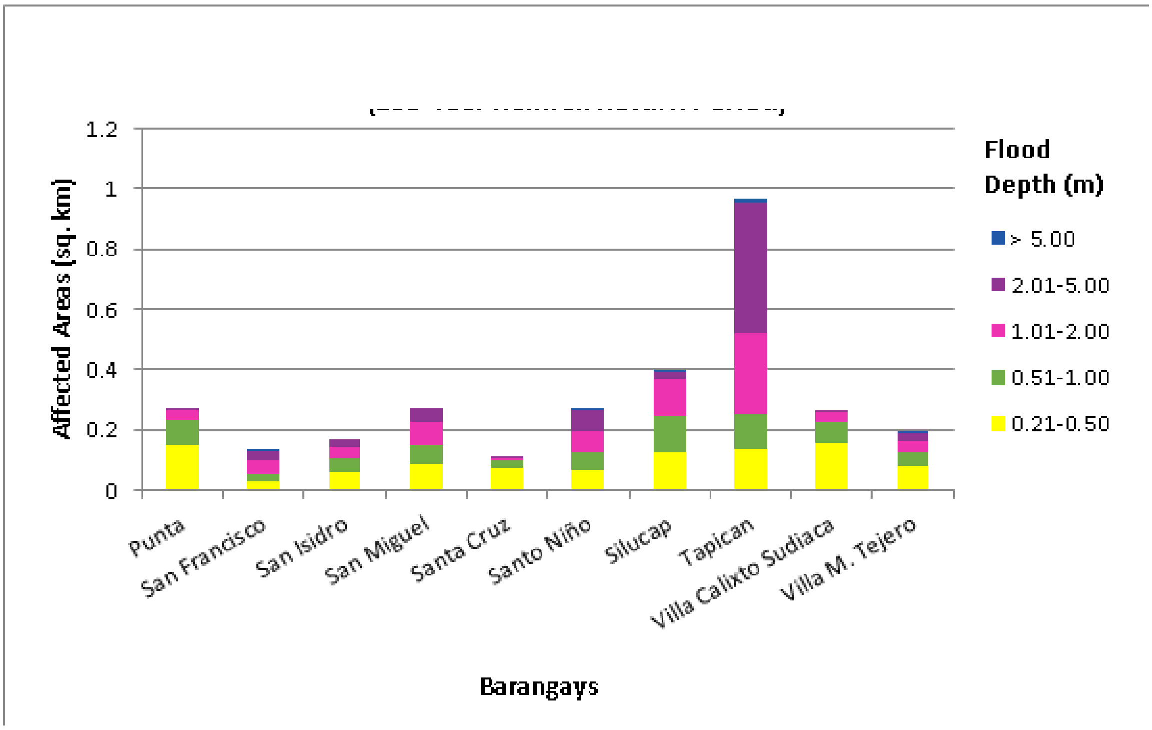


Figure 85. Affected Areas in Liloy, Zamboanga del Norte during 100-Year Rainfall Return Period

For the 100-year return period, 5.52% of the municipality of Kalawit with an area of 248.6416 sq. km. will experience flood levels of less than 0.20 meters; 0.20% of the area will experience flood levels of 0.21 to 0.50 meters while 0.21%, 0.24%, 0.26%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 52 are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Kalawit, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Kalawit (in sq. km.)		
		Fatima	Pianon	San Jose
Affected Area (sq. km.)	1	0.0013	4.84	9.55
	2	0	0.17	0.31
	3	0	0.16	0.32
	4	0	0.18	0.3
	5	0	0.12	0.18
	6	0	0.0068	0.062

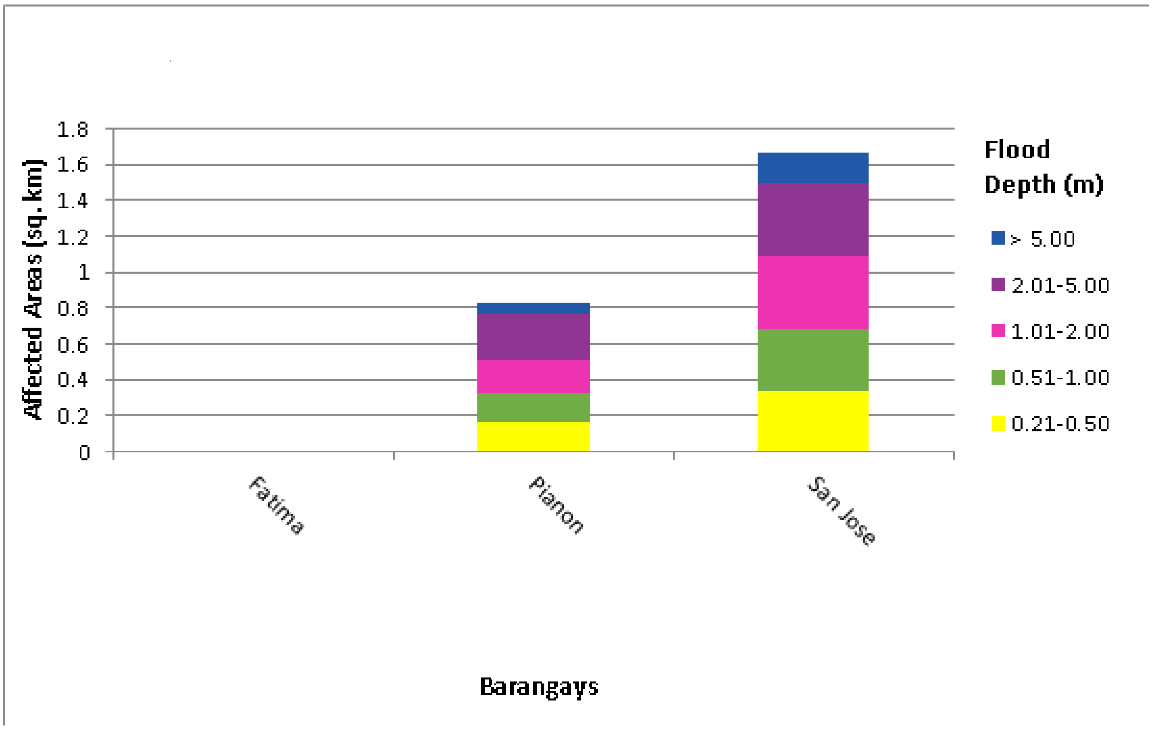


Figure 86. Affected Areas in Kalawit, Zamboanga del Norte during 100-Year Rainfall Return Period

For the 100-year return period, 13.33% of the municipality of Labason with an area of 159.4316 sq. km. will experience flood levels of less than 0.20 meters; 0.48% of the area will experience flood levels of 0.21 to 0.50 meters while 0.32%, 0.37%, 0.55%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 53 are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Labason, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Labason (in sq. km.)		
		Malintuboan	Patawag	Ubay
Affected Area (sq. km.)	1	2.85	9.63	0.73
	2	0.094	0.43	0.027
	3	0.034	0.27	0.016
	4	0.015	0.34	0.0045
	5	0.0031	0.5	0
	6	0	0.28	0

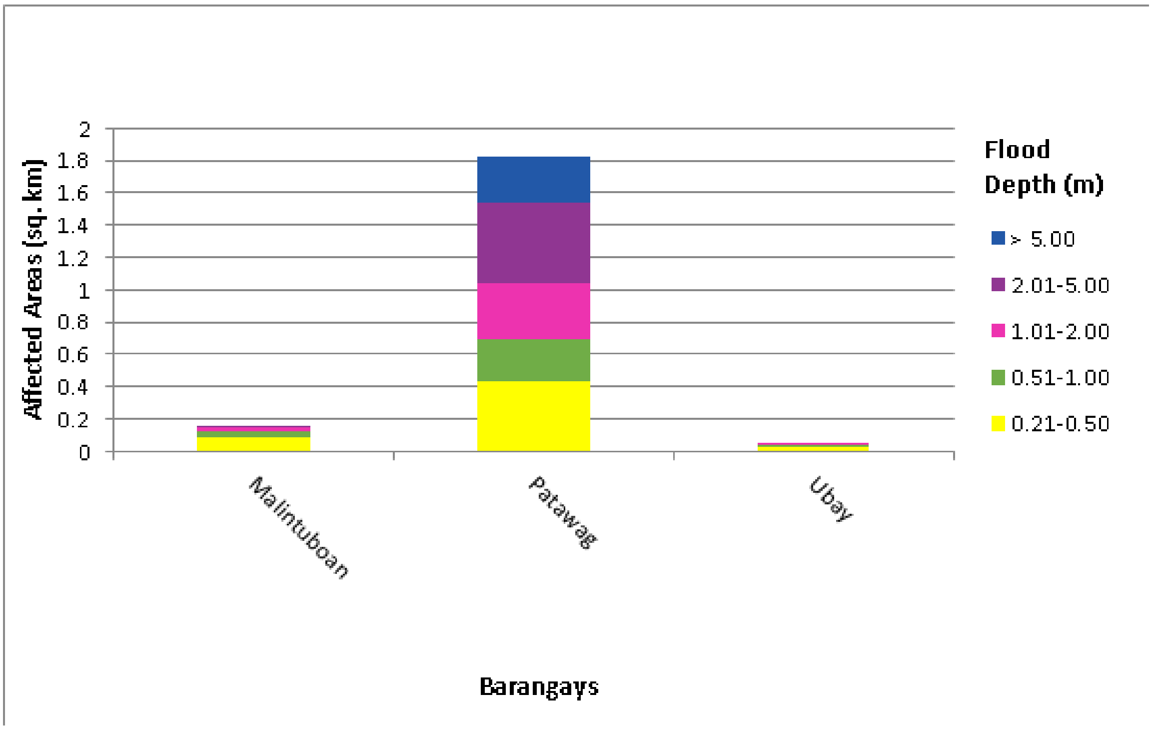


Figure 87. Affected Areas in Labason, Zamboanga del Norte during 100-Year Rainfall Return Period

For the 100-year return period, 4.75% of the municipality of Tampilisan with an area of 144.4397 sq. km. will experience flood levels of less than 0.20 meters; 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.15%, 0.25%, and 0.29% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 54 are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected Areas in Tampilisan, Zamboanga del Norte during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Tampilisan (in sq. km.)		
		Barili	Lumbayao	Malila-T
Affected Area (sq. km.)	1	0.51	1.33	5.02
	2	0.013	0.032	0.13
	3	0.013	0.015	0.14
	4	0.013	0.0095	0.19
	5	0.0032	0.0041	0.35
	6	0.0075	0	0.41

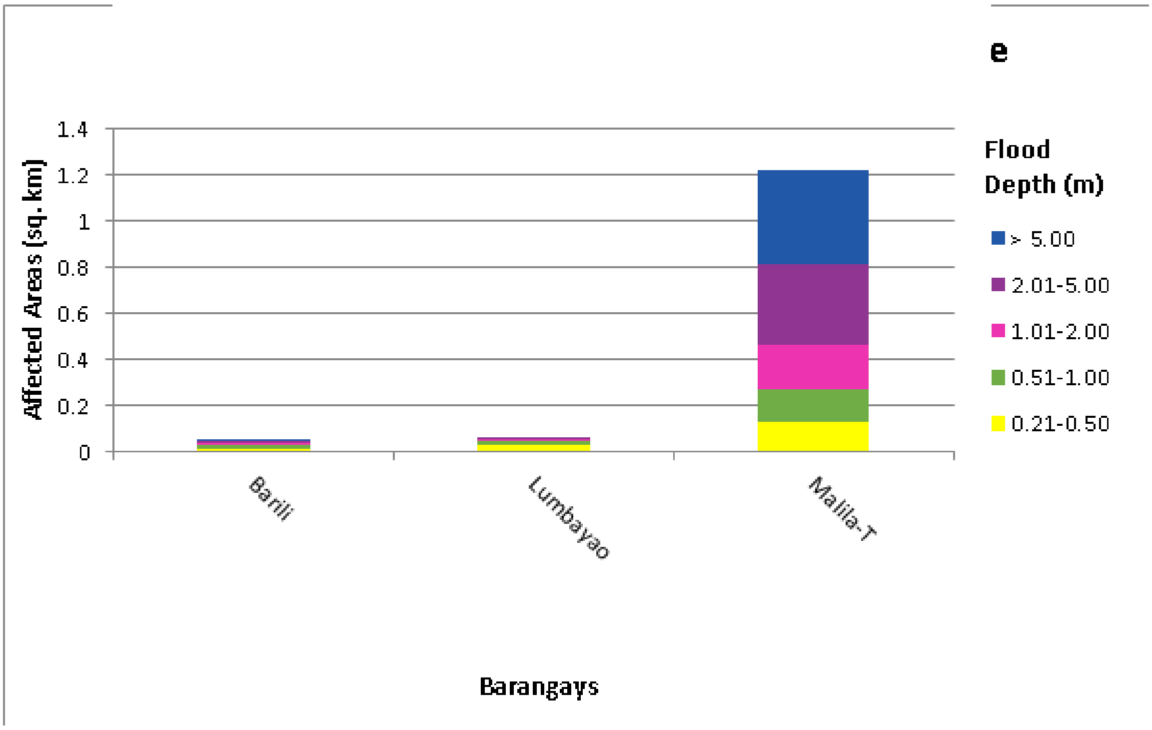


Figure 88. Affected Areas in Tampilisan, Zamboanga del Norte during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Patawag 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 55. 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	3.5178	3.8294	4.1091
Medium	4.6509	5.136	5.3101
High	3.9835	6.4296	8.1496

Table 56

None of the 34 identified educational and medical institutions and buildings in Patawag Floodplain were assessed to be exposed to any of the flood hazard levels at any of the rain return period.

5.11 Flood Validation

The flood validation consists of 109 points randomly selected all over the Patawag Floodplain. It has an RMSE value of 0.22.

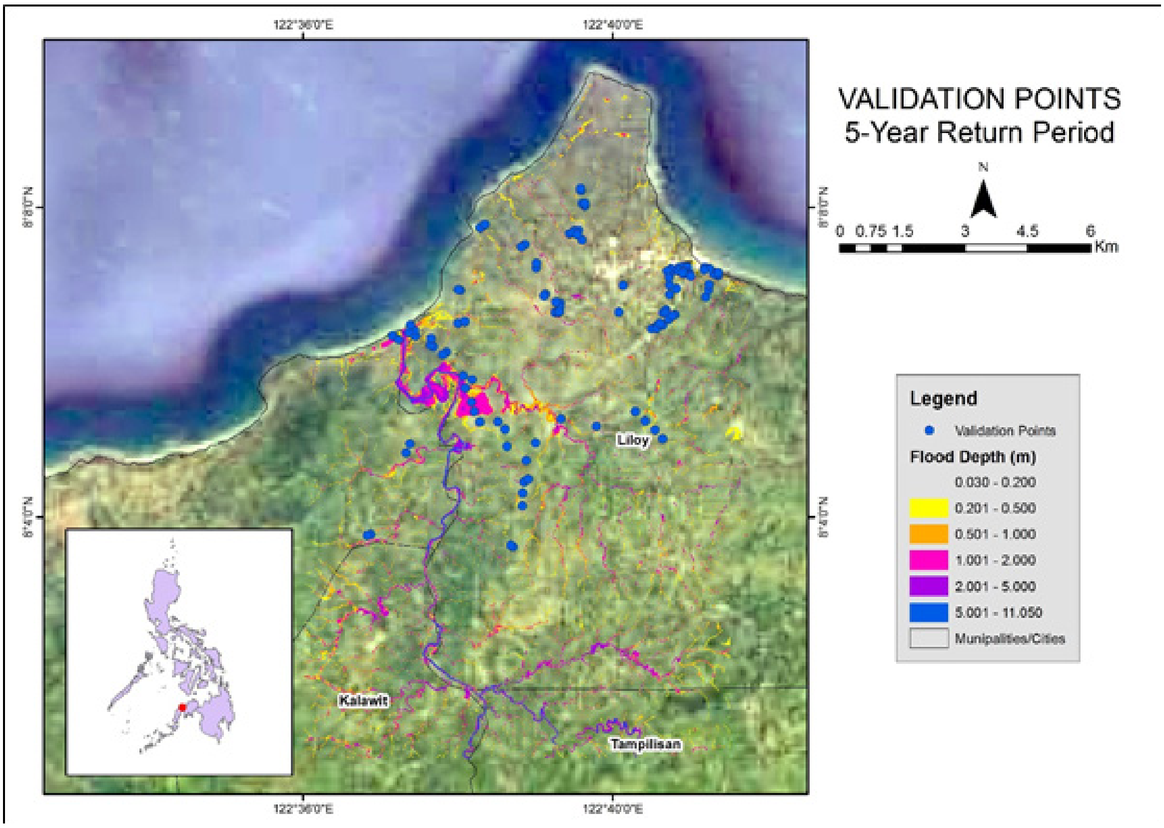


Figure 89. Validation points for 5-year Flood Depth Map ofPatawag Floodplain

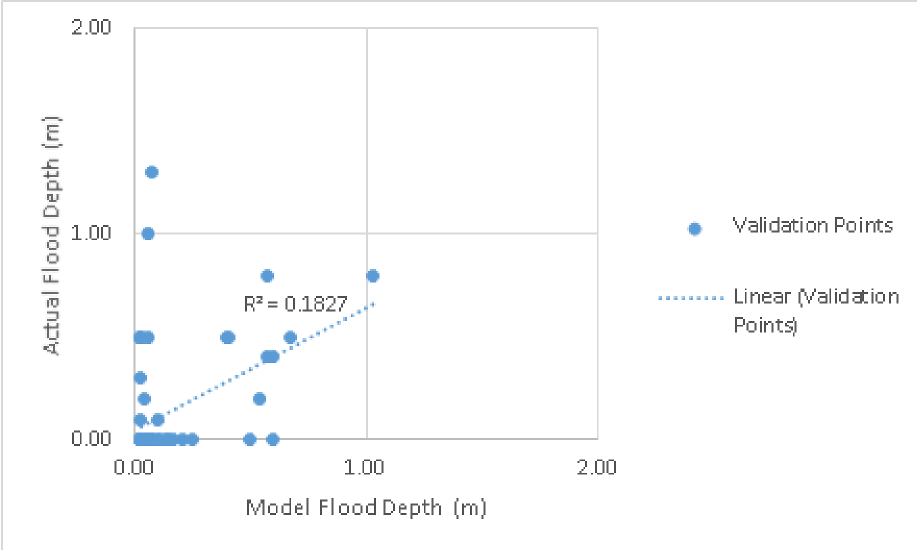


Figure 90. Flood map depth vs actual flood depth

Table 57. Actual Flood Depth vs Simulated Flood Depth in Patawag

LIBERTAD 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	86	3	2	0	0	0	91
	0.21-0.50	9	2	3	0	0	0	14
	0.51-1.00	1	0	1	1	0	0	3
	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	97	5	6	1	0	0	109

The overall accuracy generated by the flood model is estimated at 44.53%, with 89 points correctly matching the actual flood depths. In addition, there were 16 points estimated one level above and below the correct flood depths while there were 3 points and 1 point estimated two levels above and below, and three or more levels above and below the correct flood. A total of 9 points were overestimated while a total of 11 points were underestimated in the modelled flood depths of Patawag.

The validation data were gathered on October 2016.

Table 58. Summary of Accuracy Assessment in Patawag

	No. of Points	%
Correct	89	81.65
Overestimated	9	8.26
Underestimated	11	10.09
Total	109	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.

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

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

Paringit E.C, Balicanta L.P., Ang, M.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.

ANNEXES

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

Table A-1.1 Parameters and Specifications

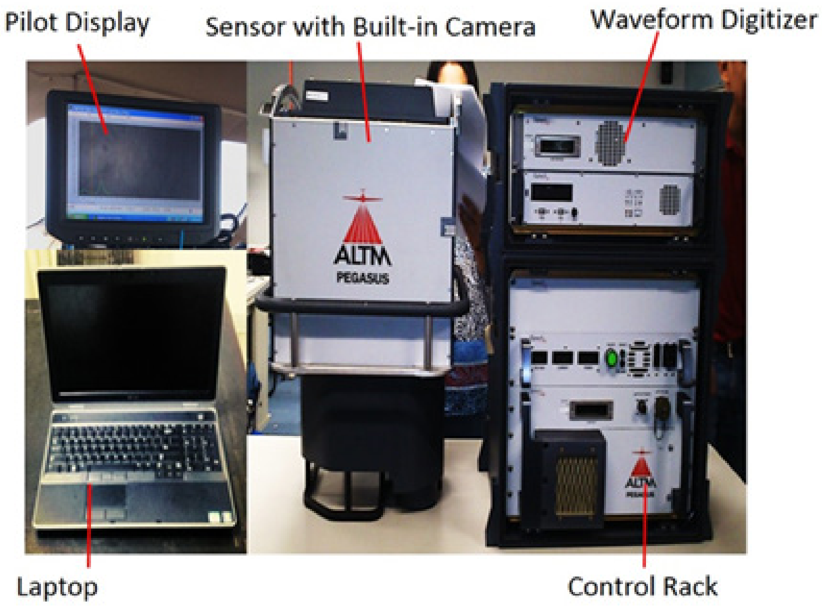


Table A-1.1 Parameters and Specifications of Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);
220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver	Programmable, 0-50˚
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	0-95% no-condensing
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

ZGN-4

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

December 09, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **ZAMBOANGA DEL NORTE**	
	Station Name: **ZGN-4**	
	Order: **1st**	
Island: **MINDANAO**	Barangay: **LAMAO**	
Municipality: **LILOY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 8' 20.40827"**	Longitude: **122° 40' 28.89097"**	Ellipsoidal Hgt: **3.84800 m.**
	WGS84 Coordinates	
Latitude: **8° 8' 16.73719"**	Longitude: **122° 40' 34.34251"**	Ellipsoidal Hgt: **67.35130 m.**
	PTM / PRS92 Coordinates	
Northing: **899937.404 m.**	Easting: **464150.413 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **899,622.41**	Easting: **464,162.96**	Zone: **51**

Location Description

ZGN-4
From Dipolog city, travel SW along the natl. highway for 131 km. or 4-3/4 hrs. drive up to Liloy town proper. Upon reaching Liloy town proper, turn right and travel N for 2 km. on the road leading to Liloy Port in Brgy. Lamao. Station is located at the concrete pavement of the wharf; at the E corner of the intersection of the concrete curbs; it is 42.9 m. SE from the end of the wharf; 87.4 m. SW of the gate of the pier; 8.1 m. SE to the concrete stairway. Mark is a crosscut on top of a 0.15 m. x 0.01 m. in dia. brass rod, set in a drilled hole, centered in a 0.3 m. x 0.3 m. cement putty with inscription of the station name. Reference marks (RM); RM 1, RM 2 and RM 3 are 0.15 m. x 0.01 m. in dia. brass rod centered in a 0.25 m. x 0.25 m. cement putty; set on top of the concrete curb of the pier and inscribed on top with the RM no. and the arrow pointing to the station.

Requesting Party: **Christopher Cruz**
Purpose: **Reference**
OR Number: **8077396 I**
T.N.: **2014-2979**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 ZGN-4

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

ZN-157

Vector Components (Mark to Mark)

From:	ZGN-4				
Grid		Local		Global	
Easting	464162.960 m	Latitude	N8°08'20.40828"	Latitude	N8°08'16.73719"
Northing	899622.410 m	Longitude	E122°40'28.89097"	Longitude	E122°40'34.34251"
Elevation	2.145 m	Height	3.948 m	Height	67.351 m

To:	ZN-157				
Grid		Local		Global	
Easting	470917.760 m	Latitude	N8°06'05.34724"	Latitude	N8°06'01.69150"
Northing	895470.122 m	Longitude	E122°44'09.71575"	Longitude	E122°44'15.17027"
Elevation	4.934 m	Height	7.394 m	Height	71.024 m

Vector					
ΔEasting	6754.799 m	NS Fwd Azimuth	121°32'02"	ΔX	-6007.200 m
ΔNorthing	-4152.288 m	Ellipsoid Dist.	7932.054 m	ΔY	-3156.889 m
ΔElevation	2.789 m	ΔHeight	3.445 m	ΔZ	-4106.710 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000260206		
Y	-0.0000371612	0.0000625828	
Z	-0.0000078882	0.0000133987	0.0000046610

ZGN-4E

Vector Components (Mark to Mark)

From:	ZGN-4				
Grid		Local		Global	
Easting	464330.109 m	Latitude	N8°08'16.73719"	Latitude	N8°08'16.73719"
Northing	899566.355 m	Longitude	E122°40'34.34251"	Longitude	E122°40'34.34251"
Elevation	2.145 m	Height	67.351 m	Height	67.351 m

To:	ZGN-4E				
Grid		Local		Global	
Easting	464334.463 m	Latitude	N8°08'16.81854"	Latitude	N8°08'16.81854"
Northing	899568.850 m	Longitude	E122°40'34.48473"	Longitude	E122°40'34.48473"
Elevation	2.145 m	Height	67.351 m	Height	67.351 m

Vector					
ΔEasting	4.354 m	NS Fwd Azimuth	60°08'28"	ΔX	-3.473 m
ΔNorthing	2.495 m	Ellipsoid Dist.	5.020 m	ΔY	-2.649 m
ΔElevation	0.000 m	ΔHeight	0.000 m	ΔZ	2.474 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'13"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000003395		
Y	-0.0000002924	0.0000006451	
Z	-0.0000000919	0.0000000865	0.0000001375

Figure A-3.2 ZGN-4E

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE 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)	JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		ENGR. GRACE SINADJAN	UP-TCAGP
		KRISTINE JOY ANDAYA	UP-TCAGP
		ENGR. GEF SORIANO	UP-TCAGP
		JERIEL PAUL ALAMBAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
		MERLIN FERNANDO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RONALD MONTENEGRO	PHILIPPINE AIR FORCE (PAF)
		SSG. GERONIMO BALICAO III	PAF
	Pilot	CAPT. JOHN BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. ANTON RETSE DAYO	AAC
		CAPT. FERDINAND DE OCAMPO	AAC
		CAPT. ERNESTO SAYSAY JR.	AAC

Annex 5. Data Transfer Sheet Patawag Floodplain

DATA TRANSFER SHEET
11/17/2014(dipolog)

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	
19-Oct	2099P	1BLK69CALIB292A	PEGASUS	106	na	3.84	113	9.11	83	3.84	na	4.08	1KB	1KB	47/23	na	Z:\DAC\RAW DATA
22-Oct	2111P	1BLK69B295A	PEGASUS	2.01	453	12.4	236	29.5	292	22.2	na	7.59	1KB	1KB	292/48/58	na	Z:\DAC\RAW DATA
23-Oct	2113P	1BLK69B296A	PEGASUS	1.62	394	10	216	36.4	260	19.4	na	15.1	1KB	1KB	48/51/44/61	na	Z:\DAC\RAW DATA
23-Oct	2115P	1BLK6970A296B	PEGASUS	754	171	6.26	105	13.6	115	8.18	na	15.1	1KB	1KB	40/51/25	na	Z:\DAC\RAW DATA
24-Oct	2117P	1BLK69B297A	PEGASUS	1.24	237	5.73	113	18.6	164	12.4	na	7.64	1KB	1KB	48/51/50	na	Z:\DAC\RAW DATA
26-Oct	2125P	1BLK69C299A	PEGASUS	1.5	267	8.41	211	32	239	15.4	na	37.4	1KB	1KB	48/51/50/41/56/43/22	na	Z:\DAC\RAW DATA
26-Oct	2127P	1BLK6970A299B	PEGASUS	2.54	na	5.91	114	16	1	12.9	na	37.4	1KB	1KB	27/1	na	Z:\DAC\RAW DATA
28-Oct	2133P	1BLK69FE301A	PEGASUS	2.05	244/454	10.2	225	57.4	343	na	na	37.3	1KB	1KB	73/51/81/39	na	Z:\DAC\RAW DATA
28-Oct	2135P	1BLK69F301B	PEGASUS	268	170/187	3.42	94.6	na	na	5.4	na	37.3	1KB	1KB	92	na	Z:\DAC\RAW DATA
29-Oct	2137P	1BLK70D302A	PEGASUS	1.05	453/220	7.37	190	28.3	181	11.2	na	19.4	1KB	1KB	106/93/82/75	na	Z:\DAC\RAW DATA
31-Oct	2145P	1BLK69C304A	PEGASUS	2.33	1118/434	9.11	182	48.6	342	22.8	na	6.52	1KB	1KB	74	na	Z:\DAC\RAW DATA
1-Nov	2149P	1BLK70B305A	PEGASUS	1.79	338	7.39	192	32.1	227	20.3	na	29.2	1KB	1KB	54/79	na	Z:\DAC\RAW DATA
3-Nov	2157P	1BLK70C307A	PEGASUS	2.26	198	11.3	240	40.6	295	25.1	na	35.5	1KB	1KB	33	na	Z:\DAC\RAW DATA
6-Nov	2169P	1BLK73A310A	PEGASUS	3.01	523	12.1	240	62.9	na	26.9	na	21.3	1KB	1KB	80	na	Z:\DAC\RAW DATA
8-Nov	2177P	1BLK70C312A	PEGASUS	1.75	327	8.89	199	23.1	na	17.5	na	17.8	1KB	1KB	60/53/57	na	Z:\DAC\RAW DATA
9-Nov	2181P	1BLK69F313A	PEGASUS	1.46	291	8.11	182	22.4	182	15.2	na	17	1KB	1KB	65/62/51	na	Z:\DAC\RAW DATA

Received from
Name C. JOAQUIN
Position RA
Signature [signature]

Received by
Name Angelo Carlo Bongat
Position SSRS
Signature [signature] 11/19/2014

Figure A-5.1. Transfer Sheet for Patawag Floodplain (a)

DATA TRANSFER SHEET
12/09/2014[illegible]

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	
10-Nov	2185P	1BLK73A314A	PEGASUS	1.15	na	9.84	253	na	na	13.1	na	19.5	1KB	1KB	56/48/56/58	na	Z:\DAC\RAW DATA
11-Nov	2189P	1BLK73S315A	PEGASUS	1.6	na	7.23	219	na	na	16.8	na	29.5	1KB	1KB	56/48/56/59	na	Z:\DAC\RAW DATA

Received from

Name

Position

Signature

Received by

Name JOIDA PRIETO

Position SUPERS

Signature

12/9/14

Figure A-5.2. Transfer Sheet for Libertad Floodplain - B

DATA TRANSFER SHEET
DIPOLOG 12/6/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 20, 2016	23558P	1BLK69BC325A	PEGASUS	249	NA	11.2	274	NA	NA	24.8	NA	175	1KB	1KB	234	NA	Z:\DAC\RAW DATA
November 21, 2016	23562P	1BLK69BD326A	PEGASUS	2.64	NA	12.2	289	NA	NA	29.5	NA	165	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA
November 22, 2016	23566P	1BLK69E327A	PEGASUS	1.65	NA	9.58	267	NA	NA	18	NA	188	1KB	1KB	652	NA	Z:\DAC\RAW DATA
November 24, 2016	23574P	1BLK69AD329A	PEGASUS	1.92	NA	10	264	NA	NA	21.7	NA	126	1KB	1KB	421	NA	Z:\DAC\RAW DATA
November 26, 2016	23582P	1BLK73DE331A	PEGASUS	2.46	NA	11.6	281	25.1	274	25.5	NA	162	1KB	1KB	1.33	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 12/6/16

Figure A-5.3. Transfer Sheet for Patawag Floodplain (c)

DATA TRANSFER SHEET
DIPOLOG 12/8/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
November 28, 2016	23590P	1BLK73DEF333A	PEGASUS	1.56	NA	7.69	203	32.6	298	16.6	NA	42.3	1KB	1KB	1.19	NA	Z:\DAC\RAW DATA
November 30, 2016	23598P	1BLK76A335A	PEGASUS	600	NA	6.93	239	NA	NA	7.85	NA	48.2	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA
December 01, 2016	23602P	1BLK76AB336A	PEGASUS	1.56	NA	9.08	287	NA	NA	16.5	NA	53.9	1KB	1KB	2.14	NA	Z:\DAC\RAW DATA

Received from

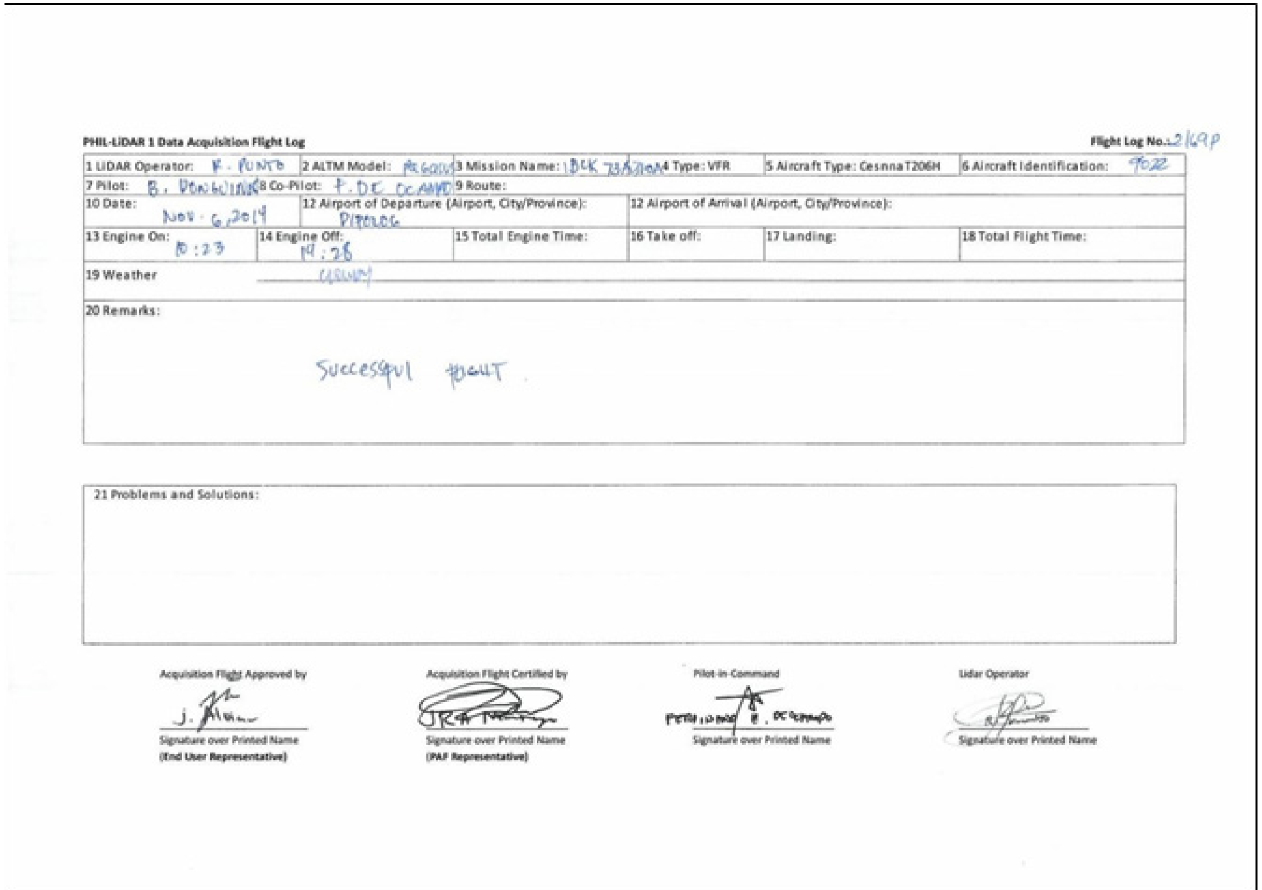
Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 12/8/16

Figure A-5.4. Transfer Sheet for Patawag Floodplain (d)

Annex 6. Flight Logs for the Flight MIssions



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2169P

1 LIDAR Operator: F. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK73A310A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: B. DONGUINES	8 Co-Pilot: F. DE OCAMPO	9 Route:			
10 Date: NOV. 6, 2014	12 Airport of Departure (Airport, City/Province): PITOGO		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 10:23	14 Engine Off: 14:28	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: CLOUDY					

20 Remarks:

Successful flight.

21 Problems and Solutions:

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

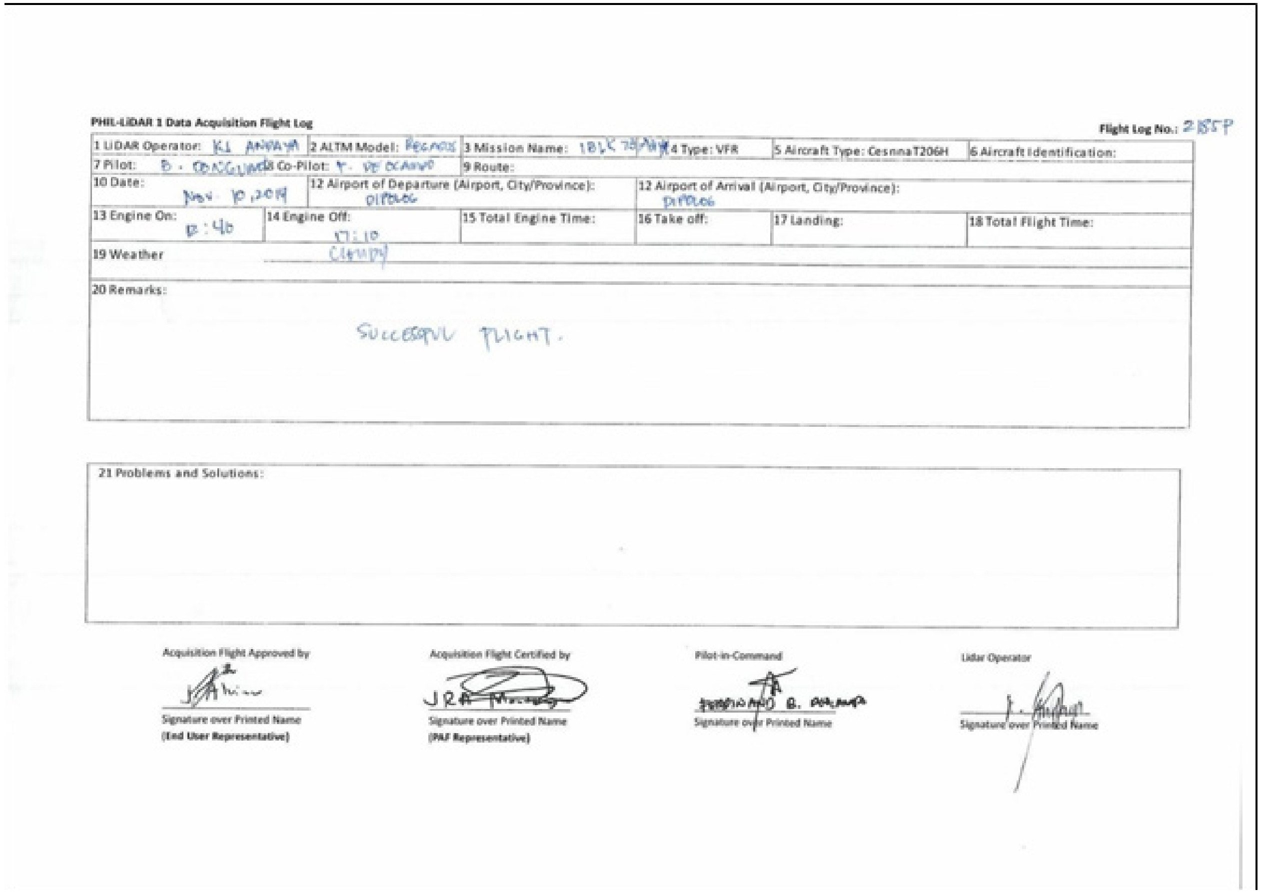
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.1 Flight Log for 1BLK73A310A Mission

Flight Log for 1BLK73A314A Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2185P

1 LiDAR Operator: K1 ANAYA	2 ALTM Model: Pegasus	3 Mission Name: 1BLK73A314A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: B. Donguines	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: Nov. 10, 2014	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 13:46	14 Engine Off: 17:10	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

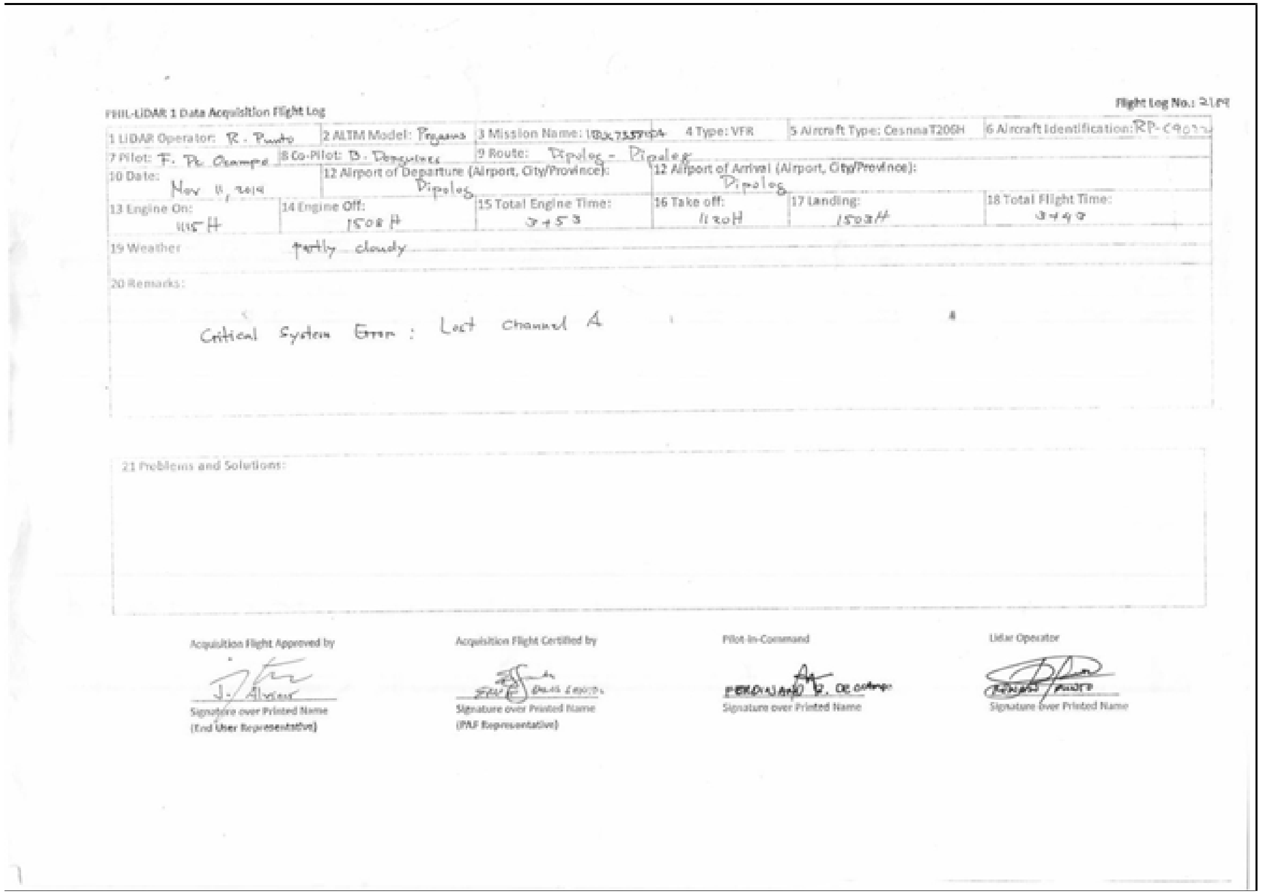
Successful flight.

21 Problems and Solutions:

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

Figure A-6.2 Flight Log for 1BLK73A314A Mission

Flight Log for 1BLK73A315A Mission


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2184

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C90…
7 Pilot: F. De Ocampo	8 Co-Pilot: B. Dongallas	9 Route: Dipolog - Dipolog			
10 Date: Nov 11, 2014	12 Airport of Departure (Airport, City/Province): Dipolog		12 Airport of Arrival (Airport, City/Province): Dipolog		
13 Engine On: 1115 H	14 Engine Off: 1508 H	15 Total Engine Time: 3+53	16 Take off: 1120H	17 Landing: 1503H	18 Total Flight Time: 3+43
19 Weather	partly cloudy				

20 Remarks:

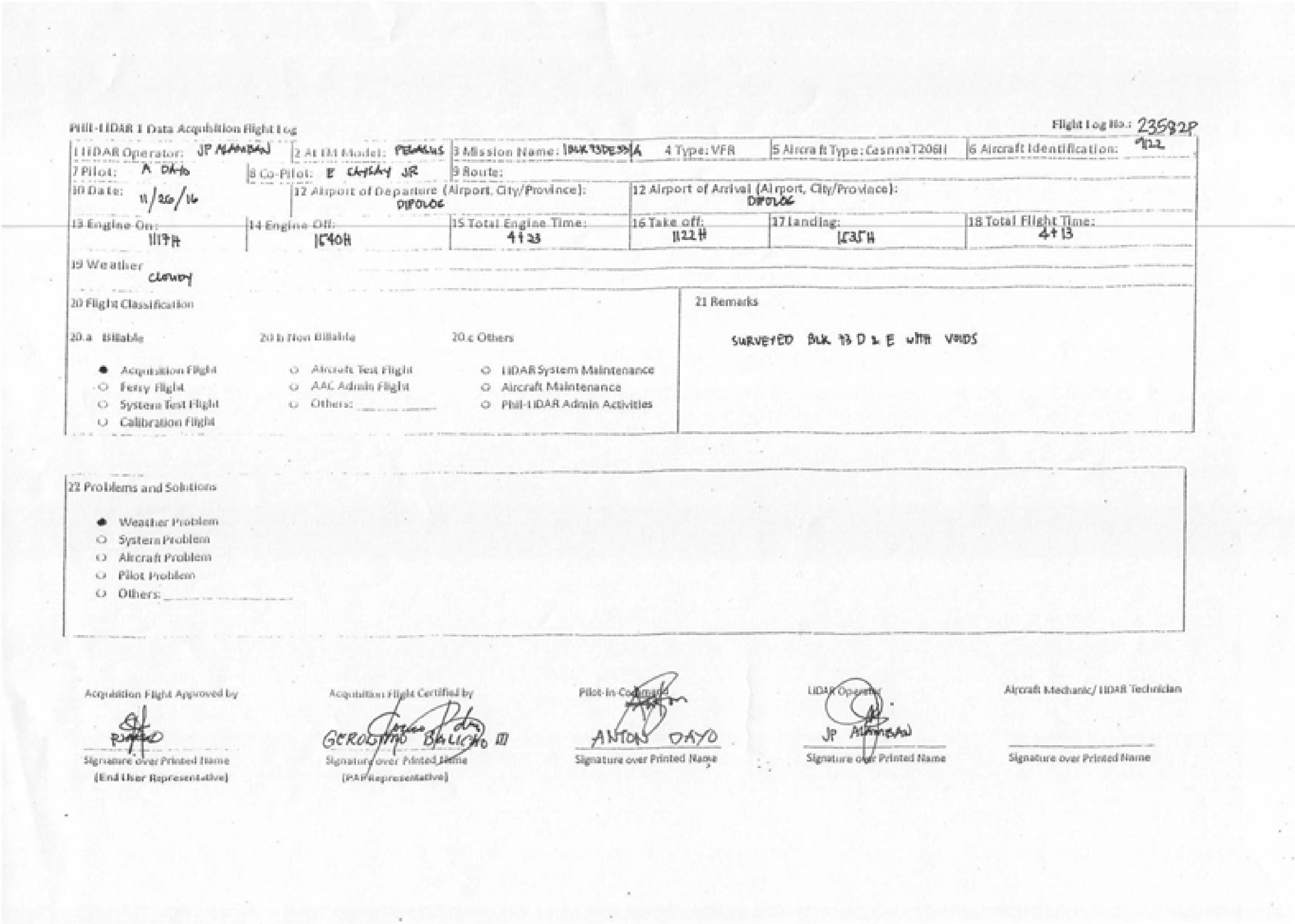
Critical System Error : Lost Channel A

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar		Ferdinand B. De Ocampo	R. Punto
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3 Flight Log for 1BLK73A315A Mission

Flight Log for 1BLK73DE331A Mission



Phil-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23582P

1 LIDAR Operator: JP ALAMBAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK73DE331A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: A DAYO	8 Co-Pilot: E CAYSAY JR	9 Route:			
10 Date: 11/26/16	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 1117H	14 Engine Off: 1540H	15 Total Engine Time: 4+23	16 Take off: 1122H	17 Landing: 1535H	18 Total Flight Time: 4+13
19 Weather: CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

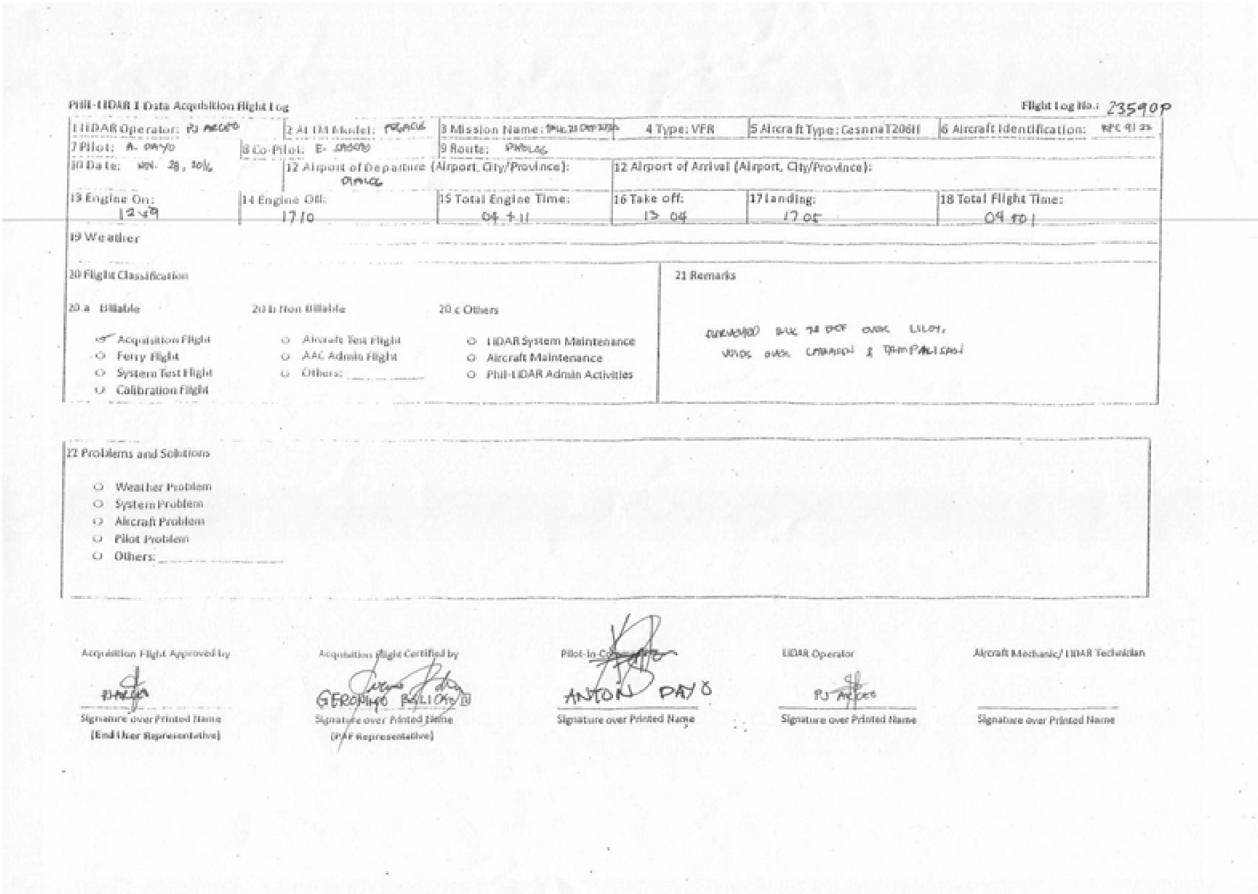
SURVEYED BLK 73 D & E WITH VOIDS

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]	GEROSIMO BALICANO III	ANTON DAYO	JP ALAMBAN	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.4 Flight Log for 1BLK73DE331A Mission

Flight Log for 1BLK73DEF333A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23590P

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK73DEF333A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC 9122
7 Pilot: A. DAYO	8 Co-Pilot: E. JASON	9 Route: PAGADIAN			
10 Date: NOV. 28, 2016	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 12 59	14 Engine Off: 1710	15 Total Engine Time: 04 + 11	16 Take off: 13 04	17 Landing: 17 05	18 Total Flight Time: 04 + 01

19 Weather

20 Flight Classification

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

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

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

21 Remarks

SURVEYED BLK 73 DEF OVER LILOY, VOIDS OVER LABASON & TAMPALISAN

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
DAHILA	GERONIMO BALIONG III	ANTON DAYO	PJ ARCEO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for 1BLK73DEF333A Mission

Annex 7. Flight status reports

Table A-7.1. Flight Status Report

DIPOLOG-ZAMBOANGA DEL NORTE
(October 8 to November 11, 2014 and November 20 to 26, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2169P	BLK 73A	1BLK73A310A	R PUNTO	November 6, 2014	Successful flight over BLK 73A
2185P	BLK 73A	1BLK73A314A	KJ ANDAYA	November 10, 2014	Surveyed BLK 73A
2189P	BLK73A	1BLK73A315A	R PUNTO	November 11, 2014	Successful flight over BLK 73A
23582P	BLK 73D, 73E	1BLK73DE331A	JP ALAMBAN	November 26, 2016	Surveyed BLK 73D and 73D over Kipit and Patawag floodplain
23590P	BLK 73D, 73E, 73F	1BLK73DEF333A	PJ ARCEO	November 28, 2016	Surveyed Dipolog and Paro Dapitan floodplain with voids due to build up and strong winds

SWATH PER FLIGHT MISSION

Flight No.: 2169P

Area: BLK 73A

Mission Name: 1BLK73A310A

Parameters: Altitude: 750 m; Scan Frequency: 30 Hz;

Scan Angle: 25 deg; Overlap: 30%

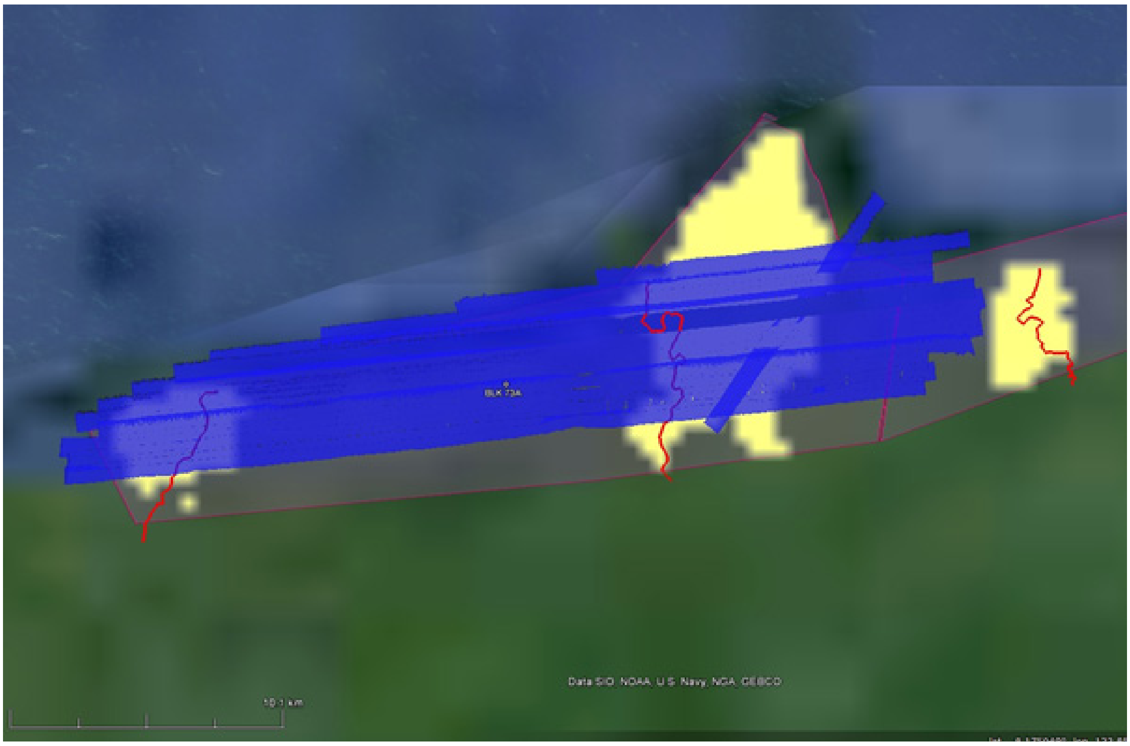


Figure A-7.1. Swath Coverage of Mission 1BLK73A310A

Flight No.: 2185P

Area: BLK 73A

Mission Name: 1BLK73A314A

Parameters: Altitude: 750/850/1000 m; Scan Frequency: 30 Hz;

Scan Angle: 25 deg; Overlap: 20%

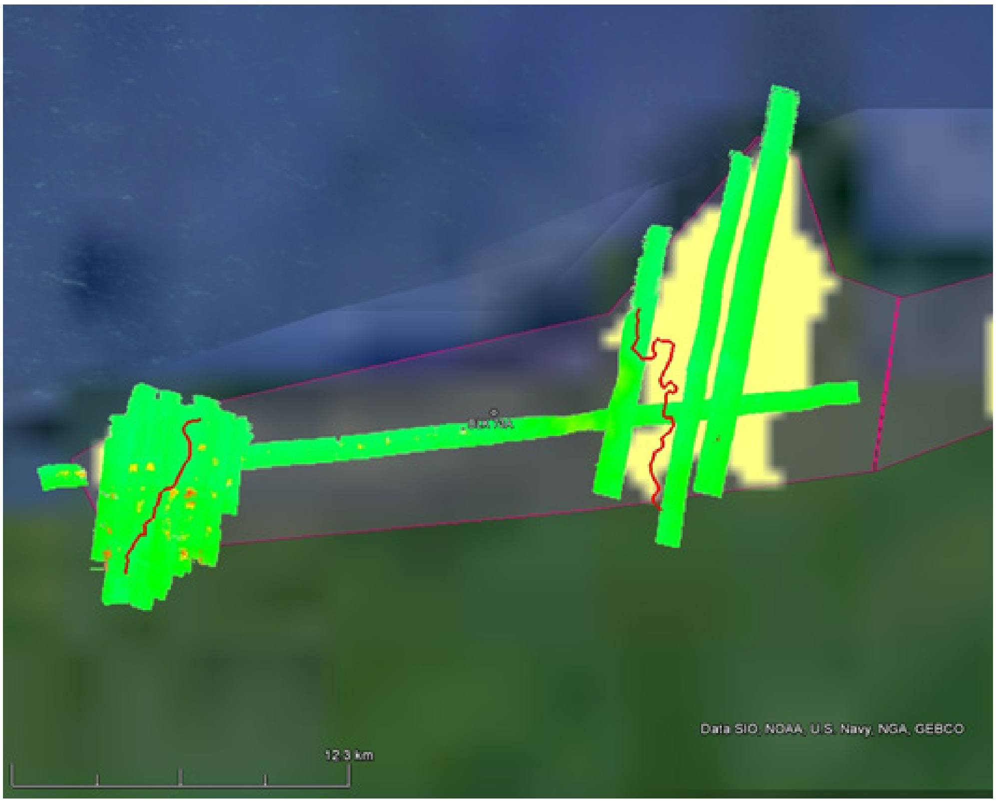


Figure A-7.2. Swath Coverage of Mission 1BLK73A314A

Flight No.: 2189P
Area: BLK 73A
Mission Name: 1BLK73A315A
Parameters: Altitude: 750/850/1000 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 20%

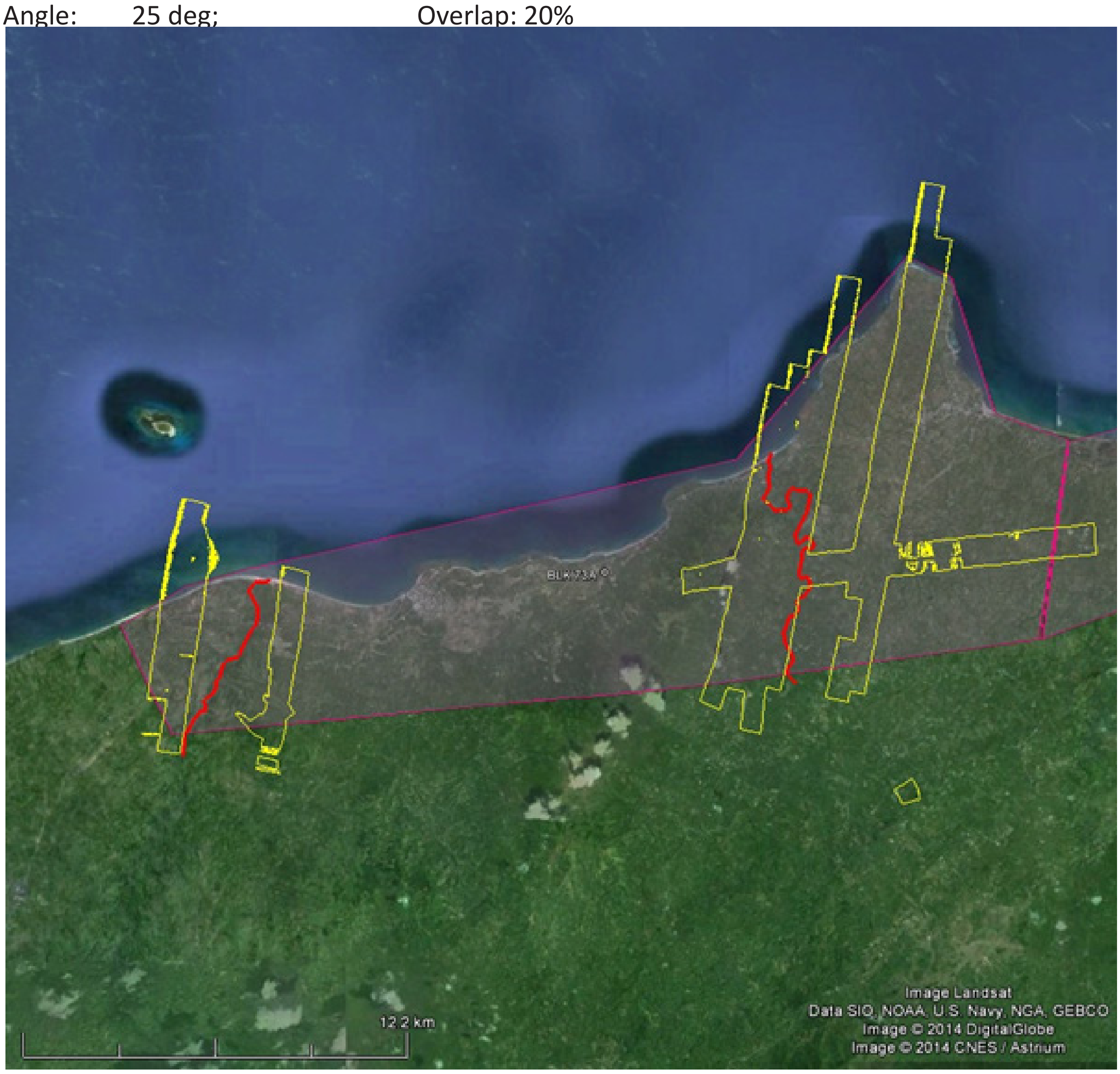


Figure A-7.3. 1BLK73A315A

Flight No.: 23582P

Area: BLK 73D, BLK 73E

Mission Name: 1BLK73DE331A

Parameters: Altitude: 600/700/800/1000/1100/1200 m; Scan Frequency: 30 Hz;

Scan Angle: 20 deg; Overlap: 30%

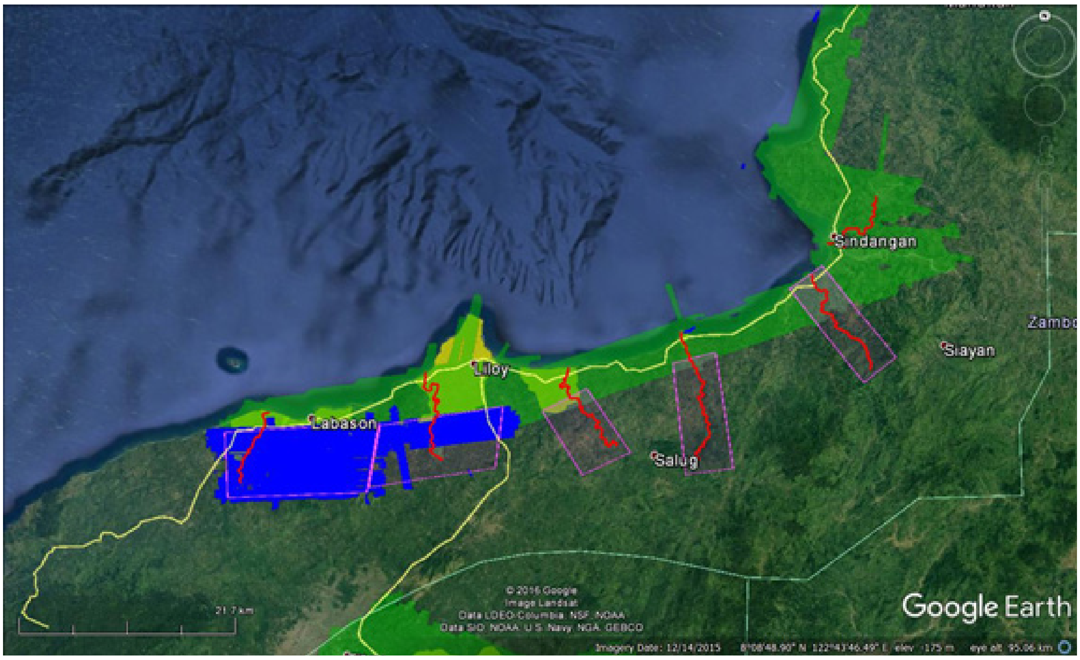


Figure A-7.4. Swath Coverage of Mission 1BLK73DE331A

FFlight No.: 23590P
Area: BLK 73D, BLK 73E, BLK 73F
Mission Name: 1BLK73DEF333A
Parameters: Altitude: 700/800/1000/1100/1200 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

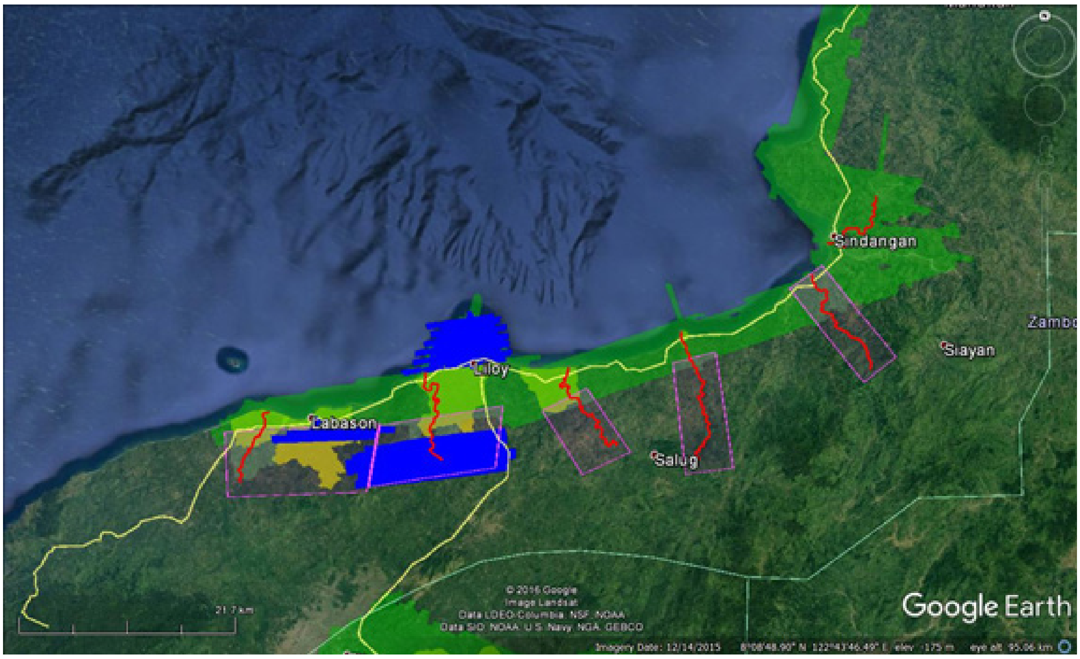


Figure A-7.5. Swath Coverage of Mission 1BLK73DEF333A

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission 1BLK73A314A

Flight Area	Negros
Mission Name	Blk73A
Inclusive Flights	2169P, 2185P, 2189P
Mission Name	1BLK73A314A
Range data size	13.1 GB
POS	253 MB
Image	NONE
Transfer date	December 9, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.14
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.45
Boresight correction stdev (<0.001deg)	0.000281
IMU attitude correction stdev (<0.001deg)	0.002285
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	59.36%
Ave point cloud density per sq.m. (>2.0)	6.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	281
Maximum Height	432.78 m
Minimum Height	62.42 m
Classification (# of points)	
Ground	316,257,459
Low vegetation	393,916,474
Medium vegetation	547,399,563
High vegetation	356,827,606
Building	11,617,652
Orthophoto	No

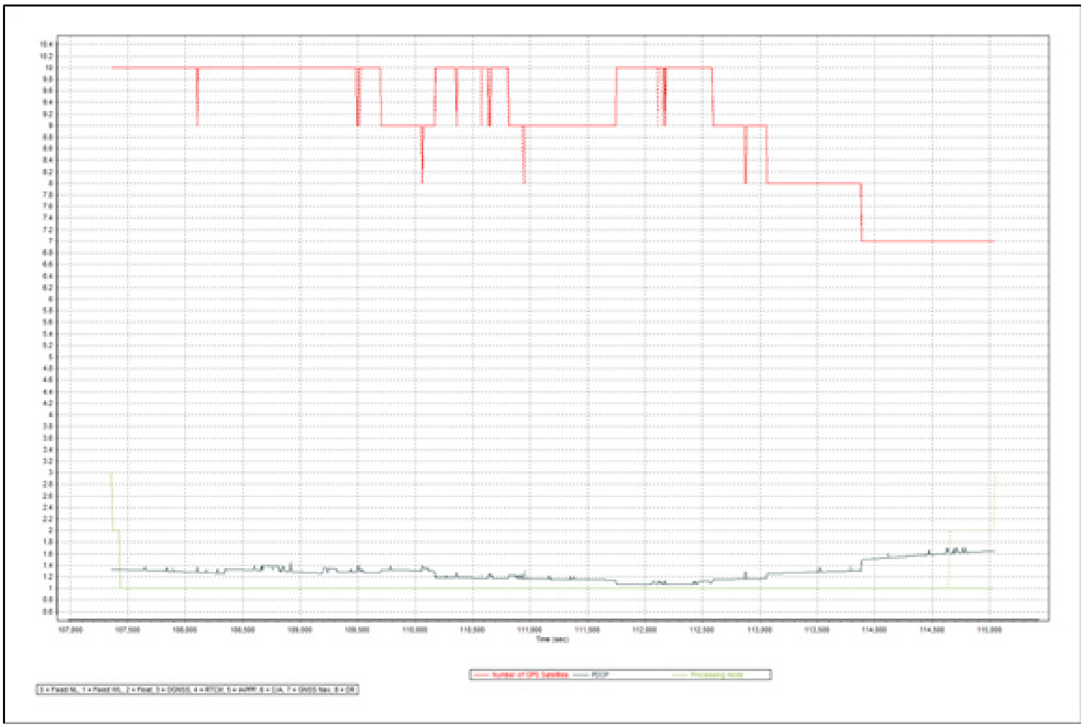


Figure A-8.1 Solution Status

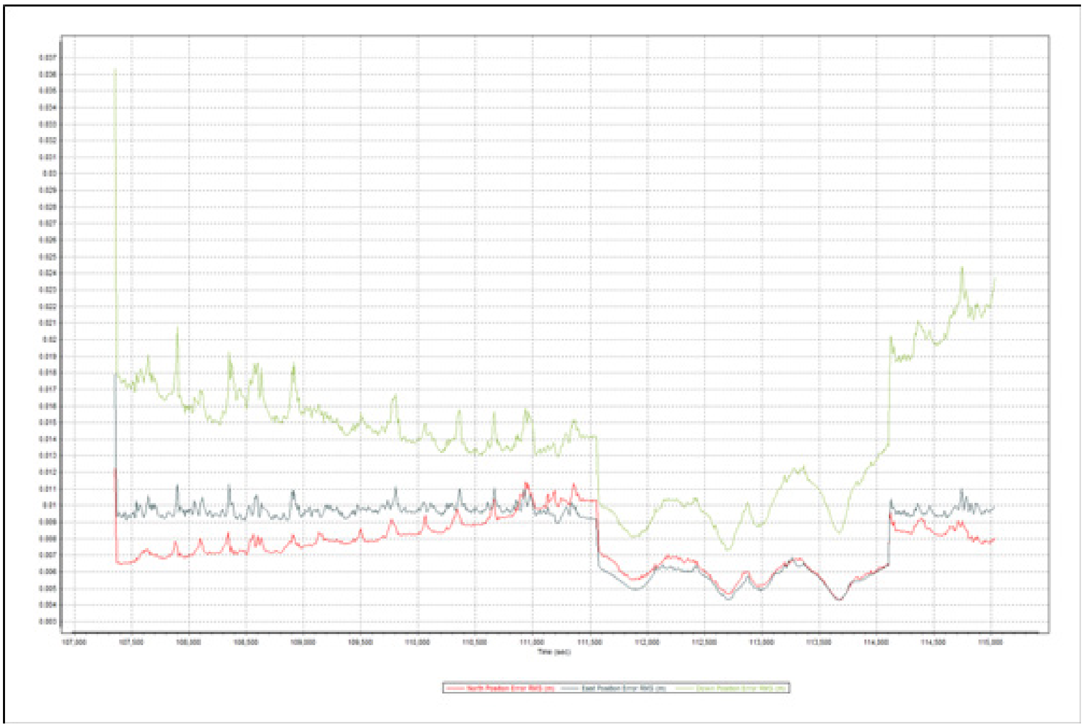


Figure A-8.2. Smoothed Performance Metric Parameters

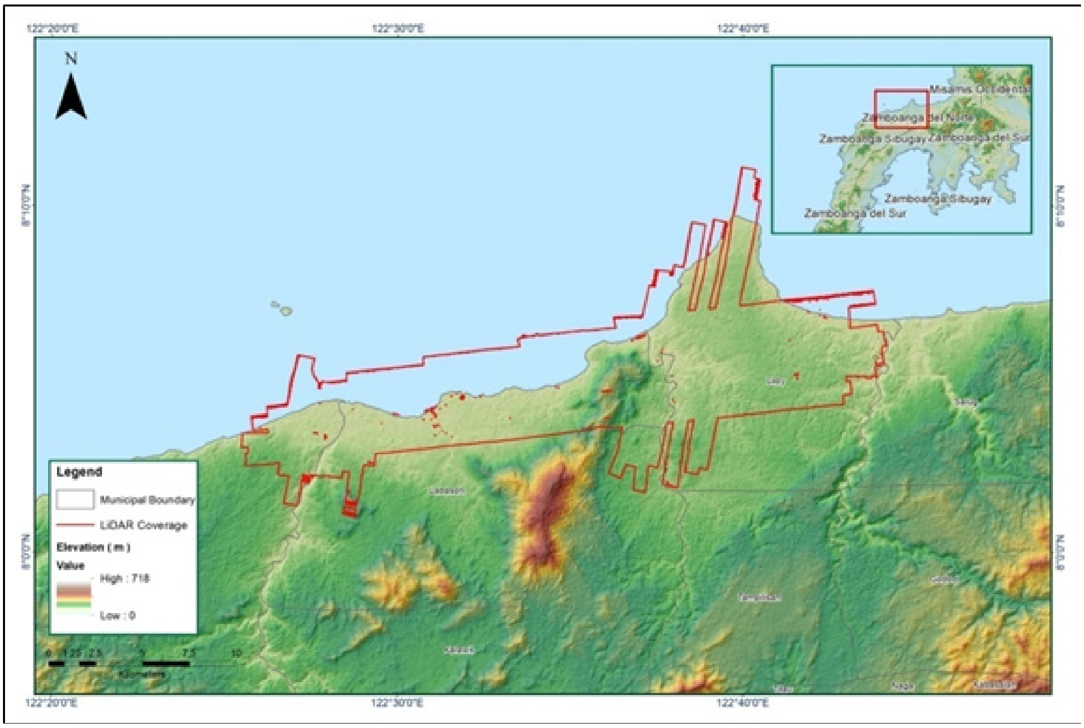


Figure A-8.3. Best Estimated Trajectory

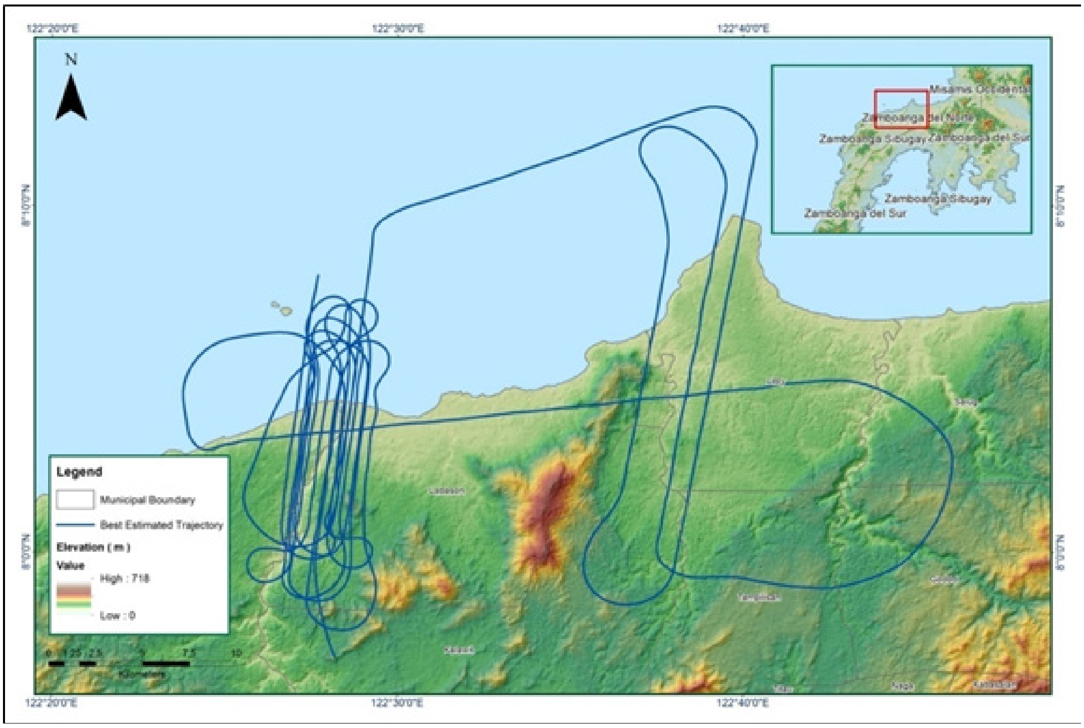


Figure A-8.4. Coverage of LiDAR data

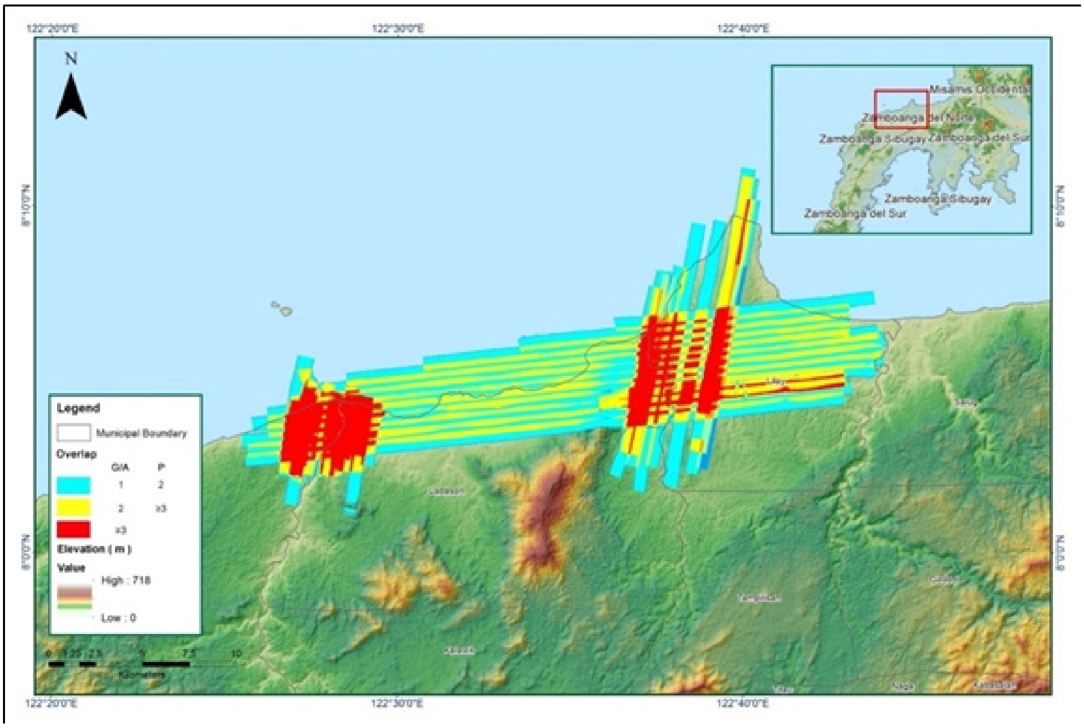


Figure A-8.5. Image of data overlap

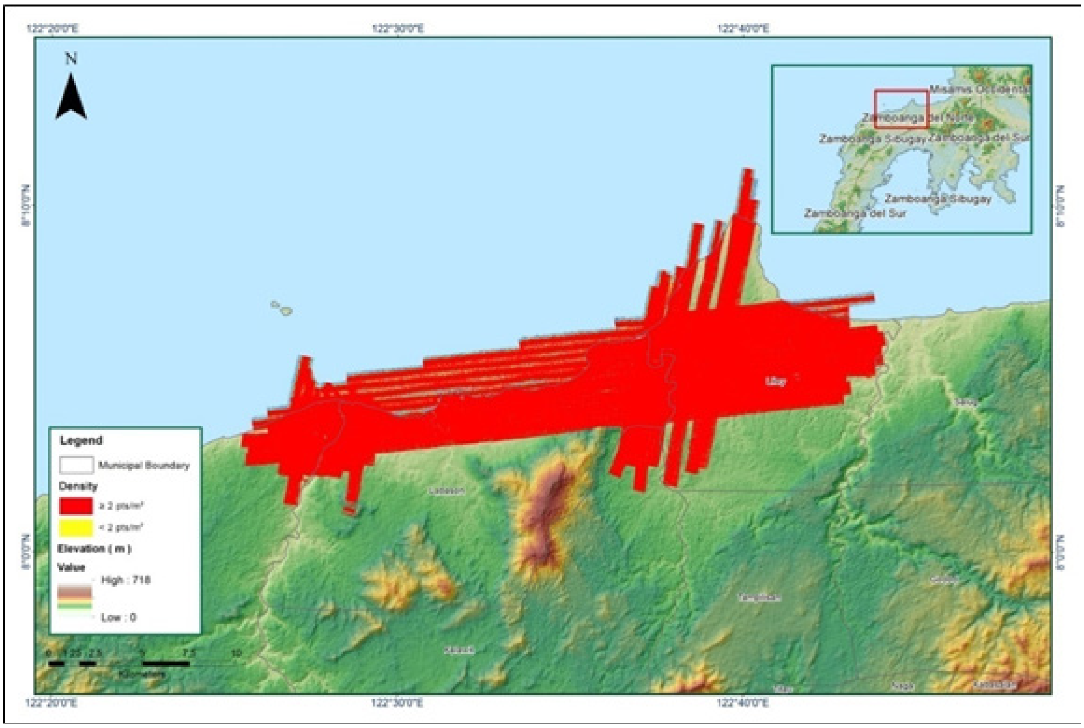


Figure A-8.6. Density map of merged LiDAR data

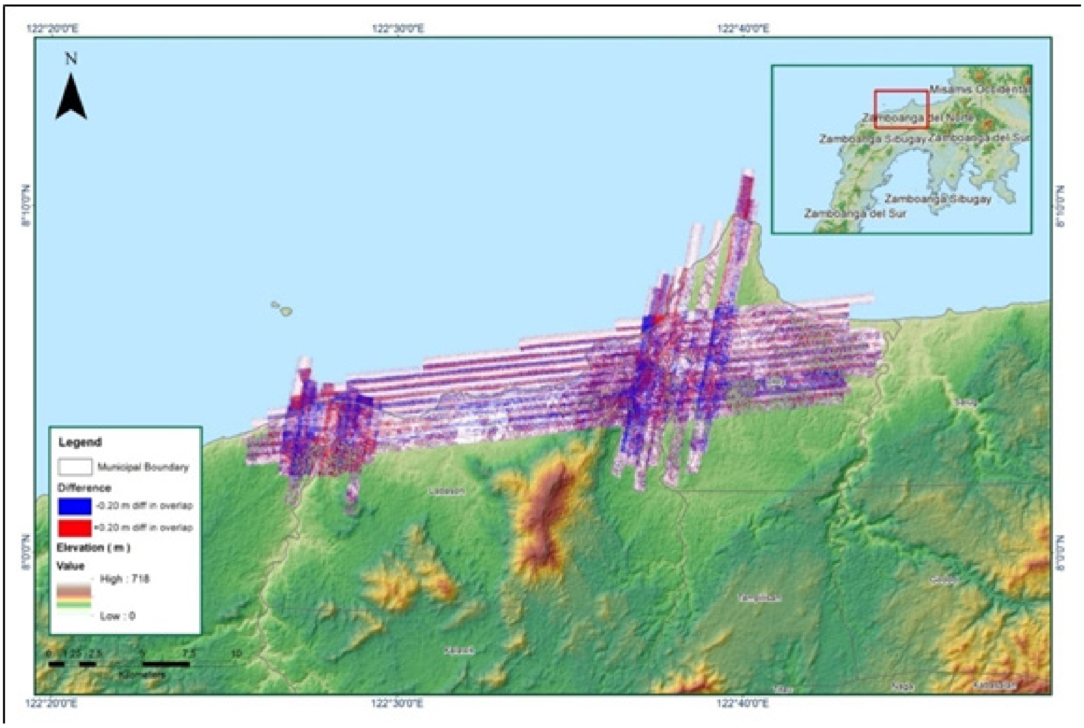


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk73A_additional

Flight Area	Bacolod
Mission Name	Blk73A_additional
Inclusive Flights	23590P
Range data size	16.6 GB
POS data size	203 MB
Base data size	42.3 MB
Image	32.6 GB
Transfer date	December 8, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.304
RMSE for East Position (<4.0 cm)	1.277
RMSE for Down Position (<8.0 cm)	3.261
Boresight correction stdev (<0.001deg)	0.000127
IMU attitude correction stdev (<0.001deg)	0.006477
GPS position stdev (<0.01m)	0.0248
Minimum % overlap (>25)	52.29 %
Ave point cloud density per sq.m. (>2.0)	3.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	182
Maximum Height	845.3 m
Minimum Height	61.35 m
Classification (# of points)	
Ground	153,461,764
Low vegetation	114,346,778
Medium vegetation	202,928,794
High vegetation	443,554,236
Building	6,868,610
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr Merven Matthew Natino, Engr. Vincent Louise Azucena

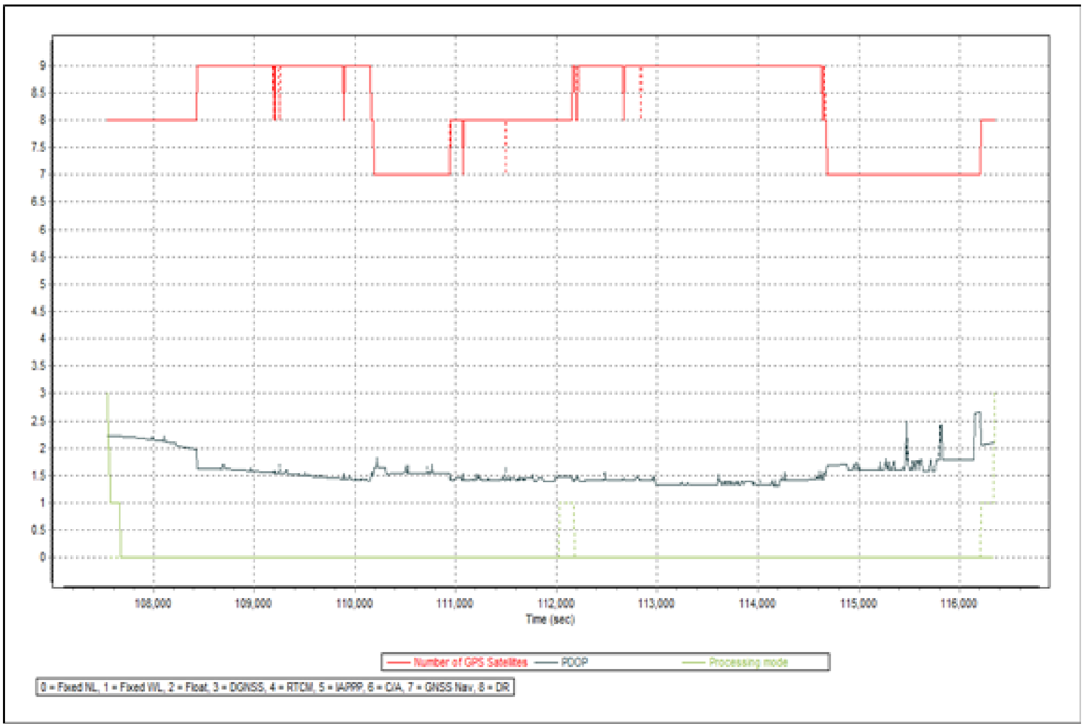


Figure A-8.8. Solution Status

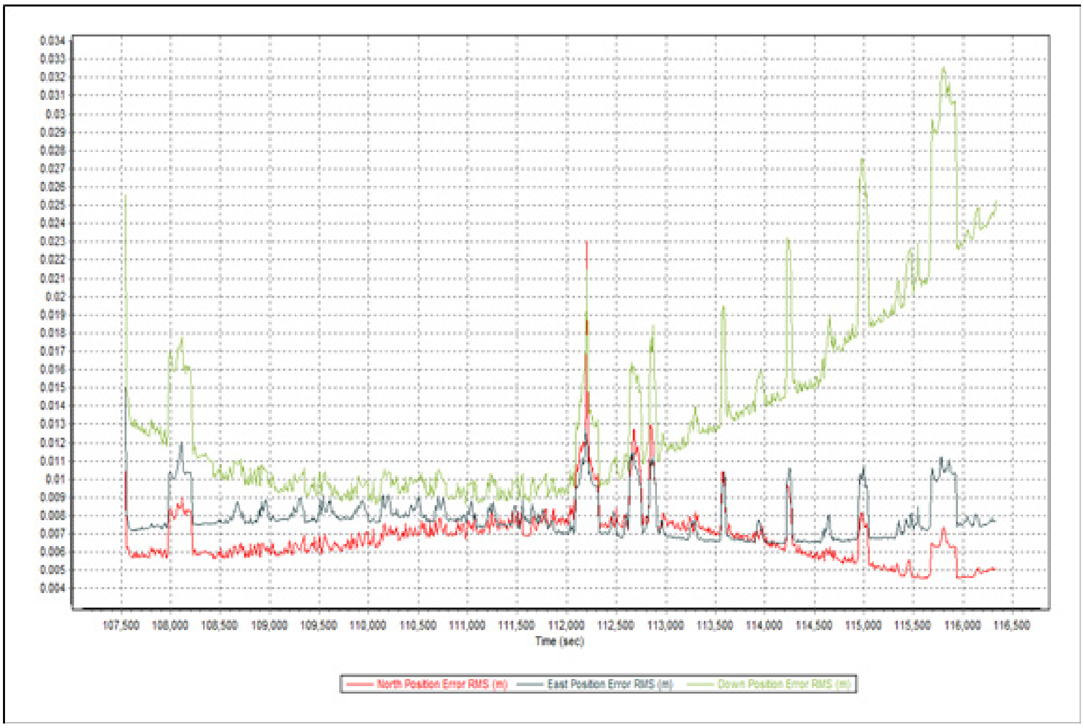


Figure A-8.9. Smoothed Performance Metric Parameters

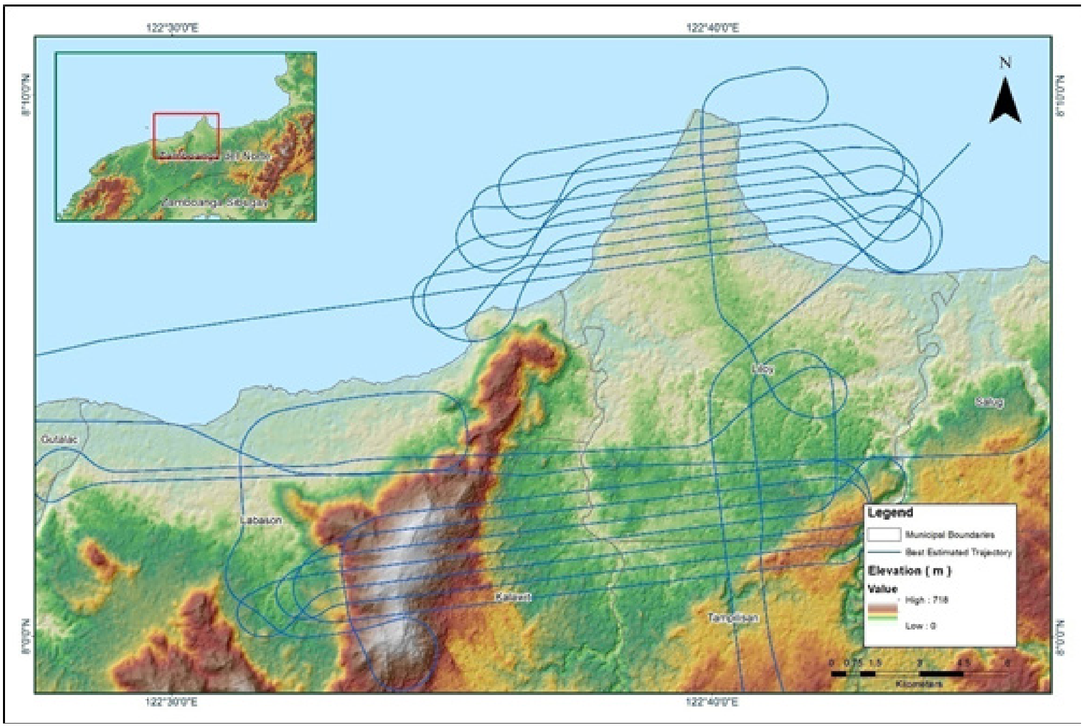


Figure A-8.10. Best Estimated Trajectory

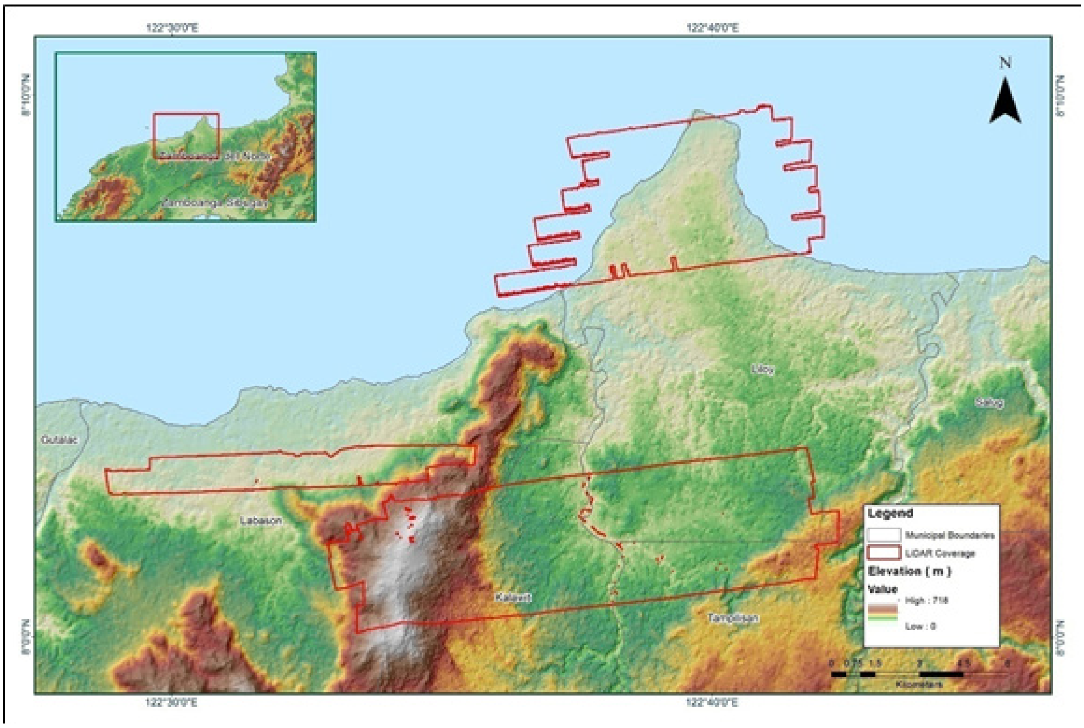


Figure A-8.11. Coverage of LiDAR data

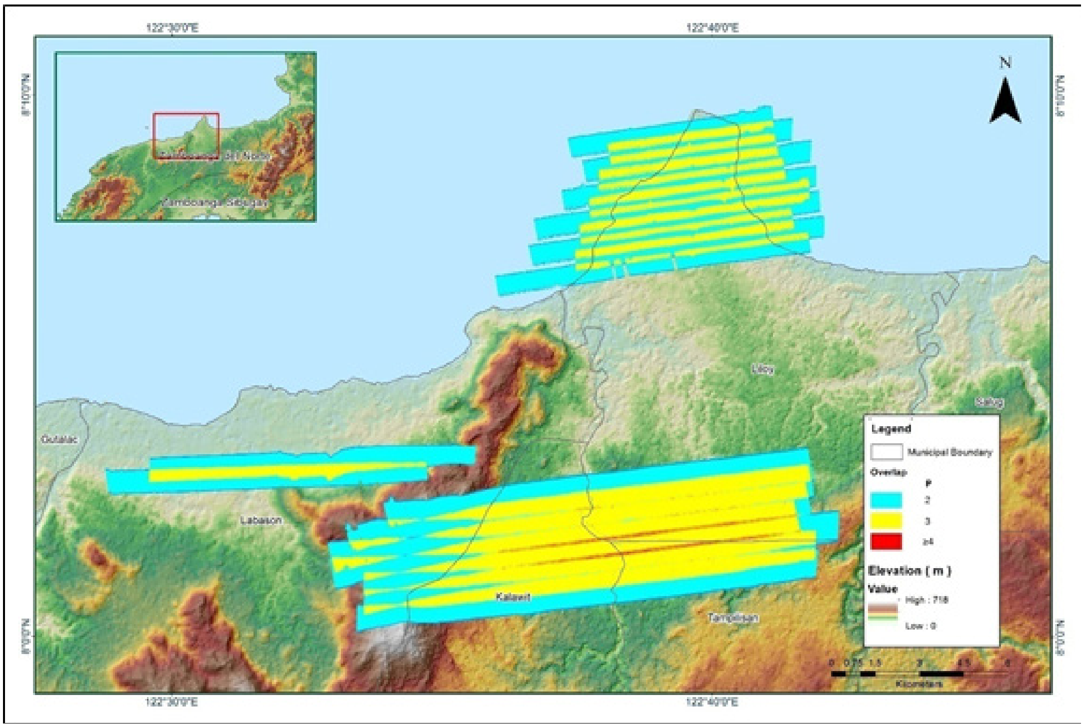


Figure A-8.12. Image of data overlap

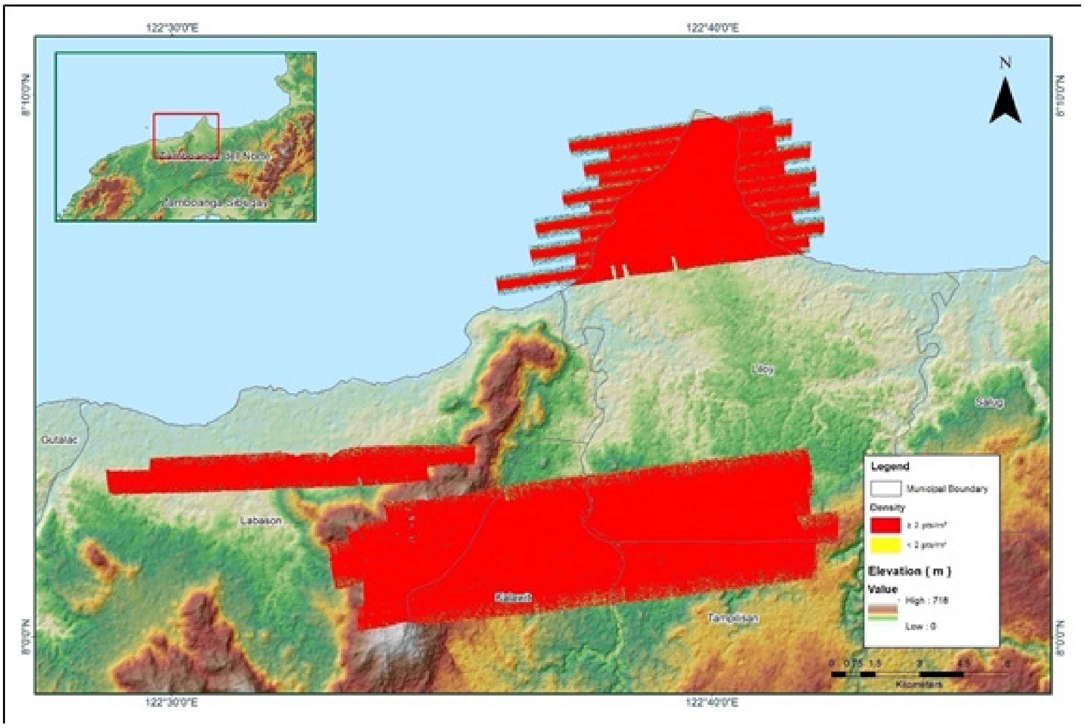


Figure A-8.13. Density map of merged LiDAR data

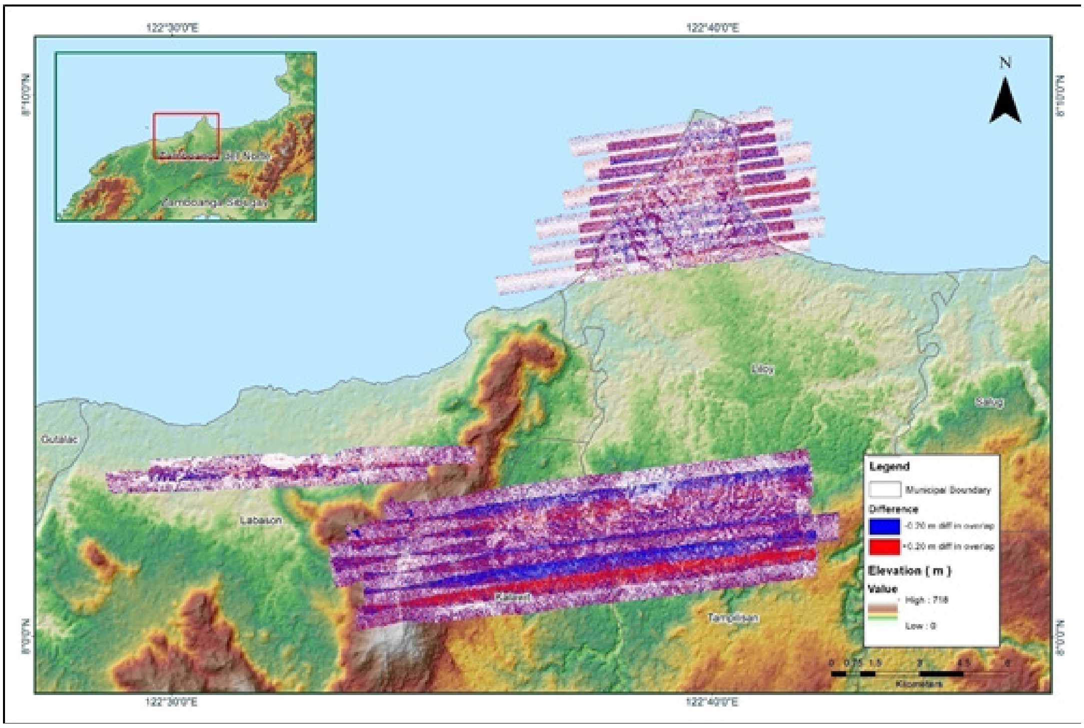


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk73A_supplement

Flight Area	Negros
Mission Name	Blk73A_supplement
Inclusive Flights	23582P
Range data size	25.5 GB
POS data size	281 MB
Base data size	162 MB
Image	25.1 GB
Transfer date	December 6, 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)	1.425
RMSE for East Position (<4.0 cm)	1.519
RMSE for Down Position (<8.0 cm)	4.281
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	41.33 %
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20 m)z	Yes
Number of 1km x 1km blocks	70
Maximum Height	720.99 m
Minimum Height	74.29 m
Classification (# of points)	
Ground	34,708,535
Low vegetation	34,009,055
Medium vegetation	81,708,836
High vegetation	178,864,166
Building	1,541,224
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Monalyne Rabino, Engr. Justine Francisco

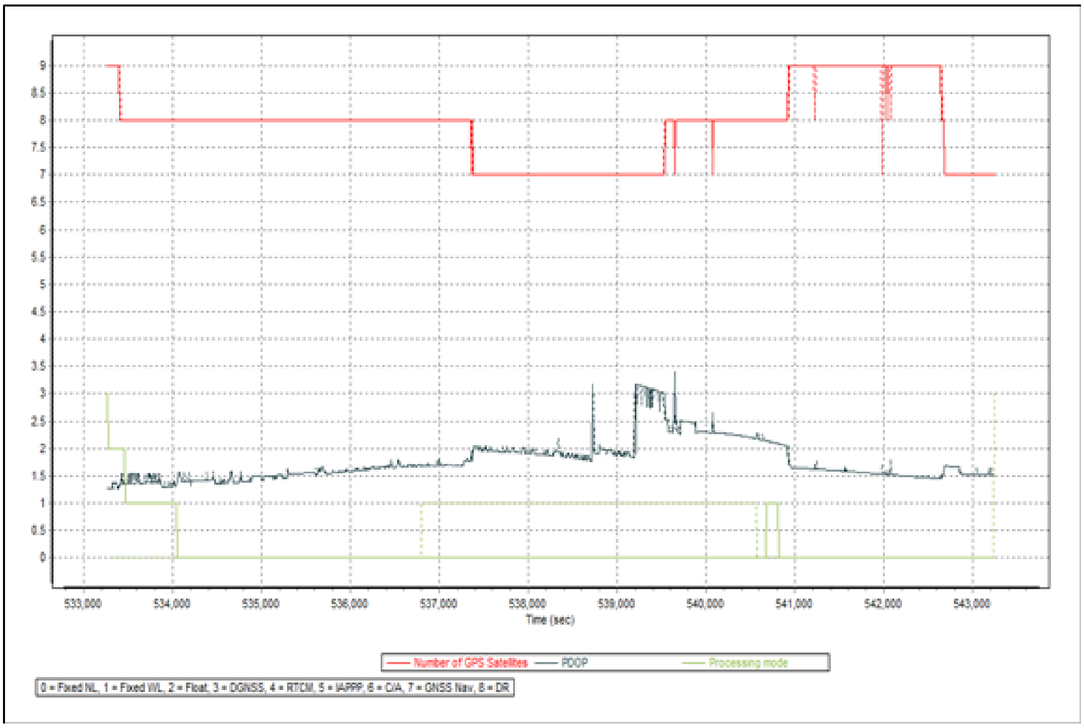


Figure A-8.15 Solution Status

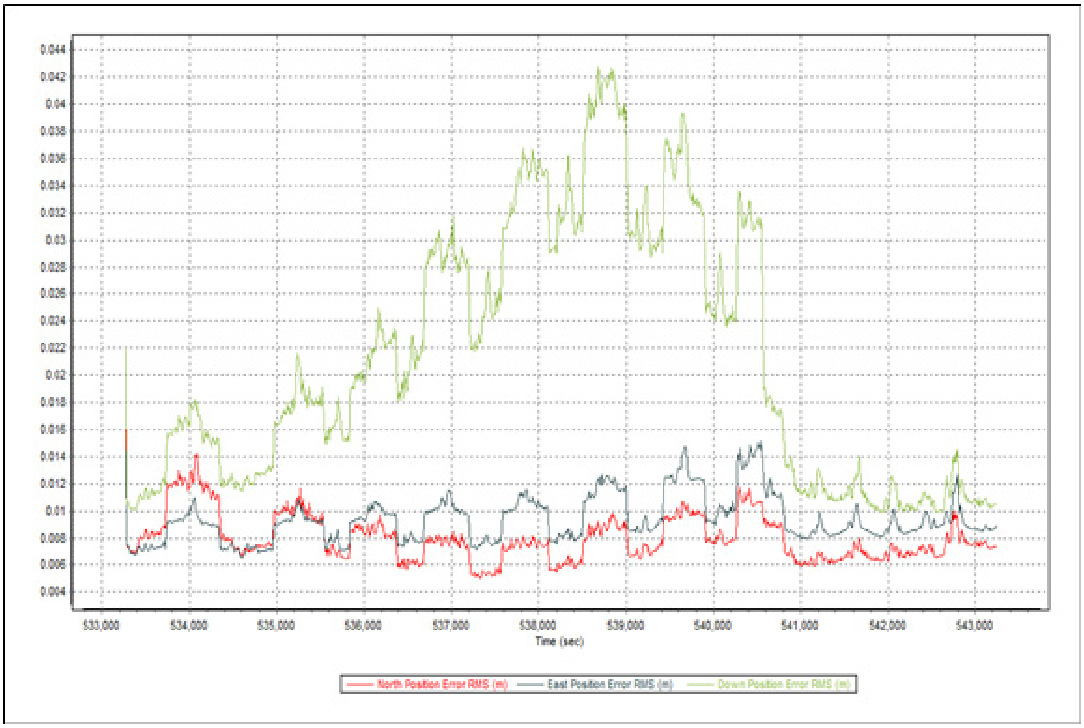


Figure A-8.16 Smoothed Performance Metric Parameters

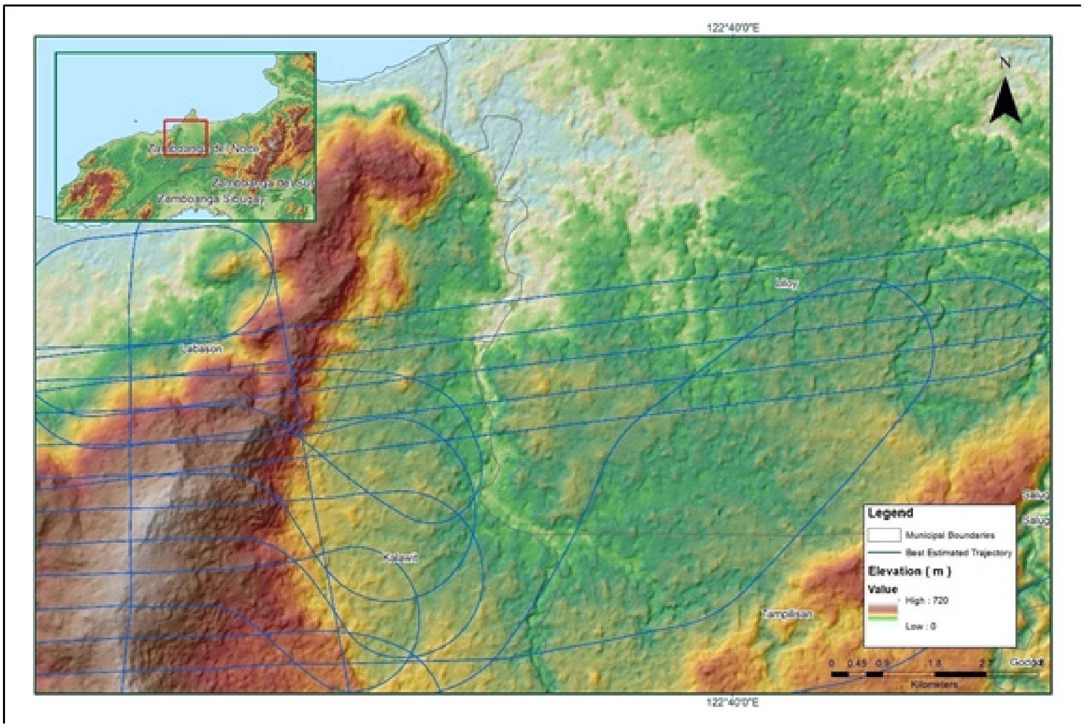


Figure A-8.17 Best Estimated Trajectory

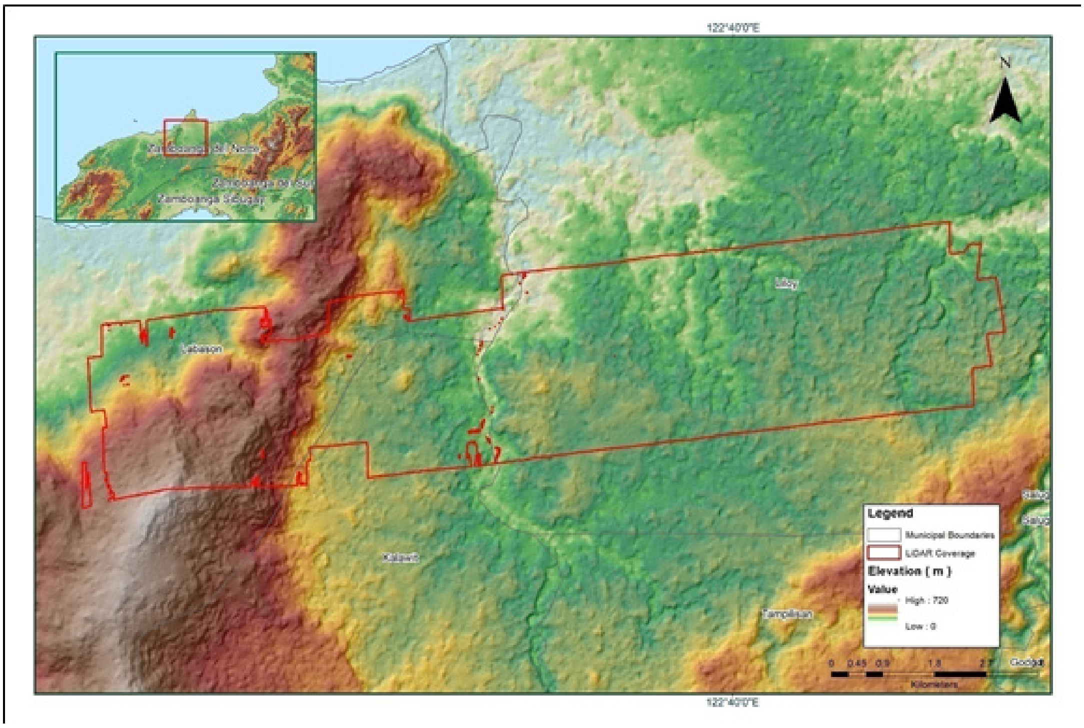


Figure A-8.18 Coverage of LiDAR Data

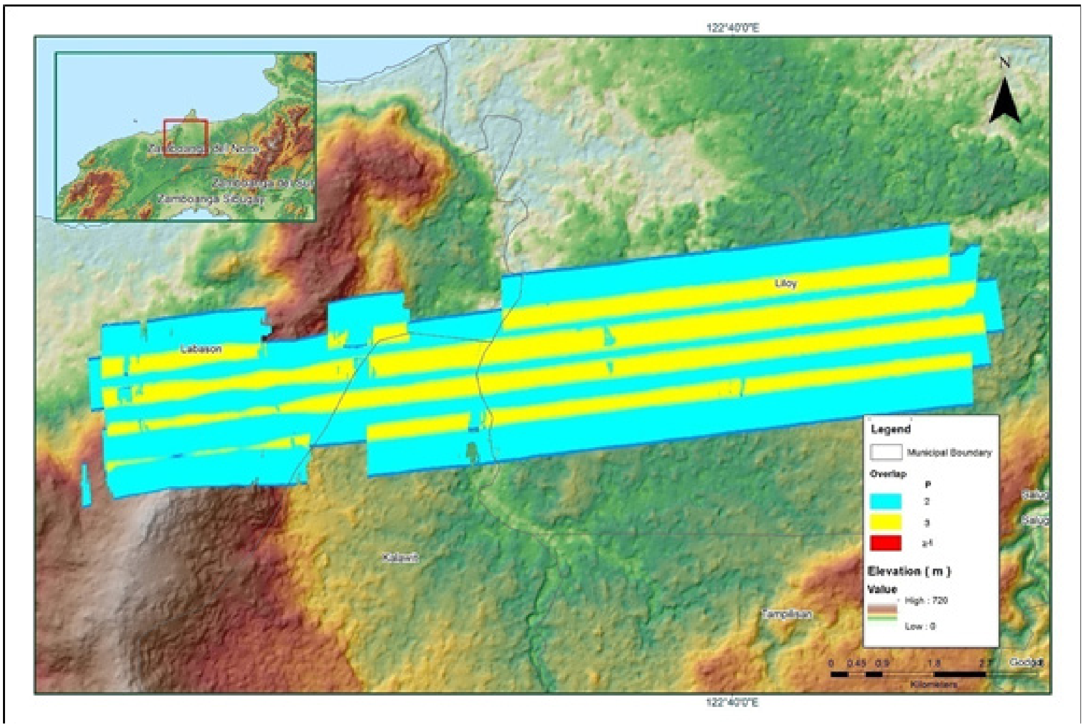


Figure A-8.19 Image of data overlap

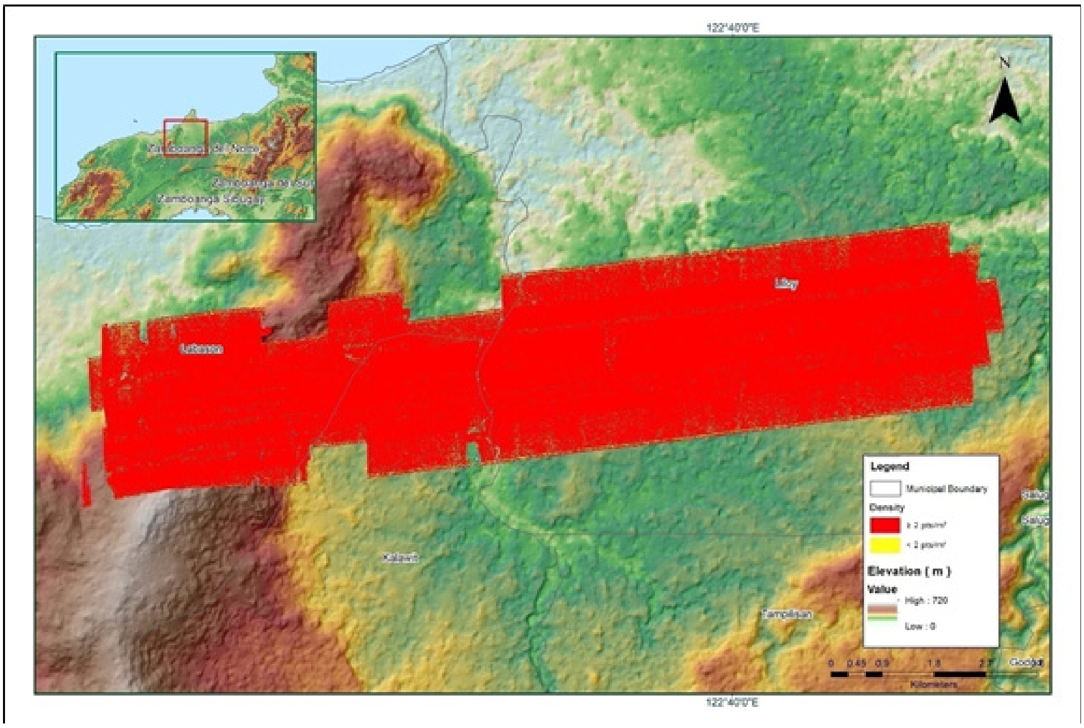


Figure A-8.20 Density map of merged LiDAR data

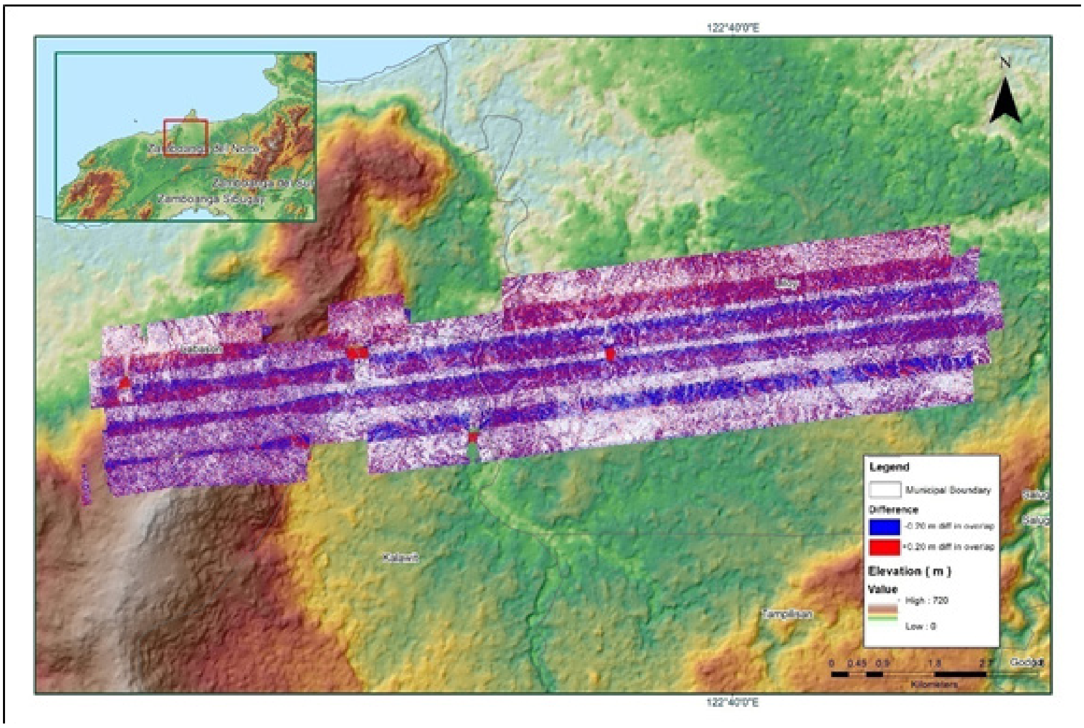


Figure A-8.21 Elevation difference between flight lines

Annex 9. Patawag Model Basin Parameters

Table A-9.1. Patawag 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
W560	31.159	71.166	0	1.326675	2.05128	Discharge	0.05023	0.47	Ratio to Peak	0.2
W570	24.813	99	0	1.069415	1.65348	Discharge	0.03133	0.47	Ratio to Peak	0.2
W580	14.829	89.214	0	1.252765	1.93698	Discharge	0.03258	0.47	Ratio to Peak	0.2
W590	14.379	99	0	0.674757	1.5336	Discharge	0.00063	0.47	Ratio to Peak	0.2
W600	18.705	99	0	0.77539	1.20024	Discharge	0.0345	0.47	Ratio to Peak	0.2
W610	34.101	69.45	0	2.188325	3.38328	Discharge	0.00793	0.47	Ratio to Peak	0.2
W620	11.883	99	0	0.965675	2.25207	Discharge	0.081	0.47	Ratio to Peak	0.2
W630	18.795	99	0	1.13506	1.19385	Discharge	0.02275	0.47	Ratio to Peak	0.2
W640	9.552	90.063	0	1.11473	1.12608	Discharge	0.08574	0.47	Ratio to Peak	0.2
W650	36.786	66.7	0	0.596743	0.92259	Discharge	0.04152	0.47	Ratio to Peak	0.2
W660	21.121	99	0	0.58444	0.599481	Discharge	0.06488	0.47	Ratio to Peak	0.2
W670	19.422	99	0	0.854069	1.32048	Discharge	0.05297	0.47	Ratio to Peak	0.2
W680	27.743	99	0	1.347385	2.08323	Discharge	0.02817	0.47	Ratio to Peak	0.2
W690	14.041	99	0	1.28744	1.35405	Discharge	0.12916	0.47	Ratio to Peak	0.2
W700	14.041	99	0	1.00187	1.02726	Discharge	0.01541	0.47	Ratio to Peak	0.2
W710	14.041	90.044	0	1.23348	2.80341	Discharge	0.00481	0.47	Ratio to Peak	0.2
W720	32.87	69.329	0	1.928595	2.98188	Discharge	0.03491	0.47	Ratio to Peak	0.2
W730	14.041	99	0	0.518757	0.545607	Discharge	0.04138	0.47	Ratio to Peak	0.2
W740	17.723	57.534	0	3.180885	7.40979	Discharge	0.01492	0.47	Ratio to Peak	0.2
W750	21.612	99	0	0.90345	1.43226	Discharge	0.03647	0.47	Ratio to Peak	0.2
W760	16.126	87.605	0	0.79173	2.75418	Discharge	0.00309	0.47	Ratio to Peak	0.2

W770	9.552	99	0	0.446016	1.5516	Discharge	0.00447	0.47	Ratio to Peak	0.2
W780	17.859	73.857	0	0.94164	1.45593	Discharge	0.01062	0.47	Ratio to Peak	0.2
W790	39.255	74.382	0	1.50803	2.33154	Discharge	0.07161	0.47	Ratio to Peak	0.2
W800	21.172	81.108	0	0.730427	1.66014	Discharge	0.03908	0.47	Ratio to Peak	0.2
W810	32.204	70.092	0	0.611629	2.12769	Discharge	0.01717	0.47	Ratio to Peak	0.2
W820	19.839	55.593	0	1.57586	2.43648	Discharge	0.10511	0.47	Ratio to Peak	0.2
W830	21.882	80.319	0	1.557905	2.40876	Discharge	0.05994	0.47	Ratio to Peak	0.2
W840	35.271	70.666	0	0.849813	1.31391	Discharge	0.00129	0.47	Ratio to Peak	0.2
W850	21.492	87.906	0	1.40372	2.17035	Discharge	0.28913	0.47	Ratio to Peak	0.2
W860	25.946	84.515	0	1.807375	2.79432	Discharge	0.01319	0.47	Ratio to Peak	0.2
W870	17.873	73.838	0	1.572155	2.43063	Discharge	0.05115	0.47	Ratio to Peak	0.2
W880	17.447	99	0	0.539334	1.2258	Discharge	0.02833	0.47	Ratio to Peak	0.2
W890	17.918	56.727	0	1.21049	1.87155	Discharge	0.03348	0.47	Ratio to Peak	0.2
W900	25.647	99	0	0.634914	0.98163	Discharge	0.02941	0.47	Ratio to Peak	0.2
W910	21.779	79.62	0	1.258845	1.94625	Discharge	0.04765	0.47	Ratio to Peak	0.2
W920	17.365	74.521	0	1.42671	1.50048	Discharge	0.04097	0.47	Ratio to Peak	0.2
W930	23.667	58.908	0	0.777984	1.20285	Discharge	0.12435	0.47	Ratio to Peak	0.2
W940	18.314	84.033	0	1.399445	1.47195	Discharge	0.0853	0.47	Ratio to Peak	0.2
W950	14.423	89.59	0	1.40448	2.17143	Discharge	0.03065	0.47	Ratio to Peak	0.2
W960	26.17	75.9	0	1.21087	1.87218	Discharge	0.07433	0.47	Ratio to Peak	0.2
W970	24.184	78.214	0	2.290545	3.54141	Discharge	0.17416	0.47	Ratio to Peak	0.2
W980	22.982	69.23	0	0.989235	1.52946	Discharge	0.02952	0.47	Ratio to Peak	0.2
W990	24.775	67.413	0	2.042025	3.15729	Discharge	0.00412	0.47	Ratio to Peak	0.2
W1000	38.852	76.474	0	1.67637	2.59182	Discharge	0.0624	0.47	Ratio to Peak	0.2
W1010	24.497	78.118	0	0.8607	1.33074	Discharge	0.01094	0.47	Ratio to Peak	0.2
W1020	33.767	69.791	0	1.90551	2.94615	Discharge	0.05065	0.47	Ratio to Peak	0.2
W1030	26.301	99	0	0.254382	0.578151	Discharge	0.05747	0.47	Ratio to Peak	0.2
W1040	39.255	99	0	1.14779	1.77462	Discharge	0.09175	0.47	Ratio to Peak	0.2

W1050	26.17	99	0	0.644832	1.01736	Discharge	0.04901	0.47	Ratio to Peak	0.2
W1060	23.026	84.161	0	2.960295	4.46472	Discharge	0.04747	0.47	Ratio to Peak	0.2
W1070	39.255	99	0	0.828077	1.28034	Discharge	0.02623	0.47	Ratio to Peak	0.2
W1080	26.184	99	0	1.44837	2.00763	Discharge	0.15775	0.47	Ratio to Peak	0.2
W1090	39.255	74.382	0	1.10789	1.71288	Discharge	0.04038	0.47	Ratio to Peak	0.2
W1100	26.087	74.382	0	1.103235	1.69767	Discharge	0.05905	0.47	Ratio to Peak	0.2

Annex 10. Patawag Model Reach Parameters

Table A-10.1. Patawag Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R50	Automatic Fixed Interval	1449.1	0.0020148	0.04	Trapezoid	25	0.01
R60	Automatic Fixed Interval	2819.1	0.002861	0.04	Trapezoid	25	0.01
R70	Automatic Fixed Interval	754.97	0.0111753	0.04	Trapezoid	25	0.01
R90	Automatic Fixed Interval	825.27	0.0209314	0.04	Trapezoid	25	0.01
R100	Automatic Fixed Interval	272.99	0.025205	0.04	Trapezoid	25	0.01
R110	Automatic Fixed Interval	213.85	0.0321758	0.04	Trapezoid	25	0.01
R120	Automatic Fixed Interval	916.69	0.0165572	0.04	Trapezoid	25	0.01
R140	Automatic Fixed Interval	942.25	0.00125	0.04	Trapezoid	25	0.01
R150	Automatic Fixed Interval	799.71	0.0130961	0.04	Trapezoid	25	0.01
R160	Automatic Fixed Interval	4069.1	0.0095136	0.04	Trapezoid	25	0.01
R170	Automatic Fixed Interval	2074.8	0.0064914	0.04	Trapezoid	25	0.01
R200	Automatic Fixed Interval	1338.5	0.0215731	0.04	Trapezoid	25	0.01
R220	Automatic Fixed Interval	1187.1	0.0231428	0.04	Trapezoid	25	0.01
R250	Automatic Fixed Interval	1226.7	0.0294203	0.04	Trapezoid	25	0.01
R260	Automatic Fixed Interval	1109.1	0.0079838	0.04	Trapezoid	25	0.01
R280	Automatic Fixed Interval	643.85	0.0124334	0.04	Trapezoid	25	0.01
R320	Automatic Fixed Interval	2051.1	0.0110563	0.04	Trapezoid	25	0.01
R350	Automatic Fixed Interval	1270.5	0.0113155	0.04	Trapezoid	25	0.01
R360	Automatic Fixed Interval	4512	0.0204781	0.04	Trapezoid	25	0.01
R370	Automatic Fixed Interval	2221.1	0.0162326	0.04	Trapezoid	25	0.01
R380	Automatic Fixed Interval	1630.5	0.0099017	0.04	Trapezoid	25	0.01

R400	Automatic Fixed Interval	1458.8	0.0050029	0.04	Trapezoid	25	0.01
R430	Automatic Fixed Interval	9928.4	0.0122011	0.04	Trapezoid	25	0.01
R450	Automatic Fixed Interval	387.28	0.0350356	0.04	Trapezoid	25	0.01
R460	Automatic Fixed Interval	2055.1	0.0093164	0.04	Trapezoid	25	0.01
R500	Automatic Fixed Interval	933.26	0.0150258	0.04	Trapezoid	25	0.01
R520	Automatic Fixed Interval	1074	0.0097336	0.04	Trapezoid	25	0.01

Annex 11. Patawag Field Validation Points

Table A-11.1. Patawag Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	8.091371	122.63623	1.03	0.80	0.23	Not Defined	5 -Year
2	8.118603	122.68934	0.60	0.40	0.20	Not Defined	5 -Year
3	8.120389	122.68091	0.67	0.50	0.17	Not Defined	5 -Year
4	8.120532	122.68182	0.57	0.80	-0.23	Not Defined	5 -Year
5	8.120433	122.68265	0.57	0.40	0.17	Not Defined	5 -Year
6	8.071793	122.64722	0.03	0.00	0.03	Not Defined	5 -Year
7	8.07417	122.64754	0.03	0.00	0.03	Not Defined	5 -Year
8	8.074832	122.64842	0.03	0.00	0.03	Not Defined	5 -Year
9	8.060207	122.64519	0.06	0.00	0.06	Not Defined	5 -Year
10	8.060592	122.64472	0.03	0.00	0.03	Not Defined	5 -Year
11	8.069034	122.64717	0.03	0.00	0.03	Not Defined	5 -Year
12	8.078757	122.64802	0.03	0.00	0.03	Not Defined	5 -Year
13	8.082621	122.64996	0.03	0.00	0.03	Not Defined	5 -Year
14	8.087756	122.65549	0.03	0.00	0.03	Not Defined	5 -Year
15	8.089358	122.67147	0.03	0.00	0.03	Not Defined	5 -Year
16	8.087266	122.67362	0.03	0.00	0.03	Not Defined	5 -Year
17	8.085404	122.67574	0.06	0.00	0.06	Not Defined	5 -Year
18	8.081827	122.64388	0.03	0.00	0.03	Not Defined	5 -Year
19	8.085526	122.64348	0.03	0.00	0.03	Not Defined	5 -Year
20	8.087143	122.6419	0.03	0.00	0.03	Not Defined	5 -Year
21	8.087084	122.638	0.03	0.00	0.03	Not Defined	5 -Year
22	8.089339	122.63684	0.03	0.00	0.03	Not Defined	5 -Year
23	8.094359	122.63486	0.60	0.00	0.60	Not Defined	5 -Year
24	8.096211	122.6364	0.03	0.00	0.03	Not Defined	5 -Year
25	8.09699	122.63448	0.03	0.00	0.03	Not Defined	5 -Year
26	8.102075	122.63085	0.03	0.00	0.03	Not Defined	5 -Year
27	8.101615	122.63007	0.03	0.00	0.03	Not Defined	5 -Year
28	8.103323	122.62805	0.04	0.00	0.04	Not Defined	5 -Year
29	8.103641	122.62742	0.03	0.00	0.03	Not Defined	5 -Year
30	8.105646	122.62419	0.07	0.00	0.07	Not Defined	5 -Year
31	8.106753	122.62399	0.21	0.00	0.21	Not Defined	5 -Year
32	8.106353	122.6228	0.41	0.50	-0.09	Not Defined	5 -Year
33	8.107978	122.62315	0.03	0.50	-0.47	Not Defined	5 -Year
34	8.105073	122.62753	0.11	0.00	0.11	Not Defined	5 -Year
35	8.108328	122.63333	0.03	0.00	0.03	Not Defined	5 -Year
36	8.108719	122.63482	0.03	0.00	0.03	Not Defined	5 -Year
37	8.062887	122.61452	0.03	0.00	0.03	Not Defined	5 -Year
38	8.062713	122.61386	0.03	0.00	0.03	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
39	8.080494	122.62212	0.03	0.00	0.03	Not Defined	5 -Year
40	8.082387	122.62302	0.03	0.00	0.03	Not Defined	5 -Year
41	8.128886	122.63807	0.03	0.00	0.03	Not Defined	5 -Year
42	8.129573	122.63918	0.03	0.00	0.03	Not Defined	5 -Year
43	8.125251	122.6477	0.04	0.00	0.04	Not Defined	5 -Year
44	8.124781	122.64697	0.05	0.00	0.05	Not Defined	5 -Year
45	8.114616	122.65214	0.03	0.00	0.03	Not Defined	5 -Year
46	8.114206	122.65186	0.03	0.00	0.03	Not Defined	5 -Year
47	8.112646	122.65531	0.03	0.00	0.03	Not Defined	5 -Year
48	8.111833	122.65527	0.04	0.00	0.04	Not Defined	5 -Year
49	8.110702	122.65427	0.03	0.00	0.03	Not Defined	5 -Year
50	8.110673	122.65499	0.03	0.00	0.03	Not Defined	5 -Year
51	8.110822	122.65519	0.03	0.00	0.03	Not Defined	5 -Year
52	8.127621	122.65875	0.03	0.00	0.03	Not Defined	5 -Year
53	8.128297	122.65918	0.13	0.00	0.13	Not Defined	5 -Year
54	8.128229	122.65834	0.08	0.00	0.08	Not Defined	5 -Year
55	8.127609	122.65733	0.03	0.00	0.03	Not Defined	5 -Year
56	8.127781	122.65804	0.03	0.00	0.03	Not Defined	5 -Year
57	8.133572	122.66066	0.17	0.00	0.17	Not Defined	5 -Year
58	8.134148	122.6601	0.08	0.00	0.08	Not Defined	5 -Year
59	8.134188	122.66065	0.03	0.00	0.03	Not Defined	5 -Year
60	8.136899	122.65981	0.10	0.00	0.10	Not Defined	5 -Year
61	8.137351	122.65969	0.05	0.00	0.05	Not Defined	5 -Year
62	8.119332	122.68893	0.25	0.00	0.25	Not Defined	5 -Year
63	8.118785	122.68882	0.40	0.50	-0.10	Not Defined	5 -Year
64	8.119011	122.68834	0.06	0.00	0.06	Not Defined	5 -Year
65	8.119202	122.68304	0.08	0.00	0.08	Not Defined	5 -Year
66	8.119072	122.68242	0.06	0.00	0.06	Not Defined	5 -Year
67	8.119576	122.68185	0.03	0.00	0.03	Not Defined	5 -Year
68	8.119693	122.68057	0.50	0.00	0.50	Not Defined	5 -Year
69	8.113979	122.68664	0.03	0.00	0.03	Not Defined	5 -Year
70	8.115493	122.68724	0.03	0.50	-0.47	Not Defined	5 -Year
71	8.1166	122.68736	0.03	0.00	0.03	Not Defined	5 -Year
72	8.119145	122.68167	0.14	0.00	0.14	Not Defined	5 -Year
73	8.115751	122.68033	0.03	0.00	0.03	Not Defined	5 -Year
74	8.116586	122.67883	0.03	0.00	0.03	Not Defined	5 -Year
75	8.107147	122.67499	0.03	0.00	0.03	Not Defined	5 -Year
76	8.10781	122.67615	0.03	0.00	0.03	Not Defined	5 -Year
77	8.10721	122.6761	0.03	0.00	0.03	Not Defined	5 -Year
78	8.107901	122.67738	0.03	0.00	0.03	Not Defined	5 -Year
79	8.108351	122.6768	0.03	0.00	0.03	Not Defined	5 -Year
80	8.110211	122.68001	0.03	0.00	0.03	Not Defined	5 -Year
81	8.110145	122.67857	0.03	0.00	0.03	Not Defined	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	8.110599	122.67747	0.03	0.00	0.03	Not Defined	5 -Year
83	8.111267	122.67805	0.03	0.00	0.03	Not Defined	5 -Year
84	8.11058	122.67806	0.03	0.00	0.03	Not Defined	5 -Year
85	8.10919	122.67869	0.03	0.00	0.03	Not Defined	5 -Year
86	8.109998	122.67951	0.03	0.00	0.03	Not Defined	5 -Year
87	8.120102	122.67911	0.03	0.00	0.03	Not Defined	5 -Year
88	8.11901	122.67892	0.15	0.00	0.15	Not Defined	5 -Year
89	8.119632	122.67838	0.03	0.00	0.03	Not Defined	5 -Year
90	8.1182	122.67869	0.05	0.00	0.05	Not Defined	5 -Year
91	8.110737	122.66794	0.03	0.00	0.03	Not Defined	5 -Year
92	8.118453	122.68342	0.03	0.00	0.03	Not Defined	5 -Year
93	8.114534	122.67888	0.03	0.00	0.03	Not Defined	5 -Year
94	8.083452	122.67735	0.04	0.20	-0.16	Not Defined	5 -Year
95	8.115438	122.63381	0.03	0.50	-0.47	Not Defined	5 -Year
96	8.115548	122.63341	0.03	0.30	-0.27	Not Defined	5 -Year
97	8.120357	122.68644	0.10	0.10	0.00	Not Defined	5 -Year
98	8.116515	122.66888	0.03	0.50	-0.47	Not Defined	5 -Year
99	8.126267	122.65999	0.06	0.50	-0.44	Not Defined	5 -Year
100	8.120254	122.65015	0.03	0.50	-0.47	Not Defined	5 -Year
101	8.112983	122.65438	0.03	0.50	-0.47	Not Defined	5 -Year
102	8.119231	122.68937	0.06	1.00	-0.94	Not Defined	5 -Year
103	8.120116	122.68743	0.08	1.30	-1.22	Not Defined	5 -Year
104	8.105654	122.61933	0.03	0.50	-0.47	Not Defined	5 -Year
105	8.104768	122.62056	0.03	0.00	0.03	Not Defined	5 -Year
106	8.086166	122.66308	0.03	0.00	0.03	Not Defined	5 -Year
107	8.121234	122.65019	0.03	0.10	-0.07	Not Defined	5 -Year
108	8.127438	122.65903	0.03	0.00	0.03	Not Defined	5 -Year
109	8.11985	122.68628	0.54	0.20	0.34	Not Defined	5 -Year
				RMSE	0.22		

Annex 12. Educational Institutions affected by flooding in Patawag Floodplain

Table A-12.1. Educational Institutions affected by flooding in Patawag Floodplain (a)

Liloy				
		Rainfall Scenario		
Barangay	Building	5-year	25-year	100-year
Communal	Daycare center			
Communal	Maigang elementary school			
Communal	School office			
Communal	Store			
Communal	Communal Elementary School			
Communal	Gate			
Communal	TESDA			
Fatima	Ave Maria colleges			
New Bethlehem	Silucap central school			
Patawag	Patawag Elementary School			
Patawag	Vacant room			
Patawag	School Stage			
Patawag	Zozobrado family			
Patawag	Daycare center			
Banigan	School kitchen			
Banigan	Banigan elem. School			
Baybay	LESSON SCHOOL			
Baybay	Liloy 2 Elementary			
Baybay	Liloy All Elemtary			
Baybay	TESDA			
Baybay	Ave Maria colleges			
Baybay	Day Care Center			
San Miguel	Lomoljo family			
Silucap	Silucap Elementary School			

Table A-12.2. Educational Institutions affected by flooding in Patawag Floodplain (b)

Labason				
		Rainfall Scenario		
Barangay	Building	5-year	25-year	100-year
Patawag	Patawag Labason elementary School			
Patawag	Patawag High School			
Patawag	Patawag elem. School			

Annex 13. Health Institutions affected by flooding in Patawag Floodplain

Table A-13.1. Health Institutions affected by flooding in Patawag Floodplain

Liloy				
Barangay	Building	Rainfall Scenario		
		5-year	25-year	100-year
Communal	Health center			
Communal	Day care TAPICAN			
Patawag	Health center			
Baybay	Saint Vincent medical clinic			
Baybay	Barangay Health Center			
Santa Cruz	Health center			
Tapican	Day care TAPICAN			