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

LiDAR Surveys and Flood Mapping of Limpapa River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
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LIST OF ACRONYMS AND ABBREVIATIONS

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

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

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods (Paringit et al., 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Zamboanga University (ADZU). ADZU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the ________ river basins in the ___________________ (LiDAR covered area). The university is located in Zamboanga City in the province of Zamboanga Sibugay.

1.2 Overview of the Lumpapa River Basin

Figure 1. The boulder Limpapa River in ZC.

The Limpapa River Basin covers one (1) municipality in Zamboanga del Sur, namely the municipality of Sibuco. The DENR River Basin Control Office (RBCO) states that the Limpapa River Basin has a drainage area of 110 km² and an estimated 83 cubic meter (MCM) annual run-off (RBCO, 2015).

Limpapa, also known as Alimpaya River, is at the west coast of Zamboanga City. Situated at the boundary of the city and Zamboanga del Norte, it covers 42.36 sq.km of catchment area and traverses through barangays Limapapa and Labuan. It may be the smallest river system in the city but it produces a significant 146, 000 cubic meters of water daily. This flow rate was measured at a hanging bridge (7.141523N, 121.913613E) in June 2016. The river endured the test of time and still lies strong with its untainted water running through the boulders along its riverbed. Until now, the local residents enjoy the clean and fresh water of the river which they usually use for bathing and washing clothes.

Its main stem, Limpapa River, is part of the eighteen (18) river systems under the PHIL-LIDAR 1 Program partner HEI, Ateneo de Zamboanga University.

The name Limpapa came from a Subanen word “Lipapa” which is the Subanen term for the Molave tree. The Subanen or Subanon tribe is a group of indigenous people particularly living in the mountainous areas in the Zamboanga Peninsula. Subanon locally means “a person or people from the river.” The name implies that the Subanons originally lived in the low-lying areas near the river. However due to disturbances caused by the Muslims and Cebuanos who migrated to these areas, they were forced to move into the mountains and remained a minority until now. It was believed that when this tribe settled in Limpapa, Molave tress forested the place. But with the increased demand for their versatile applications, these trees are now gone in Limpapa’s habitat.

Figure 2. Limapapa River’s mouth.

In July 2011, the Mines and Geosciences Bureau (MGB) of the Department of Environment and Natural Resources (DENR) of region 9 identified Limpapa and Labuan among the 36 barangays prone to floods. This declaration was announced by the agency’s OIC at the time, Vhiena Marie Quintana. She further added that landslides are also likely to occur in these areas during heavy rains.

Last September 2012, Typhoon Lawin, internationally known as Jelawat, caused flooding and heavy rains for three days in Zamboanga City. A number of 171 families were evacuated in the city (http://newsinfo.inquirer.net/276310/1-missing-hundreds-evacuated-due-to-typhoon-lawin).

Unsurprisingly, in August 2013, Limpapa and Labuan were affected by floods and landslides when heavy rains caused by an Intertropical Convergence Zone (ITCZ) hit Zamboanga City. It was also the same event that caused Manicahan River to swell displacing 20 families in barangay Manicahan.

Meanwhile, Limpapa is among the four rivers identified by the PhilCarbon Incorporated as potential sites for a hydroelectric power plant in the west coast of the city. The other three rivers are Patalon, Ayala, and Tagpangi. Philcarbon is a renewable energy (RE) company in the country venturing into energy efficiency projects focusing on the utilization of biomass, wind, hydropower, solar and geothermal energy sources.

The economy of Zamboanga City is mainly agricultural and aqua cultural with its main produce being coconut and seaweed, respectively. Zamboanga City is also known for exporting their products locally like coconut oil, marine products, and processed food (info.philtravelcenter.com/zamboangacity-economy.php).

Sources:

ABS-CBN News
Doe.gov.ph
PhilCarbon Incorporated
Sunstar Zamboanga
Zamboanga.com
Zamboanga Today Online

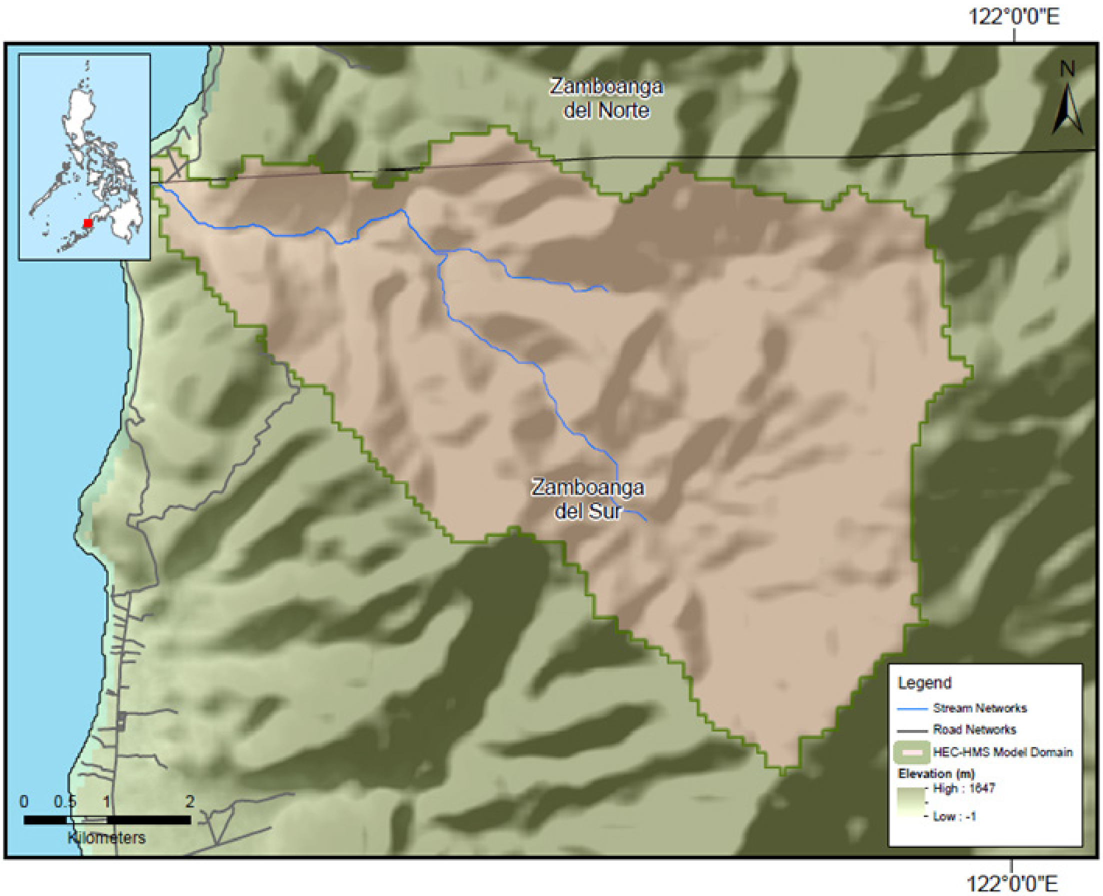

Figure 3. Map of Limpapa River Basin (in brown).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LIMPAPA FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Limpapa Floodplain located along the boundary of Zamboanga City and Sibuco. 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 Gemini and Pegasus LiDAR system are found in Table 1 and Table 2, respectively. Figure 4 shows the flight plans for Limpapa Floodplain survey.

Table 1. Flight planning parameters for the 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)
BLK75G	1000	40	40	100	50	130	5

Table 2. 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)
BLK75C	1100	15	50	200	30	130	5
BLK75D	1100	15	50	200	30	130	5
BLK75E	1100	15	50	200	30	130	5
BLK75F	1200	30	50	200	30	130	5
BLK75G	1200	30	50	200	30	130	5
BLK75BS	1000	50	40	200	35	130	5
BLK75FS	1100	15	50	200	30	130	5
BLK75GS	1100	15	50	200	30	130	5

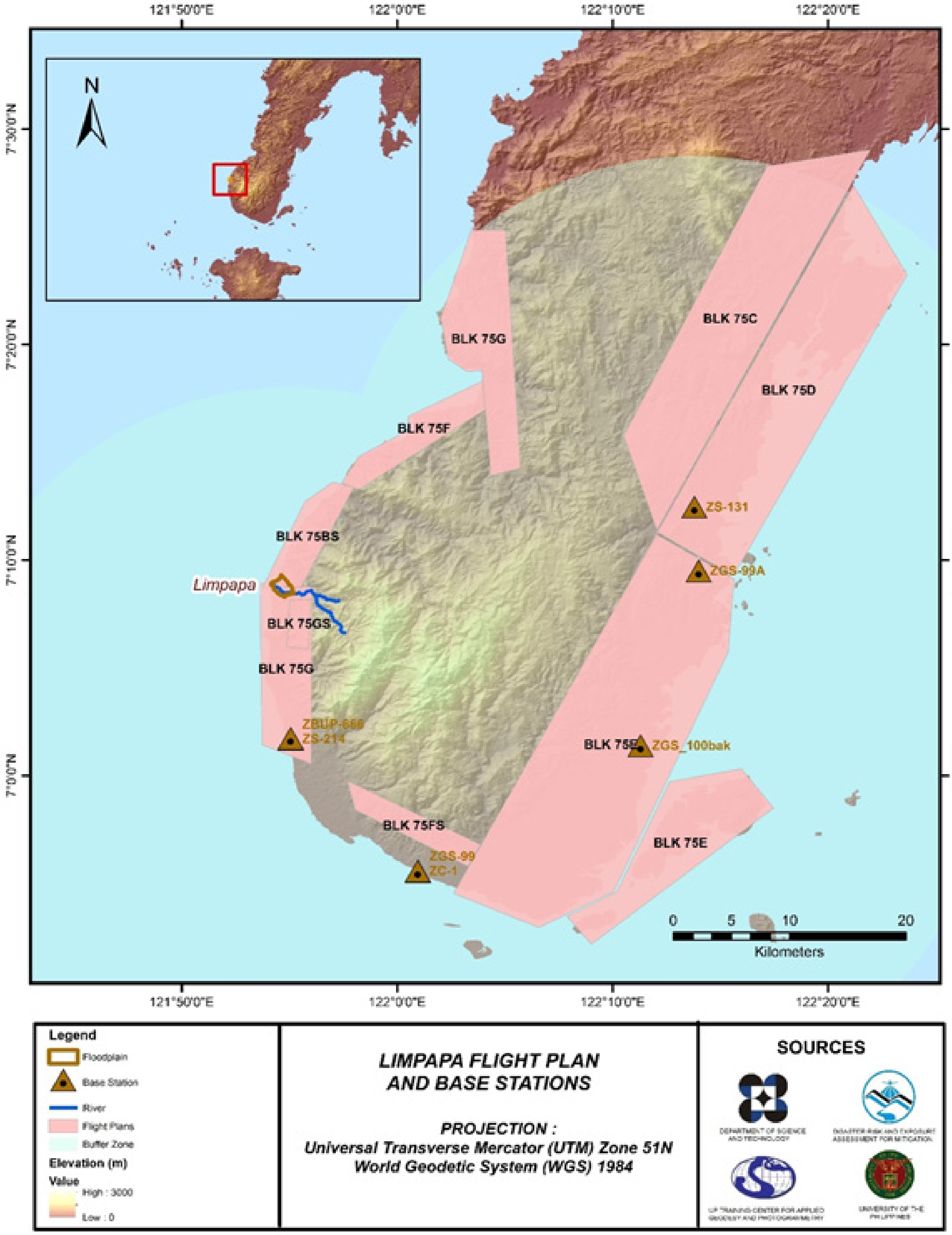

Figure 4. Flight plan and base stations used to cover Limpapa Floodplain.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point: ZGS-99 which isof second (2nd) order accuracy. Three (3) NAMRIA benchmarks: ZC-1, ZS-214 and ZS-131 were also recovered. The project team also established three (3) ground control points: ZGS-99A, ZBUP-666 and ZGS-100bak.

The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing reports for the benchmarks and established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (August 18 to September 10, 2014; February 5 to 11, 2015; May 19 to 31, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Limpapa Floodplain are shown in Figure 4.

Figure 5 to Figure 8 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table9 present the details about the following NAMRIA control stations, while Table 10 lists all ground control points occupied during the acquisition together with the corresponding dates of utilization.

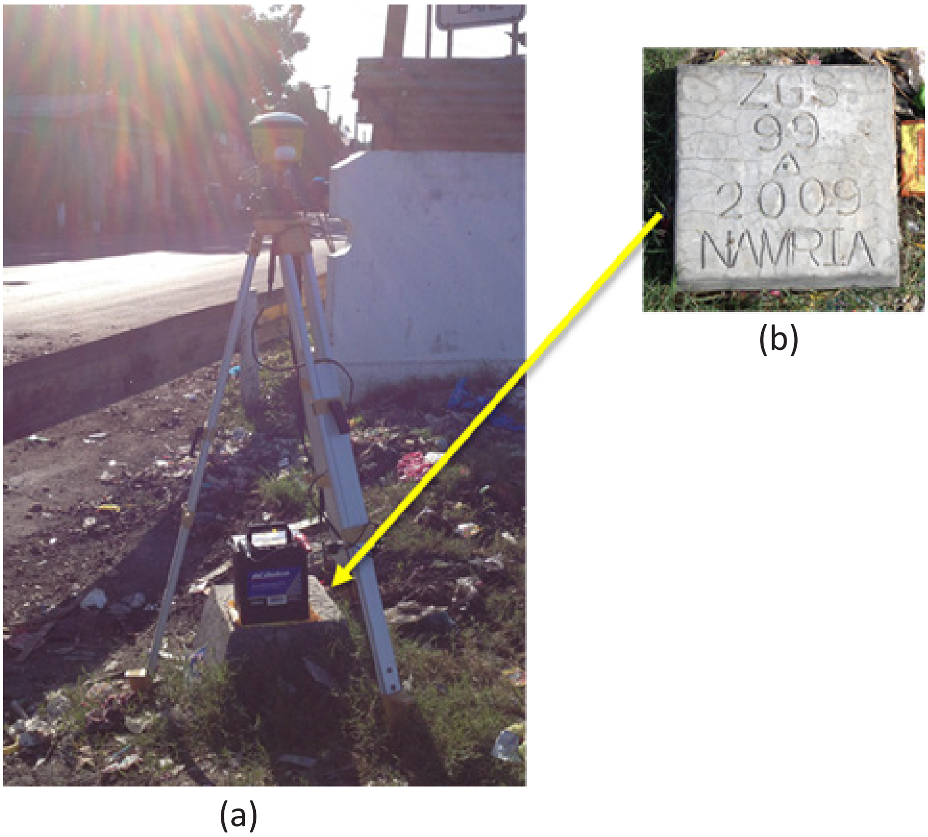

Figure 5. GPS set-up over ZGS-99 beside the seawall in Calarian, Zamboanga City (a) and NAMRIA reference point ZGS-99 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGS-99 used as base station for the LiDAR acquisition.

Station Name	ZGS-99	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6° 55’ 37.48971” North 122° 0’ 52.66431” East 8.149 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	391,103.346 meters 766,020.391 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 55’ 34.07737” North 122° 0’ 58.23072” East 72.23 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	391,141.46 meters 765,752.27 meters

Table 4. Details of the recovered NAMRIA benchmark ZC-1with processed coordinates used as base station for the LiDAR acquisition.

Station Name	ZC-1	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6° 55’ 37.81345” North 122° 00’ 52.07670” East 7.666 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6° 55’ 34.40107” North 122° 00’ 57.64310” East 71.746 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	391,295.31 meters 765,705.61 meters

(a)

(b)

Figure 6. GPS set-up over ZS-214in Tinuba, Zamboanga del Sur (a) and NAMRIA reference point ZS-214 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA benchmarkZS-214with processed coordinates used as base station for the LiDAR acquisition.

Station Name	ZS-214	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 01′ 45.63620″ North 121° 54′ 58.78958″ East 13.222 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 01′ 42.18785″ North 121° 55′ 4.34718″ East 76.870 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	380,478.39 meters 777,024.91 meters

Figure 7. GPS set-up over ZS-131in Curuan, Zamboanga City (a) and NAMRIA reference point ZS-131 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA benchmarkZS-131with processed coordinates used as base station for the LiDAR acquisition.

Station Name	ZS-131	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 12’ 31.41328” North 122° 13’ 42.74840” East 10.811 meter
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 12’ 27.94616” North 122° 13’ 48.28765” East 74.904 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	414,997.21 meters 796,788.09 meters

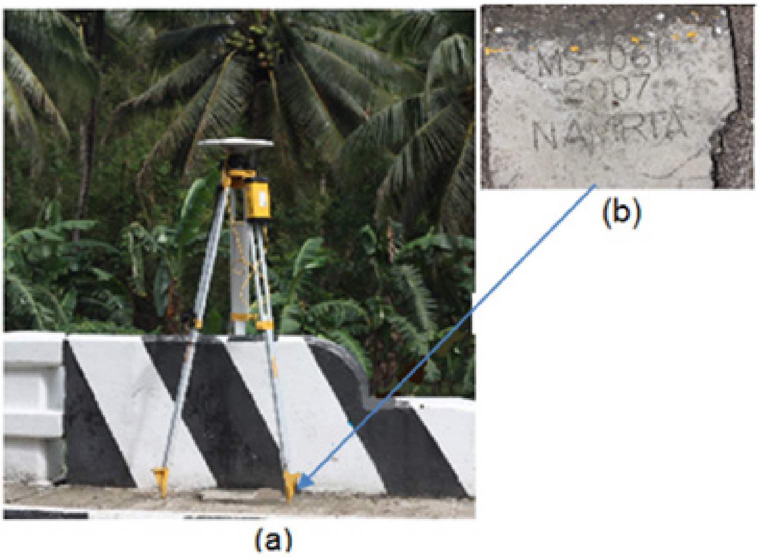

Figure 8. GPS set-up over MS-61 (a) as recovered in Nabangig Bridge, Brgy. Nabangig, municipality of Palanas, Masbate; NAMRIA reference point MS-61 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point MS-61 used as base station for the LiDAR acquisition.

Station Name	MS-61	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 06' 1.51238"
	Longitude	123° 57' 21.24483"
	Ellipsoidal Height	4.74 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	12° 05' 56.94091" North
	Northing	123° 57' 26.33451" East
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	65.257 meters
	Longitude	604178.664 meters
	Ellipsoidal Height	1337699.951 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	586236.32 meters
	Northing	1346237.33 meters

Table 8. Details of the established control point ZBUP-666with processed coordinates used as base station for the LiDAR acquisition.

Station Name	ZGS-99A	
Order of Accuracy	2nd (established control point)	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 01’ 48.04214” North 121° 54’ 58.32497” East 124.333 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 01’ 44.59360” North 121° 55’ 03.88251” East 77.615 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	380,464.30 meters 777,098.83 meters

Table 9. Details of the established control point ZGS-100bakwith processed coordinates used as base station for the LiDAR acquisition.

Station Name	ZGS-100bak	
Order of Accuracy	2nd (established control point)	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 01’ 26.95286” North 122° 11’ 12.71974” East 11.430 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 01’ 23.53066” North 122° 11’ 18.27616” East 77.615 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	410,360.56 meters 776,391.50 meters

Table 10. Ground Control Points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
August 24, 2014	7452GC	2BLK75G236A	ZGS-99; ZC-1
February 11, 2015	2557P	1BLK75S42A	ZGS-99; ZGS-99A
May 25, 2016	23390P	1BLK75BS146A	ZS-214; ZBUP-666
May 26, 2016	23392P	1BLK75FG147A	ZS-131; ZGS-100bak

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Limpapa Floodplain, for a total of twelve hours and twenty minutes (12+20) of flying time for RP-C9022, RP-C9122 and RP-C9322. The missions were acquired using the Gemini and Pegasus LiDAR system. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in Limpapa Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within Floodplain (km²)	Area Surveyed Outside Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
August 24, 2014	7452GC	62.3	71.7	1.80	69.9	0	2	23
February 11, 2015	2557P	849.66	204.72	0.82	203.9	474	4	23
May 25, 2016	23390P	29.11	33.09	1.81	31.28	0	1	41
May 26, 2016	23392P	117.63	203.00	1.81	201.19	0	3	53
TOTAL		1,058.7	512.51	6.24	506.27	474	12	20

Table 12. 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)
7452GC	1000	40	40	100	50	130	5
2557P	1100	15	50	200	30	130	5
23390P	1000	50	40	200	35	130	5
23392P	1200	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Limpapa Floodplain (See Annex 7). Limpapa Floodplain is located along Zamboanga with majority of the floodplain situated within the municipalityofZamboanga City. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Limpapa floodplain is presented in Figure 9.

Table 13. List of municipalities and cities surveyed during Limpapa floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Zamboanga del Norte	Sibuco	600.1	153.1	25.51%
Zamboanga del Sur	Zamboanga City	1,461.04	172.1	11.78%
Total		2061.14	325.2	15.78%

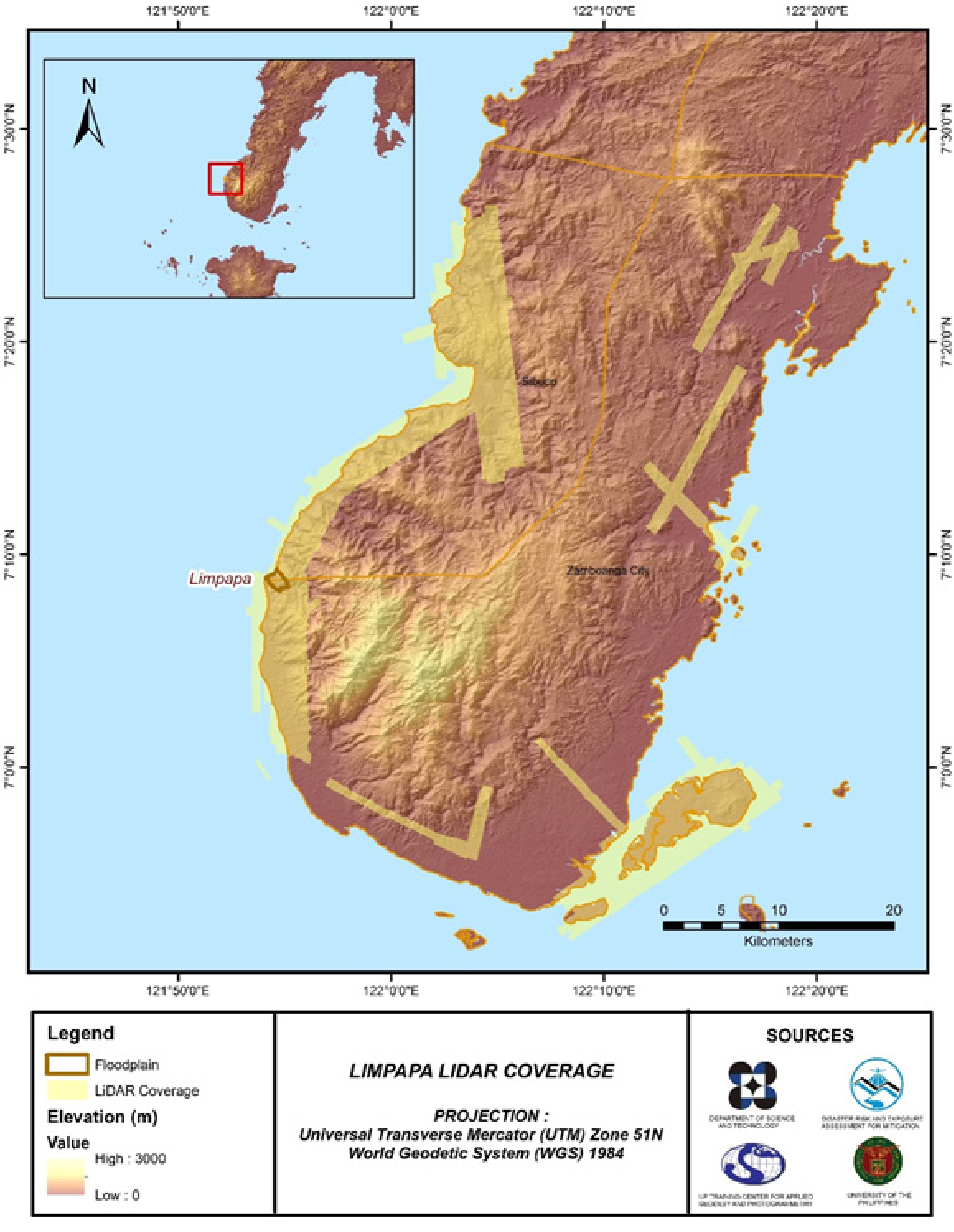

Figure 9. Actual LiDAR survey coverage for Limpapa Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LIMPAPA FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 10.

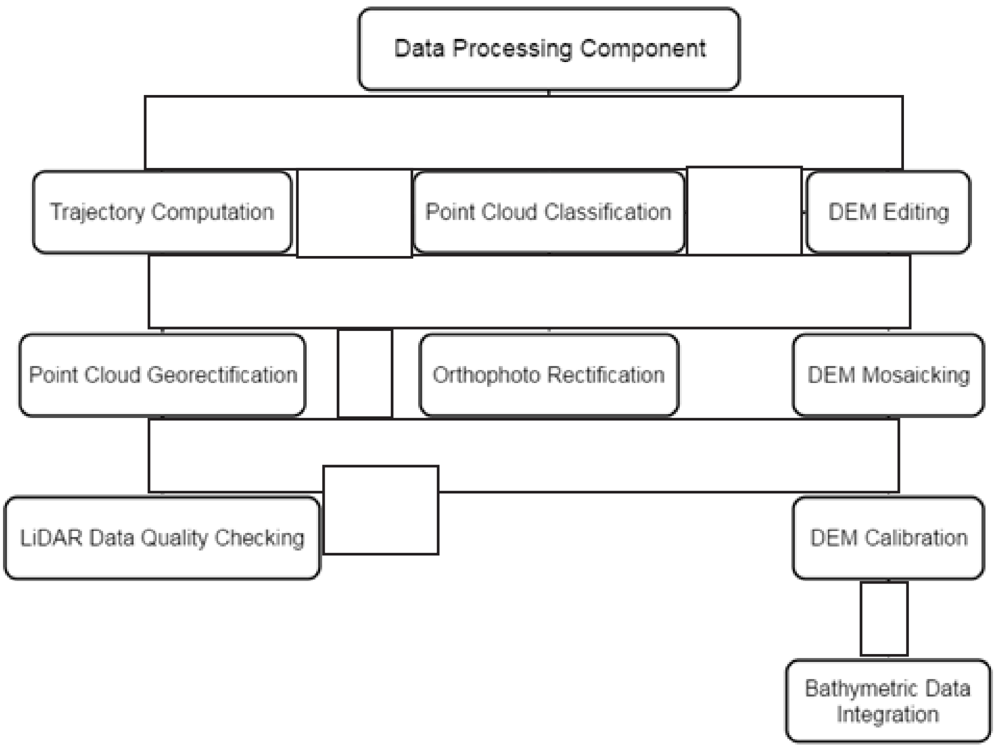

Figure 10. Schematic Diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Limpapa Floodplain can be found in Annex 5. Missions flown during the first survey conducted on August 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.)Gemini system while missions acquired during the lastsurvey on May 2016 were flown using the Pegasus system over Zamboanga. The Data Acquisition Component (DAC) transferred a total of61.83 Gigabytes of Range data, 0.74 Gigabytes of POS data, 240.34 Megabytes of GPS base station data, and 34.90 Gigabytes of raw image datadata to the data server on August 24, 2014 for the first survey and May 26, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Limpapawas fully transferred on July 14, 2016, as indicated on the Data Transfer Sheets for Limpapa Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metricparameters of the computed trajectory for flight 23392P, one of the Limpapaflights, which is the North, East, and Down position RMSE values are shown in Figure 11. 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 onMay 26, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

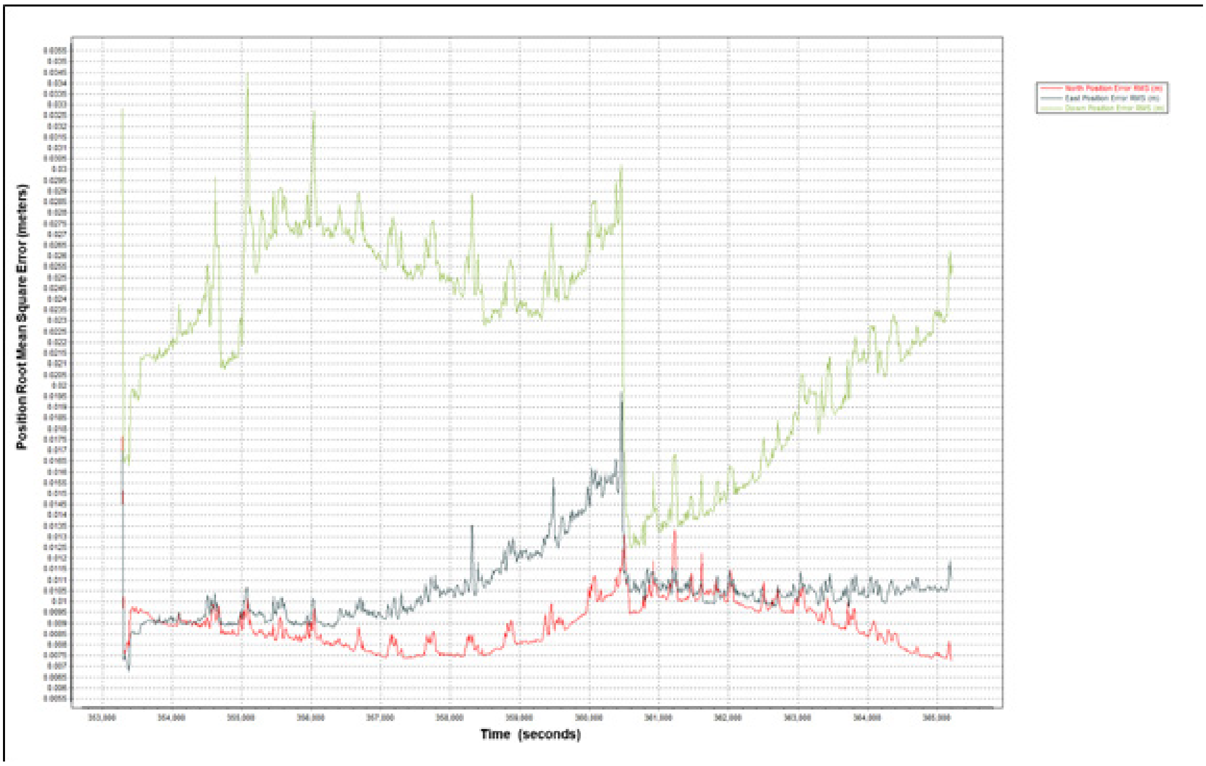

Figure 11. Smoothed Performance Metric Parameters of Limpapa Flight 23392P.

The time of flight was from 353000 seconds to 365000 seconds, which corresponds to morning of May 26, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly 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 10 shows that the North position RMSE peaks at 1.35 centimeters, the East position RMSE peaks at 2.00centimeters, and the Down position RMSE peaks at 3.45centimeters, which are within the prescribed accuracies described in the methodology.

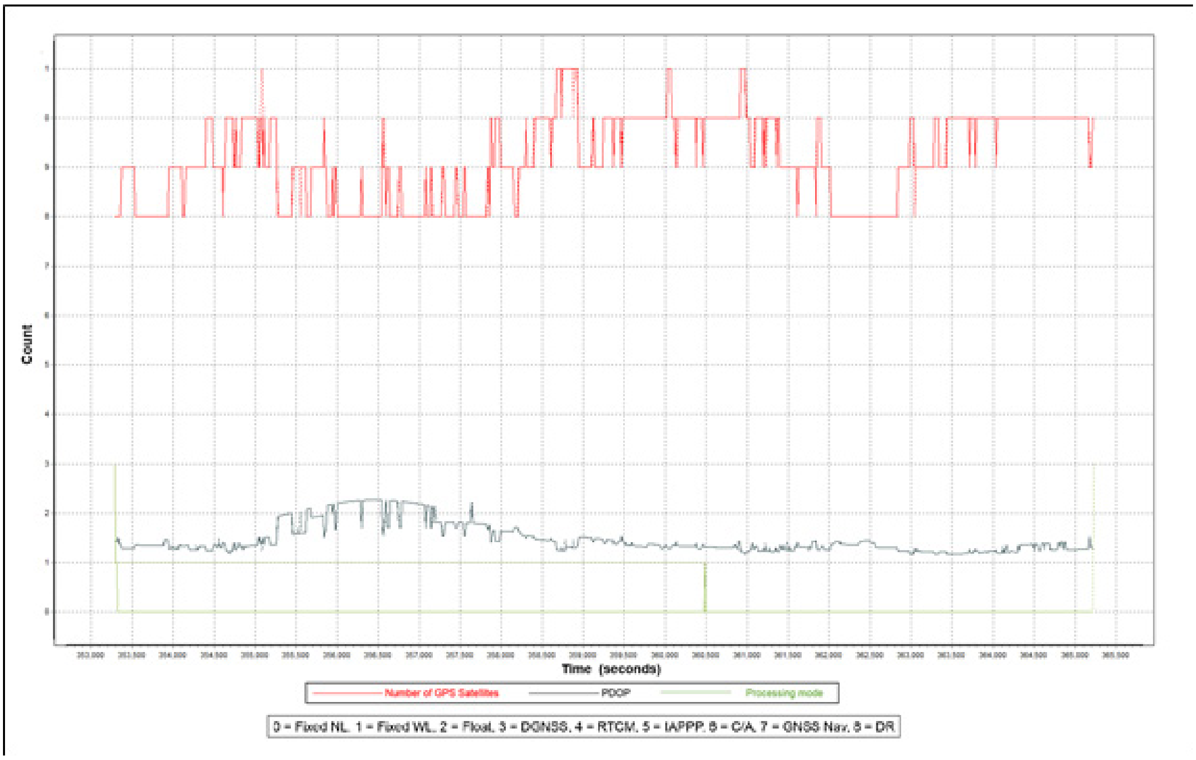

Figure 12. Solution Status Parameters of Limpapa Flight 23392P.

The Solution Statusparameters of flight 23392P,one of the Limpapaflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. 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 8 and 11. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with a peak 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 Limpapa flights is shown in Figure 13.

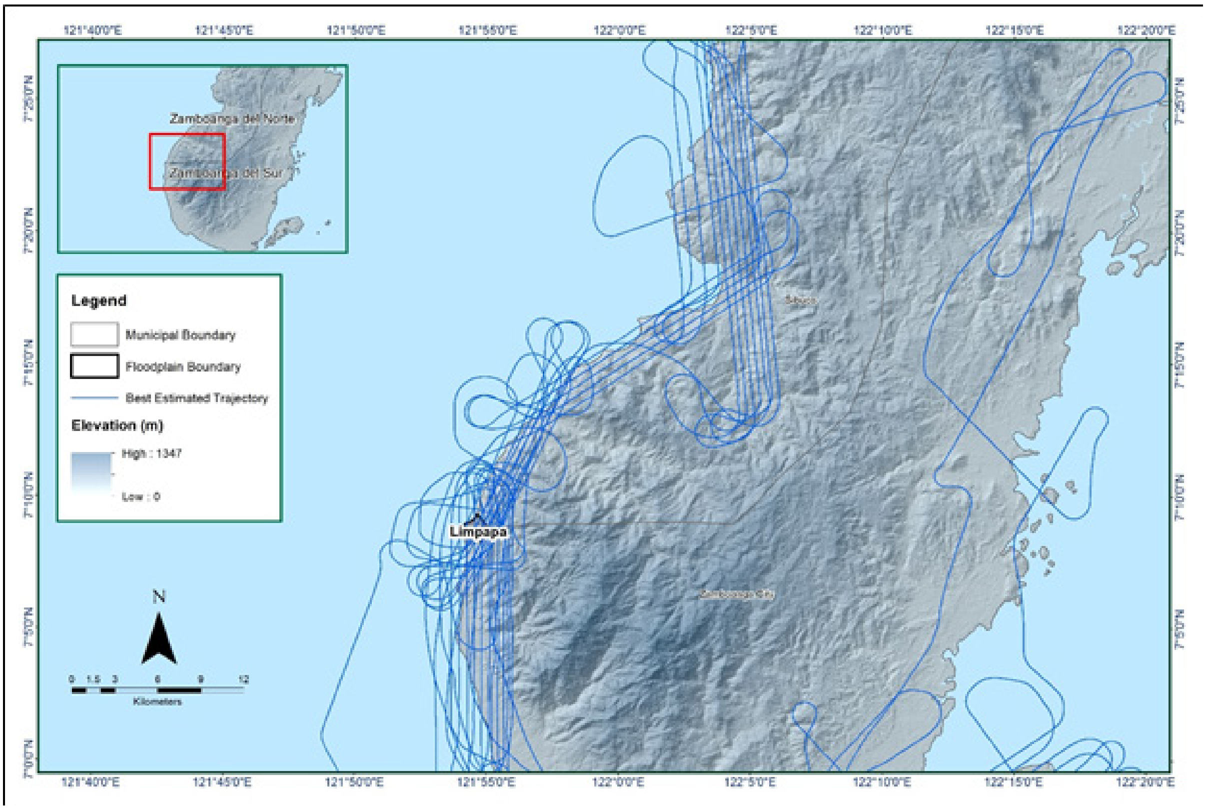

Figure 13. Best Estimated Trajectory for Limpapa Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 37flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Limpapa Floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Limpapa flights.

Parameter	Value	
Boresight Correction stdev	<0.001degrees	0.000189
IMU Attitude Correction Roll and Pitch Corrections stdev	<0.001degrees	0.000609
GPS Position Z-correction stdev	<0.01meters	0.0024

The optimum accuracy was obtained for all Limpapa 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 Limpapa Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

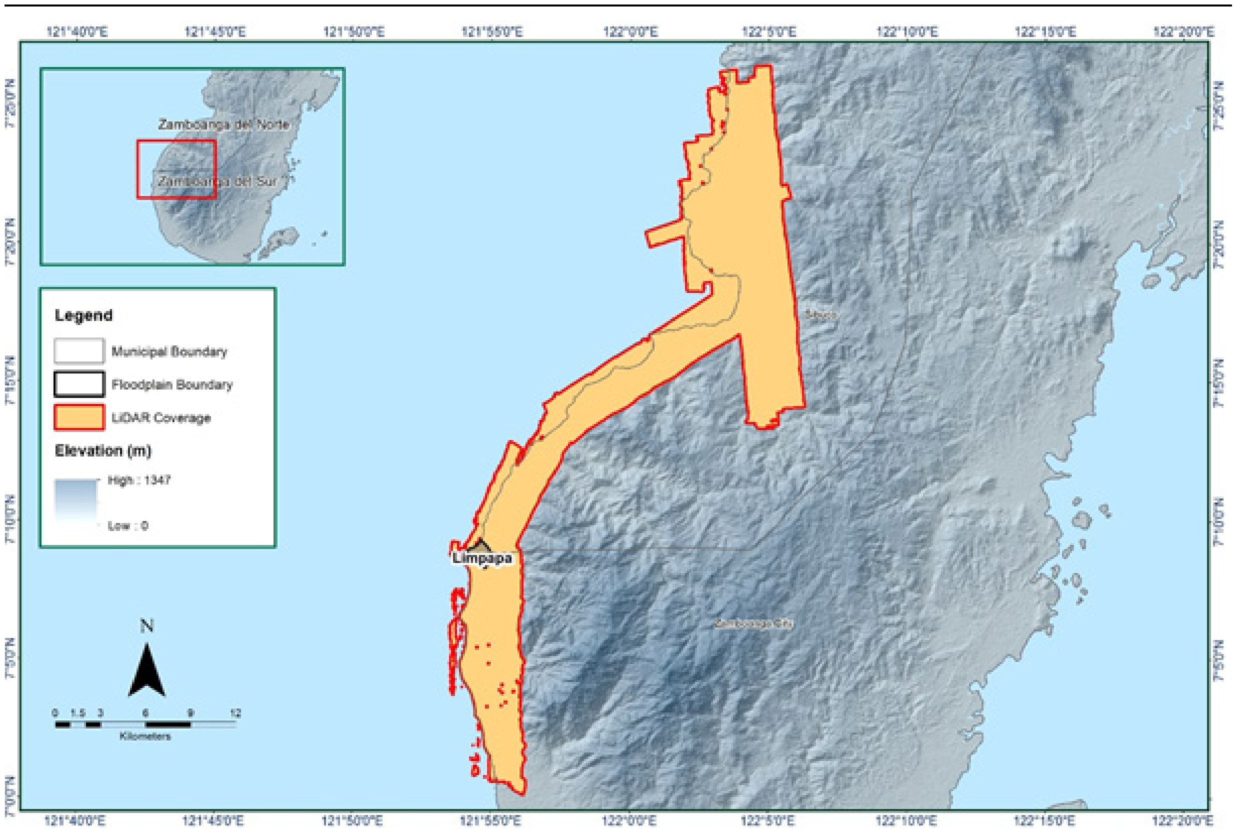

Figure 14. Boundary of the processed LiDAR data over Limpapa Floodplain.

The total area covered by the Limpapa missions is 269.21 sq.km that is comprised of four (4) flight acquisitions grouped and merged into six (6) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Limpapa floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Zamboanga_Blk75G	7452G	55.05
Zamboanga_Blk75G_additional	2557P	0.89
Zamboanga_reflights_Blk75G	23390P	29.92
	23392P	
Zamboanga_reflights_Blk75G_additional	23392P	7.53
Zamboanga_reflights_Blk75H	23392P	54.72
Zamboanga_reflights_Blk75I	23392P	121.10
	TOTAL	**269.21 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 15. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. Since the Pegasus system which 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.

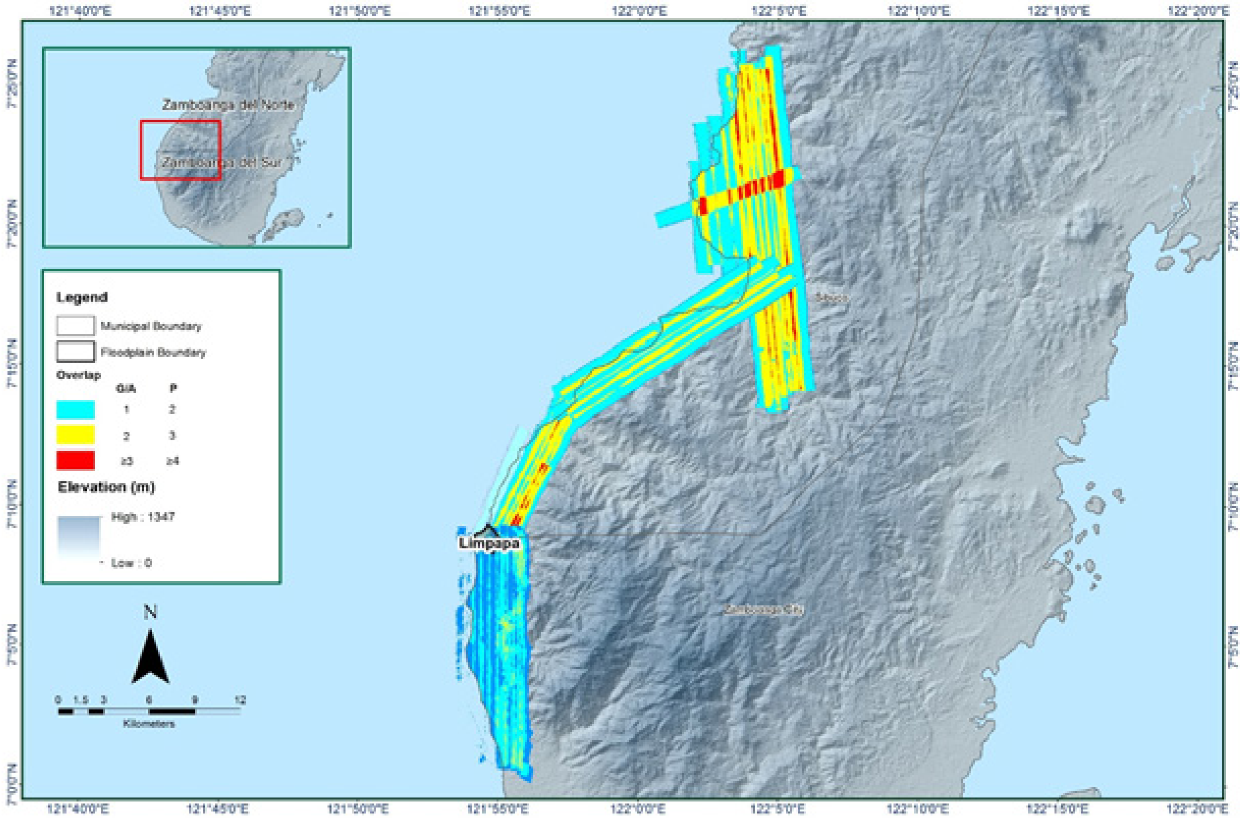

Figure 15. Image of data overlap for Limpapa Floodplain.

The overlap statistics per block for the Limpapa 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 overlapsare32.65% and 90.86% 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 16. It was determined that all LiDAR data for Limpapa Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.50 points per square meter.

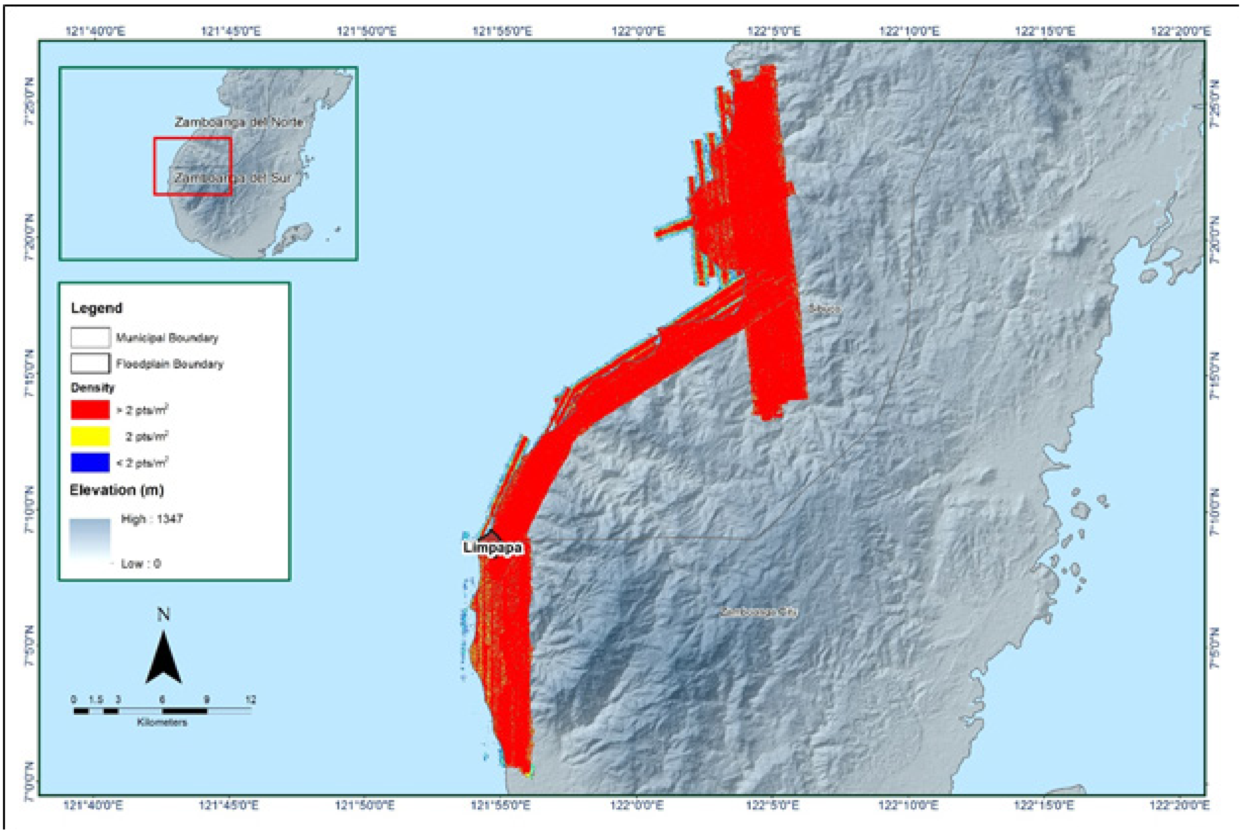

Figure 16. Pulse density map of merged LiDAR data for Limpapa Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. 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.

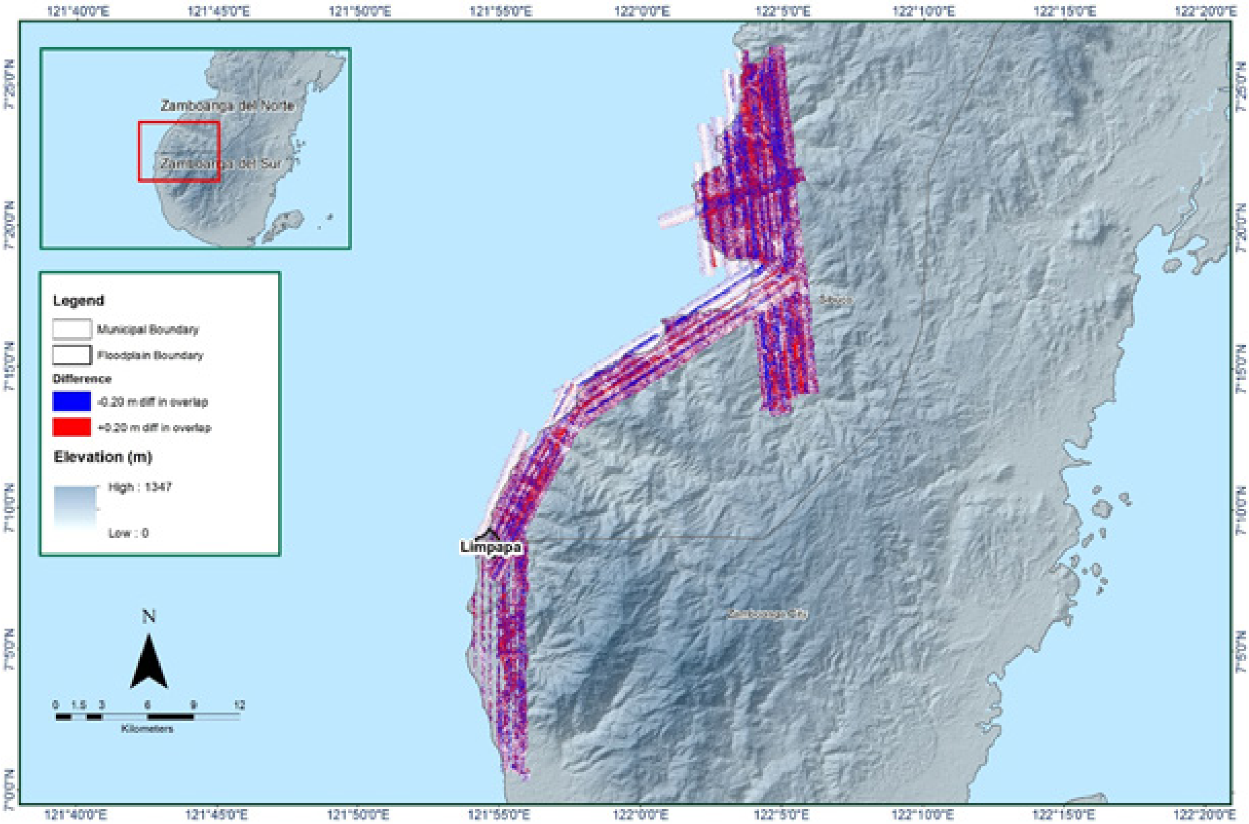

Figure 17. Elevation difference map between flight lines for Limpapa floodplain.

A screen-capture of the processed LAS data from Nainday flight 1245P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

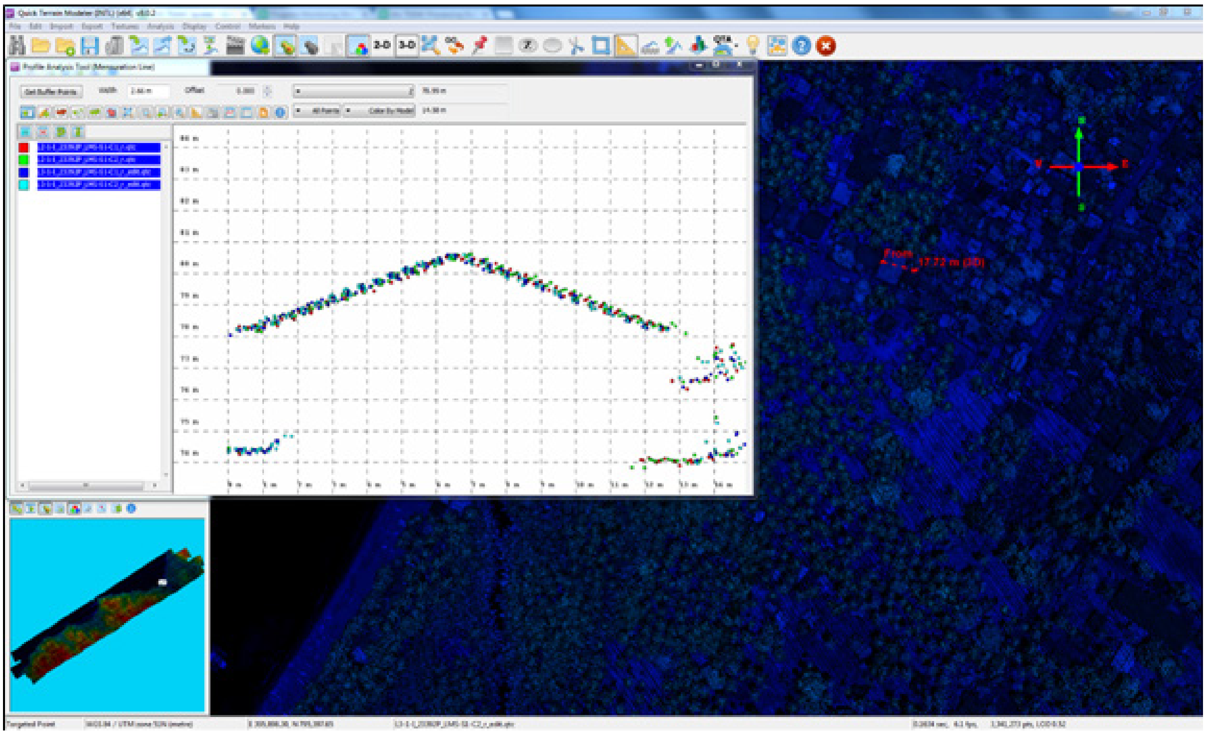

Figure 18. Quality checking for Limpapa flight 23392P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Limpapa classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	273,218,195
Low Vegetation	167,522,437
Medium Vegetation	384,593,799
High Vegetation	1,158,936,291
Building	8,399,177

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Limpapa Floodplain is shown in Figure 19. A total of 422 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 743.58 meters and 65.65 meters respectively.

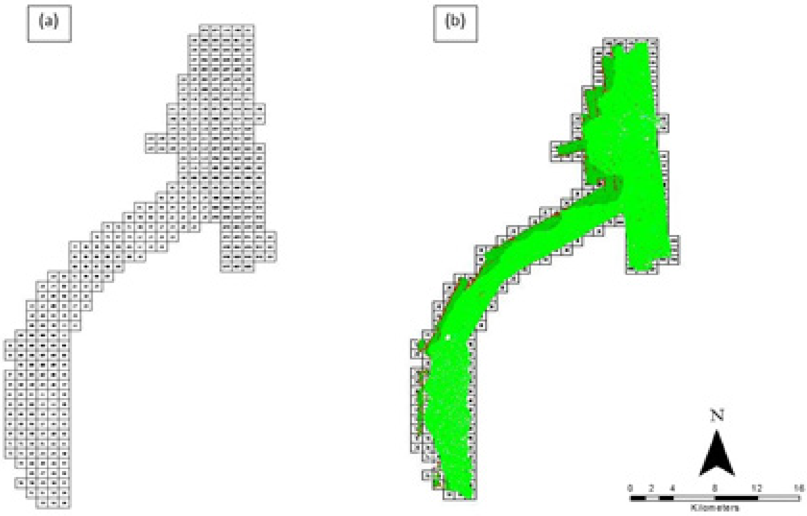

Figure 19. Tiles for Limpapa floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

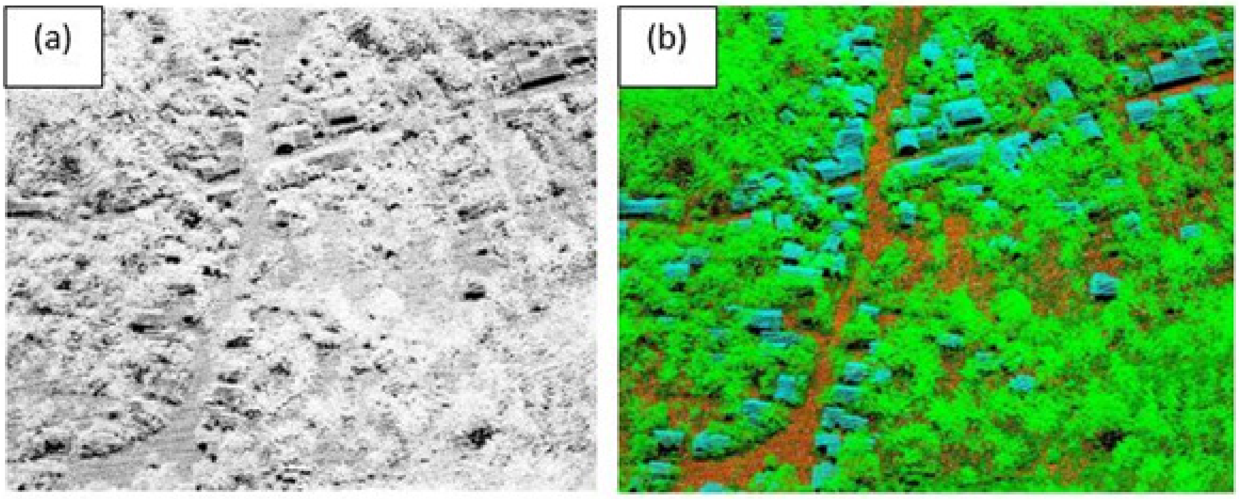

Figure 20. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show in Figure 21. It shows that DTMs are the representation of the bare earth, while on the DSM, all features are present such as buildings and vegetation.

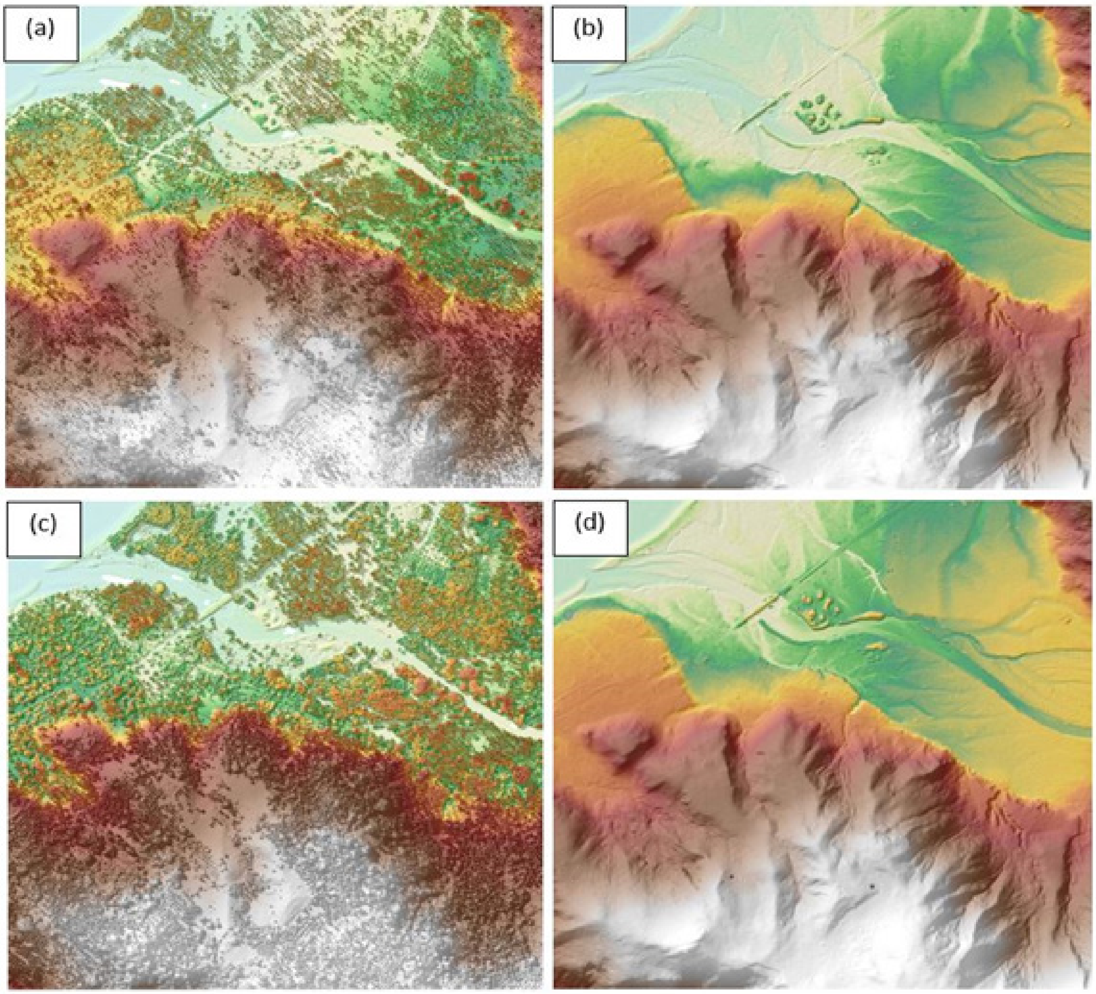

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Limpapa floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for Limpapa floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Limpapa Floodplain. These blocks are composed of Zamboanga and Zamboanga_reflights blocks with a total area of 269.21 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Zamboanga_Blk75G	55.05
Zamboanga_Blk75G_additional	0.89
Zamboanga_reflights_Blk75G	29.92
Zamboanga_reflights_Blk75G_additional	7.53
Zamboanga_reflights_Blk75H	54.72
Zamboanga_reflights_Blk75I	121.10
TOTAL	269.21 sq.km

Portions of DTM before and after manual editing are shown in Figure 22. The part of the mountain (Figure 22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22b) to allow the correct flow of water. The bridge (Figure 22c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22d) in order to hydrologically correct the river.

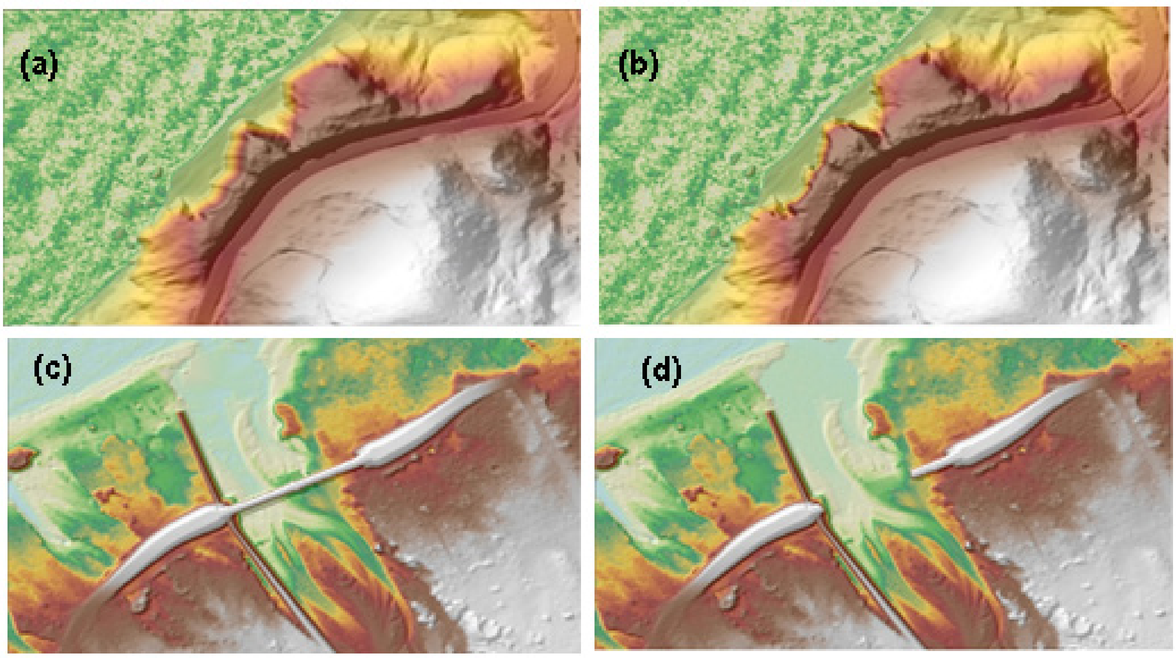

Figure 22. Portions in the DTM of Limpapa floodplain – a part of a mountain before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Simultaneous mosaicking was done to all the available LiDAR data (Zamboanga_Blk75G, Zamboanga_Blk75G_additional, Zamboanga_reflights_Blk75G, Zamboanga_reflights_Blk75G_additional, Zamboanga_reflights_Blk75H and Zamboanga_reflights_Blk75I). Zamboanga_Blk75G was used as the reference block at the start of mosaicking because it is the first available LiDAR data.Table 18 shows the shift values applied to each LiDAR block during mosaicking.

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

Table 18. Shift Values of each LiDAR Block of Limpapa Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Zamboanga_Blk75G	0.00	0.00	0.00
Zamboanga_Blk75G_additional	0.00	0.00	0.00
Zamboanga_reflights_Blk75G	2.00	-3.00	-1.16
Zamboanga_reflights_Blk75G_additional	2.00	-3.00	-1.16
Zamboanga_reflights_Blk75H	2.00	-2.00	-4.06
Zamboanga_reflights_Blk75I	3.00	-1.00	-4.06

Figure 23. Map of Processed LiDAR Data for Limpapa 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 Limpapa Floodplains to collect points with which the LiDAR dataset is validated is shown in Figure 24.

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

A total of 1,739 survey points from Tumaga data were used for calibration and validation of all the blocks of Zamboanga LiDAR data. Random selection of 80% of the survey points, resulting in 1,391 points, were used for calibration. The good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 8.06 meters with a standard deviation of 0.07 meters. Calibration for Zamboanga LiDAR data

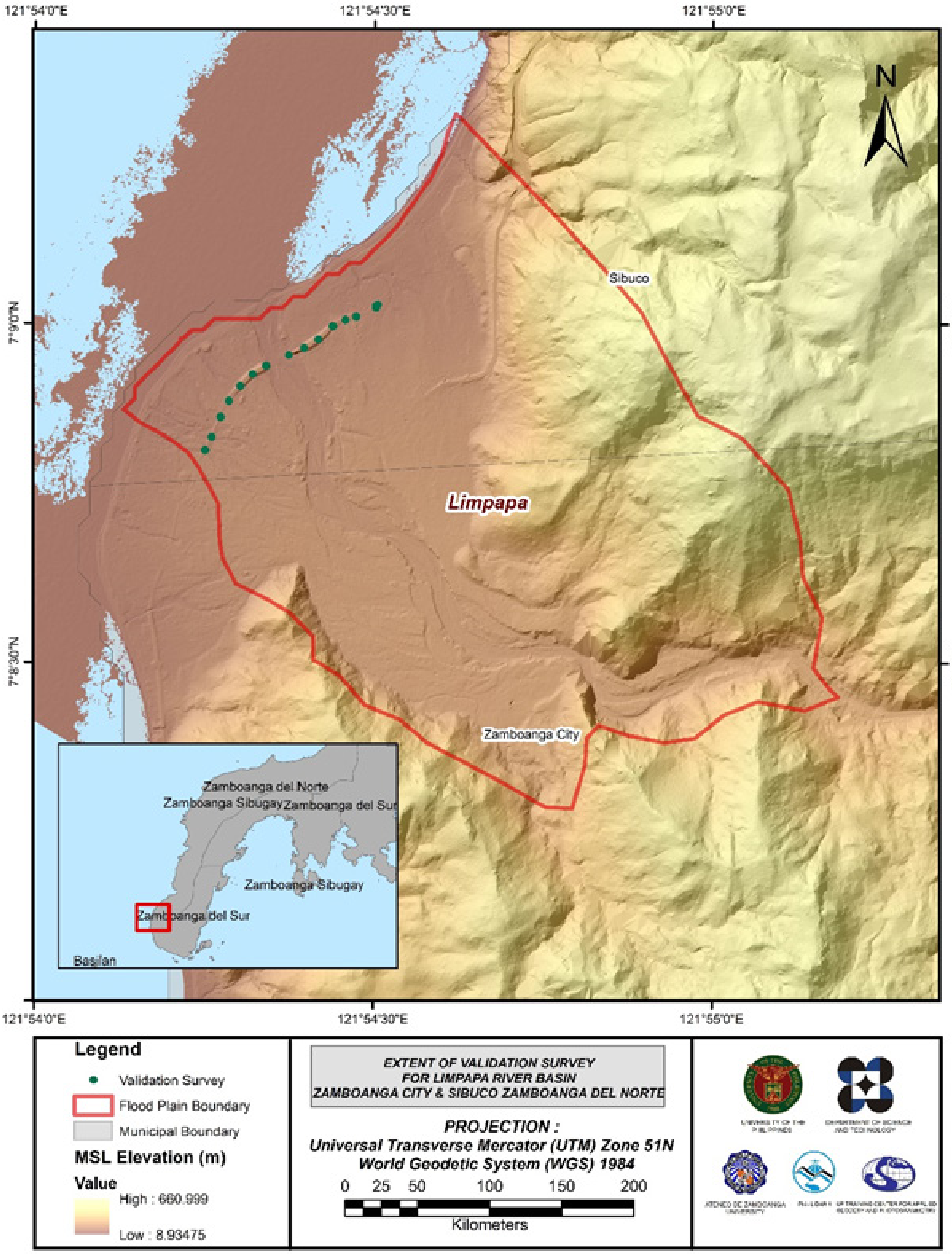

Figure 24. Map of Limpapa Flood plain with validation survey points in green.

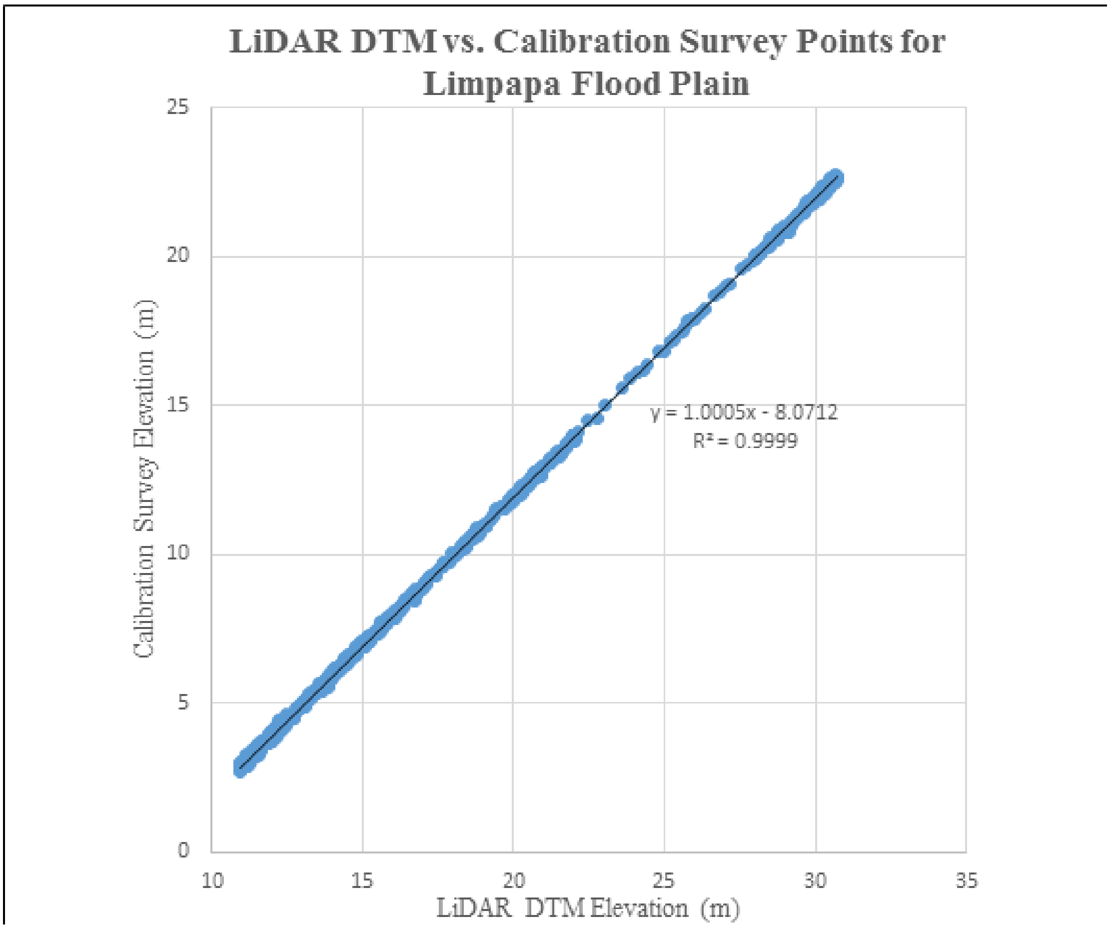

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

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

No validation data was collected for Limpapa, instead survey points from San Jose floodplain which lie on the Limpapa floodplain was used. From the randomly selected 20% of the total survey points for San Jose, resulting in 944 points, only 7 points lie on the Limpapa floodplain and was used for the validation of the calibrated Limpapa DTM. The 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.09 meters with a standard deviation of 0.10 meters, as shown in Table 20.

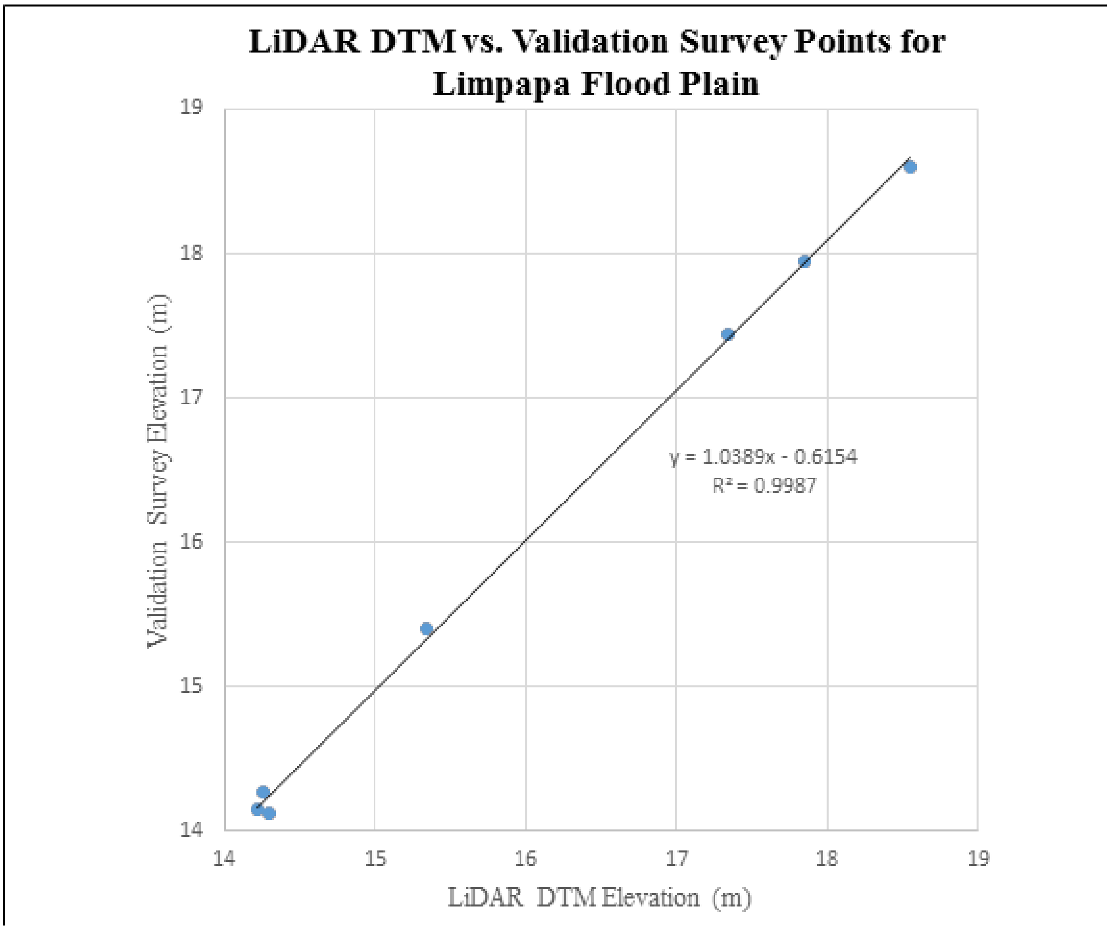

Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.09
Standard Deviation	0.10
Average	-0.00
Minimum	-0.21
Maximum	0.19

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, cross-section data was available for Limpapa with 914 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 0.18 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Limpapa integrated with the processed LiDAR DEM as shown in Figure 27.

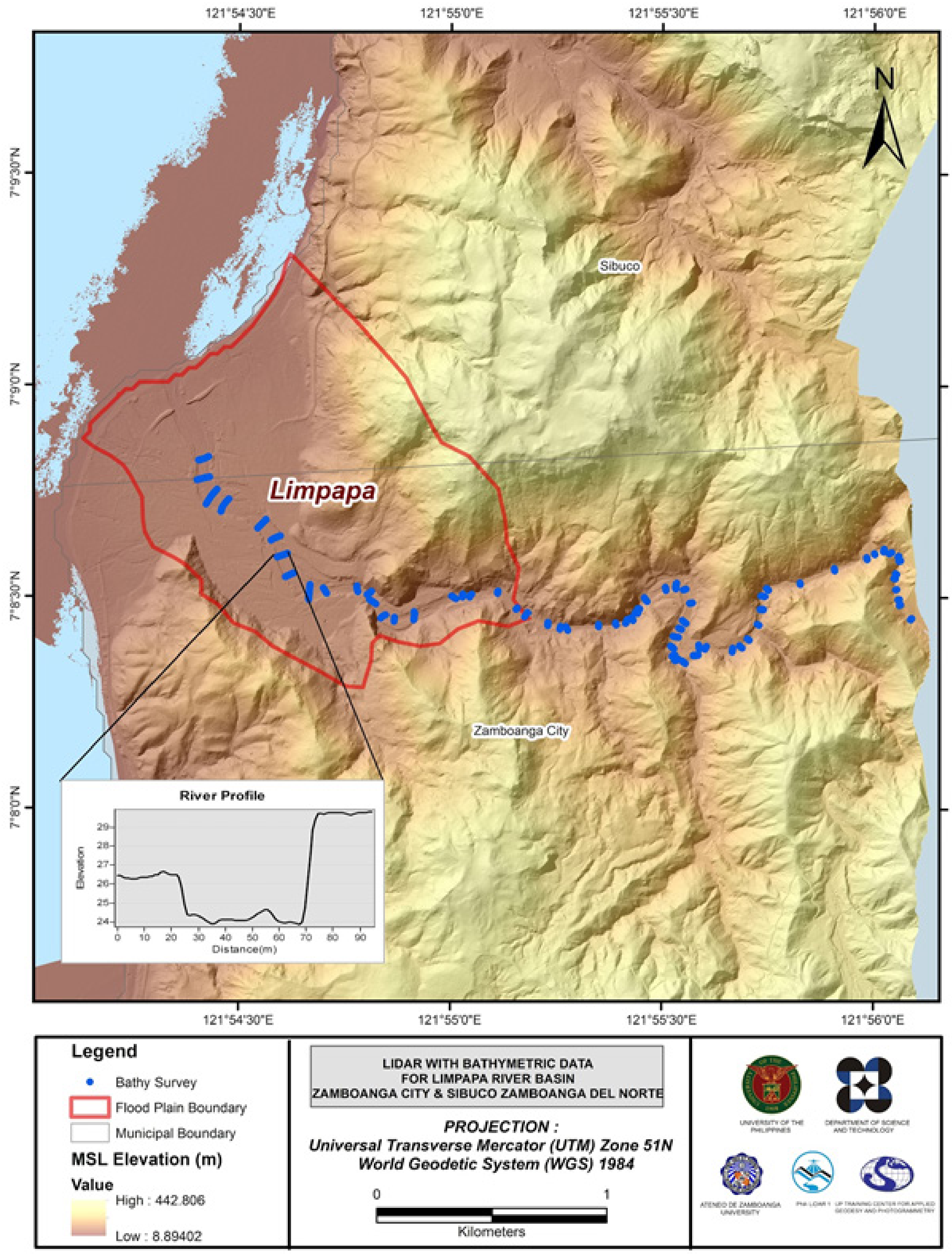

Figure 27. Map of Limpapa Floodplain with bathymetric survey points shown in blue.

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

Limpapa Floodplain, including its 200 m buffer, has a total area of 3.22 sq km. For this area, a total of 1.0 sq km, corresponding to a total of 156 building features, are considered for QC. Figure 28 shows the QC blocks for Limpapa Floodplain.

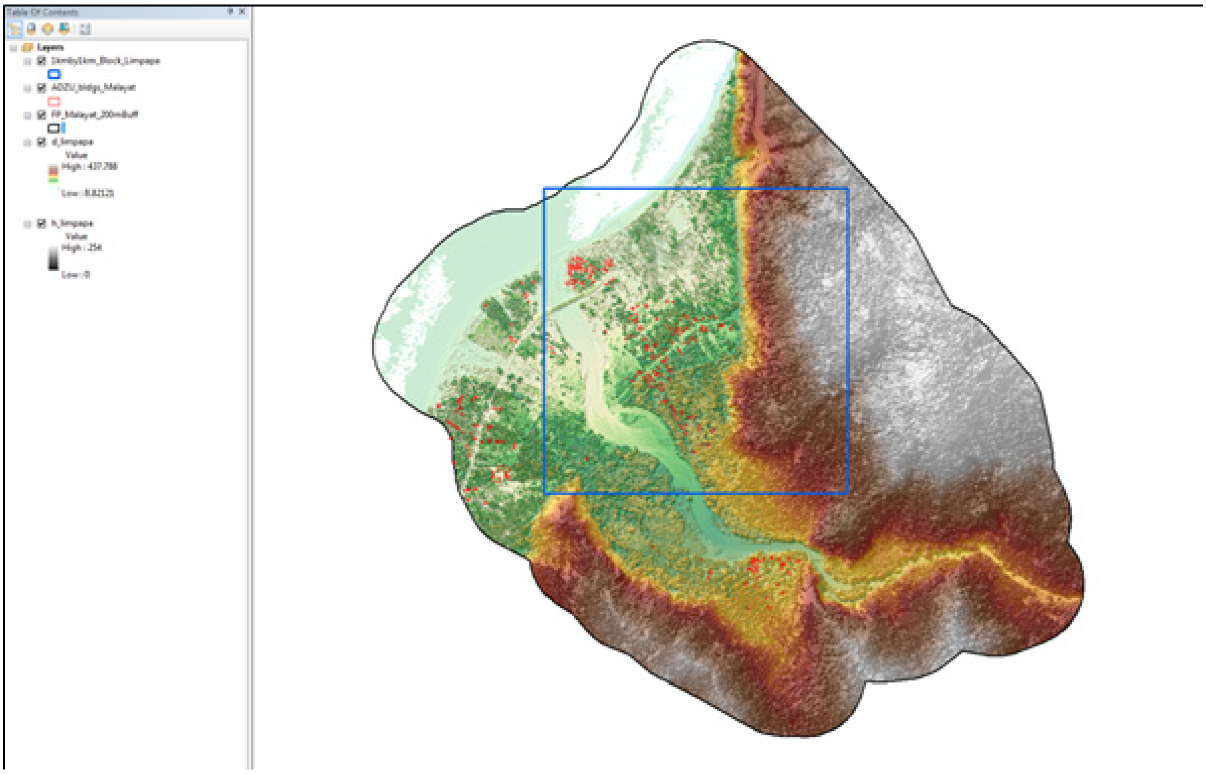

Figure 28. Blocks (in blue) of Limpapa building features that were subjected in QC.

Quality checking of Limpapa building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Limpapa Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Limpapa	100.00	96.15	92.31	PASSED

3.12.2 Height Extraction

Height extraction was done for 459 building features in Limpapa Floodplain. Of these building features, none was filtered out after height extraction, resulting in 459 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.82 m.

3.12.3 Feature Attribution

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

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

Table 22 summarizes the number of building features per type. On the other hand, Table 23 shows the total length of each road type while Table 24 presents the number of water features extracted per type.

Table 22. Building Features Extracted for Limpapa Floodplain.

Facility Type	No. of Features
Residential	416
School	15
Market	14
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	1
Barangay Hall	0
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	2
Religious Institutions	7
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	0
Other Commercial Establishments	0
Total	459

Table 23. Total Length of Extracted Roads for Limpapa Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Limpapa	0.94	2.06	0.00	2.45	0.00	**5.45**

Table 24. Number of Extracted Water Bodies for Limpapa Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Limpapa	4	0	0	0	0	**4**

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 29 shows the Digital Surface Model (DSM) ofLimpapa floodplain overlaid with its ground features.

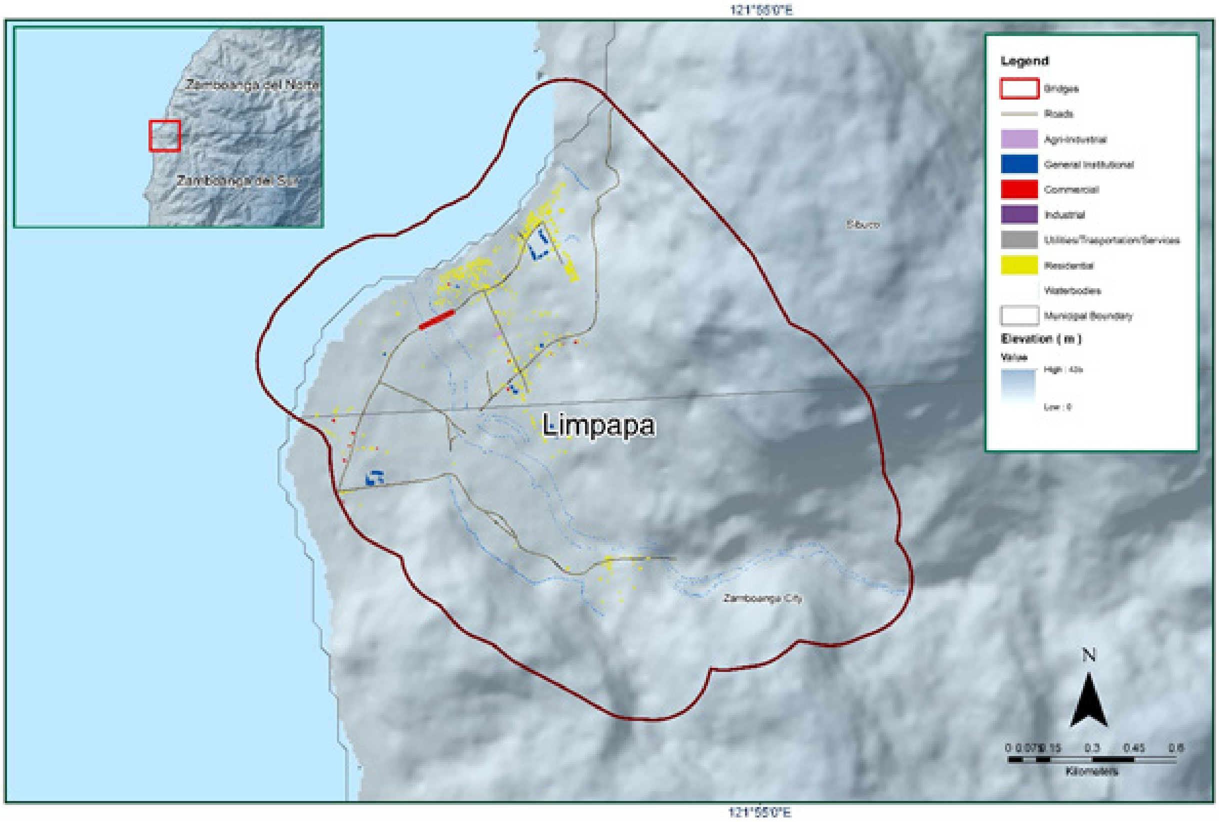

Figure 29. Extracted features for Limpapa Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE LANANG 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, 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 Limpapa River on April 23 to 27, 2016 with the following scope: cross-section, bridge as-built and water level marking in MSL of Limpapa Bridge and manual bathymetric survey from the mouth of the river in Brgy. Limpapa, Sibuco, Zambonga Del Norte to the upstream of the river in Brgy. Limpapa, Zamboaga City, Zamboanga Del Norte Random checking points for the contractor's cross-section and bathymetry data were gathered by DVC on August 21-31, 2016using 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 Limpapa River Basin area. The entire survey extent is illustrated in Figure 30.

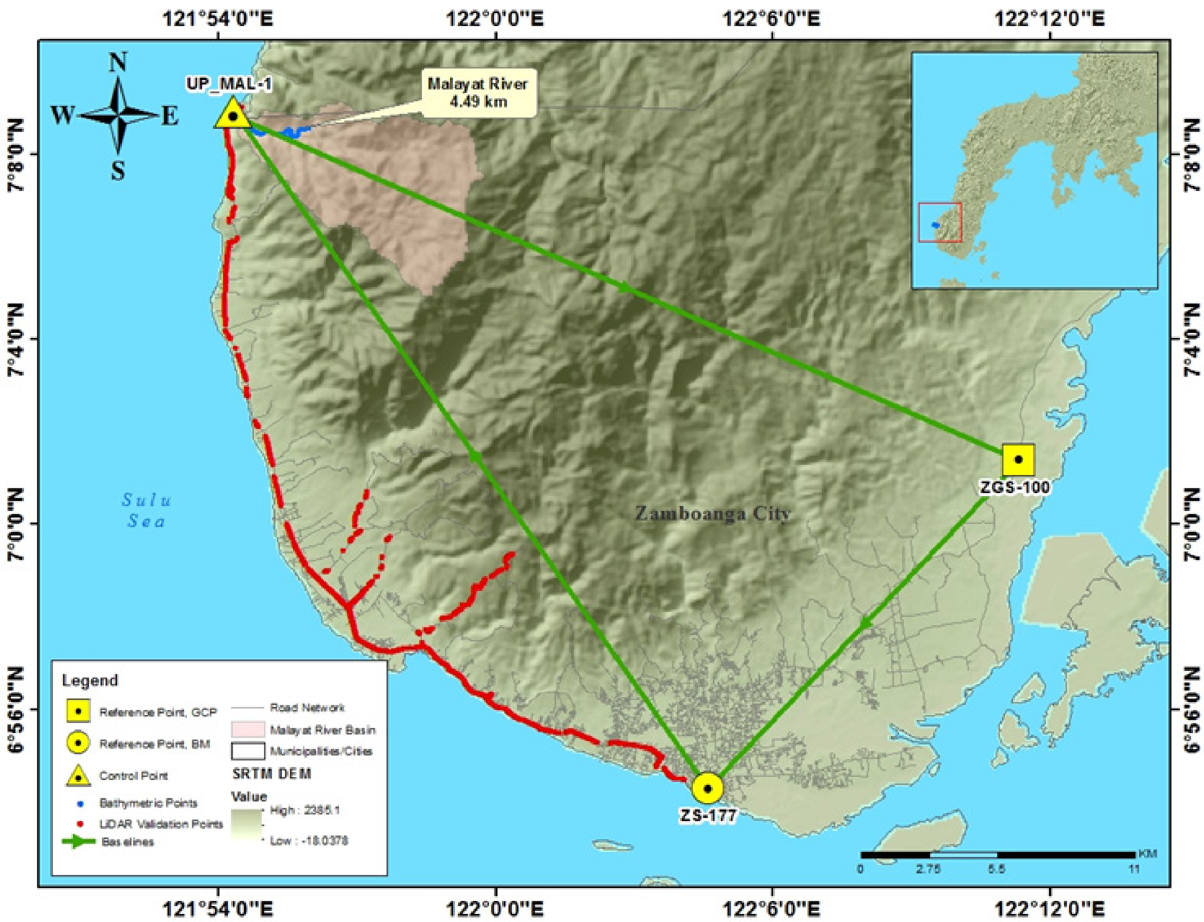

Figure 30. Extent of the bathymetric survey (in blue line) in Limpapa River and the LiDAR data validation suvery (in red)

4.2 Control Survey

The GNSS network used for Limpapa River is composed of one (1) loop established on October 27, 2016 occupying the following reference points: ZGS-100, a second-order GCP, in Brgy. Manicahan, Zamboanga City, Zamboanga del Sur; and ZS-177, a first-order BM, in Brgy. Poblacion, Zamboanga City, Zamboanga del Sur.

One (1) control point established in the area by ABSD was also occupied: UP_MAL-1 at side of Limpapa Bridge foot walk in Brgy. Limpapa, Sibuco, Province of Zamboanga Del Norte.

Figure 31.

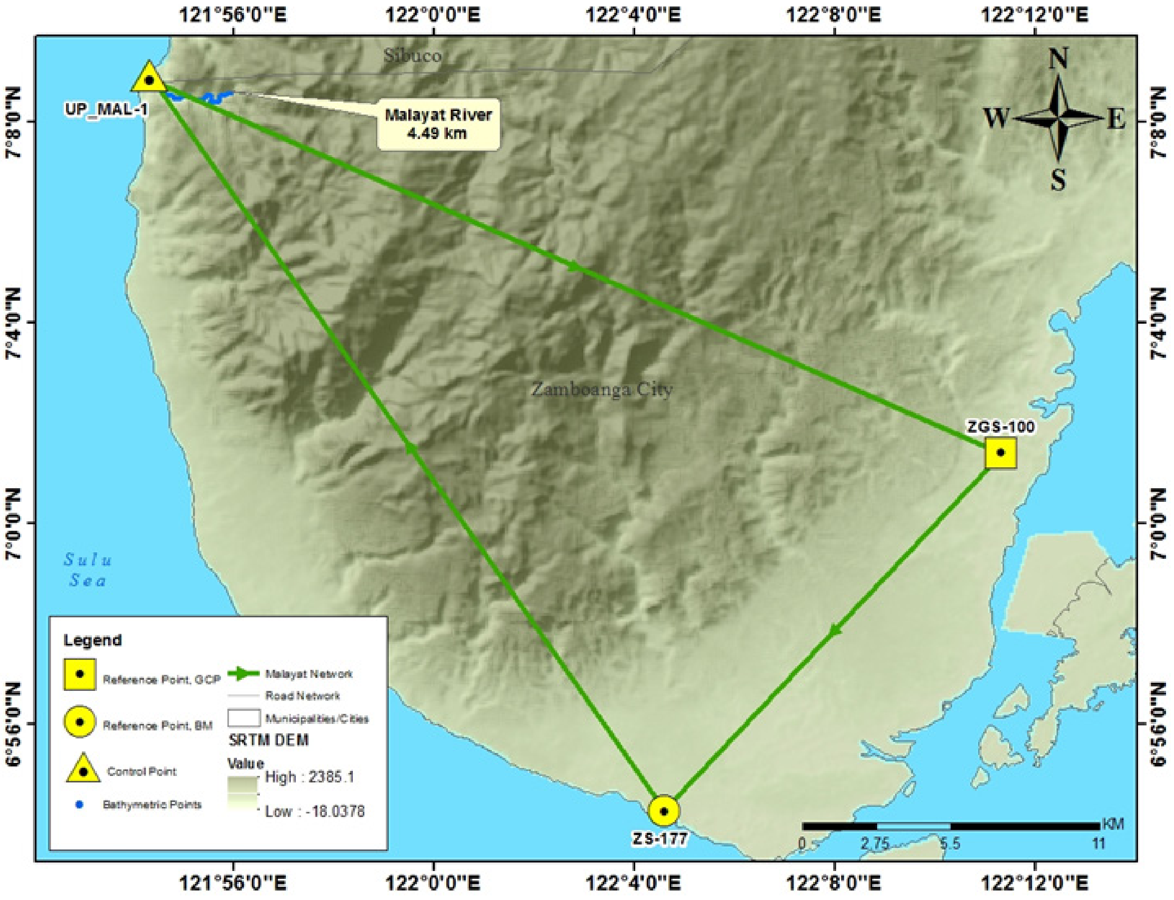

Figure 32.Limpapa River Basin Control Survey Extent.

Table 25. List of reference and control points used during the survey in Limpapa River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84 N)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
ZS-117	2nd order, GCP	6°54'16.64510" N	117°55'26.91800"E	70.847	3.155	2007
ZGS-100	1st order, BM	7°01'23.30183" N	118°4'53.42391"E	75.201	7.344	2009
UP_MAL-1	Established	7°08'56.29812" N	121°54'20.43320" E	75.879	9.779	12-12-15

The GNSS set-ups on recovered reference points and established control points in Limpapa River are shown from Figure 32 to Figure 34.

Figure 33. GNSS receiver set up, Trimble® SPS 985, at ZGS-100, located at Brgy. Manicahan, Zamboanga City, Province of Zamboanga del Sur.

Figure 34.GNSS base set up, Trimble® SPS 882, at ZS-177, located in Brgy. Poblacion, Zamboanga City, Province of Zamboanga del Sur.

Figure 35. GNSS receiver set up, Trimble® SPS 985, at UP_mal-1, located at the approach of Limpapa Bridge foot walk in Brgy. Limpapa, Sibuco, 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/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Limpapa River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline Processing Report for Limpapa River Static Survey.

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP_MAL-1 --- ZGS-100	10-27-2016	Fixed	0.003	0.022	113°59'45"	34195.307	-0.685
ZS-177 --- UP_MAL-1	10-27-2016	Fixed	0.004	0.004	325°05'24"	32956.432	5.033
ZS-177 --- ZGS-100	10-27-2016	Fixed	0.004	0.022	43°21'01"	18026.234	4.355

As shown Table 26 a total of three (3) baselines were processed with coordinate and ellipsoidal height values of ZS-177 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:

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

Where:

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

for each control point. See the Network Adjustment Report shown from Table 27 to Table 29 for the complete details. Refer to Annex A for the computation for the accuracy of ABSD.
The three (3) control points, ZGS-100, ZS-177, and UP_MAL-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of ZGS-100 and ZS-177 were held fixed during the processing of the control points as presented in Table 27. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 27. Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZGS-100	Global	Fixed	Fixed		
ZS-177	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 28. All fixed control points have no values for grid errors and elevation error.

Table 28. Adjusted Grid Coordinated.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
ZS-117	397964.993	?	763304.231	?	3.155	?	LLh
ZGS-100	410361.314	?	776384.475	?	7.344	0.058	LL
UP_MAL-1	379162.349	0.013	790360.848	0.016	9.779	0.059	

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

a. **ZS-117**
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. **ZGS-100**
horizontal accuracy = Fixed
vertical accuracy = Fixed

c. **UP_IRA-2**
horizontal accuracy = $\sqrt{((1.3)^2 + (1.6)^2}$
= $\sqrt{(1.69 + 2.56)}$
= 2.06< 20 cm
vertical accuracy = 3.5 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the three (3) occupied control points are within the required precision.

Table 29. Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
ZS-117	6°54'16.64510" N	117° 55' 26.91800"E	70.847	?	LLh
ZGS-100	7°01'23.30183" N	118° 4' 53.42391"E	75.201	0.058	LL
UP_MAL-1	7°08'56.29812" N	121°54'20.43320" E	75.879	0.059	

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

Table 30. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZS-117	2nd order, GCP	6° 54' 16.64510" N	117° 55' 26.91800"E	70.847	763304.231	397964.993	3.155
ZGS-100	1st order, BM	7° 01' 23.30183" N	118° 4' 53.42391"E	75.201	776384.475	410361.314	7.344
UP_MAL-1	Established	7° 08' 56.29812" N	121° 54' 20.43320" E	75.879	790360.848	379162.349	9.779

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

Cross-section and as-built surveys were conducted on April 24, 2016 at the upstream side of Limpapa Bridge in Brgy. Limpapa, Municipality of Sibuco as shown in Figure 35. A Horizon® Total Station was utilized for this survey as shown in Figure 36.

Figure 36. Limpapa Bridge facing upstream.

Figure 37. As-built survey of Limpapa Bridge

The cross-sectional line of Limpapa Bridge is about 320.343 m with ninety-five (95)cross-sectional points using the control pointsUP_MAL-1 and UP_MAL-2as the GNSS base stations. The cross-section diagram and the bridge data form are shown in Figure 38 and Figure 39.

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

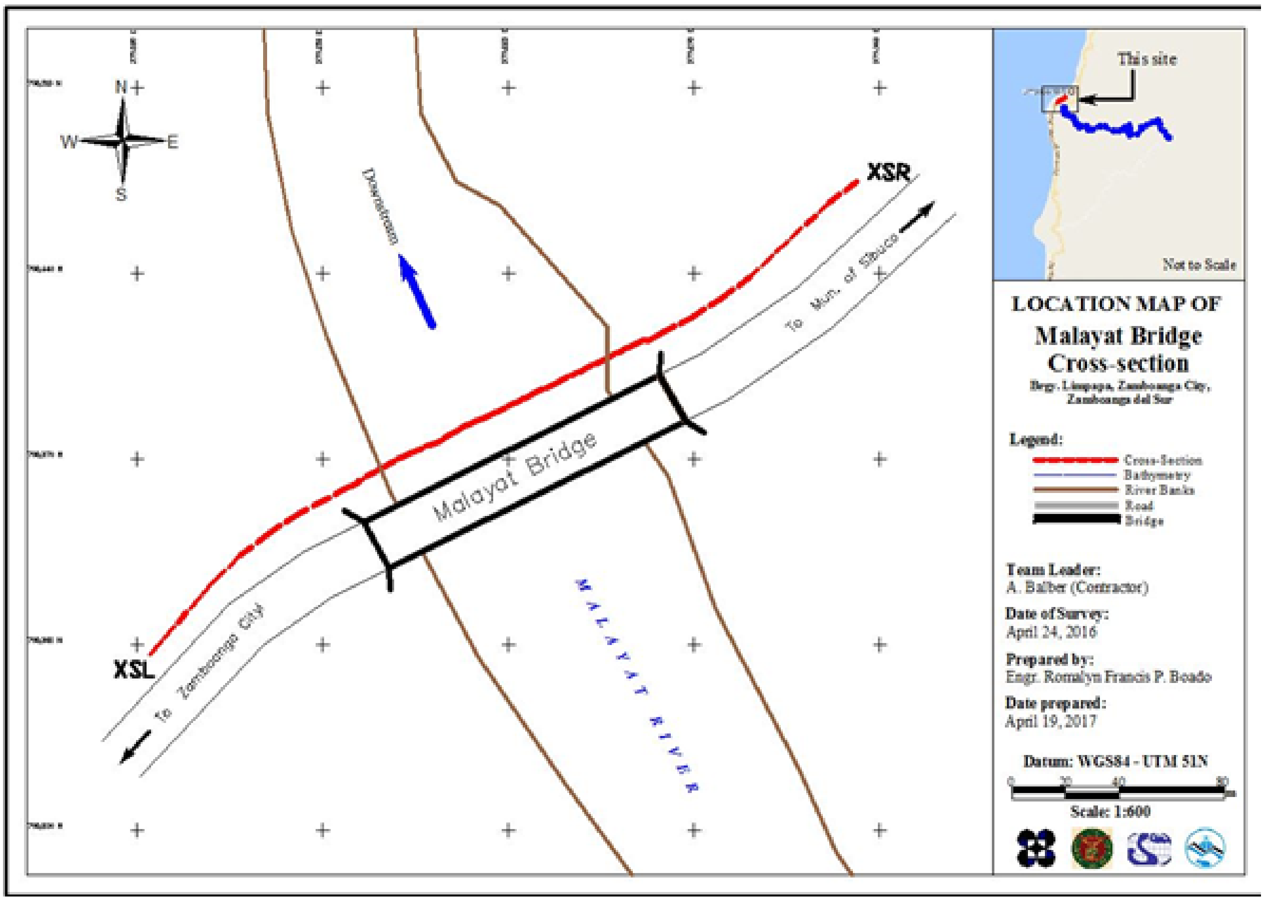

Figure 38.Location map of Limpapa Bridge cross section survey .

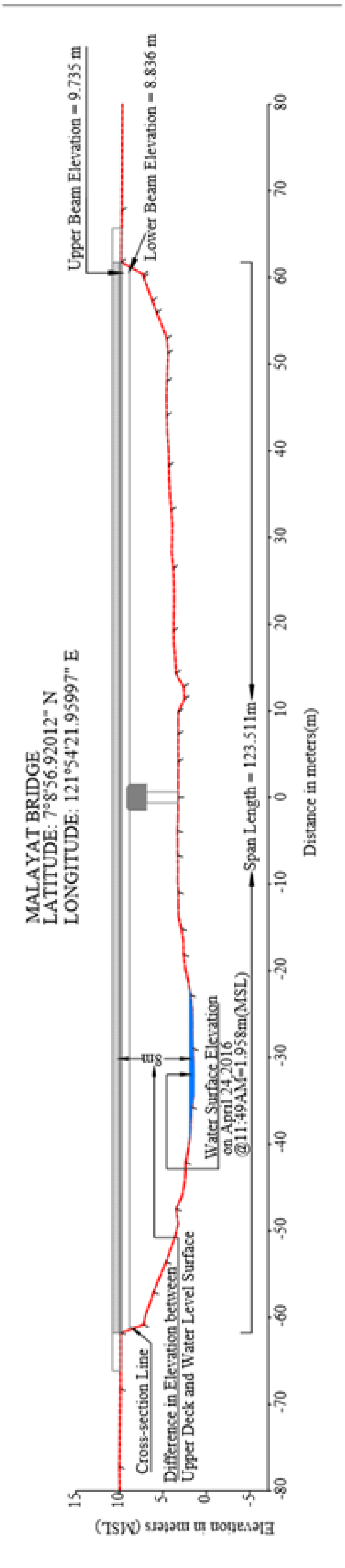

Figure 39. Limpapa Bridge Cross-section Diagram.

Figure 40. Limpapa Bridge Data Sheet.

Water surface elevation of Limpapa River was determined by a Horizon® Total Station on April 24, 2016 at 11:49 A.M at Limpapa Bridge area with a value of 1.958 m in MSL as shown in Figure 38. This was translated into marking on the bridge's pier as shown in Figure 40. The marking served as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Limpapa River, the Ateneo de Zamboanga University.

Figure 41. Water-level markings on Limpapa Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 13, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 41. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.90 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 ZGS-99 occupied as the GNSS base station in the conduct of the survey.

Figure 42. Validation points acquisition survey set-up for Limpapa River.

The survey started from Brgy. Sto. Nino, City of Zamboanga, Zamboanga del Sur going south west along national high way covering six (6) barangays in the City of Zamboanga, Zamboanga del Sur, and endinginBrgy. Limpapa, Municipality of Sibuco, Zamboanga del Norte. The survey gathered a total of 6,266 points with approximate length of 53 km using ZGS-99 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 42.

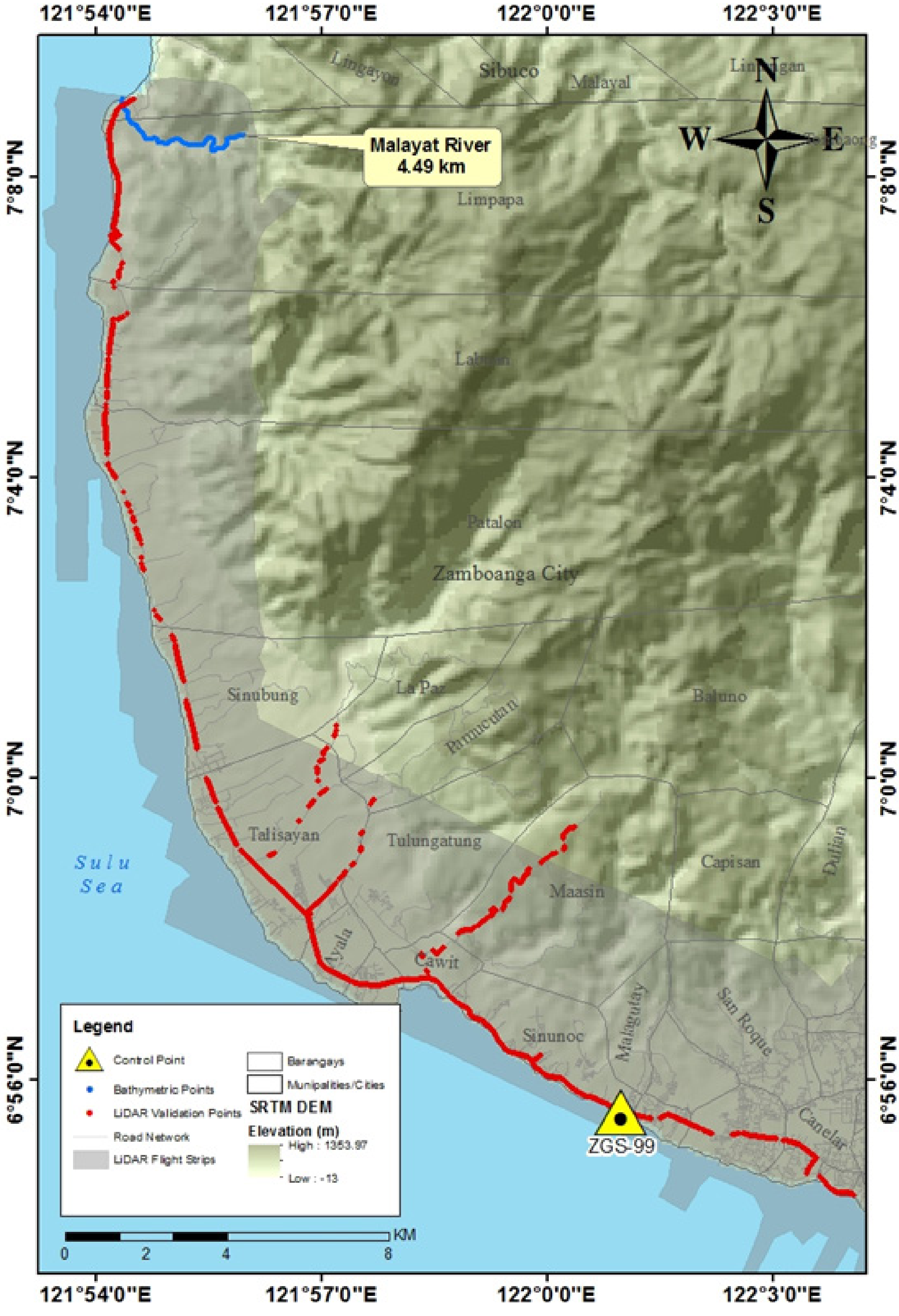

Figure 43. Validation points acquisition covering the Limpapa River Basin Area.

4.7 Bathymetric Survey

Bathymetric survey was conducted on February 8, 2017 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as shown in Figure 48. The survey started in the upstream part of the river in Brgy. Nainday, Municipality of Placer with coordinates 11°56'18.13511"N, 123°50'22.12322"E, and ended at the mouth of the river with coordinates 11°54'55.79921"N, 123°48'55.99941"E in the same Barangay. The control UP-NAU3 was used as GNSS base station all throughout the bathymetric survey.

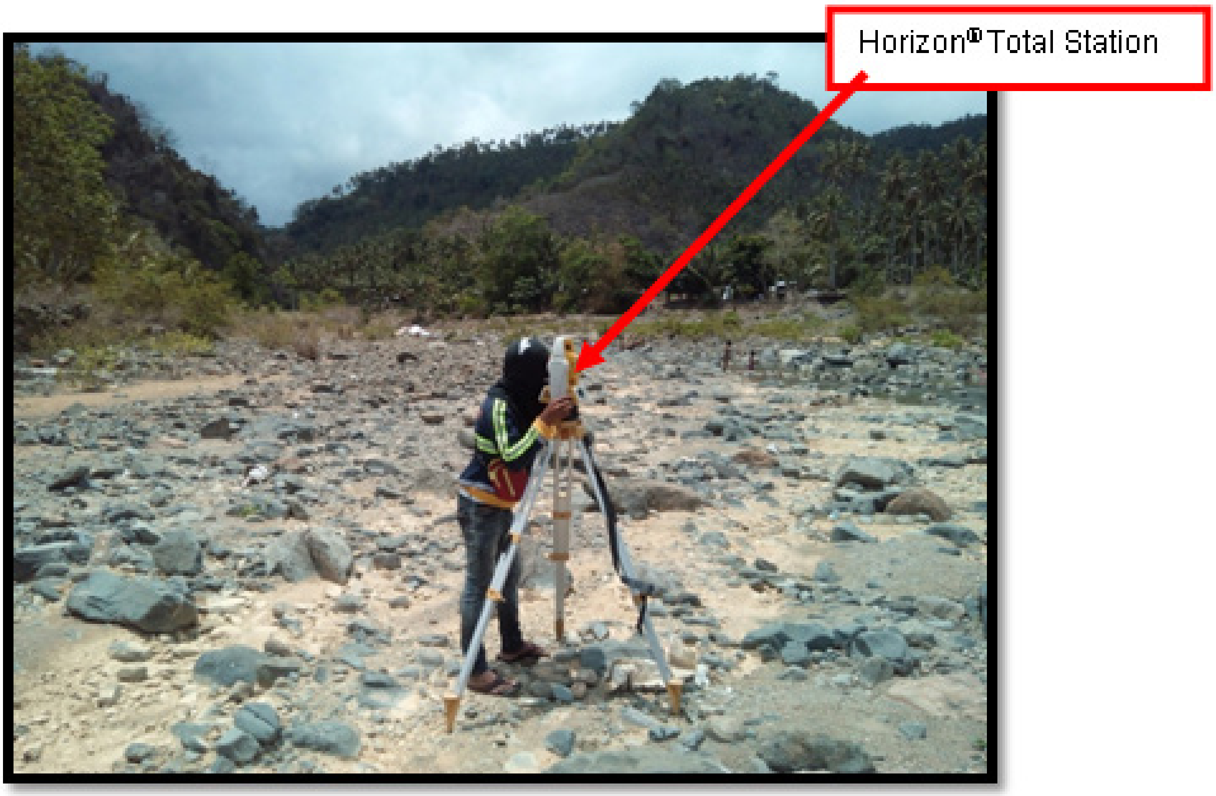

Figure 44. Bathymetric survey of ABSD at Limpapa River using Hi-Target™ Echo Sounder (upstream).

The bathymetric survey for Limpapa River gathered a total of 1,074 points covering 4.820 km km of the river traversing Brgy. Limpapa in the Municipality of Sibuco to Brgy. Limpapa in the City of Zamboanga. A CAD drawing was also produced to illustrate the riverbed profile of Limpapa River. As shown in Figure 45,elevation drop of 148.22 m of the river bed was recorded. The highest and lowest elevation has a 5-m difference. The highest elevation observed was 153.79m (EGM 2008) located in Brgy. Limpapa, Zamboanga City while the lowest was 5.56 m (EGM 2008) located in Brgy. Limpapa. Municipality of Sibulo.

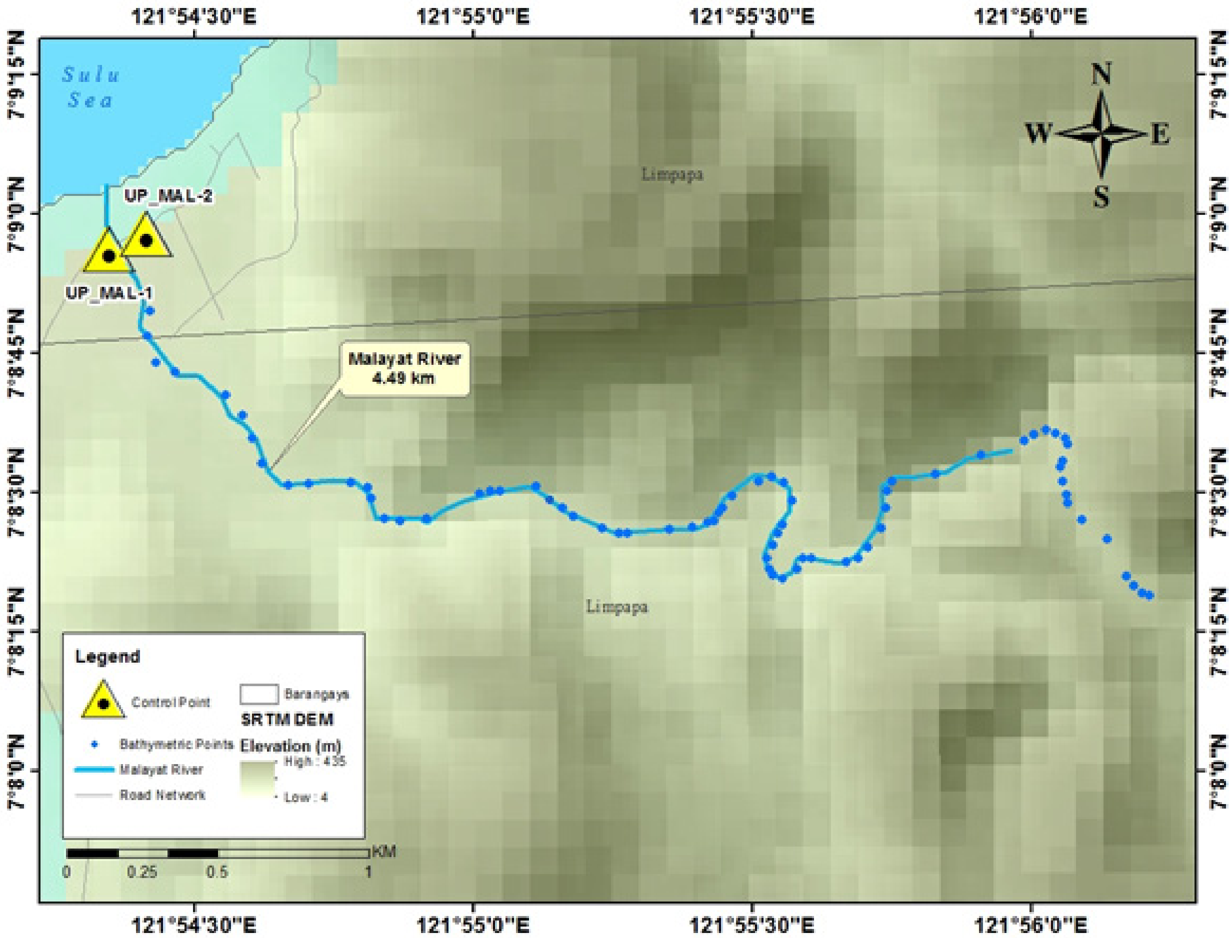

Figure 45. Bathymetric survey of Limpapa River.

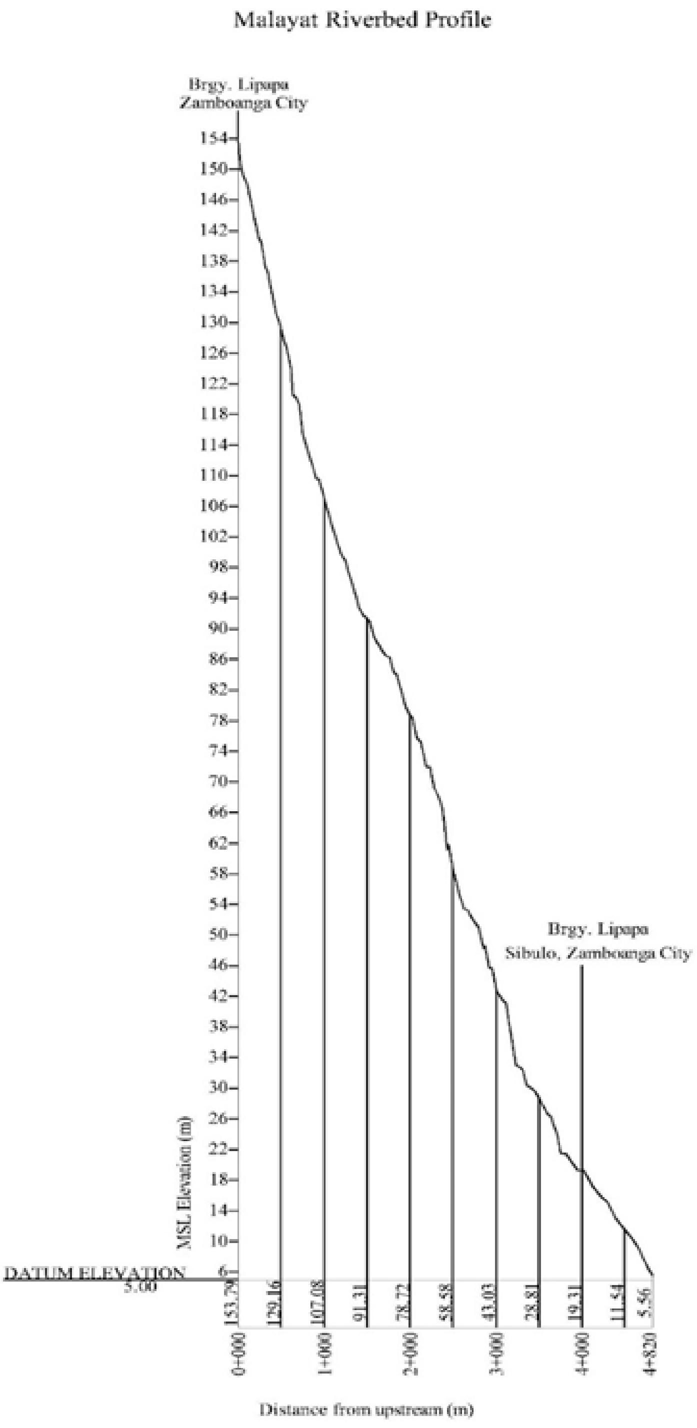

Figure 46. Limpapa Riverbed Profile.

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 river basin was monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from a manually read Rain Gauge at Brgy. Limpapa, Zamboanga City(7° 8' 29.07" N, 122° 2' 32.76" E). (Figure 46). The precipitation data collection started from June20, 2016 at 4:00 PMtoJune22, 2016 at 6:00AM with 10 minutes recording interval.

The total precipitation for this event in Brgy. Limpapa was 107.6mm. It has a peak rainfall of 7.8 mm. on June20, 2016 at 9:00PM. The lag time between the peak rainfall and discharge is 5 hours and 50 minutes.

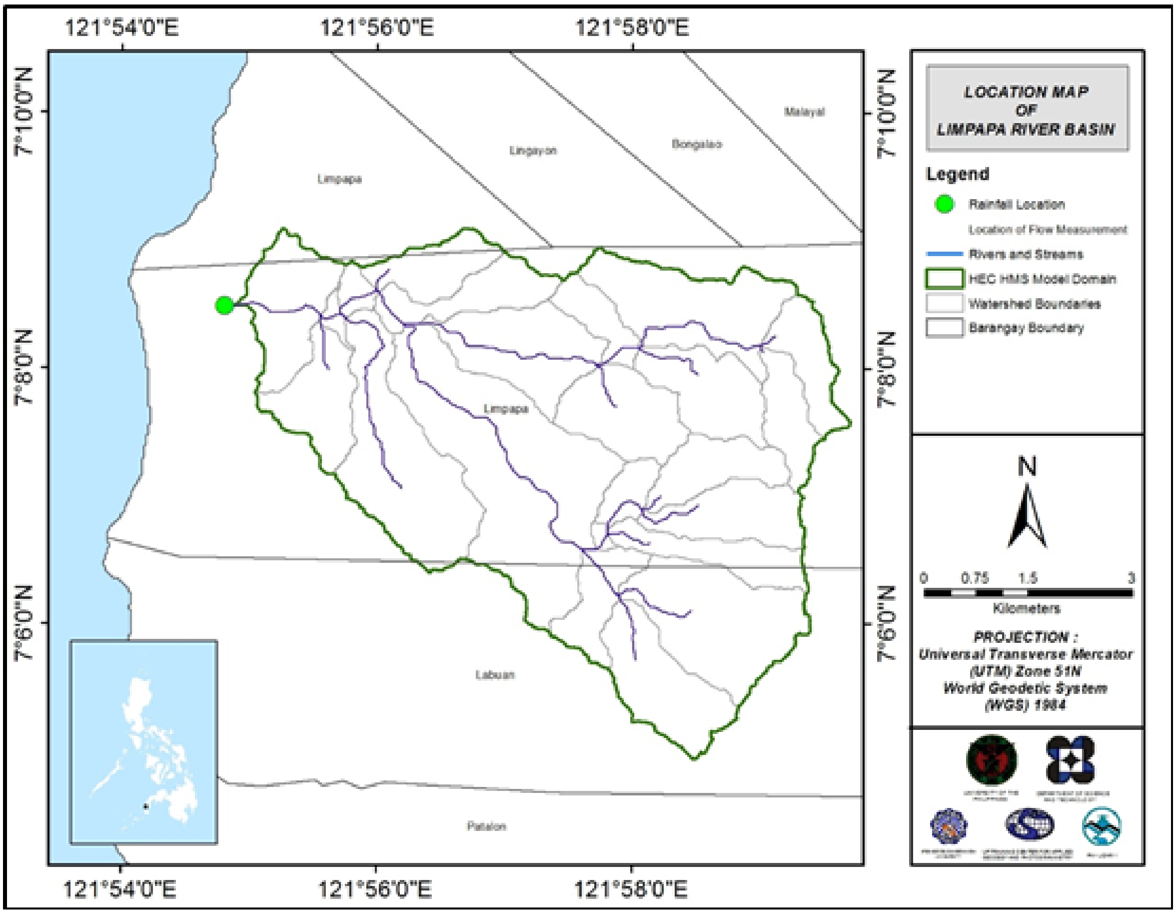

Figure 47. The location map of Limpapa HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at a Hanging BrdigeinBrgy. Limpapa, Zamboanga City(7° 8’ 39.31” N, 121° 54’ 49.06” E). It gives the relationship between the observed water levels at Limpapa Bridge and outflow of the watershed at this location.

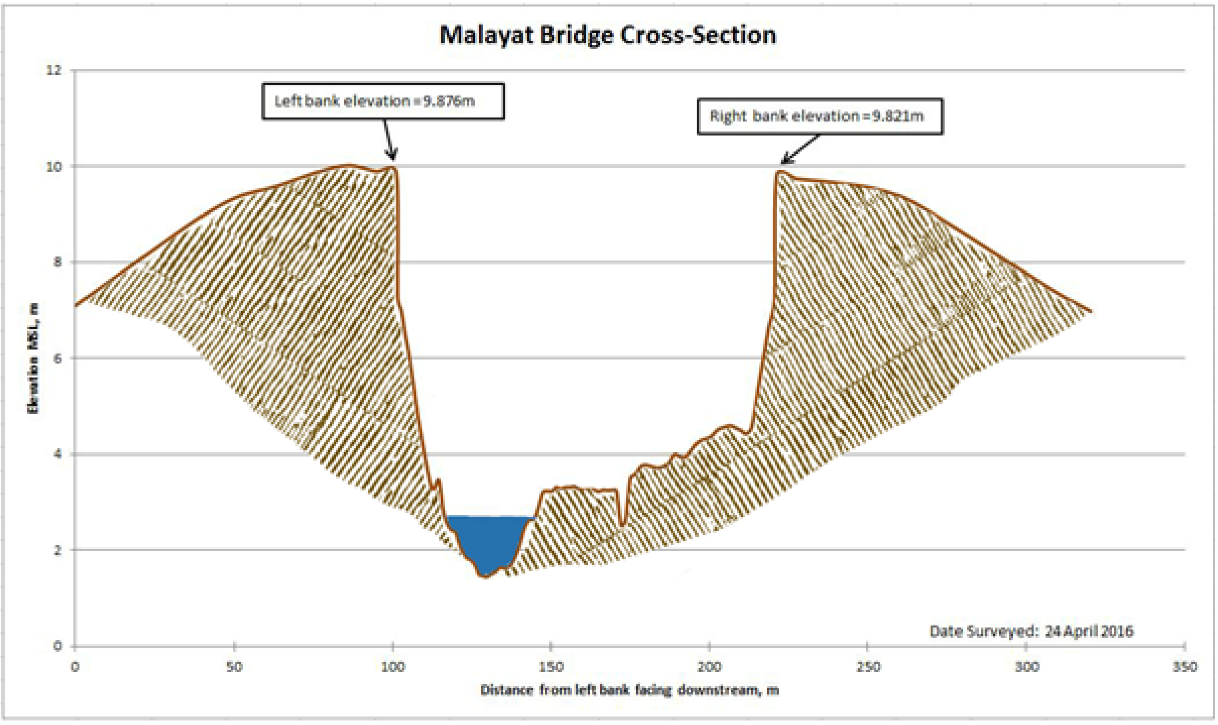

Figure 48. Cross-Section Plot of Limpapa Bridge.

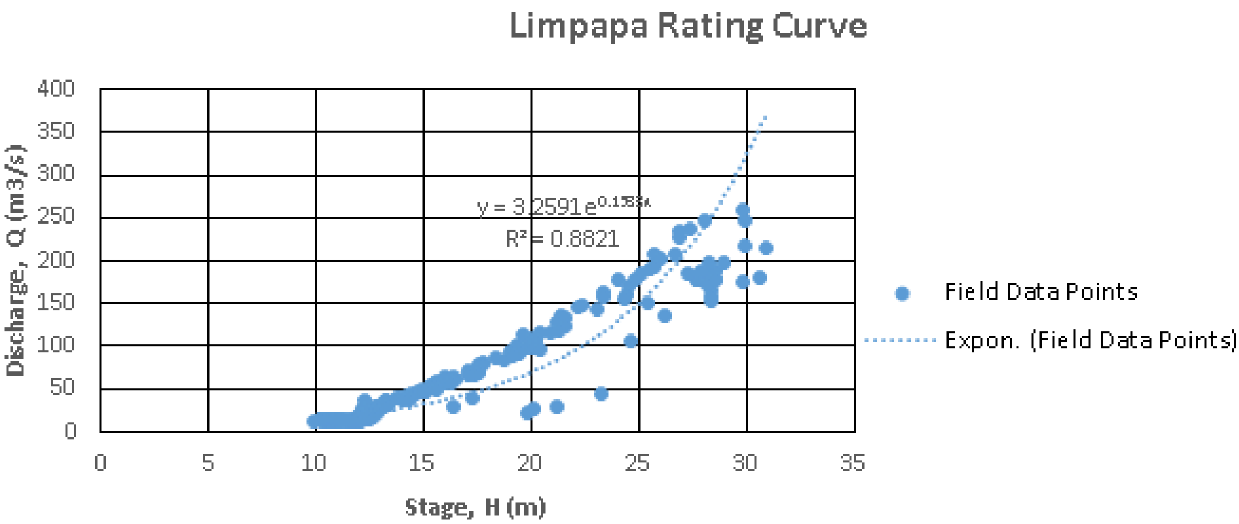

Figure 49. Rating Curve at Spillway, Brgy. Doña Josefa, Ipil, Zamboanga Sibugay.

This rating curve equation was used to compute the river outflow at LimpapaBridgefor the calibration of the HEC-HMS model shown in Figure 49. Peak discharge is 258.8cubic meters per second at 2:50 AM, June21, 2016.

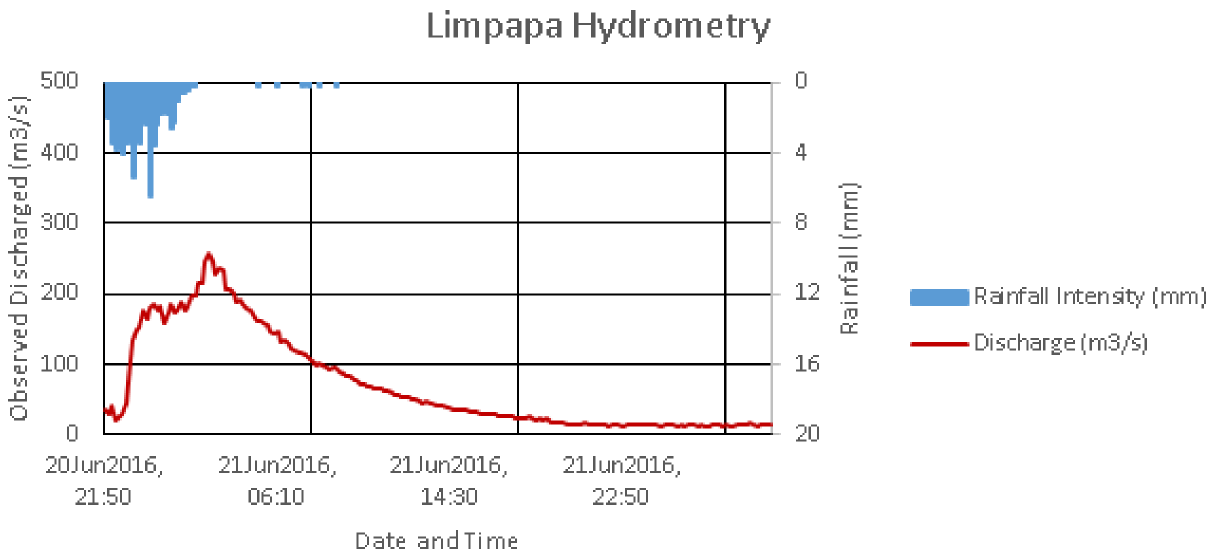

Figure 50. Rainfall and outflow data at Limpapa Bridge used for modeling.

5.2 RIDF Station

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

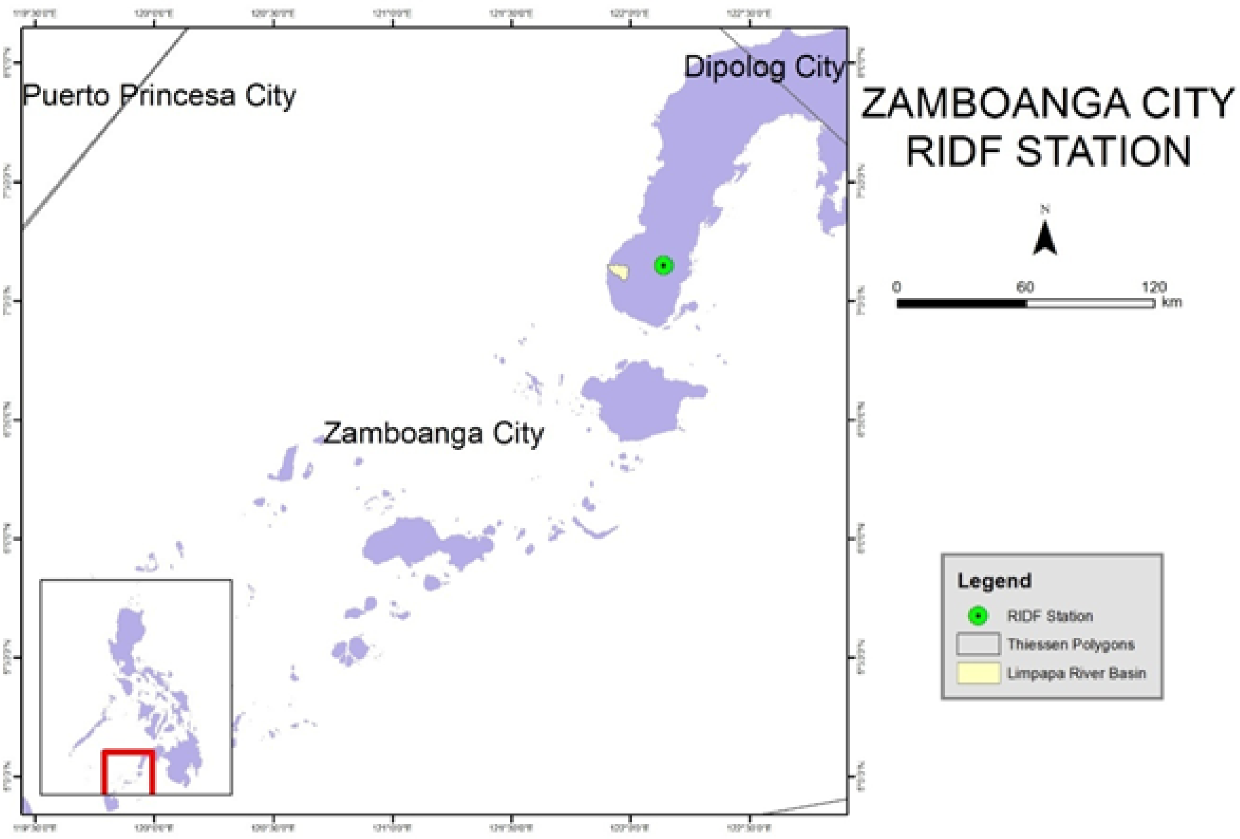

Figure 51.Zamboanga City RIDF location relative to Limpapa River Basin.

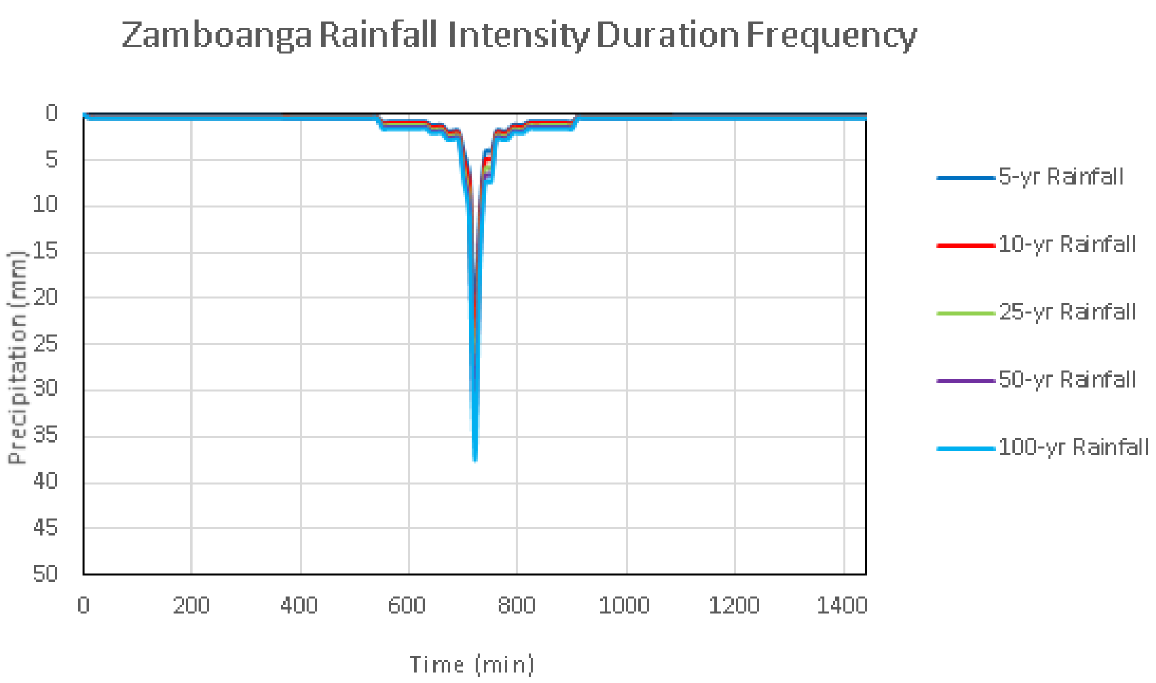

Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was 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 Limpapa River Basin are shown in Figure 52 and Figure 53, respectively.

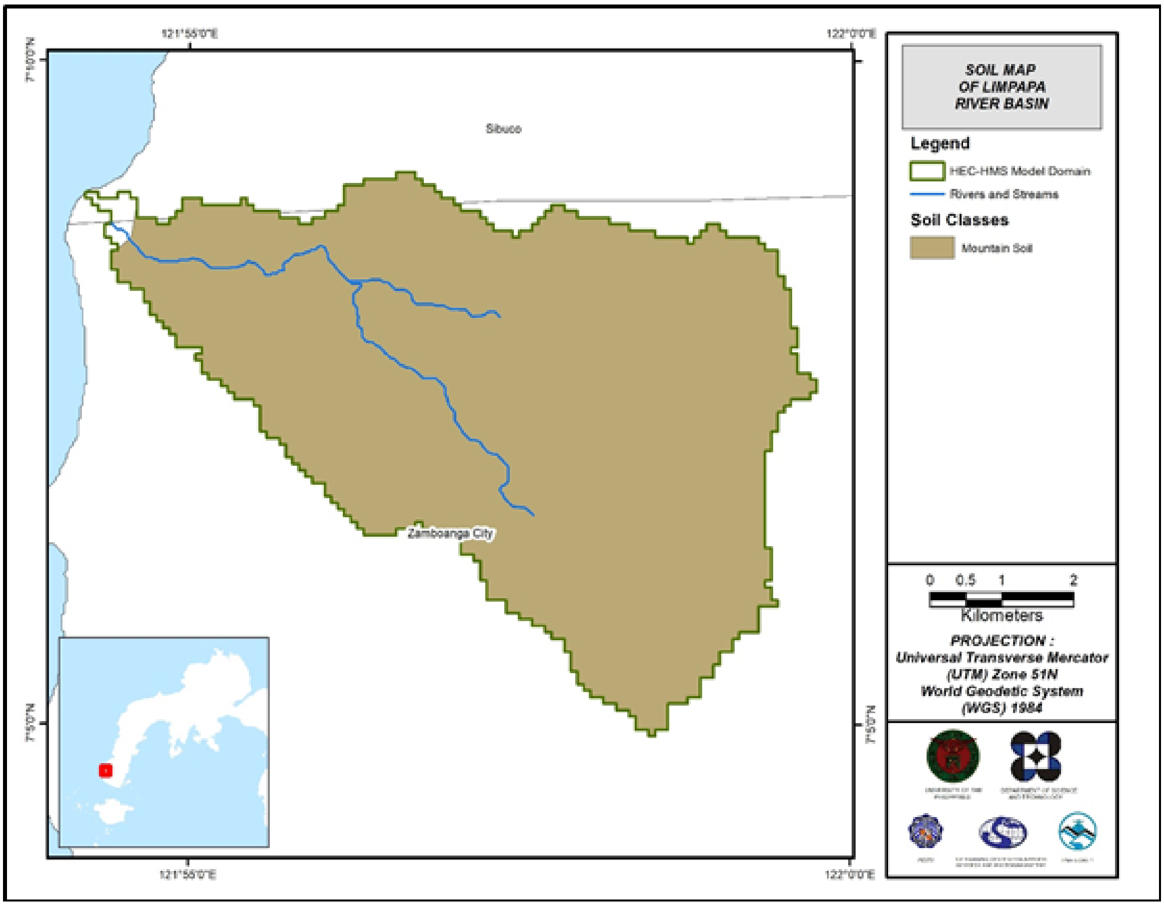

Figure.53 Soil Map of Limpapa River Basin

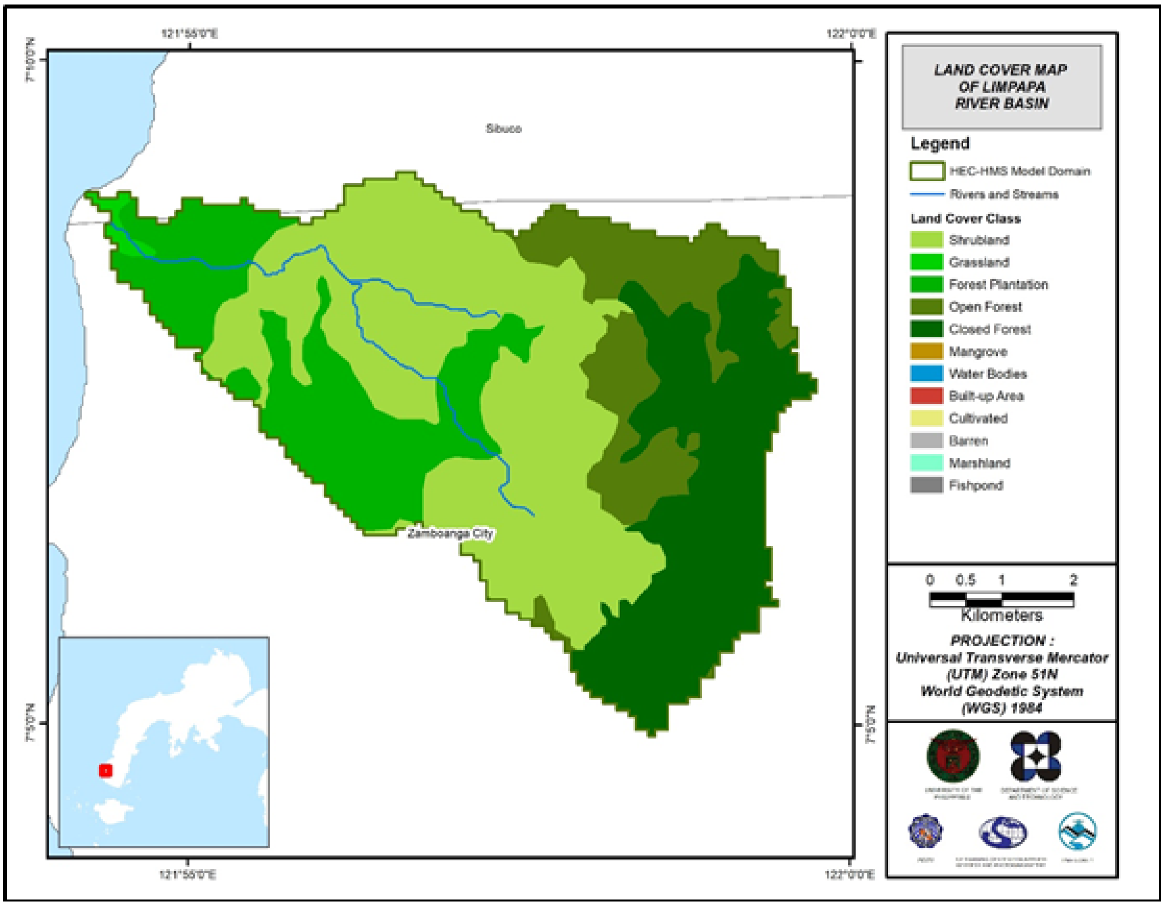

Figure 54. Land Cover Map of Limpapa River Basin.

For Limpapa, the soil classes identified was undifferentiated mountain soil. The land cover types identified were open and closed canopy forests, grassland, brushland and tree plantations.

Figure 55. [insert Slope Map]

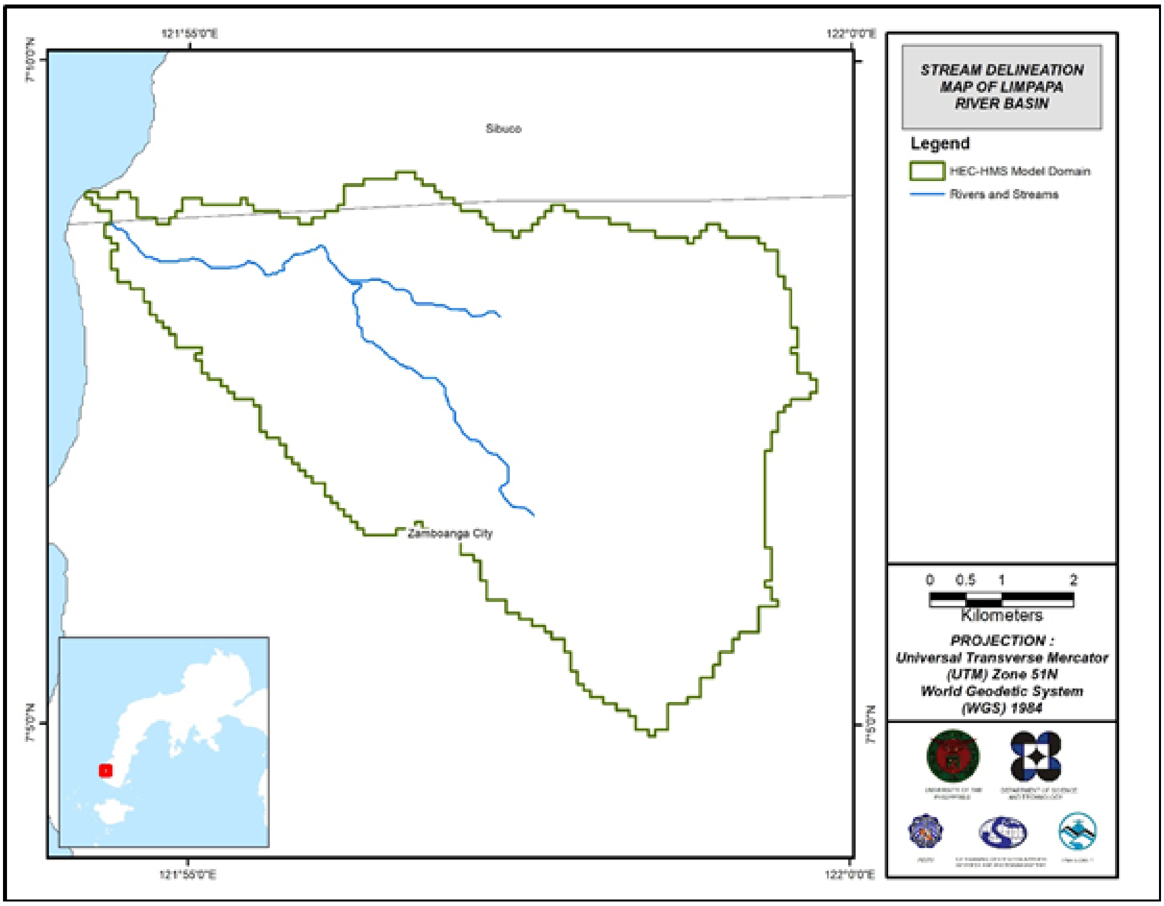

Figure 56. Stream delineation map of Limpapa river basin.

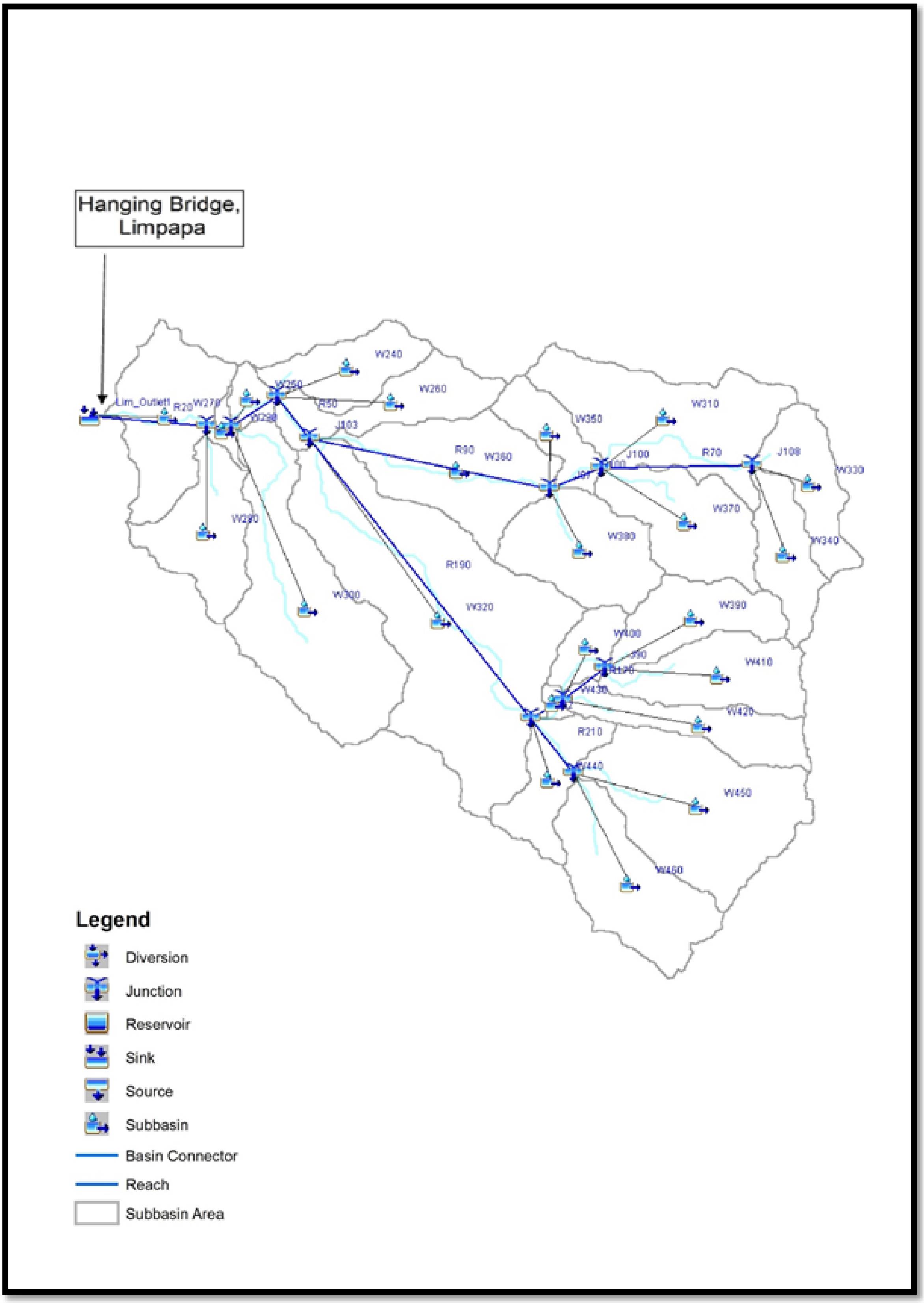

Figure 57. The Limpapa river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

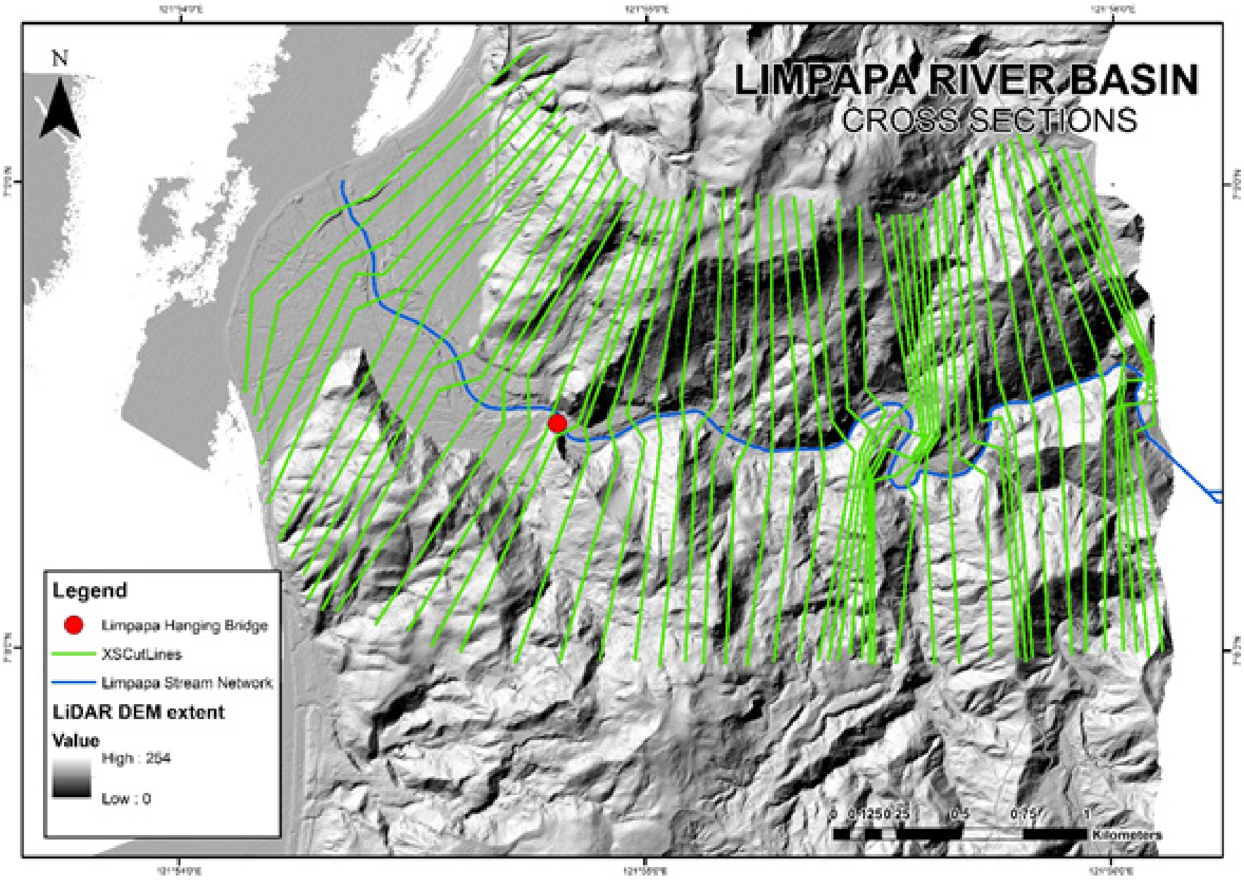

Figure 58. River cross-section of Limpapa River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

The automated modeling 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 was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

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

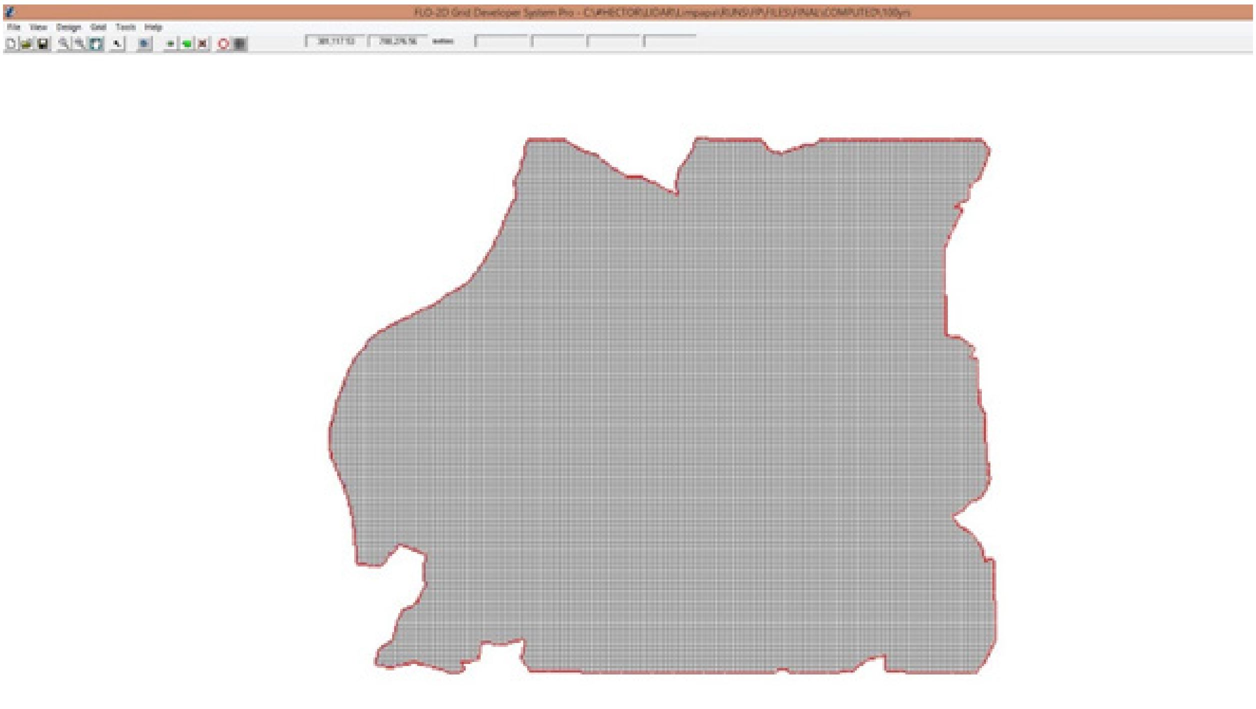

Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro.

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 4.05176 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) was set at 0 m2/s.

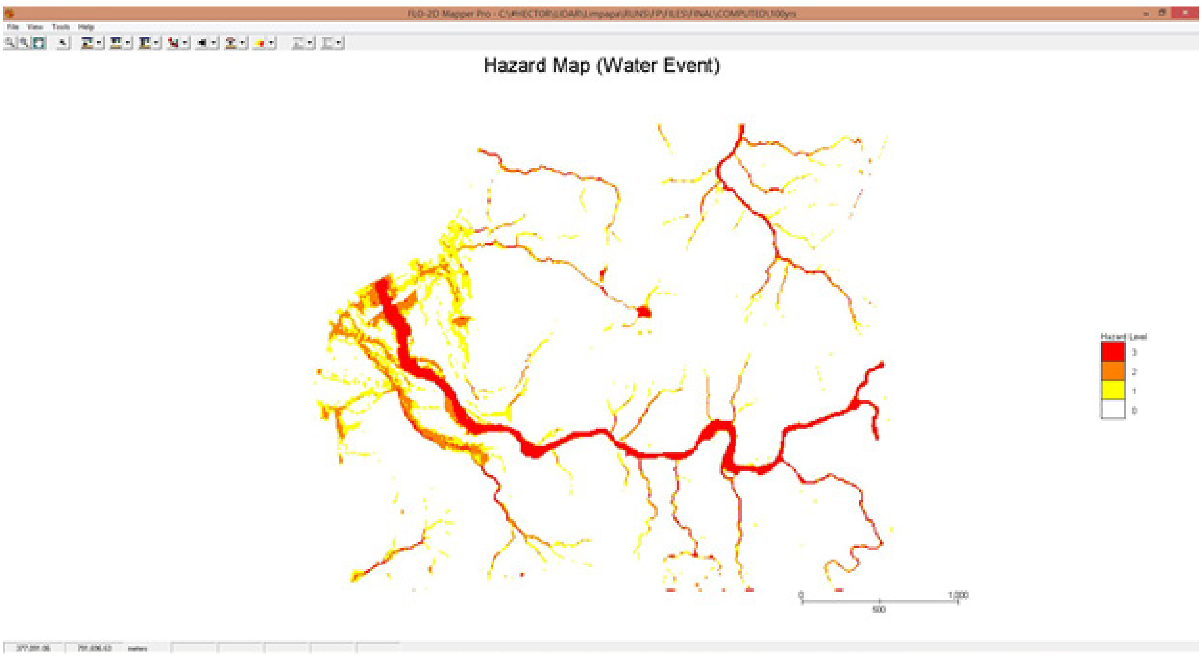

Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper.

The creation of a flood hazard map from the model also automatically 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 9275500.00 m2.

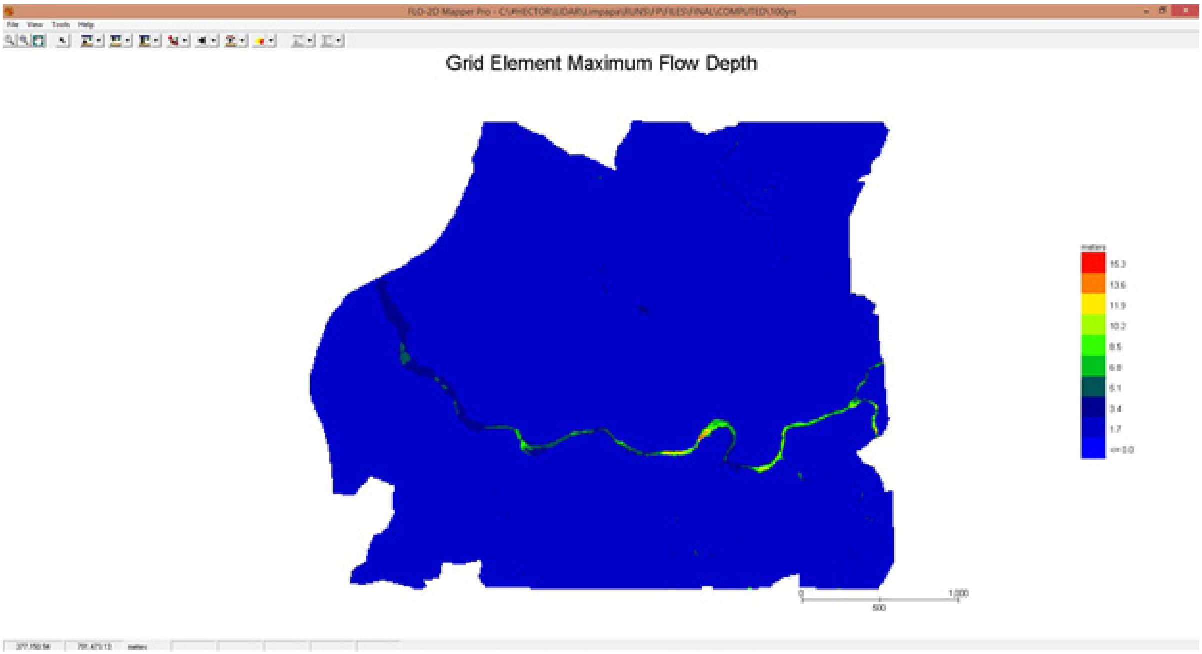

Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper.

There is a total of 6123691.72 m3 of water entering the model. Of this amount, 1803023.89 m3 is due to rainfall while 4320667.83 m3 is inflow from other areas outside the model. 424498.12 m3 of this water is lost to infiltration and interception, while 329601.79 m3 is stored by the flood plain. The rest, amounting up to 5369591.91 m3,is outflow.

Discharge data using Dr. Horritts's recommended hydrologic method

The river discharge values for the nine rivers entering the floodplain are shown in Figure 61 to Figure 62 and the peak values are summarized in Table 32 to Table 33.

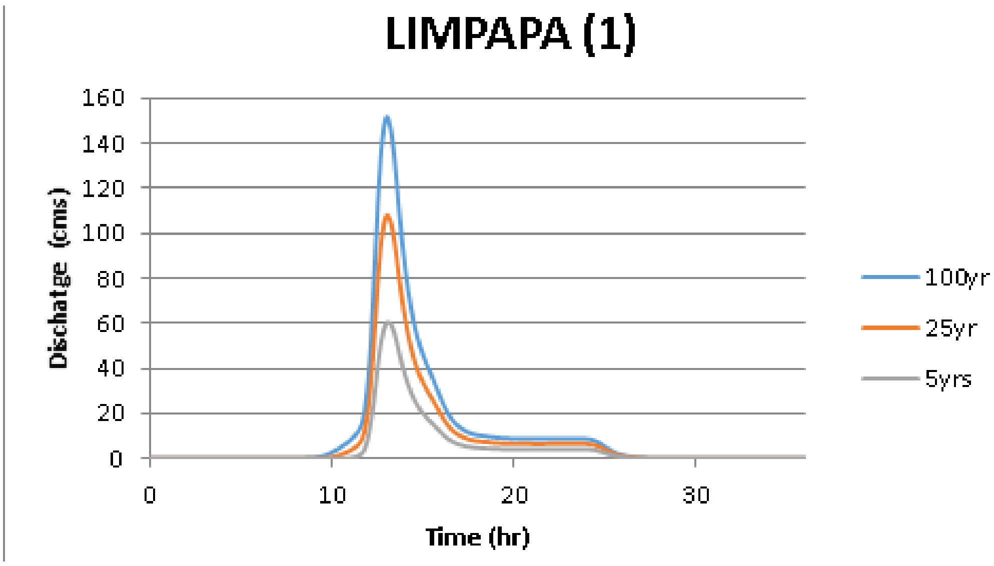

Figure 62. Limpapa river (1) generated discharge using 5-, 25-, and 100-year Zamboanga City rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

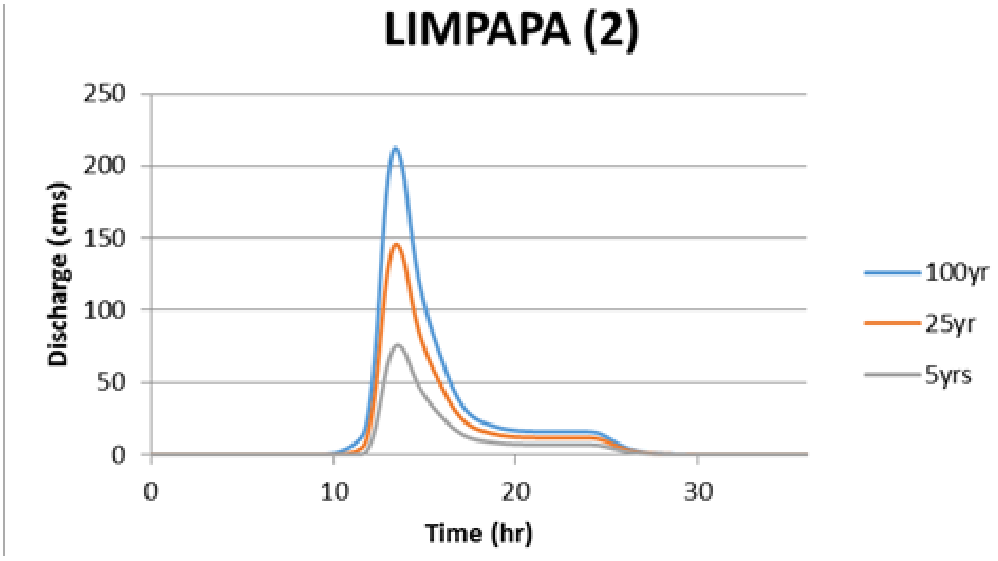

Figure 63. Limpapa river (2) generated discharge using 5-, 25-, and 100-year Zamboanga City rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

Table 32. Summary of Limpapa river (1) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	151.6	13 hours
25-Year	107.9	13 hours
5-Year	60.3	13 hours

Table 33. Summary of Limpapa river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	211.6	13 hours, 20 minutes
25-Year	145.6	13 hours, 30 minutes
5-Year	75.7	13 hours, 30 minutes

Table 34. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Limpapa (1)	53.064	67.267	80.958	PASS	PASS
Limpapa (2)	66.616	59.553	132.715	PASS	PASS

Two from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The passing values are based on theory but were supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.6 Results of HMS Calibration

After calibrating the Limpapa HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

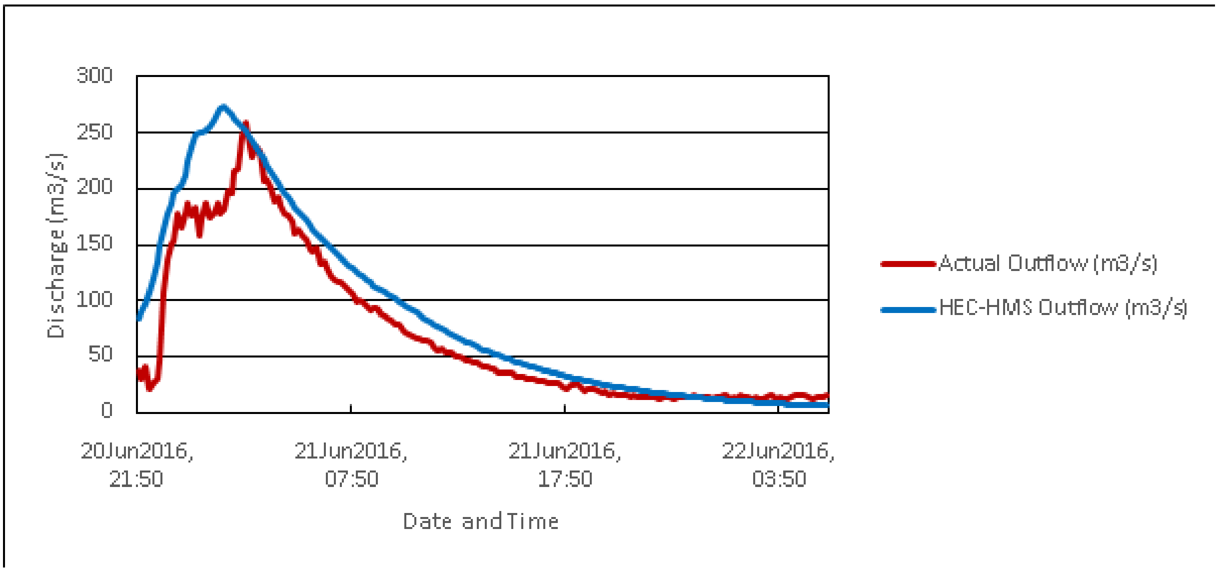

Figure 64. Outflow Hydrograph of Limpapa produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 2 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 35. Range of Calibrated Values for Limpapa.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.0026 – 0.0055
			Curve Number	60 – 82.375
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 0.13
			Storage Coefficient (hr)	0.032 – 0.24
	Baseflow	Recession	Recession Constant	0.03
			Ratio to Peak	0.
Reach	Routing	Muskingum-Cunge	Slope	0.4
			Manning's Coefficient	0.004-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.0026mm to 0.0055mm 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 range of curve numbers in this area is 60 – 82.375.The magnitude of the outflow hydrograph increases as curve number increases. For Limpapa, the soil classes identified was undifferentiated mountain soil. The land cover types identified were open and closed canopy forests, grassland, brushland and tree plantations.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 0.24 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 0.03indicates that the basin is moderately likely to go back to its original discharge. Ratio to peak of 0.9 indicates a steeper receding limb of the outflow hydrograph.

Table 36. Summary of the Efficiency Test of Limpapa HMS Model.

Accuracy Measure	Value
RMSE	411.8189
r2	0.8821
NSE	0.827145
PBIAS	-24.7402
RSR	0.145758

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as411.8189 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8821.

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 0.827145.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -24.7402.

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 0.145758.

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 64) shows the Limpapa outflow using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (100-year, 50-year, 25-year, 10-year, and 5-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.

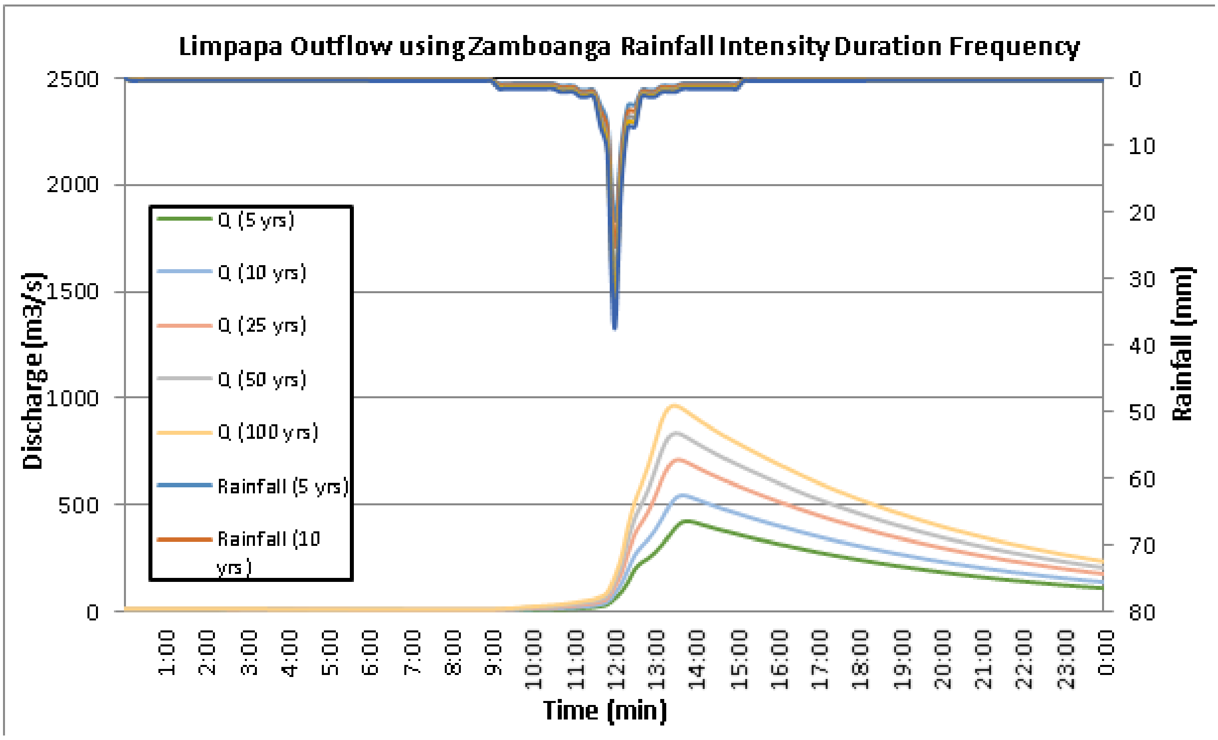

Figure 65. Outflow hydrograph at Limpapa Bridge Station generated using Zamboanga City RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Limpapa discharge using the Zamboanga City Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 37.

Table 37. Peak values of the Limpapa 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	424.76	13 hours 50 minutes
10-Year	127.9	25.3	547.04	13 hours 40 minutes
25-Year	153.4	30.2	711.44	13 hours 30 minutes
50-Year	172.3	33.9	837.67	13 hours 30 minutes
100-Year	191.1	37.5	965.61855	13 hours 30 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 Limpapa River using the calibrated HMS base flow is shown in Figure 65.

Figure 66. Sample output of Limpapa RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 15 to Figure 19 shows the 5-, 25-, and 100-year rain return scenarios of the Limpapa floodplain.

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

Table 38. Municipalities affected in Limpapa Floodplain.

Municipality	Total Area (km2)	Area Flooded (km2)	% Flooded
Zamboanga City	1496.29	5.39	0.36%
Sibuco	597.90	3.77	0.63%

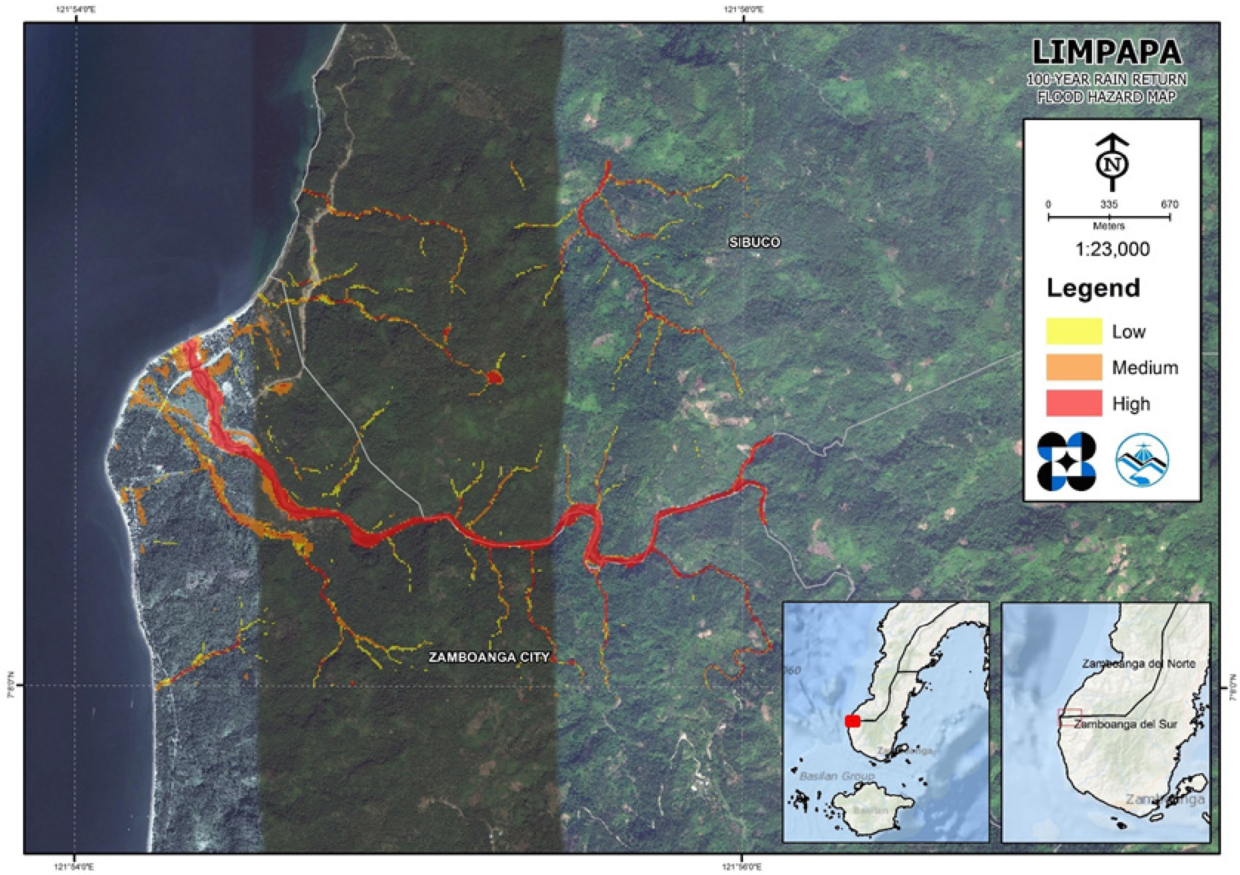

Figure 67. 100-year Flood Hazard Map for Limpapa Floodplain.

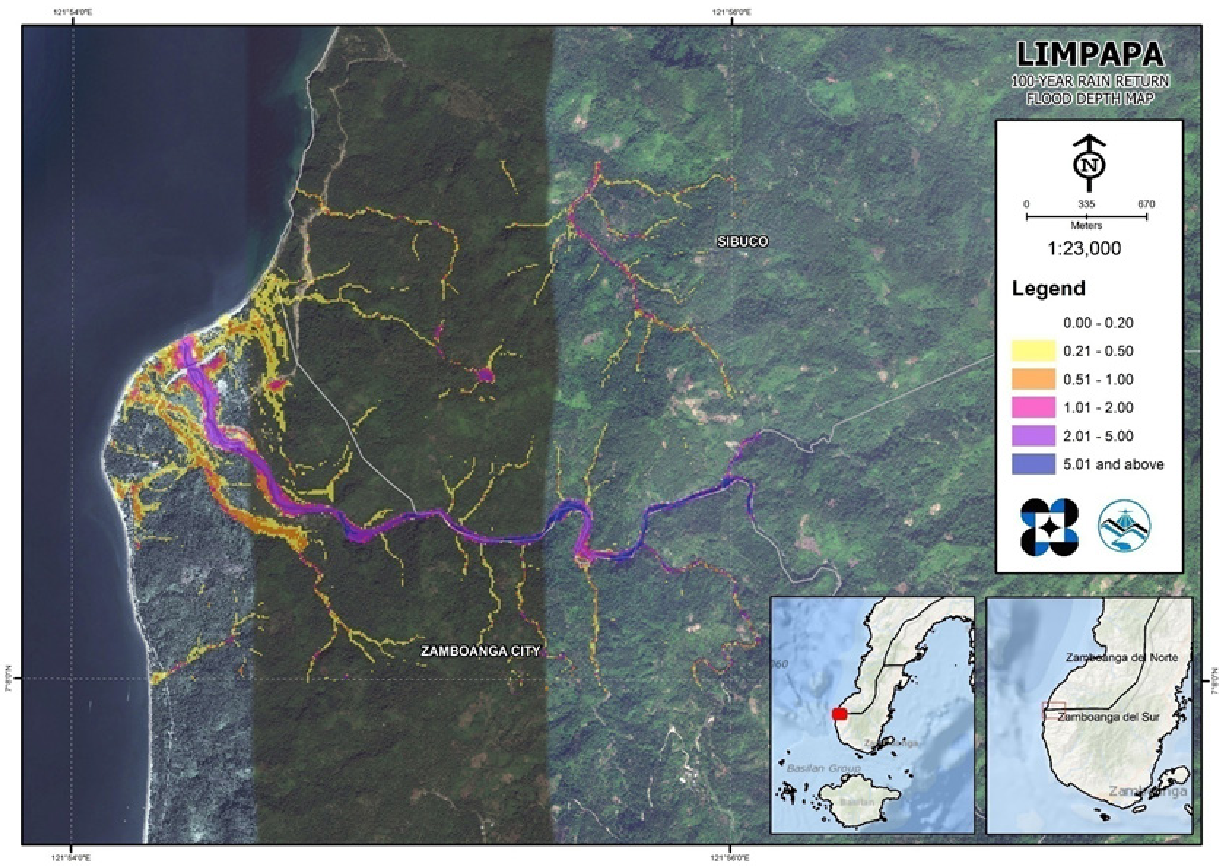

Figure 68. 100-year Flow Depth Map for Limpapa Floodplain.

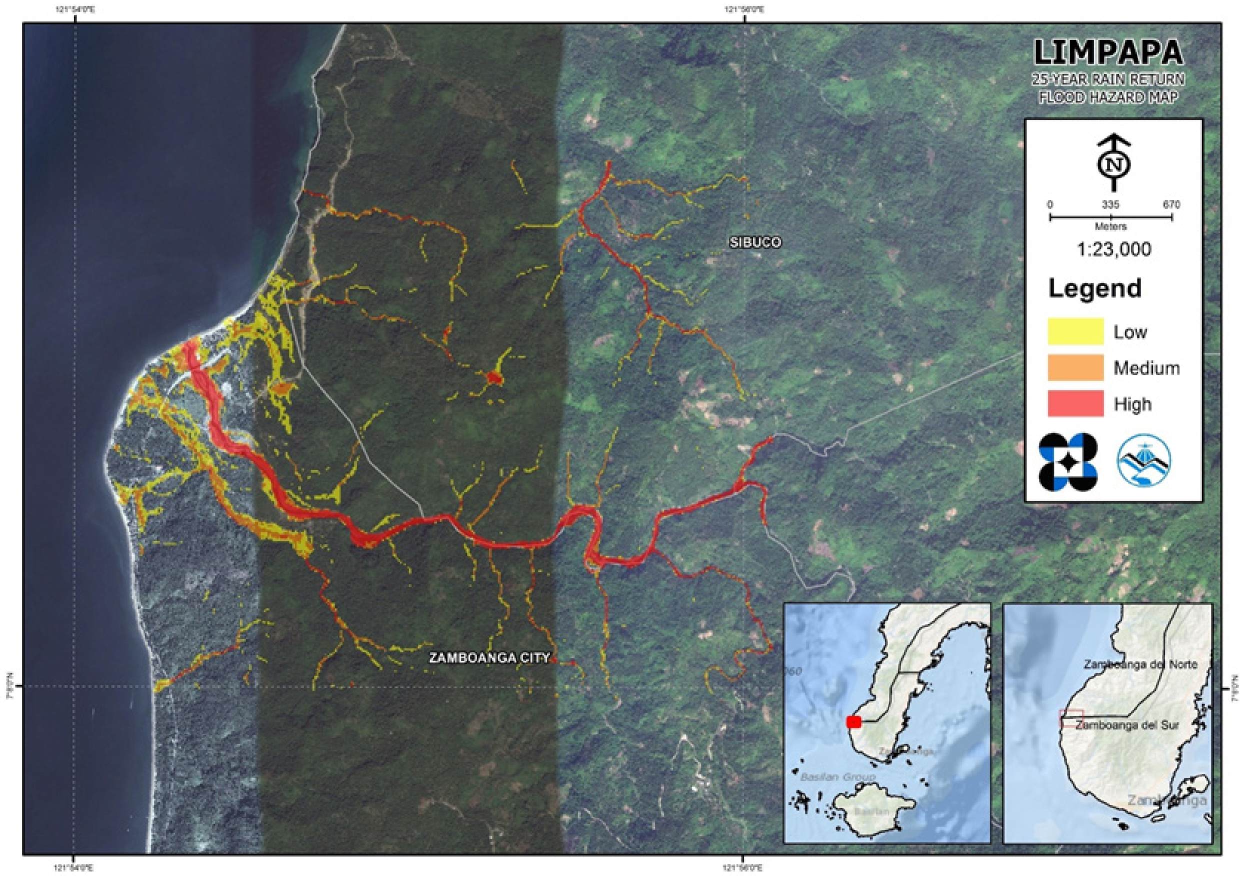

Figure 69. 25-year Flood Hazard Map for Limpapa Floodplain.

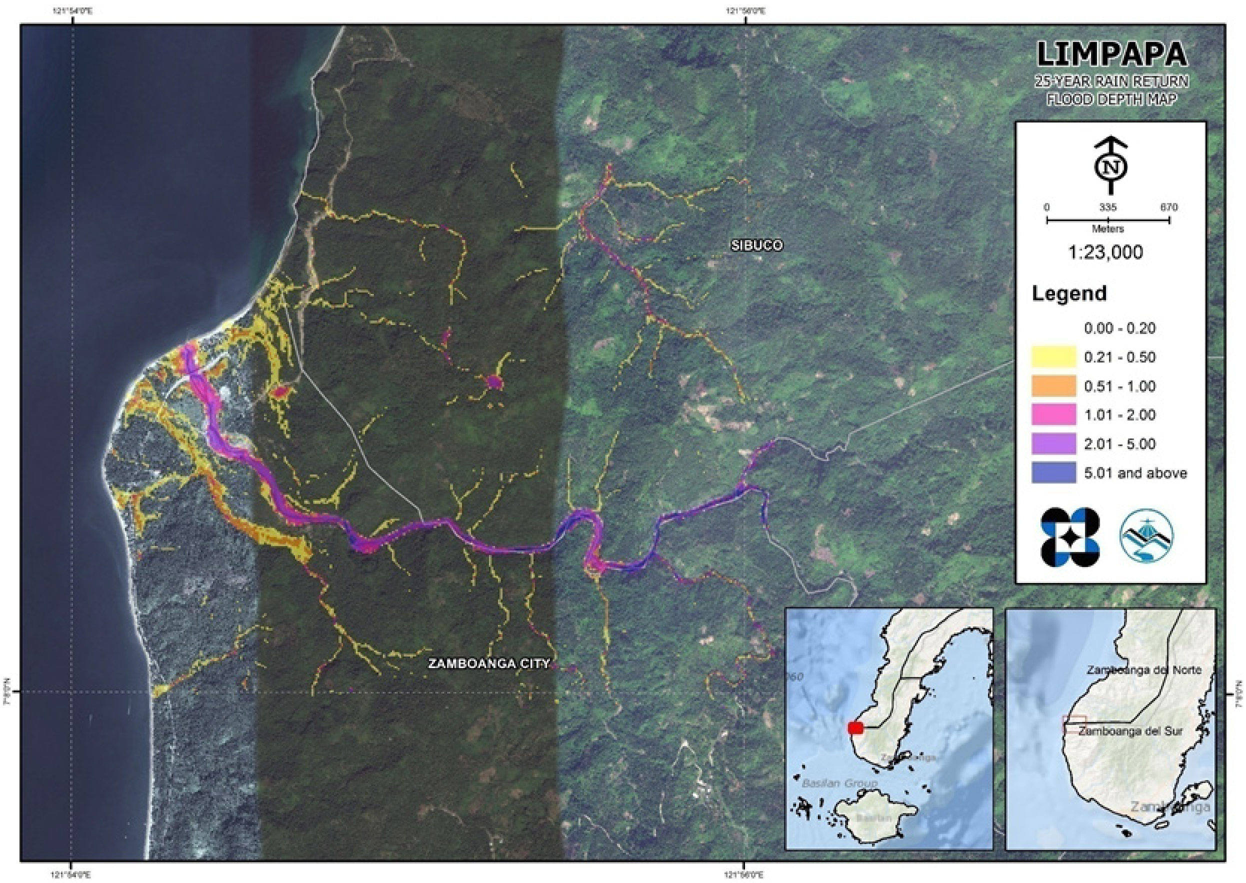

Figure 70. 25-year Flow Depth Map for Limpapa Floodplain.

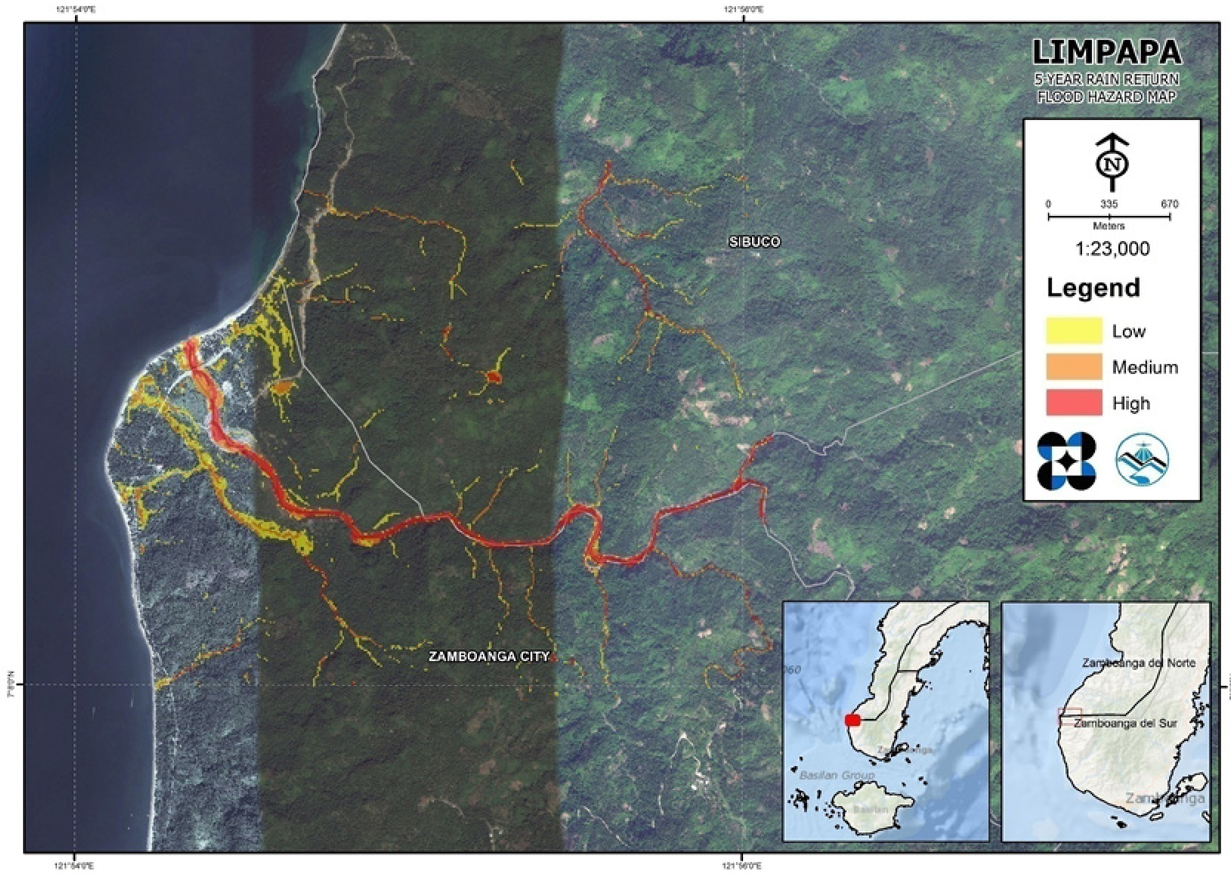

Figure 71. 5-year Flood Hazard Map for Limpapa Floodplain.

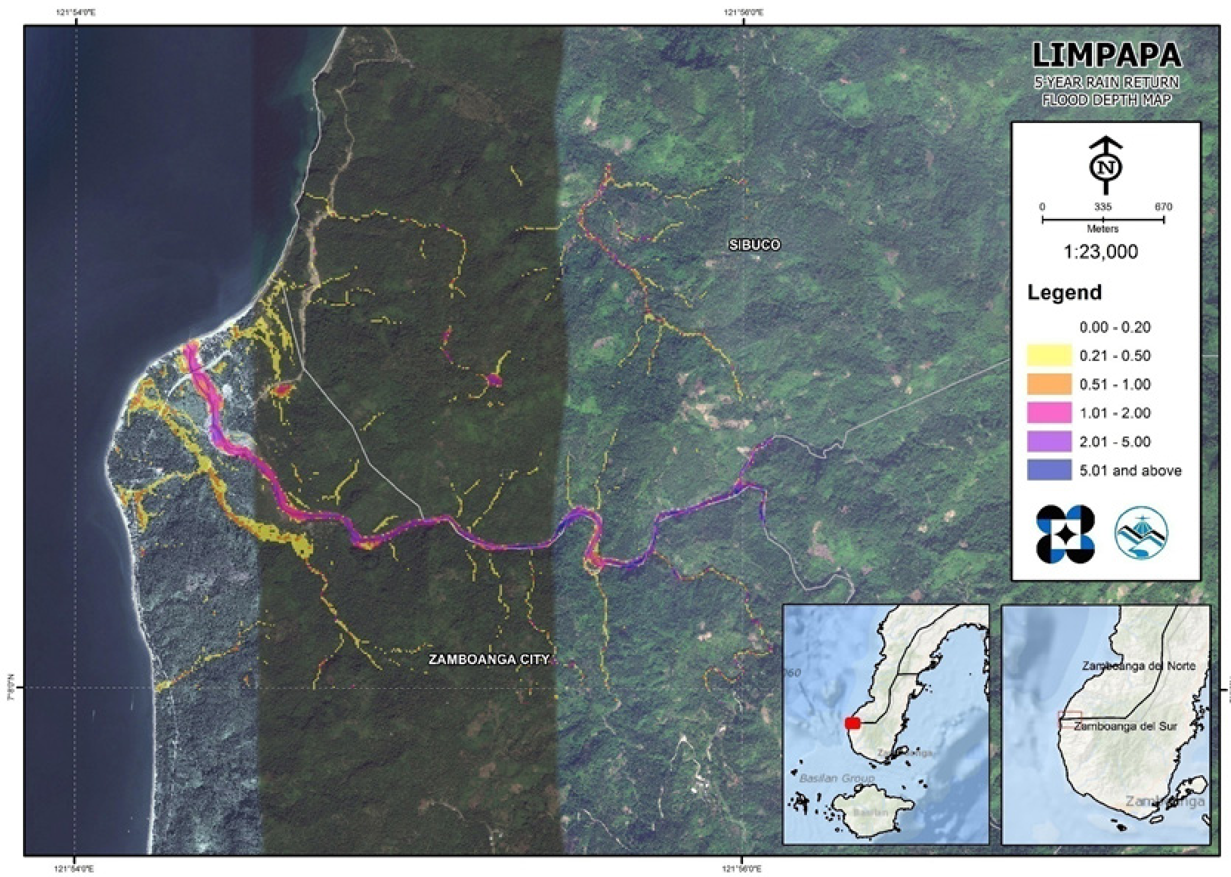

Figure 72. 5-year Flood Depth Map for LimpapaFloodplain.

5.10 Inventory of Areas Exposed to Flooding

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

For the 5-year return period, 0.34% of the municipality of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.01%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Zamboanga City (in sq. km.)
	Limpapa
0.03-0.20	5.02
0.21-0.50	0
0.51-1.00	0.13
1.01-2.00	0.11
2.01-5.00	0.14

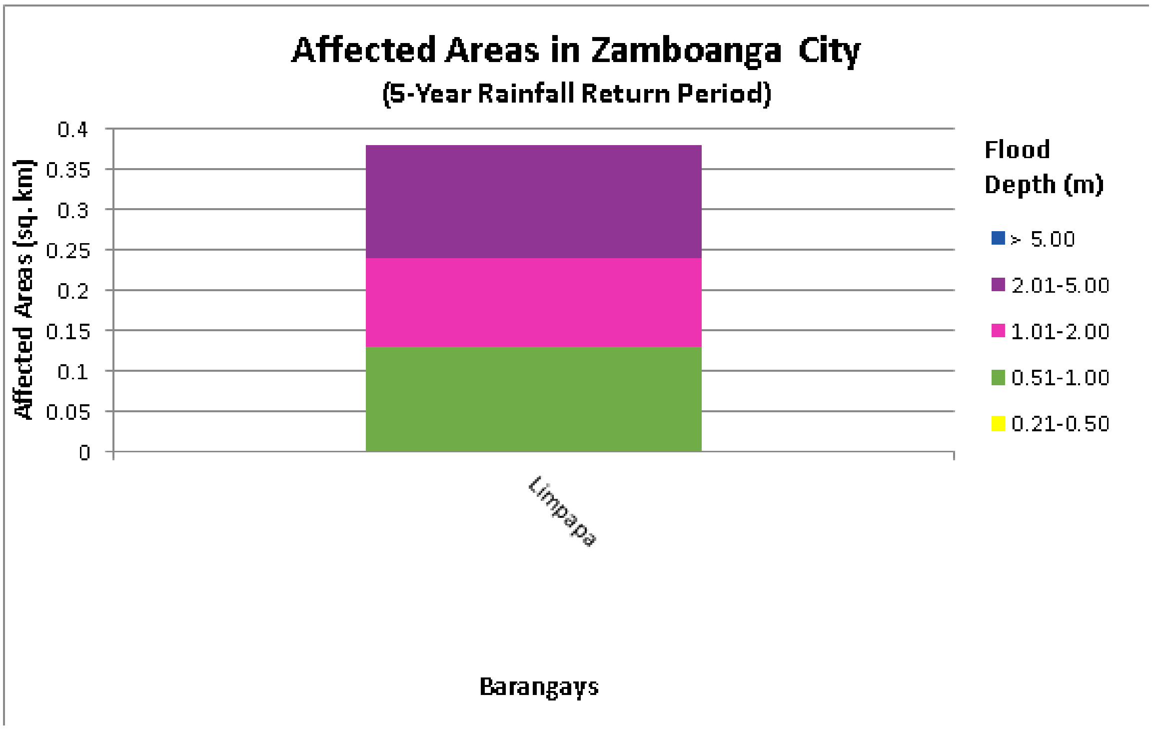

Figure 73. Affected Areas in Zamboanga City during 5-Year Rainfall Return Period.

For the 5-year return period, 0.59% of the municipality of Sibuco with an area of 597.9016 sq. km. will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.01%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Areas of affected barangays in Sibuco (in sq. km.)
	Limpapa
1	3.52
2	0
3	0.12
4	0.081
5	0.038
6	0

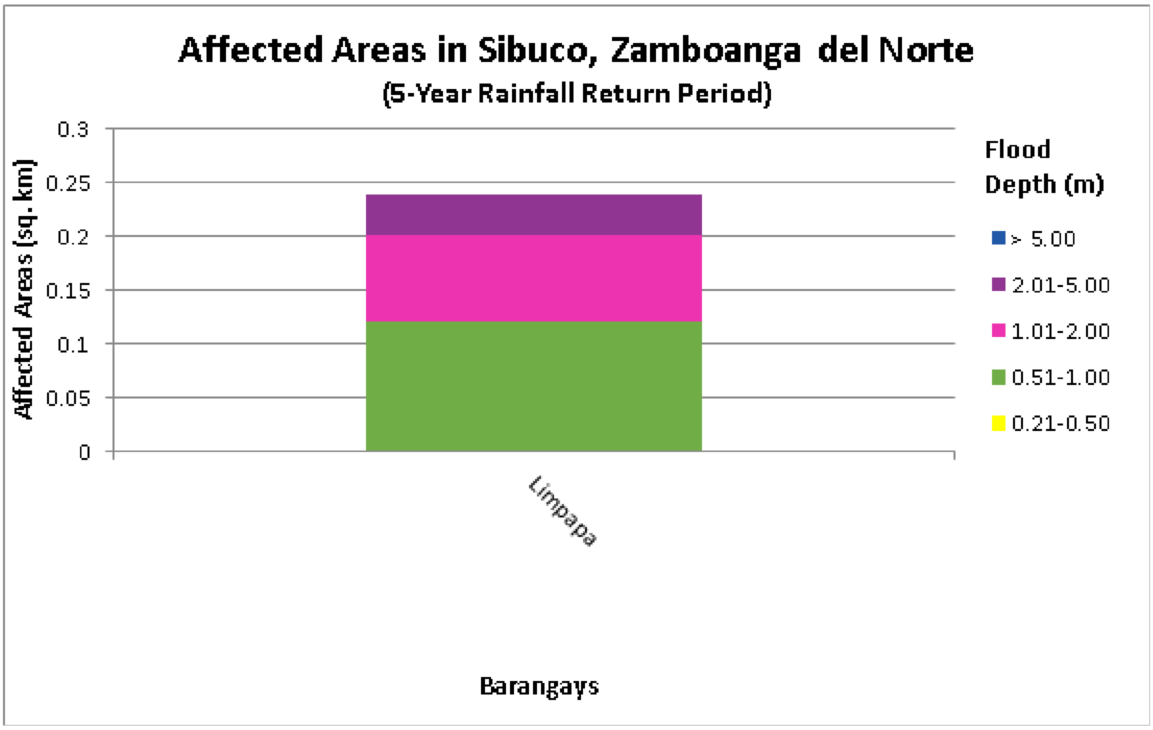

Figure 74. Affected Areas in Sibuco, Zamboanga del Norte during 5-Year Rainfall Return Period.

For the 25-year return period, 0.33% of the municipality of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.00%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected barangays in Zamboanga City (in sq. km.)
	Limpapa
1	4.94
2	0.19
3	0.084
4	0.058
5	0.1
6	0.028

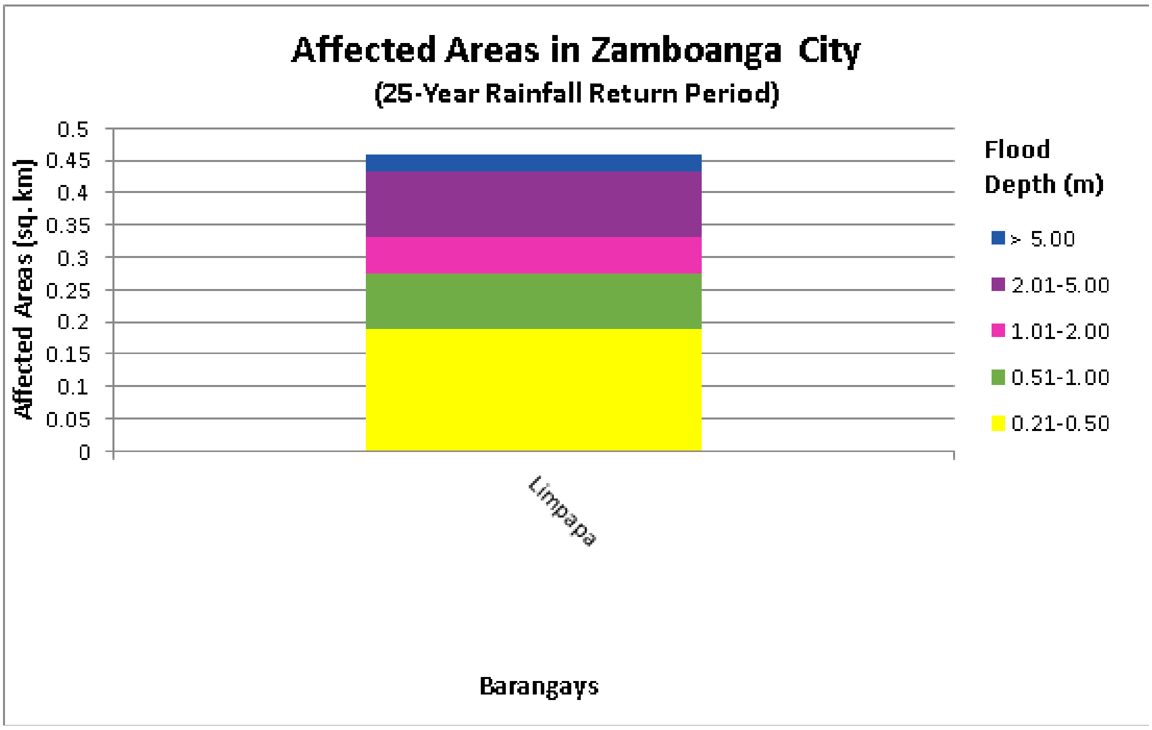

Figure 75. Affected Areas in Zamboanga City during 25-Year Rainfall Return Period.

For the 25-year return period, 0.58% of the municipality of Sibuco with an area of 597.9016 sq. km. will experience flood levels of less than 0.20 meters. 0.03% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.01%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Areas of affected barangays in Sibuco (in sq. km.)
	Limpapa
1	3.44
2	0.2
3	0.062
4	0.043
5	0.022
6	0

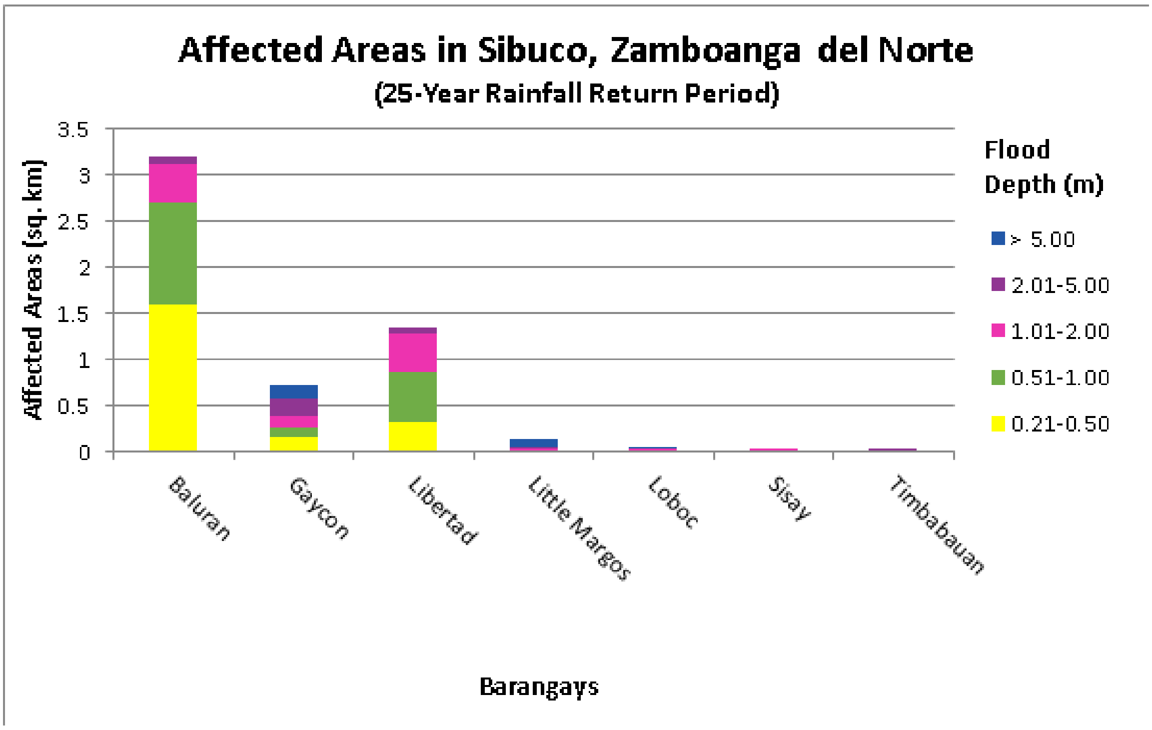

Figure 76. Affected Areas in Sibuco, Zamboanga del Norte during 25-Year Rainfall Return Period.

For the 100-year return period, 0.32% of the municipality of Zamboanga City with an area of 1496.293 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.00%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected barangays in Zamboanga City (in sq. km.)
	Limpapa
1	4.85
2	0.21
3	0.11
4	0.051
5	0.12
6	0.047

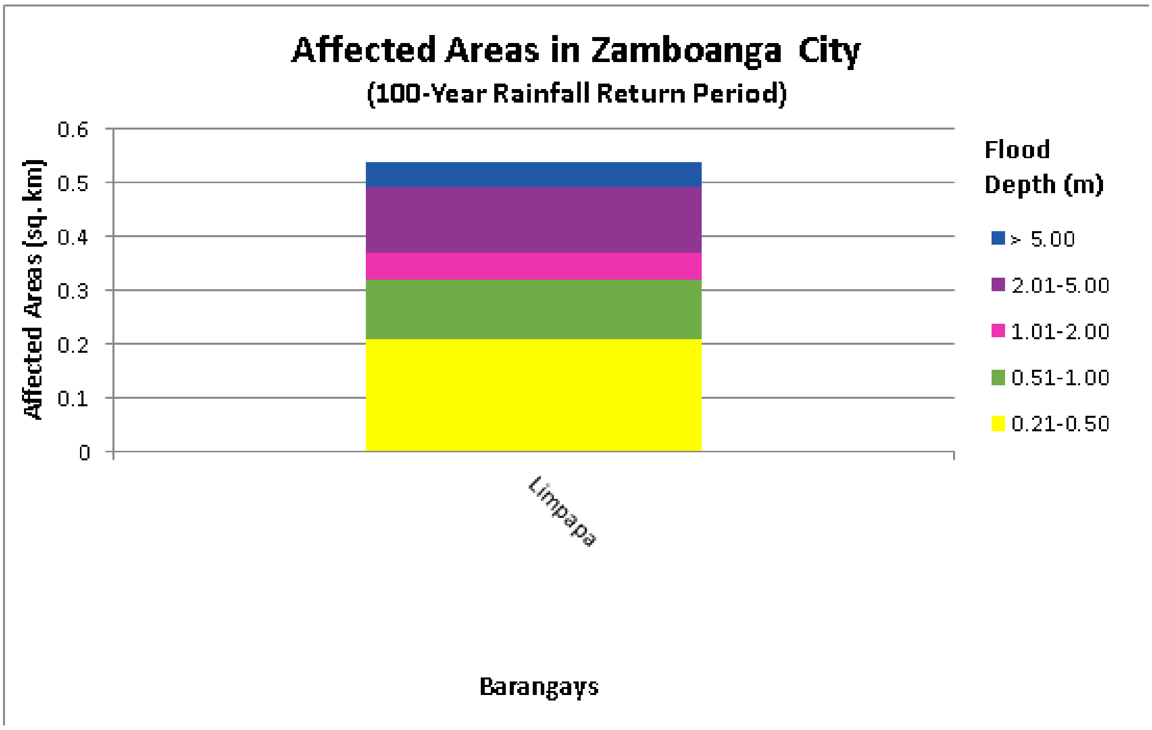

Figure 77. Affected Areas in Zamboanga City during 100-Year Rainfall Return Period.

For the 100-year return period, 0.56% of the municipality of Sibuco with an area of 597.9016 sq. km. will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, 0.01%, 0.01%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Sibuco, Zamboanga del Norte during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Areas of affected barangays in Sibuco (in sq. km.)
	Limpapa
1	3.36
2	0.24
3	0.087
4	0.045
5	0.037
6	0

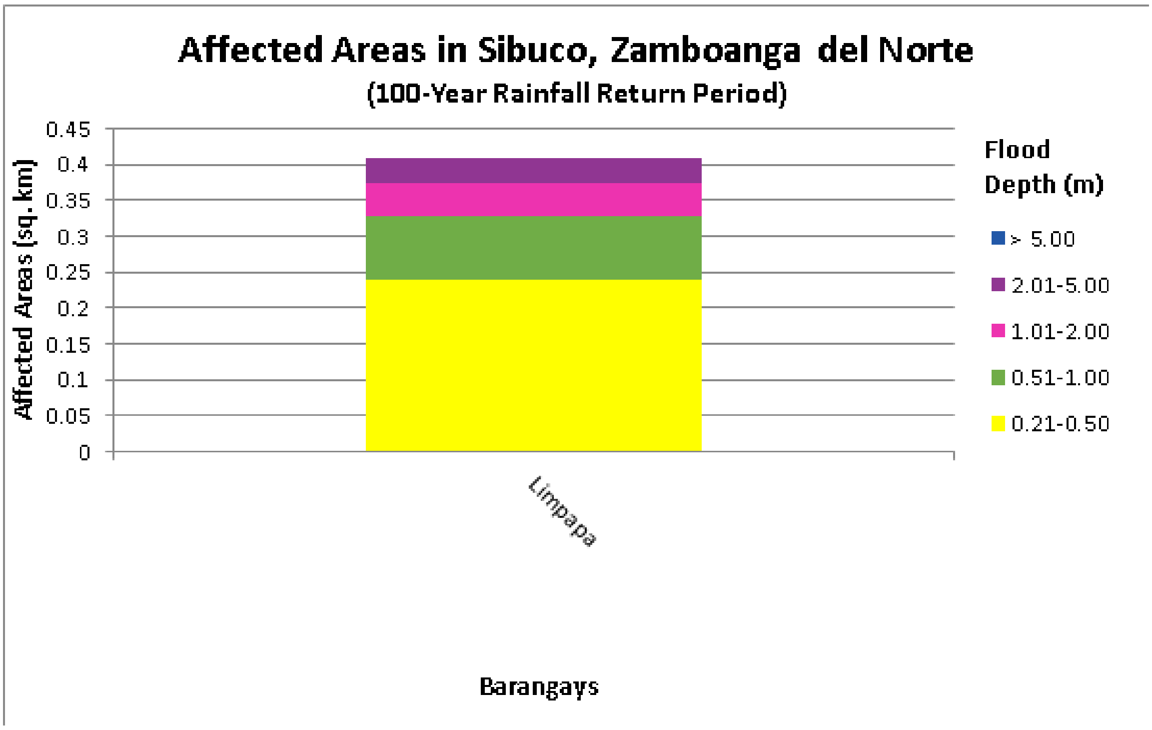

Figure 78. Affected Areas in Sibuco, Zamboanga del Norte during 100-Year Rainfall Return Period.

Moreover, the generated flood hazard maps for the Limpapa 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 45. 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	0.26	0.33	0.13
Medium	0.19	0.23	0.28
High	0.18	0.25	0.30
Total	0.63	0.81	0.71

Of the 3 identified educational and medical institutions and buildings in Limpapa Floodplain only 1 educationalinstitution was assessed to be exposed to flood hazard levels. The Limpapa National High School in Brgy. Limpapa, Sibuco was assessed to be exposed to low flood hazard levels for the 5-year scenario and to medium flood hazard levels for the 25- and 100-year scenarios. See Annex 12 and Annex 13 for a detailed enumeration of schools, hospitals and clinics in the Limpapa Floodplain.

5.11 Flood Validation

The flood validation consists of 192 points randomly selected all over the Limpapa Floodplain . It has an RMSE value of 0.12.

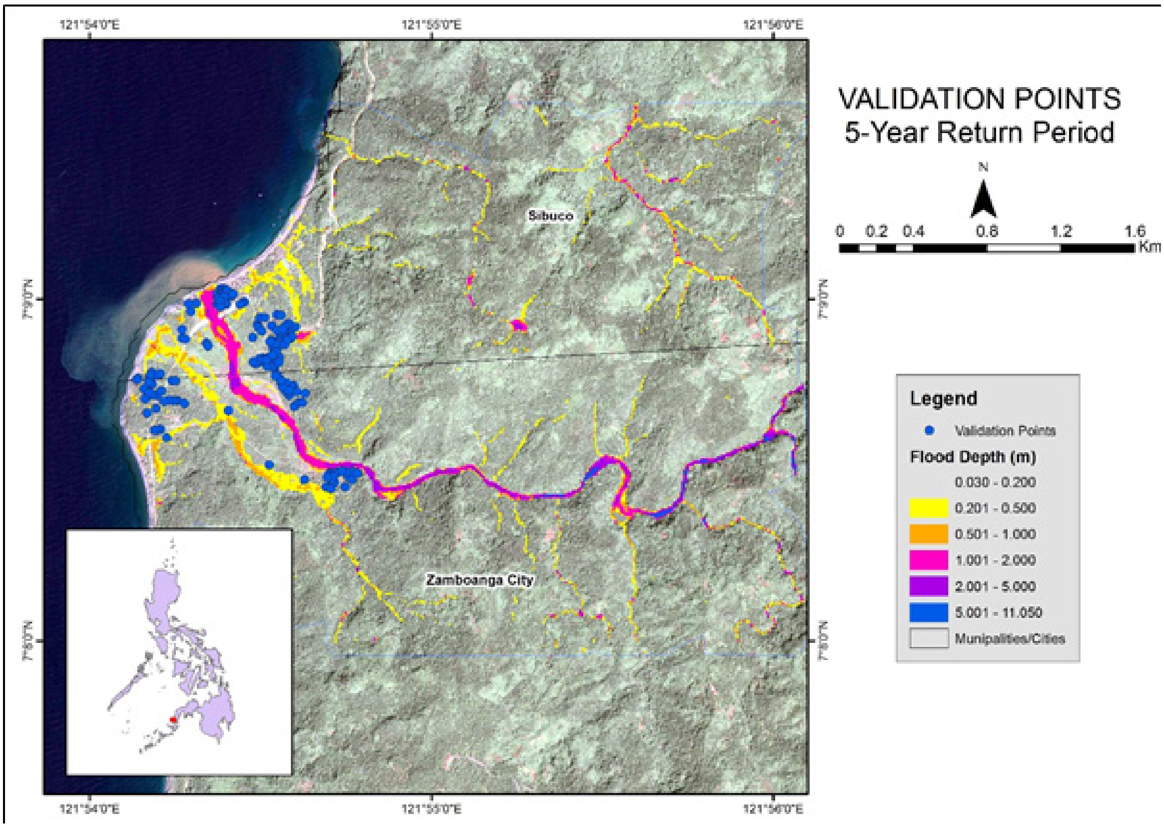

Figure 79. Validation points for 5-year Flood Depth Map of Limpapa Floodplain.

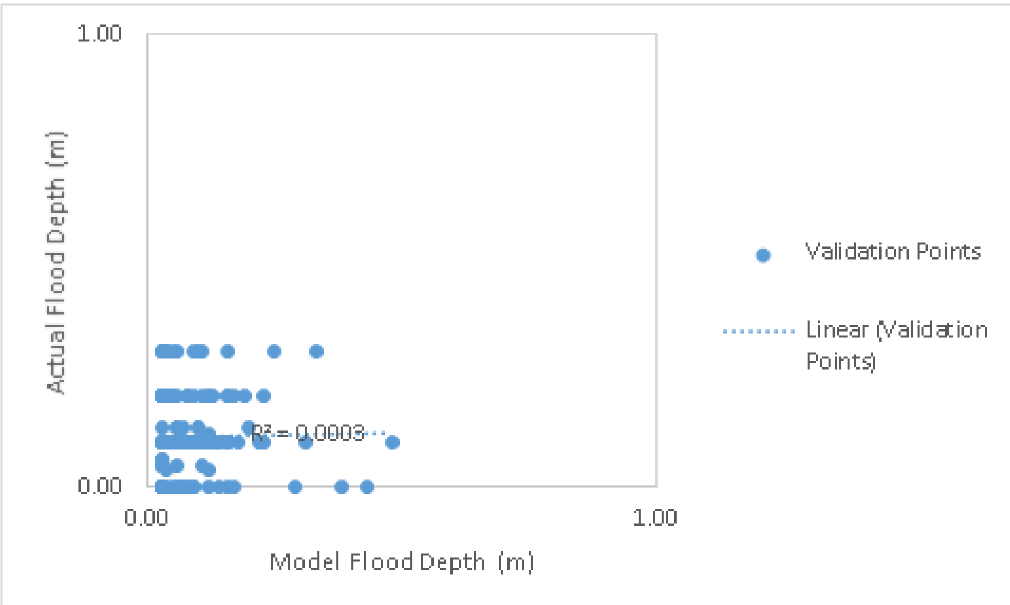

Figure 80. Flood map depth vs actual flood depth.

Actual Flood Depth vs Simulated Flood Depth in Limpapa.

LIMPAPA BASIN		Modeled Flood Depth (m)						
		169	8	0	0	0	0	177
Actual Flood Depth (m)	0-0.20	13	2	0	0	0	0	15
	0.21-0.50	0	0	0	0	0	0	0
	0.51-1.00	0	0	0	0	0	0	0
	1.01-2.00	0	0	0	0	0	0	0
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	182	10	0	0	0	0	192
	Total	52	39	82	1	0	0	174

The overall accuracy generated by the flood model is estimated at 89.06%, with 171 points correctly matching the actual flood depths. In addition, there were 21 points estimated one level above and below the correct flood depths. A total of 8 points were overestimated while a total of 13 points were underestimated in the modeled flood depths of Limpapa.

Table 47. Summary of Accuracy Assessment in Limpapa.

LANANG	No. of Points	%
Correct	171	**89.06**
Overestimated	8	4.17
Underestimated	13	6.77
Total	192	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.

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

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

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

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

ANNEXES

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

Figure A-1.2: Gemini Sensor

Table A-1.2: Gemini 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 (FOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

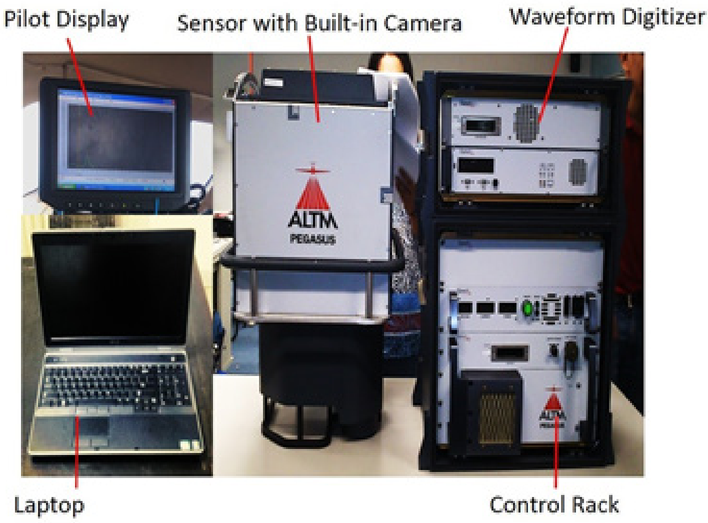


Figure A-1.1: Prgasus Sensor

Table A-1.1: Prgasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV™ AP50 (OEM)
Scan width (FOV)	Programmable, 0-75˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

1. ZGS-99

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

August 29, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **ZAMBOANGA DEL SUR**		
	Station Name: **ZGS-99**		
	Order: **2nd**		
Island: **MINDANAO**	Barangay: **CALARIAN**		
Municipality: **ZAMBOANGA CITY**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **6° 55' 37.48971"**	Longitude: **122° 0' 52.66431"**	Ellipsoidal Hgt:	**8.14900 m.**
	WGS84 Coordinates		
Latitude: **6° 55' 34.07737"**	Longitude: **122° 0' 58.23072"**	Ellipsoidal Hgt:	**72.23000 m.**
	PTM / PRS92 Coordinates		
Northing: **766020.391 m.**	Easting: **391103.346 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **765,752.27**	Easting: **391,141.46**	Zone:	**51**

Location Description

ZGS-99

The station is located beside a seawall, 10 m from the centerline and 50 m from the Airforce Beach, in Brgy. Upper Calarian. It is marked by a 4" copper nail flushed at the center of a cement putty on a concrete open canal with inscriptions " ZGS-99, 2009, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8799780 A**
T.N.: **2014-1901**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1: ZGS-99

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

1. ZC-1

ZGS-99 - ZC-1 (6:31:44 AM-9:12:54 AM) (S2)

Baseline observation:	ZGS-99 --- ZC-1 (B2)
Processed:	9/18/2014 4:09:19 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.000 m
Maximum PDOP:	3.344
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	8/24/2014 6:31:59 AM (Local: UTC+8hr)
Processing stop time:	8/24/2014 9:12:54 AM (Local: UTC+8hr)
Processing duration:	02:40:55
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	ZGS-99				
Grid		Local		Global	
Easting	391141.462 m	Latitude	N6°55'37.48971"	Latitude	N6°55'34.07737"
Northing	765752.270 m	Longitude	E122°00'52.66432"	Longitude	E122°00'58.23072"
Elevation	4.653 m	Height	8.149 m	Height	72.230 m

To:	ZC-1				
Grid		Local		Global	
Easting	391123.448 m	Latitude	N6°55'37.81345"	Latitude	N6°55'34.40107"
Northing	765762.250 m	Longitude	E122°00'52.07670"	Longitude	E122°00'57.64310"
Elevation	4.170 m	Height	7.666 m	Height	71.746 m

Vector					
ΔEasting	-18.013 m	NS Fwd Azimuth	298°52'03"	ΔX	16.186 m
ΔNorthing	9.979 m	Ellipsoid Dist.	20.598 m	ΔY	8.139 m
ΔElevation	-0.483 m	ΔHeight	-0.483 m	ΔZ	9.813 m

Figure A-2.2: ZC-1

2. ZS-214

Vector Components (Mark to Mark)

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

To:	ZS-214				
Grid		Local		Global	
Easting	380306.738 m	Latitude	N7°01'45.63620"	Latitude	N7°01'42.18785"
Northing	777081.996 m	Longitude	E121°54'58.78958"	Longitude	E121°55'04.34718"
Elevation	9.876 m	Height	13.222 m	Height	76.870 m

Vector					
ΔEasting	-29883.229 m	NS Fwd Azimuth	271°07'48"	ΔX	25372.441 m
ΔNorthing	641.317 m	Ellipsoid Dist.	29897.981 m	ΔY	15804.956 m
ΔElevation	2.131 m	ΔHeight	1.951 m	ΔZ	575.988 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000158991		
Y	-0.0000197090	0.0000353874	
Z	-0.0000044666	0.0000056096	0.0000025350

Figure A-2.3: ZS-214

3. ZS-131

Vector Components (Mark to Mark)

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

To:	ZS-131				
Grid		Local		Global	
Easting	414826.524 m	Latitude	N7°12'31.41328"	Latitude	N7°12'27.94616"
Northing	796844.403 m	Longitude	E122°13'42.74840"	Longitude	E122°13'48.28765"
Elevation	7.052 m	Height	10.811 m	Height	74.904 m

Vector					
ΔEasting	4636.557 m	NS Fwd Azimuth	12°42'06"	ΔX	-2545.750 m
ΔNorthing	20403.725 m	Ellipsoid Dist.	20930.290 m	ΔY	-4593.707 m
ΔElevation	-0.693 m	ΔHeight	-0.460 m	ΔZ	20260.657 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000227893		
Y	-0.0000323435	0.0000634026	
Z	-0.0000043665	0.0000093098	0.0000024763

Figure A-2.3: ZS-131

4. ZGS-99A

Vector Components (Mark to Mark)

From:	ZGS-99				
Grid		Local		Global	
Easting	391141.462 m	Latitude	N6°55'37.48971"	Latitude	N6°55'34.07737"
Northing	765752.270 m	Longitude	E122°00'52.66432"	Longitude	E122°00'58.23072"
Elevation	4.653 m	Height	8.149 m	Height	72.230 m

To:	ZGS-99A				
Grid		Local		Global	
Easting	391136.071 m	Latitude	N6°55'37.63895"	Latitude	N6°55'34.22659"
Northing	765756.864 m	Longitude	E122°00'52.48834"	Longitude	E122°00'58.05475"
Elevation	4.354 m	Height	7.850 m	Height	71.931 m

Vector					
ΔEasting	-5.391 m	NS Fwd Azimuth	310°19'07"	ΔX	5.031 m
ΔNorthing	4.594 m	Ellipsoid Dist.	7.085 m	ΔY	2.144 m
ΔElevation	-0.299 m	ΔHeight	-0.299 m	ΔZ	4.515 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'11"	σ ΔX	0.000 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	0.0000002239		
Y	-0.0000001250	0.0000004533	
Z	-0.0000000277	0.0000000071	0.0000000770

Figure A-2.4: ZGS-99A

5. ZBUP-666

Vector Components (Mark to Mark)

From:	ZS-214				
Grid		Local		Global	
Easting	380306.750 m	Latitude	N7°01'45.63636"	Latitude	N7°01'42.18801"
Northing	777082.001 m	Longitude	E121°54'58.78998"	Longitude	E121°55'04.34758"
Elevation	9.929 m	Height	13.274 m	Height	76.922 m

To:	ZBUP-666				
Grid		Local		Global	
Easting	380292.652 m	Latitude	N7°01'48.04214"	Latitude	N7°01'44.59360"
Northing	777155.917 m	Longitude	E121°54'58.32497"	Longitude	E121°55'03.88251"
Elevation	10.624 m	Height	13.969 m	Height	77.615 m

Vector					
ΔEasting	-14.098 m	NS Fwd Azimuth	349°04'10"	ΔX	16.533 m
ΔNorthing	73.916 m	Ellipsoid Dist.	75.266 m	ΔY	0.455 m
ΔElevation	0.696 m	ΔHeight	0.695 m	ΔZ	73.429 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	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	0.0000004139		
Y	-0.0000002444	0.0000007473	
Z	-0.0000000788	0.0000002094	0.0000001901

Figure A-2.5: ZBUP-666

6. ZGS-100bak

Vector Components (Mark to Mark)

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

To:	ZGS-100bak				
Grid		Local		Global	
Easting	410189.234 m	Latitude	N7°01'26.95286"	Latitude	N7°01'23.53066"
Northing	776447.718 m	Longitude	E122°11'12.71974"	Longitude	E122°11'18.27616"
Elevation	7.904 m	Height	11.430 m	Height	75.762 m

Vector					
ΔEasting	-0.732 m	NS Fwd Azimuth	353°57'36"	ΔX	1.005 m
ΔNorthing	7.039 m	Ellipsoid Dist.	7.079 m	ΔY	-0.198 m
ΔElevation	0.159 m	ΔHeight	0.159 m	ΔZ	7.007 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'11"	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	0.0000003584		
Y	-0.0000002914	0.0000004823	
Z	-0.0000000657	0.0000000631	0.0000000991

Figure A-2.6:ZGS-100bak

Annex 4. The LiDAR Survey Team Composition

Table A-4.1: The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	
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
		JULIE PEARL MARS	
		ENGR. IRO NIEL ROXAS	
	Research Associate (RA)	KRISTINE JOY ANDAYA	UP-TCAGP
		ENGR. LARAH KRISELLE PARAGAS	
		MA. VERLINA TONGA	
		JONATHAN ALMALVEZ	
		SANDRA POBLETE	
Ground Survey, Data Download and Transfer	RA	ENGR. RENAN PUNTO	UP-TCAGP
		JERIEL PAUL ALAMBAN	
		ENGR. FRANK NICOLAS ILEJAY	
LiDAR Operation	Airborne Security	SSG. RONALD MONTE-NEGRO	PHILIPPINE AIR FORCE (PAF)
		SSG. JULIUS RENDON	
		SSG. JAYCO MANZANO	
	Pilot	CAPT. CESAR SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JOHN BRYAN DONGUINES	
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. ANTON RETSE DAYO	AAC

Annex 5. Data Transfer Sheet for Nainday Floodplain

DATA TRANSFER SHEET
02/24/2015(Zamboanga)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
5-Feb-15	2535P	1BLK75E36A	PEGASUS	2.95	2608	12.7	232	43.6	360	30.7	NA	7.53	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2537P	1BLK75C37A	PEGASUS	3.55	1872	13.9	263	52.4	410	35.8	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
6-Feb-15	2539P	1BLK75C37B	PEGASUS	1.37	332	7.95	175	25.2	222	17.6	NA	8.2	1KB	1KB	38	NA	Z:\DAC\RAW DATA
7-Feb-15	2545P	1BLK75C39A	PEGASUS	2.33	473	11.3	259	41.7	305	26.2	NA	7.77	1KB	1KB	70/76	NA	Z:\DAC\RAW DATA
9-Feb-15	2549P	1BLK75A40A	PEGASUS	3.95	2608	10.9	230	32.6	244	22.3	NA	4.37	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
10-Feb-15	2553P	1BLK75S41A	PEGASUS	2.03	566	11.3	256	31.9	247	22.4	NA	6.81	1KB	1KB	89	NA	Z:\DAC\RAW DATA
11-Feb-15	2557P	1BLK75S42A	PEGASUS	1.62	301	10.6	255	34.9	240	20.5	NA	8.47	1KB	1KB	31/88	NA	Z:\DAC\RAW DATA

Received from
Name C JOAQUIN
Position
Signature [signature]

Received by
Name AC Bongat 3/13/15
Position GRS
Signature [signature]

Table A-5.1: Data transfer sheet for Barotac Floodplain - 1

Annex 6. Flight Logs for the Flight Missions

Flight Log for 2BLK75G236A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7972

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini	3 Mission Name: 2BLK75G236A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: B. Dongguines	8 Co-Pilot: N. Aguin	9 Route: Zamboanga			
10 Date: 8-24-14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 06:50	14 Engine Off: 9:13	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fine					
20 Remarks: Mission completed					
21 Problems and Solutions:					

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

Acquisition Flight Certified by: SSC RENDON JR PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: B. DONGGUINES — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Table A-6.1:Flight Log for 2BLK75G236A Mission

Flight Log for 1BLK75S42A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 2557

1 LiDAR Operator: J. Alviar	2 ALTM Model: 1BLK75S42A	3 Mission Name: 1BLK75S42A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Dongulnes	9 Route: Zambo - Zambo			
10 Date: Feb. 11, 2015	12 Airport of Departure (Airport, City/Province): Zamboanga		12 Airport of Arrival (Airport, City/Province): Zambo		
13 Engine On: 0902	14 Engine Off: 1325 H	15 Total Engine Time: 4+23	16 Take off: 0907 H	17 Landing: 1320 H	18 Total Flight Time: 4+13
19 Weather: Partly cloudy					

20 Remarks:

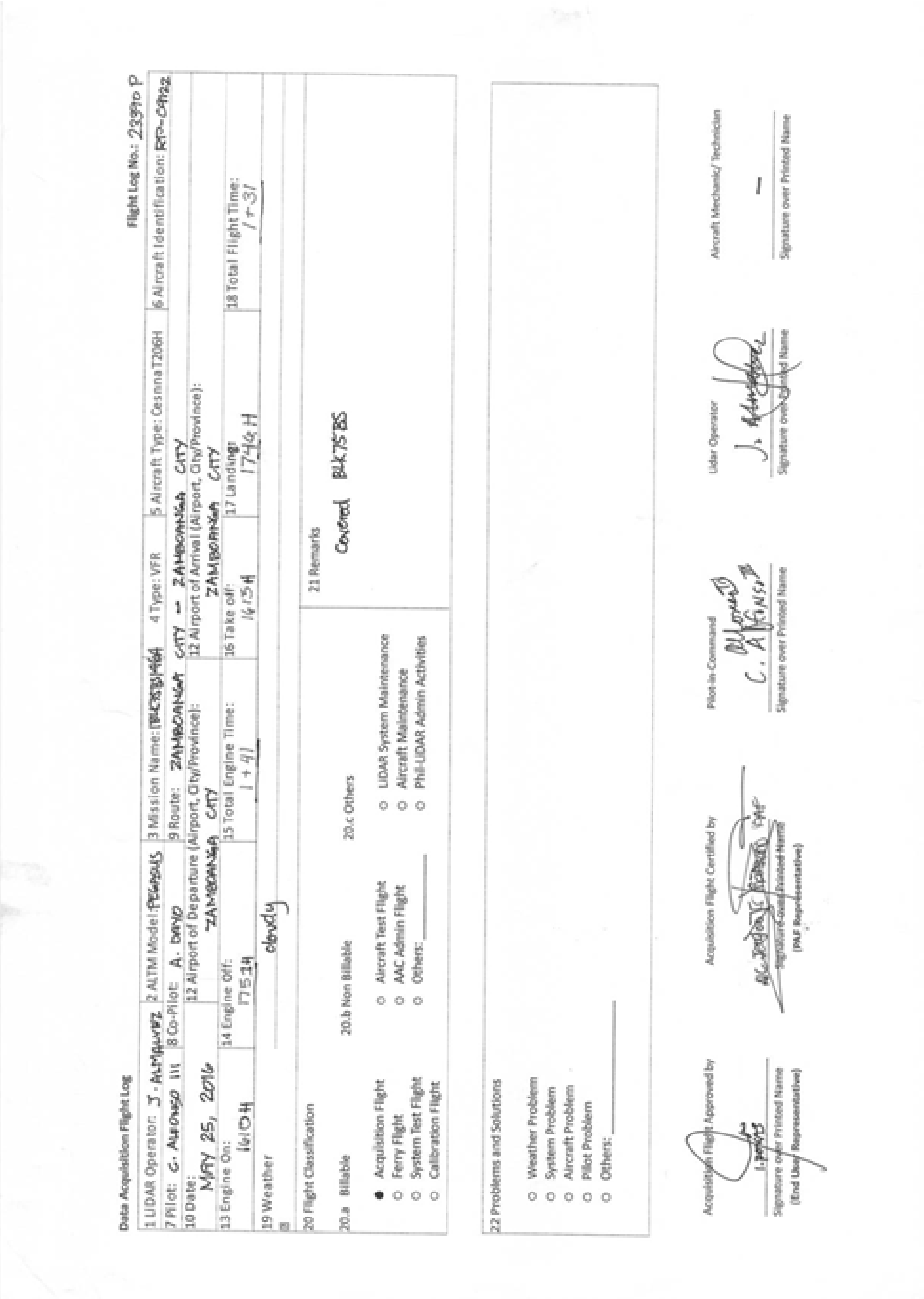
Surveyed remaining gaps in BLK 75C, D, E, 65 F5, Sacol Island

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	[illegible]	Alfonso III	J. Alviar
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Table A-6.2:Flight Log for 1BLK75S42A Mission

Flight Log for 1BLK75BS146A Mission


Data Acquisition Flight Log

Flight Log No.: 23390 P

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK75BS146A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: A. DAYO	9 Route: ZAMBOANGA CITY – ZAMBOANGA CITY			
10 Date: MAY 25, 2016	12 Airport of Departure (Airport, City/Province): ZAMBOANGA CITY		12 Airport of Arrival (Airport, City/Province): ZAMBOANGA CITY		
13 Engine On: 1610H	14 Engine Off: 1751H	15 Total Engine Time: 1+41	16 Take off: 1615H	17 Landing: 1746H	18 Total Flight Time: 1+31
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

Covered BLK75BS

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

Acquisition Flight Approved by: J. Dayas — Signature over Printed Name (End User Representative)

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

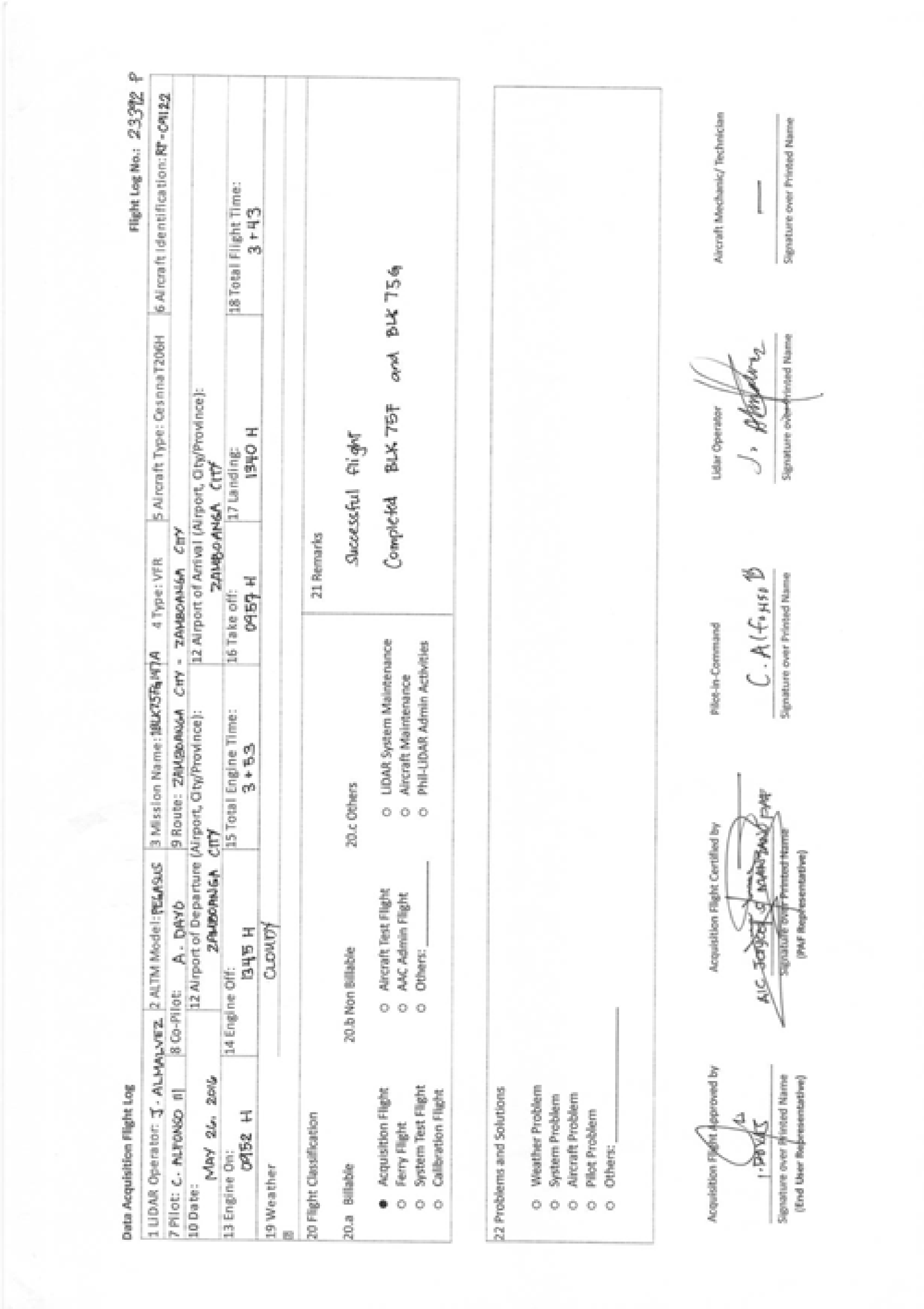
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

Lidar Operator: J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ Technician: — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1271P

Flight Log for 1BLK75FG147A Mission



Data Acquisition Flight Log — Flight Log No.: 23392 P

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK75FG147A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: A. DAYO	9 Route: ZAMBOANGA CITY - ZAMBOANGA CITY			
10 Date: MAY 26, 2016	12 Airport of Departure (Airport, City/Province): ZAMBOANGA CITY		12 Airport of Arrival (Airport, City/Province): ZAMBOANGA CITY		
13 Engine On: 0952 H	14 Engine Off: 1345 H	15 Total Engine Time: 3+53	16 Take off: 0957 H	17 Landing: 1340 H	18 Total Flight Time: 3+43
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

Successful flight

Completed BLK 75F and BLK 75G

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/ Technician
J. DAVIS	A1C Jonjon(?) S. MANTANO PAF	C. Alfonso III	J. Almalvez	—
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 1BLK75FG147A Mission

Annex 7. Flight Status Reports

ZAMBOANGA CITY-ZAMBOANGA DEL NORTE
(August 18 to September 10, 2014; February 5 to 11, 2015; May 19 to 31, 2016)

Table A-7.1 Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7452GC	BLK 75G	2BLK75G236A	LK Paragas	August 24, 2014	Covered BLK 75G @1000m; fast cloud build up
2557P	BLK 75C, 75D,75E, 75FS	1BLK75S42A	J.Alviar	February 11, 2015	Survey 6 descended to 1000 due to clouds
					Returned to 1100m for survey over Sacol
					Gaps due to clouds, descended to 1000m to fill up voids in Sacol and Blk 75EFG
					Added 1 small line (Corridor 18), descended to 800m
					Corridor 16 which should cover gap in Blk 75E, up to all lines in Blk 75FG @800m
23390P	BLK 75BS	1BLK75BS146A	J. Almalvez	May 25, 2016	Covered BLK75BS
23392P	BLK 75F, 75G	1BLK75FG147A	J. Almalvez	May 26, 2016	Completed BLK75F and 75G

LAS BOUNDARIES PER FLIGHT

Flight No.: 7452GC
Area: BLK 75G
Mission Name: 2BLK75G236A
Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;
Scan Angle: 20 deg; Overlap: 40%

LAS

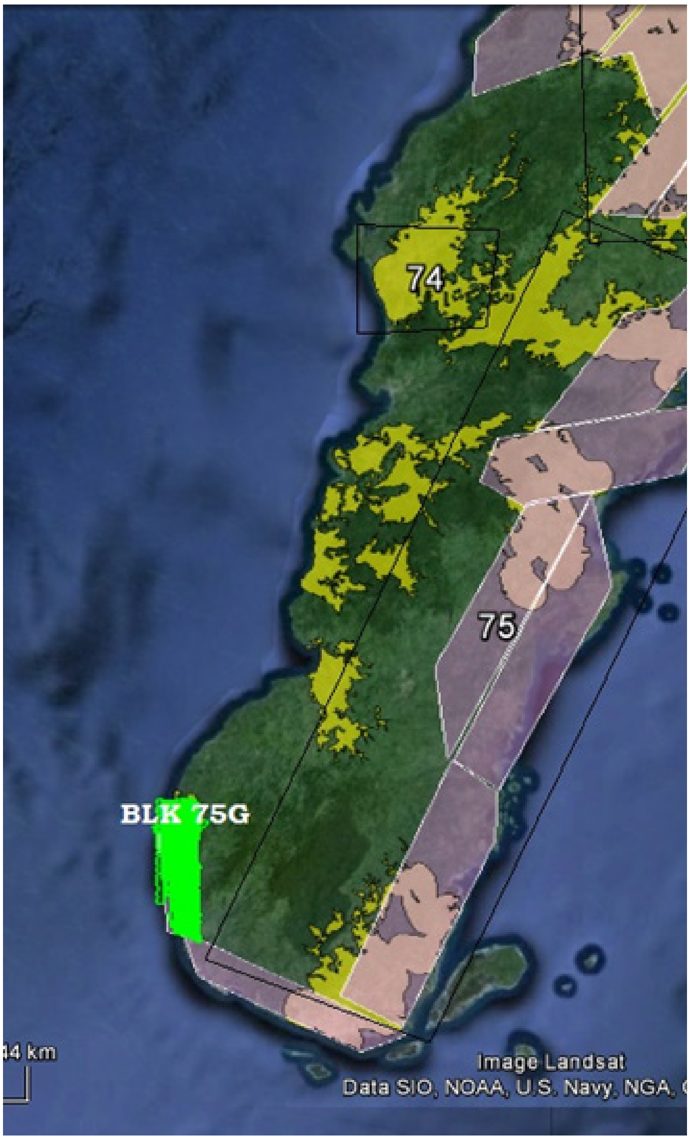


Figure A-7.1. Swath for Flight No. 7452GC

Flight No.: 2557P
Area: BLK 75C, 75D, 75E, 75FS, 75GS
Mission Name: 1BLK75S42A
Parameters: Altitude: 1100 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 15%

LAS

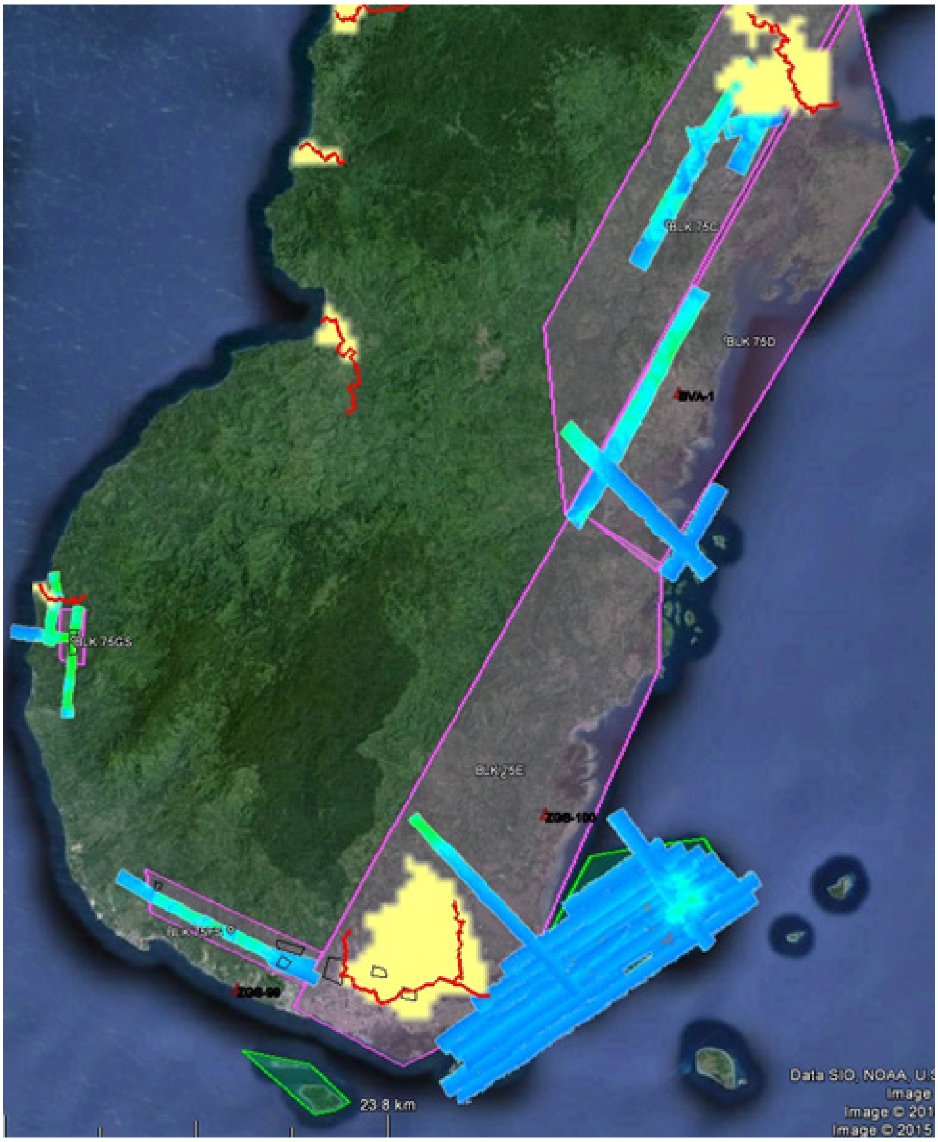


Figure A-7.2. Swath for Flight No. 2557P

Flight No.: 23390P
Area: BLK 75BS
Mission Name: 1BLK75BS146A
Parameters: Altitude: 1000 m; Scan Frequency: 35 Hz;
Scan Angle: 20 deg; Overlap: 50%

LAS

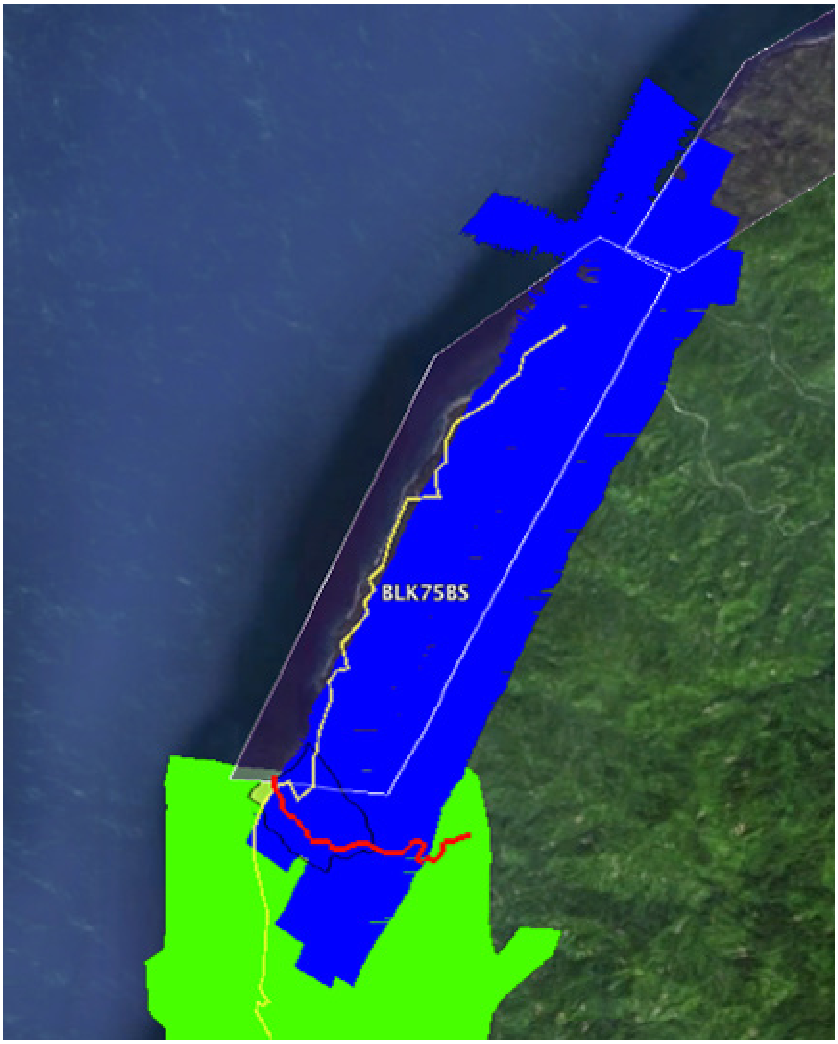


Figure A-7.3. Swath for Flight No. 23390P

Flight No.: 23392P
Area: BLK 75F, 75G
Mission Name: 1BLK75FG147A
Parameters: Altitude:1200 m; Scan Frequency: 30 Hz;
Scan Angle: 25 deg; Overlap: 30%

LAS

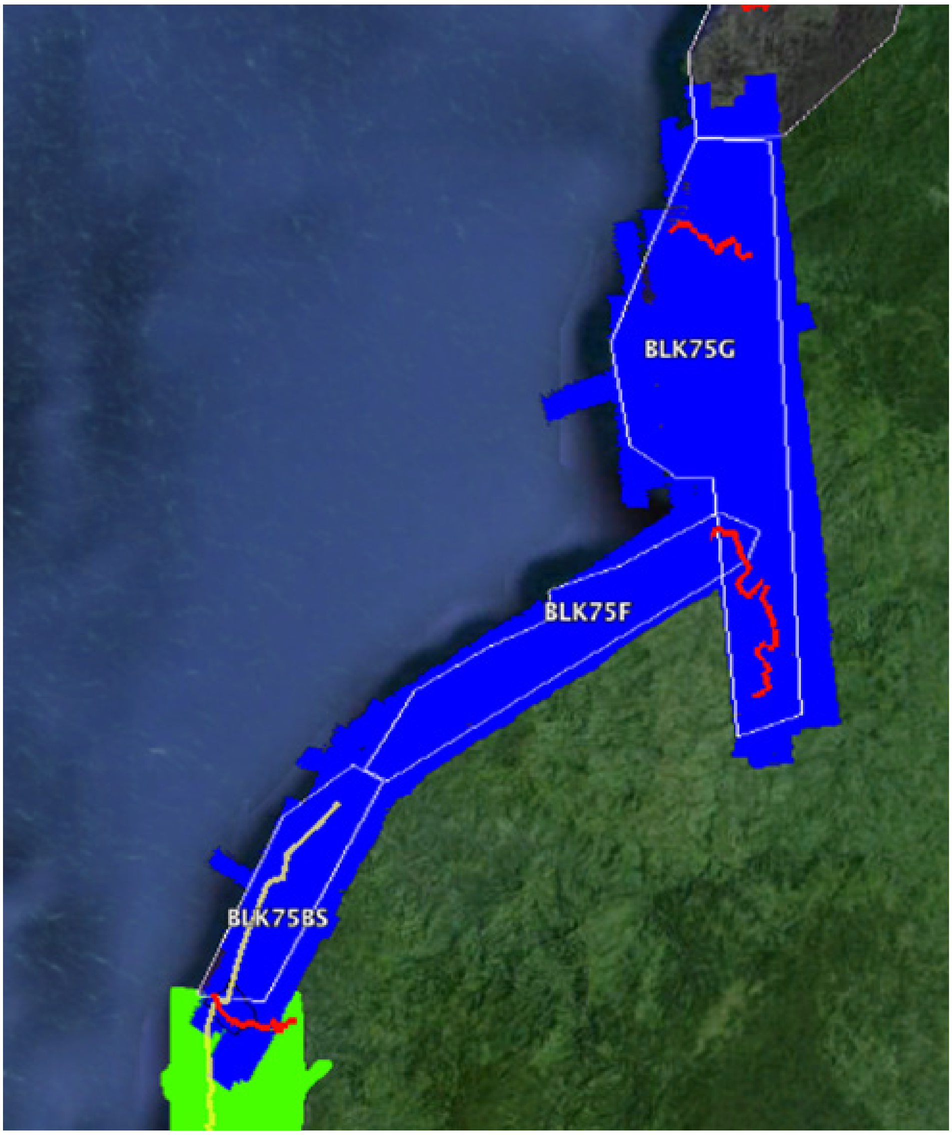


Figure A-7.4. Swath for Flight No. 23392P

Flight No. : 1281P
Area: BLK32I
Mission Name: 1BLK32I088B
Area Surveyed: 129.109 sq.km.
Altitude: 1000m
PRF: 200kHz SCF:30Hz
Lidar FOV: 50deg Sidelap: 40%

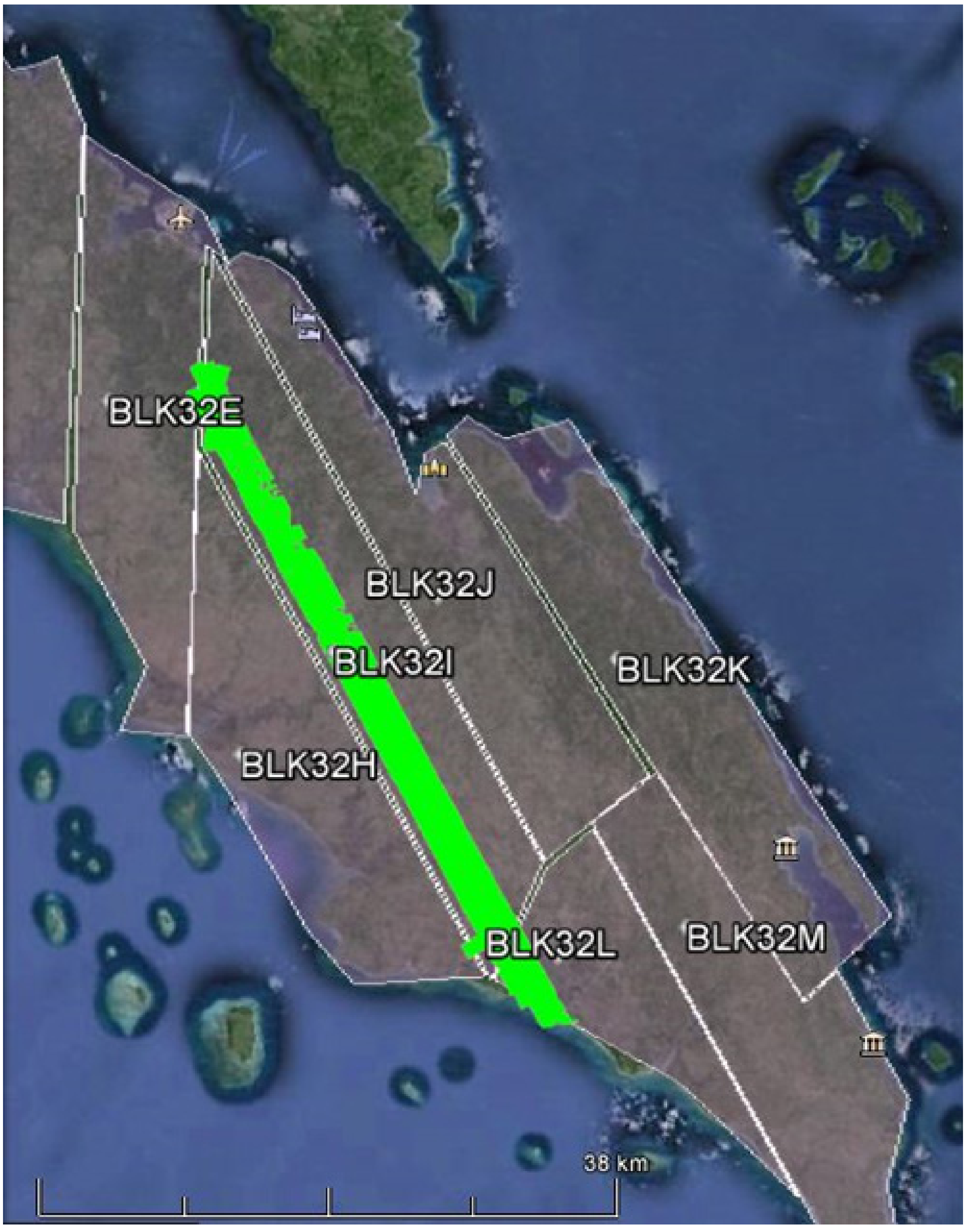


Figure A-7.5. Swath for Flight No. 1281P

Flight No. : 1291P
Area: BLK32K & BLK32L
Mission Name: 1BLK32KL091A
Area Surveyed: 173.14 sq.km.
BLK32L
Altitude: 800m
PRF: 200 kHz SCF: 30 Hz
Lidar FOV: 50 deg Overlap: 30%

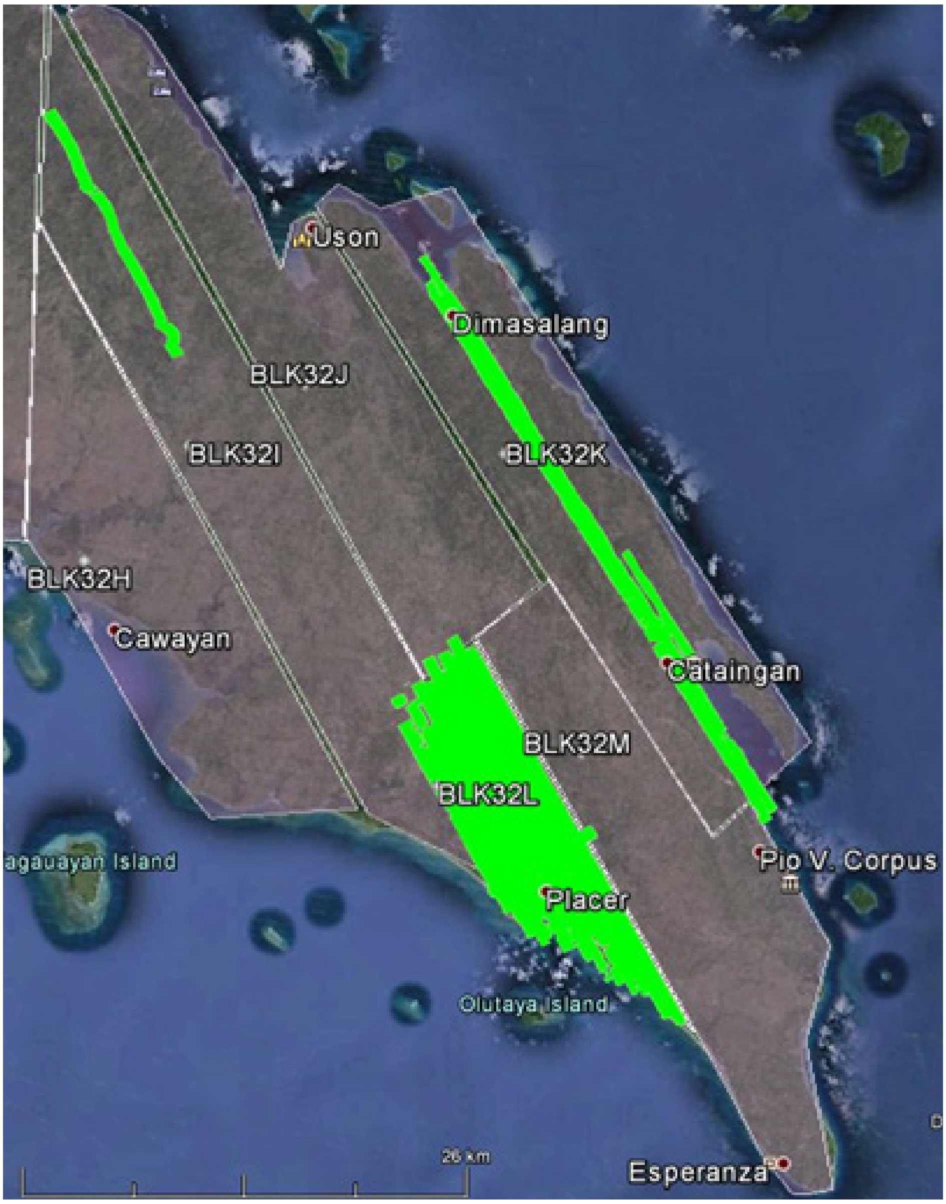


Figure A-7.6. Swath for Flight No. 1291P

Flight No. : 1293P
Area: BLK32H
Mission Name: 1BLK32H091B
Area Surveyed: 83.369 sq.km.
Altitude: 800m
PRF: 250 kHz SCF: 36 Hz
Lidar FOV: 40 deg Sidelap: 25%

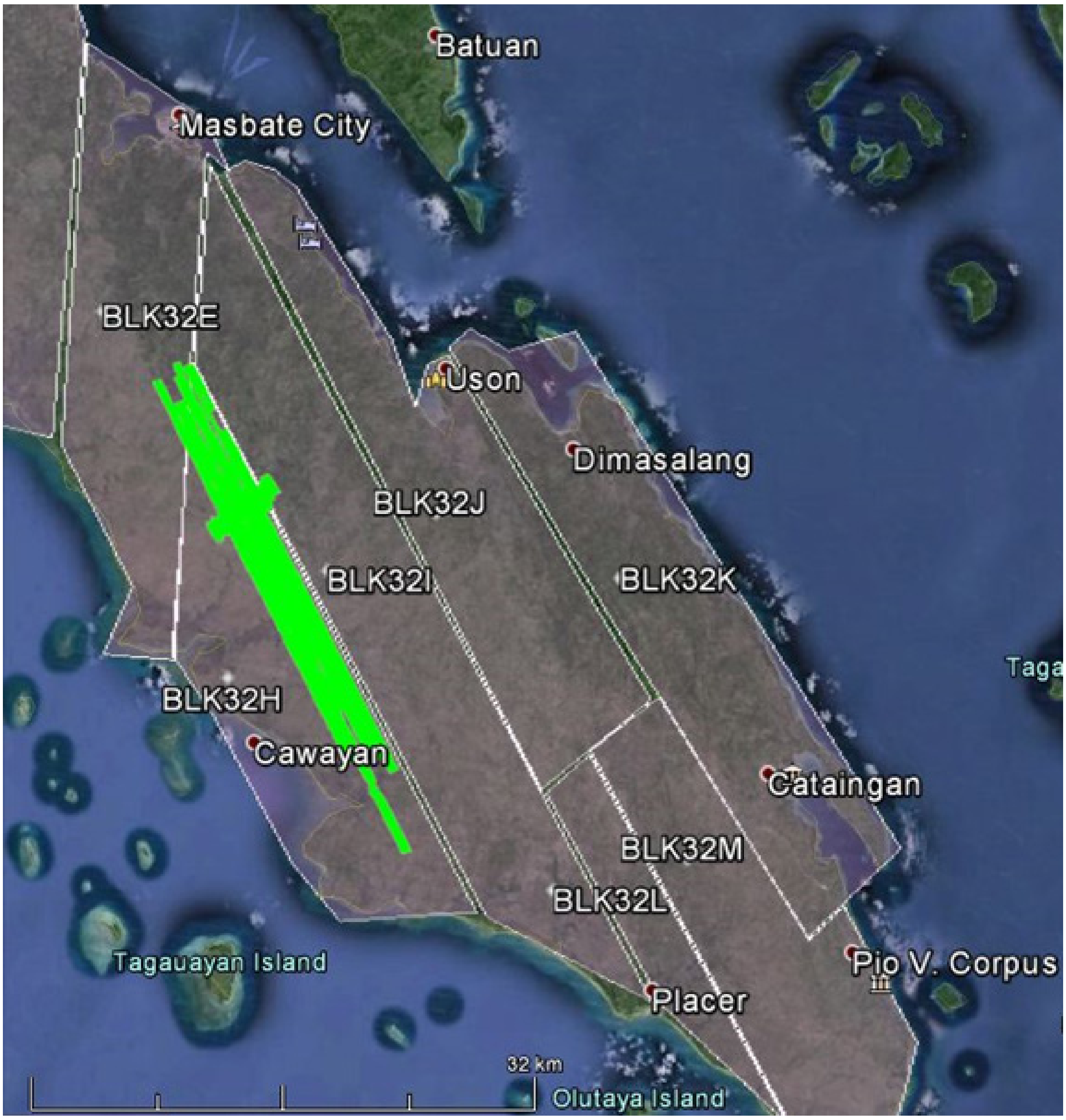


Figure A-7.6. Swath for Flight No. 1293P

Annex 8. Mission Summary Reports

Flight Area	Zamboanga
Mission Name	**Blk75G**
Inclusive Flights	7452GC, 2557P
Mission Name	2BLK75G236A, 1BLK75S42A
Range data size	11.0 GB
Base data size	11.54 MB
POS	138 MB
Image	0 GB
Transfer date	September 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.04
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	1.79
Boresight correction stdev (<0.001deg)	0.000467
IMU attitude correction stdev (<0.001deg)	0.000867
GPS position stdev (<0.01m)	0.0100
Minimum % overlap (>25)	53.63%
Ave point cloud density per sq.m. (>2.0)	4.48
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	94
Maximum Height	743.58 m
Minimum Height	67.35 m
Classification (# of points)	
Ground	16,272,441
Low vegetation	13,504,357
Medium vegetation	46,434,264
High vegetation	149,751,624
Building	1,620,100
Orthophoto	No
Processed by	Engr. AnalynNaldo, Engr. Harmond Santos, Engr. RoaShalemar Redo

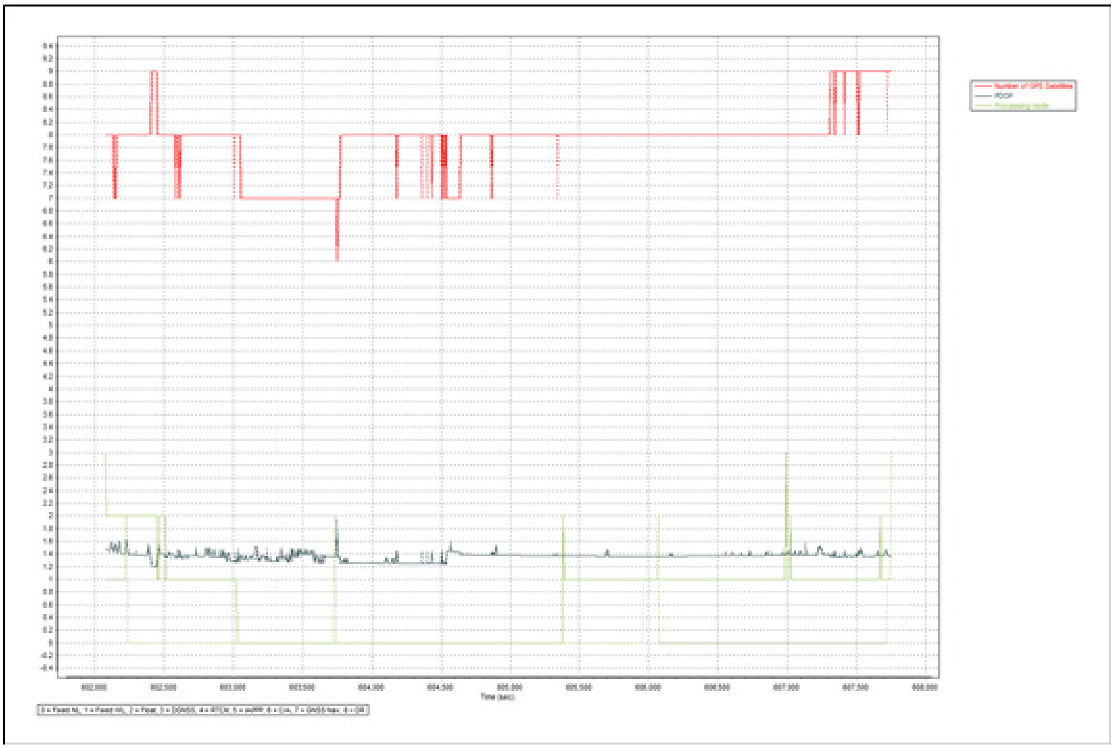


Figure A-8.1 Solution Status

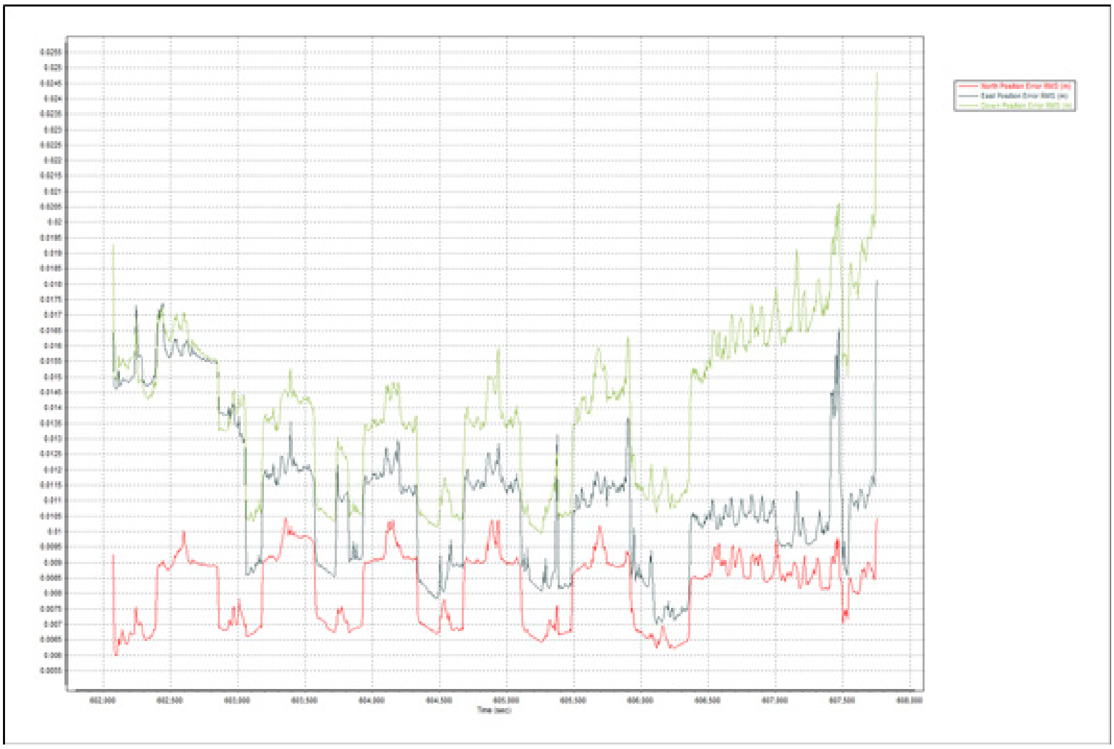


Figure A-8.2 Smoothed Performance Metric Parameters

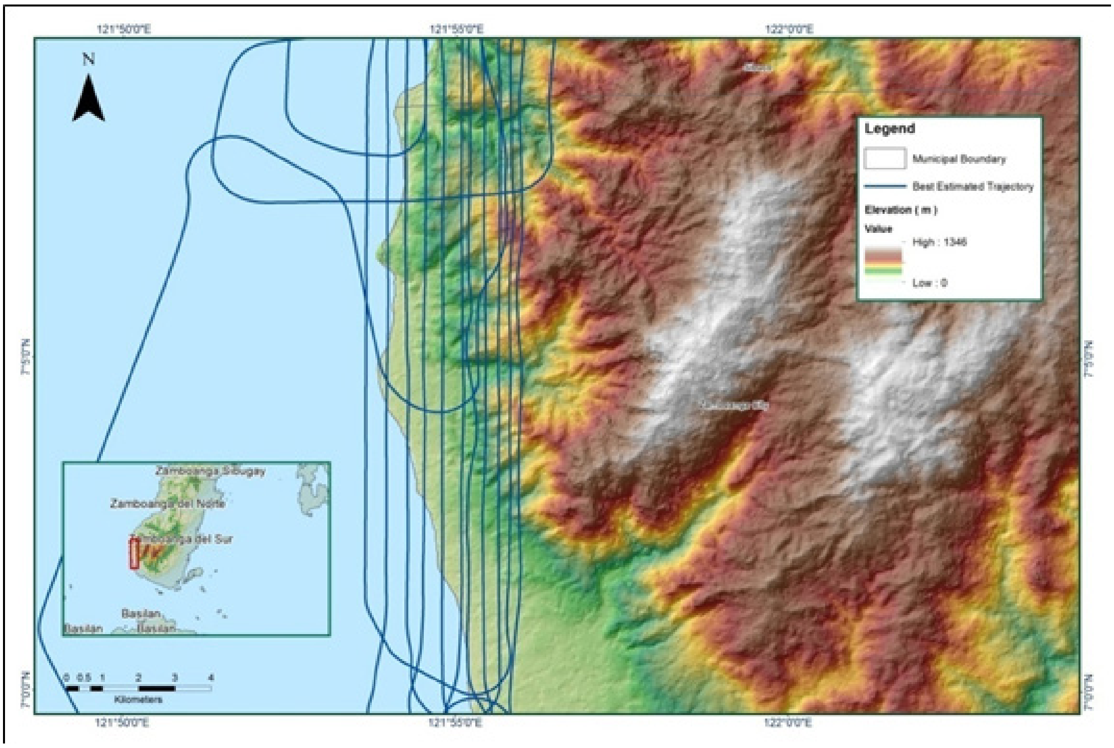


Figure A-8.3 Best Estimated Trajectory

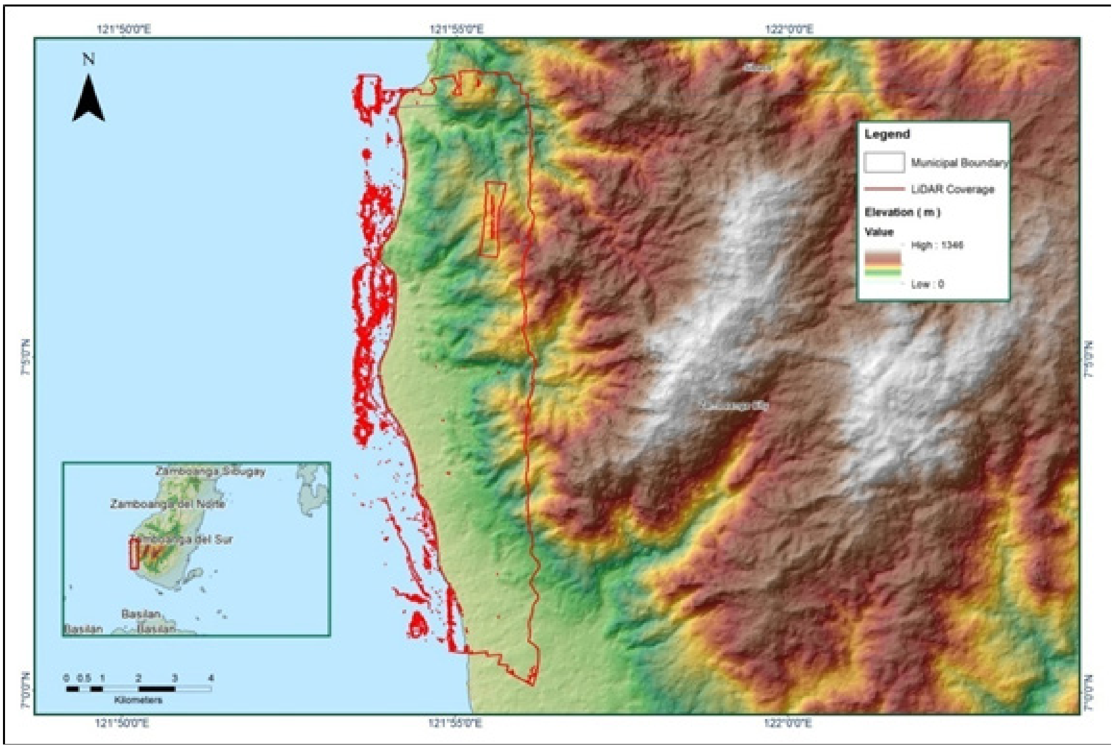


Figure A-8.4 Coverage of LiDAR data

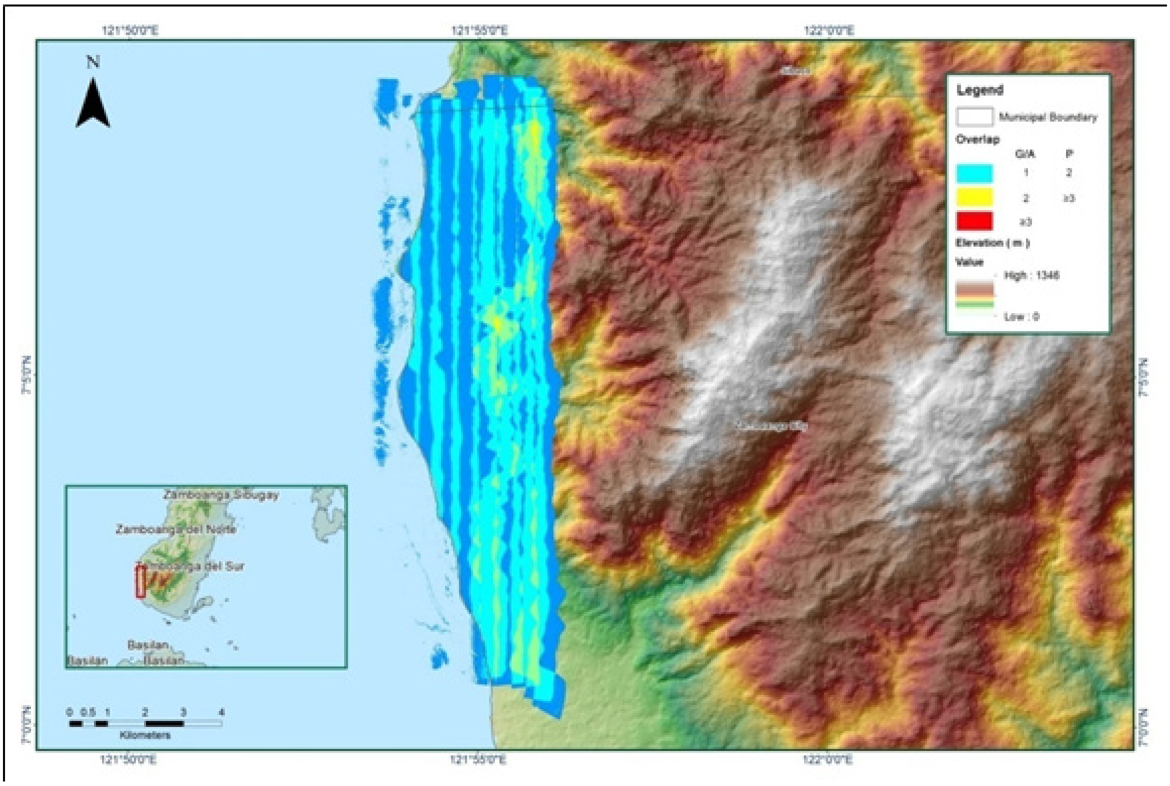


Figure A-8.5 Image of data overlap

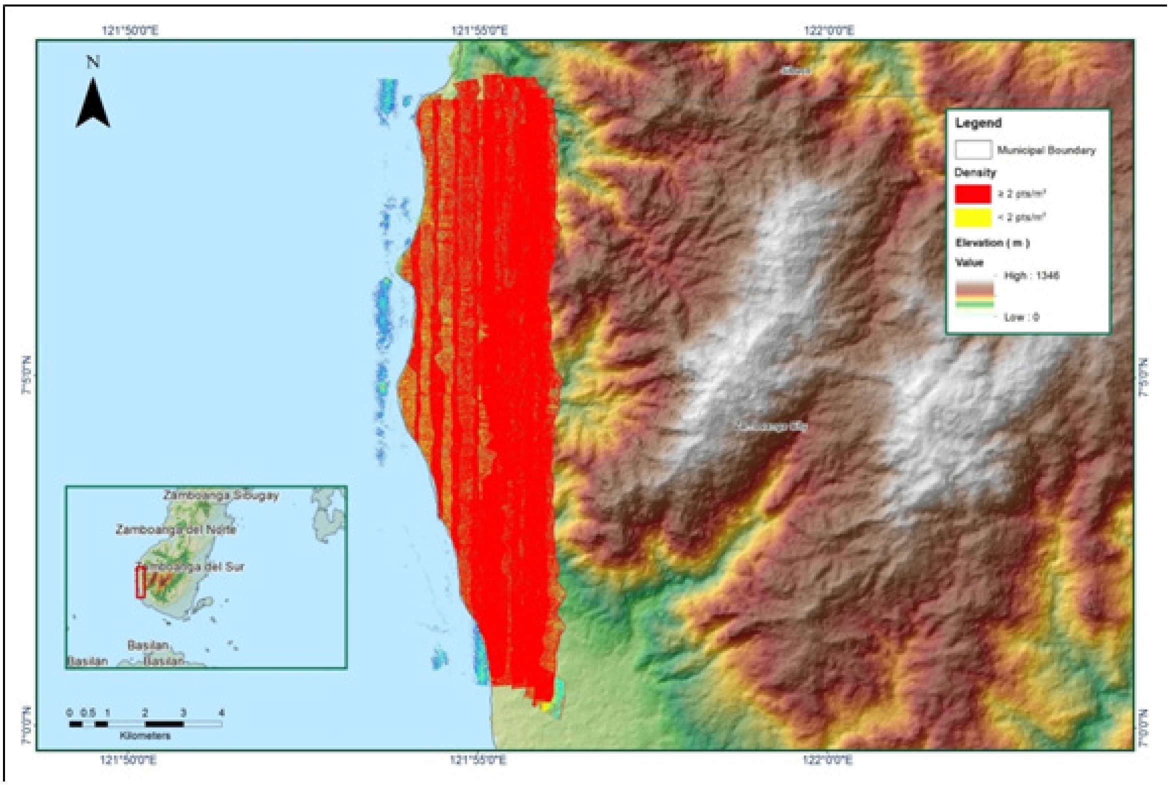


Figure A-8.6 Density map of merged LiDAR data

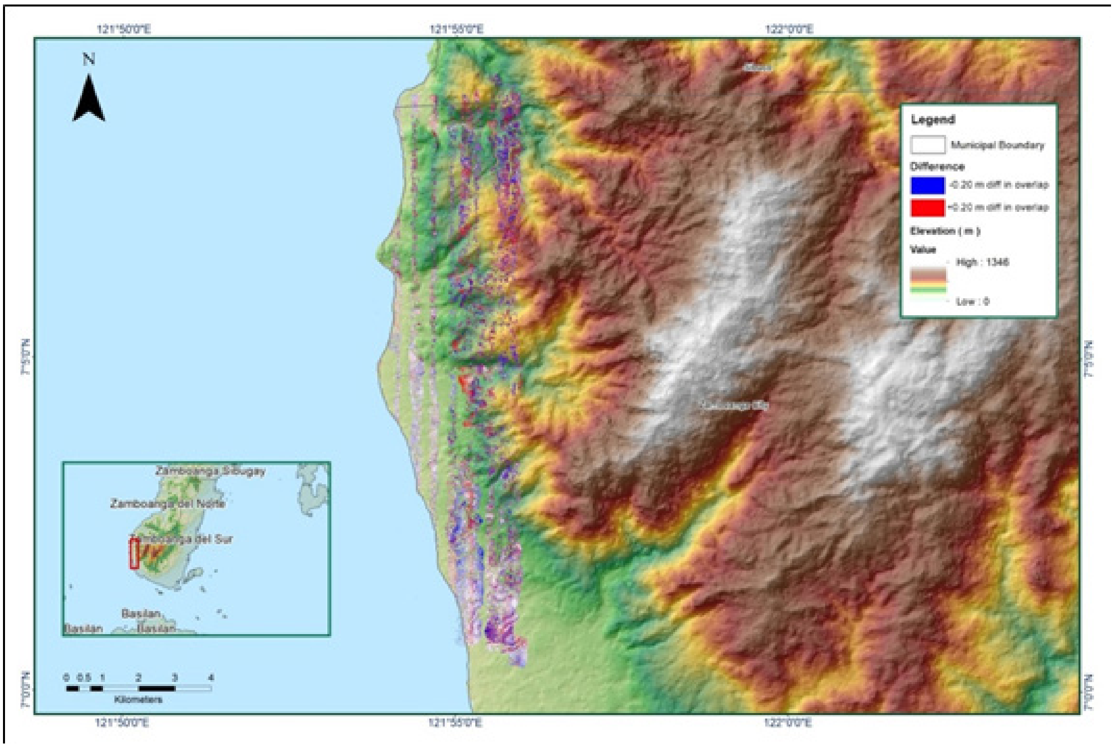


Figure A-8.7 Elevation difference between flight lines

Annex 9. Limpapa Model Basin Parameters

Table A-9.1 Limpapa 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
W460	0.0045786	65.74375	0.0	0.053397	0.096825	Discharge	0.83653	0.03	Ratio to Peak	0.9
W450	0.0046004	65.59625	0.0	0.0658575	0.11942	Discharge	1.3027	0.03	Ratio to Peak	0.9
W440	0.0054413	60.35375	0.0	0.061677	0.111845	Discharge	0.42839	0.03	Ratio to Peak	0.9
W430	0.0055033	60	0.0	0.026487	0.04803	Discharge	0.0375467	0.03	Ratio to Peak	0.9
W420	0.004184	68.545	0.0	0.065115	0.118075	Discharge	0.48350	0.03	Ratio to Peak	0.9
W410	0.0038204	71.345	0.0	0.0498465	0.090385	Discharge	0.62120	0.03	Ratio to Peak	0.9
W400	0.0055033	60	0.0	0.0378904	0.06871	Discharge	0.21142	0.03	Ratio to Peak	0.9
W390	0.0041385	68.88375	0.0	0.049545	0.08984	Discharge	0.50192	0.03	Ratio to Peak	0.9
W380	0.0044739	66.465	0.0	0.0514575	0.093305	Discharge	0.72100	0.03	Ratio to Peak	0.9
W370	0.0040492	69.5575	0.0	0.0543105	0.09848	Discharge	0.68173	0.03	Ratio to Peak	0.9
W360	0.0052789	61.3	0.0	0.076113	0.138015	Discharge	0.90862	0.03	Ratio to Peak	0.9
W350	0.0045483	65.95125	0.0	0.0421124	0.076365	Discharge	0.30002	0.03	Ratio to Peak	0.9
W340	0.0039419	70.38375	0.0	0.0450045	0.081605	Discharge	0.40216	0.03	Ratio to Peak	0.9
W330	0.0038893	70.7975	0.0	0.0494055	0.08959	Discharge	0.43674	0.03	Ratio to Peak	0.9
W320	0.0045642	65.8425	0.0	0.13266	0.24056	Discharge	2.5883	0.03	Ratio to Peak	0.9
W310	0.0034443	74.4925	0.0	0.0640035	0.11606	Discharge	1.1337	0.03	Ratio to Peak	0.9
W300	0.0030758	77.85875	0.0	0.0731295	0.13261	Discharge	1.5034	0.03	Ratio to Peak	0.9
W290	0.0036129	73.0475	0.0	0.0174730	0.0316845	Discharge	0.0617843	0.03	Ratio to Peak	0.9
W280	0.0041749	68.6125	0.0	0.0515025	0.09339	Discharge	0.61121	0.03	Ratio to Peak	0.9
W270	0.0026286	82.375	0.0	0.0504495	0.091485	Discharge	0.75351	0.03	Ratio to Peak	0.9
W260	0.0054956	60.04375	0.0	0.0628875	0.114035	Discharge	0.50911	0.03	Ratio to Peak	0.9
W250	0.0035791	73.33375	0.0	0.0234729	0.042564	Discharge	0.11803	0.03	Ratio to Peak	0.9
W240	0.0053207	61.05375	0.0	0.0449361	0.081485	Discharge	0.44752	0.03	Ratio to Peak	0.9

Annex 10. Limpapa Model Reach Parameters

Table A-9.1 Limpapa Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R20	Automatic Fixed Interval	1529.0	0.0291690	0.4	Trapezoid	30	0.01
R30	Automatic Fixed Interval	745.98	0.0836539	0.4	Trapezoid	30	0.01
R40	Automatic Fixed Interval	359.71	0.0354376	0.4	Trapezoid	30	0.01
R50	Automatic Fixed Interval	659.12	0.0375782	0.4	Trapezoid	30	0.01
R70	Automatic Fixed Interval	2287.8	0.0807023	0.4	Trapezoid	30	0.01
R90	Automatic Fixed Interval	3182.4	0.0976951	0.4	Trapezoid	30	0.01
R100	Automatic Fixed Interval	707.70	0.0779838	0.4	Trapezoid	30	0.01
R170	Automatic Fixed Interval	892.55	0.0570009	0.4	Trapezoid	30	0.01
R190	Automatic Fixed Interval	5088.4	0.0782778	0.4	Trapezoid	30	0.01
R200	Automatic Fixed Interval	503.85	0.0175435	0.4	Trapezoid	30	0.01
R210	Automatic Fixed Interval	870.54	0.0416564	0.4	Trapezoid	30	0.01

Annex 11. Limpapa Field Validation Points

Table A-11.1 Limpapa Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	7.14399	121.9044	0.03	0.00	0.03		5 -Year
2	7.143635	121.9035	0.03	0.00	0.03	Ondoy	5 -Year
3	7.141444	121.9127	0.03	0.20	-0.17	yolanda	5 -Year
4	7.141327	121.9126	0.03	0.20	-0.17	yolanda	5 -Year
5	7.141183	121.9128	0.04	0.20	-0.16	yolanda	5 -Year
6	7.140828	121.9124	0.16	0.10	0.06	yolanda	5 -Year
7	7.140996	121.9119	0.04	0.10	-0.06	yolanda	5 -Year
8	7.14106	121.9119	0.05	0.20	-0.15	yolanda	5 -Year
9	7.141186	121.9118	0.12	0.20	-0.08	yolanda	5 -Year
10	7.141517	121.9117	0.03	0.20	-0.17	yolanda	5 -Year
11	7.141526	121.9118	0.03	0.20	-0.17	yolanda	5 -Year
12	7.141558	121.9121	0.03	0.00	0.03	yolandaa	5 -Year
13	7.141584	121.9128	0.03	0.20	-0.17	yolanda	5 -Year
14	7.144646	121.9032	0.12	0.00	0.12	Ondoy	5 -Year
15	7.145296	121.9033	0.03	0.00	0.03	Yolanda	5 -Year
16	7.145528	121.9035	0.06	0.00	0.06	Yolanda	5 -Year
17	7.146023	121.904	0.04	0.20	-0.16	Yolanda	5 -Year
18	7.14601	121.9042	0.16	0.20	-0.04	Yolanda	5 -Year
19	7.148084	121.9045	0.03	0.00	0.03	yolanda	5 -Year
20	7.14805	121.9047	0.03	0.20	-0.17	yolanda	5 -Year
21	7.149744	121.9062	0.03	0.13	-0.10	yolanda	5 -Year
22	7.149735	121.9063	0.10	0.13	-0.03	yolanda	5 -Year
23	7.149833	121.9065	0.12	0.12	0.00	yolanda	5 -Year
24	7.150058	121.9062	0.06	0.13	-0.07	yolanda	5 -Year
25	7.150141	121.9062	0.06	0.13	-0.07	yolanda	5 -Year
26	7.150194	121.9063	0.03	0.00	0.03	yolanda	5 -Year
27	7.150241	121.9064	0.03	0.00	0.03	yolanda	5 -Year
28	7.150273	121.9062	0.20	0.13	0.07	yolanda	5 -Year
29	7.150462	121.9063	0.03	0.10	-0.07	yolanda	5 -Year
30	7.150516	121.9065	0.03	0.06	-0.03	yolanda	5 -Year
31	7.150409	121.9065	0.03	0.05	-0.02	yolanda	5 -Year
32	7.150478	121.9066	0.03	0.06	-0.03	yolanda	5 -Year
33	7.150351	121.9066	0.03	0.10	-0.07	yolanda	5 -Year
34	7.15033	121.9065	0.03	0.10	-0.07	yolanda	5 -Year
35	7.150273	121.9065	0.03	0.05	-0.02	yolanda	5 -Year
36	7.15025	121.9065	0.03	0.00	0.03	yolanda	5 -Year
37	7.150161	121.9064	0.03	0.10	-0.07	yolanda	5 -Year
38	7.150165	121.9068	0.03	0.00	0.03	yolanda	5 -Year
39	7.150128	121.9069	0.03	0.00	0.03	yolanda	5 -Year
40	7.149818	121.907	0.03	0.00	0.03		5 -Year
41	7.149724	121.9067	0.03	0.05	-0.02	yolanda	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
42	7.150315	121.9075	0.16	0.00	0.16		5 -Year
43	7.148733	121.9082	0.14	0.10	0.04	Yolanda	5 -Year
44	7.148618	121.9082	0.16	0.10	0.06	Yolanda	5 -Year
45	7.148427	121.9084	0.11	0.10	0.01	Yolanda	5 -Year
46	7.148687	121.9089	0.06	0.10	-0.04	Yolanda	5 -Year
47	7.149086	121.9083	0.07	0.10	-0.03	Yolanda	5 -Year
48	7.149091	121.9085	0.05	0.10	-0.05	Yolanda	5 -Year
49	7.146625	121.909	0.04	0.30	-0.26	yolanda	5 -Year
50	7.146775	121.909	0.05	0.10	-0.05	yolanda	5 -Year
51	7.14688	121.9088	0.08	0.10	-0.02	yolanda	5 -Year
52	7.14703	121.909	0.03	0.10	-0.07	yolanda	5 -Year
53	7.147005	121.9088	0.03	0.10	-0.07	yolanda	5 -Year
54	7.147085	121.9089	0.03	0.10	-0.07	yolanda	5 -Year
55	7.147116	121.9084	0.03	0.10	-0.07	yolanda	5 -Year
56	7.147101	121.9083	0.05	0.10	-0.05	yolanda	5 -Year
57	7.14756	121.9091	0.06	0.10	-0.04	yolanda	5 -Year
58	7.14762	121.9089	0.08	0.10	-0.02	yolanda	5 -Year
59	7.147153	121.9088	0.05	0.10	-0.05	yolanda	5 -Year
60	7.147464	121.909	0.04	0.10	-0.06	yolanda	5 -Year
61	7.148099	121.9085	0.08	0.00	0.08		5 -Year
62	7.147979	121.9089	0.07	0.10	-0.03	yolanda	5 -Year
63	7.148047	121.9093	0.06	0.10	-0.04	yolanda	5 -Year
64	7.148271	121.9095	0.11	0.10	0.01	Yolanda	5 -Year
65	7.148384	121.9096	0.11	0.30	-0.19	yolanda	5 -Year
66	7.148443	121.9097	0.14	0.10	0.04	Yolanda	5 -Year
67	7.148556	121.9098	0.13	0.10	0.03	Yolanda	5 -Year
68	7.148635	121.91	0.18	0.10	0.08	Yolanda	5 -Year
69	7.148683	121.9102	0.29	0.00	0.29		5 -Year
70	7.148734	121.9098	0.08	0.10	-0.02	Yolanda	5 -Year
71	7.148803	121.9097	0.11	0.10	0.01	Yolanda	5 -Year
72	7.148052	121.9098	0.31	0.10	0.21	Yolanda	5 -Year
73	7.148156	121.9099	0.48	0.10	0.38	Yolanda	5 -Year
74	7.147763	121.9095	0.04	0.10	-0.06	Yolanda	5 -Year
75	7.147799	121.9091	0.06	0.10	-0.04	yolanda	5 -Year
76	7.148254	121.9093	0.07	0.10	-0.03	Yolanda	5 -Year
77	7.146958	121.9085	0.08	0.10	-0.02	yolanda	5 -Year
78	7.147784	121.9086	0.07	0.00	0.07		5 -Year
79	7.145777	121.9099	0.03	0.20	-0.17	yolanda	5 -Year
80	7.145773	121.9098	0.17	0.20	-0.03	yolanda	5 -Year
81	7.14939	121.9049	0.03	0.30	-0.27	yolanda	5 -Year
82	7.149776	121.9052	0.23	0.10	0.13	yolanda	5 -Year
83	7.149754	121.9048	0.07	0.00	0.07	yolanda	5 -Year
84	7.148512	121.9045	0.03	0.20	-0.17	yolanda	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
85	7.14322	121.9038	0.23	0.20	0.03	Yolanda	5 -Year
86	7.143295	121.9032	0.06	0.00	0.06		5 -Year
87	7.149208	121.905	0.03	0.00	0.03		5 -Year
88	7.14785	121.9057	0.03	0.05	-0.02	yolanda	5 -Year
89	7.147708	121.9058	0.06	0.05	0.01	yolanda	5 -Year
90	7.141904	121.9088	0.06	0.20	-0.14	Yolanda	5 -Year
91	7.141181	121.9105	0.09	0.20	-0.11	yolanda	5 -Year
92	7.140564	121.9126	0.03	0.00	0.03		5 -Year
93	7.14155	121.9125	0.03	0.20	-0.17	yolanda	5 -Year
94	7.144554	121.9068	0.33	0.30	0.03	Yolanda	5 -Year
95	7.146134	121.9023	0.03	0.00	0.03	Yolanda	5 -Year
96	7.146074	121.9023	0.09	0.30	-0.21	Yolanda	5 -Year
97	7.149866	121.9063	0.10	0.13	-0.03	yolanda	5 -Year
98	7.150008	121.9063	0.07	0.13	-0.06	yolanda	5 -Year
99	7.150222	121.9066	0.03	0.00	0.03	yolanda	5 -Year
100	7.150189	121.9066	0.03	0.00	0.03	yolanda	5 -Year
101	7.150273	121.9069	0.03	0.20	-0.17	yolanda	5 -Year
102	7.150405	121.9067	0.03	0.00	0.03	yolanda	5 -Year
103	7.150116	121.9067	0.03	0.00	0.03	yolanda	5 -Year
104	7.150088	121.9066	0.11	0.05	0.06	yolanda	5 -Year
105	7.14979	121.9066	0.03	0.10	-0.07	1m	5 -Year
106	7.14962	121.9064	0.09	0.10	-0.01	yolanda	5 -Year
107	7.150156	121.9071	0.17	0.00	0.17		5 -Year
108	7.146841	121.9086	0.03	0.10	-0.07	yolanda	5 -Year
109	7.146866	121.9082	0.03	0.10	-0.07	yolanda	5 -Year
110	7.146994	121.9082	0.03	0.10	-0.07	yolanda	5 -Year
111	7.149226	121.9091	0.12	0.10	0.02	Yolanda	5 -Year
112	7.149196	121.9093	0.03	0.10	-0.07	Yolanda	5 -Year
113	7.148756	121.9104	0.14	0.00	0.14		5 -Year
114	7.148408	121.9095	0.09	0.10	-0.01	Yolanda	5 -Year
115	7.148367	121.9094	0.06	0.10	-0.04	Yolanda	5 -Year
116	7.148406	121.9093	0.08	0.10	-0.02	Yolanda	5 -Year
117	7.148471	121.9091	0.10	0.10	0.00	Yoanda	5 -Year
118	7.148665	121.9095	0.06	0.10	-0.04	Yolanda	5 -Year
119	7.148531	121.9094	0.08	0.10	-0.02	Yolanda	5 -Year
120	7.145881	121.9093	0.03	0.20	-0.17	yolanda	5 -Year
121	7.145911	121.9096	0.08	0.20	-0.12	yolanda	5 -Year
122	7.146107	121.9093	0.03	0.20	-0.17	yolanda	5 -Year
123	7.146285	121.9091	0.03	0.20	-0.17	yolanda	5 -Year
124	7.14547	121.9101	0.12	0.20	-0.08	yolanda	5 -Year
125	7.144774	121.91	0.05	0.20	-0.15	yolanda	5 -Year
126	7.145297	121.9097	0.05	0.20	-0.15	yolanda	5 -Year
127	7.145443	121.9096	0.03	0.20	-0.17	yloanda	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
128	7.145529	121.9095	0.03	0.20	-0.17	yolanda	5 -Year
129	7.145726	121.9094	0.03	0.20	-0.17	yolanda	5 -Year
130	7.144953	121.9102	0.19	0.20	-0.01	yolanda	5 -Year
131	7.148408	121.911	0.07	0.00	0.07		5 -Year
132	7.148003	121.9096	0.11	0.10	0.01	Yolanda	5 -Year
133	7.140143	121.9122	0.03	0.00	0.03		5 -Year
134	7.149091	121.9037	0.03	0.00	0.03		5 -Year
135	7.144916	121.9046	0.10	0.30	-0.20	Ondoy	5 -Year
136	7.145032	121.9043	0.04	0.20	-0.16	Ondoy	5 -Year
137	7.145031	121.9042	0.06	0.00	0.06	Ondoy	5 -Year
138	7.145044	121.9041	0.08	0.00	0.08	Ondoy	5 -Year
139	7.145062	121.9039	0.05	0.30	-0.25	Ondoy	5 -Year
140	7.145014	121.9036	0.25	0.30	-0.05	Yolanda	5 -Year
141	7.145462	121.9038	0.03	0.00	0.03		5 -Year
142	7.149859	121.9075	0.05	0.00	0.05	Ondoy	5 -Year
143	7.149781	121.9074	0.03	0.20	-0.17	yolanda	5 -Year
144	7.149722	121.9073	0.03	0.20	-0.17	yolanda	5 -Year
145	7.148127	121.9079	0.03	0.20	-0.17	yolanda	5 -Year
146	7.14834	121.9073	0.03	0.00	0.03		5 -Year
147	7.144945	121.9104	0.11	0.20	-0.09	yolanda	5 -Year
148	7.145555	121.9097	0.16	0.20	-0.04	yolanda	5 -Year
149	7.146024	121.9093	0.08	0.20	-0.12	yolanda	5 -Year
150	7.14624	121.9091	0.03	0.30	-0.27	yolanda	5 -Year
151	7.146689	121.9089	0.09	0.10	-0.01	yolanda	5 -Year
152	7.146705	121.9087	0.03	0.10	-0.07	yolanda	5 -Year
153	7.147031	121.9086	0.05	0.10	-0.05	yolanda	5 -Year
154	7.146843	121.9081	0.05	0.10	-0.05	yolanda	5 -Year
155	7.14694	121.908	0.07	0.10	-0.03	yolanda	5 -Year
156	7.147921	121.9088	0.09	0.10	-0.01	yolanda	5 -Year
157	7.147253	121.9091	0.05	0.10	-0.05	yolanda	5 -Year
158	7.147153	121.9092	0.03	0.10	-0.07	yolanda	5 -Year
159	7.146917	121.9092	0.03	0.10	-0.07	yolanda	5 -Year
160	7.1415	121.9131	0.03	0.20	-0.17	yolanda	5 -Year
161	7.141593	121.9123	0.03	0.20	-0.17	yolanda	5 -Year
162	7.141492	121.9119	0.03	0.20	-0.17	yolanda	5 -Year
163	7.141455	121.9117	0.03	0.00	0.03	yolanda	5 -Year
164	7.141354	121.9118	0.03	0.20	-0.17	yolanda	5 -Year
165	7.141354	121.9119	0.03	0.20	-0.17	yolanda	5 -Year
166	7.141291	121.9116	0.03	0.20	-0.17	yolanda	5 -Year
167	7.140839	121.9115	0.22	0.10	0.12	yolanda	5 -Year
168	7.14075	121.9118	0.16	0.10	0.06	yolanda	5 -Year
169	7.140102	121.9116	0.38	0.00	0.38		5 -Year
170	7.143617	121.9033	0.07	0.00	0.07	Ondoy	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
171	7.1436	121.9032	0.07	0.00	0.07	Ondoy	5 -Year
172	7.144429	121.9028	0.03	0.30	-0.27	Yolanda	5 -Year
173	7.145134	121.9027	0.09	0.00	0.09	Yolanda	5 -Year
174	7.14549	121.9029	0.03	0.00	0.03	Yolanda	5 -Year
175	7.145533	121.9027	0.04	0.00	0.04	Yolanda	5 -Year
176	7.145615	121.9027	0.03	0.30	-0.27	Yolanda	5 -Year
177	7.145316	121.9031	0.03	0.00	0.03	Yolanda	5 -Year
178	7.145426	121.9029	0.03	0.00	0.03	Yolanda	5 -Year
179	7.146227	121.9029	0.09	0.00	0.09	Yolanda	5 -Year
180	7.146036	121.903	0.16	0.30	-0.14	Ondoy	5 -Year
181	7.145861	121.903	0.03	0.20	-0.17	Ondoy	5 -Year
182	7.146397	121.903	0.04	0.04	0.00	Yolanda	5 -Year
183	7.146316	121.903	0.12	0.04	0.08	Yolanda	5 -Year
184	7.146273	121.9033	0.03	0.30	-0.27	Yolanda	5 -Year
185	7.146349	121.9034	0.04	0.30	-0.26	Yolanda	5 -Year
186	7.147395	121.9091	0.06	0.10	-0.04	yolanda	5 -Year
187	7.150218	121.907	0.03	0.00	0.03	yolanda	5 -Year
188	7.145388	121.9105	0.13	0.20	-0.07	yolanda	5 -Year
189	7.145939	121.9029	0.06	0.30	-0.24	Yolanda	5 -Year
190	7.147252	121.9089	0.03	0.10	-0.07	yolanda	5 -Year
191	7.146805	121.9059	0.03	0.00	0.03		5 -Year
				RMSE	0.12		

Annex 12. Educational Institutions affected by flooding in Limpapa Flood Plain

Table A-12.1 Educational Institutions Affected in Limpapa Floodplain

Zamboanga City				
		Rainfall Scenario		
Barangay	Building	5-year	25-year	100-year
Limpapa	New Hope Academy	None	None	None

Sibuco				
		Rainfall Scenario		
Barangay	Building	5-year	25-year	100-year
Limpapa	LIMPAPA NATIONAL HIGH SCHOOL	Low	Medium	Medium

Annex 13. Health Institutions affected by flooding in Limpapa Floodplain

Table A-12.1 Health Institutions Affected in Limpapa Floodplain

Sibuco				
Barangay	Building	Rainfall Scenario		
		5-year	25-year	100-year
Limpapa	limpapa, health center	Low	Medium	Medium