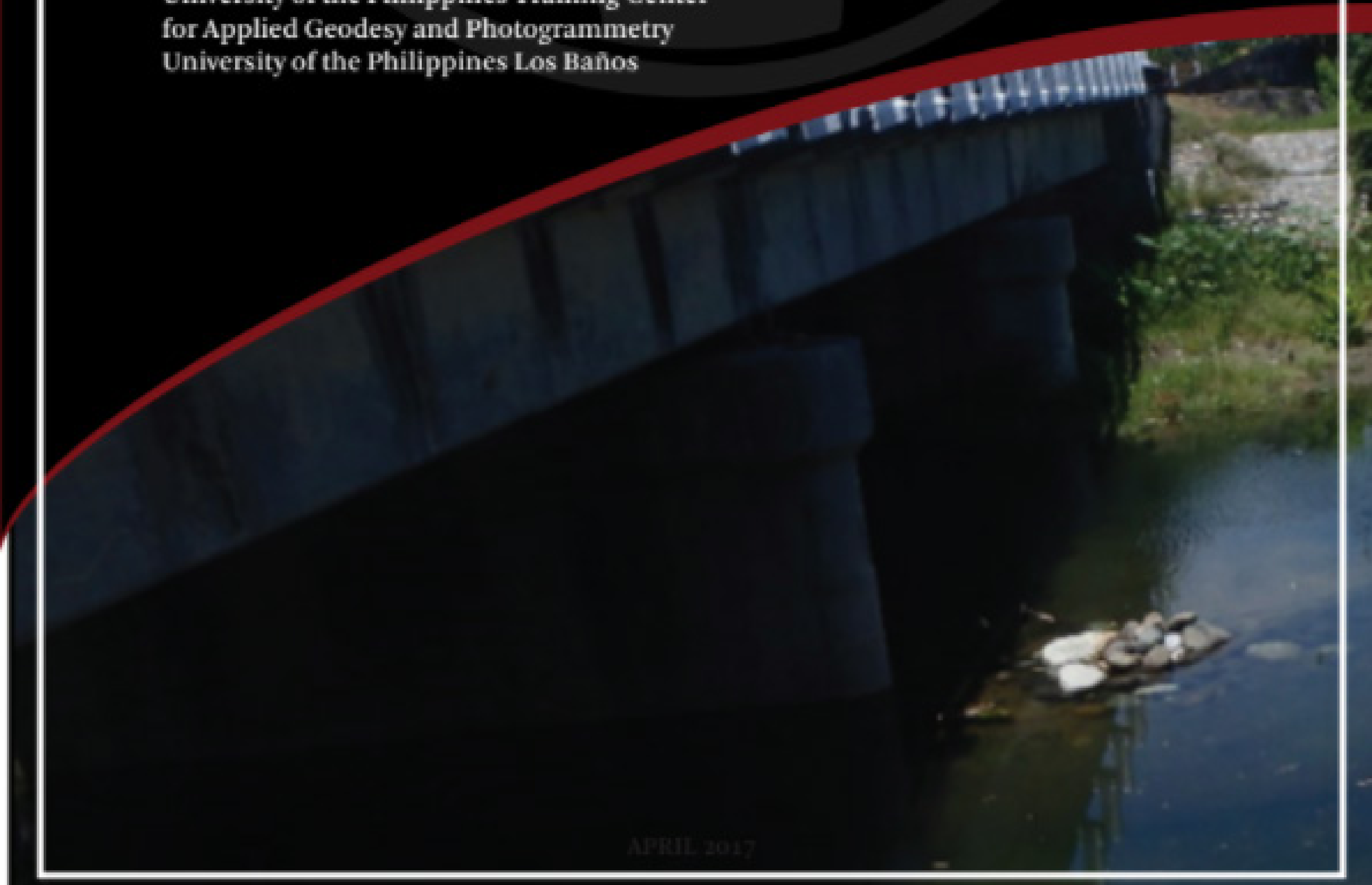
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Sumagui River

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



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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
BSWM	Bureau of Soil and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
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
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RBCO	River Basin Control Office
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
UPLB	University of the Philippines Los Baños
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SUMAGUI RIVER

Enrico C. Paringit, Dr. Eng. and Dr. Edwin R. Abucay

1.1 Background of the Phil-LiDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 45 river basins in the Southern Luzon region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Sumagui River Basin

The Sumagui River Basin is a 10,870-hectare watershed located in Oriental Mindoro. covers six (6) barangays in Municipality of Bansud and five (5) barangays in Municipality of Bongabong. Specifically, it encompasses the barangays of Conrazon, Pag-asa, Poblacion, Alcadesma, Proper Bansud, Proper Tiguisan, Salcedo, Rosacara, Manihala, Malo, Bato and Sumagui in the municipality of Bansud; and Tawas, Sigange, Carmundo, Libertad, Labasan and Sta.Cruz in Bongabong. The DENR River Basin Control Office identified the basin to have a drainage area of approximately 97 square kilometers and an estimated 155 million cubic meter (MCM) annual runoff (DENR RBCO, 2015).

In the Sumagui River Basin area, Climate Type I and III prevails as 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.

The river basin is generally characterized by 8-50% slope and elevation of 0-250 meters above mean sea level. It also has five geological classifications with Upper Miocene-Pliocene rocks as the most dominant type while others include Oligocene-Miocene, Oligocene and Pliocene-Pleistocene. The soils in the river basin consist of Maranlig gravelly sandy clay loam, San Miguel loam, Quingua clay loam, and San Miguel sandy loam. Other areas are rough mountainous land (unclassified) and beach sand. Cultivated lands (annual crops) is predominant in the area along with open forests and cultivated lands (perennial crops).

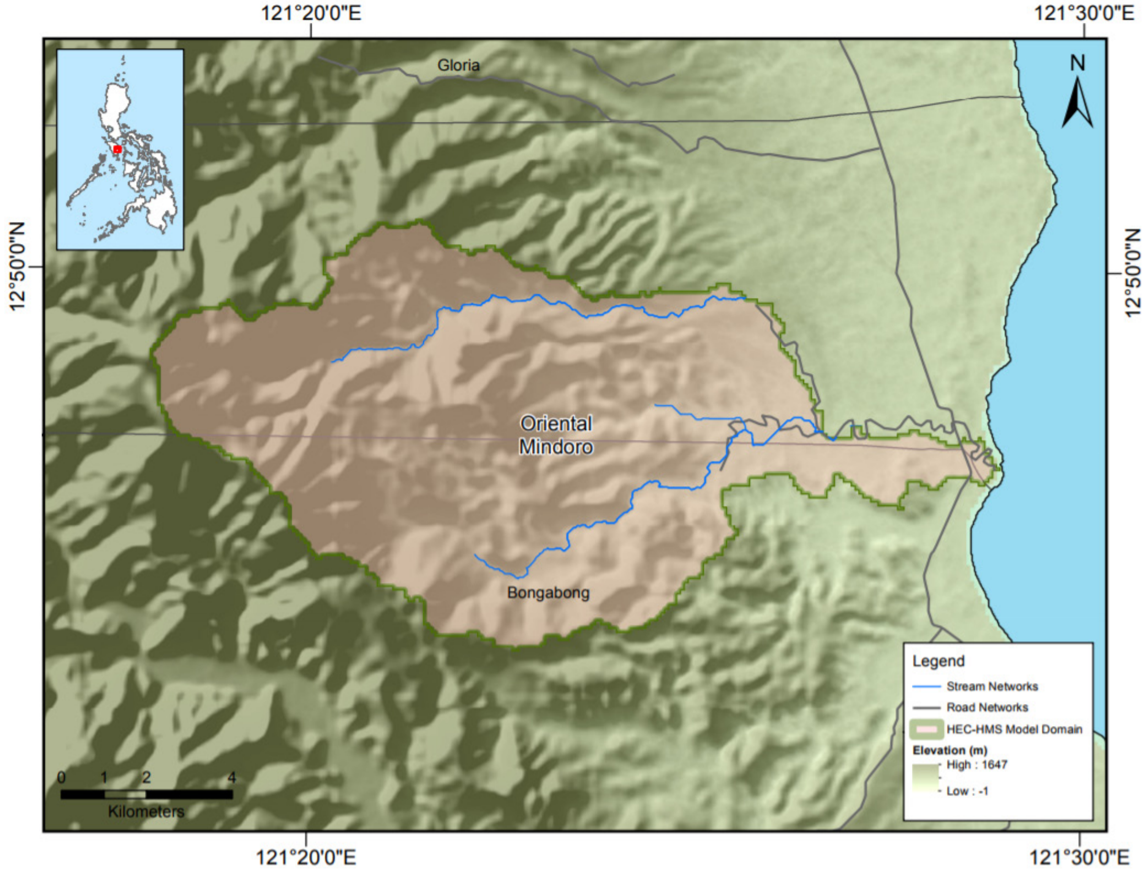

Figure 1. Map of Sumagui River Basin

Meanwhile, its main stem, the Sumagui River, is part of the 45 river systems in the Southern Luzon Region. It passes through barangays of Manguyang, Conrazon, Pag-asa, Poblacion, Alcadesma, Proper Bansud, Proper Tiguisan, Salcedo, Rosacara, Manihala, Malo, Bato and SUmagui in Bansud; and Tawas, Sigange, Carmundo, Libertad, Labasan and Sta.Cruz in Bongabong. There is a total population estimate of 7,727 living within the immediate vicinity of the river distributed in the area of Brgy. Sumagui in Municipality of Bansud, and Brgy. Labsan Municipality of Bongabong according to the National Statstics Office 2015 National Census. This vicinity along Sumagui River reflects moderate to low susceptibility of flooding according to the 2012 Mines and Geosciences Bureau (MGB)'s hazard maps.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SUMAGUI FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Sumagui Floodplain in Oriental Mindoro. These missions were planned for 21 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Sumagui Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28A	600	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
BLK28F	600	30	36	50	45	130	5
BLK28G	600	30	36	50	45	130	5
BLK 28H	600	30	36	50	45	130	5
BLK28I	600, 1000	30	36	50	45	130	5
BLK28J	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 (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28E	1200	30	30	100	50	130	5
BLK28F	1000	30	40	100	50	130	5
BLK28H	1200	30	30	100	50	130	5
BLK28I	1200	30	30	100	50	130	5

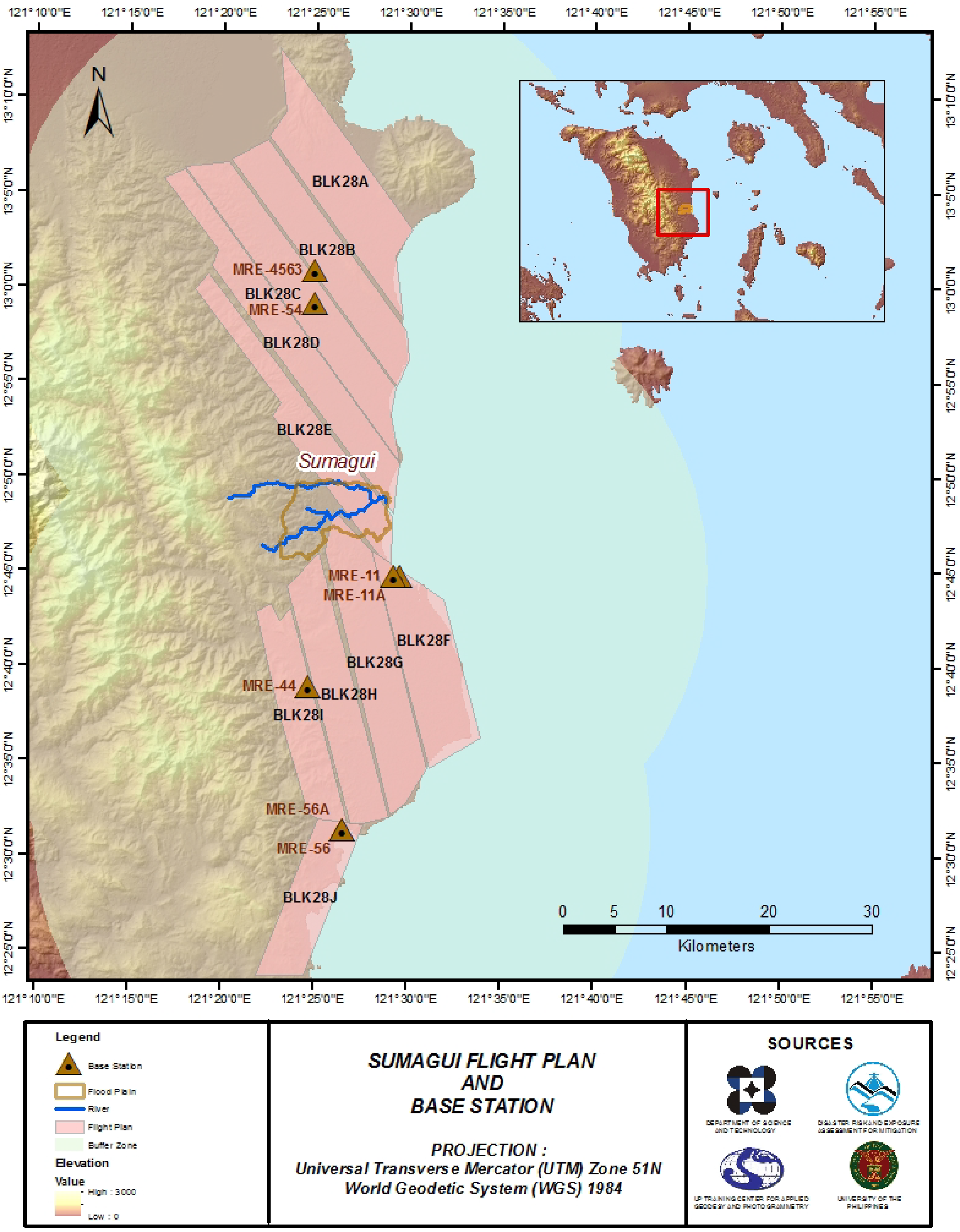


Figure 2. Flight plans and base stations used for Sumagui Floodplain

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: MRE-54, MRE-44, MRE-56, and MRE-4563 which are of second (2nd) order accuracy and MRE-11 which is of third (3rd) order accuracy. The project team also established two (2) ground control points MRE-11A and MRE 56a. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing report for the established control points is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 5-12, 2014; October 24-26, 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 Sumagui floodplain are shown in Figure 2.The list of team members are shown in Annex 4.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area, in addition Table 3 to Table 9 show the details about the following NAMRIA control stations and established points, Table 10 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

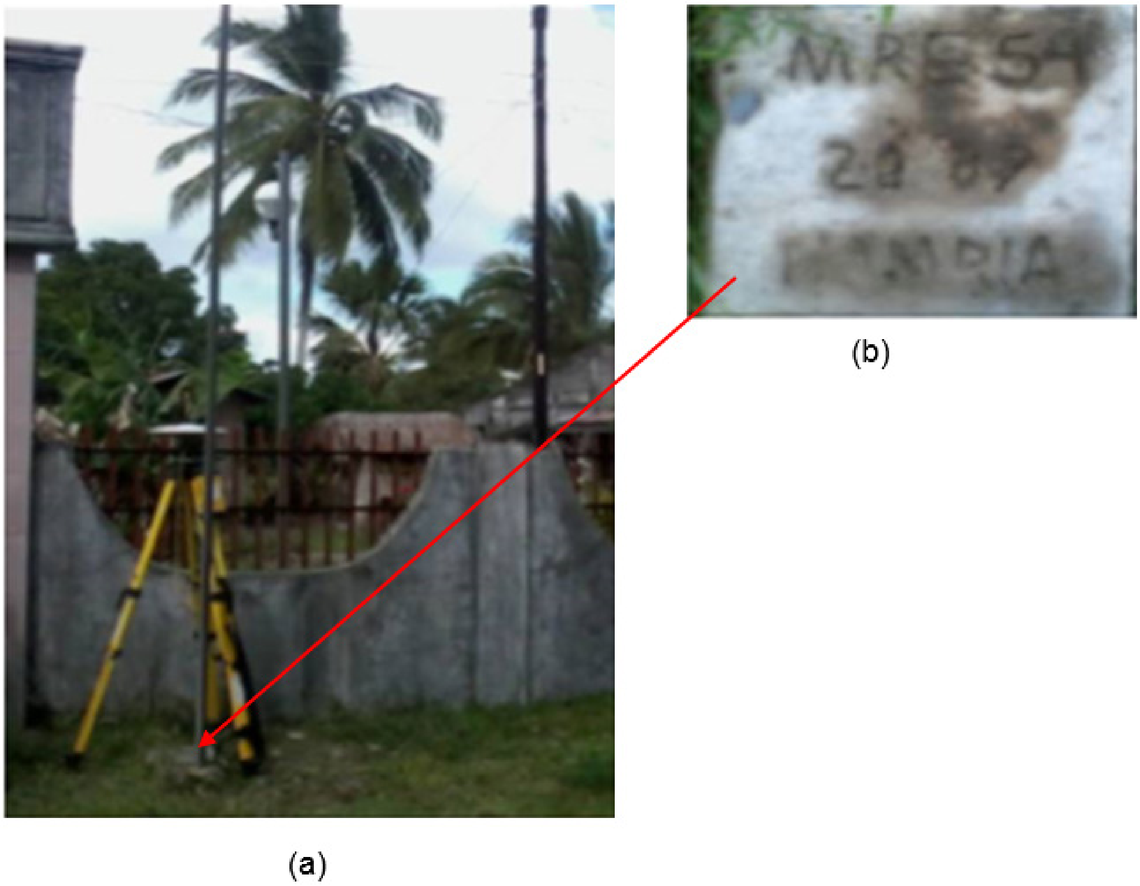
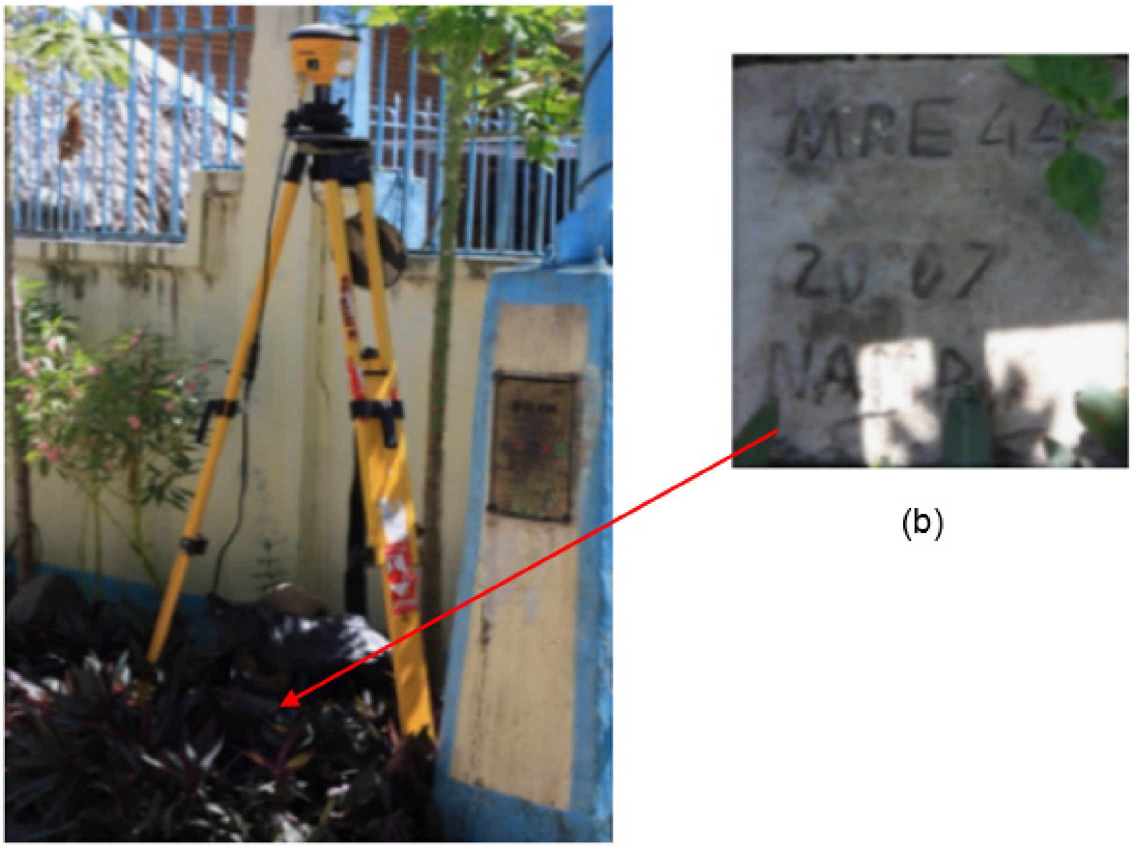


Figure 3. GPS set-up over MRE-54 inside the compound of the barangay hall of Maliangcog, municipality of Pinamalayan, Oriental Mindoro (a) and NAMRIA reference point MRE-54 (b) as recovered by the field team.

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)	**1:50,000**	
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, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327864.09 meters 1436121.49 meters

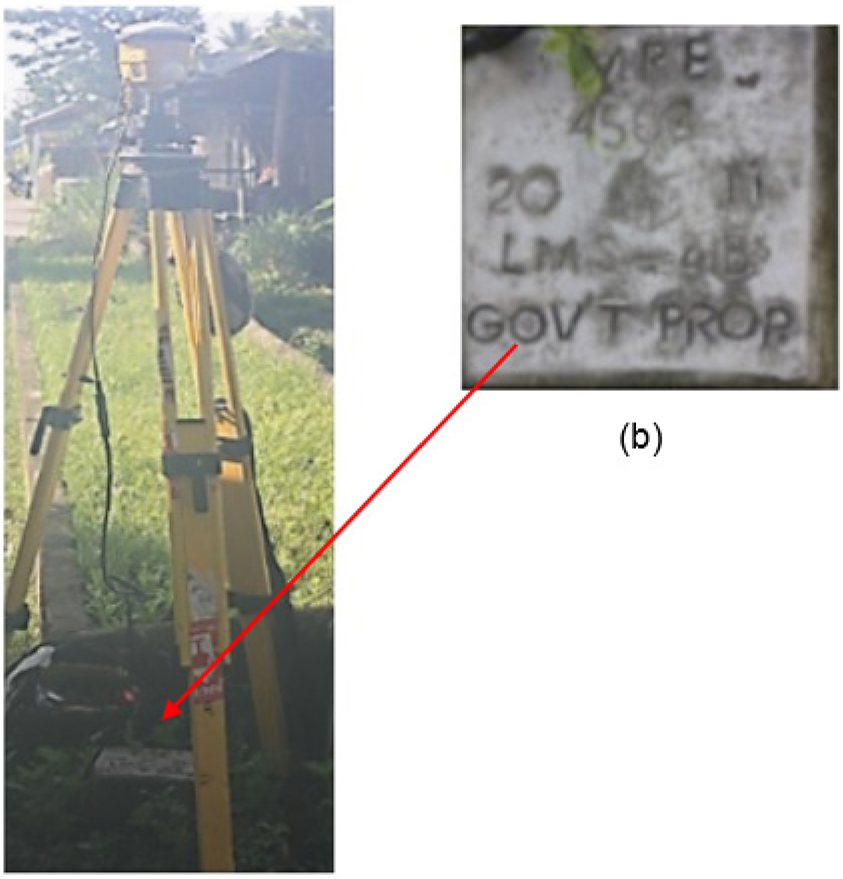


(a) (b)

Figure 4. GPS set-up over MRE-44 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)	**1:50,000**	
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, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327214.81 meters 1398840.08 meters



(a)

Figure 5. GPS set-up over MRE-4563 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	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°00’53.01692’’ North 121°24’51.45337’’ East 73.715 meters
Grid Coordinates, Philippine 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-11 used as base station for the LiDAR Acquisition.

Station Name	MRE-11	
Order of Accuracy	3rd	
Relative Error (Horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°44’50.41380’’ North 121°29’7.80130’’ East 5.11500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	552720.766 meters 1409650.153 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°44’45.47630’’ North 121°29’12.85191’’ East 54.91100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	335581.55 meters 1409587.05 meters

Table 7. 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	3rd	
Relative Error (Horizontal positioning)	1:20,000	
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°44’45.50783’’ North 121°29’29.79714’’ East 55.558 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	338880.152 meters 1409583.946 meters

Table 8. Details of the recovered NAMRIA horizontal control point MRE-56 used as base station for the LiDAR Acquisition.

Station Name	MRE-56	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31'25.76362" North 121°26'25.21109' East 7.87000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	547,857.861 meters 1,384,916.657 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31'20.87629" North 121°26'30.28143" East 58.13600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	330,530.08 meters 1,384,892.31 meters

Table 9. Details of the recovered NAMRIA horizontal control point MRE-56A used as base station for the LiDAR Acquisition.

Station Name	MRE-56A	
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°31'20.59653" North 121°26'30.40791" East 57.601 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	330,688.179 meters 1,384,818.639 meters

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
5-feb-14	1066A	3BLK28DS036A	MRE-54, MRE-4563
6-Feb-14	1070A	3BLK28DSE037A	MRE-54, MRE-4563
7-Feb-14	1072A	3BLK28F038A	MRE-44
8-Feb-14	1076A	3BLK28G039A	MRE-44
8-Feb-14	1078A	3BLK28GSH039B	MRE-44
11-Feb-14	1088A	3BLK28HS042A	MRE-44
12-Feb-14	1092A	3BLK28ABES043A	MRE-54, MRE-4563
24-Oct-15	8304G	2BLK28FHS297A	MRE-54, MRE-11
25-Oct-15	8306G	2CALIBBLK28FSGS298A	MRE-11, MRE11A
26-oct-15	8308G	2BLK28J299A	MRE-56,MRE-56a

2.3 Flight Missions

Ten (10) missions were conducted to complete the LiDAR Data Acquisition in Sumagui Floodplain, for a total of thirty-nine hours and thirty-seven minutes (39+37) of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Aquarius and Gemini LiDAR systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

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

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
5-Feb-14	1066A	132.98	95.19	1.17	94.02	N/A	3	35
6-Feb-14	1070A	243.37	134.14	18.35	115.79	1517	4	29
7-Feb-14	1072A	112.27	106.58	0.31	106.27	1143	4	23
8-Feb-14	1076A	210.47	100.75	9.39	91.36	1041	4	05
8-Feb-14	1078A	318.37	68.06	1.53	316.84	869	3	29
11-Feb-14	1088A	107.9	90.59	0.85	89.74	1235	4	29
12-Feb-14	1092A	314.3	99.90	7.68	92.22	1176	4	05
24-Oct-15	8304G	220.17	110.37	22.65	87.72	368	3	30
25-Oct-15	8306G	112.27	70.58	18.07	52.51	N/A	3	41
26-Oct-15	8308G	99.08	103.41	6.60	96.81	N/A	3	51
TOTAL		1241.87	979.57	86.6	1143.28	7349	39	37

Table 12. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	PRF (Hz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Times (Minutes)
1066A	600	30	36	50	40	115	5
1070A	600	30	36	50	40	130	5
1072A	600	30	36	50	50, 40	130	5
1076A	600	30	36	50	50	130	5
1078A	600, 1000	30	36, 30, 20	50, 70	50	130	5
1088A	600	30	36	50	50	130	5
1092A	600	30	36	50	40	130	5
8304G	1200, 900	35	30, 36	100	50	130	5
8306G	1200, 900	35	30, 40	100	50	130	5
8308G	1100	35	36	100	50	120	5

2.4 Survey Coverage

Sumagui floodplain is located in the provinces of Oriental Mindoro with majority of the floodplain situated within the municipality of Sumagui. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Sumagui floodplain is presented in Figure 6.

Table 13. List of municipalities and cities surveyed during the Sumagui Floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Leyte	Bansud	197.00	86.77	44%
	Bongabong	493.74	231.26	47%
	Bulalacao	365.58	83.73	23%
	Gloria	327.28	93.62	29%
	Mansalay	477.24	56.67	12%
	Naujan	431.57	3.69	1%
	Pinamalayan	206.87	45.90	22%
	Pola	127.04	30.28	24%
	Roxas	90.14	61.58	68%
	Socorro	206.05	32.83	16%
	Victoria	216.22	5.15	2%
Total		3138.73	731.48	23.30%

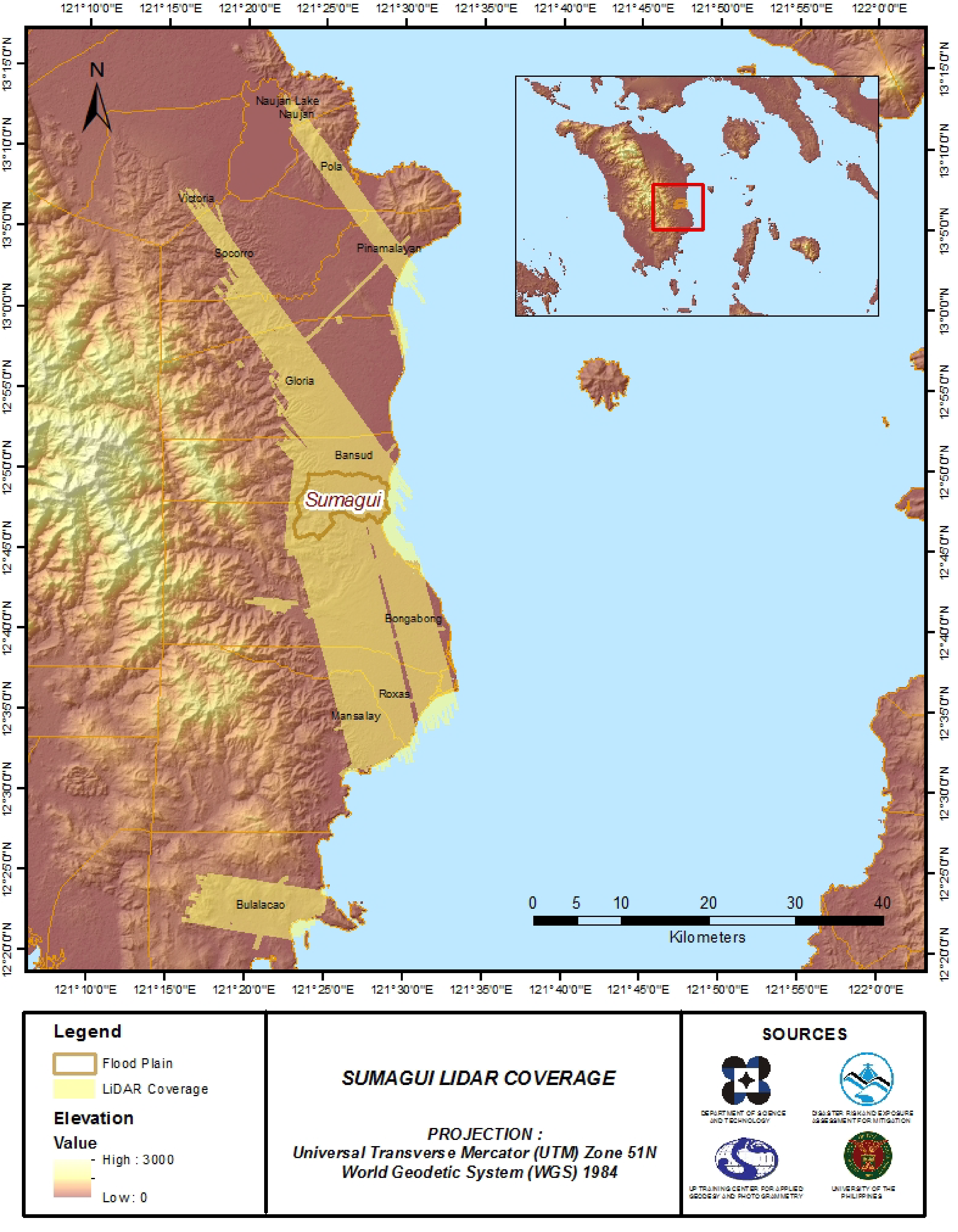


Figure 6. Actual LiDAR survey coverage for Sumagui Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SUMAGUI FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

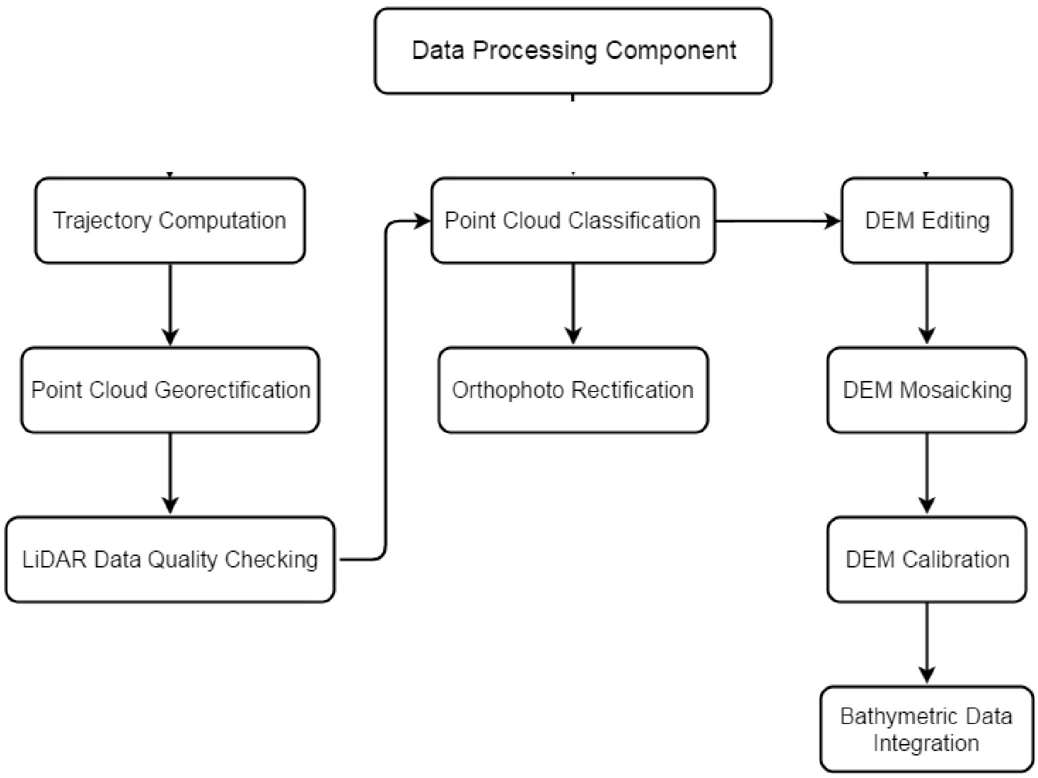

Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Sumagui 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 Bansud, Oriental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 126.91 Gigabytes of Range data, 2.34 Gigabytes of POS data, 127.79 Megabytes of GPS base station data, and 522.1 Gigabytes of raw image data to the data server on June 4, 2014 for the first survey and February 6, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sumagui was fully transferred on November 11, 2015, as indicated on the Data Transfer Sheets for Sumagui floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1072A, one of the Sumagui 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 7, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

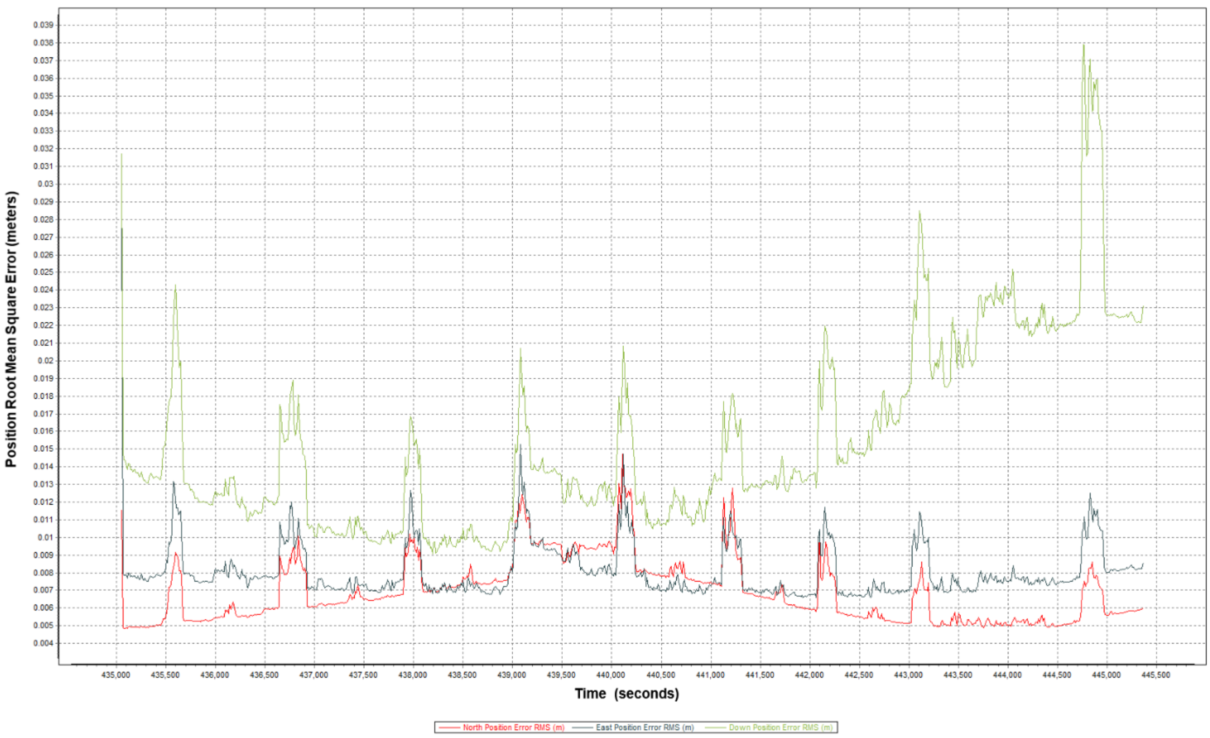

Figure 8. Smoothed Performance Metric Parameters of Sumagui Flight 1072A.

The time of flight was from 435000 seconds to 445500 seconds, which corresponds to morning of February 7, 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 POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1. 70 centimeters, and the Down position RMSE peaks at 4.10 centimeters, which are within the prescribed accuracies described in the methodology.

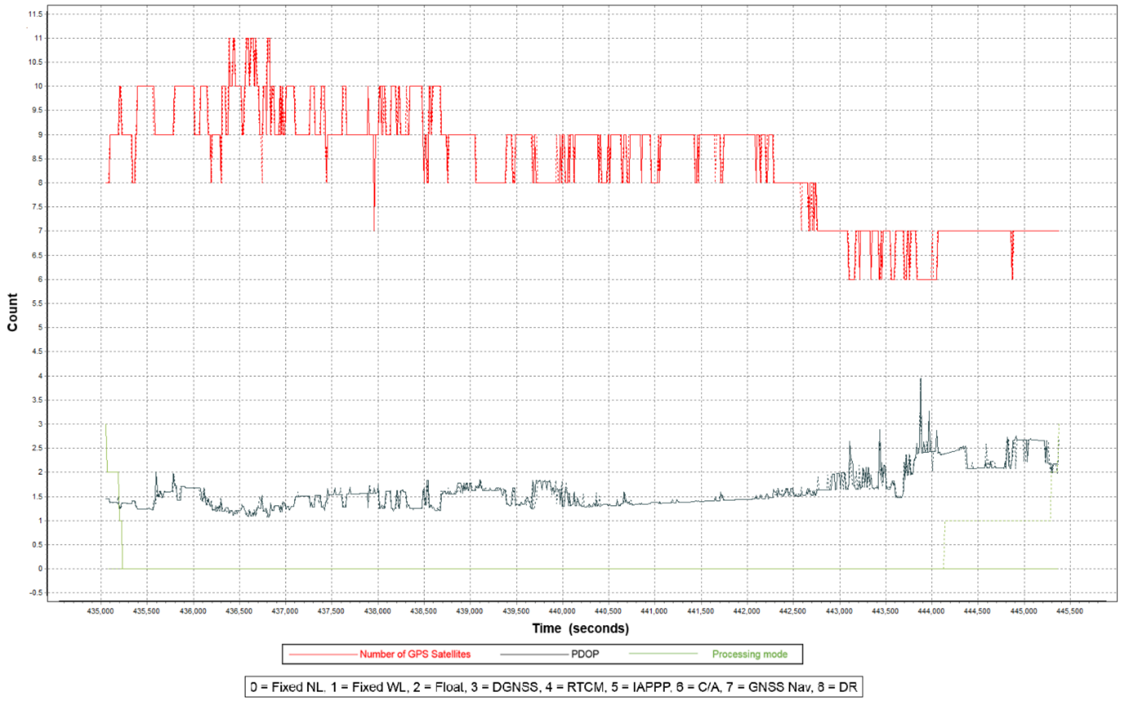

Figure 9. Solution Status Parameters of Sumagui Flight 1072A.

The Solution Status parameters of flight 1072A, one of the Sumagui 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 11. The PDOP value also did not go above the value of 4, 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 Sumagui flights is shown in Figure 10.

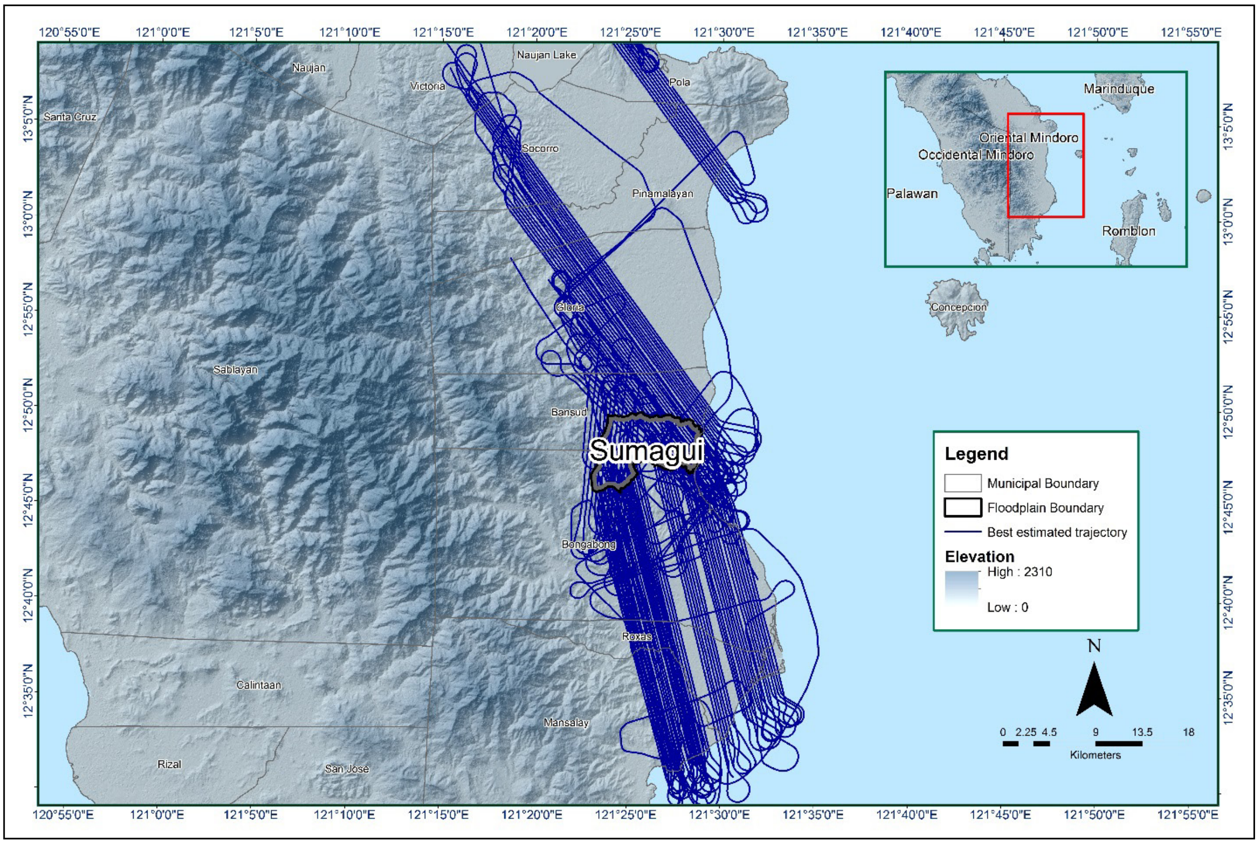

Figure 10. Best Estimated Trajectory for Sumagui Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 116 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 Sumagui floodplain are given in Table 14.

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

Parameter	Value
Boresight Correction stdev (<0.001degrees)	0.000424
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000955
GPS Position Z-correction stdev (<0.01meters)	0.0019

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Sumagui Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

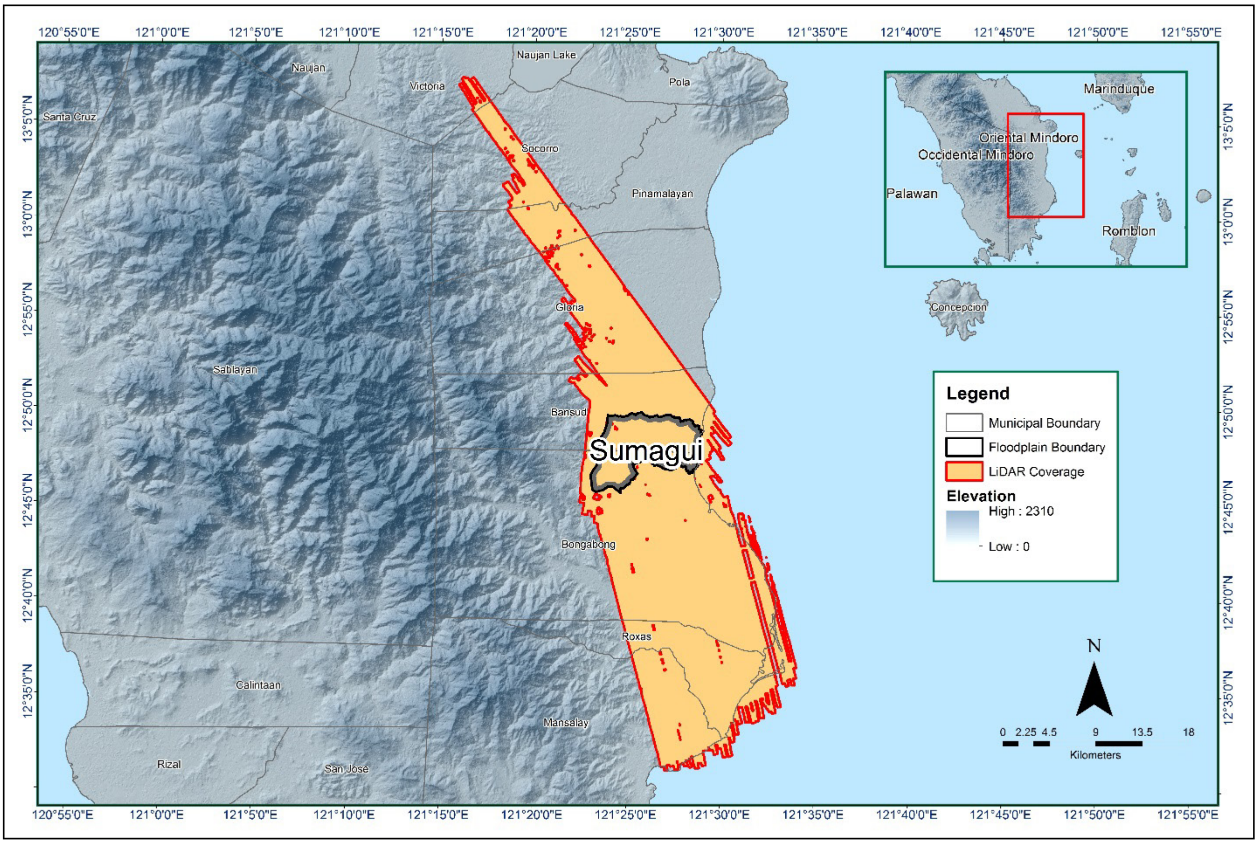

Figure 11. Boundary of the processed LiDAR data over Sumagui Floodplain

The total area covered by the Sumagui missions is 691.87 sq.km that is comprised of ten (10) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Sumagui Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OrientalMindoro_Blk28D supplement	1066A	88.65
OrientalMindoro_Blk28E	1070A	125.84
OrientalMindoro_Blk28E_supplement	1092A	29.82
OrientalMindoro_Blk28F	1072A	124.61
OrientalMindoro_Blk28G	1076A	95.35
OrientalMindoro_Blk28G_supplementH	1078A	62.40
OrientalMindoro_Blk28H_supplement	1088A	84.37
OrientalMindoro_reflights_Blk28E	8306G	29.31
	8308G	
OrientalMindoro_reflights_Blk28H_ supplement	8304G	51.52
	8306G	
TOTAL		**691.87 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, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

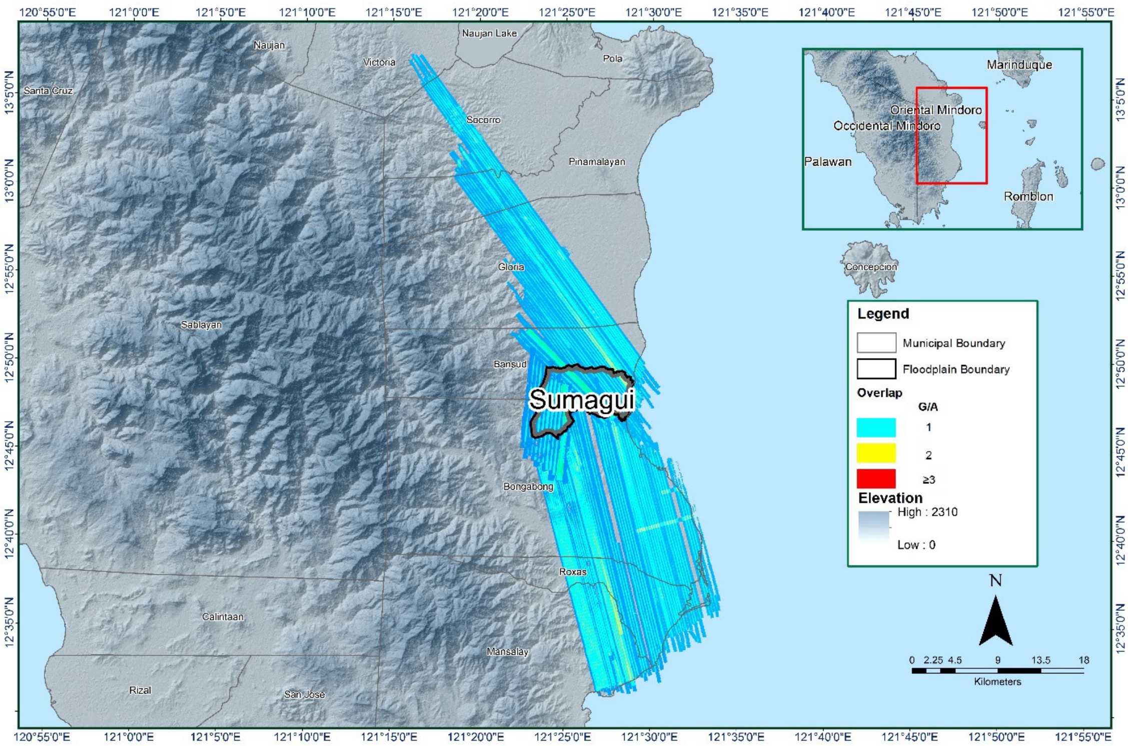

Figure 12. Image of data overlap for Sumagui Floodplain.

The overlap statistics per block for the Sumagui floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.89% and 66.45% 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 Sumagui floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.68 points per square meter.

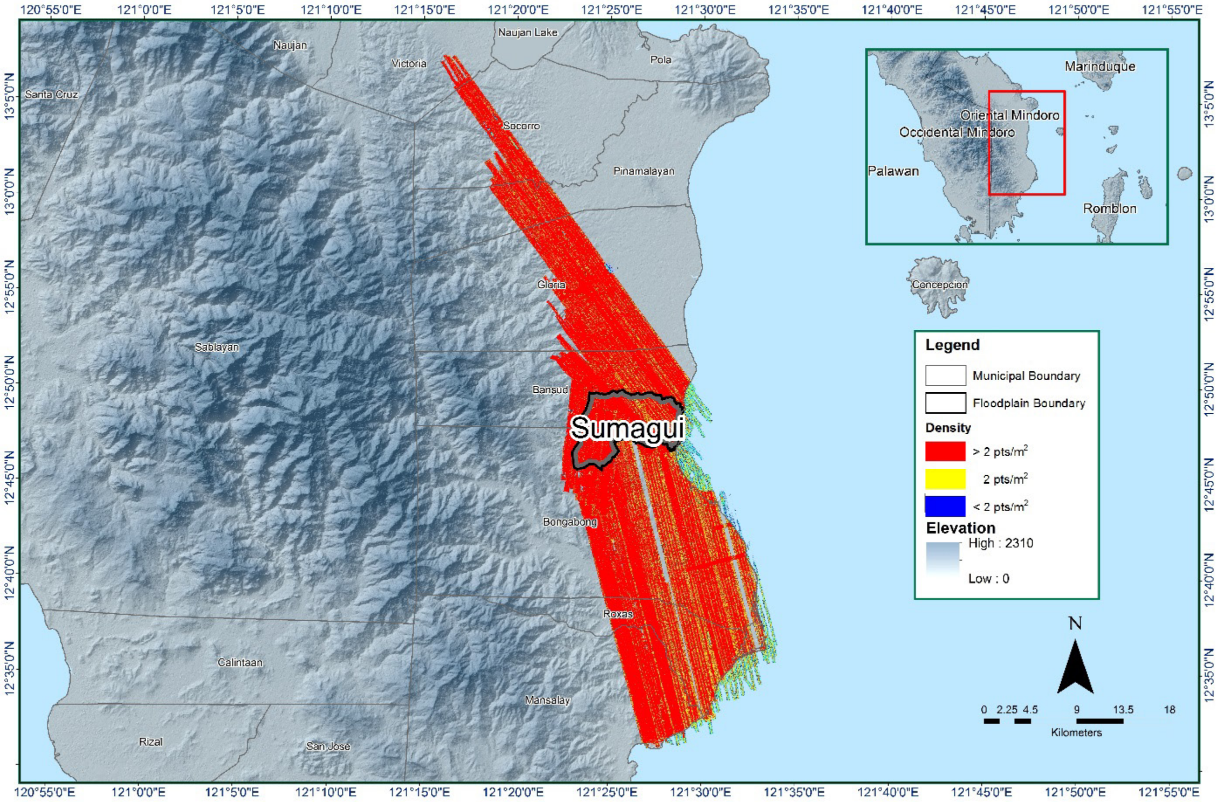

Figure 13. Pulse density map of merged LiDAR data for Sumagui Floodplain.

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 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

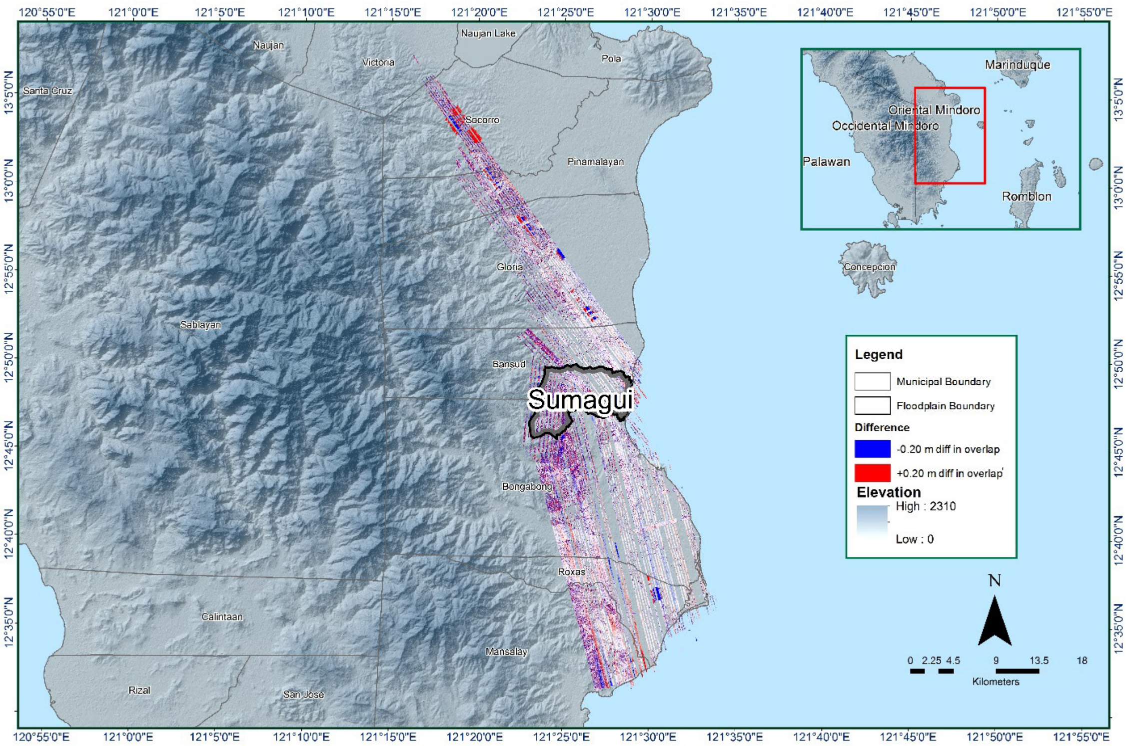

Figure 14. Elevation difference map between flight lines for Sumagui Floodplain.

A screen capture of the processed LAS data from a Sumagui flight 1072A 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 red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

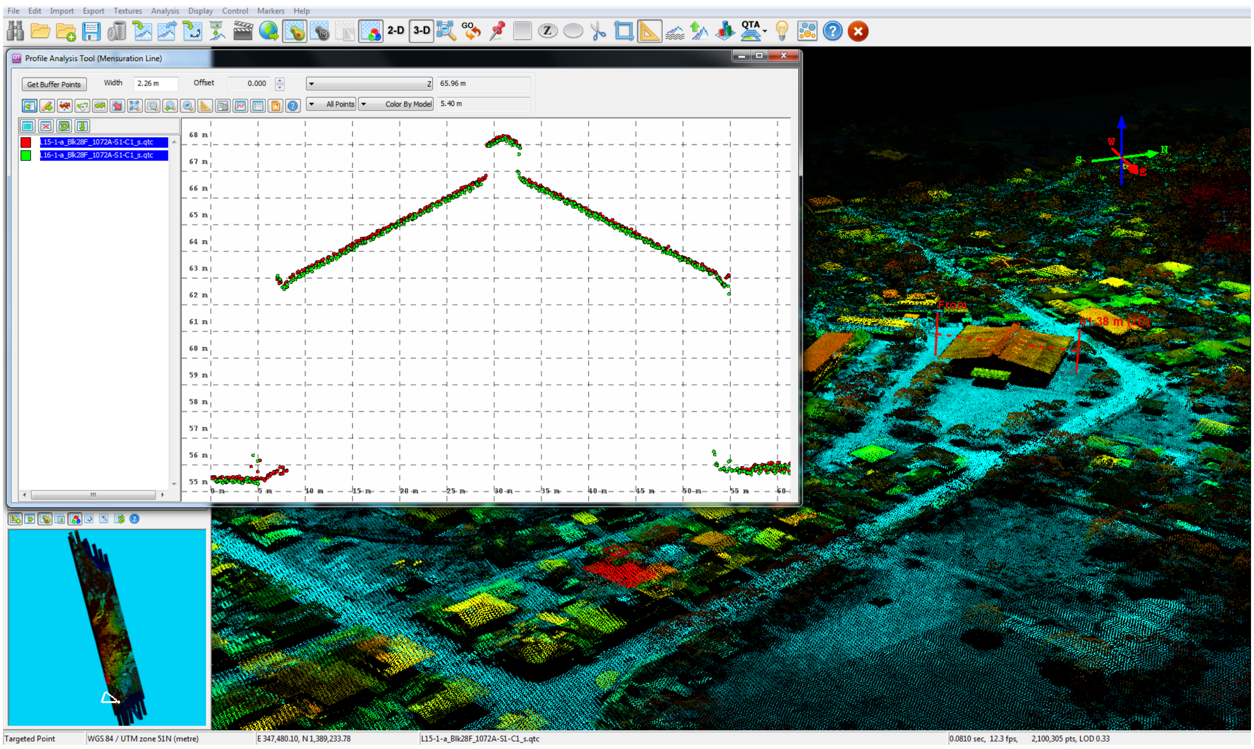

Figure 15. Quality checking for Sumagui flight 1072A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Sumagui classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	482,567,141
Low Vegetation	560,354,469
Medium Vegetation	511,118,838
High Vegetation	604,661,744
Building	22,317,481

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sumagui floodplain is shown in Figure 16. A total of 1,131 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 437.09 meters and 31.32 meters respectively.

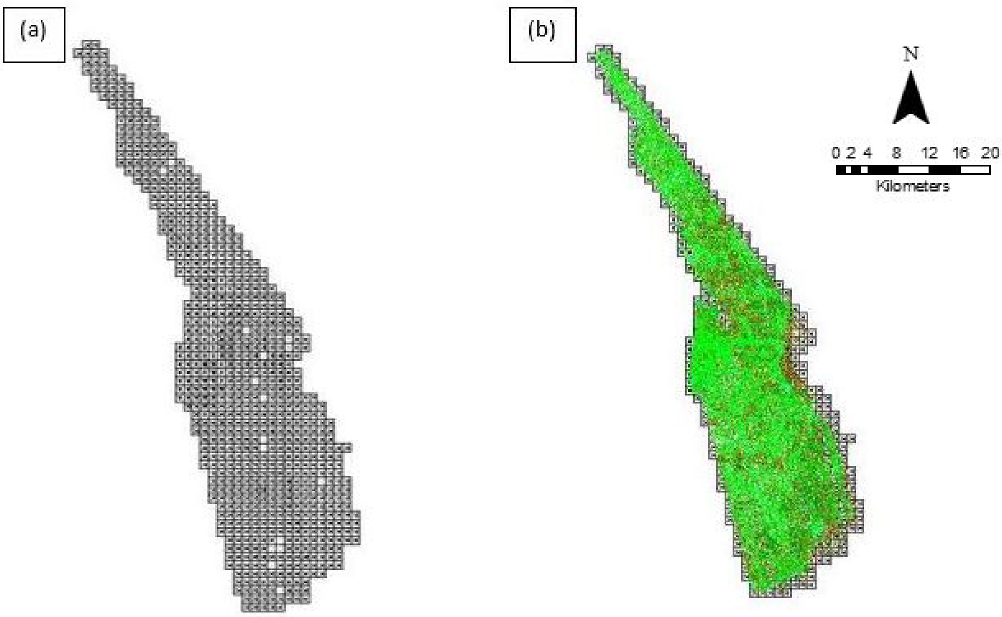

Figure 16. Tiles for Sumagui Floodplain (a) and classification results (b) in TerraScan.

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.

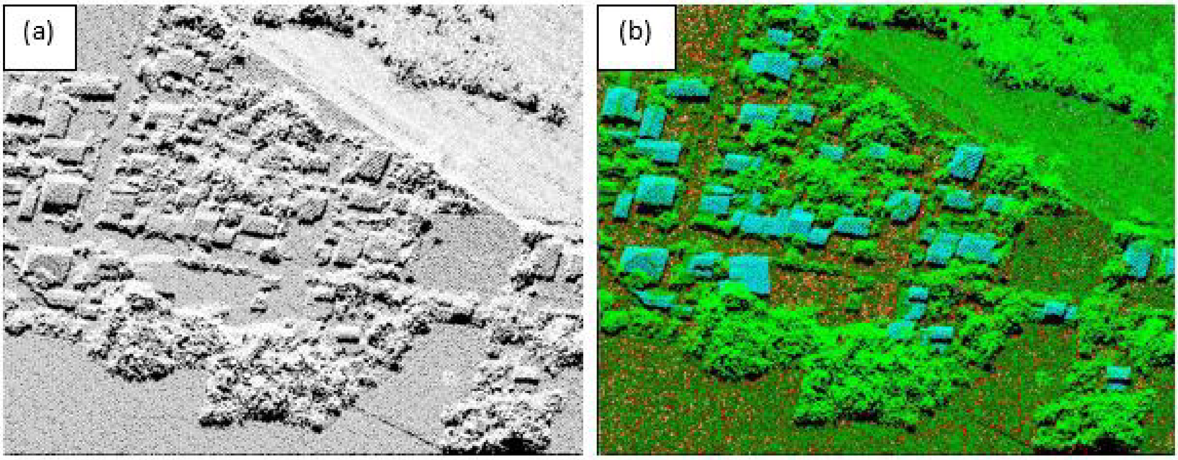

Figure 17. Point cloud before (a) and after (b) classification.

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.

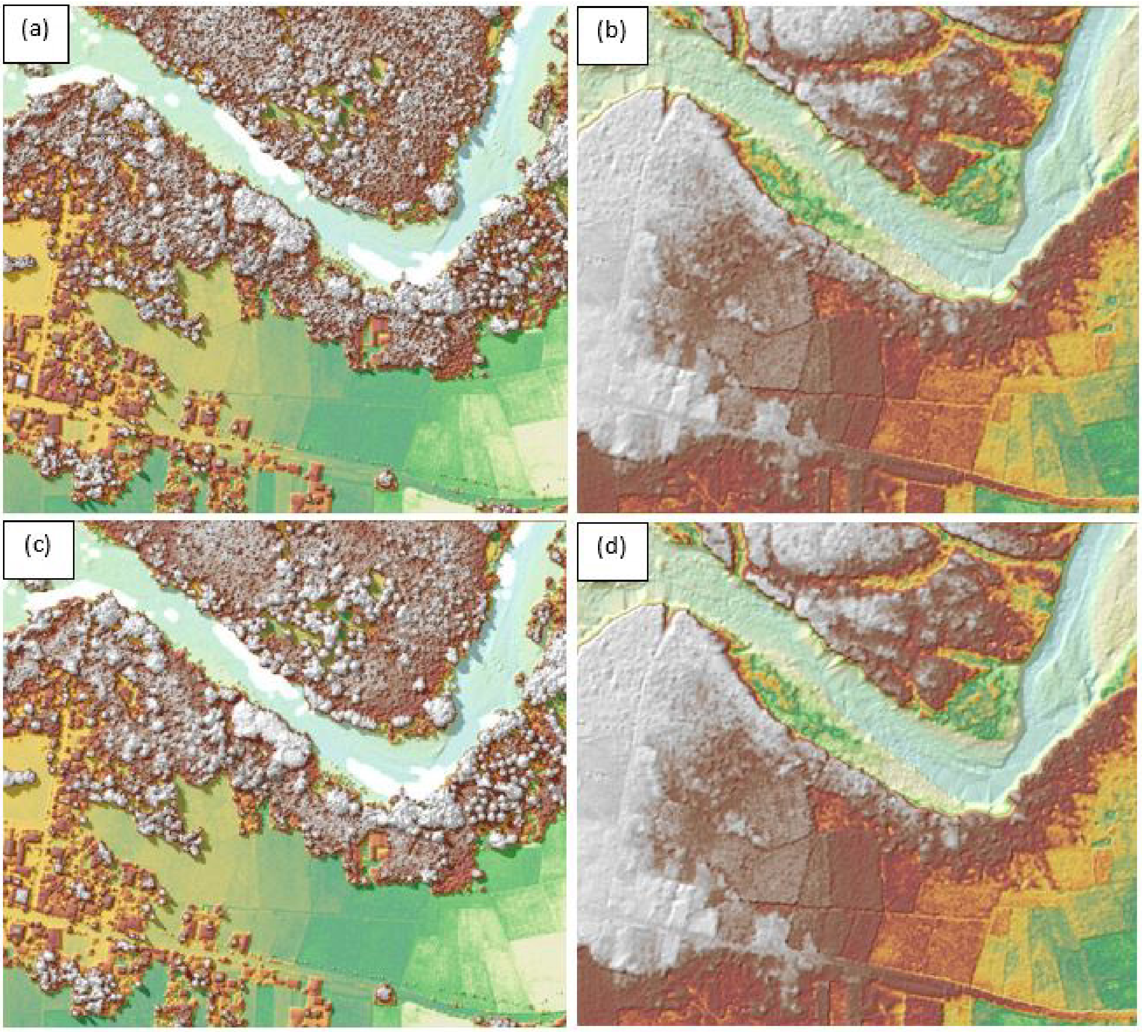

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sumagui floodplain.

3.7LiDAR Image Processing and Orthophotograph Rectification

The 694 1km by 1km tiles area covered by Sumagui 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 Sumagui floodplain has a total of 502.01 sq.km orthophotogaph coverage comprised of 5,432 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

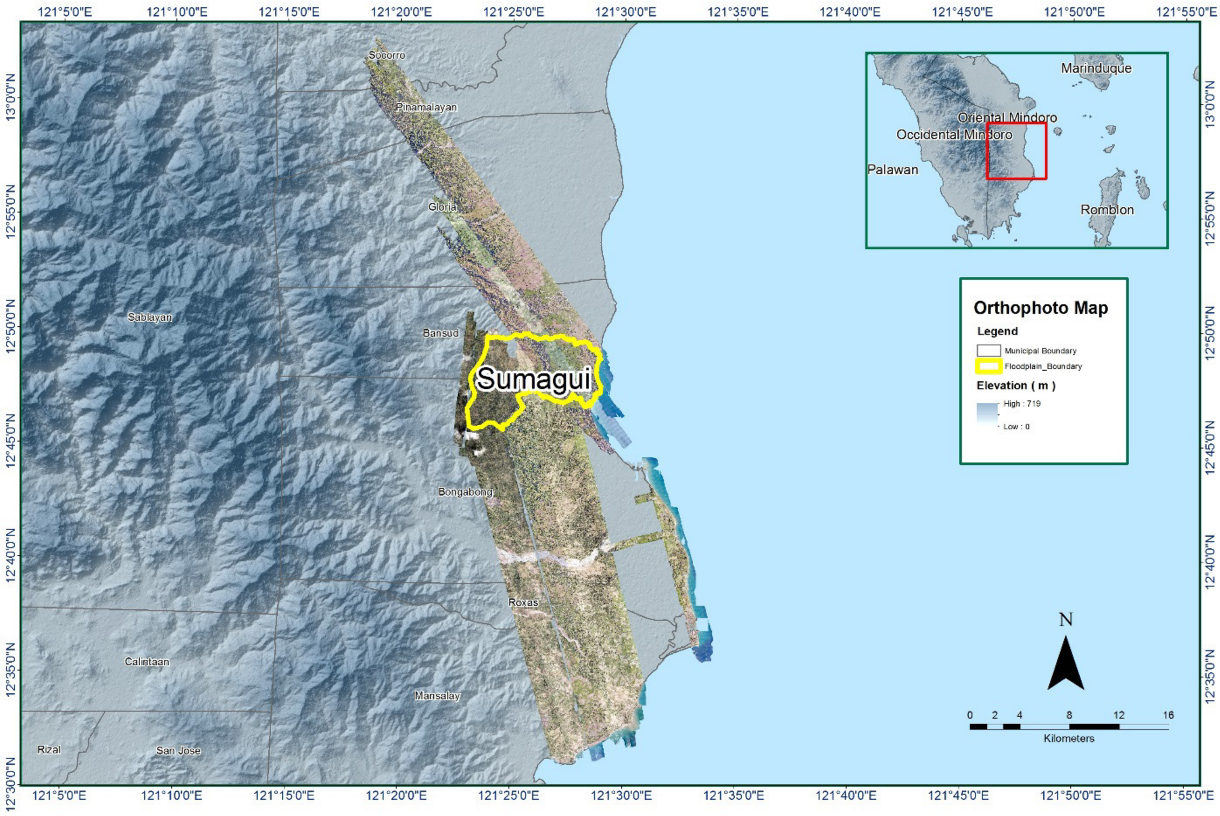

Figure 19. Sumagui floodplain with available orthophotographs

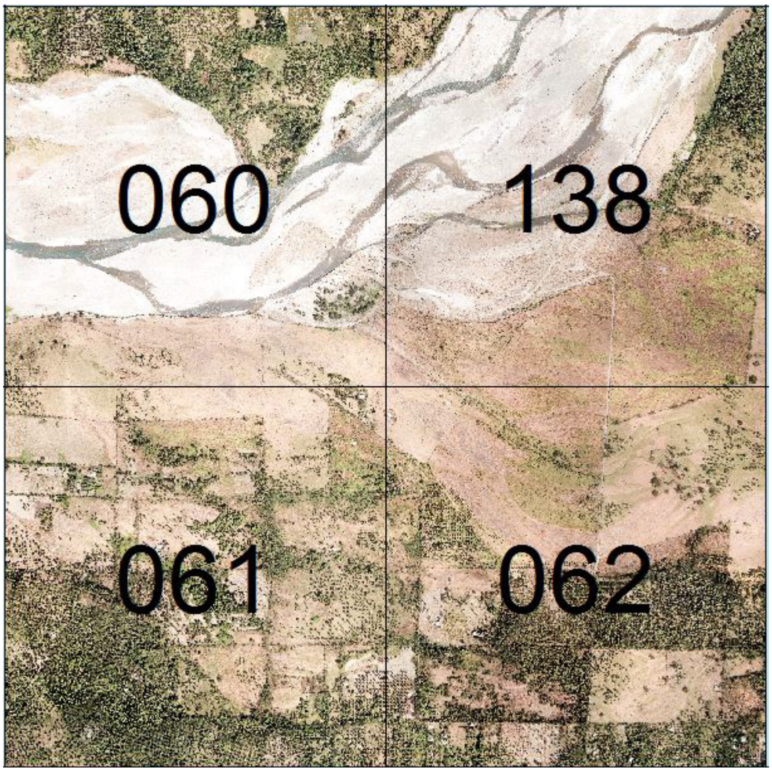

Figure 20. Sample orthophotograph tiles for Sumagui Floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Sumagui flood plain. These blocks are composed of OrientalMindoro and OrientalMindoro_reflights blocks with a total area of 691.87 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
OrientalMindoro_Blk28D_supplement	88.65
OrientalMindoro_Blk28E	125.84
OrientalMindoro_Blk28E_supplement	29.82
OrientalMindoro_Blk28F	124.61
OrientalMindoro_Blk28G	95.35
OrientalMindoro_Blk28G_supplementH	62.40
OrientalMindoro_Blk28H_supplement	84.37
OrientalMindoro_reflights_Blk28E	29.31
OrientalMindoro_reflights_Blk28H_supplement	51.52
TOTAL	**691.87 sq.km**

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The road (Figure 21c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water. Example of area with no data in the DTM (Figure 21e) after classification and has been retrieved through manual editing (Figure 21f) is also shown. The areas with no data could cause errors in the flood simulation.

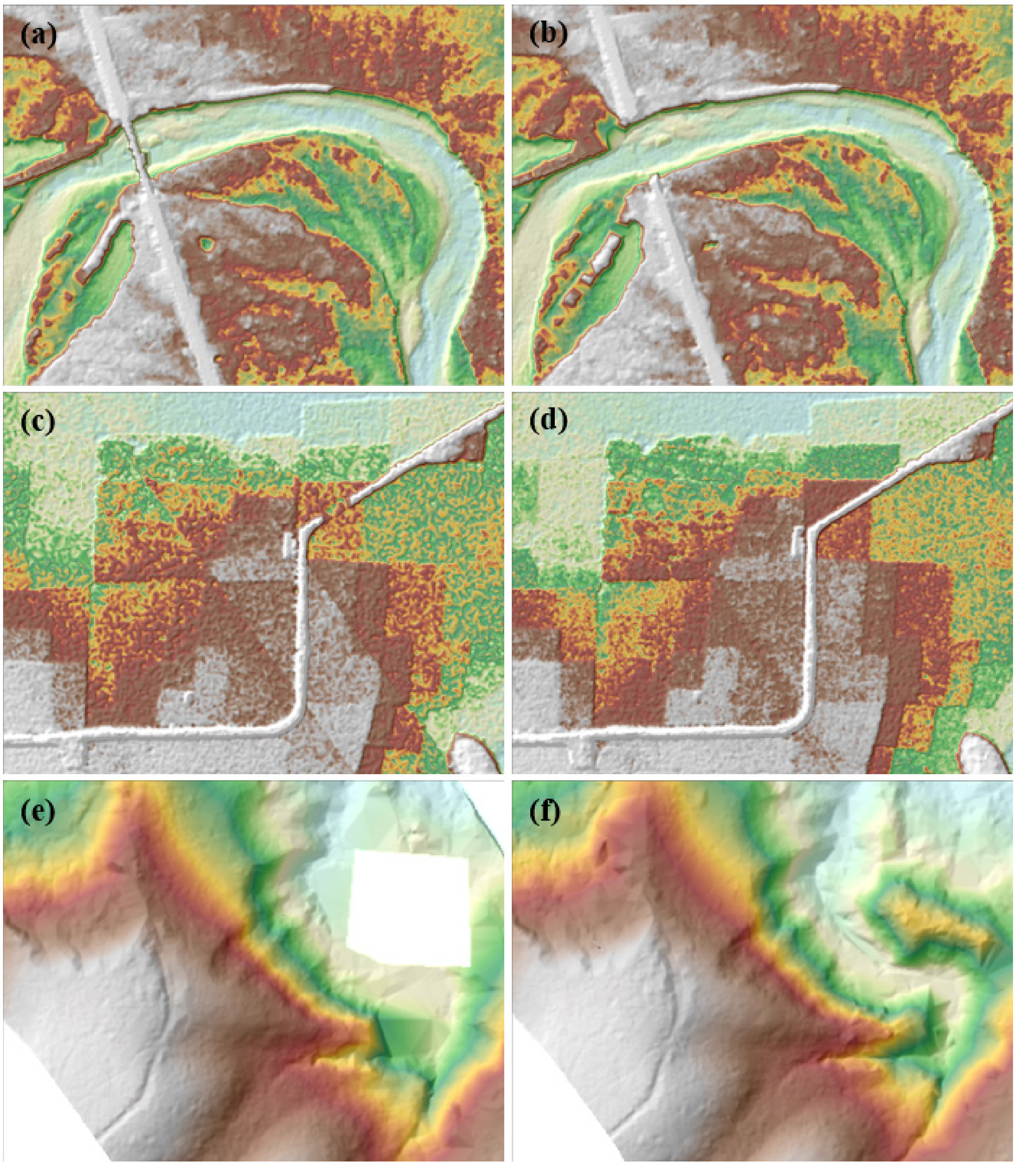

Figure 21. Portions in the DTM of Sumagui floodplain – a bridge before (a) and after (b) manual editing; a road before (c) and after (d) data retrieval; and a no data DTM before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

OrientalMindoro_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 18 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sumagui floodplain is shown in Figure 22. It can be seen that the entire Sumagui floodplain is 99.18% covered by LiDAR data.

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

Mission Blocks	Shift Values		
	x	y	z
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_Blk28F	0.00	0.00	0.84
OrientalMindoro_Blk28G	0.00	0.00	0.86
OrientalMindoro_Blk28G_supplementH	0.00	0.00	-0.08
OrientalMindoro_Blk28H_supplement	0.00	0.00	-0.29
OrientalMindoro_Reflights_Blk28E	0.00	0.00	-0.14
OrientalMindoro_Reflights_Blk28H_supplement	0.00	0.00	49.56

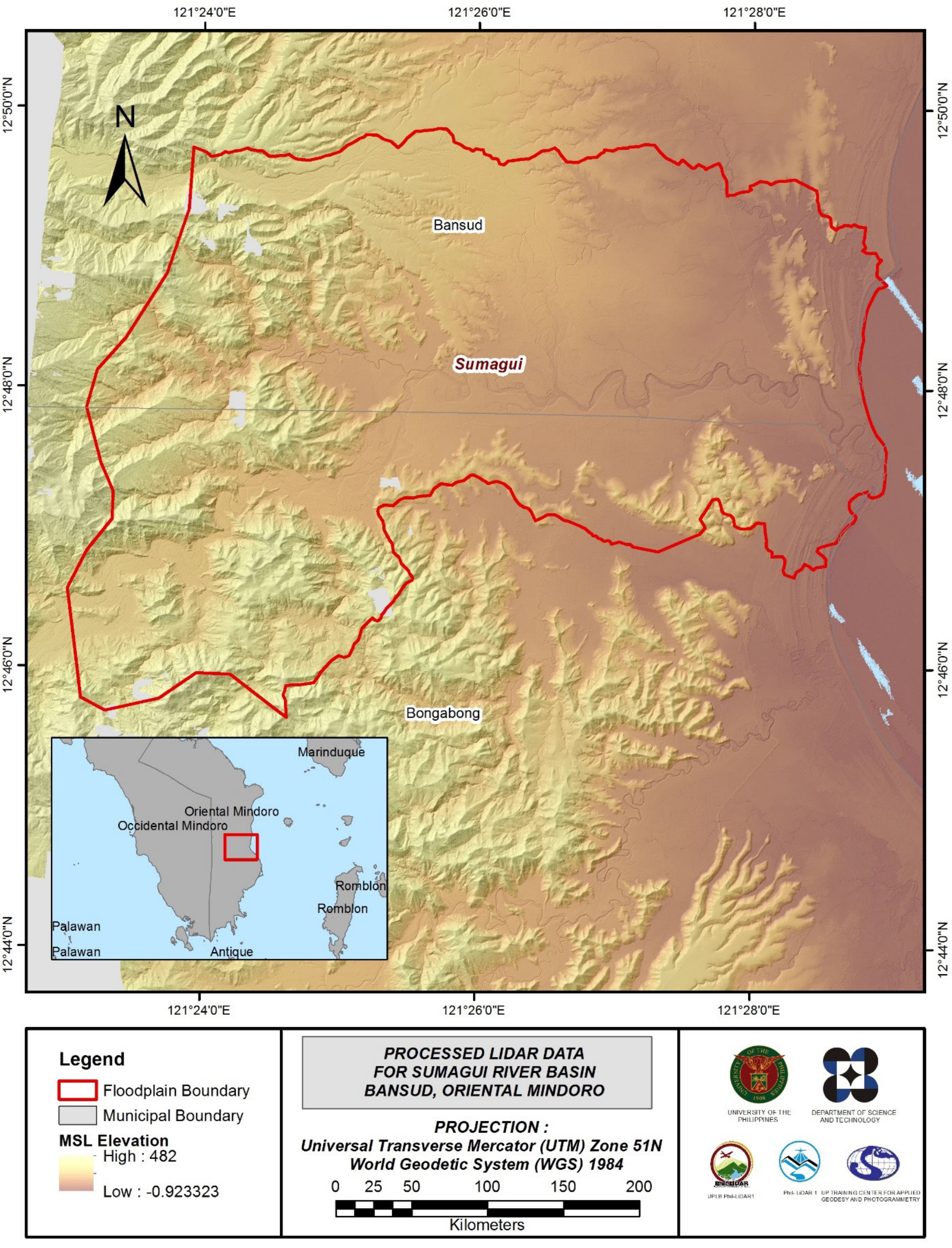

Figure 22. Map of Processed LiDAR Data for Sumagui Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Sumagui to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 2,986 survey points were used for calibration and validation of Sumagui LiDAR data. Random selection of 80% of the survey points, resulting to 2,392 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 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 2.62 meters with a standard deviation of 0.06 meters. Calibration of Sumagui LiDAR data was done by subtracting the height difference value, 2.62 meters, to Sumagui mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

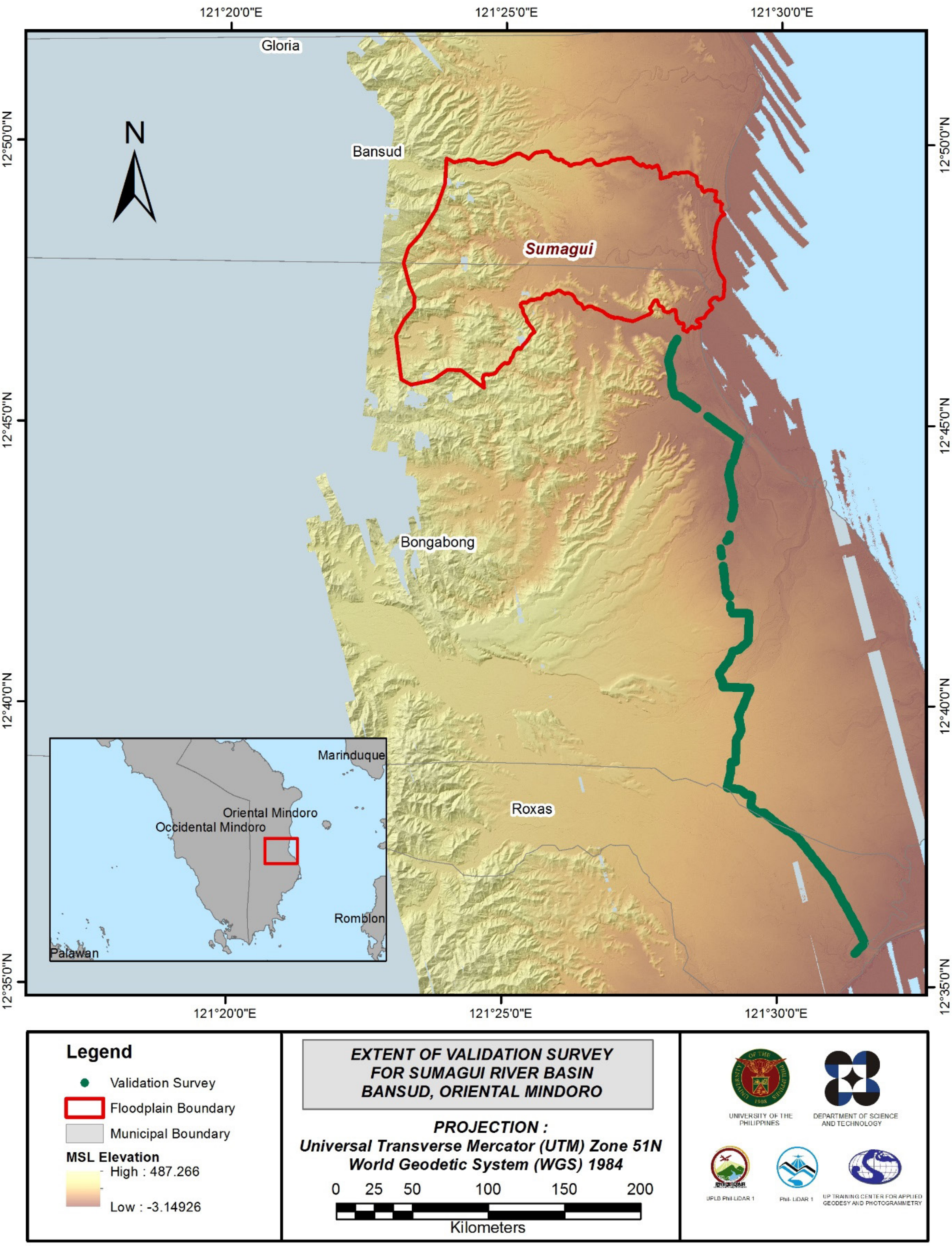

Figure 23. Map of Sumagui Floodplain with validation survey points in green.

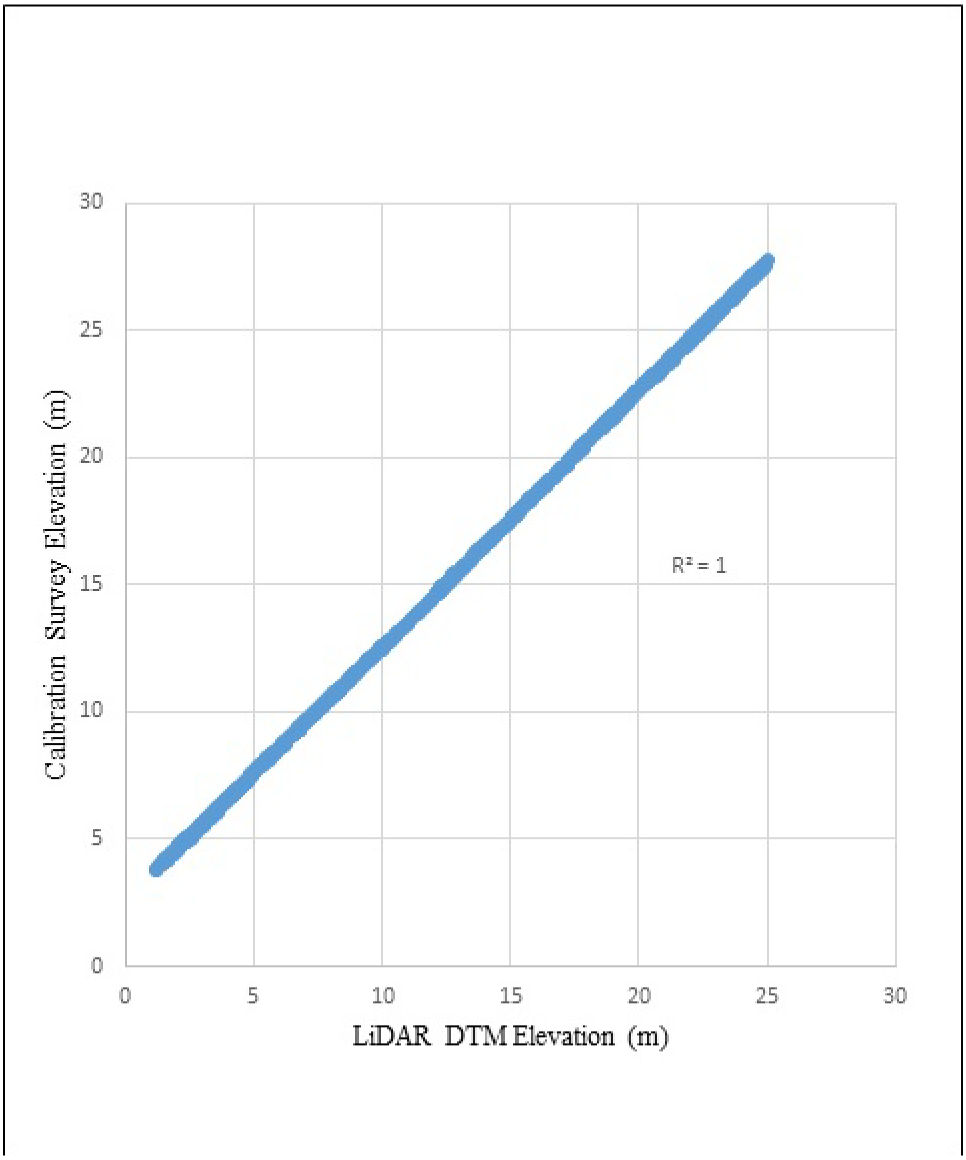

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	2.62
Standard Deviation	0.06
Average	-2.62
Minimum	-2.74
Maximum	-2.50

The remaining 20% of the total survey points, resulting to 594 points, were used for the validation of calibrated Sumagui 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 0.06 meters with a standard deviation of 0.06 meters, as shown in Table 20.

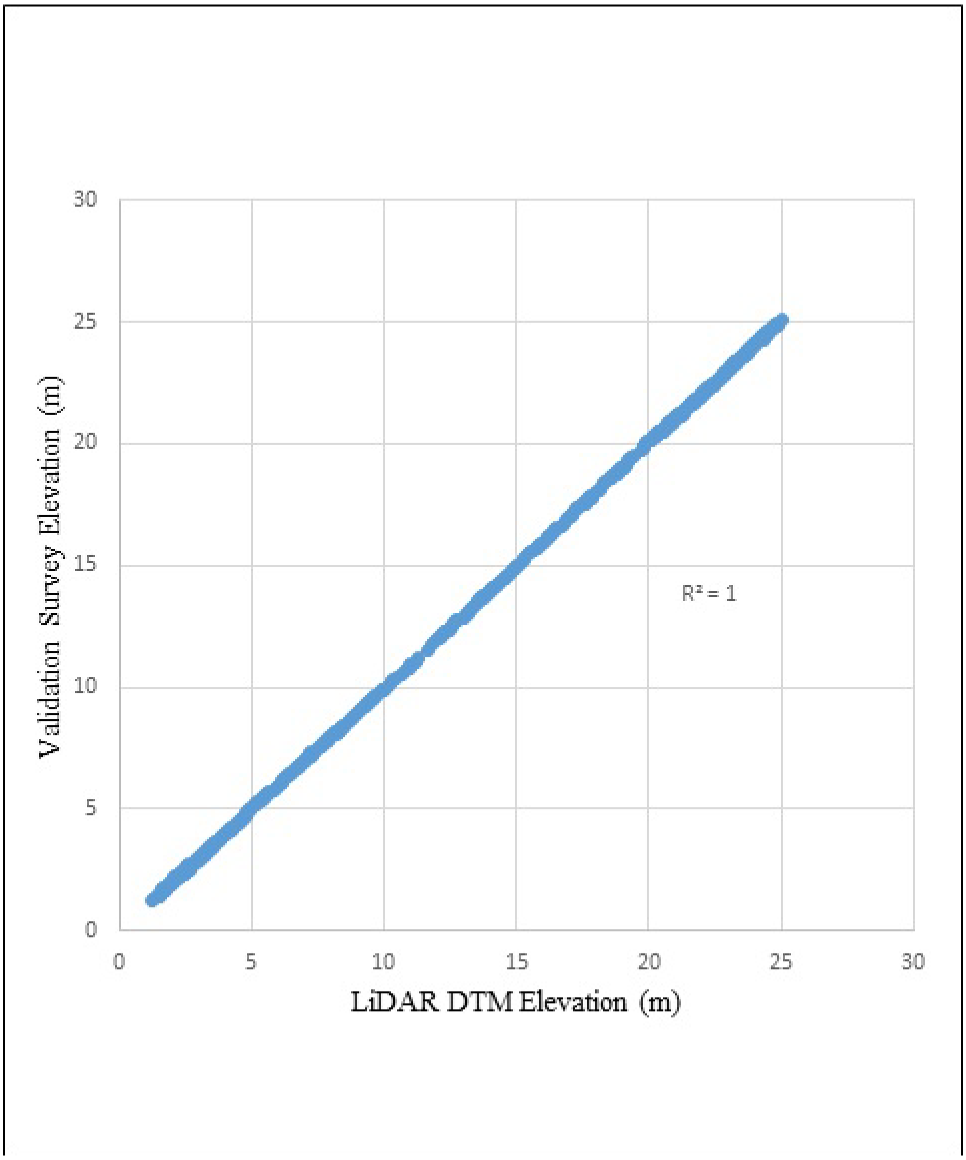

Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.06
Standard Deviation	0.06
Average	-0.001
Minimum	-0.12
Maximum	0.12

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Sumagui with 1,609 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 0.13 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sumagui integrated with the processed LiDAR DEM is shown in Figure 26.

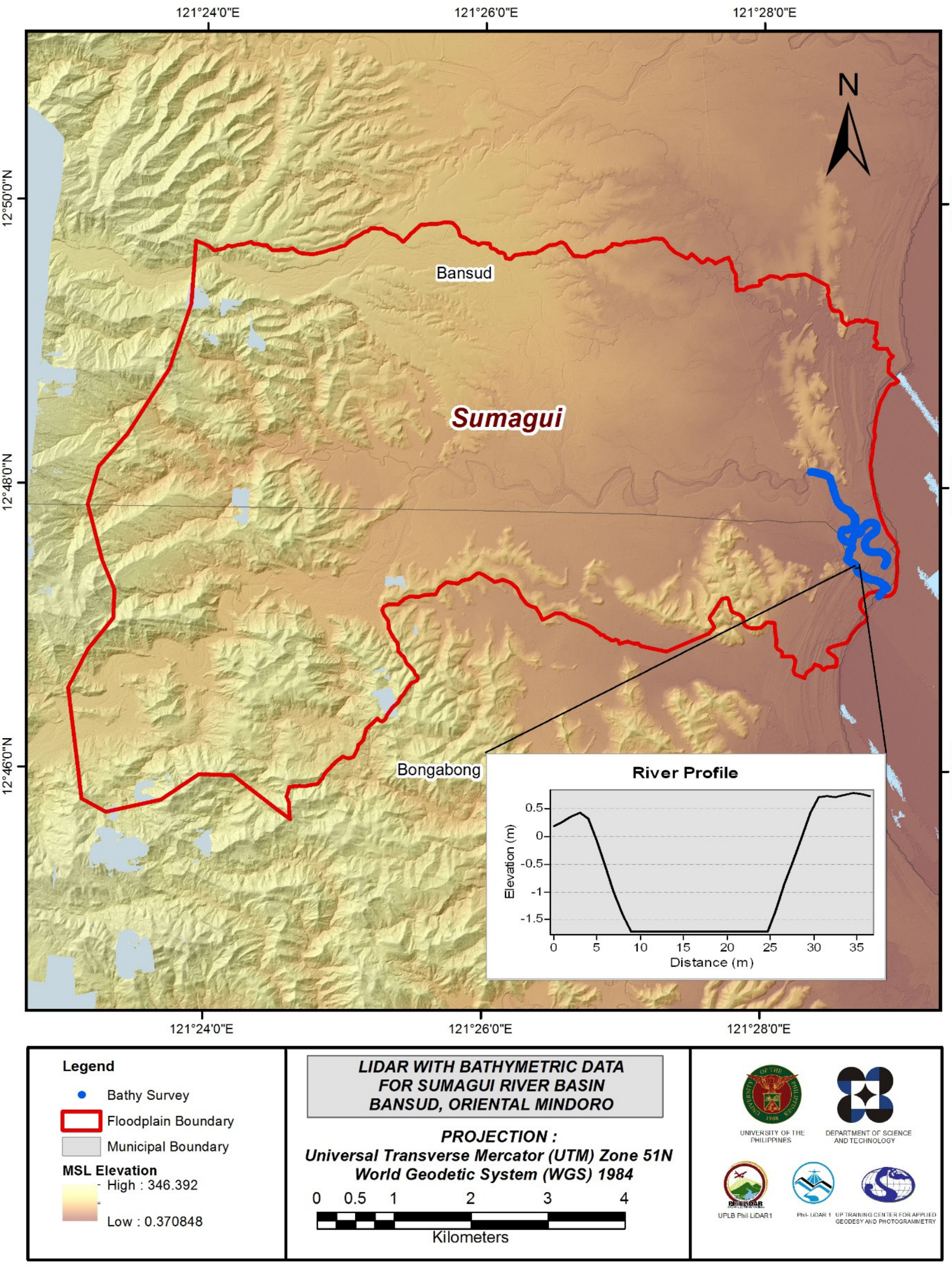

Figure 26. Map of Sumagui Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Sumagui River Survey on May 30 to June 11, 2014 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey and retrieval of control points to be used; courtesy call to the University of Los Baños, and LGU of Sumagui; control survey for the establishment of control point at the approach of Sumagui bridge occupied as base station for GNSS surveys; cross-section, bridge-as-built and water level marking of Sumagui bridge in Brgy. Sumagui, Municipality of Bansud; and bathymetric survey of Sumagui River of approximately 3.48 km starting from the Sumagui Bridge, to the upstream of Brgy. Sumagui down to mouth of Tablas Strait utilizing Trimble® SPS 882 GNSS PPK survey technique. LiDAR ground validation survey covering the river basin with estimated distance of 12.0 km was also conducted on November 3, 2014. The entire survey extent is illustrated in Figure 27.

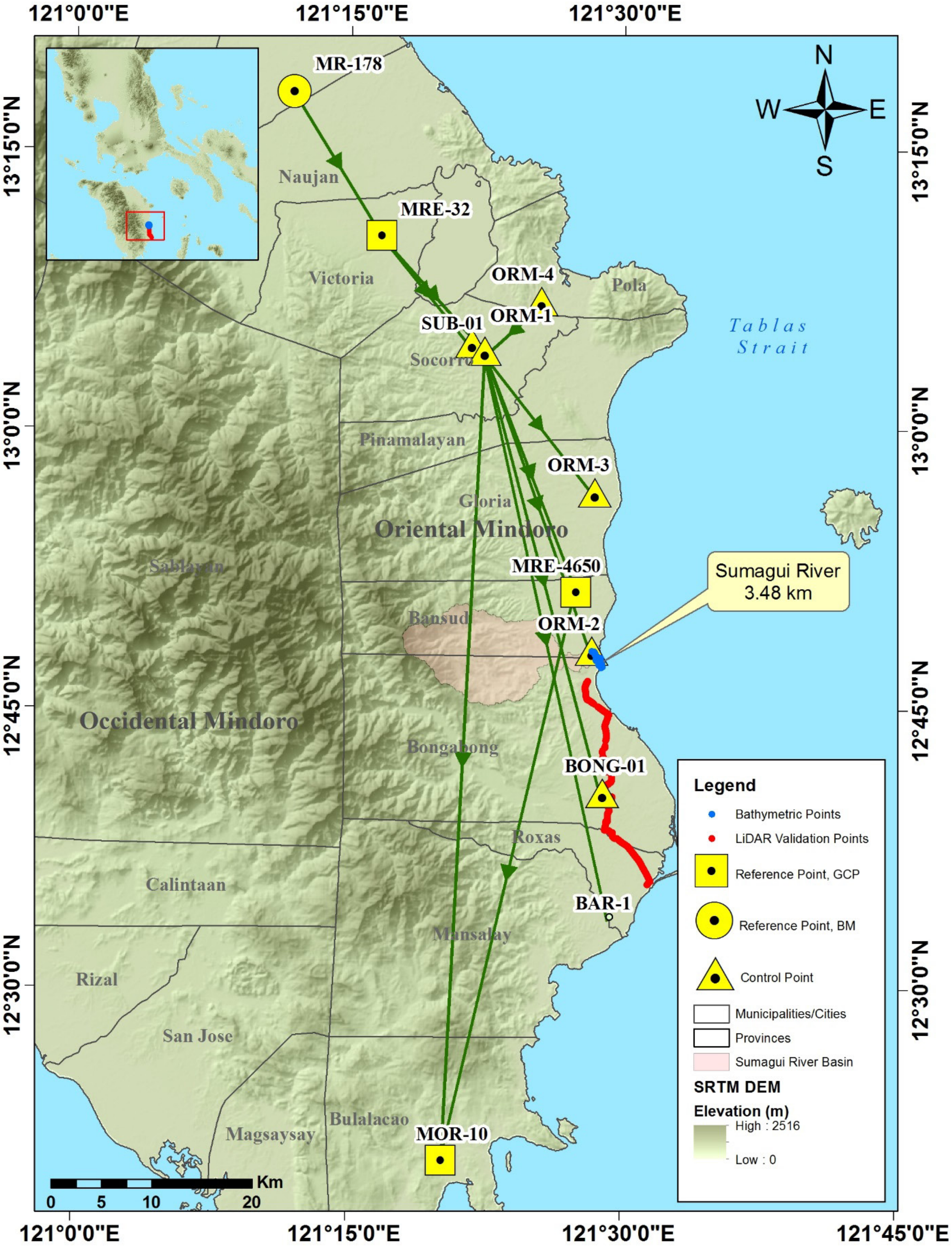


Figure 27. Sumagui River Survey Extent

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 Sumagui River Basin 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 references and control points and its location is summarized in Table 25 while the GNSS network established is illustrated in Figure 28.

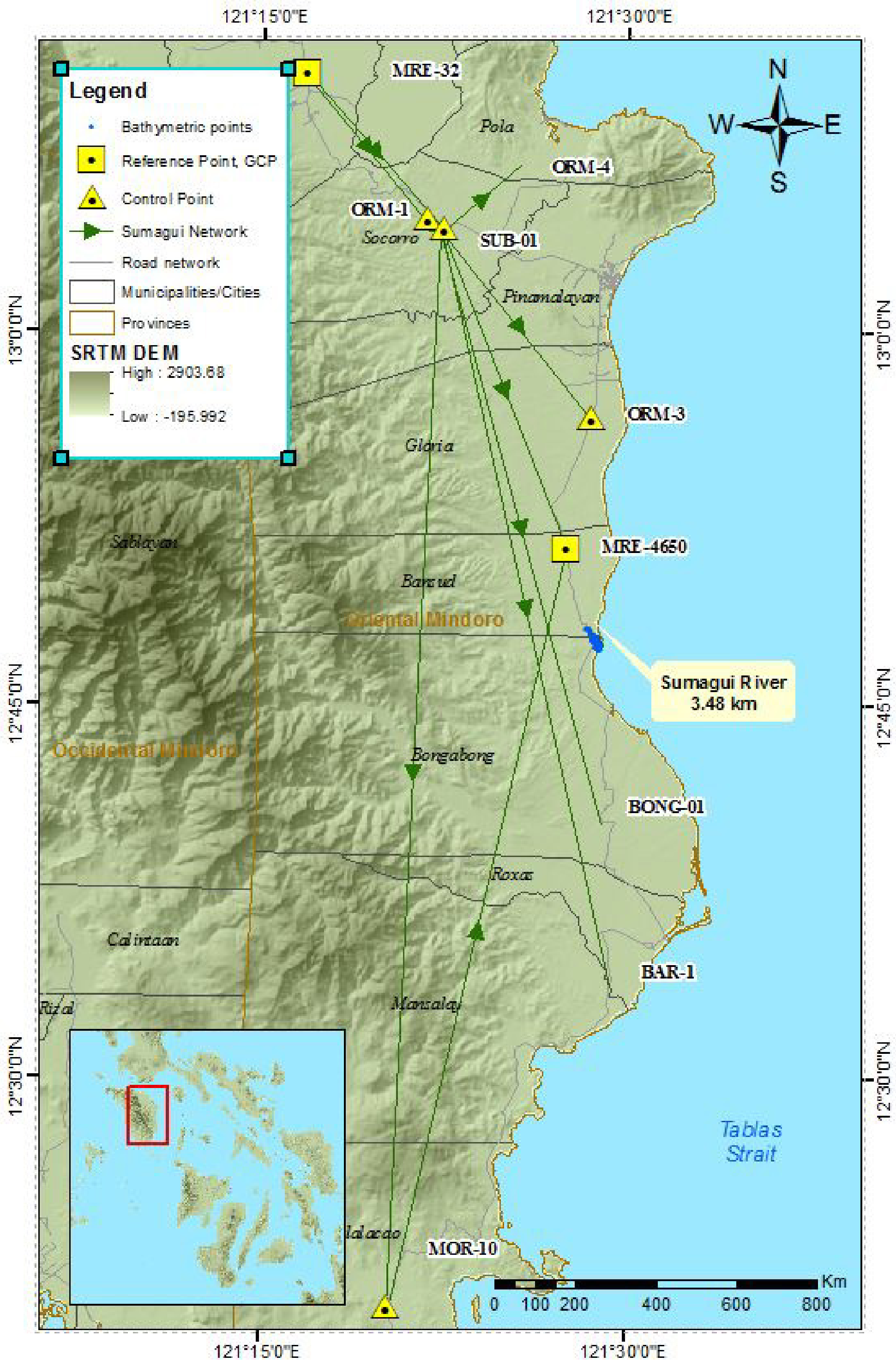


Figure 28. GNSS Network covering Sumagui River

Table 21. List of reference and control points used during the survey in Sumagui River
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (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 29 to Figure 37.

Figure 29. GPS setup of Trimble® SPS 882 at MRE-32, located at the Municipal Park of Victoria, in Brgy. Poblacion 1, Oriental Mindoro

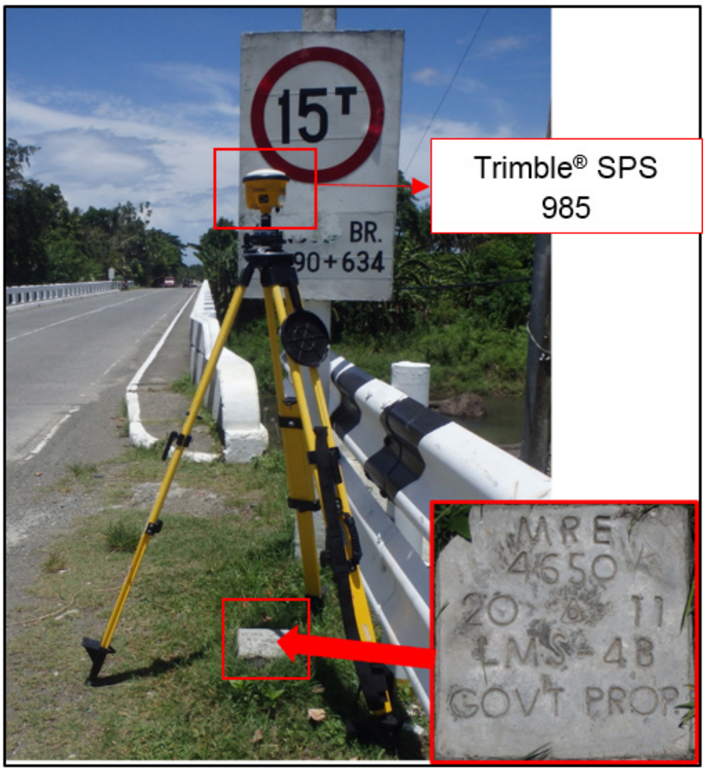


Figure 30. The GPS setup of Trimble® SPS 985 at MRE-4650, an LMS control point located at the approach of Bansud Bridge, in Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro

Figure 31. GPS setup of Trimble® SPS 882 at BAR-1, an established control point located in Baroc Bridge, Brgy. San Isidro, Mansalay, Oriental Mindoro

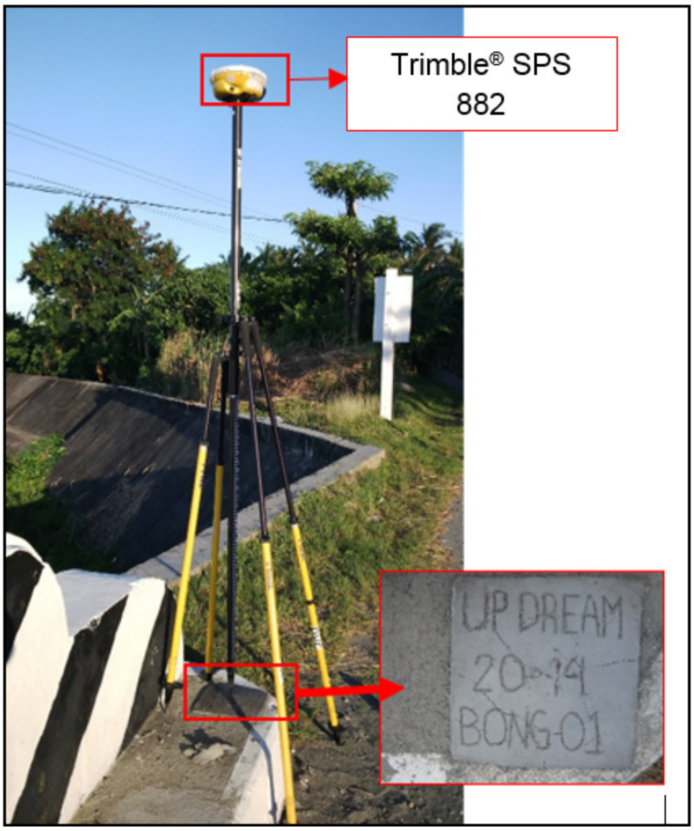


Figure 32. GNSS setup of Trimble® SPS 882 on BONG-01 in Brgy. San Isidro, Municipality of Bongabong, Oriental Mindoro

Figure 33. GPS setup of Trimble® SPS 852 at MOR-10, located in the approach of the Cawacat Bridge, in Bry. Campasaan, Municipality of Bulalacao, Oriental Mindoro

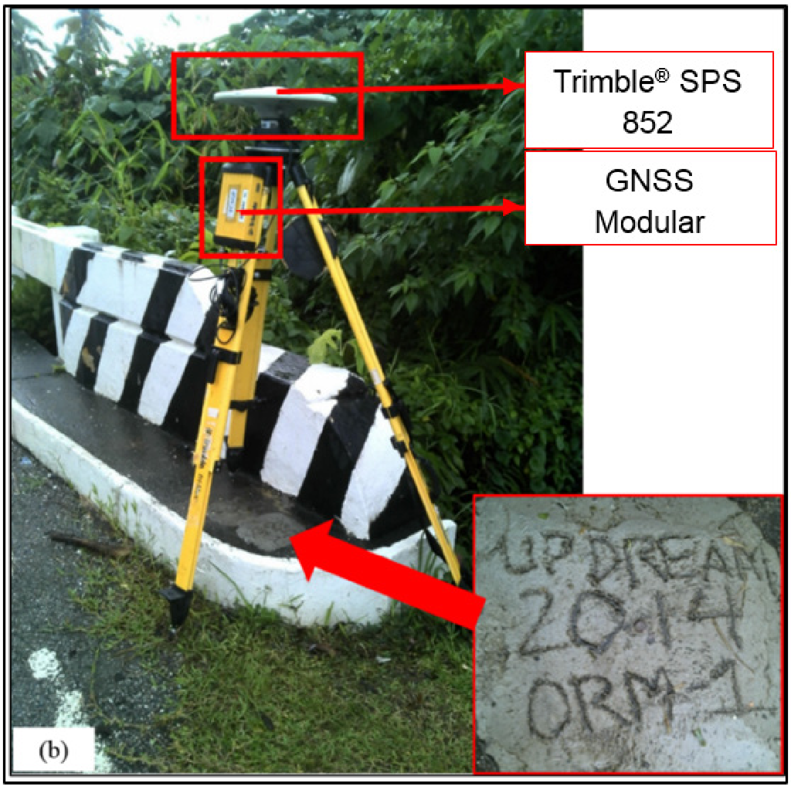


Figure 34. GPS setup of Trimble® SPS 852 at ORM-1, located on Subaan Bridge, Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

Figure 35. Trimble® SPS 985 setup at ORM-3 located at the approach of Balete Bridge, Brgy. Balete, Municipality of Gloria, Oriental Mindoro

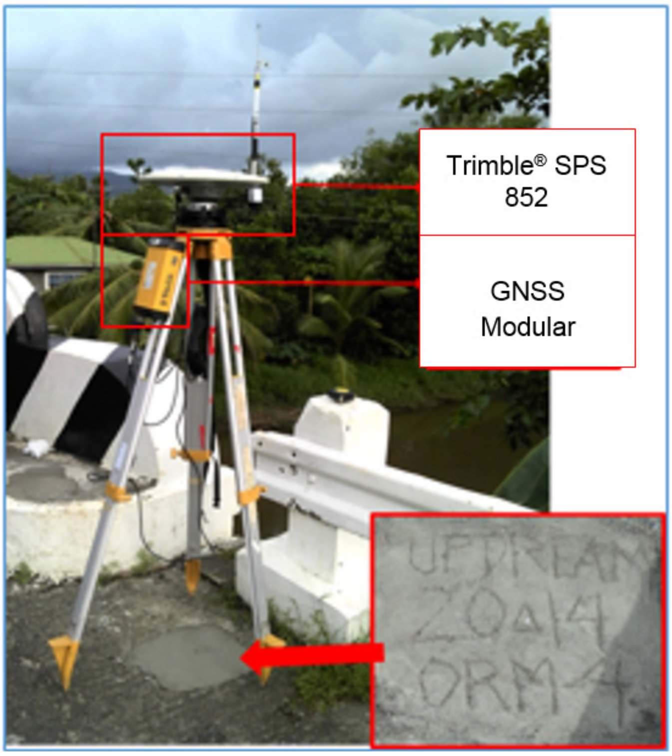


Figure 36. GNSS receiver Trimble® SPS 852 setup at ORM-4, located at the right side of the approach of Pola Bridge in Barangay Casiligan, Municipality of Pola, Oriental Mindoro

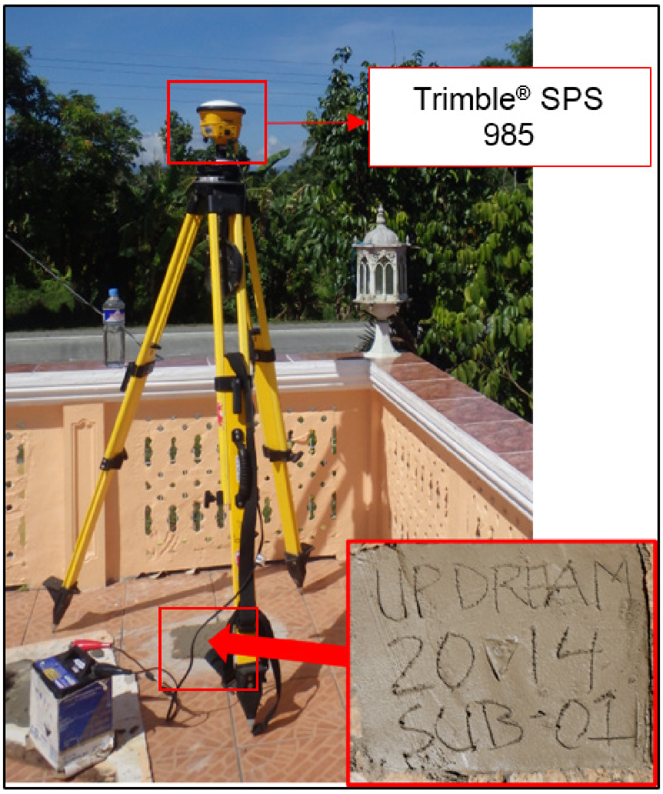


Figure 37. GPS setup of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

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 +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Sumagui River Basin is summarized in Table 22 generated TBC software.

Table 22. Baseline Processing Report for Sumagui River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
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 22, 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:

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

Where:

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

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

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 23. Through these reference points, the coordinates and elevation of the unknown control points were computed.

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

Table 24. 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 C-5.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:

a.MRE-32

Horizontal accuracy = Fixed
Vertical accuracy = Fixed

b.MOR-10

Horizontal accuracy = √ ((1.0) ² + (1.0) ²
= √(1.0 + 1.0)
= 1.1 cm < 20 cm
Vertical accuracy = 1.4 cm< 10 cm

c.MRE-4650

Horizontal accuracy = √ ((0.8) ² + (0.6) ²
= √(0.64 + 0.36)
= 1.0 cm < 20 cm
Vertical accuracy = 4.9 cm < 10 cm

d.ORM-1

Horizontal accuracy	=	√ ((0.7) ² + (0.3) ²
	=	√(0.49 + 0.90)
	=	1.2 cm < 20 cm
Vertical accuracy	=	2.8 cm < 10 cm

e.SUB-01

Horizontal accuracy	=	√ ((0.7) ² + (0.3) ²
	=	√(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 25. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	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-4650	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 corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	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 Cross-section, Bridge As-Built Survey and Water Level Marking

Cross-section and As-built survey was conducted on June 1, 2014 along the downstream side of Sumagui Bridge in Brgy. Sumagui, Municipality of Bansud using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 38. The bridge deck was also measured to get the high cord, and meter tapes to get its low cord elevation.

Figure 38. Cross-section and bridge as-built survey for Sumagui Bridge, Brgy Sumagui, Oriental Mindoro

The cross-sectional line for the Sumagui Bridge is about 70 meters with 27 cross-sectional points using the control point SUB-1 as the GNSS base station. The location map, summary of gathered cross-section and as-built data for Sumagui Bridge in diagram, and bridge as-bulilt form are displayed in Figure 39 to Figure 41, respectively.

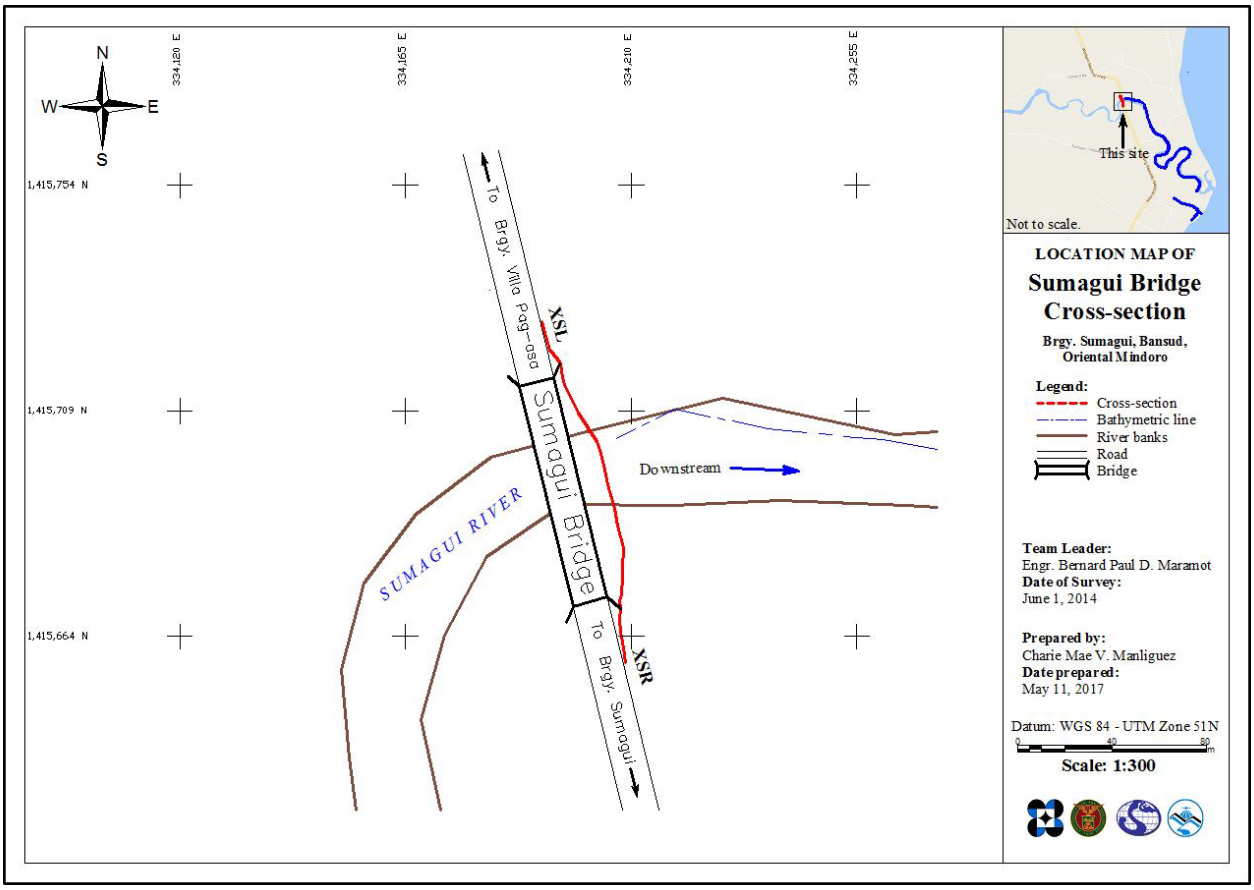


Figure 39. Location Map of Sumagui Bridge River Cross-Section survey

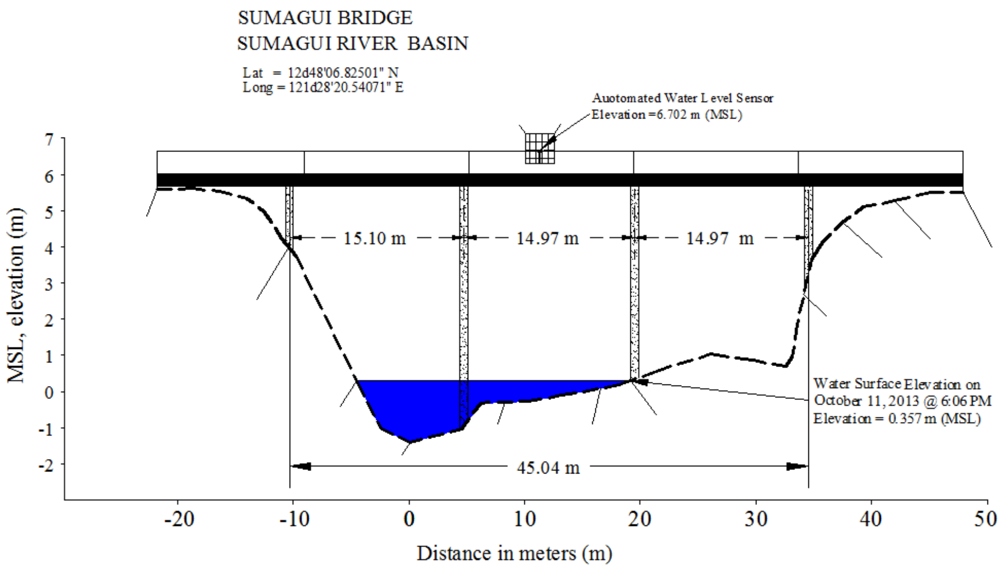


Figure 40. Sumagui Bridge cross-section diagram

Bridge Data Form

Bridge Name: SUMAGUI BRIDGE **Date:** October 30, 2014

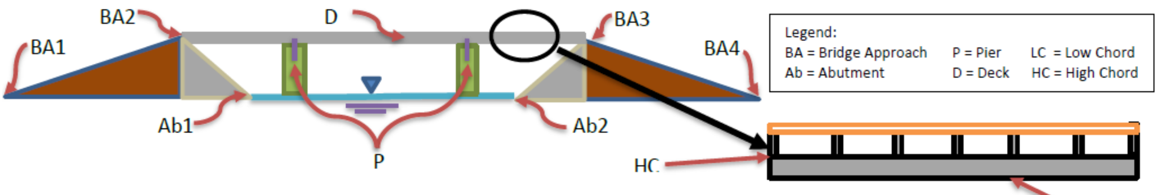
River Name: SUMAGUI RIVER **Time:** 2:55 PM

Location (Brgy, City, Region): Brgy. Sumagui, Municipality of Bansud, Oriental Mindoro

Survey Team: TEAM BERNARD

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

Latitude: 12d48'06.82501"N **Longitude:** 121d28'20.54071"E



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

Elevation 5.888 m **Width:** ______ **Span (BA3-BA2):** 48.010 m

	Station	High Chord Elevation	Low Chord Elevation
1		5.887 m	4.18 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	6.693	BA3	90.152	5.871
BA2	42.143	5.899	BA4	139.537	5.599

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

	Station (Distance from BA1)	Elevation
Ab1	50.1123531	1.266 m
Ab2	88.26931607	1.291 m

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

Shape: CYLINDRICAL **Number of Piers:** 4 **Height of column footing:** ______

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	45.25622	5.844	
Pier 2	60.1916	5.903	
Pier 3	75.18152	5.822	
Pier 4	90.61941	5.797	
Pier 5			
Pier 6			

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

Figure 41. Bridge as-built form of Sumagui Bridge

4.6. Validation Points Acquisition Survey

Validation points acquisition survey was conducted on June 5, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached in front of the vehicle as shown in Figure 42. 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 1.498m from the ground up to the bottom of notch of the GNSS Rover receiver.

The survey was conducted using PPK technique on a continuous topography mode, which started from Barangay Happy Valley, Municipality of Socorro to Barangay Panikihan, Municipality of Pola which gathered 1,900 validation points covering an approximate distance of 30 kilometers. The gaps in the validation line as shown in Figure 43 were due to some difficulties in acquiring satellite due to the presence of obstruction such as dense canopy cover of trees along the roads.

Figure 42. Trimble SPS®882 set-up for validation points acquisition survey for Sumagui River

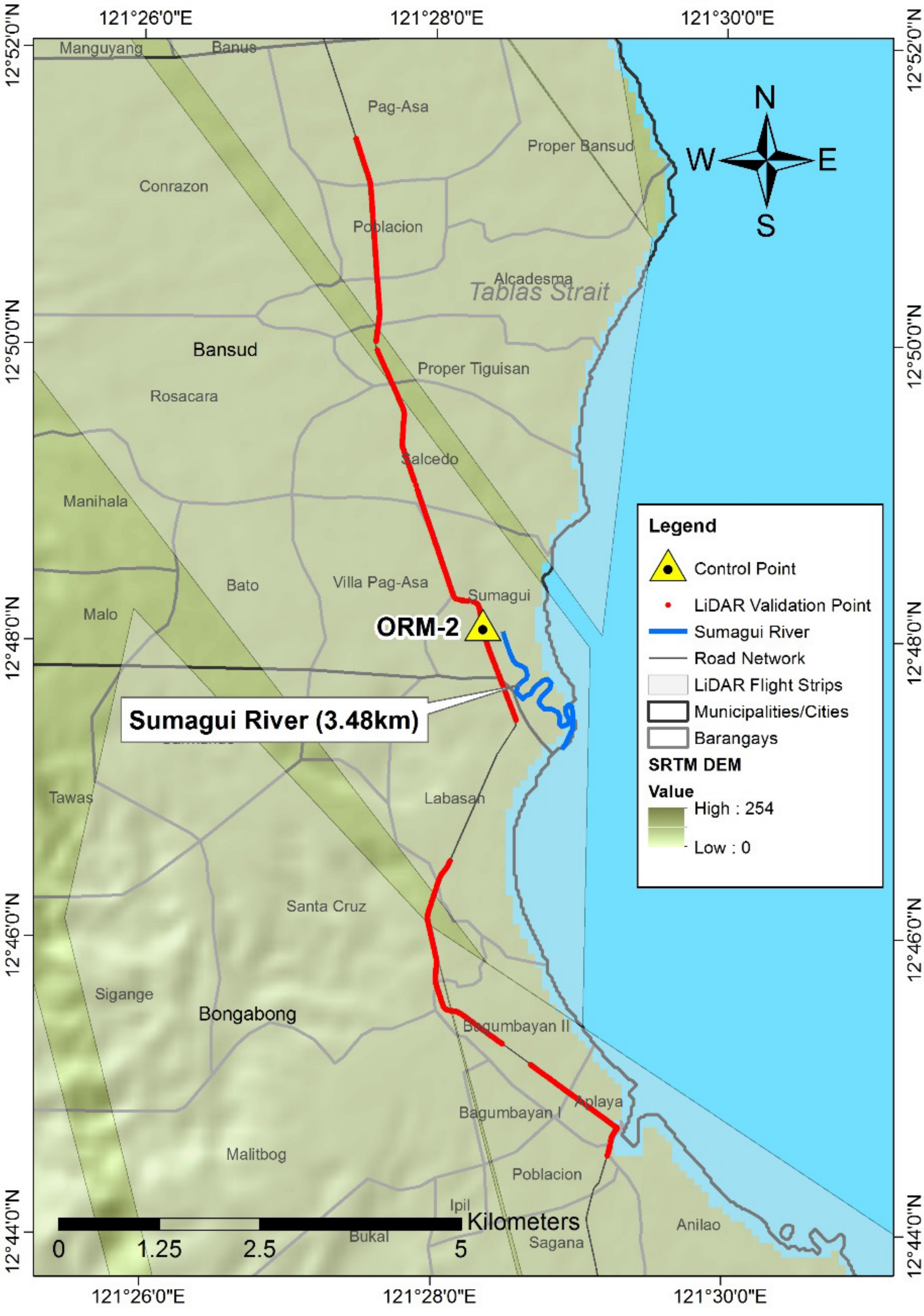


Figure 43. Validation point acquisition survey of Sumagui River Basin

4.7 Bathymetric Survey

Bathymetric survey was conducted from June 2 to 7, 2014 at Sumagui River using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 44. The survey started in the upstream part of the river in Brgy. Sumagui, Municipality of Bansud with coordinates 12°48'06.82501" 121°28'20.54071" and ended at the mouth of the river also in Brgy. Sumagui with coordinates 12°47'14.24208" 121°28'50.77234". The control point ORM-2 was used as the GNSS base station all throughout the survey.

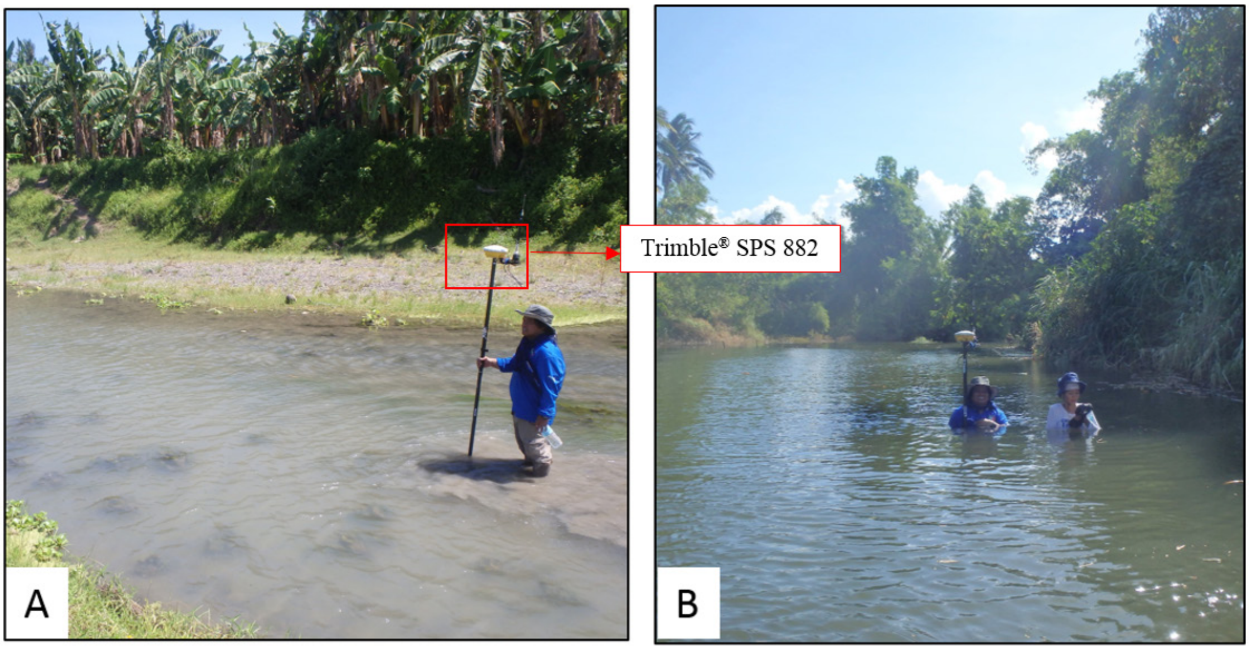


Figure 44. Bathymetric survey in Sumagui River: (a) upstream and (b) downstream

The bathymetric line surveyed has an estimated length of 3.48 km with 1,678 bathymetric poits acquired covering only Brgy. Sumagui, in Bansud as shown in Figure 45. A CAD drawing was also produced to illustrate the Sumagui Riverbed Profile that illustrate the Sumagui riverbed profile. As shown in Figure 46, the highest and lowest elevation has a 3-m difference. The highest elevation observed was 1.047 m in MSL located 200 m from the upstream while the lowest elevation observed was -2.269 m below MSL located near the mouth of the river.

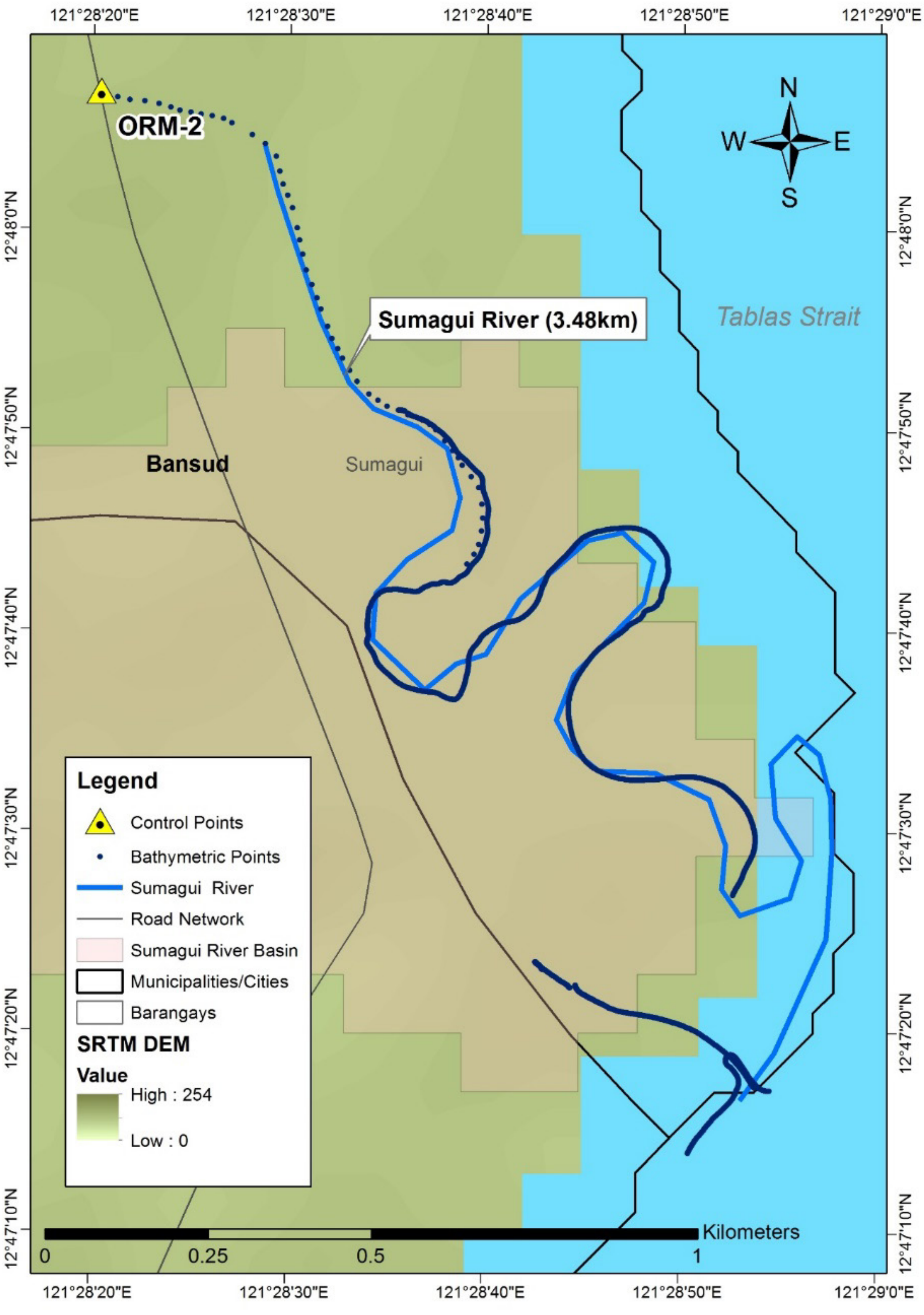


Figure 45. Bathymetric survey of Sumagui River

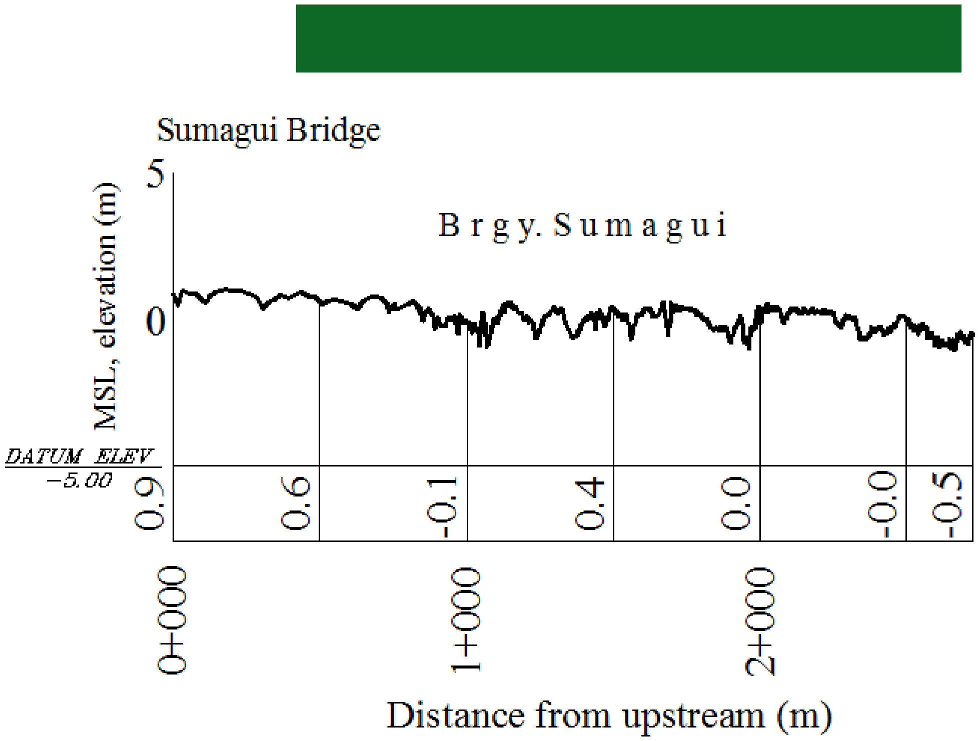


Figure 46. Sumagui Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed in Brgy. Villa Pag-asa (12.7932 N, 121.431817 E). The location of the rain gauge is seen in Figure 47.

The total rainfall for this event from the Brgy Villa Pag-asa rain gauge is 52.6 mm. It has peak rainfall of 10.8

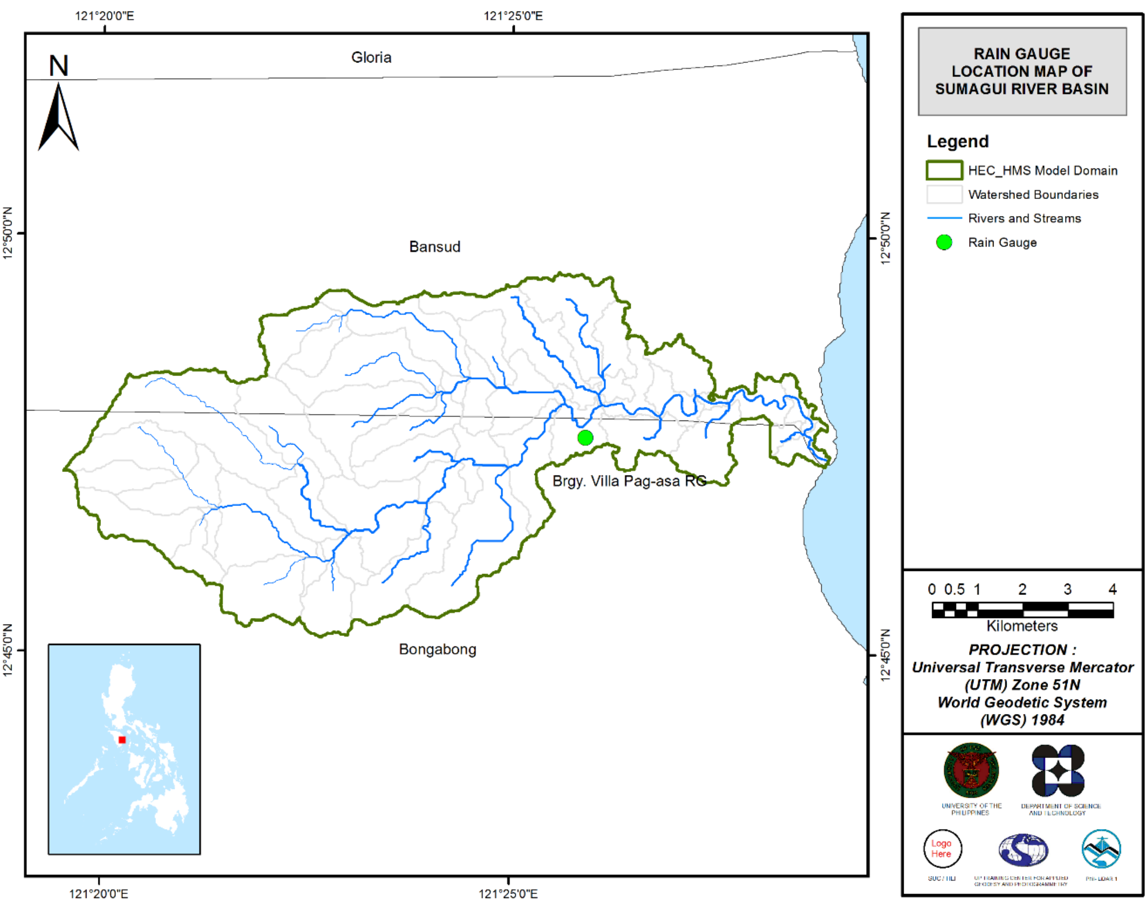


Figure 47. The location map of Sumagui HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sumague Bridge, Sumagui, Oriental Mimdoro (12 48' 6.82501" N, 121 28' 20.54071" E). It gives the relationship between the observed water levels from the AWLS and the outflow of the watershed at this location.

For Sumagui Bridge, the rating curve is expressed as $Q = 48.975e^{0.4786x}$ as shown in Figure 49.

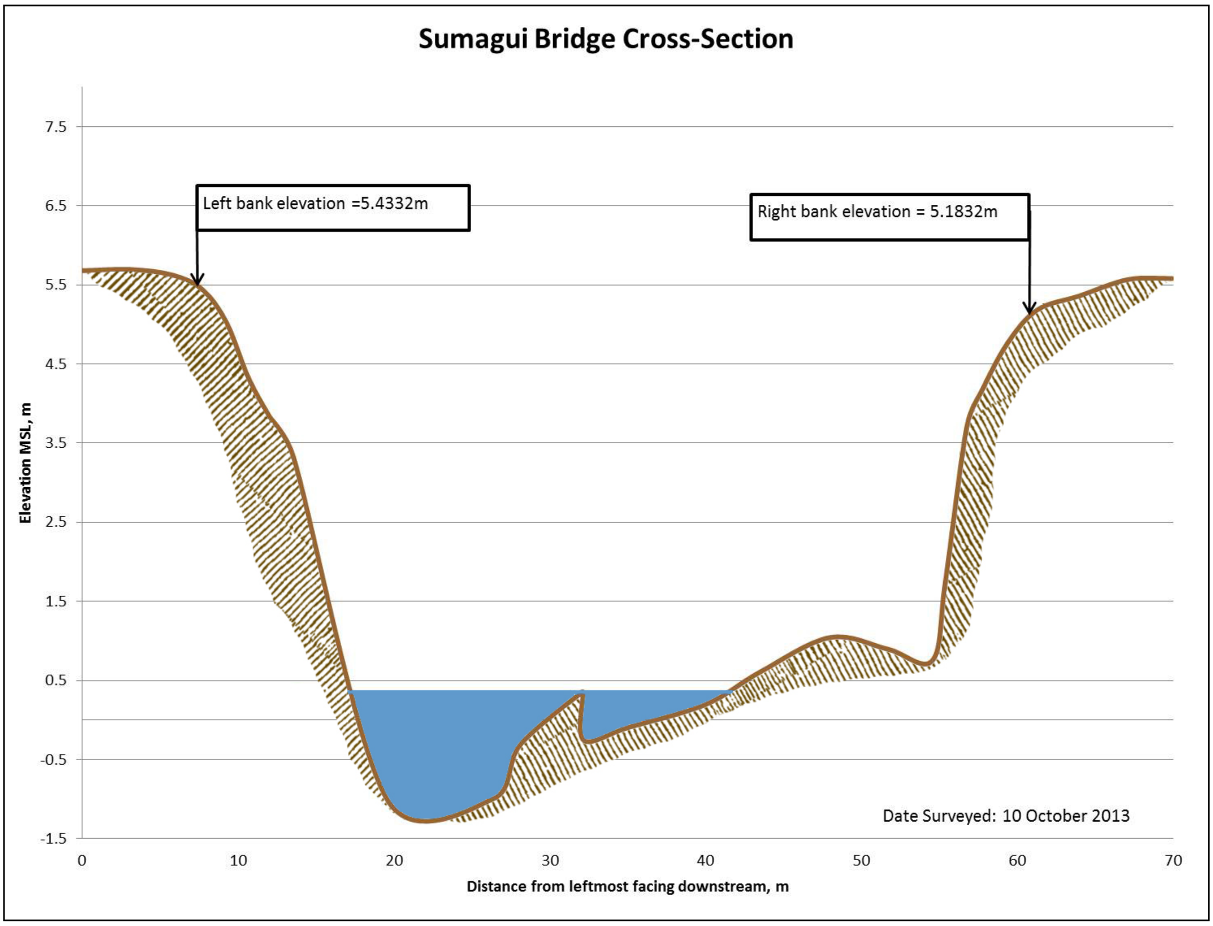


Figure 48. Cross-Section Plot of Sumagui Bridge

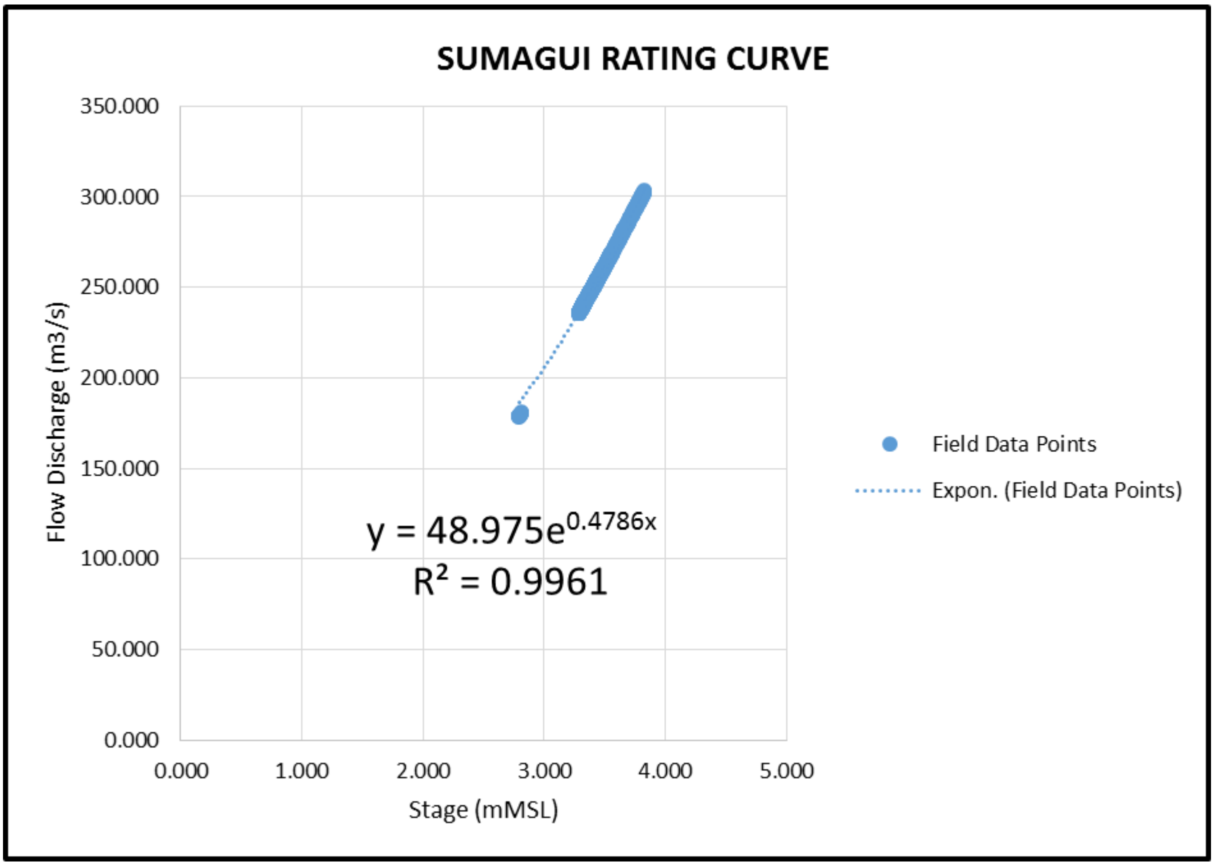


Figure 49. Rating curve at Sumagui Bridge, Sumagui, Oriental Mindoro

This rating curve equation was used to compute the river outflow at Sumagui (also spelled as "Sumague") Bridge for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge was found to be 156.30 cu.m/s at 9:20 AM, March 27, 2015.

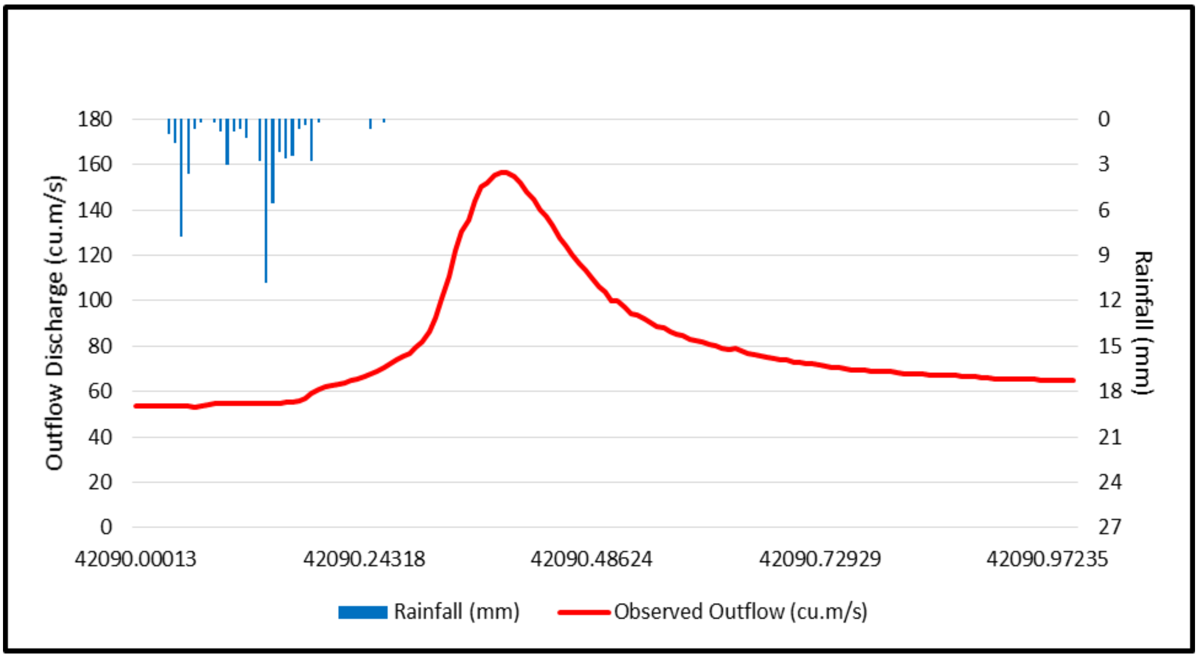


Figure 50. Rainfall and outflow data at Sumagui River Basin used for modeling

5.2 RIDF Station

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

Table 27. RIDF values for Sumagui Rain Gauge computed by PAGASA

T (yrs)	10 min	20 min	30 min	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

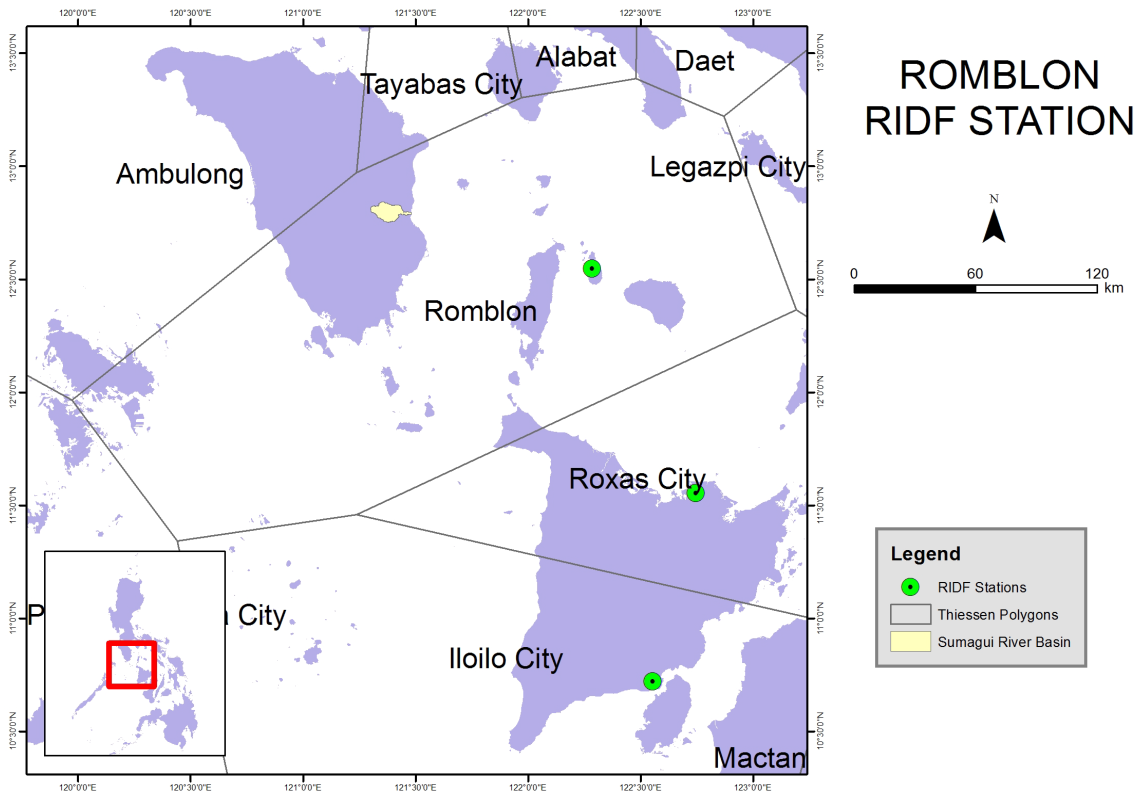


Figure 51.Location of Romblon RIDF relative to Sumagui River Basin

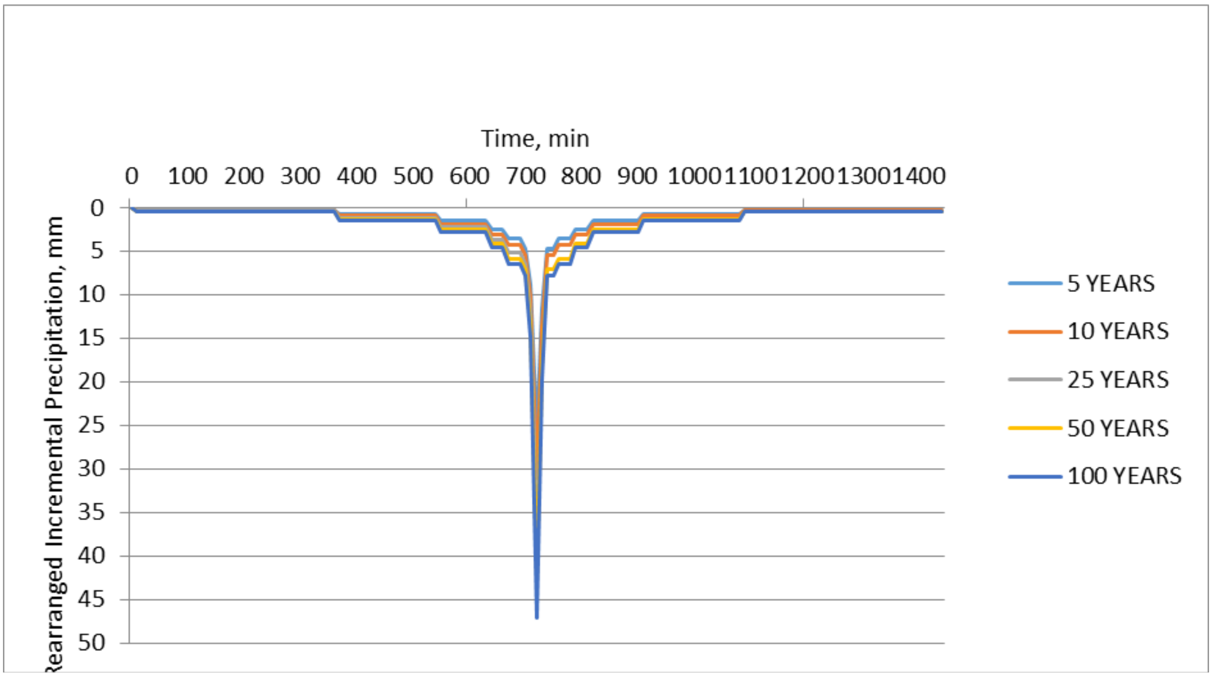


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Sumagui River Basin are shown in Figure 53 and Figure 54, respectively.

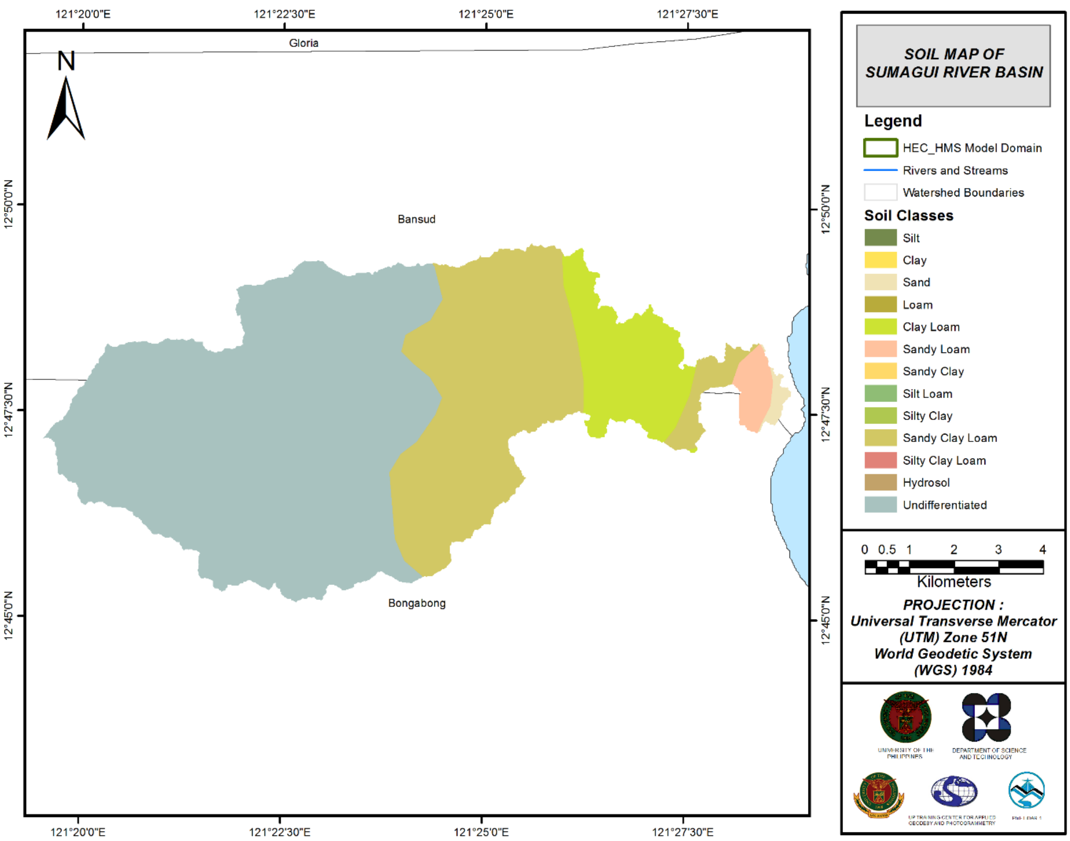


Figure 53. Soil map of Sumagui River Basin used for the estimation of the CN parameter. (Source: DA)

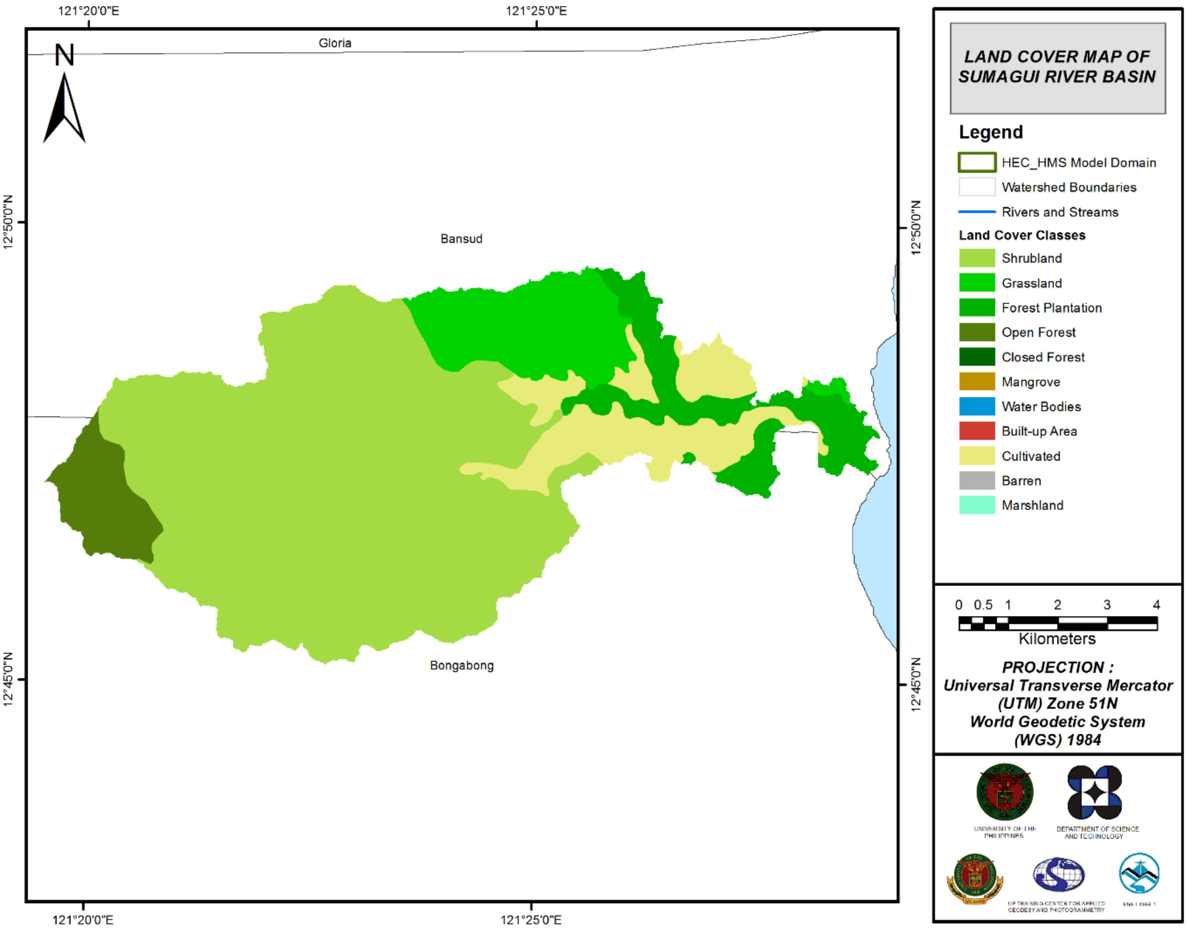


Figure 54. Land cover map of Sumagui River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Sumagui river basin, the five (5) soil classes identified were sandy clay loam, clay loam, sandy loam, and sand, while the rest is undifferentiated. The three (3) land cover types identified were largely shrubland, with portions of grassland, forest plantation, open forest, and cultivated land.

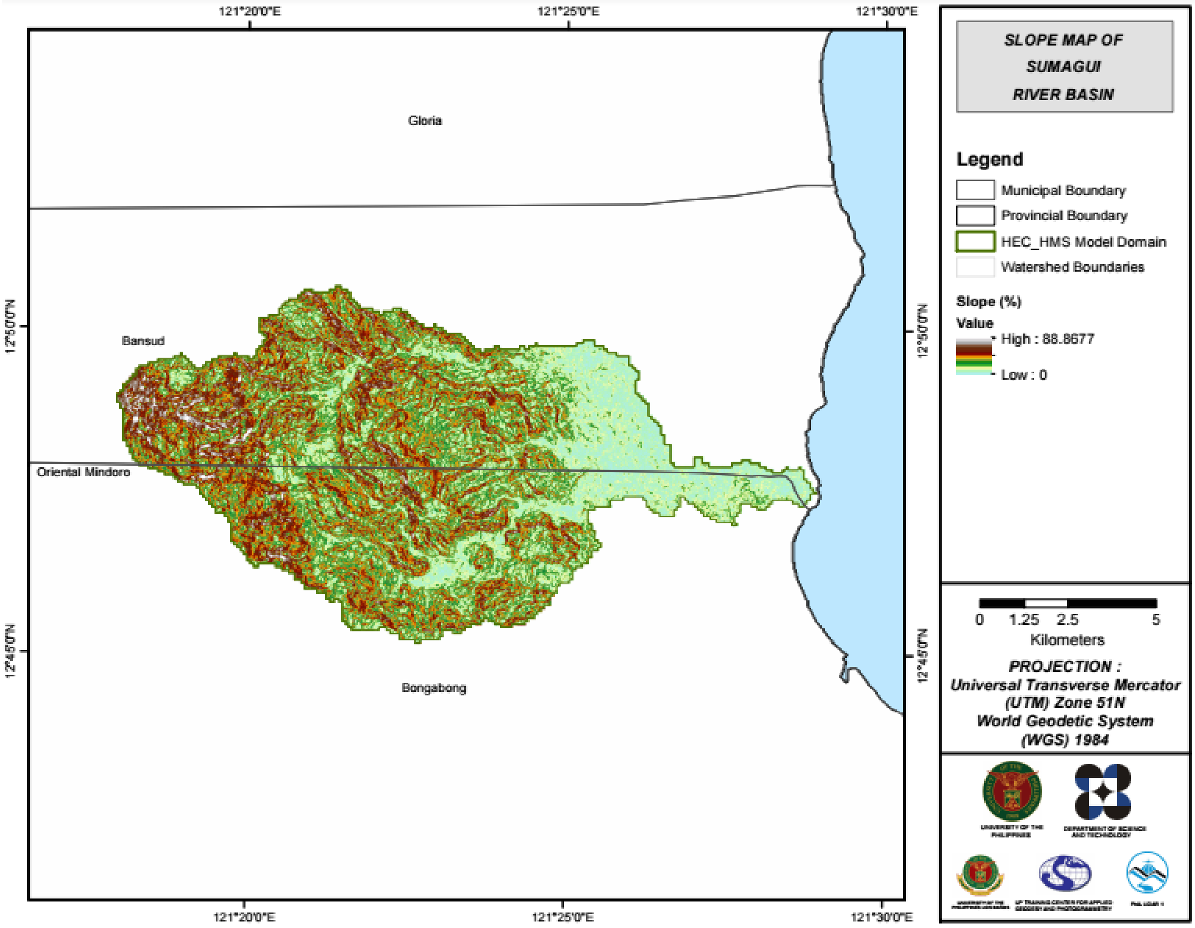


Figure 55. Slope map of Sumagui River Basin

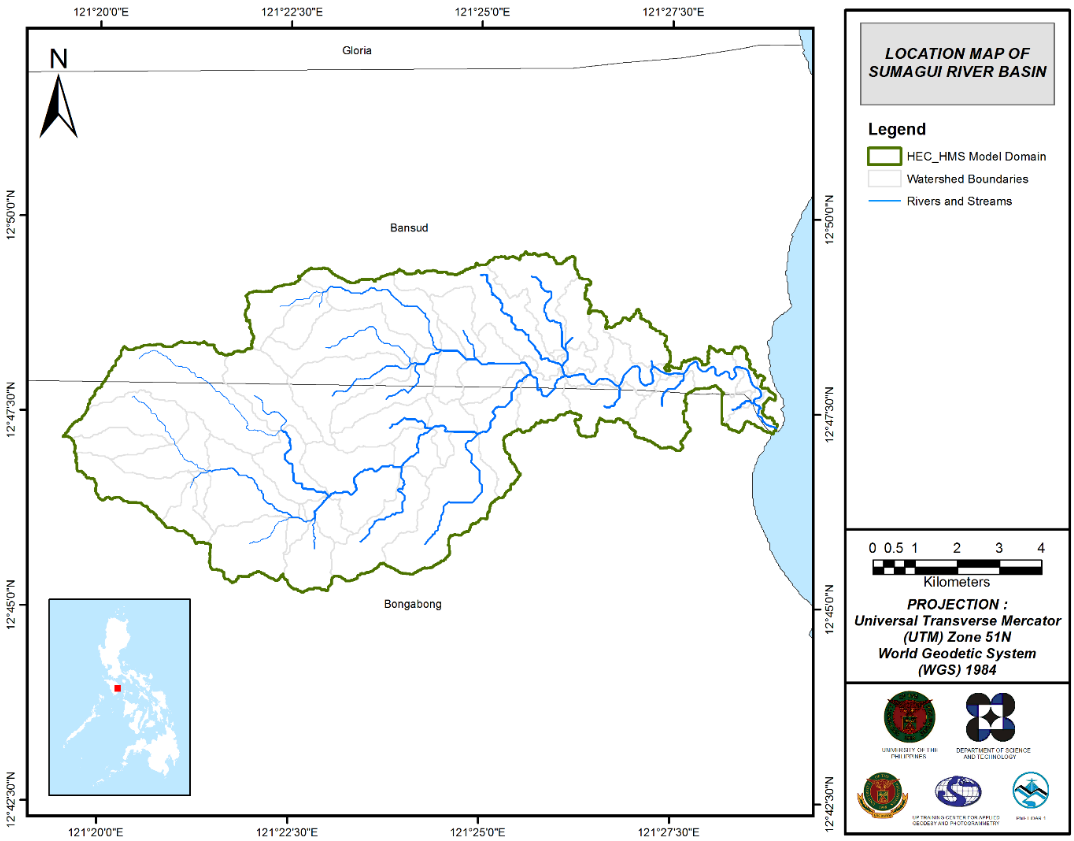


Figure 56. Stream delineation map of Sumagui River Basin

Using the SAR-based DEM, the Sumagui basin was delineated and further subdivided into subbasins. The model consists of 49 sub basins, 25 reaches, and 25 junctions as shown in Figure 57. The main outlet is at Sumague Bridge.

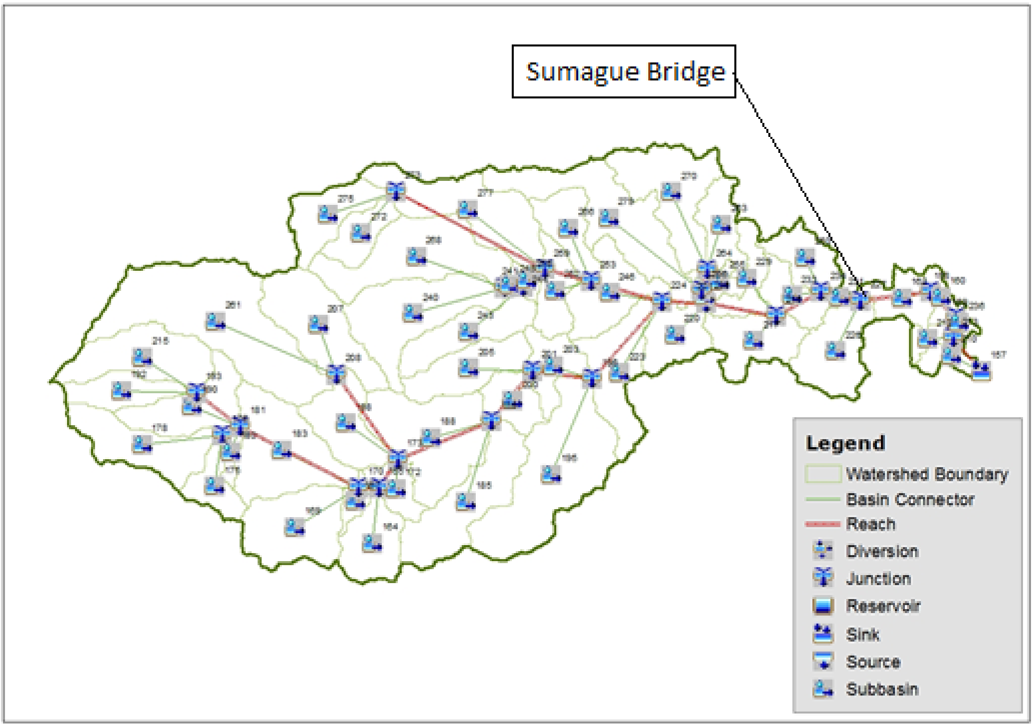


Figure 57. HEC-HMS generated Sumagui River Basin Model.

5.4 Cross-section Data

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

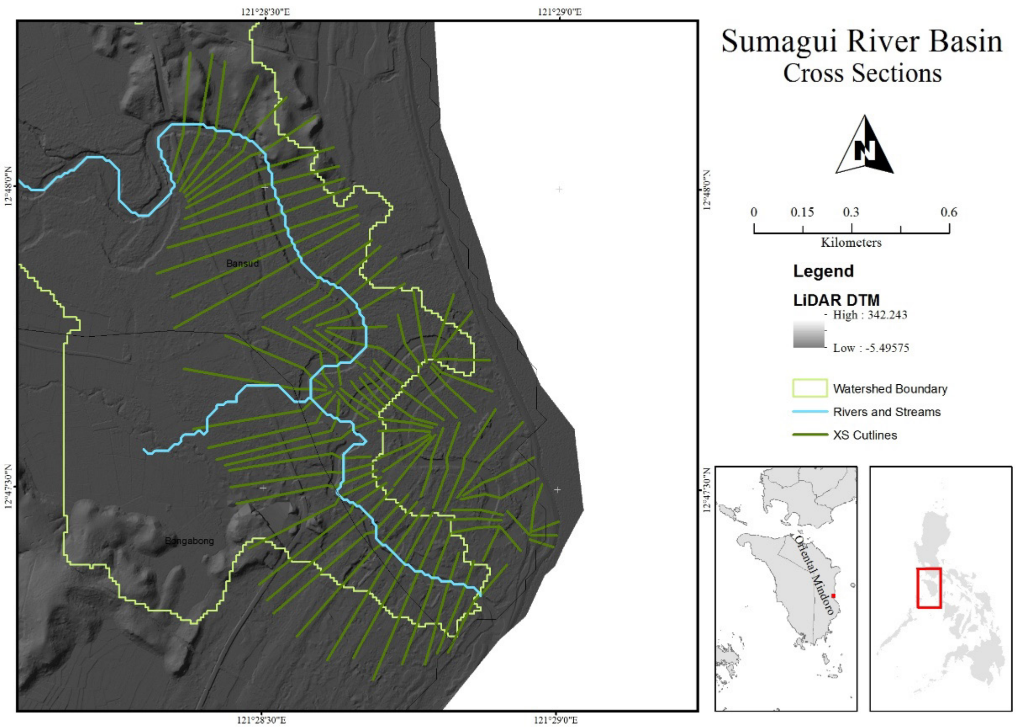


Figure 58. River cross-section of Sumagui River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

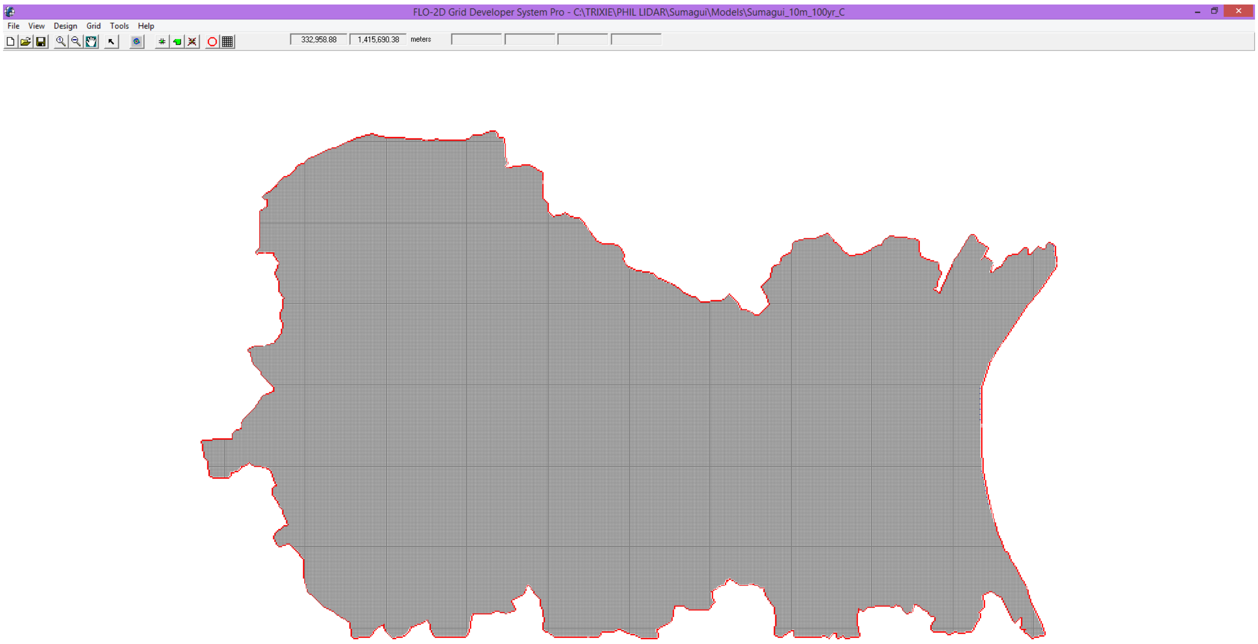


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 11.87866 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 17 573 000.00 m^2.

There is a total of 6366160.83 m^3 of water entering the model. Of this amount, 6366160.83 m^3 is due to rainfall while 0.00 m^3 is inflow from other areas outside the model. 1938742.50 m^3 of this water is lost to infiltration and interception, while 1535566.41 m^3 is stored by the floodplain. The rest, amounting up to 2891851.37 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Sumagui HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

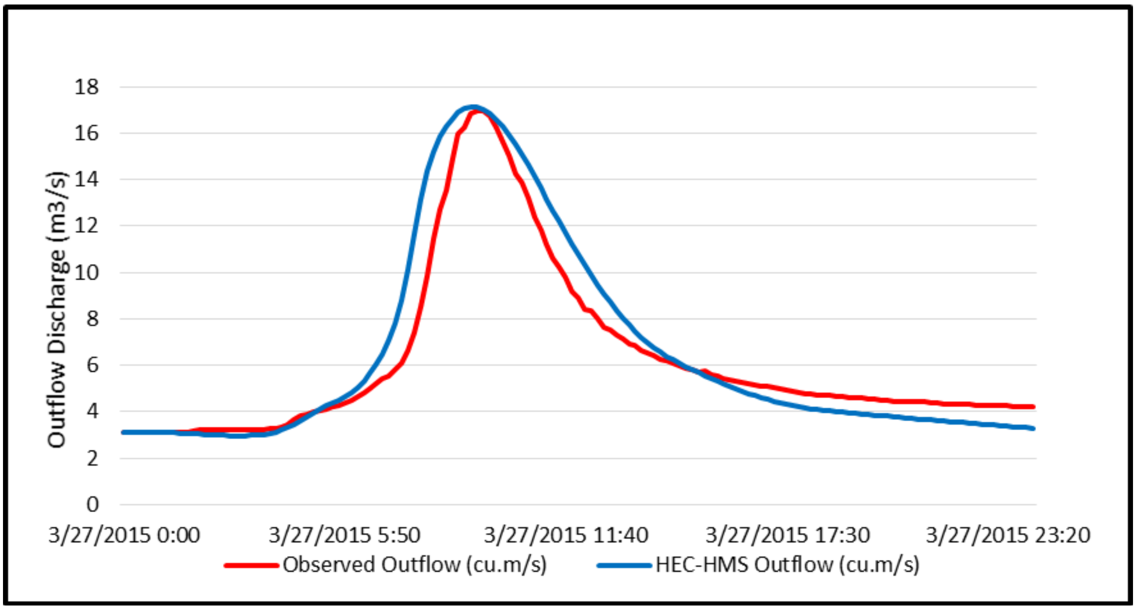


Figure 60. Outflow Hydrograph of Sumagui produced by the HEC-HMS model compared with observed outflow.

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

Table 28. Range of calibrated values for Sumagui River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.003 – 0.03
			Curve Number	25 - 79
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 25
			Storage Coefficient (hr)	0.2 - 2
	Baseflow	Recession	Recession Constant	0.2 – 0.5
			Ratio to Peak	0.07 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.002 – 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 0.003 to 0.03mm means that there is a high 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 25 to 79 for curve number is lower than the advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 hours to 25 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 0.2 to 0.5 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.07 to 0.5 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.002 to 0.03 is relatively low compared to the common roughness of watersheds (Brunner, 2010).

Table 33. Summary of the Efficiency Test of Daguitan-Marabong HMS Model

Accuracy measure	Value
RMSE	11.847
r2	0.9580
NSE	0.8155
PBIAS	1.6156
RSR	0.4296

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 11.847.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9580.

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 0.8155.

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 1.6156.

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 0.4296.

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

5.7.1 Hydrograph using the Rainfall Runoff Mode

The summary graph (Figure 61) shows the Sumagui outflow using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

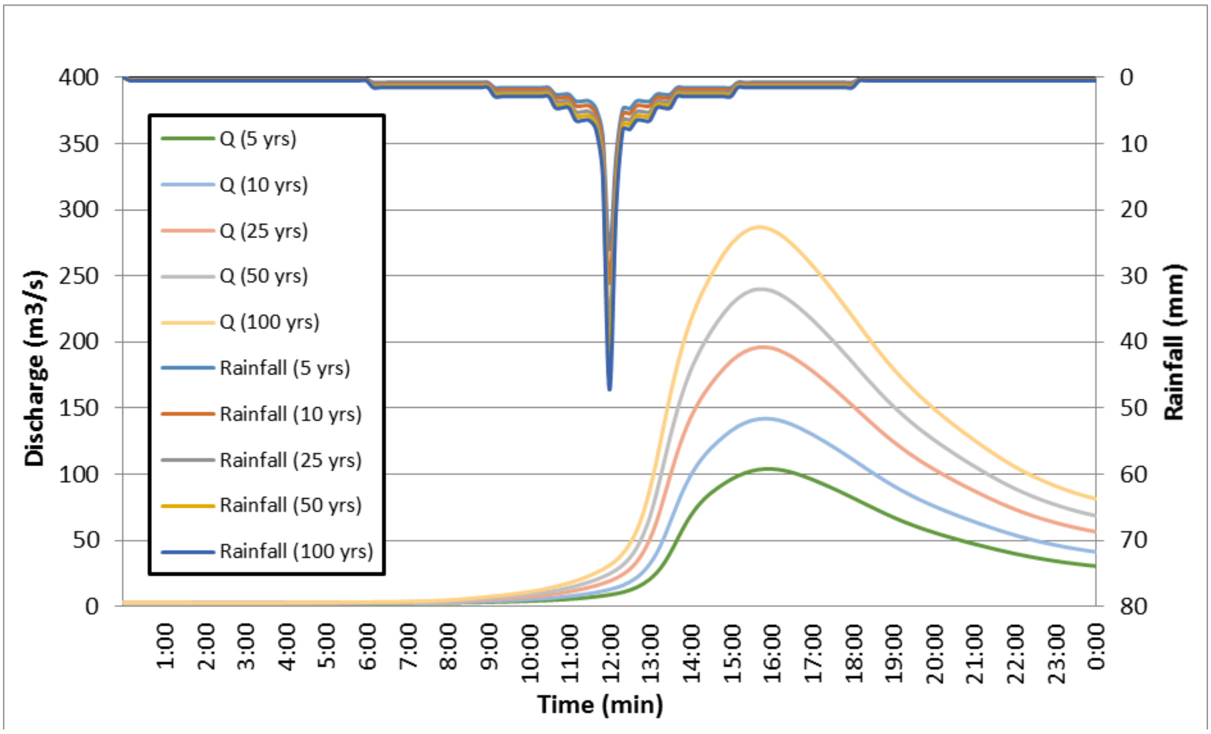


Figure 61. Outflow hydrograph at Sumagui Station generated using Romblon RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Sumagui HECHMS Model outflow using the Romblon RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (m^3/s)	Time to Peak	Lag Time
5-yr	152.9	26.0	104.104	16 hours	4 hours
10-yr	183.4	31.1	142.178	15 hours 50 minutes	3 hours 50 minutes
25-yr	221.8	37.6	196.195	15 hours 50 minutes	3 hours 50 minutes
50-yr	250.3	42.4	239.991	15 hours 40 minutes	3 hours 40 minutes
100-yr	278.6	47.2	286.880	15 hours 40 minutes	3 hours 40 minutes

5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method

The river discharge values for the nine rivers entering the floodplain are shown in Figure 62 to Figure 65 and the peak values are summarized in Table 31 to Table 34.

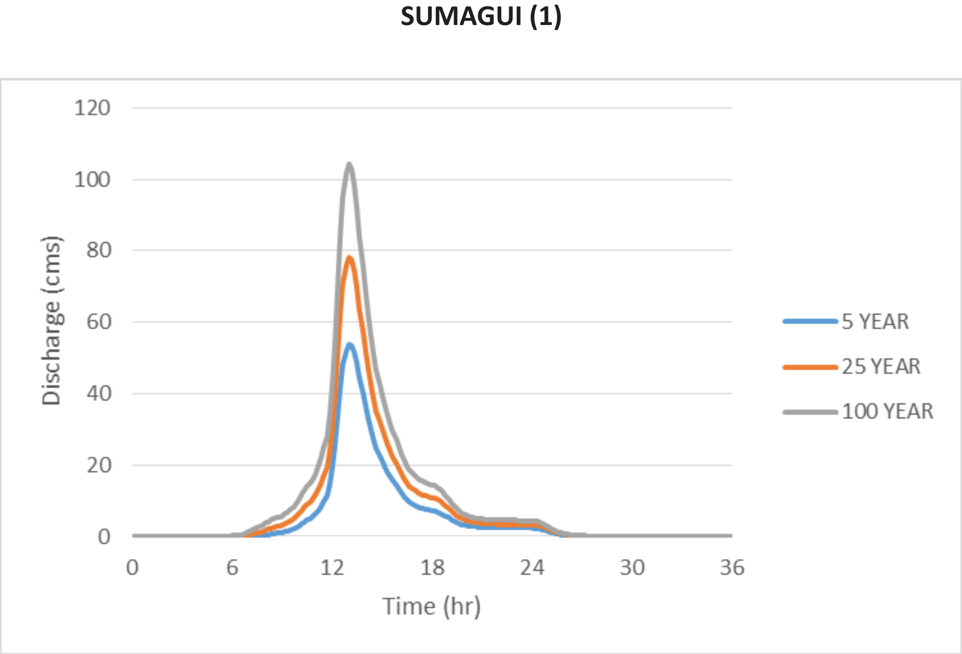


Figure 62. Sumagui river (1) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

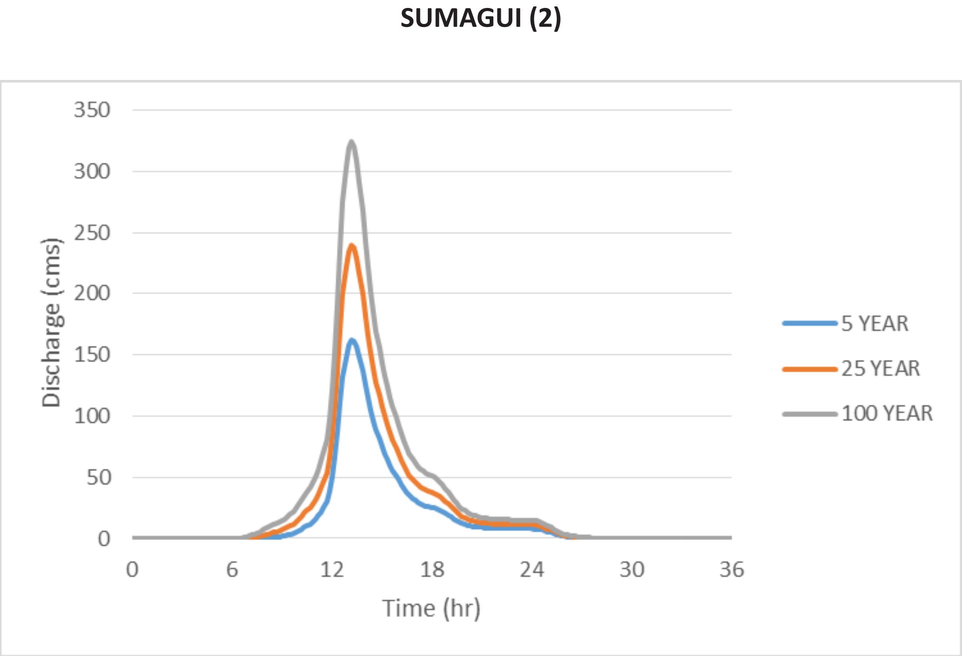


Figure 63. Sumagui river (2) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

SUMAGUI (3)

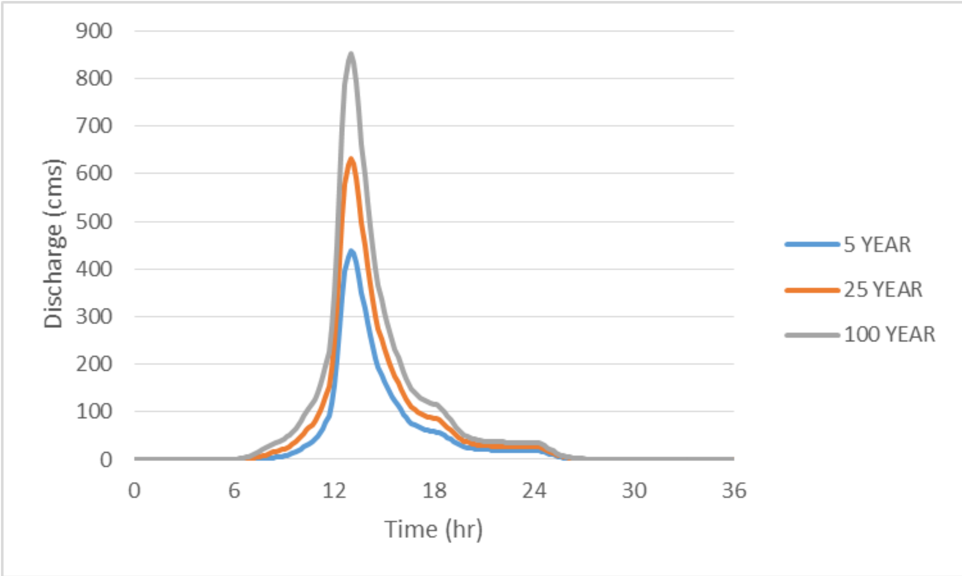


Figure 64. Sumagui river (3) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

SUMAGUI (4)

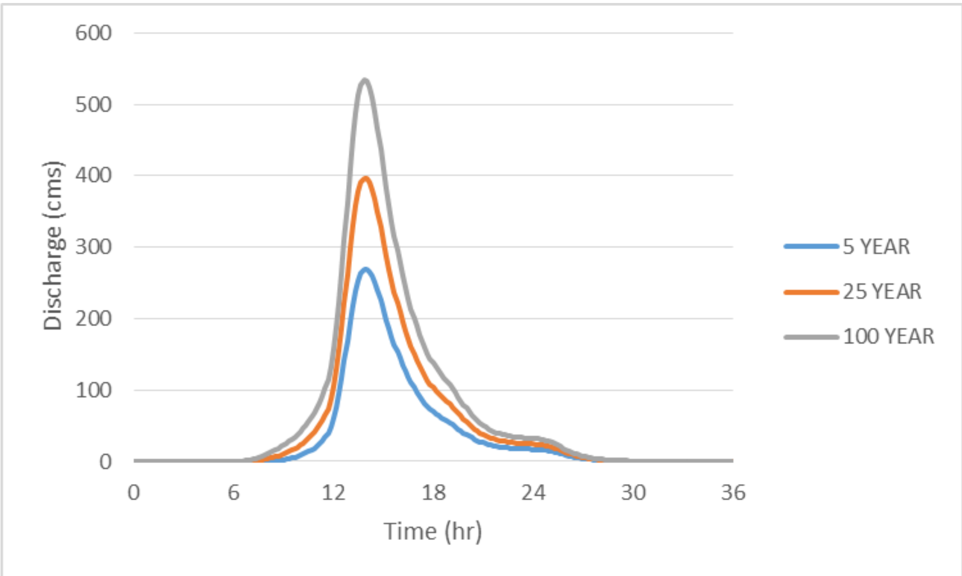


Figure 65. Sumagui river (4) generated discharge using 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Sumagui river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	104.2	70 minutes
25-Year	78.3	70 minutes
5-Year	53.8	70 minutes

Table 32. Summary of Sumagui river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	534.7	116 minutes
25-Year	396.8	116 minutes
5-Year	269.2	116 minutes

Table 33. Summary of Sumagui river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	324.8	77 minutes
25-Year	239.6	77 minutes
5-Year	162.3	77 minutes

Table 34. Summary of Sumagui river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	852.4	67 minutes
25-Year	632.4	67 minutes
5-Year	437.9	67 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 35.

Table 35. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Sumagui (1)	47.344	10.059	67.191	Fail	Pass
Sumagui (2)	236.896	10.526	305.277	Fail	Pass
Sumagui (3)	142.824	401.878	182.023	Fail	Pass
Sumagui (4)	385.352	30.763	342.212	Fail	Pass

All the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the specific discharge method. The passing 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 Sumagui River using the HMS base flow is shown on Figure 66 below.

Figure 66. Sample output of Sumagui RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Sumagui floodplain are shown in Figure 67 to Figure 72. The floodplain, with an area of 44.13 sq. km., covers two municipalities namely Bansud, and Bongabong. Table shown the percentage of area affected by flooding per municipality. Table 36 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Daguitan-Marabong Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Bansud	197	22.58	11.46
Bongabong	493.74	21.46	4.35

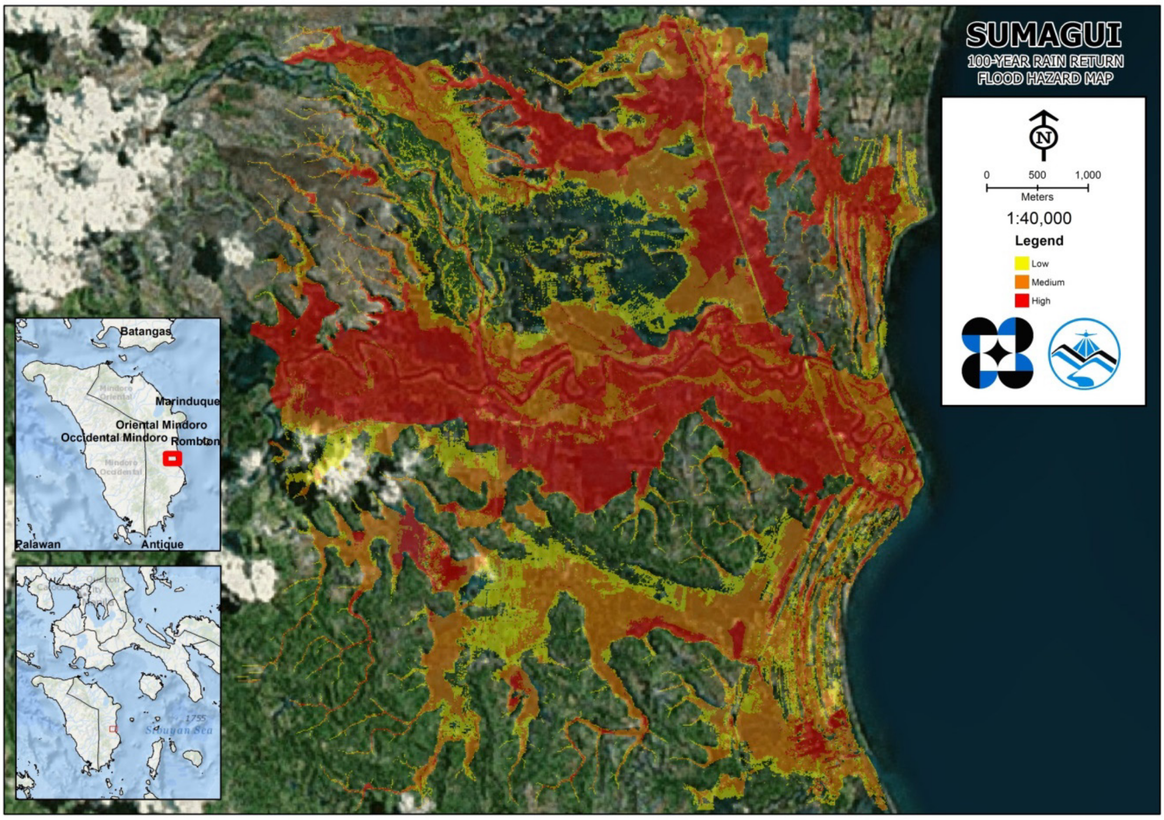


Figure 67. 100-year Flood Hazard Map for Sumagui Floodplain overlaid on Google Earth imagery

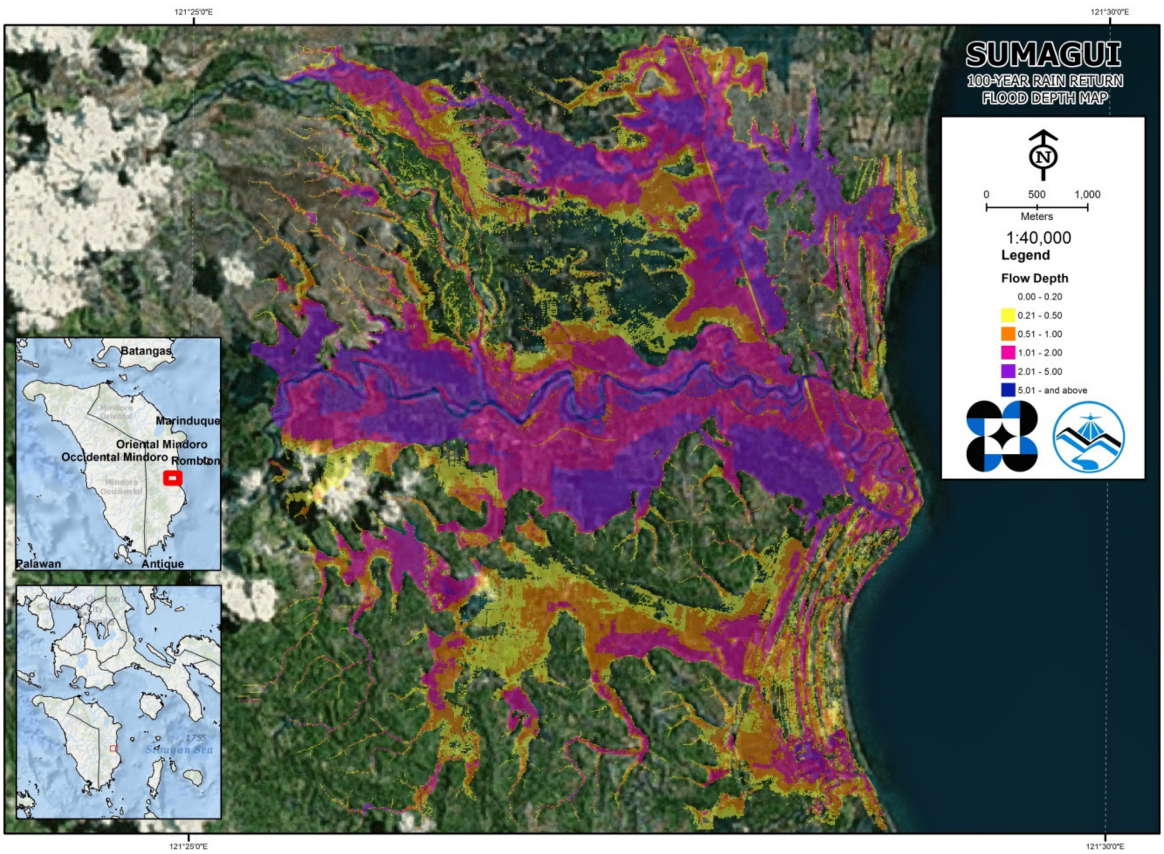


Figure 68. 100-year Flow Depth Map for Sumagui Floodplain overlaid on Google Earth imagery

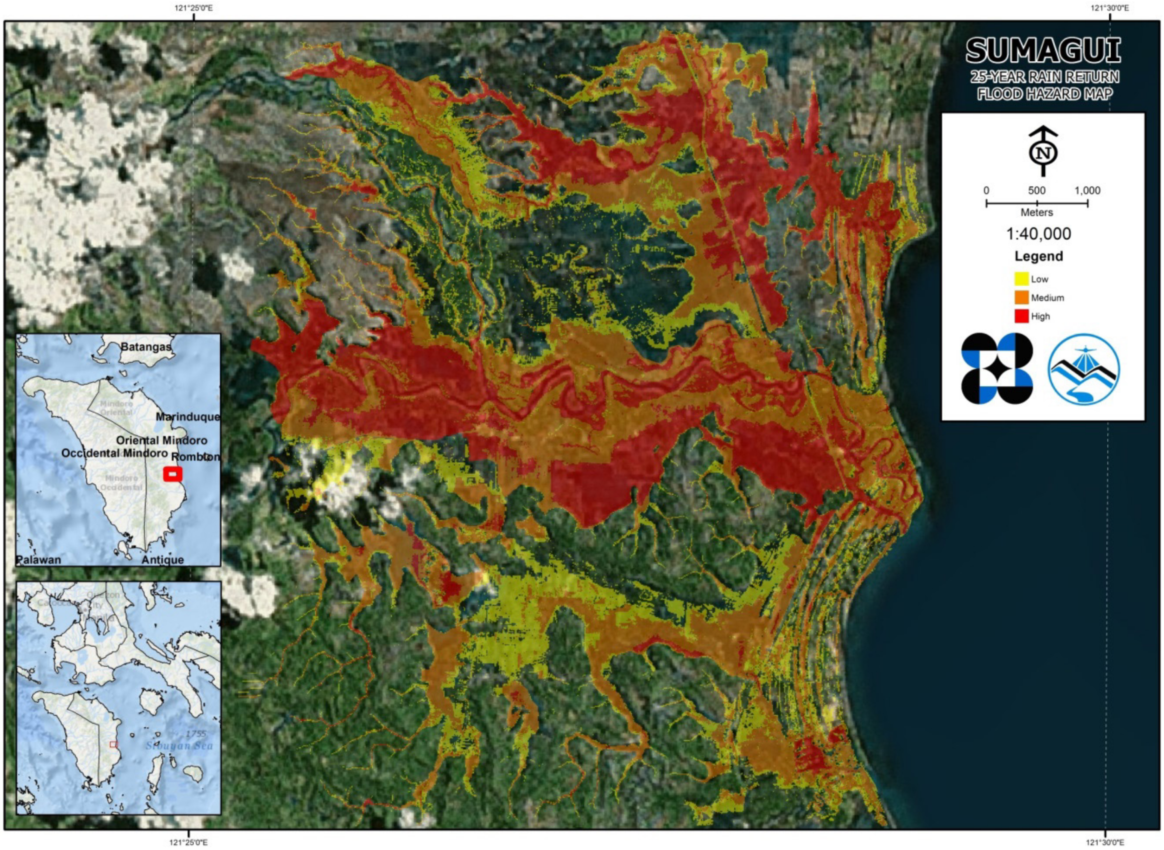


Figure 69. 25-year Flood Hazard Map for Sumagui Floodplain overlaid on Google Earth imagery

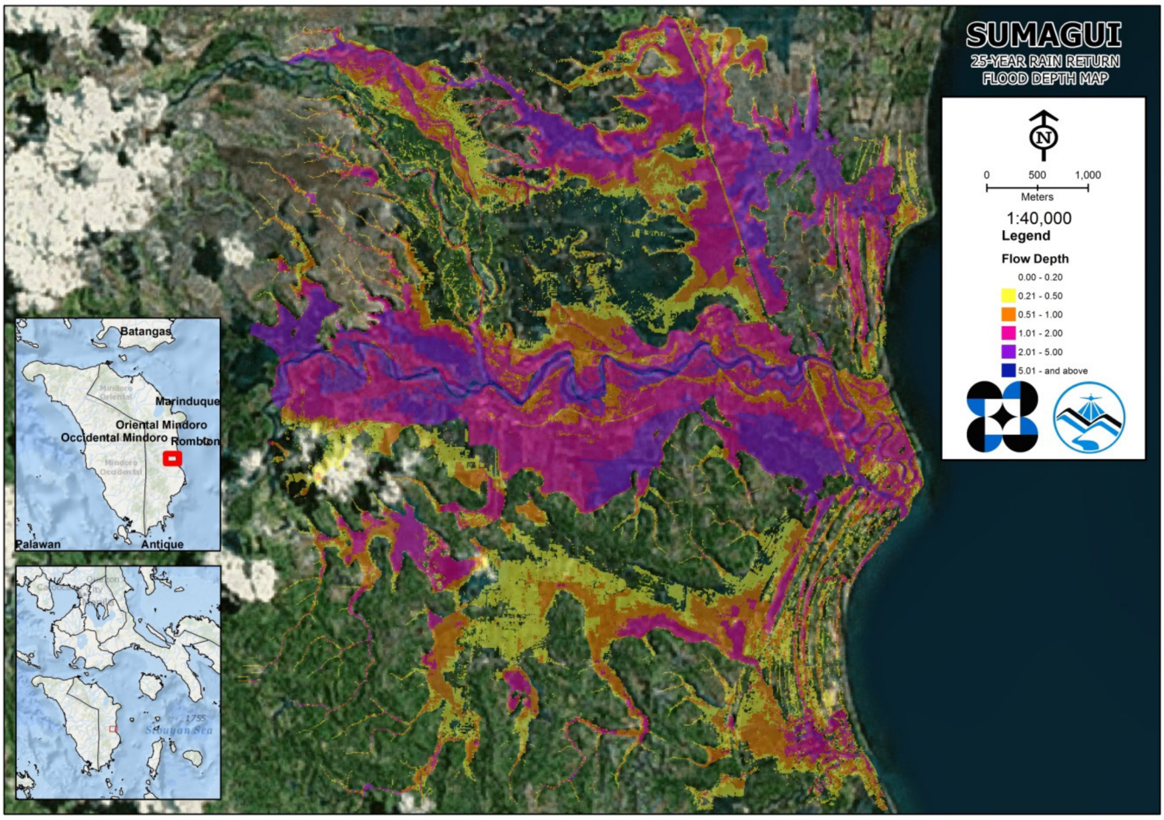


Figure 70. 25-year Flow Depth Map for Sumagui Floodplain overlaid on Google Earth imagery

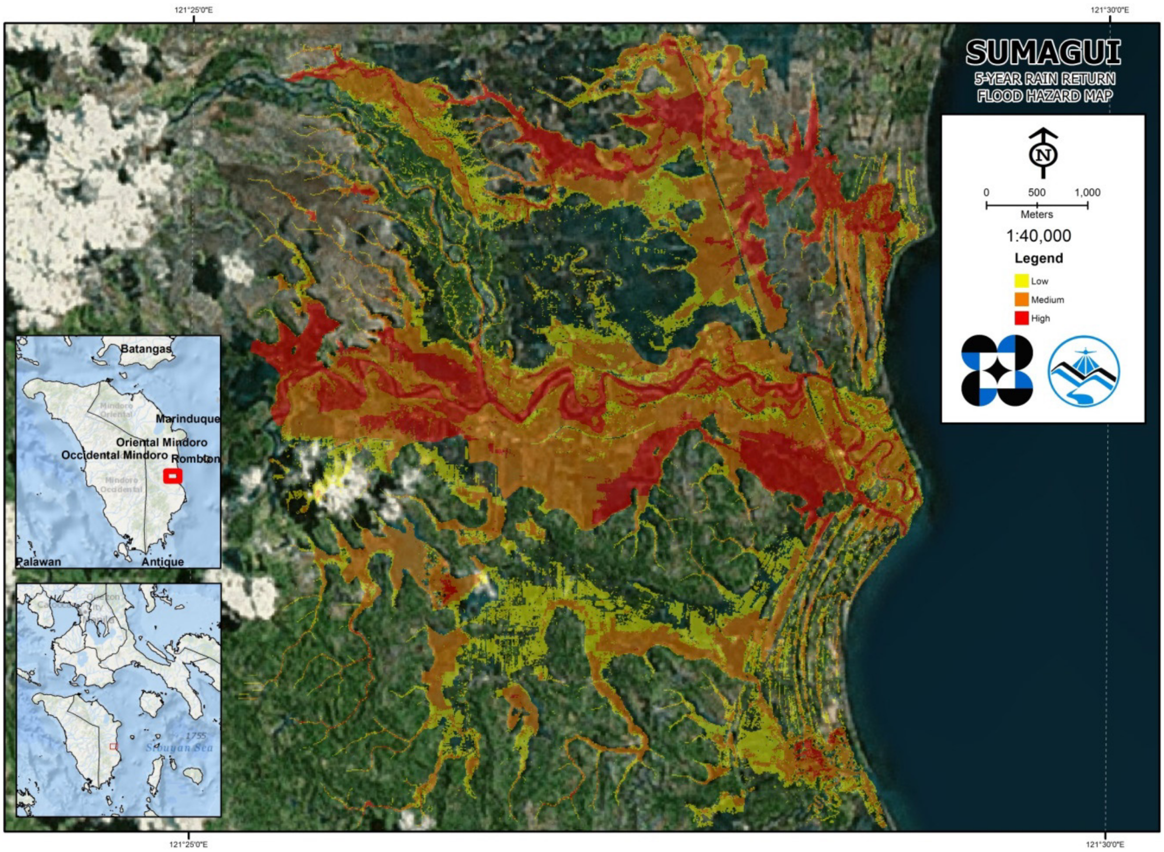


Figure 71. 5-year Flood Hazard Map for Sumagui Floodplain overlaid on Google Earth imagery

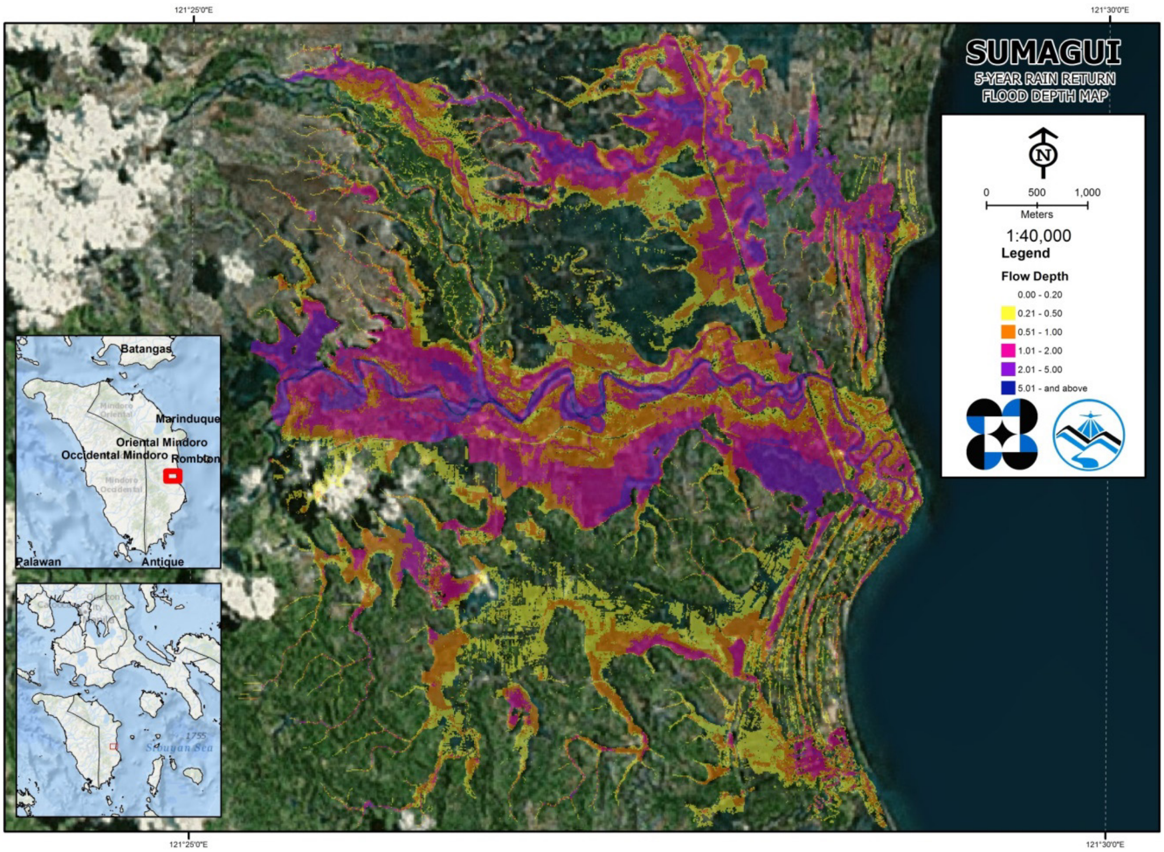


Figure 72. 5-year Flood Depth Map for Sumagui Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Sumagui River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 15 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 5.31% of the municipality of Bansud with an area of 196.999 sq. km. will experience flood levels of less 0.20 meters, while 1.25% of the area will experience flood levels of 0.21 to 0.50 meters; 1.76%, 2.09%, 1.02%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Listed in Table 37 and shown in Figure 73 are the affected areas in Bansud in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Bansud, Oriental Mindoro during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bansud							
	Bato	Malo	Manihala	Proper Tiguisan	Rosacara	Salcedo	Sumagui	Villa Pag-Asa
0.03-0.20	1.69	0.44	1.79	0.19	2.16	1.48	1.16	1.53
0.21-0.50	0.4	0.037	0.17	0.074	0.53	0.42	0.35	0.48
0.51-1.00	0.47	0.15	0.13	0.093	0.51	0.63	0.73	0.75
1.01-2.00	0.67	0.51	0.067	0.079	0.4	1.17	0.7	0.52
2.01-5.00	0.38	0.42	0.0045	0.0009	0.17	0.67	0.21	0.14
> 5.00	0.042	0.019	0	0	0.0006	0	0.0065	0.014

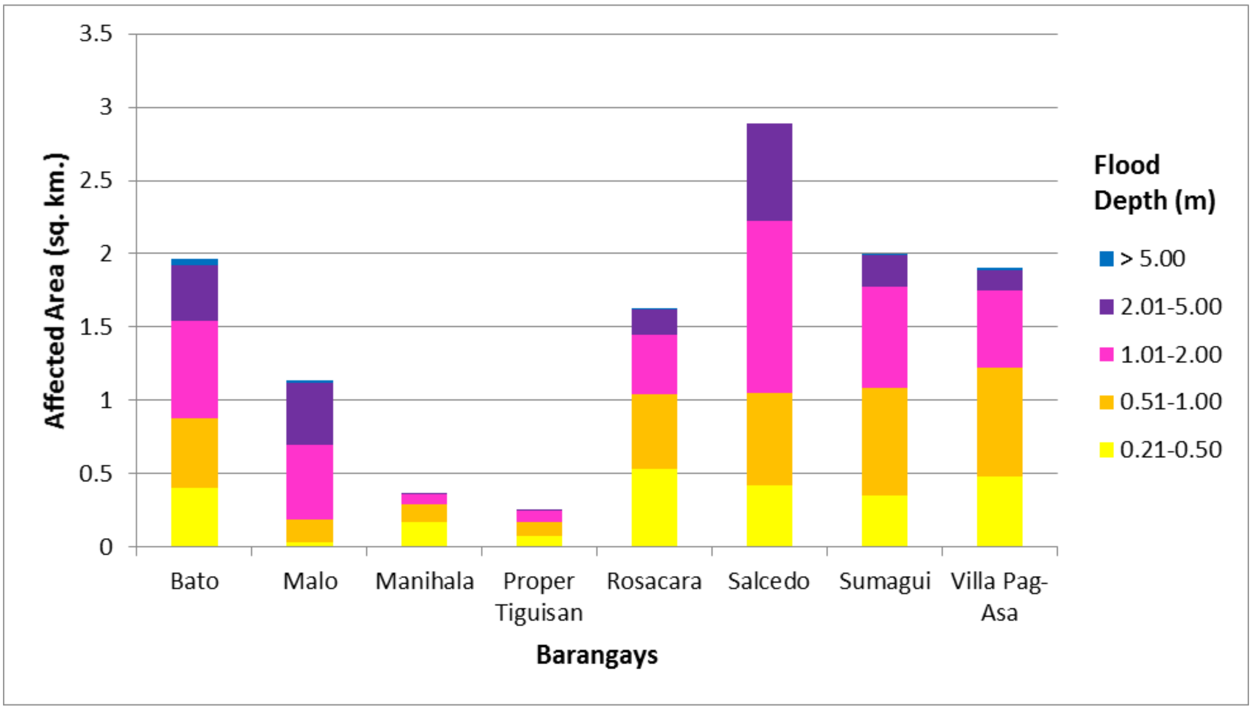


Figure 73. Affected Areas in Bansud, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Bongabong, with an area of 493.74 sq. km., 2.80% will experience flood levels of less 0.20 meters. 0.57% of the area will experience flood levels of 0.21 to 0.50 meters while 0.48%, 0.38%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 38 and shown in Figure 74 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Bongabong, Oriental Mindoro during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bongabong						
	Bagumbayan II	Carmundo	Labasan	Libertad	Santa Cruz	Sigange	Tawas
0.03-0.20	0.12	2.26	2.49	0.66	4.71	1.67	1.9
0.21-0.50	0.051	0.55	0.73	0.058	1.16	0.17	0.11
0.51-1.00	0.033	0.74	0.59	0.15	0.55	0.17	0.12
1.01-2.00	0.018	0.79	0.44	0.38	0.16	0.029	0.064
2.01-5.00	0	0.02	0.4	0.13	0.0036	0.0065	0.0074
> 5.00	0	0	0	0	0	0	0

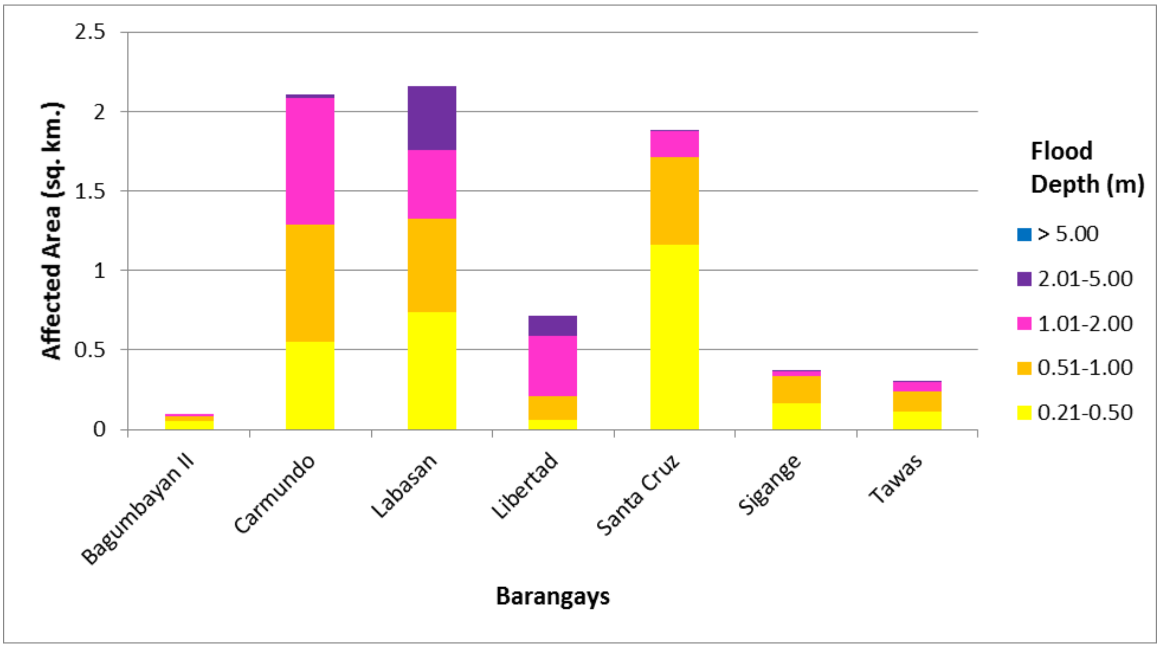


Figure 74. Affected Areas in Bongabong, Oriental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 4.75% of the municipality of Bansud with an area of 196.999 sq. km. will experience flood levels of less 0.20 meters, while 1.06% of the area will experience flood levels of 0.21 to 0.50 meters; 1.48%, 2.58%, 1.53%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Listed in Table 39 and shown in Figure 75 are the areas affected in Bansud in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Bansud, Oriental Mindoro during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bansud							
	Bato	Malo	Manihala	Proper Tiguisan	Rosacara	Salcedo	Sumagui	Villa Pag-Asa
0.03-0.20	1.5	0.43	1.74	0.16	1.95	1.26	1.03	1.28
0.21-0.50	0.35	0.018	0.17	0.069	0.56	0.37	0.17	0.4
0.51-1.00	0.47	0.053	0.15	0.11	0.52	0.55	0.54	0.5
1.01-2.00	0.7	0.49	0.092	0.096	0.49	1.21	1.01	0.99
2.01-5.00	0.57	0.56	0.009	0.005	0.25	0.99	0.39	0.24
> 5.00	0.064	0.028	0	0	0.0045	0.0002	0.013	0.031

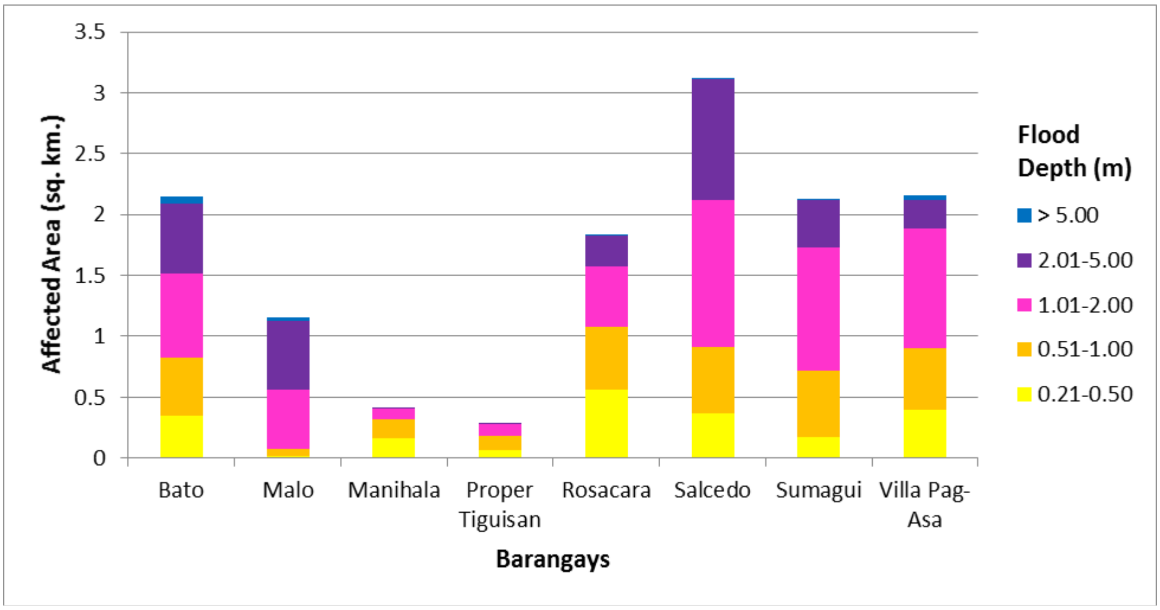


Figure 75. Affected areas in Bansud, Oriental Mindoro during the 25-Year Rainfall Return Period

For the municipality of Bongabong, with an area of 493.74 sq. km., 2.55% will experience flood levels of less 0.20 meters. 0.57% of the area will experience flood levels of 0.21 to 0.50 meters while 0.53%, 0.51%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 40 and shown in Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Bongabong, Oriental Mindoro during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bongabong						
	Bagumbayan II	Carmundo	Labasan	Libertad	Santa Cruz	Sigange	Tawas
0.03-0.20	0.087	2.05	2.08	0.63	4.24	1.62	1.85
0.21-0.50	0.053	0.54	0.7	0.042	1.21	0.15	0.12
0.51-1.00	0.054	0.53	0.8	0.057	0.85	0.21	0.11
1.01-2.00	0.024	1.15	0.56	0.32	0.28	0.047	0.12
2.01-5.00	0.0025	0.085	0.51	0.32	0.0054	0.01	0.011
> 5.00	0	0	0	0	0	0	0

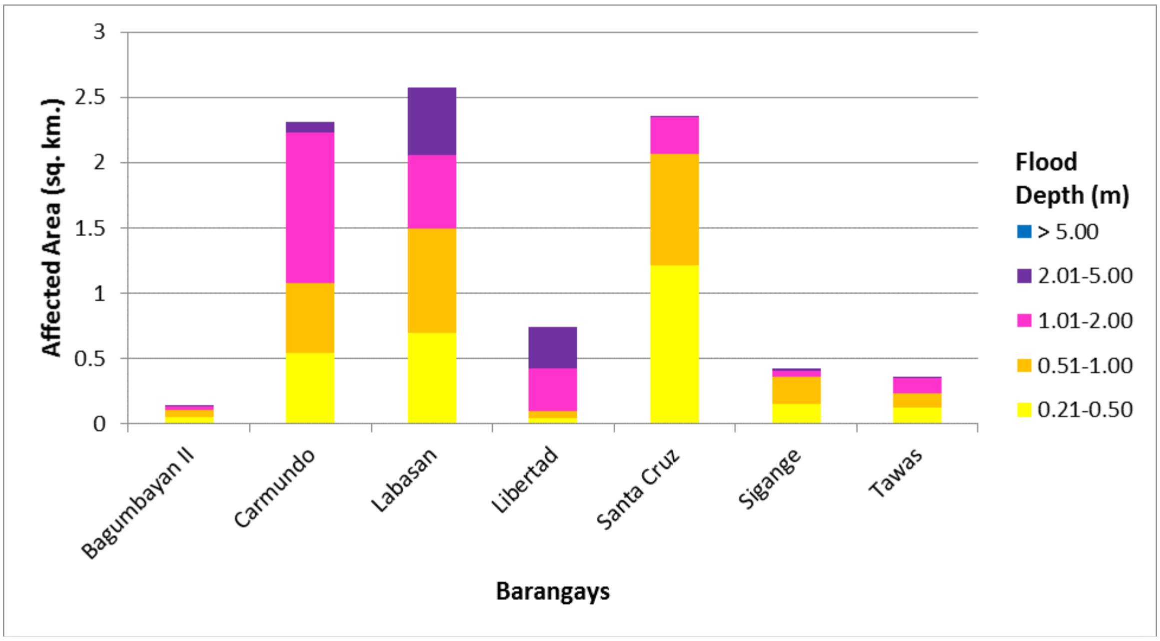


Figure 76. Affected Areas in Bongabong, Oriental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 4.28% of the municipality of Bansud with an area of 196.999 sq. km. will experience flood levels of less 0.20 meters, while 1.05% of the area will experience flood levels of 0.21 to 0.50 meters; 1.18%, 2.66%, 2.20%, and 0.10% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Listed in Table 41 and shown in Figure 77 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Bansud, Oriental Mindoro during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bansud							
	Bato	Malo	Manihala	Proper Tiguisan	Rosacara	Salcedo	Sumagui	Villa Pag-Asa
0.03-0.20	1.33	0.41	1.7	0.14	1.78	1.08	0.97	1.03
0.21-0.50	0.4	0.018	0.16	0.056	0.56	0.31	0.14	0.42
0.51-1.00	0.36	0.026	0.17	0.12	0.55	0.53	0.26	0.3
1.01-2.00	0.72	0.37	0.11	0.12	0.54	1.09	1.16	1.15
2.01-5.00	0.76	0.71	0.021	0.01	0.34	1.36	0.62	0.51
> 5.00	0.085	0.038	0	0	0.012	0.0006	0.019	0.04

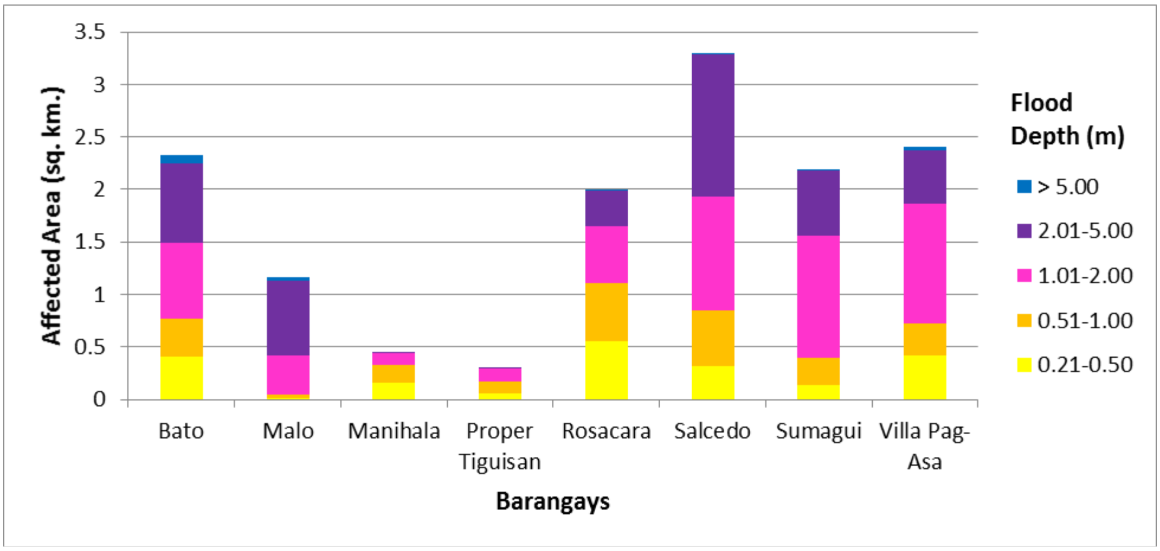


Figure 77. Affected Areas in Bansud, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Bongabong, with an area of 493.74 sq. km., 2.36% will experience flood levels of less 0.20 meters. 0.50% of the area will experience flood levels of 0.21 to 0.50 meters while 0.59%, 0.60%, 0.30%, and 0.00002% 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 shown in Figure 78 are the areas affected in Roxas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Bongabong, Oriental Mindoro during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Bongabong						
	Bagumbayan II	Carmundo	Labasan	Libertad	Santa Cruz	Sigange	Tawas
0.03-0.20	0.061	1.89	1.74	0.61	3.96	1.58	1.81
0.21-0.50	0.05	0.53	0.61	0.041	0.98	0.13	0.12
0.51-1.00	0.072	0.51	0.88	0.036	1.13	0.2	0.11
1.01-2.00	0.034	1.15	0.8	0.18	0.52	0.1	0.16
2.01-5.00	0.0041	0.29	0.62	0.5	0.011	0.015	0.016
> 5.00	0	0	0	0.0001	0	0	0

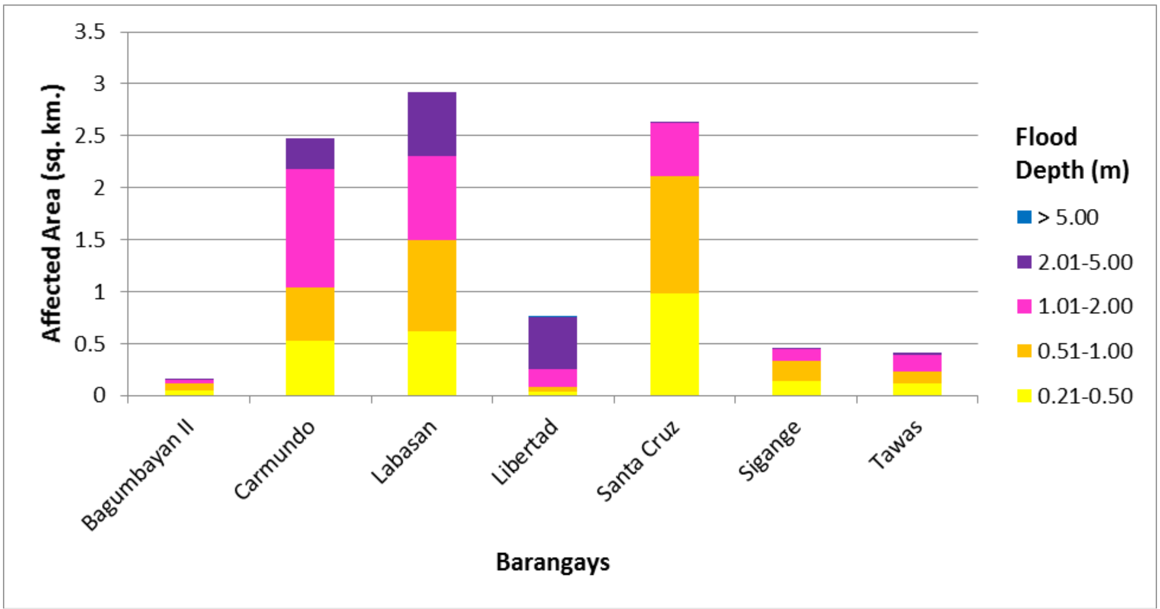


Figure 78. Affected areas in Bongabong, Oriental Mindoro during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Bansud, Salcedo is projected to have the highest percentage of area that will experience flood levels at 2.22%. Meanwhile, Rosacara posted the second highest percentage of area that may be affected by flood depths at 1.92%.

Among the barangays in the municipality of Bongabong, Santa Cruz is projected to have the highest percentage of area that will experience flood levels at 1.33%. Meanwhile, Labasan posted the second highest percentage of area that may be affected by flood depths at 0.94%.

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

Table 43. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
LOW			
MEDIUM			
HIGH			
TOTAL			

… as shown in Annex 12.

…The medical institutions exposed to flooding are shown in Annex 13.

5.11 Flood Validation

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

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

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

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

The flood validation consisted of 101 points randomly selected all over the Sumagui flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.48m. Table 44 shows a contingency matrix of the comparison.

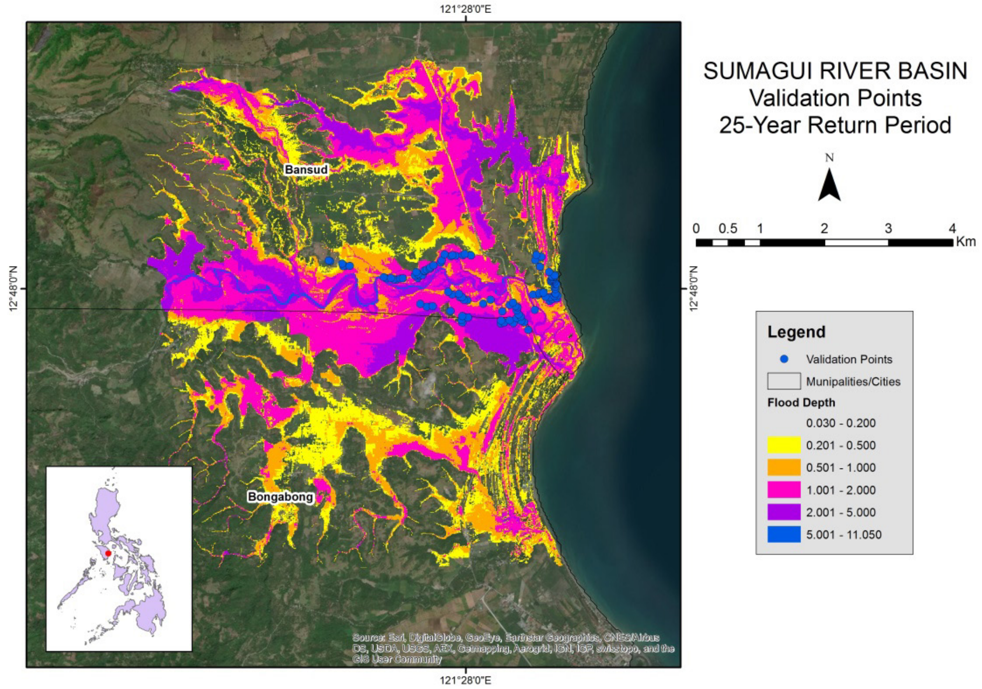


Figure 79. Validation points for 25-year Flood Depth Map of Sumagui Floodplain

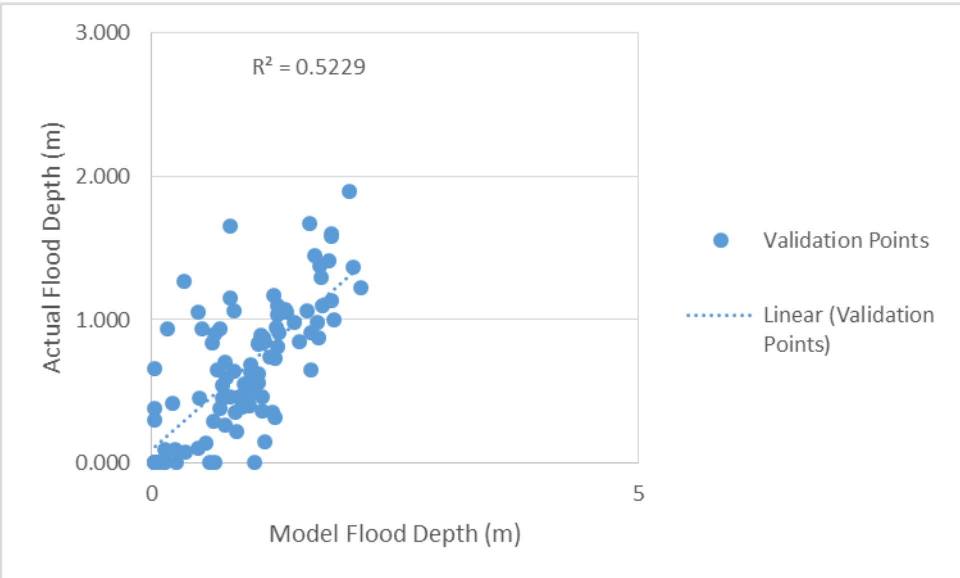


Figure 80. Flood map depth vs. actual flood depth

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

MAINIT-TUBAY BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	>5.00	Total
Actual Flood Depth (m)	0-0.20	12	4	3	2	0	0	21
	0.21-0.50	2	2	12	5	0	0	21
	0.51-1.00	2	0	11	23	0	0	36
	1.01-2.00	0	2	3	15	3	0	23
	2.01-5.00	0	0	0	0	0	0	0
	>5.00	0	0	0	0	0	0	0
	Total	16	8	29	45	3	0	101

The overall accuracy generated by the flood model is estimated at 39.60% with 40 points correctly matching the actual flood depths. In addition, there were 47 points estimated one level above and below the correct flood depths while there were 12 points and 2 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 9 points were underestimated in the modelled flood depths of Sumagui. Table 45 depicts the summary of the Accuracy Assessment in the Sumagui River Basin Survey.

Table 45. Summary of the Accuracy Assessment in the Sumagui River Basin Survey

	No. of Points	%
Correct	40	**39.60**
Overestimated	52	**51.49**
Underestimated	9	**8.91**
Total	101	**100.00**

REFERENCES

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

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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.C., Lagmay, A.F., Sarmiento, C. 2017, Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Daguitan-Marabong Floodplain Survey

Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

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

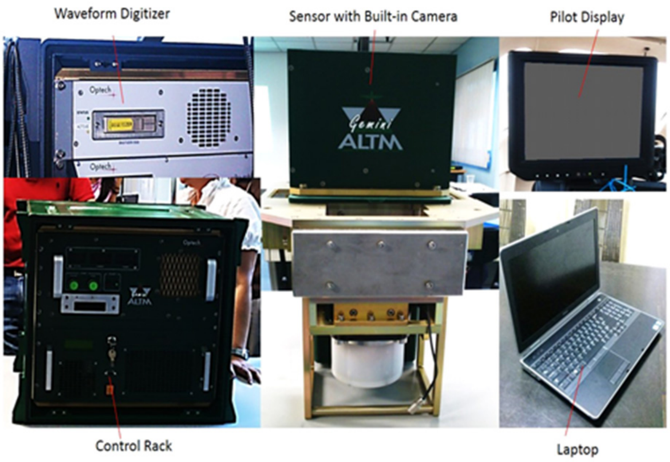

Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the 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 certification 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**		Barangay: **MALIANGCOG**
Municipality: **PINAMALAYAN**		
	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

9 9 0 2 0 4 2 0 1 4 1 2 5 8 5 5

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

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

Figure A-2.1. MRE-54

2. 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**
Order: **2nd**

Island: **LUZON**
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

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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-44

3. MRE-11

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

October 28, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ORIENTAL MINDORO**	
	Station Name: **MRE-11**	
	Order: **3rd**	
Island: **LUZON**	Barangay:	
Municipality: **BONGABONG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 44' 50.41380"**	Longitude: **121° 29' 7.80130"**	Ellipsoidal Hgt: **5.11500 m.**
	WGS84 Coordinates	
Latitude: **12° 44' 45.47630"**	Longitude: **121° 29' 12.85191"**	Ellipsoidal Hgt: **54.91100 m.**
	PTM / PRS92 Coordinates	
Northing: **1409650.153 m.**	Easting: **552720.766 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,409,587.05**	Easting: **335,581.55**	Zone: **51**

Location Description

MRE-11
To reach the station from Calapan town proper, travel SE to S ìalong the nat'l. road for about 120 kms. leading to the town of ìBongabong, passing by the towns of Victoria, Pinamalayan and ìBansud. Station is located inside the school compound of ìMagdalena Umali Suyon Elem. School on the SE corner of the ìfooting of a concrete landmark bearing the school name. It is ìabout 20 m. W of the main gate along Gov. Umali St. Mark is the ìhead of a 4 in. copper nail embedded and centered on a 0.15 m. x ì0.15 m. cement putty, with inscriptions "MRE-11 1997 NAMRIA".

Requesting Party:	**ENGR. CHRISTOPHER CRUZ**
Purpose:	**Reference**
OR Number:	**8088472 I**
T.N.:	**2015-3525**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 9 1 1

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/01/814

Figure A-2.3. MRE-11

4. MRE-56

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

October 28, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-56**
Order: **2nd**

Island: **LUZON**	Barangay:	
Municipality: **MANSALAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 31' 25.76362"**	Longitude: **121° 26' 25.21109"**	Ellipsoidal Hgt: **7.87000 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 20.87629"**	Longitude: **121° 26' 30.28143"**	Ellipsoidal Hgt: **58.13600 m.**
	PTM / PRS92 Coordinates	
Northing: **1384916.657 m.**	Easting: **547857.861 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,384,892.31**	Easting: **330,530.08**	Zone: **51**

Location Description

MRE-56

From Calapan City to Bulalacao, along Nat'l Road approx. 4 Km. from Roxas Proper is an intersection of Roxas, Mansalay, Bongabong Road, turn left, approx. 14 Km. travel, right side of Nat'l Road located Mun. Hall of Mansalay, Oriental Mindoro, in front of Mansalay Hospital. Station is located in corner wall of Mun. Park in front of Mun. Hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscritions, "MRE-56, 2007, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3523**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 8 1 7

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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CIF/4701/12/01/814

Figure A-2.4. MRE-56

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

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. Baseline Processing Report - A

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-3.2. Baseline Processing Report - B

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

11/5/2015 5:01:03 PM		Business Center - HCE

2

Figure A-3.3. Baseline Processing Report – C

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. Baseline Processing Report – D

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

11/5/2015 5:01:03 PM		Business Center - HCE

2

Figure A-3.5. Baseline Processing Report – E

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

2

Figure A-3.6. Baseline Processing Report – F

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

1

Figure A-3.7. Baseline Processing Report – G

MRE54 - 22 - MRE11 PM2 - 22 (1:23:53 PM-4:46:28 PM) (S2)

Baseline observation:	MRE54 - 22 --- MRE11 PM2 - 22 (B2)
Processed:	11/5/2015 4:50:38 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.023 m
RMS:	0.006 m
Maximum PDOP:	8.263
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/22/2015 1:23:53 PM (Local: UTC+8hr)
Processing stop time:	10/22/2015 4:46:28 PM (Local: UTC+8hr)
Processing duration:	03:22:35
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 PM2 - 22				
Grid		**Local**		**Global**	
Easting	335735.139 m	**Latitude**	N12°44'45.47157"	**Latitude**	N12°44'45.47157"
Northing	1409521.771 m	**Longitude**	E121°29'12.85328"	**Longitude**	E121°29'12.85328"
Elevation	5.716 m	**Height**	55.095 m	**Height**	55.095 m

Vector					
ΔEasting	7718.215 m	**NS Fwd Azimuth**	163°25'41"	**ΔX**	-9779.933 m
ΔNorthing	-26534.099 m	**Ellipsoid Dist.**	27635.232 m	**ΔY**	890.818 m
ΔElevation	-37.400 m	**ΔHeight**	-36.300 m	**ΔZ**	-25831.824 m

11/5/2015 4:52:33 PM		Business Center - HCE

3

Figure A-3.8. Baseline Processing Report – H

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)
MRE56 - 26 --- MRE56a - 26 (B1)	MRE56 - 26	MRE56a - 26	Fixed	0.001	0.002	-3.920	-0.909	-8.525	156°03'00"	9.407	-0.535

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

1

Figure A-3.9. Baseline Processing Report – I

MRE56 - 26 - MRE56a - 26 (6:52:03 AM-10:24:32 AM) (S1)

Baseline observation:	MRE56 - 26 --- MRE56a - 26 (B1)
Processed:	11/5/2015 5:05:12 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	12.356
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/26/2015 6:52:03 AM (Local: UTC+8hr)
Processing stop time:	10/26/2015 10:24:32 AM (Local: UTC+8hr)
Processing duration:	03:32:29
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE56 - 26				
Grid		**Local**		**Global**	
Easting	330684.411 m	**Latitude**	N12°31'20.87629"	**Latitude**	N12°31'20.87629"
Northing	1384827.258 m	**Longitude**	E121°26'30.28143"	**Longitude**	E121°26'30.28143"
Elevation	7.925 m	**Height**	58.136 m	**Height**	58.136 m

To:	MRE56a - 26				
Grid		**Local**		**Global**	
Easting	330688.179 m	**Latitude**	N12°31'20.59653"	**Latitude**	N12°31'20.59653"
Northing	1384818.639 m	**Longitude**	E121°26'30.40791"	**Longitude**	E121°26'30.40791"
Elevation	7.390 m	**Height**	57.601 m	**Height**	57.601 m

Vector					
ΔEasting	3.768 m	**NS Fwd Azimuth**	156°03'00"	**ΔX**	-3.958 m
ΔNorthing	-8.619 m	**Ellipsoid Dist.**	9.407 m	**ΔY**	-0.847 m
ΔElevation	-0.535 m	**ΔHeight**	-0.535 m	**ΔZ**	-8.509 m

11/5/2015 5:06:23 PM		Business Center - HCE

2

Figure A-3.10. Baseline Processing Report – J

Annex 4. The Survey Team

Date 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
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	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)	MARY CATHERINE BALIGUAS	UP-TCAGP
	RA	ENGR. MILLIE SHANE REYES	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data download and transfer	RA	GRACE SINADJAN	UP-TCAGP
	RA	ENGR. GEF SORIANO	
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC

Annex 5. Data Transfer Sheet for Daguitan-Marabong Floodplain

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-5.1. Data Transfer Sheet for Sumagui Floodplain - A

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	80.968 / 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	28.468 / 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
Position Supervising SRS
Signature 02/21/2014

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

Verified by

Name JOIDA F. PRIETO
Position SSRS
Signature

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

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	39.1/10.6	307/87	22.7	na	15.0	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

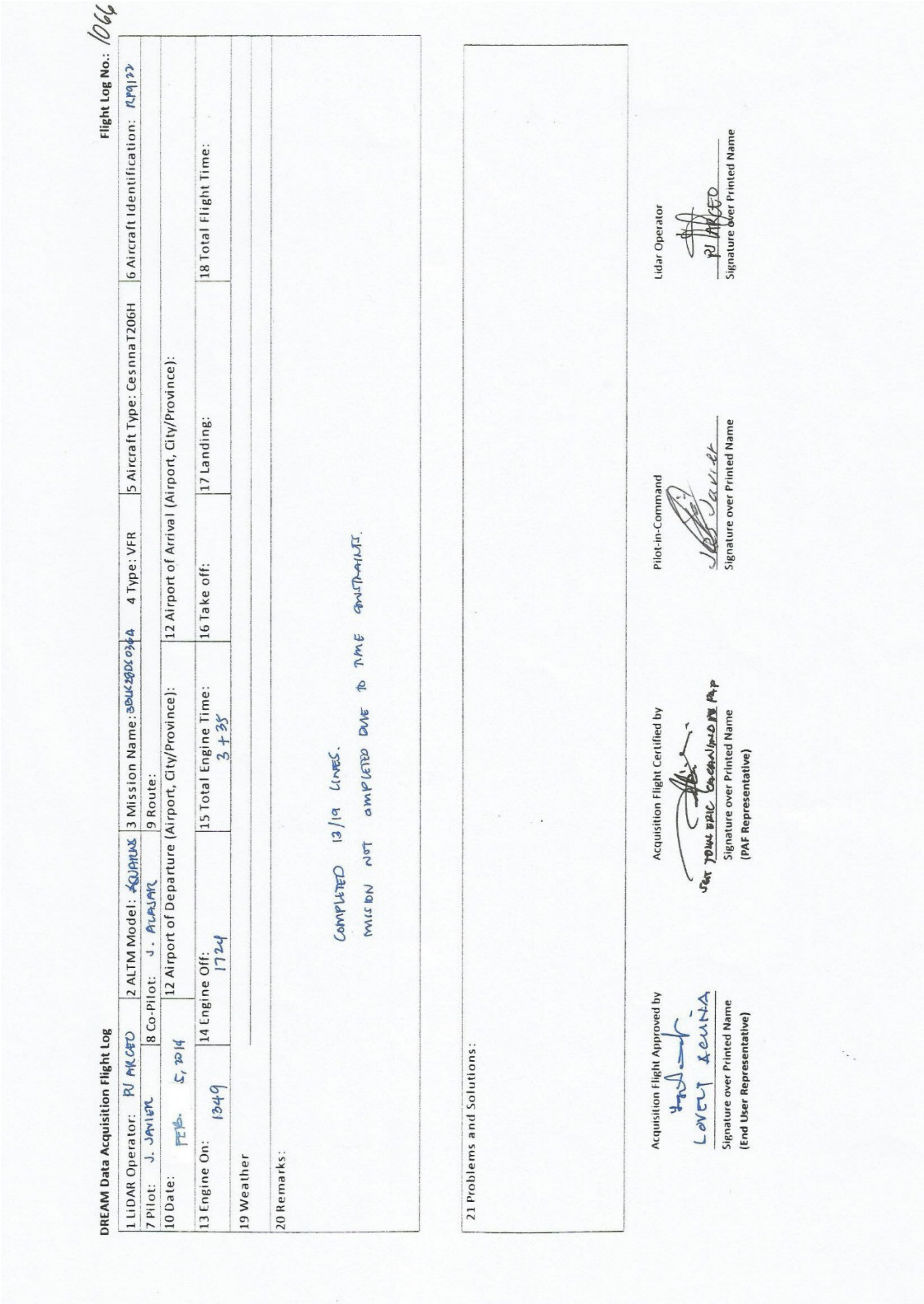
Received from
Name C. Joaquin
Position RA
Signature [signature]

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

Figure A-5.3. Data Transfer Sheet for Sumagui Floodplain - C

Annex 6. Flight logs for the Flight Missions

1. Flight Log for 3BLK28DS036A 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: CesnnaT206H	6 Aircraft Identification: RP9122
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 13/19 LINES.
MISSION NOT COMPLETED DUE TO TIME CONSTRAINT.

21 Problems and Solutions:

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

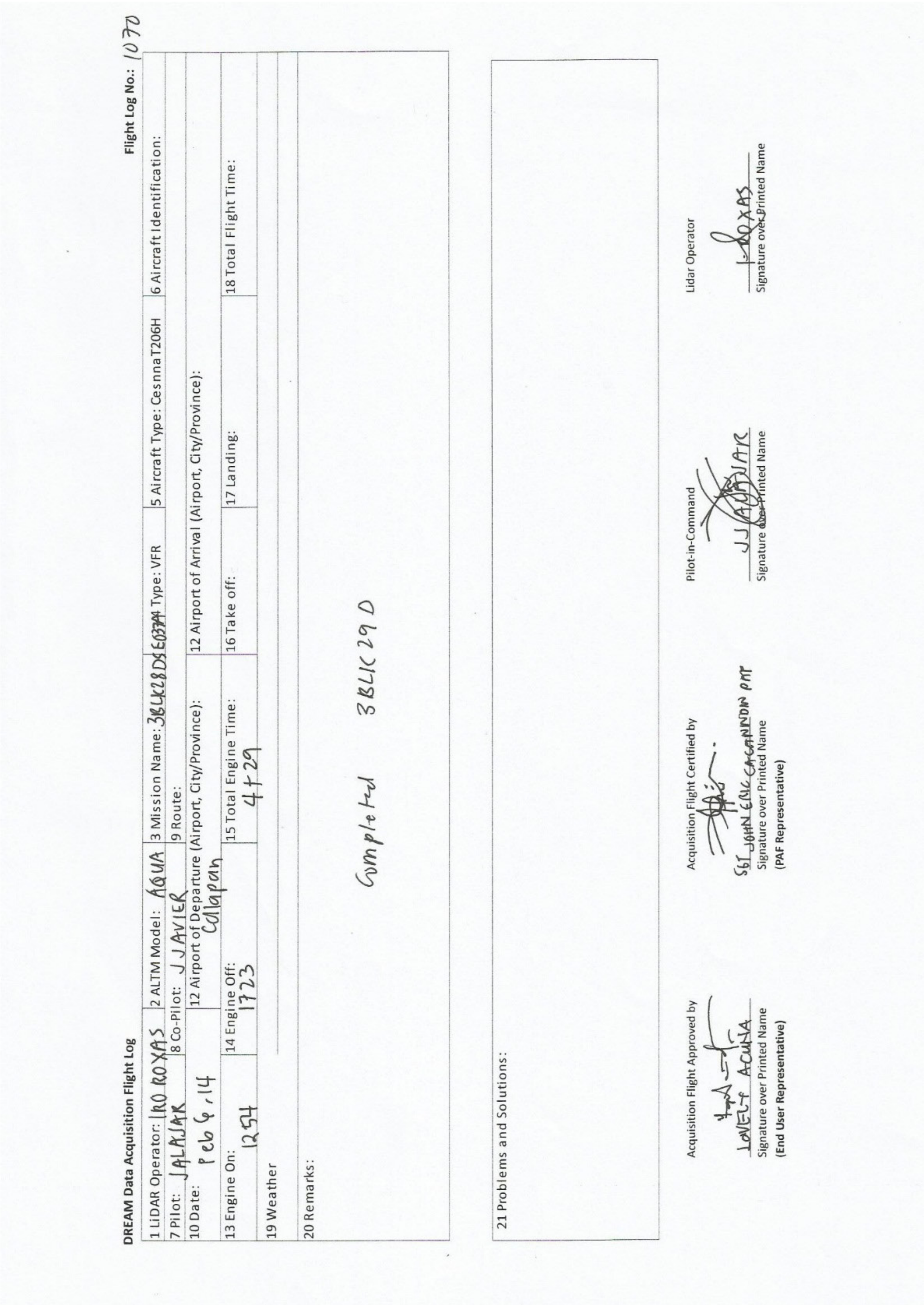
Acquisition Flight Certified by — SSGT JOHN ERIC CASANUEVA PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator — RJ ARCEO — Signature over Printed Name

Figure A-6.1. Flight Log for 3BLK28DS036A Mission

2. Flight Log for 3BLK28DSE037A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1070

1 LiDAR Operator: I RO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK28DSE037A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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): Calapan		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 3BLK 29D					

21 Problems and Solutions:

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

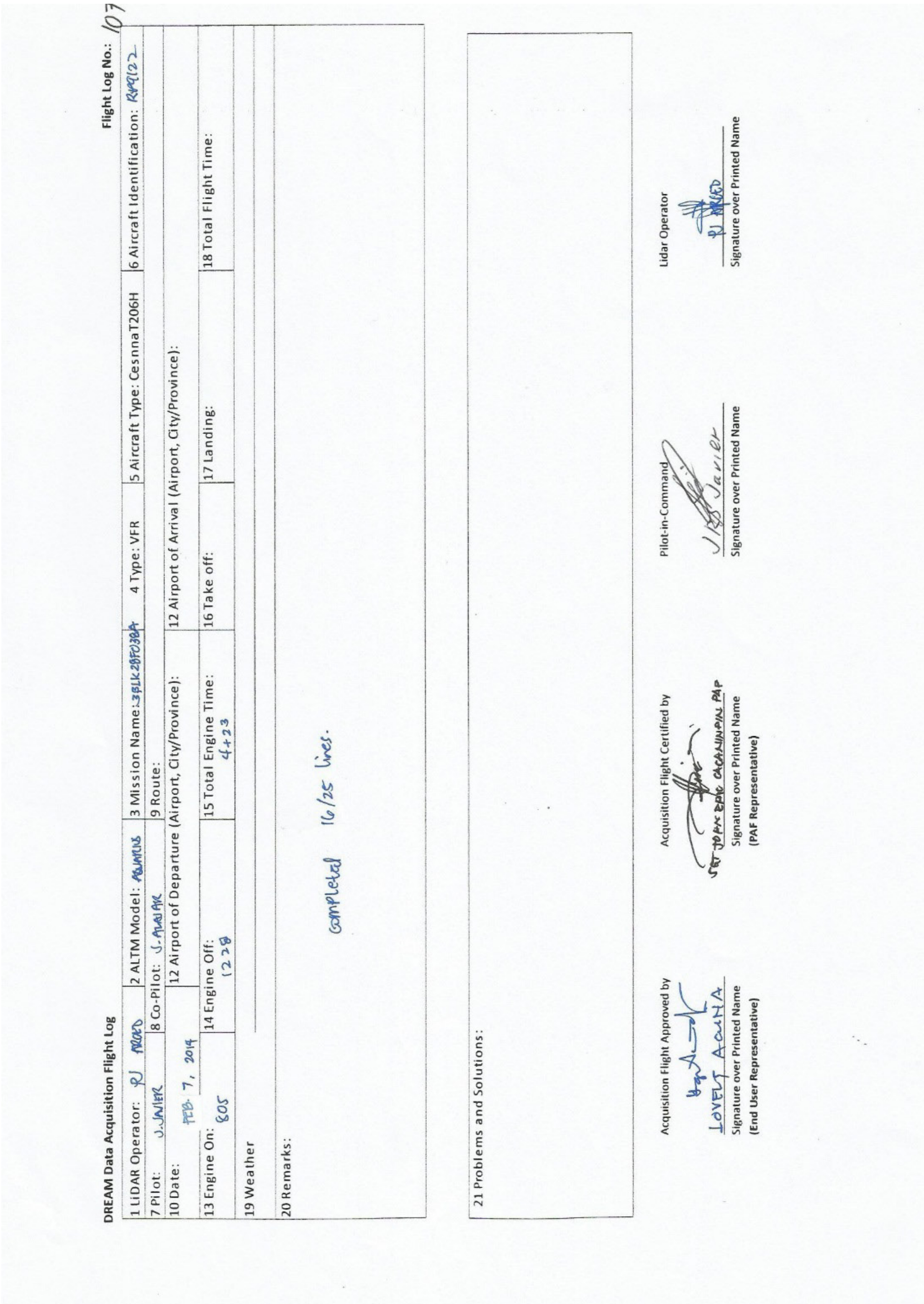
Acquisition Flight Certified by: SGT JOHN ERIC CACANINDIN PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: I ROXAS — Signature over Printed Name

Figure A-6.2. Flight Log for 3BLK28DSE037A Mission

3. Flight Log for 3BLK28F038A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 107

1 LiDAR Operator: RJ	2 ALTM Model: Pegasus	3 Mission Name: 3BLK28F038A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. Javier	8 Co-Pilot:	9 Route:			
10 Date: FEB. 7, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 805	14 Engine Off: 1228	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 16/25 lines.					

21 Problems and Solutions:

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

Figure A-6.3. Flight Log for 3BLK28F038A Mission

4. Flight Log for 3BLK28G039A Mission

DREAM Data Acquisition Flight Log Flight Log No.: 107

1 LIDAR Operator: ILO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK28G039A	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: FEB. 8, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8 25	14 Engine Off: 1230	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: finished 21/25 lines					

21 Problems and Solutions:

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

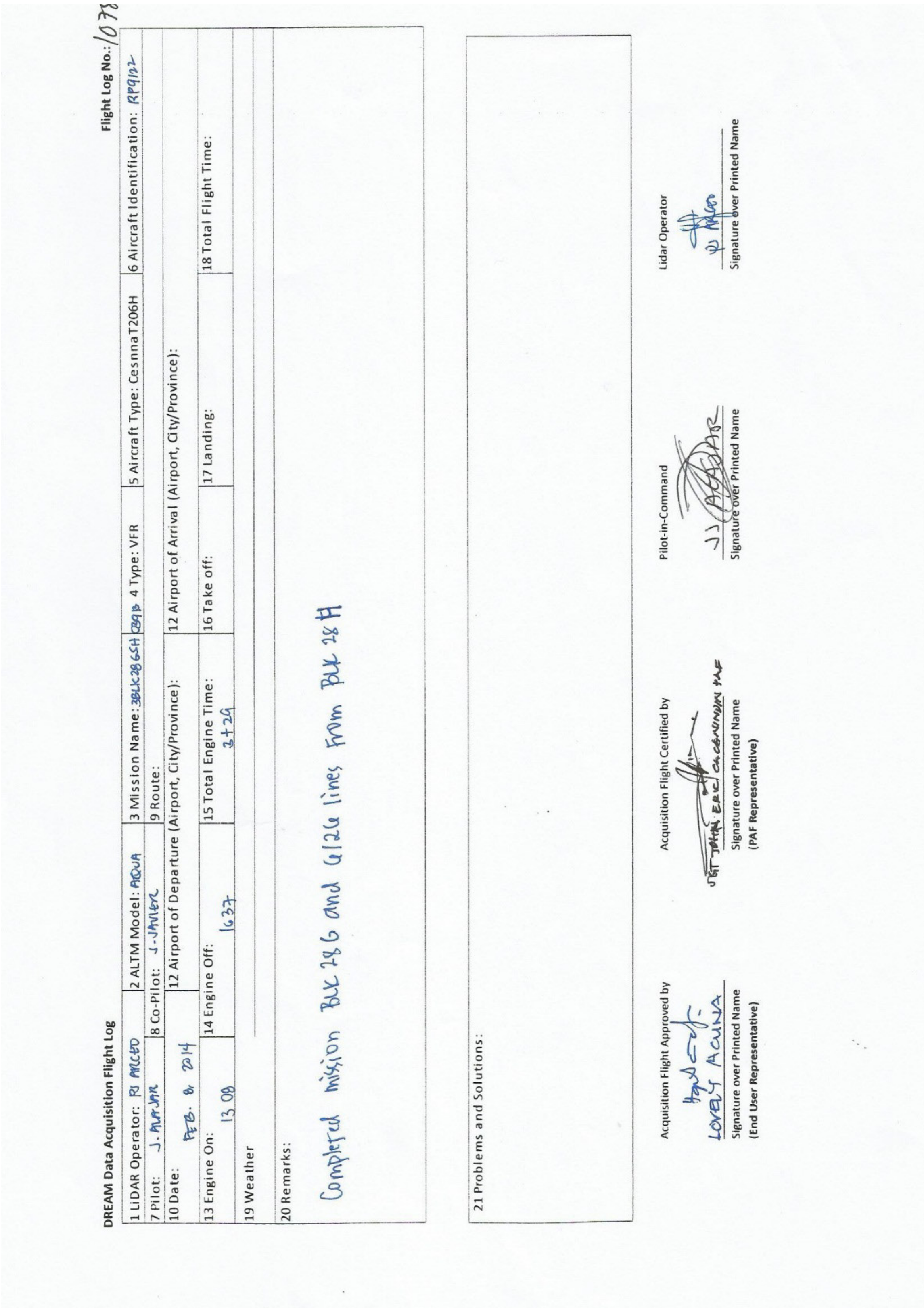
Acquisition Flight Certified by: SGT JOHN ERIC CAMINIDING PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: I. ROXAS — Signature over Printed Name

Figure A-6.4. Flight Log for 3BLK28G039A Mission

5. Flight Log for 3BLK28GSH039B Mission


Flight Log No.: 1078

DREAM Data Acquisition Flight Log

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK28GSH039B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEB. 8, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1308	14 Engine Off: 1637	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission BLK 28G and G126 lines from BLK 28H					

21 Problems and Solutions:

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

Acquisition Flight Certified by: — 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-6.5. Flight Log for 3BLK28GSH039B Mission

6. Flight Log for 3BLK28HS042A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 108

1 LiDAR Operator: PJ Arceo	2 ALTM Model: Aqua	3 Mission Name: 3BLK28HS042A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9122
7 Pilot: J. Alajar	8 Co-Pilot: J. Javier	9 Route:			
10 Date: Feb. 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 851	14 Engine Off: 1320	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED.					
21 Problems and Solutions:					

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

Acquisition Flight Certified by
SGT John Earl Cabanilon PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JJ Alajar
Signature over Printed Name

Lidar Operator
Lovely Acuna
Signature over Printed Name

Figure A-6.6. Flight Log for 3BLK28HS042A Mission

7.Flight Log for 3BLK28ABES043A Mission

DREAM Data Acquisition Flight Log | Flight Log No.: 1092

1 LiDAR Operator: I. Roxas	2 ALTM Model: AQUA	3 Mission Name: 3BLKABES043A	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: 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
Loren Acuna	SGT John Eric Escanindin 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-6.7. Flight Log for 3BLK28ABES043A Mission

8. Flight Log for 2BLK28FHS297A Mission

Data Acquisition Flight Log — Flight Log No.: 83046

1 LiDAR Operator: MS REYES	2 ALTM Model: Gemini	3 Mission Name: 2BLK28FHS297A	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. 24, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0711	14 Engine Off: 1041	15 Total Engine Time: 3+30	16 Take off: 0716	17 Landing: 1036	18 Total Flight Time: 3+20
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered BLK 28F ...

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.C. TANGONAN — Signature over Printed Name	MS REYES — Signature over Printed Name	G. ALFONSO — Signature over Printed Name

Figure A-6.8. Flight Log for 2BLK28FHS297A Mission

9. Flight Log for 2CALIBBLK28FSGS298A Mission

Data Acquisition Flight Log — 2CALIBBLK28FSGS298A — **Flight Log No.:** 8306G

1 LiDAR Operator: MCE BALIGUAS / PJ ARCEO	2 ALTM Model: Gemini	3 Mission Name:	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. 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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[signature]	[signature] AWIC CHRISTINA NAVARRO PAF	M. L. TANGONAN	[signature]	G. ANTONIO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.9. Flight Log for 2CALIBBLK28FSGS298A Mission

10. Flight log for 2BLK28J299A Mission

Data Acquisition Flight Log

Flight Log No.: 23086

1 LiDAR Operator: MS REYES	2 ALTM Model: Gemini	3 Mission Name: 2BLK28J299A	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. 26, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0712	14 Engine Off: 1103	15 Total Engine Time: 3+51	16 Take off: 0717	17 Landing: 1058	18 Total Flight Time: 3+41
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

Supplemental flight for BLK 28F and covered BLK28E with voids due to clouds. Experienced digitizer hard drive writing error

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)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.10. Flight Log for 2BLK28J299A Mission

Annex 7. Flight Status Reports

SUMAGUI FLOODPLAIN
February 2-15, 2014; October 23-25, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1066A	BLOCK 28D	3BLK28DS036A	PAULINE ARCEO	FEB 5, 2014	FEB 5, 2014
1070A	BLOCK 28D & 28E	3BLK28DSE037A	IRO ROXAS	FEB 6, 2014	Finished Block 28D and some lines of Block 28E
1072A	BLOCK 28F	3BLK28F038A	PAULINE ARCEO	FEB 7, 2014	Mission Complete
1076A	BLOCK 28G	3BLK28GS039A	IRO ROXAS	FEB 8, 2014	Mission Complete
1078A	BLOCK 28G & BLOCK 28H	3BLK28GSH039B	PAULINE ARCEO	FEB 8, 2014	Mission Complete
1088A	BLK 28H	3BLK28HS042A	IRO ROXAS	FEB 11, 2014	Mission Complete
1092A	BLK 28A,B,E	3BLK28ABES043A	IRO ROXAS	FEB 12, 2014	Mission Complete
8304G	BLK28FH	2BLK28FHS297A	CATH BALIGUAS, SHANE REYES	OCT 24, 2014	Covered BLK 28 F&H
8306G	BLK28F	2CALIBBLK28FSGS298A	PAU ARCEO, CATH BALIGUAS	OCT 25, 2014	LMS Calib over Pinamalayan; completed BLK 28F and covered BLK 28G
Oct. 26, 2015	8308	MS Reyes	2BLK28J299A	OCT 26, 2014	Supplemental flight for BLK28F and covered BLK28J with voids due to clouds. Experienced Digitizer hard drive writing error.

LAS/SWATH BOUNDARIES PER MISSION FLIGHT
FLIGHT LOG NO. 1066A
AREA: BLOCK 28D
MISSION NAME: 3BLK28DS036A

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

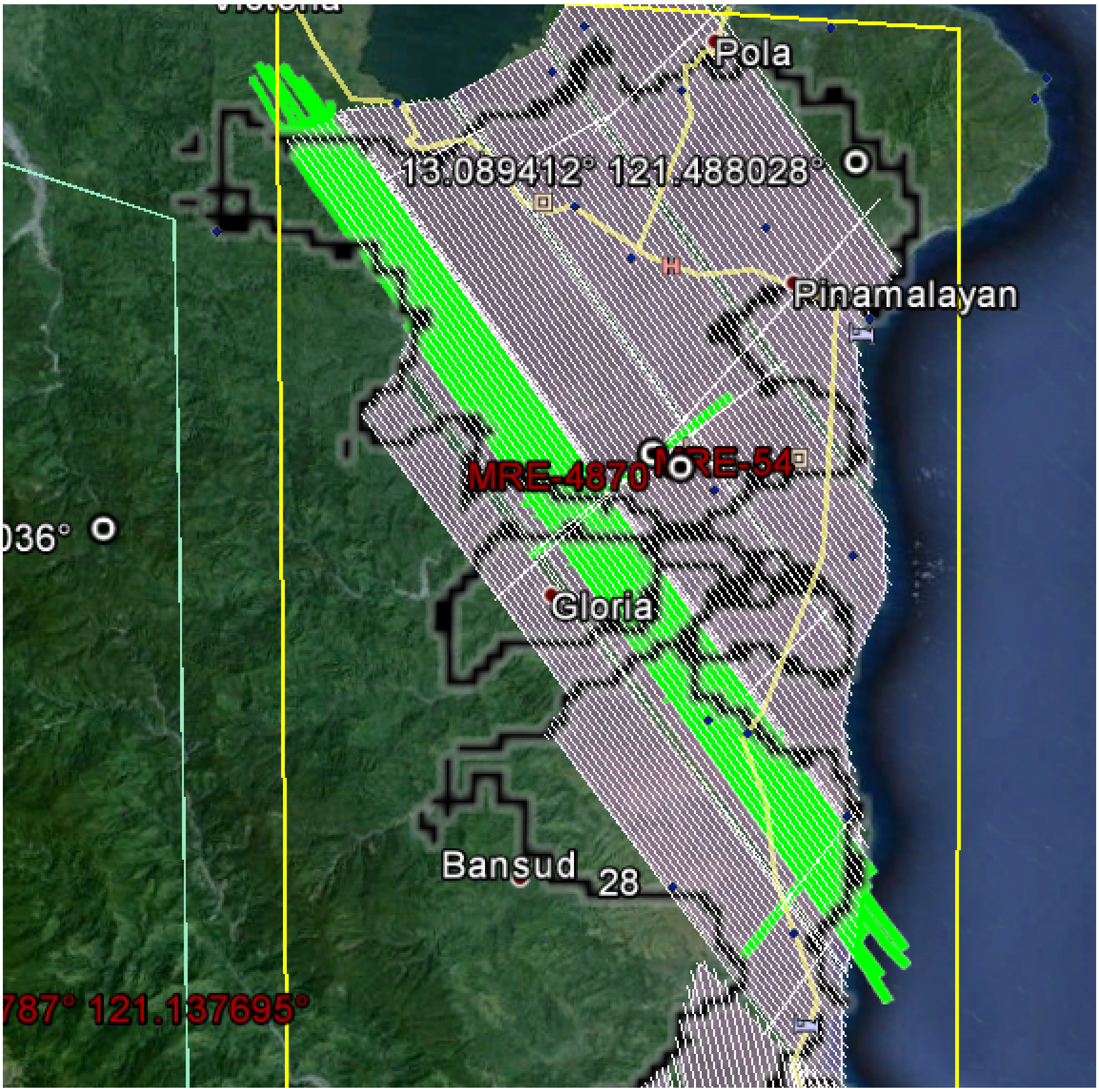


Figure A-7.1. Swath for Flight No. 1066A

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

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

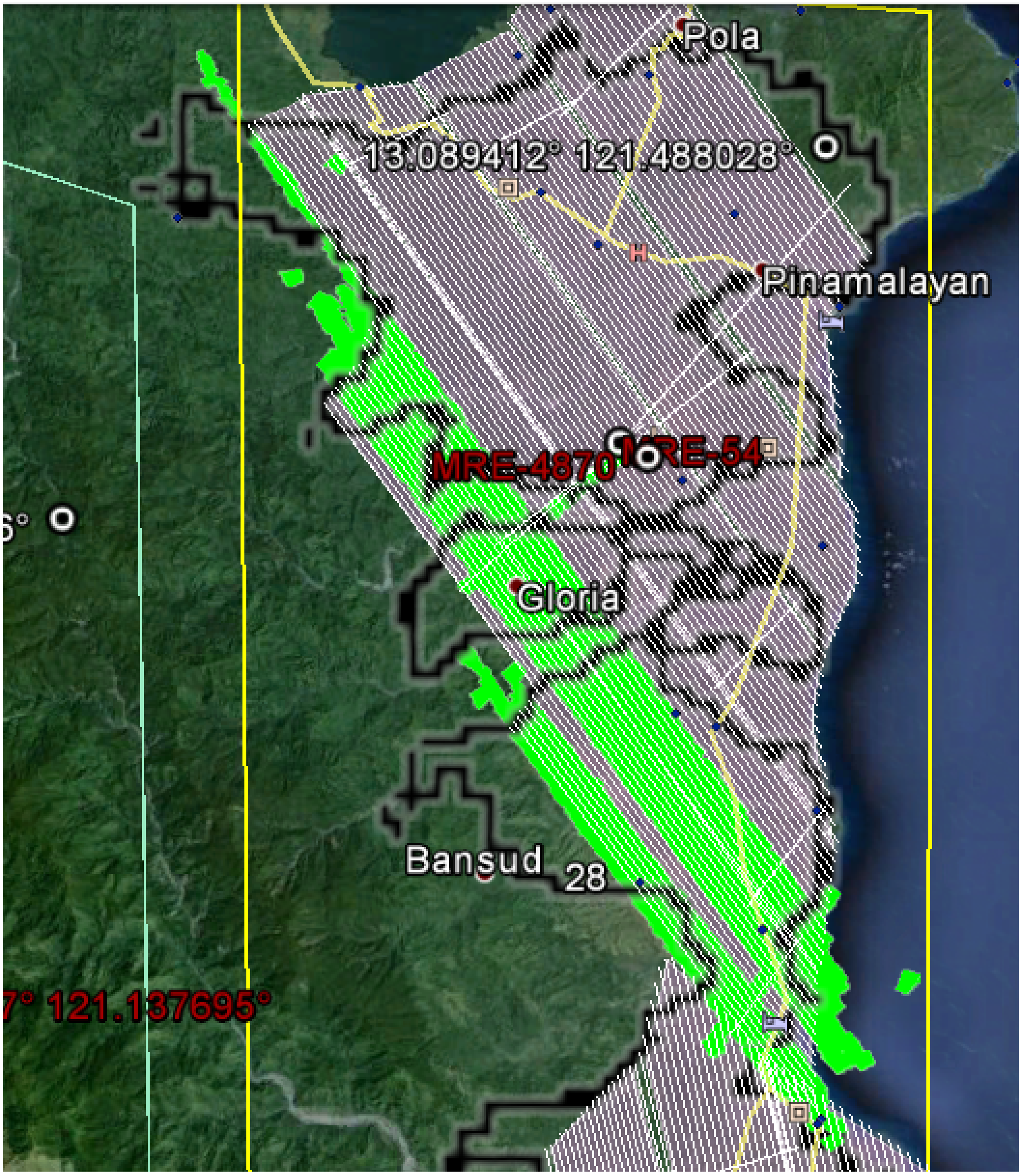


Figure A-7.2. Swath for Flight No. 1070A

FLIGHT LOG NO. 1072A
AREA: BLOCK 28F
MISSION NAME: 3BLK28F038A

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

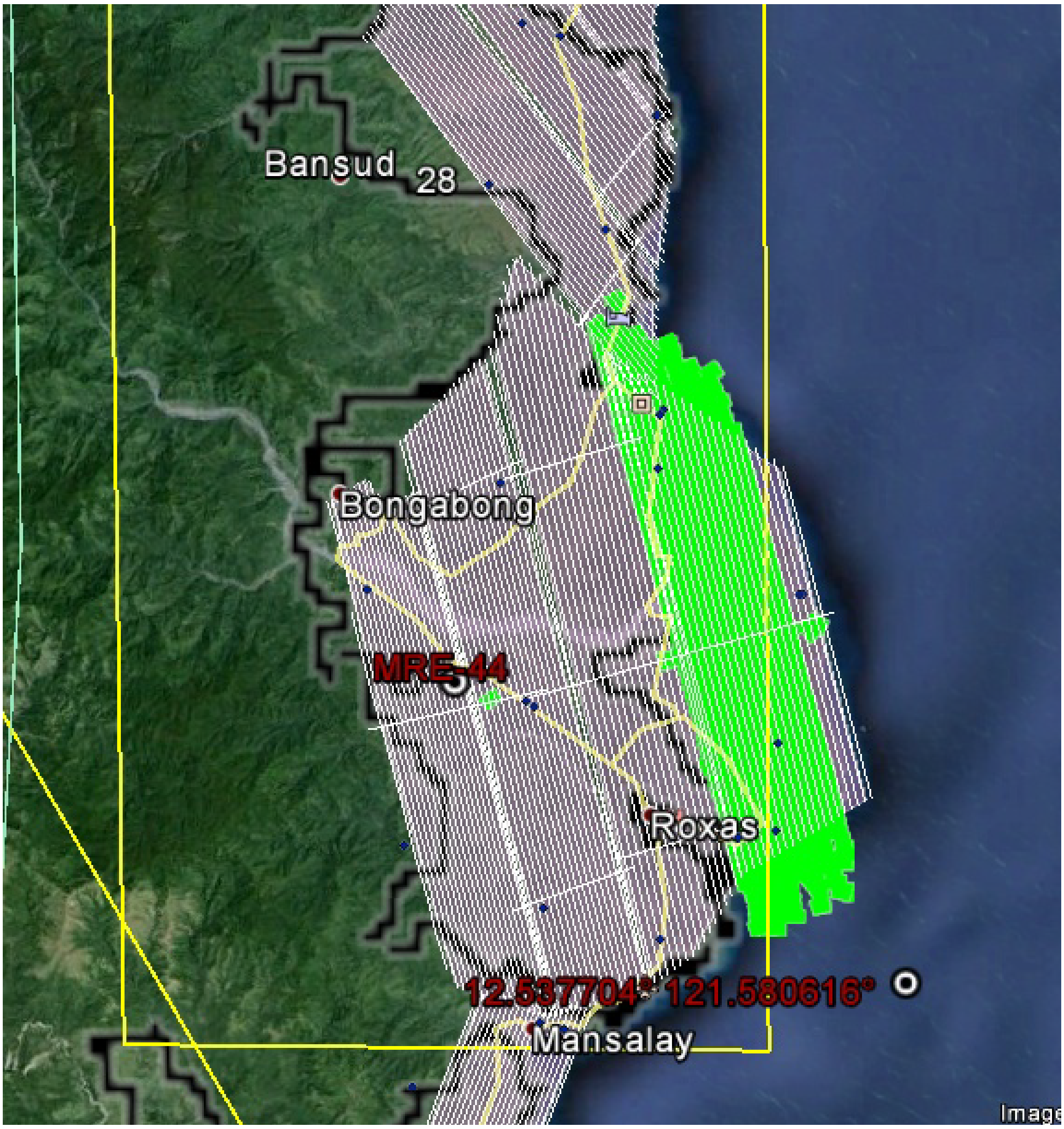


Figure A-7.3. Swath for Flight No. 1072A

FLIGHT LOG NO. 1076A
AREA: BLOCK 28G
MISSION NAME: 3BLK28G039A

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

Figure A-7.4. Swath for Flight No. 1076A

FLIGHT LOG NO. 1078A
AREA: BLOCK 28G, 28H
MISSION NAME: 3BLK28GSH039B

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

Figure A-7.5. Swath for Flight No. 1078A

FLIGHT LOG NO. 1088A
AREA: BLOCK 28H
MISSION NAME: 3BLK28HS042A

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

Figure A-7.6. Swath for Flight No. 1088A

FLIGHT LOG NO. 1092A
AREA: BLOCK 28A, B, E
MISSION NAME: 3BLK28ABES43A

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

SURVEY COVERAGE:

Figure A-7.7. Swath for Flight No. 1092A

FLIGHT LOG NO. 8304G
AREA: BLOCK 28F & 28H
MISSION NAME: 2BLK28FHS297A

Scan Freq: 50 kHz
Scan Angle: 15 deg
Alt: 1200 m

SURVEY COVERAGE:

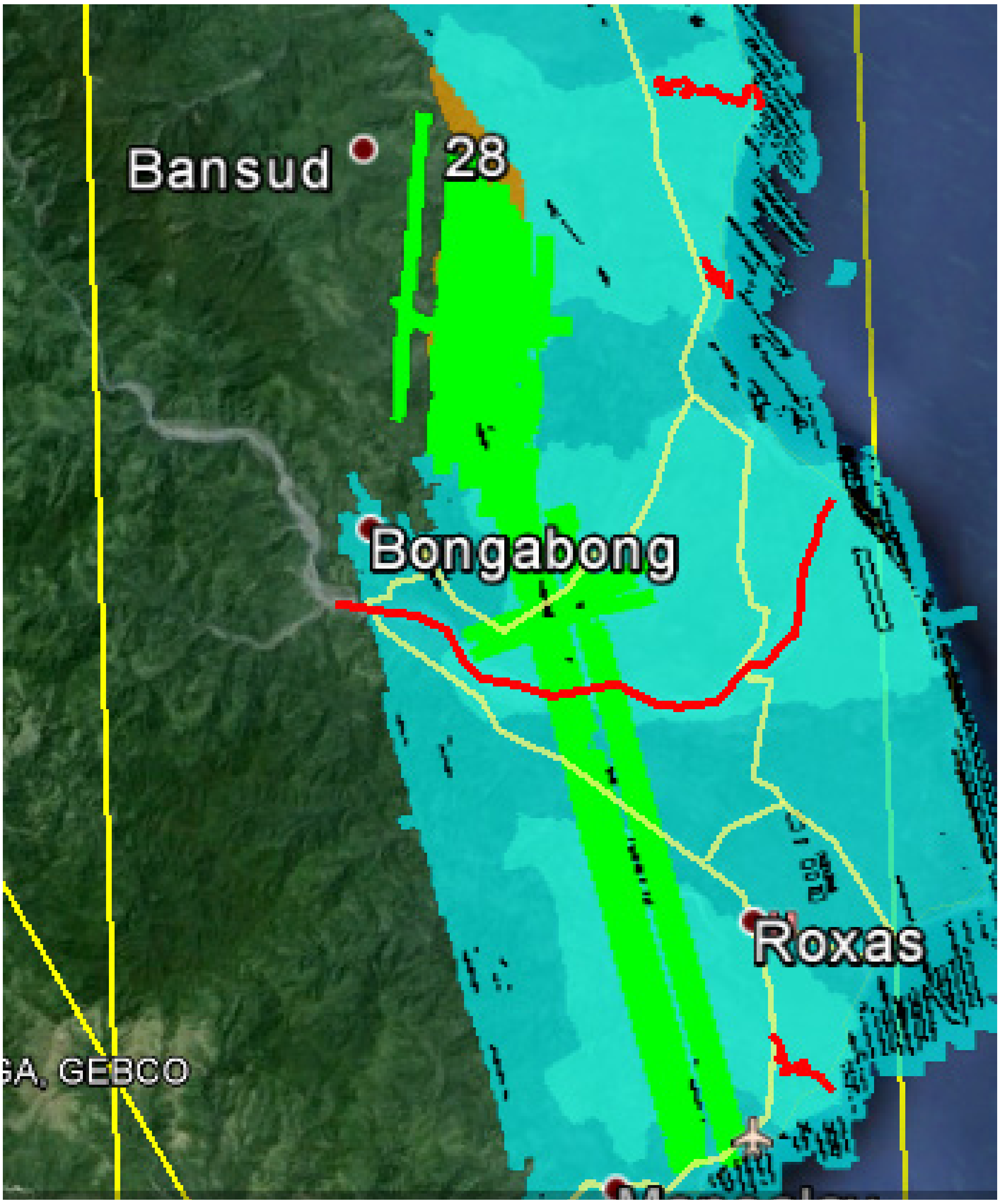


Figure A-7.8. Swath for Flight No. 8304G

FLIGHT LOG NO. 8306G
AREA: BLOCK 28F & 28G
MISSION NAME: 2CALIBBLK28FSGS298A

Scan Freq: 50 kHz
Scan Angle: 20 deg
Alt: 1000 m

SURVEY COVERAGE:

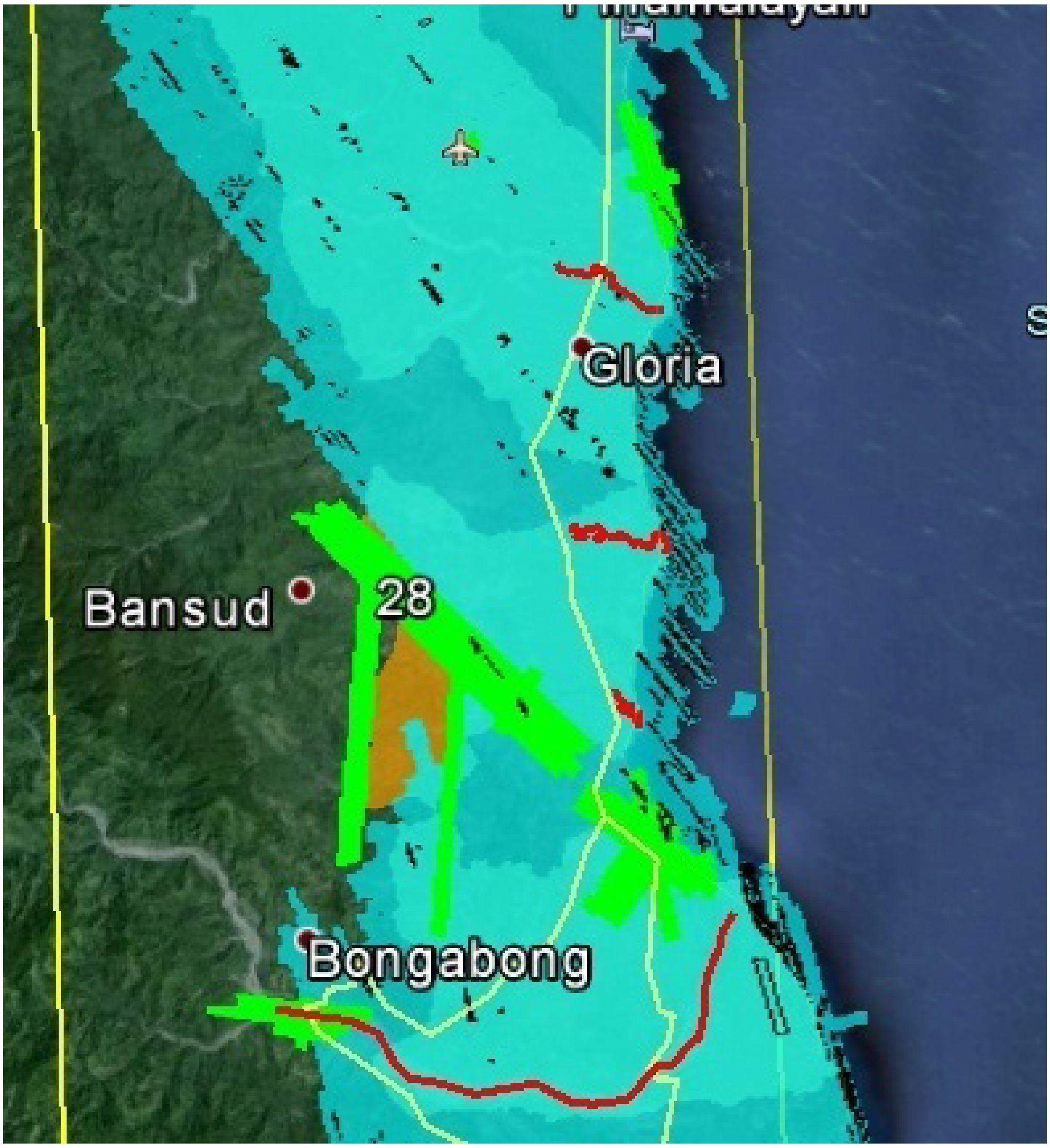


Figure A-7.9. Swath for Flight No. 8306G

FLIGHT NO.: 8308G
AREA: Oriental Mindoro
MISSION NAME: 2BLK28J299A
ALT: 1000 m SCAN FREQ: 50 SCAN ANGLE: 18

SURVEY COVERAGE:

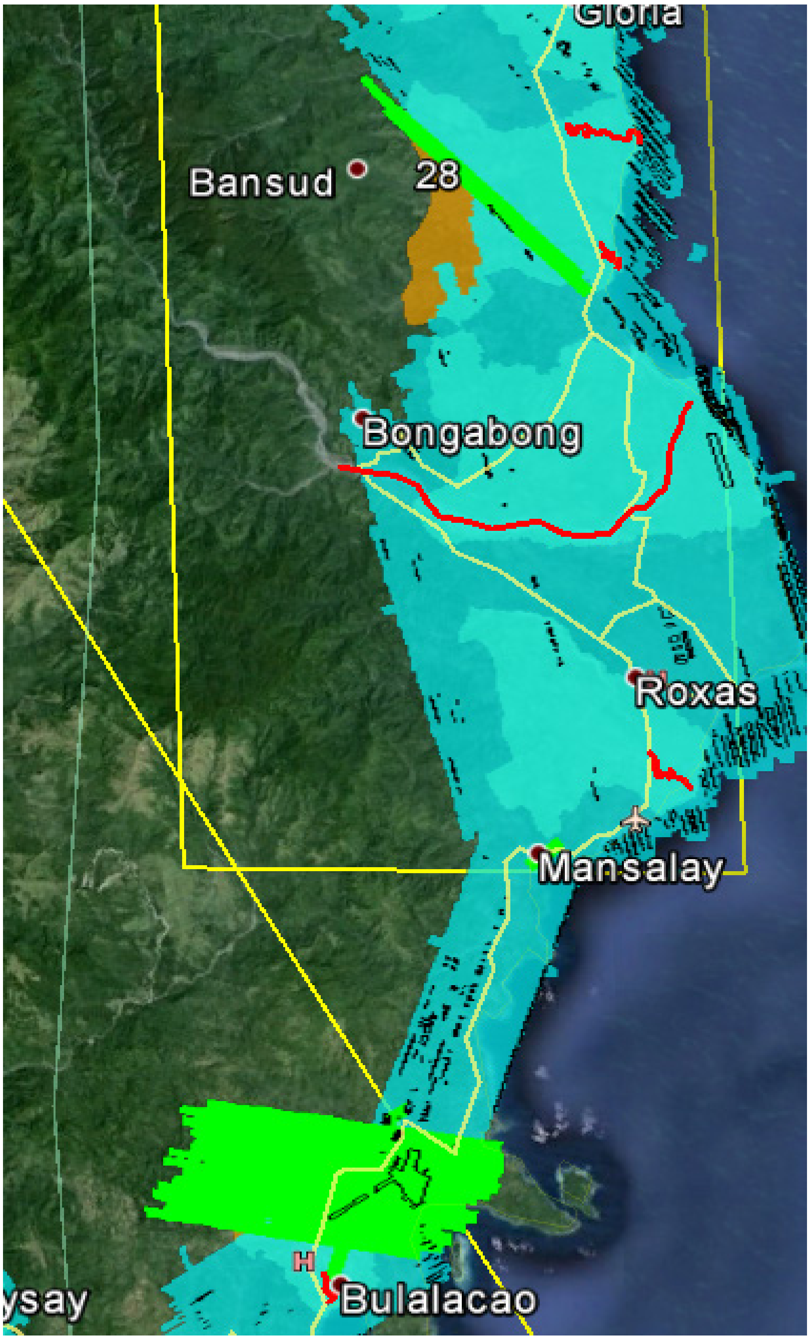


Figure A-7.10. Swath for Flight No. 8308G

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk28F

Flight Area	Oriental Mindoro
Mission Name	Blk28F
Inclusive Flights	1072A
Range data size	12.5 GB
Base data size	256 MB
POS data size	81.4 GB
Image	February 20, 2014
Transfer date	
Solution Status	YES
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	
Smoothed Performance Metrics(in cm)	1.4
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	3.8
RMSE for Down Position (<8.0 cm)	
	0.000425
Boresight correction stdev (<0.001deg)	0.009525
IMU attitude correction stdev (<0.001deg)	0.0318
GPS position stdev (<0.01m)	
	42.58%
Minimum % overlap (>25)	2.86
Ave point cloud density per sq.m. (>2.0)	YES
Elevation difference between strips (<0.20m)	
	190
Number of 1km x 1km blocks	146.32 m
Maximum Height	31.32 m
Minimum Height	
Classification (# of points)	83,396,476
Ground	114,178,225
Low vegetation	59,793,586
Medium vegetation	34,546,932
High vegetation	3,692,979
Building	2,285,212
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Antonio Chua Jr., Engr. Elainne Lopez

Figure A-8.1 Solution Status

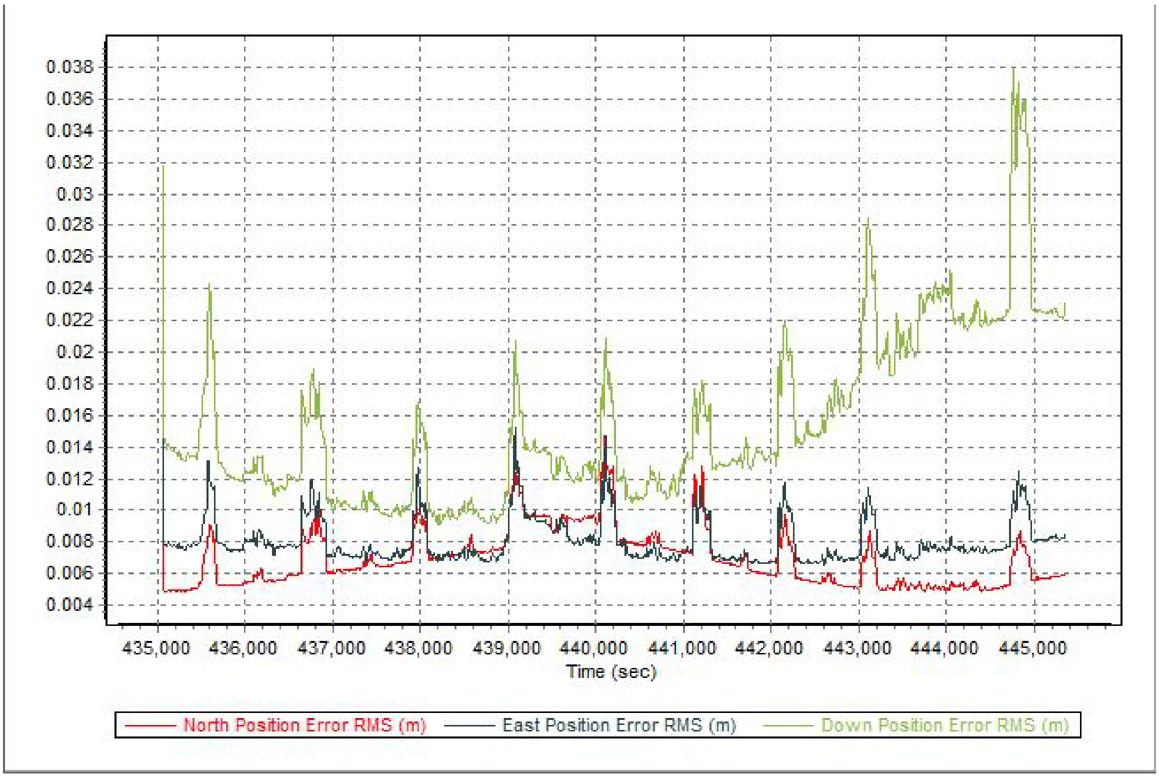


Figure A-8.2 Smoothed Performance Metrics Parameters

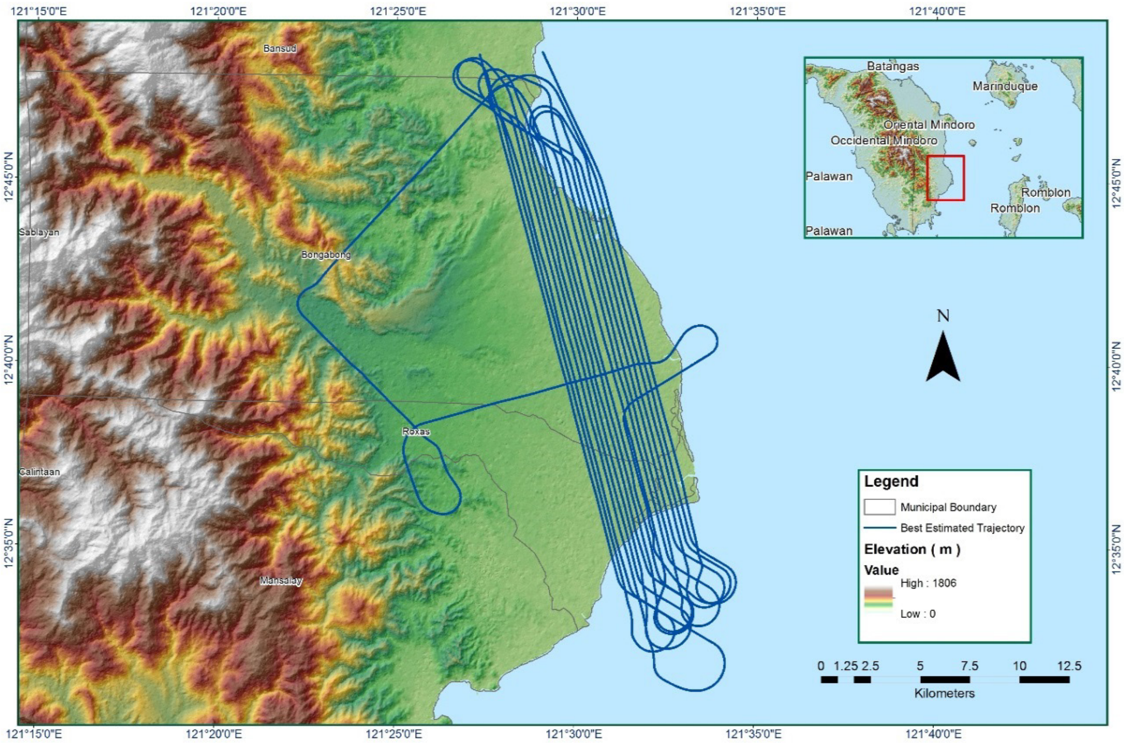


Figure A-8.3 Best Estimated Trajectory

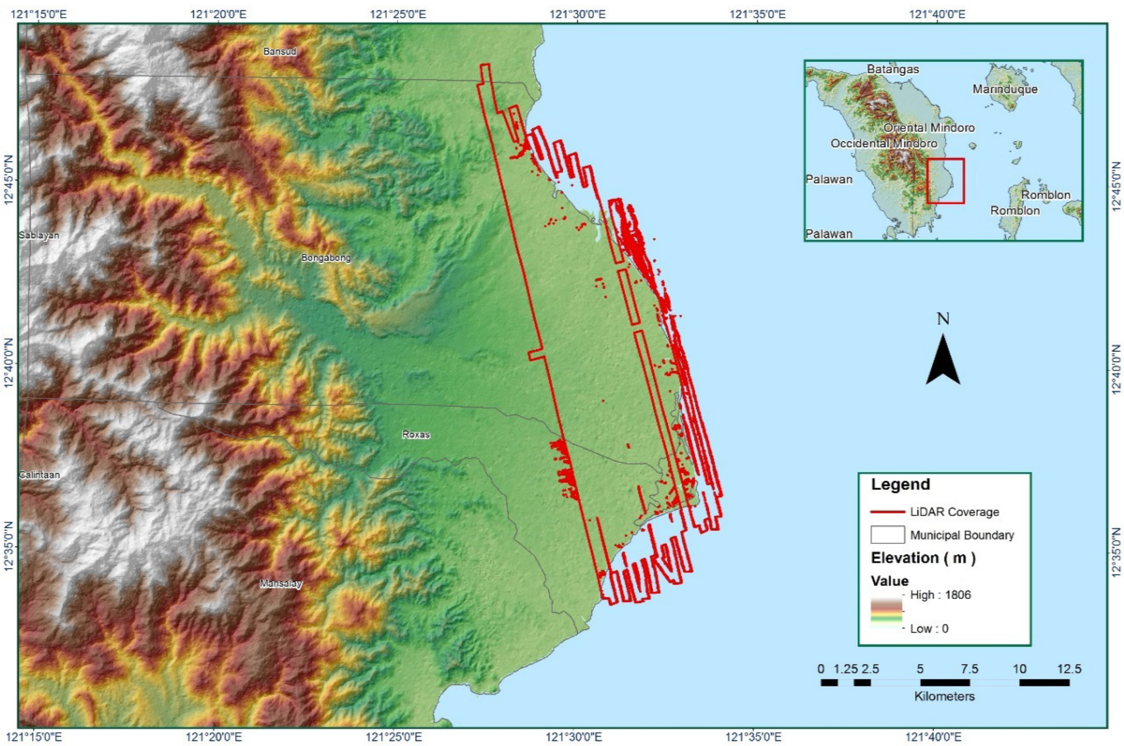


Figure A-8.4. Coverage of LiDAR data

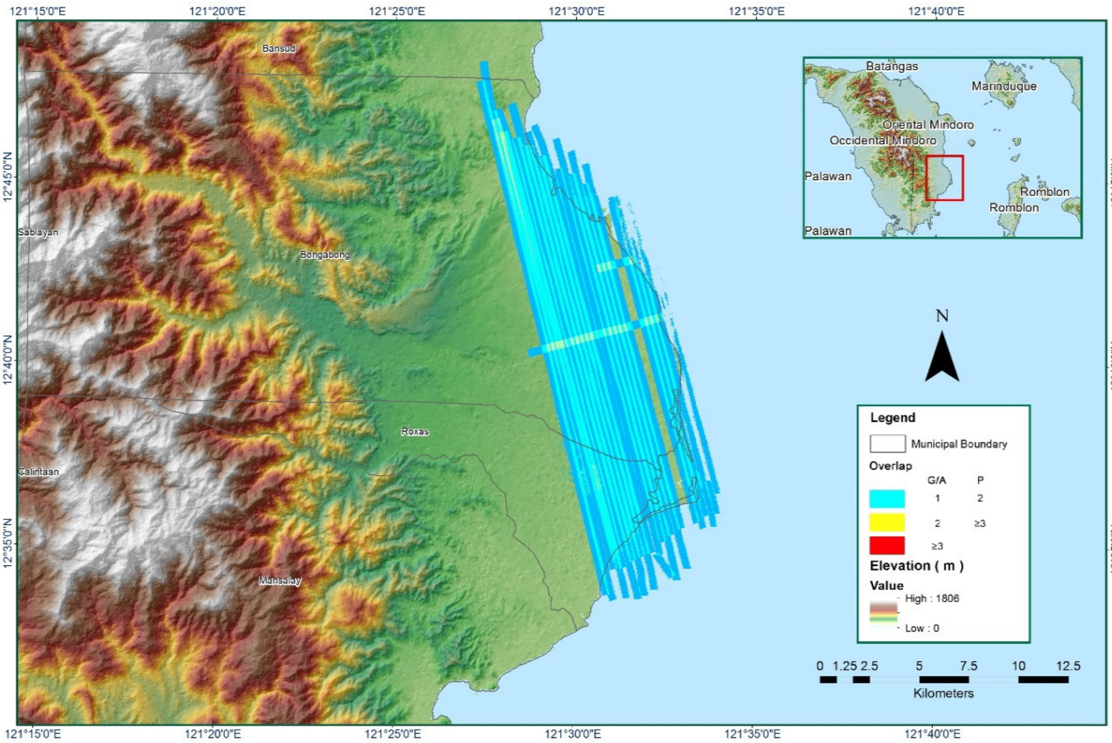


Figure A-8.5. Image of data overlap

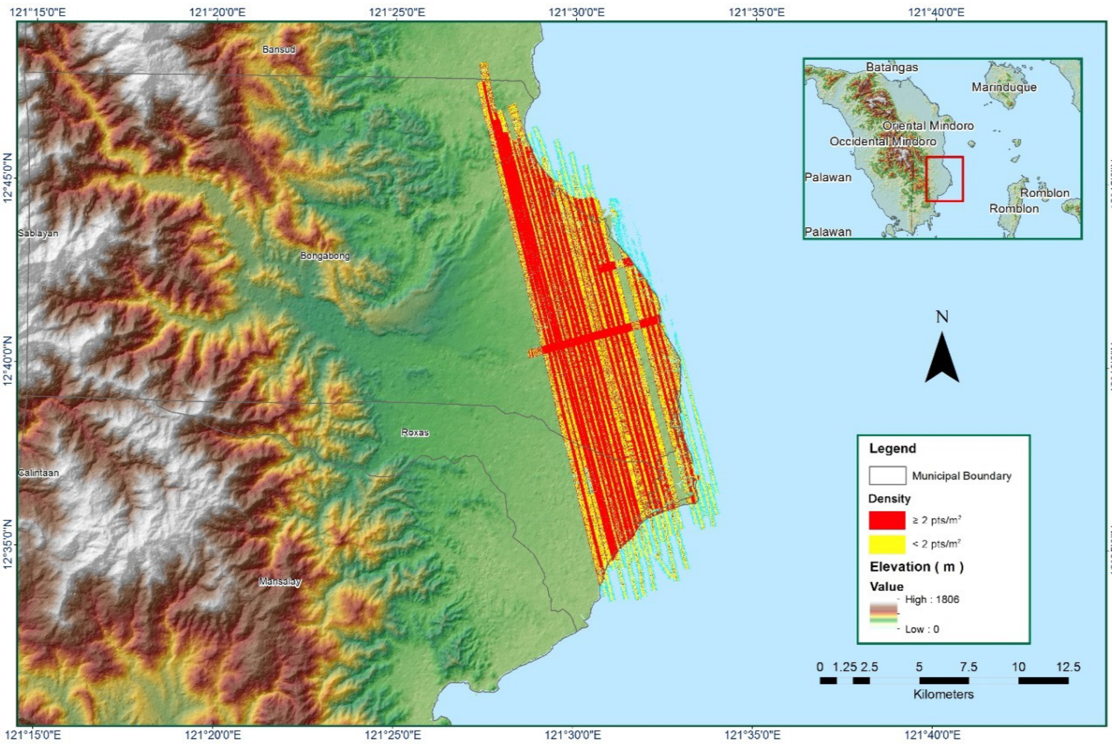


Figure A-8.6 Density of merged LiDAR data

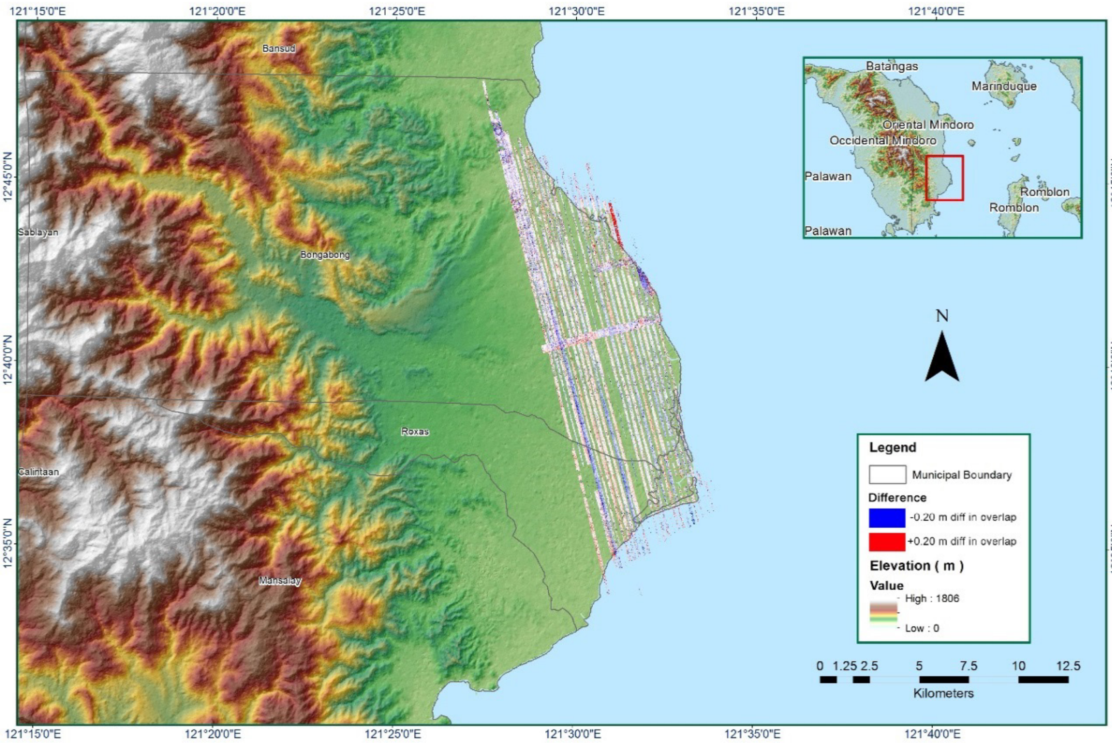


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk28G

Flight Area	Oriental Mindoro
Mission Name	Blk28G
Inclusive Flights	1076A
Range data size	11.5 GB
POS	233 MB
Image	76.8 GB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.8
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	8.6
Boresight correction stdev (<0.001deg)	0.000407
IMU attitude correction stdev (<0.001deg)	0.001355
GPS position stdev (<0.01m)	0.0097
Minimum % overlap (>25)	33.27%
Ave point cloud density per sq.m. (>2.0)	2.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	141
Maximum Height	216.76 m
Minimum Height	35.08 m
Classification (# of points)	
Ground	67,283,967
Low vegetation	77,300,272
Medium vegetation	51,202,535
High vegetation	45,765,772
Building	1,511,333
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. John Dill Macapagal

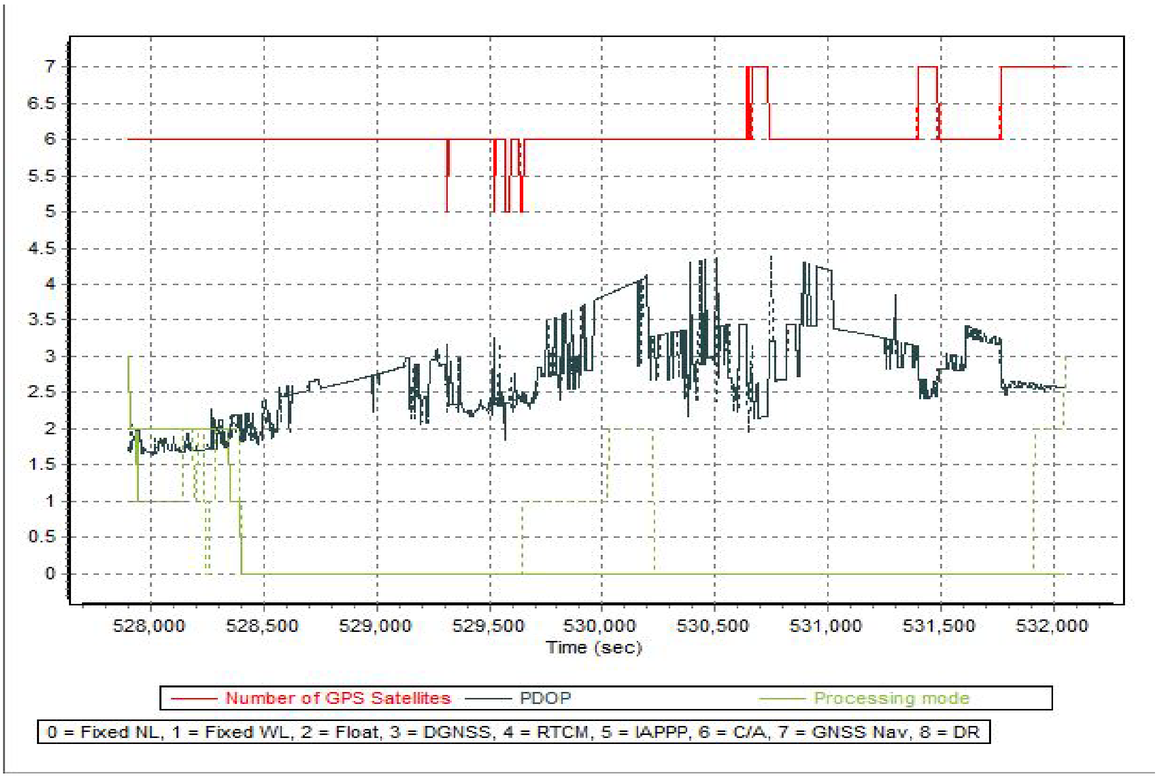


Figure A-8.8. Solution Status

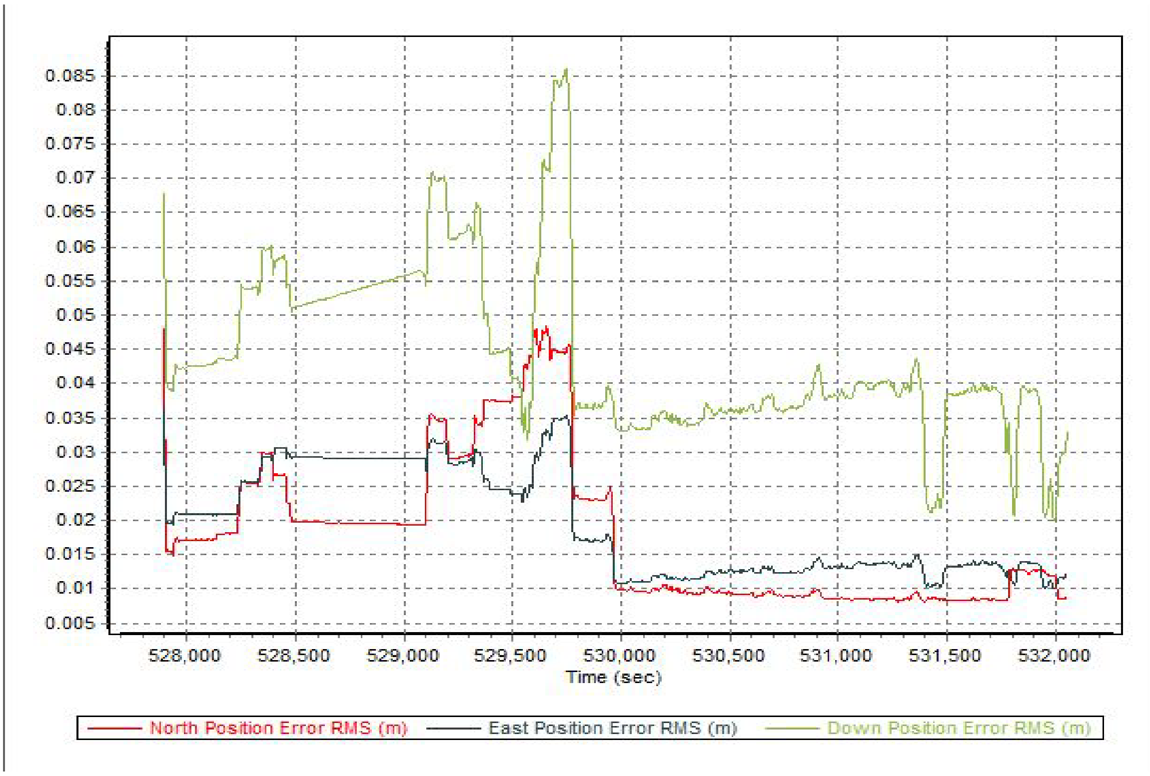


Figure A-8.9. Smoothed Performance Metrics Parameters

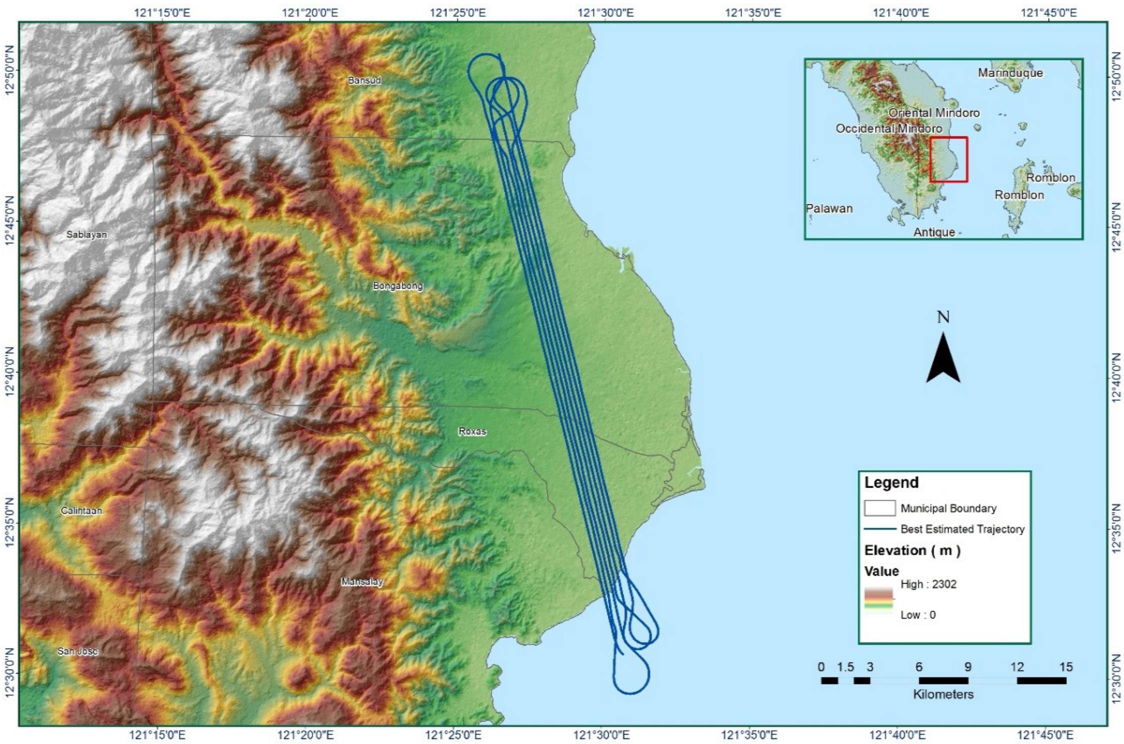


Figure A-8.10. Best Estimated Trajectory

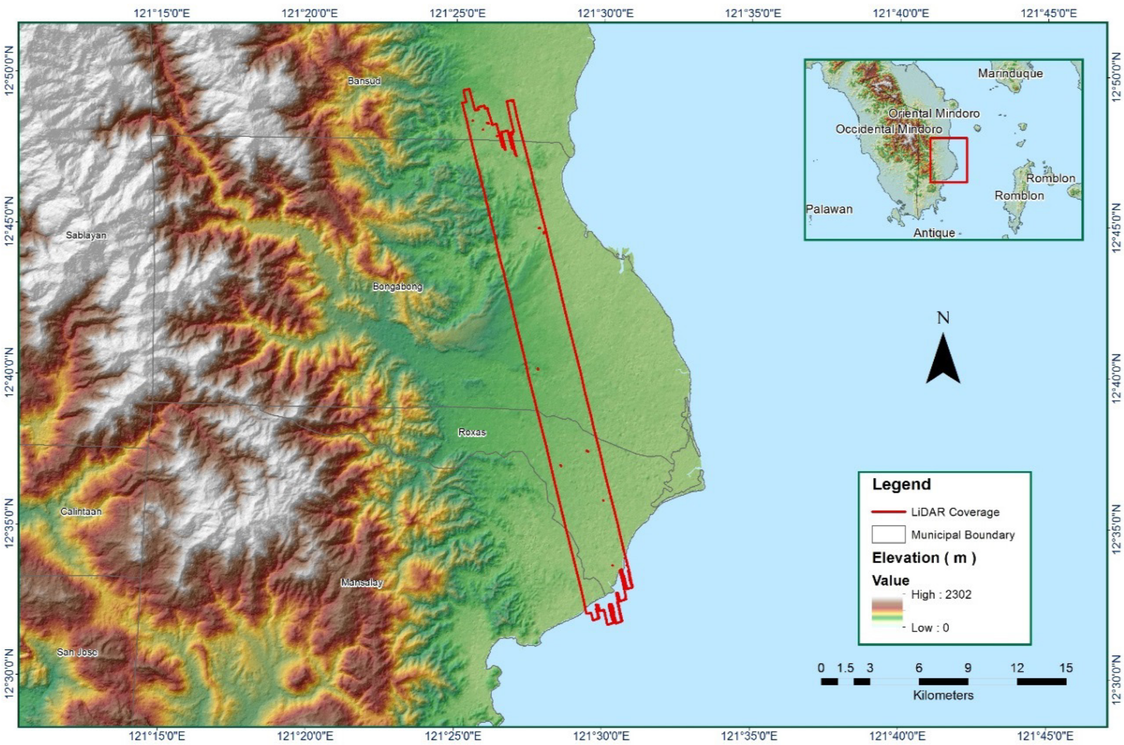


Figure A-8.11. Coverage of LiDAR data

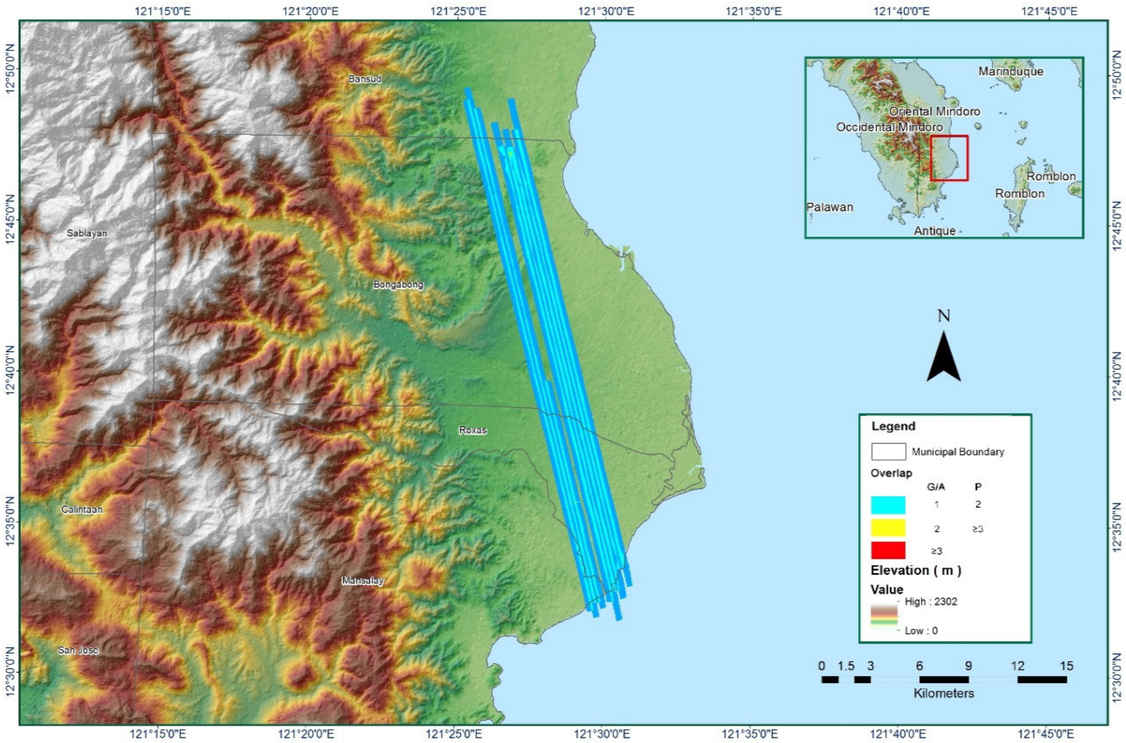


Figure A-8.12. Image of data overlap

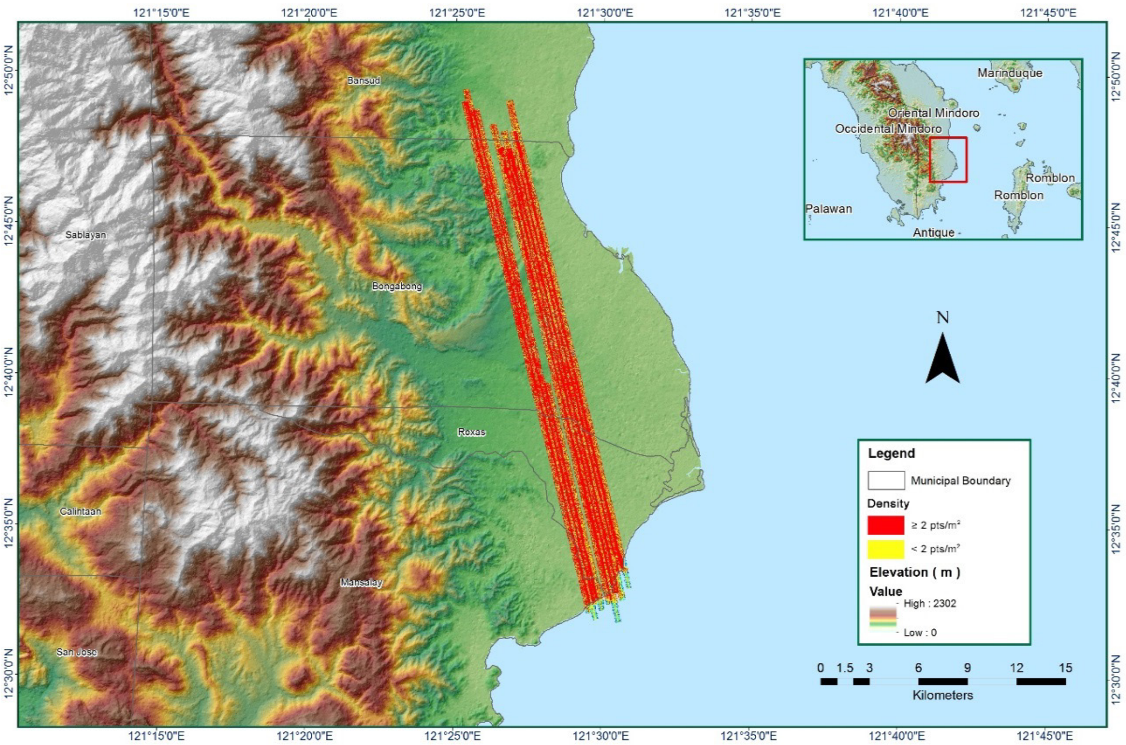


Figure A-8.13. Density of merged LiDAR data

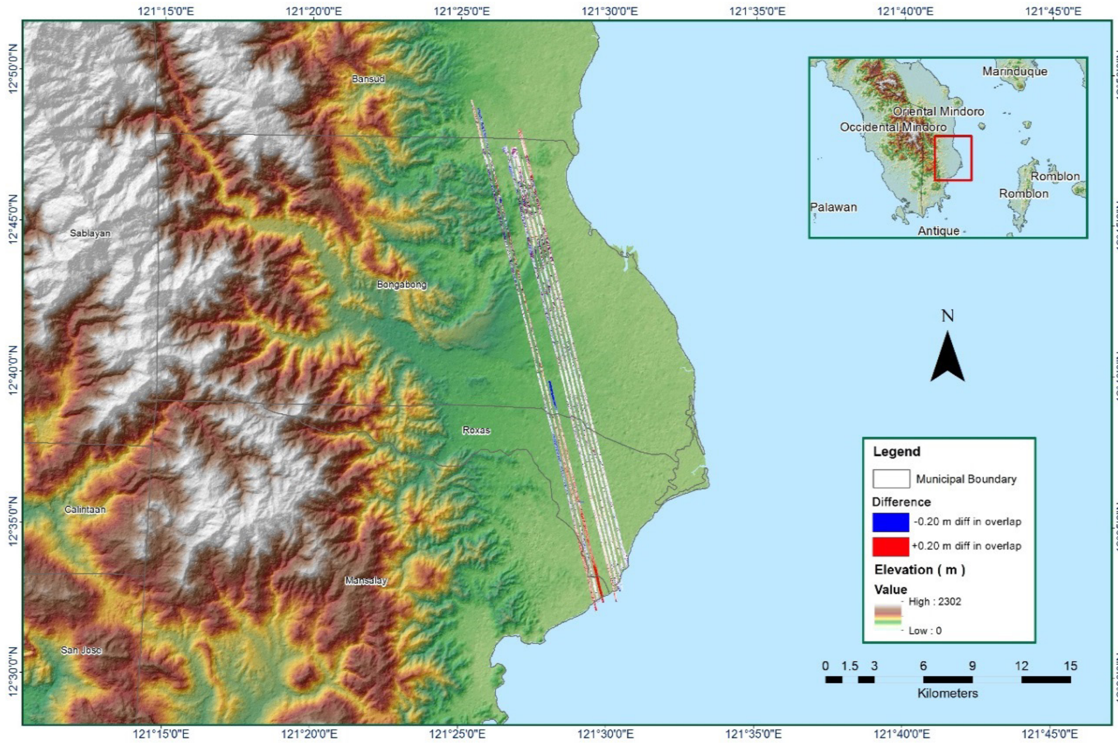


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk28GsH

Flight Area	Oriental Mindoro
Mission Name	Blk28GsH
Inclusive Flights	1078A
Range data size	9.71 GB
POS	197 MB
Image	56.8 GB
Transfer date	February 20, 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)	1.6
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	6.0
Boresight correction stdev (<0.001deg)	0.000552
IMU attitude correction stdev (<0.001deg)	0.004258
GPS position stdev (<0.01m)	0.0143
Minimum % overlap (>25)	58.5%
Ave point cloud density per sq.m. (>2.0)	4.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	107
Maximum Height	288.11 m
Minimum Height	48.43 m
Classification (# of points)	
Ground	46,444,727
Low vegetation	58,505,631
Medium vegetation	50,918,523
High vegetation	49,004,112
Building	1,332,080
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Celina Rosete, Engr. Elainne Lopez

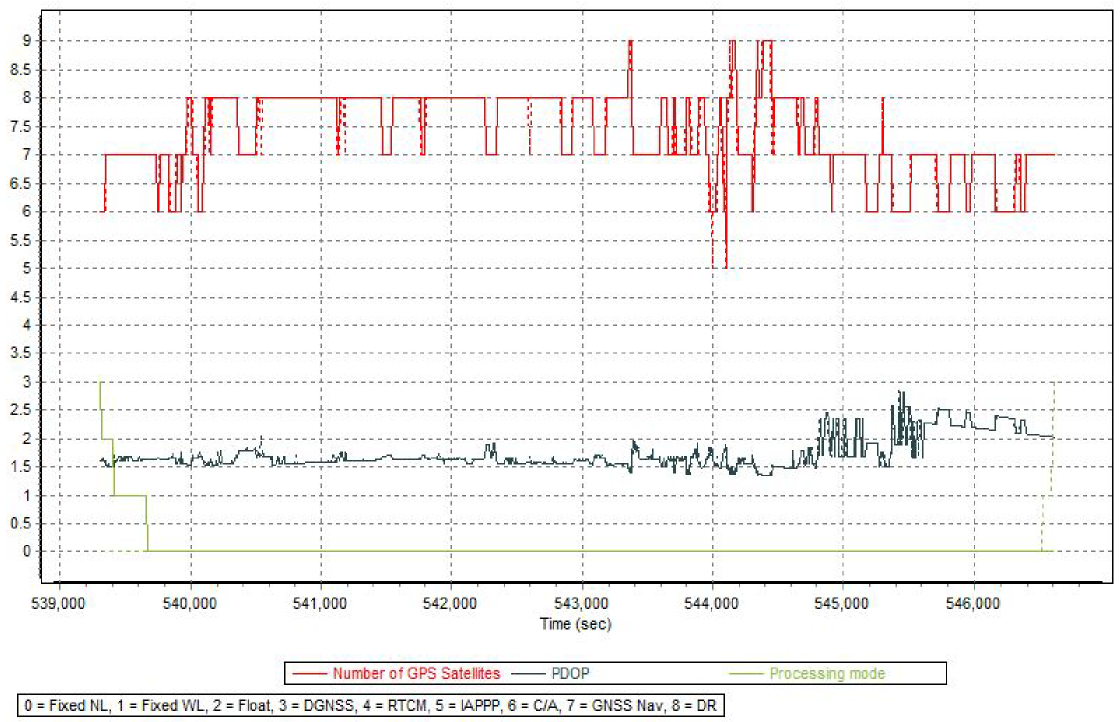


Figure A-8.15. Solution Status

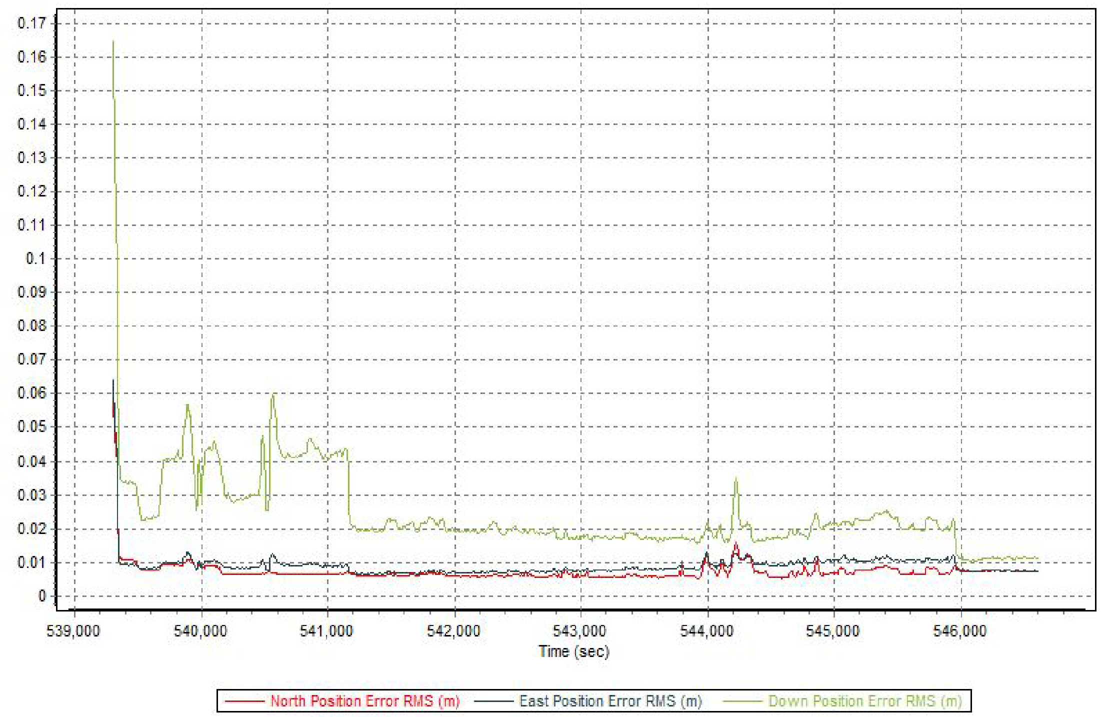


Figure A-8.16. Smoothed Performance Metrics Parameters

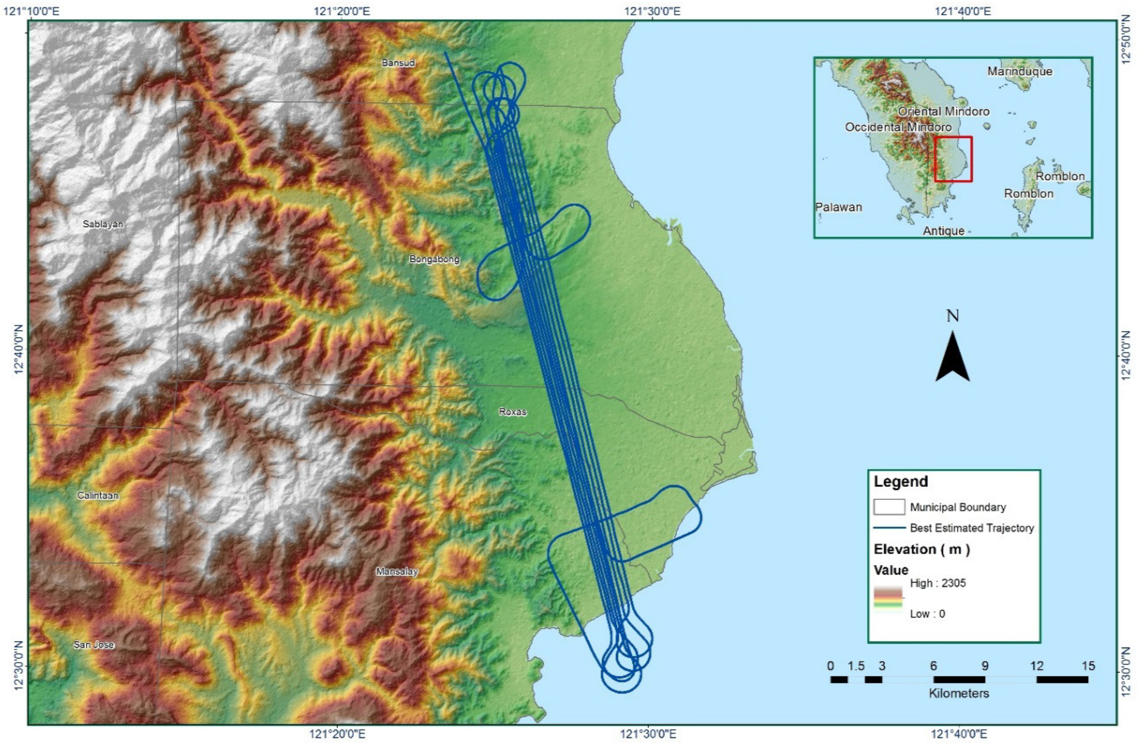


Figure A-8.17. Best Estimated Trajectory

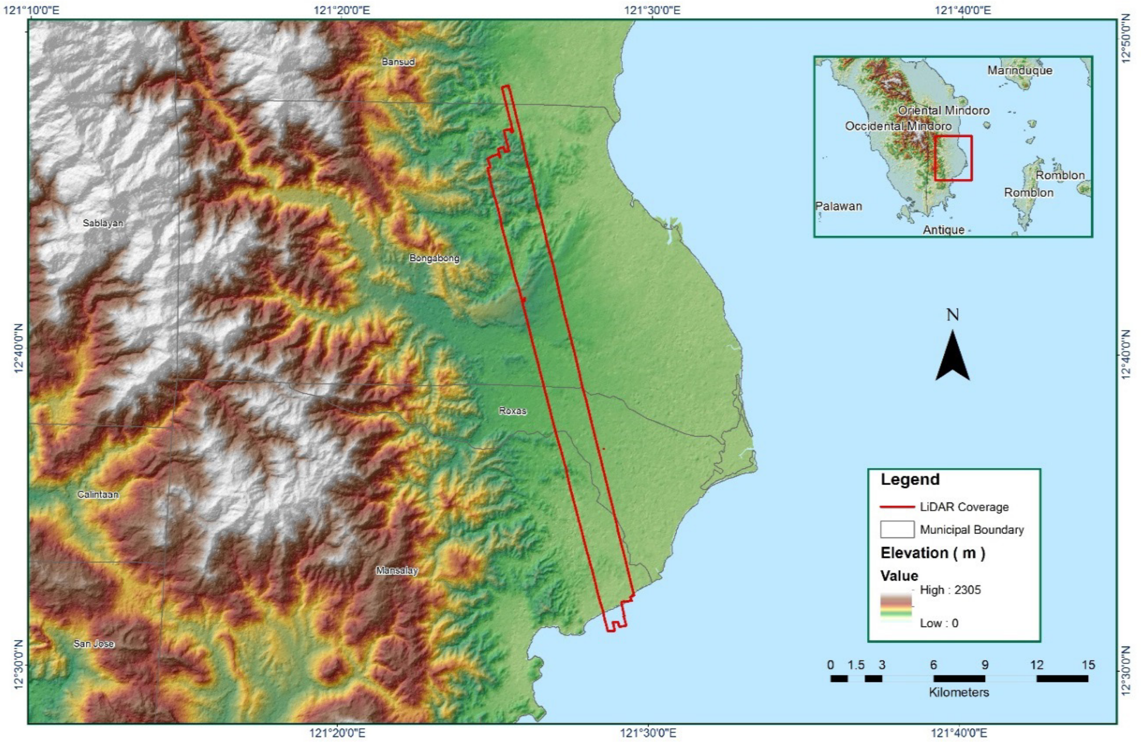


Figure A-8.18. Coverage of LiDAR data

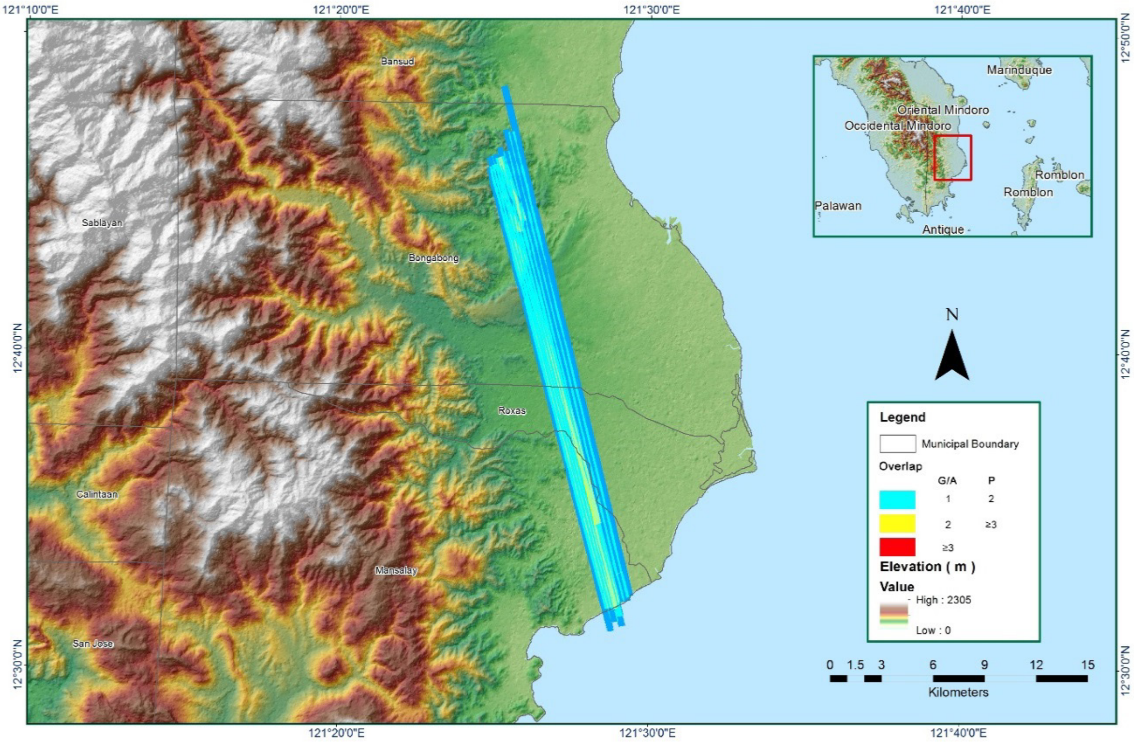


Figure A-8.19. Image of data overlap

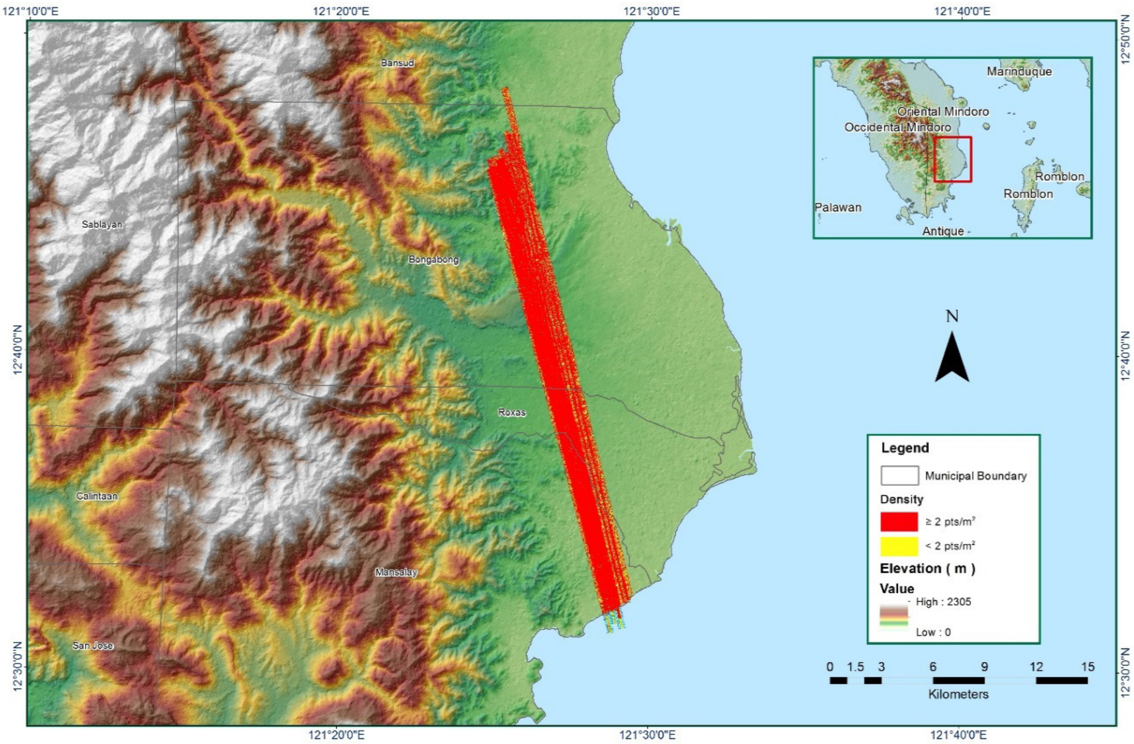


Figure A-8.20. Density of merged LiDAR data

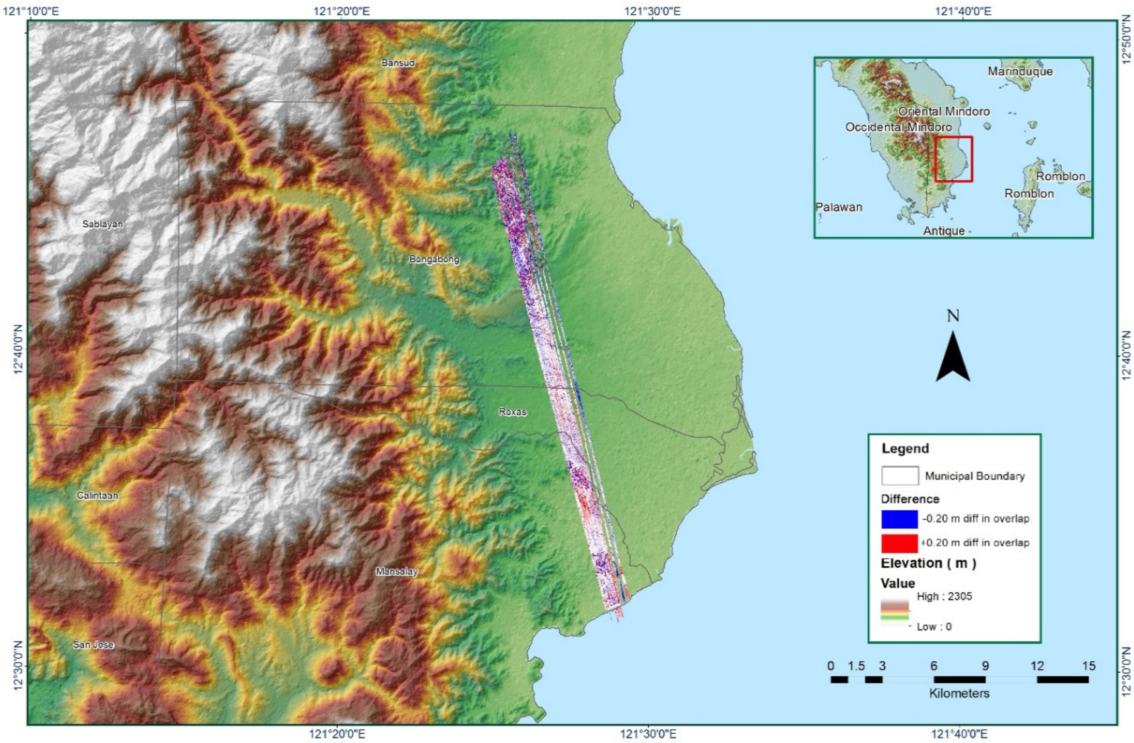


Figure A-8.21. Elevation difference between flight lines

Figure A-8.21. Elevation difference between flight lines

Flight Area	Oriental Mindoro
Mission Name	Blk28Hs
Inclusive Flights	1088A
Range data size	14 GB
POS	269 MB
Image	80.7 GB
Transfer date	February 21, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.6
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	5.3
Boresight correction stdev (<0.001deg)	0.000304
IMU attitude correction stdev (<0.001deg)	0.000768
GPS position stdev (<0.01m)	0.0088
Minimum % overlap (>25)	66.45%
Ave point cloud density per sq.m. (>2.0)	4.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	418.58 m
Minimum Height	42.03 m
Classification (# of points)	
Ground	67,410,264
Low vegetation	78,245,475
Medium vegetation	73,011,298
High vegetation	74,100,895
Building	2,106,955
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Elyn Pama, Marie Joyce Ilagan

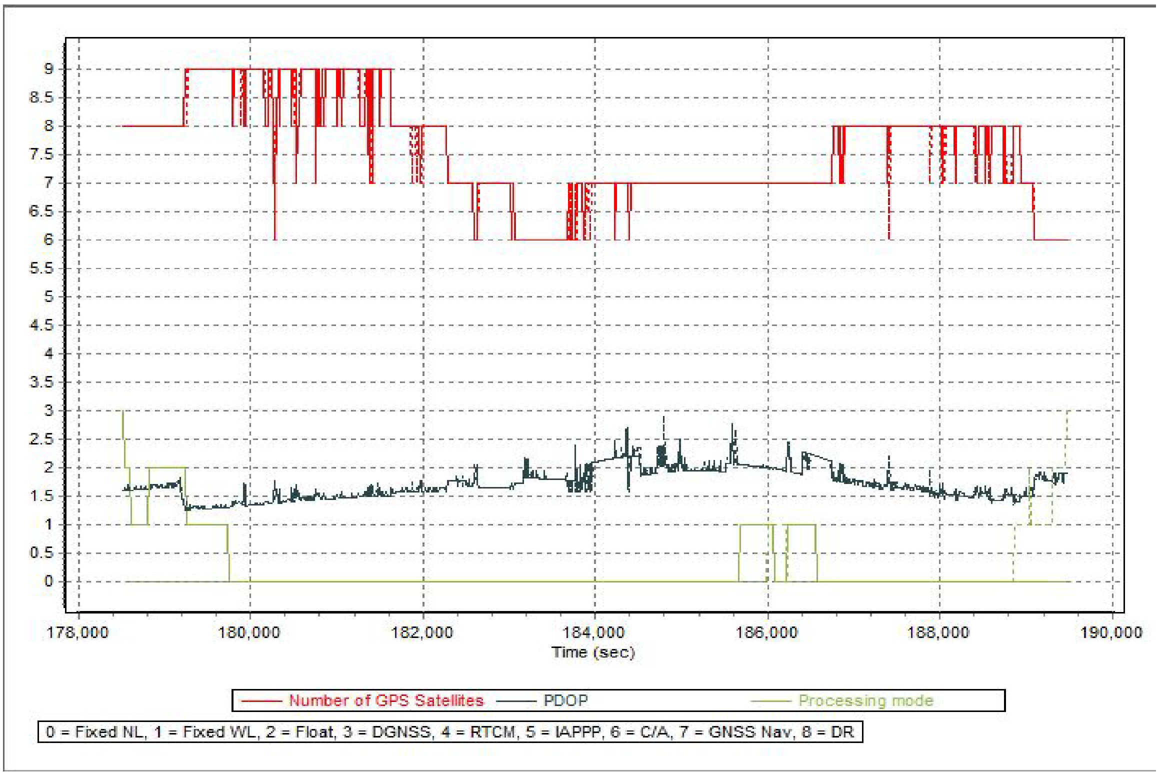


Figure A-8.22. Solution Status

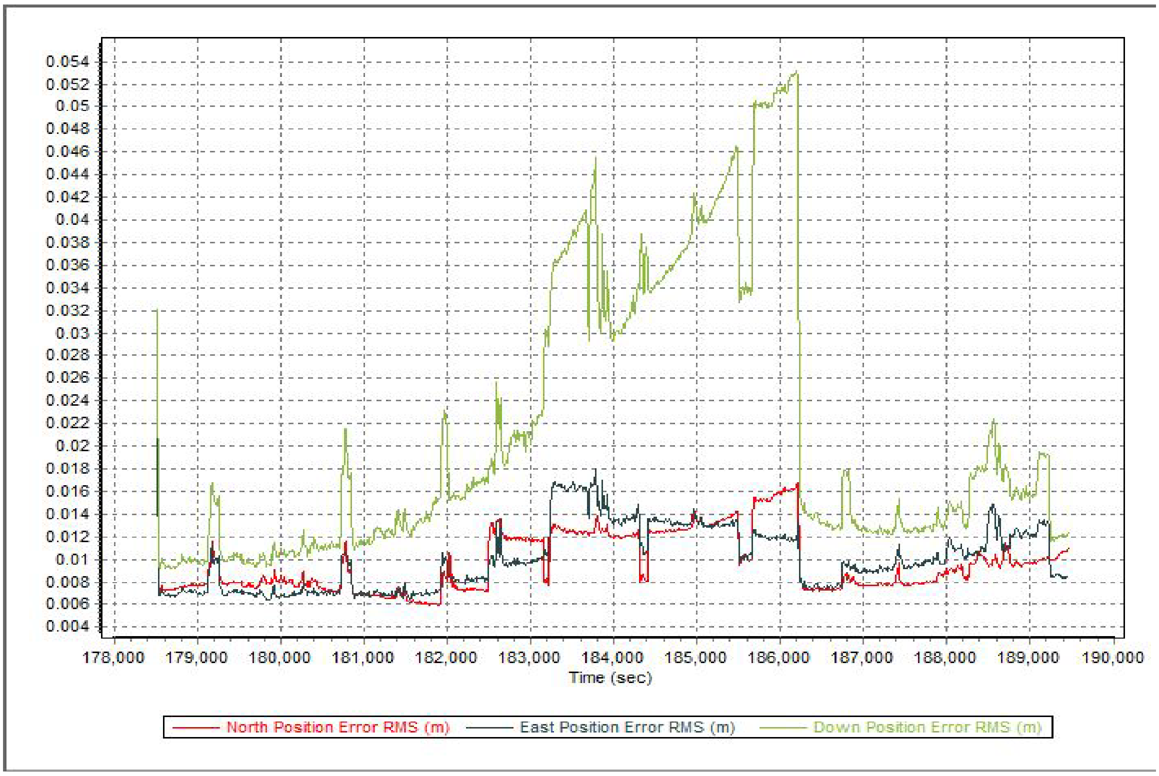


Figure A-8.23. Smoothed Performance Metrics Parameters

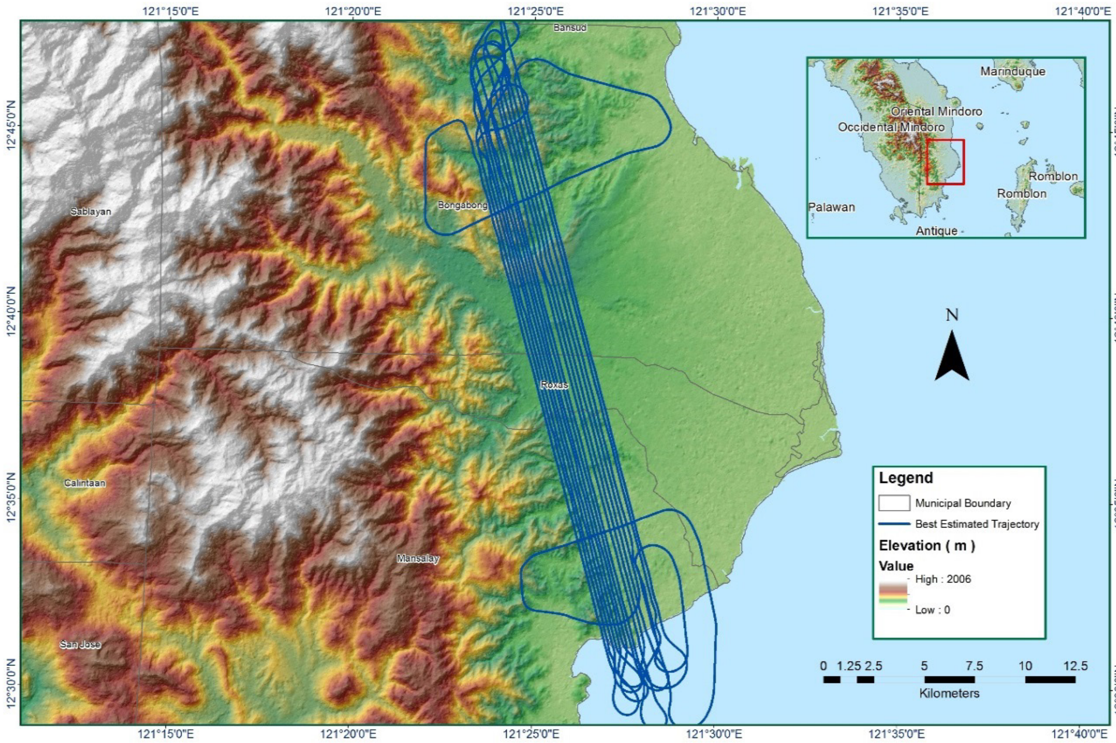


Figure A-8.24. Best Estimated Trajectory

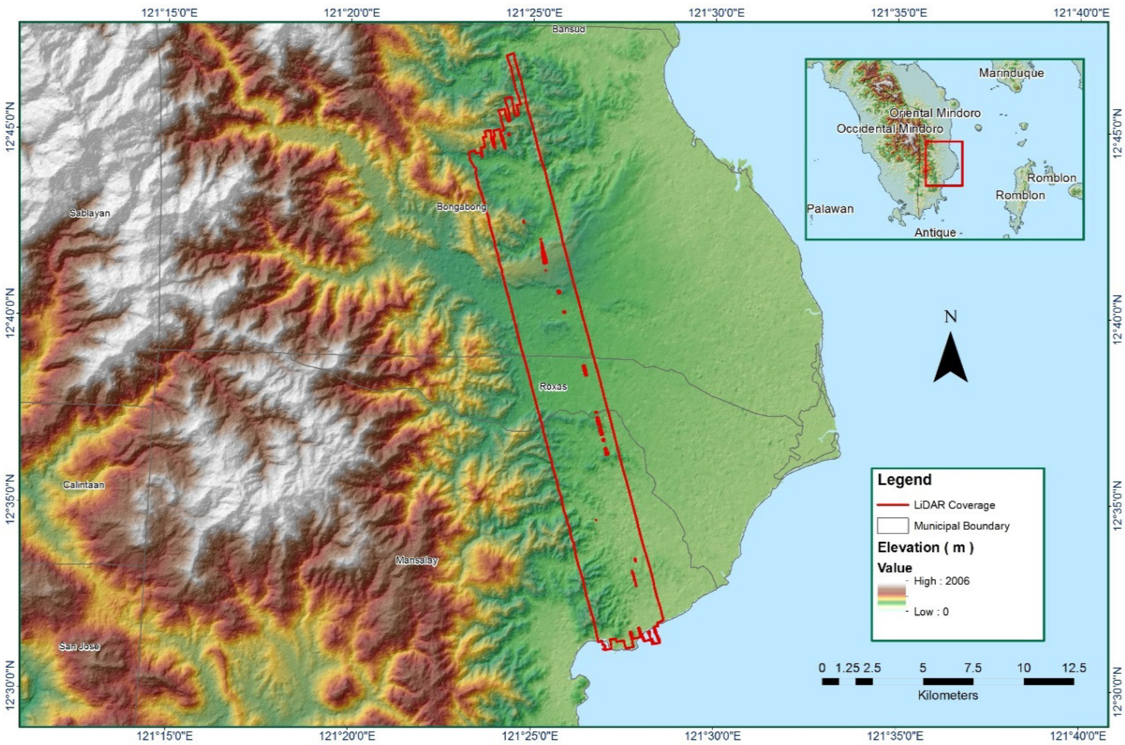


Figure A-8.25. Coverage of LiDAR data

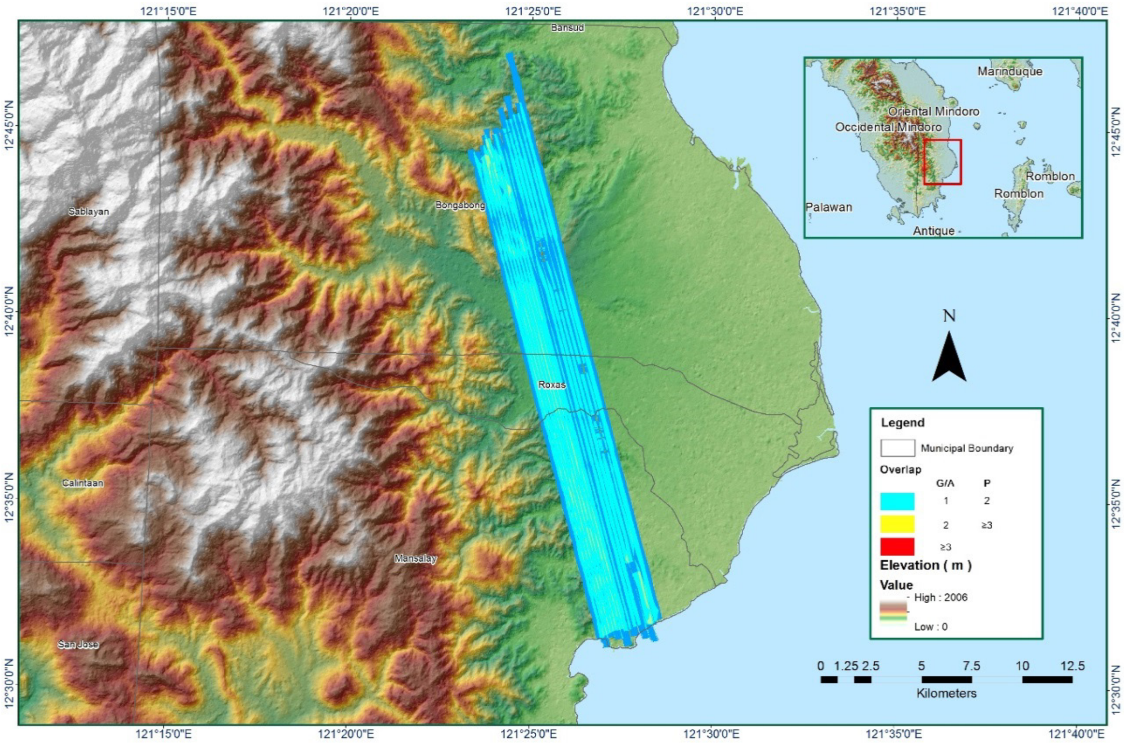


Figure A-8.26. Image of data overlap

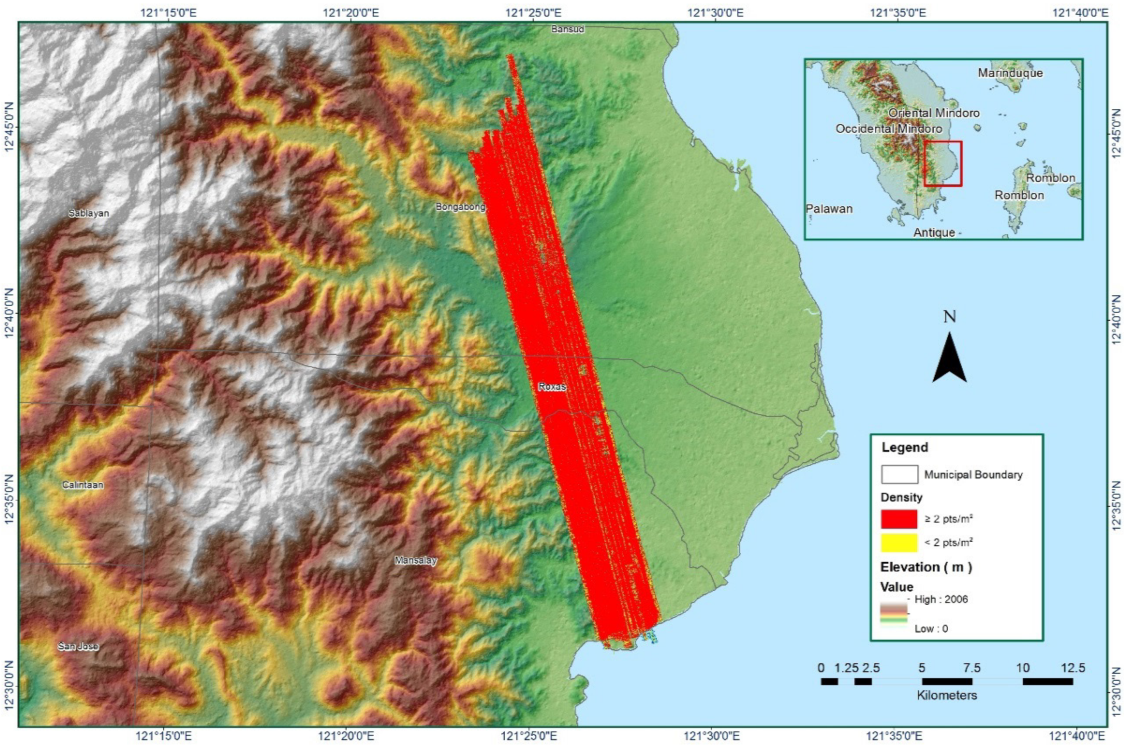


Figure A-8.27. Density of merged LiDAR data

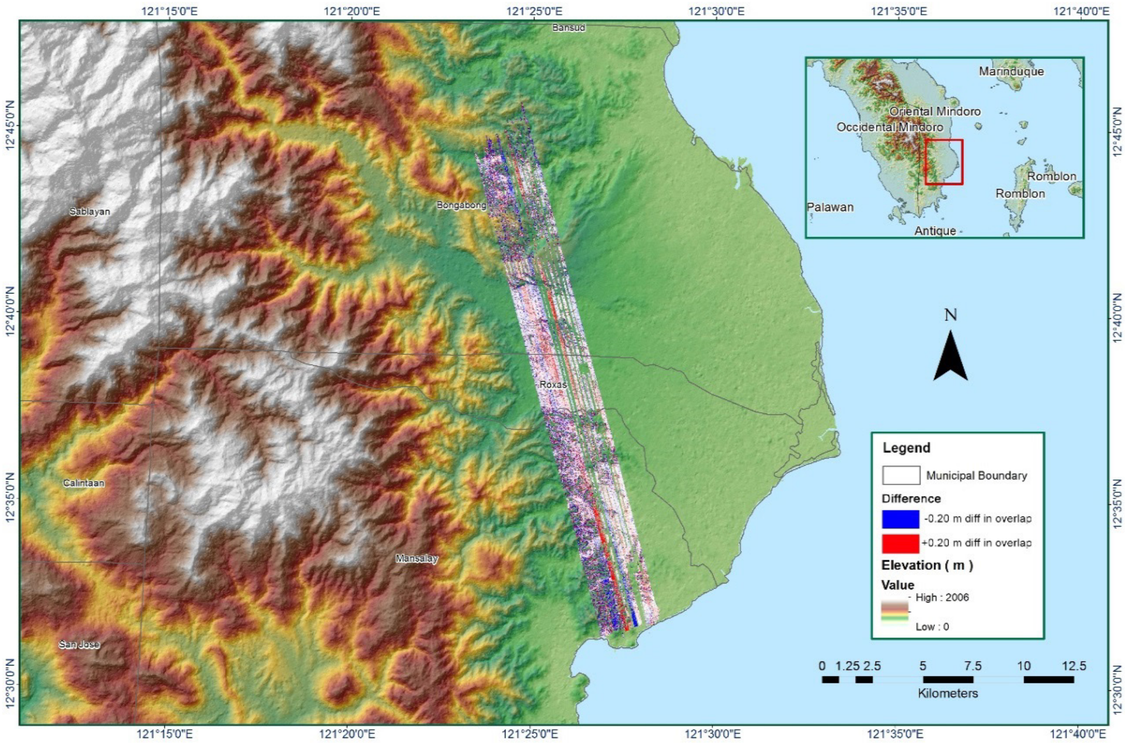


Figure A-8.28. Elevation difference between flight lines

Figure A-8.28. Elevation difference between flight lines

Flight Area	Oriental Mindoro
Mission Name	Blk28IJ
Inclusive Flights	1104A
Range data size	10.3 GB
POS	276 MB
Image	56.2 GB
Transfer date	February 21, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.4
RMSE for East Position (<4.0 cm)	3.9
RMSE for Down Position (<8.0 cm)	1.1
Boresight correction stdev (<0.001deg)	0.000220
IMU attitude correction stdev (<0.001deg)	0.001457
GPS position stdev (<0.01m)	0.0037
Minimum % overlap (>25)	47.15%
Ave point cloud density per sq.m. (>2.0)	3.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	254
Maximum Height	570.88 m
Minimum Height	37.28 m
Classification (# of points)	
Ground	110,601,059
Low vegetation	99,664,631
Medium vegetation	142,219,461
High vegetation	131,163,224
Building	4,203,923
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

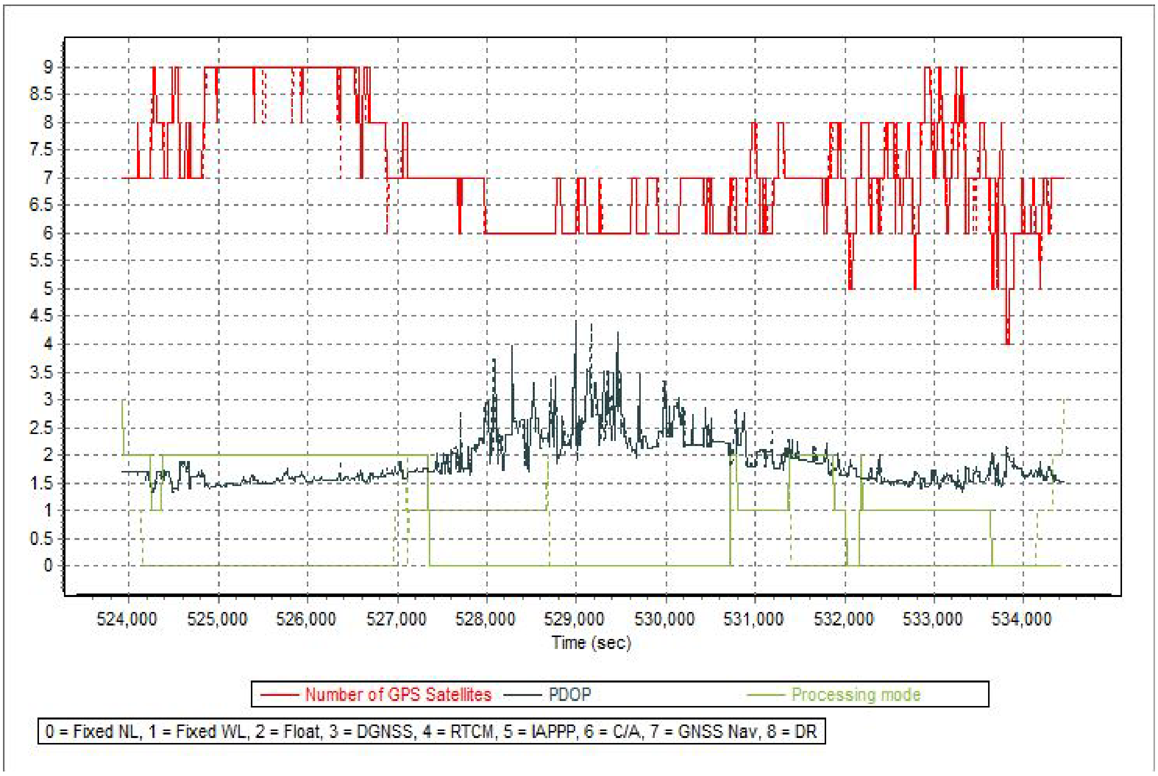


Figure A-8.29 Solution Status

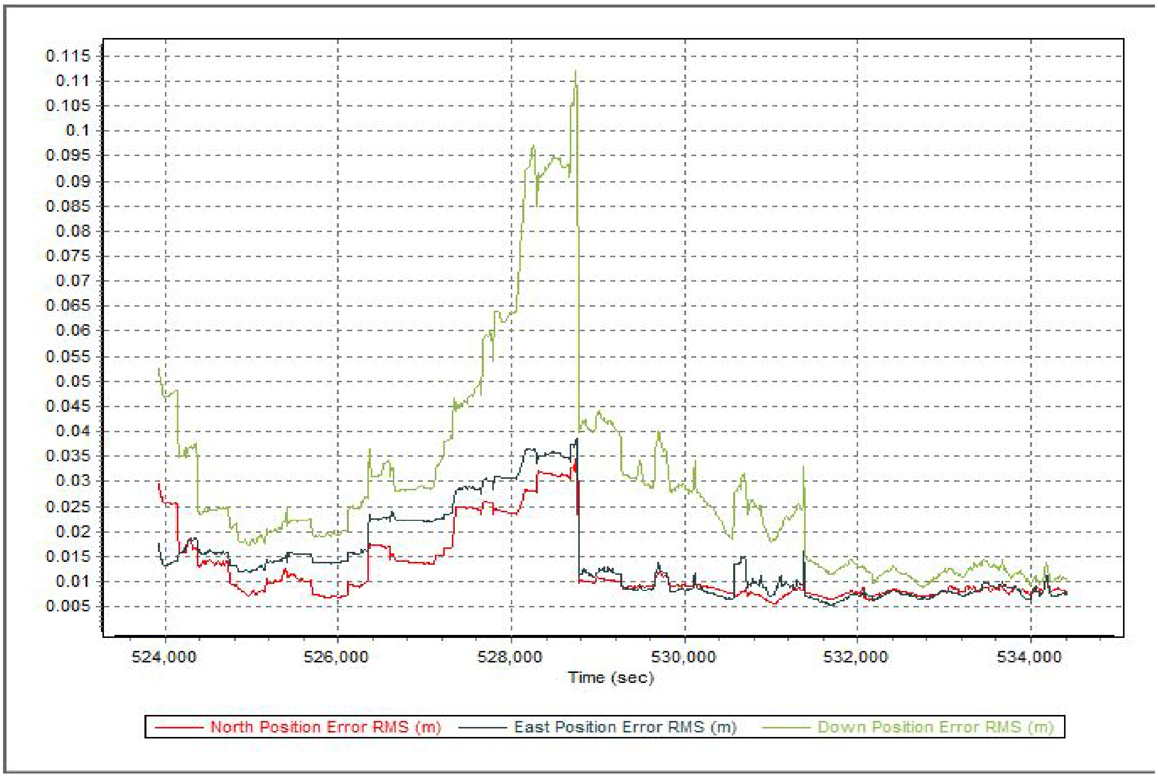


Figure A-8.30. Smoothed Performance Metrics Parameters

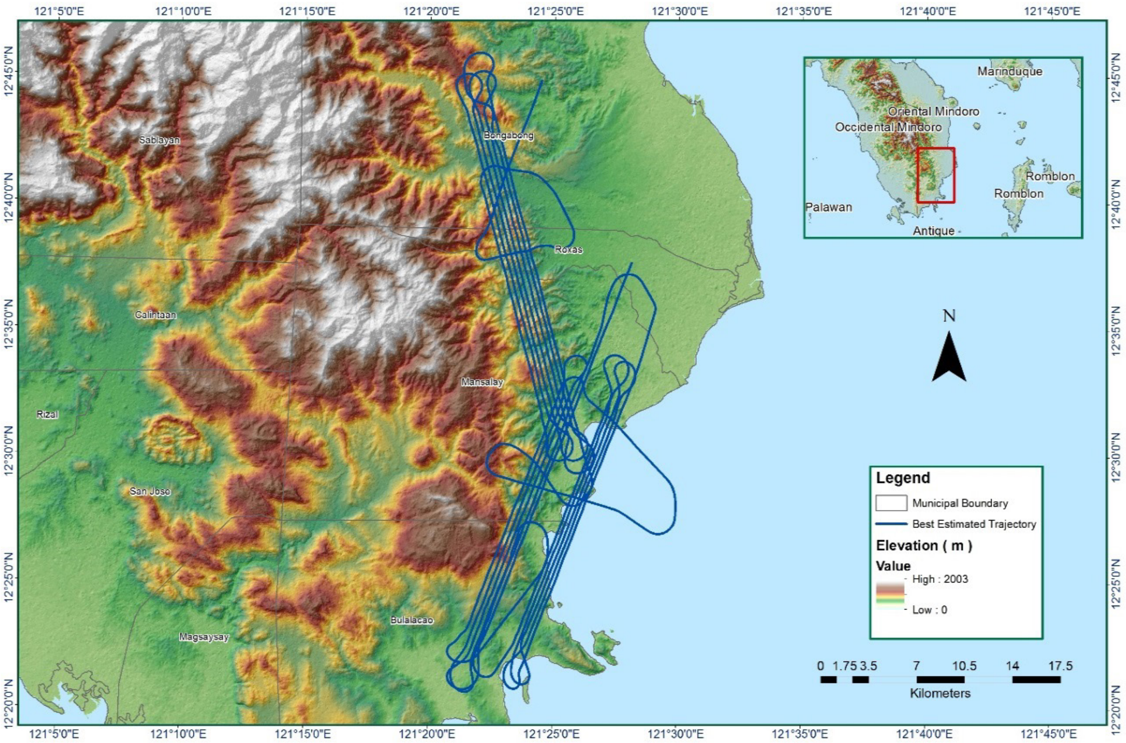


Figure A-8.31. Best Estimated Trajectory

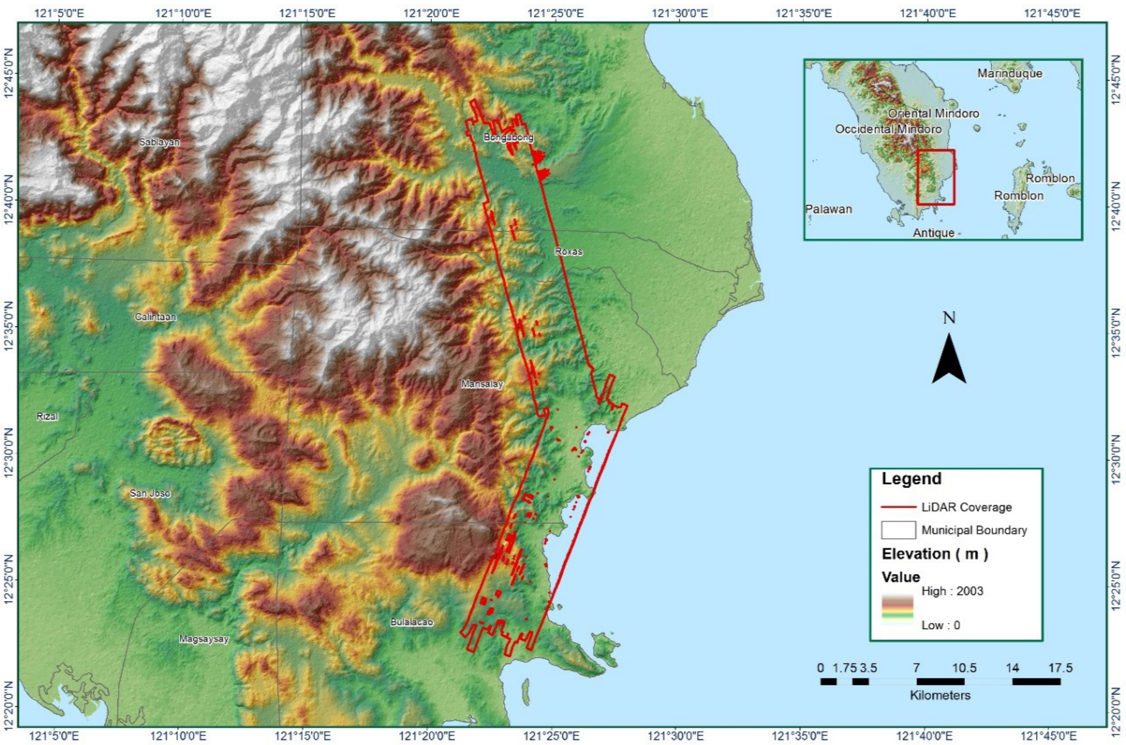


Figure A-8.32. Coverage of LiDAR data

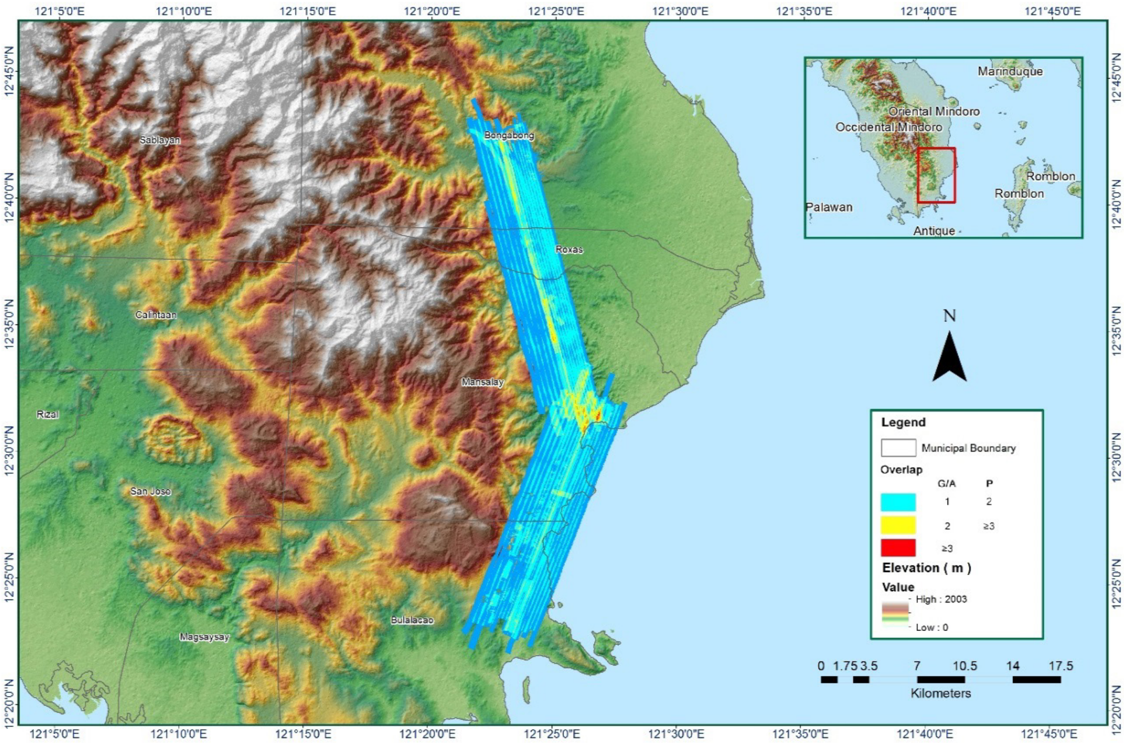


Figure A-8.33. Image of data overlap

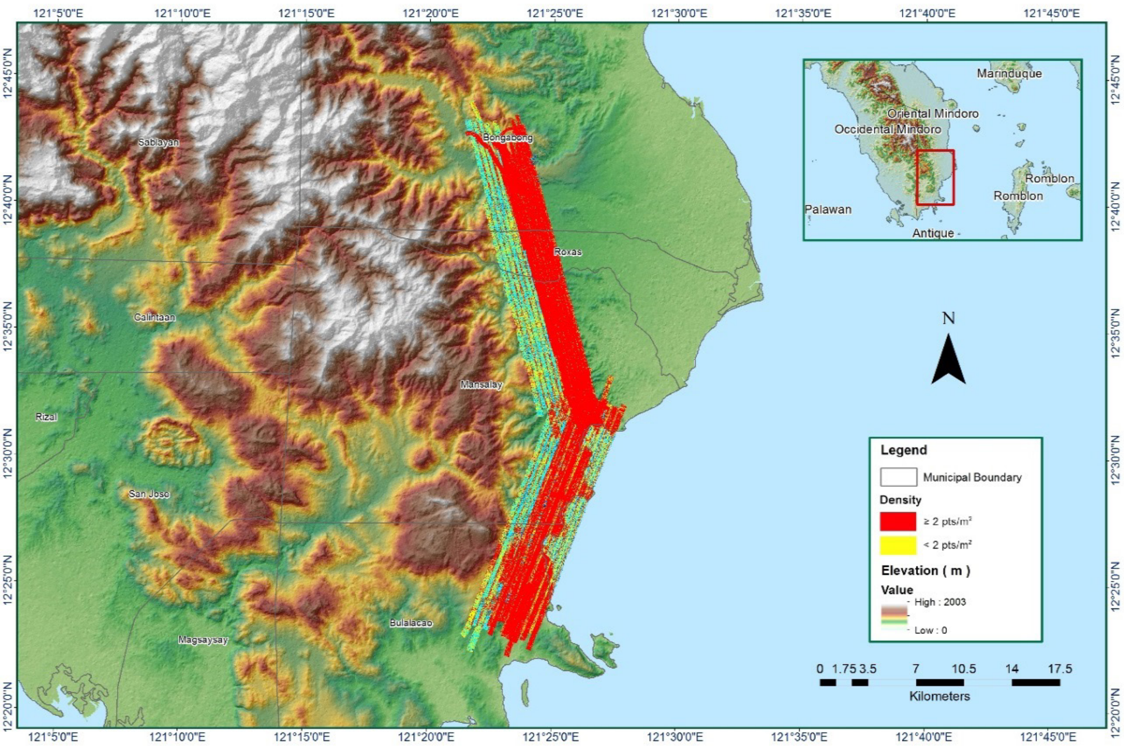


Figure A-8.34. Density of merged LiDAR data

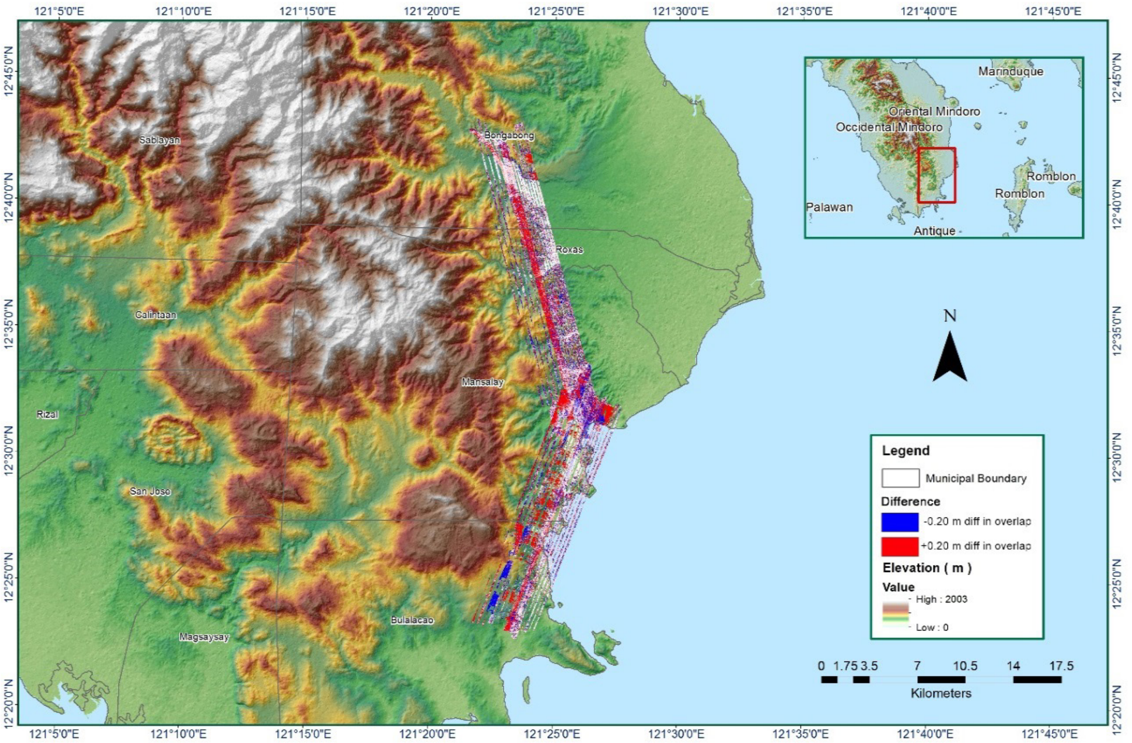


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk28I

Flight Area	Oriental Mindoro Reflights
Mission Name	Blk28I
Inclusive Flights	8312G
Range data size	11 GB
POS	215 MB
Image	NA
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)	1.12
RMSE for East Position (<4.0 cm)	1.39
RMSE for Down Position (<8.0 cm)	3.39
Boresight correction stdev (<0.001deg)	0.001626
IMU attitude correction stdev (<0.001deg)	0.001230
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	21.53
Ave point cloud density per sq.m. (>2.0)	5.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	33
Maximum Height	557.48 m
Minimum Height	126.09 m
Classification (# of points)	
Ground	1,981,953
Low vegetation	1,683,213
Medium vegetation	17,835,445
High vegetation	47,444,332
Building	1,304,633
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Justine Francisco, Engr. Mark Sueden Lyle Magtalas

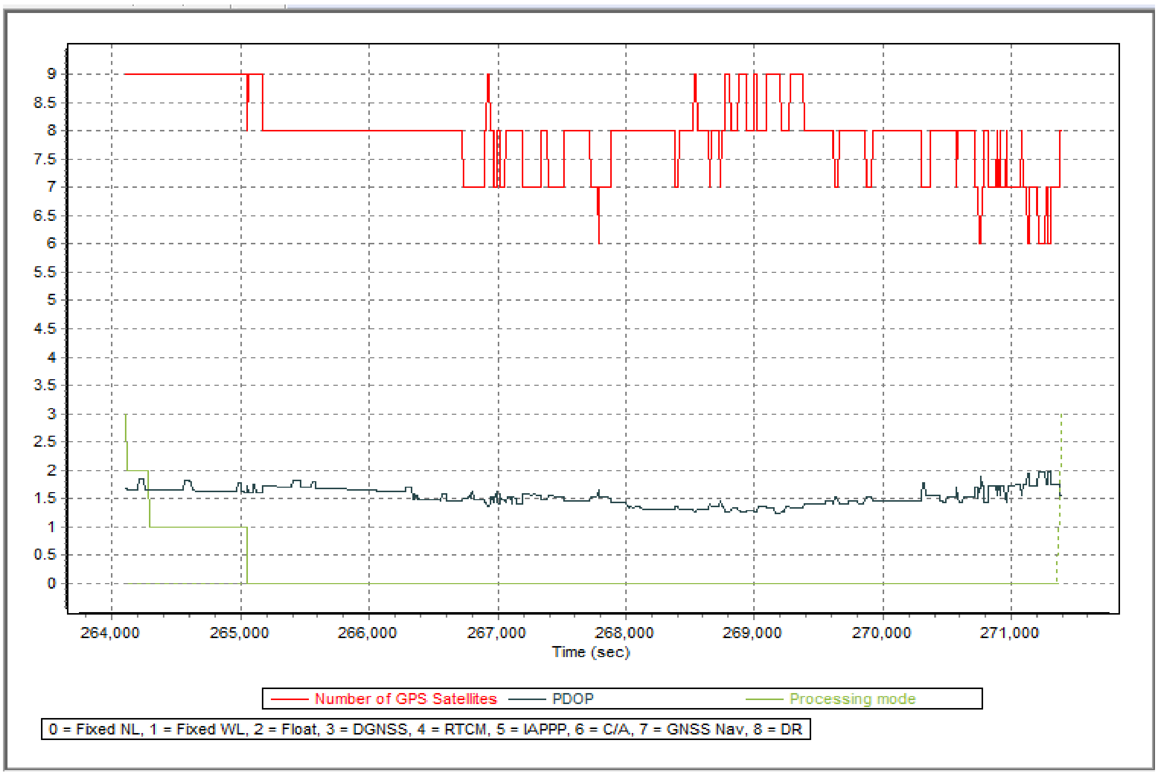


Figure A-8.36. Solution Status

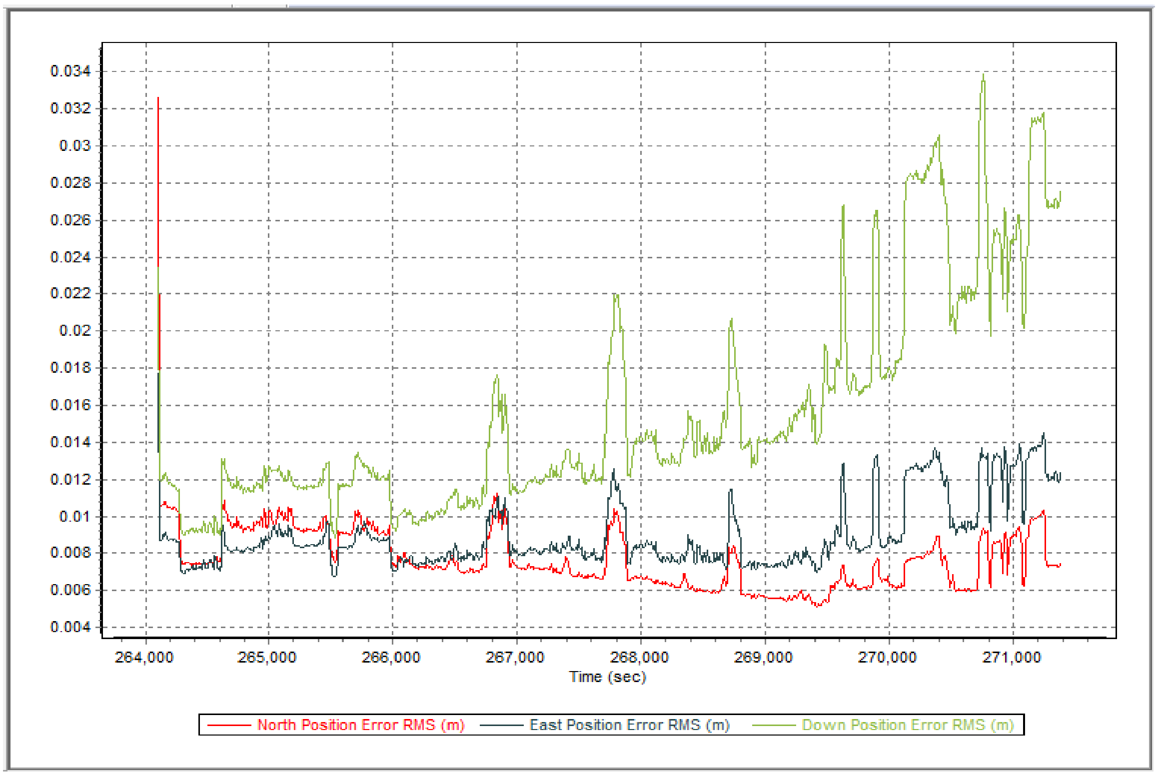


Figure A-8.37. Smoothed Performance Metric Parameters

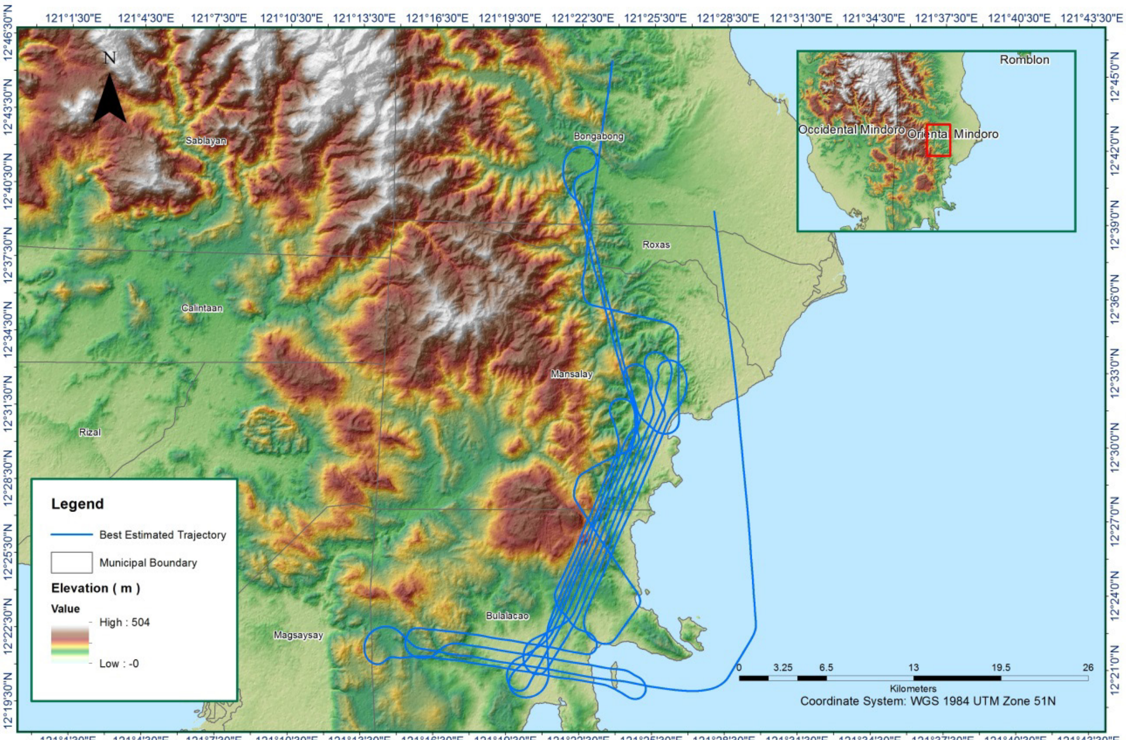


Figure A-8.38. Best Estimate Trajectory

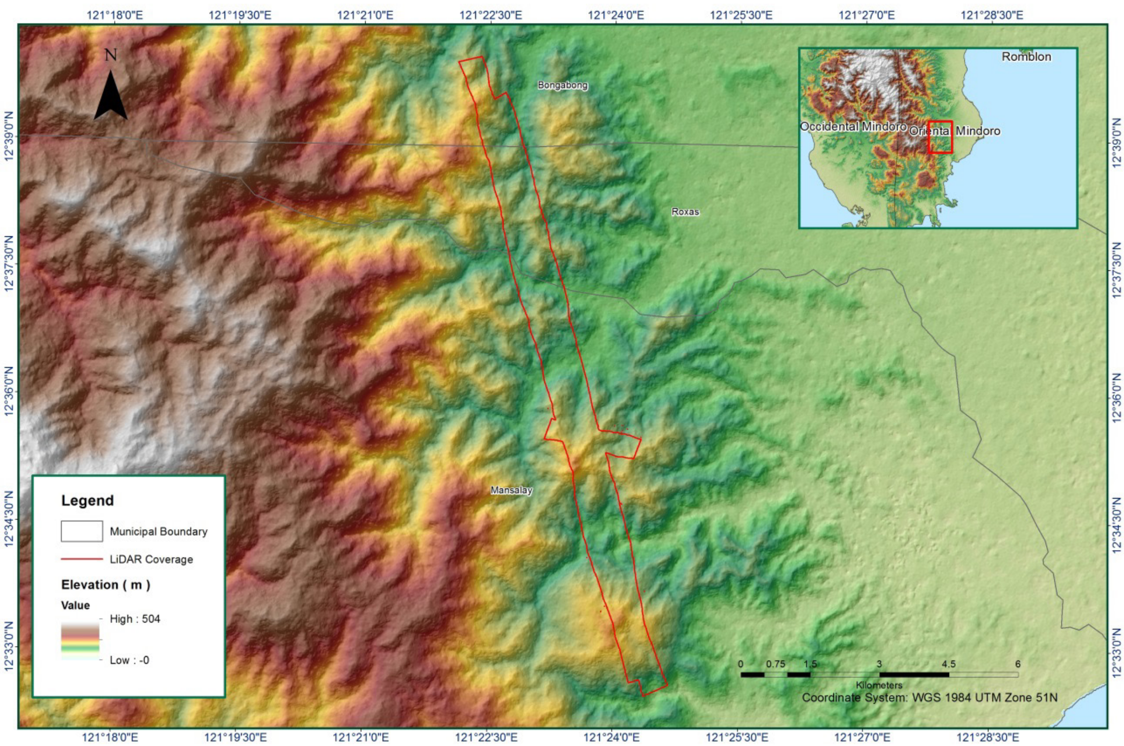


Figure A-8.39. Coverage of LiDAR data

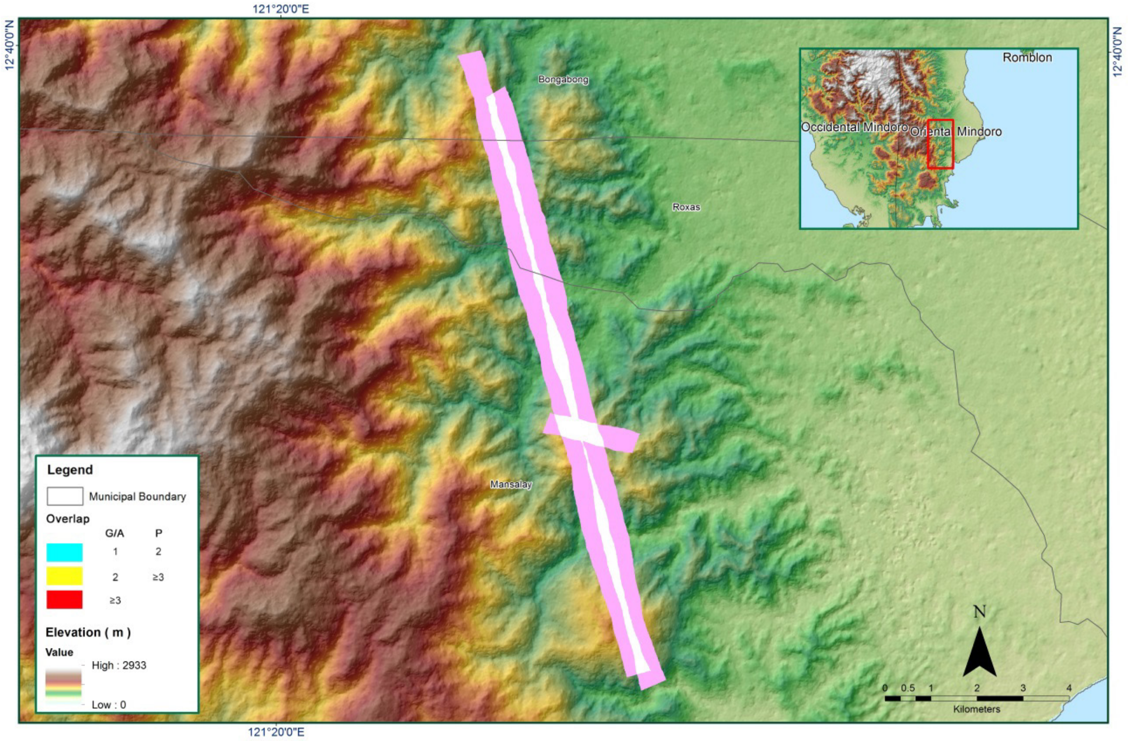


Figure A-8.40 Image of data overlap

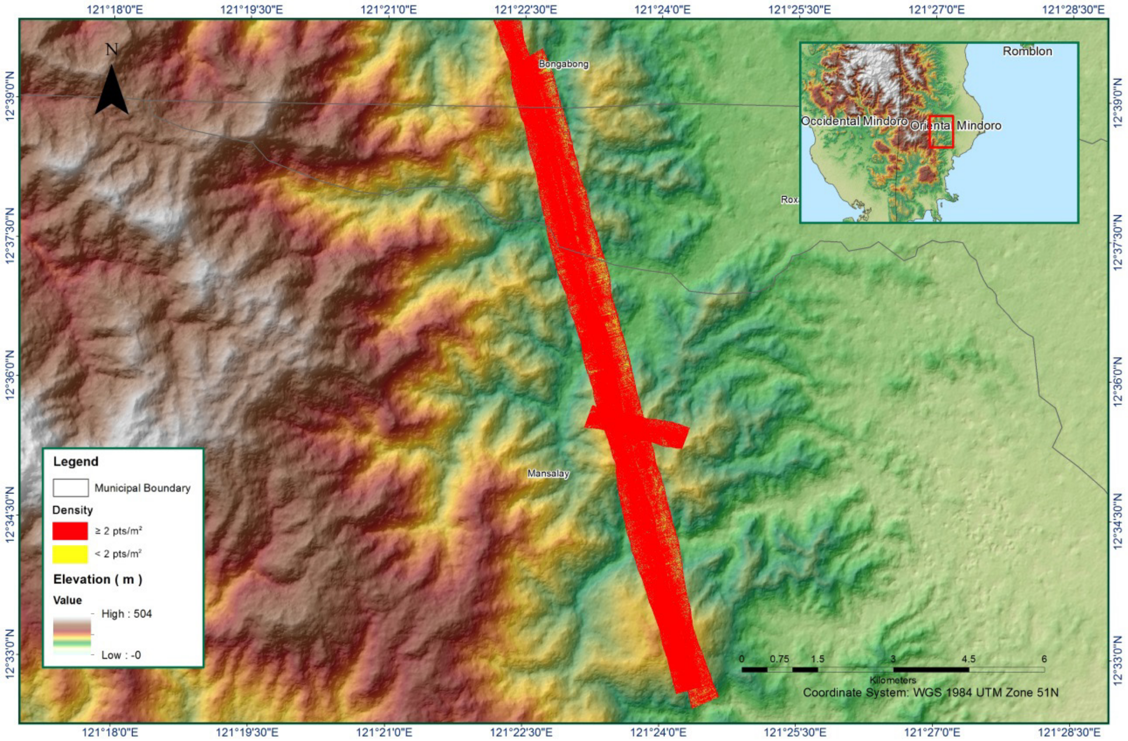


Figure A-8.41 Density Map of merged LiDAR data

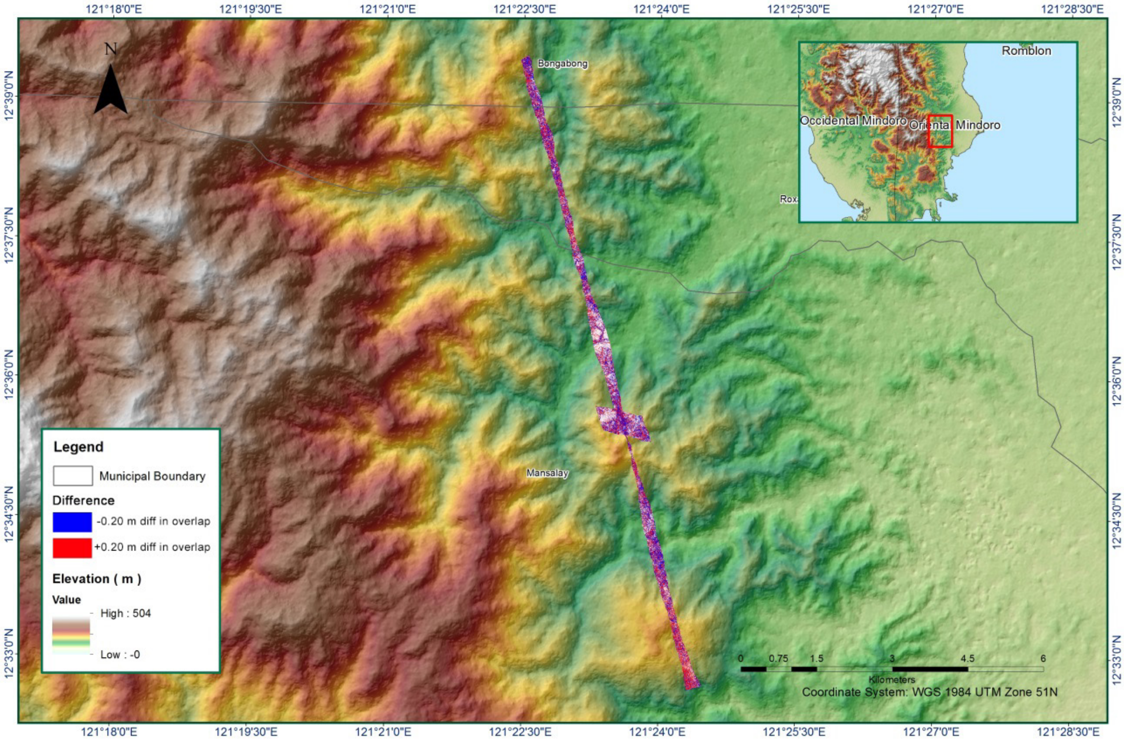


Figure A-8.42 Elevation Difference Between flight lines

Annex 9. Sumagui Model Basin Parameters

Table A-9.1 Sumagui 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 (M3/S)	Recession Constant	Ratio to Peak
W1010	0.015	73.4711172	0	10.0683	2.19084	0.138352601	0.5	0.15
W1020	0.015	79.2396	0	10.7973	2.34954	0.138352601	0.5	0.15
W480	0.0056517	24.98553	0	4.5969	1.26429	0.138352601	0.19948	0.111605
W490	0.0056517	25.89642	0	5.6528	0.52461	0.11512876	0.29775	0.111725
W500	0.0084354	25.71633	0	3.071	0.44106	0.059861787	0.19948	0.071135
W510	0.0025759	26.31402	0	4.1641	0.37332	0.03851549	0.25123	0.1125
W520	0.0084354	24.66972	0	3.287	1.02474	0.106645361	0.19948	0.159585
W530	0.0056517	25.10211	0	4.682	0.70179	0.12886153	0.375	0.108185
W540	0.0056517	26.93781	0	5.7434	0.53691	0.047898904	0.251235	0.1125
W550	0.0057383	25.73721	0	10.585	0.44358	0.043390214	0.19948	0.111875
W560	0.0056517	36.82101	0	1.4411	0.8643	0.227217276	0.25123	0.42336
W570	0.0084354	24.7167	0	3.9622	0.2812947	0.011838001	0.251235	0.1125
W580	0.0125901	26.39493	0	5.3499	0.30816	0.016910815	0.251235	0.1125
W590	0.0084354	25.76592	0	3.9812	0.63174	0.042412686	0.251235	0.1125
W600	0.0056517	24.66972	0	6.4965	1.34388	0.046650079	0.19949	0.11166
W610	0.0280465	26.35143	0	2.816	0.166905	0.001042123	0.251235	0.169595
W620	0.0056517	26.04693	0	5.735	0.75423	0.072948614	0.251235	0.103765
W630	0.0056517	25.8129	0	4.9178	0.66477	0.06749254	0.251235	0.11965
W640	0.0038447	26.52891	0	8.7837	0.85275	0.120115448	0.25123	0.1093
W650	0.0125901	24.66972	0	5.0158	0.65925	0.001640698	0.251235	0.11306
W670	0.0038447	26.26617	0	10.507	0.42309	0.0382485	0.19949	0.11163

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 (M3/S)	Recession Constant	Ratio to Peak
W680	0.0125901	24.66972	0	6.0645	0.40077	0.00695897	0.19949	0.1125
W690	0.0085647	27.09963	0	19.772	1.11813	0.040582511	0.251235	0.1125
W700	0.0084354	24.93942	0	6.61	0.5847	0.07591565	0.251235	0.103765
W710	0.0056517	26.98914	0	6.9661	0.58875	0.084330148	0.19948	0.1117
W720	0.0056517	26.48193	0	5.8367	0.58863	0.05441002	0.251235	0.1125
W730	0.0037866	26.50107	0	6.2831	0.2773476	0.064409234	0.19948	0.113805
W740	0.0084354	27.1788	0	3.4262	0.41259	0.09204272	0.25123	0.157925
W750	0.015	72.6971304	0	7.3368	1.59648	0.09204272	0.5	0.15
W760	0.015	73.384674	0	9.96165	2.16768	0.09204272	0.5	0.15
W770	0.0084354	26.38101	0	4.9116	0.48681	0.104401782	0.25123	0.163425
W780	0.0084354	27.21273	0	6.6499	0.56973	0.066299696	0.251235	0.1125
W790	0.0083934	39.1587	0	3.9842	0.80595	0.043278251	0.251235	0.1125
W800	0.0056236	26.2653	0	5.9705	0.51222	0.041581571	0.251235	0.1125
W810	0.0056236	27.87219	0	3.9948	0.70659	0.069331327	0.251235	0.109085
W820	0.0038256	27.02916	0	9.515	0.765	0.181587789	0.251235	0.109075
W830	0.0056236	27.69471	0	2.1421	0.40854	0.044595977	0.375	0.5
W840	0.0056236	39.13521	0	3.7435	0.34296	0.071910797	0.251195	0.10636
W850	0.0056236	26.34708	0	6.0066	0.73758	0.135187475	0.251235	0.110865
W860	0.0083934	26.49063	0	5.2636	0.94185	0.107721935	0.251235	0.1125
W870	0.0038256	27.05004	0	8.6329	0.58206	0.124792083	0.251215	0.111785
W880	0.0125275	25.75548	0	5.7197	0.2433	0.012841368	0.25123	0.1125
W890	0.0038256	26.3871	0	9.0175	0.24345	0.08453685	0.375	0.075
W900	0.0056236	27.87219	0	3.6065	0.5295	0.03490251	0.25123	0.1125
W910	0.0083934	27.87219	0	5.928	0.5454	0.030432577	0.251235	0.11025

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 (M3/S)	Recession Constant	Ratio to Peak
W920	0.0056236	27.87219	0	5.7183	0.67398	0.098032774	0.251235	0.111475
W930	0.0083934	27.87219	0	2.8919	0.57183	0.013853347	0.251235	0.16875
W940	0.0056235	27.87219	0	6.0024	0.47922	0.060408687	0.251235	0.1125
W970	0.0085221	27.87219	0	25.082	1.36272	0.041482526	0.251235	0.11025

Annex 10. Sumagui Model Reach Parameters

Table A-10.1 Sumagui Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (M)	Slope (M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R100	Automatic Fixed Interval	346.57	0.0351422	0.00252215	Trapezoid	25	1
R1040	Automatic Fixed Interval	787.70	0.0014250	0.016	Trapezoid	25	1
R120	Automatic Fixed Interval	458.70	0.0028230	0.03287955	Trapezoid	25	1
R140	Automatic Fixed Interval	811.13	0.0028230	0.0056557	Trapezoid	25	1
R150	Automatic Fixed Interval	1566.7	0.0031805	0.0082347	Trapezoid	25	1
R160	Automatic Fixed Interval	253.14	0.0031805	0.0083638	Trapezoid	25	1
R170	Automatic Fixed Interval	1582.0	.00058606	0.0052352	Trapezoid	25	1
R180	Automatic Fixed Interval	1879.9	0.0021393	0.0081041	Trapezoid	25	1
R200	Automatic Fixed Interval	1544.4	0.0018828	0.00556765	Trapezoid	25	1
R220	Automatic Fixed Interval	532.84	0.0014250	0.016	Trapezoid	25	1
R270	Automatic Fixed Interval	1053.1	0.0105674	0.016	Trapezoid	25	1
R290	Automatic Fixed Interval	1303.6	0.0047430	0.01839775	Trapezoid	25	1
R30	Automatic Fixed Interval	3914.3	0.0288190	0.0084193	Trapezoid	25	1
R300	Automatic Fixed Interval	2330.4	0.0063254	0.0143523	Trapezoid	25	1
R340	Automatic Fixed Interval	1366.1	0.0104579	0.01476165	Trapezoid	25	1
R350	Automatic Fixed Interval	1198.8	0.0606752	0.01880945	Trapezoid	25	1
R360	Automatic Fixed Interval	397.99	0.0554098	0.00729635	Trapezoid	25	1
R390	Automatic Fixed Interval	2597.2	0.0161147	0.0127095	Trapezoid	25	1
R400	Automatic Fixed Interval	2433.1	0.0088802	0.0213701	Trapezoid	25	1
R410	Automatic Fixed Interval	2890.1	0.0274625	0.00913445	Trapezoid	25	1
R420	Automatic Fixed Interval	700.83	0.0114633	0.00362135	Trapezoid	25	1
R430	Automatic Fixed Interval	462.84	0.0324958	0.0016697	Trapezoid	25	1

R70	Automatic Fixed Interval	939.41	0.0080121	0.0083141	Trapezoid	25	1
R80	Automatic Fixed Interval	563.55	0.0080121	0.02418868	Trapezoid	25	1
R990	Automatic Fixed Interval	2221.1	0.0033695	0.02732268	Trapezoid	25	1

Annex 11. Sumagui Flood Validation Data

Table A-11.1 Sumagui Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	12.79424	121.4754	1.31	0.91	-0.4	Yolanda	Nov. 8, 2013	25-Year
2	12.79514	121.4716	2.03	1.9	-0.13	Ofel	Oct. 2012	25-Year
3	12.79518	121.4733	1.74	1.3	-0.44	Ofel	Oct. 2012	25-Year
4	12.79524	121.4662	1.73	1.38	-0.35	Caloy	May 2006	25-Year
5	12.79527	121.4721	1.85	1.6	-0.25	Ofel	Oct. 2012	25-Year
6	12.7953	121.4749	1.51	0.85	-0.66	Ofel	Oct. 2012	25-Year
7	12.7955	121.4745	1.84	1.58	-0.26	Ofel	Oct. 2012	25-Year
8	12.79553	121.4717	2.07	1.37	-0.7	Ofel	Oct. 2012	25-Year
9	12.79559	121.4728	1.87	1	-0.87	Atang		25-Year
10	12.79561	121.4661	1.82	1.41	-0.41	Nona	Dec. 15, 2015	25-Year
11	12.7959	121.4738	1.62	1.67	0.05	Ofel	Oct. 2012	25-Year
12	12.79596	121.467	1.7	0.98	-0.72	Caloy	May 2006	25-Year
13	12.79607	121.4744	0.8	1.15	0.35	Ofel	Oct. 2012	25-Year
14	12.79618	121.4662	1.38	1.05	-0.33	Caloy	May 2006	25-Year
15	12.79642	121.4741	1.37	1.07	-0.3		Dec. 9,2014	25-Year
16	12.79685	121.4718	1.29	1.1	-0.19		2012	25-Year
17	12.79688	121.4645	0.03	0.3	0.27		2010	25-Year
18	12.79696	121.4738	1.01	0.63	-0.38		Oct. 2014	25-Year
19	12.79702	121.4764	1.24	0.35	-0.89	Nona	Dec. 15, 2015	25-Year
20	12.79738	121.4739	0.49	0.45	-0.04	Caloy	May 2006	25-Year
21	12.79745	121.4612	1.75	1.1	-0.65	Nona	Dec. 15, 2015	25-Year
22	12.79756	121.4737	0.62	0.84	0.22	Caloy	May 2006	25-Year
23	12.79754	121.462	2.15	1.22	-0.93		2011	25-Year
24	12.79771	121.4728	1.29	0.81	-0.48		Oct. 2011	25-Year
25	12.79791	121.4691	0.95	0.55	-0.4	Yolan-da	Nov. 8, 2013	25-Year
26	12.79786	121.4603	1.63	0.65	-0.98	Nona	Dec. 15, 2015	25-Year
27	12.79805	121.4733	1.25	1.17	-0.08	Caloy	May 2006	25-Year
28	12.79831	121.4784	1	0.4	-0.6	Yolan-da	Nov. 8, 2013	25-Year
29	12.79839	121.4669	0.65	0.9	0.25	Yolan-da	Nov. 8, 2013	25-Year
30	12.79844	121.4664	0.99	0.45	-0.54	Yolan-da	Nov. 8, 2013	25-Year
31	12.79852	121.4788	0.86	0.35	-0.51	Nona	Dec. 15, 2015	25-Year
32	12.79848	121.4702	0.75	0.7	-0.05	Yolan-da	Nov. 8, 2013	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
33	12.79865	121.4794	1.12	0.84	-0.28		Nov. 2014	25-Year
34	12.79879	121.4785	0.51	0.94	0.43	Lando	Jun. 24, 2009	25-Year
35	12.79885	121.4779	0.8	0.46	-0.34	Yolan-da	Nov. 8, 2013	25-Year
36	12.7988	121.4658	1.16	0.15	-1.01	Nona	Dec. 15, 2015	25-Year
37	12.79881	121.4662	0.73	0.45	-0.28	Caloy	May 2006	25-Year
38	12.79903	121.4796	1.27	0.32	-0.95	Ruby	Dec. 2015	25-Year
39	12.79902	121.4791	1.16	0.85	-0.31	Yolan-da	November 2013	25-Year
40	12.79911	121.4768	1.27	0.73	-0.54		Dec. 2012	25-Year
41	12.79915	121.4761	0.87	0.22	-0.65	Nona	Dec. 15, 2015	25-Year
42	12.79917	121.4648	1.15	0.87	-0.28	Ofel	Oct. 2012	25-Year
43	12.79933	121.4792	1.09	0.83	-0.26	Yolan-da	Nov. 8, 2013	25-Year
44	12.79933	121.4793	0.7	0.94	0.24	Yolan-da	November 2013	25-Year
45	12.79927	121.4657	0.47	1.05	0.58		May 2010	25-Year
46	12.79939	121.477	0.96	0.53	-0.43	Nona	Dec. 15, 2015	25-Year
47	12.79945	121.4776	0.77	0.6	-0.17		Nov./ Dec. 2014	25-Year
48	12.79956	121.4642	1.04	0.5	-0.54	Nona	Dec. 15, 2015	25-Year
49	12.79994	121.4793	0.33	1.27	0.94	Ty-phoon	1993	25-Year
50	12.80028	121.4792	0.14	0.09	-0.05	Nona	December 2015	25-Year
51	12.80066	121.4791	0.16	0.94	0.78	Ondoy	September 2009	25-Year
52	12.80068	121.4794	0.04	0	-0.04			25-Year
53	12.80095	121.4791	0.03	0	-0.03			25-Year
54	12.801	121.4786	0.21	0.42	0.21	Nona	December 2015	25-Year
55	12.80114	121.4789	0.24	0.09	-0.15	Nona	December 2015	25-Year
56	12.8012	121.4786	0.13	0	-0.13			25-Year
57	12.80129	121.4787	0.25	0	-0.25			25-Year
58	12.80138	121.4789	0.13	0.02	-0.11	Nona	December 2015	25-Year
59	12.80128	121.4569	0.85	0.64	-0.21	Yolan-da	November 2013	25-Year
60	12.80132	121.4566	0.75	0.26	-0.49	Yolan-da	November 2013	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
61	12.80142	121.4575	0.65	0	-0.65			25-Year
62	12.80145	121.4555	0.63	0.29	-0.34	Yolan-da	November 2013	25-Year
63	12.80148	121.4579	1.06	0	-1.06			25-Year
64	12.80161	121.479	0.07	0	-0.07			25-Year
65	12.80161	121.4788	0.35	0.08	-0.27	Nona	December 2015	25-Year
66	12.80152	121.46	0.85	1.06	0.21		2011	25-Year
67	12.80151	121.4562	0.9	0.46	-0.44	Nona	December 2015	25-Year
68	12.80172	121.4788	0.6	0	-0.6			25-Year
69	12.80164	121.4552	0.55	0.14	-0.41	Caloy	May, 2006	25-Year
70	12.80185	121.4791	0.03	0.66	0.63	Yolan-da	November 2013	25-Year
71	12.80182	121.4601	1.02	0.69	-0.33			25-Year
72	12.80186	121.4596	1.59	1.06	-0.53	Pablo	November 2012	25-Year
73	12.80189	121.4606	1.09	0.62	-0.47			25-Year
74	12.80206	121.46	1.68	1.45	-0.23	Nona	December 2015	25-Year
75	12.80239	121.4784	0.7	0.38	-0.32			25-Year
76	12.80232	121.4597	1.12	0.89	-0.23	Nona	December 2015	25-Year
77	12.80244	121.461	1.1	0.84	-0.26	Nona	December 2015	25-Year
78	12.80252	121.4609	1.09	0.56	-0.53		2011	25-Year
79	12.8027	121.4612	1.28	0.95	-0.33	Nona	December 2015	25-Year
80	12.80281	121.4616	1.71	0.87	-0.84	Caloy	2006	25-Year
81	12.80299	121.4618	1.85	1.13	-0.72	Nona	December 2015	25-Year
82	12.80309	121.4771	0.03	0	-0.03			25-Year
83	12.80314	121.4498	0.68	0.65	-0.03	Caloy	May 2006	25-Year
84	12.80314	121.4495	0.72	0.54	-0.18	Yolan-da	November 2013	25-Year
85	12.80319	121.4504	0.8	1.65	0.85	Yolan-da	November 2013	25-Year
86	12.80326	121.4622	1.47	0.98	-0.49	Caloy	May 2006	25-Year
87	12.80352	121.4493	0.12	0	-0.12			25-Year
88	12.80369	121.4632	1.06	0.56	-0.5	Lando	October 2015	25-Year
89	12.804	121.4764	0.03	0	-0.03			25-Year
90	12.80388	121.4477	0.09	0	-0.09			25-Year
91	12.804	121.4633	1.13	0.46	-0.67	Nona	December 2015	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
92	12.80395	121.4475	0.11	0	-0.11			25-Year
93	12.80445	121.4773	0.48	0.1	-0.38	Caloy	May 2006	25-Year
94	12.80453	121.4646	1.14	0.36	-0.78	Nona	December 2015	25-Year
95	12.80461	121.4653	1.29	1.04	-0.25	Nona	December 2015	25-Year
96	12.80465	121.4674	0.95	0.42	-0.53	Nona	December 2015	25-Year
97	12.80469	121.4663	1.63	0.91	-0.72	Nona	December 2015	25-Year
98	12.80475	121.4766	0.03	0	-0.03			25-Year
99	12.8047	121.4648	1.21	0.74	-0.47	Nona	December 2015	25-Year
100	12.80484	121.4637	0.93	0.39	-0.54	Nona	December 2015	25-Year
101	12.80486	121.4666	0.03	0.38	0.35	Yolan-da	November 2013	25-Year

Annex 12. Educational Institutions Affected in Sumagui Floodplain

There are no affected educational Institutions in this floodplain.

Annex 13. Health Institutions Affected in Sumagui Floodplain

There are no affected merdical Institutions in this floodplain.

Annex 11. Phil-LiDAR 1 UPLB Team Composition

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

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