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

LiDAR Surveys and Flood Mapping of Labangan River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LABANGAN RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Mr. Dante Gideon K. Vergara

1.1 Background of the Phil-LIDAR 1 Program

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

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 implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB 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 45 river basins in the Southern Luzon region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Labangan River Basin

Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

Labangan River Basin is a 14,200-hectare watershed located in Occidental Mindoro. It covers the barangays of Mangarin, Mapaya, Mabini, Magbay and Bayotbot in San Jose municipality; and, Paclolo and Lourdes in Magsaysay. Labangan River Basin is located in the Municipality of San Jose in the province of Occidental Mindoro. The DENR River Basin Control Office (RCBO) states that the Labangan River Basin has a drainage area of 159 km2 with the estimated annual run-off of 254 million cubic meter (MCM). The basin area has seven geological classifications dominated by Pliocene-Pleistocene. The remaining areas has Paleocene-Eocene, Recent, Oligocene-Miocene, Oligocene-Miocene (Sedimentary and Metamorphic), Upper Miocene-Pliocene and Pliocene-Quaternary geologic materials. The river basin is generally characterized by 8-18% slope and elevation of more than 300 meters above mean sea level. Six soil types can be found in the basin area including Maranlig gravelly sandy clay loam, Quingua clay loam, Magsaysay clay, Quingua clay, San Manuel silt and San Manuel silt loam. Beach sand, hydrosol and rough mountain land (unclassified) can also be found in the area. Shrubs dominate the area while the other land cover types include open forest (broadleaved), cultivated annual crop, cultivated perennial crop, fishpond, natural barren land, natural grassland, built-up area, wooded grassland and inland water.

Labangan River passes through Poblacion in Sablayan municipality; and, Barangay 8, Mangarin, Mabini, Magbay and Bayotbot. Its water is used mainly for domestic and agricultural activities. Poblacion, Sablayan is considered to be the most populated barangay based on the 2010 NSO Census of Population and Housing. According to the same source, a total of 22,220 locals are residing in the said barangays.

Based on the studies conducted by the Mines and Geosciences Bureau, Barangay 8 in San Jose has the highest risk to flooding. The field surveys conducted by the PHIL-LiDAR 1 validation team showed five notable weather disturbances, which caused flooding in 1984 (Undang), 2006 (Caloy), 2009 (Ondoy), 2013 (Yolanda) and 2014 (Glenda). According to National Disaster Risk Reduction and Management Council (NDRRMC), on August 2011, heavy rains brought by southwest monsoon caused swelling of Labangan River affecting 200 families in Brgy. Mangarin and 150 in Bgry. Mapaya. For the landslide susceptibility, Bayotbot in San Jose and Poblacion in Sablayan have low to high and low to moderate risks, respectively.

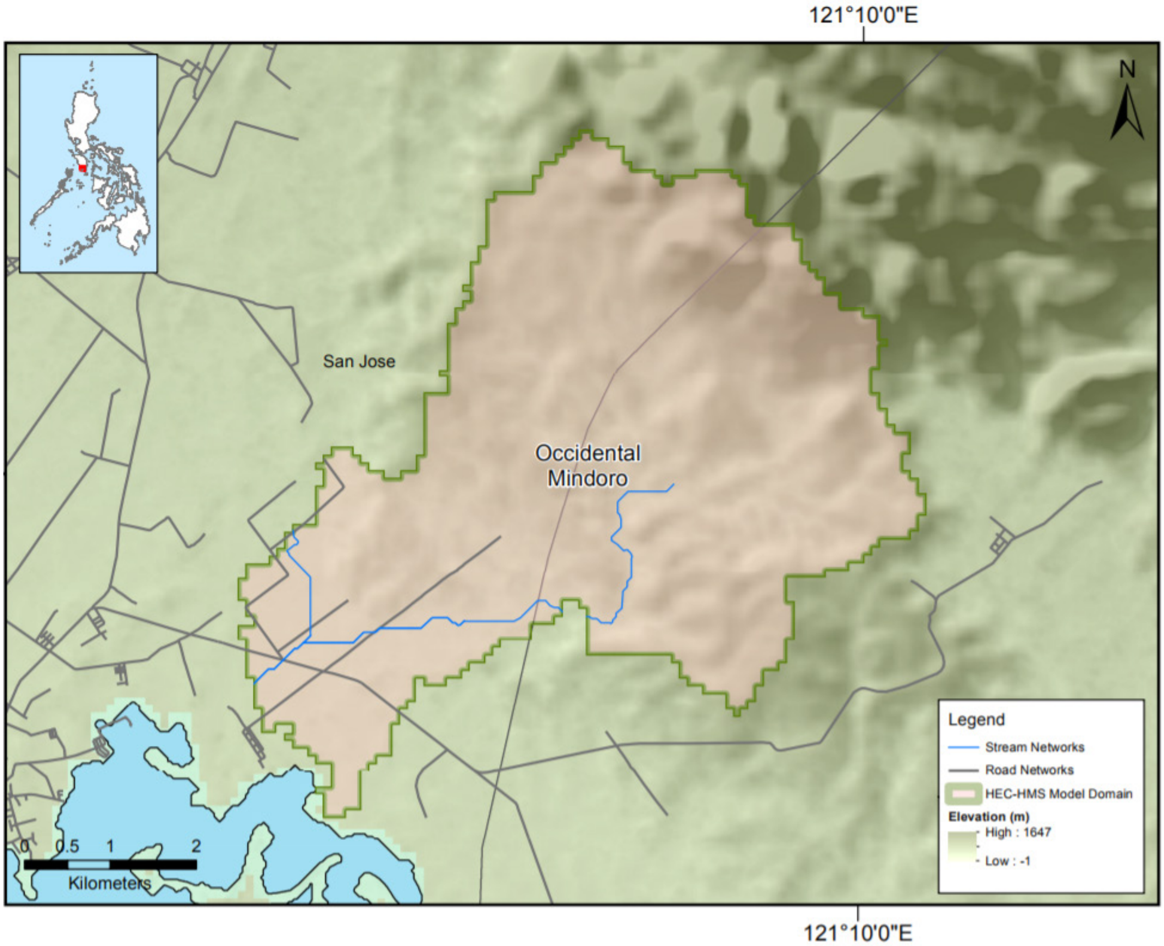


Figure 1. Map of Labangan River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LABANGAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, and Ms. Rowena M. Gabua

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Labangan floodplain in Occidental Mindoro. These missions were planned for 12 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameter used for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plans and location of base stations for Labangan Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (Hz)	Scan Frequency (kHz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29K	1100	30	50	200	30	130	5
BLK29L	1100	30	50	200	30	130	5
BLK29M	1100	30	50	200	30	130	5
BLK29N	850	30	50	200	32	130	5
BLK29O	1100	30	50	200	30	130	5
BLK18Q	850	30	50	200	32	130	5
BLK18R	850	30	50	200	32	130	5
BLK18S	850	30	50	200	32	130	5

Table 2. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (Hz)	Scan Frequency (kHz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29A	550	30	36	50	40	130	5
BLK29B	600	30	36	50	40	130	5
BLK29C	550, 600	30, 40	36, 40	50	40	130	5
BLK29D	550, 600	30	40	50	40	130	5
BLK29G	550, 600	30, 40	36, 40	50	40	130	5
BLK29K	550, 600	30	40	50	40	130	5
BLK29N	600	30	40	50	40	130	5

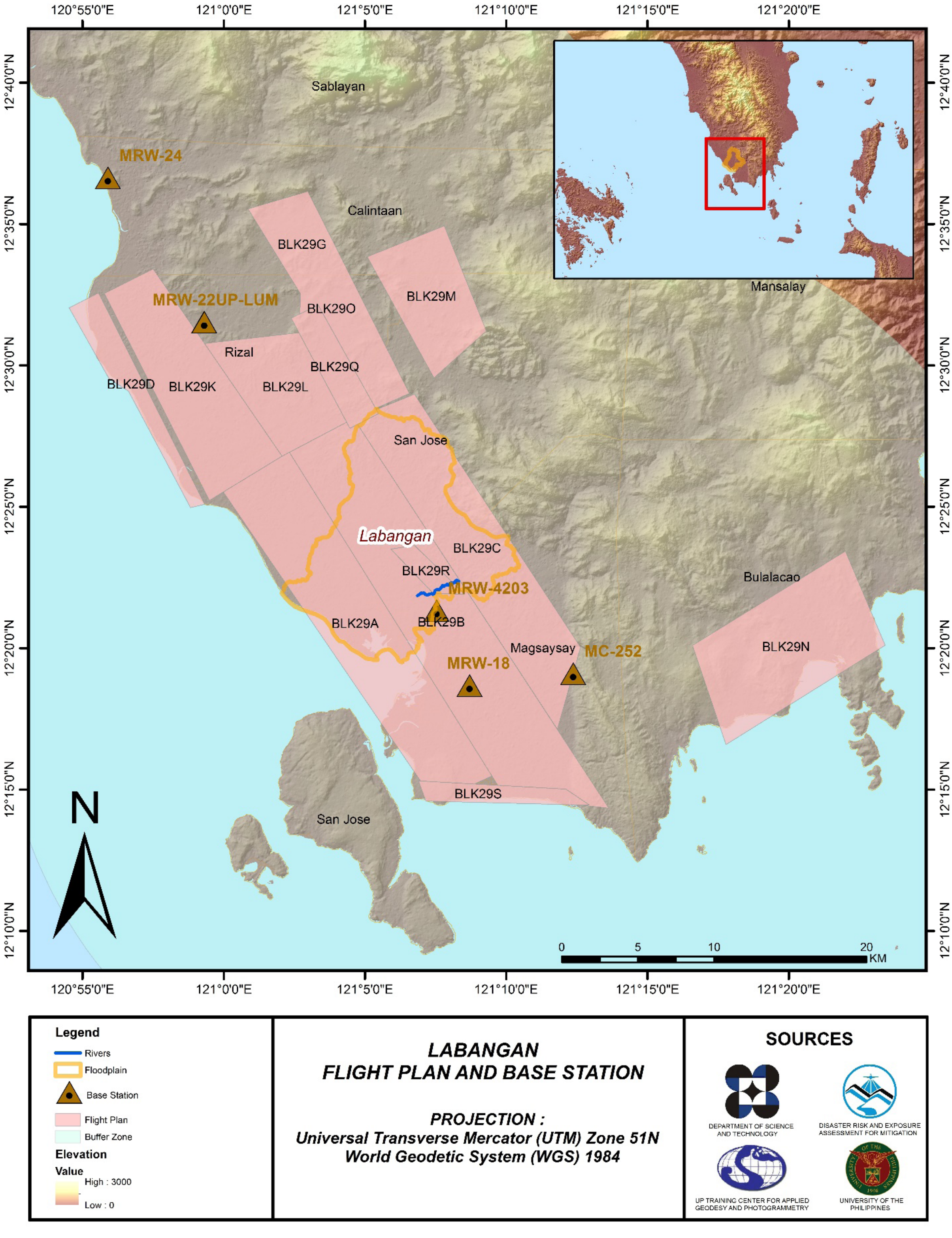


Figure 2. Flight plan and base stations used for Labangan Floodplain

2.2 Ground Base Station

The project team was able to recover four (4) NAMRIA ground control points (GCPs): MRW-18, MRW-22, MRW-24, which are of second (2nd) order accuracy, MRW-4203, which is of third (3rd) order accuracy, and one (1) NAMRIA benchmark MC-252. The project team also established one GCP, UP-Lum. The certifications for the NAMRIA reference points are found in Annex A-3 while the baseline processing report for the established GCP is found in Annex A-4. These were used as base stations during flight operations for the entire duration of the survey (February 27 - March 3, 2014 and December 10 - 11, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Labangan floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 8 show the recovered NAMRIA reference point within the area. In addition, Table 3 to Table 8 show the details about the NAMRIA control stations and the established point while Table 9 shows the list of all GCPs occupied during the acquisition together with the corresponding dates of utilization.

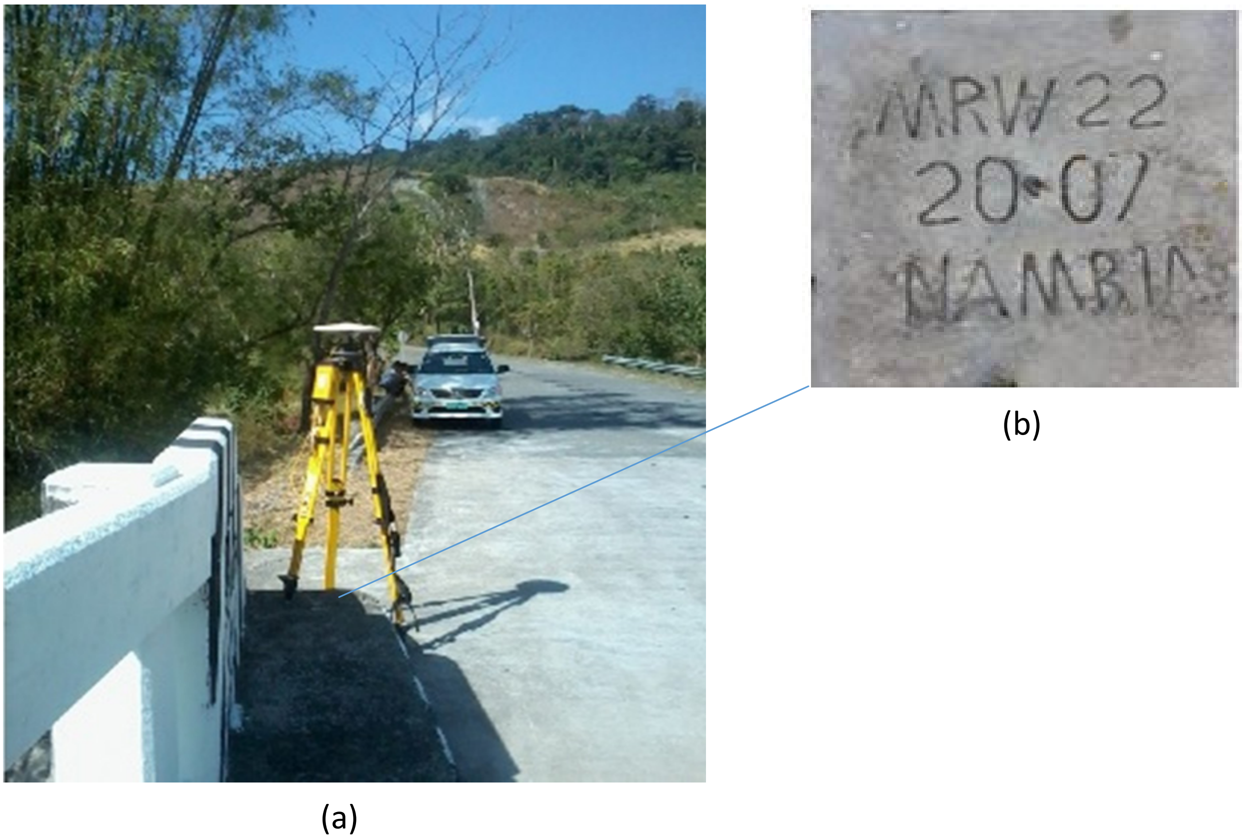


Figure 3. GPS set-up over MRW-22 in Lumintao Bridge in Brgy. Tanyag, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-22 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MRW-22 used as base station for the LiDAR acquisition.

Station Name	MRW-22	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31’36.76881” North 120°59’13.46492” East 35.12700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	498595.125 meters 1385214.96 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31’31.84278” North 120°59’18.53734” East 84.27100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	281265.62 meters 1385563.72 meters

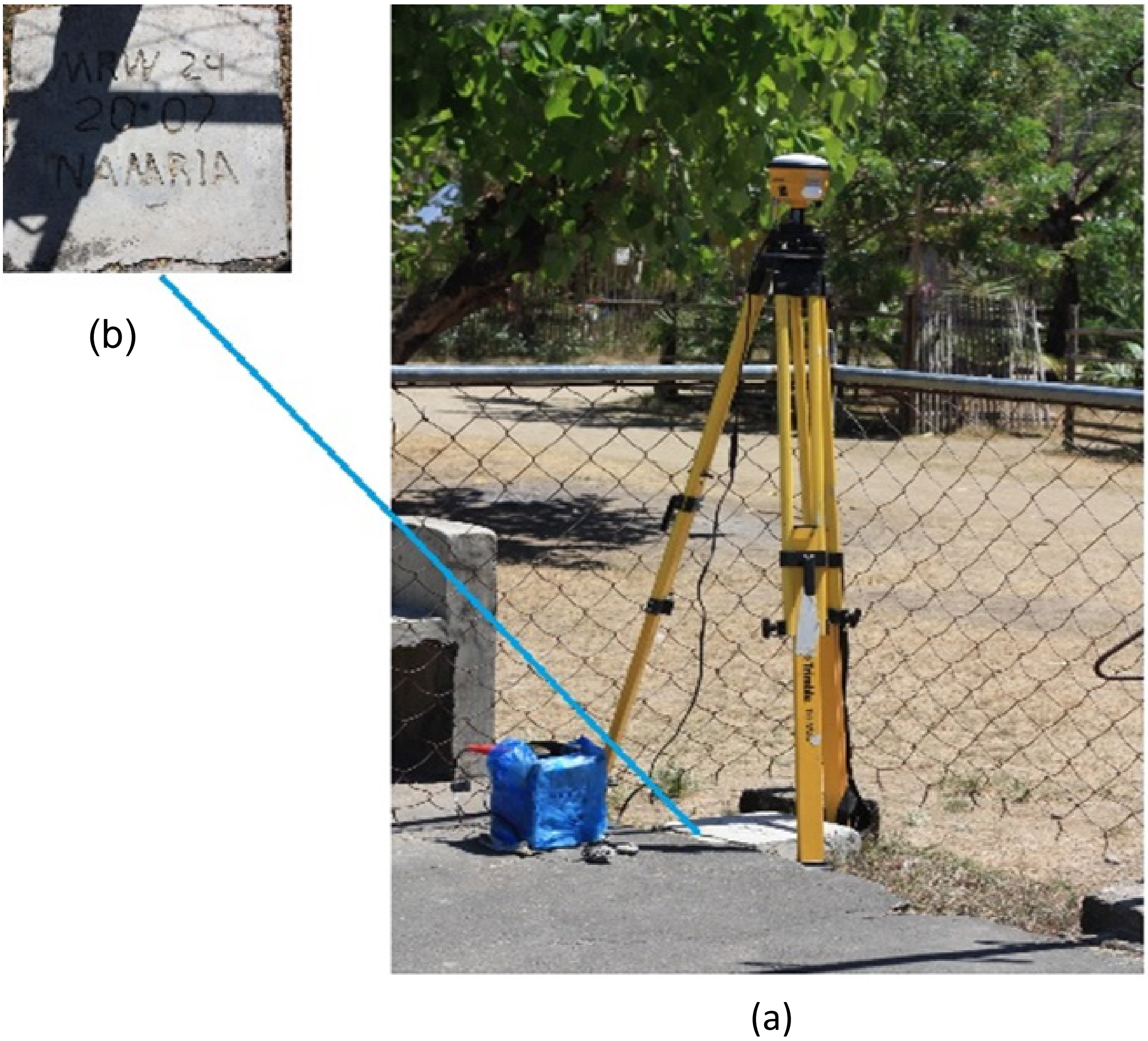
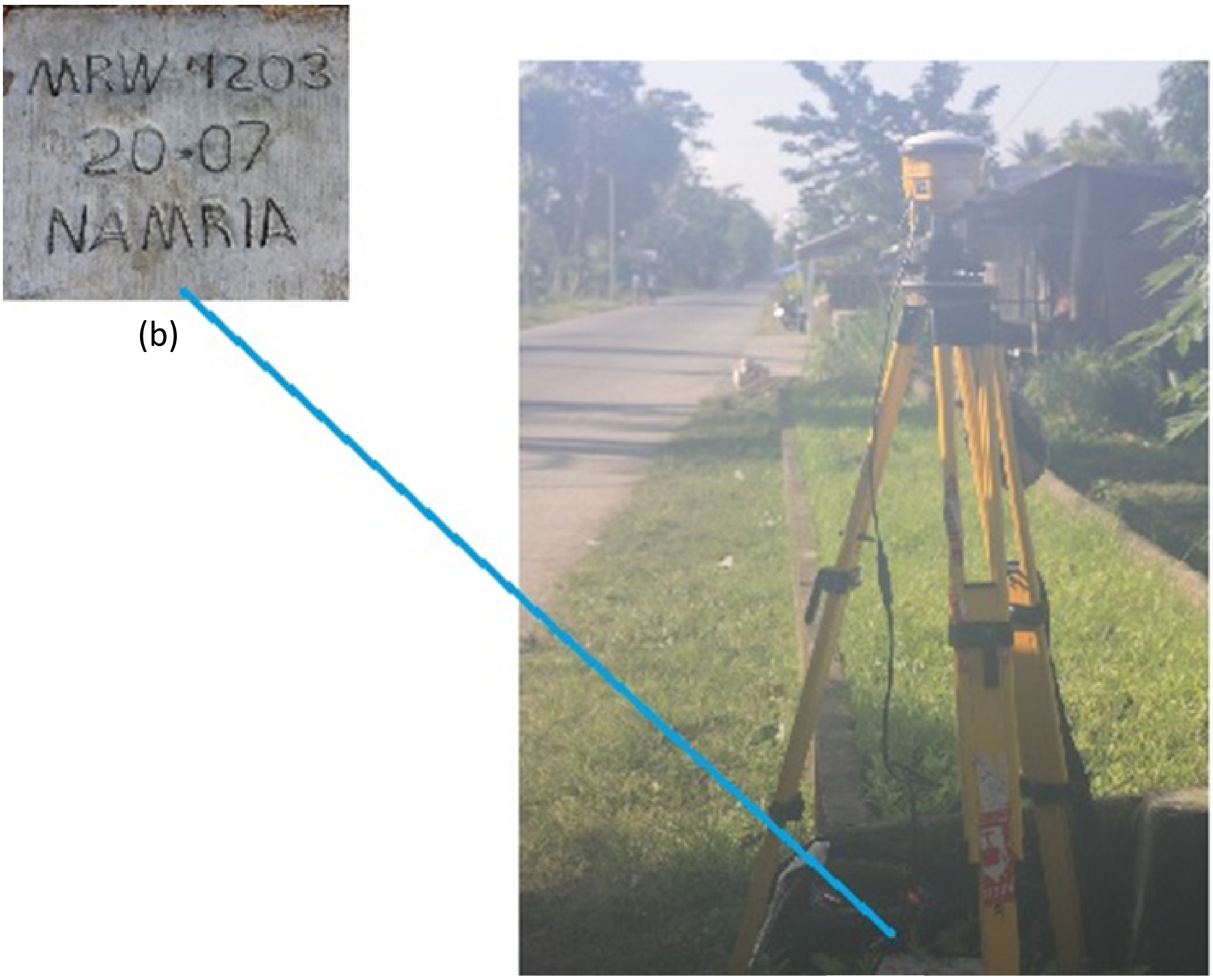


Figure 4. GPS set-up over MRW-24 in the basketball court in Brgy. Iriron, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-24 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRW-24 used as base station for the LiDAR acquisition.

Station Name	MRW-24	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°36’42.98691” North 120°55’49.01762” East 5.69500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	492425.435 meters 1394624.897 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°36’38.03549” North 120°55’54.08296” East 54.47900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	275166.05 meters 1395022.71 meters



(b)

(a)

Figure 5. GPS set-up over MRW-4203 in front of the barangay hall of Brgy. Mapaya, municipality of San Jose, Occidental Mindoro (a) and NAMRIA reference point MRW-4203 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRW-4203 used as base station for the LiDAR acquisition.

Station Name	MRW-4203	
Order of Accuracy	3rd Order	
Relative Error (horizontal positioning)	1 in 20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°21'24.45294" North 121°07'26.92407" East 7.40100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	513501.246 meters 1366404.003 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°21'19.57973" North 121°07'32.01059" East 57.32000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	296032.79 meters 1366637.32 meters

(a) (b)

Figure 6. GPS set-up over MRW-18 inside the municipal compound of Magsaysay, Occidental Mindoro (a) and NAMRIA reference point MRW-18 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point MRW-18 used as base station for the LiDAR acquisition.

Station Name	MRW-18	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°18'45.39463" North 121°8'35.92441" East 21.29500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	515618.524 meters 1361517.851 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°18'40.53383" North 121°8'42.01469" East 71.37500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	298113.89 meters 1361734.74 meters

(a)

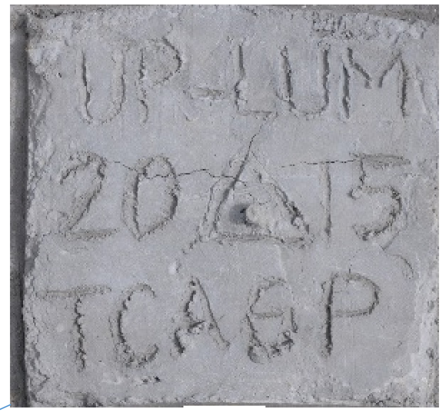
(b)

Figure 7. GPS set-up over MC-252 along National road beside KM post 211 in the municipality of Magsaysay, Occidental Mindoro (a) and NAMRIA reference point MC-252 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA vertical control point MC-252 used as base station for the LiDAR Acquisition with the re-processed coordinates.

Station Name	MC-252	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°19'10.66357" North 121°12'17.05287" East 76.241 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°19'05.80624" North 121°12'22.14215" East 126.454 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	304770.876 meters 1362466.012 meters

(a)



(b)

Figure 8. GPS set-up over UP-LUM in the municipality of Rizal, Occidental Mindoro (a) and reference point UP-LUM (b) as established by the field team.

Table 8. Details of the horizontal control point UP-LUM used as base station for the LiDAR Acquisition with the re-processed coordinates.

Station Name	UP-LUM	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31’36.65200” North 120°59’13.78049” East 35.185 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31’31.72599” North 120°59’18.85291” East 84.296 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	281275.130 meters 1385560.055 meters

Table 9. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 27, 2014	1152A	3BLK29GSD58A	MRW-22, MRW-24
February 28, 2014	1158A	3BLK29A59B	MRW-22, MRW-4203
March 1, 2014	1160A	3BLK29C60A	MRW-22, MRW-4203
March 1, 2014	1162A	3BLK29AS60B	MRW-22, MRW-4203
March 2, 2014	1164A	3BLK29N61A	MRW-22, MRW-4203
March 2, 2014	1166A	3BLK29B61B	MRW-22, MRW-4203
March 3, 2014	1168A	3BLK29BS62A	MRW-22, MRW-4203
December 10, 2015	3074P	1BLK29KLMO344A	MRW-24, UP-Lum 2015 TCGAP
December 11, 2015	3078P	1BLK29NQRS345A	MC-252, MRW-18

2.3 Flight Missions

Nine (9) missions were conducted to complete LiDAR data acquisition in Labangan floodplain, for a total of thirty six hours and thirty three minutes (36+33) of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Pegasus and Aquarius LiDAR systems. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Labangan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km²)	Surveyed Area (km²)	Area Surveyed within the Floodplain (km²)	Area Surveyed outside the Floodplain (km²)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 27, 2014	1152A	79.80	89.81	3.54	86.27	1077	4	23
February 28, 2014	1158A	110.88	66.28	10.74	55.55	580	3	41
March 1, 2014	1160A	90.72	107.85	45.53	62.32	200	4	35
March 1, 2014	1162A	110.88	87.17	27.24	59.93	594	3	41
March 2, 2014	1164A	77.98	112.10	6.95	105.15	311	4	53
March 2, 2014	1166A	140.48	115.93	39.69	76.24	NA	3	59
March 3, 2014	1168A	21.31	69.25	15.29	53.96	NA	4	29
December 10, 2015	3074P	39.52	84.97	-	84.97	455	4	5
December 11, 2015	3078P	33.26	60.65	13.05	47.61	212	2	47
TOTAL		704.83	794.02	162.03	547.03	3429	36	33

Table 11. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap(%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (Hz)	Scan Frequency (kHz)	Average Speed (kts)	Average Turn Time (Minutes)
1152A	550	30	36	50	40	130	5
1158A	550	30	36	50	40	130	5
1160A	600	40	36	50	40	130	5
1162A	600	30	36	50	40	130	5
1164A	600	30	36	50	40	130	5
1166A	600	30	40	50	40	130	5
1168A	550	30	40	50	40	130	5
3074P	1100	30	50	200	30	130	5
3078P	850	30	50	200	32	130	5

2.4. Survey Coverage

Labangan floodplain is located in the province of Occidental Mindoro. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Ibod floodplain is presented in Figure 9.

Table 12. List of municipalities and cities surveyed during the Labangan Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Occidental Mindoro	Magsaysay	256.56	154.69	60%
	San Jose	449.82	231.09	51%
	Rizal	184.98	59.66	32%
	Calintaan	282.31	53.73	19%
Oriental Mindoro	Bulalacao	365.58	77.68	21%
Total		1539.25	576.85	37.48%

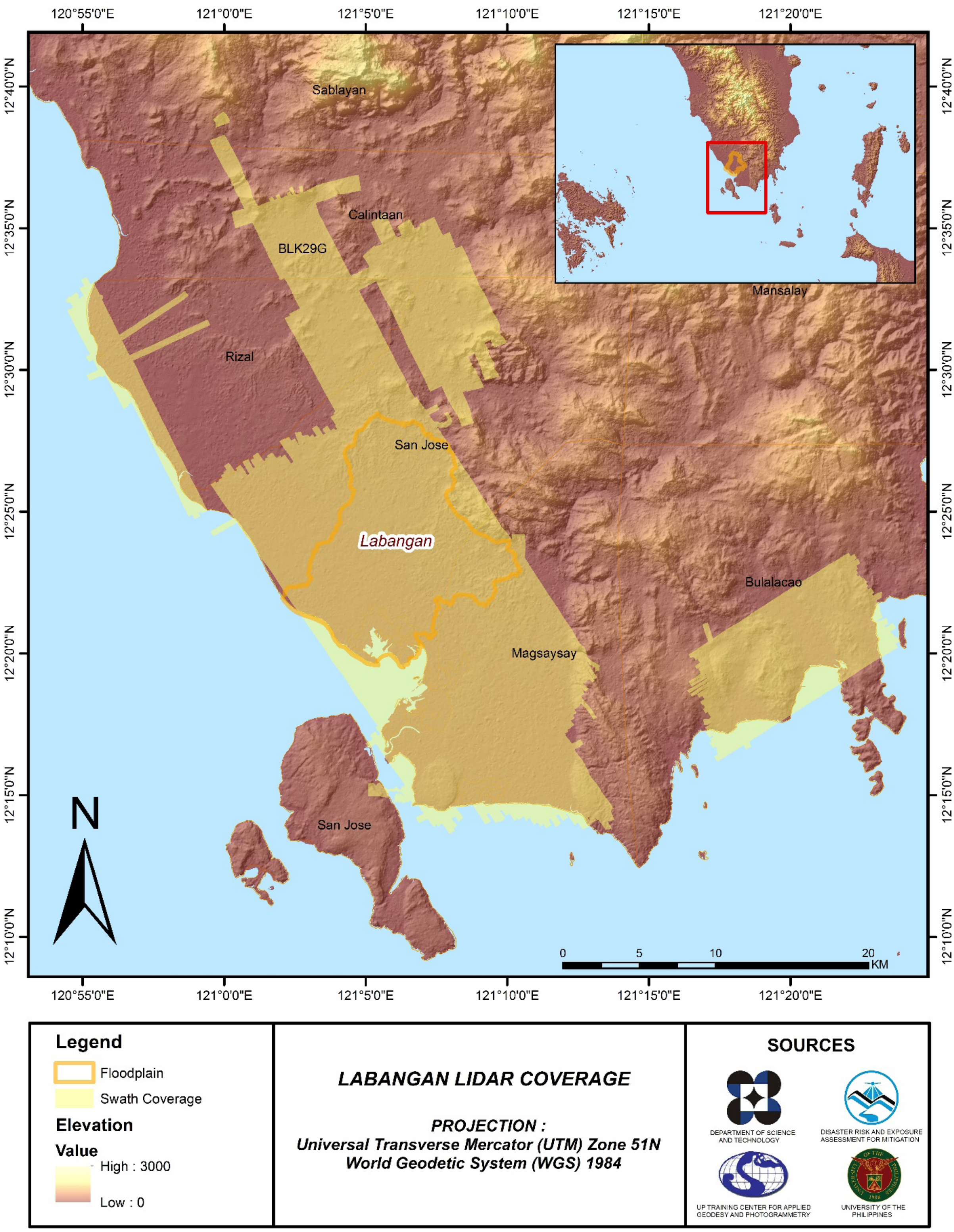


Figure 9. Actual LiDAR survey coverage for Labangan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LABANGAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are 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 is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds 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 are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

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

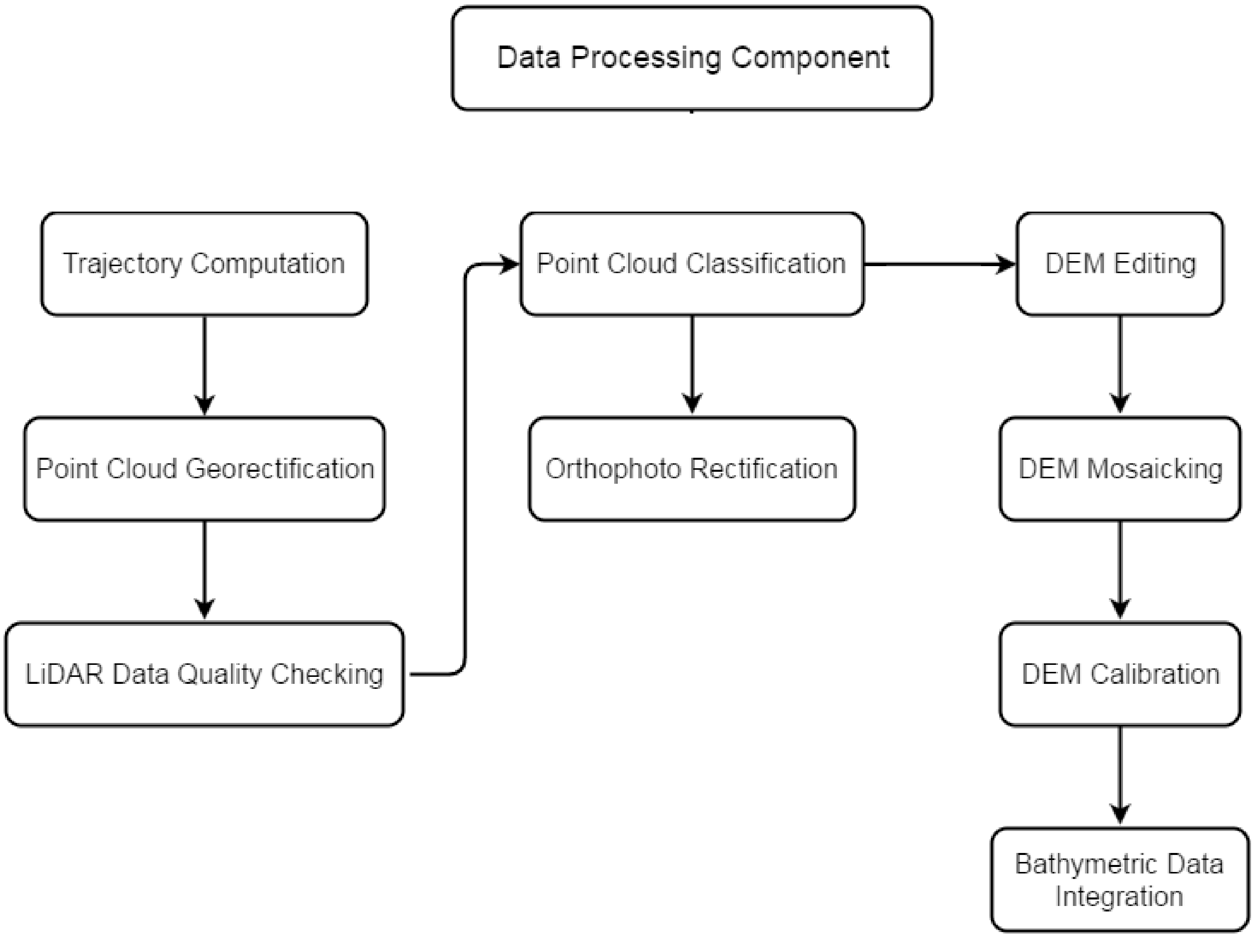

Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Labangan floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on December 2015 were flown using the Pegasus system over San Jose, Occidental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 112.88 Gigabytes of Range data, 2.165 Gigabytes of POS data, 151.42 Megabytes of GPS base station data, and 229.72 Gigabytes of raw image data to the data server on March 19, 2014 for the first survey and January 13, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Labangan was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for Labangan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3074P, one of the Labangan flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on December 10, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

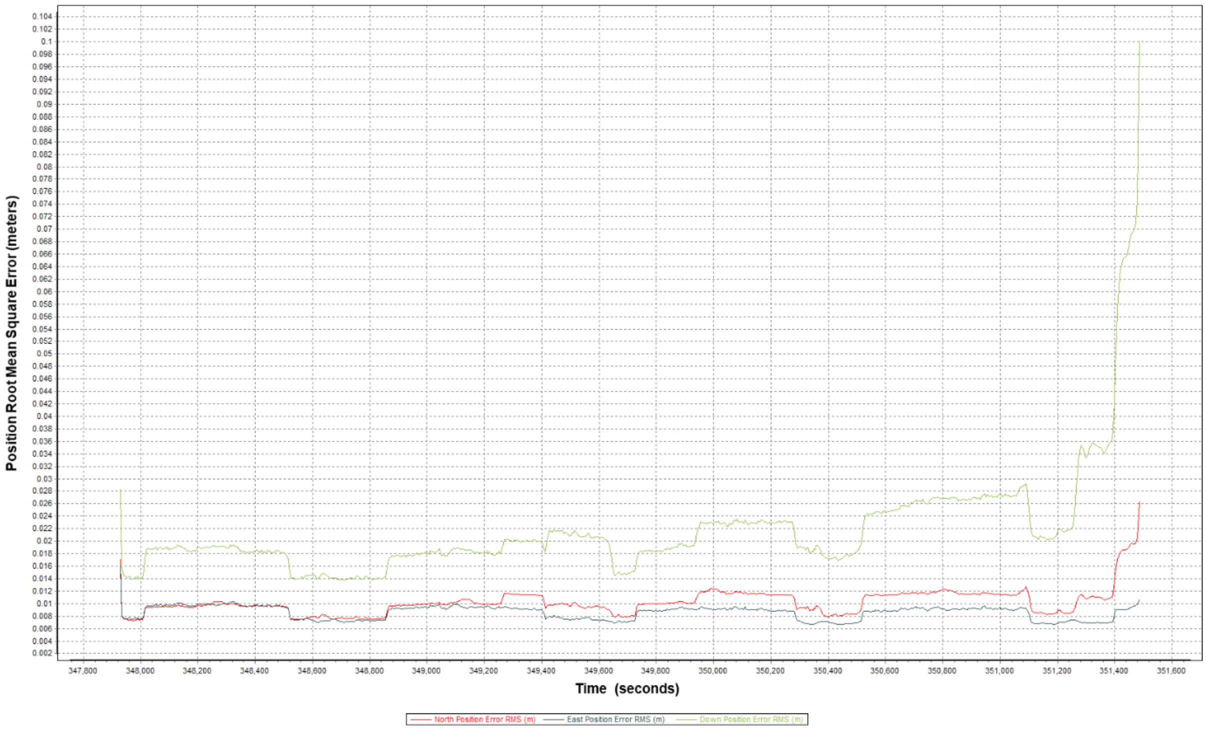

Figure 11. Smoothed Performance Metrics of Labangan Flight 3074P.

The time of flight was from 347900 seconds to 351500 seconds, which corresponds to morning of December 10, 2015. 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 11 shows that the North position RMSE peaks at 1.24 centimeters, the East position RMSE peaks at 1.00 centimeters, and the Down position RMSE peaks at 2.36 centimeters, which are within the prescribed accuracies described in the methodology.

Figure 12. Solution Status Parameters of Labangan Flight 3074P.

The Solution Status parameters of flight 3074P, one of the Labangan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Labangan flights is shown in Figure 13.

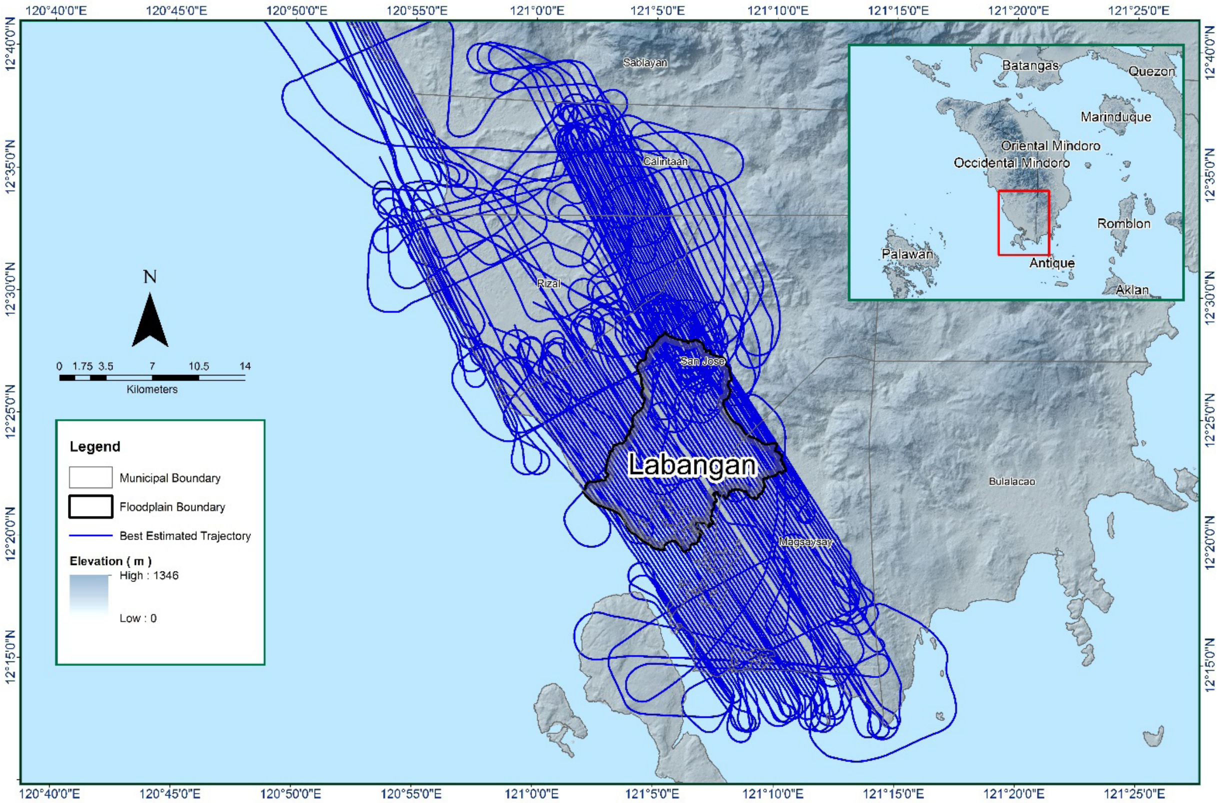

Figure 13. Best Estimated Trajectory for Labangan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 110 flight lines, with each flight line either containing one or two channels, since the Gemini system contains one channel while Pegasus system contains two. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Labangan floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Labangan flights.

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000261
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000678
GPS Position Z-correction stdev (<0.01meters)	0.0014

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Labangan Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

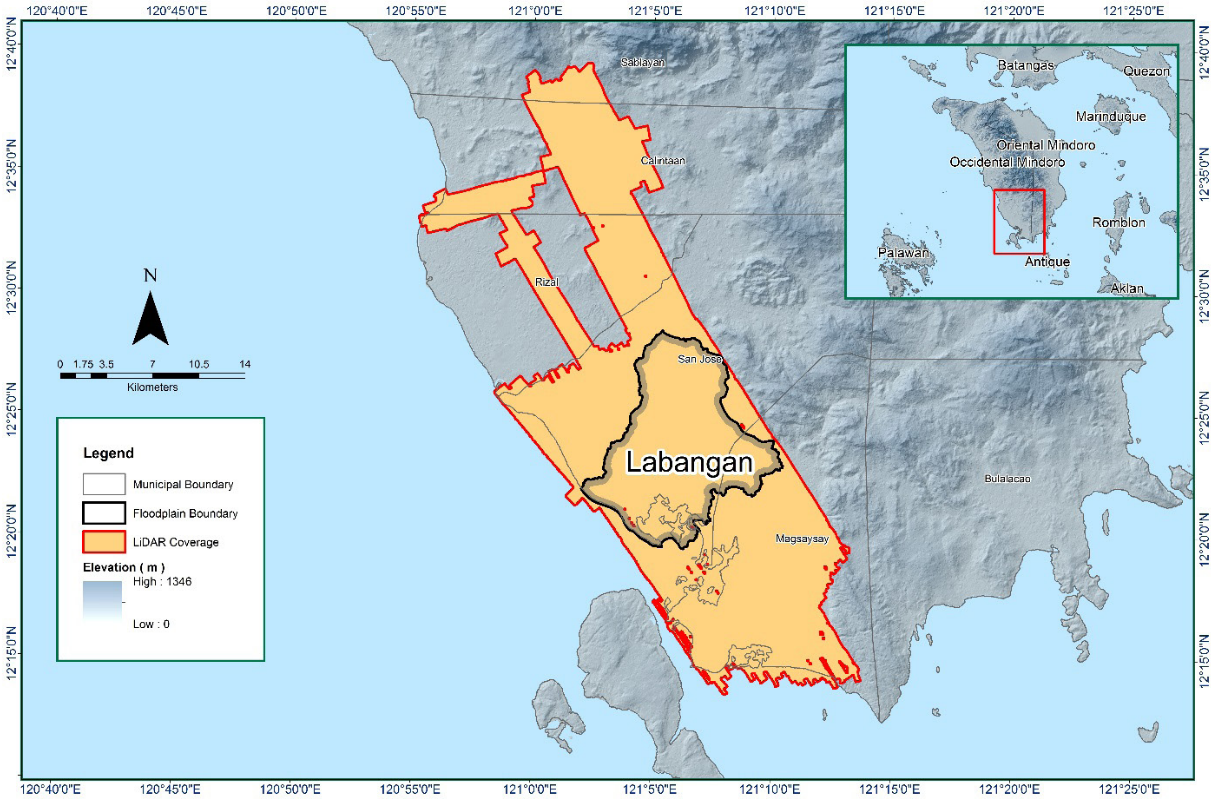

Figure 14. Boundary of the processed LiDAR data over Labangan Floodplain

The total area covered by the Labangan missions is 640.27 sq.km that is comprised of ten (10) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Labangan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29A	1158A	140.61
	1162A	
OccidentalMindoro_Blk29B	1164A	146.16
	1166A	
	1168A	
OccidentalMindoro_Blk29C	1160A	102.42
OccidentalMindoro_Blk29G	1152A	65.98
OccidentalMindoro_reflights_Blk29A	3076P	28.04
OccidentalMIndoro_reflights_Blk29B_additional	3078P	8.95
OccidentalMindoro_reflights_Blk29F	3078P	24.57
OccidentalMindoro_reflights_Blk29G_additional	3074P	123.54
TOTAL		640.27 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

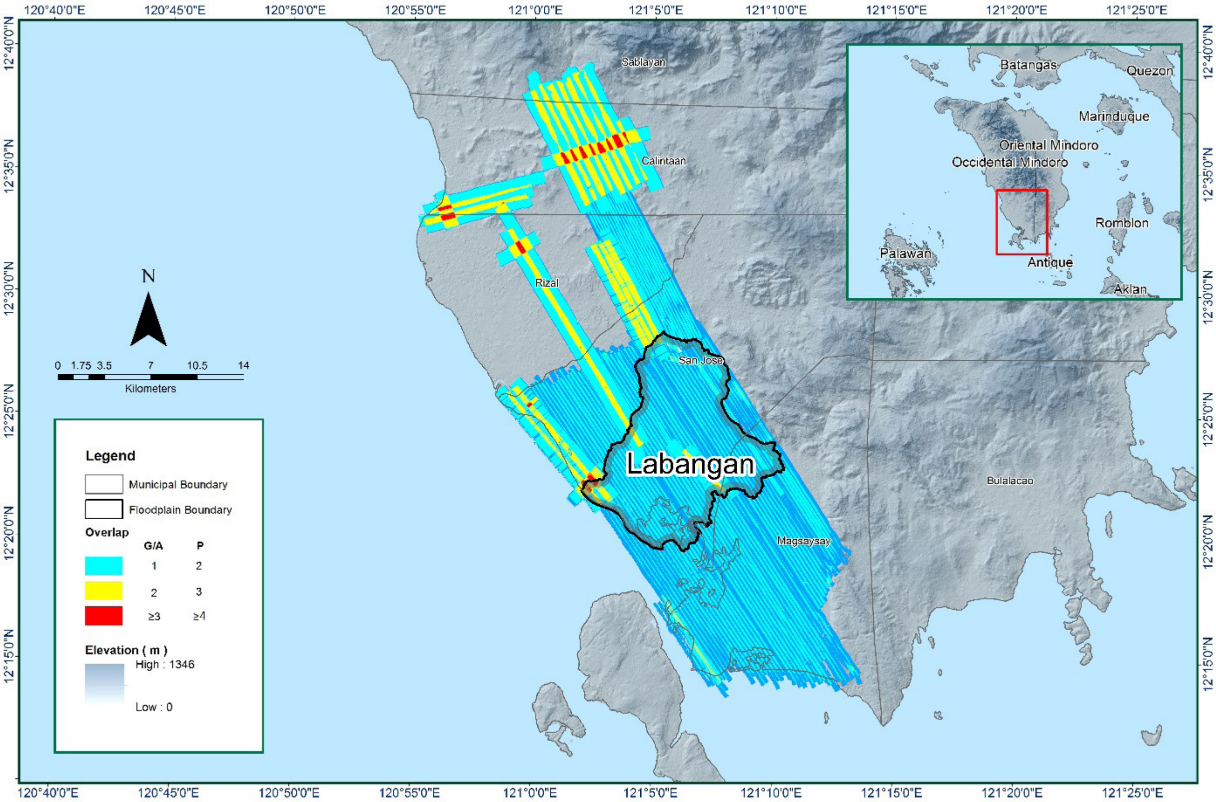

Figure 15. Image of data overlap for Labangan Floodplain.

The overlap statistics per block for the Labangan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 36.55% and 60.10% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Labangan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.00 points per square meter.

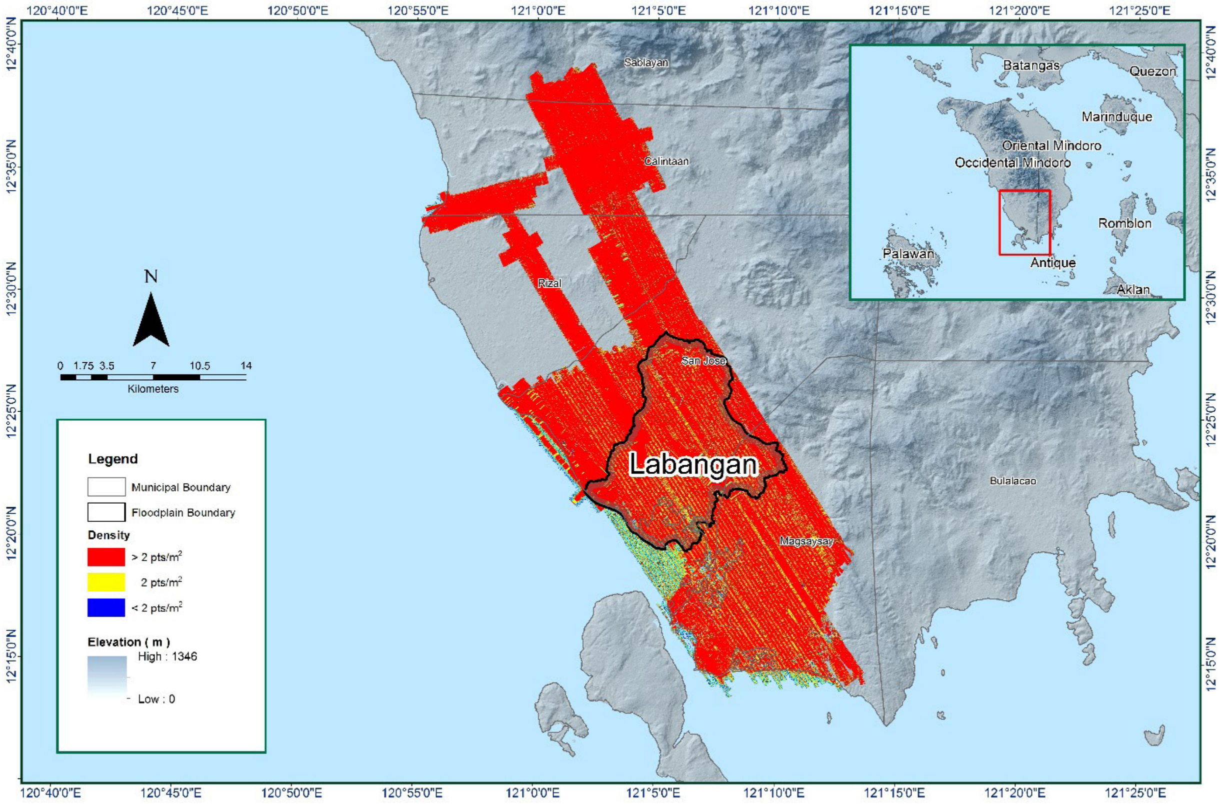

Figure 16. Pulse density map of merged LiDAR data for Labangan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

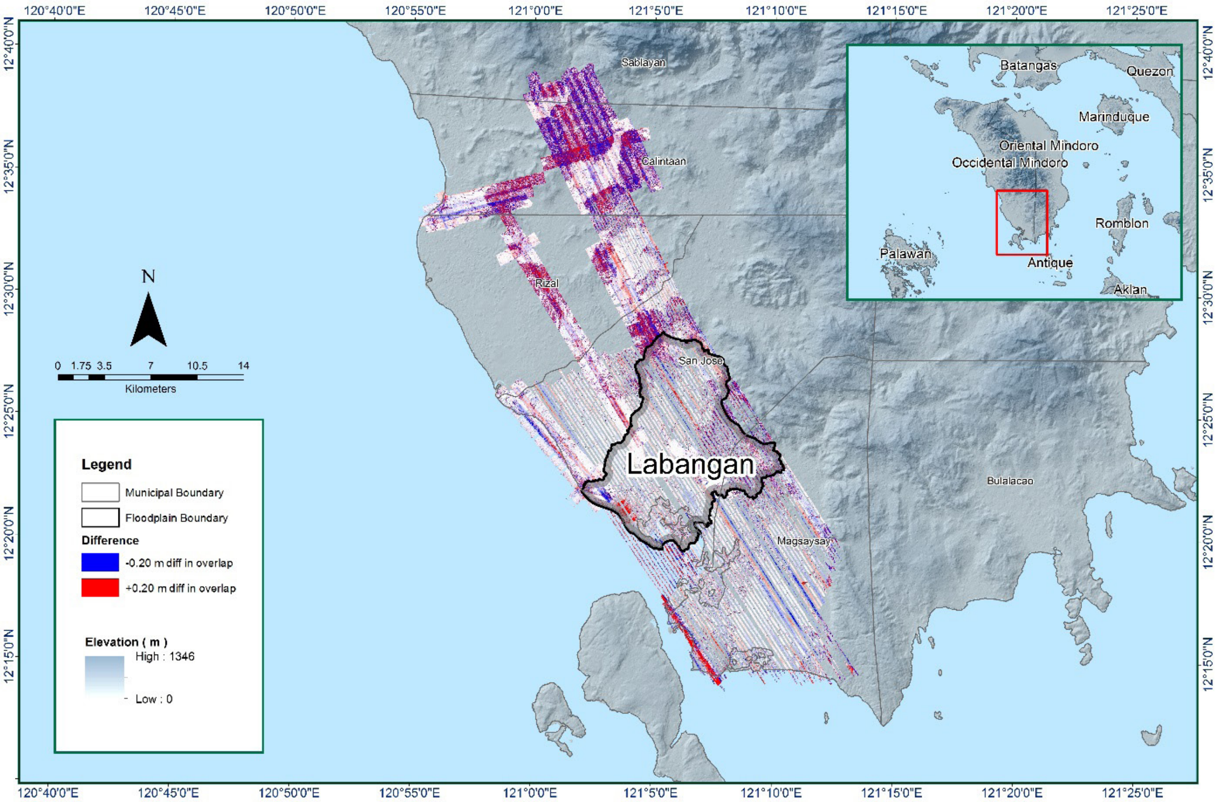

Figure 17. Elevation difference map between flight lines for Labangan Floodplain.

A screen capture of the processed LAS data from a Labangan flight 3074P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

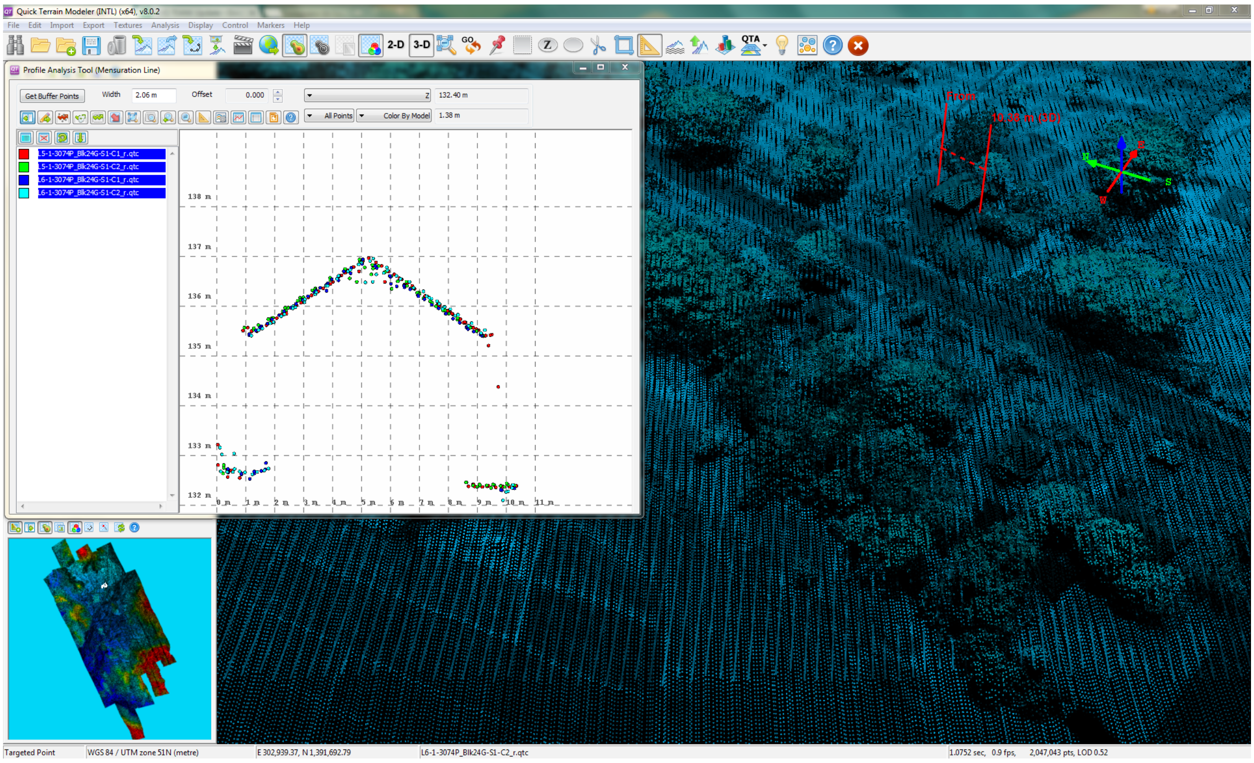

Figure 18. Quality checking for Labangan flight 3074P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Labangan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,038,982,888
Low Vegetation	691,069,951
Medium Vegetation	661,676,112
High Vegetation	1,316,680,891
Building	37,269,685

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Labangan floodplain is shown in Figure 19. A total of 1,023 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 544.26 meters and 3.64 meters respectively.

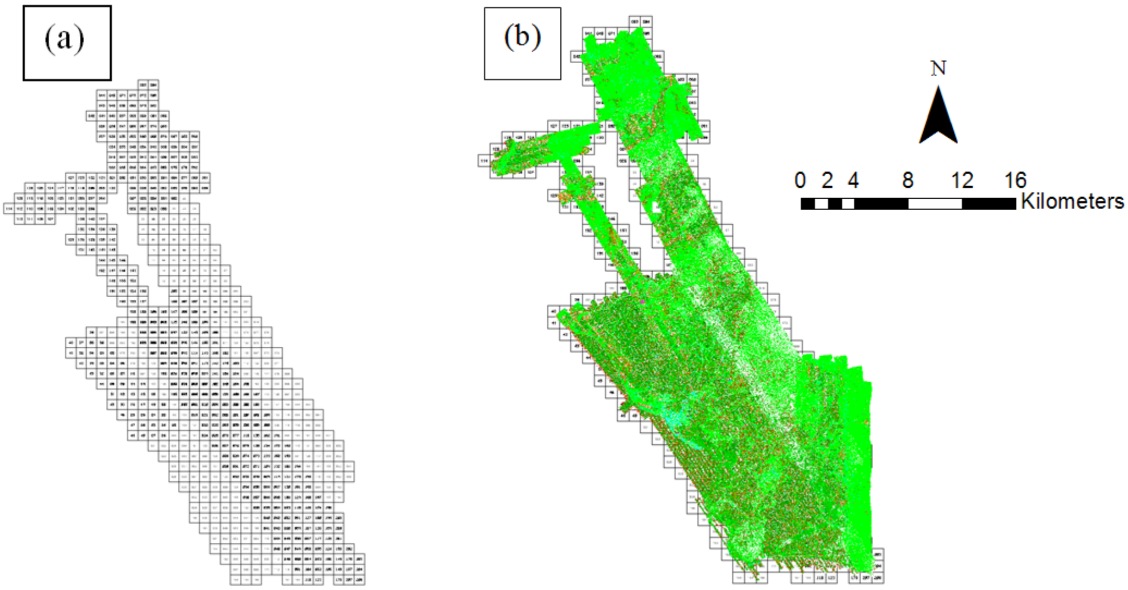

Figure 19. Tiles for Ibod Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

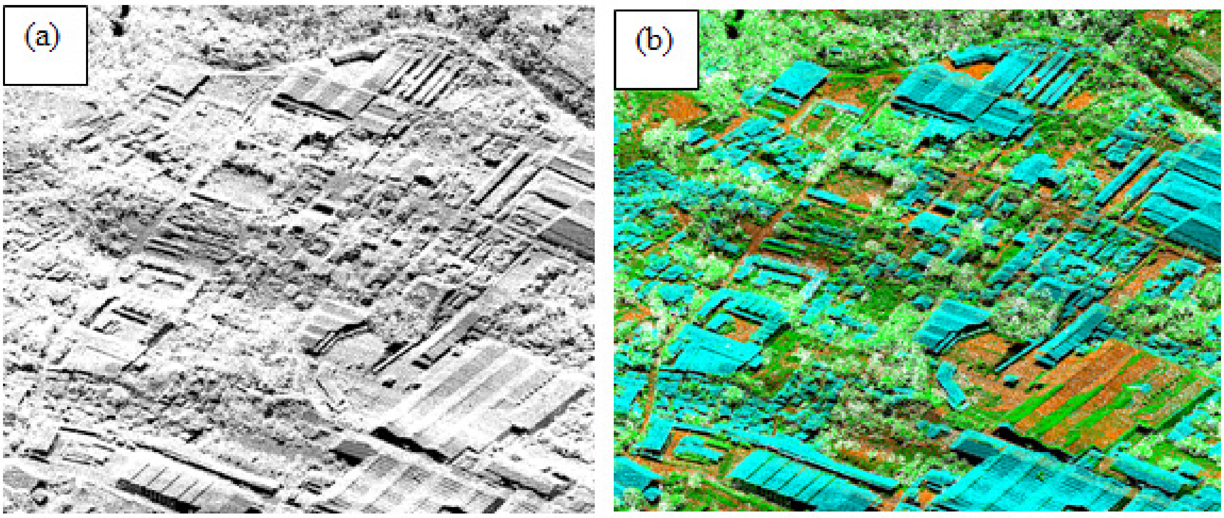

Figure 20. Point cloud before (a) and after (b) classification.

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

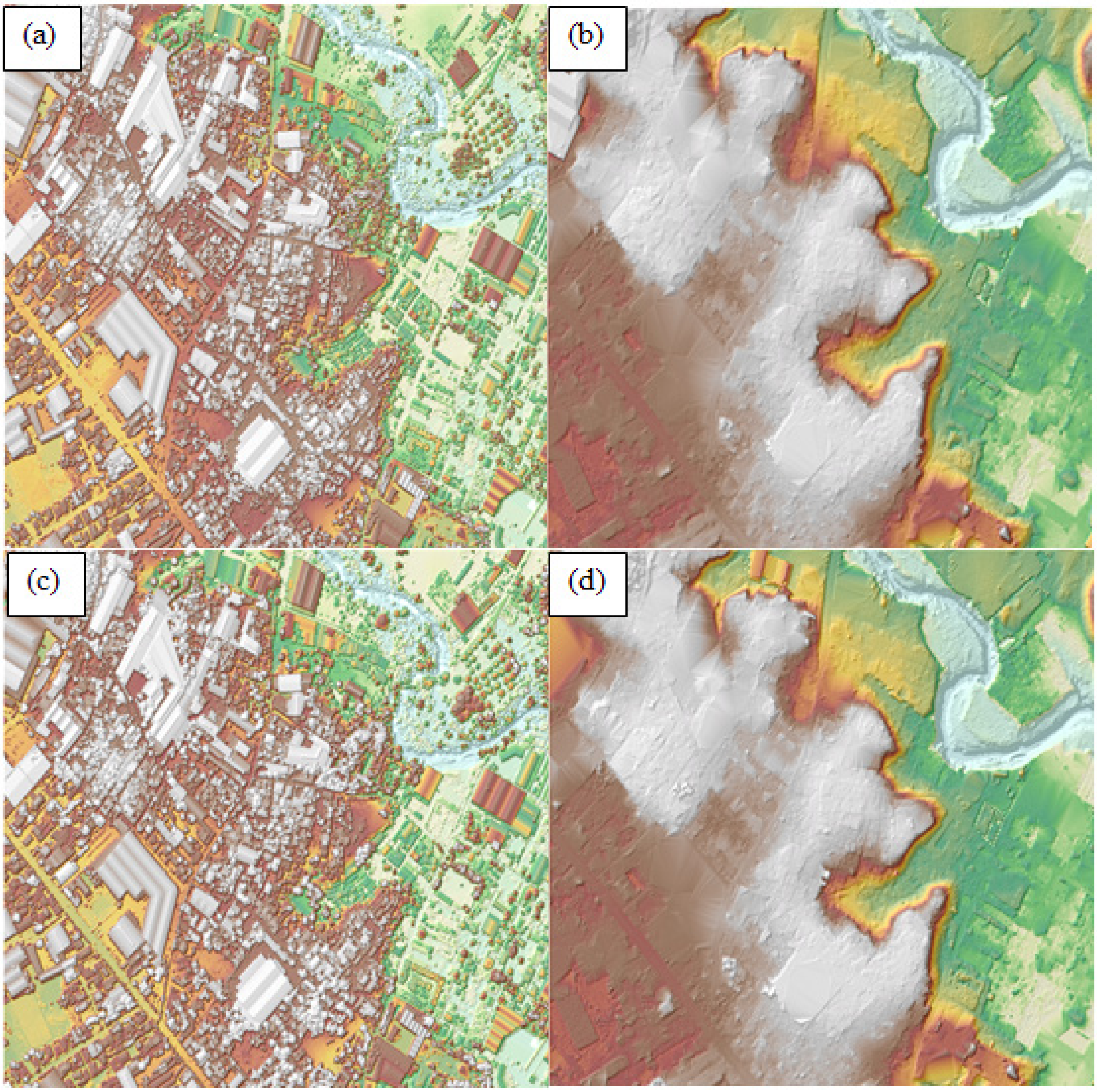

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Labangan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 672 1km by 1km tiles area covered by Labangan floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Labangan floodplain has a total of 420.20 sq.km orthophotogaph coverage comprised of 2,642 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

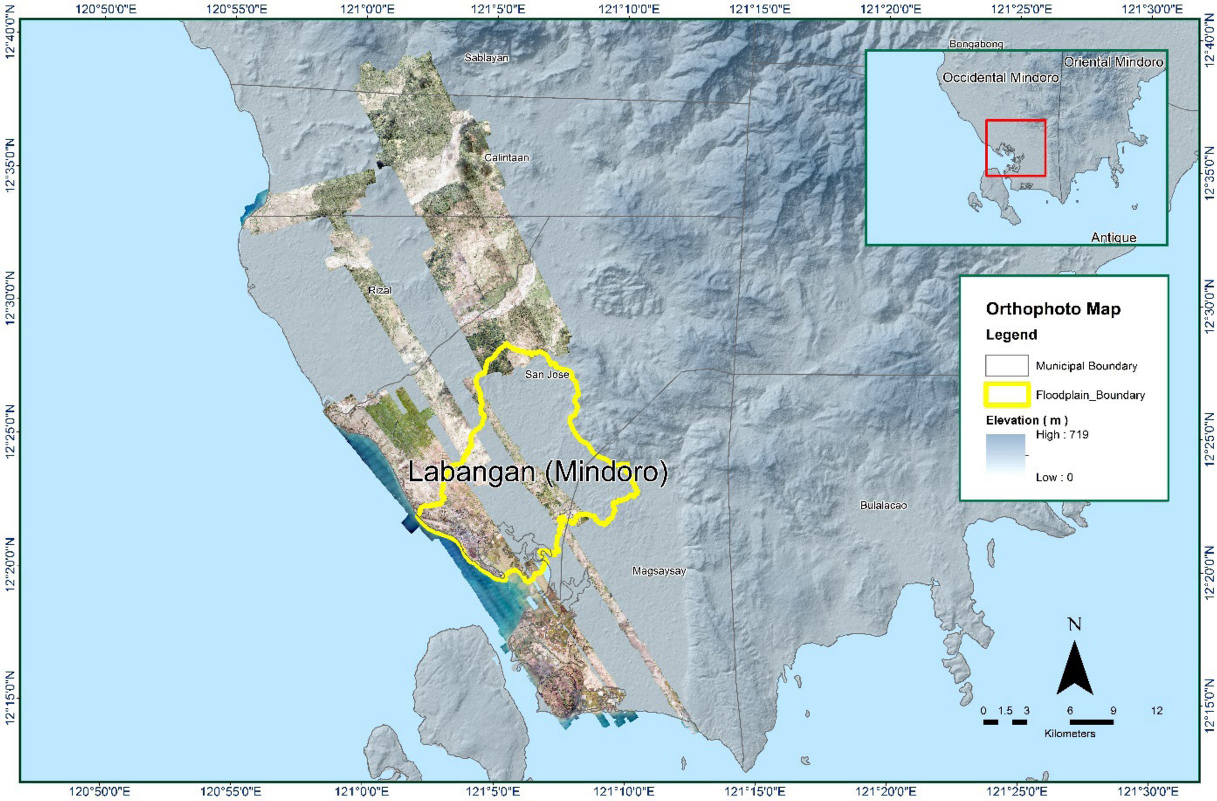

Figure 22. Labangan Floodplain with available orthophotographs

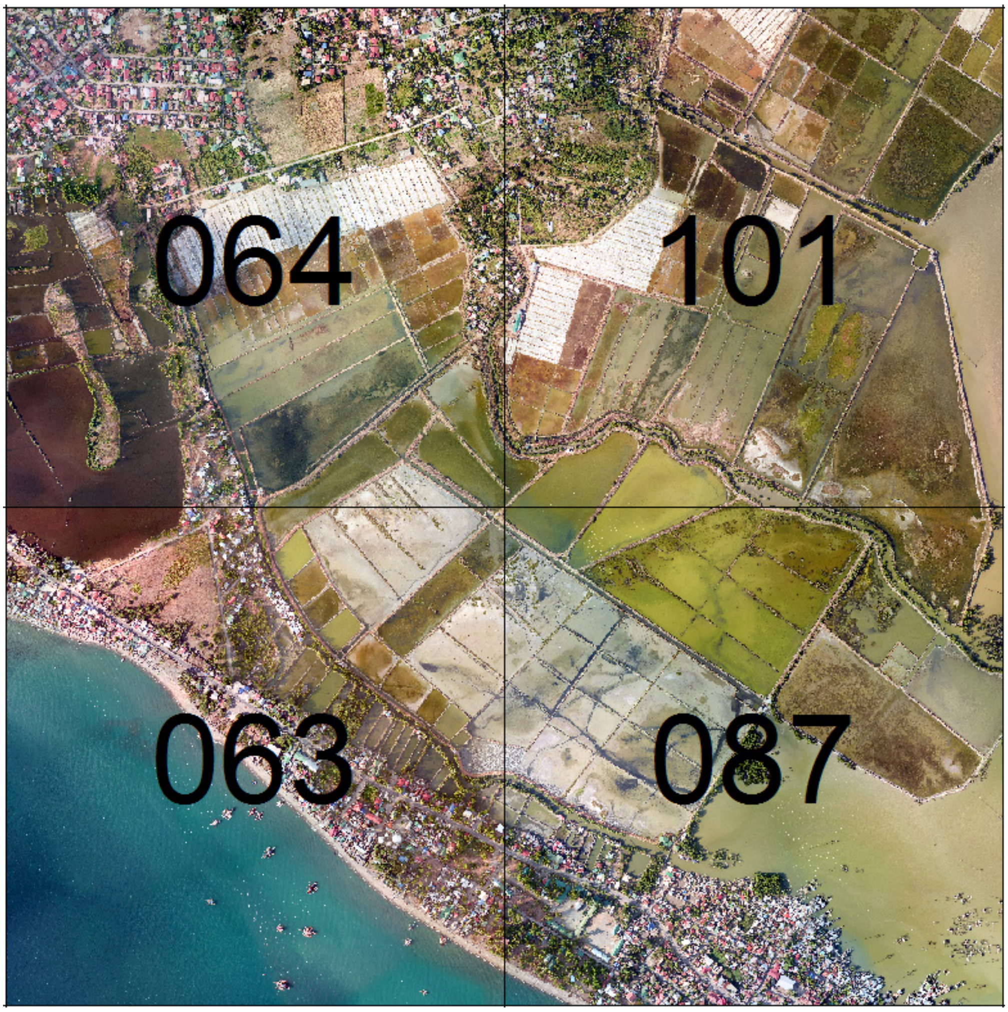

Figure 23. Sample orthophotograph tiles for Labangan Floodplain

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Labangan flood plain. These blocks are composed of OccidentalMindoro and OccidentalMindoro_reflight blocks with a total area of 640.27 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km)
OccidentalMindoro_Blk29A	140.61
OccidentalMindoro_Blk29B	146.16
OccidentalMindoro_Blk29C	102.42
OccidentalMindoro_Blk29G	65.98
OccidentalMindoro_reflights_Blk29A	28.04
OccidentalMIndoro_reflights_Blk29B_additional	8.95
OccidentalMindoro_reflights_Blk29F	24.57
OccidentalMindoro_reflights_Blk29G_additional	123.54
TOTAL	640.27 sq.km

Portions of DTM before and after manual editing are shown in Figure 24. The land bridge in Figure 24a would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 24b. Another portion of the DTM presented in Figure 24c shows the part of the river which was previously flattened during pre-processing and retrieved as shown in Figure 24d.

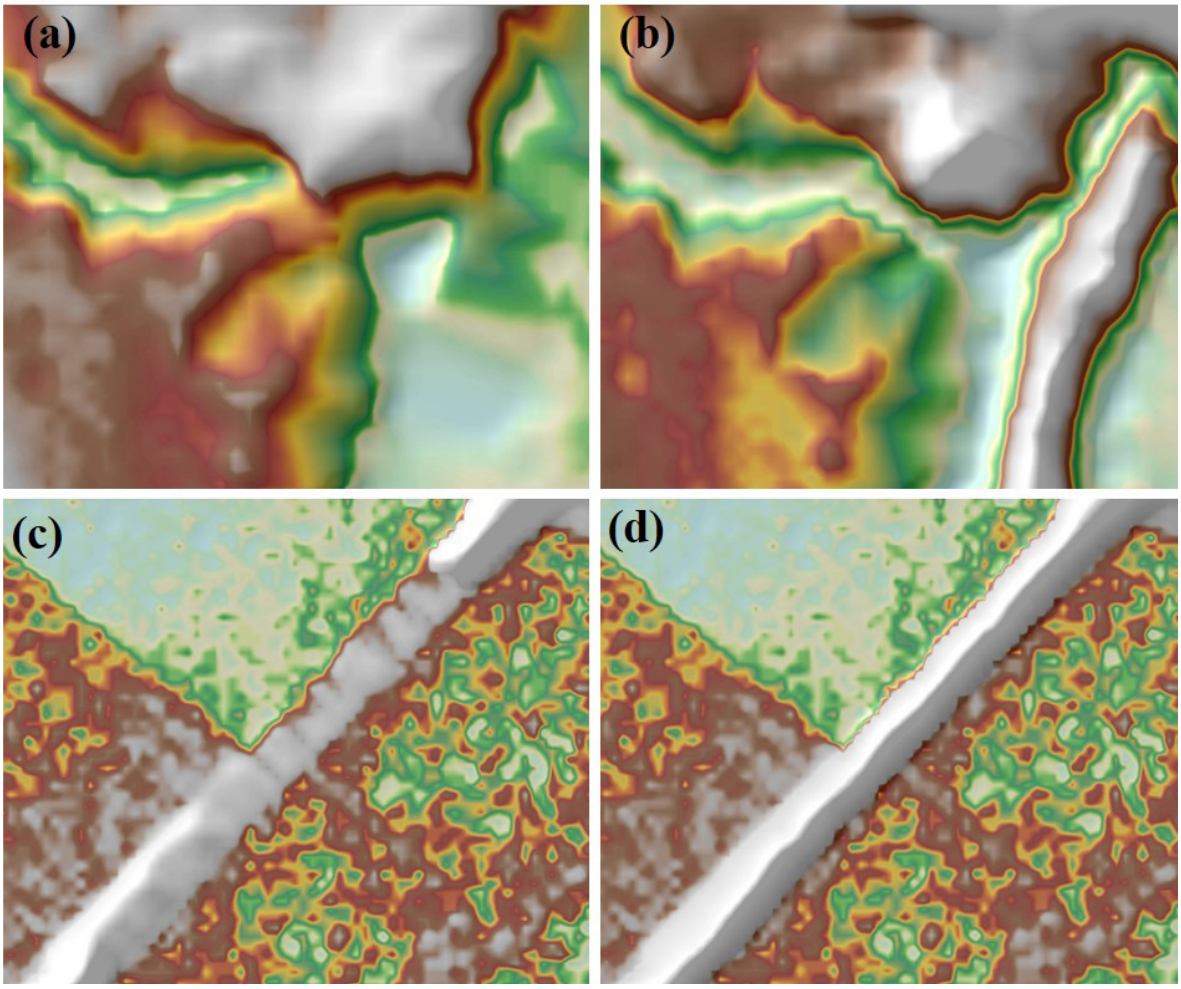

Figure 24. Portions in the DTM of Labangan Floodplain – a land bridge before (a) and after (b) data interpolation and flattened part of the floodplain before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Mosaicked DEM of Occidental Mindoro was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 17 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Ibod floodplain is shown in Figure 25. It can be seen that the entire Labangan floodplain is 100% covered by LiDAR data.

Table 17. Shift Values of each LiDAR Block of Labangan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29A	0.00	0.00	-0.44
OccidentalMindoro_Blk29B	0.00	0.00	-0.55
OccidentalMindoro_Blk29C	0.00	-0.34	0.99
OccidentalMindoro_Blk29G	0.00	0.00	-0.40
OccidentalMindoro_reflights_Blk29A	0.00	0.00	-1.72
OccidentalMIndoro_reflights_Blk29B_additional	0.00	0.00	-0.50
OccidentalMindoro_reflights_Blk29F	0.00	0.00	-1.41
OccidentalMindoro_reflights_Blk29G_additional	0.00	0.00	-1.69

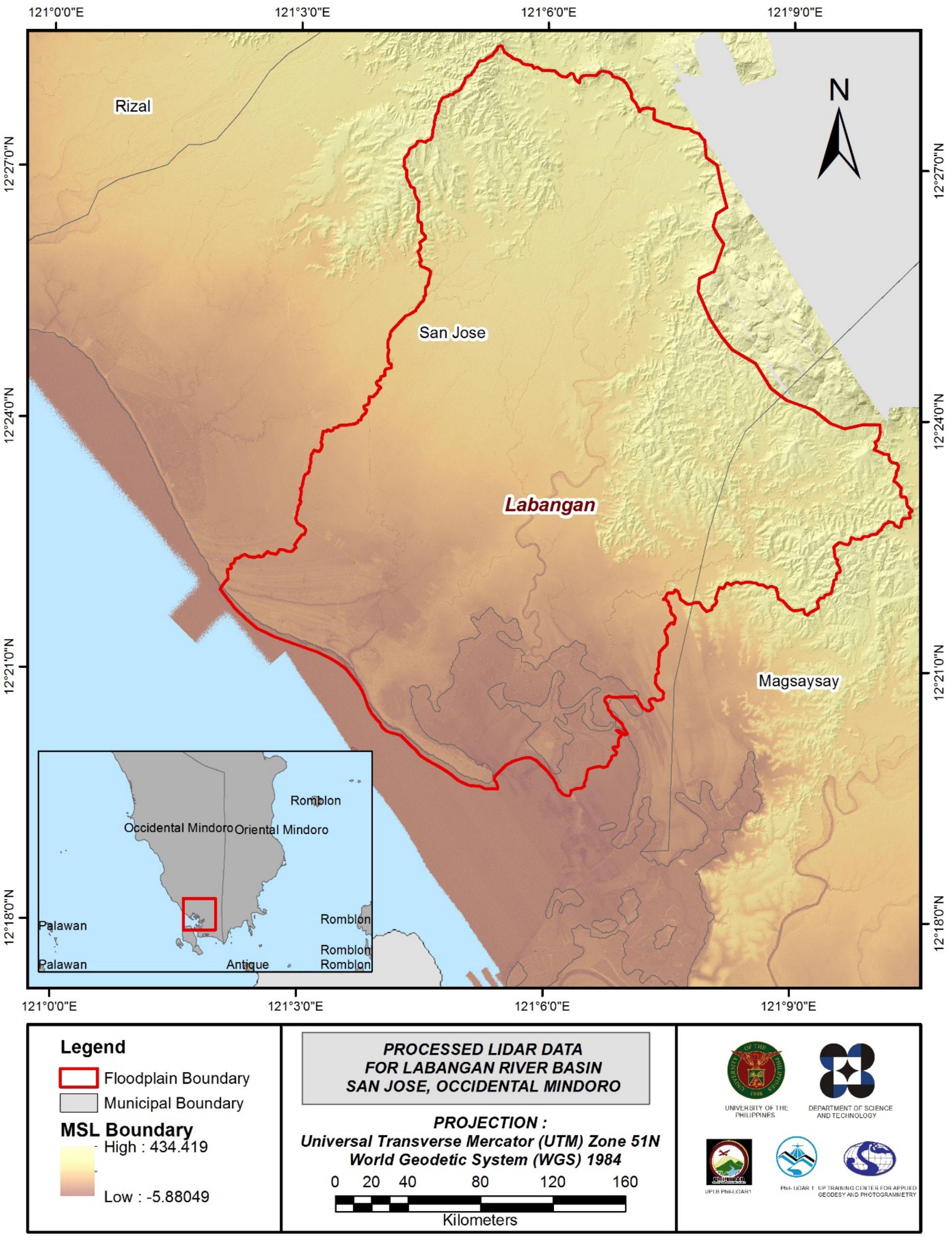

Figure 25. Map of Processed LiDAR Data for Labangan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Labangan to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 28,494 survey points were used for calibration and validation of Labangan LiDAR data. Random selection of 80% of the survey points, resulting to 22,795 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Labangan LiDAR data was done by adding the height difference value, 0.23 meters, to Labangan mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

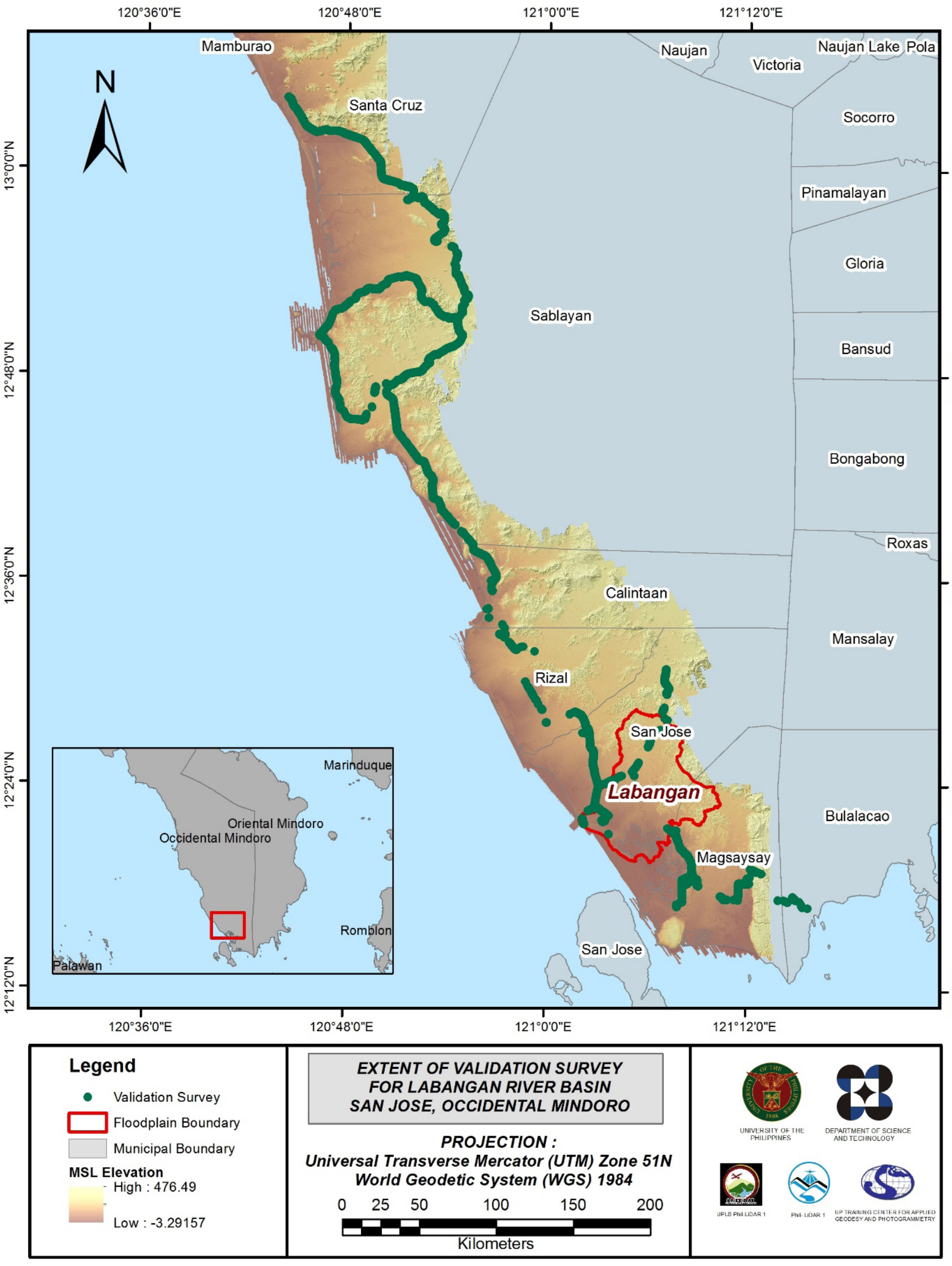

Figure 26. Map of Labangan Floodplain with validation survey points in green.

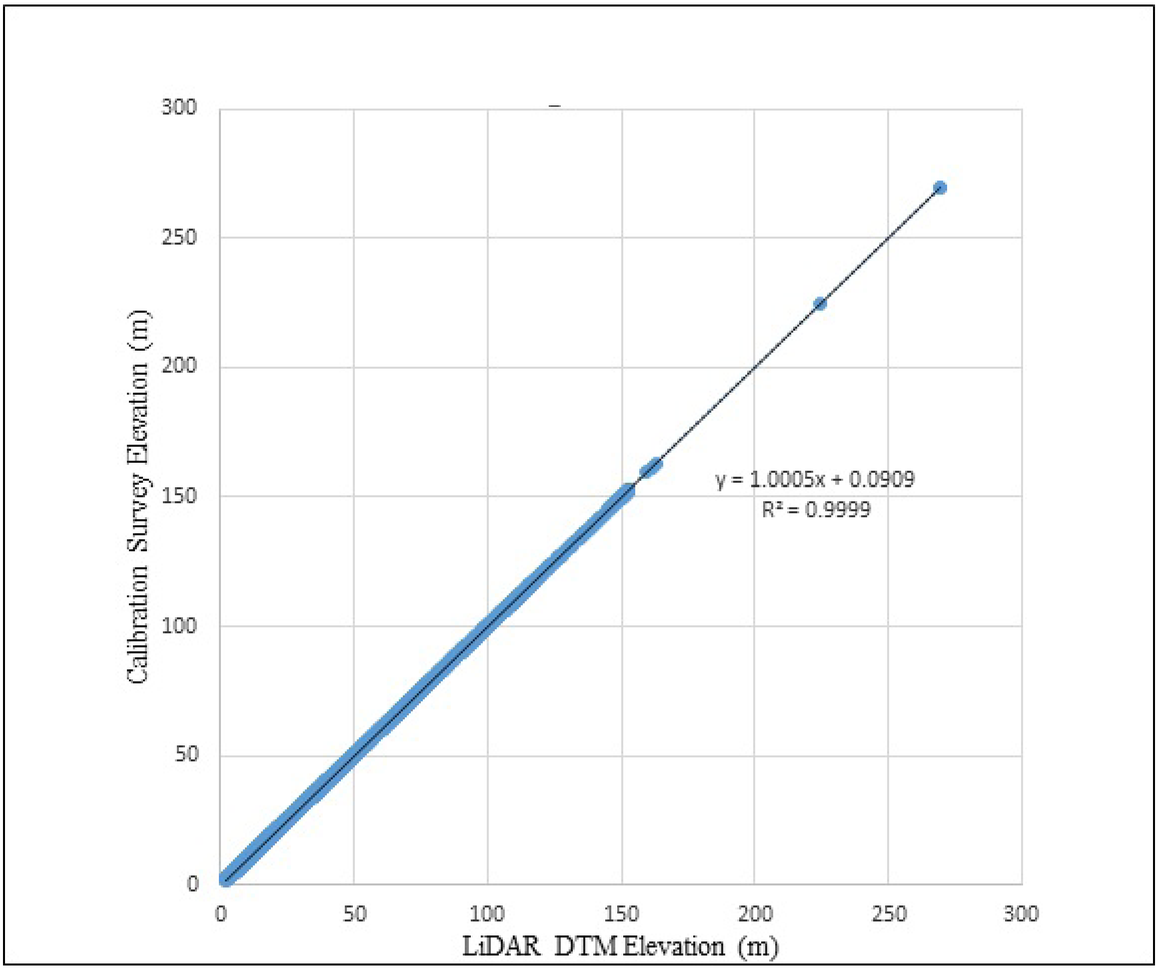

Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.23
Standard Deviation	0.20
Average	0.10
Minimum	-0.33
Maximum	0.53

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 195 points. These were used for the validation of calibrated Labangan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.20 meters, as shown in Table 19.

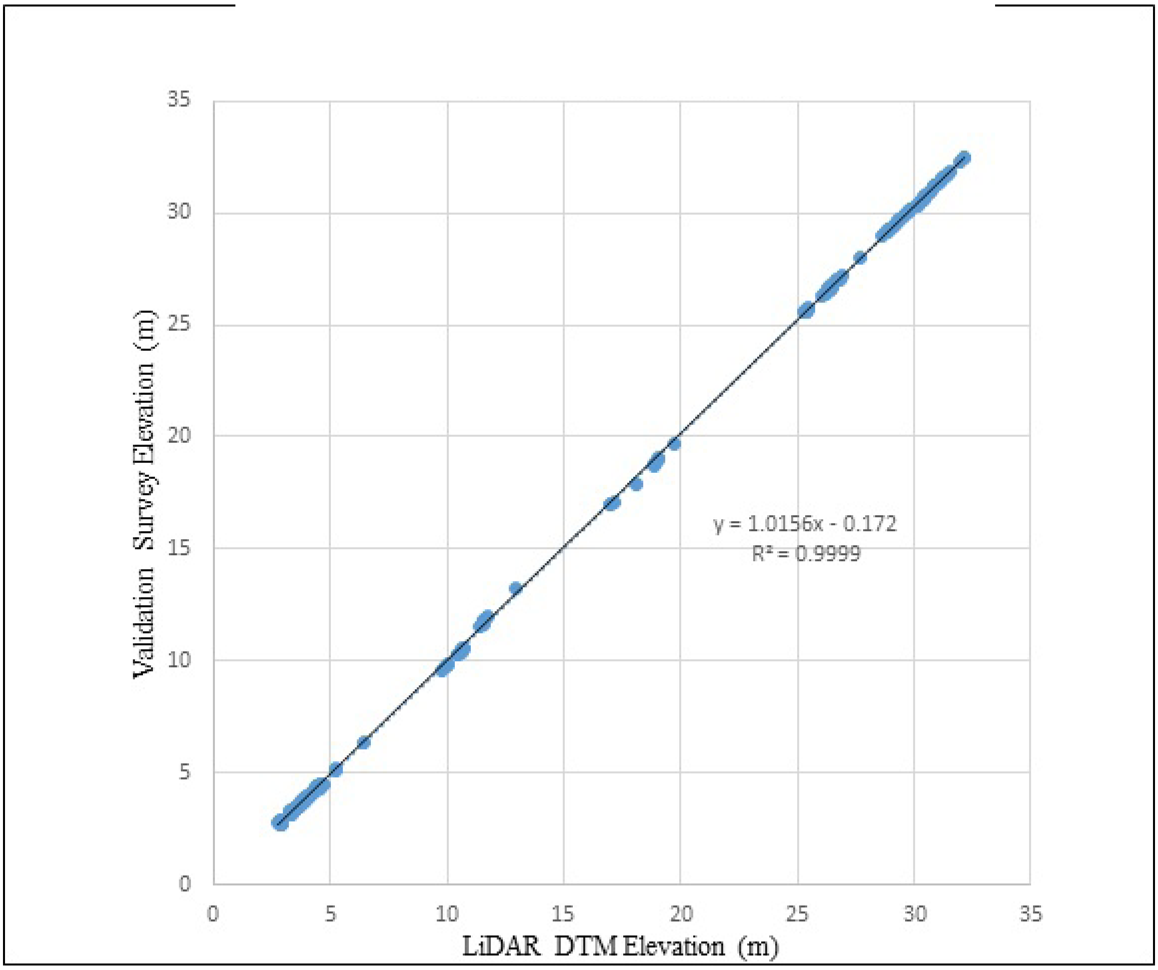

Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 19. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.20
Average	0.06
Minimum	-0.20
Maximum	0.35

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data was available for Labangan with 9,976 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barrier 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 Labangan integrated with the processed LiDAR DEM is shown in Figure 29.

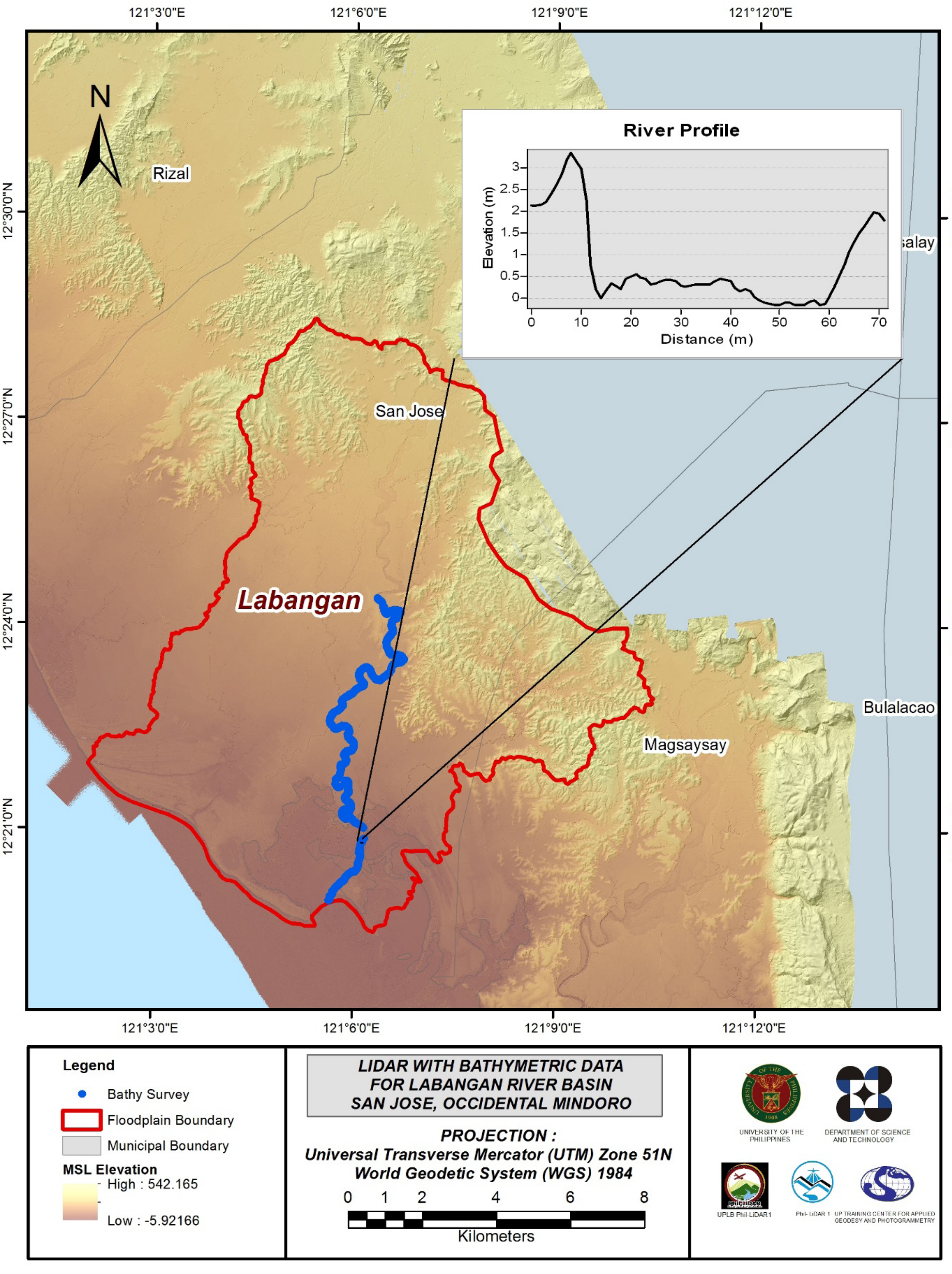

Figure 29. Map of Labangan Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF LABANGAN RIVER BASIN

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field survey in Labangan River on November 3-24, 2015 with the following scope of work: reconnaissance to determine the viability of traversing the planned routes for bathymetric survey; courtesy call with UPLB, San Jose LGUs and MDRRMC; control survey; cross-section survey, bridge as-built features determination and water level marking at Pinamanaan Bridge with coordinates Lat 12d22’07.55024”N and Long 121d05’54.64311”E; ground validation survey along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate distance of 191 km. Lastly, bathymetric survey from Brgy. Monte Claro down to the mouth of the river in Brgy. Mapaya, Municipality of San Jose with an approximate length of 22.48 km using GNSS PPK survey technique. The entire survey extent is illustrated in Figure 30.

Figure 30. Labangan River Survey Extent

4.2 Control Survey

The GNSS network used for Labangan River Basin is composed of five (5) loops established on November 5, 15 and 17, 2015 occupying the following reference points: MRW-24, a second order GCP in Brgy. Iriron, Municipality of Calintaan; MRW-30, a second order GCP in Bry. Pinagturilan, Municipality of Sta. Cruz; MC-200, a first order BM in Brgy. Magsikap, Municipality of Rizal; and MC-212, also a first order BM in Brgy. Sto. Niño in Rizal.

Three (3) control points were established along the approach of bridges, namely: UP-PIN at Pinamanaan Bridge in Brgy. Mapaya, Municipality of San Jose; UP-ALI at Alipid Bridge in Brgy. Sto. Niño, Municipality of Sablayan; and UP-MOM at Mompong Bridge in Brgy. Lumang Bato, also in Sablayan. The control point established by DPWH, namely GPS-4, in Brgy. Poblacion, Municipality of Magsaysay; and MC-90, established by NAMRIA, in Brgy. Barahan, Municipality of Sta. Cruz were also occupied to use as a marker for the network.

The summary of reference and control points and its location is summarized in Table 20 while the GNSS network established is illustrated in Figure 31.

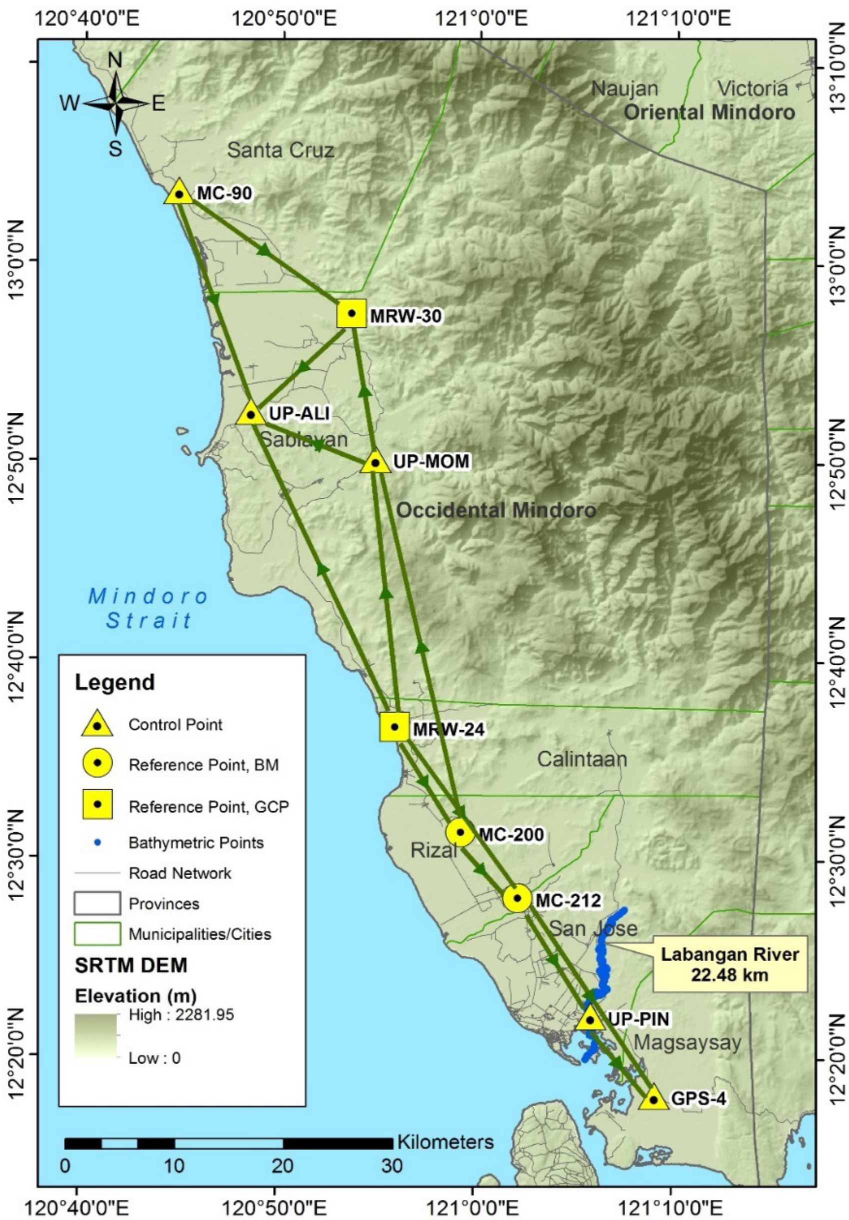


Figure 31. GNSS Network covering Labangan River

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

Control Point	Order of Accuracy	Geographic Coordinates (UTM Zone 51)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation in MSL (Meter)	Date Established
MC-200	1st order, BM	-	-	83.225	-	2007
MC-212	1st order, BM	-	-	74.473	-	2007
MRW-24	2nd order, GCP	12°36’38.03550”	120°55’54.08297”	53.435	4.746	2007
MRW-30	2nd order, GCP	12°57’27.19115”	120°53’33.54441”	88.823	41.752	2007
MC-90	UP Established	-	-	-	-	2007
UP-ALI	UP Established	-	-	-	-	2015
UP-MOM	UP Established	-	-	-	-	2015
UP-PIN	UP Established	-	-	-	-	2015
GPS-4	DPWH Established	-	-	-	-	2013

The GNSS set up in reference points and established control points in the Occidental Mindoro survey are shown in Figure 32 to Figure 40.

Figure 32. GNSS receiver set-up, Trimble® SPS 852, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

Figure 33. GNSS receiver setup, Trimble® SPS 882, at MRW-30 Amnay Bridge approach in Sitio Kabangkalan, Brgy. Pinagturilan, Municipality of Santa Cruz, Occidental Mindoro

Figure 34. GNSS receiver set-up, Trimble® SPS 882, at MC-200, Lumintao Bridge approach in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

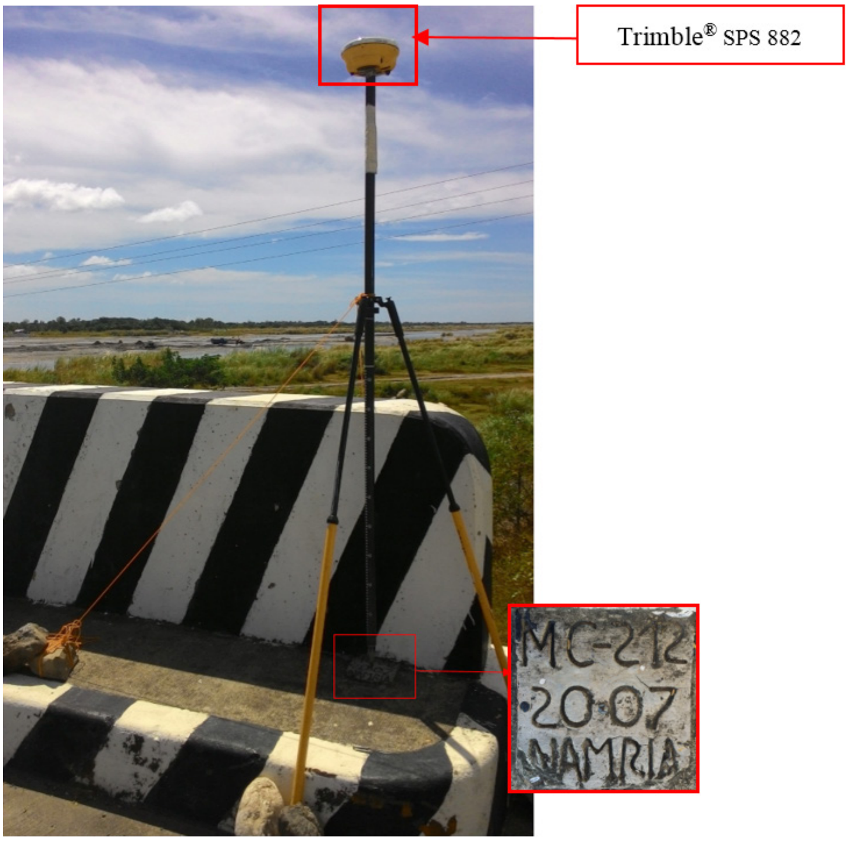


Figure 35. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

Figure 36. GNSS receiver, Trimble® SPS 852, at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

Figure 37. GNSS receiver, Trimble® SPS 882, at GPS-4 on right side of the road abutment after Caguray Bridge going to Bulalacao in Brgy. Poblacion, Municipality of Magsaysay, Occidental Mindoro

Figure 38. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 39. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro

Figure 40. GNSS receiver set up, Trimble® SPS 882, at UP-ALI, Alipid Bridge approach in Brgy. Sto. Niño, Municipality of Sablayan, Occidental Mindoro

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Labangan River Basin is summarized in Table 21 generated by TBC software.

Table 21. Baseline Processing Report for Labangan River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MC-212 --- GPS-4	11-05-2015	Fixed	0.003	0.015	145°21’06”	22241.566	-11.807
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.011	0.017	170°24’13”	13704.513	55.240
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.003	0.023	170°24’12”	13704.541	55.249
MRW-30 --- MC-90	11-17-2015	Fixed	0.010	0.018	305°24’12”	19473.086	-35.515
UP-PIN --- MC-212	11-05-2015	Fixed	0.003	0.007	328°11’40”	12856.399	14.631
UP-PIN --- GPS-4	11-05-2015	Fixed	0.003	0.006	141°30’11”	9422.221	2.872
MC-200 --- UP-PIN	11-05-2015	Fixed	0.003	0.022	144°37’57”	20841.368	-23.356
MC-200 --- UP-MOM	11-05-2015	Fixed	0.009	0.014	346°57’26”	35544.301	60.755
MC-200 --- UP-MOM	11-05-2015	Fixed	0.004	0.014	346°57’27”	35544.309	60.692
MC-200 --- MC-212	11-05-2015	Fixed	0.003	0.006	138°58’31”	8048.668	-8.741
UP-ALI --- UP-MOM	11-15-2015	Fixed	0.008	0.013	110°57’37”	12258.370	88.024
UP-MOM --- UP-ALI	11-15-2015	Fixed	0.004	0.036	110°57’37”	12258.373	88.139
UP-ALI --- MRW-30	11-17-2015	Fixed	0.009	0.012	45°05’52”	12929.488	32.865
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.017	45°05’52”	12929.476	32.850
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.007	45°05’51”	12929.529	32.747
MC-90 --- UP-ALI	11-17-2015	Fixed	0.004	0.008	341°46’30”	21480.592	-2.784

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-24 --- UP-PIN	11-05-2015	Fixed	0.003	0.006	145°50’52”	32317.096	6.413
MRW-24 --- MC-200	11-05-2015	Fixed	0.005	0.007	148°04’31”	11489.166	29.777
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.009	0.015	355°30’36”	24950.818	90.611
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.003	0.006	355°30’36”	24950.824	90.574
MRW-24 --- UP-ALI	11-15-2015	Fixed	0.006	0.007	335°24’00”	32186.124	2.579

As shown in Table 21, a total of twenty-one (21) baselines were processed with reference point MRW-24 and MRW-30 held fixed for coordinates; and MC-200 and MC-212 fixed for elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for complete details.

The nine (9) control points, MRW-24, MRW-30, MC-200, MC-212, MC-90, GPS-4, UP-PIN, UP-MOM, and UP-ALI were occupied and observed simultaneously to form a GNSS loop. All 14 baselines acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively as shown in Table 23.

Table 22. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MC-200	Grid				Fixed
MC-212	Grid				Fixed
MRW-24	Global	Fixed	Fixed		
MRW-30	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. The fixed control points MRW-24 and MRW-30; and MC-200 and MC-212 have no values for grid and elevation errors, respectively.

Table 23. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
GPS-4	299069.894	0.039	1360649.962	0.032	12.062	0.068	
MC-200	281320.527	0.022	1385155.121	0.016	34.024	?	e
MC-212	286558.124	0.028	1379041.958	0.022	24.884	?	e
MC-90	255607.924	0.039	1444800.407	0.023	8.195	0.095	
MRW-24	275320.607	?	1394955.913	?	4.746	0.045	LL
MRW-30	271390.777	?	1433384.691	?	41.752	0.091	LL
UP-ALI	262152.459	0.020	1424334.041	0.015	9.503	0.071	
UP-MOM	273564.872	0.015	1419850.456	0.012	96.192	0.055	
UP-PIN	293256.669	0.031	1368066.413	0.024	9.659	0.045	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table C-5.Using the equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for horizontal and $z_e < 10\ cm z_e < 10\ cm$ for the vertical; below is the computation for accuracy that passed the required precision:

GPS-4
Horizontal accuracy = √ ((3.9) ² + (3.2) ²
= √(15.21 + 10.24)
= 5.0 cm < 20 cm
Vertical accuracy = 6.8 cm < 10 cm

MC-200
Horizontal accuracy = √ ((2.2) ² + (1.6) ²
= √(4.84 + 2.56)
= 7.4 cm < 20 cm
Vertical accuracy = Fixed

MC-212
Horizontal accuracy = √ ((2.8) ² + (2.2) ²
= √(7.84+ 4.84)
= 3.6 cm < 20 cm
Vertical accuracy = Fixed

MC-90
Horizontal accuracy = √ ((3.9) ² + (2.3) ²
= √(15.21 + 5.29)
= 4.5 cm < 20 cm
Vertical accuracy = 9.5 cm < 10 cm

MRW-24
Horizontal accuracy = Fixed
Vertical accuracy = 4.5 cm < 10 cm

MRW-30
Horizontal accuracy = Fixed
Vertical accuracy = 9.1 cm < 10 cm

UP-ALI
Horizontal accuracy = $\sqrt{((2.0)^2 + (1.5)^2}$
= $\sqrt{(4.0 + 2.25)}$
= 2.5 cm < 20 cm
Vertical accuracy = 7.1 cm < 10 cm

UP-MOM
Horizontal accuracy = $\sqrt{((1.5)^2 + (1.2)^2}$
= $\sqrt{(2.25 + 1.44)}$
= 1.9 cm < 20 cm
Vertical accuracy = 5.5 cm < 10 cm

UP-PIN
Horizontal accuracy = $\sqrt{((3.1)^2 + (2.4)^2}$
= $\sqrt{(9.61 + 5.76)}$
= 3.9 cm < 20 cm
Vertical accuracy = 4.5 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the nine (9) occupied control points are within the required accuracy of the program.

Table 24. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
GPS-4	N12°18'07.55698"	E121°09'08.74194"	62.705	0.068	
MC-200	N12°31'20.68884"	E120°59'15.31613"	83.225	?	e
MC-212	N12°28'03.07503"	E121°02'10.26310"	74.473	?	e
MC-90	N13°03'34.14427"	E120°44'46.70844"	53.232	0.095	
MRW-24	N12°36'38.03549"	E120°55'54.08296"	53.435	0.045	LL
MRW-30	N12°57'27.19115"	E120°53'33.54442"	88.823	0.091	LL
UP-ALI	N12°52'30.24359"	E120°48'29.69149"	55.998	0.071	
UP-MOM	N12°50'07.47193"	E120°54'49.30855"	144.013	0.055	
UP-PIN	N12°22'07.54999"	E121°05'54.64323"	59.843	0.045	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 25. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM Zone 51		
		Latitude	Longitude	Ellipsoid Height (m)	Northing	Easting	Elevation in MSL (Meter)
MC-200	1st order, BM	12°31'20.68883"	120°59'15.31614"	83.225	1385155.121	281320.527	34.024
MC-212	1st order, BM	12°28'03.07504"	121°02'10.26310"	74.473	1379041.958	286558.124	24.884
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MC-90	UP Established	13°03'34.14426"	120°44'46.70845"	53.232	1444800.407	255607.924	8.195
UP-ALI	UP Established	12°52'30.24358"	120°48'29.69148"	55.998	1424334.041	262152.459	9.503
UP-MOM	UP Established	12°50'07.47192"	120°54'49.30854"	144.013	1419850.456	273564.872	96.192
UP-PIN	UP Established	12°22'07.55000"	121°05'54.64323"	59.843	1368066.413	293256.669	9.659
GPS-4	DPWH Established	12°18'07.55700"	121°09'08.74194"	62.706	1360649.962	299069.894	12.062

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

Bridge cross-section and as-built survey were conducted on November 11 and 23, 2015 at the downstream side of Pinamanaan Bridge across Labangan River in Brgy. Mangarin, Municipality of San Jose using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 41.

Figure 41. Bridge as-built and cross-section survey at the downstream side of Pinamanaan Bridge, Brgy. Mangarin, Municipality of San Jose

The cross-sectional line length in Labangan is about 70.556 meters with 30 cross-sectional points using UP-PIN and MC-200 as the GNSS base stations. The cross section diagram and the bridge data form are shown in Figure 42 to Figure 44, respectively

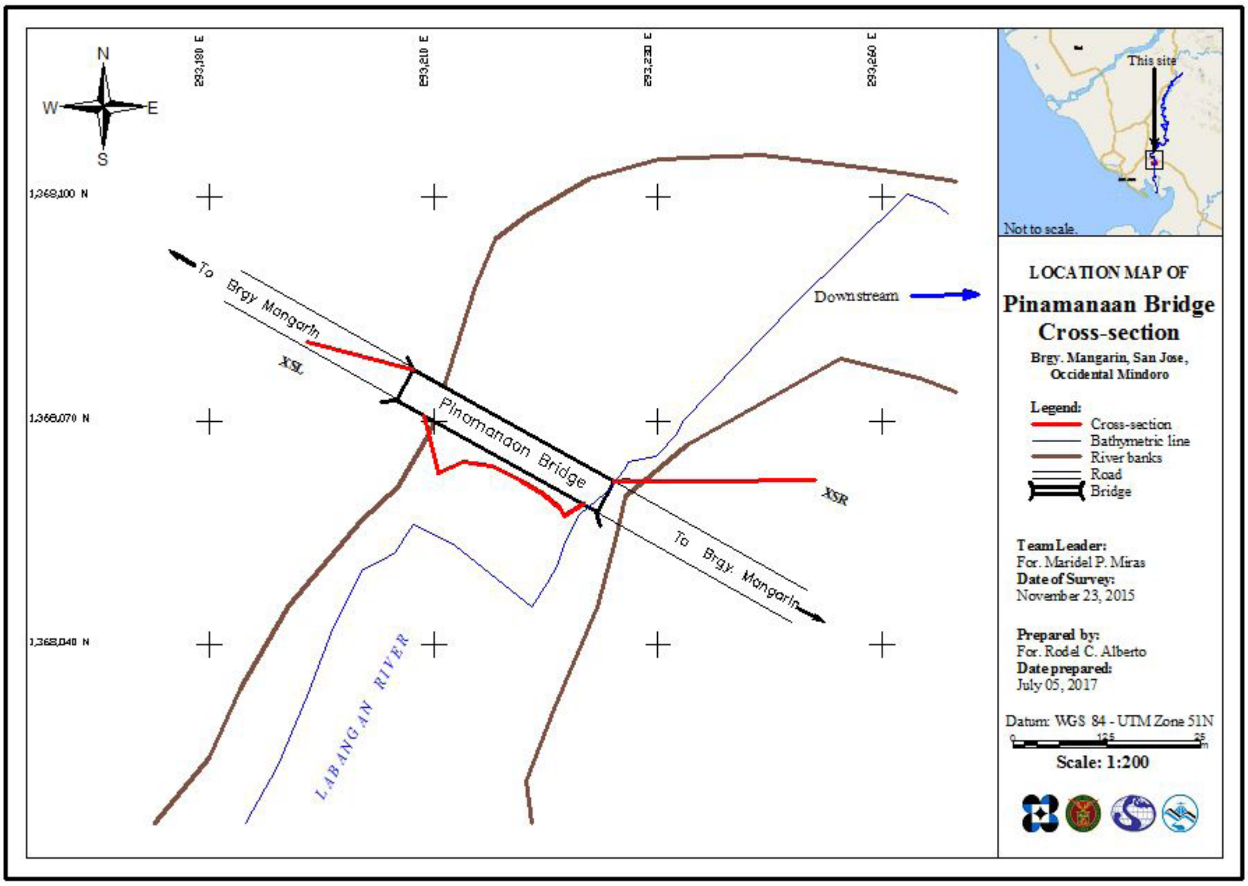


Figure 42. Location Map of Pinamanaan Bridge (over Labangan River) Cross-Section survey

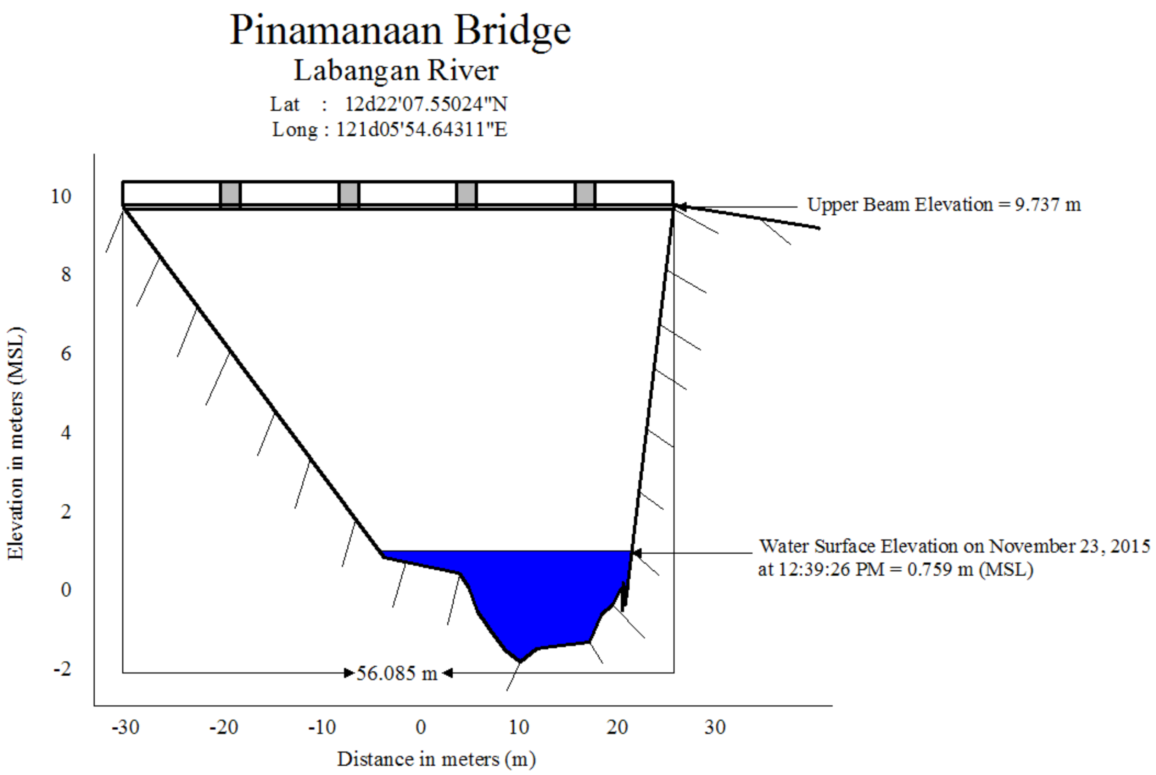


Figure 43. Pinamanaan Bridge (over Labangan River) cross-section diagram

Bridge Data Form

Bridge Name: Pinamanaan Bridge **Date:** November 23, 2015

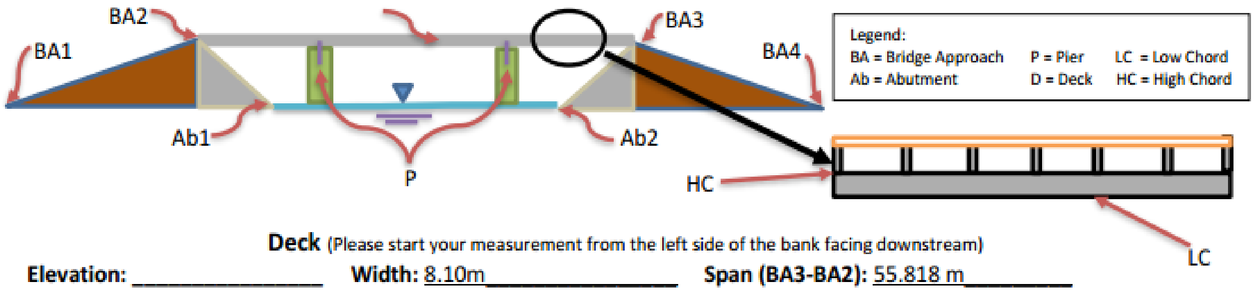
River Name: Labangan River **Time:** 11:23 A.M.

Location (Brgy, City, Region): Brgy Mangarin, San Jose, Occidental Mindoro

Survey Team: Team Kei and Team Mady

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

Latitude: 12d22'07.55024"N **Longitude:** 121d05'54.64311"E



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

Elevation: ______ **Width:** 8.10m **Span (BA3-BA2):** 55.818 m

	Station	High Chord Elevation	Low Chord Elevation
1	BA2	9.626 m	9.126 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	**0**	7.13	**BA3**	142.998 m	9.737 m
BA2	87.239 m	9.626 m	**BA4**	157.693 m	9.123 m

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: NA **Number of Piers:** 0 **Height of column footing:** NA

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

Figure 44. Bridge as-built form of Pinamanaan Bridge (over Labangan River)

Water surface elevation in MSL of Labangan River was determined using a Trimble® SPS 882 in PPK mode technique on November 23, 2015 at 12:39:26 PM with a value of 0.759 m in MSL. This was translated onto marking on the abutment using a digital level. The value of 5.507 m is still an assumed elevation and yet to be changed to the computed 4.463 m in MSL by UP Los Baños. They shall update the marked post in Figure 45 to reflect its corresponding MSL value. The marked abutment will serve as their reference for flow data gathering and depth gauge deployment for Labangan River.

Figure 45. Water level marking on the abutment at Pinamanaan Bridge in Brgy. Mangarin, Municipality of San Jose

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 6, 7, 8 14, 17, 18, and 21, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached either to the front or side of vehicle as shown in Figure 46. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.460 and 1.91 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with MC-212, GPS-4, MC-90 and MRW-30 occupied as the GNSS base stations in the conduct of the survey.

Figure 46. Validation points acquisition survey set-up for Labangan River

The survey was along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate length of 191 km with 26,449 validation points gathered. The gaps in the validation line as shown in Figure 47 were due to road contractions and difficulties in receiving satellite signals because of the presence of obstructions such as dense canopy cover of trees along the roads.

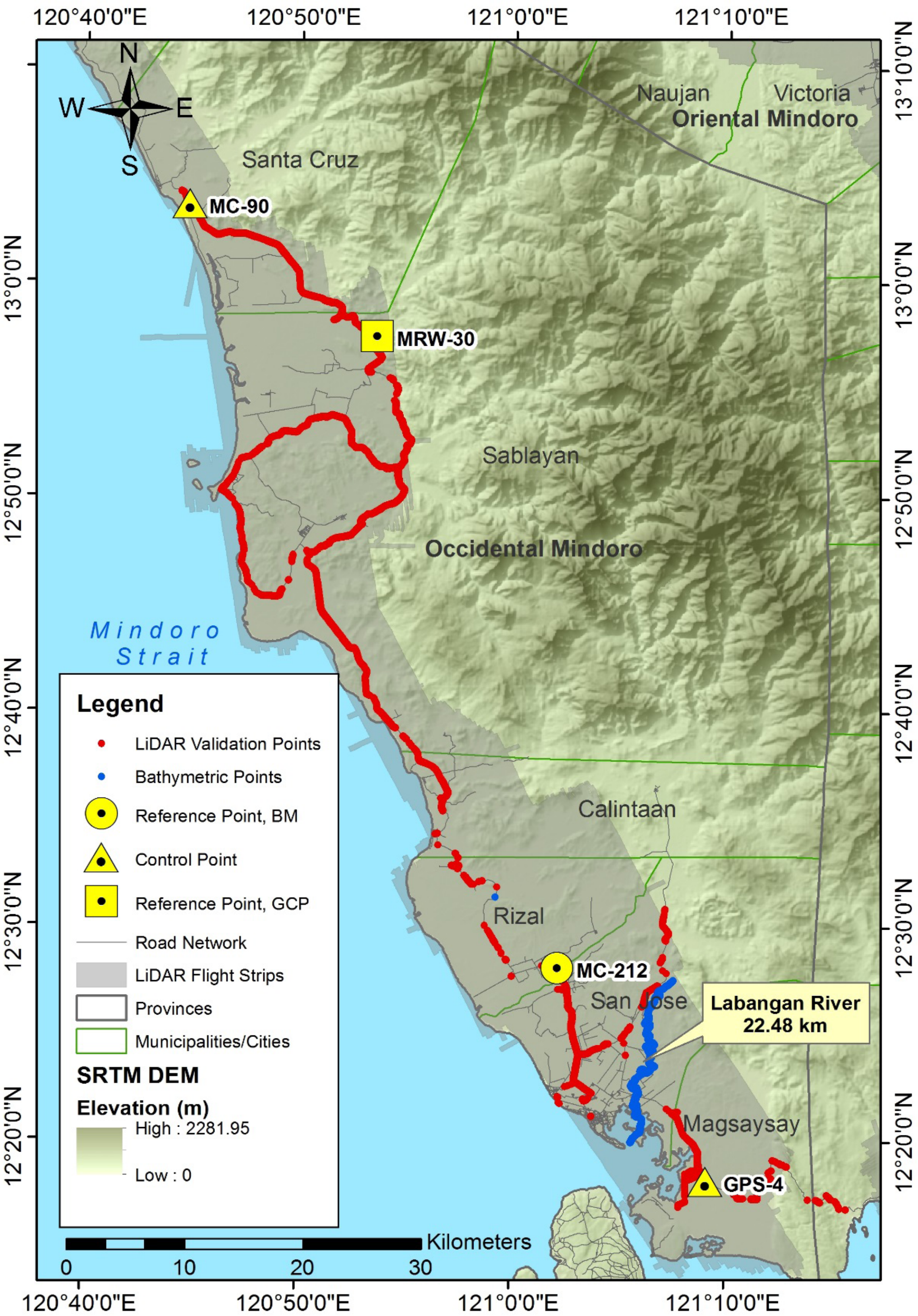


Figure 47. Validation point acquisition survey of Labangan River Basin

4.7 Bathymetric Survey

Bathymetric survey was conducted on November 12, 2015 using Hi-Target™ echo sounder and a Trimble® SPS 882 attached on a boat as shown in Figure 48. The control point MC-200 was used as base station on November 12, 2015 while UP-PIN was used on November 13, 2015. It started in Brgy. Mangarin, Municipality of San Jose with coordinates 12°21'53.35945" 121°05'49.08612", and ended at the mouth of the river also in San Jose with coordinates 12°19'59.50873" 121°05'40.00199".

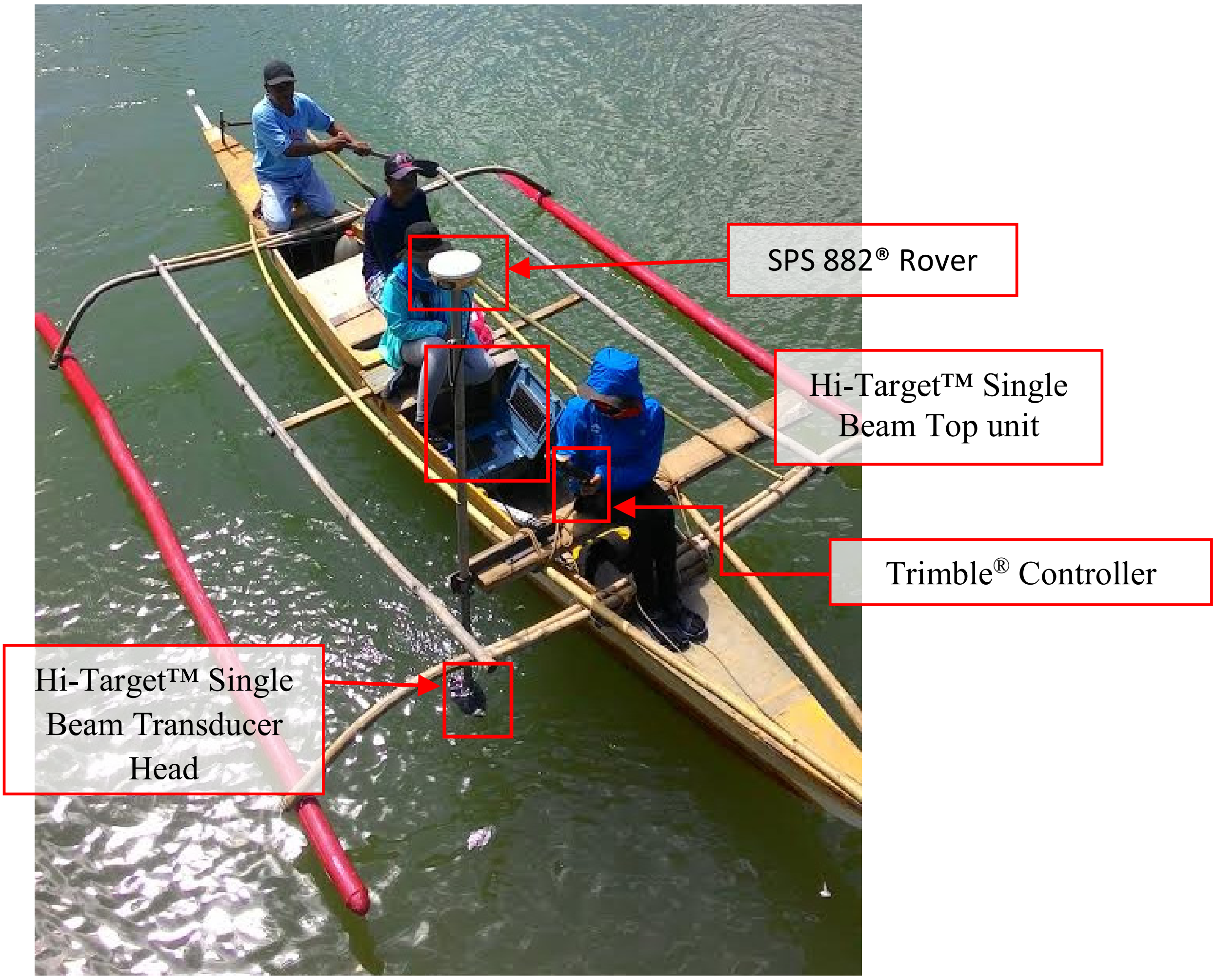


Figure 48. Bathymetric survey using Hi-Target™ Echo Sounder along Labangan River from Brgy. Mangarin down to the mounth of the river in Brgy. Mapaya

The second group performed manual bathymetric survey on November 13, 2015 carrying a trimble bag with installed Trimble® SPS-882 as illustrated in Figure 49. The survey started from the upstream in Brgy. Monte Claro with coordinates 12°27'29.61402" 121°07'35.13395", traversed down by foot, and ended at the starting point of bathymetric survey using boat.

Figure 49. Manual Bathymetry along Labangan River

The entire bathymetric data coverage for Labangan River is illustrated in Figure 50. There is about 4.5 km planned bathymetric line in the upstream part of Monte Claro which was not covered because the area is not populated and not prone to flooding according to the courtesy call with San Jose LGU and upon reconnaissance of the area.

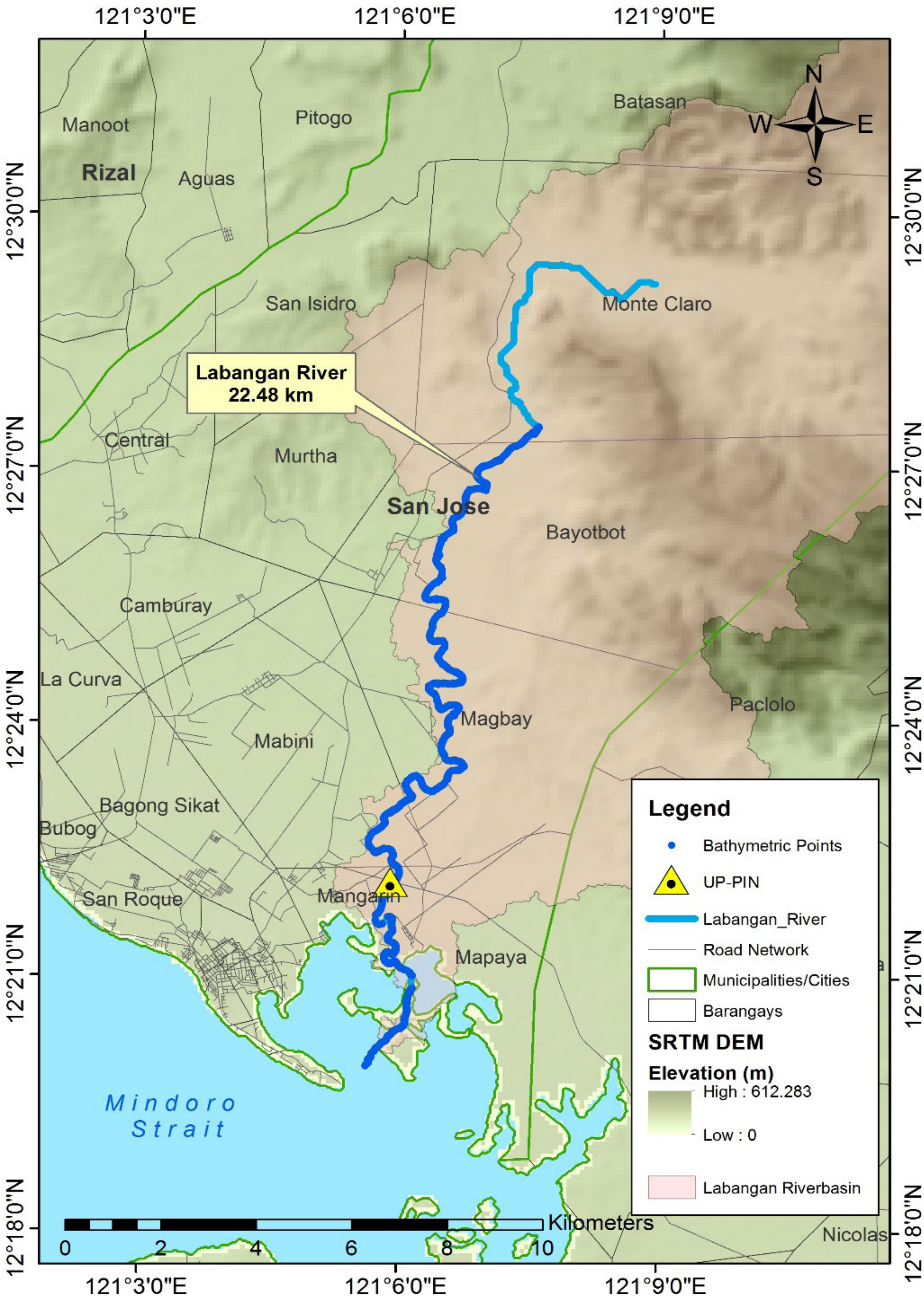


Figure 50. Bathymetric survey of Labangan River

A CAD diagram was also produced to illustrate the Labangan riverbed profile as illustrated in Figure 51. An elevation drop of 21.2 meters in MSL was observed within the distance of approximately 28.48 km from the upstream in Brgy. Monte Claro down to Brgy. Mapaya with a total of 25,614 bathymetric points gathered. Gradual change in elevation can also be seen in the illustration with an average change elevation of about 0.74 for every 500-meter interval.

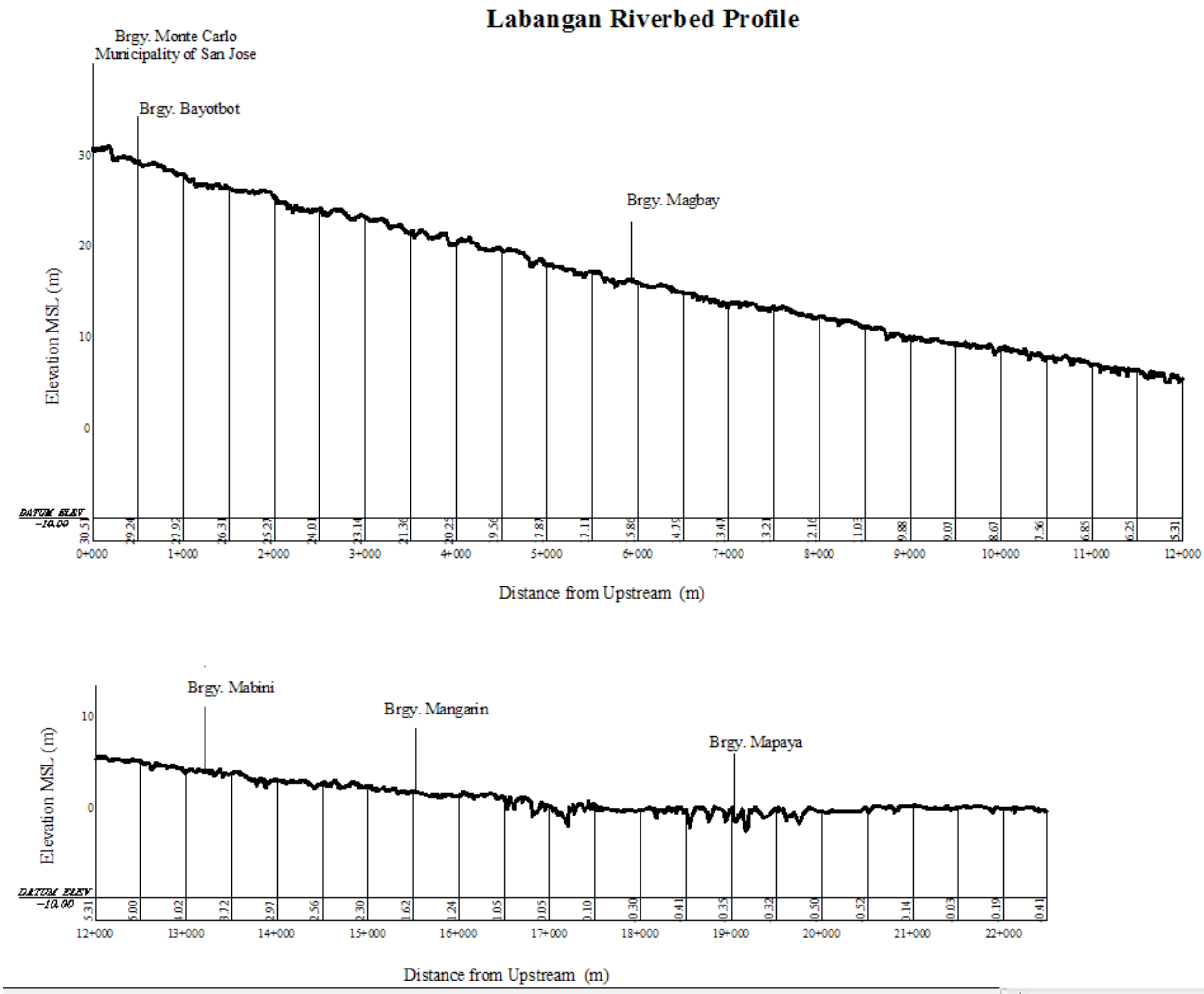


Figure 51. Labangan riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Raphael P. Gonzales, and Kevin M. Manalo

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

5.1 Data used in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Labangan 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 Labangan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a portable rain collector deployed on a strategic location within the riverbasin (12.3698°N, 121.09909722°E). The location of the rain gauge is seen in Figure 52.

The total precipitation for this event is 6.604 mm. It has a peak rainfall of 1.016 mm. on October 7, 2016 at 10:15 pm. The lag time between the peak rainfall and discharge is 2 hour and 30 minutes, as seen in Figure 55.

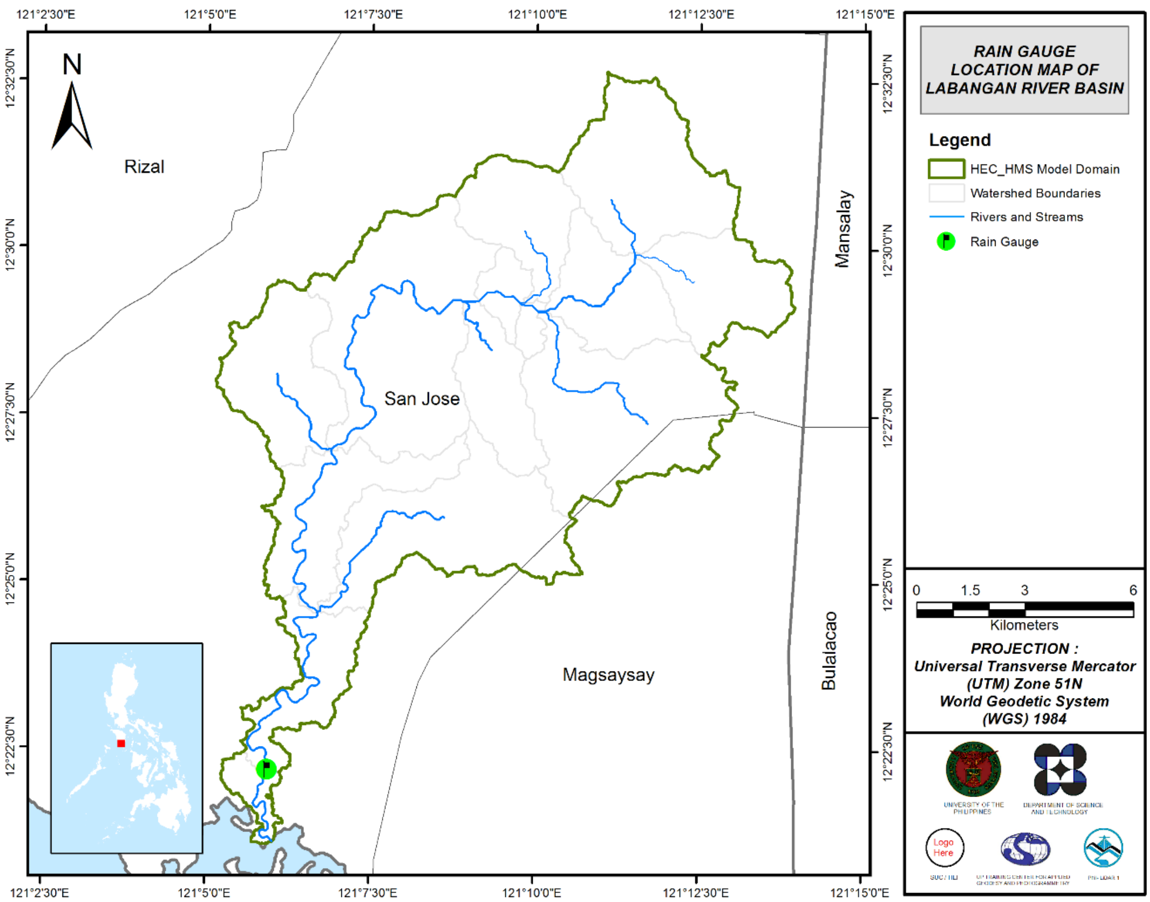


Figure 52. The location map of Labangan HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Pinamanaan Bridge, Occidental Mindoro (12.368953° N, 121.098221° E). It gives the relationship between the observed water levels from the Pinamanaan Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Pinamanaan Bridge, the rating curve is expressed as $Q = 9.6305e^{0.4258x}$ as shown Figure 54.

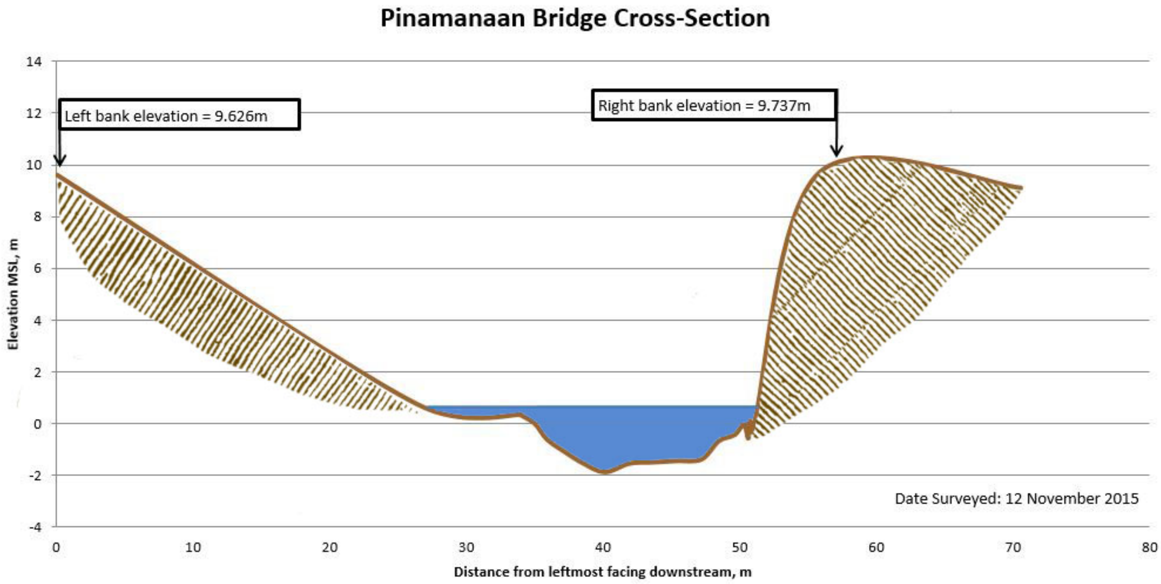


Figure 53. Cross-Section Plot of Pinamanaan Bridge (over Labangan River)

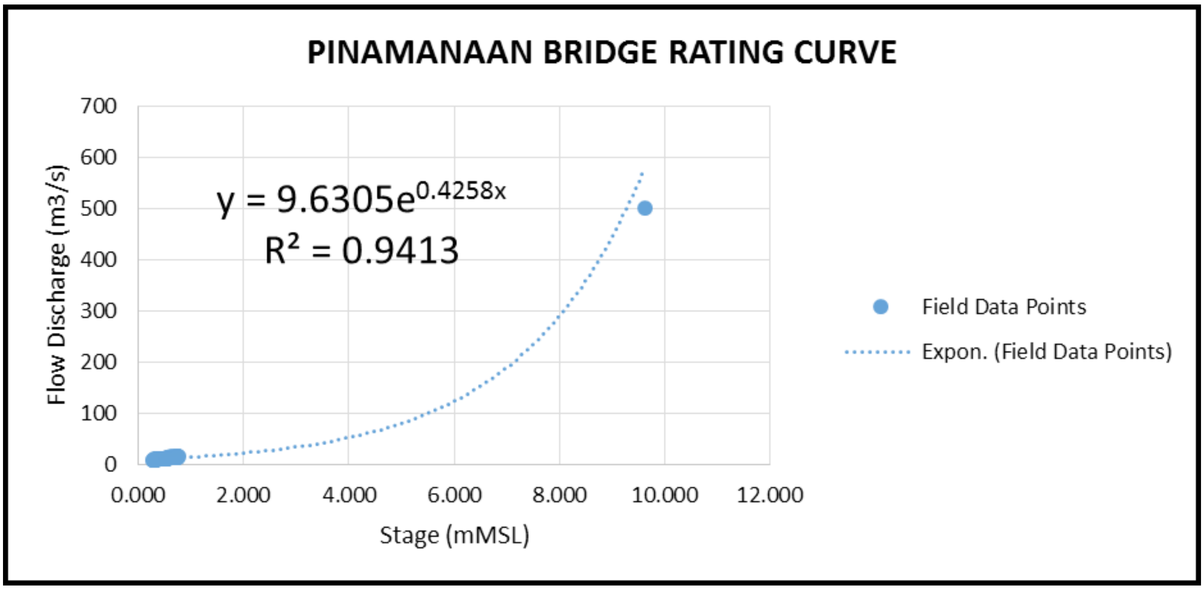


Figure 54. Rating curve at Pinamanaan Bridge, Occidental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 55, actual flow discharge during a rainfall event was collected in the Pinamanaan Bridge. Peak discharge is 18.87 cu.m/s on October 8, 2016 at 12:45 am.

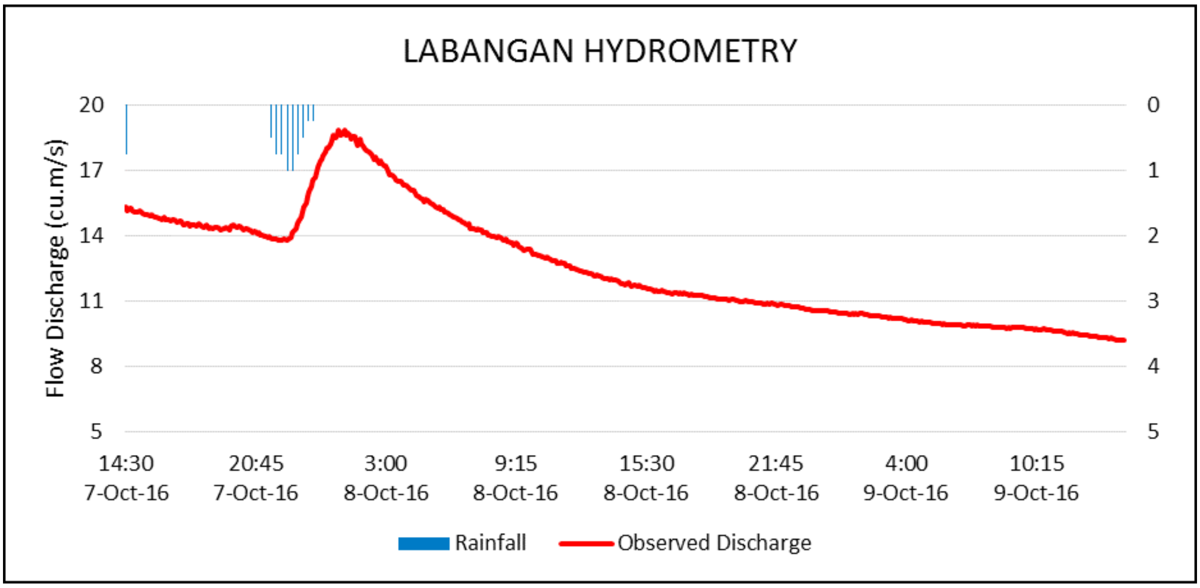


Figure 55. Rainfall and outflow data at Labangan River Basin used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Romblon Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Labangan watershed. The extreme values for this watershed were computed based on a 48-year record, with the computed extreme values shown in Table 27.

Table 26. RIDF values for Romblon Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	18.2	27	33.5	44.3	59.5	70.4	89.5	107	119.8
5	26	37.7	46.5	60.7	82.2	97.6	125.5	152.9	171.6
10	31.1	44.8	55	71.5	97.3	115.7	149.3	183.4	205.9
15	34	48.8	59.9	77.7	105.8	125.8	162.8	200.5	225.2
20	36	51.6	63.3	82	111.8	133	172.2	212.6	238.8
25	37.6	53.8	65.9	85.3	116.4	138.4	179.4	221.8	249.2
50	42.4	60.4	74	95.4	130.5	155.3	201.8	250.3	281.4
100	47.2	67	81.9	105.5	144.5	172.1	223.9	278.6	313.3

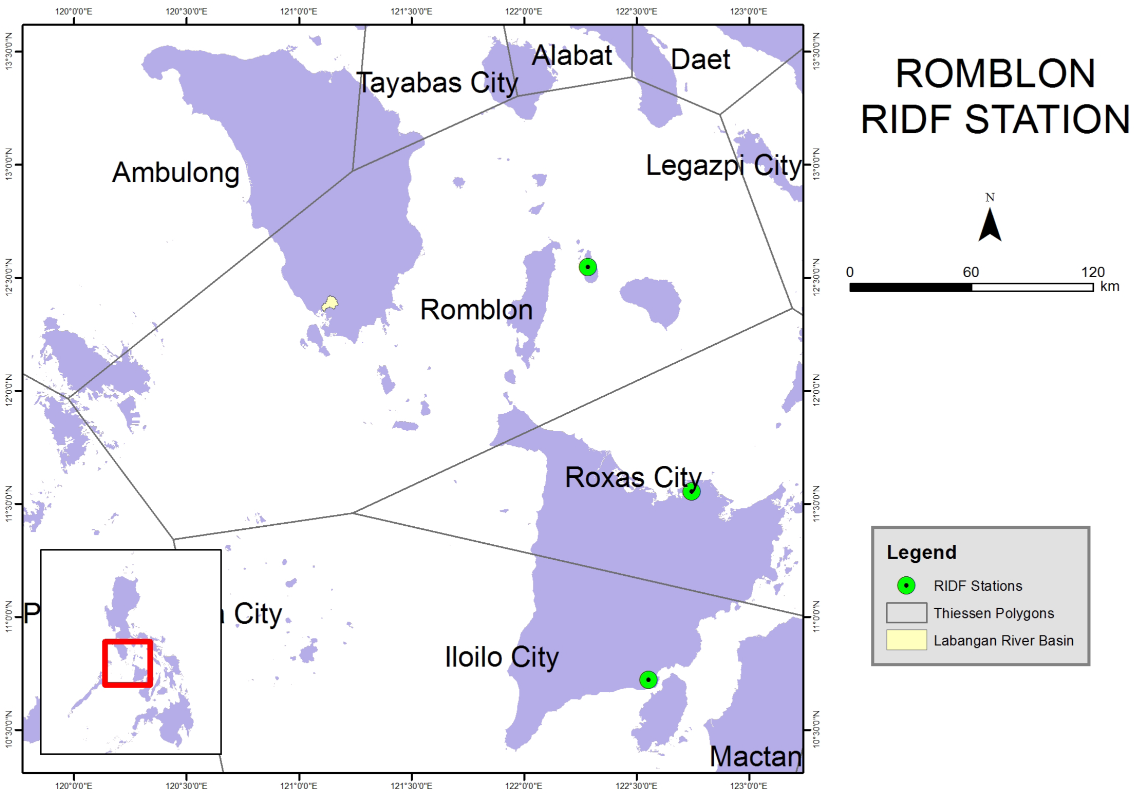


Figure 56.Location of Romblon RIDF relative to Labangan River Basin

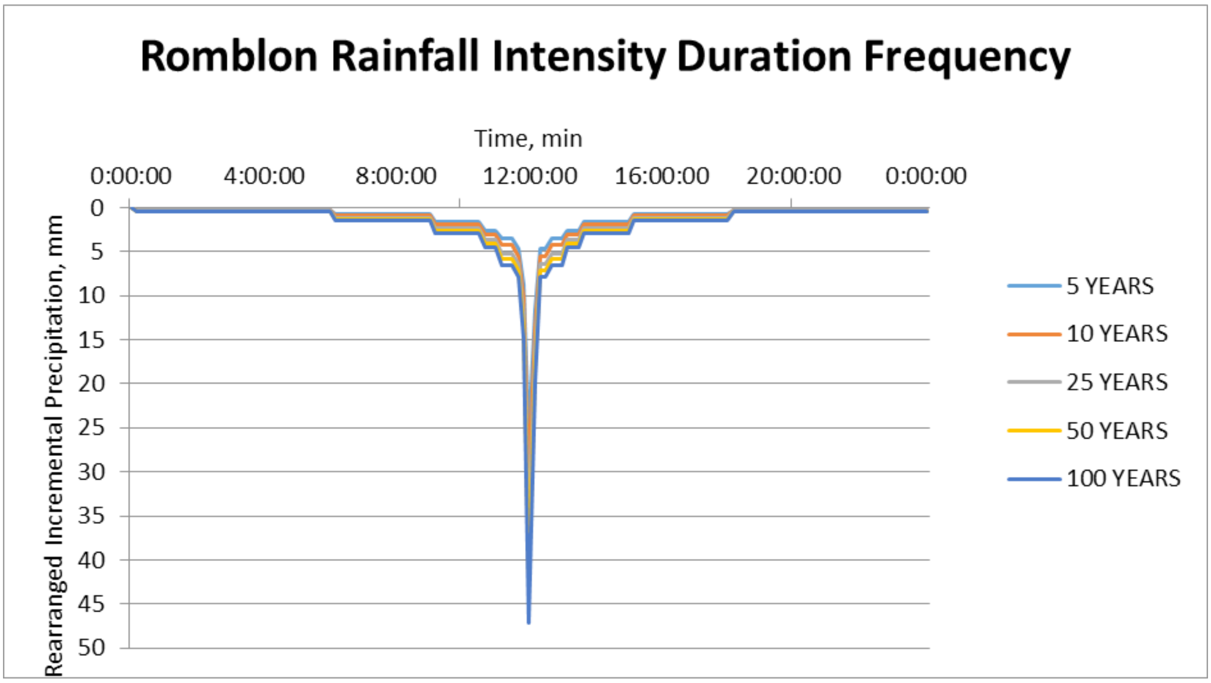


Figure 57. Synthetic storm generated for a 24-hr period rainfall for various return periods.

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5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Labangan River Basin are shown in Figure 58 and Figure 59, respectively.

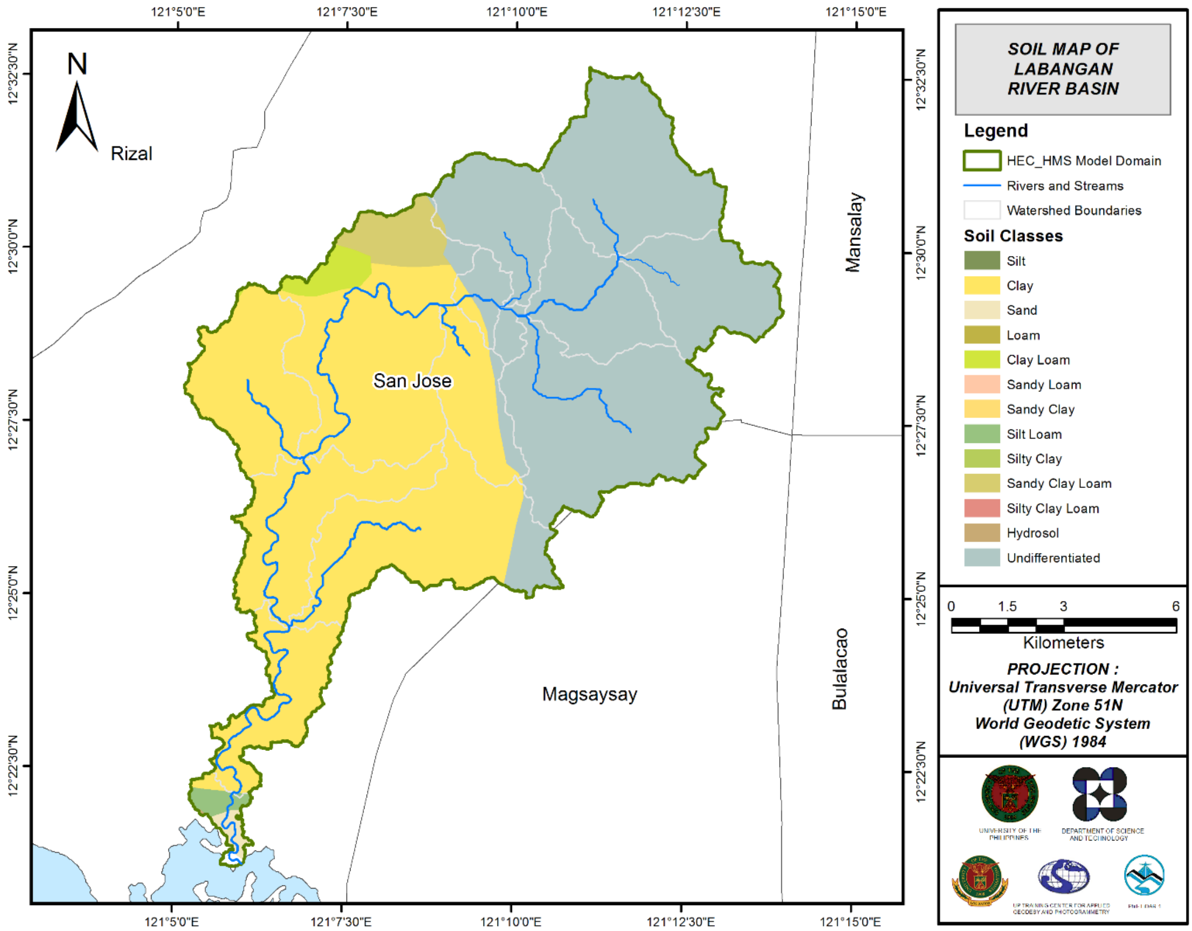

Figure 58. Soil map of Labangan River Basin used for the estimation of the CN parameter. (Source: DA)

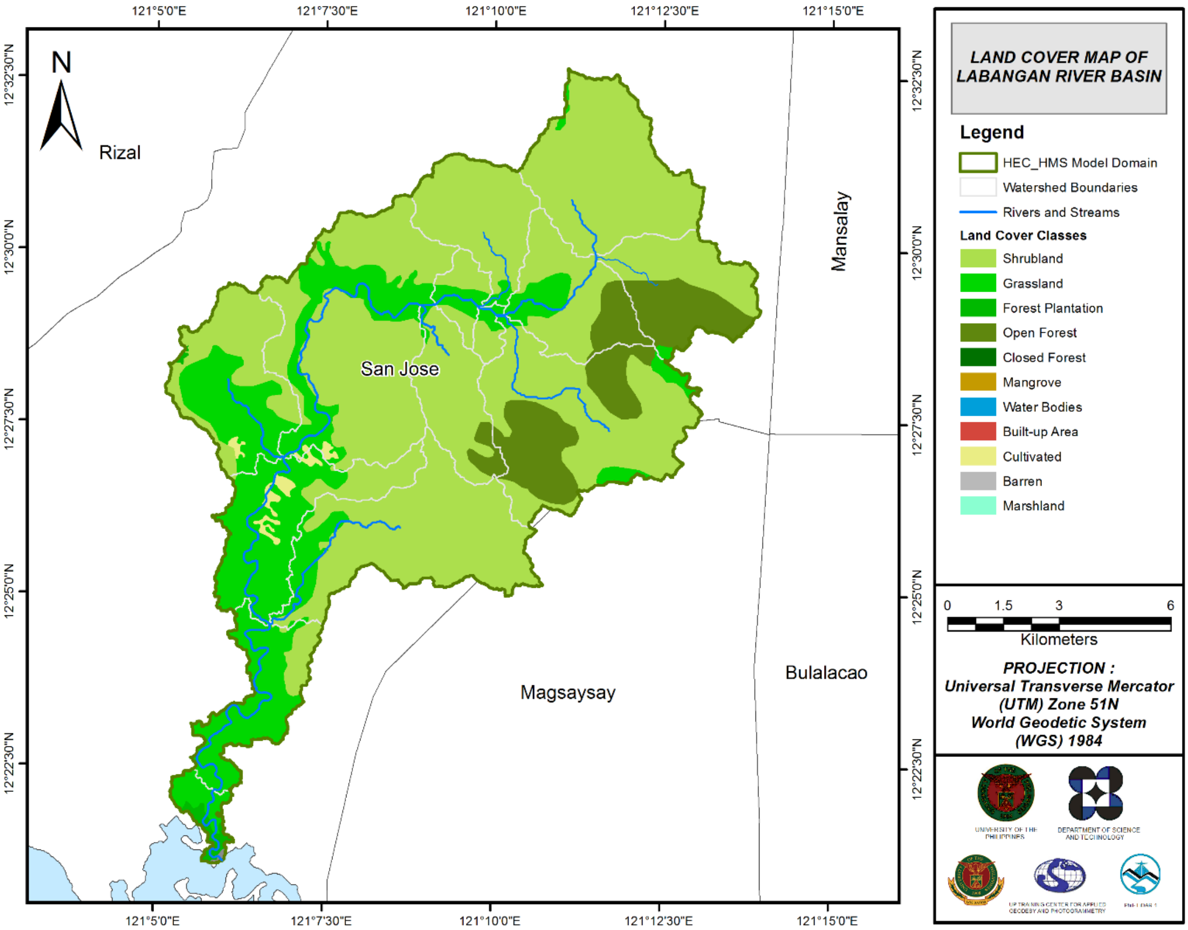

Figure 59. Land cover map of Labangan River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Labangan river basin, the six (6) soil classes identified were clay, clay loam, sandy clay loam, silty clay, and sand, while the rest is undifferentiated. The five (5) land cover types identified were largely shrubland, followed by grassland, open forest, cultivated land, and forest plantation.

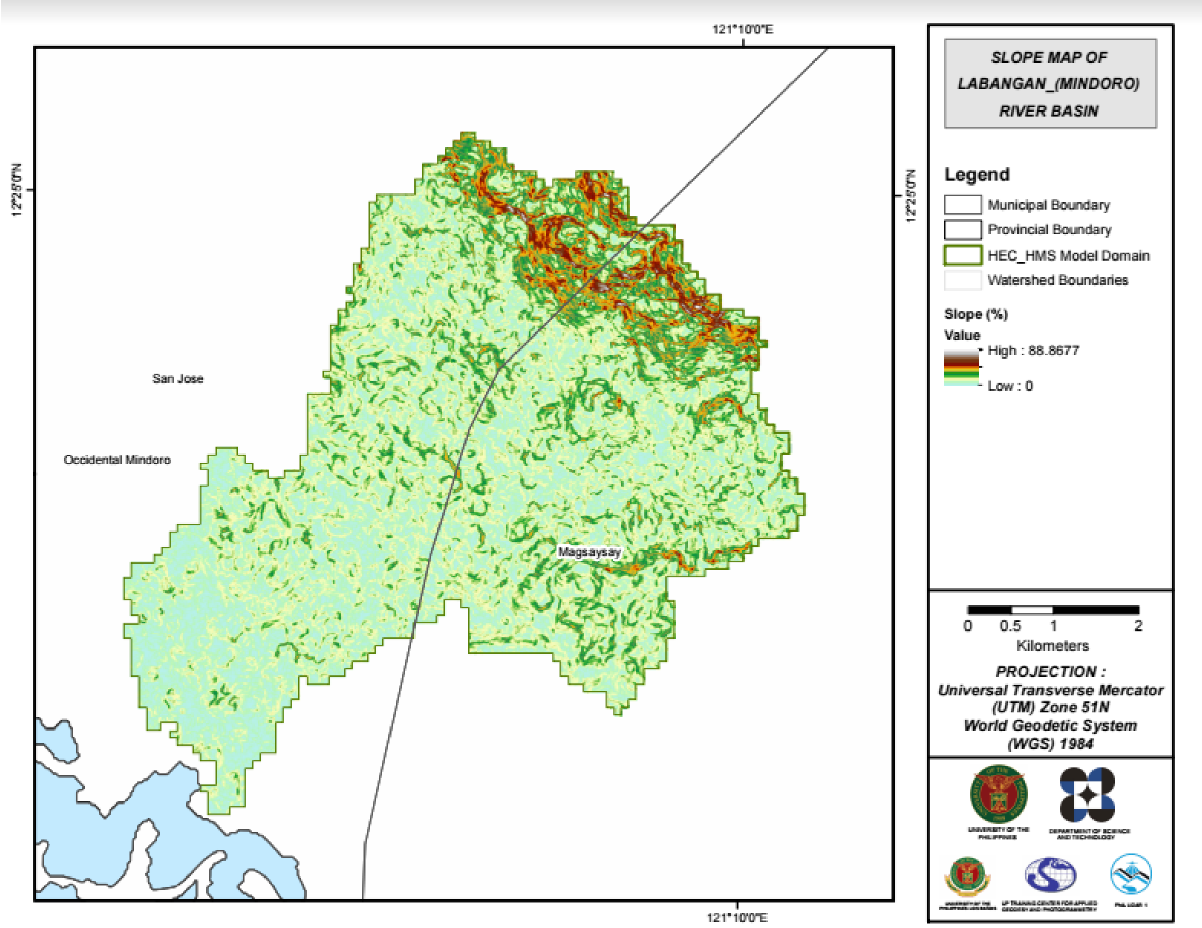

Figure 60. Slope map of Labangan River Basin

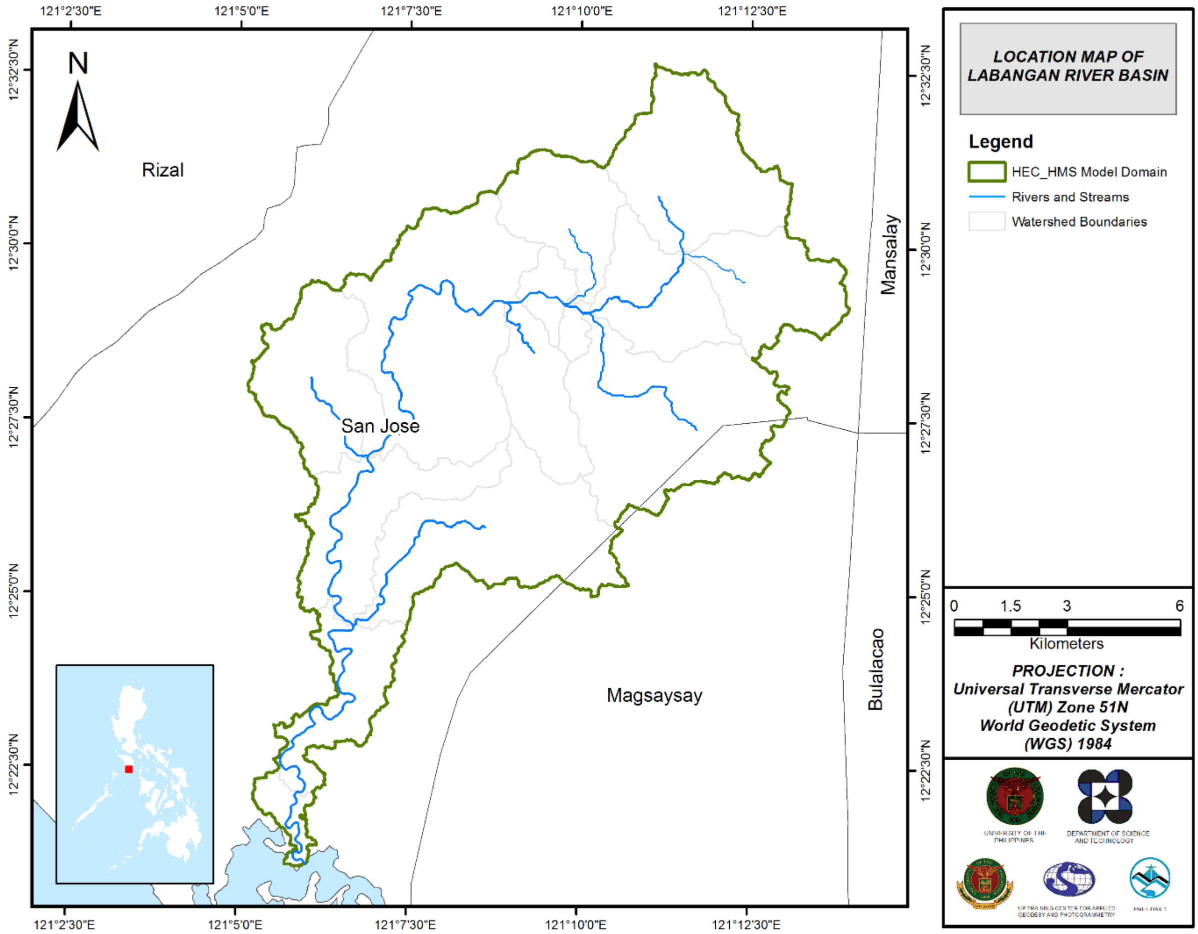

Figure 61. Stream delineation map of Labangan River Basin

Using SAR-based DEM, the Labangan basin was delineated and further subdivided into subbasins. The model consists of 14 sub basins, 7 reaches, and 7 junctions. The basin model is illustrated in Figure 62. The main outlet is labelled as 51. The main outlet is at Pinamanaan Bridge.

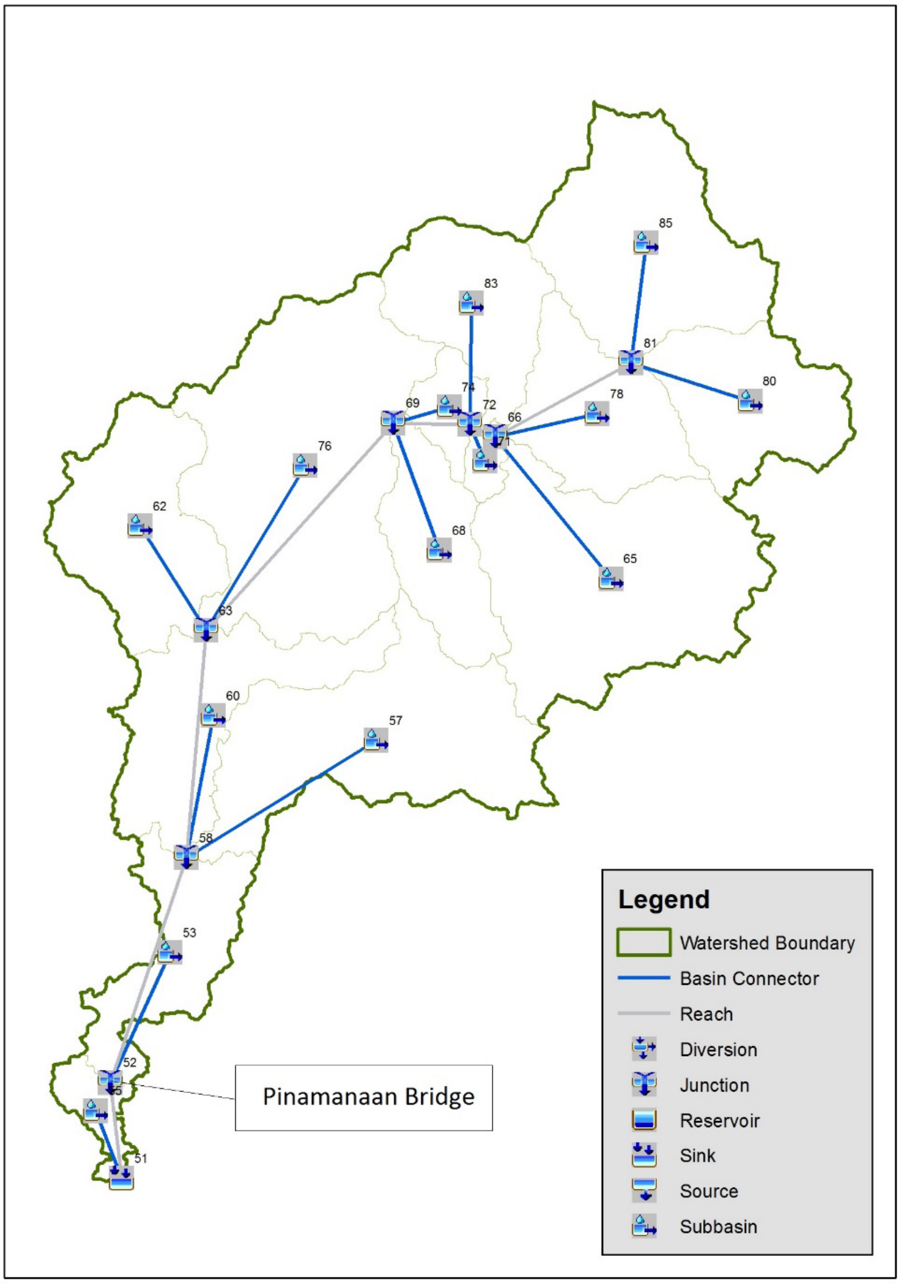

Figure 62. HEC-HMS generated Labangan River Basin Model.

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS. This is illustrated in Figure 63.

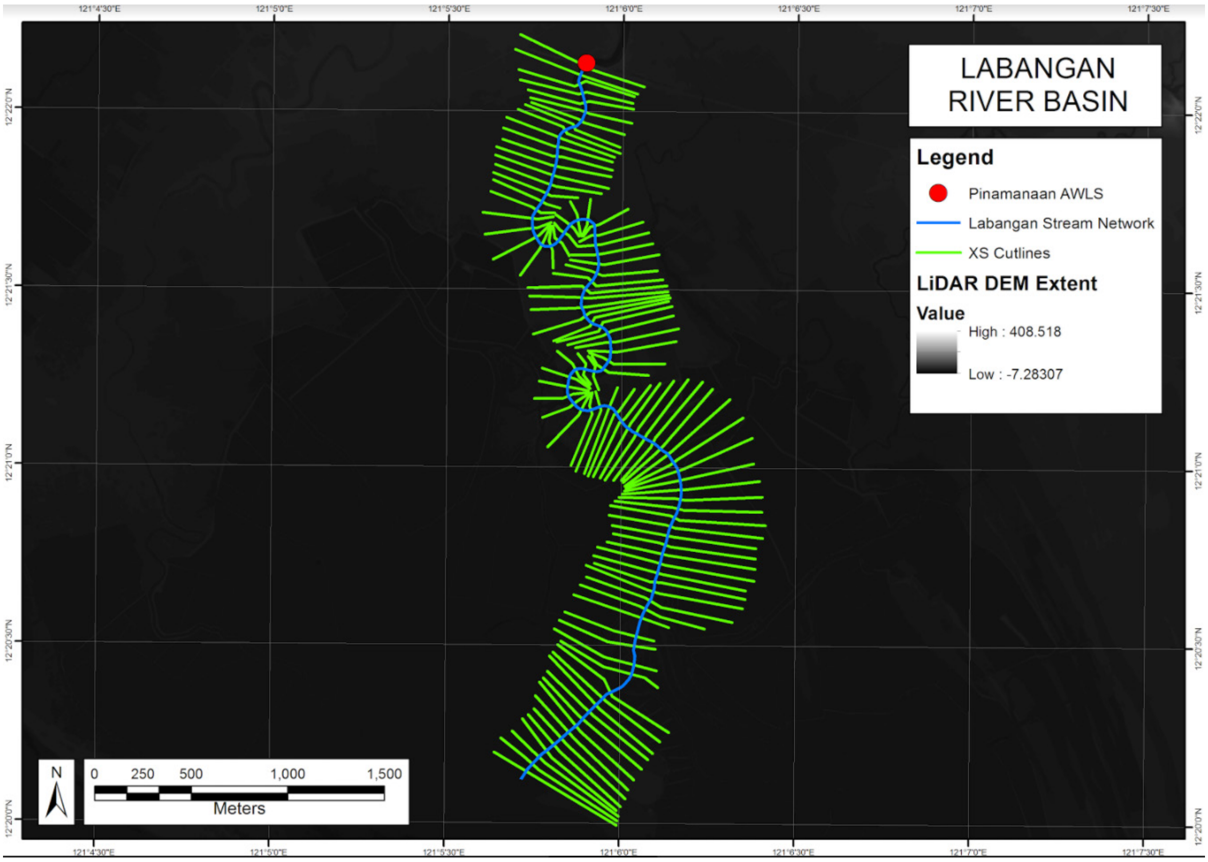

Figure 63. River cross-section of Labangan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

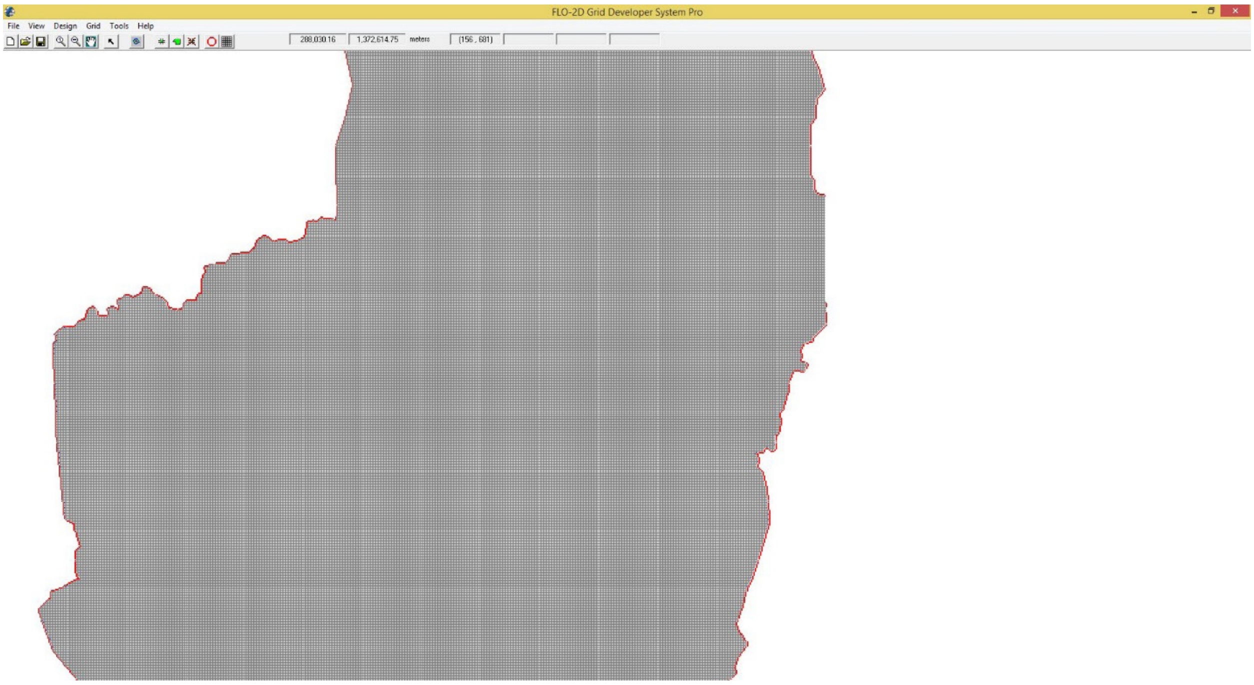

Figure 64. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 29.80908 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 m^2/s.

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 57482500.00 m^2.

There is a total of 18455290.13 m^3 of water entering the model. Of this amount, 18455290.13 m^3 is due to rainfall while 0.00 m^3 is inflow from other areas outside the model. 7772151.50 m^3 of this water is lost to infiltration and interception, while 8616026.68 m^3 is stored by the flood plain. The rest, amounting up to 2067123.87 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Labangan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 65 shows the comparison between the two discharge data.

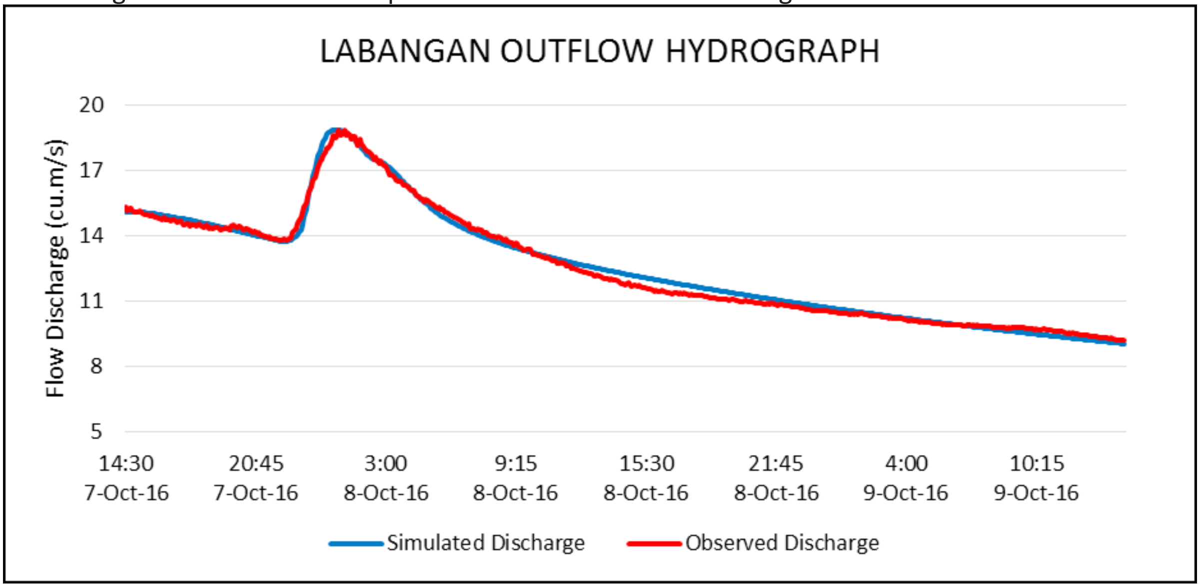

Figure 65. Outflow Hydrograph of Labangan produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of calibrated values for Labangan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2 - 11
			Curve Number	54 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 - 8
			Storage Coefficient (hr)	0.5 - 13
	Baseflow	Recession	Recession Constant	0.5 - 1
			Ratio to Peak	0.4
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.007 – 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 2 to 11mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 54 to 89 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 0.02 hours to 13 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.5 to 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.4 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.007 to 0.04 indicates a diverse characteristic of the basin per reach (Brunner, 2010).

Table 28. Summary of the Efficiency Test of Labangan HMS Model

Accuracy measure	Value
RMSE	0.243
r^2	0.996
NSE	0.920
PBIAS	-0.481
RSR	0.095

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.243.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.996.

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 0.920.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.481.

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 0.095.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 66) shows the Labangan outflow using the Romblon Rainfail 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 (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

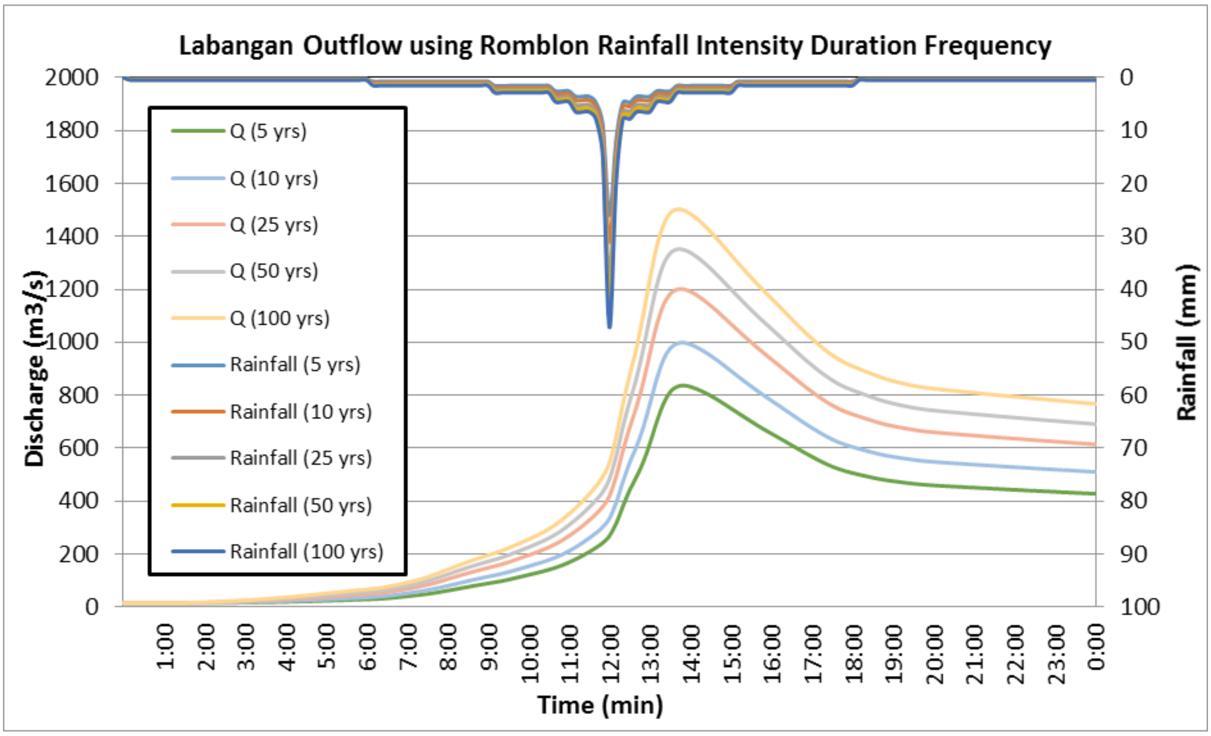

Figure 66. Outflow hydrograph at Labangan Station generated using Romblon RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Labangan discharge using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

.

Table 29. Peak values of the Labangan HECHMS Model outflow using the Romblon RIDF 24-hour values

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak	Lag Time
5-yr	171.60	26.0	836.86	1 hour 50 minutes	-
10-yr	205.90	31.10	998.46	1 hour 50 minutes	-
25-yr	249.20	37.60	1200.35	1 hour 50 minutes	-
50-yr	281.40	42.40	1351.06	1 hour 40 minutes	-
100-yr	313.30	47.20	1502.27	1 hour 40 minutes	-

5.8 River Analysis 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. The sample map of Labangan River using the HMS base flow is shown on Figure 67.

Figure 67. Sample output of Labangan RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Labangan floodplain are shown in Figure 68 to Figure 73. The floodplain, with an area of _____ sq. km., covers one municipality namely San Jose. Table 31 shown the percentage of area affected by flooding per municipality.

Table 30. Municipalities affected in Labangan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
San Jose	449.82		

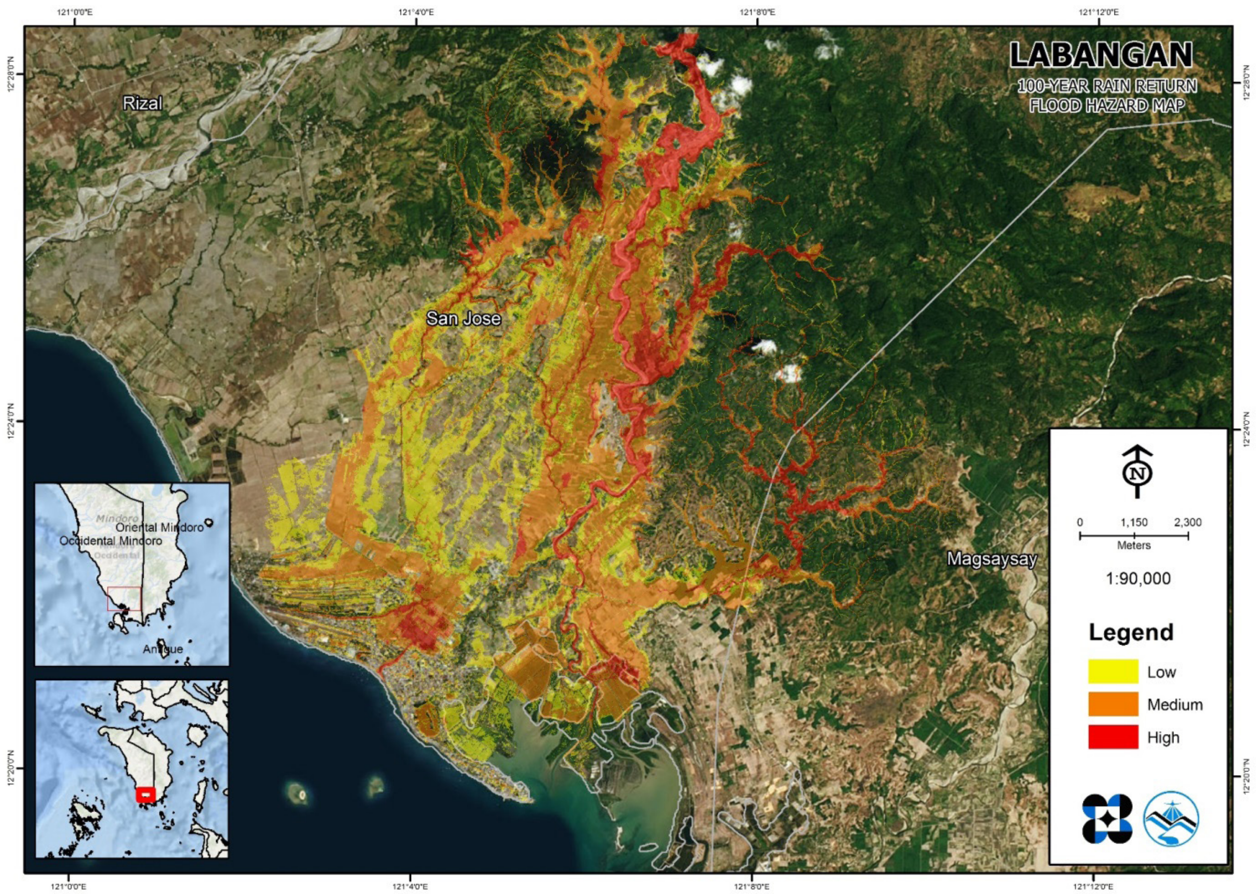

Figure 68. 100-year Flood Hazard Map for Labangan Floodplain overlaid on Google Earth imagery

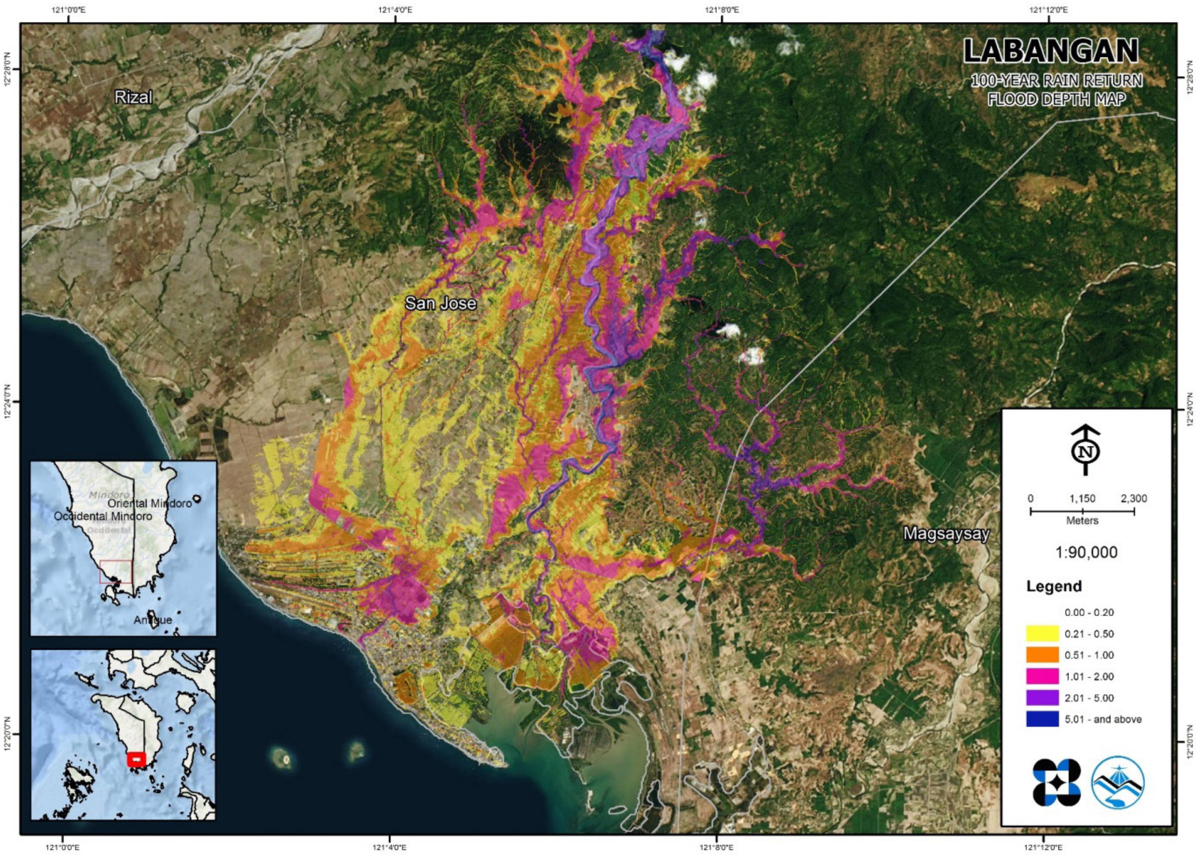

Figure 69. 100-year Flow Depth Map for Labangan Floodplain overlaid on Google Earth imagery

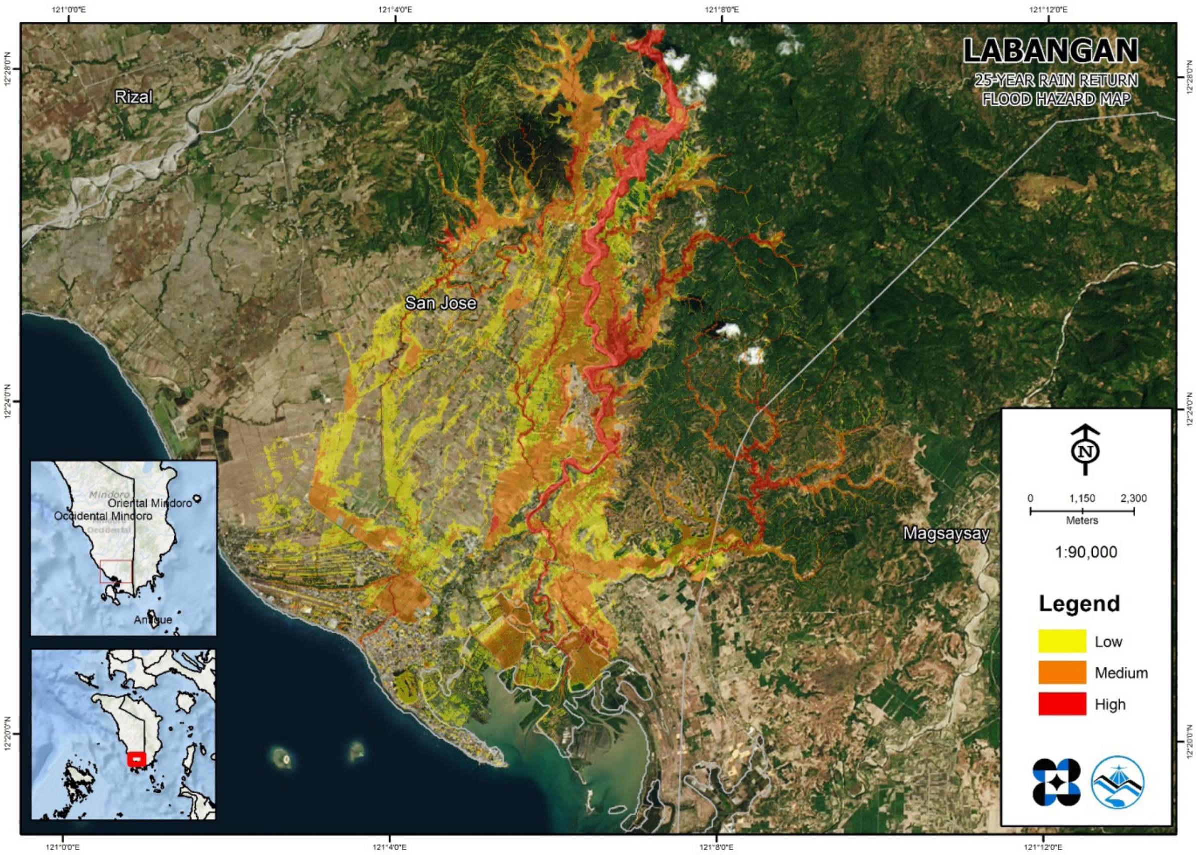

Figure 70. 25-year Flood Hazard Map for Labangan Floodplain overlaid on Google Earth imagery

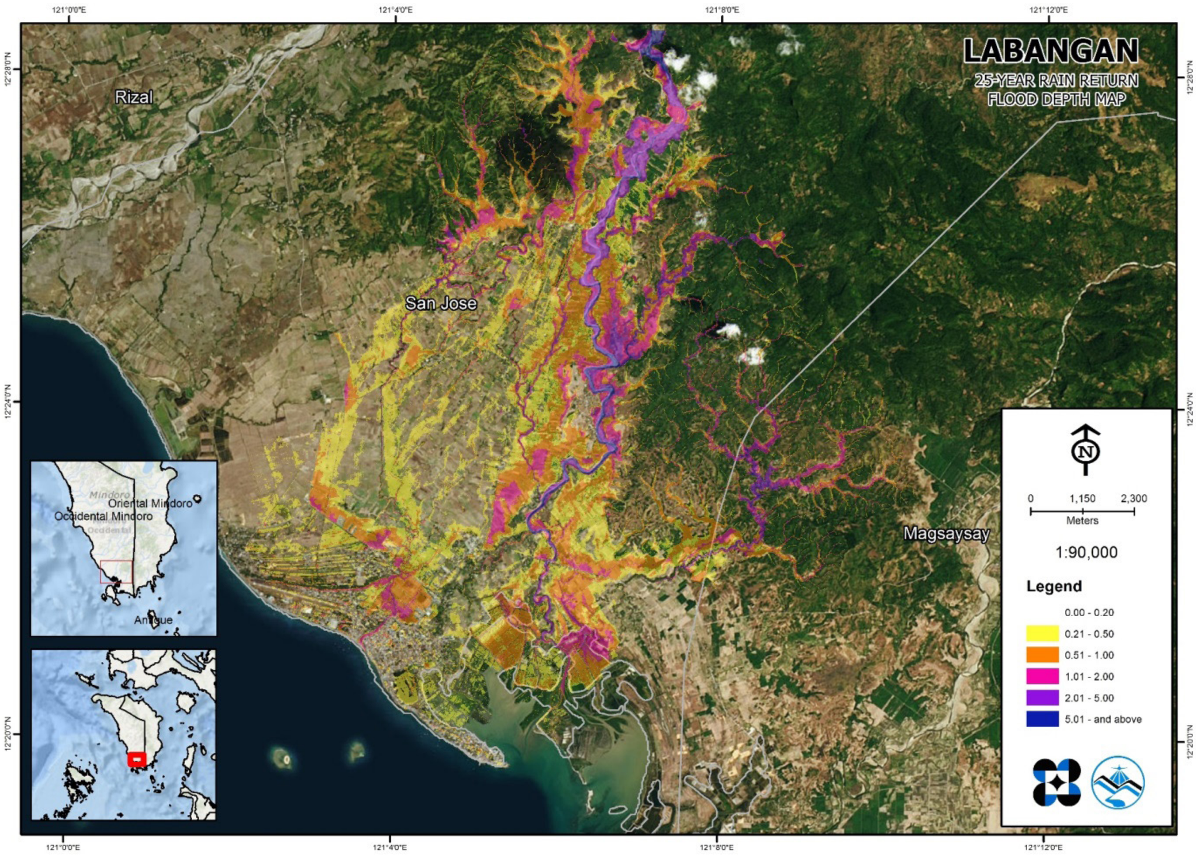

Figure 71. 25-year Flow Depth Map for Labangan Floodplain overlaid on Google Earth imagery

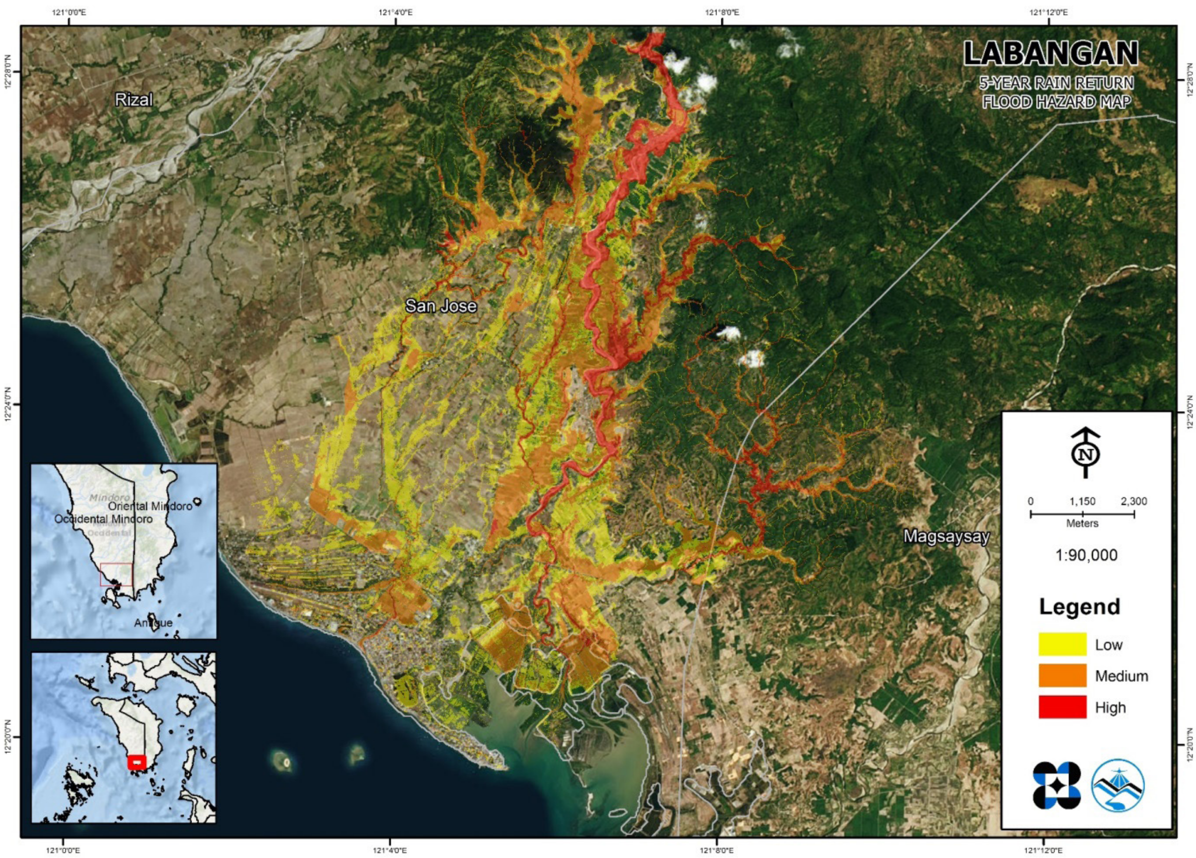

Figure 72. 5-year Flood Hazard Map for Labangan Floodplain overlaid on Google Earth imagery

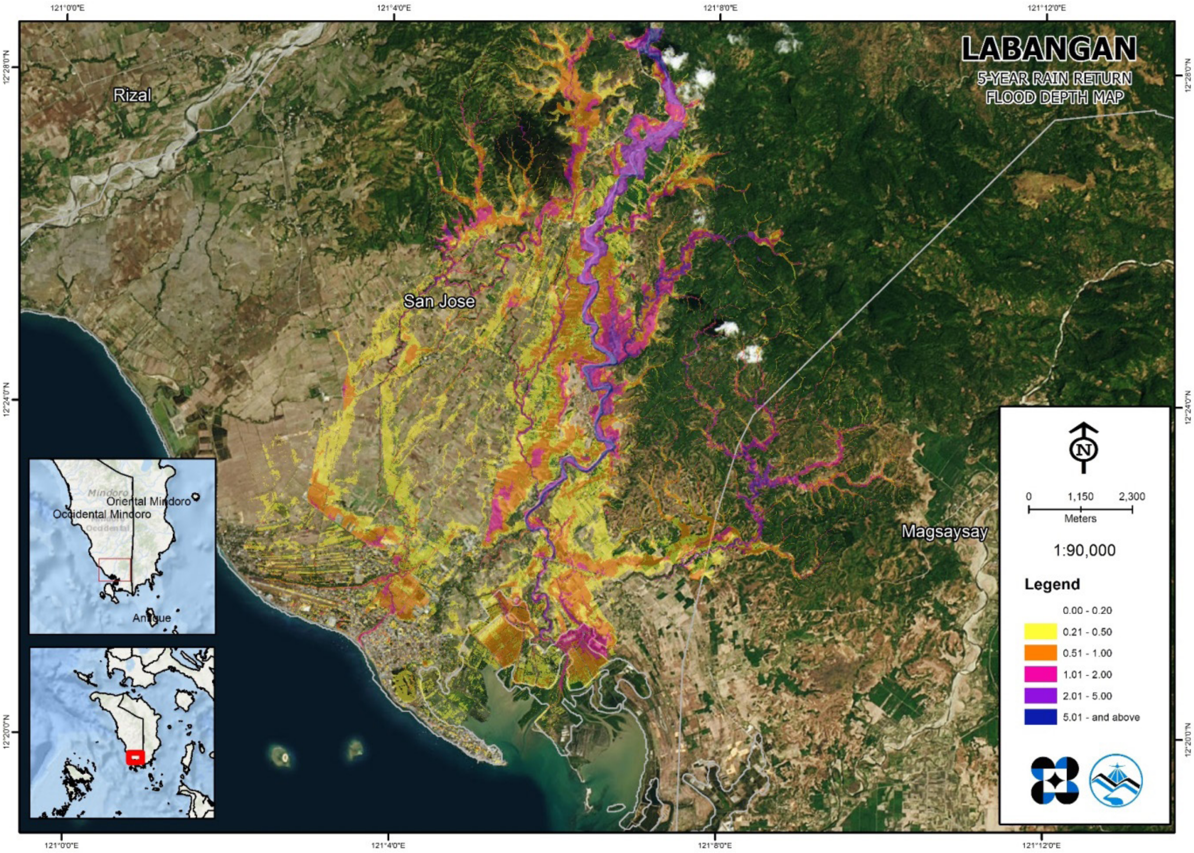

Figure 73. 5-year Flood Depth Map for Labangan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Labangan river basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 4 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 16.21% of the municipality of San Jose with an area of 449.82 sq. km. will experience flood levels of less 0.20 meters. 3.53% of the area will experience flood levels of 0.21 to 0.50 meters while 3.45%, 4.19%, 2.27%, and 0.76% 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 31 and shown in Figure 74 are the affected areas in square kilometres by flood depth per barangay.

Table 31. Affected Areas in San Jose, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)			
	Mabini	Magbay	Mangarin	Mapaya
0.03-0.20	0.66	4.48	1.05	1.03
0.21-0.50	0.99	2.15	1	0.52
0.51-1.00	1.17	1.67	1.01	0.56
1.01-2.00	0.83	0.66	0.41	0.25
2.01-5.00	0.7	0.46	0.19	0.0082
> 5.00	0.094	0.3	0.0065	0

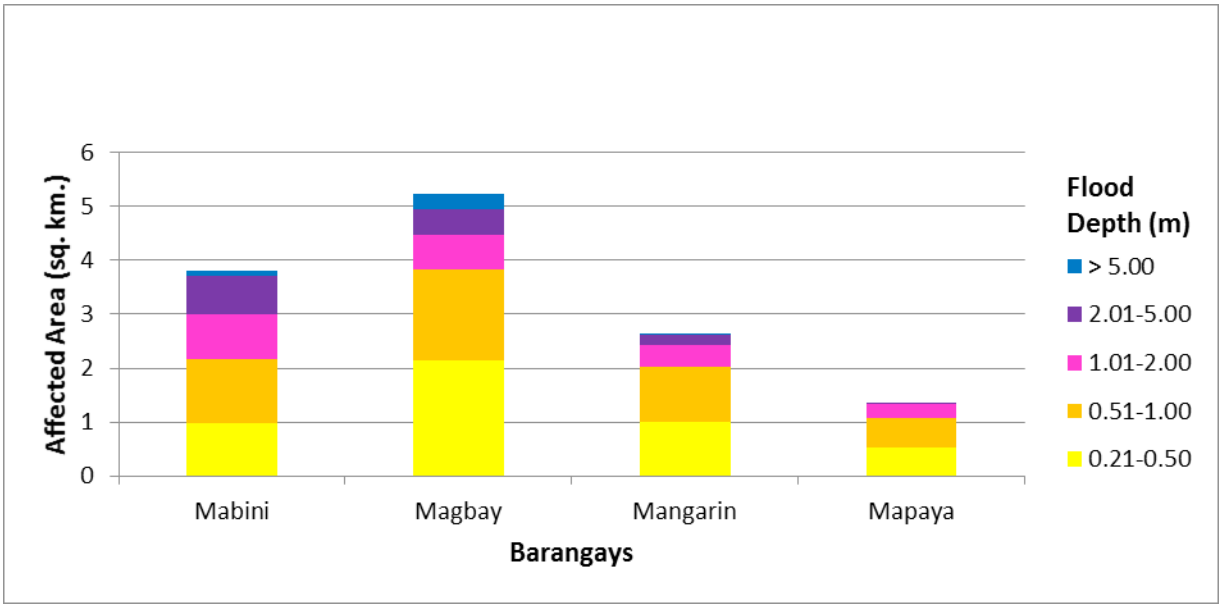

Figure 74. Affected Areas in San Jose, Occidental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 1.48% of the municipality of San Jose with an area of 449.82 sq. km. will experience flood levels of less 0.20 meters. 0.96% of the area will experience flood levels of 0.21 to 0.50 meters while 1.11%, 0.54%, 0.33%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meter, respectively. Listed in Table 32 and shown in Figure 75 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in San Jose, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)			
	Mabini	Magbay	Mangarin	Mapaya
0.03-0.20	0.54	4.21	0.9	0.99
0.21-0.50	0.87	2.04	0.91	0.48
0.51-1.00	1.26	1.92	1.19	0.61
1.01-2.00	0.92	0.75	0.47	0.29
2.01-5.00	0.77	0.48	0.2	0.0089
> 5.00	0.095	0.32	0.0064	0

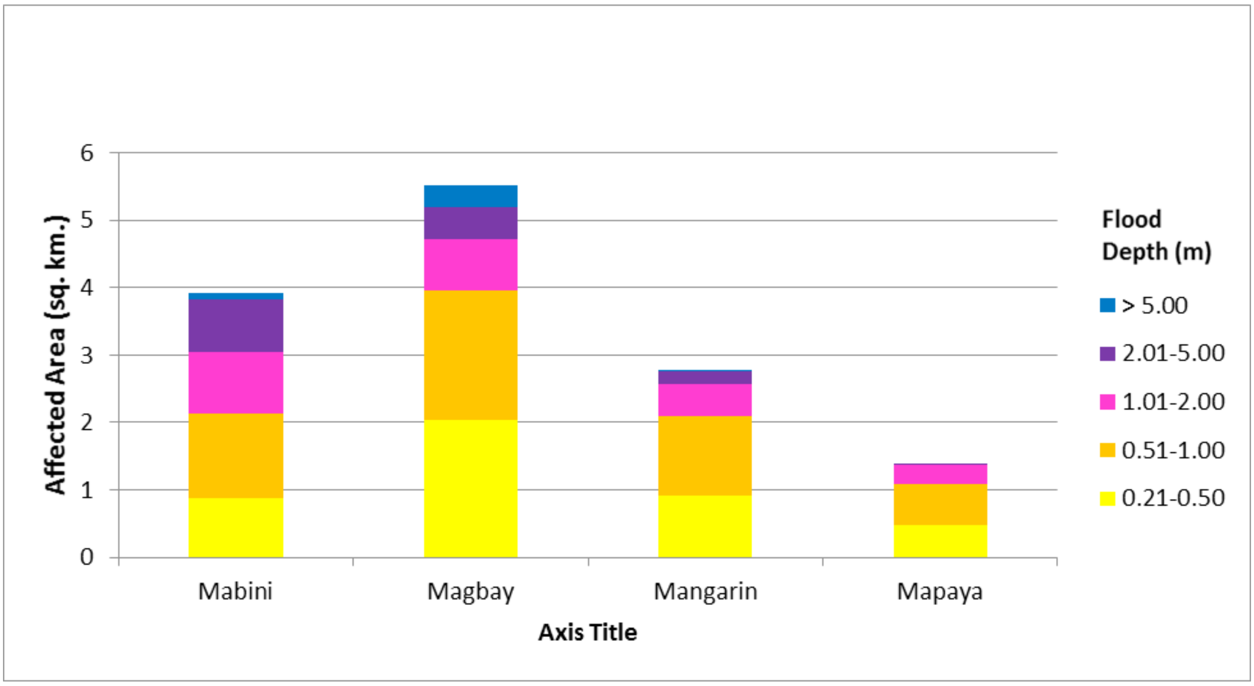

Figure 75. Affected Areas in San Jose, Occidental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 1.04% of the municipality of San Jose with an area of 449.82 sq. km. will experience flood levels of less 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 1.33%, 1.02%, 0.52%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 and shown in Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in San Jose, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)			
	Mabini	Magbay	Mangarin	Mapaya
0.03-0.20	0.14	3.33	0.42	0.8
0.21-0.50	0.36	1.05	0.46	0.32
0.51-1.00	1.38	2.79	1.27	0.54
1.01-2.00	1.2	1.41	1.26	0.7
2.01-5.00	1.28	0.75	0.26	0.025
> 5.00	0.099	0.38	0.0085	0

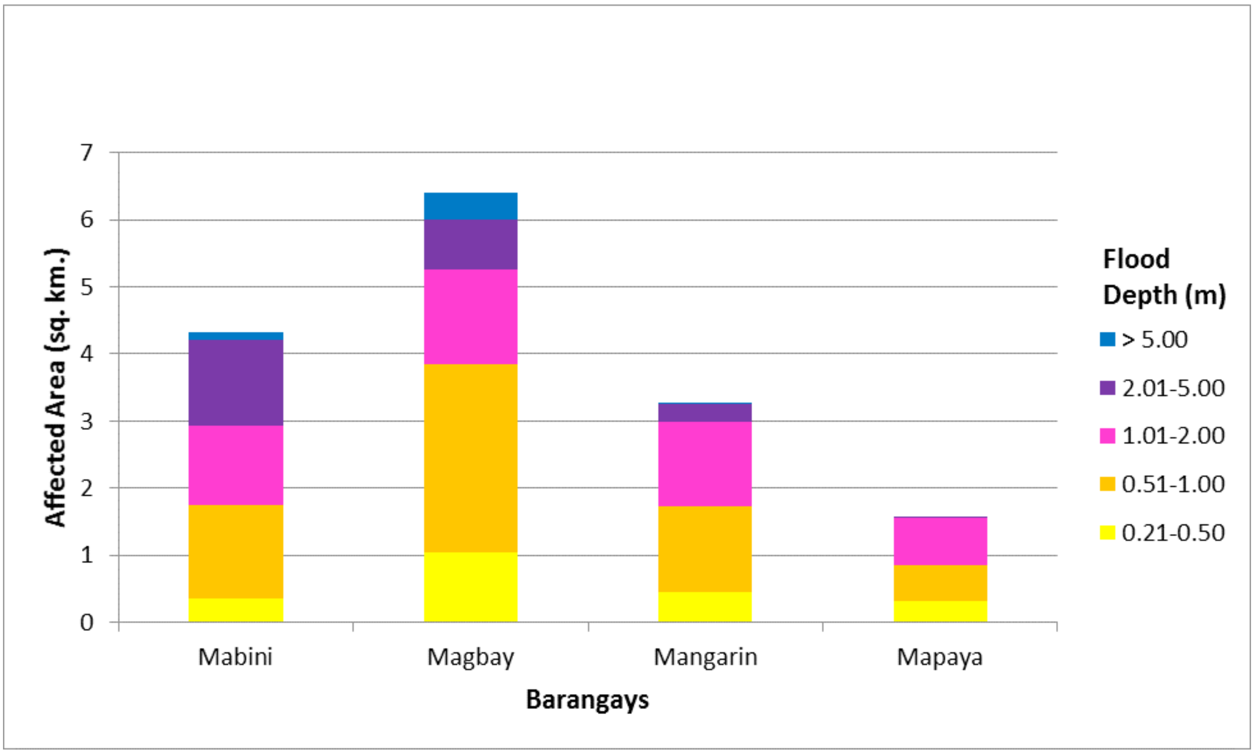

Figure 76. Affected Areas in San Jose, Occidental Mindoro during 100-Year Rainfall Return Period

Among the barangays in the municipality of San Jose, Magbay is projected to have the highest percentage of area that will experience flood levels at 2.16%. Meanwhile, Mabini posted the second highest percentage of area that may be affected by flood depths at 0.99%.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there was 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 was done through a local DRRM office to obtain maps or situation reports about the past flooding events and through interviews with some residents who have knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 78.

The flood validation consists of 96 points randomly selected all over the Labangan floodplain (Figure 77). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.605m. Table 34 shows a contingency matrix of the comparison.

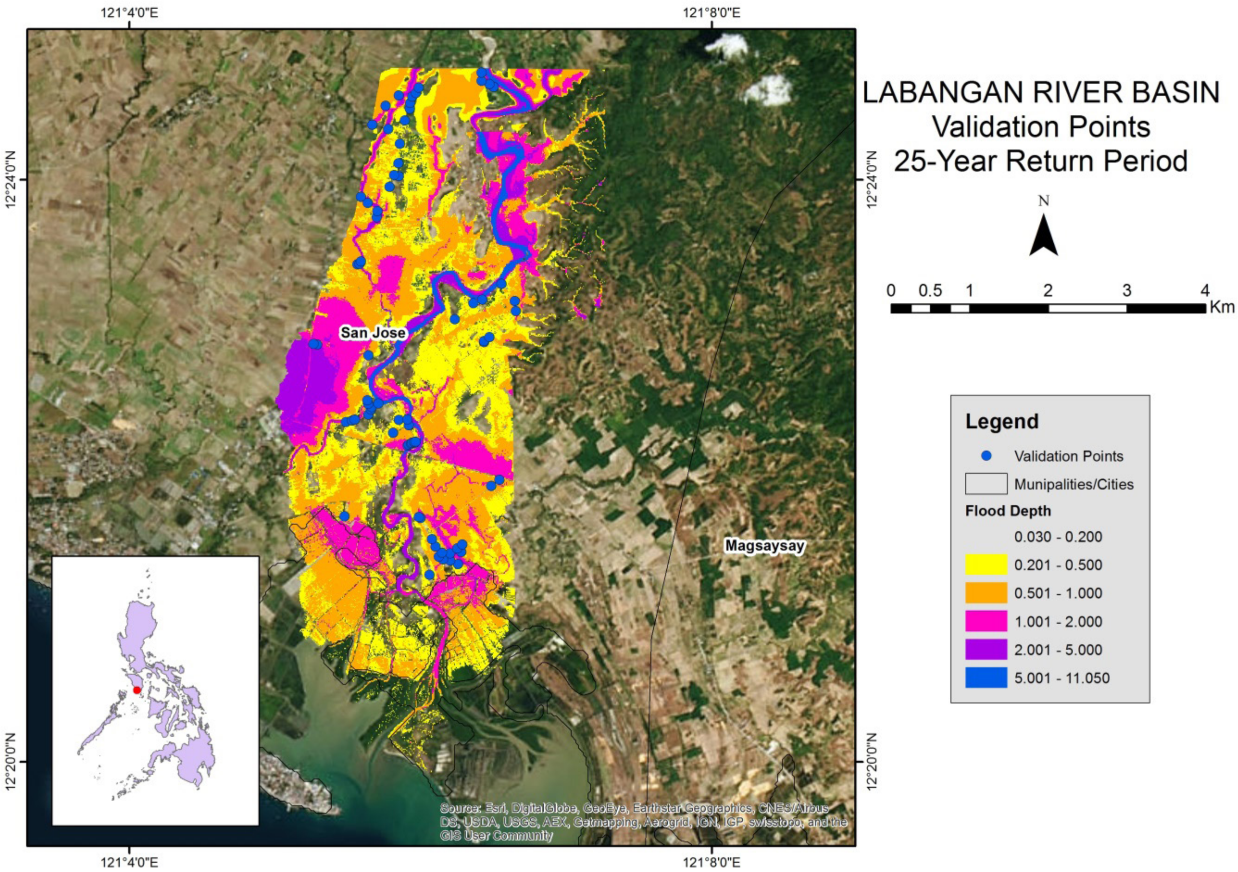

Figure 77. Validation points for 25-year Flood Depth Map of Labangan Floodplain

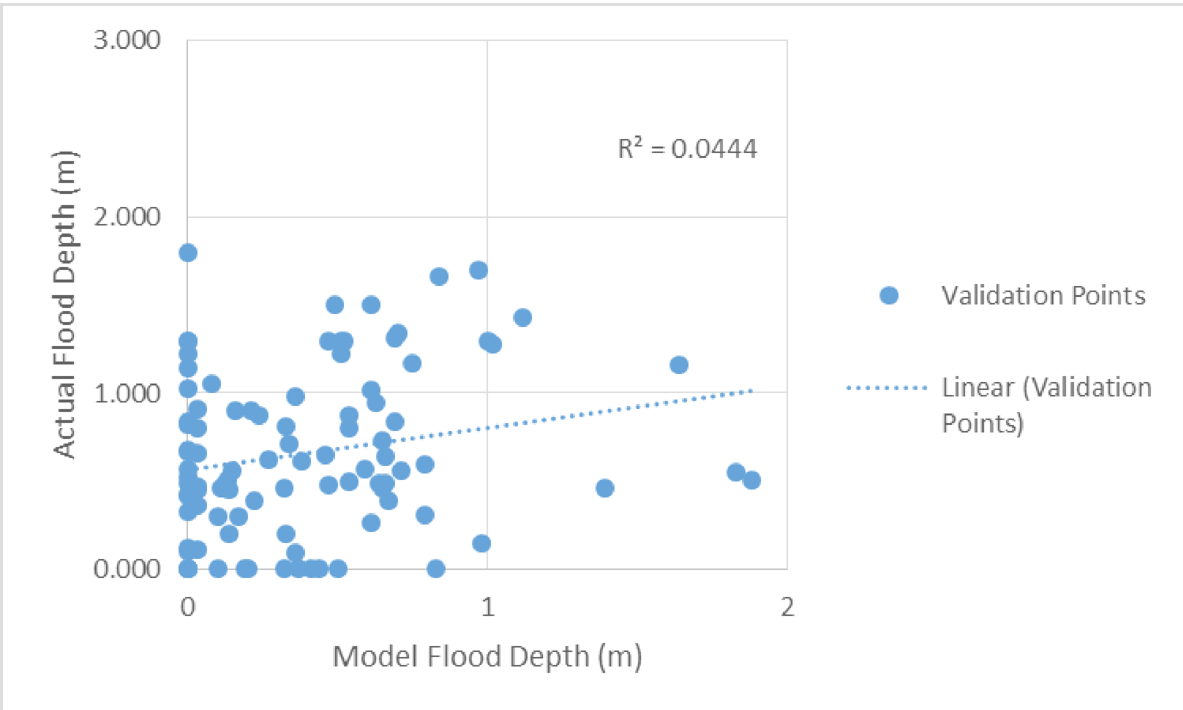

Figure 78. Flood map depth vs. actual flood depth

Table 34. Actual flood vs simulated flood depth at different levels in the Labangan 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	10	7	2	0	0	0	19
0.21-0.50	12	3	7	1	0	0	23
0.51-1.00	12	8	9	2	0	0	31
1.01-2.00	7	2	11	3	0	0	23
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	41	20	29	6	0	0	96

The overall accuracy generated by the flood model is estimated at 26.04% with 25 points correctly matching the actual flood depths. In addition, there were 39 points estimated one level above and below the correct flood depths while there were 17 points and 7 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 52 points were underestimated in the modelled flood depths of Labangan. Table 35 depicts the summary of the Accuracy Assessment in the Labangan River Basin Survey.

Table 35. Summary of the Accuracy Assessment in the Labangan River Basin Survey

	No. of Points	%
Correct	25	26.04
Overestimated	19	19.79
Underestimated	52	54.17
Total	96	**100.00**

REFERENCES

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

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Paringit, E.C., Balicanta, L.P., Ang, M.C., Lagmay, A.F., 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.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition 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. Optech Technical Specification of the Pegasus and Aquarius Sensors

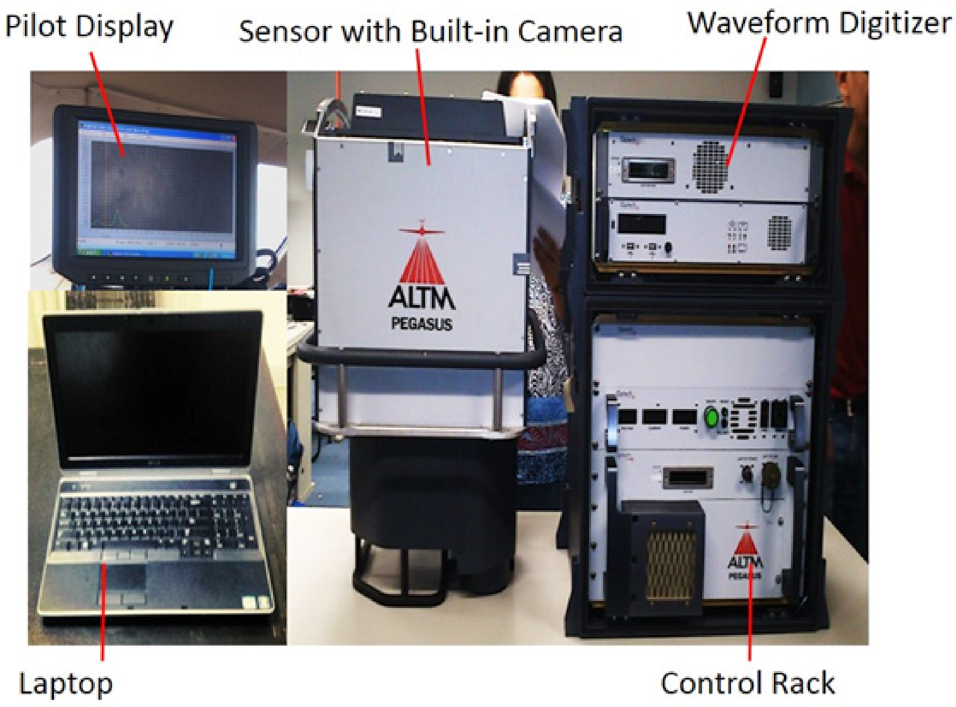

Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)

Parameter	Specification
Vertical target separation distance	<0.7 m
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)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

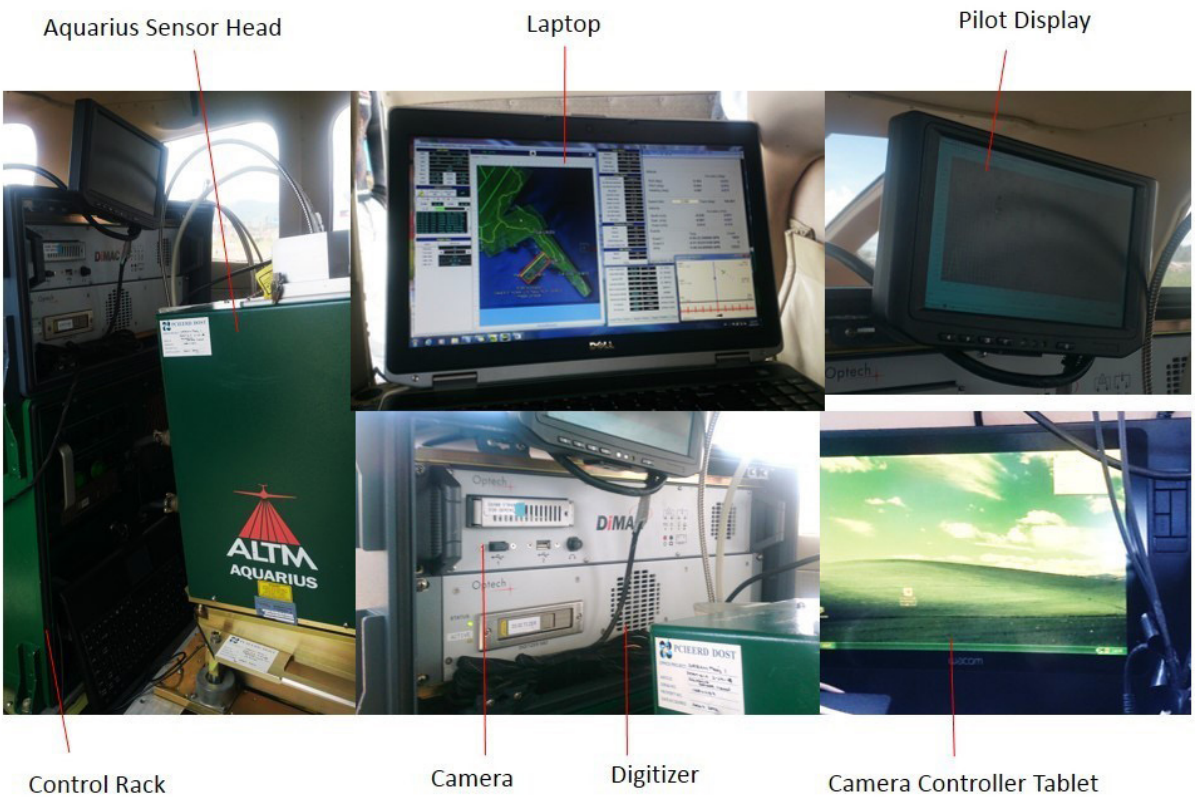

Figure A-1.2 Aquarius Sensor

Table A-1.2 Parameters and Specifications of the Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

MRW-22

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-22**
Order: **2nd**

Island: **LUZON**		Barangay: **TANYAG**
Municipality: **CALINTAAN**		
	PRS92 Coordinates	
Latitude: **12° 31' 36.76881"**	Longitude: **120° 59' 13.46492"**	Ellipsoidal Hgt: **35.12700 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 31.84278"**	Longitude: **120° 59' 18.53734"**	Ellipsoidal Hgt: **84.27100 m.**
	PTM Coordinates	
Northing: **1385214.96 m.**	Easting: **498595.125 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,385,563.72**	Easting: **281,265.62**	Zone: **51**

Location Description

MRW-22

From Abra de Ilog to San Jose, along Nat'l Road, approx. 9 Km. from Calintaan Town Proper, located Lumintao Bridge at Brgy. Tanyag, Sitio Marilao, Calintaan, Occ. Mindoro. Station is located at the N end of the catwalk of Lumintao Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-22, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-446**

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

9 9 0 3 0 4 2 0 1 4 1 6 0 1 5 0

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

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

Figure A-2.1. MRW-22

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

March 04, 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-24**
Order: **2nd**

Island: **LUZON**
Municipality: **CALINTAAN**
Barangay: **IRIRON**

PRS92 Coordinates

Latitude: **12° 36' 42.98691"**	Longitude: **120° 55' 49.01762"**	Ellipsoidal Hgt: **5.69500 m.**

WGS84 Coordinates

Latitude: **12° 36' 38.03549"**	Longitude: **120° 55' 54.08296"**	Ellipsoidal Hgt: **54.47900 m.**

PTM Coordinates

Northing: **1394624.897 m.**	Easting: **492425.435 m.**	Zone: **3**

UTM Coordinates

Northing: **1,395,022.71**	Easting: **275,166.05**	Zone: **51**

Location Description

MRW-24

From San Jose to Abra de Ilog, along Nat'l Road, approx. 9.2 Km. from Calintaan Proper, right side of the road located Evelyn's Welding Shop, left turn to Brgy. Road leading to Brgy. Iriron, approx. 1.9 Km. travel to reach Brgy. Plaza, in front of Iriron Elem. School located at Brgy. Iriron, Calintaan, Occ. Mindoro.Station is in NE corner of basketball court, about 10 m N of Goal. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-24, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-447**

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

9 9 0 3 0 4 2 0 1 4 1 6 0 2 0 7

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

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

MRW-24

Figure A-2.2. MRW-24

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

March 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: **OCCIDENTAL MINDORO**
Station Name: **MRW-4203**
Order: **3rd**

Island: **LUZON**
Municipality: **SAN JOSE**
Barangay: **MAPAYA**

PRS92 Coordinates

Latitude: **12° 21' 24.45294"**	Longitude: **121° 7' 26.92407"**	Ellipsoidal Hgt: **7.40100 m.**

WGS84 Coordinates

Latitude: **12° 21' 19.57973"**	Longitude: **121° 7' 32.01059"**	Ellipsoidal Hgt: **57.32000 m.**

PTM Coordinates

Northing: **1366404.003 m.**	Easting: **513501.246 m.**	Zone: **3**

UTM Coordinates

Northing: **1,366,637.32**	Easting: **296,032.79**	Zone: **51**

Location Description

MRW-4203

From San Jose Town Proper to Brgy. Mapaya, approx. 7.8 Km. travel to reach brgy. hall. The station is located inside the compound of brgy. plaza, beside the gate post, left side fronting brgy. hall about 40 m NE of brgy. hall, 200 m NW of post Km. post 228, along Nat'l Road, 7 Km. to San Jose. Station is located in Brgy. Mapaya, San Jose, Occ., Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4203, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795829 A**
T.N.: **2014-643**

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

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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
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

MRW-4203

Figure A-2.3. MRW-4203

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

December 11, 2015

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: **OCCIDENTAL MINDORO**
Station Name: **MRW-18**
Order: **2nd**

Island: **LUZON**	Barangay:	
Municipality: **MAGSAYSAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 18' 45.39463"**	Longitude: **121° 8' 36.92441"**	Ellipsoidal Hgt: **21.29500 m.**
	WGS84 Coordinates	
Latitude: **12° 18' 40.53383"**	Longitude: **121° 8' 42.01469"**	Ellipsoidal Hgt: **71.37500 m.**
	PTM / PRS92 Coordinates	
Northing: **1361517.851 m.**	Easting: **515618.524 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,361,734.74**	Easting: **298,113.89**	Zone: **51**

Location Description

MRW-18

From Municipality of Magsaysay, located in front of statue of President Ramon Magsaysay, inside the Municipal Compound, about 40 m SE of Municipal Bldg. of Magsaysay. Station is located in Municipality of Magsaysay, Occ. Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-18, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088861 I**
T.N.: **2015-4114**

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

9912112015132937

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

CIP/4701/12/09/814

Figure A-2.4. MRW-18

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

December 11, 2015

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: **OCCIDENTAL MINDORO**
Station Name: **MC-252**

Island: **Luzon**	Municipality: **MAGSAYSAY**	Barangay: **NICOLAS (BULO)**
Elevation: **73.9140 +/- 0.11 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

Mark is the head of a 4" copper nail flushed in a cement block embedded in the groun with inscriptions "MC-252 2008 NAMRIA"

The station is situated beside KM post 211, 26 KM to Bulalacao, 11 KM from Magsaysay 2 KM from Nicolas Brgy. Hall. From Magsaysay located along National road beside KM post 211, Magsaysay Occidental Mindoro.

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8088861 I**
T.N.:	**2015-4115**

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

MC-252

Figure A-2.5. MC-252

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

MC-252

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-18 — MC-252 (B1)	MRW-18	MC-252	Fixed	0.011	0.042	83°20'06"	6696.437	54.946

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	MRW-18				
Grid		Local		Global	
Easting	298113.895 m	Latitude	N12°18'45.39483"	Latitude	N12°18'40.53383"
Northing	1361734.745 m	Longitude	E121°08'36.92444"	Longitude	E121°08'42.01469"
Elevation	20.797 m	Height	21.295 m	Height	71.375 m

To:	MC-252				
Grid		Local		Global	
Easting	304770.876 m	Latitude	N12°19'10.66357"	Latitude	N12°19'05.80624"
Northing	1362466.012 m	Longitude	E121°12'17.05287"	Longitude	E121°12'22.14215"
Elevation	75.616 m	Height	76.241 m	Height	126.454 m

Vector					
ΔEasting	6656.981 m	NS Fwd Azimuth	83°20'06"	ΔX	-5632.860 m
ΔNorthing	731.267 m	Ellipsoid Dist.	6696.437 m	ΔY	-3538.801 m
ΔElevation	54.818 m	ΔHeight	54.946 m	ΔZ	770.489 m

Standard Errors

Vector errors:					
σ ΔEasting	0.005 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.011 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.005 m	σ ΔY	0.019 m
σ ΔElevation	0.021 m	σ ΔHeight	0.021 m	σ ΔZ	0.005 m

Figure A-3.1. Baseline Processing Report - A

UP-Lum

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-24 --- UP-LUM_2015_TCAGP (B1)	MRW-24	UP-LUM_2015_TCAGP	Fixed	0.005	0.018	146°42'11"	11260.986	29.457
MRW-24 --- UP-LUM_2015_TCAGP (B2)	MRW-24	UP-LUM_2015_TCAGP	Fixed	0.004	0.018	146°42'11"	11260.989	29.463

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	MRW-24				
Grid		Local		Global	
Easting	275166.053 m	Latitude	N12°36'42.98690"	Latitude	N12°36'38.03549"
Northing	1395022.712 m	Longitude	E120°55'49.01761"	Longitude	E120°55'54.08296"
Elevation	5.790 m	Height	5.694 m	Height	54.479 m

To:	UP-LUM_2015_TCAGP				
Grid		Local		Global	
Easting	281275.130 m	Latitude	N12°31'36.65200"	Latitude	N12°31'31.72599"
Northing	1385560.055 m	Longitude	E120°59'13.78049"	Longitude	E120°59'18.85291"
Elevation	35.101 m	Height	35.151 m	Height	84.296 m

Vector					
ΔEasting	6109.077 m	NS Fwd Azimuth	146°42'11"	ΔX	-6369.234 m
ΔNorthing	-9462.657 m	Ellipsoid Dist.	11260.986 m	ΔY	-1398.516 m
ΔElevation	29.311 m	ΔHeight	29.457 m	ΔZ	-9180.860 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Figure A-3.2. Baseline Processing Report - B

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. CZAR JAKIRI S. SARMIENTO	UP-TCAGP
		ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUNA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH PARAGAS	UP-TCAGP
	RA	PATRICIA YSABEL ALCANTARA	UP-TCAGP
		MILLIE SHANE REYES	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
		FRANK NICOLAS ILEJAY	UP-TCAGP
LiDAR Operation	Airborne Security	SGT. OLIVIER SACLOT SGT. BENJIE CARBOLLEDO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR SHERWIN ALFONSO	AAC
		CAPT. JACKSON JAVIER	AAC
		CAPT. JUSTIN REI JOYA	AAC

Annex 5. Data Transfer Sheets

DATA TRANSFER SHEET
3/19/2014(OCCMIIN)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Feb 27, 2014	1152A	3BLK29GSDS8A	AQUARIUS	NA	NA	1.12MB	255MB	73GB	544KB	12.6GB	53.8GB	15.9MB	1KB	1KB	339KB	135/556KB	Z:\Airborne_Raw\1152A
Feb 27, 2014	1154A\	3BLK29DS58B	AQUARIUS	NA	NA	NA	214MB	39.9GB	283/29KB	44.5GB	9.42GB	15.9MB	1KB	2KB	687KB	NA	Z:\Airborne_Raw\1154A
Feb 28, 2014	1156A	3BLK29F59A	AQUARIUS	NA	NA	1.72MB	268MB	89.5GB	NA	14.3GB	69.8GB	17.1MB	1KB	1KB	352KB	813KB	Z:\Airborne_Raw\1156A
Feb 28, 2014	1158A	3BLK29AS9B	AQUARIUS	NA	NA	683 KB	210 MB	38GB	95/199KB	8.14GB	13.7GB	17.1MB	1KB	1KB	6/144KB	424KB	Z:\Airborne_Raw\1158A
Mar 1, 2014	1160A	3BLK29C60A	AQUARIUS	NA	NA	1.03MB	268MB	13.5GB	10/50/40KB	14.1GB	57GB	17.8MB	1KB	1KB	519KB	399/16KB	Z:\Airborne_Raw\1160A
Mar 1, 2014	1162A	3BLK29AS60B	AQUARIUS	NA	NA	759KB	199MB	34.6GB	147/88KB	9.54GB	87.2GB	17.8MB	1KB	1KB	11/176KB	445KB	Z:\Airborne_Raw\1162A
Mar 2, 2014	1164A	3BLK29N61A	AQUARIUS	NA	NA	878KB	293MB	22.5GB	147KB	13.6GB	73.8GB	18.4MB	1KB	1KB	237KB	76/44KB	Z:\Airborne_Raw\1164A
Mar 2, 2014	1166A	3BLK29B61B	AQUARIUS	NA	NA	1.16MB	230MB	NA	NA	12.5GB	144GB	18.4MB	1KB	1KB	9/242KB	714/714KB	Z:\Airborne_Raw\1166A
Mar 3, 2014	1168A	3BLK29BS62A	AQUARIUS	NA	NA	2.37MB	268MB	NA	NA	12.3GB	15.7GB	10.8MB	1KB	1KB	184KB	300/686/670KB	Z:\Airborne_Raw\1168A

Received from

Name: CHRIS JOAQUIN
Position: RA
Signature: 04/21/14

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: 04/23/14

Figure A-5.1. Data Transfer Sheet for Labangan Floodplain - A

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

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	
6-Dec-15	3058P	1BLK29C340A	pegasus	752	189	5.69	120	9.79	74	7.56	na	15.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	460	108	3.43	115	6.09	48	4.79	na	15.4	1KB	1KB	394/344/58	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.45	430	9.18	206	26.6	192	14.4	na	7.51	1KB	1KB	100/89/95	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDI342A	pegasus	982	276	7.18	177	17	121	9.79	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	0	67	2.7	114	4.63	37	2.77	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	953	217	5.7	143	14.3	na	9.37	na	5.96	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.09	212	9.12	225	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	259	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/318/295/313/146/156	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	551	171	5.23	167	12.9	105	6.2	na	7.02	1KB	1KB	47/394/344/313/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	932	206	6.85	174	13.1	95	9.22	na	7.61	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from
Name C. Joaquin
Position
Signature

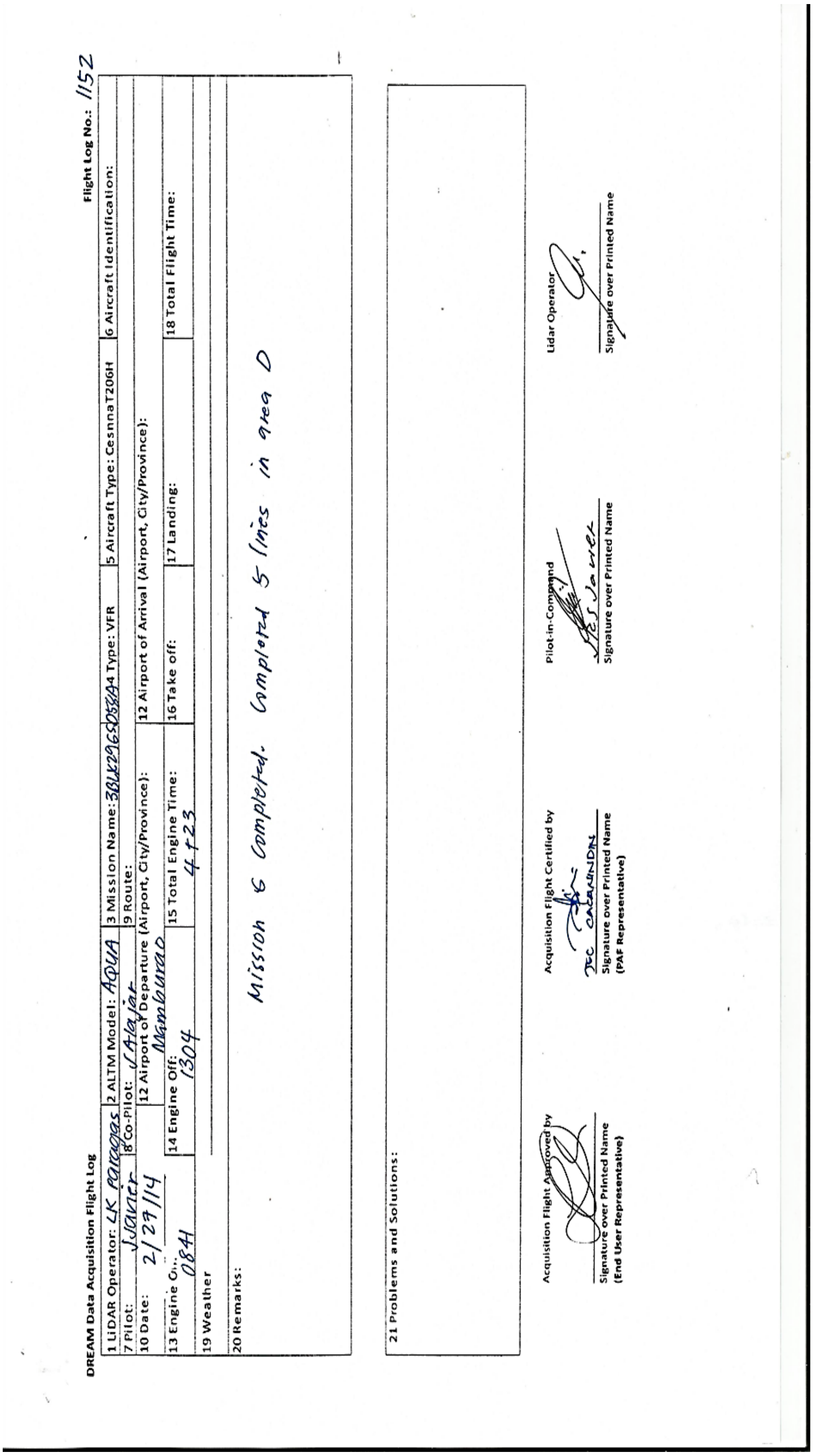
Received by
Name AC Bongat AcBongat
Position SSRA
Signature AcBongat 1/15/16

16-04

Figure A-5.2. Data Transfer Sheet for Labangan Floodplain - B

Annex 6. Flight Logs

1. Flight Log for 3BLK29GSD58A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1152

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29GSD58A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: C Alajar	9 Route:			
10 Date: 2/27/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0841	14 Engine Off: 1304	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission 6 Completed. Completed 5 lines in area D					
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)

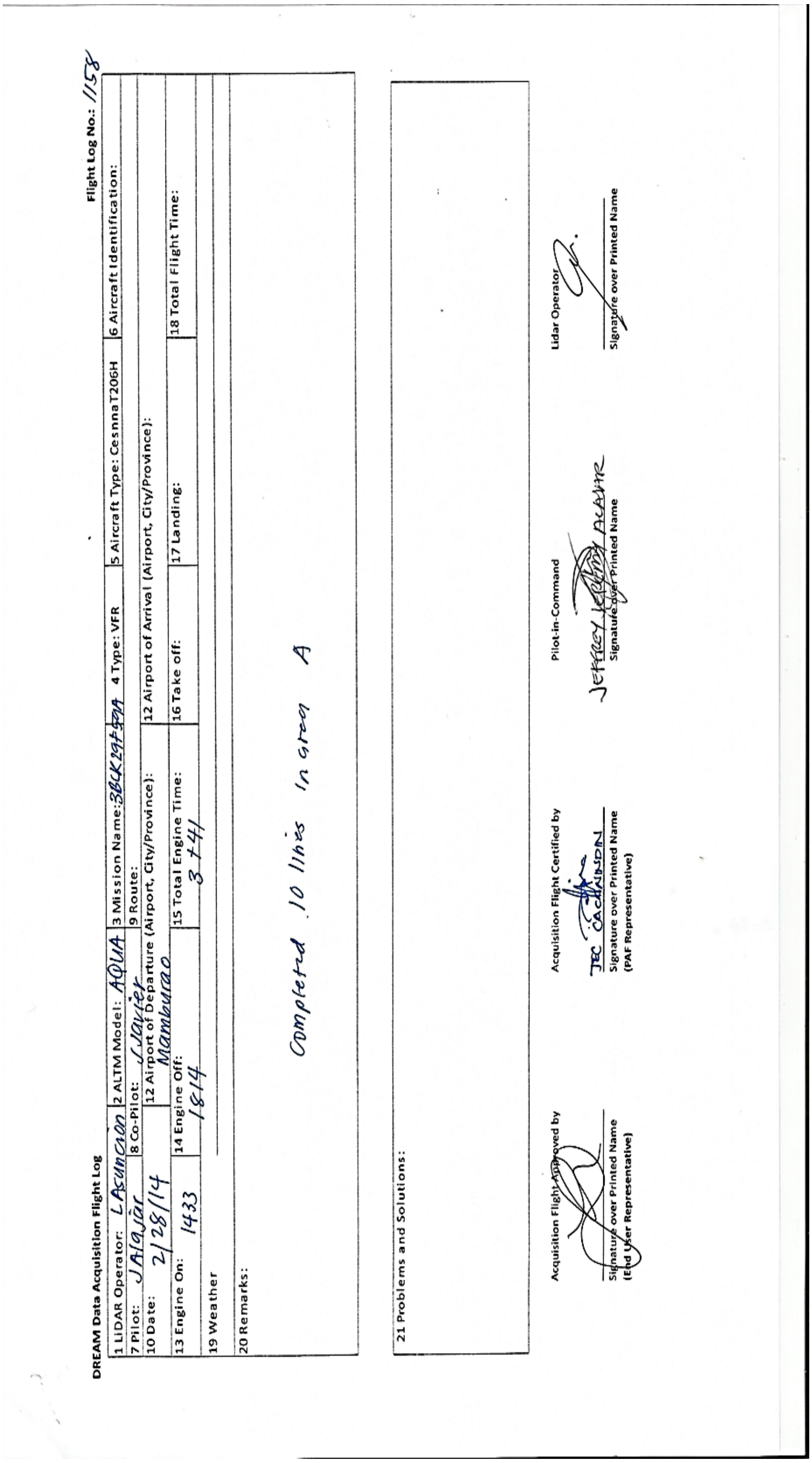
Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

MRW-18

Figure A-6.1. Flight Log for 3BLK29GSD58A Mission

Flight Log for 3BLK29A59B Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1158

1 LiDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29F59A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/28/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1433	14 Engine Off: 1814	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 10 lines in area A

21 Problems and Solutions:

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

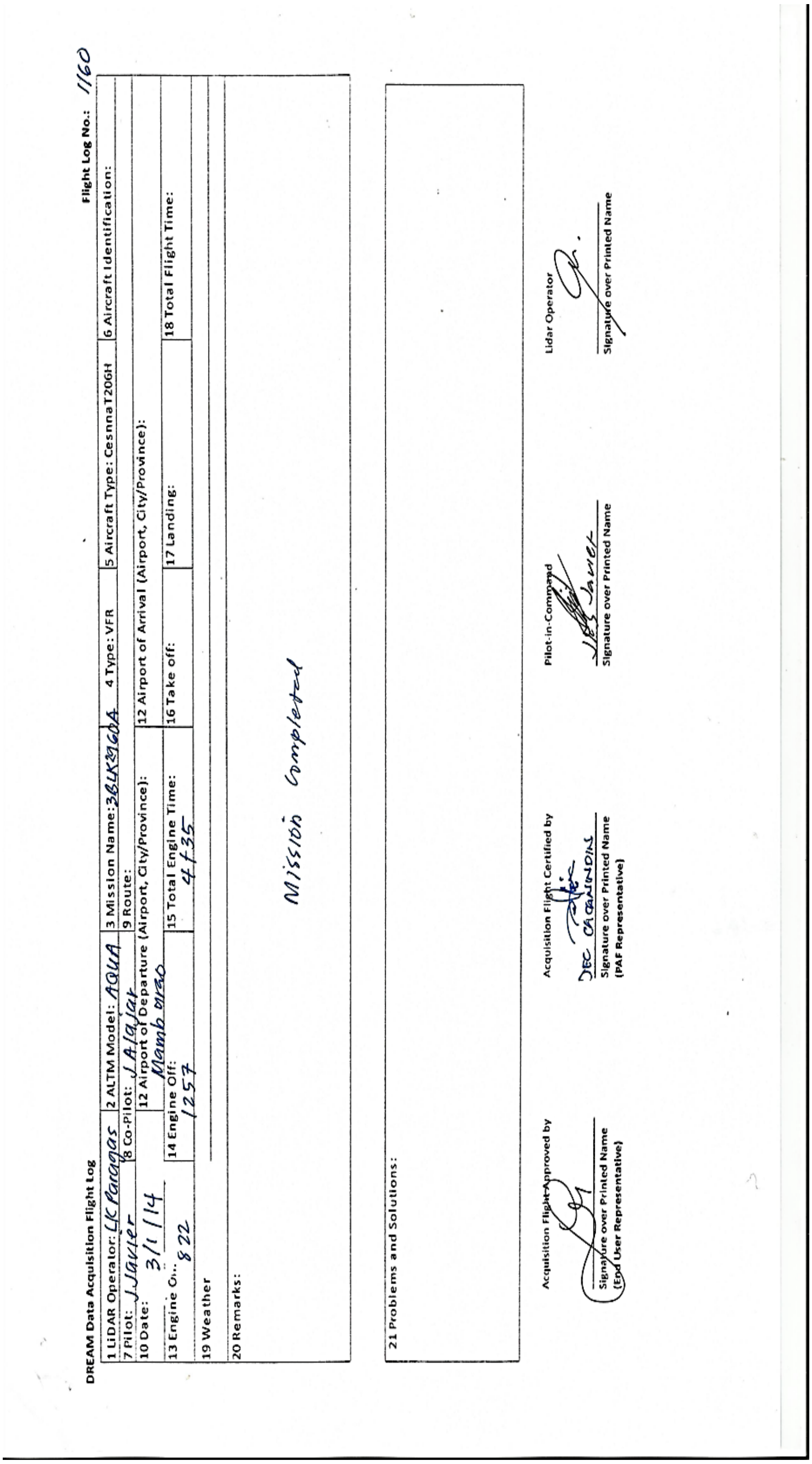
Acquisition Flight Certified by
JEC CACHINSON
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JEFFREY JEREMY ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.2. Flight Log for 3BLK29A59B Mission

Flight Log for 3BLK29C60A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1160

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29C60A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): [illegible]		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 822	14 Engine Off: 1257	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

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

Acquisition Flight Certified by — [illegible] — Signature over Printed Name (PAF Representative)

Pilot-in-Command — J. Javier — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.3. Flight Log for 3BLK29C60A Mission

Flight Log for 3BLK29AS60B Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1162

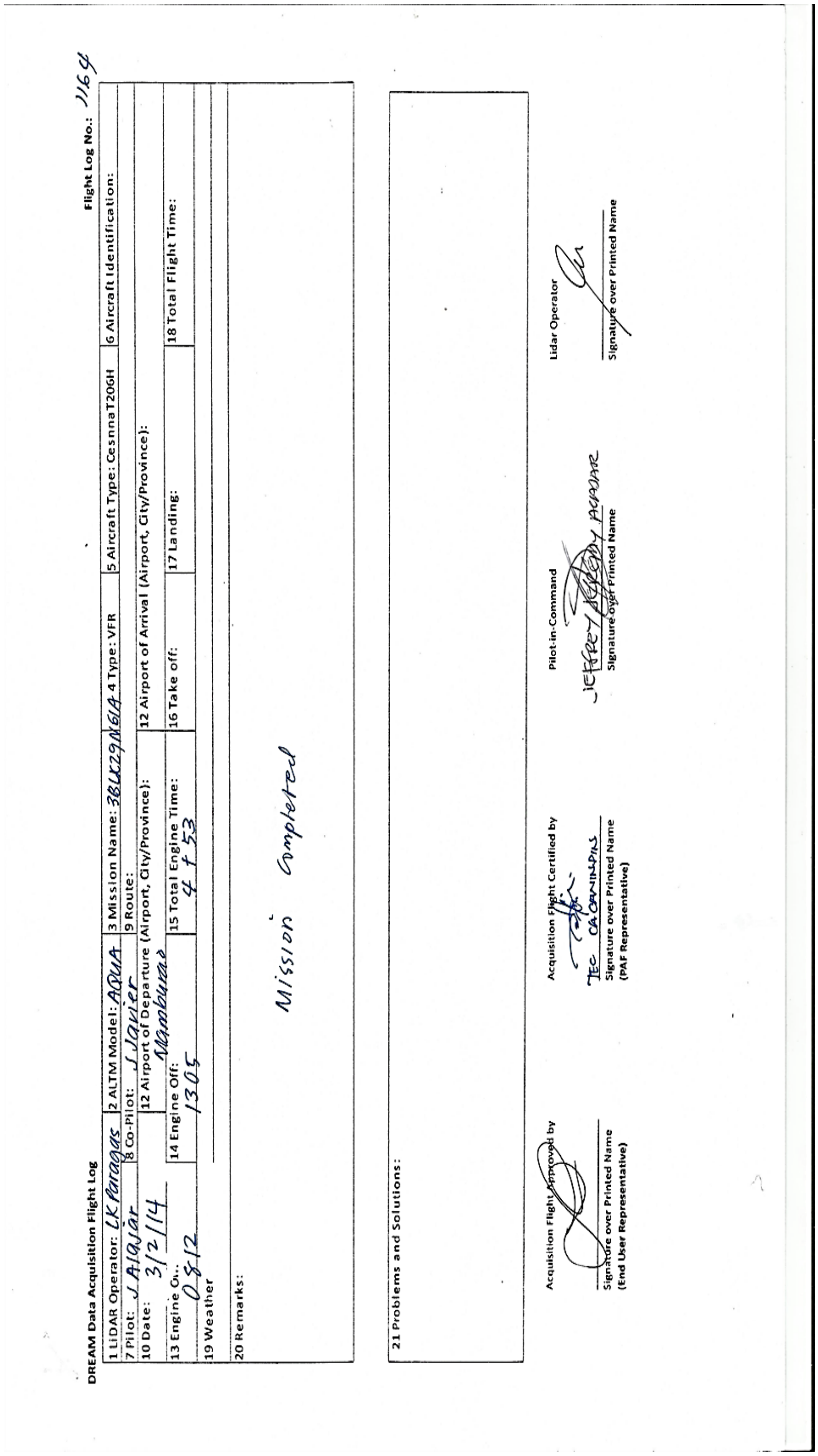
1 LiDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29AS60B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1438	14 Engine Off: 1819	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	Jec Cacanindin	J. Javier	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for 3BLK29AS60B Mission

Flight Log for 3BLK29N61A Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1164

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29N61A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 3/2/14	12 Airport of Departure (Airport, City/Province): Nambuan		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0812	14 Engine Off: 1305	15 Total Engine Time: 4+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

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

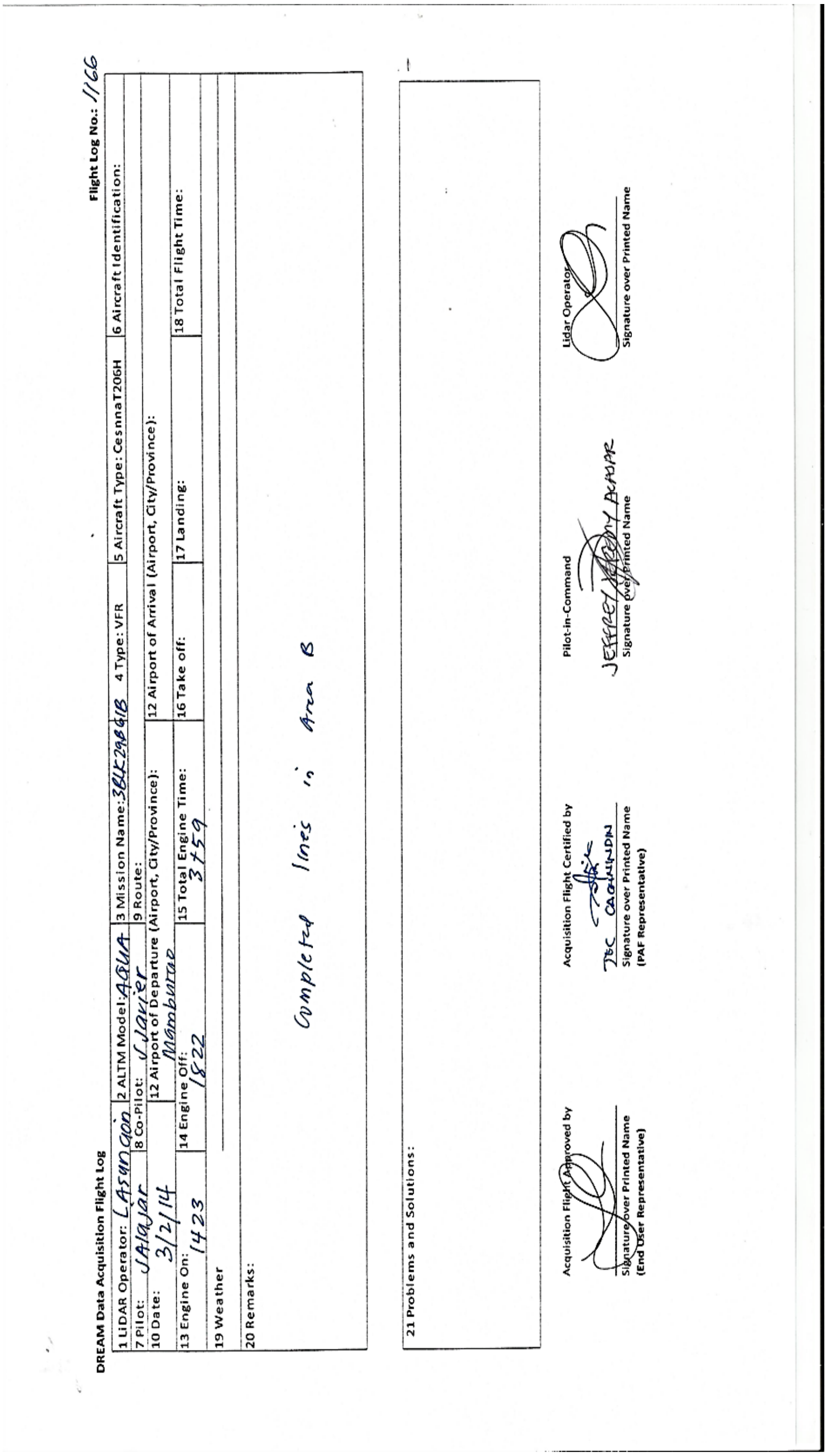
Acquisition Flight Certified by
TEC CACANINDIN
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JEFFREY ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.5. Flight Log for 3BLK29N61A Mission

Flight Log for 3BLK29B61B Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1166

1 LIDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29B61B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 3/2/14	12 Airport of Departure (Airport, City/Province): Mambutao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1423	14 Engine Off: 1822	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed lines in Area B					
21 Problems and Solutions:					

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

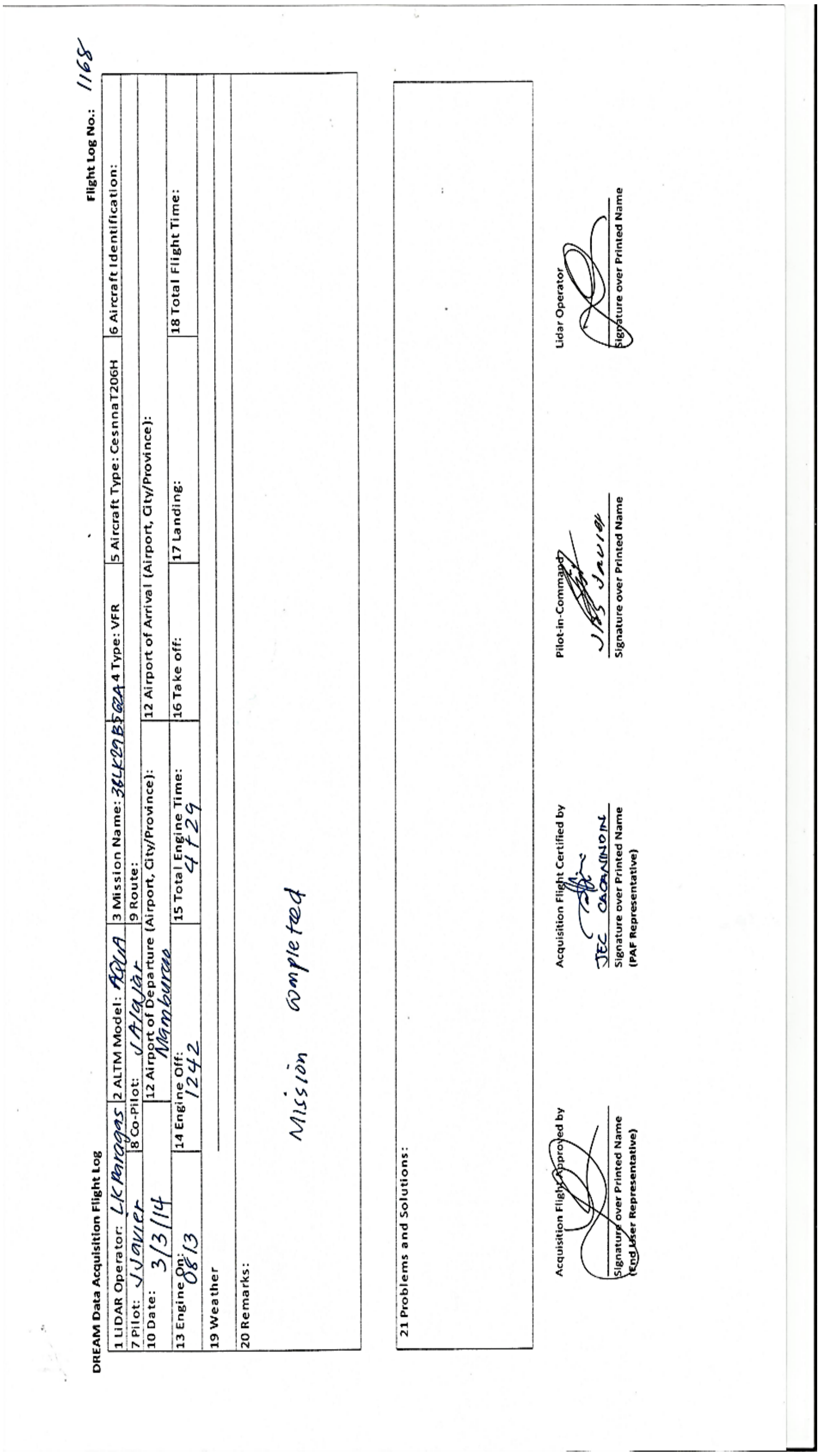
Acquisition Flight Certified by
2LC CAGUINDAN
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JEFFREY ... ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.6. Flight Log for 3BLK29B61B Mission

Flight Log for 3BLK29BS62A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1168

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29BS62A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/3/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0813	14 Engine Off: 1242	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

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

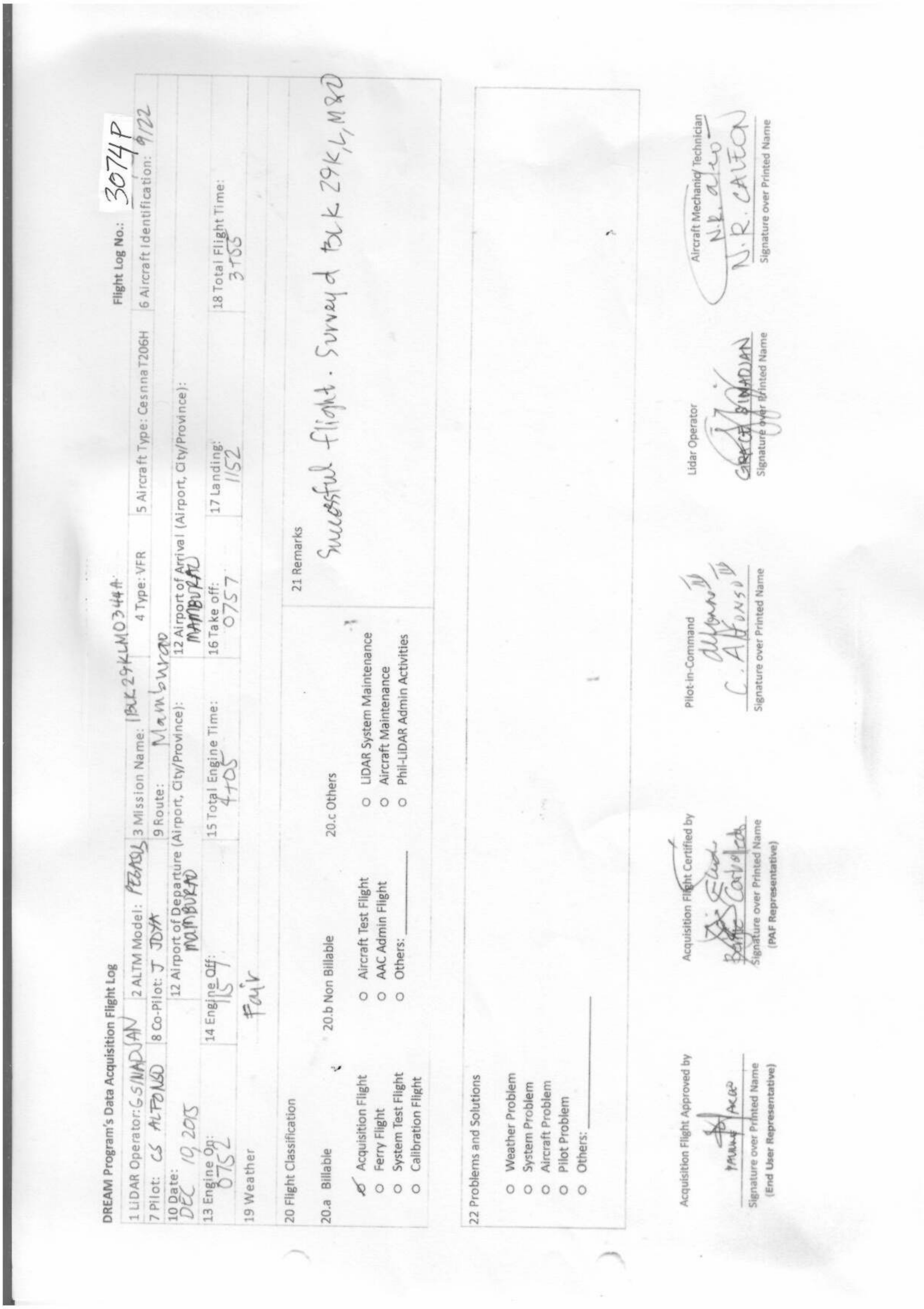
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — J. Javier — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.7. Flight Log for 3BLK29BS62A Mission

Flight Log for 1BLK29KLMO344A Mission


DREAM Program's Data Acquisition Flight Log

Flight Log No.: 3074P

1 LiDAR Operator: G.SINADJAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29KLMO344A	4 Type: VFR	5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9122				
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao		
10 Date: DEC 10 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO	12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0752	14 Engine Off: 1157	15 Total Engine Time: 4+05	16 Take off: 0757	17 Landing: 1152
18 Total Flight Time: 3+55				
19 Weather: Fair				

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

Successful flight. Surveyed BLK 29K,L,M&O

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

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

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

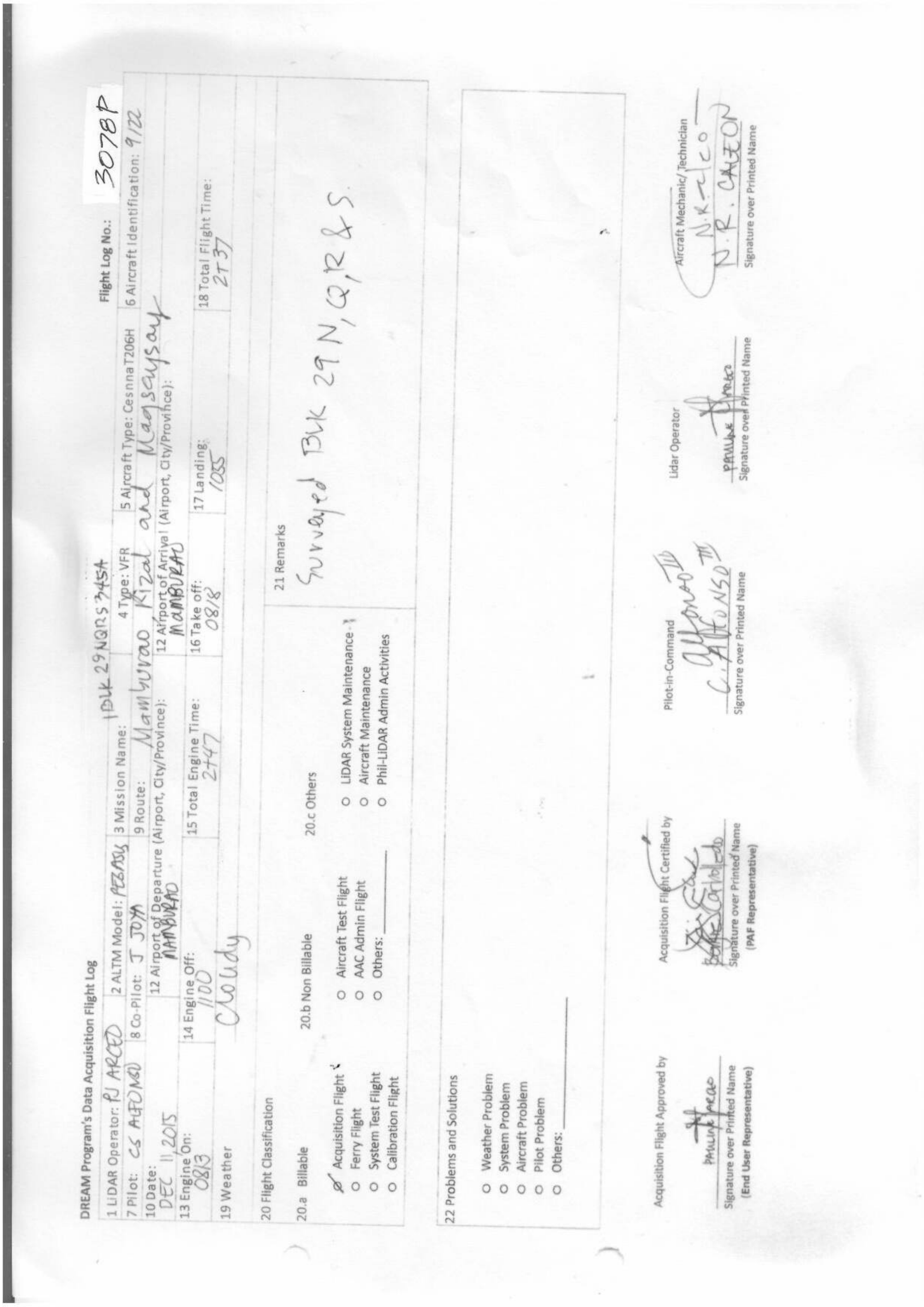
Pilot-in-Command: C. ALFONSO III Signature over Printed Name

Lidar Operator: GRACE SINADJAN Signature over Printed Name

Aircraft Mechanic/ Technician: N.R. CALEON Signature over Printed Name

Figure A-6.8. Flight Log for 1BLK29KLMO344A Mission

Flight Log for 1BLK29NQRS345A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 3078P

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29NQRS345A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao Rizal and Magsaysay			
10 Date: DEC 11, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0813	14 Engine Off: 1100	15 Total Engine Time: 2+47	16 Take off: 0818	17 Landing: 1055	18 Total Flight Time: 2+37
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29 N, Q, R & S

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

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

Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

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

Lidar Operator: PAULINE ARCEO — Signature over Printed Name

Aircraft Mechanic/ Technician: N.R. CALEON — Signature over Printed Name

Figure A-6.9. Flight Log for 1BLK29NQRS345A Mission

Annex 7. Flight Status Report

Table A-7.1 Flight Status Report

OCCIDENTAL MINDORO
(February 27 – March 3, 2014 and December 10-11, 2015)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1152A	BLK 29G and BLK 29D	3BLK29GSD58A	L. Paragas	February 27, 2014	Covered 18 lines over BLK29G and 4 lines over BLK 29D.
1158A	BLK 29A	3BLK29A59B	L. Asuncion	February 28, 2014	Covered 10 lines. Digitizer freeze in line 14, camera assertion failed in line 15. Restarted the camera in line 11 then images went to test folder and pixel resolution automatically set at 15cm instead of 7.20 cm
1160A	BLK 29C and BLK 29G	3BLK29C60A	L. Paragas	March 1, 2014	Mission completed and covered gap in BLK29G. Images manually captured in lines 1, 14 and 16 while no cam images for 2, 3 and 15. Digitizer hanged in line 14. Strong wind near mountainous area.
1162A	BLK 29A and BLK 29D	3BLK29AS60B	L. Asuncion	March 1, 2014	Mission completed. Continuation of BLK29A and covered voids in BLK29D. Restarted the system due to high system temperature. Camera hanged in line 3, no images for half of the line while manually for the rest of the line and entire line 8 while no images for lines 1, 4 and 7.
1164A	BLK 29N and BLK 29B	3BLK29N61A	L. Paragas	March 2, 2014	Mission completed. Covered lines 10 and 11 of BLK29B. Manually captured images in line 25. No images in lines 17, 21 and 24. Restarted the system in line 6.

OCCIDENTAL MINDORO
(February 27 – March 3, 2014 and December 10-11, 2015)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1166A	BLK 29B	3BLK29B61B	L. Asuncion	March 2, 2014	Covered 13 lines and gap in line 10 from the morning flight.
1168A	BLK 29B, A, D, C and K	3BLK29BS62A	L. Paragas	March 3, 2014	Mission completed. Bathy in BLK29A and D but the digitizer hanged in line 2 of area A. Covered voids of BLK29 C and K.
3074P	BLK 29K, L, M and O	1BLK29KLMO344A	G. Sinadjan	December 10, 2015	Surveyed BLK 29K, L, M and O
3078P	BLK 29N, Q, R and S	1BLK29NQRS345A	P.J. Arceo	December 11. 2015	Surveyed BLK 29N, Q, R and S

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO.	1152A		
AREA:	BLK29G, BLK29D		
MISSION NAME:	3BLK29GSD59A		
PARAMETERS:	Alt: 550 m	Scan Freq: 40 kHz	Scan Angle: 18 deg
SURVEY AREA:	95 km^2		
SURVEY COVERAGE:			

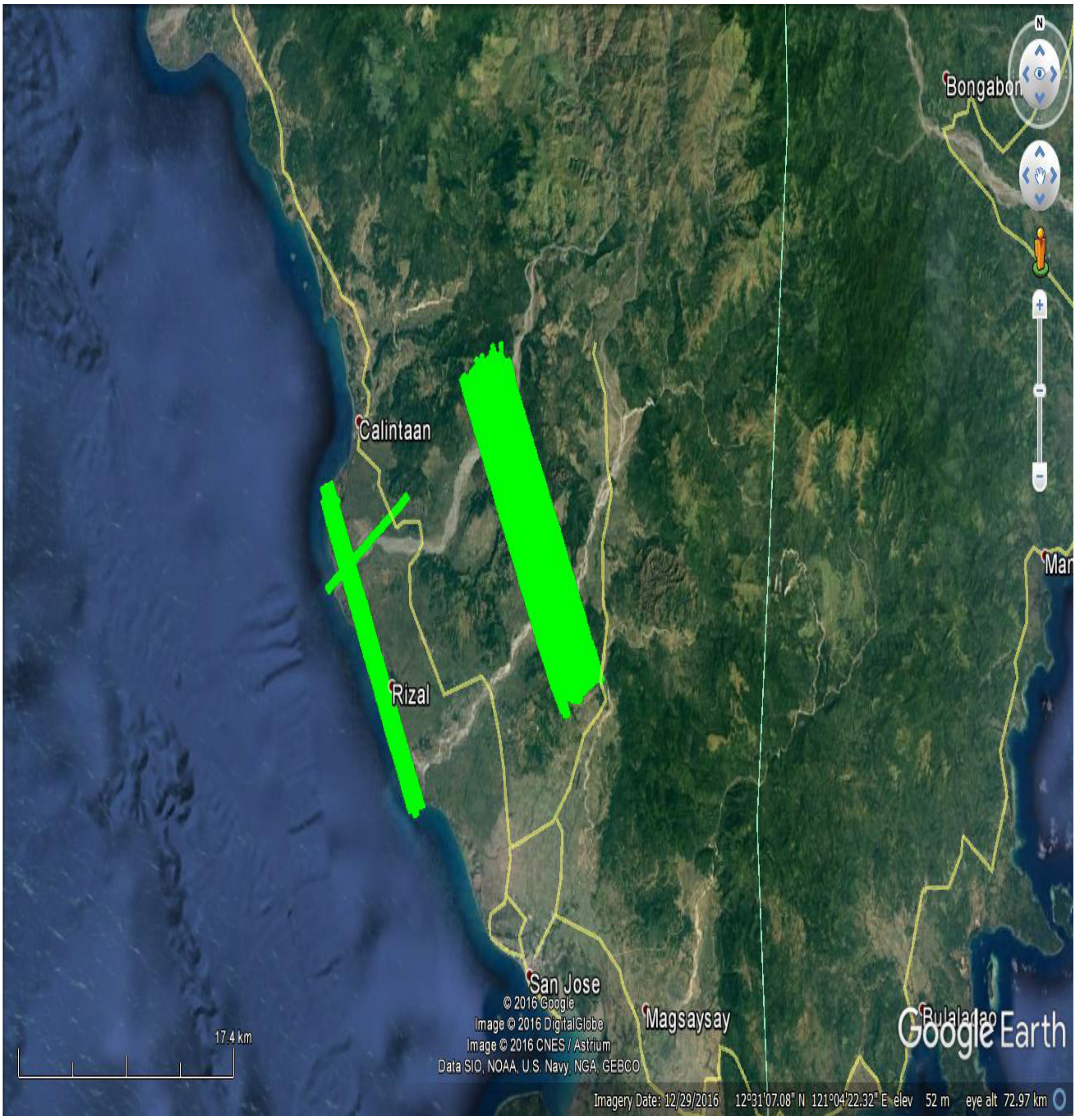


Figure A-7.1. Swath for Flight No. 1152A

FLIGHT LOG NO.	1158A		
AREA:	BLK29A		
MISSION NAME:	3BLK29A59B		
PARAMETERS:	Alt: 550 m	Scan Freq: 40 kHz	Scan Angle: 18 deg
SURVEY AREA:	65.181 km^2		
SURVEY COVERAGE:			

Figure A-7.2. Swath for Flight No. 1158A

FLIGHT LOG NO. 1160A
AREA: BLK29C AND BLK29G
MISSION NAME: 3BLK29C+GV60A
PARAMETERS: Alt: 600 m Scan Freq: 40 kHz Scan Angle: 18 deg

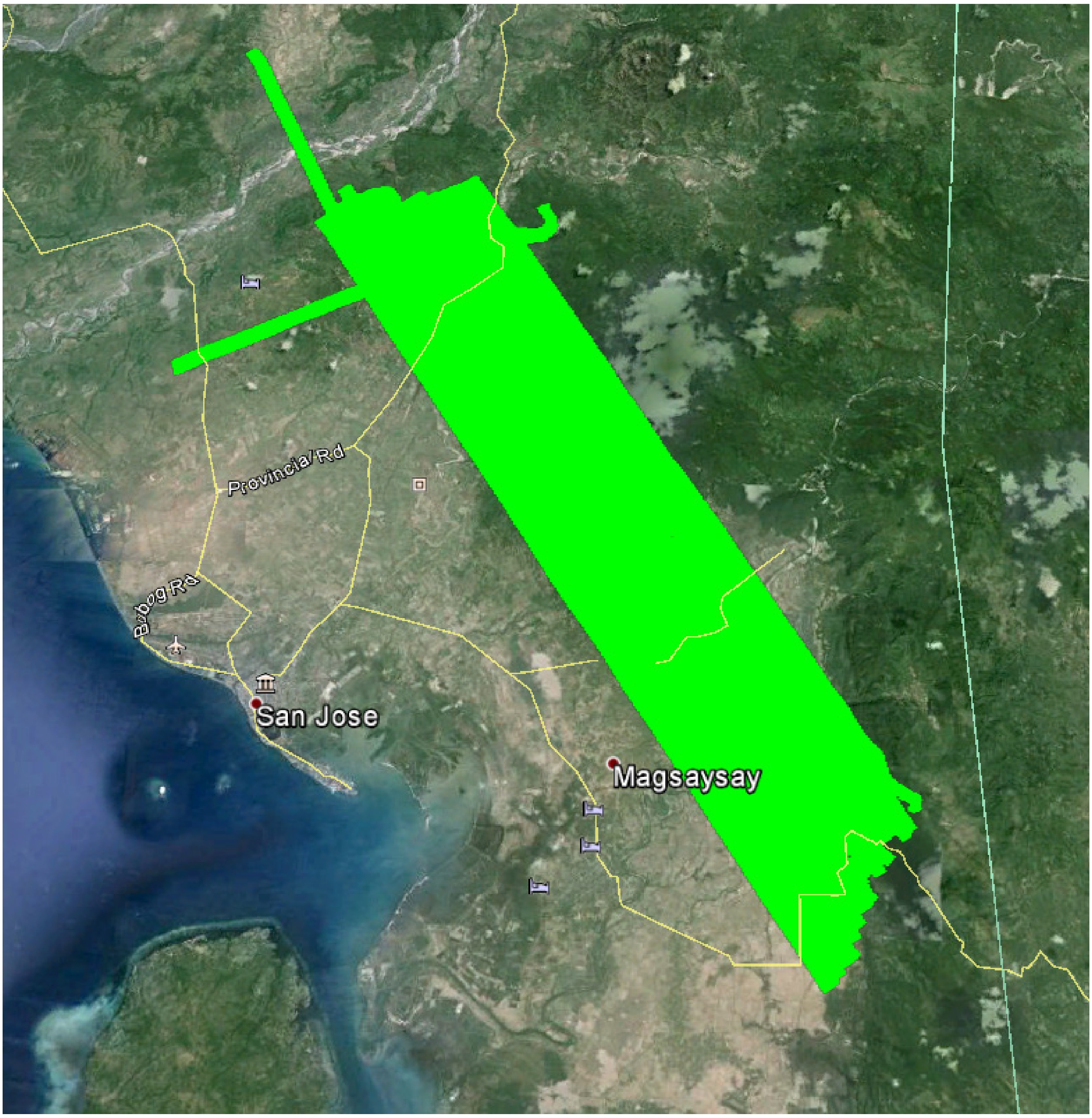


Figure A-7.4. Swath for Flight No. 1160A

FLIGHT LOG NO. 1162A
AREA: BLK29A AND BLK29D
MISSION NAME: 3BLK29AS+DV60B
PARAMETERS: Alt: 600 m Scan Freq: 40 kHz Scan Angle: 18 deg

Figure A-7.5. Swath for Flight No. 1162A

FLIGHT LOG NO. 1164A
AREA: BLK29N AND BLK29B
MISSION NAME: 3BLK29N+B61A
PARAMETERS: Alt: 600 m Scan Freq: 40 kHz Scan Angle: 18 deg

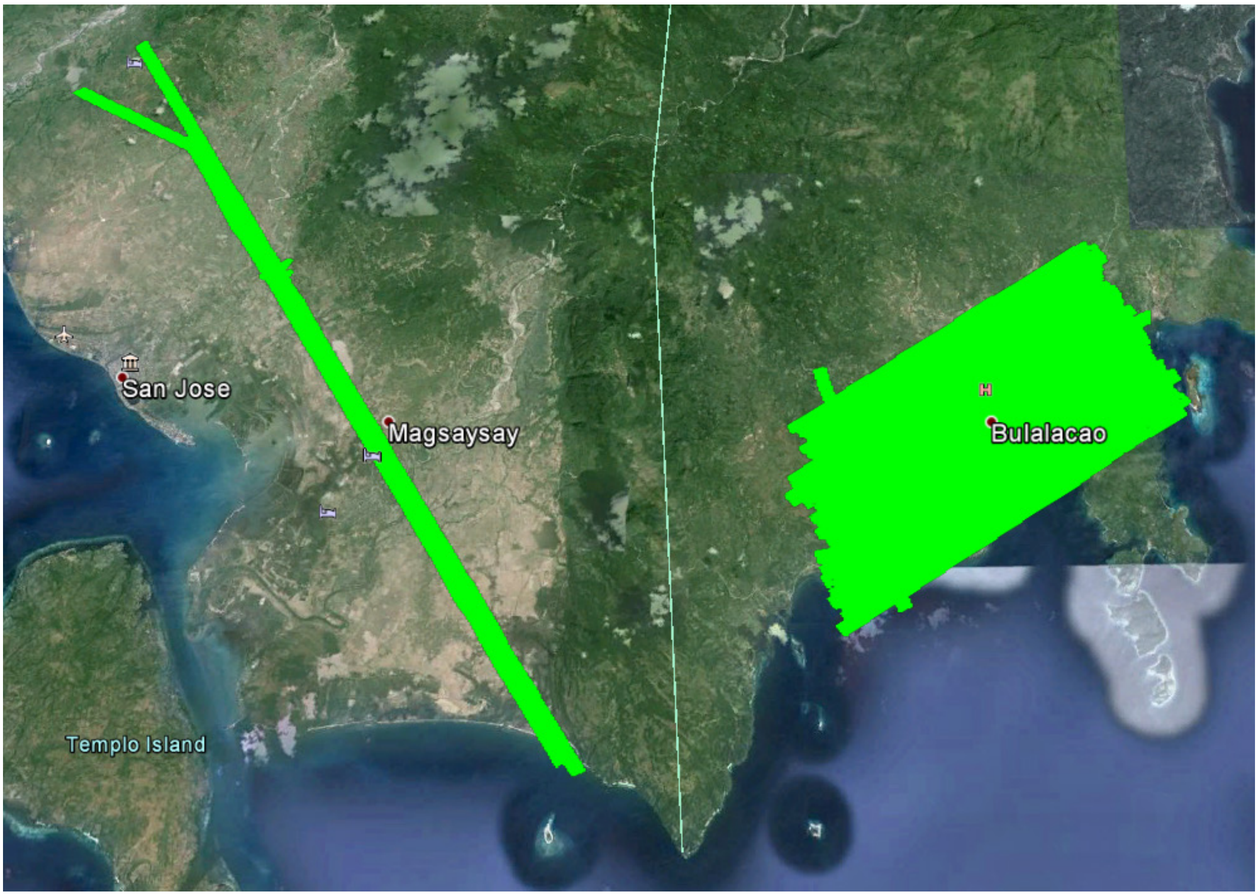


Figure A-7.6. Swath for Flight No. 1164A

FLIGHT LOG NO. 1166A
AREA: BLK29B
MISSION NAME: 3BLK29B61B
PARAMETERS: Alt: 600 m Scan Freq: 40 kHz Scan Angle: 18 deg

Figure A-7.7. Swath for Flight No. 1166A

FLIGHT LOG NO. 1168A
AREA: BLK29B, BLK29A, BLK29D, BLK29C AND BLK29K
MISSION NAME: 3BLK29BS+AB+DB+CV+KV62B
PARAMETERS: Alt: 550 m Scan Freq: 40 kHz Scan Angle: 18 deg

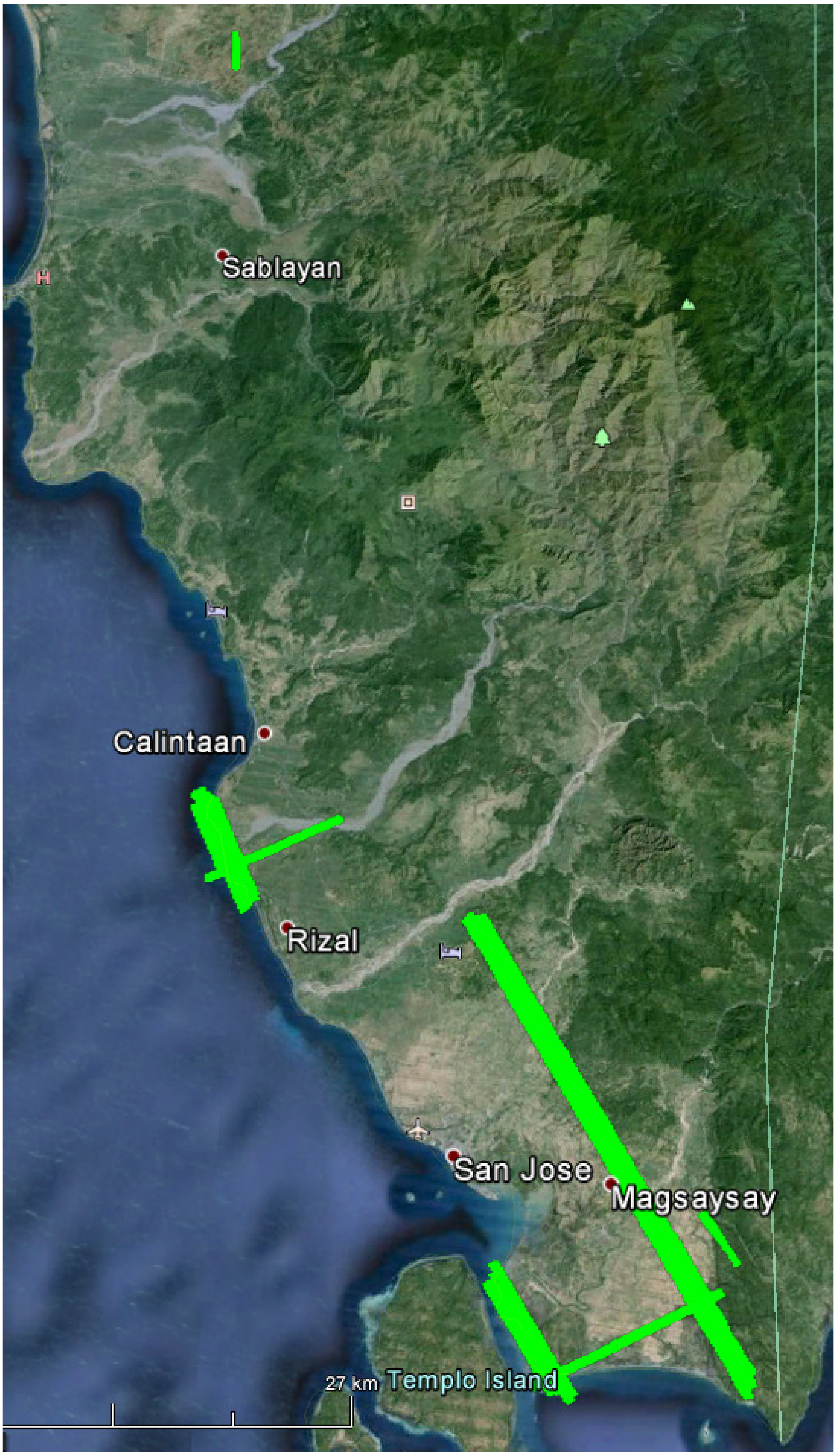


Figure A-7.8. Swath for Flight No. 1168A

FLIGHT NO.: 3074P
AREA: CALINTAAN
MISSION NAME: 1BLK29KLMO344A
ALT: 1100 m SCAN FREQ:30 khz SCAN ANGLE: 25deg

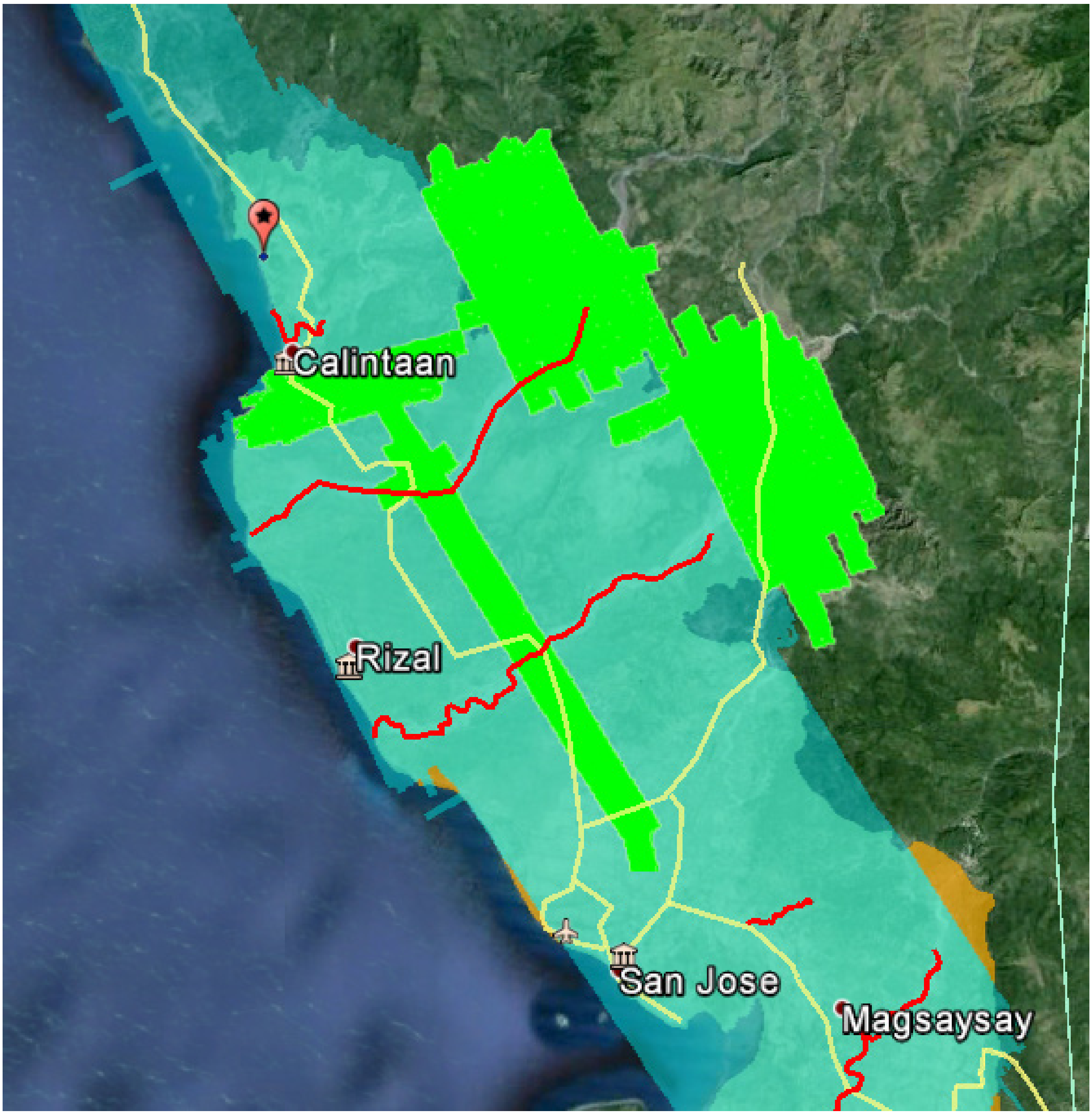


Figure A-7.9. Swath for Flight No. 3074P

FLIGHT NO.: 3078P
AREA: RIZAL AND MAGSAYSAY
MISSION NAME: 1BLK29NQRS345A
ALT: 850 m SCAN FREQ:32 khz SCAN ANGLE: 25 deg

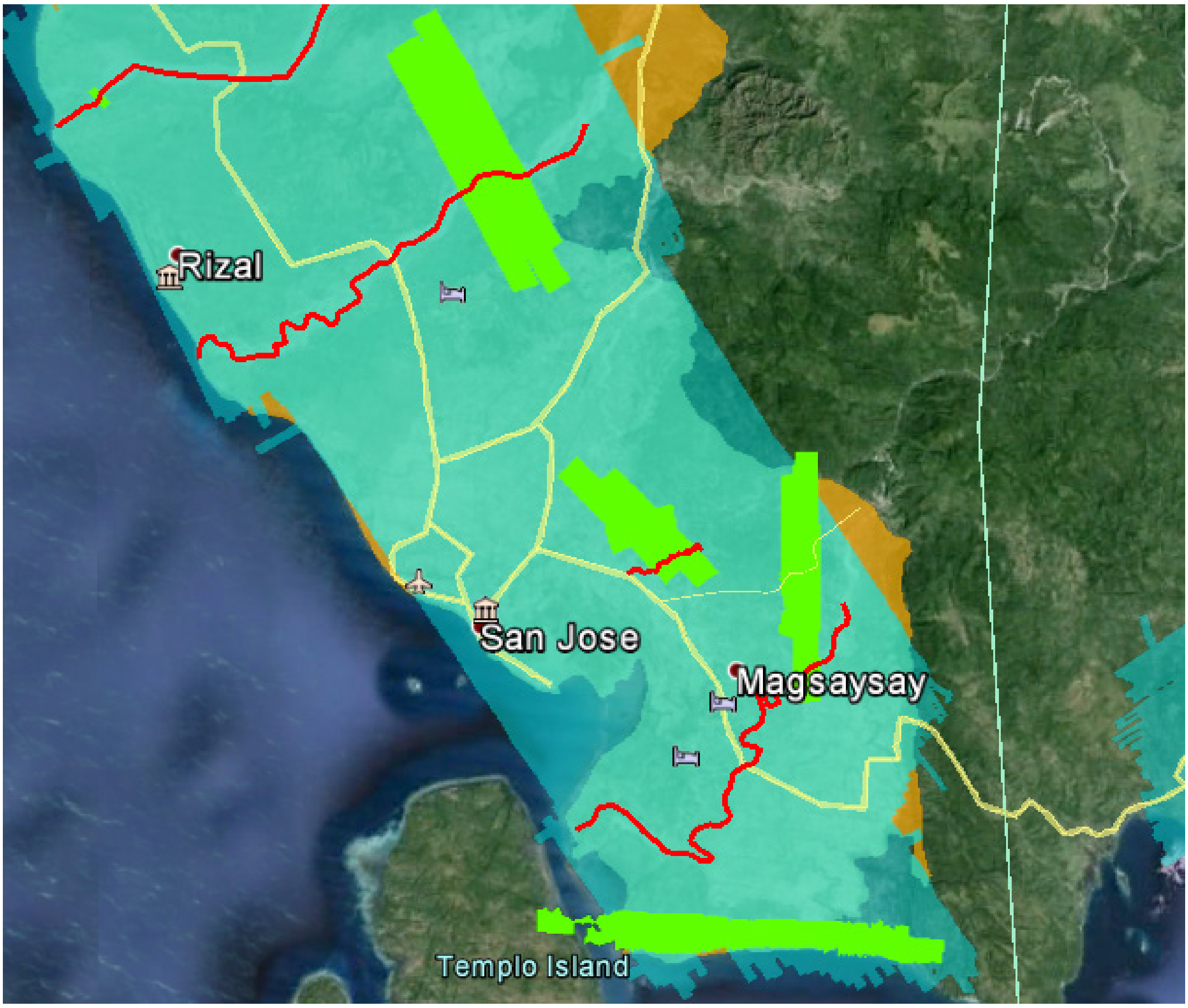


Figure A-7.10. Swath for Flight No. 3078P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk29A

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29A**
Inclusive Flights	3076P
Range data size	3.2GB
Base data size	14.1MB
POS	102MB
Image	4.32MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.43
RMSE for East Position (<4.0 cm)	1.29
RMSE for Down Position (<8.0 cm)	1.87
Boresight correction stdev (<0.001deg)	0.000451
IMU attitude correction stdev (<0.001deg)	0.000826
GPS position stdev (<0.01m)	0.0123
Minimum % overlap (>25)	36.55%
Ave point cloud density per sq.m. (>2.0)	2.04
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	194
Maximum Height	165.41 m
Minimum Height	43.10 m
Classification (# of points)	
Ground	104,722,532
Low vegetation	130,224,088
Medium vegetation	60,206,940
High vegetation	16,625,237
Building	4,886,963
Orthophoto	Yes
Processed By	Engr. Jennifer Saguran, Engr. Ma. Joanne Balaga, Engr. Ma. Ailyn Olanda

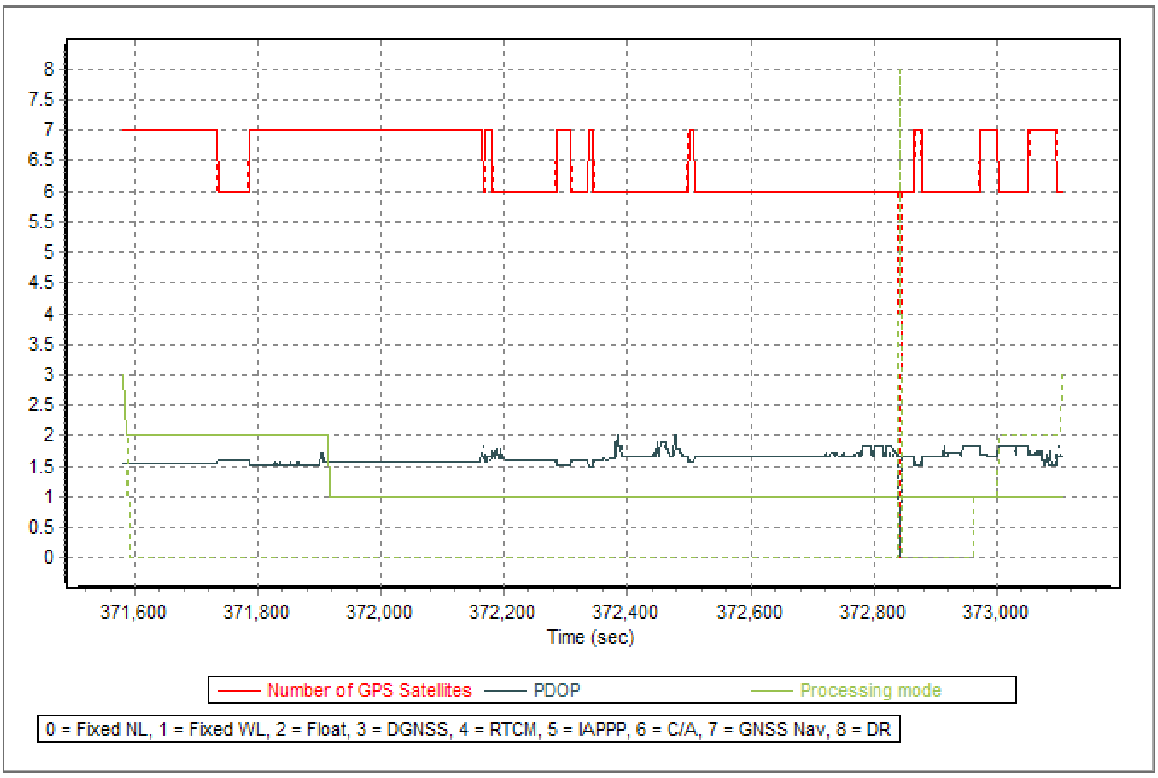


Figure A-8.1 Solution Status

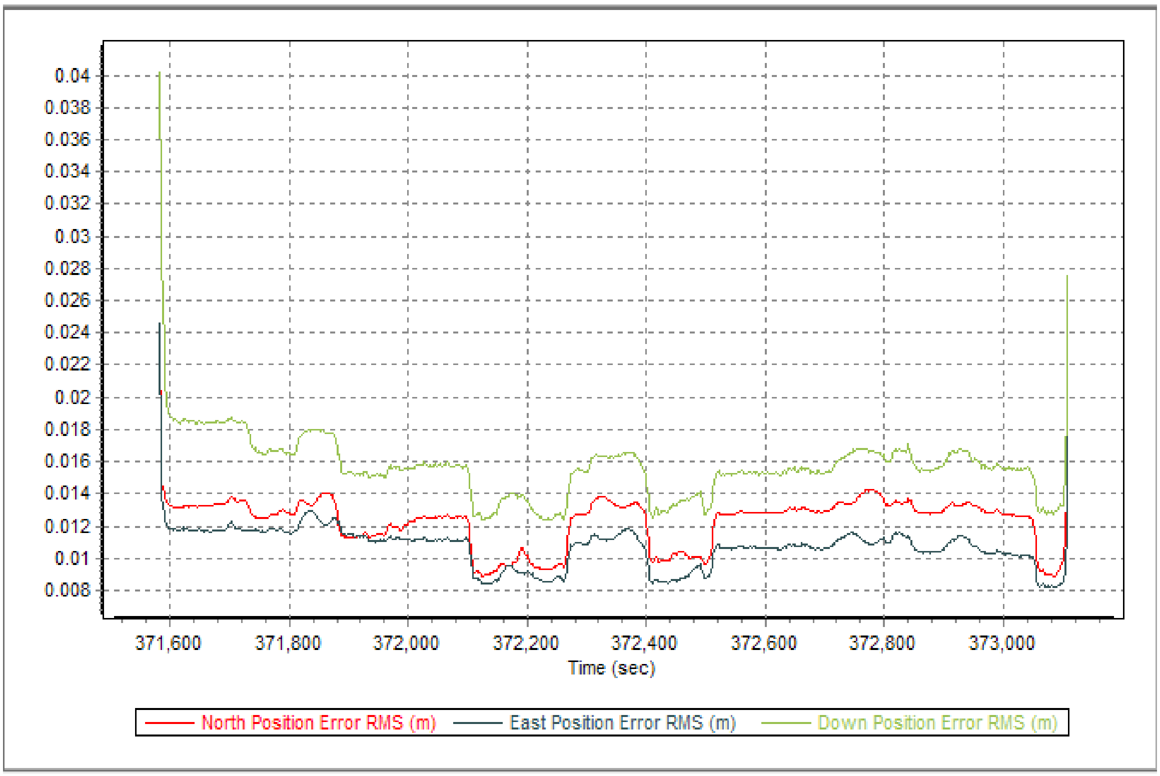


Figure A-8.2 Smoothed Performance Metrics Parameters

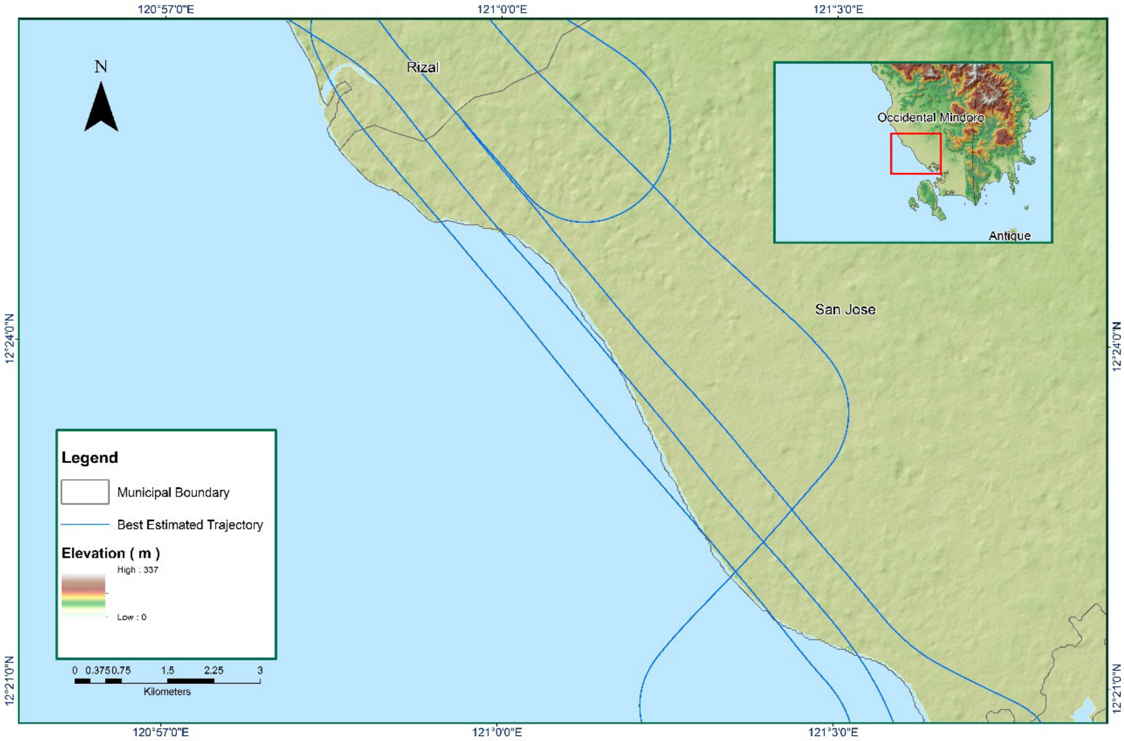


Figure A-8.3 Best Estimated Trajectory

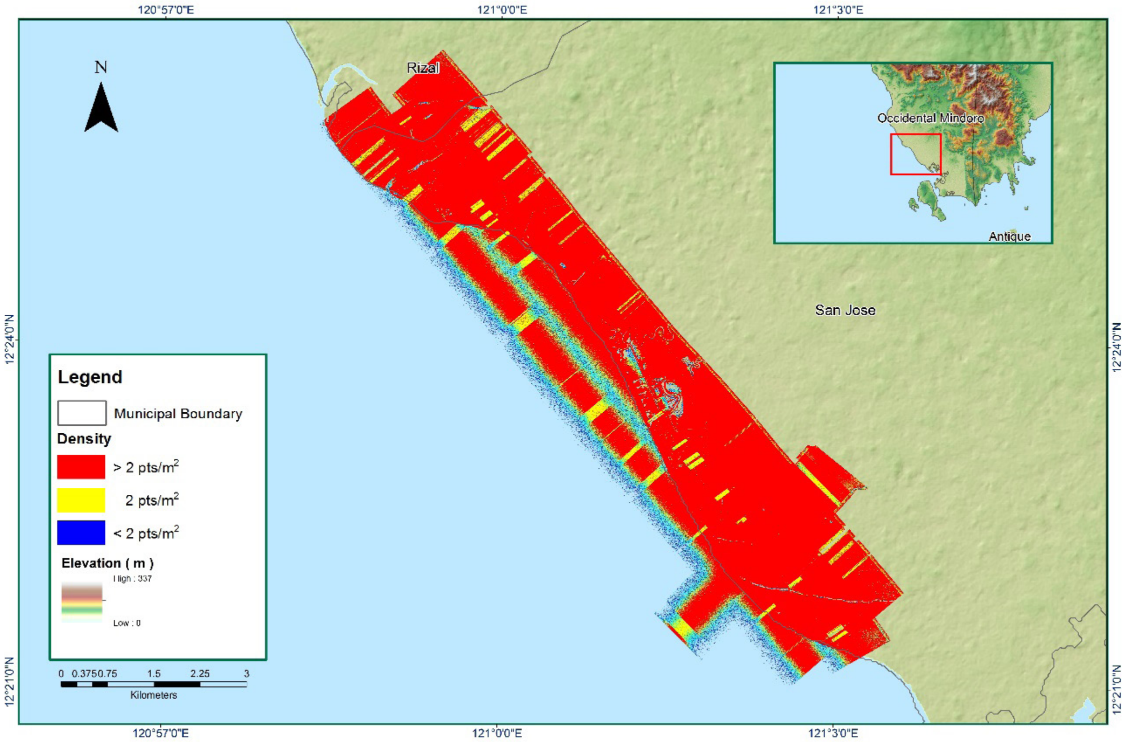


Figure A-8.4. Coverage of LiDAR data

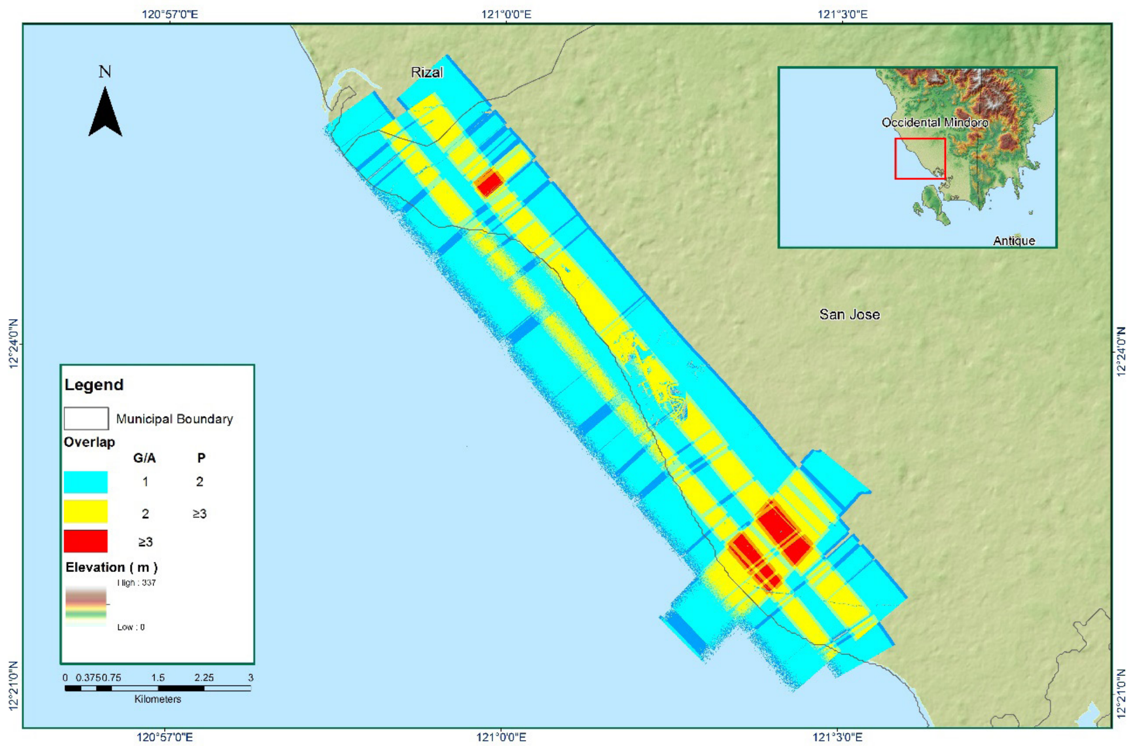


Figure A-8.5. Image of data overlap

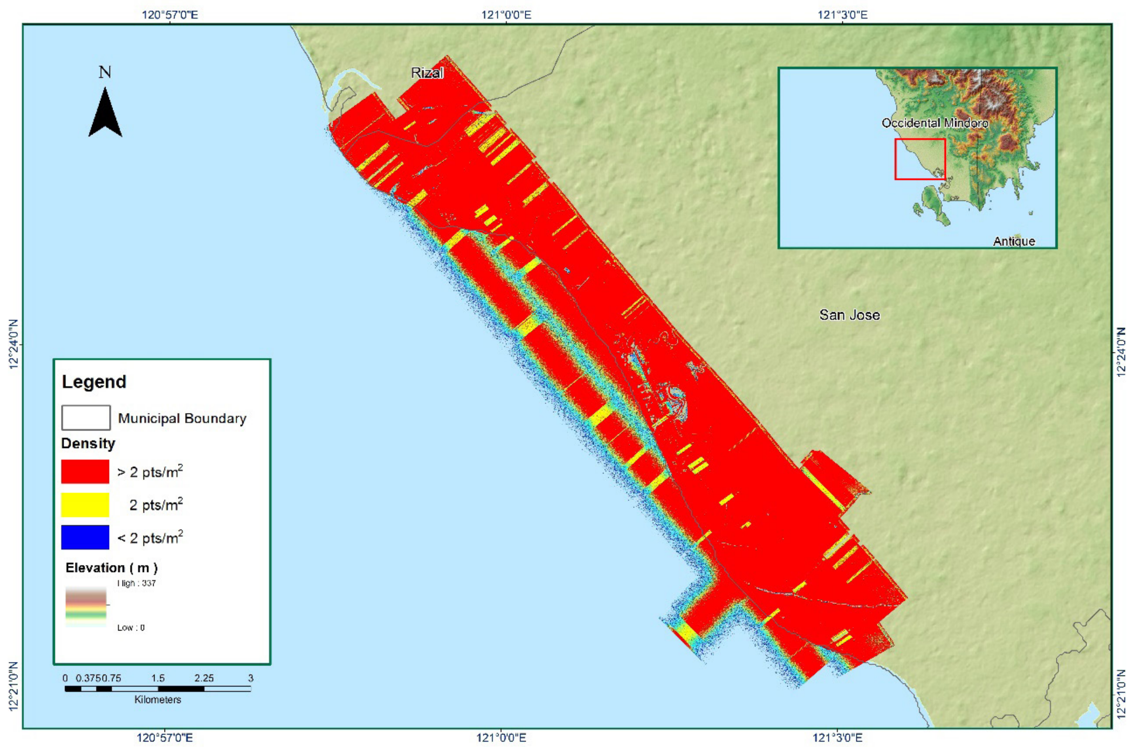


Figure A-8.6 Density of merged LiDAR data

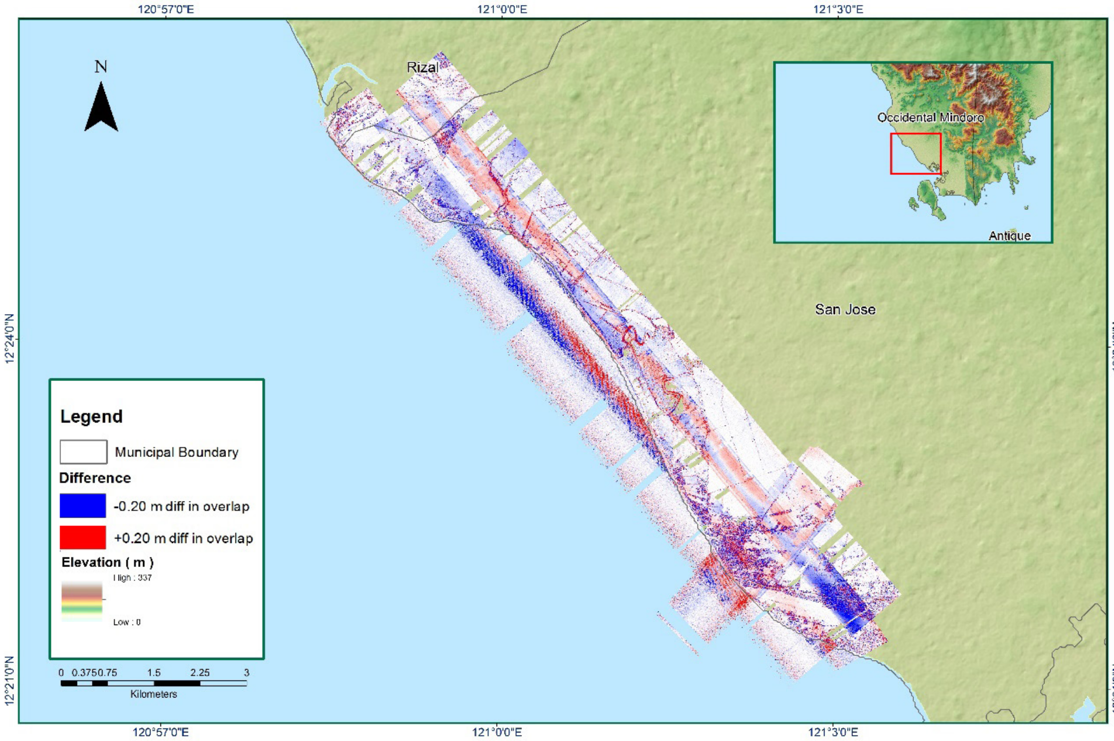


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk29B_additional

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29B_additional**
Inclusive Flights	3078P
Range data size	6.2GB
Base data size	7.02MB
POS	167MB
Image	12.9MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.01
RMSE for East Position (<4.0 cm)	1.16
RMSE for Down Position (<8.0 cm)	4.25
Boresight correction stdev (<0.001deg)	0.359804
IMU attitude correction stdev (<0.001deg)	0.083211
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	17.73%

Flight Area	Occidental Mindoro Reflights
Ave point cloud density per sq.m. (>2.0)	1.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	197
Maximum Height	258.38 m
Minimum Height	46.77 m
Classification (# of points)	
Ground	115,311,089
Low vegetation	138,979,099
Medium vegetation	95,318,939
High vegetation	30,819,969
Building	2,104,153
Orthophoto	Yes
Processed By	Engr. Abigail Joy Ching, Engr. Ma. Joanne Balaga, Jovy Narisma

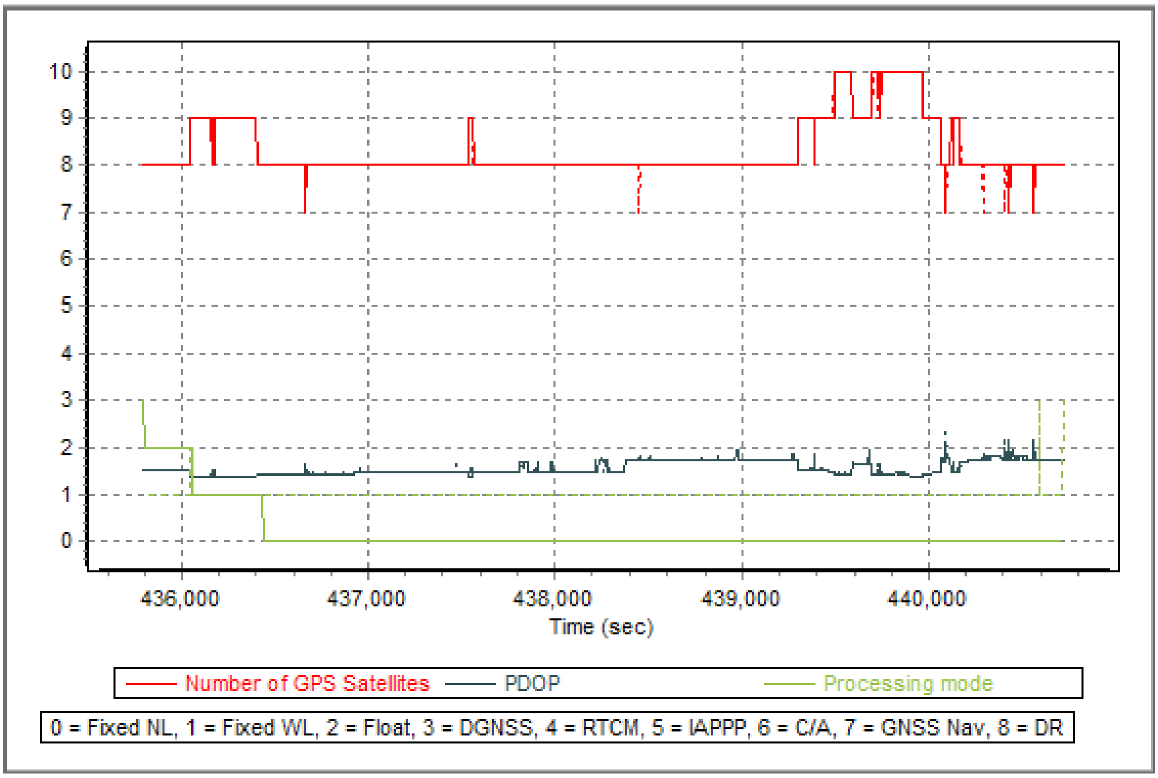


Figure A-8.8. Solution Status

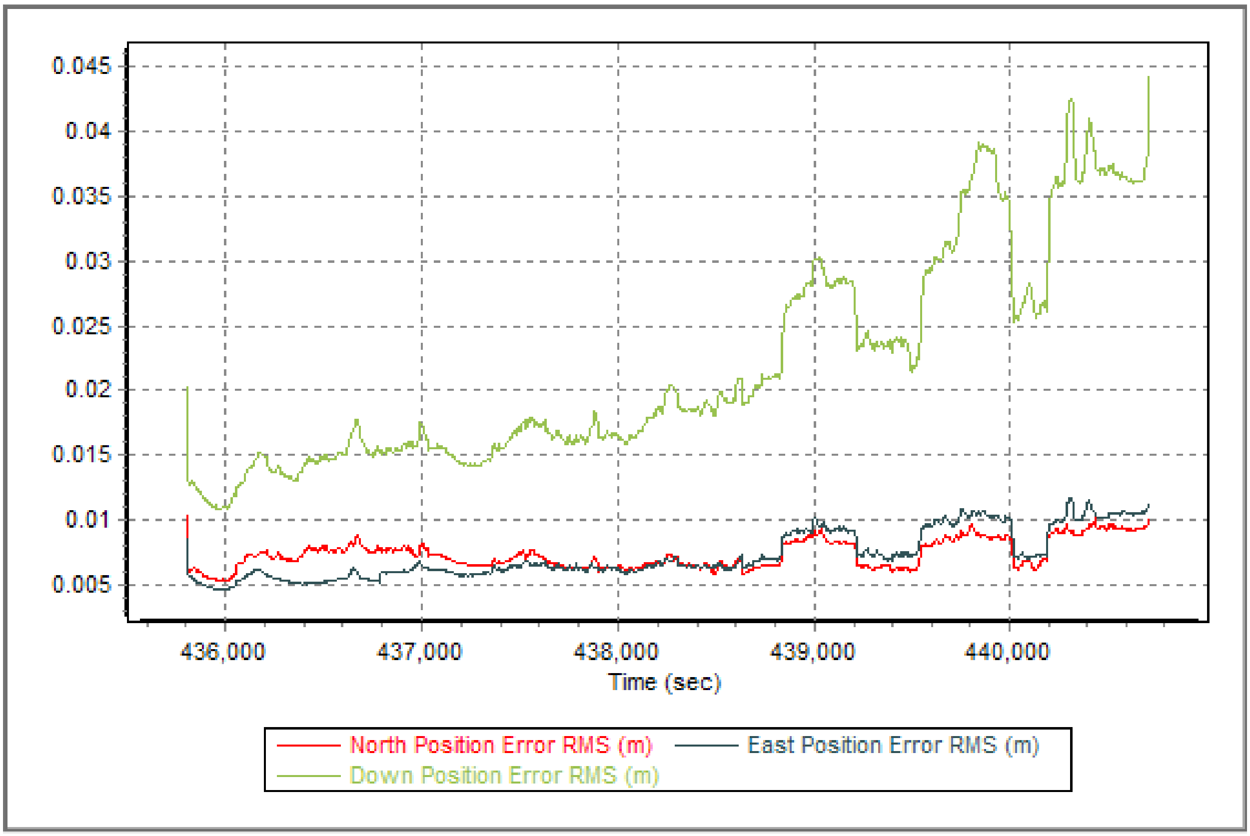


Figure A-8.9. Smoothed Performance Metrics Parameters

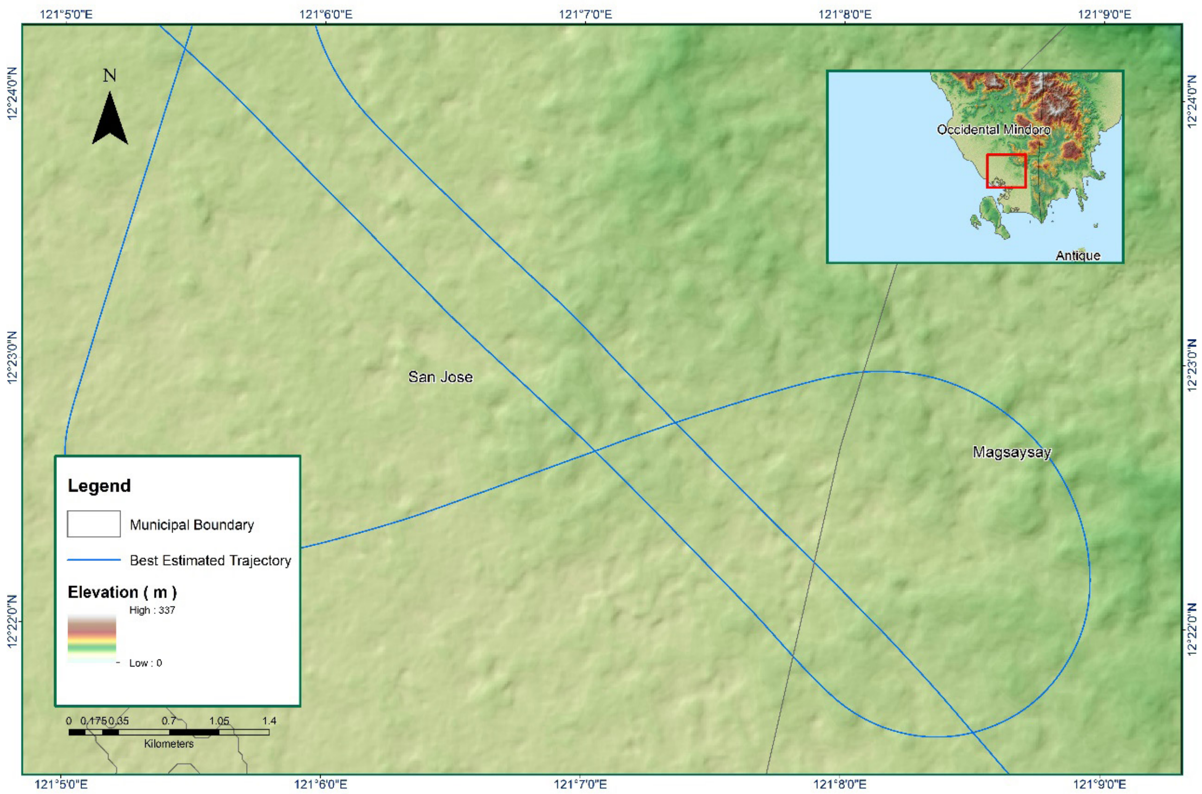


Figure A-8.10. Best Estimated Trajectory

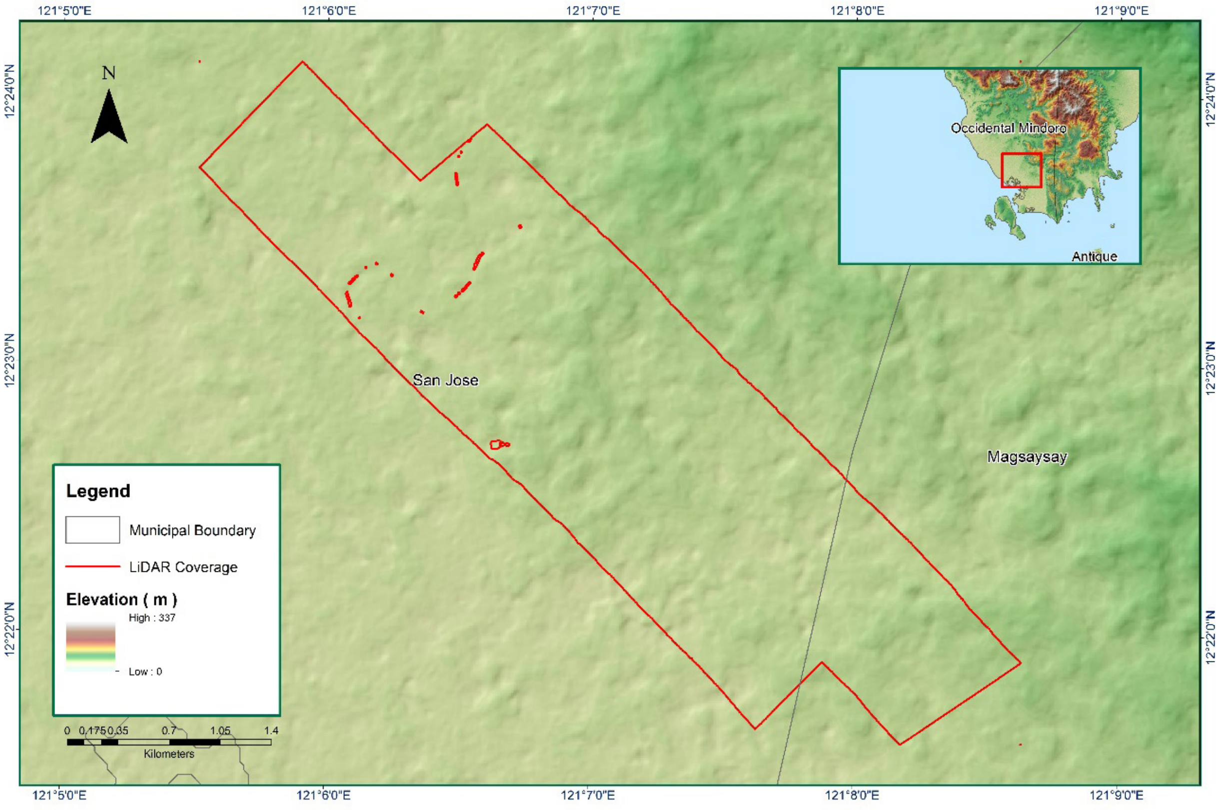


Figure A-8.11. Coverage of LiDAR data

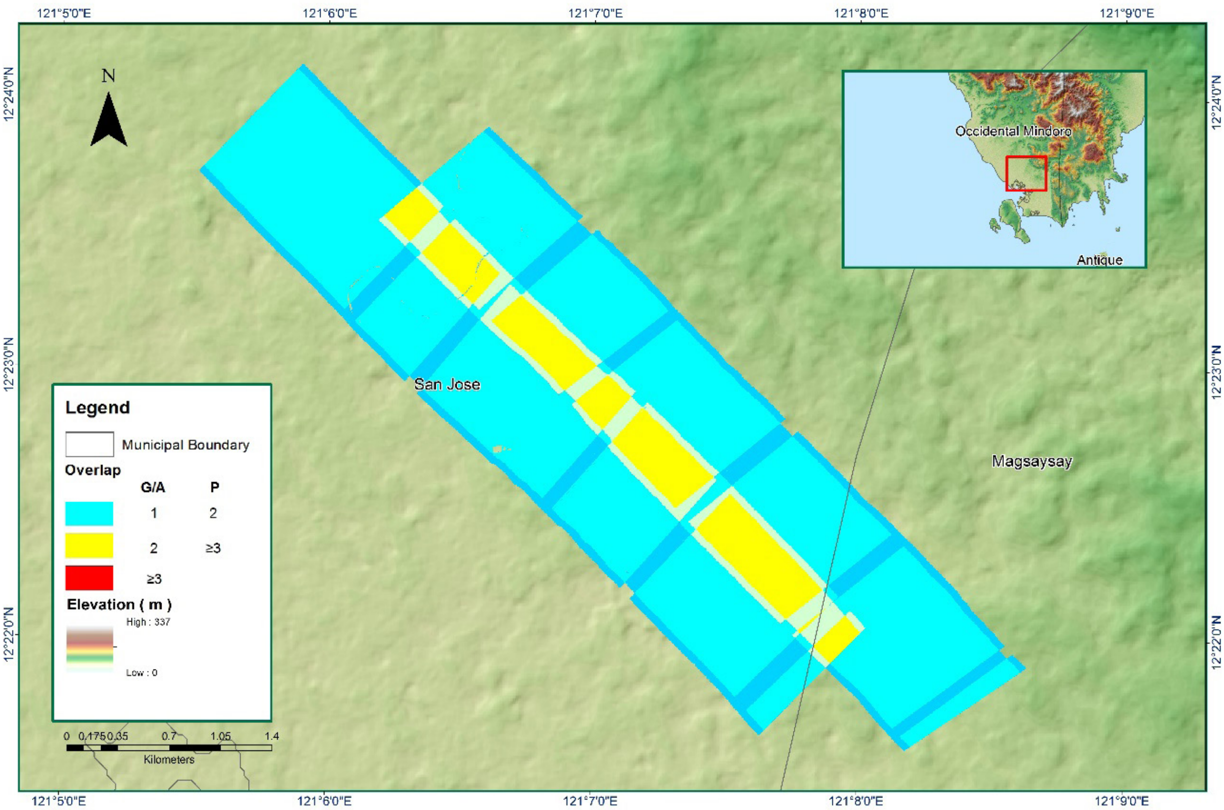


Figure A-8.12. Image of data overlap

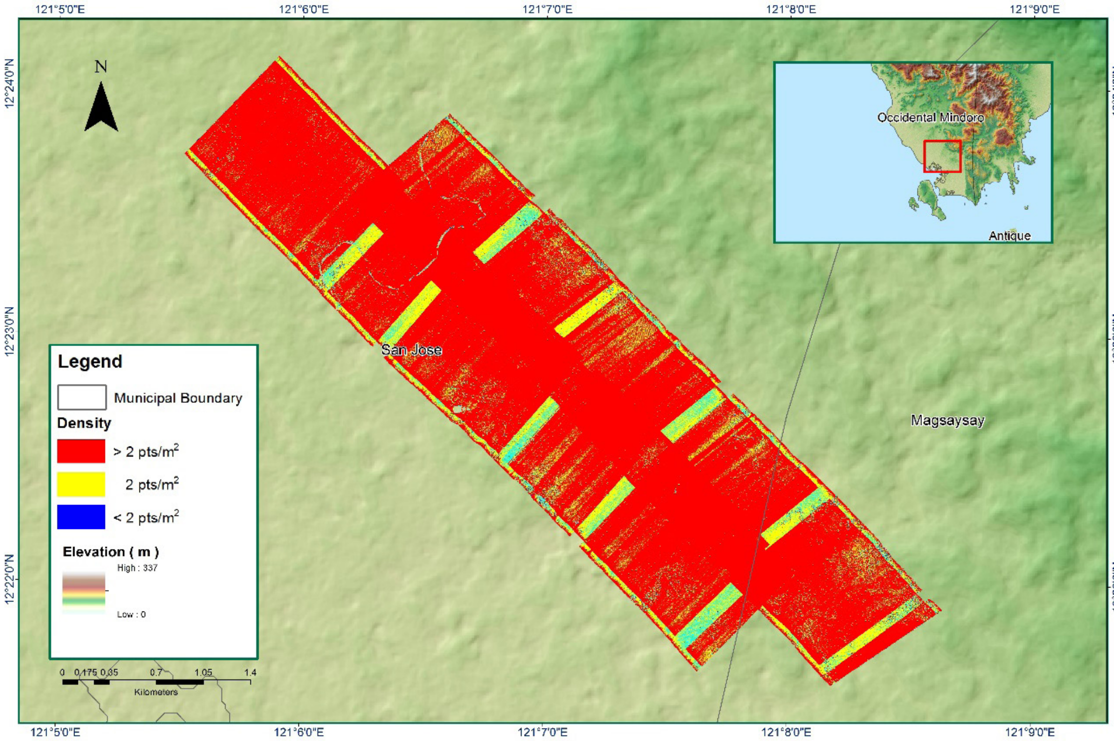


Figure A-8.13. Density of merged LiDAR data

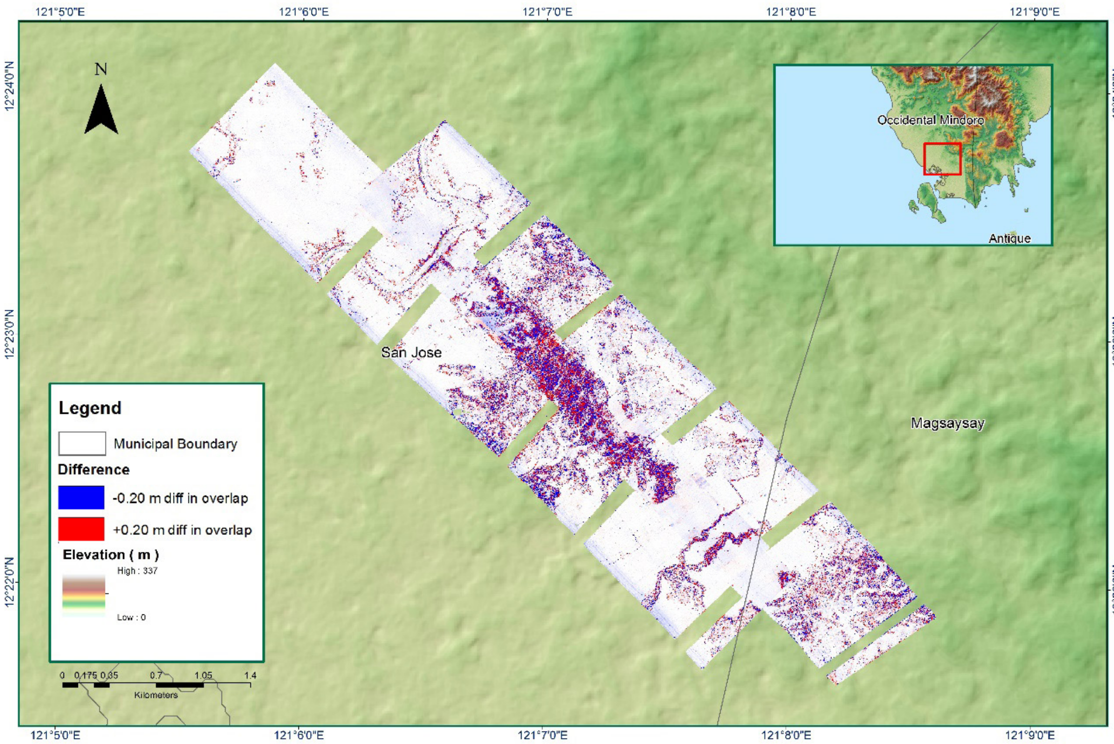


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk29F

Flight Area	**Occidental Mindoro Reflights**
Mission Name	**Blk29F**
Inclusive Flights	3078P
Range data size	6.2GB
Base data size	7.02MB
POS	167MB
Image	12.9MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.01
RMSE for East Position (<4.0 cm)	1.16
RMSE for Down Position (<8.0 cm)	4.25
Boresight correction stdev (<0.001deg)	0.000465
IMU attitude correction stdev (<0.001deg)	0.000422
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	49.34%
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	41
Maximum Height	240.78 m
Minimum Height	76.36 m
Classification (# of points)	
Ground	28,310,043
Low vegetation	18,698,190
Medium vegetation	20,493,071
High vegetation	23,229,602
Building	211,958
Orthophoto	Yes
Processed By	Engr. Abigail Joy Ching, Engr. Ma. Joanne Balaga, Marie Denise Bueno

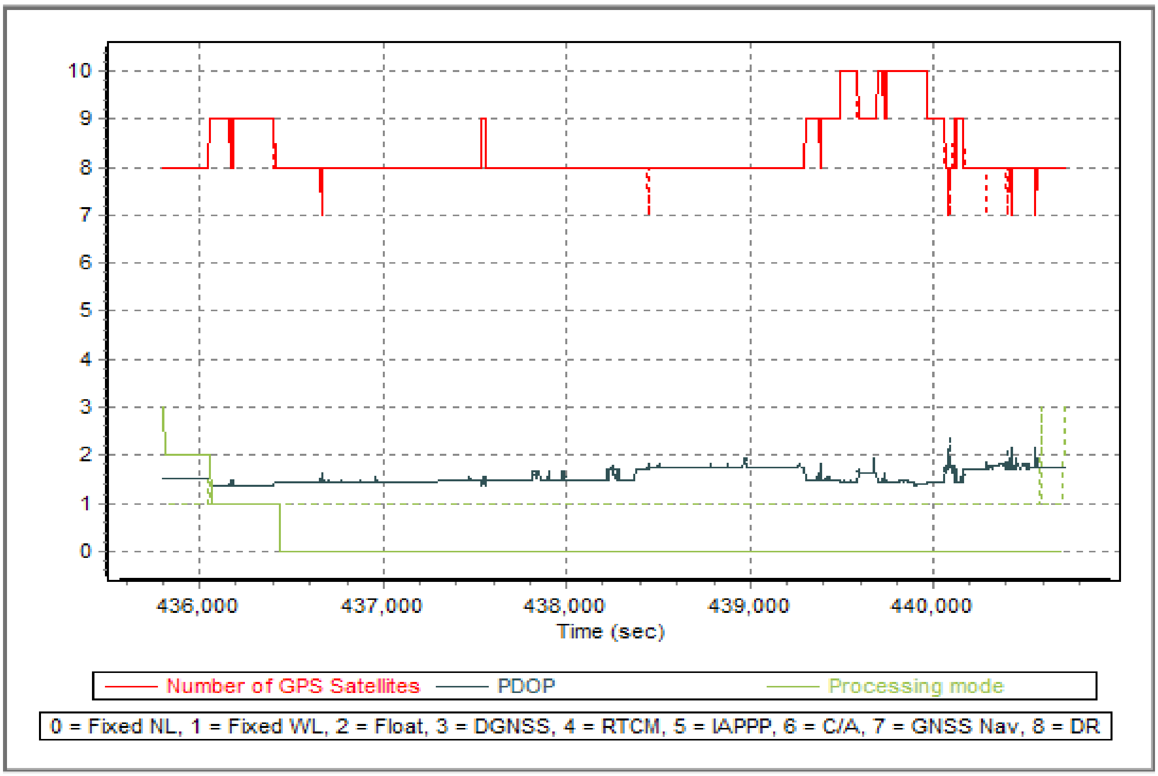


Figure A-8.15. Solution Status

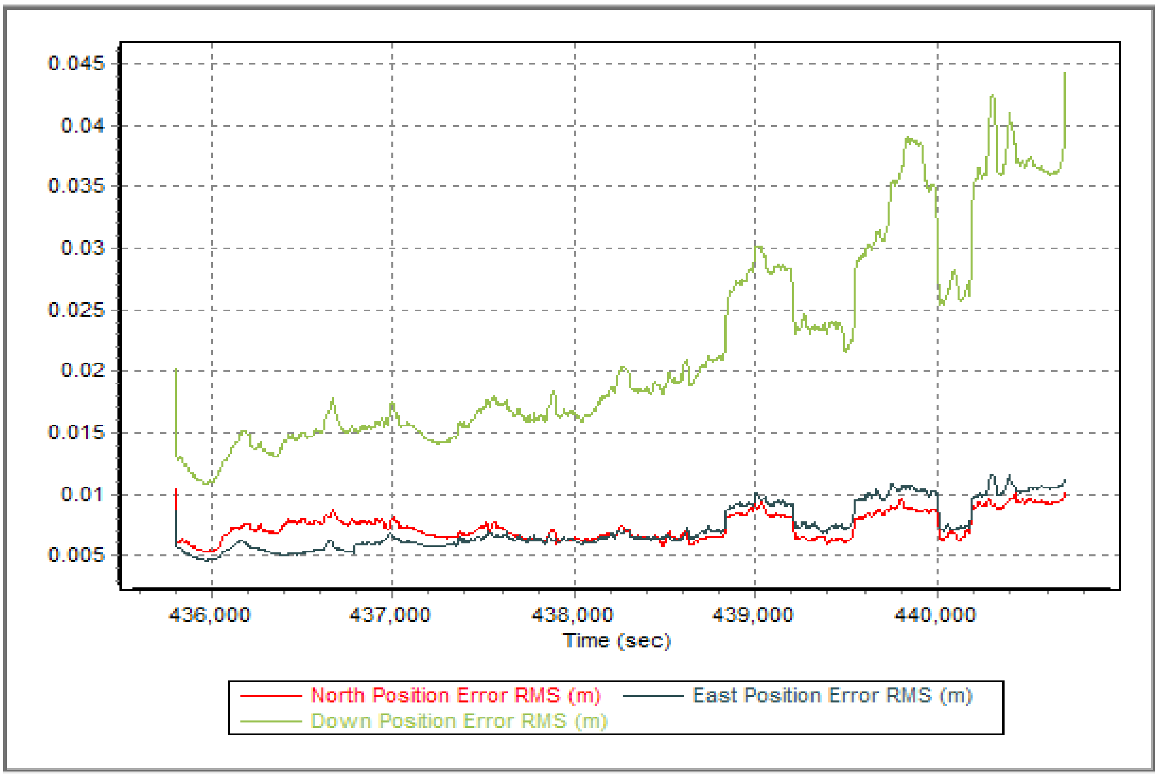


Figure A-8.16. Smoothed Performance Metrics Parameters

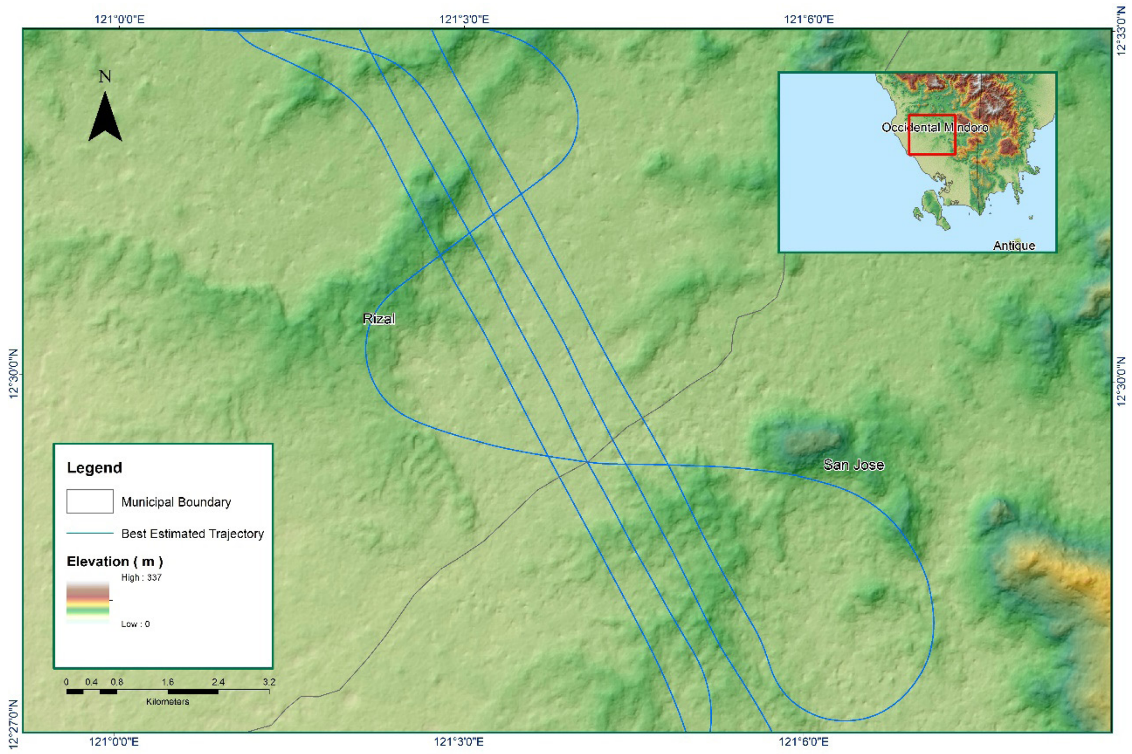


Figure A-8.17. Best Estimated Trajectory

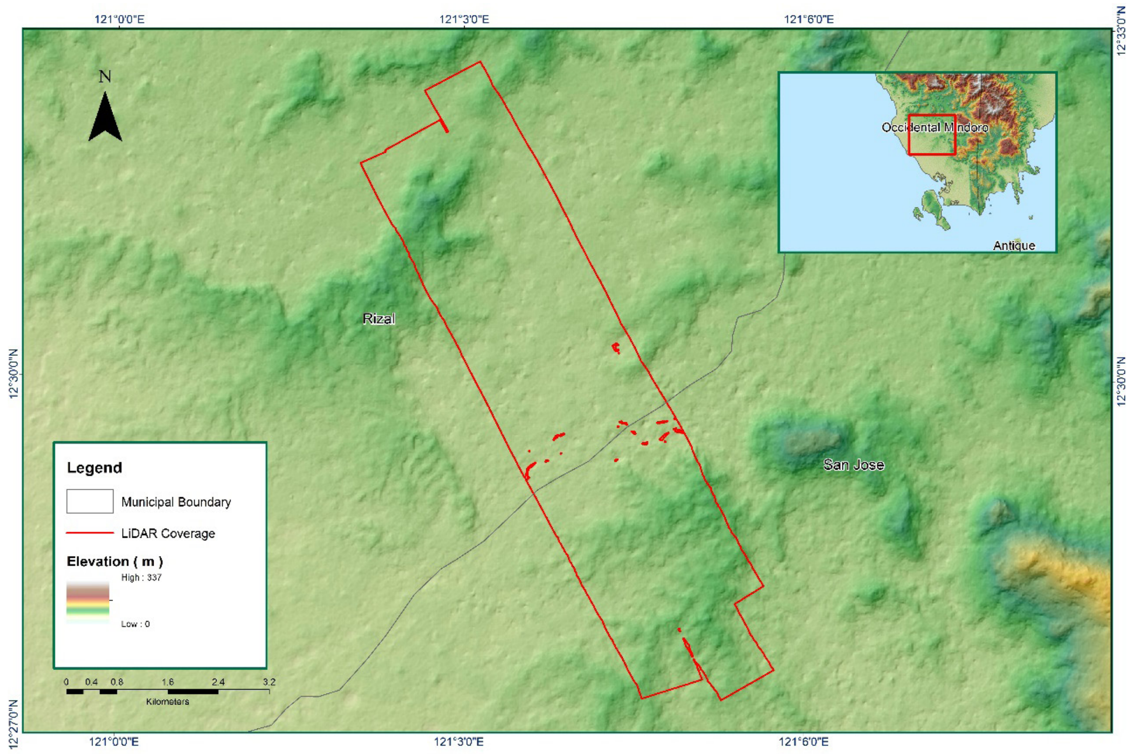


Figure A-8.18. Coverage of LiDAR data

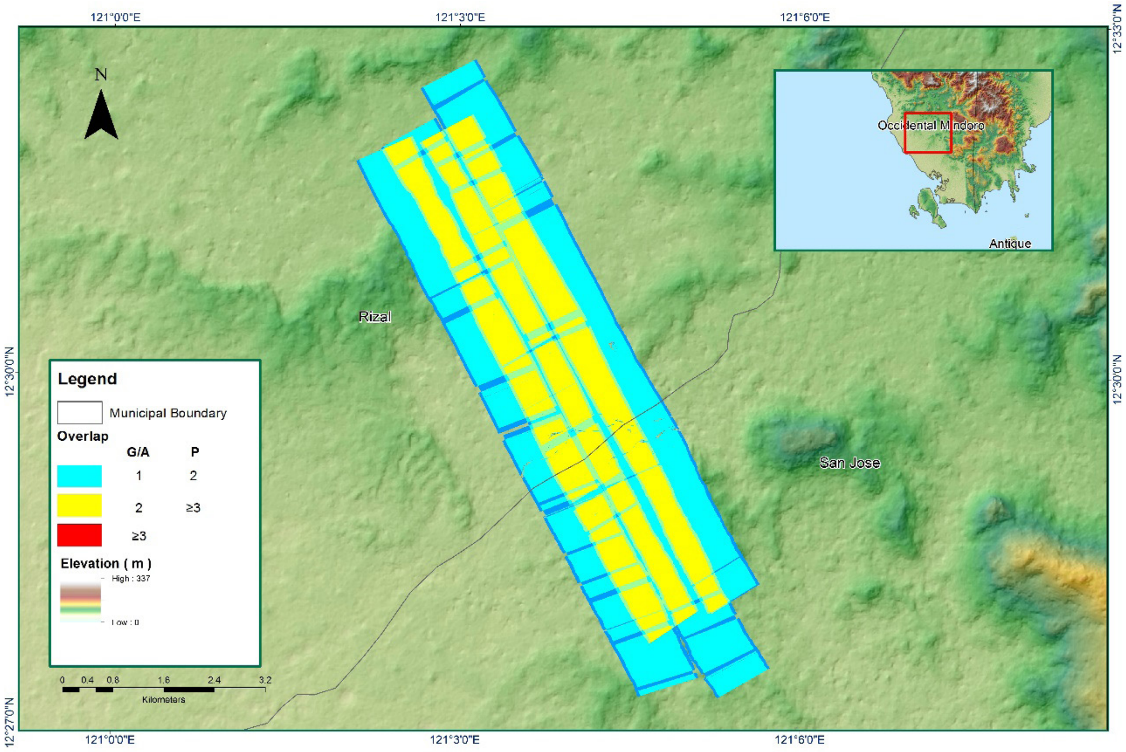


Figure A-8.19. Image of data overlap

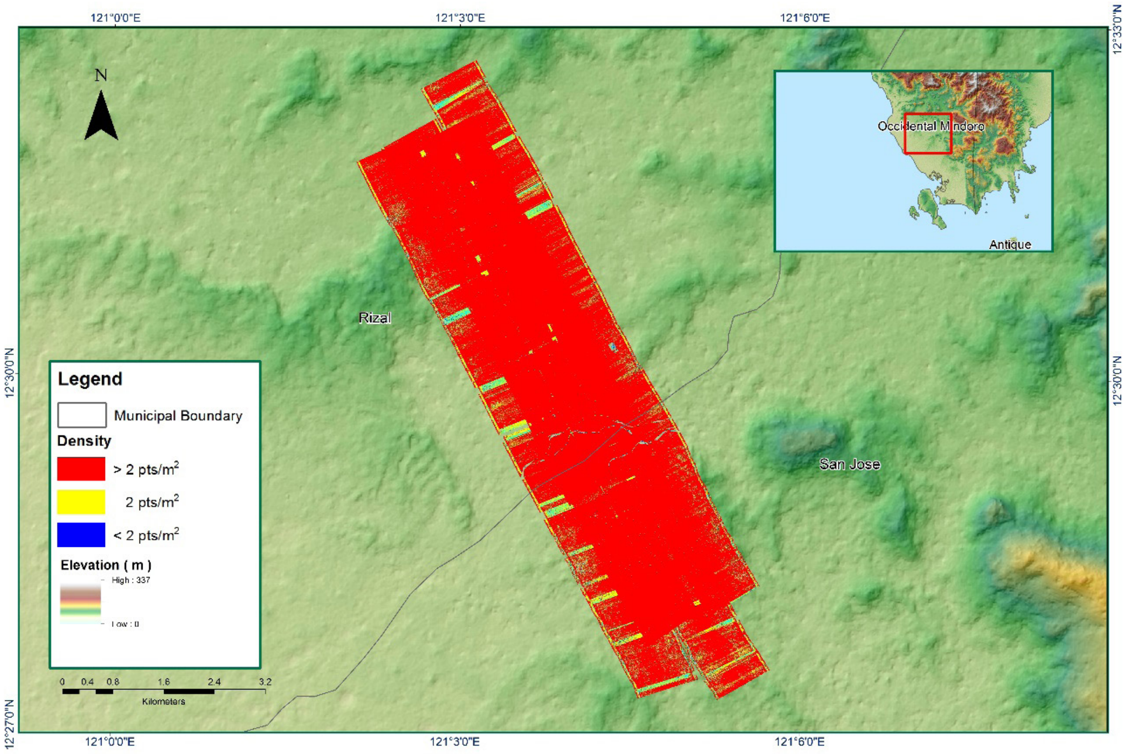


Figure A-8.20. Density of merged LiDAR data

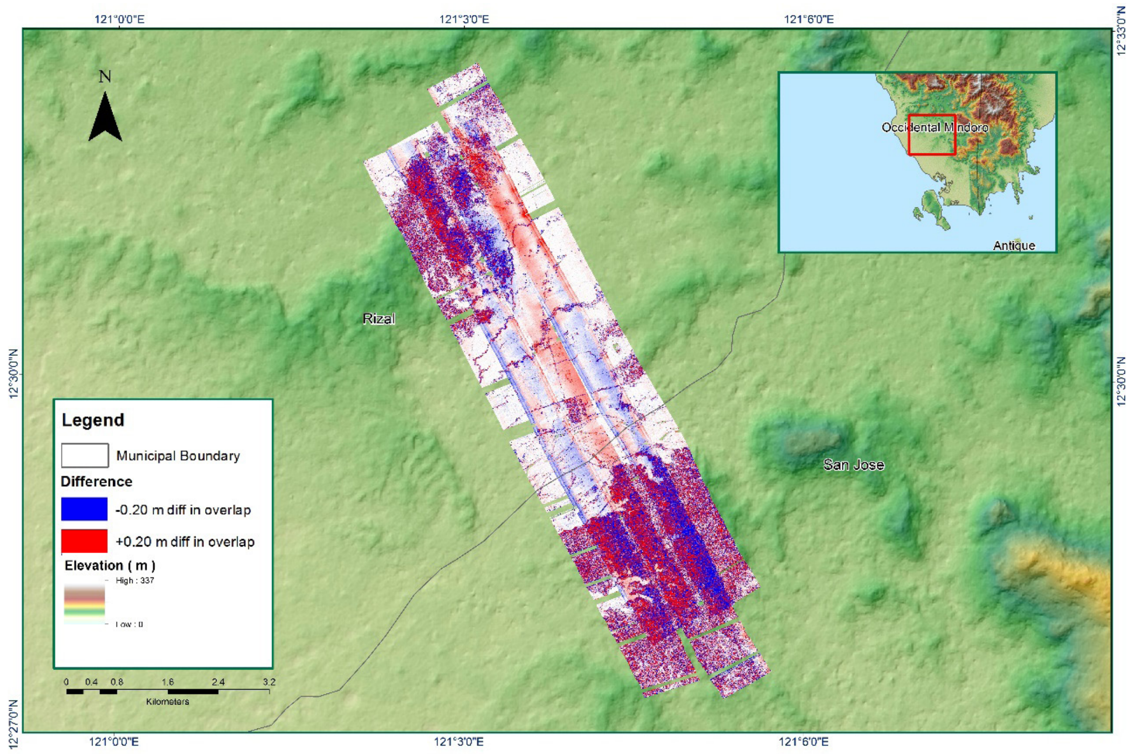


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk29G_additional

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29G_additional**
Inclusive Flights	3074P
Range data size	20.7GB
Base data size	14.1MB
POS	225MB
Image	30.9MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.27
RMSE for East Position (<4.0 cm)	1.03
RMSE for Down Position (<8.0 cm)	2.94
Boresight correction stdev (<0.001deg)	0.000280
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0009

Flight Area	Occidental Mindoro Reflights
Minimum % overlap (>25)	39.69%
Ave point cloud density per sq.m. (>2.0)	3.72
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	193
Maximum Height	544.26 m
Minimum Height	50.35 m
Classification (# of points)	
Ground	136,702,504
Low vegetation	91,637,024
Medium vegetation	147,161,052
High vegetation	487,991,012
Building	8,949,606
Orthophoto	Yes
Processed By	Engr. Don Matthew Banatin, Engr. Merven Natino, Engr. Vincent Louise Azucena

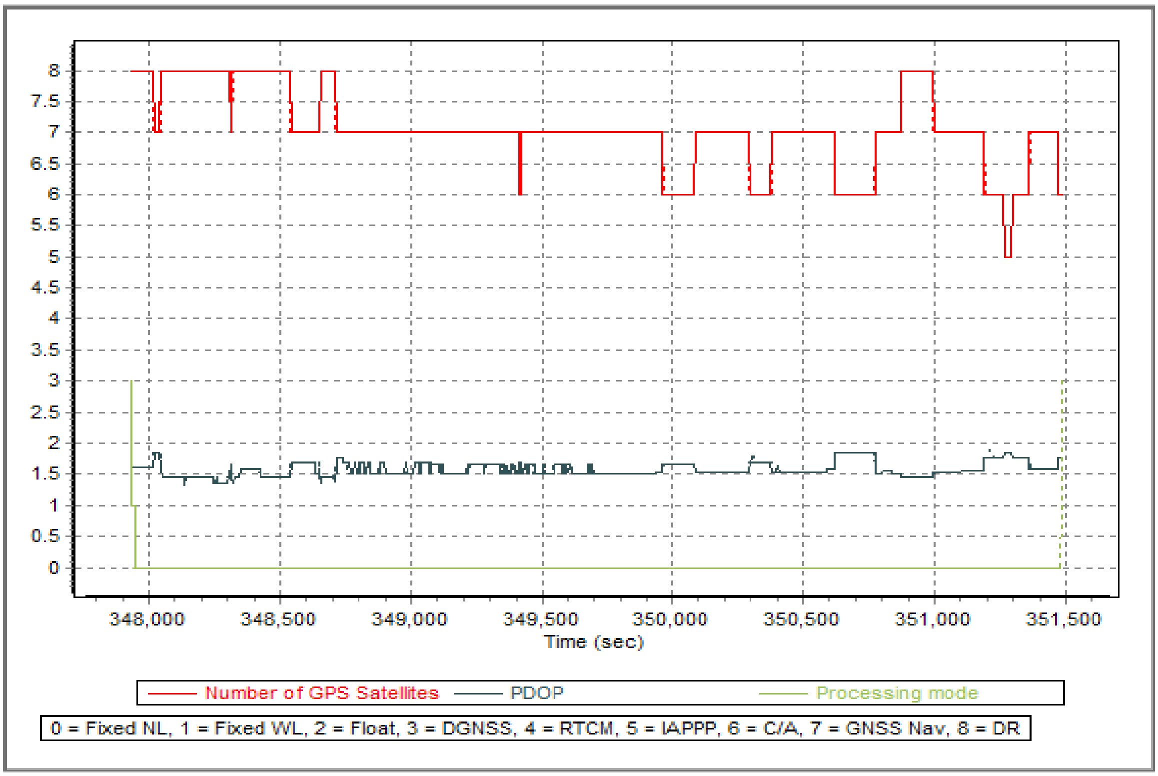


Figure A-8.22. Solution Status

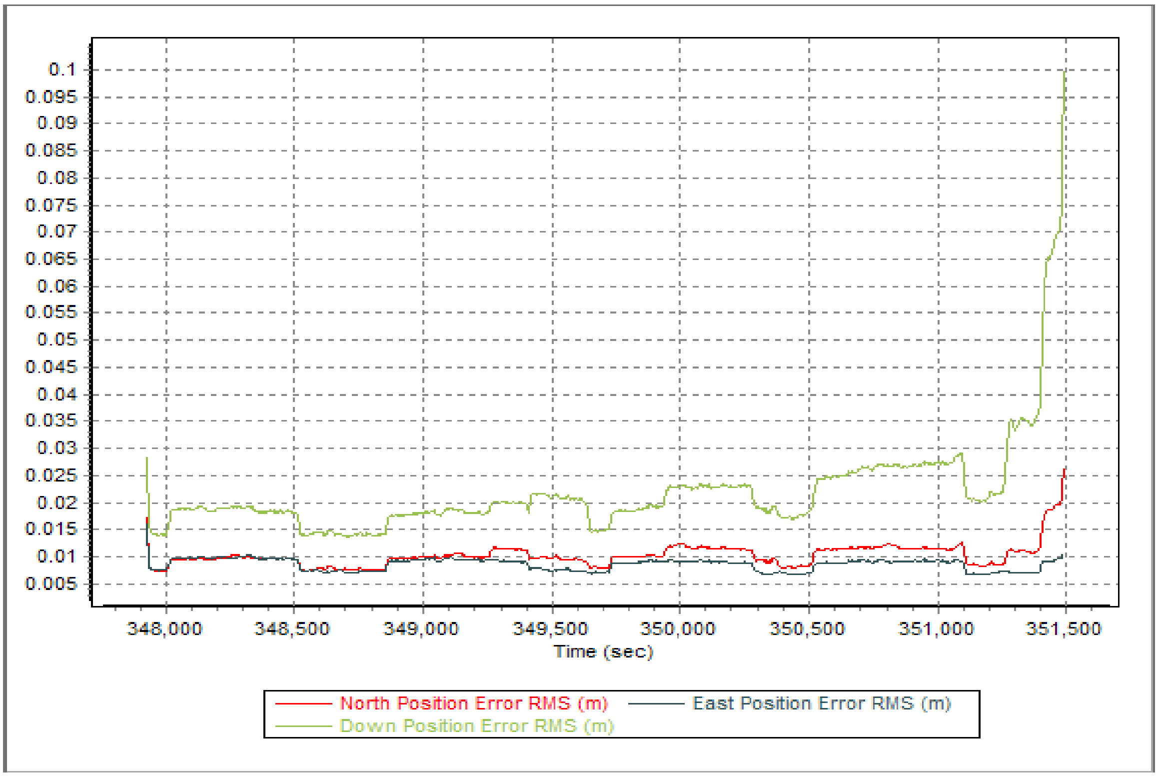


Figure A-8.23. Smoothed Performance Metrics Parameters

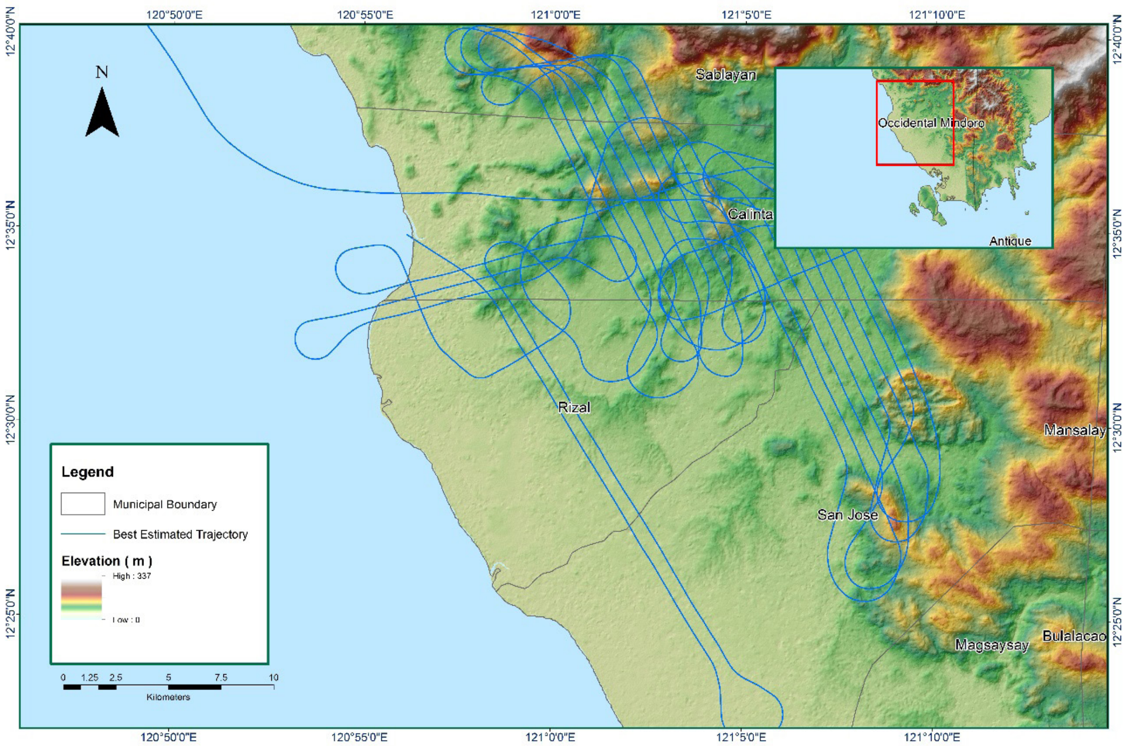


Figure A-8.24. Best Estimated Trajectory

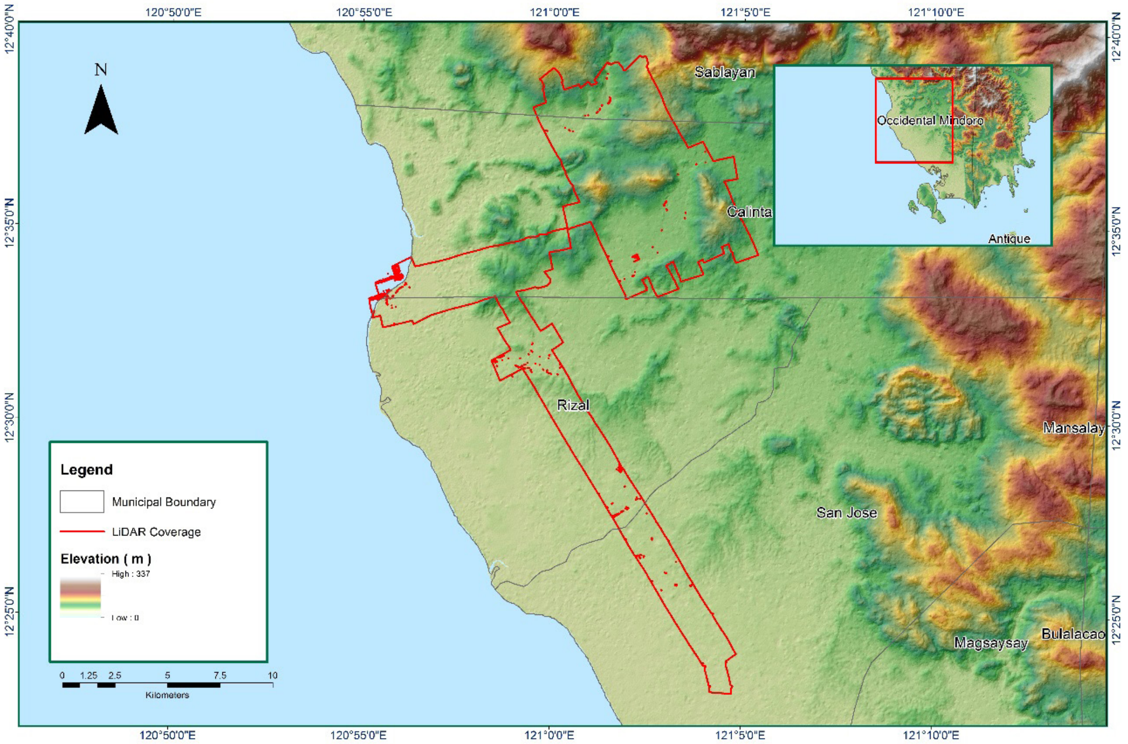


Figure A-8.25. Coverage of LiDAR data

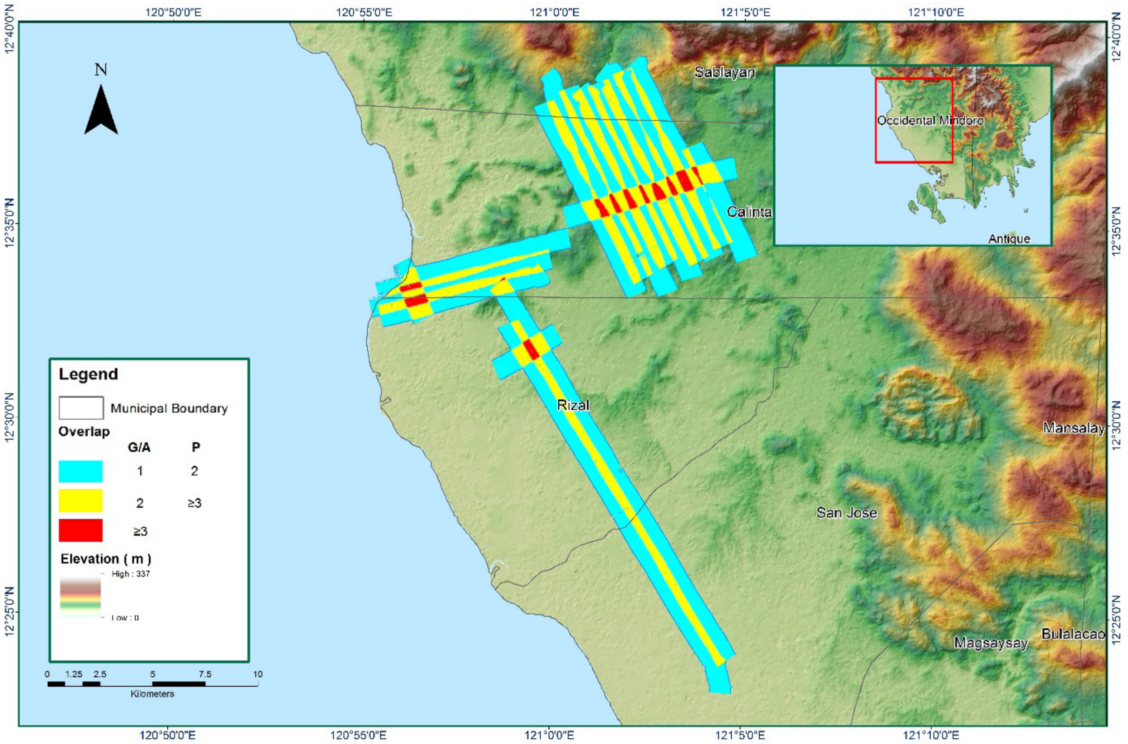


Figure A-8.26. Image of data overlap

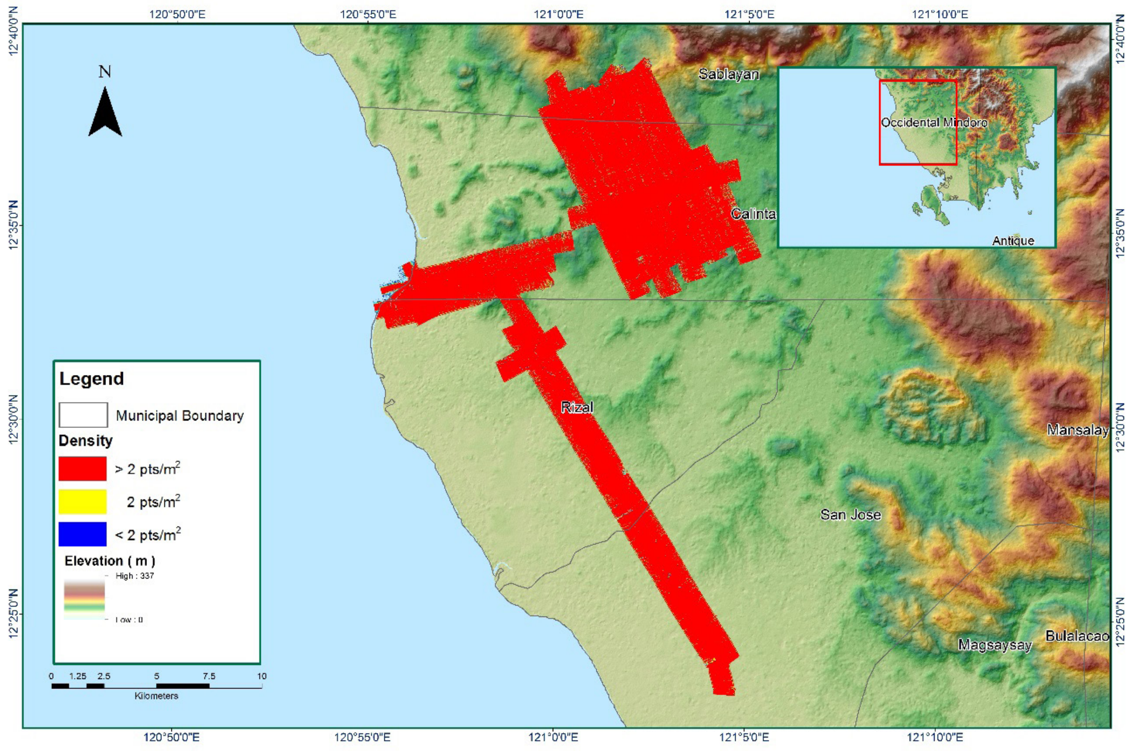


Figure A-8.27. Density of merged LiDAR data

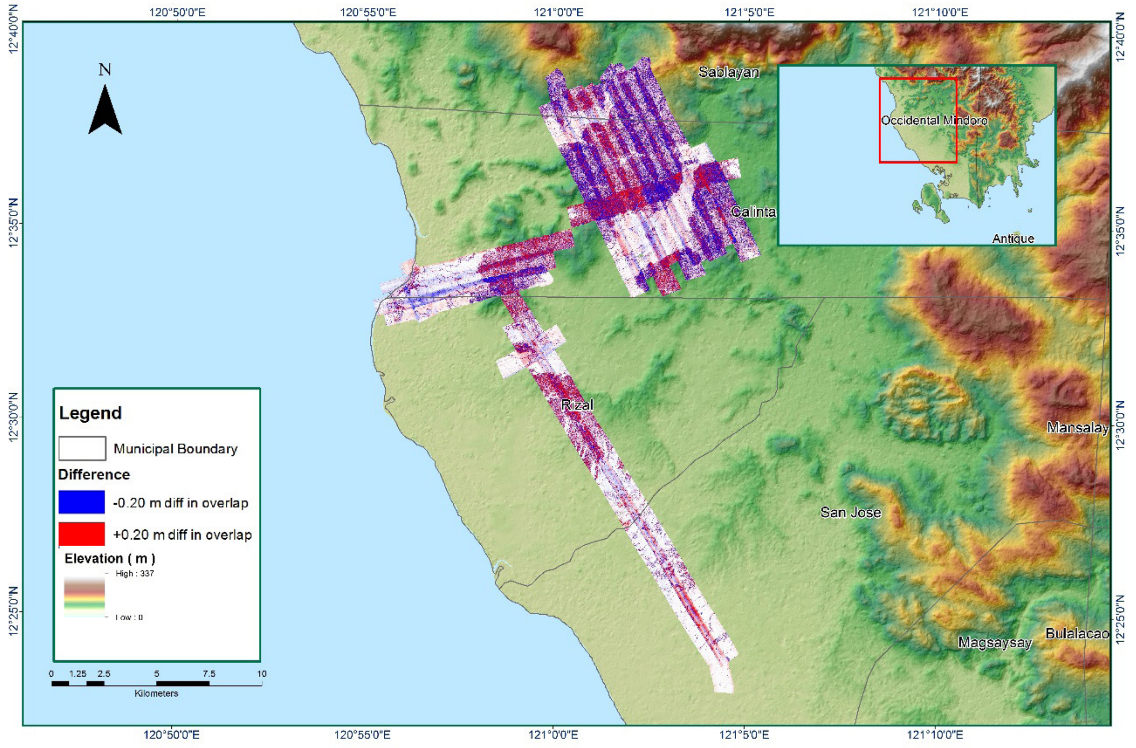


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk29A

Flight Area	Occidental Mindoro
Mission Name	Blk29A
Inclusive Flights	1158A. 1162A, 1168A
Range data size	29.98 GB
POS	677 MB
Image	72.6 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000443
IMU attitude correction stdev (<0.001deg)	0.002081
GPS position stdev (<0.01m)	0.0294
Minimum % overlap (>25)	43.28%
Ave point cloud density per sq.m. (>2.0)	2.76
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	194
Maximum Height	165.41 m
Minimum Height	43.10 m
Classification (# of points)	
Ground	104,722,532
Low vegetation	130,224,088
Medium vegetation	60,206,940
High vegetation	16,625,237
Building	4,886,963
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Ma. Joanne Balaga, Rngr. Gladys Mae Apat

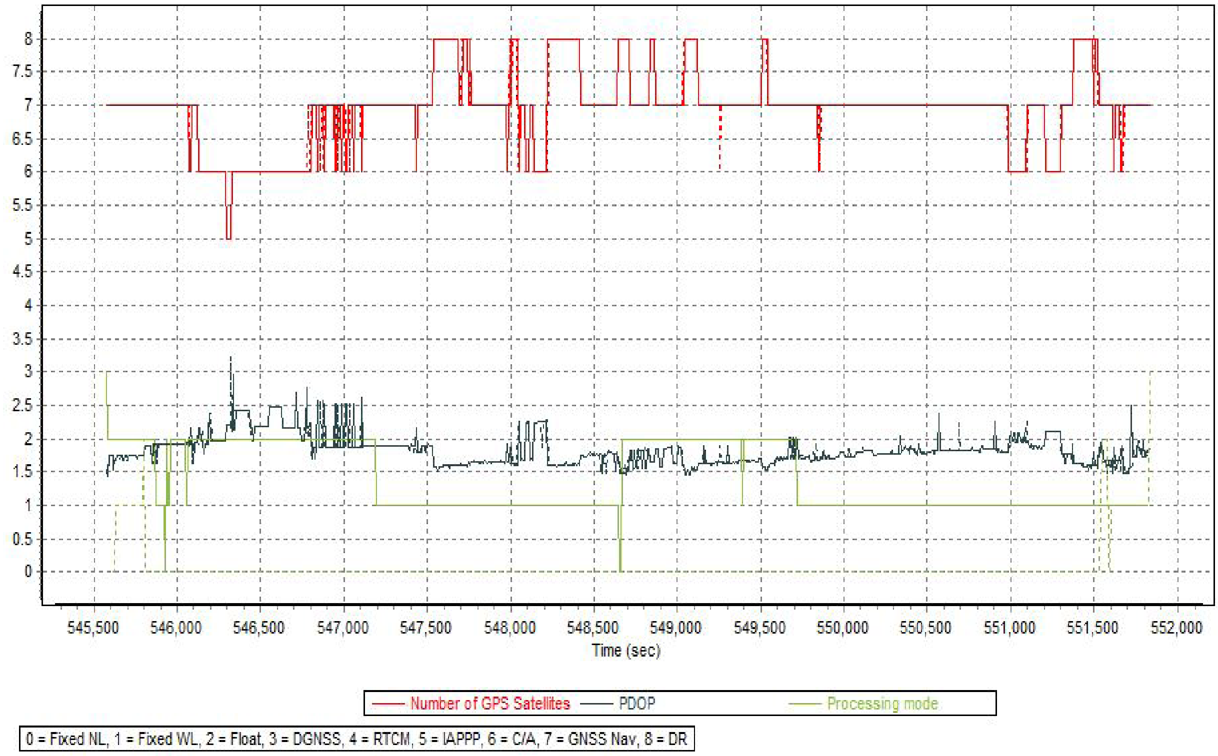


Figure A-8.29. Solution Status

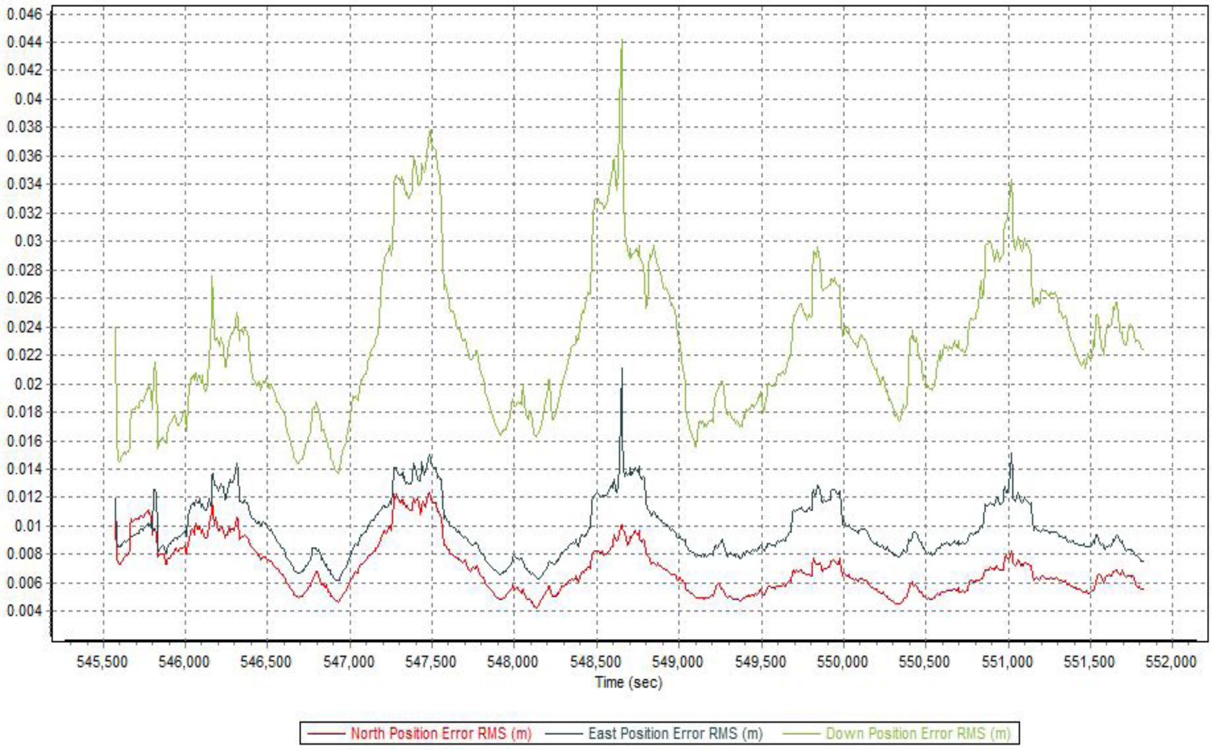


Figure A-8.30. Smoothed Performance Metrics Parameters

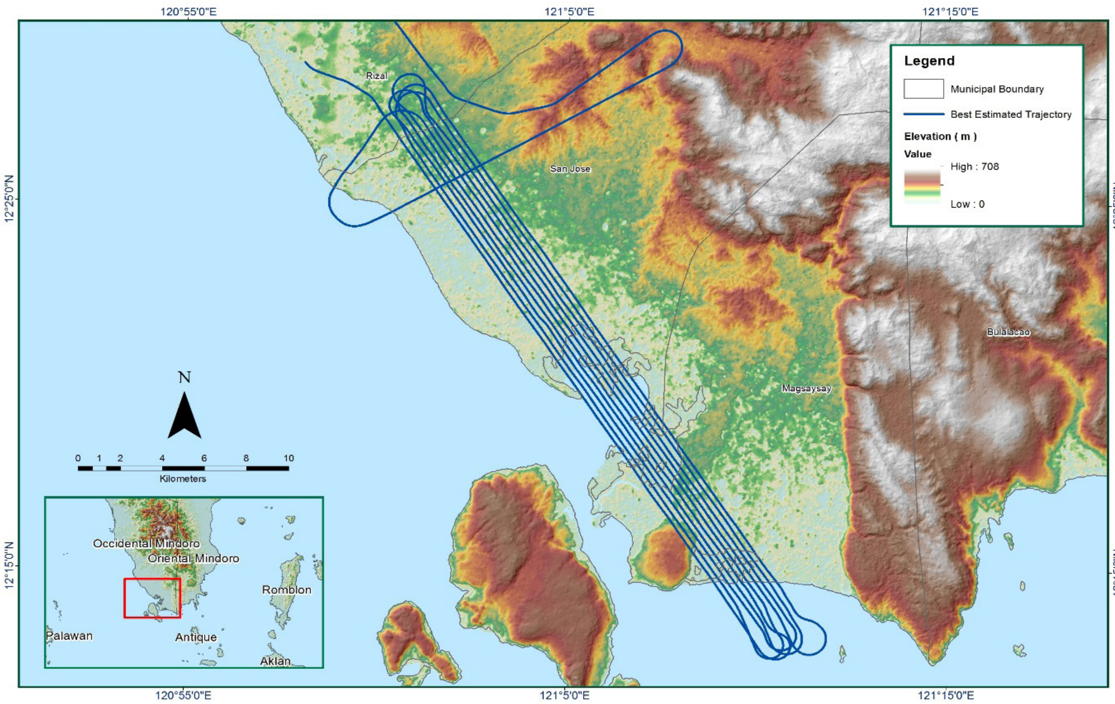


Figure A-8.31. Best Estimated Trajectory

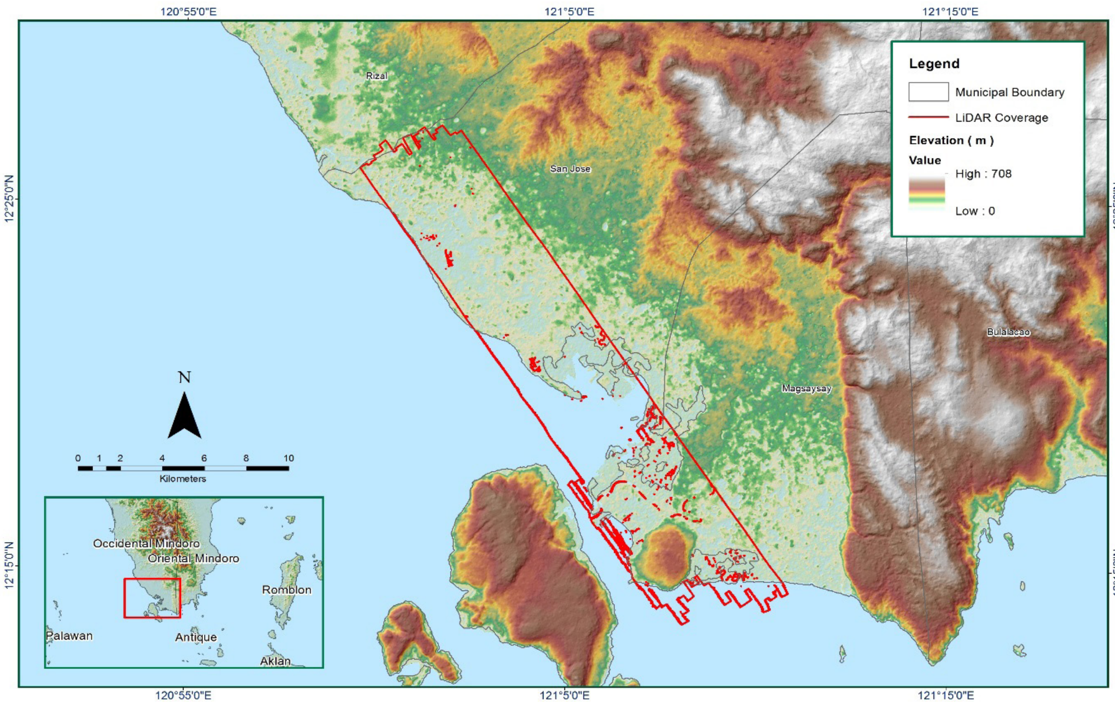


Figure A-8.32. Coverage of LiDAR data

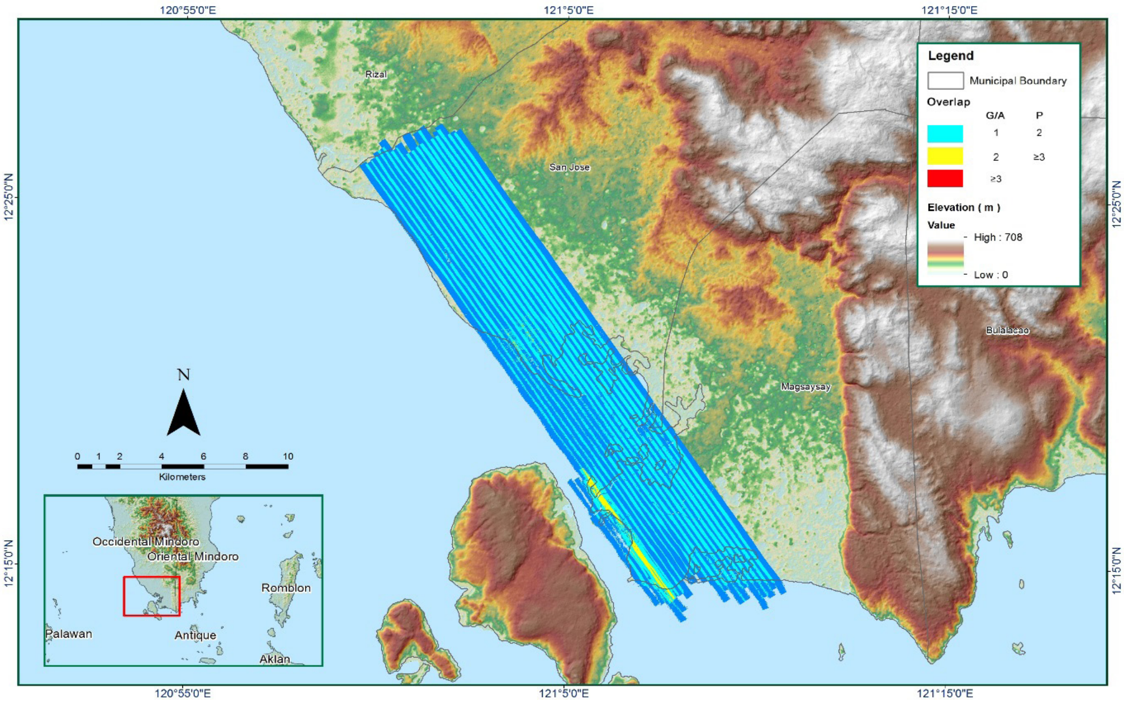


Figure A-8.33. Image of data overlap

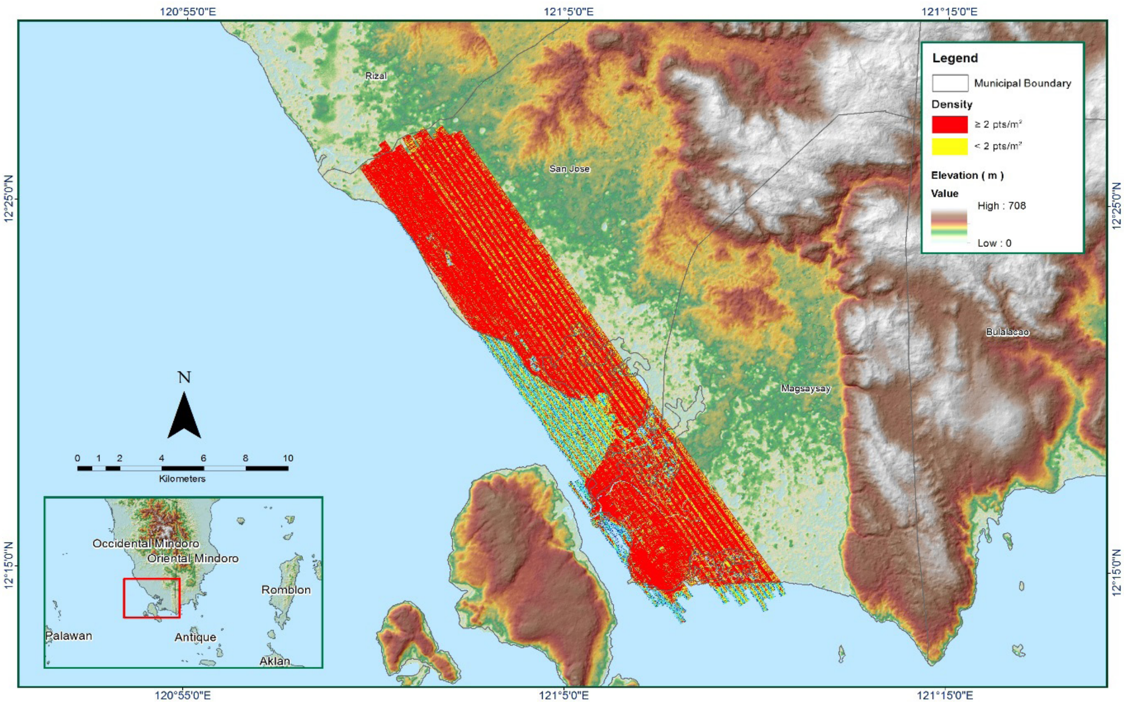


Figure A-8.34. Density of merged LiDAR data

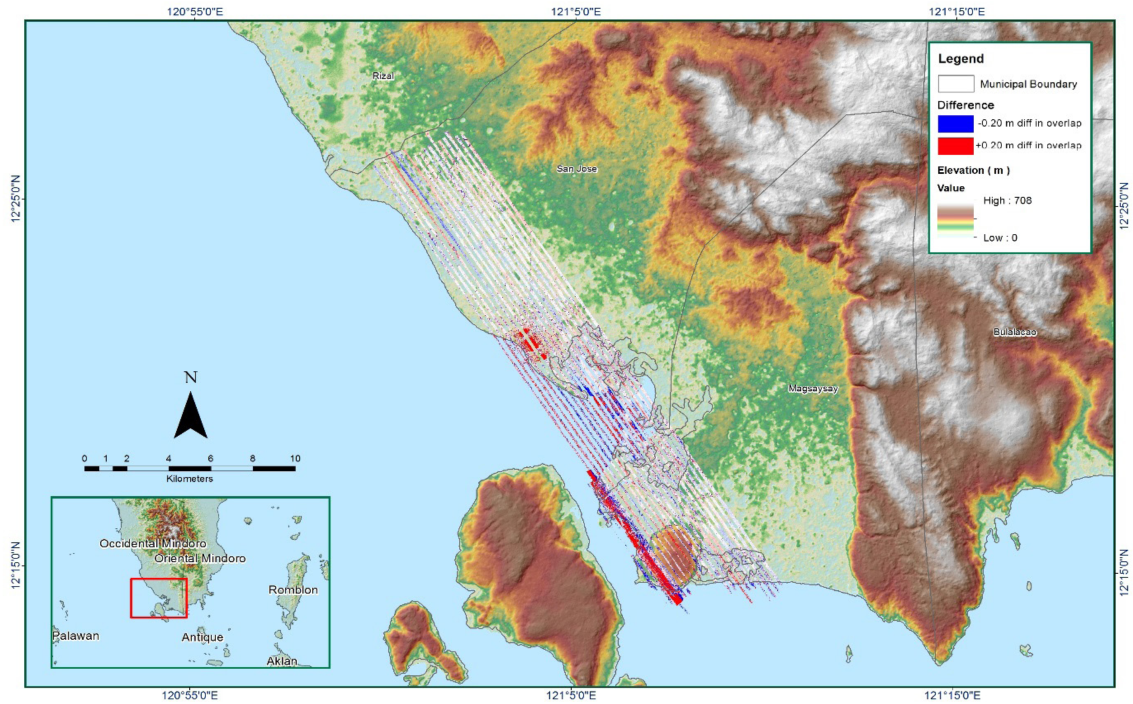


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk29B

Flight Area	Occidental Mindoro
Mission Name	Blk29B
Inclusive Flights	1164A. 1166A, 1168A
Range data size	38.4 GB
POS	791 MB
Image	22.5 GB
Transfer date	04/23/2014
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)	1.3
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000629
IMU attitude correction stdev (<0.001deg)	0.002510
GPS position stdev (<0.01m)	0.0158
Minimum % overlap (>25)	43.01%

Flight Area	Occidental Mindoro
Ave point cloud density per sq.m. (>2.0)	3.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	197
Maximum Height	258.38 m
Minimum Height	46.77 m
Classification (# of points)	
Ground	115,311,089
Low vegetation	138,979,099
Medium vegetation	95,318,939
High vegetation	30,819,969
Building	2,104,153
Orthophoto	Yes
Processed by	Victoria Maria Rejuso, Engr. Justine Francisco, Engr. John Dill Macapagal

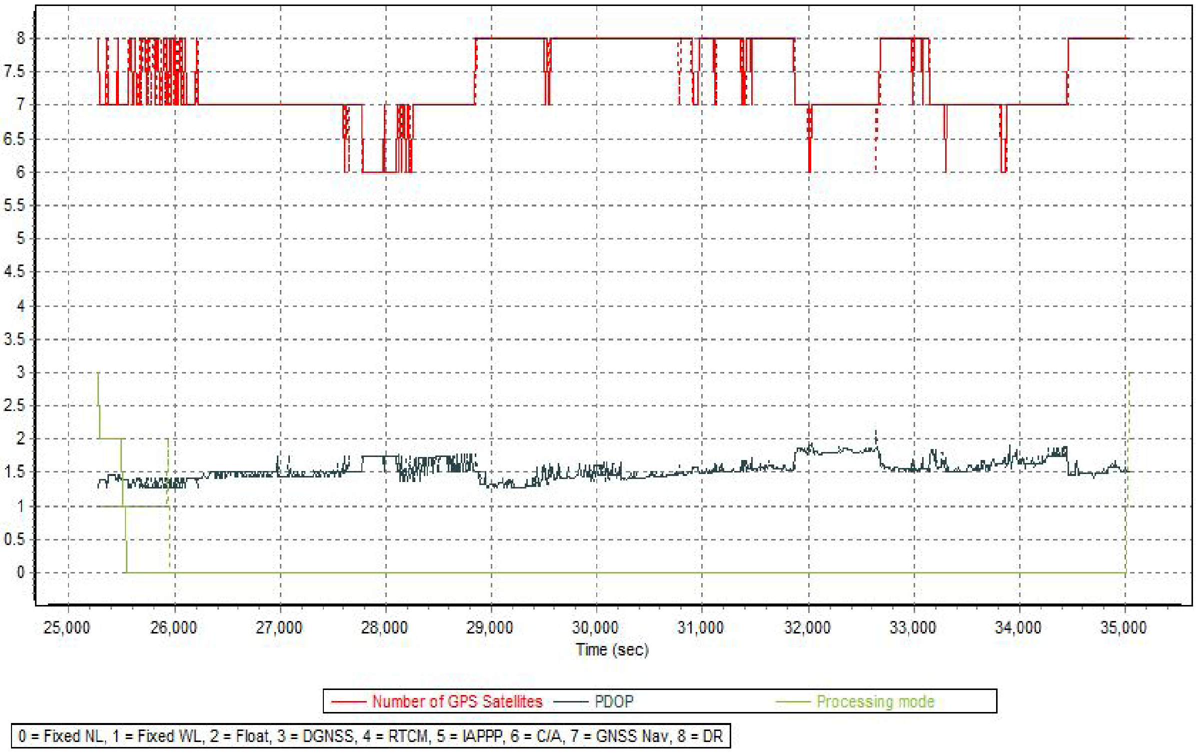


Figure A-8.36. Solution Status

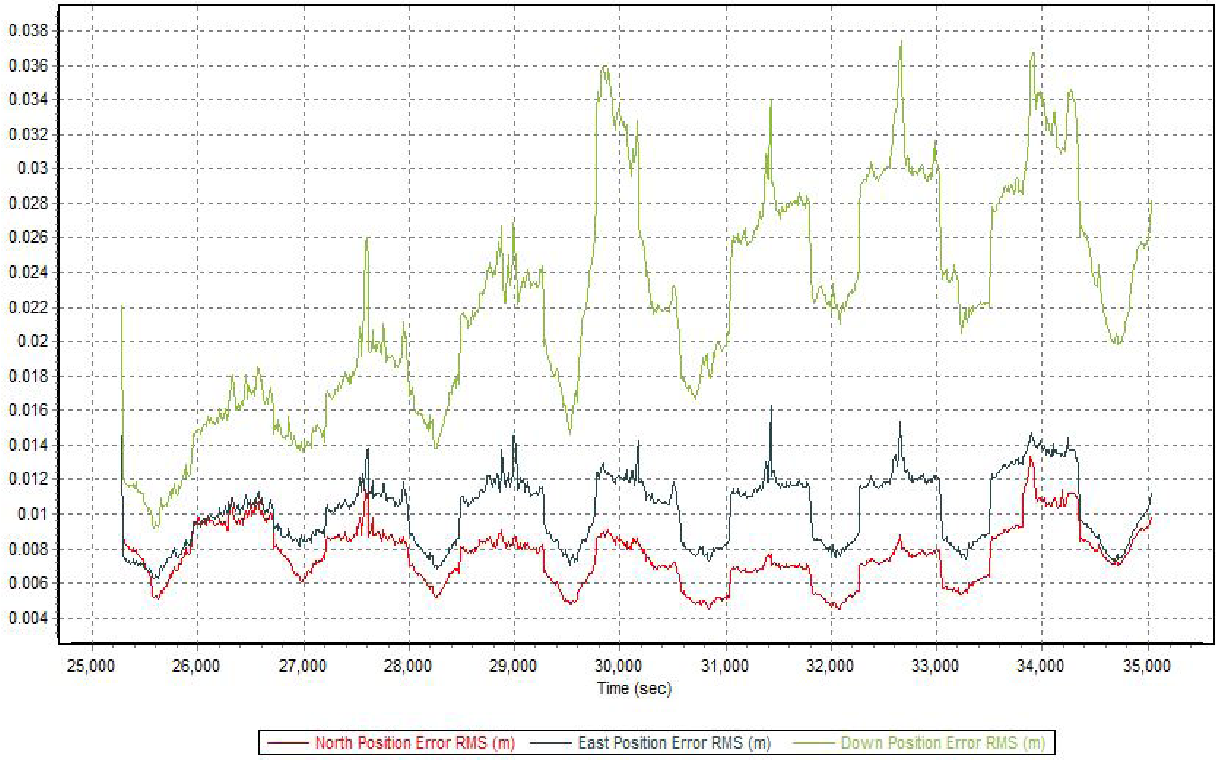


Figure A-8.37. Smoothed Performance Metric Parameters

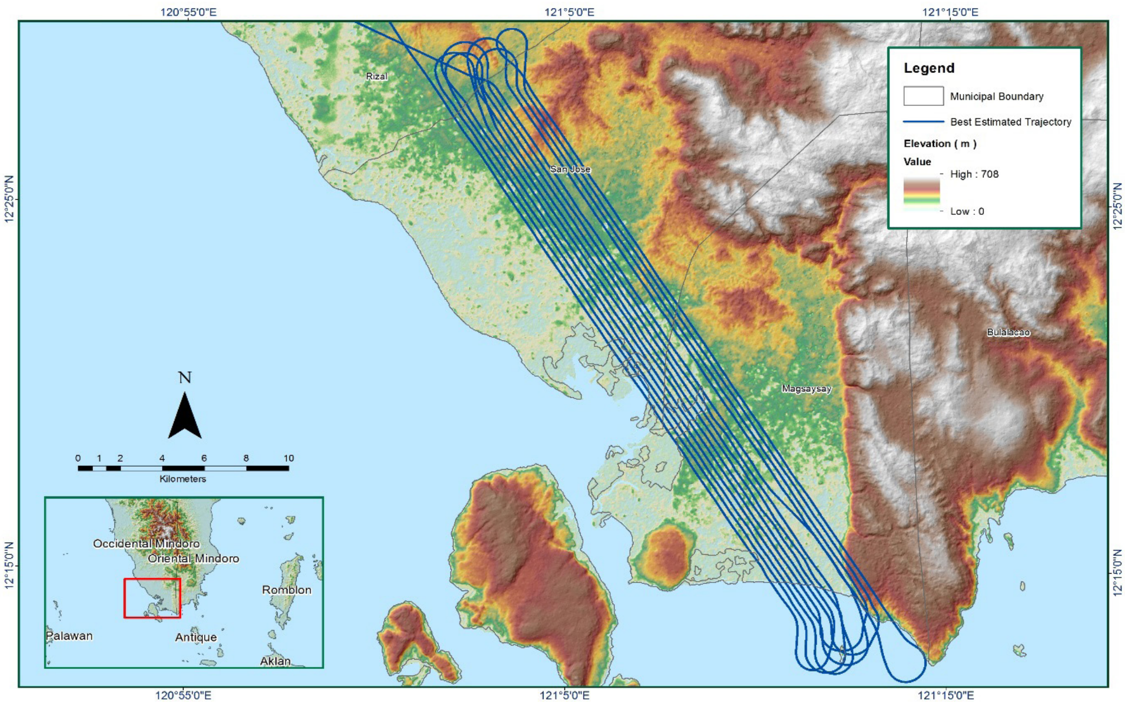


Figure A-8.38. Best Estimate Trajectory

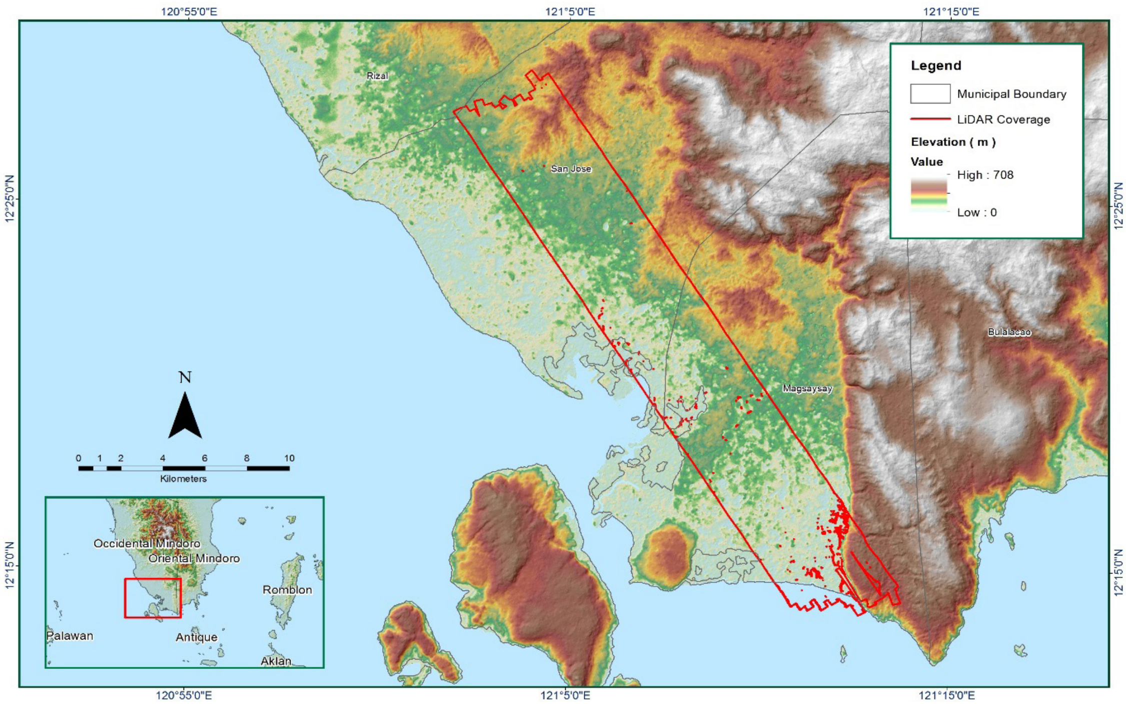


Figure A-8.39. Coverage of LiDAR data

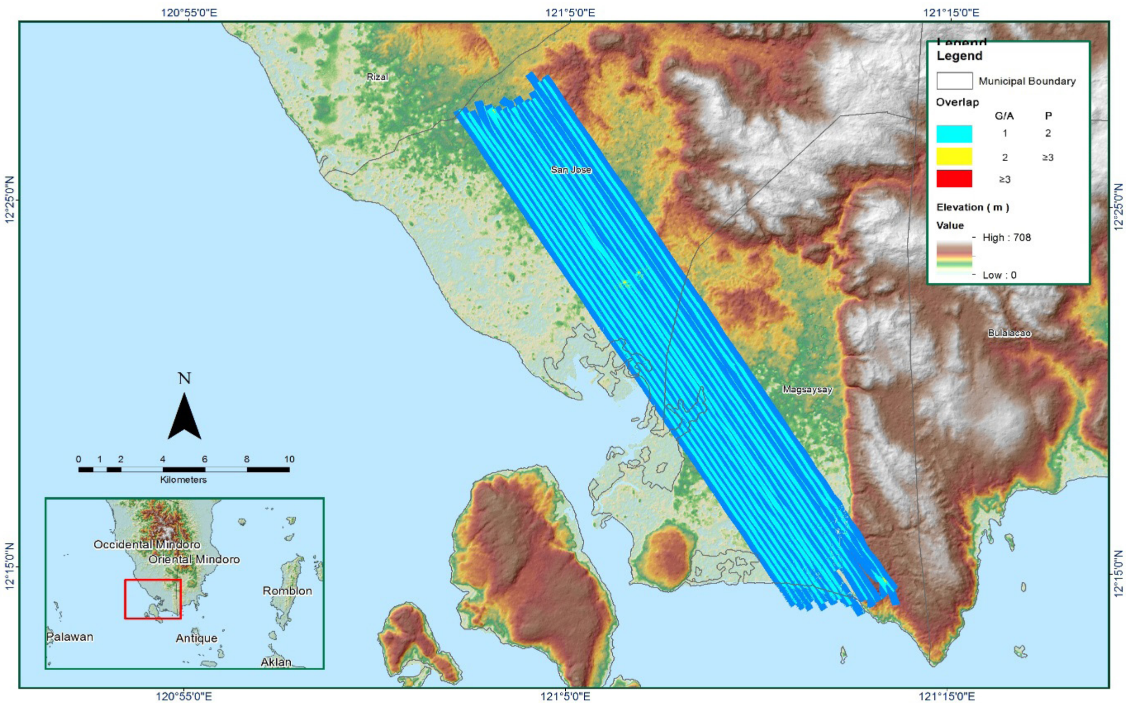


Figure A-8.40 Image of data overlap

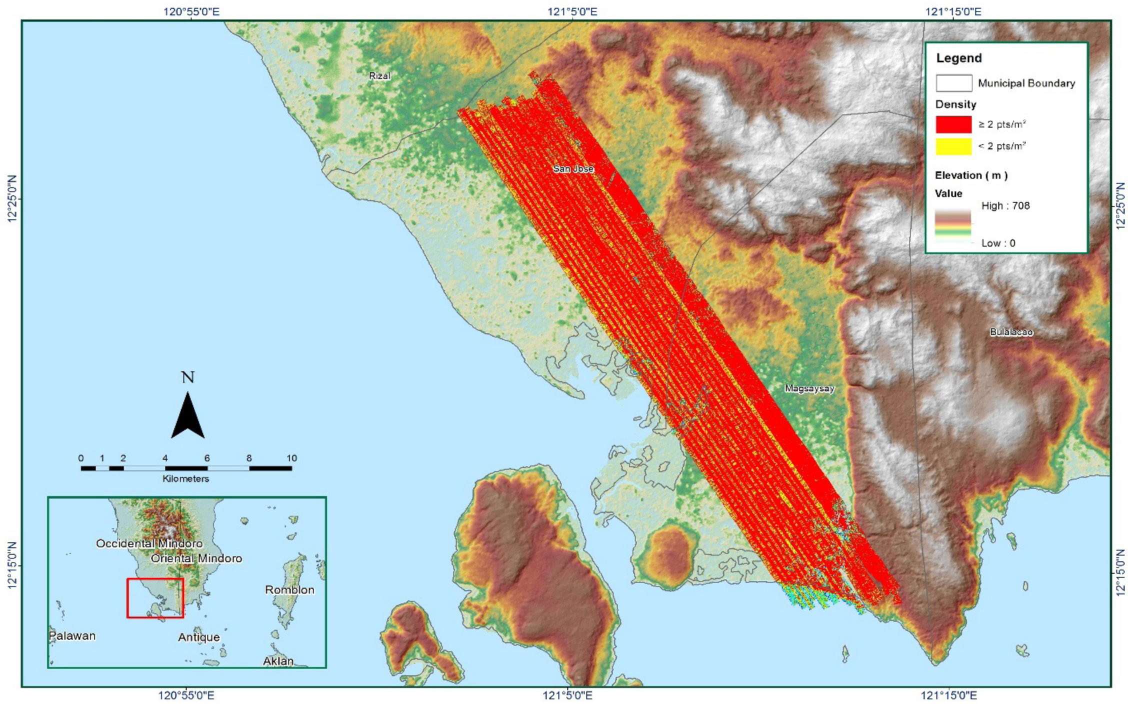


Figure A-8.41 Density Map of merged LiDAR data

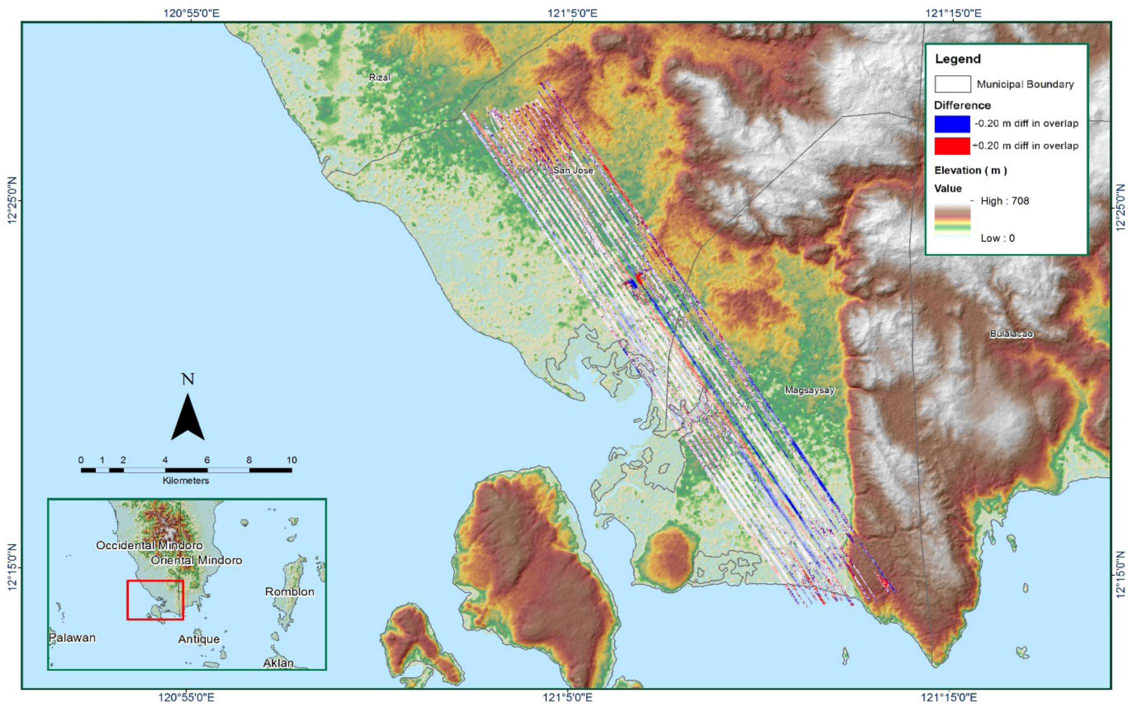


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7 Mission Summary Report for Mission Blk29C

Flight Area	Occidental Mindoro
Mission Name	Blk29C
Inclusive Flights	1160A
Range data size	14.1 GB
POS	268 MB
Image	13.5 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.8
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000373
IMU attitude correction stdev (<0.001deg)	0.001768
GPS position stdev (<0.01m)	0.0032
Minimum % overlap (>25)	44.16%
Ave point cloud density per sq.m. (>2.0)	3.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	143
Maximum Height	481.99 m
Minimum Height	51.54 m
Classification (# of points)	
Ground	109,156,938
Low vegetation	80,757,959
Medium vegetation	73,247,510
High vegetation	71,877,948
Building	1,281,773
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

Figure A-8.43. Solution Status

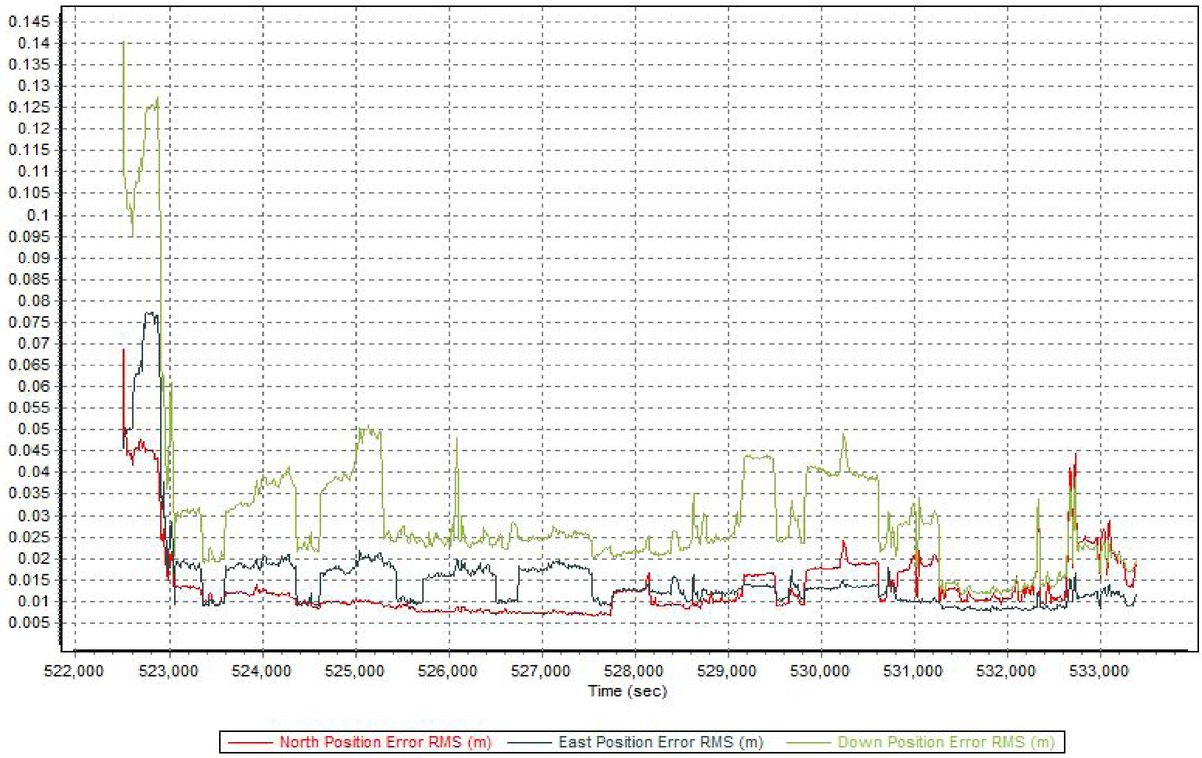


Figure A-8.44. Smoothed Performance Metric Parameters

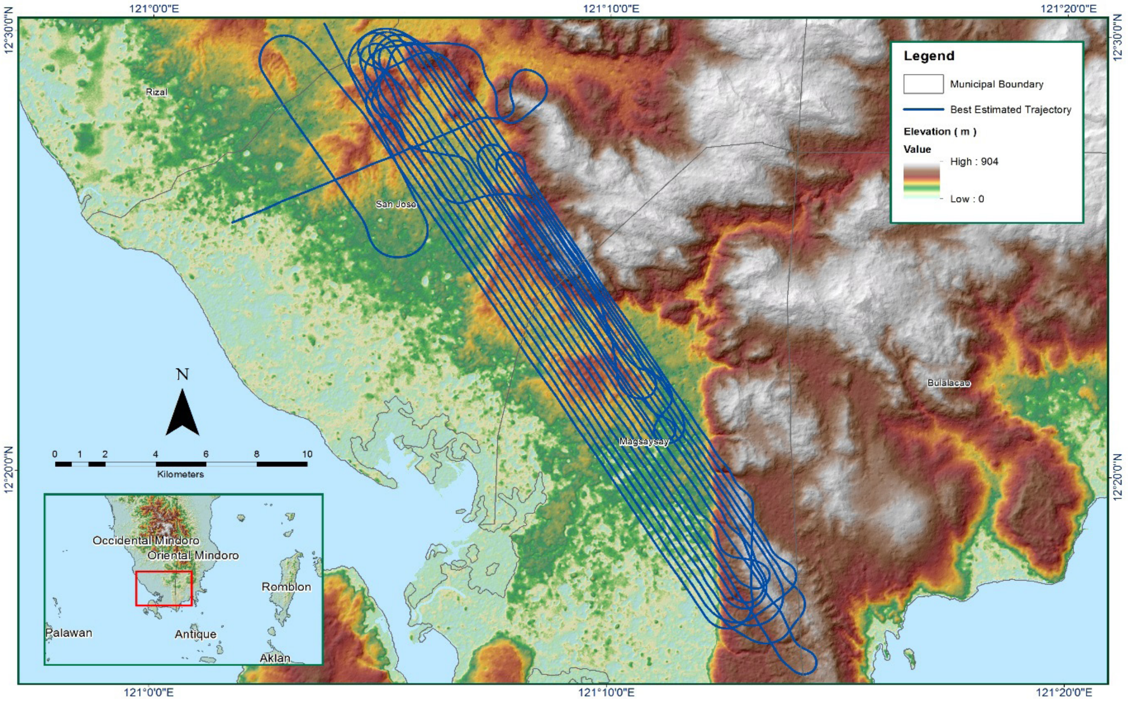


Figure A-8.45. Best Estimate Trajectory

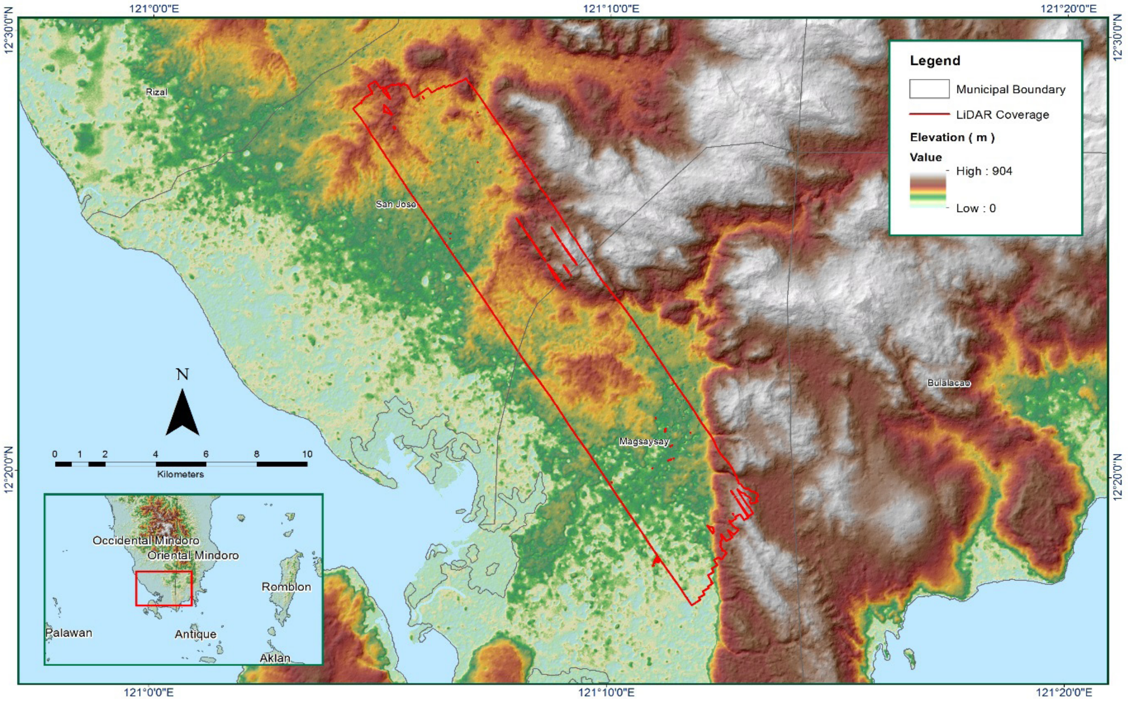


Figure A-8.46. Coverage of LiDAR data

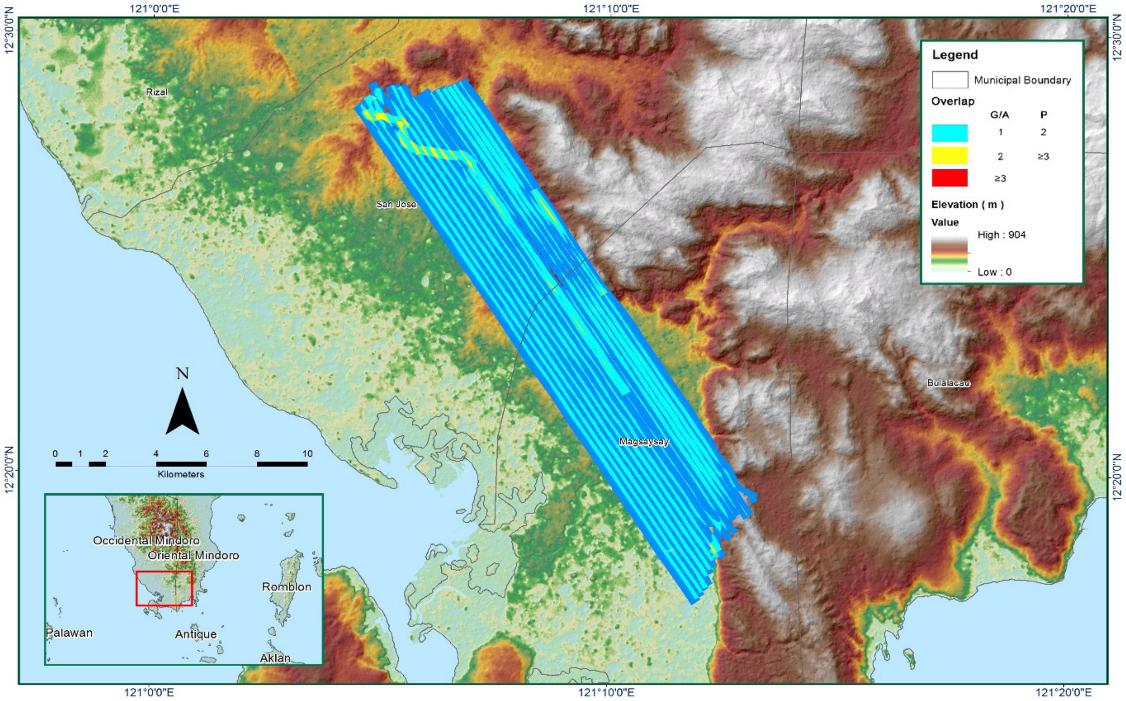


Figure A-8.47 Image of data overlap

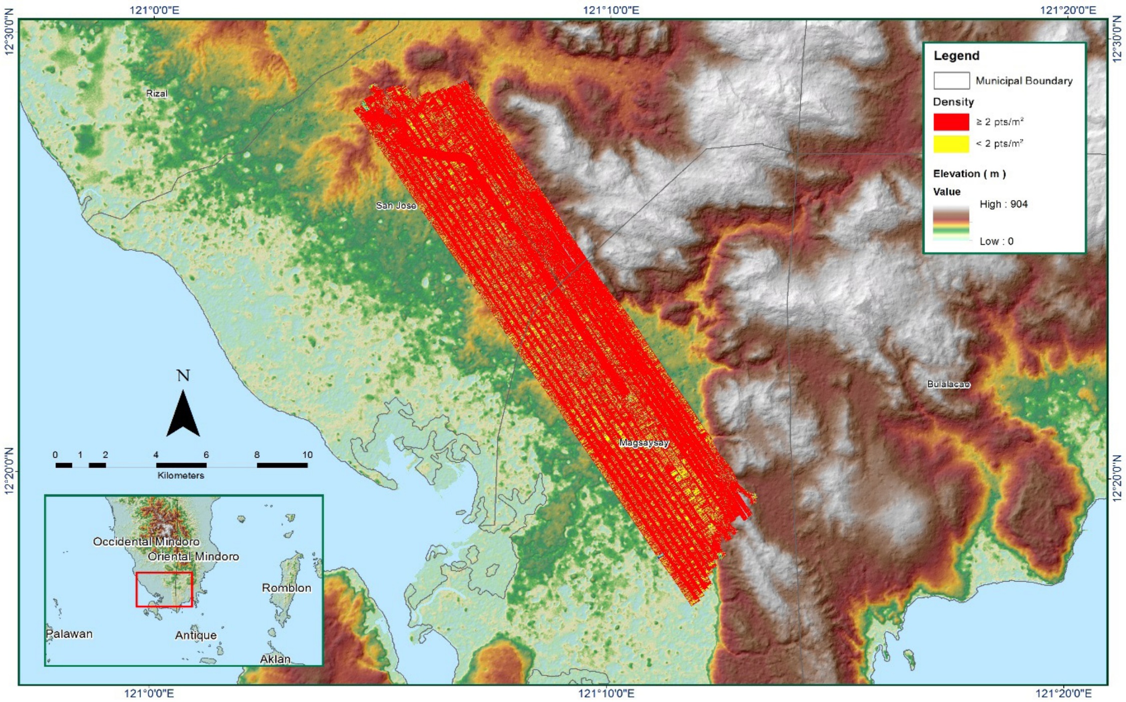


Figure A-8.48 Density Map of merged LiDAR data

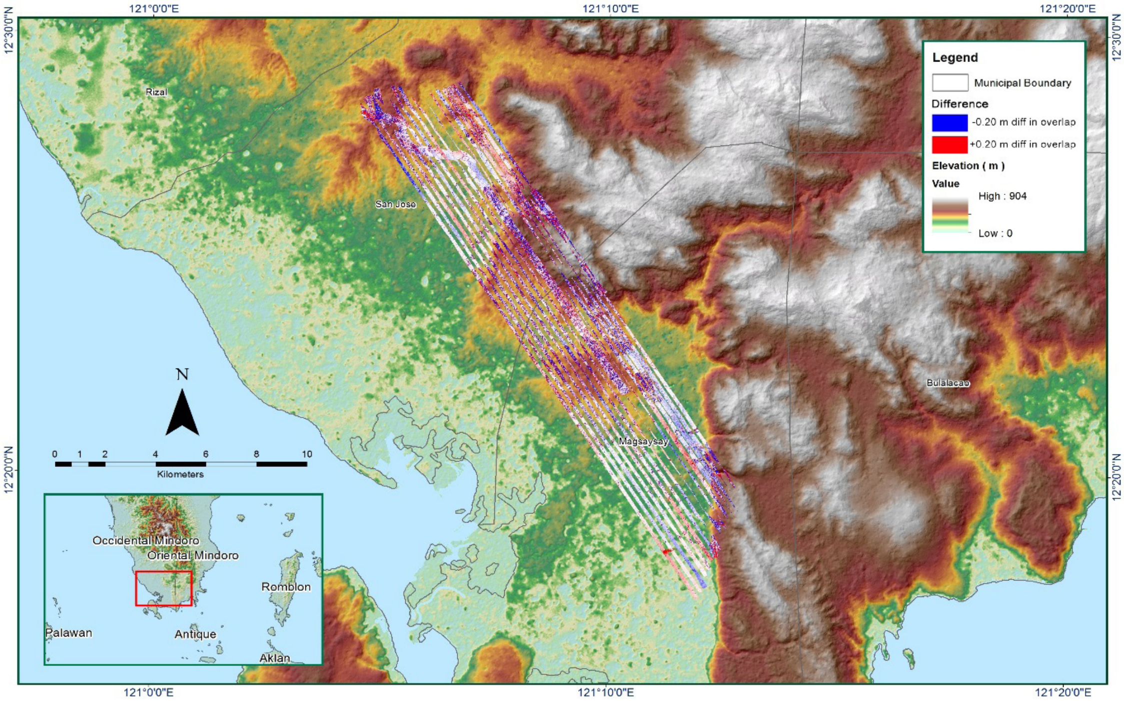


Figure A-8.49 Elevation Difference Between flight lines

Table A-8.8 Mission Summary Report for Mission Blk29G

Flight Area	Occidental Mindoro
Mission Name	Blk29G
Inclusive Flights	1152A
Range data size	12.6 GB
POS	255 MB
Image	73 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000285
IMU attitude correction stdev (<0.001deg)	0.001430
GPS position stdev (<0.01m)	0.0028

Flight Area	Occidental Mindoro
Minimum % overlap (>25)	60.10%
Ave point cloud density per sq.m. (>2.0)	4.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	96
Maximum Height	541.38 m
Minimum Height	78.73 m
Classification (# of points)	
Ground	54,125,921
Low vegetation	76,301,921
Medium vegetation	53,828,629
High vegetation	47,597,034
Building	1,659,318
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Charmaine Cruz, Engr. Roa Shalemar Redo

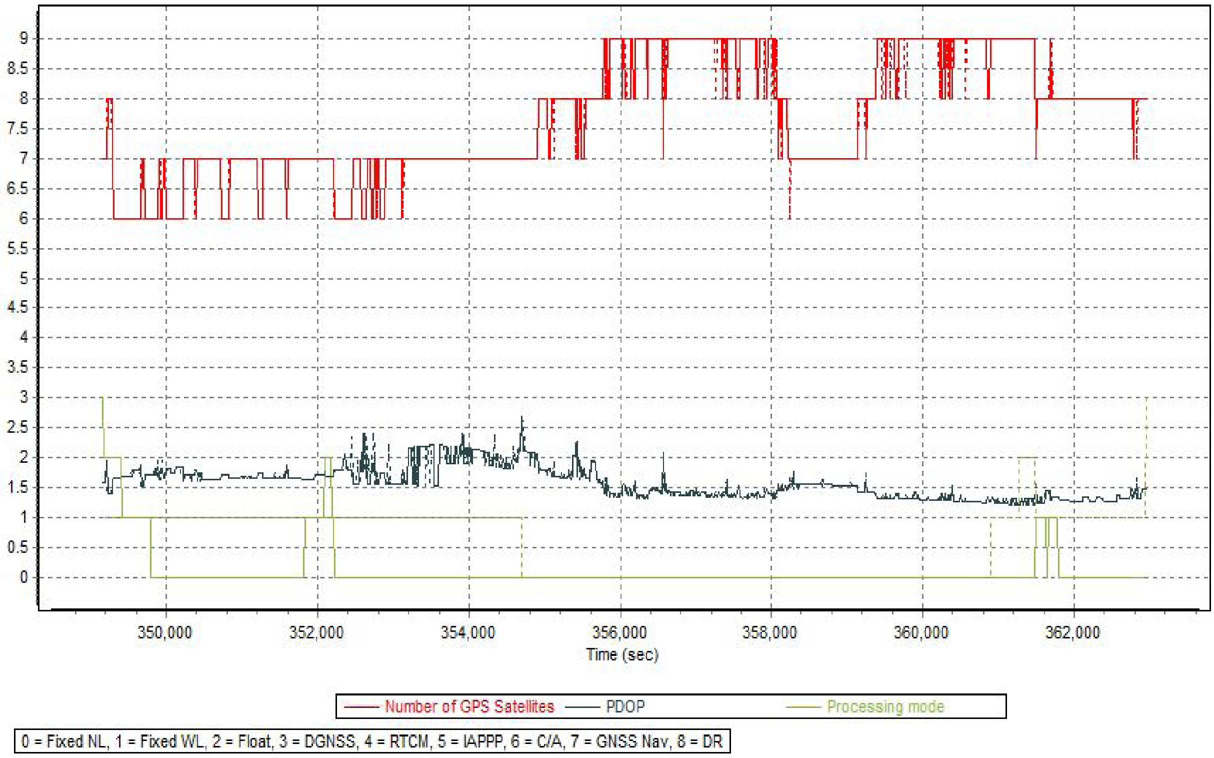


Figure A-8.50. Solution Status

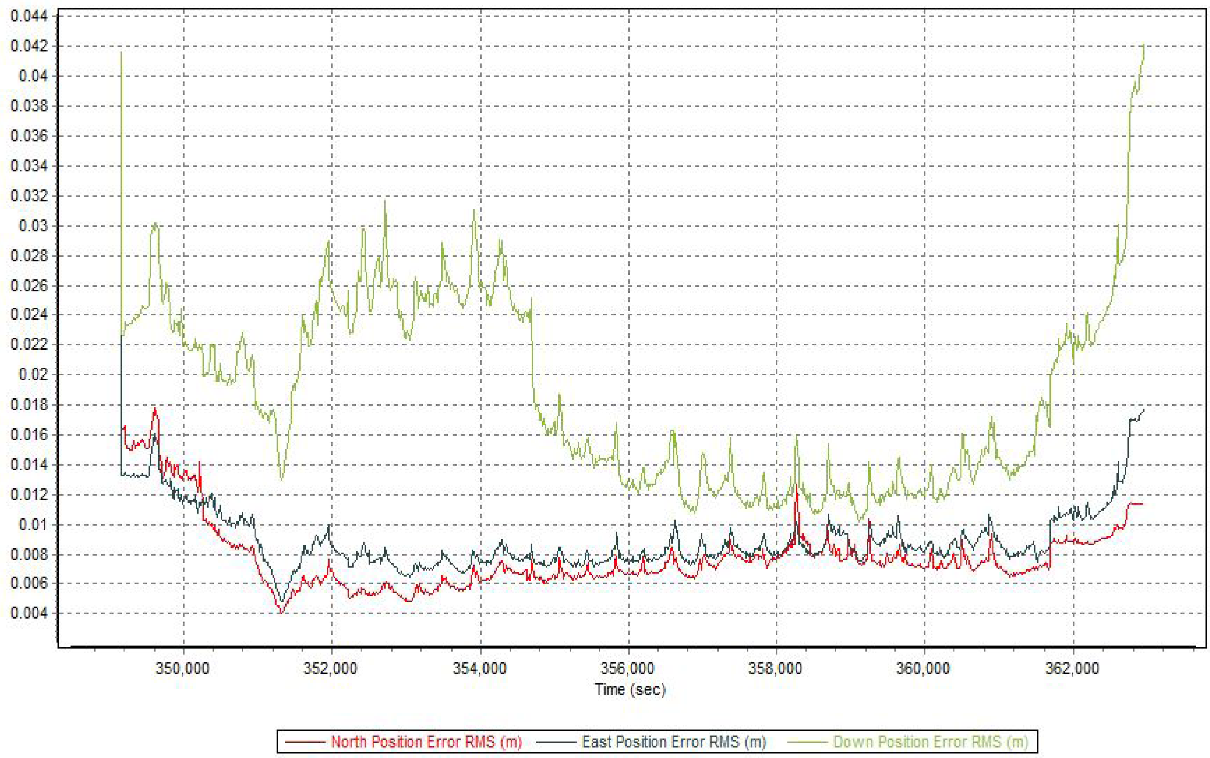


Figure A-8.51. Smoothed Performance Metric Parameters

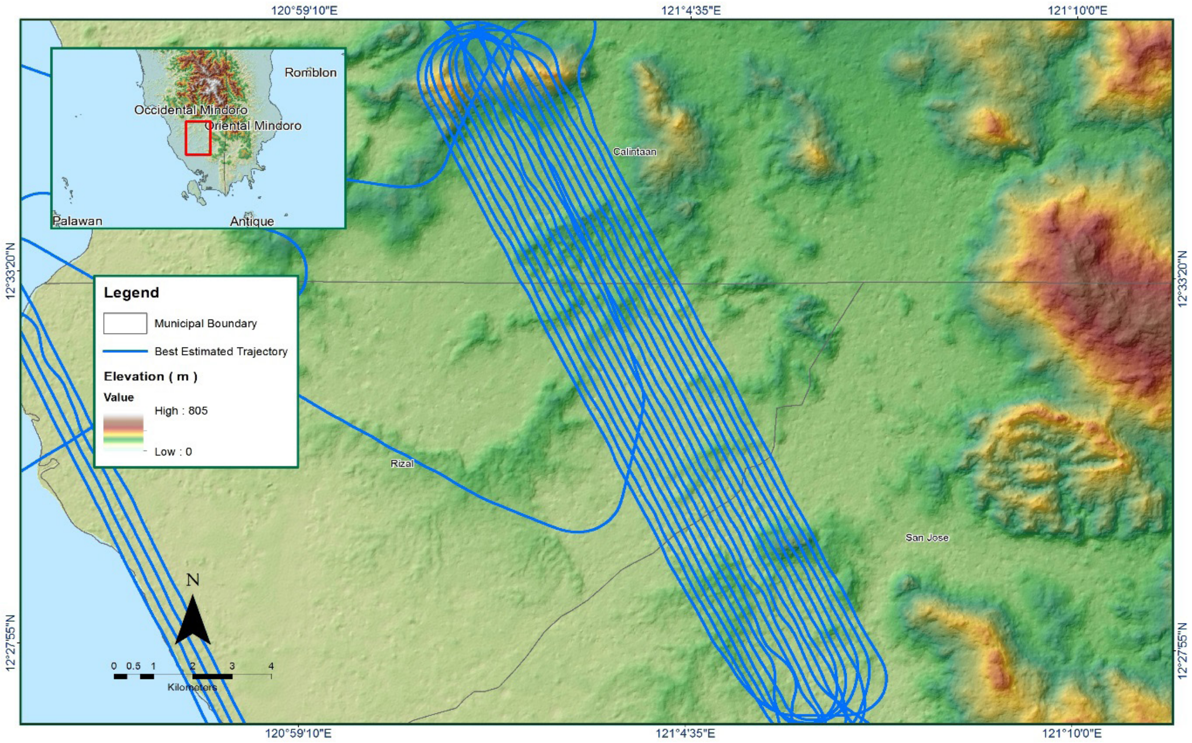


Figure A-8.52. Best Estimate Trajectory

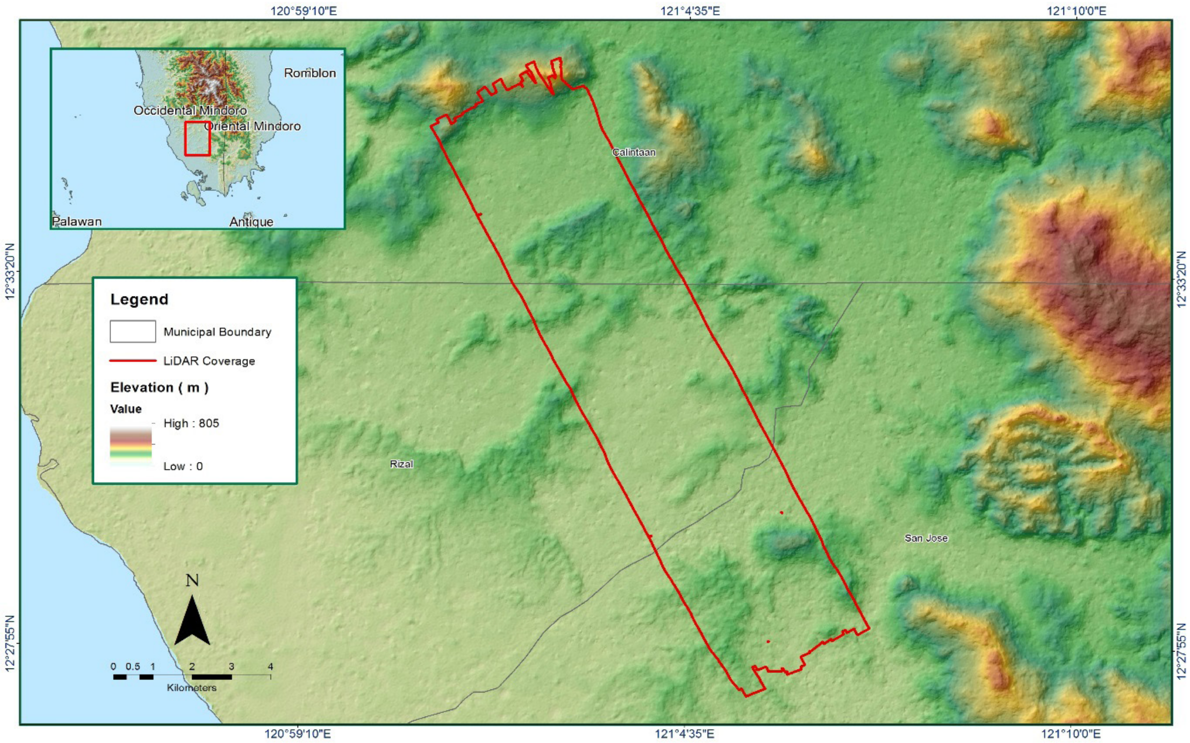


Figure A-8.53. Coverage of LiDAR data

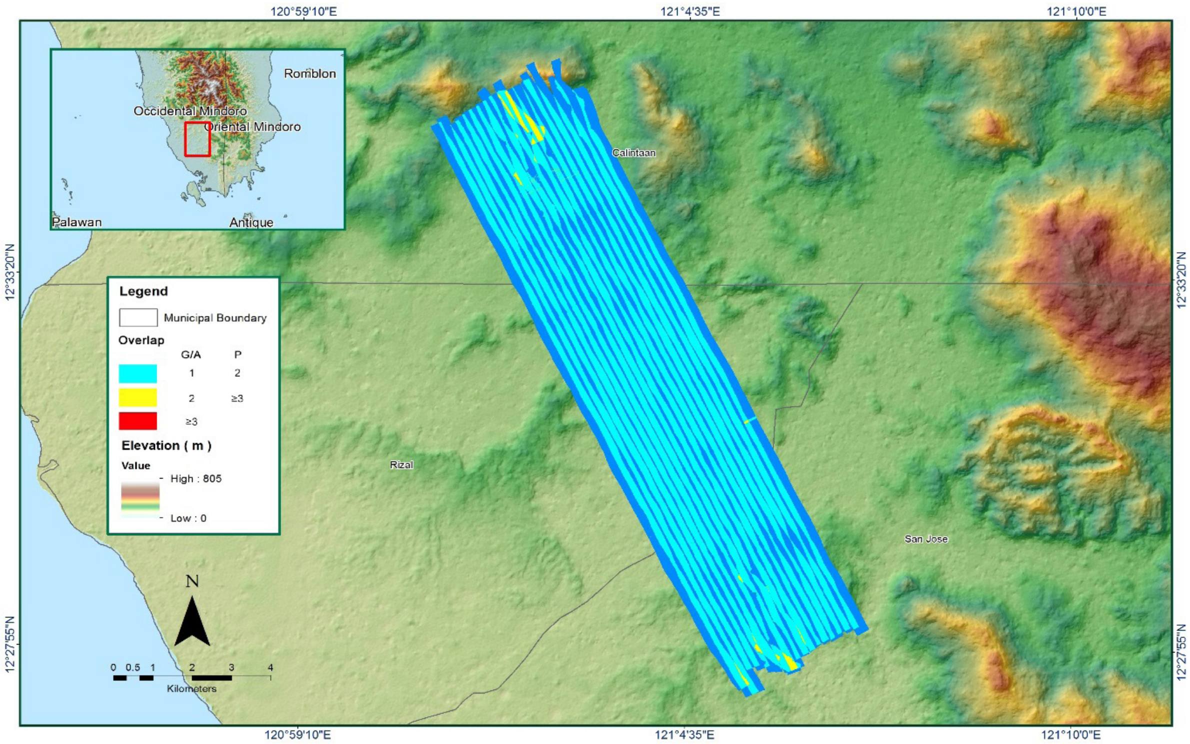


Figure A-8.54. Image of data overlap

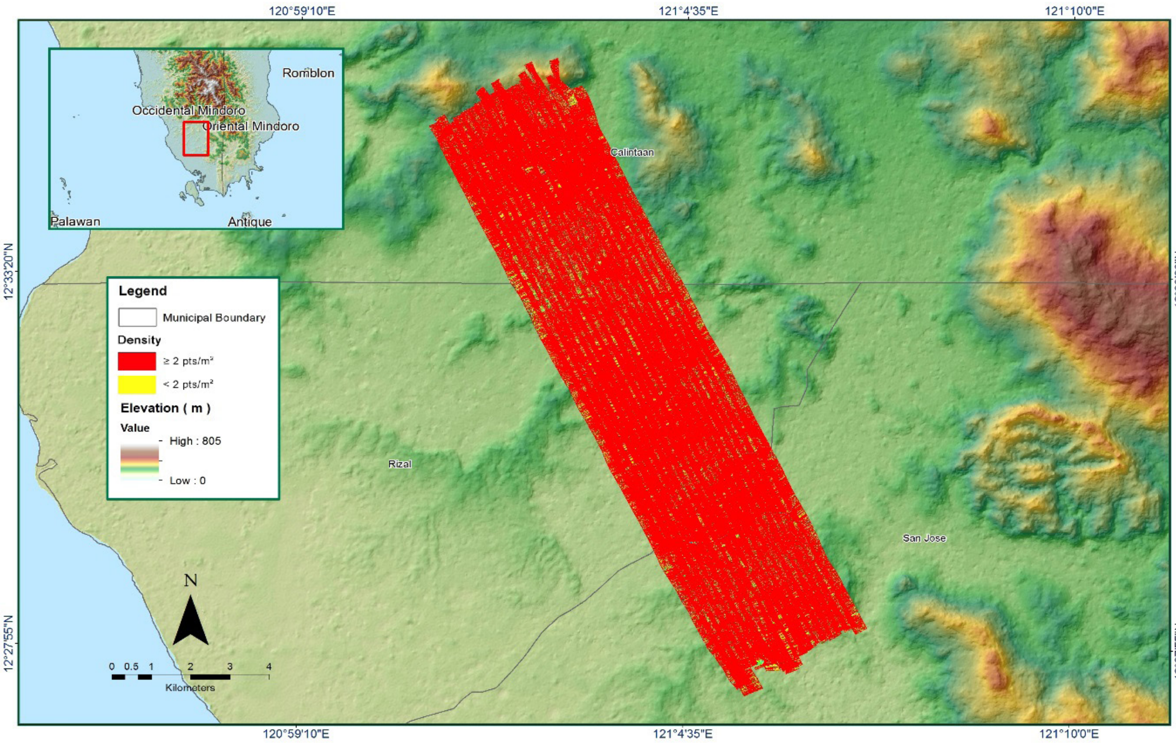


Figure A-8.55 Density Map of merged LiDAR data

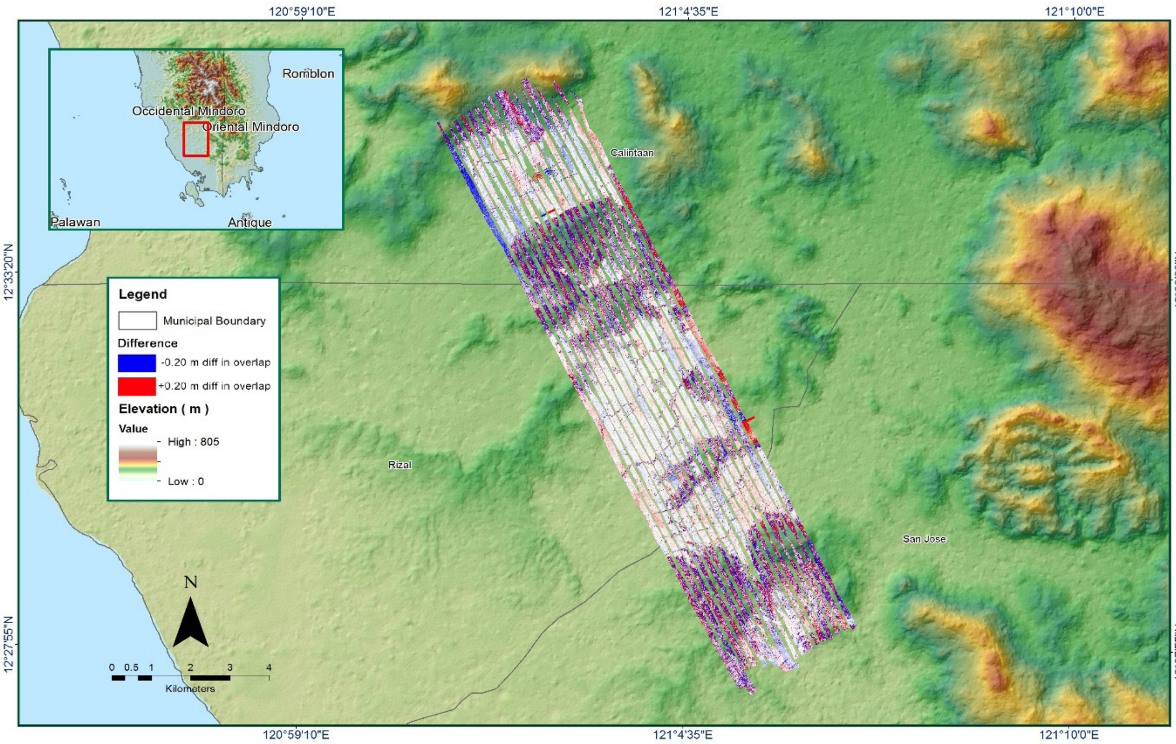


Figure A-8.56 Elevation Difference Between flight lines

Annex 9. Labangan Model Basin Parameters

Table A-9.1 Labangan Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W140	6.7787	99	0.0	0.32782	2.675	1.5510	1	0.5
W150	6.7826	99	0.0	0.3659	2.9857	0.86496	0.77214	0.5
W160	3.4238	97.609	0.0	0.0166667	2.4919	0.95384	0.68041	0.70568
W170	5.2185	88.533	0.0	0.4002	2.5018	0.91063	0.67749	0.5
W180	3.4511	98.782	0.0	1.5206	3.8483	2.5938	0.45185	0.54114
W190	4.3045	78.42	0.0	0.0859165	0.51181	0.24627	0.67922	0.5
W200	7.5603	99	0.0	0.15898	2.8895	0.11088	0.67984	0.5
W210	2.7185	93.619	0.0	0.0717467	4.313	0.71890	1	0.4975
W220	4.9998	98.352	0.0	0.74528	3.9506	2.1589	0.66425	0.5
W230	2.9913	99	0.0	0.0722667	2.9455	1.1933	0.66212	0.74797
W240	1.7126	99	0.0	0.1458	4.311	1.1596	0.45164	0.49271
W250	2.6536	99	0.0	0.10786	3.1974	1.8307	1	0.479
W280	10.605	54.495	0.0	8.0863	13.197	0.21099	1	0.5
W290	1.7046	99	0.0	0.29231	7.0991	0.79624	0.4525	0.32868

Annex 10. Labangan Model Reach Parameters

Table A-10.1 Labangan Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R100	Automatic Fixed Interval	10472	0.0030501	0.0342342	Trapezoid	14	1
R110	Automatic Fixed Interval	6902.5	0.001363	0.0067933	Trapezoid	14	1
R130	Automatic Fixed Interval	3210.0	6.98E-5	0.04	Trapezoid	14	1
R30	Automatic Fixed Interval	1771.0	0.0048913	0.0227741	Trapezoid	14	1
R310	Automatic Fixed Interval	9022.2	0.0015295	0.0092682	Trapezoid	14	1
R50	Automatic Fixed Interval	599.41	0.0048913	0.0151641	Trapezoid	14	1
R60	Automatic Fixed Interval	3904.0	0.0114884	0.0228127	Trapezoid	14	1

Annex 11. Labangan Flood Validation Data

Table A-11.1 Labangan Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	12.38139	121.1073	0.5	0	-0.5	Yolanda	Nov. 2013	25-Year
2	12.38152	121.1072	0.46	0.65	0.19	Yolanda	Nov. 2013	25-Year
3	12.38199	121.1079	0.37	0	-0.37	Glenda	Nov. 2013	25-Year
4	12.38495	121.1109	0.54	0.8	0.26	Yolanda	Nov. 2013	25-Year
5	12.3861	121.1108	0.33	0.2	-0.13		2015	25-Year
6	12.38804	121.1093	0.16	0.9	0.74	Ondoy	Sept. 2009	25-Year
7	12.38624	121.107	0.32	0	-0.32	Ondoy	Sept. 2009	25-Year
8	12.38585	121.106	0.44	0	-0.44	Ondoy	Sept. 2009	25-Year
9	12.384	121.1039	0.21	0.9	0.69	Ondoy	Sept. 2009	25-Year
10	12.36975	121.0989	0.52	1.3	0.78	Yolanda	Nov. 2013	25-Year
11	12.36954	121.0985	0.47	0.48	0.01	Yolanda	Nov. 2013	25-Year
12	12.36968	121.0986	0.51	1.22	0.71	Gelnda	July 2014	25-Year
13	12.36988	121.099	0.54	0.87	0.33	Gelnda	July 2014	25-Year
14	12.36983	121.0992	0.24	0.87	0.63	Gelnda	July 2014	25-Year
15	12.36998	121.0993	0.33	0.81	0.48	Gelnda	July 2014	25-Year
16	12.37	121.0994	0.49	1.5	1.01	Gelnda	July 2014	25-Year
17	12.37189	121.0986	0.14	0.45	0.31	Gelnda	July 2014	25-Year
18	12.37252	121.0985	0.15	0.56	0.41	Gelnda	July 2014	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
19	12.37248	121.0975	0.34	0.71	0.37	Gelnda	July 2014	25-Year
20	12.37102	121.0968	0.47	1.3	0.83	Gelnda	July 2014	25-Year
21	12.37252	121.0925	1.88	0.51	-1.37	Yolanda	Nov. 2013	25-Year
22	12.37401	121.1107	0	0.42	0.42	Yolanda	Nov. 2013	25-Year
23	12.37472	121.0939	0.27	0.62	0.35	Glenda	July 2014	25-Year
24	12.37432	121.094	1.02	1.28	0.26	Yolanda	Nov. 2013	25-Year
25	12.37396	121.0944	0.03	0.91	0.88	Yolanda	Nov. 2013	25-Year
26	12.37438	121.0952	1	1.3	0.3	Glenda	July 2014	25-Year
27	12.37368	121.0943	0.08	1.05	0.97	Yolanda	Nov. 2013	25-Year
28	12.3731	121.094	0.03	0.11	0.08	Yolanda	Nov. 2013	25-Year
29	12.3724	121.0922	0.63	0.95	0.32	Yolanda	Nov. 2013	25-Year
30	12.37225	121.0915	0.83	0	-0.83	Yolanda	Nov. 2013	25-Year
31	12.36147	121.0913	0.41	0	-0.41	Ondoy	Sept. 2009	25-Year
32	12.34785	121.1208	0	1.14	1.14	Yolanda	November 2013	25-Year
33	12.34911	121.1209	0	0	0			25-Year
34	12.34941	121.12	0	1.8	1.8	Yolanda	November 2013	25-Year
35	12.35018	121.1196	0	1.3	1.3	Yolanda	November 2013	25-Year
36	12.3517	121.1208	0	1.22	1.22	Caloy		25-Year
37	12.35111	121.1193	0	1.3	1.3	Yolanda	November 2013	25-Year
38	12.35282	121.1185	0	0.84	0.84	Yolanda	November 2013	25-Year
39	12.35334	121.1194	0	0	0			25-Year
40	12.35411	121.1191	0	0	0			25-Year
41	12.41131	121.107	0.79	0.6	-0.19	Undang	1984	25-Year
42	12.41092	121.1079	0.11	0.46	0.35	Undang	1984	25-Year
43	12.41062	121.1084	0.03	0.47	0.44	Undang	1984	25-Year
44	12.41222	121.107	1.39	0.46	-0.93	Undang	1984	25-Year
45	12.41422	121.1064	0	0.52	0.52	Undang	1984	25-Year
46	12.41471	121.106	0	0.49	0.49	Yolanda	November 2013	25-Year
47	12.41537	121.1059	0	0.33	0.33	Yolanda	November 2013	25-Year
48	12.41509	121.1048	0	1.03	1.03	Undang	1984	25-Year
49	12.41442	121.1016	0	0.57	0.57	Glenda	July 2014	25-Year
50	12.40579	121.0963	0.98	0.15	-0.83	Undang	1984	25-Year
51	12.40675	121.0982	0.14	0.2	0.06	Glenda	July 2014	25-Year
52	12.40811	121.0988	0.03	0.45	0.42	Glenda	July 2014	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
53	12.40878	121.0988	0.13	0.51	0.38	Glenda	July 2014	25-Year
54	12.4095	121.0991	0.64	0.49	-0.15	Glenda	July 2014	25-Year
55	12.40989	121.0995	0.1	0.3	0.2	Glenda	July 2014	25-Year
56	12.41051	121.0998	0.54	0.5	-0.04	Glenda	July 2014	25-Year
57	12.39917	121.0965	0.1	0	-0.1			25-Year
58	12.40041	121.0975	0.2	0	-0.2			25-Year
59	12.40052	121.097	0.03	0.36	0.33	Yolanda	November 2013	25-Year
60	12.40184	121.0975	0.17	0.3	0.13	Yolanda	November 2013	25-Year
61	12.40411	121.0976	0.32	0.46	0.14	Yolanda	November 2013	25-Year
62	12.40962	121.0975	0.79	0.31	-0.48	Glenda	July 2014	25-Year
63	12.40844	121.096	0.71	0.56	-0.15	Glenda	July 2014	25-Year
64	12.40629	121.0945	0.66	0.49	-0.17	Glenda	July 2014	25-Year
65	12.40651	121.0938	0	0.67	0.67	Glenda	July 2014	25-Year
66	12.40686	121.0928	0	0.68	0.68	Glenda	July 2014	25-Year
67	12.40719	121.0921	0	0.43	0.43	Glenda	July 2014	25-Year
68	12.40742	121.0916	0	0.12	0.12	Glenda	July 2014	25-Year
69	12.39732	121.0939	0.61	0.26	-0.35	Glenda	July 2014	25-Year
70	12.39639	121.095	0.7	1.34	0.64	Glenda	July 2014	25-Year
71	12.39569	121.095	0.69	0.84	0.15	Glenda	July 2014	25-Year
72	12.39801	121.0932	0.97	1.7	0.73	Glenda	July 2014	25-Year
73	12.39031	121.0928	0.59	0.57	-0.02	Glenda	July 2014	25-Year
74	12.39033	121.093	0.67	0.39	-0.28	Glenda	July 2014	25-Year
75	12.39062	121.0932	0.65	0.73	0.08	Glenda	July 2014	25-Year
76	12.37989	121.094	0.19	0	-0.19	-		25-Year
77	12.38111	121.0882	1.64	1.16	-0.48	Glenda	July 2014	25-Year
78	12.38121	121.0877	1.83	0.55	-1.28	Glenda	July 2014	25-Year
79	12.35823	121.1048	0.66	0.64	-0.02	-	2010/2014	25-Year
80	12.35779	121.1042	0.61	1.5	0.89	Yolanda	November 2013	25-Year
81	12.35737	121.1046	0.69	1.31	0.62	Ondoy	September 2009	25-Year
82	12.3572	121.1034	1.12	1.43	0.31	Yolanda	November 2013	25-Year
83	12.35641	121.1034	0.36	0.09	-0.27			25-Year
84	12.356	121.1043	0.61	1.02	0.41	Yolanda	November 2013	25-Year
85	12.35651	121.1026	0.03	0.66	0.63			25-Year
86	12.35476	121.101	0.03	0.8	0.77	Habagat		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
87	12.35686	121.1021	0.84	1.66	0.82			25-Year
88	12.3573	121.1024	0.36	0.98	0.62	Yolanda	November 2013	25-Year
89	12.35798	121.1017	0.12	0.48	0.36	Glenda	July 2014	25-Year
90	12.35883	121.1013	0.22	0.39	0.17	Glenda	July 2014	25-Year
91	12.36128	121.1	0.38	0.61	0.23	Yolanda	November 2013	25-Year
92	12.36138	121.0998	0.51	1.3	0.79	Glenda	July, 2014	25-Year
93	12.36492	121.1081	0.65	0.465	-0.185	Yolanda	November 2013	25-Year
94	12.36564	121.109	0.75	1.17	0.42	-		25-Year
95	12.36909	121.1144	0	0.82	0.82	Yolanda	November 2013	25-Year
96	12.36586	121.1173	0	0.1	0.1	Yolanda	November 2013	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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