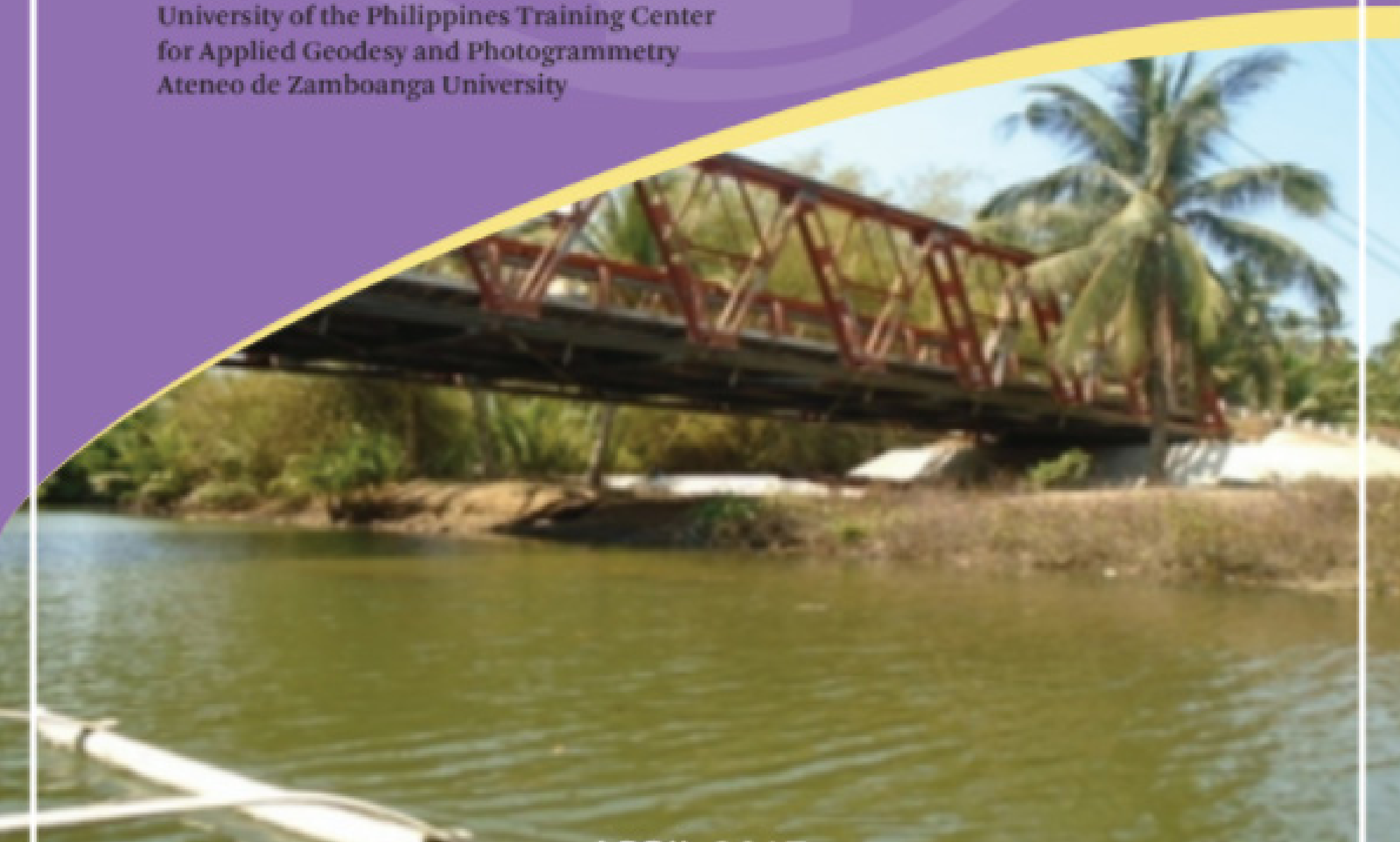
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Labason River

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



APRIL 2017

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

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

L. P. Balicanta, C. Cruz, L. G. Acuña, G. Hipolito, G. B. Sinadjan, S. C. Poblete, M. O. Ang, J. D. Fabila, S. D. Samalburo, G. M. Apat , M. L. Olanda , D. B. Banatin, J. Y. Francisco, C. Lubiano , D. M. Bool, E. C. Tong, J. S. Caballero, P. P. dela Cruz, K. B. Borromeo, J. M. Amante, M. R. Estipona, C. V. Manliguez, J. Jupiter, V. M. Rivera, A. M. Lagmay, C. Uichanco, S. Sueno, M. Moises, H. Ines, M. del Rosario, K. Punay, N. Tingin (2017), LiDAR Surveys and Flood Mapping Report of Labason River, in Enrico C. Paringit (Ed.) Flood Hazard Mapping of the Philippines using LIDAR. Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-155 pp.

For questions/queries regarding this report, contact:

Mr. Mario S. Rodriguez
Project Leader, Phil-LiDAR 1 Program
Ateneo de Zamboanga University
Zamboanga City, Philippines 7000
E-mail: rodriguezmars@adzu.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADZU	Ateneo de Zamboanga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LABASON RIVER

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

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 18 river basins in the Western Mindanao Region. The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Labason River Basin

The Labason River Basin covers one (1) small municipality in Zamboanga del Norte, which is the municipality of Labason. The DENR River Basin Control Office (RBCO) states that the Labason River Basin has a drainage area of 203 km² and an estimated 152 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Labason River, is part of the eighteen (18) river systems under the PHIL-LIDAR 1 Program partner HEI, ADZU. It is located at the center of the municipality and comprises a watershed area of 34.48 sq km. It is 13.98 km long and traverses through the most populated barangays of the municipality.

The area was first inhabited by the Subanen Tribe and eventually followed by the Muslims, Cebuanos and Boholanos. In fact, the name of the municipality came from the Cebuano word “Lab-as” which means fresh. Historically, the municipality was said to be a source of fresh seafood products from the Sulu Sea.
According to the 2015 national census of PSA, a total of 4,195persons are residing in Brgy. Osukanin the Municipality of Labason, which is within the immediate vicinity of the river.

Figure 1. Labason River, January 2017

The economy of the province Zamboanga del Norte largely rests on agriculture particularly fishing, and mineral extraction (Zambonor, n.d.). In this way, the Labason River plays an important role in the economy of the municipality as it is one of major water resource in the municipality. It supplies water for the irrigation of vast areas of rice fields and also provides growing spaces for nipa palms.

Labason is also known in the province for Murcielagos Island (locally known as Bayangan Island). The Department of Environment and Natural Resources has declared this island as a protected area. Aside from the marine life, Murcielagos- Bayangan Island is also known for the different species of waterbirds which often visits the area.

Figure 2. Murcielagos- Bayangan Island, Labason

However, flooding is prominent in the areas near the Labason River. The Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Labason has recorded several incidences in which the river overflowed. In 2000, 2001 and 2012, the overflow resulted in flooding in the Poblacion area of the municipality. Most of the barangays affected were the densely populated barangays but no casualty was recorded. On February 1, 2017, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Labason 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 (NDRRMC, 2017).

Figure 3. Labason River Flooding in 2012

Because of this recurrent situation, Mayor Eddie Quimbo pointed out the active preparedness and response of the MDRRM Office of the Municipality. Moreover, the Local Government of Labason has also proposed to the Department of Public Works and Highways Region 9, a Php 3,000,000.00 worth flood control project for Labason River last 2016 to ease the flooding incidence in the area.

Sources: Municipal Profile of Labason, LGU of Labason, Municipal MDRRM Plan, LGU of Labason, Historical Flood Events, LGU of Labason, Department of Environment and Natural Resources, Philippine Information Agency, Department of Public Works and Highways

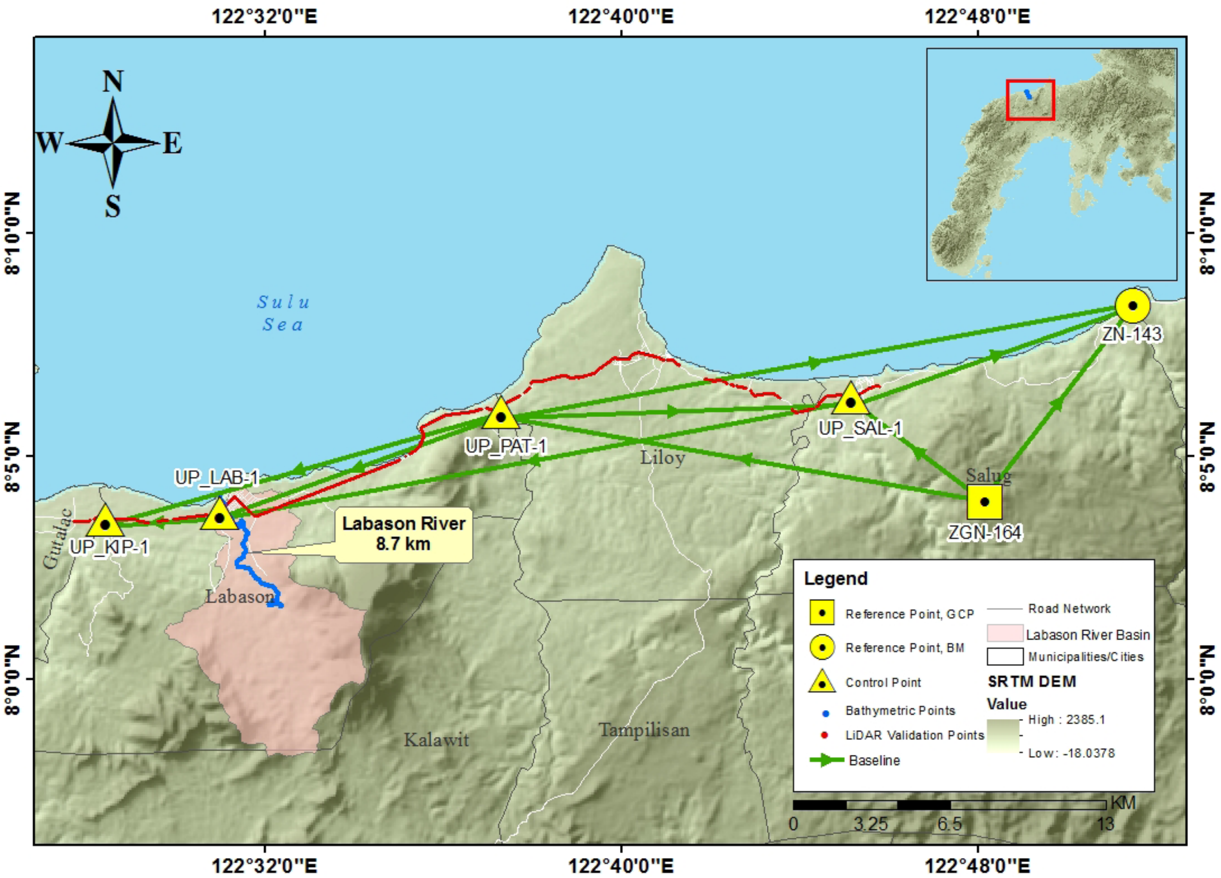


Figure 4. Map of Labason River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LABASON FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, and 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 Labason 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 5 shows the flight plan for Labason 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

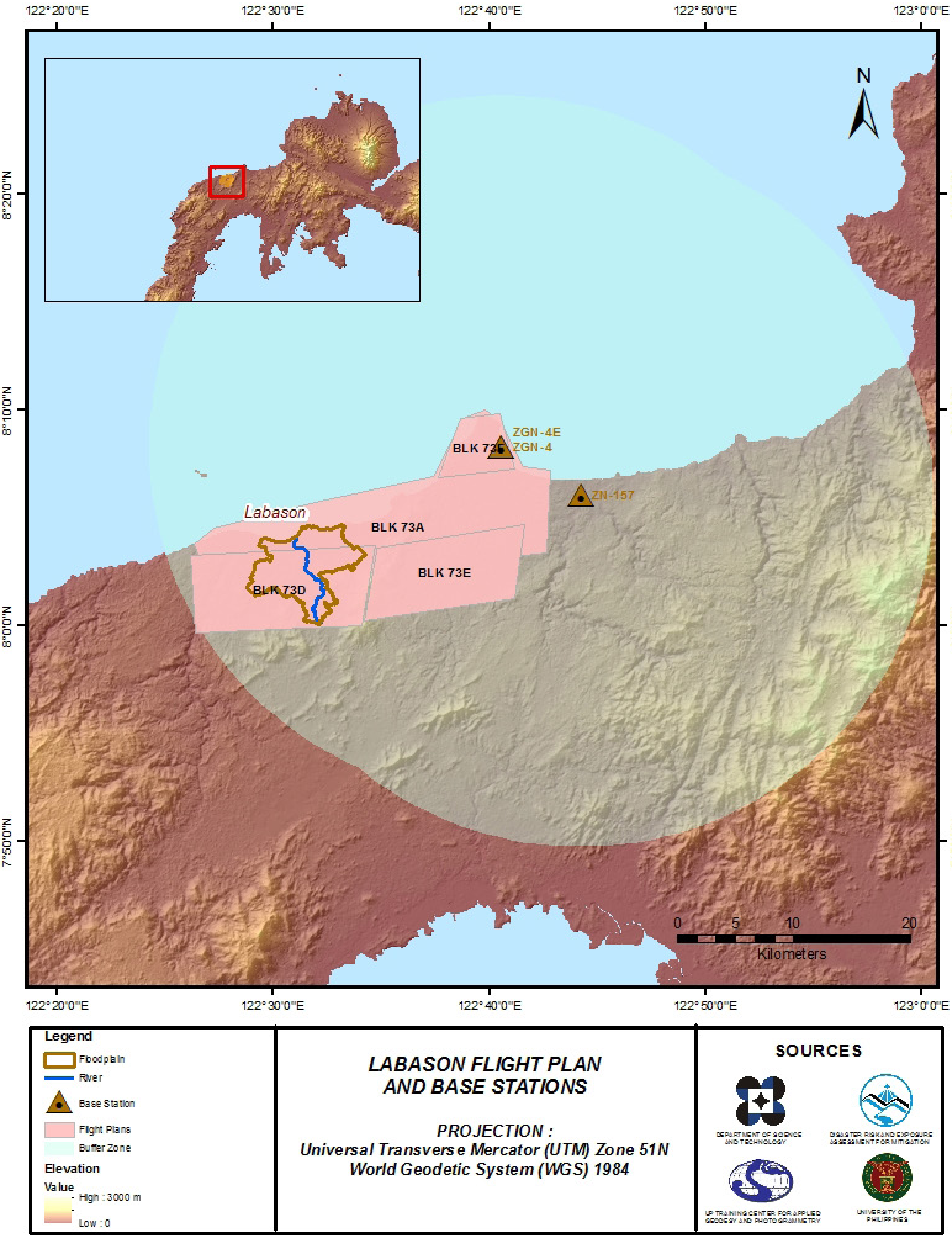


Figure 5. Flight plan and base stations used for Labason Floodplain.

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point,ZGN-4, which is offirst (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 (October 8 to November 11, 2014 and November 20 to 26, 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 Labason Floodplain are shown in Figure 5. The list of team members is found in Annex 4.

Figure 6 shows the recovered NAMRIA reference point within the area. In addition, Table 2 to Table 4 present 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 6. 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	ZGN-4	
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° 8' 20.40827" North 122° 40' 28.89097" East 3.848 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	464,150.413 meters 899,937.404 meters
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	464,162.96 meters 899,622.41 meters

Table 3. Details of the recovered NAMRIA vertical horizontal 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 51 North (UTM 51N PRS 1992)	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 51 North (UTM 51N PRS 1992)	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 Labason 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 Labason Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
November 6, 2014	2169P	223.6	170.41	16.99	153.42	559	4	5
November 10, 2014	2185P	223.6	83.00	6.18	76.82	611	4	30
November 11, 2014	2189P	223.6	79.52	0.12	79.4	950	3	53
November 26, 2016	23582P	178.01	181.39	35.18	146.21	NA	4	23
November 28, 2016	23590P	202.03	130.22	11.88	118.34	NA	4	11
TOTAL		1,050.84	1,050.84	70.35	574.19	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

This certain LiDAR acquisition survey covered the Labason Floodplain (See Annex 7). Labason Floodplain is located along the province of Zamboanga del Norte, with majority of the floodplain situated within the municipality of Labason. 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 Labason Floodplain is presented in Figure 7.

Table 8. List of municipalities and cities surveyed during Labason 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%

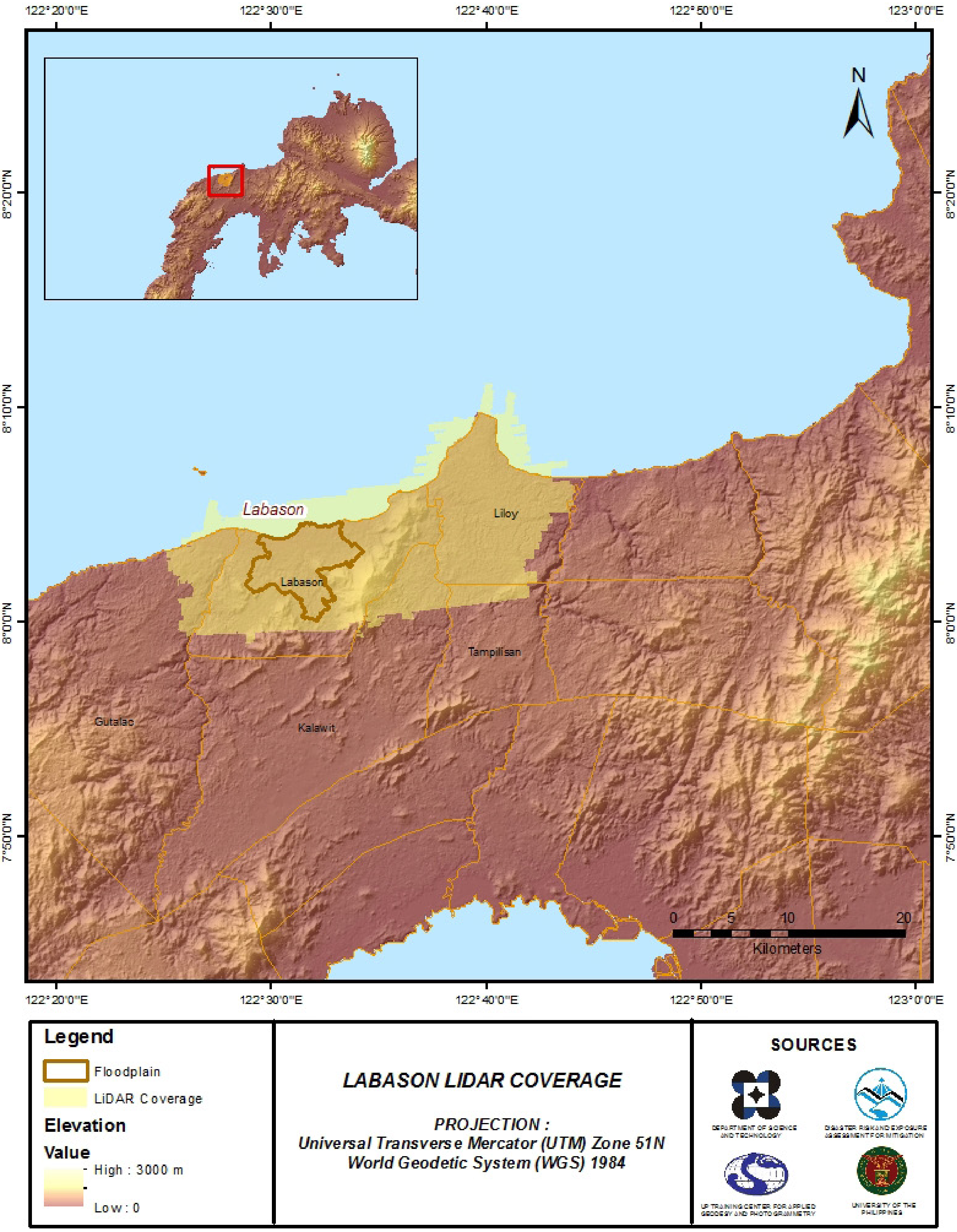


Figure 7. Actual LiDAR survey coverage for Labason Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR LABASON 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. Justine Y. Francisco, Engr. Christy Lubiano , Deane Leonard M. Bool, and 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 8.

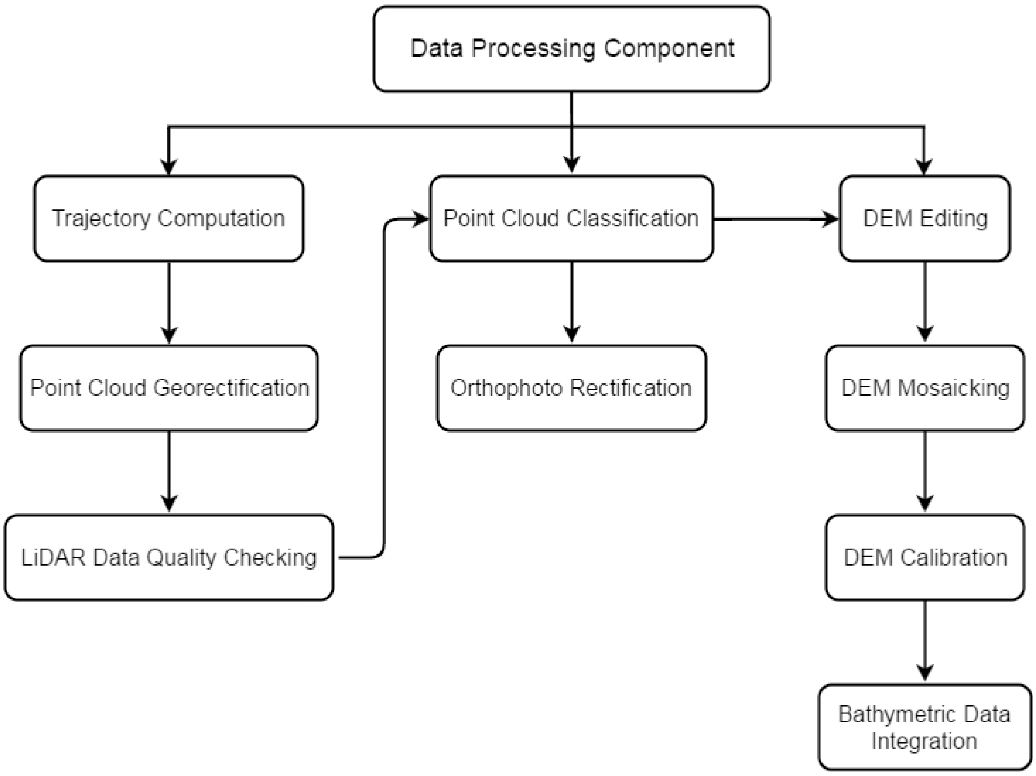


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Labason Floodplain can be found in Annex 5. Missions flown during the survey conducted in November 2011 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.)Pegasus system over Dipolog. The Data Acquisition Component (DAC) transferred a total of98.9 Gigabytes of Range data, 1.20Gigabytes 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 2011.The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Labason was fully transferred on December 6, 2011, as indicated in the Data Transfer Sheets for Labason Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23582P, one of the Labasonflights, which is the North, East, and Down position RMSE values are shown in Figure 9. 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 onDecember 6, 2011 00:00AM. The y-axis is the RMSE value for that particular position.

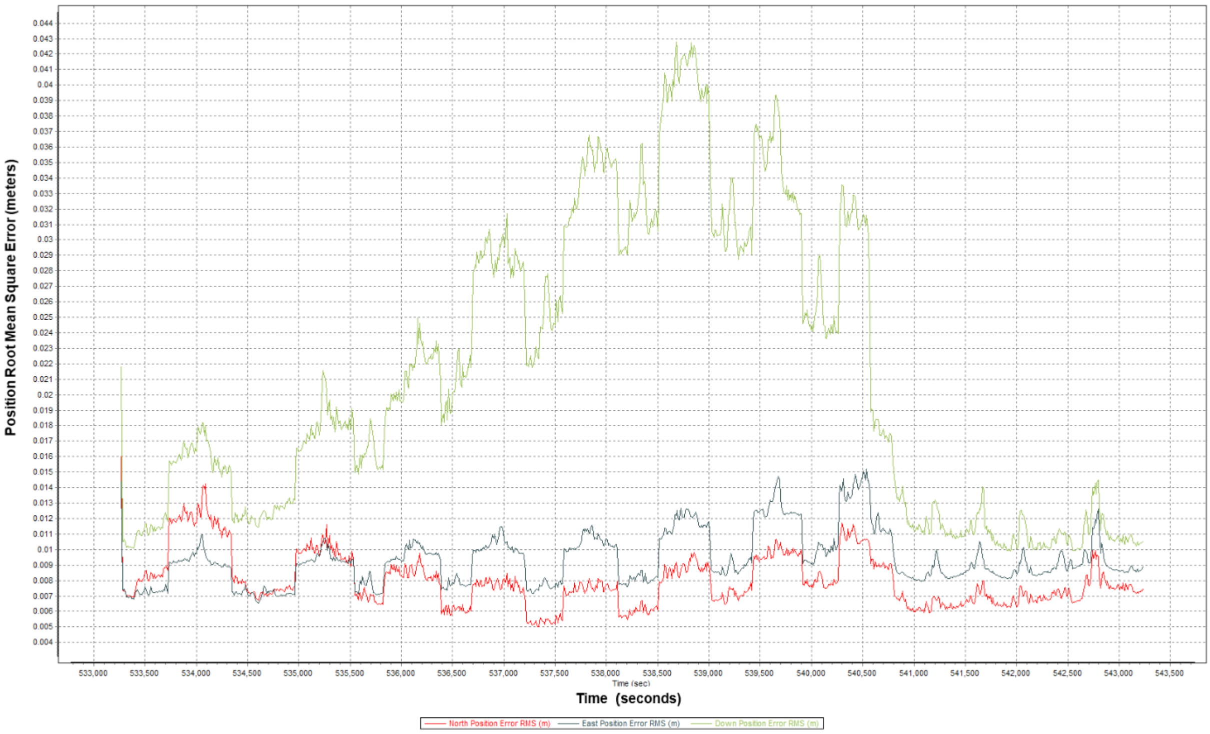


Figure 9. Smoothed Performance Metrics of a LabasonFlight 23582P

The time of flight was from 533000 seconds to 543500 seconds, which corresponds to morning of December 6, 2011. 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 1.40 centimeters, the East position RMSE peaks at 1.50 centimeters, and the Down position RMSE peaks at 4.30centimeters, which are within the prescribed accuracies described in the methodology.

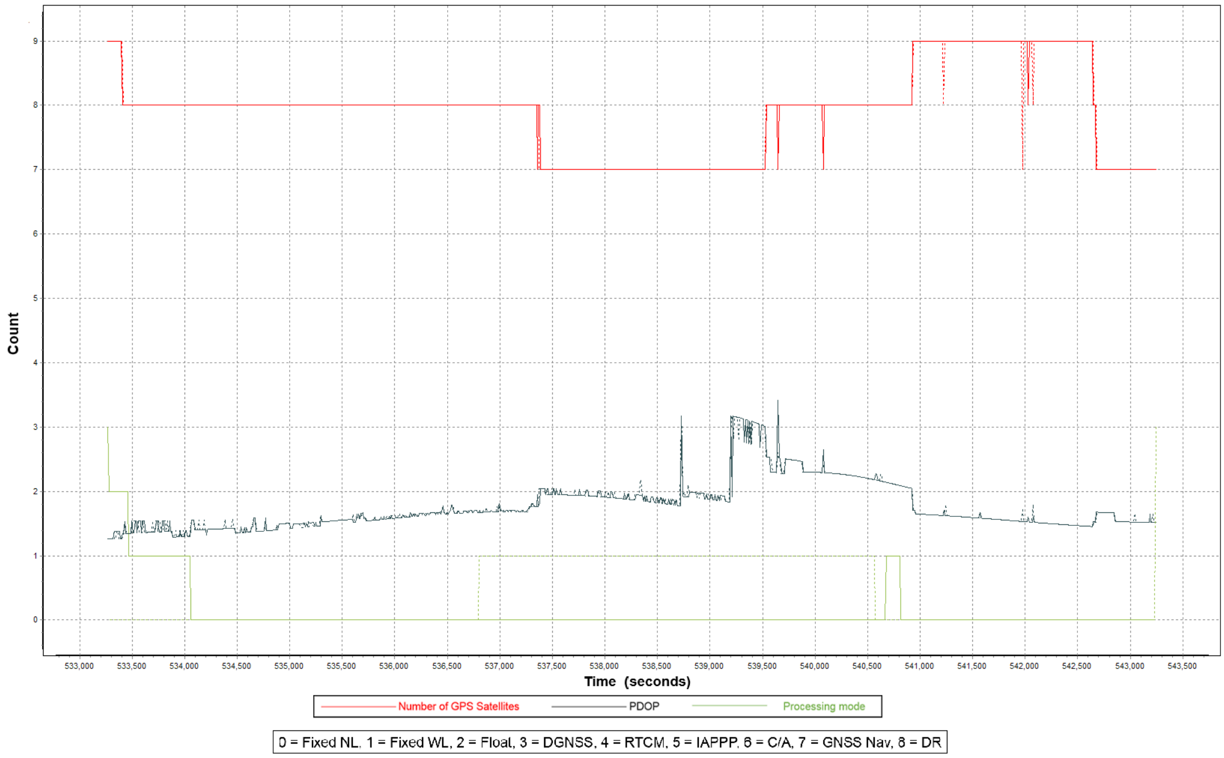


Figure 10. Solution Status Parameters of LabasonFlight 23582P.

The Solution Statusparameters of flight 23582P,one of the Labasonflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6.Majority of the time, the number of satellites tracked was between 7 and 9.The PDOP value also did go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Labason flights is shown in Figure 11.

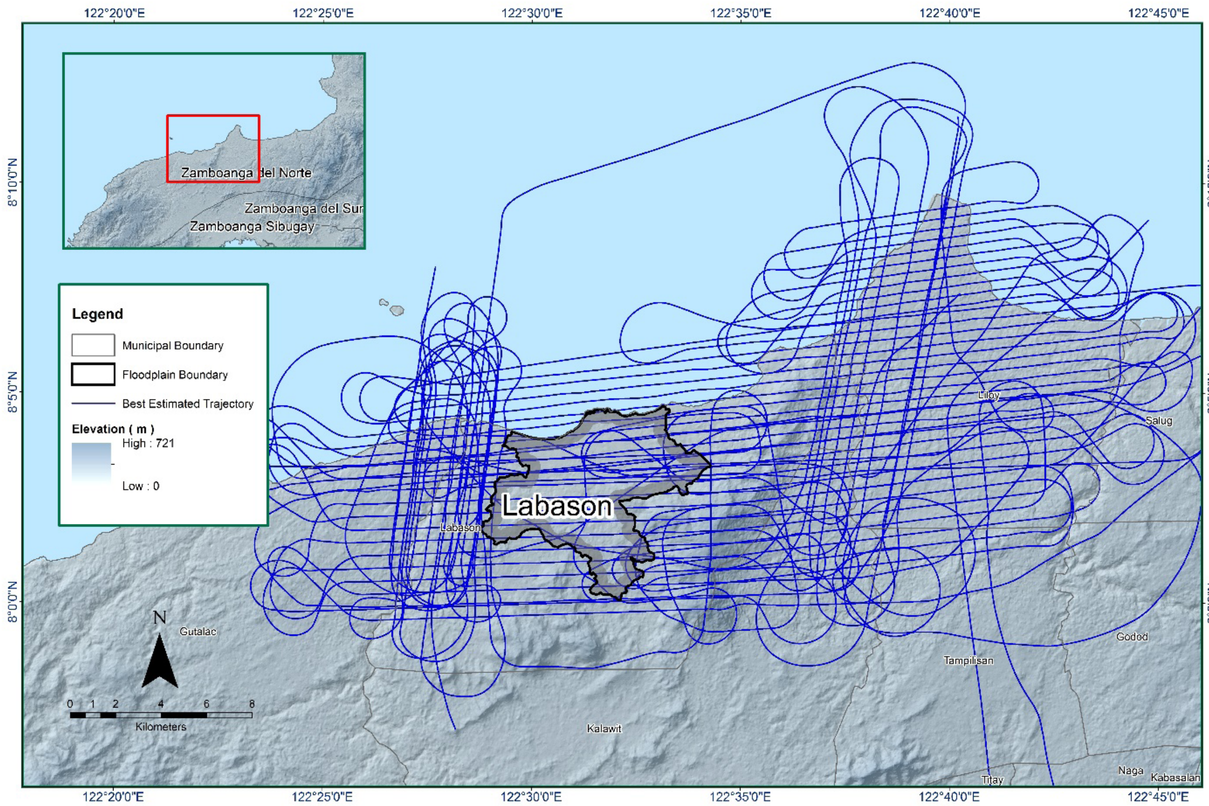


Figure 11. Best Estimated Trajectory of the LiDAR missions conducted over the Labason Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 106flight lines, with each flight line containing two channels, since the Pegasus system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Labason Floodplain are given in Table 9.

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

Parameter	Value
Boresight Correction stdev(<0.001degrees)	0.000147
IMU Attitude Correction Roll and Pitch Corrections stdev(<0.001degrees)	0.000270
GPS Position Z-correction stdev(<0.01meters)	0.0008

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Labason Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

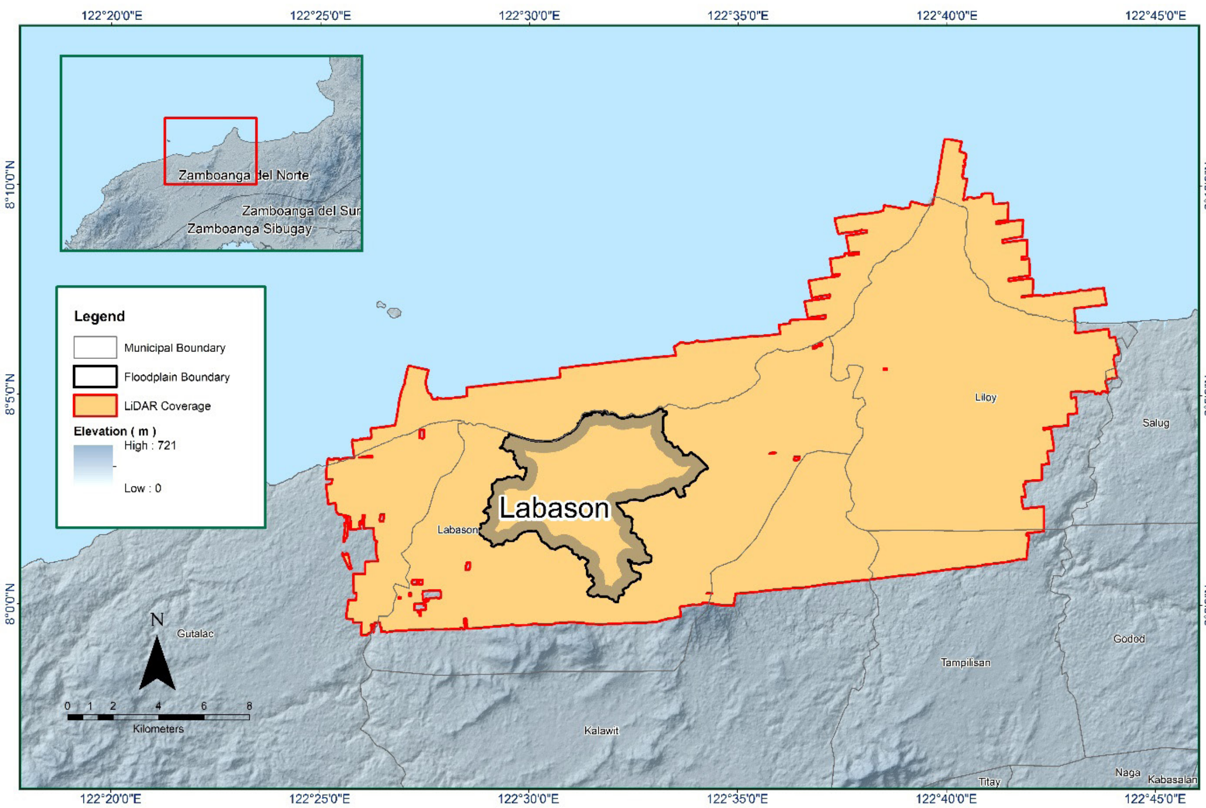


Figure 12. Boundary of the processed LiDAR data over Labason Floodplain

The total area covered by the Labason missions is 510.05 sq.km that is comprised of five (5) flight acquisitions grouped and merged into five (5) blocks as shown in Table 10.

Table 10. Lisst of LiDAR blocks for Labason floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Dipolog_Blk73A	2169P	199.65
	2185P	
	2189P	
Dipolog_Blk73A_additional	2185P	11.77
Dipolog_reflights_Blk73A	23582P	125.71
Dipolog_reflights_Blk73A_additional	23590P	126.40
Dipolog_reflights_Blk73A_supplement	23582P	46.52
TOTAL		**510.05 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 13. Since the Pegasus system employs two channels, an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines are expected.

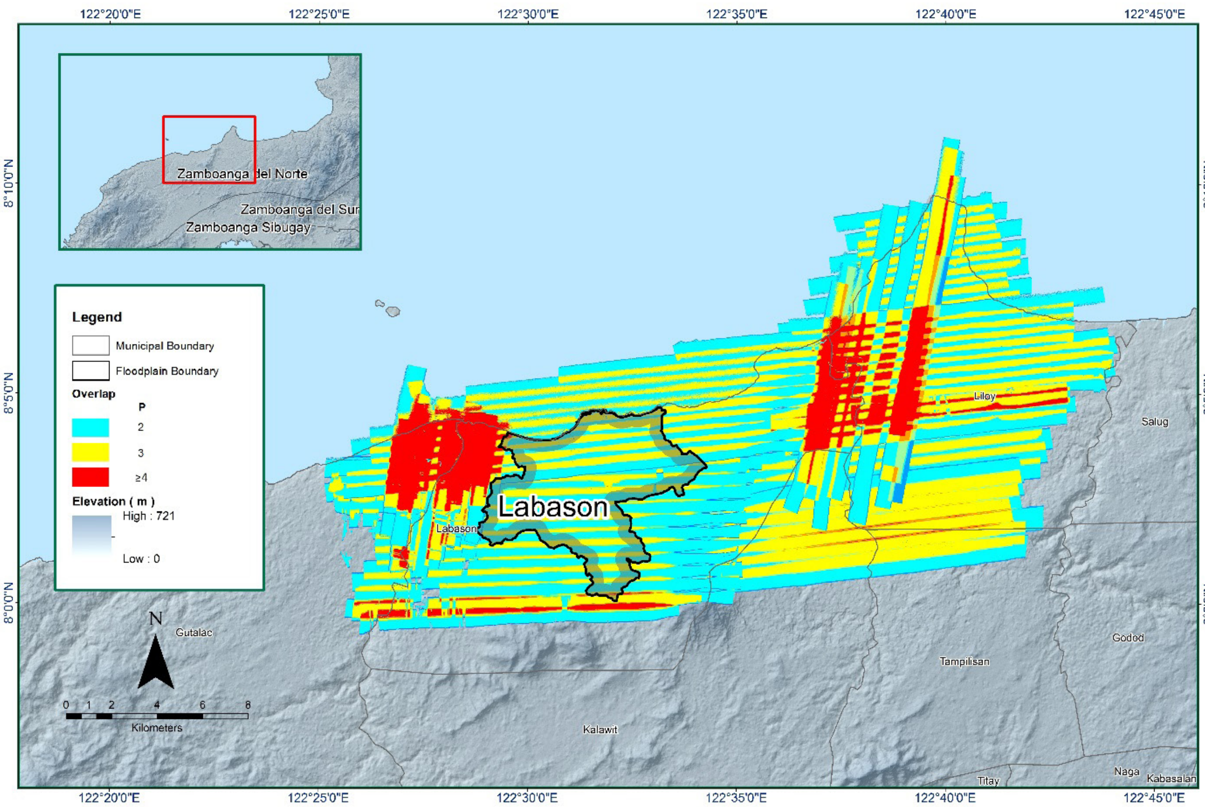


Figure 13. Image of data overlap for Labason Floodplain.

The overlap statistics per block for the Labason Floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlapsare41.33% and 61.13% 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 14. It was determined that all LiDAR data for Labason Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.95 points per square meter.

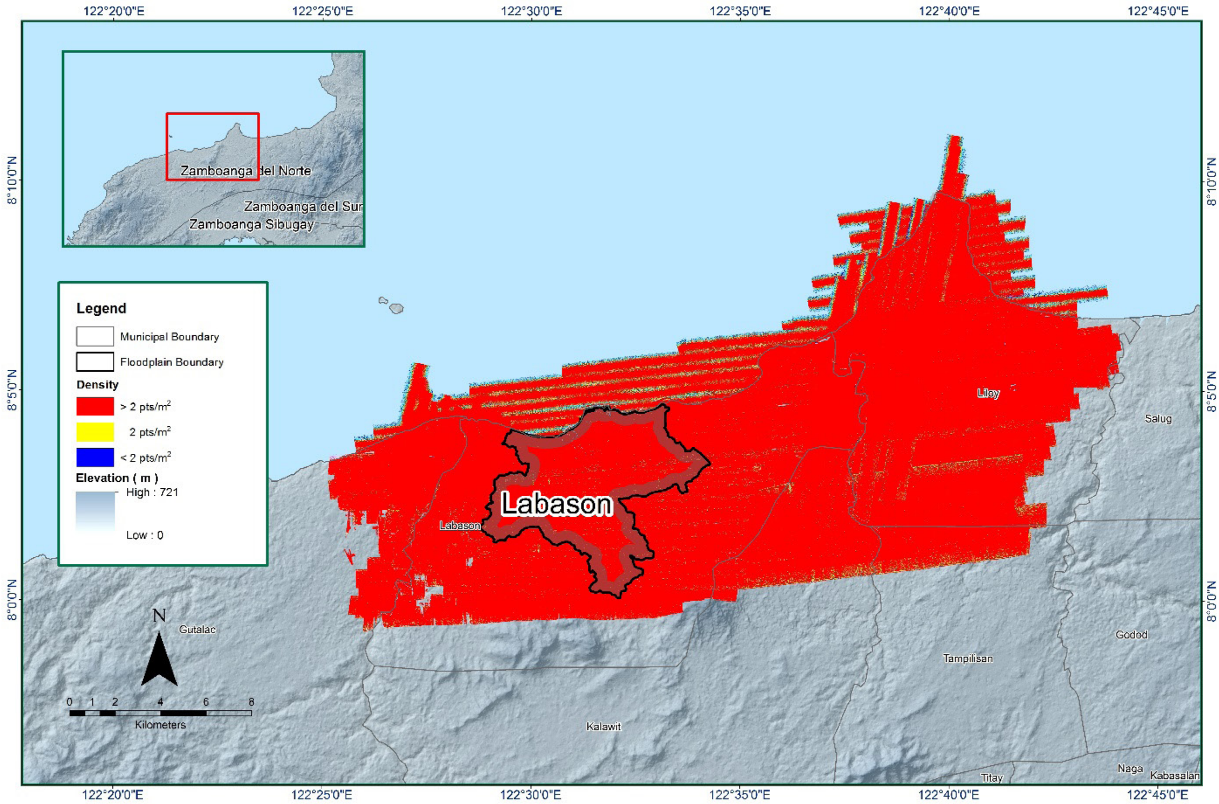


Figure 14. Pulse density map of merged LiDAR data for Labason Floodplain.

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

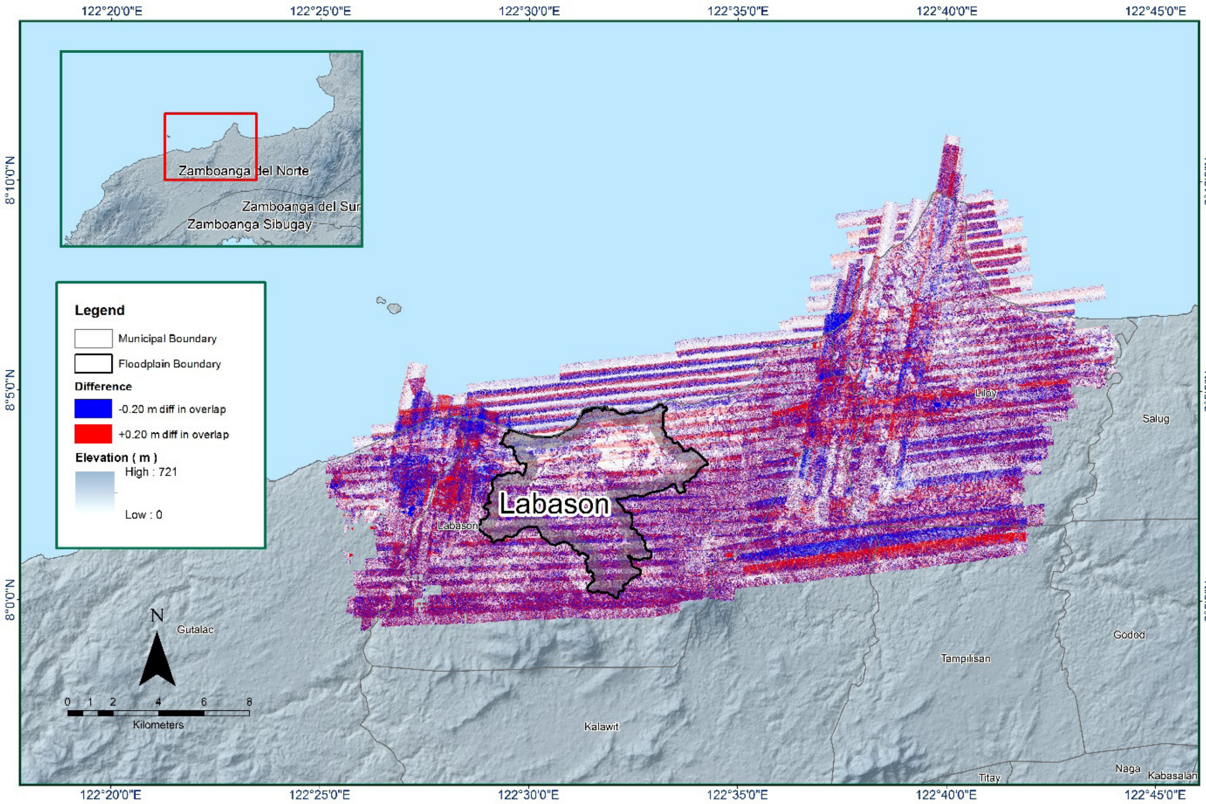


Figure 15. Elevation difference map between flight lines for Labason Floodplain.

A screen capture of the processed LAS data from a Labason flight 23582P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line.The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

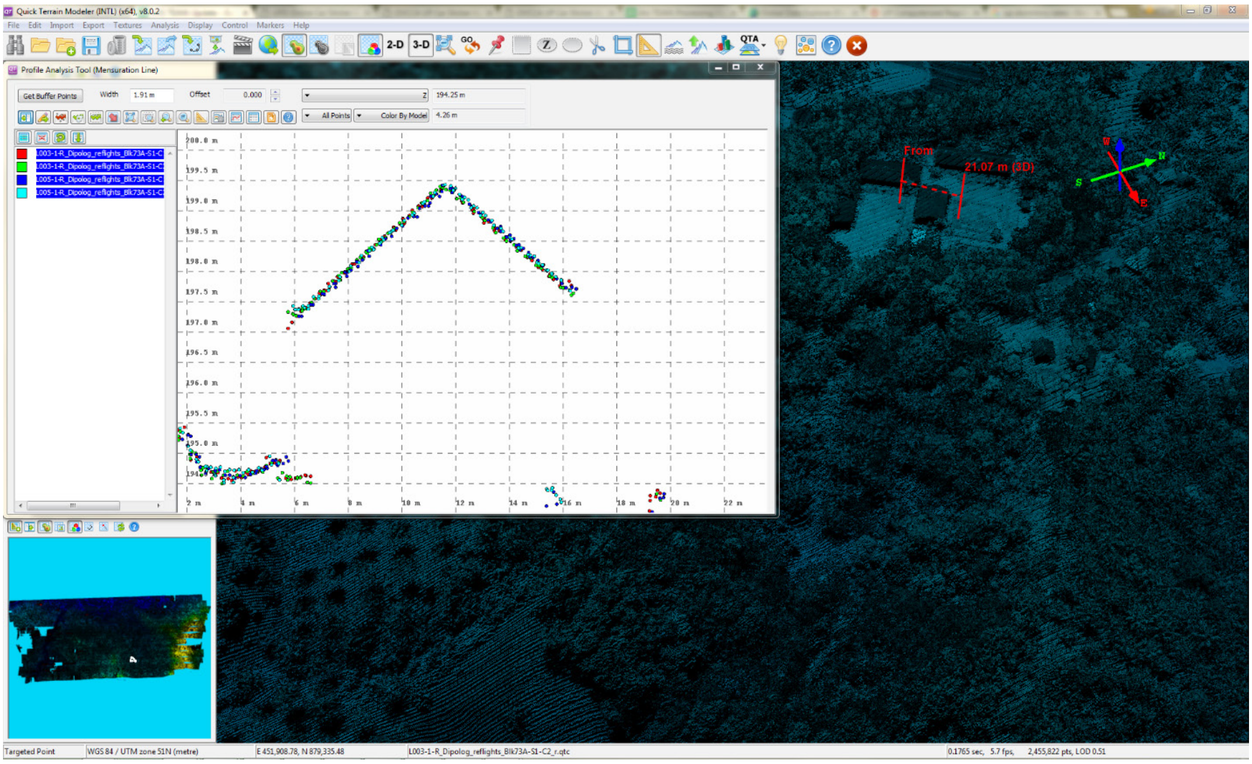


Figure 16. Quality checking for Labason flight 23582P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Labason classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	634,839,060
Low Vegetation	652,728,625
Medium Vegetation	1,138,703,473
High Vegetation	1,621,799,926
Building	31,977,136

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Labason Floodplain is shown in Figure 17. A total of 723 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 845.05meters and 53.96meters respectively.

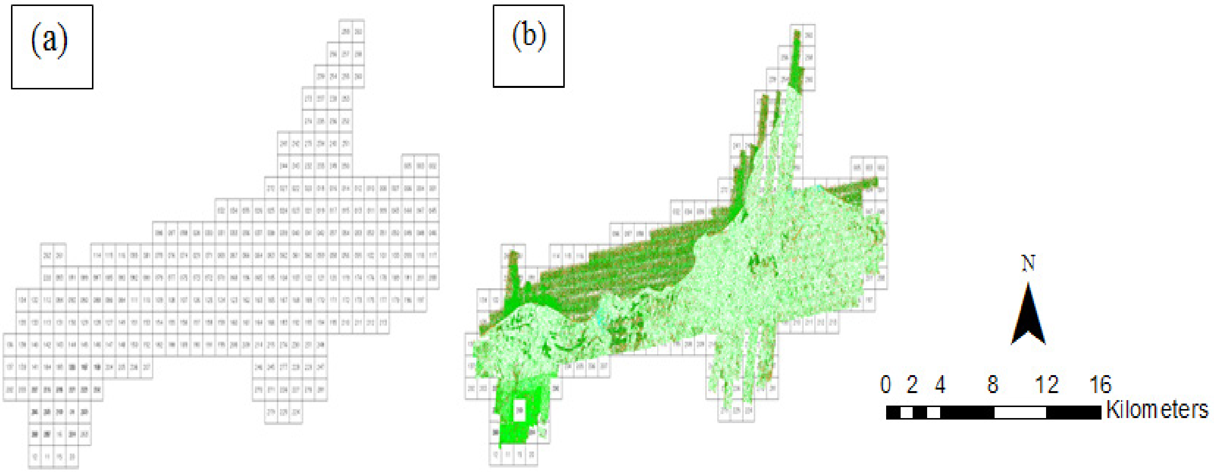


Figure 17. Tiles for Labason Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are 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.

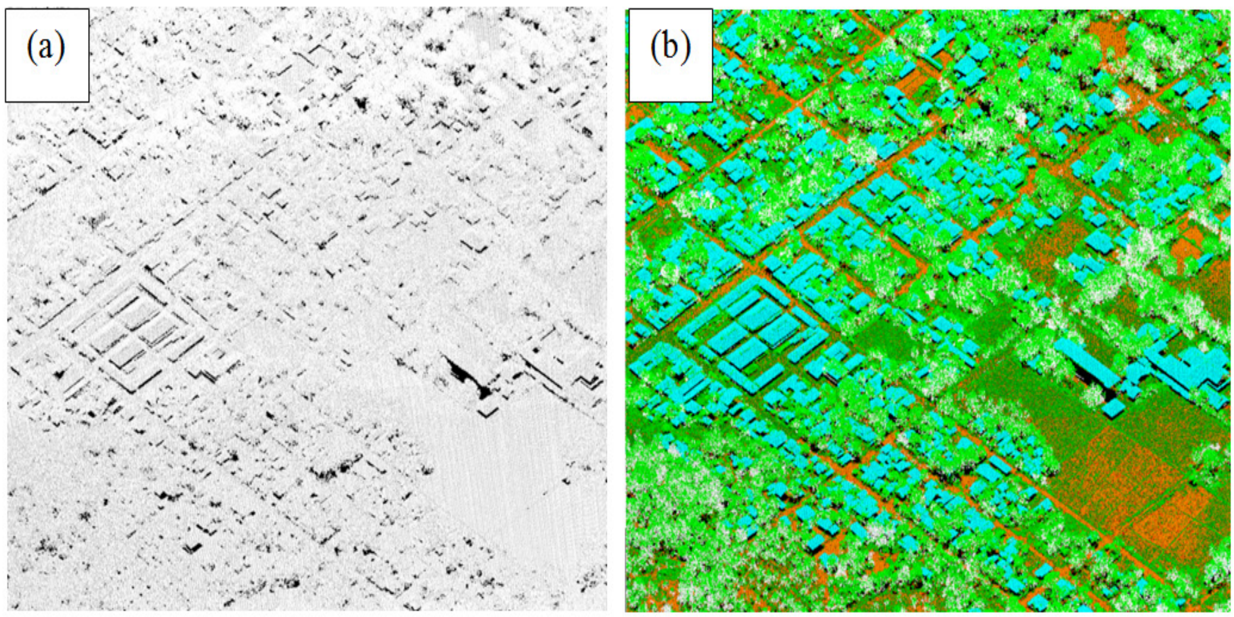


Figure 18. Point cloud before (a) and after (b) classification.

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

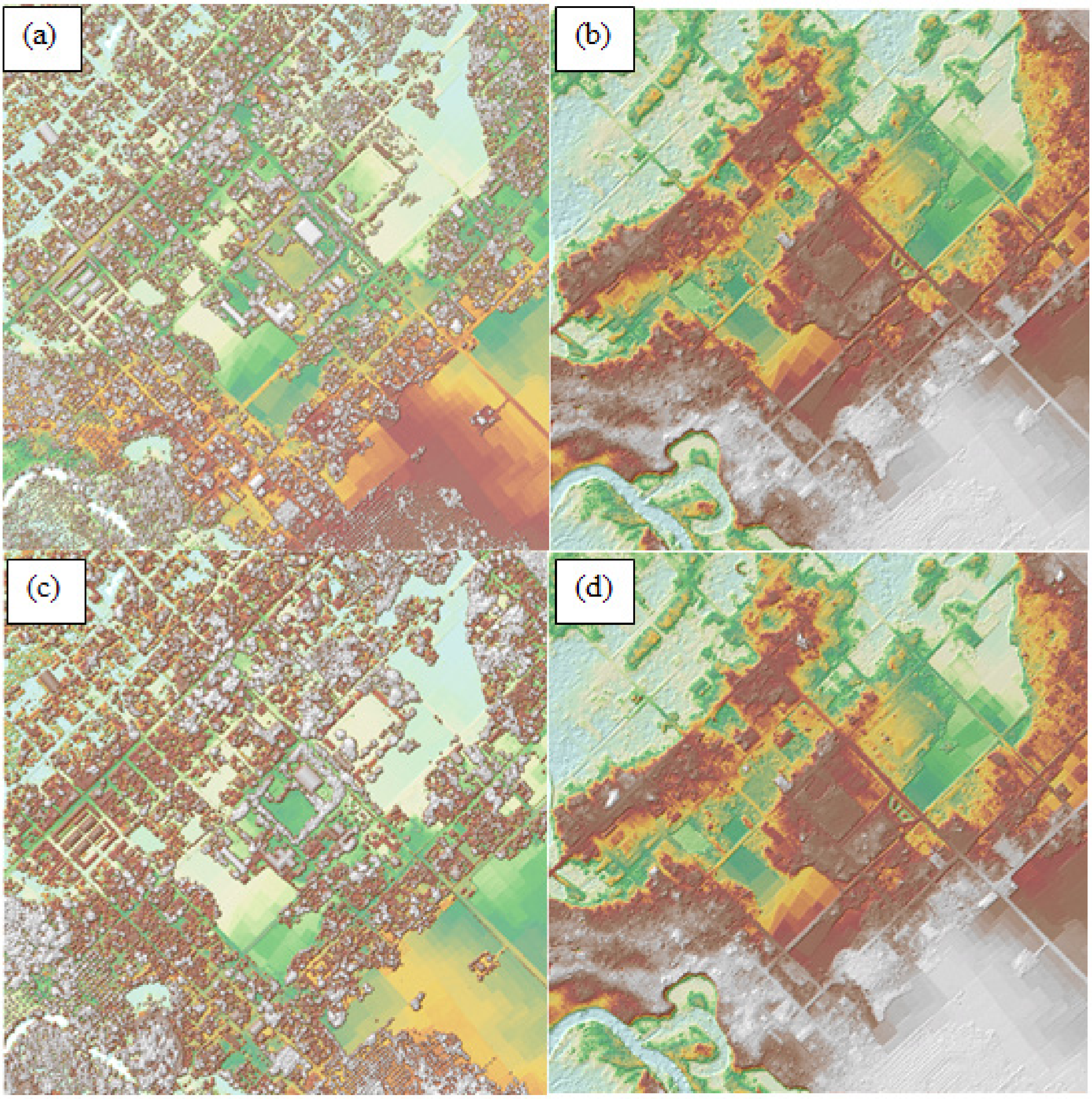


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Labason Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Labason floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Labason Floodplain. These blocks are composed of Dipolog and Dipolog_reflights blocks with a total area of 510.05 sq. km. 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_Blk73A_additional	11.77
Dipolog_reflights_Blk73A	125.71
Dipolog_reflights_Blk73A_additional	126.40
Dipolog_reflights_Blk73A_supplement	46.52
TOTAL	**510.05 sq.km**

Portions of DTM before and after manual editing are shown in Figure 20. The portion of the mountain (Figure 20a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 20b) to allow the correct flow of water. The bridge (Figure 20c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 20d) in order to hydrologically correct the river.

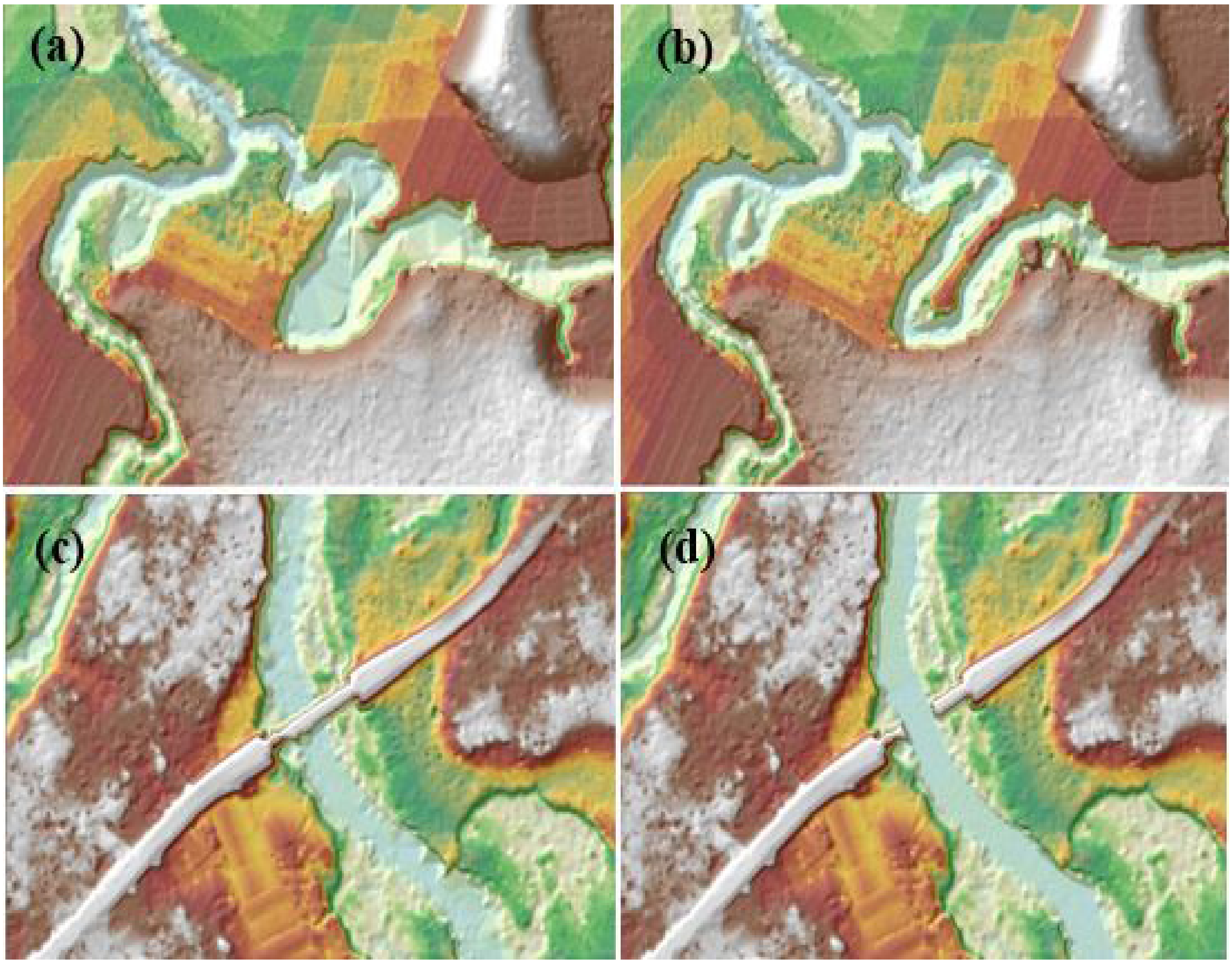


Figure 20. Portions in the DTM of Labason Floodplain – a cut portion of the mountain before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

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 Labason Floodplain is shown in Figure 21. It can be seen that the entire Labason Floodplain is 100% covered by LiDAR data.

Table 13. Shift Values of each LiDAR Block of Labason 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_reflight_Blk73A	0.00	0.00	0.68
Dipolog_reflights_Blk73A_additional(Upper)	0.85	0.39	0.58
Dipolog_reflights_Blk73A_additional(Lower)	0.26	0.52	0.49
Dipolog_reflight_Blk73A_supplement	0.00	0.00	0.58

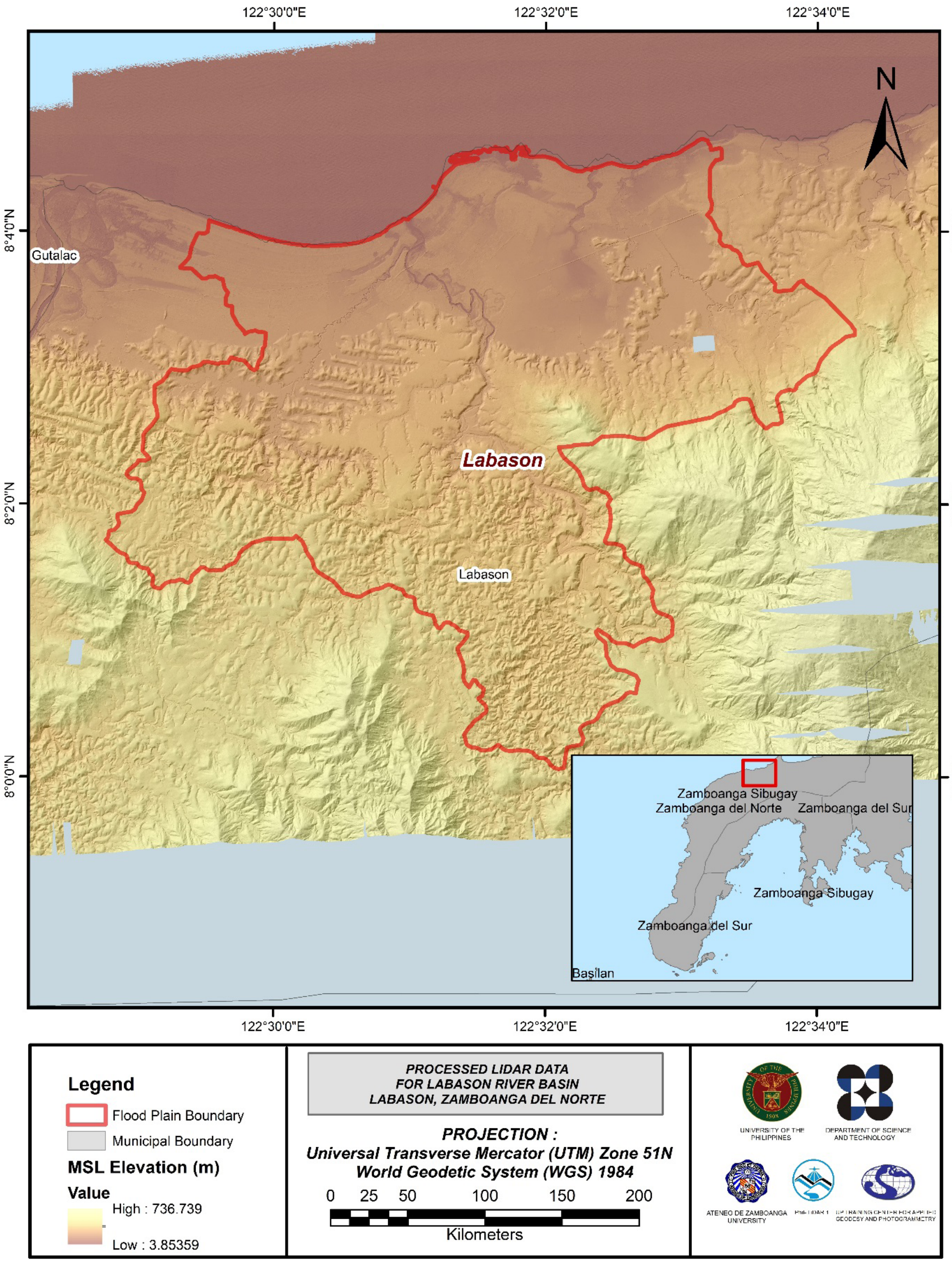


Figure 21. Map of Processed LiDAR Data for Labason Floodplain.

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 Labason to collect points with which the LiDAR dataset is validated is shown in Figure 22. 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 Labason 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 23. 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.

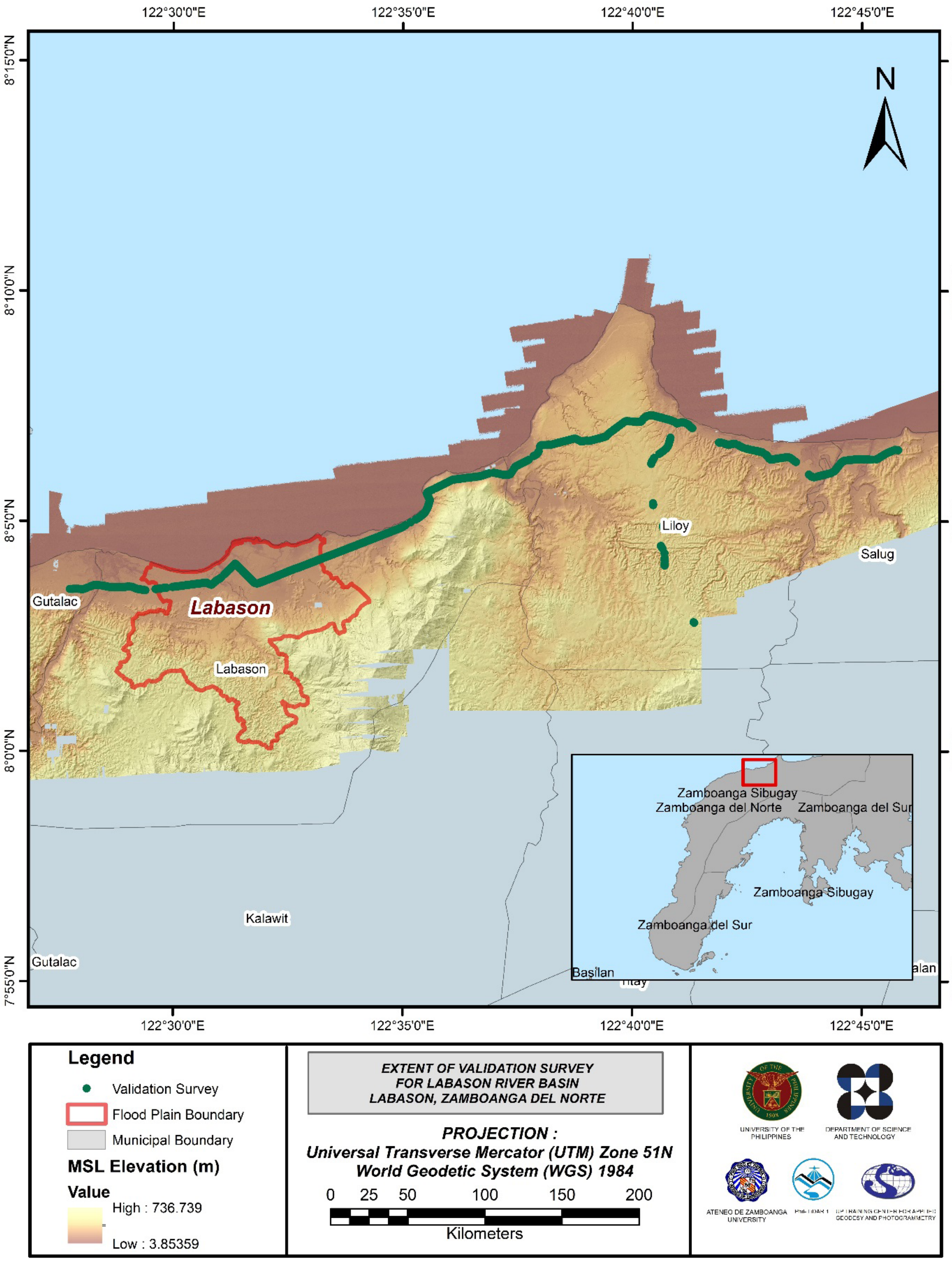


Figure 22. Map of Labason Floodplain with validation survey points in green.

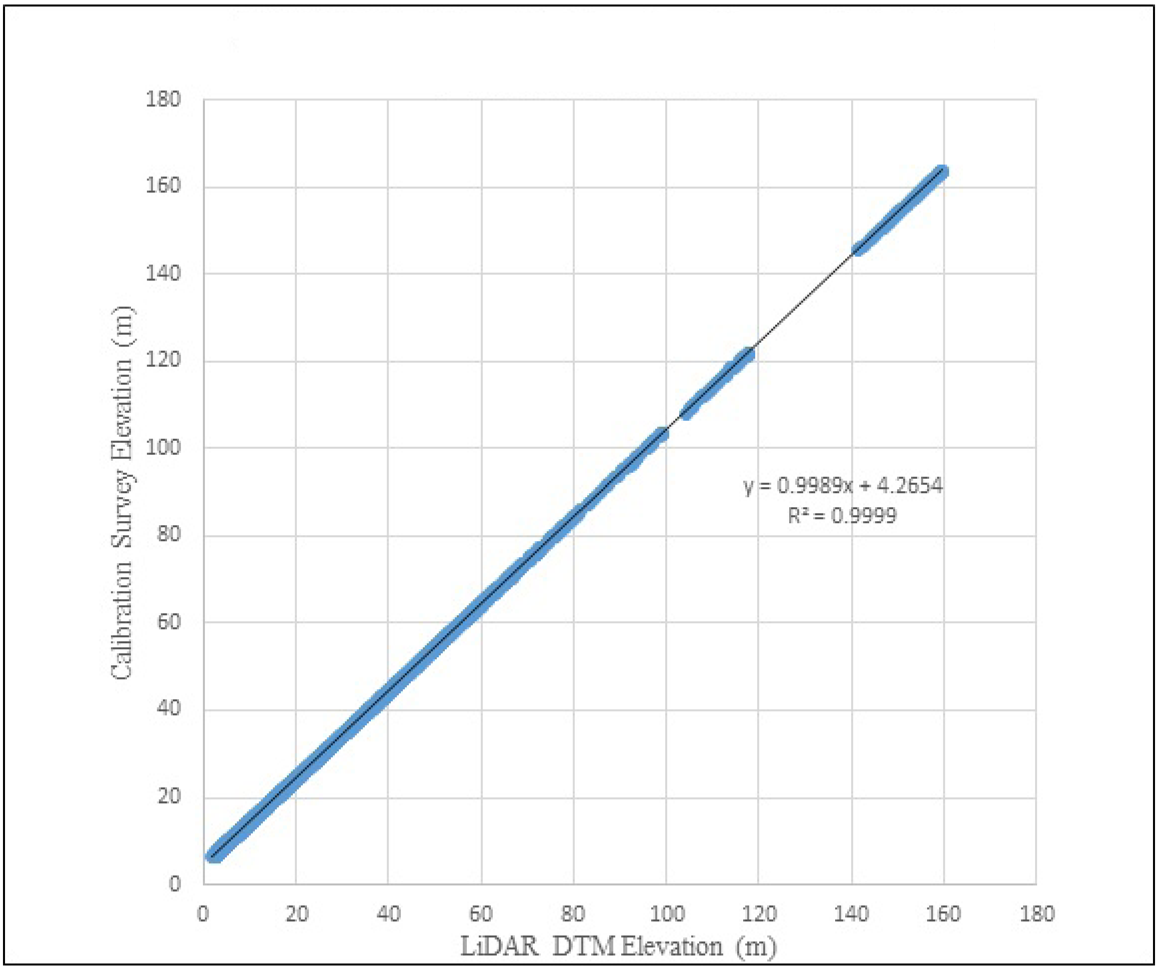


Figure 23. Correlation plot between calibration survey points and LiDAR data.

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 245 points, were used for the validation of calibrated Labason 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 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.13 meters with a standard deviation of 0.13 meters, as shown in Table 15.

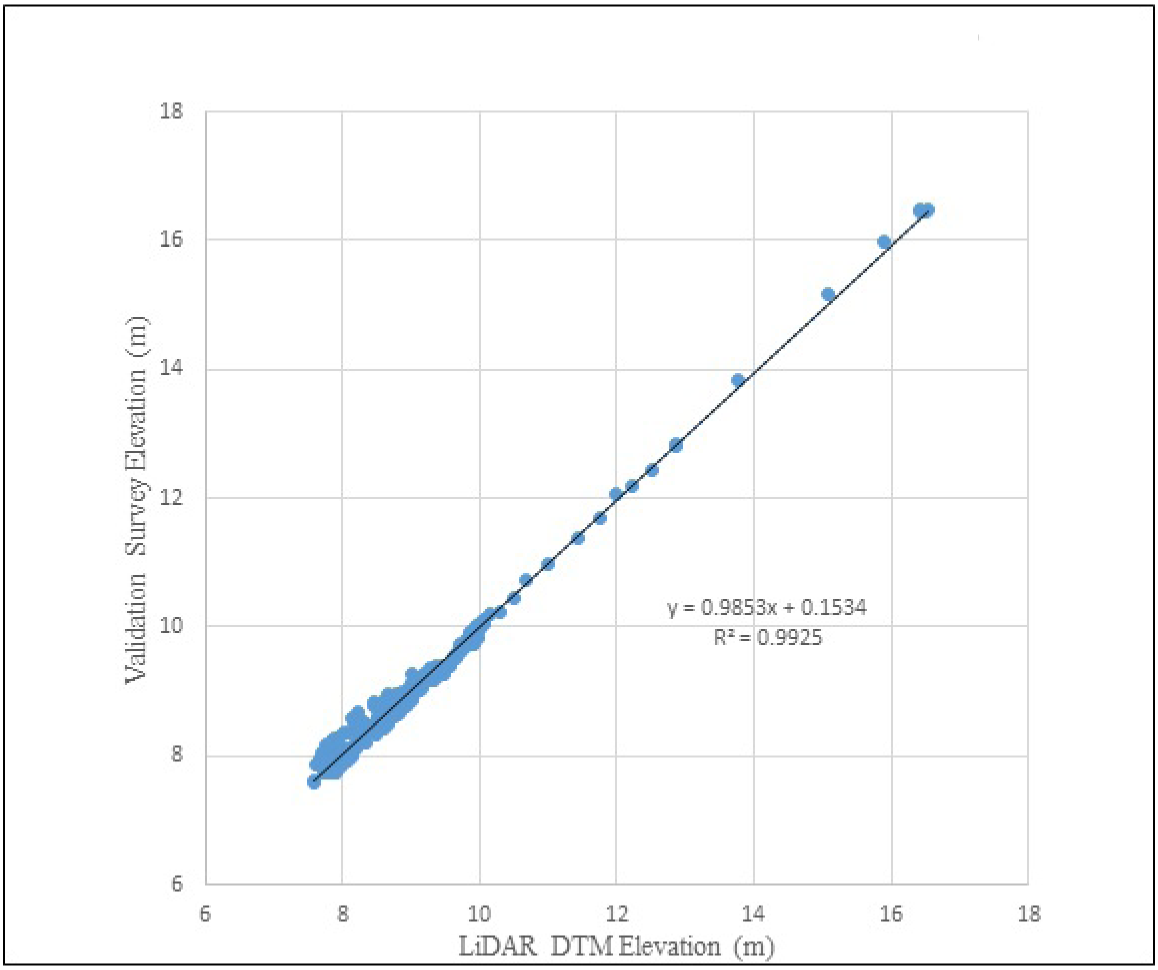


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.13
Average	0.02
Minimum	-0.24
Maximum	0.28

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross section data were available for Labason with 3,208 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.44 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Labason integrated with the processed LiDAR DEM is shown in Figure 25.

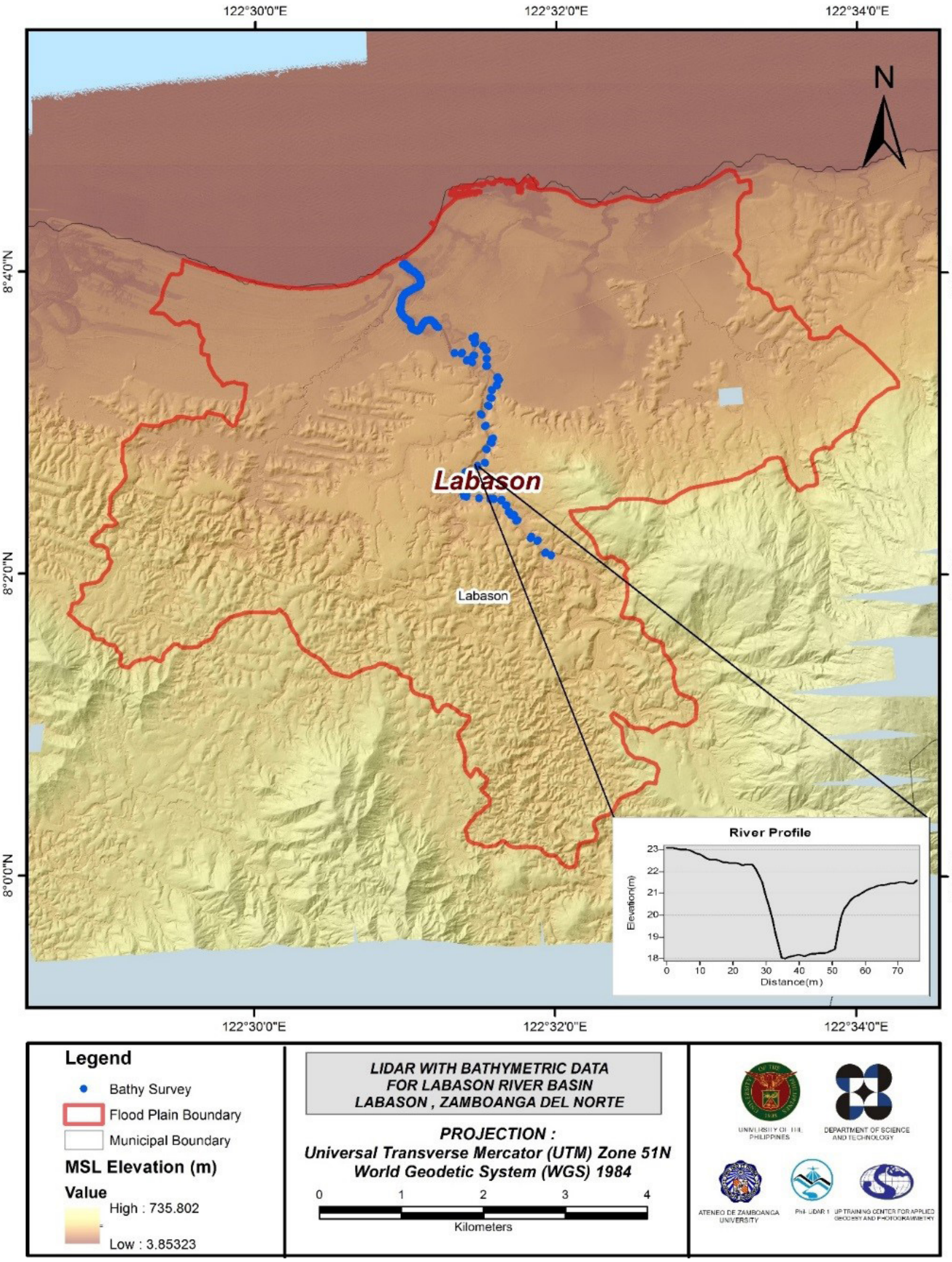


Figure 25. Map of Labason Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Labason Floodplain, including its 200 m buffer, has a total area of 50.91sq km. For this area, a total of 5.00sq km, corresponding to a total of 923 building features, are considered for QC. Figure 26 shows the QC blocks for Labason Floodplain.

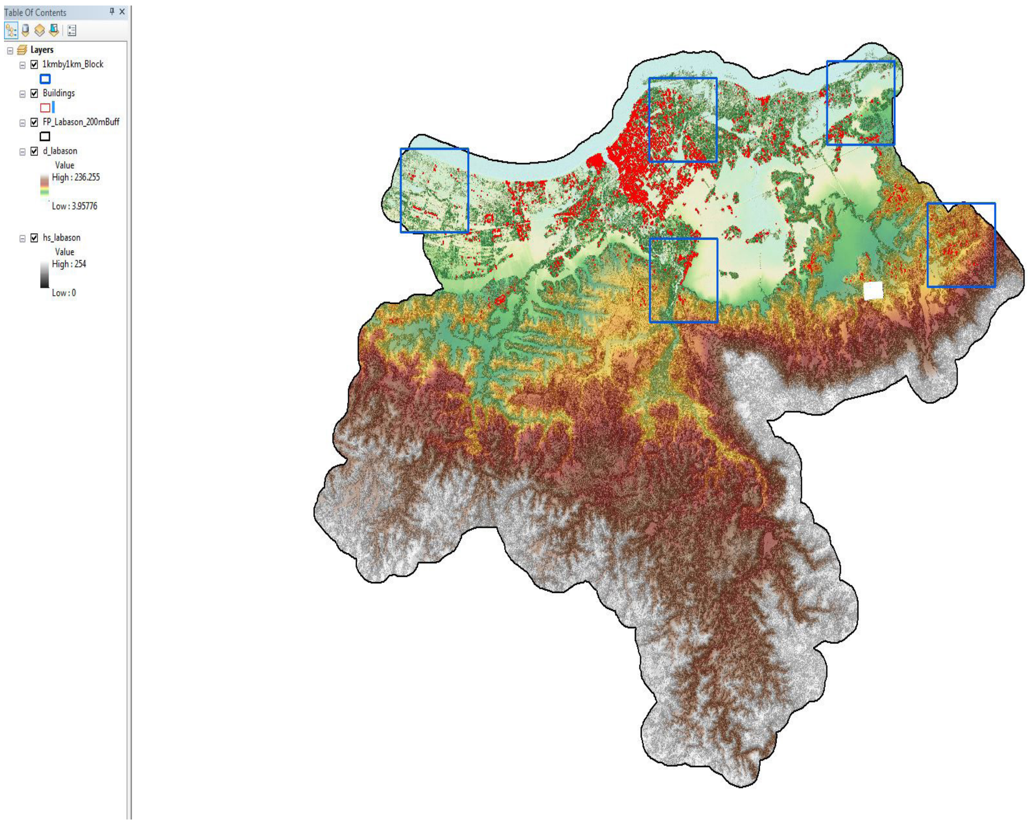


Figure 26. Blocks (in blue) of Labason building features that were subjected in QC.

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

Table 16. Quality Checking Ratings for Labason Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Labason	95.51	94.58	82.23	PASSED

3.12.2 Height Extraction

Height extraction was done for 6,389 building features in Labason Floodplain. Of these building features, none was filtered out after height extraction, resulting in 6,389 buildings with height attributes. The lowest building height is at 2.00 m while the highest building is at 8.44 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 conducted a 2-day Feature Attribution thru Community based Mapping. Through the help of the Mayor's Office and the Local Disaster Risk Reduction and Management Office, 2-3 Representatives from the Barangay identified as included in the riverbasin flood plain were invited in the said activity. The representatives aided in identifying the features in the flood plain thru the use of GEONYT.

For the features which were not covered, the LGUs, thru LDRRM, endorsed a number of enumerators and hired them to conduct the house-to-house survey of the features also 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 the remaining features which is yet to be covered in flood plain of the riverbasin; likewise, the number of enumerators are also dependent on the availability of the tablet and the number of features of the floodplain.

Table 17 summarizes the number of building features per type. 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 Labason Floodplain.

Facility Type	No. of Features
Residential	6,068
School	65
Market	37
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	7
Barangay Hall	3
Military Institution	8
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	1
Transport Terminal	1
Warehouse	35
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	37
Bank	1
Factory	2
Gas Station	4
Fire Station	1
Other Government Offices	19
Other Commercial Establishments	73
Total	6,389

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Labason	21.55	22.27	0.00	6.27	0.00	80.09

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

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Labason	87	0	0	0	0	87

One (1) bridge over small channels that arepart of the river network was 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 27 the Digital Surface Model (DSM) of Labason Floodplain overlaid with its ground features.

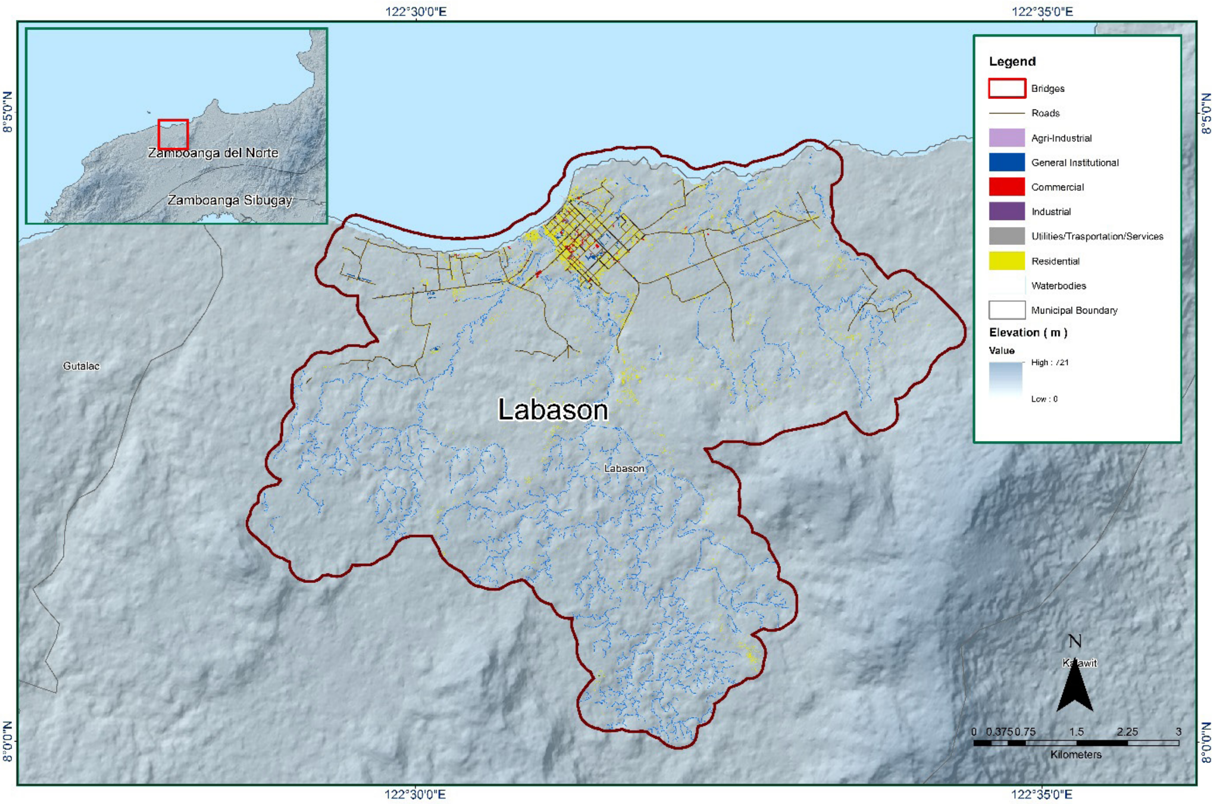


Figure 27. Extracted features for Labason Floodplain.

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

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

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

4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted a field survey in Labason River April 2, 2016 to April 5, 2016 with the following scope of work: cross-section, bridge as-built and water level marking in MSL of Labason Bridge, manual river cross-section from the mouth of the river Brgy. Osukan to the upstream in Brgy. La Union using Total Station, and bathymetric survey from the mouth of the river in Brgy. Osukan to the upstream in Brgy. Lawigan in the Municipality of Labason using GNSS survey technique and Hi-Target™ echo sounder. Bathymetry data were gathered by DVC on August 21-31, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the LabasonRiver Basin area. The entire survey extent is illustrated in Figure 28.

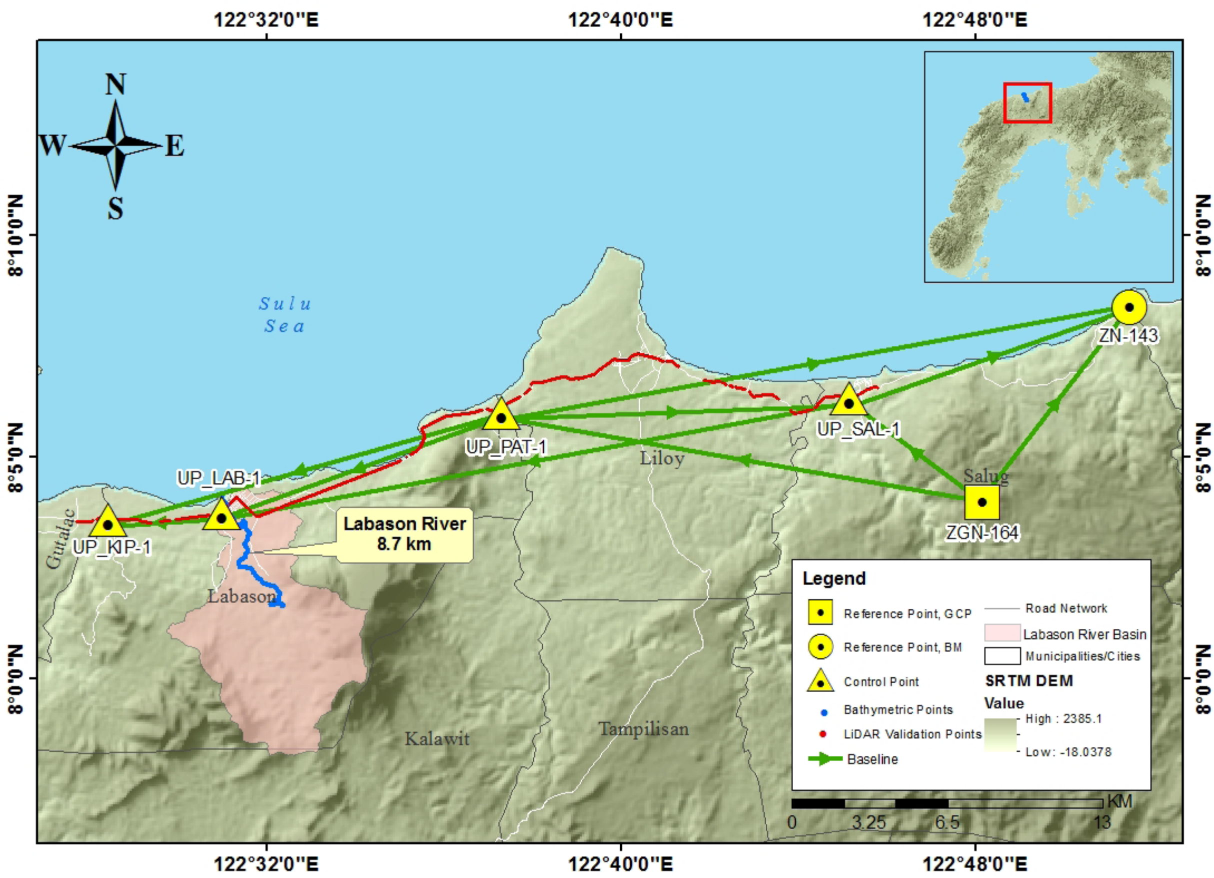


Figure 28. Extent of the bathymetric survey (in blue line) in Labason River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for LabasonRiver 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 were 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 Table 21 while GNSS network established is illustrated in Figure 29.

Table 20. List of reference and control points used during the survey in Labason River
(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_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

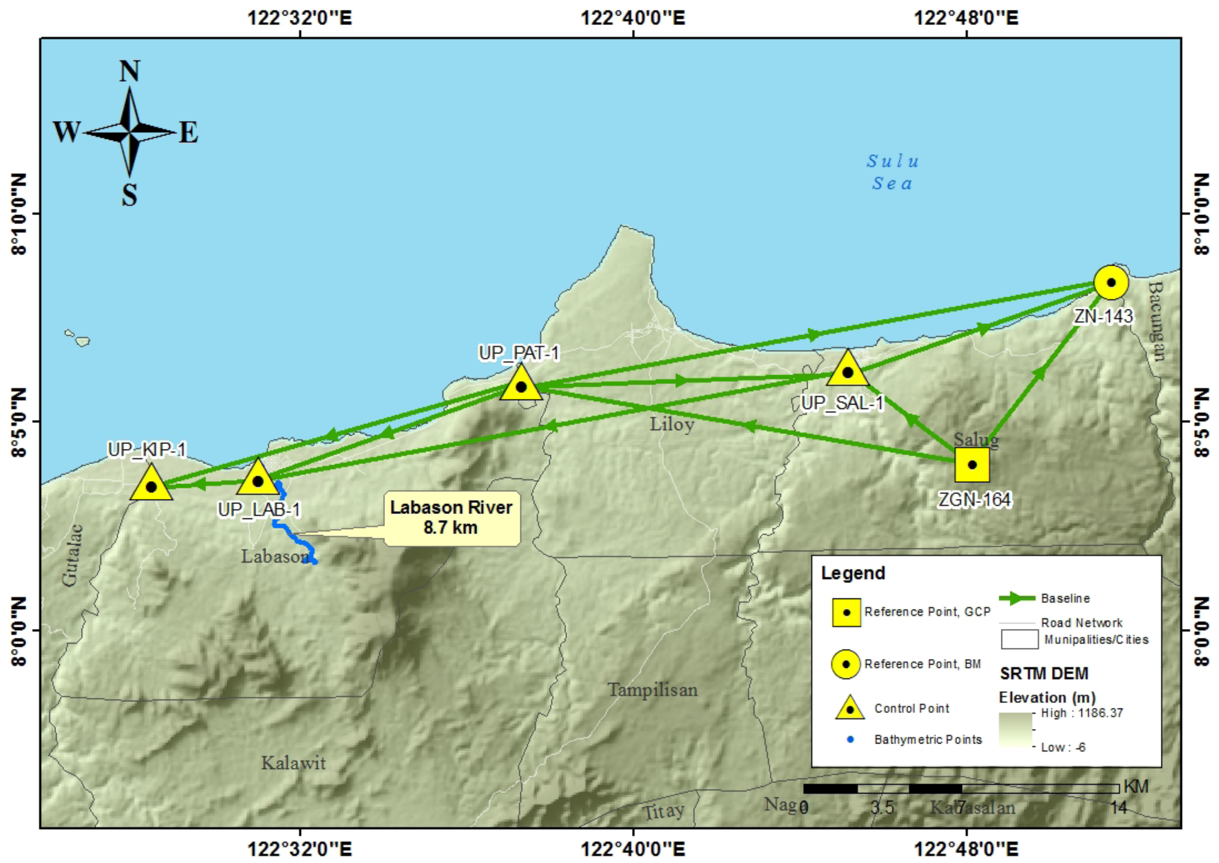


Figure 29. Labason River Basin Control Survey Extent

The GNSS set-ups on recovered reference points and established control points in Labason River are shown from Figure 30 to Figure 35.

Figure 30. 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 31. 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 32. UP_KIP-1 located at the approach of Kipit Bridge in Brgy. Kipit, Municipality of Labason, Province of Zamboanga del Norte

Figure 33. 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

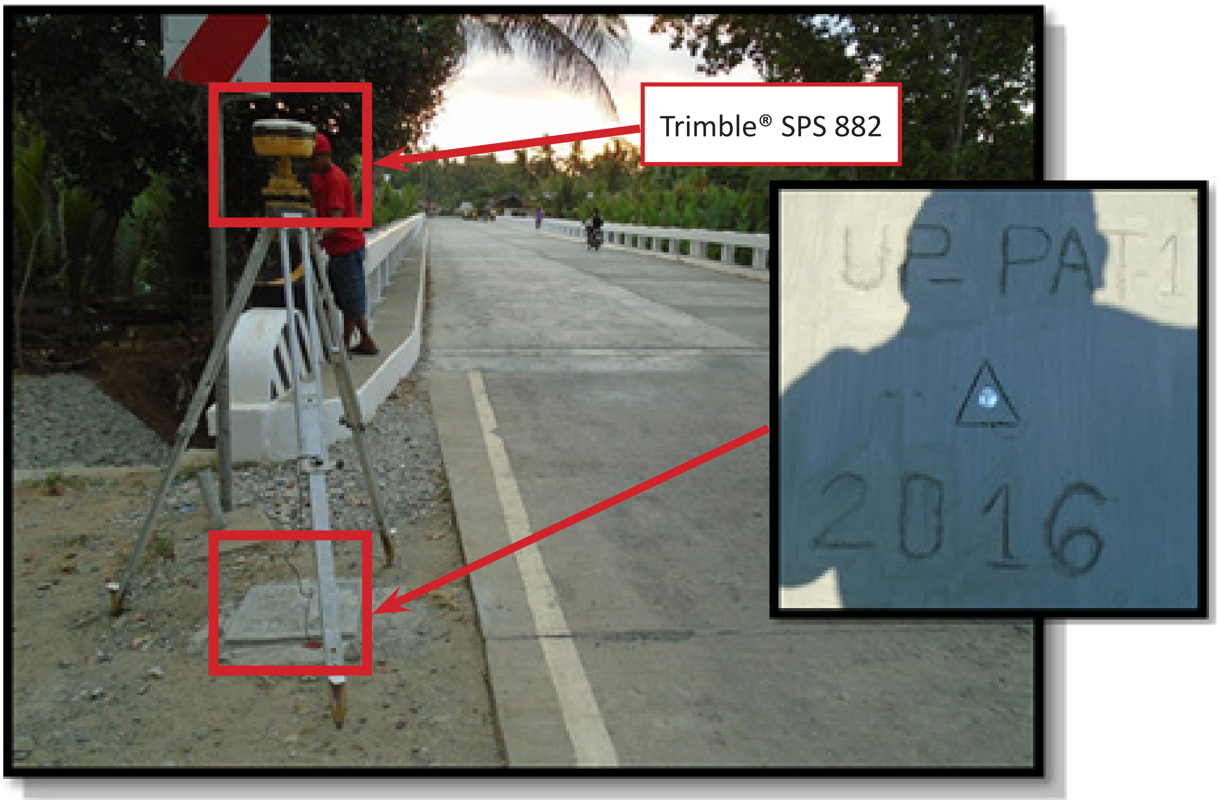


Figure 34. GNSS receiver set up, Trimble® SPS 882, UP_PAT-1 at the side of Labason-Liloy Road near Patawag Bridge in Brgy. Patawag, Municipality of Labason, Province of Zamboanga del Norte

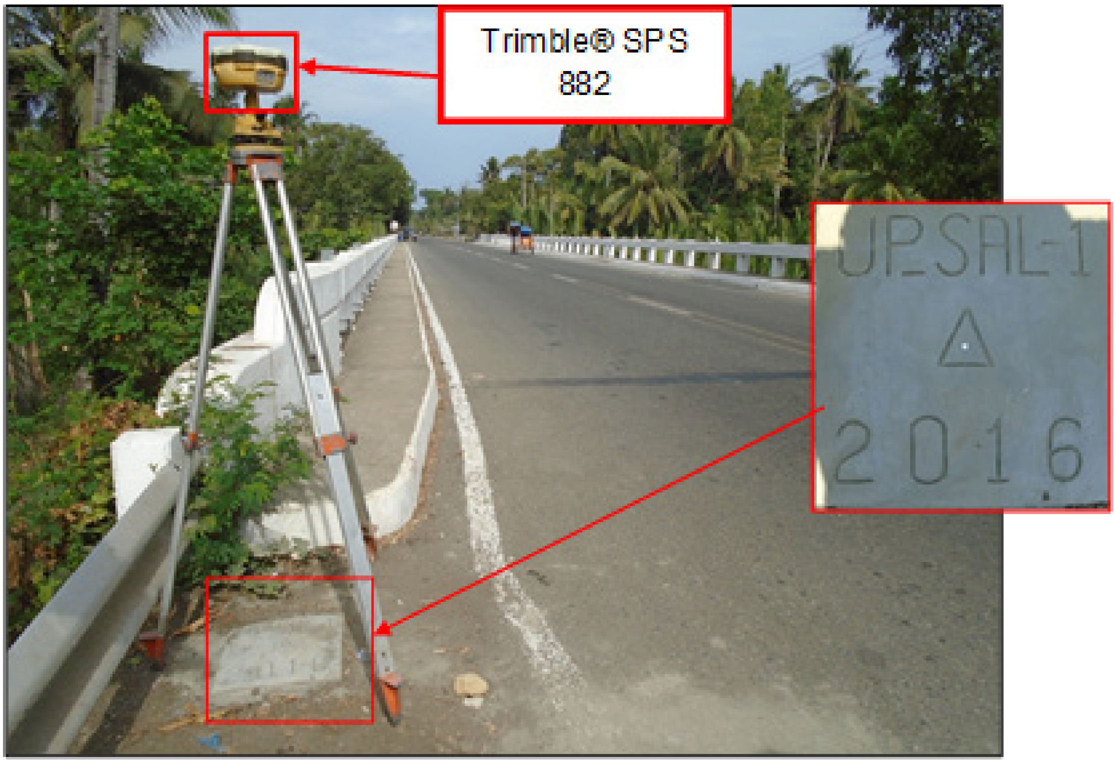


Figure 35. GNSS receiver set up, Trimble® SPS 882, UP_SAL-1 located at the side of Ipil-Dipolog Highway near Salug Bridge in Brgy. La Libertad, Municipality of Gutalac, Province of Zamboanga del Norte

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 is performed. Masking is done by removing/mas.king 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 LabasonRiver Basin is summarized in Table 21 generated by TBC software.

Table 21. Baseline Processing Report for Labason River Static Survey (First Network)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
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 Table 21 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 22. Baseline Processing Report for Labason River Static Survey (Second Network)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
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 Table 22 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 is 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:

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

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 23 to Table 25 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 Table 23 and Table 24. Through this reference point, the coordinates and ellipsoidal height of the unknown control points were computed.

Table 23. 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 24. 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 Table 25 and Table 26. All fixed control points have no values for grid errors and elevation error.

Table 25. 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	440245.506	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, for horizontal and for the vertical; the computation for the accuracy are as follows:

UP_KIP-1
horizontal accuracy = $\sqrt{((0.1)^2 + (1.1)^2}$
= $\sqrt{(0.01 + 1.21)}$
= 1.10 < 20 cm
vertical accuracy = 5.3 < 10 cm

UP_LAB-1
horizontal accuracy = $\sqrt{((0.1)^2 + (1.1)^2}$
= $\sqrt{(0.01 + 1.21)}$
= 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 26. 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	0.005	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 27. Adjusted Geodetic Coordinates (First Network)

Point ID	Latitude	Longitude	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 28. Adjusted Geodetic Coordinates (Second Network)

Point ID	Latitude	Longitude	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 Table 27 and Table 28. 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 Table 29 and Table 30.

Table 29. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM Zone 51N		
		Latitude	Longitude	Ellipsoidal Height (Meter)	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 30. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 51N)					
		Latitude	Longitude	Ellipsoidal Height (Meter)	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°37'19.54470" 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

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

Cross-section and as-built surveys were conducted on April 2, 2016 at the upstream side of Labason Bridge in Brgy. San Jose, Municipality of Labason, Province of Zamboanga del Norte as shown in Figure 36. A Horizon™ Total Station was utilized for this survey as shown in Figure 37.

Figure 36. Downstream side of Labason Bridge

Figure 37. As-built survey of Labason Bridge

The cross-sectional line of Labason Bridge is about 252.28 m with one hundred ninety-five (195) cross-sectional points using the control points UP_LAB-1and UP_LAB-2 as the GNSS base stations. The cross-section diagram and the bridge data form are shown in Figure 39 and Figure 40.

No bridge cross-section or bridge points checking data were gathered for Labason Bridge because the contractor's data passed the quality assessment.

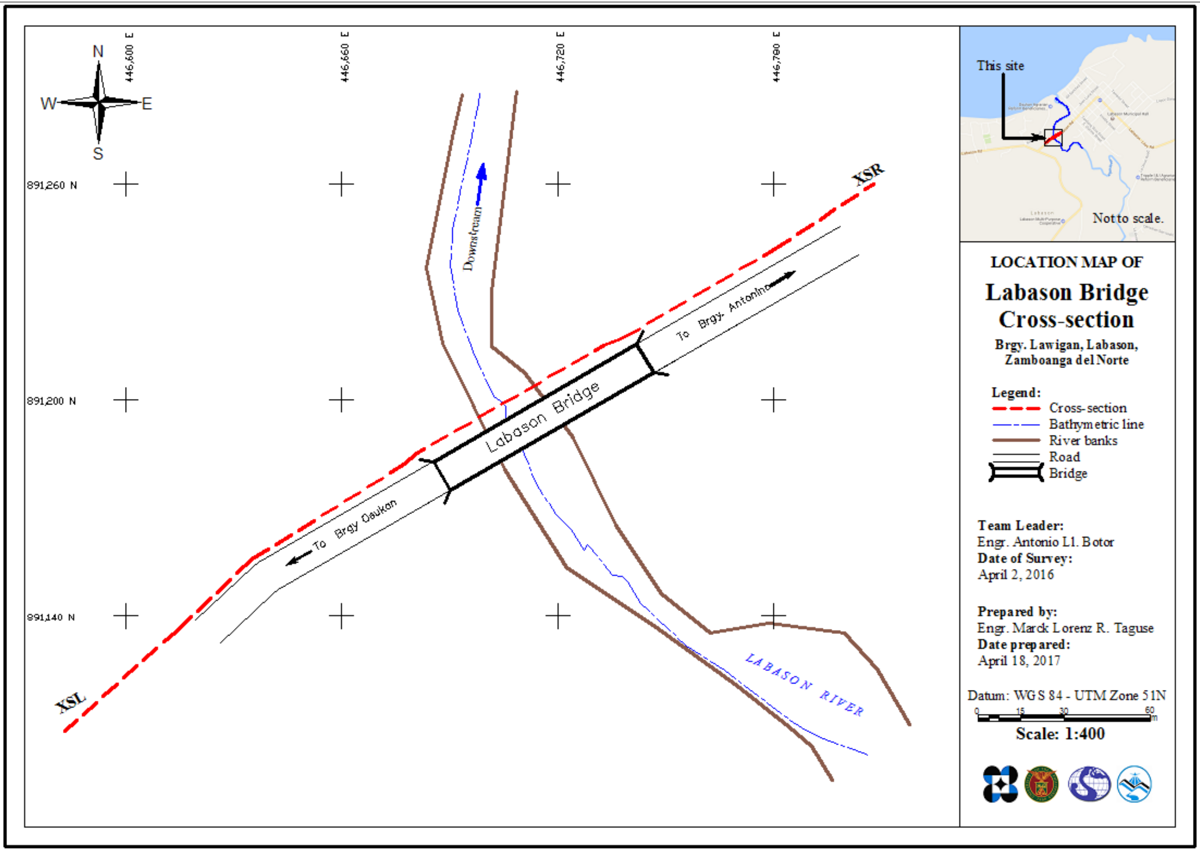


Figure 38. Location Map of the Labason Bridge Cross Section

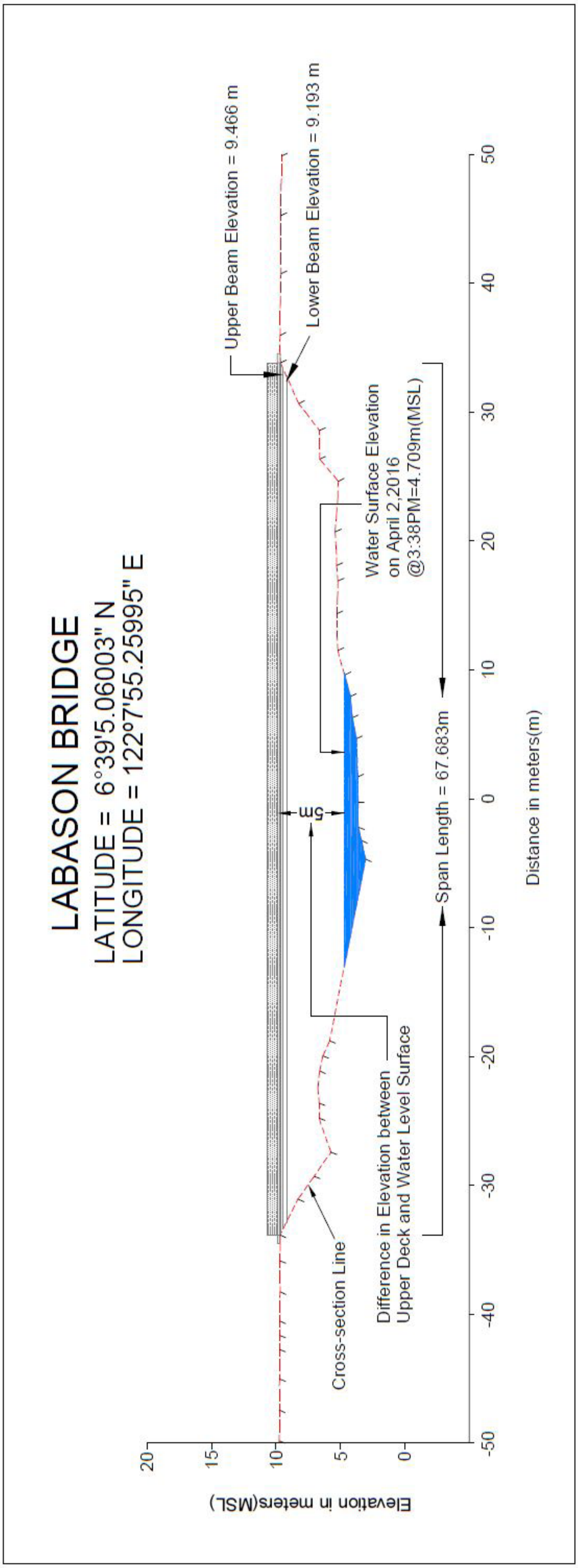


Figure 39. Labason Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Labason Bridge

River Name: Labason River

Location (Brgy,City,Region): Labason River

Survey Team: Jayson Ilustre Ryan Antonio, Agapito Cinco

Date and Time: April 2, 2016, 3:38 P.M .

Flow Condition: low 3 normal high

Weather Condition: fair 3 rainy

Cross-sectional View (not to scale)

please make illustration clear. thanks po.

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	71 cm	
2. BA2-BA3	67.683 m	
3. BA3-BA4	60 m	
4. BA1-Ab1	11.79 m	
5. Ab2-BA4	8.05 m	
6. Deck/beam thickness	87.6 cm	
7. Deck elevation	9.481 m	

Note: Observer should be facing downstream

Figure 40. Labason Bridge Data Sheet

Water surface elevation of Labason River was determined by a Nikon® Total Station on April 2, 2016 at 3:38 PM at Labason Bridge area with a value of 4.709 m in MSL as shown in Figure 40. This was translated into marking on the bridge's pier as shown in Figure 41. The marking served as reference for flow data gathering and depth gauge deployment of ADZU, the partner HEI responsible for Labason River.

Figure 41. Water-level markings on Labason Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 27, 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 42.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 42. Validation points acquisition survey set-up for Labason River

The survey started from Brgy. Bacungan, Municipality of Bacungan, Zamboanga del Norte going west along the national highway covering thirteen (13) barangays in three (3) municipalities, namely the municipalities of Bacungan, Salug, and Liloy, and ending in Brgy. Kayok, Municipality of Liloy, Zamboanga del Norte. The survey gathered a total of 993 points with approximate length of 24 km using ZN-143 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 43.

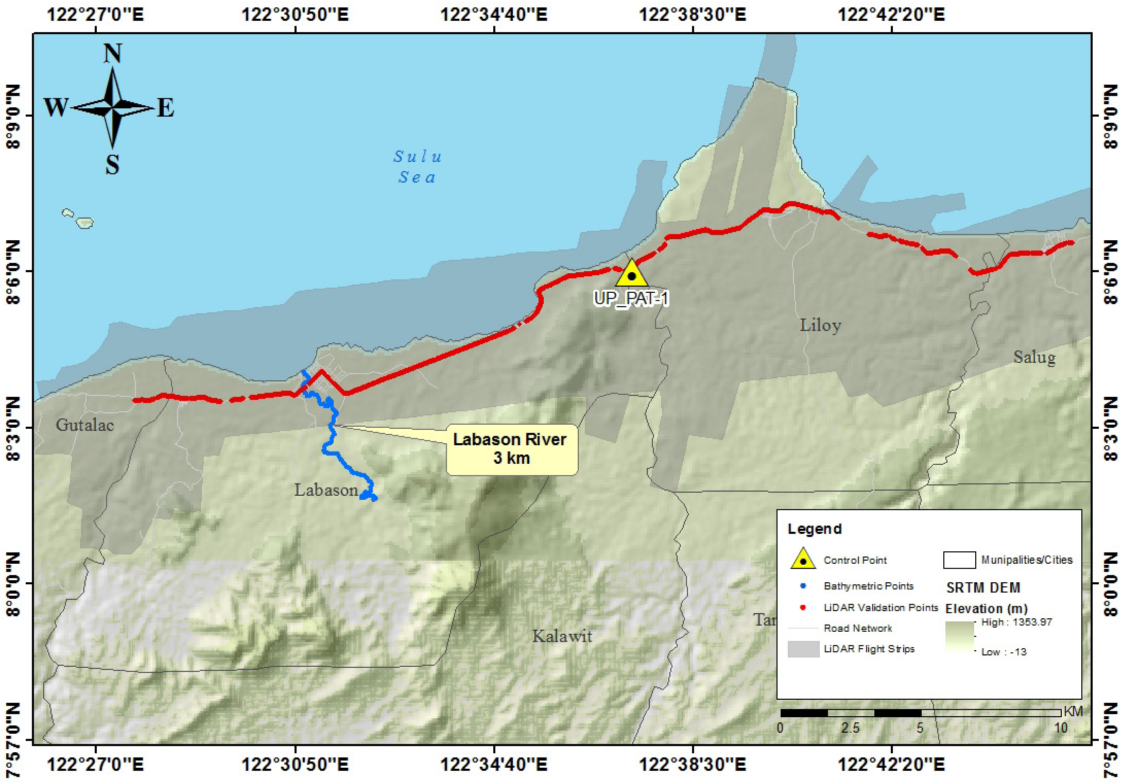


Figure 43. Validation points acquisition covering the Labason River Basin Area

4.7 Bathymetric Survey

Bathymetric survey was executed on April 2,3,13 and 17, 2016 at Labason River using a Horizon™ Total Station as illustrated in Figure 44. The survey started from the mouth of the river at Brgy. Imelda, Labason, Zamboanga del Norte with coordinates 8°2'7.05693"N, 122°31'58.22027"E and ended in Brgy. La Union, Labason, Zamboanga Del Norte, with coordinates 8°3'31.83212"N, 122°31'19.71951"E. The control pointsAB-3 and AB-4 were used as GNSS base stations all throughout the entire survey.

Figure 44. Bathymetric survey at Labason River using a Horizon™ Total Station

The bathymetric survey for Labason River gathered a total of 1,327 points covering 6.55 km of the river traversing Brgy. Imelda to Brgy. La Union, both in the municipality of Labason. A CAD drawing was also produced to illustrate the riverbed profile of Labason River. As shown in Figure 47, the highest and lowest elevation has a 30-m difference. The highest elevation observed was 33.50 m above MSL located in Brgy. La Union, Labason, Zamboanga del Norte while the lowest was 2.45 m above MSL located in Brgy. Antonio, Municipality of Labason.

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 DVBC bathymetric checking points is shown in Figure 46.

Linear square correlation (R^2) 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 R^2 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 R^2 value of 0.87 was obtained was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.176

which is within the accuracy required by the program.

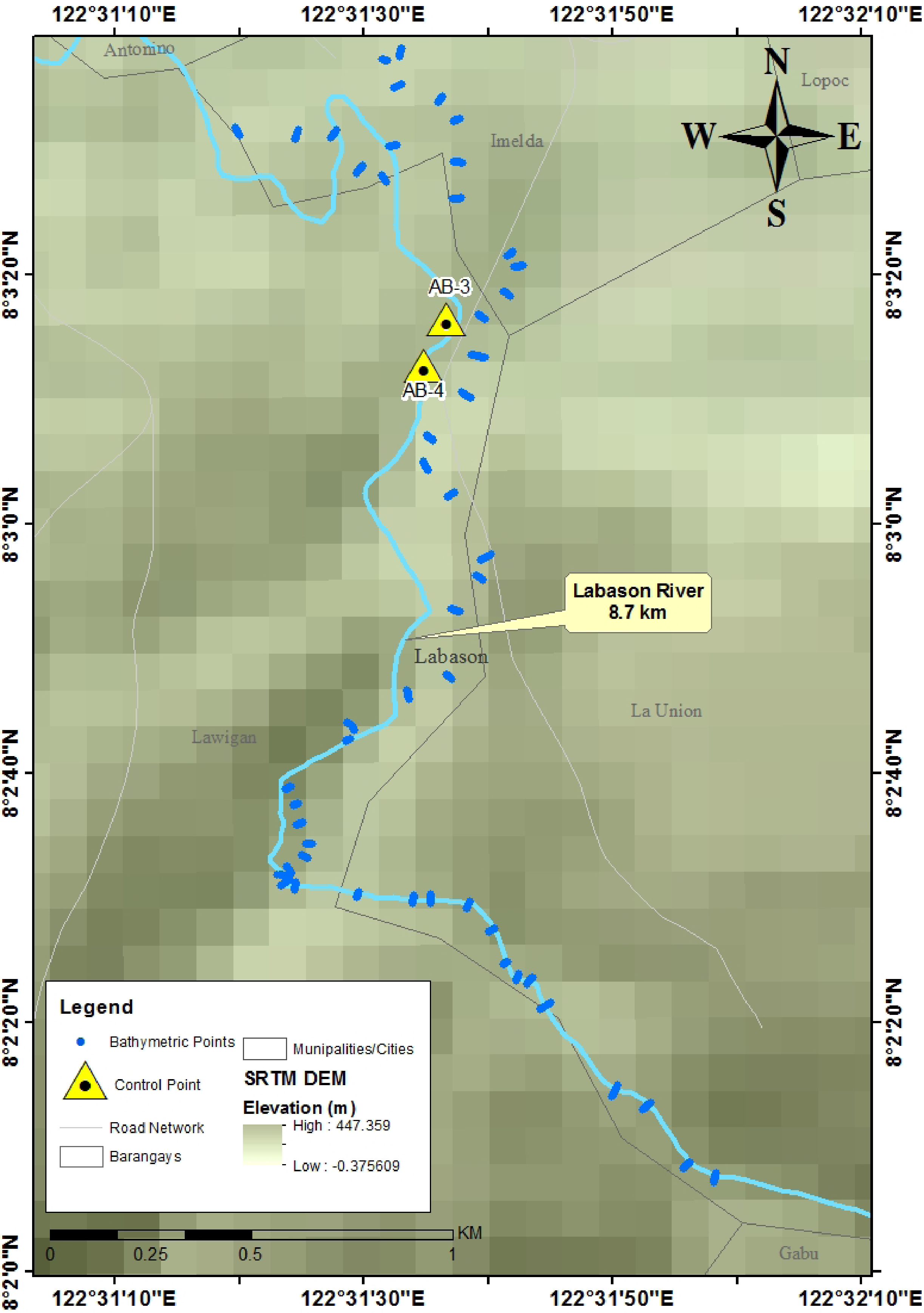


Figure 45. Bathymetric survey of Labason River

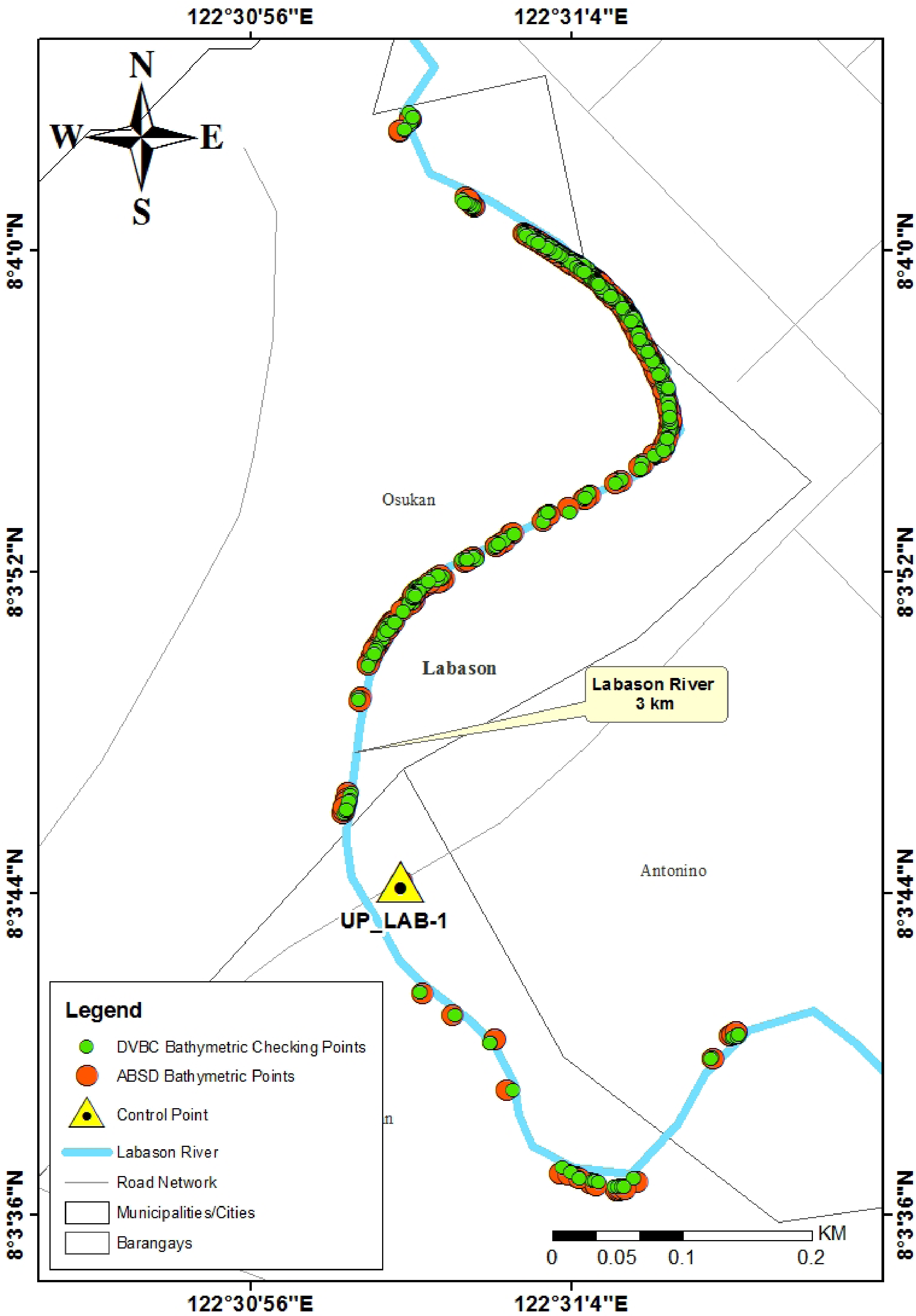


Figure 46. Quality checking points gathered along Labason River by DVBC

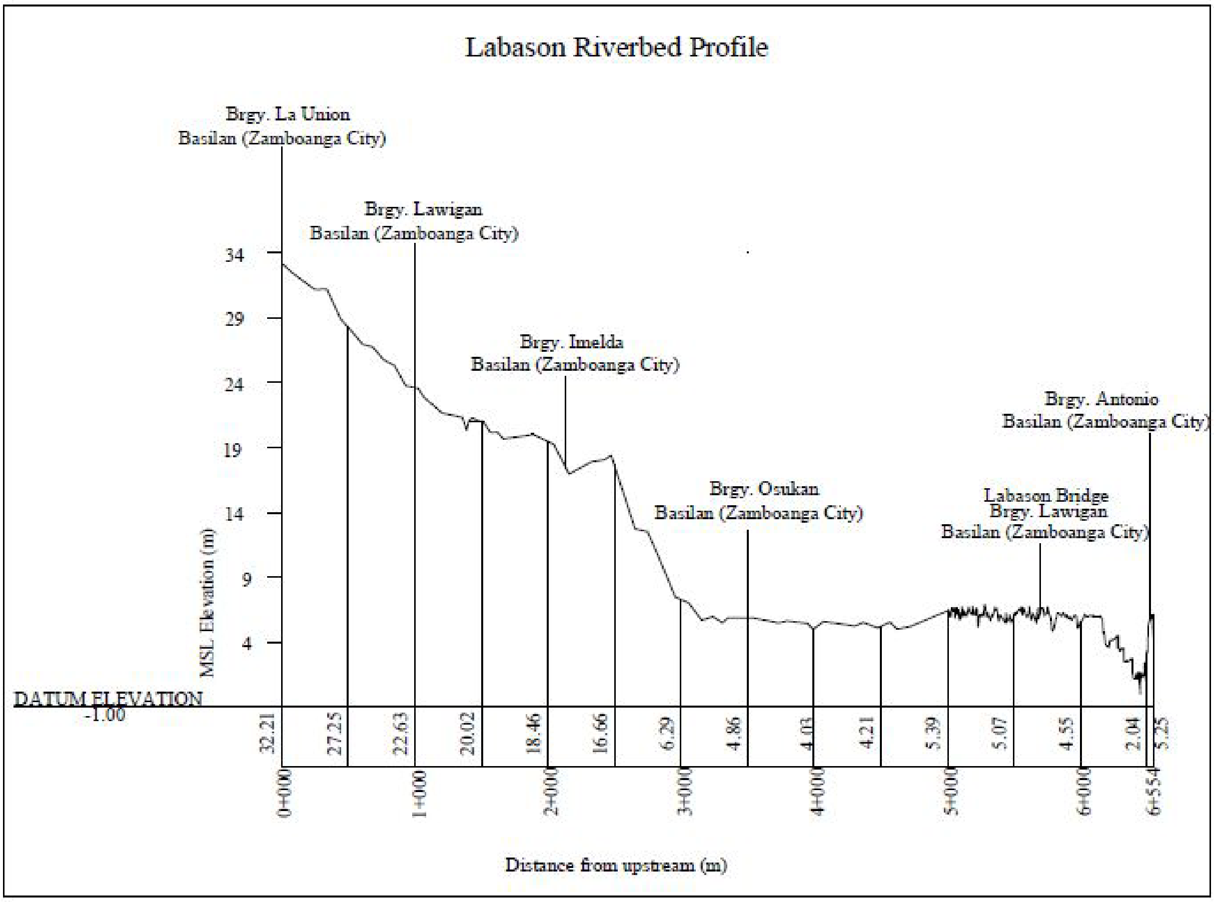


Figure 47. Labason Riverbed Profile

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 (Lagmay et al., 2014) and further enhanced and updated in Paringit et al. (2017).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. La Union, Labason, Zamboanga del Norte (8° 2' 30.00" N, 122° 31' 35.30" E) (Figure 48). The precipitation data collection started from June 27, 2016 at 10:00 AM to June 28, 2016 at 03:10 AM with 10 minutes recording interval.

The total precipitation for this event in Brgy. La Union was 16.4 mm. It has a peak rainfall of 4.2 mm. on June 27, 2016 at 12:20 PM. The lag time between the peak rainfall and discharge is 5 hours and 50 minutes.

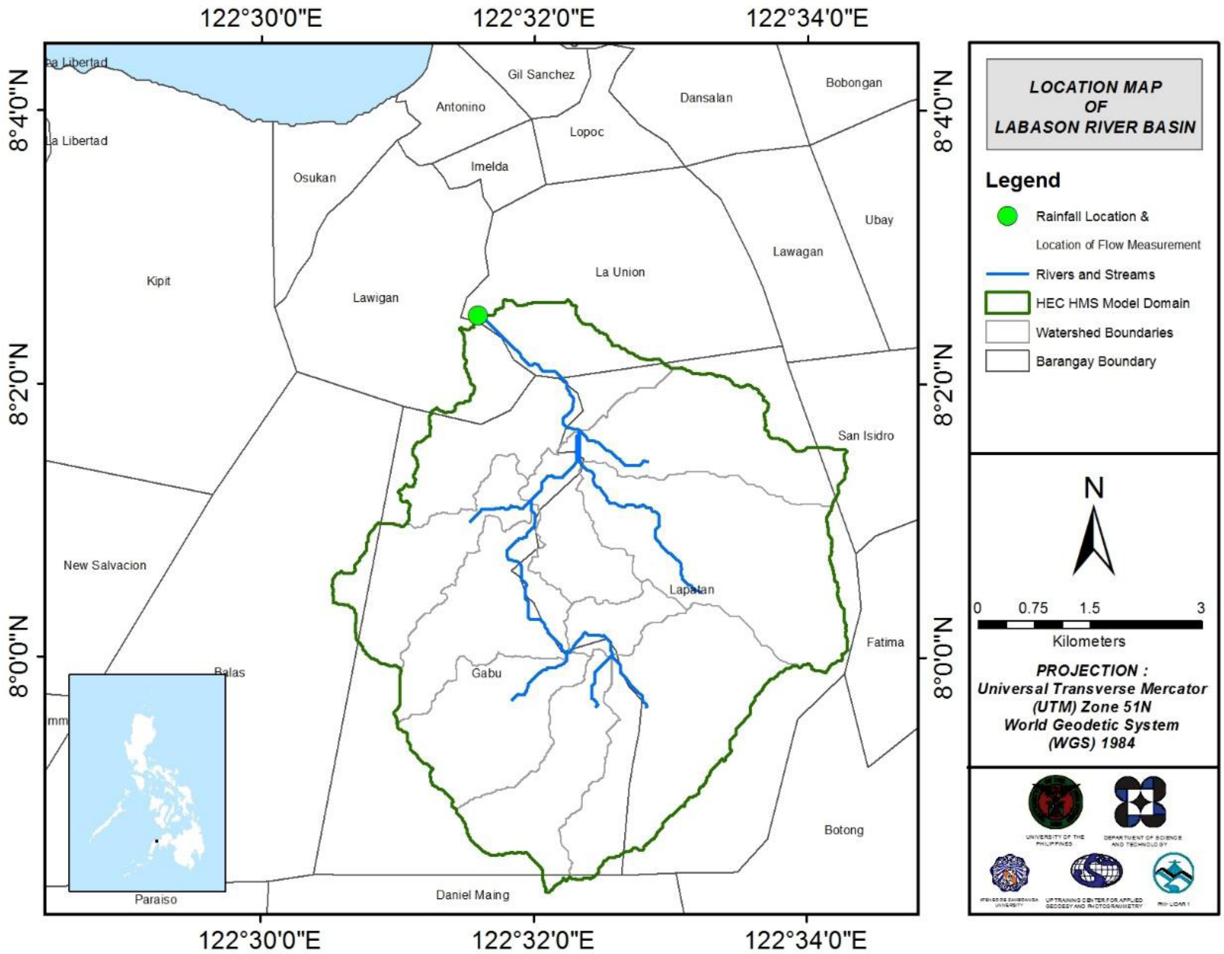


Figure 48. The location map of Labason HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at a spillway at Brgy. La Union, Labason, Zamboanga del Norte (8° 2' 29.77" N, 122° 31' 35.17" E). It gives the relationship between the observed water levels at Brgy. La Union and outflow of the watershed at this location.

For Brgy. La Union, the rating curve is expressed as $Q = 2E\text{-}103e^{2.7137h}$ as shown in Figure 50.

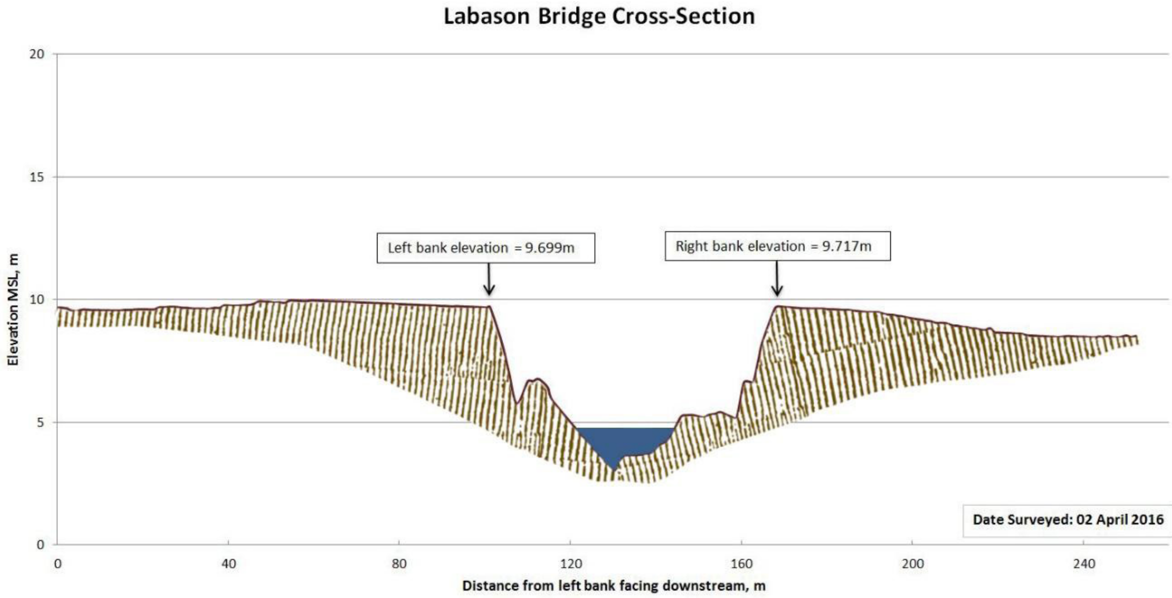


Figure 49. Cross-Section Plot of Brgy. La Union

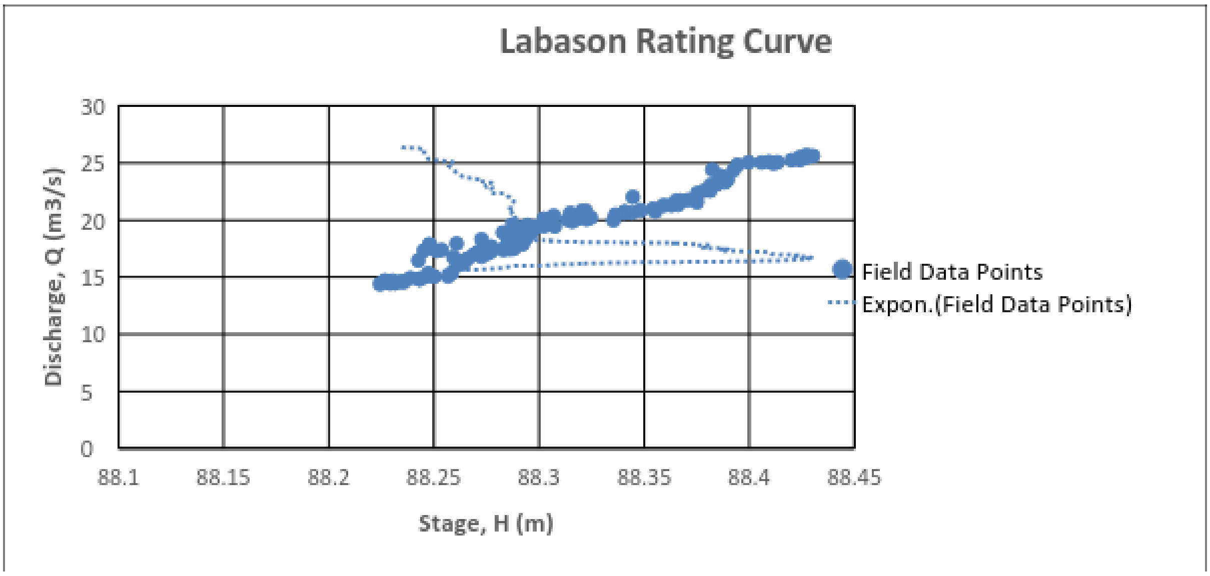


Figure 50. Rating Curve at Brgy. La Union, Labason, Zamboanga del Norte

This rating curve equation was used to compute the river outflow at Brgy. La Union for the calibration of the HEC-HMS model shown in Figure 51. Peak discharge is 25.70 cubic meters per second at 6:10 PM, June 17, 2016.

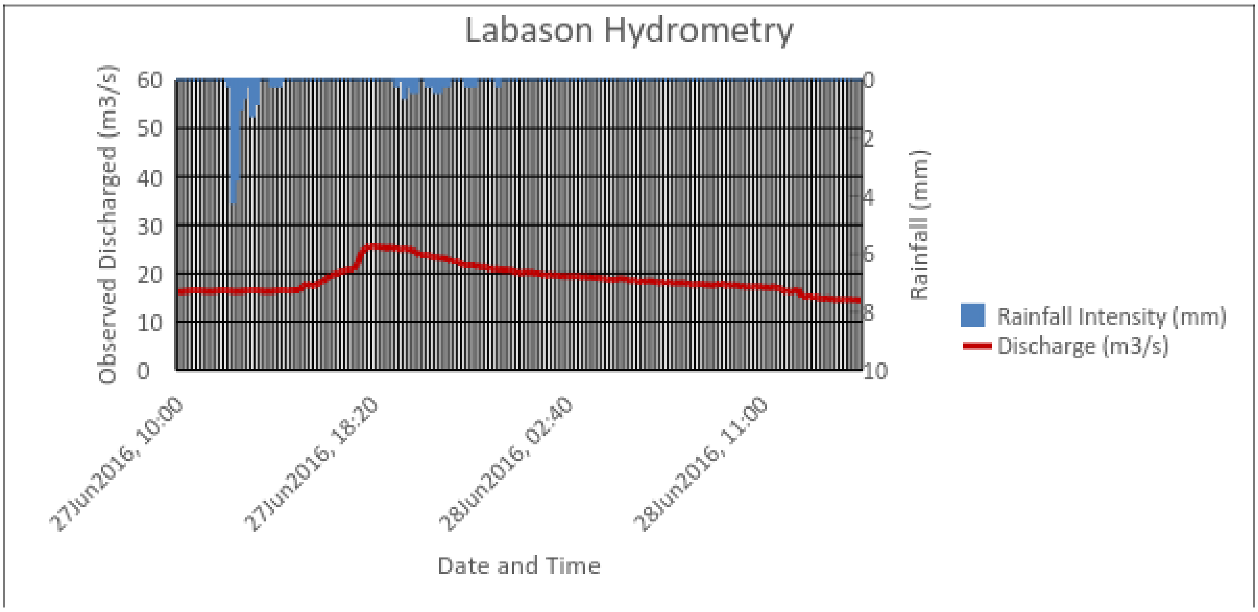


Figure 51. Rainfall and outflow data at Brgy. La Union used for modeling

5.2 RIDF Station

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

Table 31. 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

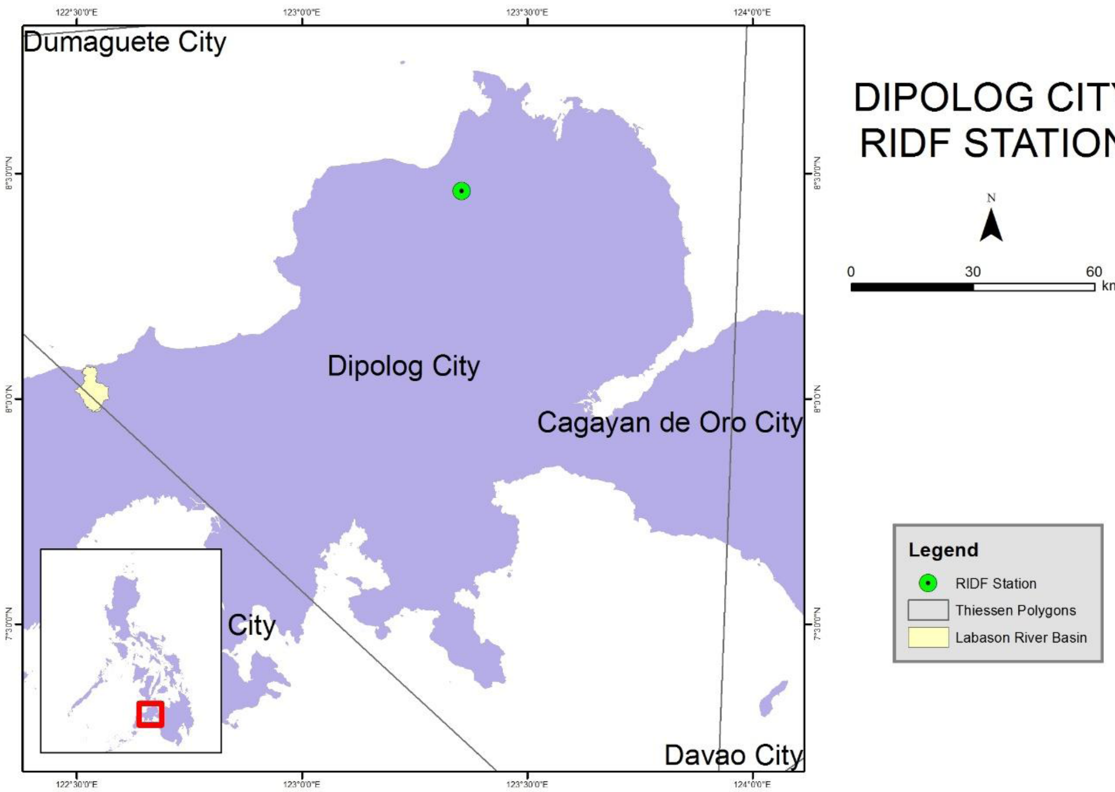


Figure 52. Dipolog City RIDF location relative to Labason River Basin

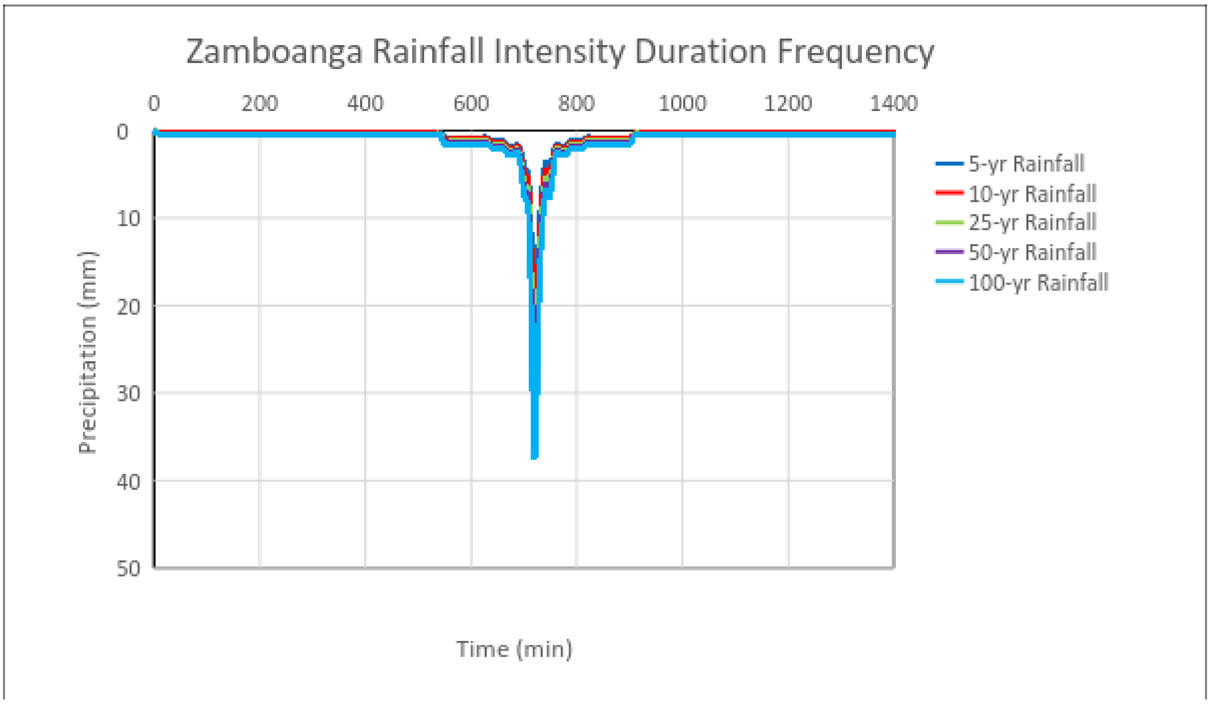


Figure 53. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Labason River Basin are shown in Figures 54 and 55, respectively.

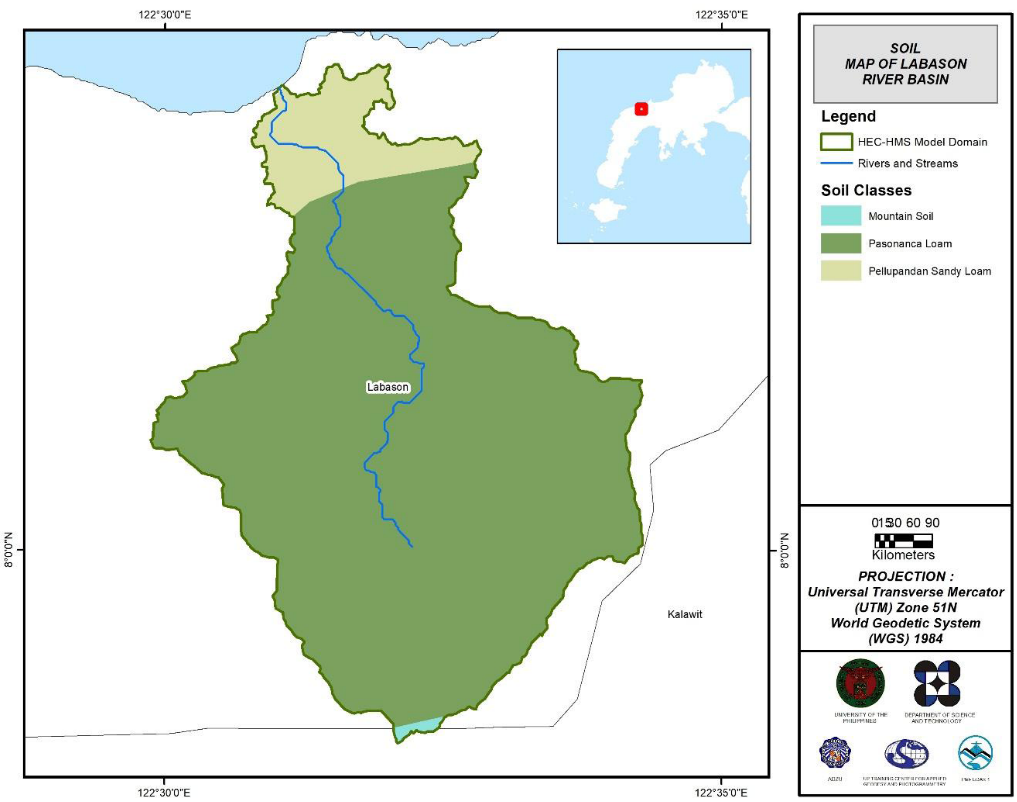


Figure 54. Soil Map of Labason River Basin

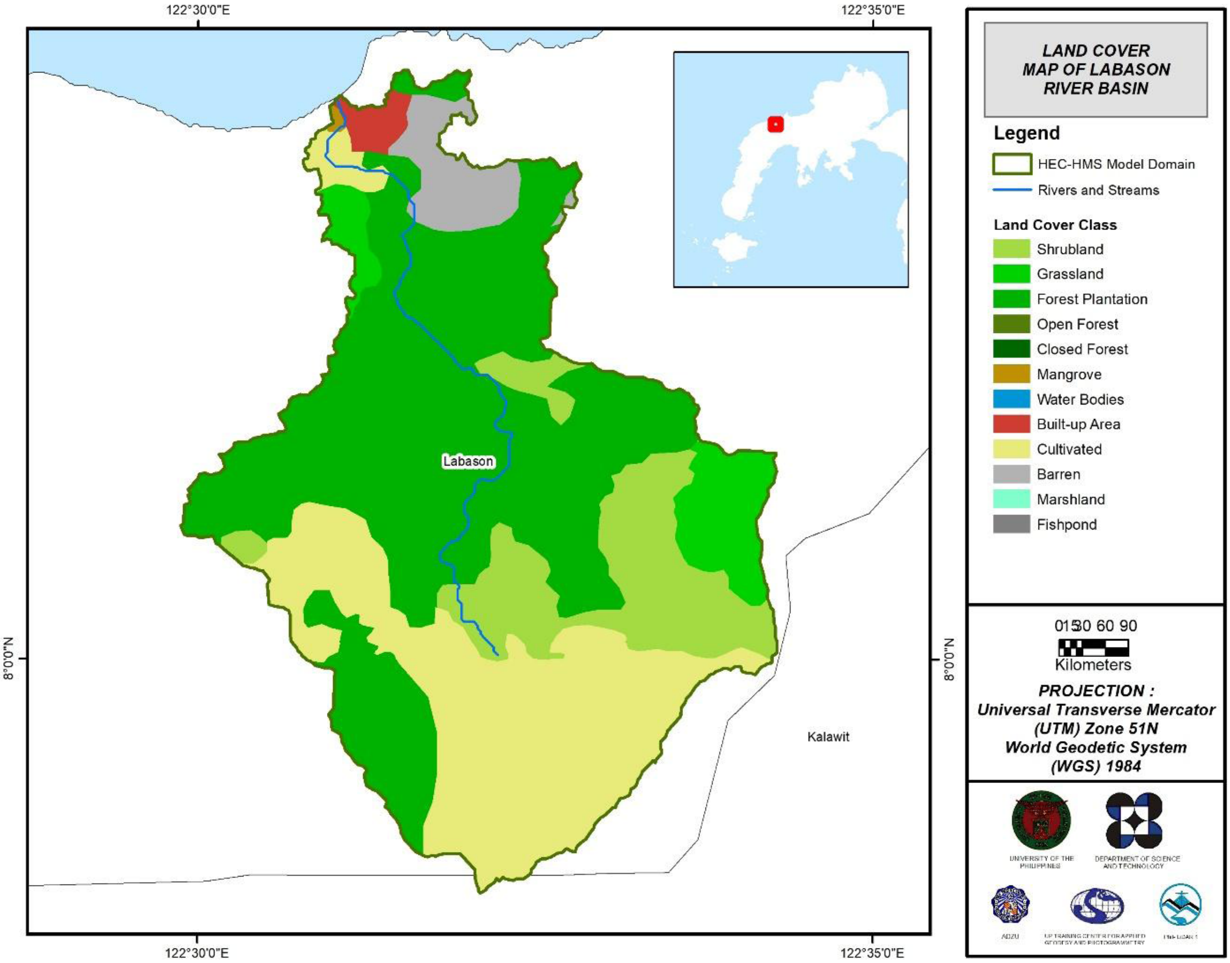


Figure 55. Land Cover Map of Labason River Basin

For Labason, the soil classes identified were loam, sandy loam, and mountain soil. The land cover types identified were Mangrove, Brushland, Open Areas, Grassland, Tree Plantations, Built-up areas and Cultivated Areas.

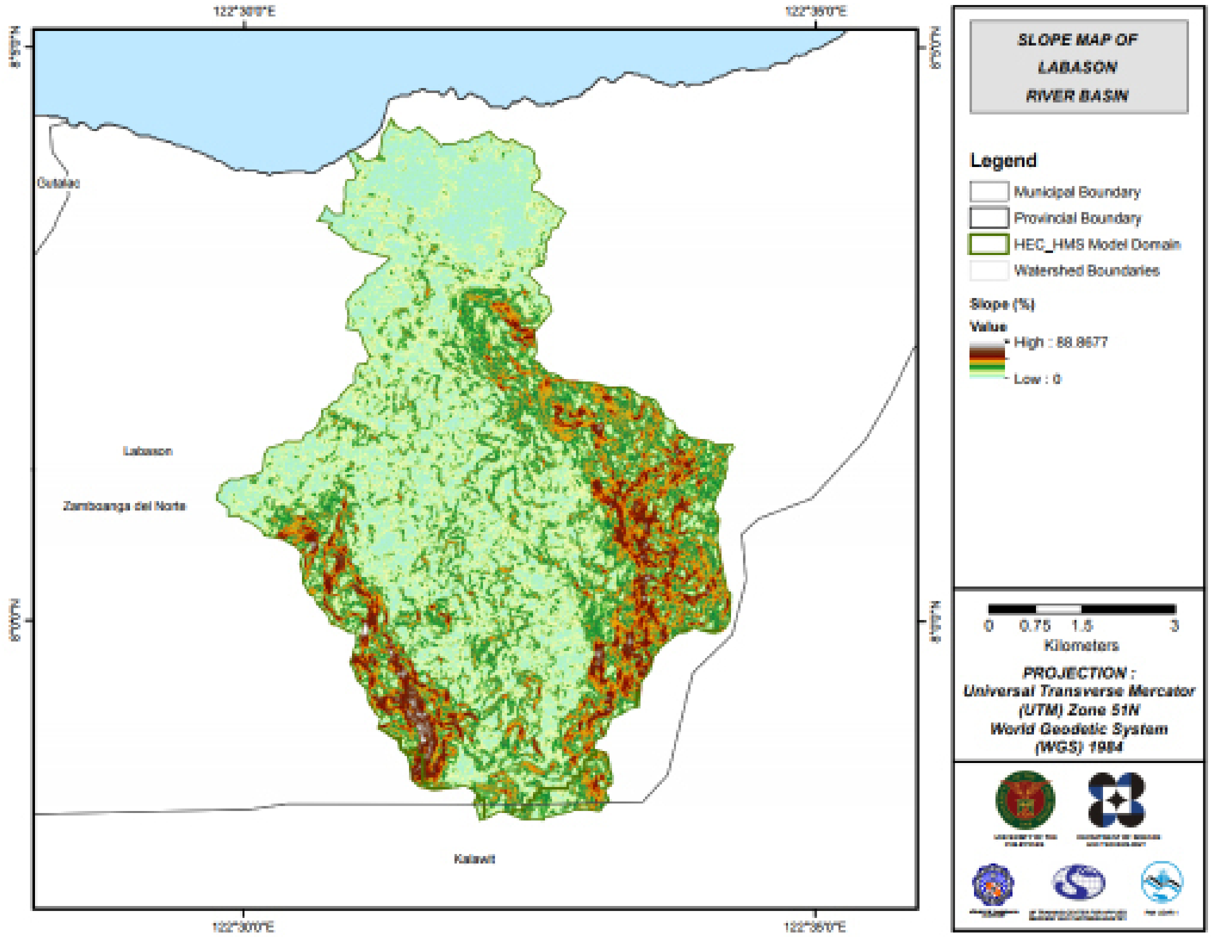


Figure 56. Slope Map

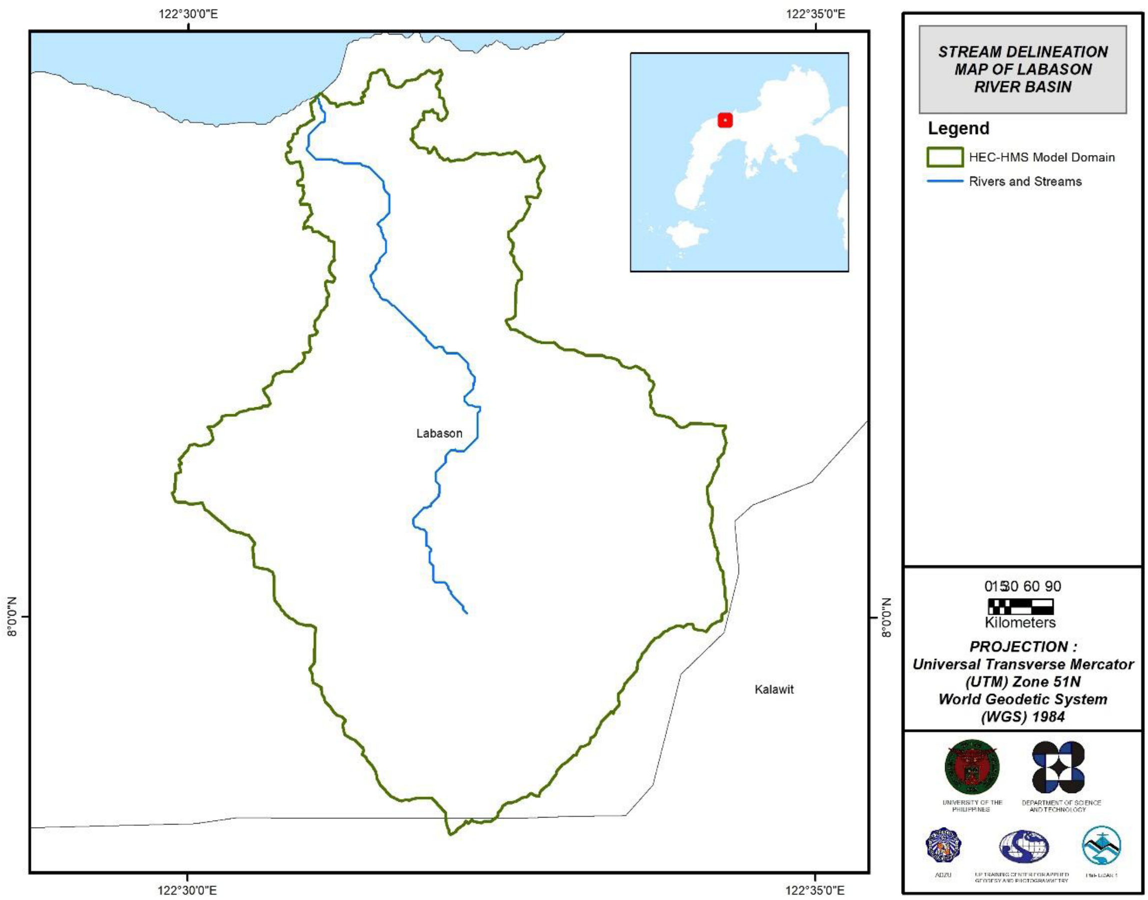


Figure 57. Stream delineation map of Labason river basin

Using the SAR-based DEM, the Labason basin was delineated and further subdivided into subbasins. The model consists of 11 sub basins, 5 reaches, and 5 junctions as shown in Figure 58 (See Annex 10). The main outlet is at Brgy. La Union, Labason, Zamboanga del Norte.

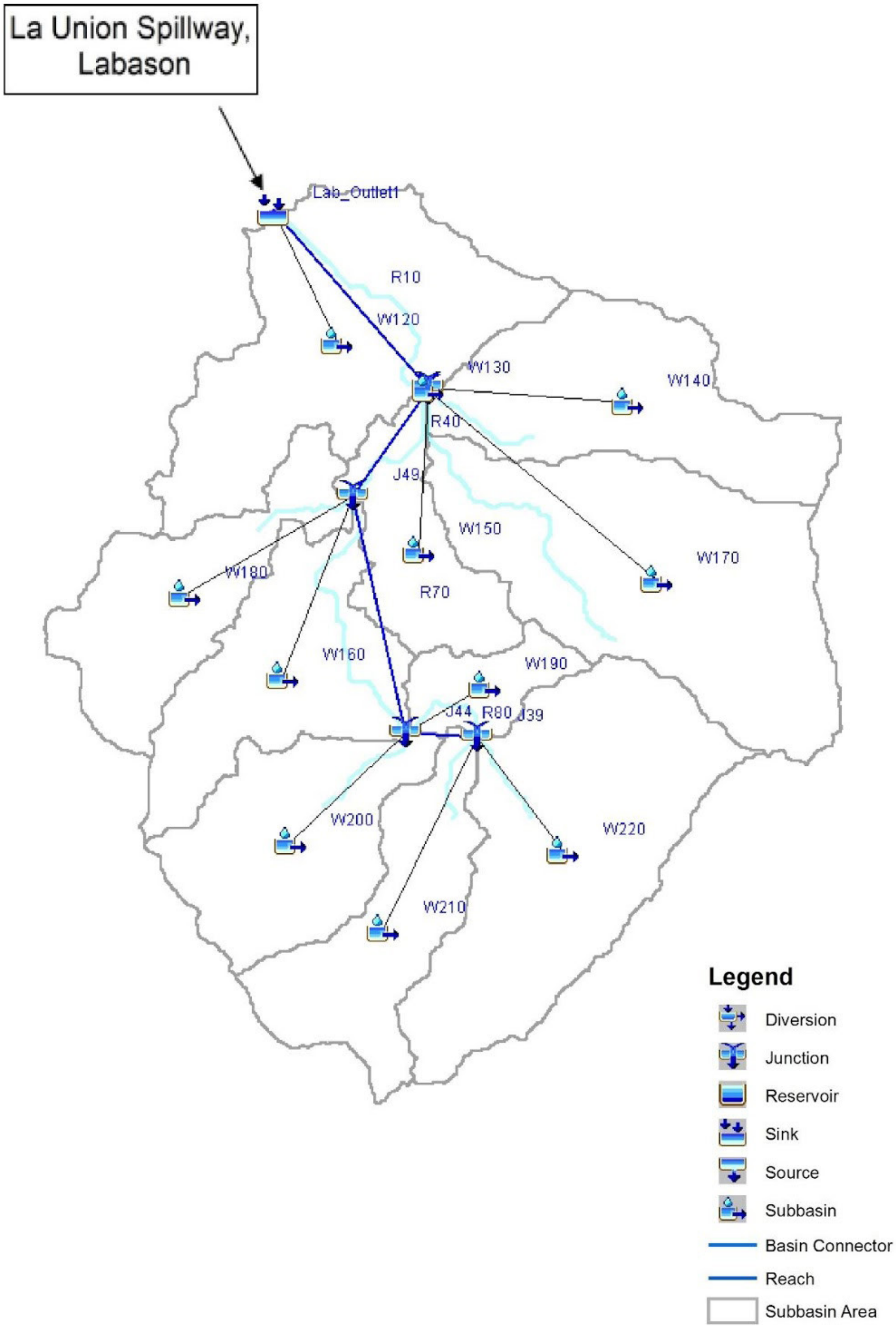


Figure 58. The Labason river basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 59).

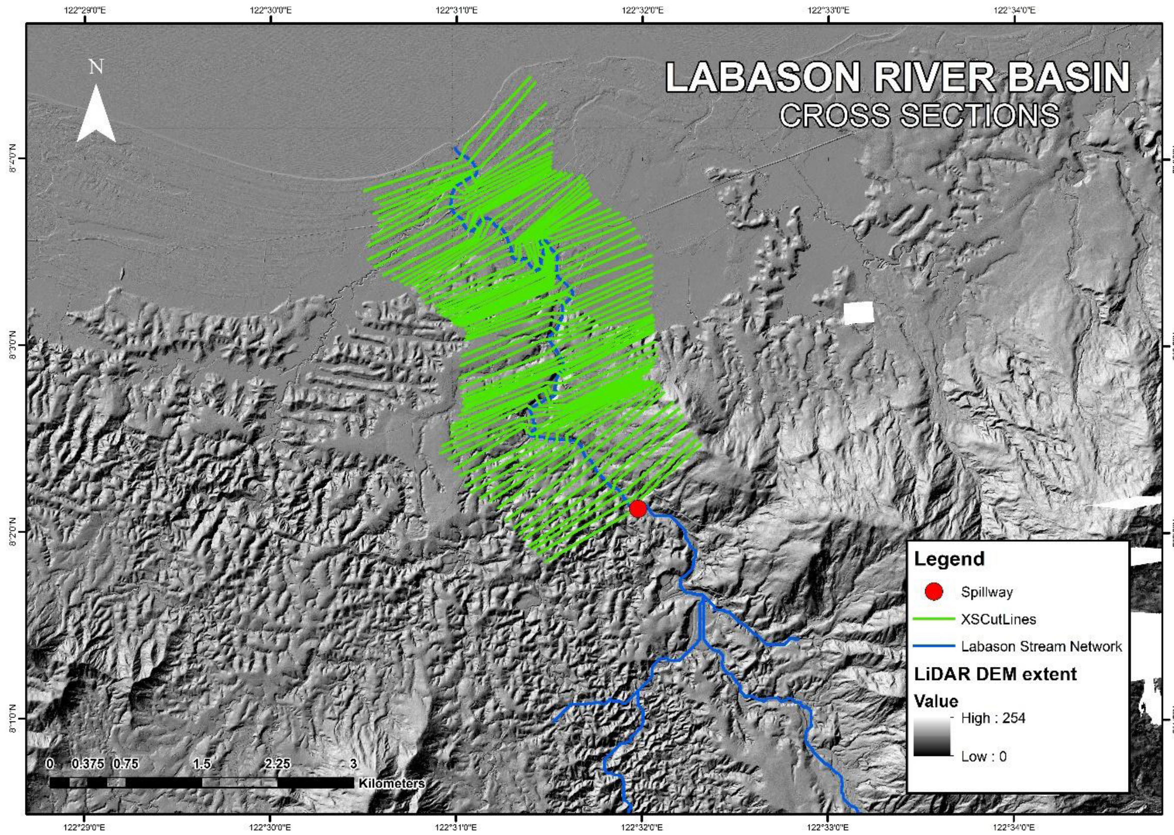


Figure 59. River cross-section of Labason River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 60. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 33.90338 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

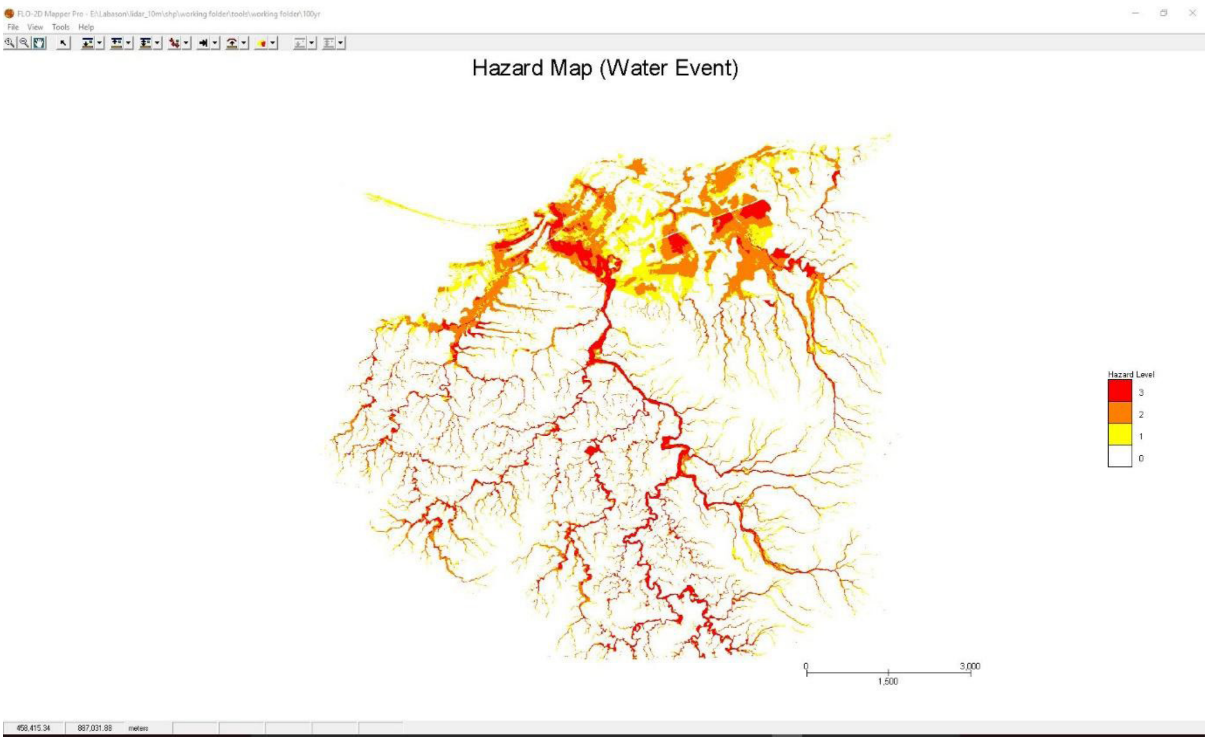


Figure 61. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 74353632.00 m2.

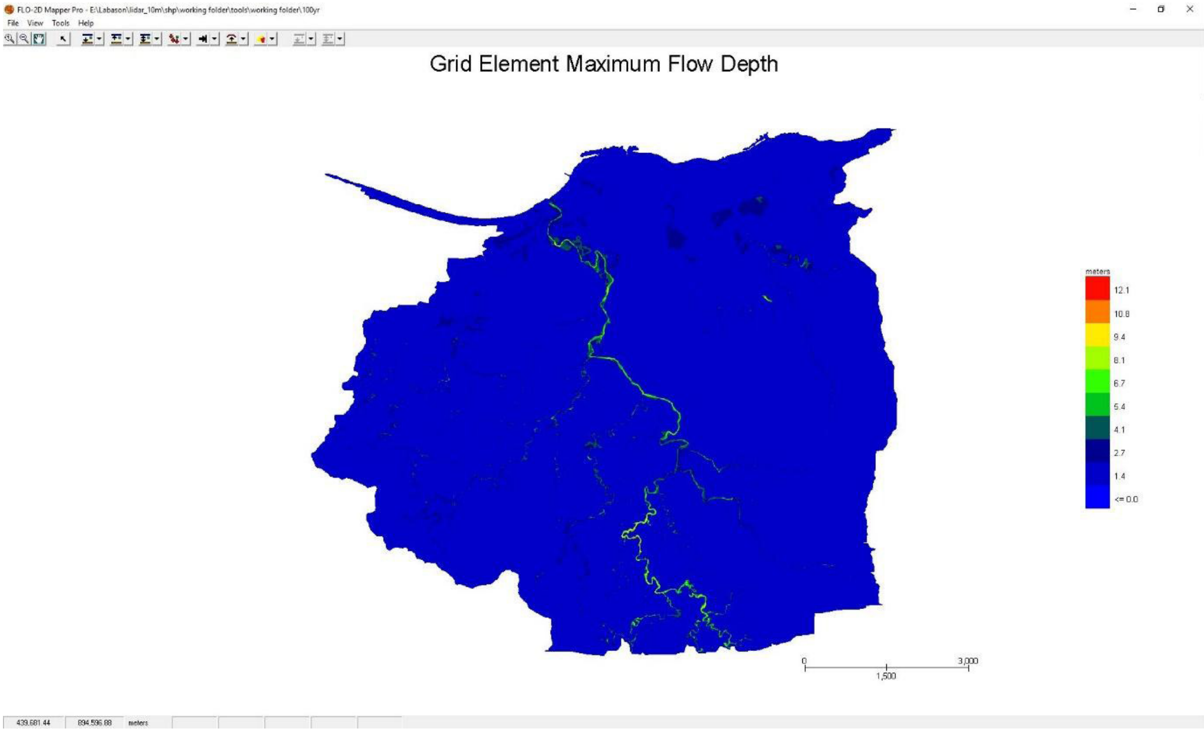


Figure 62. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 15371632.51 m3 of water entering the model. Of this amount, 14517458.62 m3 is due to rainfall while 854173.90 m3 is inflow from other areas outside the model. 4722716.50 m3 of this water is lost to infiltration and interception, while 4544043.21 m3 is stored by the flood plain. The rest, amounting up to 6104876.45 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Labason HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

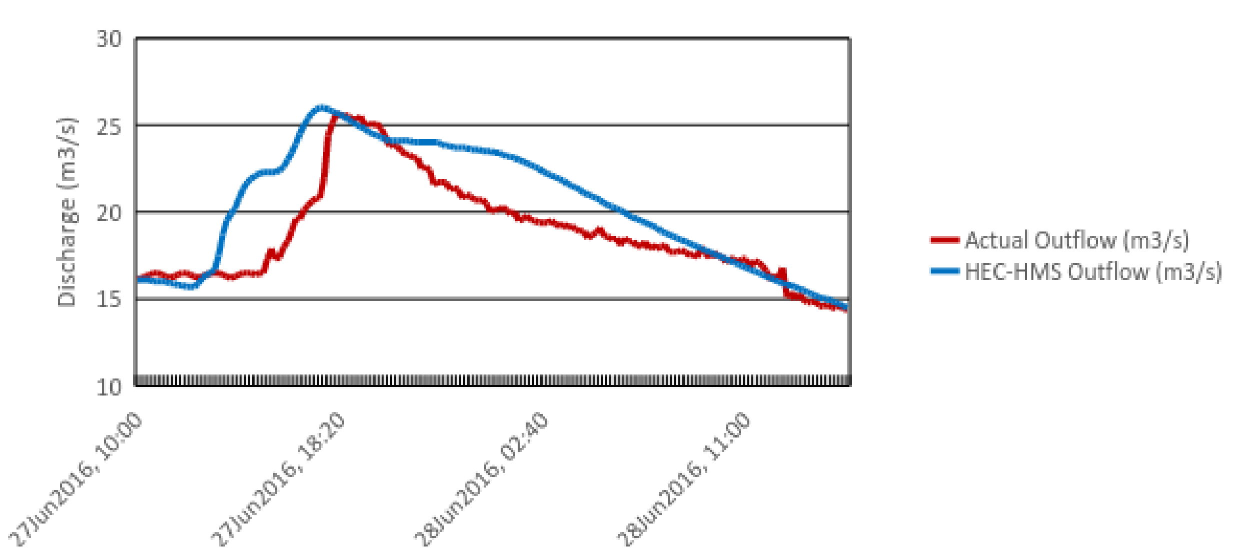


Figure 63. Outflow Hydrograph of Labason produced by the HEC-HMS model compared with observed outflow

The adjusted ranges of values of the parameters used in calibrating the model are enumerated in Table 32.

Table 32. Range of Calibrated Values for Labason

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.0017 – 0.0047
			Curve Number	99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 0.45
			Storage Coefficient (hr)	0.11 – 9.20
	Baseflow	Recession	Recession Constant	0.425
			Ratio to Peak	1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.35

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.0017 mm to 0.0047 mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 9.20 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 0.425 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 1 indicates a shallow receding limb of the outflow hydrograph.

Table 33. Summary of the Efficiency Test of Labason HMS Model

Accuracy Measure	Values
RMSE	31.1225
r2	0.9307
NSE	0.623785
PBIAS	-8.11284
RSR	0.613364

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 31.1225 (m3/s).
The Pearson correlation coefficient (r^2) 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 0.9307.

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 0.623785.

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 -8.11284.

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 0.613364.

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

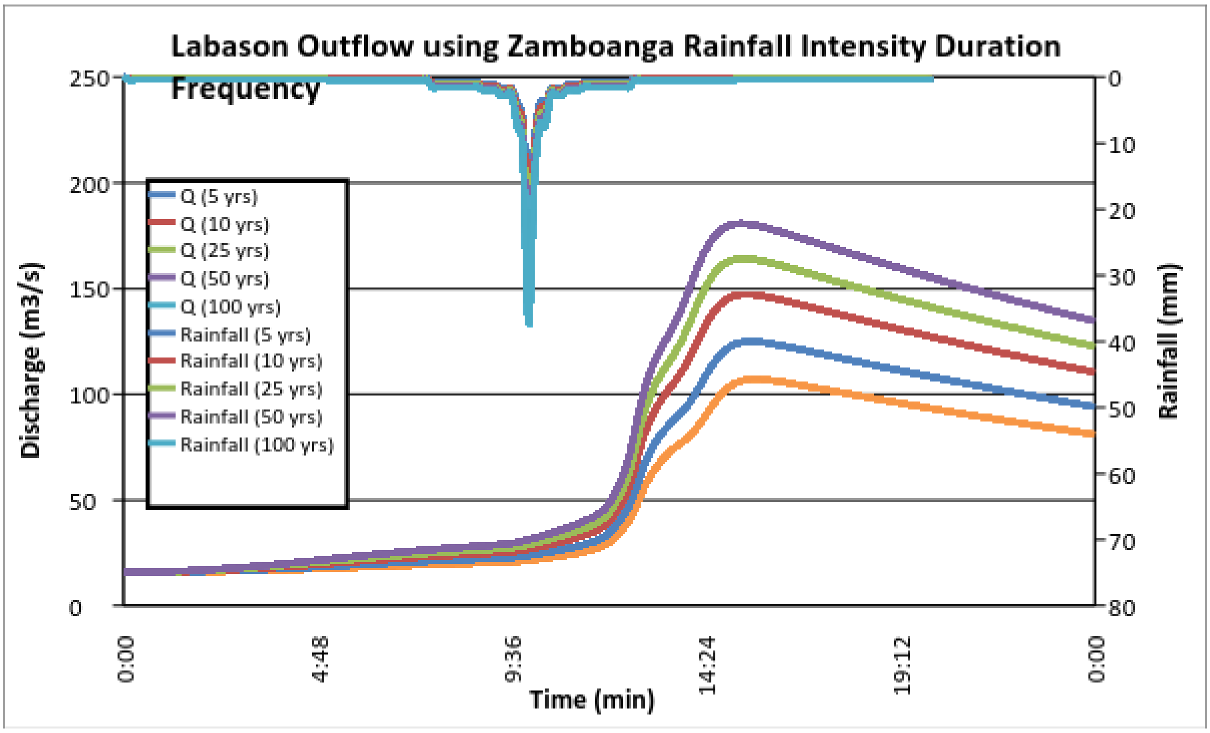


Figure 64. Outflow hydrograph at Brgy. La Union Station generated using Zamboanga City RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Labason discharge using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Labason 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	107.18	15 hours 40 minutes
10-Year	127.9	25.3	124.99	15 hours 30 minutes
25-Year	153.4	30.2	147.37	15 hours 20 minutes
50-Year	172.3	33.9	164.12	15 hours 20 minutes
100-Year	191.1	37.5	180.62	15 hours 20 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 was an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Labason River using the calibrated HMS base flow is shown in Figure 65.

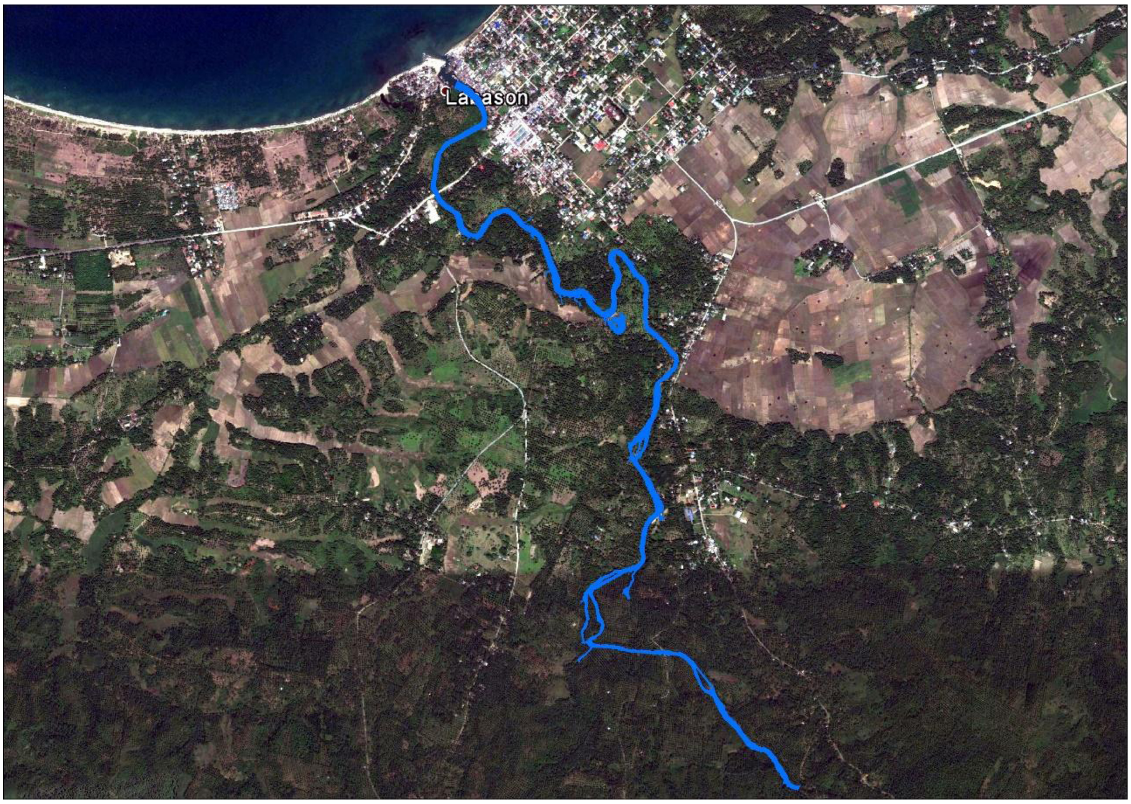


Figure 65. Sample output of Labason RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 show the 5-, 25-, and 100-year rain return scenarios of the Labason Floodplain.

Table 35. Municipalities affected in Labason Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Labason	159.43	74.17	46.52%

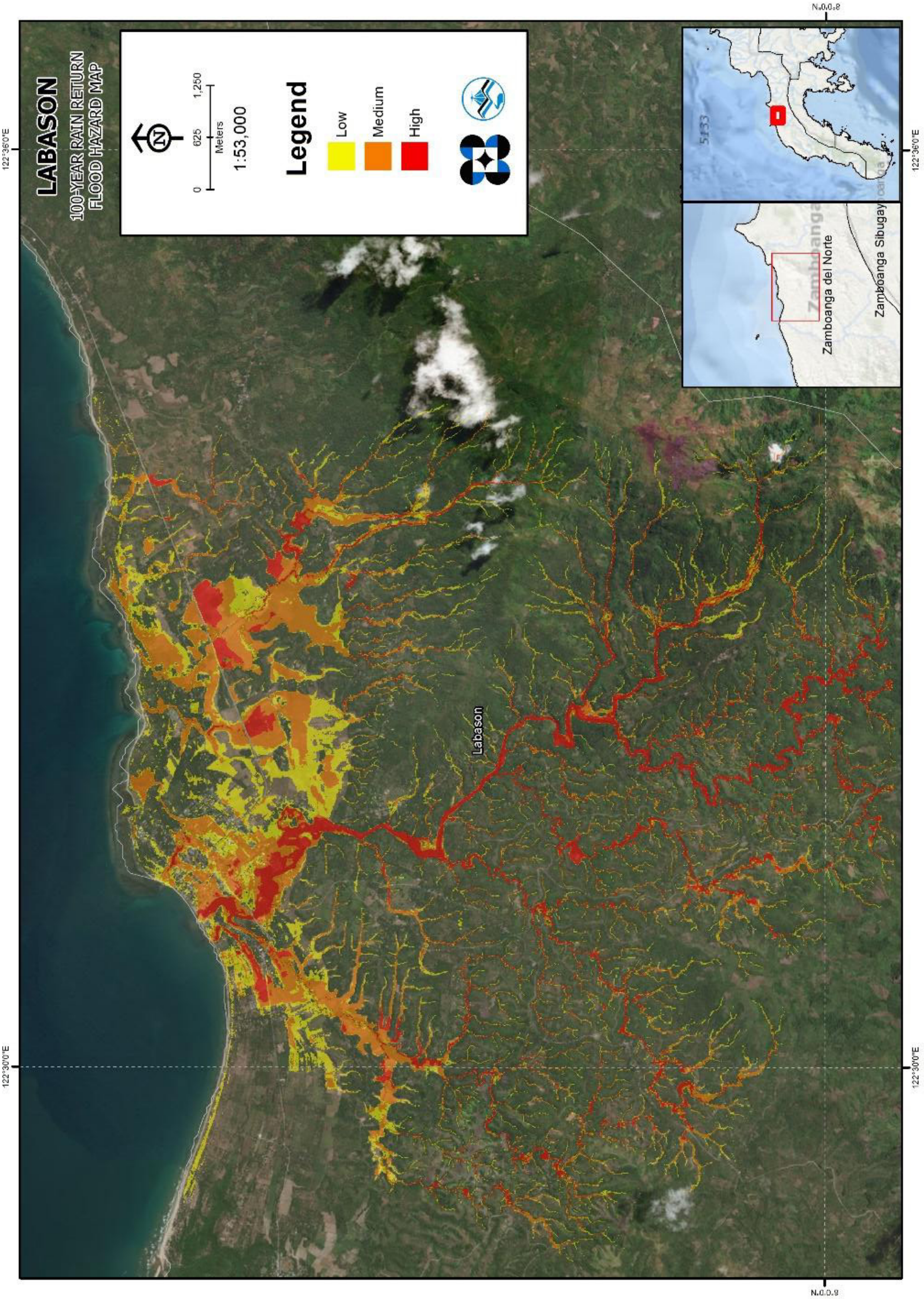


Figure 66. 100-year Flood Hazard Map for Labason Floodplain

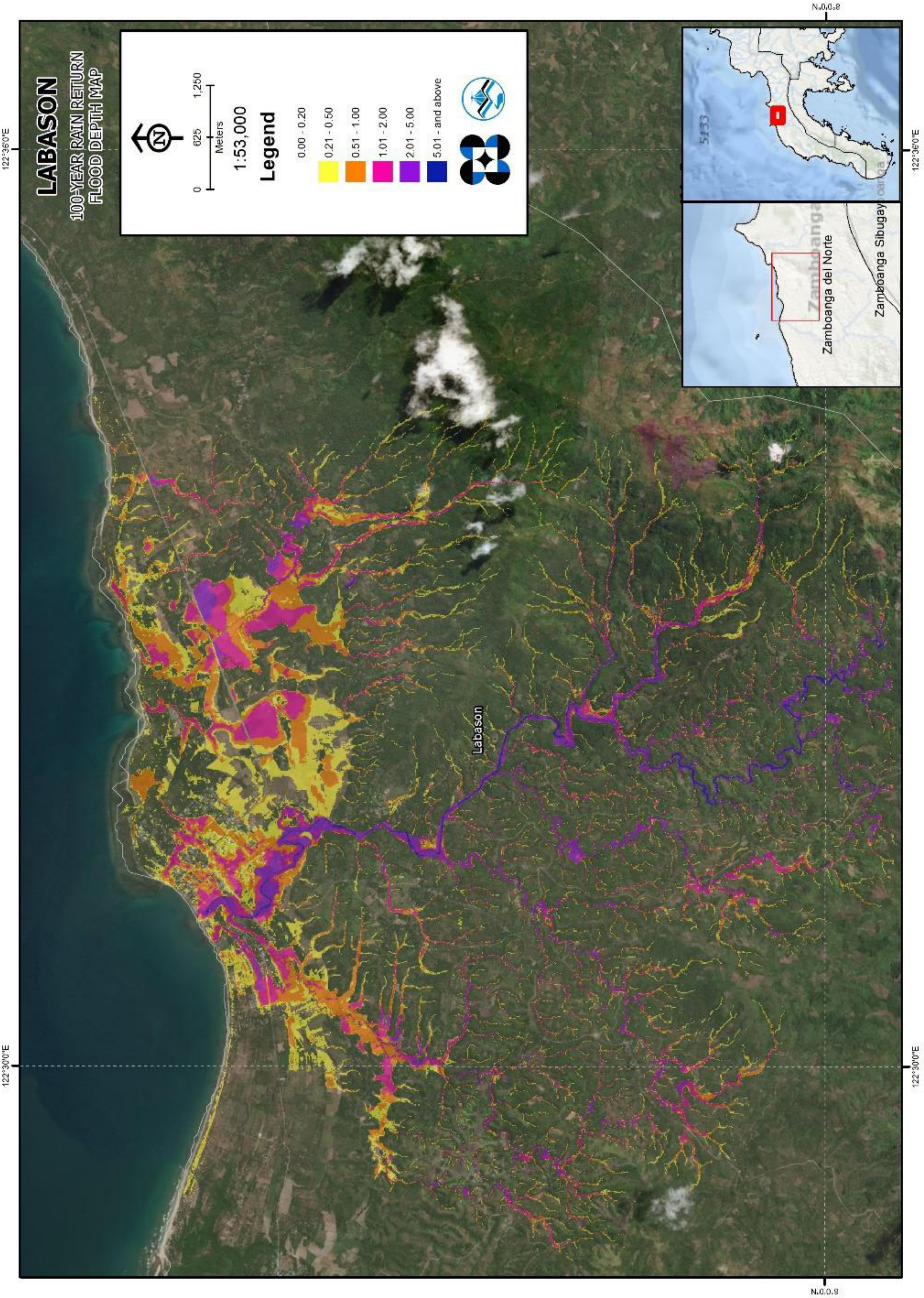


Figure 67. 100-year Flow Depth Map for Labason Floodplain

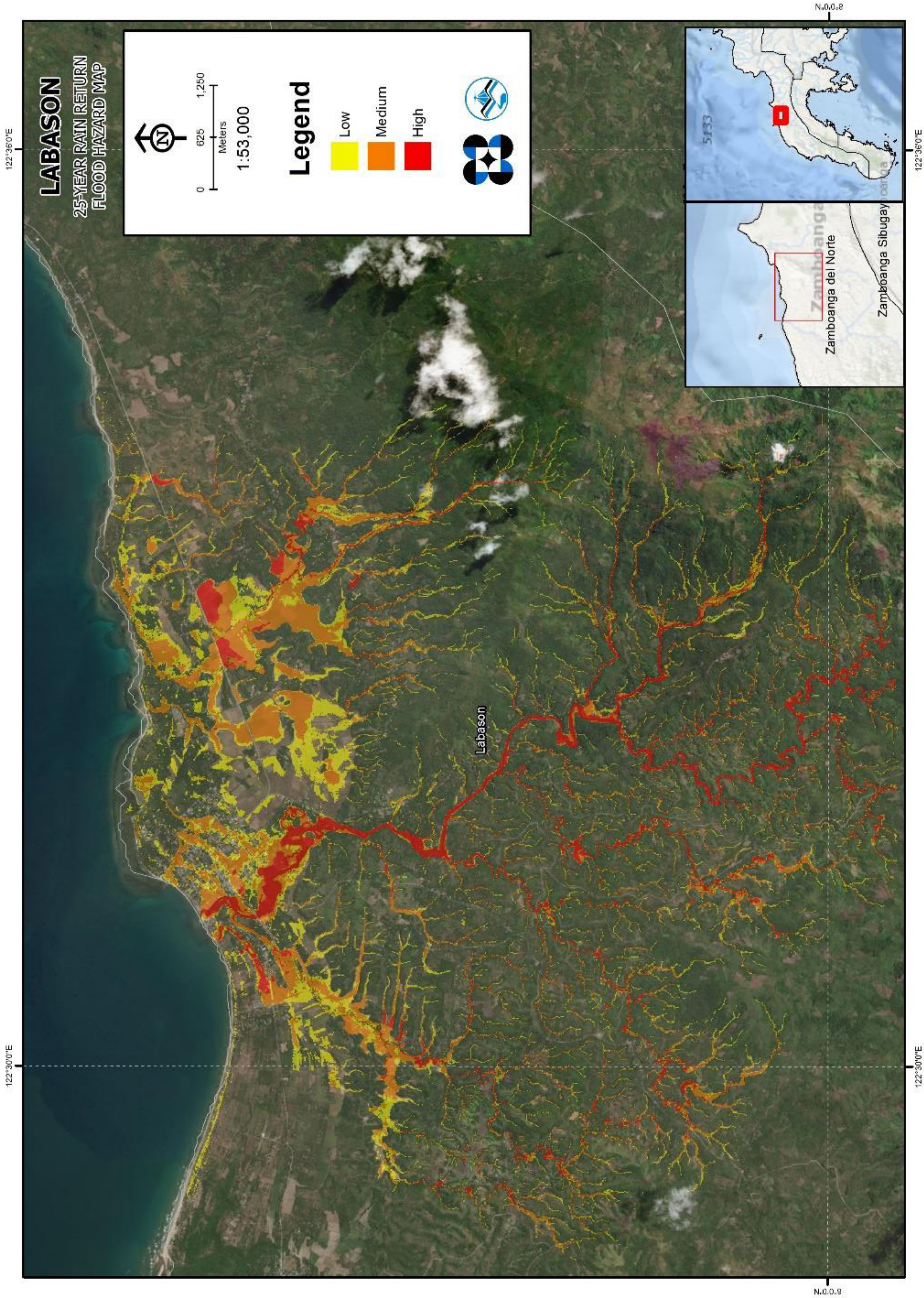


Figure 68. 25-year Flood Hazard Map for Labason Floodplain

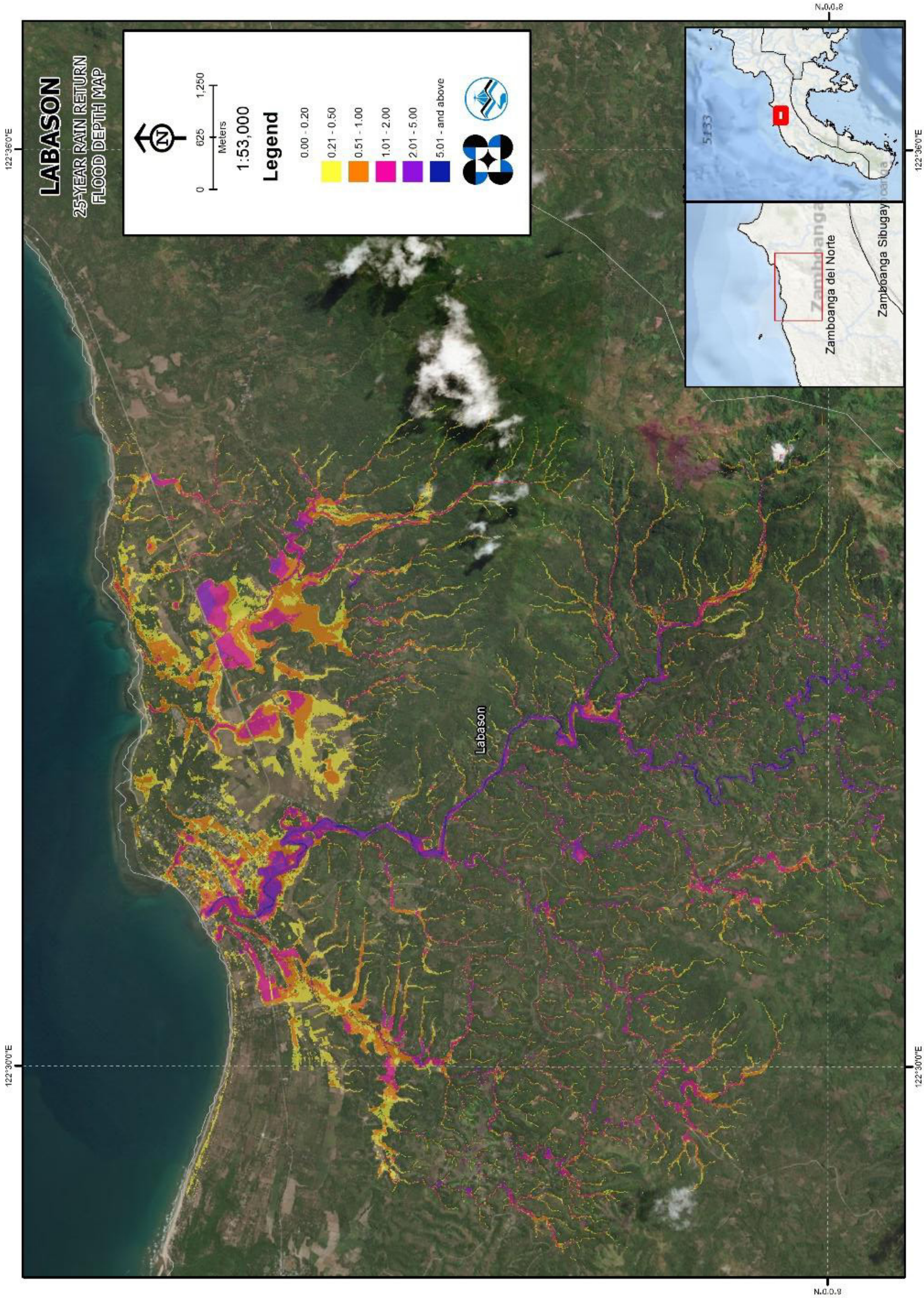


Figure 69. 25-year Flow Depth Map for Labason Floodplain

Figure 34.

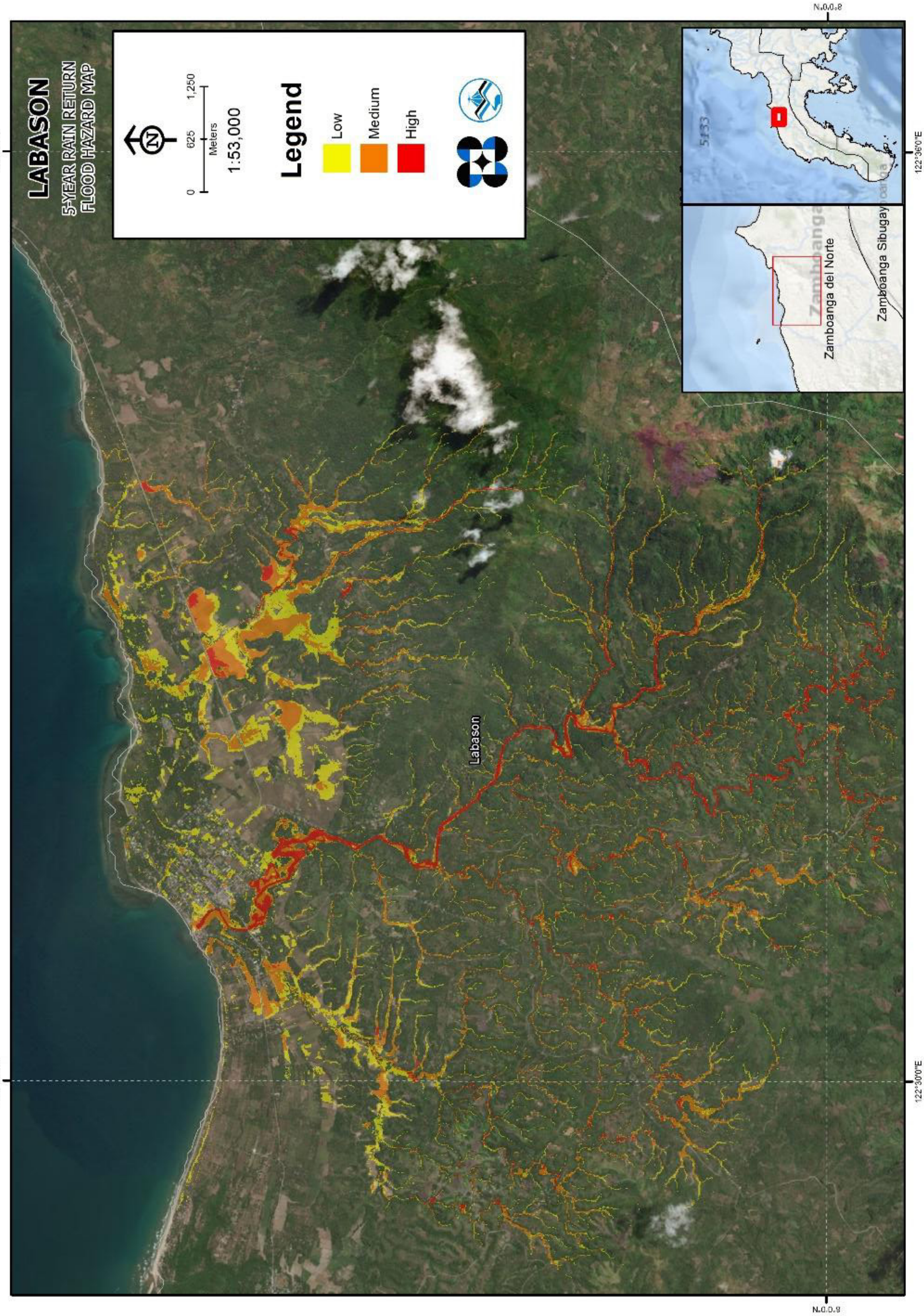


Figure 70. 5-year Flood Hazard Map for Labason Floodplain

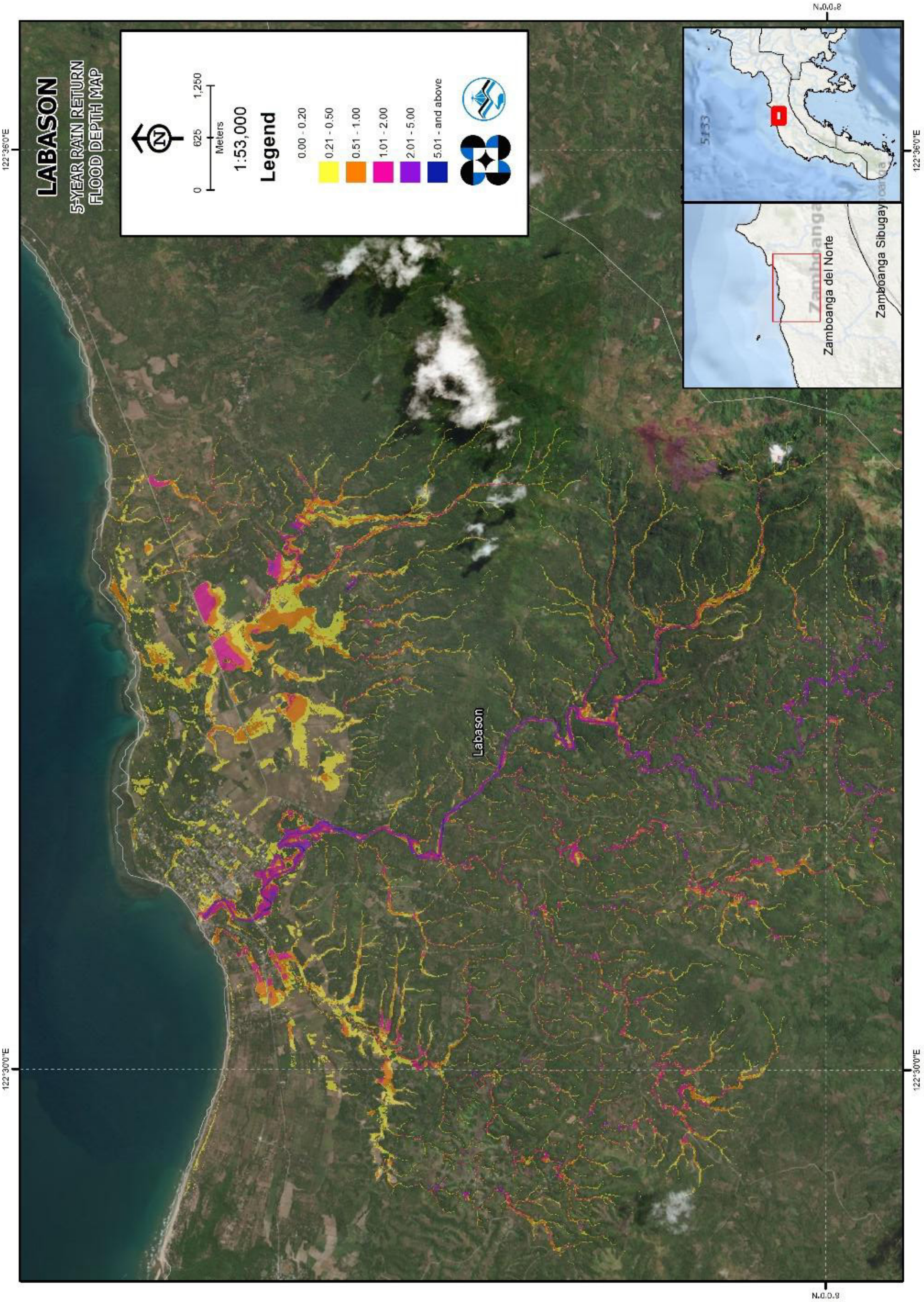


Figure 71. 5-year Flood Depth Map for Labason Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Labason river basin, grouped by municipality, are listed below. For the said basin, 17 barangays in the municipality of Labason, Zamboanga del Norte are expected to experience flooding when subjected to the flood hazard scenarios.

For the 5-year return period, 41.06% of the municipality of Labason with an area of 159.4316 sq. km. will experience flood levels of less than 0.20 meters; 2.47% of the area will experience flood levels of 0.21 to 0.50 meters while 1.58%, 1.00%, 0.39%; and 0.02% 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. . Annex 12 and Annex 13 show the educational and health institutions exposed to flooding, respectively.

Table 71. Affected Areas in Labason during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labason (in sq. km.)										
	Antonino	Balas	Bobongan	Dansalan	Gabu	Gil Sanchez	Imelda	Kipit	La Union	Lapatan	Lawagan
0.03-0.20	1.41	6.11	0.61	3.19	9.3	1.23	0.82	6.2	7.48	14.54	3.27
0.21-0.50	0.17	0.21	0.027	0.36	0.3	0.13	0.077	0.33	0.75	0.47	0.18
0.51-1.00	0.034	0.19	0.0084	0.19	0.3	0.013	0.031	0.22	0.4	0.32	0.17
1.01-2.00	0.036	0.15	0.01	0.12	0.33	0.0012	0.045	0.14	0.097	0.22	0.078
2.01-5.00	0.015	0.012	0.0004	0.0025	0.21	0	0.03	0.025	0.048	0.12	0.02
> 5.00	0.0018	0	0	0	0.0047	0	0.0023	0	0.008	0.0021	0

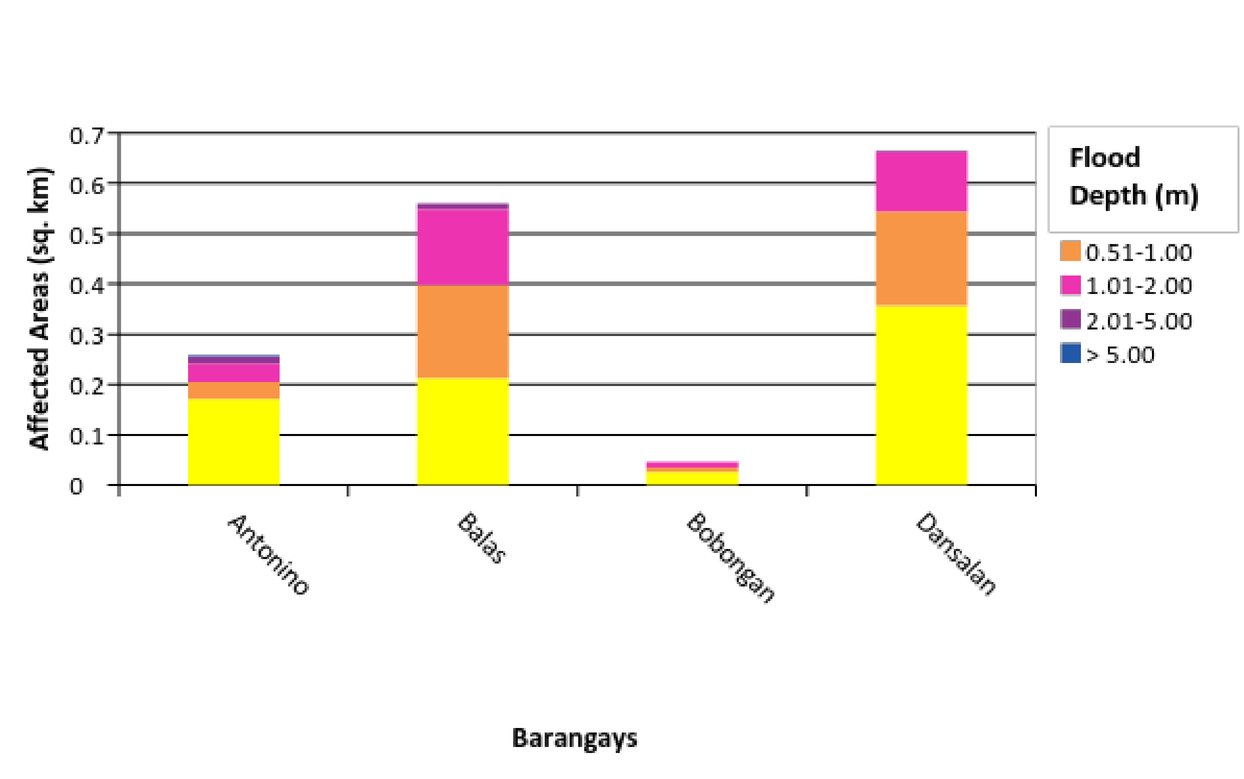


Figure 72. Affected Areas in Labason during 5-Year Rainfall Return Period

Table 37. Affected Areas in Labason during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labason (in sq. km.)					
	Lawigan	Lopoc	New Salvacion	Osukan	San Isidro	Ubay
0.03-0.20	7	1.2	0.57	1.34	1.13	0.054
0.21-0.50	0.31	0.32	0.025	0.26	0.019	0
0.51-1.00	0.22	0.25	0.01	0.18	0.0044	0
1.01-2.00	0.2	0.061	0.0009	0.11	0.0002	0
2.01-5.00	0.12	0.0012	0	0.014	0.0001	0
> 5.00	0.01	0	0	0.0003	0	0

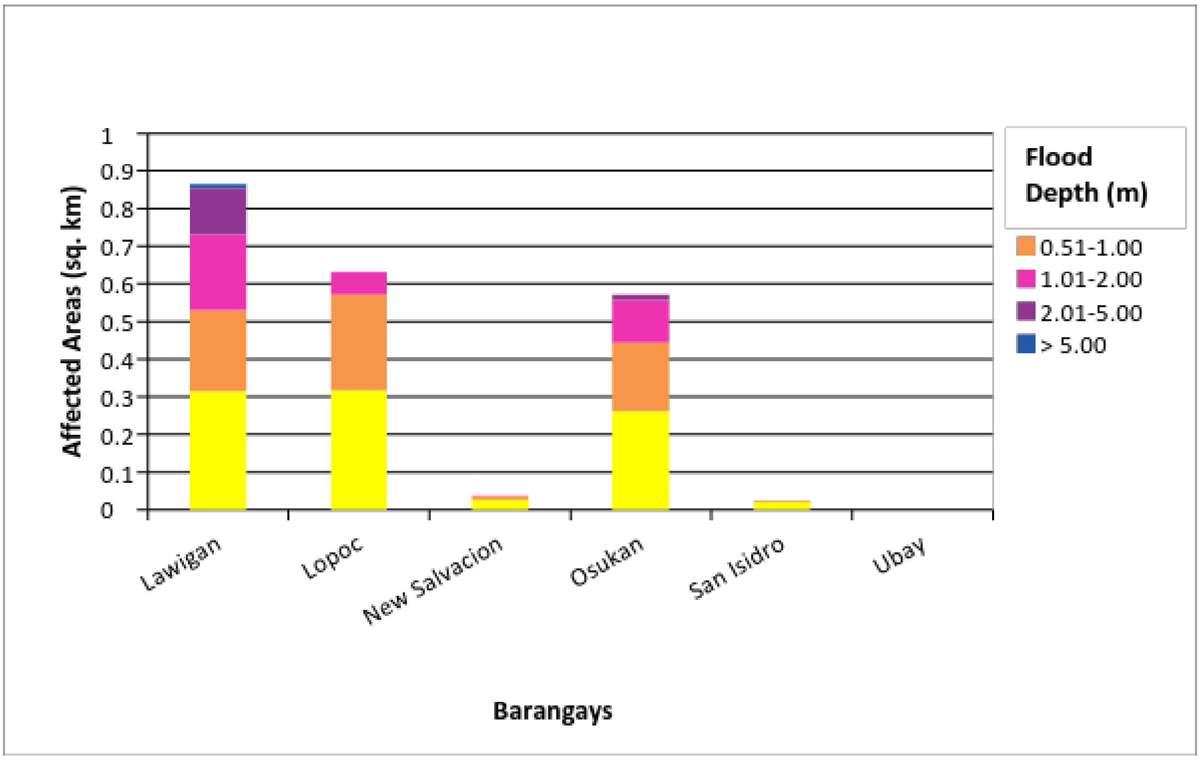


Figure 73. Affected Areas in Labason during 5-Year Rainfall Return Period

For the 25-year return period, 38.80% of the municipality of Labason with an area of 159.4316 sq. km. will experience flood levels of less than 0.20 meters; 2.85% of the area will experience flood levels of 0.21 to 0.50 meters while 2.32%, 1.64%, 0.82%; 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Labason during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labason (in sq. km.)										
	Antonino	Balas	Bobongan	Dansalan	Gabu	Gil Sanchez	Imelda	Kipit	La Union	Lapatan	Lawagan
0.03-0.20	0.94	5.98	0.58	2.77	9.01	1.09	0.66	5.93	7.13	14.23	3.17
0.21-0.50	0.31	0.21	0.037	0.5	0.31	0.17	0.16	0.38	0.76	0.53	0.18
0.51-1.00	0.27	0.21	0.021	0.32	0.29	0.085	0.061	0.28	0.62	0.37	0.18
1.01-2.00	0.093	0.21	0.0096	0.19	0.4	0.017	0.058	0.25	0.2	0.28	0.14
2.01-5.00	0.05	0.057	0.0047	0.067	0.38	0	0.066	0.071	0.066	0.22	0.046
> 5.00	0.0035	0	0	0	0.062	0	0.0046	0	0.018	0.024	0

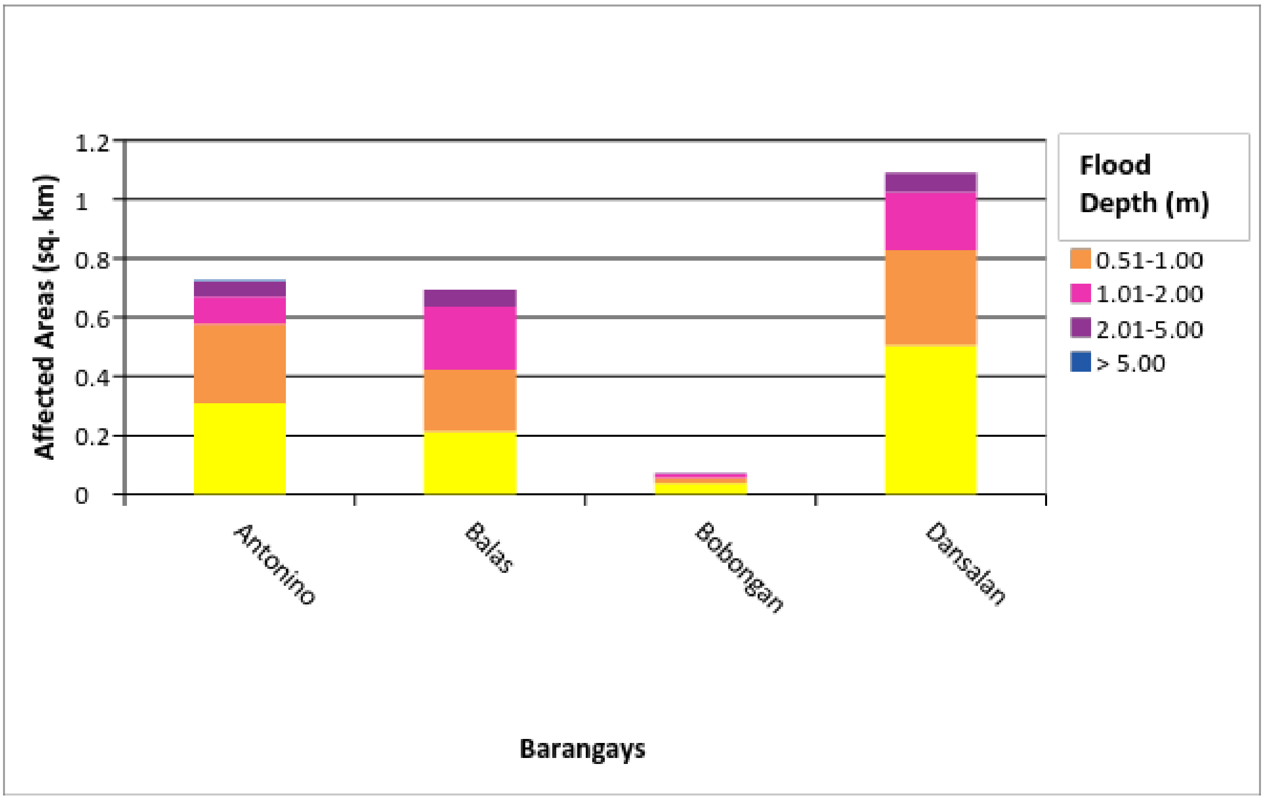


Figure 74. Affected Areas in Labason during 25-Year Rainfall Return Period

Table 39. Affected Areas in Labason during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labason (in sq. km.)					
	Lawigan	Lopoc	New Salvacion	Osukan	San Isidro	Ubay
0.03-0.20	6.7	0.96	0.56	0.97	1.12	0.054
0.21-0.50	0.35	0.26	0.024	0.33	0.023	0
0.51-1.00	0.29	0.36	0.019	0.32	0.01	0
1.01-2.00	0.25	0.25	0.0024	0.26	0.0007	0
2.01-5.00	0.25	0.0052	0.0001	0.034	0.0002	0
> 5.00	0.03	0	0	0.002	0	0

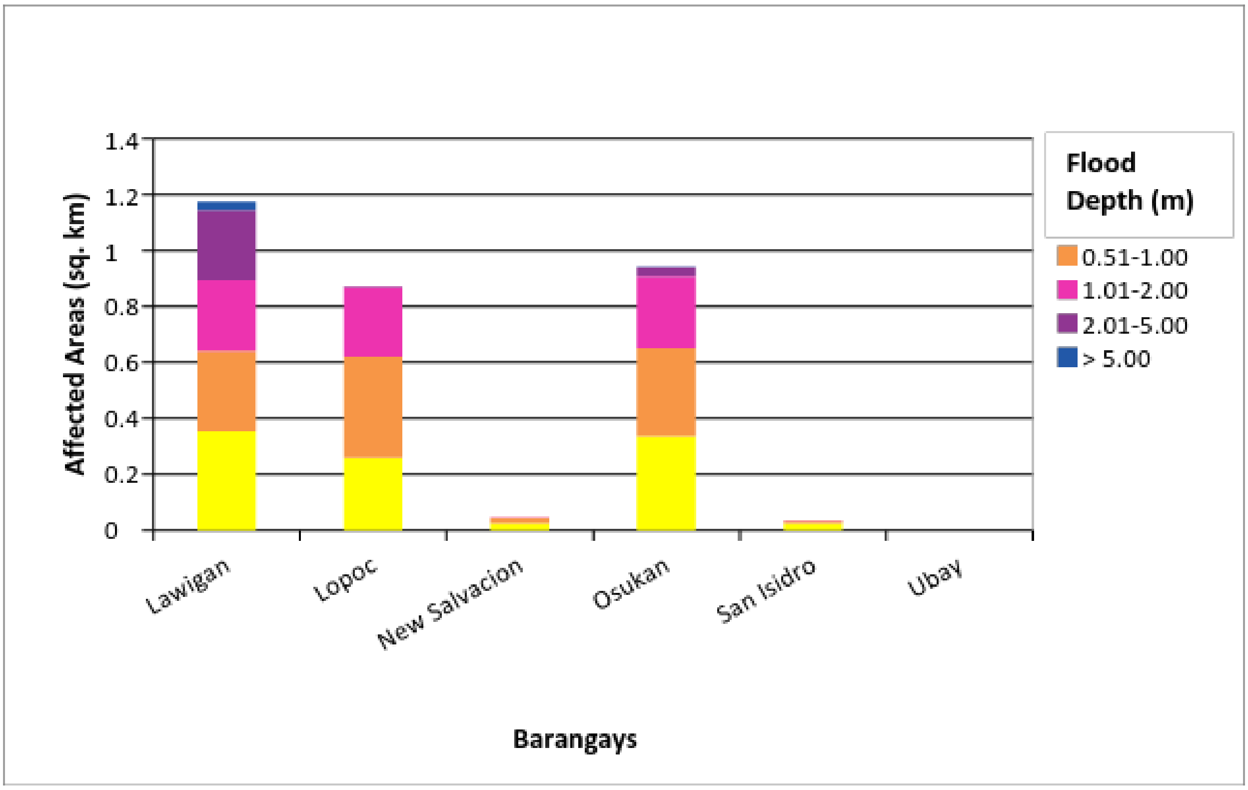


Figure 75. Affected Areas in Labason during 25-Year Rainfall Return Period

For the 100-year return period, 37.38% of the municipality of Labason with an area of 159.4316 sq. km. will experience flood levels of less than 0.20 meters; 3.09% of the area will experience flood levels of 0.21 to 0.50 meters while 2.67%, 2.13%, 1.10%; and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Labason during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labason (in sq. km.)										
	Antonino	Balas	Bobongan	Dansalan	Gabu	Gil Sanchez	Imelda	Kipit	La Union	Lapatan	Lawagan
0.03-0.20	0.64	5.91	0.57	2.53	8.86	1.01	0.41	5.8	6.91	14.06	3.12
0.21-0.50	0.39	0.22	0.042	0.5	0.3	0.17	0.34	0.38	0.78	0.58	0.19
0.51-1.00	0.34	0.21	0.029	0.42	0.29	0.13	0.11	0.31	0.68	0.38	0.18
1.01-2.00	0.24	0.23	0.0097	0.31	0.4	0.055	0.065	0.3	0.31	0.33	0.17
2.01-5.00	0.059	0.099	0.0074	0.095	0.47	0	0.079	0.12	0.079	0.26	0.067
> 5.00	0.0039	0.0001	0	0	0.11	0	0.0052	0.0003	0.027	0.05	0

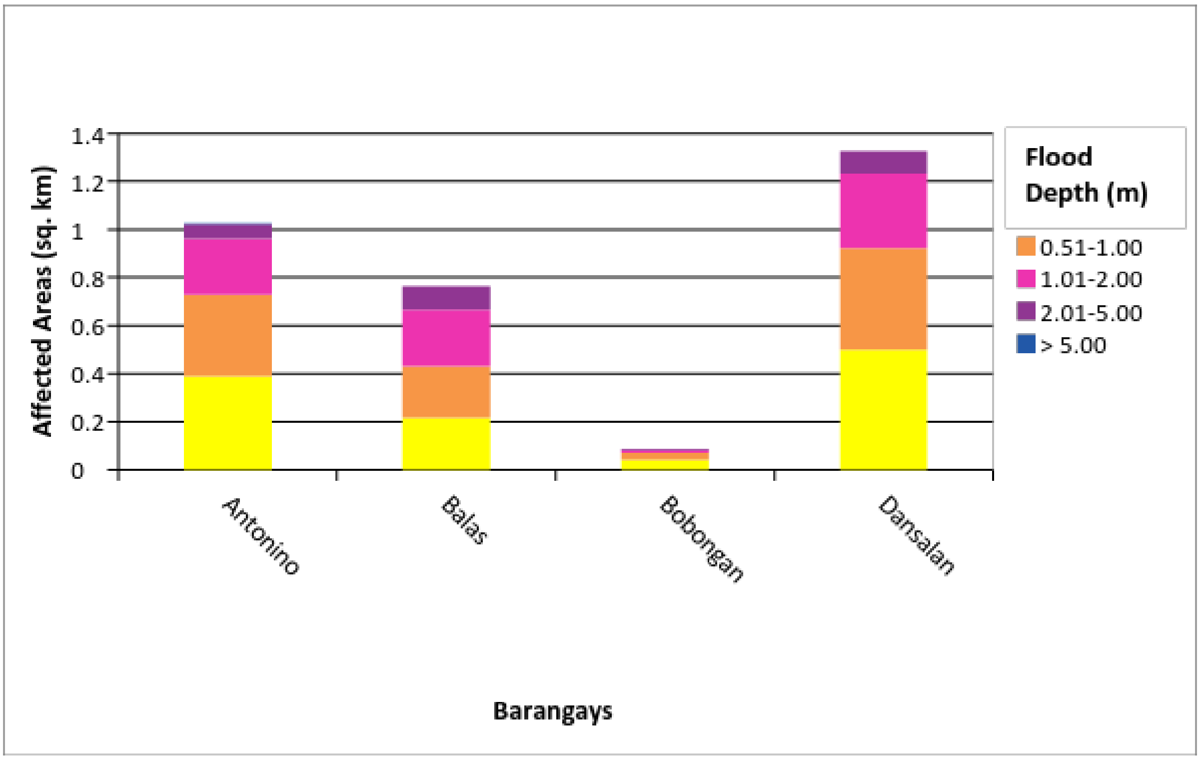


Figure 76. Affected Areas in Labason during 100-Year Rainfall Return Period

Table 41. Affected Areas in Labason during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labason (in sq. km.)					
	Lawigan	Lopoc	New Salvacion	Osukan	San Isidro	Ubay
0.03-0.20	6.54	0.78	0.55	0.72	1.12	0.054
0.21-0.50	0.35	0.24	0.024	0.38	0.028	0
0.51-1.00	0.34	0.4	0.022	0.41	0.012	0
1.01-2.00	0.28	0.39	0.0048	0.3	0.0013	0
2.01-5.00	0.32	0.01	0.0001	0.098	0.0002	0
> 5.00	0.039	0	0	0.0035	0	0

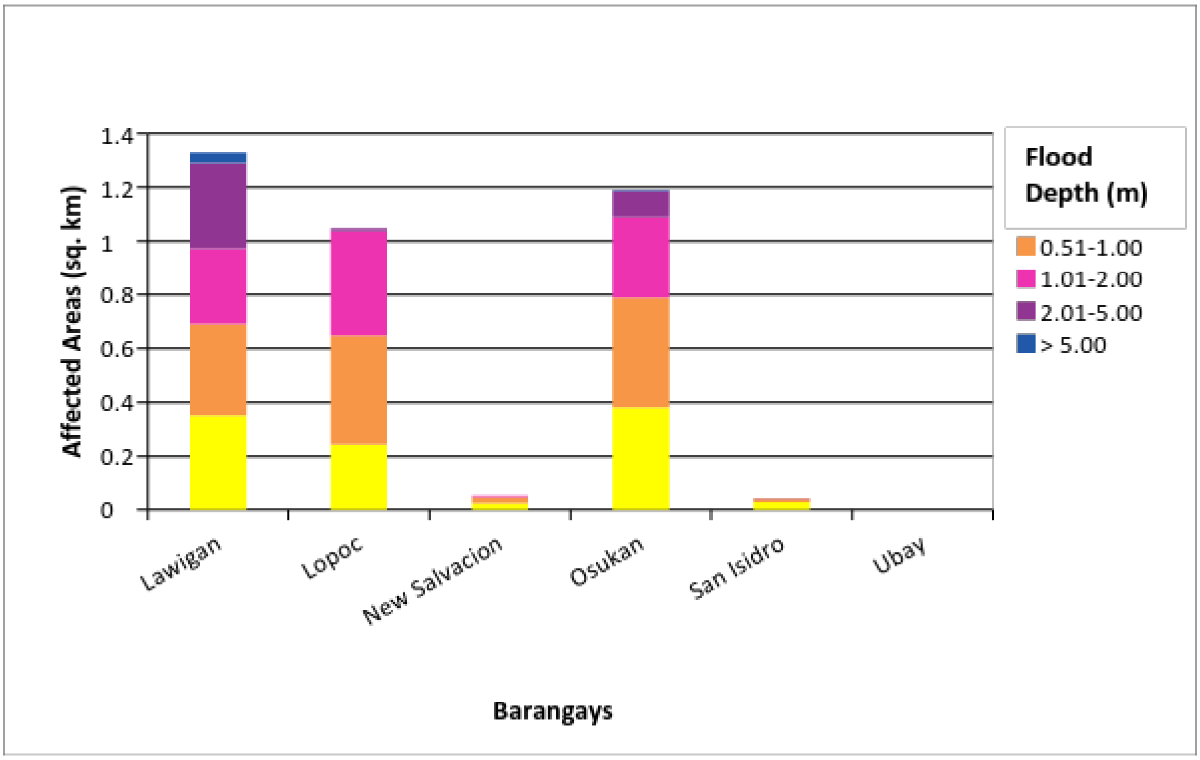


Figure 77. Affected Areas in Labason during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Labason 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 42. 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	4.01	4.61	4.98
Medium	3.58	5.36	6.42
High	1.34	2.57	3.42
Total	**8.93**	**12.54**	**14.82**

One identified educational institution in Labason Floodplain was assessed to be exposed to medium flood levels for the 25 and 100 year scenarios.

Of the 7 identified health institutions in Labason Floodplain, 4 sites were assessed to have low flood levels while 2 sites were assessed to have medium flood levels for the 25 year scenario. Two sites were assessed to be exposed to low flood levels while 5 sites were assessed to have medium flood levels for the 100 year scenario.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 80.

The flood validation data were obtained on October 2016. The flood validation consisted of 112 points randomly selected all over the Labason Floodplain. It has an RMSE value of 0.29.

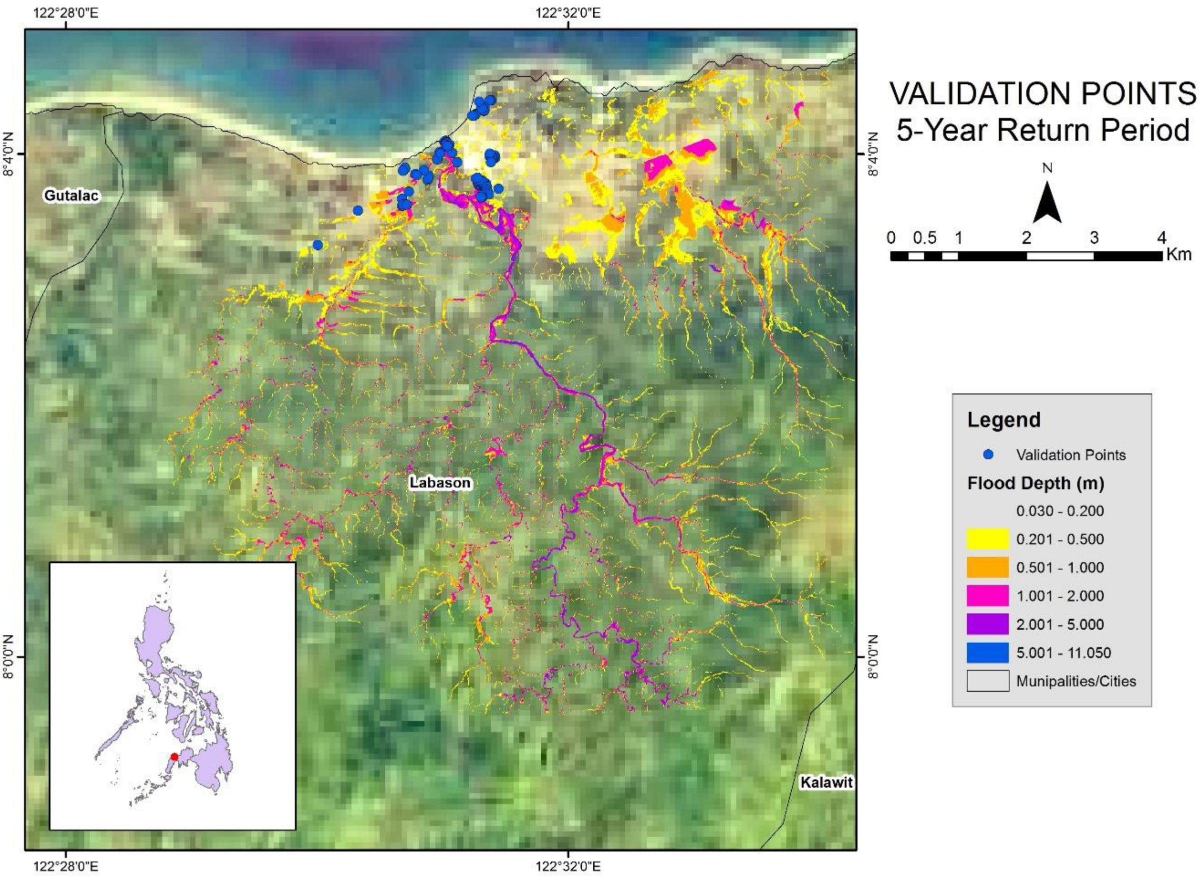


Figure 78. Validation points for 5-year Flood Depth Map of Labason Floodplain

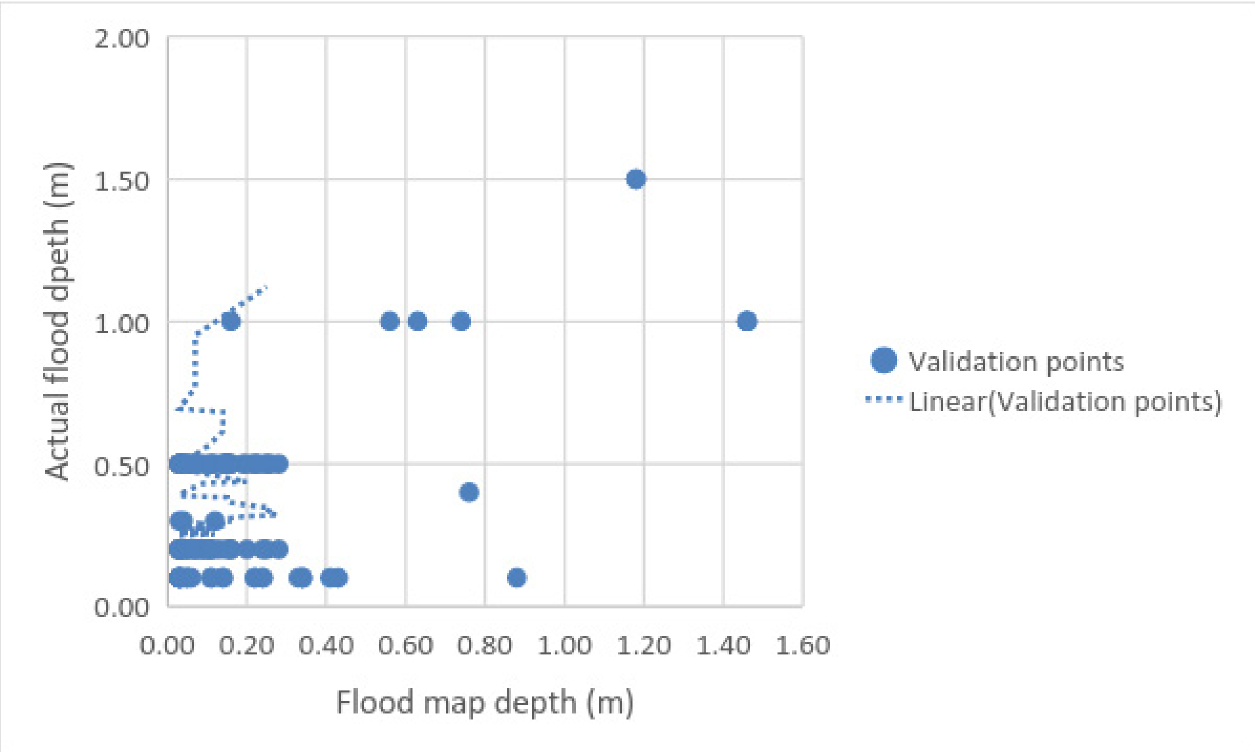


Figure 79. Flood map depth vs actual flood depth

Table 43. Actual Flood Depth vs Simulated Flood Depth in Labason

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
0-0.20	47	13	1	0	0	0	61
0.21-0.50	34	7	1	0	0	0	42
0.51-1.00	1	0	3	3	0	0	7
1.01-2.00	0	0	0	2	0	0	2
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	82	20	5	5	0	0	112

The overall accuracy generated by the flood model is estimated at 52.68%, with 59 points correctly matching the actual flood depths. In addition, there were 51 points estimated one level above and below the correct flood depths while there were 2 points estimated two levels above and below. A total of 18 points were overestimated while a total of 35 points were underestimated in the modelled flood depths of Labason.

Table 44. Summary of Accuracy Assessment in Labason River Basin Survey

	No. of Points	**%**
Correct	59	52.68
Overestimated	18	16.07
Underestimated	35	31.25
Total	112	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.

National Disaster Risk Reduction and Management Council (NDRRMC), 2017. Flood Advisory on 1 February 2017, retrieved from <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>

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.

www.islandproperties.com n.d. Zambonor, retrieved from <http://www.islandsproperties.com/places/zambonor.htm>

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensor used in the Labason Floodplain Survey

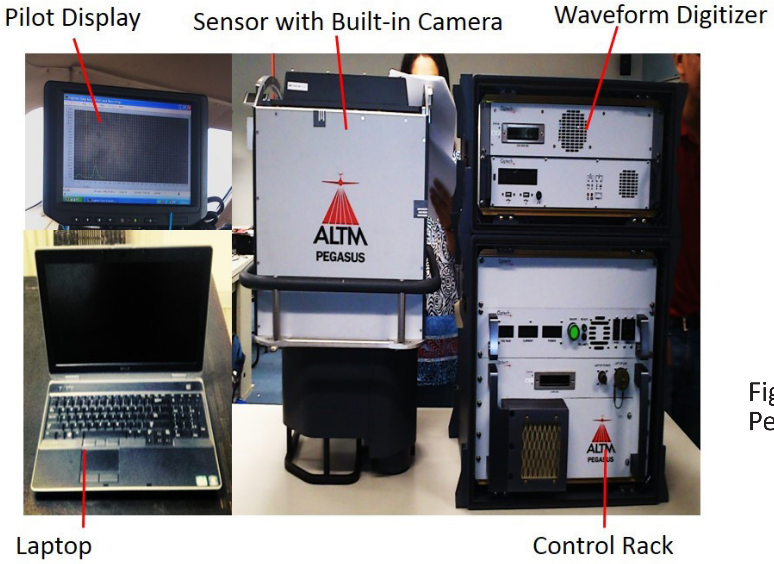


Figure A-1.1 Pegasus Sensor

Table A-1.1 Technical Specifications and Parameters of the 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
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/814

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

1. 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

Figure A-3.1 ZN-157

2. 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 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 for Labason 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	290/48/58	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	2.64	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	1701/87	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	65/62/61	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name Angelo Carlo Bongat
Position SSRS
Signature ABongat 11/19/2014

Figure A-5.1 Data Transfer Sheet for Labason Floodplain - A

DATA TRANSFER SHEET
12/09/2014(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	
10-Nov	2185P	1BLK73A314A	PEGASUS	1.15	na	9.84	253	na	na	13.1	na	19.5	1KB	1KB	56/49/45/58	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	56/49/45/59	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SUPSRS
Signature 12/9/14

Figure A-5.2 Data Transfer Sheet for Labason 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 Data Transfer Sheet for Labason 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 Data Transfer Sheet for Labason Floodplain - D

Annex 6. Flight Logs for the Flight Missions

PHIL-LiDAR 1 Data Acquisition Flight Log | **Flight Log No.:** 2169P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK 73A310A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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): PIPOLOG		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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. ALMALVEZ	JRA	FERDINAND E. 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-6.1 Flight Log for Mission 1BLK73A310A

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2185P

1 LiDAR Operator: KJ ANDAYA	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: 12:40	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
	JRA [illegible]	FERDINAND B. DOCAMPO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for Mission 1BLK73A314A

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2189

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK73S315A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: F. De Ocampo	8 Co-Pilot: B. Donguines	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: 1115H	14 Engine Off: 1508H	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	Erwin F. Dalos Santos	Ferdinand B. De Ocampo	Renan 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 Mission 1BLK73A315A

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: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A DAYO	8 Co-Pilot: E SAYSAY 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
PINATO	GEROLYMO BALICAO 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 Mission 1BLK73DE331A

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. SAGUITO	9 Route: DIPOLOG			
10 Date: NOV. 28, 2016	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1259	14 Engine Off: 1710	15 Total Engine Time: 04+11	16 Take off: 1304	17 Landing: 1705	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
R ARCEO	GERONIMO BALIOSO 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 Mission 1BLK73DEF333A

Annex 7. Flight Status Reports

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

Table A-7.1 Flight Status Report

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

LAS BOUNDARIES PER FLIGHT

Flight No.: 2169P
Area: BLK 73A
Mission Name: 1BLK73A310A
Parameters: Altitude: 750 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS

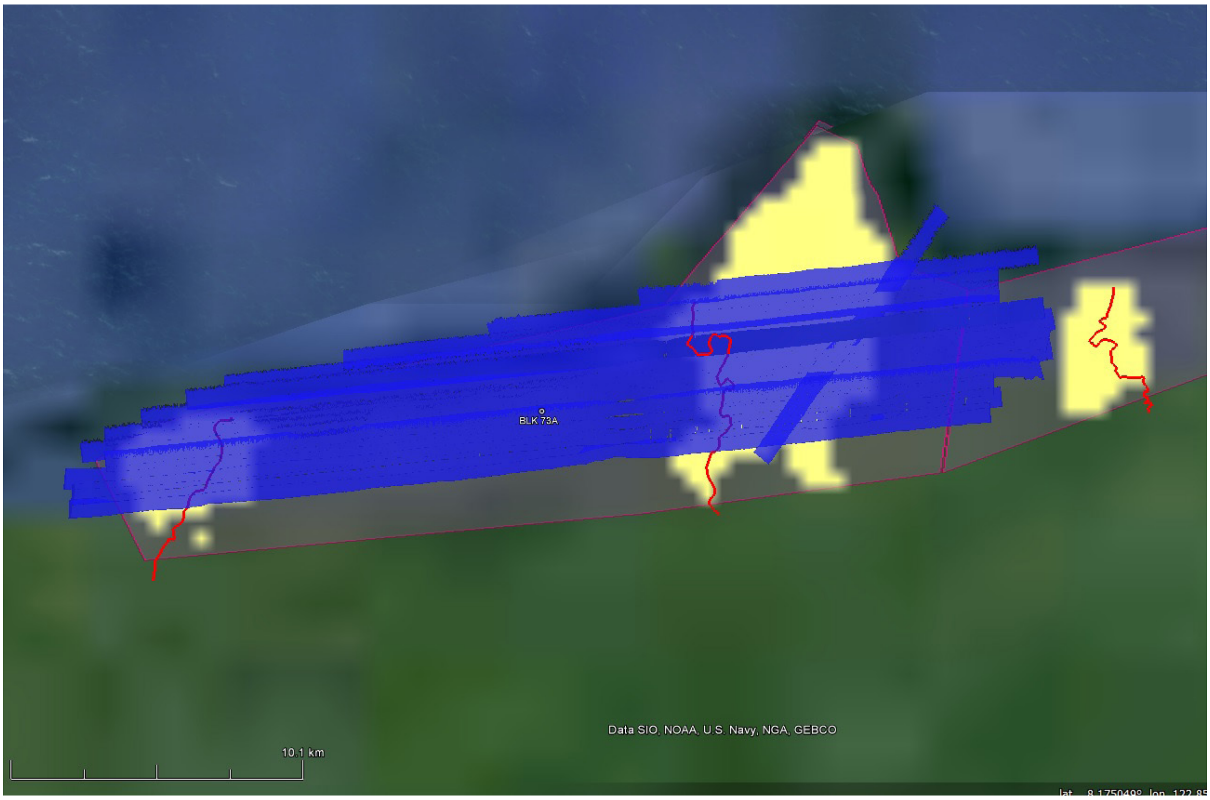


Figure A-7.1 Swath for Flight No. 2169P

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%

LAS

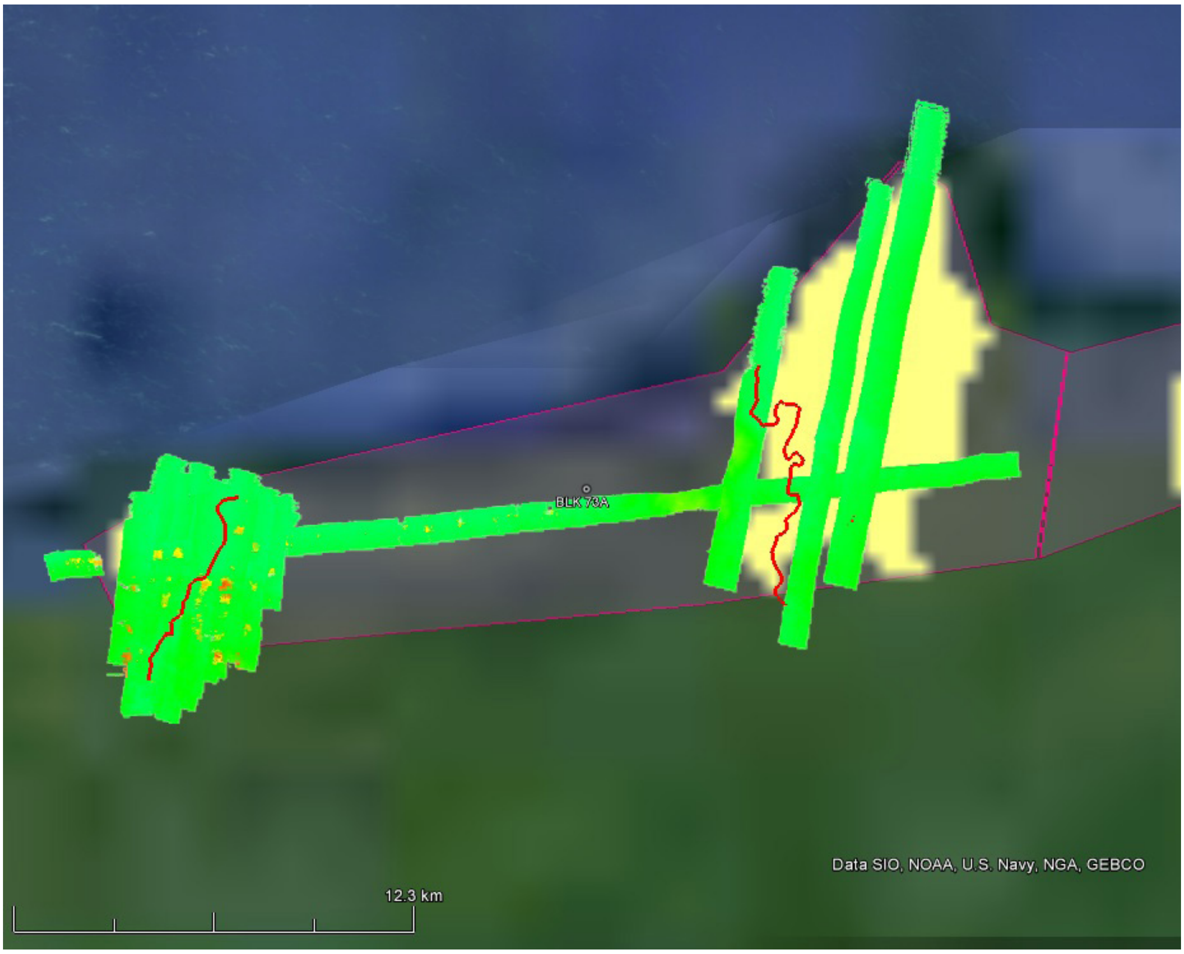


Figure A-7.2 Swath for Flight No. 2185P

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%

LAS

Figure A-7.3 Swath for Flight No. 2189P

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%

LAS

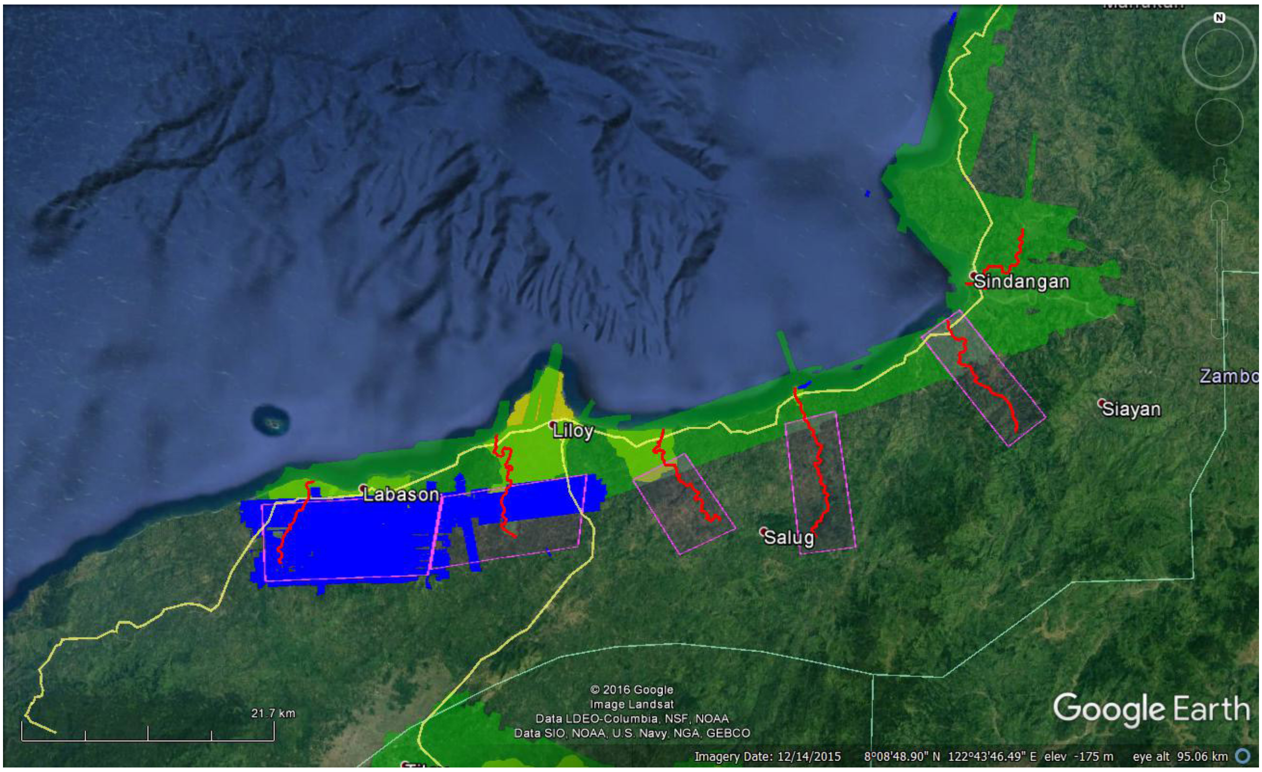


Figure A-7.4 Swath for Flight No. 23582P

Flight 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%

LAS

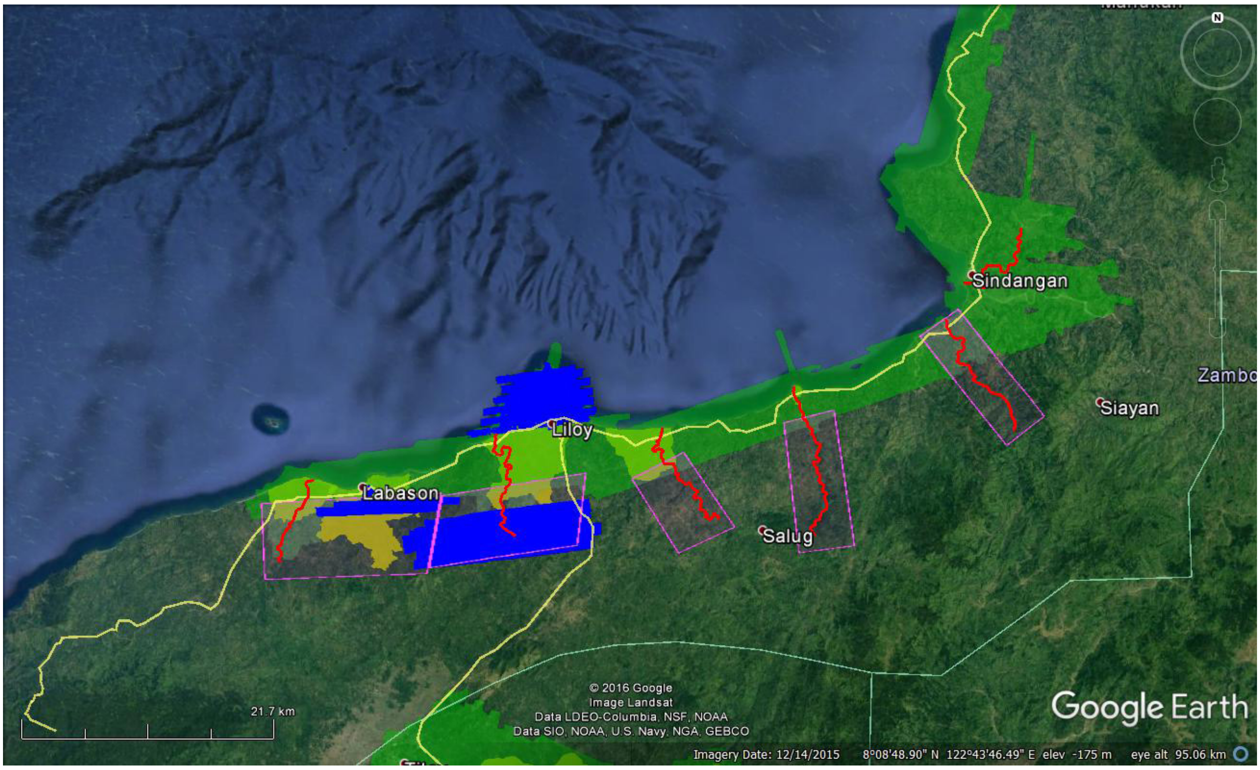


Figure A-7.5 Swath for Flight No. 23590P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report of Blk73A

Flight Area	Dipolog
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

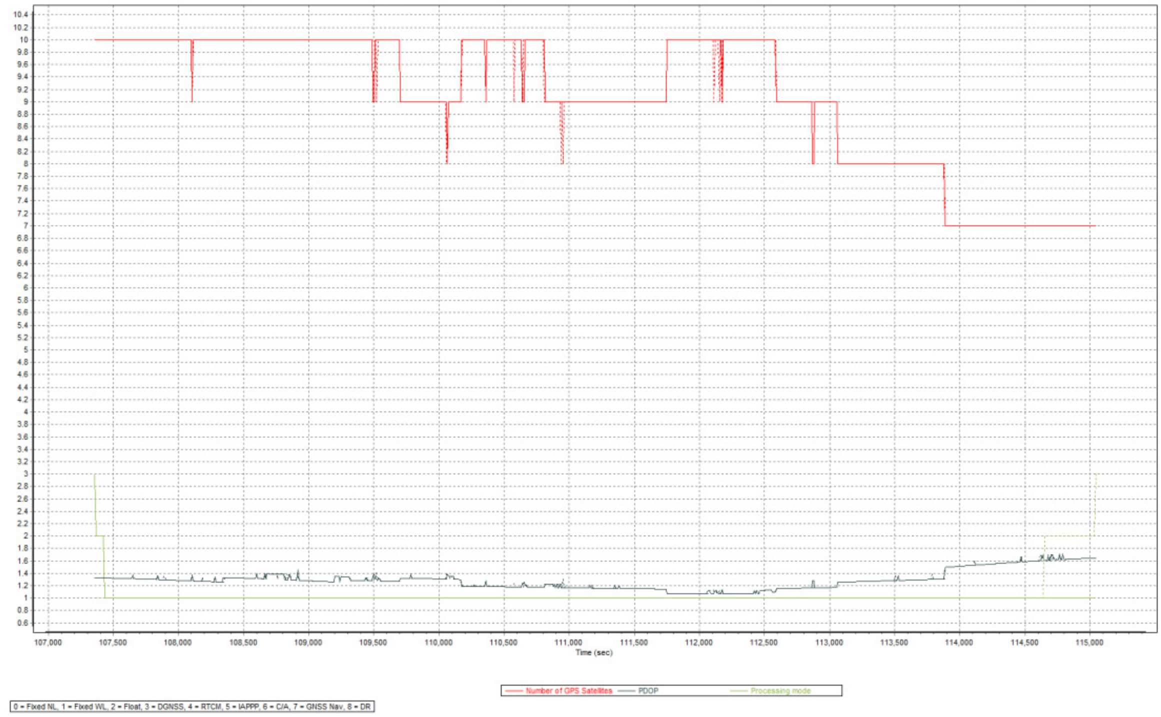


Figure A-8.1. Solution Status

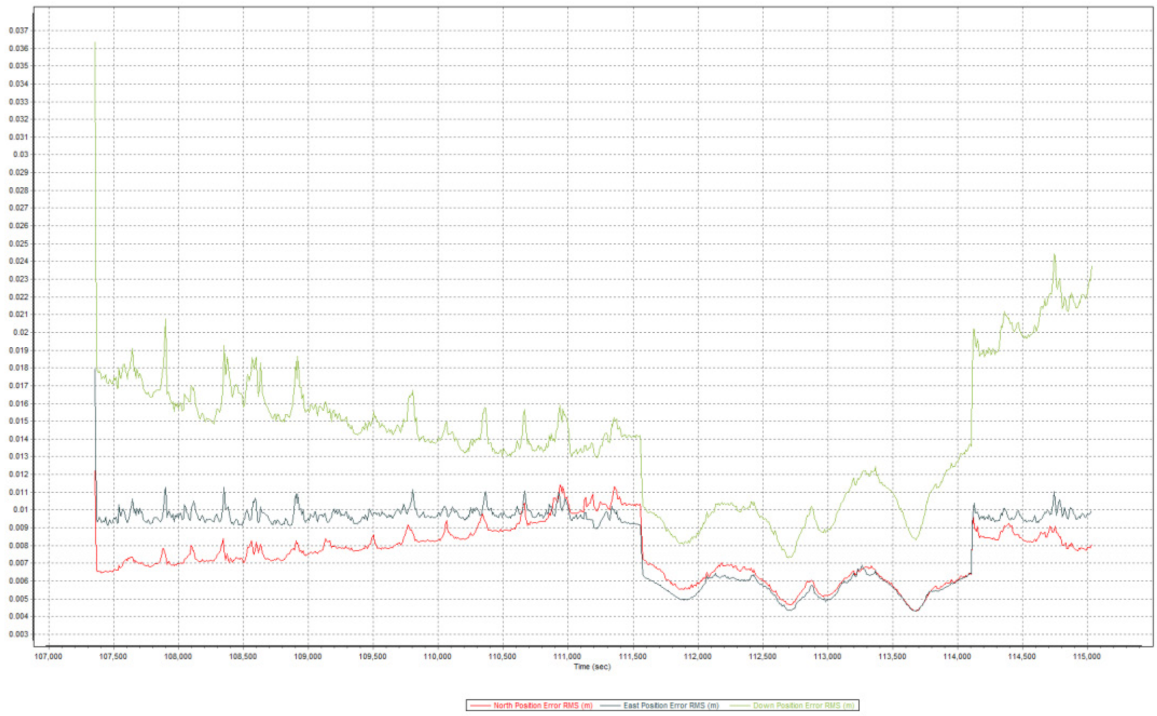


Figure A-8.2. Smoothed Performance Metric Parameters

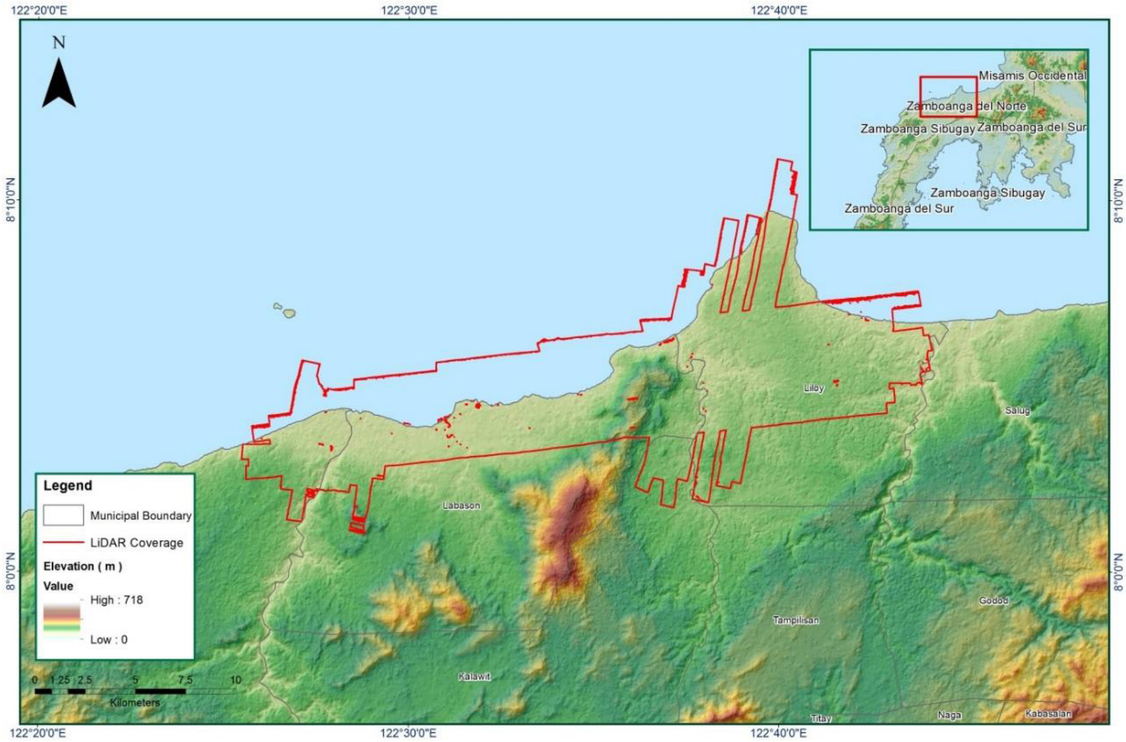


Figure A-8.3. Best Estimated Trajectory

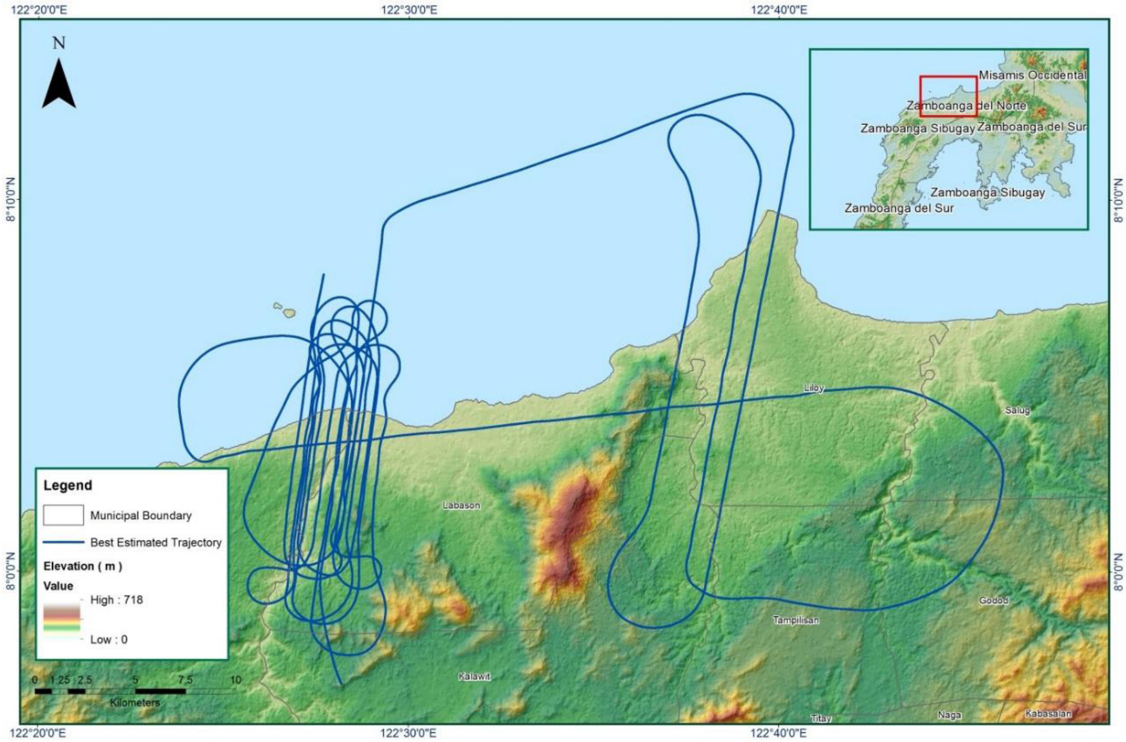


Figure A-8.4. Coverage of LiDAR Data

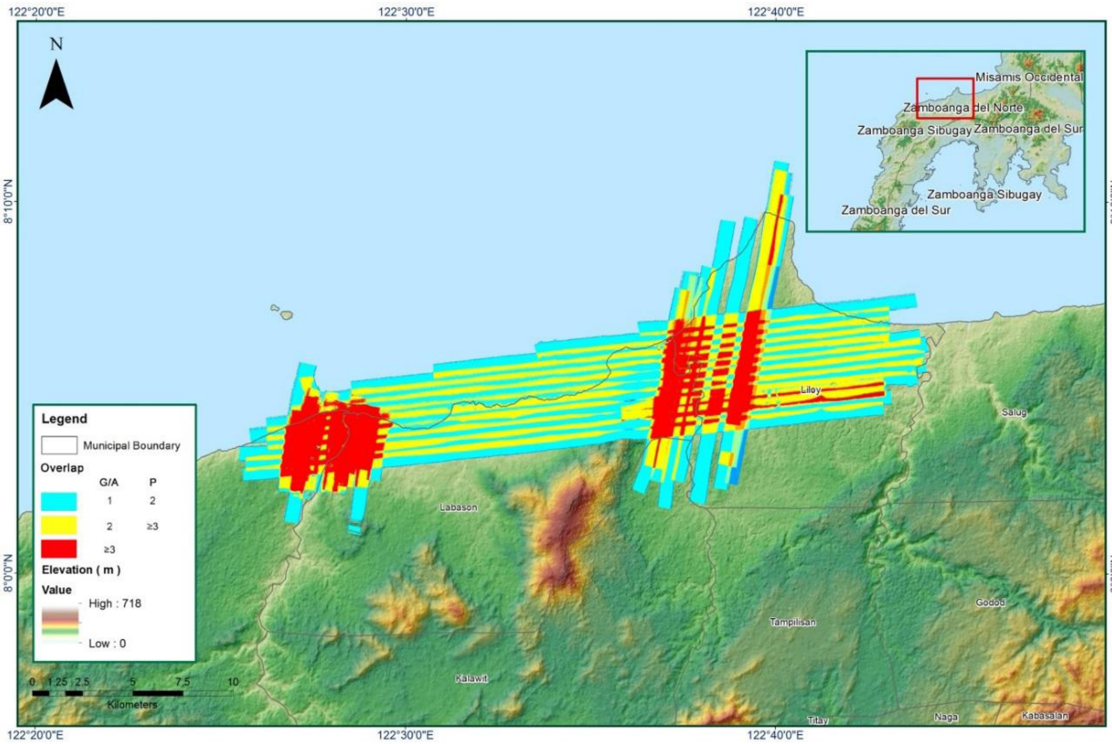


Figure A-8.5. Image of Data Overlap

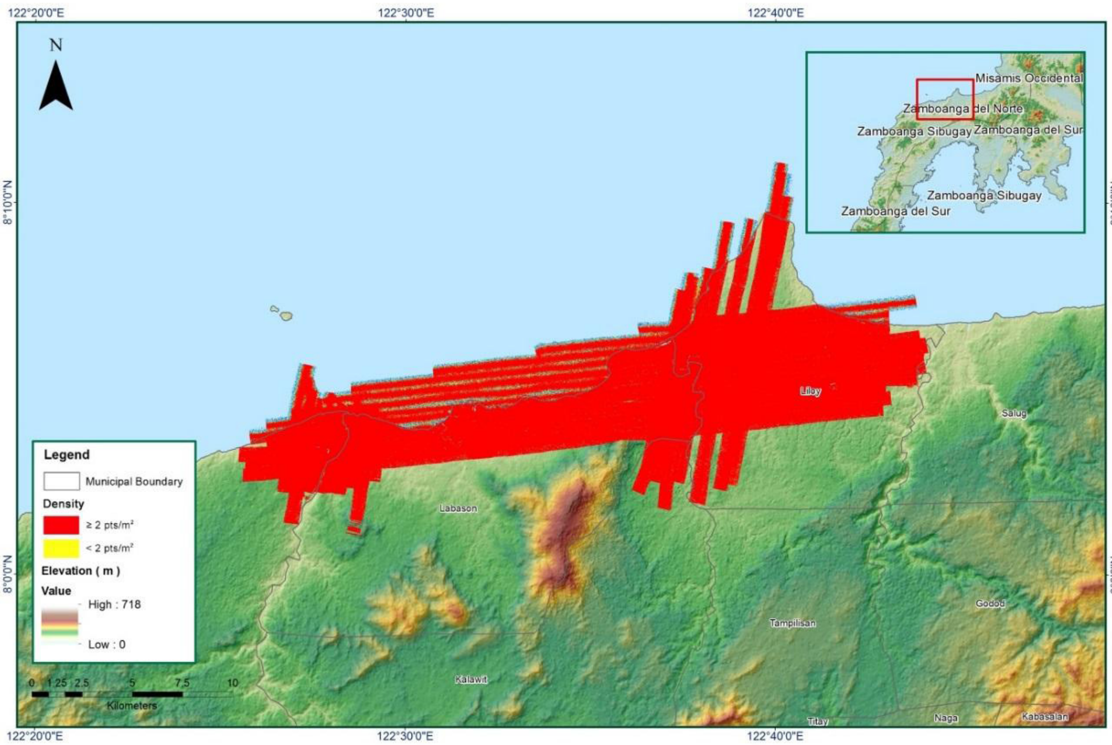


Figure A-8.6. Density Map

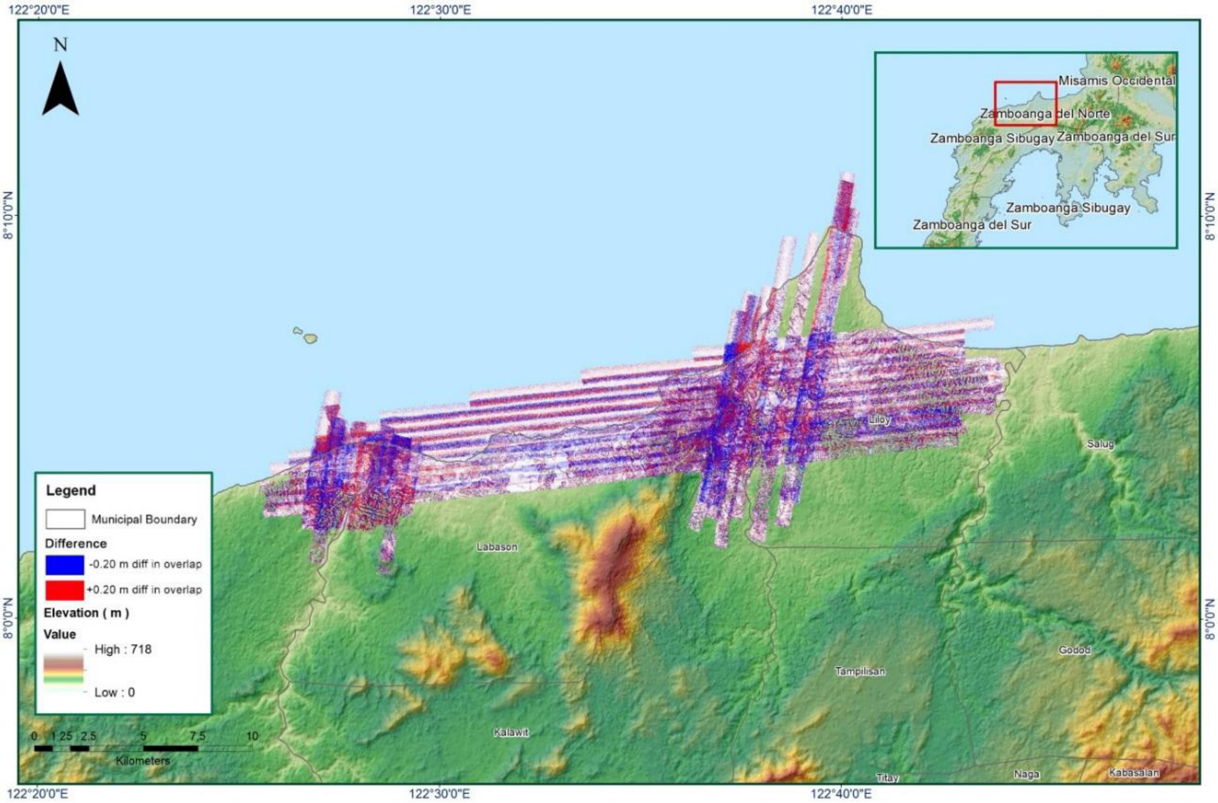


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report of Blk73A_additional

Flight Area	Dipolog
Mission Name	Blk73A_additional
Inclusive Flights	2185P
Range data size	13.1 GB
Base data size	19.5 MB
POS	253 MB
Image	NA
Transfer date	December 09, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
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)	1.13
RMSE for Down Position (<8.0 cm)	2.44
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.002572
GPS position stdev (<0.01m)	0.0088
Minimum % overlap (>25)	61.13
Ave point cloud density per sq.m. (>2.0)	6.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	25
Maximum Height	300 m
Minimum Height	65.91 m
Classification (# of points)	
Ground	13,149,001
Low vegetation	13,403,807
Medium vegetation	36,628,573
High vegetation	72,067,315
Building	1,991,455
Ortophoto	No
Processed by	

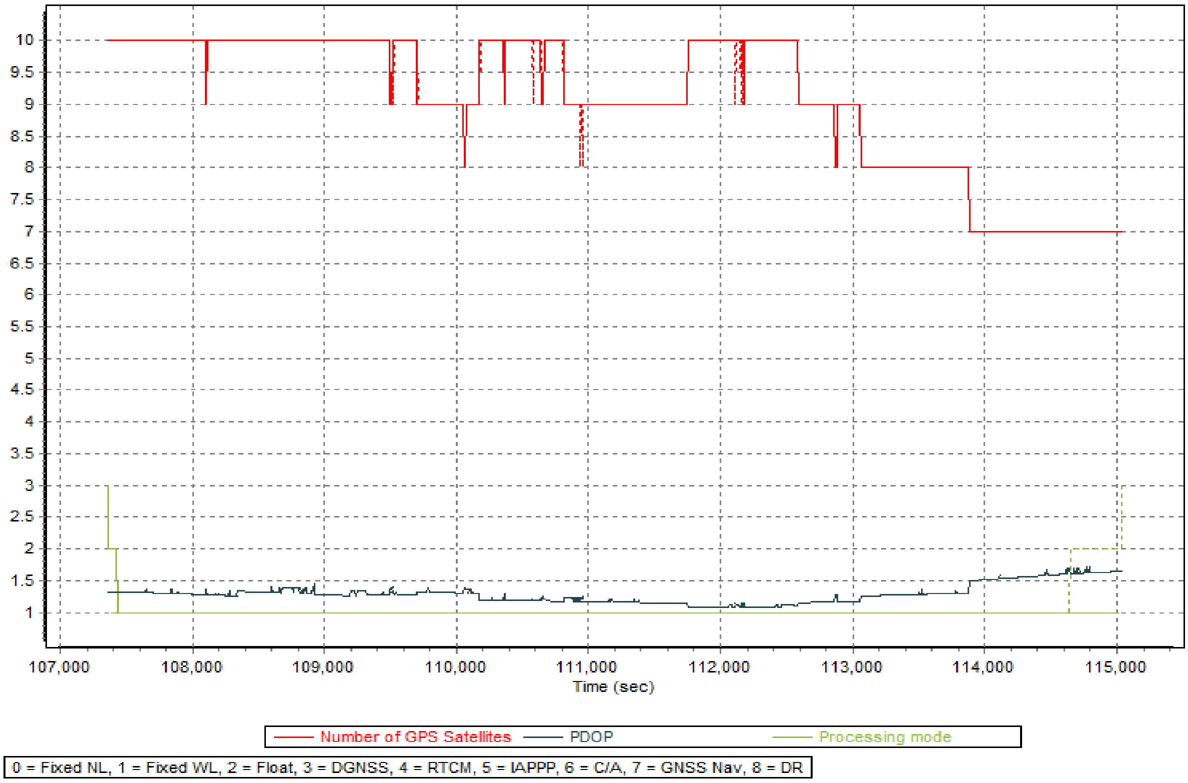


Figure A-8.8. Solution Status

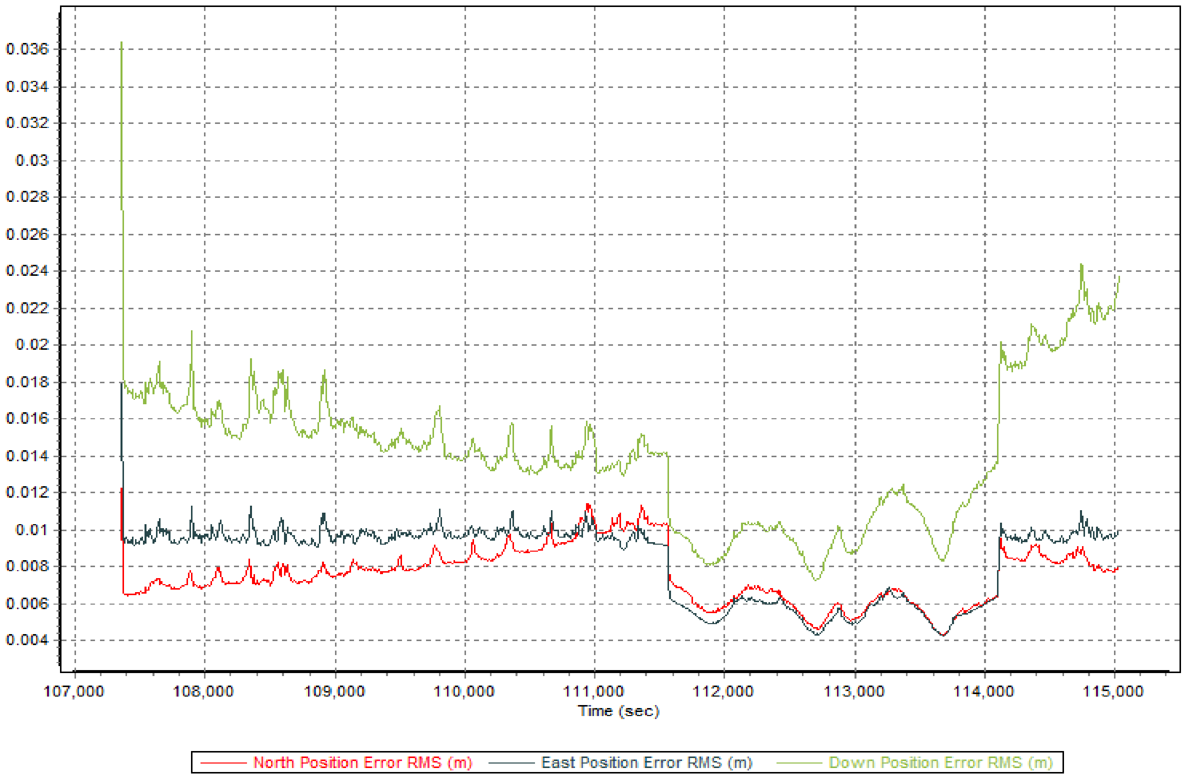


Figure A-8.9. Smoothed Performance Metric Parameters

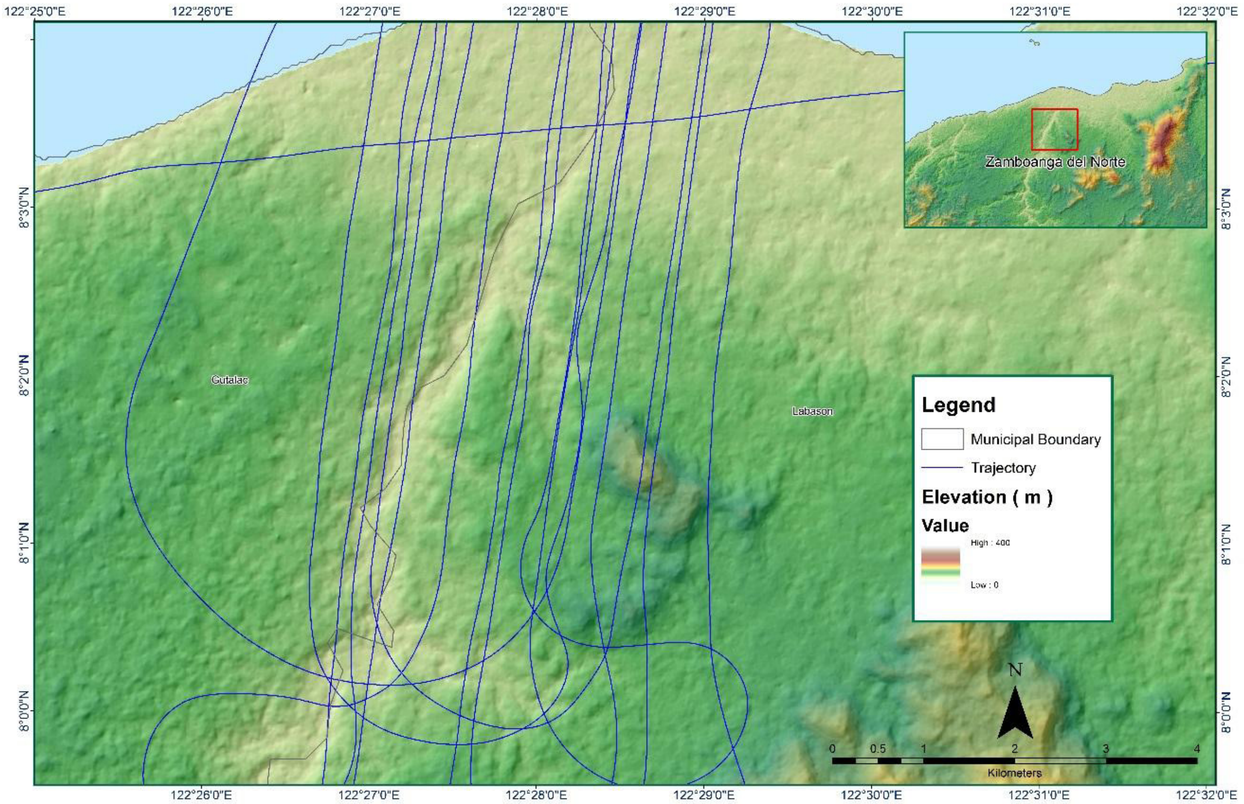


Figure A-8.10. Best Estimated Trajectory

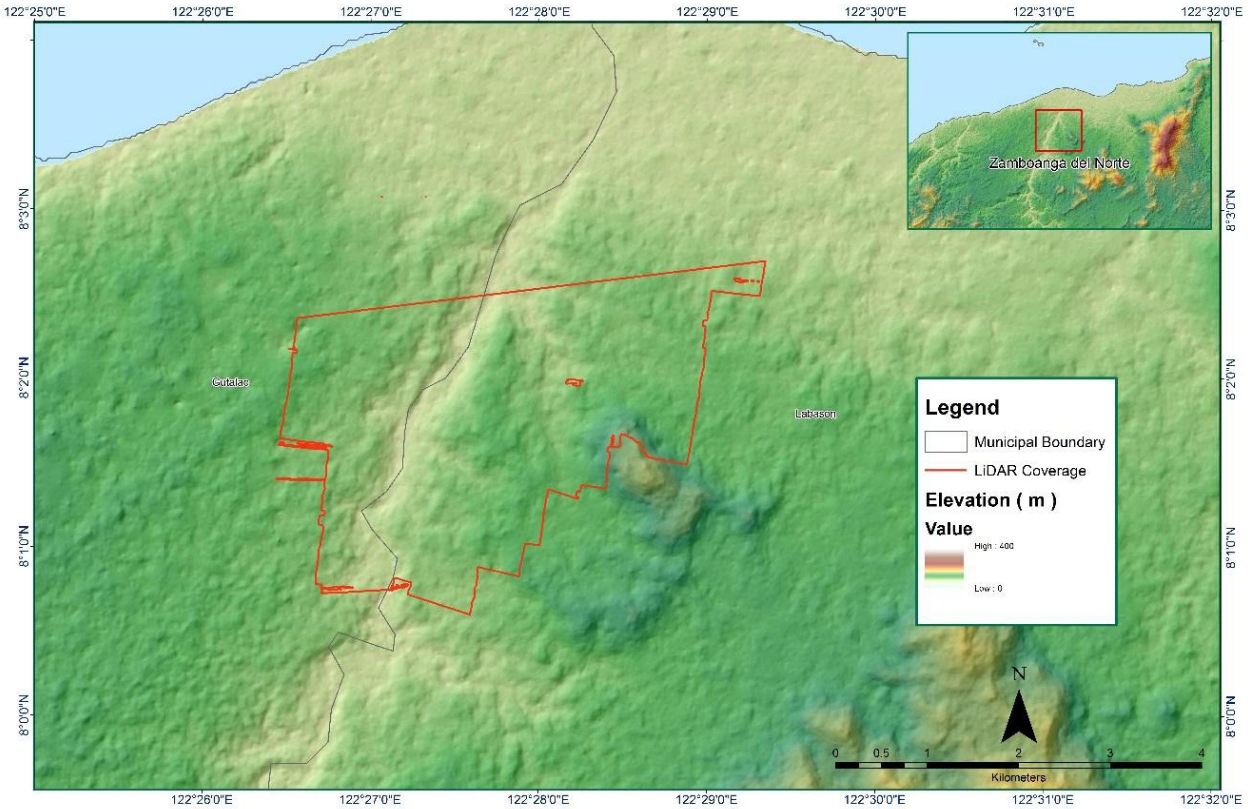


Figure A-8.11. Coverage of LiDAR data

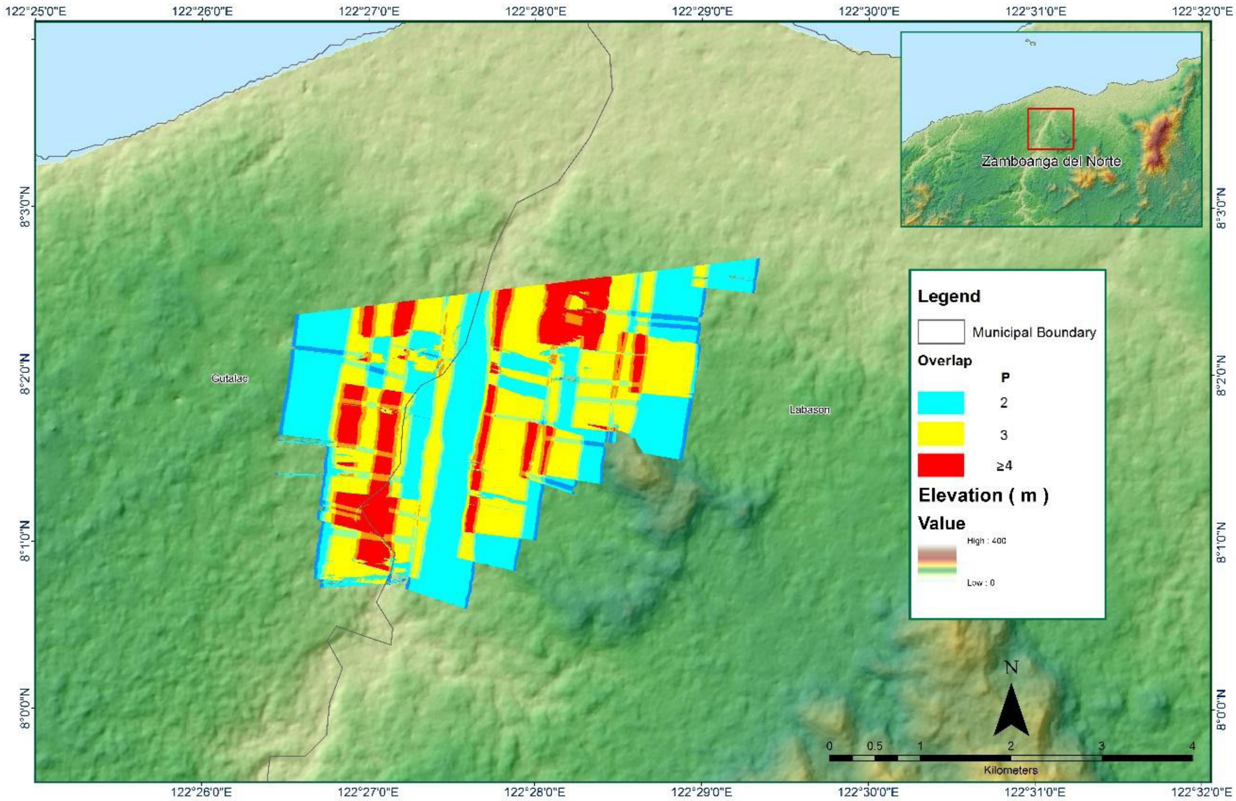


Figure A-8.12. Image of data overlap

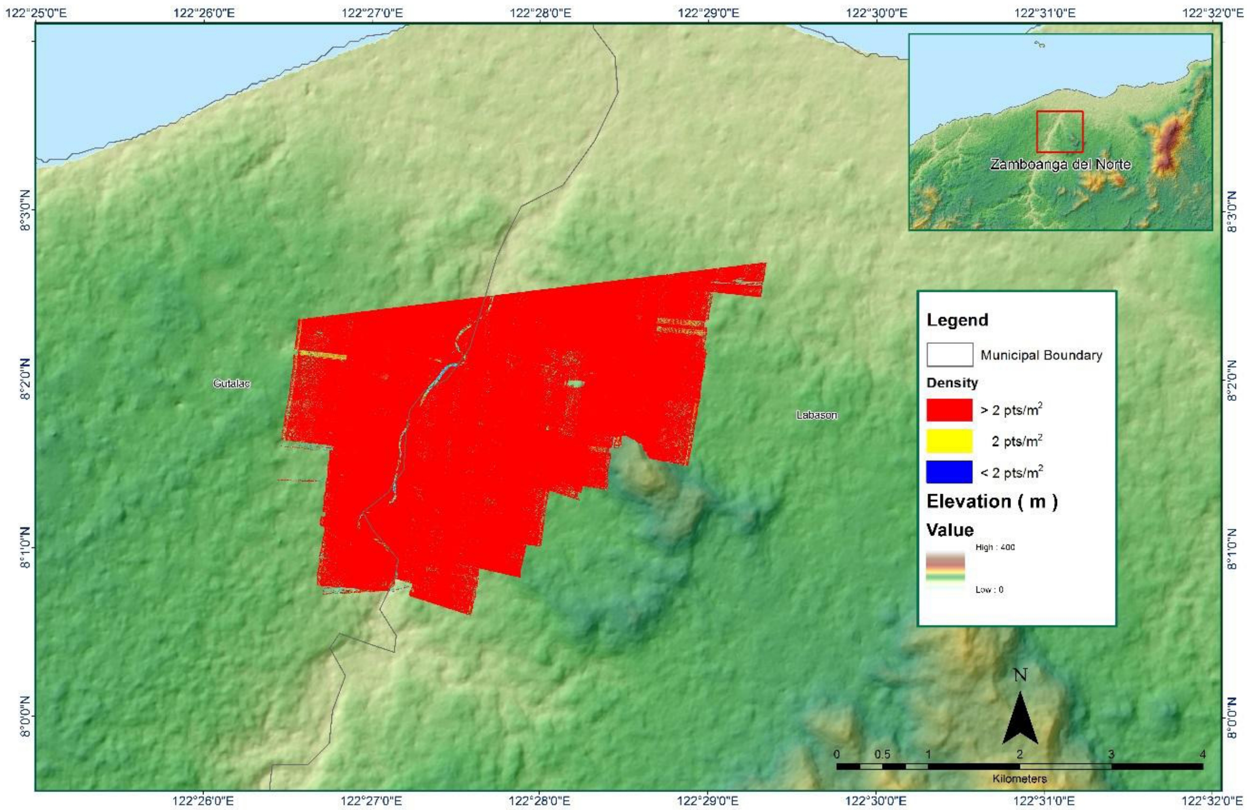


Figure A-8.13. Density Map of merged LiDAR data

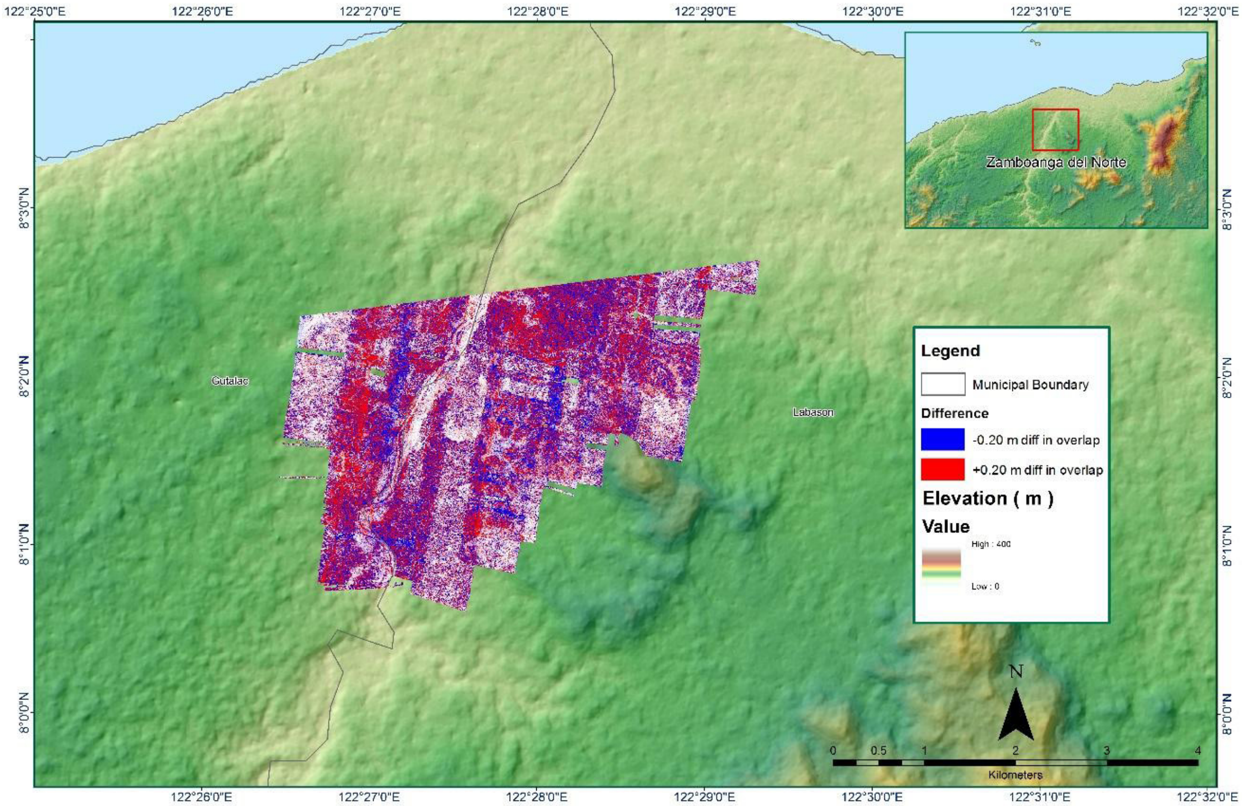


Figure A-8.14. Elevation Difference Between flight lines

Table A-8.3 Mission Summary Report of Blk73A

Flight Area	Dipolog
Mission Name	Blk73A
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)	0.000147
IMU attitude correction stdev (<0.001deg)	0.000270
GPS position stdev (<0.01m)	0.0008
Minimum % overlap (>25)	41.91 %
Ave point cloud density per sq.m. (>2.0)	4.62
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	165
Maximum Height	845.05 m
Minimum Height	845.05 m
Classification (# of points)	
Ground	117,262,301
Low vegetation	97,052,511
Medium vegetation	270,037,707
High vegetation	570,486,603
Building	9,958,195
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Mark Joshua Salvacion, Alex John Escobido

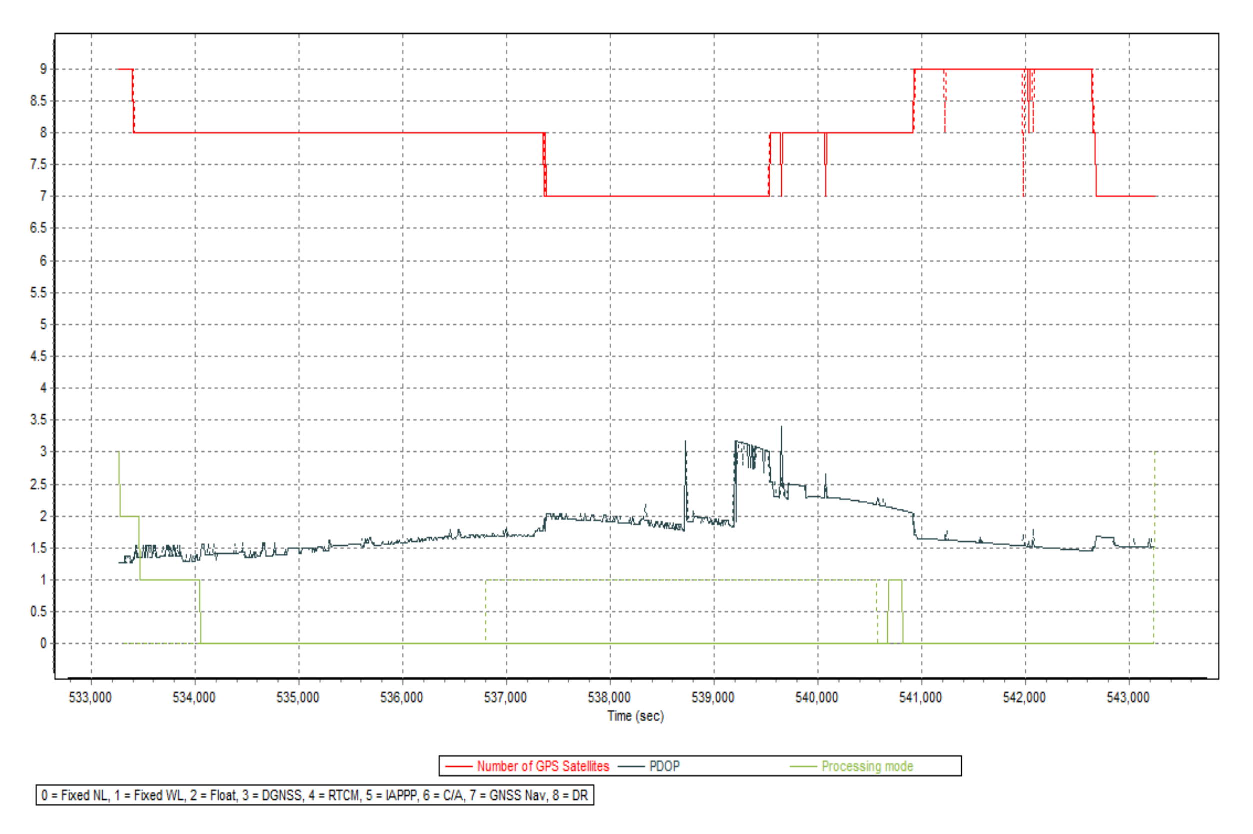


Figure A-8.15. Solution Status

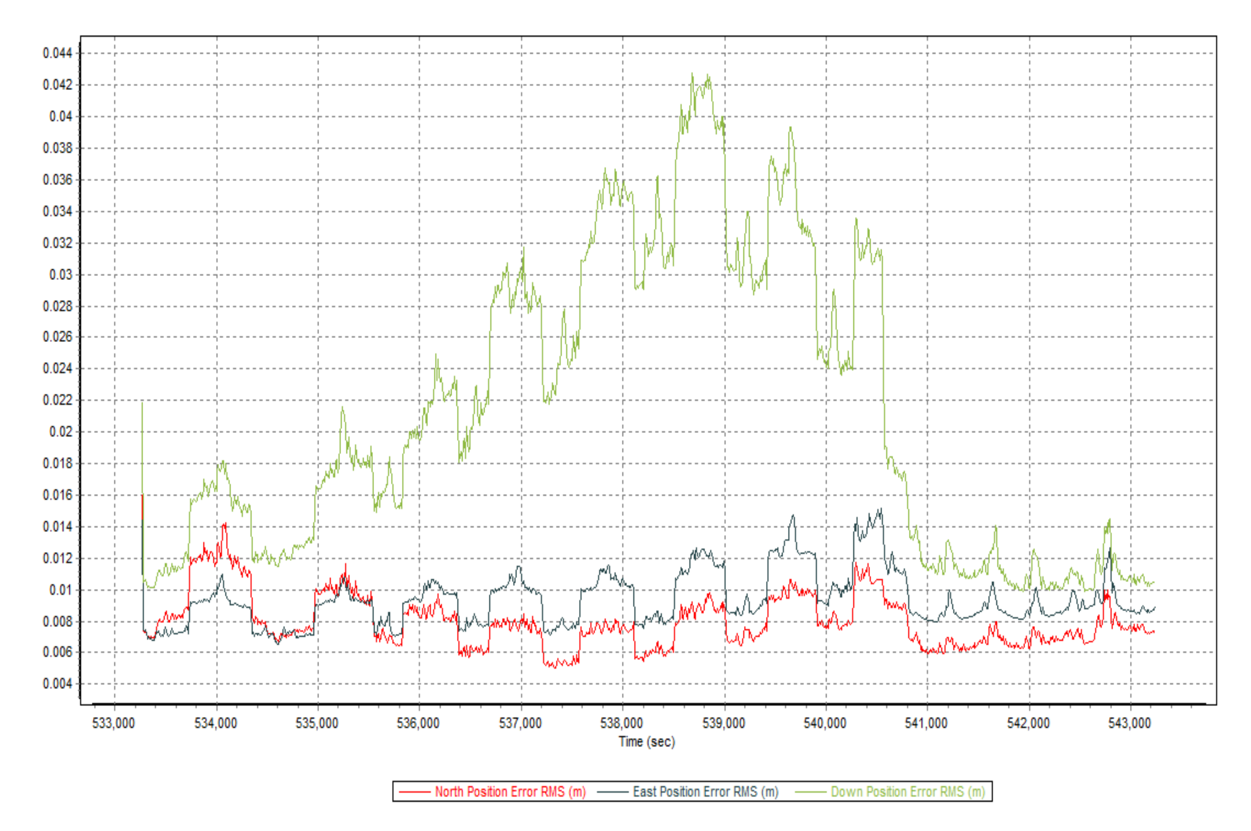


Figure A-8.16. Smoothed Performance Metric Parameters

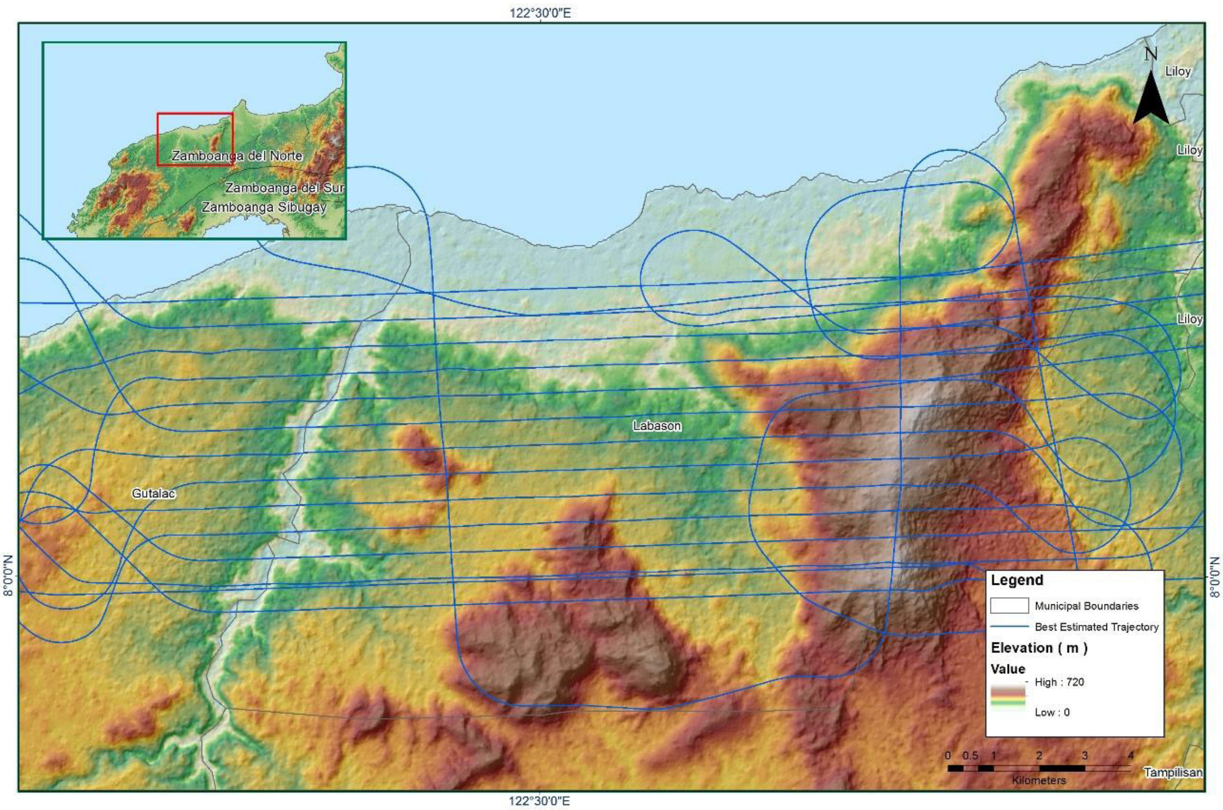


Figure A-8.17. Best Estimated Trajectory

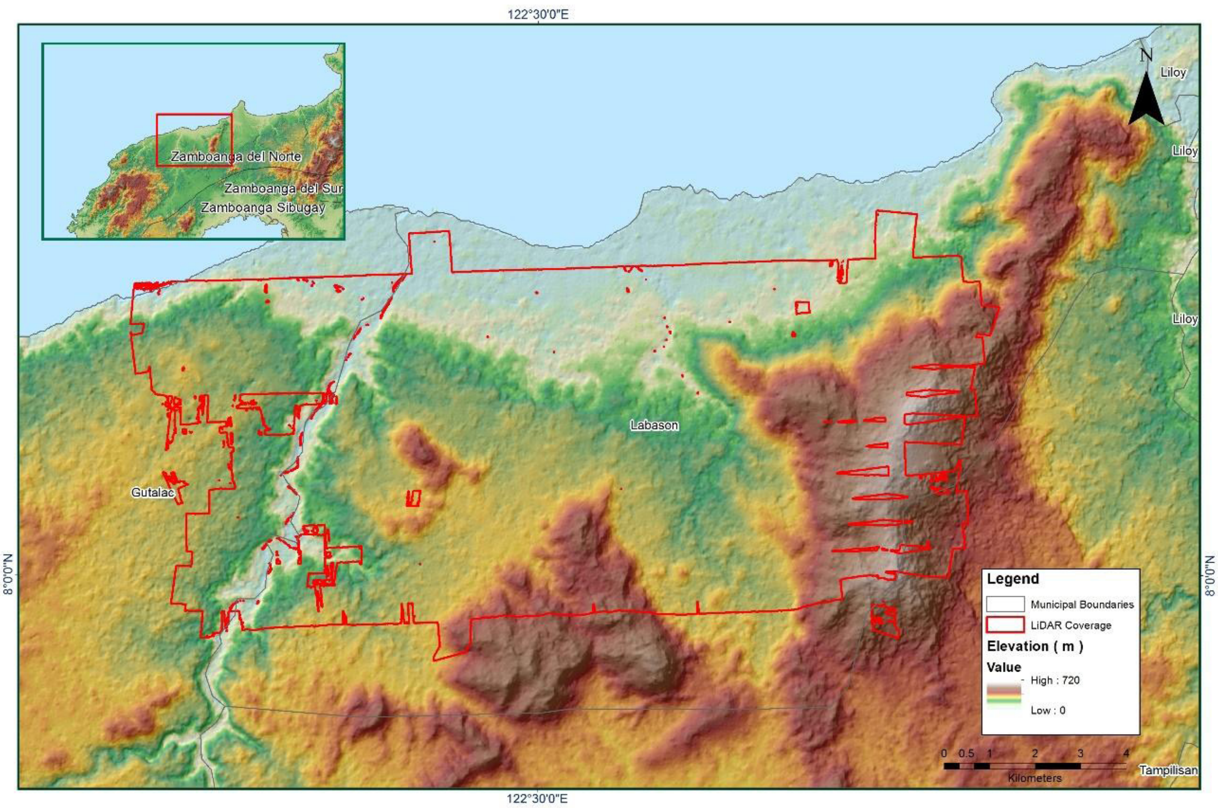


Figure A-8.18. Coverage of LiDAR Data

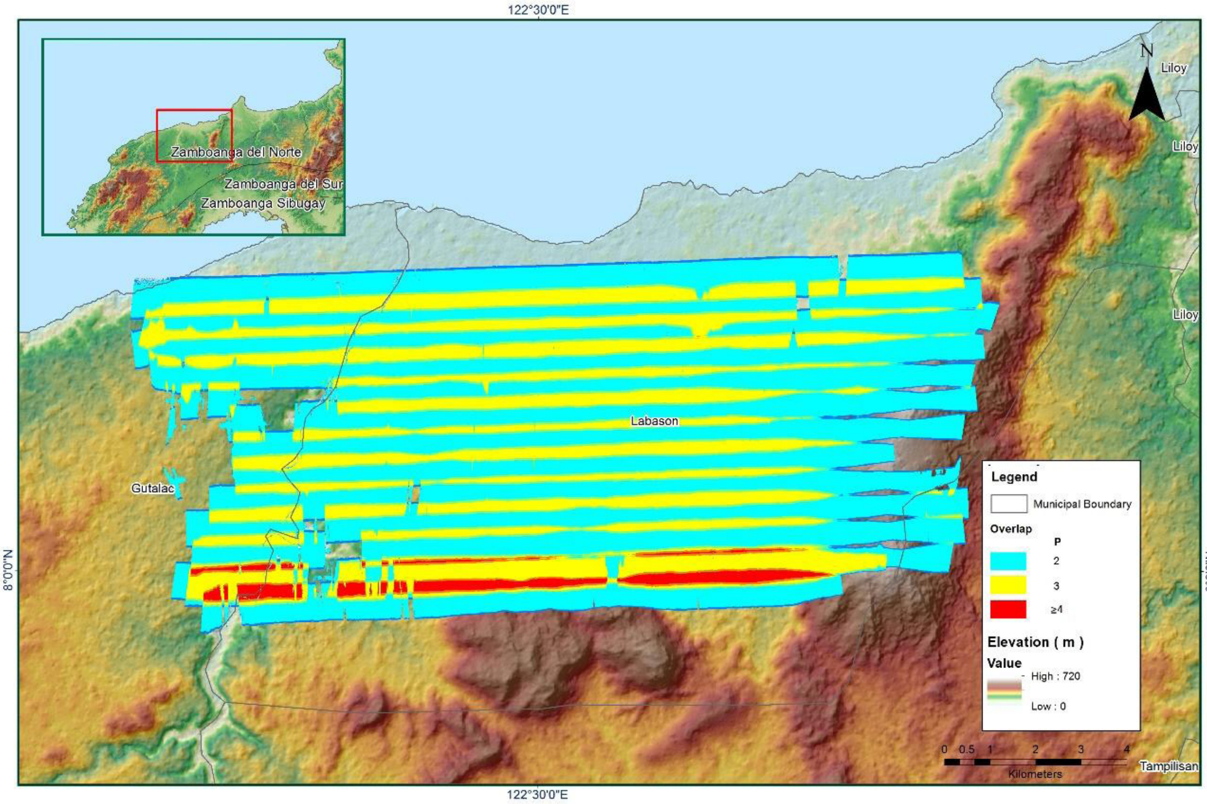


Figure A-8.19. Image of data overlap

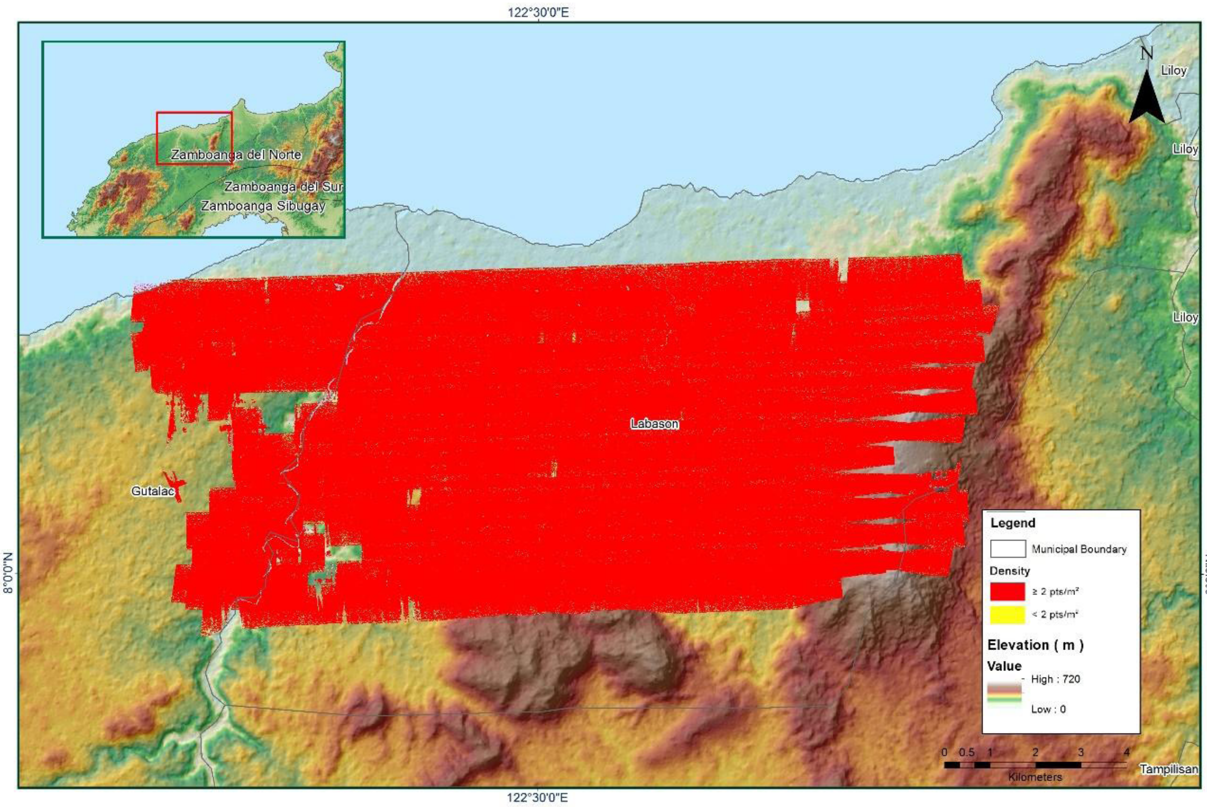


Figure A-8.20. Density map of merged LiDAR data

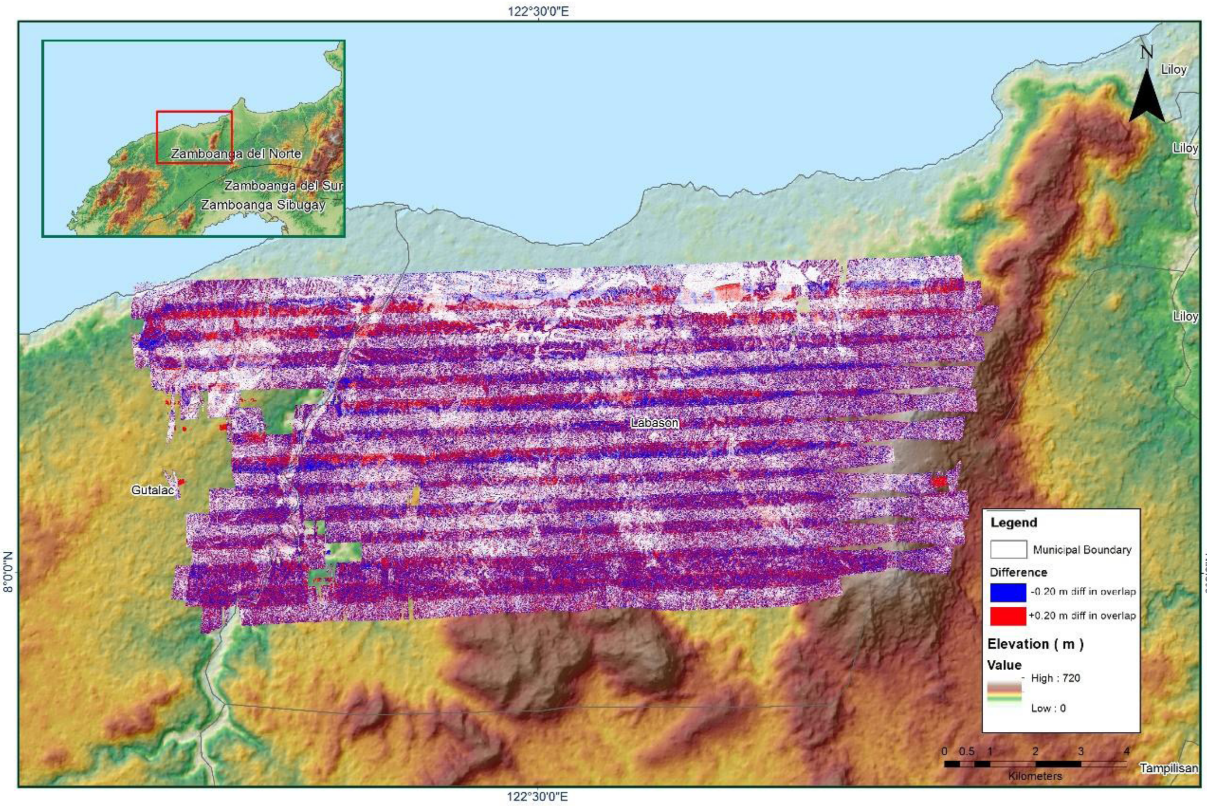


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report of Blk73A_additional

Flight Area	Dipolog
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

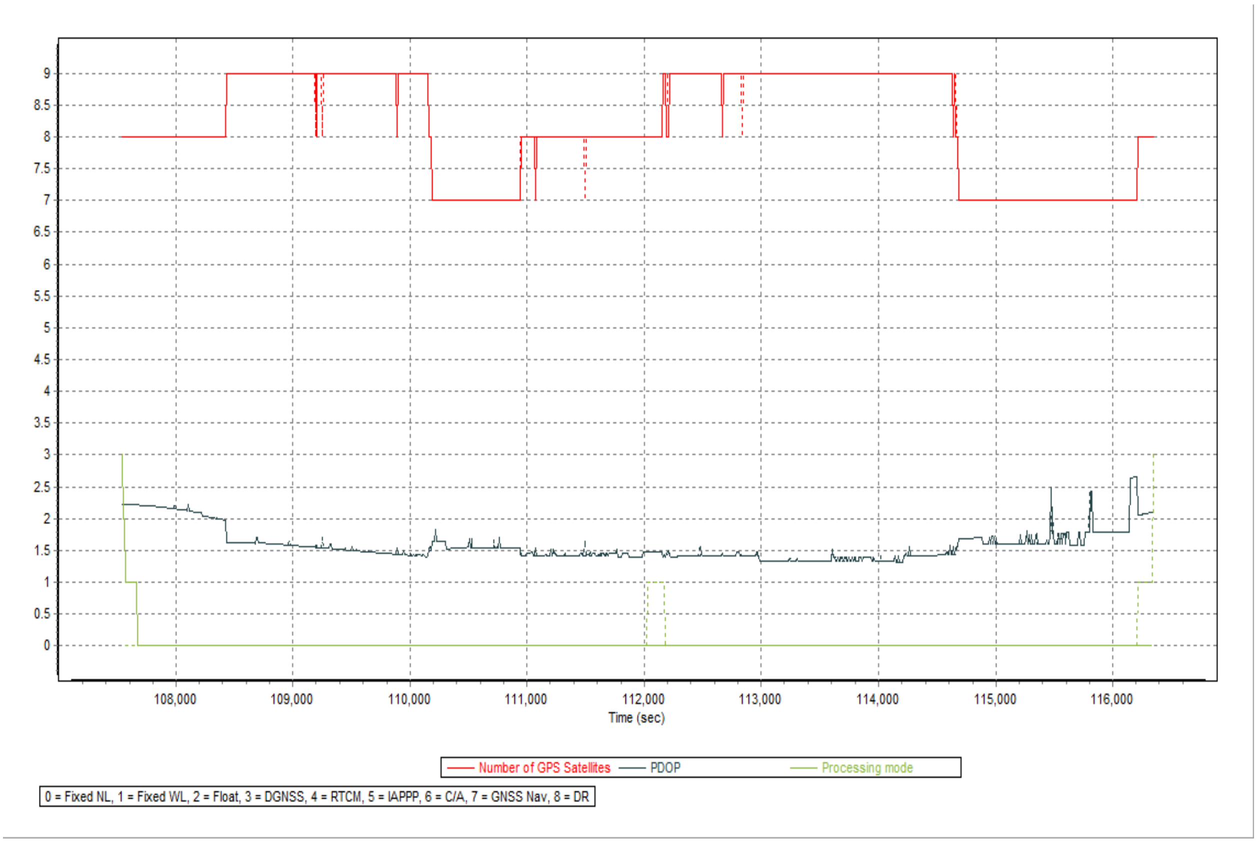


Figure A-8.22. Solution Status

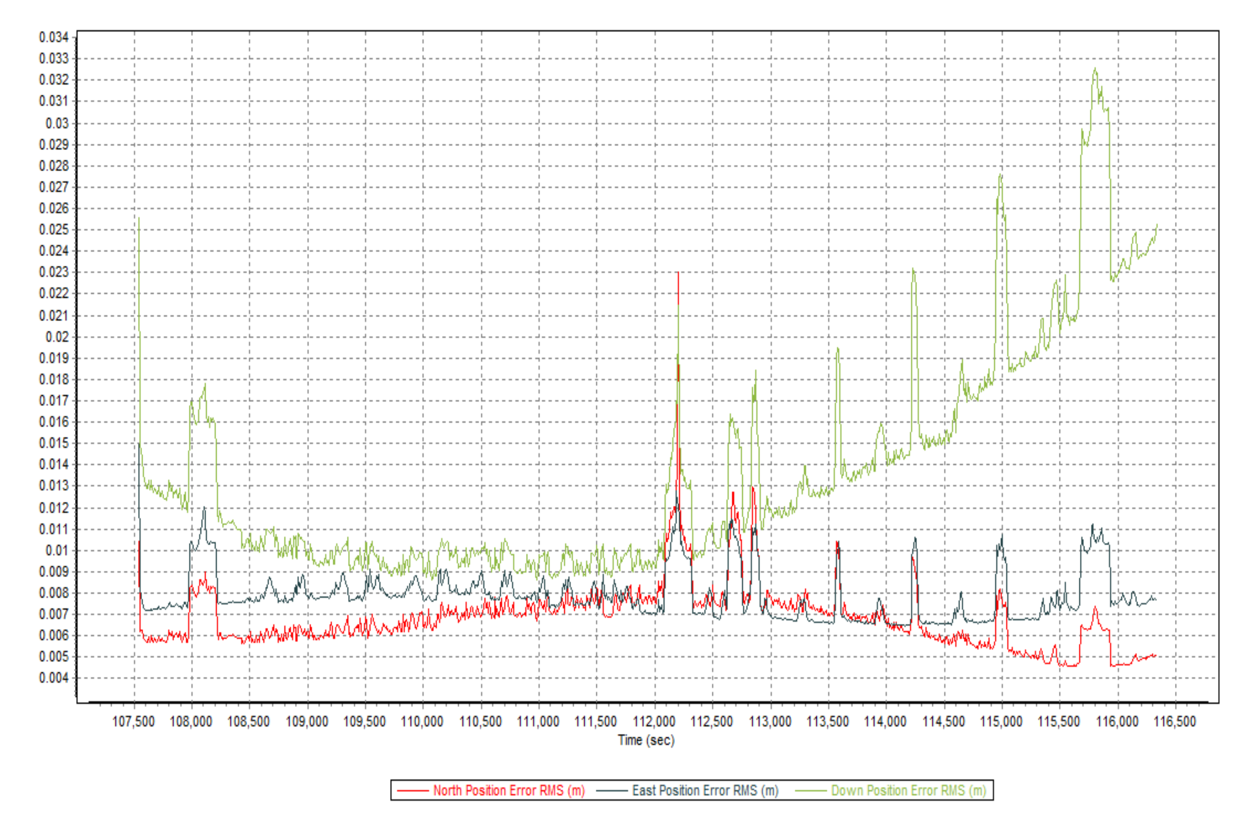


Figure A-8.23. Smoothed Performance Metric Parameters

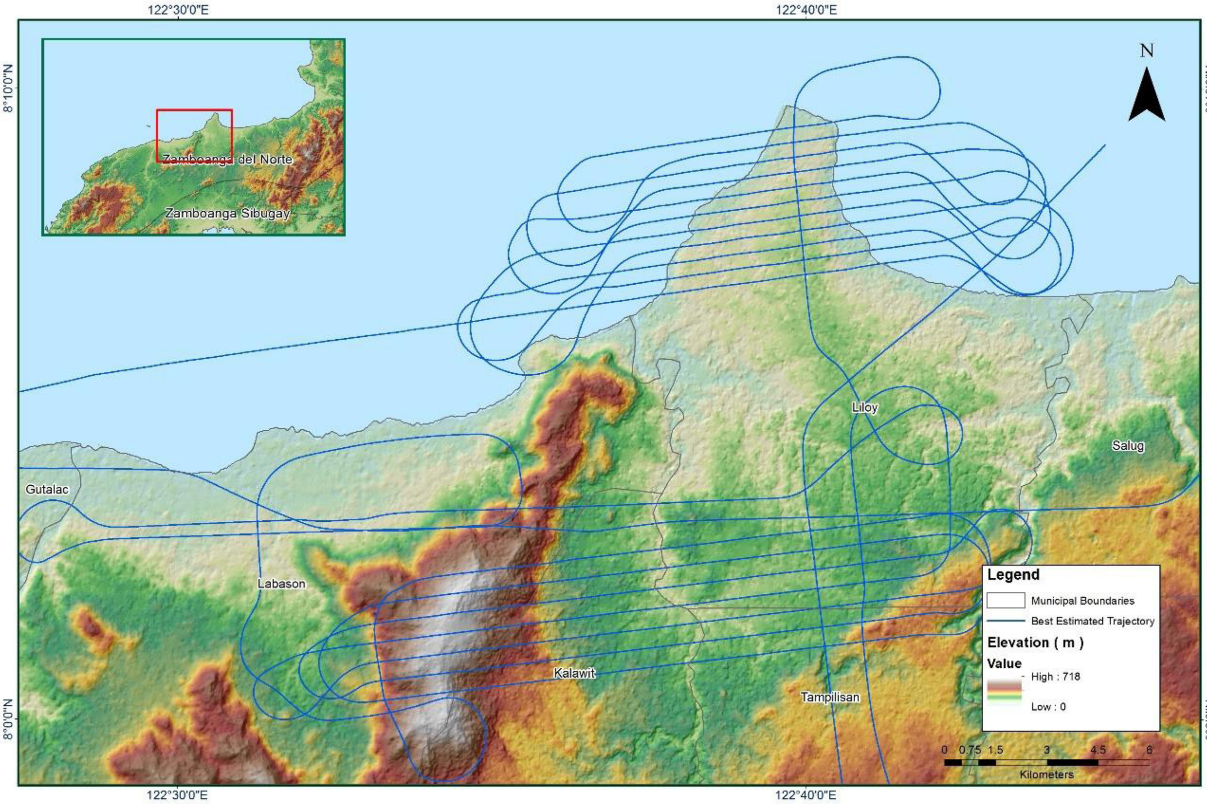


Figure A-8.24. Best Estimated Trajectory

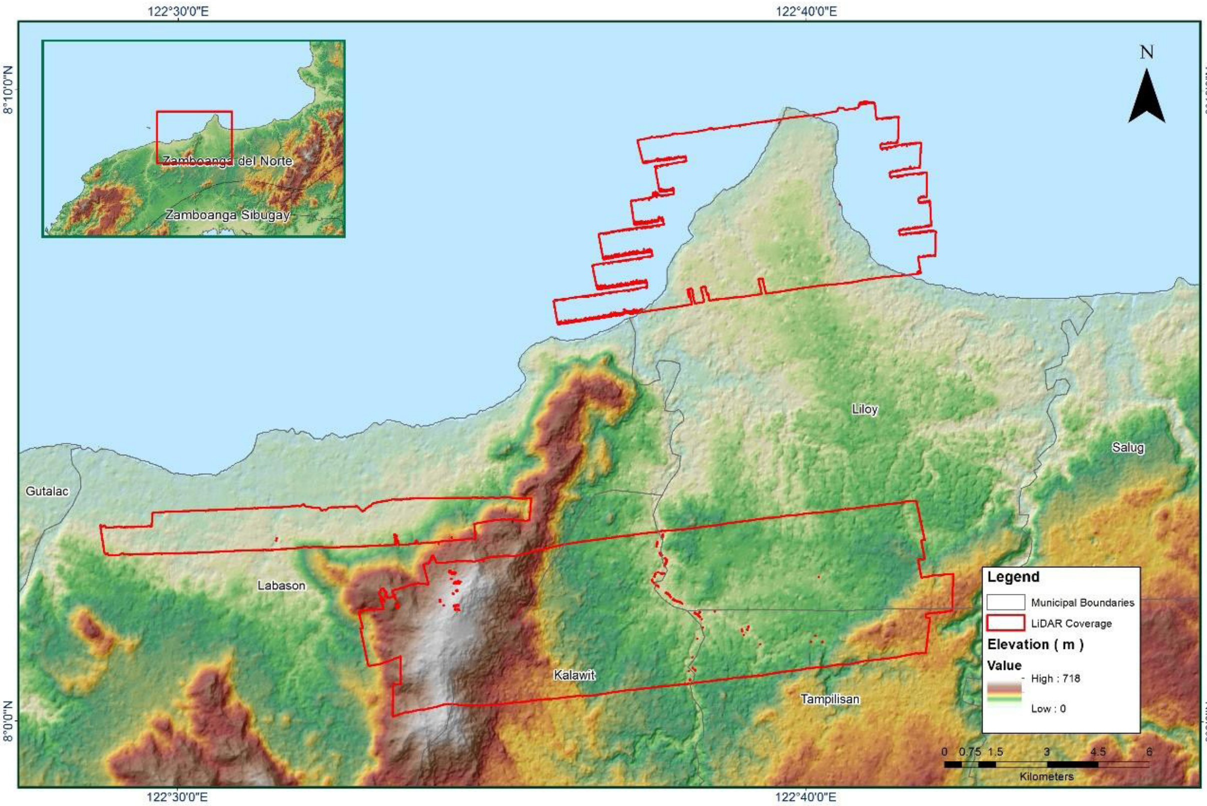


Figure A-8.25. Coverage of LiDAR Data

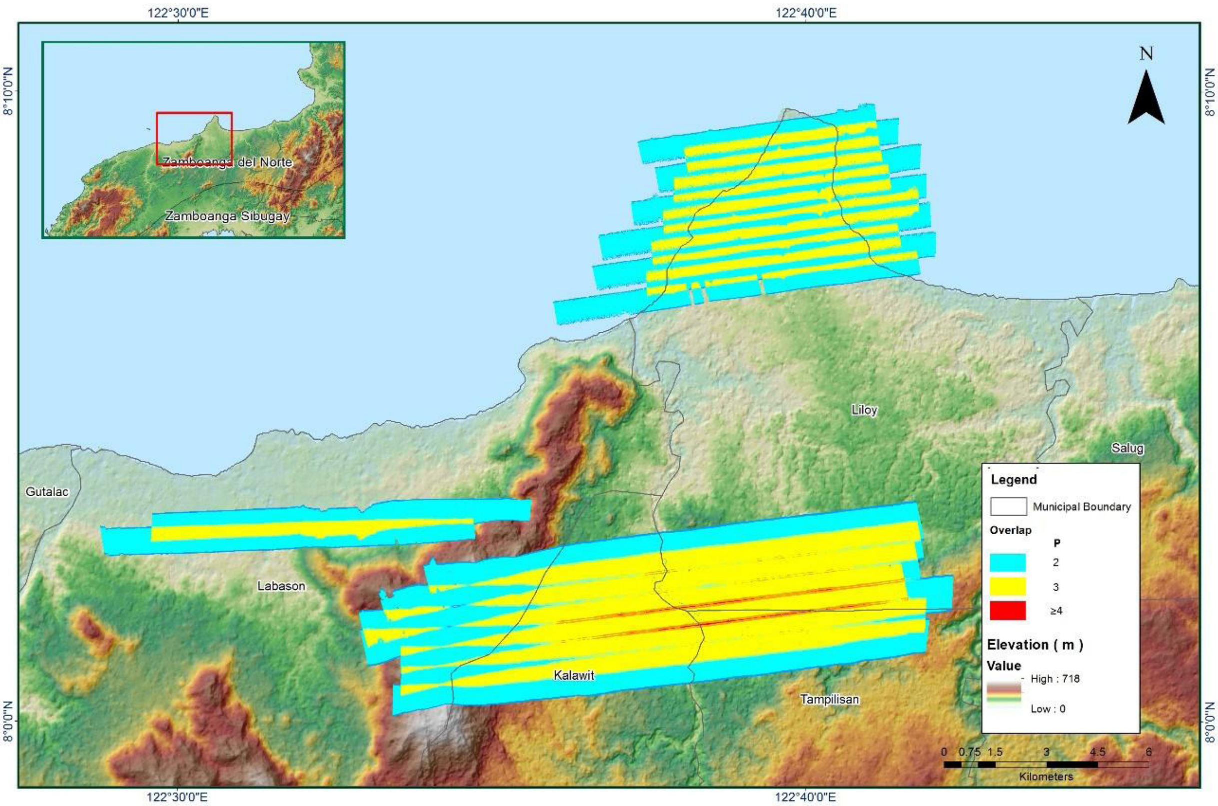


Figure A-8.26. Image of data overlap

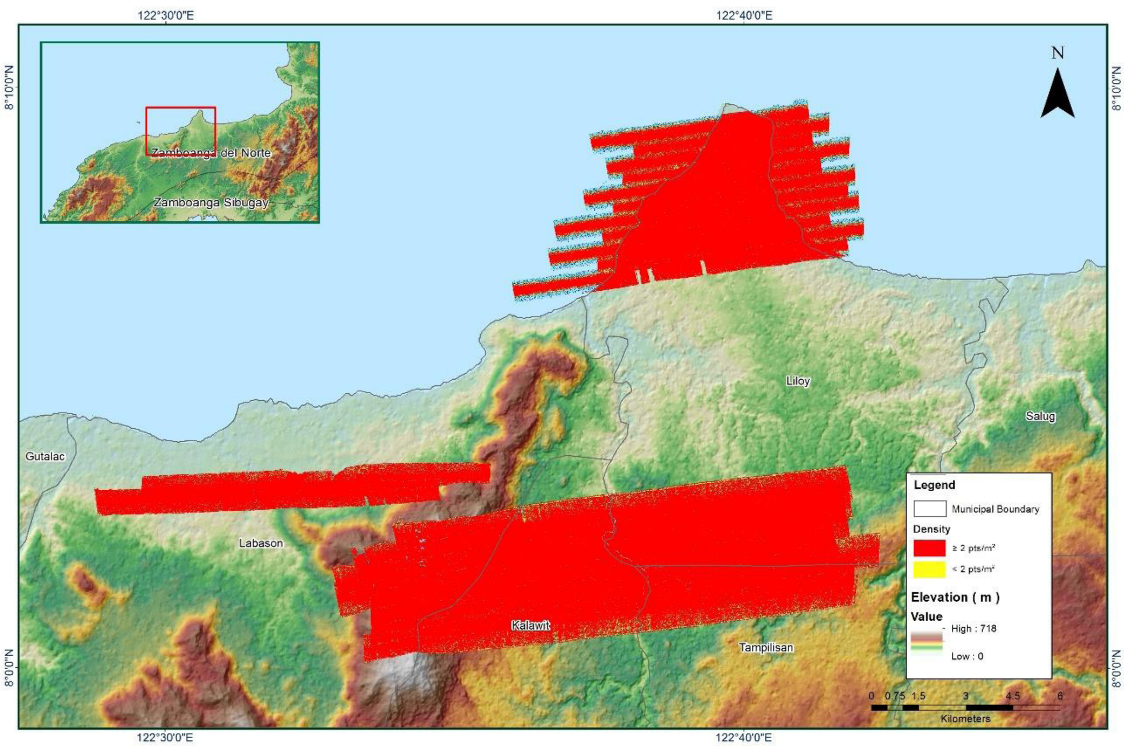


Figure A-8.27. Density map of merged LiDAR data

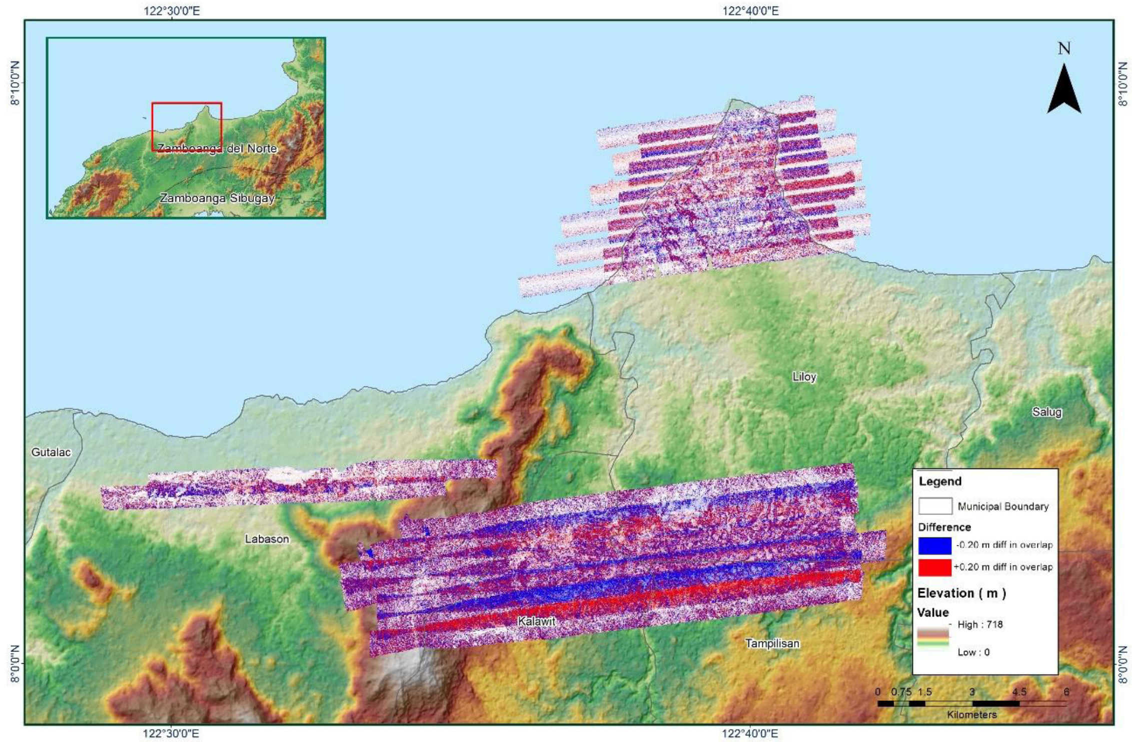


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report of Blk73A_supplement

Flight Area	Dipolog
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

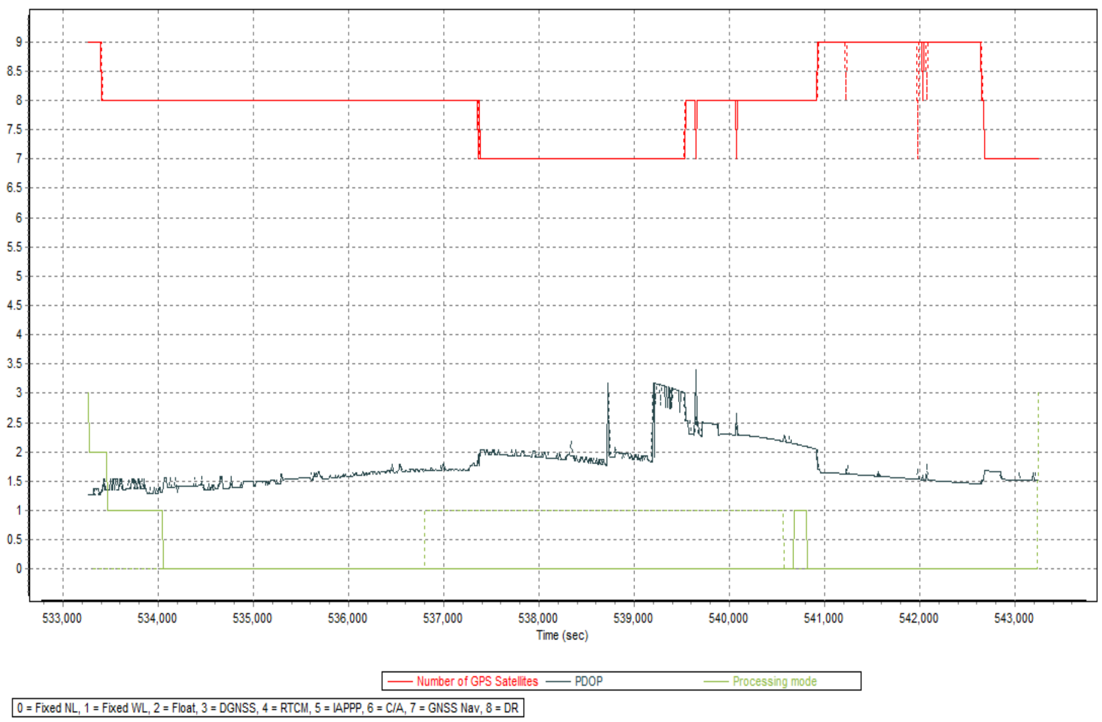


Figure A-8.29. Solution Status

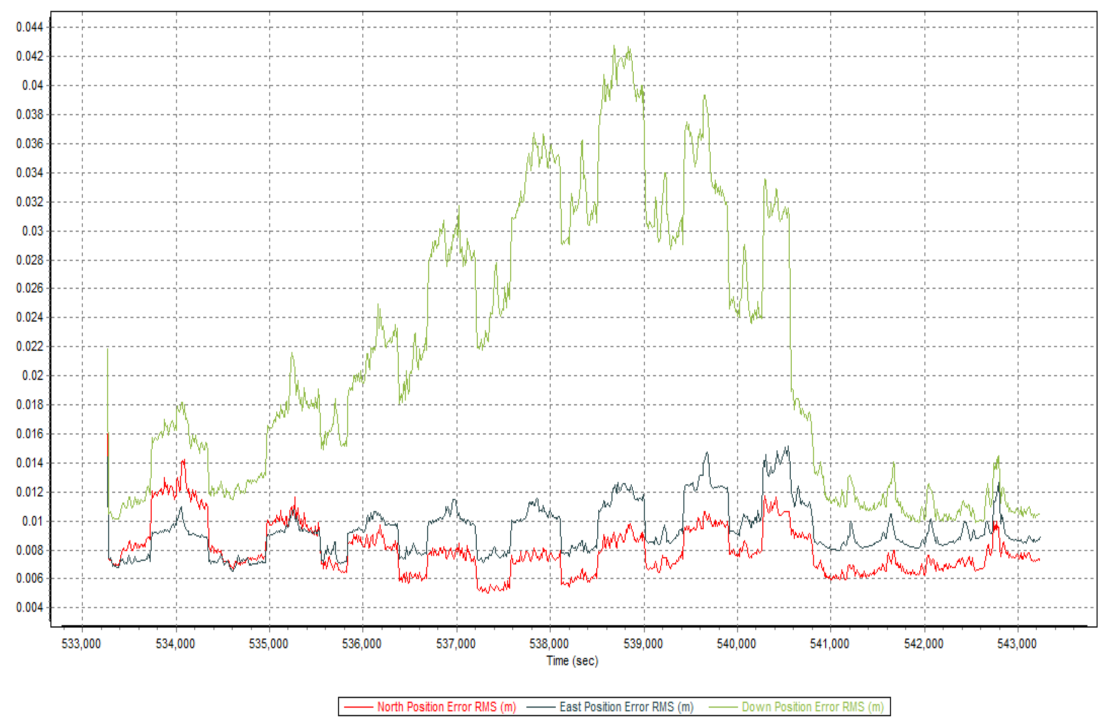


Figure A-8.30. Smoothed Performance Metric Parameters

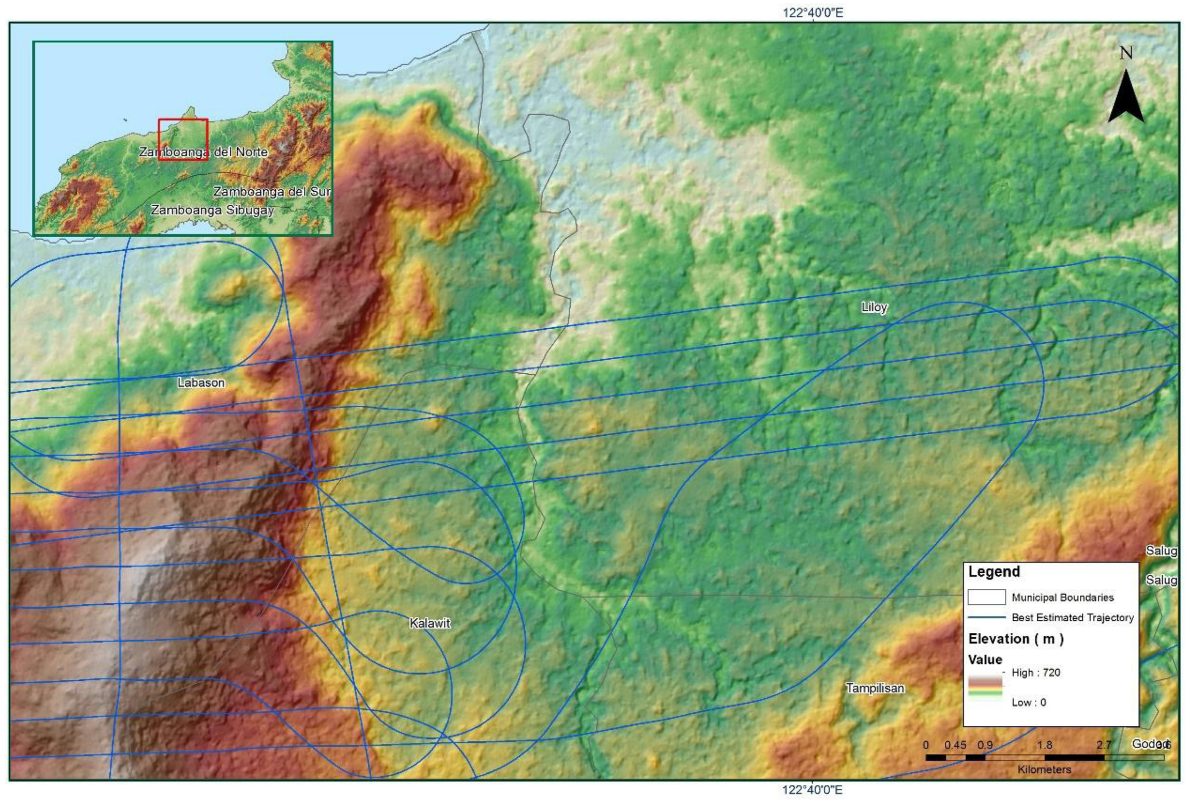


Figure A-8.31. Best Estimated Trajectory

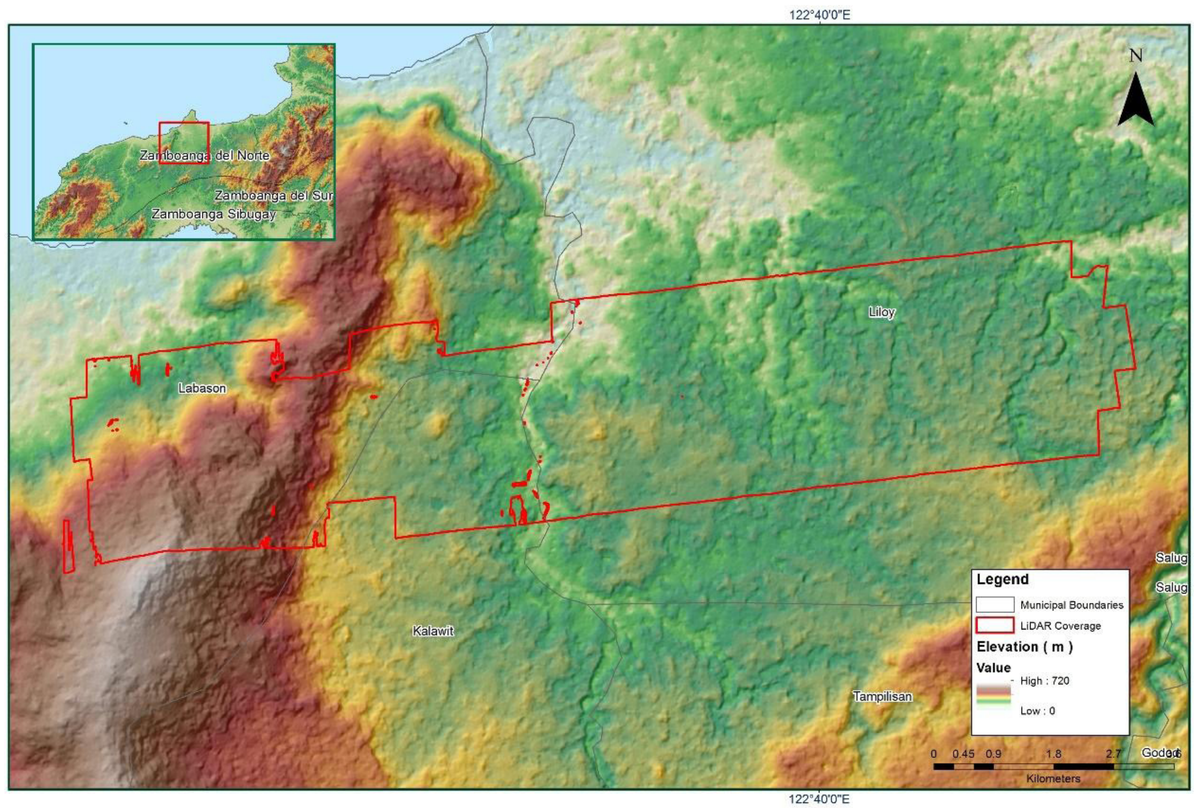


Figure A-8.32. Coverage of LiDAR Data

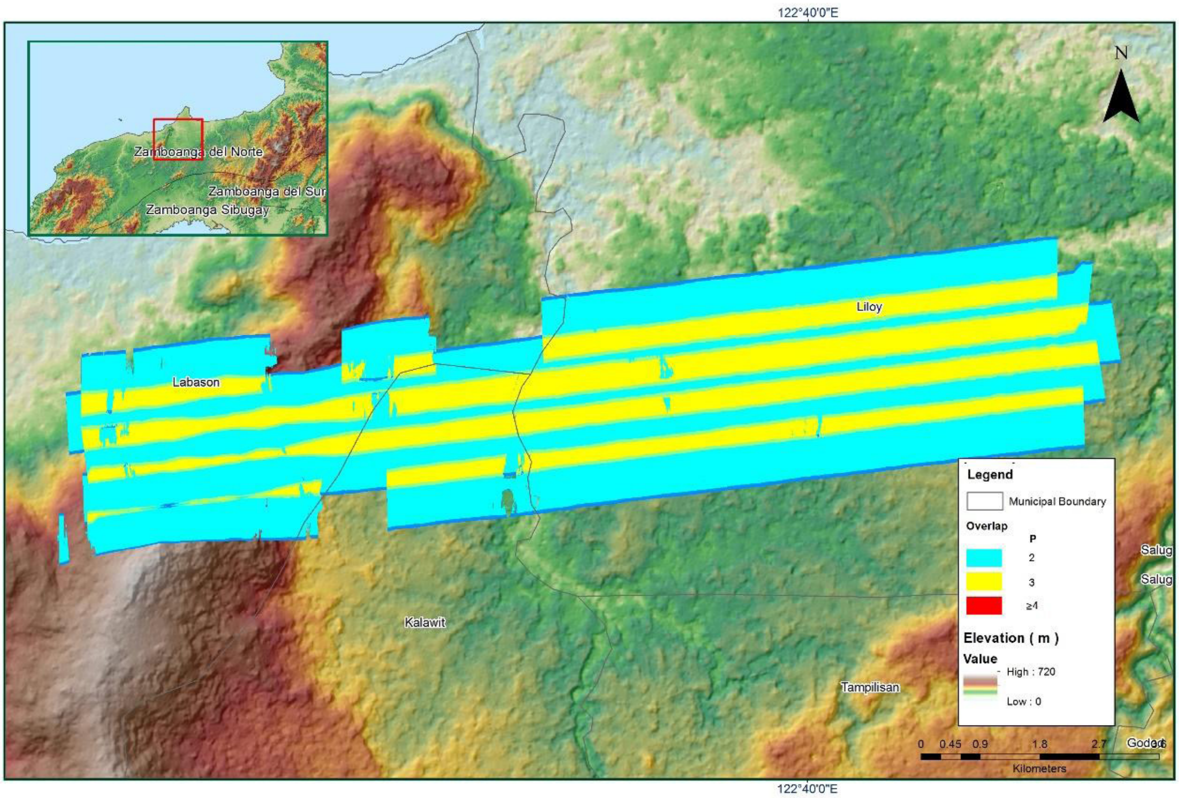


Figure A-8.33. Image of data overlap

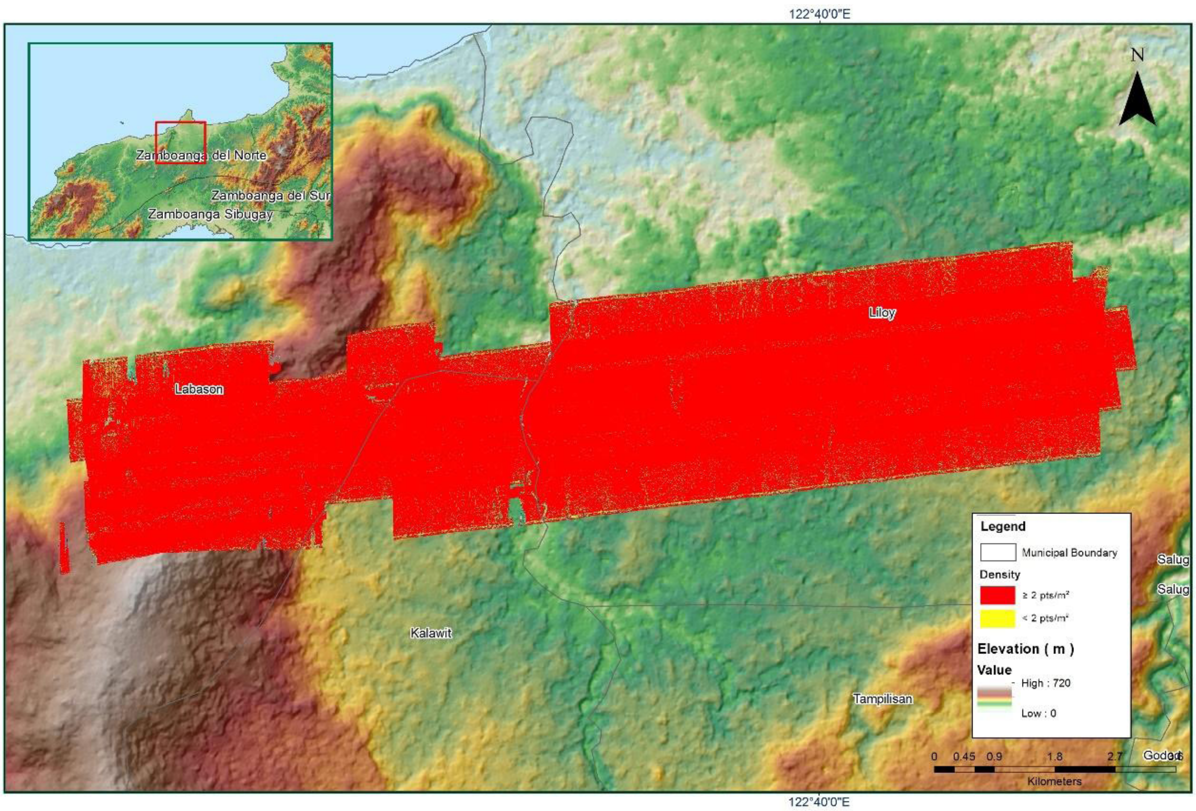


Figure A-8.34. Density map of merged LiDAR data

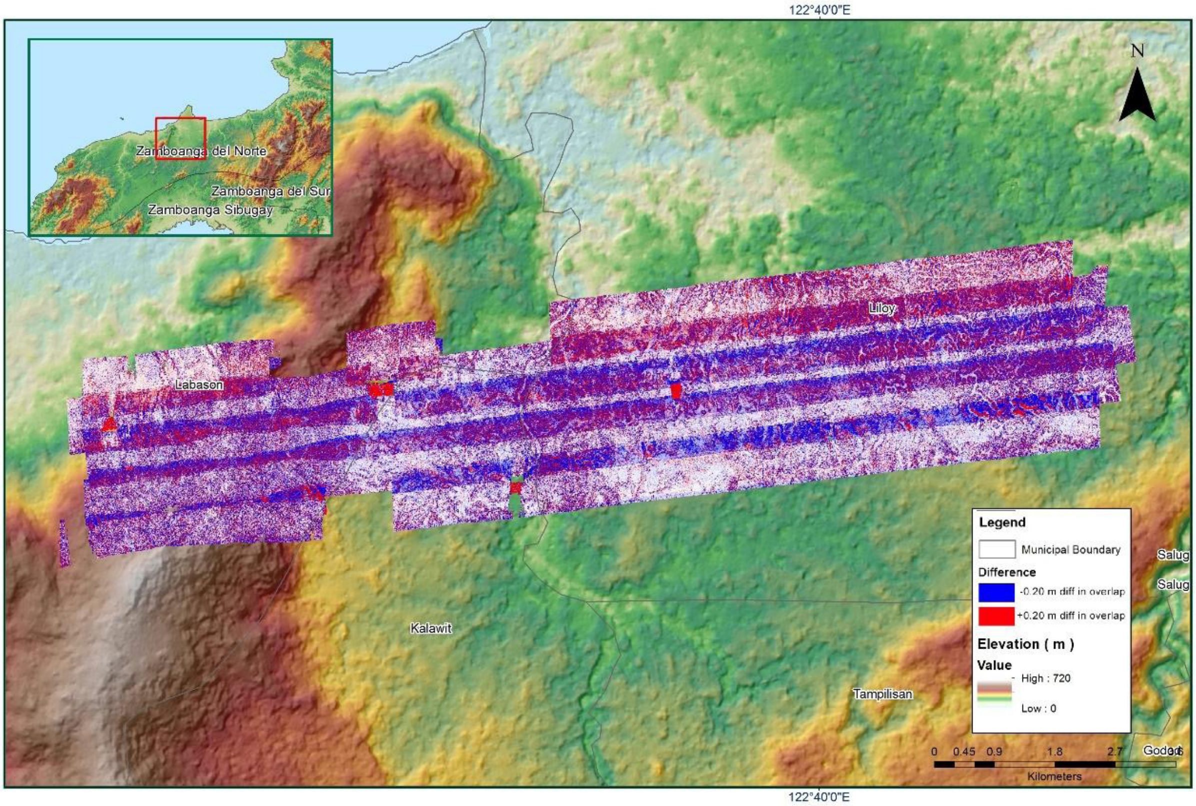


Figure A-8.35. Elevation difference between flight lines

Annex 9. Labason Model Basin Parameters

Table A-9.1 Labason 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
W220	0.0018795	99	0.0	0.257745	5.32798	Discharge	2.5500	0.425	Ratio to Peak	1
W210	0.0017114	99	0.0	0.20898	4.31984	Discharge	1.2475	0.425	Ratio to Peak	1
W200	0.0022479	99	0.0	0.16698	3.45173	Discharge	1.4264	0.425	Ratio to Peak	1
W190	0.004674	99	0.0	0.264885	5.47561	Discharge	0.42656	0.425	Ratio to Peak	1
W180	0.0018102	99	0.0	0.22602	4.6721	Discharge	1.3133	0.425	Ratio to Peak	1
W170	0.0039604	99	0.0	0.37431	7.73756	Discharge	2.7380	0.425	Ratio to Peak	1
W160	0.0023686	99	0.0	0.23694	4.89801	Discharge	1.4796	0.425	Ratio to Peak	1
W150	0.0032435	99	0.0	0.370485	7.65871	Discharge	0.8529891	0.425	Ratio to Peak	1
W140	0.0030605	99	0.0	0.221655	4.58204	Discharge	1.6993	0.425	Ratio to Peak	1
W130	0.002617	99	0.0	0.0183622	0.11387	Discharge	.000140087	0.425	Ratio to Peak	1
W120	0.002795	99	0.0	0.44505	9.19999	Discharge	2.3663	0.425	Ratio to Peak	1

Annex 10. Labason Model Reach Parameters

Table A-10.1 Labason Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	2524.1	0.0293828	0.35	Trapezoid	30	0.01
R20	Automatic Fixed Interval	20	0.001	0.35	Trapezoid	30	0.01
R40	Automatic Fixed Interval	1348.8	0.0045645	0.35	Trapezoid	30	0.01
R70	Automatic Fixed Interval	2776.9	0.0093182	0.35	Trapezoid	30	0.01
R80	Automatic Fixed Interval	1039.1	0.0093309	0.35	Trapezoid	30	0.01

Annex 11. Labason Field Validation Points

Table A-11.1 Labason Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return /Scenario
	Lat	Long					
1	8.062539	122.52188	0.03	0.50	-0.47	Not Defined	5 -Year
2	8.062524	122.52202	0.12	0.50	-0.38	Not Defined	5 -Year
3	8.062449	122.52172	0.03	0.50	-0.47	Not Defined	5 -Year
4	8.062285	122.5221	0.03	0.50	-0.47	Not Defined	5 -Year
5	8.062239	122.52196	0.11	0.50	-0.39	Not Defined	5 -Year
6	8.062172	122.52205	0.04	0.50	-0.46	Not Defined	5 -Year
7	8.062101	122.52209	0.15	0.50	-0.35	Not Defined	5 -Year
8	8.061927	122.52216	0.07	0.50	-0.43	Not Defined	5 -Year
9	8.062101	122.52238	0.16	0.50	-0.34	Not Defined	5 -Year
10	8.062683	122.52181	0.15	0.50	-0.35	Not Defined	5 -Year
11	8.062595	122.52182	0.15	0.50	-0.35	Not Defined	5 -Year
12	8.062735	122.52177	0.19	0.50	-0.31	Not Defined	5 -Year
13	8.062819	122.52166	0.28	0.50	-0.22	Not Defined	5 -Year
14	8.062658	122.52161	0.25	0.50	-0.25	Not Defined	5 -Year
15	8.062876	122.52157	0.26	0.50	-0.24	Not Defined	5 -Year
16	8.062704	122.52155	0.22	0.50	-0.28	Not Defined	5 -Year
17	8.062604	122.52145	0.16	0.50	-0.34	Not Defined	5 -Year
18	8.062681	122.5214	0.15	0.50	-0.35	Not Defined	5 -Year
19	8.062764	122.52135	0.15	0.50	-0.35	Not Defined	5 -Year
20	8.062916	122.52146	0.15	0.50	-0.35	Not Defined	5 -Year
21	8.063017	122.52146	0.03	0.50	-0.47	Not Defined	5 -Year
22	8.06311	122.52133	0.04	0.50	-0.46	Not Defined	5 -Year

23	8.063394	122.52109	0.09	0.50	-0.41	Not Defined	5 -Year
24	8.062786	122.52239	0.20	0.50	-0.30	Not Defined	5 -Year
25	8.062732	122.5222	0.04	0.50	-0.46	Not Defined	5 -Year
26	8.062717	122.52209	0.03	0.50	-0.47	Not Defined	5 -Year
27	8.062849	122.52212	0.11	0.50	-0.39	Not Defined	5 -Year
28	8.062831	122.52195	0.14	0.50	-0.36	Not Defined	5 -Year
29	8.062948	122.52198	0.14	0.50	-0.36	Not Defined	5 -Year
30	8.063144	122.52193	0.03	0.50	-0.47	Not Defined	5 -Year
31	8.063232	122.5216	0.07	0.50	-0.43	Not Defined	5 -Year
32	8.063534	122.52131	0.07	0.50	-0.43	Not Defined	5 -Year
33	8.062324	122.52254	0.25	0.50	-0.25	Not Defined	5 -Year
34	8.061906	122.52257	0.06	0.50	-0.44	Not Defined	5 -Year
35	8.061617	122.52271	0.22	0.50	-0.28	Not Defined	5 -Year
36	8.06133	122.52277	0.05	0.50	-0.45	Not Defined	5 -Year
37	8.071946	122.52105	0.16	0.20	-0.04	Not Defined	5 -Year
38	8.071845	122.52097	0.16	0.20	-0.04	Not Defined	5 -Year
39	8.071721	122.52079	0.28	0.20	0.08	Not Defined	5 -Year
40	8.07175	122.5206	0.10	0.20	-0.10	Not Defined	5 -Year
41	8.059187	122.50545	0.05	0.20	-0.15	Not Defined	5 -Year
42	8.060754	122.51129	0.11	0.20	-0.09	Not Defined	5 -Year
43	8.061697	122.51218	0.05	0.20	-0.15	Not Defined	5 -Year
44	8.063266	122.51465	0.03	0.10	-0.07	Not Defined	5 -Year
45	8.063767	122.51486	0.03	0.10	-0.07	Not Defined	5 -Year
46	8.065992	122.51594	0.05	0.10	-0.05	Not Defined	5 -Year
47	8.066845	122.51636	0.15	0.20	-0.05	Not Defined	5 -Year

48	8.066927	122.51626	0.08	0.20	-0.12	Not Defined	5 -Year
49	8.06472	122.5117	0.03	0.10	-0.07	Not Defined	5 -Year
50	8.064898	122.51167	0.05	0.10	-0.05	Not Defined	5 -Year
51	8.066221	122.52337	0.25	0.20	0.05	Not Defined	5 -Year
52	8.066039	122.52335	0.04	0.20	-0.16	Not Defined	5 -Year
53	8.066145	122.52325	0.24	0.20	0.04	Not Defined	5 -Year
54	8.066493	122.52362	0.03	0.20	-0.17	Not Defined	5 -Year
55	8.066162	122.52364	0.03	0.20	-0.17	Not Defined	5 -Year
56	8.066172	122.52345	0.03	0.20	-0.17	Not Defined	5 -Year
57	8.066034	122.52335	0.04	0.30	-0.26	Not Defined	5 -Year
58	8.066142	122.52326	0.24	0.10	0.14	Not Defined	5 -Year
59	8.065967	122.52324	0.03	0.10	-0.07	Not Defined	5 -Year
60	8.066379	122.52288	0.03	0.10	-0.07	Not Defined	5 -Year
61	8.066717	122.52294	0.34	0.10	0.24	Not Defined	5 -Year
62	8.065708	122.52311	0.03	0.20	-0.17	Not Defined	5 -Year
63	8.065595	122.52306	0.03	0.20	-0.17	Not Defined	5 -Year
64	8.0724	122.52211	0.03	0.20	-0.17	Not Defined	5 -Year
65	8.072497	122.52222	0.11	0.20	-0.09	Not Defined	5 -Year
66	8.073834	122.52312	0.09	0.20	-0.11	Not Defined	5 -Year
67	8.073773	122.523	0.04	0.20	-0.16	Not Defined	5 -Year
68	8.073775	122.52287	0.20	0.20	0.00	Not Defined	5 -Year
69	8.072859	122.52222	0.13	0.20	-0.07	Not Defined	5 -Year
70	8.073021	122.52201	0.09	0.20	-0.11	Not Defined	5 -Year
71	8.072941	122.52179	0.07	0.20	-0.13	Not Defined	5 -Year
72	8.072711	122.52189	0.07	0.20	-0.13	Not Defined	5 -Year

73	8.073602	122.52153	0.03	0.20	-0.17	Not Defined	5 -Year
74	8.054605	122.50012	0.05	0.50	-0.45	Not Defined	5 -Year
75	8.060744	122.51129	0.11	0.20	-0.09	Not Defined	5 -Year
76	8.060004	122.51155	0.23	0.50	-0.27	Not Defined	5 -Year
77	8.059779	122.5113	0.63	1.00	-0.37	Not Defined	5 -Year
78	8.059835	122.51141	0.56	1.00	-0.44	Not Defined	5 -Year
79	8.059984	122.51142	0.16	1.00	-0.84	Not Defined	5 -Year
80	8.059957	122.51191	1.18	1.50	-0.32	Not Defined	5 -Year
81	8.059955	122.5119	1.18	1.50	-0.32	Not Defined	5 -Year
82	8.063435	122.51476	0.03	0.10	-0.07	Not Defined	5 -Year
83	8.064483	122.51419	0.03	0.20	-0.17	Not Defined	5 -Year
84	8.061123	122.52193	0.03	0.10	-0.07	Not Defined	5 -Year
85	8.061176	122.52186	0.34	0.10	0.24	Not Defined	5 -Year
86	8.061231	122.52195	0.04	0.10	-0.06	Not Defined	5 -Year
87	8.060935	122.52195	1.46	1.00	0.46	Not Defined	5 -Year
88	8.060893	122.52183	1.46	1.00	0.46	Not Defined	5 -Year
89	8.061	122.52174	1.46	1.00	0.46	Not Defined	5 -Year
90	8.066808	122.51792	0.74	1.00	-0.26	Not Defined	5 -Year
91	8.068435	122.5171	0.03	0.10	-0.07	Not Defined	5 -Year
92	8.068293	122.5171	0.03	0.10	-0.07	Not Defined	5 -Year
93	8.068257	122.51698	0.43	0.10	0.33	Not Defined	5 -Year
94	8.068321	122.51687	0.03	0.10	-0.07	Not Defined	5 -Year
95	8.068196	122.51702	0.76	0.40	0.36	Not Defined	5 -Year
96	8.065962	122.51592	0.05	0.10	-0.05	Not Defined	5 -Year
97	8.064468	122.51142	0.11	0.10	0.01	Not Defined	5 -Year

98	8.064026	122.51306	0.12	0.30	-0.18	Not Defined	5 -Year
99	8.063898	122.51323	0.03	0.30	-0.27	Not Defined	5 -Year
100	8.065607	122.5186	0.06	0.20	-0.14	Not Defined	5 -Year
101	8.068124	122.51708	0.34	0.10	0.24	Not Defined	5 -Year
102	8.068191	122.51721	0.14	0.10	0.04	Not Defined	5 -Year
103	8.068094	122.51713	0.88	0.10	0.78	Not Defined	5 -Year
104	8.068149	122.51722	0.14	0.10	0.04	Not Defined	5 -Year
105	8.068015	122.51719	0.24	0.10	0.14	Not Defined	5 -Year
106	8.067908	122.51758	0.22	0.10	0.12	Not Defined	5 -Year
107	8.067707	122.51742	0.22	0.10	0.12	Not Defined	5 -Year
108	8.067774	122.51738	0.33	0.10	0.23	Not Defined	5 -Year
109	8.067707	122.51734	0.41	0.10	0.31	Not Defined	5 -Year
110	8.066788	122.51635	0.06	0.10	-0.04	Not Defined	5 -Year
111	8.064456	122.51141	0.11	0.10	0.01	Not Defined	5 -Year
112	8.062051	122.52407	0.03	0.10	-0.07	Not Defined	5 -Year
				RMSE	0.29		

Annex 12. Educational Institutions affected by flooding in Labason Floodplain

Table A-12.1 Educational Institutions in Labason, Zamboanga del Norte Affected by Flooding in Labason Floodplain

Zamboanga del Norte				
Labason				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
FELIX QUIMBO MEMORIAL SCHOOL	ANTONINO		Medium	Medium

Annex 13. Health Institutions affected by flooding in Labason Floodplain

Table A-13.1 Health Institutions in Labason, Zamboanga del Norte Affected by Flooding in Labason Floodplain

Zamboanga del Norte				
Labason				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Rural Health Center	Antonino			Low
Alfuerto Abandoned Hospital	Antonino		Medium	Medium
Mabilog Clinic	Antonino		Medium	Medium
Health Center	Antonino		Low	Low
Brgy. Health Station	Osukan		Low	Medium
Brgy. Health Center Antonino	Antonino		Low	Medium
Antonino Birth Center	Antonino		Low	Medium