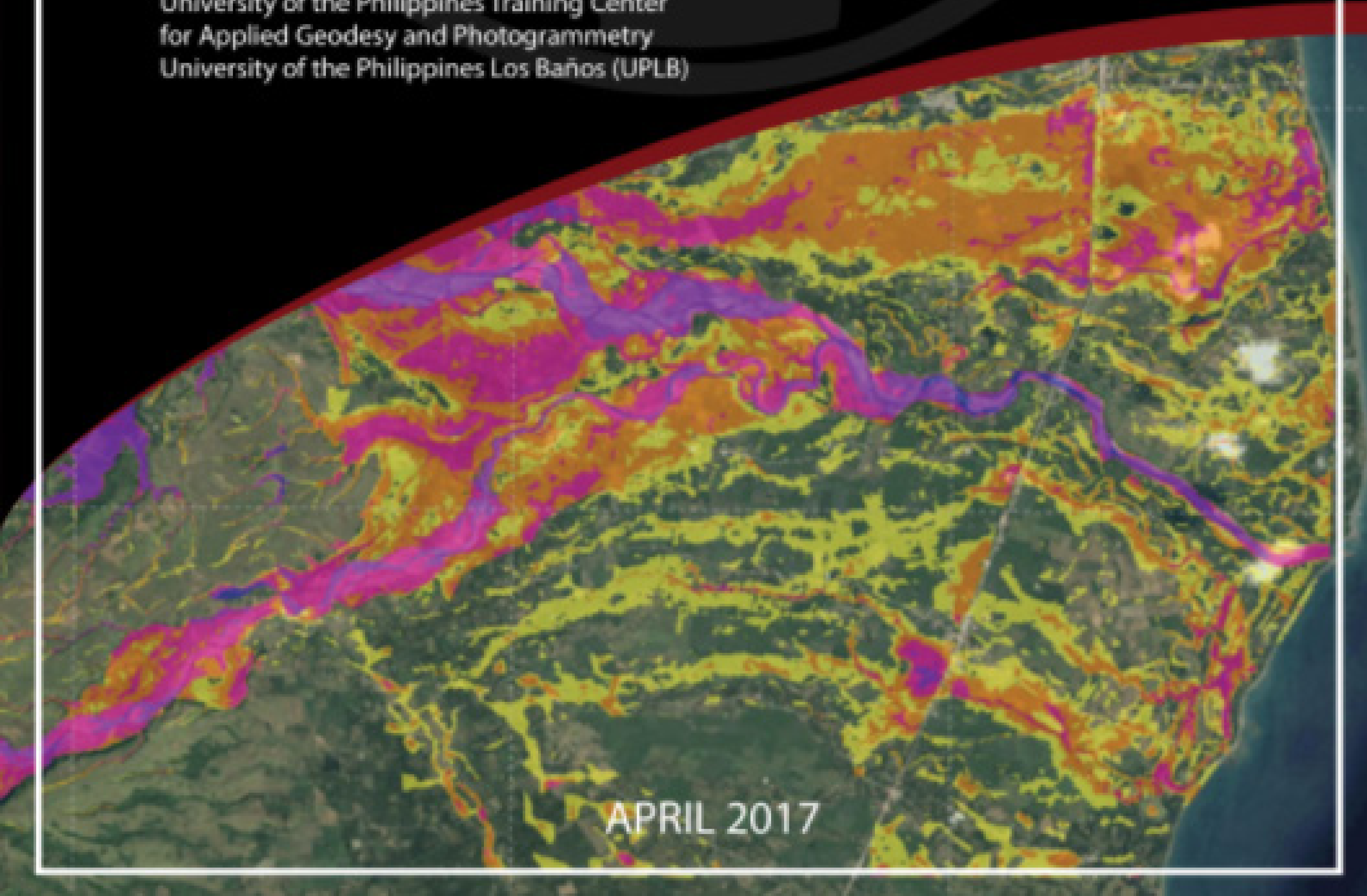
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Agsalin River

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



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For questions/queries regarding this report, contact:

Asst. Prof. Edwin R. Abucay
Project Leader Phil-LiDAR 1 Program
University of the Philippines, Los Banos
Los Banos, Philippines 4031
erabucay@up.edu.ph

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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND AGSALIN RIVER

Prof. Edwin R. Abucay, and Enrico C. Paringit, Dr. Eng., Miyah D. Queliste

1.1 Background of the Phil-LIDAR 1 Program

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

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

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 MIMAROPA. The university is located in the Municipality of Los Baños in the province of Laguna.

1.2 Overview of the Agsalin River Basin

Agsalin River Basin is a 34,670-hectare watershed located in Oriental Mindoro. It covers the barangays of Conrazon in Bansud Municipality; Balete, Banutan, Buong Lupa, Lucio Laurel, Macario Adriatico, Malamig, Malayong, Malubay, Manguyang, Mirayan, Papandungin, and Santa Theresa in Gloria; and Marayos and Sabang in Pinamalayan. The basin area has seven geological classifications, with Cretaceous-Paleogene as the most dominant type while the rest include Basement Complex, Jurassic, Oligocene-Miocene, Pliocene-Pleistocene, Recent and Upper Miocene-Pliocene. The river basin is generally characterized by 8–18% slope and elevation of 300–2,200 meters above mean sea level. It also has five soil types including Buguay loamy sand, Maranlig gravelly sandy clay loam, Quingua clay loam, San Manuel clay loam, and San Manuel loam. Four land cover types can be found in the river basin including cultivated area mixed with brushland/grassland, arable land (crops mainly cereals and sugar), crop land mixed with coconut plantation, and grassland (grass covering >70%).

Agsalin River passes through the barangays of Balete, Banutan, Malamig, Malayong, Malubay, and Papandungin. The 2010 NSO Census of Population and Housing record showed that Malamig is the most populated in the most populated barangay. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, there were only three notable weather disturbance that caused flooding—Undang in 1984, Caloy in 2006, and Nona in 2015.

Climate Types I and III prevail 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.

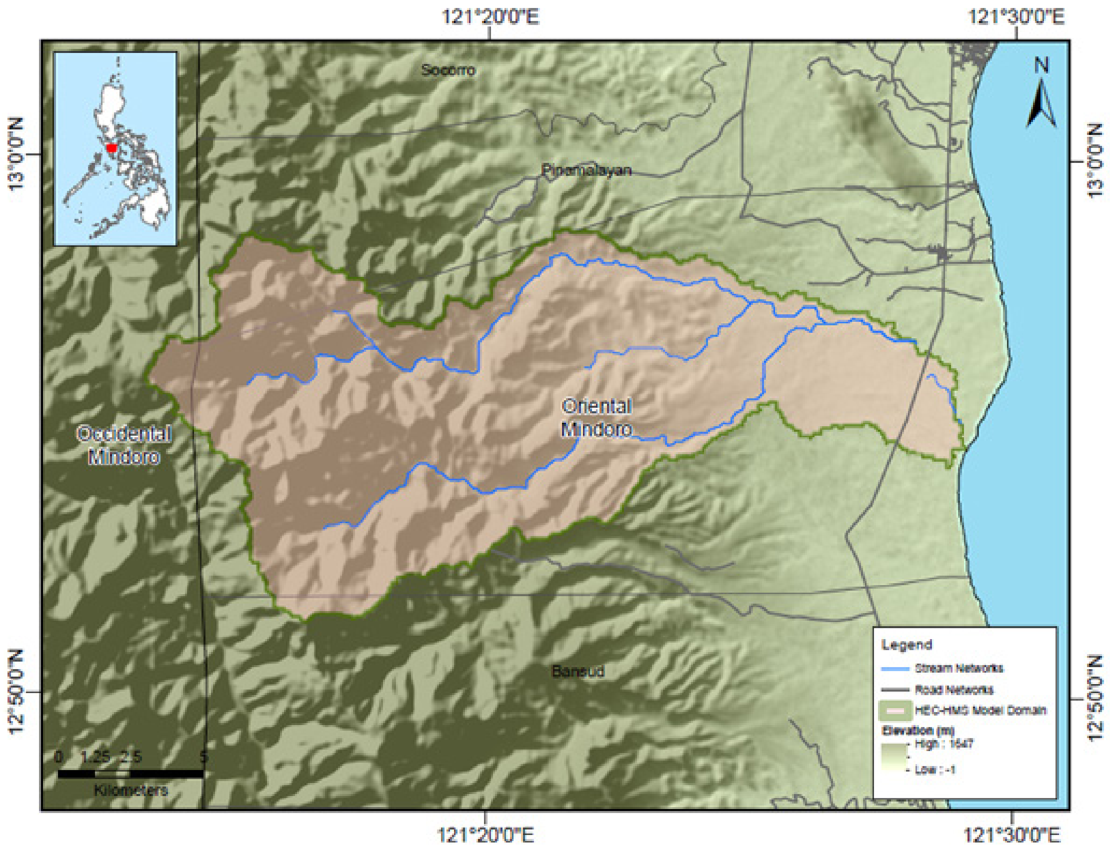


Figure 1. Map of the Agsalin River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN AGSALIN FLOODPLAIN

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

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 Agsalin Floodplain in Oriental Mindoro. These missions were planned for 16 lines that run for at most four (4) hours including take-off, landing, and turning time. The flight planning parameters for Aquarius and Gemini LiDAR systems are found in Table 1 and Table 2, respectively. Figure 2 shows the flight plan for Agsalin Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Max. Field of View (θ)	Pulse Rate Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	750	30	36	50	45	130	5
BLK28B	600	30	36	50	45	130	5
BLK28C	600	30	36	50	45	130	5
BLK28D	600	30	36	50	45	130	5
BLK28E	600	30	36	50	45	130	5
BLK28J	600	30	36	50	45	130	5
BLK28I	600	30	36	50	45	130	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	800/1000/1200	30	30/36/40	100	50	130	5
BLK28AS	800/1000/1200	30	30/36/40	100	50	130	5
BLK28B	800/1000/1200	30	30/36/40	100	50	130	5
BLK28C	800/1000/1200	30	30/36/40	100	50	130	5
BLK28D	800/1000/1200	30	30/36/40	100	50	130	5
BLK28F	800/1200	30	30/40	100	50	130	5
BLK28GS	800/1200	30	30/40	100	50	130	5
BLK28H	1000	30	36	100	50	130	5
BLK28I	800/1200	30	30/40	100	50	130	5

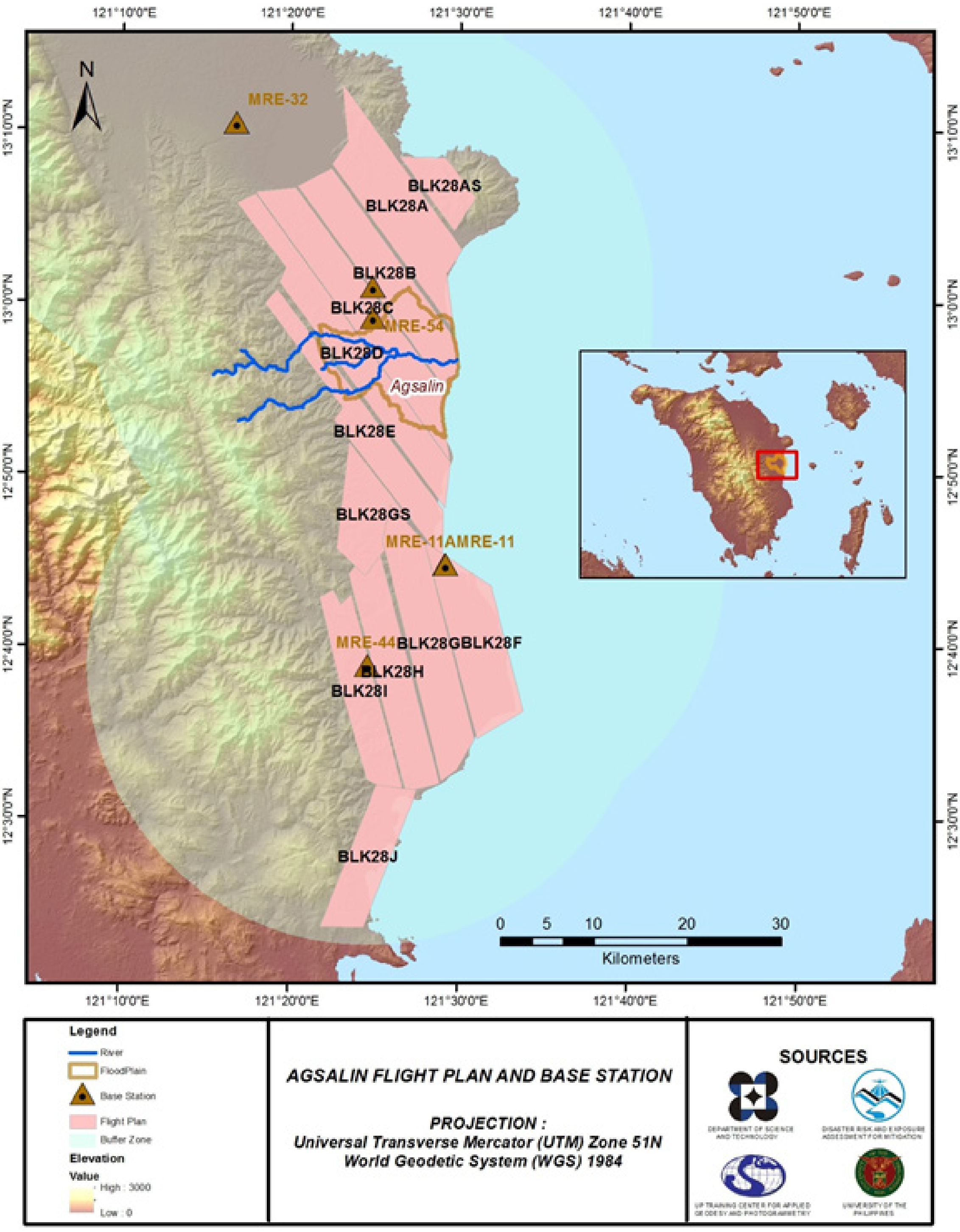


Figure 2. Flight plan and base stations used for Agsalin Floodplain

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA ground control points: MRE-32, MRE-44, and MRE-54, which are of second (2nd)-order accuracy. The project team also established three (3) ground control points, MRE-4563, MRE-11, and MRE-11A. The certifications for the base stations are found in ANNEX 2 while the baseline processing reports for the re-processed ground control point and established points are found in ANNEX 3. These points were used as base stations during flight operations for the entire duration of the survey (February 2–15, 2014 and October 16–31, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Agsalin Floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 8 present the details about the following NAMRIA control stations and established control points while Table 9 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3. GPS set-up over MRE-54 as recovered inside the compound of the barangay hall of Maliangcog, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-54 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point MRE-54 used as base station for the LiDAR acquisition

Station Name		MRE-54
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°59'12.43671" North 121°24'46.52637" East 42.40800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	544797.009 meters 1436124.562 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°59'7.43505" North 122°41'8.09853" East 91.39500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327864.09 meters 1436121.49 meters

Figure 4. GPS set-up over MRE-44 as recovered just outside the compound of the barangay hall of Happy Valley, municipality of Roxas, Oriental Mindoro (a) and NAMRIA reference point MRE-44 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point MRE-44 used as base station for the LiDAR acquisition

Station Name		MRE-44
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°38’59.03778’’ North 121°24’32.60444’’ East 87.94200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	544436.519 meters 1398838.995 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°38’54.11733’’ North 121°24’37.66392’’ East 137.80400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327214.81 meters 1398840.08 meters

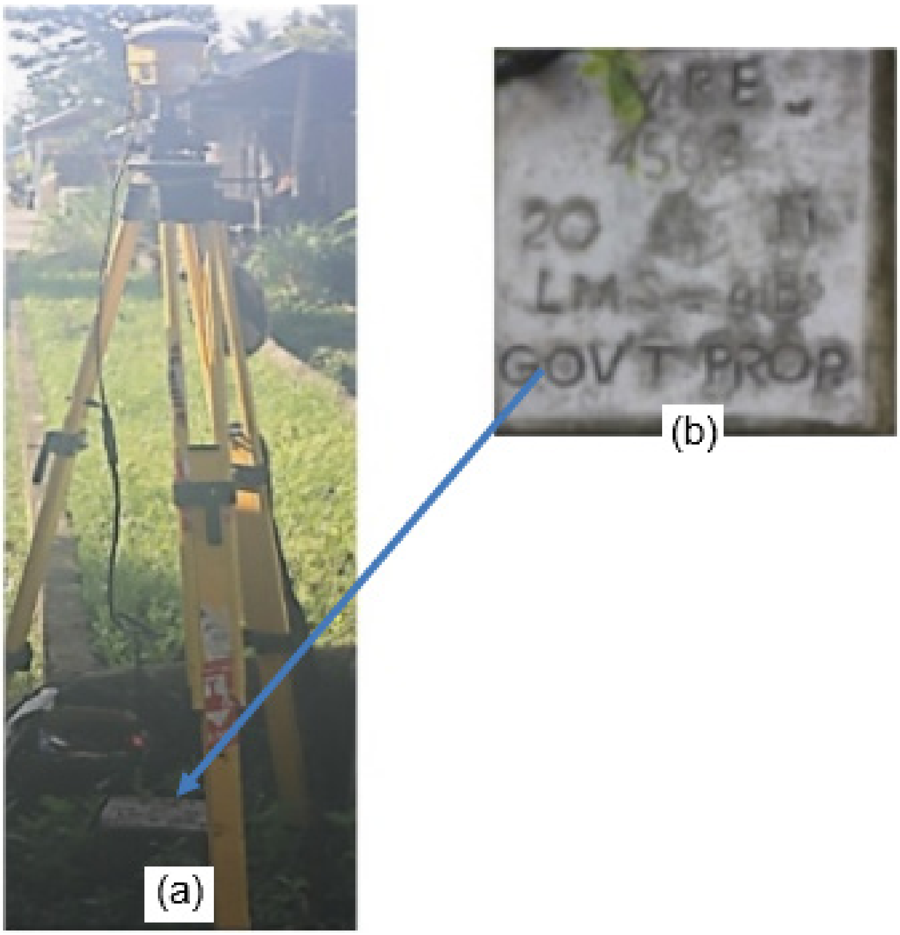


Figure 5. GPS set-up over MRE-4563 as recovered, just outside the compound of the barangay hall of Brgy. Pagala-gala, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-4563 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point MRE-4563 used as base station for the LiDAR acquisition

Station Name		MRE-4563
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°00'53.01692'' North 121°24'51.45337'' East 73.715 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	328034.015 meters 1439300.319 meters

Table 6. Details of the recovered NAMRIA horizontal control point MRE-32 used as base station for the LiDAR acquisition

Station Name		MRE-32
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°10'28.85064'' North 121°16'38.44761'' East 19.49300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	530065.679 meters 1456889.419 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°10'23.79251'' North 121°16'43.46244'' East 67.64700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	313296.85 meters 1457002.75 meters

Table 7. Details of the recovered NAMRIA horizontal control point MRE-11 used as base station for the LiDAR acquisition

Station Name		MRE-11
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°44'45.47242'' North 121°29'12.85426'' East 54.990 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	335735.169 meters 1409521.797 meters

Table 8. Details of the recovered NAMRIA horizontal control point MRE-11A used as base station for the LiDAR acquisition

Station Name		MRE-11A
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1:50,000
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°44'45.50783'' North 121°29'12.79714'' East 55.558 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	335733.771 meters 1409518.693 meters

Table 9. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 2, 2014	1054A	3BLK28B033B	MRE-54
February 3, 2014	1056A	3BLK28C034A	MRE-54
February 3, 2014	1058A	3BLK28CD034B	MRE-54
February 5, 2014	1066A	3BLK28DS036A	MRE-54, MRE-4563
February 6, 2014	1070A	3BLK28DSE037A	MRE-54, MRE-4563
February 12, 2014	1092A	3BLK28ABES043A	MRE-54, MRE-4563
February 12, 2014	1094A	3BLK28BS043B	MRE-54, MRE-4563
February 13, 2014	1098A	3BLK28JSI044B	MRE-44, MRE-32
October 22, 2015	8300G	2BLK28ABC295A	MRE-54, MRE-11
October 22, 2015	8301G	2BLK28CSD295B	MRE-54, MRE-11
October 23, 2015	8302G	2BLK28ASEHI296A	MRE-54, MRE-11
October 25, 2015	8306G	2CALIBBLK28FSGS298A	MRE-11, MRE-11A

2.3 Flight Missions

Twelve (12) missions were conducted to complete the LiDAR data acquisition in Agsalin Floodplain, for a total of forty four hours and forty six minutes (44+46) of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Aquarius and Gemini 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 Agsalin 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 2, 2014	1054A	103.26	90.45	24.68	65.76	1094	3	41
February 3, 2014	1056A	118.79	89.97	30.94	59.03	1111	3	41
February 3, 2014	1058A	236.00	100.03	34.28	65.75	1016	3	23
February 5, 2014	1066A	117.20	116.30	28.43	87.87	1088	3	35
February 6, 2014	1070A	204.55	134.14	19.23	114.91	1509	4	29
February 12, 2014	1092A	322.44	225.61	19.39	206.22	1176	4	5
February 12, 2014	1094A	103.26	50.74	17.54	33.22	500	2	29
February 13, 2014	1098A	248.23	76.47	4.43	72.03	909	3	59
October 22, 2015	8300G	251.55	141.964	11.4155	130.5485	430	3	50
October 22, 2015	8301G	436.28	176.032	34.791	141.241	776	4	6
October 23, 2015	8302G	366.66	117.197	38.8832	78.3138	443	3	47
October 25, 2015	8306G	455.53	70.5849	1.92204	68.66286	0	3	41
TOTAL		2963.75	1389.49	265.94	1123.56	10052	44	46

Table 11. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1054A	1000, 600	30	36	50	45	130	5
1056A	600	30	40, 36	50	45	130	5
1058A	600	30	36	50	40/50	130	5
1066A	600	30	36	50	45	130	5
1070A	600	30	36	50	30/40	130	5
1092A	600	30	36	50	45	130	5
1094A	600	30	36	50	45	130	5
1098A	600, 700	30	36	50	45	130	5
8300G	1000/1200	30	30/36	100	50	130	5
8301G	1000	30	36	100	50	130	5
8302G	800/1200	30	30/40	100	50	130	5
8306G	800/1200	30	30/40	100	50	130	5

2.4 Survey Coverage

Agsalin Floodplain is located in the province of Oriental Mindoro with majority of the floodplain situated within the Municipality of Gloria and Pinamalayan. Socorro is mostly covered by the survey. 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 Agsalin Floodplain is presented in Figure 6.

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

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Oriental Mindoro	Socorro	206.06	151.42	73%
	Gloria	327.28	185.73	57%
	Pola	127.04	71.02	56%
	Pinamalayan	206.87	114.93	56%
	Bansud	197.00	81.82	42%
	Bongabong	493.74	86.43	18%
	Naujan Lake	76.11	11.45	15%
	Roxas	90.14	12.80	14%
	Mansalay	477.24	41.90	9%
	Victoria	216.22	10.56	5%
	Bulalacao	365.58	5.24	1%
	Naujan	431.58	5.79	1%

Total	3214.86	779.09	28.92%

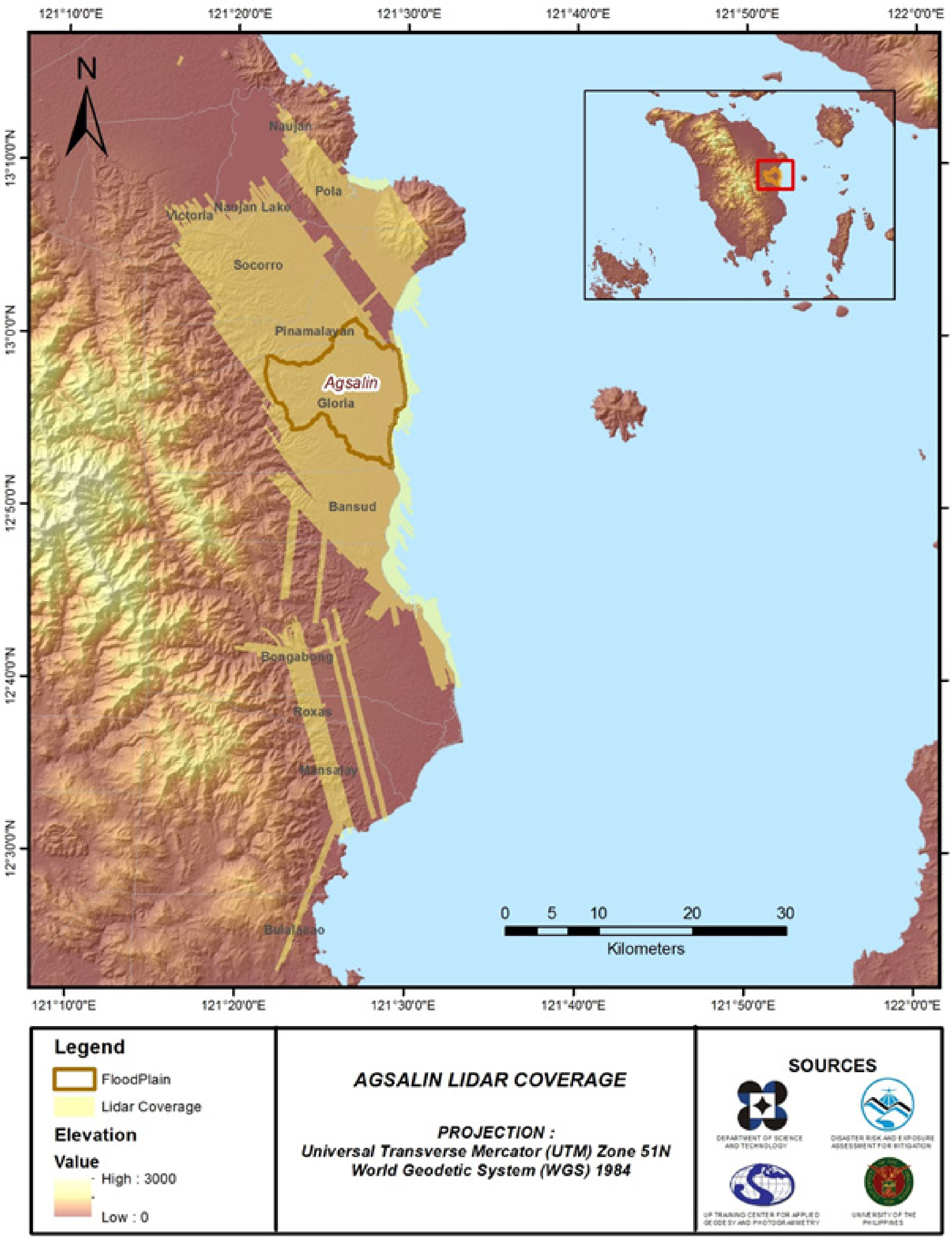


Figure 6. Actual LiDAR data acquisition for Agsalin Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR AGSALIN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Harmond F. Santos, Engr. Angelo Carlo B. Bongat, Engr. Ma. Ailyn L. Olanda, Engr. Jovelle Anjeanette S. Canlas, Marie Denise V. Bueno, Engr. Regis R. Guhiting, Engr. Merven Matthew D. Natino, Gillian Katherine L. Inciong, Gemmalyn E. Magnaye, Leendel Jane D. Punzalan, Sarah Joy A. Acepcion, Ivan Marc H. Escamos, Allen Roy C. Roberto, Jan Martin C. Magcale

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 (DAC) were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which were the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 7.

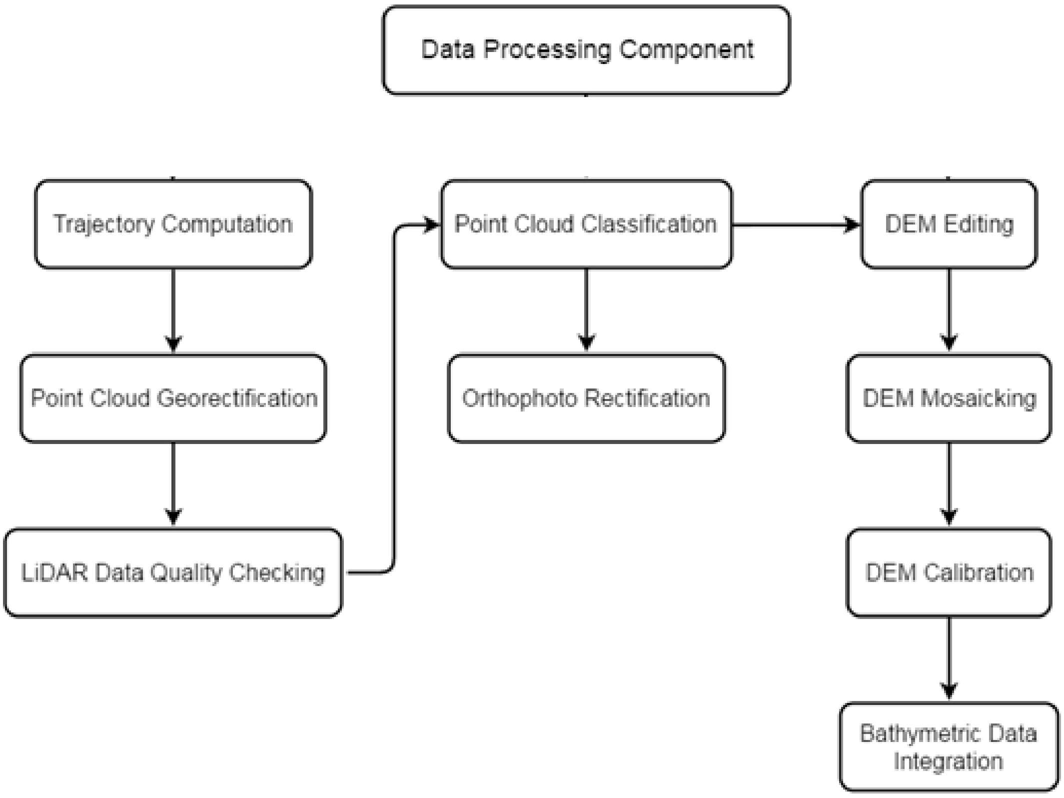


Figure 7. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Agsalin 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 October 2015 were flown using the Gemini system over Gloria, Oriental Mindoro. The Data Acquisition Component transferred a total of 158.75 Gigabytes of Range data, 2.63 Gigabytes of POS data, 143.18 Megabytes of GPS base station data, and 576.97 Gigabytes of raw image data to the data server on February 1, 2014 for the first survey and October 28, 2015 for the second survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Agsalin was fully transferred on November 12, 2015, as indicated on the data transfer sheets for Agsalin Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1056A, one of the Agsalin flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 3, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

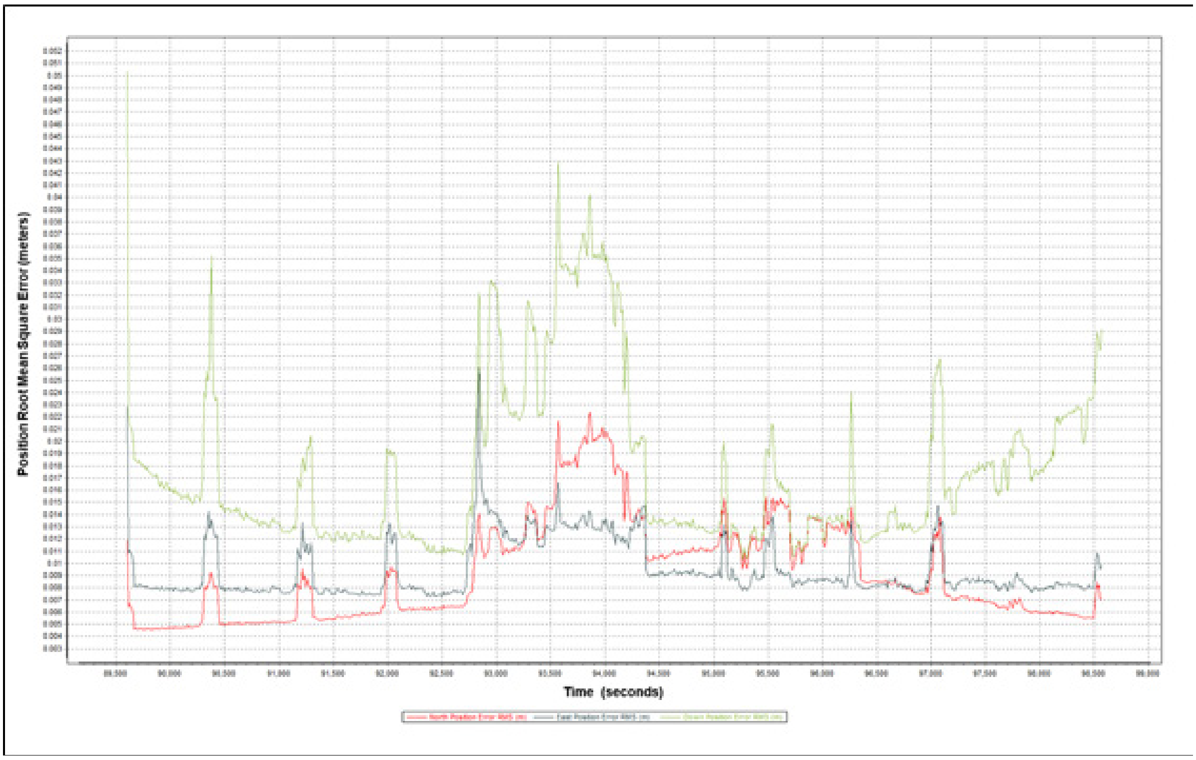


Figure 8. Smoothed Performance Metric parameters of an Agsalin Flight 1056A

The time of flight was from 89500 seconds to 99000 seconds, which corresponds to morning of February 3, 2014. 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 time the POS system started 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 8 shows that the North position RMSE peaks at 2.30 centimeters, the East position RMSE peaks at 2.60 centimeters, and the Down position RMSE peaks at 4.30 centimeters, which are within the prescribed accuracies described in the methodology.

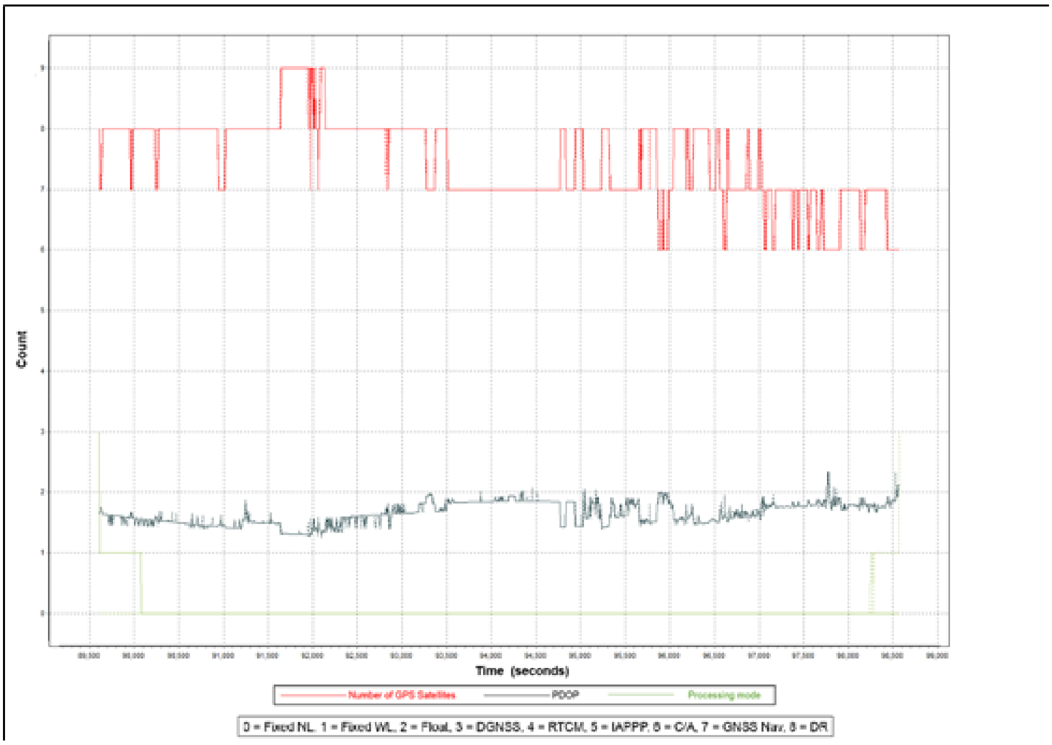


Figure 9. Solution Status parameters of Agsalin Flight 1056A

The Solution Status parameters of flight 1056A, one of the Agsalin flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 9. 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 Agsalin flights is shown in Figure 10.

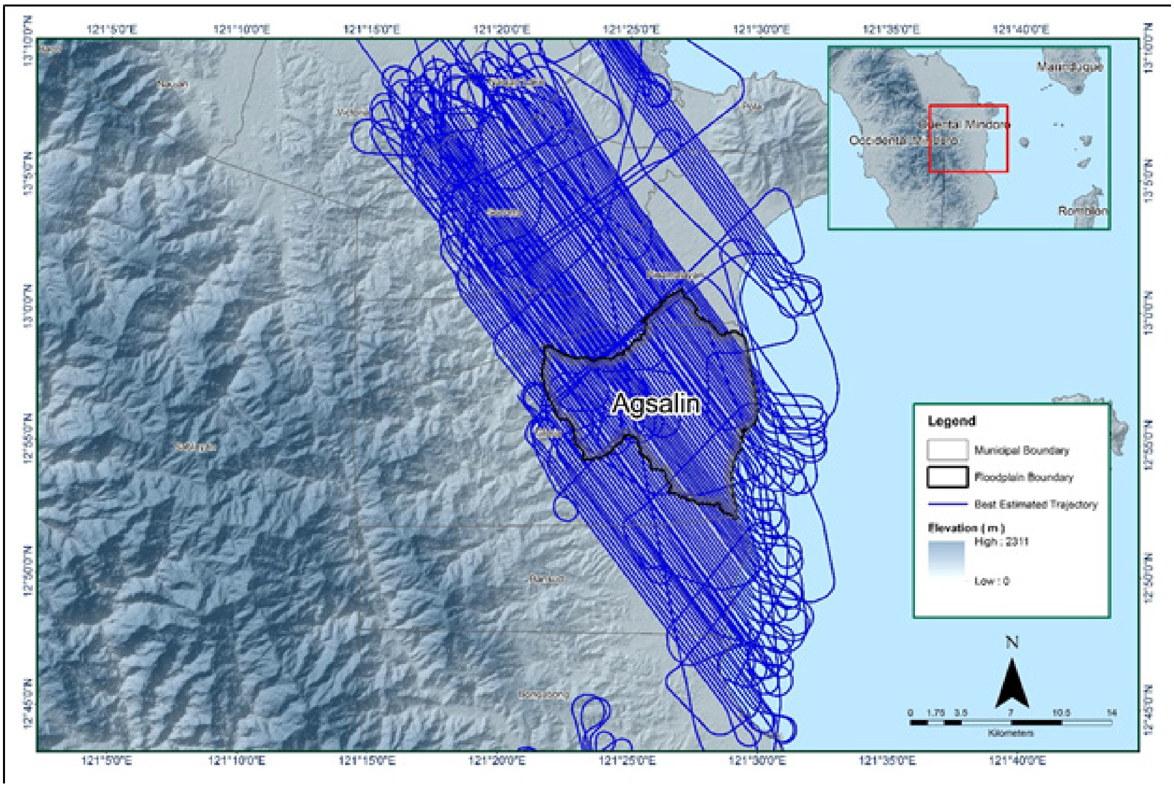


Figure 10. Best estimated trajectory of LiDAR missions conducted over Agsalin Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 113 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Agsalin Floodplain are given in Table 13.

Table 13. Self-calibration results values for Agsalin flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000552
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000955
GPS Position Z-correction stdev (<0.01meters)	0.0087

The optimum accuracy is obtained for all Agsalin 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.

3.5 LiDAR Data Quality Checking

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

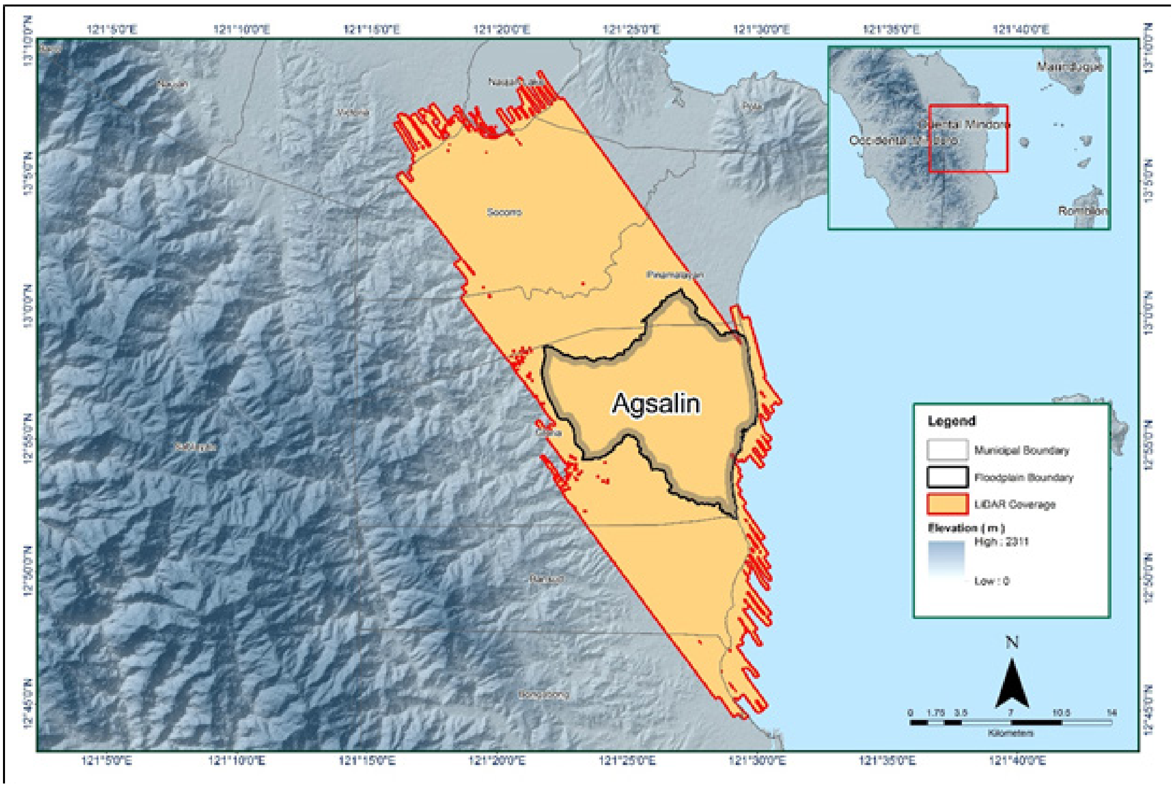


Figure 11. Boundary of the processed LiDAR data over Agsalin Floodplain

The total area covered by the Agsalin missions is 797.49 sq km comprised of twelve (12) flight acquisitions grouped and merged into twelve (12) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Agsalin Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
OrientalMindoro_Blk28B	1054A	74.11
OrientalMindoro_Blk28B_supplement	1094A	47.08
OrientalMindoro_Blk28B_supplement_additional	1098A	11.37
OrientalMindoro_Blk28C	1056A	29.38
OrientalMindoro_Blk28C_supplement	1056A	87.46
OrientalMindoro_Blk28D	1058A	67.39
OrientalMindoro_Blk28D_supplement	1066A	88.65
OrientalMindoro_Blk28E	1070A	125.84
OrientalMindoro_Blk28E_supplement	1092A	29.82
OrientalMindoro_reflights_Blk28A_additional	8306G	5.27
OrientalMindoro_reflights_Blk28B	8301G	73.59
	8300G	
OrientalMindoro_reflights_Blk28C	8302G	48.58
OrientalMindoro_reflights_Blk28D	8301G	108.95
TOTAL		797.49 sq km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is shown in Figure 12. Since the Gemini and Aquarius systems both employ one channel, an average value of 1 (blue) would be expected 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.

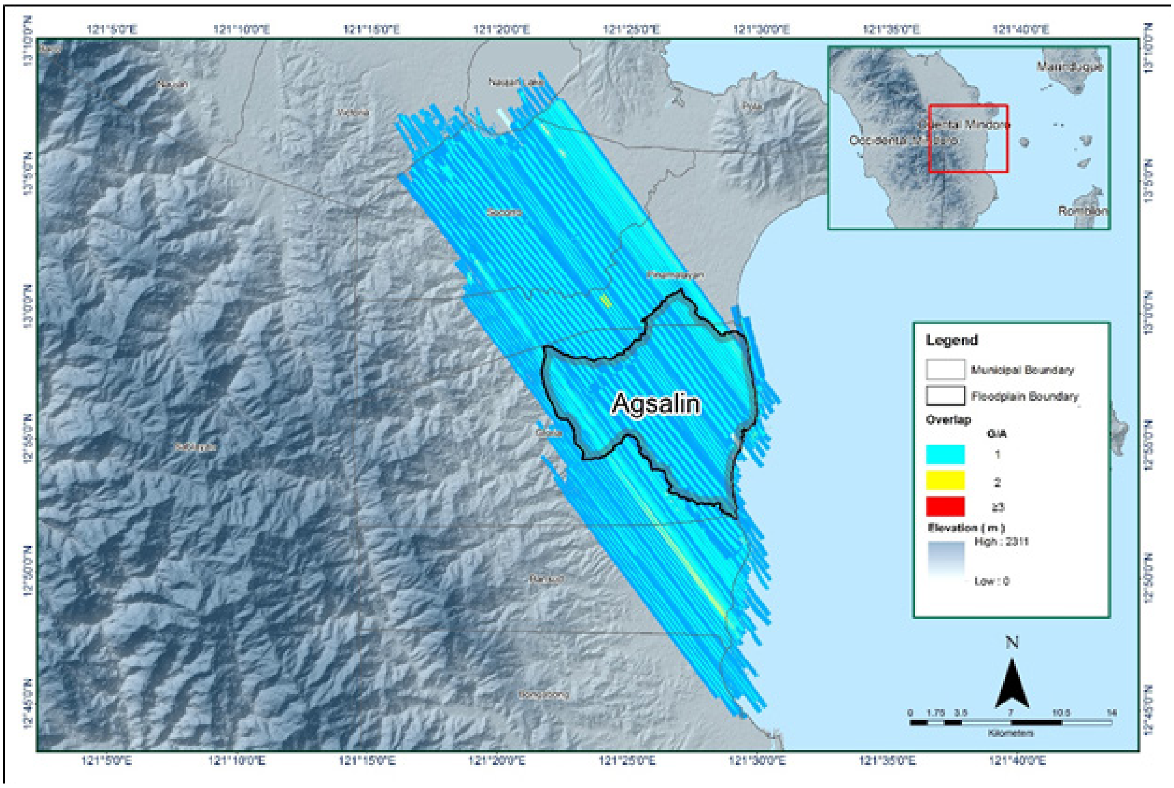


Figure 12. Image of data overlap for Agsalin Floodplain

The overlap statistics per block for the Agsalin 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 25.89% and 65.39%, respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion, is shown in Figure 13. It was determined that all LiDAR data for Agsalin Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.12 points per square meter.

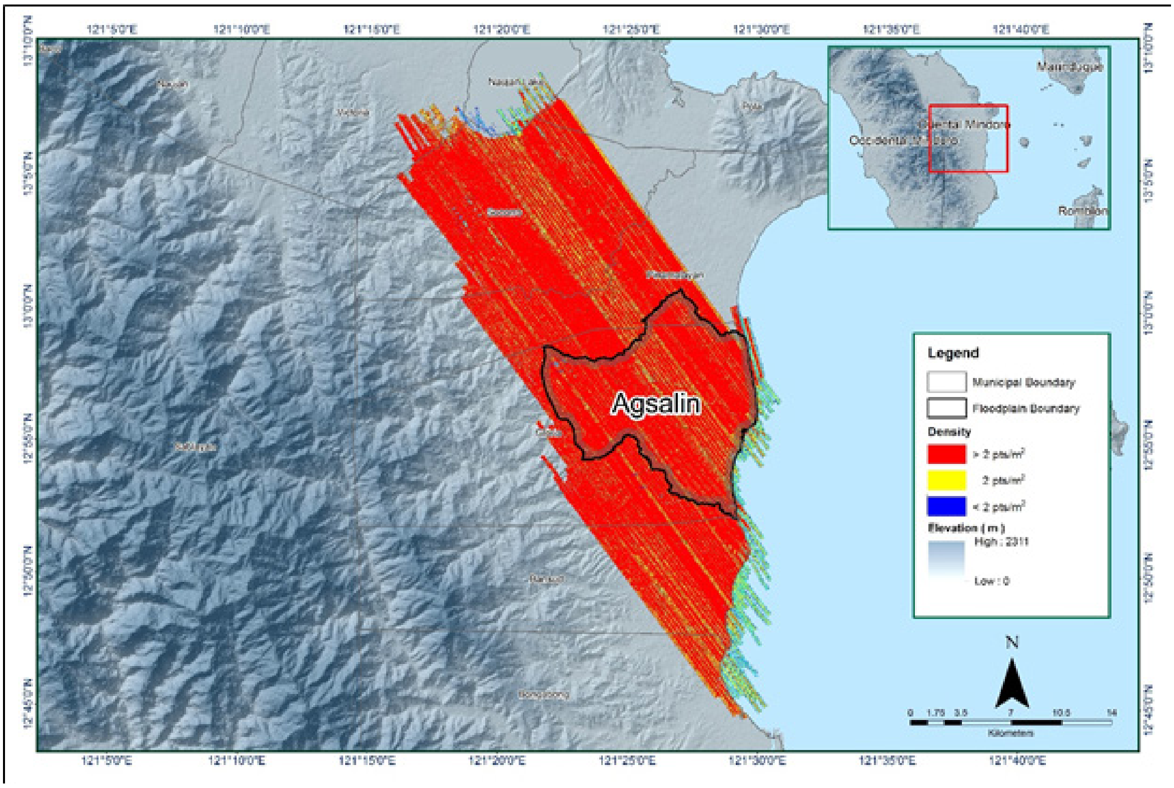


Figure 13. Pulse density map of merged LiDAR data for Agsalin Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 m 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 0.20 m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

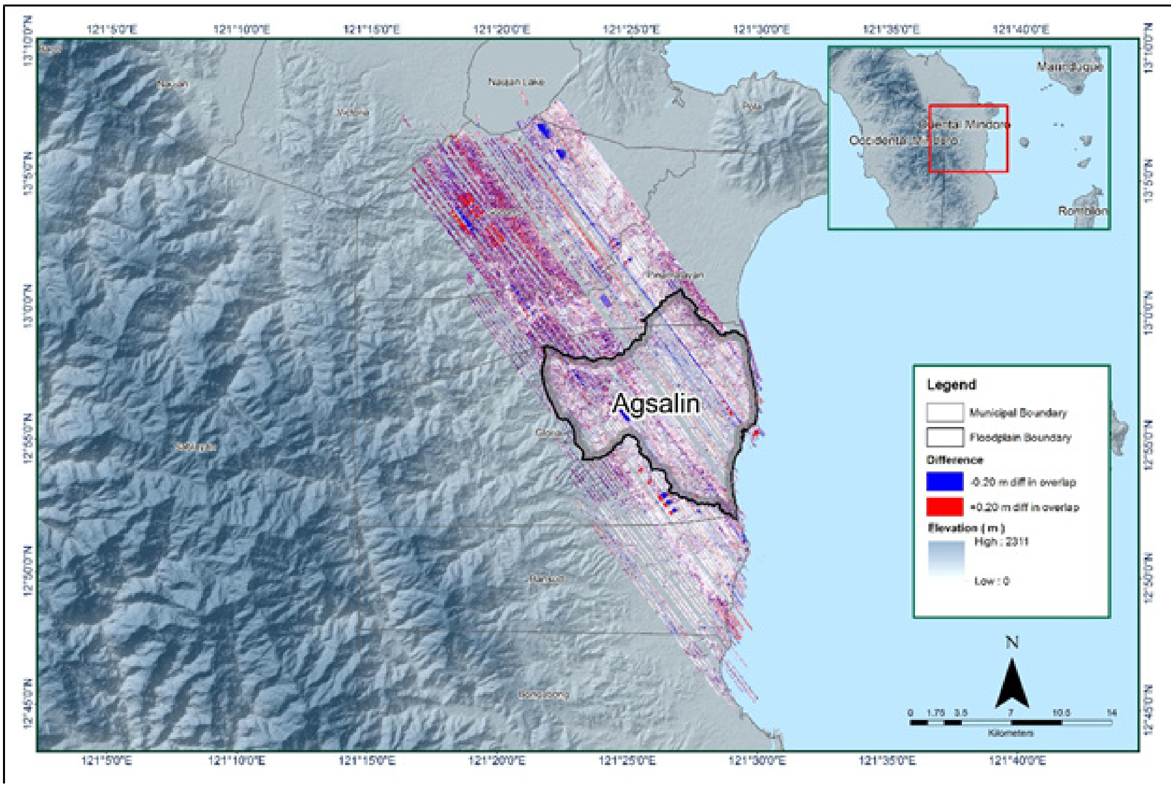


Figure 14. Elevation difference map between flight lines for Agsalin Floodplain

A screen capture of the processed LAS data from Agsalin flight 1056A loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

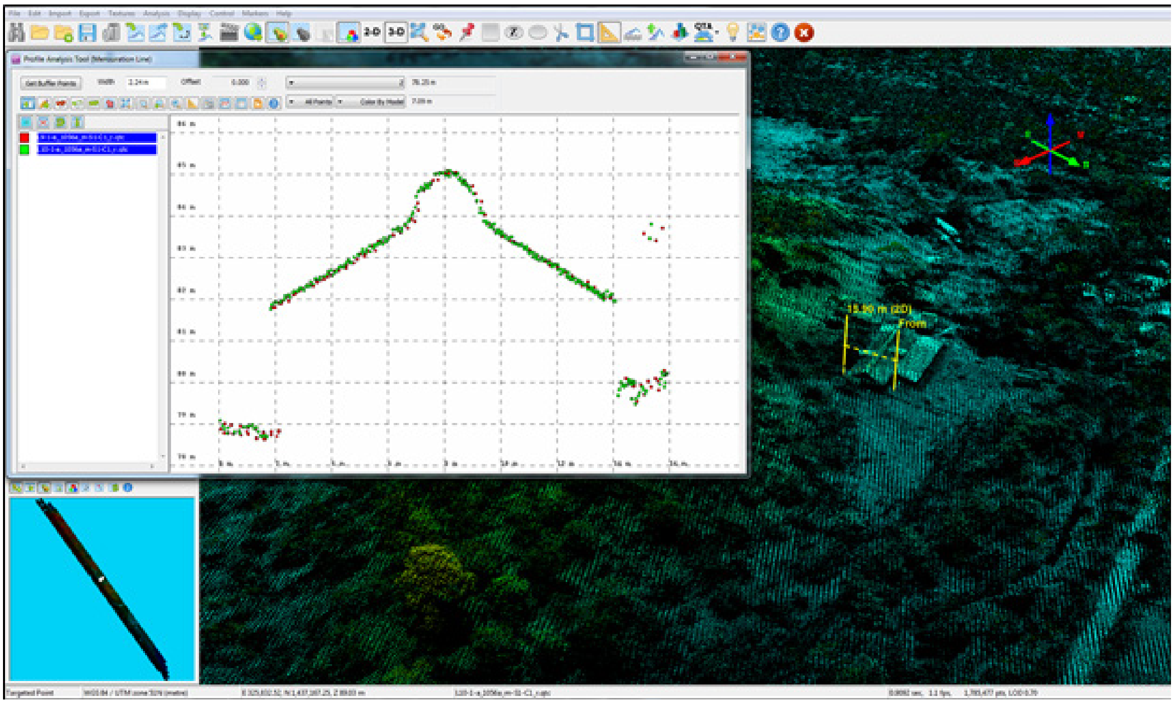


Figure 15. Quality checking for a Agsalin flight 1056A using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Agsalin classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	507,505,701
Low Vegetation	597,441,458
Medium Vegetation	659,032,482
High Vegetation	896,916,170
Building	21,666,425

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Agsalin Floodplain is shown in Figure 16. A total of 1,607 1 km by 1 km 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 388.61 meters and 45.57 meters, respectively.

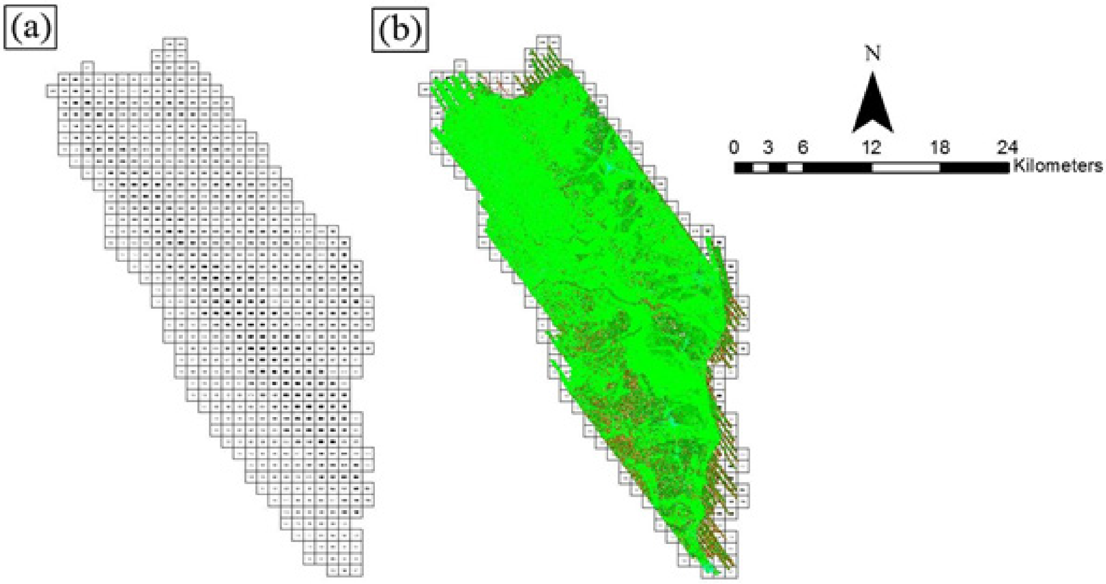


Figure 16. Tiles for Agsalin Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly due to the density of the LiDAR data.

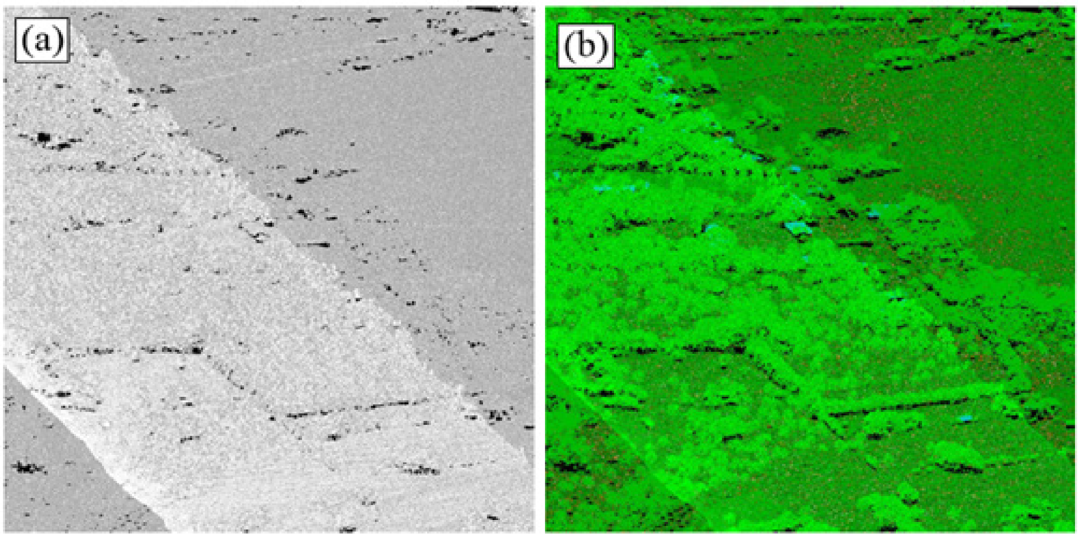


Figure 17. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 18. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

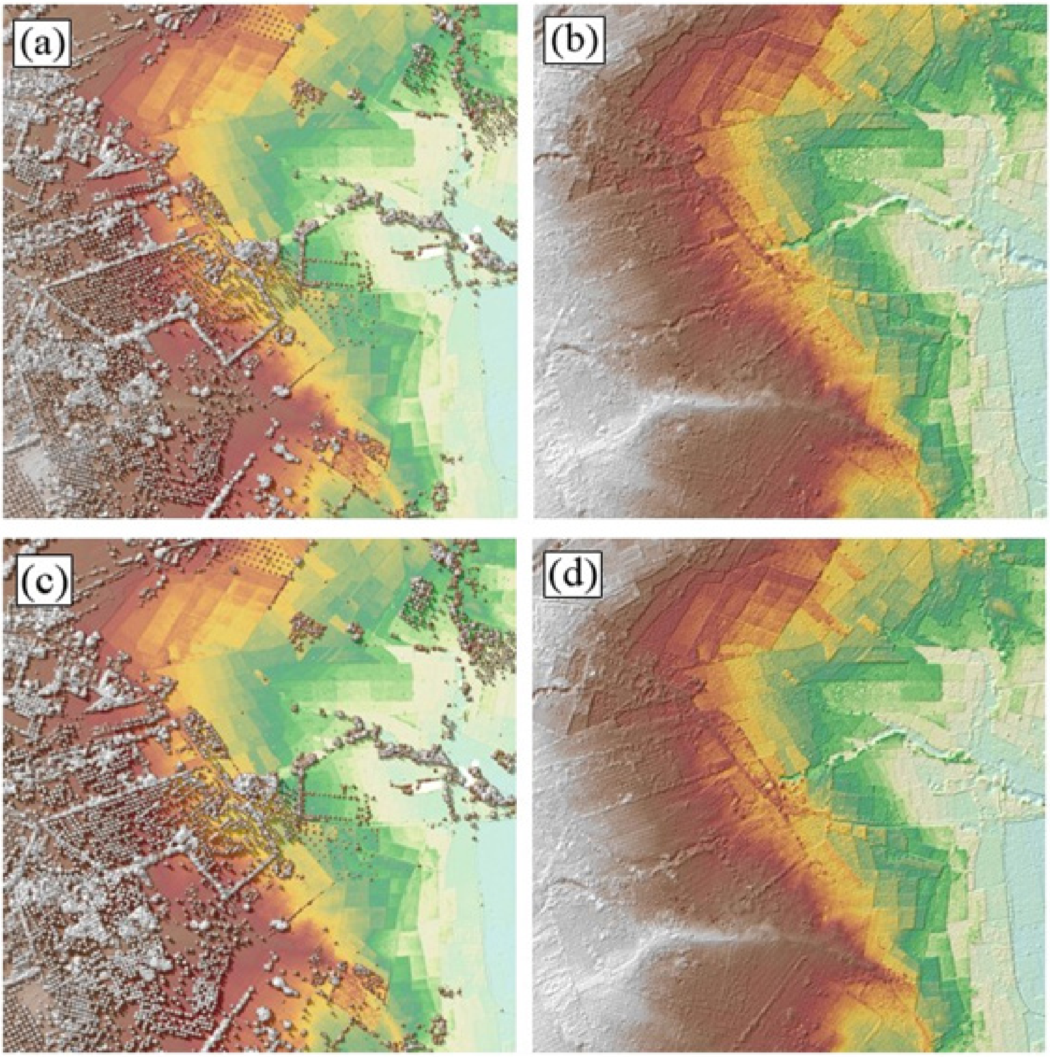


Figure 18. The production of last return DSM (a) and DTM (b); first return DSM (c) and secondary DTM (d) in some portion of Agsalin Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 961 1 km by 1 km tiles area covered by Agsalin Floodplain is shown in Figure 19. After tie-point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Agsalin Floodplain attained a total of 433.06 sq km in orthophotogaph coverage comprised of 4,483 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

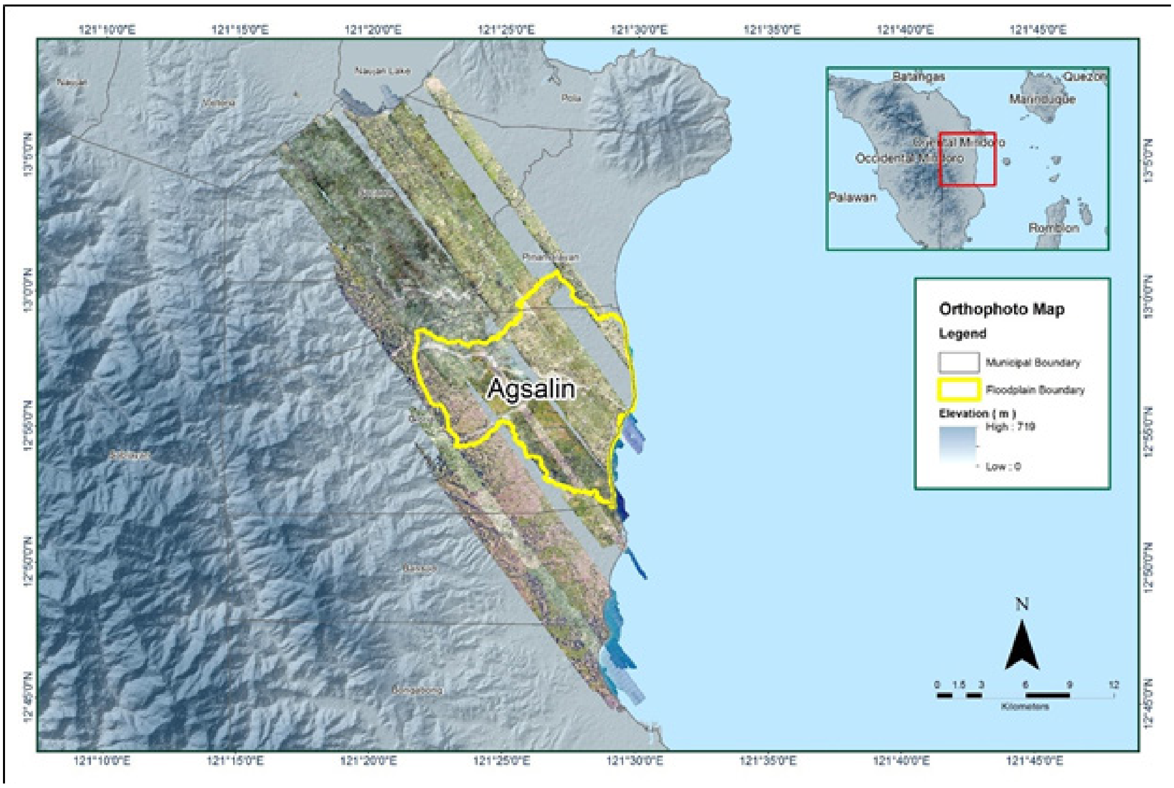


Figure 19. Agsalin Floodplain with available orthophotographs

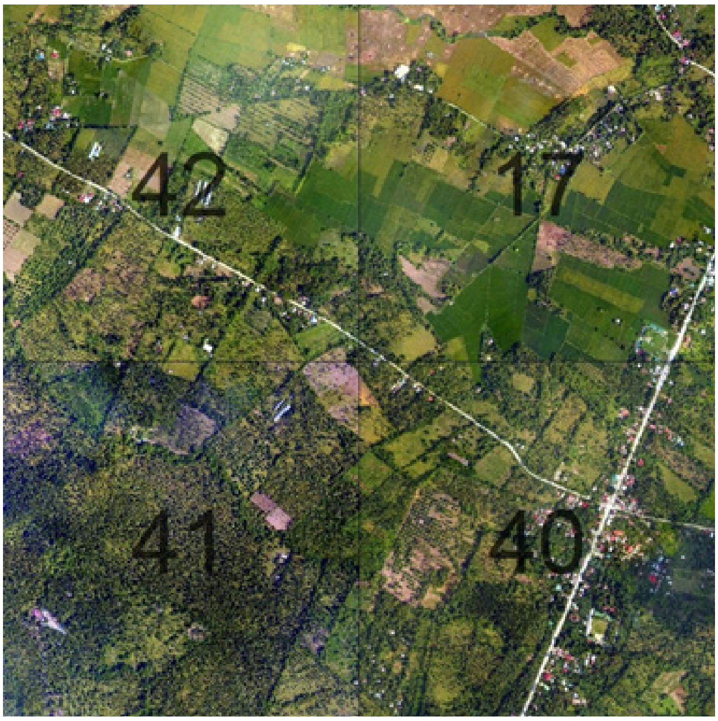


Figure 20. Sample orthophotograph tiles for Agsalin Floodplain

3.8 DEM Editing and Hydro-Correction

Twelve (12) mission blocks were processed for Agsalin Floodplain. These blocks are composed of Mindoro and OrientalMindoro_reflights blocks with a total area of 797.49 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with their corresponding area

LiDAR Blocks	Area (sq km)
OrientalMindoro_Blk28B	74.11
OrientalMindoro_Blk28B_supplement	47.08
OrientalMindoro_Blk28B_supplement_additional	11.37
OrientalMindoro_Blk28C	29.38
OrientalMindoro_Blk28C_supplement	87.46
Mindoro_Blk28D	67.39
Mindoro_Blk28D_supplement	88.65
Mindoro_Blk28E	125.84
Mindoro_Blk28E_supplement	29.82
OrientalMindoro_reflights_Blk28A_additional	5.27
OrientalMindoro_reflights_Blk28B	73.59
OrientalMindoro_reflights_Blk28C	48.58
OrientalMindoro_reflights_Blk28D	108.95
TOTAL	797.49 sq km.

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) was considered to be an impedance to the flow of water along the river and had to be removed (Figure 21b) in order to hydrologically correct the river. Also, the mountain (Figure 21c) had been misclassified and removed during classification process and had to be retrieved to complete the surface (Figure 21d).

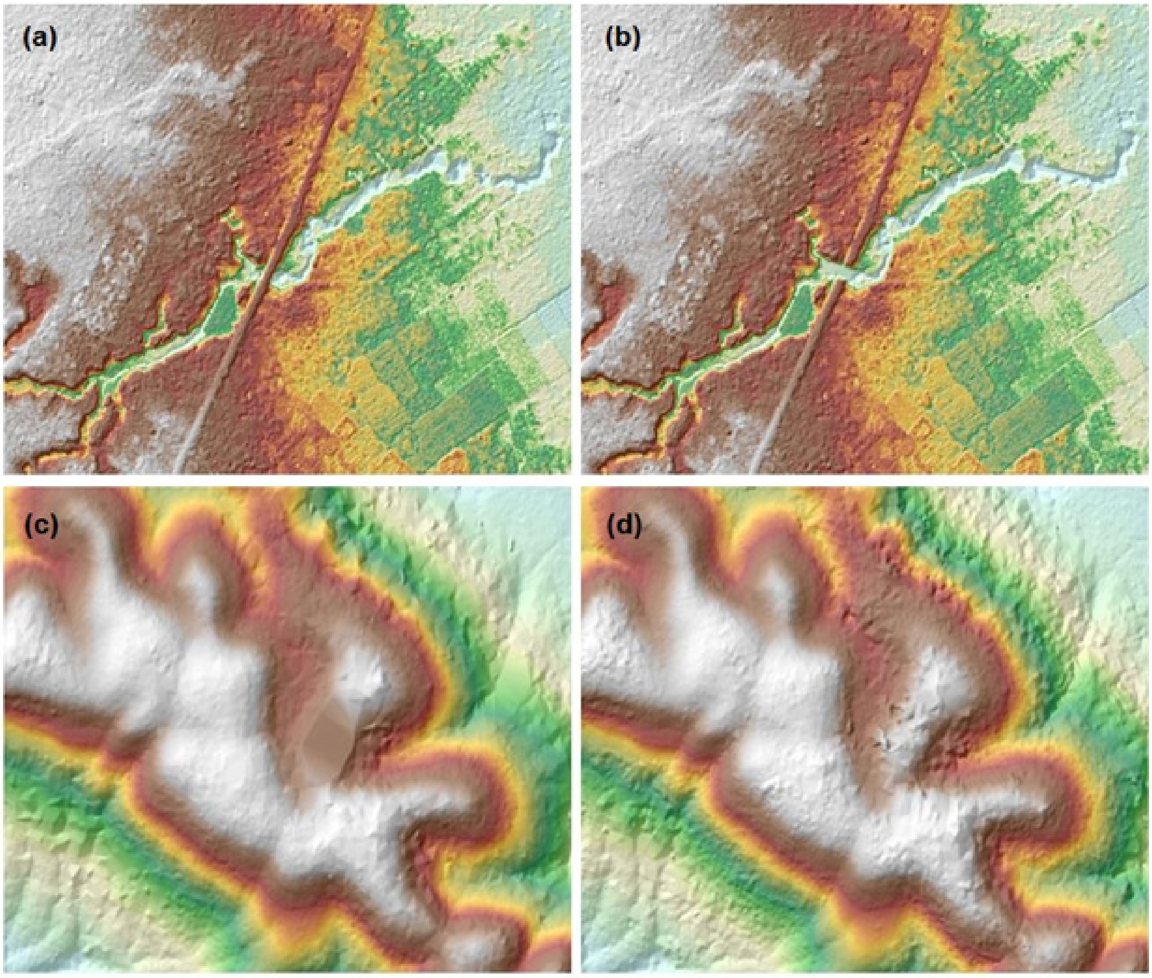


Figure 21. Portions in the DTM of Agsalin Floodplain—a bridge before (a) and after (b) manual editing; and a misclassified mountain before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

Mindoro_Blk29N 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.

Table 17. Shift values of each LiDAR Block of Agsalin Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
OrientalMindoro_ Blk28B	0.00	0.00	0.90
OrientalMindoro_ Blk28B_supplement	0.00	0.00	0.68
OrientalMindoro_ Blk28B_supplement_ additional	0.00	0.00	0.68
OrientalMindoro_ Blk28C	0.00	0.00	0.68
OrientalMindoro_ Blk28C_supplement	-0.17	0.00	0.68
OrientalMindoro_ Blk28D	0.00	0.00	0.75
OrientalMindoro_ Blk28D_supplement	0.00	0.00	0.92
OrientalMindoro_ Blk28E	0.00	0.00	0.69
OrientalMindoro_ Blk28E_supplement	0.00	0.00	0.78
OrientalMindoro_ Reflights_Blk28A_ additional	0.00	0.00	0.00
OrientalMindoro_ Reflights_Blk28B	0.00	0.00	0.00
OrientalMindoro_ Reflights_Blk28C	0.00	0.00	0.20
OrientalMindoro_ Reflights_Blk28D	0.00	0.00	-0.12

Mosaicked LiDAR DTM for Agsalin Floodplain is shown in Figure 21. It can be seen that the entire Agsalin Floodplain is 99.88% covered by LiDAR data.

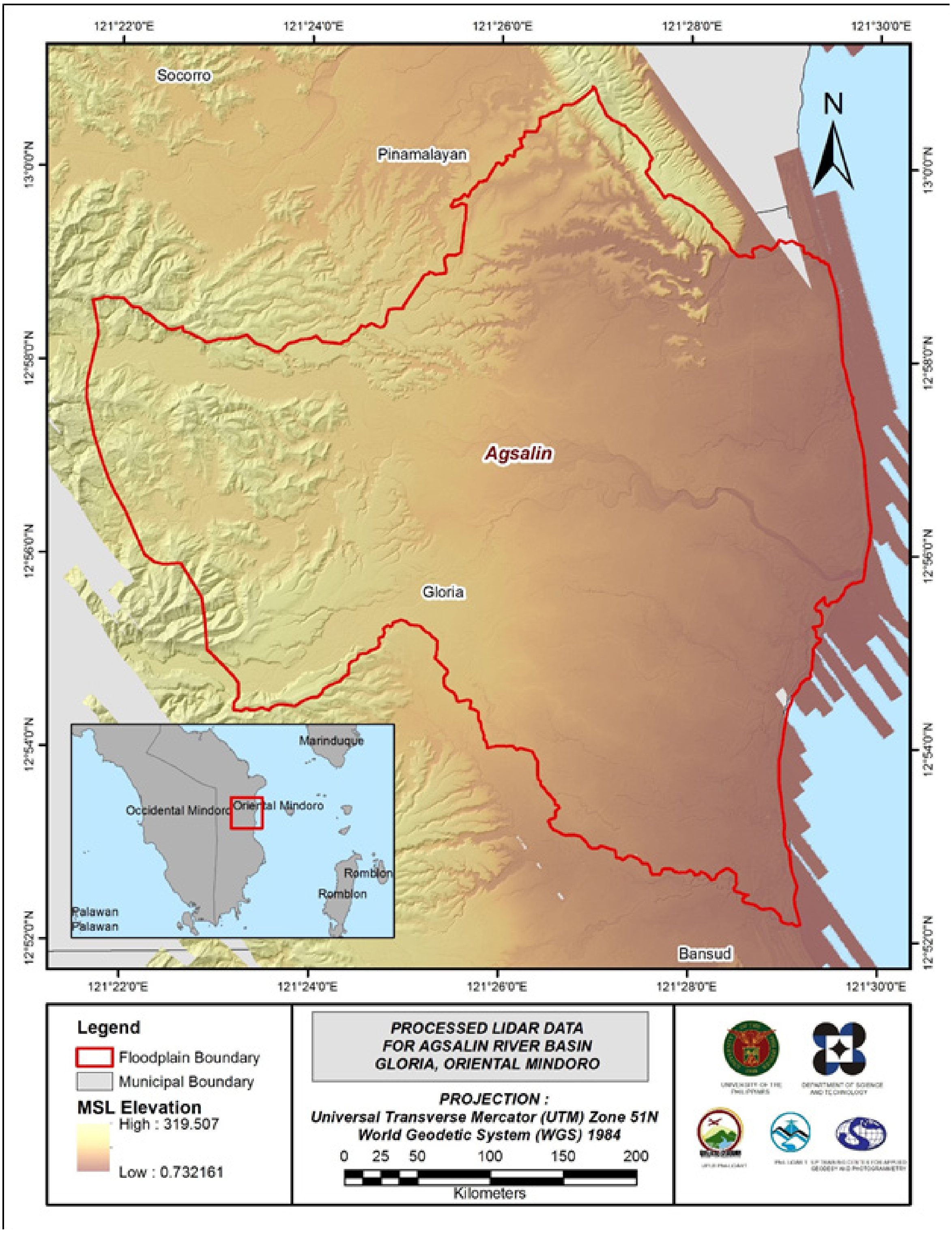


Figure 22. Map of processed LiDAR data for Agsalin Floodplain

3.10 Mosaicking of Blocks

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Agsalin to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 2,063 survey points were used for calibration and validation of Agsalin LiDAR data. Eighty percent of the survey points, resulting in 1,672 points, were randomly selected and used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 24. 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 2.70 meters with a standard deviation of 0.11 meters. Calibration of Agsalin LiDAR data was done by adding the height difference value, 2.70 meters, to Agsalin mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

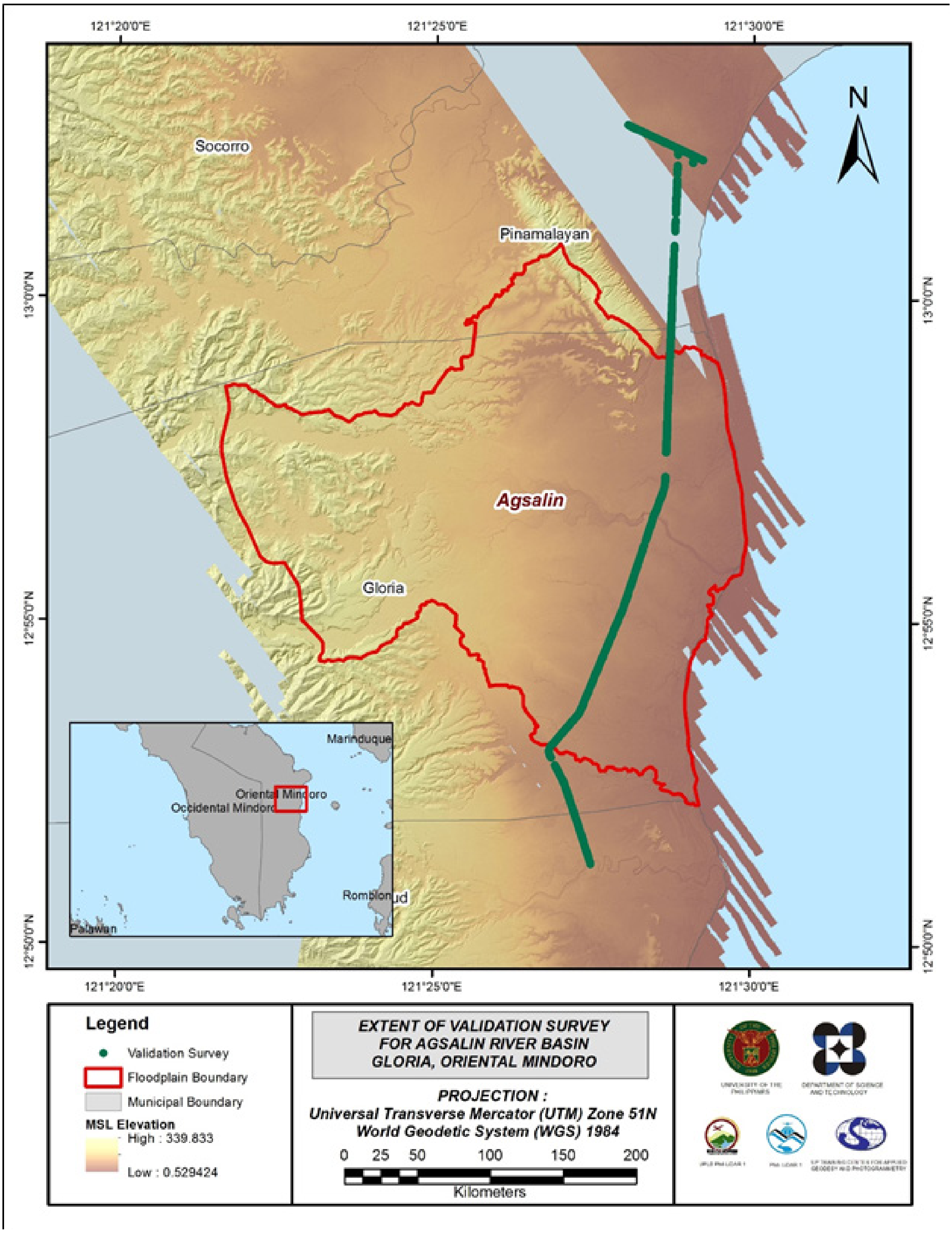


Figure 23. Map of Agsalin Floodplain with validation survey points in green

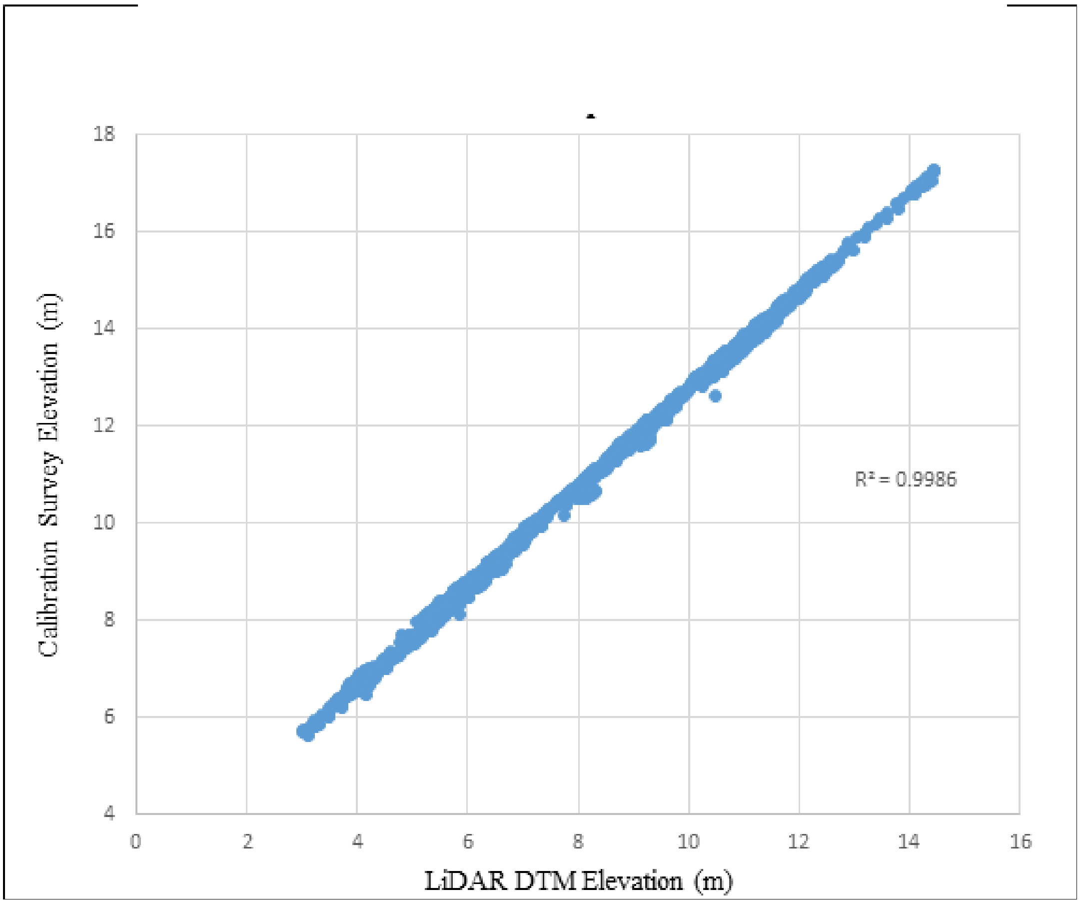


Figure 24. Correlation plot between calibration survey points and LiDAR data

Table 18. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.70
Standard Deviation	0.11
Average	-2.70
Minimum	-2.91
Maximum	-2.49

The remaining 20% of the total survey points, resulting in 391 points, were used for the validation of calibrated Agsalin 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.01 meters with a standard deviation of 0.01 meters, as shown in Table 19.

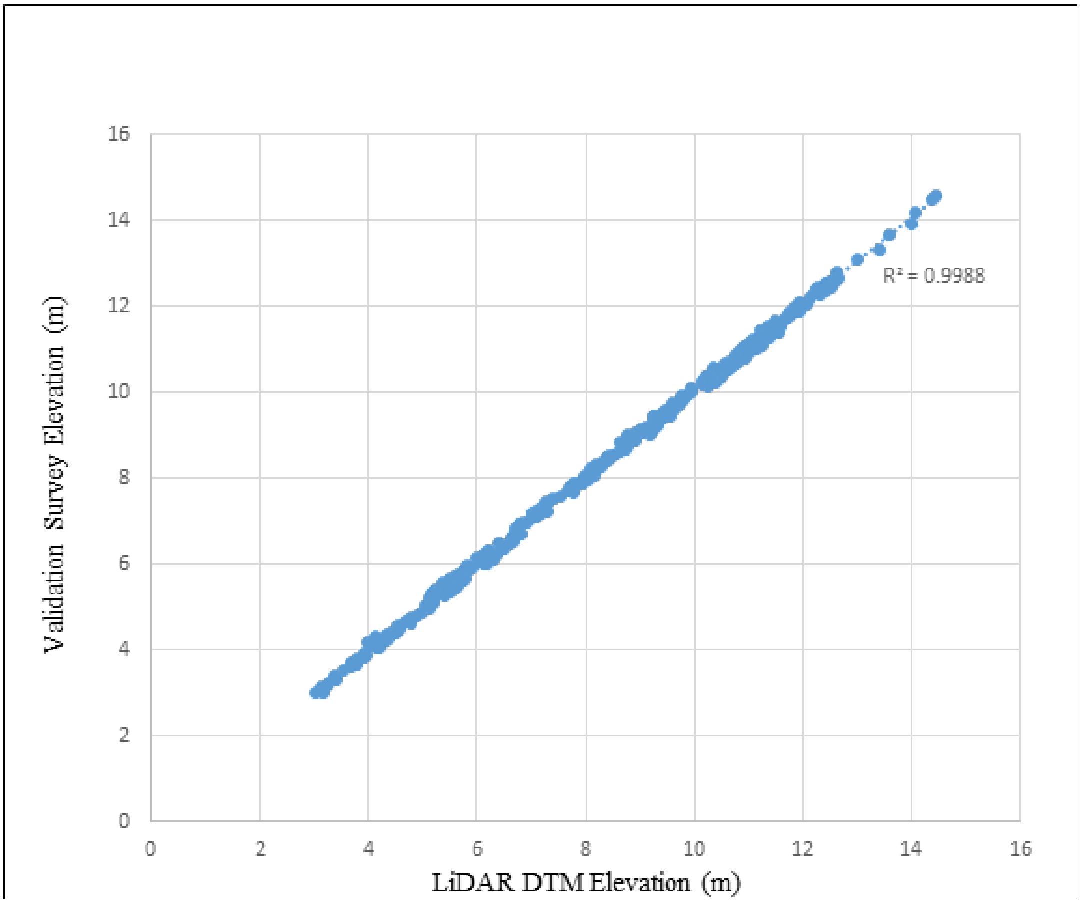


Figure 25. Correlation plot between validation survey points and LiDAR data

Table 19. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.01
Standard Deviation	0.01
Average	-0.01
Minimum	-0.20
Maximum	0.18

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Agsalin with 140 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.002 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Agsalin integrated with the processed LiDAR DEM is shown in Figure 26.

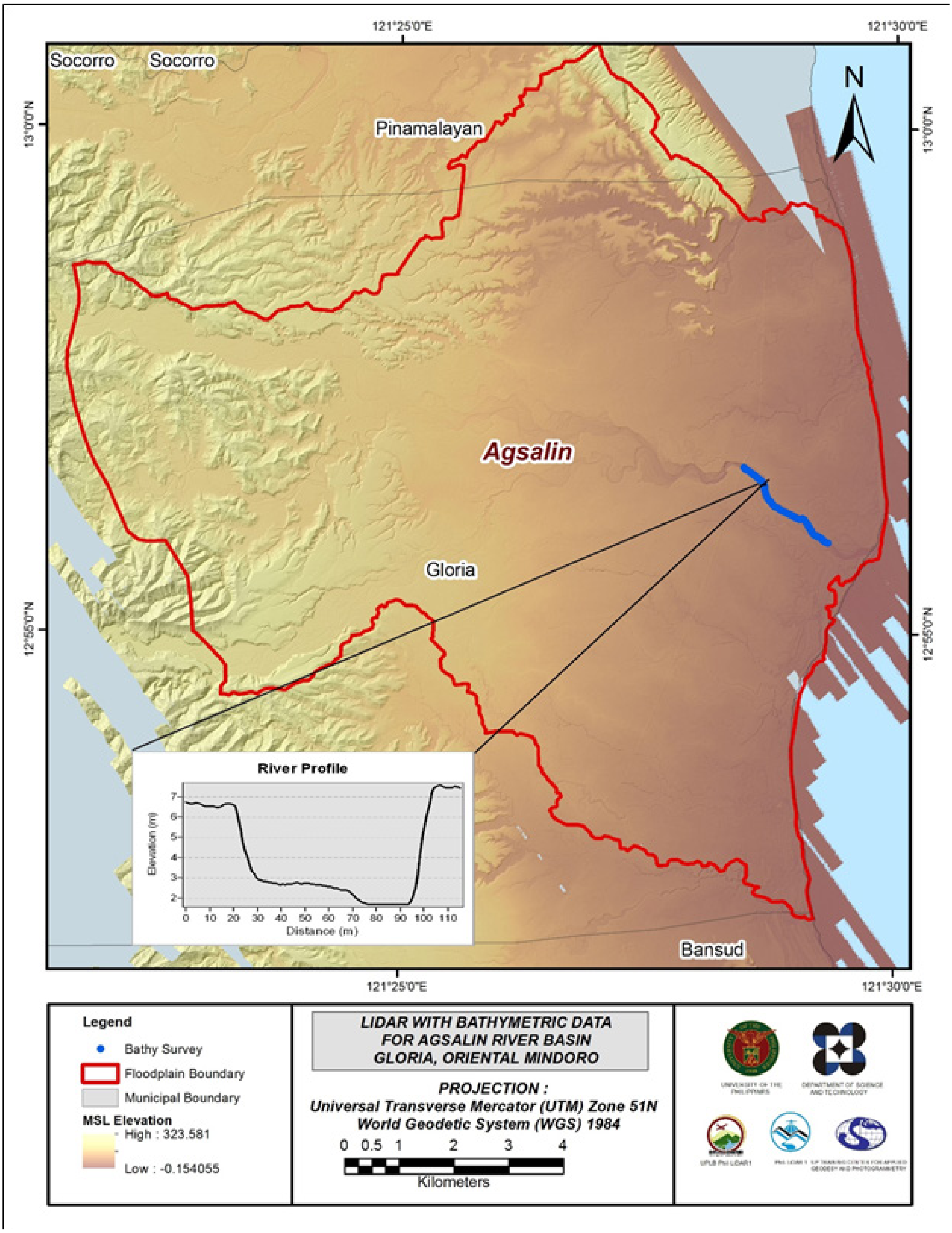


Figure 26. Map of Agsalin Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Agsalin Floodplain, including its 200 m buffer, has a total area of 208.01 sq km. For this area, a total of 6.0 sq km, corresponding to a total of 1,031 building features, were considered for QC. Figure 27 shows the QC blocks for Agsalin Floodplain.

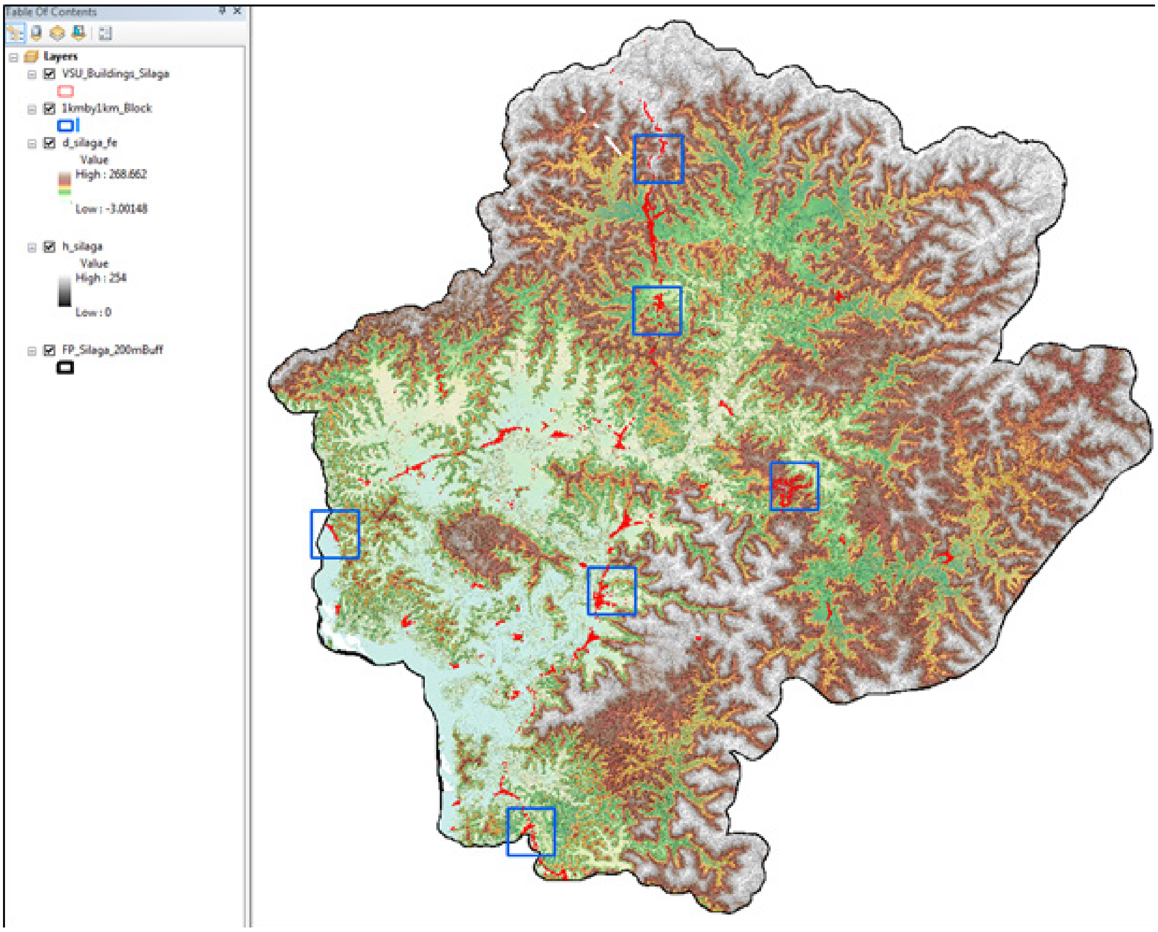


Figure 27. Blocks of Agsalin building features subjected to QC

Quality checking of Agsalin building features resulted in the ratings shown in Table 20.

Table 20. Quality Checking Ratings for Agsalin Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Agsalin	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Agsalin Floodplain. Of these building features, none was filtered out after height extraction, resulting in 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

Table 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 presents the number of water features extracted per type.

Table 21. Building features extracted for Agsalin Floodplain

Facility Type	No. of Features
Residential	5,486
School	83
Market	1
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	2
Barangay Hall	9
Military Institution	14
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	4
Power Plant/Substation	3
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	18
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	21
Other Commercial Establishments	21
Total	5,690

Table 22. Total length of extracted roads for Agsalin Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Agsalin	11,139.38	1,237.66	465.98	524.05	0.00	13,367.07

Table 23. Number of extracted water bodies for Agsalin Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Agsalin	1,530	13,793	0	0	0	15,323

A total of 44 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

Figure 28 shows the Digital Surface Model (DSM) of Agsalin Floodplain overlaid with its ground features.

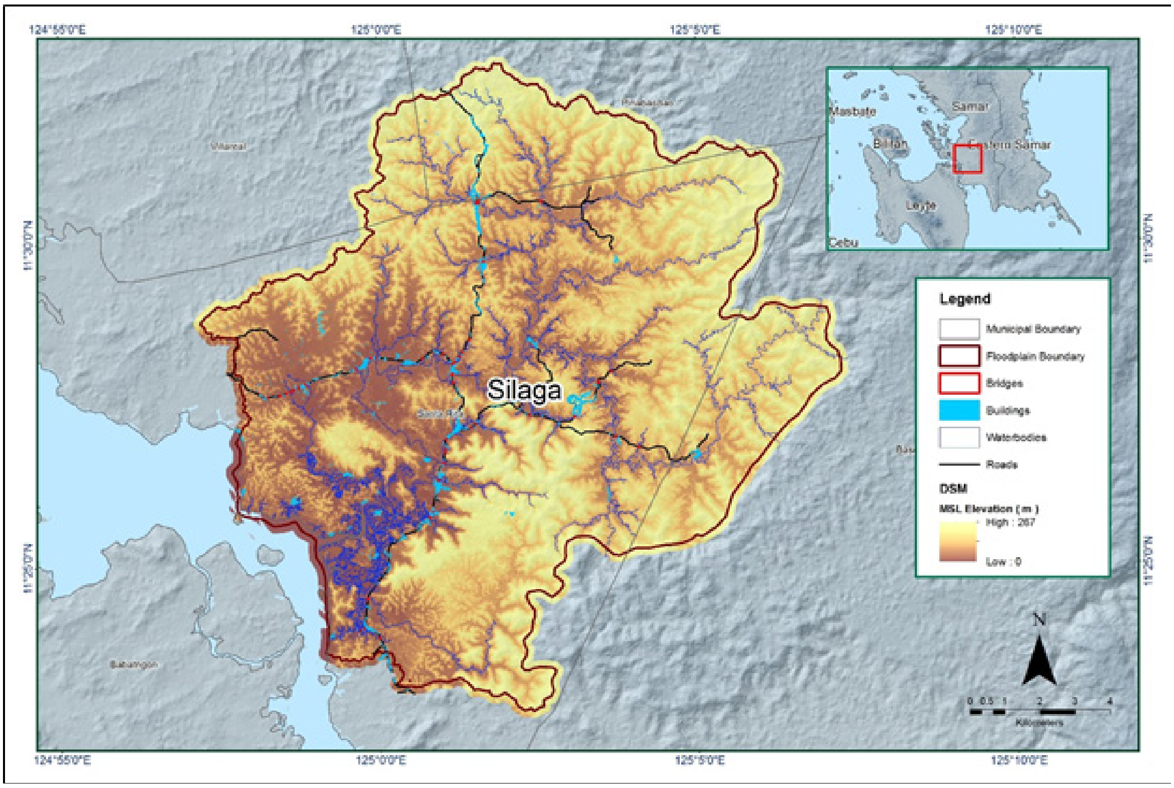


Figure 28. Extracted features for Agsalin Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE AGSALIN RIVER BASIN

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

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

DVBC conducted a field survey in Agsalin River on May 30 to June 11, 2014 with the following scope of work: reconnaissance; control survey for the establishment of control point at the approach of new Balete Bridge occupied as base station for GNSS surveys; bridge as-built and cross-section survey of old and new Balete Bridge; deployment of flow meter and depth sensor within the vicinity of the old Balete Bridge with an installed AWLS; and bathymetric survey from Brgy. Balete towards the mouth of the river in Brgy. Balete, Municipality of Gloria, Oriental Mindoro with the planned bathymetric length of 2.4 km. Another fieldwork was conducted on October 27 to November 3, 2014 to perform bridge as-built survey, water level marking of both bridges and validation points acquisition survey of about 30 km.

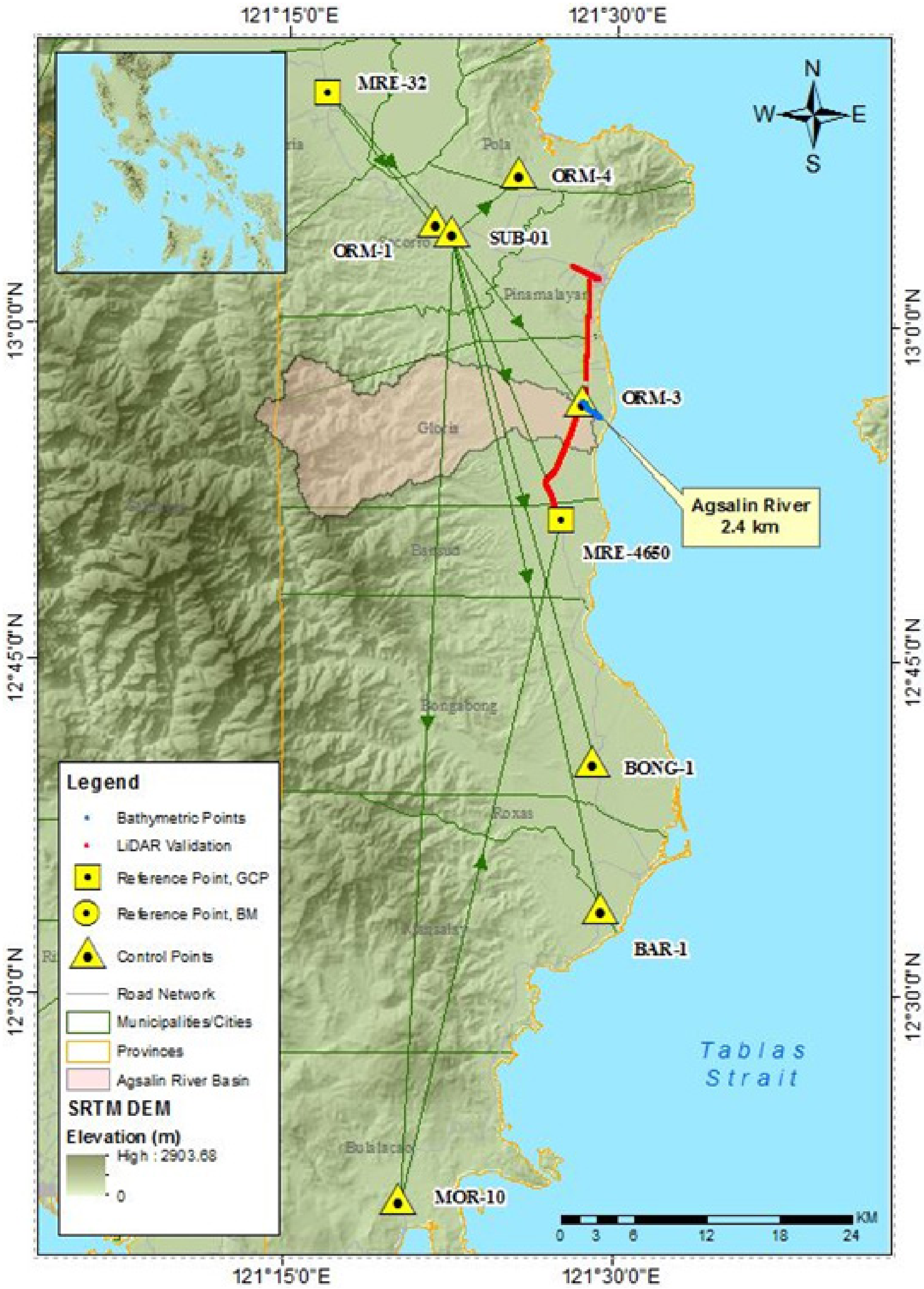


Figure 29. Extent of the bathymetric survey (in blue) in Agsalin River and the LiDAR validation survey (in red)

4.2 Control Survey

A GNSS network was established for previous PHIL-LiDAR fieldwork in Mindoro on February 28–March 11, 2013 occupying MR-178, a first-order BM located at the approach of Panggalaan Bridge in Brgy. Bucayao, Calapan City, Oriental Mindoro; and MRE-32, a second-order GCP in Brgy. Poblacion 1, Mun. of Victoria, Oriental Mindoro.

The GNSS network used for Agsalin River is composed of two (2) loops and four (4) baselines established on May 30 and May 31, 2014, occupying the reference point MRE-32, a second-order GCP fixed from the previous field survey in Mindoro Oriental for Mag Asawang Tubig river.

Seven (7) control points were established namely: BAR-1 located at the approach of Baroc Bridge in Brgy. San Isidro, Municipality of Mansalay; BONG-01 located near Bongabong Bridge in Brgy. San Isidro, Municipality of Luna; MOR-10, located at the approach of Cawacat Bridge in Brgy. Campaasan, Municipality of Bulalacao; ORM-1, located in Subaan Bridge in Barangay Subaan, Municipality of Socorro; ORM-3 located in Balete bridge in Brgy. Balete, Municipality of Gloria; ORM-4 in Pola Bridge, Brgy. Casiligan, Municipality of Pola; and SUB-01, located within the Maramot Residence in Brgy. Subaan, Municipality of Socorro. An LMS-established control point namely MRE-4650, located at Bansud Bridge, Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro was also occupied to use as marker in the survey.

The summary of reference and control points and their location is summarized in Table 24, while the GNSS network established is illustrated in Figure 30.

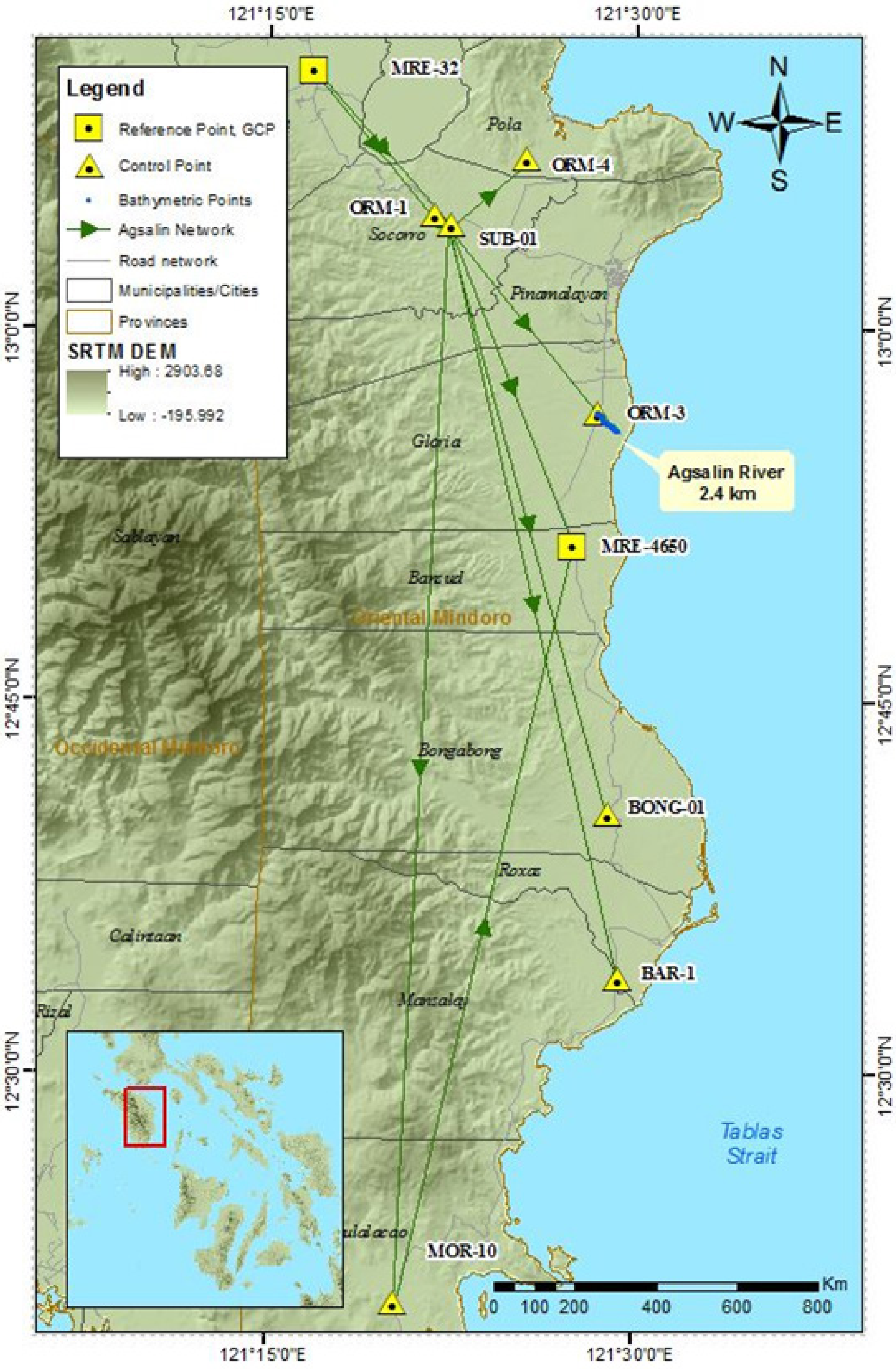


Figure 30. GNSS network of Agsalin River field survey

Table 24. List of reference and control points used in Agsalin River, Balete River Basin survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid height (Meter)	Elevation in MSL (m)	Date Established
MRE-32	2nd order, GCP	13°10'23.79251"	121°16'43.46244"	65.638	17.175	2007
MRE-4650	Used as marker	-		-	-	2011
BAR-1	UP Established	-	-	-	-	6-1-20014
BONG-01	UP Established	-	-	-	-	6-1-2014
MOR-10	UP Established	-	-	-	-	5-31-2014
ORM-1	UP Established	-	-	-	-	5-30-2014
ORM-3	UP Established	-	-	-	-	5-31-2014
ORM-4	UP Established	-	-	-	-	5-31-2014
SUB-01	UP Established	-	-	-	-	5-31-2014

The GNSS set-ups made in the location of the reference and control points are exhibited in Figure 31 to Figure 39.

Figure 31. GPS set-up of Trimble® SPS 882 at MRE-32, located at the Municipal Park of Victoria, in Brgy. Poblacion 1, Oriental Mindoro

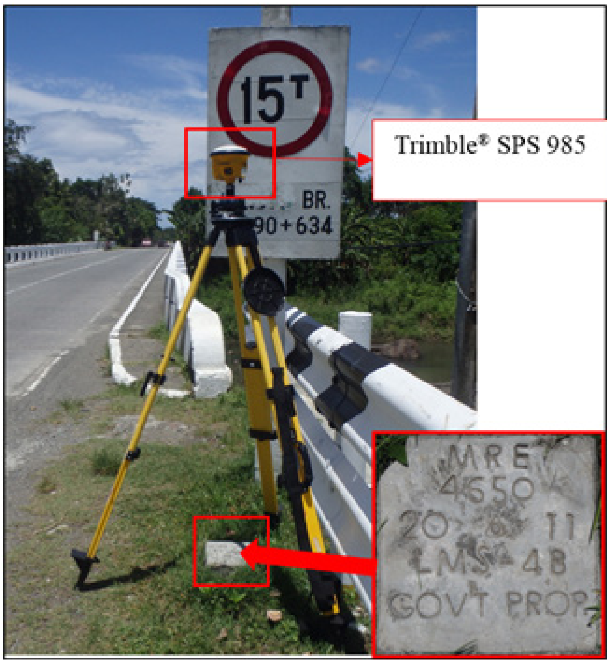


Figure 32. The GPS set-up of Trimble® SPS 985 at MRE-4650, an LMS control point located at the approach of Bansud Bridge, in Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro

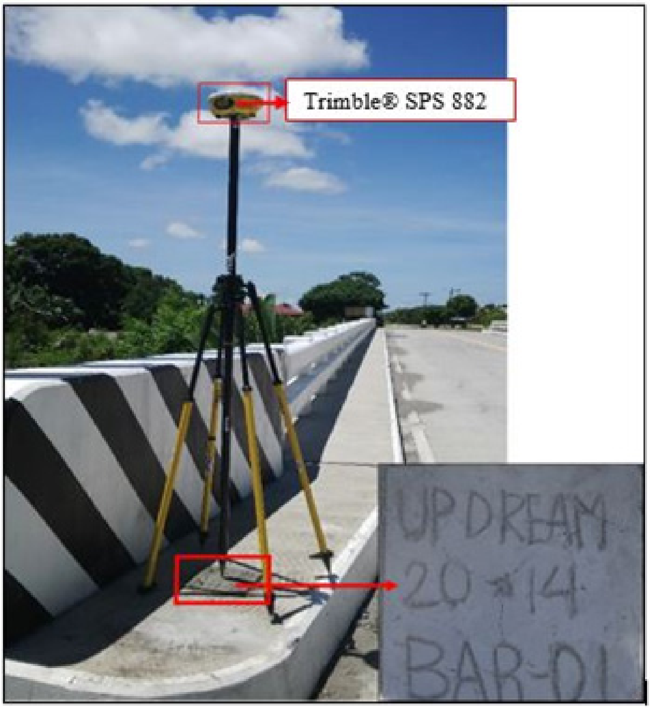


Figure 33. GPS set-up of Trimble® SPS 882 at BAR-1, an established control point located in Baroc Bridge, Brgy. San Isidro, Mansalay, Oriental Mindoro

Figure 34. GNSS set-up of Trimble® SPS 882 on BONG-01 in Brgy. San Isidro, Municipality of Bongabong, Oriental Mindoro

Figure 35. GPS set-up of Trimble® SPS 852 at MOR-10, located in the approach of the Cawacat Bridge, in Bry. Campasaan, Municipality of Bulalacao, Oriental Mindoro

Figure 36. GPS set-up of Trimble® SPS 852 at ORM-1, located on Subaan Bridge, Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

Figure 37. Trimble® SPS 985 set-up at ORM-3 located at the approach of Balete Bridge, Brgy. Balete, Municipality of Gloria, Oriental Mindoro

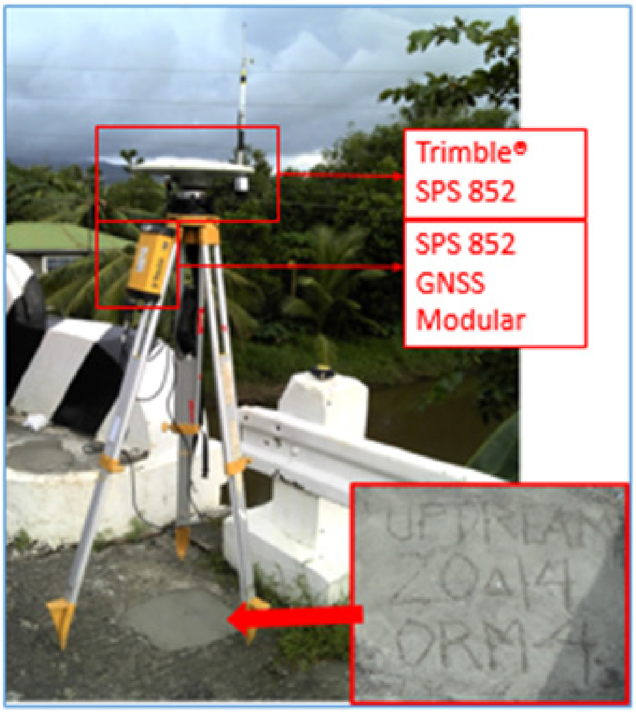


Figure 38. GNSS receiver Trimble® SPS 852 set-up at ORM-4, located at the right side of the approach of Pola Bridge in Barangay Casiligan, Municipality of Pola, Oriental Mindoro

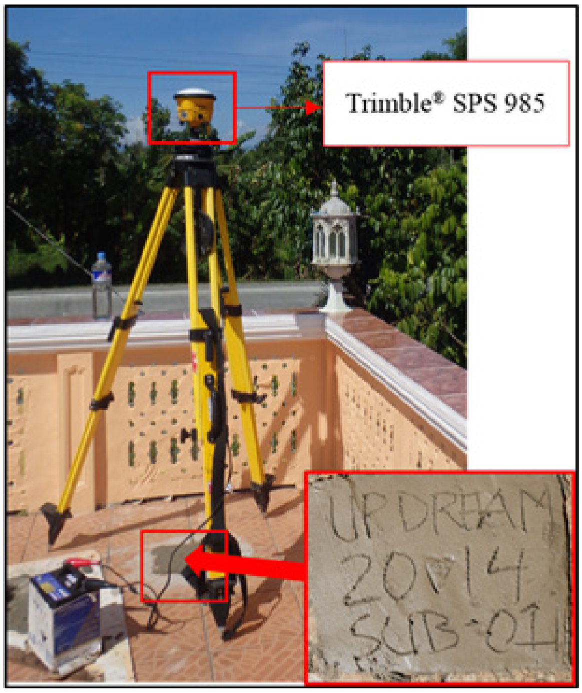


Figure 39. GPS set-up of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

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 was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Agsalin River, Balete River Basin is summarized in Table 25 generated TBC software.

Table 25. Baseline processing report for Agsalin River Static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ORM-1 --- SUB-01	05-30-2014	Fixed	0.004	0.006	301°40'27"	1466.251	4.823
SUB-01 --- MRE-32	05-30-2014	Fixed	0.010	0.031	318°11'52"	15342.18	-9.283
SUB-01 --- MOR-10	05-31-2014	Fixed	0.014	0.044	182°47'52"	80162.62	-16.502
SUB-01 --- MRE-4650	05-31-2014	Fixed	0.006	0.038	158°49'08"	25506.78	-9.971
SUB-01 --- ORM-3	5-31-2014	Fixed	0.007	0.028	141°48'05"	17755.532	-12.886
SUB-01 --- ORM-4	6-1-2014	Fixed	0.003	0.022	48°43'17"	7475.934	-19.149
SUB-01 --- BAR-1	6-1-2014	Fixed	0.024	0.107	167°15'17"	57308.832	-16.370
SUB-01 --- BONG-01	6-1-2014	Fixed	0.021	0.035	164°45'51"	45313.95	0.212
ORM-1 --- MRE 32	05-30-2014	Fixed	0.010	0.032	319°54'33"	13942.72	-14.146
MOR-10 --- MRE 4650	05-31-2014	Fixed	0.012	0.051	13°07'21"	57794.34	6.484

As shown in Table 25, a total of ten (10) baselines were processed and all of them passed the required accuracy set by the project.

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:

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

Where:

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

The five (5) control points, MRE-32, ORM-1, MOR-10, MRE-4650, and SUB-01, were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MRE-32 were held fixed during the processing of the control points as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 26. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MRE-32	Grid	Fixed	Fixed	Fixed	Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 27. All fixed control points have no values for grid and elevation errors.

Table 27. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MOR-10	319188.891	0.010	1365393.240	0.010	6.868	0.052	
MRE-32	313449.201	?	1456936.499	?	17.175	?	ENe
MRE-4650	332665.789	0.008	1421592.819	0.006	14.627	0.049	
ORM-1	322358.982	0.007	1446211.774	0.003	30.565	0.028	
SUB-01	323601.847	0.007	1445433.872	0.003	25.687	0.028	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 27. Using the equation $\sqrt{((x_e))^2+((y_e))^2)}<20cm$ for horizontal and $z_e<10$ cm for the vertical; below is the computation for accuracy that passed the required precision:

MRE-32
Horizontal accuracy = Fixed
Vertical accuracy = Fixed

MOR-10
Horizontal accuracy = $\sqrt{((1.0)^2 + (1.0)^2}$
= $\sqrt{(1.0 + 1.0)}$
= 1.1 cm < 20 cm
Vertical accuracy = 1.4 cm< 10 cm

MRE-4650
Horizontal accuracy = $\sqrt{((0.8)^2 + (0.6)^2}$
= $\sqrt{(0.64 + 0.36)}$
= 1.0 cm < 20 cm
Vertical accuracy = 4.9 cm < 10 cm

ORM-1
Horizontal accuracy = $\sqrt{((0.7)^2 + (0.3)^2}$
= $\sqrt{(0.49 + 0.90)}$
= 1.2 cm < 20 cm
Vertical accuracy = 2.8 cm < 10 cm

SUB-01
Horizontal accuracy = $\sqrt{((0.7)^2 + (0.3)^2}$
= $\sqrt{(0.49 + 0.90)}$
= 1.2 cm < 20 cm
Vertical accuracy = 2.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required accuracy of the project.

Table 28. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
MOR-10	N12°20'46.18547"	E121°20'13.54772"	58.186	0.052	
MRE-32	N13°10'23.79251"	E121°16'43.46244"	65.368	?	ENe
MRE-465	N12°51'17.70515"	E121°27'28.71020"	64.693	0.049	
ORM-1	N13°04'36.74731"	E121°21'41.63863"	79.500	0.028	
SUB-01	N13°04'11.69491"	E121°22'23.06063"	74.676	0.028	

The adjusted geodetic coordinates is shown in Table 28. The height errors for CG-343 and CG-521 are less than the 10 cm accuracy requirement by the project. All of the points complied with the vertical accuracy required by the program.

The summary of reference and control points used is indicated in Table 29.

Table 29. List of references and control points used in Agsalin River survey

Control Point	Order	Geographic Coordinates (WGS 84)			UTM Zone N51		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Elevation in MSL
MRE-32	2nd Order, GCP	13°10'23.79251"	121°16'43.46244"	65.368	1456936.499	313449.201	17.175
MRE-4650	Used as Marker	12°51'17.70515"	121°27'28.71020"	64.693	1421592.819	332665.789	14.627
BAR-1	UP Established	12°33'52.65149"	121°29'21.90040"	58.344	1389460.775	335892.131	6.953
BONG-01	UP Established	12°40'28.89755"	121°28'57.71173"	74.917	1401640.553	335232.485	23.974
MOR-10	UP Established	12°20'46.18547"	121°20'13.54772"	58.186	1365393.24	319188.891	6.868
ORM-1	UP Established	13°04'36.74731"	121°21'41.63863"	79.5	1446211.774	322358.982	30.565
ORM-3	UP Established	12°56'37.56304"	121°28'27.33712"	61.799	1431410.893	334491.821	12.031
ORM-4	UP Established	13°06'52.16736"	121°25'29.58456"	55.523	1450329.531	329251.554	6.585
SUB-01	UP Established	13°04'11.69491"	121°22'23.06063"	74.676	1445433.872	323601.847	25.687

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

The GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized to acquire the cross section of Agsalin River along the downstream side of old Balete Bridge and new Balete Bridge in Brgy. Balete, Municipality of Gloria on June 2, 2014 as shown in Table 40.

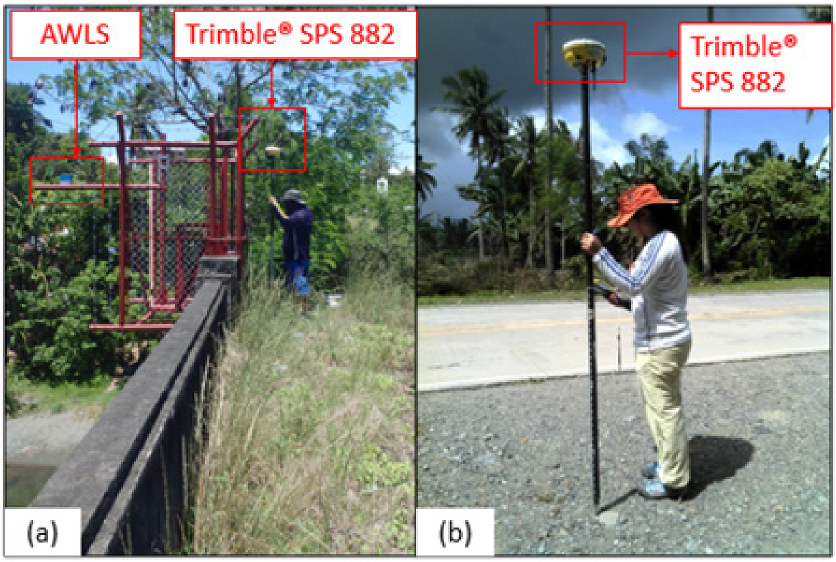


Figure 40. (a) Cross-section and as-built survey at the Old Balete Bridge and (b) the New Balete

As-built surveys for both the old and new Balete Bridges in Brgy. Balete, Agsalin River, Oriental Mindoro were conducted on October 31, 2014. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high chord and meter tapes to get its low chord elevation. The control point ORM-4 was used as the base station for both cross-section and bridge as-built survey.

The cross-sectional line for both the old and new Balete Bridges is about 206.68 m with 30 cross-sectional points. The summary of gathered planimetric map, cross-section, and as-built data for the bridges are shown in Table 41 to Table 45, respectively.

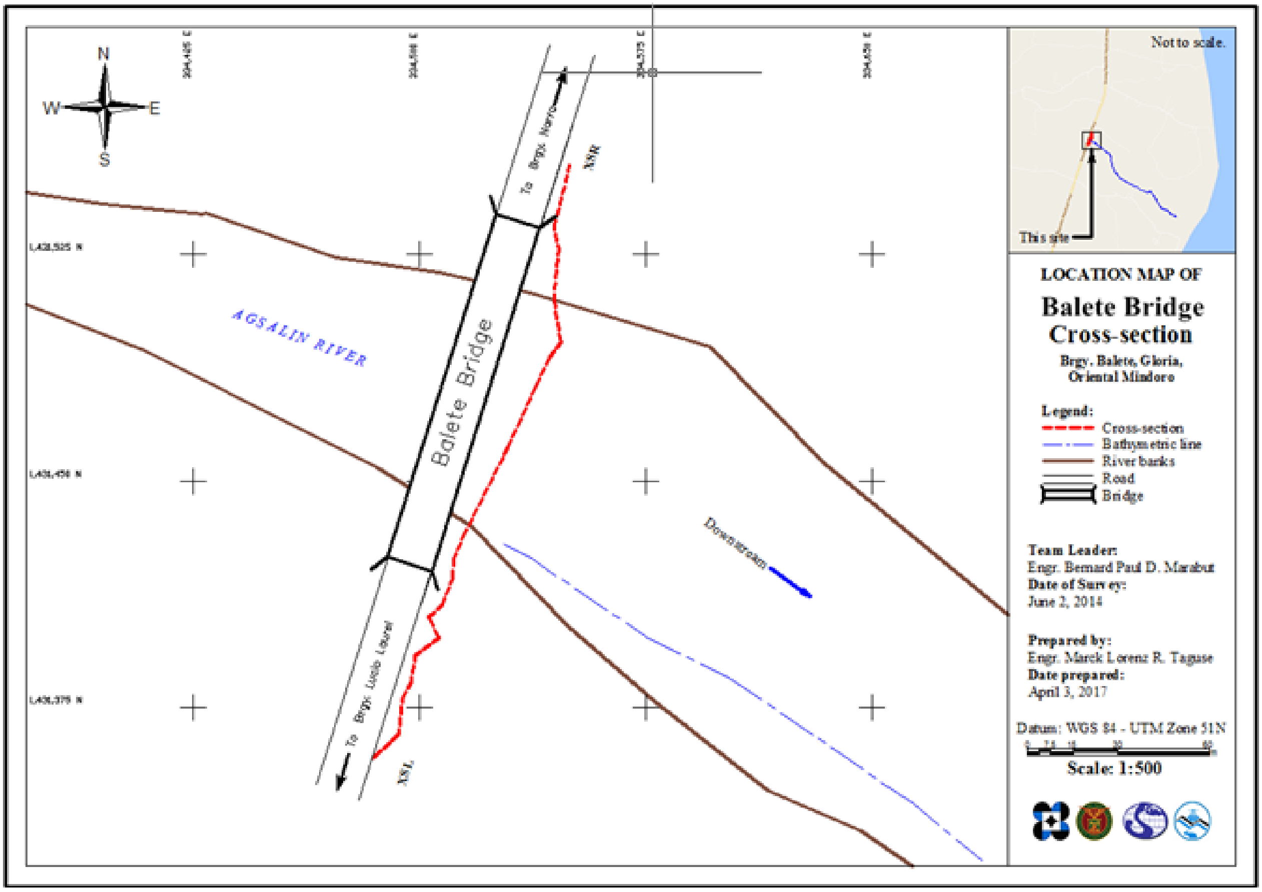


Figure 41. Balete Bridge planimetric map

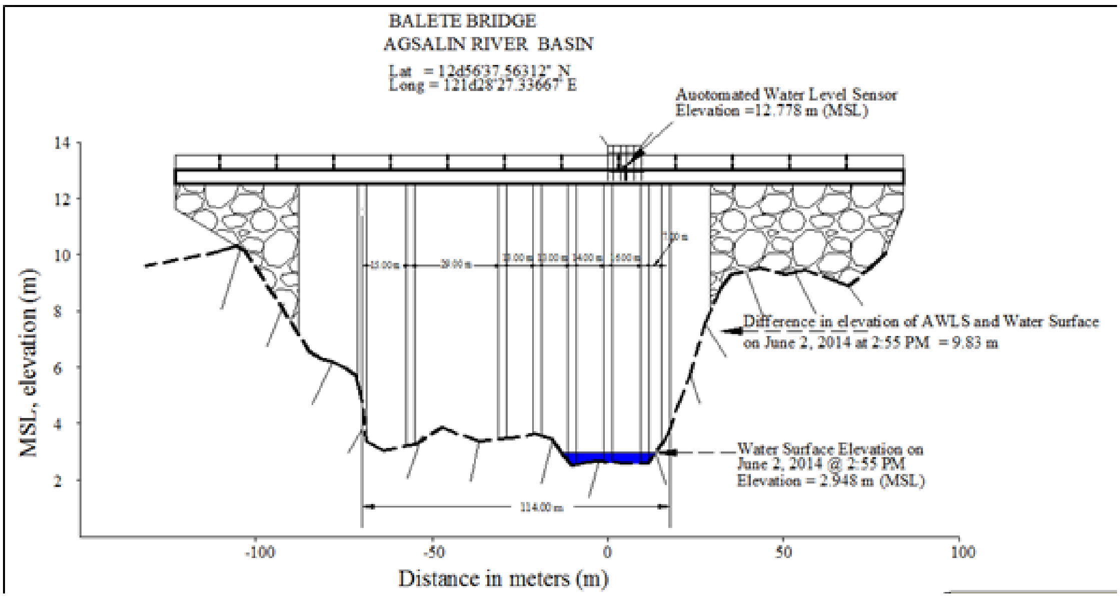


Figure 42. Old Balete Bridge cross-sectional diagram

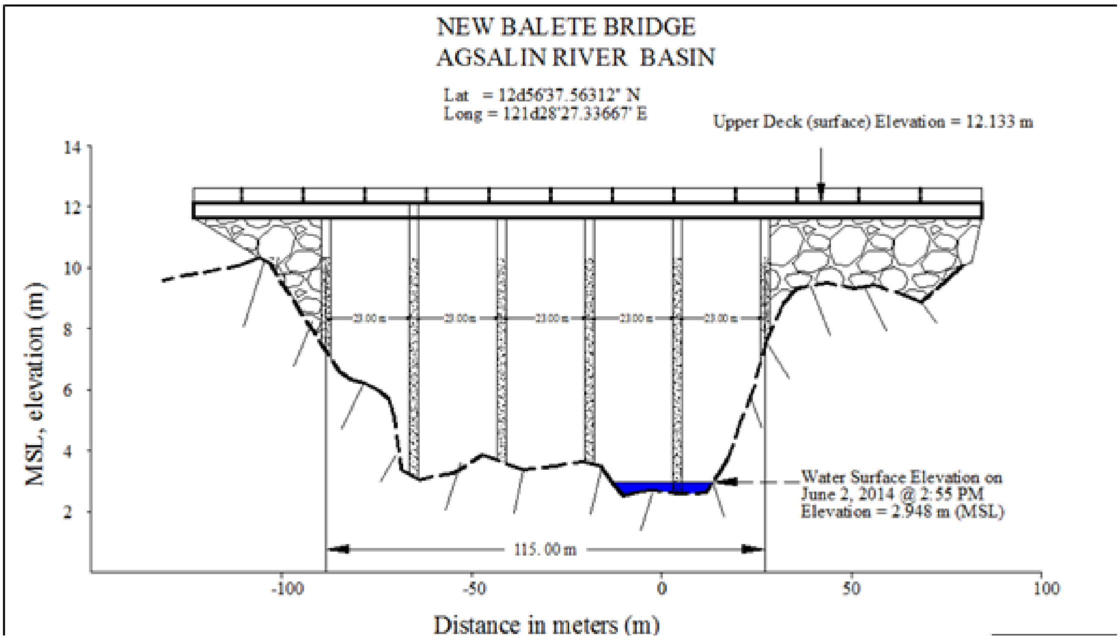


Figure 43. New Balete Bridge cross-sectional diagram

Bridge Data Form

Bridge Name: Old Balete Bridge **Date:** June 2, 2014

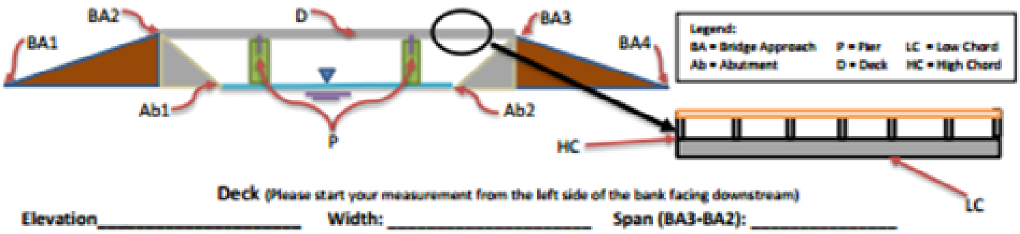
River Name: Agsalin River **Time:** 12:30 P.M.

Location (Brgy, City, Region): Barangay Balete, Municipality of Gloria, Oriental Mindoro

Survey Team: Team Bernard's Team

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

Latitude: 12d56'37.56312" N **Longitude:** 121d28'27.33667" E



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

Elevation________ Width: ________ Span (BA3-BA2): ________

	Station	High Chord Elevation	Low Chord Elevation
1		12.545	11.873
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	12.83	BA3	14.99767	13.093
BA2	5.117054	12.892	BA4	24.76762	13.439

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

	Station (Distance from BA1)	Elevation
Ab1	44.07995	13.235
Ab2	143.6386	13.104

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

Shape: Rectangular Cylinder **Number of Piers:** 7 **Height of column footing:** ________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	40.76332	13.201	
Pier 2	47.46954	13.175	
Pier 3	63.95486	13.39	
Pier 4	78.17299	13.277	
Pier 5	91.9669	13.17	
Pier 6	105.929	13.203	
Pier 7	134.7588	13.452	

Figure 44. Old Balete Bridge data form

Bridge Data Form

Bridge Name: Balete Bridge   Date: October 31, 2014

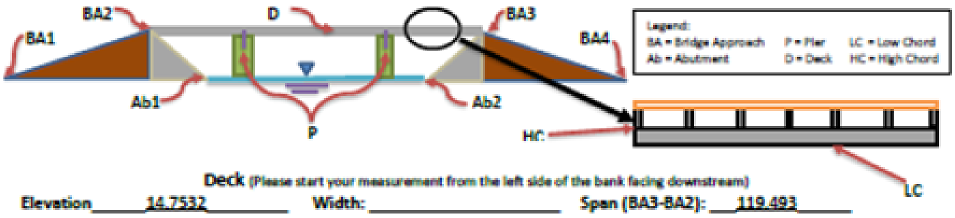
River Name: Agsalin River   Time: 11:32am

Location (Brgy, City, Region): Brgy. Balete, Municipality of Gloria, Oriental Mindoro

Survey Team: Bernard's Team

Flow condition: low normal high   Weather Condition: fair rainy

Latitude: 12d51'17.70562" N   Longitude: 121d27'28.70961" E



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

Elevation: 14.7532   Width: ______   Span (BA3-BA2): 119.493

	Station	High Chord Elevation	Low Chord Elevation
1		12.956	10.245
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	8.356	BA3	308.780	12.154
BA2	189.373	12.083	BA4	476.5391	9.571

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

	Station (Distance from BA1)	Elevation
Ab1	200.999	4.496
Ab2	299.895	6.739

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

Shape: CYLINDRICAL   Number of Piers: 6   Height of column footing: ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	191.9616	12.107	
Pier 2	214.6602	12.13	
Pier 3	238.0631	12.123	
Pier 4	260.7833	12.133	
Pier 5	283.9146	12.129	
Pier 6	306.9171	12.119	

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

Figure 45. New Balete Bridge data form

Figure 46. Water marking at the New Balete Bridge

The water surface elevation was translated as markings on the piers of the bridge using a digital level. The marked piers shall serve as reference for flow data gathering and depth gauge deployment of the partner HEI, the University of the Philippines Los Baños, responsible for monitoring of Agsalin River.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 31, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle utilizing PPK technique on a continuous topography mode, as shown in Figure 47. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 1.498 m from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey began from the Municipality of Socorro to the Municipality of Bansud.

Figure 47. Validation points acquisition survey set-up

The survey acquired 2,618 ground validation points with an approximate length of 23.76 km using ORM-3 as the GNSS base station as illustrated in the map in Figure 48.

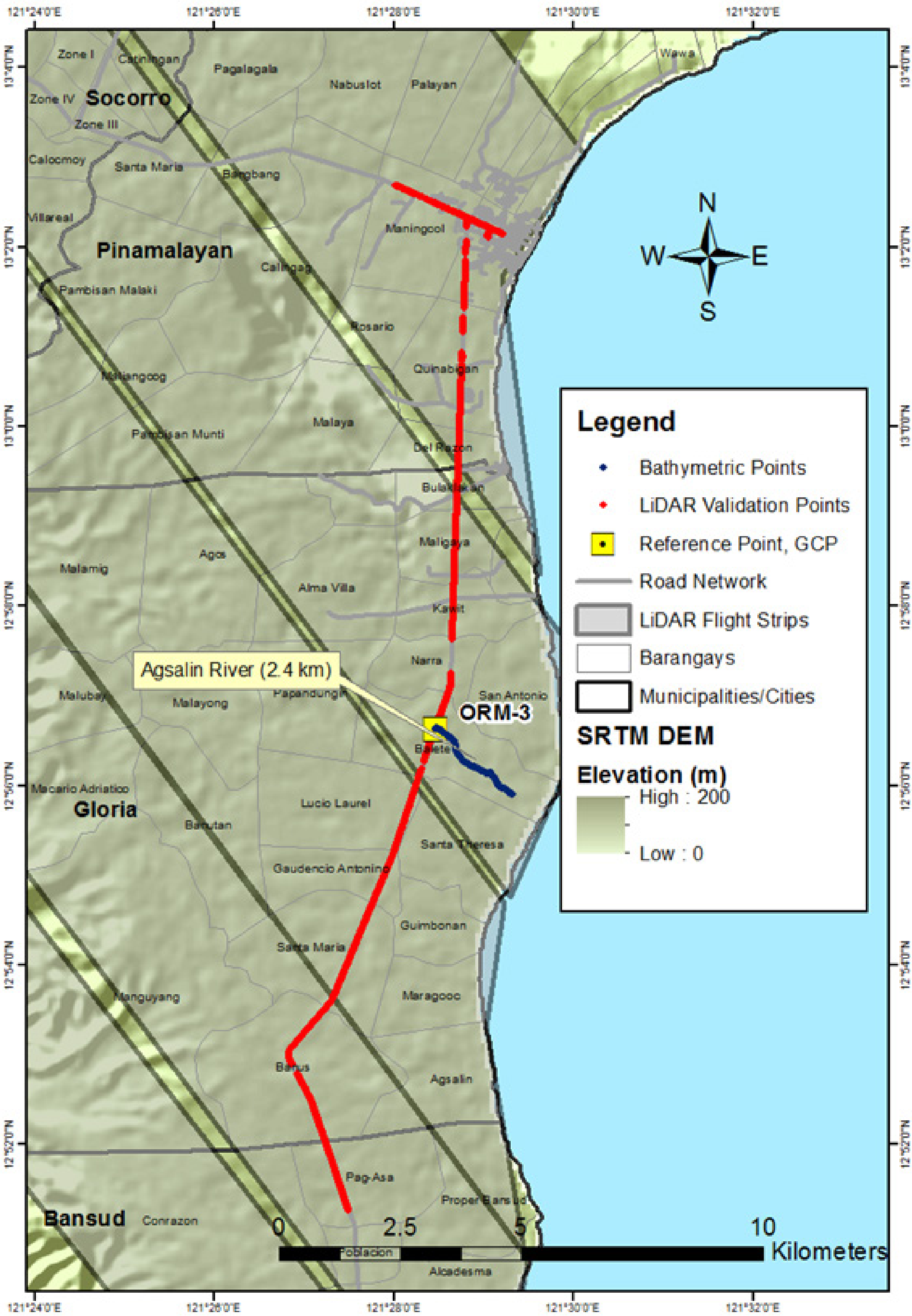


Figure 48. Validation points acquisition survey along Balete River Basin

4.7 River Bathymetric Survey

Bathymetric survey was conducted on June 2, 2014 using a GNSS rover receiver, Trimble® SPS 882, using post process kinematic survey technique as shown in Figure 49. The river was traversed by foot from the Agsalin River upstream in Brgy. Balete with coordinates 12°56'38.66703" 121°28'28.31470" down to its mouth in the same barangay with coordinates 12°55'54.00041" 121°29'19.37386", draining into Tablas Strait. The control point ORM-4 was used as the base station throughout the survey.

Figure 49. Manual bathymetric survey in Agsalin River

The bathymetric survey has a length of 2.4 km with 146 bathymetric points gathered covering only Brgy. Balete in Municipality of Gloria, Oriental Mindoro. A CAD drawing was also produced to illustrate the Agsalin Riverbed profile, as shown in Figure 51. An elevation drop of 3 m in MSL was observed within the stretch of the river. The highest elevation value observed was 3.298 m in MSL located at the upstream portion of the river, while the lowest elevation value observed was -0.517 m below MSL locate in the downstream portion of the river.

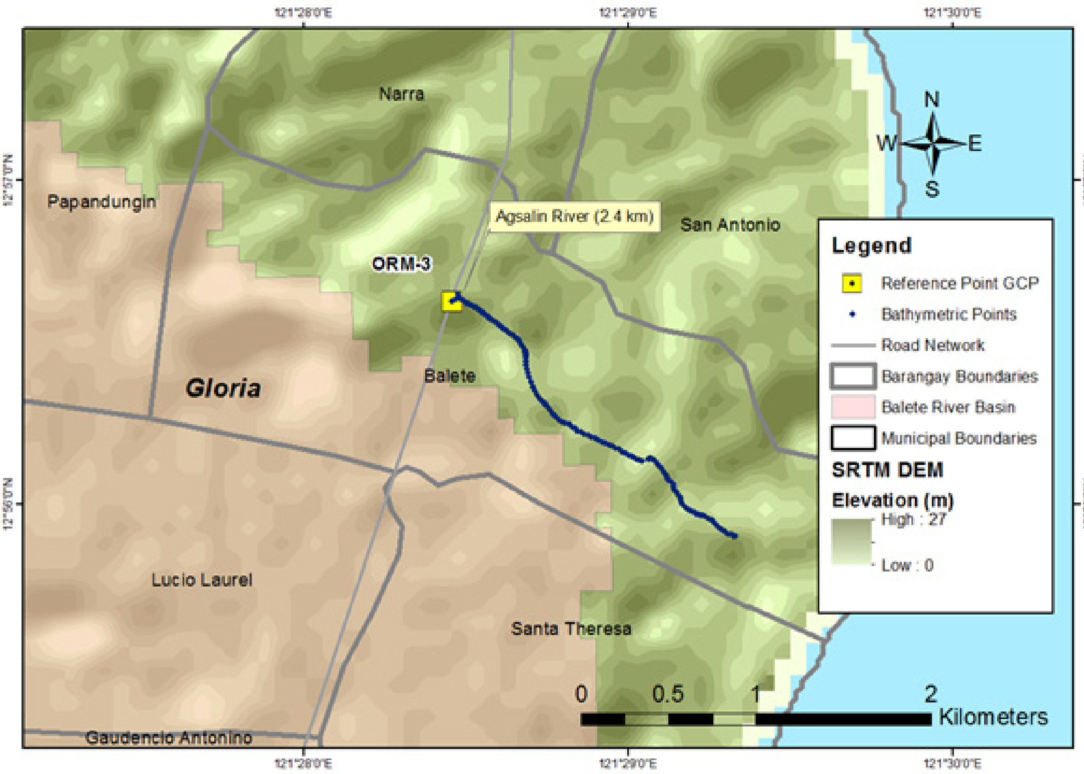


Figure 50. Bathymetric points gathered along Agsalin River

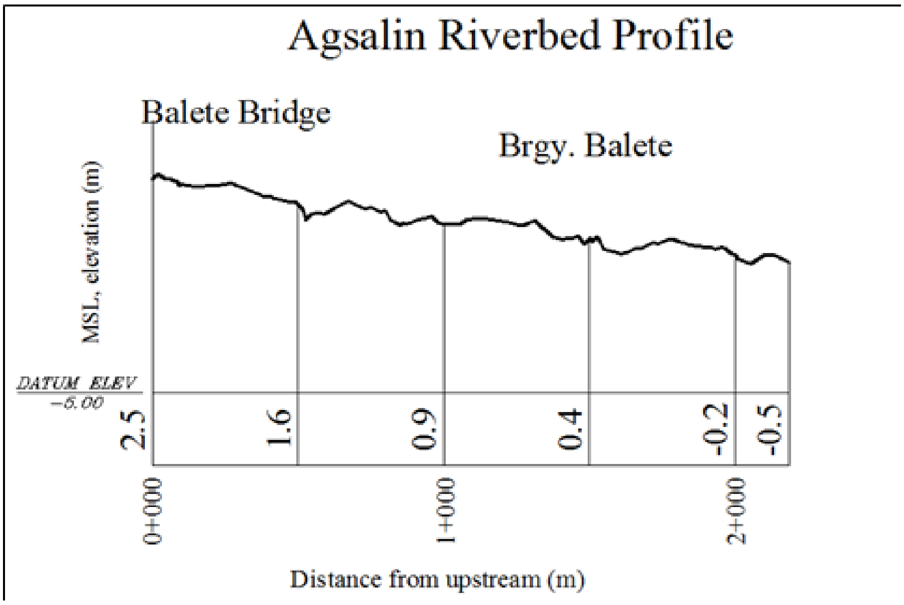


Figure 51. Riverbed profile of Agsalin River

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, 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 for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the rain gauge station installed in Manguyang Elementary School (12.906111˚ N, 121.421389˚ E). The location of the rain gauge is seen in Figure 52.

The total amount of rainfall for this event is 96.0 mm. It has a peak rainfall of 8.0 mm on December 15, 2015 at 8:40 am. The lag time between the peak rainfall and observed discharge is 4 hours and 40 minutes, as seen in Figure 55.

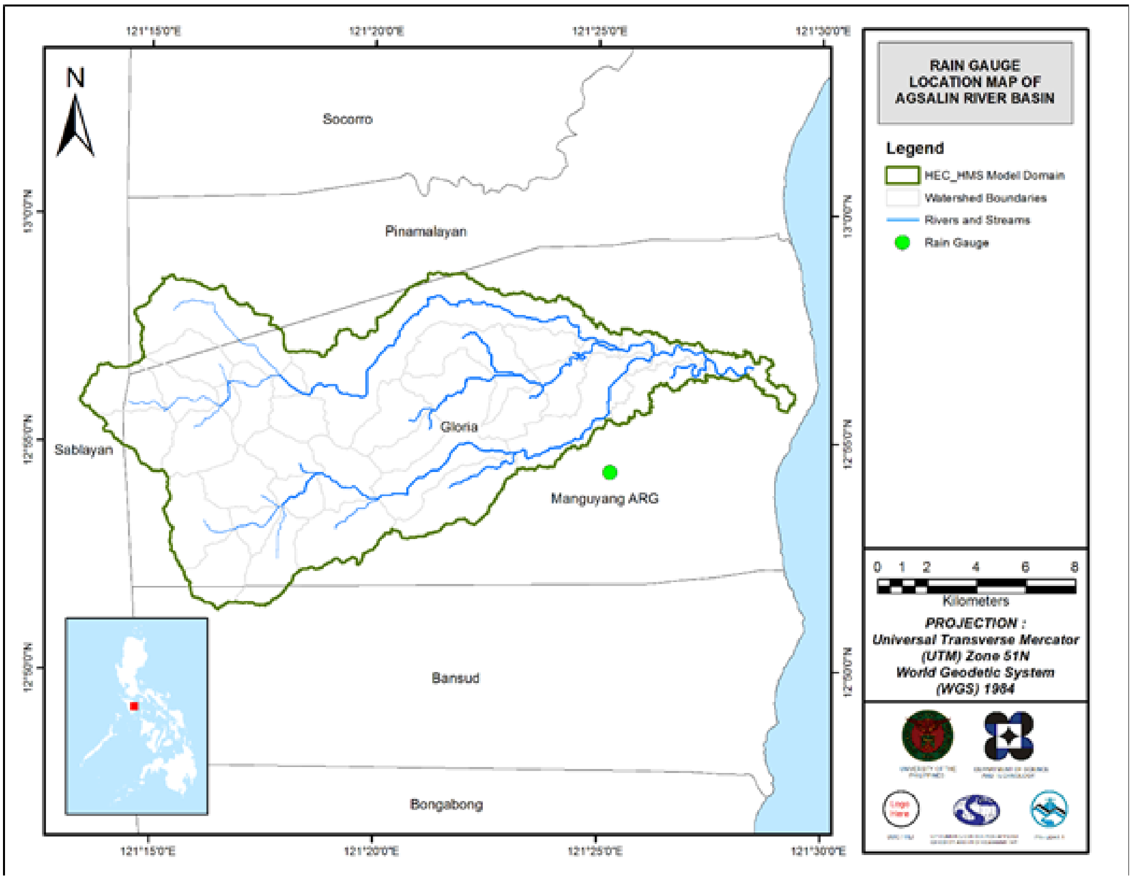


Figure 52. Location map of Agsalin HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Balete Bridge, Oriental Mindoro (12°56'39.06"N, 121°28'28.57"E). It gives the relationship between the observed water levels from the Balete Bridge and outflow of the watershed at this location using Bankful Method in Manning's Equation.

For Balete Bridge, the rating curve is expressed as Q = 1.0101e0.5006x as shown in Figure 53.

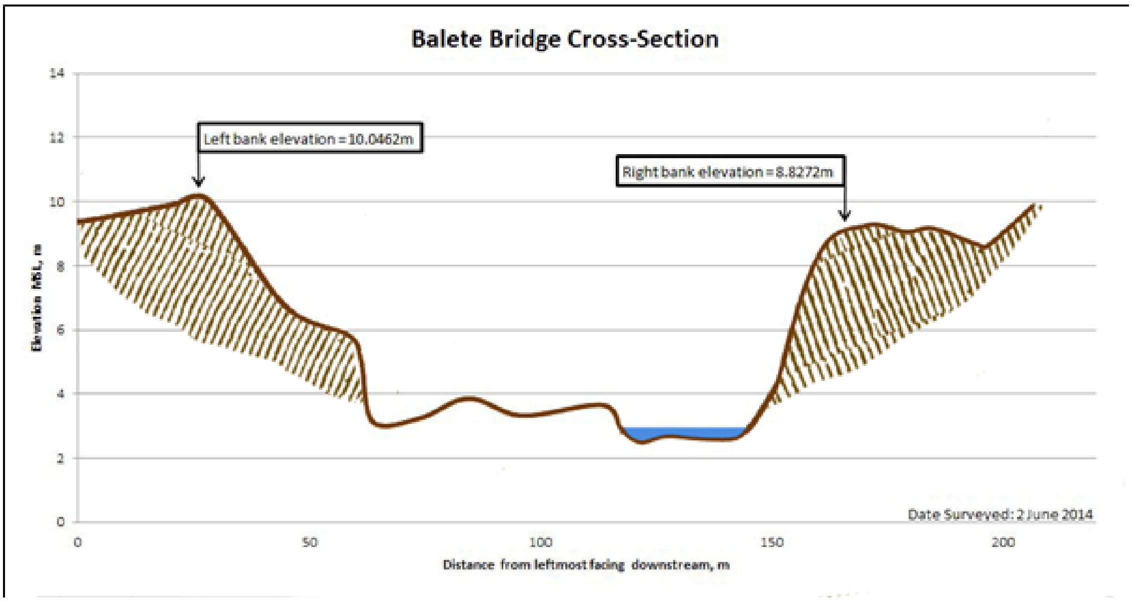


Figure53.Cross-section plot of Balete Bridge

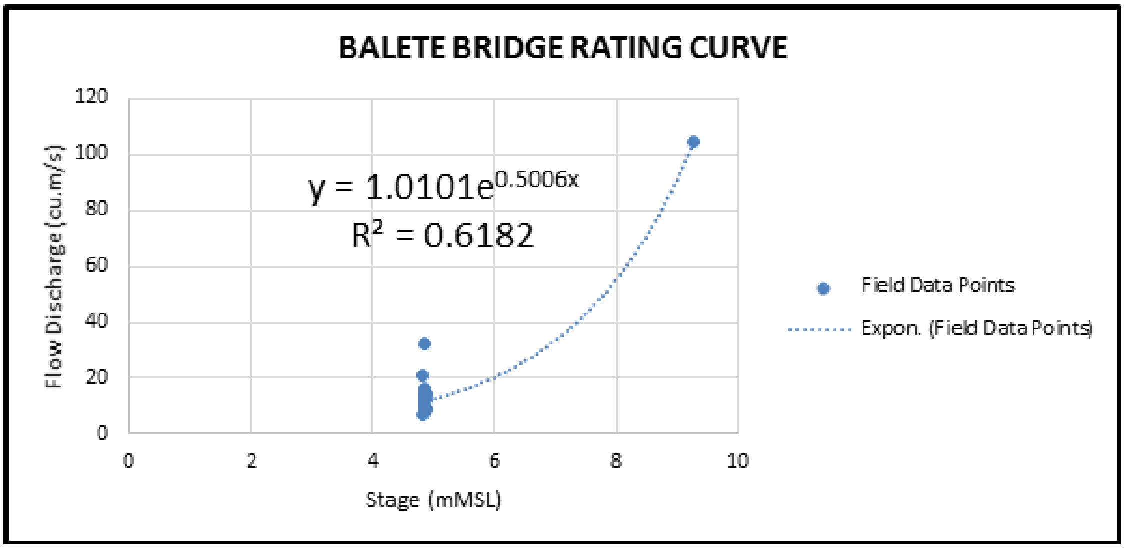


Figure 54. Rating curve at Balete Bridge, Oriental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 55, actual flow discharge during a rainfall event was collected in the Balete Bridge. Peak discharge is 18.983 m3/s at December 15, 2015, 3:20 pm.

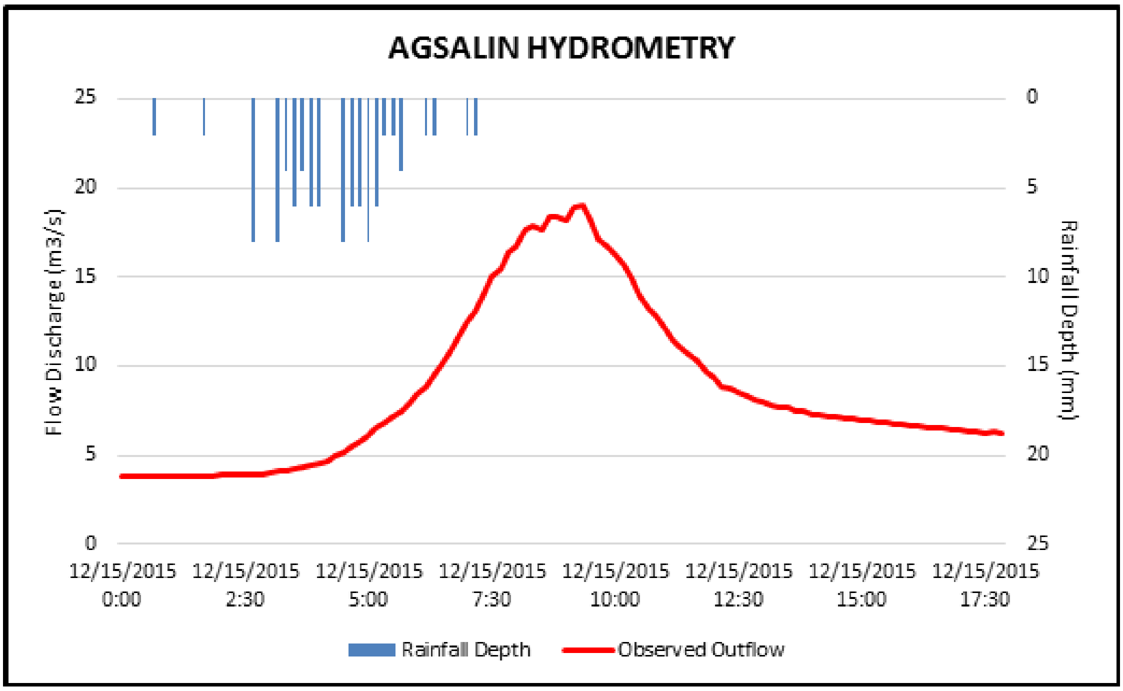


Figure 55. Rainfall and outflow data at Agsalin used for modeling

5.2 RIDF Station

The Philippine 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 was chosen based on its proximity to the Agsalin watershed. The extreme values for this watershed were computed based on a 48-year record.

Table 30. 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

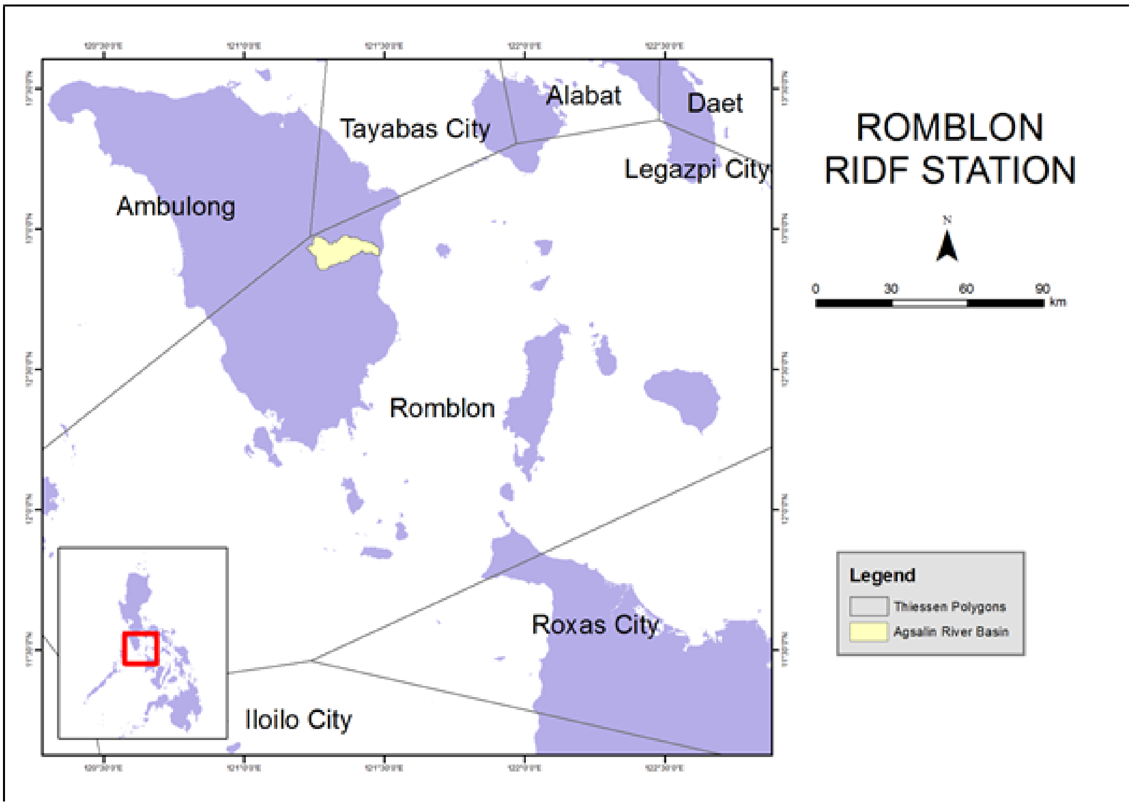


Figure 56. Location of Romblon RIDF relative to Agsalin River Basin

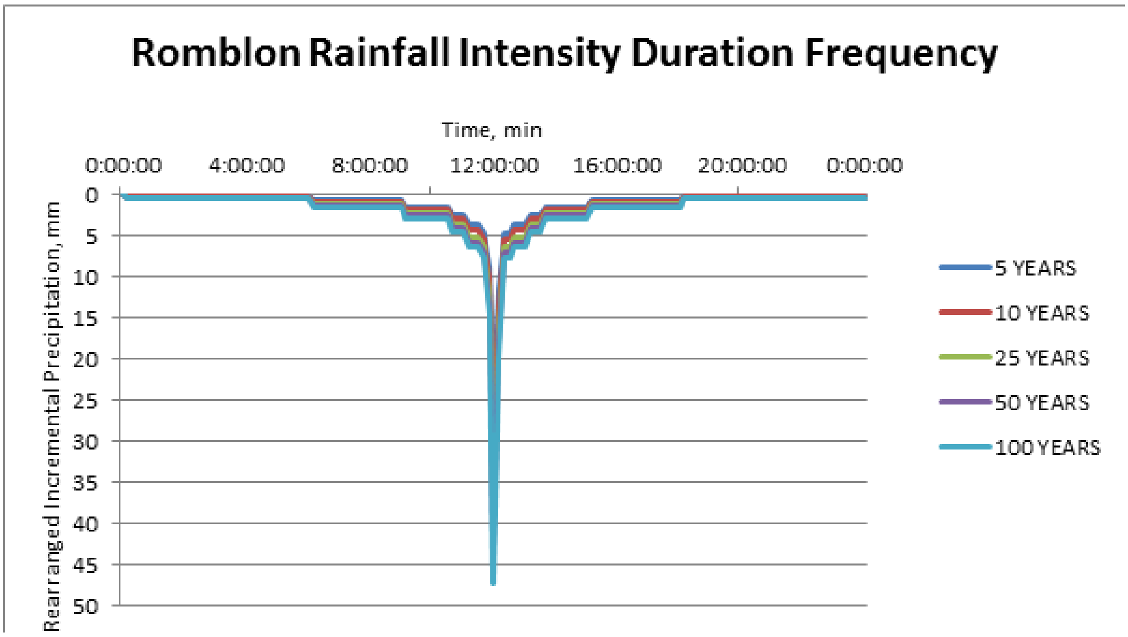


Figure 57. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset was taken from the National Mapping and Resource Information Authority (NAMRIA).

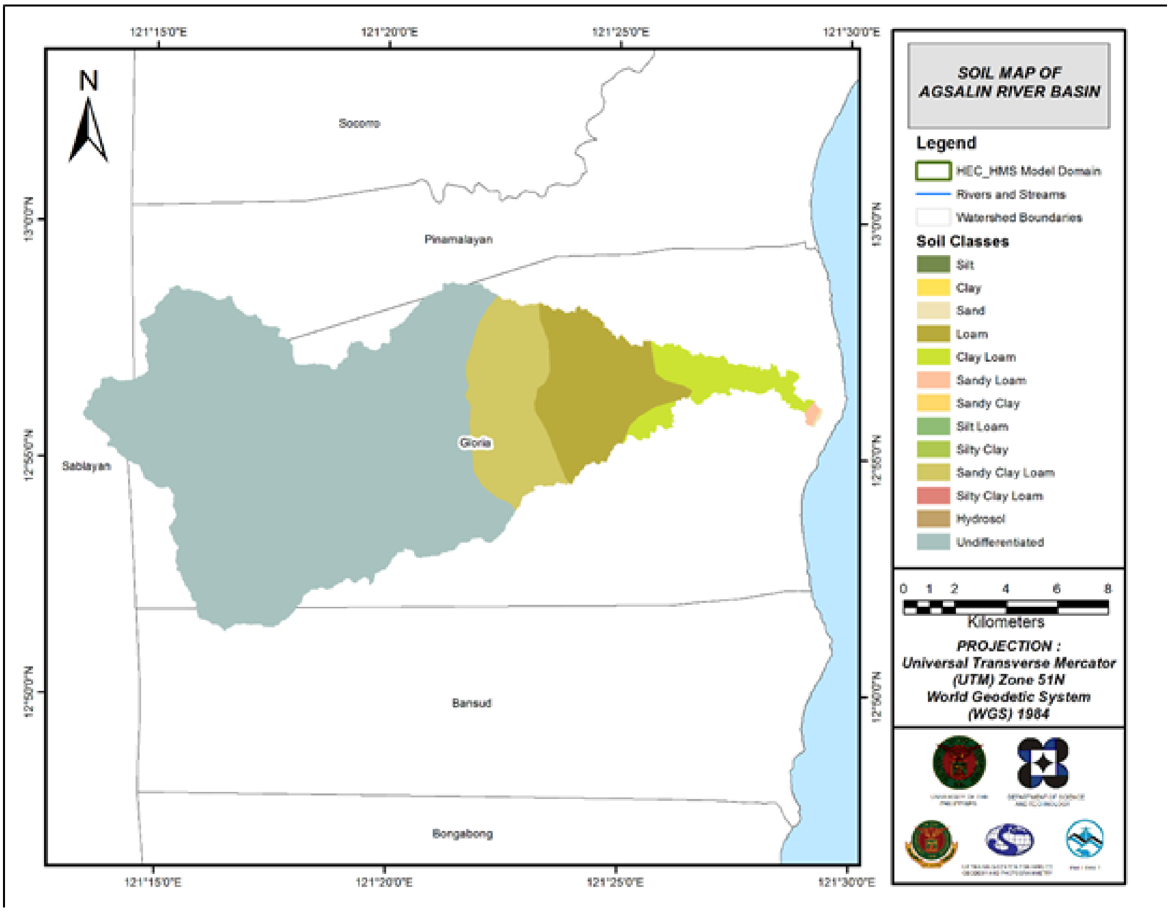


Figure 58. Soil map of the Agsalin River Basin used for the estimation of the CN parameter (Source: DA-BSWM)

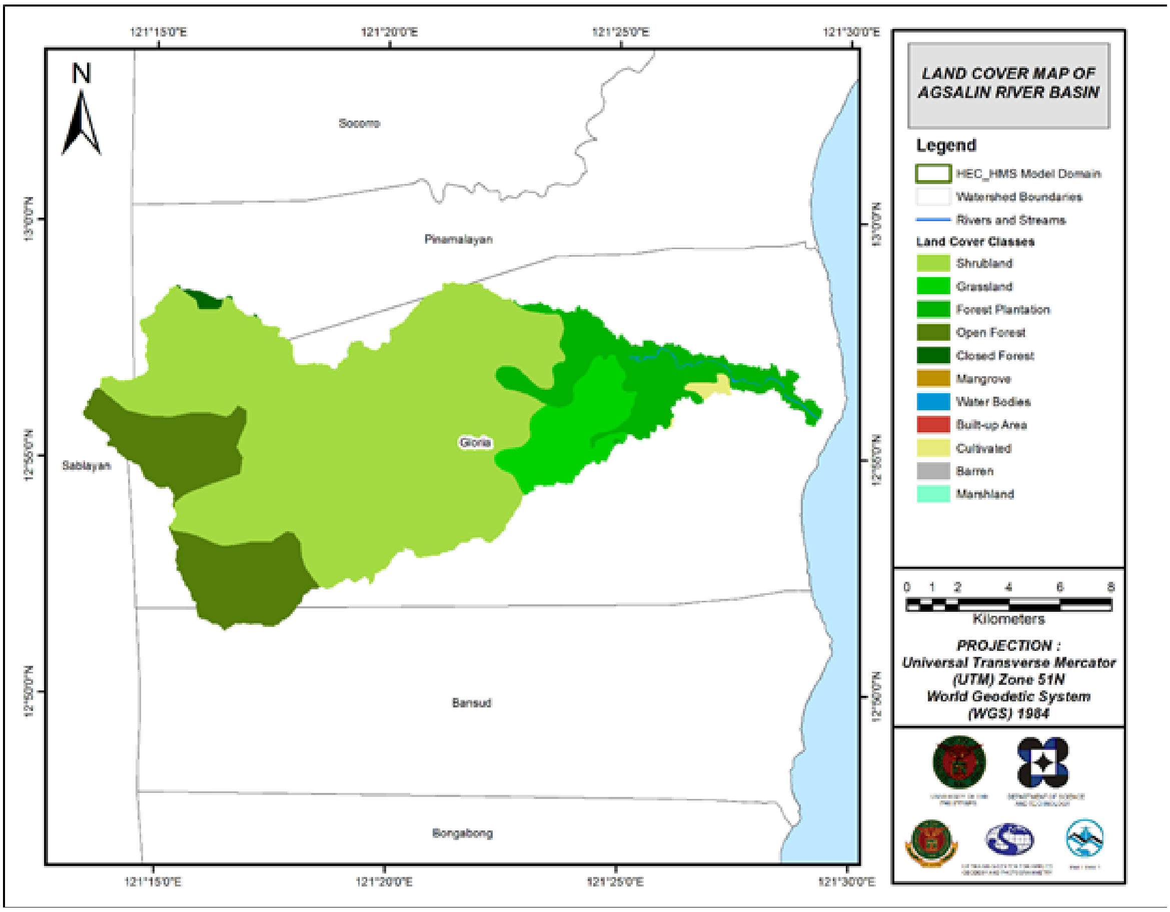


Figure 59. Land cover map of the Agsalin River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model (Source: NAMRIA)

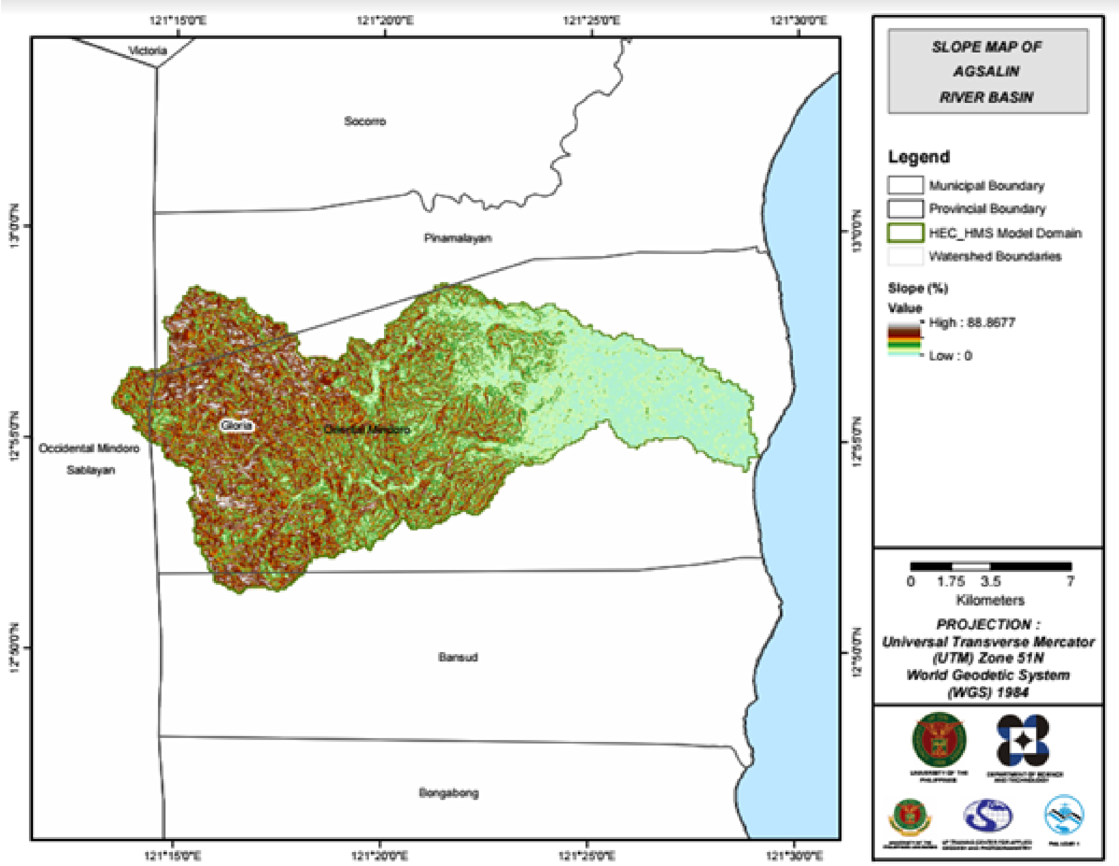


Figure 60. Slope map of the Agsalin River Basin

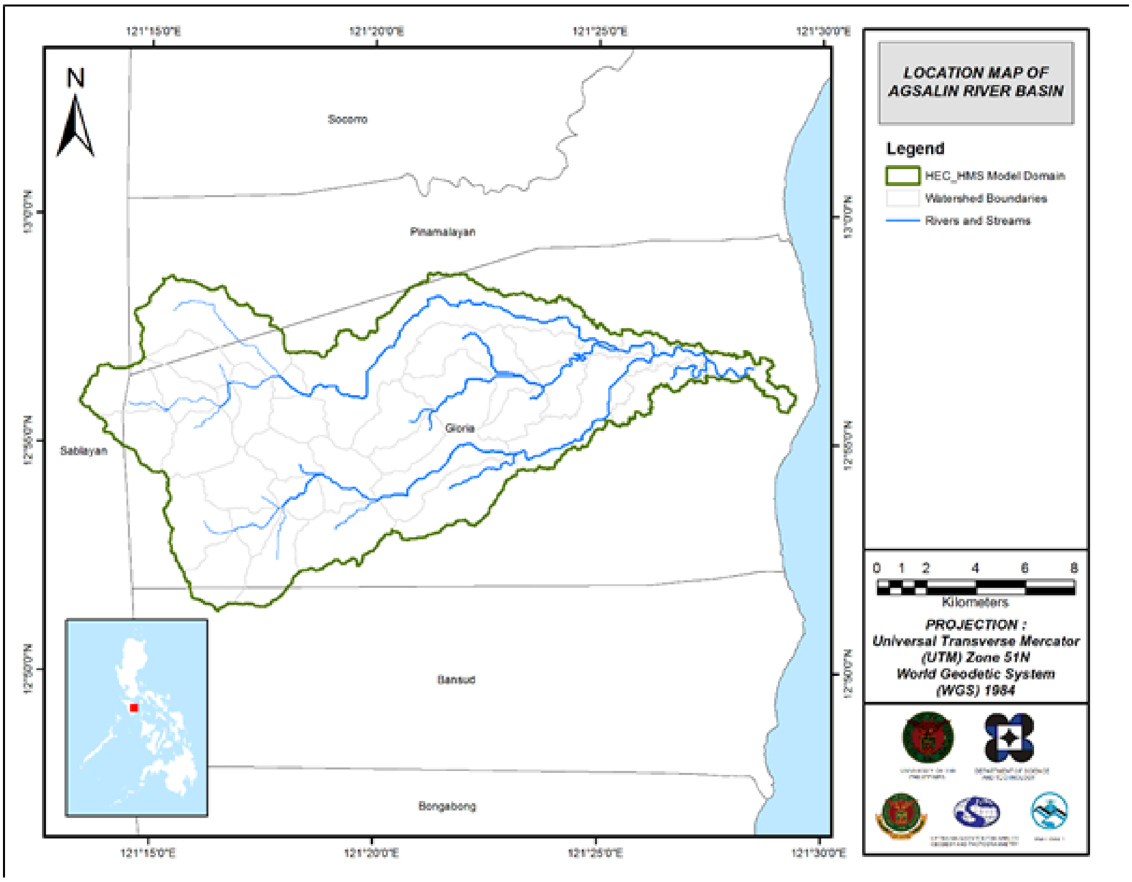


Figure 61. Stream delineation map of the Agsalin River Basin

Using the SAR-based DEM, the Agsalin basin was delineated and further subdivided into subbasins. The model consists of 48 subbasins, 24 reaches, and 24 junctions. The main outlet is labeled as 162. This basin model is illustrated in Figure 62. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from the Automatic Rain Gauge Station (ARG) located in Manguyang Elementary School (12.906111˚ N, 121.421389˚ E). Finally, it was calibrated using the data collected from the Automatic Water Level Sensor (AWLS) Station installed on the bridge itself (12.944367˚ N, 121.474367˚ E).

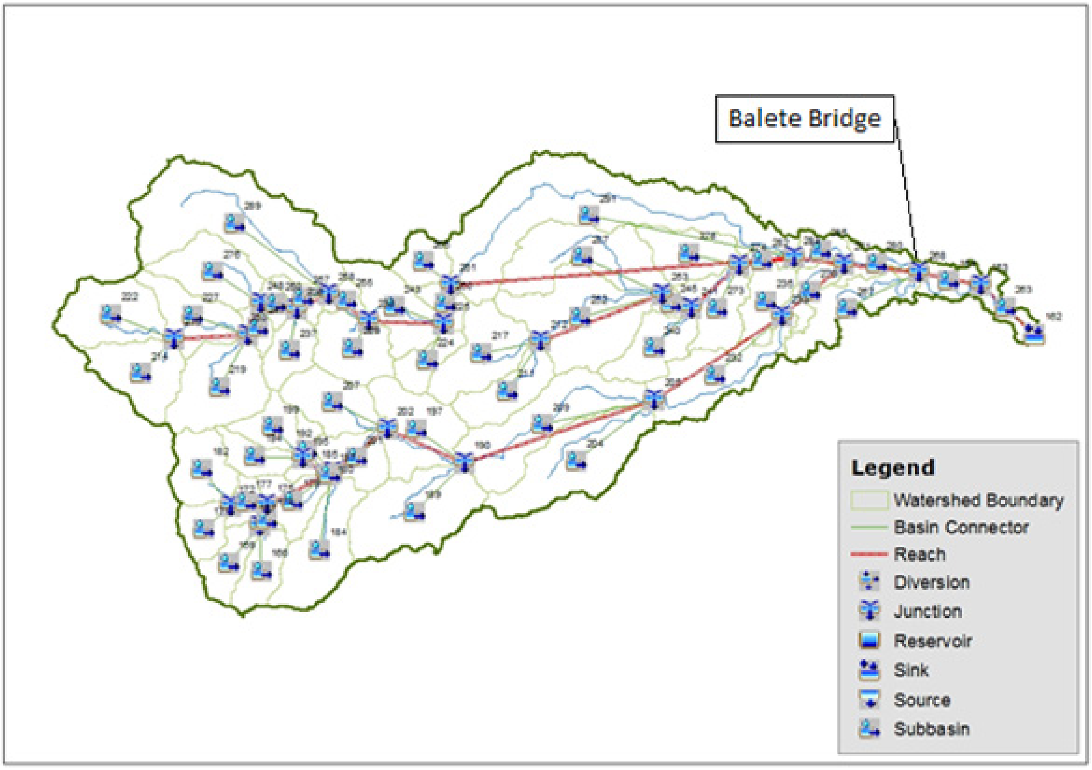


Figure 62. The Agsalin River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

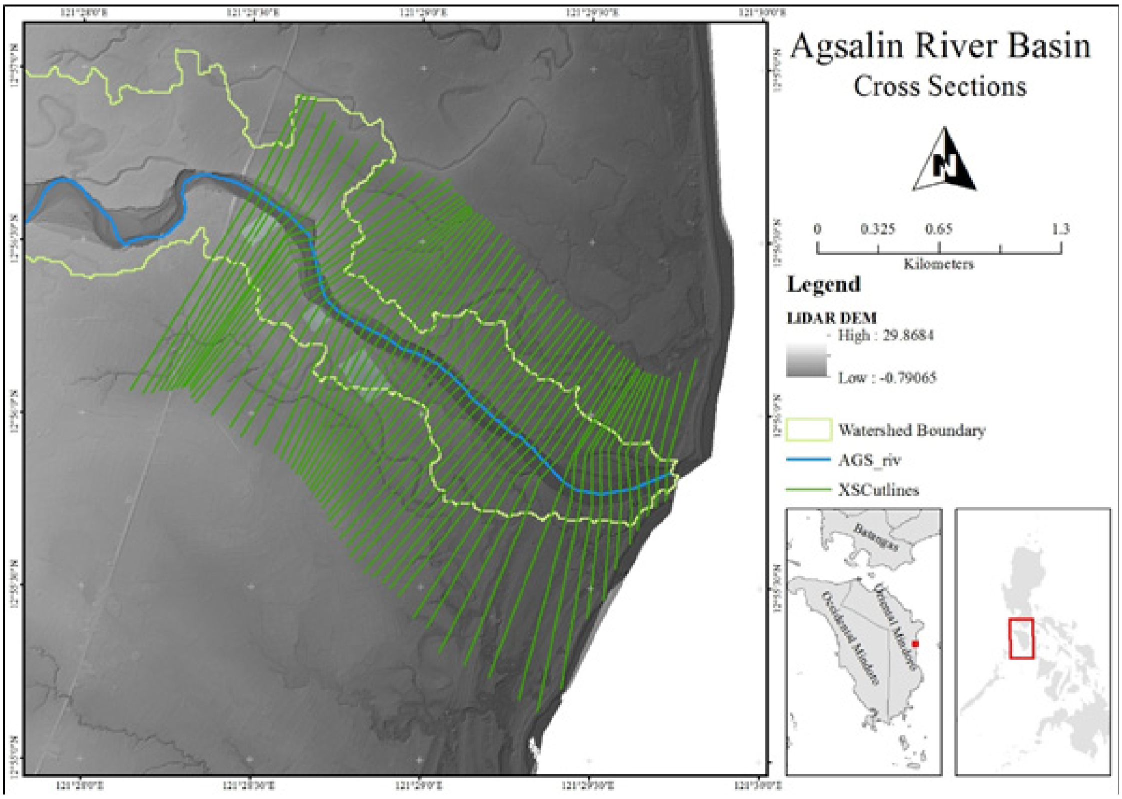


Figure 63. River cross-section of Agsalin River Generated Through ArcMap HEC GeoRAS Tool

5.5 FLO-2D Model

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

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

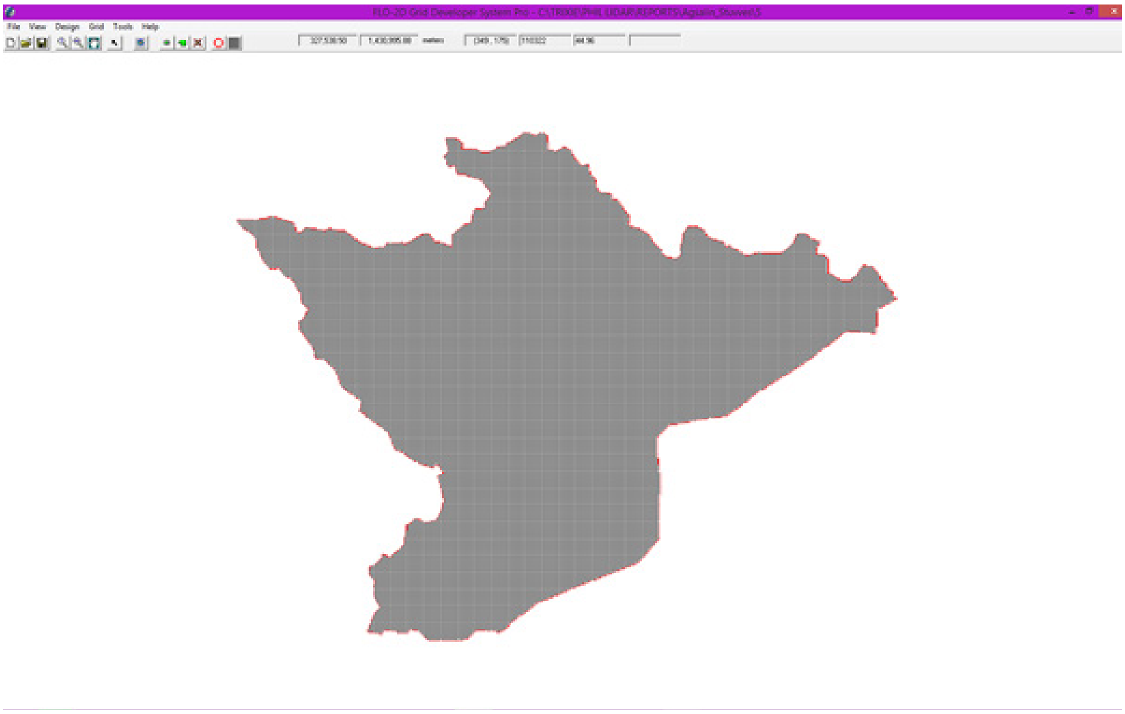


Figure 64. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 25.22363 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that show 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 created the flood hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) was set at 0 m2/s.

The creation of a flood hazard map from the model also automatically created a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts cover a maximum land area of 27873000.00 m2.

There is a total of 8727058.18 m3 of water entering the model. Of this amount, 8727058.18 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. About 1462661.00 m3 of this water is lost to infiltration and interception, while 1464478.16 m3 is stored by the floodplain. The rest, amounting up to 5799923.35 m3, is outflow.

5.6 Results of HMS Calibration

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

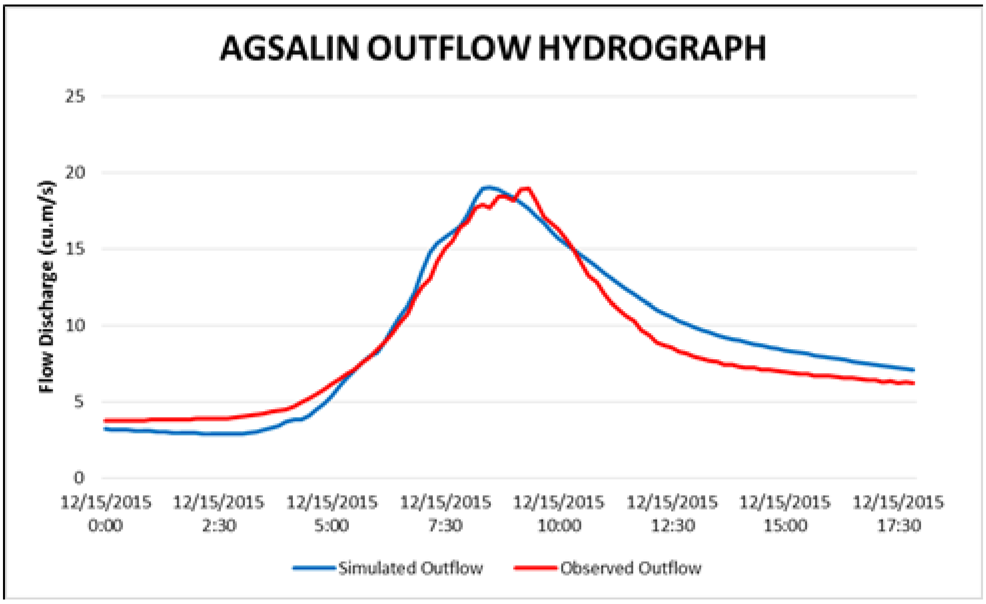


Figure 65. Outflow hydrograph of Agsalin produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of calibrated values for Agsalin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.7 - 36
			Curve Number	10 - 19
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.08 - 2
			Storage Coefficient (hr)	0.6 - 75
	Baseflow	Recession	Recession Constant	0.1 – 0.6
			Ratio to Peak	0.02 – 0.1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.003 – 0.03

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.7 to 36 mm means that there is a minimal to average 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 10 to 19 for curve number is lower than the advisable for Philippine watersheds.

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 0.0.8 to 75 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 0.1 to 0.6 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.02 to 0.1 indicates a steeper receding limb of the outflow hydrograph.

Table 32. Summary of the efficiency test of Agsalin HMS Model

Root Mean Square Error (RMSE)	1.0050
Pearson Correlation Coefficient (r2)	0.9819
Nash-Sutcliffe (E)	0.9500
Percent Bias (PBIAS)	-3.3427
Observation Standard Deviation Ratio (RSR)	0.2236

Manning's roughness coefficient of 0.017 is relatively low compared to the common roughness of watersheds (Brunner, 2010). The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed at 1.0050.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A value 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 0.9819.

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 0.9500.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -3.3427.

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 0.2236.

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 Agsalin outflow using the Romblon RIDF curves in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

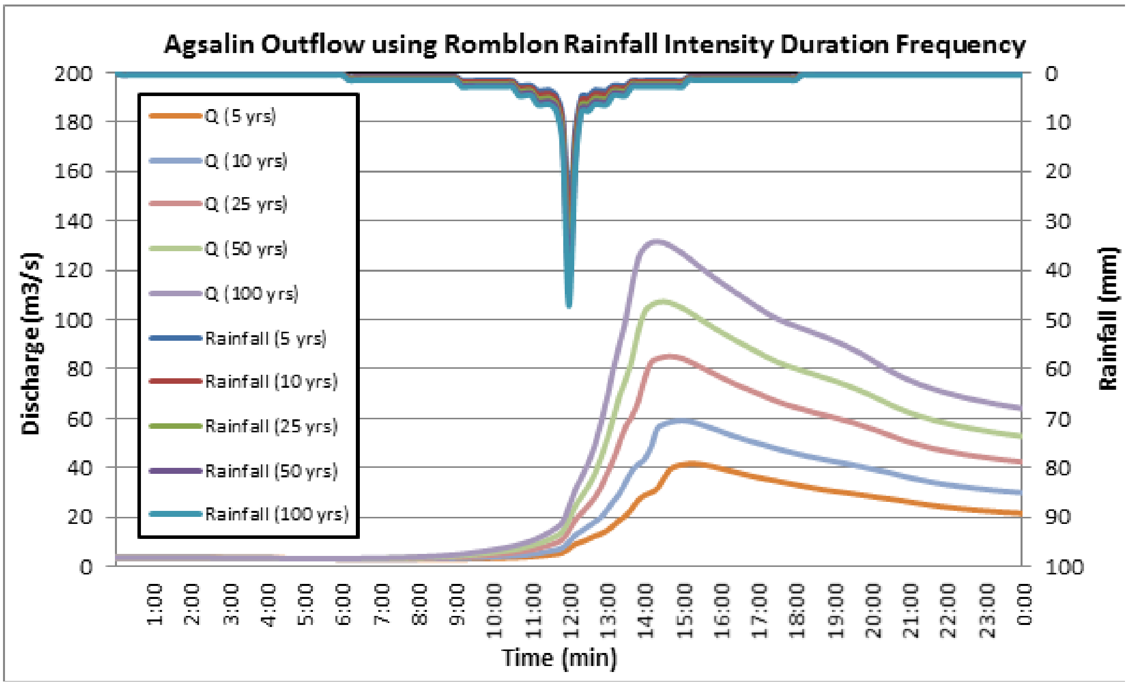


Figure 66. Outflow hydrograph at Agsalin Station generated using Romblon RIDF simulated in

A summary of the total precipitation, peak rainfall, peak outflow, time to peak, and lag time of the Agsalin discharge using the Romblon RIDF curves in five different return periods is shown in Table 33.

Table 33. Peak values of the Agsalin HECHMS Model outflow using the Romblon RIDF

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak	Lag Time
5-yr	171.60	26	41.645	15 hours 20 minutes	3 hours 20 minutes
10-yr	205.90	31.1	59.237	15 hours	3 hours
25-yr	249.20	37.6	85.247	14 hours 40 minutes	2 hours 40 minutes
50-yr	281.40	42.4	107.328	14 hours 30 minutes	2 hours 30 minutes
100-yr	313.30	47.2	131.663	14 hours 20 minutes	2 hours 20 minutes

5.7.2 Discharge Data Using Dr. Horritts's Recommended Hydrologic Method

The river discharges for the three points in the floodplain are shown in Figure 67 and Figure 68 and are summarized in Table 34 to Table 35.

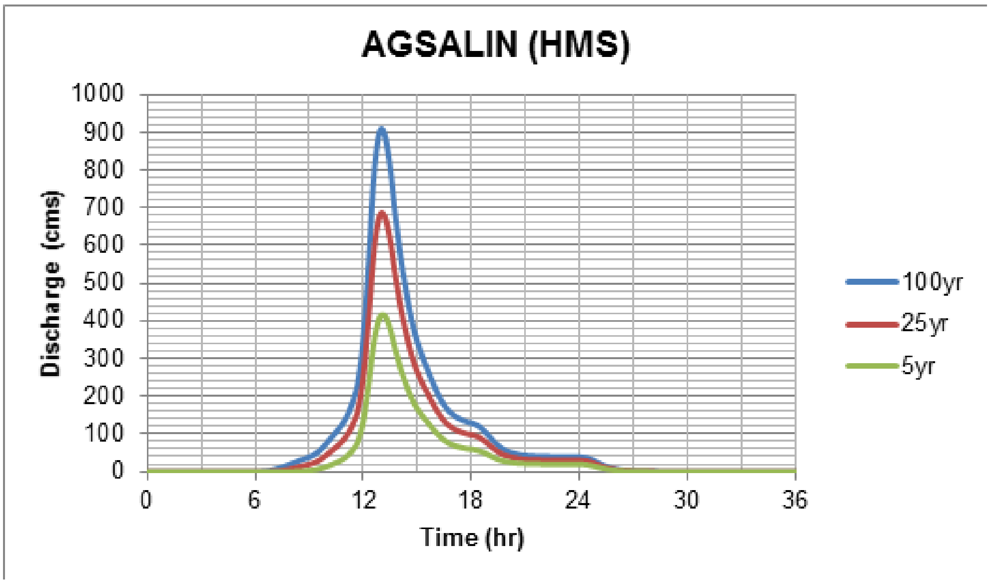


Figure 67. Agsalin River (1) generated discharge using 5-, 25-, and 100-year Romblon RIDF in HEC-

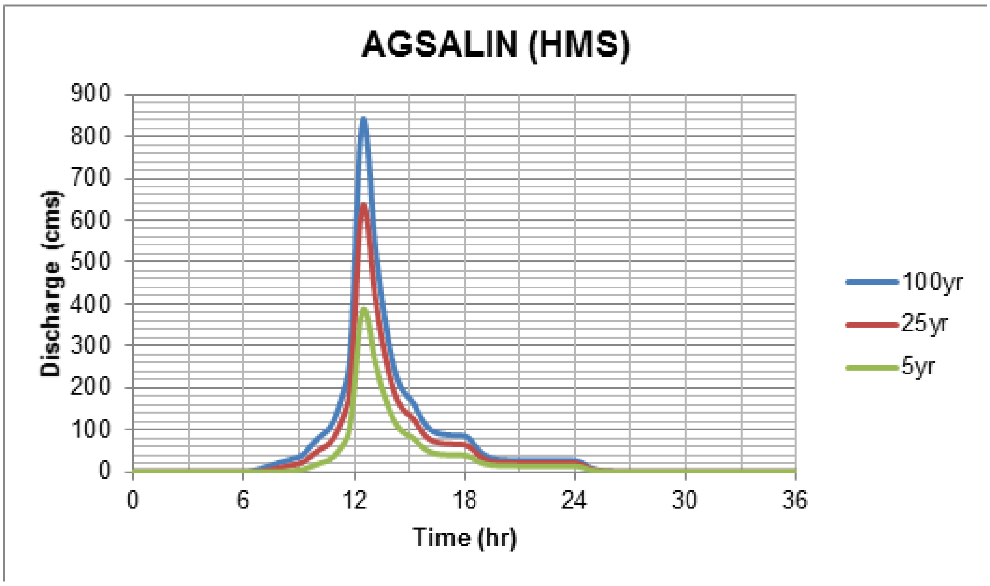


Figure 68. Agsalin River (2) generated discharge using 5-, 25-, and 100-year Romblon RIDF in HEC-

Table 34. Summary of Agsalin River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	909.9	13 hours
25-Year	686.6	13 hours
5-Year	416.0	13 hours

Table 35. Summary of Agsalin River (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	841.6	12 hours, 30 minutes
25-Year	637.0	12 hours, 30 minutes
5-Year	388.8	12 hours, 30 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 36.

Table 36. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Agsalin (1)	366.080	234.531	408.756	Fail	Pass
Agsalin (2)	341.704	380.122	320.135	Pass	Pass

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

5.8 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 Agsalin River using the HMS base flow is shown on Figure 69.

Figure 69. Agsalin HEC-RAS output

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 100-, 25-, and 5-year rain return scenarios of the Agsalin Floodplain are shown in Figure 70 to Figure 75. The floodplain, with an area of 93.15 sq km, covers one municipality—Gloria. Table 37 shows the percentage of area affected by flooding.

Table 37. Municipalities affected in Agsalin Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Gloria	327.277	93.06669	28.43667

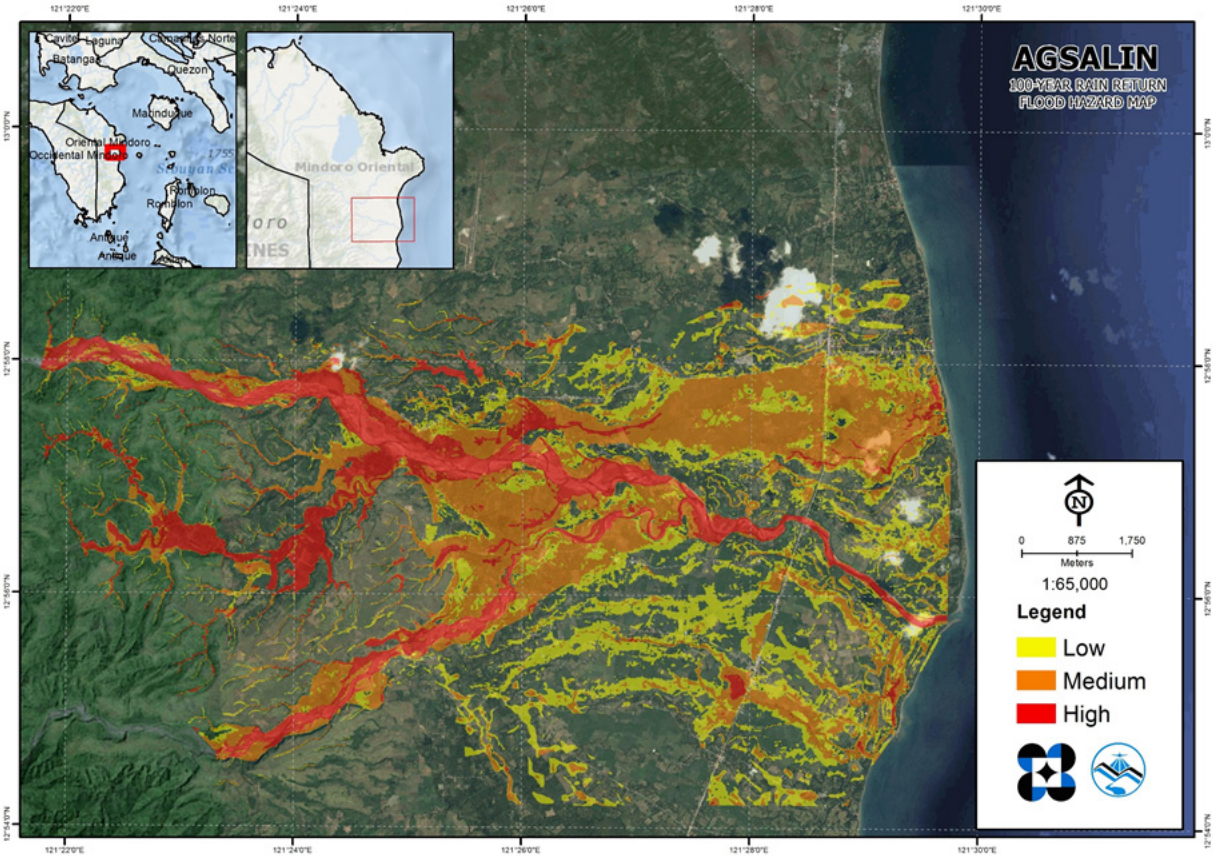


Figure 70. 100-year flood hazard map for Agsalin Floodplain

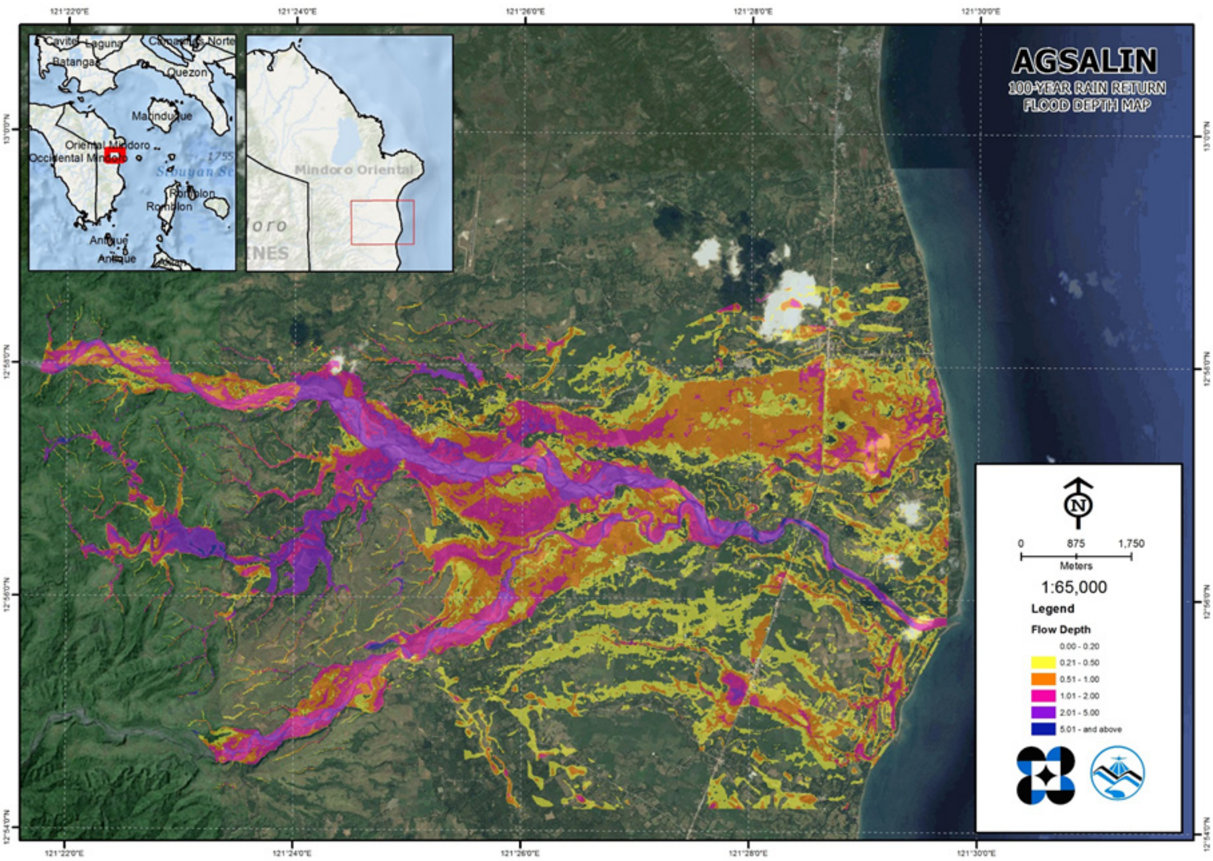


Figure 71. 100-year flow depth map for Agsalin Floodplain

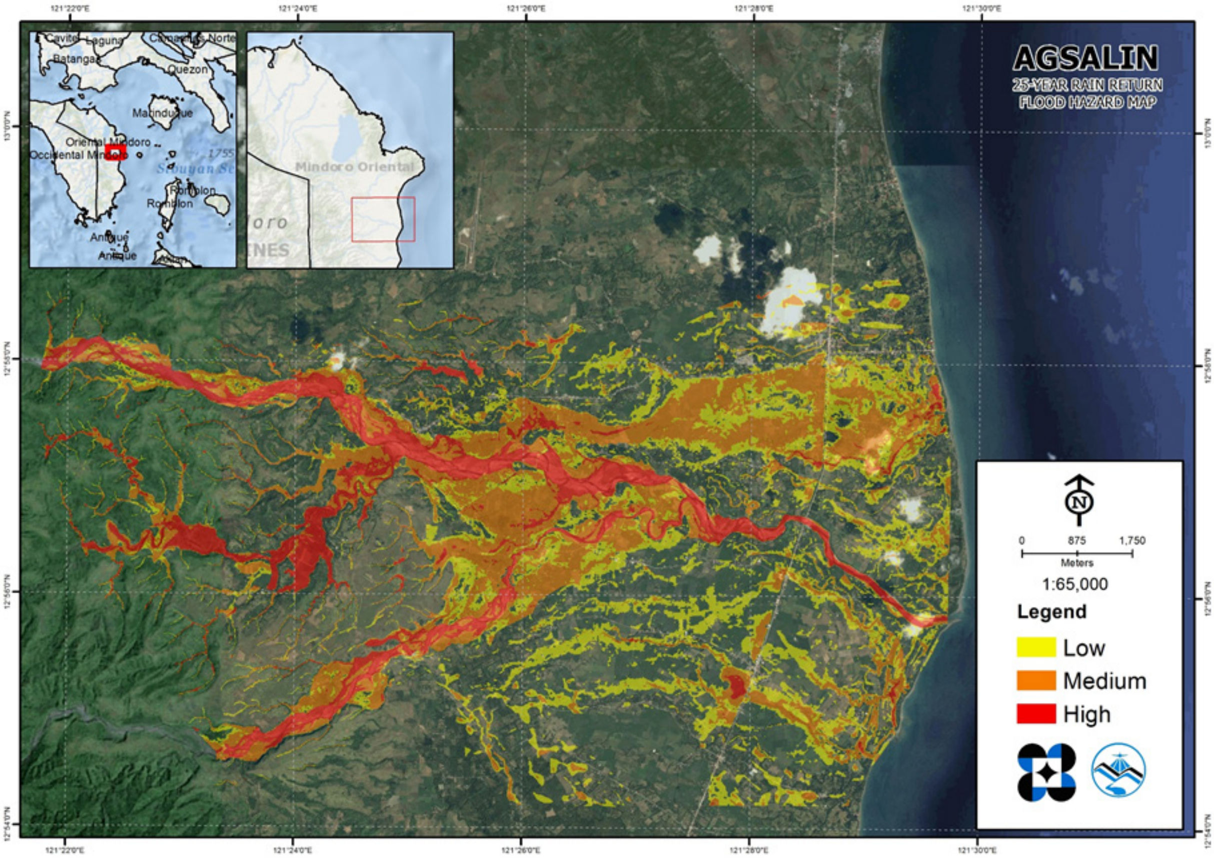


Figure 72. 25-year flood hazard map for Agsalin Floodplain

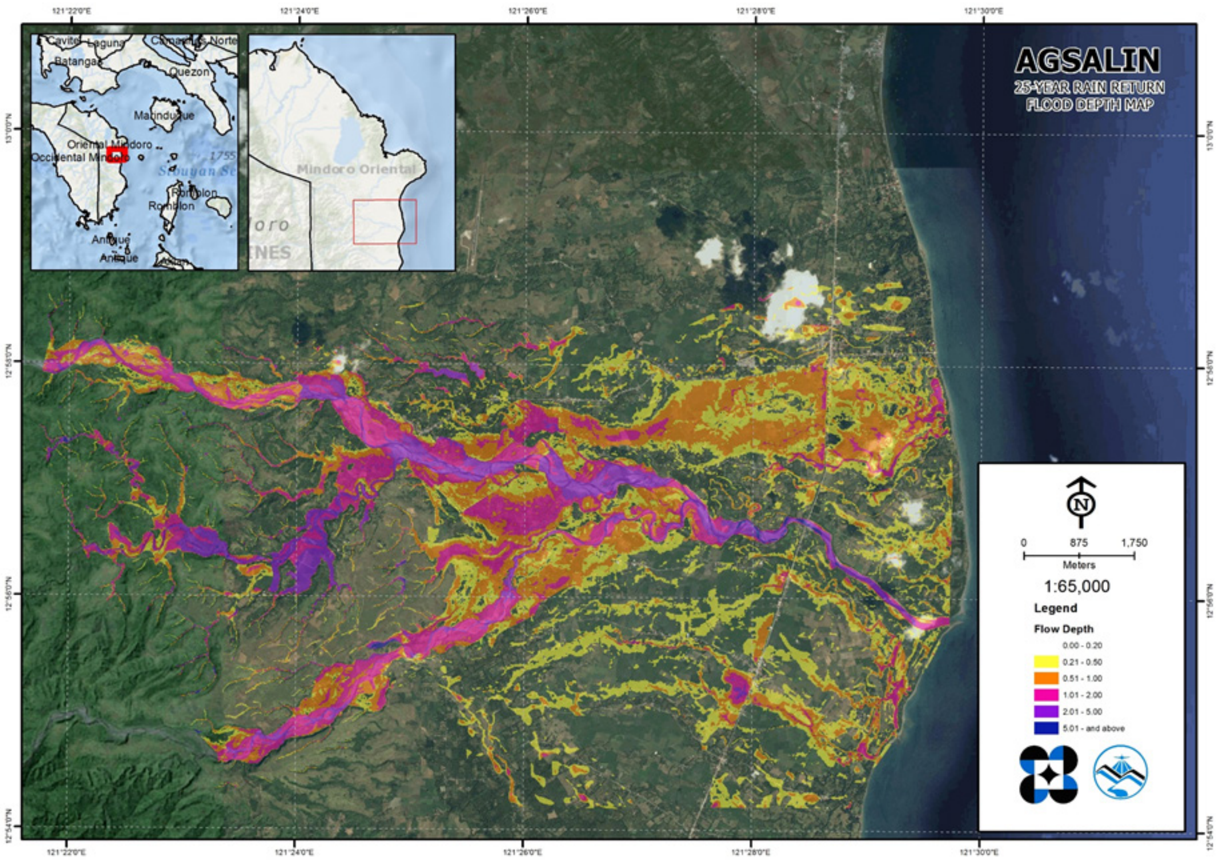


Figure 73. 25-year flow depth map for Agsalin Floodplain

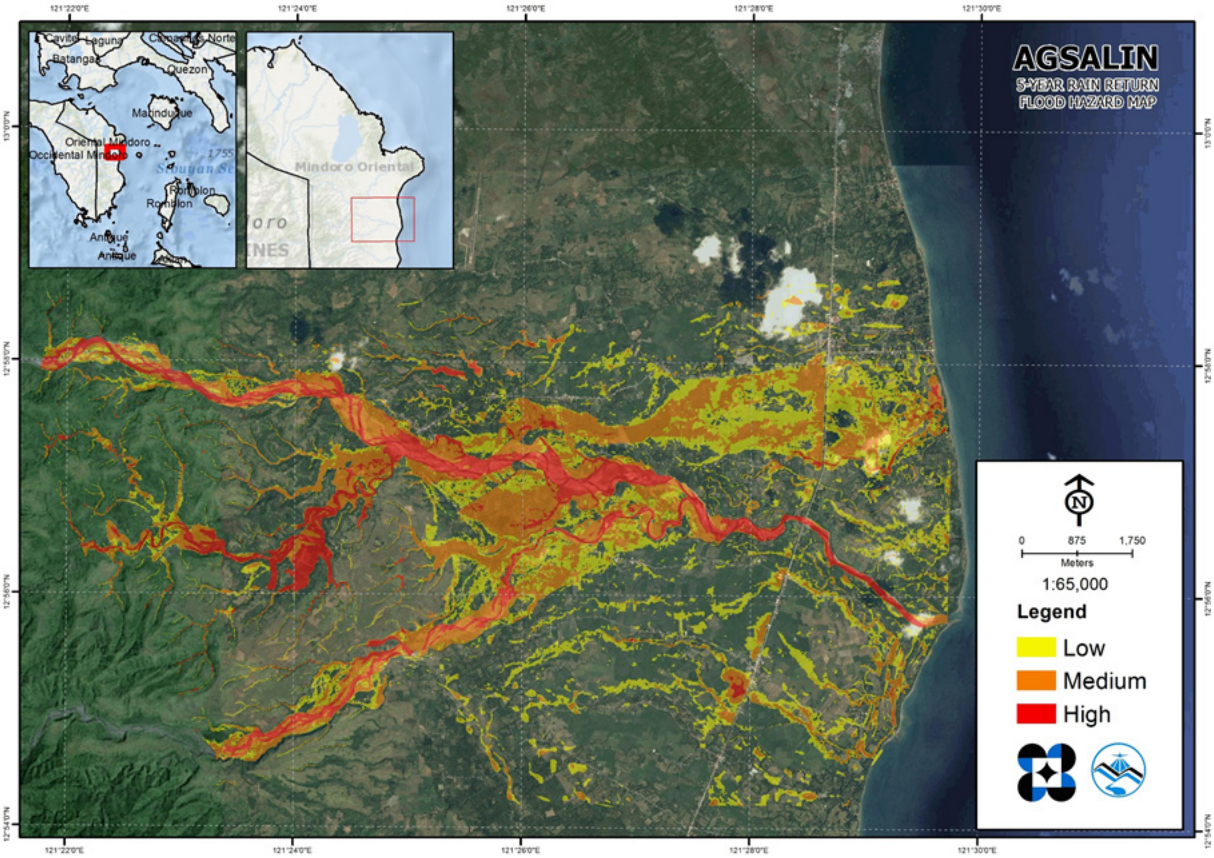


Figure 74. 5-year flood hazard map for Agsalin Floodplain

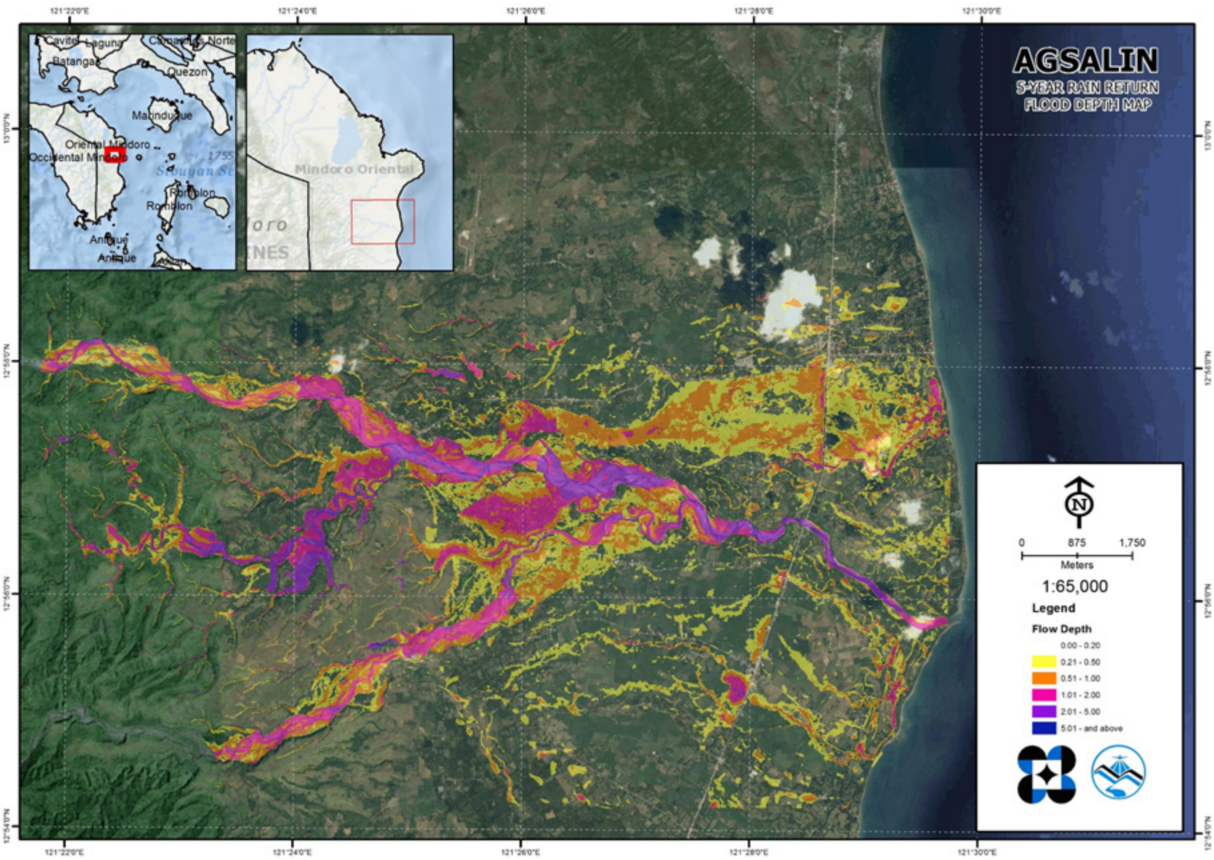


Figure 75. 5-year flow depth map for Agsalin Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Agsalin River Basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 22 barangays is expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 24.37% of the municipality of Gloria with an area of 256.09 sq km will experience flood levels of less 0.20 meters; 5.1% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.51%, 2.35%, 1%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 and Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected areas in Gloria, Oriental Mindoro during a 5-year rainfall return period

Affected area (sq km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq km.)										
	Agos	Alma Villa	Balete	Banutan	Buong Lupa	Gaudencio Antonino	Guimbonan	Kawit	Lucio Laurel	Macario Adriatico	Malamig
0.03-0.20	2.98	2.61	4.06	4.31	2.35	1.52	1.69	1.45	4.61	7.27	2.74
0.21-0.50	0.33	0.69	0.69	1.07	0.48	0.39	0.23	0.89	0.82	0.44	0.25
0.51-1.00	0.18	0.32	0.23	0.57	0.55	0.11	0.051	0.42	0.17	0.23	0.39
1.01-2.00	0.13	0.0069	0.25	0.45	0.31	0.076	0.0014	0.029	0.031	0.2	0.53
2.01-5.00	0.028	0	0.39	0.055	0.034	0.0085	0	0	0.0029	0.37	0.026
> 5.00	0	0	0.013	0	0.0002	0	0	0	0	0.008	0

Table 39. Affected areas in Gloria, Oriental Mindoro during a 5-year rainfall return period

Affected area (sq km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq km.)										
	Malayong	Maligaya	Malubay	Manguyang	Mirayan	Narra	Papandungin	San Antonio	Santa Maria	Santa Theresa	Tambong
0.03-0.20	0.85	1.05	5.17	3.3	6.35	0.87	1.58	2.26	0.97	3.66	0.75
0.21-0.50	1.1	0.2	0.35	0.52	0.36	0.94	1.2	0.98	0.14	0.84	0.15
0.51-1.00	1.25	0.062	0.67	0.66	0.35	0.56	1.37	0.48	0.018	0.35	0.018
1.01-2.00	1.35	0.0057	0.92	0.59	0.26	0.058	0.53	0.18	0.0095	0.092	0.0002
2.01-5.00	0.5	0	0.51	0.056	0.051	0.01	0.49	0.0052	0.000066	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

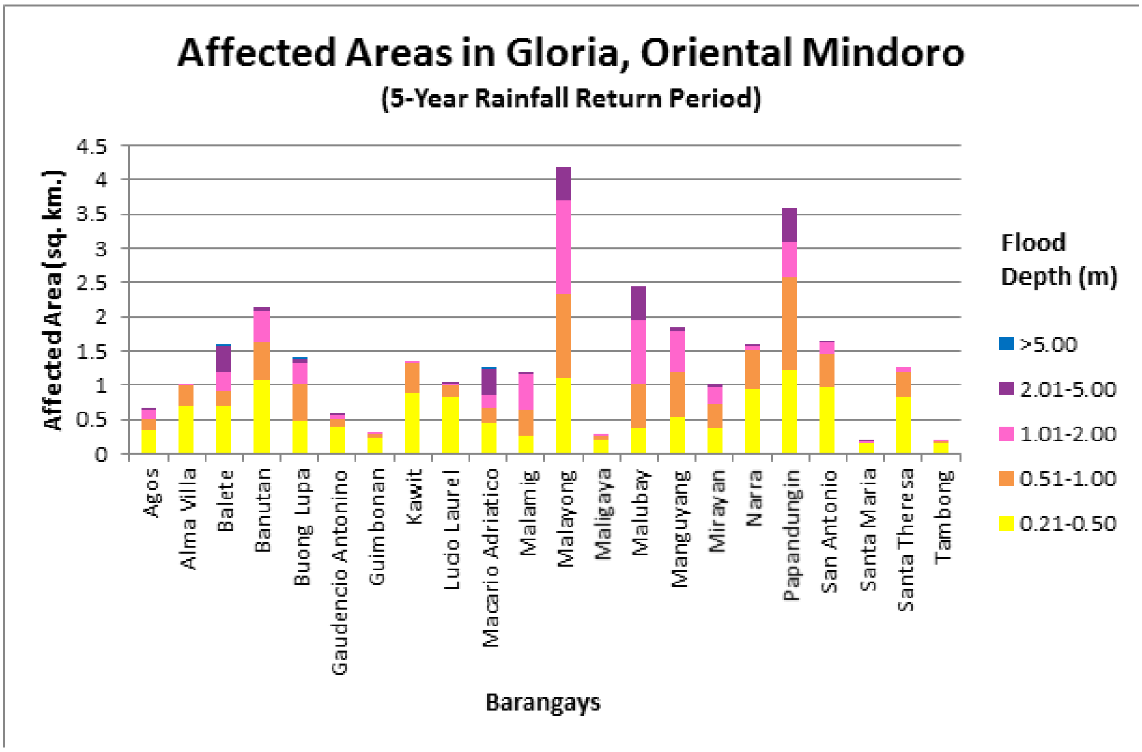


Figure 76. Affected areas in Gloria, Oriental Mindoro during a 5-year rainfall return period

For the 25-year return period, 21.6% of the municipality of Gloria with an area of 256.09 sq km will experience flood levels of less 0.20 meters; 5.7% of the area will experience flood levels of 0.21 to 0.50 meters; while 4.49%, 3.1%, 1.41%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 and Table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Gloria, Oriental Mindoro during a 25-year rainfall return period

Affected area (sq km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq km.)										
	Agos	Alma Villa	Balete	Banutan	Buong Lupa	Gaudencio Antonino	Guimbonan	Kawit	Lucio Laurel	Macario Adriatico	Malamig
0.03-0.20	2.76	2.31	3.61	3.57	2.12	1.25	1.49	1.16	3.81	7.03	2.49
0.21-0.50	0.43	0.81	0.97	1.33	0.38	0.57	0.38	0.94	1.44	0.43	0.27
0.51-1.00	0.22	0.48	0.32	0.81	0.66	0.17	0.096	0.65	0.32	0.36	0.35
1.01-2.00	0.16	0.021	0.25	0.63	0.49	0.091	0.0045	0.055	0.053	0.23	0.64
2.01-5.00	0.079	0	0.44	0.11	0.063	0.023	0	0	0.0051	0.45	0.19
> 5.00	0	0	0.05	0	0.0003	0	0	0	0	0.021	0

Table 41. Affected areas in Gloria, Oriental Mindoro during a 25-year rainfall return period

Affected area (sq km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq km.)										
	Malayong	Maligaya	Malubay	Manguyang	Mirayan	Narra	Papandungin	San Antonio	Santa Maria	Santa Theresa	Tambong
0.03-0.20	0.55	0.92	4.97	2.97	6.14	0.65	1.22	1.79	0.85	2.96	0.7
0.21-0.50	0.8	0.26	0.26	0.43	0.3	0.8	1.12	1.06	0.24	1.17	0.19
0.51-1.00	1.52	0.11	0.53	0.58	0.38	0.89	1.55	0.79	0.037	0.63	0.037
1.01-2.00	1.58	0.016	1.05	0.96	0.43	0.095	0.75	0.24	0.013	0.19	0.0008
2.01-5.00	0.6	0.0013	0.81	0.19	0.12	0.013	0.52	0.016	0.000066	0	0
> 5.00	0	0	0.01	0.018	0.0089	0	0	0	0	0	0

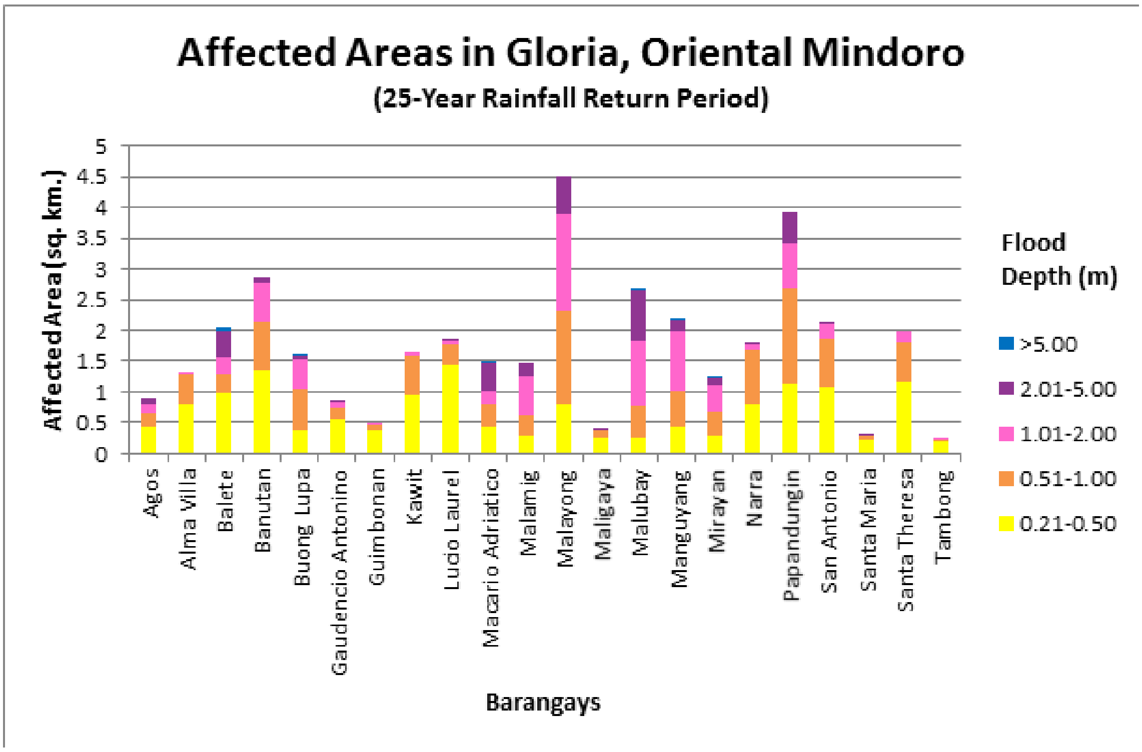


Figure 77. Affected areas in Gloria, Oriental Mindoro during a 25-year rainfall return period

For the 100-year return period, 19.71% of the municipality of Gloria with an area of 256.09 sq km will experience flood levels of less 0.20 meters; 5.82% of the area will experience flood levels of 0.21 to 0.50 meters; while 5.18%, 3.64%, 1.94%, and 0.07% 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 42 and Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Gloria, Oriental Mindoro during a 100-year rainfall return period

Affected area (sq km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq km.)										
	Agos	Alma Villa	Balete	Banutan	Buong Lupa	Gaudencio Antonino	Guimbonan	Kawit	Lucio Laurel	Macario Adriatico	Malamig
0.03-0.20	2.58	1.96	3.29	3.24	2.04	1.09	1.33	0.91	3.21	6.91	2.35
0.21-0.50	0.45	0.91	1.15	1.34	0.29	0.65	0.49	0.83	1.92	0.46	0.19
0.51-1.00	0.29	0.7	0.43	0.97	0.66	0.23	0.15	0.93	0.44	0.39	0.27
1.01-2.00	0.21	0.056	0.24	0.74	0.62	0.11	0.01	0.13	0.063	0.26	0.58
2.01-5.00	0.12	0.0003	0.46	0.15	0.098	0.027	0	0	0.0059	0.48	0.56
> 5.00	0	0	0.072	0	0.0003	0	0	0	0	0.029	0.0005

Table 43. Affected areas in Gloria, Oriental Mindoro during a 100-year rainfall return period

Affected area (sq km.) by flood depth (in m.)	Area of affected barangays in Gloria (in sq km.)										
	Malayong	Maligaya	Malubay	Manguyang	Mirayan	Narra	Papandungin	San Antonio	Santa Maria	Santa Theresa	Tambong
0.03-0.20	0.33	0.84	4.82	2.83	6.04	0.42	0.88	1.48	0.78	2.48	0.66
0.21-0.50	0.62	0.29	0.26	0.48	0.26	0.55	1.01	0.91	0.29	1.34	0.2
0.51-1.00	1.48	0.15	0.39	0.56	0.34	1.22	1.65	1.08	0.056	0.83	0.056
1.01-2.00	1.8	0.029	0.96	1.01	0.52	0.23	1.07	0.39	0.017	0.28	0.0012
2.01-5.00	0.82	0.0039	1.18	0.25	0.2	0.019	0.55	0.04	0.000066	0.0036	0
> 5.00	0	0	0.036	0.019	0.017	0	0	0	0	0	0

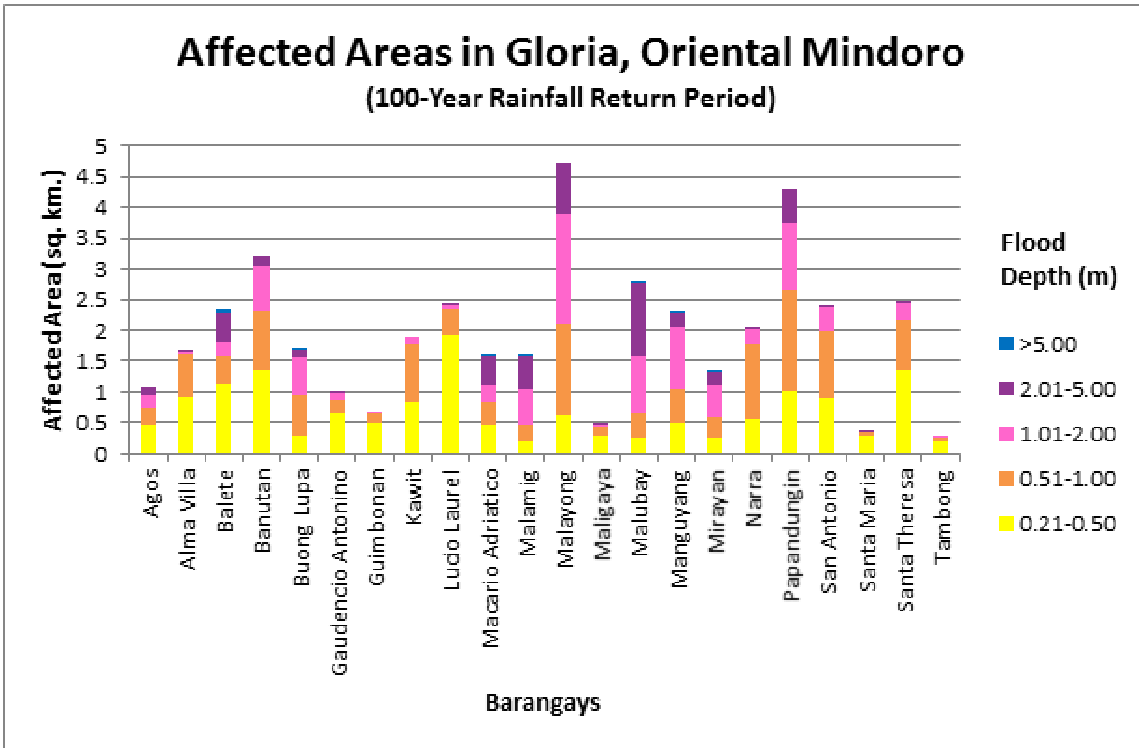


Figure 78. Affected areas in Gloria, Oriental Mindoro during a 100-year rainfall return period

Among the barangays in the municipality of Gloria, Macario Adriatico is projected to have the highest percentage of area that will experience flood levels at 3.33%. Meanwhile, Malubay posted the second highest percentage of area that may be affected by flood depths at 2.98%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 79.

The flood validation consists of 129 points randomly selected all over the Agsalin Floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.37m. Table 44 shows a contingency matrix of the comparison.

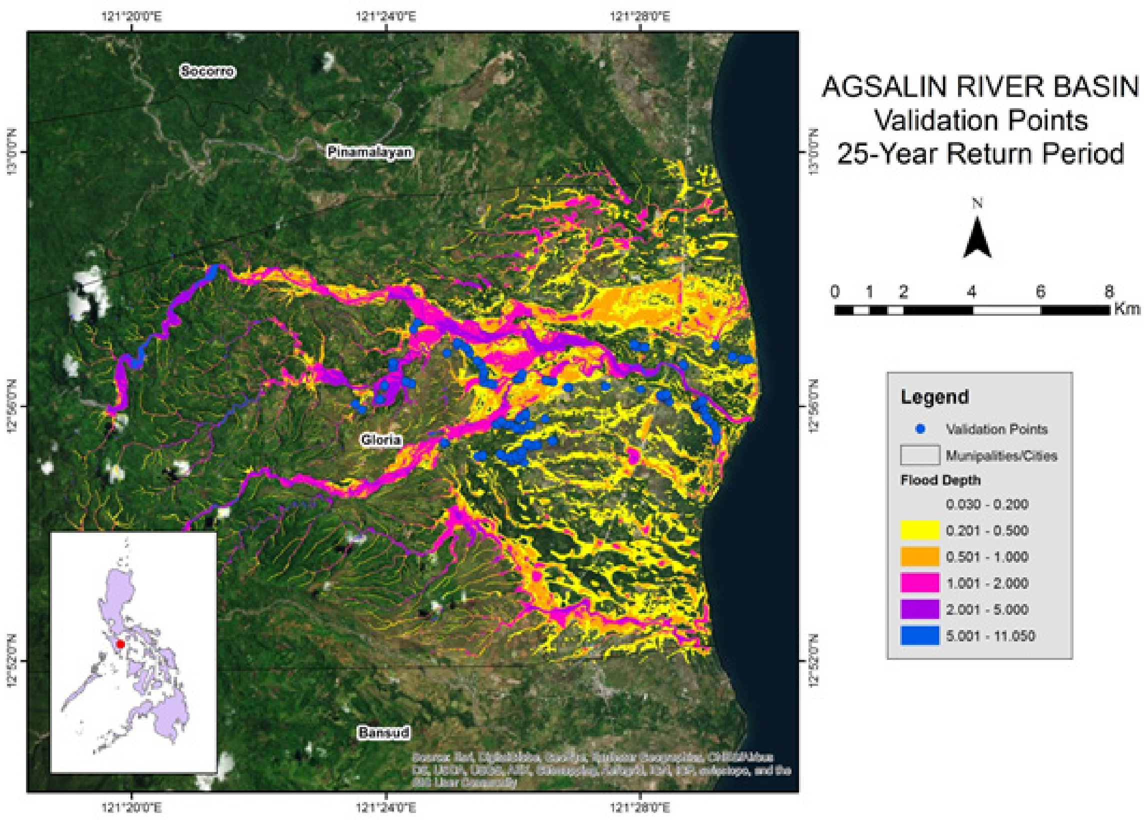


Figure 79. Validation points for 25-year flood depth map of Agsalin Floodplain

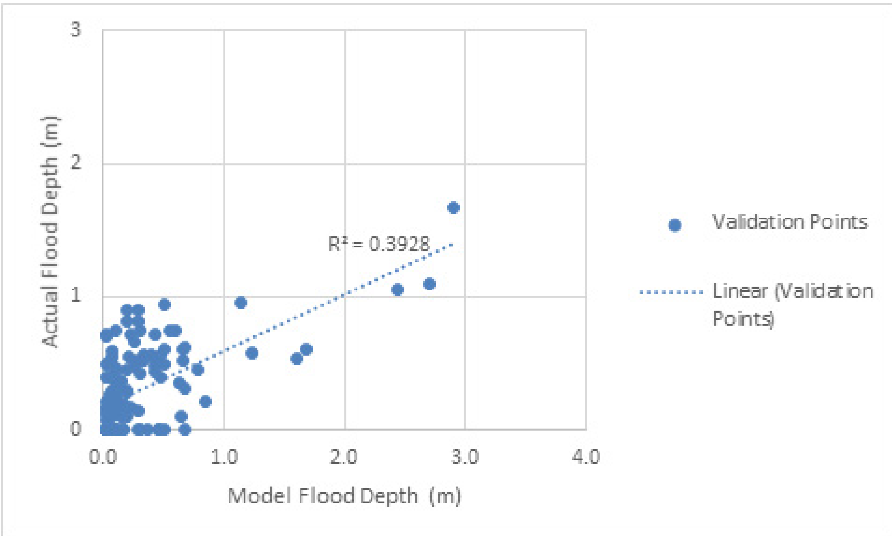


Figure 80. Flood map depth vs. actual flood depth

Table 44. Actual flood depth vs. simulated flood depth at different levels in the Agsalin River Basin

ABONGAN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0,51-1.00	1.00-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	56	9	3	0	0	0	68
	0.21-0.50	15	6	5	0	0	0	26
	0.51-1.00	7	14	7	4	0	0	32
	1.01-2.00	0	0	0	0	3	0	3
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	78	29	15	4	3	0	129

The overall accuracy generated by the flood model is estimated at 53.49% with 69 points correctly matching the actual flood depths. In addition, there were 36 points estimated one level above and below the correct flood depths while there were 10 points and 0 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 36 points were underestimated in the modeled flood depths of Agsalin. Table 45 depicts the summary of the accuracy assessment in the Agsalin River Basin survey.

Table 45. Summary of accuracy assessment in the Agsalin River Basin survey

No. of Points		%
Correct	69	53.49
Overestimated	24	18.60
Underestimated	36	27.91
Total	129	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors Used in the Agsalin Floodplain Survey

1. Aquarius Sensor

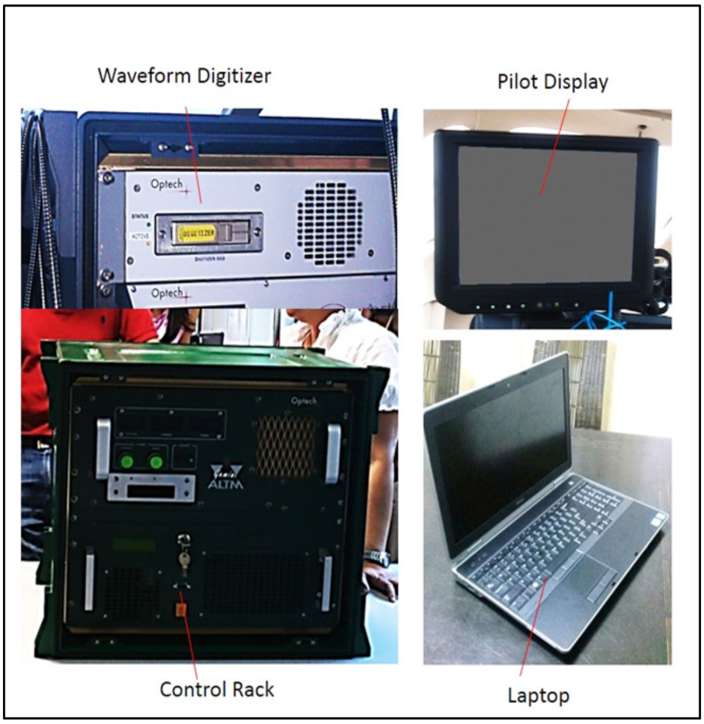


Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specifications of 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

2. Gemini Sensor

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specifications of Gemini Sensor

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

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

1. MRE-54

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

February 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: **ORIENTAL MINDORO**
Station Name: **MRE-54**
Order: **2nd**

Island: **LUZON**
Municipality: **PINAMALAYAN**
Barangay: **MALIANGCOG**

PRS92 Coordinates

Latitude: **12° 59' 12.43671"** Longitude: **121° 24' 46.52637"** Ellipsoidal Hgt: **42.40800 m.**

WGS84 Coordinates

Latitude: **12° 59' 7.43505"** Longitude: **121° 24' 51.55668"** Ellipsoidal Hgt: **91.39500 m.**

PTM Coordinates

Northing: **1436124.562 m.** Easting: **544797.009 m.** Zone: **3**

UTM Coordinates

Northing: **1,436,121.49** Easting: **327,864.09** Zone: **51**

Location Description

MRE-54

From Calapan City to Roxas, along Nat'l Road, approx. 100 m from Pula Bridge, along Brgy. Sto. Niño, right turn to Brgy. Road leading to Gloria Airport, passing through Brgy. Sto. Niño, Brgy. Sta. Maria, Brgy. Pambigan Malaki, all in Mun. of Pinamalayan. approx. 7.8 Km. from Nat'l Road, 1.1 Km. from Brgy. Chapel, 600 m from Maliangkog Elem. School, left side of road located Brgy. Hall of Maliangkog, Pinamalayan, Oriental Mindoro. Station is located beside of flagpole near gate of brgy. hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-54, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-196**

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

9902042014125855

Figure A-2.1. MRE-54

2. MRE-32

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

April 05, 2013

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: **ORIENTAL MINDORO**
Station Name: **MRE-32**
Order: **2nd**

Island: **LUZON**
Municipality: **VICTORIA**
Barangay:

PRS92 Coordinates

Latitude: **13° 10' 28.85064"**	Longitude: **121° 16' 38.44761"**	Ellipsoidal Hgt: **19.49300 m.**

WGS84 Coordinates

Latitude: **13° 10' 23.79251"**	Longitude: **121° 16' 43.46244"**	Ellipsoidal Hgt: **67.64700 m.**

PTM Coordinates

Northing: **1456889.419 m.**	Easting: **530065.679 m.**	Zone: **3**

UTM Coordinates

Northing: **1,457,002.75**	Easting: **313,296.85**	Zone: **51**

Location Description

MRE-32

From Calapan City to Roxas, along Nat'l. Road approx. 34 Km. travel to Victoria Town Proper, 10 Km. from intersection of Naujan, left turn to Shell Gasoline Station, approx. 150 m, right side of road located Mun. Hall of Victoria, Oriental Mindoro. Station is located in Mun. Park in front of Former Mayor Statue, along corner of pathwalk. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-32, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943485 B**
T.N.: **2013-0270**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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

Figure A-2.2. MRE-32

3. MRE-44

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

February 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: **ORIENTAL MINDORO**	
	Station Name: **MRE-44**	
Island: **LUZON**	Order: **2nd**	
Municipality: **ROXAS**		Barangay: **HAPPY VALLEY**
	PRS92 Coordinates	
Latitude: **12° 38' 59.03778"**	Longitude: **121° 24' 32.60444"**	Ellipsoidal Hgt: **87.94200 m.**
	WGS84 Coordinates	
Latitude: **12° 38' 54.11733"**	Longitude: **121° 24' 37.66392"**	Ellipsoidal Hgt: **137.80400 m.**
	PTM Coordinates	
Northing: **1398838.995 m.**	Easting: **544436.519 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,398,840.08**	Easting: **327,214.81**	Zone: **51**

MRE-44

Location Description

From Calapan City to Bulalacao, approx. 4 Km. from Roxas Town Proper, along Nat'l Road is an intersection going to Roxas Proper, Mansalay, and Bongabong, Oriental Mindoro. Turn right to road leading to Bongabong Town Proper, approx. 6.9 Km., passing through Brgy. San Aquilino, Brgy. Libertad, Brgy. Little Tanauan, and Brgy. San Mariano, all in Mun. of Roxas. Along Brgy. San Rafael, left side of road located Km. post 130 about 50 m after RCBCulvert, turn left to Brgy. Road leading to Sitio Amawan, approx. 800 m passing through San Rafael Elem. School, and GK Village, left side of road located Brgy. Hall of Happy Valley, Roxas, Oriental Mindoro. Station is located beside of streetlight outside wall of brgy. hall. Mark is the head of a 4 in. copper nial flushed in a cement block embedded in the ground with inscriptions, "MRE-44, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-198**

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

9 9 0 2 0 4 2 0 1 4 1 2 5 9 4 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-2.3. MRE-44

Annex 3. Baseline Processing Reports of Reference Points Used in the LiDAR Survey

1. MRE-4563

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE-4563 --- MRE-54 (B1)	MRE-54	MRE-4563	Fixed	0.005	0.015	359°56'42"	3244.605	-17.680

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

MRE-4563 - MRE-54 (7:57:34 AM-5:20:54 PM) (S1)

Baseline observation:	MRE-4563 --- MRE-54 (B1)
Processed:	2/11/2014 3:05:00 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.015 m
RMS:	0.001 m
Maximum PDOP:	6.448
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	2/6/2014 7:57:51 AM (Local: UTC+8hr)
Processing stop time:	2/6/2014 5:20:54 PM (Local: UTC+8hr)
Processing duration:	09:23:03
Processing interval:	1 second

Figure A-3.1. MRE-4563

2. MRE-11

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE54 - 22 --- MRE11 AM1 -22 (B3)	MRE54 - 22	MRE11 AM1 -22	Fixed	0.006	0.035	-9779.846	890.616	-25831.853	163°25'41"	27635.215	-36.405
MRE54 - 22 --- MRE11 PM2 - 22 (B2)	MRE54 - 22	MRE11 PM2 - 22	Fixed	0.004	0.023	-9779.877	890.724	-25831.856	163°25'41"	27635.232	-36.300

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Figure A-3.2. MRE-11

MRE54 - 22 - MRE11 AM1 -22 (7:40:13 AM-8:58:26 AM) (S3)

Baseline observation:	MRE54 - 22 --- MRE11 AM1 -22 (B3)
Processed:	11/5/2015 4:50:09 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.035 m
RMS:	0.005 m
Maximum PDOP:	3.705
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/22/2015 7:40:33 AM (Local: UTC+8hr)
Processing stop time:	10/22/2015 8:58:26 AM (Local: UTC+8hr)
Processing duration:	01:17:53
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE54 - 22				
Grid		Local		Global	
Easting	328016.924 m	Latitude	N12°59'07.43505"	Latitude	N12°59'07.43505"
Northing	1436055.870 m	Longitude	E121°24'51.55668"	Longitude	E121°24'51.55668"
Elevation	43.116 m	Height	91.395 m	Height	91.395 m

To:	MRE11 AM1 -22				
Grid		Local		Global	
Easting	335735.169 m	Latitude	N12°44'45.47242"	Latitude	N12°44'45.47242"
Northing	1409521.797 m	Longitude	E121°29'12.85426"	Longitude	E121°29'12.85426"
Elevation	5.611 m	Height	54.990 m	Height	54.990 m

Vector					
ΔEasting	7718.245 m	NS Fwd Azimuth	163°25'41"	ΔX	-9779.902 m
ΔNorthing	-26534.073 m	Ellipsoid Dist.	27635.215 m	ΔY	890.711 m
ΔElevation	-37.505 m	ΔHeight	-36.405 m	ΔZ	-25831.822 m

Figure A-3.3. MRE-11 (B)

3. MRE-11A

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE11 -25 --- MRE11A - 25 (B1)	MRE11 - 25	MRE11A - 25	Fixed	0.001	0.002	1.673	0.540	1.035	302°48'16"	2.032	0.515

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Figure A-3.4. MRE-11A

MRE11 -25 - MRE11A - 25 (7:49:43 AM-10:53:15 AM) (S1)

Baseline observation:	MRE11 -25 --- MRE11A - 25 (B1)
Processed:	11/5/2015 4:59:57 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.001 m
Maximum PDOP:	3.139
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/25/2015 7:49:43 AM (Local: UTC+8hr)
Processing stop time:	10/25/2015 10:53:15 AM (Local: UTC+8hr)
Processing duration:	03:03:32
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE11 -25				
Grid		Local		Global	
Easting	0.310 m	Latitude	N12°44'45.47200"	Latitude	N12°44'45.47200"
Northing	-4.205 m	Longitude	E121°29'12.85377"	Longitude	E121°29'12.85377"
Elevation	55.043 m	Height	55.043 m	Height	55.043 m

To:	MRE11A - 25				
Grid		Local		Global	
Easting	-1.398 m	Latitude	N12°44'45.50783"	Latitude	N12°44'45.50783"
Northing	-3.104 m	Longitude	E121°29'12.79714"	Longitude	E121°29'12.79714"
Elevation	55.558 m	Height	55.558 m	Height	55.558 m

Vector					
ΔEasting	-1.708 m	NS Fwd Azimuth	302°48'16"	ΔX	1.321 m
ΔNorthing	1.101 m	Ellipsoid Dist.	2.032 m	ΔY	1.114 m
ΔElevation	0.515 m	ΔHeight	0.515 m	ΔZ	1.188 m

Figure A-3.5. MRE-11A (B)

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		MILLIE SHANE REYES	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
		GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	TSG ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
		TSG AWIC CHARISMA NAVARRO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC
		CAPT. MARK TANGONAN	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. Data Transfer Sheet for Agsalin Floodplain

DATA TRANSFER SHEET
~~Jan~~ Feb 6, 2014

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 1, 2014	1052A	3BLK28A033A	AQUARIUS	N/A	528KB	920KB	222MB	52.9GB	385KB	14.8GB	46.3GB	6.12MB	19B	626B	888KB	N/A	X:\Airborne_Raw\1052A
Feb 1, 2014	1054A	3BLK28B033B	AQUARIUS	N/A	672KB	1.70MB	206MB	73.7GB	385KB	11.8GB	N/A	6.12MB	19B	625B	314KB	N/A	X:\Airborne_Raw\1054A
Feb 3, 2014	1056A	3BLK28C034A	AQUARIUS	N/A	700KB	1.06MB	210MB	77.2GB	558KB	12.2GB	172GB	6.29MB	19B	651B	239KB	N/A	X:\Airborne_Raw\1056A
Feb 3,2014	1058A	3BLK28CD034B	AQUARIUS	N/A	646KB	1.82MB	201MB	65.8GB	491KB	11.3GB	N/A	6.29MB	19B	328B	9.10KB	N/A	X:\Airborne_Raw\1058A

Received from
Name Faith Sable
Position RA
Signature

Received by
Name JOIDA F. PRIETO 02/06/14
Position SSRS
Signature

Verified by
Name JOIDA F. PRIETO 02/06/14
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Agsalin Floodplain (A)

DATA TRANSFER SHEET
Feb 18, 2014

DATE of Operation	FLIGHT NO.	SENSOR	MISSION NAME	RAW LAS (MB)	LOGS (KB)	POS (MB)	RAW IMAGES	MISSION LOG FILE	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S) (MB)	OPERATOR COMMENTS (DPC LOGS) (Bytes)	FLIGHT PLAN (KB)	SERVER LOCATION
2/7/2014	1072A	Aquarius	3BLK28F038A	703KB	1.16MB	256	81.4GB	563KB	12.5	174	14.1	767	13	\\FREENAS\geostorage3\Airborne_Raw\1072A
2/7/2014	1074A	Aquarius	3BLK28G038B	134 KB	968 KB	174	33.7GB	274KB	6.4	60.9	14.1	258	11 (28F)&12(28G)	\\FREENAS\geostorage3\Airborne_Raw\1074A
2/8/2014	1076A	Aquarius	3BLK28GS039A	643KB	1.21MB	233	76.8	308KB&218KB	11.5	101	14.3	357	12	\\FREENAS\geostorage3\Airborne_Raw\1076A
2/5/2014	1066A	Aquarius	3BLK28DS036A	360KB	1.38MB	203	73.9	311KB	11.7	N/A	14.5	414	11	\\FREENAS\geostorage3\Airborne_Raw\1066A
2/6/2014	1070A	Aquarius	3BLK28DSE037A	932KB	1.46MB	270	104	764KB	15.9	249	14.9	300	12	\\FREENAS\geostorage3\Airborne_Raw\1070A
2/8/2014	1078A	Aquarius	3BLK28GSH039B	530KB	892KB	197	56.8	442KB	9.71	N/A	14.3	738	12 (28G) & 12 (28H)	\\FREENAS\geostorage3\Airborne_Raw\1078A

Received from
Name/Signature Lovely Acuña
Position Supervising SRS
Date 02/19/2014

Received by
Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/2014

Verified by
Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/14

Figure A-5.2. Transfer Sheet for Agsalin Floodplain (B)

DATA TRANSFER SHEET
Feb 21, 2014

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	
2/11/2014	1088A	3BLK28HS042A	AQUARIUS	N/A	781	1.23MB	269	80.4GB ~~25.4~~	565	14	N/A	14.7	143	506	6	12	\\FREENAS\geostorage3\Airborne_Raw\1088A
2/11/2014	1090A	3BLK28J042B	AQUARIUS	N/A	215	822KB	156	19.4	162	4.96	N/A	14.7	143	267	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1090A
2/12/2014	1092A	3BLK28ABES043A	AQUARIUS	N/A	1657	1.70MB	242	23.7	601	12.7	N/A	15.4	123	364	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1092A
2/12/2014	1094A	3BLK28BS043B	AQUARIUS	N/A	332	2.27MB	128	28.4GB ~~22.1~~	186	6.05	N/A	15.4	123	334	8	N/A	\\FREENAS\geostorage3\Airborne_Raw\1094A
2/13/2014	1096A	3BLK28NAJ044A	AQUARIUS	N/A	449	772KB	207	36.6	291	7.46	N/A	13.3	175	411	6	N/A	\\FREENAS\geostorage3\Airborne_Raw\1096A
2/13/2014	1098A	3BLK28JSI044B	AQUARIUS	N/A	582	954KB	235	23.9	291	11	N/A	13.3	175	725	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1098A
2/15/2014	1104A	3BLK28JSI046A	AQUARIUS	N/A	787	1.08MB	276	56.2	288KB&170KB	10.3	N/A	9.85	134	325	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1104A

Received from

Name Lovely Acuña / [signature]
Position Supervising SRS
Signature [signature] 02/21/2014

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature [signature]

Verified by

Name JOIDA F. PRIETO
Position SSRS
Signature [signature]

Figure A-5.3. Transfer Sheet for Agsalin Floodplain (C)

DATA TRANSFER SHEET
Calapan 11/9/15

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	
Oct. 22, 2015	8300	2BLK28ABC295A	Gemini	na	400	675	236	28.5	214	18.2	247	15.6	1KB	1KB	24	na	Z:\DAC\RAW DATA
Oct. 22, 2015	8301	2BLK28CSD295B	Gemini	na	587	947	249	39.1/10.5	307/87	22.7	na	15.6	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 23, 2015	8302	2BLK28ASEHI296A	Gemini	na	343	593	228	28.2	223	14.5	na	11.5	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 24, 2015	8304	2BLK28FHS297A	Gemini	na	315	519	214	24.8	187	14.2	221	8.92	1KB	1KB	5/11/24/14/13	na	Z:\DAC\RAW DATA
Oct. 25, 2015	8306	2CALIBBLK28FSGS298A	Gemini	na	136	366	220	na	na	10.7	4.29	8.28	1KB	1KB	28/27	na	Z:\DAC\RAW DATA
Oct. 26, 2015	8308	2BLK28J299A	Gemini	na	312	356	235	na	na	14	153	8.39	1KB	1KB	7/5/2	na	Z:\DAC\RAW DATA
Oct. 28, 2015	8312	2BLK28JKLS301A	Gemini	na	40	292	215	na	na	11	427	7.5	1KB	1KB	7	270	Z:\DAC\RAW DATA

Received from
Name C. Joaquin
Position RA
Signature

Received by
Name AC Bongat
Position SSRS
Signature 11/12/15

15-38

Figure A-5.4. Transfer Sheet for Agsalin Floodplain (D)

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1054A Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 105

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28B033B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J.R. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEBRUARY 2, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1253	14 Engine Off: 1634	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 15/21 LINES.					

21 Problems and Solutions:

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

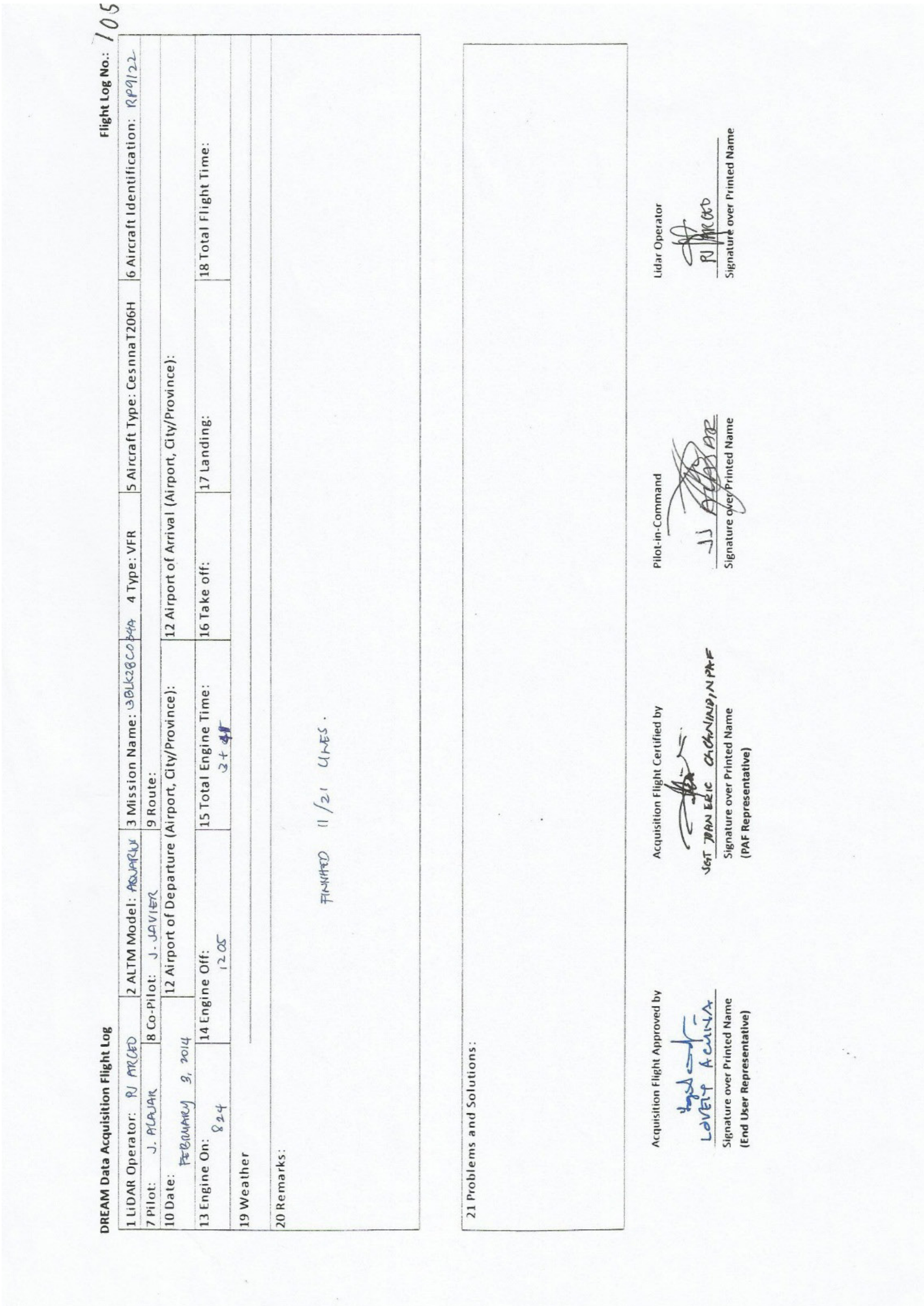
Acquisition Flight Certified by
SGT JOHN ERIC CLEMENTE PAF
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
RJ Arceo
Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1054A

2. Flight Log for 1056A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 105

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28C034A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEBRUARY 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 824	14 Engine Off: 1205	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 11/21 LINES.					

21 Problems and Solutions:

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

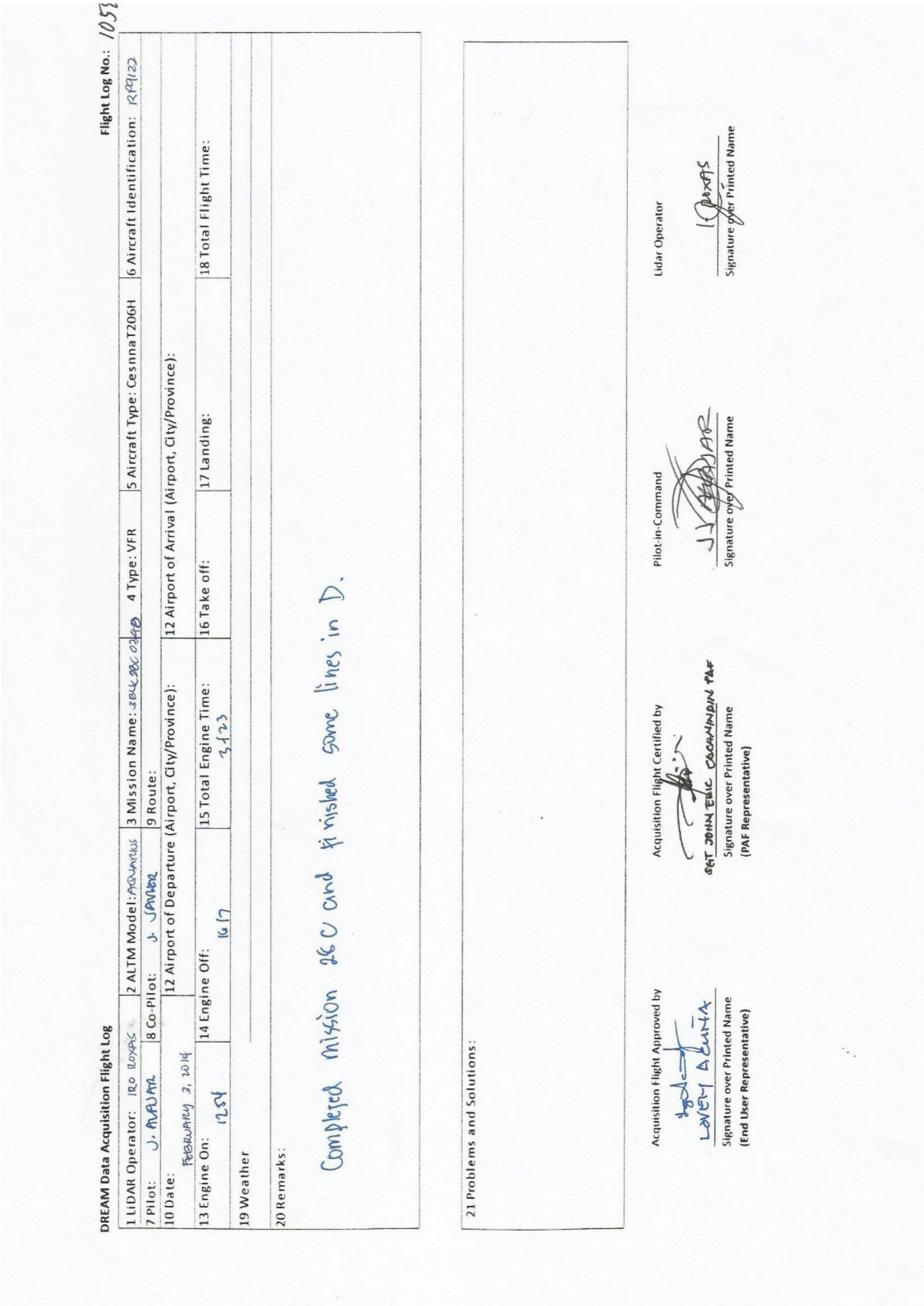
Acquisition Flight Certified by: SGT JUAN ERIC CACANINDIN PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: JJ ALAJAR — Signature over Printed Name

Lidar Operator: RJ ARCEO — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1056A

3. Flight Log for 1058A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1058

1 LiDAR Operator: I. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK28C034B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. Alajar	8 Co-Pilot: J. Javier	9 Route:			
10 Date: February 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1617	15 Total Engine Time: 3+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission 28C and finished some lines in D.

21 Problems and Solutions:

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

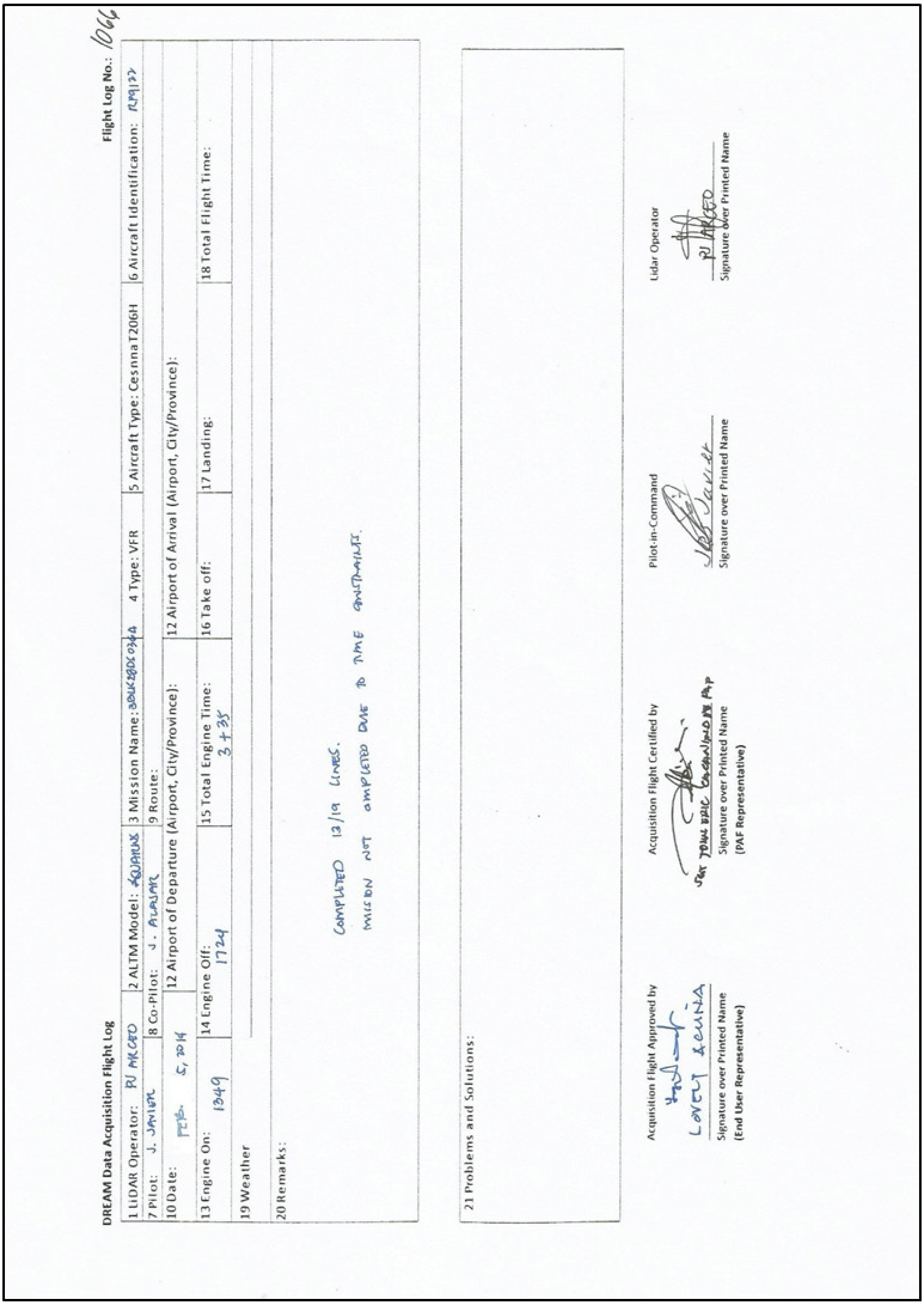
Acquisition Flight Certified by
SGT John Eric Cochingin PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J. Alajar
Signature over Printed Name

Lidar Operator
I. Roxas
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1058A

4. Flight Log for 1066A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1066

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28DS036A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 5, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1349	14 Engine Off: 1724	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

COMPLETED 12/19 LINES.

MISSION NOT COMPLETED DUE TO TIME CONSTRAINTS.

21 Problems and Solutions:

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

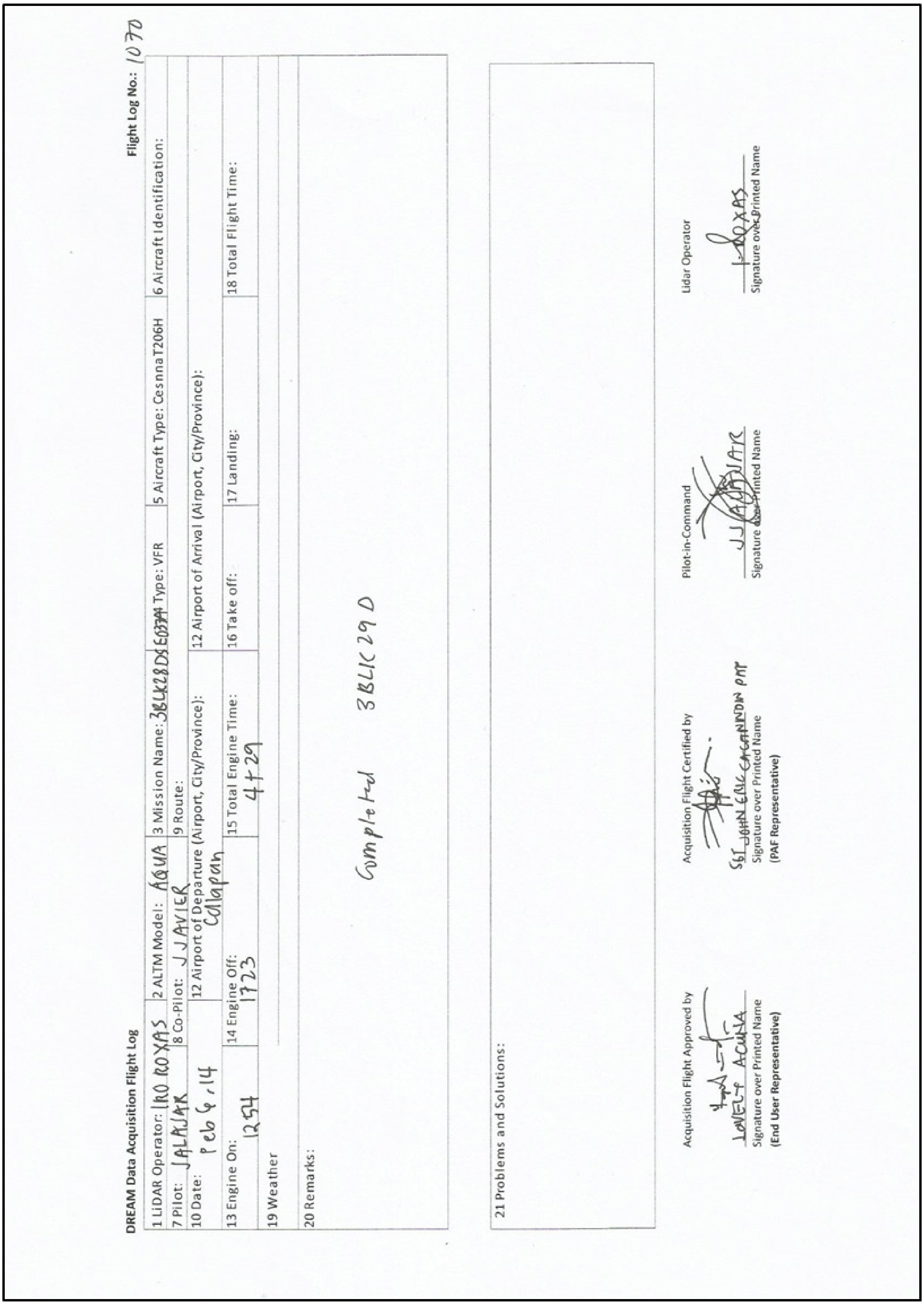
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. JAVIER — Signature over Printed Name

Lidar Operator: RJ ARCEO — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1066A

5. Flight Log for 1070A Mission


Flight Log No.: 1070

DREAM Data Acquisition Flight Log

1 LiDAR Operator: I RO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK28DSE037A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J ALAJAR	8 Co-Pilot: J JAVIER	9 Route:			
10 Date: Feb 6, 14	12 Airport of Departure (Airport, City/Province): Collapun		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1723	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 3BLK29D					

21 Problems and Solutions:

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

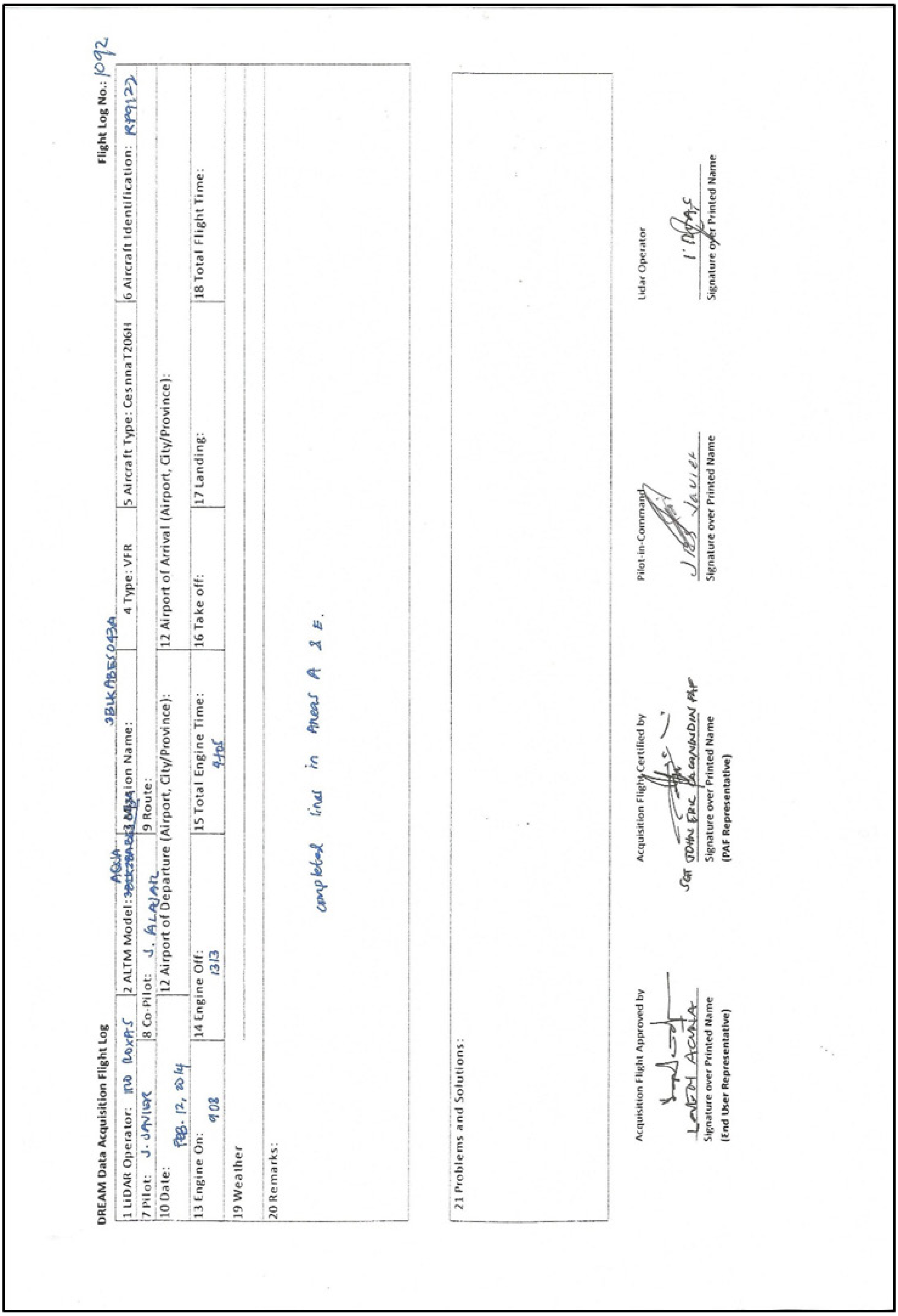
Acquisition Flight Certified by
SGT JOHN ERIC CACANINDIN PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J JALAJAR
Signature over Printed Name

Lidar Operator
I ROXAS
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1070A

6. Flight Log for 1092A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1092

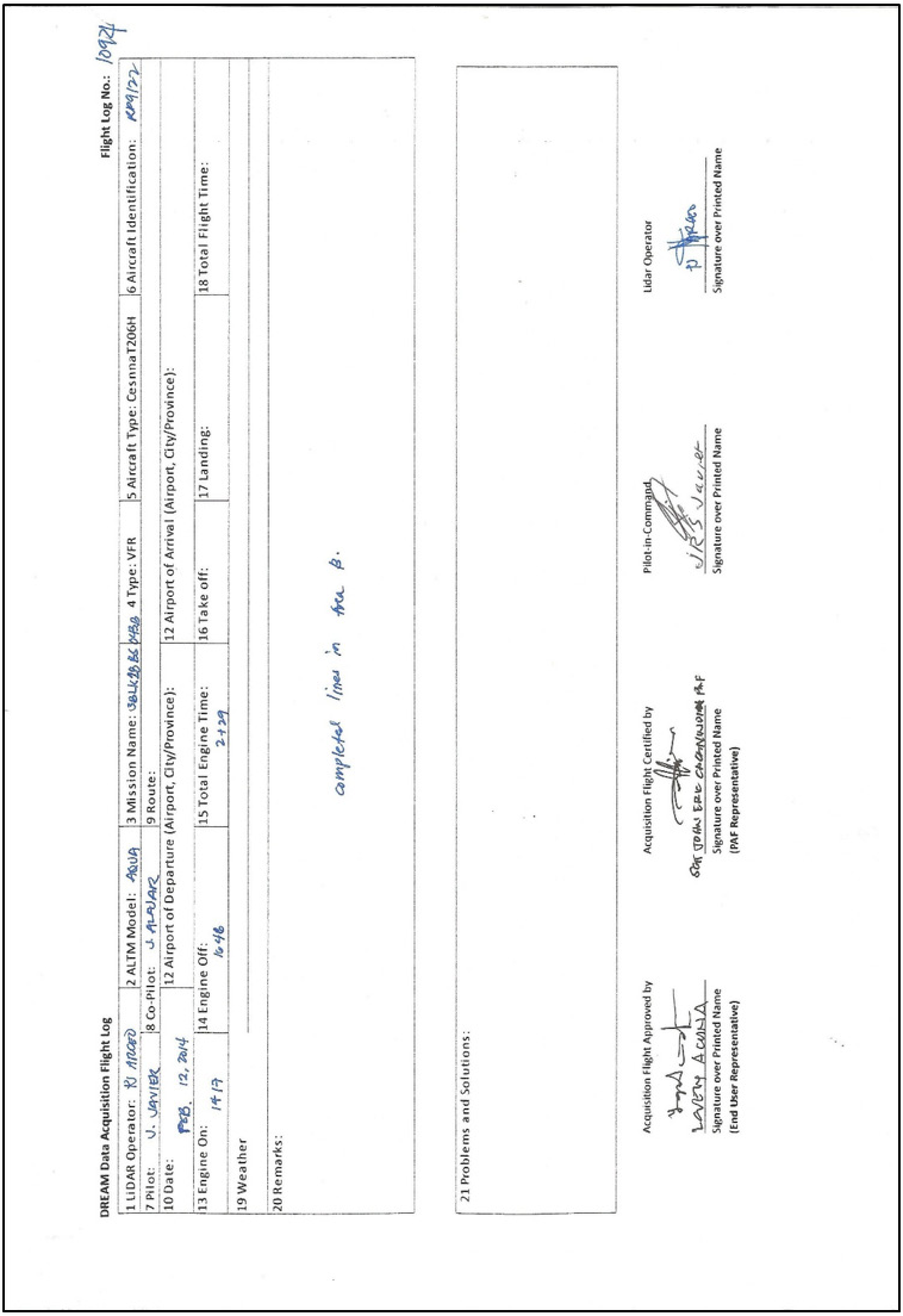
1 LiDAR Operator: I'RO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLKABES043A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 12, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 908	14 Engine Off: 1313	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed lines in Areas A & E.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN ERIC CACANINDIN PAF	J. JAVIER	I'. ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6. Flight Log for Mission 1092A

7. Flight Log for 1094A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1094

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK28BS049B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 12, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1417	14 Engine Off: 1646	15 Total Engine Time: 2+29	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
LARRY ACUNA
Signature over Printed Name
(End User Representative)

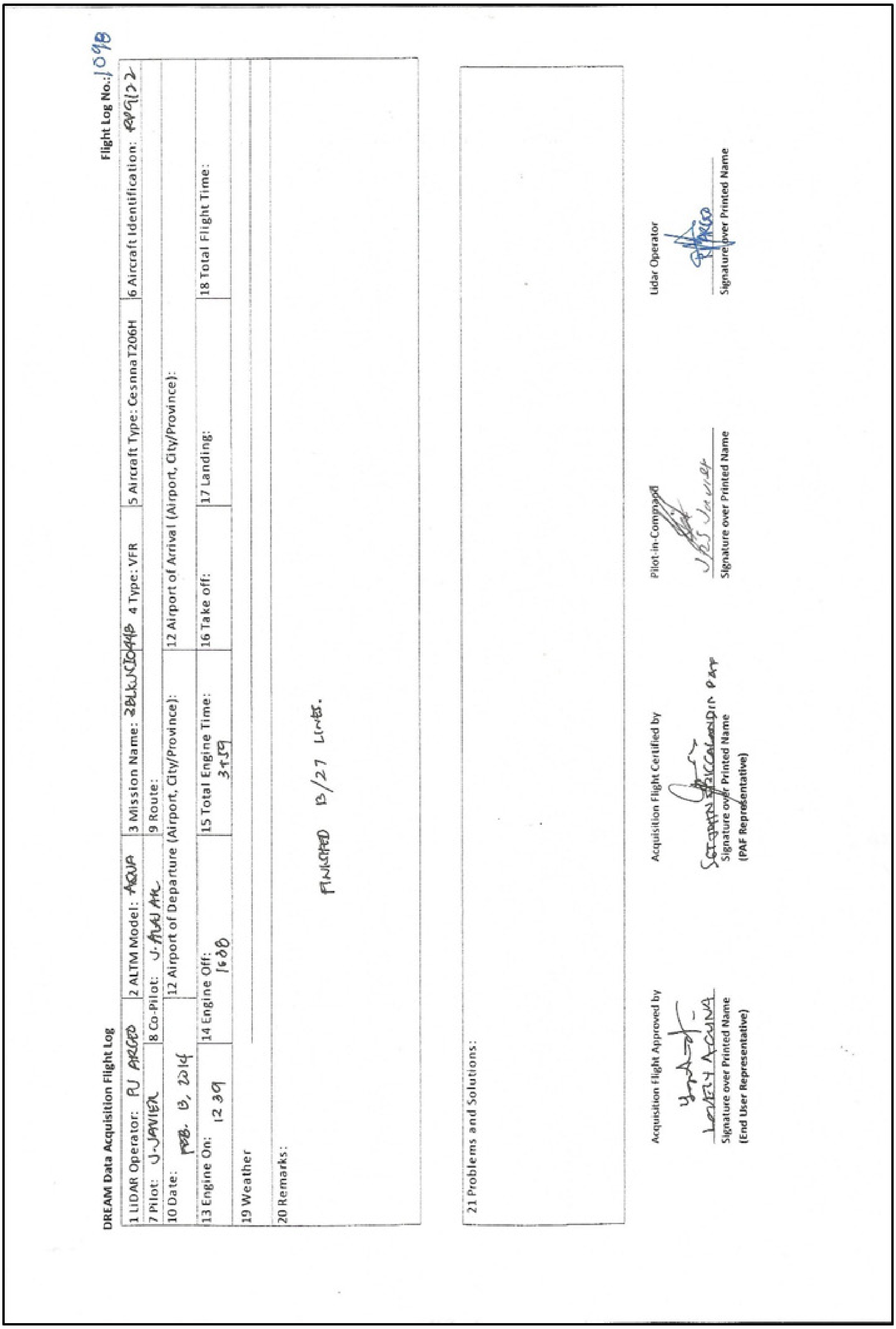
Acquisition Flight Certified by
SSGT JOHN ERIC [illegible] PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J R S Javier
Signature over Printed Name

Lidar Operator
RJ ARCEO
Signature over Printed Name

Figure A-6.7. Flight Log for Mission 1094A

8. Flight Log for 1098A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1098

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 2BLK33CI044B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1239	14 Engine Off: 1638	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 13/27 LINES.					

21 Problems and Solutions:

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

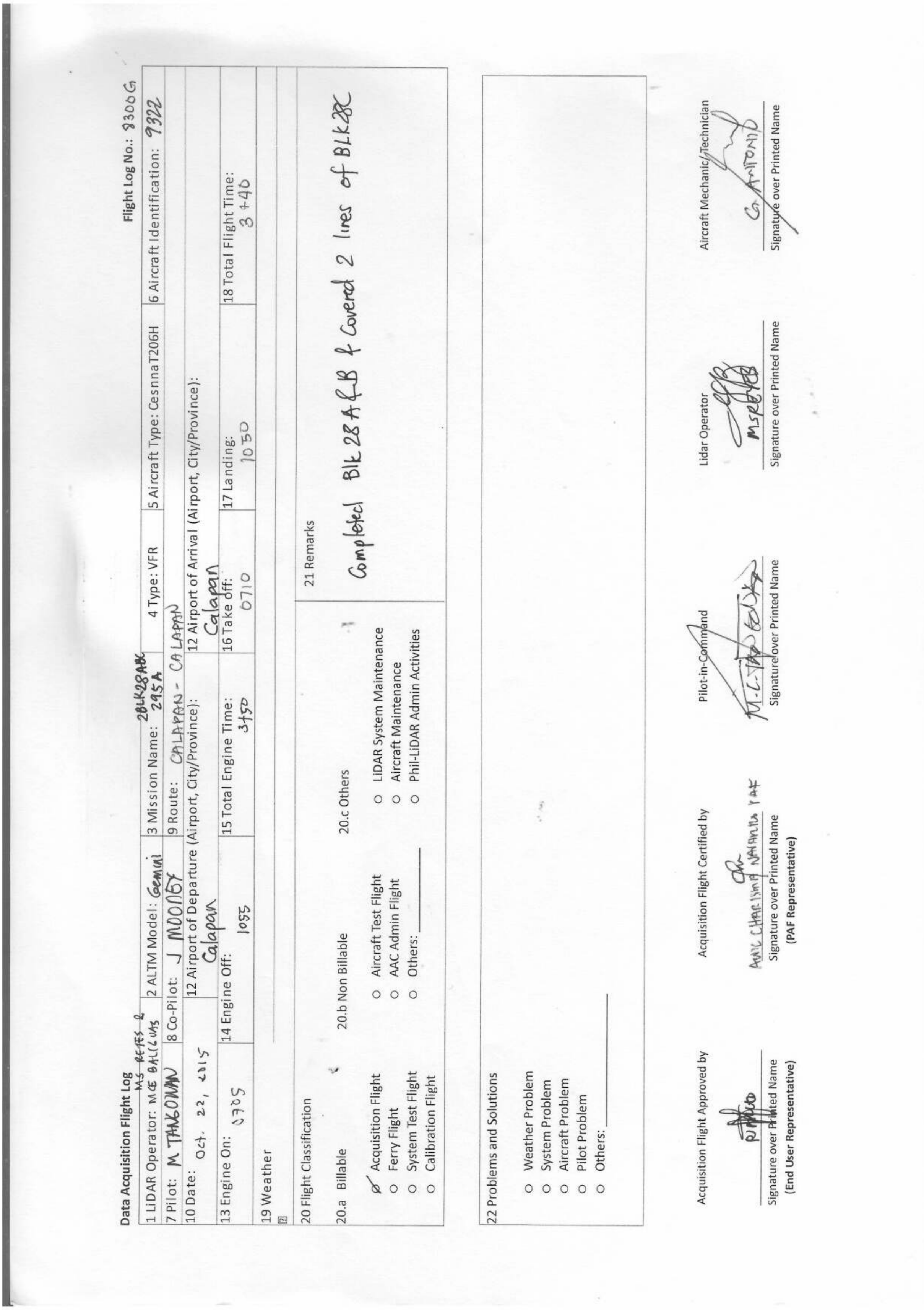
Acquisition Flight Certified by
SGT JOHN ERIC CALONDIR PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
PJ ARCEO
Signature over Printed Name

Figure A-6.8. Flight Log for Mission 1098A

9. Flight Log for 8300G Mission



Data Acquisition Flight Log — Flight Log No.: 8300G

1 LiDAR Operator: MCE BALICUATAS, MS REYES - 2	2 ALTM Model: Gemini	3 Mission Name: 2BLK28ABC 295A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct. 22, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0705	14 Engine Off: 1055	15 Total Engine Time: 3+50	16 Take off: 0710	17 Landing: 1050	18 Total Flight Time: 3+40
19 Weather					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
☑ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: ____	○ Phil-LIDAR Admin Activities
○ Calibration Flight		

21 Remarks

Completed BLK 28A & B & Covered 2 lines of BLK28C

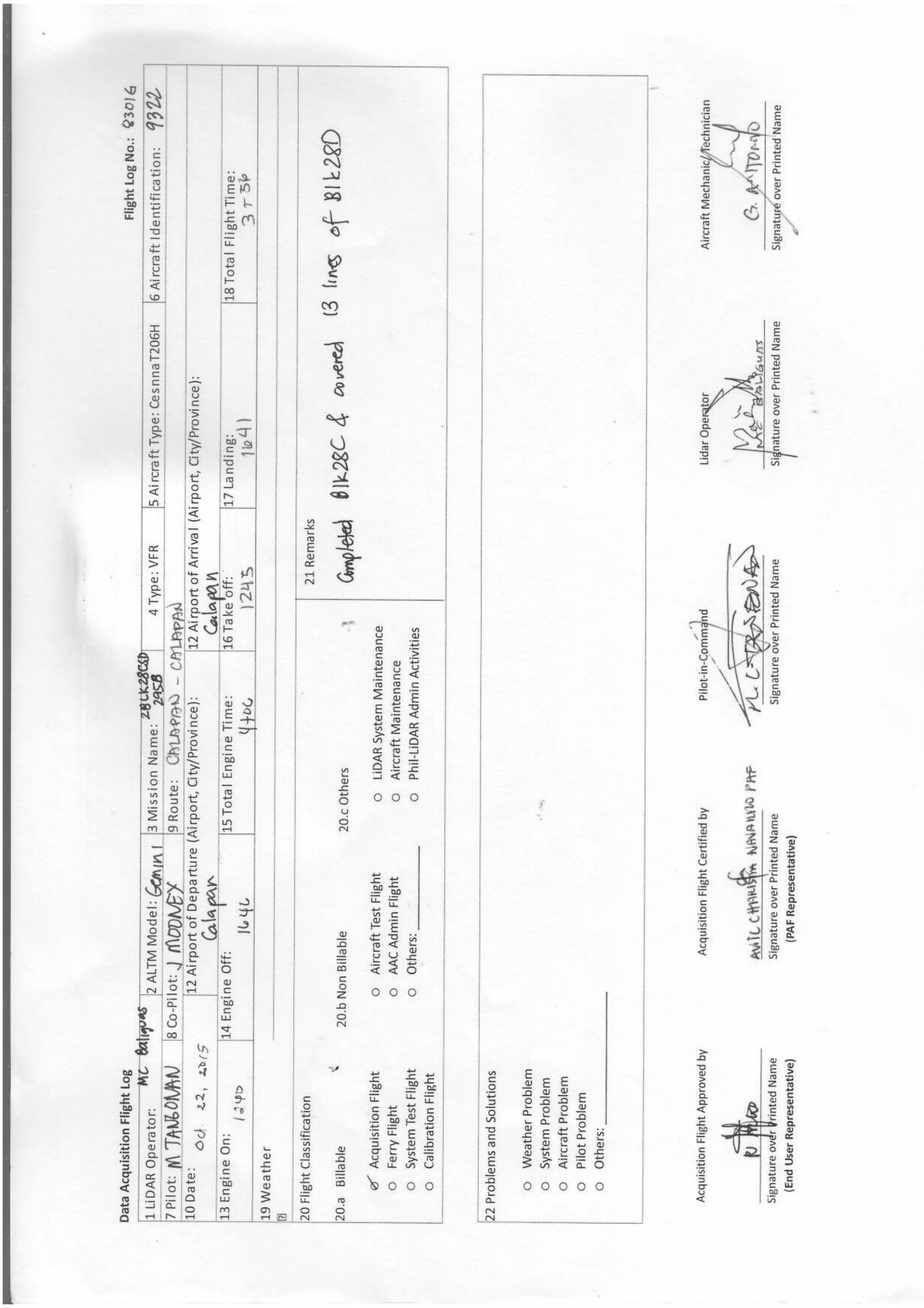
22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	M. L. TANGONAN — Signature over Printed Name	MS REYES — Signature over Printed Name	G. ANTONIO — Signature over Printed Name

Figure A-6.10. Flight Log for Mission 8300G

10. Flight Log for 8301G Mission



Data Acquisition Flight Log — Flight Log No.: 8301G

1 LiDAR Operator: MC Baliguas	2 ALTM Model: Gemini	3 Mission Name: 2BLK28CSD 295B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct 22, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 1240	14 Engine Off: 1646	15 Total Engine Time: 4+06	16 Take off: 1245	17 Landing: 1641	18 Total Flight Time: 3+56
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Completed BLK28C & covered 13 lines of BLK28D

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

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

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

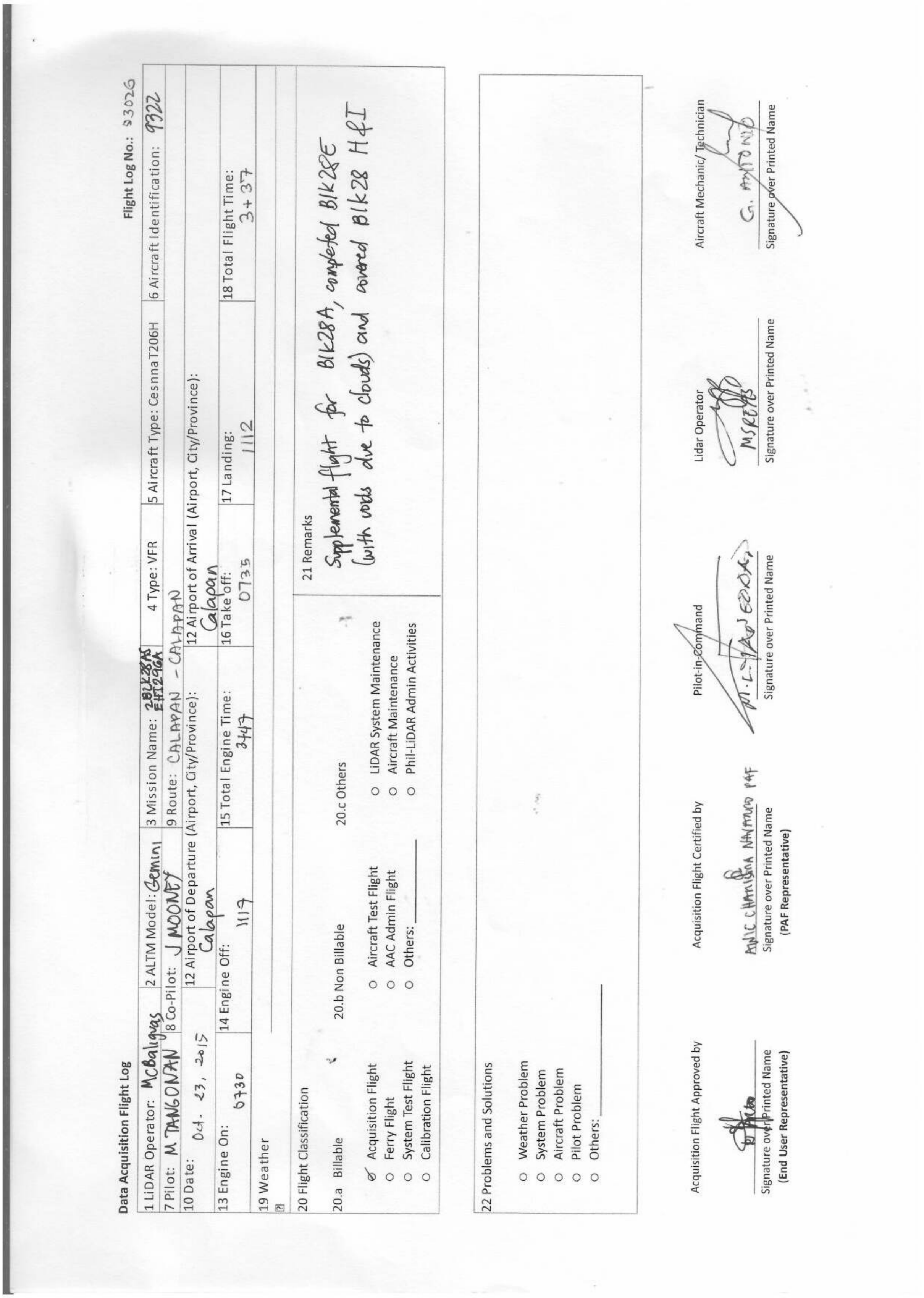
Pilot-in-Command — Signature over Printed Name

Lidar Operator — MC BALIGUAS — Signature over Printed Name

Aircraft Mechanic/Technician — Signature over Printed Name

Figure A-6.11. Flight Log for Mission 8301G

11. Flight Log for 8302G Mission



Data Acquisition Flight Log — **Flight Log No.:** 8302G

1 LiDAR Operator: MCBaliguas	2 ALTM Model: Gemini	3 Mission Name: 2BLK28AS296A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: CALAPAN - CALAPAN			
10 Date: Oct. 23, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0730	14 Engine Off: 1117	15 Total Engine Time: 3+47	16 Take off: 0735	17 Landing: 1112	18 Total Flight Time: 3+37
19 Weather					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
✓ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: ______	○ Phil-LiDAR Admin Activities
○ Calibration Flight		

21 Remarks

Supplemental flight for BlK28A, completed BlK28E (with voids due to clouds) and covered BlK28 H&I

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ______

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	M. L. TANGONAN	M. BALIGUAS	G. ANTONIO
		Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.12. Flight Log for Mission 8302G

12. Flight Log for 8306G Mission

Data Acquisition Flight Log — Flight Log No.: 8306G

1 LiDAR Operator: MCE BALIGUAS / JM PARCEO	2 ALTM Model: Gemini	3 Mission Name: 2CALIBBLK28FSGS298A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: Calapan - Calapan			
10 Date: Oct. 25, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0746	14 Engine Off: 1127	15 Total Engine Time: 3+41	16 Take off: 0751	17 Landing: 1122	18 Total Flight Time: 3+31
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

LMS Calib over Pinamalayan. Completed BlK28F and covered 3 lines of BlK28G

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

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

Aircraft Mechanic/ Technician — Signature over Printed Name

Figure A-6.13. Flight Log for Mission 8306G

Annex 7. Flight Status Reports

AGSALIN FLOODPLAIN

(February 2-15, 2014 and October 16-31, 2015)

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1054A	BLK 28B	3BLK28B033B	PAULINE ARCEO	FEB 2, 2014	Change parameters due to high dropouts (600agl, 50prf, 18degrees scan angle), not finished
1056A	BLK 28C	3BLK28C034A	PAULINE ARCEO	FEB 3, 2014	Finished lower half of BLK28C
1058A	BLK 28CD	3BLK28CD034B	IRO ROXAS	FEB 3, 2014	Finished the rest of BLK28C and some lines of BLK28D
1066A	BLK 28D	3BLK28DS036A	PAULINE ARCEO	FEB 5, 2014	Survey 8 lines BLK28D
1070A	BLOCK 28D & 28E	3BLK28DSE037A	IRO ROXAS	FEB 6, 2014	Finished Block 28D and some lines of Block 28E
1092A	BLK 28A, BLK 28D, BLK 28E	3BLK28ABES043A	IRO ROXAS	FEB 12, 2014	Survey lines in BLK28A, 28D and 28E
1094A	BLK 28B	3BLK28BS043B	PAU ARCEO	FEB 12, 2014	Mission Complete
1098A	BLK28J,I	3BLK28JSI044B	PAU ARCEO	FEB 13, 2014	Mission Complete
8300G	BLK 28A, B, AS	2BLK28ABC295A	MCE BALIGUAS & MS REYES	Oct. 22, 2015	Completed BLK28 A & B and covered 2 lines of BLK28C.
8301G	BLK 28B,C,D,H	2BLK28CSD295B	MCE BALIGUAS & MS REYES	Oct. 22, 2015	Completed BLK28C and covered 13 lines of BLK28D.
8302G	BLK 28AS,C,D,F	2BLK28ASEHI296A	MCE BALIGUAS	Oct. 23, 2015	Supplemental flight for BLK28A, completed BLK28 E (with voids due to clouds) and covered BLK28 H & I.
8306G	BLK 28A, B, F, GS, I	2CALIBBLK28FSG-S298A	MCE BALIGUAS & PJ ARCEO	Oct. 25, 2015	LMS calib over Pinamalayan. Completed BLK28F and covered 3 lines of BLK28G.

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO. 1054A
AREA: BLOCK 28B
MISSION NAME: 3BLK28B033B

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600m

SURVEY COVERAGE:

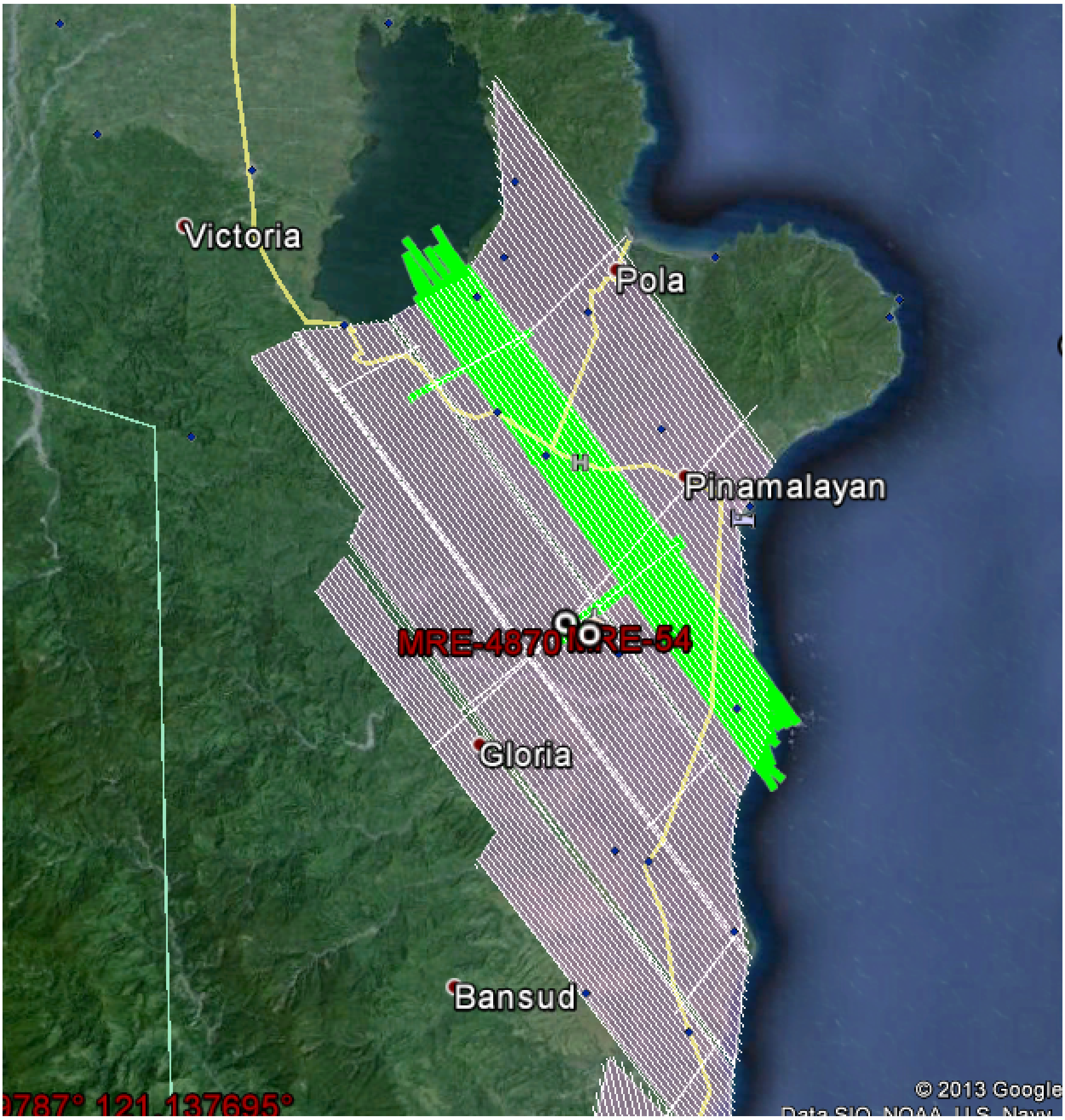


Figure A-7.1. Swath for Flight No. 1054A

FLIGHT LOG NO. 1056A
AREA: BLOCK 28C
MISSION NAME: 3BLK28C034A

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

SURVEY COVERAGE:

Figure A-7.2. Swath for Flight No. 1056A

FLIGHT LOG NO. 1058A
AREA: BLOCK 28CD
MISSION NAME: 3BLK28CD034B

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

SURVEY COVERAGE:

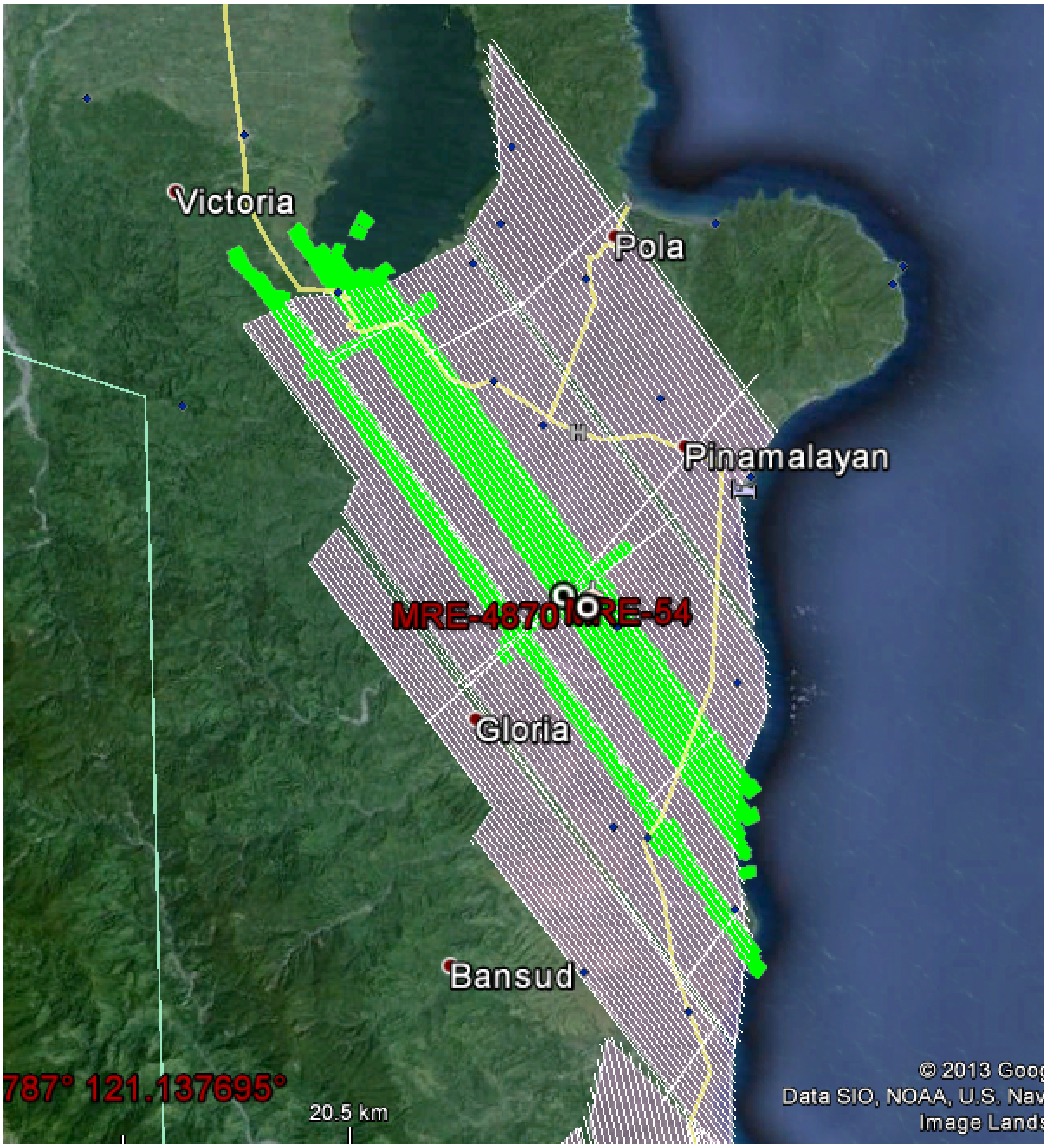


Figure A-7.3. Swath for Flight No. 1058A

FLIGHT LOG NO. 1066A
AREA: BLOCK 28D
MISSION NAME: 3BLK28DS036A
Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

SURVEY COVERAGE:

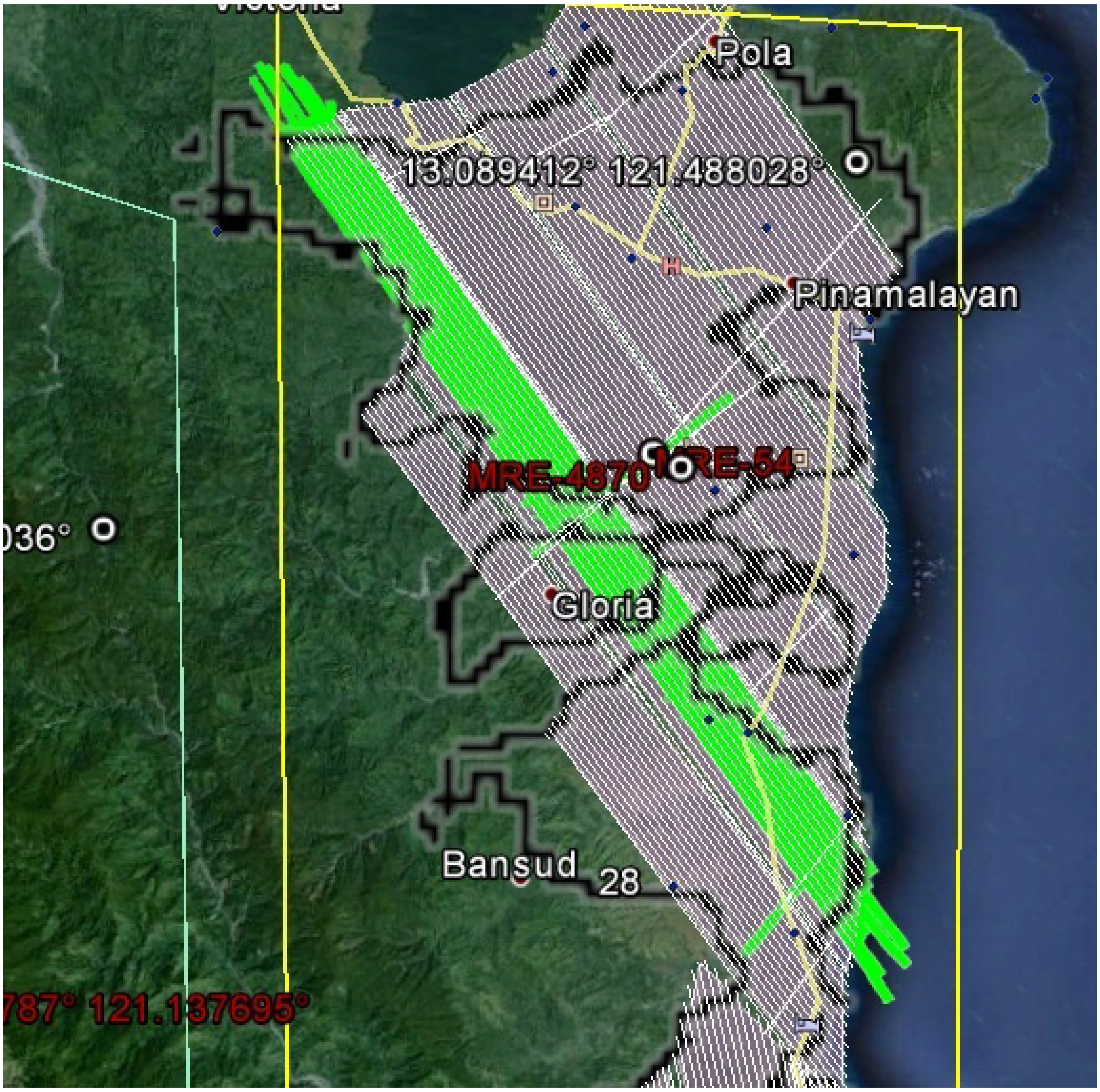


Figure A-7.4. Swath for Flight No. 1066A

FLIGHT LOG NO. 1070A
AREA: 28D & BLOCK 28E
MISSION NAME: 3BLK28DSE037A

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

SURVEY COVERAGE:

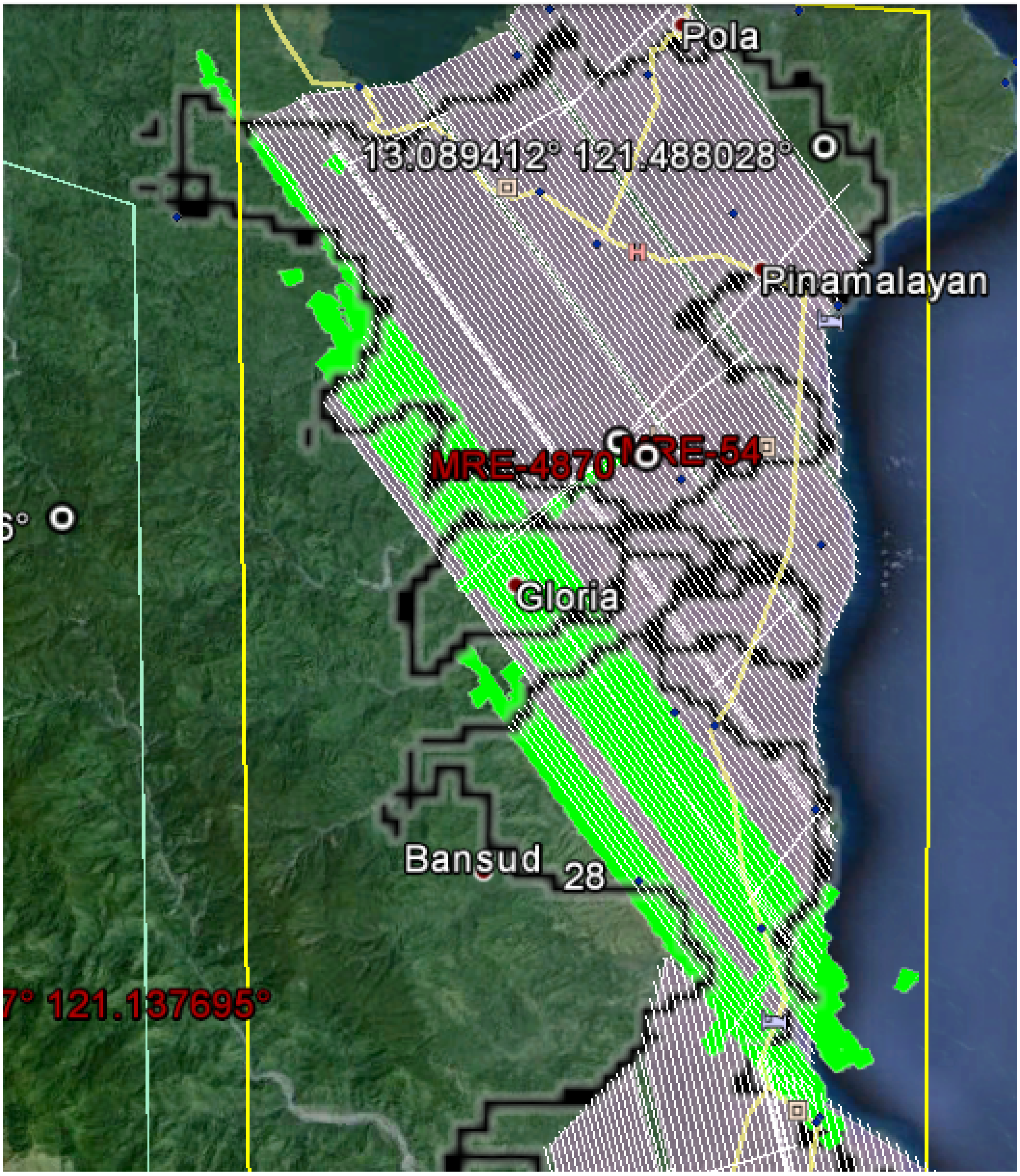


Figure A-7.5. Swath for Flight No. 1070A

FLIGHT LOG NO. 1092A
AREA: BLK 28A,28D and 28E
MISSION NAME: 3BLK28ABES043A
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

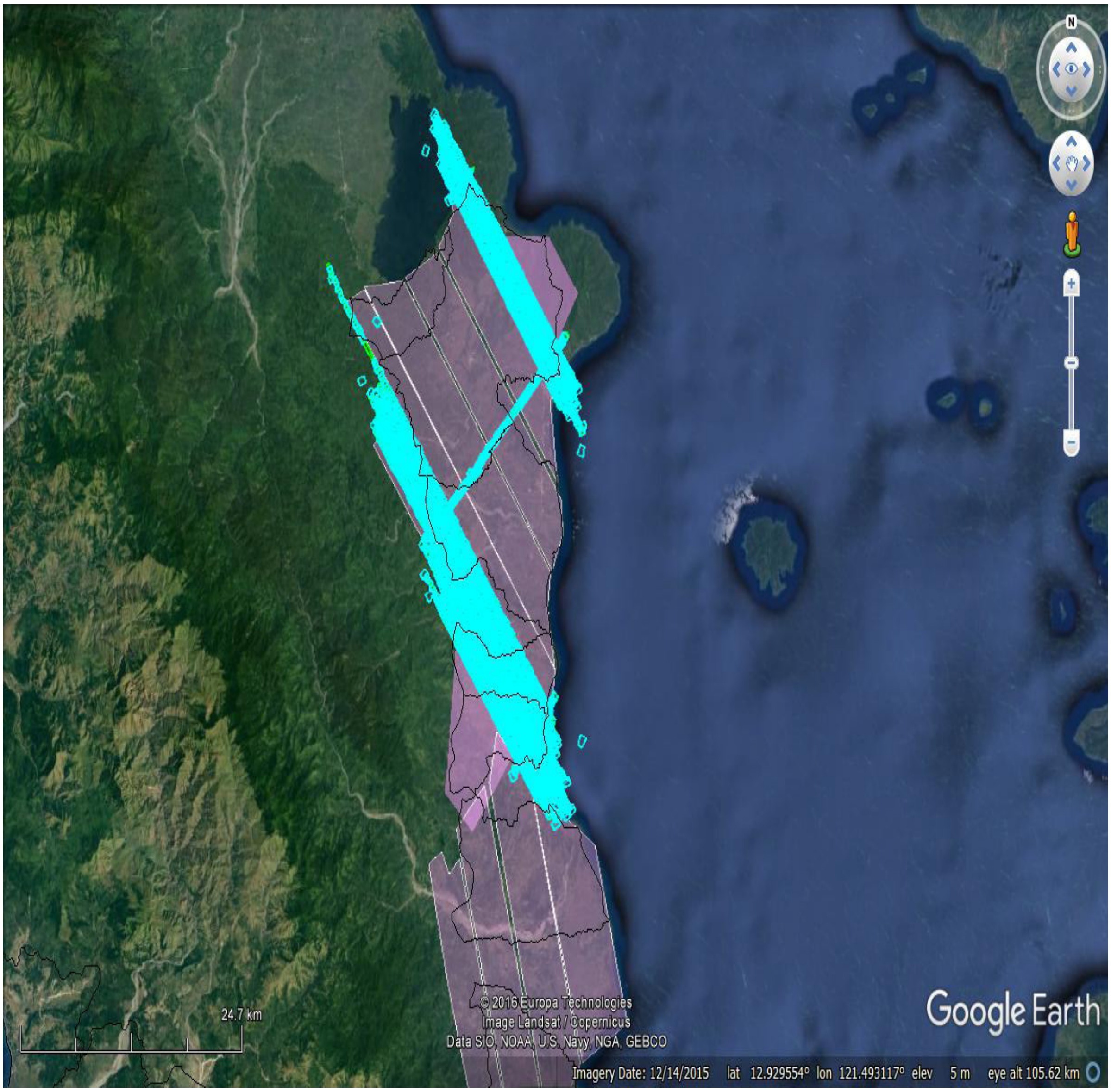


Figure A-7.6. Swath for Flight No. 1092A

FLIGHT LOG NO. 1094A
AREA: BLOCK 28B
MISSION NAME: 3BLK28BS043B
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

Figure A-7.7. Swath for Flight No. 1094A

FLIGHT LOG NO. 1098A
AREA: BLOCK 28JI
MISSION NAME: 3BLK28JSI044B

Scan Freq: 45 kHz
Scan Angle: 36 deg
Alt: 600 m

SURVEY COVERAGE:

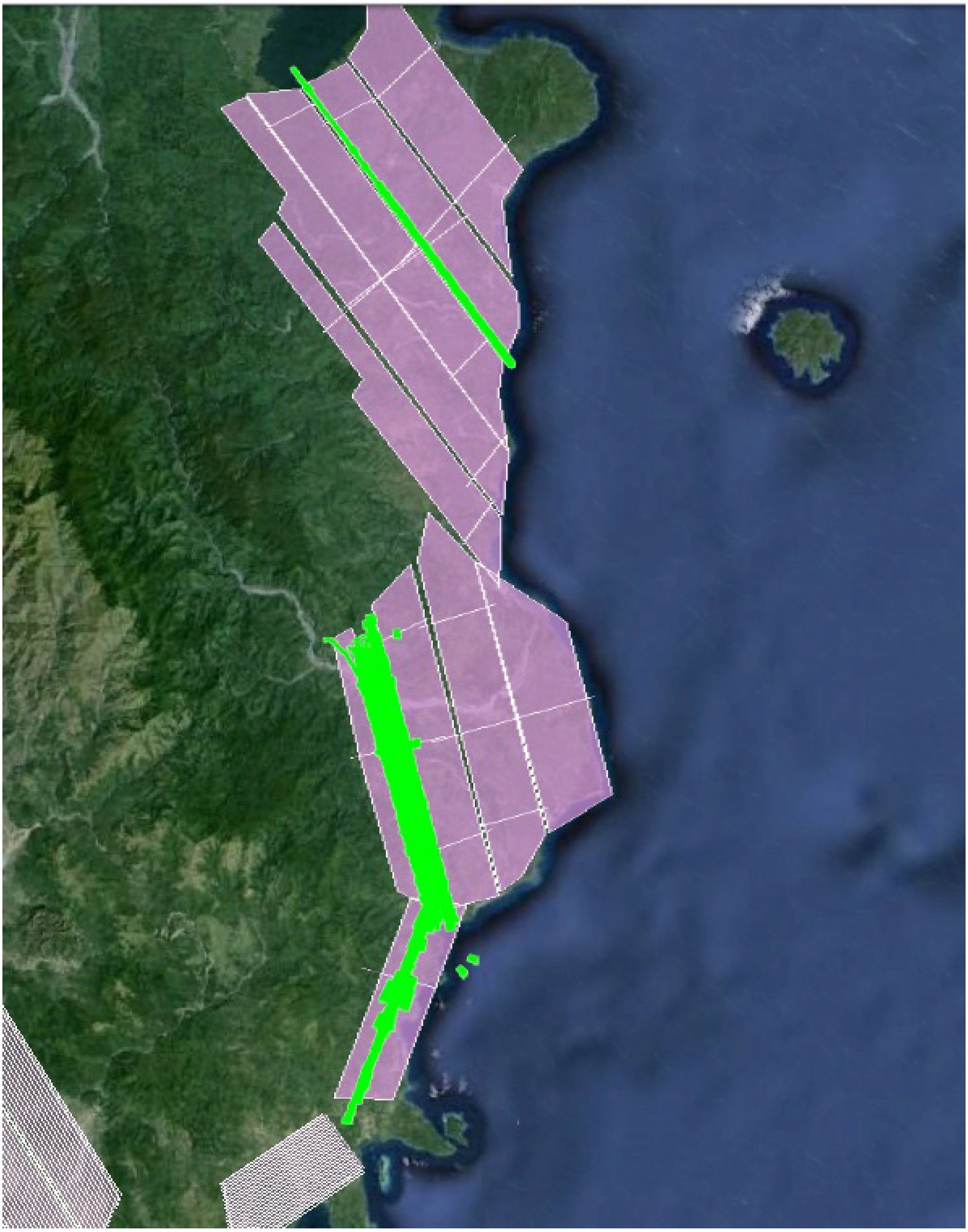


Figure A-7.8. Swath for Flight No. 1098A

FLIGHT NO.: 8300G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28ABC295A
ALT: 1200 m SCAN FREQ:50 SCAN ANGLE: 36

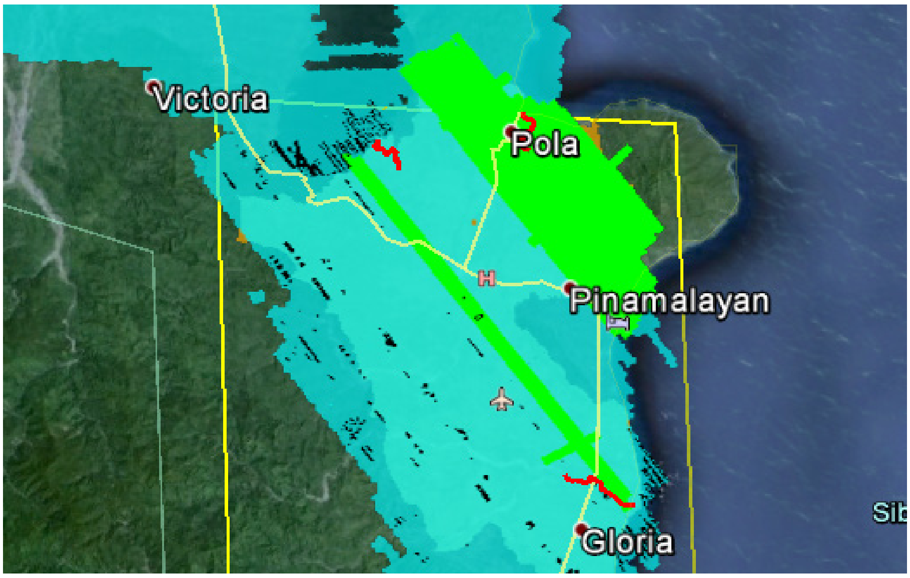


Figure A-7.9. Swath for Flight No. 8300G

FLIGHT NO.: 8301G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28CSD295B
ALT: 1000 m SCAN FREQ: 50 SCAN ANGLE: 40

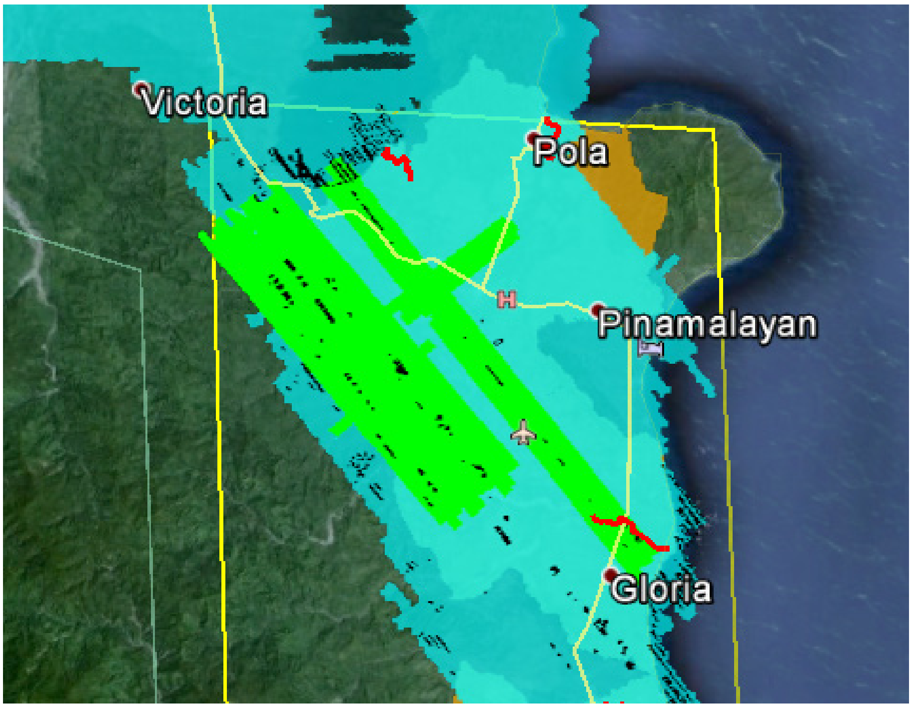


Figure A-7.10. Swath for Flight No. 8301G

FLIGHT NO.: 8302G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28ASEHI296A
ALT: 1200 m SCAN FREQ: 50 SCAN ANGLE: 30

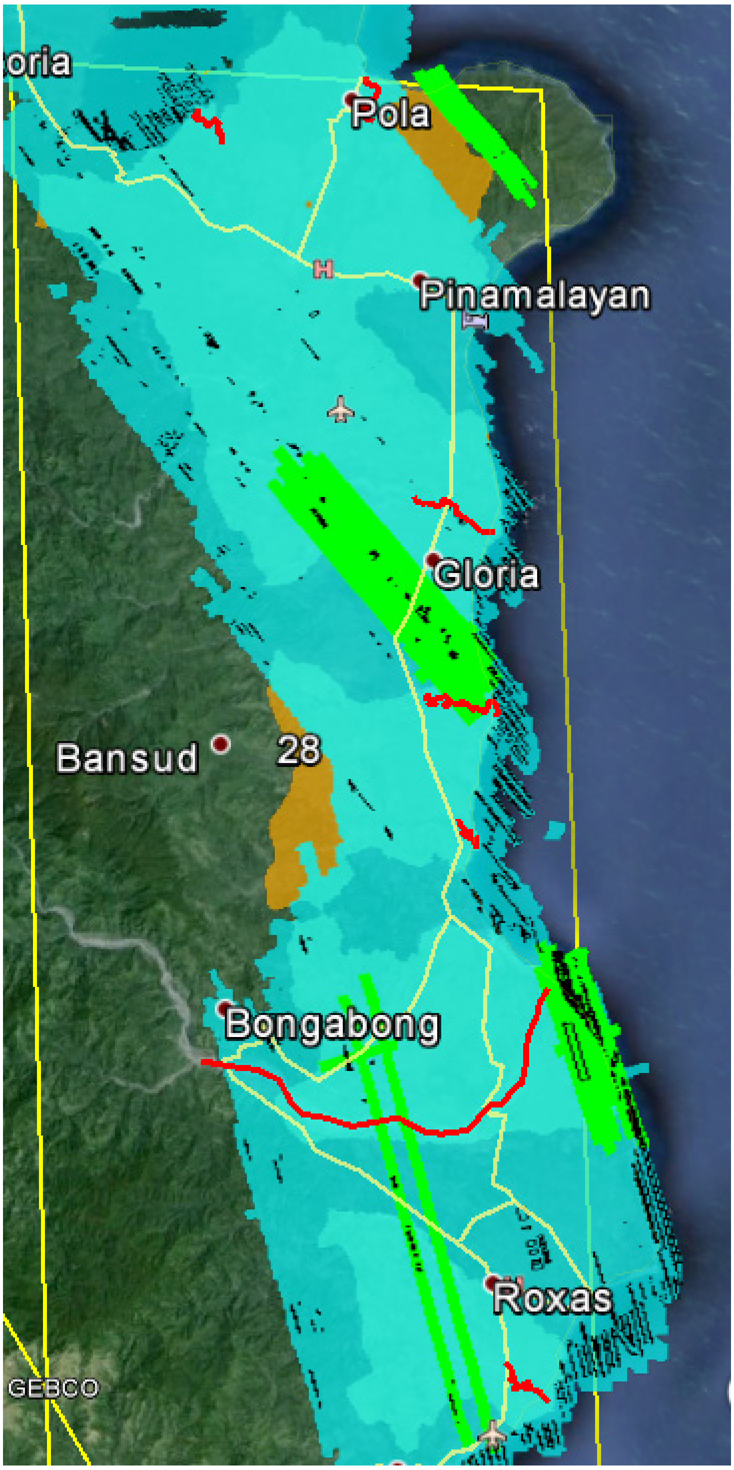


Figure A-7.11. Swath for Flight No. 8302G

FLIGHT NO.: 8306G
AREA: Oriental Mindoro
MISSION NAME: 2CALIBBLK28FSGS298A
ALT: 1000 m SCAN FREQ: 50 SCAN ANGLE: 40

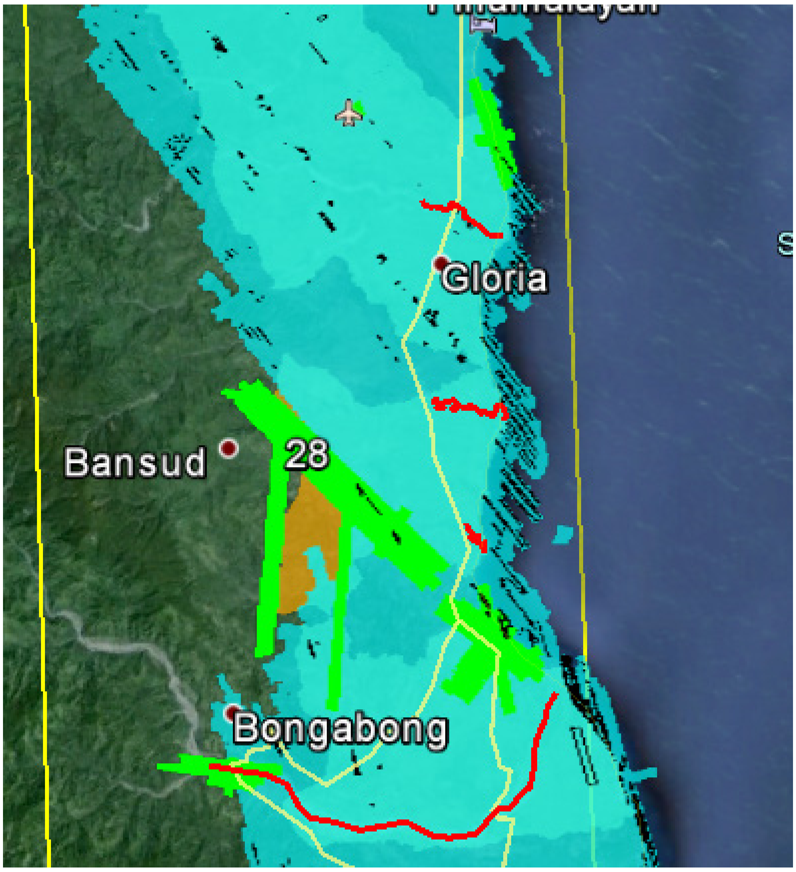


Figure A-7.12. Swath for Flight No. 8306G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk28B

Flight Area	Oriental Mindoro
Mission Name	Blk28B
Inclusive Flights	1054A
Range data size	11.8 GB
Base data size	6.12 MB
POS	206 MB
Image	73.7 GB
Transfer date	February 6, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.1
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	5.9
Boresight correction stdev (<0.001deg)	0.000367
IMU attitude correction stdev (<0.001deg)	0.001614
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	61.38%
Ave point cloud density per sq.m. (>2.0)	3.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	294.12 m
Minimum Height	47.14 m
Classification (# of points)	
Ground	46,703,583
Low vegetation	67,959,863
Medium vegetation	42,244,141
High vegetation	45,621,798
Building	2,327,559
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

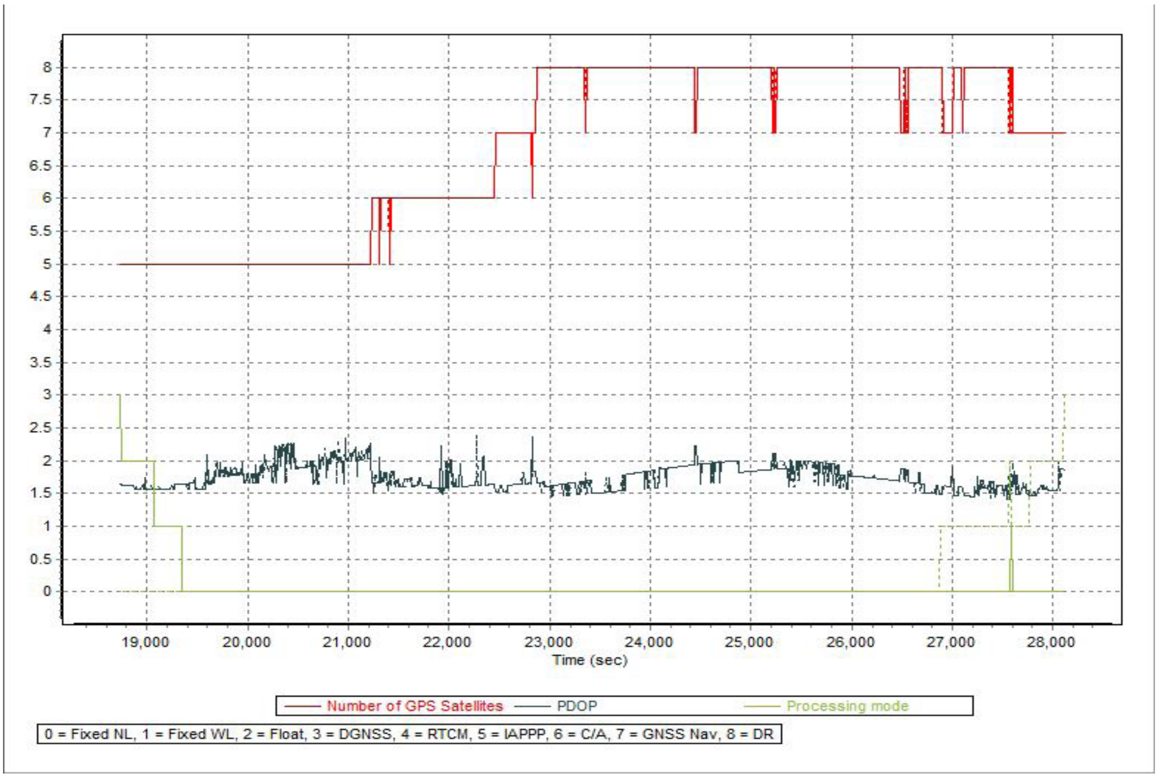


Figure A-8.1. Solution Status

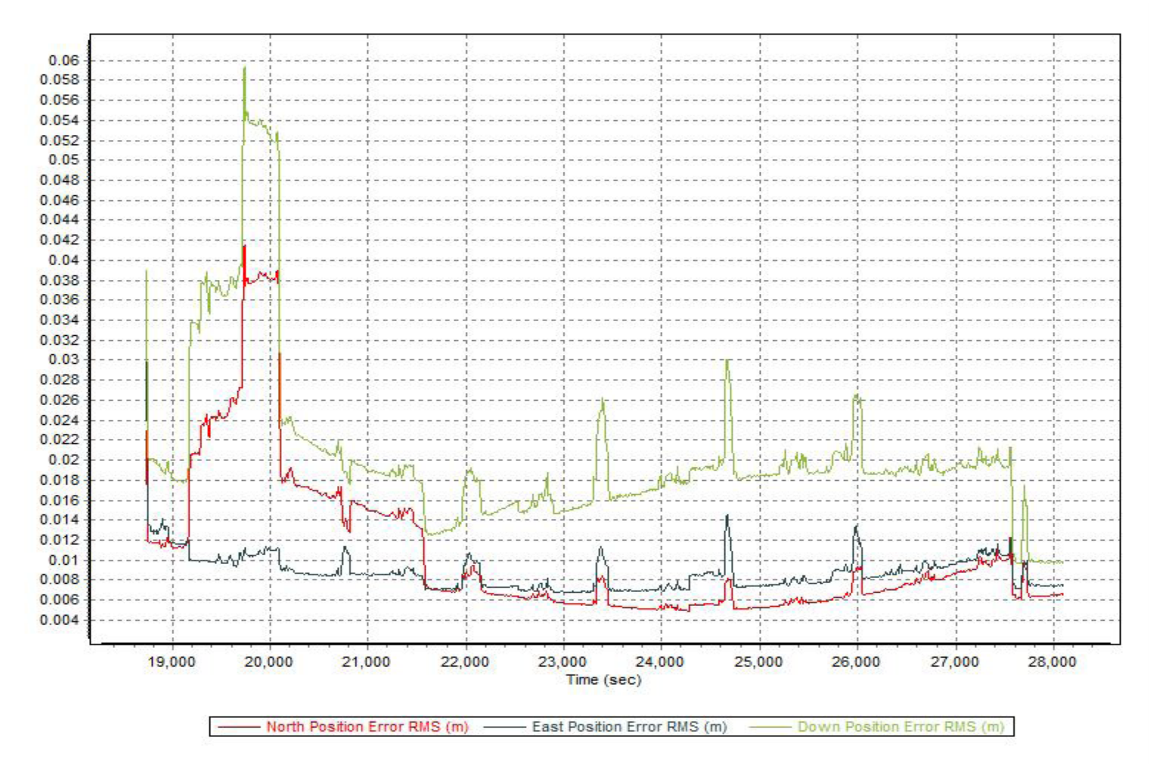


Figure A-8.2. Smoothed Performance Metrics Parameters

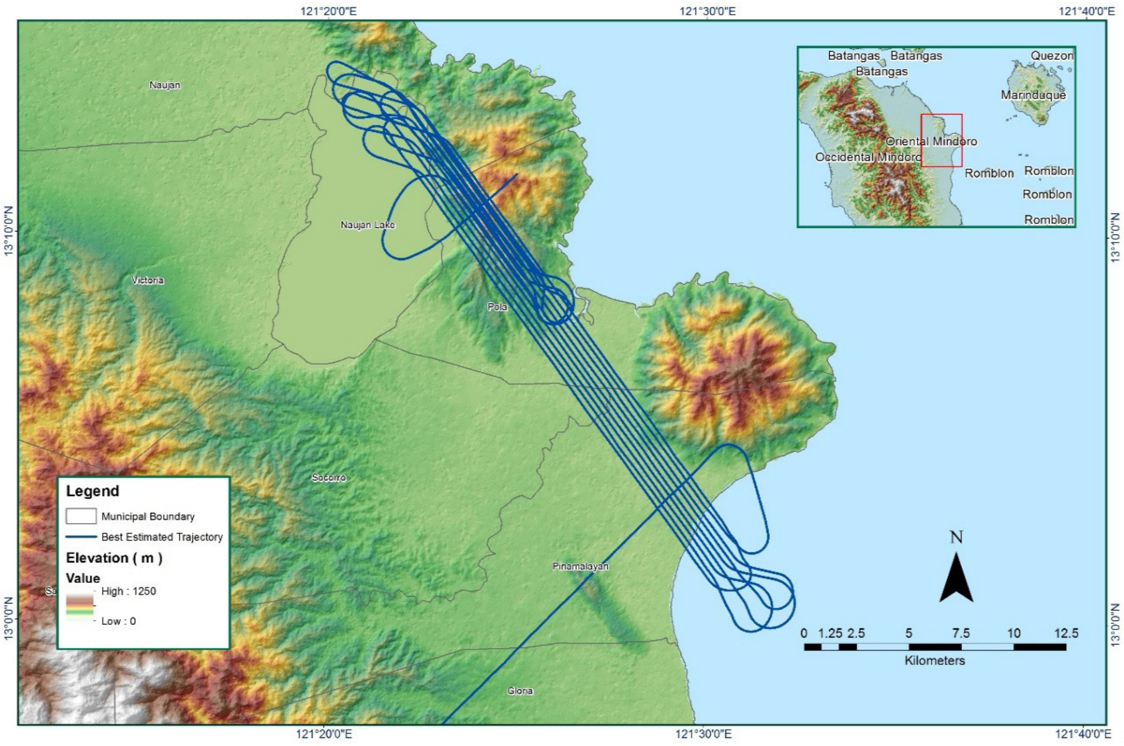


Figure A-8.3. Best Estimated Trajectory

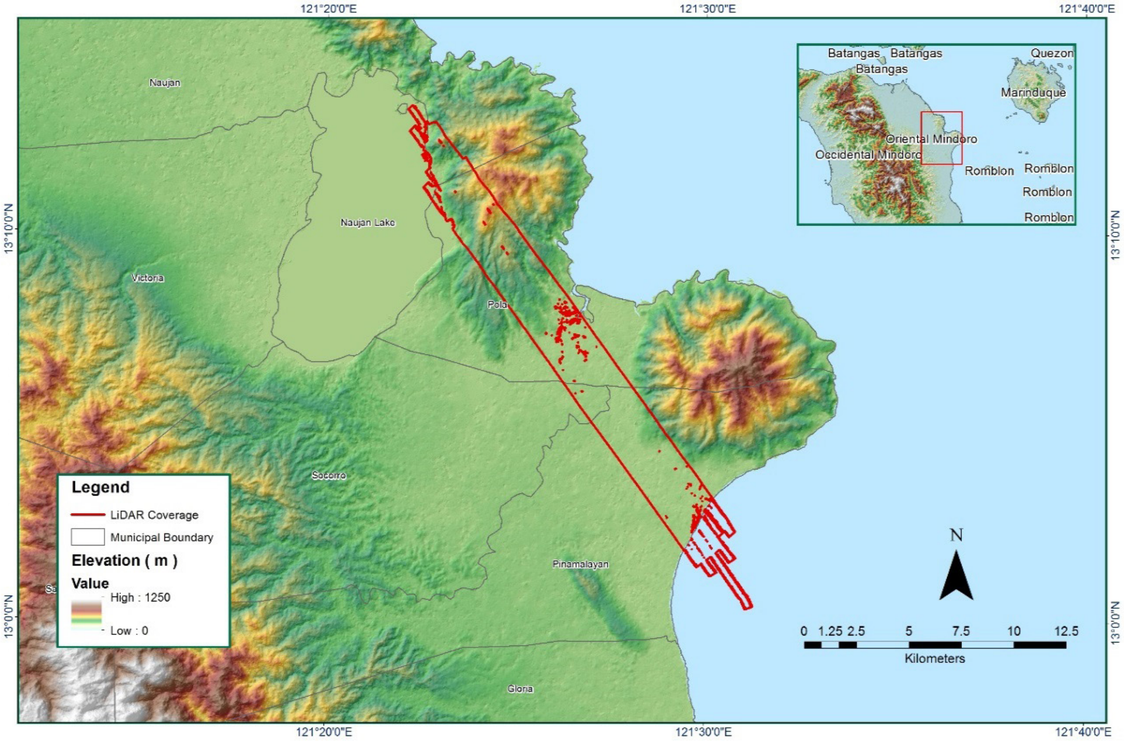


Figure A-8.4. Coverage of LiDAR data

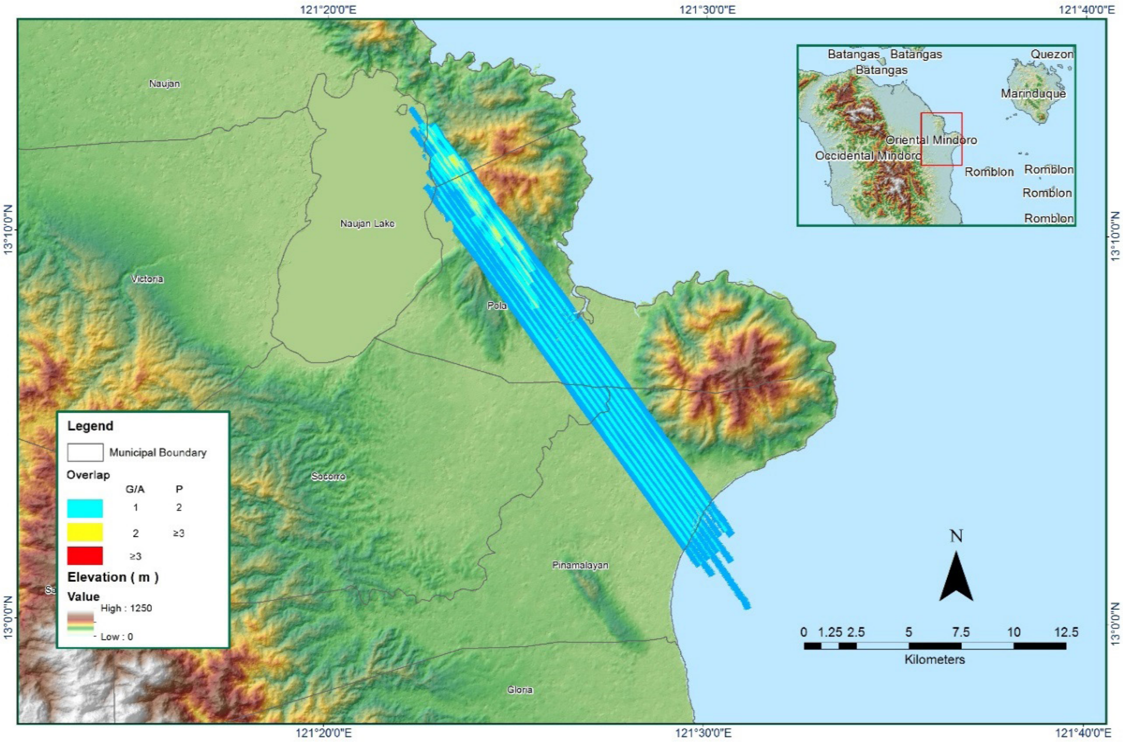


Figure A-8.5. Image of data overlap

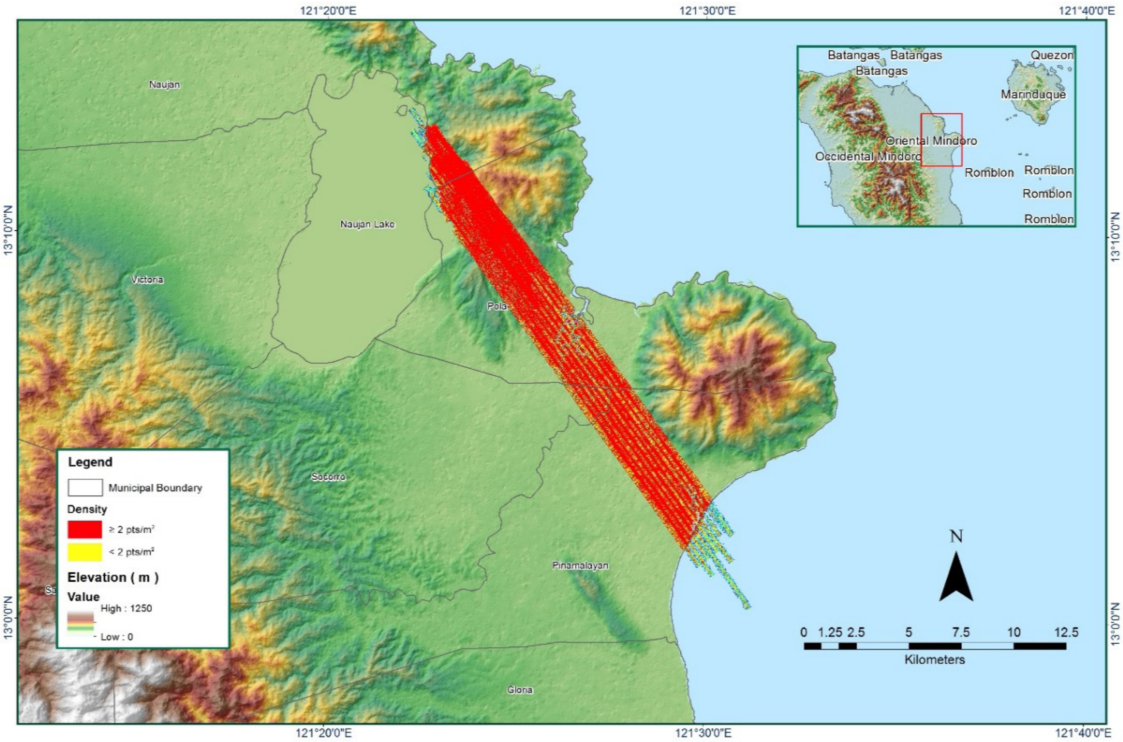


Figure A-8.6. Density map of merged LiDAR data

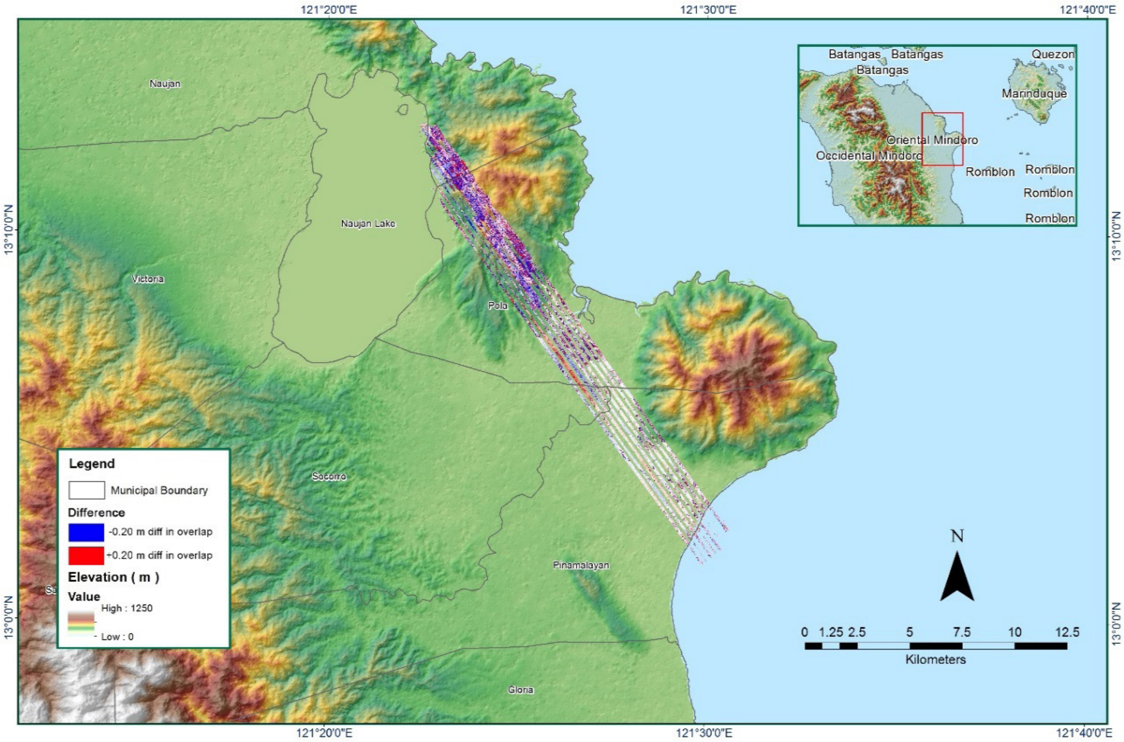


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk28B_suppement

Flight Area	Oriental Mindoro
Mission Name	Blk28B_suppement
Inclusive Flights	1094A
Range data size	6.05 GB
Base data size	15.4 MB
POS	128 MB
Image	28.4 GB
Transfer date	February 21, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.9
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.9
Boresight correction stdev (<0.001deg)	0.000552
IMU attitude correction stdev (<0.001deg)	0.001576
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	43.55 %
Ave point cloud density per sq.m. (>2.0)	2.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	94
Maximum Height	139.48 m
Minimum Height	45.57 m
Classification (# of points)	
Ground	30,981,185
Low vegetation	41,966,312
Medium vegetation	21,333,039
High vegetation	20,413,373
Building	706,790
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, For. Simonette Lat

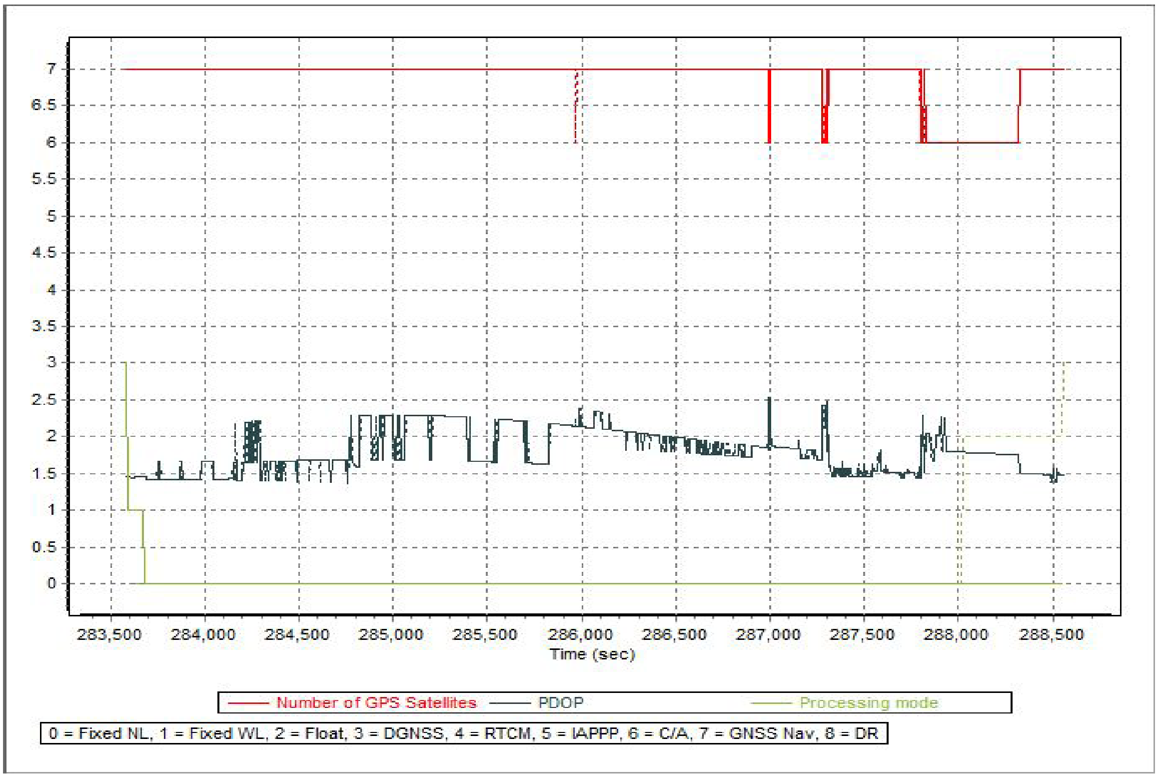


Figure A-8.8. Solution Status

Figure A-8.9. Smoothed Performance Metrics Parameters

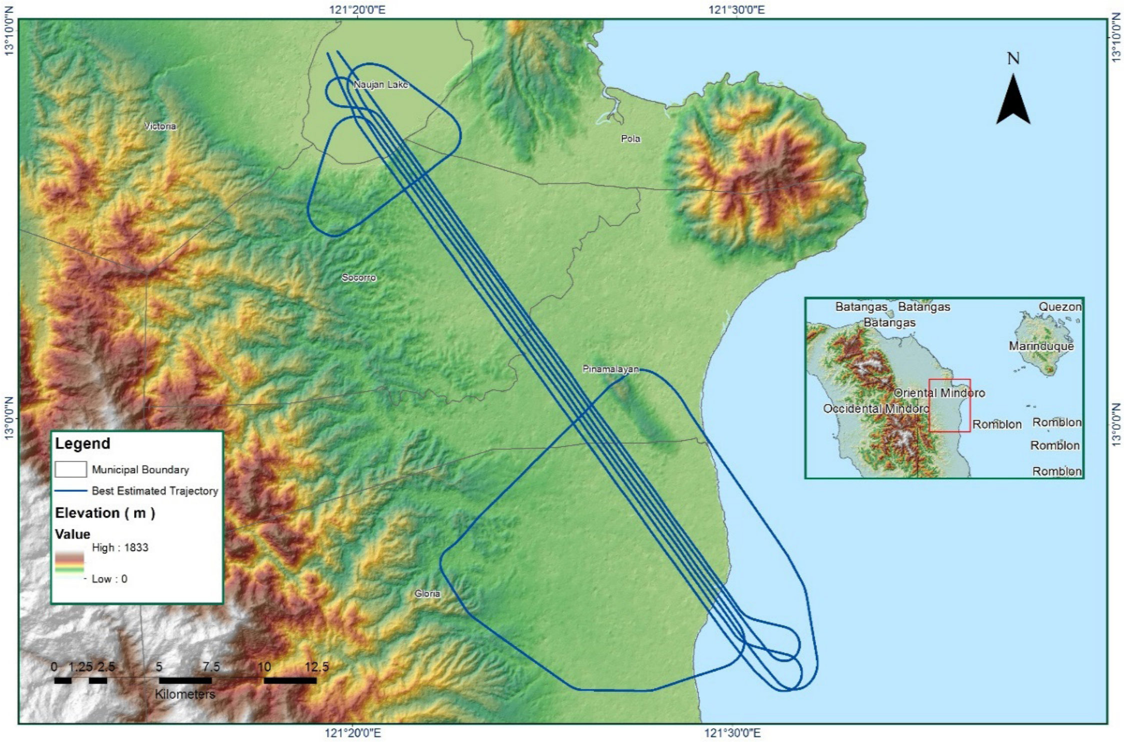


Figure A-8.10. Best Estimated Trajectory

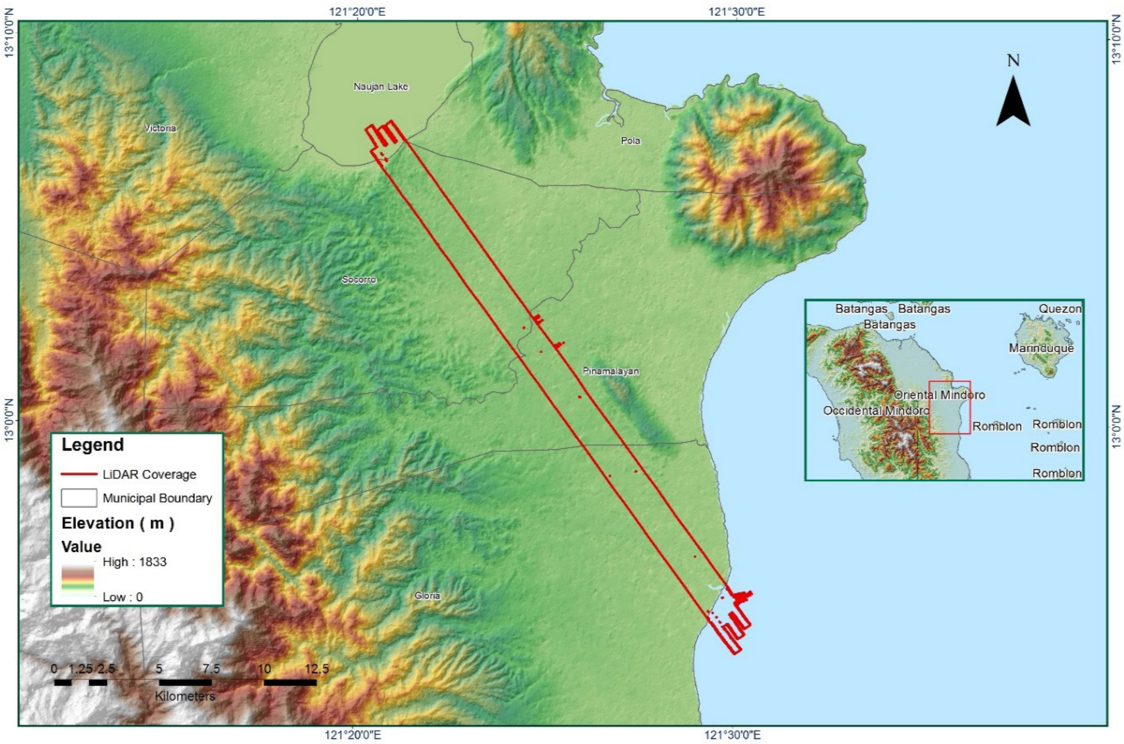


Figure A-8.11. Coverage of LiDAR data

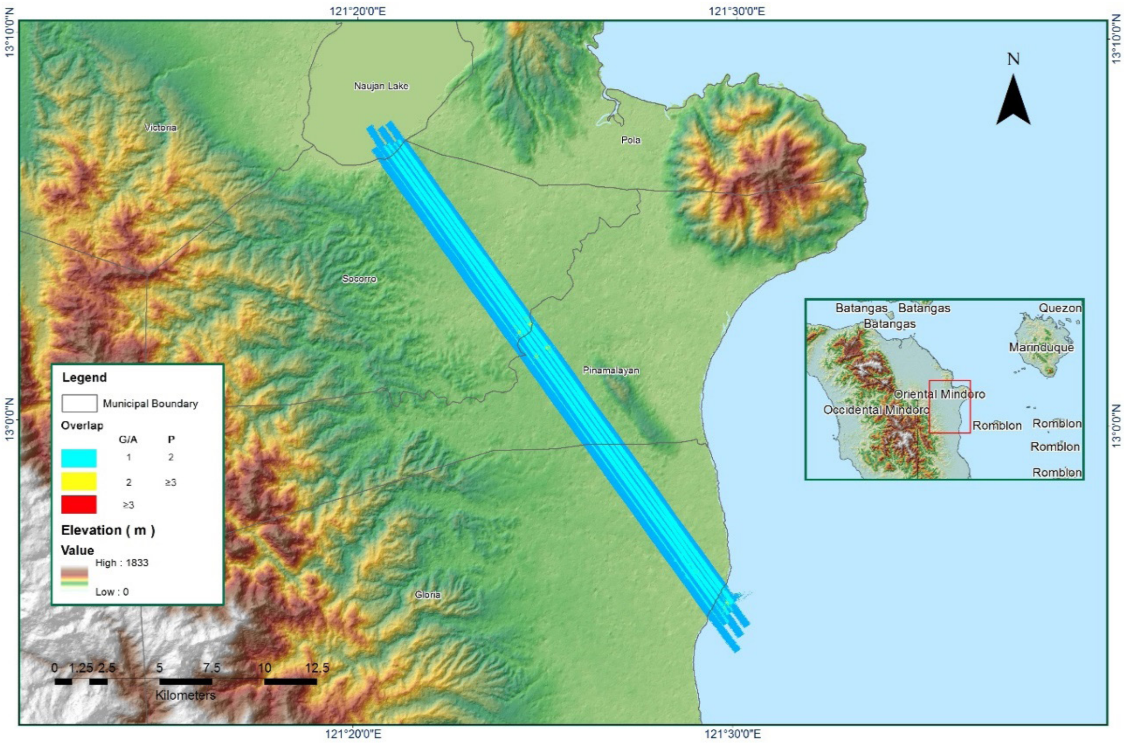


Figure A-8.12. Image of data overlap

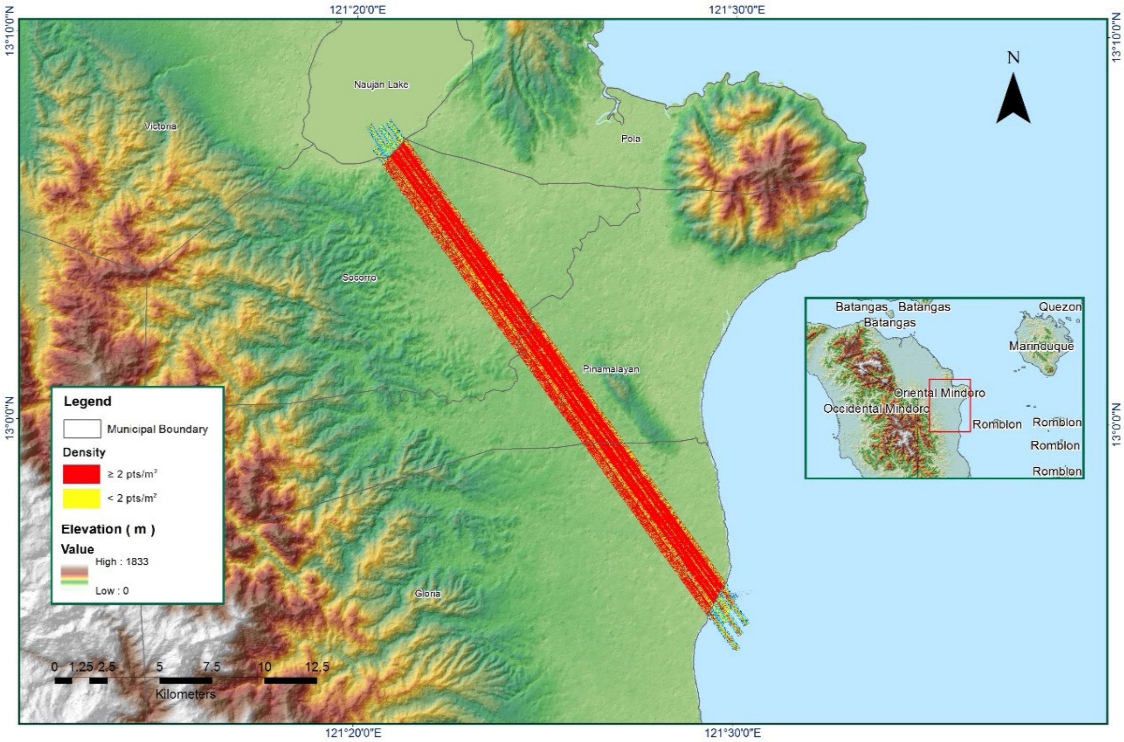


Figure A-8.13. Density map of merged LiDAR data

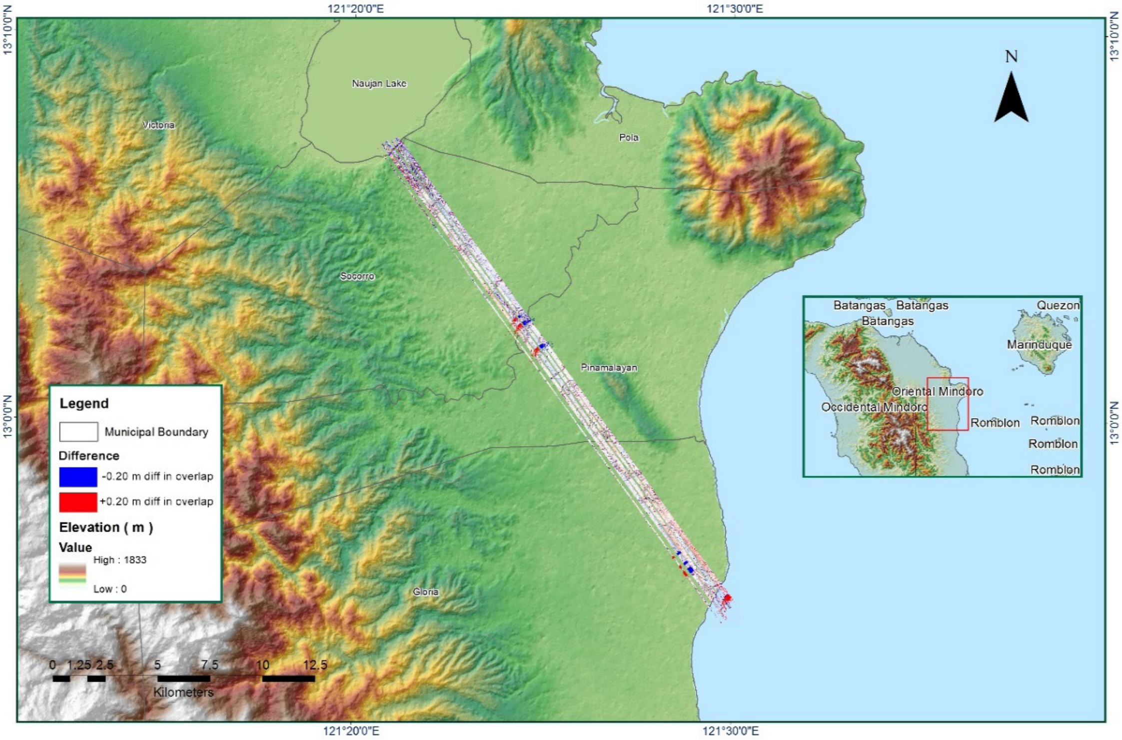


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk28Bs_additional

Flight Area	Oriental Mindoro
Mission Name	Blk28Bs_additional
Inclusive Flights	1098A
Range data size	11 GB
Base data size	13.3 MB
POS	235 MB
Image	23.9 GB
Transfer date	February 21, 2014
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)	1.82
RMSE for East Position (<4.0 cm)	1.70
RMSE for Down Position (<8.0 cm)	3.73
Boresight correction stdev (<0.001deg)	0.000552
IMU attitude correction stdev (<0.001deg)	0.001001
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	n/a
Ave point cloud density per sq.m. (>2.0)	2.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	137.64 m
Minimum Height	49.21 m
Classification (# of points)	
Ground	6,664,904
Low vegetation	6,268,121
Medium vegetation	2,801,715
High vegetation	3,548,231
Building	97,077
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Melanie Hingpit, Engr. Jeffrey Delica

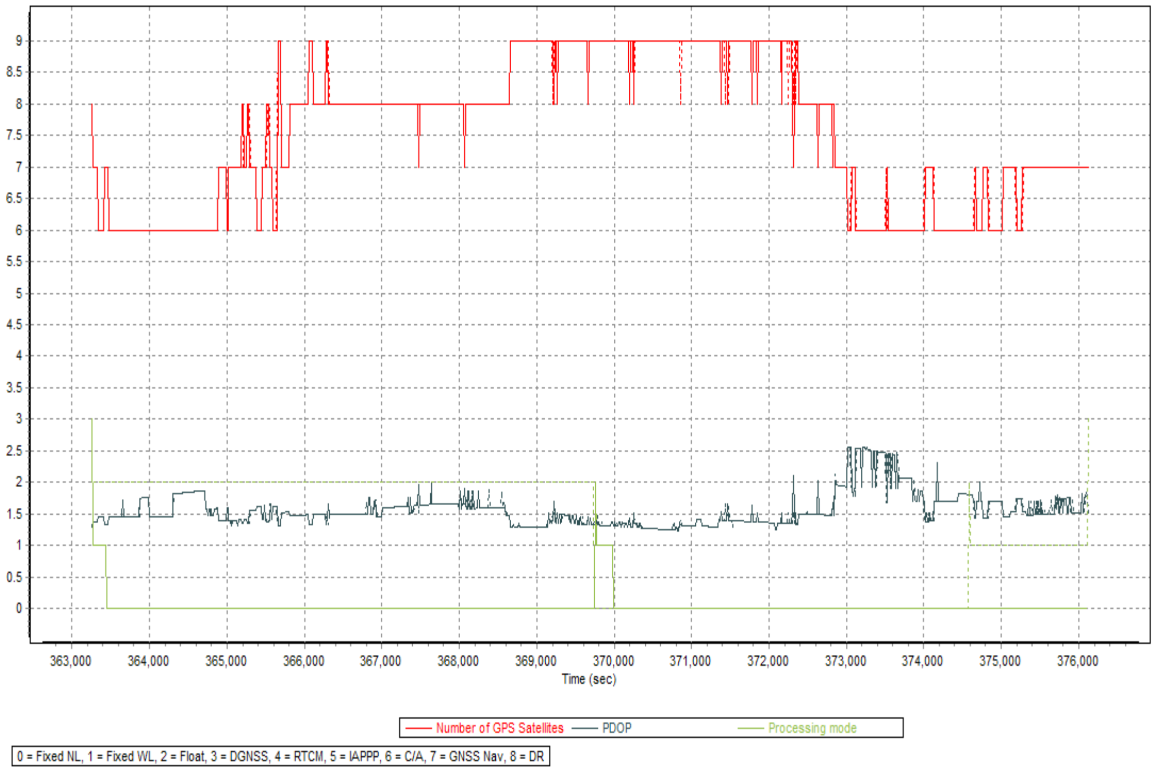


Figure A-8.15. Solution Status

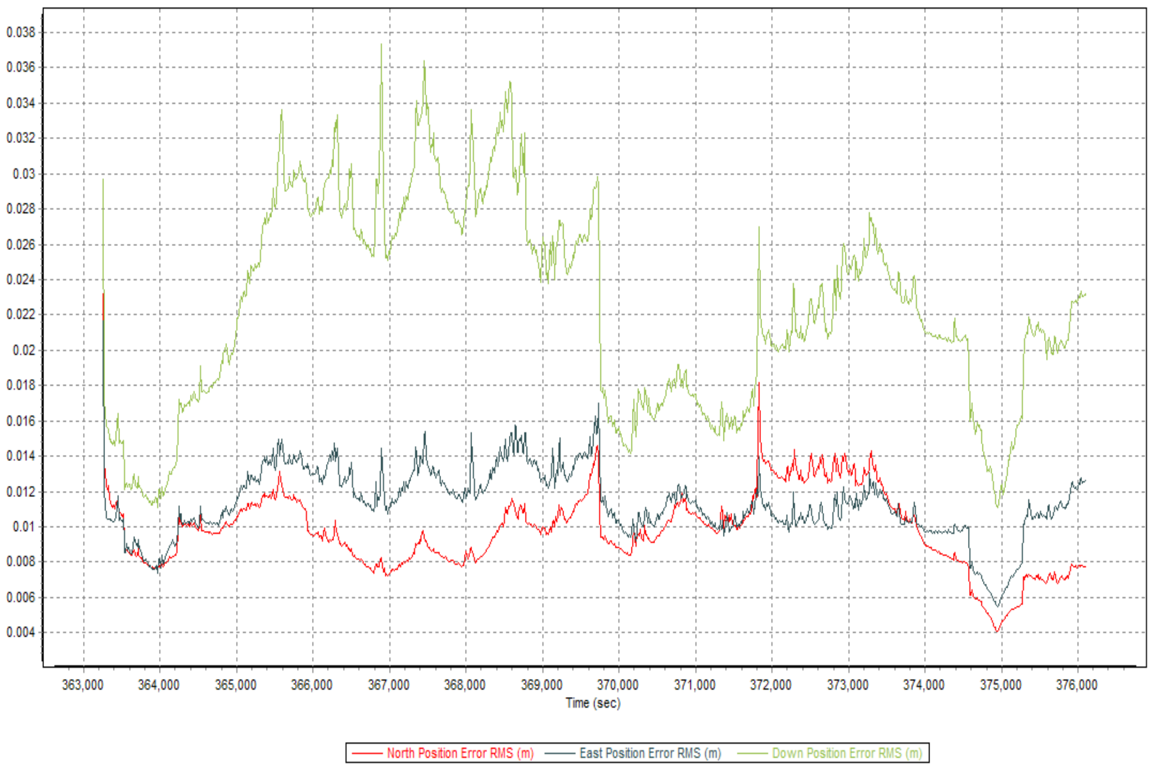


Figure A-8.16. Smoothed Performance Metrics Parameters

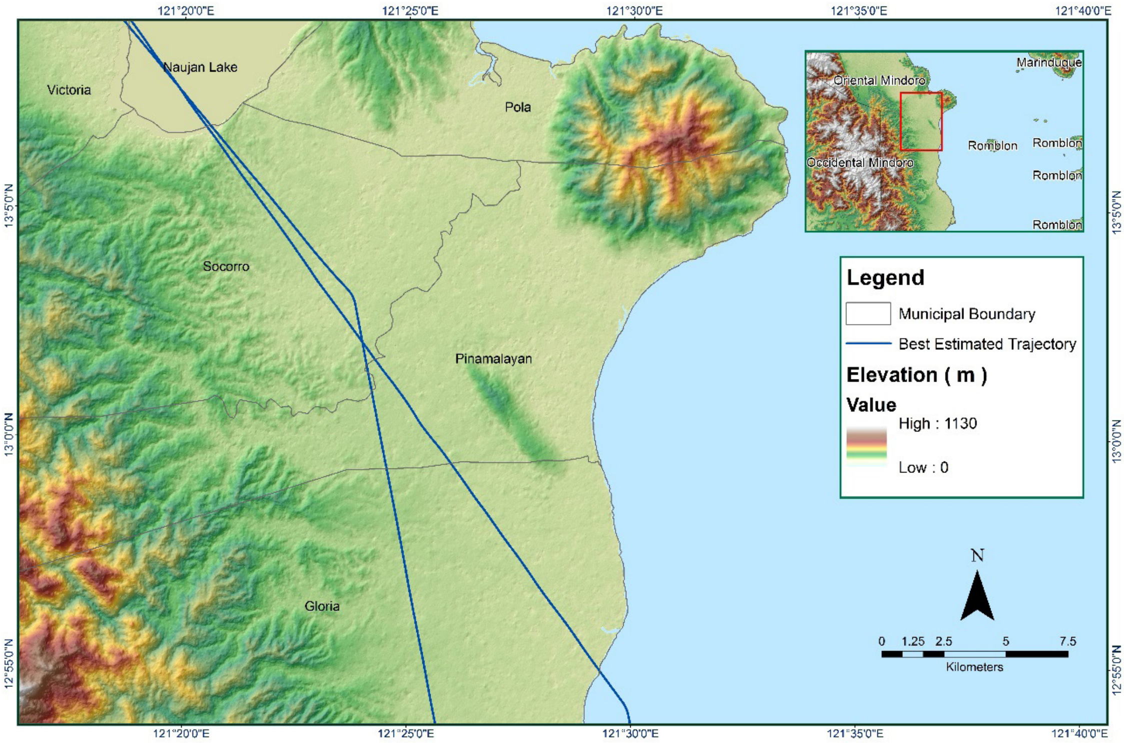


Figure A-8.17. Best Estimated Trajectory

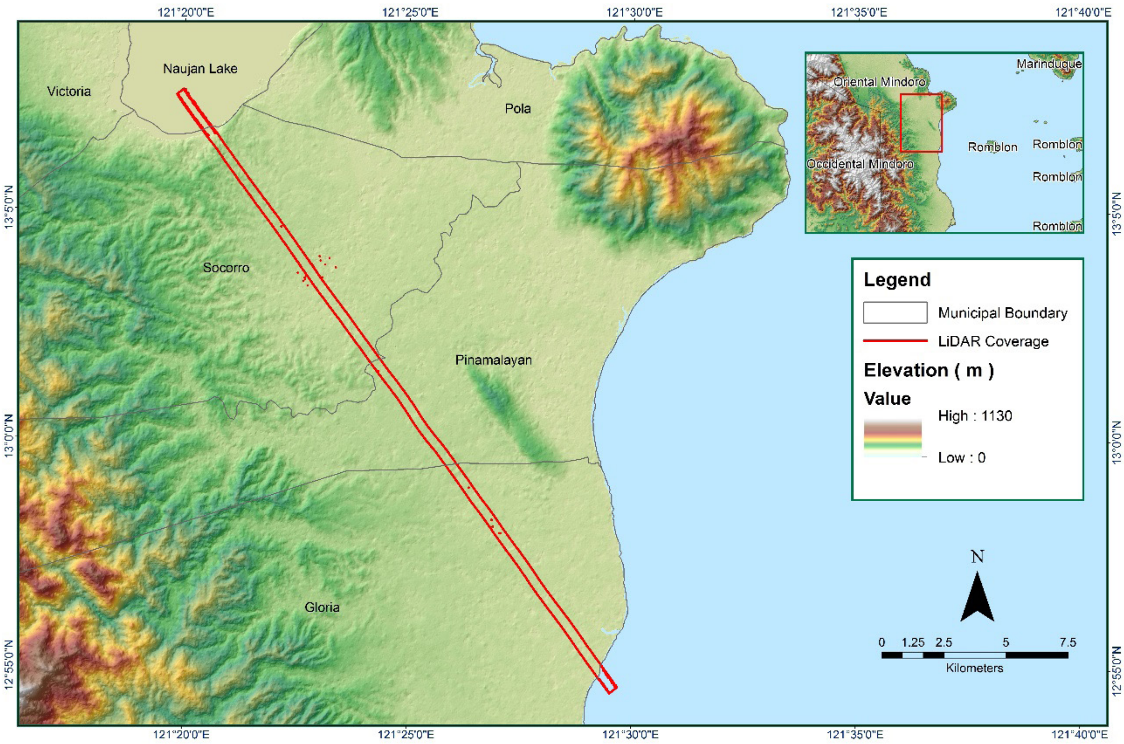


Figure A-8.18. Coverage of LiDAR data

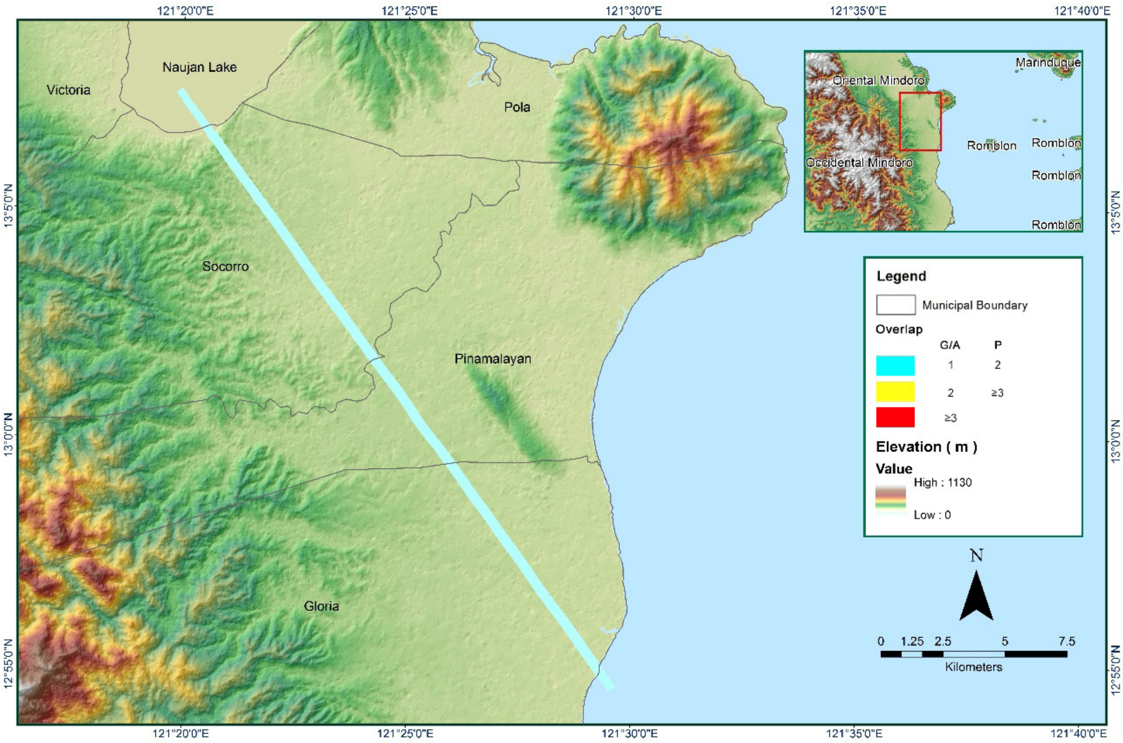


Figure A-8.19. Image of data overlap

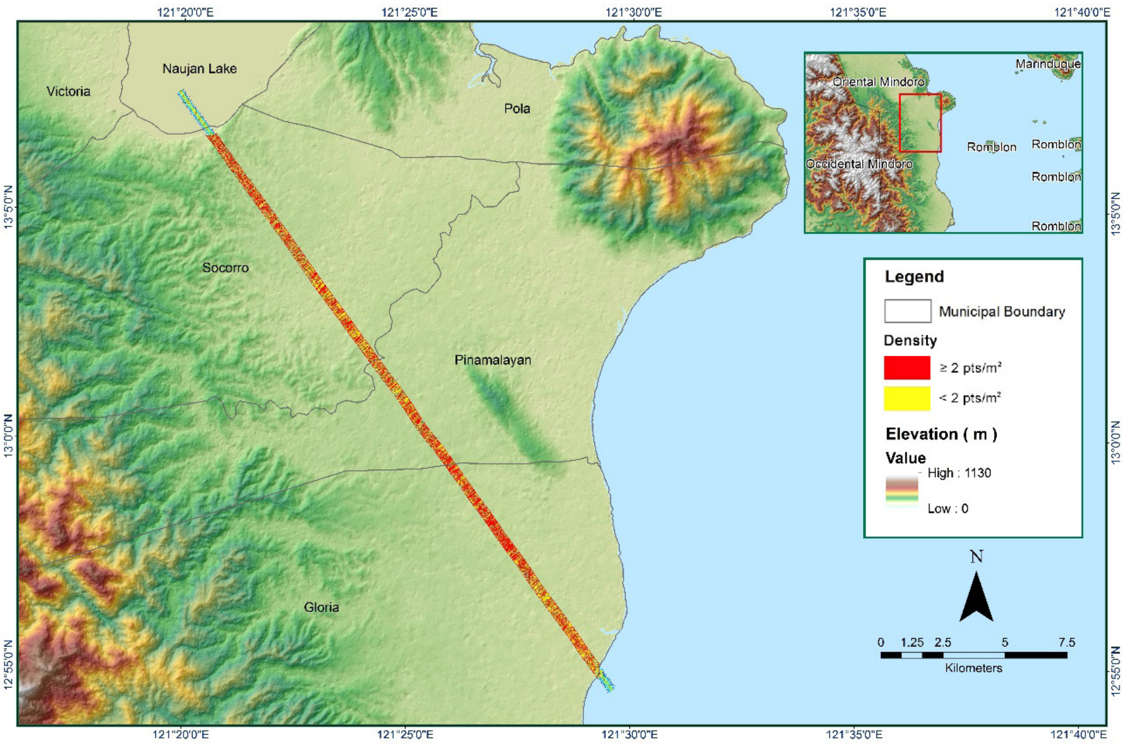


Figure A-8.20. Density map of merged LiDAR data

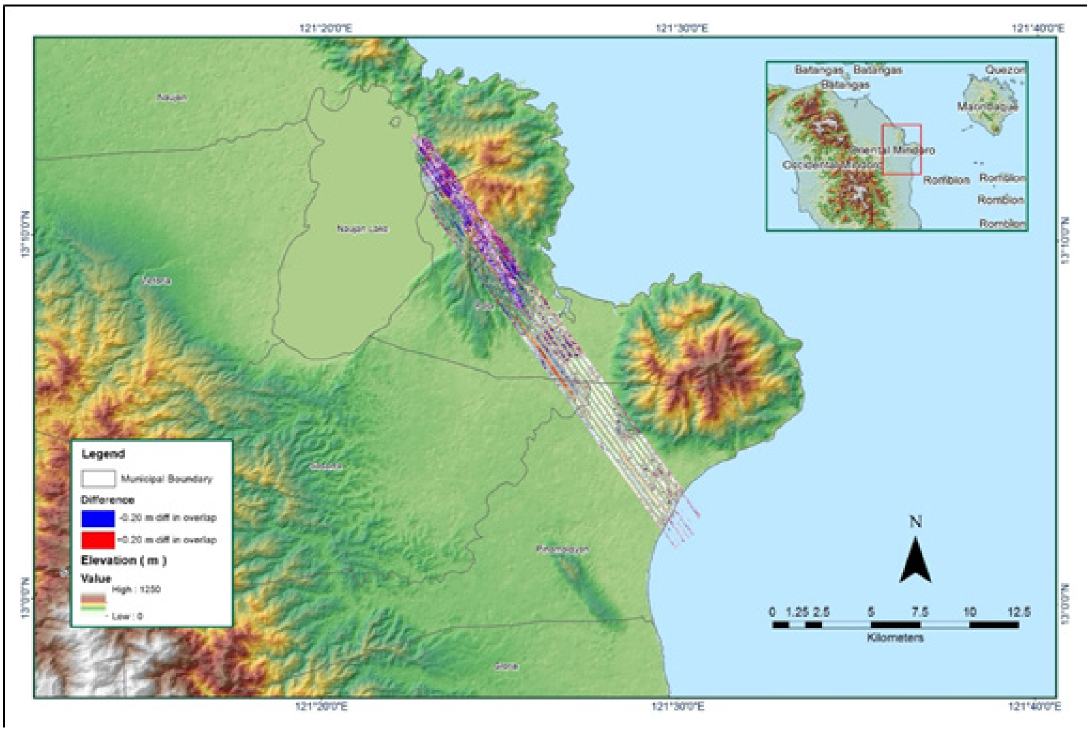


Figure A-8.21. Elevation difference between flight lines

Figure A-8.22.

Table A-8.4. Mission Summary Report for Mission Blk 28C

Flight Area	Oriental Mindoro
Mission Name	Blk 28C
Inclusive Flights	1056A
Range data size	12.2 GB
Base data size	6.29 MB
POS	210 MB
Image	77.2 GB
Transfer date	February 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000367
IMU attitude correction stdev (<0.001deg)	0.011964
GPS position stdev (<0.01m)	0.0209
Minimum % overlap (>25)	65.39%
Ave point cloud density per sq.m. (>2.0)	2.77
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	257
Maximum Height	254.22 m
Minimum Height	48.61 m
Classification (# of points)	
Ground	60,654,258
Low vegetation	70,685,819
Medium vegetation	65,858,614
High vegetation	99,720,386
Building	2,215,401
Orthophoto	Yes
Processed by	Engr. Carlyn Ibañez, Engr. Christy Lubiano, Engr. Melissa Fernandez

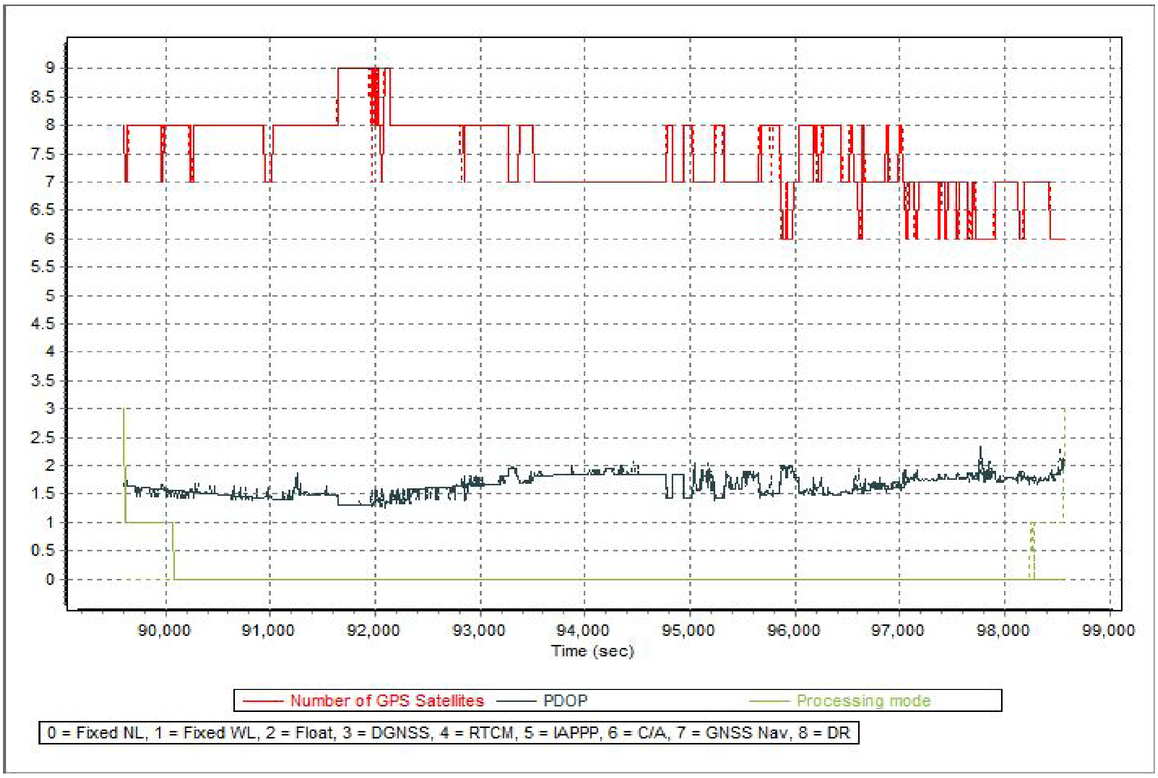


Figure A-8.23. Solution Status

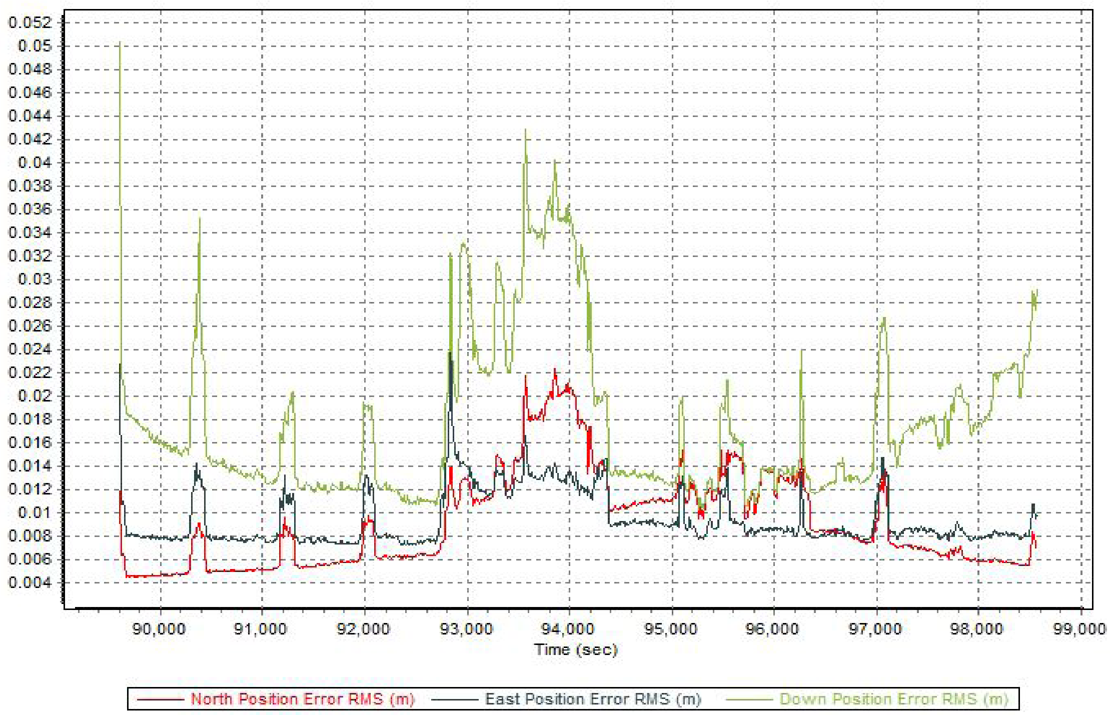


Figure A-8.24. Smoothed Performance Metrics Parameters

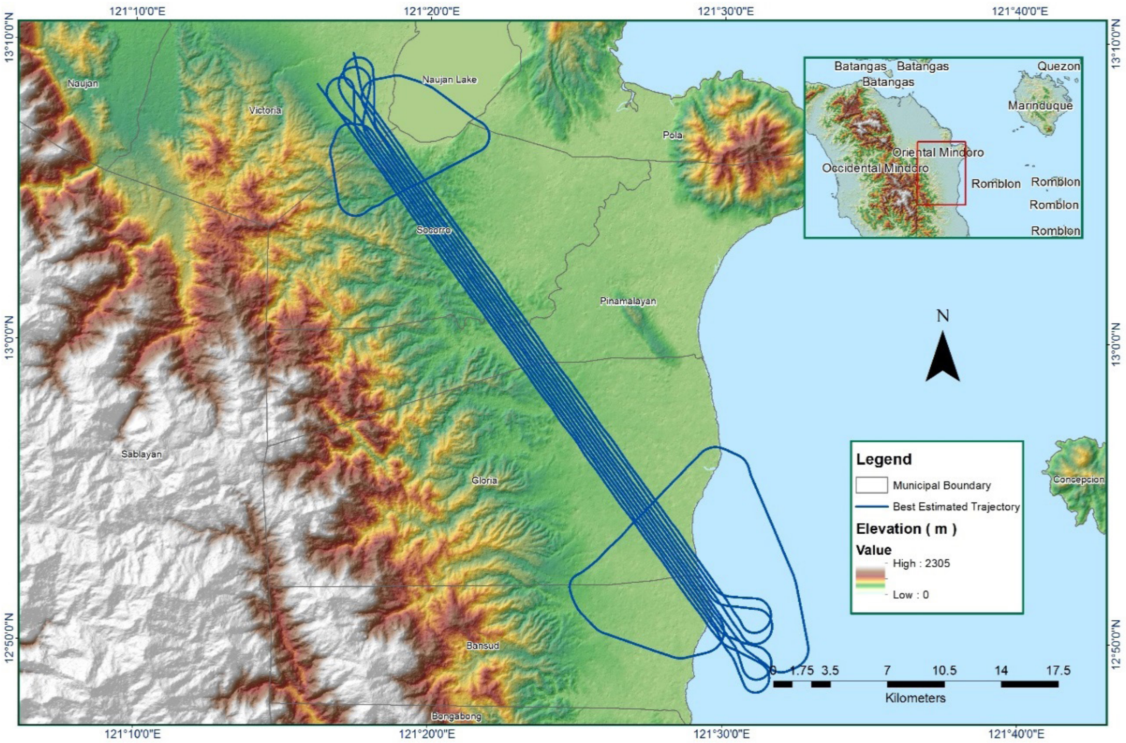


Figure A-8.25. Best Estimated Trajectory

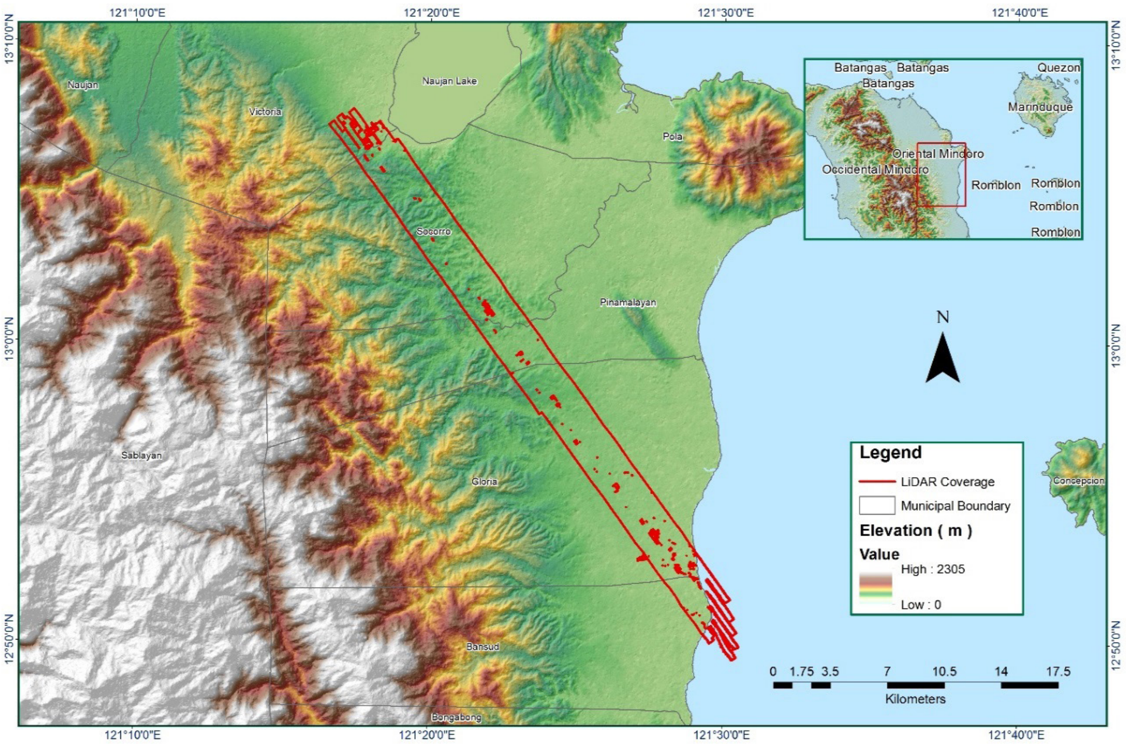


Figure A-8.26. Coverage of LiDAR data

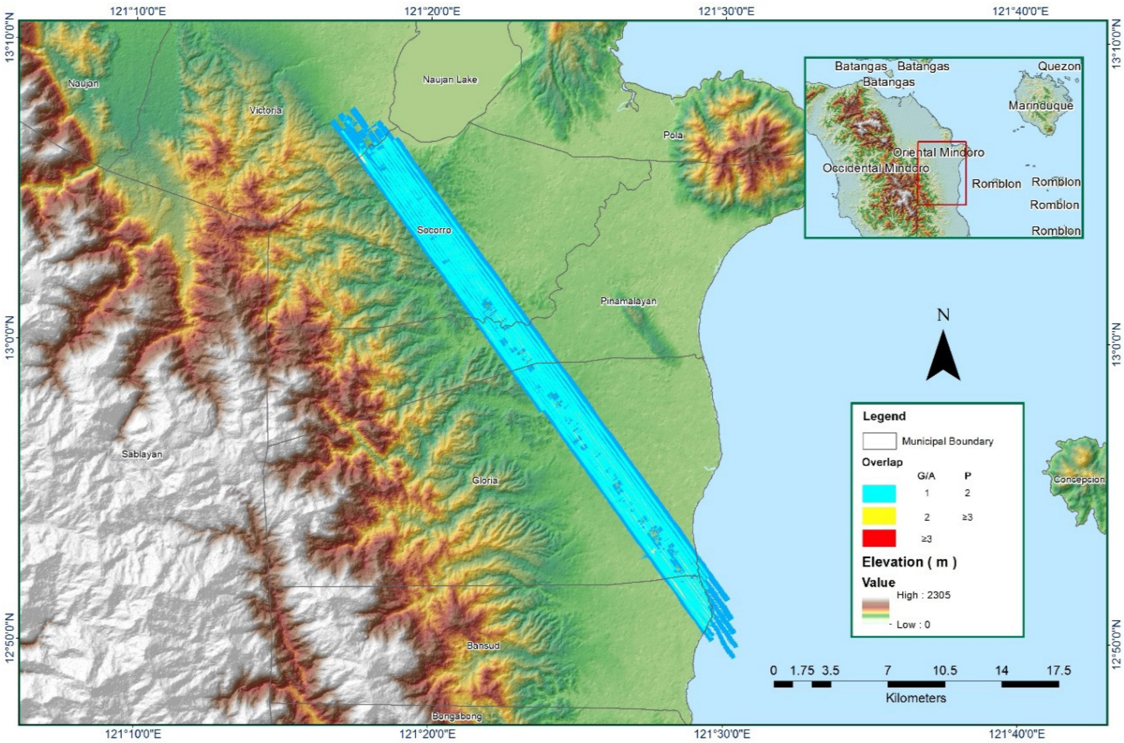


Figure A-8.27. Image of data overlap

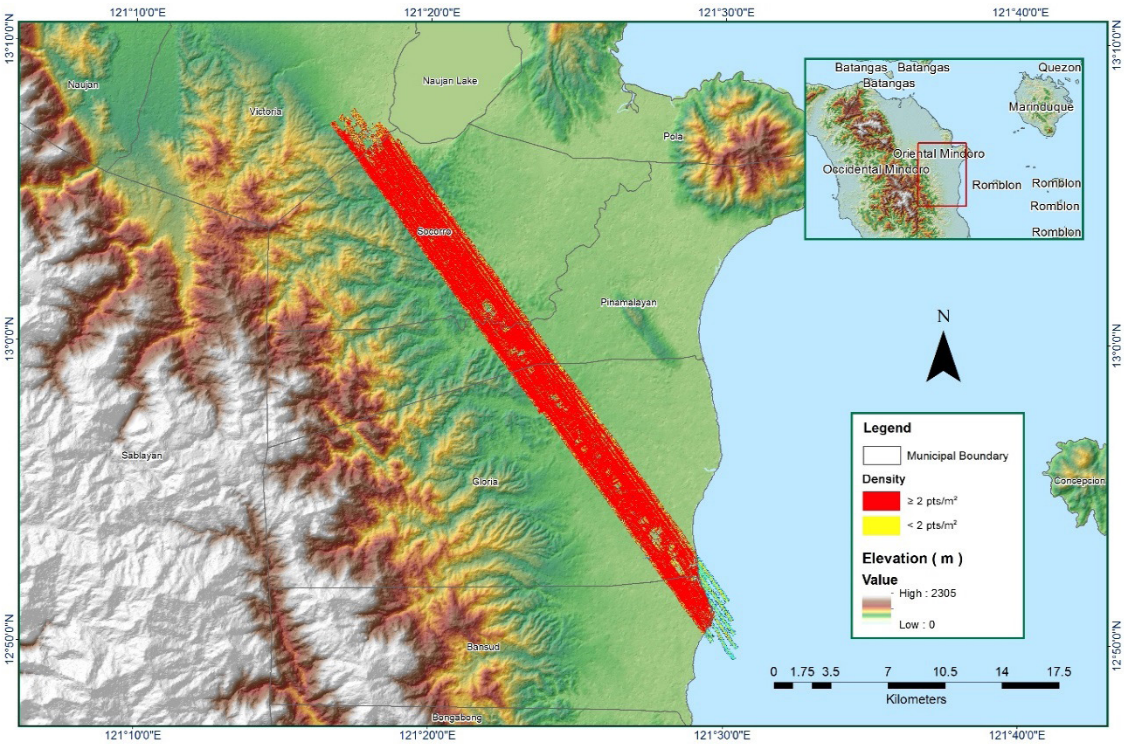


Figure A-8.28. Density map of merged LiDAR data

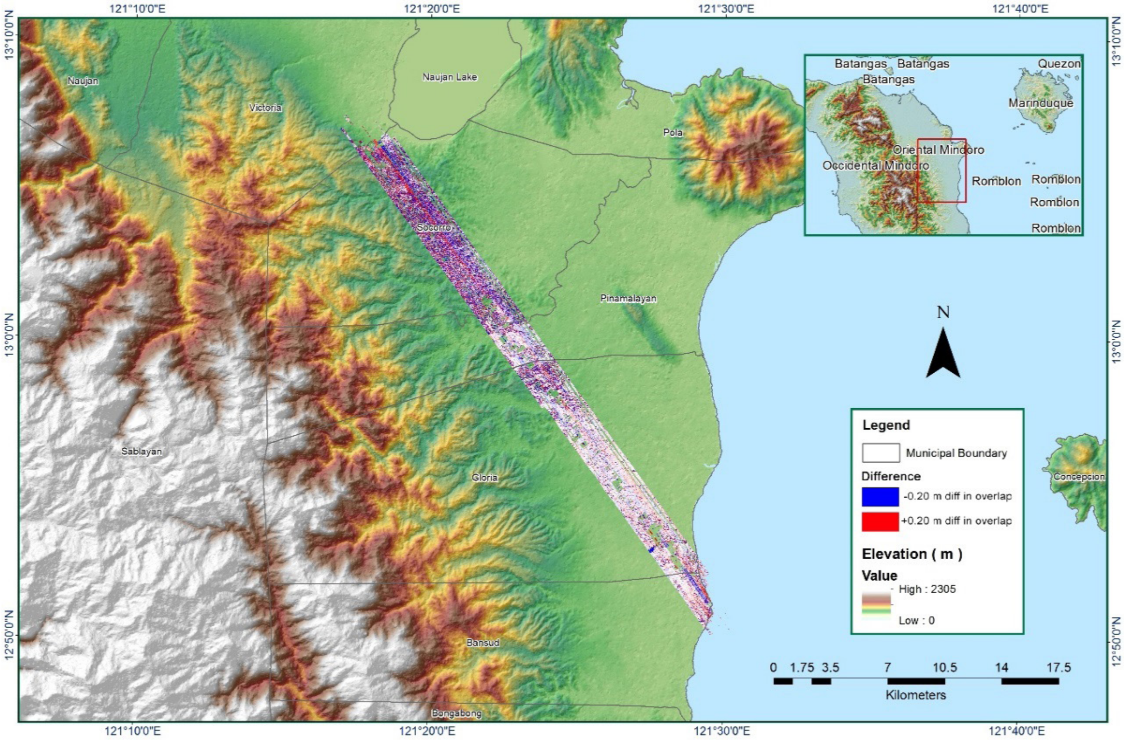


Figure A-8.29. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk 28C

Flight Area	Oriental Mindoro
Mission Name	Blk28C_supplement
Inclusive Flights	1056A
Range data size	12.2 GB
Base data size	6.29 MB
POS	210 MB
Image	77.2 GB
Transfer date	February 6,2014
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)	2.2
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	4.3
Boresight correction stdev (<0.001deg)	0.000367
IMU attitude correction stdev (<0.001deg)	0.011964
GPS position stdev (<0.01m)	0.0209
Minimum % overlap (>25)	52.68%
Ave point cloud density per sq.m. (>2.0)	3.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	161
Maximum Height	236.75 m
Minimum Height	48.61 m
Classification (# of points)	
Ground	46,847,528
Low vegetation	57,381,551
Medium vegetation	53,054,311
High vegetation	75,091,227
Building	1,786,653
Ortophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Gladys Mae Apat

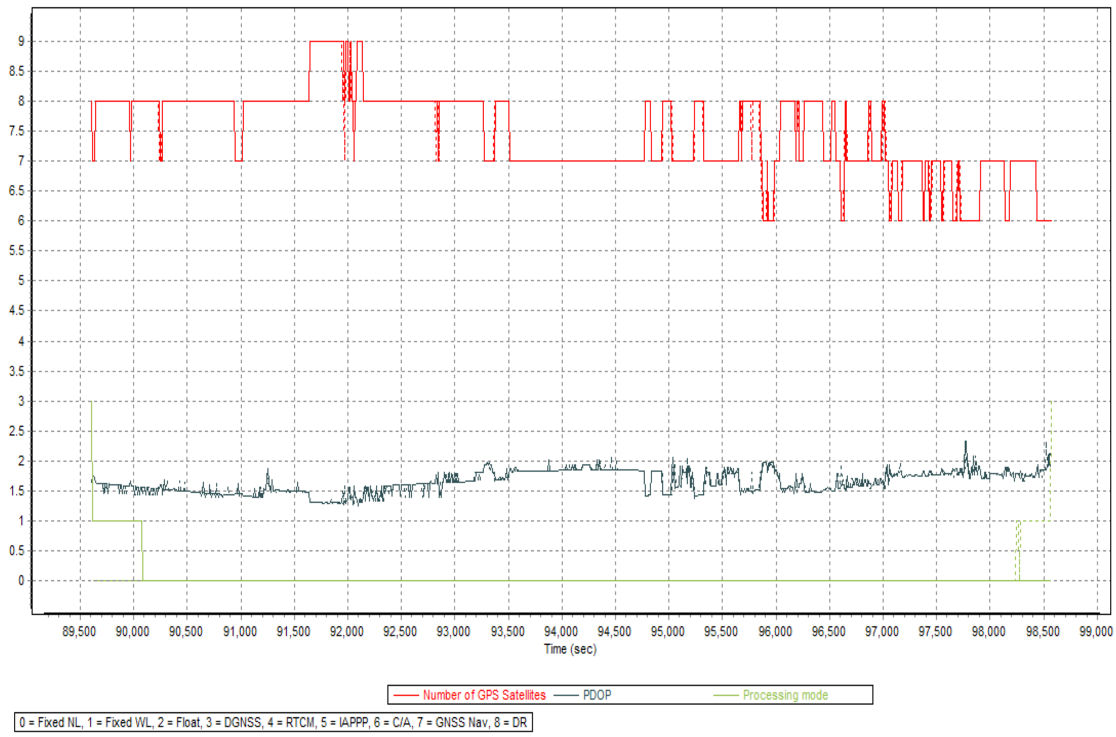


Figure A-8.30. Solution Status

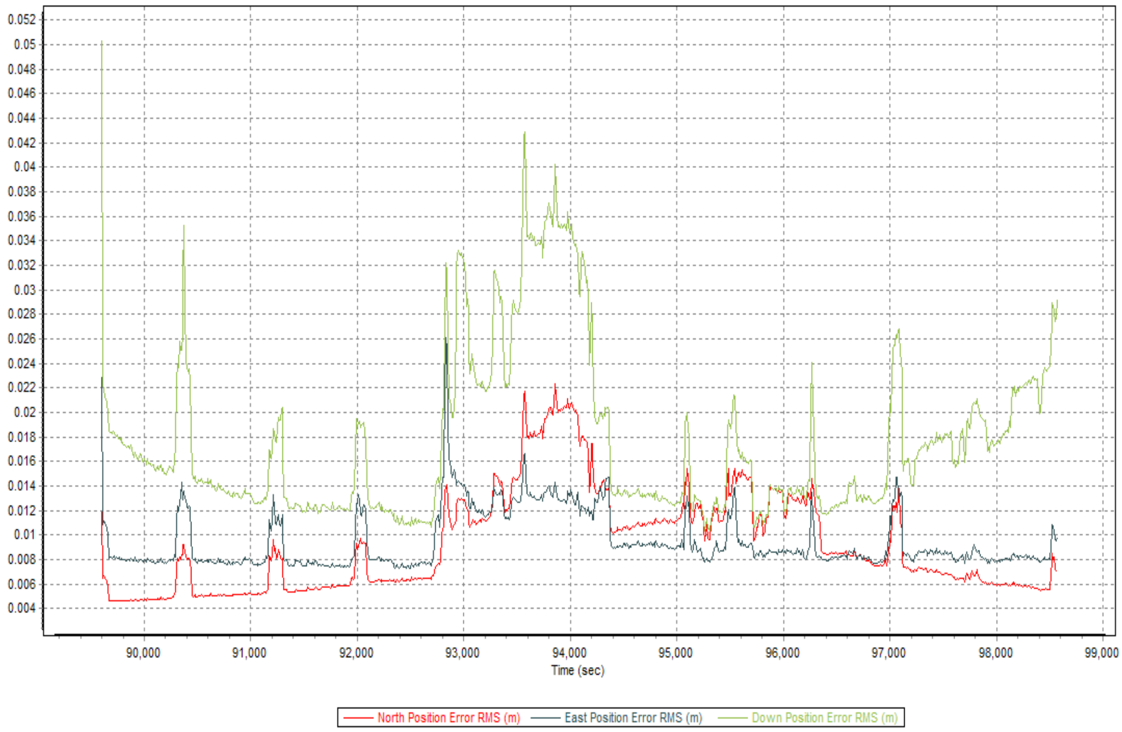


Figure A-8.31. Smoothed Performance Metric Parameters

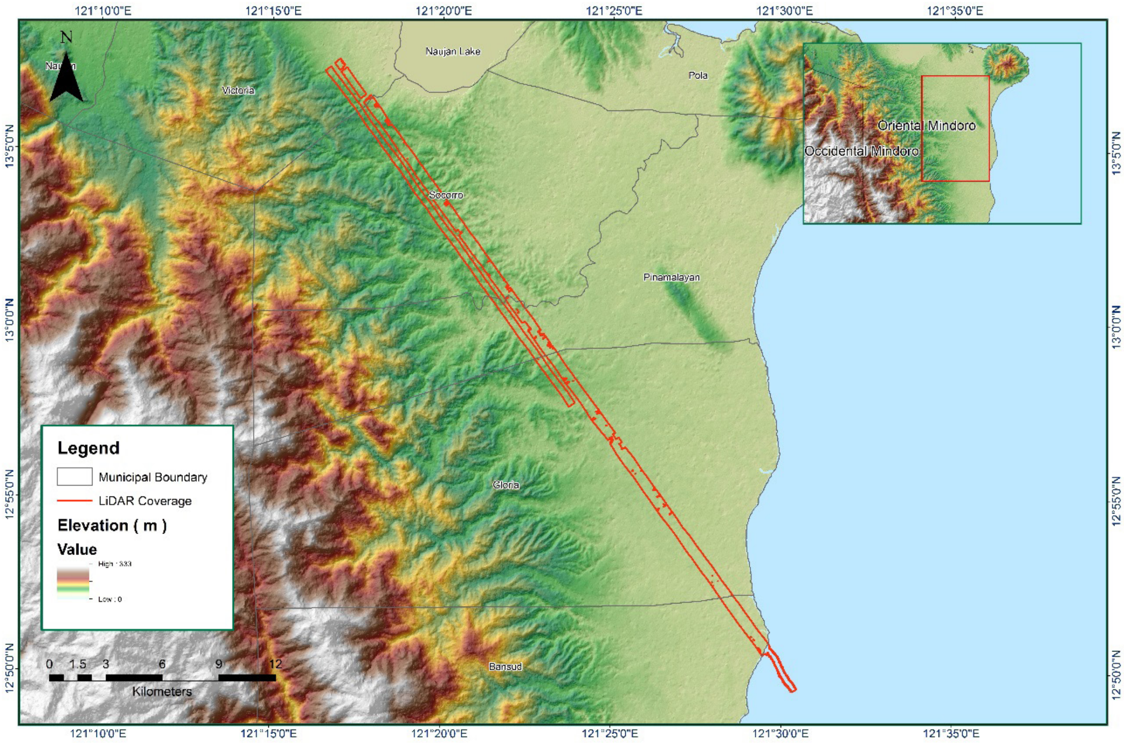


Figure A-8.32. Best Estimated Trajectory

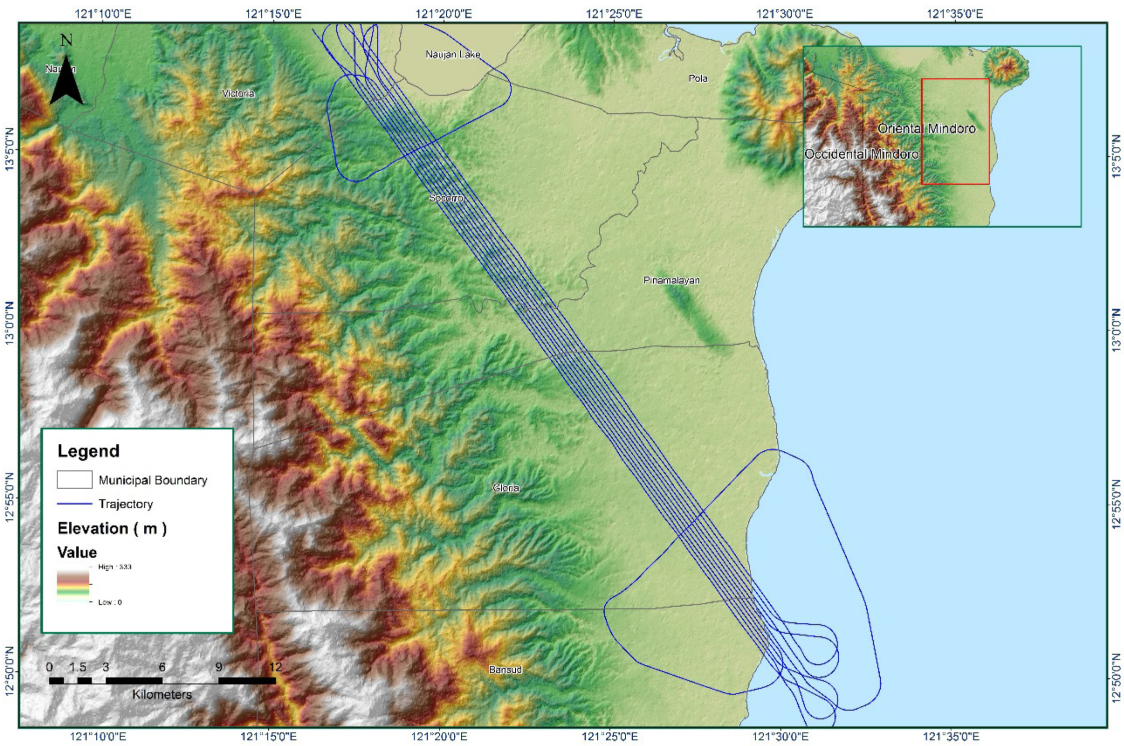


Figure A-8.33. Coverage of LiDAR data

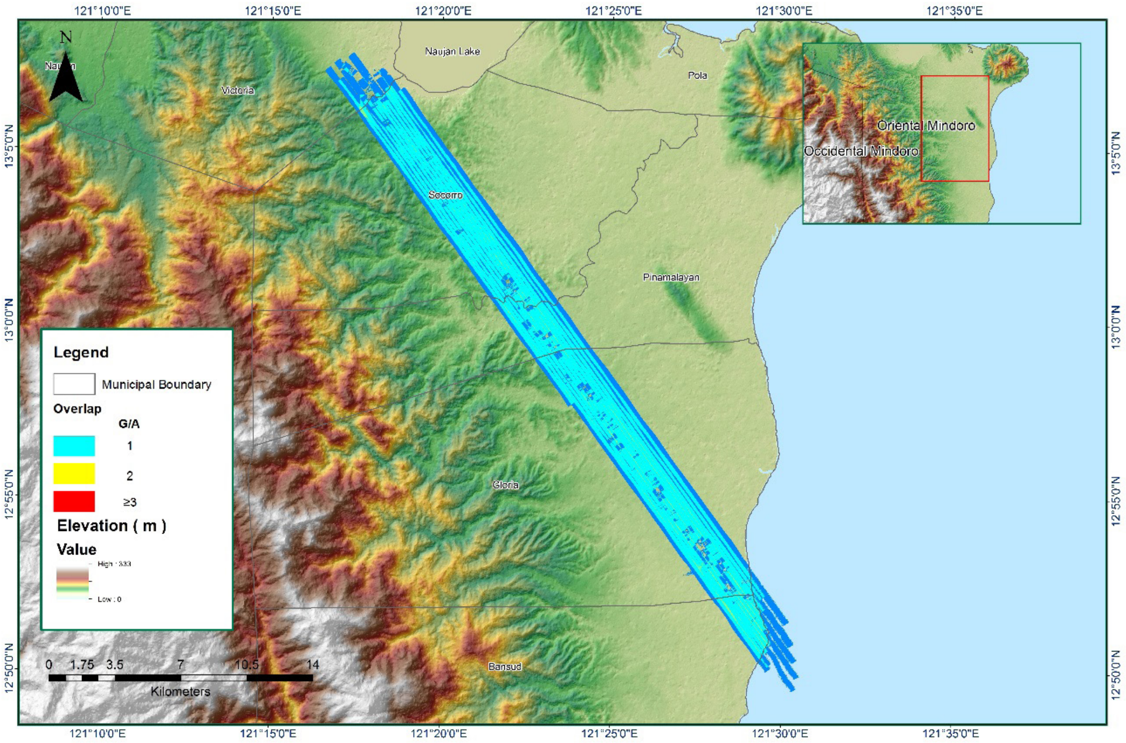


Figure A-8.34. Image of data overlap

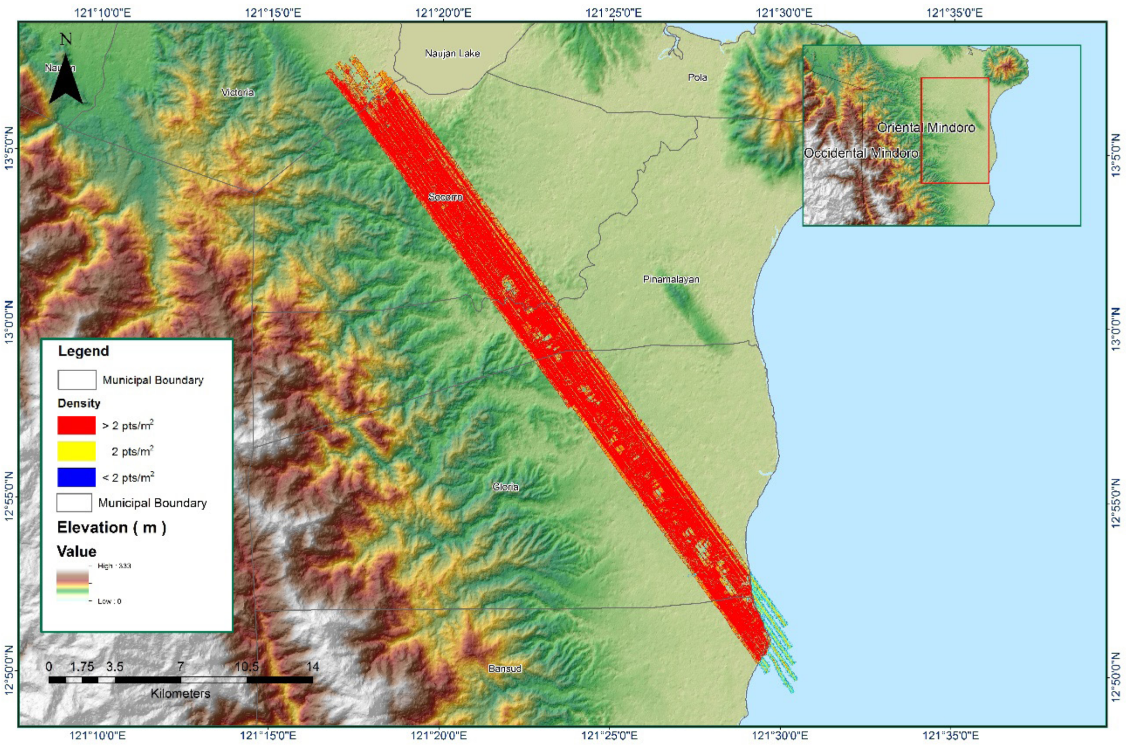


Figure A-8.35. Density Map of merged LiDAR data

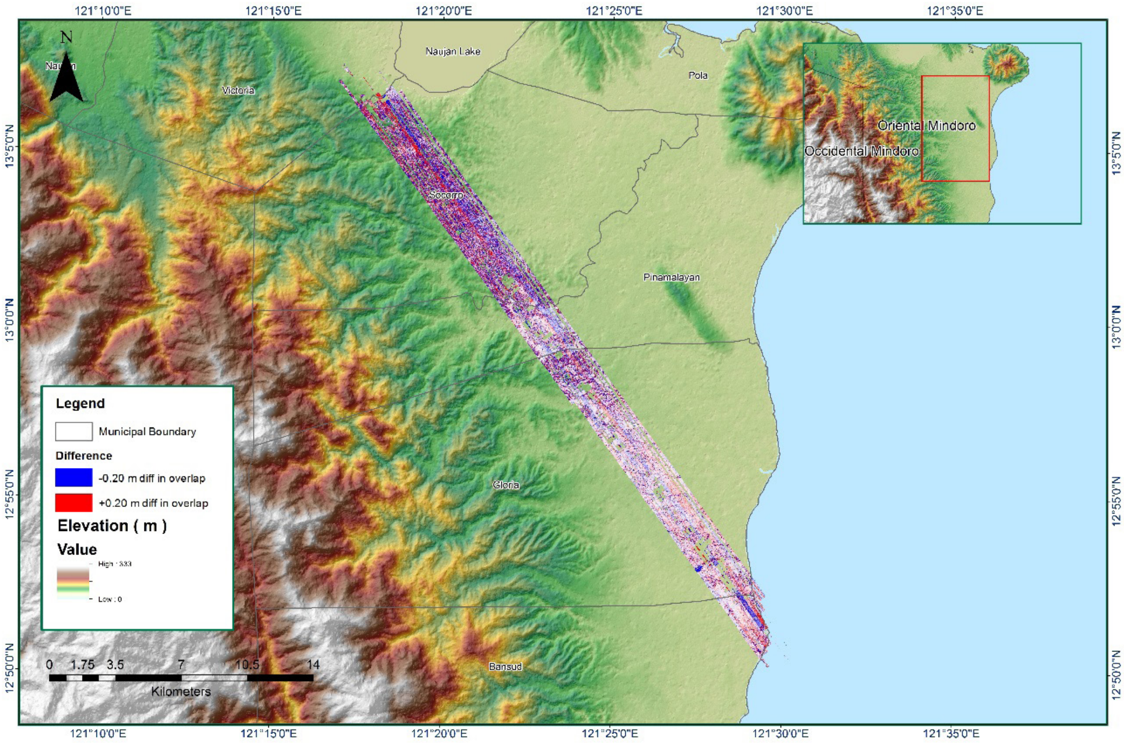


Figure A-8.36. Elevation Difference Between flight lines

Table A-8.6. Mission Summary Report for Mission Blk 28D

Flight Area	Oriental Mindoro
Mission Name	Blk 28D
Inclusive Flights	1058A
Range data size	11.3 GB
Base data size	6.29 MB
POS	201 MB
Image	65.8 GB
Transfer date	February 6, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000526
IMU attitude correction stdev (<0.001deg)	0.000830
GPS position stdev (<0.01m)	0.0115
Minimum % overlap (>25)	37.87%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	121
Maximum Height	195.43 m
Minimum Height	50.30 m
Classification (# of points)	
Ground	40,245,323
Low vegetation	47,622,749
Medium vegetation	36,130,731
High vegetation	35,894,152
Building	929,168
Orthophoto	Yes
Processed by	Ma. Victoria Rejuso, Celina Rosete, Ryan Nicholai Dizon

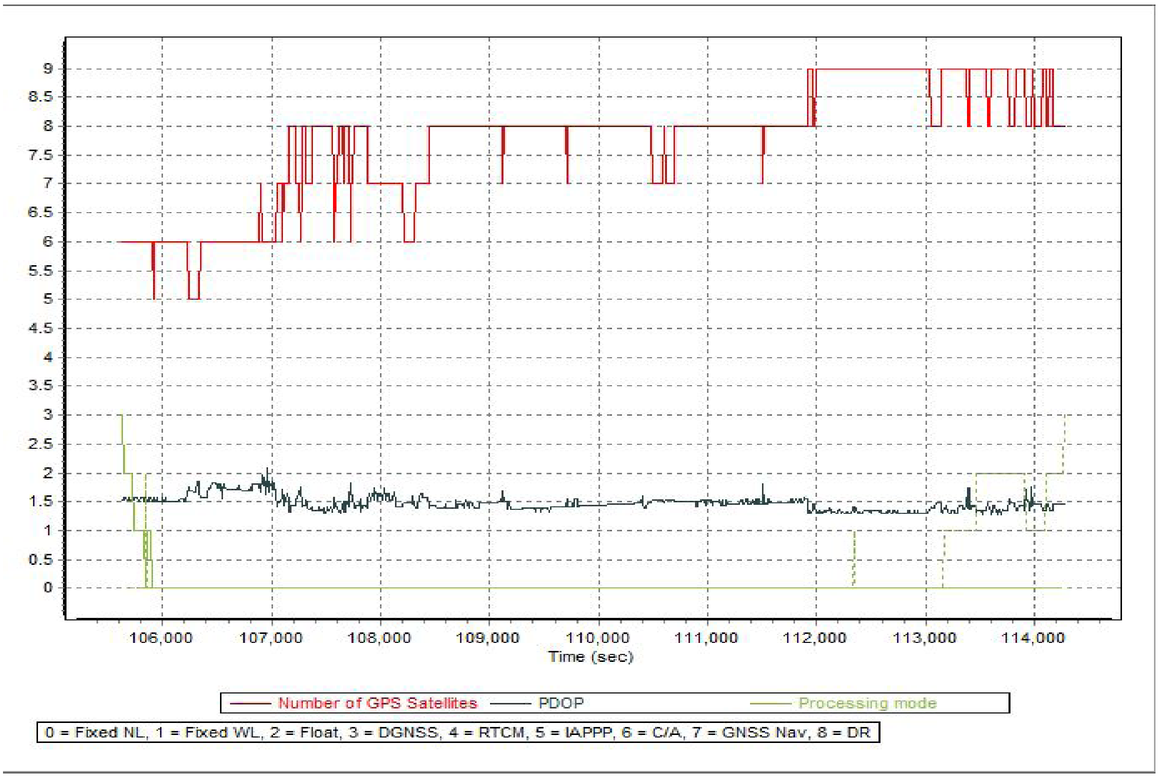


Figure A-8.37. Solution Status

Figure A-8.38. Smoothed Performance Metrics Parameters

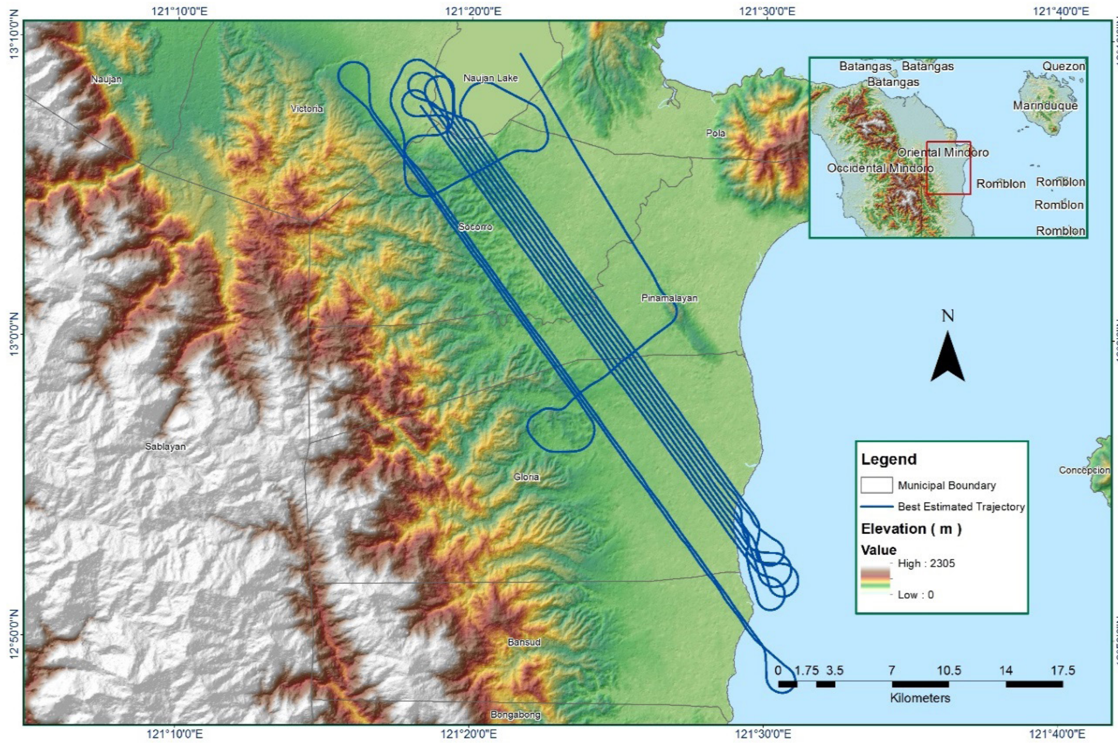


Figure A-8.39. Best Estimated Trajectory

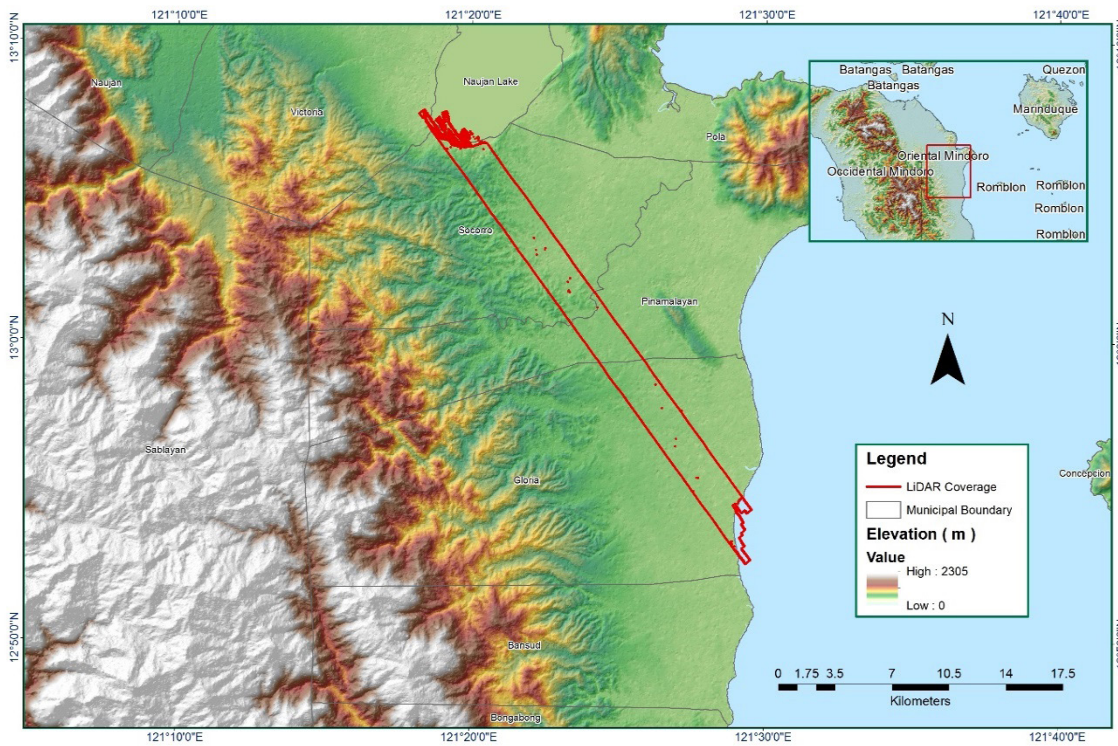


Figure A-8.40. Coverage of LiDAR data

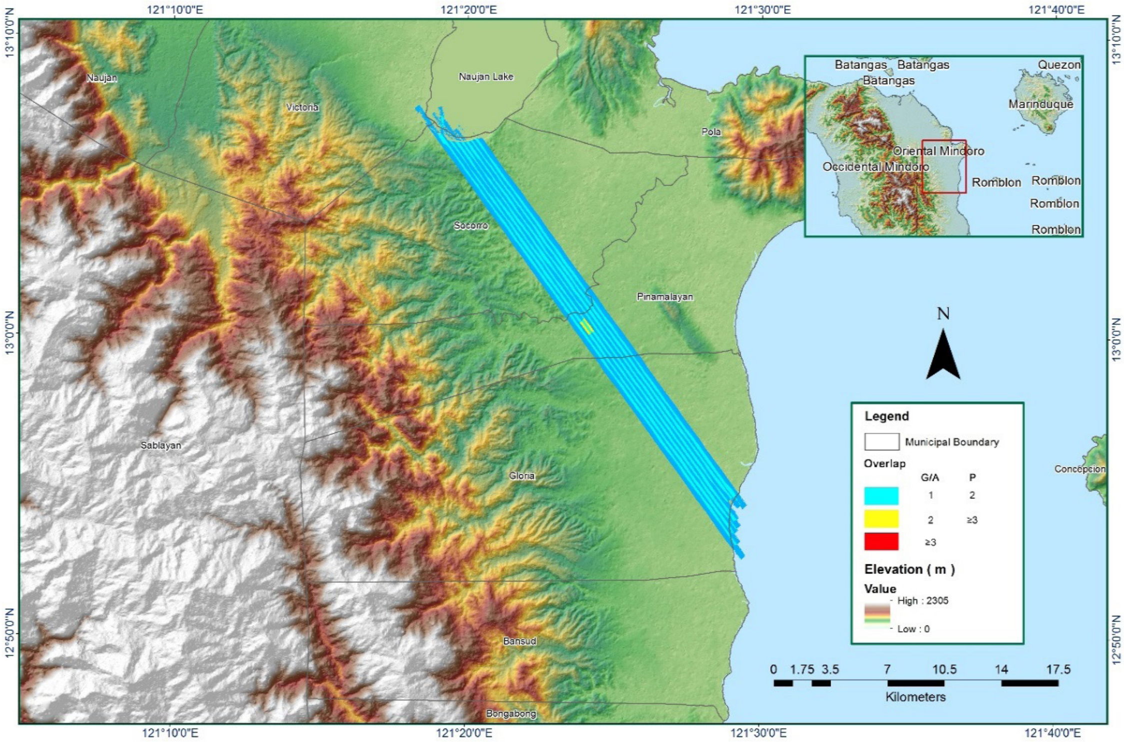


Figure A-8.41. Image of data overlap

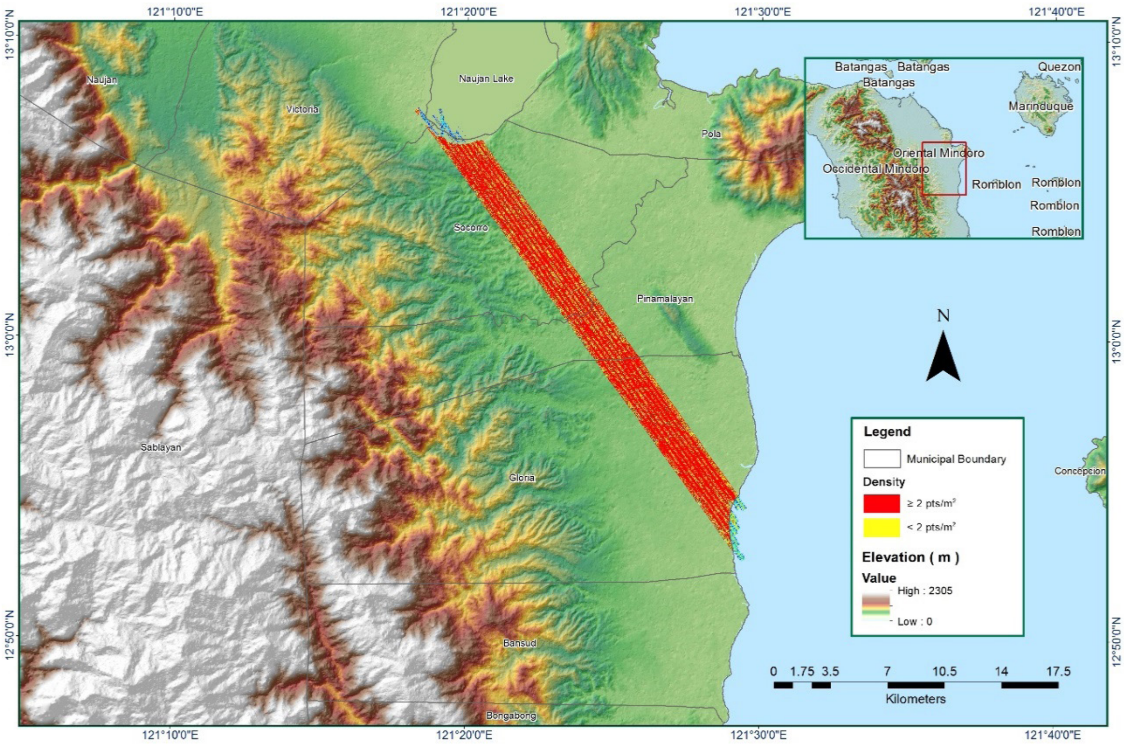


Figure A-8.42. Density map of merged LiDAR data

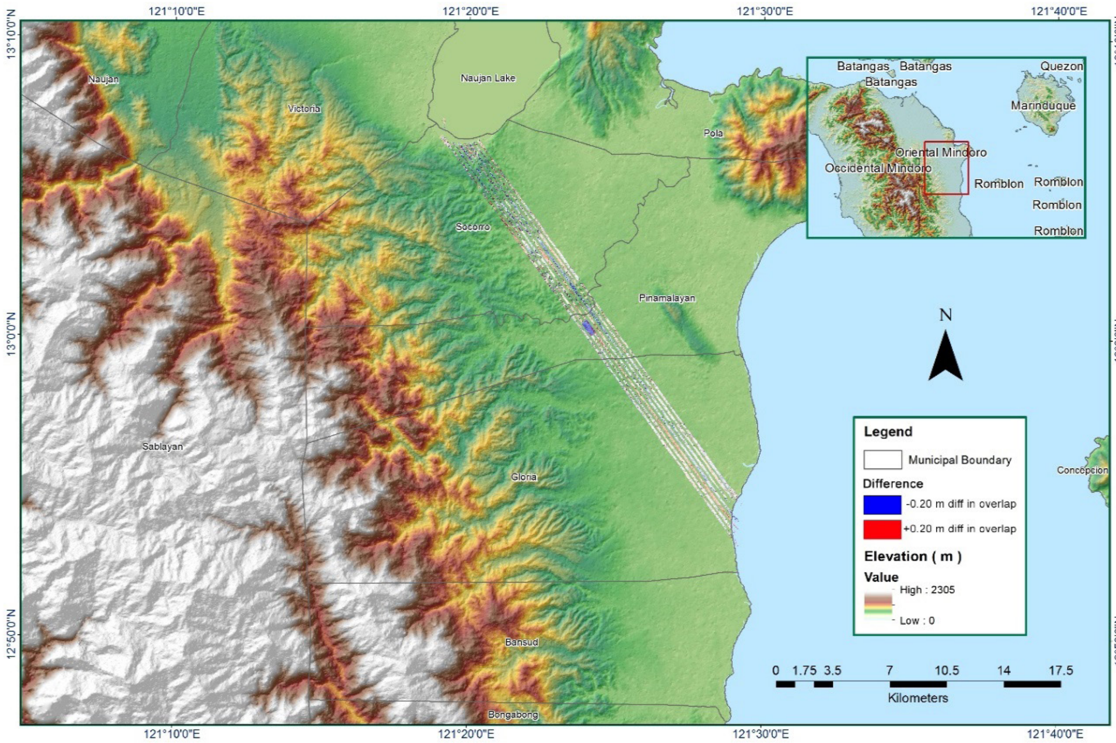


Figure A-8.43. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk28D_supplement

Flight Area	Oriental Mindoro
Mission Name	Blk28D_supplement
Inclusive Flights	1066A
Range data size	11.7 GB
Base data size	14.5 MB
POS	203 MB
Image	73.9 GB
Transfer date	February 20, 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)	1.4
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.1
Boresight correction stdev (<0.001deg)	0.000424
IMU attitude correction stdev (<0.001deg)	0.000955
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	49.41%
Ave point cloud density per sq.m. (>2.0)	3.47
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	159
Maximum Height	358.99 m
Minimum Height	47.66 m
Classification (# of points)	
Ground	51,219,472
Low vegetation	61,022,435
Medium vegetation	58,444,262
High vegetation	84,379,495
Building	3,448,633
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Jeffrey Delica

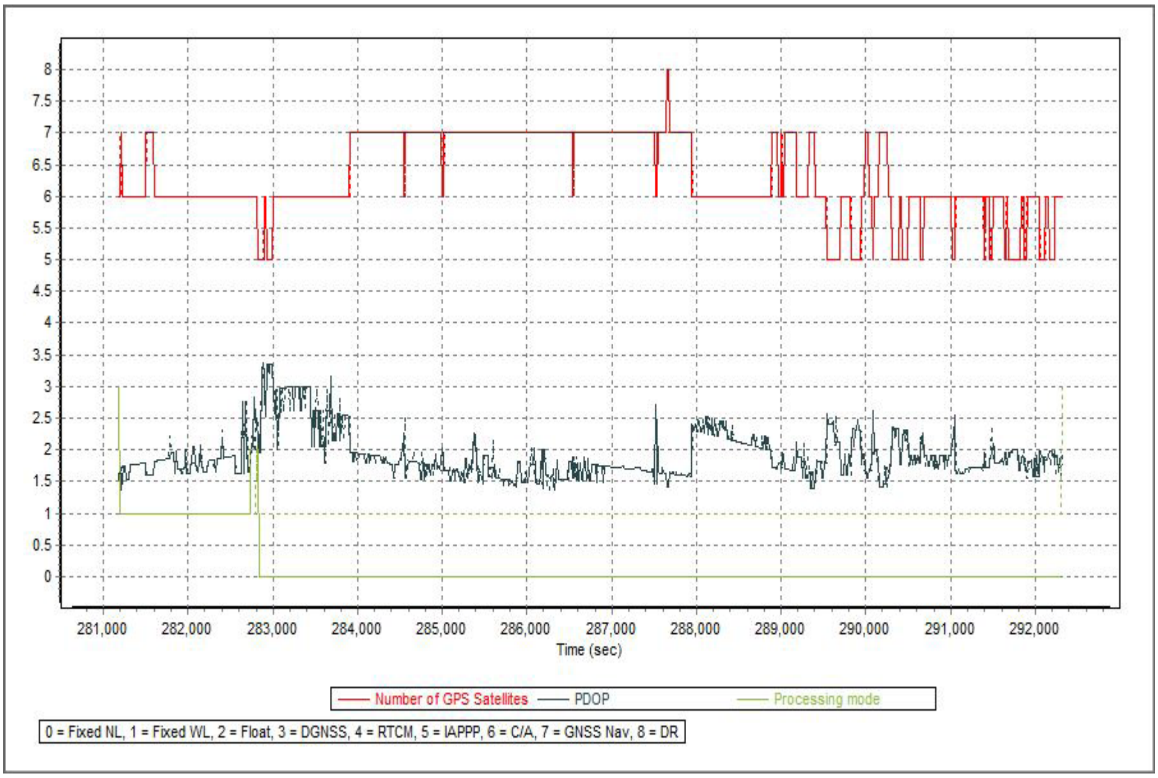


Figure A-8.44. Solution Status

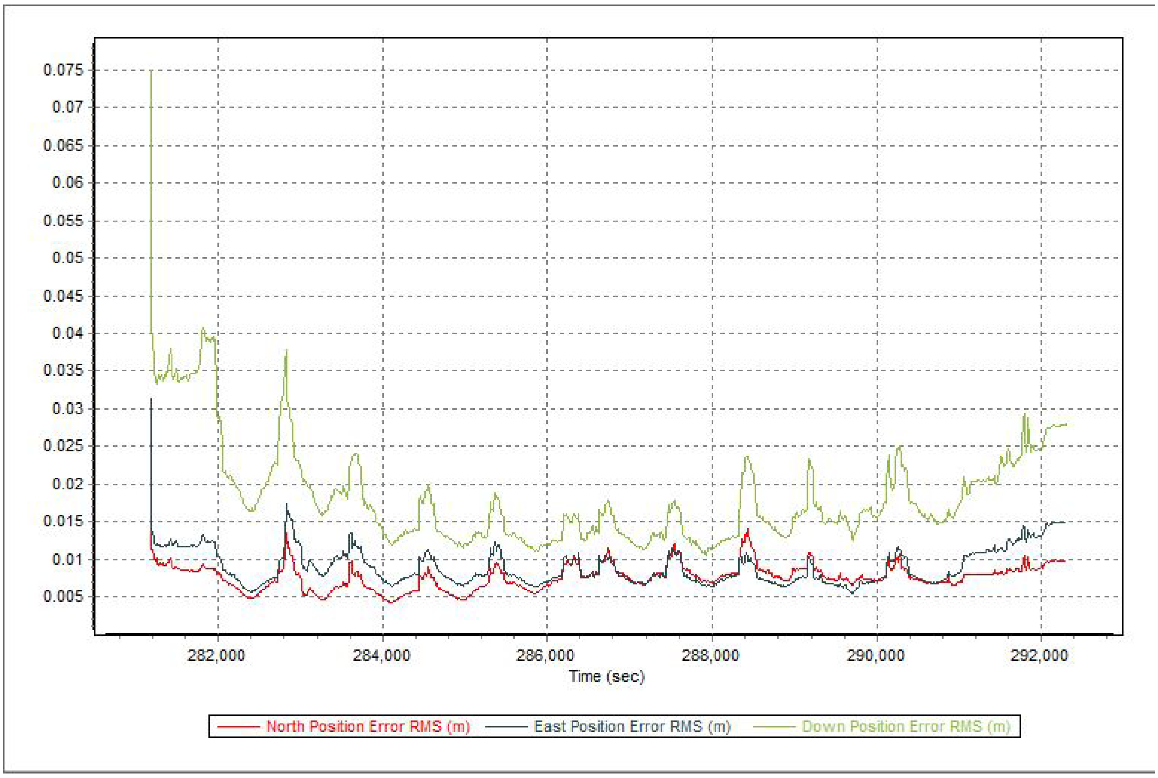


Figure A-8.45. Smoothed Performance Metrics Parameters

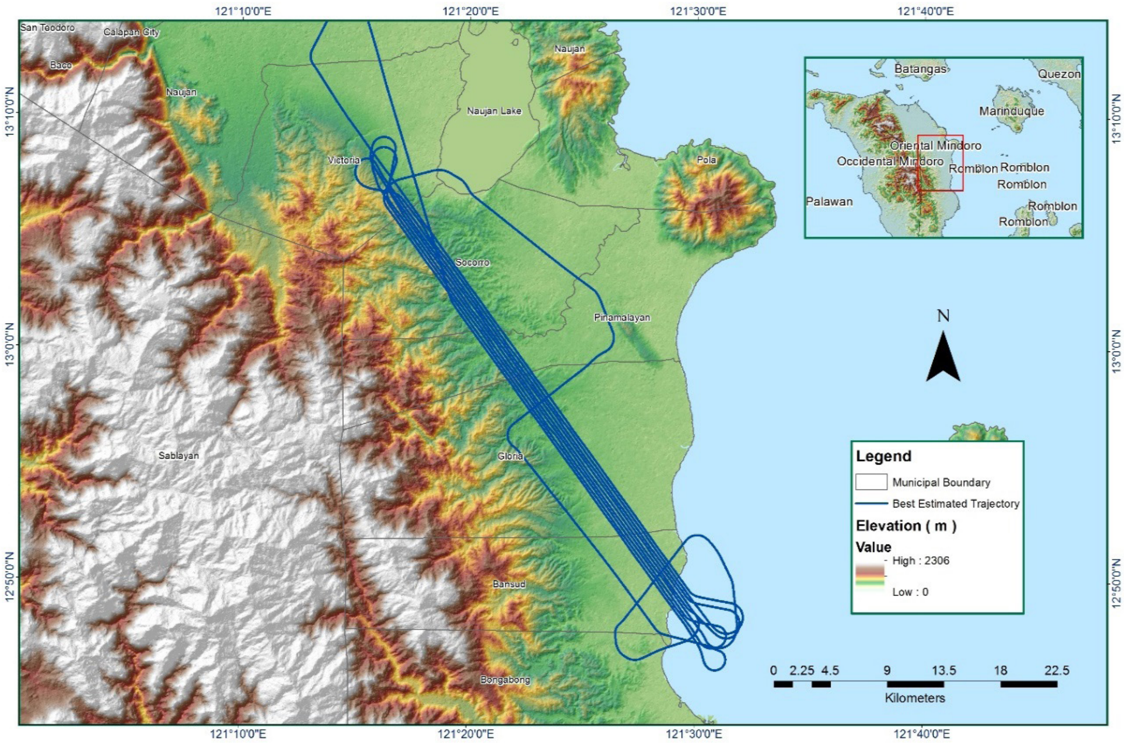


Figure A-8.46. Best Estimated Trajectory

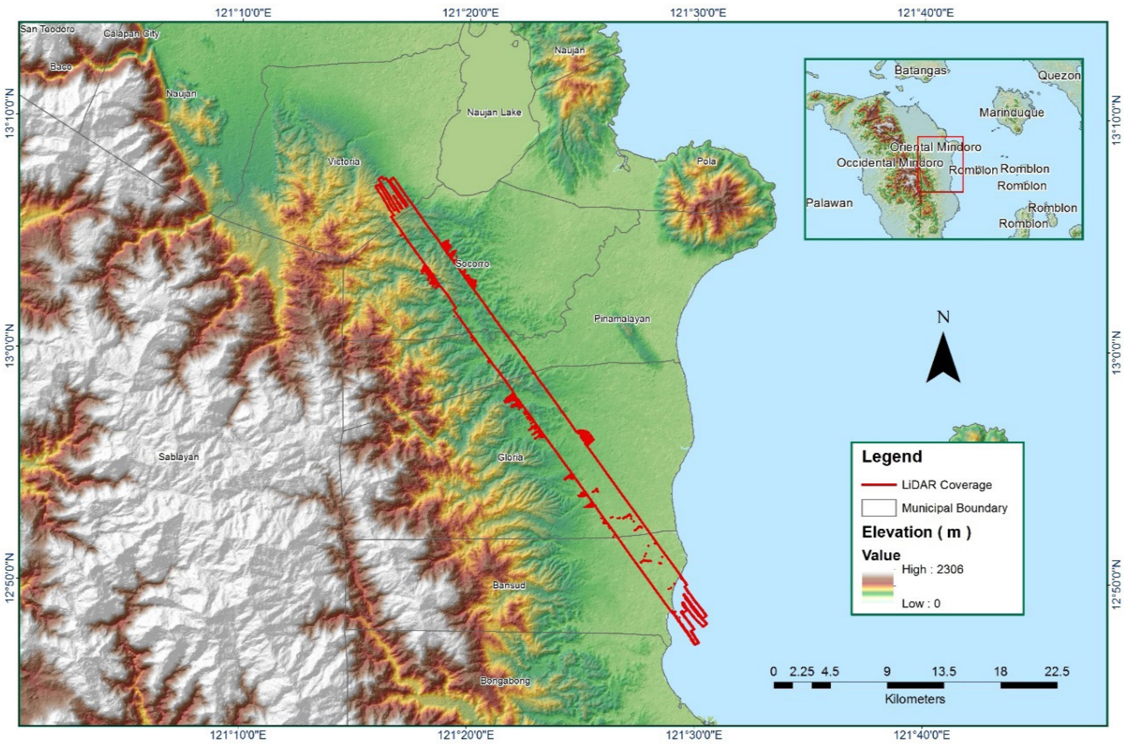


Figure A-8.47. Coverage of LiDAR data

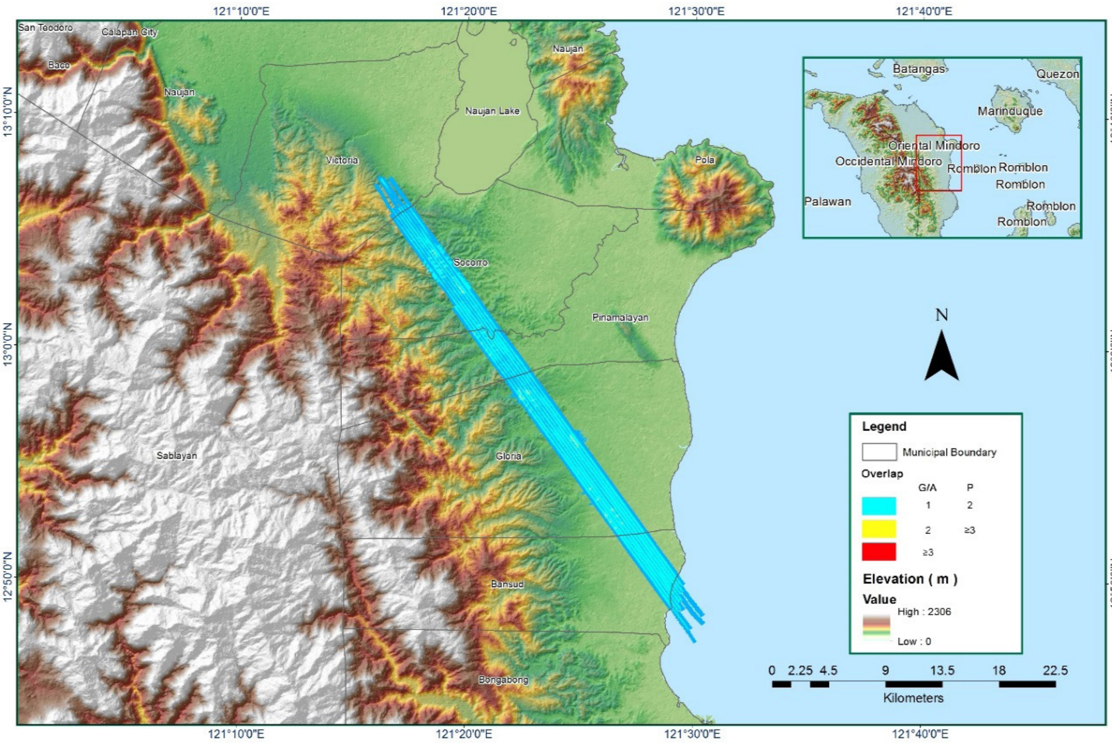


Figure A-8.48. Image of data overlap

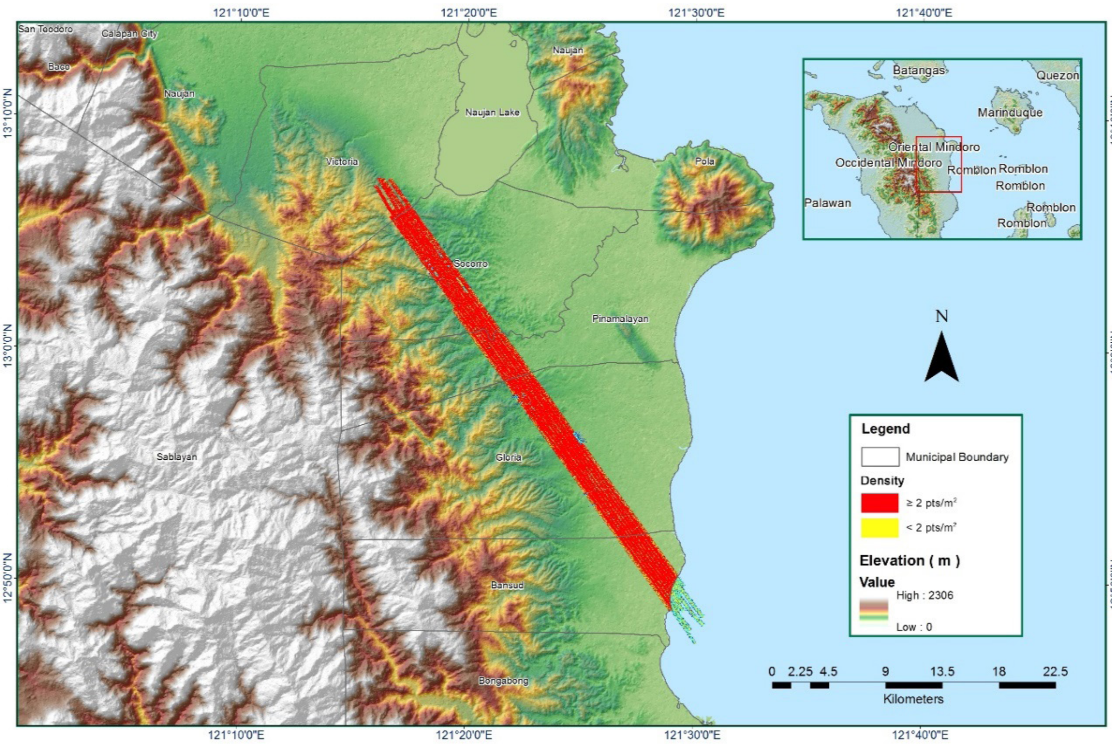


Figure A-8.49. Density map of merged LiDAR data

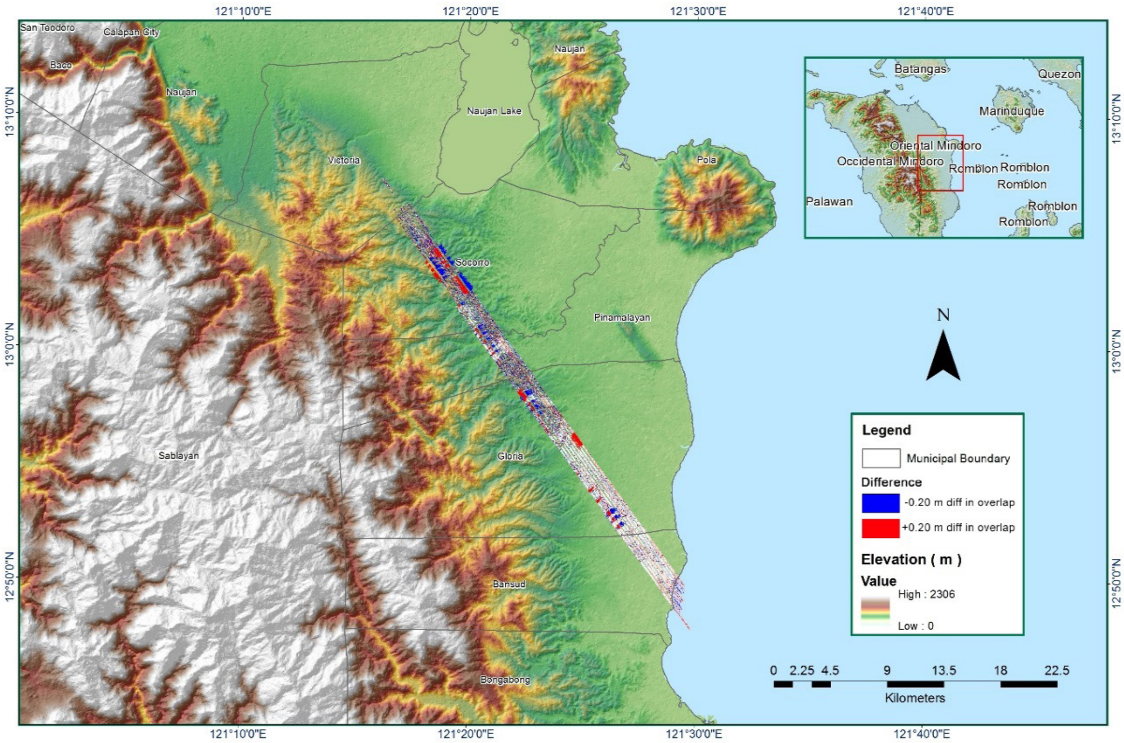


Figure A-8.50. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk28E

Flight Area	Oriental Mindoro
Mission Name	Blk28E
Inclusive Flights	1070A
Range data size	15.9 GB
Base data size	14.9 MB
POS	270 MB
Image	104 GB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000346
IMU attitude correction stdev (<0.001deg)	0.0001166
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	38.34%
Ave point cloud density per sq.m. (>2.0)	3.35
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	202
Maximum Height	388.91 m
Minimum Height	48.91 m
Classification (# of points)	
Ground	81,447,001
Low vegetation	92,938,121
Medium vegetation	85,912,374
High vegetation	92,936,807
Building	3,360,220
Orthophoto	Yes
Processed by	Engr. Carlyn Ibañez, Engr. Charmaine Cruz, Engr. Jeffrey Delica, Engr. John Dill Macapagal

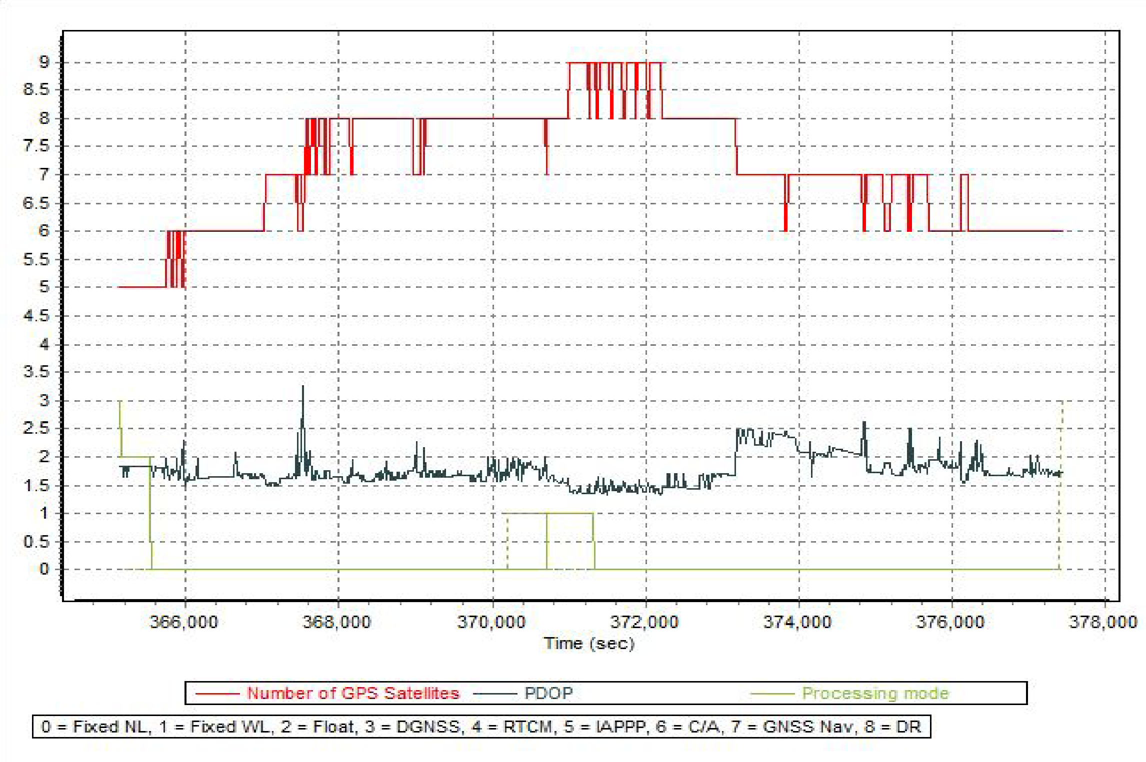


Figure A-8.51. Solution Status

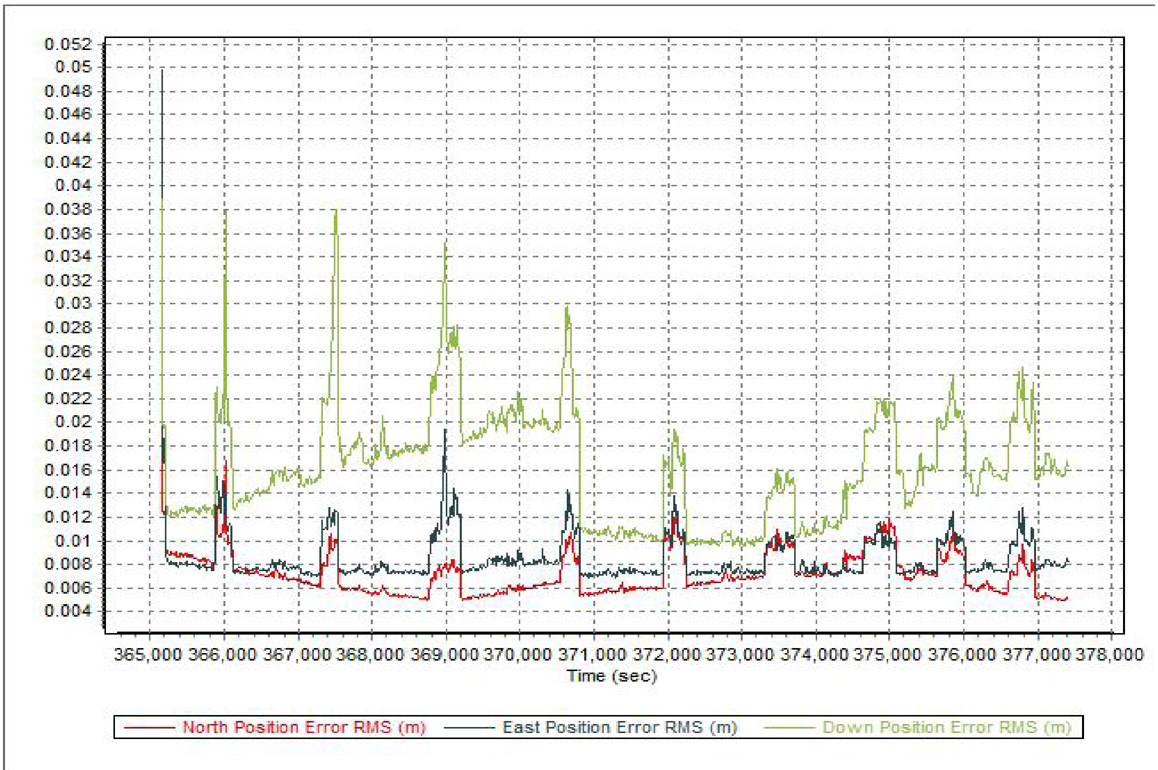


Figure A-8.52. Smoothed Performance Metrics Parameters

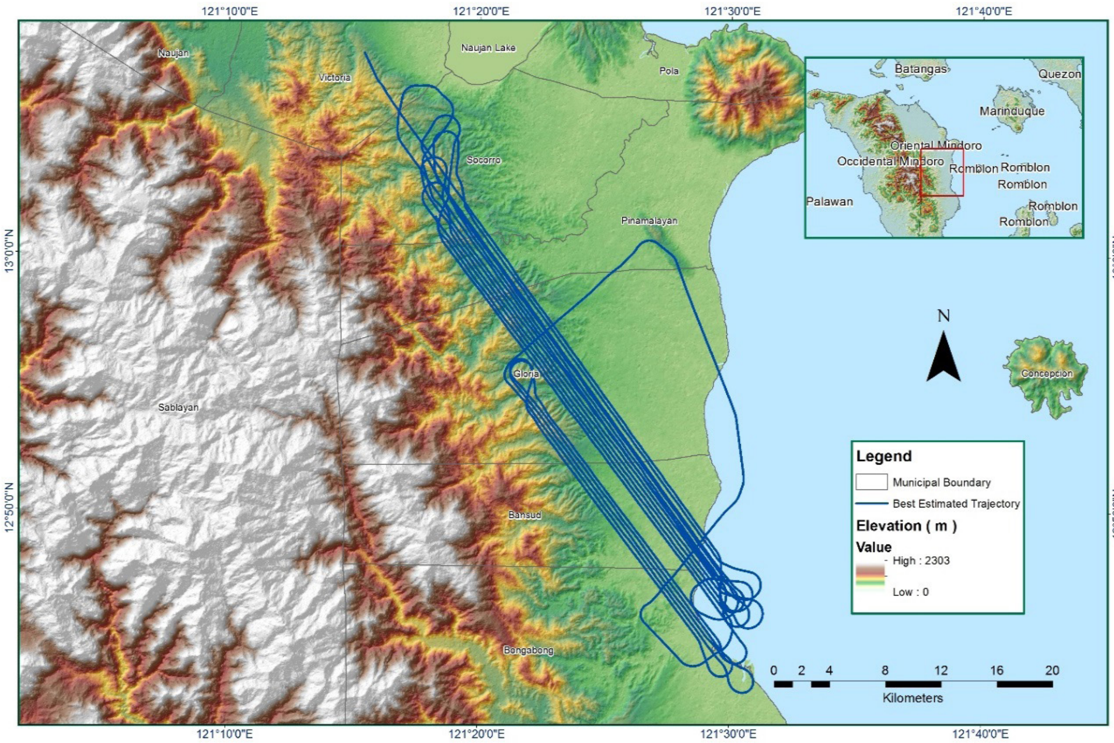


Figure A-8.53. Best Estimated Trajectory

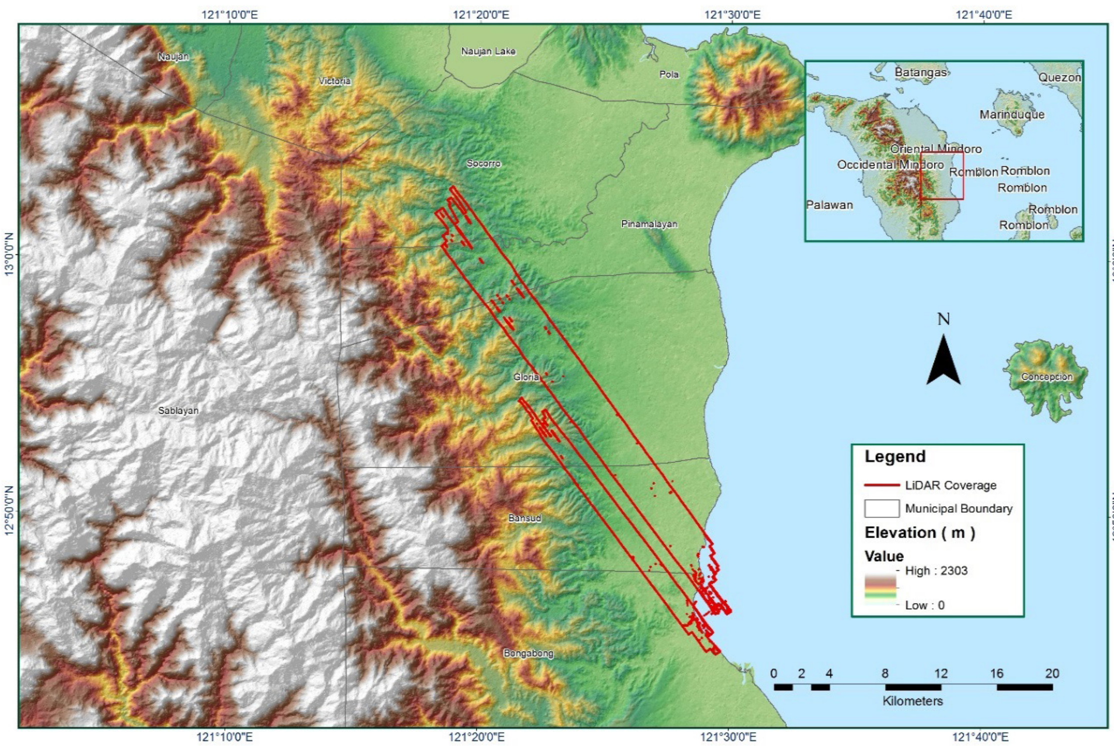


Figure A-8.54. Coverage of LiDAR data

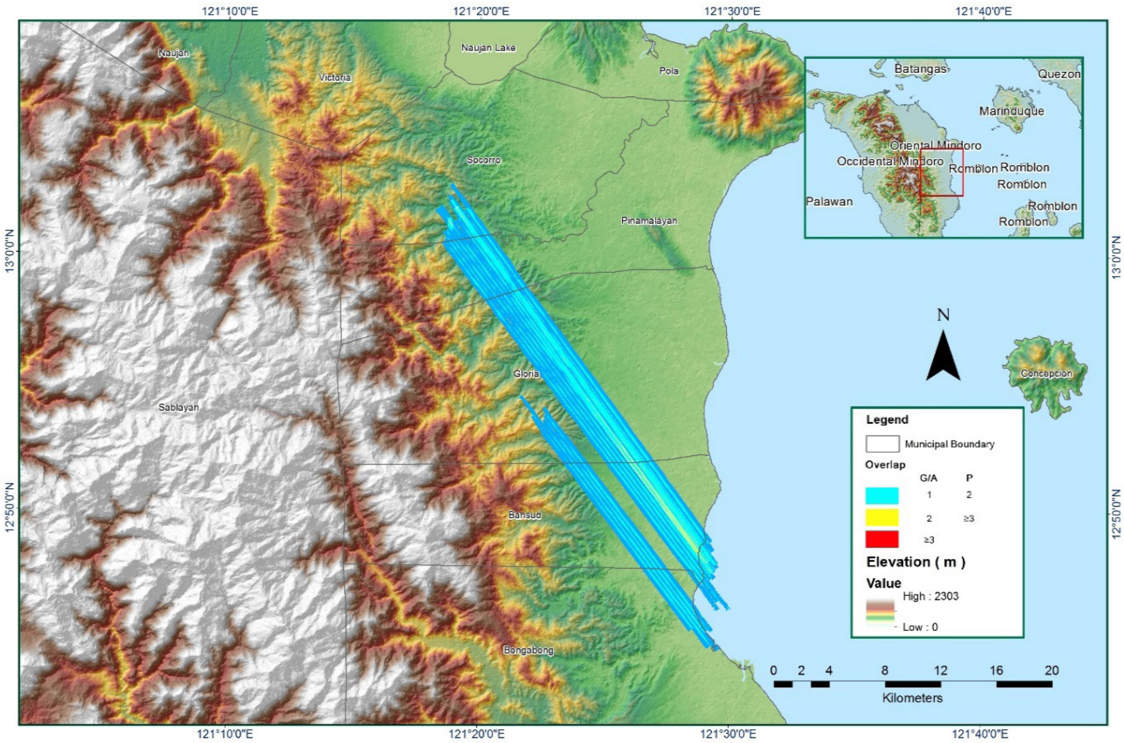


Figure A-8.55. Image of data overlap

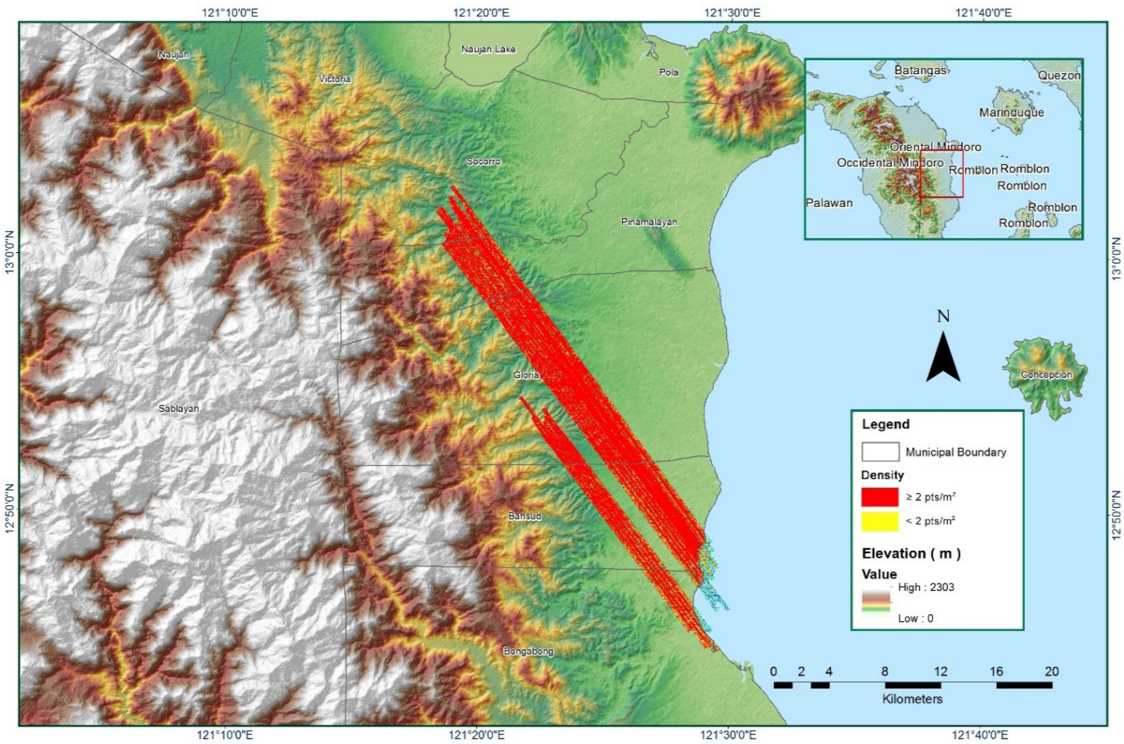


Figure A-8.56. Density map of merged LiDAR data

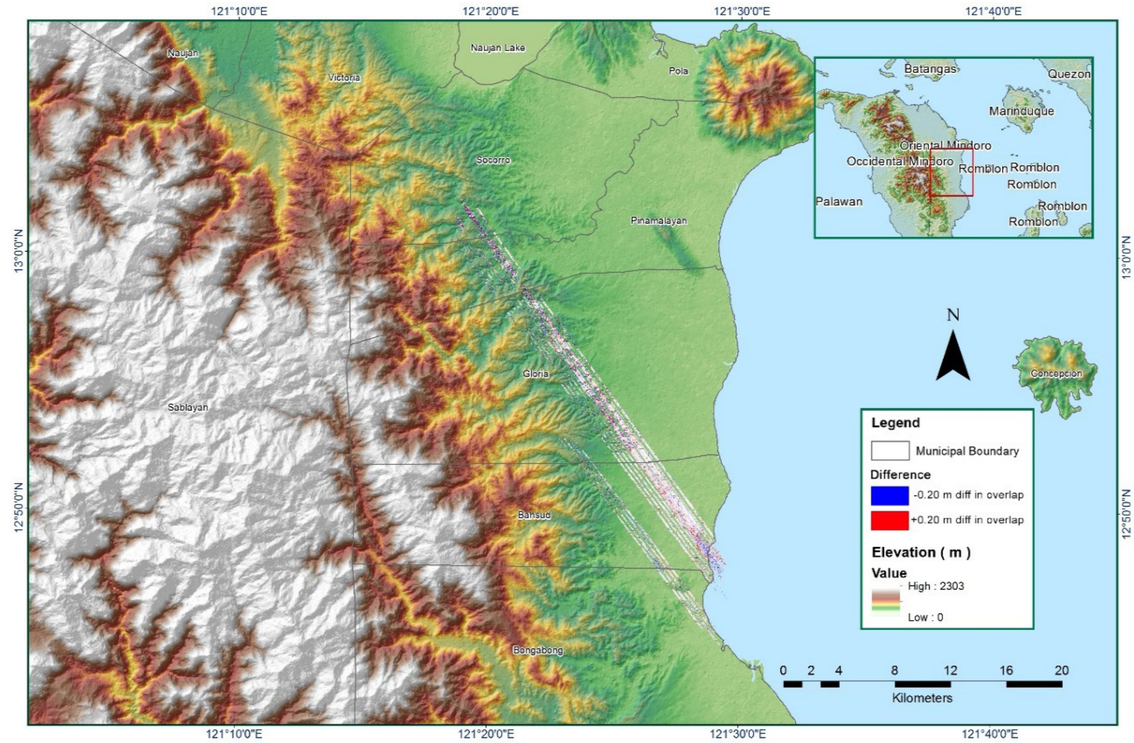


Figure A-8.57. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk28E_supplement

Flight Area	Oriental Mindoro
Mission Name	Blk28E_supplement
Inclusive Flights	1092A
Range data size	12.7 GB
Base data size	15.4 MB
POS	242 MB
Image	23.7 GB
Transfer date	February 21, 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)	1.8
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	5.6
Boresight correction stdev (<0.001deg)	0.000491
IMU attitude correction stdev (<0.001deg)	0.001513
GPS position stdev (<0.01m)	0.0156
Minimum % overlap (>25)	25.89%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	70
Maximum Height	344.97 m
Minimum Height	50.00 m
Classification (# of points)	
Ground	32,795,240
Low vegetation	33,440,686
Medium vegetation	23,067,538
High vegetation	28,790,559
Building	759,771
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Jovy Narisma

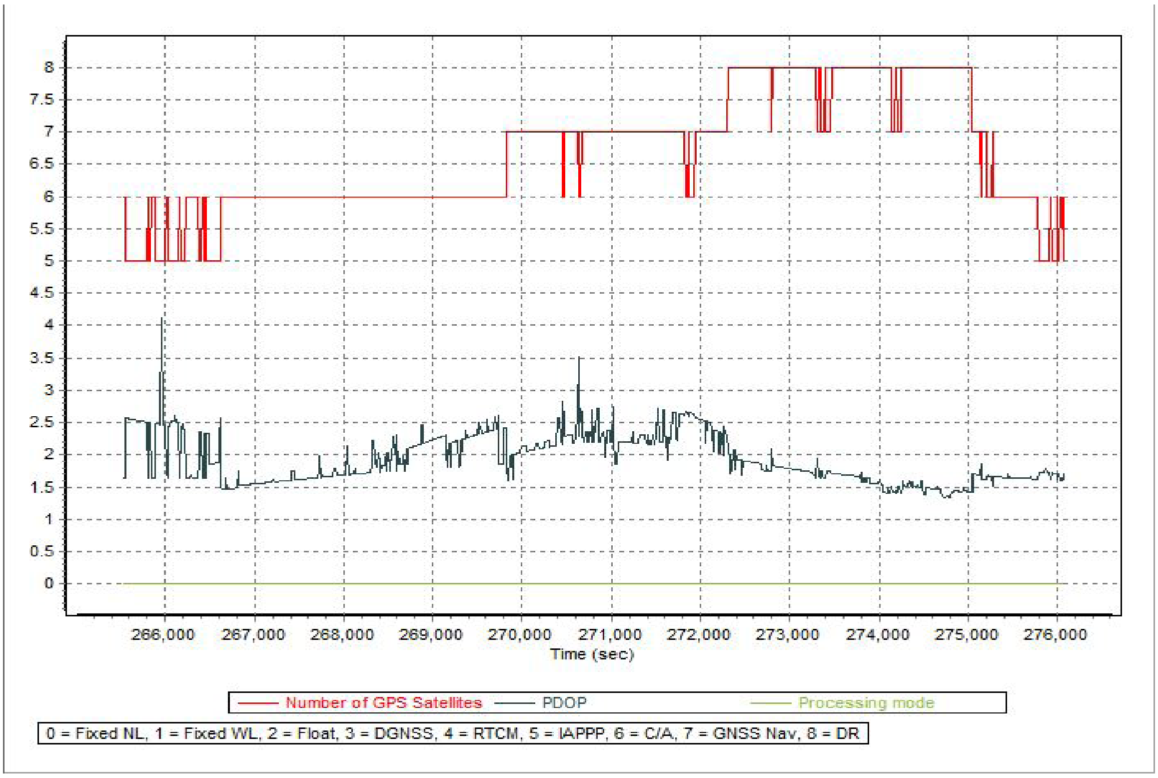


Figure A-8.58. Solution Status

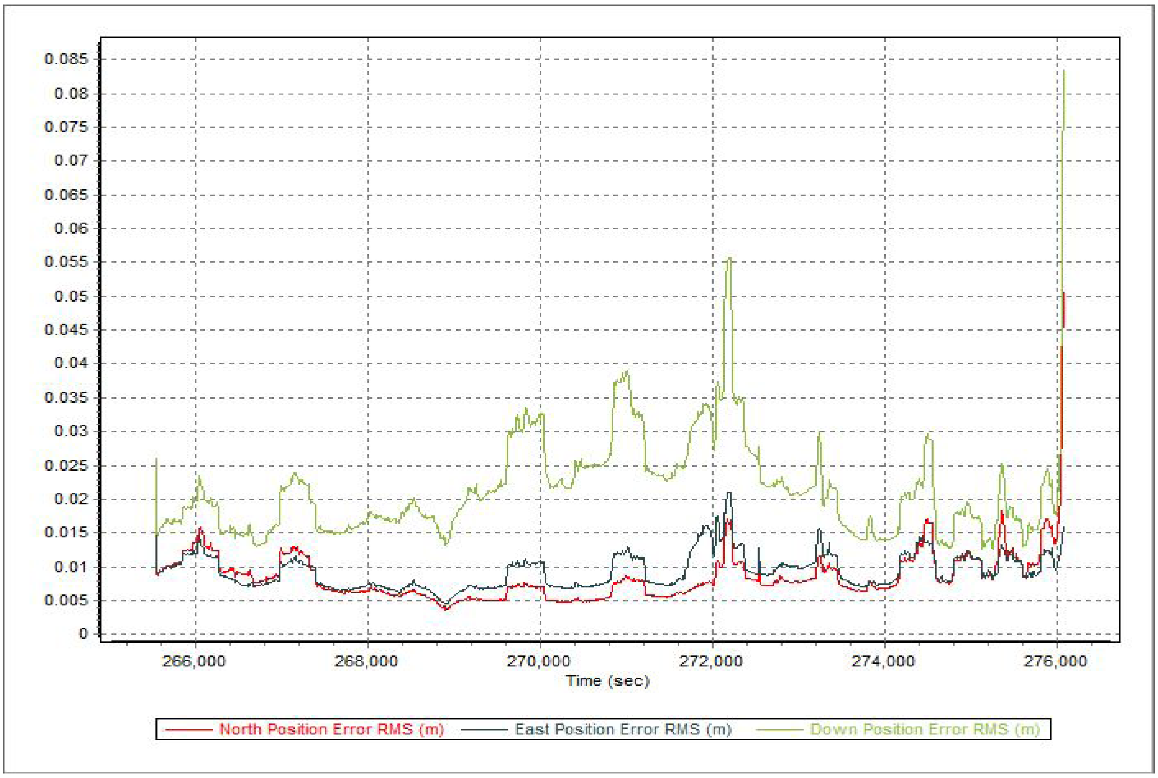


Figure A-8.59. Smoothed Performance Metrics Parameters

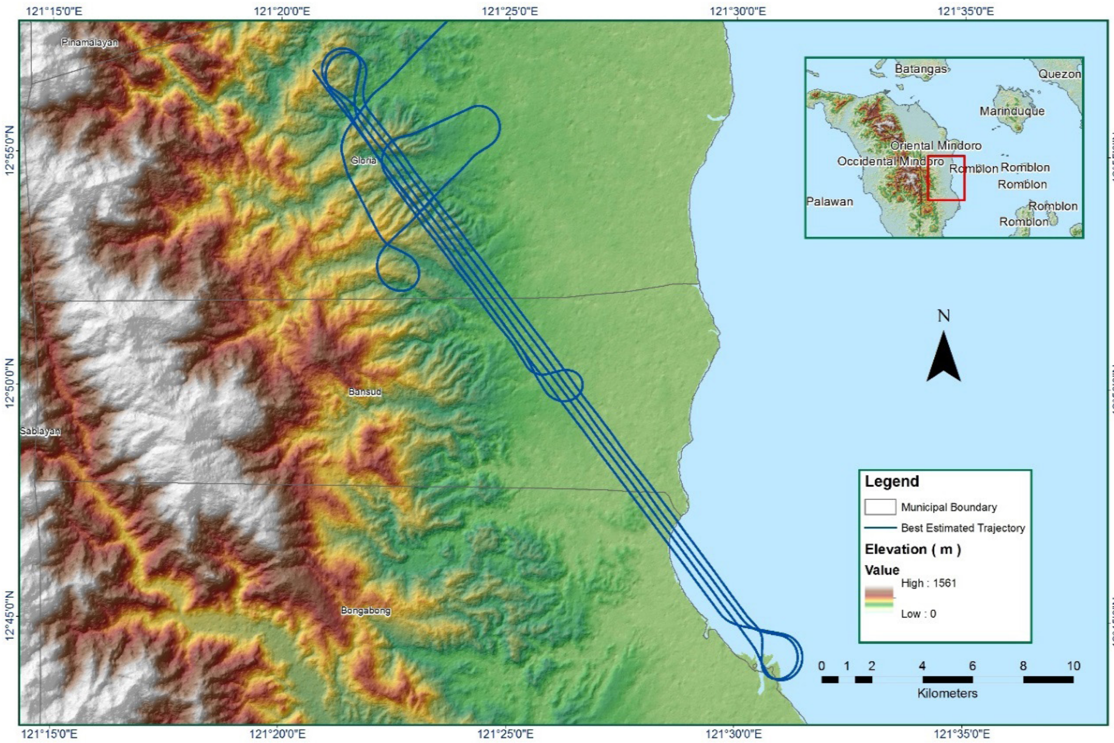


Figure A-8.60. Best Estimated Trajectory

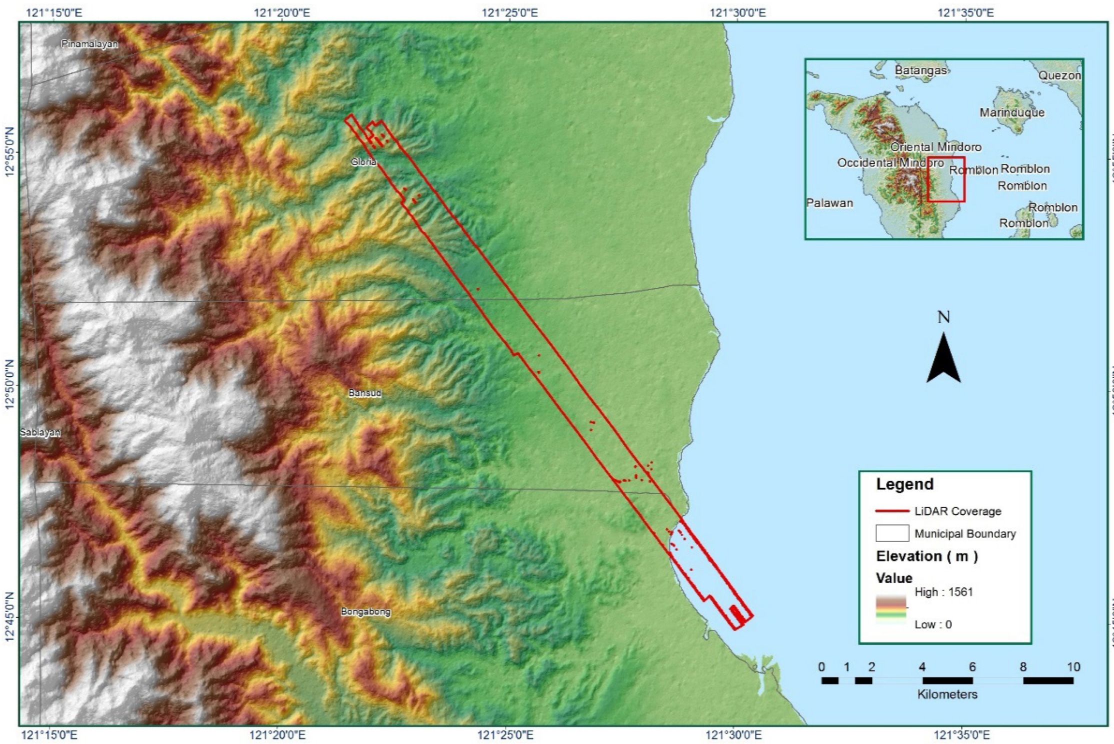


Figure A-8.61. Coverage of LiDAR data

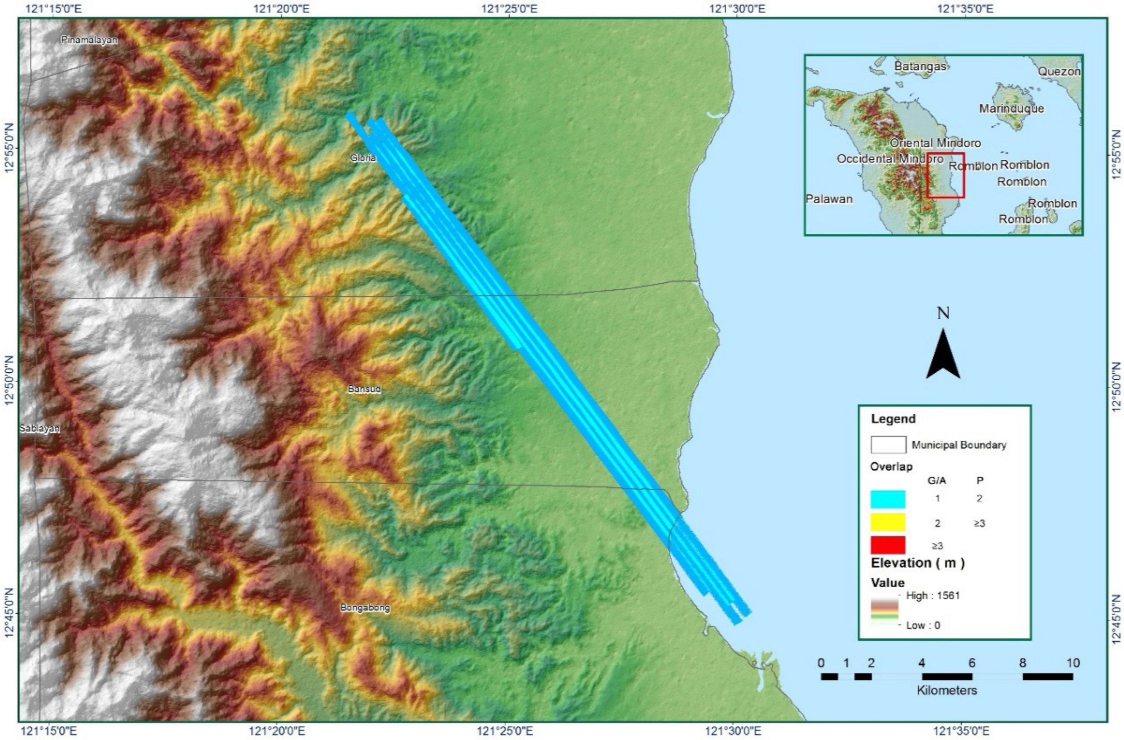


Figure A-8.62. Image of data overlap

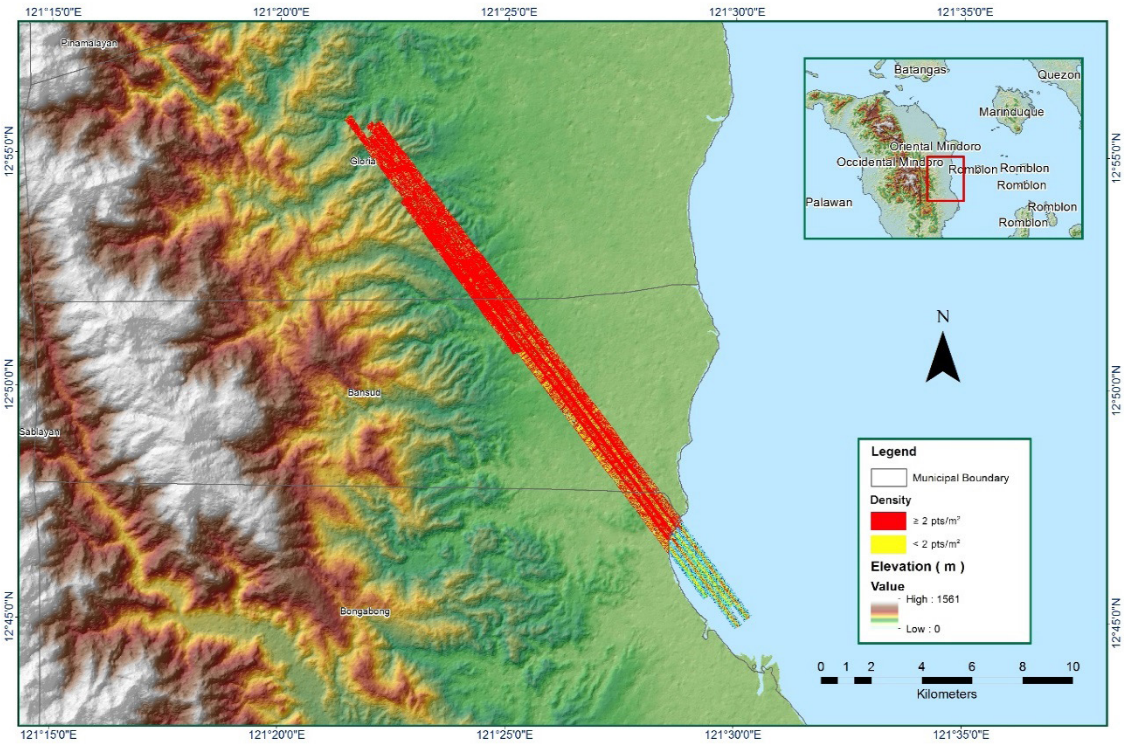


Figure A-8.63. Density map of merged LiDAR data

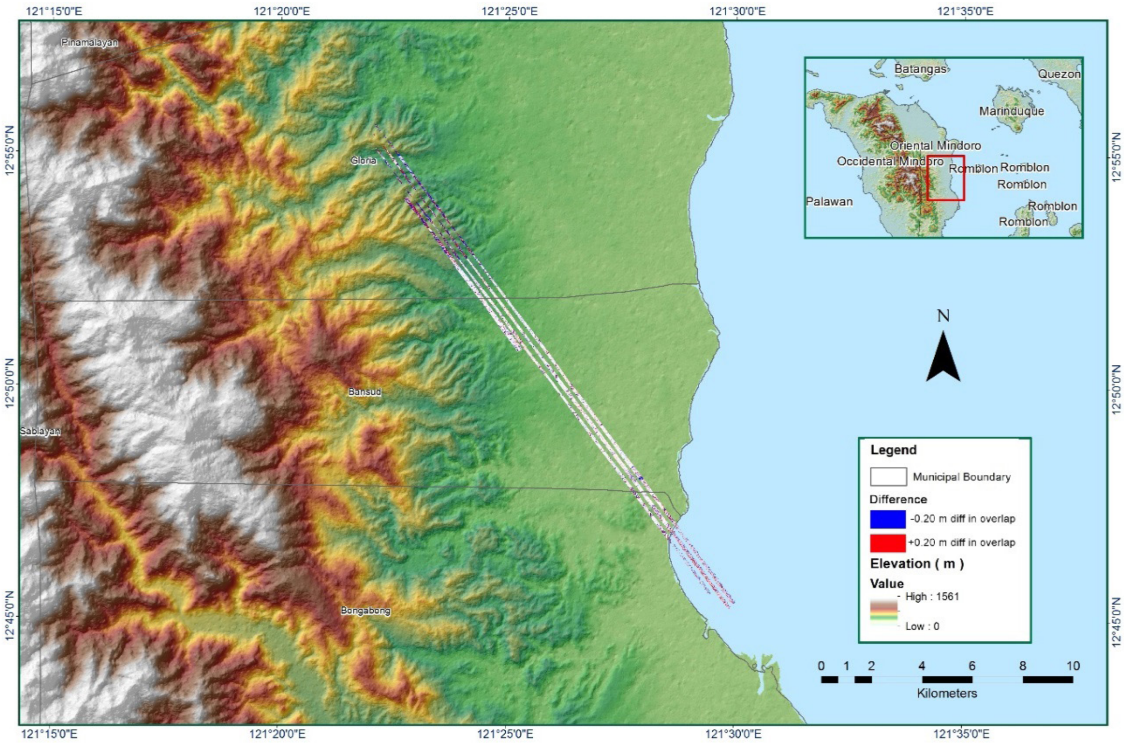


Figure A-8.64. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk28A_additional

Flight Area	Oriental Mindoro Reflights
Mission Name	Blk28A_additional
Inclusive Flights	8306G
Range data size	10.7 GB
Base data size	8.28 MB
POS	220 MB
Image	NA
Transfer date	November 12, 2015
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)	0.92
RMSE for East Position (<4.0 cm)	1.15
RMSE for Down Position (<8.0 cm)	1.93
Boresight correction stdev (<0.001deg)	0.015221
IMU attitude correction stdev (<0.001deg)	0.004899
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	13.66
Ave point cloud density per sq.m. (>2.0)	1.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	14
Maximum Height	83.45
Minimum Height	51.34
Classification (# of points)	
Ground	1,993,511
Low vegetation	1,926,299
Medium vegetation	3,017,784
High vegetation	1,879,976
Building	52,772
Orthophoto	No
Processed by	Engr. Abigail Ching, Engr. Edgardo Gubatanga, Jr., Engr. Melissa Fernandez

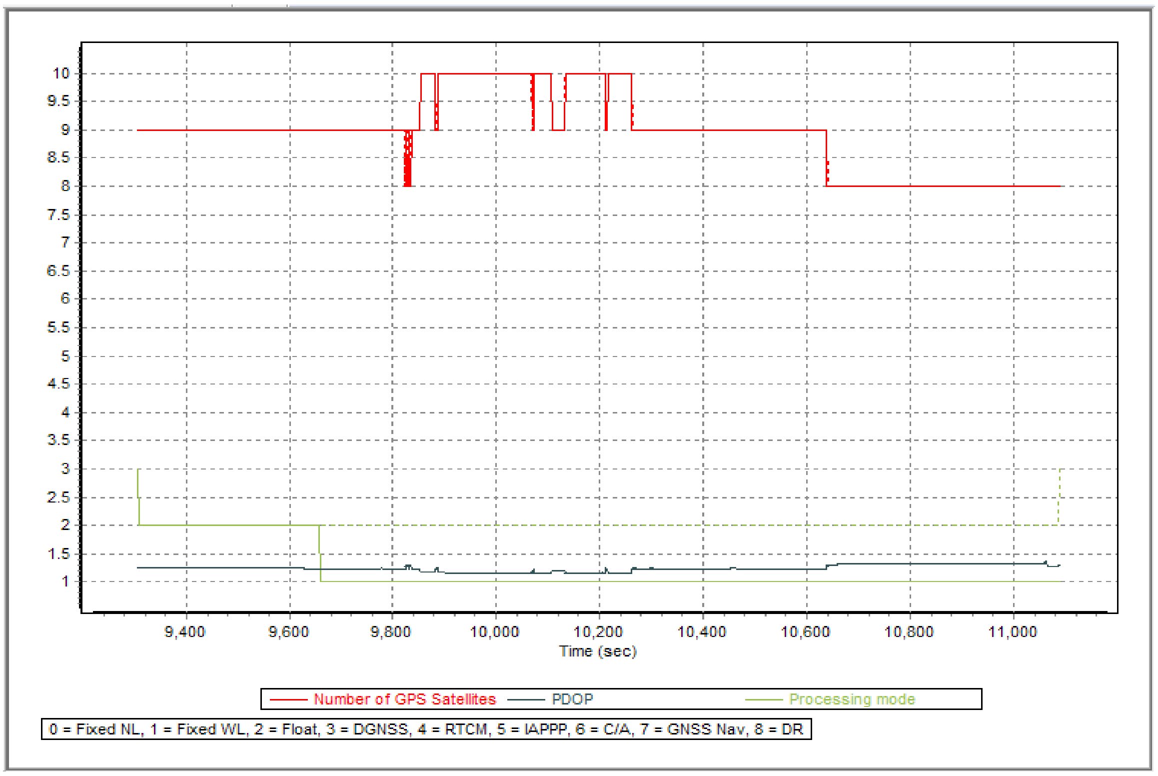


Figure A-8.65. Solution Status

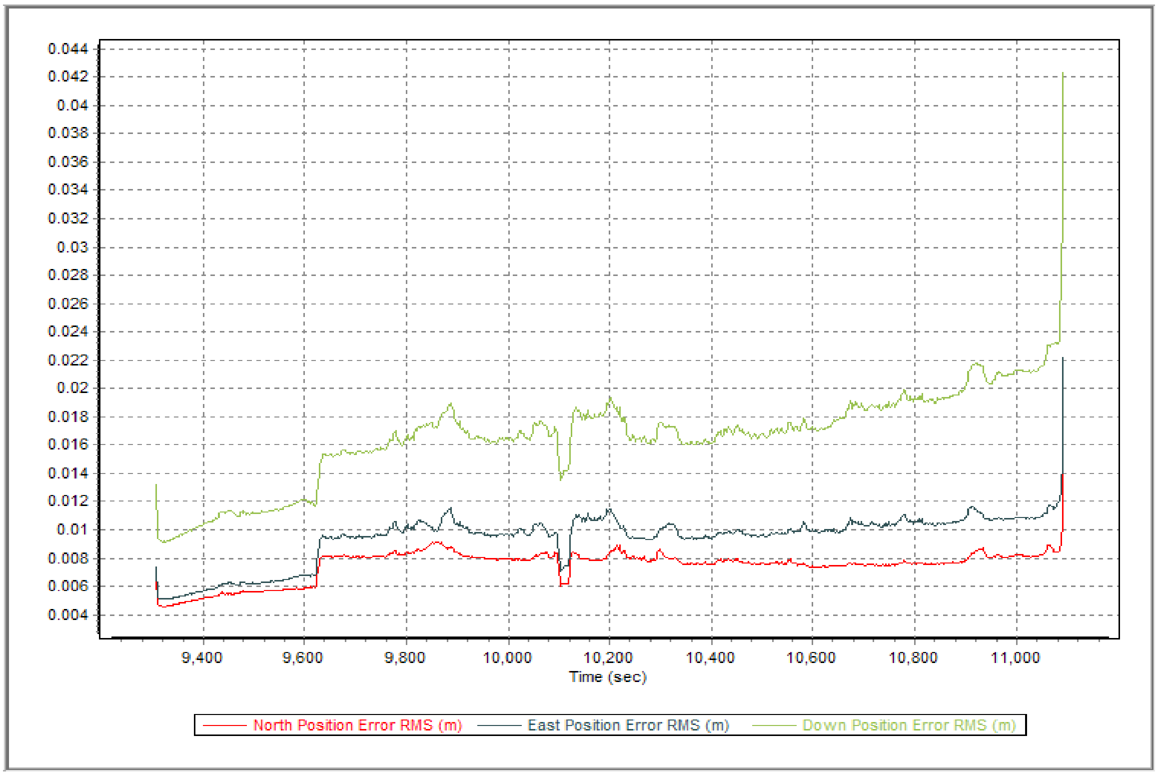


Figure A-8.66. Smoothed Performance Metric Parameters

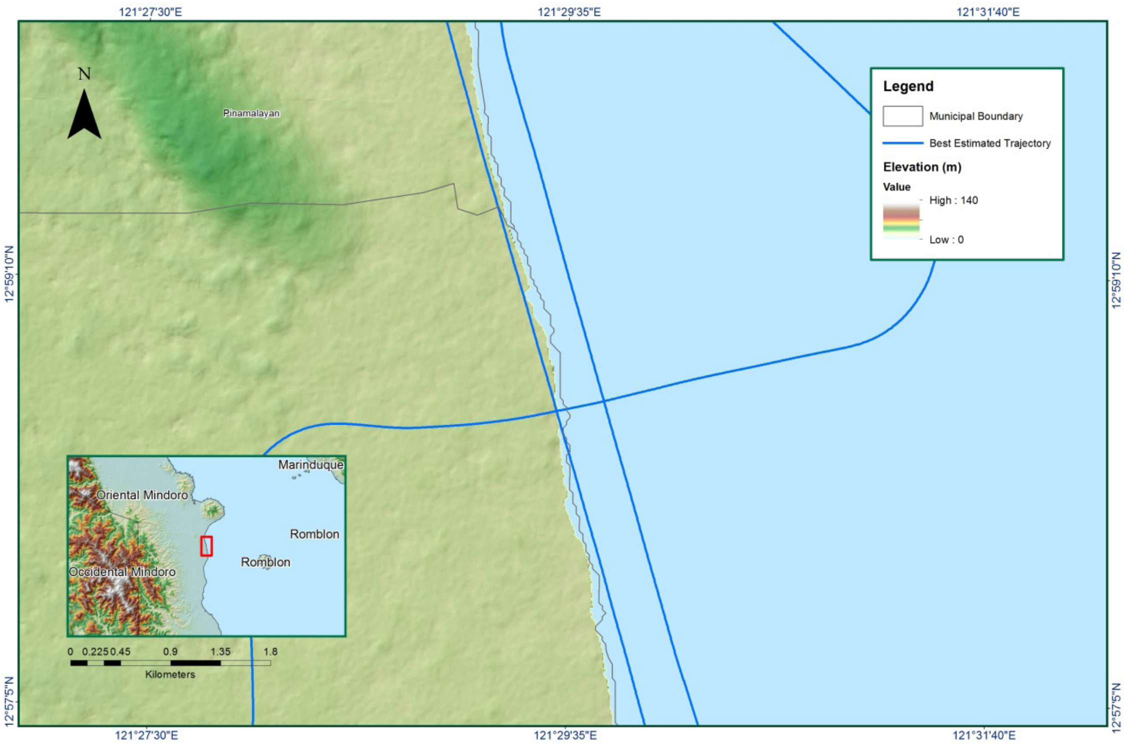


Figure A-8.67. Best Estimate Trajectory

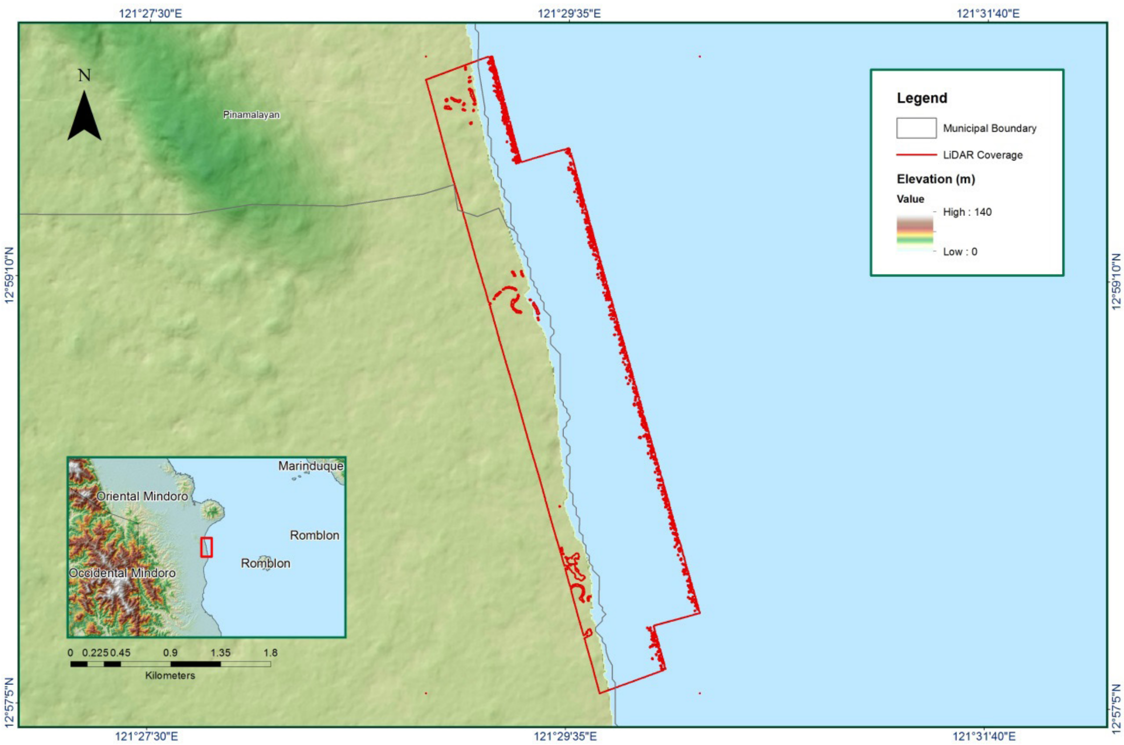


Figure A-8.68. Coverage of LiDAR data

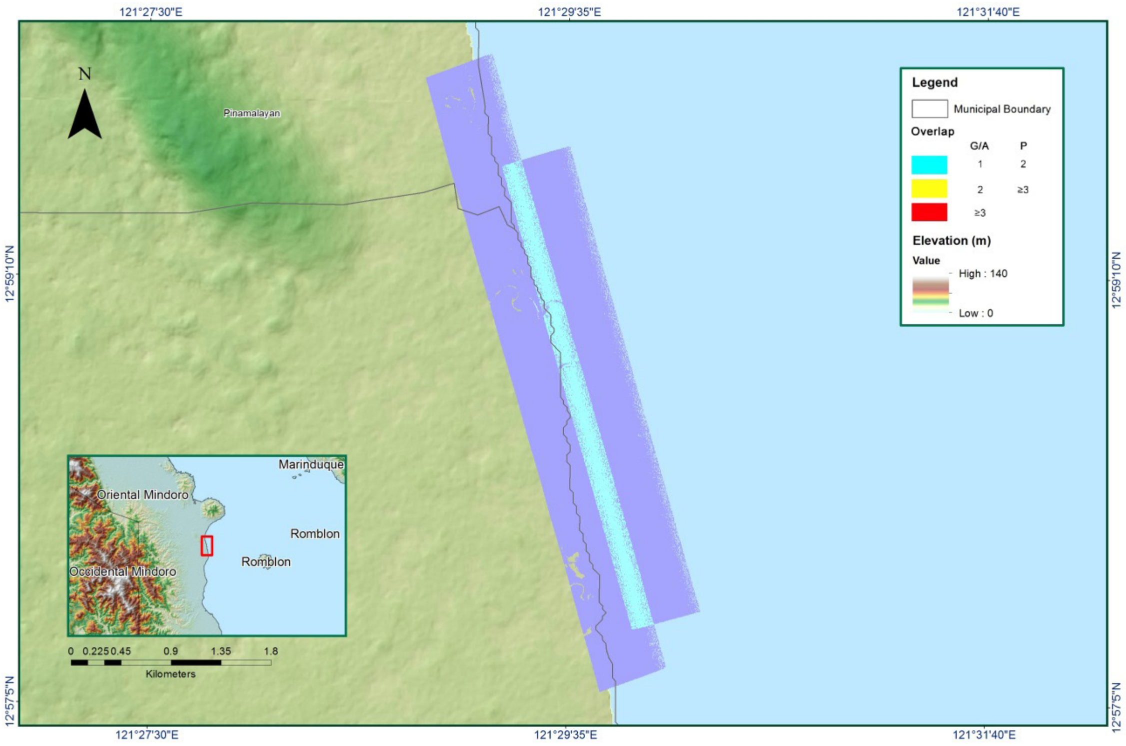


Figure A-8.69. Image of data overlap

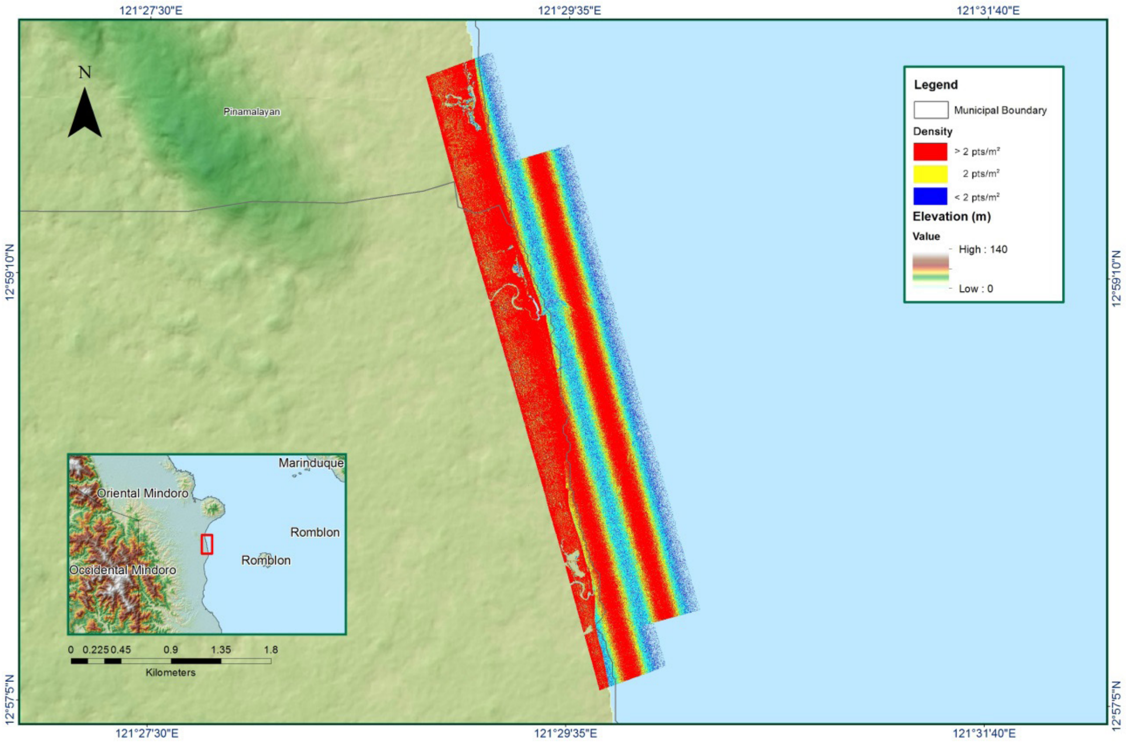


Figure A-8.70. Density map of merged LiDAR data

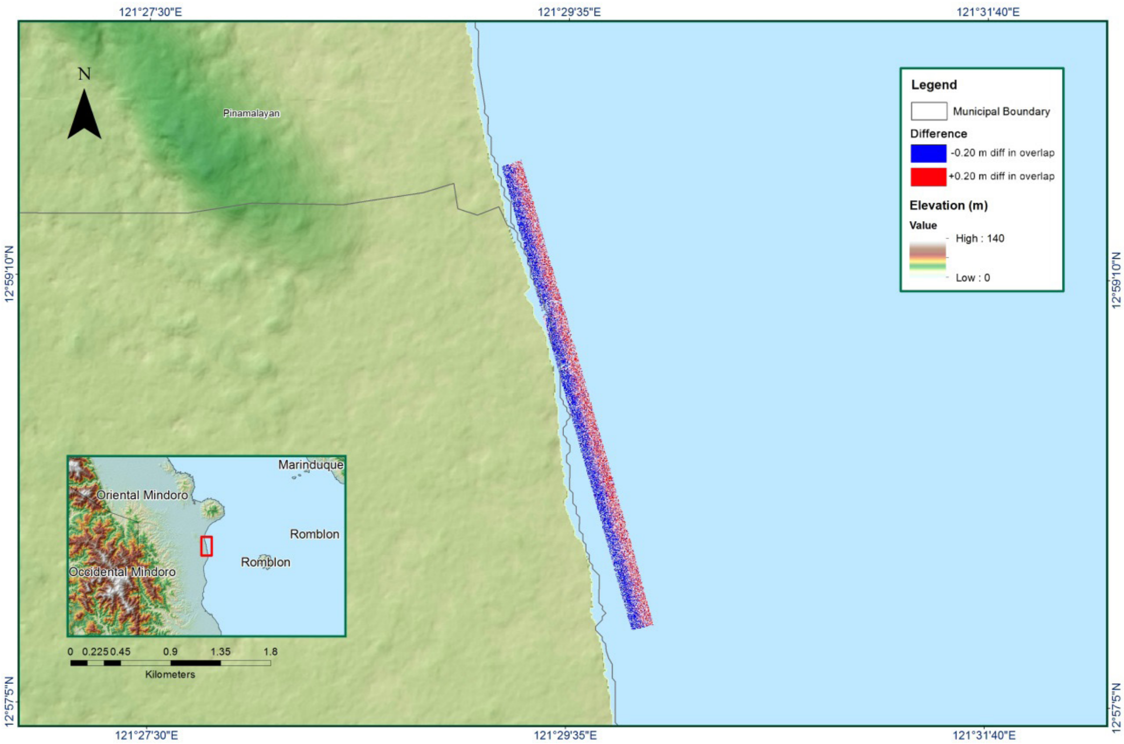


Figure A-8.71. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk28B

Flight Area	Oriental Mindoro Reflights
Mission Name	Blk28B
Inclusive Flights	8300G, 8301G
Range data size	40.9 GB
Base data size	31.2 MB
POS	485 MB
Image	78.1 GB
Transfer date	November 12, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.44
RMSE for East Position (<4.0 cm)	1.48
RMSE for Down Position (<8.0 cm)	4.11
Boresight correction stdev (<0.001deg)	0.003093
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	0.0132
Minimum % overlap (>25)	31.26
Ave point cloud density per sq.m. (>2.0)	3.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	119
Maximum Height	196.11
Minimum Height	51.36
Classification (# of points)	
Ground	38,270,206
Low vegetation	49,857,781
Medium vegetation	86,899,663
High vegetation	86,933,737
Building	1,042,632
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Justine Franciso, Engr. Melissa Fernandez

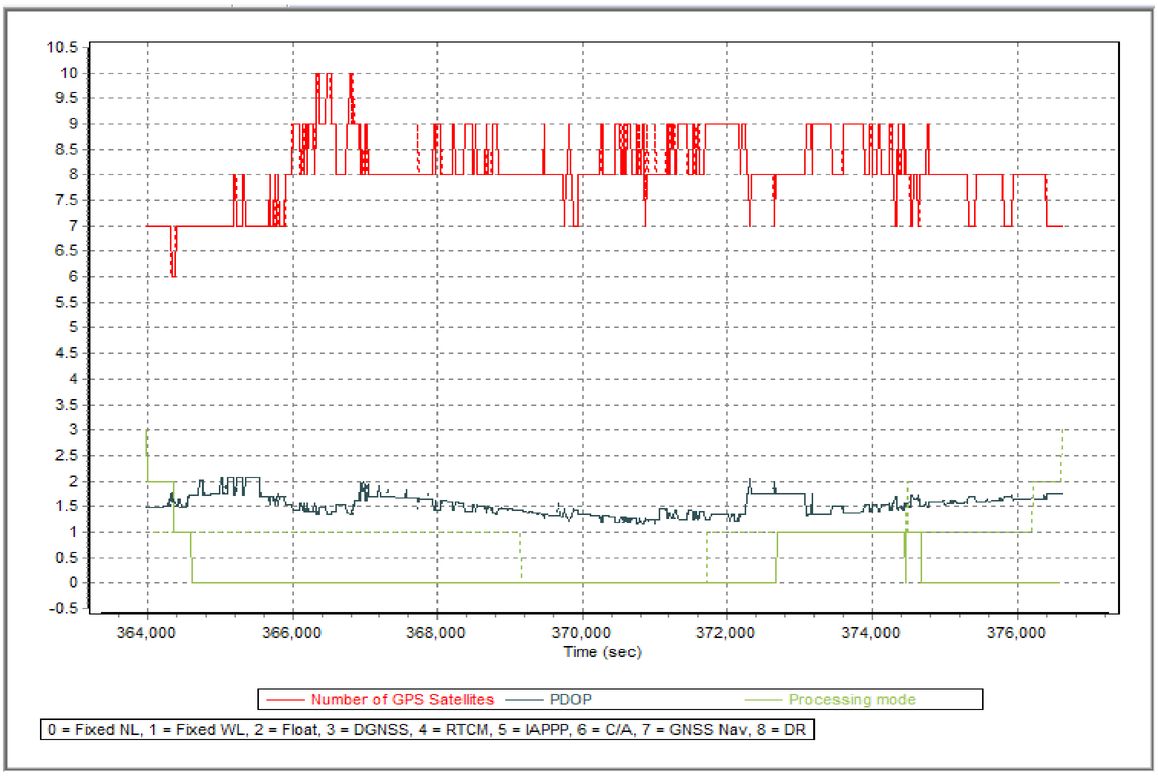


Figure A-8.72. Solution Status

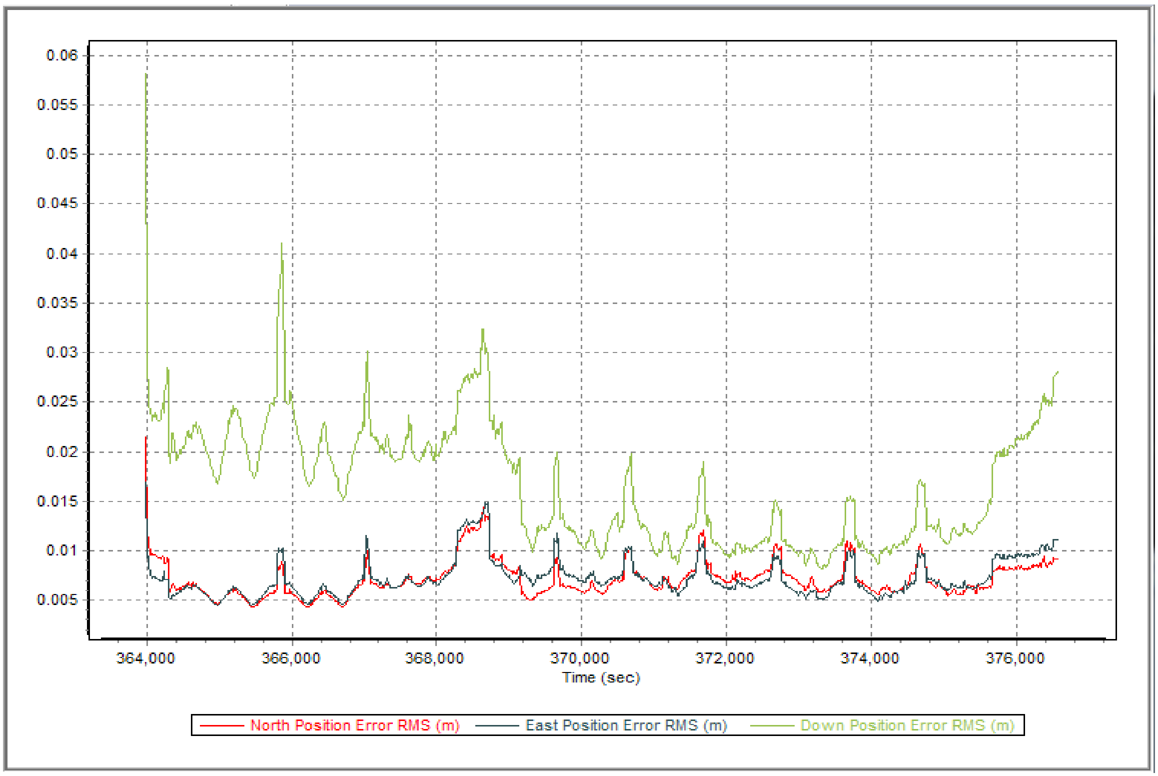


Figure A-8.73. Smoothed Performance Metric Parameters

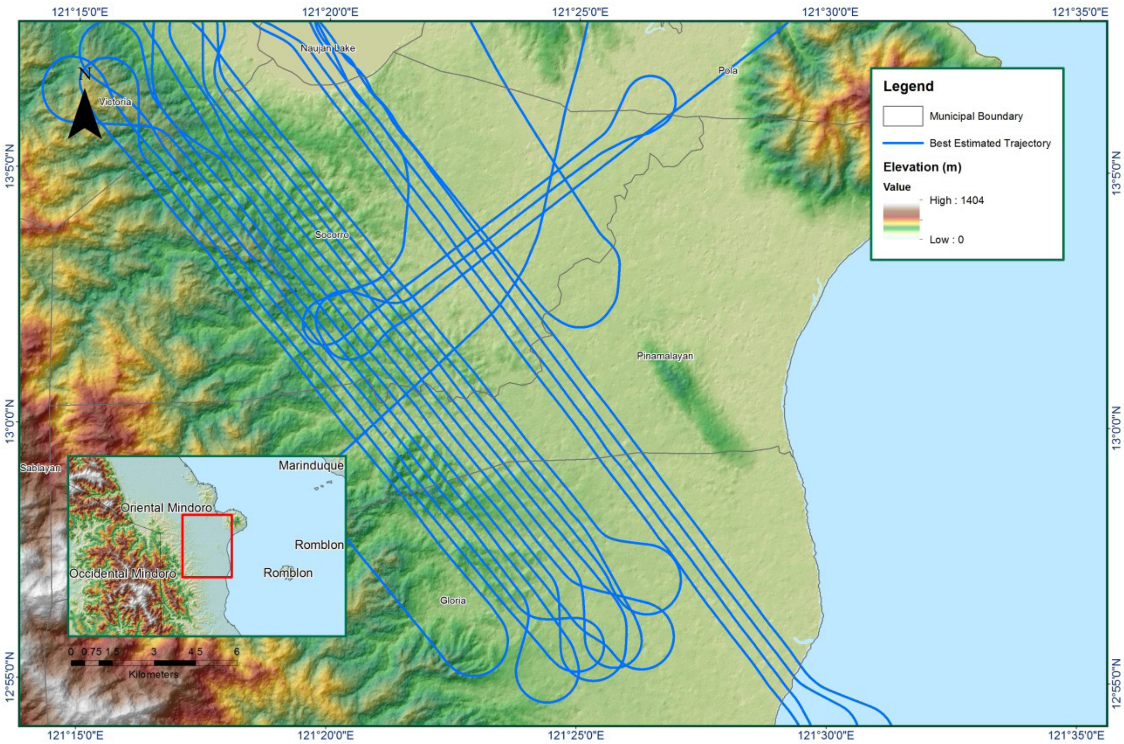


Figure A-8.74. Best Estimate Trajectory

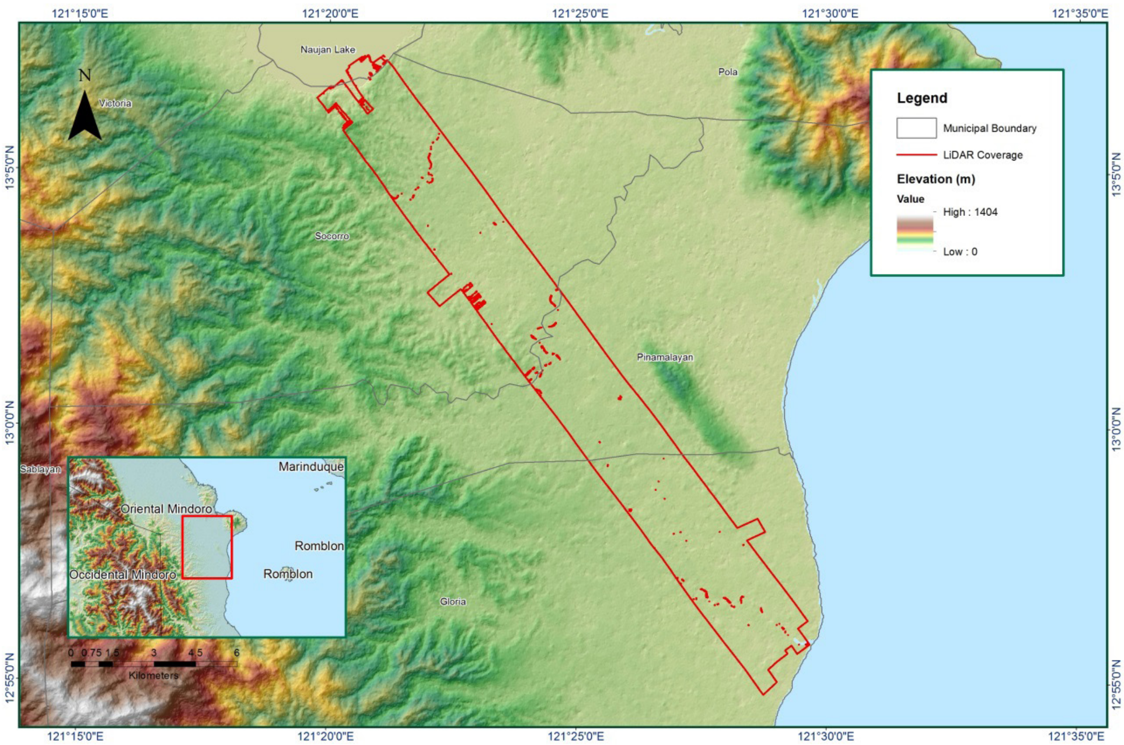


Figure A-8.75. Coverage of LiDAR data

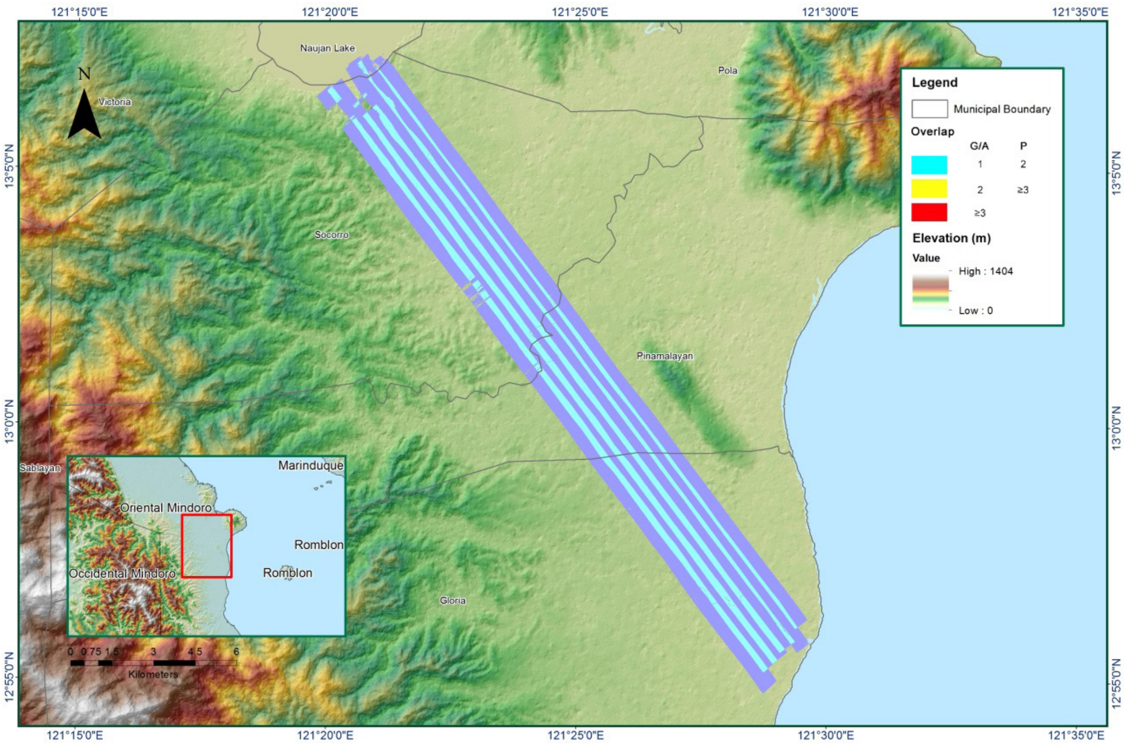


Figure A-8.76. Image of data overlap

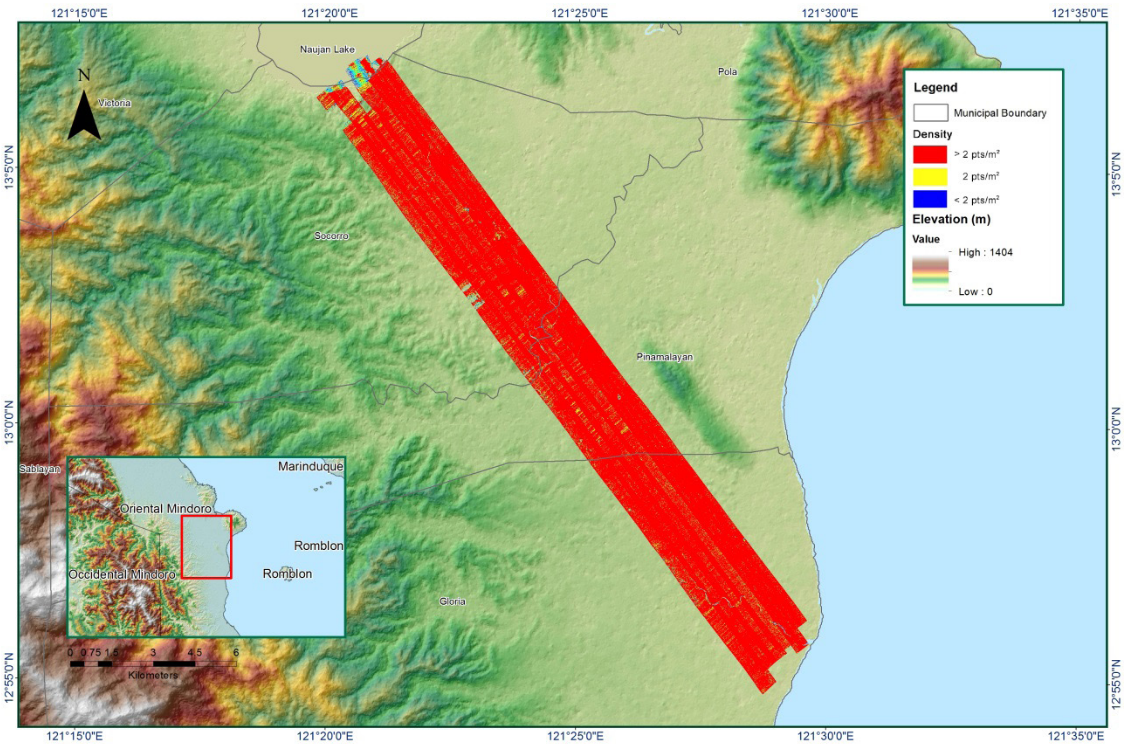


Figure A-8.77. Density map of merged LiDAR data

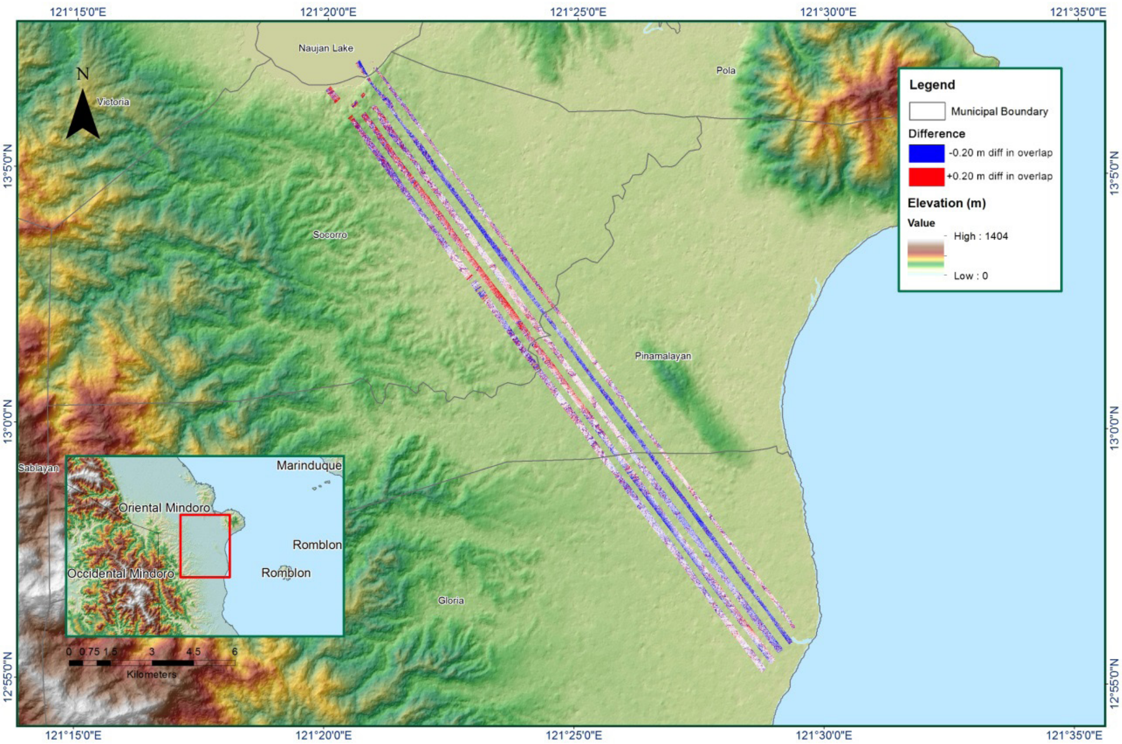


Figure A-8.78. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission Blk28C

Flight Area	Oriental Mindoro Reflights
Mission Name	Blk28C
Inclusive Flights	8302G
Range data size	14.5 GB
Base data size	11.5 MB
POS	228 MB
Image	28.2 GB
Transfer date	November 12, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.58
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.86
Boresight correction stdev (<0.001deg)	0.006431
IMU attitude correction stdev (<0.001deg)	0.044182
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	35.65
Ave point cloud density per sq.m. (>2.0)	3.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	78
Maximum Height	172.45
Minimum Height	51.2
Classification (# of points)	
Ground	23,964,162
Low vegetation	31,143,186
Medium vegetation	61,650,233
High vegetation	57,492,838
Building	320,789
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Alex John Escobido

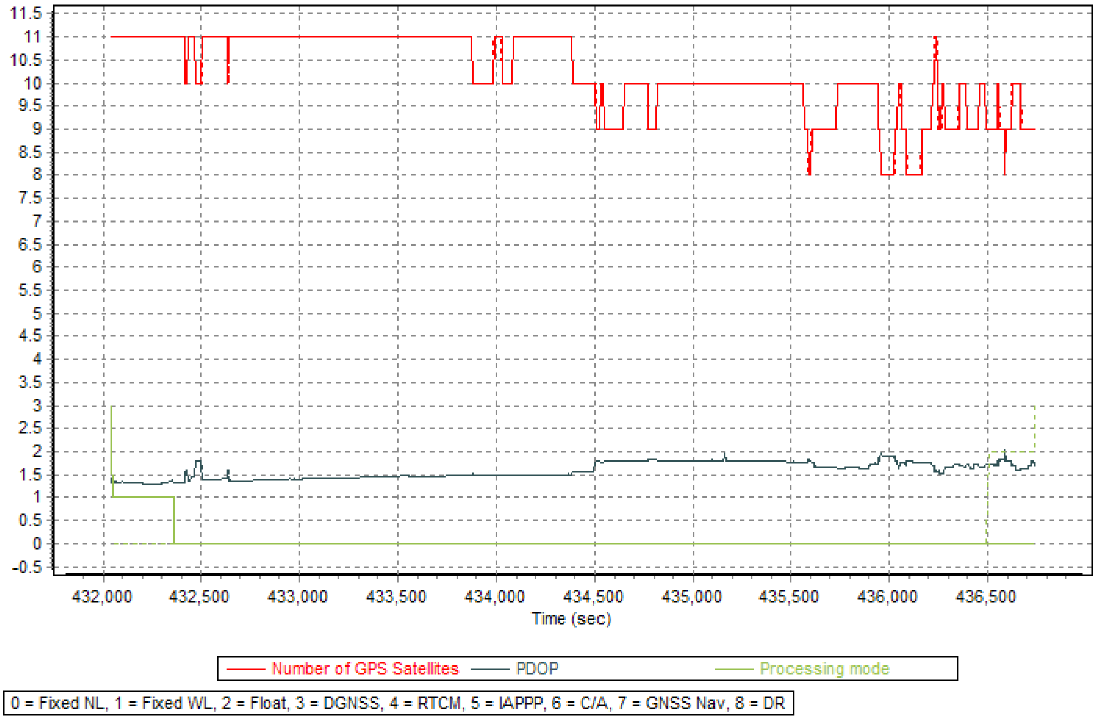


Figure A-8.79. Solution Status

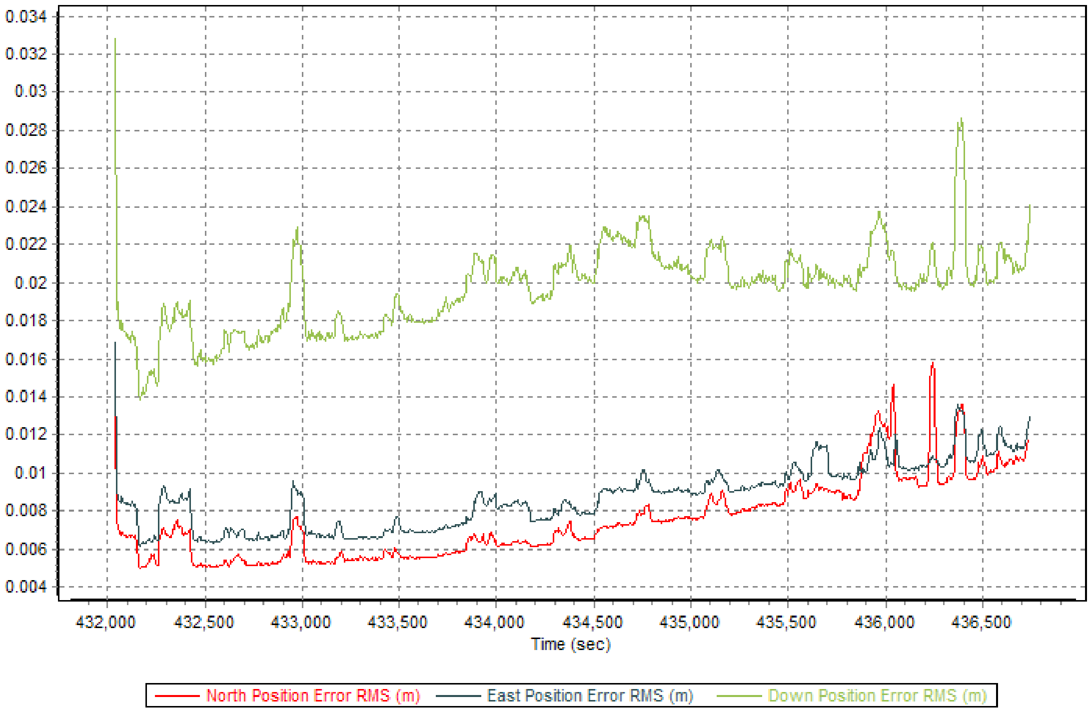


Figure A-8.80. Smoothed Performance Metric Parameters

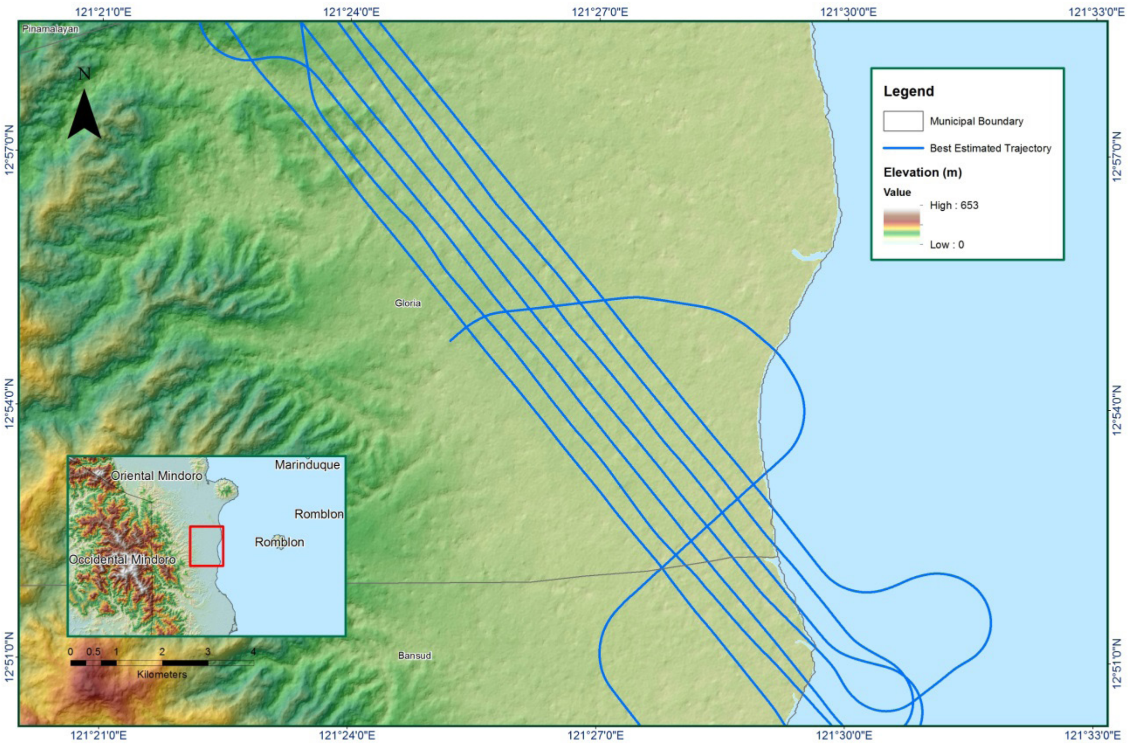


Figure A-8.81. Best Estimate Trajectory

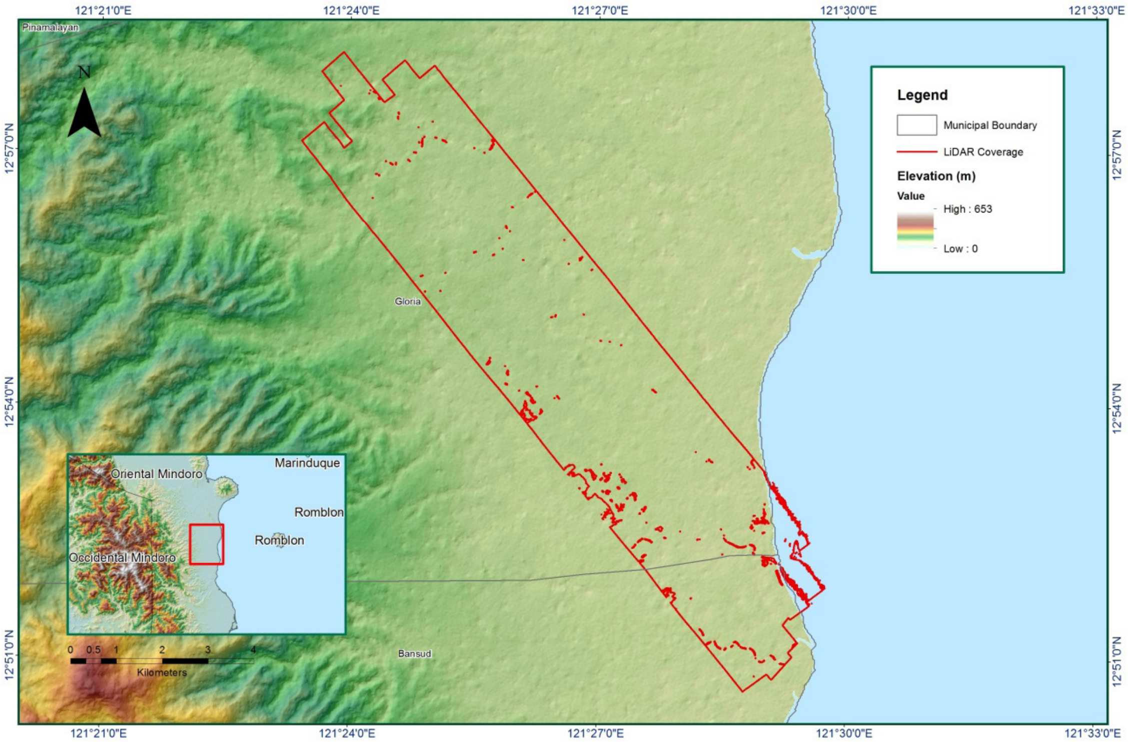


Figure A-8.82. Coverage of LiDAR data

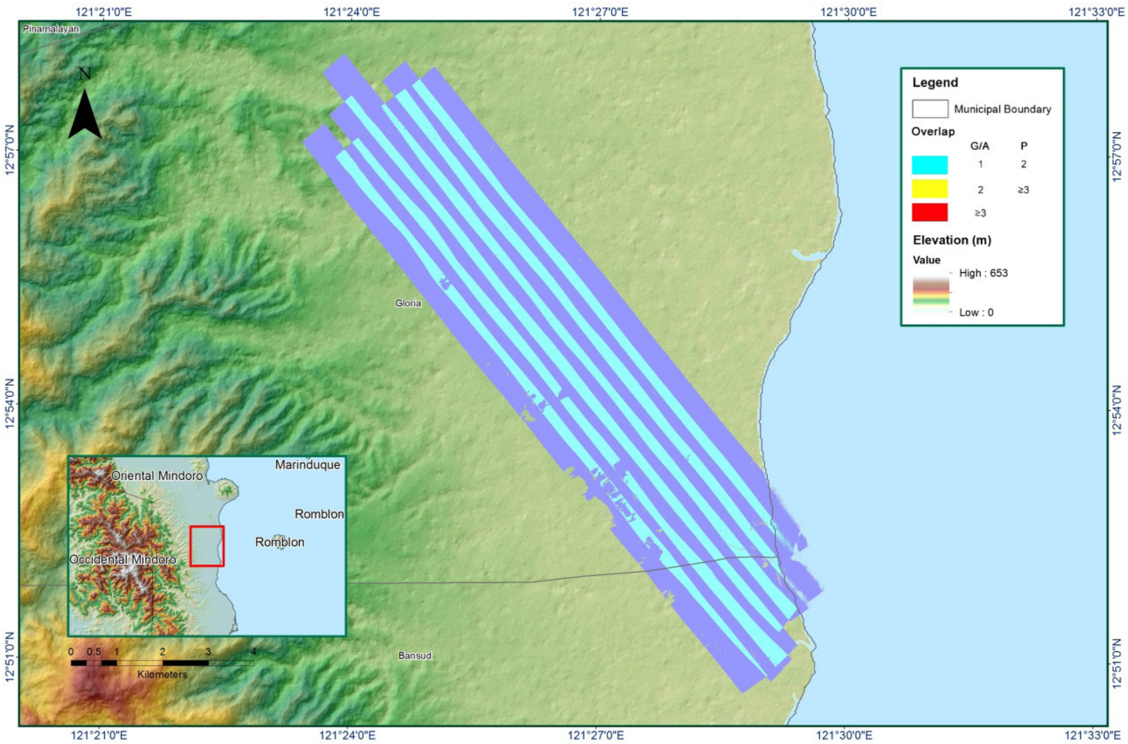


Figure A-8.83. Image of data overlap

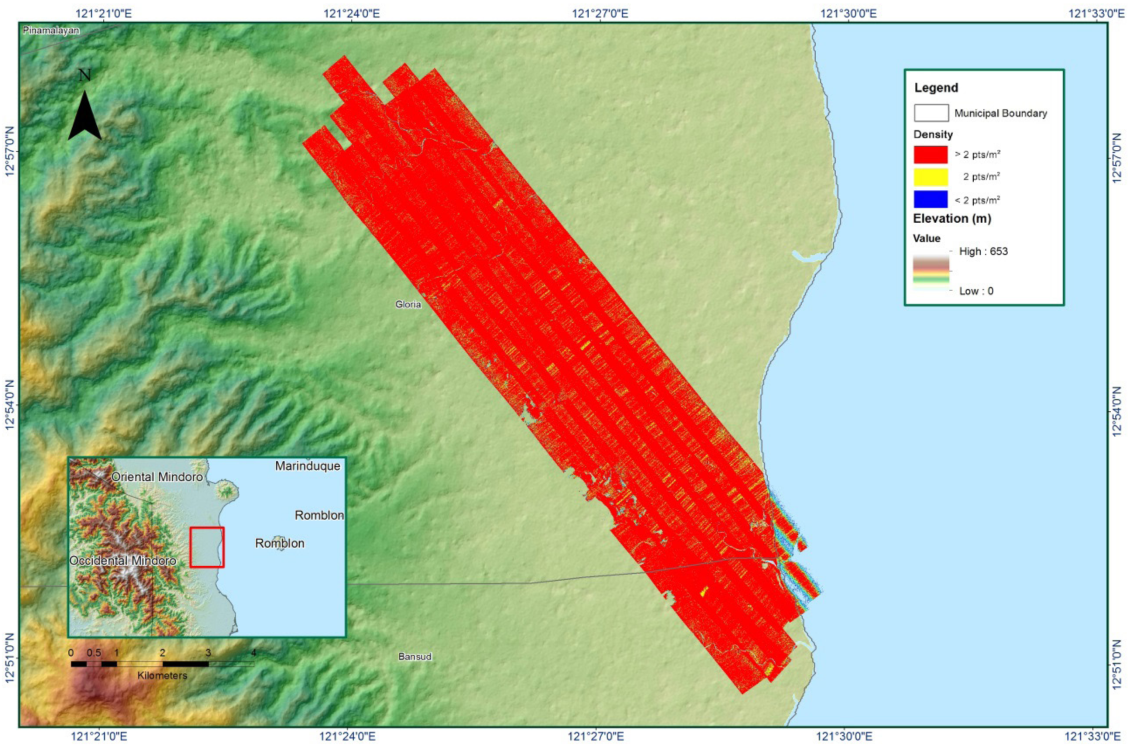


Figure A-8.84. Density map of merged LiDAR data

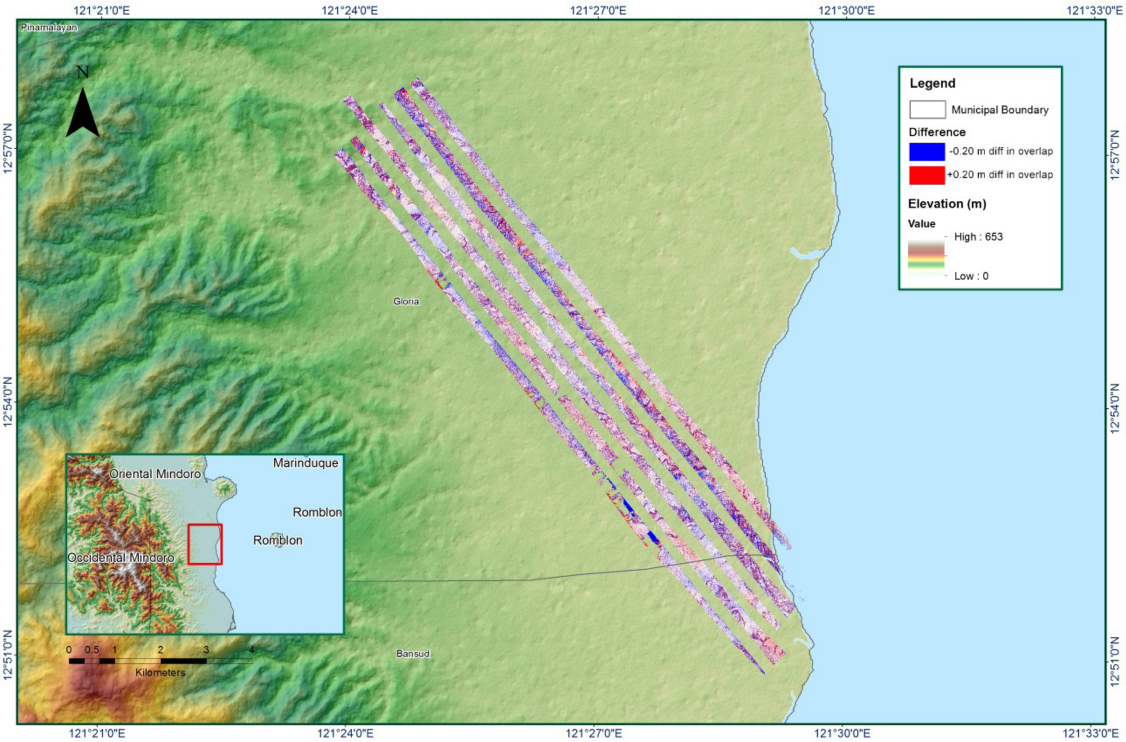


Figure A-8.85. Elevation difference between flight lines

Table A-8.13. Mission Summary Report for Mission Blk28D

Flight Area	Oriental Mindoro Reflights
Mission Name	Blk28D
Inclusive Flights	8301G
Range data size	22.7 GB
Base data size	15.6 MB
POS	249 MB
Image	49.6 GB
Transfer date	November 12, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.44
RMSE for East Position (<4.0 cm)	1.49
RMSE for Down Position (<8.0 cm)	4.11
Boresight correction stdev (<0.001deg)	0.001554
IMU attitude correction stdev (<0.001deg)	0.004825
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	38.80
Ave point cloud density per sq.m. (>2.0)	4.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	147
Maximum Height	385.39
Minimum Height	60.38
Classification (# of points)	
Ground	45,719,328
Low vegetation	35,228,535
Medium vegetation	118,618,077
High vegetation	286,250,507
Building	4,618,960
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Jovelle Anjeanette Canlas, Alex John Escobido

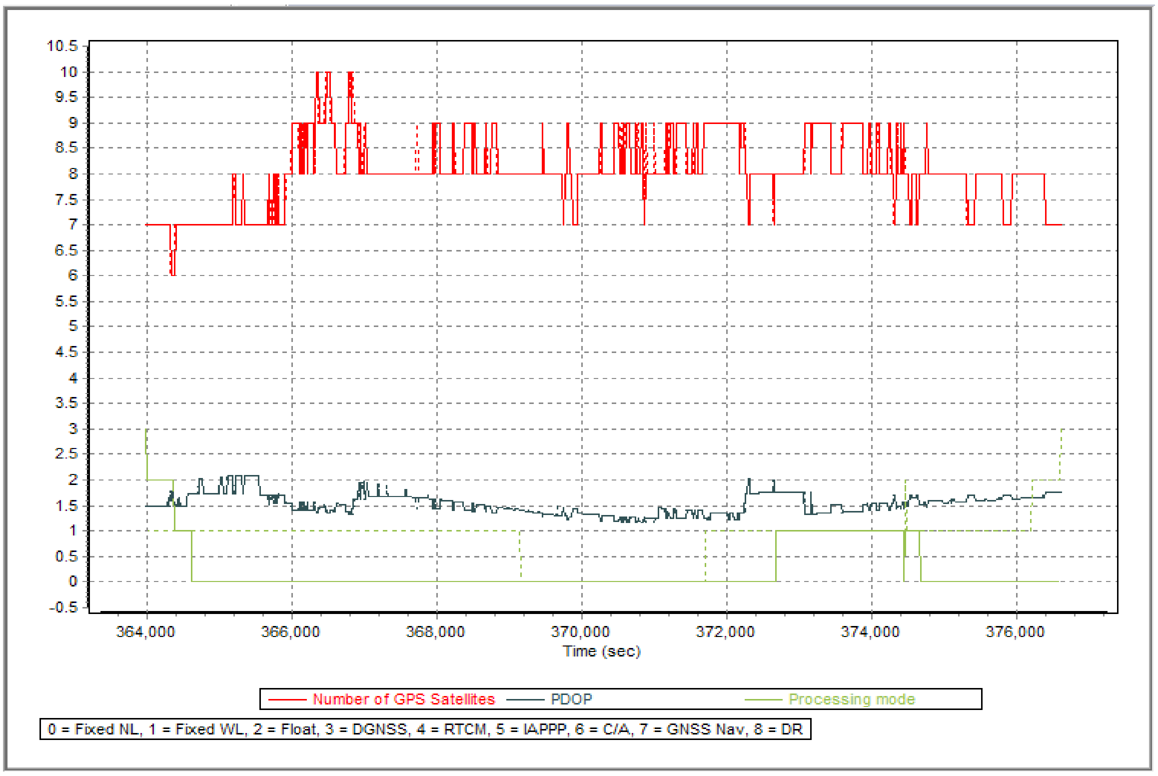


Figure A-8.86. Solution Status

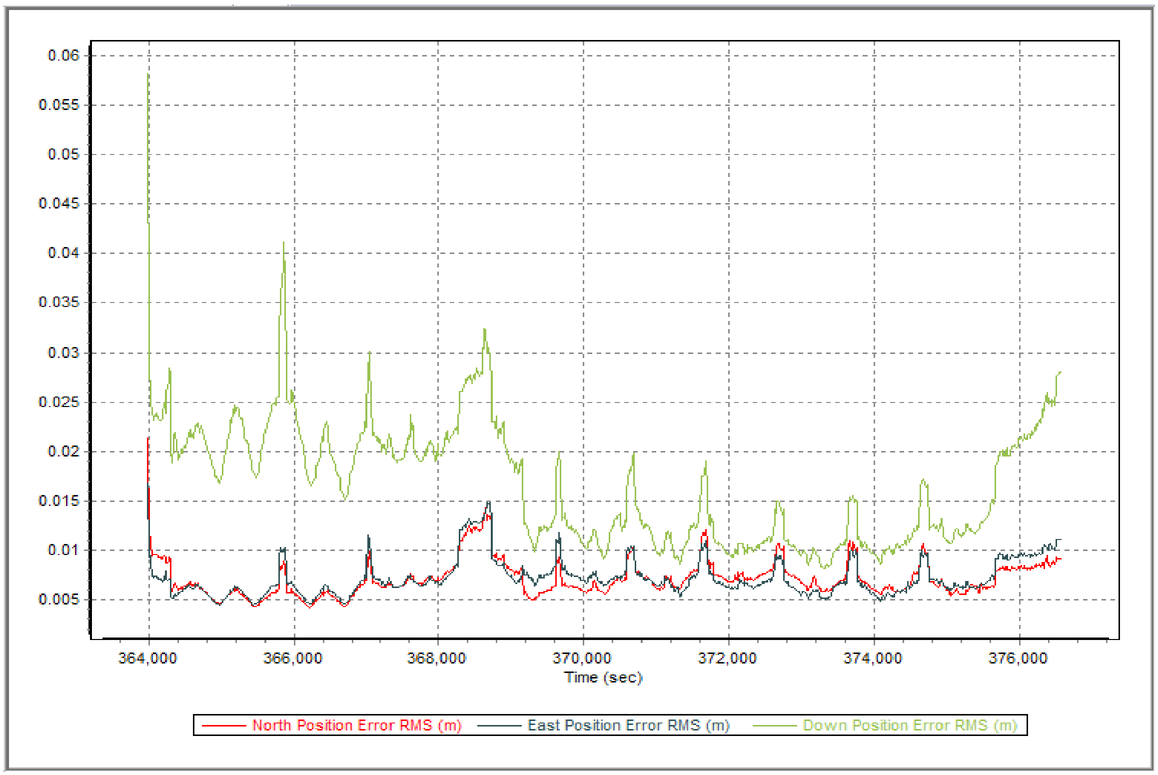


Figure A-8.87. Smoothed Performance Metric Parameters

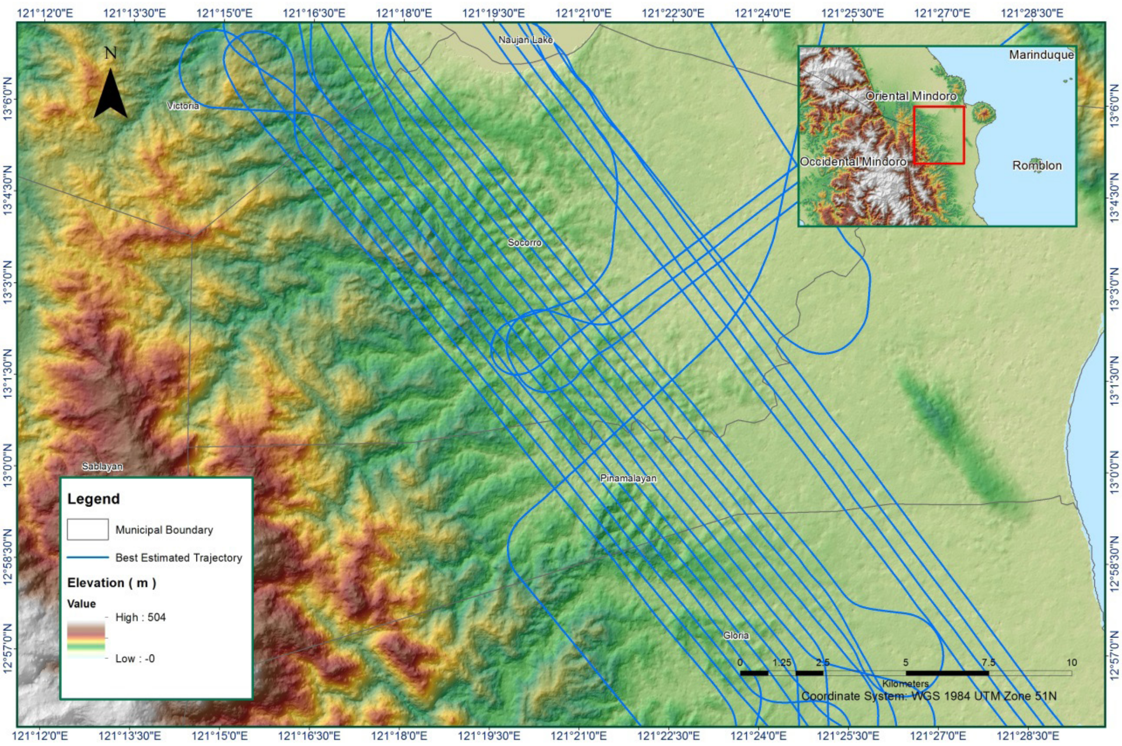


Figure A-8.88. Best Estimated Trajectory

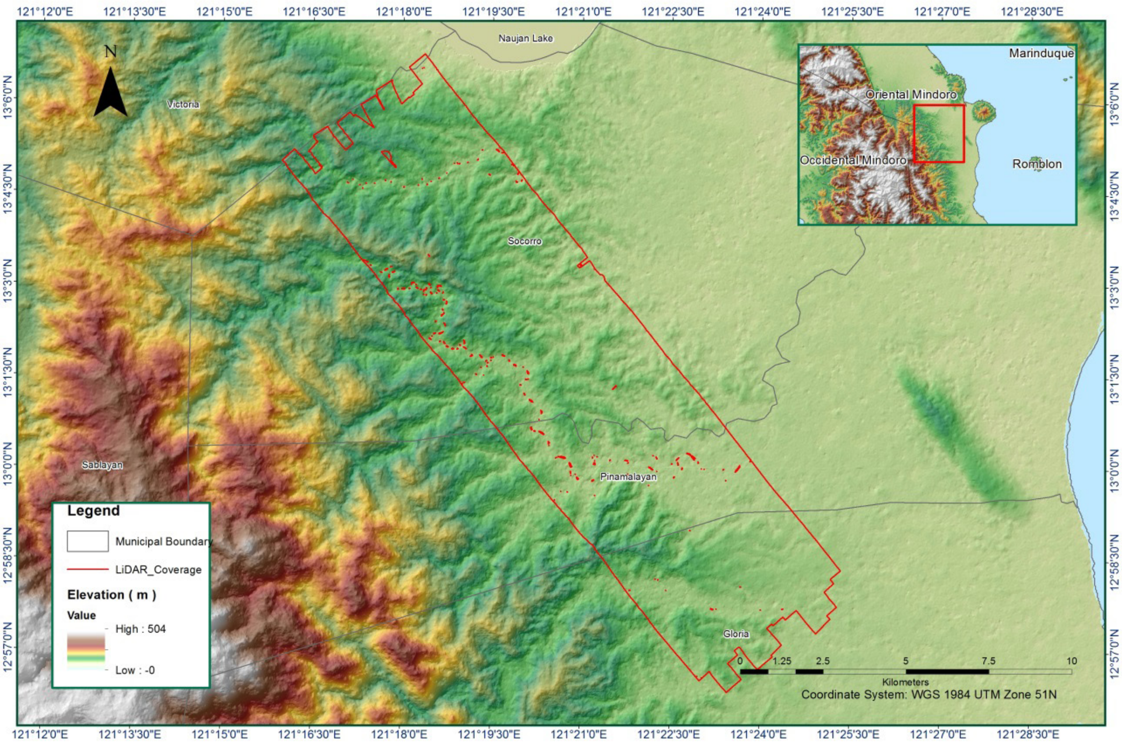


Figure A-8.89. Coverage of LiDAR data

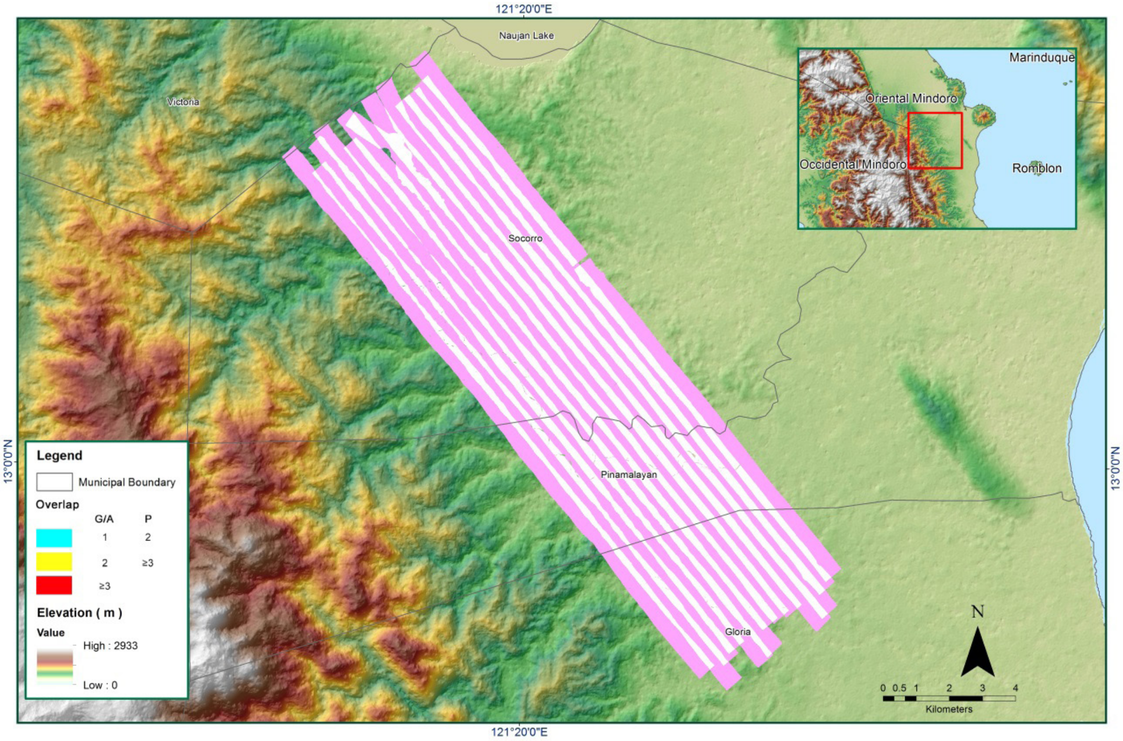


Figure A-8.90. Image of data overlap

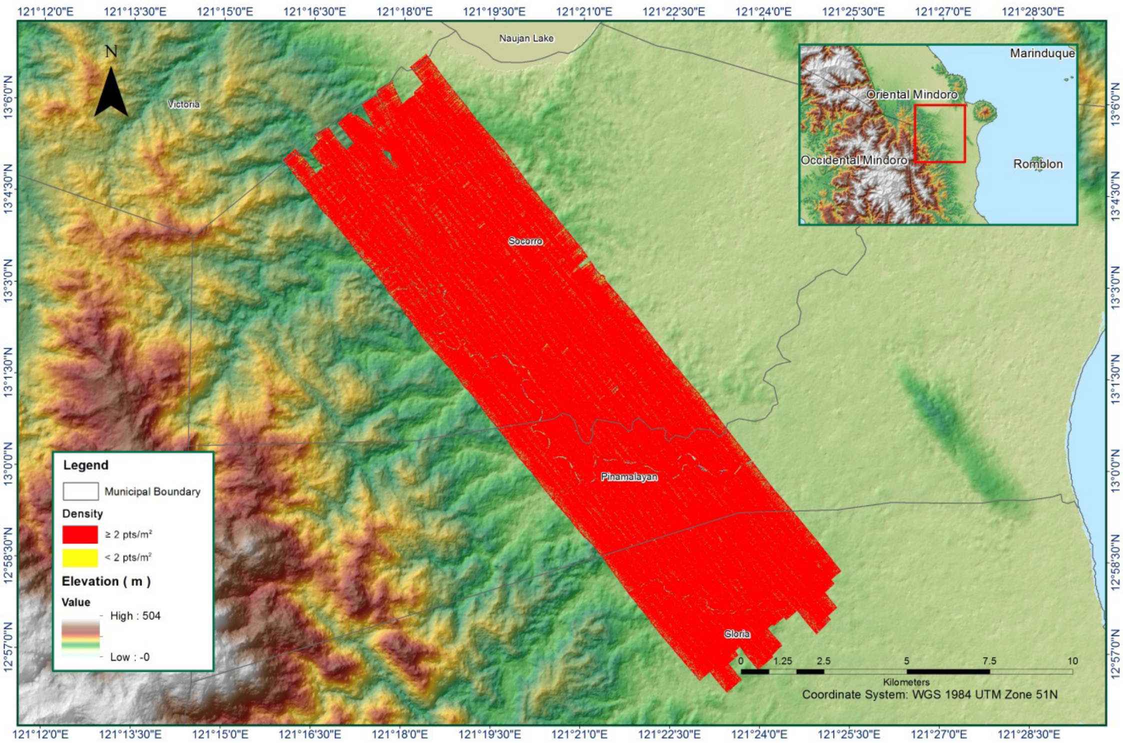


Figure A-8.91. Density map of merged LiDAR data

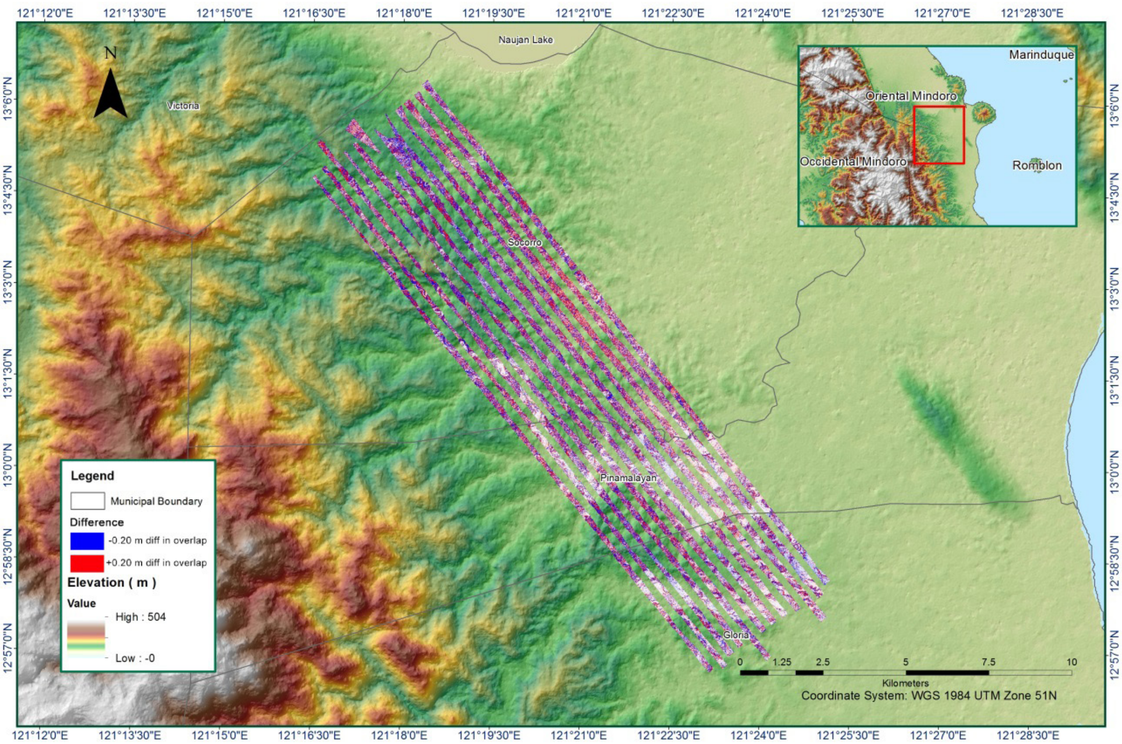


Figure A-8.92. Elevation difference between flight lines

Annex 9. Agsalin Model Basin Parameters

Table A-9.1. Agsalin 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 Con-stant	Ratio to Peak
W480	35.945	12.286	0.0	0.6087	52.774	0.32406	0.57648	0.125
W490	3.8331	10.807	0.0	0.81832	31.245	0.25719	0.18148	0.125
W500	2.5812	12.985	0.0	1.2616	74.875	0.13379	0.26991	0.125
W510	1.0402	17.271	0.0	0.14503	2.4356	0.0228900	0.26678	0.0544444
W520	2.0715	14.146	0.0	0.18803	3.493	0.0151544	0.39216	0.0533556
W530	0.70471	18.608	0.0	0.51642	1.3156	0.0385634	0.12346	0.0362963
W540	2.4453	13.276	0.0	0.27519	23.28	0.0662696	0.26678	0.125
W550	3.9286	10.667	0.0	0.83694	14.514	0.0849254	0.18148	0.125
W560	2.3515	13.484	0.0	0.4727	41.643	0.0680690	0.26678	0.125
W570	2.1593	13.932	0.0	0.18017	37.334	0.19480	0.57648	0.125
W580	0.9542	17.595	0.0	0.33101	31.75	0.0785904	0.57648	0.125
W590	3.9286	10.667	0.0	0.75472	1.8193	0.0386608	0.27222	0.125
W600	3.9286	10.667	0.0	0.42976	16.586	0.0323334	0.18519	0.125
W620	3.9286	10.667	0.0	0.14515	14.905	0.0296028	0.18519	0.125
W630	3.9286	10.667	0.0	0.16496	2.4415	0.0183868	0.27222	0.125
W640	2.6259	12.892	0.0	0.31497	1.2313	0.0270917	0.18419	0.0362963
W650	3.9286	10.667	0.0	0.31777	29.054	0.14019	0.18148	0.125
W660	3.3934	11.483	0.0	0.41966	7.0195	0.0130688	0.12346	0.125
W670	1.8958	14.596	0.0	0.19617	1.2663	0.0187837	0.18424	0.0246914
W680	3.9286	10.667	0.0	0.44758	18.088	0.0330337	0.245	0.125
W690	2.1195	14.028	0.0	0.32134	11.166	0.0737972	0.31306	0.0246914
W700	3.5889	11.172	0.0	0.29803	18.921	0.0680480	0.40017	0.125
W710	3.9286	10.667	0.0	0.46846	14.594	0.0484209	0.27222	0.125

W720	3.666	11.054	0.0	0.26454	41.317	0.0682903	0.40017	0.125
W730	3.9286	10.667	0.0	0.78543	15.003	0.0712479	0.27222	0.125
W740	3.2289	11.759	0.0	0.35406	13.962	0.0422519	0.27778	0.125
W750	2.4222	13.326	0.0	0.34237	14.101	0.0995265	0.27778	0.125
W760	3.9286	10.667	0.0	0.64378	12.991	0.11601	0.26678	0.125
W770	2.4193	13.333	0.0	0.56044	24.876	0.0982690	0.27222	0.125
W780	3.9286	10.667	0.0	0.82458	15.127	0.0899820	0.40285	0.125
W790	3.2226	11.770	0.0	0.18321	2.6957	0.0653613	0.58461	0.125
W800	3.9286	10.667	0.0	0.26944	26.352	0.15002	0.46609	0.125
W810	3.3294	11.589	0.0	0.16926	2.958	0.0744727	0.27078	0.0362963
W820	3.9286	10.667	0.0	0.30073	24.345	0.15174	0.27222	0.125
W830	3.7591	10.915	0.0	0.33212	17.293	0.0570647	0.18419	0.125
W840	3.9286	10.667	0.0	0.40659	21.492	0.10090	0.40017	0.125
W850	3.8226	10.822	0.0	0.79466	23.396	0.10271	0.3675	0.125
W860	3.9286	10.667	0.0	0.0802367	14.174	0.14610	0.27222	0.125
W870	2.525	13.104	0.0	0.25364	0.88149	.000509472	0.12346	0.0246914
W880	3.3151	11.613	0.0	0.27714	21.937	0.10617	0.27222	0.125
W890	3.3277	11.592	0.0	1.693	15.563	0.0676396	0.18519	0.125
W900	3.3354	11.579	0.0	0.1379	9.0404	0.0483541	0.3675	0.125
W910	2.4835	13.193	0.0	0.27829	5.2363	0.0216745	0.40017	0.0784327
W920	2.4191	13.333	0.0	0.14819	0.96259	0.0065506	0.39816	0.0246914
W930	2.4143	13.333	0.0	0.14762	8.653	0.0395633	0.40833	0.125
W940	2.4143	13.333	0.0	0.13384	5.7728	0.0449328	0.41451	0.125
W960	1.2775	16.436	0.0	0.85327	5.26575	0.0469001	0.625	0.125
W970	0.69746	18.640	0.0	0.16688	0.60019	0.0332054	0.18148	0.0784327

Annex 10. Agsalin Model Reach Parameters

Table A-10.1. Agsalin 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)
R10	Automatic Fixed Interval	2166.8	0.00041	0.0042684	Trapezoid	90	1
R110	Automatic Fixed Interval	2553.1	0.004974	0.0064404	Trapezoid	90	1
R120	Automatic Fixed Interval	2965.3	0.002982	0.0094119	Trapezoid	90	1
R130	Automatic Fixed Interval	13416	0.007528	0.0042848	Trapezoid	90	1
R140	Automatic Fixed Interval	1072.3	0.006692	0.0043283	Trapezoid	90	1
R150	Automatic Fixed Interval	2539.1	0.002711	0.0064335	Trapezoid	90	1
R170	Automatic Fixed Interval	1229.4	0.035043	0.009604	Trapezoid	90	1
R180	Automatic Fixed Interval	1163.3	0.042704	0.0095593	Trapezoid	90	1
R210	Automatic Fixed Interval	1487.2	0.010127	0.01	Trapezoid	90	1
R230	Automatic Fixed Interval	2841.4	0.034468	0.0064327	Trapezoid	90	1
R250	Automatic Fixed Interval	1700.5	0.001995	0.0043694	Trapezoid	90	1
R260	Automatic Fixed Interval	1182.3	0.035607	0.006	Trapezoid	90	1
R30	Automatic Fixed Interval	2690.1	0.0671	0.0062746	Trapezoid	90	1
R310	Automatic Fixed Interval	4696.1	0.007546	0.0042474	Trapezoid	90	1
R330	Automatic Fixed Interval	9045.2	0.005563	0.025875	Trapezoid	90	1
R340	Automatic Fixed Interval	2824.9	0.025668	0.0097456	Trapezoid	90	1
R350	Automatic Fixed Interval	7155.5	0.013654	0.015701	Trapezoid	90	1
R380	Automatic Fixed Interval	2342.5	0.01369	0.0029037	Trapezoid	90	1
R390	Automatic Fixed Interval	197.28	0.063866	0.0097448	Trapezoid	90	1
R40	Automatic Fixed Interval	2425.2	0.051029	0.0041831	Trapezoid	90	1
R420	Automatic Fixed Interval	1129.4	0.074915	0.008513	Trapezoid	90	1
R440	Automatic Fixed Interval	616.98	0.19554	0.0075276	Trapezoid	90	1
R60	Automatic Fixed Interval	2331.7	0.11535	0.0042684	Trapezoid	90	1
R990	Automatic Fixed Interval	2879.8	0.002605	0.0064356	Trapezoid	90	1

Annex 11. Agsalin Field Validation

Table A-11.1. Agsalin Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	12.91866600000	121.43609000000	0.79	0.45	-0.34	Nona	December 2015	25-Year
2	12.91922700000	121.43290000000	0.05	0	-0.05			25-Year
3	12.91946000000	121.43489000000	0.46	0	-0.46			25-Year
4	12.91972500000	121.43446000000	0.12	0.17	0.05	Nona	December 2015	25-Year
5	12.91972500000	121.43446000000	0.12	0.44	0.32	Nona	December 2015	25-Year
6	12.91972500000	121.43446000000	0.12	0.17	0.05	Nona	December 2015	25-Year
7	12.91980400000	121.43440000000	0.09	0.23	0.14	Nona	December 2015	25-Year
8	12.92006500000	121.43257000000	0.6	0.75	0.15	Nona	December 2015	25-Year
9	12.92013900000	121.43272000000	0.47	0	-0.47			25-Year
10	12.92030400000	121.43075000000	0.21	0.1	-0.11	Nona	December 2015	25-Year
11	12.92028800000	121.42409000000	0.03	0	-0.03			25-Year
12	12.92040200000	121.43409000000	0.06	0	-0.06			25-Year
13	12.92047200000	121.42541000000	0.03	0	-0.03			25-Year
14	12.92078900000	121.43553000000	0.06	0.27	0.21	Nona	December 2015	25-Year
15	12.92084200000	121.42986000000	0.08	0.17	0.09	Nona	December 2015	25-Year
16	12.92163700000	121.43563000000	0.06	0	-0.06			25-Year
17	12.92273600000	121.43788000000	0.06	0	-0.06			25-Year
18	12.92320900000	121.43965000000	0.03	0.15	0.12	Nona	December 2015	25-Year
19	12.92336300000	121.43919000000	0.04	0	-0.04			25-Year
20	12.92338400000	121.43758000000	0.03	0	-0.03			25-Year
21	12.92363800000	121.43689000000	0.1	0.12	0.02	Nona	December 2015	25-Year
22	12.92371800000	121.41553000000	0.11	0.74	0.63	Nona	December 2015	25-Year
23	12.92375300000	121.41522000000	0.04	0.72	0.68			25-Year
24	12.92391700000	121.41515000000	0.03	0	-0.03			25-Year
25	12.92430500000	121.44365000000	0.05	0	-0.05			25-Year
26	12.92464100000	121.48644300000	0.13	0	-0.13	Nona	Dec. 15, 2015	25-Year
27	12.92477400000	121.48625600000	0.22	0.55	0.33	Nona	Dec. 15, 2015	25-Year
28	12.92483500000	121.48648300000	0.13	0.13	0	Nona	Dec. 15, 2015	25-Year
29	12.92533800000	121.48663300000	0.11	0.46	0.35	Nona	Dec. 15, 2015	25-Year
30	12.92726700000	121.48656800000	0.21	0.82	0.61	Nona	Dec. 15, 2015	25-Year
31	12.92740500000	121.43526000000	0.1	0.38	0.28	Nona	December 2015	25-Year
32	12.92755500000	121.43557000000	0.03	0	-0.03			25-Year
33	12.92768300000	121.43473000000	0.08	0.3	0.22	Nona	December 2015	25-Year
34	12.92770800000	121.43395000000	0.16	0.37	0.21			25-Year
35	12.92827000000	121.48597600000	0.3	0.9	0.6	Nona	Dec. 15, 2015	25-Year
36	12.92834500000	121.43724000000	0.09	0	-0.09			25-Year
37	12.92877800000	121.48574000000	0.31	0.43	0.12	Nona	Dec. 15, 2015	25-Year
38	12.92854100000	121.42887000000	0.24	0.72	0.48	Caloy	2006	25-Year
39	12.92862900000	121.43788000000	0.03	0	-0.03			25-Year
40	12.92872800000	121.43240000000	0.06	0	-0.06			25-Year
41	12.92872300000	121.42932000000	0.18	0	-0.18	Nona	December 2015	25-Year
42	12.92879600000	121.43153000000	0.06	0.09	0.03	Caloy	2006	25-Year
43	12.92921900000	121.43059000000	0.52	0.94	0.42	Nona	December 2015	25-Year
44	12.92964600000	121.48488800000	0.86	0.21	-0.65	Nona	Dec. 15, 2015	25-Year

45	12.92976600000	121.48461500000	0.3	0.52	0.22	Nona	Dec. 15, 2015	25-Year
46	12.92964500000	121.43019000000	0.38	0	-0.38			25-Year
47	12.93014600000	121.44162000000	0.03	0	-0.03			25-Year
48	12.93022800000	121.43502000000	0.07	0.52	0.45	Nona	December 2015	25-Year
49	12.93088300000	121.48386800000	0.07	0	-0.07	Nona	Dec. 15, 2015	25-Year
50	12.93075400000	121.43659000000	0.03	0	-0.03			25-Year
51	12.93104000000	121.43604000000	0.09	0.55	0.46	Nona	December 2015	25-Year
52	12.93137700000	121.43667000000	0.08	0.59	0.51	Nona	December 2015	25-Year
53	12.93269100000	121.48237500000	0.03	0.11	0.08	Nona	Dec. 15, 2015	25-Year
54	12.93271800000	121.48319200000	0.05	0.4	0.35	Nona	Dec. 15, 2015	25-Year
55	12.93289600000	121.48180300000	0.03	0	-0.03	Nona	Dec. 15, 2015	25-Year
56	12.93298800000	121.48128400000	0.23	0.17	-0.06	Nona	Dec. 15, 2015	25-Year
57	12.93259700000	121.39370000000	0.18	0.2	0.02	Nona	December 2015	25-Year
58	12.93317700000	121.48196600000	0.04	0.39	0.35	Nona	Dec. 15, 2015	25-Year
59	12.93326300000	121.48109100000	0.03	0.17	0.14	Nona	Dec. 15, 2015	25-Year
60	12.93345700000	121.48107100000	0.21	0.15	-0.06	Nona	Dec. 15, 2015	25-Year
61	12.93359300000	121.48132500000	0.03	0.49	0.46	Nona	Dec. 15, 2015	25-Year
62	12.93380200000	121.48135400000	0.03	0.71	0.68	Typhoon	Dec. 10, 1984	25-Year
63	12.93410500000	121.48169300000	0.11	0.26	0.15	Nona	Dec. 15, 2015	25-Year
64	12.93423100000	121.48207900000	0.05	0.14	0.09	Nona	Dec. 15, 2015	25-Year
65	12.93428200000	121.48196900000	0.03	0.22	0.19	Nona	Dec. 15, 2015	25-Year
66	12.93430800000	121.48236800000	0.03	0	-0.03			25-Year
67	12.93438400000	121.48272200000	0.2	0.9	0.7	Nona	Dec. 15, 2015	25-Year
68	12.93397200000	121.39193000000	0.03	0	-0.03			25-Year
69	12.93468200000	121.47432400000	0.4	0.56	0.16	Nona	Dec. 15, 2015	25-Year
70	12.93489100000	121.48301100000	0.07	0	-0.07	Nona	Dec. 15, 2015	25-Year
71	12.93533400000	121.47346300000	0.3	0.82	0.52	Nona	Dec. 15, 2015	25-Year
72	12.93522300000	121.39835000000	0.03	0	-0.03			25-Year
73	12.93569800000	121.47269800000	0.21	0.29	0.08	Nona	Dec. 15, 2015	25-Year
74	12.93584500000	121.47256400000	0.26	0.66	0.4	Nona	Dec. 15, 2015	25-Year
75	12.93598400000	121.47329200000	0.52	0.6	0.08	Nona	Dec. 15, 2015	25-Year
76	12.93600100000	121.47352800000	0.49	0.56	0.07	Nona	Dec. 15, 2015	25-Year
77	12.93600100000	121.47211500000	0.06	0	-0.06			25-Year
78	12.93621800000	121.47182300000	0.04	0	-0.04			25-Year
79	12.93625300000	121.47343300000	0.31	0.74	0.43	Nona	Dec. 15, 2015	25-Year
80	12.93641100000	121.47258800000	0.67	0.6	-0.07	Nona	Dec. 15, 2015	25-Year
81	12.93662500000	121.47359500000	0.43	0.72	0.29	Nona	Dec. 15, 2015	25-Year
82	12.93781600000	121.46675900000	0.03	0	-0.03	Nona	Dec. 15, 2015	25-Year
83	12.93834800000	121.44803500000	0.2	0.45	0.25	Nona	Dec. 15, 2015	25-Year
84	12.93834900000	121.44802600000	0.2	0.3	0.1	Nona	Dec. 15, 2015	25-Year
85	12.93836800000	121.44751500000	0.26	0.48	0.22	Nona	Dec. 15, 2015	25-Year
86	12.93855800000	121.45754300000	0.04	0.07	0.03	Nona	Dec. 15, 2015	25-Year
87	12.93883800000	121.39957000000	1.61	0.53	-1.08	Nona	December 2015	25-Year
88	12.93910300000	121.42794000000	0.35	0.52	0.17	Nona	December 2015	25-Year
89	12.93937400000	121.42708000000	0.68	0.62	-0.06	Nona	December 2015	25-Year
90	12.93927600000	121.40661000000	0.03	0	-0.03			25-Year
91	12.93960300000	121.42559000000	1.14	0.96	-0.18	Nona	December 2015	25-Year
92	12.93982500000	121.44376200000	0.3	0.14	-0.16	Nona	Dec. 15, 2015	25-Year
93	12.94003600000	121.44254100000	0.49	0.4	-0.09	Nona	Dec. 15, 2015	25-Year
94	12.93986500000	121.40518000000	0.03	0	-0.03			25-Year
95	12.94025000000	121.44185100000	0.69	0	-0.69	Nona	Dec. 15, 2015	25-Year
96	12.94040200000	121.43417000000	0.51	0	-0.51	Nona	December 2015	25-Year

97	12.94054300000	121.43469000000	0.67	0.52	-0.15	Caloy	2006	25-Year
98	12.94068700000	121.43527000000	0.08	0	-0.08	Nona	December 2015	25-Year
99	12.94104800000	121.42563000000	0.45	0.52	0.07	Nona	December 2015	25-Year
100	12.94112400000	121.42547000000	0.43	0.48	0.05	Nona	December 2015	25-Year
101	12.94181300000	121.42558000000	0.35	0.57	0.22			25-Year
102	12.94188300000	121.43565000000	0.52	0.5	-0.02	Nona	December 2015	25-Year
103	12.94239600000	121.42569000000	0.11	0	-0.11	Nona	December 2015	25-Year
104	12.94389700000	121.47814200000	0.06	0	-0.06			25-Year
105	12.94355000000	121.40180000000	2.44	1.06	-1.38	Nona	December 2015	25-Year
106	12.94443900000	121.47787800000	0.06	0	-0.06			25-Year
107	12.94420200000	121.42496000000	0.3	0	-0.3			25-Year
108	12.94416800000	121.40194000000	2.7	1.1	-1.6	Nona	December 2015	25-Year
109	12.94483800000	121.40185000000	2.9	1.67	-1.23	Nona	December 2015	25-Year
110	12.94501500000	121.42419000000	0.69	0.31	-0.38			25-Year
111	12.94567400000	121.49504000000	0.32	0	-0.32			25-Year
112	12.94569200000	121.49411000000	0.18	0	-0.18			25-Year
113	12.94574800000	121.49332000000	0.12	0	-0.12			25-Year
114	12.94534400000	121.42380000000	0.11	0.31	0.2	Nona	December 2015	25-Year
115	12.94641400000	121.49084000000	0.04	0	-0.04			25-Year
116	12.94729100000	121.42189000000	0.16	0.1	-0.06	Nona	December 2015	25-Year
117	12.94735900000	121.41594000000	0.05	0	-0.05			25-Year
118	12.94844600000	121.42129000000	0.56	0.74	0.18			25-Year
119	12.94881500000	121.46568400000	0.08	0	-0.08	Nona	Dec. 15, 2015	25-Year
120	12.94888000000	121.46782300000	0.04	0	-0.04			25-Year
121	12.94870100000	121.42094000000	0.65	0.1	-0.55	Nona	December 2015	25-Year
122	12.94941600000	121.48628000000	0.03	0	-0.03			25-Year
123	12.94960000000	121.46542000000	0.06	0	-0.06	Nona	Dec. 15, 2015	25-Year
124	12.94962900000	121.46510200000	0.03	0	-0.03	Nona	Dec. 15, 2015	25-Year
125	12.94946700000	121.41859000000	0.44	0.44	0	Nona	December 2015	25-Year
126	12.94978900000	121.41948000000	1.24	0.58	-0.66			25-Year
127	12.95011300000	121.41868000000	1.68	0.61	-1.07			25-Year
128	12.95369600000	121.40715000000	0.64	0.35	-0.29	Nona	December 2015	25-Year
129	12.95529800000	121.40825000000	0.03	0	-0.03			25-Year

Annex 11. Phil-LiDAR 1 UPLB Team Composition

Project Leader
Asst. Prof. Edwin R. Abucay (CHE, UPLB)

Project Staffs/Study Leaders
Asst. Prof. Efraim D. Roxas (CHE, UPLB)
Asst. Prof. Joan Pauline P. Talubo (CHE, UPLB)
Ms. Sandra Samantela (CHE, UPLB)
Dr. Cristino L. Tiburan (CFNR, UPLB)
Engr. Ariel U. Glorioso (CEAT, UPLB)
Ms. Miyah D. Queliste (CAS, UPLB)
Mr. Dante Gideon K. Vergara (SESAM, UPLB)

Sr. Science Research Specialists
Gillian Katherine L. Inciong
For. John Alvin B. Reyes

Research Associates
Alfi Lorenz B. Cura
Angelica T. Magpantay
Gemmalyn E. Magnaye
Jayson L. Arizapa
Kevin M. Manalo
Leendel Jane D. Punzalan
Maria Michaela A. Gonzales
Paulo Joshua U. Quilao
Sarah Joy A. Acepcion
Ralphael P. Gonzales

Computer Programmers
Ivan Marc H. Escamos
Allen Roy C. Roberto

Information Systems Analyst
Jan Martin C. Magcale

Project Assistants
Daisili Ann V. Pelegrina
Athena Mercado
Kaye Anne A. Matre
Randy P. Porciocula