LiDAR Surveys and Flood Mapping of Maranding River

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For questions/queries regarding this report, contact:

Engr. Alan E. Milano
Project Leader, PHIL-LiDAR 1 Program
Mindanao State University – Iligan Institute of Technology
Iligan City, Philippines 9200
E-mail: aemilano1960@yahoo.com

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots

LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
MSU-IIT	Mindanao State University – Iligan Institute of Technology
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MARANDING RIVER

Enrico C. Paringit, Dr. Eng. and Engr. Alan Milano

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 in 2014" or Phil-LiDAR 1, 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.

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

The implementing partner university for the Phil-LiDAR 1 Program is the Mindanao State University – Iligan Institute of Technology (MSU-IIT). MSU-IIT 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 16 river basins in the Northern Mindanao Region. The university is located in Iligan City in the province of Lanao del Norte.

1.2 Overview of the Maranding River Basin

Maranding River Basin is situated in the province of Lanao del Norte under Region X at the northern part of Mindanao, Philippines. The main river used in delineating the basin is Maranding River, which traverses within the municipality of Lala.

Maranding River Basin covers the municipalities of Baroy, Kapatagan, Lala, Munai, Nunungan, Salvador, Sapad, Tangcal and Tubod in Lanao del Norte. Geographically, it is bounded on the northwest by Panguil Bay, on the northeast by the municipality of Baroy, on the south by the municipality of Kapatagan, and on the southeast by the municipality of Salvador. The river basin has an estimated area of 653.19 square kilometres. The floodplain area delineated within the river basin has an area of 347.17 square kilometres, which is 53.15% of the whole area of the basin. Furthermore, municipalities of Lala, Baroy, Salvador, Kapatagan, Sapad, and Nunungan are found within the floodplain. A total of 51,797 features were extracted within the floodplain which belong to the municipalities and cities within the flood prone area. In addition, the outlet of the basin where flow measurements were obtained is located specifically at Maranding Bridge, Brgy. Maranding, Lala, Lanao del Norte along Maranding River.

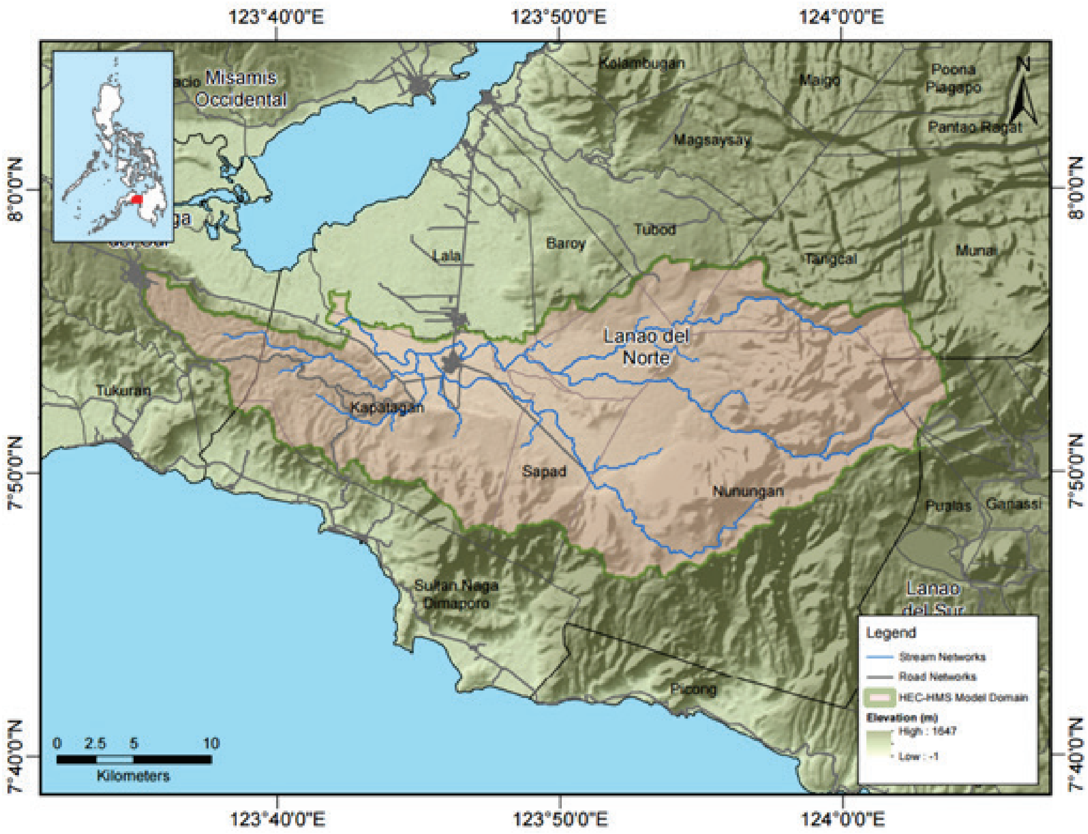


Figure 1. Map of Maranding River Basin (in brown)

Maranding River is one of the major rivers endowed to Lala, which performs both economic and ecological functions. It has been utilized by the National Irrigation Authority (NIA) to cater agriculture industry in the province, particularly rice production in the Kapatagan Valley, which is considered as the province's rice granary, as well as, for domestic uses before it empties into Panguil Bay (lanaodelnorte.gov.ph, N.D.). Its tributaries are the rivers of: Inasagan and Cabuyao rivers. The other major rivers are Butadon River and Kidalos River. Spring and creeks are also present. (worldlibrary.org, N.D.).

In terms of the landcover, this river basin has 8.6 % of Brushland, 0.25% of Built-up, 21.32% of closed canopy forest, 39.12% of cultivated area, 2.66% used as fishponds, 0.95% for grasslands, 0.38% for the inland water, 1.96% for mangroves, 4.91% for open canopy forest and 19.46% for tree plantation and perennial. A great percentage is alloted to cultivated areas.

Maranding is considered as one of the flood prone areas in Northern Mindanao (gmanetwork.com, N.D.). In the past years, Mindanao has been devastated with typhoons and other natural disasters that took thousands of lives and damaged a lot of properties. n August 2015, 130 families were affected by flash floods due to the overflowing of at least three (3) rivers in Lanao, where Maranding was one of the most affected areas. Also, last March 9, 2017, the PAGASA-DOST declared "Orange Warning" over Lanao del Norte and other provinces due to the intense rainfall brought by the tail end of the cold front. Residents in these areas were advised to be alert for possible evacuation as flooding was expected.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MARANDING FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, and Engr. Frank Nicolas H. Ilejay

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Maranding floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Maranding Floodplain in Misamis Occidental. Each flight mission had an average of 10 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2 shows the flight plan for Maranding floodplain survey.

Table 1. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Fre-quency	Average Speed	Average Turn Time (Minutes)
BLK 71A	1000m	30	50	200	30	130	5
BLK 71B	1000m	30	50	200	30	130	5
BLK 71C	1000m	30	50	200	30	130	5
BLK 71E	1000m	30	50	200	30	130	5
BLK 71ext	1000m	30	50	200	30	130	5
BLK 71F	800/900/1000m	30	50	200	30	130	5
BLK 71G	1000m	30	50	200	30	130	5
BLK 76B	1000m	30	50	200	30	130	5
BLK 76C	1000m	30	50	200	30	130	5
BLK 76H supple-ment	1000m	30	50	200	30	130	5
BLK 76I	1000m	30	50	200	30	130	5
BLK 76J	1000m	30	50	200	30	130	5
BLK 76K	1000m	30	50	200	30	130	5
BLK 76L	1000m	30	50	200	30	130	5

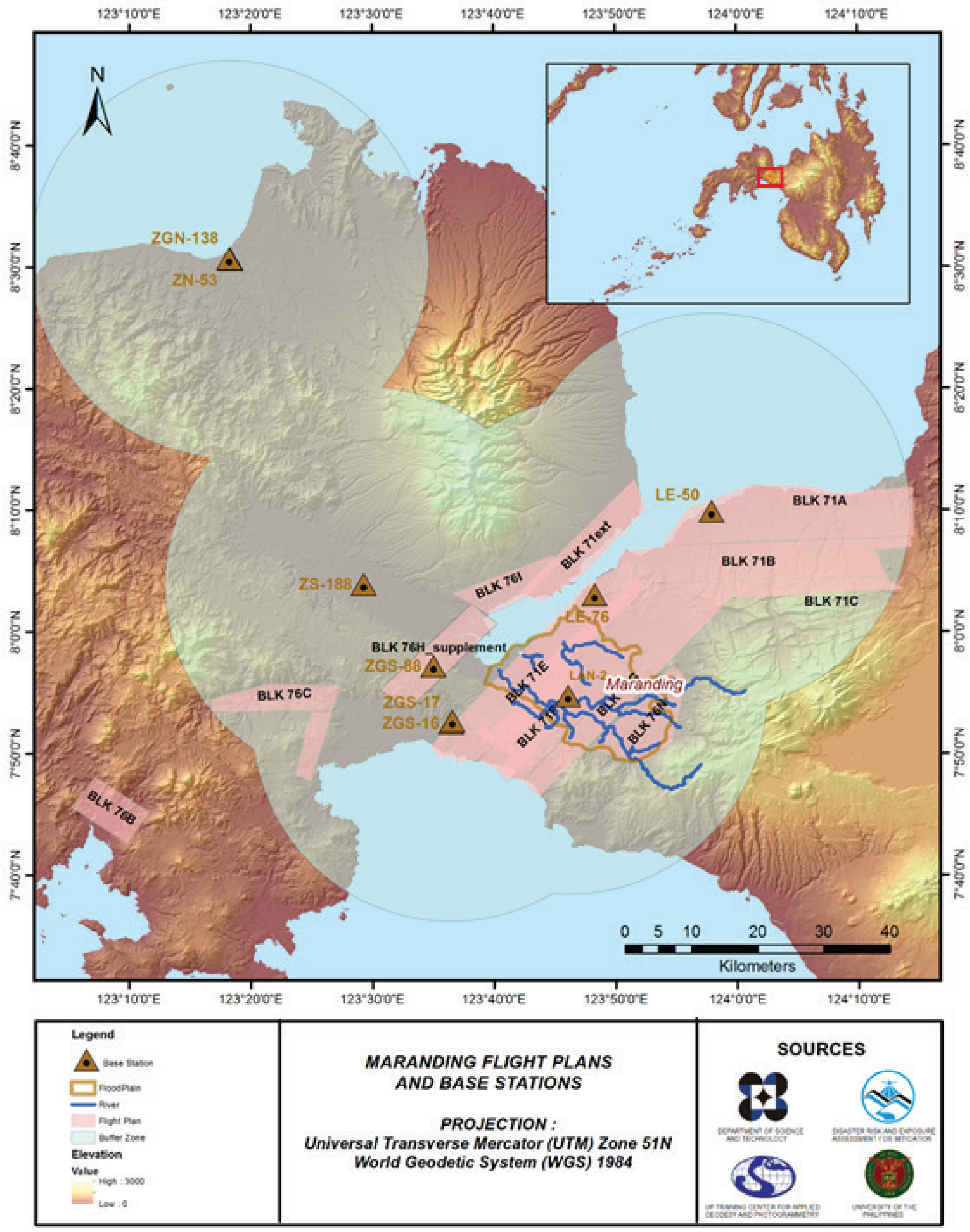


Figure 2. Flight Plan and base stations used for the Maranding Floodplain survey using Pegasus sensor.

2.2 Ground Base Station

The field team was able to recover five (5) NAMRIA ground control points: LAN-2 which is of first (1st) order accuracy, and ZGS-16, ZGS-17, ZGS-88, and ZGN-138 which are of second (2nd) order accuracy. Four (4) benchmarks were recovered: LE-50, LE-76, ZN-53, and ZS-188.

The certifications for the base stations are found in ANNEX 2 while the baseline processing report for established point is found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey from May 22 to July 10, 2014, February 4 to March 4, 2016, and February 23, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, TRIMBLE SPS 985, and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Maranding floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Maranding Floodplain LiDAR Survey. Figure 3 to Figure 11 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 2 to Table 10 show the details about the following NAMRIA control stations and established points. Table 11, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a)

(b)

Figure 3. GPS set-up over LAN-02 on top of a concrete irrigation canal water gate in Brgy. Pinoyak, Lala, Lanao del Norte (a) and NAMRIA reference point LAN-02 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point LAN-02 used as base station for the LiDAR Acquisition

Station Name	**LAN-2**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7°54’46.07859” North 123°46’0.85333” East 17.35400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	364025.74 meters 875110.149 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	7°54'46.07859" North	7°54’42.56546” North 123°46’6.31720” East 83.92120 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	584533.45 meters 874680.35 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	584533.45 meters 874680.35 meters

(a)

(b)

Figure 4. GPS set-up over ZS-188 (a) at Brgy. Licomo, Zamboanga City, Zamboanga del Sur and NAMRIA reference point ZS-188 (b) as recovered by the field team

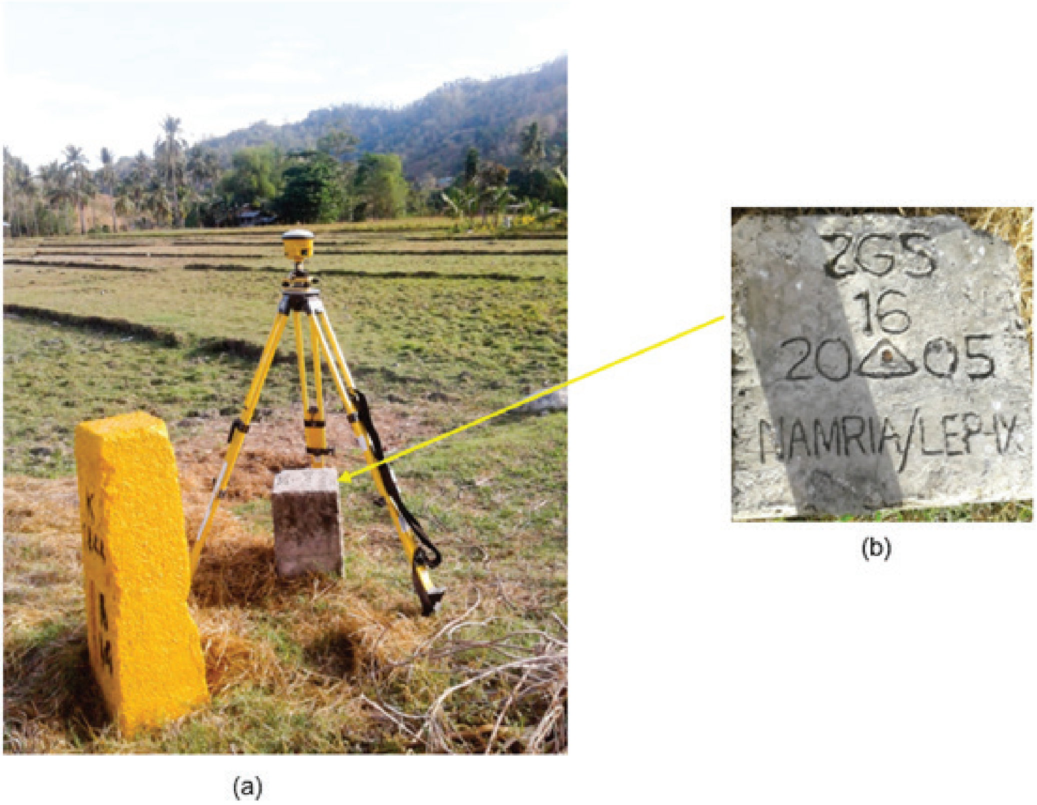


Figure 5. GPS set-up over ZGS-16 (a) in Purok Nangka, Brgy. Baclay, Tukuran, Zamboanga del Sur and NAMRIA reference point ZGS-16 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ZGN-60 used as base station for the LiDAR Acquisition.

Station Name	**ZS-188**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 03’ 56.69408” North 123° 29’ 12.15500” East 19.832 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Easting Northing	8° 03’ 53.11537” North 123° 29’ 17.60722” East 85.400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Latitude Longitude Ellipsoidal Height	553,627.634meters 891,542.089 meters

Table 4. Details of the recovered NAMRIA horizontal control point ZGS-16 used as base station for the LiDAR Acquisition

Station Name	ZGS-16	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 03’ 56.69408” North 123° 29’ 12.15500” East 19.832 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	8° 03’ 53.11537” North 123° 29’ 17.60722” East 85.400 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	553,627.634meters 891,542.089 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	566857.85 meters 870550.15 meters

(b)

Figure 6. GPS set-up over ZGS-17 (a) in Purok Kasoy, Brgy. Baclay, Tukuran, Zamboanga del Sur and NAMRIA reference point ZGS-17 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ZGS-17 used as base station for the LiDAR Acquisition.

Station Name	ZGS-17	
Order of Accuracy	**2rd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	7° 52’ 42.71658” North 123° 36’ 29.22049” East 29.68400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	567059.131 meters 871168.108 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	7° 2’ 39.19813” North 123° 36’ 34.68878” East 95.92400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	567035.66 meters 870863.18 meters

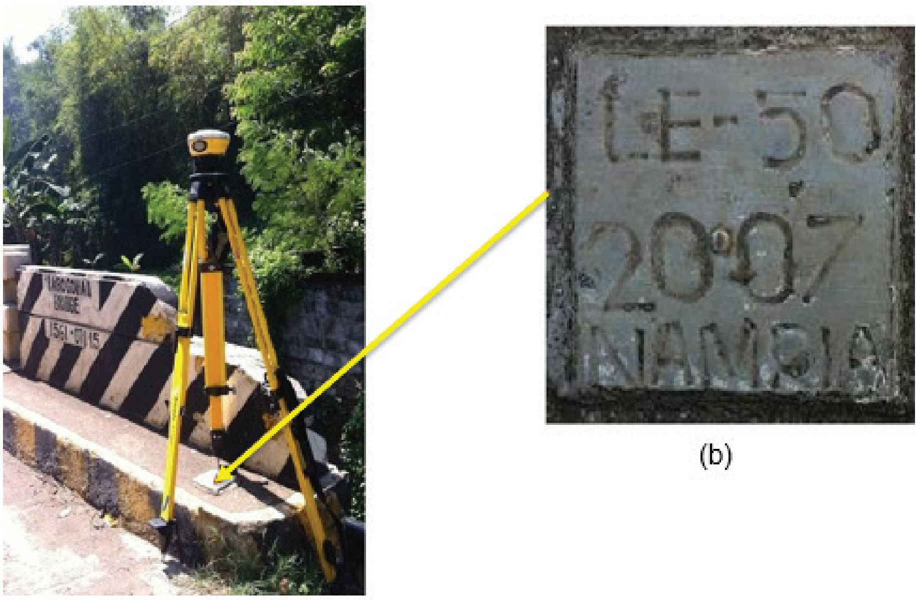
(b)

(a)

Figure 7. GPS set-up over ZGS-88 on a center island in Puroy Saray, Aurora, Zamboanga del Sur (a) and NAMRIA reference point ZGS-88 (b)as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point ZGS-88 used as base station for the LiDAR Acquisition.

Station Name	ZGS-88	
Order of Accuracy (benchmark)	**2nd**	
Elevation (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°9'54.972" North 123°57’50.357” East 6.91 m meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	385831.49 meters 902974.41 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°09’51.11024” North 123°57’55.36634” East 73.452 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	606345.902 meters 902577.426 meters



(a) (b)

Figure 8. GPS set-up over LE-50 on the Barogohan Bridge in Maigo, Lanao del Norte (a) and NAMRIA bench mark point LE-50 (b) as recovered by the field team.

Table 7. Details of the established point ZN- 53 used as base station for the LiDAR Acquisition.

Station Name	LE-50	
Order of Accuracy (benchmark)	1st	
Elevation (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°9'54.972" North 123°57'50.357" East 6.91 m meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92	Easting Northing	385831.49 meters 902974.41 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°09'51.11024" North 123°57'55.36634" East 73.452 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92	Easting Northing	606345.902 meters 902577.426 meters

(b)

(a)

Figure 9. GPS set-up over LE-76 at Bulod Bridge footwalk of Brgy. Bulod, Tubud, Lanao del Norte (a) and NAMRIA reference point LE-76 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA vertical control point LE-76 used as base station for the LiDAR Acquisition with established coordinates.

Station Name	**LE-76**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 03’ 05.36825” North 123° 48’ 12.37307”East 9.355 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 03’ 01.82183” North 123° 48’ 17.82405” East 75.717 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	588,530.790 meters 890,021.013 meters

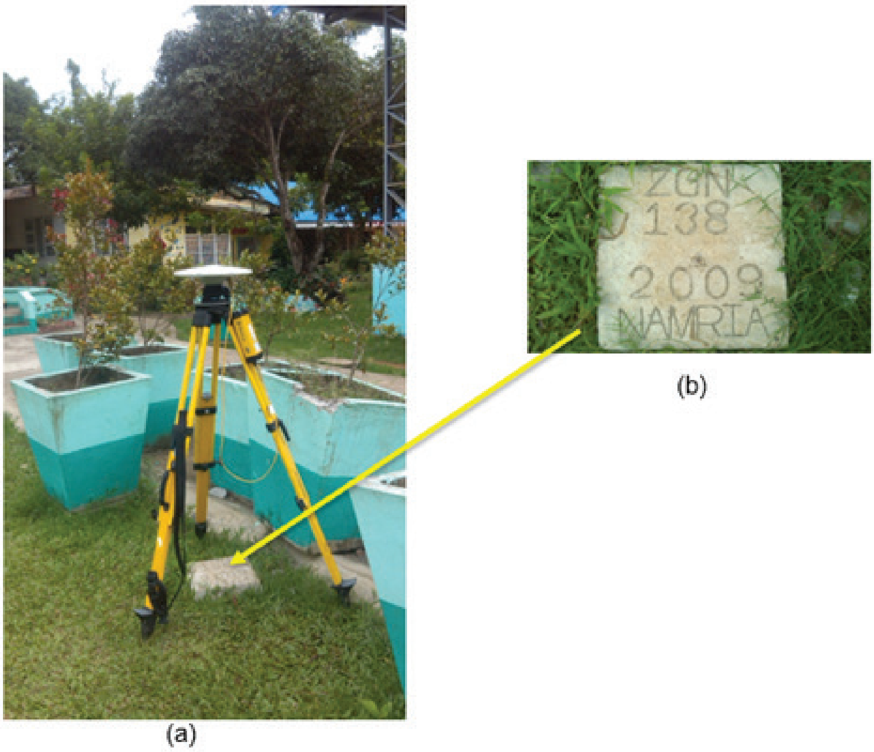


Figure 10. GPS set-up over ZGN-138 (a) in Katipinan Zamboanga del Norte and NAMRIA reference point ZGN-138 (b) as recovered by the field team.

Table 9. Ground control points used during LiDAR data acquisition

Station Name	ZGN-138	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 30’ 40.65974”North 122° 18’ 14.44217”East 6.715 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	533471.036 meters 941106.14 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84))	Latitude Longitude Ellipsoidal Height	8° 30’ 36.94779” North 123° 18’ 19.85548”East 70.925 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	533459.32 meters 940776.74 meters

(a)

Figure 11. GPS set-up over ZN-53 (a) Brgy. Daanglungsod, Katipunan, Zamboanga del Norte and reference point ZN-53 (b) as recovered by the field team.

Table 10. Flight missions for LiDAR data acquisition in Dipolog floodplain.

Station Name	ZN-53	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8°30’41.04428” North 123°18’14.33457” East 7.072 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8°30’37.33230” North 123°18’19.74787” East 71.282 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	533456.022 meters 940788.542 meters

Table 11. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
June 8, 2014	1565P	1BLK71B159A	LE-50, LAN-2
June 20, 2014	1613P	1BLK71G171A	LE-50, LAN-2
July 3, 2014	1665P	1BLK71ES184A	LE-50, LAN-2
July 5, 2014	1673P	1BLK71ES186A	ZGS-88, LAN-2
July 6, 2014	1677P	1BLK71S187A	ZGS-88, LAN-2
July 8, 2014	1685P	1BLK71S189A	LE-50, LAN-2
July 9, 2014	1689P	1BLK71S190A	LE-50, LE-76
February 12, 2016	23084P	1BLK76JKLCs043A	ZS-188, ZGS-16
February 13, 2016	23088P	1BLK76ILM044A	ZS-188, ZGS-16
February 17, 2016	23104P	1BLK76DLM048A	ZS-188, ZGS-16
February 23, 2016	23128P	1BLK70B054A	ZGS-17, ZGS-16
December 1, 2016	23602P	1BLK76AB336A	ZGN-138, ZN-53
June 4, 2014	1549P	1BLK 71D155A	LE-50, LAN-2
June 8, 2014	1565P	1BLK71B159A	LE-50, LAN-2

2.3 Flight Missions

A total of thirteen (13) missions were conducted to complete the LiDAR data acquisition in Maranding floodplain, for a total of fifty hours and thirty one minutes (50.31) of flying time for RP-C9022 and RP-9122. All missions were acquired using the Pegasus LiDAR systems. Table 12 shows the total area of actual coverage per mission and the flying length for each mission and Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for the LiDAR data acquisition of the Maranding Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Average Turn Time (Minutes)	
							fHr	Min
June 4, 2014	1549P	258.45	285.72	95.20	190.52	NA	4	24
June 8, 2014	1565P	258.45	88.20	32.70	55.50	324	2	53
June 20, 2014	1613P	145.33	281.80	95.64	186.16	NA	4	6
July 3, 2014	1665P	100.30	23.48	0.00	23.48	NA	2	59
July 5, 2014	1673P	100.30	67.03	0.00	67.03	330	3	5
July 6, 2014	1677P	100.30	46.06	0.00	46.06	170	2	35
July 8, 2014	1685P	825.11	163.36	54.85	108.51	569	4	5
July 9, 2014	1689P	825.11	264.52	57.19	207.34	NA	4	17
February 12, 2016	23084P	132.54	299.68	76.47	223.21	NA	4	17
February 13, 2016	23088P	216.61	209.33	94.53	114.80	536	4	23
February 17, 2016	23104P	682.02	170.16	66.91	103.25	NA	4	35
February 23, 2016	23128P	105.75	148.90	0.00	148.90	NA	4	17
December 1, 2016	23602P	67.82	130.58	50.27	80.31	0	4	35
TOTAL		3818.09	2178.79	623.74	1555.06	1929	50	31

Table 13. Actual parameters used during the LiDAR data acquisition of the Maranding Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1549P	1000	30	50	200	30	130	5
1565P	1000	30	50	200	30	130	5
1613P	1000	30	50	200	30	130	5
1665P	1100	30	50	200	30	130	5
1673P	1000	30	50	200	30	130	5
1677P	1000	30	50	200	30	130	5
1685P	1000	30	50	200	30	130	5
1689P	1200	30	50	200	30	130	5
23084P	1000	30	50	200	30	130	5
23088P	1200	30	50	200	30	130	5
23104P	1000	30	50	200	30	130	5
23128P	1000	30	50	200	30	130	5
23602P	1200/1100	30	50	200	30	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Maranding floodplain (See ANNEX 7). It is located in the provinces of Misamis Occidental, with majority of the floodplain situated within the municipality of Jimenez. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 14. The actual coverage of the LiDAR acquisition for Maranding floodplain is presented in Figure 12.

Table 14. The list of municipalities and cities surveyed of the Maranding Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Lanao del Norte	Baroy	62.08	62.08	100%
	Salvador	46.46	46.46	100%
	Lala	125.18	125.09	100%
	Kapatagan	184.76	173.6	94%
	Tubod	121.95	112.66	92%
	Kolambugan	70.7	62.54	88%
	Magsaysay	83.06	68.52	82%
	Sapad	65.13	42.91	66%
	Baloi	65.18	36.87	57%
	Sultan Naga Dimaporo	143.65	55.81	39%
	Maigo	126.36	27.8	22%
	Nunungan	418.22	61.12	15%
	Pantar	50.19	6.85	14%
	Linamon	22.21	2.25	10%
	Tagoloan	25.06	2.2	9%
	Tangcal	118.94	7.23	6%
	Iligan City	650.87	21.85	3%
	Matungao	52.5	1.45	3%
Misamis Occidental	Ozamiz City	149.44	44.44	30%
	Tangub City	141.82	38.16	27%
	Bonifacio	103.87	6.17	6%
	Clarin	113.99	6.06	5%
	Aurora	162.22	99.52	61%
	Tukuran	119.01	64.3	54%
	Kumalarang	143.51	51.19	36%
	Labangan	176.44	59.52	34%
	Pagadian City	279.33	70.86	25%
	Tambulig	142.93	27.91	20%
	Dumalinao	108.65	2.5	2%
	Sominot	97.75	2.21	2%
Zamboanga Sibugay	Buug	134.89	3	2%
Total		4306.35	1393.13	32.35%

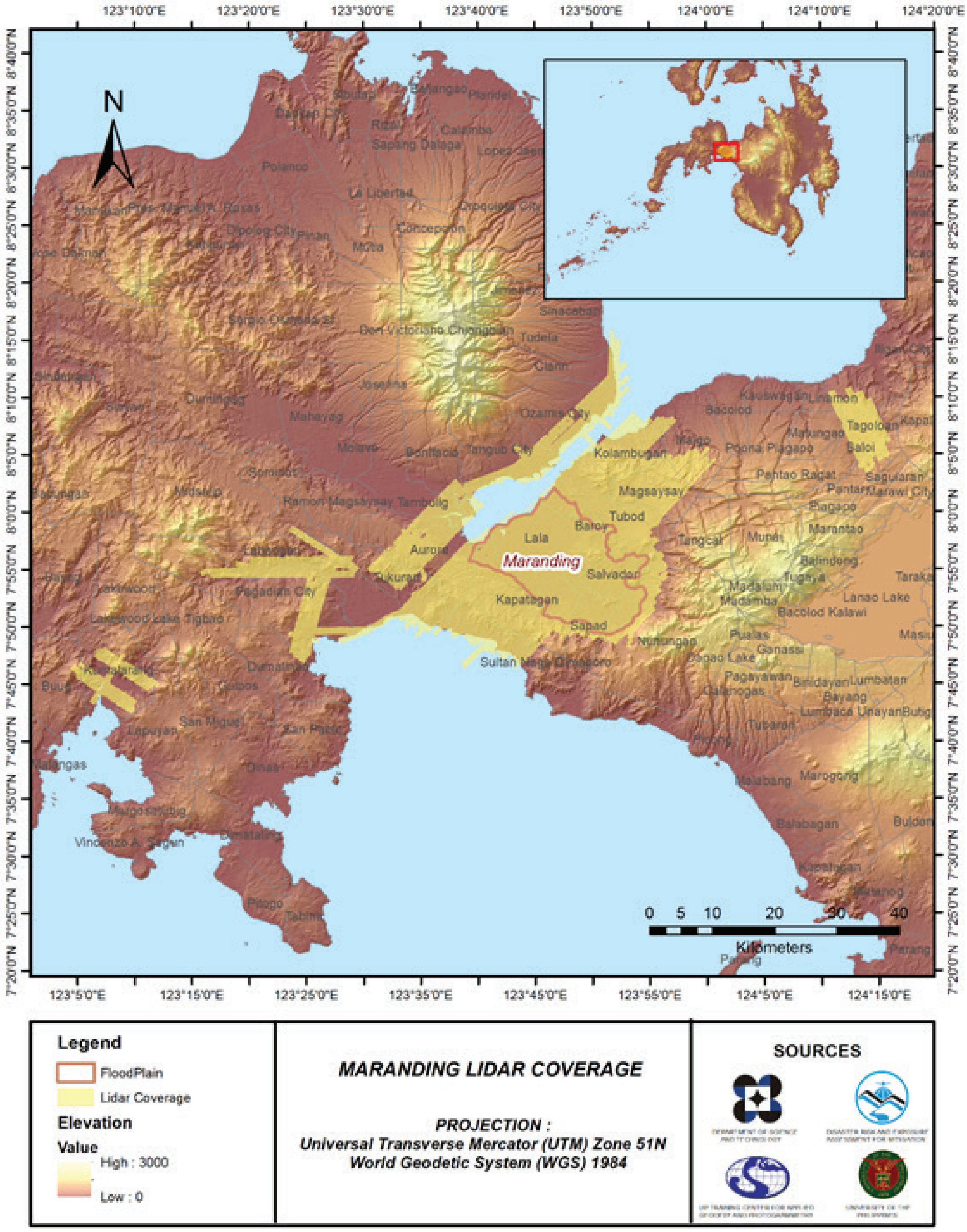


Figure 12. Actual LiDAR survey coverage of the Maranding Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MARANDING FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Engr. Harmond F. Santos , Engr. Ma. Ailyn L. Olanda, Antonio B. Chua Jr., Engr. James Kevin M. Dimaculangan , Engr. Jommer M. Medina, and John Arnold C. Jaramilla

The methods applied in this chapter were based on the DREAM methods manual (Ang, et al., 2014) and were 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 in order 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 were the minimum point density, vertical and horizontal accuracies, were met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models were calibrated. Portions of the river that were 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 13.

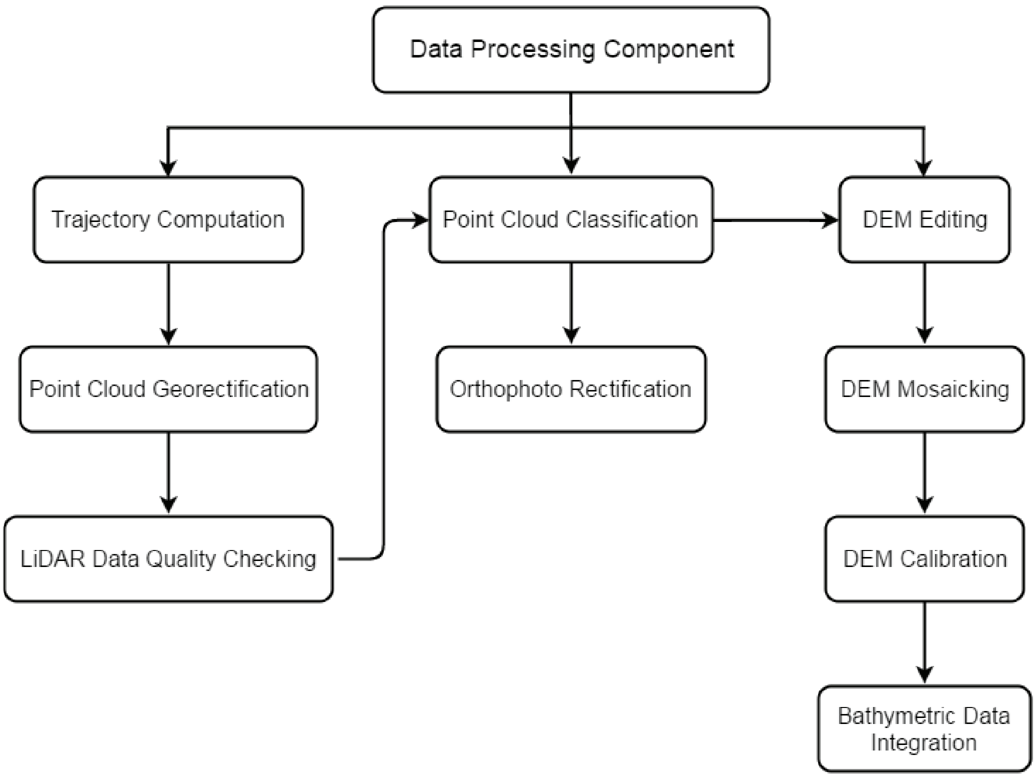


Figure 13. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Maranding Floodplain can be found in ANNEX 5. The missions flown during the conduct of the first survey in June 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. Missions acquired during the second survey on February 2016 were flown using the same system over Dipolog, Pagadian, and Northern Mindanao.

The Data Acquisition Component (DAC) transferred a total of 253.27 Gigabytes of Range data, 2.81 Gigabytes of POS data, 442.11 Megabytes of GPS base station data, and 576.84 Megabytes of raw image data to the data server on June 23, 2014 for the first survey and on March 10, 2016 for the second survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Maranding Floodplain was fully transferred on March 10, 2016, as indicated on the Data Transfer Sheets for the Maranding floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 23088P, one of the Maranding flights, which is the North, East, and Down position RMSE values are shown in Figure 14. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of February 13, 2016, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

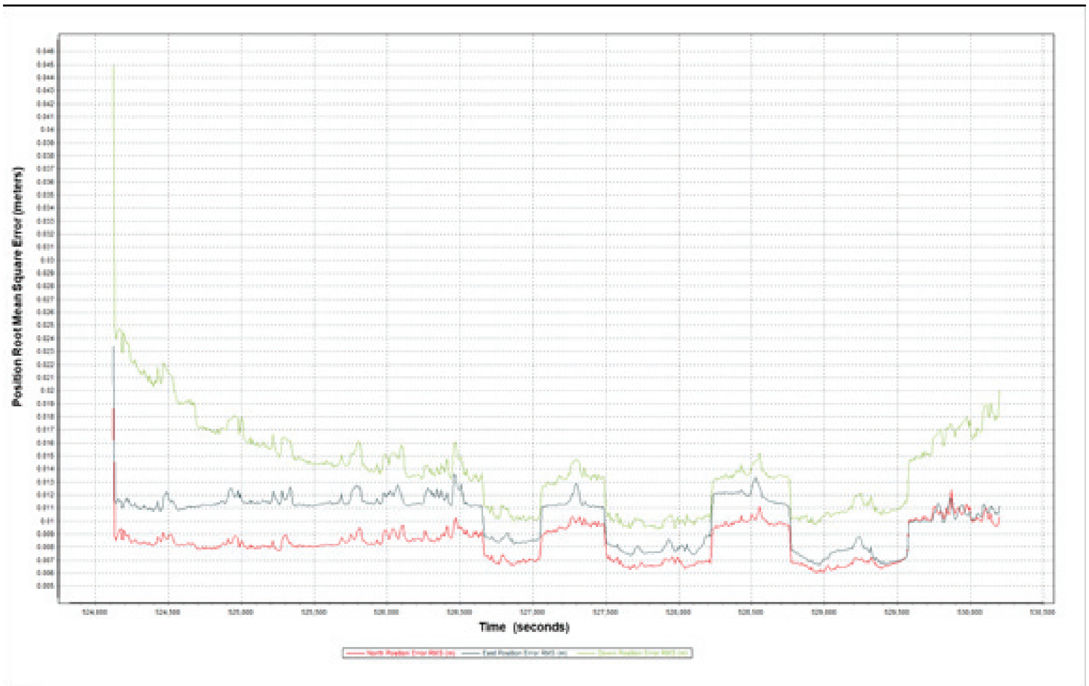


Figure 14. The Smoothed Performance Metrics of Maranding Flight 23088P.

The time of flight was from 524,000 seconds to 530,500 seconds, which corresponds to afternoon of February 13, 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 15 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.30 centimeters, and the Down position RMSE peaks at 2.40 centimeters, which are within the prescribed accuracies described in the methodology.

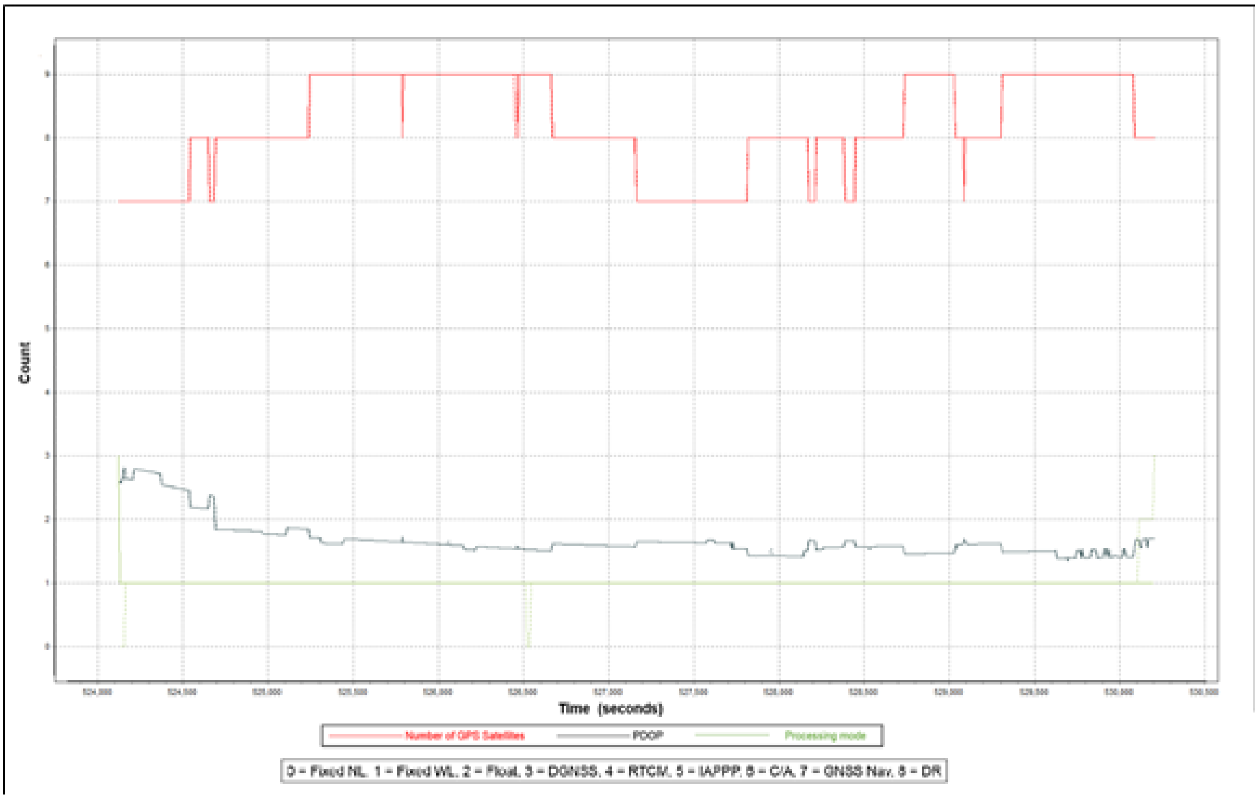


Figure 15. The Solution Status Parameters of Maranding Flight 23008P.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Maranding Flight 23088P are shown in Figure 15. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 7 and 9, not going lower than 6. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also stayed at the value of 0 for the majority of the survey stayed at the value of 0. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for the POSPAC MMS. Fundamentally, all of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Maranding flights is shown in Figure 16.

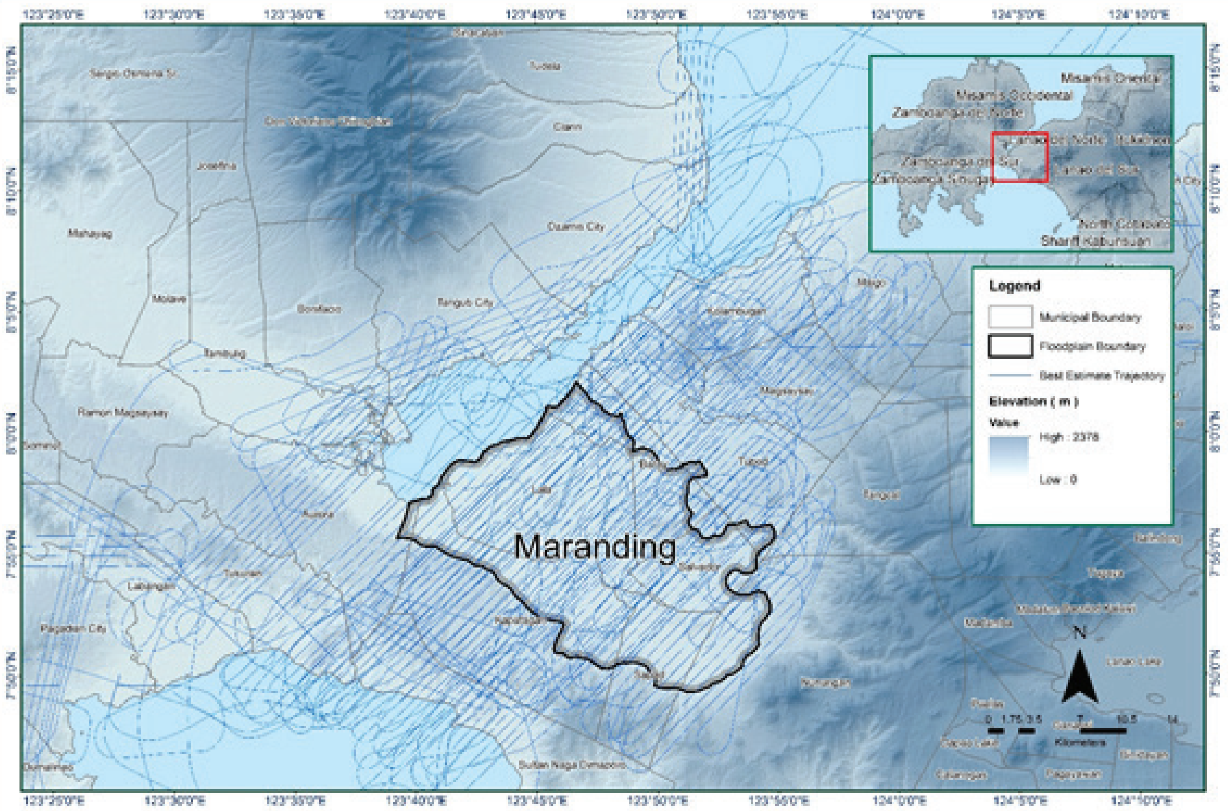


Figure 16. Best Estimated Trajectory of the LiDAR missions conducted over the Maranding Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS contains 145 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Maranding floodplain are given in Table 15.

Table 15. Self-calibration values for all Maranding Floodplain flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000274
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.001049
GPS Position Z-correction stdev)	<0.01meters	0.0073

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Maranding Floodplain is shown in Figure 17. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

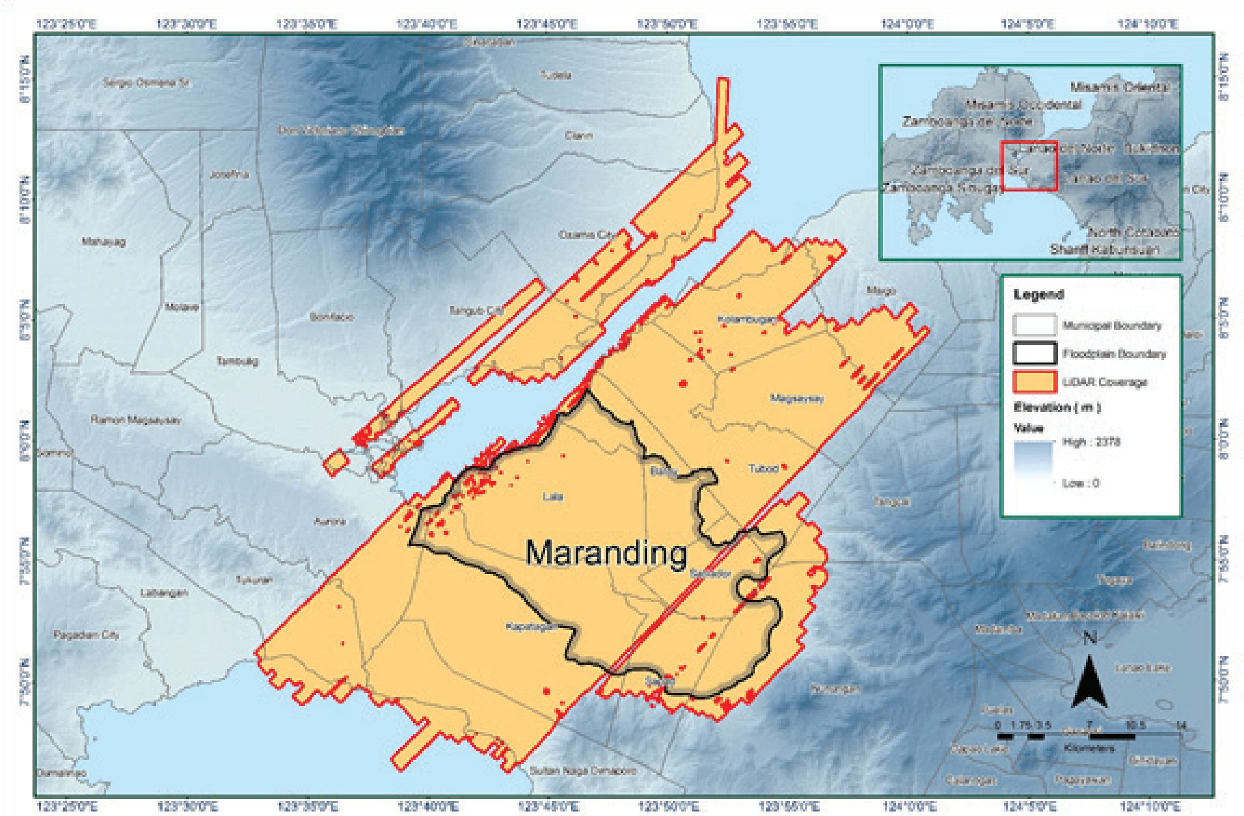


Figure 17. The boundaries of the processed LiDAR data over the Maranding Floodplain.

A total area of 1663.56 square kilometers (sq. kms.) were covered by the Maranding flight missions as a result of twelve (12) flight acquisitions, which were grouped and merged into two (2) blocks accordingly, as portrayed in Table 16.

Table 16. List of LiDAR blocks for the Maranding floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Pagadian_Blk76J	23088P	37.95
Pagadian_Blk76K	23084P	182.99
Pagadian_Blk76K_additional	23104P	53.29
Pagadian_Blk76M	23128P	71.78
Pagadian_Blk76N	23088P	136.47
Pagadian_Blk76N_additional	23104P	60.44
Pagadian_Blk76N_supplement	23104P	5.30
NorthernMindanao_Blk71_extension	1665P	138.30
	1673P	
	1677P	

NorthernMindanao_Blk71E	1689P	194.58
NorthernMindanao_Blk71F	1565P	500.10
	1549P	
	1685P	
NorthernMindanao_Blk71G	1613P	282.38
Dipolog_reflights_Blk76M	23602P	73.71
TOTAL		1,737.29

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 18. Since the Pegasus system employs one channel, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

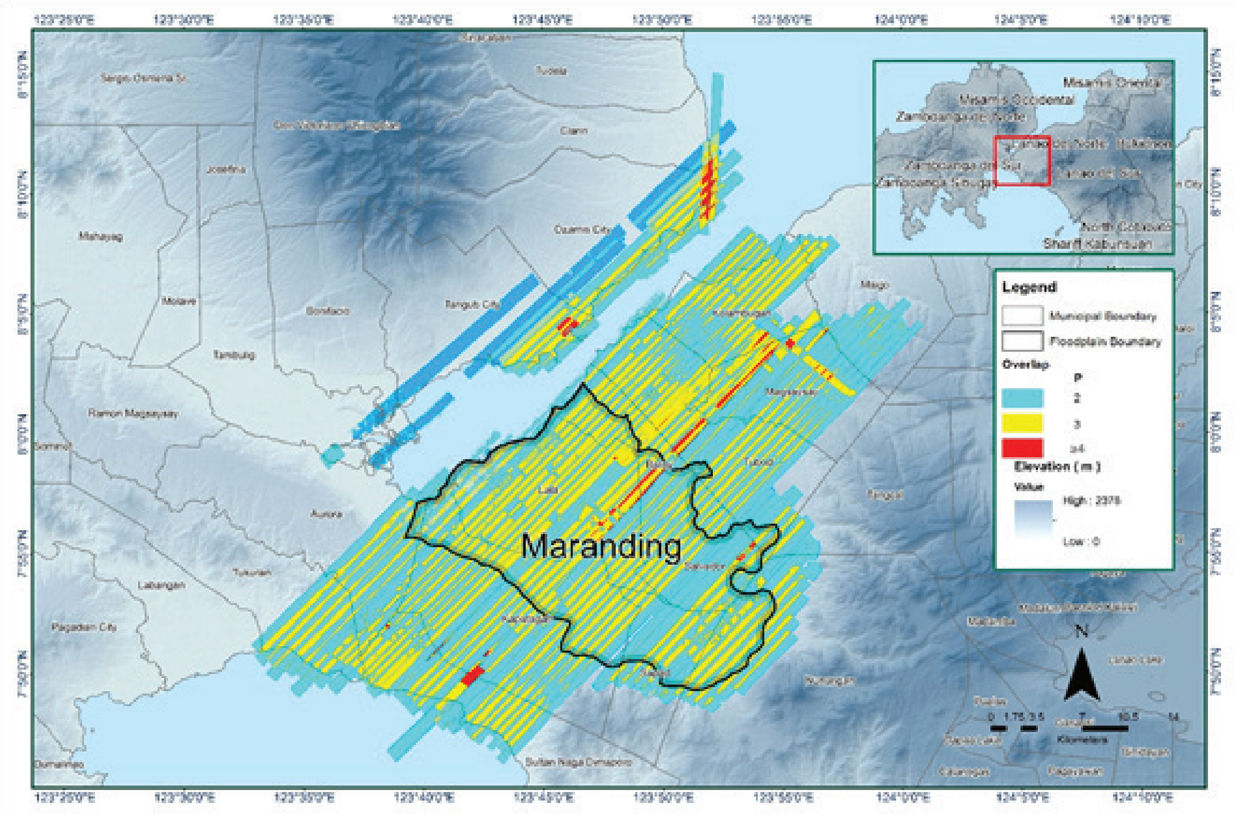


Figure 18. Data overlap between missions and flight lines for the Maranding River Floodplain Survey.

The overlap statistics per block for the Maranding Floodplain Survey can be found in the Mission Summary Reports (ANNEX 7). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.83%, and 51.56% 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 two (2) points per square meter criterion is shown in Figure 19. As seen in the figure below, it was determined that all LiDAR data for the Maranding Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.43 points per square meter.

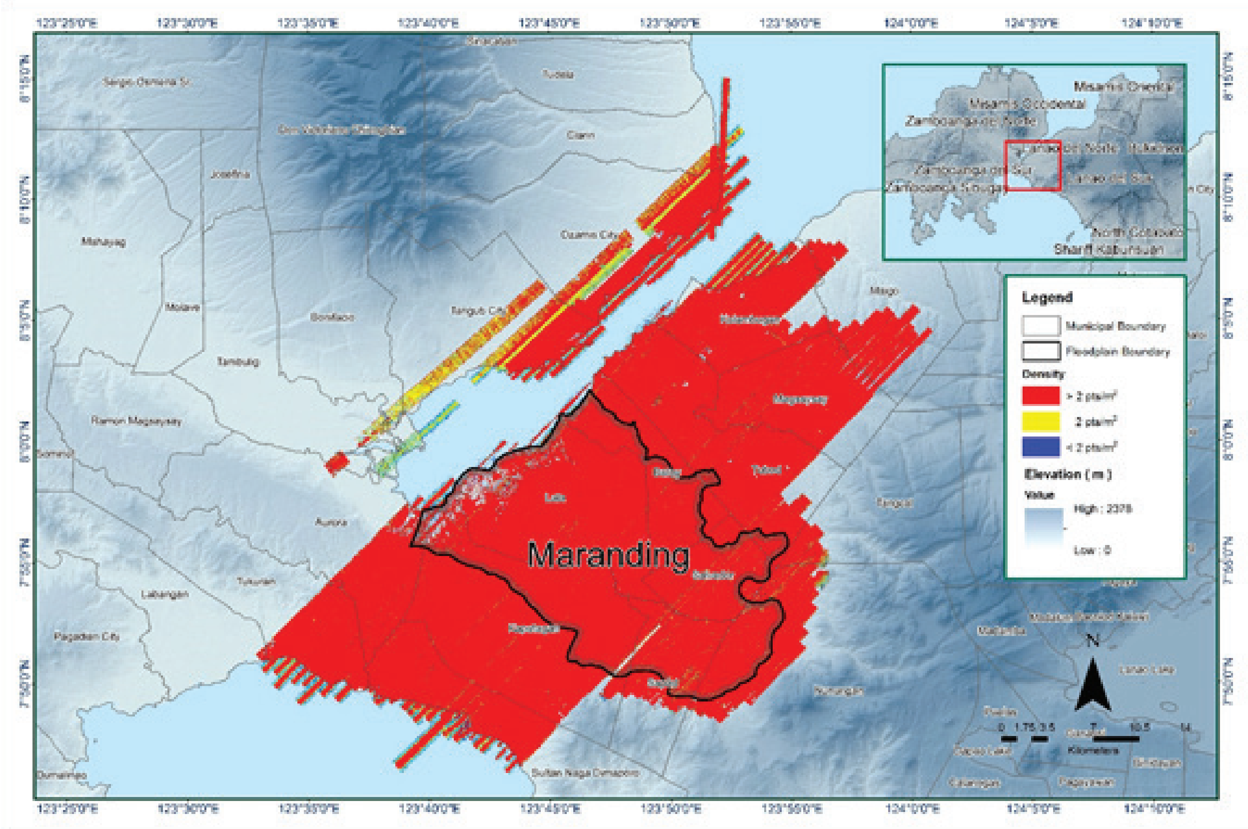


Figure 19. The pulse density map of the merged LiDAR data for the Maranding Floodplain Survey

The elevation difference between overlaps of adjacent flight lines is shown in Figure 20. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

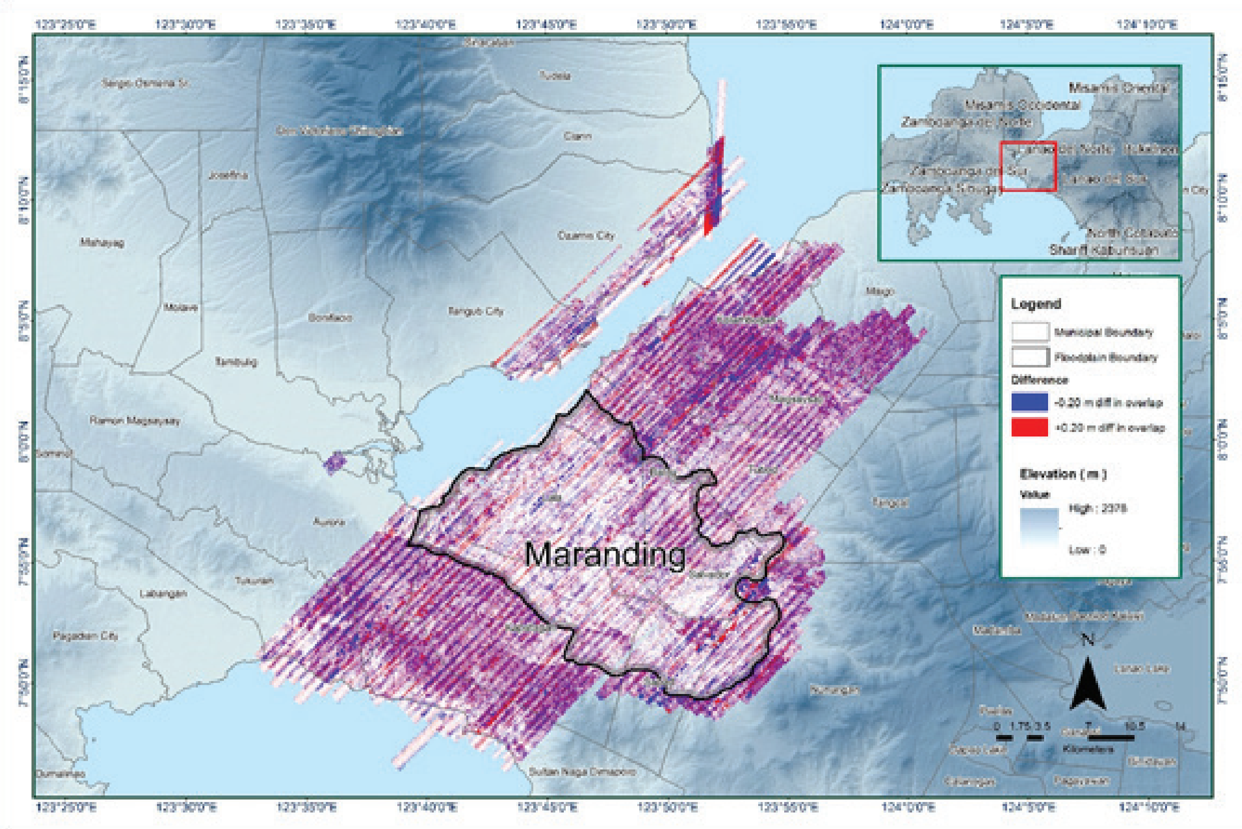


Figure 20. Map of elevation difference Map between flight lines for the Maranding Floodplain Survey.

A screen-capture of the processed LAS data from Maranding flight 23088P loaded in QT Modeler is shown in Figure 21. 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.

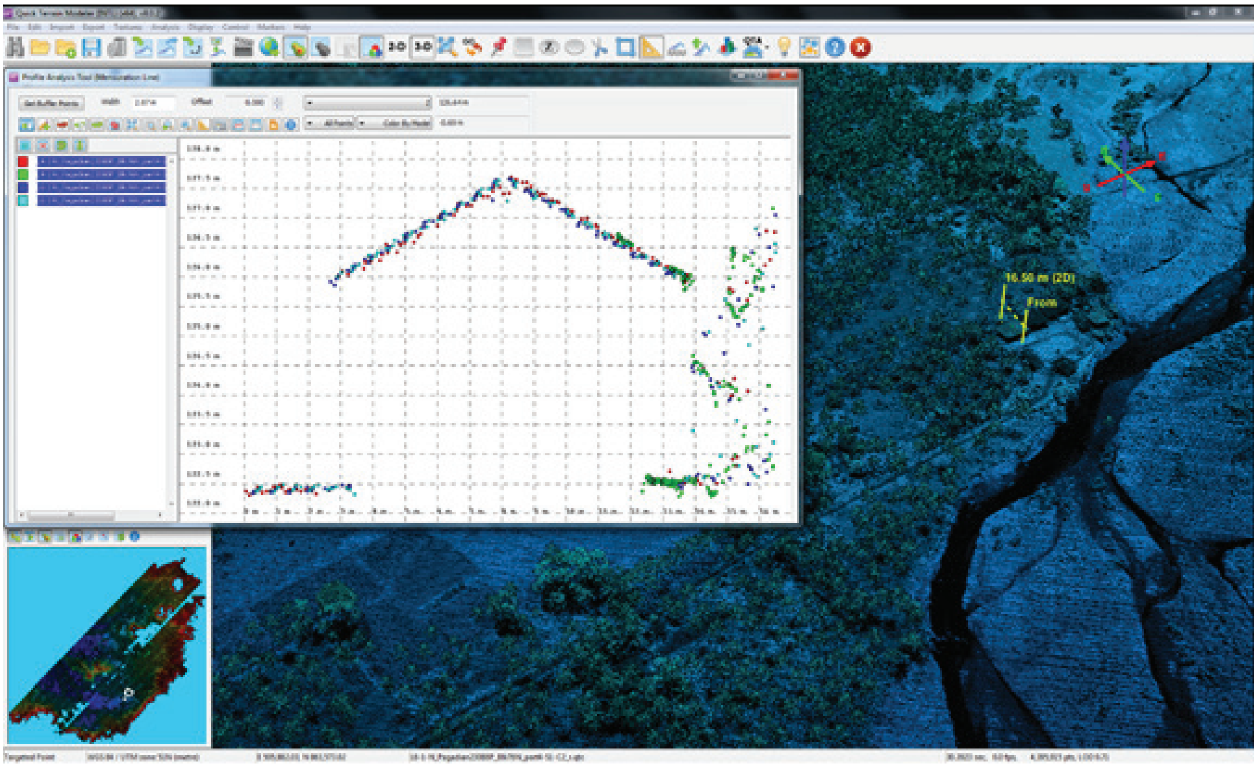


Figure 21. Screen-capture of the quality checking for Maranding Flight 23088P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. List of LiDAR blocks for the Maranding floodplain.

Pertinent Class	Total Number of Points
Ground	1,804,179,263
Low Vegetation	1,570,400,382
Medium Vegetation	1,938,471,528
High Vegetation	2,322,596,111
Building	72, 196, 121

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Maranding floodplain is shown in Figure 22. A total of 365 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 17 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 367.21 meters and 53.91 meters respectively.

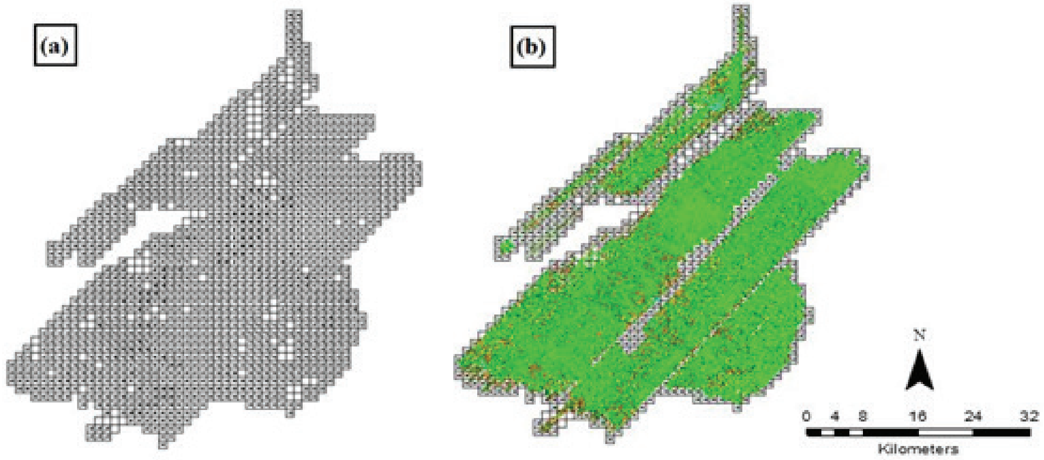


Figure 22. The coverage of the Maranding Floodplain Survey (a) the tile system (b) depicts the classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 23. The ground points are highlighted in orange, while the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

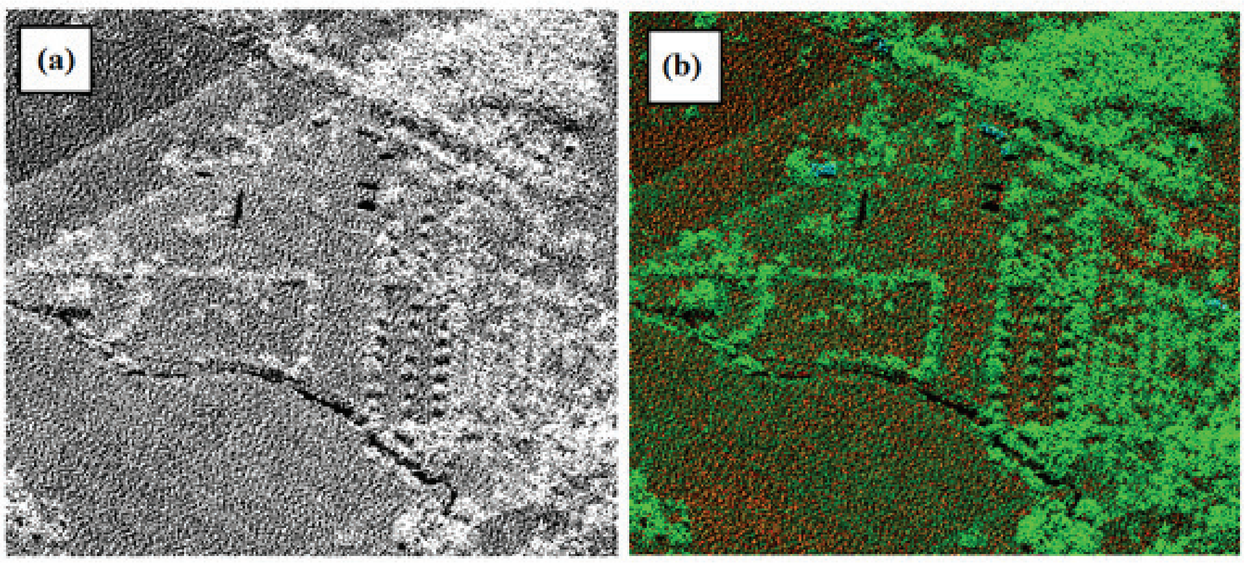


Figure 23. The images before (a) and after (b) undertaking classification.

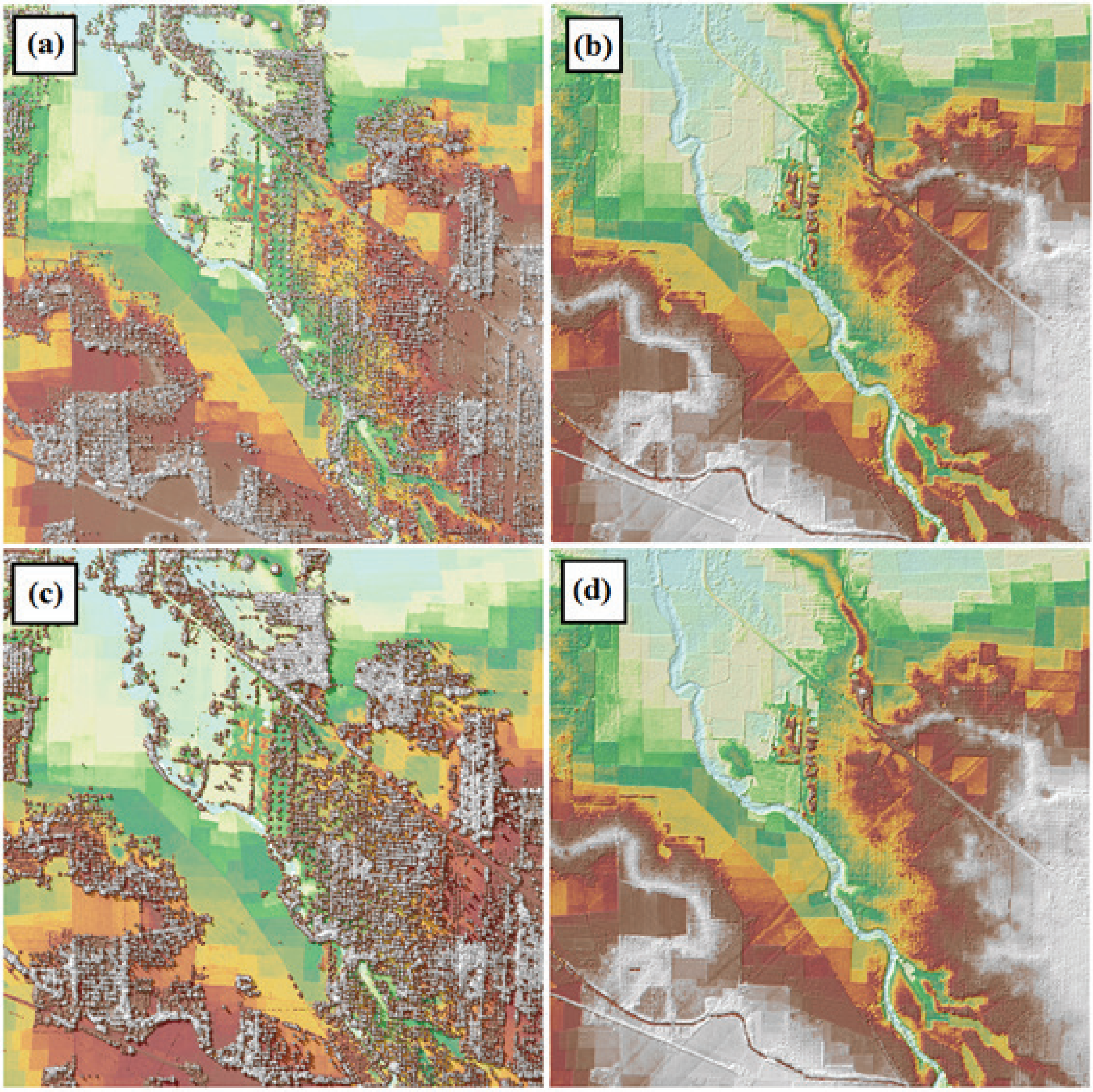


Figure 24. Photo (A) features the production of the last return DSM; (B) depicts the production of the DTM; (C) portrays the production of the first return DSM; and (D) presents the generation of the secondary DTM in some portions of the Maranding Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,746 1km by 1km tiles area covered by the Maranding floodplain is shown in Figure 25. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Maranding floodplain attained a total of 910.23 sq. kms. in orthophotograph coverage comprised of 3,350 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 26.

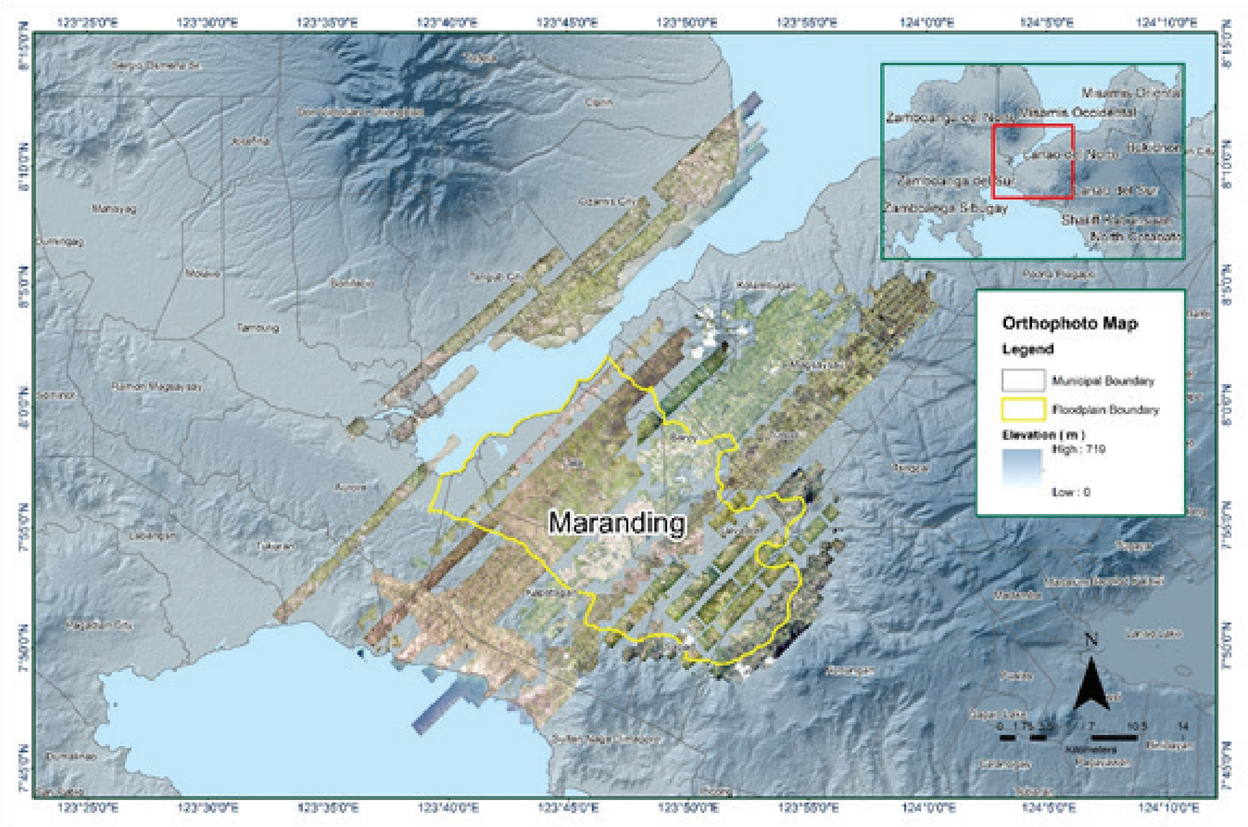


Figure 25. The Maranding Floodplain with the available orthophotographs.

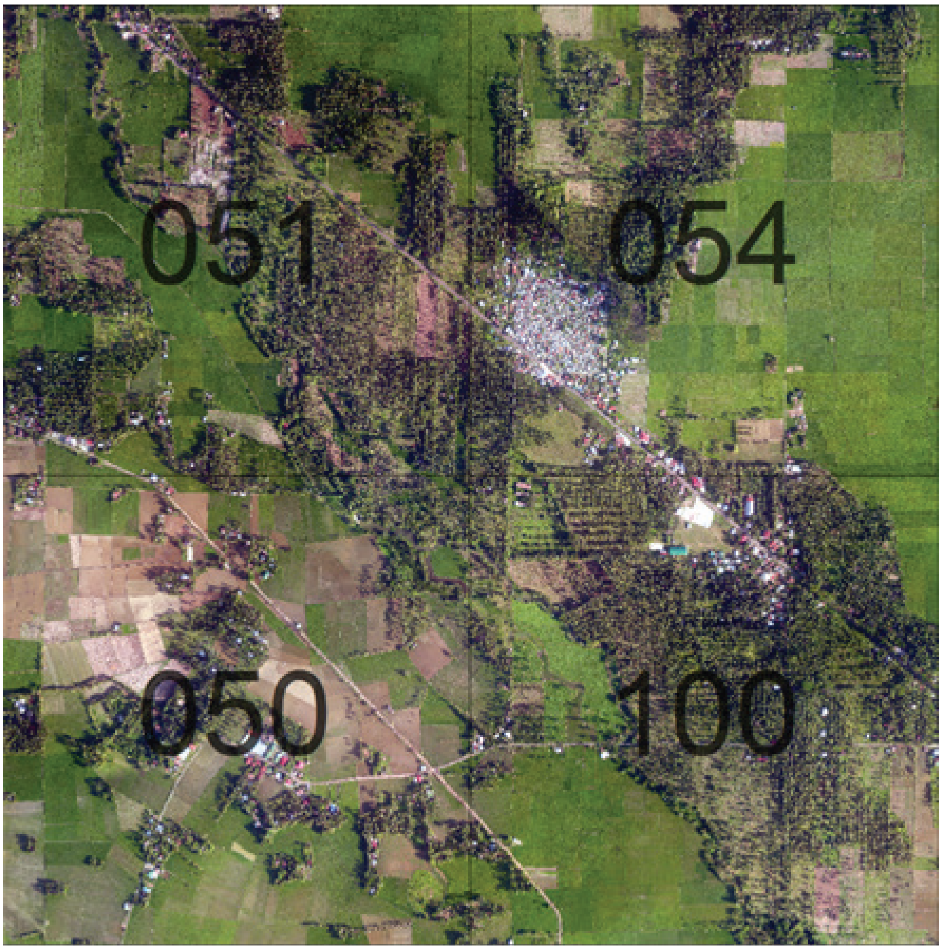


Figure 26. Sample orthophotograph tiles for the Maranding Floodplain.

3.8 DEM Editing and Hydro-Correction

Twelve (12) mission blocks were processed for the Maranding Floodplain Survey. Essentially, these blocks are composed of 'Northern Mindanao' and 'Pagadian' blocks, which arrive at a total area of 1,737.29 sq. kms. As listed in Table 18, the name and corresponding area of each block are measured out in square kilometers (sq. kms.).

Table 18. List of LiDAR blocks for the Maranding floodplain.

LiDAR Blocks	Area (sq. km.)
NorthernMindanao_Blk71E	194.58
NorthernMindanao_Blk71F	500.10
NorthernMindanao_Blk71G	282.38
NorthernMindanao_Blk71_Extension	138.30
Pagadian_Blk76J	37.95
Pagadian_Blk76K	182.99
Pagadian_Blk76K_additional	53.29
Pagadian_Blk76M	71.78
Pagadian_Blk76N	136.47
Pagadian_Blk76N_additional	60.44
Pagadian_Blk_76N_supplement	5.30
Dipolog_reflights_Blk76M	73.71
TOTAL	1,737.29 sq. km

Figure 27 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 27a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 27b). The paddy field (Figure 27c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 27d) to allow the correct flow of water.

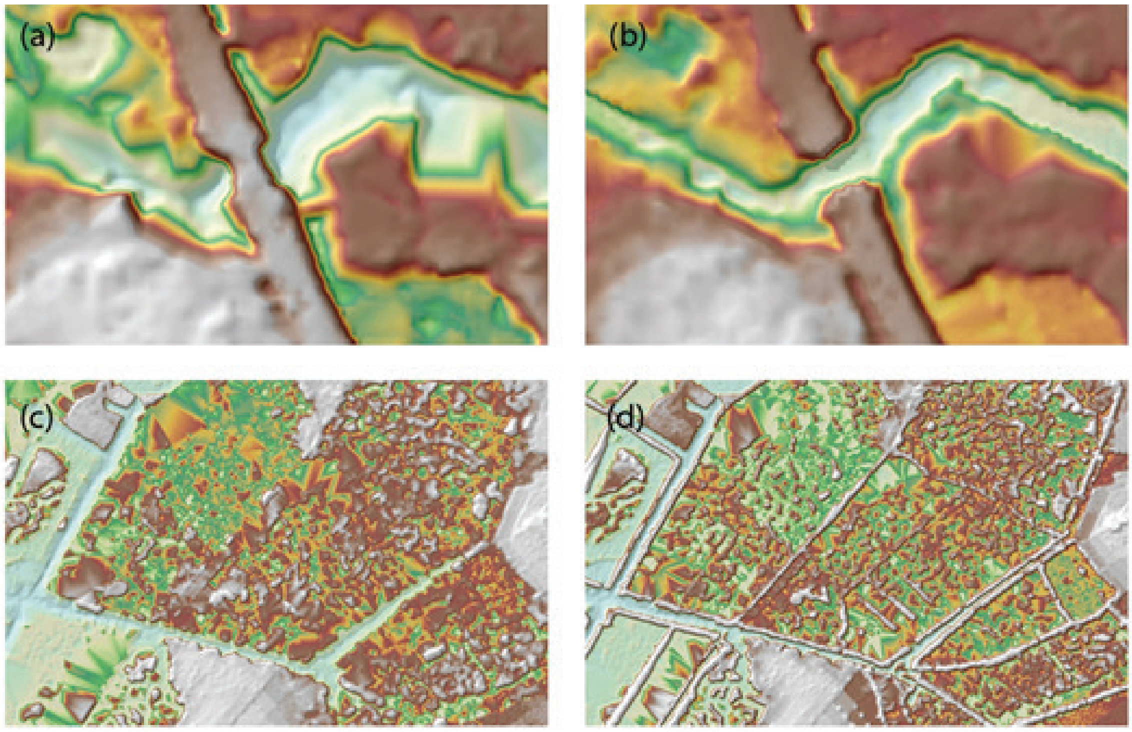


Figure 27. Portions in the DTM of the Maranding Floodplain showing (a) a bridge before undergoing manual; (b) bridge after manual editing; (c) a paddy field before undergoing manual editing; while (d) after data retrieval.

3.9 Mosaicking of Blocks

NorthernMindanao_Blk71F was used as the reference block at the start of mosaicking because it is already vertically calibrated to MSL which is the largest DTM of Maranding river basin. Table 19 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Maranding Floodplain is shown in Figure 28. It can be seen that the entire Maranding floodplain is 98.6% covered by LiDAR data.

Table 19. The shift values (in meters) for each LiDAR Block of the Maranding Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
NorthernMindanao_Blk71E	0.00	0.00	-0.30
NorthernMindanao_Blk71F	0.00	0.00	0.00
NorthernMindanao_Blk71G	0.00	0.00	0.00
NorthernMindanao_Blk71_Extension	0.00	0.00	0.00
Pagadian_Blk76J	-0.20	0.40	0.00
Pagadian_Blk76K	0.00	0.00	0.00
Pagadian_Blk76K_additional	0.00	0.00	0.00
Pagadian_Blk76M	0.00	0.00	0.00
Pagadian_Blk76N	0.00	0.00	0.00
Pagadian_Blk76N_additional	0.75	0.50	-0.45
Pagadian_Blk76N_supplement	0.05	0.05	-0.45
Dipolog_reflights_Blk76M	0.70	-0.60	-0.43
TOTAL	1,737.29 sq. km		

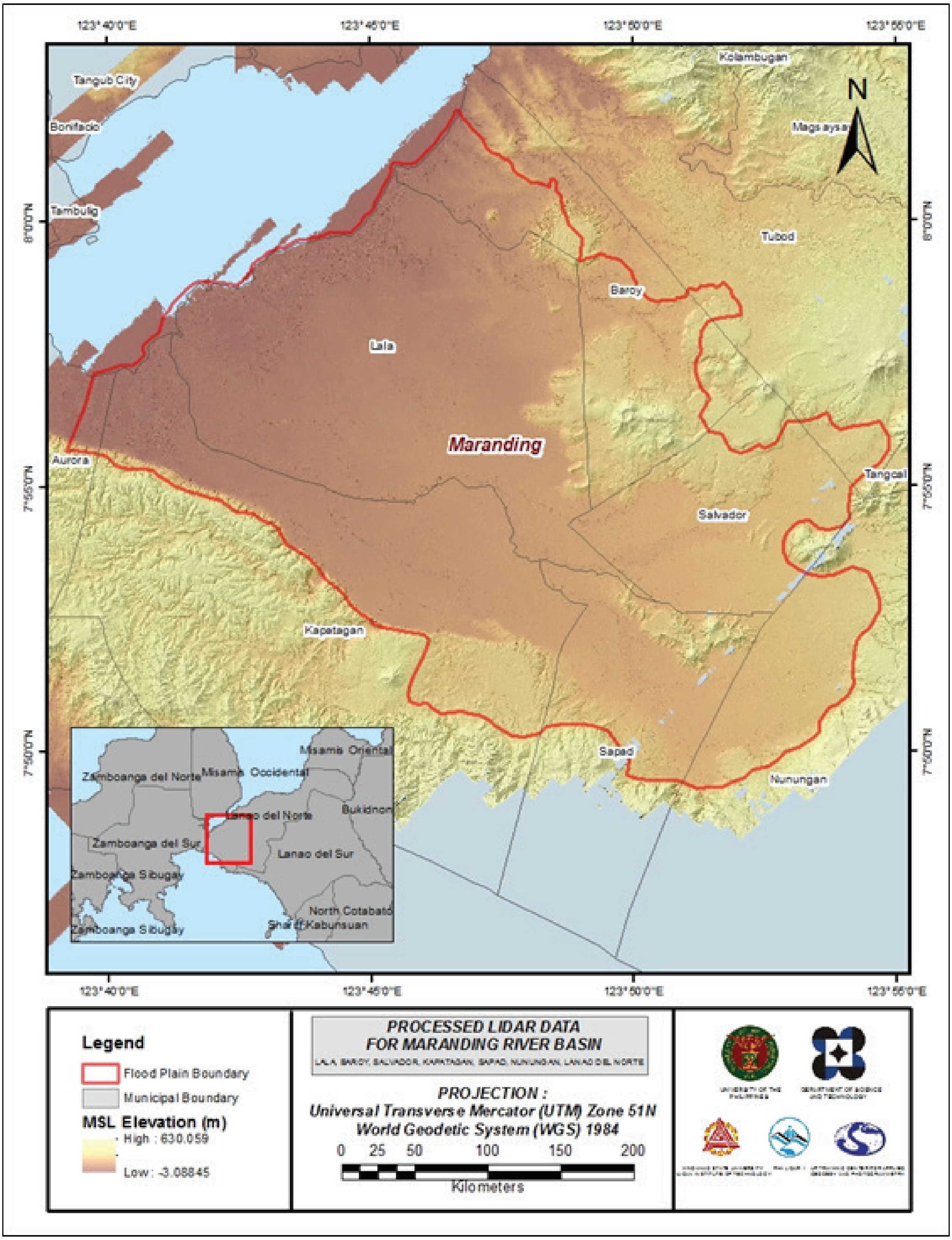


Figure 28. Portions in the DTM of the Maranding Floodplain showing (a) a bridge before undergoing manual; (b) bridge after manual editing; (c) a paddy field before undergoing manual editing; while (d) after data retrieval.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry (DVBC) in Maranding to collect points with which the LiDAR dataset is validated is shown in Figure 29, with the validation survey points highlighted in green. A total of 2,003 survey points were gathered for the Maranding floodplain. Random selection of 80% of the survey points, resulting to 1,602 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and the ground survey elevation values is shown in Figure 30. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of the data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 2.27 meters, with a standard deviation of 0.08 meters. The calibration of the Maranding LiDAR data was accomplished by subtracting the height difference value of 0.08 meters to the Maranding mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between the Maranding LiDAR data and the calibration data.

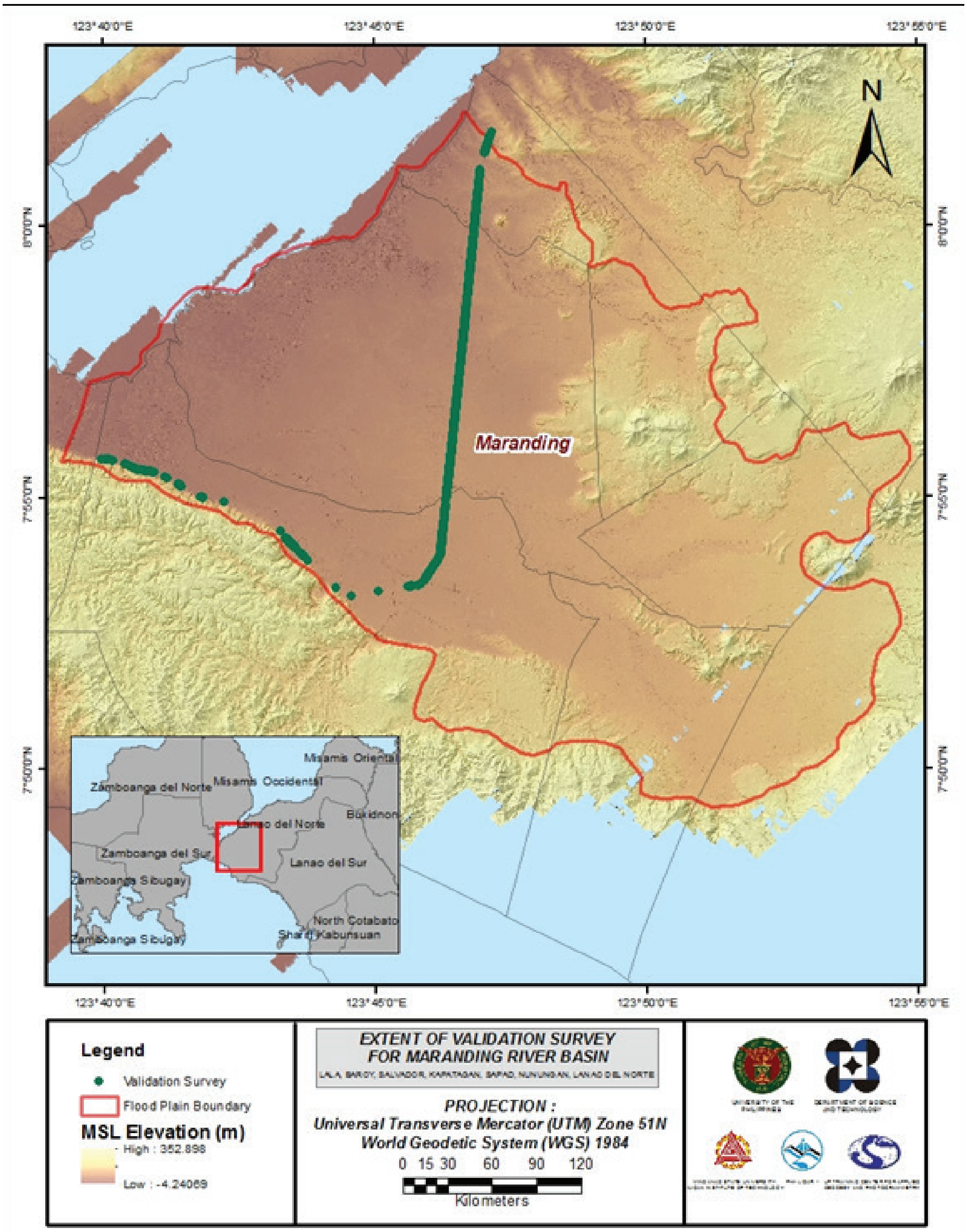


Figure 29. Map of Maranding Floodplain with validation survey points in green.

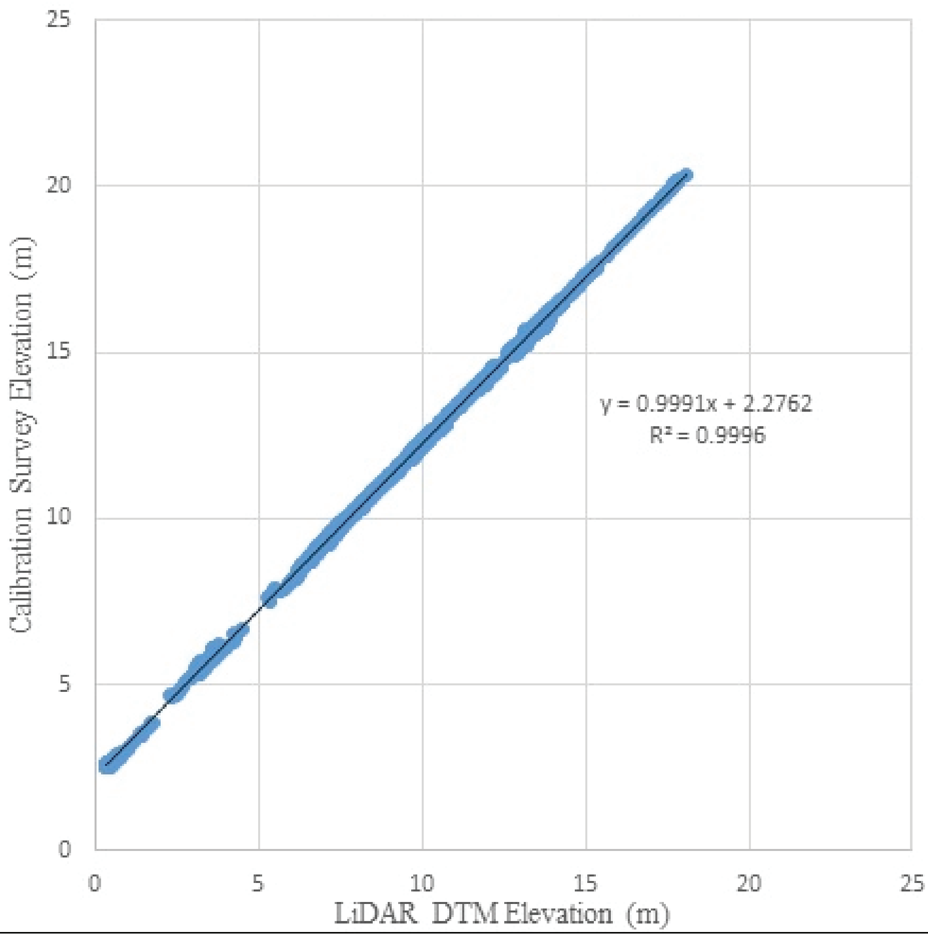


Figure 30. Correlation plot between calibration survey points and LiDAR data.

Table 20. The calibration statistical measures of the compared elevation values between the Maranding LiDAR data

Calibration Statistical Measures	Value (meters)
Height Difference	0.08
Standard Deviation	0.08
Average	0.00
Minimum	-0.21
Maximum	0.23

A total of 401 survey points lie within the Maranding Floodplain; all of which were used to validate the calibrated Maranding DTM. A good correlation between the calibrated mosaicked LiDAR elevation and the ground survey elevation values, which point toward the quality of the LiDAR DTM is shown in Figure 31. The computed RMSE value between the calibrated LiDAR DTM and the validation elevation values is at 0.08 meters with a standard deviation of 0.08 meters, as shown in Table 21.

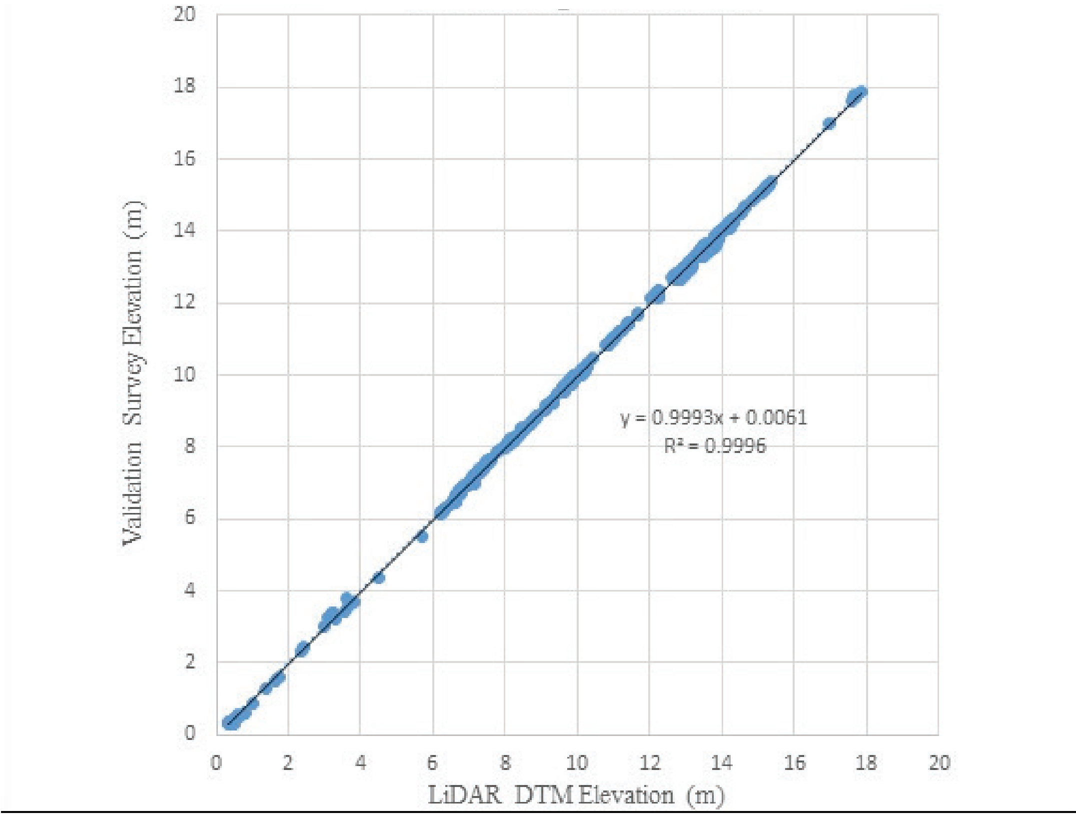


Figure 31. Correlation plot between the validation survey points and the LiDAR data.

Table 21. TStatistical measures for the Maranding River Basin DTM validation and the calibration data.

Calibration Statistical Measures	Value (meters)
Height Difference	0.08
Standard Deviation	0.08
Average	0.00
Minimum	-0.21
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Maranding with a total of 2,223 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 0.53 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Maranding integrated with the processed LiDAR DEM is shown in Figure 32.

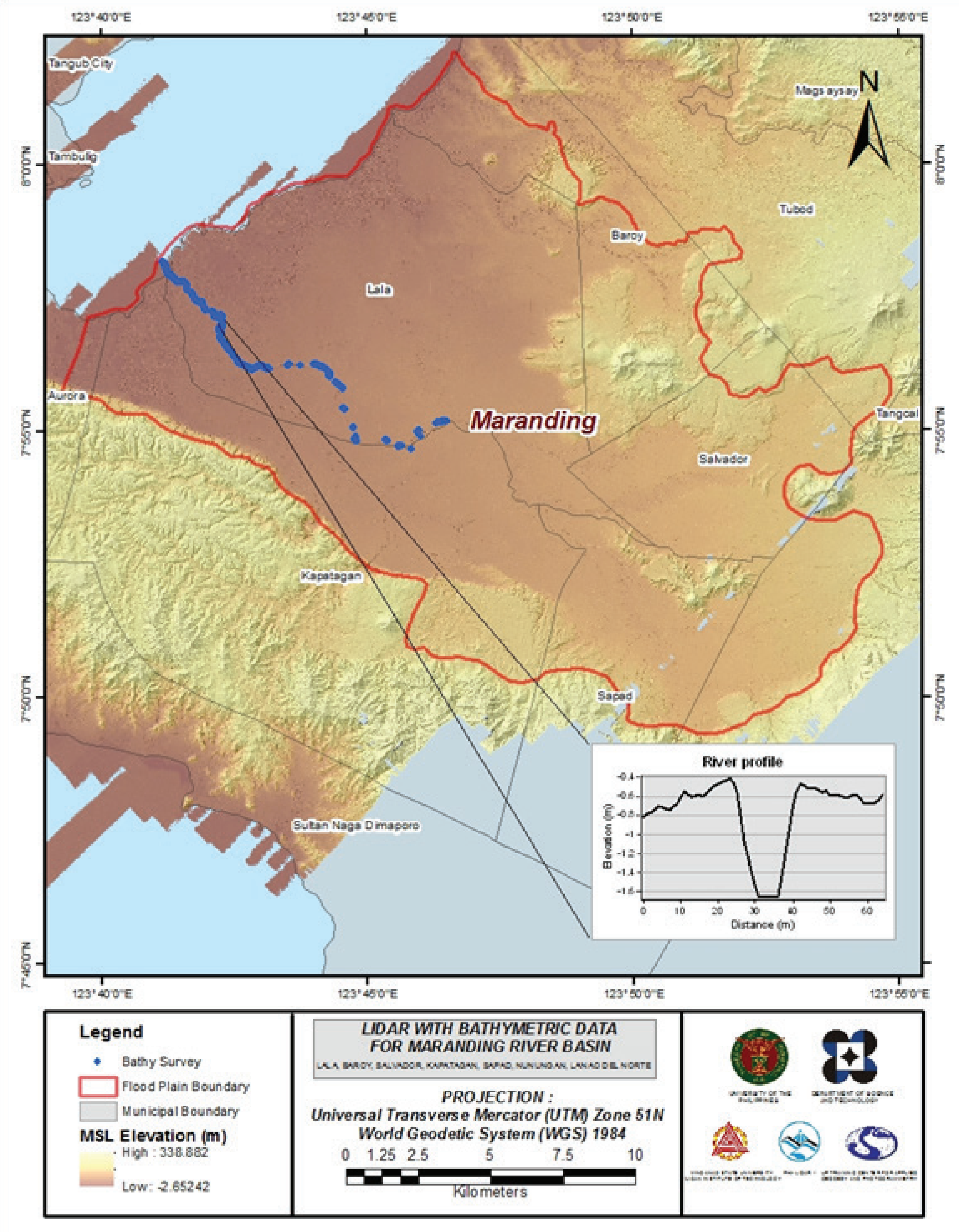


Figure 32. Map of Maranding floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Maranding floodplain, including its 200-m buffer, has a total area of 367.13 sq km. For this area, a total of 12.0 sq. km., corresponding to a total of 2,495 building features, were considered for QC. Figure 33 shows the QC blocks for the Maranding floodplain.

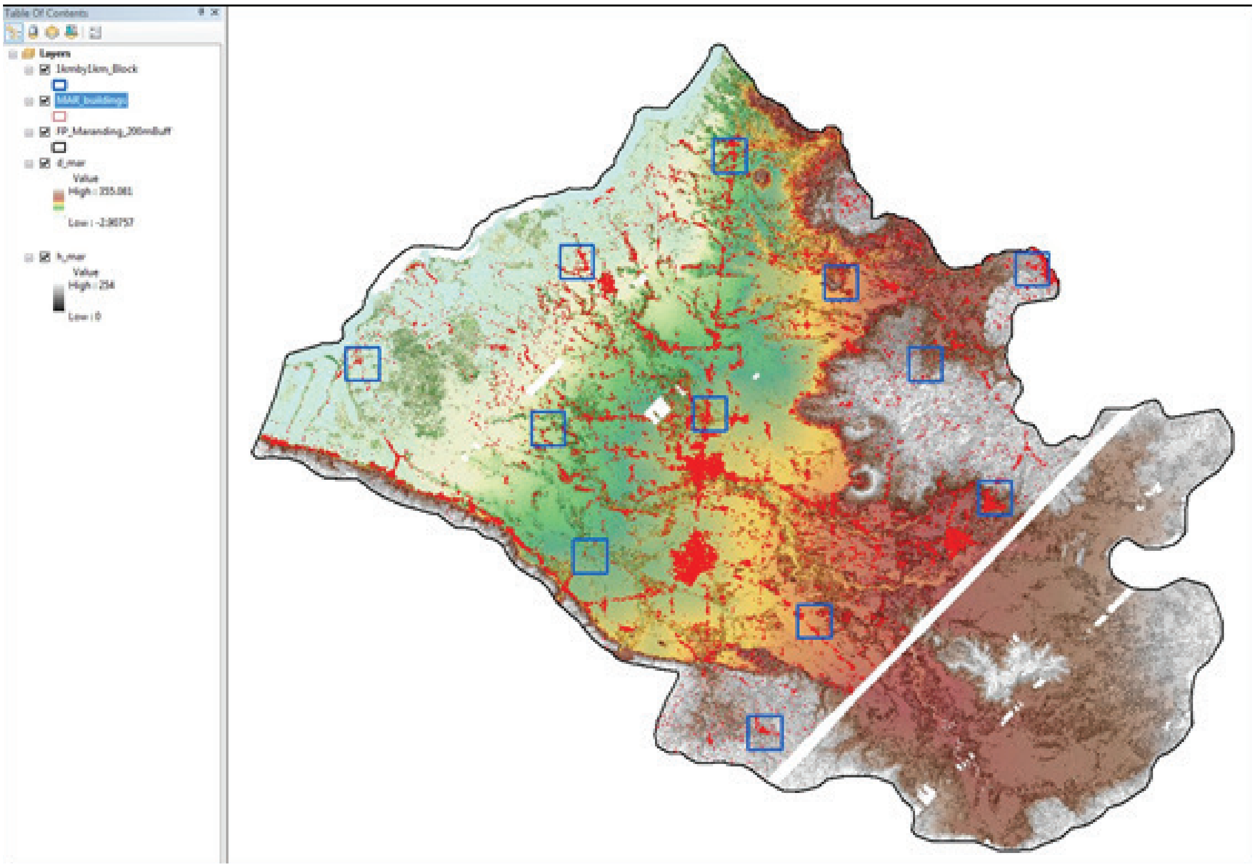


Figure 33. . Blocks (in blue) of Maranding building features that were subjected to QC.

Quality checking of Maranding building features resulted in the ratings shown in Table 22.

Table 22. Details of the quality checking ratings for the building features extracted for the Maranding River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Maranding	89.11	99.65	83.06	PASSED

3.12.2 Height Extraction

Height extraction was done for 53,418 building features in Maranding floodplain. Of these building features, none was filtered out after height extraction, resulting to 1,621 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 20.37 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the flood plain of the river basin.

Table 23 summarizes the number of building features per type, while Table 24 shows the total length of each road type. Table 25, on the other hand, shows the number of water features extracted per type.

Table 23. Building features that were extracted for the Maranding Floodplain.

Facility Type	No. of Features
Residential	49,219
School	700
Market	23
Agricultural/Agro-Industrial Facilities	365
Medical Institutions	84
Barangay Hall	87
Military Institution	38
Sports Center/Gymnasium/Covered Court	34
Telecommunication Facilities	3
Transport Terminal	4
Warehouse	167
Power Plant/Substation	1

NGO/CSO Offices	3
Police Station	5
Water Supply/Sewerage	7
Religious Institutions	298
Bank	6
Factory	2
Gas Station	13
Fire Station	3
Other Government Offices	308
Other Commercial Establishments	427
Total	**51,797**

Table 24. Total length of extracted roads for the Maranding Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Maranding	303.26	89.29	44.19	71.69	0.00	508.43

Table 25. Number of extracted water bodies in the Maranding Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Maranding	39	0	0	3	231	273

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 34 shows the completed Digital Surface Model (DSM) of the Maranding Floodplain, with all its ground features.

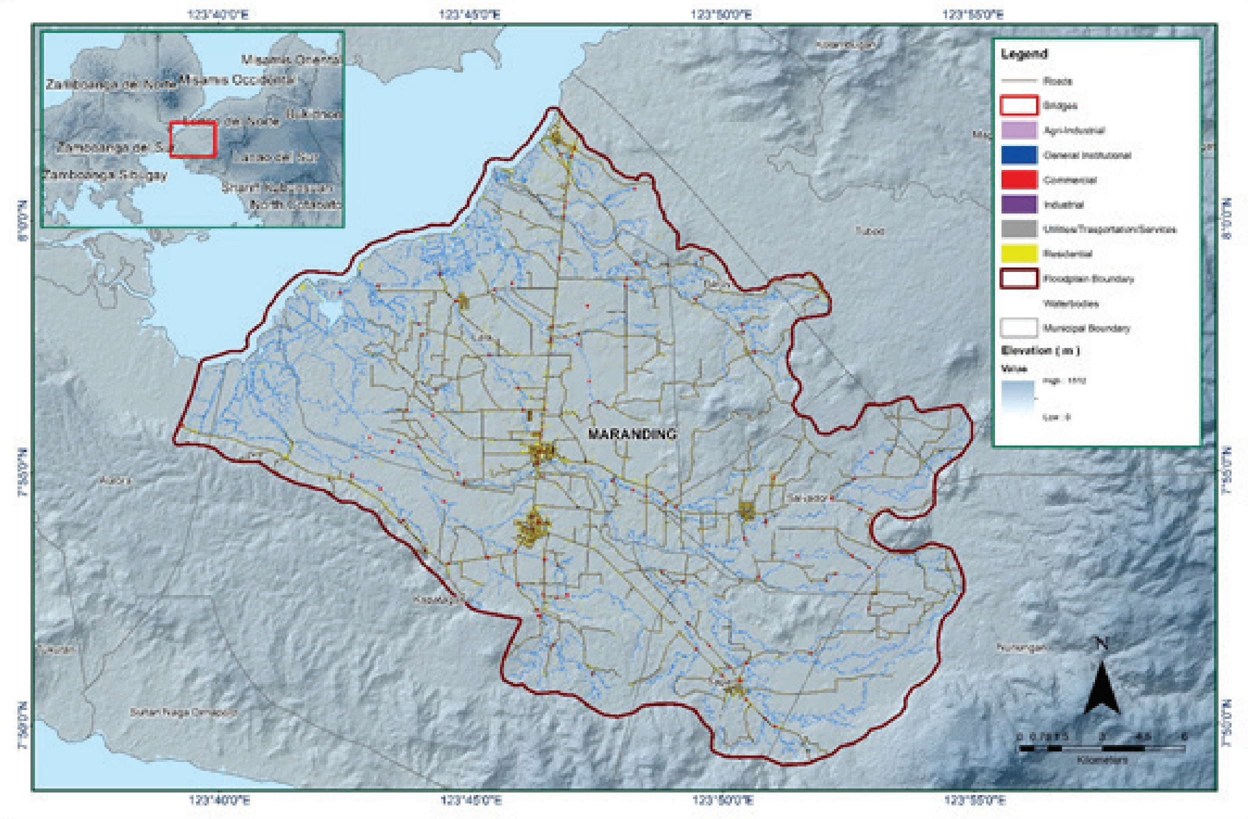


Figure 34. .Extracted features of the Maranding Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted the field survey in Maranding River from October 15 to 26, 2015 with the following scope of work: reconnaissance; courtesy call to the barangays near the survey area for information dissemination of the team's activities and to ask for a boat and a local aide's assistance; control survey for the establishment of a control point; cross-section and bridge as-built and water level marking in MSL of Lasang Bridge; ground validation data acquisition survey of about 31 km; bathymetric survey from Brgy. Maranding, Lala, Lanao del Norte down to the mouth of the river in Darumawang Bucana, Lanao del Norte using Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 utilizing GNSS PPK survey technique.

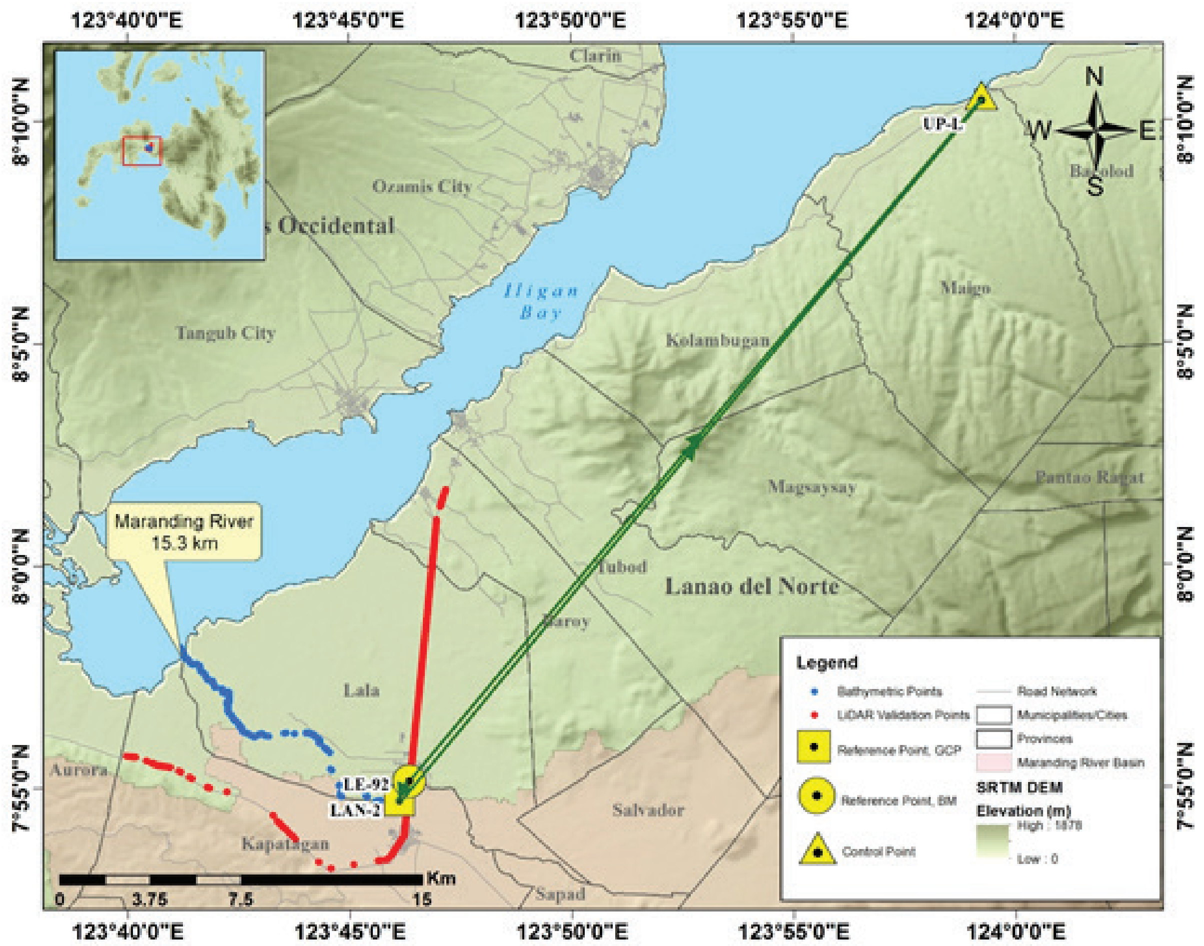


Figure 35. .Extent of the bathymetric survey (in blue line) in Maranding River.

4.2 Control Survey

The GNSS network used for Maranding River Basin is composed of single loop established on October 25, 2014 occupying the following reference points: LAN-2, a first-order GCP, in Brgy. Maranding, Municipality of Kapatagan; and LE-92, a first-order BM, in Brgy. Maranding, Municipality of Lala, all in Lanao Del Norte

Control points were established along approach of Liangan Bridge namely UP-L, located in Brgy. Liangan West, Municipality of Maigo, Lanao Del Norte.

Table 26 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 36 shows the GNSS network established in the Maranding River Survey.

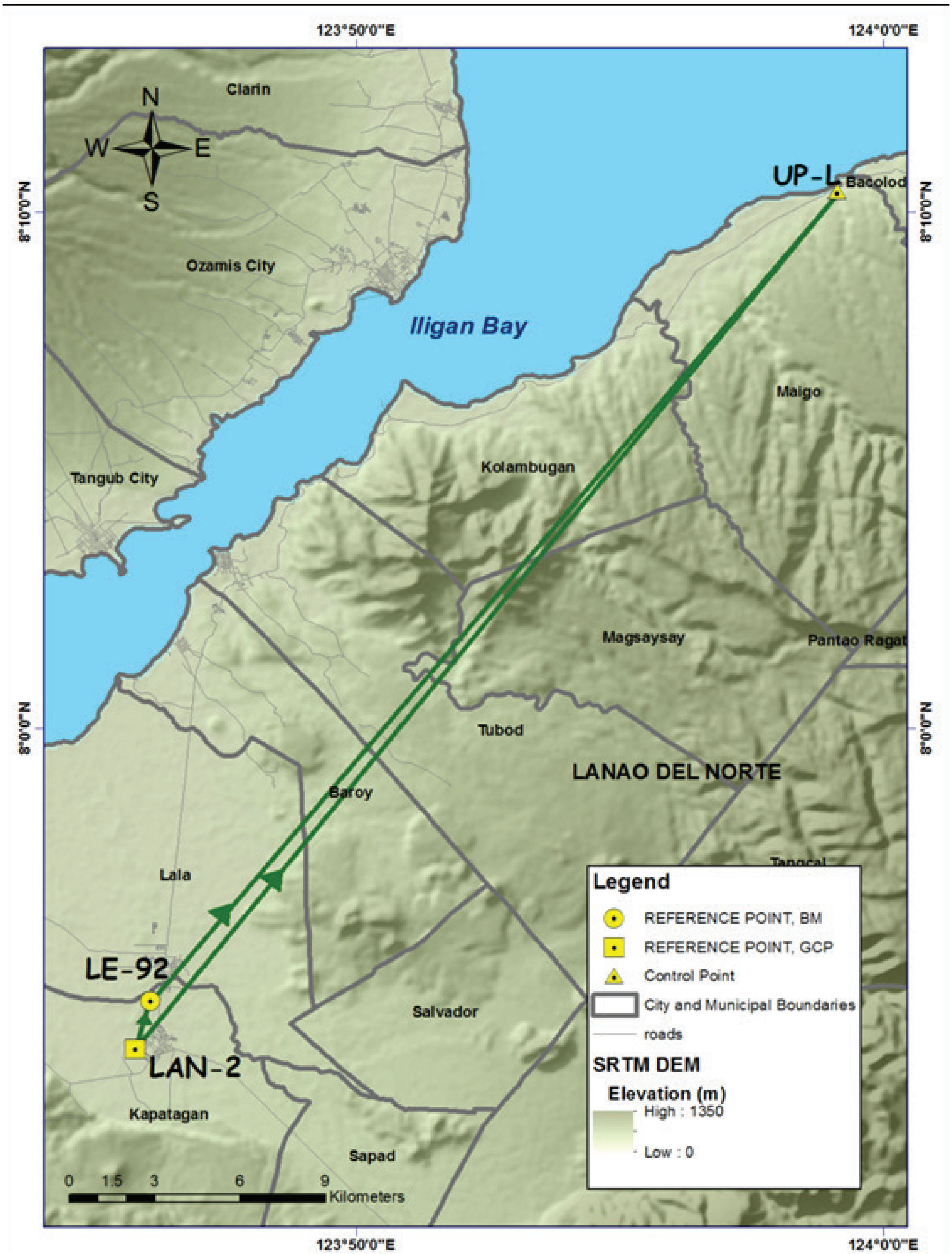


Figure 36. GNSS network established in Maranding River Field Survey

Table 26. List of references and control points occupied in Lanao del Norte survey (Source: NAMRIA; UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
LAN-2	1st order, GCP	7°54’42.56546”	123°46’06.31720”	82.151	-	1990
LE-92	1st order, BM	-	-	87.116	18.44	2007
UP-L	UP Established	-	-	71.088	2.042	Oct. 25, 2014

Figure 37 to Figure 39 depict the setup of the GNSS on recovered reference points and established control points in the Lanao del Norte Survey.

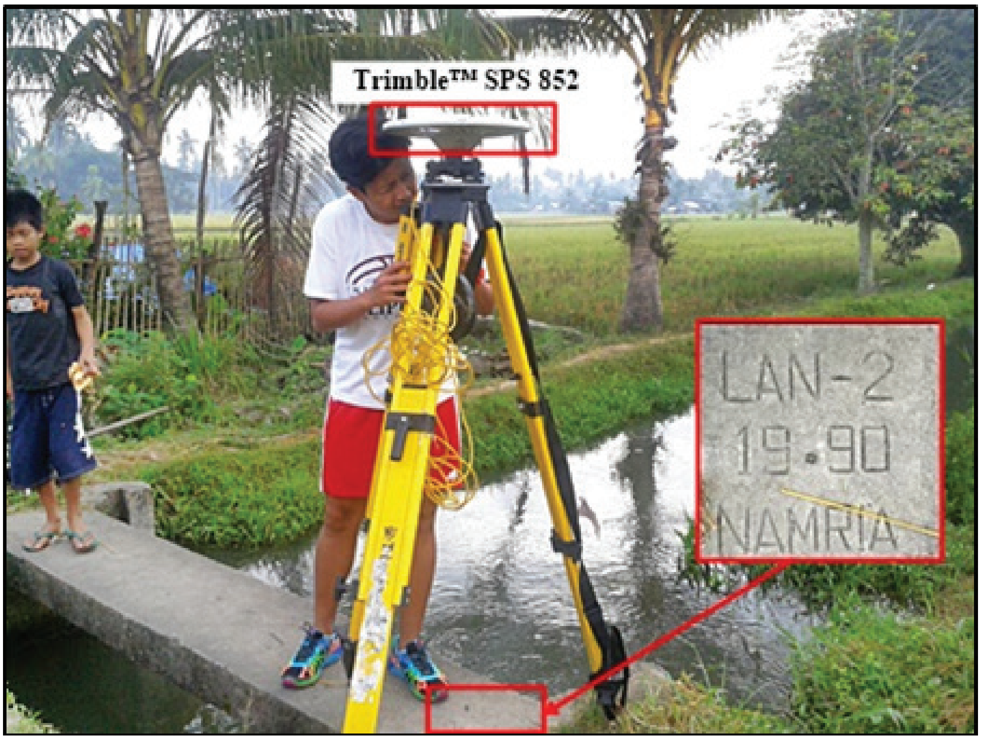


Figure 37. GNSS base set up, Trimble® SPS 852, at LAN-2, situated on top of a concrete irrigation canal gate in Brgy. Maranding, Municipality of Kapatagan, Lanao Del Norte.

Figure 38. GNSS base set up, Trimble® SPS 852, at LE-92, located at the approach of Maranding Bridge, in Brgy.

Figure 39. GNSS receiver setup, Trimble® SPS 882, at UP-L, located at the approach of Liangan Bridge, in Brgy.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 28 presents the baseline processing results of control points in the Maranding River Basin, as generated by the TBC software.

Table 27. The Baseline processing report for the Maranding River GNSS static observation survey.

Observation	Date of Observation	**Solution Type**	**H. Prec.** (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LE-92 --- LAN-2	10-25-2014	Fixed	0.001	0.002	207°34'21"	897.957	-4.965
LE-92 --- UP-L	10-25-2014	Fixed	0.005	0.014	39°53'57"	37006.02	-16.030
LAN-2 --- UP-L	10-25-2014	Fixed	0.005	0.015	39°36'31"	37883.78	-11.063

As shown in Table 28, a total of three (3) baselines were processed with the coordinates of LAN-2, and the elevation value of reference points LE-92 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 29 to Table 32.

The three (3) control points, LAN-2, LE-92, and UP-L were occupied and observed simultaneously to form a GNSS loop. Coordinates of LAN-2 and elevation values of LE-92 were held fixed during the processing of the control points as presented in Table 29. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 28. Constraints applied to the adjustment of the control points.

Point ID	Type	**East σ (Meter)**	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LAN-2	Local	Fixed	Fixed		
LE-92	Grid				Fixed
Fixed = 0.000001 (Meter)					

Table 29. The Baseline processing report for the Maranding River GNSS static observation survey.

Point ID	Easting (Meter)	**Easting Error (Meter)**	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constrain
LAN-2	584699.973	?	874628.035	?	13.471	0.009	LL
LE-92	585114.005	0.005	875424.530	0.003	18.440	?	e
UP-L	608790.643	0.012	903851.418	0.009	2.042	0.048	

The results of the computation for accuracy are as follows:

a. LAN-2
horizontal accuracy = Fixed
vertical accuracy = 0.90 cm < 10 cm

b. LE-92
horizontal accuracy = $\sqrt{((0.50)^2 + (0.30)^2}$
= $\sqrt{(0.25 + 0.09)}$
= 0.5 cm < 20 cm
vertical accuracy = Fixed

c. UP-L
horizontal accuracy = $\sqrt{((1.20)^2 + (0.90)^2}$
= $\sqrt{(1.44 + 0.81)}$
= 1.5 cm < 20 cm
vertical accuracy = 4.80 cm < 10 cm

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

Table 30. The Baseline processing report for the Maranding River GNSS static observation survey.

Point ID	Latitude	**Longitude**	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
LAN-2	N7°54'42.56546"	E123°46'06.31720"	82.151	0.009	LL
LE-92	N7°55'08.47531"	E123°46'19.88700"	87.116	?	e
UP-L	N8°10'32.39730"	E123°59'15.35400"	71.088	0.048	

The corresponding geodetic coordinates of LE-92, and UP-L which were derived are within the required accuracy as shown in Table 31. Based on the results of the computation, the accuracy conditions were satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Maranding River GNSS Static Survey are seen in Table 32.

Table 31. The reference and control points utilized in the Maranding River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	**Geographic Coordinates (WGS 84)**			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LAN-2	1st order, GCP	7°54'42.56546"	123°46'06.31720"	82.151	874628.035	584699.973	13.471
LE-92	1st order, BM	7°55'08.47531"	123°46'19.88700"	87.116	875424.53	585114.005	18.44
UP-L	UP Established	8°10'32.39730"	123°59'15.35400"	71.088	903851.418	608790.643	2.042

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

The bridge cross-section and as-built surveys were conducted on October 24, 2014 along the downstream side of Maranding Bridge in Brgy. Maranding, Municipality of Lala using the GNSS receiver Trimble® SPS 882 in PPK Survey Technique (Figure 40).

Figure 40. Cross-section survey on the downstream side of Maranding Bridge in Brgy. Maranding, Municipality of Lala.Liangan West, Municipality of Maigo, Lanao Del Norte.

The cross-sectional line of Maranding Bridge is about 77 meters with thirty-eight (38) points acquired using LE-92 as the GNSS base station. The cross-section diagram, the location maps and bridge data form are shown in Figure 41 to Figure 43.

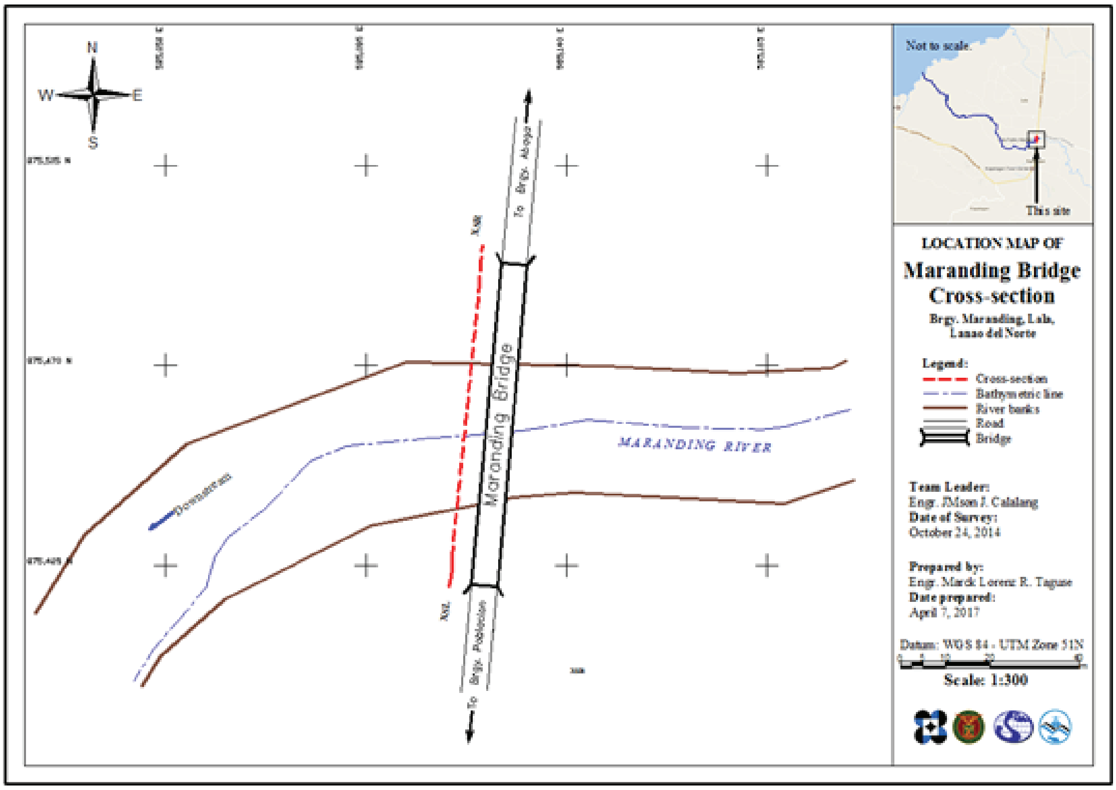


Figure 41. Location Map of Maranding bridge cross-section.

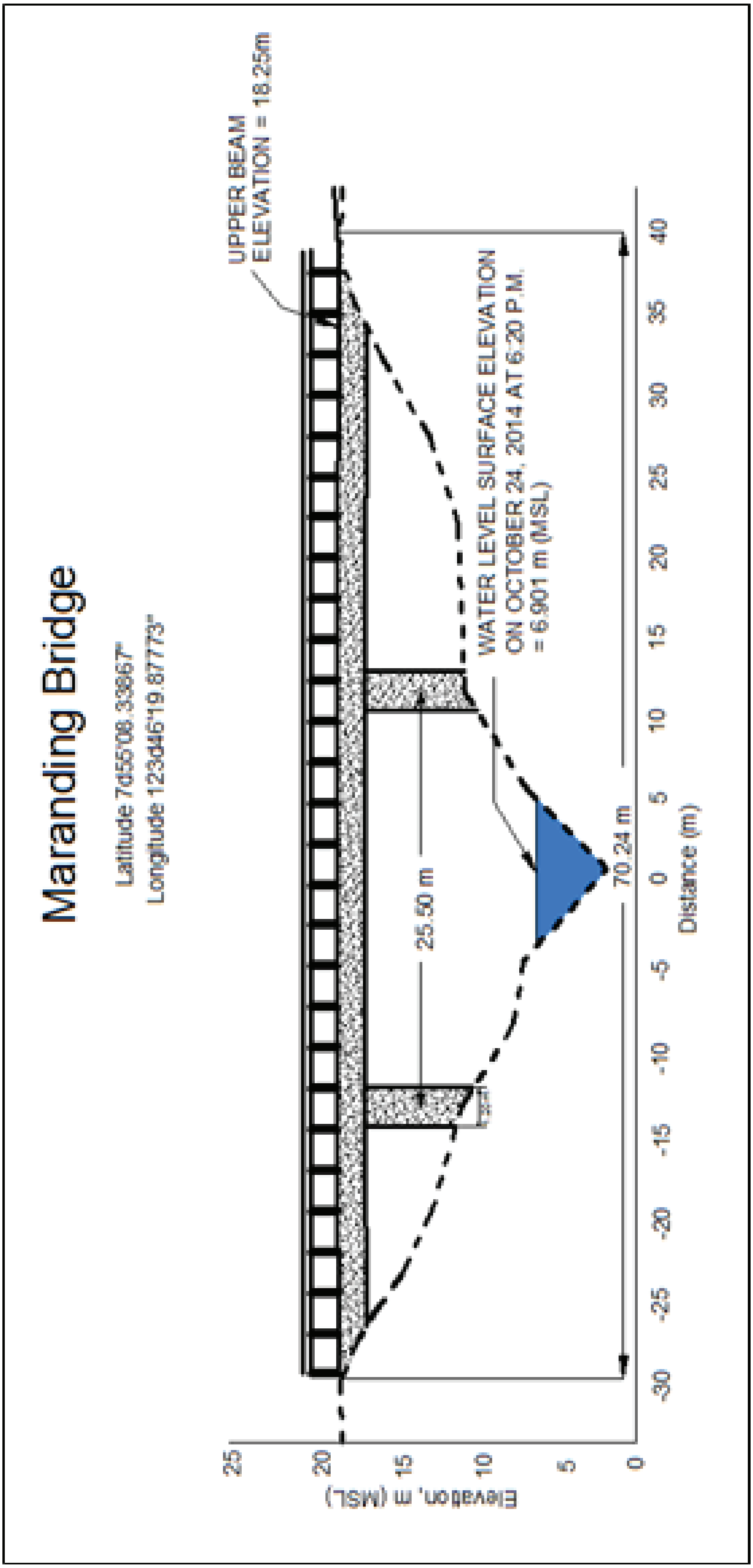


Figure 42. The Maranding Bridge cross-section survey drawn to scale.

Bridge Data Form

Bridge Name: Maranding Bridge **Date: 10/24/14**

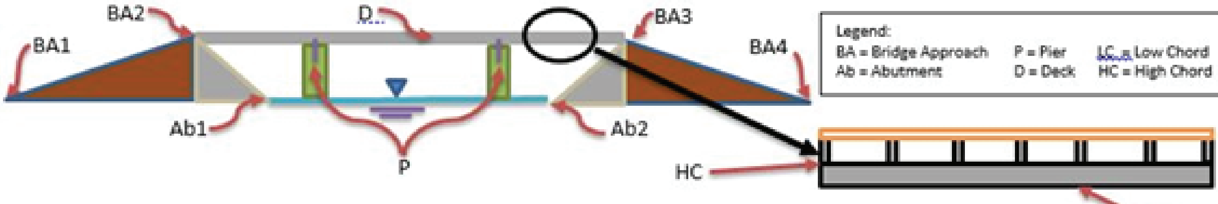
River Name: Maranding River **Time: 6:20 PM**

Location (Brgy, City,Region): Maranding, Lala, Lanao del Norte

Survey Team: JMson Calalang, Bernice Furagganan, Rodel Alberto

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

Latitude: 7d 55' 08.33867"__________ **Longitude: 123d 46' 19.87773"_______**



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

Elevation: 18.4 m **Width: 6.5 m** **Span (BA3-BA2): 78.4 m**

	Station (Distance from BA1) (m)	High Chord Elevation (m) MSL	Low Chord Elevation (m) MSL
1	20.57	18.30	16.70
2	46.07	18.35	16.65

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

	Station(Distance from BA1) (m)	Elevation (m) MSL		Station(Distance from BA1) (m)	Elevation (m) MSL
BA1	0	18.021	BA3	73.03	18.25
BA2	4.2	18.20	BA4	76.9	18.59

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

	Station (Distance from BA1) (m)	Elevation (m) MSL

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

Shape: Rectangular Number of Piers: 2

	Station (Distance from BA1) (m)	Elevation (m) MSL	Pier Width (m)
Pier 1	20.57	10.71	1.2
Pier 2	46.07	10.49	1.2

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

Figure 43. Maranding Bridge Data Form.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 23, 2015 using a survey grade GNSS rover receiver Trimble® SPS 882 mounted on a pole, which was attached in front of the vehicle as shown in Figure 44. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS rover receiver. Points were gathered along concrete roads so that data to be acquired will have a relatively minimal change in elevation, observing vehicle speed of 10 to 20 kph.

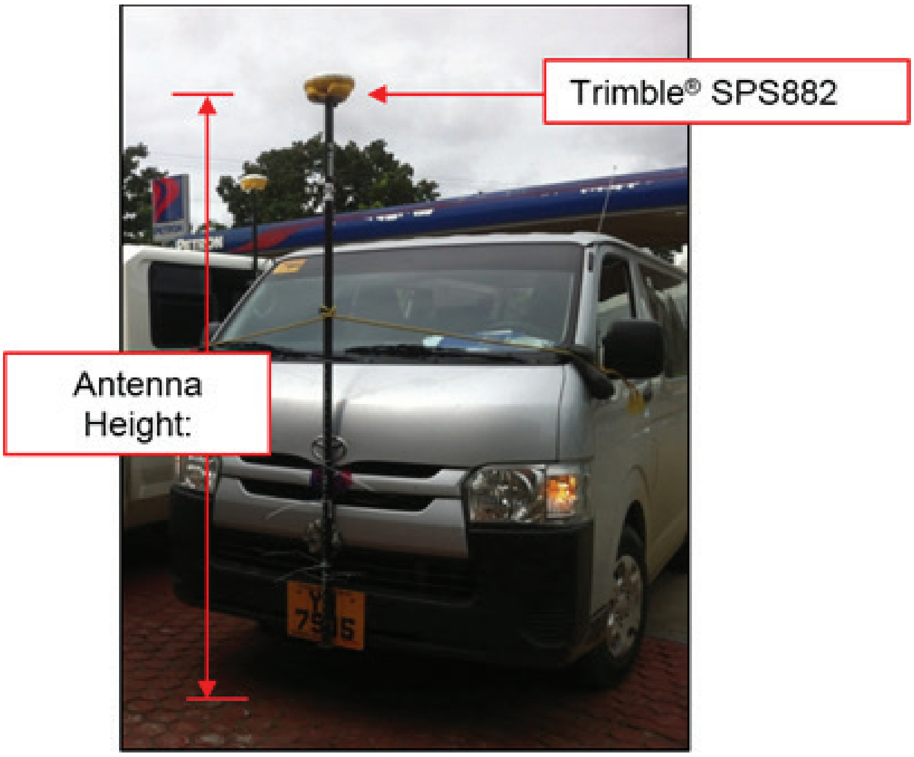


Figure 44. Trimble® SPS882 set-up on a vehicle for validation points acquisition along the major roads near Maranding River.

The survey started from the Municipality of Kapatagan, traversing the major roads eastward covering Municipality of Lala and Municipality of Baroy, in Lanao Del Norte. The survey gathered a total of 3,537 ground validation points with an approximated length of 31 km. Figure 45 shows the validation points acquisition survey coverage.

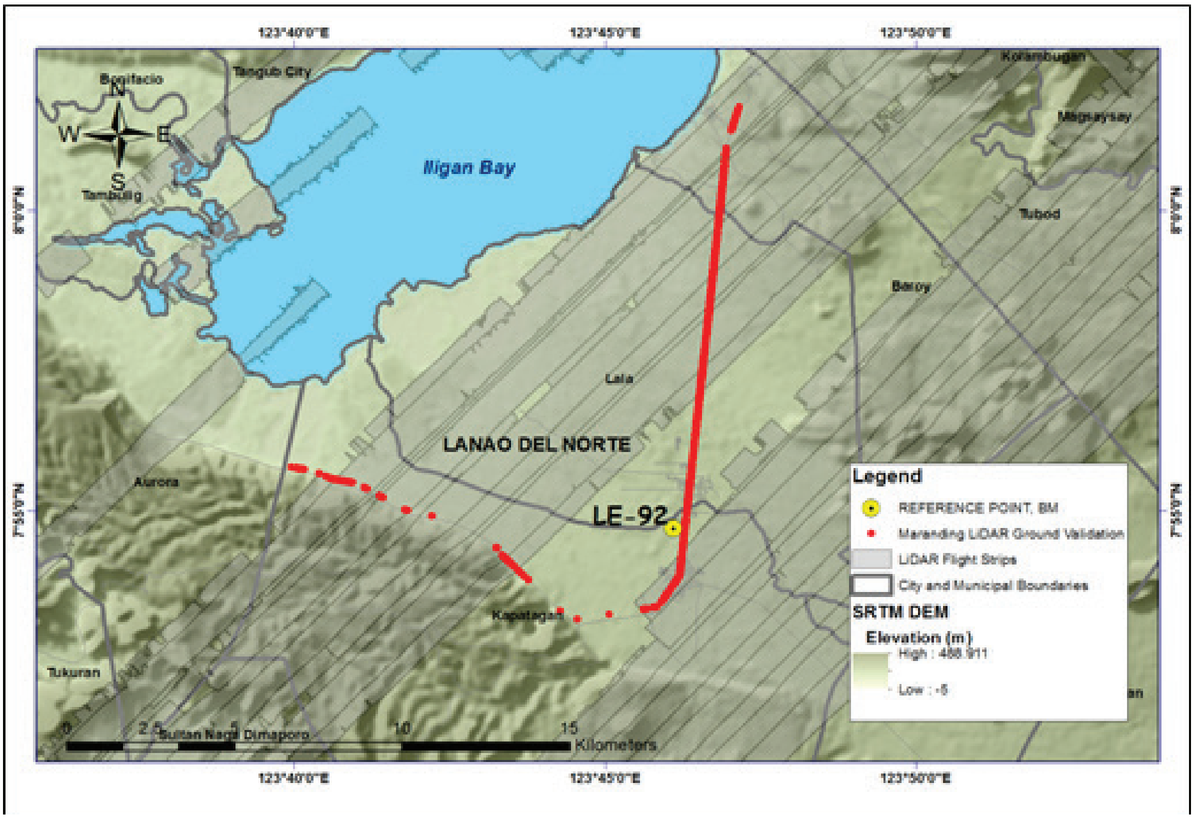


Figure 45. The extent of the LiDAR ground validation survey for Maranding River Basin.

4.7 River Bathymetric Survey

A bathymetric survey was performed on October 23 using Hi-Target™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 in GNSS PPK survey technique, installed on the boat as shown in Figure 46. The survey started in Brgy. Maranding, Municipality of Lala, with coordinates 7°55’11.1138”N, 123°46’29.56666”E down to the mouth of the river in Brgy. Darumawang, Bucana, also in Lala, with coordinates 7°58’10.37856”N, 123°41’09.23549”E. The control point SE-92 was used as the GNSS base all throughout the survey.

Figure 46. Set up of Hi-Target™ Single Beam Echo Sounder integrated with a roving GNSS receiver on a motor boat for the bathymetric survey in Maranding River.

The entire bathymetric data coverage for Maranding River is illustrated in the map in Figure 47. The bathymetric line is approximately 15.3 km in length with 4,772 bathymetric points of the river traversing Barangays Butadon and Maranding in Municipality of Kapatagan; and six (6) more barangays in Municipality of Lala, Lanao Del Norte. A CAD drawing was also produced to illustrate the riverbed profile of Maranding River. As shown in Figure 48 and Figure 49, the highest and lowest elevation value has a 11-m difference. The lowest elevation observed was -5.552 m located at the downstream mouth part of the river, and the highest was 6.051 m above MSL located in the upstream most part of the river. There is also an abrupt change in elevation in the upstream from Brgy. Simpak to Brgy. Darumawang Ilaya, for about 2.2-m in every 3000 m and a gradual change of elevation between Brgy. Salvador to Brgy. Darumawang Bucana (mouth of river), having a 1.4 m difference in every 4000 m.

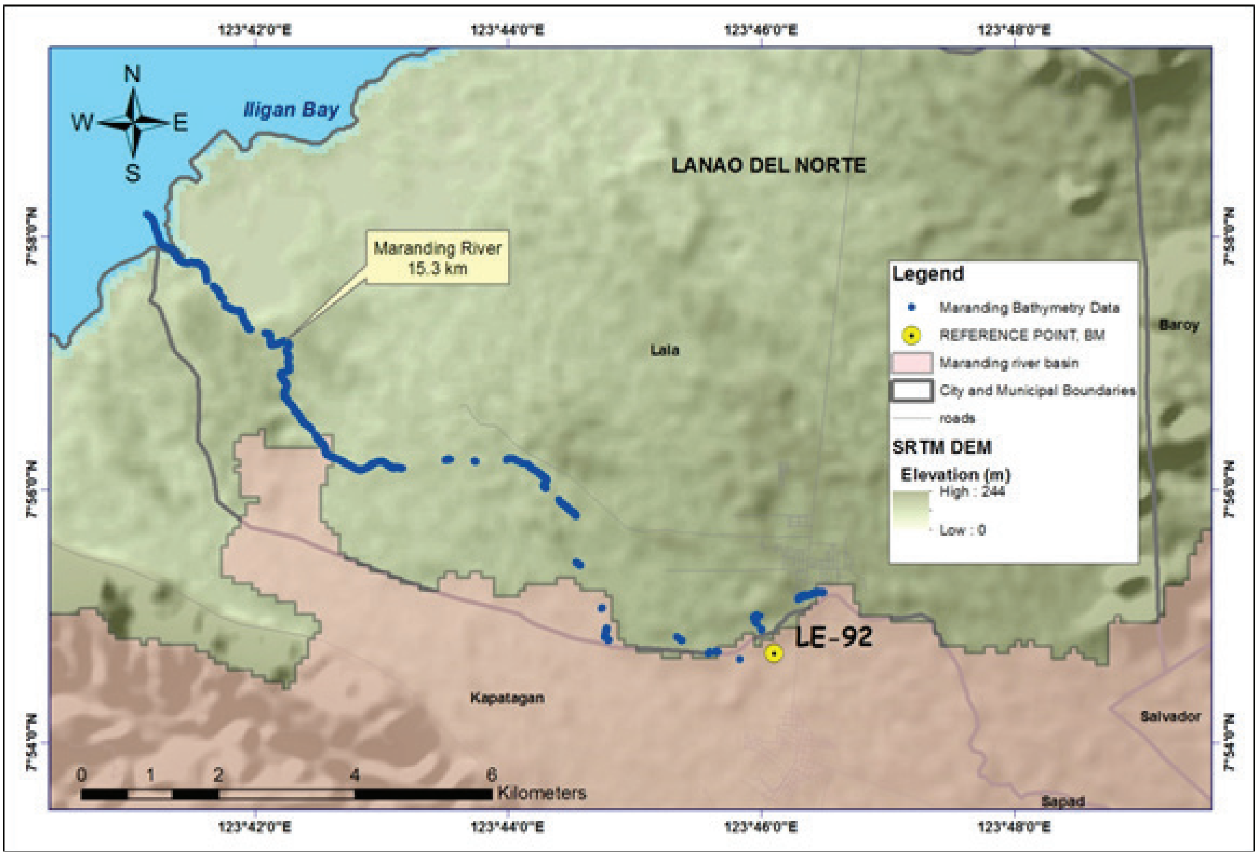


Figure 47. The extent of the Maranding River Bathymetry Survey.

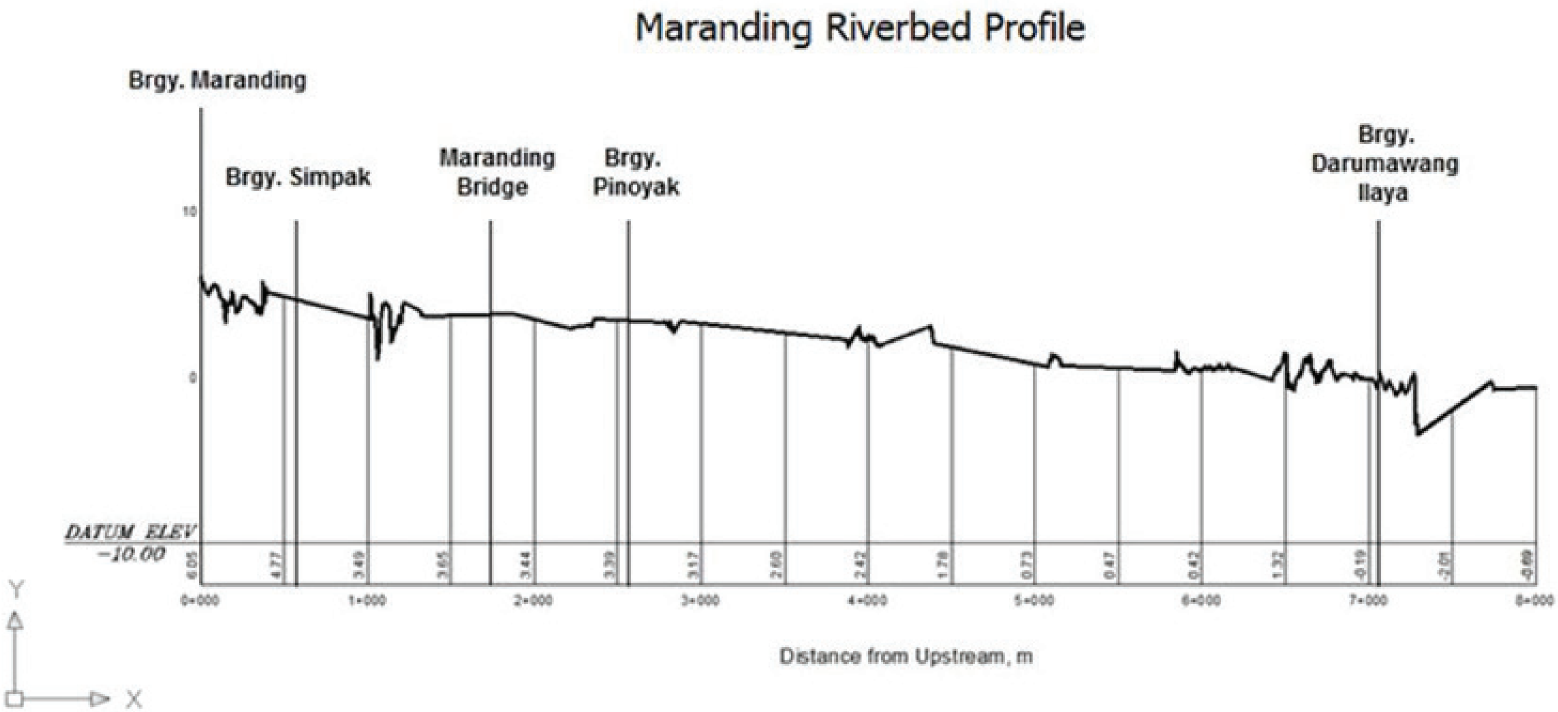


Figure 48. The Maranding river bed profile (upstream part).

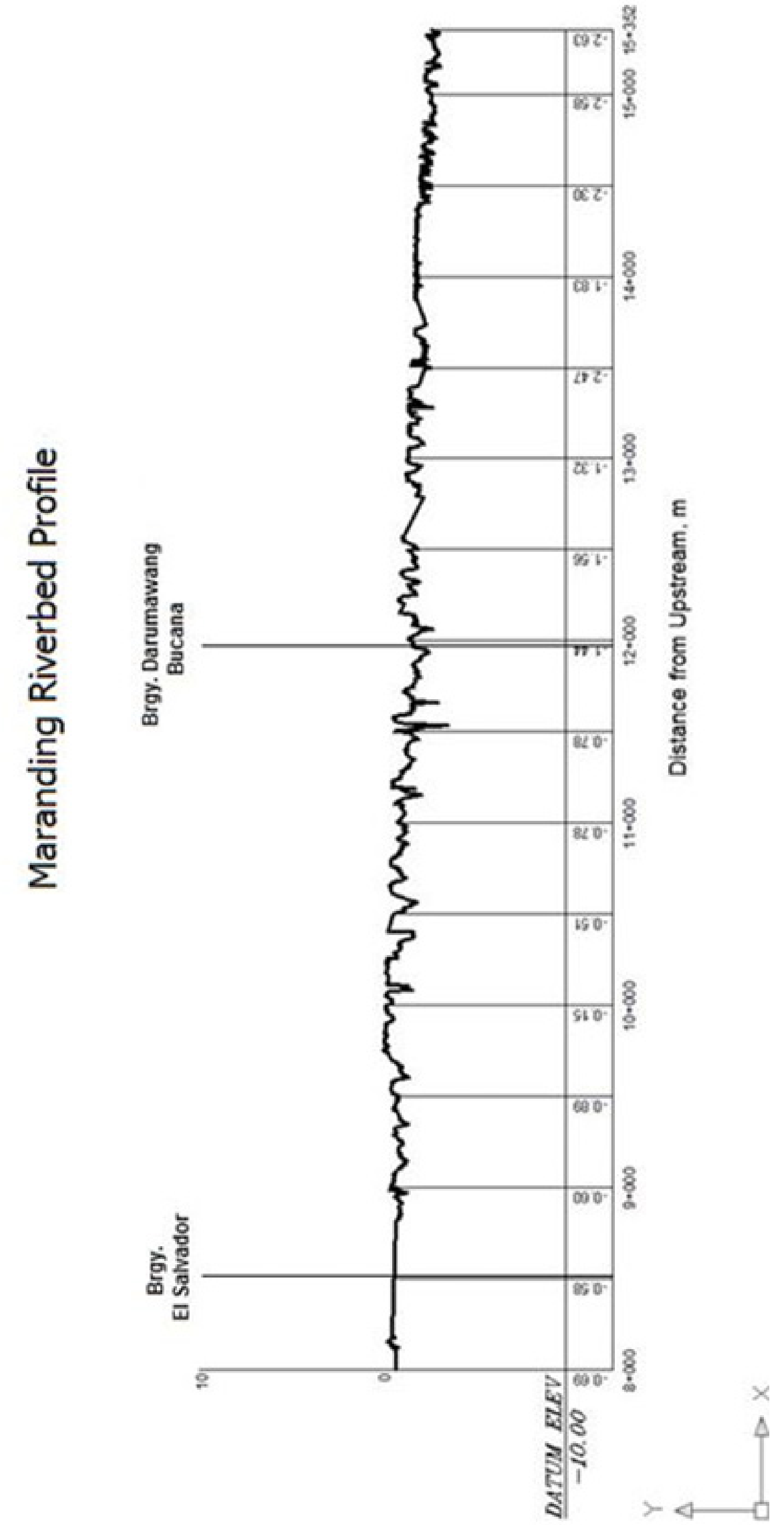


Figure 49. The Maranding river bed profile (downstream part).

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Maranding River Basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Maranding River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the Data Validation Component (DVC) of MSU-IIT. The ARG was specifically installed in the municipality of Salvador with coordinates 7.903553°N Latitude and 123.840789°E Longitude as illustrated in Figure 50.

The total precipitation for this event at Salvador ARG was 40.4 mm. It had a peak rainfall of 10.8 mm. on July 18, 2016 at 6:30 in the morning. The lag time between the peak rainfall and discharge was 6 hours and 20 minutes.

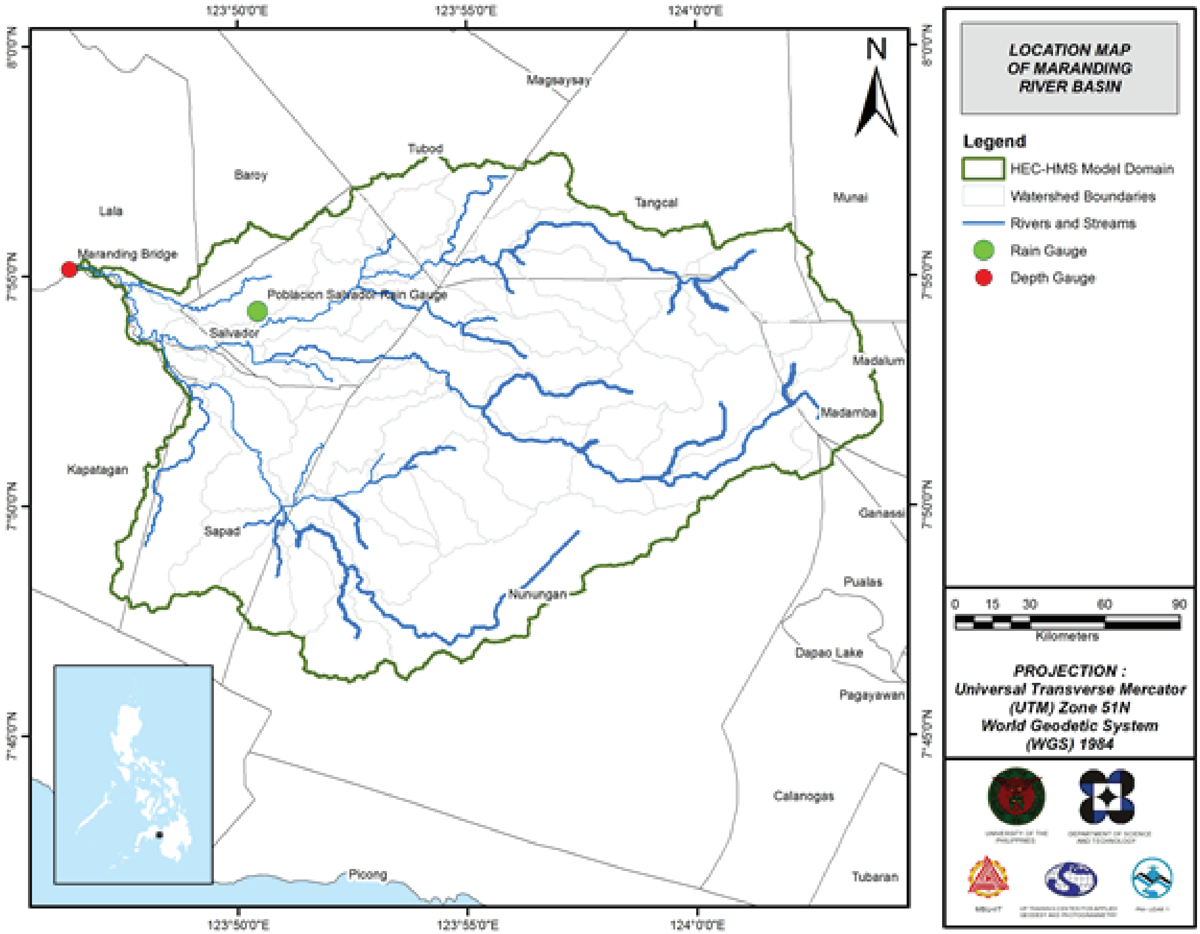


Figure 50. The location map of Maranding HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Maranding Bridge to establish the relationship between the observed water levels (H) at Maranding Bridge and outflow (Q) of the watershed at this location.

For Maranding Bridge, the rating curve is expressed as Q = 1.8371e0.3655x as shown in Figure 52.

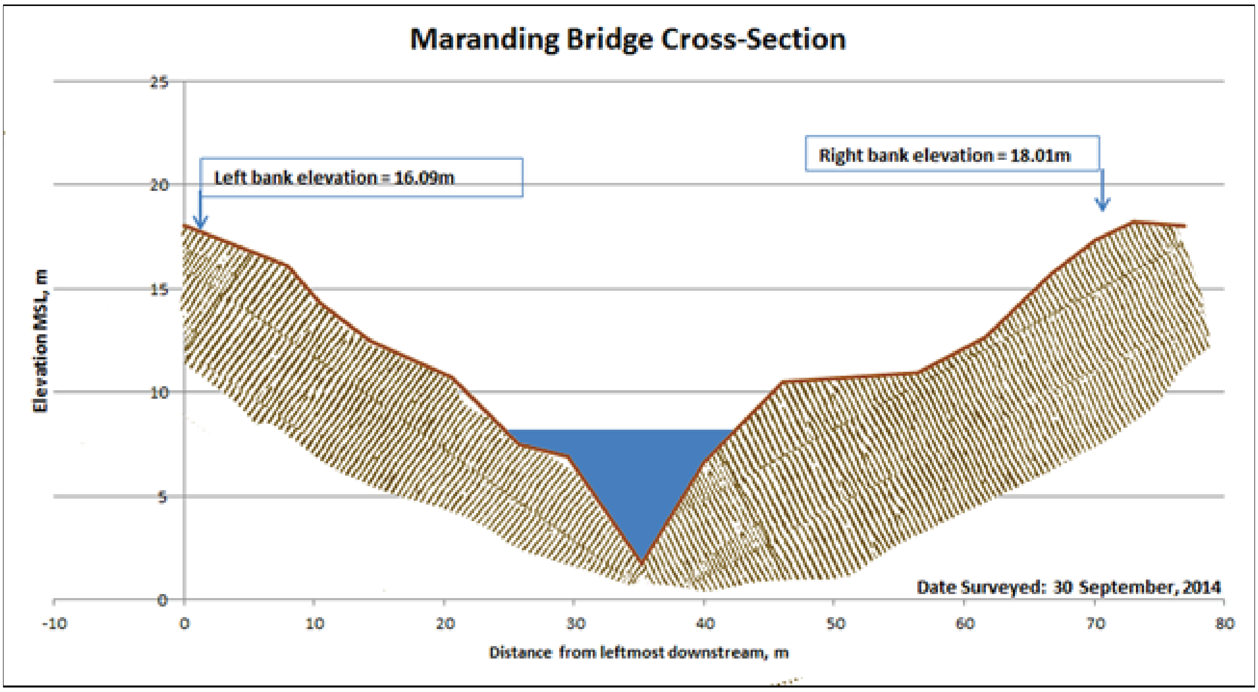


Figure 51. Cross-Section Plot of Maranding Bridge.

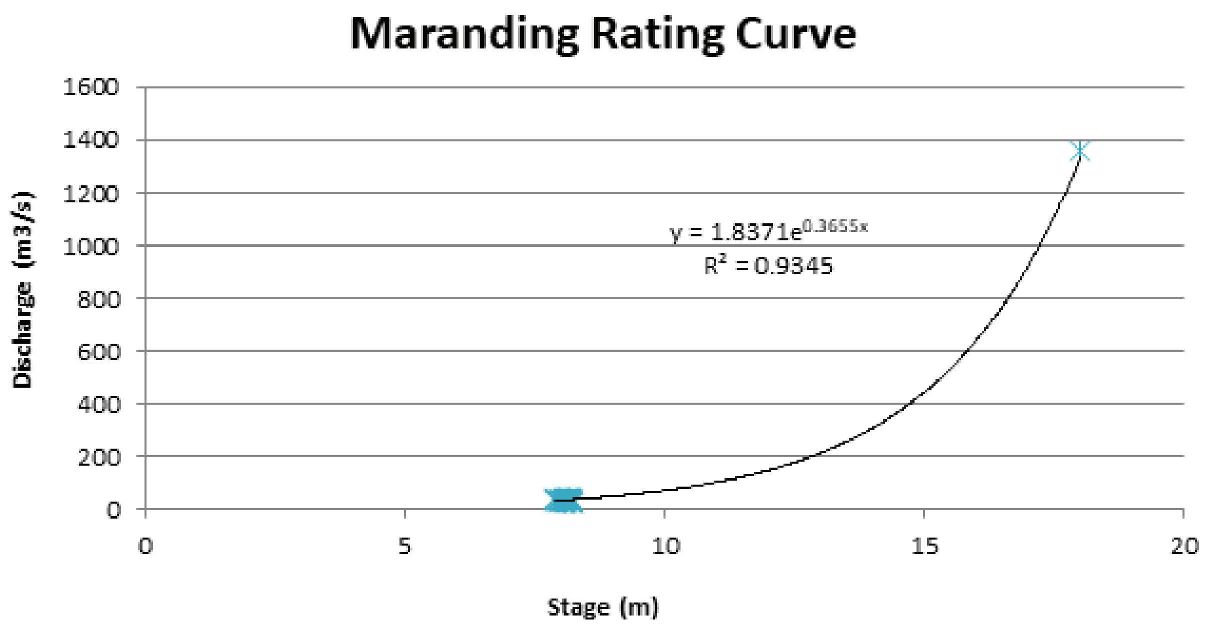


Figure 52. The rating curve plot of the Maranding Bridge.

This rating curve equation was used to compute the river outflow at Maranding Bridge for the calibration of the HEC-HMS model shown in Figure 53. The peak discharge was 33.4 cms at 6:30 in the morning, July 18, 2016.

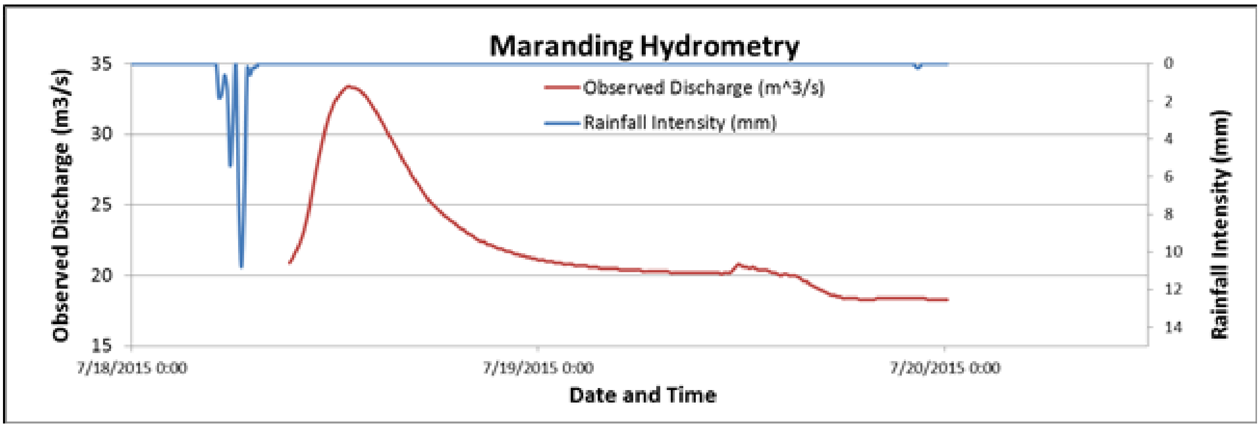


Figure 53. Rainfall and outflow data of the Maranding River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Cagayan de Oro Rain Gauge (Table 33). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 54). This station was selected based on its proximity to the Maranding watershed. The extreme values for this watershed were computed based on a 54-year record.

Table 32. RIDF values for the Cagayan de Oro Rain Gauge, as computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	18.6	29.5	37	48.3	62.3	69.4	81.6	91.8	100.1
5	24.5	38.4	48.2	63.7	84.3	92.6	109.9	128.1	141.7
10	28.4	44.3	55.6	73.9	98.8	107.9	128.7	152.1	169.2
15	30.6	47.7	59.8	79.6	107.1	116.6	139.3	165.6	184.7
20	32.2	50	62.8	83.7	112.8	122.7	146.7	175.1	195.6
25	33.3	51.8	65	86.8	117.3	127.4	152.4	182.4	204
50	37	57.3	72	96.3	130.9	141.8	170	204.9	229.8
100	40.6	62.8	78.9	105.8	144.5	156.1	187.4	227.3	255.5

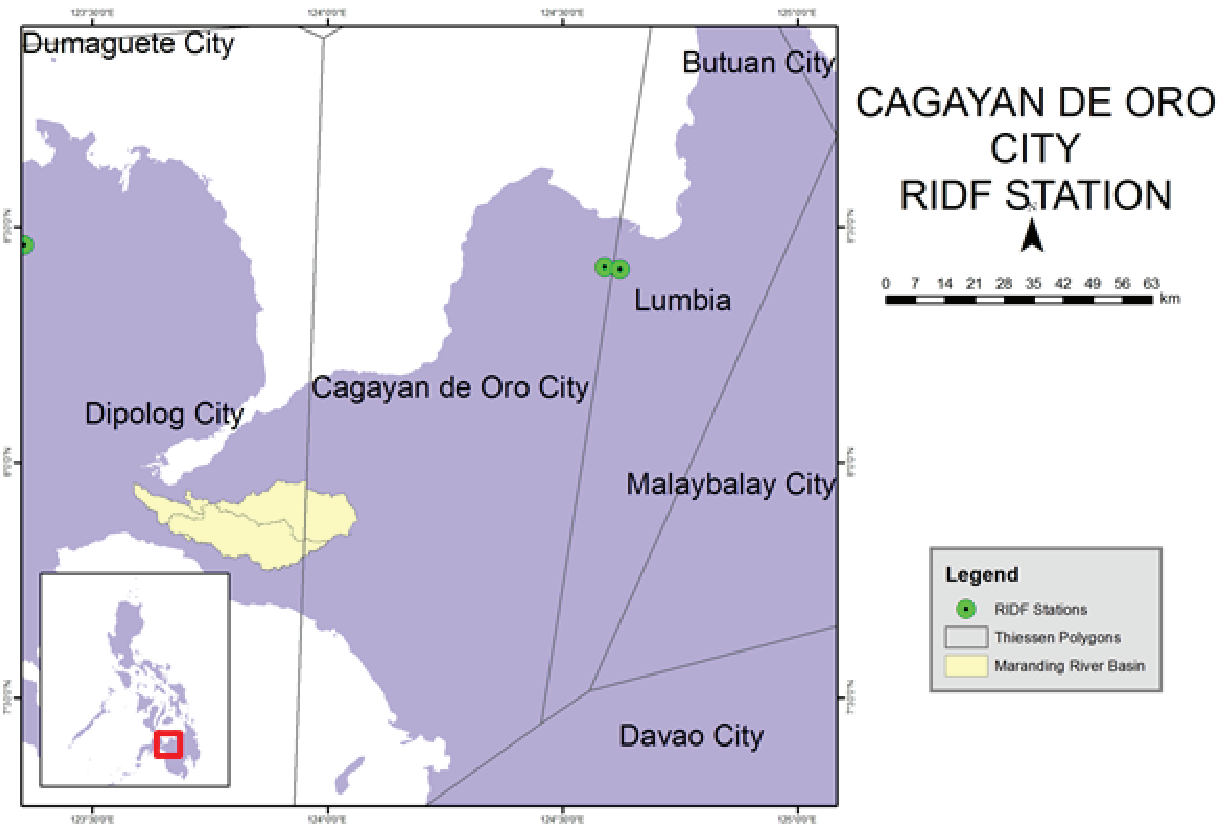


Figure 54. Location of Cagayan de Oro RIDF station relative to Maranding River Basin.

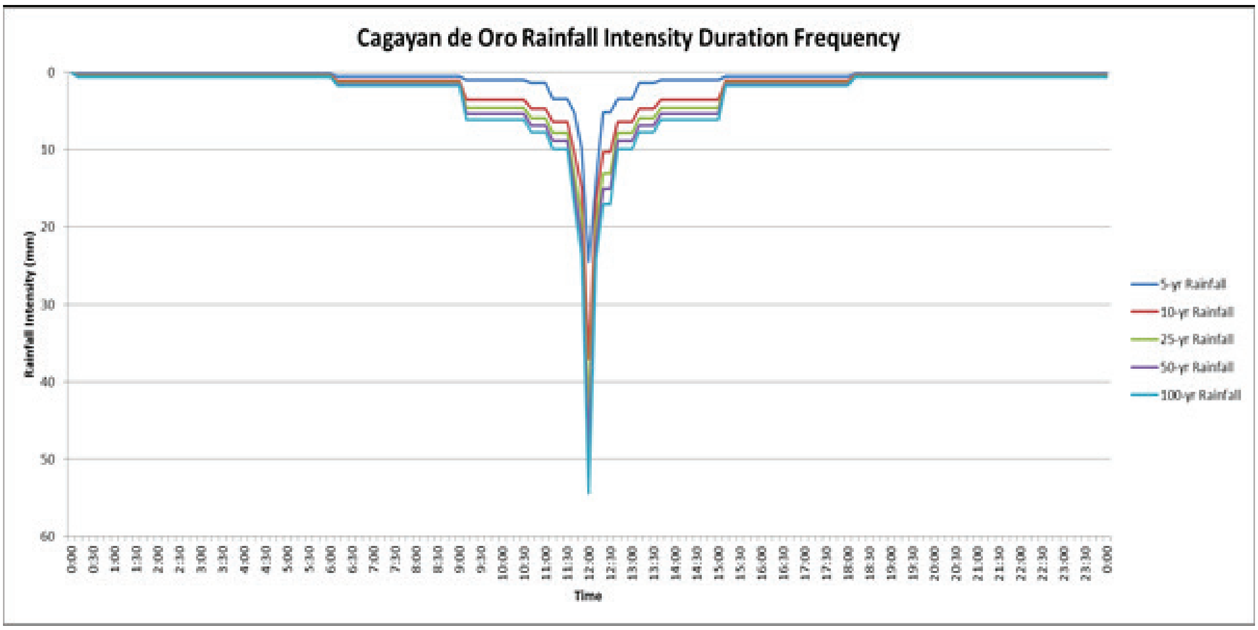


Figure 55. The synthetic storm generated for a 24-hour period rainfall for various return periods.

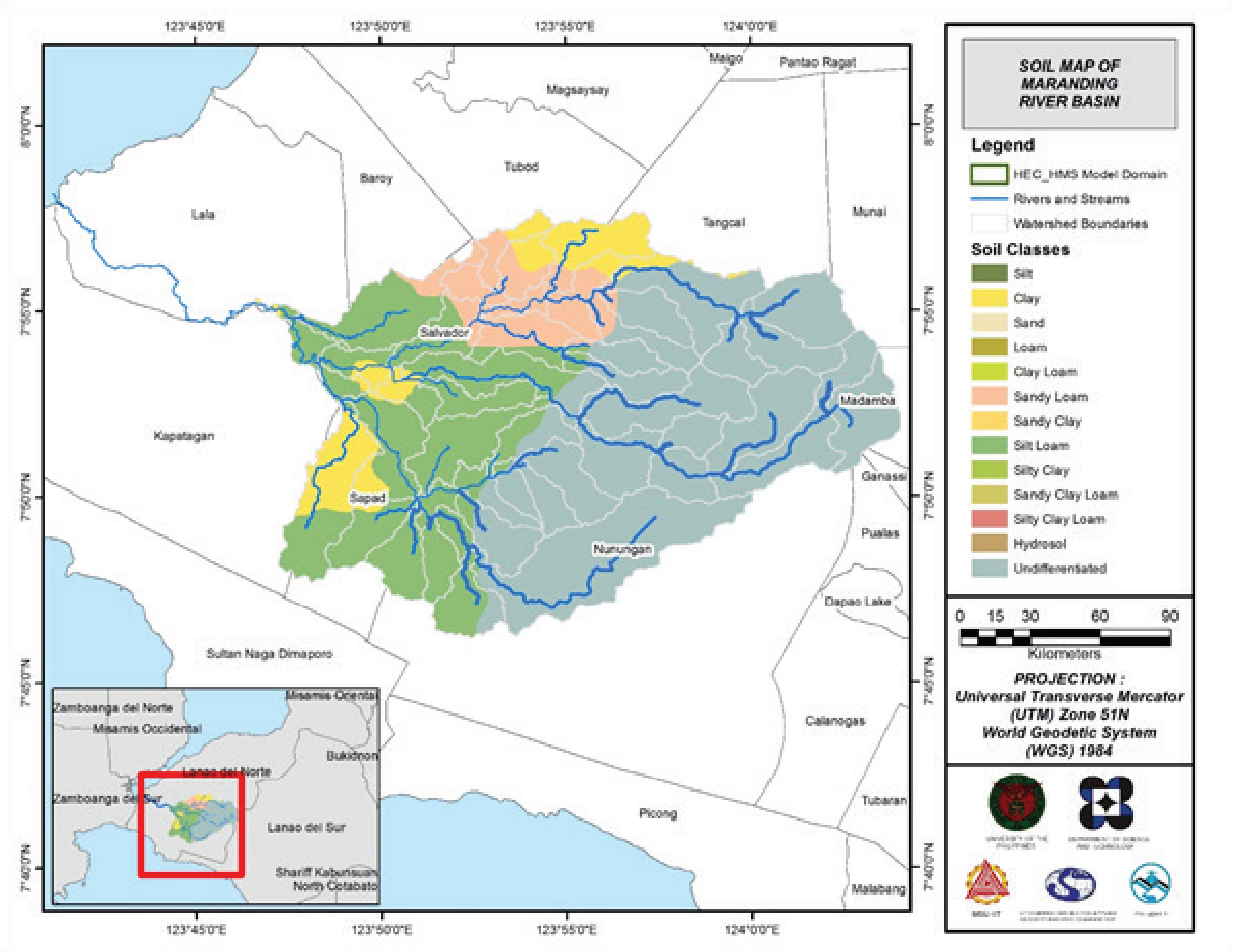


Figure 56. Soil Map of Maranding River Basin.

5.3 HMS Model

This soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is under the Department of Environment and Natural Resources Management (DENR). The land cover dataset was from the National Mapping and Resource information Authority (NAMRIA). The soil, land cover, and slope map of the Maranding River Basin are shown in Figure 56 to Figure 58.

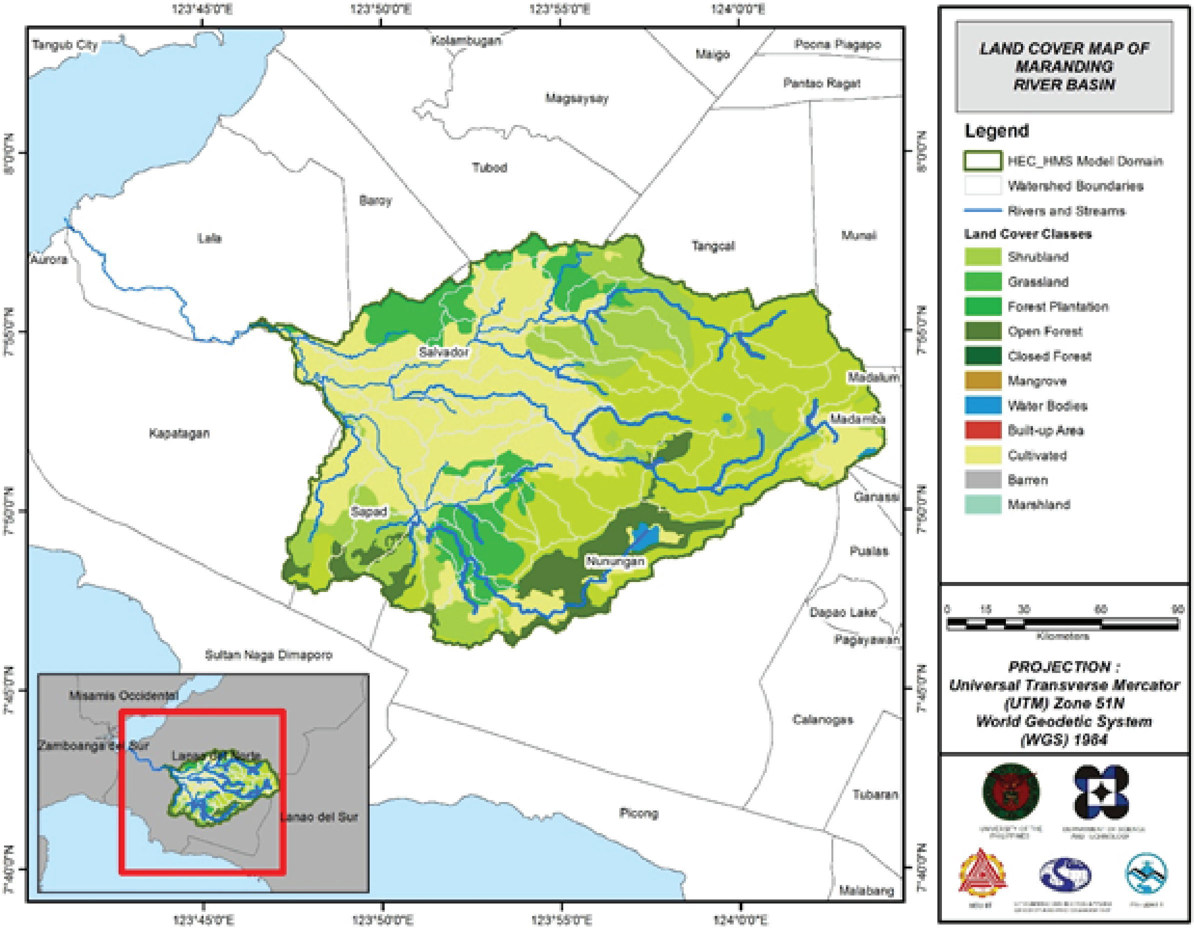


Figure 57. Land Cover Map of Maranding River Basin.

For Maranding, the soil classes identified were clay, sandy clay, sandy loam, silt loam, and undifferentiated. The land cover types identified were shrubland, grassland, forest plantation, open forest, closed forest, and cultivated.

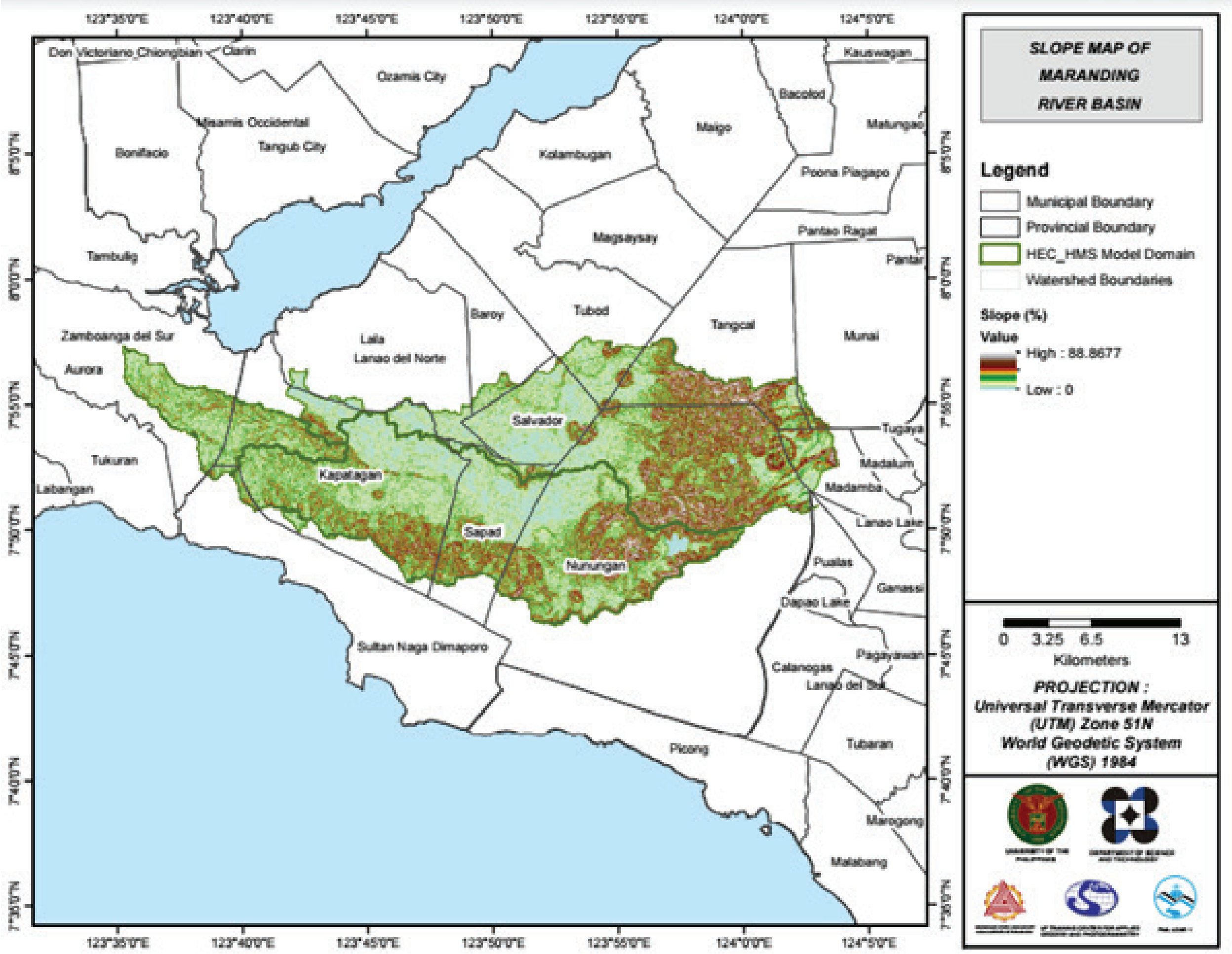


Figure 58. Slope Map of the Maranding River Basin.

Using the SAR-based DEM, the Maranding basin was delineated and further subdivided into subbasins. The model consists of 35 subbasins, 21 reaches, and 21 junctions. The main outlet is Mar_Point. This basin model is illustrated in Figure 59. Finally, it was calibrated using hydrological data derived from the depth gauge and flow meter deployed at Maranding Bridge.

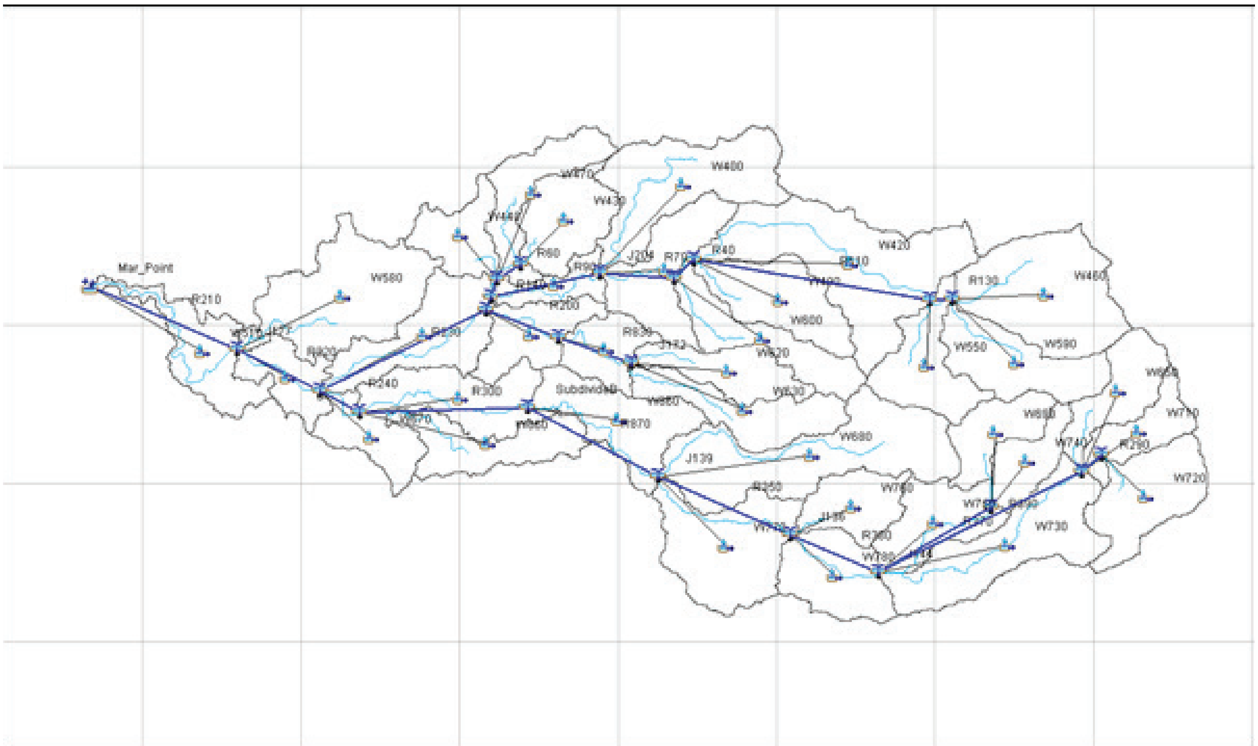


Figure 59. The Maranding river basin model generated using HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the HEC GeoRAS tool and was post-processed in ArcGIS (Figure 60).

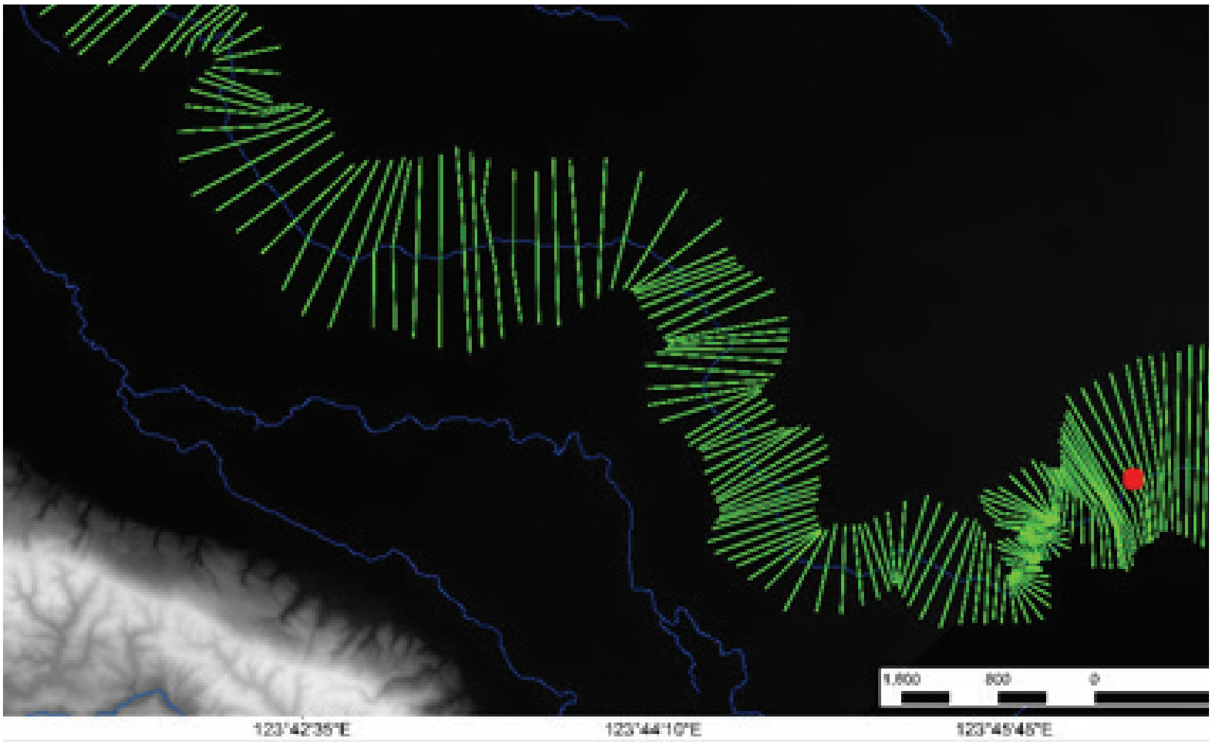


Figure 60. River cross-section of the Maranding River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

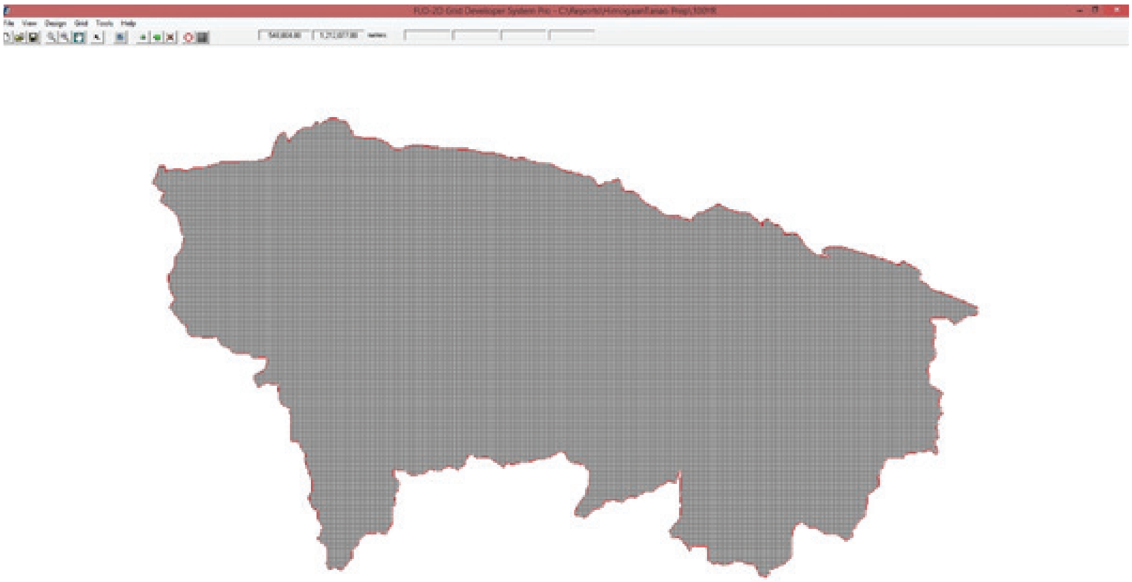


Figure 61. . A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 22.20007 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Maranding are in Figure 62, 64, and 66.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 22958400.00 m2. The generated flood depth maps for Maranding are in Figure 63, 65 and 67.

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

5.6 Results of HMS Calibration

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

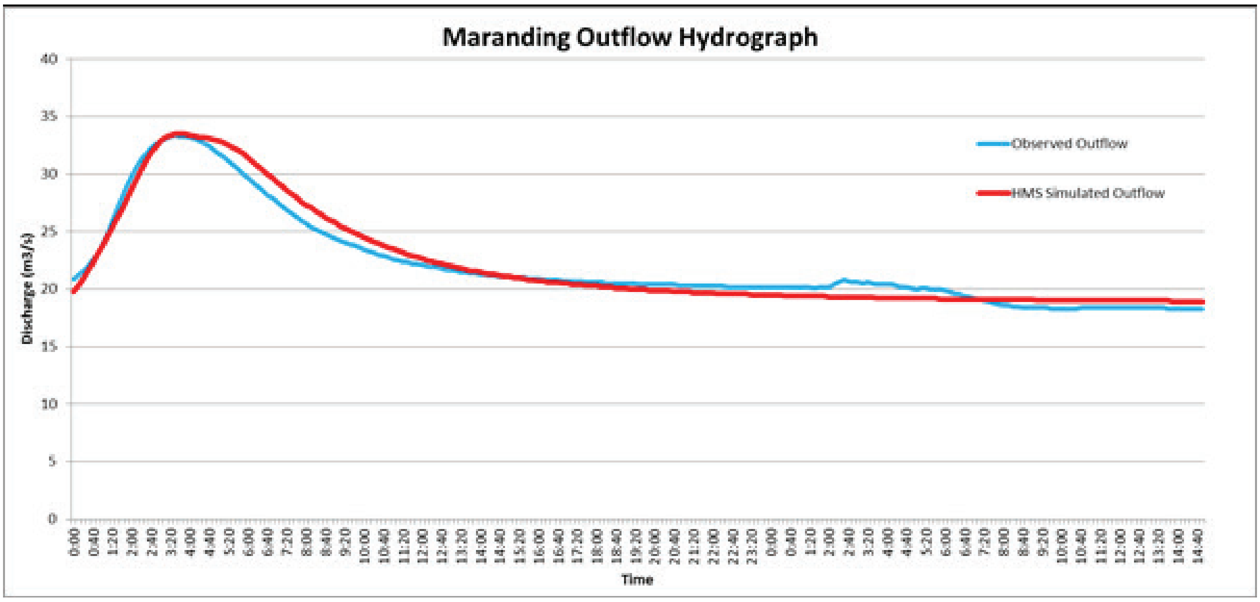


Figure 62. Outflow Hydrograph of Maranding produced by the HEC-HMS model compared with observed outflow.

Table 34 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 33. RIDF values for the Dipolog Rain Gauge, as computed by PAGASA

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	10 - 57
			Curve Number	47 - 83
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	2 - 10
			Storage Coefficient (hr)	2 - 14
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

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 10 to 57mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation per subbasin.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 47 to 83 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 2 to 14 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 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.5 indicates a relatively average steepness of receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness in Maranding watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

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

Accuracy measure	Value
RMSE	1.26
r2	0.93
NSE	0.94
PBIAS	-3.25
RSR	0.23

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.26 (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 0.93.

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 0.94.

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 -3.25.

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 0.23.

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

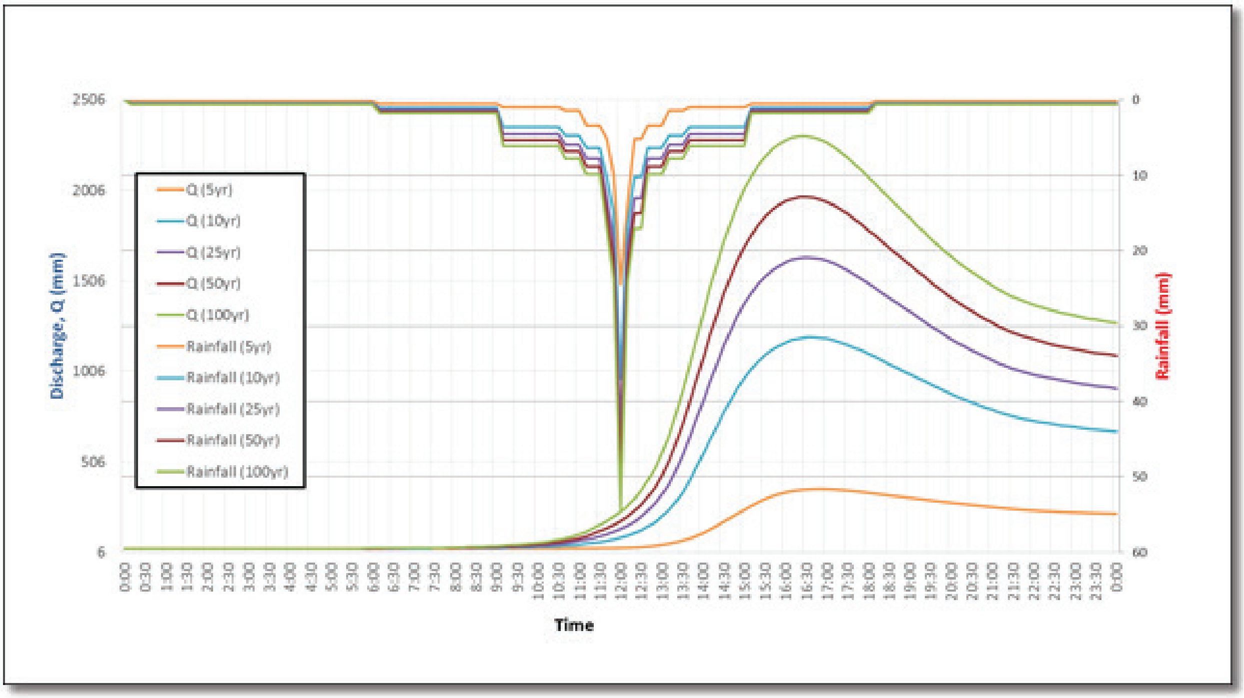


Figure 63. The Outflow hydrograph at the Maranding Station, generated using the Cagayan de Oro RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Maranding discharge using the Cagayan de Oro Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 36.

Table 35. The peak values of the Maranding HEC-HMS Model outflow using the Romblon RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	141.7	24.5	355.8	16 hours, 50 minutes
10-Year	300.7	37	1194.5	16 hours, 40 minutes
25-Year	373.6	44	1634.3	16 hours, 30 minutes
50-Year	427.6	49.2	1970	16 hours, 30 minutes
100-Year	481.2	54.4	2305.9	16 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 will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 64 shows a generated sample map of the Maranding River using the calibrated HMS base flow.

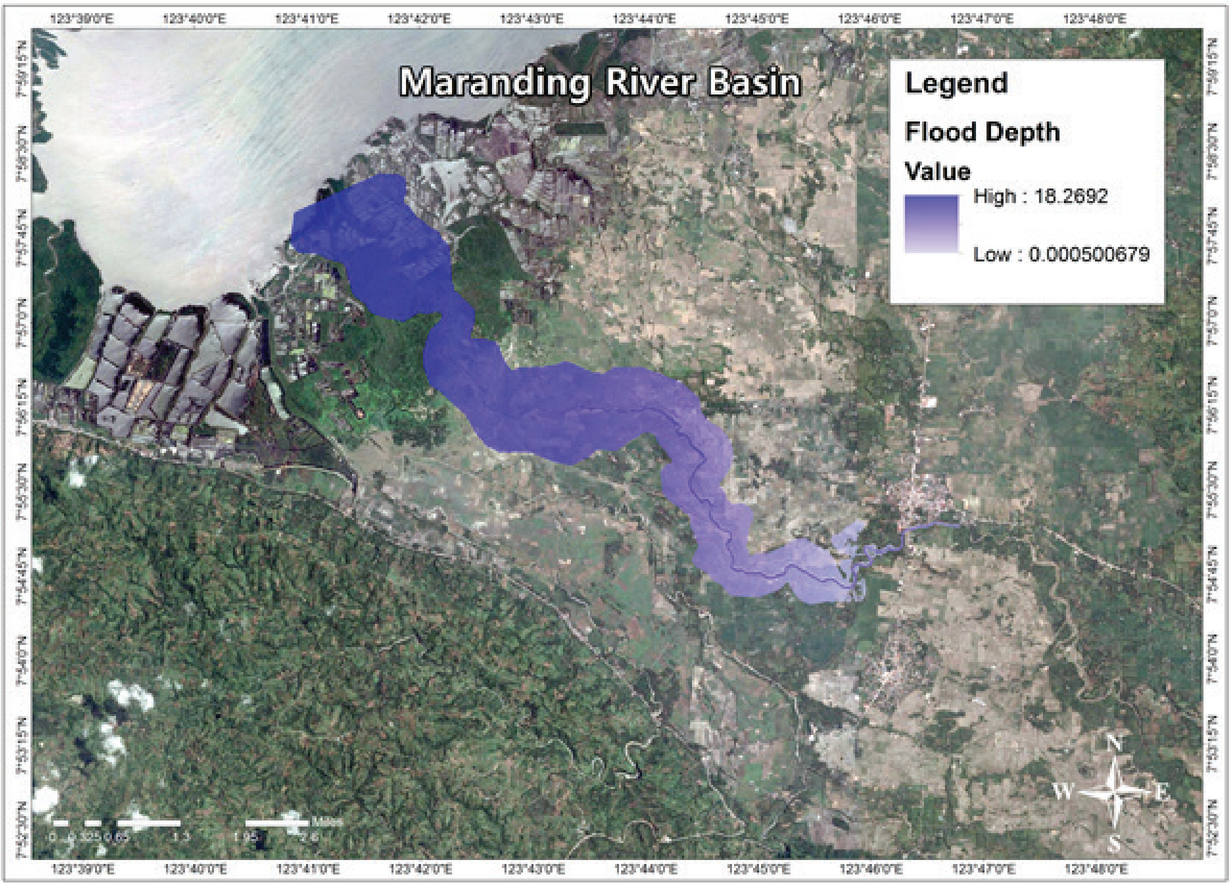


Figure 64. The sample output map of the Maranding RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Maranding floodplain are shown in Figure 65 to Figure 70. The floodplain, with an area of 254.66 sq. km., covers seven municipalities namely Baroy, Kapatagan, Lala, Salvador, Sapad, Tubod, and Aurora. Table 37 shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Maranding floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Baroy	62.0847	37.0949	60%
Kapatagan	184.766	68.9431	37%
Lala	125.181	123.919	99%
Salvador	46.4634	12.786	28%
Sapad	65.1279	4.03391	6%
Tubod	121.945	1.29683	1%
Aurora	162.225	2.32535	1%

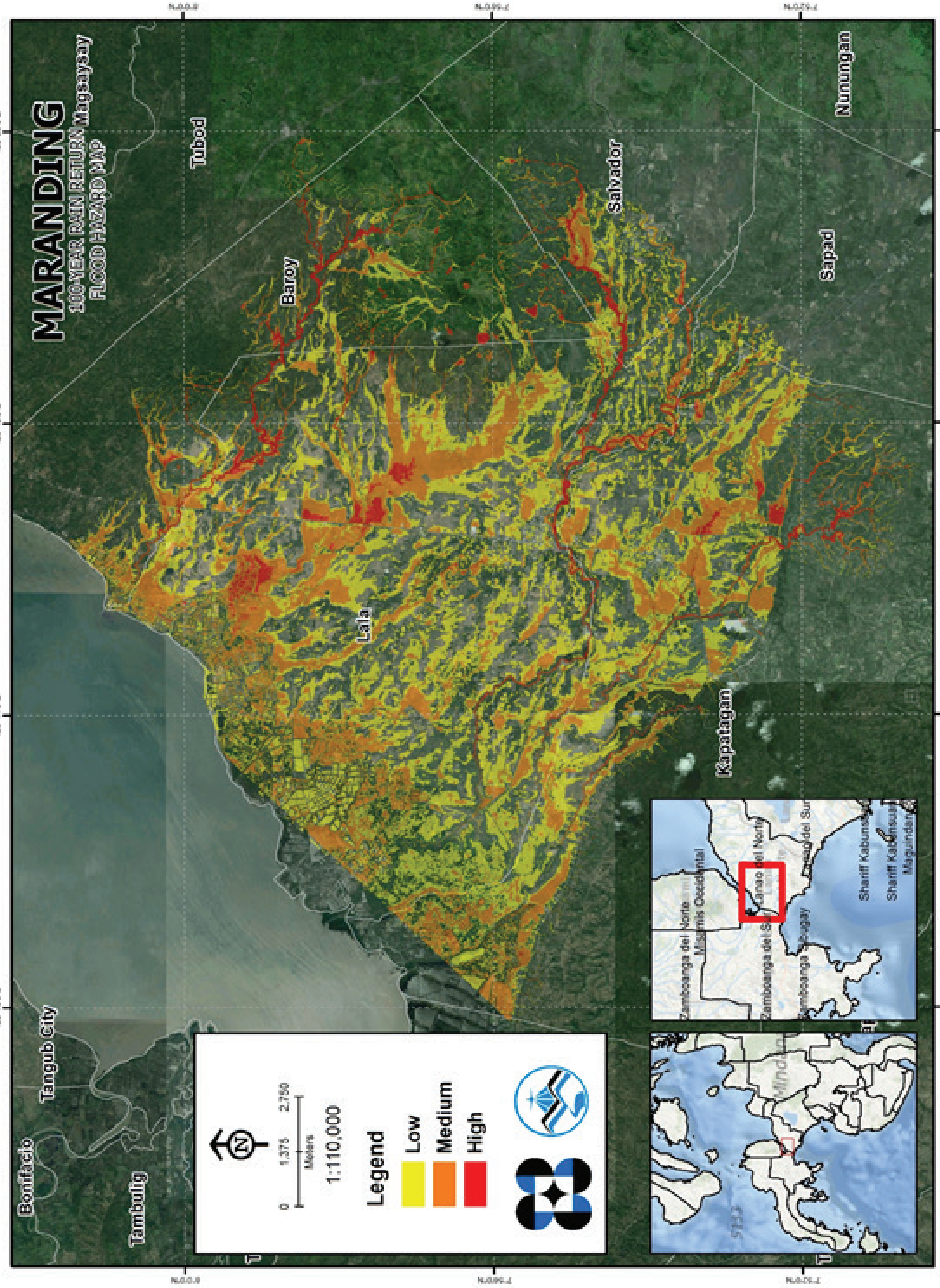


Figure 65. A 100-year Flood Hazard Map for Maranding Floodplain overlaid on Google Earth imagery

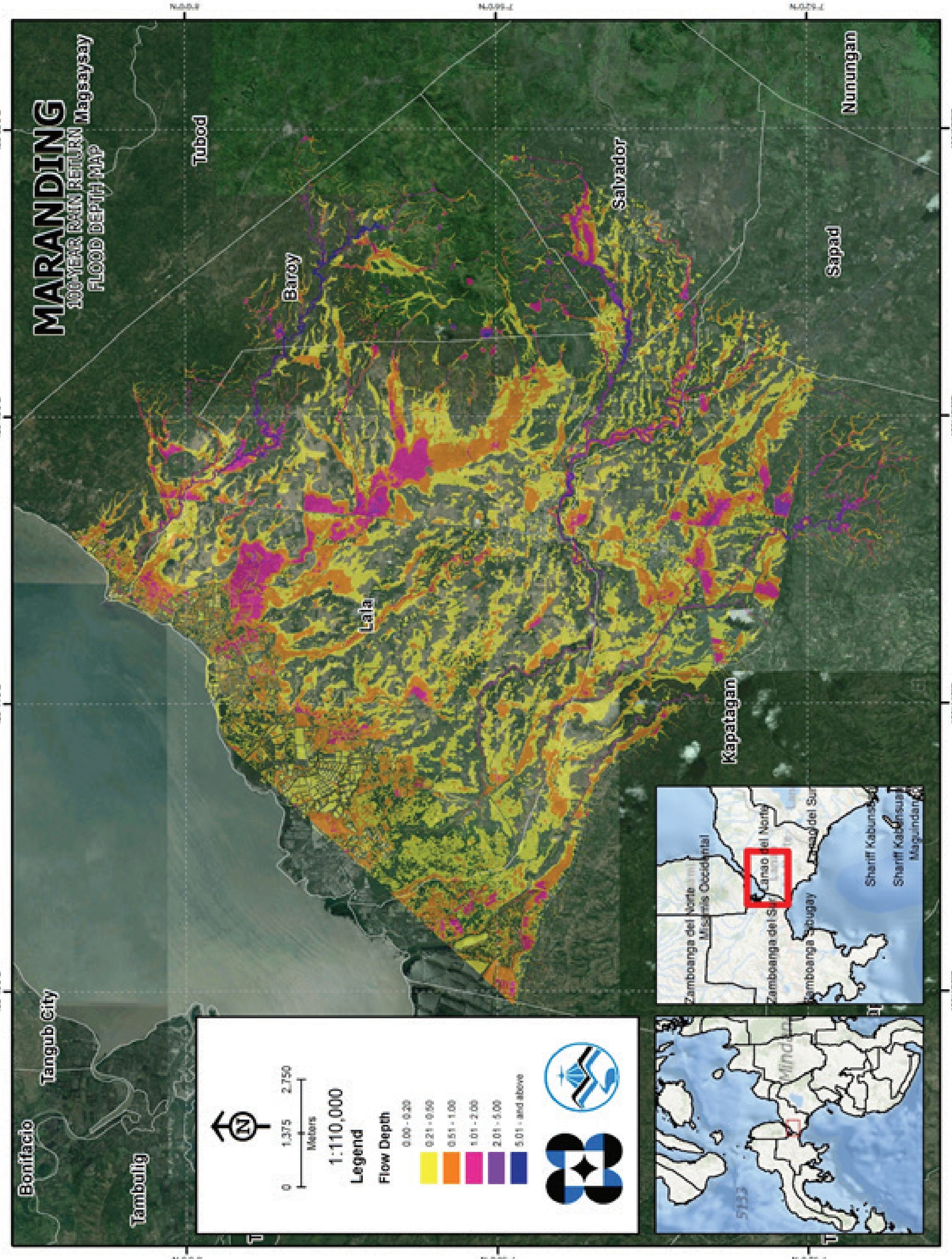


Figure 66. A 100-year Flow Depth Map for Maranding Floodplain overlaid on Google Earth imagery.

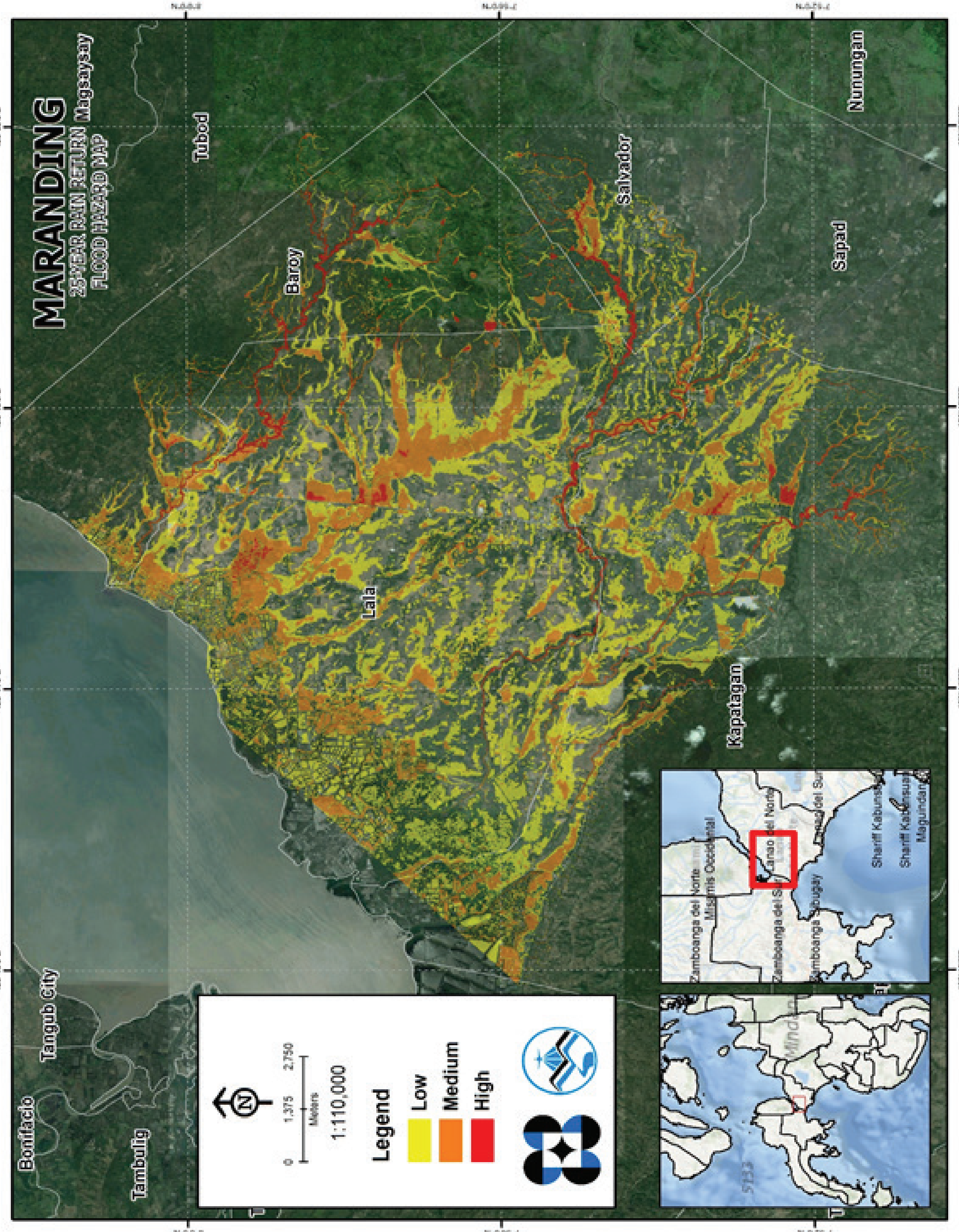


Figure 67. A 25-year Flood Hazard Map for Maranding Floodplain overlaid on Google Earth imagery.

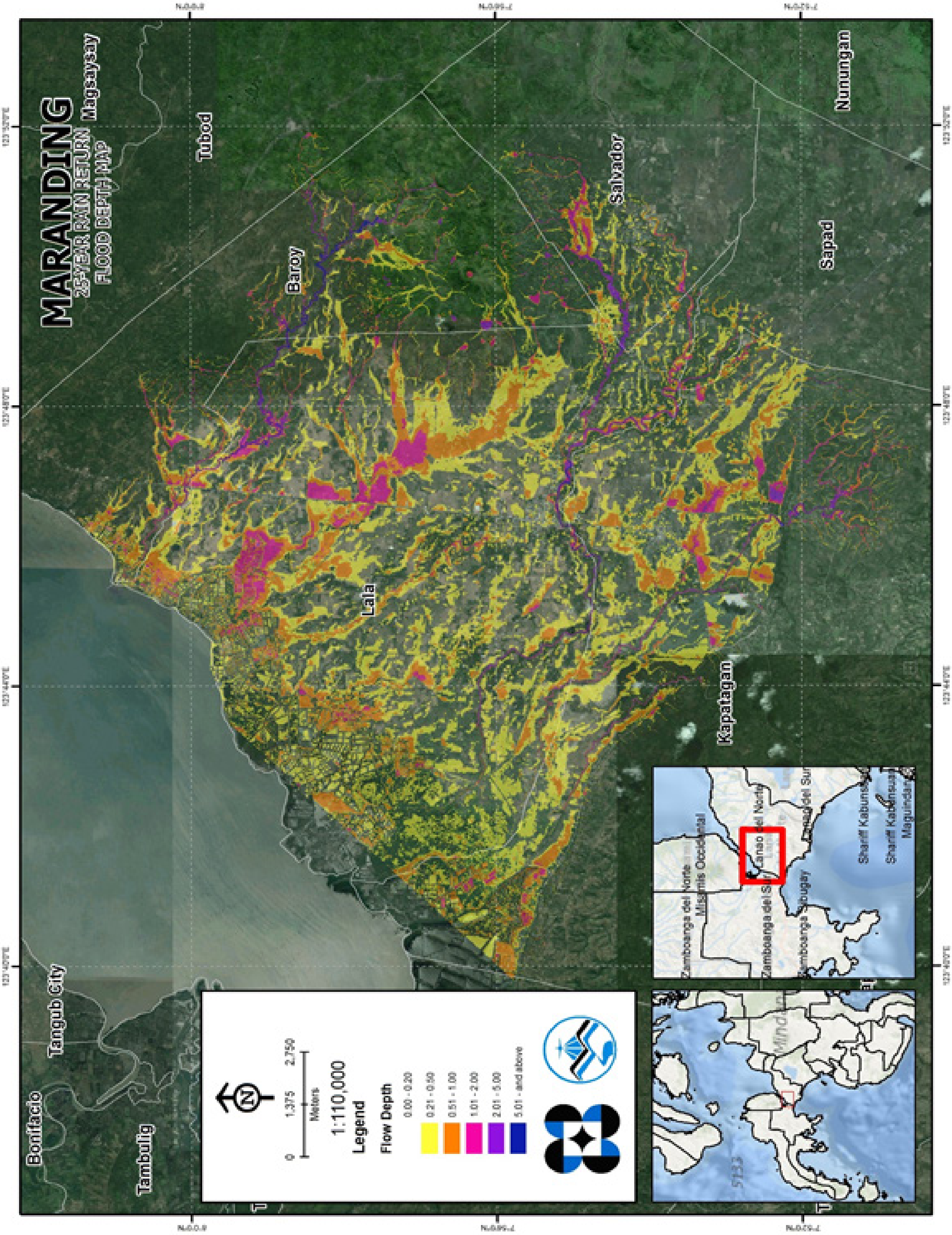


Figure 68. A 25-year Flow Depth Map for Maranding Floodplain overlaid on Google Earth imagery

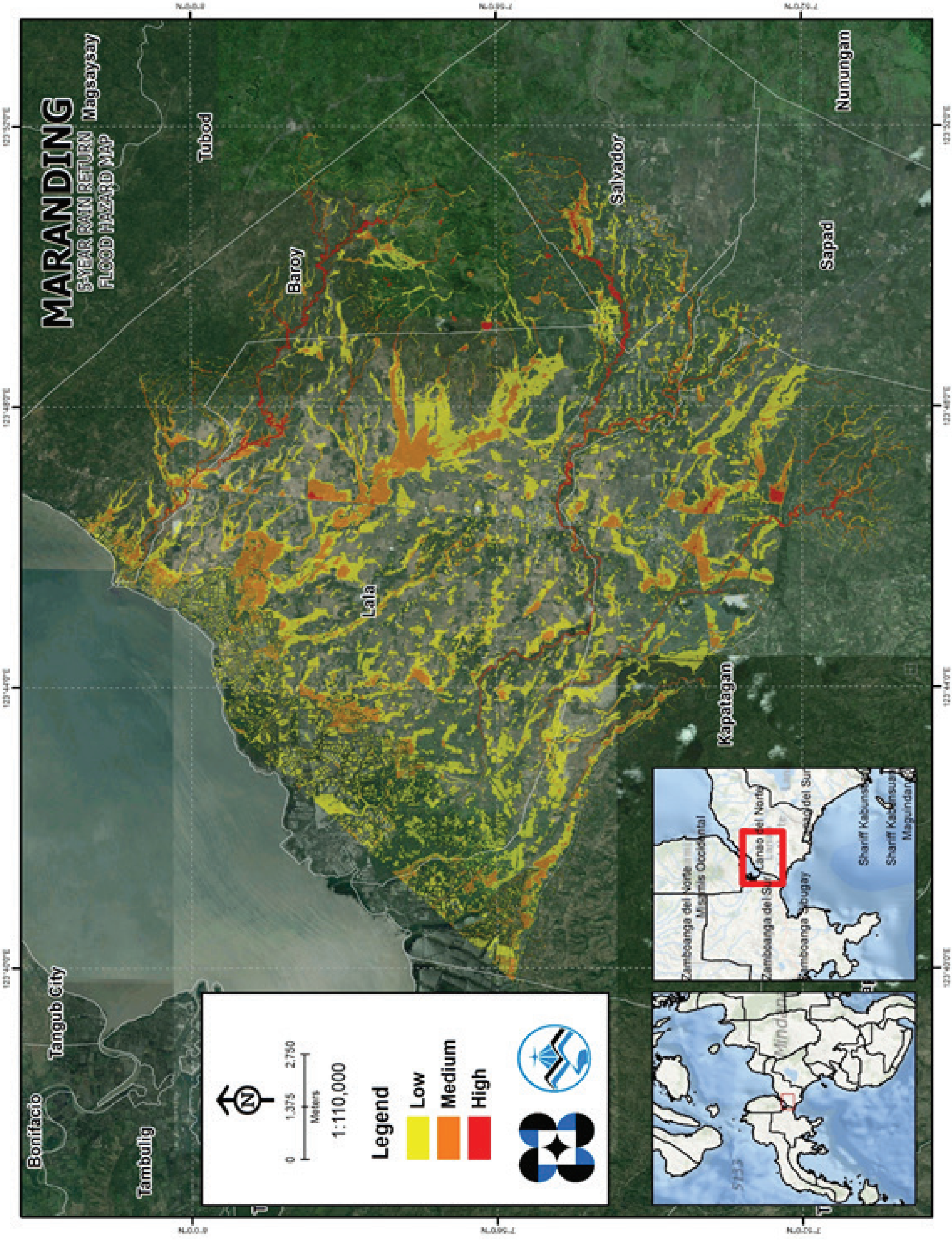


Figure 69. A 5-year Flood Hazard Map for Maranding Floodplain overlaid on Google Earth imagery.

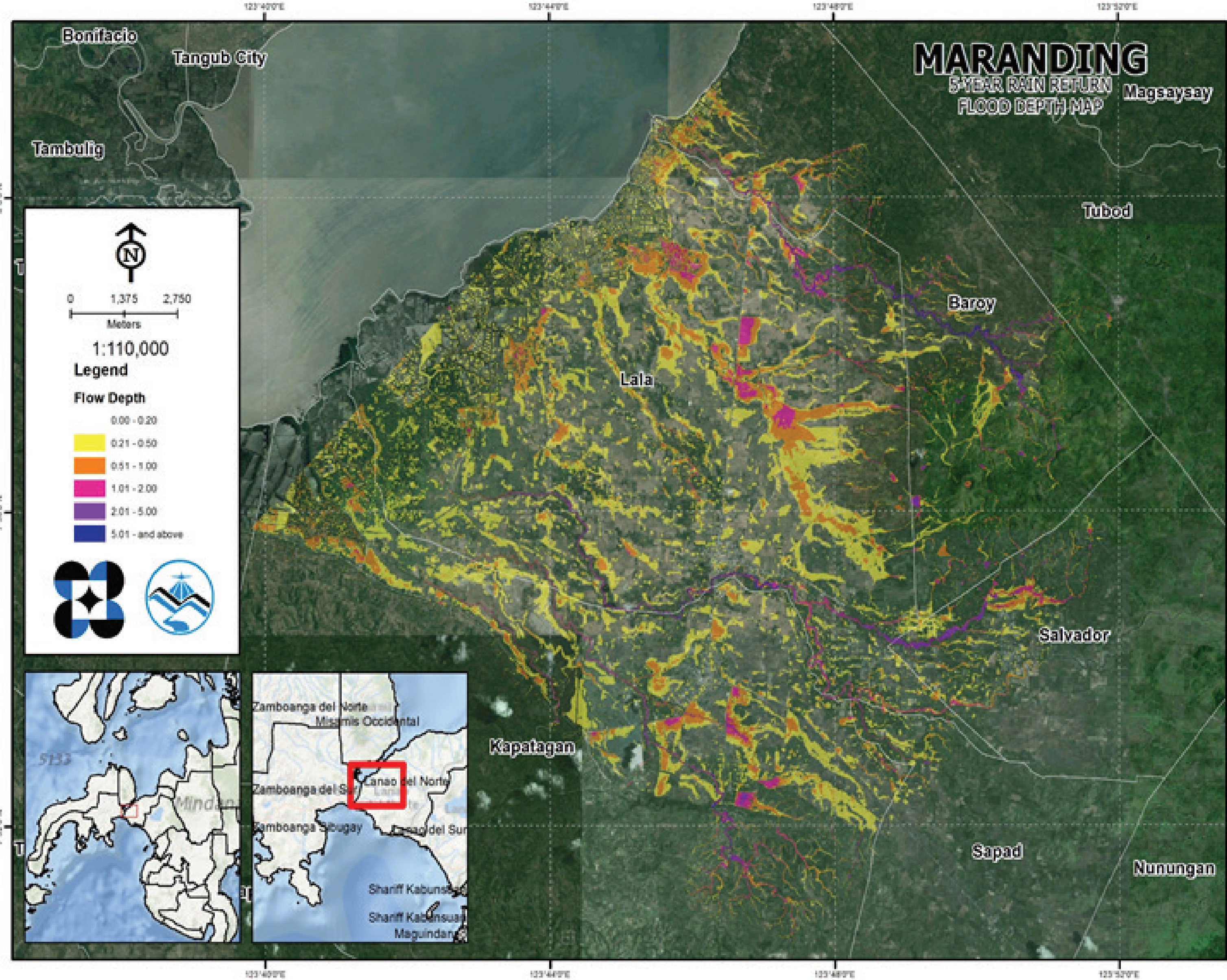


Figure 70. A 5-year Flow Depth Map for Maranding Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Maranding river basin, grouped by municipality, are listed below. For the said basin, seven municipalities consisting of 84 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 1.30% of the municipality of Aurora with an area of 162.23 sq. km. will experience flood levels of less 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.002% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Aurora (sq.km.)
	Anonang
0.03-0.20	2.11
0.21-0.50	0.22
0.51-1.00	0.0039
1.01-2.00	0
2.01-5.00	0
> 5.00	0

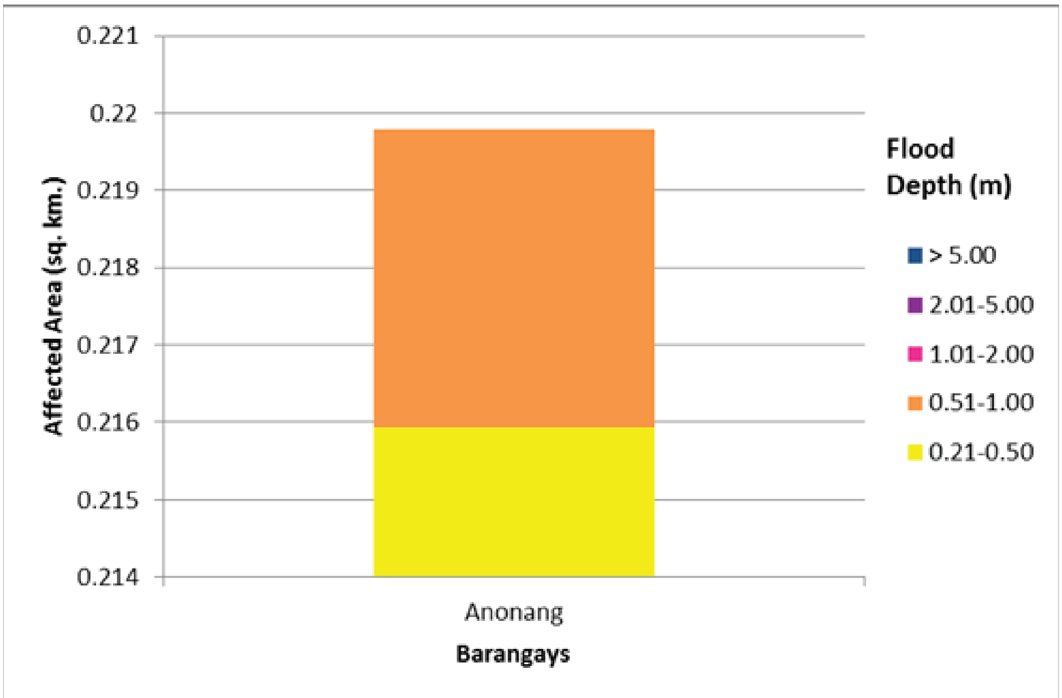


Figure 71. Affected Areas in Aurora, Zamboanga del Sur during 5-Year Rainfall Return Period.

For the municipality of Baroy, with an area of 62.08 sq. km., 50.15% will experience flood levels of less 0.20 meters. 5.43% of the area will experience flood levels of 0.21 to 0.50 meters while 2.39%, 0.92%, 0.69%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Baroy											
	Andil	Bagong Dawis	Baroy Daku	Bato	Cabasagan	Dalama	Libertad	Limwag	Lindongan	Maliwanag	Manan-Ao	Pange
0.03-0.20	4.4	1.94	0.95	1.93	2.69	1.97	1.45	1.33	2.51	3.26	1.91	1.93
0.21-0.50	0.15	0.15	0.2	0.061	0.089	0.17	0.25	0.056	0.17	0.2	0.13	0.13
0.51-1.00	0.12	0.052	0.075	0.03	0.028	0.029	0.054	0.017	0.083	0.078	0.048	0.056
1.01-2.00	0.1	0.036	0.011	0.021	0.013	0.012	0.018	0.022	0.03	0.064	0.017	0.037
2.01-5.00	0.094	0.032	0.002	0.011	0.0052	0.0094	0.012	0.044	0.0075	0.095	0.0067	0.015
> 5.00	0.037	0.013	0	0.0008	0.0002	0.001	0.00044	0.018	0	0.059	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Baroy										
	Pindolonan	Poblacion	Princesa	Rawan Point	Riverside	Sagadan	Sagadan Upper	Salong	San Juan	Tinubdan	Village
0.03-0.20	2.44	1.2	3.97	2.41	5.3	1.69	1.25	3.78	0.39	4.47	1.42
0.21-0.50	0.13	0.039	0.13	0.41	0.2	0.09	0.18	0.16	0.047	0.28	0.059
0.51-1.00	0.049	0.033	0.088	0.095	0.11	0.07	0.093	0.074	0.027	0.16	0.065
1.01-2.00	0.033	0.015	0.11	0.037	0.099	0.061	0.027	0.054	0.0059	0.09	0.042
2.01-5.00	0.024	0.0025	0.11	0.05	0.097	0.054	0.018	0.0035	0.00036	0.067	0.013
> 5.00	0	0.022	0.038	0.013	0.019	0.0074	0	0	0	0.032	0

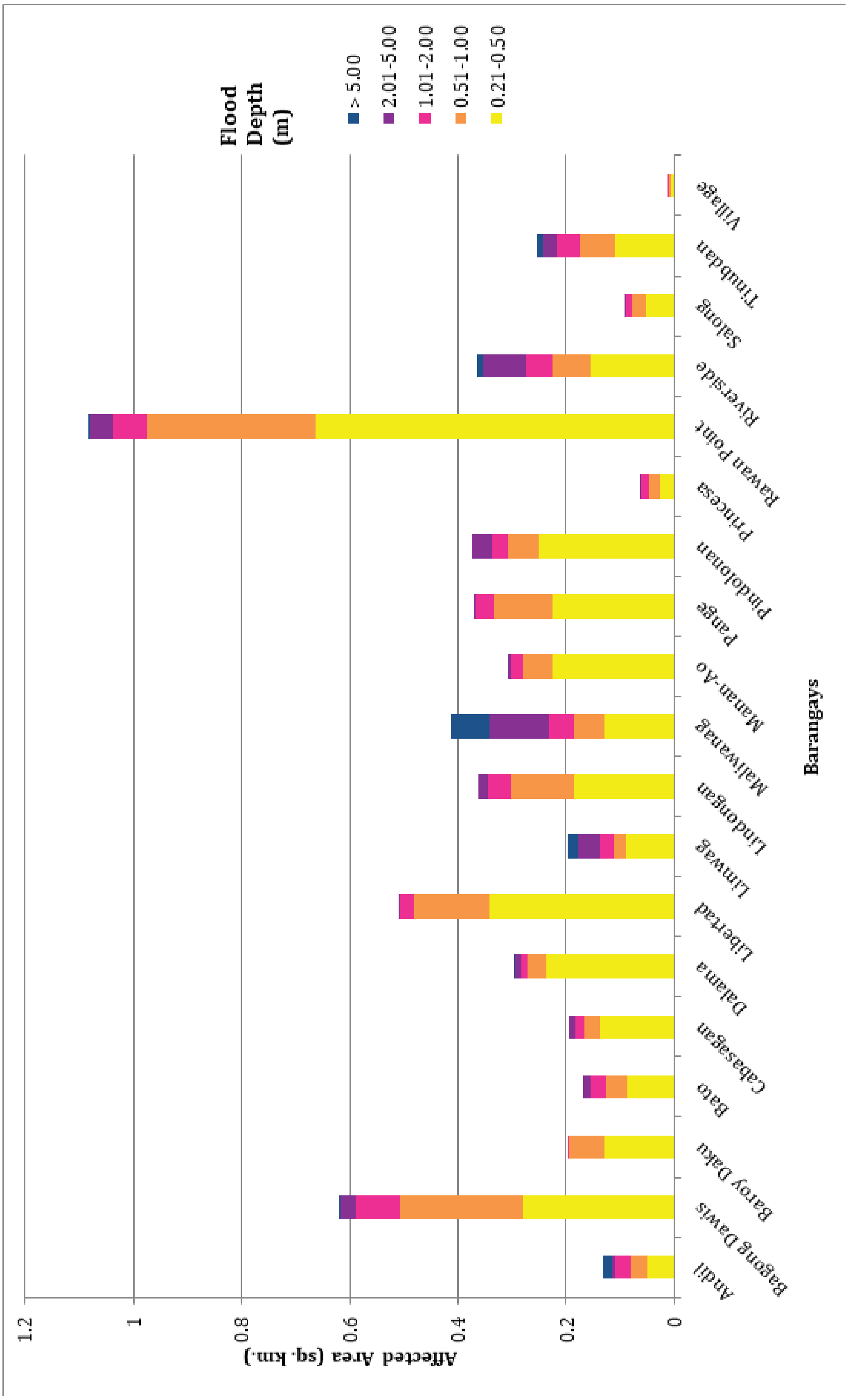


Figure 72. Affected Areas in Baroy, Lanao del Norte during 5-Year Rainfall Return Period.

For the municipality of Kapatagan, with an area of 184.77 sq. km., 28.21% will experience flood levels of less 0.20 meters. 6.58% of the area will experience flood levels of 0.21 to 0.50 meters while 1.85%, 0.51%, 0.18%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Kapatagan											
	Bagong Silang	Balili	Bansarvil	Buenavista	Butadon	Cathedral Falls	Concepcion	Curvada	De Asis	Donggoan	Durano	Lapinig
0.03-0.20	2.6	2.3	0.12	1.33	2.12	1.04	1.17	0.69	0.9	3.53	0.85	3.64
0.21-0.50	1.58	0.78	0.0022	0.082	1.5	0.49	1.16	0.22	0.96	0.18	0.01	1.64
0.51-1.00	1.36	0.83	0.00019	0.024	1.62	0.26	1.23	0.28	0.34	0.14	0.0031	1.88
1.01-2.00	0.57	0.21	0.0003	0.012	0.16	0.11	0.059	0.14	0.023	0.031	0.0021	0.28
2.01-5.00	0.088	0.069	0	0.0024	0.073	0.028	0.072	0.029	0.024	0.017	0.00041	0.063
> 5.00	0.0075	0.043	0	0.0001	0.067	0.048	0.038	0.0048	0	0.0004	0	0.0002

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Kapatagan											
	Malinas	Maranding	Margos	Poblacion	San Vicente	Santa Cruz	Santo Tomas	Suso	Taguitic	Tiacongan	Tulatulahan	Waterfalls
0.03-0.20	0.34	0.52	1.4	1.2	0.54	0.59	0.23	1.77	3.74	1.84	0.053	0.98
0.21-0.50	0.012	0.65	0.54	0.039	0.61	0.37	0.51	0.59	0.6	0.19	0	0.48
0.51-1.00	0.0041	1.02	0.42	0.033	0.32	0.035	0.77	0.21	0.099	0.055	0	0.52
1.01-2.00	0.0002	0.34	0.02	0.015	0.11	0.0036	0.015	0.019	0.02	0.021	0	0.37
2.01-5.00	0	0.0072	0.0031	0.0025	0.0038	0.0054	0.013	0.018	0.003	0.0013	0	0.04
> 5.00	0	0.02	0.0001	0.022	0	0.017	0.00074	0.039	0	0	0	0.039

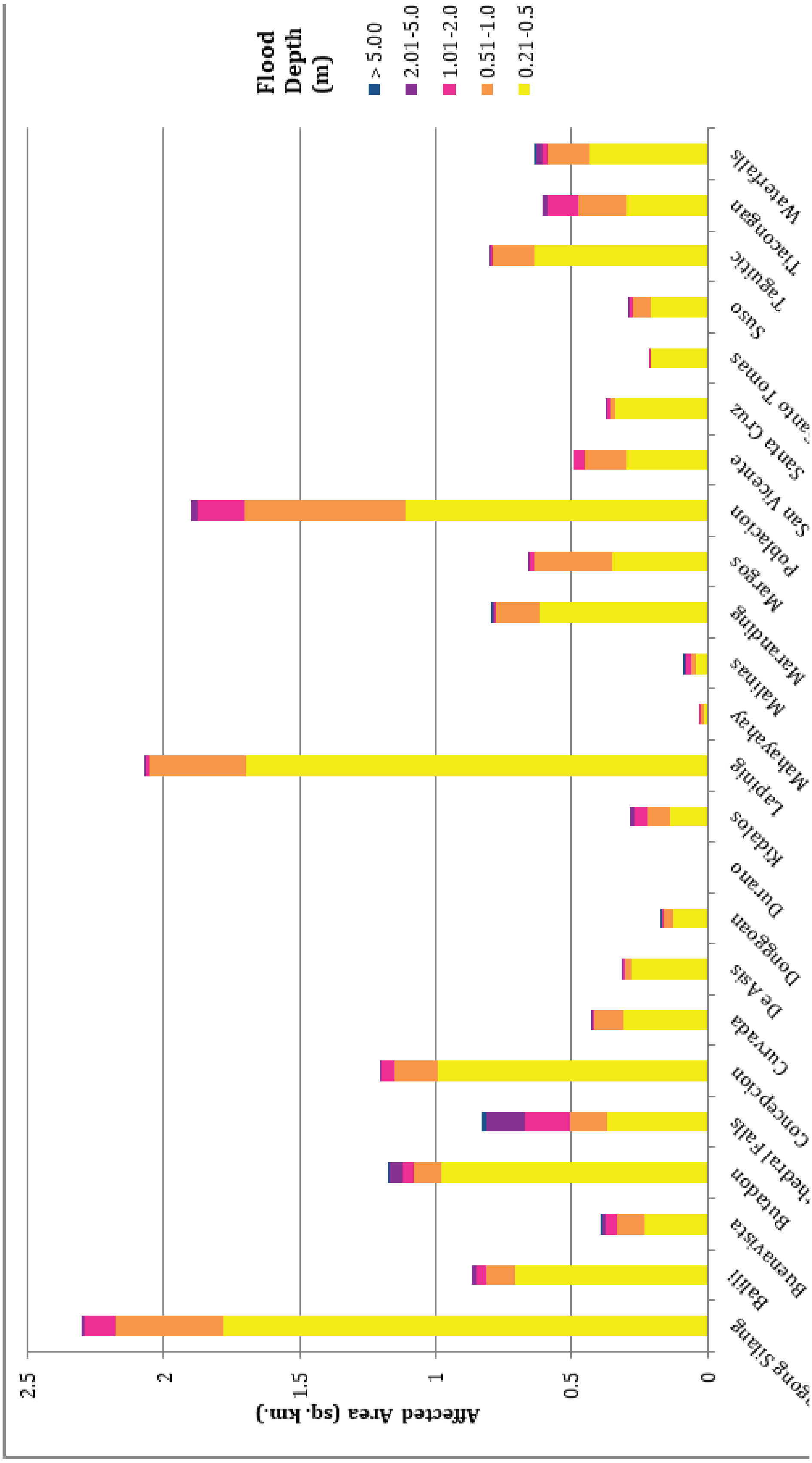


Figure 73. Affected Areas in Kapatagan, Lanao del Norte during 5-Year Rainfall Return Period.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Lala													
	Abaga	Andil	Cabasagan	Camalan	Darumawang Bucana	Darumawang Ilaya	El Salvador	Gumagamot	Lala Proper	Lanipao	Magpatao	Maranding	Matampay Bucana	Matampay Ilaya
0.03-0.20	2.01	4.4	2.69	2.9	6.94	8.41	3.18	2.67	1.2	1.54	2.87	0.52	2.72	1.37
0.21-0.50	0.19	0.15	0.089	0.7	1	1.46	2.33	0.47	0.21	0.31	0.44	0.65	0.33	0.23
0.51-1.00	0.015	0.12	0.028	0.24	0.12	0.22	2.32	0.13	0.036	0.083	0.29	1.02	0.027	0.039
1.01-2.00	0.051	0.1	0.013	0.0083	0.013	0.026	0.33	0.0002	0.014	0.0012	0.044	0.34	0	0.0041
2.01-5.00	0.01	0.094	0.0052	0	0.0008	0.031	0.17	0	0	0	0.0022	0.0072	0	0
> 5.00	0	0.037	0.0002	0	0	0.0074	0	0	0	0	0	0.02	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Lala											
	Pacita	Pendolonan	Pinoyak	Raw-An	Rebe	San Isidro Lower	San Isidro Upper	San Manuel	Santa Cruz Lower	Santa Cruz Upper	Simpak	Tenazas	Tuna-An
0.03-0.20	1.8	4.81	4.1	1.37	6.13	3.89	3.67	3.55	5.09	7.27	5.33	2.21	2.17
0.21-0.50	0.25	1.04	1.83	0.1	1.37	0.42	0.28	0.64	0.69	1.31	1.33	0.22	0.77
0.51-1.00	0.013	0.082	0.27	0.0035	0.47	0.049	0.059	0.19	0.081	0.48	0.38	0.037	0.16
1.01-2.00	0.0001	0.024	0.038	0.0016	0.32	0.036	0.054	0.13	0.0039	0.14	0.072	0.0086	0.023
2.01-5.00	0	0.011	0.064	0.000004	0.75	0.0003	0.047	0.37	0	0.06	0.021	0	0.001
> 5.00	0	0.0001	0.1	0	0.046	0	0.032	0.088	0	0.041	0.018	0	0

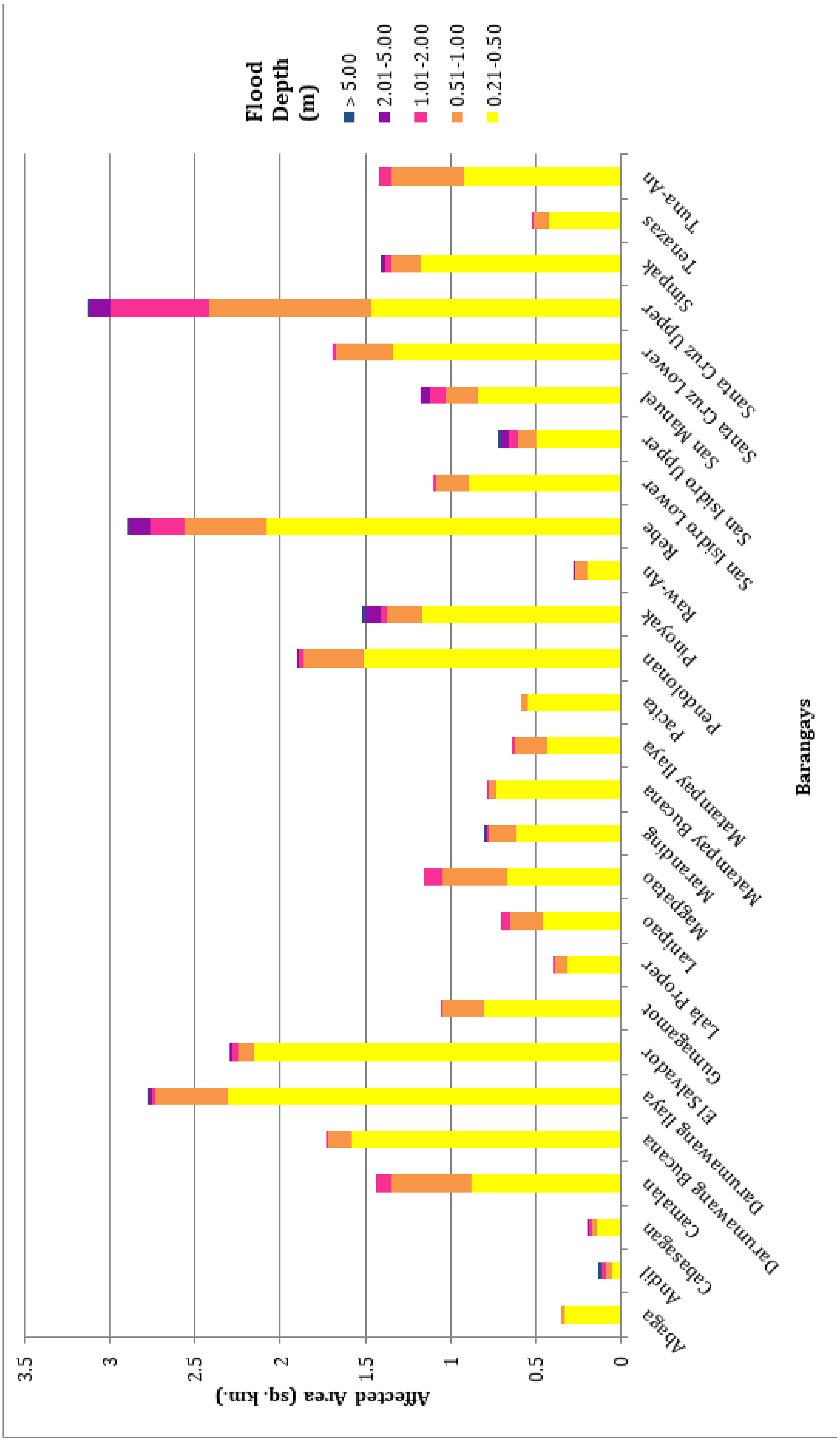


Figure 74. Affected Areas in Lala, Lanao del Norte during 5-Year Rainfall Return Period.

For the municipality of Salvador, with an area of 46.46 sq. km., 26.90% will experience flood levels of less 0.20 meters. 5.36% of the area will experience flood levels of 0.21 to 0.50 meters while 2.46%, 0.99%, 0.60%, and 0.0002% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Salvador									
	Camp III	Curva-Miagao	Inasagan	Mabatao	Padianan	Pagayawan	Panaliwad-On	Pangantapan	Poblacion	Sudlon
0.03-0.20	2.8	1.07	1.07	0.95	0.28	0.042	1.87	0.014	3.36	1.05
0.21-0.50	0.28	0.31	0.24	0.048	0.031	0.002	0.31	0.001	1.11	0.17
0.51-1.00	0.23	0.054	0.024	0.026	0.0006	0.00036	0.092	0	0.59	0.12
1.01-2.00	0.13	0.032	0.0039	0.011	0	0.00009	0.039	0	0.17	0.071
2.01-5.00	0.024	0.15	0	0.0017	0	0	0.0001	0	0.024	0.078
> 5.00	0.0001	0	0	0	0	0	0	0	0	0
> 5.00										

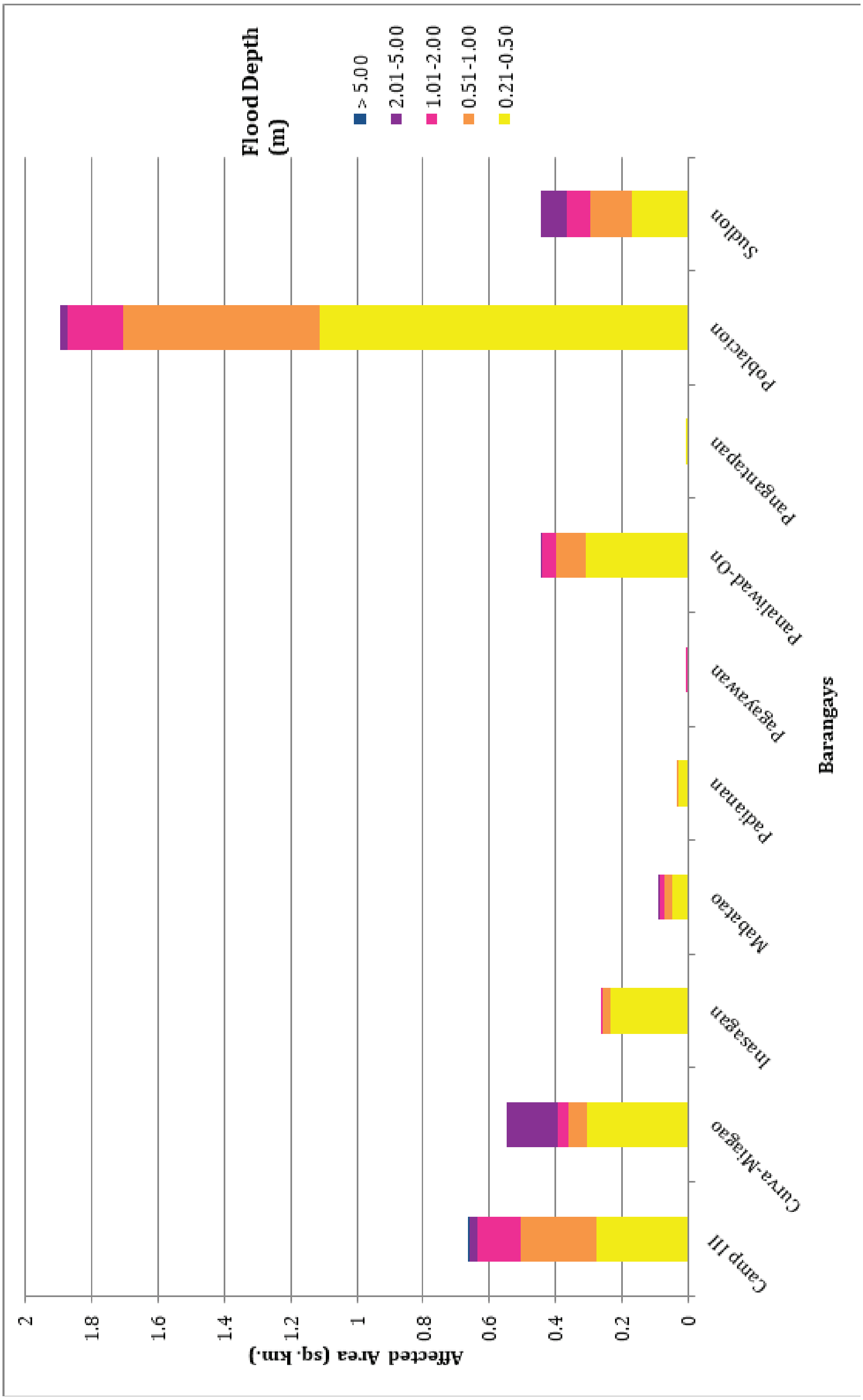


Figure 75. Affected Areas in Salvador, Lanao del Norte during 5-Year Rainfall Return Period.

For the municipality of Sapad, with an area of 65.13 sq. km., 5.16% will experience flood levels of less 0.20 meters. 0.78% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.06%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Sapad, Lanao del Norte during 5-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Sapad			
	Mabugnao	Mapurog	Pancilan	Panoloon
0.03-0.20	0.83	1.45	0.33	0.75
0.21-0.50	0.13	0.28	0.026	0.081
0.51-1.00	0.04	0.045	0.013	0.0024
1.01-2.00	0.0035	0.034	0.0037	0.00029
2.01-5.00	0.005	0.017	0	0
> 5.00	0	0	0	0

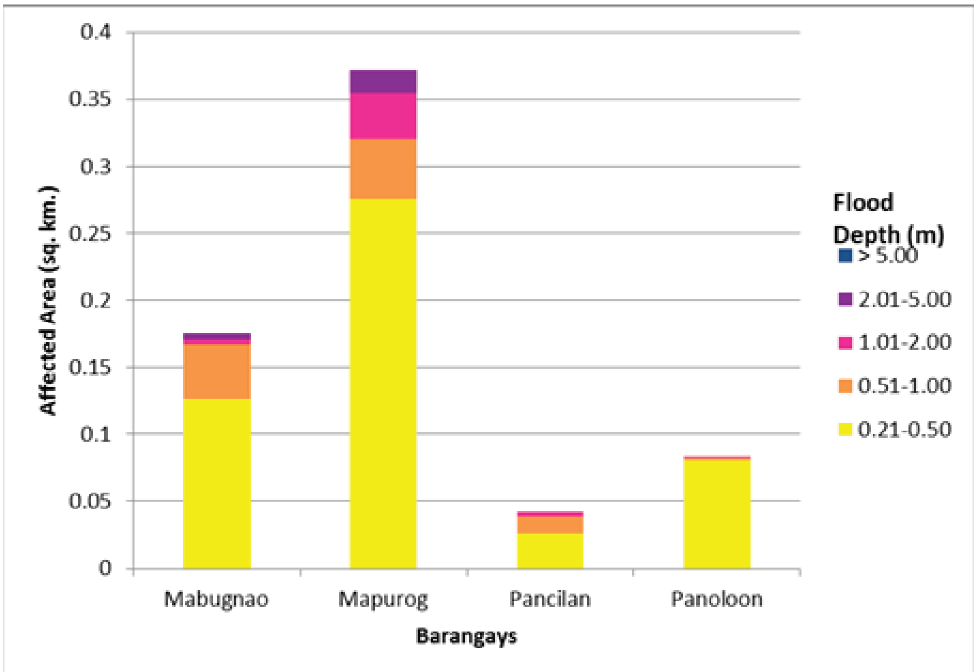


Figure 76. Affected Areas in Sapad, Lanao del Norte during 5-Year Rainfall Return Period.

For the municipality of Tubod, with an area of 121.95 sq. km., 0.99% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.01%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Tubod, Lanao del Norte during 5-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Tubod			
	Candis	Licapao	Malingao	Panoloon
0.03-0.20	0.0099	1.19	0.0043	0.748704
0.21-0.50	0	0.045	0	0.004309
0.51-1.00	0	0.029	0	0.002399
1.01-2.00	0	0.014	0	0.00029
2.01-5.00	0	0.0042	0	0
> 5.00	0	0	0	0

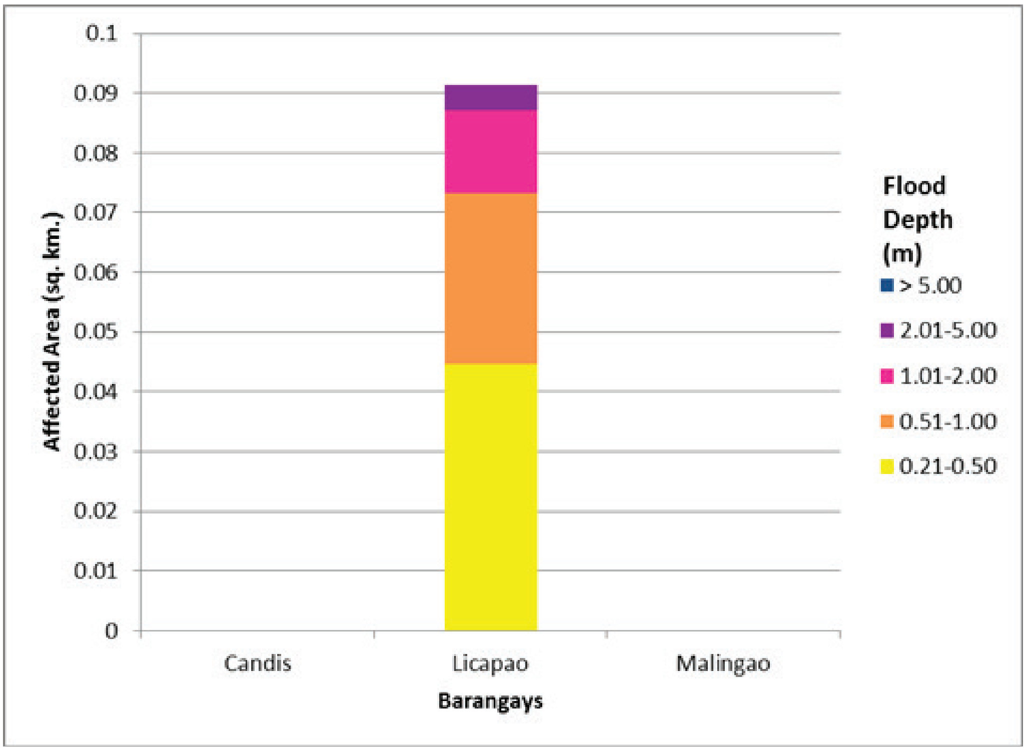


Figure 77. Affected Areas in Tubod, Lanao del Norte during 5-Year Rainfall Return Period.

For the 25-Year return period, 1.04% of the municipality of Aurora with an area of 162.23 sq. km. will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.003% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Aurora
	Anonang
0.03-0.20	1.68
0.21-0.50	0.64
0.51-1.00	0.0055
1.01-2.00	0
2.01-5.00	0
> 5.00	0

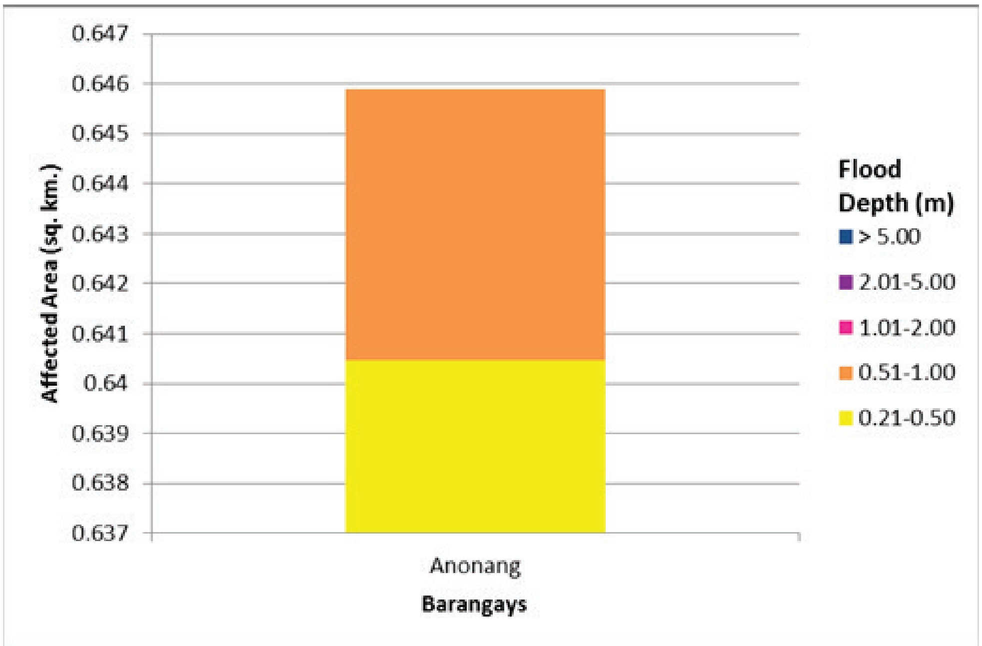


Figure 78. Affected Areas in Aurora, Zamboanga del Sur during 25-Year Rainfall Return Period.

For the municipality of Baroy, with an area of 62.08 sq. km., 47.57% will experience flood levels of less 0.20 meters. 6.43% of the area will experience flood levels of 0.21 to 0.50 meters while 3.22%, 1.40%, 0.80%, and 0.41% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Baroy											
	Bagong Dawis	Baroy Daku	Bato	Cabasagan	Dalama	Libertad	Limwag	Lindongan	Maliwanag	Manan-Ao	Pange	Pange
0.03-0.20	1.15	1.38	0.52	1.84	2.57	1.8	1.16	1.24	2.36	1.98	1.7	1.64
0.21-0.50	0.049	0.29	0.13	0.11	0.18	0.31	0.37	0.11	0.2	0.15	0.28	0.31
0.51-1.00	0.039	0.31	0.095	0.049	0.038	0.05	0.2	0.029	0.12	0.078	0.089	0.15
1.01-2.00	0.032	0.16	0.0096	0.036	0.026	0.013	0.045	0.027	0.1	0.049	0.033	0.063
2.01-5.00	0.013	0.036	0	0.018	0.014	0.011	0.0034	0.038	0.025	0.11	0.0077	0.006
> 5.00	0.025	0.0033	0	0	0.0015	0.0022	0.00023	0.038	0.0003	0.12	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Baroy										
	Pindolonan	Poblacion	Princesa	Rawan Point	Riverside	Sagadan	Sagadan Upper	Salong	San Juan	Tinubdan	Village
0.03-0.20	2.18	0.48	1.73	2.23	1.78	1.58	0.2	2.18	0.48	1.73	2.23
0.21-0.50	0.32	0.03	0.75	0.19	0.065	0.12	0.0079	0.32	0.03	0.75	0.19
0.51-1.00	0.087	0.021	0.44	0.087	0.033	0.082	0.0048	0.087	0.021	0.44	0.087
1.01-2.00	0.032	0.016	0.091	0.051	0.016	0.068	0.0018	0.032	0.016	0.091	0.051
2.01-5.00	0.053	0.0018	0.046	0.078	0.001	0.038	0	0.053	0.0018	0.046	0.078
> 5.00	0	0	0.0017	0.045	0	0.016	0	0	0	0.0017	0.045

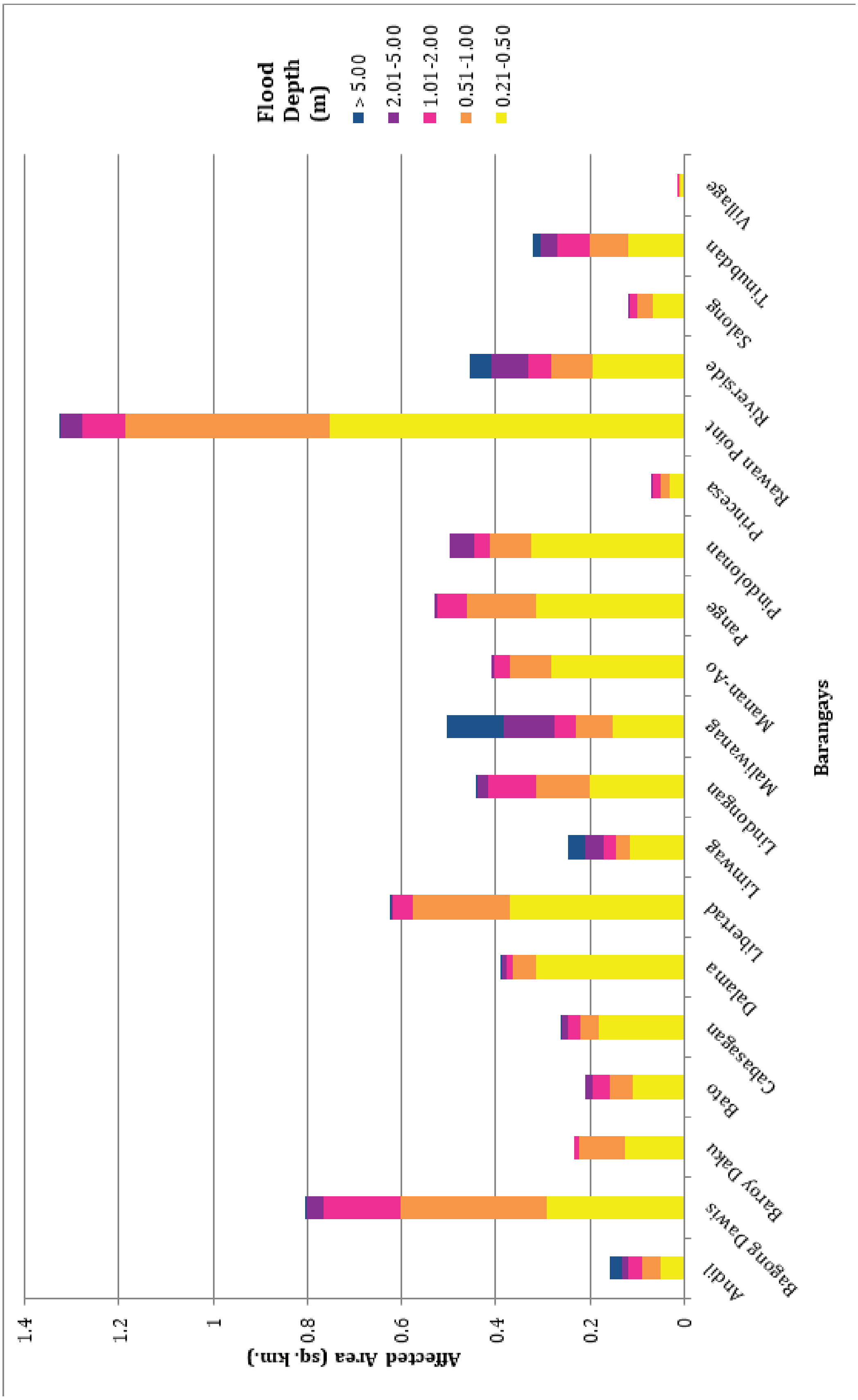


Figure 79. Affected Areas in Baroy, Lanao del Norte during 25-Year Rainfall Return Period.

For the municipality of Kapatagan, with an area of 184.77 sq. km., 24.18% will experience flood levels of less 0.20 meters. 8.64% of the area will experience flood levels of 0.21 to 0.50 meters while 3.43%, 0.81%, 0.29%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Kapatagan											
	Bagong Silang	Balili	Bansarvil	Buenavista	Butadon	Cathedral Falls	Concepcion	Curvada	De Asis	Donggoan	Durano	Lapinig
0.03-0.20	3.37	2.54	3.31	3.4	1.75	2	0.81	1.75	1.42	0.019	2.36	4.11
0.21-0.50	2.06	0.9	0.27	1.85	0.42	1.35	0.38	0.42	0.13	0	0.14	2.18
0.51-1.00	0.8	0.27	0.14	0.17	0.22	0.33	0.18	0.051	0.076	0	0.099	0.8
1.01-2.00	0.24	0.048	0.057	0.071	0.16	0.041	0.005	0.0051	0.0032	0	0.068	0.086
2.01-5.00	0.018	0.026	0.017	0.056	0.2	0.032	0.0083	0.0063	0.0013	0	0.026	0.0001
> 5.00	0	0	0.0006	0.0053	0.026	0	0	0	0.0007	0	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Kapatagan											
	Malinas	Maranding	Margos	Poblacion	San Vicente	Santa Cruz	Santo Tomas	Suso	Taguitic	Tiacongan	Tulatulahan	Waterfalls
0.03-0.20	0.35	0.91	1.35	1.45	2.36	0.88	0.6	1.16	1.8	2.76	2.85	1.39
0.21-0.50	0.013	0.043	0.79	0.45	1.58	0.4	0.37	0.36	0.29	0.72	0.3	0.56
0.51-1.00	0.012	0.026	0.39	0.35	1.01	0.24	0.03	0.014	0.11	0.45	0.24	0.34
1.01-2.00	0.0087	0.018	0.0061	0.097	0.28	0.079	0.017	0.0016	0.016	0.012	0.13	0.041
2.01-5.00	0	0.013	0.0095	0.000073	0.038	0	0.0031	0.000027	0.0053	0.00033	0.056	0.027
> 5.00	0	0.0005	0.0082	0	0	0	0	0	0.0001	0	0	0.0015

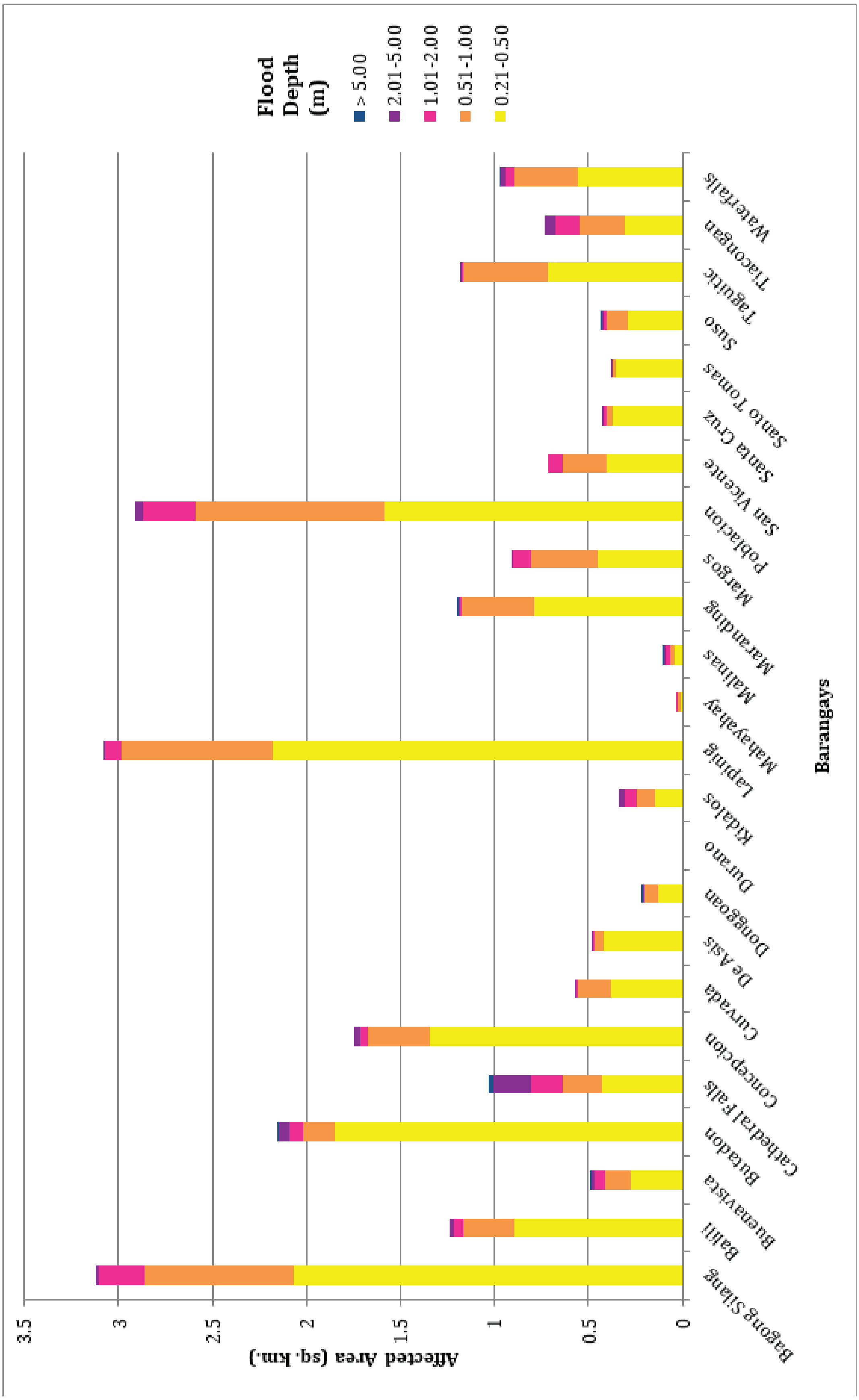


Figure 80. Affected Areas in Kapatagan, Lanao del Norte during 25-Year Rainfall Return Period.

For the municipality of Lala, with an area of 125.18 sq. km., 58.39% will experience flood levels of less 0.20 meters. 25.02% of the area will experience flood levels of 0.21 to 0.50 meters while 9.56%, 2.58%, 0.61%, and 0.10% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Lala													
	Abaga	Andil	Cabasagan	Camalan	Darumawang Bucana	Darumawang Ilaya	El Salvador	Gumagamot	Lala Proper	Lanipao	Magpatao	Maranding	Matampay Bucana	Matampay Ilaya
0.03-0.20	1.69	1.15	2.57	2.01	4.8	6.03	4.76	1.69	0.91	0.98	2.07	1.35	1.9	0.69
0.21-0.50	0.51	0.049	0.18	0.91	2.16	3.14	3.09	0.95	0.38	0.49	0.64	0.79	0.92	0.45
0.51-1.00	0.067	0.039	0.038	0.61	0.62	0.9	0.42	0.59	0.16	0.32	0.55	0.39	0.18	0.45
1.01-2.00	0.0001	0.032	0.026	0.45	0.0086	0.068	0.045	0.084	0.011	0.15	0.38	0.0061	0.0035	0.043
2.01-5.00	0	0.013	0.014	0.0031	0	0.022	0.02	0	0	0	0.003	0.0095	0	0
> 5.00	0	0.025	0.0015	0	0	0.00056	0	0	0	0	0	0.0082	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Lala												
	Pacita	Pendolonan	Pinoyak	Raw-An	Rebe	San Isidro Lower	San Isidro Upper	San Manuel	Santa Cruz Lower	Santa Cruz Upper	Simpak	Tenazas	Tuna-An
0.03-0.20	1.21	3.68	4.27	0.86	5.07	2.72	3.12	3.41	3.19	5.1	4.83	1.72	1.31
0.21-0.50	0.67	1.41	1.63	0.46	2.53	1.25	0.65	1.08	1.96	1.72	1.86	0.57	0.84
0.51-1.00	0.16	0.8	0.36	0.11	1.06	0.42	0.2	0.32	0.64	1.32	0.34	0.17	0.71
1.01-2.00	0.00087	0.054	0.063	0.035	0.19	0.019	0.068	0.13	0.067	0.94	0.068	0.04	0.25
2.01-5.00	0	0.0059	0.096	0.00031	0.24	0	0.062	0.078	0	0.17	0.022	0	0.0007
> 5.00	0	0	0.021	0	0.0039	0	0.028	0.005	0	0.024	0.01	0	0

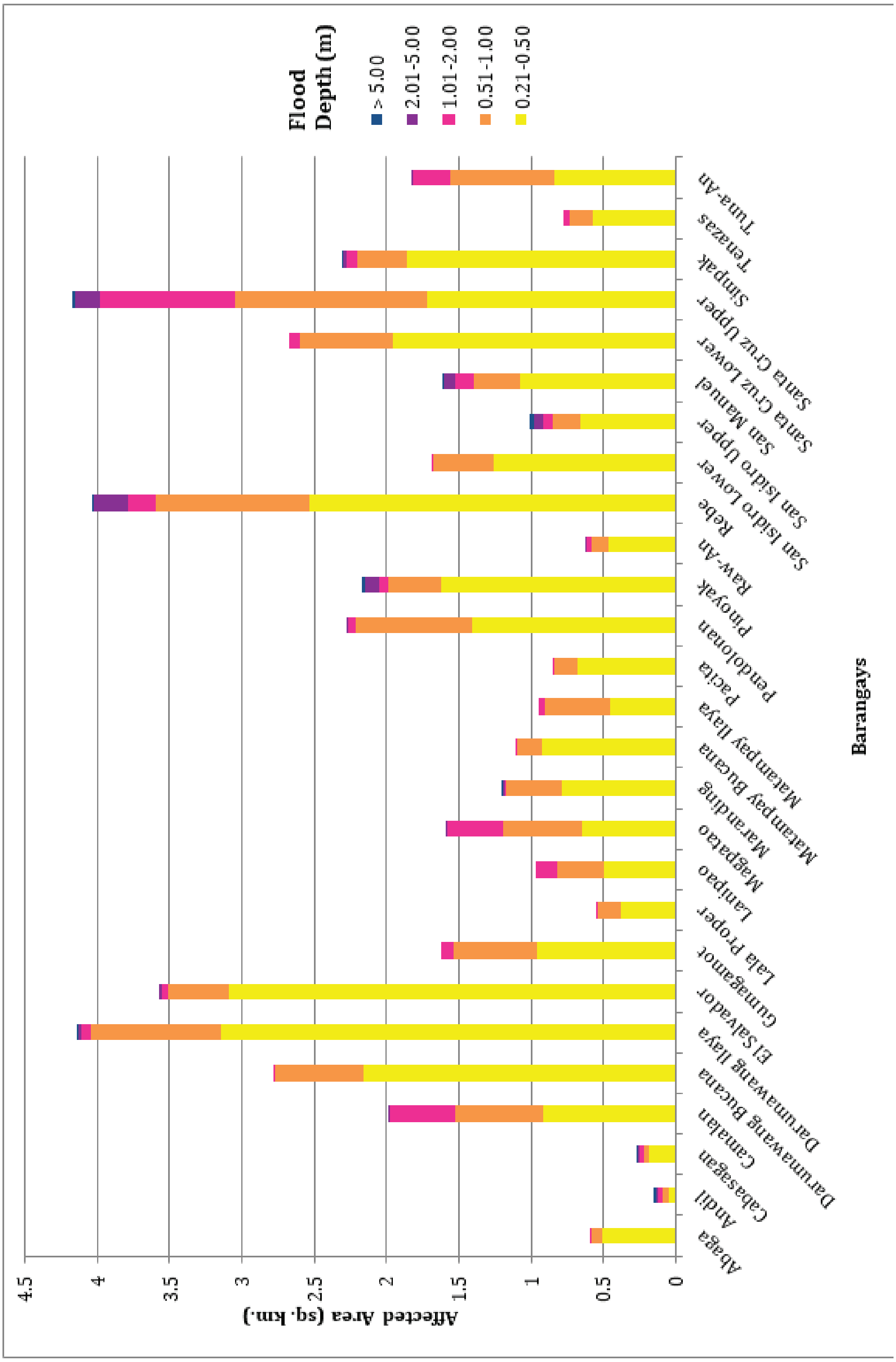


Figure 81. Affected Areas in Lala, Lanao del Norte during 25-Year Rainfall Return Period.

For the municipality of Salvador, with an area of 46.46 sq. km., 23.04% will experience flood levels of less 0.20 meters. 7.09% of the area will experience flood levels of 0.21 to 0.50 meters while 3.86%, 1.53%, 0.79%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Salvador									
	Camp III	Curva-Miagao	Inasagan	Mabatao	Padianan	Pagayawan	Panaliwad-On	Pangantapan	Poblacion	Sudlon
0.03-0.20	2.67	0.91	0.91	0.93	0.26	0.041	1.71	0.014	2.36	0.91
0.21-0.50	0.29	0.4	0.35	0.056	0.046	0.0028	0.39	0.0013	1.58	0.18
0.51-1.00	0.28	0.088	0.058	0.032	0.001	0.00036	0.14	0	1.01	0.19
1.01-2.00	0.19	0.032	0.0086	0.015	0.0001	0.00009	0.067	0	0.28	0.12
2.01-5.00	0.038	0.18	0.0002	0.0037	0	0	0.0065	0	0.038	0.1
> 5.00	0.0004	0.0094	0	0	0	0	0	0	0	0.0011

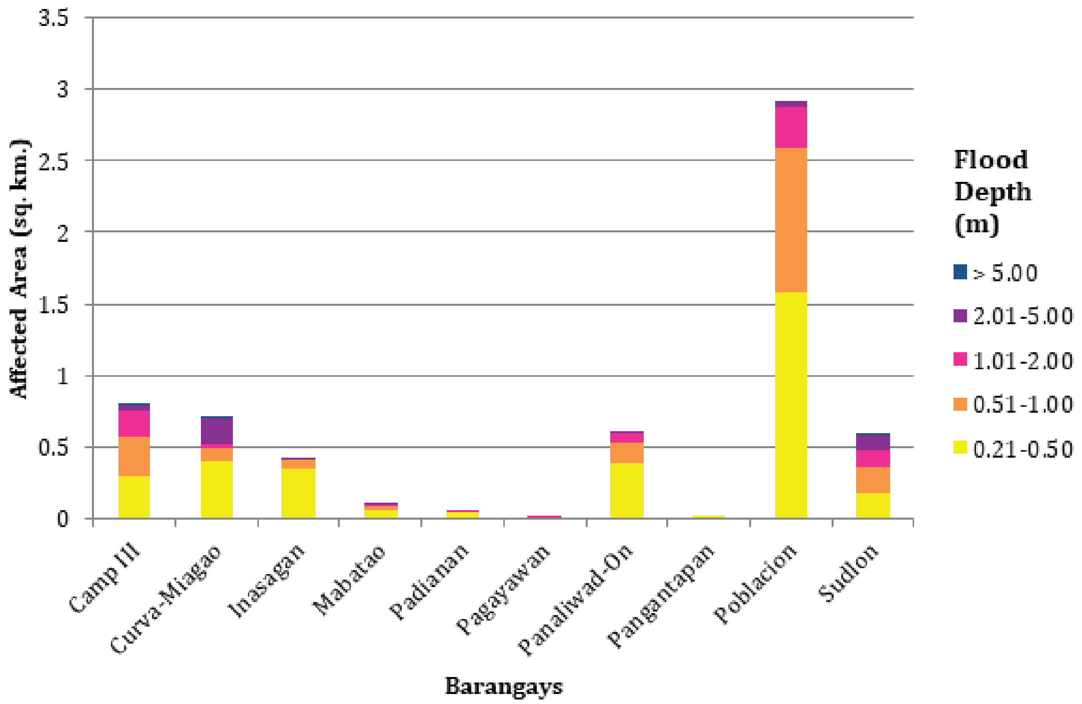


Figure 82. Affected Areas in Salvador, Lanao del Norte during 25-Year Rainfall Return Period.

For the municipality of Sapad, with an area of 65.13 sq. km., 4.75% will experience flood levels of less 0.20 meters. 1.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.22%, 0.10%, 0.05% and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 49 are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Sapad, Lanao del Norte during 25-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Sapad			
	Mabugnao	Mapurog	Pancilan	Panoloon
0.03-0.20	0.79	1.31	0.31	0.69
0.21-0.50	0.15	0.36	0.044	0.14
0.51-1.00	0.054	0.066	0.013	0.0073
1.01-2.00	0.0065	0.052	0.0083	0.00072
2.01-5.00	0.005	0.03	0	0
> 5.00	0.002	0	0	0

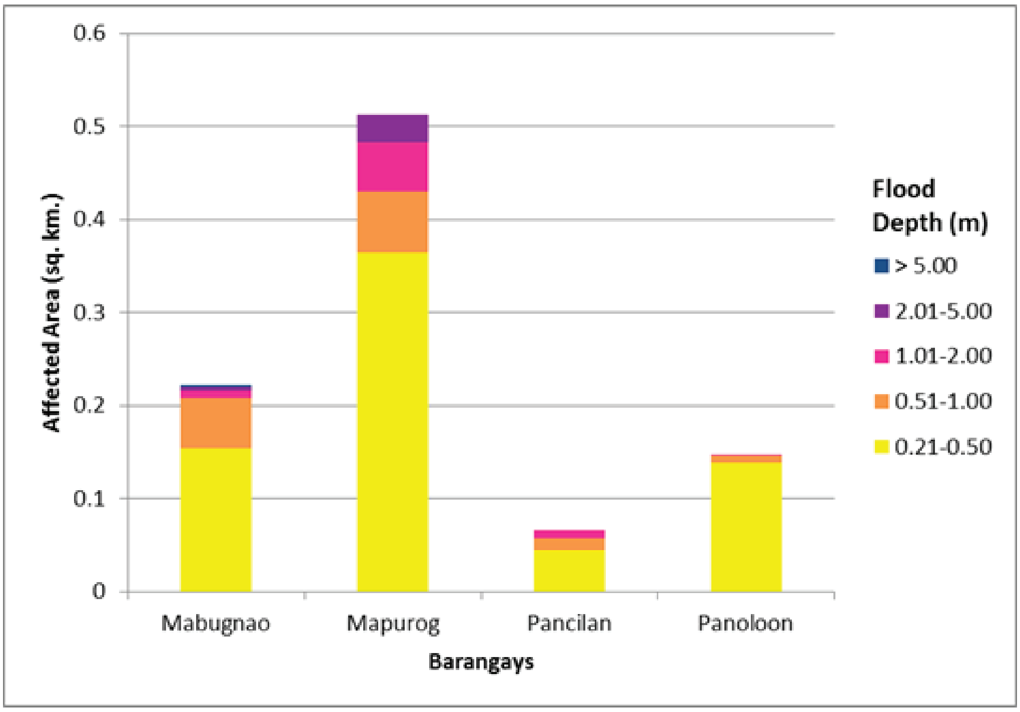


Figure 83. Affected Areas in Sapad, Lanao del Norte during 25-Year Rainfall Return Period.

For the municipality of Tubod, with an area of 121.95 sq. km., 0.98% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Tubod, Lanao del Norte during 25-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Tubod		
	Candis	Licapao	Malingao
0.03-0.20	0.0099	1.18	0.0043
0.21-0.50	0	0.047	0
0.51-1.00	0	0.033	0
1.01-2.00	0	0.021	0
2.01-5.00	0	0.0058	0
> 5.00	0	0	0

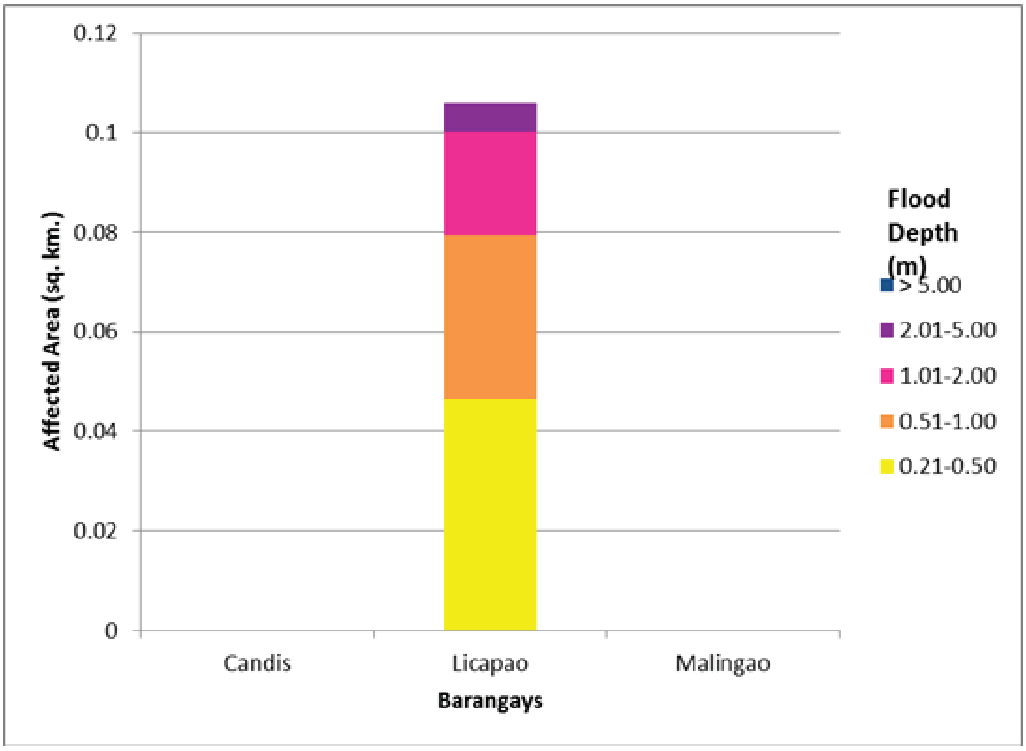


Figure 84. Affected Areas in Tubod, Lanao del Norte during 25-Year Rainfall Return Period.

For the 100-year return period, 0.90% of the municipality of Aurora with an area of 162.23 sq. km. will experience flood levels of less 0.20 meters. 53% of the area will experience flood levels of 0.21 to 0.50 meters while 0.006% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 51 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Aurora
	Anonang
0.03-0.20	1.45
0.21-0.50	0.86
0.51-1.00	0.0097
1.01-2.00	0
2.01-5.00	0
> 5.00	0

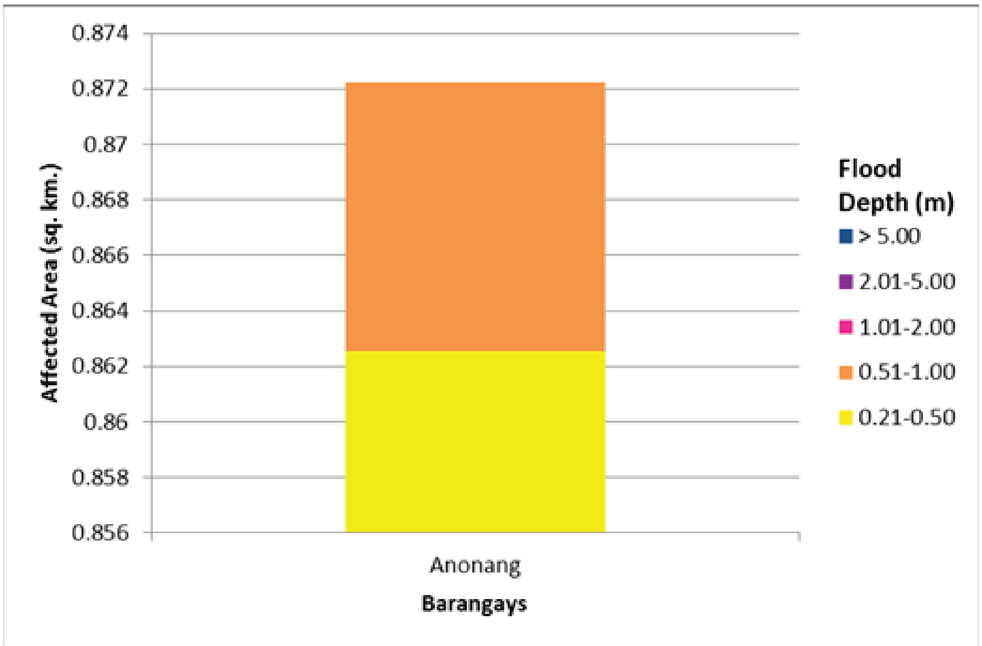


Figure 85. Affected Areas in Aurora, Zamboanga del Sur during 100-Year Rainfall Return Period.

For the municipality of Baroy, with an area of 62.08 sq. km., 45.78% will experience flood levels of less 0.20 meters. 6.83% of the area will experience flood levels of 0.21 to 0.50 meters while 4.00%, 1.77%, 0.89%, and 0.55% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 52 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Baroy											
	Andil	Bagong Dawis	Baroy Daku	Bato	Cabasagan	Dalama	Libertad	Limwag	Lindongan	Maliwanag	Manan-Ao	Pange
0.03-0.20	1.14	1.29	0.5	1.81	2.52	1.74	1.09	1.19	2.3	1.88	1.62	1.53
0.21-0.50	0.053	0.28	0.13	0.12	0.21	0.35	0.37	0.14	0.21	0.17	0.31	0.35
0.51-1.00	0.042	0.35	0.12	0.057	0.045	0.067	0.25	0.039	0.15	0.1	0.13	0.19
1.01-2.00	0.036	0.22	0.014	0.041	0.033	0.017	0.069	0.032	0.12	0.058	0.038	0.083
2.01-5.00	0.017	0.043	0	0.022	0.015	0.011	0.0075	0.041	0.032	0.11	0.011	0.0098
> 5.00	0.028	0.0038	0	0	0.0033	0.0031	0.001	0.05	0.0005	0.15	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Baroy										
	Pindolonan	Poblacion	Princesa	Rawan Point	Riverside	Sagadan	Sagadan Upper	Salong	San Juan	Tinubdan	Village
0.03-0.20	2.1	0.47	1.6	2.15	1.76	1.53	0.2	2.1	0.47	1.6	2.15
0.21-0.50	0.36	0.032	0.73	0.22	0.076	0.12	0.0082	0.36	0.032	0.73	0.22
0.51-1.00	0.11	0.024	0.56	0.11	0.038	0.092	0.0055	0.11	0.024	0.56	0.11
1.01-2.00	0.039	0.018	0.12	0.062	0.018	0.082	0.002	0.039	0.018	0.12	0.062
2.01-5.00	0.047	0.0029	0.048	0.075	0.0029	0.056	0	0.047	0.0029	0.048	0.075
> 5.00	0.015	0	0.0023	0.068	0	0.02	0	0.015	0	0.0023	0.068

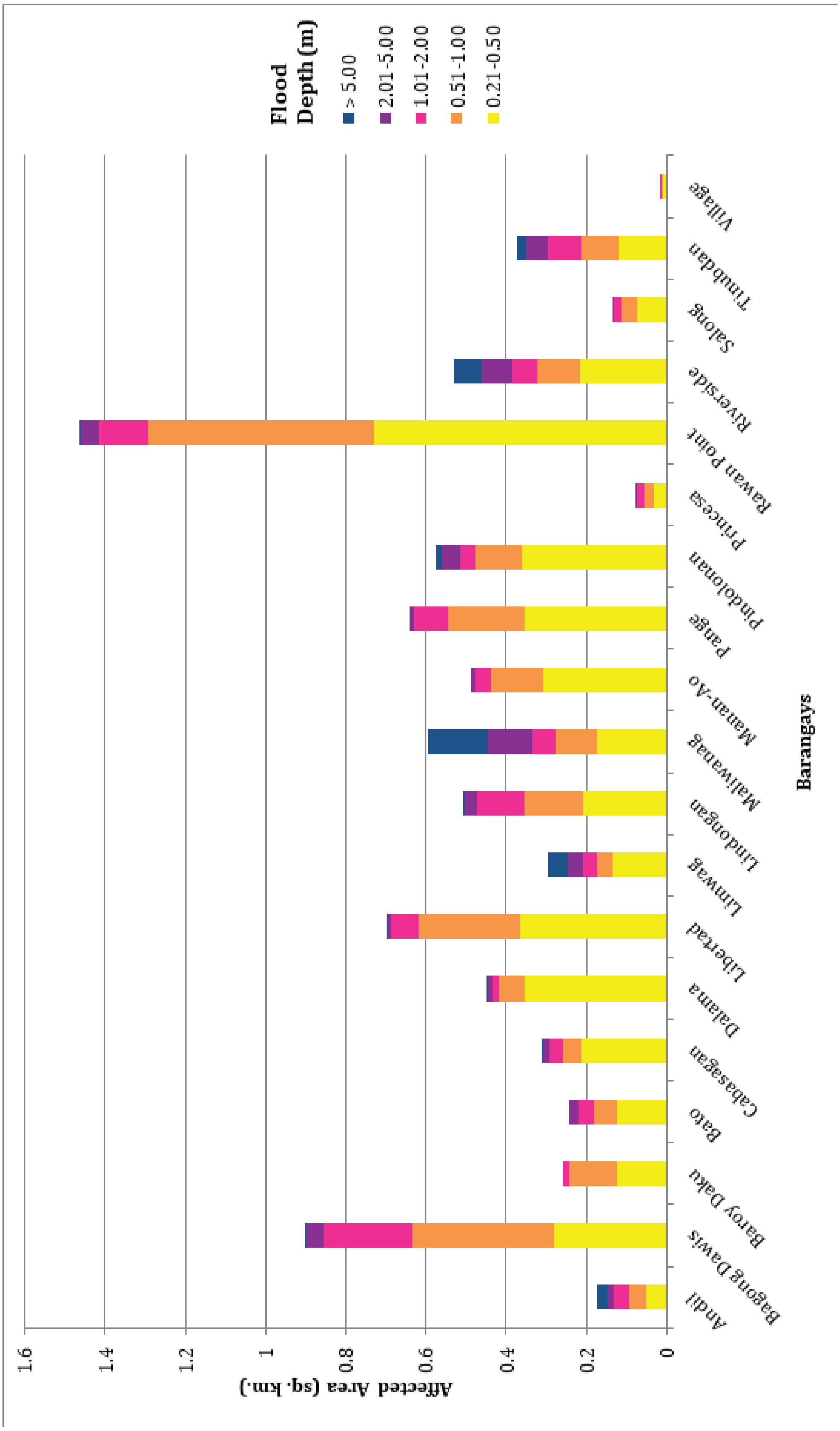


Figure 86. . Affected Areas in Baroy, Lanao del Norte during 100-Year Rainfall Return Period.

For the municipality of Kapatagan, with an area of 184.77 sq. km., 21.23% will experience flood levels of less 0.20 meters. 9.54% of the area will experience flood levels of 0.21 to 0.50 meters while 4.91%, 1.30%, 0.38%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 53 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Kapatagan											
	Bagong Silang	Balili	Bansarvil	Buenavista	Butadon	Cathedral Falls	Concepcion	Curvada	De Asis	Donggoan	Durano	Lapinig
0.03-0.20	2.88	2.32	3.25	2.78	1.63	1.62	0.72	1.6	1.39	0.019	2.33	3.31
0.21-0.50	2.04	0.92	0.29	2.23	0.41	1.49	0.39	0.55	0.13	0	0.14	2.33
0.51-1.00	1.22	0.43	0.16	0.4	0.29	0.55	0.25	0.072	0.1	0	0.1	1.3
1.01-2.00	0.33	0.062	0.07	0.081	0.17	0.048	0.0078	0.0093	0.0043	0	0.082	0.24
2.01-5.00	0.025	0.033	0.021	0.067	0.23	0.039	0.0099	0.0074	0.0013	0	0.039	0.0001
> 5.00	0	0	0.0007	0.0055	0.043	0	0	0	0.0009	0	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Kapatagan											
	Malinas	Maranding	Margos	Poblacion	San Vicente	Santa Cruz	Santo Tomas	Suso	Taguitic	Tiacongan	Tulatulahan	Waterfalls
0.03-0.20	0.35	0.89	1.04	1.32	1.7	0.7	0.56	0.97	1.67	2.19	2.76	1.22
0.21-0.50	0.014	0.043	0.85	0.47	1.75	0.47	0.32	0.51	0.37	1.05	0.3	0.54
0.51-1.00	0.013	0.03	0.56	0.39	1.34	0.3	0.11	0.044	0.14	0.61	0.27	0.39
1.01-2.00	0.01	0.02	0.084	0.16	0.44	0.12	0.02	0.003	0.042	0.082	0.15	0.17
2.01-5.00	0	0.018	0.0095	0.000073	0.052	0	0.0044	0.00016	0.012	0.00043	0.1	0.029
> 5.00	0	0.0016	0.0086	0	0	0	0	0	0.0001	0	0.00063	0.0021

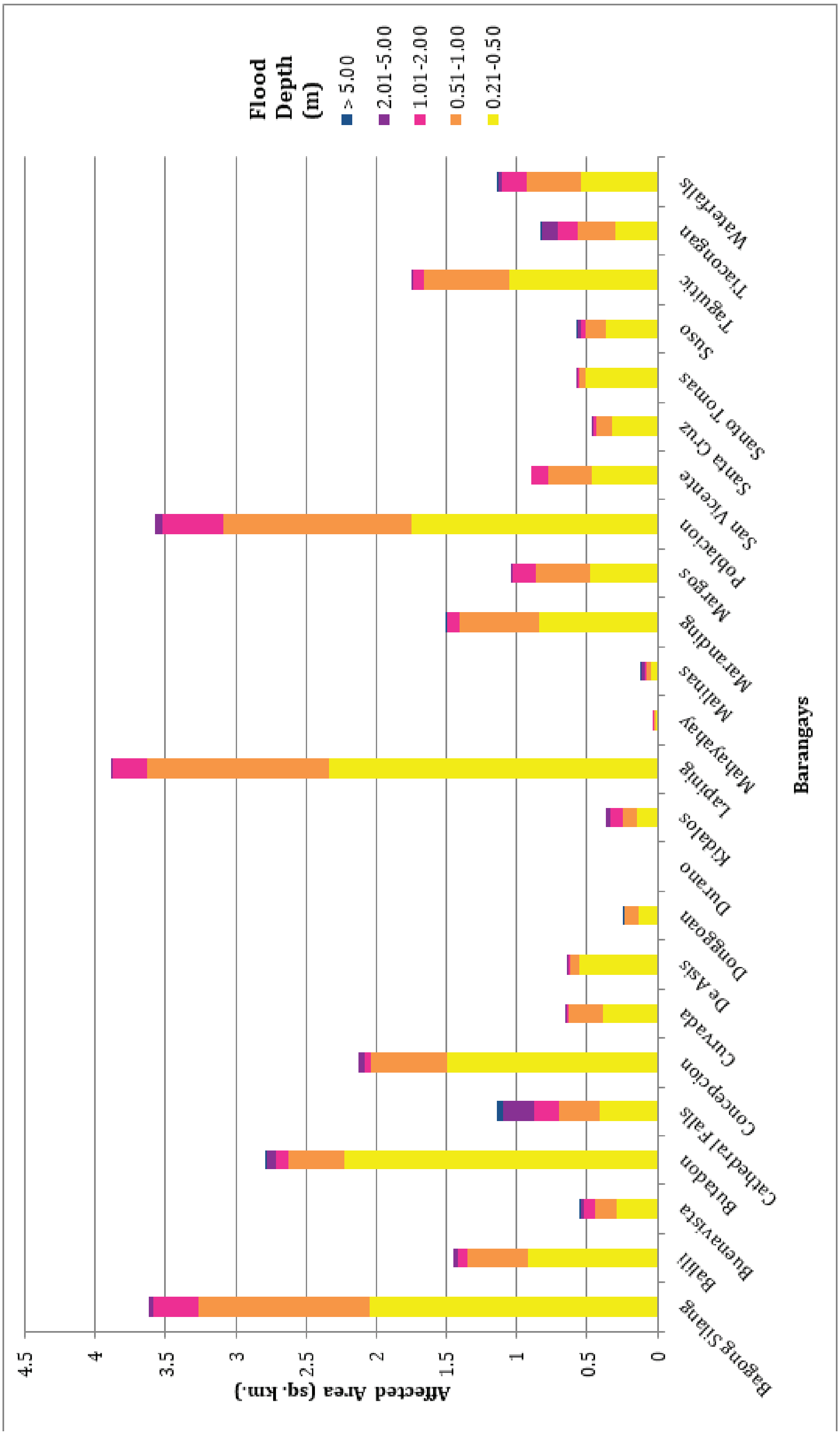


Figure 87. Affected Areas in Kapatagan, Lanao del Norte during 100-Year Rainfall Return Period.

For the municipality of Lala, with an area of 125.18 sq. km., 51.02% will experience flood levels of less 0.20 meters. 27.13% of the area will experience flood levels of 0.21 to 0.50 meters while 13.50%, 3.77%, 0.77%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 54 are the affected areas in square kilometers by flood depth per barangay.

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

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Lala													
	Abaga	Andil	Cabasagan	Camalan	Darumawang Bucana	Darumawang Ilaya	El Salvador	Gumagamot	Lala Proper	Lanipao	Magpatao	Maranding	Matampay Bucana	Matampay Ilaya
0.03-0.20	1.49	1.14	2.52	1.75	3.89	5.13	4.01	1.36	0.79	0.78	1.89	1.04	1.7	0.57
0.21-0.50	0.67	0.053	0.21	0.85	2.61	3.57	3.35	0.96	0.39	0.53	0.57	0.85	0.91	0.46
0.51-1.00	0.1	0.042	0.045	0.75	1.05	1.31	0.9	0.79	0.25	0.41	0.6	0.56	0.38	0.54
1.01-2.00	0.0003	0.036	0.033	0.62	0.03	0.13	0.059	0.21	0.026	0.23	0.58	0.084	0.0054	0.071
2.01-5.00	0	0.017	0.015	0.016	0	0.022	0.022	0	0	0.005	0.014	0.0095	0	0
> 5.00	0	0.028	0.0033	0	0	0.0007	0	0	0	0	0	0.0086	0	0

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Lala												
	Pacita	Pendolonan	Pinoyak	Raw-An	Rebe	San Isidro Lower	San Isidro Upper	San Manuel	Santa Cruz Lower	Santa Cruz Upper	Simpak	Tenazas	Tuna-An
0.03-0.20	1.05	3.52	3.84	0.68	4.28	2.35	2.89	3.13	2.65	4.58	4.2	1.52	1.11
0.21-0.50	0.63	1.27	1.89	0.54	2.68	1.38	0.79	1.17	2.21	1.76	2.31	0.63	0.73
0.51-1.00	0.37	1.07	0.53	0.2	1.55	0.66	0.27	0.46	0.88	1.49	0.5	0.26	0.92
1.01-2.00	0.0024	0.092	0.074	0.052	0.3	0.029	0.076	0.16	0.12	1.17	0.091	0.075	0.37
2.01-5.00	0	0.011	0.095	0.00031	0.29	0.0004	0.07	0.091	0	0.25	0.025	0	0.0082
> 5.00	0	0	0.024	0	0.0041	0	0.035	0.012	0	0.031	0.01	0	0

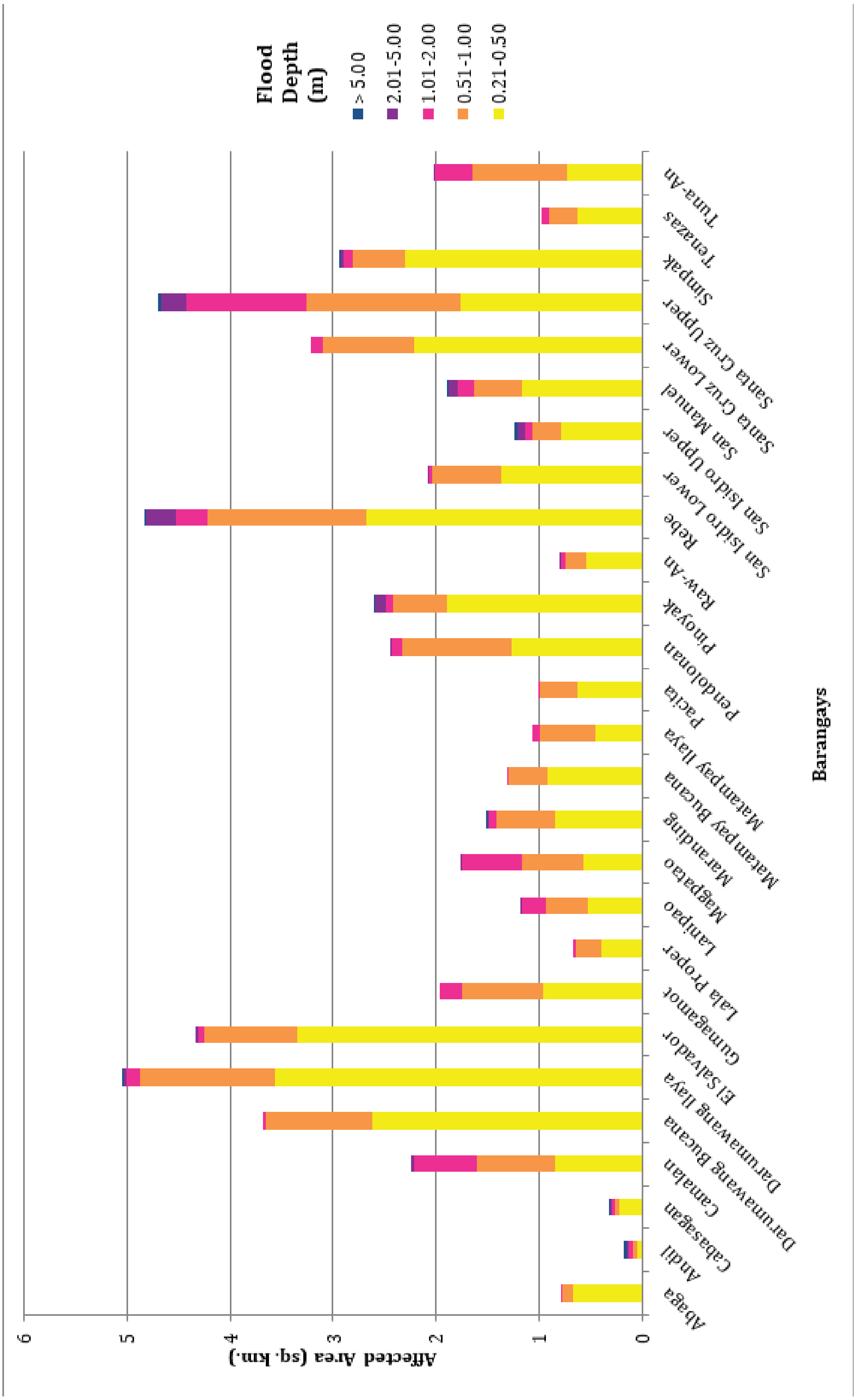


Figure 88. Affected Areas in Lala, Lanao del Norte during 100-Year Rainfall Return Period.

For the municipality of Salvador, with an area of 46.46 sq. km., 20.17% will experience flood levels of less 0.20 meters. 8.02% of the area will experience flood levels of 0.21 to 0.50 meters while 4.94%, 2.21%, 0.81%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected Areas in Salvador, Lanao del Norte during 100-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Salvador									
	Camp III	Curva-Miagao	Inasagan	Mabatao	Padianan	Pagayawan	Panaliwad-On	Pangantapan	Poblacion	Sudlon
0.03-0.20	2.58	0.72	0.79	0.91	0.25	0.04	1.58	0.013	1.7	0.78
0.21-0.50	0.3	0.48	0.44	0.062	0.056	0.0032	0.45	0.0017	1.75	0.19
0.51-1.00	0.27	0.17	0.073	0.035	0.0022	0.00036	0.17	0	1.34	0.22
1.01-2.00	0.25	0.039	0.023	0.02	0.0001	0.00009	0.09	0	0.44	0.17
2.01-5.00	0.059	0.13	0.00021	0.0059	0	0	0.018	0	0.052	0.12
> 5.00	0.0007	0.076	0	0	0	0	0	0	0	0.01

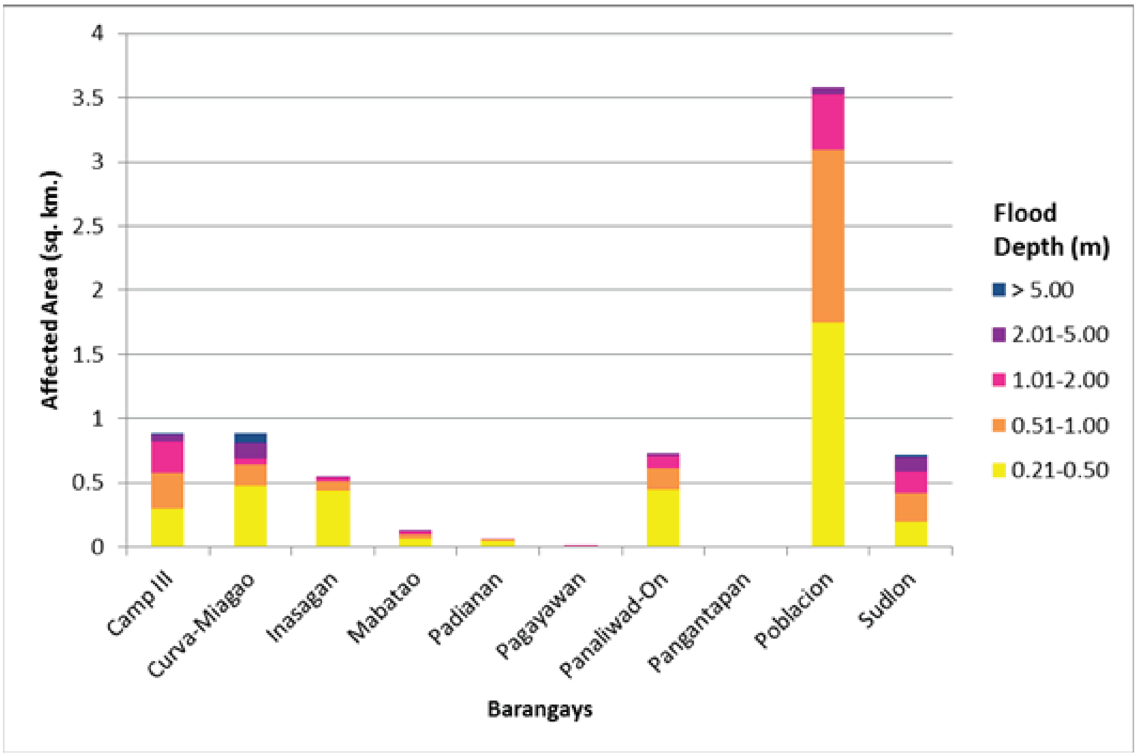


Figure 89. Affected Areas in Salvador, Lanao del Norte during 100-Year Rainfall Return Period.

For the municipality of Sapad, with an area of 65.13 sq. km., 4.42% will experience flood levels of less 0.20 meters. 1.28% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.12%, 0.06% and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 56 are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected Areas in Sapad, Lanao del Norte during 100-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Sapad			
	Mabugnao	Mapurog	Pancilan	Panoloon
0.03-0.20	0.75	1.2	0.29	0.64
0.21-0.50	0.17	0.43	0.058	0.18
0.51-1.00	0.069	0.1	0.015	0.019
1.01-2.00	0.0076	0.058	0.0095	0.00092
2.01-5.00	0.0056	0.036	0	0
> 5.00	0.0029	0	0	0

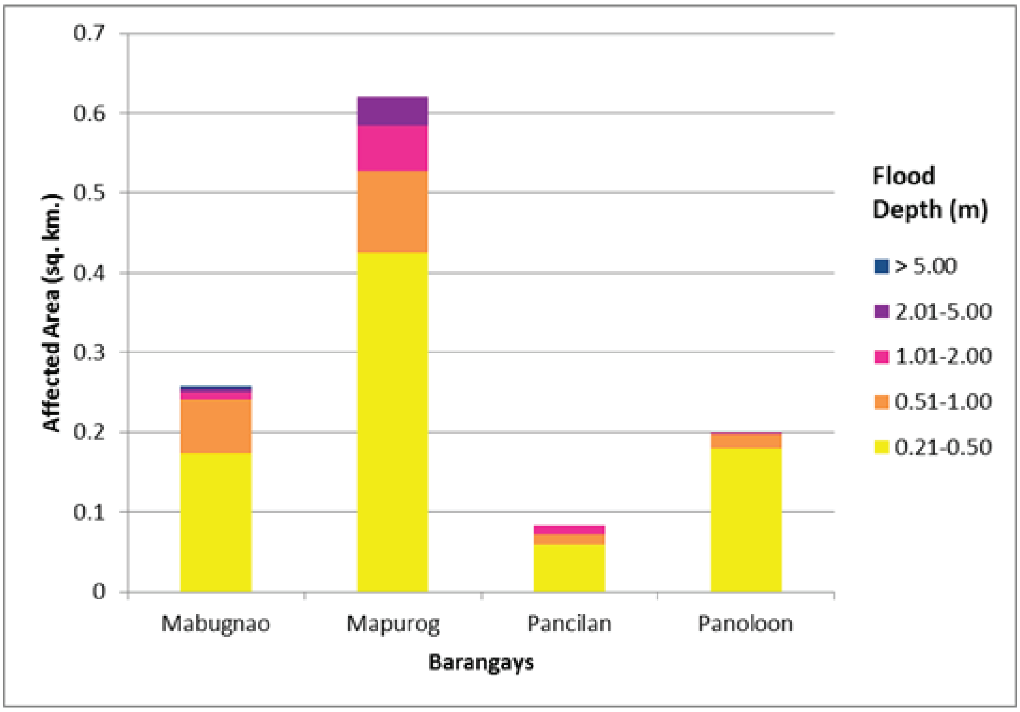


Figure 90. Affected Areas in Sapad, Lanao del Norte during 100-Year Rainfall Return Period.

For the municipality of Tubod, with an area of 121.95 sq. km., 0.97% will experience flood levels of less 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, and 0.007% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 57 are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Tubod, Lanao del Norte during 100-Year Rainfall Return Period.

Affected Area (in sq.km.) by flood depth (in m.)	Affected Barangays in Tubod		
	Candis	Licapao	Malingao
0.03-0.20	0.0099	1.17	0.0043
0.21-0.50	0	0.048	0
0.51-1.00	0	0.036	0
1.01-2.00	0	0.026	0
2.01-5.00	0	0.008	0
> 5.00	0	0	0

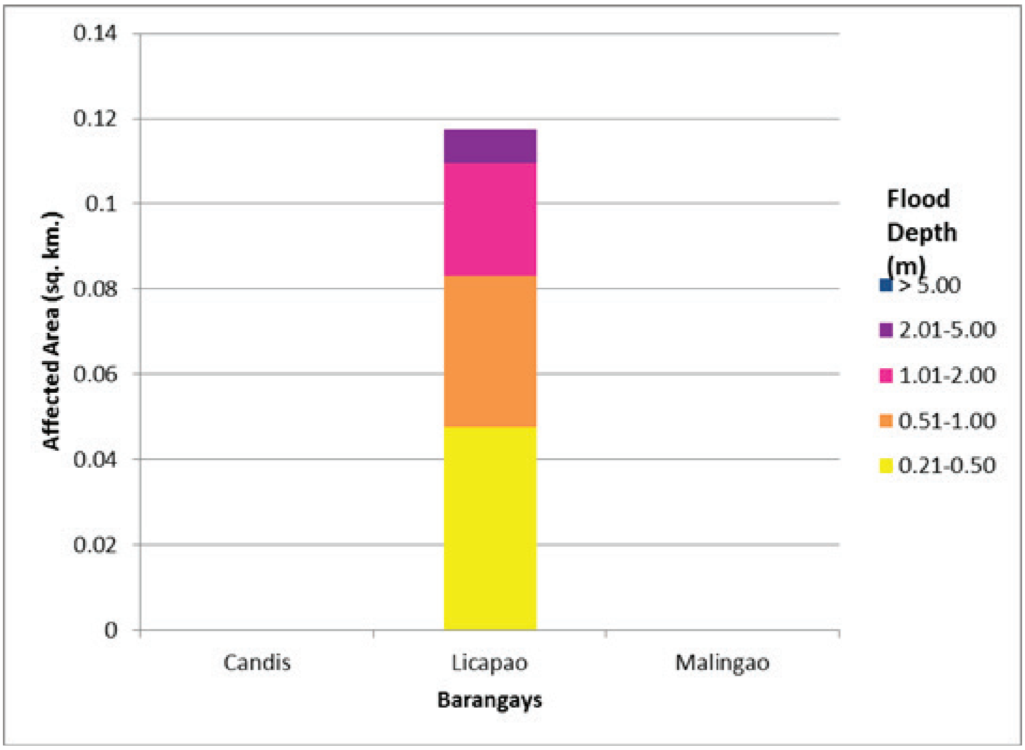


Figure 91. Affected Areas in Tubod, Lanao del Norte during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Aurora, only Anonang is projected to experience flood levels at a percentage of 1.43%.

Among the barangays in the municipality of Baroy, Rawan Point is projected to have the highest percentage of area that will experience flood levels at 4.93%. Meanwhile, Cabasagan posted the second highest percentage of area that may be affected by flood depths at 4.55%.

Among the barangays in the municipality of Kapatagan, Lapinig is projected to have the highest percentage of area that will experience flood levels at 3.89%. Meanwhile, Bagong Silang posted the second highest percentage of area that may be affected by flood depths at 3.52%.

Among the barangays in the municipality of Lala, Darumawang Ilaya is projected to have the highest percentage of area that will experience flood levels at 8.12%. Meanwhile, Santa Cruz Upper posted the second highest percentage of area that may be affected by flood depths at 7.42%.

Among the barangays in the municipality of Salvador, Poblacion is projected to have the highest percentage of area that will experience flood levels at 11.35%.

Meanwhile, Camp III posted the second highest percentage of area that may be affected by flood depths at 7.45%.

Among the barangays in the municipality of Sapad, Mapurog is projected to have the highest percentage of area that will experience flood levels at 2.79%. Meanwhile, Mabugnao posted the second highest percentage of area that may be affected by flood depths at 1.55%.

Among the barangays in the municipality of Tubod, Licapao is projected to have the highest percentage of area that will experience flood levels at 1.05%. Meanwhile, Candis posted the second highest percentage of area that may be affected by flood depths at 0.008%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 92.

The flood validation consisted of 152 points randomly selected all over the Maranding flood plain (Figure 93). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.61m. Table 58 shows a contingency matrix of the comparison. The validation points are found in ANNEX 11.

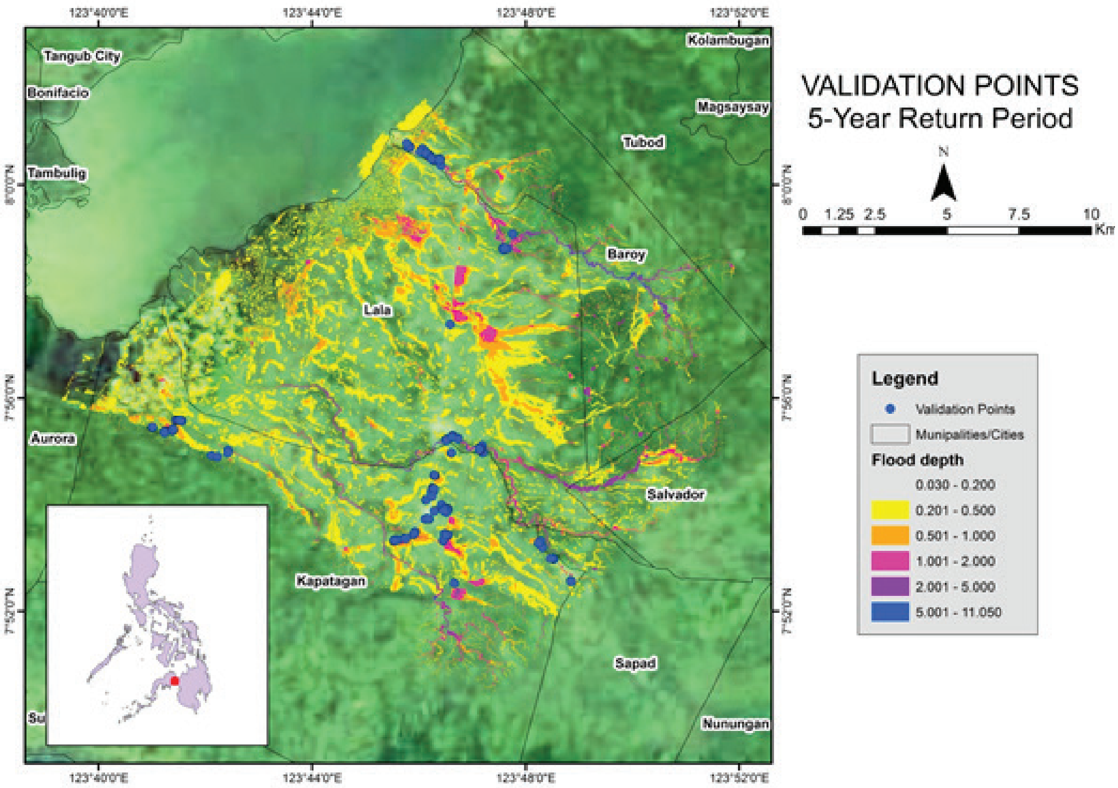


Figure 92. The Validation Points for a 5-year Flood Depth Map of the Maranding Floodplain.

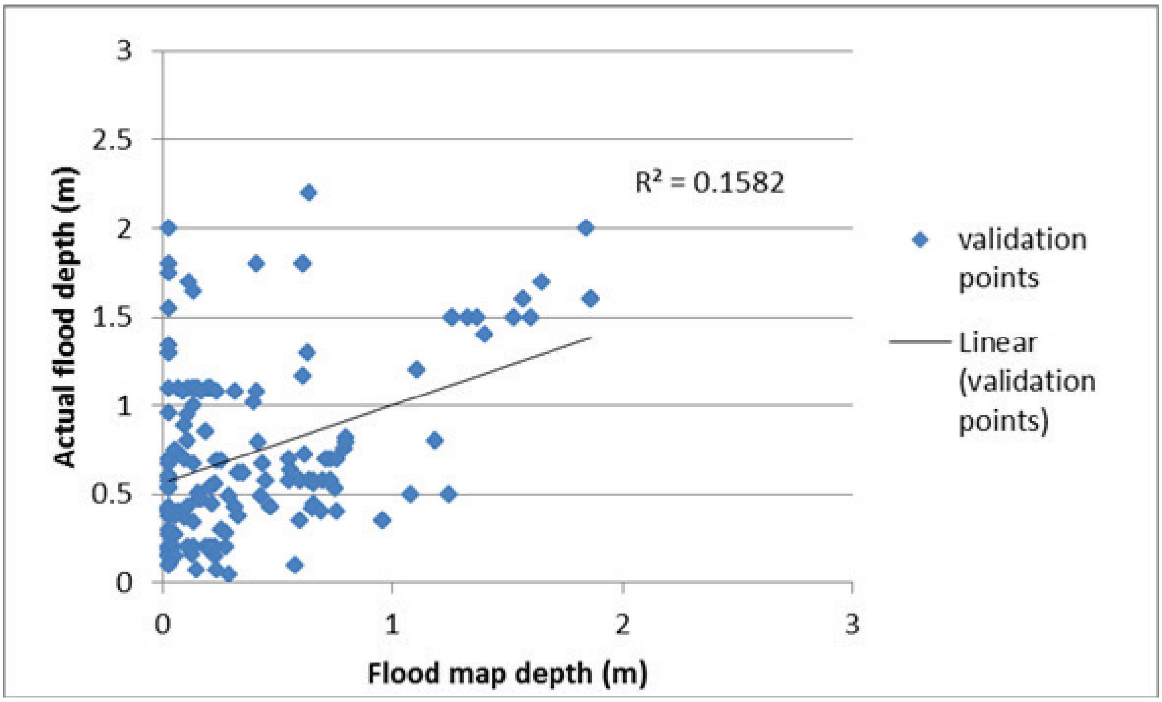


Figure 93. Flood map depth versus actual flood depth.

Table 58. Actual Flood Depth versuss Simulated Flood Depth at different levels in the Maranding River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
0-0.20	16	6	1	0	0	0	23
0.21-0.50	18	9	7	2	0	0	36
0.51-1.00	19	9	22	2	0	0	52
1.01-2.00	19	8	4	13	0	0	44
2.01-5.00	0	0	1	0	0	0	1
> 5.00	0	0	0	0	0	0	0
Total	72	32	35	17	0	0	156

On the whole, the overall accuracy generated by the flood model is estimated at 38.46%, with 60 points correctly matching the actual flood depths. In addition, there were 41 points estimated one level above and below the correct flood depths while there were 31 points and 19 points estimated two levels above and below. A total of 18 points were overestimated while a total of 78 points were underestimated in the modelled flood depths of Maranding. Table 59 depicts the summary of the Accuracy Assessment in the Maranding River Basin Flood Depth Map.

Table 59. The summary of the Accuracy Assessment in the Maranding River Basin Survey.

	No. of Points	**%**
Correct	60	38.46
Overestimated	18	11.54
Underestimated	78	50.00
Total	156	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

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

1. PEGASUS SENSOR

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

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

1. LAN-2

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

June 24, 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: LANAO DEL NORTE	
	Station Name: LAN-2	
Island: MINDANAO	Order: 1st	Barangay: PINOYAK
Municipality: LALA		
	PRS92 Coordinates	
Latitude: 7° 54' 46.07859"	Longitude: 123° 46' 0.85333"	Ellipsoidal Hgt: 17.35400 m.
	WGS84 Coordinates	
Latitude: 7° 54' 42.56546"	Longitude: 123° 46' 6.31720"	Ellipsoidal Hgt: 83.92120 m.
	PTM Coordinates	
Northing: 875110.149 m.	Easting: 364025.74 m.	Zone: 5
	UTM Coordinates	
Northing: 874,680.35	Easting: 584,533.45	Zone: 51

Location Description

LAN-2
From Iligan City, travel southwest along the National highway for 74.5 kilometers to the municipality of Lala. Travel farther along the national highway for 1.4 kilometers up to Maranding junction. Thence from the junction travel southeast along the national highway for another 1.3 kilometers to a dirt road going to Pinoyak barangay proper. Turn right on the dirt road and national highway intersection and continue travelling westward for 400 meters up to the irrigation canal. Station is located on top of the concrete irrigation canal water gate. Station mark is 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in a drill hole on top of the concrete irrigation canal water gate; centered in cement patty and inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rod, with cross cut on top, set in drill holes on top of the concrete irrigation canal water gate; centered in cement patty and inscribed with the reference mark numbers and arrow pointing to the station.

Requesting Party: Engr. Cruz
Pupose: Reference
OR Number: 8796376 A
T.N.: 2014-1441

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. ZGS-8

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

July 11, 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-88**	
	Order: **2nd**	
Island: **MINDANAO**		Barangay: **SAN JOSE**
Municipality: **AURORA**		MSL Elevation:
	PRS92 Coordinates	
Latitude: **7° 57' 13.25316"**	Longitude: **123° 34' 56.50093"**	Ellipsoidal Hgt: **258.34500 m.**
	WGS84 Coordinates	
Latitude: **7° 57' 9.71271"**	Longitude: **123° 35' 1.96243"**	Ellipsoidal Hgt: **324.37300 m.**
	PTM / PRS92 Coordinates	
Northing: **879474.685 m.**	Easting: **564207.26 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **879,166.85**	Easting: **564,184.79**	Zone: **51**

Location Description

ZGS-88
Is located on the S end of the W wedge-shaped island in Purok Saray, Brgy. San Jose, Aurora. It is about 500 m. N of the municipal hall, 30 m. W of the Seaoil Gasoline Station and 5 m. E of the W side of the road. Mark is the head of a 3 in. copper nail embedded and centered on a 27 cm. x 26 cm. x cement putty, with inscriptions "ZGS-88 2005 NAMRIA LEP IX".

Requesting Party: **UP TCAGP / Engr. Christopher Cruz**
Pupose: **Reference**
OR Number: **8796507 A**
T.N.: **2014-1601**

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

3. LE-50

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

July 25, 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: LANAO DEL NORTE
Station Name: LE-50

Island: Mindanao	Municipality: MAIGO	Barangay: CLARO M. RECTO
Elevation: 5.3895 m.	Order: 1st Order	Datum: Mean Sea Level

Location Description

BM LE-50 is in the Province of Lanao Del Norte, Town of Maigo, Brgy. C.M. Recto, along the Butuan - Zamboanga National Road, and about 50 meters North East of the Covenant Baptist Church. The station is located at the South West end of the Barogohan Bridge footwalk and about 70 meters South West of KM post 1561.

A brass rod is set on a drilled hole and cemented flushed on top of a 15cm x 15cm cement putty with inscription "LE-50; 2007, NAMRIA".

Requesting Party: UP-TCAGP / Engr. Christopher Cruz
Pupose: Reference
OR Number: 8799582 A
T.N.: 2014-1723

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

4. ZGS-17

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-17**
Order: **2nd**

Island: **MINDANAO**
Municipality: **TUKURAN**
Barangay: **BACLAY**
MSL Elevation:

PRS92 Coordinates

Latitude:	**7° 52' 42.71658"**	Longitude:	**123° 36' 29.22049"**	Ellipsoidal Hgt:	**29.68400 m.**

WGS84 Coordinates

Latitude:	**7° 52' 39.19813"**	Longitude:	**123° 36' 34.68878"**	Ellipsoidal Hgt:	**95.92400 m.**

PTM / PRS92 Coordinates

Northing:	**871168.108 m.**	Easting:	**567059.131 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**870,863.18**	Easting:	**567,035.66**	Zone:	**51**

Location Description

ZGS-17
Is located at Purok Kasoy, Brgy. Baclay, Tukuran. It is situated on the slope of a cultivated hill. It is about 100 m. NW of UCCP chapel and about 200 m. NNE of the roman catholic chapel. Mark is the head of a 4 in. copper nail embedded and centered on a 30 cm. x 30 cm. x 38 cm., with inscriptions "ZGS-17 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0333**

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

5. ZN-53

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

October 30, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL NORTE**
Station Name: **ZN-53**

Island: **Mindanao**	Municipality: **KATIPUNAN**	Barangay: **DAANGLUNGSOD**
Elevation: **10.0561 +/- 0.00 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

ZN-53
Along Dipolog Liloy National Road. The station is located at the compound of Taga Central School, near the flagpole and about 50 meters northwest of the centerline of the road. Mark is the head of a 4" copper nail set on a dsrilled hole and cemented flushed on top of 15cm x 15cm cement putty with inscription " ZN-53 2008 NAMRIA".

Requesting Party:	**PHIL-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075910 I**
T.N.:	**2014-2589**

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

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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

6. ZGS-16

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL SUR**
Station Name: **ZGS-16**
Order: **2nd**

Island: **MINDANAO**	Barangay: **BACLAY**		
Municipality: **TUKURAN**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **7° 52' 32.53106"**	Longitude: **123° 36' 23.39905"**	Ellipsoidal Hgt:	**18.17800 m.**
	WGS84 Coordinates		
Latitude: **7° 52' 29.01321"**	Longitude: **123° 36' 28.86762"**	Ellipsoidal Hgt:	**84.42000 m.**
	PTM / PRS92 Coordinates		
Northing: **870854.959 m.**	Easting: **566881.259 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **870,550.15**	Easting: **566,857.85**	Zone:	**51**

Location Description

ZGS-16
Is located at Purok Nangka, Brgy. Baclay. It is situated 1 m. NE of Km. Post # 1644 and about 50 m. SW of the chapel, approx. 3 km. from the road junction leading to Aurora town. Mark is the head of a 3 in. concrete nail embedded and centered on a 30 cm. x 30 cm. x 58 cm. concrete monument, with inscriptions "ZGS-16 2005 NAMRIA/LEP-IX".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0334**

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
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

7. ZGN-138

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

October 30, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBOANGA DEL NORTE**

Station Name: **ZGN-138**

Order: **2nd**

Island: **MINDANAO**	Barangay:	
Municipality: **KATIPUNAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 30' 40.65974"**	Longitude: **123° 18' 14.44217"**	Ellipsoidal Hgt: **6.71500 m.**
	WGS84 Coordinates	
Latitude: **8° 30' 36.94779"**	Longitude: **123° 18' 19.85548"**	Ellipsoidal Hgt: **70.92500 m.**
	PTM / PRS92 Coordinates	
Northing: **941106.14 m.**	Easting: **533471.036 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **940,776.74**	Easting: **533,459.32**	Zone: **51**

Location Description

The station is marked by an 4" copper nail with its head flushed at the center of an cement putty on a concrete open canal with inscription " ZGN-138, 2009 NAMRIA".Located at brgy. Taga katipunan zamboanga del norte. The monument is situated inside taga central school 10 meters from the main gate going north west 6 meters from the flag pole going south east.

Requesting Party:	**PHIL-LIDAR I**
Purpose:	**Reference**
OR Number:	**8075910 I**
T.N.:	**2014-2584**

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

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CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

8. LE-76

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

August 08, 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: **LANAO DEL NORTE** Station Name: **BM LE-76**	
Island: **Mindanao**	Municipality: **TUBOD (CAPITAL)**	Barangay: **BULOD**
Elevation: **5.0250 m.**	Order: **2nd Order**	Datum: **Mean Sea Level**

Location Description

BM LE-76 is in the Province of Lanao del Norte, Municipality of Tubug, Bgry. Bulod, along the Butuan-Zamboanga National Road. The station is located at the south west end of Bulod Bridge footwalk, about 2 meters north west of KM Post 1587, and about 4 meters north west of the centerline of the road

Requesting Party:	**ENGR. CHRISTOPHER CRUZ**
Pupose:	**Reference**
OR Number:	**8799670 A**
T.N.:	**2014-1787**

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

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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

9. ZS-188

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **ZAMBOANGA DEL SUR** Station Name: **ZS-188**	
Island: **Mindanao**	Municipality: **ZAMBOANGA CITY**	Barangay: **LICOMO**
Elevation: **22.1396 +/- 0.16 m.**	Accuracy Class at 95% C.L: **2 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

ZS-188 is located in Sitio Simoropan Purok 1 Brgy. Licomo Vital District Zamboanga City The BM established in hedawall of Pipe Culvert, about 4 m from the cneterline of the road leftside going to Maria Clara lobgegat Hi-way.

Mark is the head of a 4" copper nail on a drilled hole and cemented flushed on top of a 15x15cm cement putty with inscription "ZS-188, 2008, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0337**

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

9 9 0 2 1 0 2 0 1 6 1 2 2 7 4 5

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

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Reports of Reference Points Used

LE-50

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Processing Start Time	Processing Stop Time	Satellite Available
LE50 --- LAN2 (B1)	LAN2	LE50	6/20/2014 10:05:34 AM	6/20/2014 2:59:59 PM	Fixed	0.012	0.024	-15846.890	-15348.670	27636.104	37°51'51"	35361.439	-10.469	6/20/2014 10:05:34 AM	6/20/2014 2:59:59 PM	GPS: 15 GLONASS: 13 Galileo: 0 QZSS: 0

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

LE-76

Vector Components (Mark to Mark)

From:	LE-50				
Grid		Local		Global	
Easting	606180.417 m	Latitude	N8°09'54.67217"	Latitude	N8°09'51.11024"
Northing	902629.434 m	Longitude	E123°57'49.92899"	Longitude	E123°57'55.36634"
Elevation	4.394 m	Height	6.900 m	Height	73.452 m

To:	LE-76				
Grid		Local		Global	
Easting	588530.790 m	Latitude	N8°03'05.36825"	Latitude	N8°03'01.82183"
Northing	890021.013 m	Longitude	E123°48'12.37307"	Longitude	E123°48'17.82405"
Elevation	7.017 m	Height	9.335 m	Height	75.717 m

Vector					
ΔEasting	-17649.627 m	NS Fwd Azimuth	234°35'42"	ΔX	13688.663 m
ΔNorthing	-12608.421 m	Ellipsoid Dist.	21696.715 m	ΔY	11332.042 m
ΔElevation	2.623 m	ΔHeight	2.435 m	ΔZ	-12447.993 m

Standard Errors

Vector errors:					
σ ΔEasting	0.021 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.024 m
σ ΔNorthing	0.006 m	σ Ellipsoid Dist.	0.015 m	σ ΔY	0.034 m
σ ΔElevation	0.036 m	σ ΔHeight	0.036 m	σ ΔZ	0.009 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0005606089		
Y	-0.0003223999	0.0011623638	
Z	-0.0000556148	0.0002703935	0.0000791896

ZS-188

Vector Components (Mark to Mark)

From:	ZGS-1				
Grid		Local		Global	
Easting	553699.482 m	Latitude	N8°04'26.98335"	Latitude	N8°04'23.40249"
Northing	892472.300 m	Longitude	E123°29'14.53868"	Longitude	E123°29'19.99013"
Elevation	20.051 m	Height	22.611 m	Height	88.163 m

To:	ZS-188A				
Grid		Local		Global	
Easting	553627.634 m	Latitude	N8°03'56.69408"	Latitude	N8°03'53.11537"
Northing	891542.089 m	Longitude	E123°29'12.15500"	Longitude	E123°29'17.60722"
Elevation	17.277 m	Height	19.832 m	Height	85.400 m

Vector					
ΔEasting	-71.848 m	NS Fwd Azimuth	184°29'06"	ΔX	-9.705 m
ΔNorthing	-930.211 m	Ellipsoid Dist.	933.322 m	ΔY	146.900 m
ΔElevation	-2.773 m	ΔHeight	-2.778 m	ΔZ	-921.644 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.004 m	σ ΔHeight	0.004 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000013603		
Y	0.0000026352	0.0000296273	
Z	0.0000004069	0.0000057486	0.0000013978

ZN-53

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
zgn 138 --- zn 53 am (B1)	zgn 138	zn 53 am	Fixed	0.001	0.002	344°25'59"	12.263	0.357
zgn 138 --- zn 53 pm (B2)	zgn 138	zn 53 pm	Fixed	0.003	0.004	344°25'44"	12.270	0.372

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	zgn 138				
Grid		Local		Global	
Easting	533459.321 m	Latitude	N8°30'40.65974"	Latitude	N8°30'36.94779"
Northing	940776.736 m	Longitude	E123°18'14.44217"	Longitude	E123°18'19.85548"
Elevation	5.484 m	Height	6.715 m	Height	70.925 m

To:	zn 53 am				
Grid		Local		Global	
Easting	533456.022 m	Latitude	N8°30'41.04428"	Latitude	N8°30'37.33230"
Northing	940788.542 m	Longitude	E123°18'14.33457"	Longitude	E123°18'19.74787"
Elevation	5.842 m	Height	7.072 m	Height	71.282 m

Vector					
ΔEasting	-3.299 m	NS Fwd Azimuth	344°25'59"	ΔX	3.517 m
ΔNorthing	11.806 m	Ellipsoid Dist.	12.263 m	ΔY	0.641 m
ΔElevation	0.358 m	ΔHeight	0.357 m	ΔZ	11.736 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'09"	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	0.0000005629		
Y	-0.0000004033	0.0000010310	
Z	-0.0000000776	0.0000001462	0.0000001693

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP-TCAGP

FIELD TEAM

LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	SSRS	PAULINE JOANNE ARCEO	UP-TCAGP
		ENGR. RENAN PUNTO	UP-TCAGP
	Research Associate (RA)	GEF SORIANO	UP-TCAGP
		JERIEL PAUL ALAMBAN	UP-TCAGP
		MERLIN FERNANDO	UP-TCAGP
		GRACE SINADJAN	UP-TCAGP
		JONATHAN ALMALVEZ	UP-TCAGP
		IRO ROXAS	UP-TCAGP
		KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY E. PUNZALAN	PILIPPINE AIR FORCE (PAF)
		SSG. JAYCO S. MANZANO	
		SSG. GERONIMO BALICAO III	
	Pilot	CAPT. ANTON RETSE DAYO	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. ERNESTO SAYSAY JR.	
		CAPT. J. LIM	
		CAPT. CESAR ALFONSO III	
		CAPT. JERICO JECIEL	

Annex 5. Data Transfer Sheet for Maranding Floodplain

DATA TRANSFER SHEET
06/20/2014(Northern Mindanao)

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	
29-May-14	1525P	1RXB149A	PEGASUS	1.6	457	9.27	265	na	na	26.5	NA	9.83	1KB	1KB	40	NA	Z:\Airborne_Raw\1525P
31-May-14	1533P	1BLK67151A	PEGASUS	3.32	270	14.4	224	43.2	428	33.3	NA	8.87	1KB	1KB	47/38	NA	Z:\Airborne_Raw\1533P
2-Jun-14	1541P	1BLK71B153A	PEGASUS	4	242	0	286	19.7	139	39	674MB	12.6	1KB	1KB	47/45/40/34	NA	Z:\Airborne_Raw\1541P
3-Jun-14	1545P	1BLK71C154A	PEGASUS	4.13	2259	13	253	69.7	533	40.1	272MB	9.95	1KB	1KB	141	NA	Z:\Airborne_Raw\1545P
4-Jun-14	1549P	1BLK71D155A	PEGASUS	3.48	150	14.3	264	NA	NA	34.6	NA	11.2	1KB	1KB	54/50/45	NA	Z:\Airborne_Raw\1549P
7-Jun-14	1561P	1RXE158A	PEGASUS	NA	44	NA	187	NA	NA	22	NA	8.1	1KB	1KB	71	NA	Z:\Airborne_Raw\1561P
8-Jun-14	1565P	1BLK71B159A	PEGASUS	NA	16	5.36	168	22.1	163	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw\1565P

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
6/23/2014

DATA TRANSFER SHEET
07/28/2014(Northern Mindanao - ready)

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	
6/8/2014	1565P	1BLK71B159A	Pegasus	NA	16	6.93	168	NA	NA	13.3	NA	7.75	1KB	1KB	36	NA	Z:\Airborne_Raw
6/9/2014	1569P	1BLKRXE160A	Pegasus	4.16	832	16.5	290	8.86	62	38.5	NA	10	1KB	1KB	85	NA	Z:\Airborne_Raw
6/16/2014	1597P	1BLKRXE167A	Pegasus	2.18	332	10.5	237	NA	NA	21.3	NA	7.52	1KB	1KB	68	NA	Z:\Airborne_Raw
6/19/2014	1609P	1RXS170A	Pegasus	2.16	526	11.2	259	45.3	309	22.1	NA	7.07	1KB	1KB	77/76	NA	Z:\Airborne_Raw
6/20/2014	1613P	1BLK71G171A	Pegasus	3.44	177	13.7	258	67.3	437	33.2	NA	5.92	1KB	1KB	46	NA	Z:\Airborne_Raw
6/23/2014	1625P	1BLK67BC174A	Pegasus	3.09	1112	11.7	212	60.3	415	29.4	66.6	4.97	1KB	1KB	52/56	NA	Z:\Airborne_Raw
6/24/2014	1629P	1BLKRXES175A	Pegasus	2.79	370	10.7	187	36.3	268	26.1	NA	4.45	1KB	1KB	73	NA	Z:\Airborne_Raw
6/27/2014	1641P	1BLK68A178A	Pegasus	2.94	1995	12.6	268	57.4	398	28.9	57.2	7.7	1KB	1KB	65/65/60/58	NA	Z:\Airborne_Raw
6/27/2014	1643P	1BLK67ABS178B	Pegasus	532	95	4.33	119	NA	NA	5.65	NA	7.7	1KB	1KB	48	NA	Z:\Airborne_Raw
6/28/2014	1645P	1BLK71C179A	Pegasus	2.84	NA	11.4	242	51.8	375	27.4	NA	6.25	1KB	1KB	59/68	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA PRIETO
Position
Signature 7/28/14

DATA TRANSFER SHEET
08/05/2014(Northern Mindanao - ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	SHP	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	
7/3/2014	1665P	1BLK71ES184A	Pegasus	606	93	4.69	94.5	169	NA	NA	6.77	NA	6.94	1KB	1KB	35	NA	Z:\Airborne_Raw
7/5/2014	1673P	1BLK71ES186A	Pegasus	1.05	379	7.58	335	190	22.4	167	12.5	27.8	5.09	1KB	1KB	92/84	NA	Z:\Airborne_Raw
7/6/2014	1677P	1BLK71S187A	Pegasus	695	68	5.33	188	141	11.2	86	7.79	NA	4.94	1KB	1KB	130	NA	Z:\Airborne_Raw
7/8/2014	1685P	1BLK71S189A	Pegasus	2.31	515	11	578	242	37	288	22.4	47.4	4.39	1KB	1KB	184	NA	Z:\Airborne_Raw
7/8/2014	1687P	1BLK71S189B	Pegasus	749	79	4.81	176	136	NA	NA	7.47	NA	4.39	1KB	1KB	NA	NA	Z:\Airborne_Raw
7/9/2014	1689P	1BLK71S190A	Pegasus	2.56	156	12.6	740	257	NA	NA	27.1	NA	3.68	1KB	1KB	196/207	NA	Z:\Airborne_Raw
7/10/2014	1693P	1RXES191A	Pegasus	1.78	551	8.11	448	175	NA	NA	16.9	NA	4.08	1KB	1KB	53	NA	Z:\Airborne_Raw

Received from

Name TIN ANDAYA
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

8/6/14

Annex 6. Flight Logs for the flight missions

1. Flight Log for 1549P Mission

DATA TRANSFER SHEET
PAGADIAN 2/29/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2016-02-17	23104P	1BLK76DLM48A	Pegasus	1.81 GB	NA	10.09 MB	287.01 MB	25.87 GB	193.97 KB	18.3 GB	0 B	116.78 MB	133 B	1.08 KB	0 B	NA	Z:\DAC\RAW DATA\23104P
2016-02-16	23100P	1BLK76G047A	Pegasus	2.83 GB	NA	12.33 MB	285.96 MB	38 GB	297.52 KB	27.31 GB	0 B	103.23 MB	132 B	341B	0 B	NA	Z:\DAC\RAW DATA\23100P
2016-02-15	23096P	1BLK76NO46A	Pegasus	665.91 MB	NA	4.64 MB	164.2 MB	9.7 GB	82.64 KB	7.07 GB	0 B	90.32 MB	133 B	603 B	0 B	NA	Z:\DAC\RAW DATA\23096P
2016-02-14	23092P	1BLK76IG045A	Pegasus	2.19 GB	NA	10.66 MB	203.46 MB	28.87 GB	230.75 KB	22.33 GB	0 B	110.72 MB	132 B	279 B	0 B	NA	Z:\DAC\RAW DATA\23092P
2016-02-13	23088P	1BLK76ILM044A	Pegasus	2.48 GB	NA	11.64 MB	283.62 MB	35.45 GB	263.38 KB	24.65 GB	0 B	101.29 MB	133 B	889 B	0 B	NA	Z:\DAC\RAW DATA\23088P
2016-02-12	23084P	1BLK76KJLM043A	Pegasus	3.01 GB	NA	13.36 MB	276.9 MB	44.56 GB	332.83 KB	29.36 GB	0 B	129.73 MB	133 B	362 B	0 B	NA	Z:\DAC\RAW DATA\23084P

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Borgat
Position SSRS
Signature 3/1/16

16-14

2. Flight Log for 1565P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1565P

1 LIDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: 1BLK71B159A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO - CDO			
10 Date: June 8, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0806H	14 Engine Off: 1059H	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	very cloudy				

20 Remarks:

Data acquired but shortened mission due to heavy build up

21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1613P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1613P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: 1BLK76I71A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO - CDO			
10 Date: June 20, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 1010H	14 Engine Off: 1416H	15 Total Engine Time: 4+6	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

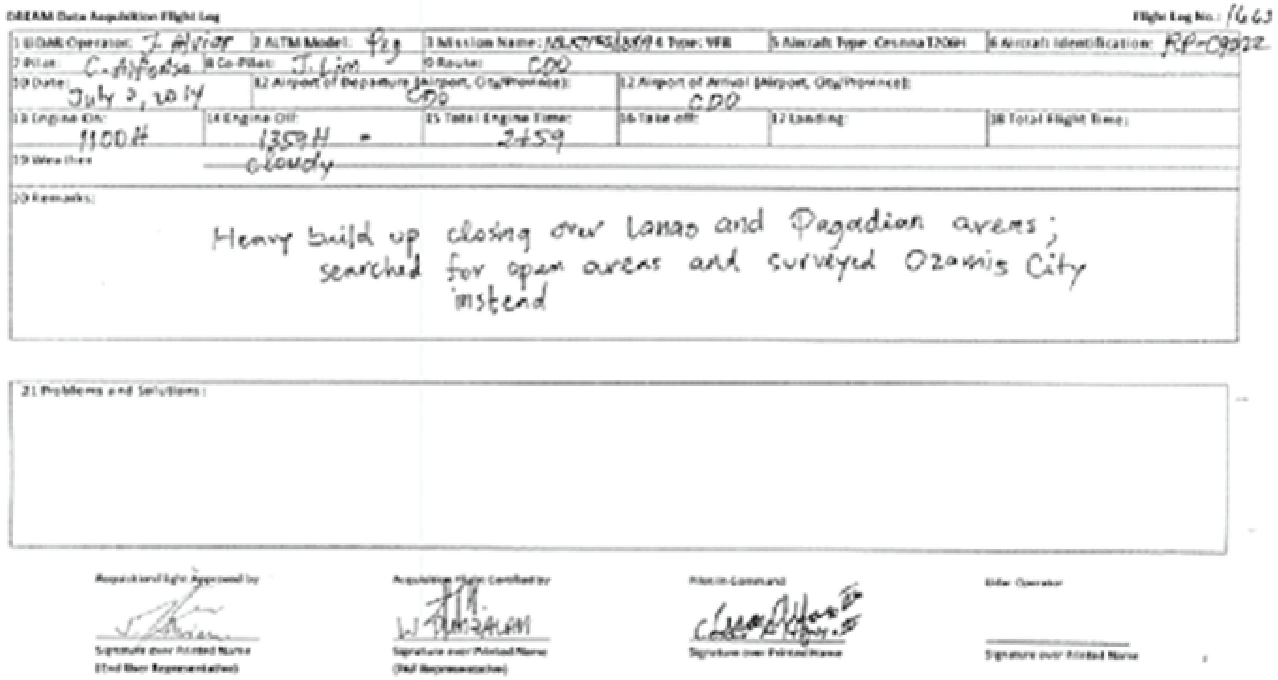
Mission successful; some lines cut due to high terrain

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	SSg PUMARAN Signature over Printed Name (PAF Representative)	CESAR ALFONSO III Signature over Printed Name	GRACE SINADJAN Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

4. Flight Log for 1665P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1663

1 LiDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 2, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 1100H	14 Engine Off: 1359H	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Heavy build up closing over Lanao and Pagadian areas; searched for open areas and surveyed Ozamis City instead

21 Problems and Solutions:

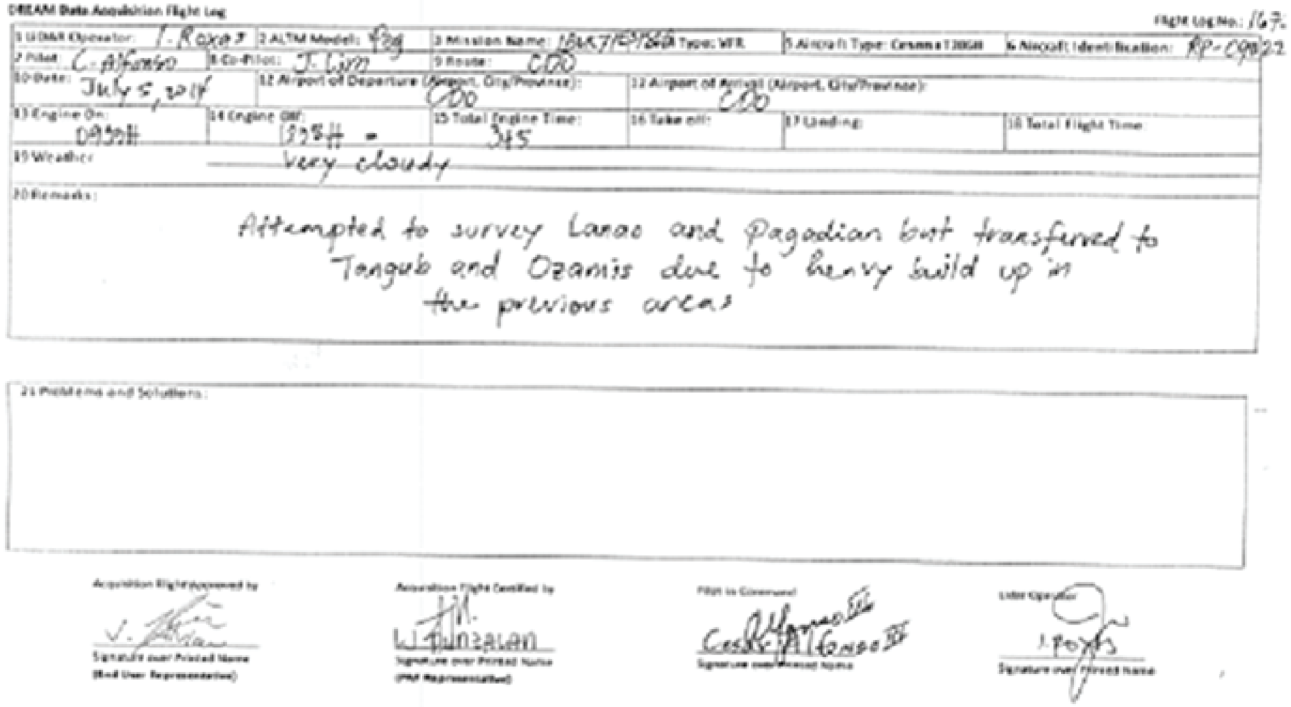
Acquisition Flight Approved by: Signature over Printed Name (End User Representative)

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

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

5. Flight Log for 1673P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 167

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK71E186A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 5, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0935H	14 Engine Off: 1320H	15 Total Engine Time: 345	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					

20 Remarks:

Attempted to survey Lanao and Pagadian but transferred to Tangub and Ozamis due to heavy build up in the previous areas

21 Problems and Solutions:

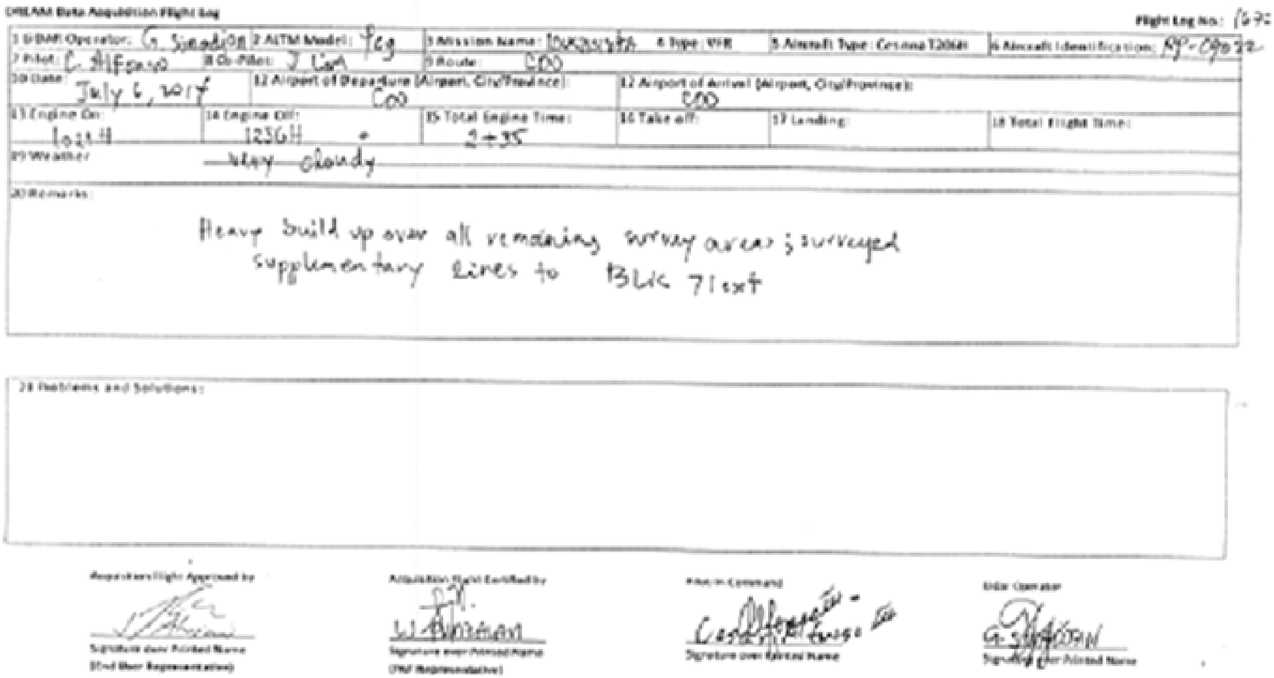
Acquisition Flight Approved by: J. [illegible] — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: L. Dunzalan — Signature over Printed Name (PAF Representative)

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

LiDAR Operator: I. Roxas — Signature over Printed Name

6. Flight Log for 1677P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1677

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK71S187A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 6, 2017	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 1023H	14 Engine Off: 1258H	15 Total Engine Time: 2+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Very cloudy					

20 Remarks:

Heavy build up over all remaining survey areas; surveyed supplementary lines to BLK 71ext

21 Problems and Solutions:

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

Acquisition Flight Certified by — W. Almazan — Signature over Printed Name (PAF Representative)

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

LiDAR Operator — G. Sinadjan — Signature over Printed Name

7. Flight Log for 1685P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1685P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK71S/87A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 8, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 0958H	14 Engine Off: 1403H	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Surveyed BLK 71F at 1200m.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	W. Punzalan	Cesar Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

8. Flight Log for 1689P Mission

Flight Log No.: 1689P

DREAM Data Acquisition Flight Log

1 LIDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Lim	9 Route: CDO			
10 Date: July 9, 2014	12 Airport of Departure (Airport, City/Province): CDO		12 Airport of Arrival (Airport, City/Province): CDO		
13 Engine On: 1135H	14 Engine Off: 1552H	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Mission successful at 1200m flying height

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	W. Punzalan	Cesar Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

9. Flight Log for 23084P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23084P

1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK76JKCL043A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jeciel	9 Route: Pagadian - Pagadian			
10 Date: 12 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0715H	14 Engine Off: 1132H	15 Total Engine Time: 4+17	16 Take off: 0720H	17 Landing: 1127H	18 Total Flight Time: 4+07
19 Weather	Partly cloudy				

20 Flight Classification

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

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ____________

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

21 Remarks

Surveyed BLK 76 C, J, K and L.

22 Problems and Solutions

- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Alborito	A1C Jayson Manzano PAF	C. Alfonso III	I. Roxas	N/A
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

10. Flight Log for 23088P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23088P

1 LIDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: [illegible]A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecrel	9 Route:			
10 Date: 13 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0720H	14 Engine Off: 1143H	15 Total Engine Time: 4+23	16 Take off: 0725H	17 Landing: 1138H	18 Total Flight Time: 4H13
19 Weather	Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK76 I, L and M with voids due to clouds.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	[signature]	C. Alfonso III	J. Almalvez	N/A
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

11. Flight Log for 23104P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2310AP

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Peg	3 Mission Name: 1BLK76DKLM	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. Alfonso III	8 Co-Pilot: J. Jecie'l	9 Route:			
10 Date: 17 Feb 16	12 Airport of Departure (Airport, City/Province): Pagadian		12 Airport of Arrival (Airport, City/Province): Pagadian		
13 Engine On: 0805 H	14 Engine Off: 1240H	15 Total Engine Time: 4+35	16 Take off: 0810 H	17 Landing: 1235 H	18 Total Flight Time: 4+25
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed voids over BLK76 D, K, L and M

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature] S. K. Polido	[signature] A1C [illegible] PAF	C. Alfonso III	[signature] J. Almalvez	N/A
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

12. Flight Log for 23128P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jecle	9 Route:			
10 Date: 2/23/2016	12 Airport of Departure (Airport, City/Province): Pagadian, Zamboanga del Sur		12 Airport of Arrival (Airport, City/Province): Pagadian, Zamboanga del Sur		
13 Engine On: 7:30	14 Engine Off: 11:47	15 Total Engine Time: 4+17	16 Take off: 7:35	17 Landing: 11:42	18 Total Flight Time: 4+07
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

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

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

13. Flight Log for 23602P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LIDAR Operator: RJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A DAYO	8 Co-Pilot: E CAYSAY JR	9 Route:			
10 Date: 12/09/2016	12 Airport of Departure (Airport, City/Province): DIPOLOG		12 Airport of Arrival (Airport, City/Province): DIPOLOG		
13 Engine On: 0839H	14 Engine Off: 1314H	15 Total Engine Time: 4+35	16 Take off: 0844H	17 Landing: 1309H	18 Total Flight Time: 4+25
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

COMPLETED BLK 76A AND BLK 71A OVER KUMALARANG AND KAPATAGAN.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
RJ ARCEO	GERONIMO BALICAO III	ANTON DAYO	RJ ARCEO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

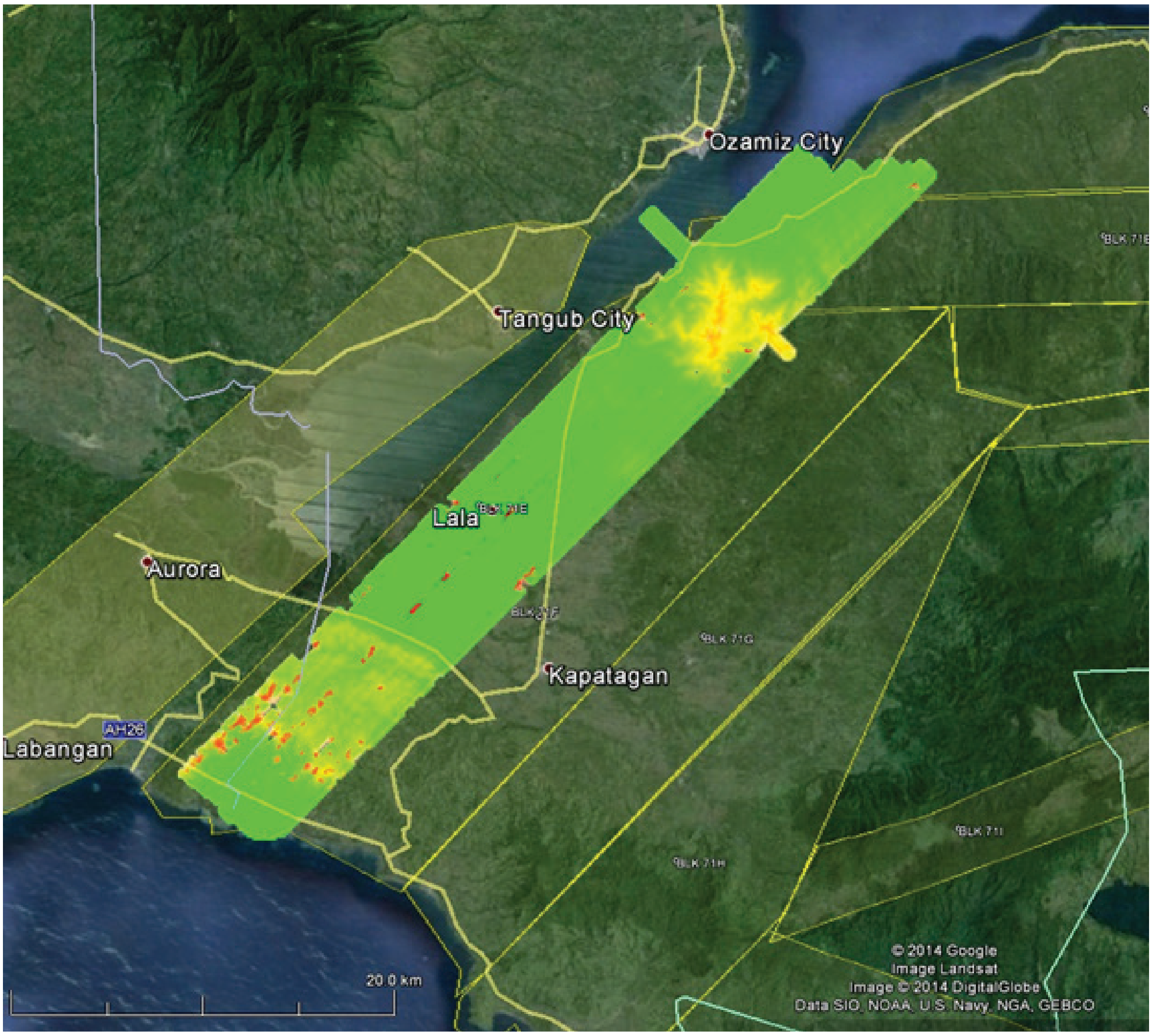
Annex 7. Flight Status Reports

NORTHERN MINDANAO
(May 22-July 10, 2014)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1549P	BLK 71E	1BLK69B295A	G. Sinadjan	Oct. 22, 2014	Surveyed BLK 69B, cloudy
1565P	BLK 71F	1BLK69B296A	I. Roxas	Oct. 23, 2014	Surveyed BLK 69 B, still cloudy
1613P	BLK 71G	1BLK69B297A	R. Punto	Oct. 24, 2014	Surveyed parts of BLK 69 A, B and C; images saved in Test folder
1665P	BLK 71 ext	1BLK69C299A	I. Roxas	Oct. 26, 2014	Surveyed BLK 69C
1673P	BLK 71 ext	1BLK6970A299B	R. Punto	Oct. 26, 2014	Surveyed BLK 69A
1677P	BLK 71 ext	1BLk69C304A	J. Alviar	Oct. 31, 2014	Surveyed BLk 69C, gaps in the middle due to clouds and terrain
1685P	BLK 71F	1BLK70B305A	J. Alviar	Nov.1 , 2014	Surveyed BLK 70A and 70B, gaps due to clouds; covered gap in BLK 69A
1689P	BLK 71E and BLK 71ABCs	1BLK70C312A	I. Roxas	Nov. 8, 2014	Filled up gaps in BLK 70B&C

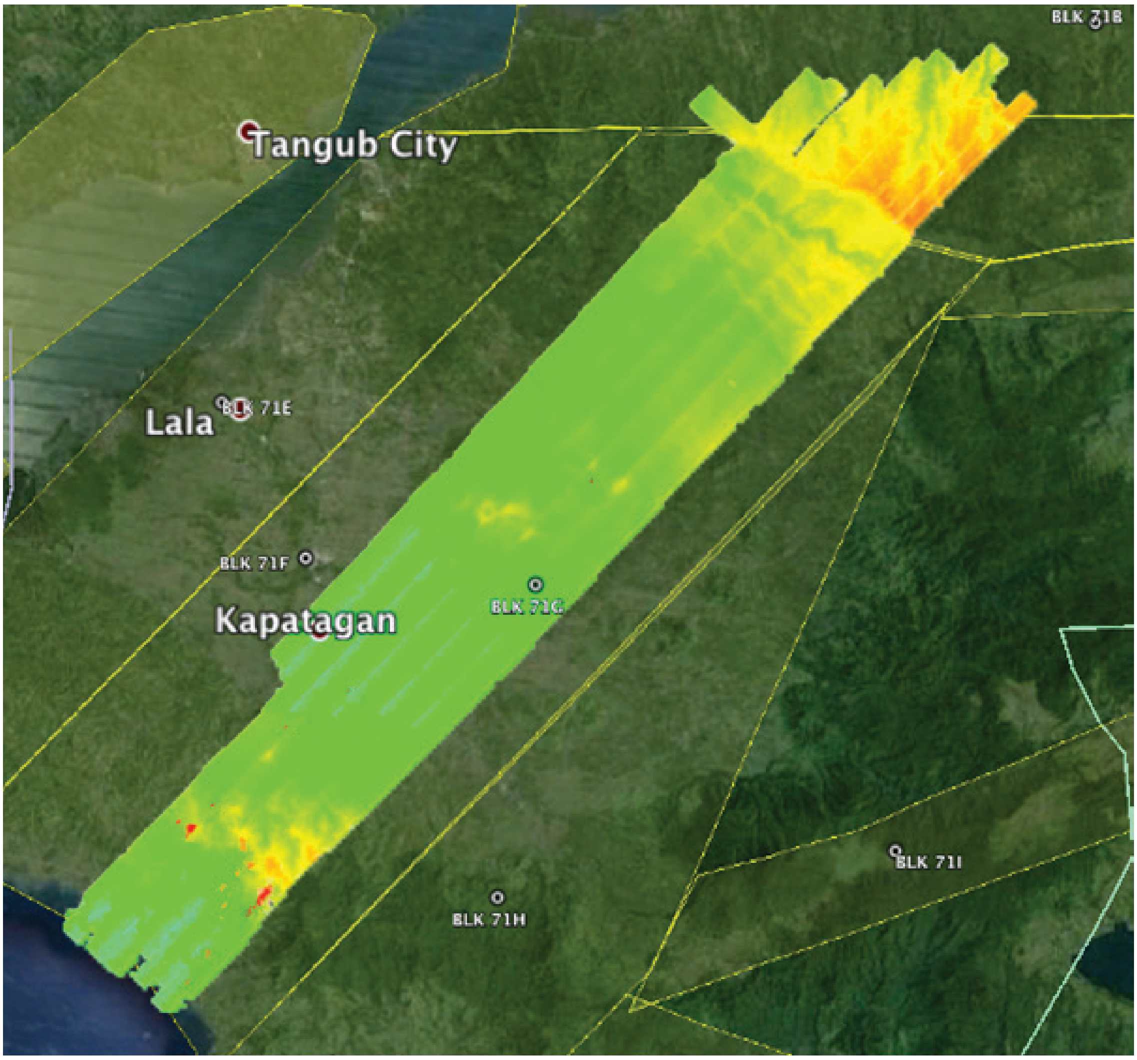
SWATH OF LIDAR BOUNDARIES PER FLIGHT

Flight No. :	1549P	
Area:	BLK 71E	
Mission Name:	1BLK71D155A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle: 25deg;	Overlap: 30%

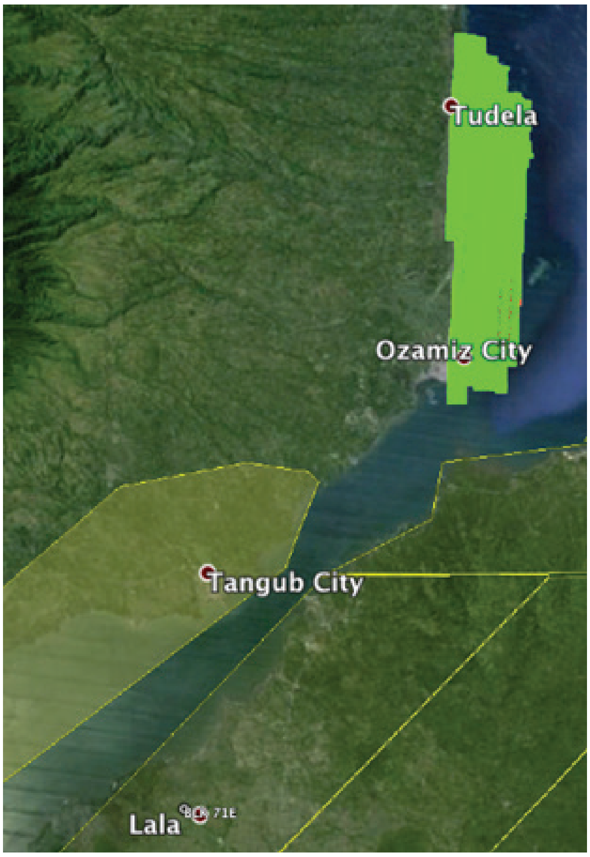


Flight No. : 1565P
Area: BLK 71F
Mission Name: 1BLK71B159A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 30%

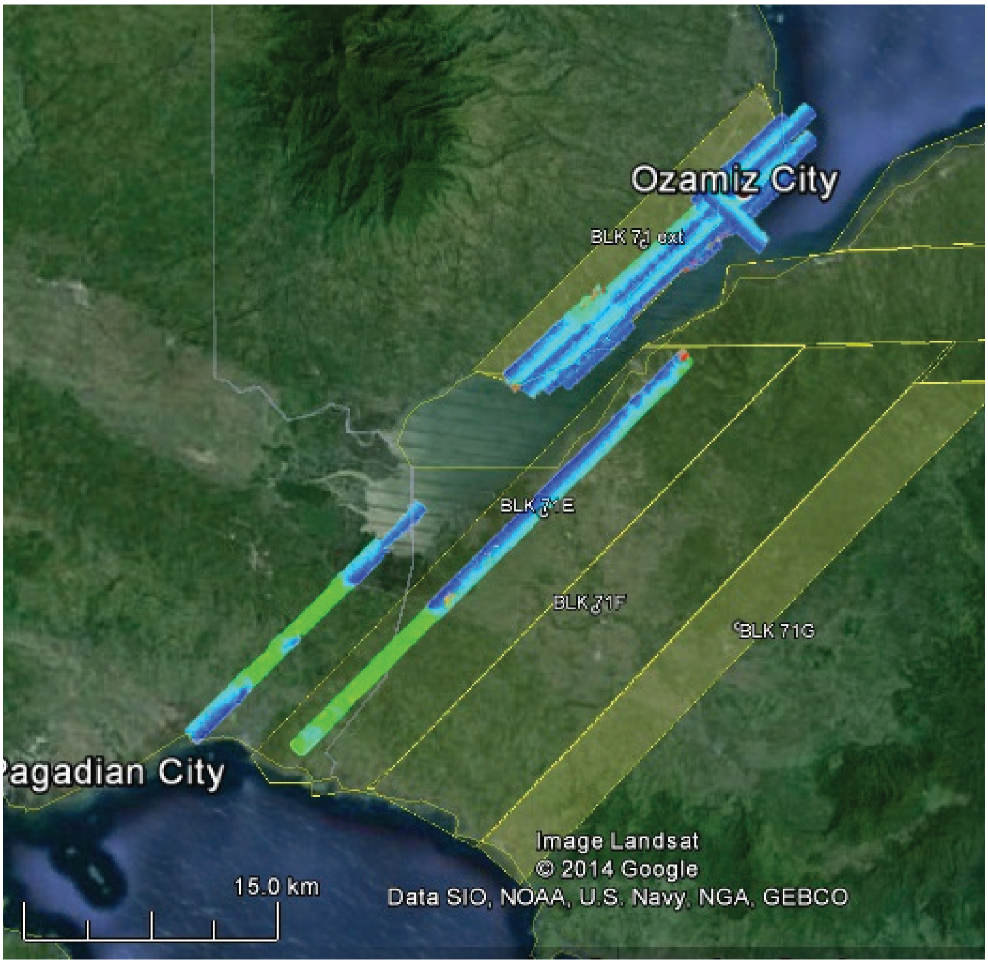
Flight No. :	1613P	
Area:	BLK 71G	
Mission Name:	1BLK71G171A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle:25deg;	Overlap: 30%



Flight No. :	1665P	
Area:	BLK 71E	
Mission Name:	1BLK71ES184A	
Parameters:	Altitude: 1100m;	Scan Frequency: 30Hz;
	Scan Angle: 25deg;	Overlap: 30%

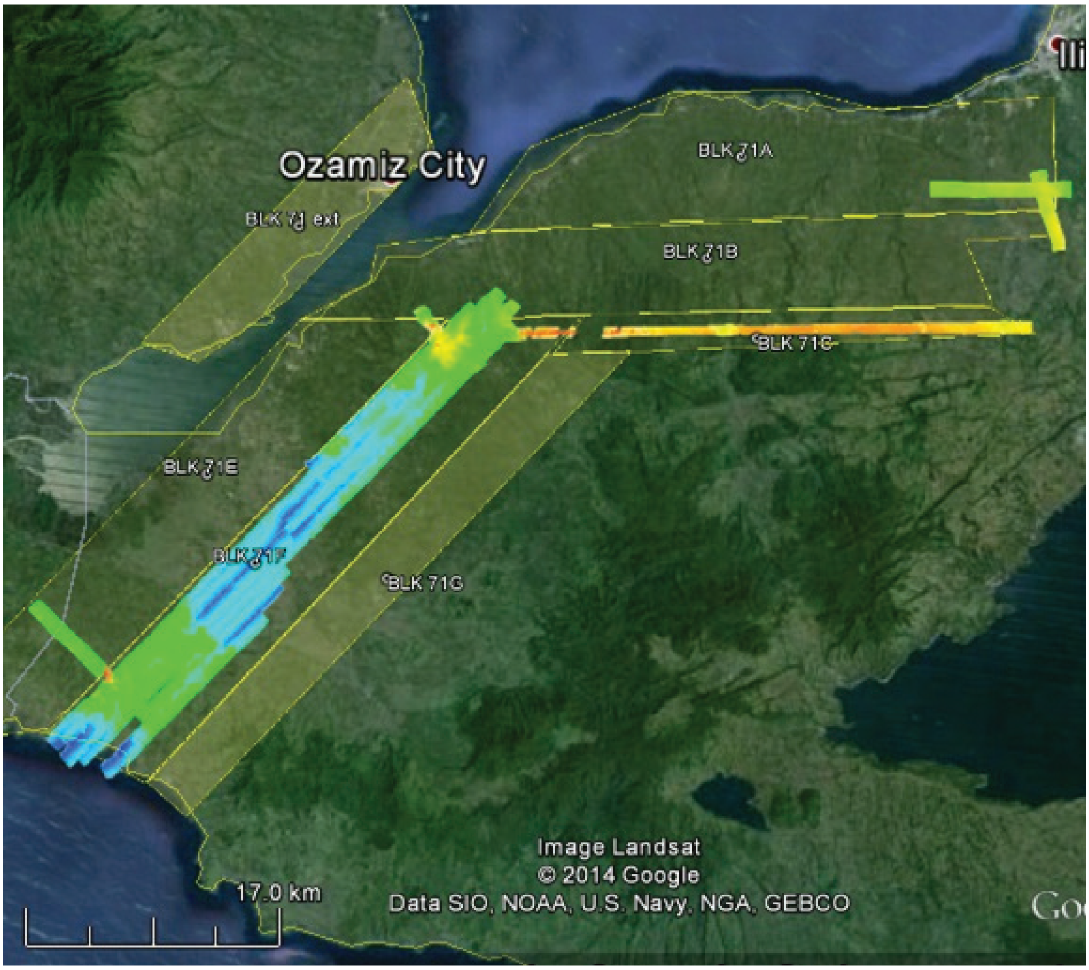


Flight No. :	1673P	
Area:	BLK 71 ext	
Mission Name:	1BLK71ES186A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle: 25deg;	Overlap: 30%

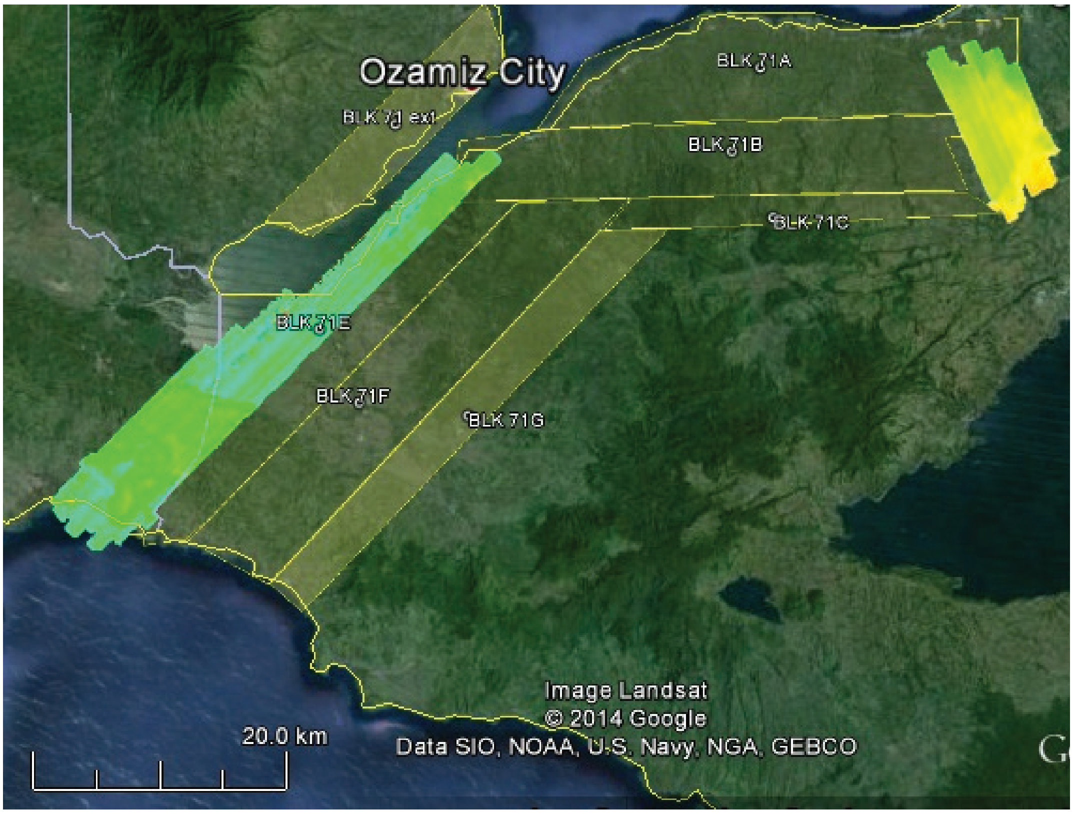


Flight No. :	1677P	
Area:	BLK 71 ext	
Mission Name:	1BLK71S187A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle:25deg;	Overlap: 30%

Flight No. :	1685P	
Area:	BLK 71F	
Mission Name:	1BLK71S189A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle: 25deg;	Overlap: 30%



Flight No. :	1689P	
Area:	BLK 71E and BLK 71ABCs	
Mission Name:	1BLK71S190A	
Parameters:	Altitude: 1200m;	Scan Frequency: 30Hz;
	Scan Angle: 25deg;	Overlap: 30%

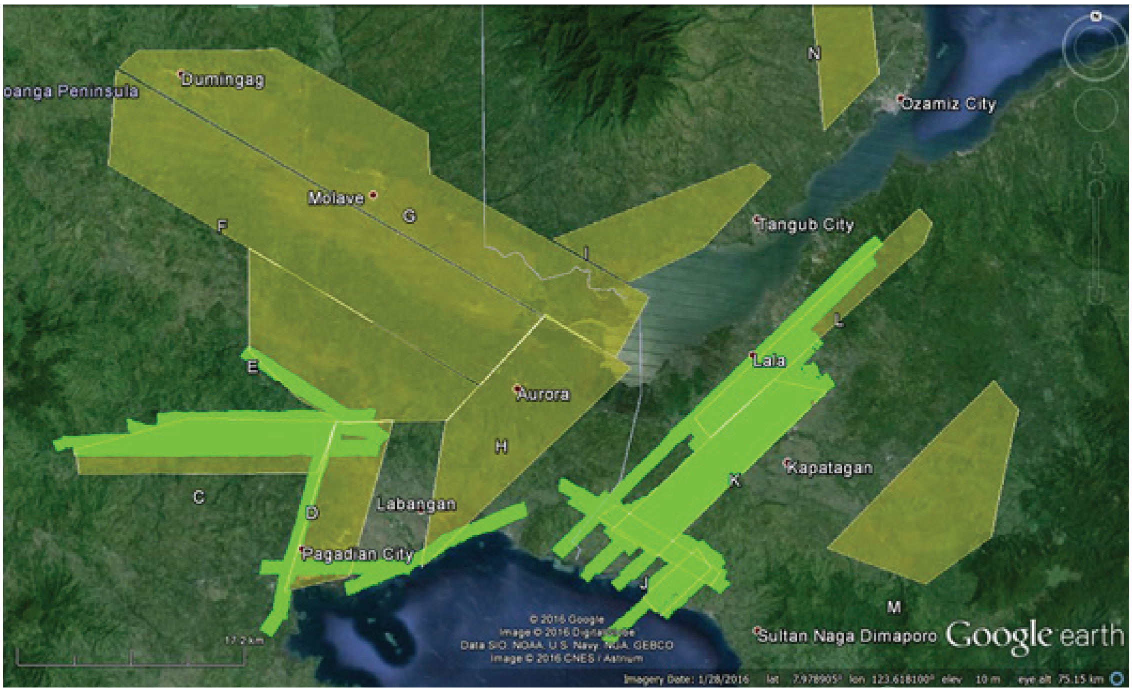


PAGADIAN (BLK 76) WITH REFLIGHTS PEGASUS (9122)
FEBRUARY 4 – MARCH 4, 2016

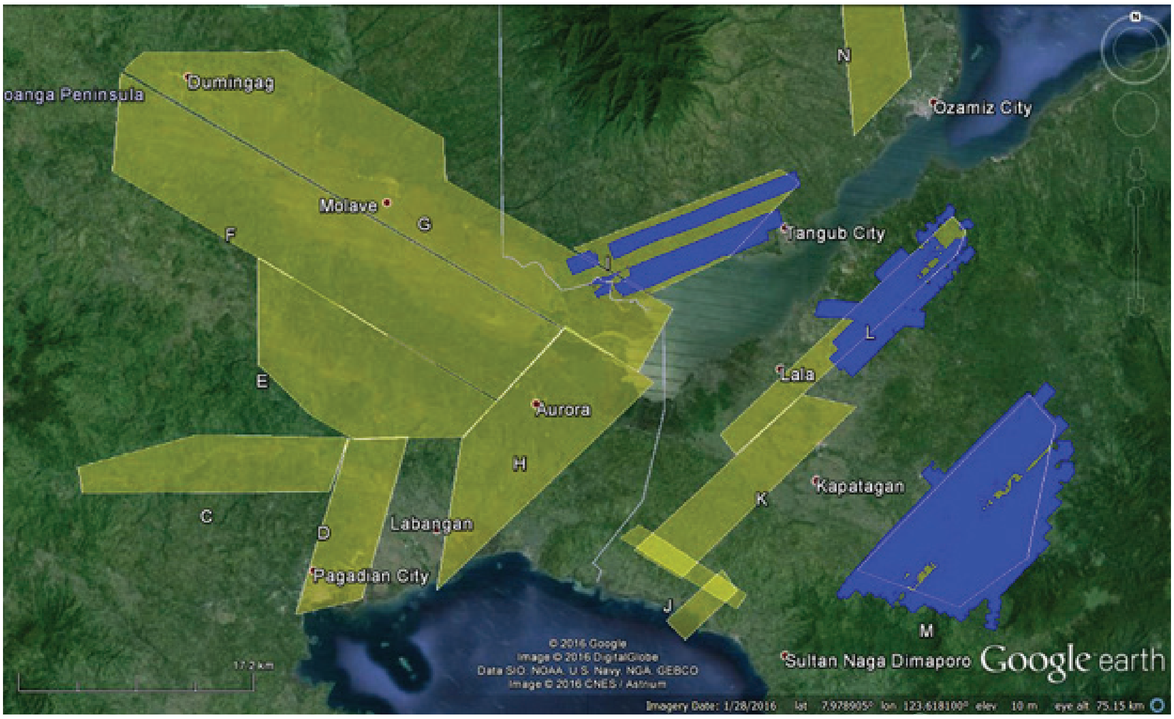
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23084	BLK C,D,E,H,J,K,L	1BLK76JKLCs043A	IN ROXAS	FEB 12, 2016	Finished BLK76C,J,K. Please also process tie lines as production data, using the intersecting line as tie line for BLK76D,E,H as they cover parts of FP
23088	BLK I,L,M	1BLK76ILM044A	JM ALMALVEZ	FEB 13, 2016	Cloudy over L & M. Pega-sus problem encountered so no tie lines over I; please use 23078's and 23092's tie line
23104	BLK D,L,M	1BLK76DLM048A	JM ALMALVEZ	FEB 17, 2016	Cloudy on BLK76M so no tie line, please use 23088's tie line; also cloudy in BLK76L

SWATH OF LIDAR BOUNDARIES PER FLIGHT

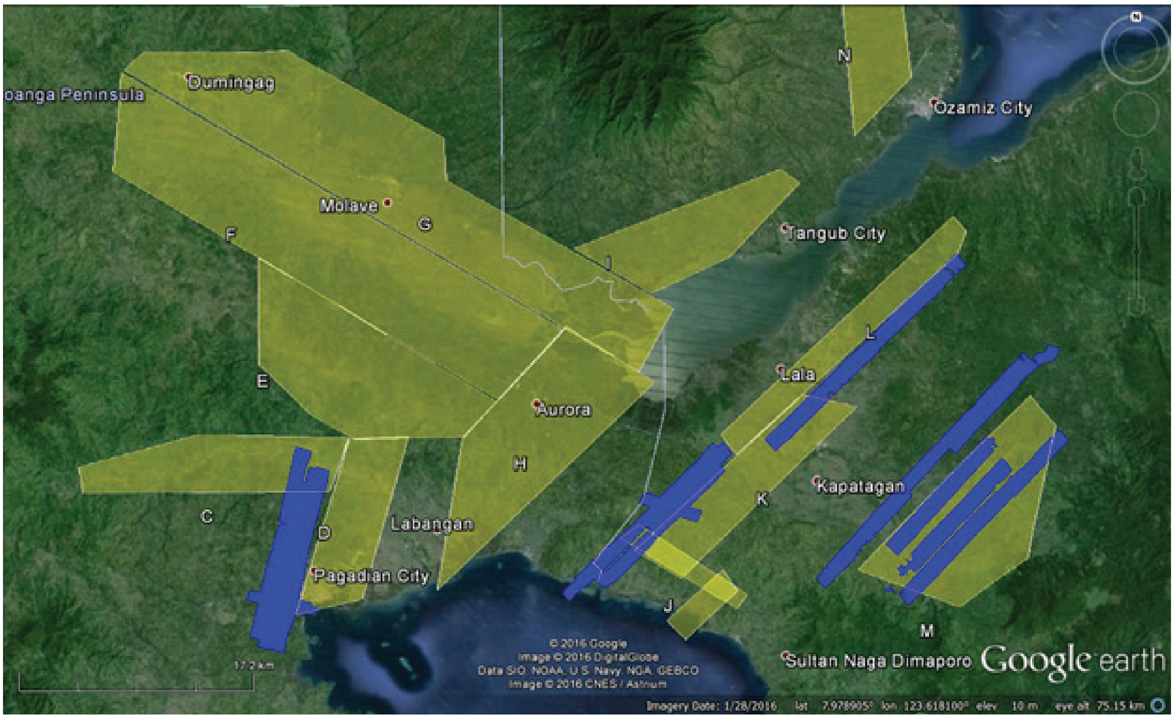
Flight No. :	23084P	
Area:	BLK C,D,E,H,J,K,L	
Mission Name:	1BLK76JKLCs043A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle:25deg;	Overlap: 30%



Flight No. :	23088P	
Area:	BLK I,L,M	
Mission Name:	1BLK76ILM044A	
Parameters:	Altitude: 1200m;	Scan Frequency: 30Hz;
	Scan Angle:25deg;	Overlap: 30%



Flight No. :	23104P	
Area:	BLK D,L,M	
Mission Name:	1BLK76DLM048A	
Parameters:	Altitude: 1000m;	Scan Frequency: 30Hz;
	Scan Angle: 25deg;	Overlap: 30%

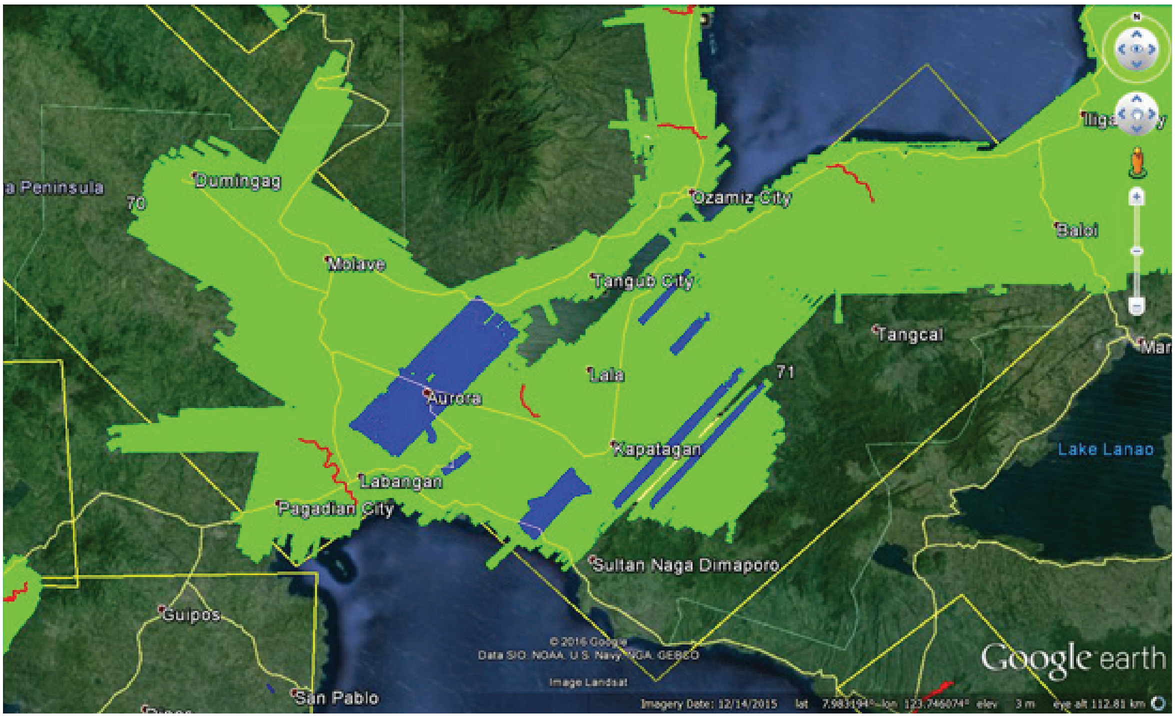


MARANDING (BLK 70, 71, 72,73 AND 69) REFLIGHTS
PEGASUS (9122)
FEBRUARY 23, 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23128P	BLK 70B, 71A	1BLK70B054A	K QUISADO	FEB 23, 2016	ENCOUNTERED LOST CHANNEL A ERROR SEVERAL TIMES. SURVEYED BLKS

SWATH OF LIDAR BOUNDARIES PER FLIGHT

Flight No. : 23128P
Area: BLK 70B, 71A
Mission Name: 1BLK70B054A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle:25deg; Overlap: 30%

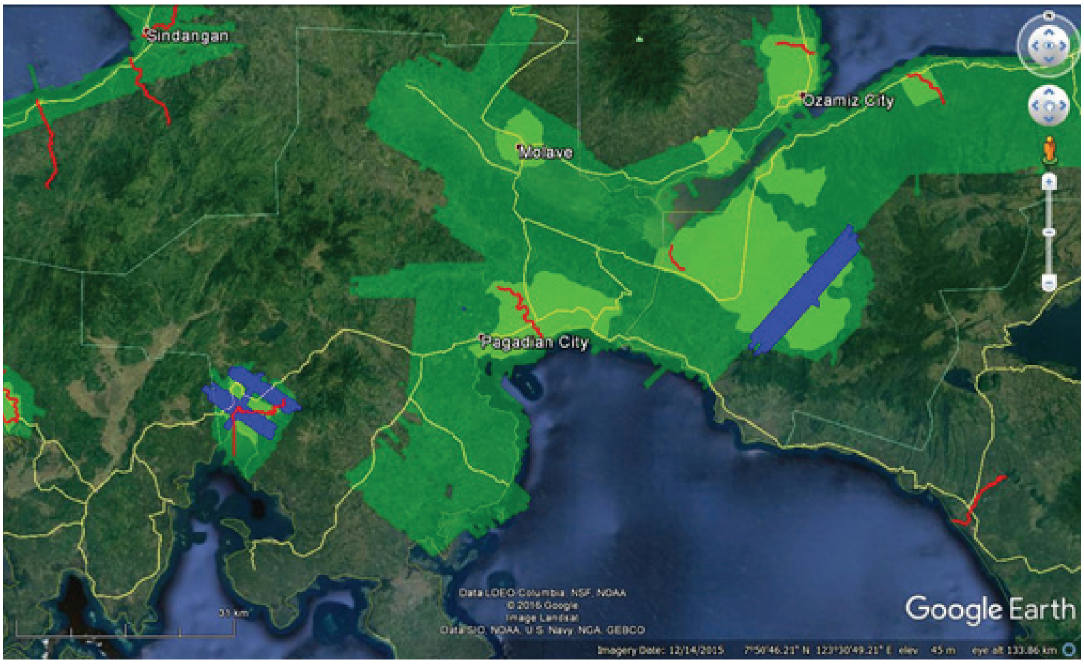


MARANDING FLIGHTS
(NOVEMBER 20 - 26, 2016)

Date	Flight No.	Operator	Mission Name	Area	Remarks
DECEMBER 1, 2016	23602	PJ ARCEO	1BLK76AB336A	KUMALARANG, KAPATAGAN BLK 76A, 71A	COMPLETED KUMALARANG FLOODPLAIN AND VOIDS OVER KAPATAGAN FLOODPLAIN

SWATH OF LIDAR BOUNDARIES PER FLIGHT

Flight No. : 23602
Area: KUMALARANG AND KAPATAGAN
Mission Name: 1BLK76AB336A
Parameters: Altitude: 1200m, 1100m; Scan Frequency: 30Hz; Scan Angle:25deg; Overlap: 30%



Annex 8. Mission Summary Reports

Flight Area	Pagadian
Mission Name	Blk76J
Inclusive Flights	23088P
Range data size	24.65
POS data size	283.62
Base data size	101.29
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.5
Boresight correction stdev (<0.001deg)	0.000281
IMU attitude correction stdev (<0.001deg)	0.000180
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	27.90
Ave point cloud density per sq.m. (>2.0)	3.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	72
Maximum Height	698.51 m
Minimum Height	68.61 m
Classification (# of points)	
Ground	34,165,050
Low vegetation	19,594,241
Medium vegetation	28,178,750
High vegetation	95,242,866
Building	801,190
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Jovelle Anjeanette Canlas, Engr. Krisha Marie Bautista

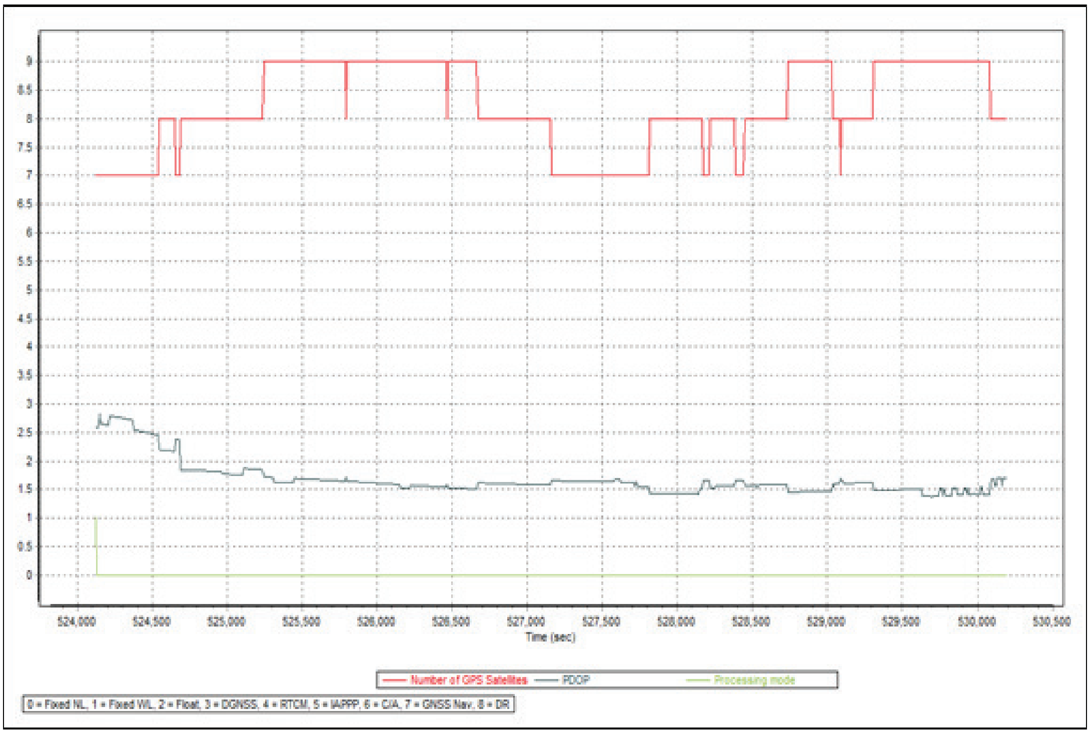


Figure A-8.1 Solution Status

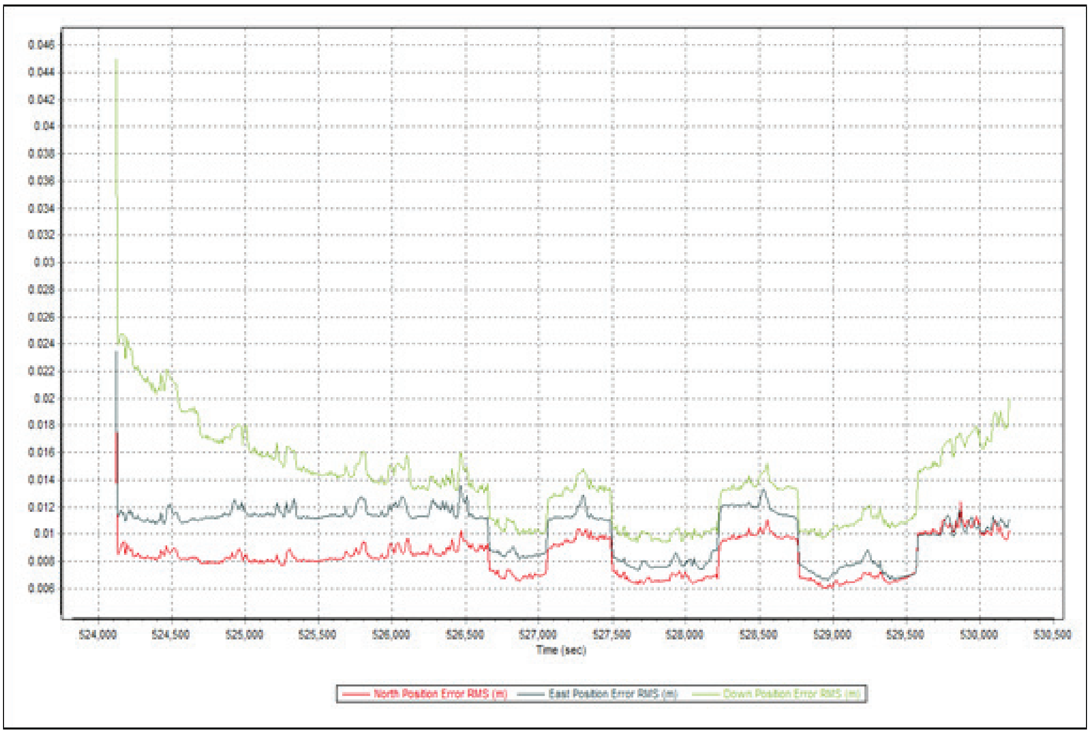


Figure A-8.2 Smoothed Performance Metric Parameters

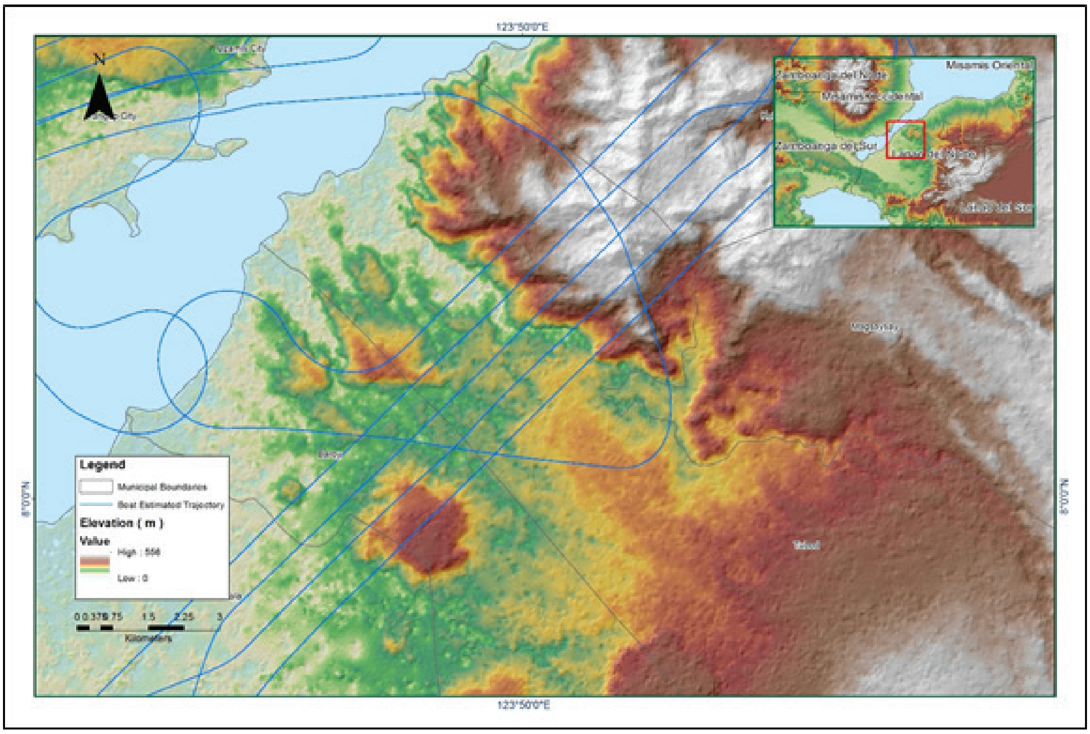


Figure A-8.3 Best Estimated Trajectory

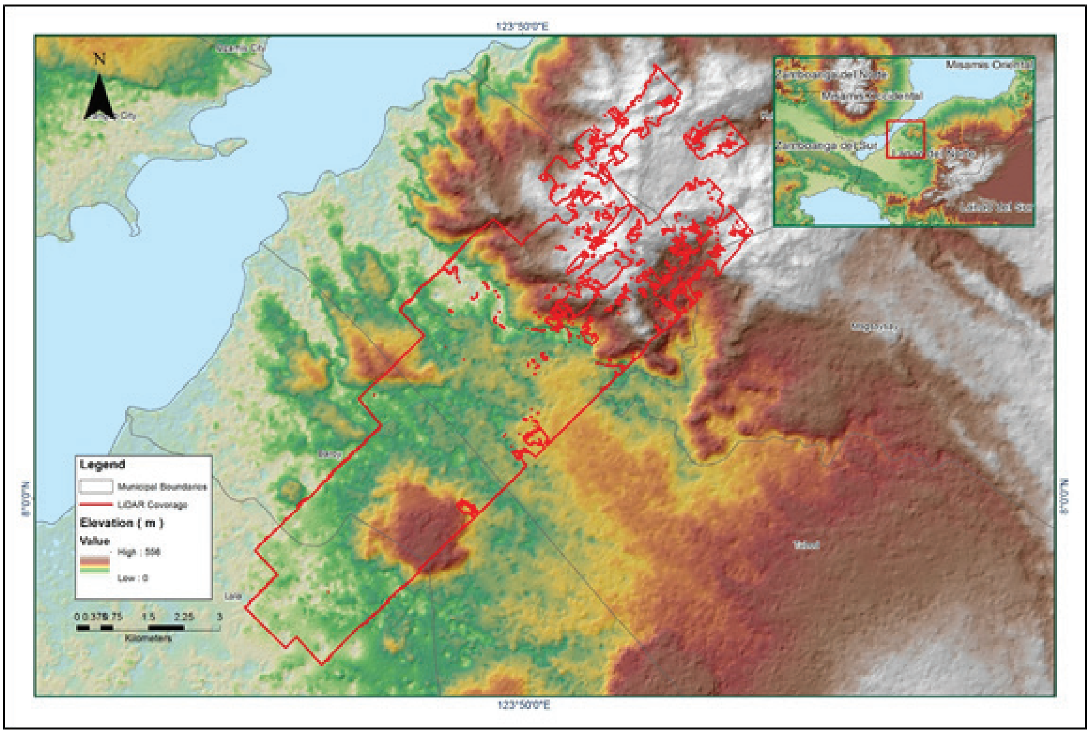


Figure A-8.4 Coverage of LiDAR Data

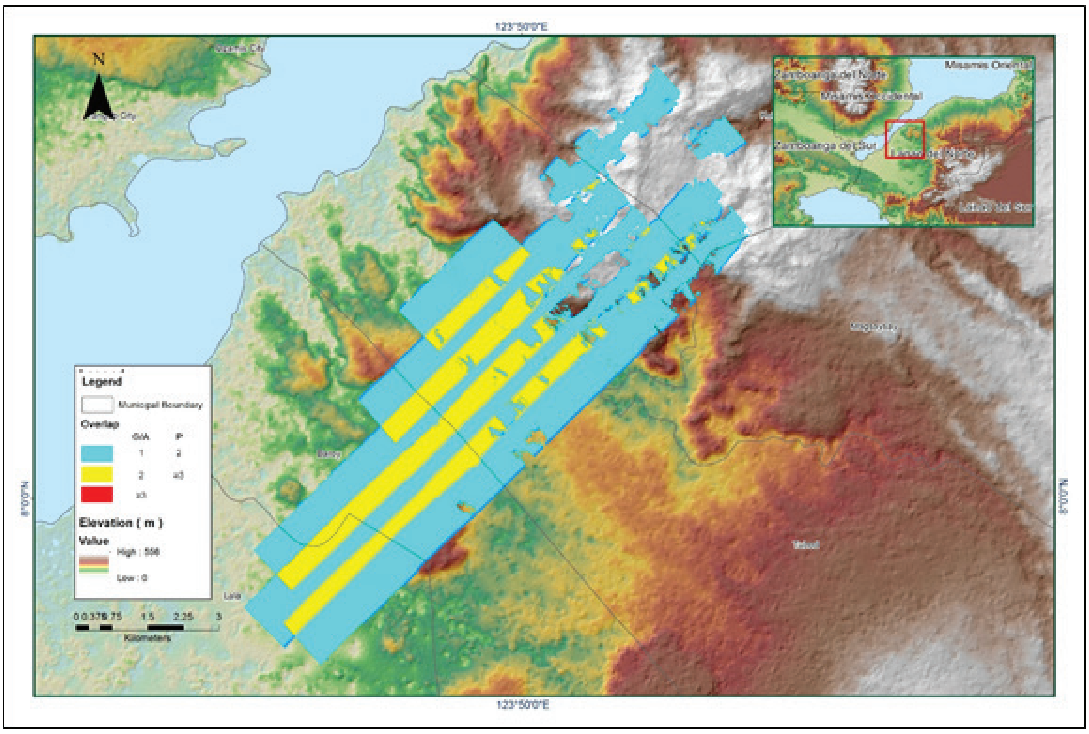


Figure A-8.5 Coverage of LiDAR Data

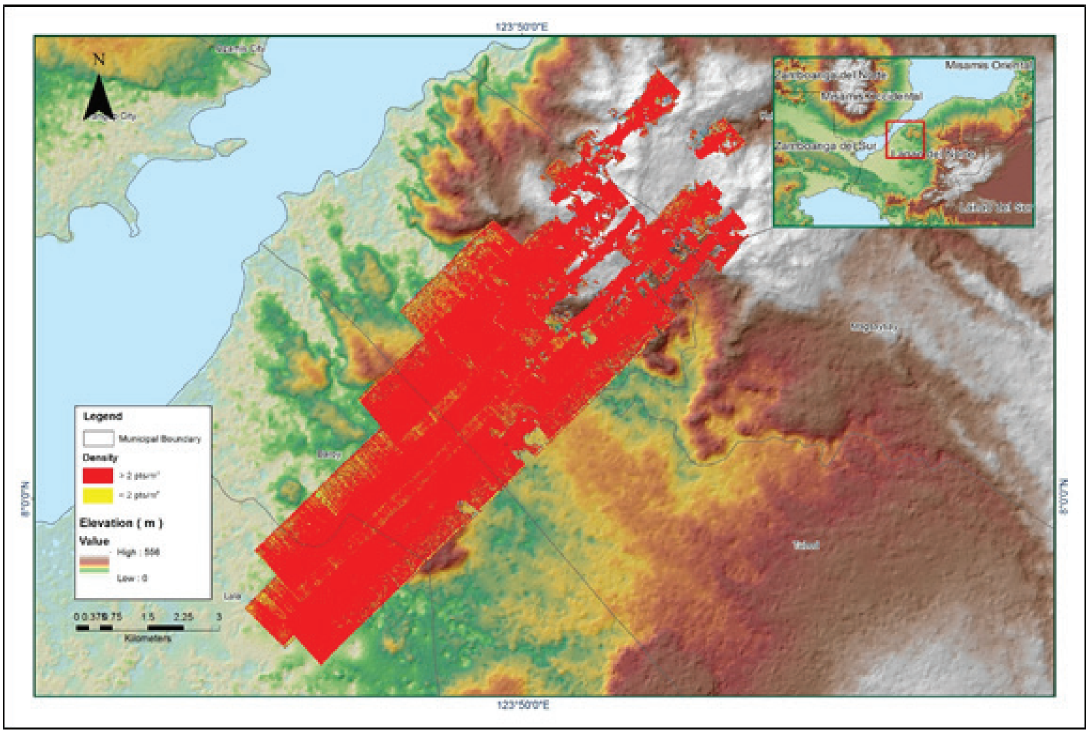


Figure A-8.6 Density map of merged LiDAR data

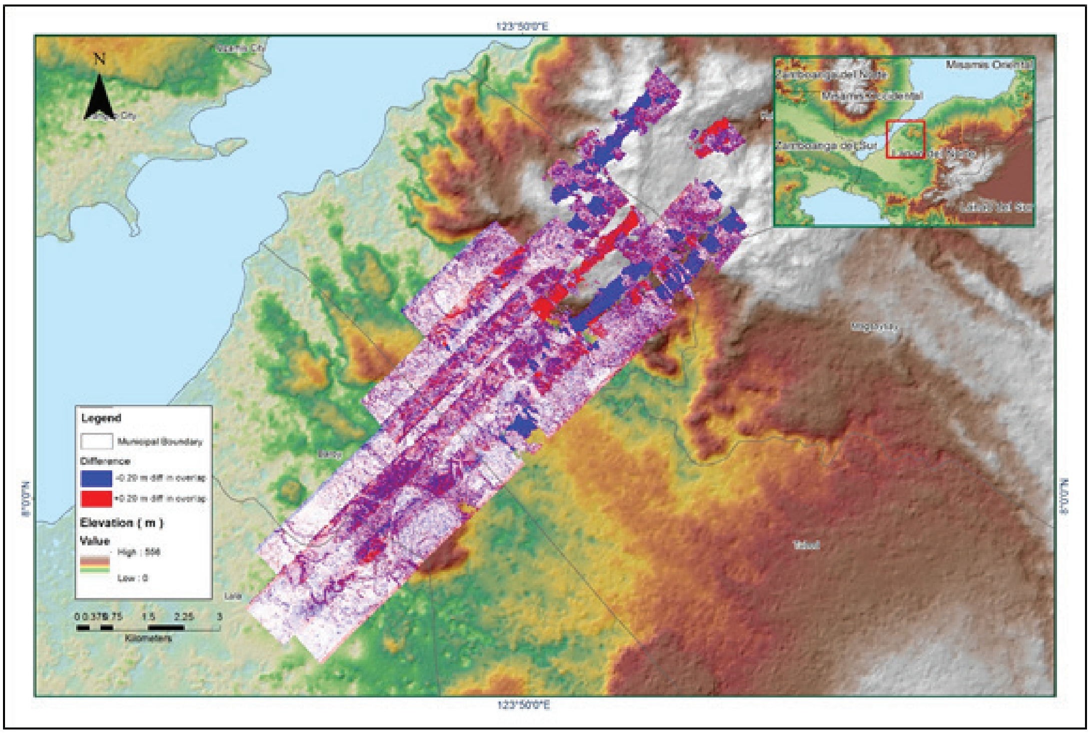


Figure A-8.7 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	Blk76N_Additional
Inclusive Flights	23104P
Range data size	18.3 GB
POS data size	287.01 MB
Base data size	116.78 MB
Image	25.87 GB
Transfer date	March 1, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	10.37
Ave point cloud density per sq.m. (>2.0)	2.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	124
Maximum Height	436.04 m
Minimum Height	90.14 m
Classification (# of points)	
Ground	56,765,012
Low vegetation	52,157,492
Medium vegetation	41,240,260
High vegetation	93,342,982
Building	1,335,125
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Merven Matthew Natino, Jovy Narisma

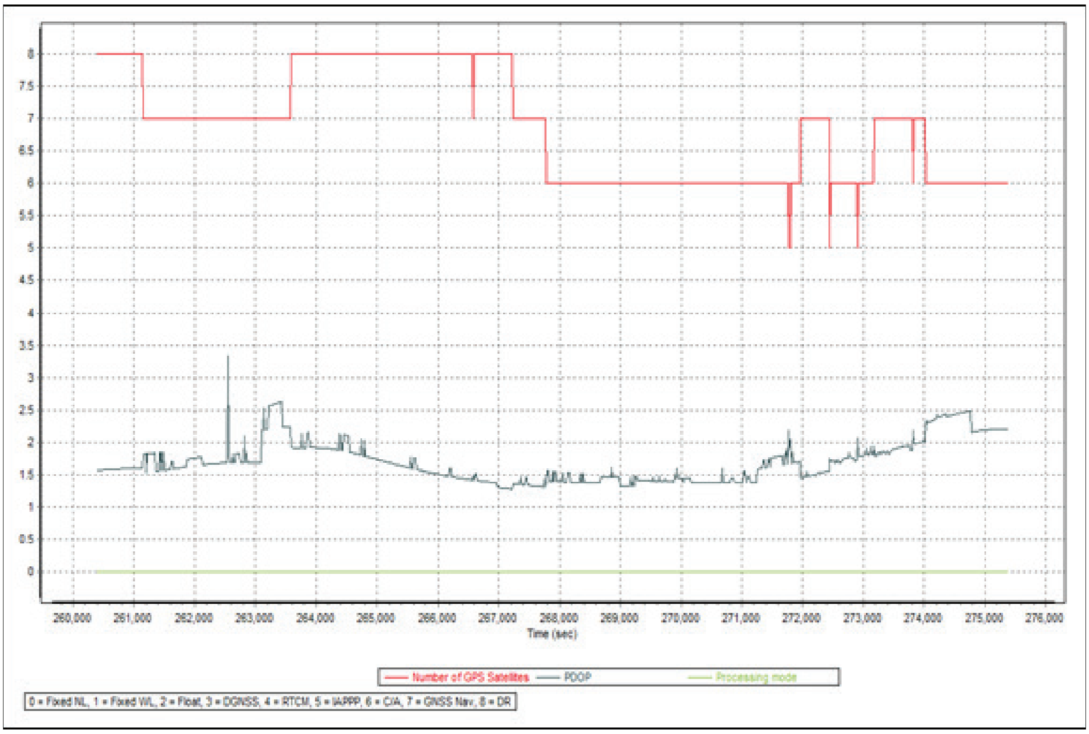


Figure A-8.8 Solution Status

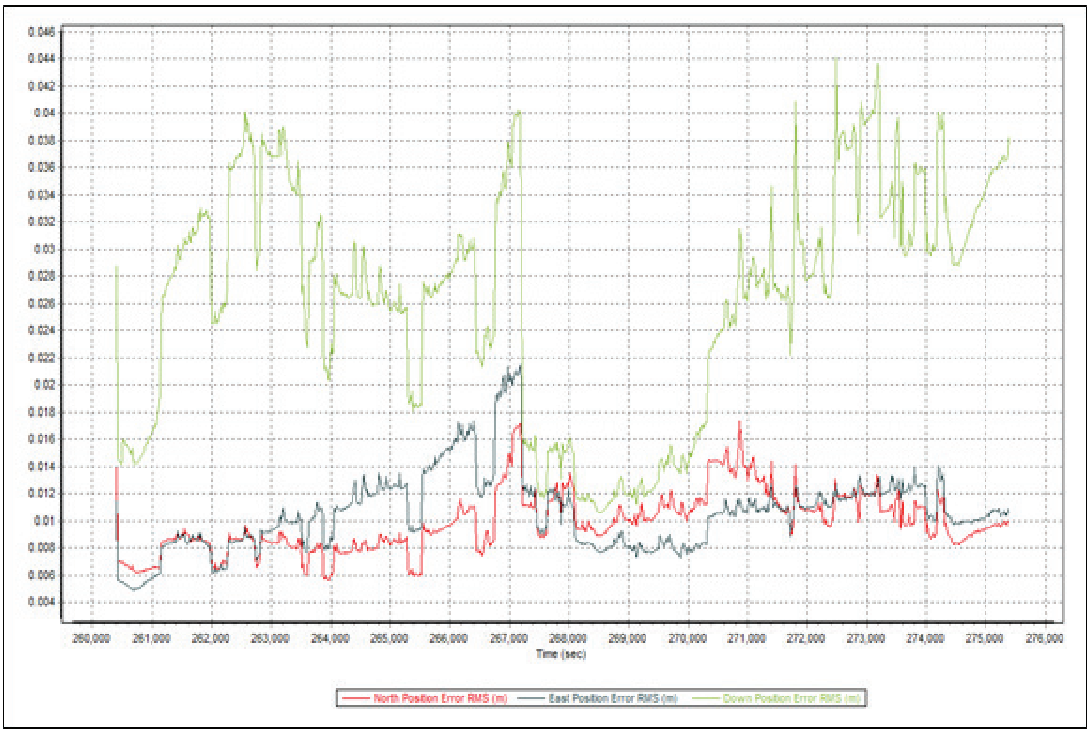


Figure A-8.9 Smoothed Performance Metric Parameters

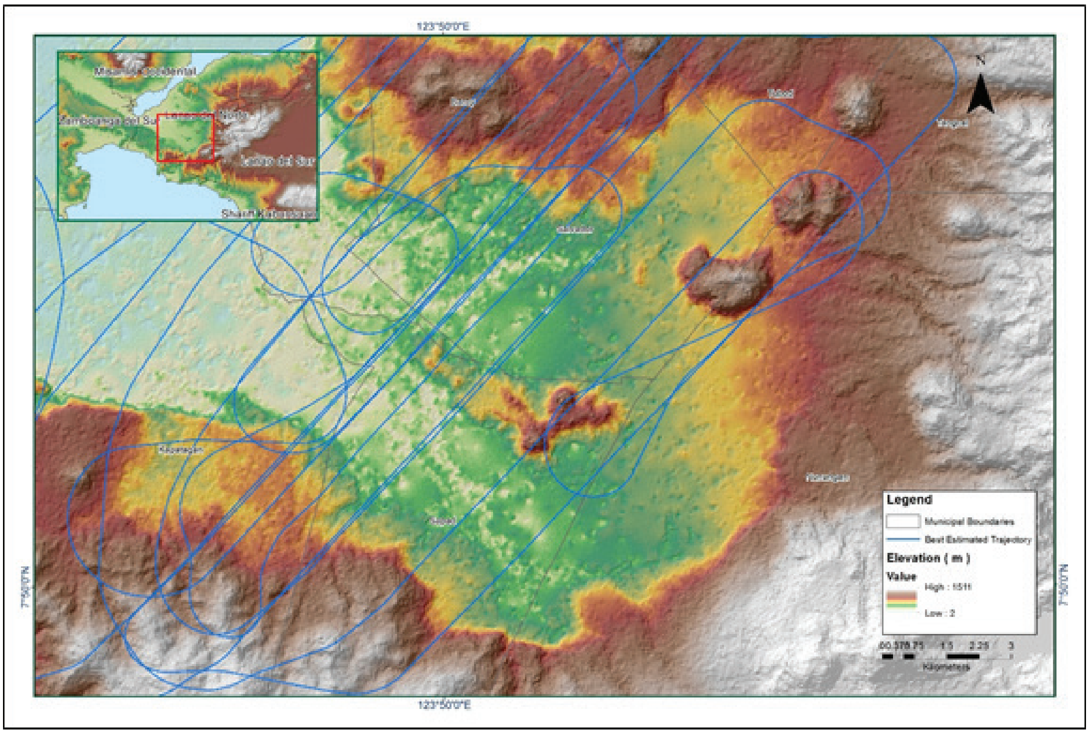


Figure A-8.10 Best Estimated Trajectory

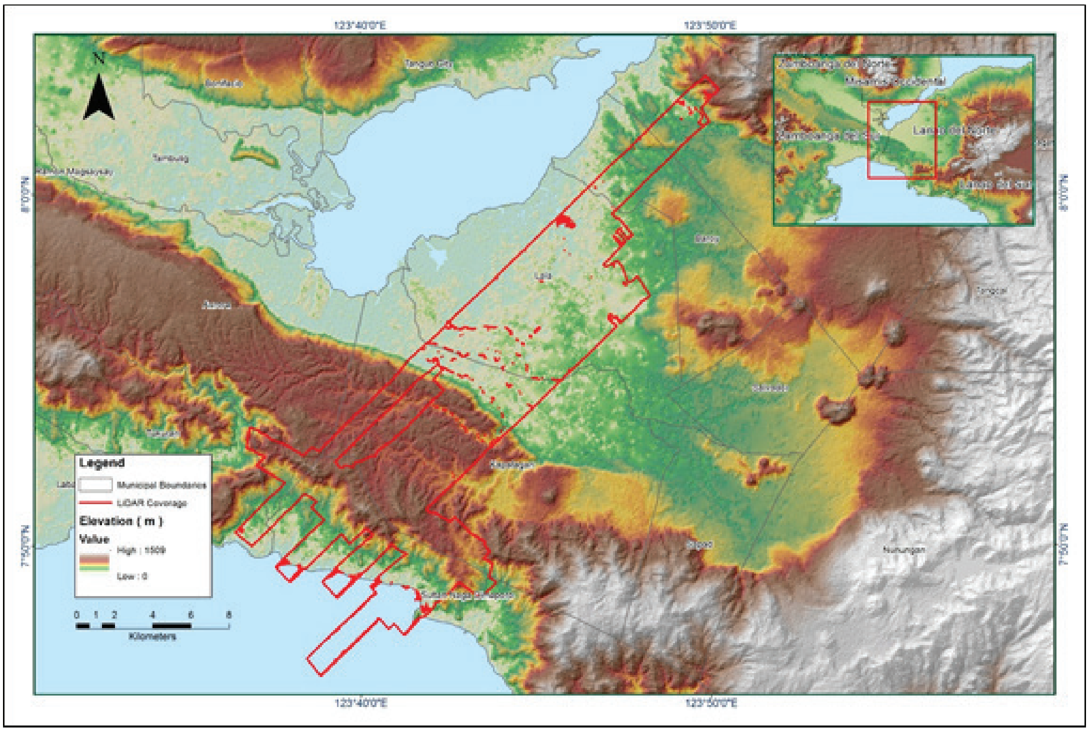


Figure A-8.11 Coverage of LiDAR Data

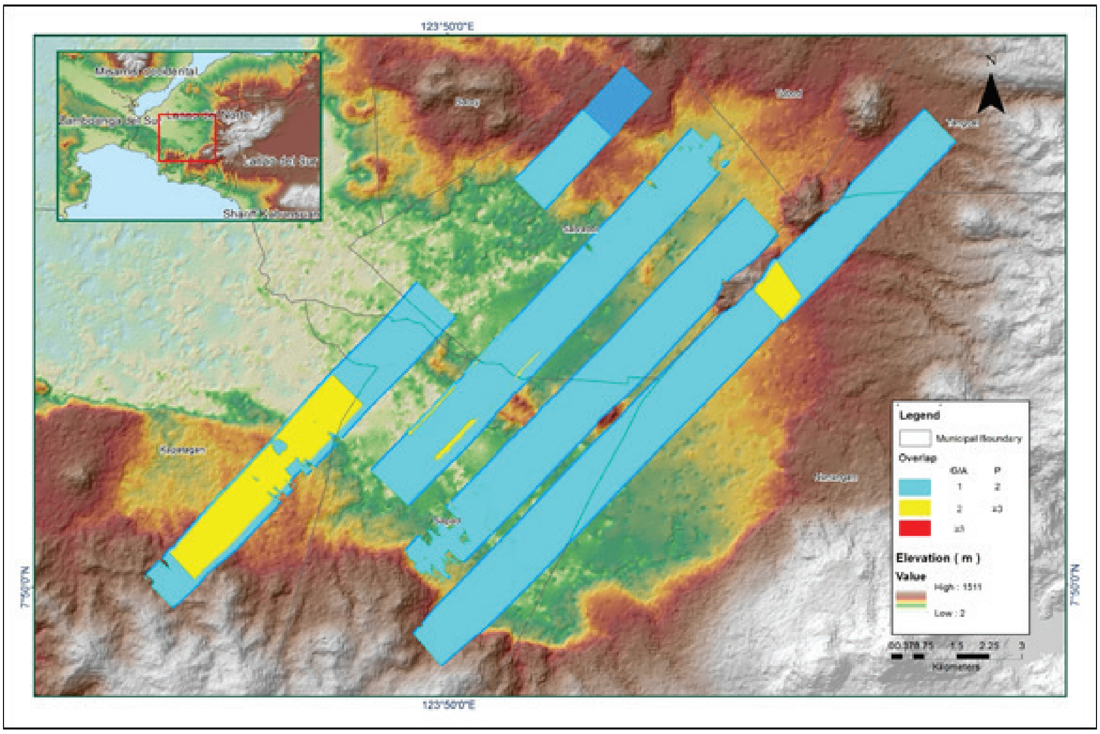


Figure A-8.12 Image of data overlap

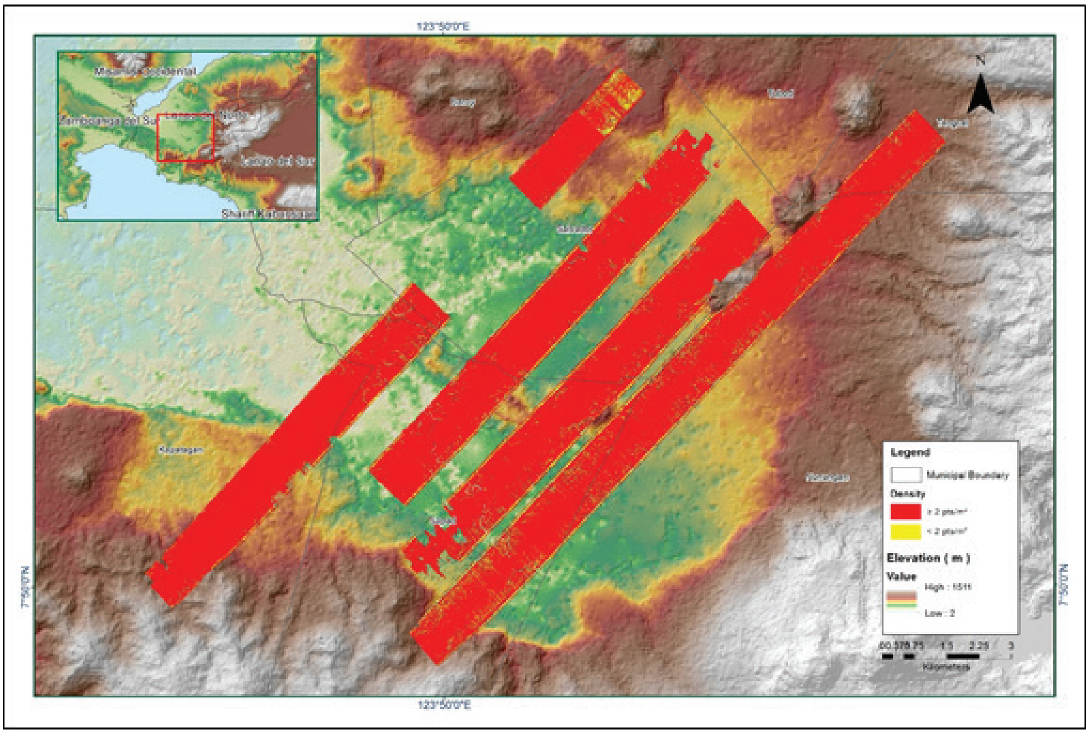


Figure A-8.13 Density map of merged LiDAR data

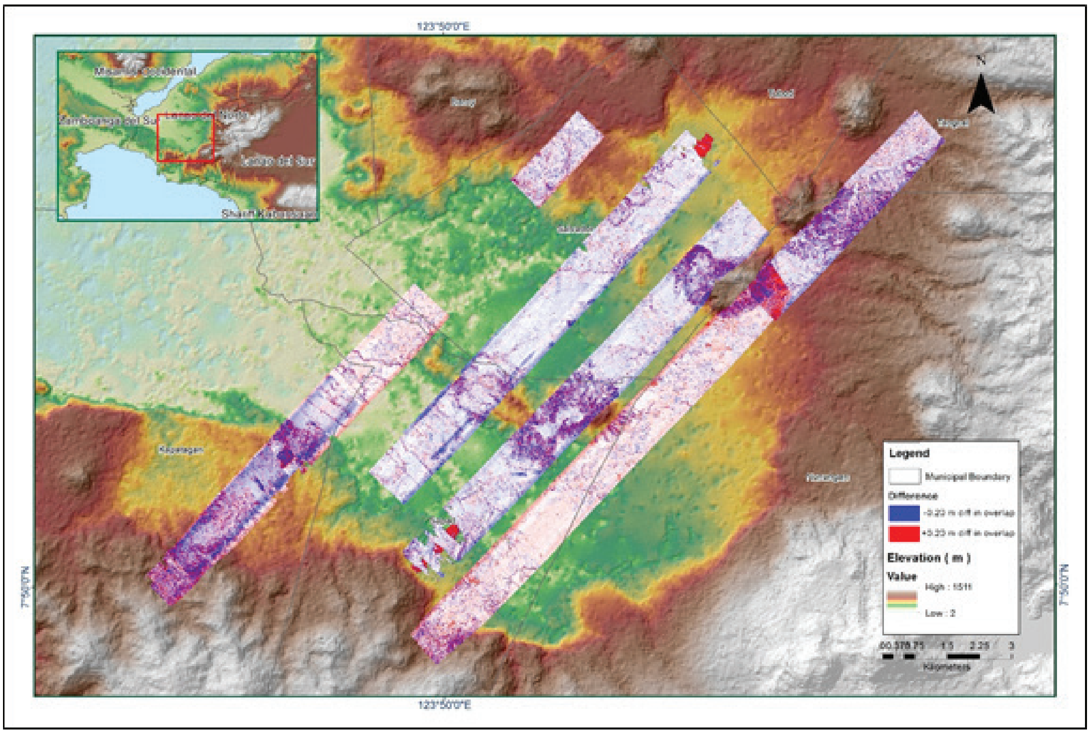


Figure A-8.14 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	Blk76N_Supplement
Inclusive Flights	23104P
Range data size	18.3 GB
POS data size	287.01 MB
Base data size	116.78 MB
Image	25.87 GB
Transfer date	March 1, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000502
IMU attitude correction stdev (<0.001deg)	0.001509
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	14.43
Ave point cloud density per sq.m. (>2.0)	2.64
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	13
Maximum Height	368.25
Minimum Height	93.58
Classification (# of points)	
Ground	4,438,634
Low vegetation	1,755,258
Medium vegetation	1,534,601
High vegetation	4,444,966
Building	34,342
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Justine Francisco, Engr. Gladys Mae Apat

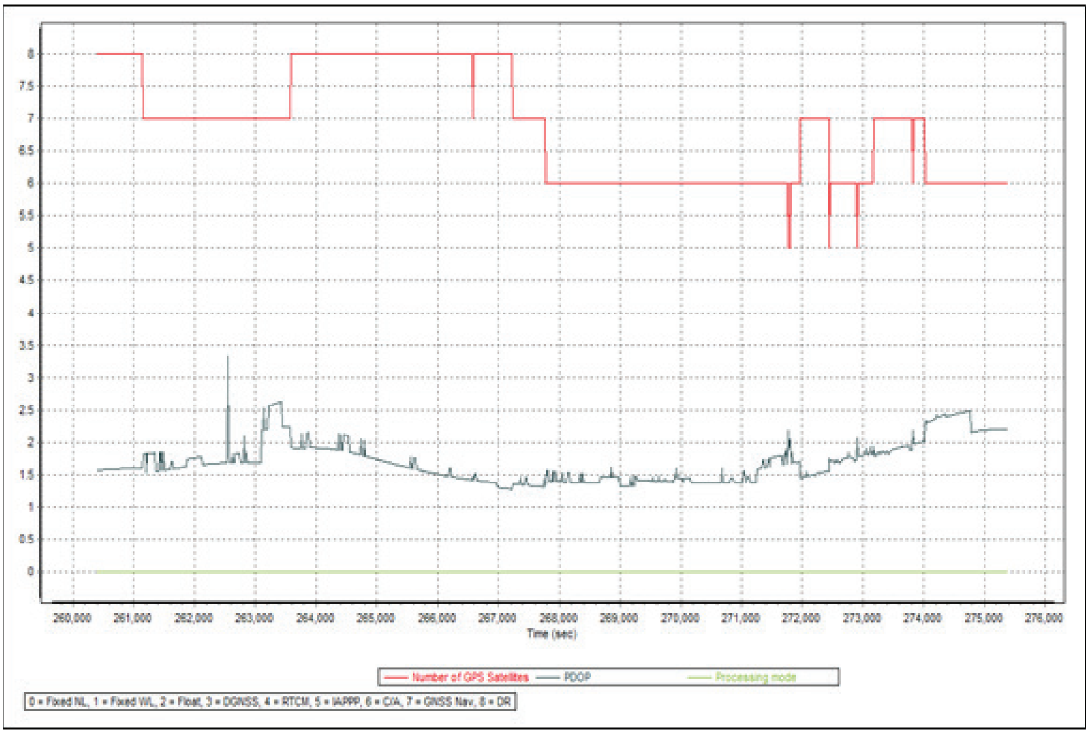


Figure A-8.15 Solution Status

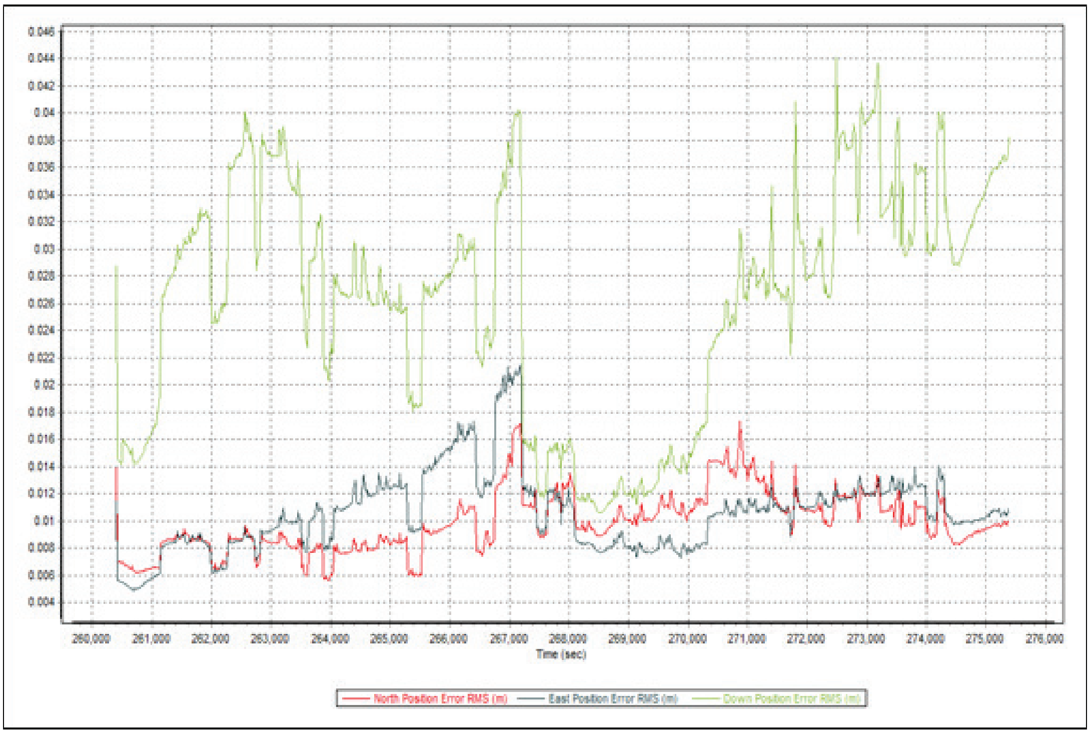


Figure A-8.16 Smoothed Performance Metric Parameters

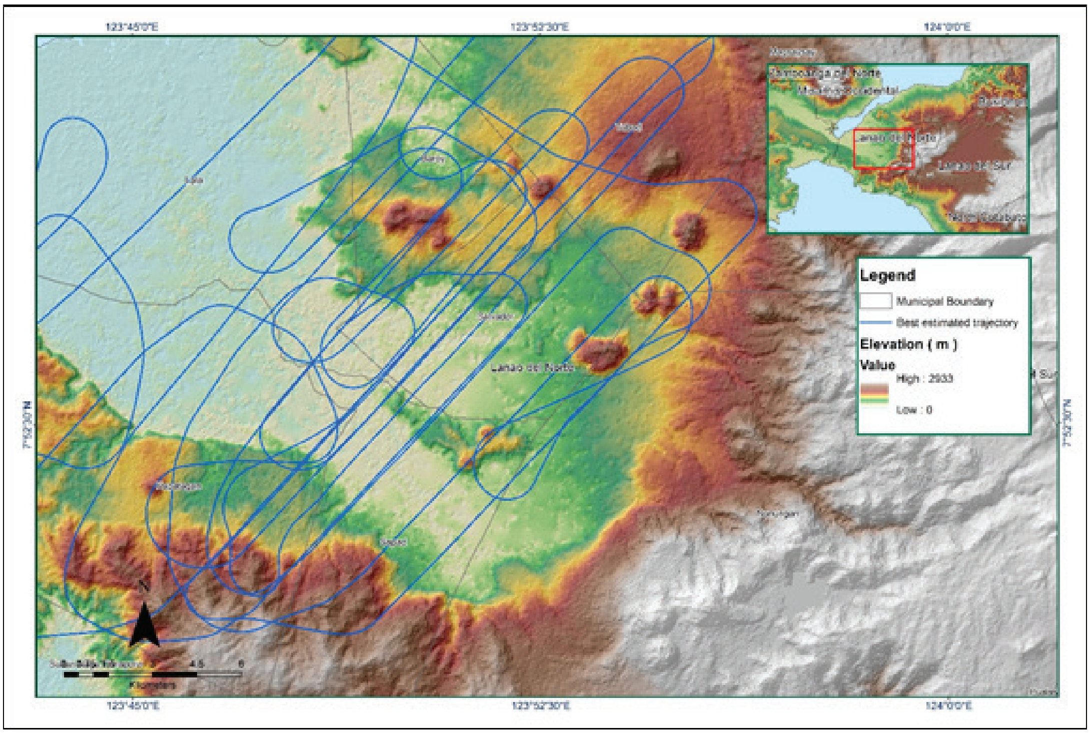


Figure A-8.17 Best Estimated Trajectory

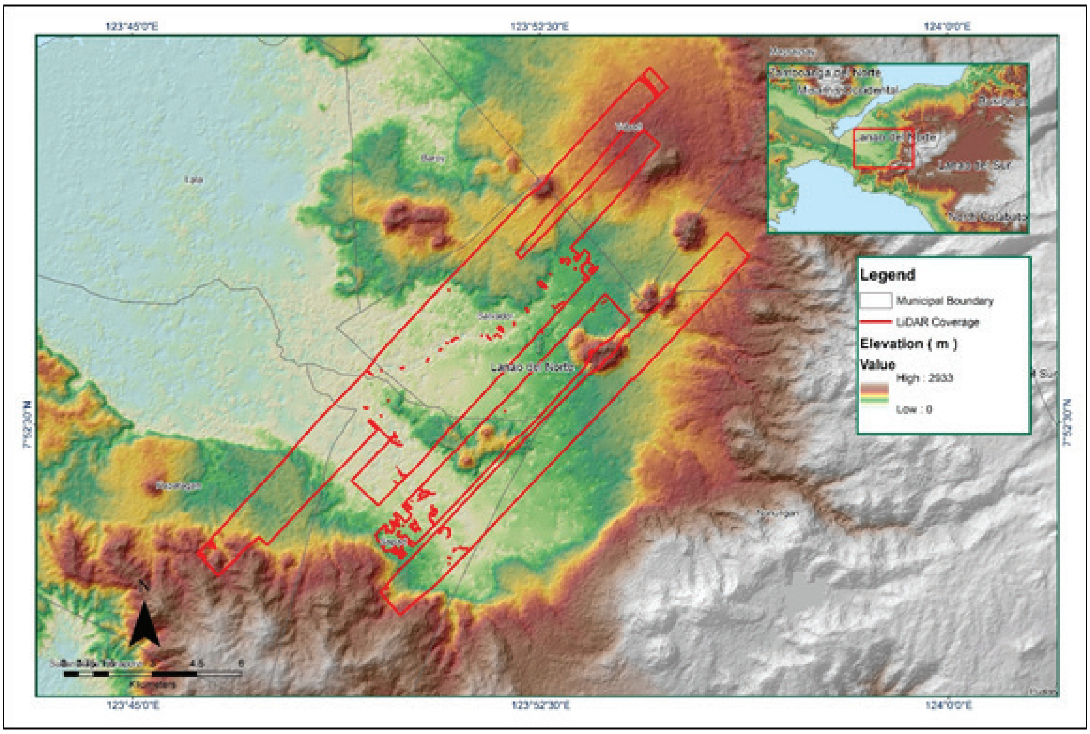


Figure A-8.18 Coverage of LiDAR Data

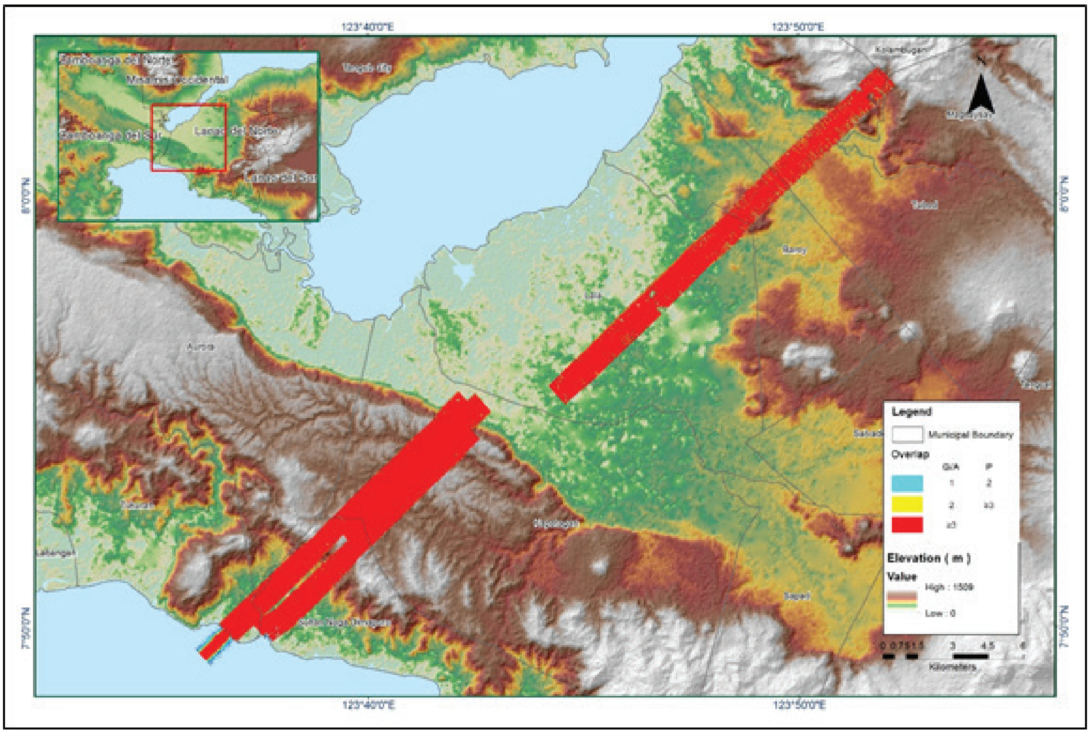


Figure A-8.19 Image of data overlap

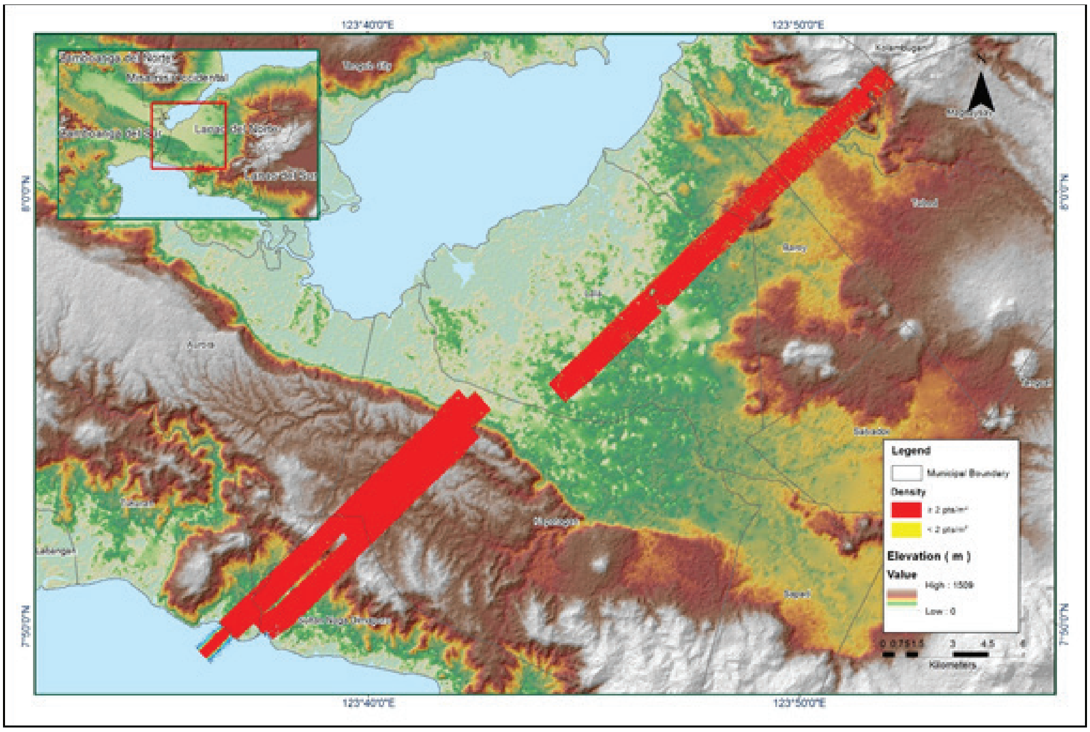


Figure A-8.20 Density map of merged LiDAR data

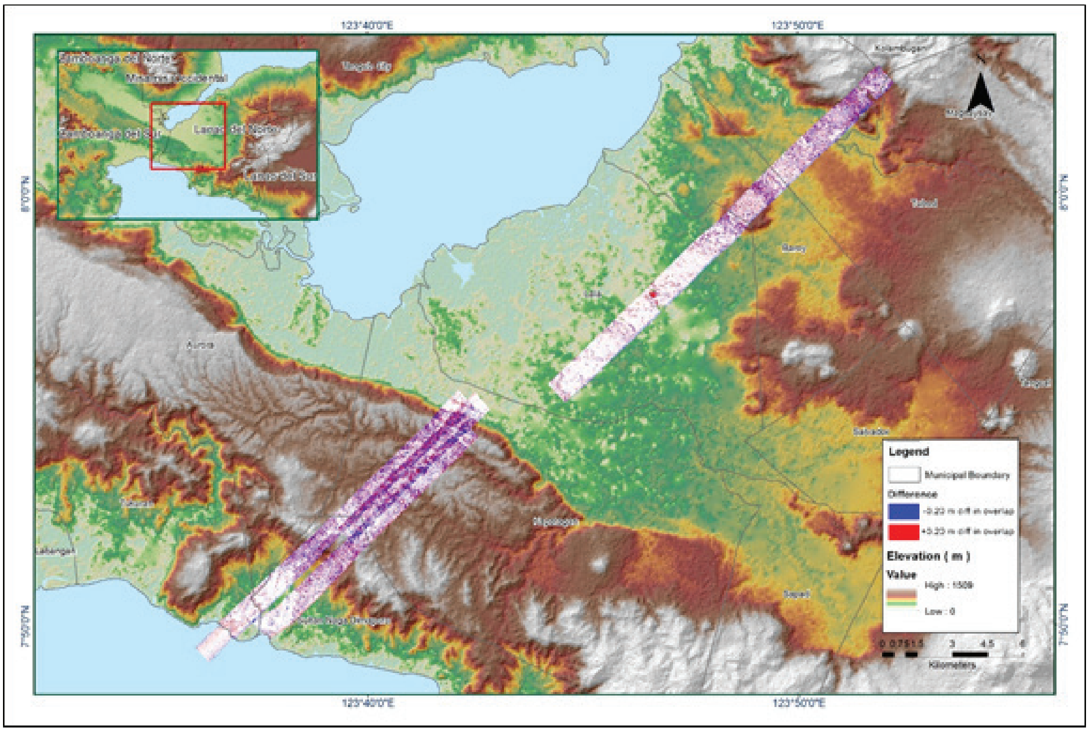


Figure A-8.21 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	76M
Inclusive Flights	23128P
Range data size	23.30 GB
POS data size	273 MB
Base data size	311 MB
Image	n/a
Transfer date	March 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000128
IMU attitude correction stdev (<0.001deg)	0.000139
GPS position stdev (<0.01m)	0.0122
Minimum % overlap (>25)	14.01
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	173
Maximum Height	503.88 m
Minimum Height	67.66 m
Classification (# of points)	
Ground	100,531,253
Low vegetation	60,833,381
Medium vegetation	70,336,602
High vegetation	177,937,163
Building	1,895,317
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Maria Tamsyn Malabanan

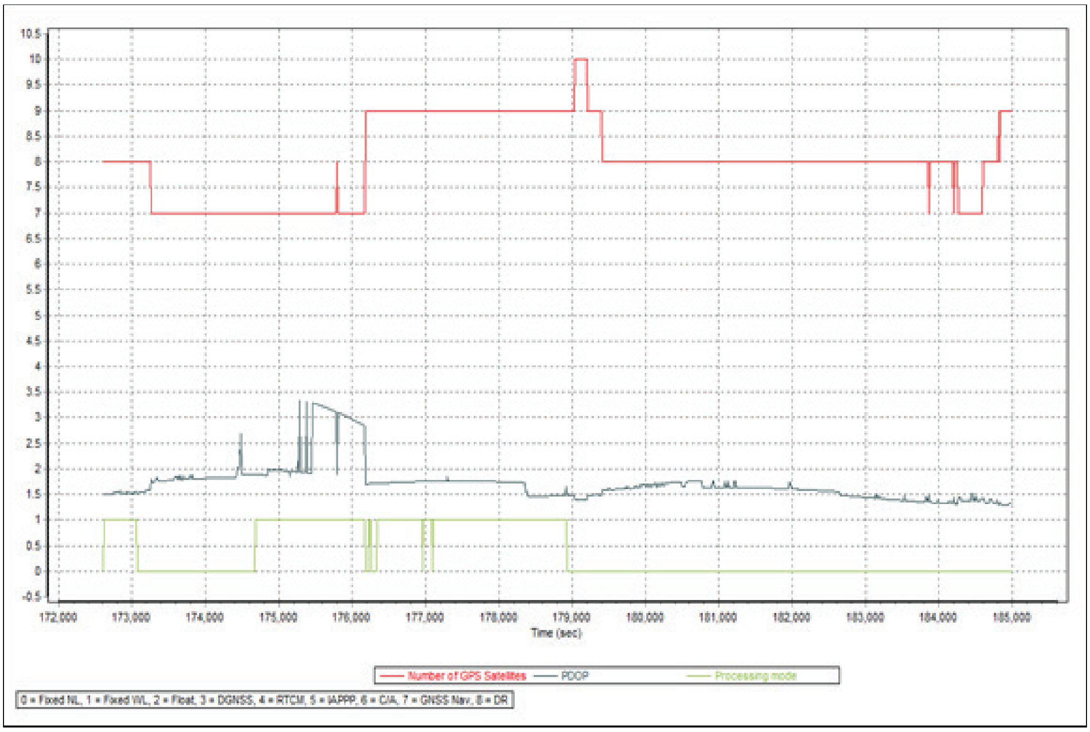


Figure A-8.22 Solution Status

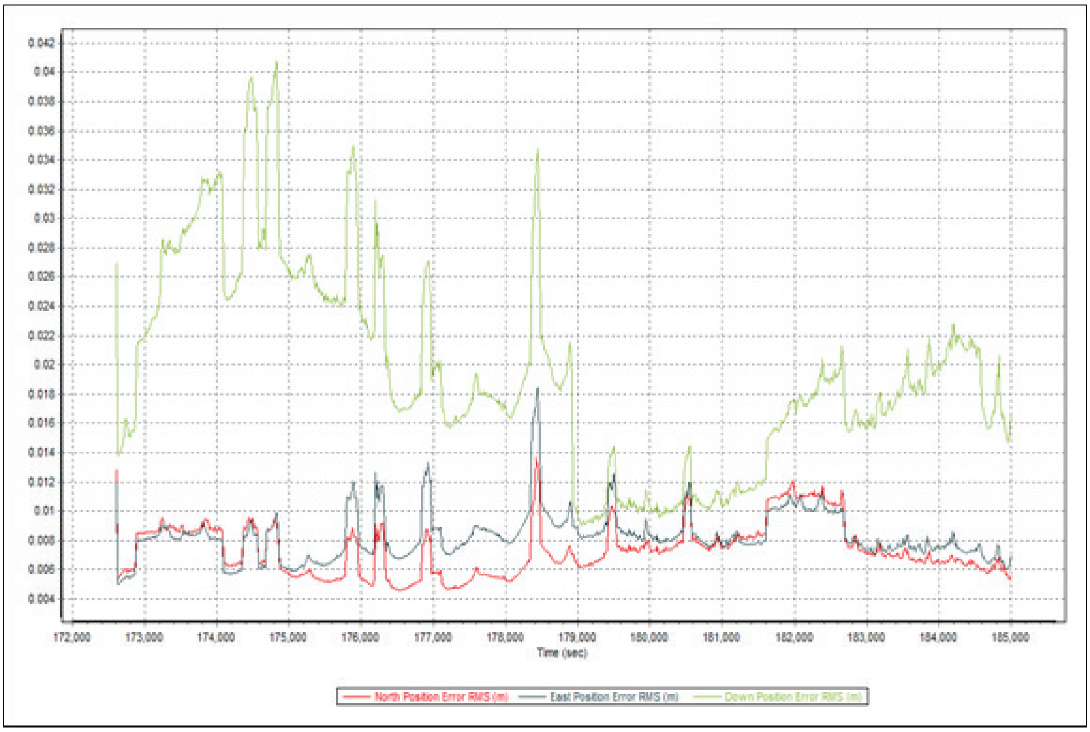


Figure A-8.23 Smoothed Performance Metric Parameters

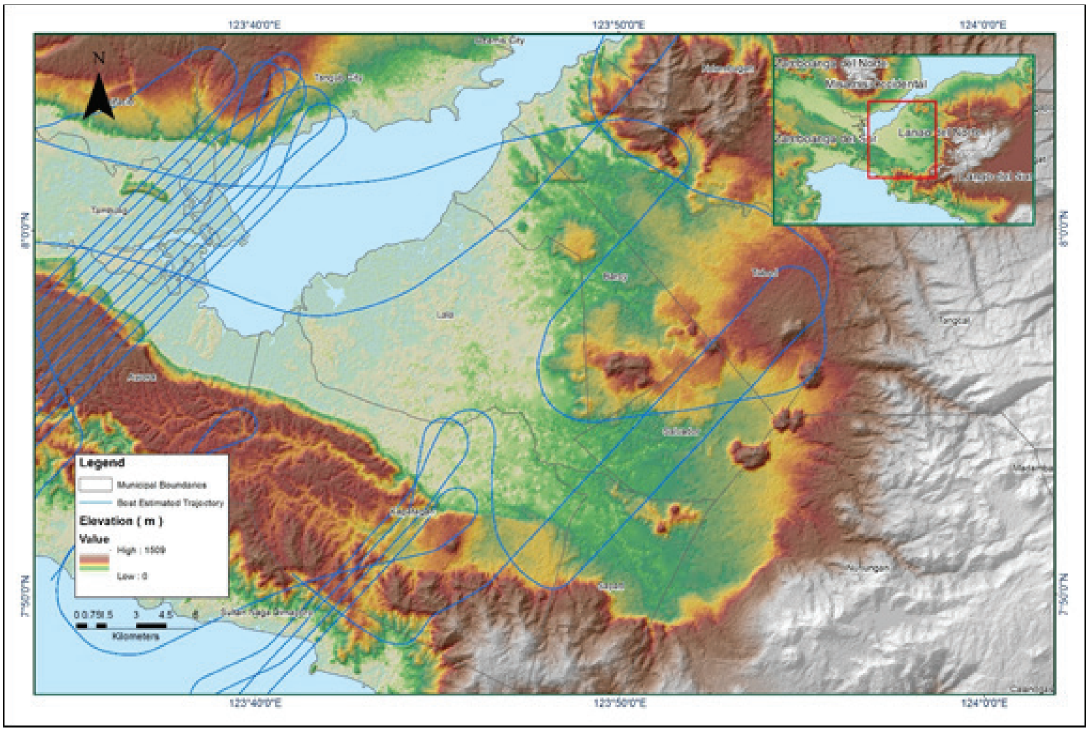


Figure A-8.24 Best Estimated Trajectory

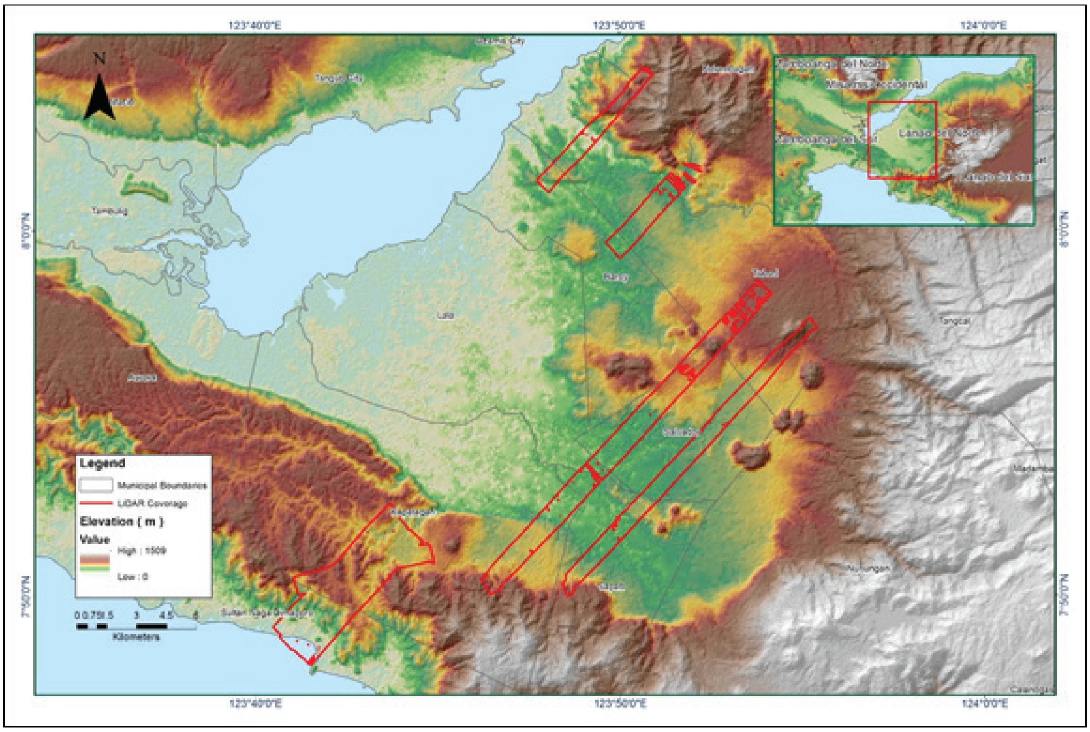


Figure A-8.25 Coverage of LiDAR Data

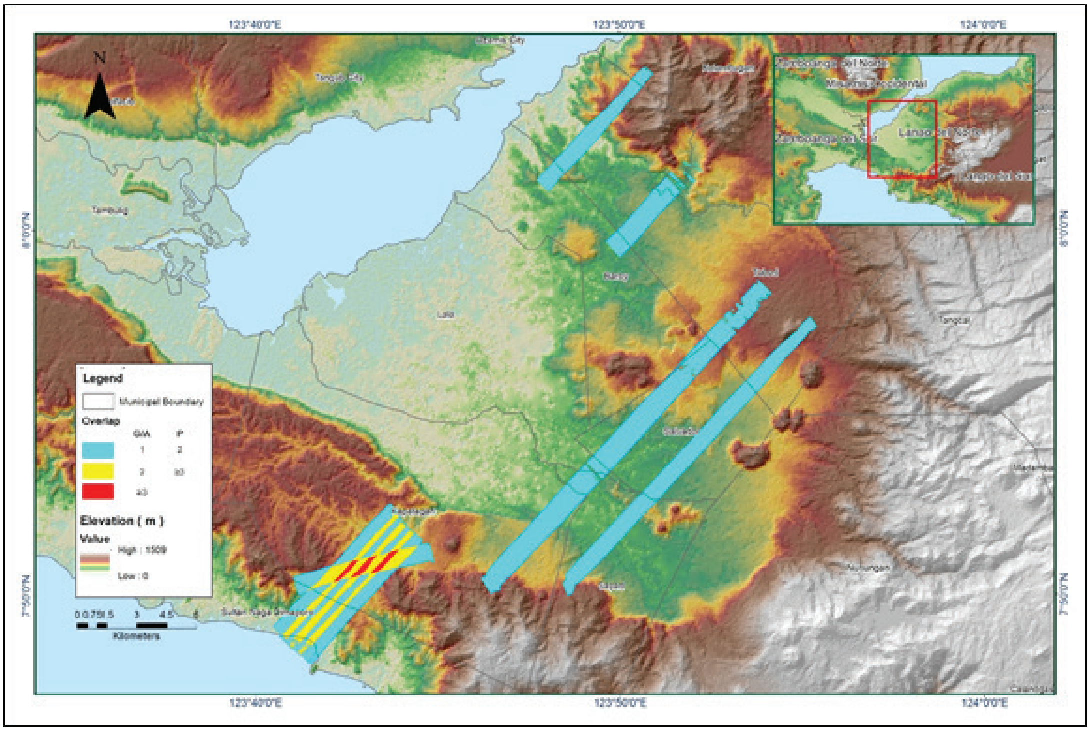


Figure A-8.26 Image of data overlap

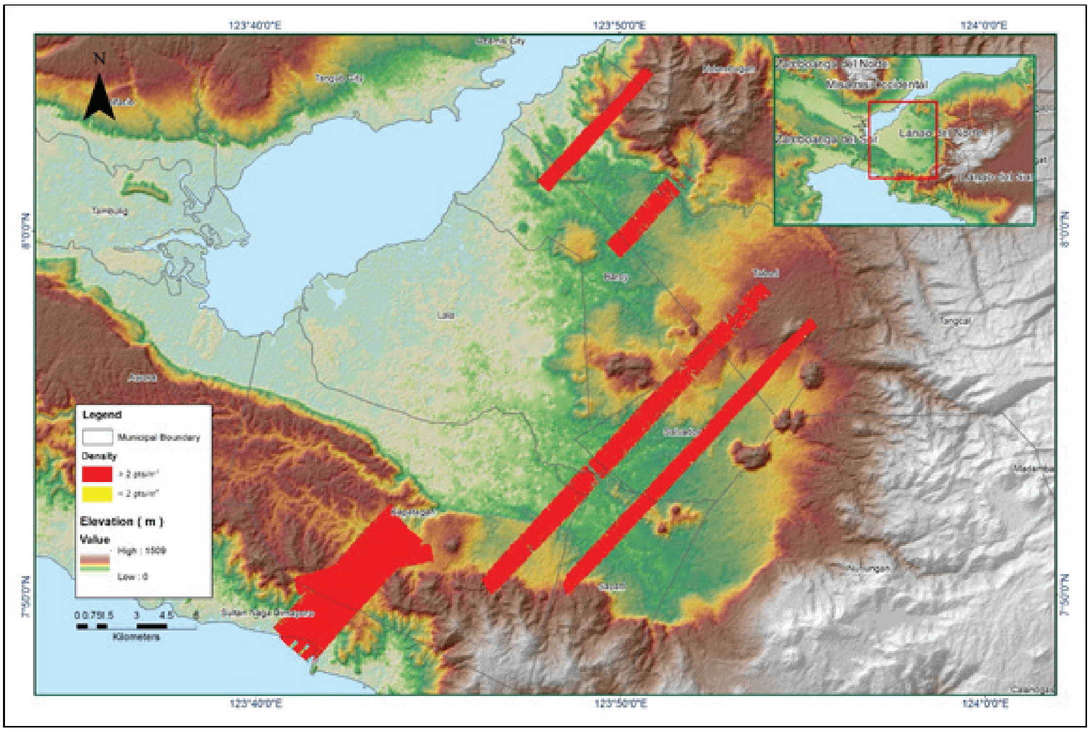


Figure A-8.27 Density map of merged LiDAR data

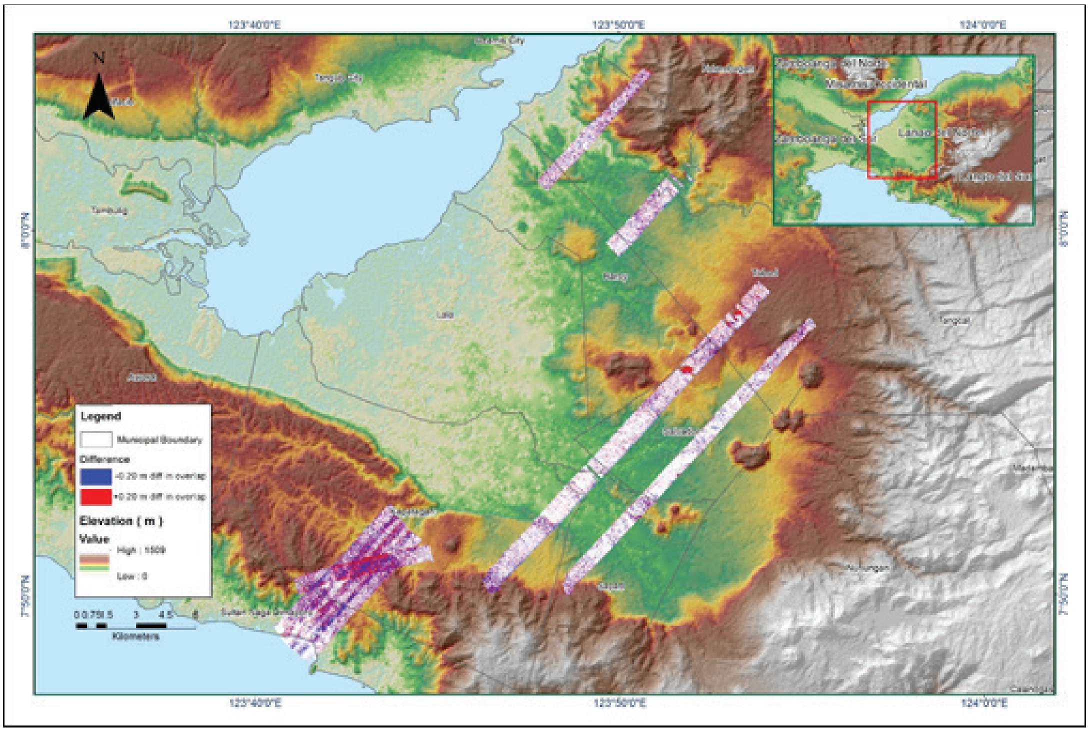


Figure A-8.28 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	Blk76N
Inclusive Flights	23088P
Range data size	24.65
POS data size	283.62
Base data size	101.29
Image	n/a
Transfer date	March 01, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	4.6
Boresight correction stdev (<0.001deg)	0.000274
IMU attitude correction stdev (<0.001deg)	0.001049
GPS position stdev (<0.01m)	0.0073
Minimum % overlap (>25)	41.91
Ave point cloud density per sq.m. (>2.0)	2.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	189
Maximum Height	726.06 m
Minimum Height	92.16 m
Classification (# of points)	
Ground	140,736,400
Low vegetation	124,627,028
Medium vegetation	126,549,841
High vegetation	285,028,320
Building	4,597,452
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew Natino, Marie Denise Bueno

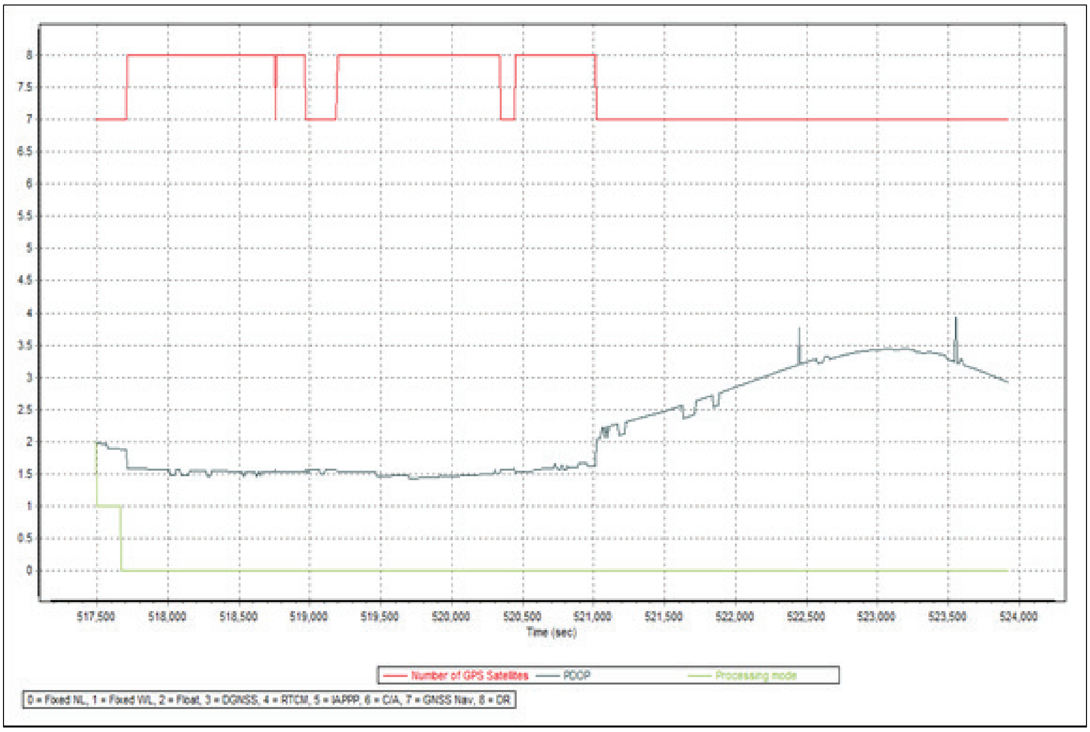


Figure A-8.29 Solution Status

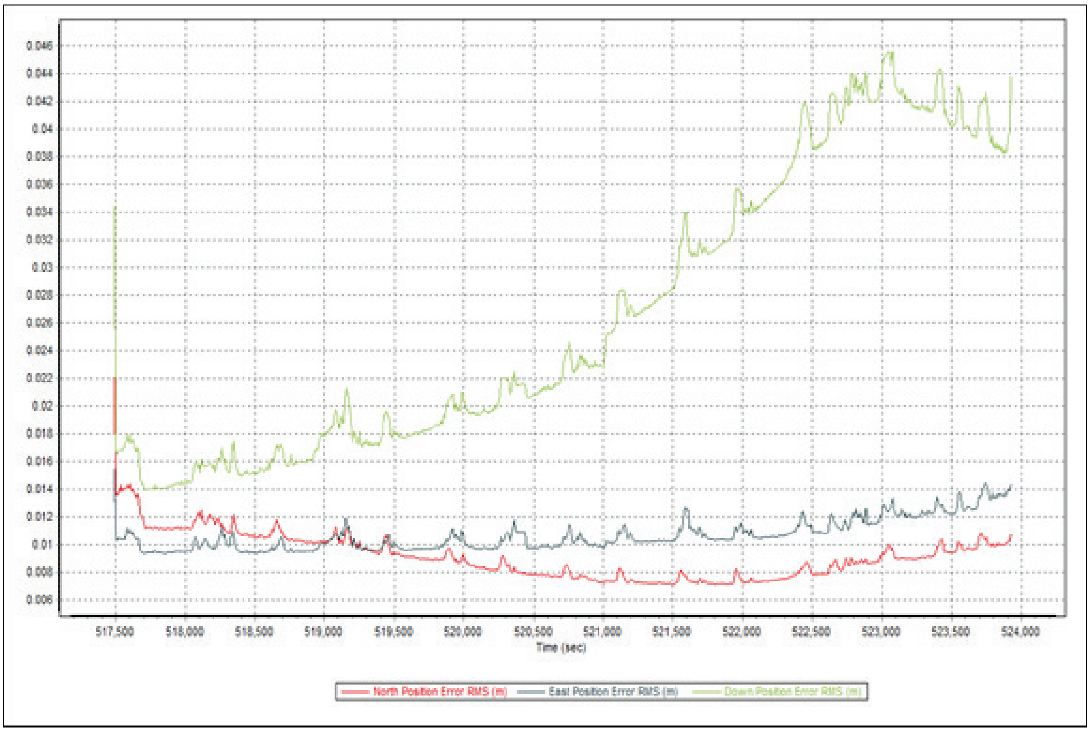


Figure A-8.30 Smoothed Performance Metric Parameters

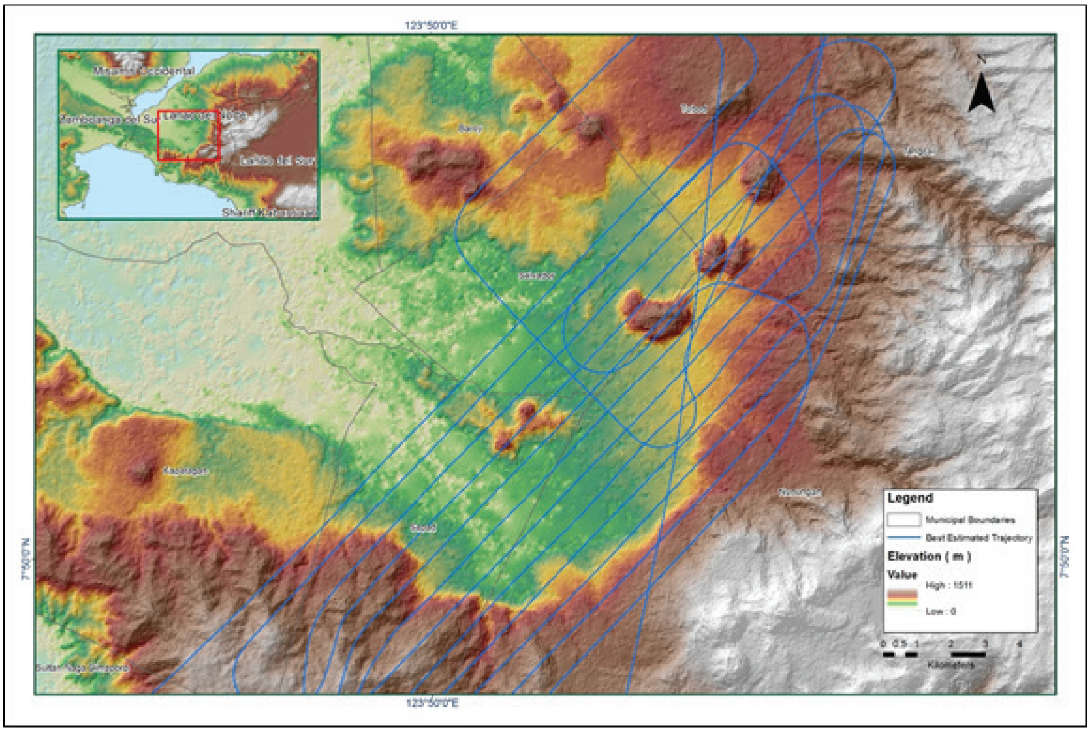


Figure A-8.31 Best Estimated Trajectory

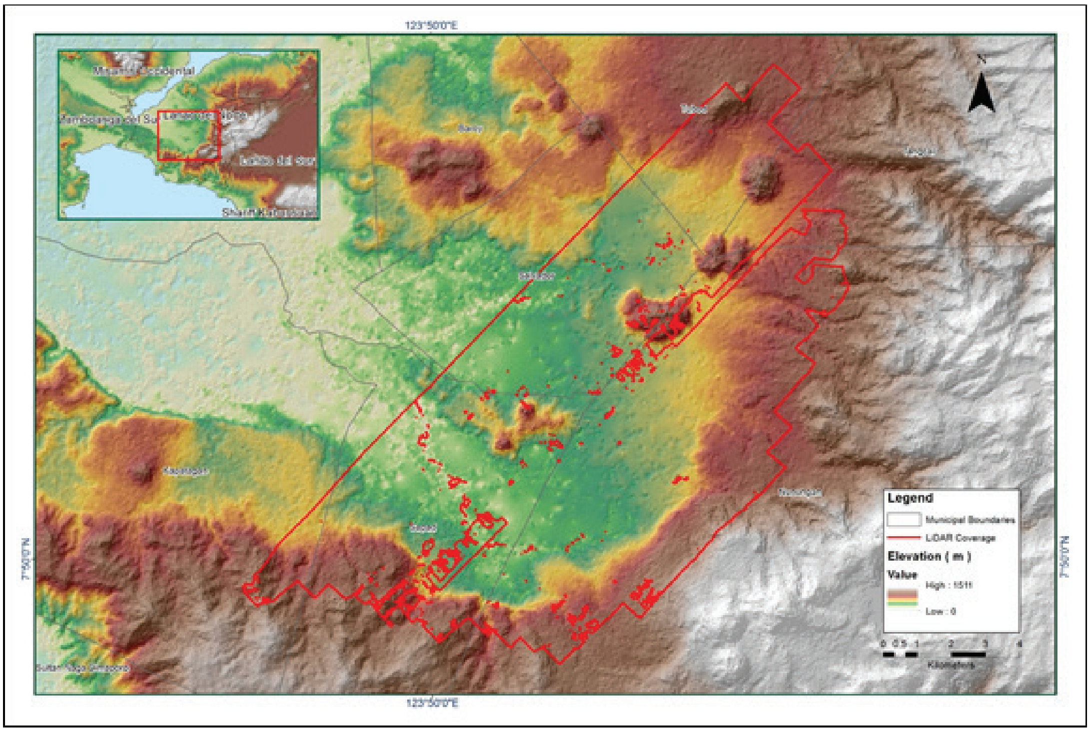


Figure A-8.32 Coverage of LiDAR Data

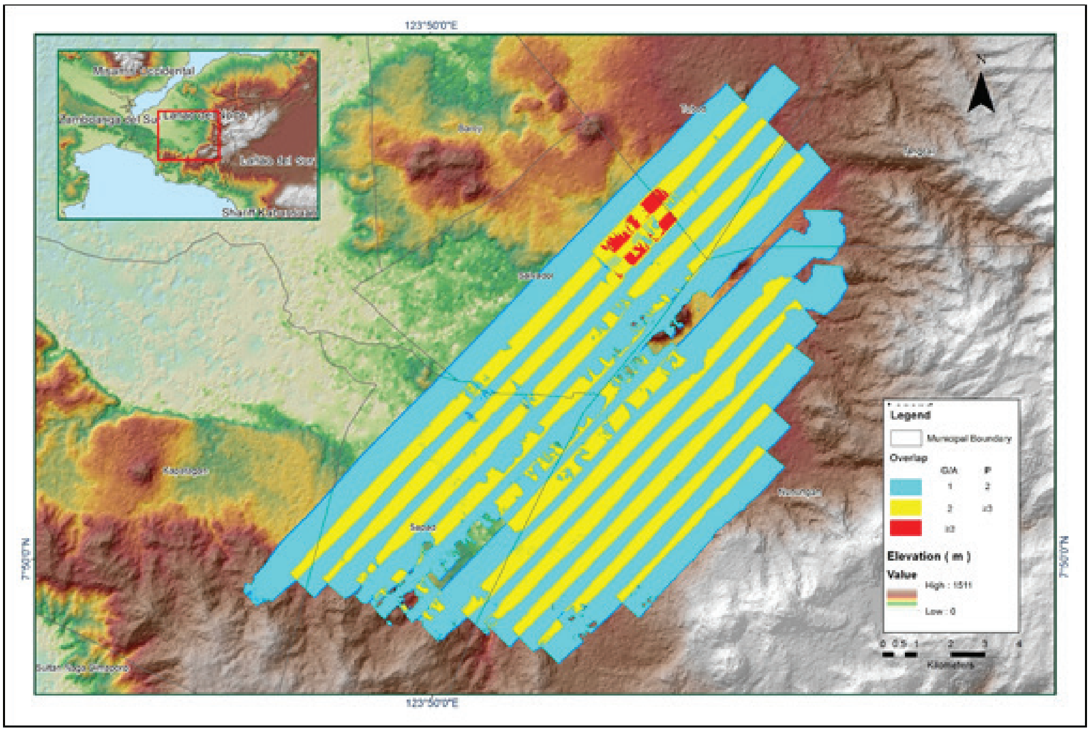


Figure A-8.33 Image of data overlap

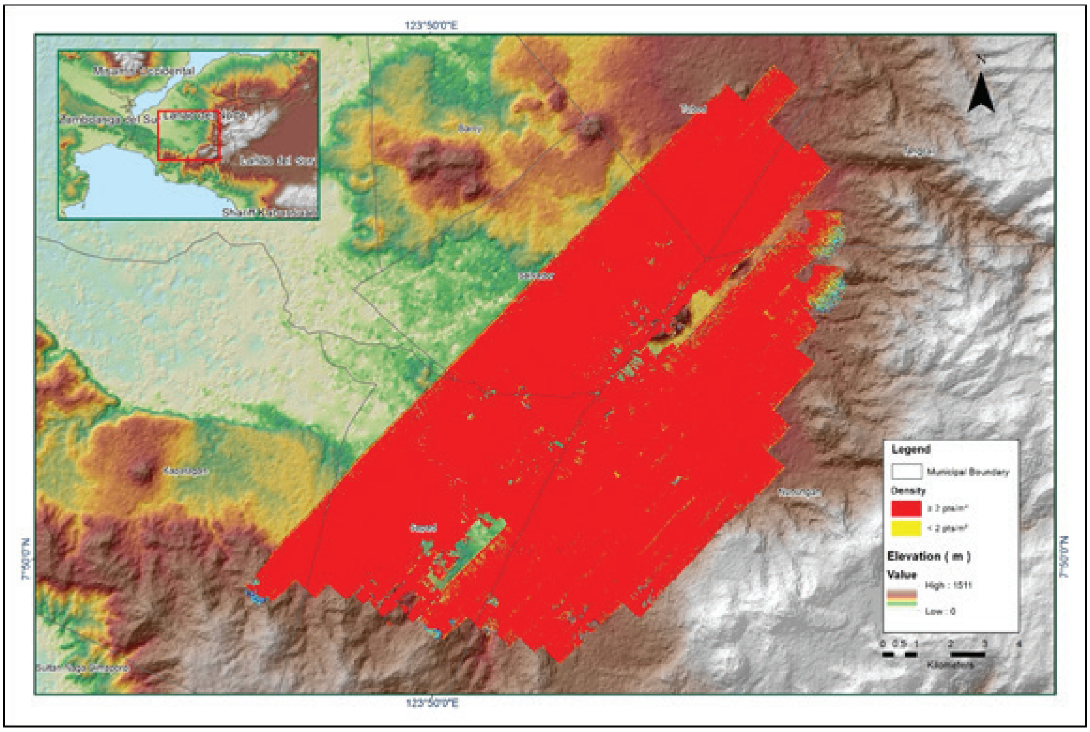


Figure A-8.34 Density map of merged LiDAR data

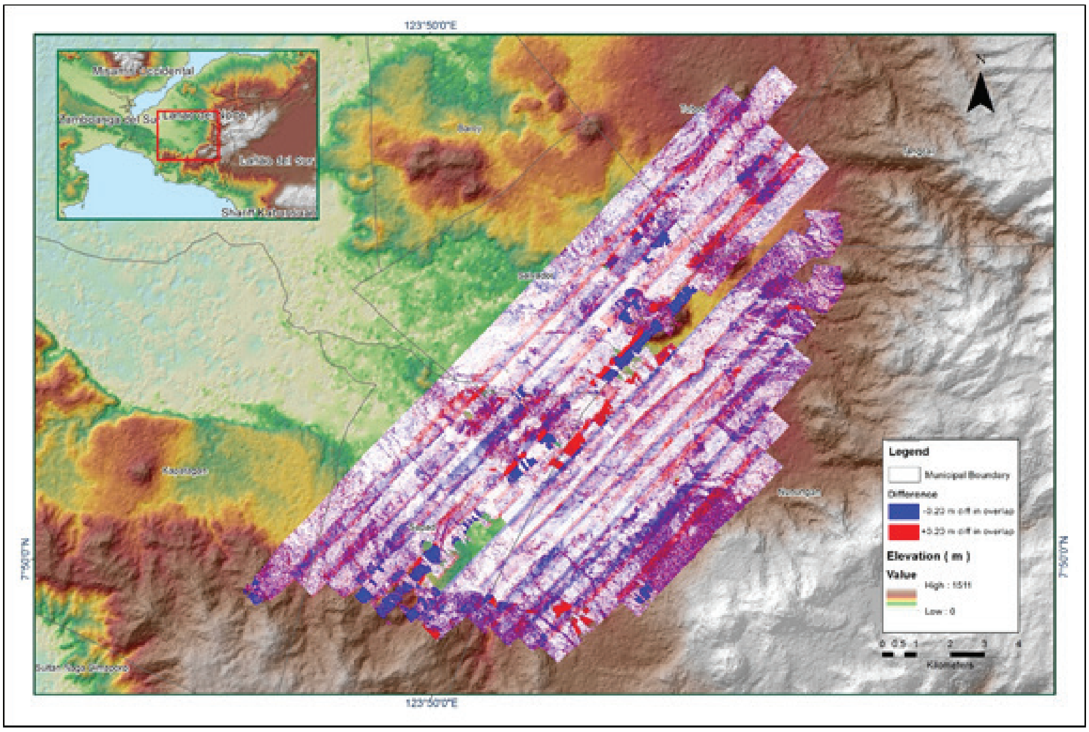


Figure A-8.35 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	Blk76N_Additional
Inclusive Flights	23104P
Range data size	18.3 GB
POS data size	287.01 MB
Base data size	116.78 MB
Image	25.87 GB
Transfer date	March 1, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	10.37
Ave point cloud density per sq.m. (>2.0)	2.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	124
Maximum Height	436.04 m
Minimum Height	90.14 m
Classification (# of points)	
Ground	56,765,012
Low vegetation	52,157,492
Medium vegetation	41,240,260
High vegetation	93,342,982
Building	1,335,125
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Merven Matthew Natino, Jovy Narisma

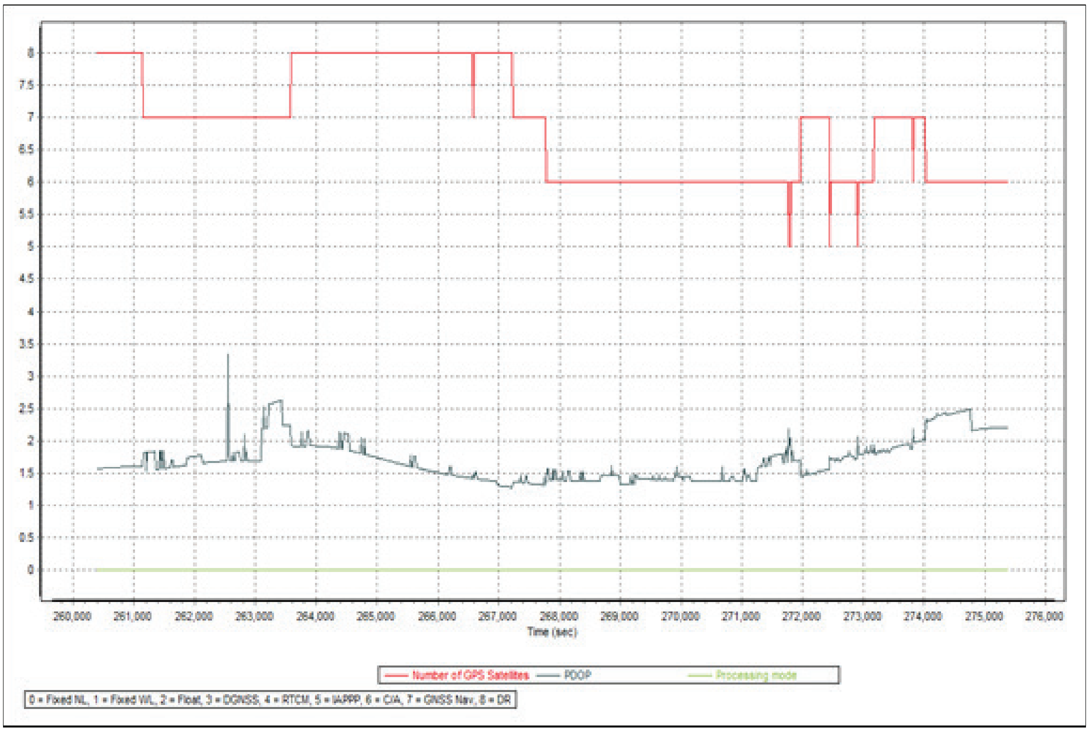


Figure A-8.36 Solution Status

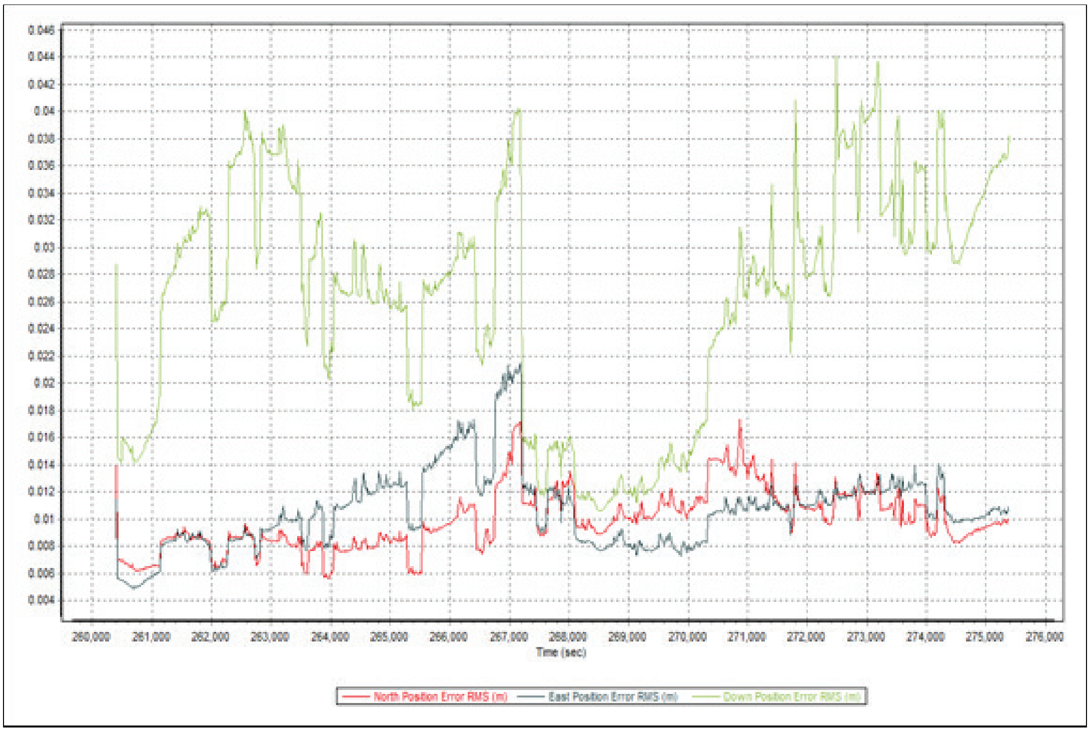


Figure A-8.37 Smoothed Performance Metric Parameters

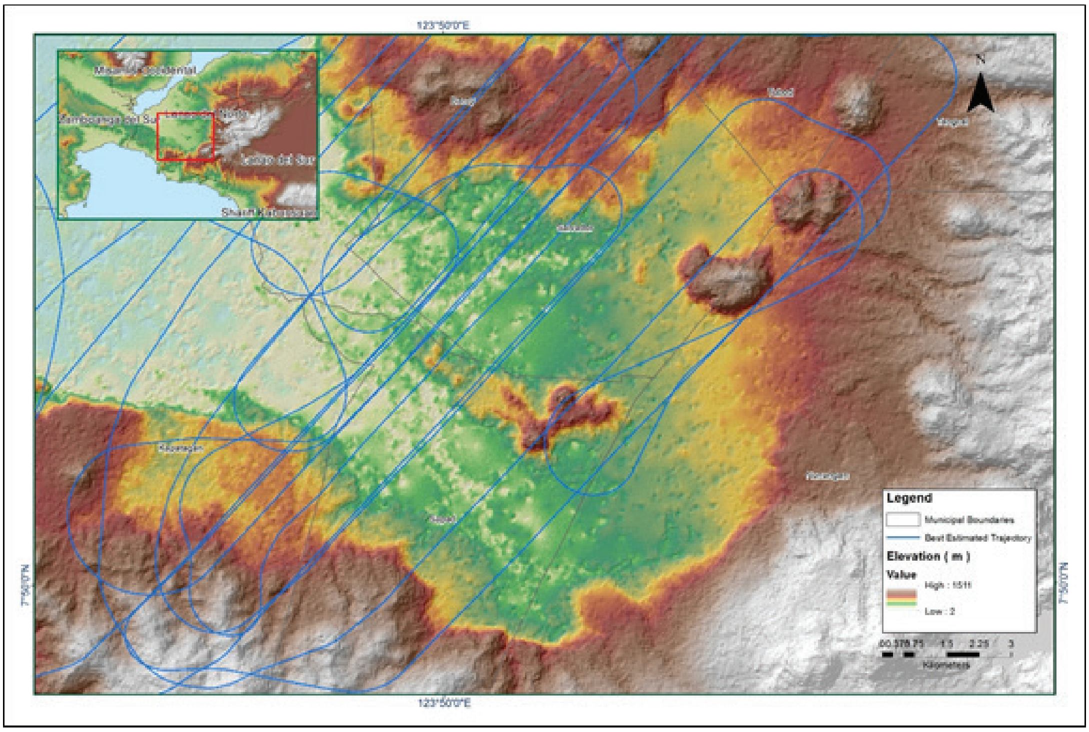


Figure A-8.38 Best Estimated Trajectory

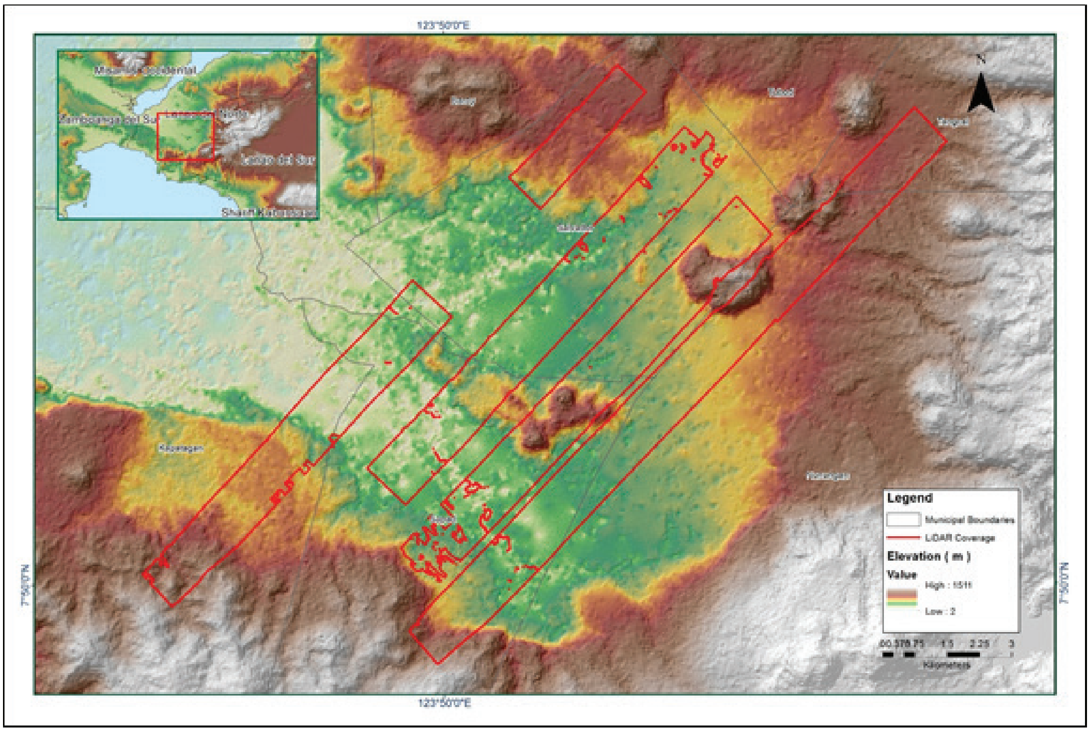


Figure A-8.39 Coverage of LiDAR Data

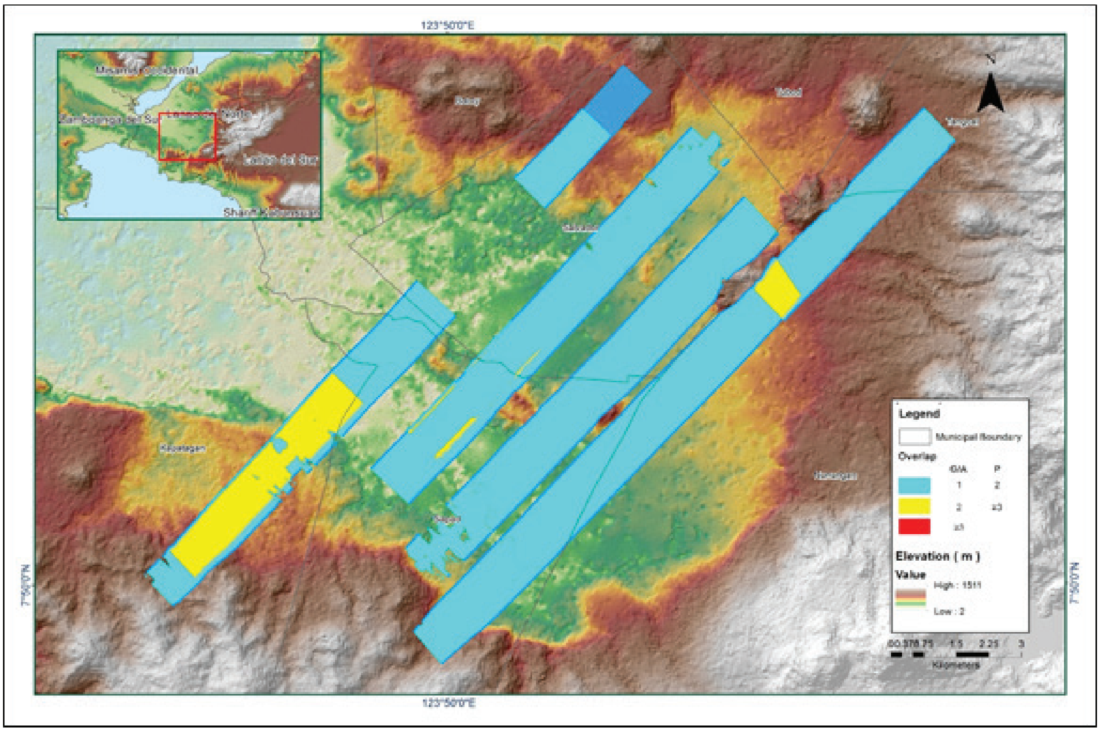


Figure A-8.40 Image of data overlap

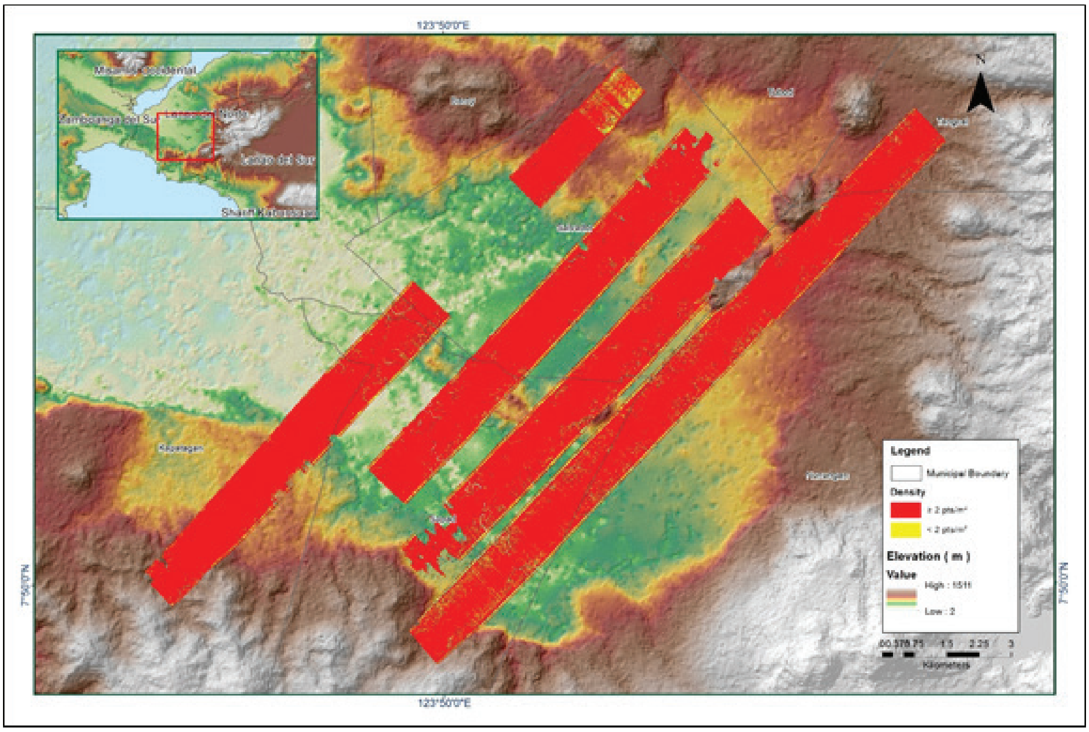


Figure A-8.41 Density map of merged LiDAR data

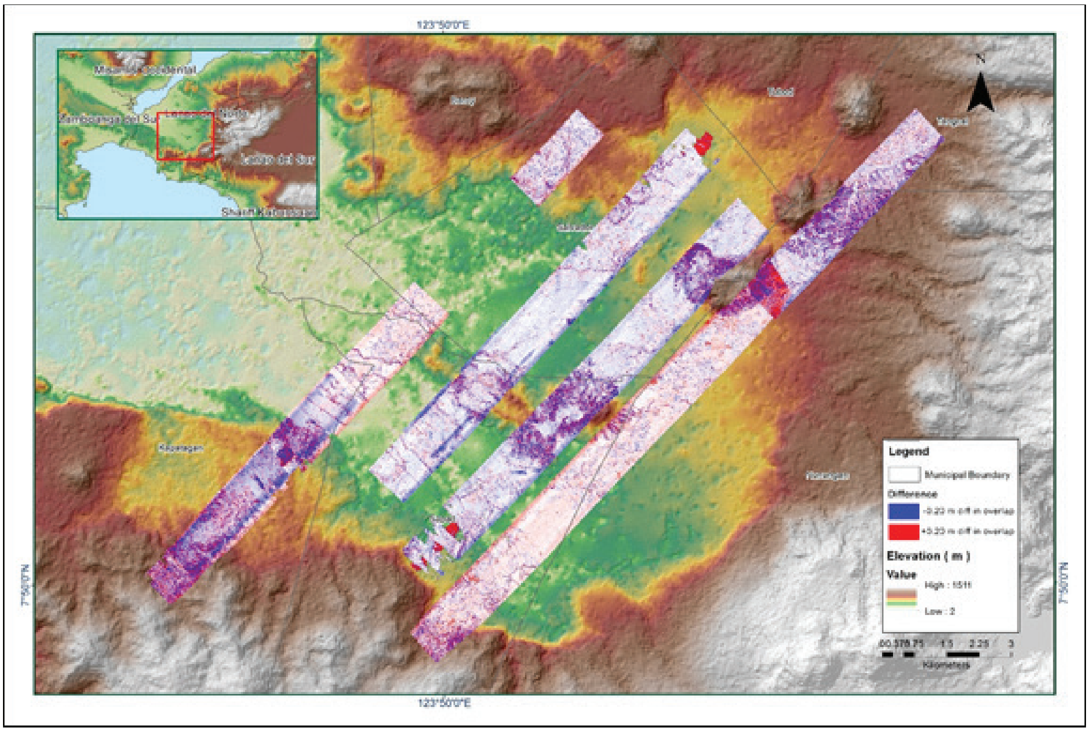


Figure A-8.42 Elevation difference between flight lines

Flight Area	Pagadian
Mission Name	Blk76N_Supplement
Inclusive Flights	23104P
Range data size	18.3 GB
POS data size	287.01 MB
Base data size	116.78 MB
Image	25.87 GB
Transfer date	March 1, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000502
IMU attitude correction stdev (<0.001deg)	0.001509
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	14.43
Ave point cloud density per sq.m. (>2.0)	2.64
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	13
Maximum Height	368.25
Minimum Height	93.58
Classification (# of points)	
Ground	4,438,634
Low vegetation	1,755,258
Medium vegetation	1,534,601
High vegetation	4,444,966
Building	34,342
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Justine Francisco, Engr. Gladys Mae Apat

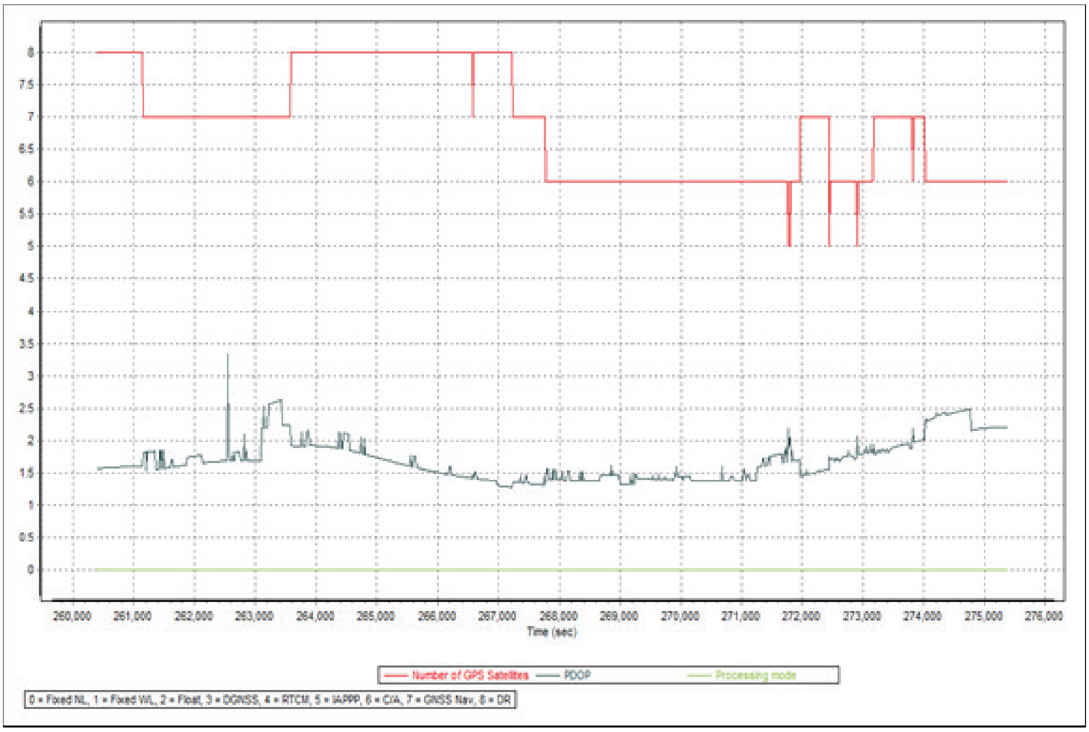


Figure A-8.43 Solution Status

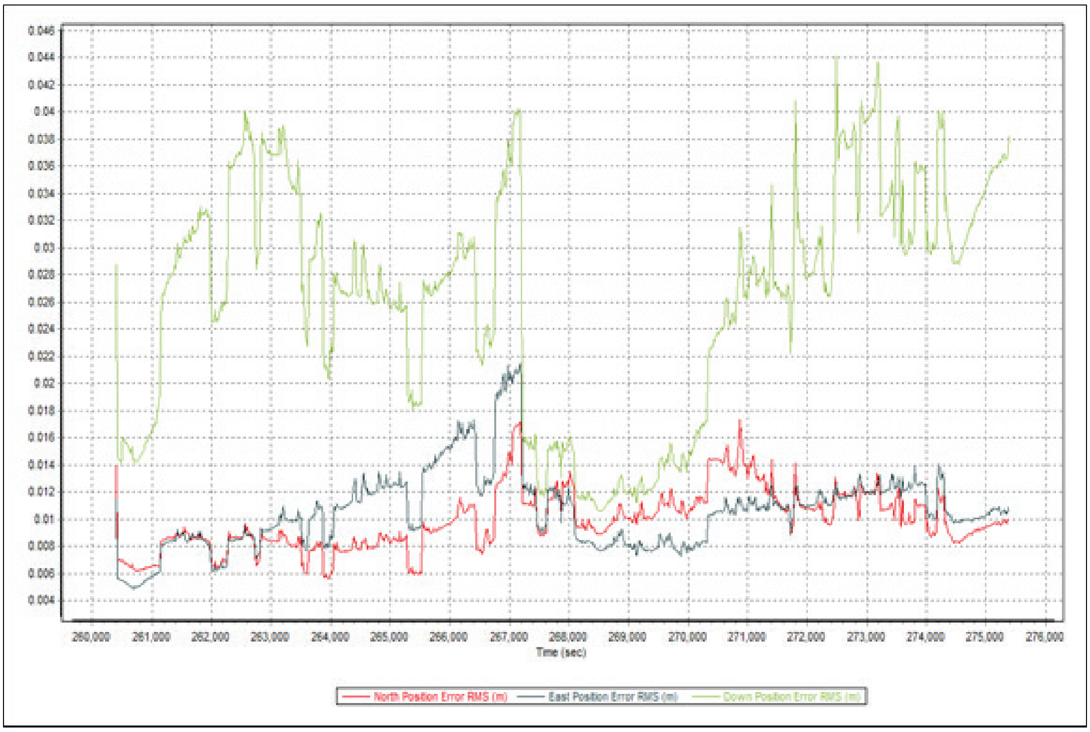


Figure A-8.44 Smoothed Performance Metric Parameters

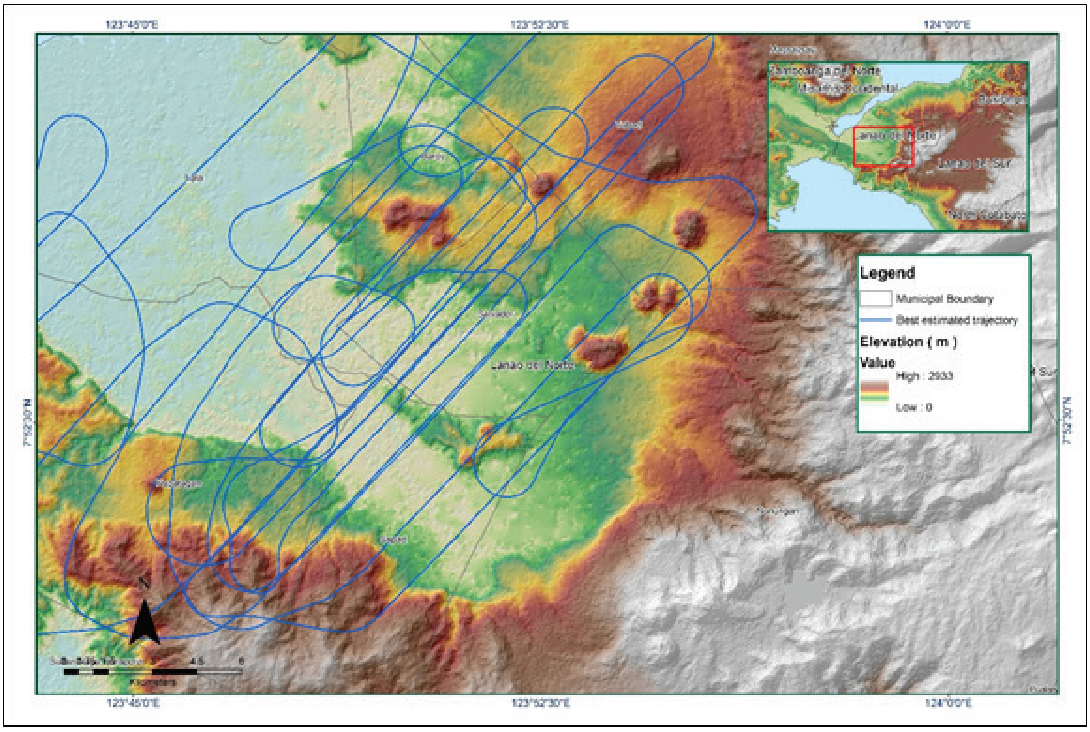


Figure A-8.45 Best Estimated Trajectory

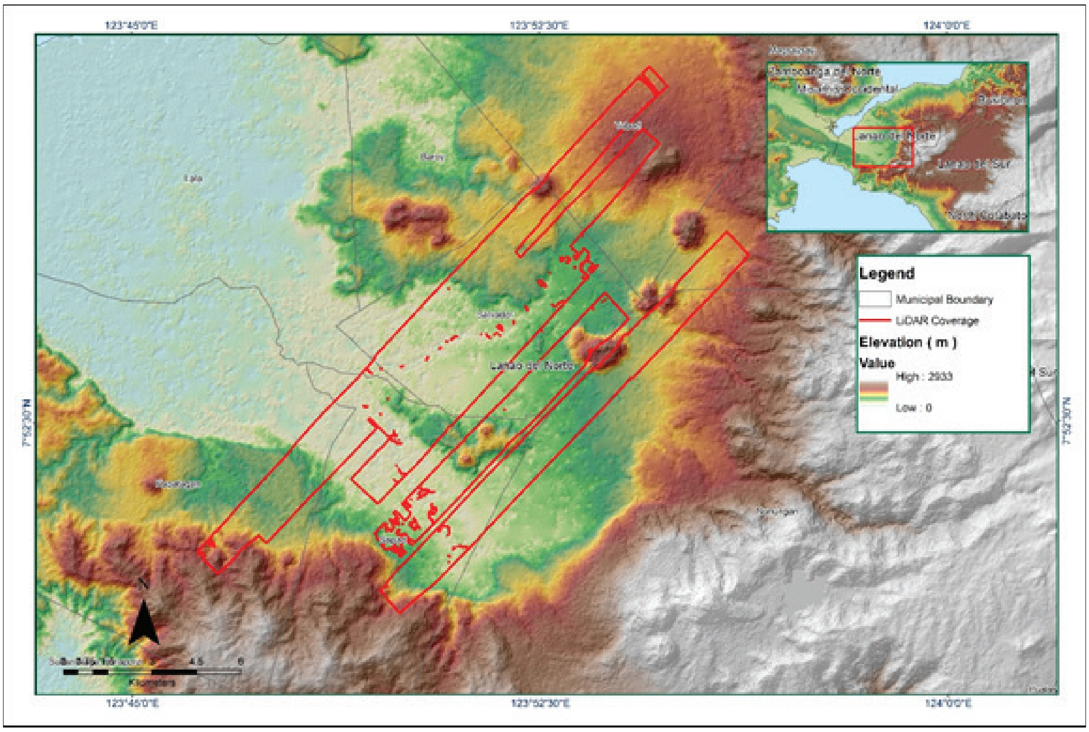


Figure A-8.46 Coverage of LiDAR Data

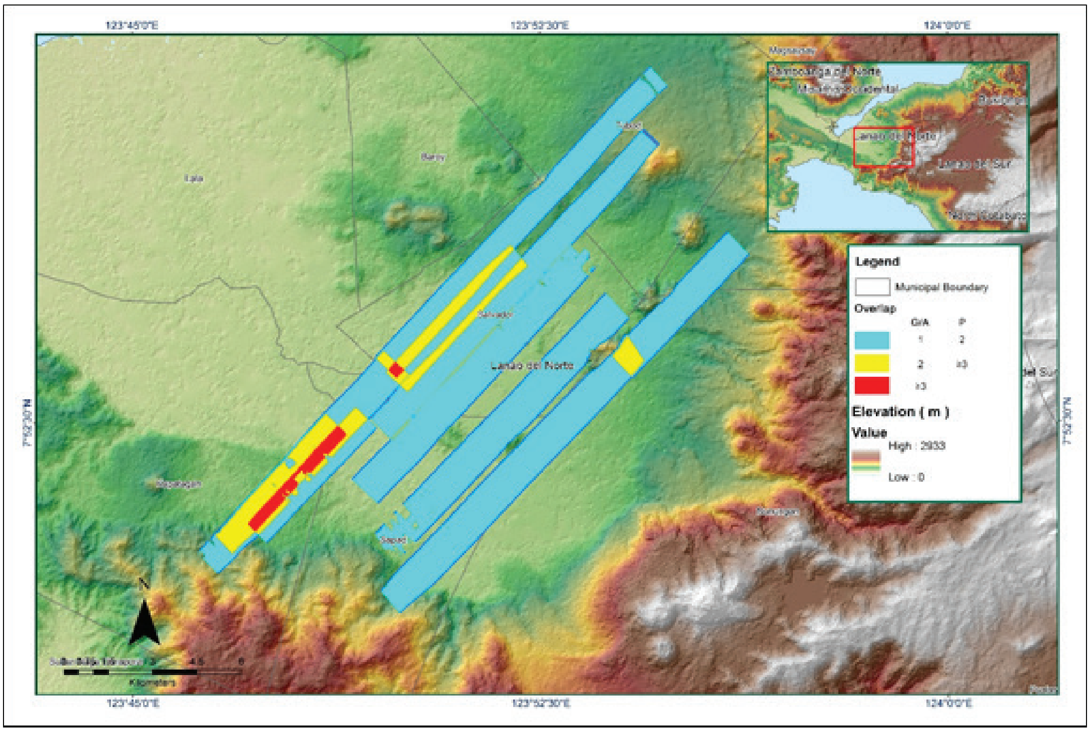


Figure A-8.47 Image of data overlap

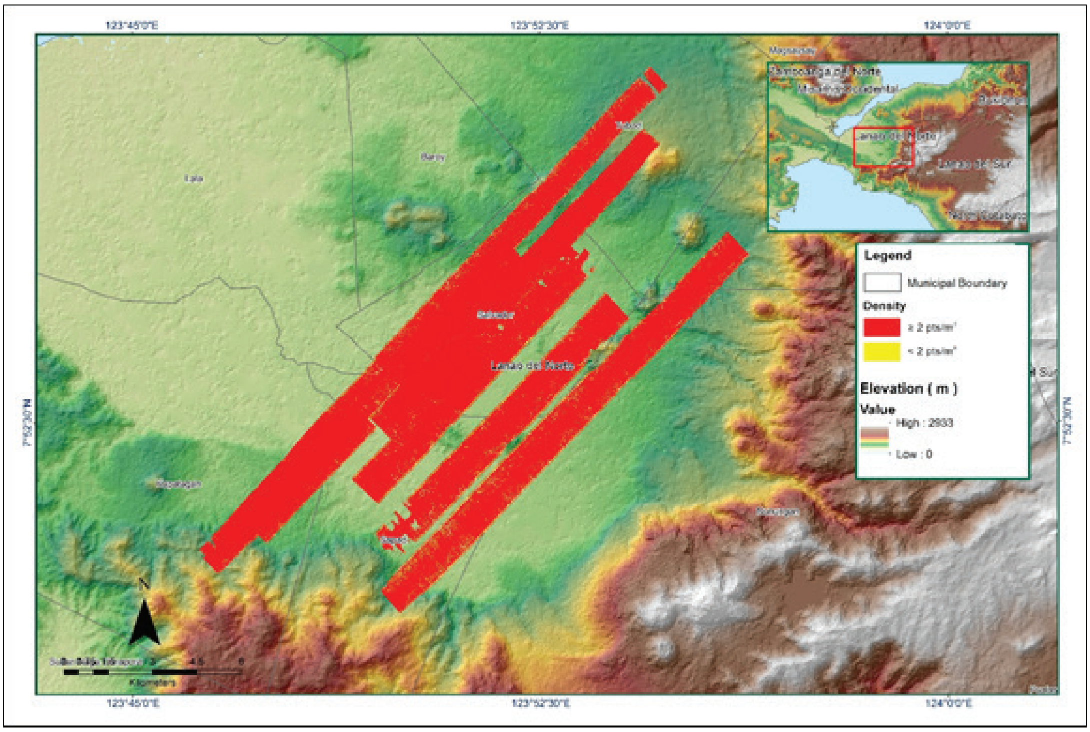


Figure A-8.48 Density map of merged LiDAR data

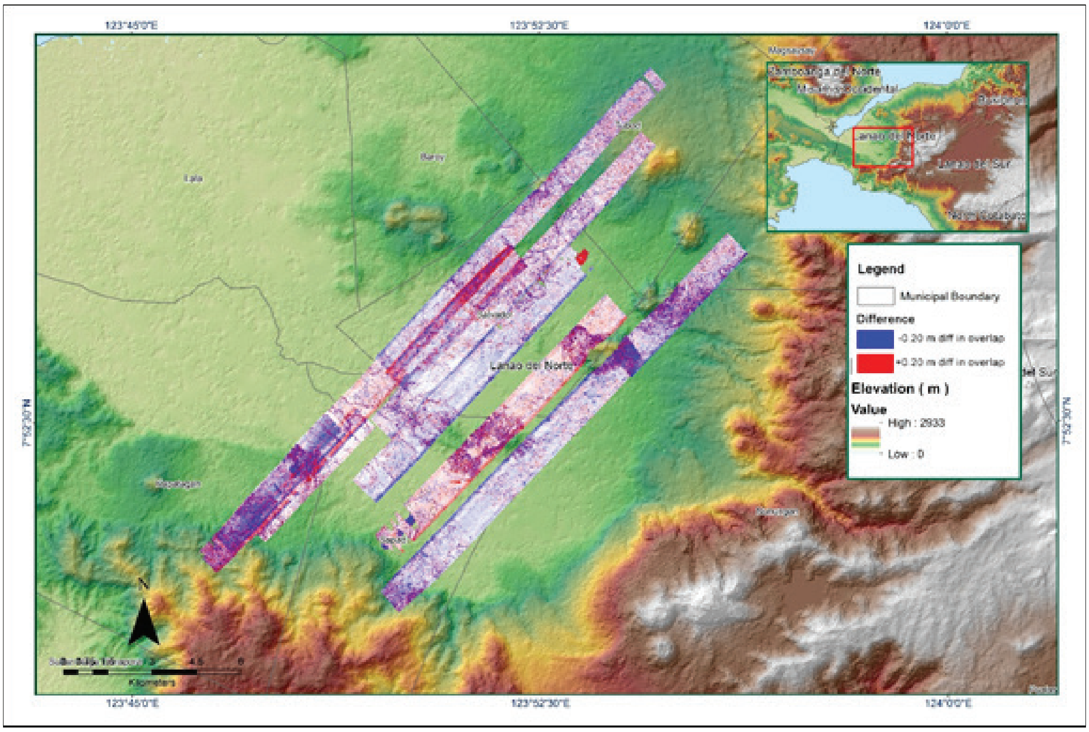


Figure A-8.49 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk71Extension
Inclusive Flights	23104P
Range data size	18.3 GB
POS	287.01 MB
Base data size	116.78 MB
Image	25.87 GB
Transfer date	March 1, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.0
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000243
IMU attitude correction stdev (<0.001deg)	0.001298
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	27.83%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	868.76 m
Minimum Height	63.2 m
Classification (# of points)	
Ground	107,907,148
Low vegetation	96,229,157
Medium vegetation	96,176,102
High vegetation	80,601,347
Building	17,253,174
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Elainne Lopez
Processed by	Engr. Don Matthew Banatin, Engr. Justine Francisco, Engr. Gladys Mae Apat

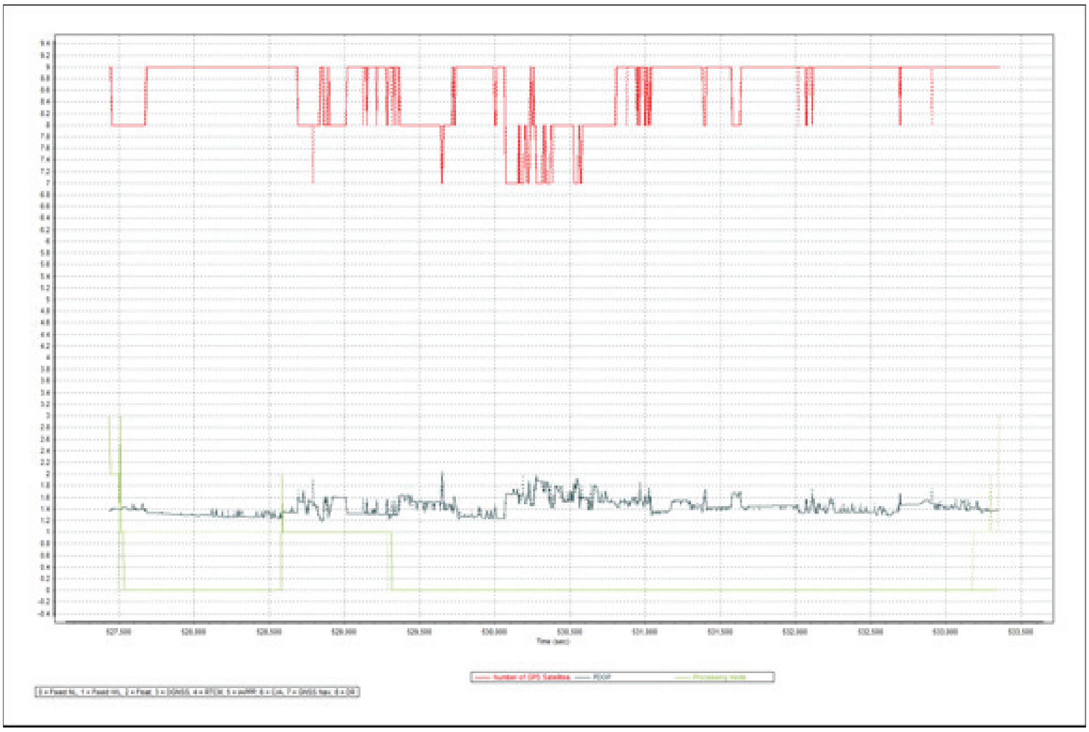


Figure A-8.50 Solution Status

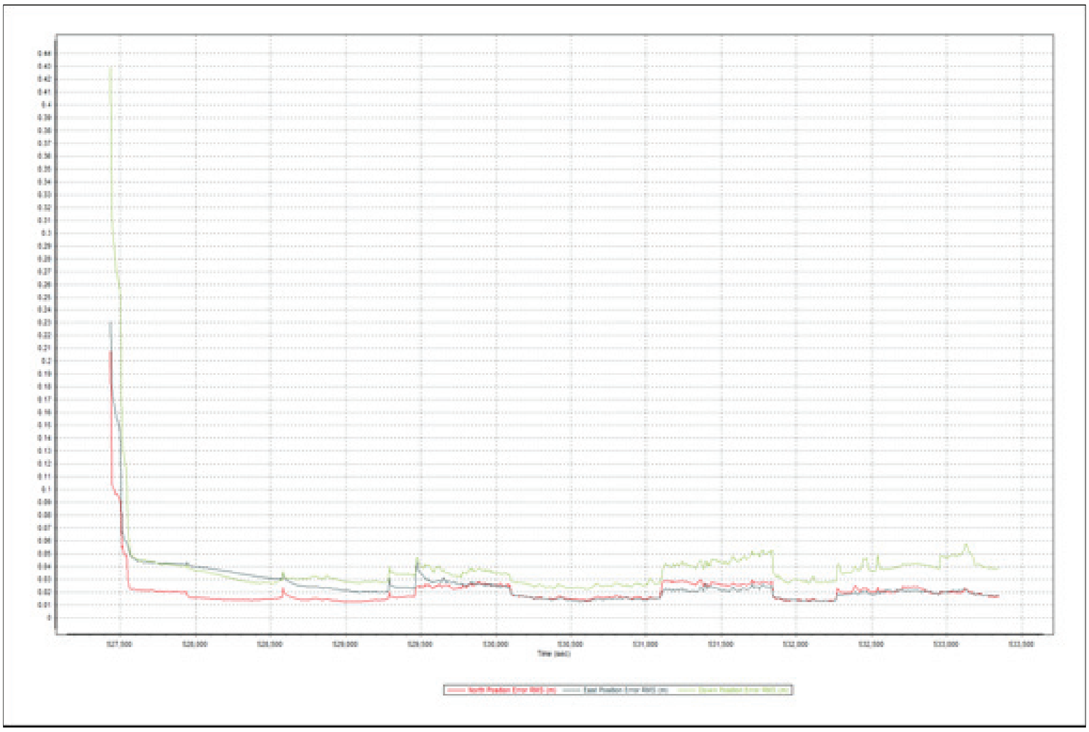


Figure A-8.51 Smoothed Performance Metric Parameters

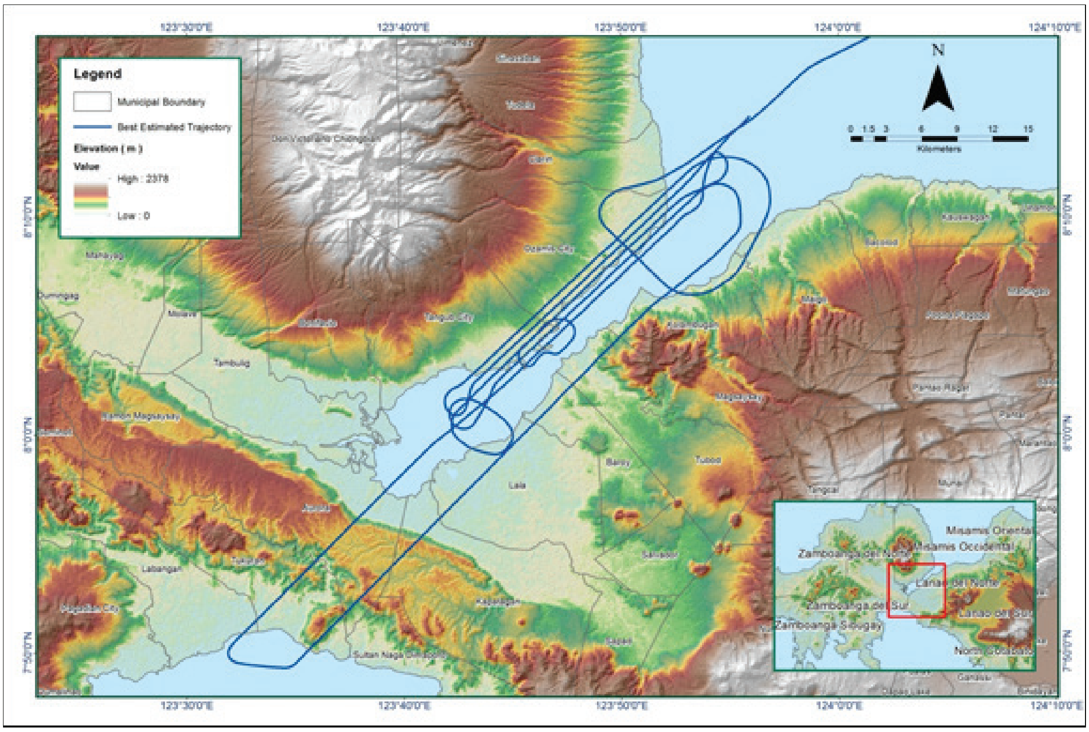


Figure A-8.52 Best Estimated Trajectory

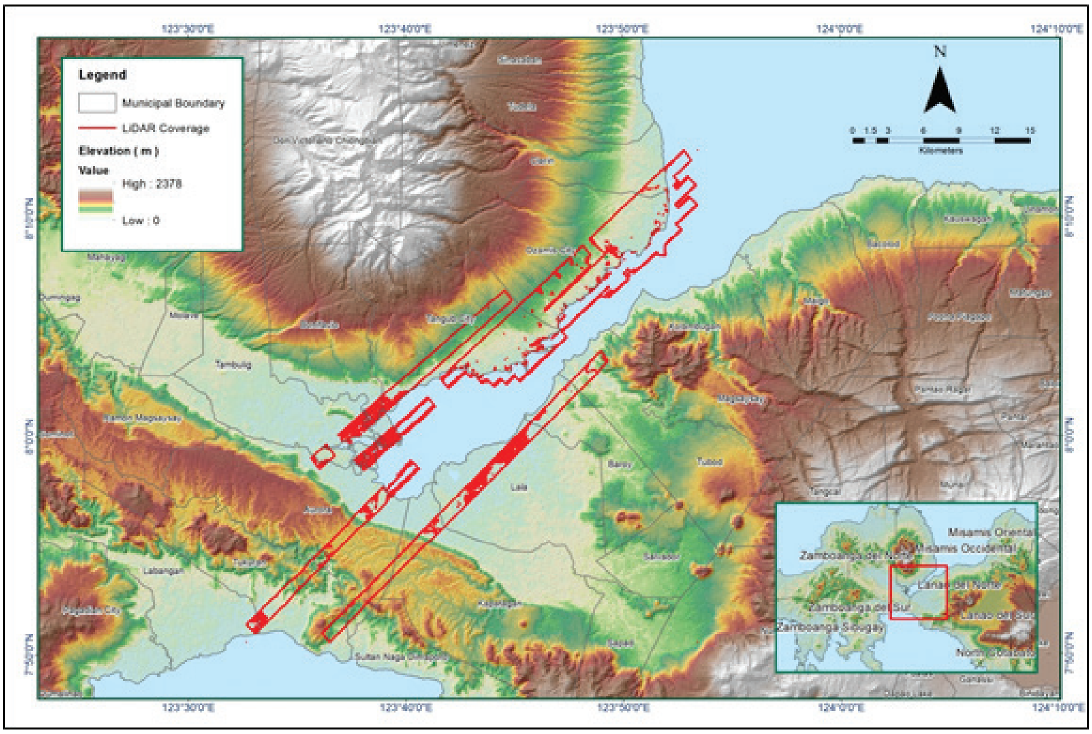


Figure A-8.53 Coverage of LiDAR data

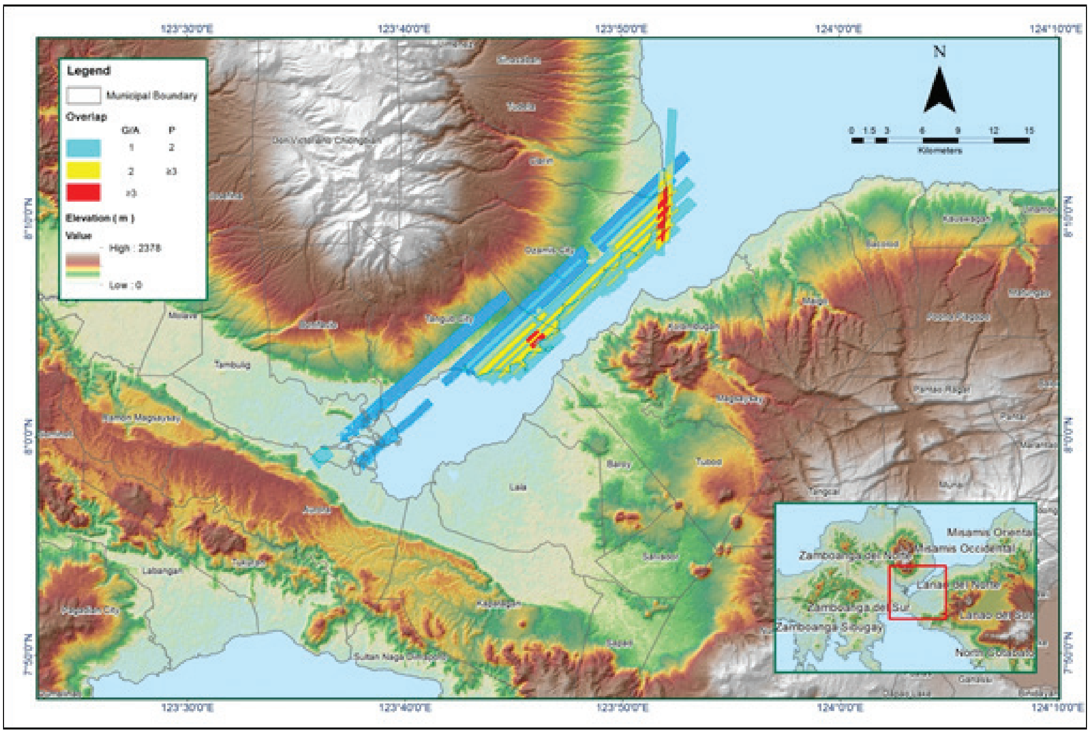


Figure A-8.54 Image of data overlap

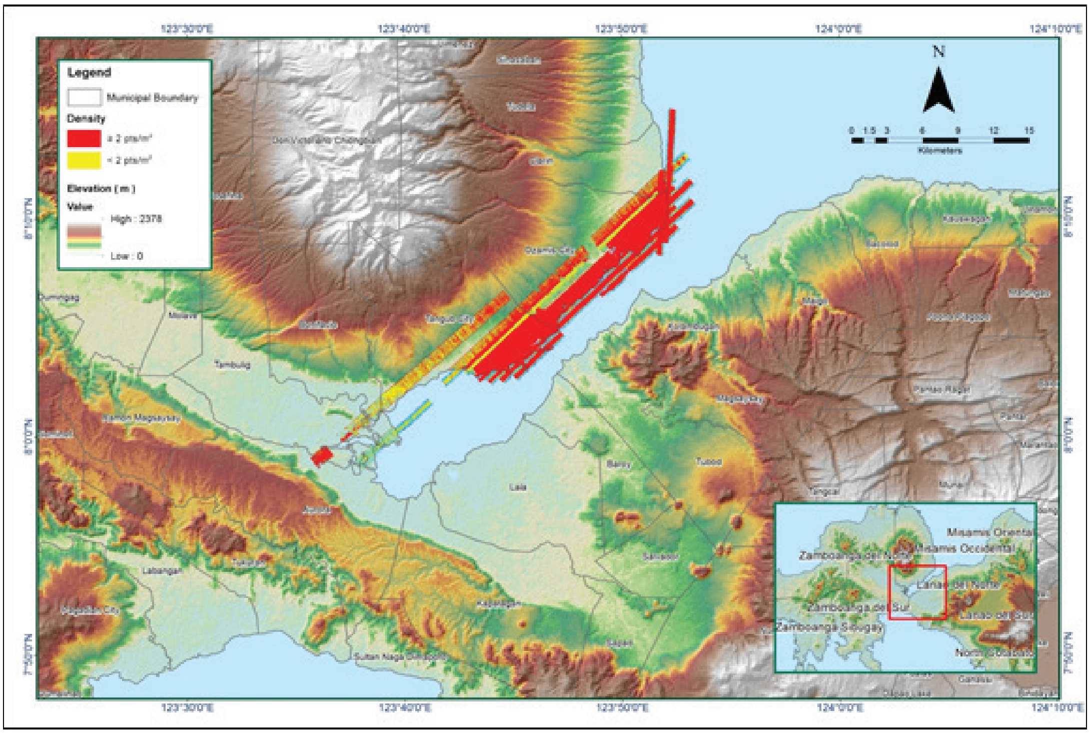


Figure A-8.55 Density map of merged LiDAR data

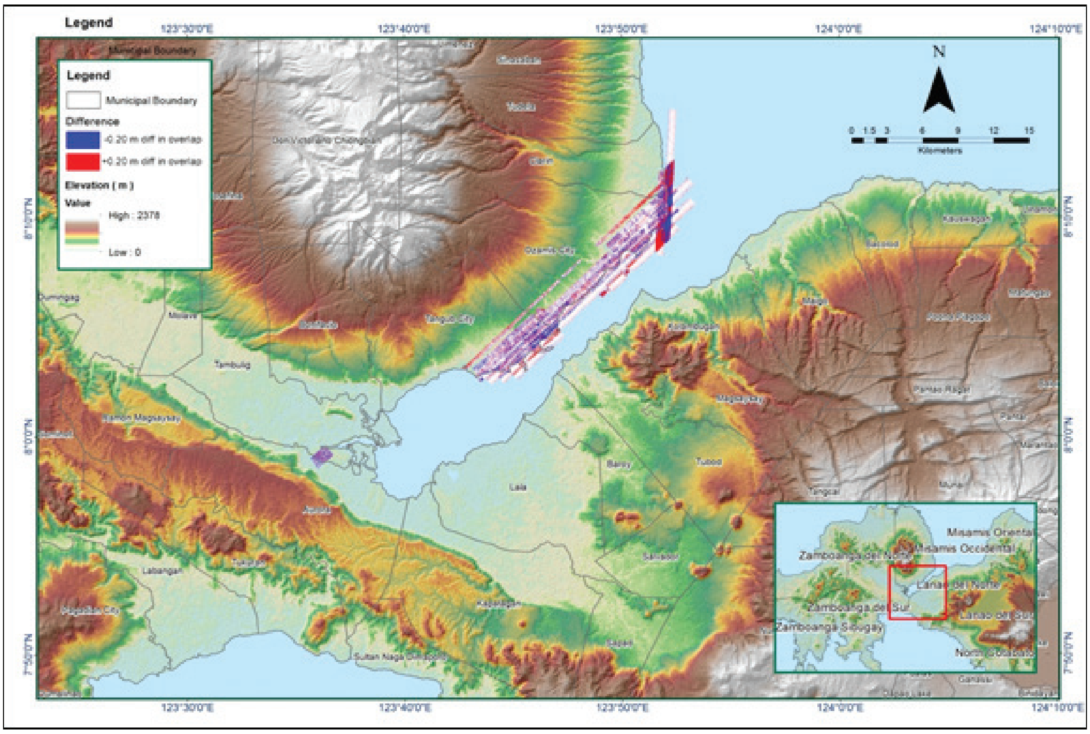


Figure A-8.56 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk71E
Inclusive Flights	1689P
Range data size	27.1 GB
POS	257 MB
Base data size	3.68 MB
Image	n/a
Transfer date	August 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	5.5
RMSE for Down Position (<8.0 cm)	10
Boresight correction stdev (<0.001deg)	0.000536
IMU attitude correction stdev (<0.001deg)	0.001171
GPS position stdev (<0.01m)	0.0079
Minimum % overlap (>25)	35.35%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	253
Maximum Height	476.79
Minimum Height	66.37
Classification (# of points)	
Ground	157,189,225
Low vegetation	118,155,426
Medium vegetation	187,516,392
High vegetation	168,342,412
Building	7,092,549
Orthophoto	
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. John Dill Macapagal
Processed by	Engr. Don Matthew Banatin, Engr. Justine Francisco, Engr. Gladys Mae Apat

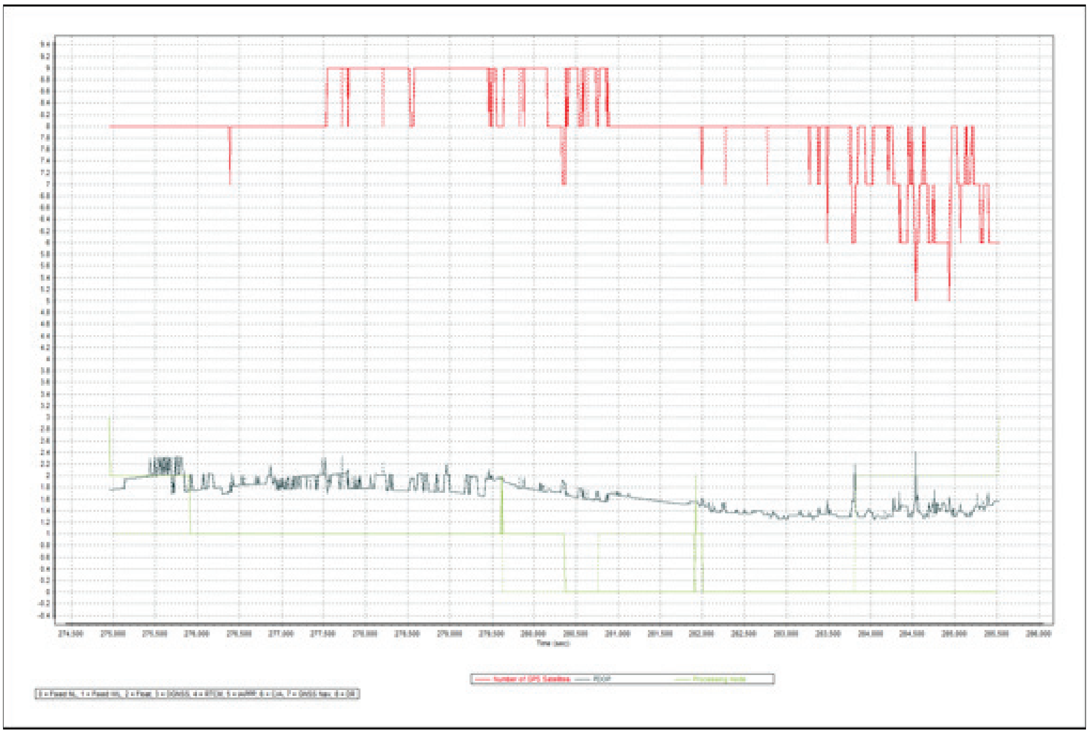


Figure A-8.57 Solution Status

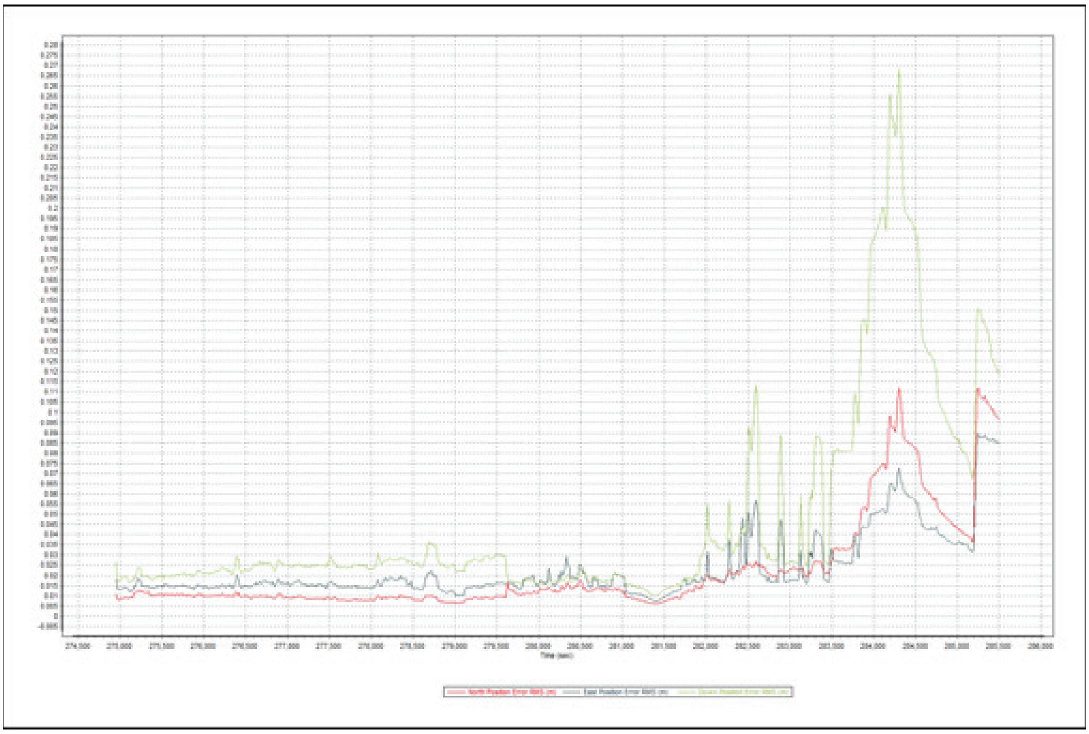


Figure A-8.58 Smoothed Performance Metric Parameters

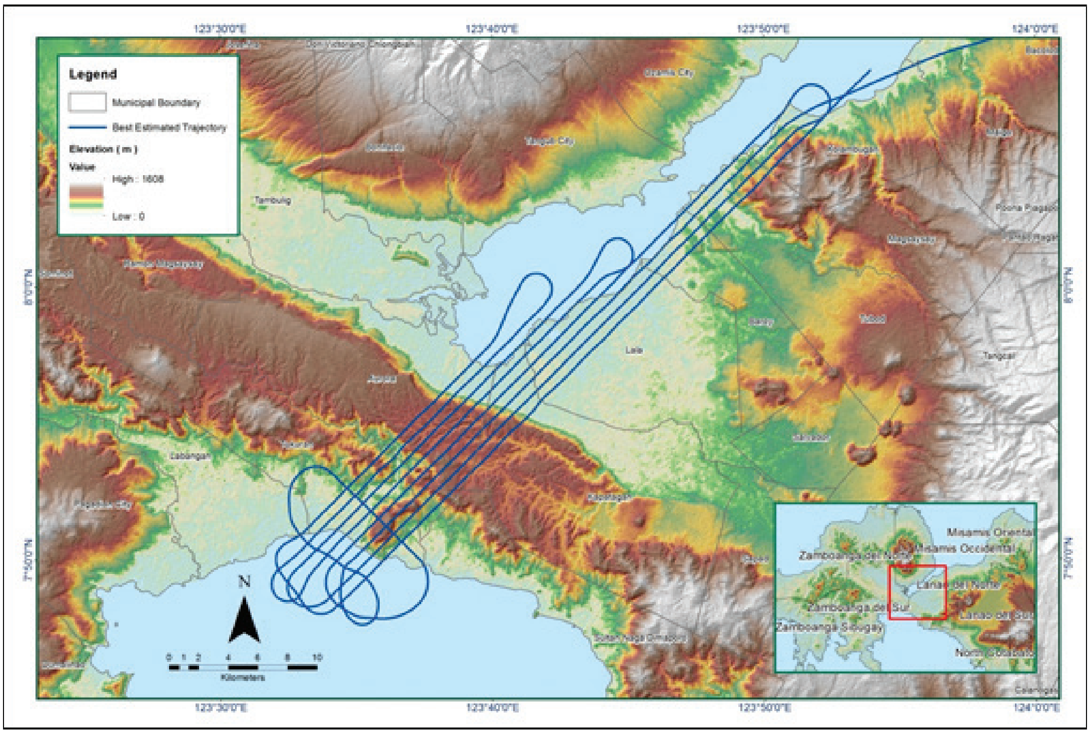


Figure A-8.59 Best Estimated Trajectory

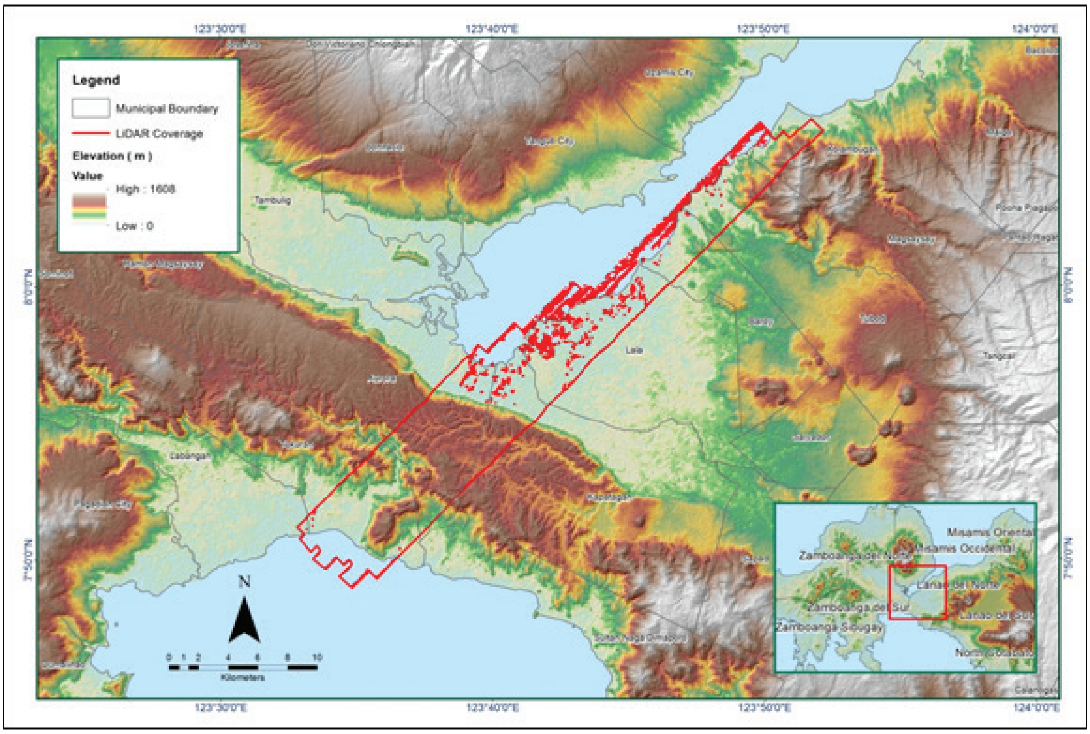


Figure A-8.60 Coverage of LiDAR data

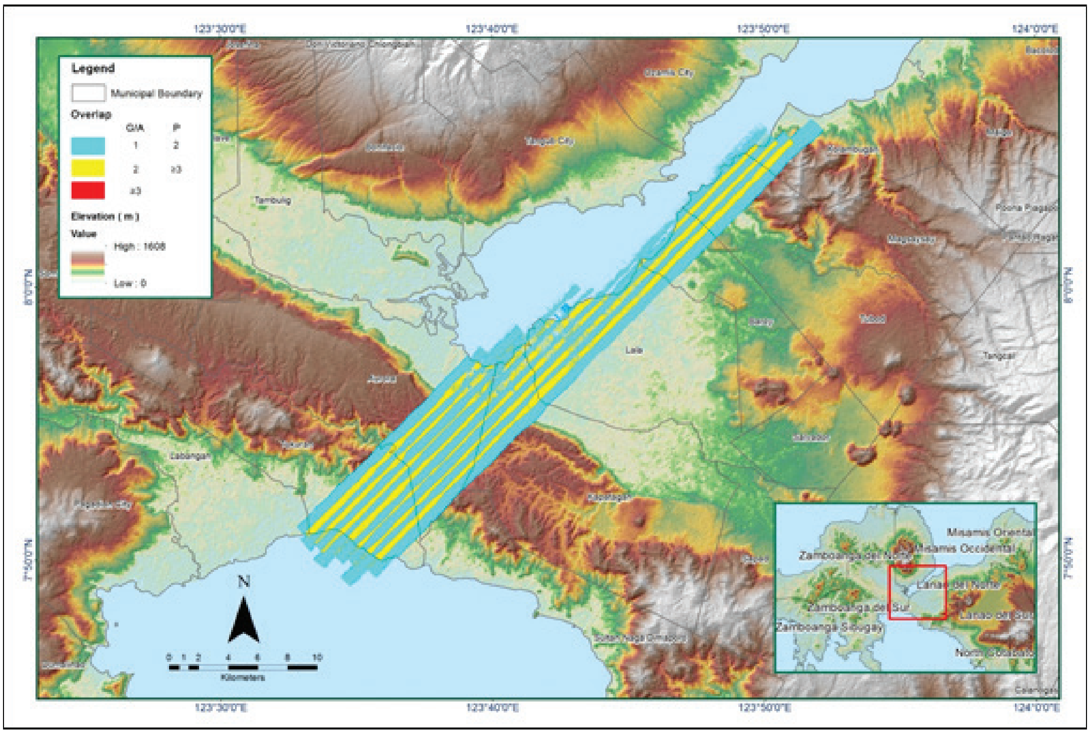


Figure A-8.61 Image of data overlap

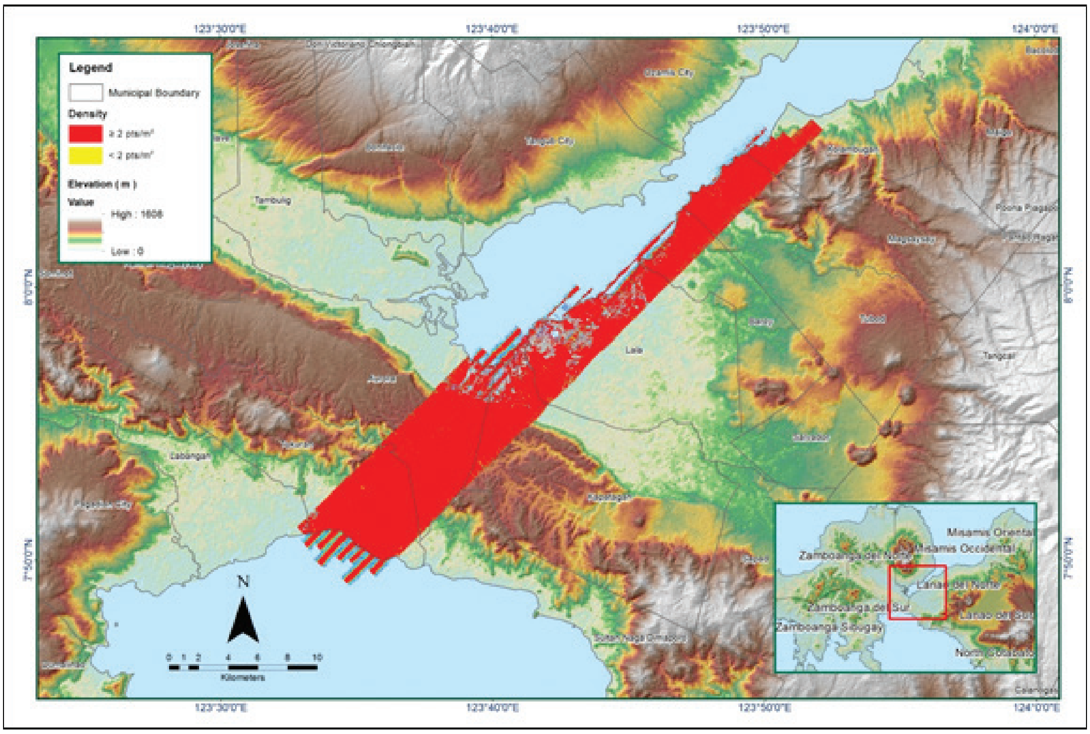


Figure A-8.62 Density map of merged LiDAR data

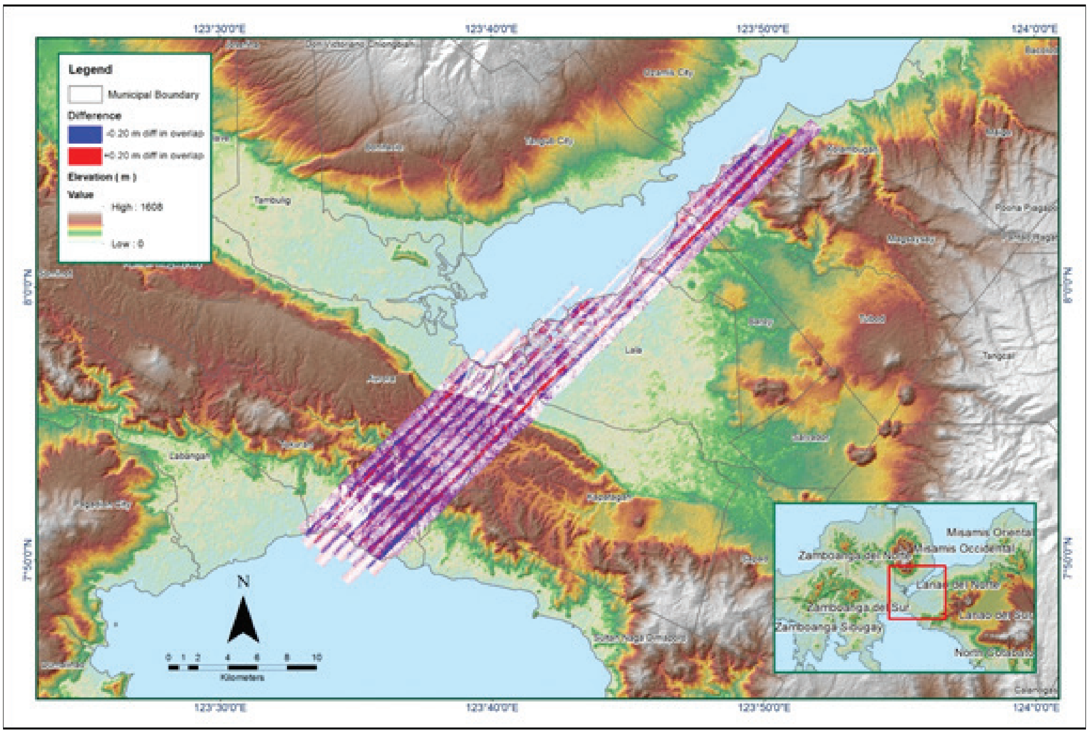


Figure A-8.63 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk71F
Inclusive Flights	1565P, 1549P, 1685P
Range data size	70.3 GB
POS	674 MB
Base data size	23.26 MB
Image	59.1 GB
Transfer date	June 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000471
IMU attitude correction stdev (<0.001deg)	0.004323
GPS position stdev (<0.01m)	0.0198
Minimum % overlap (>25)	51.56%
Ave point cloud density per sq.m. (>2.0)	4.06
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	614
Maximum Height	685.55
Minimum Height	64.65
Classification (# of points)	
Ground	591,908,481
Low vegetation	609,869,904
Medium vegetation	757,441,192
High vegetation	606,070,790
Building	21,867,436
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Engr. John Dill Macapagal

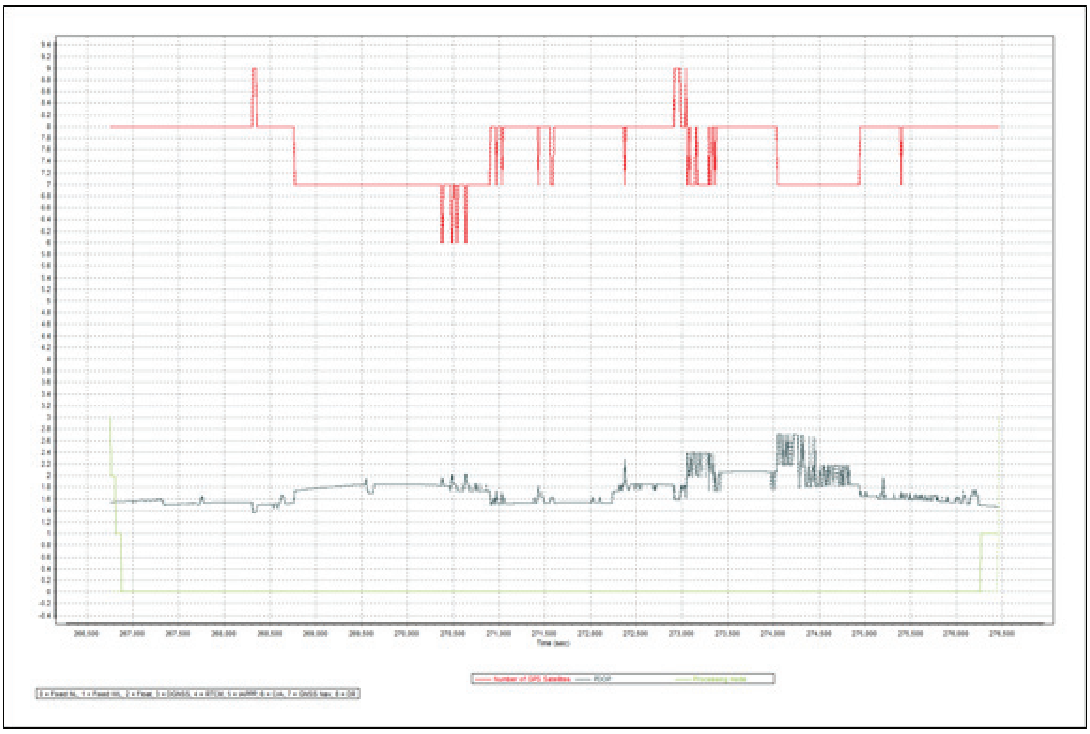


Figure A-8.64 Solution Status

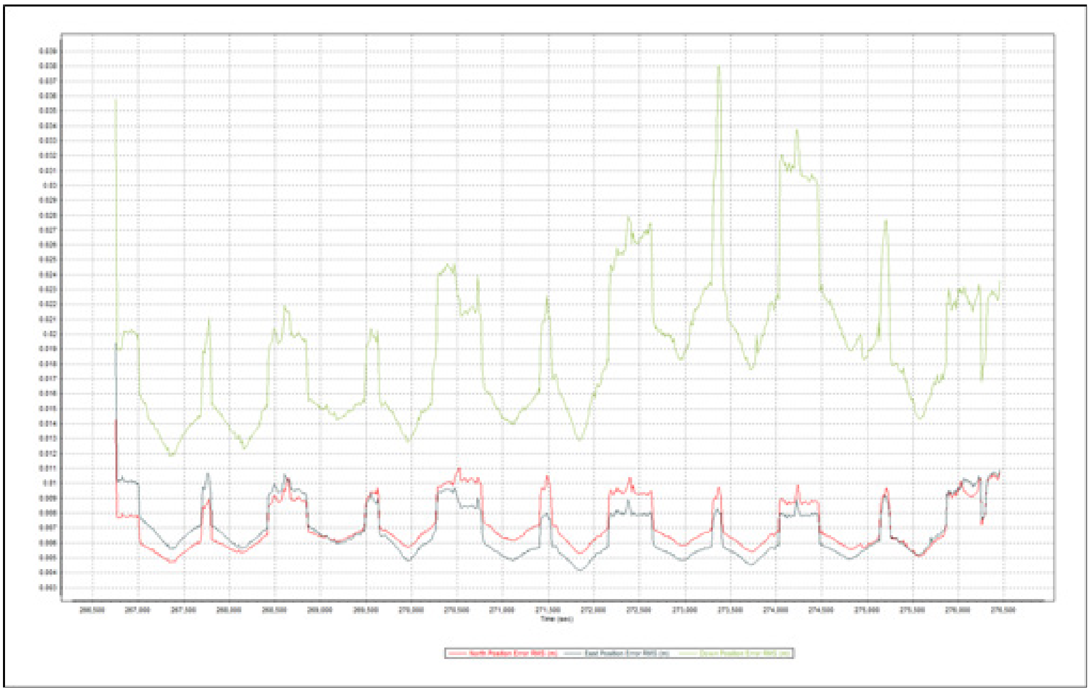


Figure A-8.65 Smoothed Performance Metric Parameters

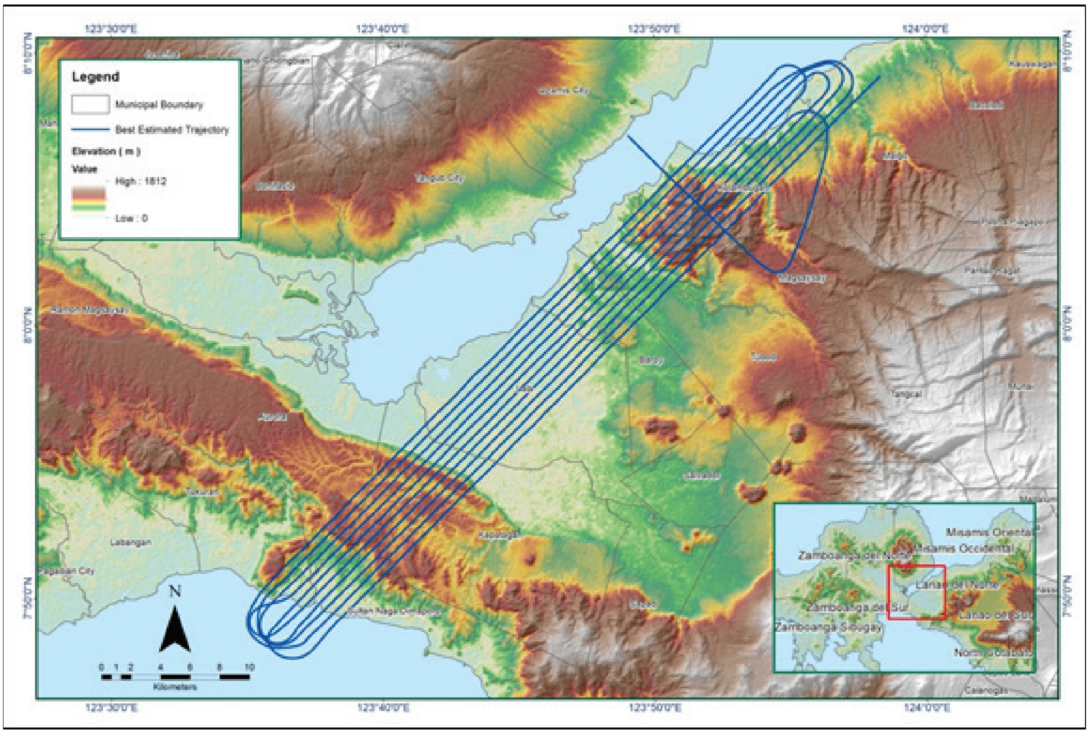


Figure A-8.66 Best Estimated Trajectory

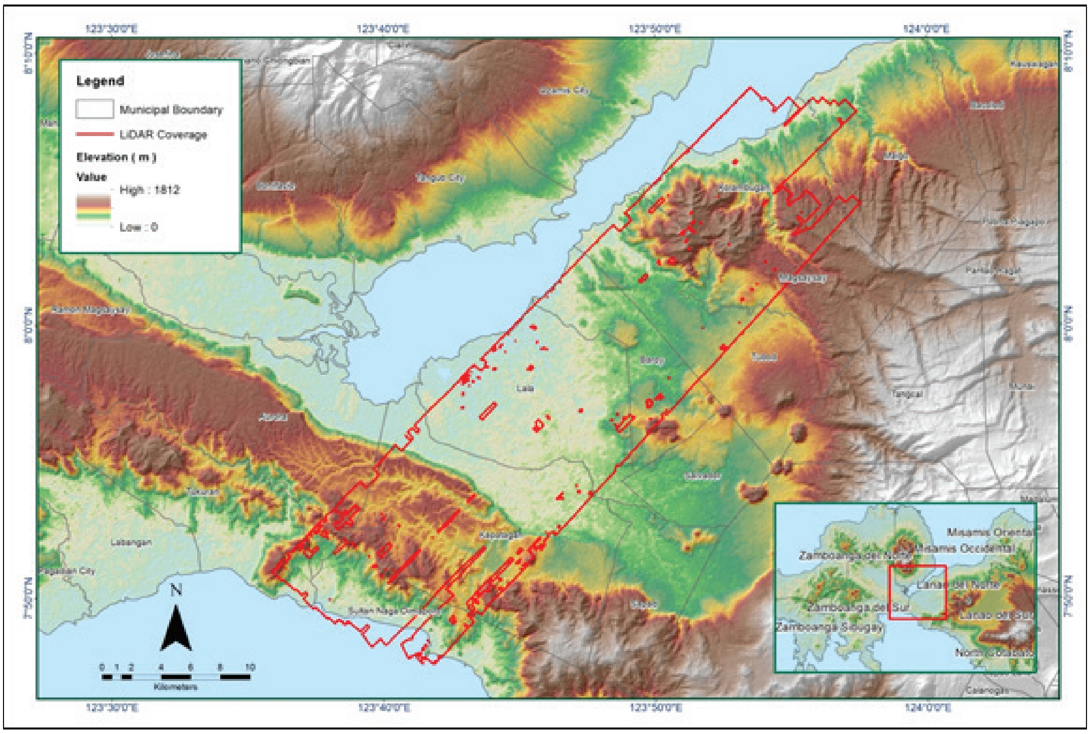


Figure A-8.67 Coverage of LiDAR data

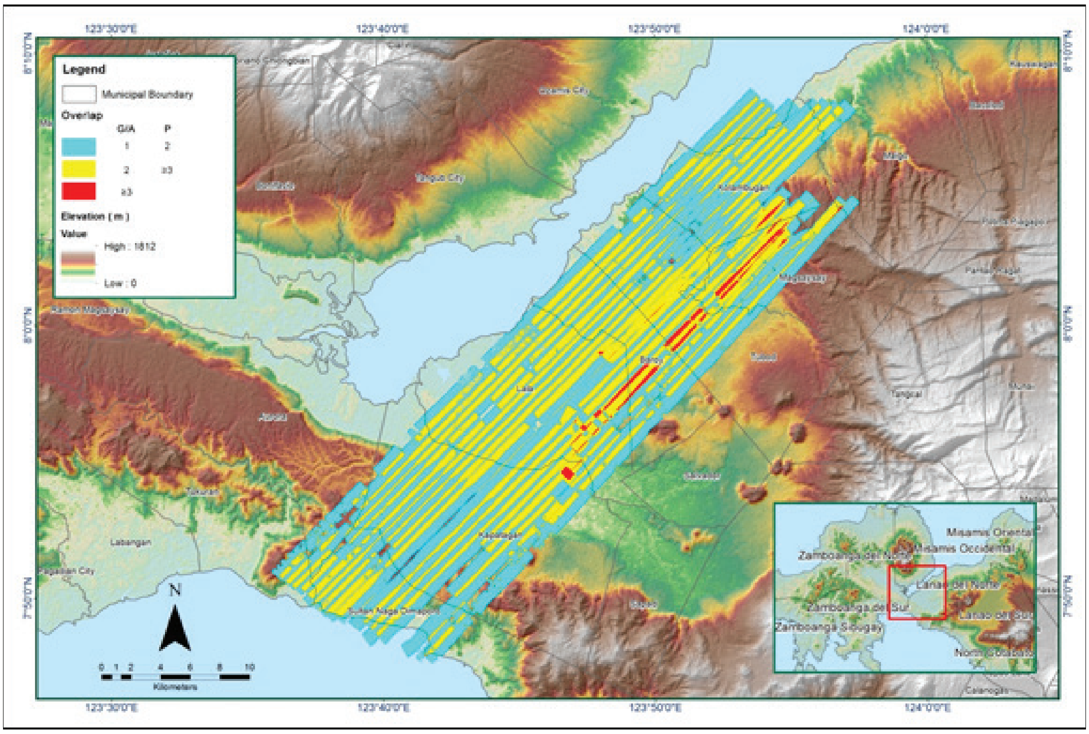


Figure A-8.68 Image of data overlap

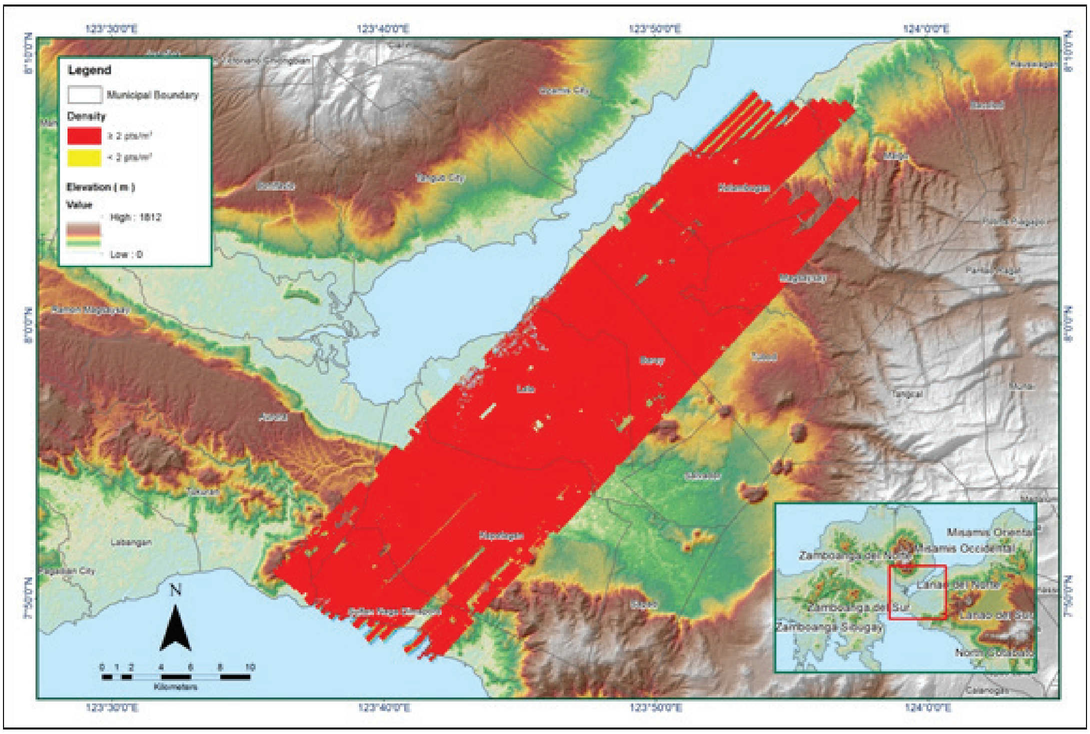


Figure A-8.69 Density map of merged LiDAR data

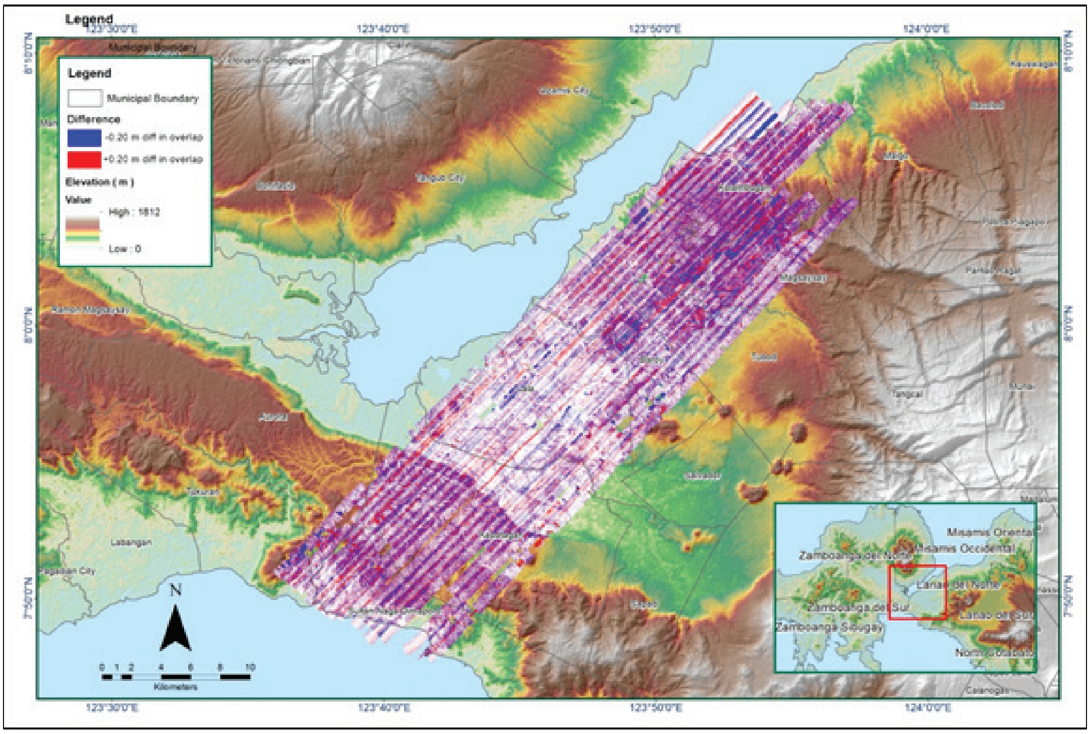


Figure A-8.70 Elevation difference between flight lines

Flight Area	Northern Mindanao
Mission Name	Blk71G
Inclusive Flights	1613P
Range data size	33.2 GB
POS	258 MB
Base data size	5.92 MB
Image	67.3 GB
Transfer date	August 1, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000236
IMU attitude correction stdev (<0.001deg)	0.000781
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	36.24%
Ave point cloud density per sq.m. (>2.0)	6.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	362
Maximum Height	766.63 m
Minimum Height	62.51 m
Classification (# of points)	
Ground	286,954,240
Low vegetation	266,488,104
Medium vegetation	404,520,939
High vegetation	376,191,706
Building	8,947,468
Orthophoto	
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Ma. Ailyn Olanda
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Engr. John Dill Macapagal

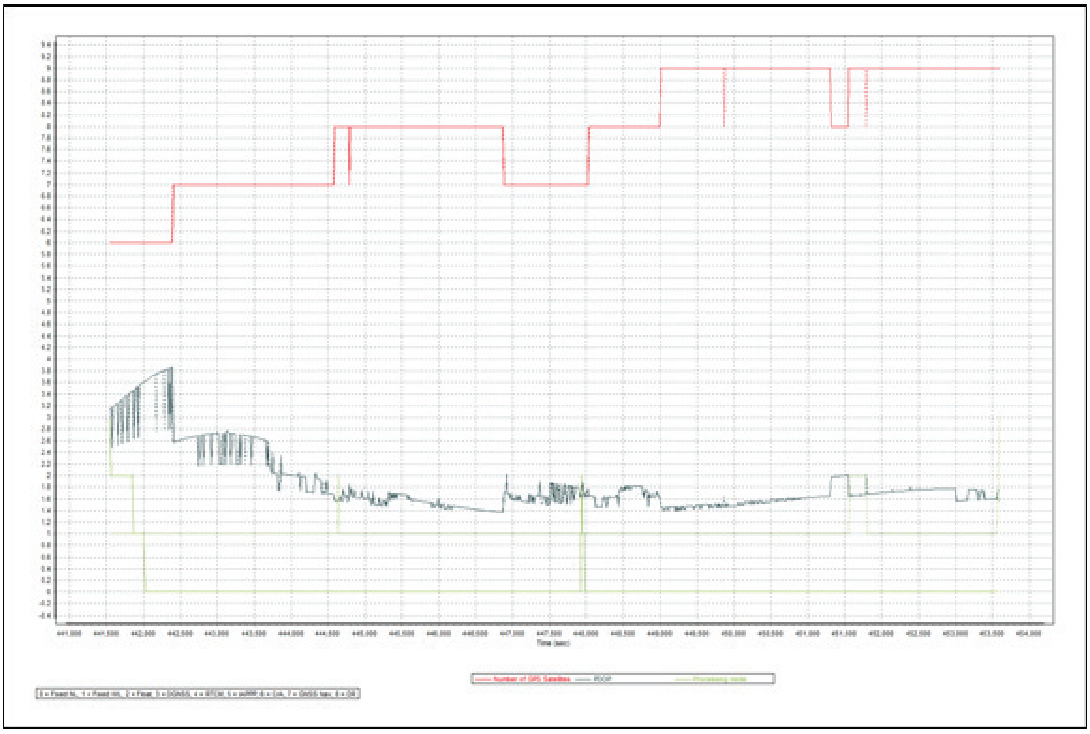


Figure A-8.71 Solution Status

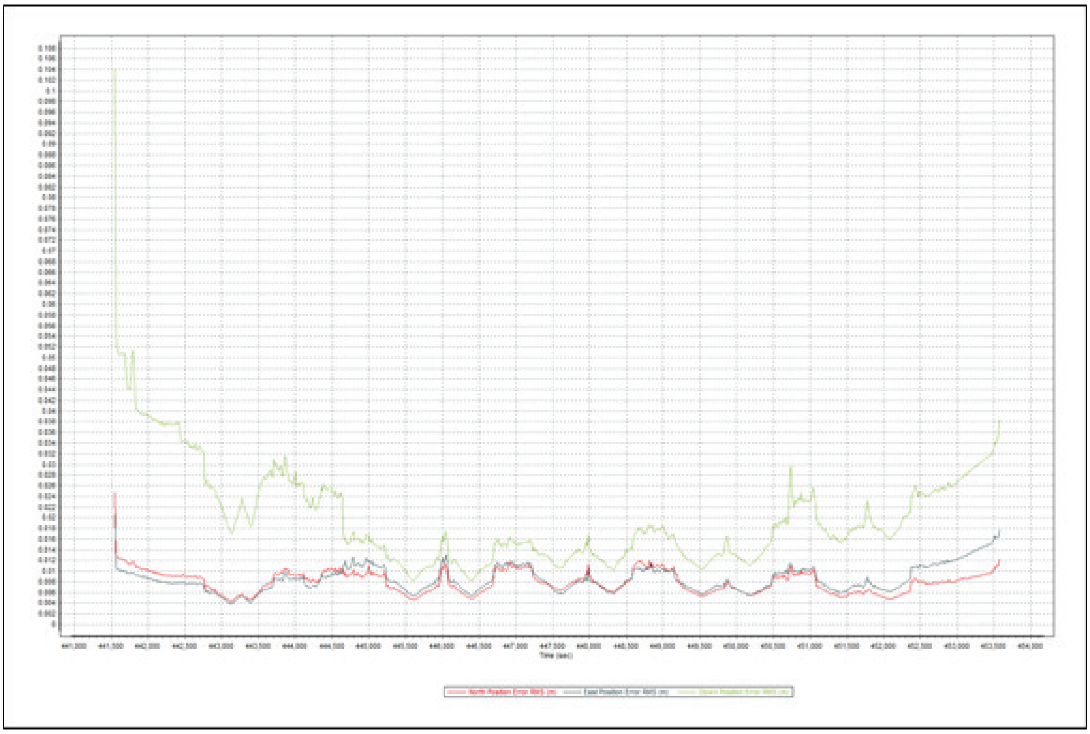


Figure A-8.72 Smoothed Performance Metric Parameters

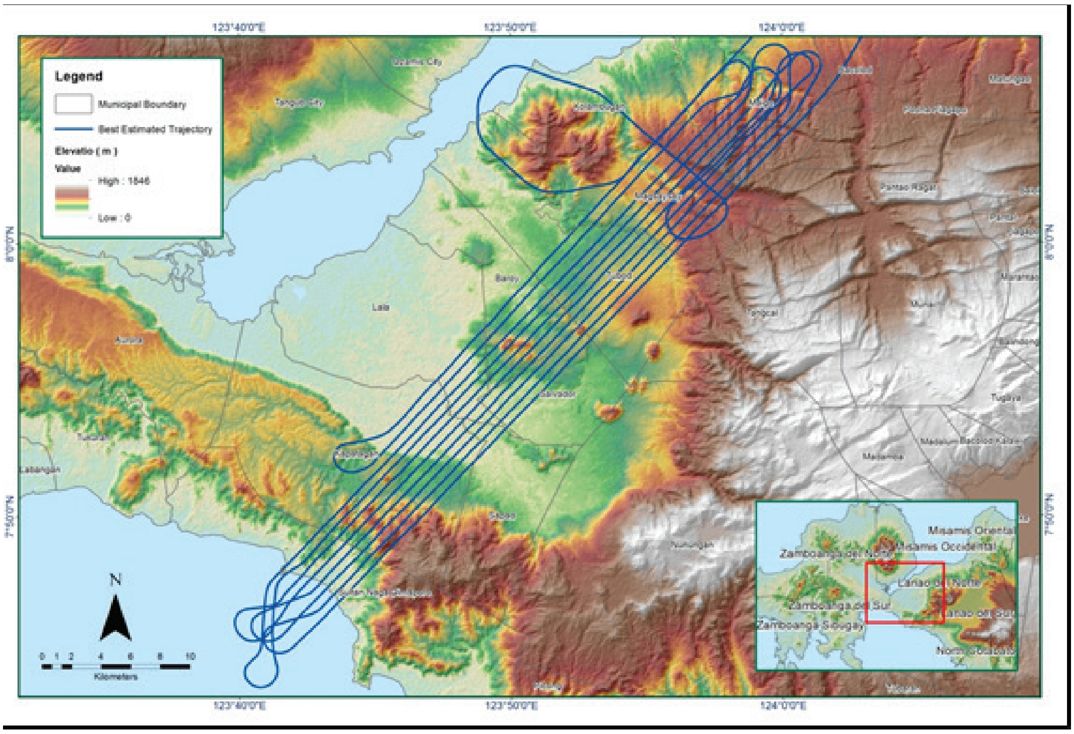


Figure A-8.73 Image of data overlap

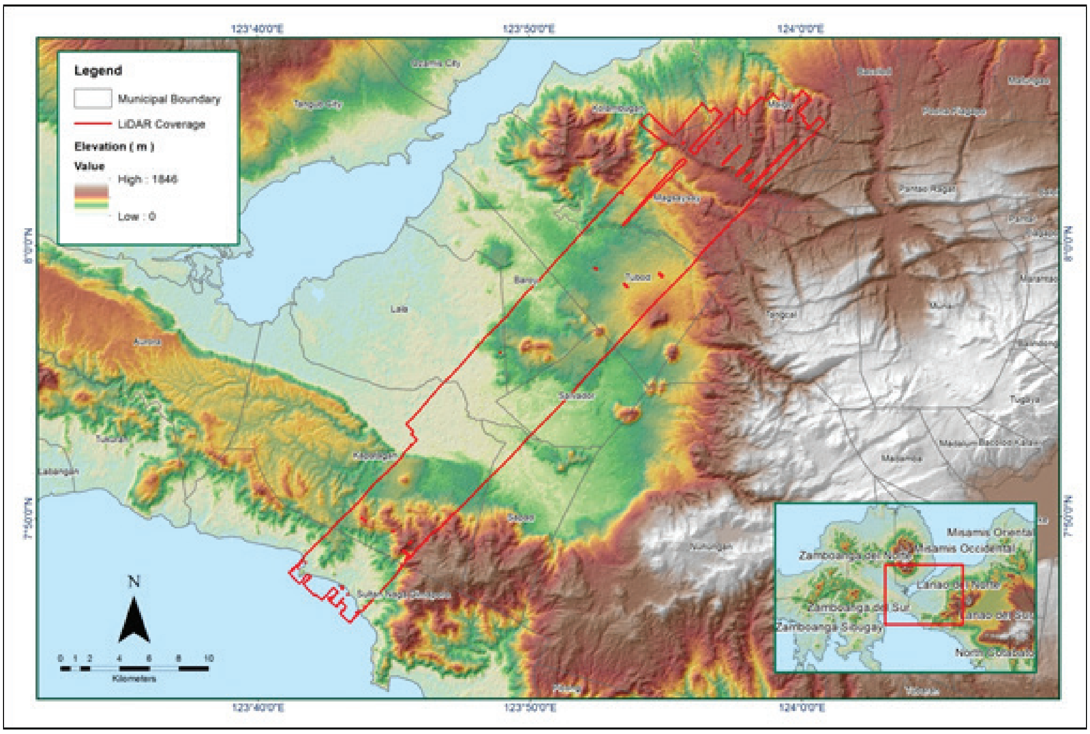


Figure A-8.74 Density map of merged LiDAR data

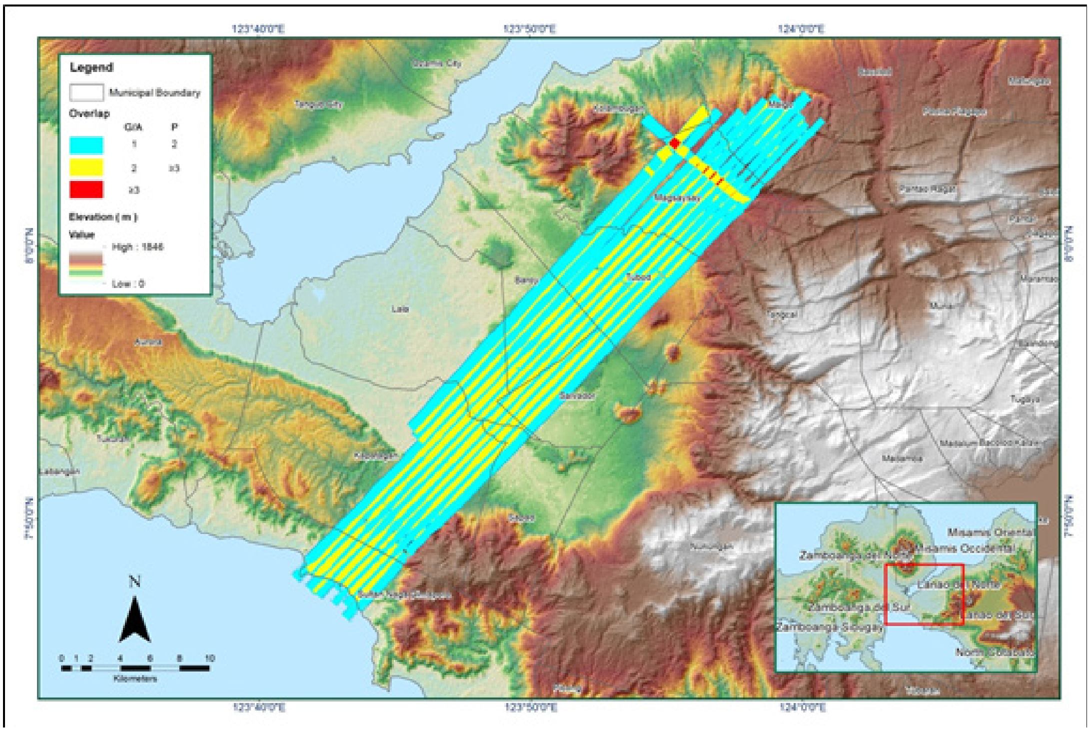


Figure A-8.75 Image of data overlap

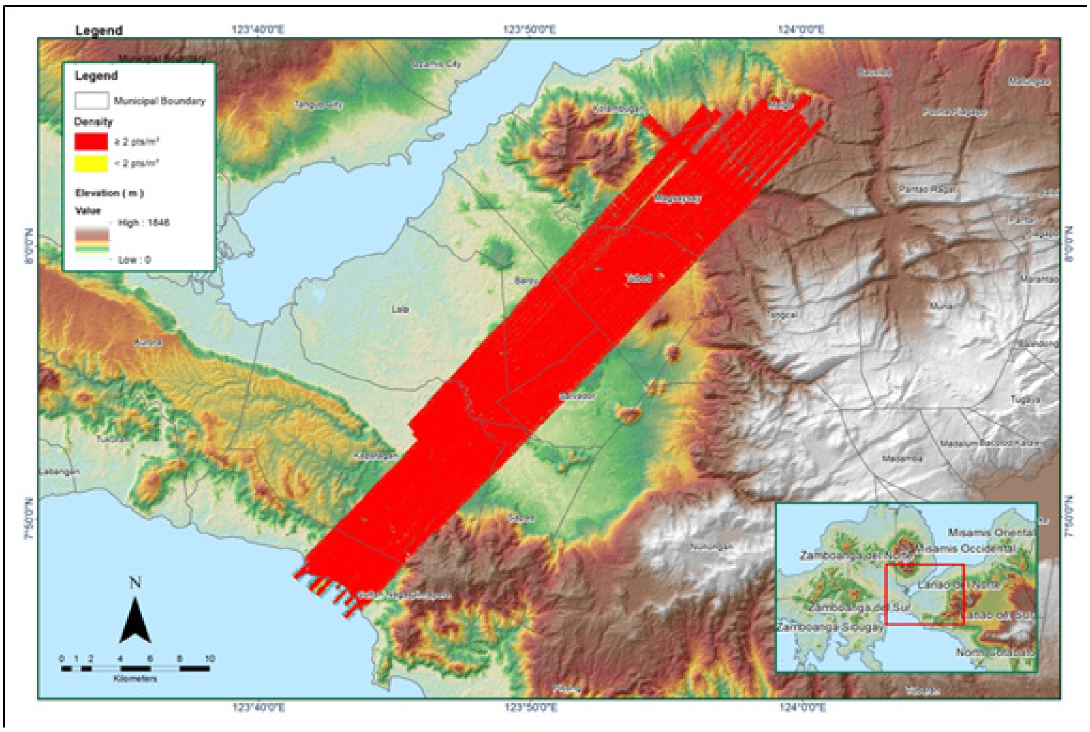


Figure A-8.76 Density map of merged LiDAR data

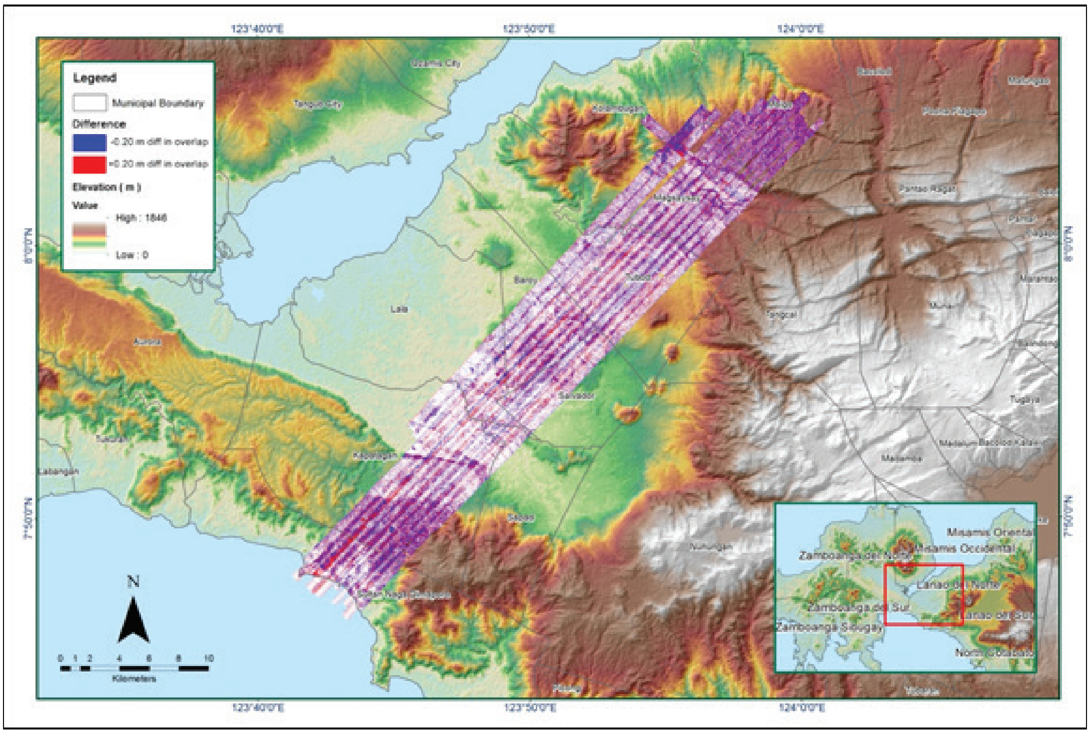


Figure A-8.77 Elevation difference between flight lines

Annex 9. Maranding Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Ab-straction (mm)	Curve Number	Impervious (%)	Time of Concentra-tion (HR)	Storage Coef-ficient (HR)	Initial Type	Initial Dis-charge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W400	16.8927177	67.7853	0	3.474	4.7247	Discharge	1.2145	1	Ratio to Peak	0.5
W420	40.803	75.03332	0	5.14644	6.9992	Discharge	1.7933	1	Ratio to Peak	0.5
W430	16.543	75.38104	0	1.82592	2.4832297	Discharge	0.67700	1	Ratio to Peak	0.5
W440	48.194	69.43055	0	5.4126	7.3611	Discharge	0.46978	1	Ratio to Peak	0.5
W460	41.564	74.415	0	3.79488	5.1611	Discharge	1.3489	1	Ratio to Peak	0.5
W470	21.323	47.67296	0	3.98784	5.4235	Discharge	0.61504	1	Ratio to Peak	0.5
W480	45.684	71.2368	0	4.16604	5.6659	Discharge	0.78810	1	Ratio to Peak	0.5
W490	56.3255351	64.16061	0	3.62172	4.9255	Discharge	0.77293	1	Ratio to Peak	0.5
W510	13.927	78.428	0	10.04904	13.667	Discharge	0.68807	1	Ratio to Peak	0.5
W520	28.243	64.22285	0	4.58916	6.2413	Discharge	0.29883	1	Ratio to Peak	0.5
W550	41.564	74.415	0	2.77476	3.7737	Discharge	0.68440	1	Ratio to Peak	0.5
W560	18.818	72.91858	0	6.0876	8.2791	Discharge	0.91024	1	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Ab-straction (mm)	Curve Number	Impervious (%)	Time of Concentra-tion (HR)	Storage Coef-ficient (HR)	Initial Type	Initial Dis-charge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W580	22.949	68.83252	0	6.23388	3.5467	Discharge	0.54554	1	Ratio to Peak	0.5
W590	41.564	74.415	0	3.2424	8.4780	Discharge	1.3693	1	Ratio to Peak	0.5
W600	57.382	63.53417	0	4.07772	4.4096	Discharge	0.79412	1	Ratio to Peak	0.5
W610	11.061	82.0608	0	2.43756	5.5457	Discharge	0.66875	1	Ratio to Peak	0.5
W620	45.419	71.43299	0	3.45228	3.3151	Discharge	0.42477	1	Ratio to Peak	0.5
W630	34.274	59.66865	0	3.951	4.6951	Discharge	0.55193	1	Ratio to Peak	0.5
W650	38.007	57.16154	0	3.26064	5.3734	Discharge	0.70292	1	Ratio to Peak	0.5
W660	14.2923209	77.98692	0	6.42336	6.5150	Discharge	0.80361	1	Ratio to Peak	0.5
W670	10.104	83.35021	0	2.04708	4.4344	Discharge	0.56458	1	Ratio to Peak	0.5
W680	36.106	58.41172	0	5.5722	8.7357	Discharge	0.65475	1	Ratio to Peak	0.5
W690	40.195	75.53393	0	2.79948	2.7841	Discharge	0.47423	1	Ratio to Peak	0.5
W710	30.967	62.08376	0	2.27496	7.5782	Discharge	1.6292	1	Ratio to Peak	0.5
W720	18.733	73.00653	0	2.05752	3.8073	Discharge	0.47852	1	Ratio to Peak	0.5

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Ab-straction (mm)	Curve Number	Impervious (%)	Time of Concentra-tion (HR)	Storage Coef-ficient (HR)	Initial Type	Initial Dis-charge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W730	36.625	58.06535	0	5.21328	3.0939	Discharge	0.43730	1	Ratio to Peak	0.5
W740	37.910	57.22243	0	2.55468	2.7983	Discharge	0.81457	1	Ratio to Peak	0.5
W750	41.507	74.461	0	3.25404	7.0901	Discharge	1.2075	1	Ratio to Peak	0.5
W760	38.220	57.02489	0	2.08572	3.4744	Discharge	0.39274	1	Ratio to Peak	0.5
W770	32.867	60.67258	0	2.70972	4.4254	Discharge	0.65354	1	Ratio to Peak	0.5
W780	40.935	74.92508	0	2.29548	2.8367	Discharge	0.50733	1	Ratio to Peak	0.5
W800	26.672	60.17738	0	2.60784	3.6853	Discharge	1.1119	1	Ratio to Peak	0.5
W810	34.690	59.37911	0	3.47544	3.1219	Discharge	0.69978	1	Ratio to Peak	0.5
W850	13.9001885	78.46047	0	4.79052	4.7266	Discharge	0.43370	1	Ratio to Peak	0.5
W860	14.4134843	77.84215	0	2.67732	3.6411	Discharge	0.81824	1	Ratio to Peak	0.5

Annex 10. Maranding Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	9390.2	0.0458972	0.040	Trapezoid	43.14	1
R130	Automatic Fixed Interval	788.41	0.0160855	0.040	Trapezoid	7.934	1
R140	Automatic Fixed Interval	468.70	.000451763898	0.040	Trapezoid	19.98	1
R200	Automatic Fixed Interval	2667.2	0.0076918	0.040	Trapezoid	32.34	1
R210	Automatic Fixed Interval	8558.1	0.0011039	0.040	Trapezoid	32.2	1
R220	Automatic Fixed Interval	3114.9	0.0029855	0.040	Trapezoid	22.06	1
R230	Automatic Fixed Interval	6397.5	0.0030730	0.040	Trapezoid	28.48	1
R240	Automatic Fixed Interval	1793.3	0.0018726	0.040	Trapezoid	7.246	1
R290	Automatic Fixed Interval	843.26	0.0336655	0.040	Trapezoid	19.3	1
R300	Automatic Fixed Interval	6180.7	0.0064050	0.040	Trapezoid	6.36	1
R350	Automatic Fixed Interval	5333.2	0.0501623	0.040	Trapezoid	30.84	1
R370	Automatic Fixed Interval	4785.8	0.0751335	0.040	Trapezoid	32.78	1
R380	Automatic Fixed Interval	3337.1	0.0531706	0.040	Trapezoid	30.84	1
R390	Automatic Fixed Interval	8469.5	0.0444460	0.040	Trapezoid	33.12	1
R40	Automatic Fixed Interval	1059.4	0.0225242	0.040	Trapezoid	26.5	1
R60	Automatic Fixed Interval	981.84	0.0015347	0.040	Trapezoid	19.6	1
R70	Automatic Fixed Interval	2864.9	0.0171491	0.040	Trapezoid	28.44	1
R80	Automatic Fixed Interval	671.42	0.0098189	0.040	Trapezoid	28.6	1
R830	Automatic Fixed Interval	3300.9	0.0164784	0.040	Trapezoid	37.22	1
R870	Automatic Fixed Interval	6009.1	0.0185912	0.040	Trapezoid	29.64	1
R90	Automatic Fixed Interval	4377.2	0.0089876	0.040	Trapezoid	37.22	1

Annex 11. Maranding Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
2	8.007788	123.7717	0.03	0.4	-0.37	2011	5-Year
3	8.008853	123.7701	0.03	0.41	-0.38		5-Year
4	8.008981	123.7701	0.03	0.43	-0.4		5-Year
5	8.009294	123.77	0.03	0.41	-0.38	2009	5-Year
6	8.009422	123.7698	0.03	0.54	-0.51		5-Year
7	8.009585	123.7694	0.03	0.19	-0.16		5-Year
8	8.01069	123.7673	0.03	0.42	-0.39		5-Year
9	7.88947	123.7622	0.03	0.58	-0.55	Yolanda / November 2015	5-Year
10	7.88869	123.7743	0.03	0.16	-0.13	2010	5-Year
11	7.876198	123.8141	0.03	1.3	-1.27	2013	5-Year
12	7.984674	123.7959	0.03	1.8	-1.77		5-Year
13	7.926459	123.6908	0.03	1.1	-1.07	Lando / August 2015	5-Year
14	7.923024	123.6876	0.03	1.55	-1.52	Lando / August 2015	5-Year
15	7.92303	123.6874	0.03	0.6	-0.57	Lando / August 2015	5-Year
16	7.922939	123.6873	0.03	0.6	-0.57	Lando / August 2015	5-Year
17	8.011248	123.7678	0.03	0.53	-0.5	2011	5-Year
18	7.898086	123.7715	0.03	0.38	-0.35	Yolanda / November 2015	5-Year
19	8.008067	123.773	0.03	0.2	-0.17	2011	5-Year
20	7.916233	123.7867	0.07	0.72	-0.65	2011	5-Year
21	7.875964	123.8142	0.03	1.3	-1.27	Pablo / November 2012	5-Year
22	8.009878	123.7687	0.03	0.27	-0.24		5-Year
23	8.010399	123.7687	0.06	0.27	-0.21		5-Year
24	8.010392	123.7671	0.08	0.72	-0.64		5-Year
25	7.924133	123.6834	0.07	0.4	-0.33	Lando / August 2015	5-Year
26	8.007821	123.7713	0.03	0.67	-0.64	2011	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
27	7.924316	123.6835	0.1	0.7	-0.6	Lando / August 2015	5-Year
28	7.924293	123.6836	0.1	0.89	-0.79	Lando / August 2015	5-Year
29	7.89798	123.7715	0.09	0.4	-0.31	Yolanda / November 2015	5-Year
30	7.890638	123.765	0.03	1.75	-1.72	Yolanda / November 2015	5-Year
31	7.926212	123.6925	0.14	1	-0.86	Lando / August 2015	5-Year
32	7.926383	123.6918	0.07	1.1	-1.03	Lando / August 2015	5-Year
33	8.006125	123.7735	0.06	0.75	-0.69	2011	5-Year
34	7.926292	123.6924	0.15	1.1	-0.95	Lando / August 2015	5-Year
35	7.926154	123.6926	0.16	1.1	-0.94	Lando / August 2015	5-Year
36	7.926376	123.692	0.11	1.1	-0.99	Lando / August 2015	5-Year
37	7.905192	123.7709	0.1	0.37	-0.27	Yolanda / November 2015	5-Year
38	7.92258	123.6873	0.14	0.34	-0.2	Lando / August 2015	5-Year
39	7.904212	123.7713	0.11	0.43	-0.32	Yolanda / November 2015	5-Year
40	7.895726	123.7691	0.14	0.2	-0.06	Yolanda / November 2015	5-Year
41	7.926413	123.6913	0.13	1.1	-0.97	Lando / August 2015	5-Year
42	8.007878	123.7735	0.04	0.12	-0.08	2012	5-Year
43	7.89553	123.7699	0.14	0.2	-0.06	Yolanda / November 2015	5-Year
44	7.926415	123.6915	0.14	1.1	-0.96	Lando / August 2015	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
45	8.007918	123.771	0.14	0.67	-0.53		5-Year
46	8.007869	123.771	0.14	1.64	-1.5		5-Year
47	7.915393	123.702	0.23	0.56	-0.33	August 2015	5-Year
48	8.009722	123.769	0.16	0.51	-0.35		5-Year
49	8.011805	123.7631	0.24	0.69	-0.45		5-Year
50	7.915007	123.7038	0.26	0.3	-0.04	August 2015	5-Year
51	7.901476	123.7689	0.15	0.072	0.078	Yolanda / November 2015	5-Year
52	7.926416	123.6917	0.2	1.1	-0.9	Lando / August 2015	5-Year
53	7.899485	123.7736	0.03	0.15	-0.12		5-Year
54	7.926368	123.6922	0.21	1.1	-0.89	Lando / August 2015	5-Year
55	7.926336	123.6921	0.21	1.1	-0.89	Lando / August 2015	5-Year
56	7.92635	123.6922	0.21	1.1	-0.89	Lando / August 2015	5-Year
57	7.895501	123.7685	0.23	0.2	0.03	Yolanda / November 2015	5-Year
58	8.011914	123.7631	0.26	0.69	-0.43		5-Year
59	7.882893	123.8087	0.09	1.08	-0.99	Pablo / November 2012	5-Year
60	7.916952	123.707	0.21	0.54	-0.33	August 2015	5-Year
61	8.011774	123.7632	0.29	0.49	-0.2		5-Year
62	7.891492	123.7654	0.13	0.16	-0.03	2011	5-Year
63	7.901485	123.769	0.24	0.072	0.168	Yolanda / November 2015	5-Year
64	8.011763	123.7639	0.33	0.62	-0.29		5-Year
65	8.011916	123.7631	0.35	0.62	-0.27	2011	5-Year
66	7.899302	123.7741	0.03	0.15	-0.12		5-Year
67	7.895651	123.7696	0.33	0.38	-0.05	Yolanda / November 2015	5-Year
68	7.90502	123.7712	0.32	0.43	-0.11	Yolanda / November 2015	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
69	7.904041	123.7705	0.29	0.05	0.24	Yolanda / November 2015	5-Year
70	7.923345	123.69	0.16	0.47	-0.31		5-Year
71	7.898449	123.7754	0.03	0.2	-0.17		5-Year
72	7.883112	123.8084	0.24	1.08	-0.84	Pablo / November 2012	5-Year
73	7.923328	123.69	0.19	0.85	-0.66	Lando / August 2015	5-Year
74	8.013006	123.7629	0.43	0.49	-0.06		5-Year
75	7.898736	123.7756	0.06	0.38	-0.32		5-Year
76	7.898853	123.7748	0.05	0.2	-0.15		5-Year
77	7.89997	123.7738	0.28	0.28	0		5-Year
78	8.007792	123.7711	0.44	0.67	-0.23		5-Year
79	7.898566	123.7758	0.06	0.15	-0.09		5-Year
80	7.883193	123.8085	0.32	1.08	-0.76	Pablo / November 2012	5-Year
81	7.886652	123.8052	0.4	1.02	-0.62	Pablo / November 2012	5-Year
82	7.905038	123.7713	0.47	0.43	0.04	Yolanda / November 2015	5-Year
83	7.904985	123.7714	0.47	0.43	0.04	Yolanda / November 2015	5-Year
84	7.921037	123.7767	0.03	0.1	-0.07		5-Year
85	7.883141	123.8078	0.41	1.08	-0.67	Pablo / November 2012	5-Year
86	7.898377	123.7751	0.11	0.2	-0.09	Yolanda / November 2015	5-Year
87	7.980171	123.7929	0.03	2	-1.97		5-Year
88	7.909178	123.7714	0.55	0.7	-0.15	Yolanda / November 2015	5-Year
89	7.898844	123.7745	0.23	0.15	0.08		5-Year
90	7.921636	123.7772	0.03	0.4	-0.37	Sendong / December 2011	5-Year
91	7.89852	123.7756	0.19	0.2	-0.01		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
92	7.889216	123.7745	0.42	0.79	-0.37	Yolanda / November 2015	5-Year
93	7.916166	123.7768	0.17	0.47	-0.3	Yolanda / November 2015	5-Year
94	7.888988	123.7599	0.45	0.58	-0.13	Yolanda / November 2015	5-Year
95	7.888591	123.8047	0.03	0.3	-0.27	Pablo / November 2012	5-Year
96	7.898437	123.7754	0.21	0.2	0.01		5-Year
97	7.898557	123.7754	0.22	0.45	-0.23		5-Year
98	7.956313	123.7764	0.12	1.7	-1.58	Frank / 2013	5-Year
99	7.921291	123.7769	0.03	1.34	-1.31		5-Year
100	7.902654	123.7708	0.58	0.1	0.48	Yolanda / November 2015	5-Year
101	7.898622	123.7749	0.28	0.2	0.08		5-Year
102	8.007904	123.7731	0.66	0.45	0.21	2011	5-Year
103	7.918463	123.7864	0.03	0.7	-0.67	Pablo / November 2012	5-Year
104	7.909165	123.7718	0.65	0.42	0.23	Yolanda / November 2015	5-Year
105	7.909201	123.7717	0.66	0.57	0.09	Yolanda / November 2015	5-Year
106	7.888854	123.7589	0.55	0.58	-0.03		5-Year
107	7.920463	123.7754	0.11	0.8	-0.69		5-Year
108	7.909238	123.7715	0.71	0.7	0.01	Yolanda / November 2015	5-Year
109	8.008247	123.7705	0.79	0.76	0.03		5-Year
110	7.920307	123.775	0.11	0.95	-0.84	2014	5-Year
111	7.909174	123.7717	0.73	0.7	0.03	Yolanda / November 2015	5-Year
112	7.888031	123.804	0.17	1.08	-0.91	Pablo / 2013	5-Year
113	7.888855	123.7591	0.6	0.58	0.02		5-Year
114	7.888916	123.759	0.6	0.58	0.02		5-Year
115	8.008168	123.7706	0.8	0.82	-0.02		5-Year
116	8.00817	123.7706	0.8	0.79	0.01		5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
117	7.890517	123.7758	0.6	0.35	0.25	Yolanda / November 2015	5-Year
118	7.909224	123.7716	0.76	0.7	0.06	Yolanda / November 2015	5-Year
119	7.909224	123.7716	0.76	0.7	0.06	Yolanda / November 2015	5-Year
120	7.923094	123.6898	0.61	1.17	-0.56	Lando / August 2015	5-Year
121	7.888814	123.759	0.64	0.58	0.06	Yolanda / November 2015	5-Year
122	7.888671	123.7589	0.64	0.58	0.06		5-Year
123	7.916201	123.707	0.75	0.53	0.22	August 2015	5-Year
124	7.923653	123.6899	0.63	1.3	-0.67	Lando / August 2015	5-Year
125	7.888833	123.7589	0.66	0.58	0.08		5-Year
126	7.923515	123.69	0.64	2.2	-1.56	Lando / August 2015	5-Year
127	7.890977	123.7747	0.69	0.4	0.29	Yolanda / November 2015	5-Year
128	7.888952	123.76	0.7	0.58	0.12	Yolanda / November 2015	5-Year
129	7.888834	123.7591	0.73	0.58	0.15		5-Year
130	7.888835	123.7591	0.73	0.58	0.15		5-Year
131	7.875455	123.7777	0.62	0.72	-0.1	Yolanda / November 2015	5-Year
132	7.890981	123.7652	0.76	0.4	0.36		5-Year
133	7.979723	123.793	0.41	1.8	-1.39		5-Year
134	7.89759	123.7753	0.56	0.64	-0.08	Yolanda / November 2015	5-Year
135	7.898055	123.7744	0.66	0.56	0.1	Yolanda / November 2015	5-Year
136	7.890399	123.7751	0.96	0.35	0.61	Yolanda / November 2015	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
137	7.890429	123.7751	0.96	0.35	0.61	Yolanda / November 2015	5-Year
138	7.979925	123.7938	0.61	1.8	-1.19		5-Year
139	7.979925	123.7938	0.61	1.8	-1.19		5-Year
140	7.889377	123.7626	1.08	0.5	0.58	Yolanda / November 2015	5-Year
141	7.980021	123.7942	1.26	1.5	-0.24		5-Year
142	7.980021	123.7942	1.26	1.5	-0.24		5-Year
143	7.920059	123.7752	1.25	0.5	0.75	Pablo / November 2012	5-Year
144	7.917468	123.7863	1.11	1.2	-0.09		5-Year
145	7.921269	123.777	1.4	1.4	0	Sendong / December 2011	5-Year
146	7.917265	123.7858	1.33	1.5	-0.17	Frank / 2013	5-Year
147	7.92071	123.7789	1.19	0.8	0.39	Pablo / November 2012	5-Year
148	7.920598	123.7789	1.19	0.8	0.39	Pablo / November 2012	5-Year
149	7.921156	123.7769	1.6	1.5	0.1	Sendong / December 2011	5-Year
150	7.917364	123.7858	1.37	1.5	-0.13		5-Year
151	7.980167	123.7934	1.84	2	-0.16		5-Year
152	7.917112	123.7857	1.53	1.5	0.03		5-Year
153	7.917249	123.7857	1.57	1.6	-0.03		5-Year
154	7.917345	123.7857	1.65	1.7	-0.05		5-Year
155	7.917361	123.7856	1.86	1.6	0.26		5-Year
156	7.917309	123.7856	1.86	1.6	0.26		5-Year

Annex 12. Educational Institutions Affected by flooding in Maranding Flood Plain

LANAO DEL NORTE							
BAROY							
Building Name			Barangay		Rainfall Scenario		
					5-year	25-year	100-year
Building Name	Barangay	Rainfall Scenario					
		5-year	25-year	100-year			
Bagong Dawis Elementary School	Bagong Daw-is						
Bag.ong Dawis Elementary School (Pre-school)	Bagong Daw-is						
Daycare Center	Bagong Daw-is		Low	Low			
Faculty Office	Bagong Daw-is						
Grade Low	Bagong Daw-is	Medium	Medium	Medium			
Grade Medium	Bagong Daw-is	Medium	Medium	Medium			
Grade High	Bagong Daw-is	Medium	Medium	Medium			
Grade 5 and 6	Bagong Daw-is						
Kindergarten	Bagong Daw-is	Medium	Medium	Medium			
daycare	Baroy Daku						
Daycare	Baroy Daku						
Day Care Center	Bato						
Day Care Center	Cabasagan						
Non-functional School	Cabasagan	Low	Low	Medium			
Pendulonan Primary School	Cabasagan						
Daycare	Dalama						
canteen	Libertad						
Central elementary	Libertad						

LANAO DEL NORTE							
BAROY							
Computer Room	Libertad	Low	Low	Low			
Diosdado Yap HIgh School	Libertad	Low	Low	Low			
Primary School	Limwag						
Day Care Center	Lindongan						
Daycare	Manan-Ao						
Manan ao Elem	Manan-Ao						
Manan ao Elem Schhol	Manan-Ao						
Manan ao Elem School	Manan-Ao						
Sario de roda elementary school (grade Low)	Pange						
Sario de roda elementary school (grade 4 and High)	Pange						
HE Building	Pindolonan		Low	Low			
Lindongan Elem. School	Pindolonan						
Principal's Office	Pindolonan	Low	Low	Low			
School Canteen	Pindolonan						
Compter Center/ Pre School	Rawan Point	Low	Low	Low			
Grade Low-High-4	Rawan Point	Low	Low	Low			
Grade 6	Rawan Point	Low	Medium	Medium			
Multi-purpose Hall	Rawan Point	Low	Low	Medium			
Raw-an Point Elem. School	Rawan Point	Low	Low	Low			
Mediumnd Yr	Riverside						
Computer Room	Riverside						
Diosdado Yap HIgh School	Riverside	Low	Low	Low			

LANAO DEL NORTE							
BAROY							
Sr High	Riverside		Low	Low			
Temporary Rooms	Riverside						
Daycare	Tinubdan						
Maliwanag Elem School	Tinubdan						

LANAO DEL NORTE				
KAPATAGAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Computer Room	Bagong Silang		Low	Low
Day Care Center	Bagong Silang			
Grade Medium	Bagong Silang			
Grade 4	Bagong Silang			
Kinder	Bagong Silang			
Principal's Office	Bagong Silang			
School Canteen	Bagong Silang			
Daycare Center Tiacongan	Bagong Silang			
Classroom	Buenavista			
Mahayahay Elem. School	Buenavista			
Day Care Center	Butadon			
Grade 4	Butadon			Low
Grade 5-6	Butadon			Low
Grade 6	Butadon			
Pinoyak Elem. School	Butadon			
Principal's Office	Butadon		Low	Low
Stage	Butadon			
Grade Low	Cathedral Falls			
Kitchen	Cathedral Falls			
Anacurita Elem School	Cathedral Falls	Low	Low	Medium
Anacurita Elem.	Cathedral Falls	Low	Low	Low
Day Care	Cathedral Falls			
Day Care Center	Cathedral Falls			
Grade High and gade 4	Cathedral Falls			
Grade 5 B	Cathedral Falls			
Grade 6 A	Cathedral Falls			
Preschool	Cathedral Falls			
Day Care	Concepcion			Low

LANAO DEL NORTE				
KAPATAGAN				
Grade High	Concepcion	Low	Medium	Medium
Grade 4	Concepcion	Medium	Medium	Medium
Grade 5&6	Concepcion	Low	Medium	Medium
principals Office	Concepcion	Medium	Medium	Medium
Daycare Center	Concepcion			
Emiliano Dizon Elem School	Concepcion	Low	Low	Low
Curvada Elem	Curvada			
Kindergarten	De Asis			
SCHOOL Stage	De Asis			
Daycare	De Asis			
Adventist School	Donggoan			
Balili Day Care Center	Donggoan			
Grade Low	Donggoan		Low	Low
Grade Low&4	Donggoan	Low	Low	Low
Grade Medium	Donggoan	Medium	Medium	Medium
Grade High	Donggoan	Medium	Medium	Medium
HE Building	Donggoan	Low	Low	Low
Kinder Low	Donggoan			
Learning Center	Donggoan			
Old Buildng	Donggoan		Low	Low
Donggoan Elem School	Donggoan			
Classroom	Kidalos			
Day Care Center	Kidalos			
Kidalos Elem School	Kidalos			
Daycare center	Lapinig			
placida mequiabas national high school	Lapinig			
Placida Mequiabas National High School	Lapinig			
Dishwashing Area	Maranding		Low	Medium
School of Born Again Church	Maranding	Low	Medium	Medium
Stage	Maranding		Low	Medium
Waiting Shed	Maranding		Low	Medium
Paradero Day Care	Maranding			
Daycare Center	Margos			
Sixto Magnanoy Sr. Central School	Margos			
Abandoned	Poblacion		Low	Low
Abandoned Day Care	Poblacion	Medium	Medium	Medium
Canteen	Poblacion			
District Office	Poblacion			
Grade Low Classroom	Poblacion			
Grade High Classroom	Poblacion			

LANAO DEL NORTE				
KAPATAGAN				
Grade 5 Classroom	Poblacion			
grade 6	Poblacion			Low
Grade 6 Classroom	Poblacion			
HE Classroom	Poblacion			
San Vicente Elem. School	Poblacion		Low	Low
School Room	Poblacion		Low	Low
Technical School	Poblacion		Low	Low
Daycare	Poblacion		Low	Low
Daycare Center	Poblacion			
reading center(purok)	Poblacion			
Day Care Center	Santo Tomas			
Grade Low	Santo Tomas			
Grade 4 Room	Santo Tomas			
Grade 6 Room	Santo Tomas			
Kindergarten	Santo Tomas			
Butadon Elementary	Suso			Low
Daycare	Suso			
Daycare Center	Suso			
Anacurita Elem.	Waterfalls	Low	Low	Low
Daycare Center	Waterfalls		Low	Low
Itans Learning Center	Waterfalls	Low	Low	Low

LANAO DEL NORTE				
LALA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Abaga Central Elementary School	Abaga		Low	Low
Classroom	Abaga			Low
CR & Hand Washing	Abaga	Low	Low	Low
Day Care Center Low	Abaga			
DU Tenazas Memorial Elem. School	Abaga			Low
Function Hall	Abaga			
Grade Low-High	Abaga			
Grade 4	Abaga			
Grade 5	Abaga			
Grade 6 & Kinder	Abaga		Low	Low
Hand Washing Area	Abaga	Low	Low	Medium

LANAO DEL NORTE				
LALA				
Maranding Christian School KLow-KMedium rooms	Abaga			
MCS Gym	Abaga			
MCS Office	Abaga			
MCS Old Buildings	Abaga			
Principal's Office	Abaga	Low	Low	Low
School Canteen	Abaga	Low	Low	Low
School Multipurpose Hall	Abaga	Low	Low	Low
Science Room	Abaga			
Sario de roda elementary school (grade Low)	Andil			
Sario de roda elementary school (grade 4 and High)	Andil	Low	Low	Low
Sario de roda elementary school stage	Andil			
Daycare center	Andil			
Sario de roda elementary school (grade 5 and 6)	Andil	Medium	Medium	Medium
Daycare Center	Cabasagan			
Francisco Bolante Memorial School (Pre-School to grade 6)	Cabasagan			
Purok 4-B Daycare Center	Cabasagan			
Purok 6 Daycare Center	Cabasagan			
Camalan Primary School	Camalan			
Grade High-4	Camalan			
C.R.	Darumawang Ilaya			
Day Care	Darumawang Ilaya			
Grade Low	Darumawang Ilaya			
Grade 4	Darumawang Ilaya			
Grade 5	Darumawang Ilaya			
Grade 6	Darumawang Ilaya			
Guidance Office	Darumawang Ilaya			
Lutuanan	Darumawang Ilaya			
Office and SchoolDormitory	Darumawang Ilaya			
Principal's Office	Darumawang Ilaya			
School Canteen	Darumawang Ilaya			
Simpak Adventist Institute of Technol-ogy	Darumawang Ilaya			
Social hall	Darumawang Ilaya			
Vocational Bldg	Darumawang Ilaya			
Vocational Bldg. Medium	Darumawang Ilaya			
Library	Darumawang Ilaya			
El Salvador Elem. School	El Salvador			
Grade 4	El Salvador			

LANAO DEL NORTE				
LALA				
Grade 4-5-6	El Salvador			
Principal's Office	El Salvador			
Stage	El Salvador			
Grade Low-6	Gumagamot	Medium	Medium	Medium
Panadtaran Elem. School	Gumagamot	Low	Medium	Medium
LALA Elem School Proper	Lala Proper	Low	Low	Medium
Daycare	Lanipao			
LALA North District School	Lanipao		Low	Low
Classroom	Magpatao			
Computer Center	Magpatao			
Grade Low-Medium-High	Magpatao			
Grade 6	Magpatao			
HE Room	Magpatao			
Magpatao Elem	Magpatao			
Prk Medium Day Care Center	Magpatao			
School Stage	Magpatao			
Stage	Magpatao			
Daycare center	Magpatao			
Magpatao Elementary School	Magpatao			
Bible Baptist School	Maranding	Low	Low	Low
Calssroom LowMedium	Maranding			
Canteen	Maranding			
Classroom	Maranding			Low
Classroom LowLow	Maranding			
Classroom 4	Maranding			
Classroom 5	Maranding	Low	Low	Low
Classroom 6	Maranding			Low
Classroom 7	Maranding	Low	Low	Low
Classroom 8	Maranding		Low	Low
Classroom 9	Maranding			Low
ClassroomLow	Maranding	Low	Low	Low
ClassroomMedium	Maranding			Low
Faculty Room	Maranding			
Grade Medium	Maranding		Low	Medium
grade High	Maranding		Low	Low
Grade 4	Maranding			
Grade 5	Maranding	Low	Low	Low
Guard House	Maranding			
Lanao Norte-Learning Resource Center	Maranding			
LNHS Gym	Maranding	Low	Low	Low
LNHS Principal's Office	Maranding			

LANAO DEL NORTE				
LALA				
Mini Canteen	Maranding			
NCMC Building	Maranding		Low	Low
NCMC Collge Department	Maranding			
NCMC Elementary Department	Maranding		Low	Low
NCMC Gym	Maranding			
NCMC HRM Department	Maranding		Low	Low
Preschool	Maranding		Low	Low
Principal's Office	Maranding			
Prk. Rambutan Day Care Center	Maranding			
PTA Office	Maranding	Low	Low	Low
School Clinic	Maranding			
Social Hall	Maranding			
Stage	Maranding		Low	Medium
Grade Low	Maranding	Low	Low	Low
Day Care Center Old	Matampay Bu-cana			
Matampay Bucana Elem. School	Matampay Bu-cana			
San Roque Chapel	Matampay Bu-cana			
Classrooms Low	Pacita			
Classrooms Medium	Pacita			
Day Care Center	Pacita			
Doggoan Elementary School	Pacita			
Grade Low-Medium	Pacita			
Grade High	Pacita			
Grade 4-5	Pacita			
Grade 6	Pacita			
Matampay Ilaya Elem. School	Pacita			
Prk Medium Day Care Center	Pacita			Low
School Clinic	Pacita			
Stage	Pacita			
Day Care Center Medium	Pendolonan	Low	Low	Low
Comfort Room	Pendolonan			
Day Care Center	Pendolonan			
Generoso Lapasaran Memorial School Canteen	Pendolonan			
Grade Low	Pendolonan			
Grade 6	Pendolonan			
Pre-school and Faculty Office	Pendolonan			
School Library	Pendolonan			
Cabrera Day Care Center	Pinoyak		Low	Low
Saavedra Day Care Center	Pinoyak			
FM Posadas Elementary School	Raw-An	Medium	Medium	Medium
Classroom Low	Raw-An	Medium	Medium	Medium

LANAO DEL NORTE				
LALA				
Classroom Medium	Raw-An	Medium	Medium	Medium
Economics building	Raw-An	Medium	Medium	Medium
Grade 5 and 6	Raw-An	Medium	Medium	Medium
Kindergarten	Raw-An	Medium	Medium	Medium
School Canteen	Raw-An	Medium	Medium	Medium
Pedro B. Liwanag Memorial Elem	Rebe			
Antonio Lim Sr. Elem School	San Isidro Lower			
Brgy. Sta. Cruz Lower Elem. School	San Isidro Lower			
Day Care	San Isidro Lower			
daycare	San Isidro Lower			
Grade Low	San Isidro Lower			
Grade Low-Medium-4	San Isidro Lower			
Grade High	San Isidro Lower			
Grade 5-6	San Isidro Lower			
HE Room	San Isidro Lower			
Pre-School	San Isidro Lower			
Canteen	San Isidro Upper			
Computer Laboratory	San Isidro Upper			
Daycare Center	San Isidro Upper			
Grade Low	San Isidro Upper			
Pre-school and faculty room	San Isidro Upper			
San Isidro Elementary School(grade Medium-6)	San Isidro Upper			
Stage	San Isidro Upper			
Daycare	San Manuel			Low
San Manuel Elem	San Manuel			
Daycare	Santa Cruz Low-er			
Daycare	Santa Cruz Up-per	Medium	Medium	Medium
Auditorium	Simpak			Low
Grade Low	Simpak			Low
Grade Medium	Simpak		Low	Low
Grade High	Simpak			
Grade 4	Simpak		Low	Low
Grade 5	Simpak		Low	Low
Kinder Garten	Simpak	Low	Low	Low
Principal's Office	Simpak		Low	Low
Saavedra Elementary School	Simpak	Low	Low	Low
School C.R.	Simpak			
School Canteen	Simpak			Low
School Clinic	Simpak		Low	Low
School Guard House	Simpak			Low
School Old Canteen	Simpak	Low	Low	Low

LANAO DEL NORTE				
LALA				
Stage	Simpak		Low	Low
Vermi Culture Center	Simpak			
D.U. Tenzasas Elem	Tenazas			
D.u.Tenazasas Elem	Tenazas			
Daycare	Tenazas			
Montesory	Tenazas			Low
BFAR Dorm Low	Tuna-An		Low	Low
BFAR Dorm Medium	Tuna-An		Low	Low
Day Care Center	Tuna-An			
Dorm High	Tuna-An	Medium	Medium	Medium
Dorm 4	Tuna-An			Low
Dorm 5	Tuna-An	Medium	Medium	Medium
Grade Low-4	Tuna-An			
Grade 5-6	Tuna-An			
Library	Tuna-An			
Tunaan Elem. School Stage	Tuna-An			

LANAO DEL NORTE				
SALVADOR				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
LANAO DEL NORTE				
SALVADOR				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Daycare Center	Camp III	Low	Medium	Medium
Grade Low - High	Camp III			
Grade Medium and 5	Camp III			Low
Grade 5	Camp III			Low
Grade 6	Camp III			Low
School Booth	Camp III			
School Stage	Camp III			
Sudlon Elementary School	Camp III	Low	Medium	Medium
Abandoned School	Curva-Miagao	Low	Low	Low
Classroom	Curva-Miagao		Low	Low

LANAO DEL NORTE				
SALVADOR				
Curva-Miagao Elem. School	Curva-Miagao		Low	Low
Day Care Center	Curva-Miagao			Medium
School Waiting Shed	Curva-Miagao	Low	Low	Low
Stage	Curva-Miagao	Low	Low	Low
San Manuel Elem	Curva-Miagao			
Classroom	Inasagan			Low
Classroom Medium	Inasagan			Low
Classroom High	Inasagan		Low	Low
Day Care Center	Inasagan	Low	Low	Low
Day Care Center Kalahi	Inasagan			Low
Former Canteen	Inasagan			Low
grade Low	Inasagan			Low
Grade Medium	Inasagan			Low
Grade 4	Inasagan			
Grade 5-6	Inasagan			
Grade 6	Inasagan			
Home Economics	Inasagan			
Kinder	Inasagan	Low	Low	Low
Pre-School	Inasagan			Low
Principal's Office	Inasagan			
School Bldg.	Inasagan		Low	Low
School Waiting Shed	Inasagan			
Stock Room	Inasagan			Low
Social Hall	Inasagan	Low	Low	Low
Day Care Center	Mabatao			
Canteen ni Pacilan	Poblacion			
Comfort Room	Poblacion			
Computer Room	Poblacion		Low	Low
Conference Hall	Poblacion			
Faculty Room	Poblacion			
Former Regina High School	Poblacion		Low	Low
Grade Low Room	Poblacion			
Grade Low0 Emerald Room	Poblacion			
Grade 7 Earth Room	Poblacion			
Grade 7 Jupiter Room	Poblacion			
Grade 7 Mercury Room	Poblacion			
Grade 7 Uranus Room	Poblacion			
Grade 8 Archimedes Room	Poblacion			
Grade 8 Bell Room	Poblacion			
Grade 8 Cury Room	Poblacion			
Grade 8 Darwin Room	Poblacion			

LANAO DEL NORTE				
SALVADOR				
Grade 8 Einstein Room	Poblacion			
Grade 9 Argon Room	Poblacion			
Grade 9 Besmot Room	Poblacion			
Grade 9 Copper Room	Poblacion			
Grade 9 Dabnium Room	Poblacion			
Guardhouse	Poblacion			
Home Economics	Poblacion	Low	Low	Low
Kinder	Poblacion	Low	Low	Low
Kinder II Room	Poblacion			
Non-Advisory Room	Poblacion			
Nurse Room	Poblacion			
Parking Area	Poblacion			
Payag	Poblacion			
School Canteen Low	Poblacion			
School Canteen Medium	Poblacion			
School Guidance Councilor Office	Poblacion			
School Library	Poblacion			
TESDA Faculty and Staff Room	Poblacion			
TESDA Function Hall	Poblacion			
TESDA Room	Poblacion			
Social Hall	Poblacion	Low	Low	Low
Daycare Center	Sudlon	Medium	High	High

LANAO DEL NORTE				
TUBOD				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Lanao Norte Provincial Science and Technology High School	Licapao			
Licapao Elem. School	Licapao			
LNPSTHS School Bldg	Licapao			
School Stage	Licapao			

LANAO DEL NORTE				
AURORA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Canteen	Anonang			
Comfort Room	Anonang			
Computer Room	Anonang			
Grade Higha	Anonang			
Grade 4	Anonang			
Grade 5	Anonang			
Margos Elementary School	Anonang			
Principal's Office	Anonang			
School Health Center	Anonang			
School Waiting Shed	Anonang			
Social Hall	Anonang			
grade 6	Anonang			
HE room	Anonang			
School Waiting Shed	Anonang			

Annex 13. Health Institutions affected by flooding in Maranding Floodplain

LANAO DEL NORTE				
BAROY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Care Center	Bagong Dawis			
Health Center	Bagong Dawis			
Health Center	Cabasagan			
Health center	Dalama			
Health Center	Libertad			
Health Center	Limwag			
Health Center	Lindongan			
Temporary Health Center	Salong			

LANAO DEL NORTE				
KAPATAGAN				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Clinic	Bagong Silang			
Polipog Health Center	Butadon	Low	Medium	Medium
Health Center	Cathedral Falls	Medium	Medium	Medium
Health Center	De Asis			
Balili Health Center Extension	Donggoan			
Health Center	Donggoan			
Health Center	Kidalos			
Health Center	Maranding	Low	Medium	Medium
Provincial Hospital	Maranding			
Provincial Hospital	Maranding			
Kapatagan Provincial Hospital	Poblacion			
Mercury	Poblacion		Low	Low
RightMeds Pharmacy	Poblacion			Low
Delbert Jon's Hospital	Poblacion			
Dr. Gatchalian Hospital (OLD)	Poblacion		Low	Low
Municipal Health Office	Poblacion			
Old Health Center	Santo Tomas			
Sto Tomas Health Center	Santo Tomas			
Clinic	Waterfalls	Low	Low	Low

LANAO DEL NORTE				
LALA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Abaga			
School Clinic	Abaga			Low
Health center	Andil			
Health Center	Cabasagan			
Health Center	Darumawang Ilaya			
Health Center	El Salvador			
Health Center	Lala Proper			Low
Vet Clinic	Lanipao			Low
Prk Medium Health Center	Magpatao			
Health Center	Magpatao			
AFC AMY Pharmacy	Maranding			
Asintesta Medical Clinic	Maranding	Low	Low	Low
Barangay Health Station	Maranding	Low	Low	Low
Bontilao Country Hospital	Maranding			
Gozo Community Hospital	Maranding			
Maranding Community Hospital	Maranding			
Mendoza Macayan Optical Clinic	Maranding		Low	Low
Mercury Drug	Maranding			
NCMC Lying In	Maranding			
The Generics Pharmacy	Maranding			Low
Bulaclac Pharmacy	Maranding			Low
Health Center	Pacita			
Pacita Health Center	Pacita	Low	Low	Low
Health Center	Pendolonan			
Health Center	Rebe			
Health Center	San Isidro Lower			
Health Center	San Isidro Upper			
Health Center	San Manuel		Low	Low
Health Center	Santa Cruz Up-per			Low
Lanipao Health Center	Santa Cruz Up-per	Medium	Medium	Medium
Health Center	Simpak			
Health Center	Tuna-An			

LANAO DEL NORTE				
SALVADOR				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Health Center	Camp III		Low	Low
Health Center	Curva-Miagao			
Barangay Health Center	Inasagan			
Health Center	Inasagan	Low	Low	Low
Health Center	Panaliwad-On			
New Rural Health Center	Poblacion			
Old Rural Health Center	Poblacion			
Temporary Health Center	Salong			

LANAO DEL NORTE				
AURORA				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Margos Health Center	Anonang			