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

LiDAR Surveys and Flood Mapping of Ibod River

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

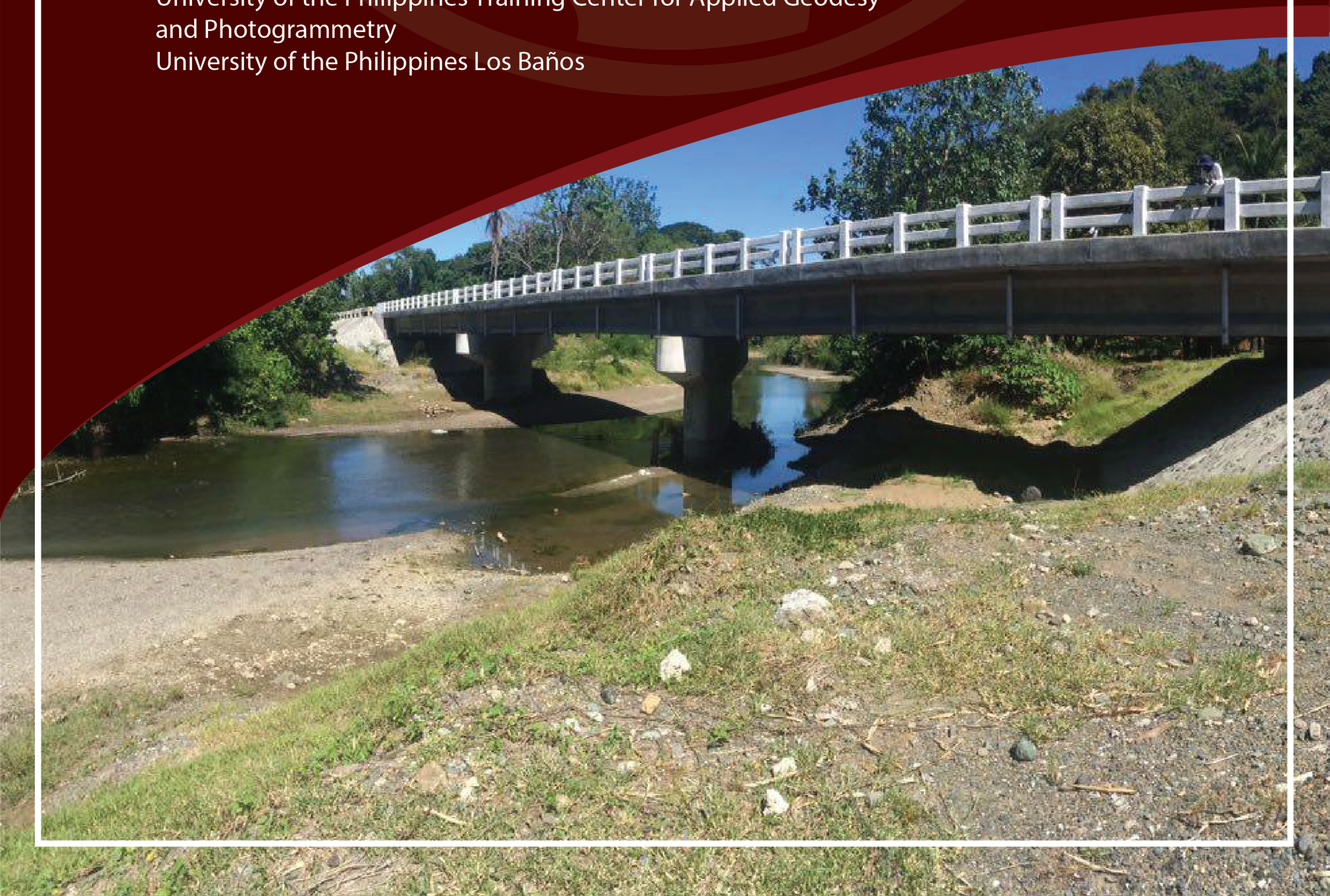

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Engr. Ariel U. Glorioso

1.1 Background of the Phil-LiDAR 1 Program

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

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

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

1.2 Overview of the Ibod River Basin

The Ibod River Basin covers portions of the following barangays in Municipality of Sablayan: Buenavista, Sto. Niño, Tagumpay, Ibud, Poblacion, Batong Buhay, San Vicente and Claudio Salgado. The DENR River Basin Control Office (RCBO) states that Ibod River Basin has a drainage area of 348 km2 and an estimated 704 million cubic meter (MCM) annual run-off.

Its main stem, Ibod River, traverses the barangays Buenavista and Sto. Niño in Municipality of Sablayan. There is a total 27,713 people residing within the immediate vicinity of the river, with Brgy. Buenavista being the most populated having 8,758 residents as of 2010 according to National Statistics Office Census of Population and Housing. The most recent flooding event of the river was on August 2011 due to 4-day continuous heavy rain brought by the southwest monsoon according to NDRRMC.

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

Ibod River Basin is a 218,000-hectare watershed located in Occidental Mindoro. It covers the barangays of San Agustin, San Francisco, San Nicolas, San Vicente, Lagnas, Malisbong, Batong Buhay, Buenavista, Burgos, Ligaya, Poblacion, Santa Lucia, Santo Niño, Tagumpay, Victoria, Tusban, Gen. Emilio Aguinaldo, Claudio Salgado, Ibud, Invita, Paetan, Pag-asa and Tanyag. The basin area has two geological classifications with Recent rocks as the most dominant type while other is Oligocene-Miocene. The river basin is generally characterized by 0-3% slope and elevation of 11-50 meters above mean sea level. Four soil types can be found within the river basin including Banto clay loam, San Manuel sandy loam, Faraon clay/river wash and San Manuel silt. Ibod River Basin is comprised of five soil classes. Moreover, the area is dominated by cultivated area mixed with brushland/grassland. Other land cover types include arable land with cereals and sugar as main crops, grassland (grass covering >70%), mangrove forest and riverbeds.

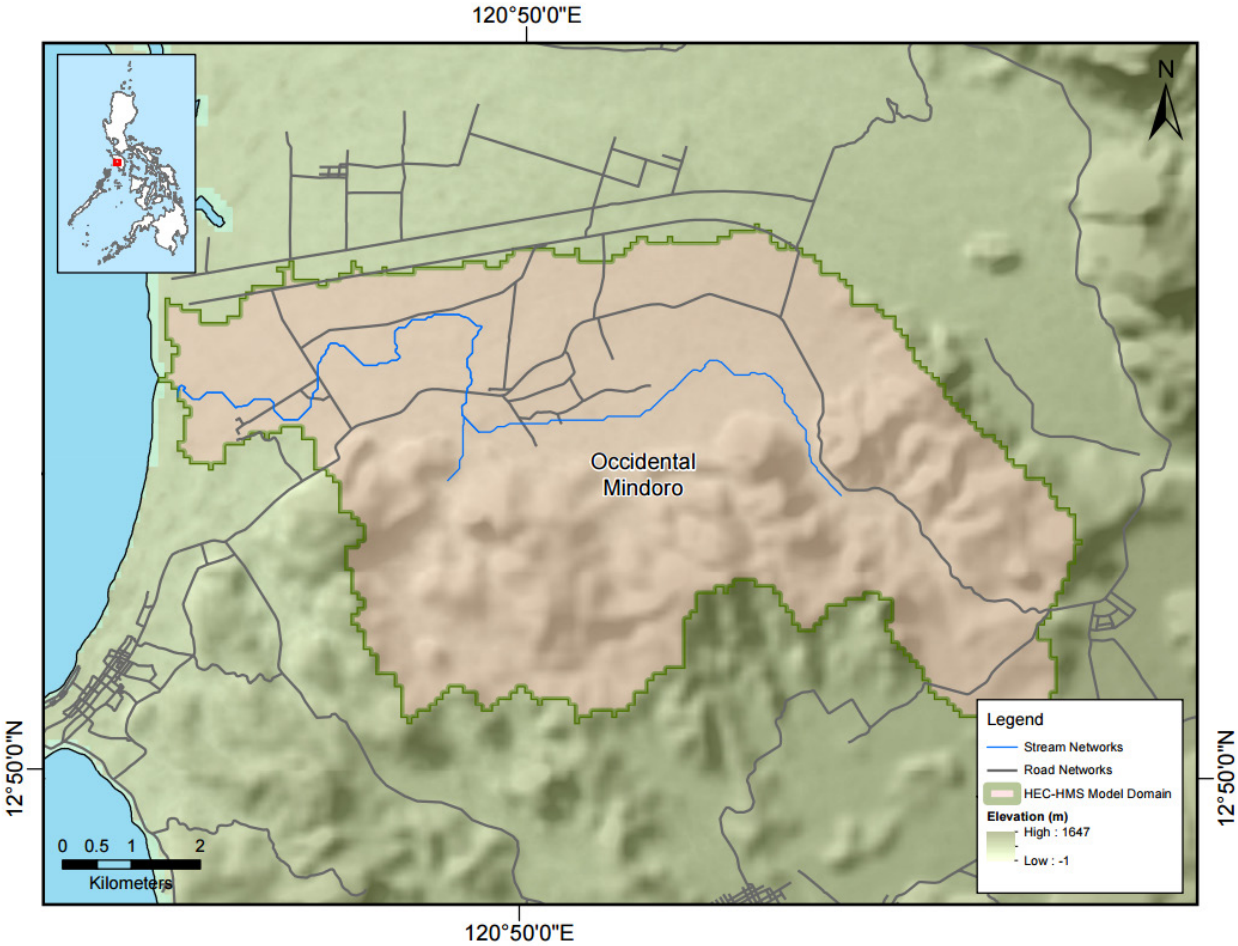

Figure 1. Map of Ibod River Basin (in brown)

Ibod River passes through Poblacion, Buenavista, Santo Niño, Tagumpay, Ibud and Batong Buhay in the municipality of Sablayan. Based on the records of the 2010 NSO Census of Population and Housing, Buenavista is the most populated barangay.

According to the Mines and Geoscience Bureau, the barangays of Sablayan have varying risk to flooding and landslide. Barangay Batong Buhay has no risk to flooding. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, about five notable weather disturbance caused flooding in 2014 (Ruby), 2015 (Lando), and 2016 (Marce and Nina). Heavy rainfall brought by southwest monsoon rains also caused flooding in August 2016.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE IBOD FLOODPLAIN

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

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Ibod Floodplain in Occidental Mindoro. These missions were planned for 15 lines and ran for at most four and a half (4.5) hours including

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)
BLK29H	600	30	36	125	40	130	5
BLK29I	600	30	36	125	40	130	5
BLK29J	600	30	36	125	40	130	5
BLK29K	600	30	36	125	40	130	5

Table 2. Flight planning parameters for Pegasus 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)
BLK29G	1100	30	50	200	30	130	5
BLK29H	1100	30	50	200	30	130	5
BLK29I	1100	30	50	200	30	130	5
BLK29J	1100	30	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

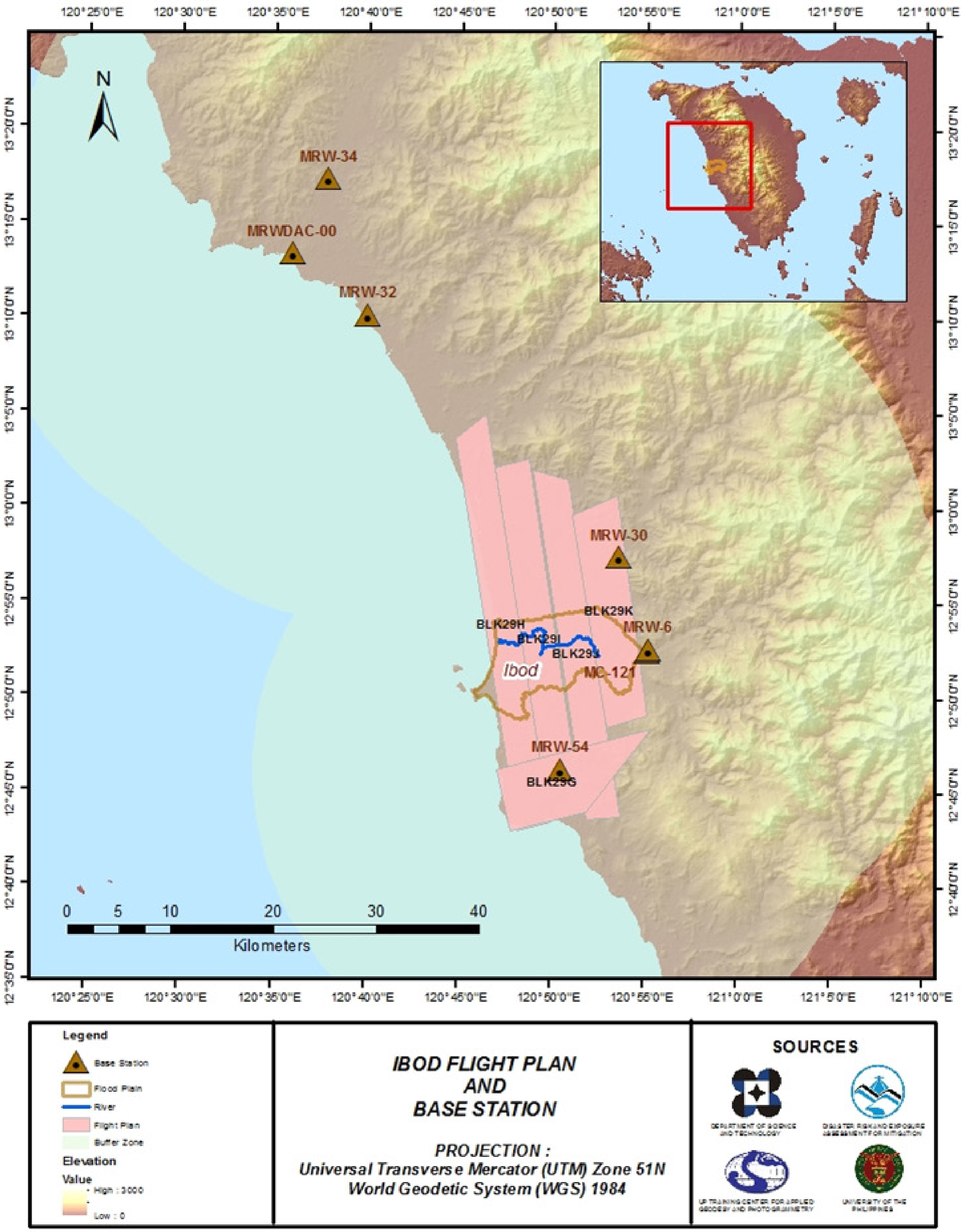

Figure 2. Flight plans and base stations used for Ibod Floodplain

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: MRW-30, MRW-32, MRW-34 and MRW-54 which are of second (2nd) order accuracy and MRW-6 which is of third (3rd) order accuracy. One (1) NAMRIA benchmark was recovered, MC-121 This benchmark was used as vertical reference point and was also established as ground control point. The project team also established one (1) ground control point, MRWDAC-00. The certifications for the NAMRIA reference points are found in Annex 2, while the processing reports for the NAMIA benchmark and established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 16-23, 2014; December 8-9, 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 Ibod floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 7 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.

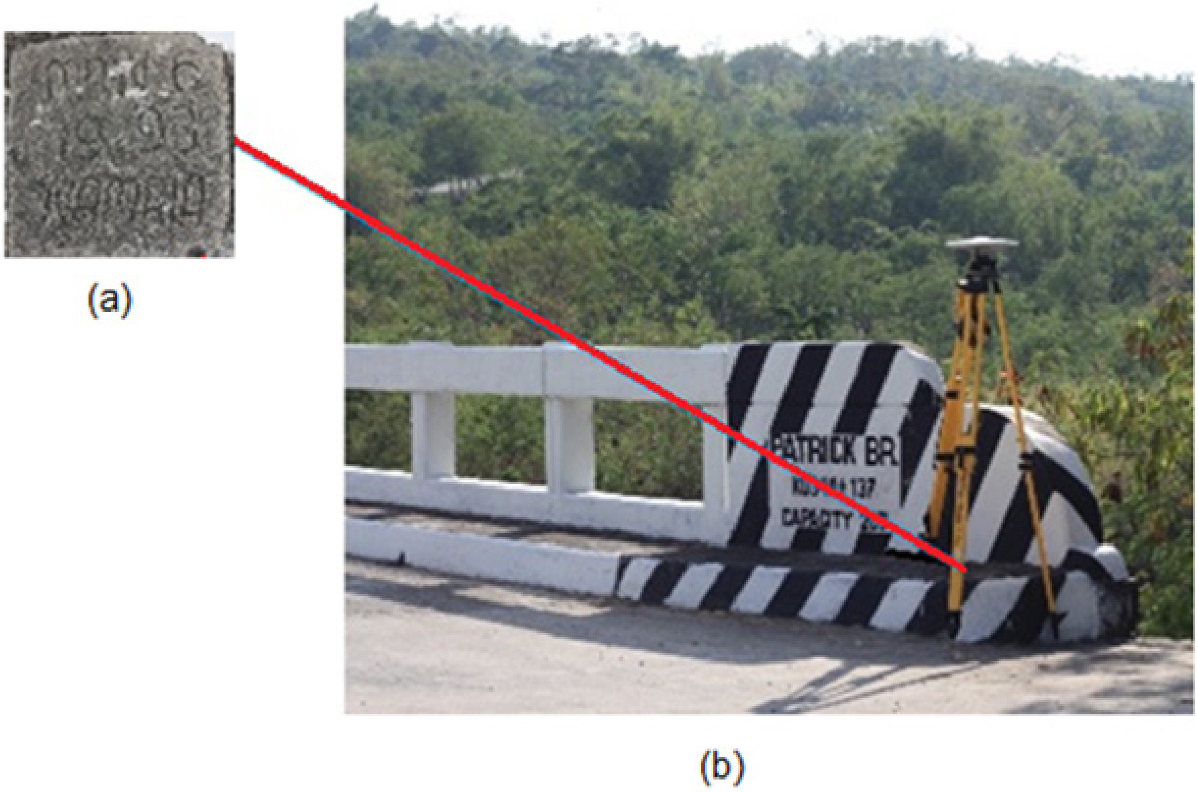

Figure 3. NAMRIA reference point MRW-6 (a) as recovered by the field team and GPS set-up over MRW-6 as recovered in Patrick Bridge in Brgy. Yabang, municipality of Sablayan, Occidental Mindoro (b).

Table 3. Details of the recovered NAMRIA horizontal control point MRW-6 used as base station for the LiDAR Acquisition.

Station Name	**MRW-6**	
Order of Accuracy	**3rd**	
Relative Error (Horizontal positioning)	**1:20,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longtitude Ellipsoidal Height	12°52’40.22762” North 120°55’6.44586” East 80.63530 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	491149.868 meters 1424038.201 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longtitude Ellipsoidal Height	12°52’35.21155” North 120°55’11.48810” East 128.69600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS PRS 92)	Easting Northing	274116.83 meters 1424453.14 meters

(a)

(b)

Figure 4. NAMRIA reference point MRW-30 (a) as recovered by the field team and GPS set-up over MRW-30 in Amnay Bridge in Brgy. Pinagturilan, municipality of Sta. Cruz, Occidental Mindoro (b).

Table 4. Details of the recovered NAMRIA horizontal control point MRW-30 used as base station for the LiDAR Acquisition.

Station Name	MRW-30	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°57'32.22950" North 120°53'28.50896" East 42.01300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	488201.05 meters 1433011.7 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°57'27.19115" North 120°53'33.54442" East 89.79300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	271237.33 meters 1433451.97 meters

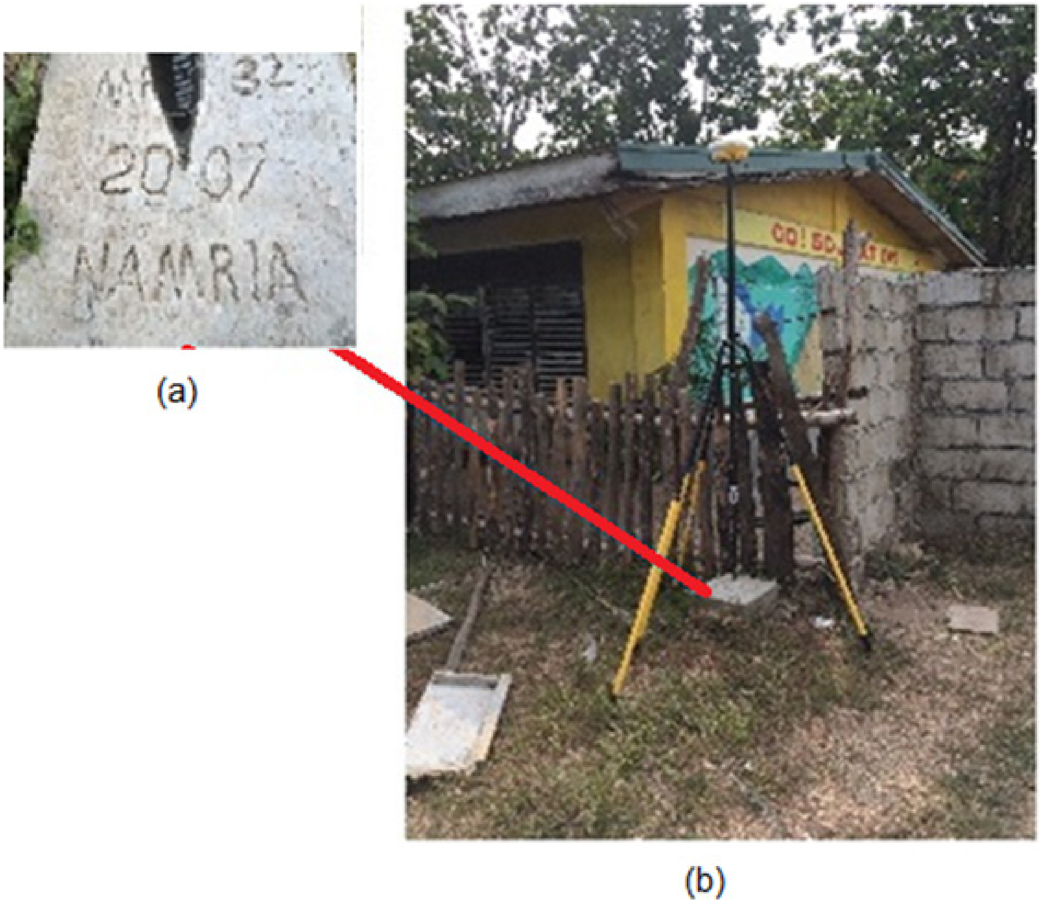

Figure 5. NAMRIA reference point MRW-32 (a) as recovered by the field team and GPS set-up over MRW-32 in the corner of a day care center in Brgy. Fatima, municipality of Mamburao, Occidental Mindoro (b).

Table 5. Details of the recovered NAMRIA horizontal control point MRW-32 used as base station for the LiDAR Acquisition.

Station Name	MRW-32	
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°10'14.92094" North 120°39'52.29557" East 1.47400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	463632.46 meters 1456469.064 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°10'9.81293" North 120°39'57.31386" East 48.13600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	246845.90 meters 1457111.12 meters

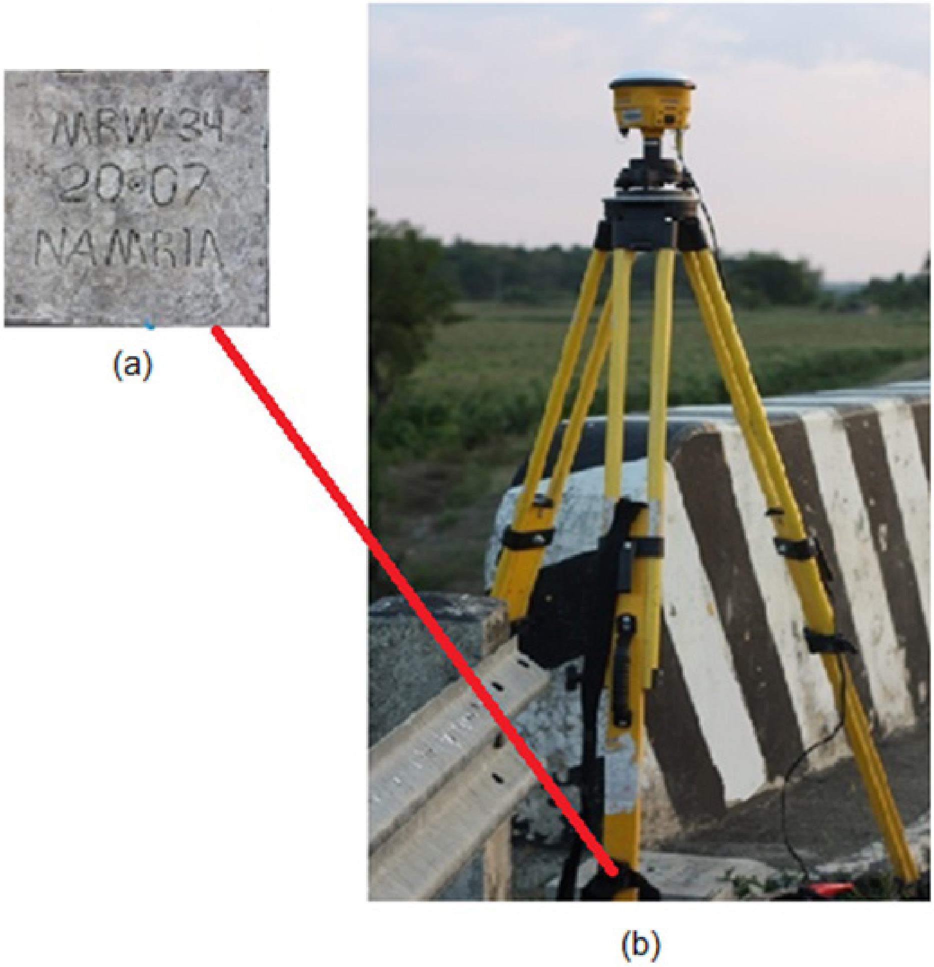

Figure 6. NAMRIA reference point MRW-34 (a) as recovered by the field team and GPS set-up over MRW-34 in Balibago Bridge in Brgy. Armado, municipality of Abra de Ilog, Occidental Mindoro (b).

Table 6. Details of the recovered NAMRIA horizontal control point MRW-34 used as base station for the LiDAR Acquisition.

Station Name	MRW-34	
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°17'25.00981" North 120°37'41.53630" East 8.01600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	459714.493 meters 1469690.588 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°17'19.87026" North 120°37' 46.54446" East 54.26900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	243032.08 meters 1470369.33 meters

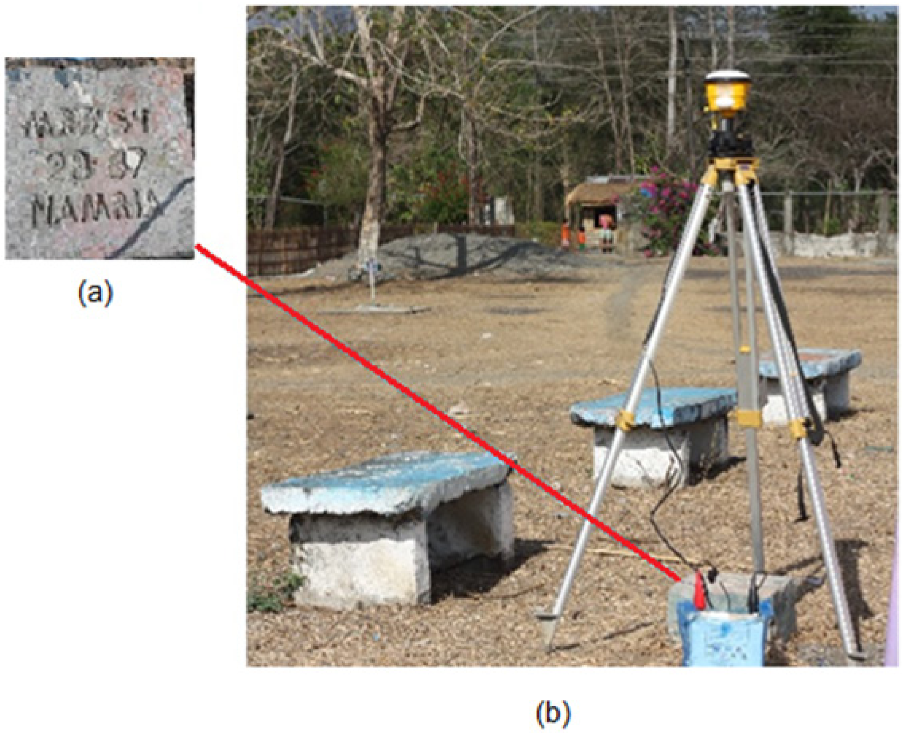

Figure 7. NAMRIA reference point MRW-54 (a) as recovered by the field team and GPS set-up over MRW-54 as recovered in near basketball open court in Brgy. Malisbong, municipality of Sablayan, Occidental Mindoro (b).

Table 7. Details of the recovered NAMRIA horizontal control point MRW-54 used as base station for the LiDAR Acquisition.

Station Name	MRW-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°46'18.56204" North 120°50'27.44152" East 28.20700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	482731.146 meters 1412314.677 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°46'13.56455" North 120°50'32.49343" East 76.35500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	265604.90 meters 1412791.69 meters

Table 8. Details of the recovered NAMRIA vertical control point MC-121 used as base station for the LiDAR Acquisition.

Station Name	MC-121	
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°52'32.96110" North 120°55'04.36932" East 79.97100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	274052.406 meters 1424230.309 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°52'27.94499" North 120°55'09.41181" East 128.03500 meters

Table 9. Details of the recovered NAMRIA horizontal control point MRWDAC-00 used as base station for the LiDAR Acquisition.

Station Name	MRWDAC-00	
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°13'23.10541" 120°35'55.10583" 11.60100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	239755.834 meters 1462963.518 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°13'17.97945" North 120°36'00.11991" East 57.96100 meters

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
16-Feb-14	1108A	3BLK29J47A	MRW-30, MRW-6
16-Feb-14	1110A	3BLK29KJS47B	MRW-30, MRW-6
18-Feb-14	1116A	3BLK29KS49A	MRW-30, MRW-6
18-Feb-14	1118A	3BLK29JS49B	MRW-30, MRW-6
21-Feb-14	1128A	3BLK29I52A	MRW-32, MRW-34
22-Feb-14	1132A	3BLK29IS53A	MRW-30, MRW-6, MRW-34, MRW-32
23-Feb-14	1136A	3BLK29HB54A	MRW-54, MRW-6
8-Dec-15	3068P	1BLK29GJ342B	MRW-30, MRWDAC-00
9-Dec-15	3070P	1BLK29GHI343A	MRW-6, MC-121

2.3 Flight Missions

Nine (9) missions were conducted to complete the LiDAR Data Acquisition in Ibod Floodplain, for a total of thirty-three hours and seventeen minutes (33+17) of flying time for RP-C9122. All missions were acquired using the Aquarius and Gemini LiDAR system. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

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

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
16-Feb-14	1108A	111.55	35.59	5.25	30.34	10	2	41
16-Feb-14	1110A	202.24	78.12	17.67	60.45	608	4	23
18-Feb-14	1116A	90.69	86.23	21.58	64.65	1056	4	23
18-Feb-14	1118A	111.55	59.60	11.04	48.56	734	3	35
21-Feb-14	1128A	117.38	116.66	22.05	94.61	99	4	35
22-Feb-14	1132A	248.63	120.42	24.38	96.04	610	4	41
23-Feb-14	1136A	131.25	69.06	NA	69.06	1241	4	29
8-Dec-15	3068P	182.62	36.42	7.78	28.64	74	1	55
9-Dec-15	3070P	319.70	98.32	25.43	72.89	209	2	35
TOTAL		1515.62	700.42	135.18	565.24	4641	33	17

Table 12. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1108A	600	30	36	125	40	130	5
1110A	600	30	36	125	40	110	5
1116A	600	30	36	125	40	130	5
1118A	600	30	36	125	40	110	5
1128A	600	30	36	125	40	130	5
1132A	600	30	36	125	40	130	5
1136A	600	30	36	125	40	130	5
3068P	1100	30	50	200	30	130	5
3070P	1100	30	50	200	30	130	5

2.4 Survey Coverage

Ibod floodplain is located in the provinces of Occidental Mindoro with majority of the floodplain situated within the municipality of Sablayan. 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 Ibod floodplain is presented in Figure 8.

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

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Occidental Mindoro	Calintaan	282.31	14.04	4.97%
	Sablayan	2350.46	408.35	17.37%
	Santa Cruz	709.53	85.762	12.09%
Total		**3342.3**	**508.152**	**11.48%**

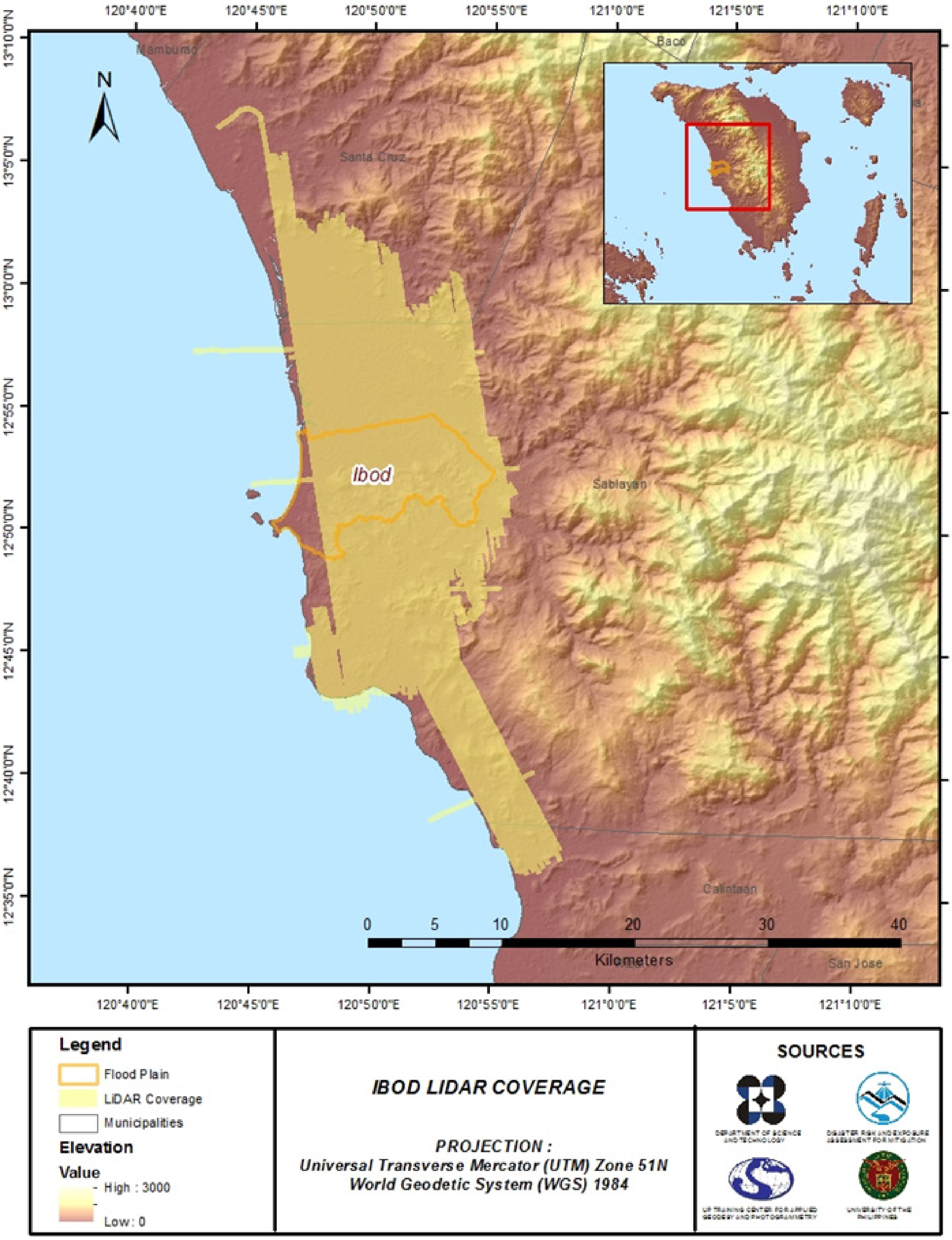

Figure 8. Actual LiDAR survey coverage for Ibod Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE IBOD FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 9.

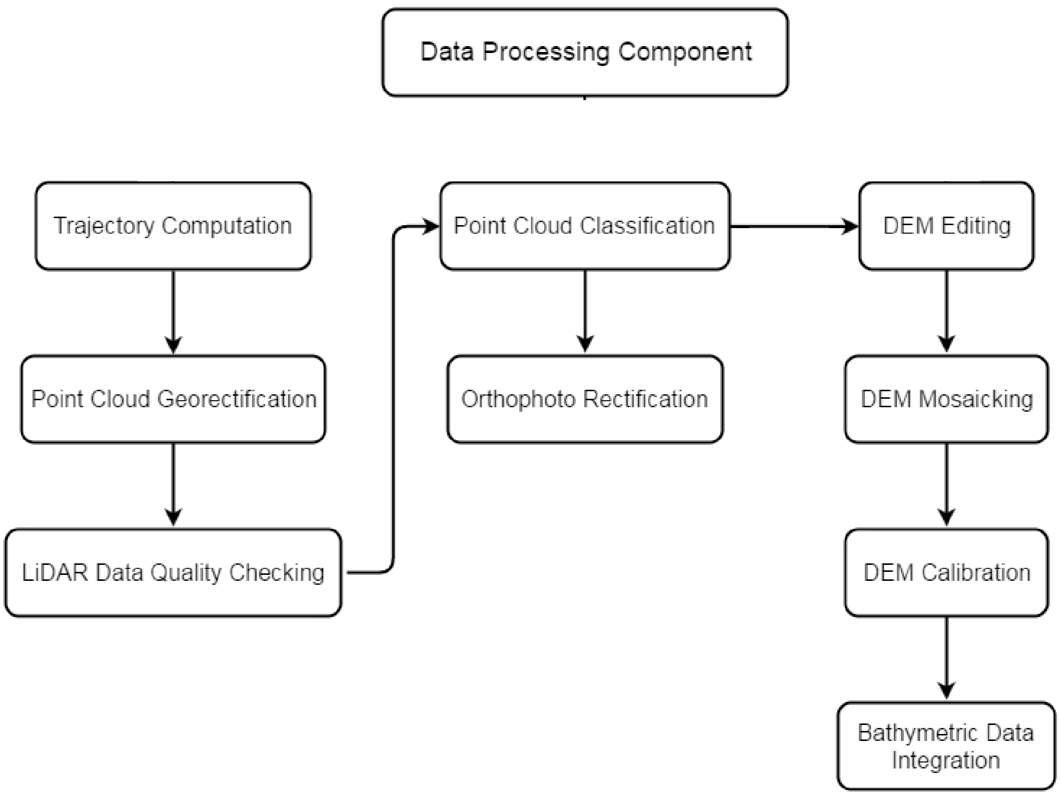

Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ibod floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 2014 and during the second survey conducted on December 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system and Pegasus system respectively over Municipality of Sablayan, Occidental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 101.31 Gigabytes of Range data, 1.88 Gigabytes of POS data, 122.06 Megabytes of GPS base station data, and 308.15 Gigabytes of raw image data to the data server on January 13, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ibod was fully transferred on January 15, 2016 as indicated on the Data Transfer Sheets for Ibod floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1128A, one of the Ibod flights, which is the North, East, and Down position RMSE values are shown in Figure 10. 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 16, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

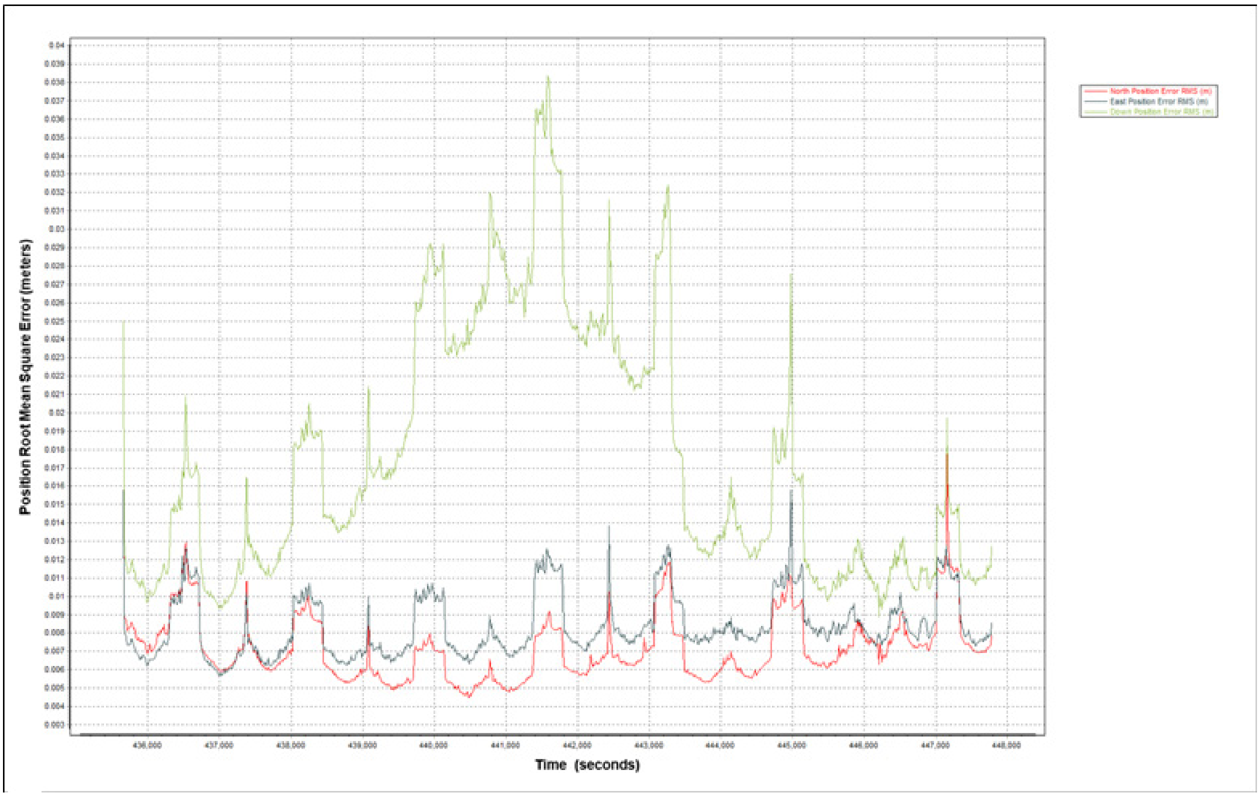

Figure 10. Smoothed Performance Metrics of Ibod Flight 1098A.

The time of flight was from 435,600 seconds to 448,000 seconds, which corresponds to morning of February 21, 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 minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.77 centimeters, the East position RMSE peaks at 1.58 centimeters, and the Down position RMSE peaks at 3.83 centimeters, which are within the prescribed accuracies described in the methodology.

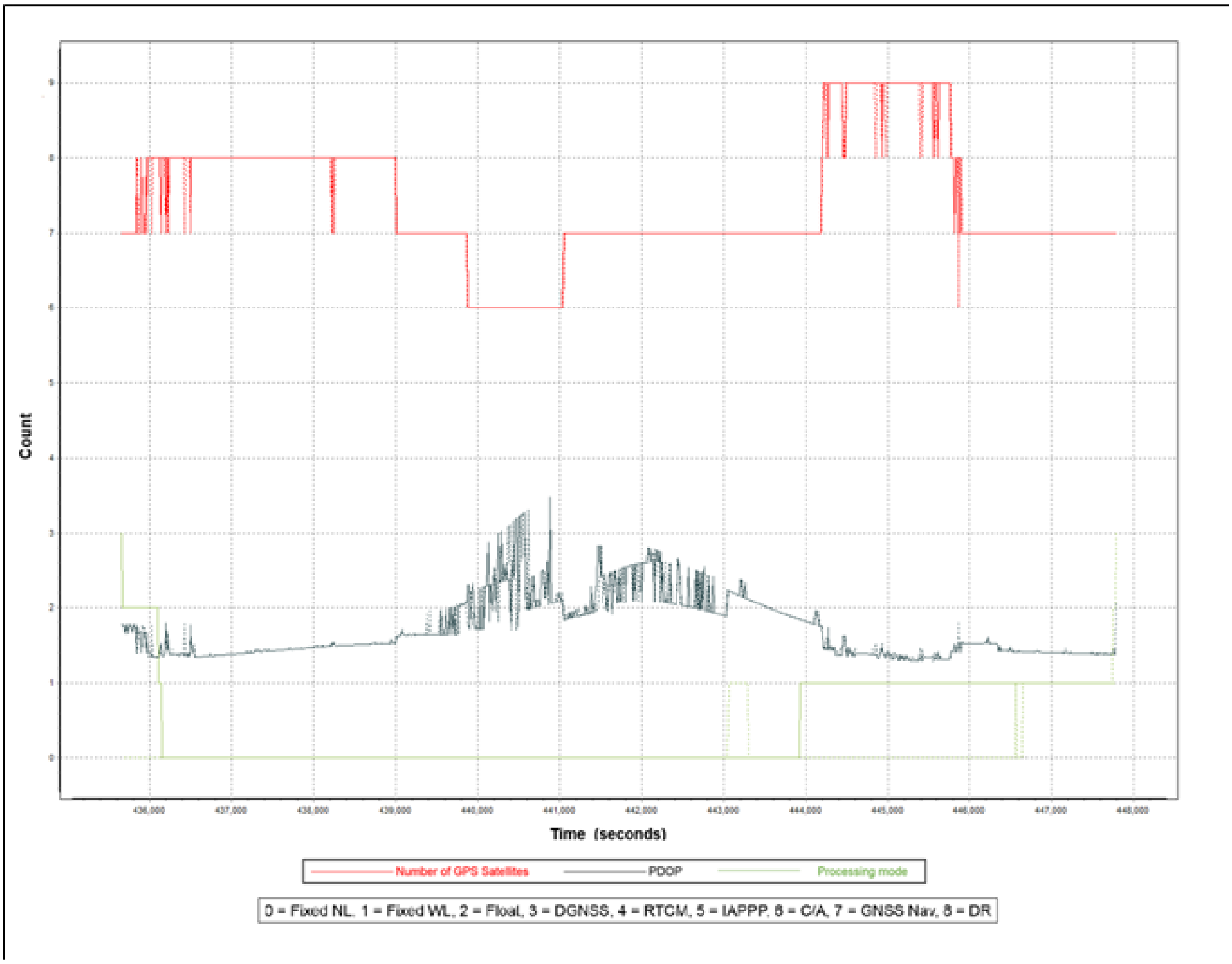

Figure 11. Solution Status Parameters of Ibod Flight 1128A.

The Solution Status parameters of flight 1128A, one of the Ibod flights, which indicate the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down below 6. Most of the time, the number of satellites tracked was between 7 and 9. The PDOP value most of the time did not go above the value of 3, which still indicates optimal GPS geometry. The processing mode remained at 0 for almost the entire survey time with some parts go to 1 attributed to the turn 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 Ibod flights is shown in Figure 12.

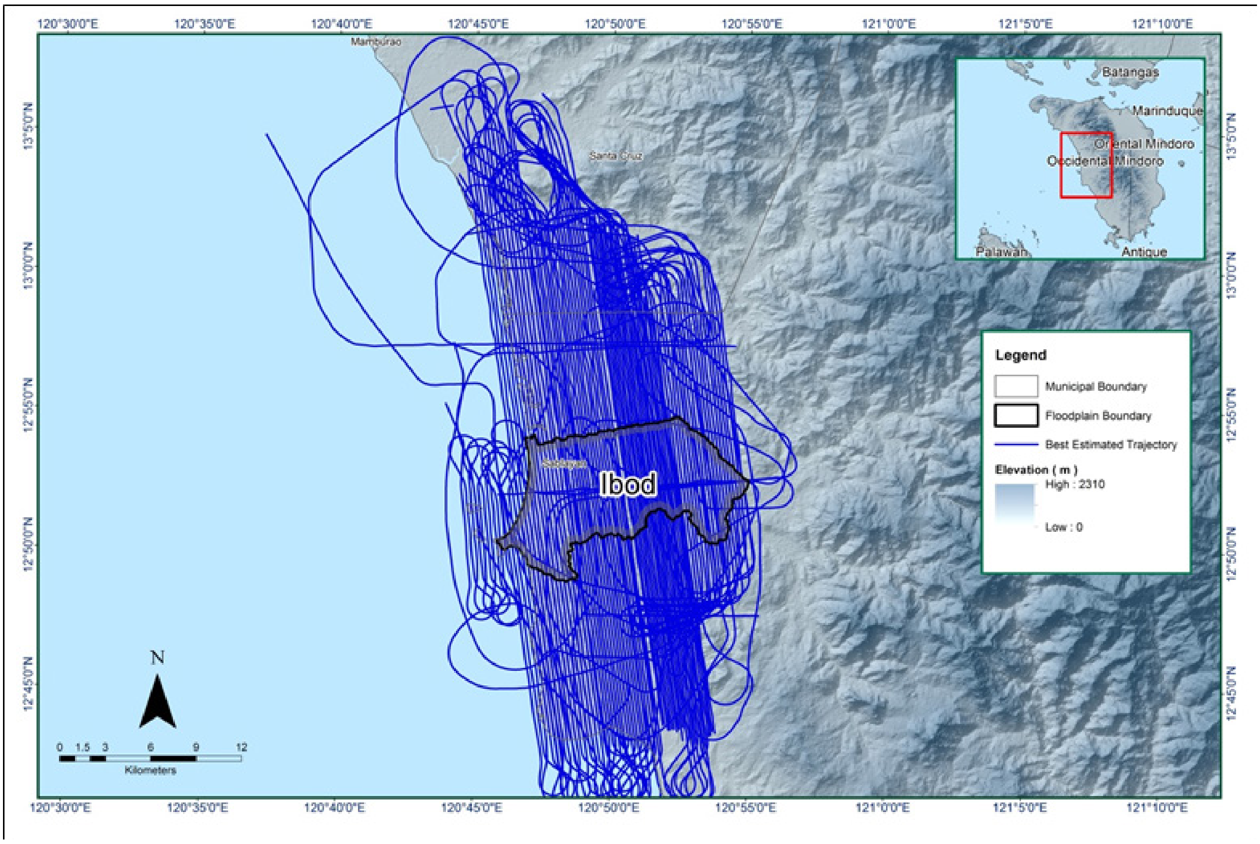

Figure 12. Best Estimated Trajectory for Ibod Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 106 flight lines, eighty nine (89) of those flight lines contains only one (1) channel for the Gemini system, and the remaining 17 flight lines contains two channels since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ibod floodplain are given in Table 14.

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

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000390
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000934
GPS Position Z-correction stdev	<0.01meters	0.0110

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Ibod Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

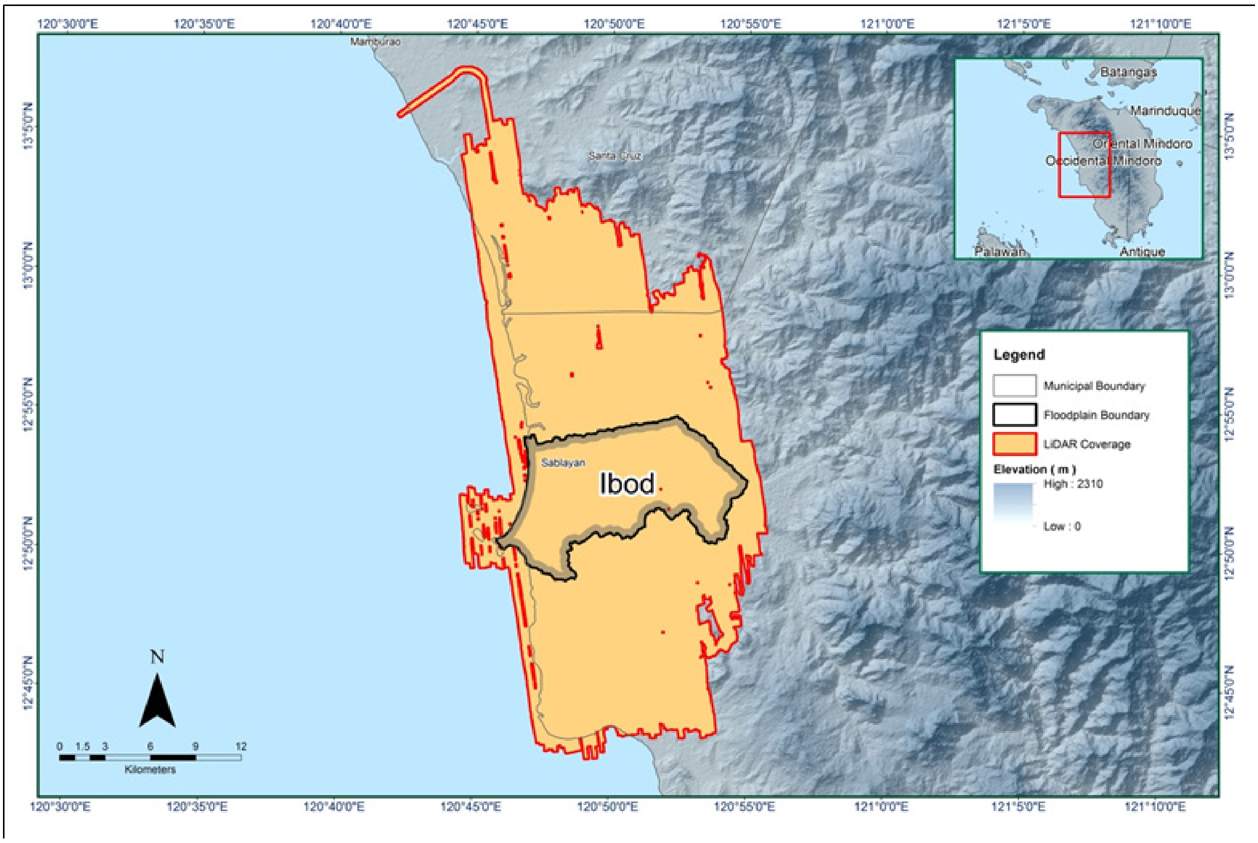

Figure 13. Boundary of the processed LiDAR data over Ibod Floodplain

The total area covered by the Ibod missions is 624.26 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Ibod Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29H	1136A	102.41
OccidentalMindoro_Blk29HI_supplement	1132A	80.80
OccidentalMindoro_Blk29I	1128A	101.94
OccidentalMindoro_Blk29JK	1108A	133.64
	1110A	
	1118A	
OccidentalMindoro_Blk29K_supplement	1116A	82.45
OccidentalMindoro_Reflights_Blk29HI	3068P	60.38
	3070P	
OccidentalMindoro_Reflights_Blk29JK	3070P	62.64
TOTAL		624.26 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 14. Since the Gemini system employs one channel, and the Pegasus system employs two channels, 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.

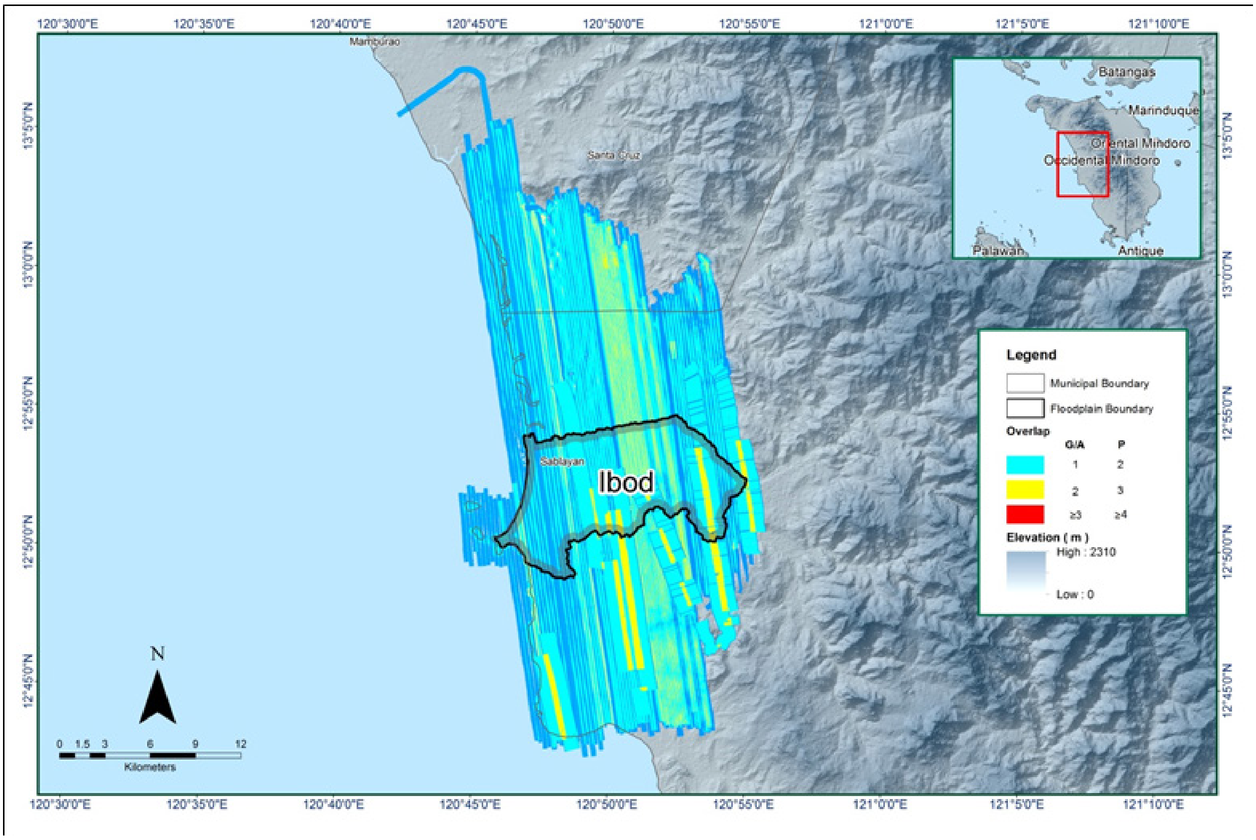

Figure 14. Image of data overlap for Ibod Floodplain.

The overlap statistics per block for the Ibod floodplain can be found in Annex 8: Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 37.19% and 82.92% 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 15. It was determined that all LiDAR data for Ibod floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.53 points per square meter.

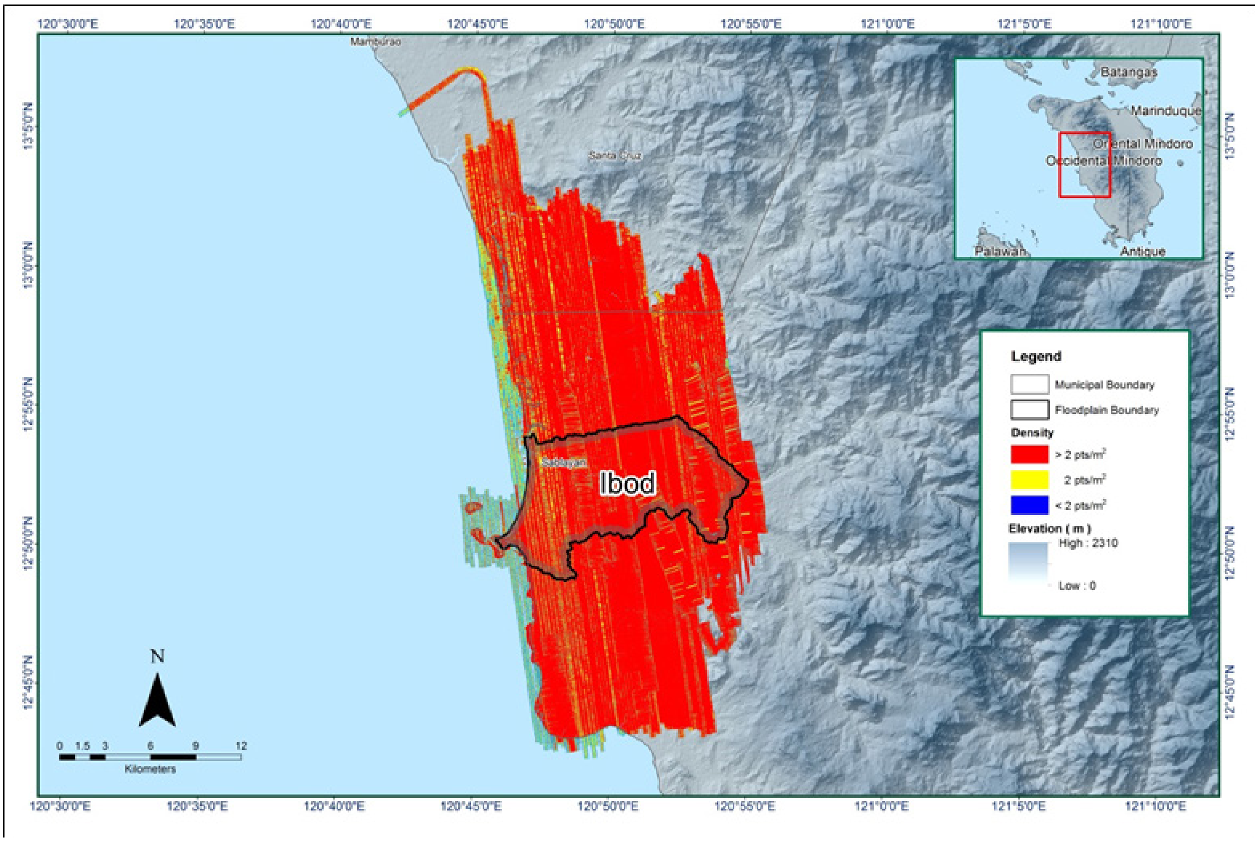

Figure 15. Pulse density map of merged LiDAR data for Ibod Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

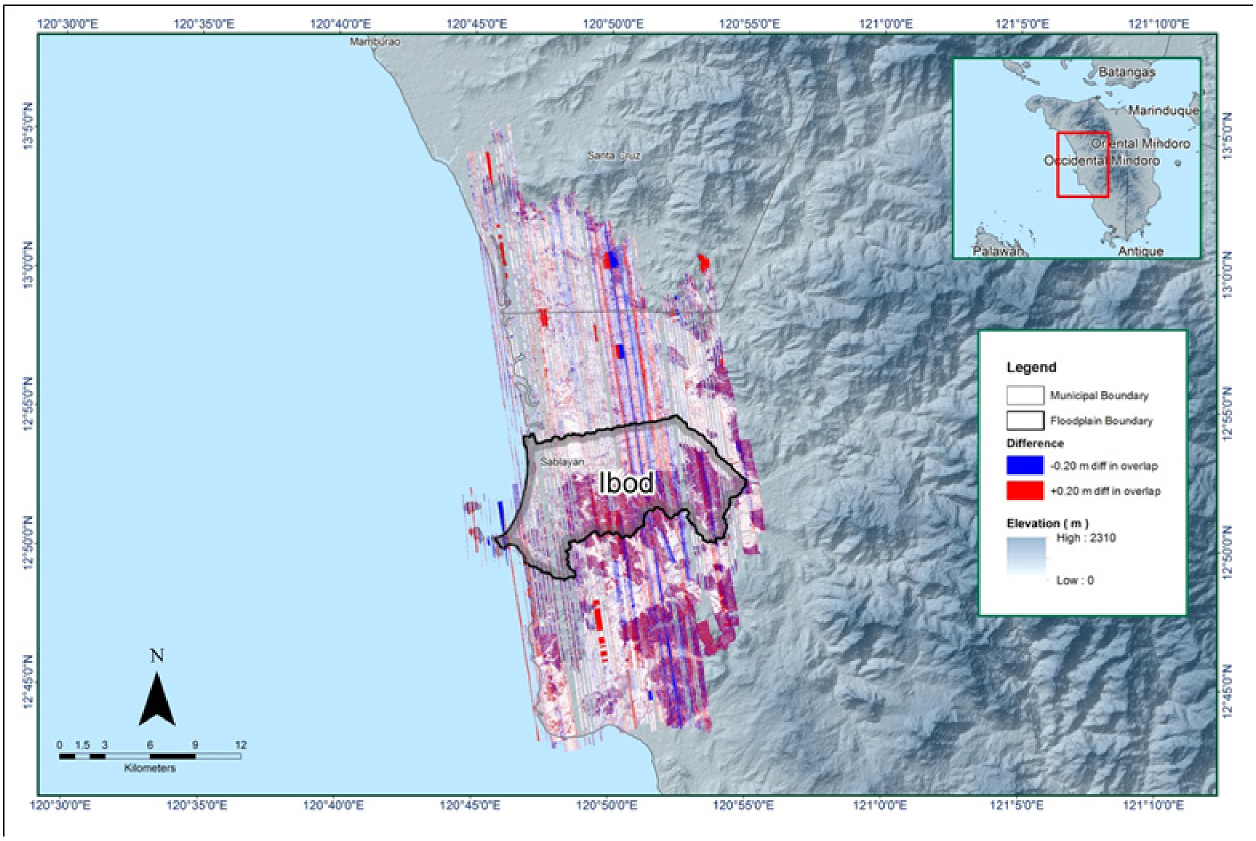

Figure 16. Elevation difference map between flight lines for Baroc Floodplain.

A screen capture of the processed LAS data from an Ibod flight 1128A loaded in QT Modeler is shown in Figure 17. 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.

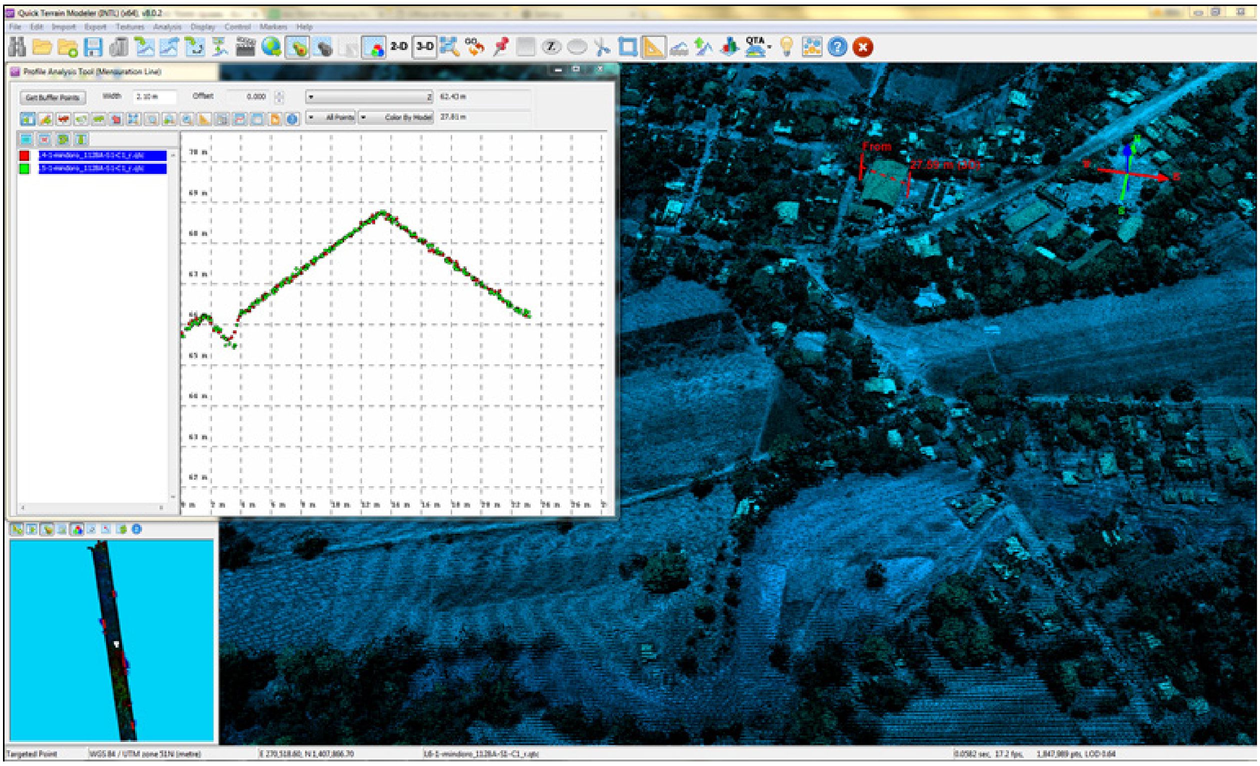

Figure 17. Quality checking for Ibod flight 1128A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Ibod classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	497,866,536
Low Vegetation	594,574,070
Medium Vegetation	661,814,942
High Vegetation	505,582,747
Building	13,353,980

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ibod floodplain is shown in Figure 18. A total of 1,025 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 613.49 meters and 39.16 meters respectively.

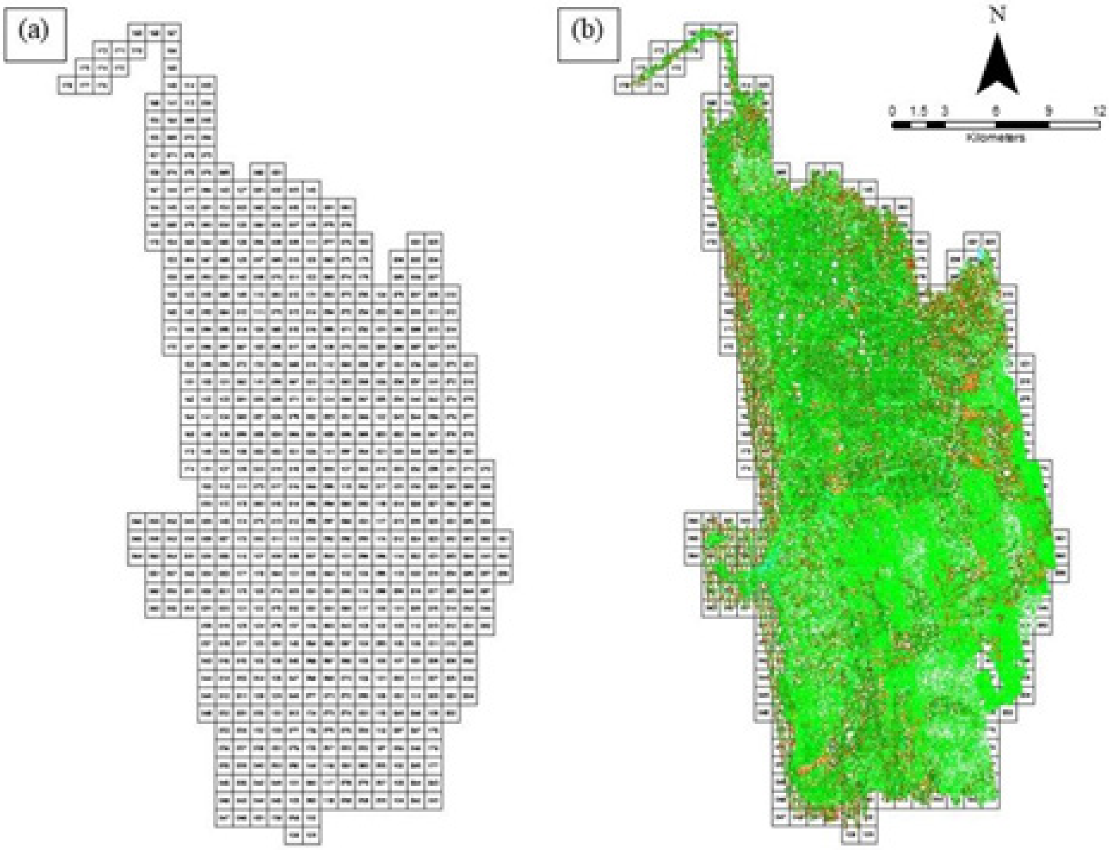

Figure 18. Tiles for Ibod Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

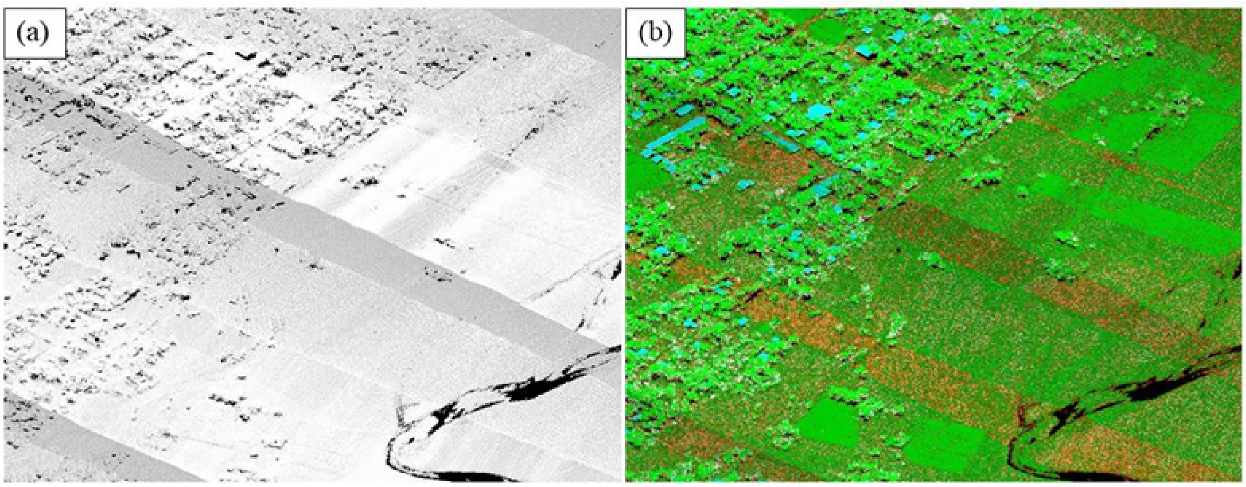

Figure 19. Point cloud before (a) and after (b) classification.

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 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

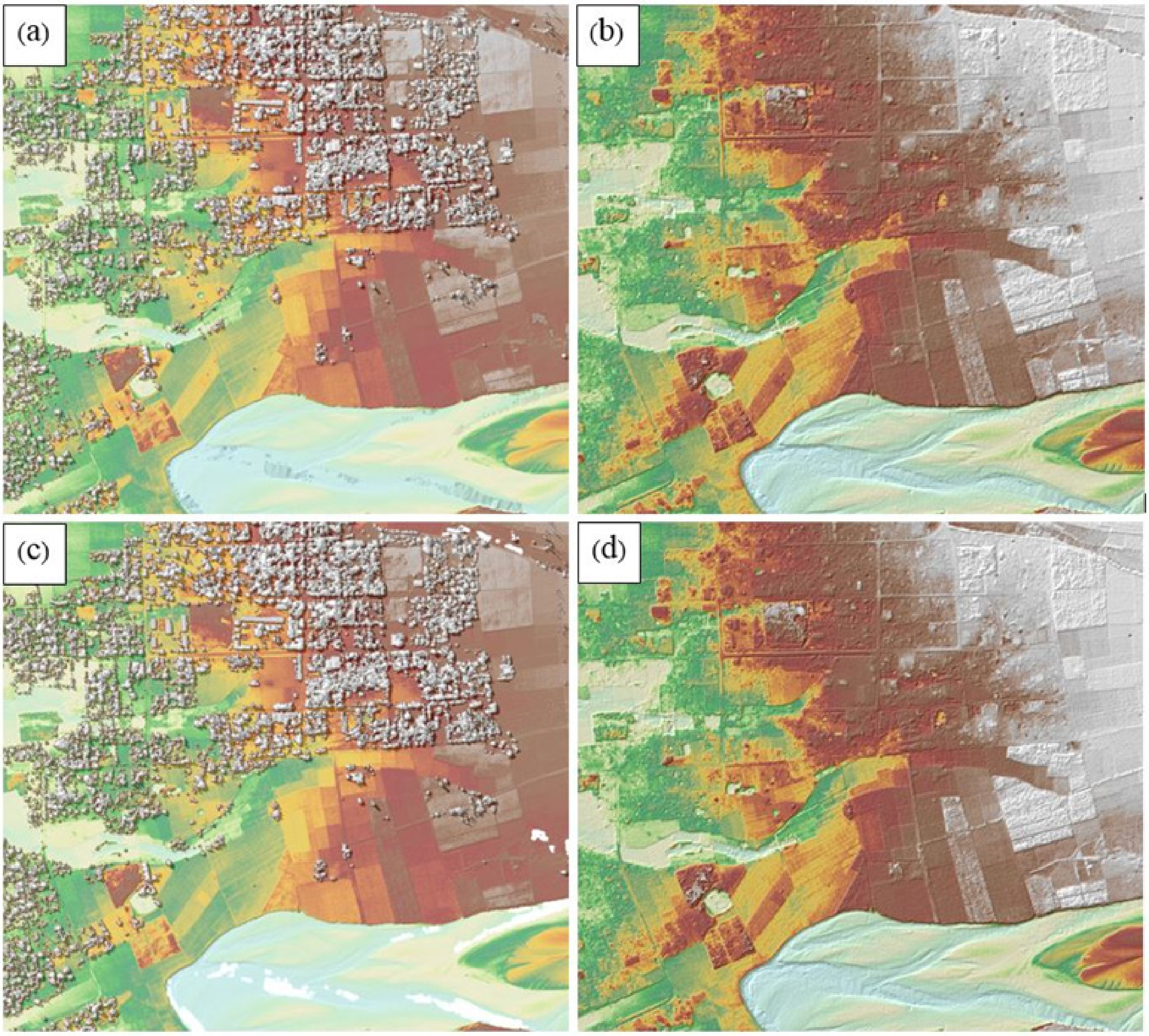

Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ibod floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 501 1km by 1km tiles area covered by Ibod floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Ibod floodplain has a total of 300.06 sq.km orthophotogaph coverage comprised of 3,375 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

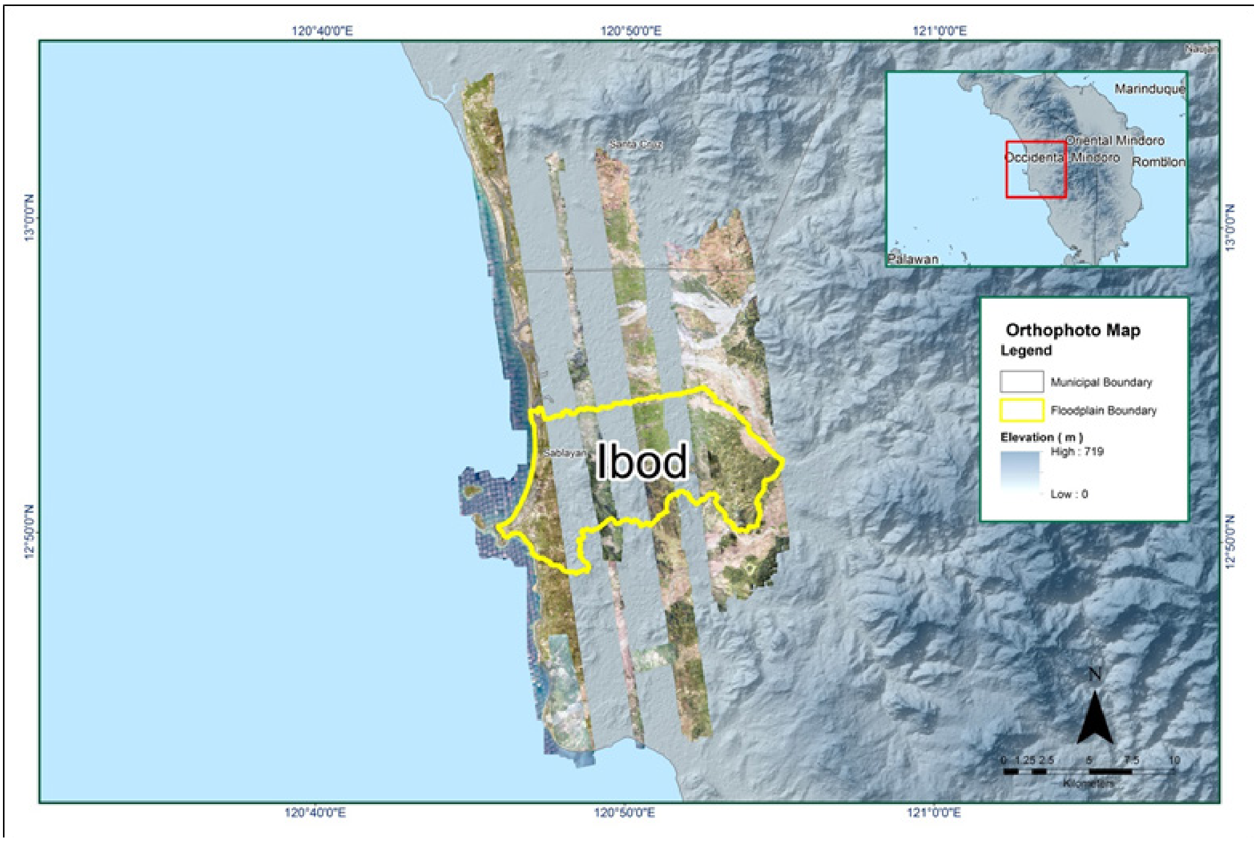

Figure 21. Ibod floodplain with available orthophotographs

Figure 22. Sample orthophotograph tiles for Ibod Floodplain

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Ibod flood plain. These blocks are composed of Occidental Mindoro and Occidental Mindoro Reflights blocks with a total area of 624.26 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)
OccidentalMindoro_Blk29H	102.41
OccidentalMindoro_Blk29HI_supplement	80.80
OccidentalMindoro_Blk29I	101.94
OccidentalMindoro_Blk29JK	133.64
OccidentalMindoro_Blk29K_supplement	82.45
OccidentalMindoro_Reflights_Blk29HI	60.38
OccidentalMindoro_Reflights_Blk29JK	62.64
TOTAL	624.26 sq. km

Portions of DTM before and after manual editing are shown in Figure 23. The land bridge in Figure 23a would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 23b. Another portion of the DTM presented in Figure 23c shows the part of the DTM which was flattened. This was resolved by retrieving the part of the data as shown in the output in Figure 23d.

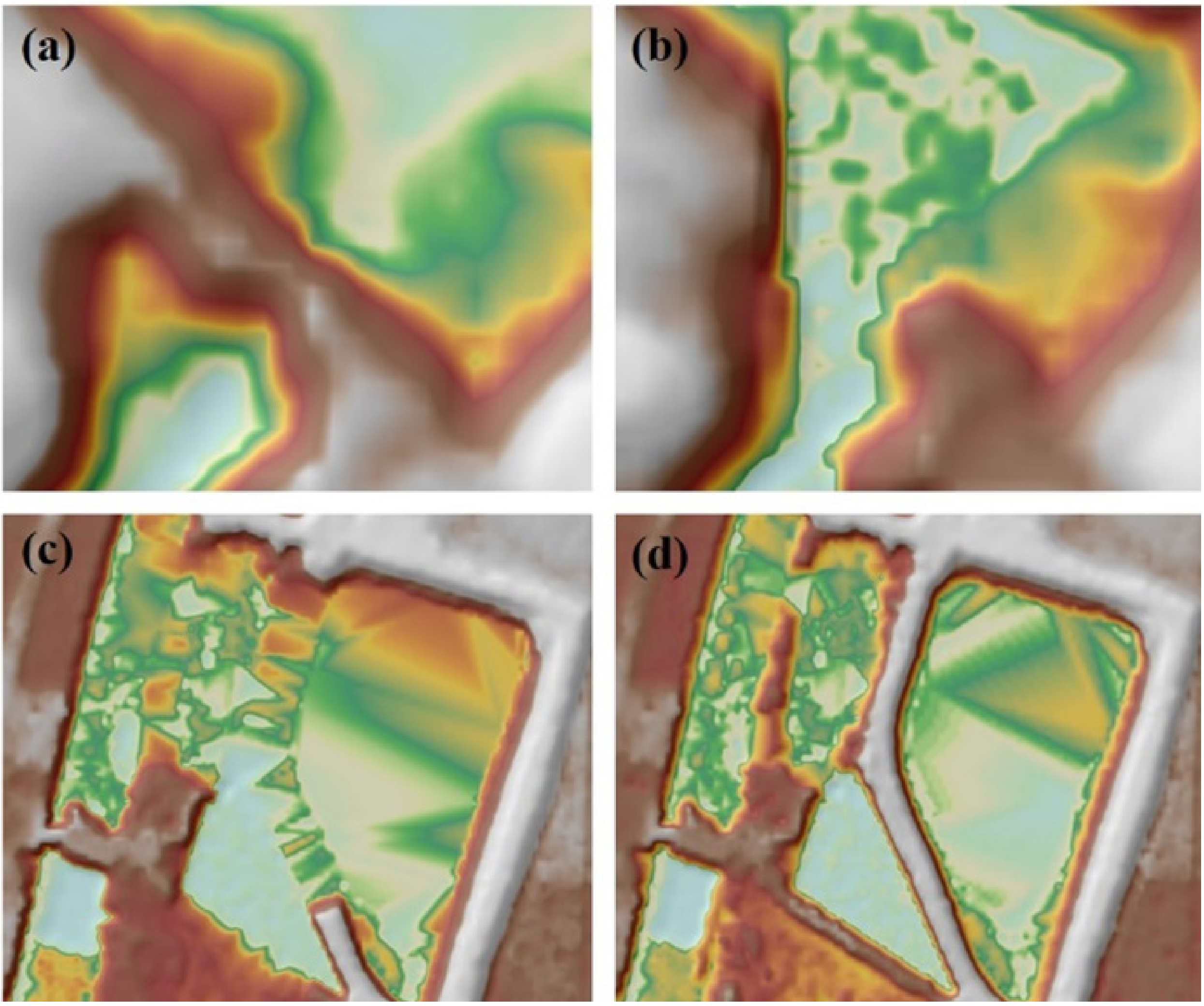

Figure 23. Portions in the DTM of Ibod Floodplain – a land bridge before (a) and after (b) data interpolation and a flattened area before (a) and after (b) data retrieval.

3.9 Mosaicking of Blocks

OccidentalMindoro_Blk29M 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 Ibod floodplain is shown in Figure 24. It can be seen that the entire Ibod floodplain is 100% covered by LiDAR data.

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

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29H	0.00	0.00	-0.83
OccidentalMindoro_Blk29HI_supplement	0.00	0.00	-0.88
OccidentalMindoro_Blk29I	0.00	0.00	-0.44
OccidentalMindoro_Blk29JK	0.00	0.00	-1.14
OccidentalMindoro_Blk29K_supplement	0.00	0.00	-0.96
OccidentalMindoro_Reflights_Blk29HI (Left)	0.00	0.00	-1.64
OccidentalMindoro_Reflights_Blk29HI (Right)	0.00	1.01	-1.64
OccidentalMindoro_Reflight_Blk29JK (Left)	0.00	0.00	-2.13
OccidentalMindoro_Reflight_Blk29JK (Upper_ Middle)	0.00	0.00	-2.51
OccidentalMindoro_Reflight_Blk29JK (Lower_ Middle)	0.00	0.00	-3.25
OccidentalMindoro_Reflight_Blk29JK (Right)	0.00	0.00	-2.36

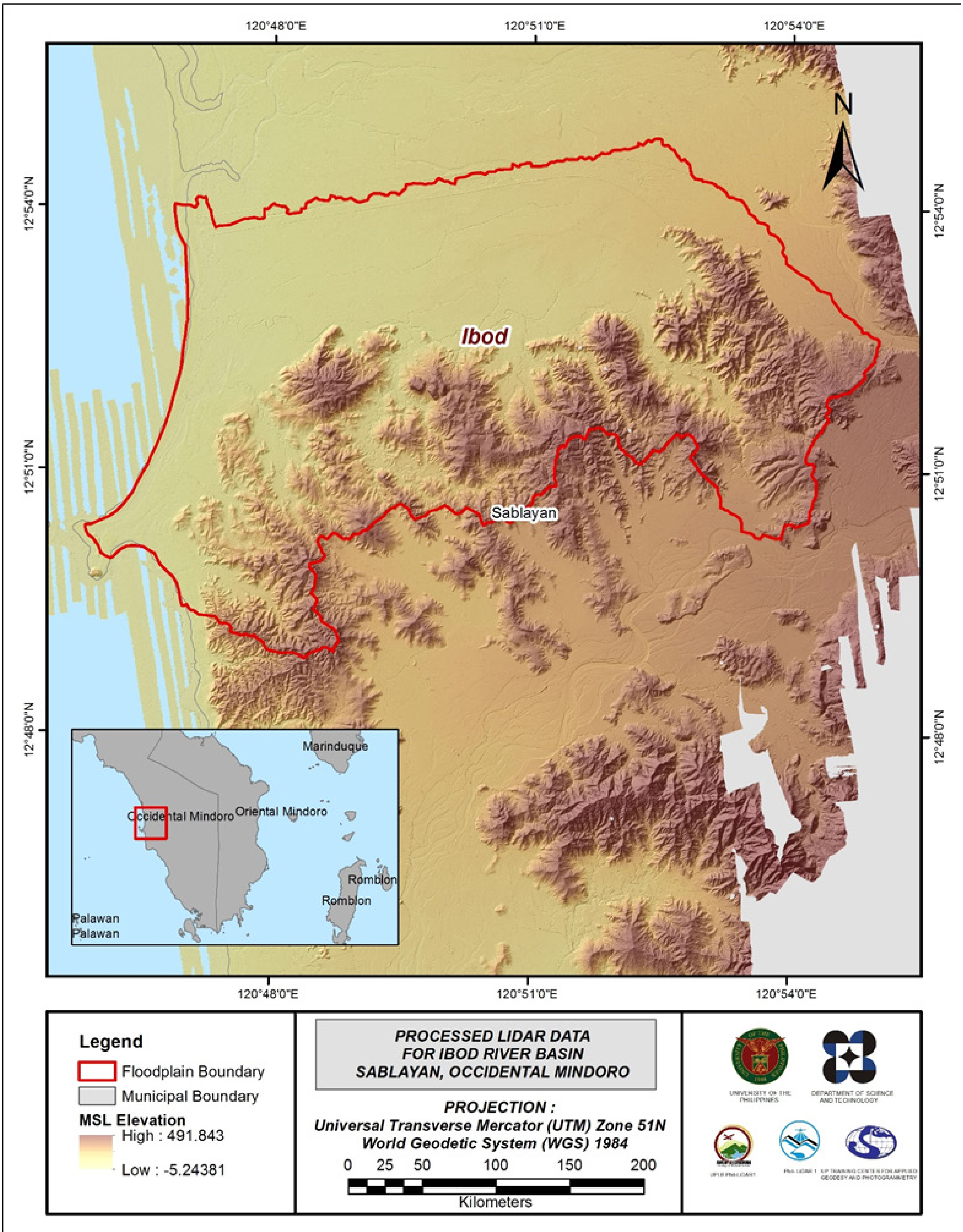

Figure 24. Map of Processed LiDAR Data for Ibod Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ibod to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 28,494 survey points were gathered for all the flood plains within Occidental Mindoro wherein the Ibod floodplain is located. Random selection of 80% of the survey points, resulting to 22,795 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Ibod LiDAR data was done by adding the height difference value, 0.23 meters, to Ibod mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

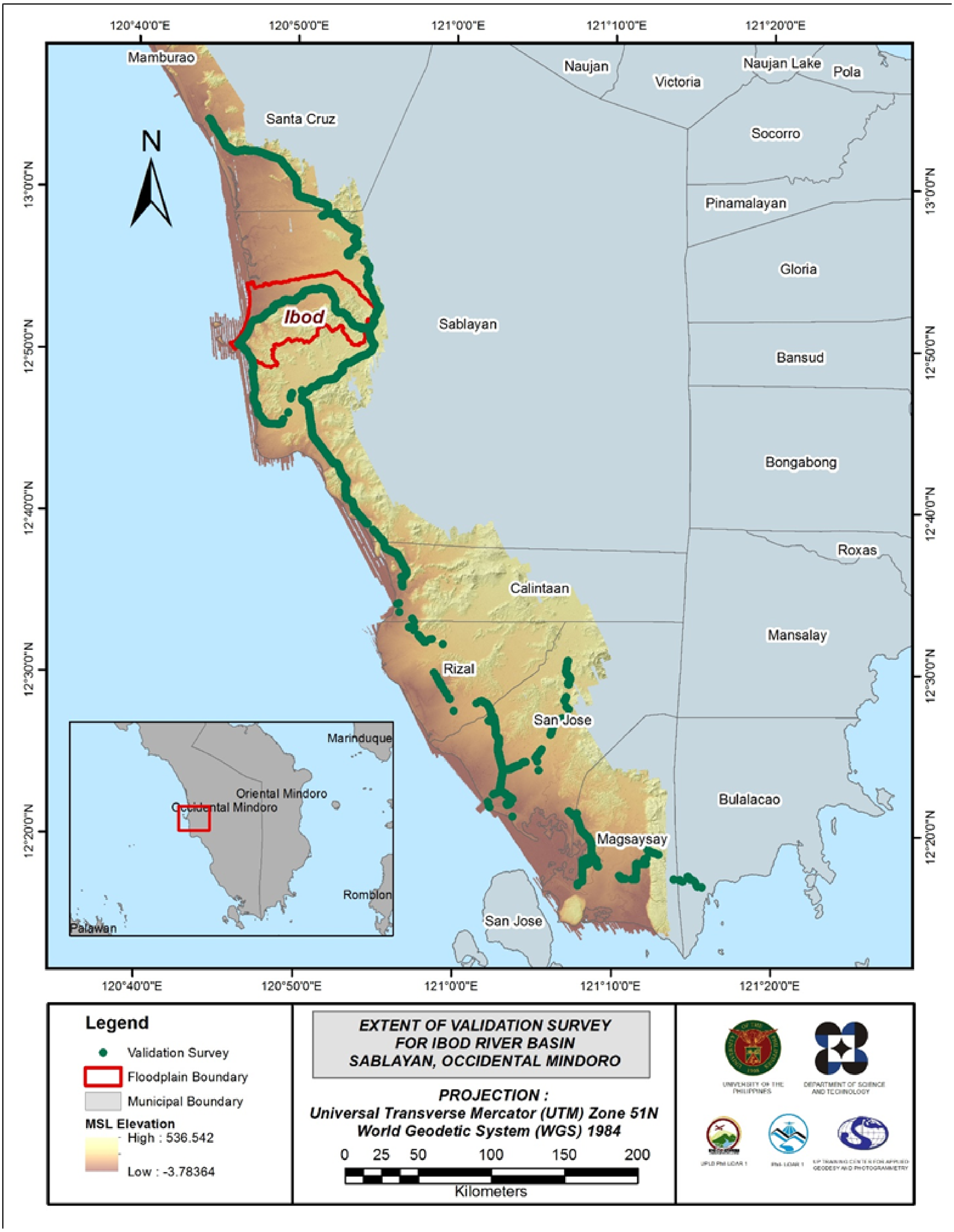

Figure 25. Map of Ibod Floodplain with validation survey points in green.

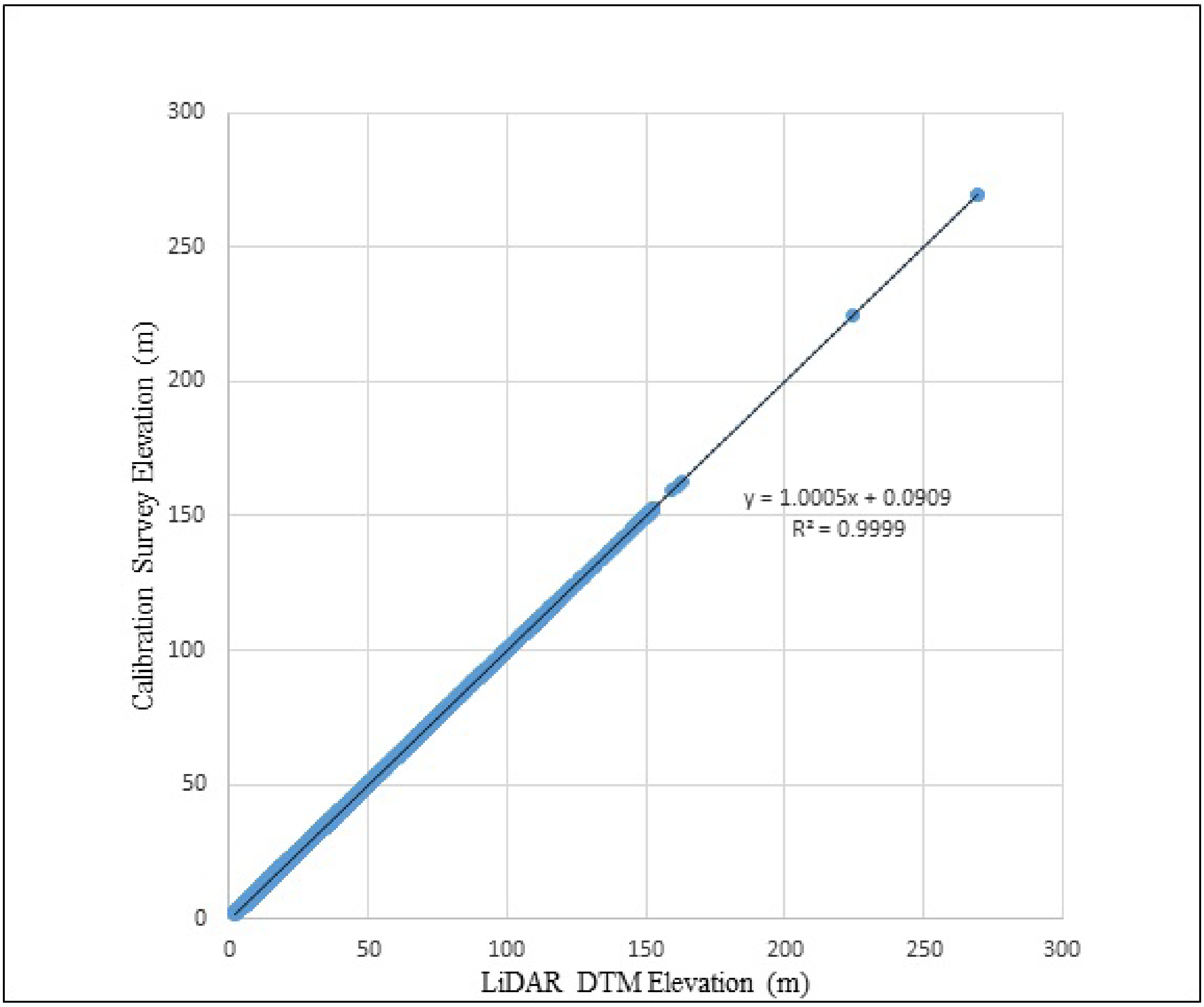

Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

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

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 466 points. These were used for the validation of calibrated Ibod 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.18 meters, as shown in Table 20.

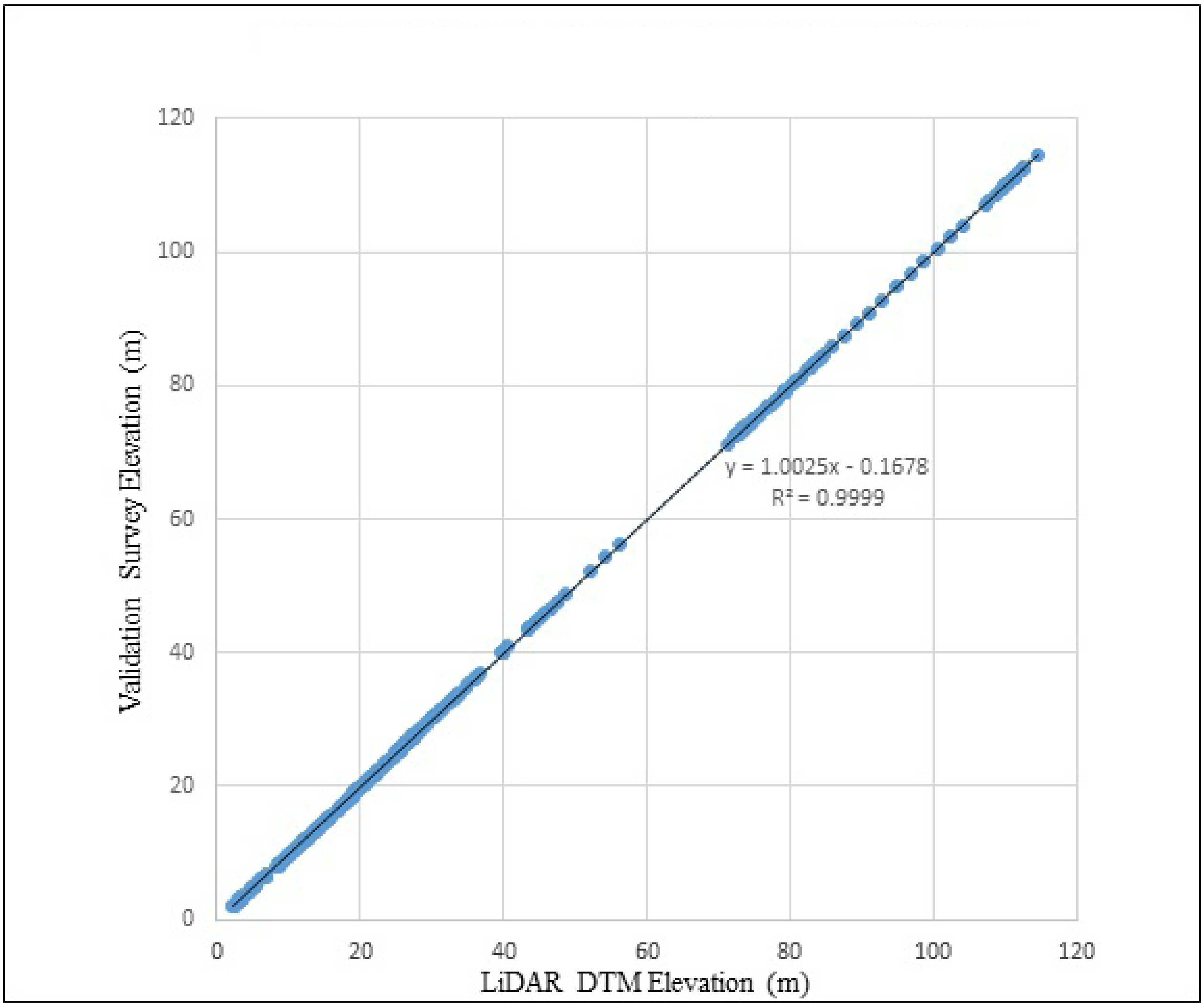

Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.18
Average	-0.09
Minimum	-0.35
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

Centerline and zigzag data were available for Ibod with 6,144 and 700 bathymetric survey points respectively. However, no bathy integration was performed because the geometry of the river is best represented by the acquired LiDAR data. This is applicable for areas flown during dry season where the wetted perimeter of the river corresponds to only 10% of its width. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ibod overlayed with the processed LiDAR DEM is shown in Figure 28.

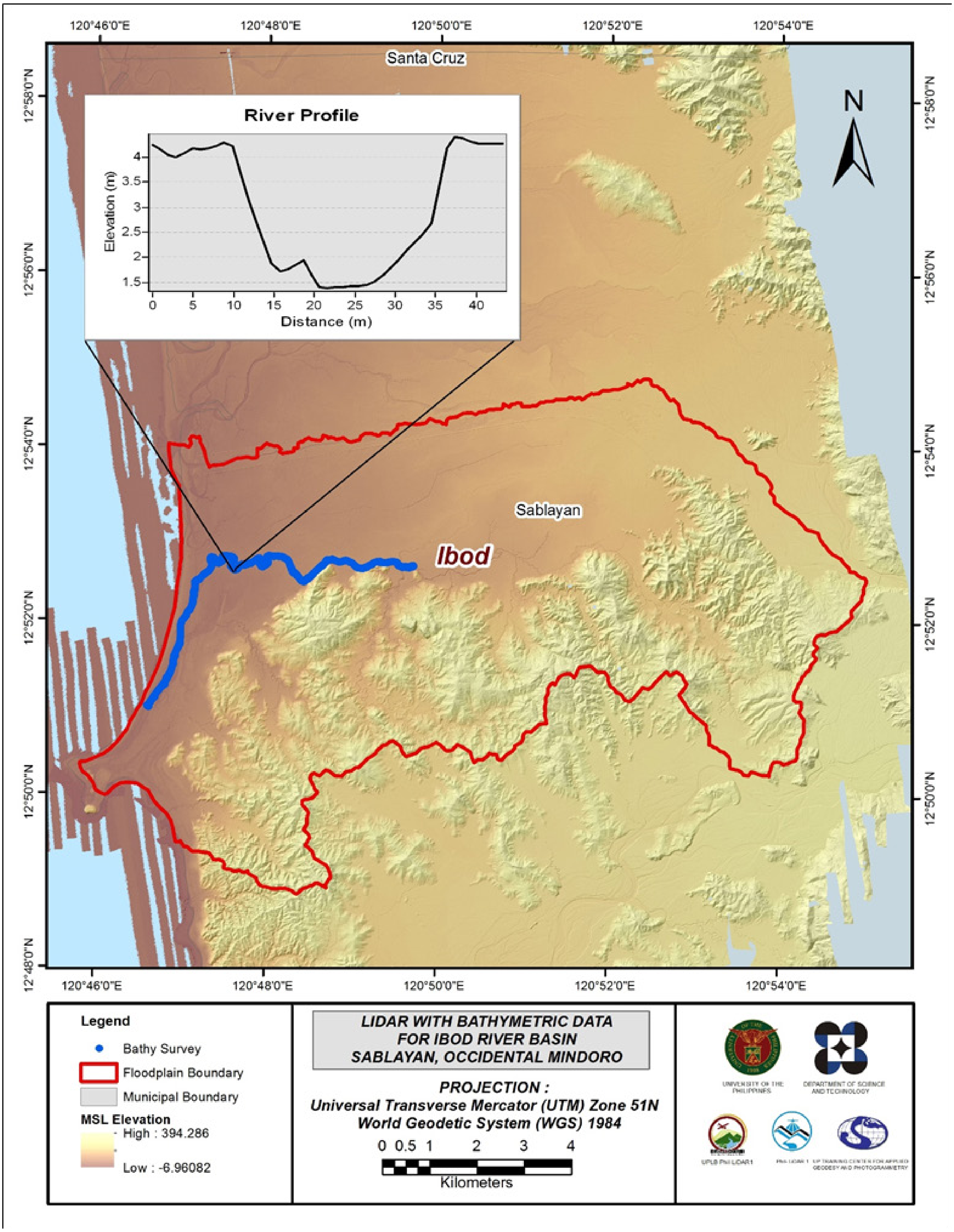

Figure 28. Map of Ibod Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted survey in Ibod River on November 3 to 24, 2015 with the following scope of work: cross-section, bridge as-built and water level marking in MSL of Alipid Bridge in Brgy. Sto, Niño, Municipality of Sablayan, Occidental Mindoro; validation points acquisition in the province of Occidental Mindoro which covers Ibod River Basin; and bathymetry survey from the mouth of the river in Brgy. Buenavista to Brgy. Sto. Niño by feet using Trimble® GNSS PPK survey technique. The entire survey extent is illustrated in Figure 29.

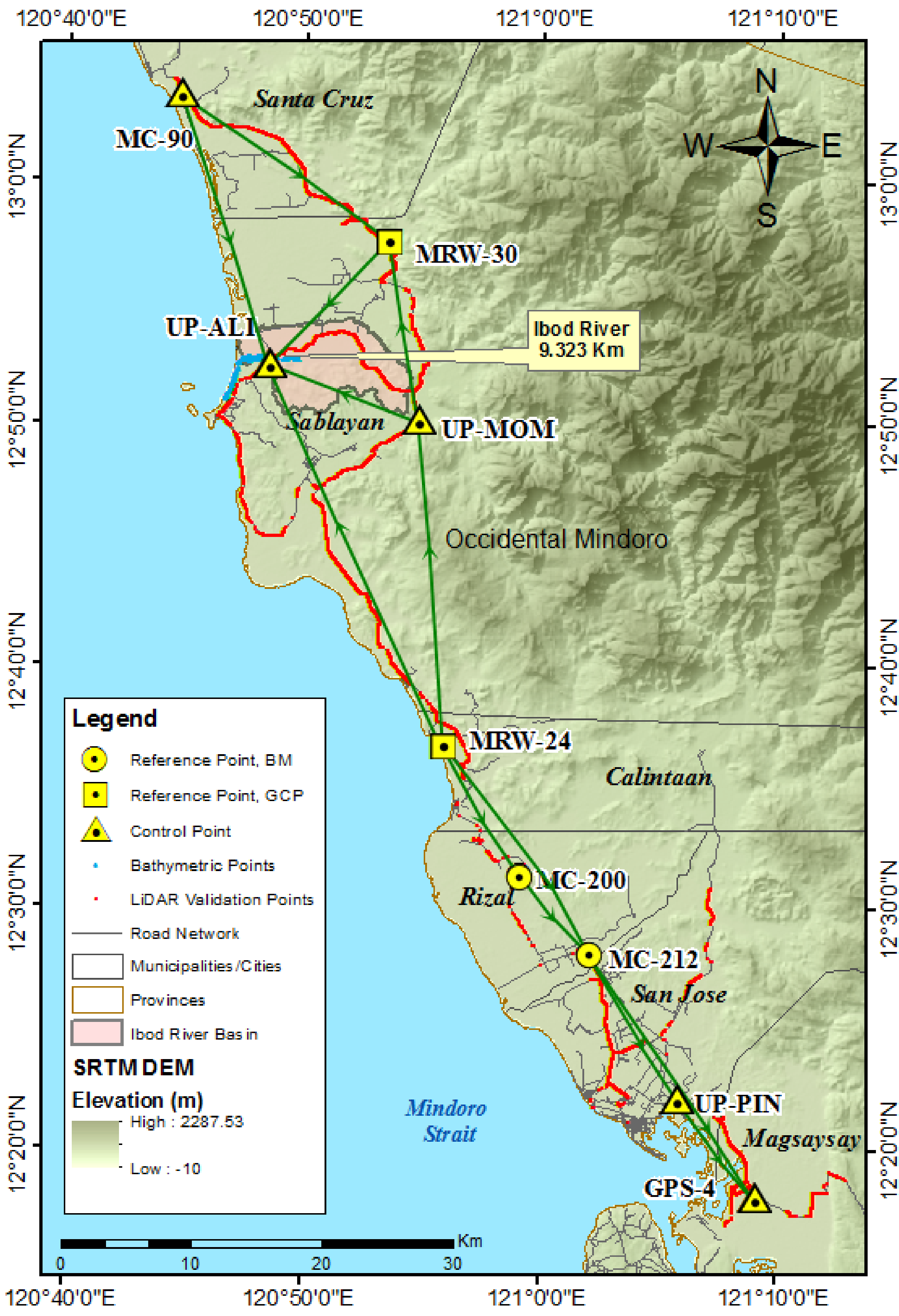


Figure 29. Ibod River Survey Extent

4.2 Control Survey

The GNSS network used for Ibod River Basin is composed of eight (8) loops established on November 5, 15 and 17, 2015 occupying the following reference points: MRW-24, a second order GCP in Brgy. Iriron, Municipality of Calintaan; MRW-30, a second order GCP in Bry. Pinagturilan, Municipality of Sta. Cruz; MC-200, a first order BM in Brgy. Magsikap, Municipality of Rizal; and MC-212, also a first order BM in Brgy. Sto. Niño in Rizal.

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

The summary of reference and control points and its location is summarized in Table 21 while the GNSS network established is illustrated in Figure 30.

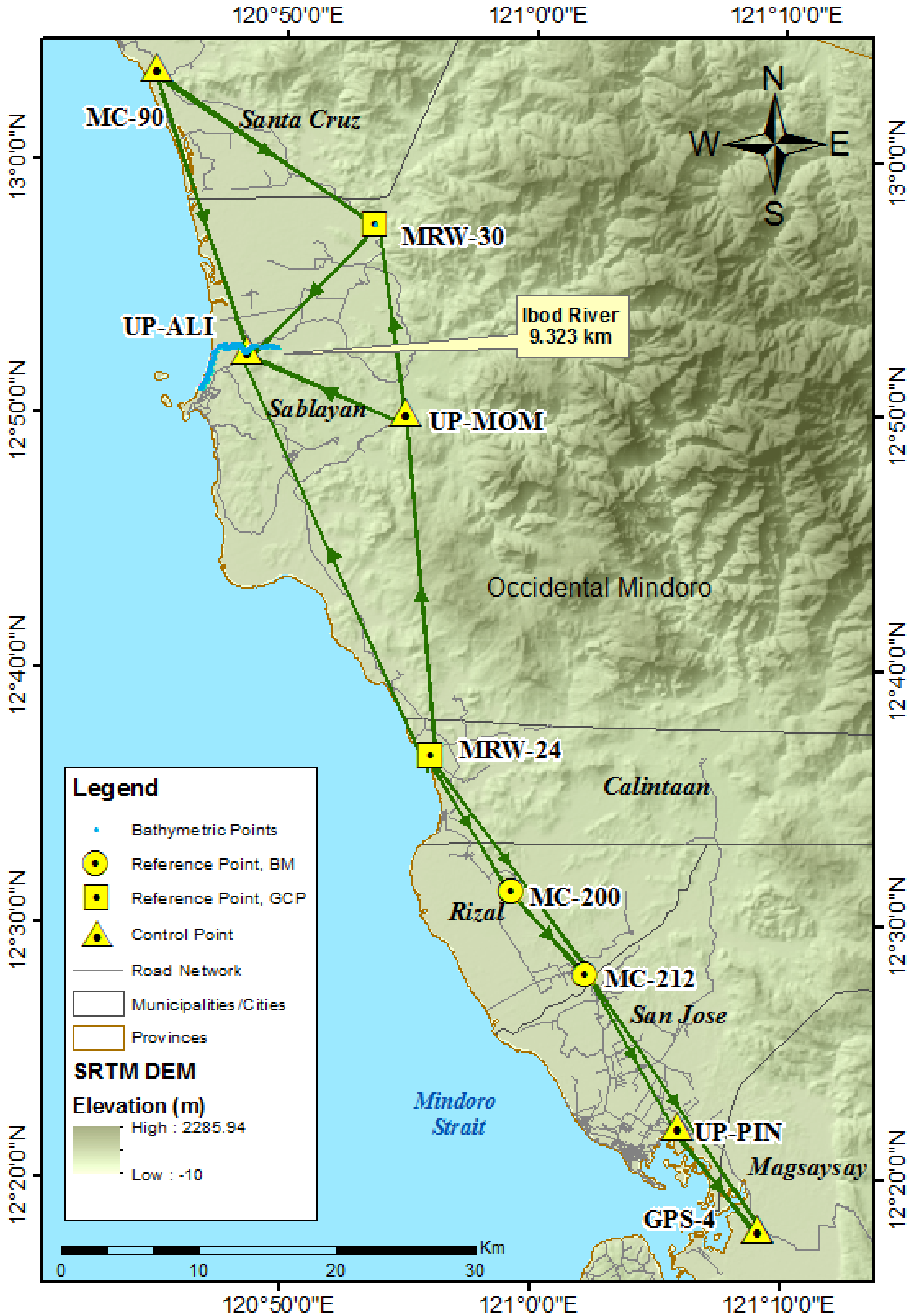


Figure 30. GNSS Network covering Ibod River

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MRW-24	2nd order, GCP	12°36'38.035"N	120°55'54.083"E	54.479	-	2007
MRW-30	2nd order, GCP	12°57'27.191"N	120°53'33.544"E	89.793	-	2007
MC-200	1st order, BM	-	-	84.263	34.024	2007
MC-212	1st order, BM	-	-	75.525	24.884	2007
MC-90	Used as Marker	-	-	-	-	2007
GPS-4	Used as Marker	-	-	-	-	2013
UP-PIN	UP Established	-	-	-	-	11-05-2015
UP-MOM	UP Established	-	-	-	-	11-05-2015
UP-ALI	UP Established	-	-	-	-	11-05-2015

The GNSS set up in reference points and established control points in Occidental Mindoro survey are shown in Figure 31 to Figure 39.

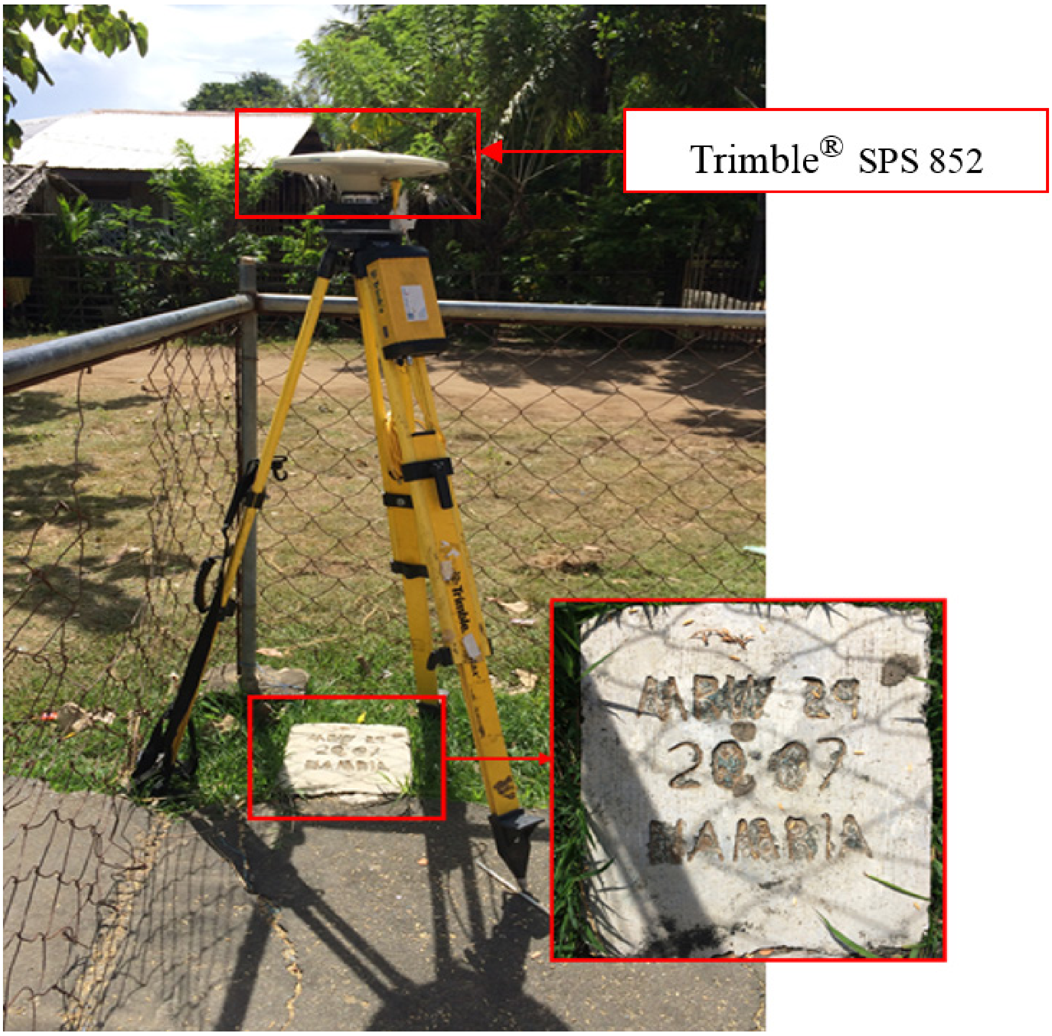


Figure 31. GNSS receiver set-up, Trimble® SPS 852, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

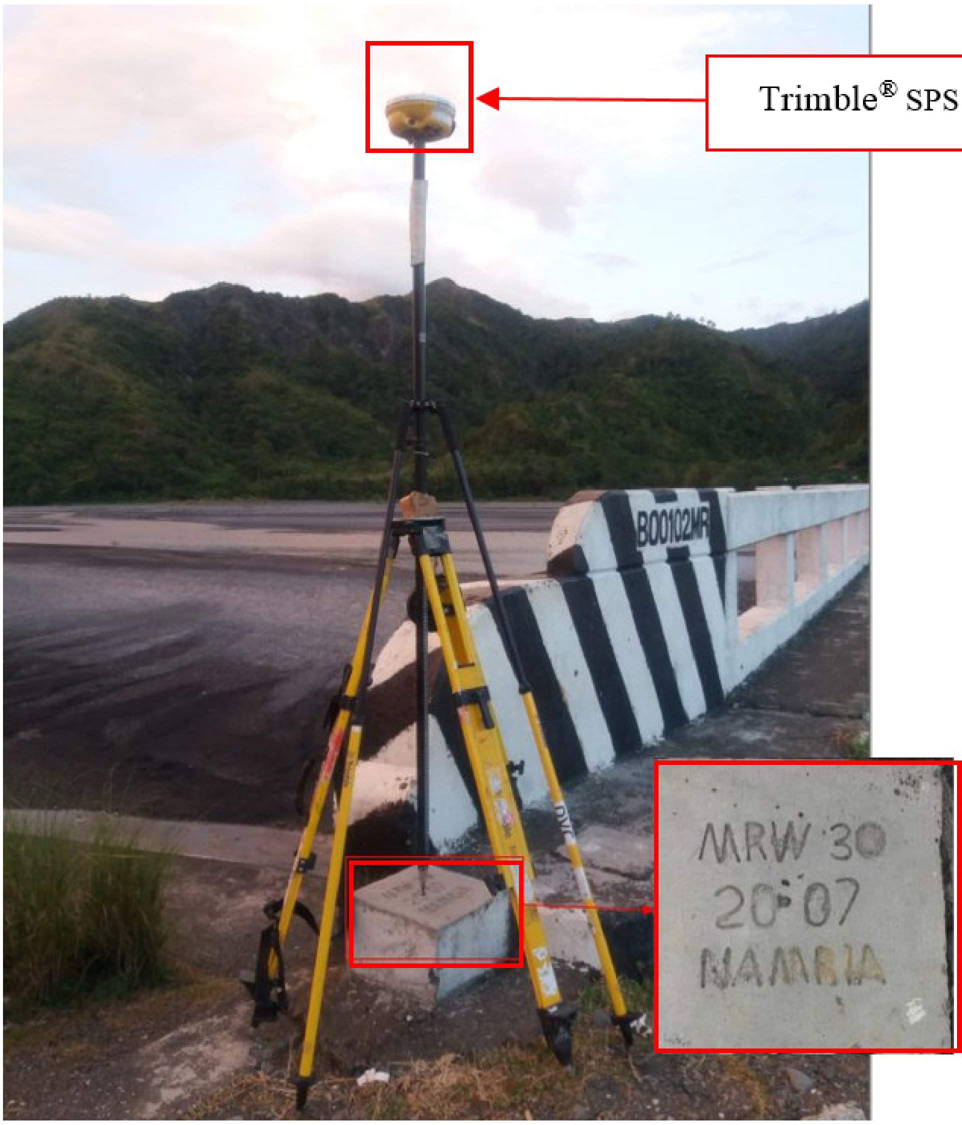


Figure 32. GNSS receiver setup, Trimble® SPS 882, at MRW-30 Amnay Bridge approach in Sitio Kabangkalan, Brgy. Pinagturilan, Municipality of Santa Cruz, Occidental Mindoro

Figure 33. GNSS receiver set-up, Trimble® SPS 882, at MC-200, Lumintao Bridge approach in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

Figure 34. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

Figure 35. GNSS receiver, Trimble® SPS 852, at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

Figure 36. GNSS receiver, Trimble® SPS 882, at GPS-4 on right side of the road abutment after Caguray Bridge going to Bulalacao in Brgy. Poblacion, Municipality of Magsaysay, Occidental Mindoro

Figure 37. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 38. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro

Figure 39. GNSS receiver set up, Trimble® SPS 882, at UP-ALI, Alipid Bridge approach in Brgy. Sto. Niño, Municipality of Sablayan, Occidental Mindoro

4.3 Baseline Processing

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

Table 22. Baseline Processing Report for Ibod River Static Survey

(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
MC-212 --- GPS-4 (B8751)	11-05-2015	Fixed	0.003	0.015	145°21'06"	22241.566
MRW-30 --- UP-MOM (B8774)	11-05-2015	Fixed	0.011	0.017	170°24'13"	13704.513
MRW-30 --- UP-MOM (B8775)	11-05-2015	Fixed	0.003	0.023	170°24'12"	13704.541
MRW-30 --- MC-90 (B8781)	11-17-2015	Fixed	0.010	0.018	305°24'12"	19473.086
UP-PIN --- MC-212 (B8758)	11-05-2015	Fixed	0.003	0.007	328°11'40"	12856.399
UP-PIN --- GPS-4 (B8759)	11-05-2015	Fixed	0.003	0.006	141°30'11"	9422.221
MC-200 --- UP-PIN (B8761)	11-05-2015	Fixed	0.003	0.022	144°37'57"	20841.368
MC-200 --- UP-MOM (B8762)	11-05-2015	Fixed	0.009	0.014	346°57'26"	35544.301
MC-200 --- UP-2MOM (B8763)	11-05-2015	Fixed	0.004	0.014	346°57'27"	35544.309
MC-200 --- MC-212 (B8752)	11-05-2015	Fixed	0.003	0.006	138°58'31"	8048.668
UP-ALI --- UP-MOM (B8765)	11-05-2015	Fixed	0.008	0.013	110°57'37"	12258.370

As shown Table 16, a total of three (3) baselines were processed. All of them passed the required accuracy.

Table 23. Baseline Processing Report for Ibod River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
UP-MOM --- UP-ALI (B8766)	11-05-2015	Fixed	0.004	0.036	110°57'37"	12258.373
UP-ALI --- MRW-30 (B8777)	11-05-2015	Fixed	0.009	0.012	45°05'52"	12929.488
MRW-30 --- UP-ALI (B8772)	11-05-2015	Fixed	0.004	0.017	45°05'52"	12929.476
MRW-30 --- UP-ALI (B8779)	11-05-2015	Fixed	0.004	0.007	45°05'51"	12929.529
MC-90 --- UP-ALI (B8780)	11-17-2015	Fixed	0.004	0.008	341°46'30"	21480.592
MRW-24 --- UP-PIN (B8757)	11-05-2015	Fixed	0.003	0.006	145°50'52"	32317.096
MRW-24 --- MC-200 (B8756)	11-05-2015	Fixed	0.005	0.007	148°04'31"	11489.166
MRW-24 --- UP-MOM (B8769)	11-05-2015	Fixed	0.009	0.015	355°30'36"	24950.818
MRW-24 --- UP-MOM (B8770)	11-05-2015	Fixed	0.003	0.006	355°30'36"	24950.824
MRW-24 --- UP-ALI (B8767)	11-05-2015	Fixed	0.006	0.007	335°24'00"	32186.124

As shown in Table 22 and Table 23, a total of twenty-one (21) baselines were processed with reference point MRW-24 and MRW-30 held fixed for coordinates; and MC-200 and MC-212 fixed for elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

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 17 to Table 20 for complete details.

The nine (9) control points were occupied and observed simultaneously to form a GNSS loop. Coordinates of MRW-24 and MRW-30, and elevation values of MC-200 and MC-212 were held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints

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

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

Table 25. Adjusted Grid Coordinates

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

With the mentioned equation for the horizontal and for the vertical; the computation for the accuracy for:

a.MRW-24

horizontal accuracy	=	Fixed
vertical accuracy	=	$4.5 < 10$ cm

b.MRW-30

horizontal accuracy	=	Fixed
vertical accuracy	=	$9.1 < 10$ cm

c.MC-200

horizontal accuracy	=	$\sqrt{((2.2)^2 + (1.6)^2}$
	=	$\sqrt{(4.84 + 2.56)}$
	=	7.4 cm < 20 cm
vertical accuracy	=	Fixed

d.MC-212

horizontal accuracy	=	$\sqrt{((2.8)^2 + (2.2)^2}$
	=	$\sqrt{(7.84 + 4.84)}$
	=	3.56 cm < 20 cm
vertical accuracy	=	Fixed

e.MC-90

horizontal accuracy	=	$\sqrt{((3.9)^2 + (2.3)^2}$
	=	$\sqrt{(15.21 + 5.29)}$
	=	4.53 cm < 20 cm
vertical accuracy	=	$9.5 < 10$ cm

f.GPS-4

horizontal accuracy	=	$\sqrt{((3.9)^2 + (3.2)^2}$
	=	$\sqrt{(15.21 + 10.24)}$
	=	5.04 cm < 20 cm
vertical accuracy	=	$6.8 < 10$ cm

g.UP-PIN

horizontal accuracy	=	$\sqrt{((3.1)^2 + (2.4)^2}$
	=	$\sqrt{(9.61 + 5.76)}$
	=	3.92 cm < 20 cm
vertical accuracy	=	$4.5 < 10$ cm

h.UP-MOM

horizontal accuracy	=	$\sqrt{((1.5)^2 + (1.2)^2}$
	=	$\sqrt{(2.25 + 1.44)}$
	=	1.92 cm < 20 cm
vertical accuracy	=	$5.5 < 10$ cm

i.UP-ALI

horizontal accuracy	=	$\sqrt{((2.0)^2 + (1.5)^2}$
	=	$\sqrt{(4.0 + 2.25)}$
	=	2.5 cm < 20 cm
vertical accuracy	=	$7.1 < 10$ cm

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

Table 26. Adjusted Geodetic Coordinates

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

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

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

Table 27. 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)	BM Ortho (m)
MRW-24	2nd order, CGP	12°36'38.035"N	120°55'54.083"E	54.479	1394955.913	275320.607	5.790
MRW-30	2nd order, GCP	12°57'27.191" N	120°53'33.544"E	89.793	1433384.691	271390.777	42.722
MC-200	1st order, BM	12°31'20.689" N	120°59'15.316"E	84.263	1385155.124	281320.526	35.061
MC-212	1st order, BM	12°28'03.075" N	121°02'10.263"E	75.525	1379041.963	286558.122	25.935
MC-90	Used as marker	13°03'34.144" N	120°44'46.709"E	54.252	1444800.395	255607.929	9.215
GPS-4	Used as marker	12°18'07.557" N	121°09'08.742"E	63.753	1360649.971	299069.889	13.109
UP-PIN	UP Established	12°22'07.550" N	121°05'54.643"E	60.889	1368066.420	293256.665	10.706
UP-MOM	UP Established	12°50'07.472" N	120°54'49.309"E	145.047	1419850.451	273564.873	97.226
UP-ALI	UP Established	12°52'30.243" N	120°48'29.692"E	57.025	1424334.027	262152.463	10.530

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

Cross-section and as-built surveys were conducted on November 21, 2015 along the downstream portion of Alipid Bridge located in Brgy. Sto, Niño, Municipality of Sablayan using Trimble® SPS 882 GNSS PPK survey technique. The panoramic view of the bridge is shown in Figure 40.

Figure 40. Alipid Bridge over Ibod River in Brgy. Sto. Niño, Municipality of Sablayan

A total of fourteen (14) points with corresponding length of 92.61 meters were gathered from the survey of the bridge using the control point MRW-30 as base station. The location map, cross section diagram, and the bridge data form are shown in Figure 41 to Figure 43, respectively

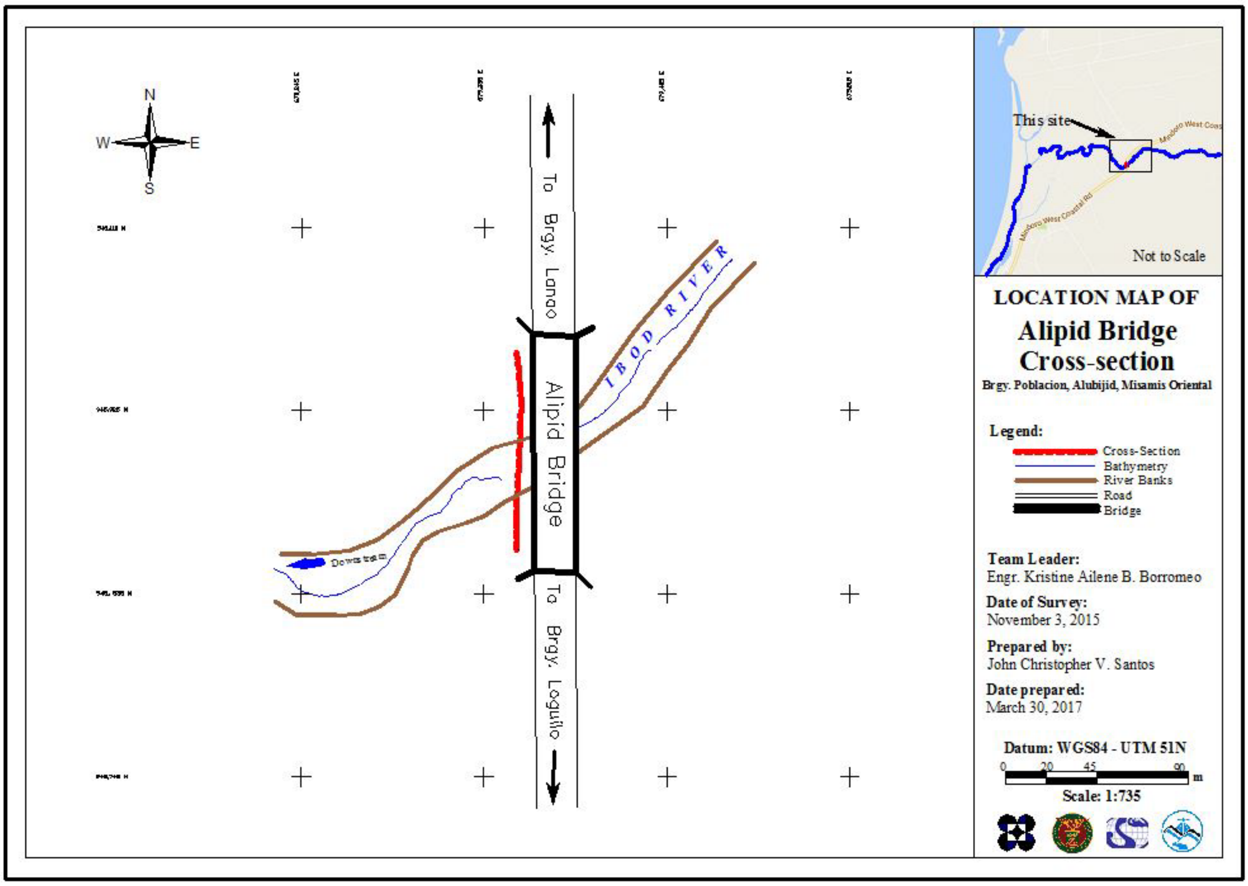


Figure 41. Location Map of Alipid Bridge River Cross-Section survey

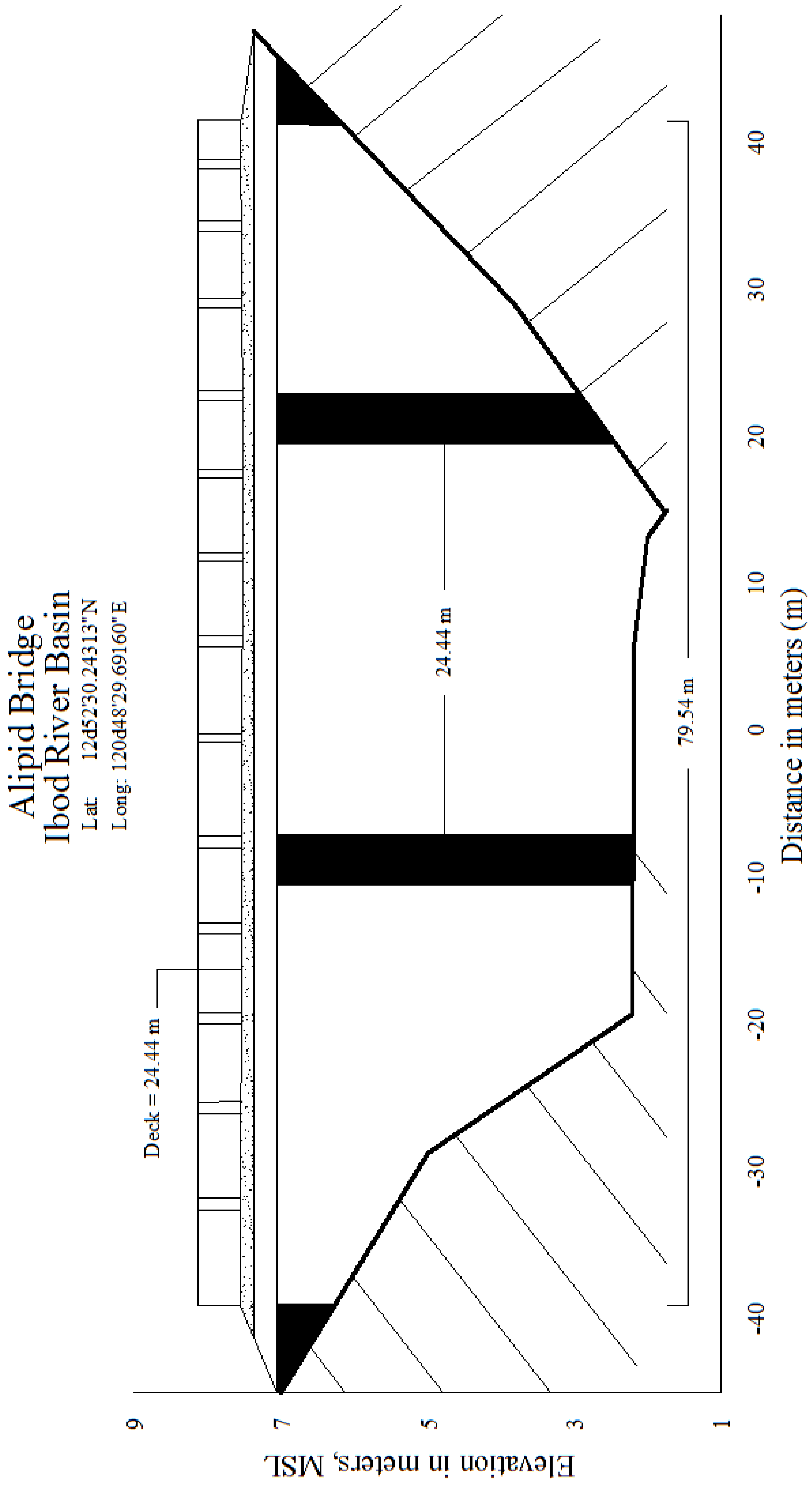


Figure 42. Alibid Bridge cross-section diagram

Bridge Data Form

Bridge Name: Alipid Bridge **Date: November 21, 2015**

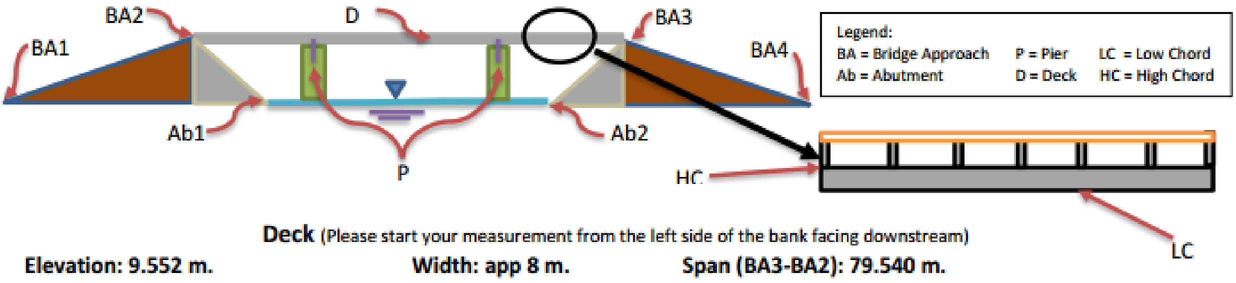
River Name: Ibod River **Time: 2:30 PM**

Location: Brgy. Pagasa, Municipality of Sablayan, Occidental Mindoro

Survey Team: Kristine Ailene Borromeo, Maridel Miras, Precious Annie Lopez, Dona Rina Patricia Tajora, Kim Patrick Tort, Rodel Alberto, Caren Joy Ordoña

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

Latitude: 12°52'30.24313"N **Longitude: 120°48'29.69160"E**



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

Elevation: 9.552 m. **Width: app 8 m.** **Span (BA3-BA2): 79.540 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	NA	NA	NA

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	9.050 m	BA3	86.617 m	9.552 m
BA2	7.077 m	9.552 m	BA4	92.602 m	9.363 m

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

	Station (Distance from BA1)	Elevation
Ab1	NA	NA
Ab2	NA	NA

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

Shape: Cylindrical Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	33.750 m	App 9.5 m	approx. 0.9 m.
Pier 2	58.190 m	App 9.5 m	approx. 0.9 m.

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

Figure 43. Bridge as-built form of Alipid Bridge

The water level marking for Alipid Bridge, as shown in Figure 44, has an EGMOrtho value of 4.61 meters which was then translated into a marking on the bridge's pier using a digital level. This value shall be updated by UPLB PHIL-LiDAR 1 to its respective MSL value of 3.566 m to serve as reference for their flow data gathering and depth gauge deployment.

Figure 44. Water level marking at Alipid Bridge, Brgy. Sto. Niño, Municipality of Sablayan

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 6, 7, 8 14, 17, 18, and 21, 2015 using a survey-grade GNSS Rover, Trimble® SPS 882, receiver mounted on a pole which was attached either to the front or side of vehicle as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.460 and 1.91 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with MC-212, GPS-4, MC-90 and MRW-30 occupied as the GNSS base stations all throughout the conduct of the survey.

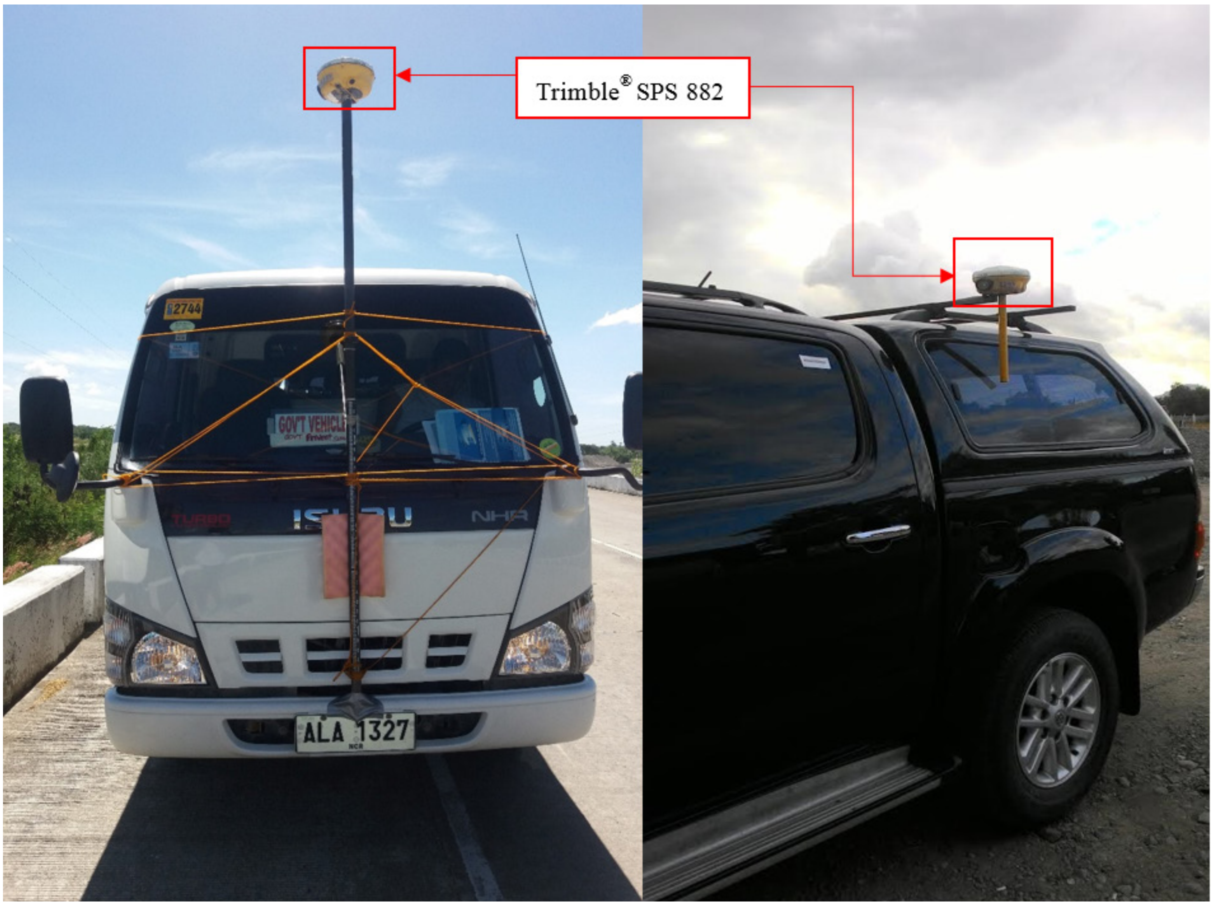


Figure 45. Validation points acquisition survey set-up for Ibod River

The validation points acquisition survey for the Ibod River Basin traversed the municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay. The survey perpendicularly traversed the LiDAR flight strips in the survey area. A total of 26,449 points with an approximate length of 191 km was acquired for the validation points acquisition survey as shown in the map in Figure 46.

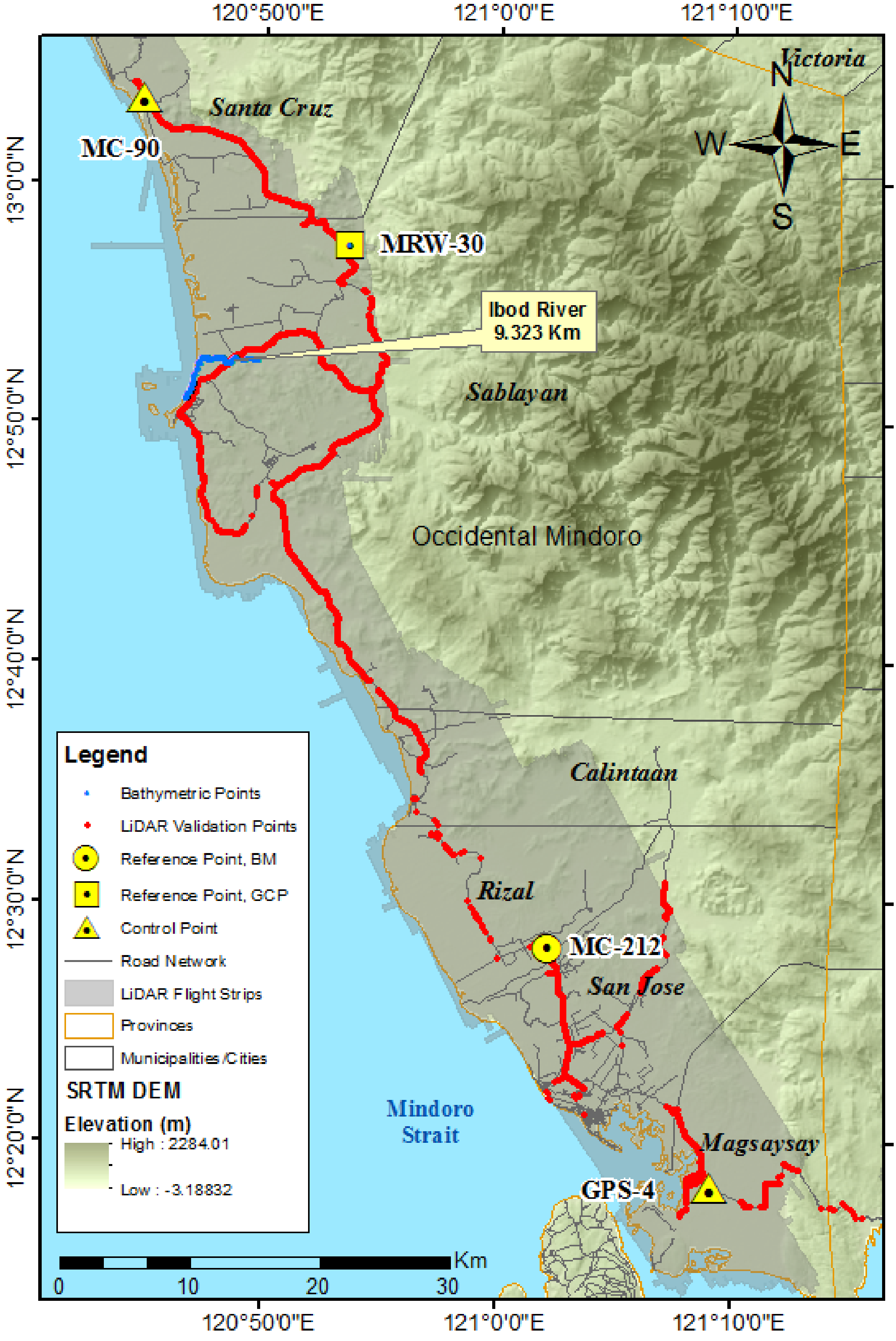


Figure 46. Validation point acquisition survey of Ibod River Basin

4.7 River Bathymetric Survey

Manual bathymetric survey was conducted on November 16, 2015 using Trimble® SPS 882 GNSS PPK technique in continuous topo mode as shown in Figure 47. The survey began at the upstream portion of the river in Brgy. Sto. Niño with coordinates 12°52’37.55753” 120°49’42.99960” traversed at the centerline of the river by foot down to the mouth of the river in Brgy. Buenavista with coordinates 12°51’00.48543” 120°46’36.98379” both of which in Municipality of Sablayan. The control point MRW-30 was used as the GNSS base station all throughout the survey.

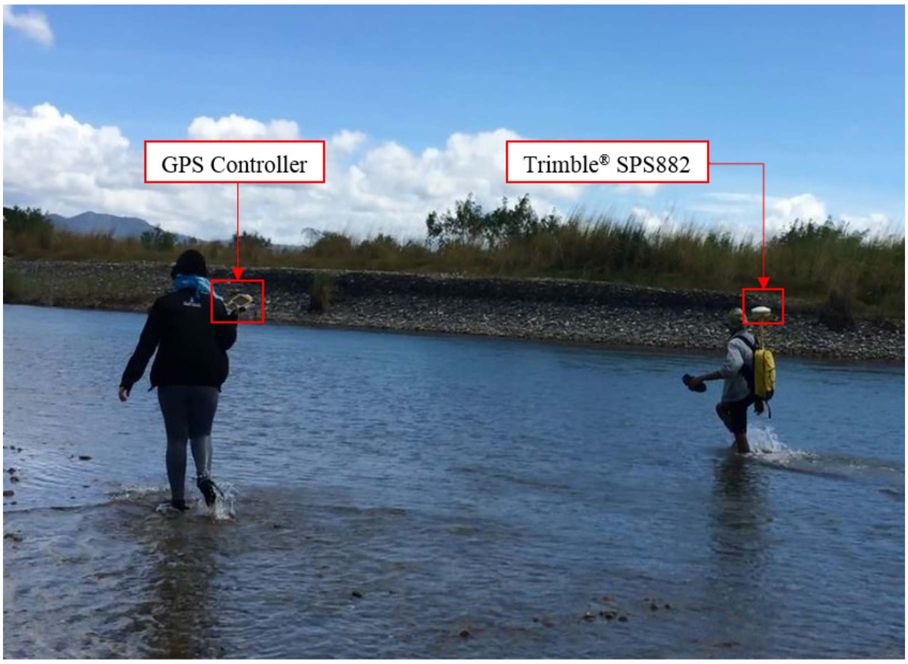


Figure 47. Bathymetry set-up and execution for Ibod River

The bathymetric survey coverage for Ibod river gathered a total of 6,939 bathymetric points with an estimates length of 9.323 km. covering Brgy. Santo Niño and Brgy. Buenavista, both in Municipality of Sablayan as illustrated in Figure 48. Approximately 3 km of the delineated target bathymetric line was not covered due to dense canopy.

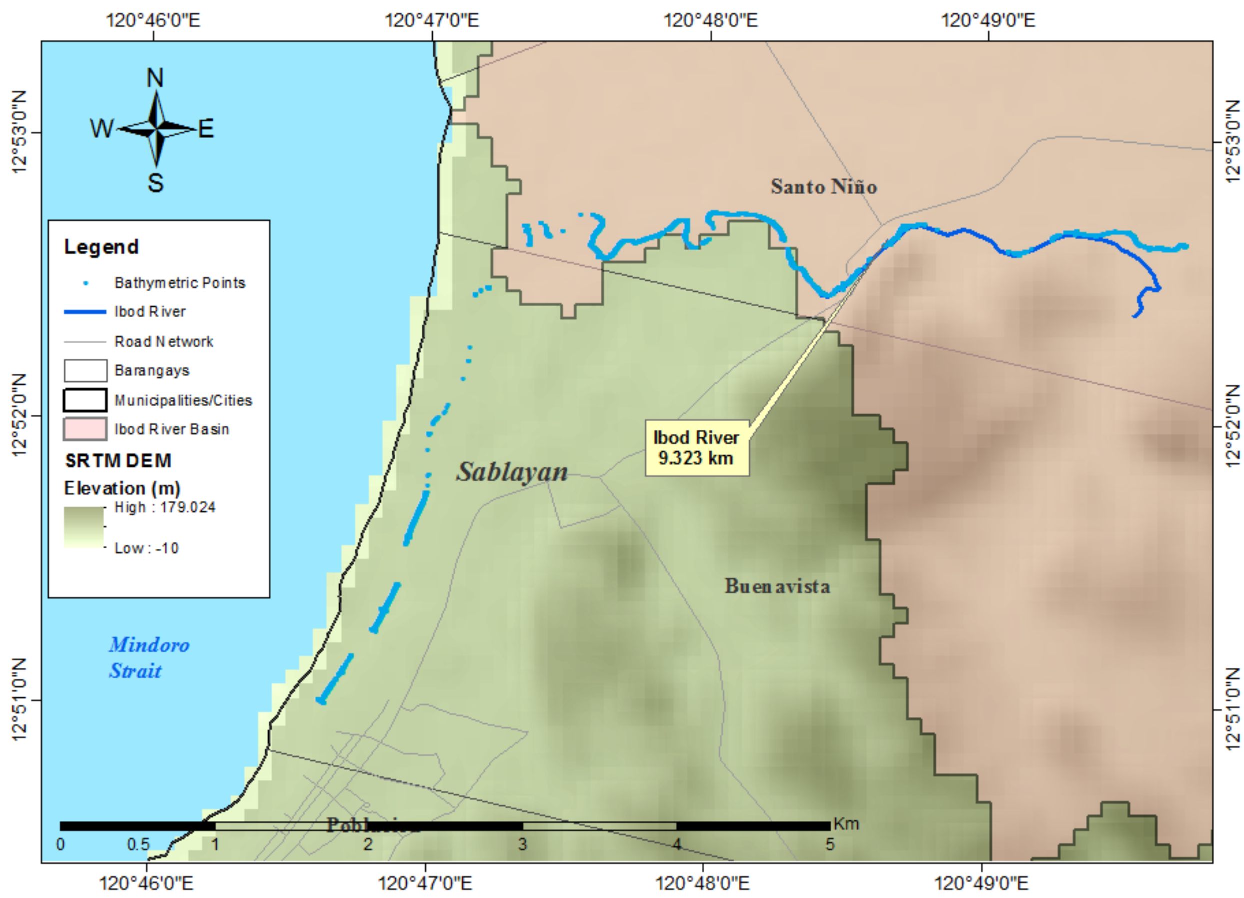


Figure 48. Bathymetric survey of Ibod River

A CAD drawing was also produced to illustrate the Ibod riverbed centerline profile as shown in Figure 49. There is about 3-km change in elevation observed within the 9.323-km bathymetric data from its upstream in Brgy. Sto. Niño down to the mouth of the river in Brgy. Buenavista in Sablayan, Occidental Mindoro. The highest elevation observed was 5.388 m in MSL and the lowest elevation value observed was -0.906 m below MSL both located in Brgy. Sto. Niño, Sablayan.

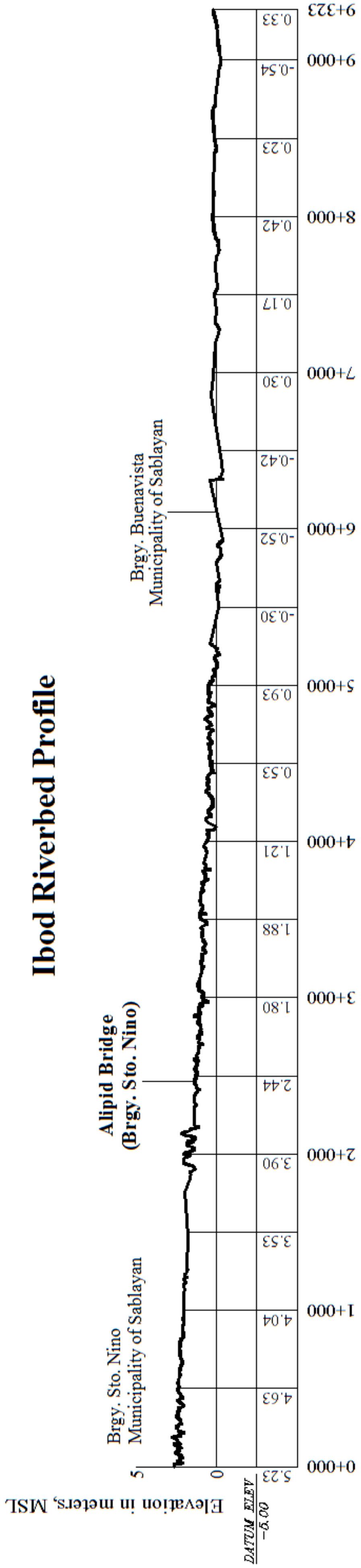


Figure 49. Ibod centerline riverbed profile (Upstream)

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable rain collector deployed on a strategic location within the riverbasin (12.894309°N, 120.844072°E). The location of the rain gauge is seen in Figure 50.

The total precipitation for this event is 54.61 mm. It has a peak rainfall of 11.684 mm. on August 5, 2016 at 3:45 pm. The lag time between the peak rainfall and discharge is 3 hour and 25 minutes, as seen in Figure 52.

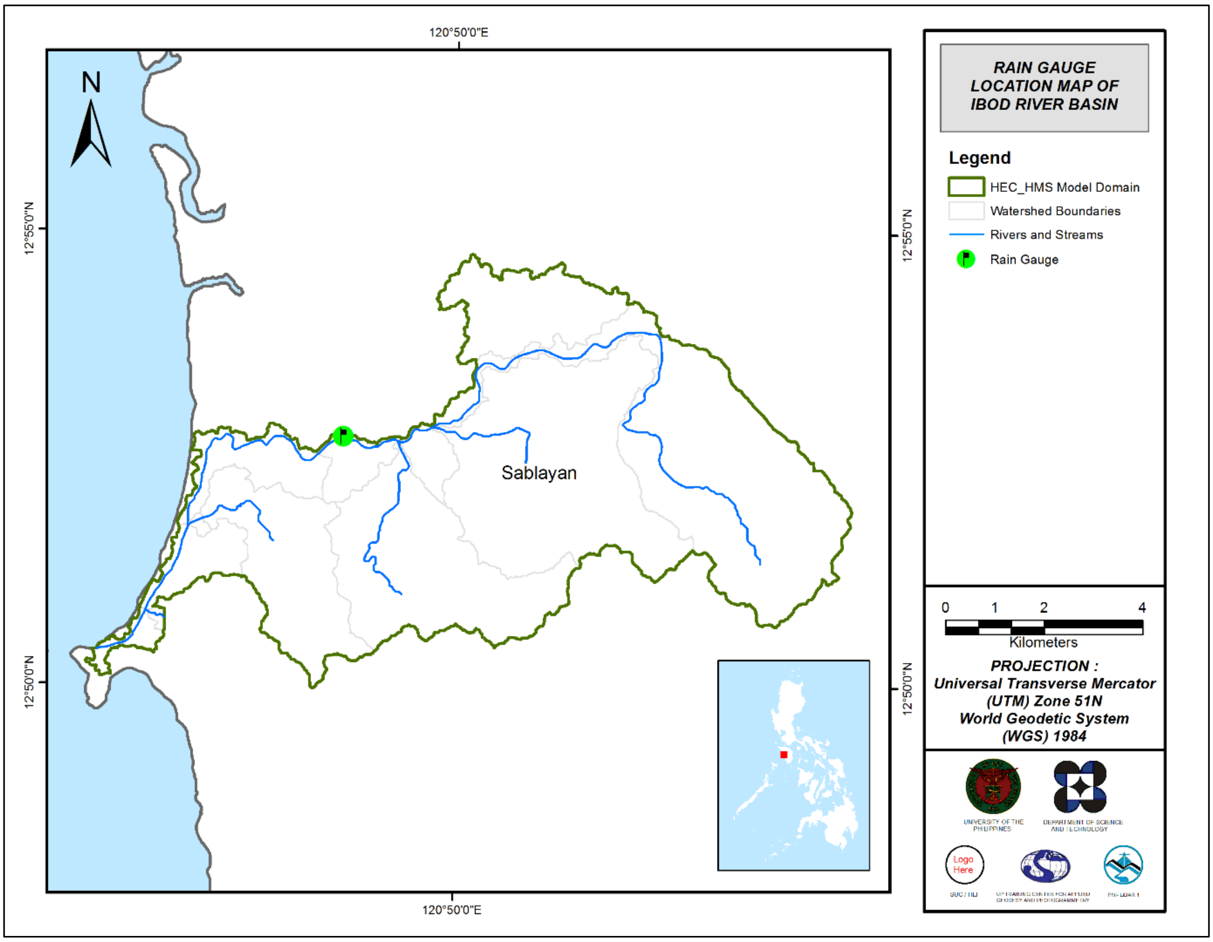


Figure 50. The location map of Ibod HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Alipid Bridge, Occidental Mindoro (12.874928° N, 120.808636° E). It gives the relationship between the observed water levels from the Ibod Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Alipid Bridge, the rating curve is expressed as Q = 0.0123e1.26x as shown in Figure 52.

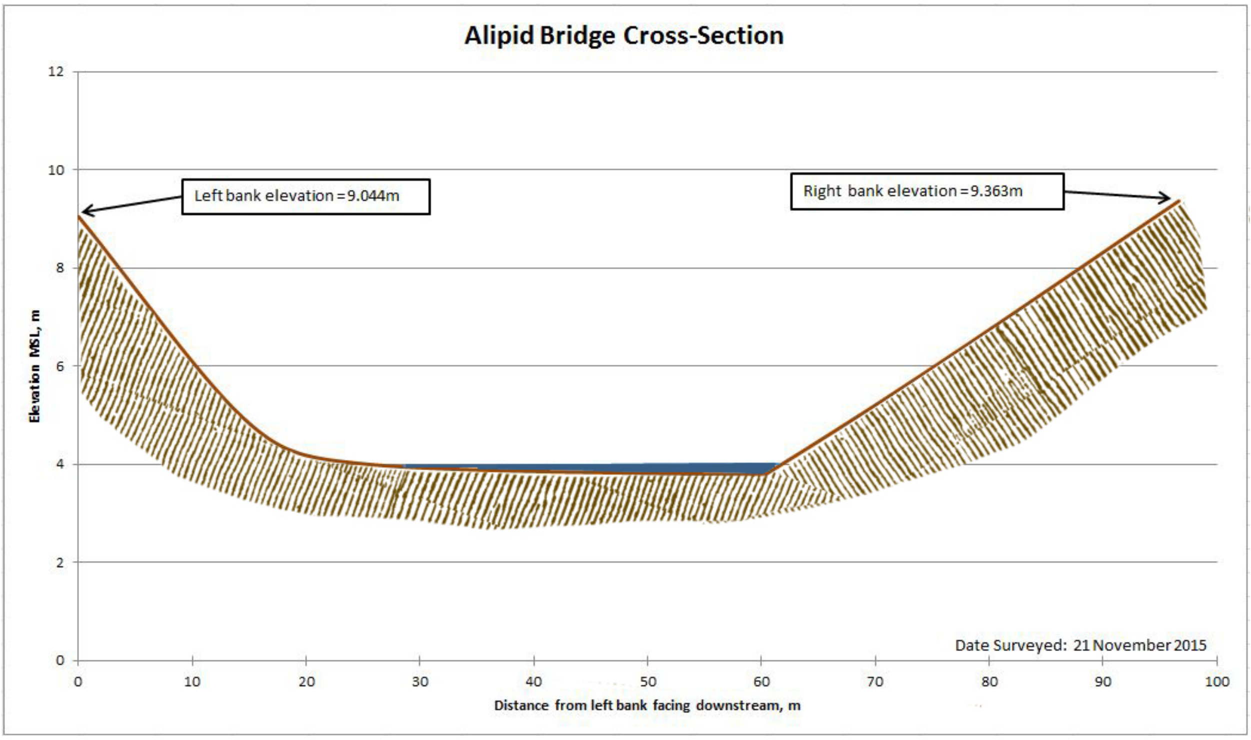


Figure 51. Cross-Section Plot of Ibod Bridge

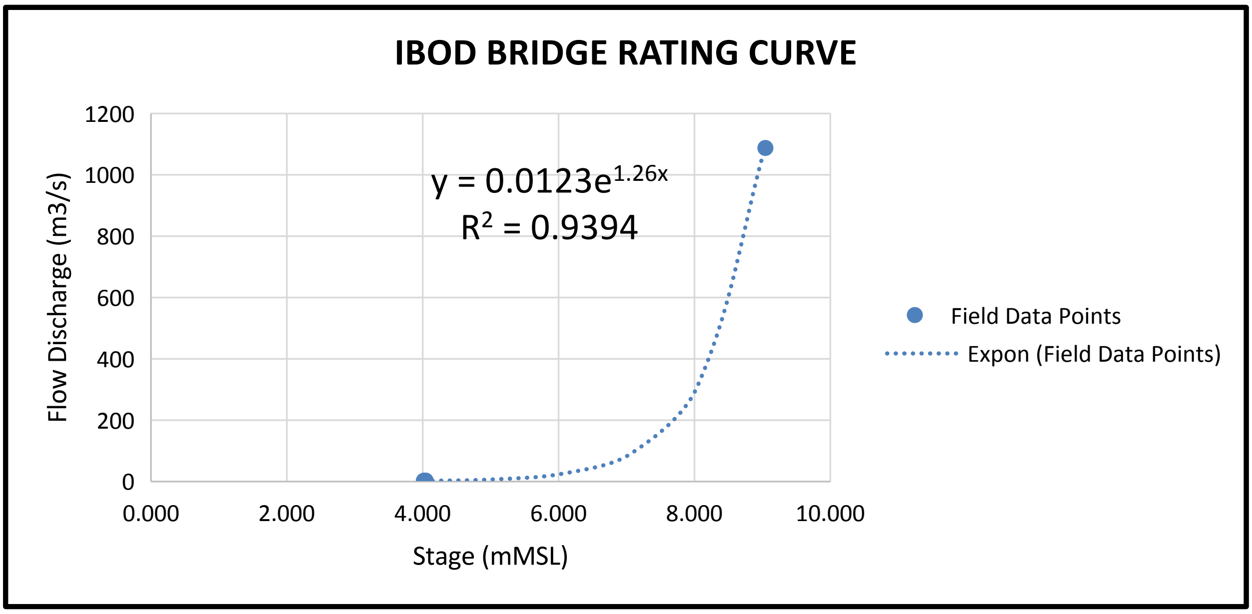


Figure 52. Rating curve at Ibod Bridge, Occidental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 53, actual flow discharge during a rainfall event was collected in the Ibod bridge. Peak discharge is 75.743 cu.m/s on August 5, 2016 at 7:10 pm.

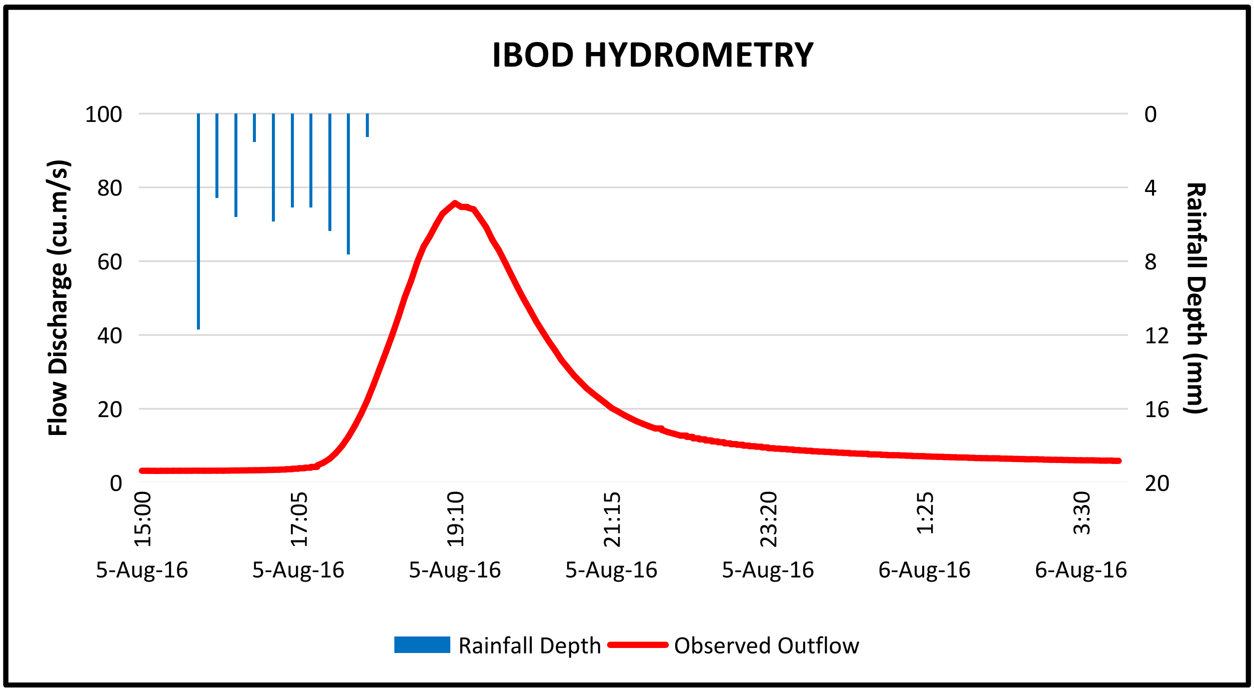


Figure 53. Rainfall and outflow data at Ibod River Basin used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Ambulong 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 Ibod watershed. The extreme values for this watershed were computed based on a 54-year record, with the computed extreme values shown in Table 28.

Table 28. RIDF values for Ambulong Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	22.7	35.5	36.3	50.2	68.2	80.1	104.1	125.7	150.8
5	27.9	45.5	53.8	74.2	103.4	122.5	159.7	192.9	226.7
10	34.2	52.1	65.4	90.1	126.7	150.6	196.5	237.3	276.9
15	37.8	57.4	71.9	99	139.8	166.4	217.3	262.4	305.3
20	40.3	61	76.5	105.3	149	177.5	231.9	280	325.1
25	42.2	63.9	80	110.1	156.1	186	243.1	293.5	340.4
50	48.1	72.6	90.9	125	178	212.3	277.6	335.2	387.5
100	54	81.2	101.6	139.8	199.7	238.4	311.8	376.6	434.3

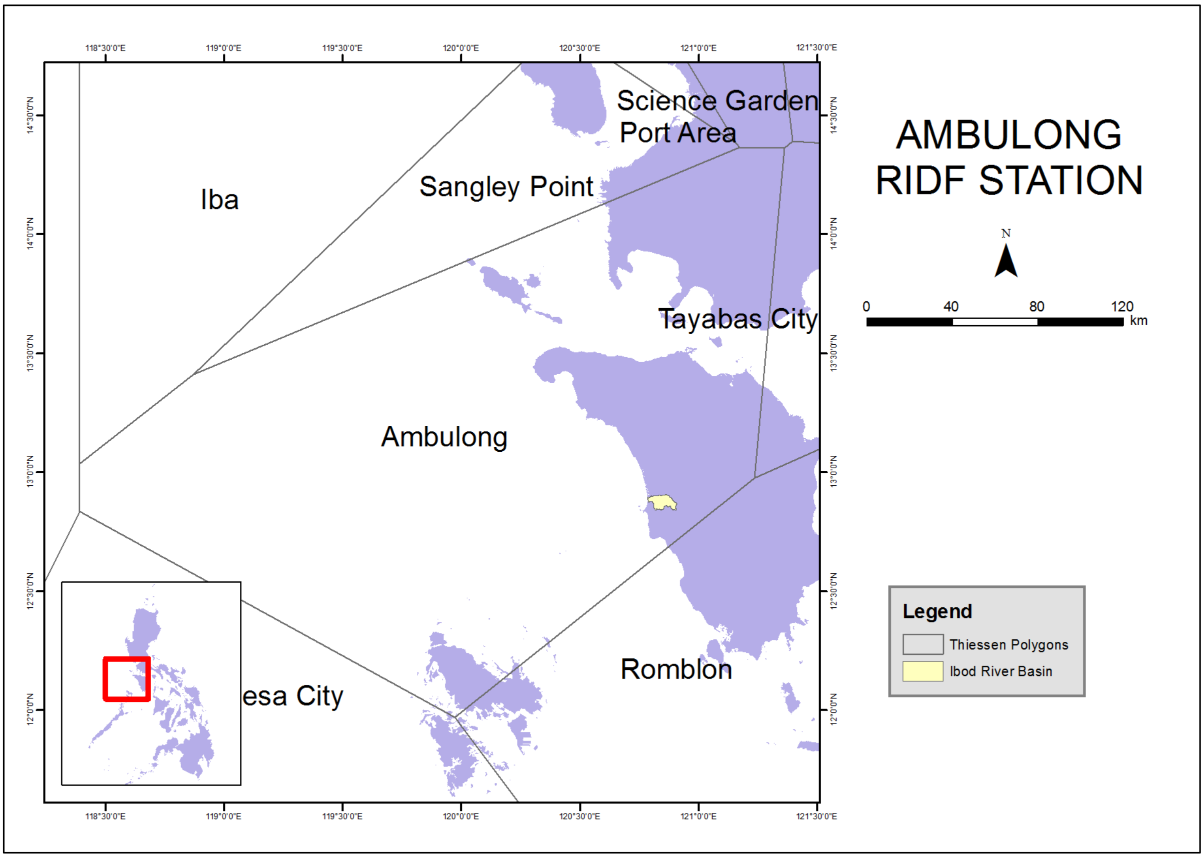


Figure 54.Location of Ambulong RIDF relative to Ibod River Basin

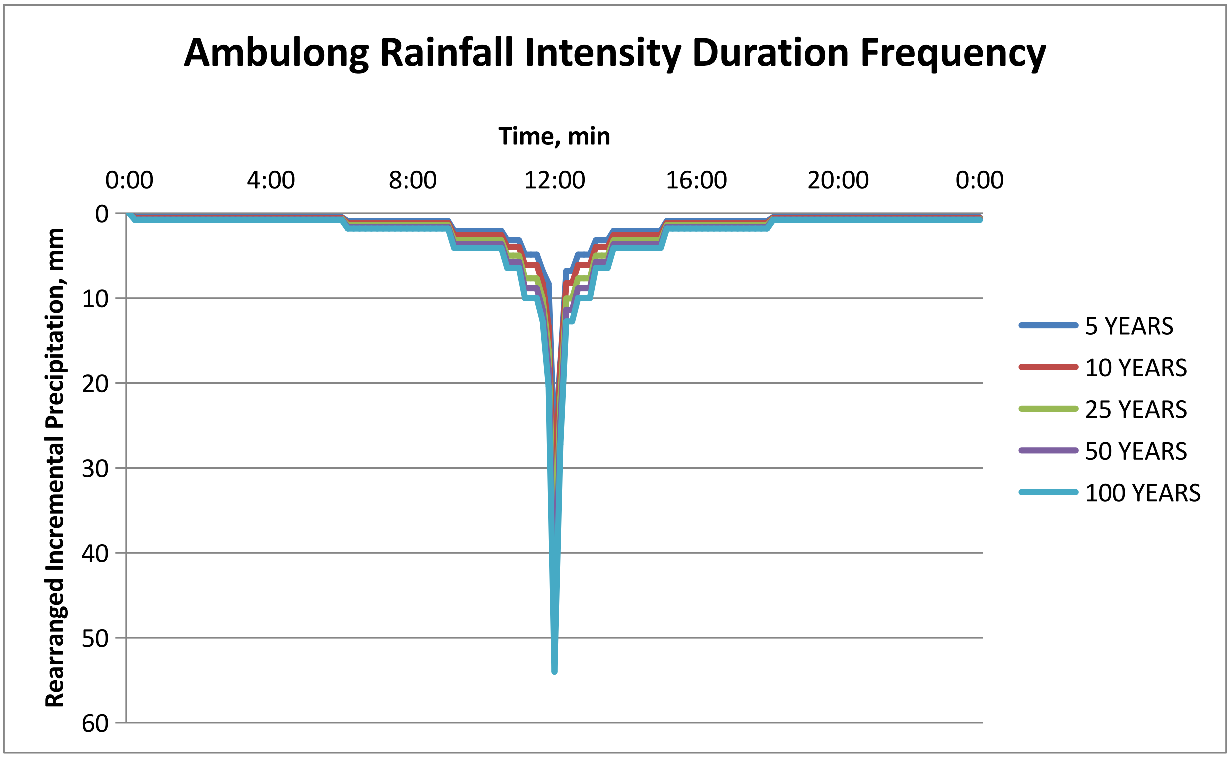


Figure 55. Synthetic storm generated for a 24-hr period rainfall for various return periods.

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 Ibod River Basin are shown in Figure 56 and Figure 57, respectively.

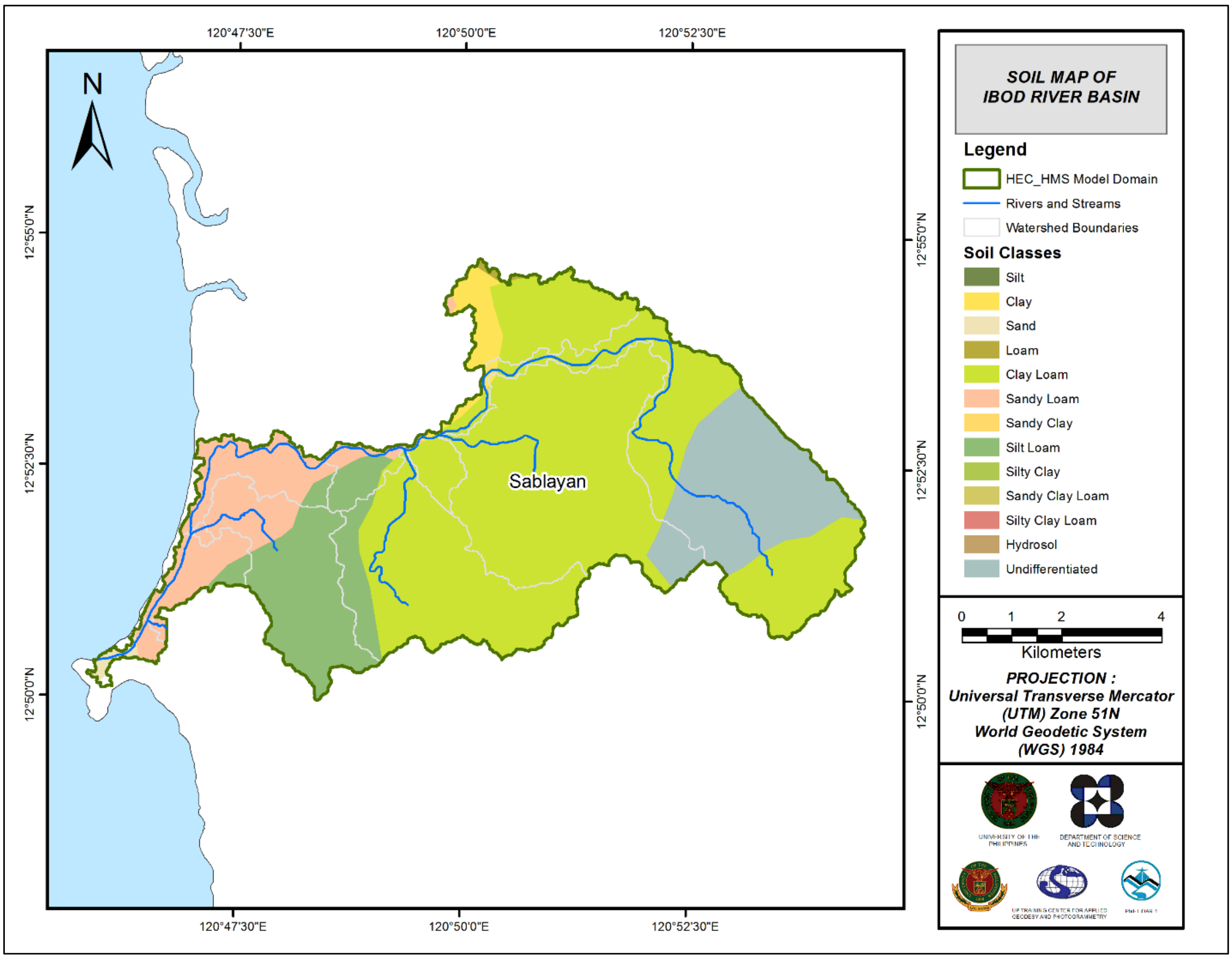


Figure 56. Soil map of Ibod River Basin used for the estimation of the CN parameter. (Source: DA)

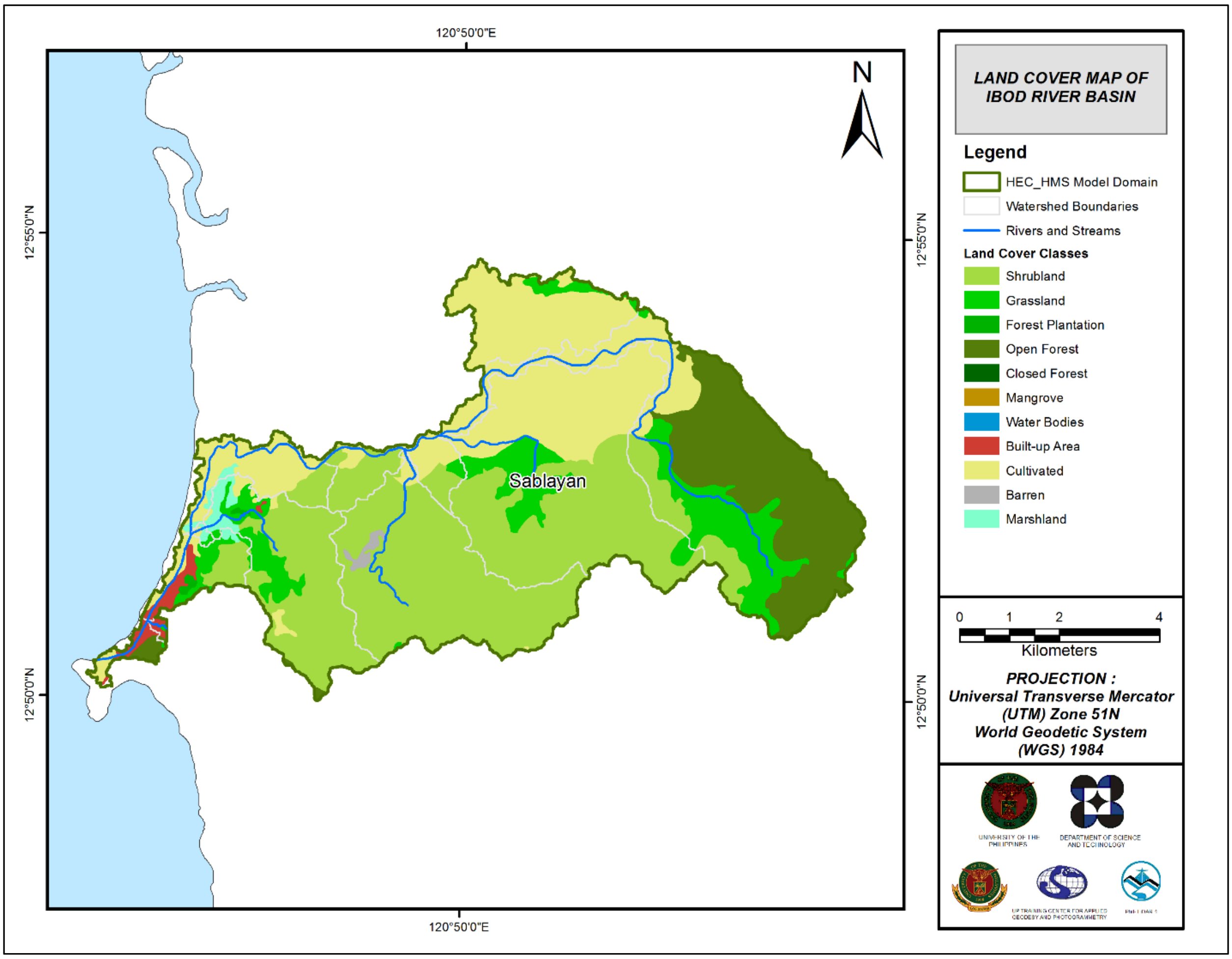


Figure 57. Land cover map of Ibod River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Ibod river basin, the five (5) soil classes identified were clay loam, silt loam, clay, and sandy loam, while the rest is undifferentiated. The six (6) land cover types identified were largely shrubland, cultivated land, and open forest, with smaller portions of grassland, marshland, and built-up area.

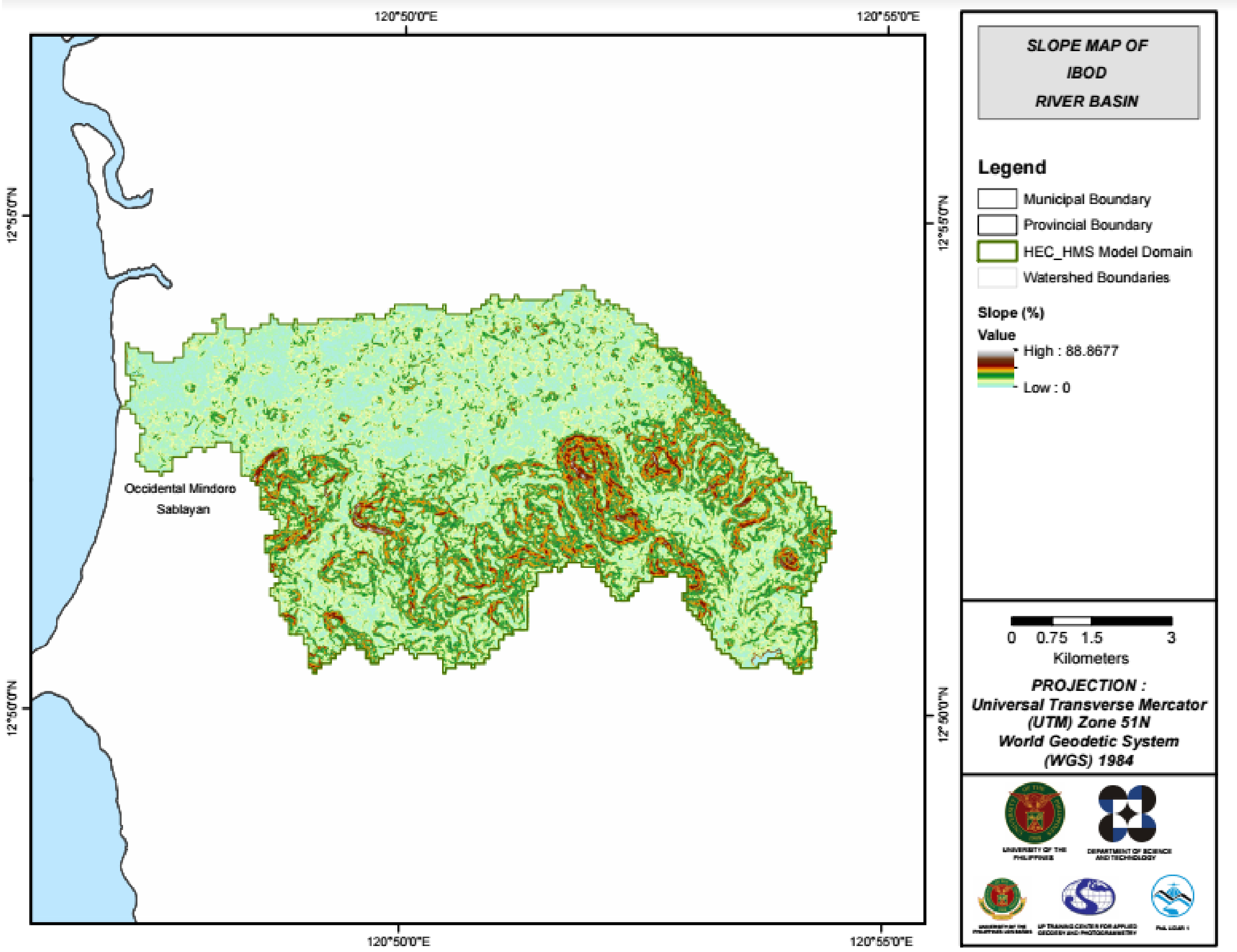


Figure 58. Slope map of Ibod River Basin

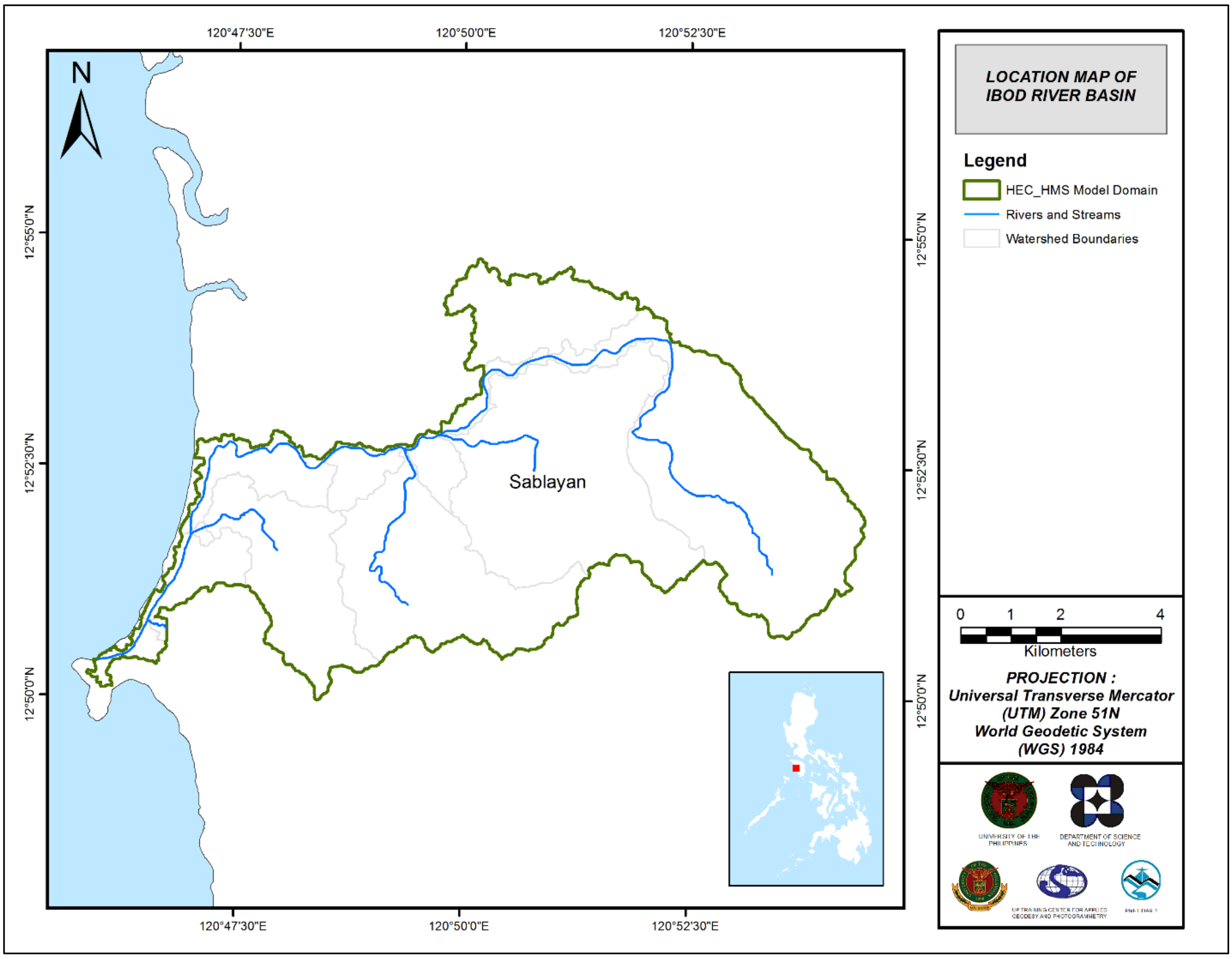


Figure 59. Stream delineation map of Ibod River Basin

Using SAR-based DEM, the Ibod basin was delineated and further subdivided into subbasins. The model consists of 51 sub basins, 16 reaches, and 16 junctions. The main outlet is labelled as 108. This basin model is illustrated in Figure 60. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from the portable rain gauge set up by the Data Validation team of UPLB (DVC-UPLB) on a strategic point within the river basin. Finally, it was calibrated using the flow data collected from the Ibod Bridge.

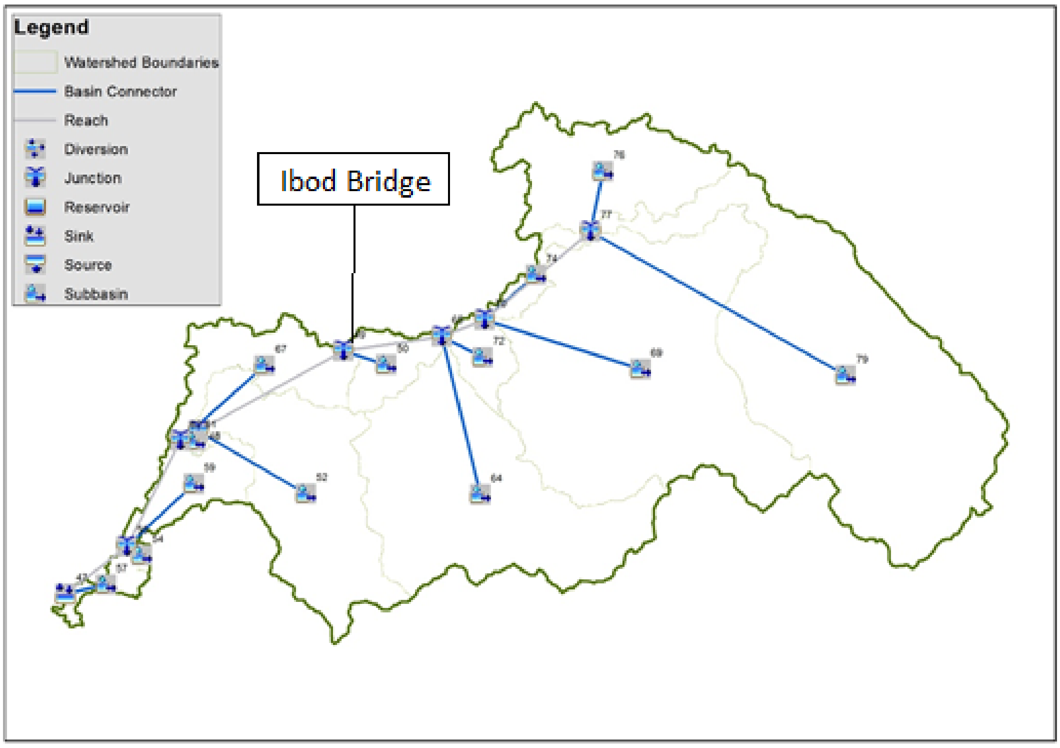


Figure 60. HEC-HMS generated Ibod River Basin Model.

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.

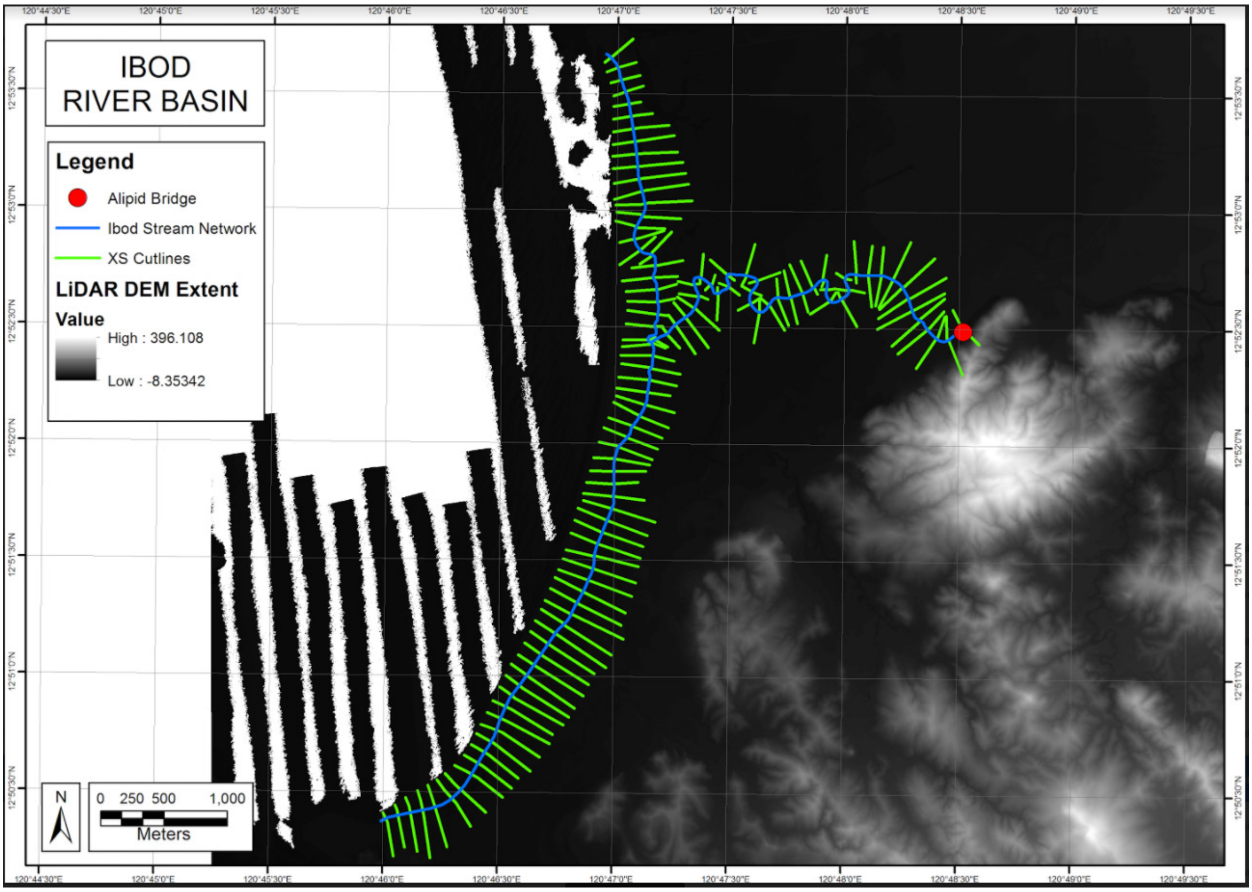


Figure 61. River cross-section of Ibod River generated through Arcmap HEC GeoRAS tool

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 east of the model to the west, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

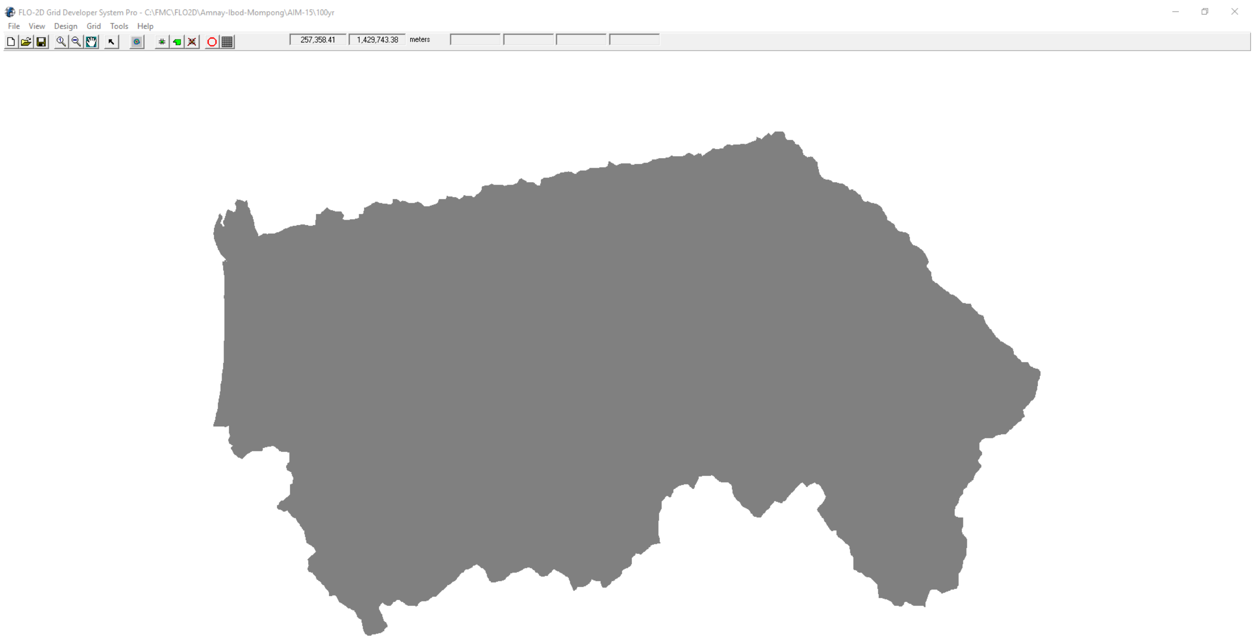


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 56.67261 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The 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 85 377 120.00 m2.

There is a total of 31 901 219.95 m3 of water entering the model. Of this amount, 31 901 219.95 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. 10 046 270.00 m3 of this water is lost to infiltration and interception, while 12 697 027.47 m3 is stored by the flood plain. The rest, amounting up to 9 157 948.76 m3, is outflow.

5.6 Results of HMS Calibration

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

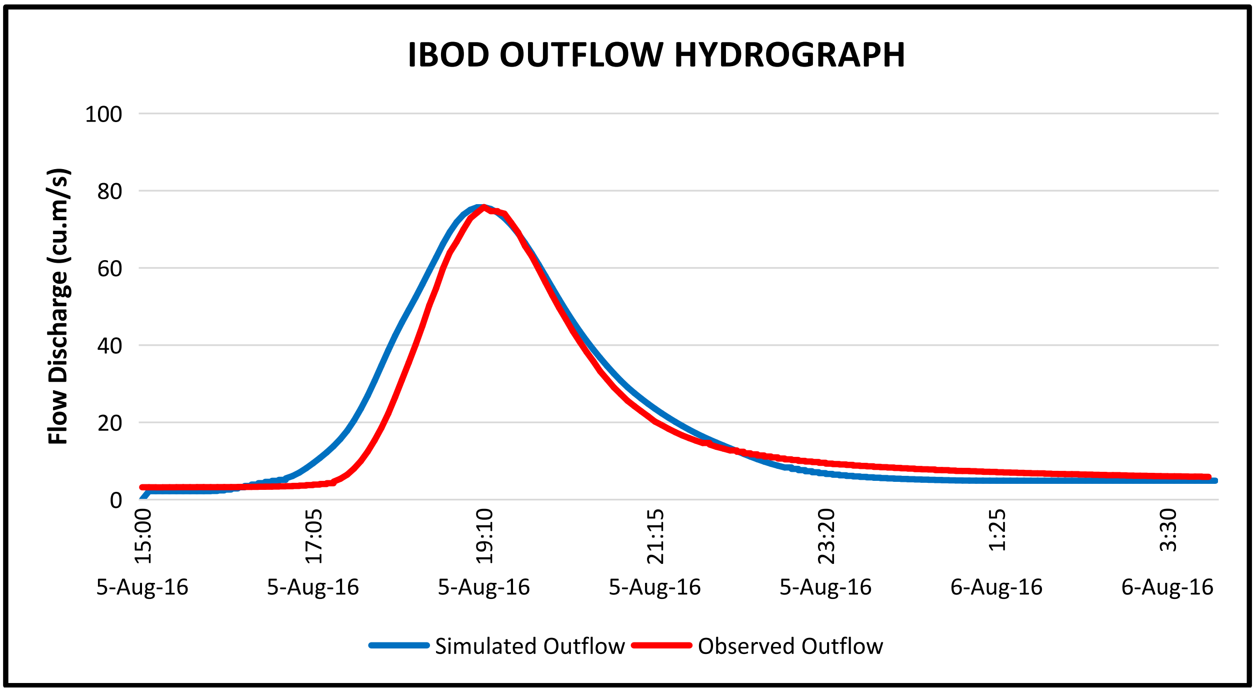


Figure 63. Outflow Hydrograph of Ibod produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of calibrated values for Ibod River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3 - 27
			Curve Number	51 - 90
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.5 - 5
			Storage Coefficient (hr)	0.2 - 7
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.05 - 5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04 – 0.2

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 3 to 27mm means that there is an average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 51 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 to 7 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.05 to 5 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 to 0.2 indicates a diverse characteristic of the roughness of each reach within the basin. (Brunner, 2010).

Table 30. Summary of the Efficiency Test of Ibod HMS Model

Accuracy measure	Value
RMSE	5.754
r2	0.968
NSE	0.920
PBIAS	-6.776
RSR	0.283

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 5.754.

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 0.968.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.920.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -6.776.

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 0.283.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 64) shows the Ibod outflow using the Ambulong Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

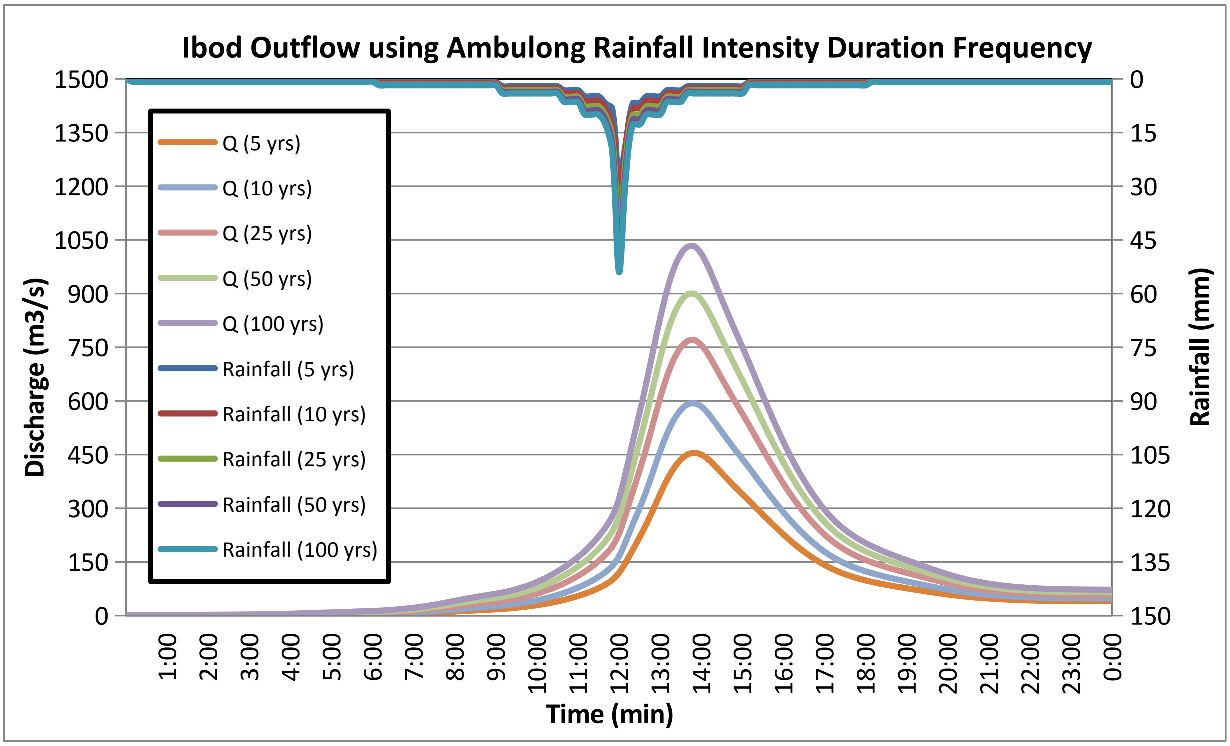


Figure 64. Outflow hydrograph at Ibod Station generated using Ambulong RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Ibod discharge using the Ambulong Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Ibod HECHMS Model outflow using the Ambulong RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak	Lag Time
5-Year	226.70	27.90	454.724	13 hours 50 minutes	1 hour 50 minutes
10-Year	276.90	34.20	593.210	13 hours 50 minutes	1 hour 50 minutes
25-Year	340.40	42.20	769.715	13 hours 50 minutes	1 hour 50 minutes
50-Year	387.50	48.10	898.984	13 hours 50 minutes	1 hour 50 minutes
100-Year	434.30	54.0	1031.784	13 hours 50 minutes	1 hour 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM/ Phil-LiDAR 1 website. The sample map of Ibod River using the HMS base flow is shown on Figure 65 below.

Figure 65. Sample output of Ibod RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The generated flood hazard maps for the Tambang Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA 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). The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Ibod floodplain are shown in Figure 66 to Figure 71. The floodplain, with an area of 509.59 sq. km., covers two municipalities namely Sablayan, and Santa Cruz. Table 32 shown the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Ibod Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Sablayan	2350.46	358.08	0.15
Santa Cruz	709.53	147.95	0.21

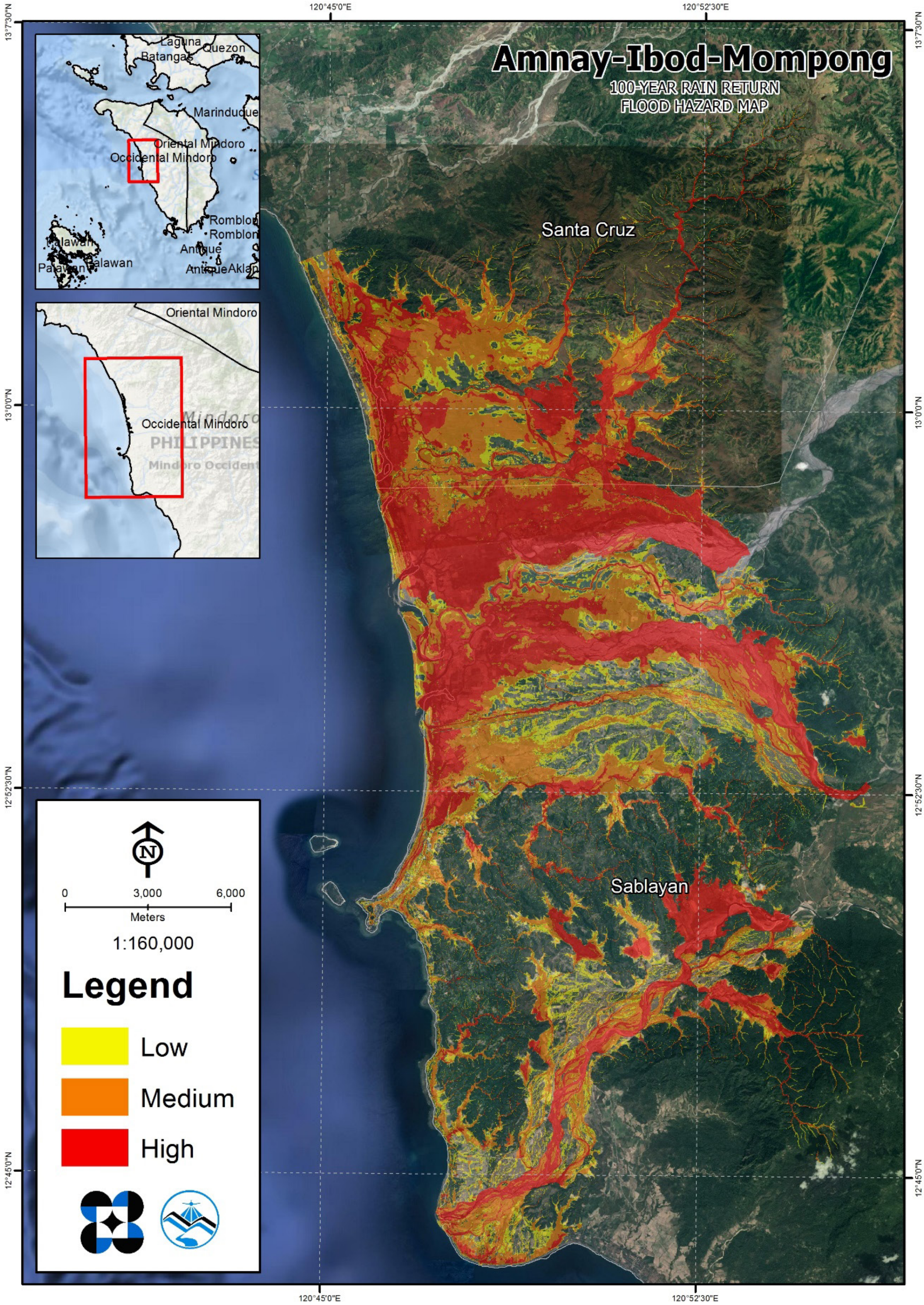


Figure 66. 100-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

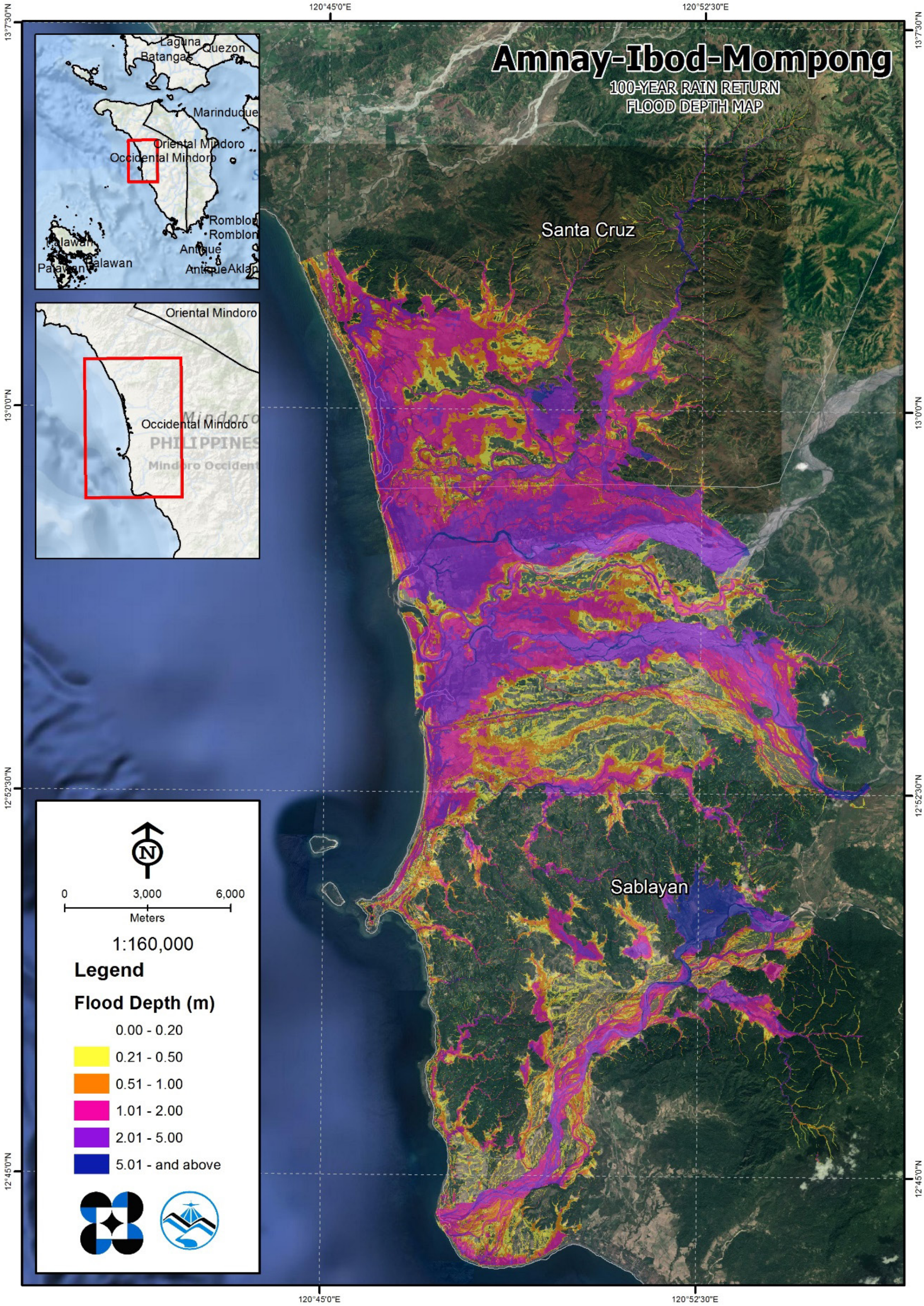


Figure 67. 100-year Flow Depth Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

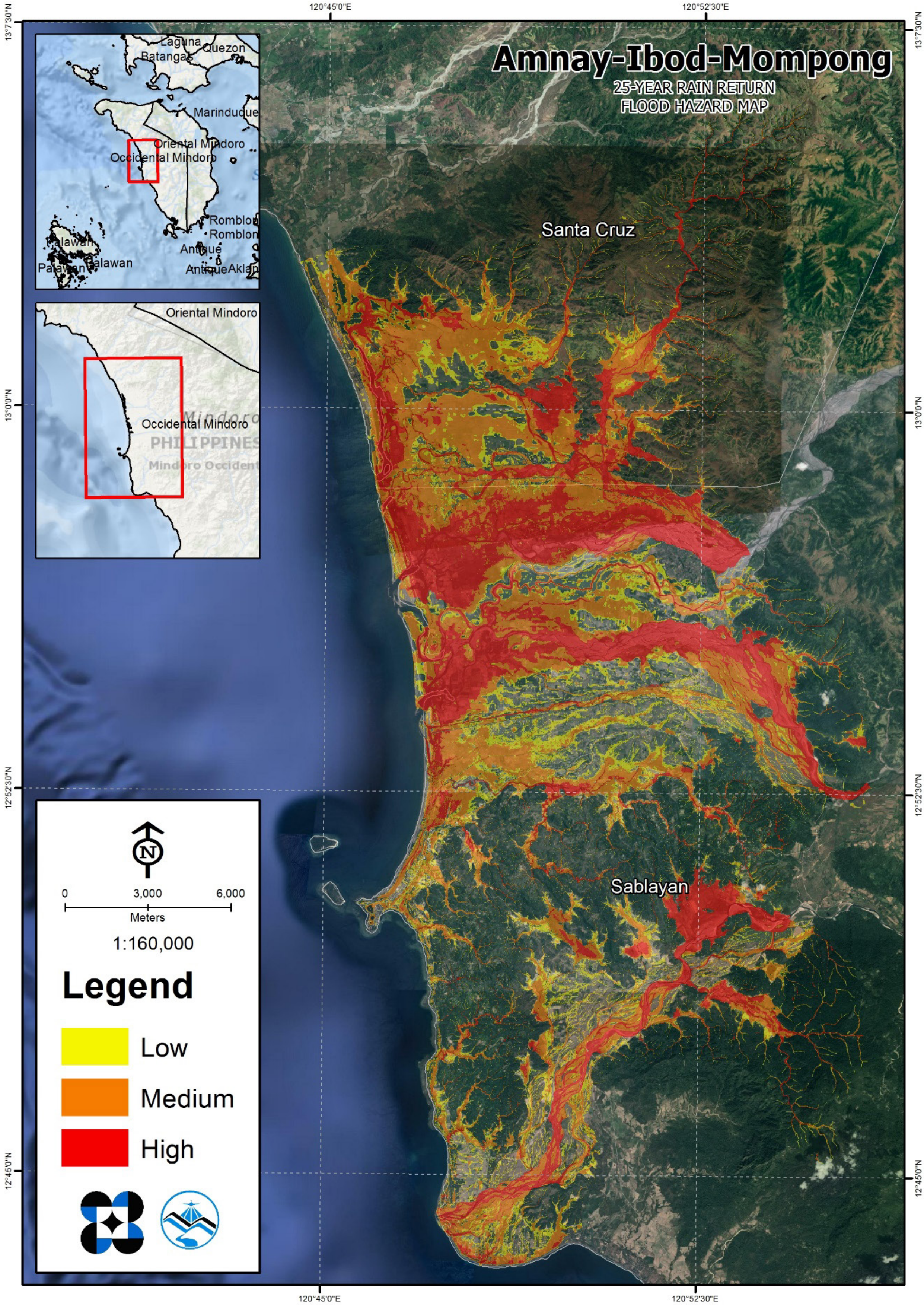


Figure 68. 25-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

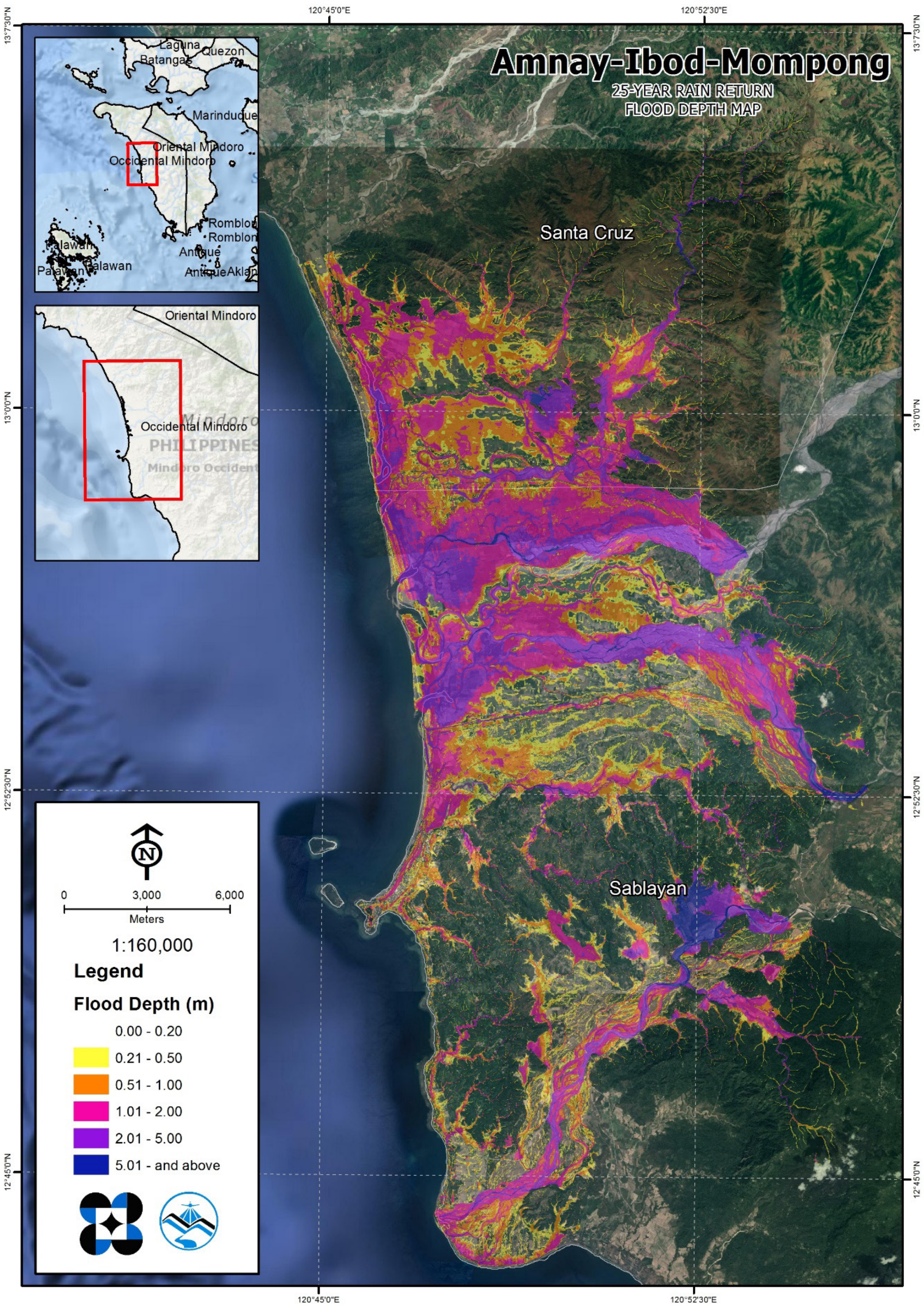


Figure 69. 25-year Flow Depth Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

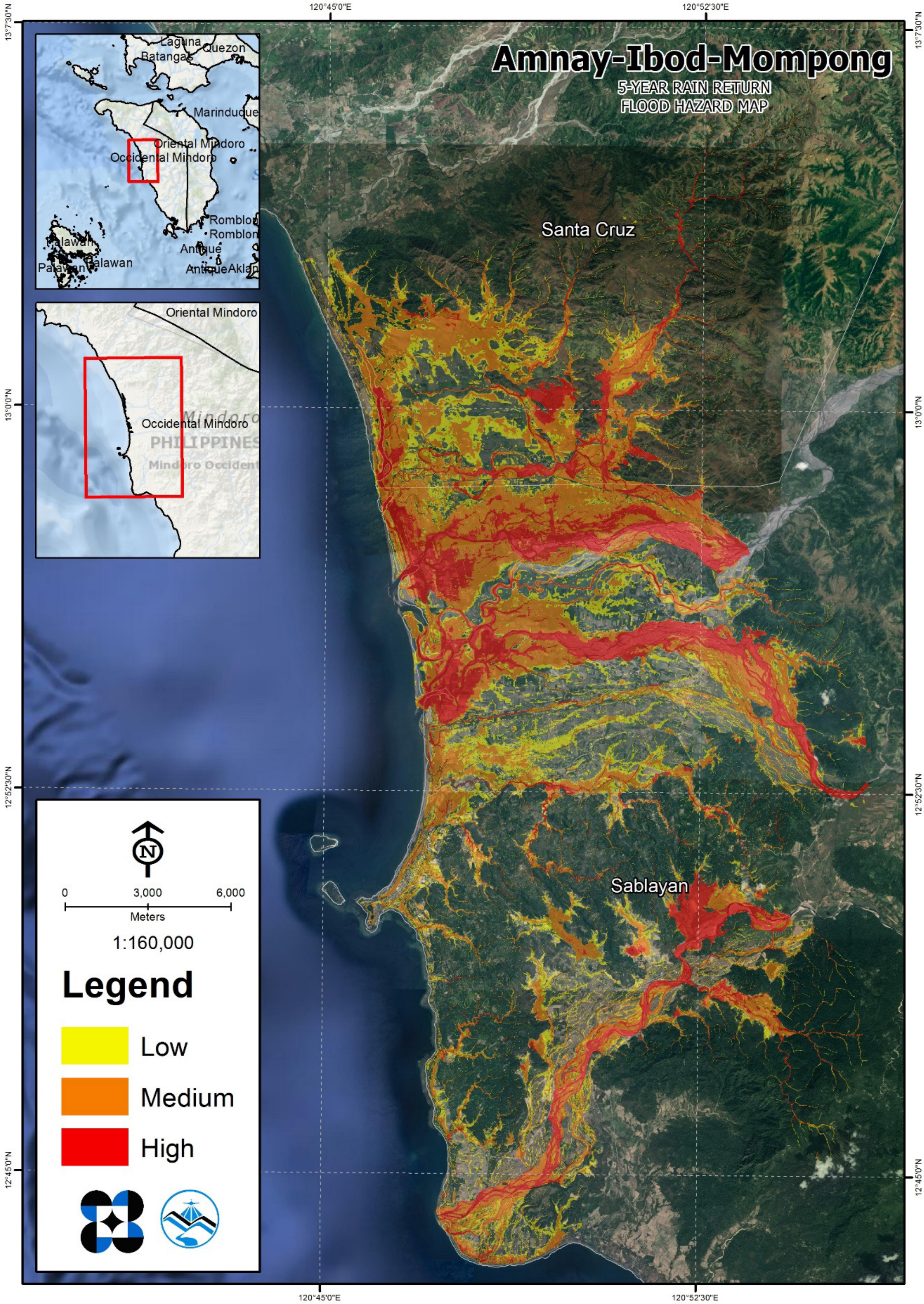


Figure 70. 5-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

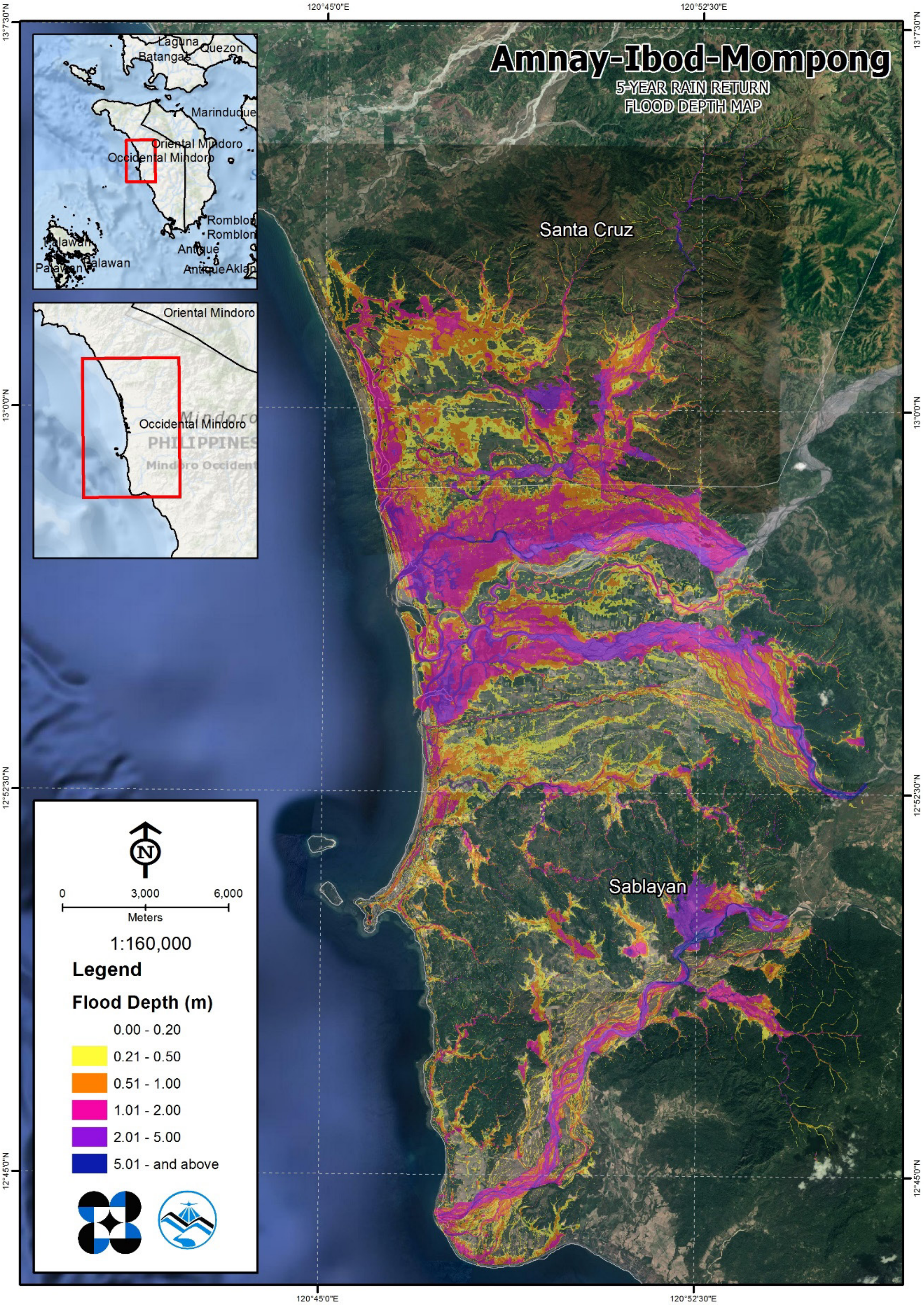


Figure 71. 5-year Flood Depth Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Ibod river basin, grouped by municipality, are listed below. For the said basin, two (2) municipalities consisting of 20 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 10.1% of the municipality of Sablayan with an area of 2103.82 sq. km. will experience flood levels of less 0.20 meters. 1.78% of the area will experience flood levels of 0.21 to 0.50 meters while 1.79%, 2.25%, 1.06%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 33 and Table 34, and shown in Figure 72 are the affected areas in Sablayan in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Batong Buhay	Buenavista	Claudio Salgado	Ibud	Ilvita	Lagnas	Paetan	Pag-Asa
0.03-0.20	13.02	21.06	11.84	4.8	9.85	6.49	5.41	3.9
0.21-0.50	0.59	2.34	5.57	0.75	3.21	0.77	1.17	0.33
0.51-1.00	0.46	2.55	9.73	0.56	3.36	1.2	1.74	0.2
1.01-2.00	0.39	1.37	21.02	0.28	7.14	1.69	1.53	0.11
2.01-5.00	0.3	0.28	7.91	0.072	2.13	1.08	0.62	0.071
> 5.00	0.15	0.0043	0.14	0.0001	0.0095	0.003	0.043	0.01

Table 34. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Poblacion	San Francisco	San Nicolas	San Vicente	Santa Lucia	Santo Niño	Tagumpay	Victoria
0.03-0.20	43.23	0.029	9.32	6.21	50.05	15.25	6.92	4.81
0.21-0.50	5.62	0	0.34	0.88	7.43	5.69	1.71	1
0.51-1.00	4.89	0	0.091	0.77	6.86	3.93	0.76	0.51
1.01-2.00	3.6	0	0.036	0.64	6.51	1.2	0.19	1.68
2.01-5.00	3.99	0	0.035	0.5	2.26	0.49	0.018	2.6
> 5.00	0.71	0	0.0036	0.35	0.043	0.048	0	0.0005

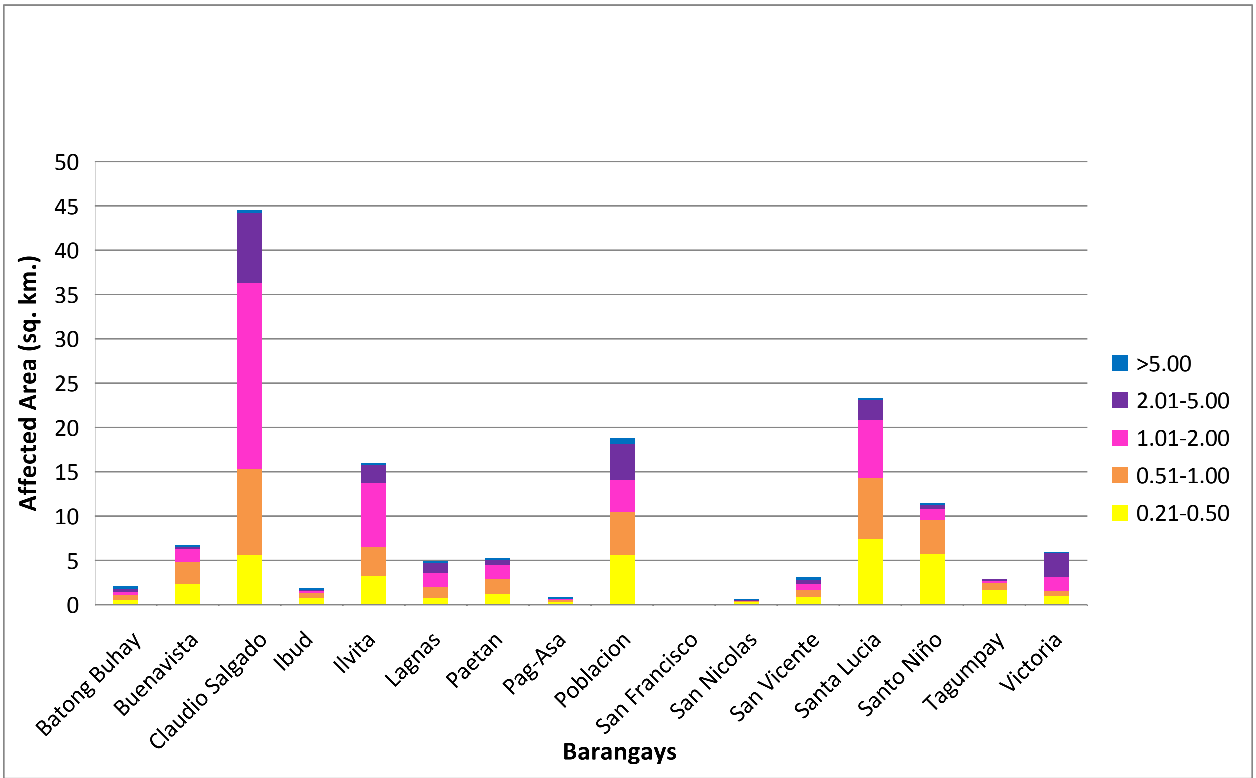


Figure 72. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

For the municipality of Santa Cruz, with an area of 689.03 sq. km., 14.5% will experience flood levels of less 0.20 meters. 2.22% of the area will experience flood levels of 0.21 to 0.50 meters while 2.57%, 1.64%, 0.55%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 and shown in Figure 73 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km.)			
	Barahan	Dayap	Lumangbayan	Pinagturilan
0.03-0.20	11.96	19.27	8.97	59.63
0.21-0.50	2.67	2.51	0.19	9.95
0.51-1.00	2.93	4.16	0.058	10.55
1.01-2.00	2.38	1.4	0.044	7.46
2.01-5.00	0.088	0.037	0.038	3.59
> 5.00	0	0	0.0058	0.16

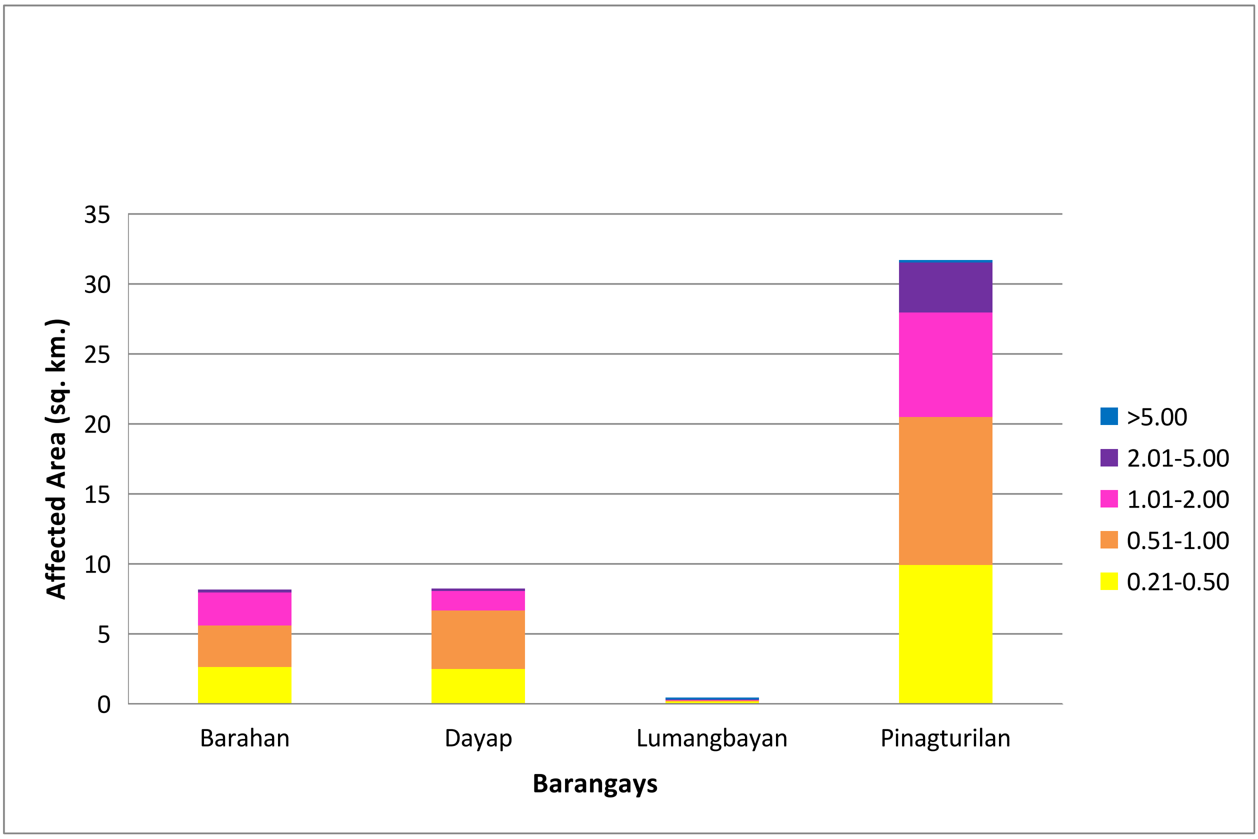


Figure 73. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 9.1% of the municipality of Sablayan with an area of 2103.82 sq. km. will experience flood levels of less 0.20 meters. 1.66% of the area will experience flood levels of 0.21 to 0.50 meters while 1.77%, 2.53%, 1.75%, and 0.22% 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 36 and Table 37, and shown in Figure 74 are the areas affected in Mansalay in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Batong Buhay	Buenavista	Claudio Salgado	Ibud	Ilvita	Lagnas	Paetan	Pag-Asa
0.03-0.20	12.75	20.13	7.11	4.4	7.76	6.17	4.95	3.75
0.21-0.50	0.62	2	4.24	0.78	2.82	0.54	0.78	0.39
0.51-1.00	0.47	2.55	7.07	0.72	3.72	0.82	1.38	0.24
1.01-2.00	0.5	2.43	21.56	0.46	6.56	1.82	2.34	0.13
2.01-5.00	0.37	0.48	15.9	0.1	4.81	1.81	1.01	0.085
> 5.00	0.21	0.0066	0.39	0.0006	0.027	0.064	0.062	0.024

Table 37. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Poblacion	San Francisco	San Nicolas	San Vicente	Santa Lucia	Santo Niño	Tagumpay	Victoria
0.03-0.20	40.64	0.029	9.17	5.57	46.69	12.71	6.02	3.63
0.21-0.50	5.73	0	0.42	0.81	7.92	4.74	2.06	1.16
0.51-1.00	4.69	0	0.14	0.87	7.1	5.45	1.1	0.91
1.01-2.00	4.35	0	0.048	0.92	8.02	2.86	0.39	0.91
2.01-5.00	3.57	0	0.042	0.7	3.34	0.78	0.031	3.86
> 5.00	3.06	0	0.01	0.51	0.095	0.063	0	0.11

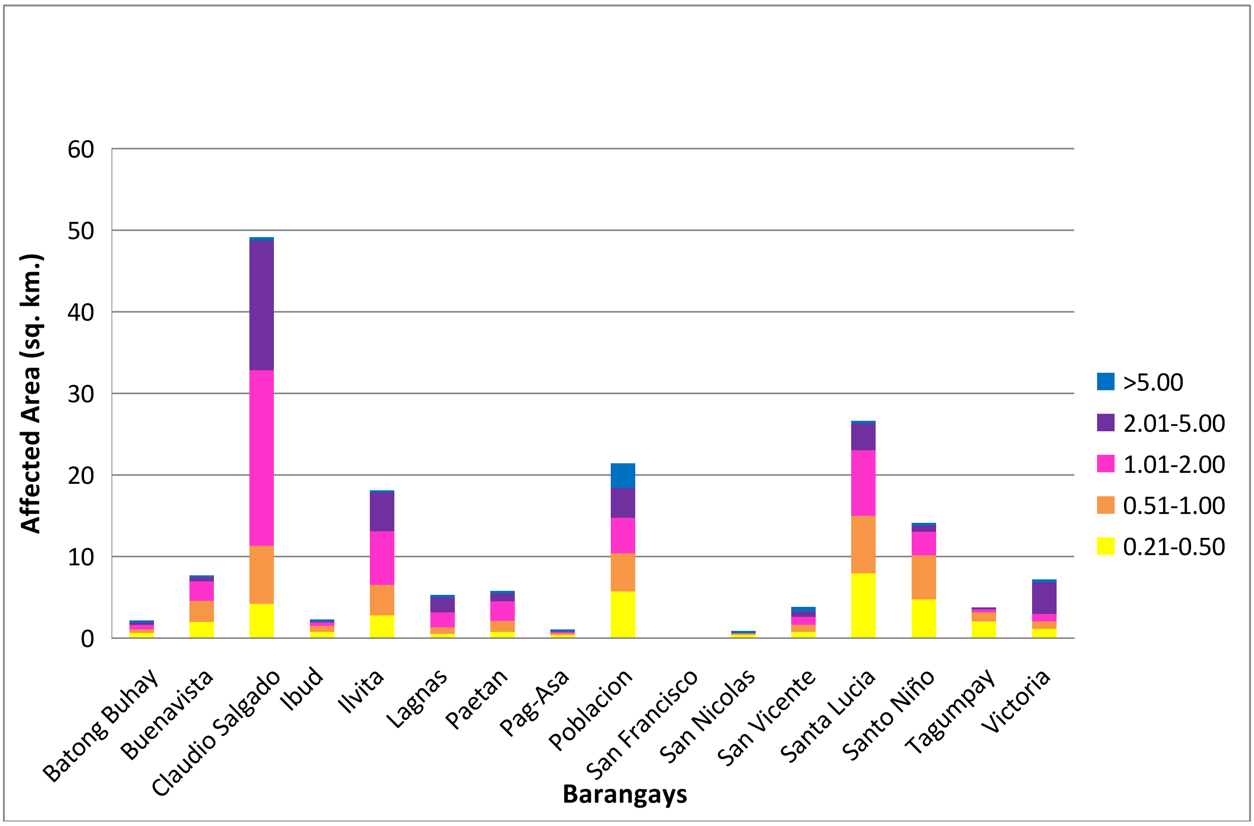


Figure 74. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

For the municipality of Santa Cruz, with an area of 689.03 sq. km., 13.2% will experience flood levels of less 0.20 meters. 1.62% of the area will experience flood levels of 0.21 to 0.50 meters while 2.7%, 2.97%, 0.92%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 and shown in Figure 75 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km.)			
	Barahan	Dayap	Lumangbayan	Pinagturilan
0.03-0.20	10.08	17.9	8.87	54.08
0.21-0.50	1.91	1.95	0.24	7.09
0.51-1.00	3.23	3.36	0.08	11.93
1.01-2.00	4.31	4.05	0.052	12.08
2.01-5.00	0.5	0.12	0.055	5.66
> 5.00	0	0.0012	0.0097	0.54

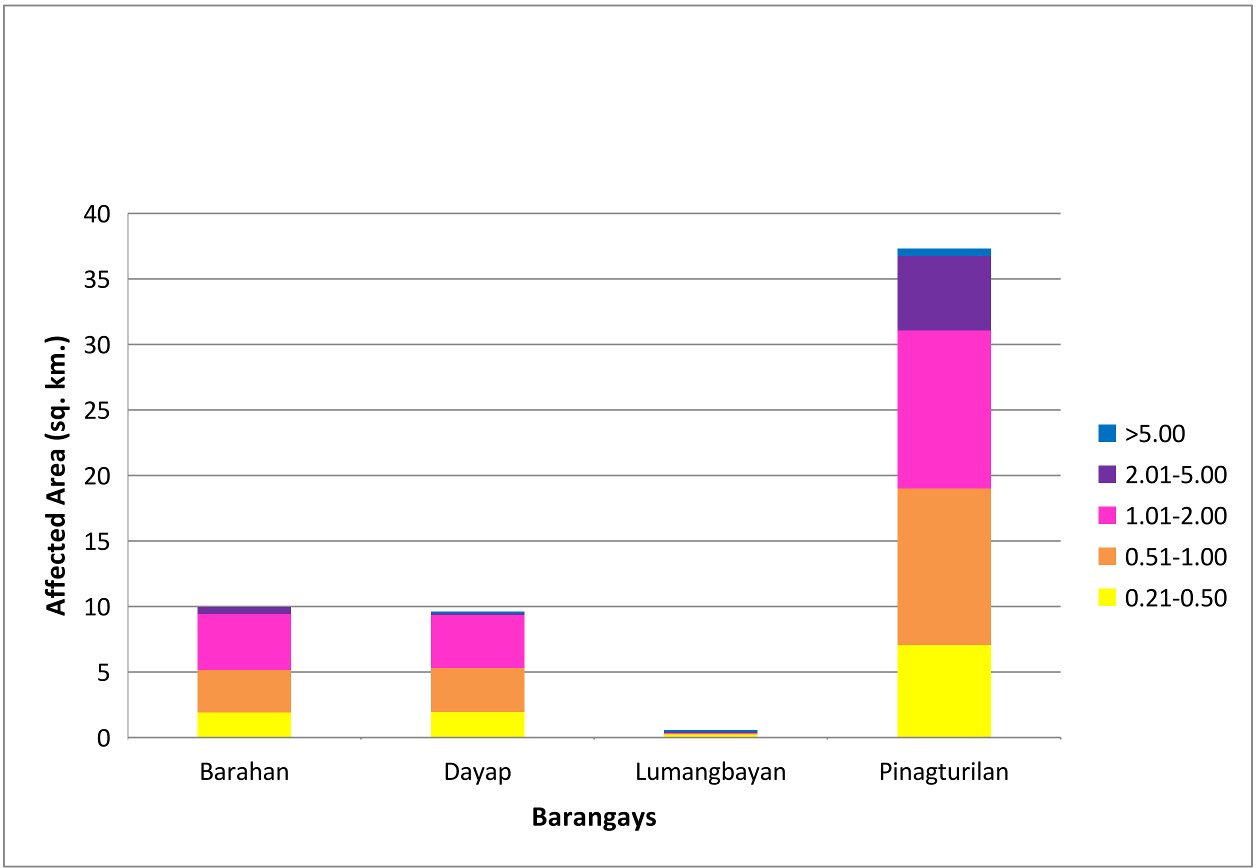


Figure 75. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 8.4% of the municipality of Sablayan with an area of 2103.82 sq. km. will experience flood levels of less 0.20 meters. 1.58% of the area will experience flood levels of 0.21 to 0.50 meters while 1.69%, 2.56%, 2.47%, and 0.35% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 and Table 40, and shown in Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Batong Buhay	Buenavista	Claudio Salgado	Ibud	Ilvita	Lagnas	Paetan	Pag-Asa
0.03-0.20	12.5	19.41	4.42	4.04	6.78	5.98	4.69	3.6
0.21-0.50	0.69	1.82	3.3	0.84	2.36	0.5	0.78	0.45
0.51-1.00	0.48	2.4	5.26	0.73	3.31	0.56	1.14	0.27
1.01-2.00	0.52	2.74	18.12	0.72	5.75	1.72	2.52	0.17
2.01-5.00	0.5	1.22	24.44	0.13	7.43	2.35	1.31	0.076
> 5.00	0.24	0.013	0.74	0.0009	0.063	0.12	0.074	0.053

Table 40. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Poblacion	San Francisco	San Nicolas	San Vicente	Santa Lucia	Santo Niño	Tagumpay	Victoria
0.03-0.20	38.19	0.029	9.02	5.29	43.4	11.22	5.28	2.8
0.21-0.50	5.83	0	0.49	0.82	8.05	3.93	2.25	1.18
0.51-1.00	4.96	0	0.18	0.92	7.64	5.24	1.38	1.06
1.01-2.00	5.03	0	0.06	1.01	9	4.66	0.63	1.19
2.01-5.00	3.19	0	0.05	0.79	4.86	1.48	0.048	4.1
> 5.00	4.85	0	0.017	0.54	0.21	0.084	0	0.27

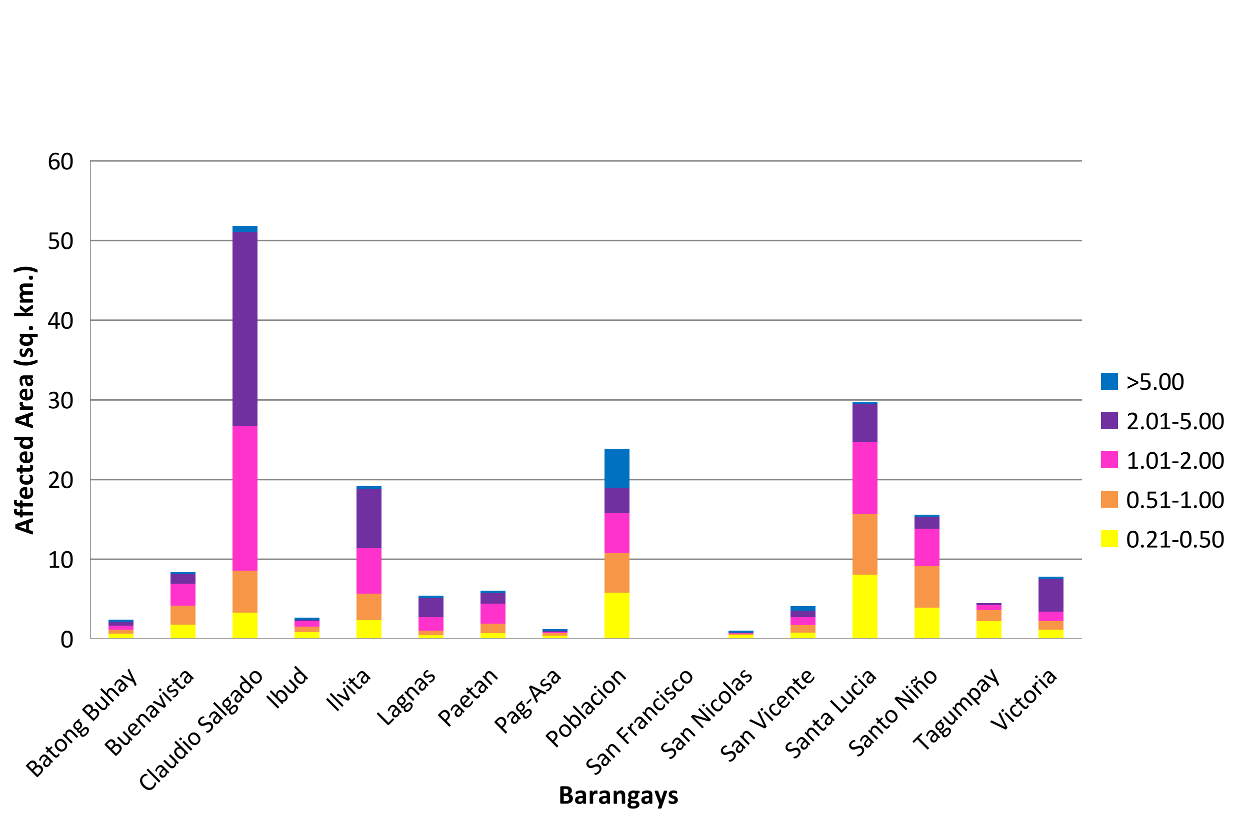


Figure 76. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of Santa Cruz, with an area of 689.03 sq. km., 12.5% will experience flood levels of less 0.20 meters. 1.37% of the area will experience flood levels of 0.21 to 0.50 meters while 2.04%, 3.94%, 1.58%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and shown in Figure 77 are the areas affected in Santa Cruz in square kilometers by flood depth per barangay.

Table 41. Affected areas in Santa Cruz, Occidental Mindoro during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km.)			
	Barahan	Dayap	Lumangbayan	Pinagturilan
0.03-0.20	8.86	17.23	8.8	50.95
0.21-0.50	1.57	1.38	0.26	6.22
0.51-1.00	2.49	2.64	0.1	8.86
1.01-2.00	5.42	5.34	0.061	16.3
2.01-5.00	1.69	0.78	0.066	8.34
> 5.00	0	0.0066	0.015	0.71

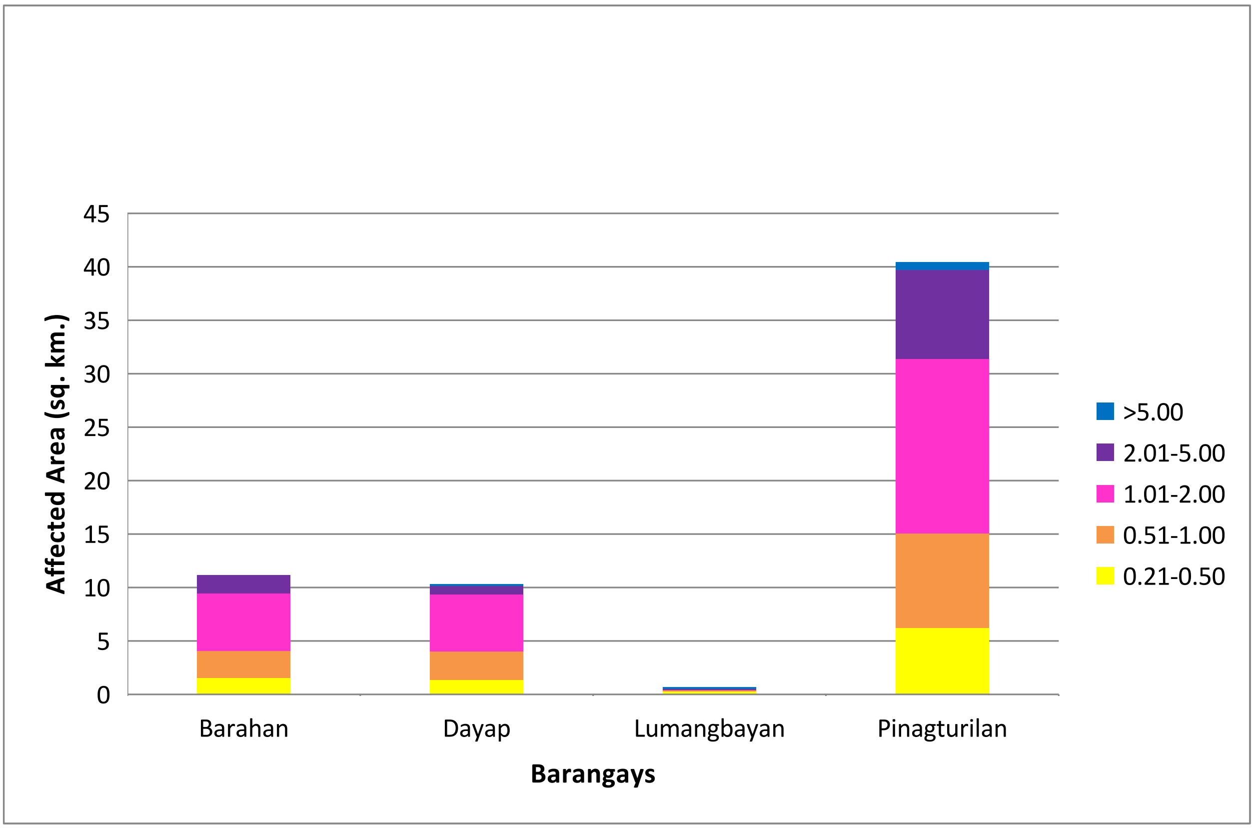


Figure 77. Affected areas in Santa Cruz, Occidental Mindoro during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Sablayan, Santa Lucia is projected to have the highest percentage of area that will experience flood levels at 3.48%. Meanwhile, Poblacion posted the second highest percentage of area that may be affected by flood depths at 2.95%.

Among the barangays in the municipality of Santa Cruz, Pinagturilan is projected to have the highest percentage of area that will experience flood levels at 13.26%. Meanwhile, Dayap posted the second highest percentage of area that may be affected by flood depths at 3.97%.

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 79.

The flood validation consisted of 106 points randomly selected all over the Ibod flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.49m. Table 42 shows a contingency matrix of the comparison.

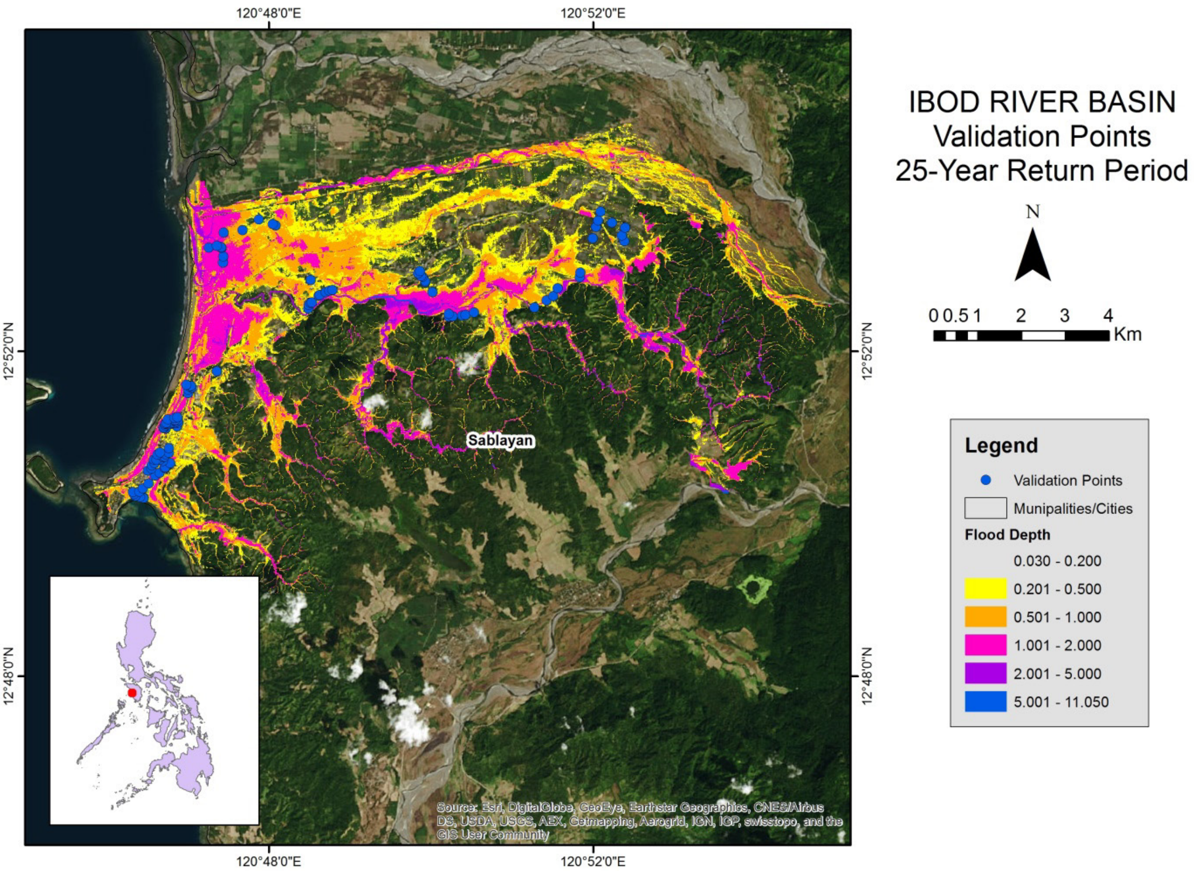


Figure 78. Validation points for 25-year Flood Depth Map of Ibod Floodplain

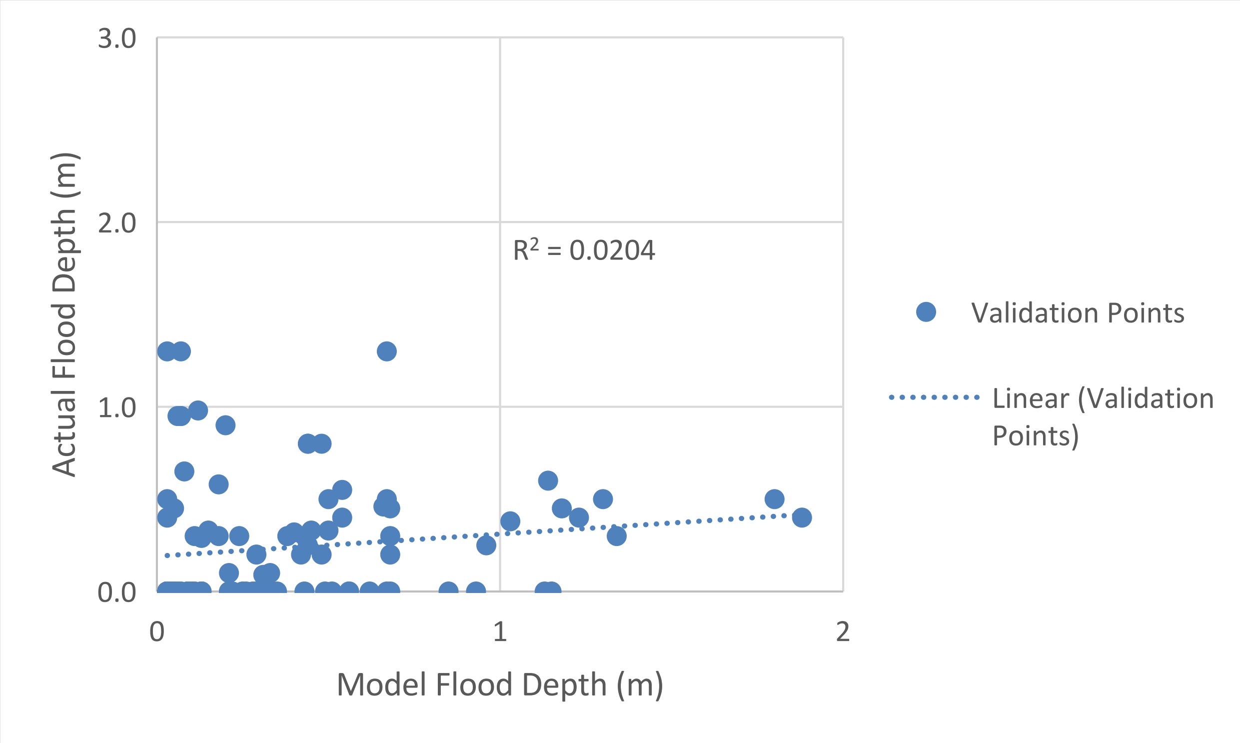


Figure 79. Flood map depth vs. actual flood depth

Table 42. Actual flood vs simulated flood depth at different levels in the Tawiran-Tagum River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
0-0.20	31	21	9	2	0	0	63
0.21-0.50	7	8	6	7	0	0	28
0.51-1.00	7	3	1	1	0	0	12
1.01-2.00	2	0	1	0	0	0	3
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	47	32	17	10	0	0	106

The overall accuracy generated by the flood model is estimated at 37.74% with 40 points correctly matching the actual flood depths. In addition, there were 36 points estimated one level above and below the correct flood depths while there were 23 points and 4 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 20 points were underestimated in the modelled flood depths of Ibod. Table 43 depicts the summary of the Accuracy Assessment in the Ibod River Basin Survey.

Table 43. Summary of the Accuracy Assessment in the Ibod River Basin

	No. of Points	%
Correct	22	37.74
Overestimated	27	43.40
Underestimated	12	18.87
Total	61	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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Aquarius and Pegasus Sensors

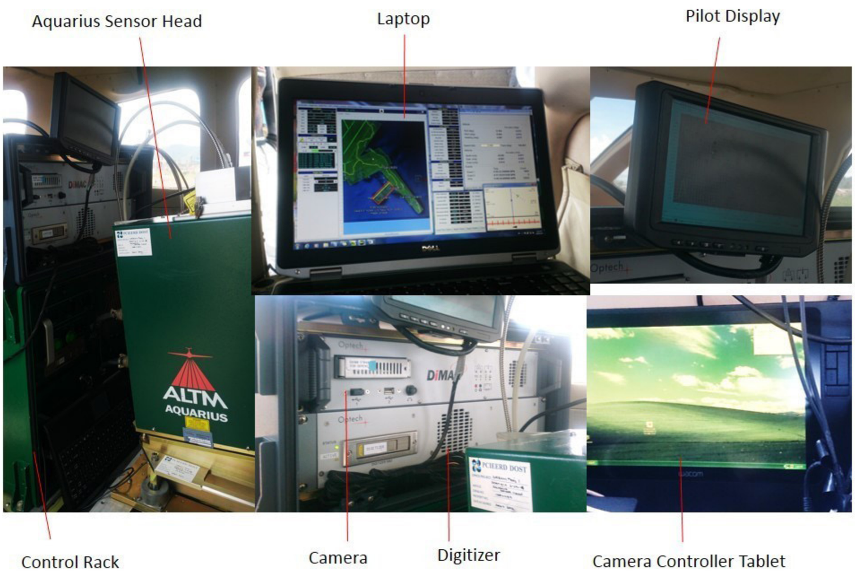


Figure A-1.1 Aquarius Sensor

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

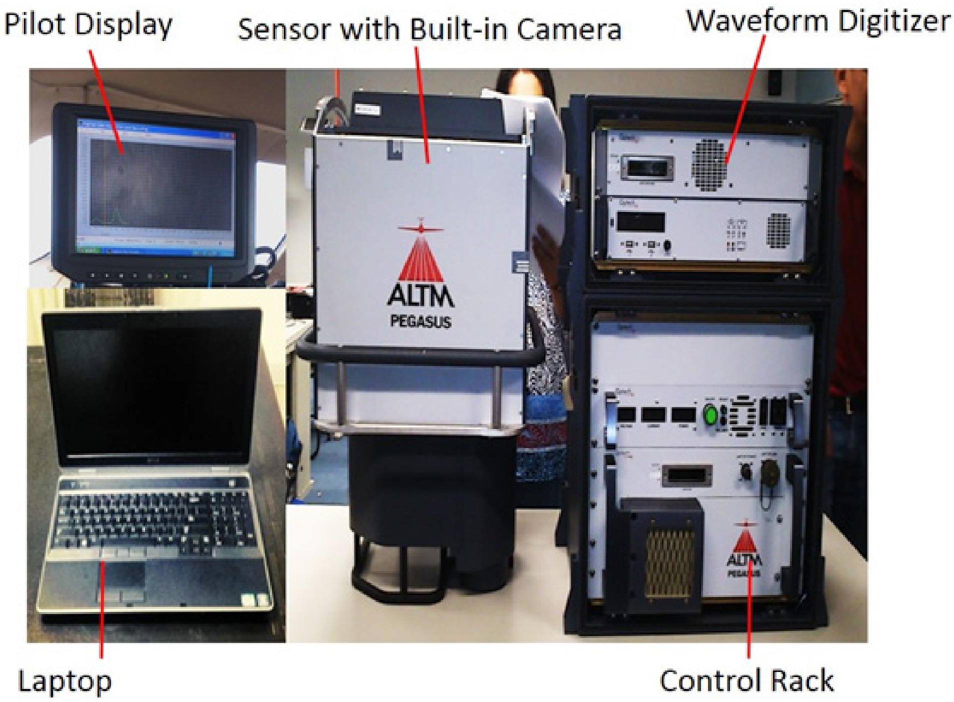


Figure A-1.2 Pegasus Sensor

Table A-1.2 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™ AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

1. MRW-6

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-6 (PCP-2992A)**
Order: **3rd**

Island: **LUZON**
Municipality: **SABLAYAN**
Barangay: **YAPANG**

	PRS92 Coordinates	
Latitude: **12° 52' 40.22762"**	Longitude: **120° 55' 6.44586"**	Ellipsoidal Hgt: **80.63530 m.**
	WGS84 Coordinates	
Latitude: **12° 52' 35.21155"**	Longitude: **120° 55' 11.48810"**	Ellipsoidal Hgt: **128.69600 m.**
	PTM Coordinates	
Northing: **1424038.201 m.**	Easting: **491149.868 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,424,453.14**	Easting: **274,116.83**	Zone: **51**

Location Description

MRW-6 (PCP-2992)
From the Deepartment of Agrarian Reform Office in Yapang, travel north along the national road for about 5 Kms. up to Patrick bridge. The point is permanently marked and located at the NW end of the catwalk of Patrick bridge and about 15 meters southwest of Km. Post 344. Mark is a 4" copper nail drilled in a hole and cement flush to the catwalk with inscription "MRW-6, 1993, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795394 A**
T.N.: **2014-357**

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

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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-2.1. MRW-6

2. MRW-30

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-6 (PCP-2992A)**
Order: **3rd**

Island: **LUZON**		Barangay: **YAPANG**
Municipality: **SABLAYAN**		
	PRS92 Coordinates	
Latitude: **12° 52' 40.22762"**	Longitude: **120° 55' 6.44586"**	Ellipsoidal Hgt: **80.63530 m.**
	WGS84 Coordinates	
Latitude: **12° 52' 35.21155"**	Longitude: **120° 55' 11.48810"**	Ellipsoidal Hgt: **128.69600 m.**
	PTM Coordinates	
Northing: **1424038.201 m.**	Easting: **491149.868 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,424,453.14**	Easting: **274,116.83**	Zone: **51**

Location Description

MRW-6 (PCP-2992)
From the Depeartment of Agrarian Reform Office in Yapang, travel north along the national road for about 5 Kms. up to Patrick bridge. The point is permanently marked and located at the NW end of the catwalk of Patrick bridge and about 15 meters southwest of Km. Post 344. Mark is a 4" copper nail drilled in a hole and cement flush to the catwalk with inscription "MRW-6, 1993, NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795394 A**
T.N.:	**2014-357**

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

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

Figure A-2.2. MRW-30

3. MRW-32

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-32**
Order: **2nd**

Island: **LUZON**		Barangay: **FATIMA (TII)**
Municipality: **MAMBURAO (CAPITAL)**		
	PRS92 Coordinates	
Latitude: **13° 10' 14.92094"**	Longitude: **120° 39' 52.29557"**	Ellipsoidal Hgt: **1.47400 m.**
	WGS84 Coordinates	
Latitude: **13° 10' 9.81293"**	Longitude: **120° 39' 57.31386"**	Ellipsoidal Hgt: **48.13600 m.**
	PTM Coordinates	
Northing: **1456469.064 m.**	Easting: **463632.46 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,457,111.12**	Easting: **246,845.90**	Zone: **51**

Location Description

MRW-32
From Abra de Ilog to San Jose, along Nat'l Road, approx. 11.4 Km. from Mamburao Town Proper, 400 m from Km. post 396, 12.6 Km. before Sta. Cruz Town Proper, right side of road located brgy. hall of Fatima, Mamburao, Occ. Mindoro, beside Fatima Elem. School. Station is located in corner fence of Day Care Center. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-32, 2007, NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795440 A**
T.N.:	**2014-397**

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

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Figure A-2.3. MRW-32

4. MRW-34

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-34**
Order: **2nd**

Island: **LUZON**		Barangay: **ARMADO**
Municipality: **ABRA DE ILOG**		
	PRS92 Coordinates	
Latitude: **13° 17' 25.00981"**	Longitude: **120° 37' 41.53630"**	Ellipsoidal Hgt: **8.01600 m.**
	WGS84 Coordinates	
Latitude: **13° 17' 19.87026"**	Longitude: **120° 37' 46.54446"**	Ellipsoidal Hgt: **54.26900 m.**
	PTM Coordinates	
Northing: **1469690.588 m.**	Easting: **459714.493 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,470,369.33**	Easting: **243,032.08**	Zone: **51**

Location Description

MRW-34

From Abra de Ilog to San Jose, along Nat'l Road approx. 20.3 Km. from Abra de Ilog Town Proper, 300 m from Km. post 418, 9.7 Km. before Mamburao Proper, located Balibago Bridge at Brgy. Armado, Sitio Balibago, Abra de Ilog, Occ. Mindoro. Station is located near footpath of Balibago Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-34, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-396**

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

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CIP/4701/12/09/814

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Figure A-2.4. MRW-34

5. MRW-54

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-54**
Order: **2nd**

Island: **LUZON**
Municipality: **SABLAYAN**
Barangay: **MALISBONG**

PRS92 Coordinates

Latitude: **12° 46' 18.56204"**	Longitude: **120° 50' 27.44152"**	Ellipsoidal Hgt: **28.20700 m.**

WGS84 Coordinates

Latitude: **12° 46' 13.56455"**	Longitude: **120° 50' 32.49343"**	Ellipsoidal Hgt: **76.35500 m.**

PTM Coordinates

Northing: **1412314.677 m.**	Easting: **482731.146 m.**	Zone: **3**

UTM Coordinates

Northing: **1,412,791.69**	Easting: **265,604.90**	Zone: **51**

Location Description

MRW-54

From Abra de Ilog to San Jose, along Nat'l Road, turn right to Brgy. Road, approx. 1.1 Km. travel, right side of Brgy. Road located brgy. hall boundary of Malisbong, Sablayan, Occ., Mindoro. Station is located at the back of goal post of basketball court. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-54, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-445**

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

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Figure A-2.5. MRW-54

6. MC-121

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MC-121**

Island: **Luzon**	Municipality: **SABLAYAN**	Barangay: **BATONG BUHAY**
Elevation: **77.8103 +/- 0.14 m.**	Accuracy Class at 95% C.L:	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

MC-121
Marked is the head of a 4" copper nail flushed in a cement block embedded in the ground with inscription MC-121 2007 NAMRIA". The station is in Sitio Yapang Brgy. Batong Buhay, Sablayan Occidental Mindoro. From Sablayan located along National road in the South end of the Catwalk of Patrick bridge.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0330**

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

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CIP/4701/12/09/814

Figure A-2.6. MC-121

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

Project information		Coordinate System	
Name:	I:\Doc\DAC\2015\Fieldwork\2015-12-3_17 Mamburao, Occidental Mindoro\Baseline Processing Reports\2015-dec mamburao, occ mindoro.vce	Name:	UTM
		Datum:	PRS 92
		Zone:	51 North (123E)
Size:	779 KB	Geoid:	EGMPH
Modified:	7/14/2016 3:00:46 PM (UTC:8)	Vertical datum:	
Time zone:	Taipei Standard Time		
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-6 --- MC-121 (B6)	MRW-6	MC-121	Fixed	0.002	0.004	195°39'56"	232.244	-0.011

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

MRW-6 - MC-121 (7:30:43 AM-10:37:36 AM) (S6)

Baseline observation:	MRW-6 --- MC-121 (B6)
Processed:	7/14/2016 2:46:55 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.004 m
RMS:	0.000 m
Maximum PDOP:	2.183
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/9/2015 7:30:43 AM (Local: UTC+8hr)
Processing stop time:	12/9/2015 10:37:36 AM (Local: UTC+8hr)
Processing duration:	03:06:53
Processing interval:	1 second

1

Figure A-3.1. Baseline Processing Report - A

Vector Components (Mark to Mark)

From:	MRW-6				
Grid		Local		Global	
Easting	274116.940 m	Latitude	N12°52'40.23826"	Latitude	N12°52'35.22171"
Northing	1424453.462 m	Longitude	E120°55'06.44928"	Longitude	E120°55'11.49159"
Elevation	80.387 m	Height	79.981 m	Height	128.042 m

To:	MC-121				
Grid		Local		Global	
Easting	274052.406 m	Latitude	N12°52'32.96110"	Latitude	N12°52'27.94499"
Northing	1424230.309 m	Longitude	E120°55'04.36932"	Longitude	E120°55'09.41181"
Elevation	80.376 m	Height	79.971 m	Height	128.035 m

Vector					
ΔEasting	-64.535 m	NS Fwd Azimuth	195°39'56"	ΔX	28.194 m
ΔNorthing	-223.153 m	Ellipsoid Dist.	232.244 m	ΔY	74.963 m
ΔElevation	-0.011 m	ΔHeight	-0.011 m	ΔZ	-218.000 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.002 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000017736		
Y	-0.0000014707	0.0000026993	
Z	-0.0000001320	0.0000005128	0.0000003728

2

Figure A-3.2. Baseline Processing Report - B

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
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)
MRWDAC-00 --- MRW-30 (B1)	MRW-30	MRWDAC-00	Fixed	0.003	0.011	312°40'19"	43136.391	-30.412
MRWDAC-00 --- MRW-30 (B2)	MRW-30	MRWDAC-00	Fixed	0.006	0.016	312°40'19"	43136.383	-30.384

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

MRWDAC-00 - MRW-30 (7:22:03 AM-9:48:26 AM) (S1)

Baseline observation:	MRWDAC-00 --- MRW-30 (B1)
Processed:	12/15/2015 5:32:10 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.011 m
RMS:	0.004 m
Maximum PDOP:	2.308
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/8/2015 7:22:11 AM (Local: UTC+8hr)
Processing stop time:	12/8/2015 9:48:26 AM (Local: UTC+8hr)
Processing duration:	02:26:15
Processing interval:	1 second

1

Figure A-3.3. Baseline Processing Report – C

Vector Components (Mark to Mark)

From:	MRW-30				
Grid		Local		Global	
Easting	271237.336 m	Latitude	N12°57'32.22951"	Latitude	N12°57'27.19115"
Northing	1433451.975 m	Longitude	E120°53'28.50896"	Longitude	E120°53'33.54442"
Elevation	42.722 m	Height	42.013 m	Height	89.793 m

To:	MRWDAC-00				
Grid		Local		Global	
Easting	239755.834 m	Latitude	N13°13'23.10541"	Latitude	N13°13'17.97945"
Northing	1462963.518 m	Longitude	E120°35'55.10583"	Longitude	E120°36'00.11991"
Elevation	15.198 m	Height	11.601 m	Height	57.961 m

Vector					
ΔEasting	-31481.502 m	NS Fwd Azimuth	312°40'19"	ΔX	30671.804 m
ΔNorthing	29511.543 m	Ellipsoid Dist.	43136.391 m	ΔY	10509.502 m
ΔElevation	-27.524 m	ΔHeight	-30.412 m	ΔZ	28452.496 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000093026		
Y	-0.0000128686	0.0000223985	
Z	-0.0000041460	0.0000065394	0.0000035059

2

Figure A-3.4. Baseline Processing Report – D

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist	PAULINE JOANNE ARCEO	UP-TACGP
	Research Associate (RA)	PATRICIA YSABEL ALCANTARA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	ENGR. MILLIE SHANE REYES	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. FRANK NICOLAS ILEJAY	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJAMIN CARBOLLEDO	PAF
	Pilot	CAPT. JEFFREY JEREMY ALAAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC
		CAPT. SHERWIN ALFONSO III	AAC
		CAPT. JUSTINE JOYA	AAC

Annex 5. Data Transfer Sheets

DATA TRANSFER SHEET
Mar 4, 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	
16-2-14	1108A	3BLK29J47A	AQUARIUS	NA	368KB	622KB	134MB	699MB	2/1/6/1KB	5.37GB	NA	14MB	1KB	1KB	194KB	N/A	X:\Airborne_Raw\1108A
16-2-14	1110A	3BLK29K47B	AQUARIUS	NA	562/138KB	1.01MB	240MB	39.7 ~~14.7~~GB	1KB	13.3GB	43.6GB	14MB	1KB	1KB	46KB	N/A	X:\Airborne_Raw\1110A
18-2-14	1116A	3BLK29KS49A	AQUARIUS	NA	659KB	4.08MB	245MB	71.7GB	32/165/2535KB	12GB	61.6GB	15.3MB	1KB	1KB	46KB	N/A	X:\Airborne_Raw\1116A
18-2-14	1118A	3BLK29JS49B	AQUARIUS	NA	540KB	1.04MB	204MB	48GB	1/372KB	11.3GB	59.2GB	15.3MB	1KB	1KB	211KB	N/A	X:\Airborne_Raw\1118A
19-2-14	1120A	3BLK29L50A	AQUARIUS	NA	691KB	1.13MB	251MB	75.8GB	526KB	14.2GB	19.8GB	13.2MB	1KB	1KB	252KB	N/A	X:\Airborne_Raw\1120A
19-2-14	1122A	3BLK29O50B	AQUARIUS	NA	168KB	1.48MB	98.3MB	17.1GB	3/150KB	3.74GB	17.3GB	13.2MB	1KB	1KB	57KB	N/A	X:\Airborne_Raw\1122A
20-2-14	1124A	3BLK29OS51A	AQUARIUS	NA	308KB	1.34MB	246MB	75.4GB ~~42.5GB~~	1/103/418/24KB	12.6GB	16.7GB	17.7MB	1KB	1KB	18KB	N/A	X:\Airborne_Raw\1124A
20-2-14	1126A	3BLK29M51B	AQUARIUS	NA	803KB	1.71MB	235MB	78GB	NA	13.9GB	74.8GB	17.7MB	1KB	1KB	NA	N/A	X:\Airborne_Raw\1126A

Received from
Name CHRIS JOAQUIN
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature

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

DATA TRANSFER SHEET
Mar 19, 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	
Jan 15, 2014	989P	1PAMS015A	PEGASUS	1.02MB	NA	5.85MB	168MB	NA	NA	9.2GB	N/A	11MB	1KB	1KB	NA	N/A	X:\Airborne_Raw\989P
Jan 21, 2014	1004A	3PNG1AB021A	AQUARIUS	NA	NA	620KB	209MB	23.4GB	194KB	10.6GB	47.7GB	8.24MB	1KB	2KB	7/114/114KB	389/16KN	X:\Airborne_Raw\1004A
Jan 21, 2014	1006A	3PNG1ABS021B	AQUARIS	NA	NA	214KB	128MB	6.78GB	65KB	4.08GB	15.5GB	8.24MB	1KB	1KB	16/46/7KB	124KB	X:\Airborne_Raw\1006A
Jan 22, 2014	1008A	3PNG1AS022A	AQUARIUS	NA	NA	482KB	204MB	26.3GB	209KB	8.14GB	33.1GB	10.6MB	1KB	1KB	1/7/101KB	281KB	X:\Airborne_Raw\1008A
Feb 21, 2014	1128A	3BLK29IS2A	AQUARIUS	NA	NA	1.34MB	269MB	6.32GB	1/672KB	16.1GB	NA	12.3MB	1KB	1KB	6/303KB	854KB	X:\Airborne_Raw\1128A
Feb 22, 2014	1132A	3BLK29ISS3A/3BLK29HS3A	AQUARIUS	NA	NA	1.62MB	276MB	34.3GB	251/1/326KB	16.1GB	83.7GB	13.4MB	1KB	1KB	432KB	383/506/320/384KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1132A
Feb 22, 2014	1134A	3BLK29MSS3B/3BLK29MRS3B	AQUARIUS	NA	NA	1.06MB	144MB	27.8GB	105/28/1/30/55/44KB	4.99GB	12.6GB	13.4MB	1KB	1KB	102KB	131KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1134A
Feb 23, 2014	1136A	3BLK29HSS4A/3BLK29HBS4A	AQUARIUS	NA	NA	1.37MB	256MB	86.5GB	227/337/61KB	15GB	NA	15.6MB	1KB	1KB	268KB	265/265/520/36KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1136A
Feb 23, 2014	1138A	3BLK29ES4B	AQUARIUS	NA	NA	833KB	196MB	50.4GB	408KB	8.89GB	42.6GB	15.6MB	1KB	1KB	172KB	500KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1138A
Feb 24, 2014	1140A	3BLK29ESS5A/3BLK29GS5A	AQUARIUS	NA	NA	961KB	241MB	53.3GB	401KB	9.99GB	40.8GB	12.1MB	1KB	1KB	367KB	244/264KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1140A
Feb 24, 2014	1142A	3BLK29PS5B	AQUARIUS	NA	NA	2.04MB	228MB	61.7GB	56/490KB	12.4GB	64.2GB	12.1MB	1KB	1KB	709KB	247KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1142A

TRANSFERRED IN FREENAS.

Received from

Name CHRIS JOAQUIN

Position RA

Signature

Received by

Name JOIDA PRIETO

Position SSRS

Signature

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

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6-Dec-15	3058P	1BLK29C340A	pegasus	752	189	5.69	120	9.79	74	7.56	na	15.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	460	108	3.43	115	6.09	48	4.79	na	15.4	1KB	1KB	394/344/58	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.45	430	9.18	206	26.6	192	14.4	na	7.51	1KB	1KB	100/89/95	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDI342A	pegasus	982	276	7.18	177	17	121	9.79	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	0	67	2.7	114	4.63	37	2.77	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	953	217	5.7	143	14.3	na	9.37	na	5.96	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.09	212	9.12	225	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	259	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/318/295/313/146/156	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	551	171	5.23	167	12.9	105	6.2	na	7.02	1KB	1KB	47/394/344/313/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	932	206	6.85	174	13.1	95	9.22	na	7.61	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

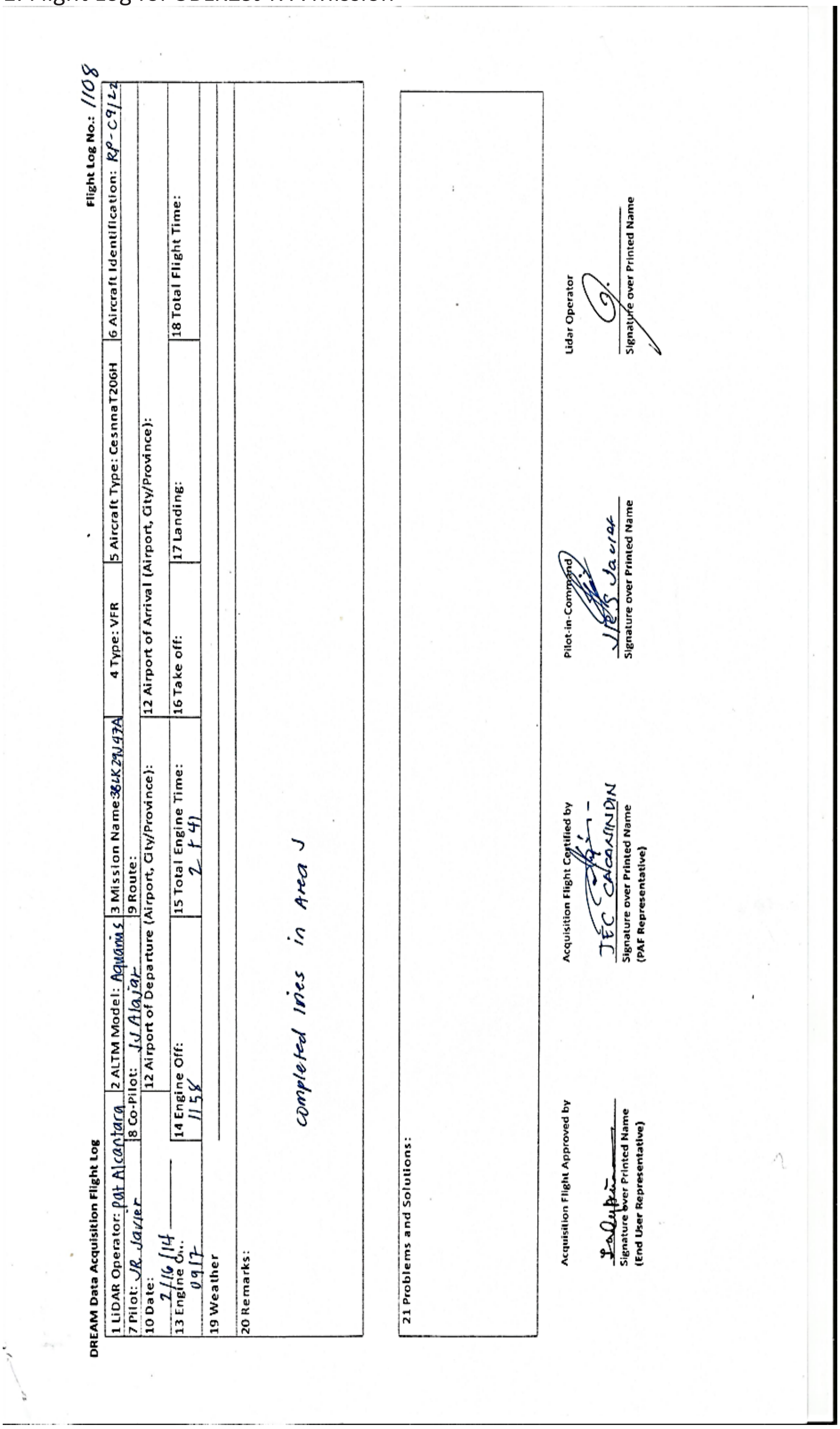
Received by

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

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

Annex 6. Flight Logs

1. Flight Log for 3BLK29J47A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1108

1 LiDAR Operator: Pat Alcantara	2 ALTM Model: Aquarius	3 Mission Name: 3BLK29J47A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajar	9 Route:			
10 Date: 2/16/14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0917	14 Engine Off: 1158	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed lines in Area J					
21 Problems and Solutions:					

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

JEC CALAMINDIN

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

JRS Javier

Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.1. Flight Log for 3BLK29J47A Mission

2. Flight Log for 3BLK29K+JS47B Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1110

1 LiDAR Operator: Larah Paragas	2 ALTM Model: Aqua	3 Mission Name: 3BLK29K47B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajar	9 Route:			
10 Date: 2/16/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1717	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

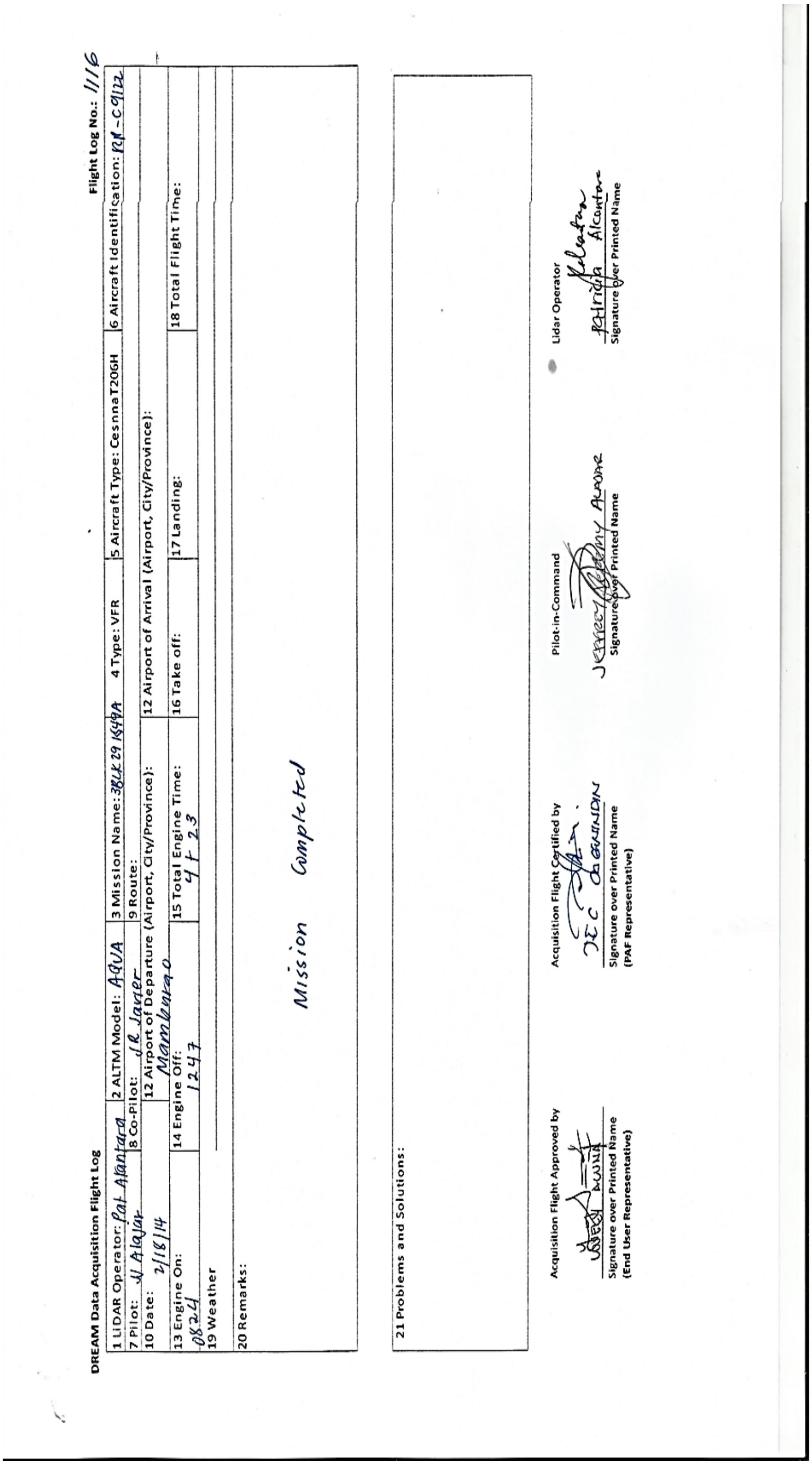
Completed lines in J and K

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	JE C GALINDIN Signature over Printed Name (PAF Representative)	JRS Javier Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for 3BLK29K+JS47B Mission

3. Flight Log for 3BLK29KS49A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1116

1 LiDAR Operator: Pat Alcantara	2 ALTM Model: AQUA	3 Mission Name: 3BLK29KS49A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JJ Alajar	8 Co-Pilot: JR Jayer	9 Route:			
10 Date: 2/18/14	12 Airport of Departure (Airport, City/Province): Mambajao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0824	14 Engine Off: 1247	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

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

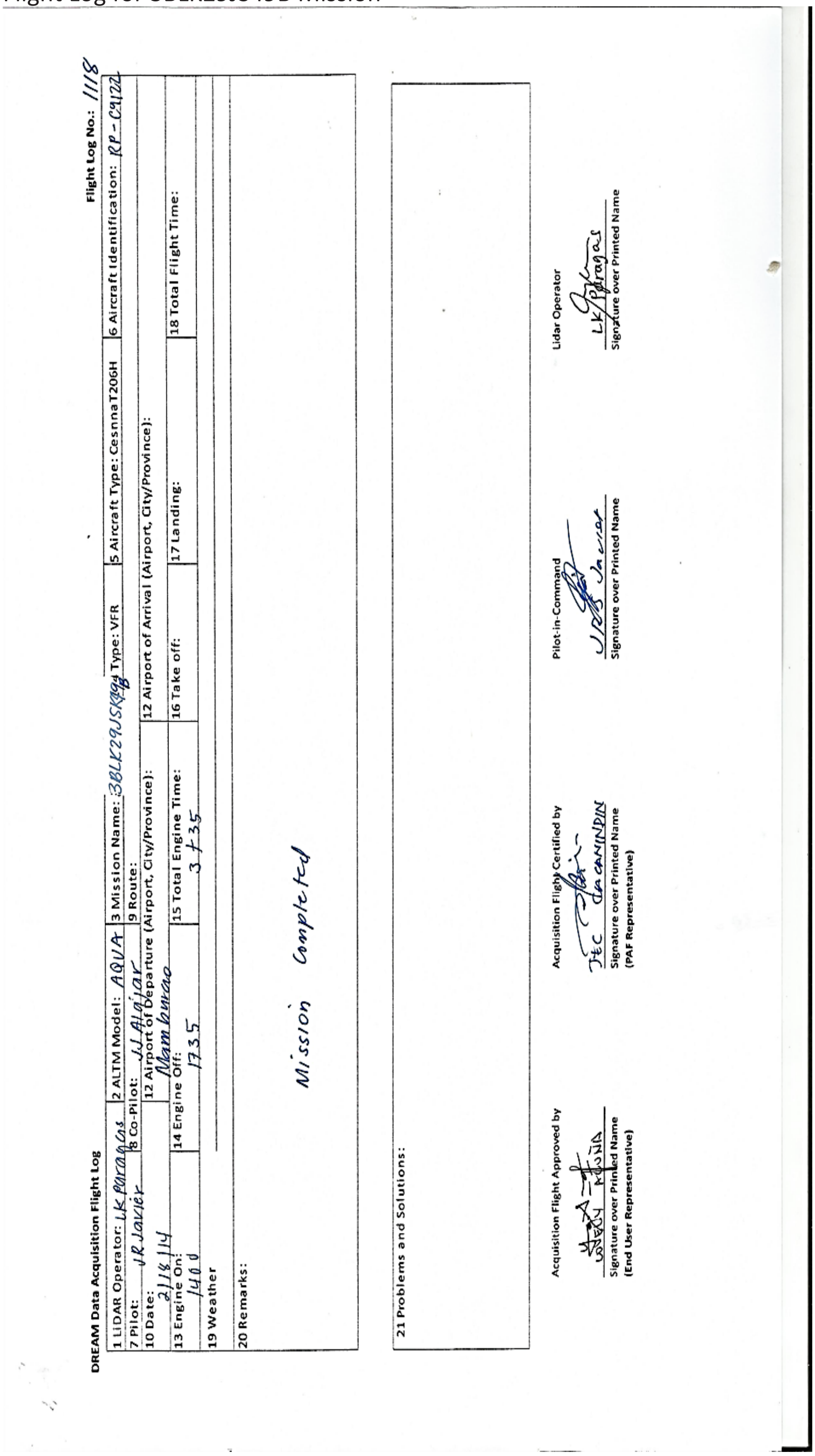
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Jeffrey Alajar
Signature over Printed Name

Lidar Operator
Patricia Alcantara
Signature over Printed Name

Figure A-6.3. Flight Log for 3BLK29KS49A Mission

4. Flight Log for 3BLK29JS49B Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1118

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29JS49B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajar	9 Route:			
10 Date: 2/18/14	12 Airport of Departure (Airport, City/Province): Mambucao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1400	14 Engine Off: 1735	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission Completed

21 Problems and Solutions:

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

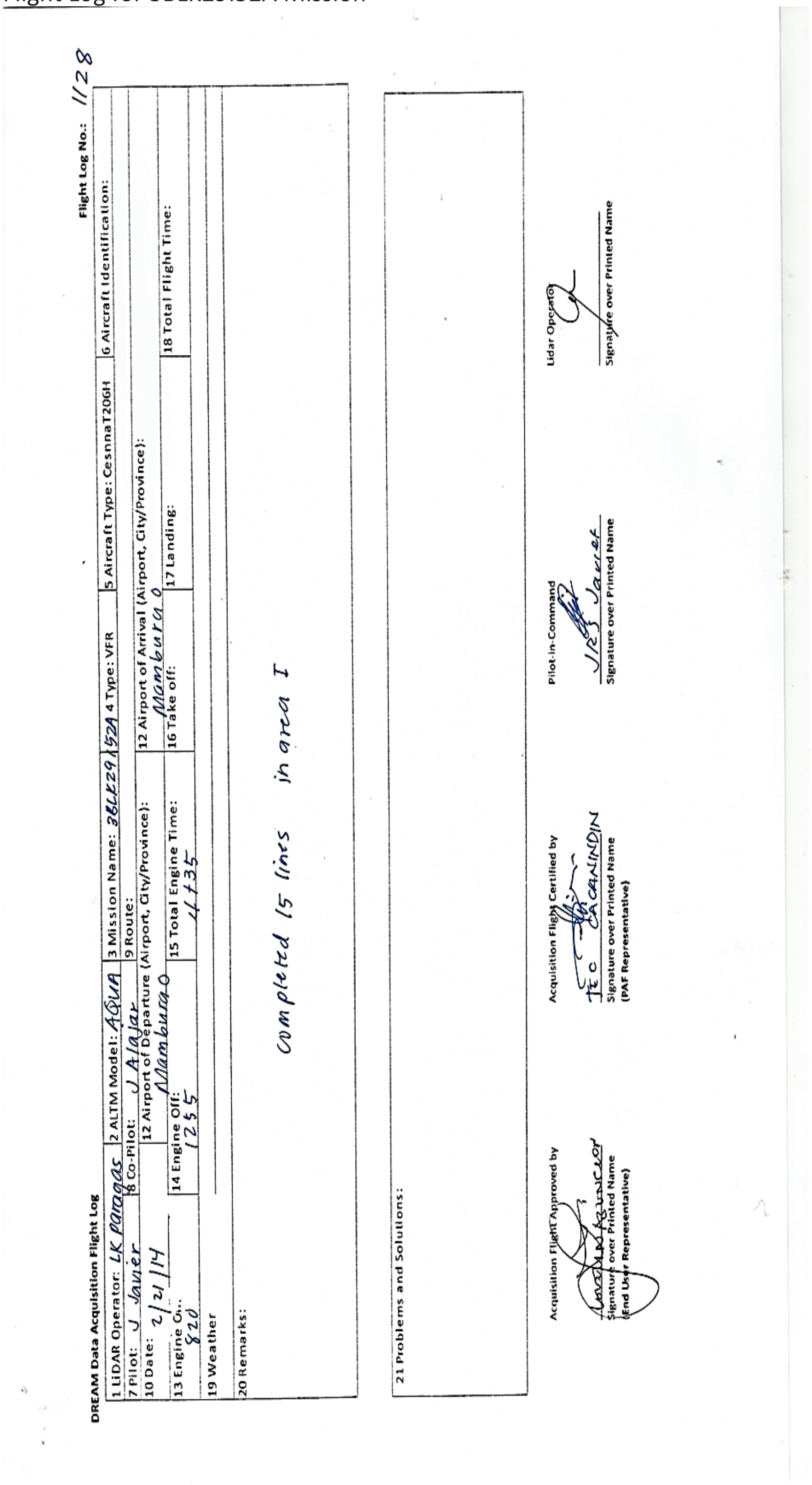
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — JR Javier — Signature over Printed Name

Lidar Operator — LK Paragas — Signature over Printed Name

Figure A-6.4. Flight Log for 3BLK29JS49B Mission

5. Flight Log for 3BLK29I52A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1128

1 LIDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29I52A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/21/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province): Mamburao		
13 Engine On: 820	14 Engine Off: 1255	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed 15 lines in area I					

21 Problems and Solutions:

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

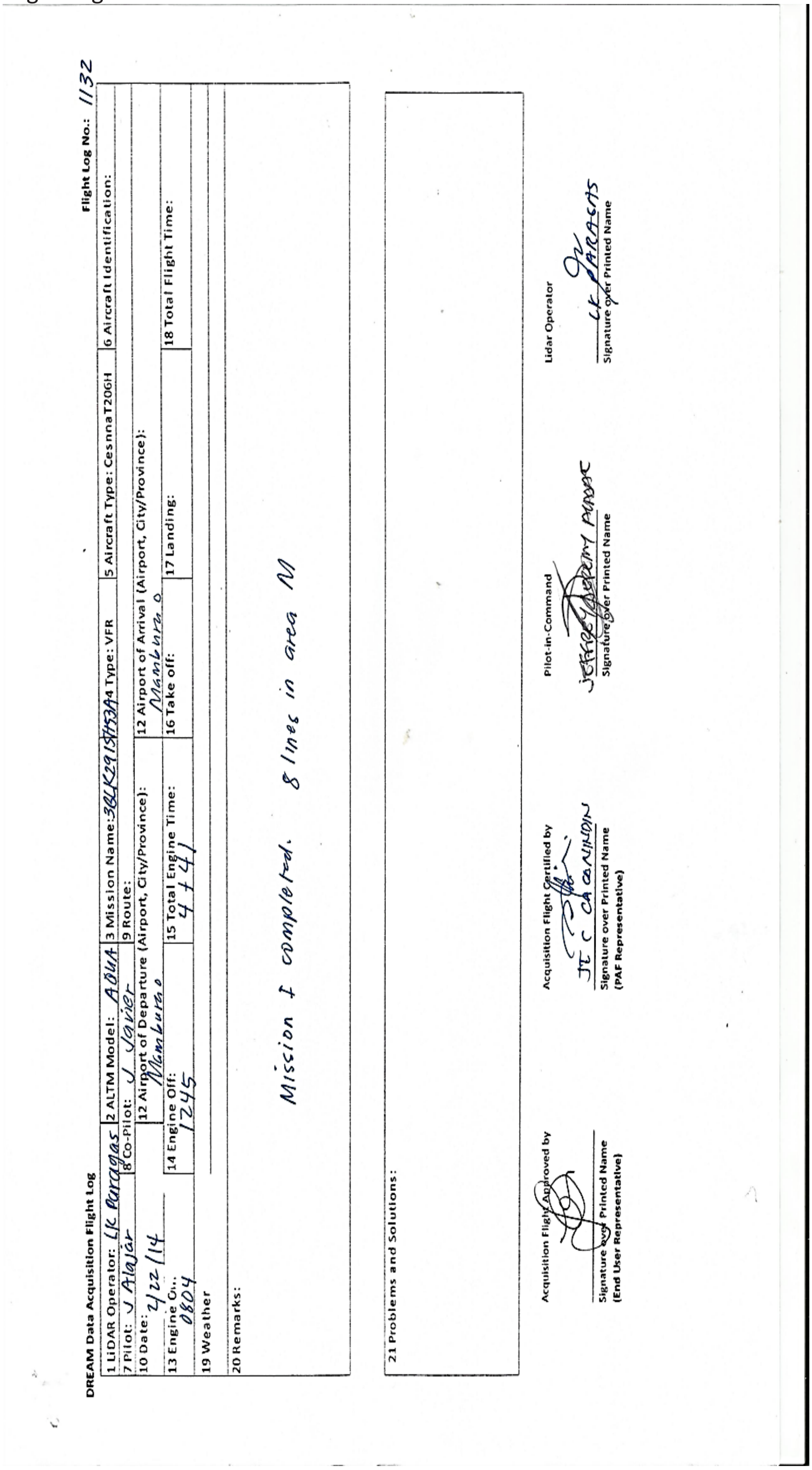
Acquisition Flight Certified by
CACANINDIN
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.5. Flight Log for 3BLK29I52A Mission

6. Flight Log for 3BLK29IS+H53A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1132

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29IS+H53A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/22/14	12 Airport of Departure (Airport, City/Province): Mambureo		12 Airport of Arrival (Airport, City/Province): Mambureo		
13 Engine On: 0804	14 Engine Off: 1245	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 1 completed. 8 lines in area M

21 Problems and Solutions:

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

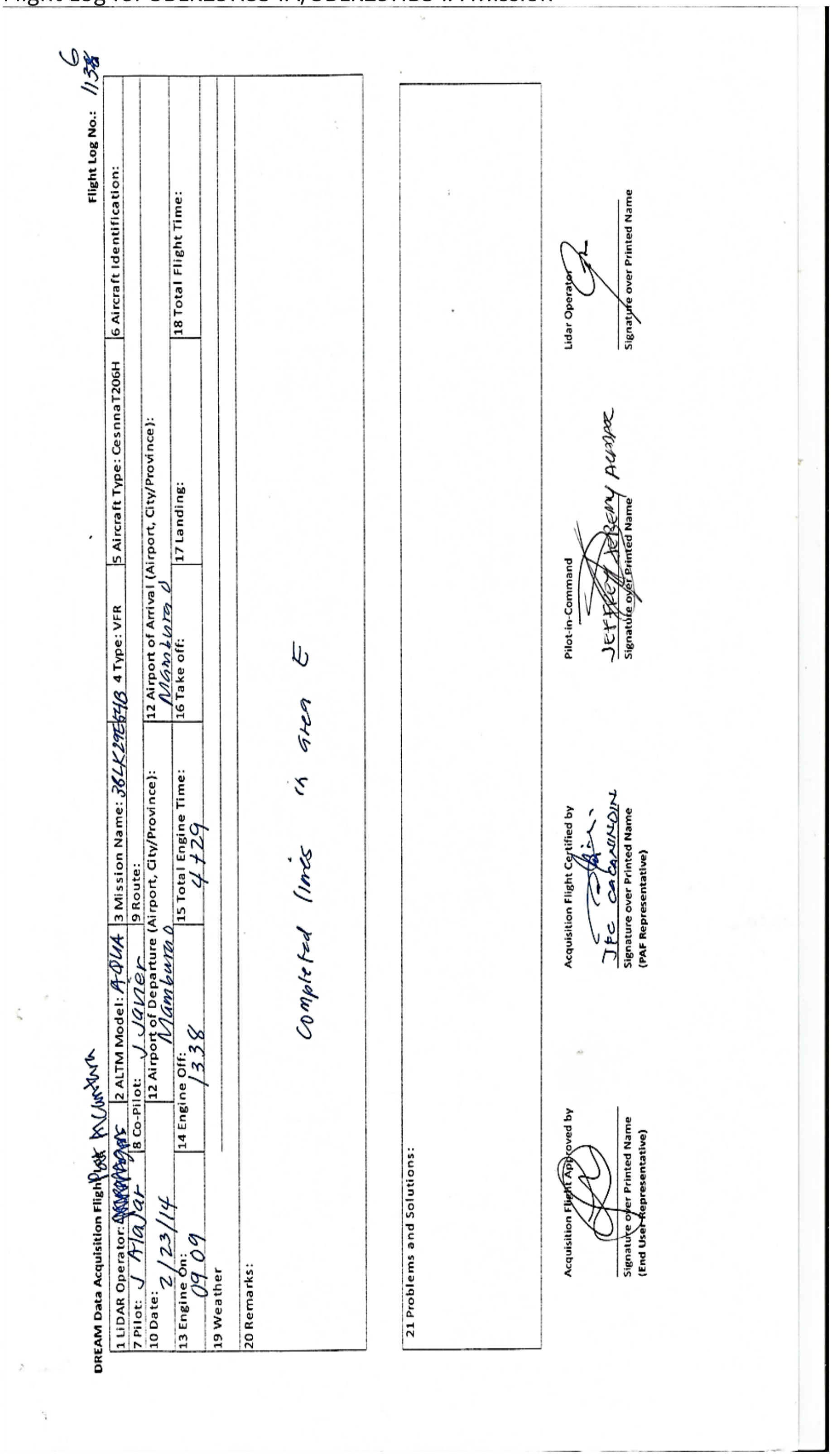
Acquisition Flight Certified by — JE C CACANINDIN — Signature over Printed Name (PAF Representative)

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

Lidar Operator — LK PARAGAS — Signature over Printed Name

Figure A-6.6. Flight Log for 3BLK29IS+H53A Mission

7. Flight Log for 3BLK29HS54A/3BLK29HB54A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1136

1 LiDAR Operator: [illegible]	2 ALTM Model: AQUA	3 Mission Name: 3BLK29HB54B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/23/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province): Mamburao		
13 Engine On: 0909	14 Engine Off: 1338	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed lines in area E

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

JPC Cabangindin

Signature over Printed Name (PAF Representative)

Pilot-in-Command

Jeffrey Jeremy Alajar

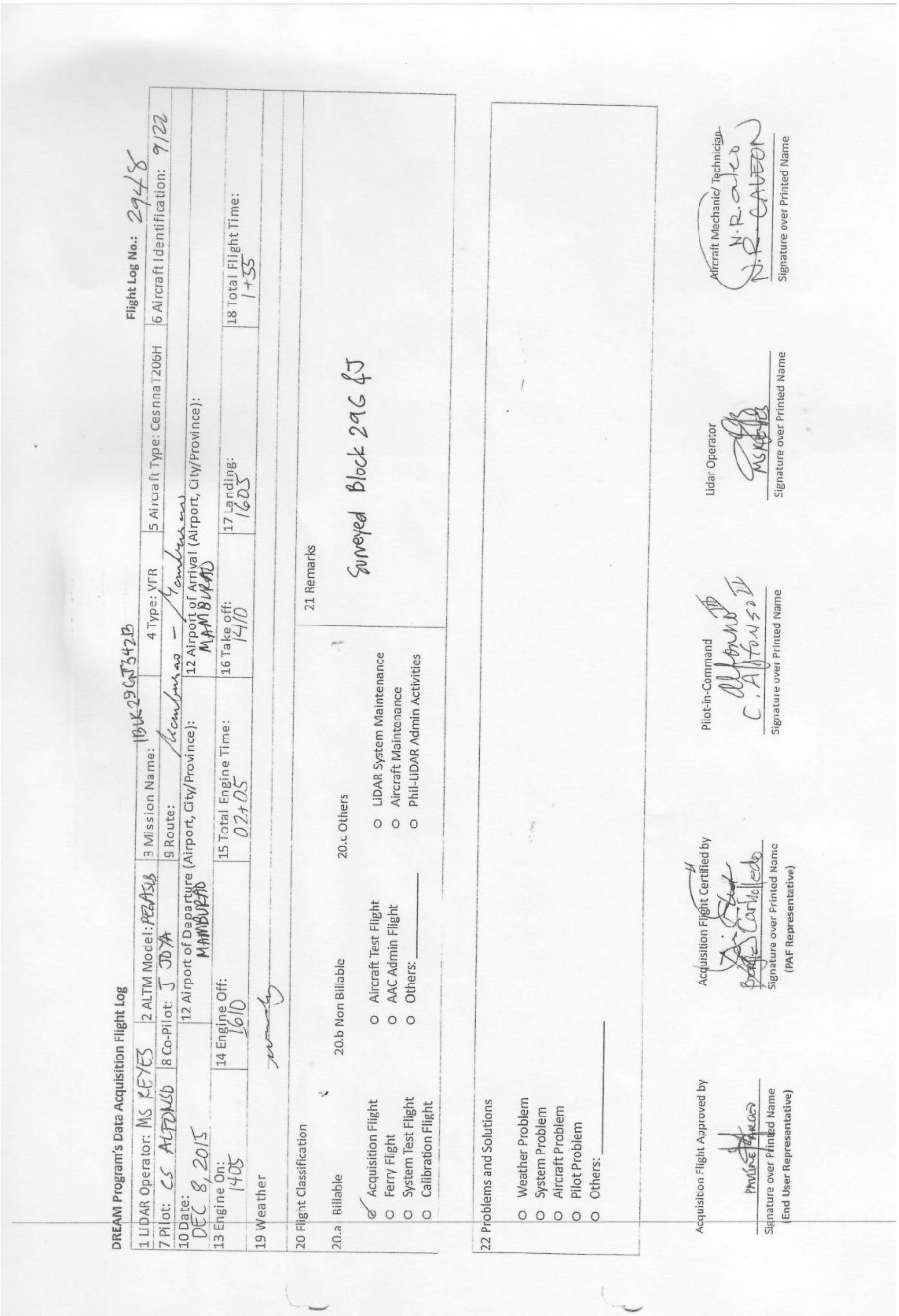
Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.7. Flight Log for 3BLK29HS54A/3BLK29HB54A Mission

8. Flight Log for 1BLK29GJ342B Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2948

1 LiDAR Operator: MS REYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29GJ342B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOTA	9 Route: Mambusao – Mambusao			
10 Date: DEC 8, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 1405	14 Engine Off: 1610	15 Total Engine Time: 02+05	16 Take off: 1410	17 Landing: 1605	18 Total Flight Time: 1+55
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed Block 29G & J

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

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

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

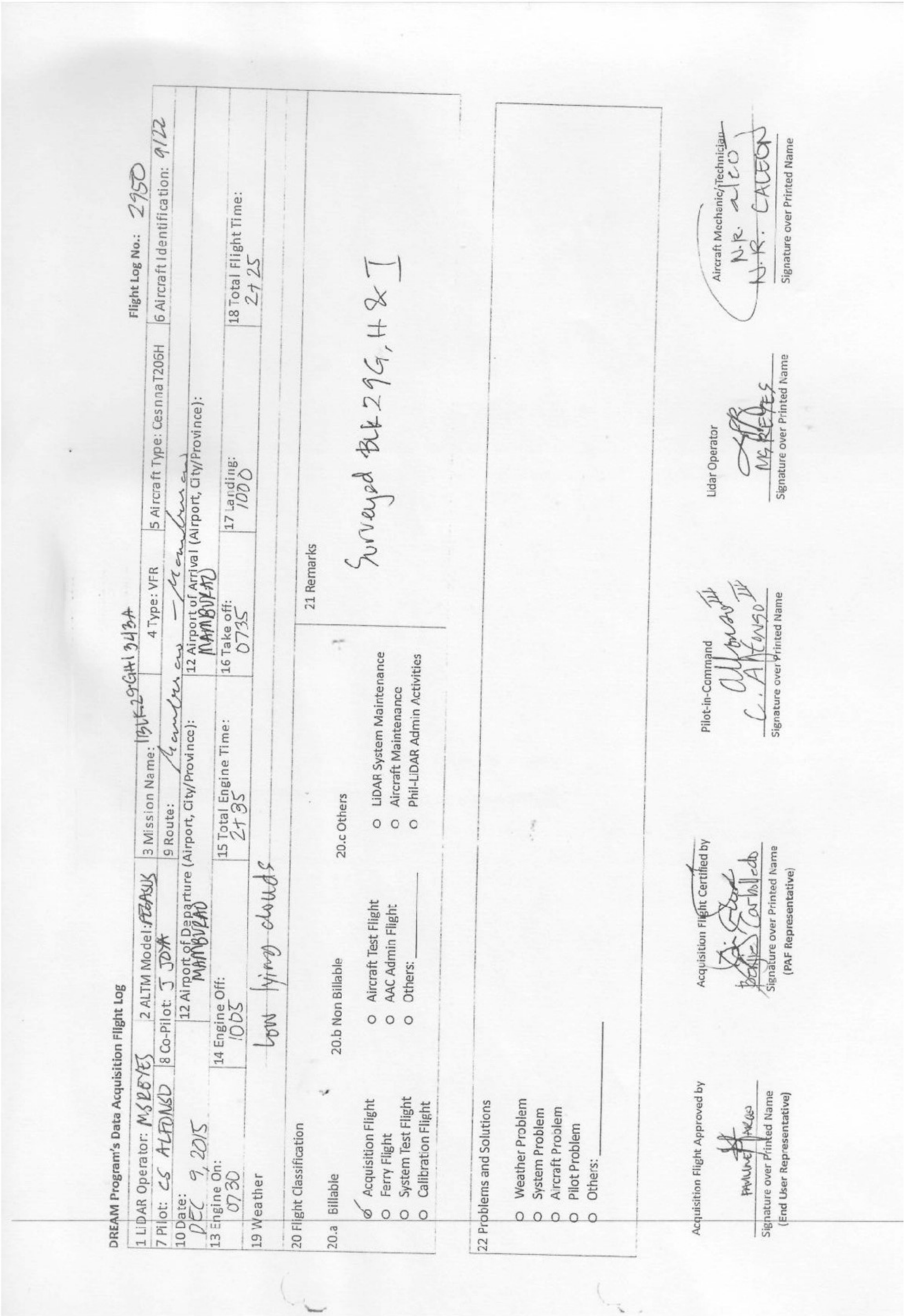
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

Lidar Operator: MS Reyes — Signature over Printed Name

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

Figure A-6.8. Flight Log for 1BLK29GJ342B Mission

9. Flight Log for 1BLK29GHI343A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2950

1 LiDAR Operator: MS REYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29GHI343A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOA	9 Route: Mambucal – Mambucal			
10 Date: DEC 9, 2015	12 Airport of Departure (Airport, City/Province): MAMBUCAL		12 Airport of Arrival (Airport, City/Province): MAMBUCAL		
13 Engine On: 0730	14 Engine Off: 1005	15 Total Engine Time: 2+35	16 Take off: 0735	17 Landing: 1000	18 Total Flight Time: 2+25
19 Weather: low lying clouds					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29G, H & I

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

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

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

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

Lidar Operator: MS REYES — Signature over Printed Name

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

Figure A-6.9. Flight Log for 1BLK29GHI343A Mission

Annex 7. Flight Status Report

IBOD FLOODPLAIN
February 16-23, 2014; December 8-9, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1108A	BLK29J	3BLK29J47A	PY ALCANTARA	16-Feb-14	Completed 6 lines of Area J.
1110A	BLK29 K & BLK29J	3BLK29K+JS47B	L ASUNCION/ LK PARAGAS	16-Feb-14	Completed 4 lines of Area K and 10 lines of J.
1116A	BLK29K	3BLK29KS49A	PY ALCANTARA	18-Feb-14	Completed Area K
1118A	BLK29J	3BLK29JS49B	LK PARAGAS	18-Feb-14	Completed Area J.
1128A	BLK29I	3BLK29I52A	LK PARAGAS	21-Feb-14	Completed 15 lines in area I.
1132A	BLK29I & BLK29H	3BLK29IS+H53A	LK PARAGAS	22-Feb-14	Completed area I and 8 lines in area H.
1136A	BLK29H	3BLK29HS54A	PY ALCANTARA	23-Feb-14	Mission completed.
3068P	BLK29G & 29J	1BLK29GJ342B	MS REYES	8-DEC-15	Surveyed BLK29G & J
3070P	BLK29G, 29H & 29I	1BLK29GHI343A	MS REYES	9-DEC-15	Surveyed BLK29G, H & I

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT NO.	1108A
AREA:	BLK29J
MISSION NAME:	3BLK29J47A
PARAMETERS:	Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

Figure A-7.1. Swath for Flight No. 1108A

FLIGHT NO. 1110A
AREA: BLK29K and BLK29J
MISSION NAME: 3BLK29K+JS47B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

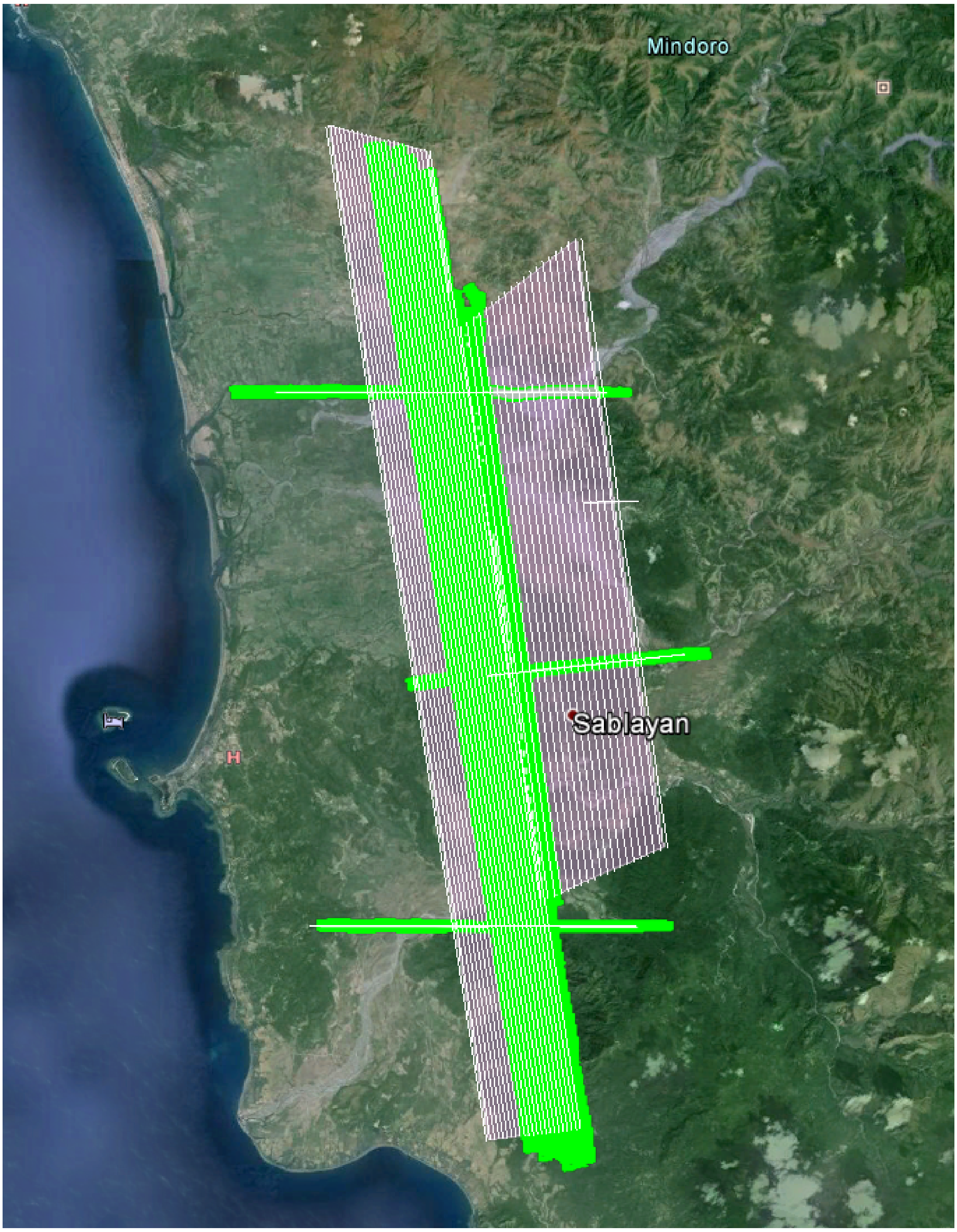


Figure A-7.2. Swath for Flight No. 1110A

FLIGHT NO. 1116A
AREA: BLK29K
MISSION NAME: 3BLK29KS49A
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

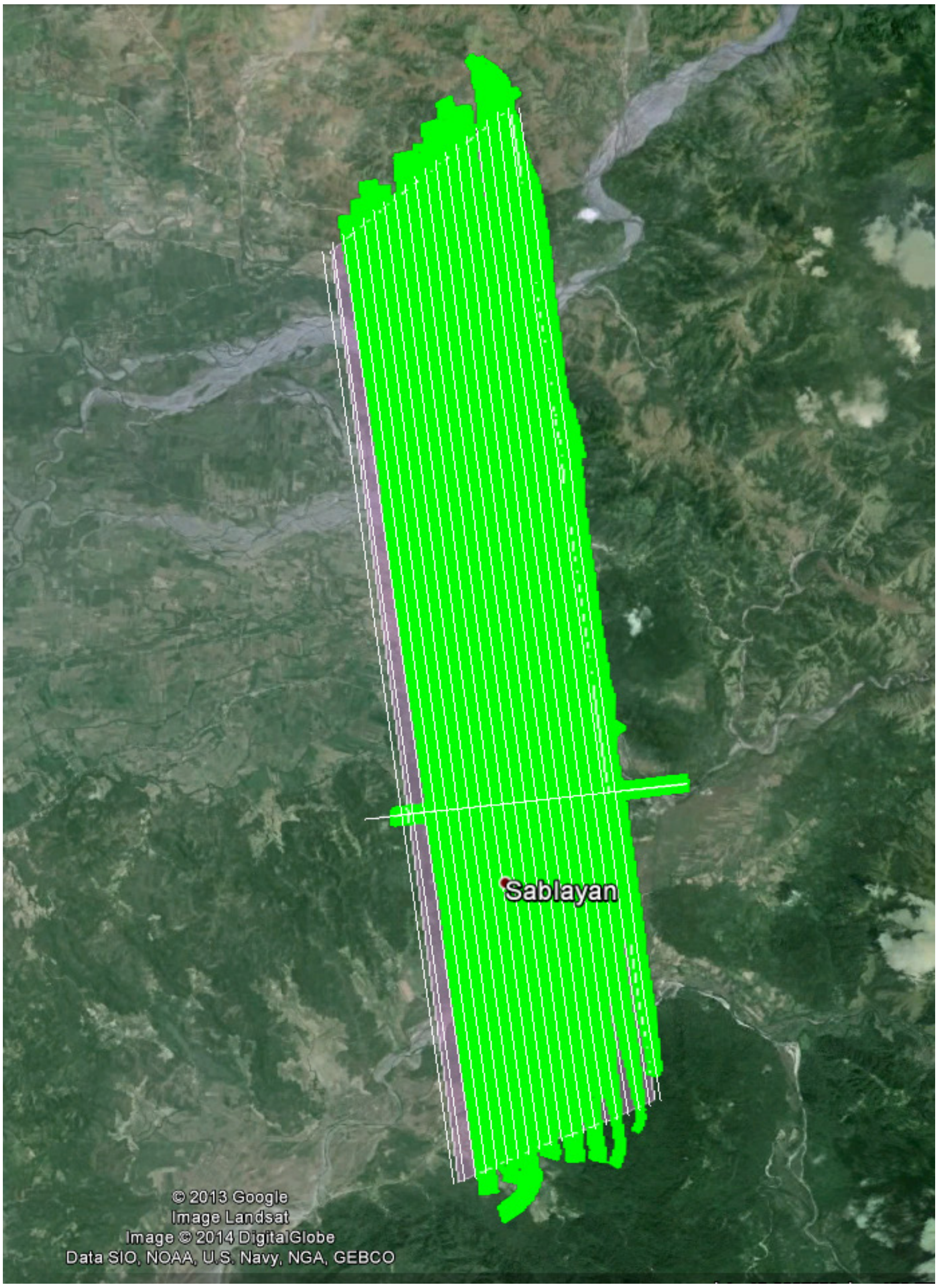


Figure A-7.4. Swath for Flight No. 1116A

FLIGHT NO. 1118A
AREA: BLK29J
MISSION NAME: 3BLK29JS49B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

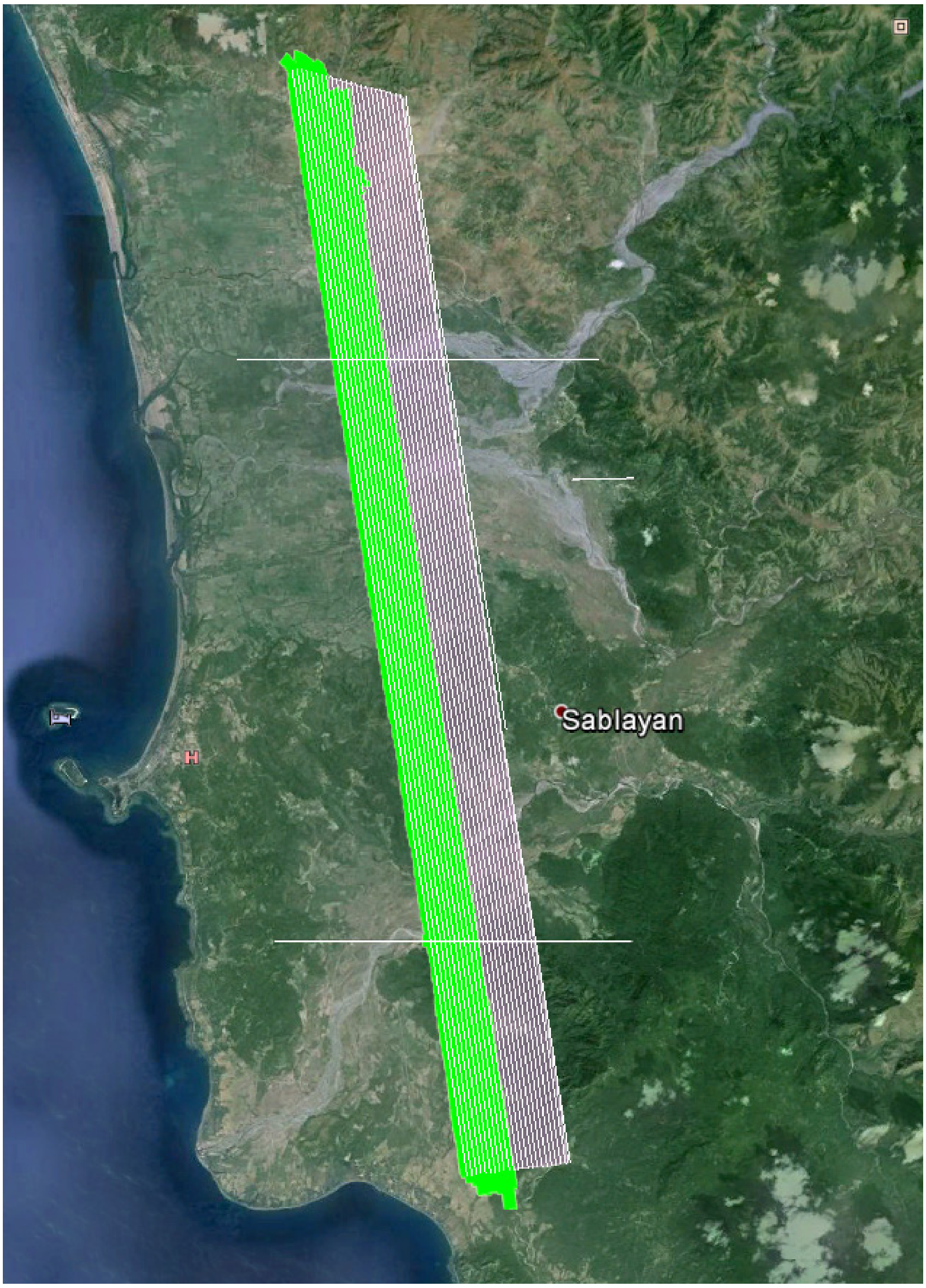


Figure A-7.5. Swath for Flight No. 1118A

FLIGHT NO. 1128A
AREA: BLK29I
MISSION NAME: 3BLK29I52A
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

Figure A-7.6. Swath for Flight No. 1128A

FLIGHT NO. 1132A
AREA: BLK29I AND BLK29H
MISSION NAME: 3BLK29IS+H53A
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

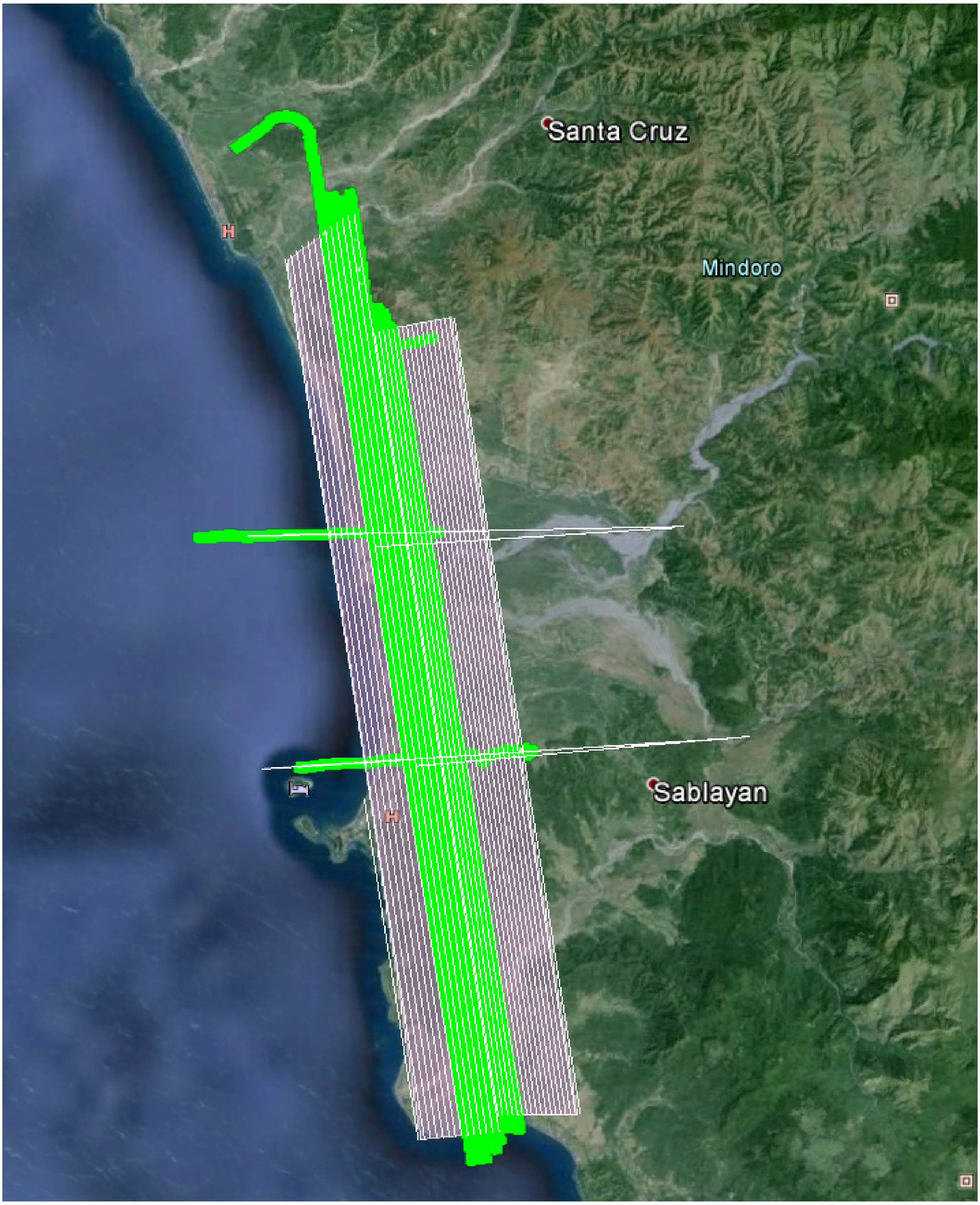


Figure A-7.7. Swath for Flight No. 1132A

FLIGHT NO. 1136A
AREA: BLK29H
MISSION NAME: 3BLK29HS54A
PARAMETERS Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

Figure A-7.8. Swath for Flight No. 1136A

FLIGHT NO: 3068P
AREA: BLK29G & 29J
MISSION NAME: 1BLK29GJ342B
PARAMETERS: Alt: 1100 m Scan Freq: 30 Hz Scan Angle: 25 deg

SURVEY COVERAGE:

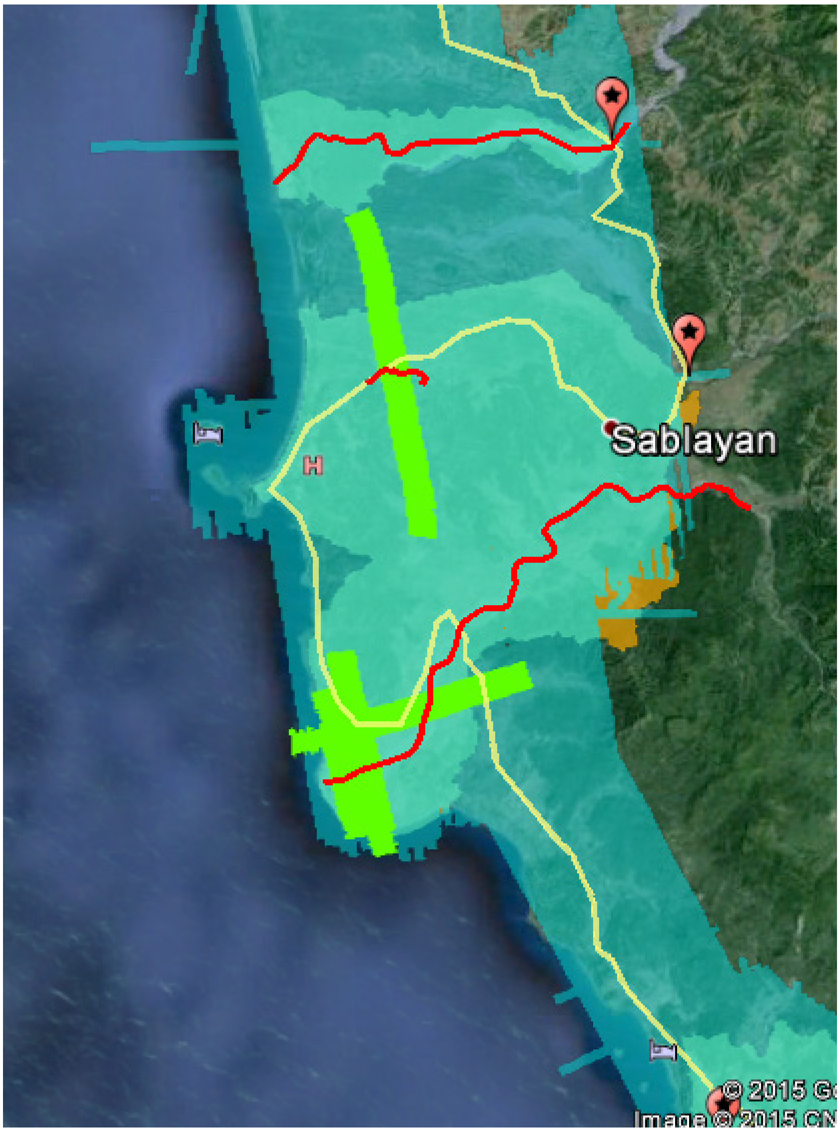


Figure A-7.9. Swath for Flight No. 3068P

FLIGHT NO.:	3070P
AREA:	BLK29G, 29H & 29I
MISSION NAME:	1BLK29GHI343A
PARAMETERS:	Alt: 1100 m Scan Freq: 30 Hz Scan Angle: 25 deg

SURVEY COVERAGE:

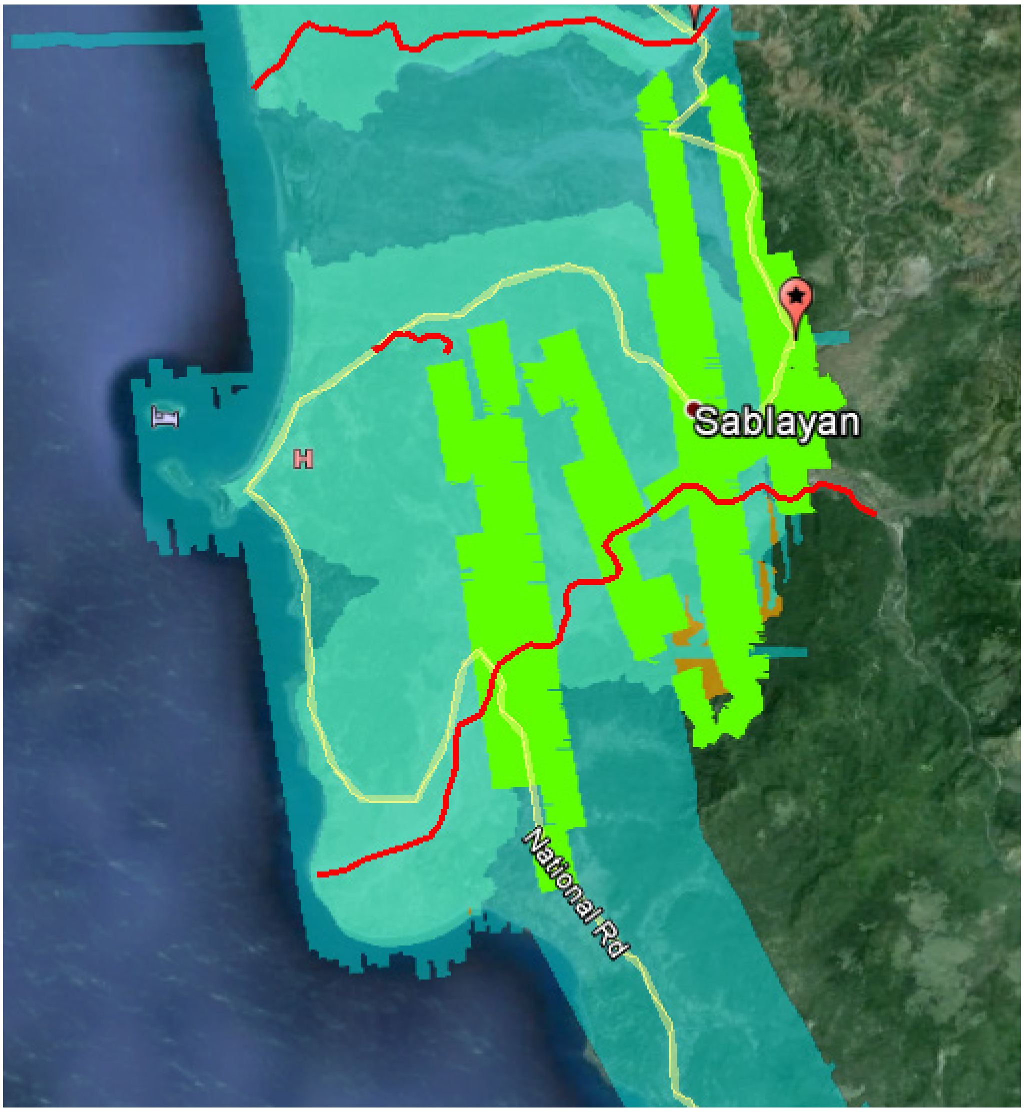


Figure A-7.10. Swath for Flight No. 3070P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk29H

Flight Area	Occidental Mindoro
Mission Name	**Blk29H**
Inclusive Flights	1136A
Range data size	15 GB
Base data size	15.8 MB
POS	256 MB
Image	86.5 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000355
IMU attitude correction stdev (<0.001deg)	0.074523
GPS position stdev (<0.01m)	0.0409
Minimum % overlap (>25)	37.19%
Ave point cloud density per sq.m. (>2.0)	2.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	174
Maximum Height	613.49 m
Minimum Height	39.16 m
Classification (# of points)	
Ground	53,263,528
Low vegetation	57,288,707
Medium vegetation	68,165,762
High vegetation	30,718,677
Building	1,782,193
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Celina Rosete, Jovy Narisma

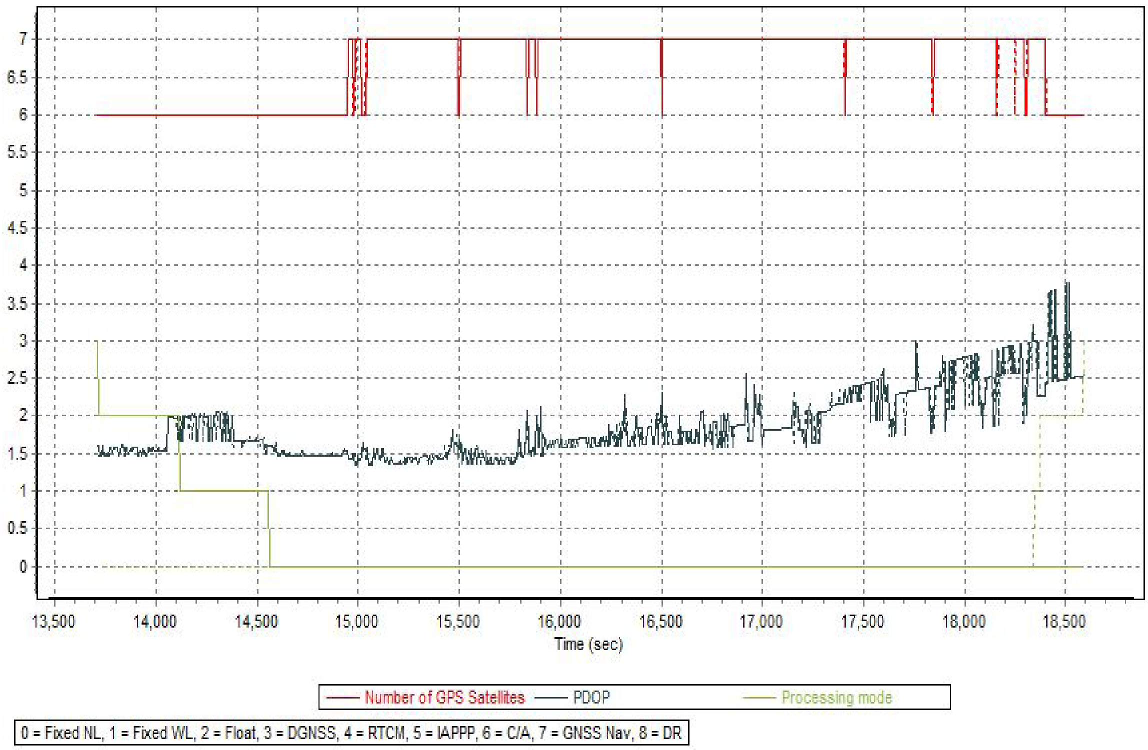


Figure A-8.1 Solution Status

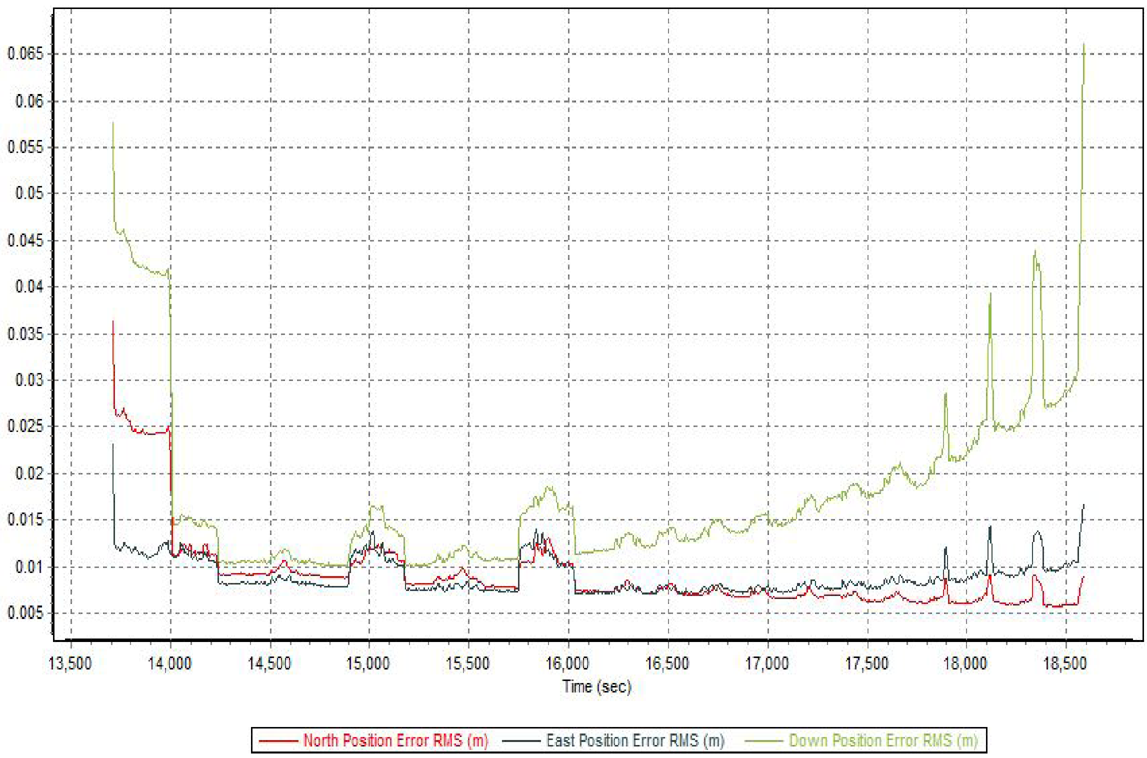


Figure A-8.2 Smoothed Performance Metrics Parameters

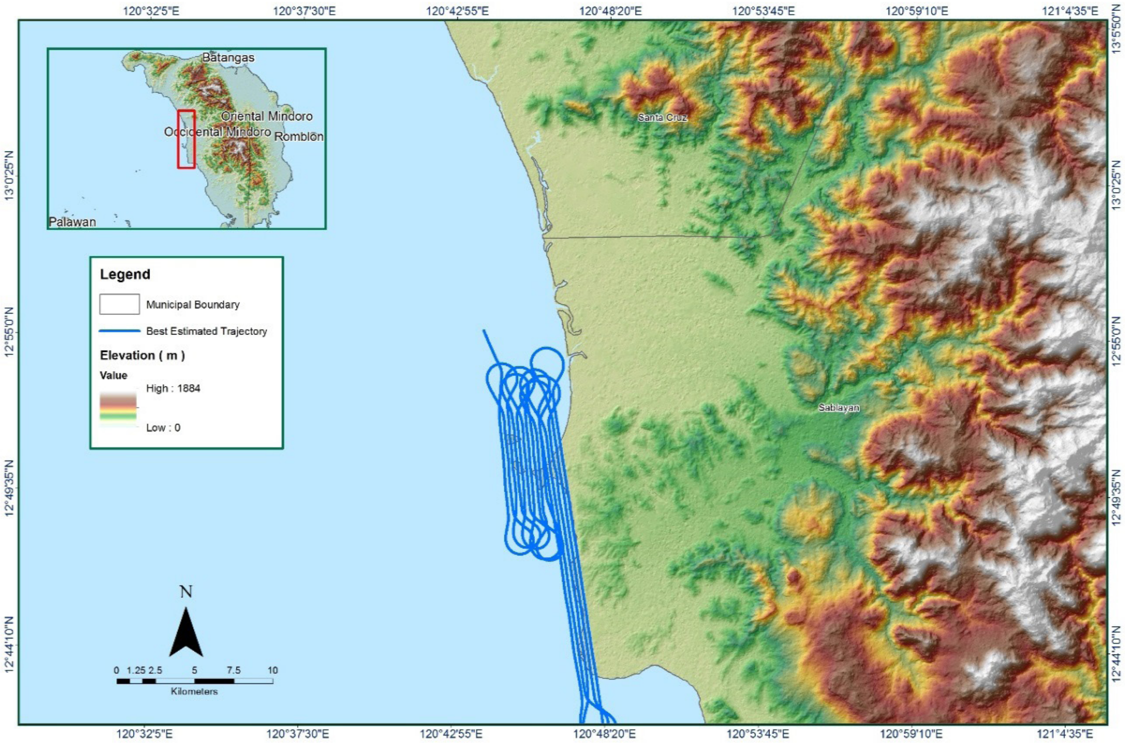


Figure A-8.3 Best Estimated Trajectory

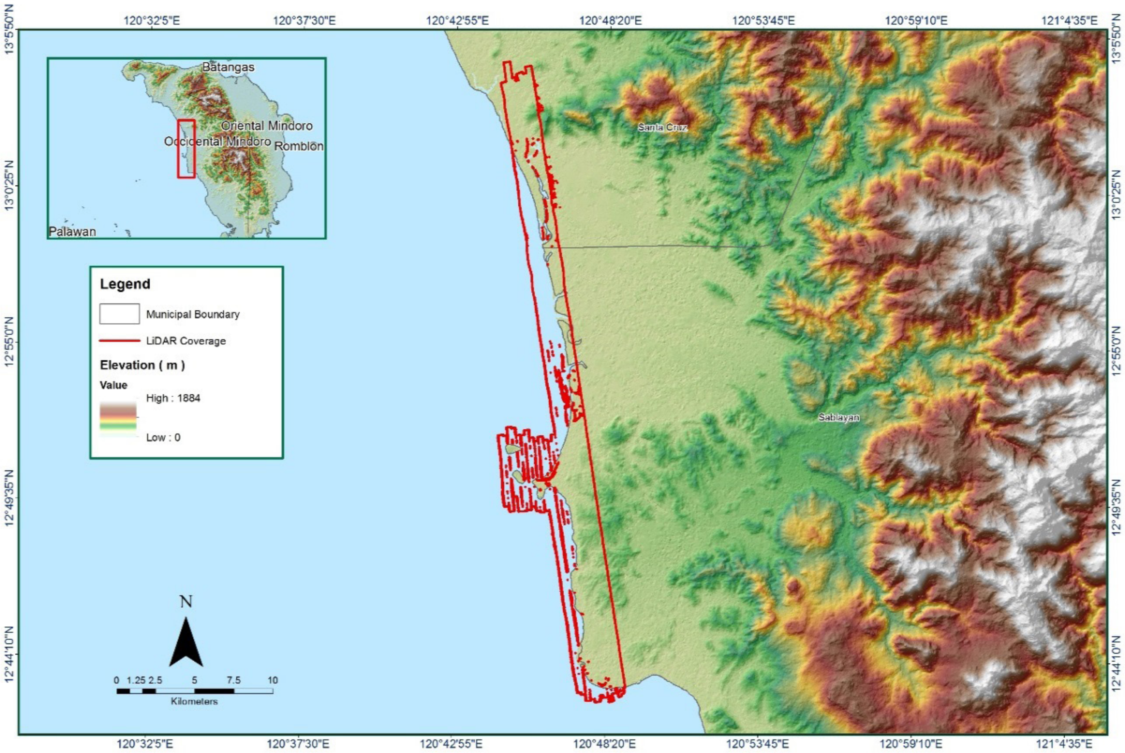


Figure A-8.4. Coverage of LiDAR data

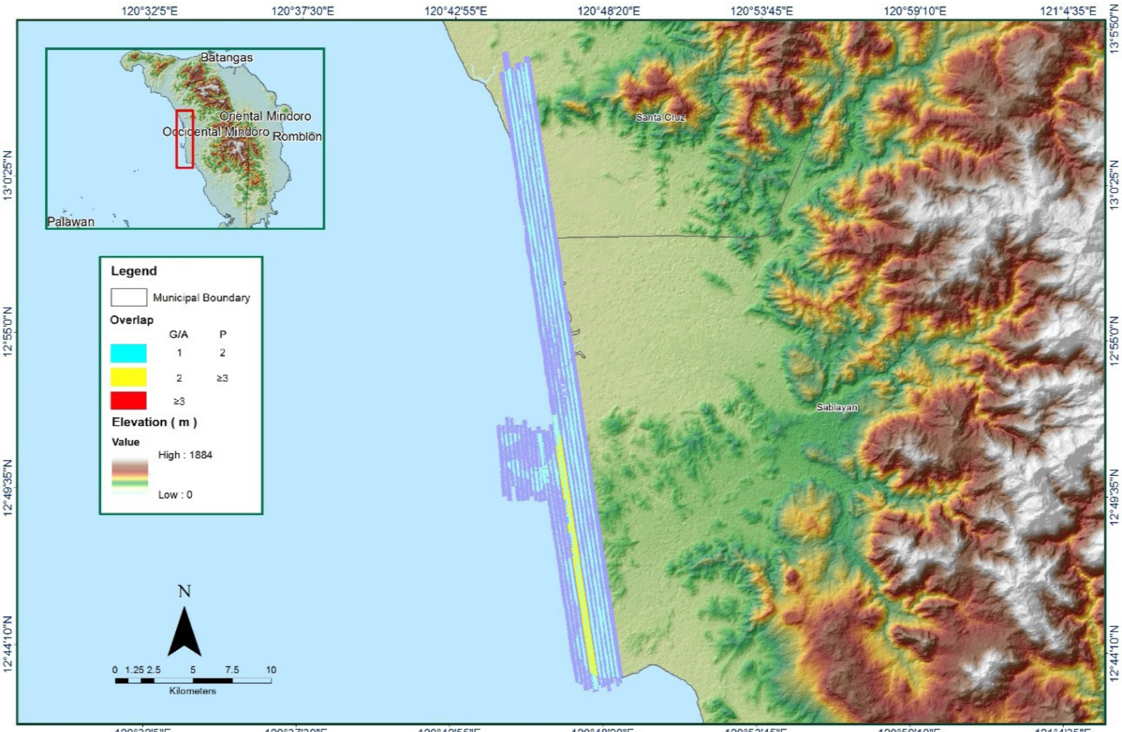


Figure A-8.5. Image of data overlap

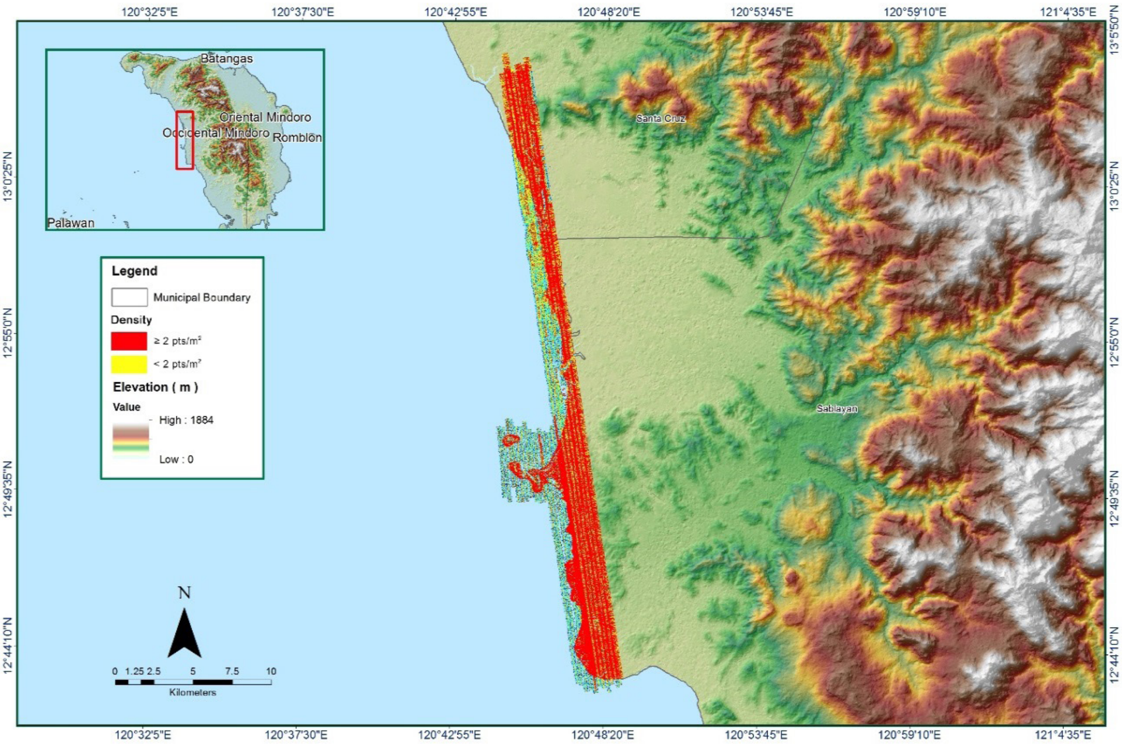


Figure A-8.6 Density of merged LiDAR data

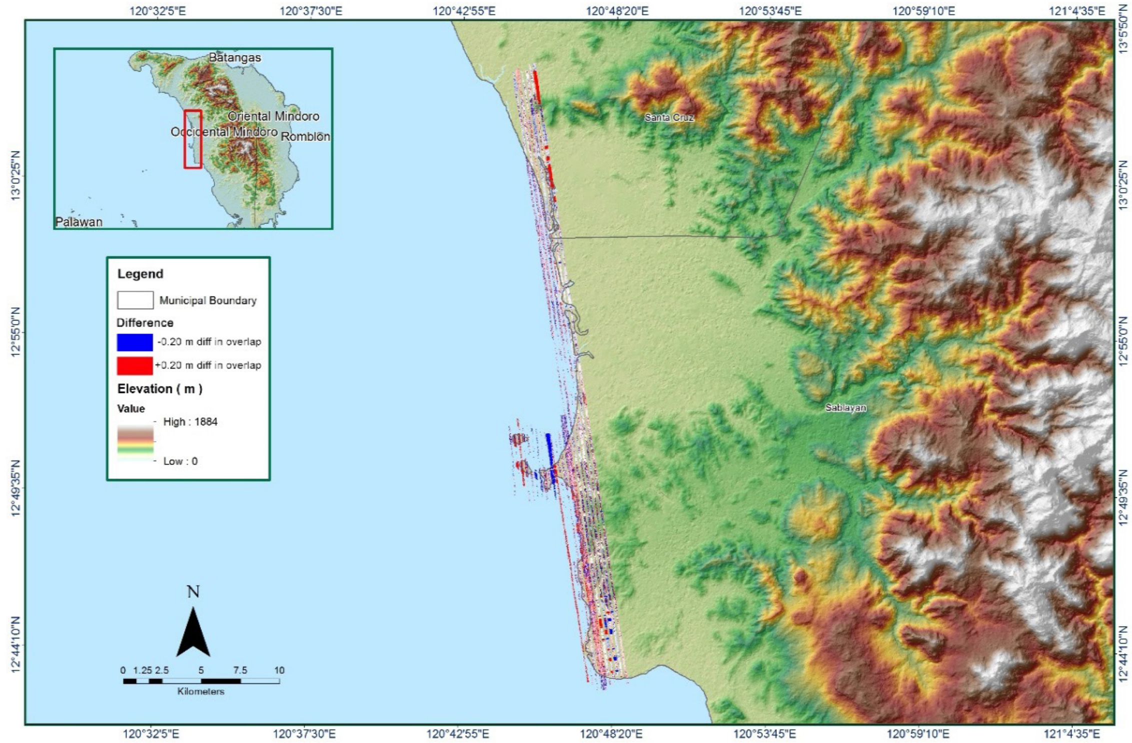


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk29HI_supplement

Flight Area	Occidental Mindoro
Mission Name	**Blk29HI_supplement**
Inclusive Flights	1132A
Range data size	16.1 GB
Base data size	13.4 MB
POS	276 MB
Image	34.3 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000400
IMU attitude correction stdev (<0.001deg)	0.005740
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	55.11%
Ave point cloud density per sq.m. (>2.0)	3.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	175
Maximum Height	308.28 m
Minimum Height	43.14 m
Classification (# of points)	
Ground	75,373,003
Low vegetation	106,983,904
Medium vegetation	125,916,220
High vegetation	46,925,200
Building	1,788,962
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Engr. Jeffrey Delica

Figure A-8.8. Solution Status

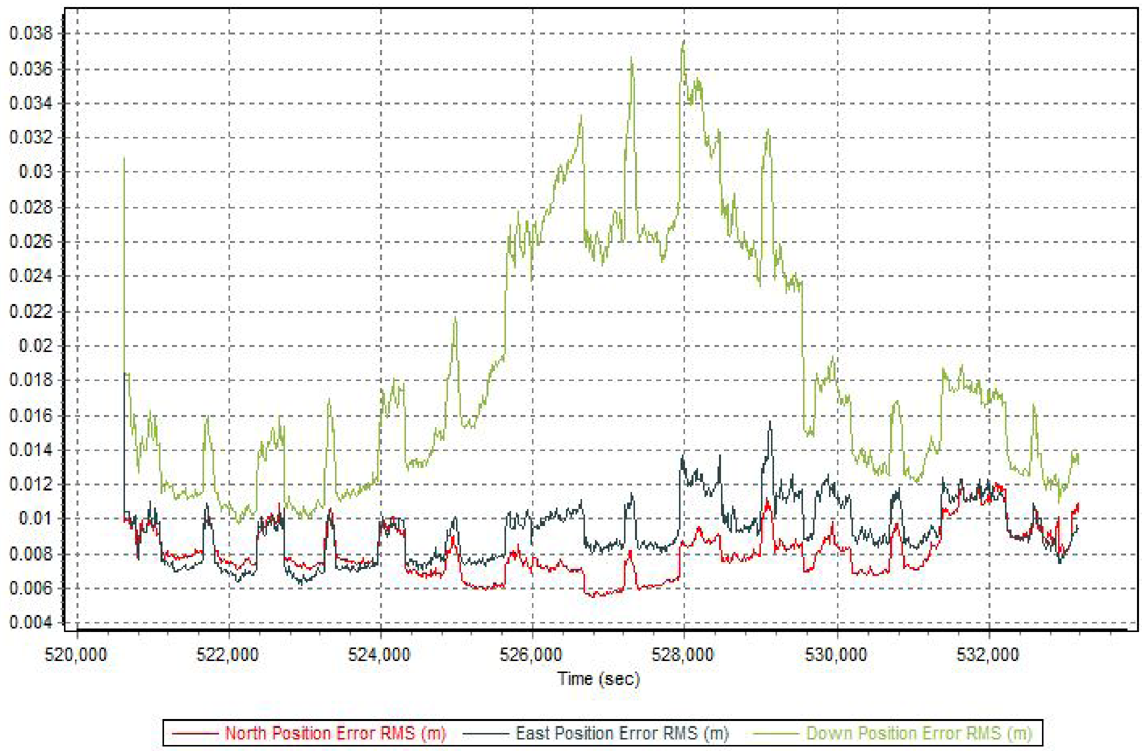


Figure A-8.9. Smoothed Performance Metrics Parameters

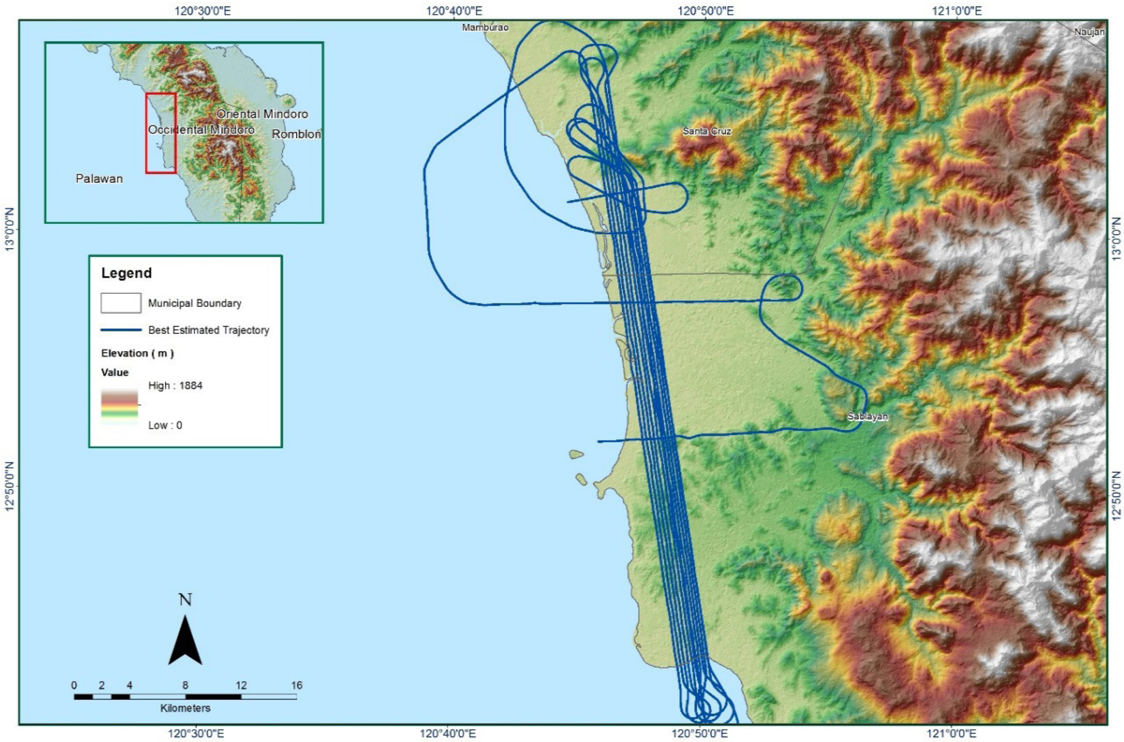


Figure A-8.10. Best Estimated Trajectory

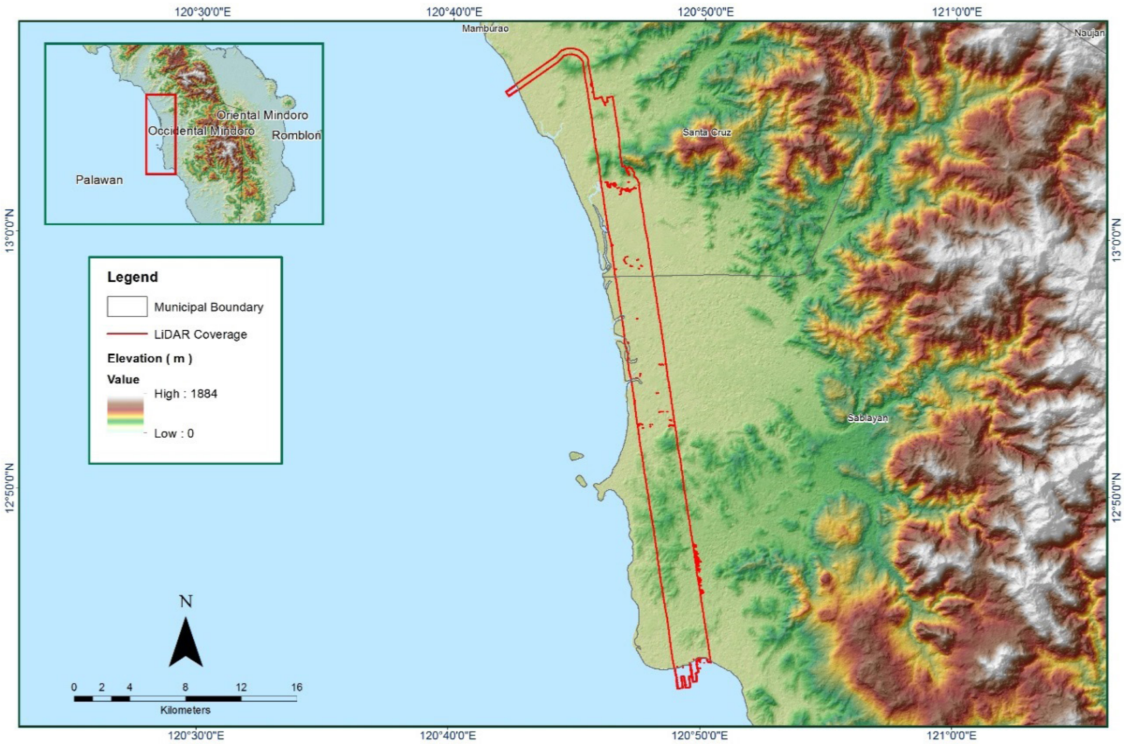


Figure A-8.11. Coverage of LiDAR data

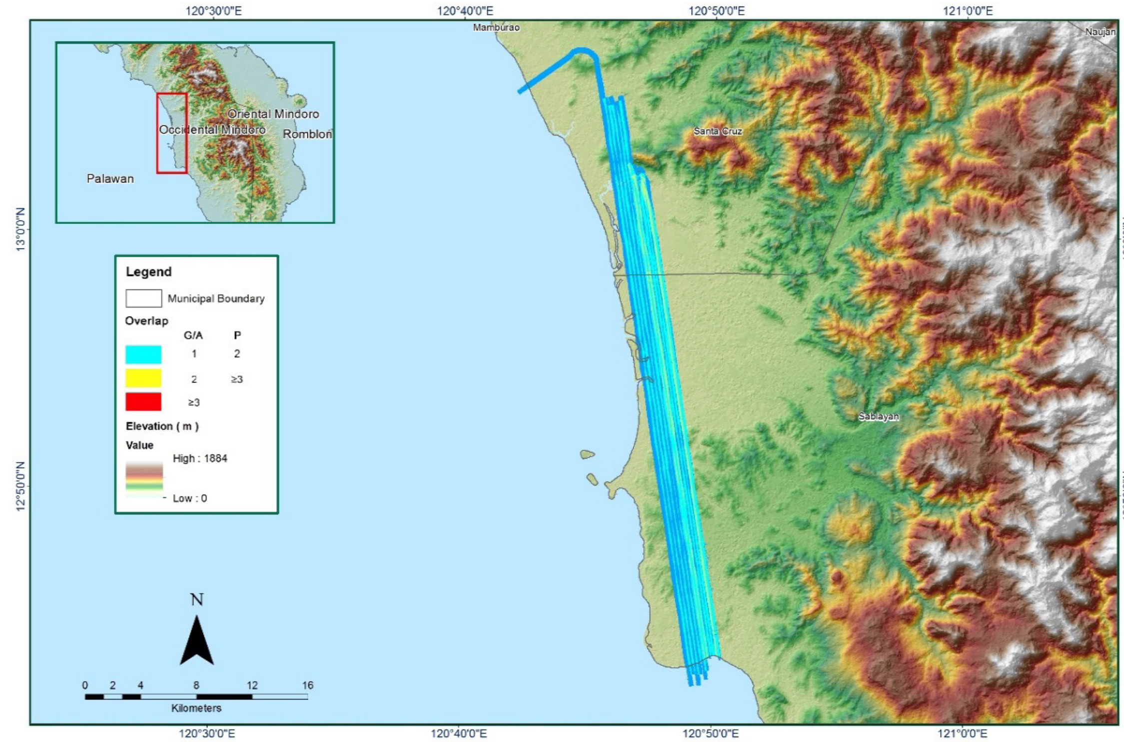


Figure A-8.12. Image of data overlap

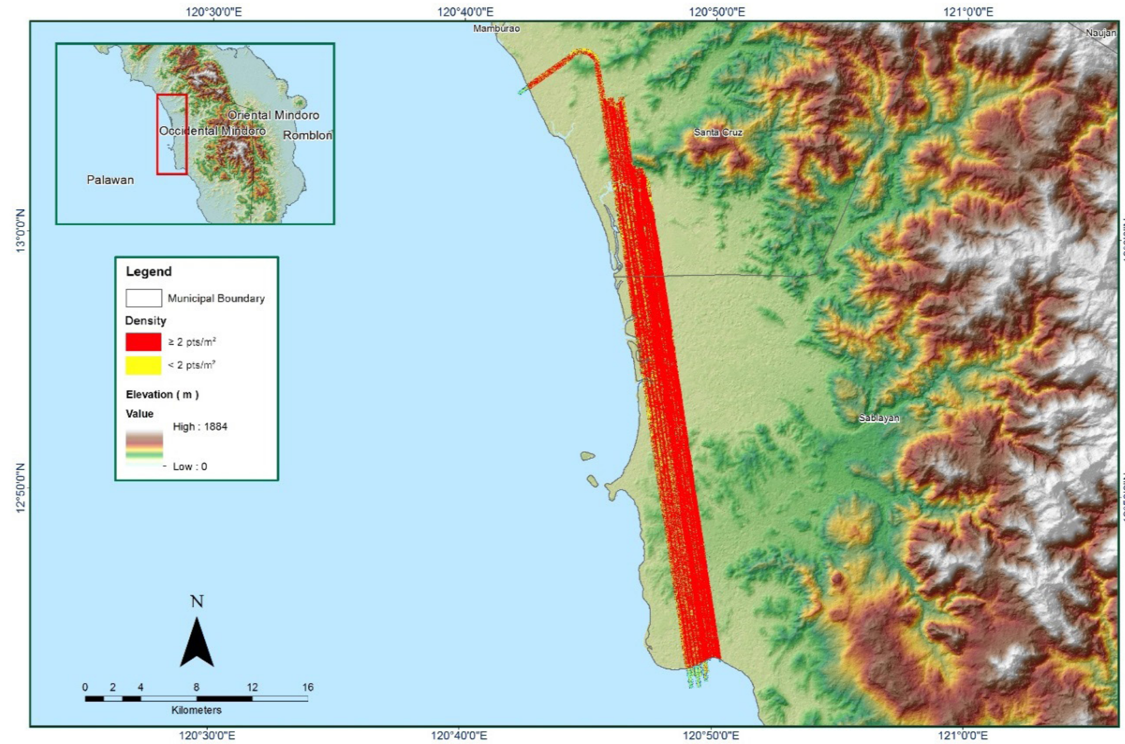


Figure A-8.13. Density of merged LiDAR data

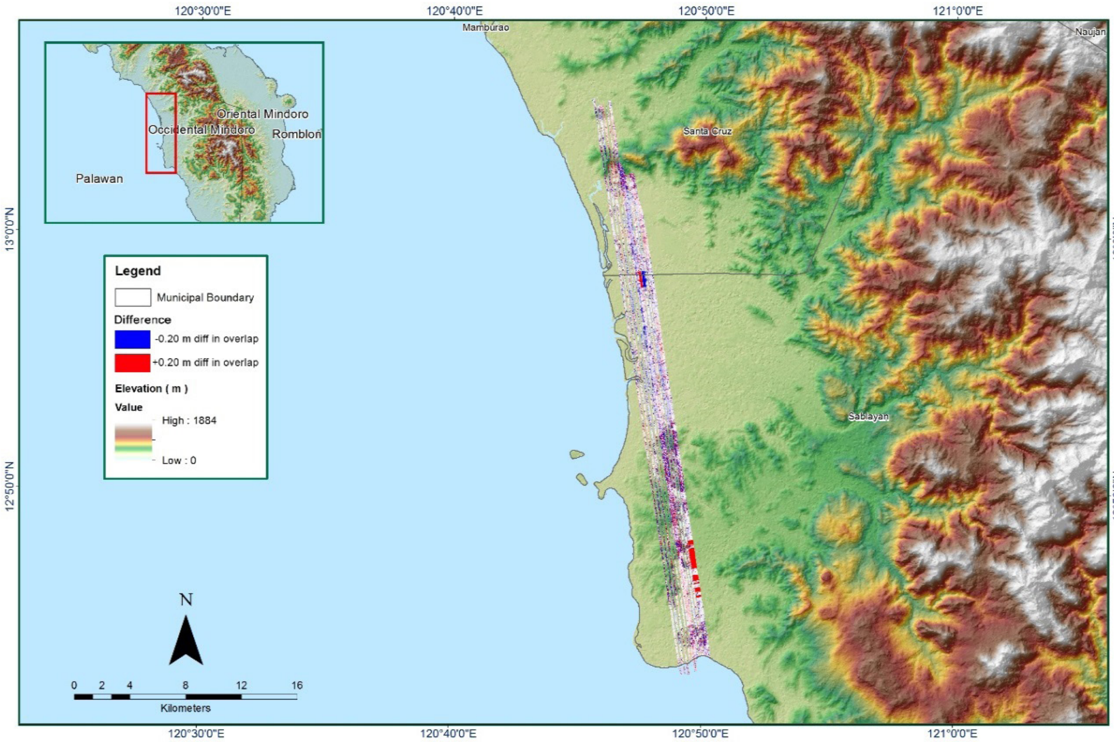


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk29I

Flight Area	Occidental Mindoro
Mission Name	**Blk29I**
Inclusive Flights	1128A
Range data size	16.1 GB
Base data size	12.3 MB
POS	269 MB
Image	6.32 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000390
IMU attitude correction stdev (<0.001deg)	0.002145
GPS position stdev (<0.01m)	0.0110
Minimum % overlap (>25)	64.97%
Ave point cloud density per sq.m. (>2.0)	3.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	150
Maximum Height	303.6 m
Minimum Height	42.27 m
Classification (# of points)	
Ground	74,217,818
Low vegetation	115,333,090
Medium vegetation	94,560,605
High vegetation	27,638,490
Building	1,366,906
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Jovy Narisma

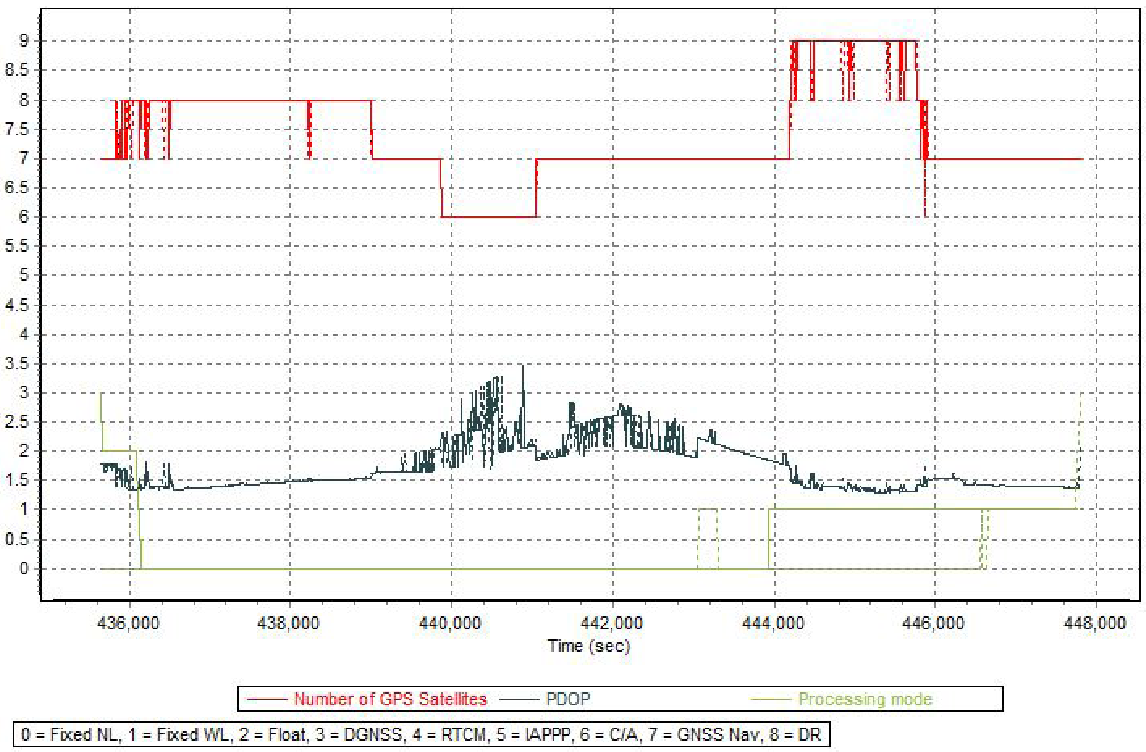


Figure A-8.15. Solution Status

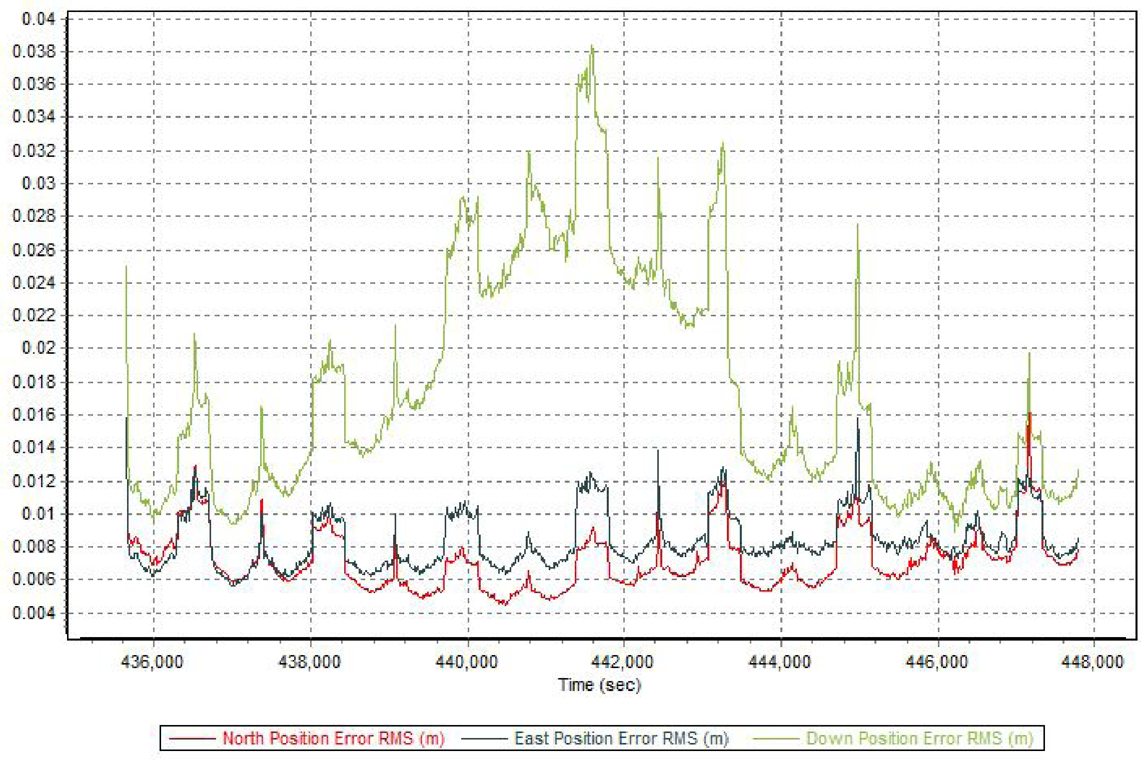


Figure A-8.16. Smoothed Performance Metrics Parameters

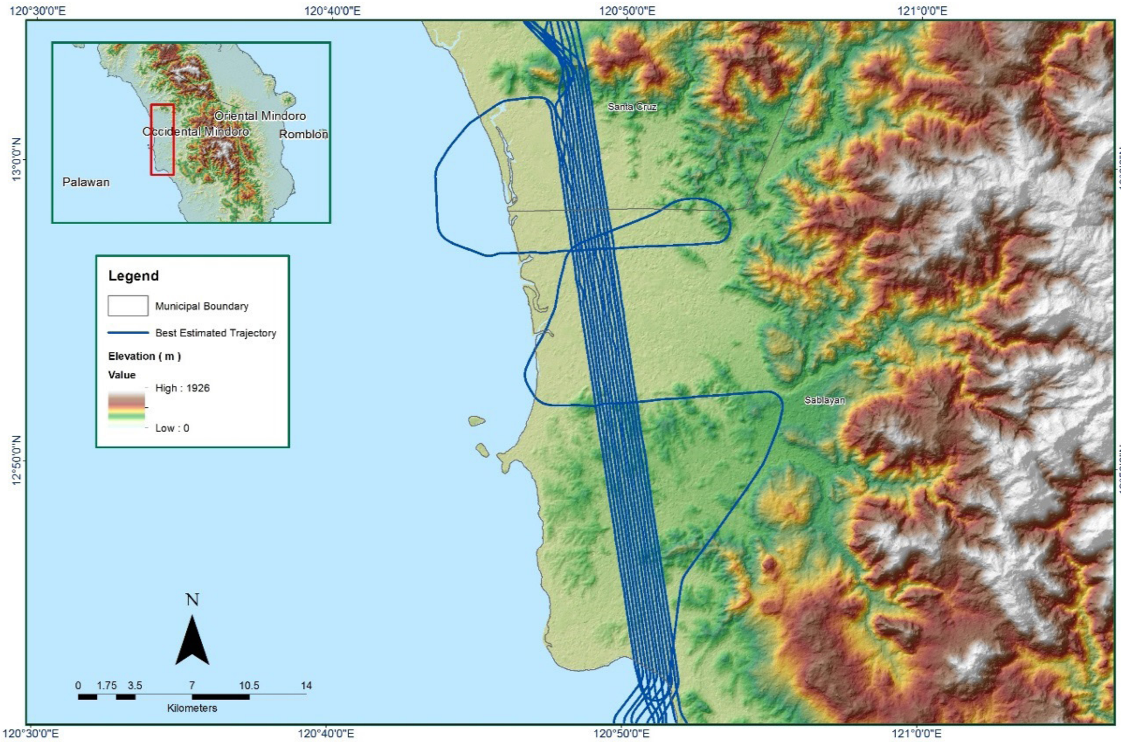


Figure A-8.17. Best Estimated Trajectory

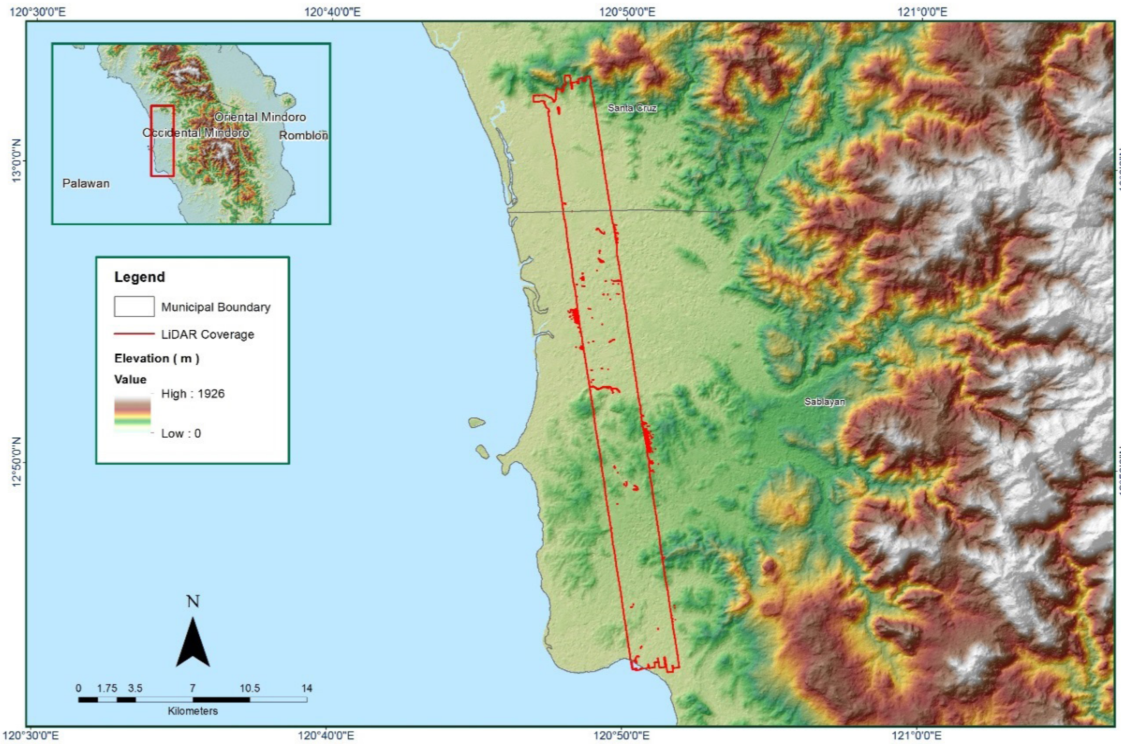


Figure A-8.18. Coverage of LiDAR data

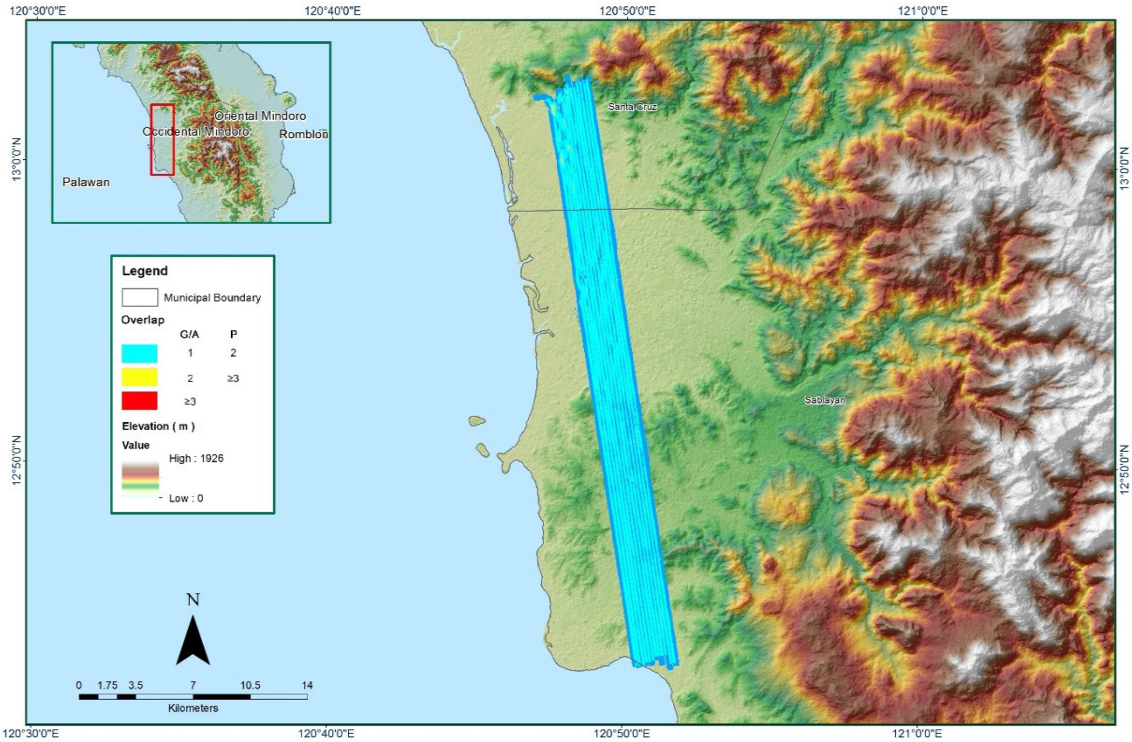


Figure A-8.19. Image of data overlap

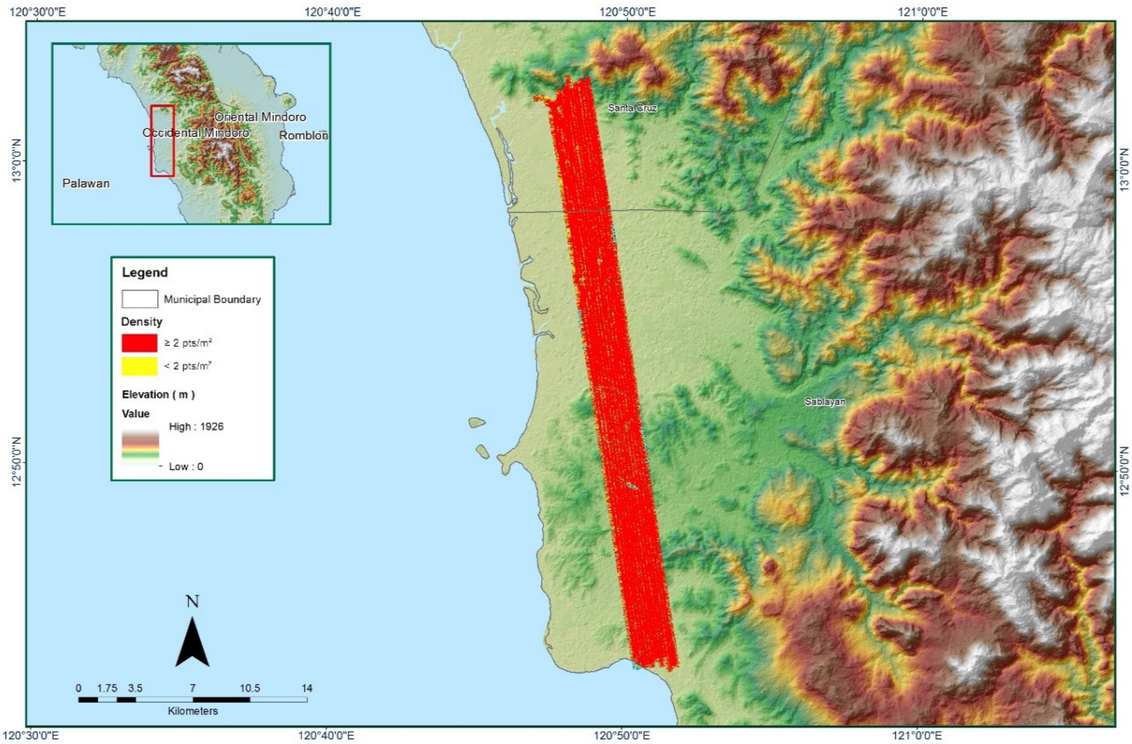


Figure A-8.20. Density of merged LiDAR data

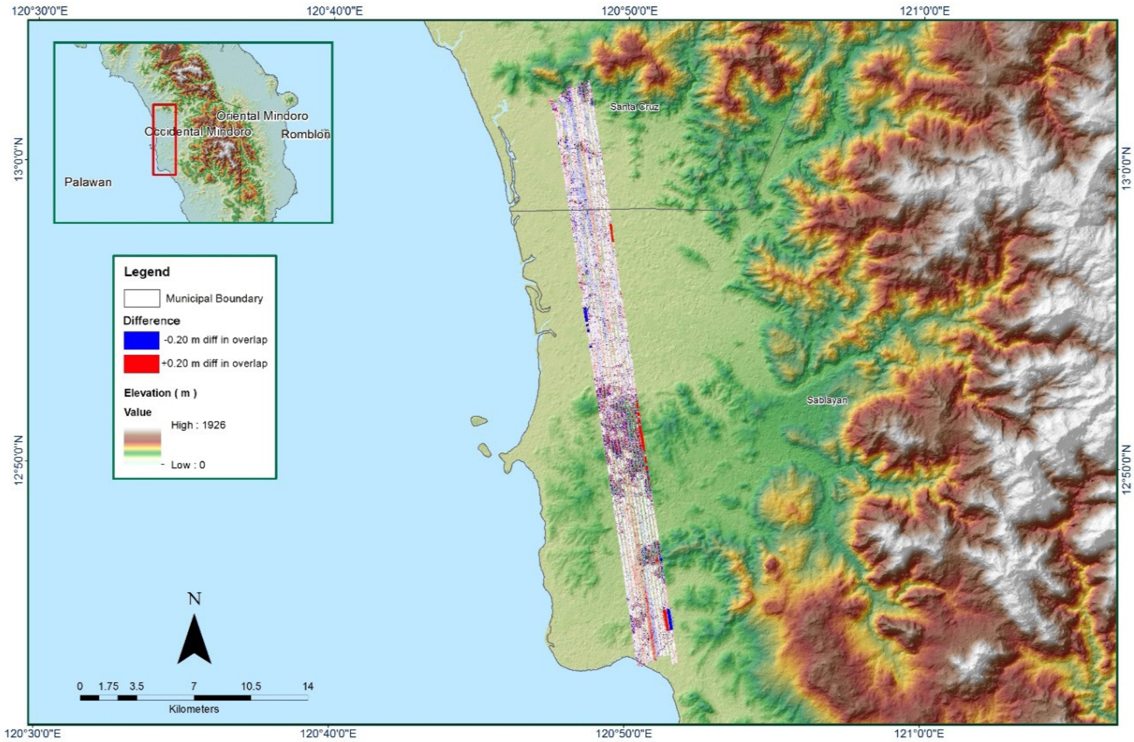


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk29JK

Flight Area	Occidental Mindoro
Mission Name	**Blk29JK**
Inclusive Flights	1110A, 1118A, 1108A
Range data size	29.97 GB
Base data size	43.3 MB
POS	578 MB
Image	88.399 GB
Transfer date	03/07/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000351
IMU attitude correction stdev (<0.001deg)	0.001607
GPS position stdev (<0.01m)	0.0035
Minimum % overlap (>25)	82.92%
Ave point cloud density per sq.m. (>2.0)	5.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	181
Maximum Height	427.61 m
Minimum Height	51.93 m
Classification (# of points)	
Ground	104,888,569
Low vegetation	178,889,703
Medium vegetation	207,266,587
High vegetation	112,361,804
Building	3,147,266
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibanez, Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Engr. Jeffrey Delica

Figure A-8.22. Solution Status

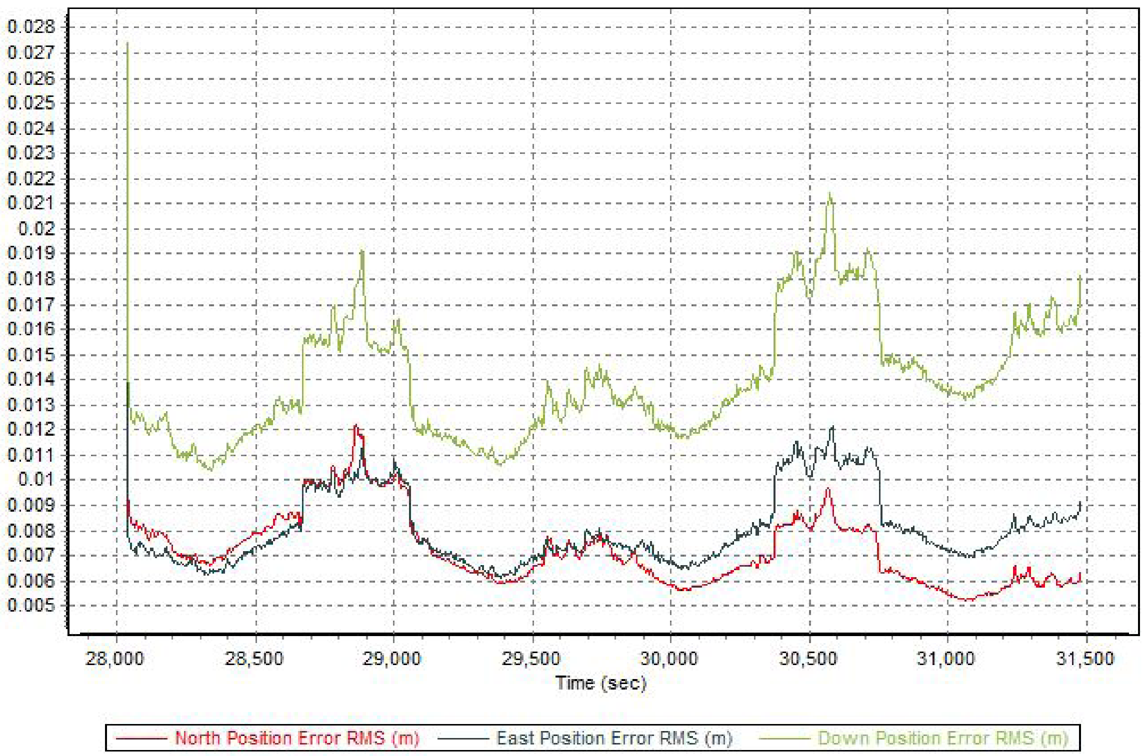


Figure A-8.23. Smoothed Performance Metrics Parameters

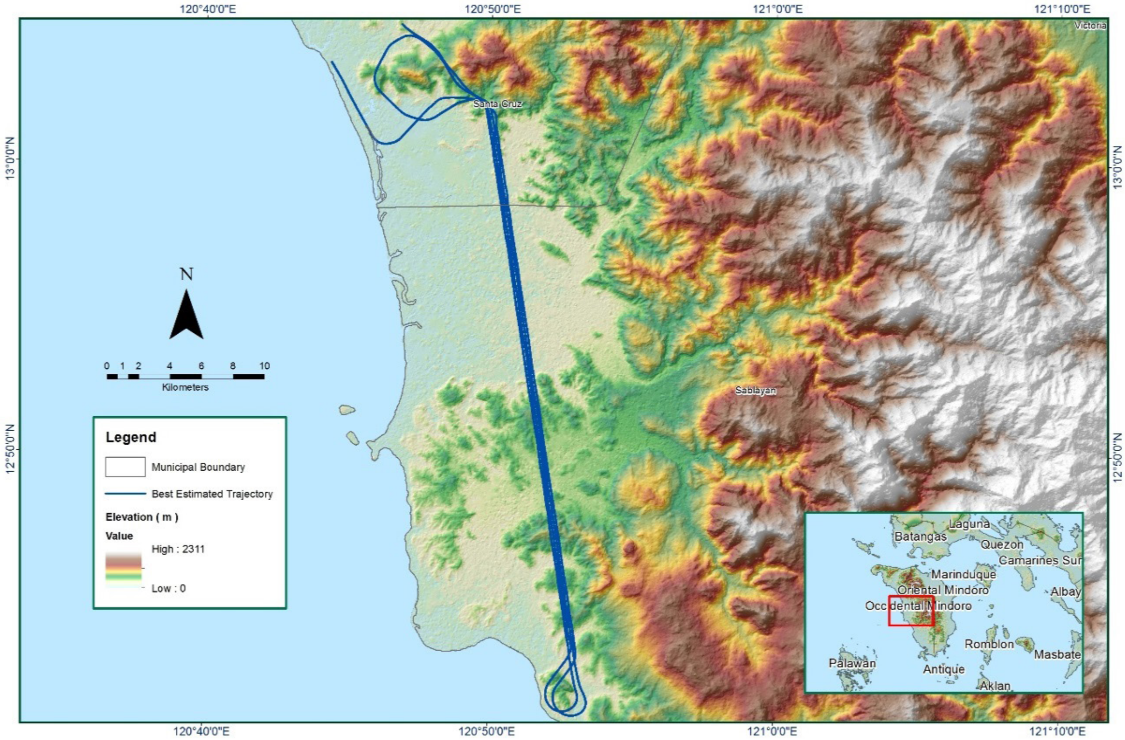


Figure A-8.24. Best Estimated Trajectory

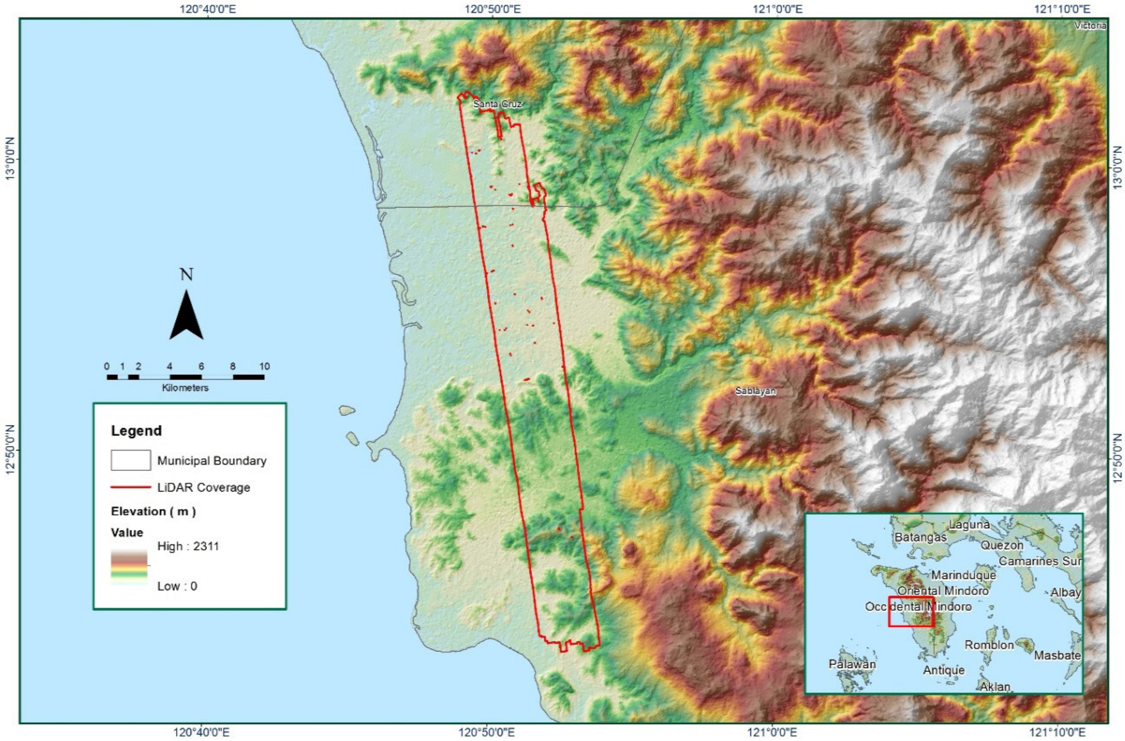


Figure A-8.25. Coverage of LiDAR data

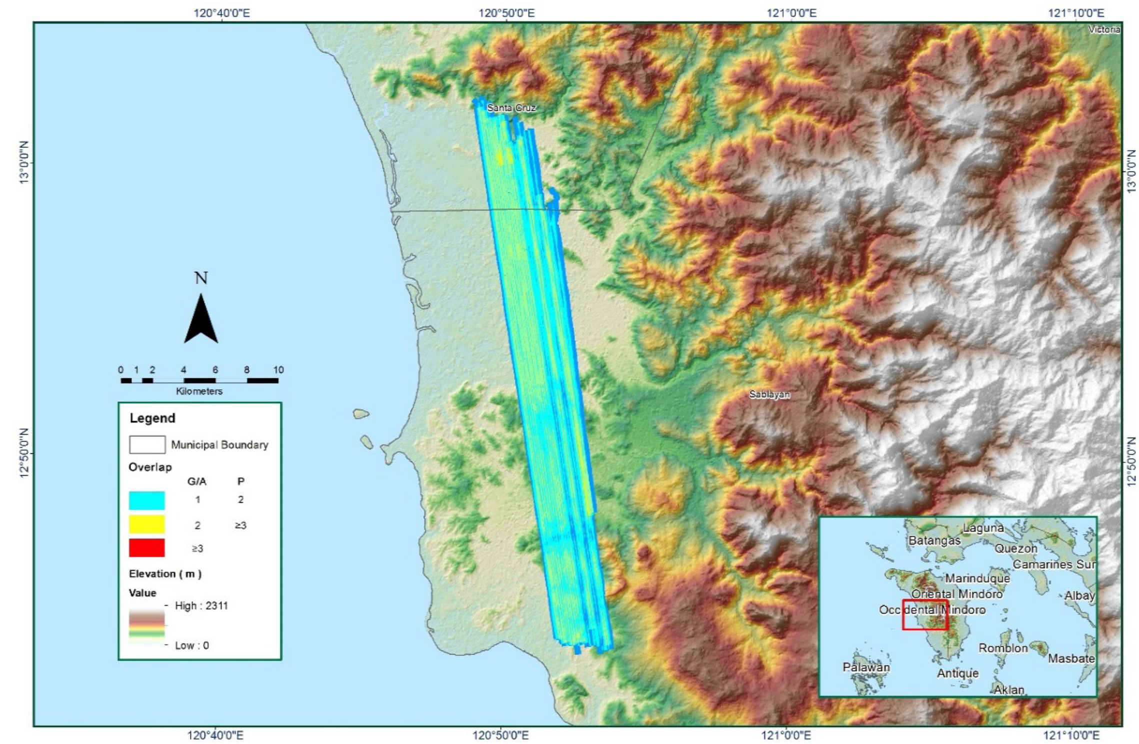


Figure A-8.26. Image of data overlap

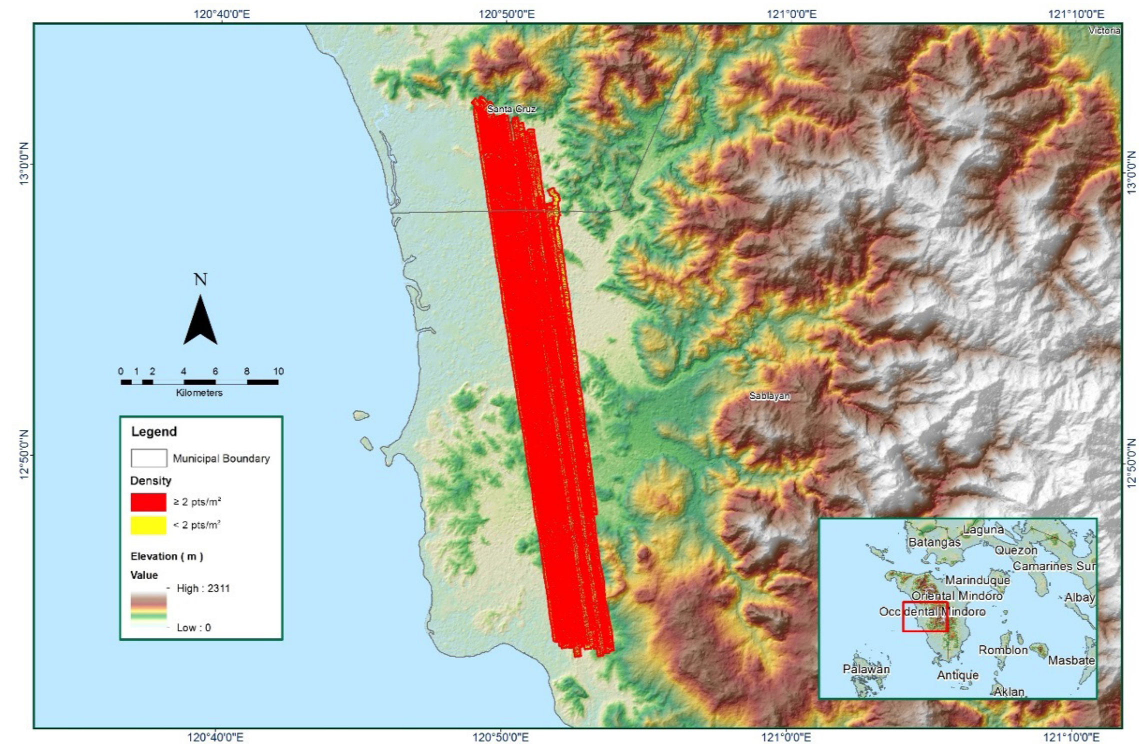


Figure A-8.27. Density of merged LiDAR data

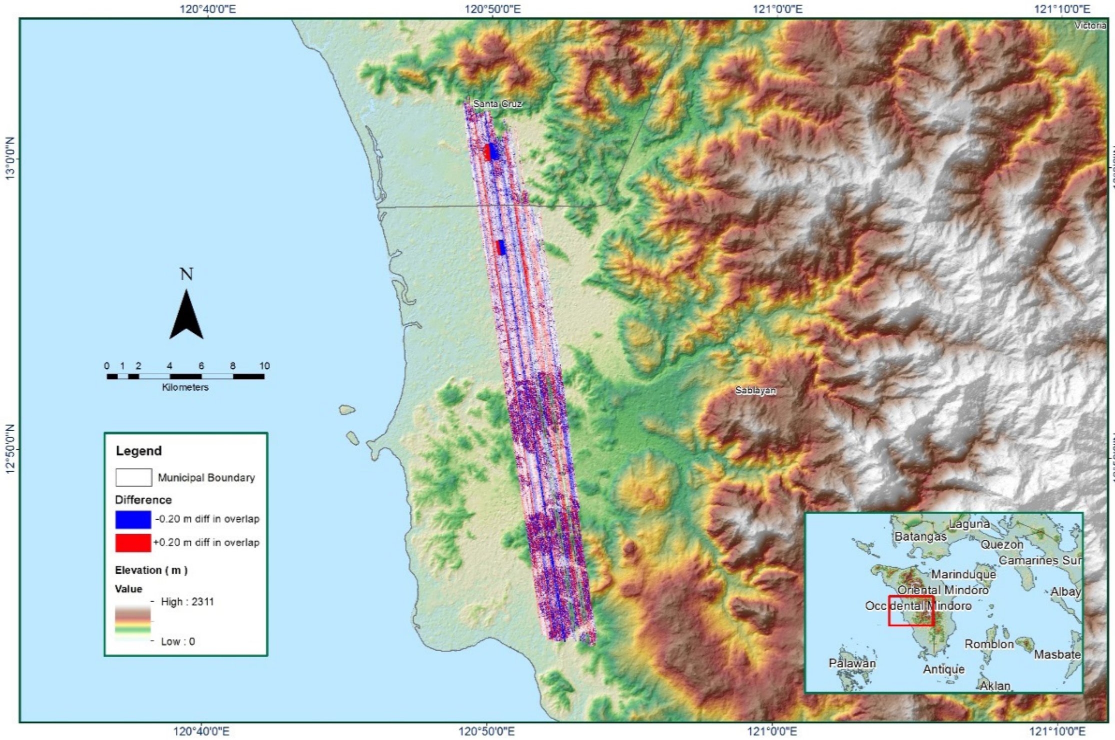


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk29Ks

Flight Area	Occidental Mindoro
Mission Name	**Blk29Ks**
Inclusive Flights	1116A
Range data size	12 GB
Base data size	15.3 MB
POS	245 MB
Image	71.7 GB
Transfer date	03/07/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000270
IMU attitude correction stdev (<0.001deg)	0.000746
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	50.49%
Ave point cloud density per sq.m. (>2.0)	3.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	480.52 m
Minimum Height	40.03 m
Classification (# of points)	
Ground	70,346,563
Low vegetation	80,229,446
Medium vegetation	59,317,225
High vegetation	53,714,475
Building	2,710,470
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Mary Celine Vasquez,

Figure A-8.29. Solution Status

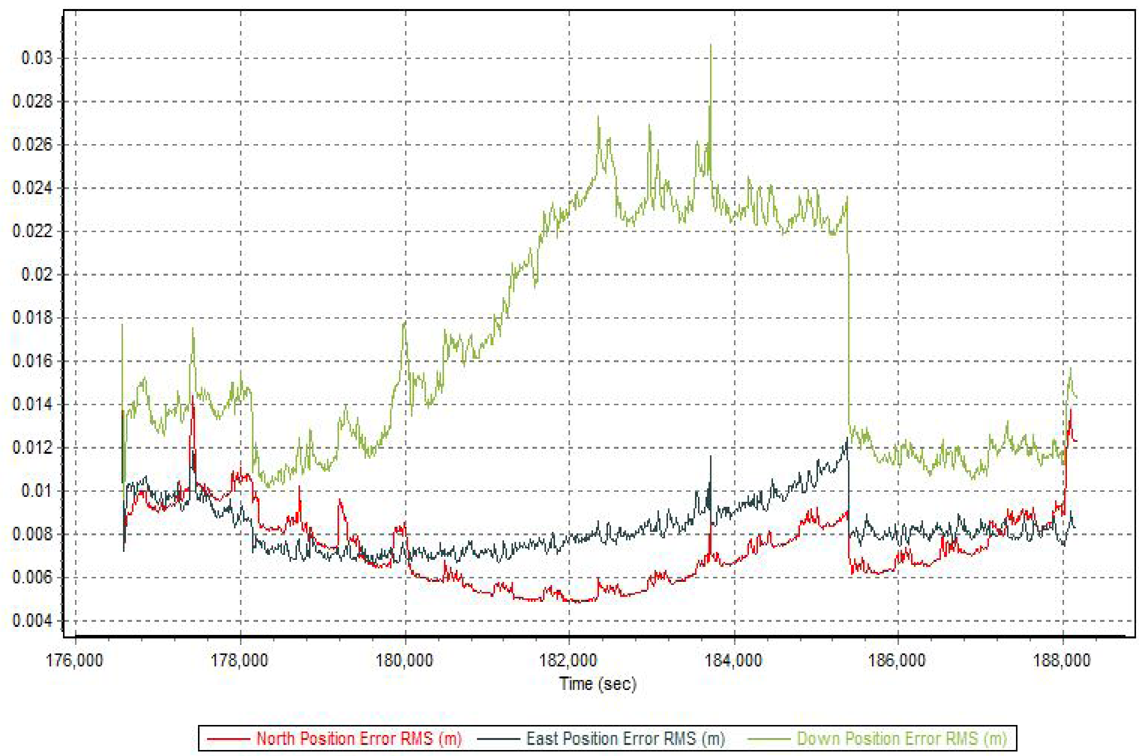


Figure A-8.30. Smoothed Performance Metrics Parameters

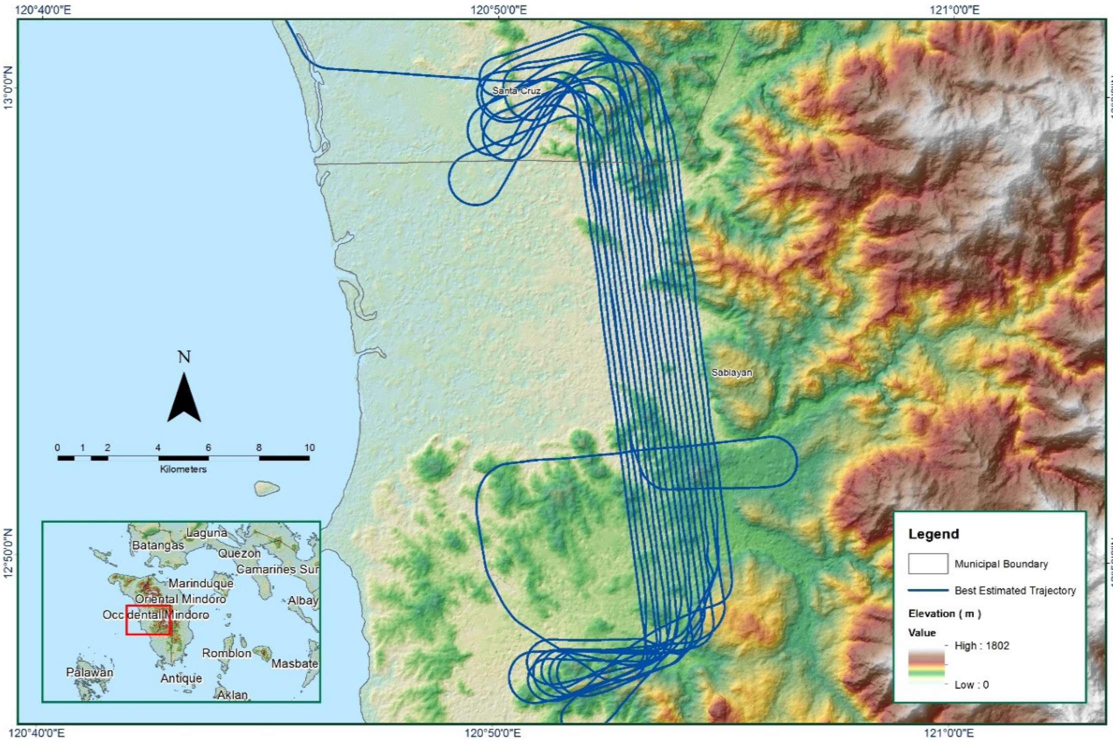


Figure A-8.31. Best Estimated Trajectory

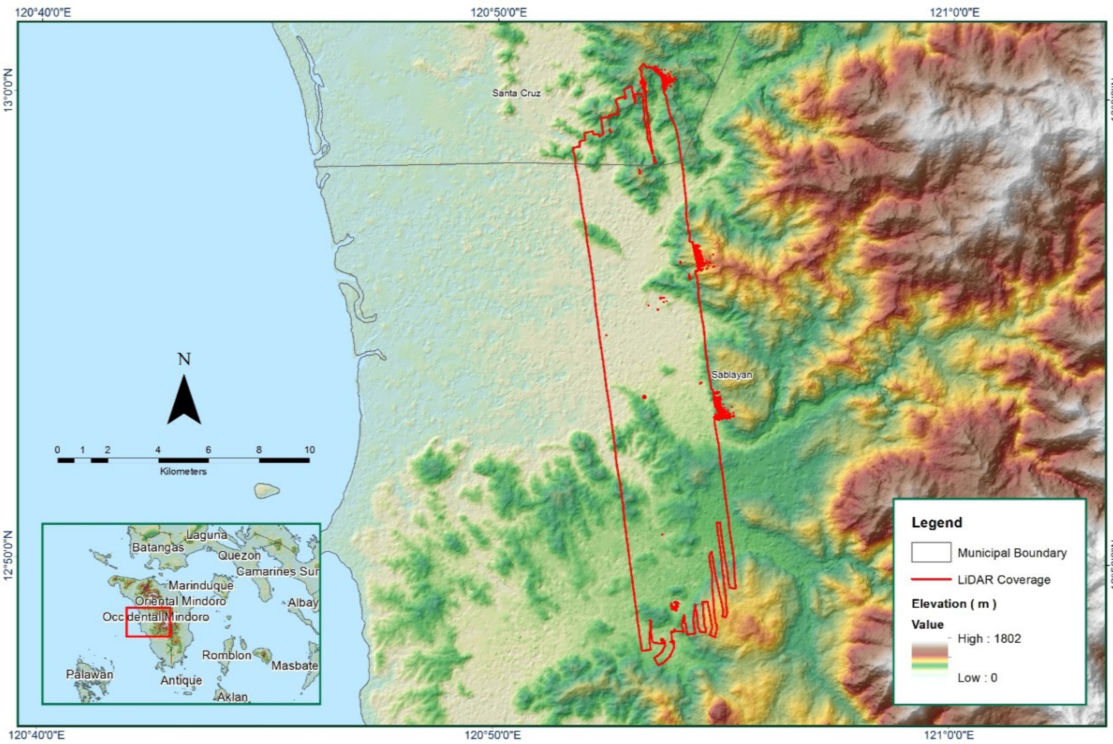


Figure A-8.32. Coverage of LiDAR data

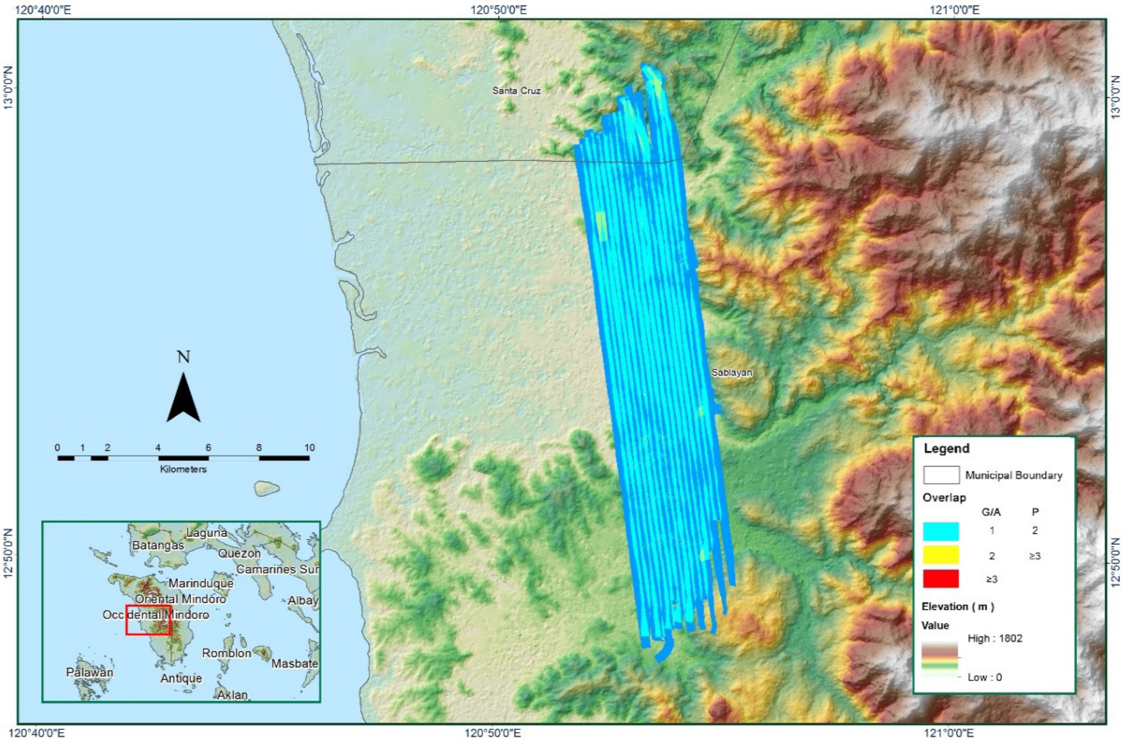


Figure A-8.33. Image of data overlap

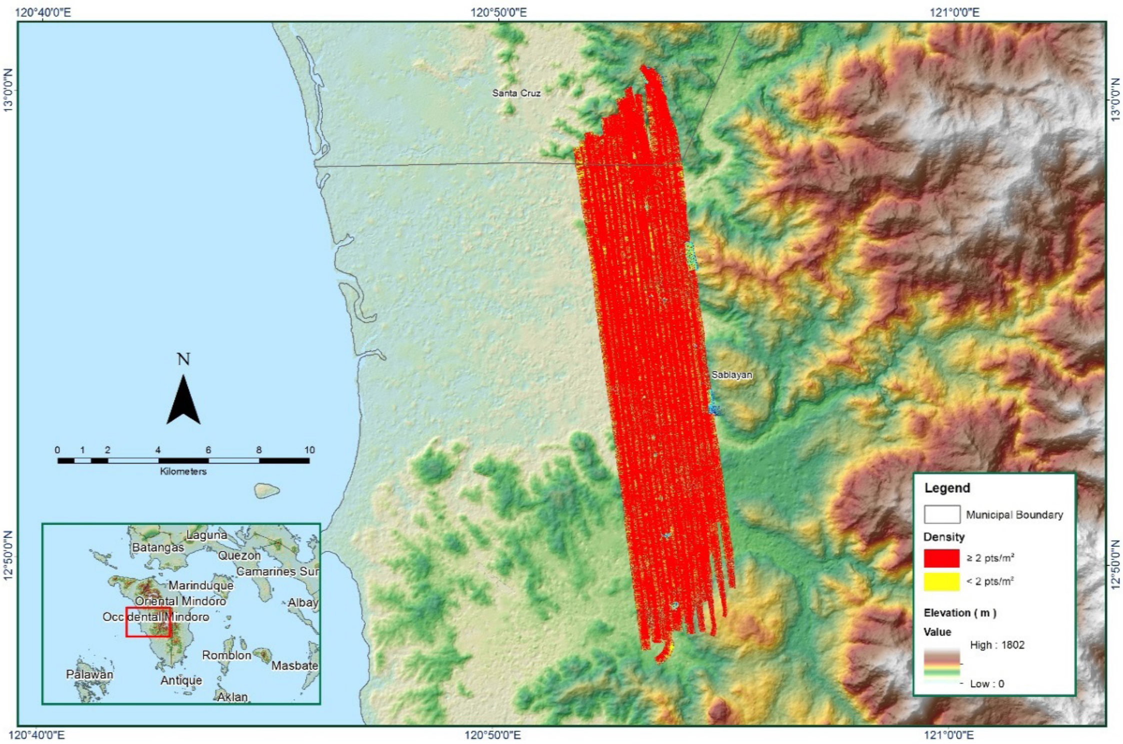


Figure A-8.34. Density of merged LiDAR data

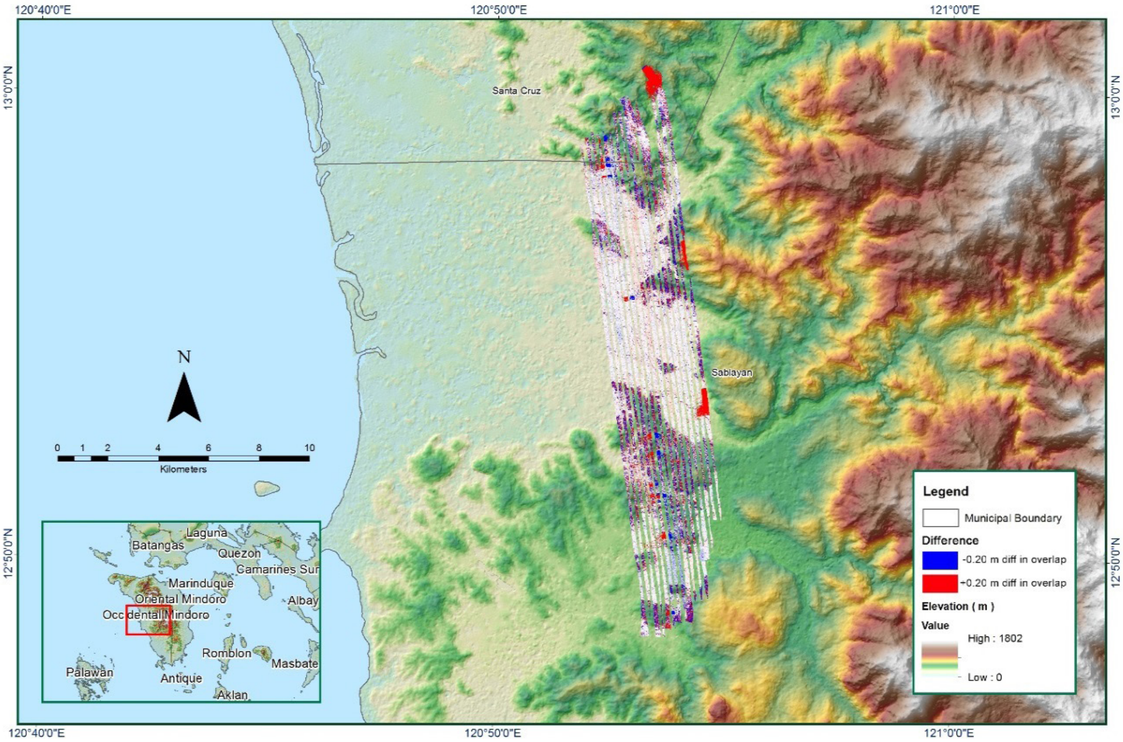


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk29HI

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29HI**
Inclusive Flights	3068P, 3070P
Range data size	12.14GB
Base data size	21.96 MB
POS	257 MB
Image	18.93 MB
Transfer date	January 15, 2016
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)	1.20
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.52
Boresight correction stdev (<0.001deg)	0.000567
IMU attitude correction stdev (<0.001deg)	0.000448
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	20.41
Ave point cloud density per sq.m. (>2.0)	1.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	107
Maximum Height	270.48 m
Minimum Height	47.62 m
Classification (# of points)	
Ground	54,972,808
Low vegetation	33,840,636
Medium vegetation	55,240,382
High vegetation	47,256,226
Building	347,251
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Velina Angela Bemida, Jovy Narisma

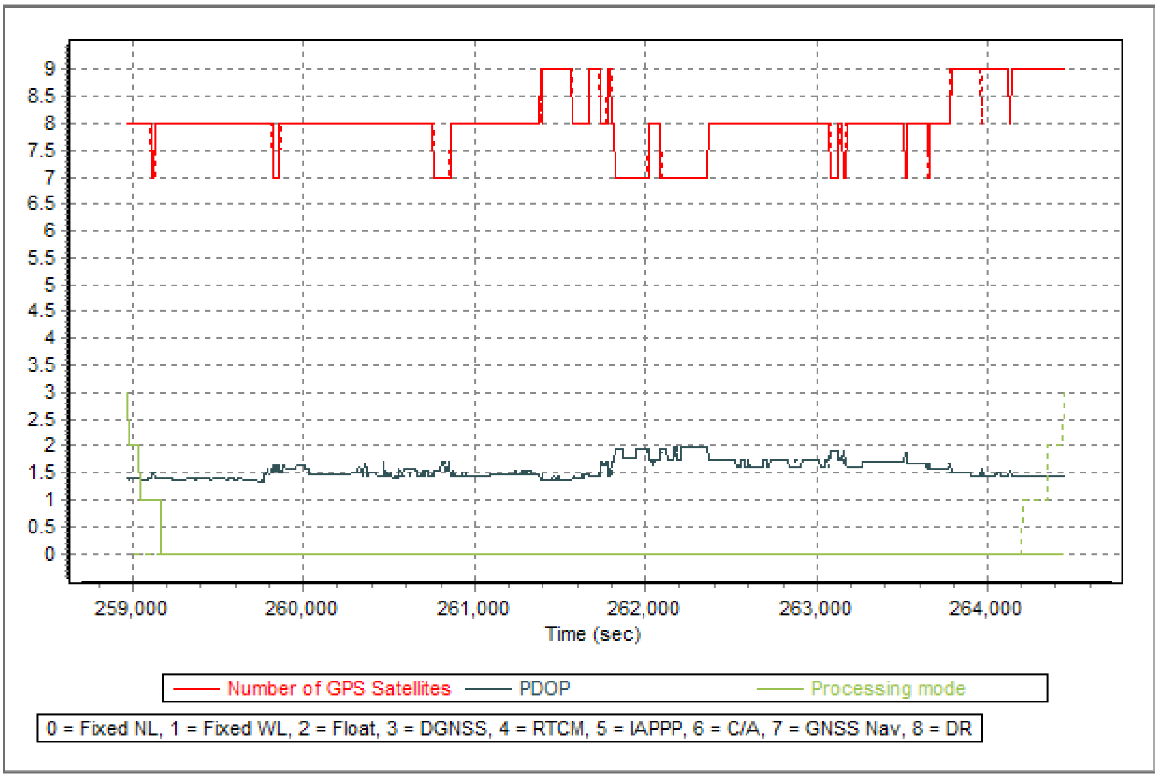


Figure A-8.36. Solution Status

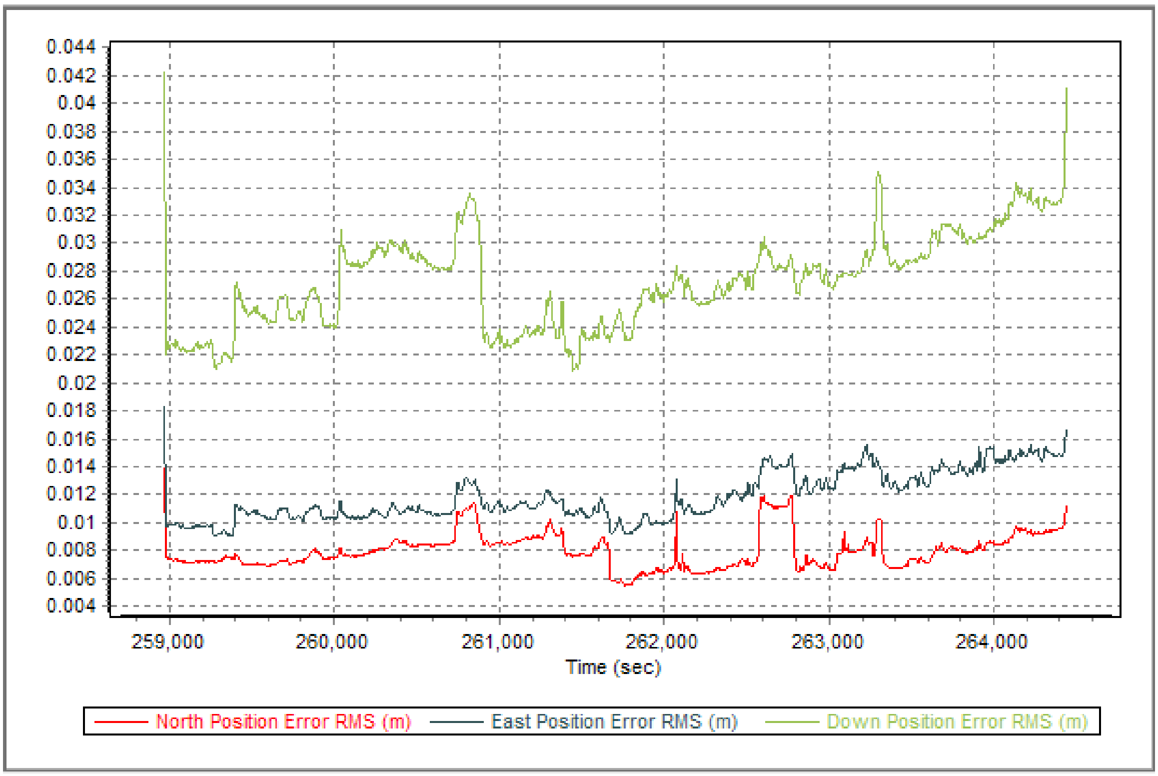


Figure A-8.37. Smoothed Performance Metric Parameters

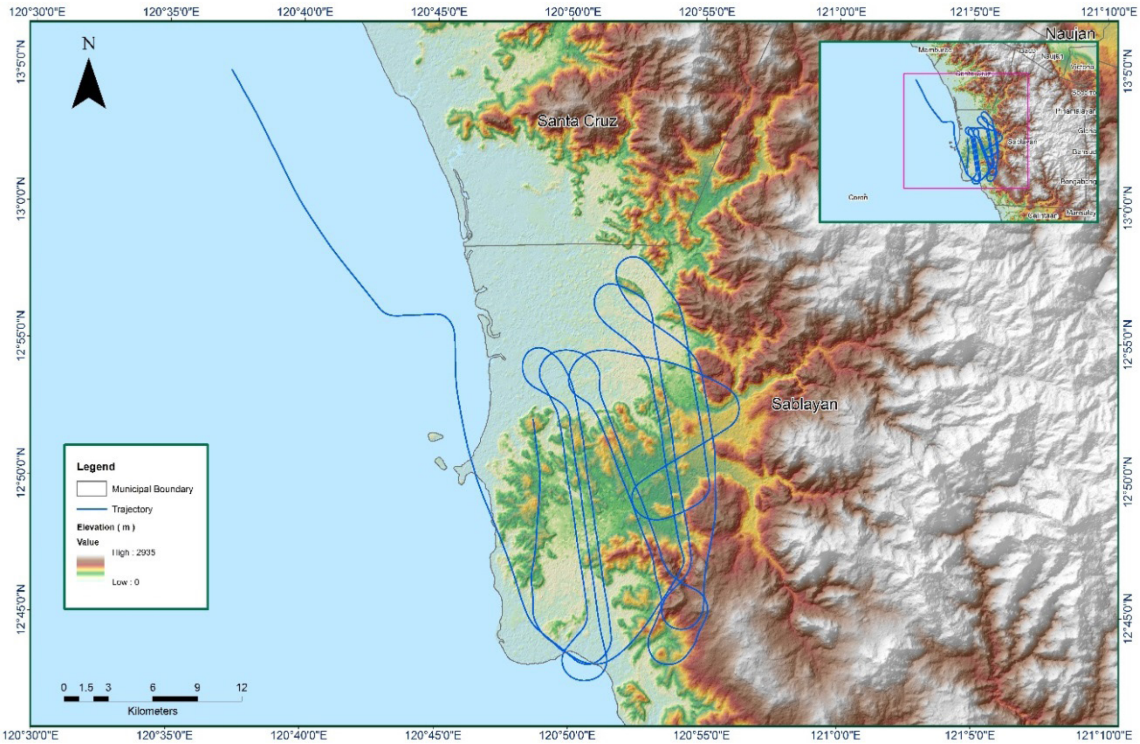


Figure A-8.38. Best Estimate Trajectory

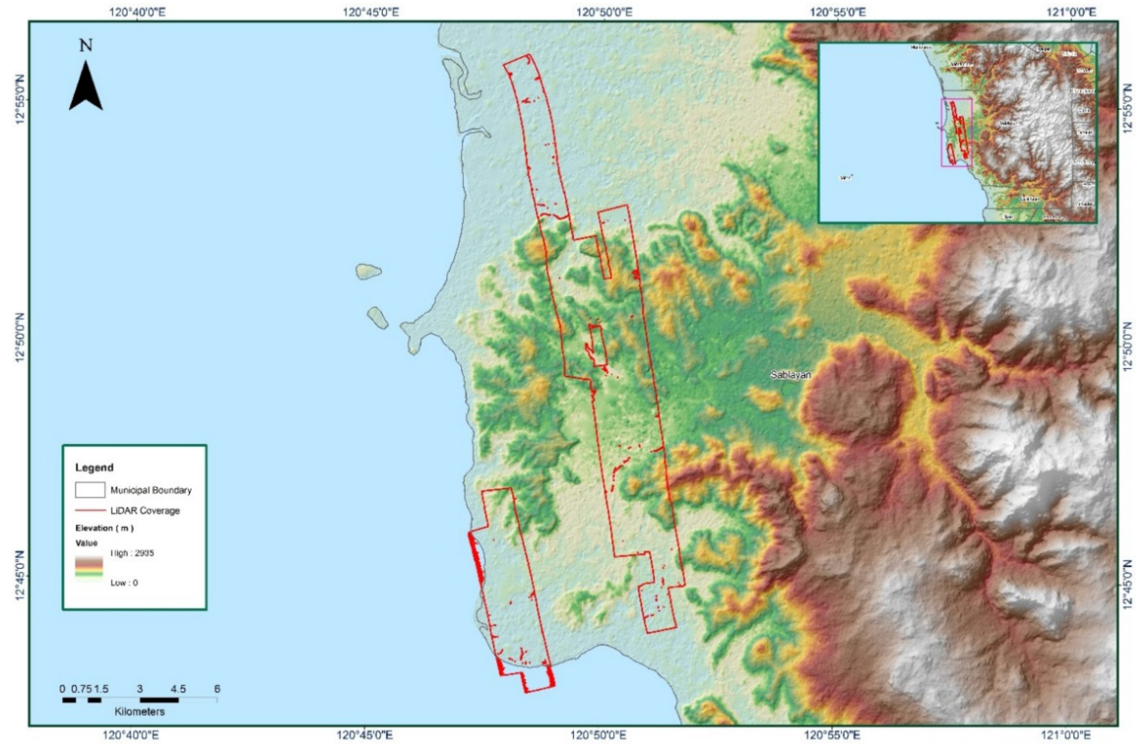


Figure A-8.39. Coverage of LiDAR data

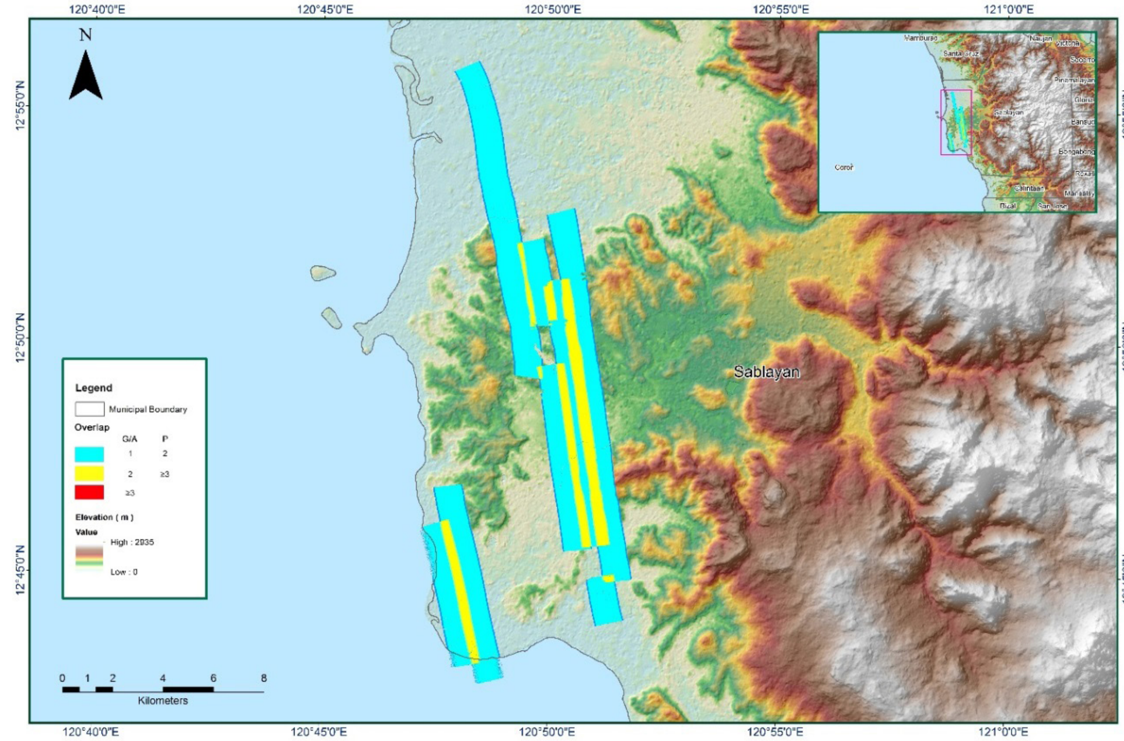


Figure A-8.40 Image of data overlap

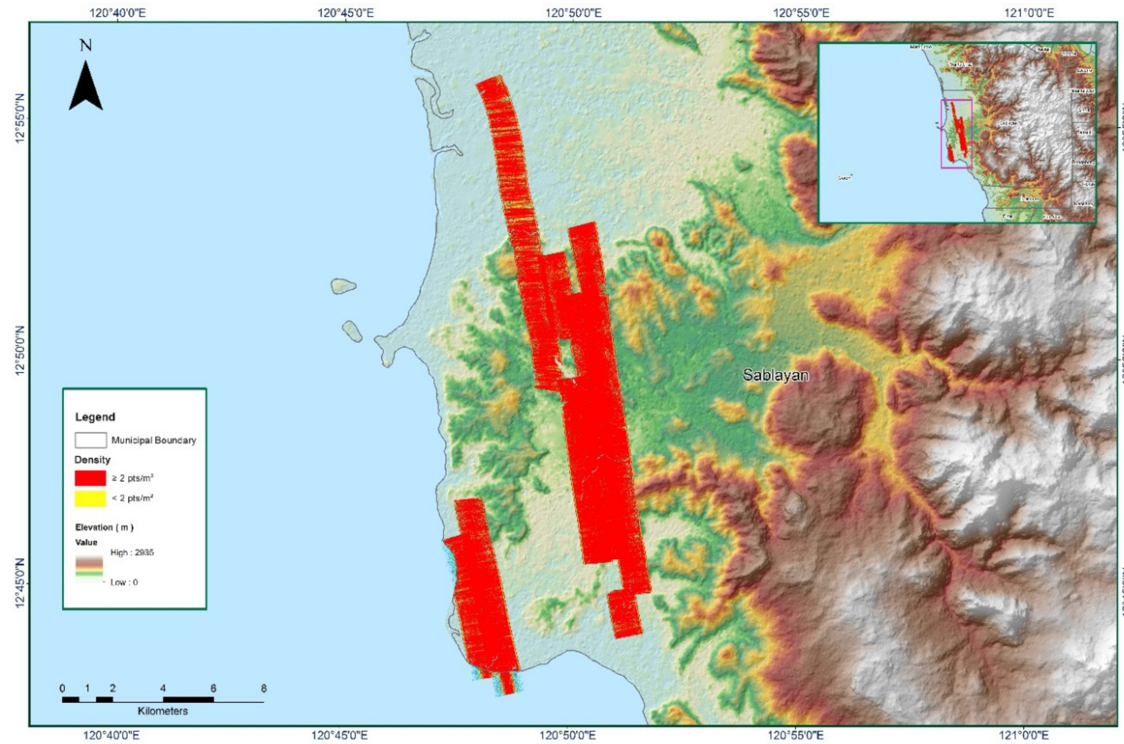


Figure A-8.41 Density Map of merged LiDAR data

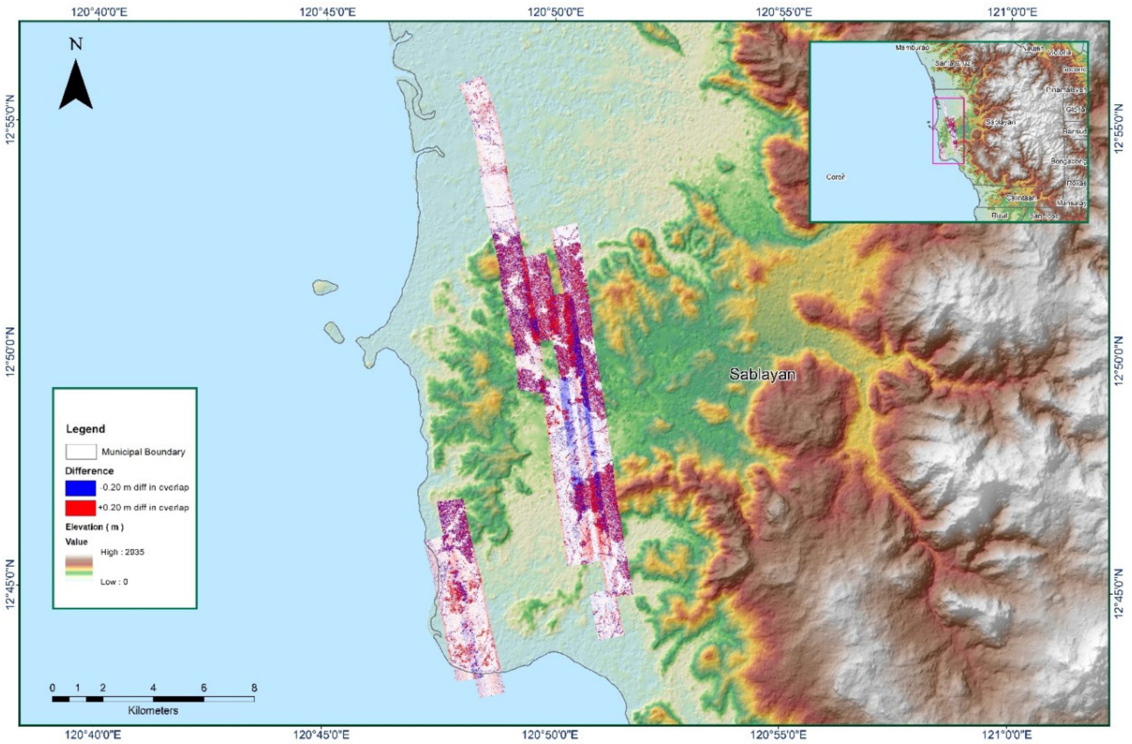


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7 Mission Summary Report for Mission Blk29JK

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29JK**
Inclusive Flights	3070P
Range data size	9.37GB
Base data size	5.96 MB
POS	143MB
Image	14.3MB
Transfer date	January 15, 2016
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)	1.20
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.52
Boresight correction stdev (<0.001deg)	0.000474
IMU attitude correction stdev (<0.001deg)	0.000477
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	15.48
Ave point cloud density per sq.m. (>2.0)	1.80
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	119
Maximum Height	569.33 m
Minimum Height	60.49 m
Classification (# of points)	
Ground	66,099,632
Low vegetation	22,449,167
Medium vegetation	52,375,898
High vegetation	190,706,605
Building	2,255,129
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Justine Francisco, Engr. Krisha Marie Bautista

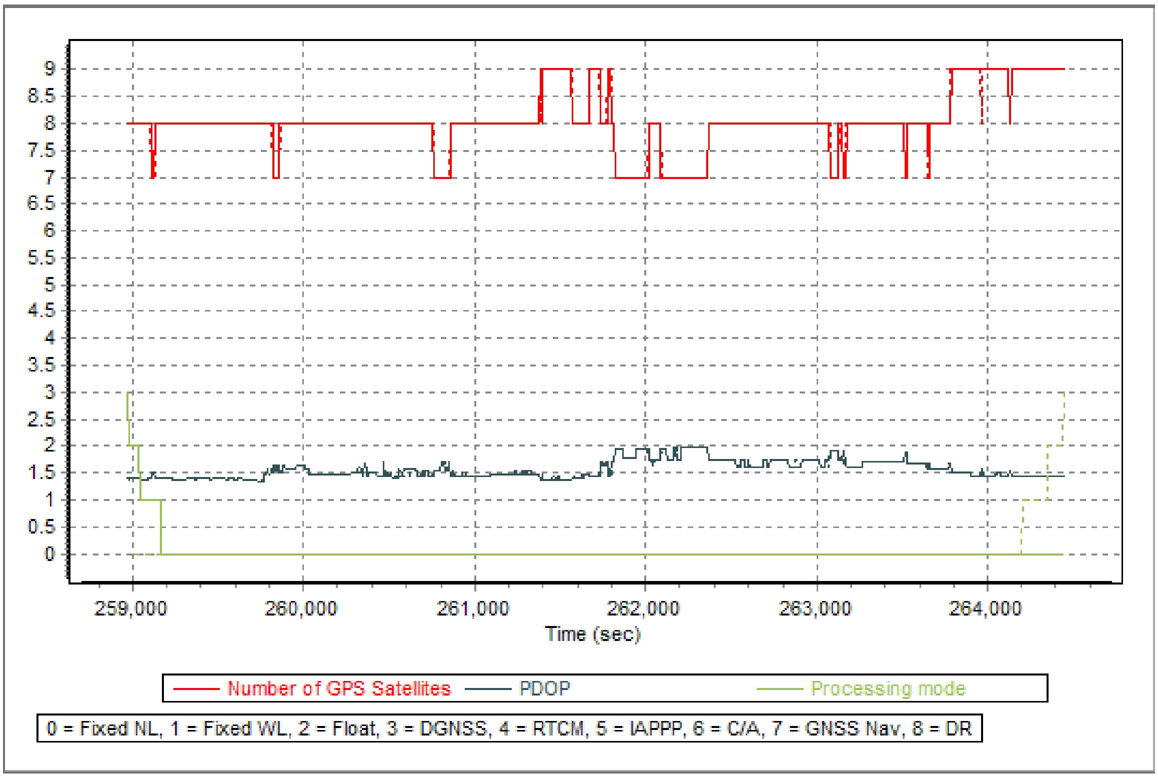


Figure A-8.43. Solution Status

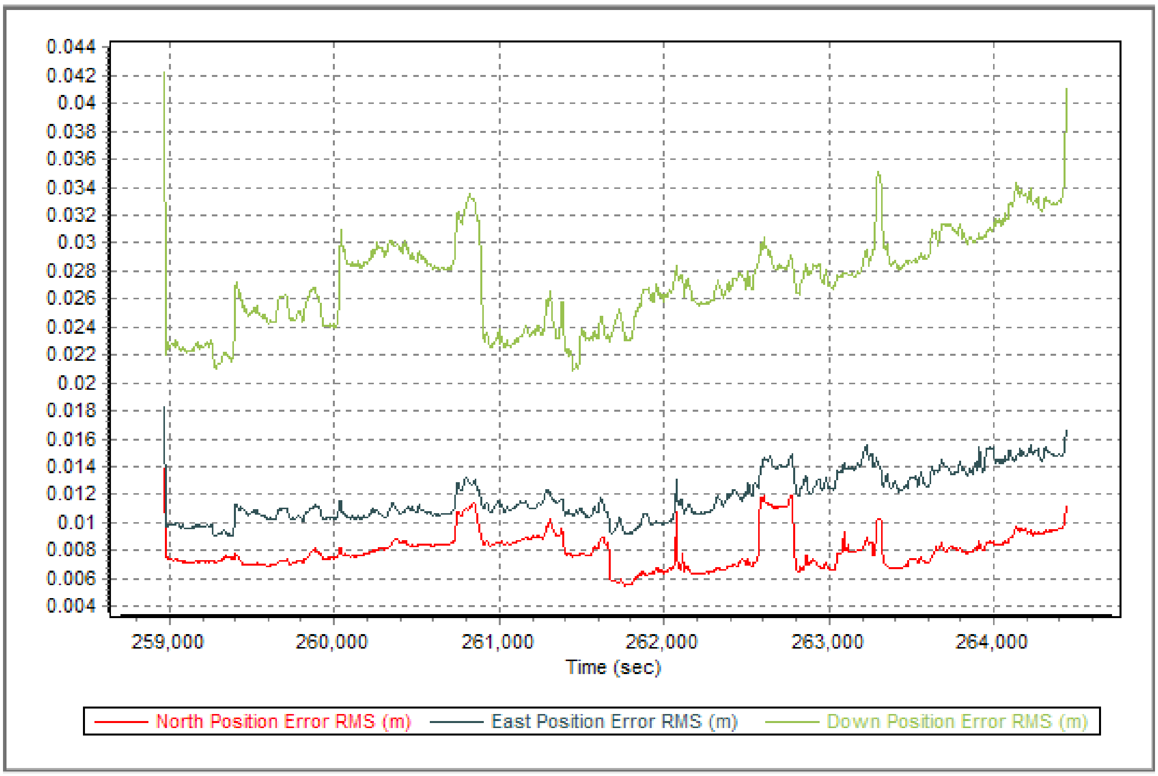


Figure A-8.44. Smoothed Performance Metric Parameters

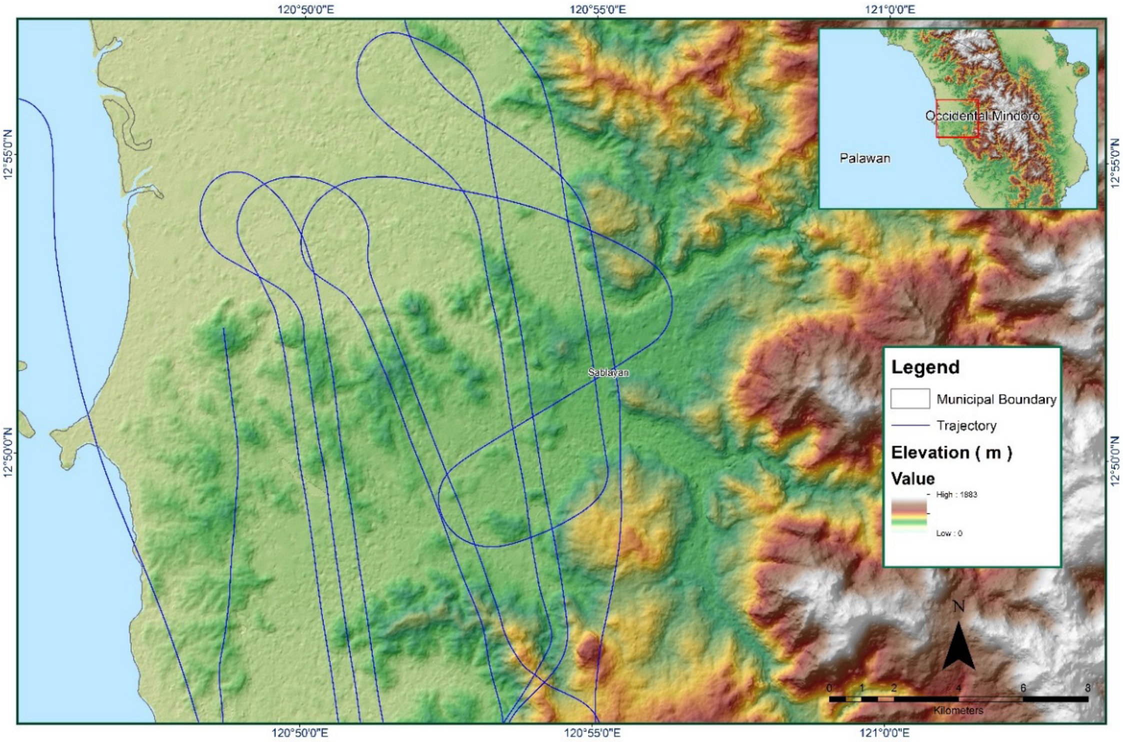


Figure A-8.45. Best Estimate Trajectory

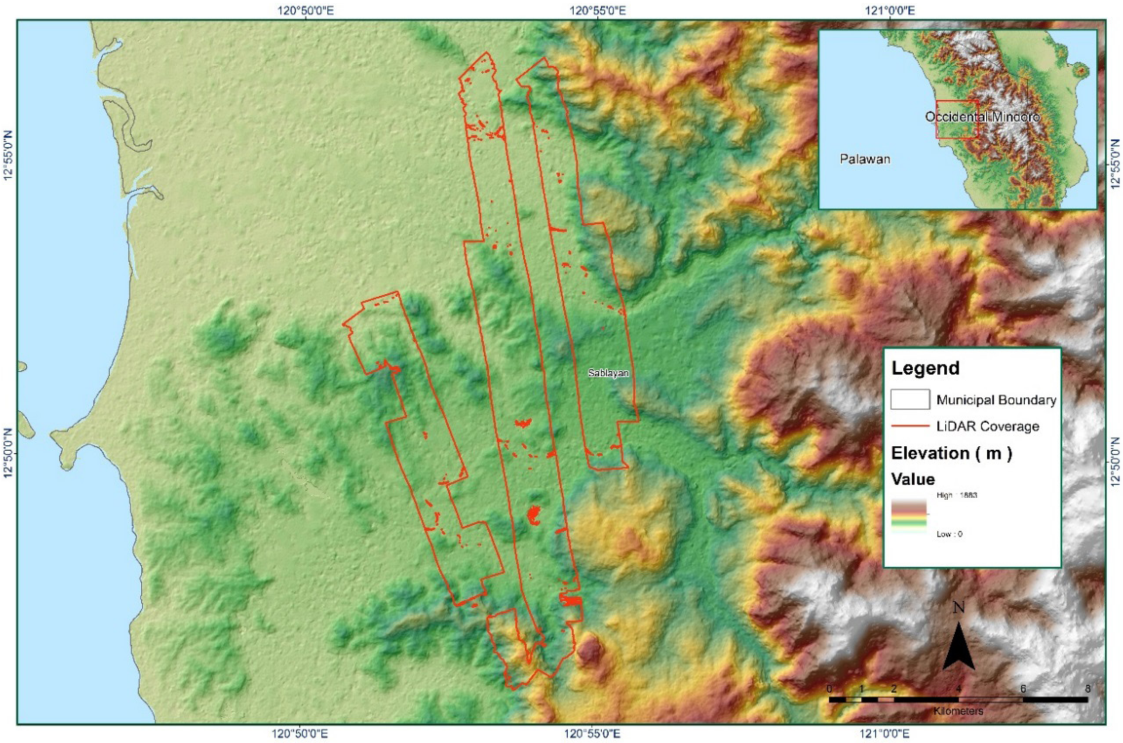


Figure A-8.46. Coverage of LiDAR data

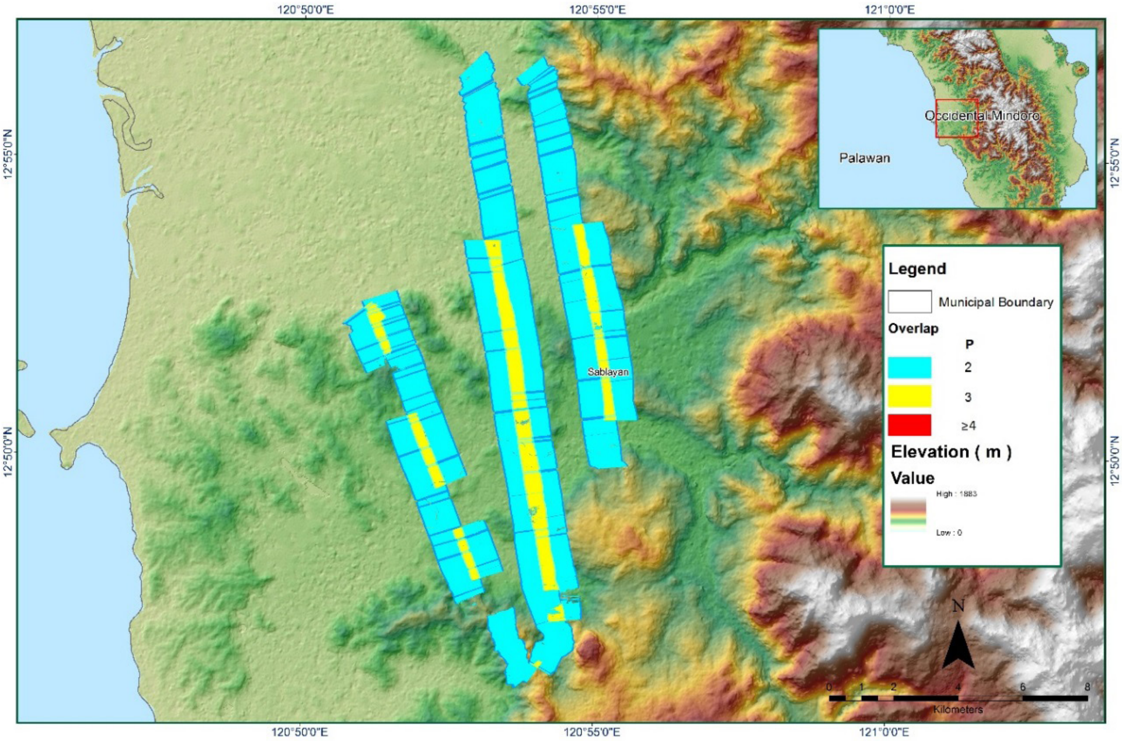


Figure A-8.47 Image of data overlap

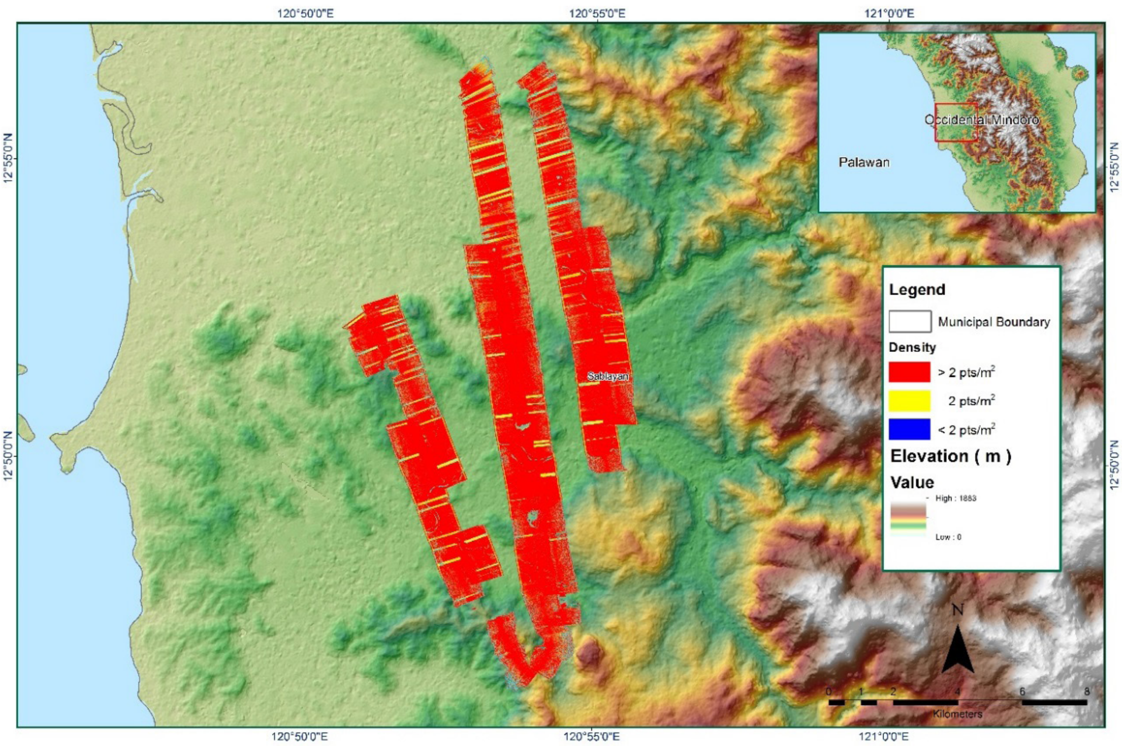


Figure A-8.48 Density Map of merged LiDAR data

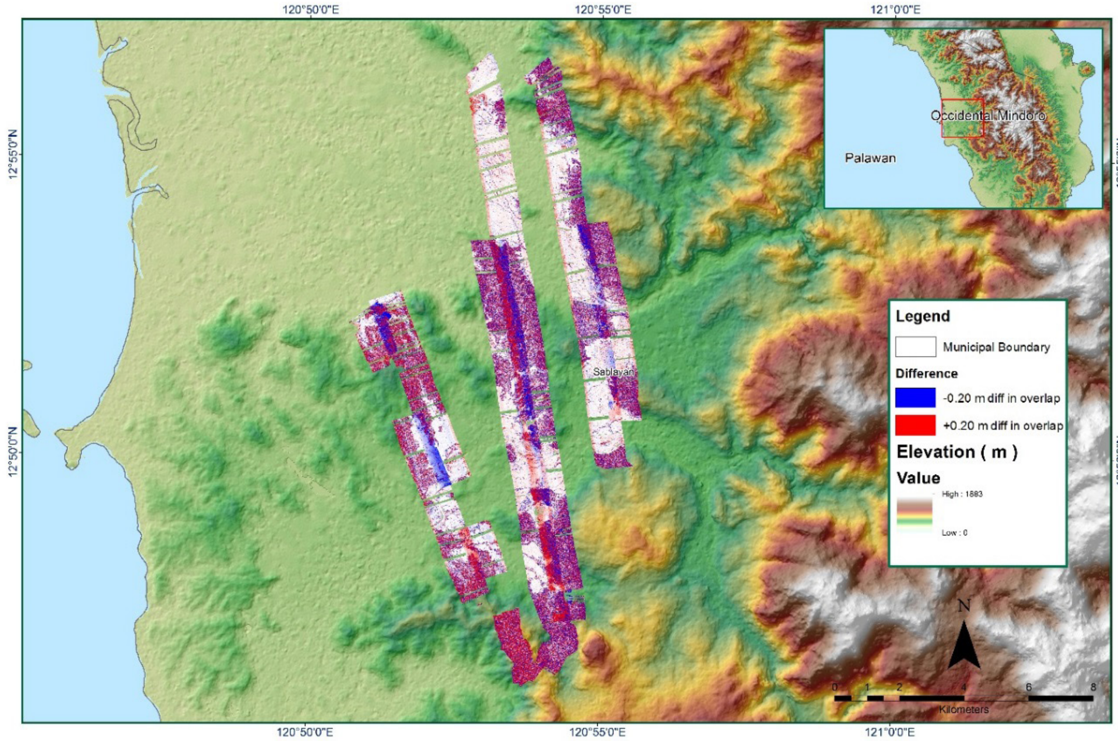


Figure A-8.49 Elevation Difference Between flight lines

Annex 11. Ibod Flood Validation Data

Annex 11. Ibod Flood Validation Data

Annex 9. Ibod Model Basin Parameters

Table A-9.1 Ibod Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W120	15.892	70.566	0.0	3.3838	0.7303	0.0709366	1	0.05
W130	5.5029	87.38	0.0	2.0715	0.45077	0.0058193	1	0.5
W140	4.1489	90	0.0	3.0679	0.45474	0.0963967	1	0.5
W150	6.1266	86.147	0.0	0.48865	0.16276	0.0059346	1	0.5
W160	10.075	79.086	0.0	2.0528	0.38052	0.53159	1	0.5
W180	16.256	70.094	0.0	3.3254	0.72361	0.0332867	1	0.5
W200	7.5088	62.844	0.0	2.8137	4.592	0.14527	1	0.05
W210	4.5256	73.727	0.0	2.3203	3.7867	0.35429	1	0.5
W220	3.3654	79.052	0.0	0.5954	0.97169	0.78975	1	0.05
W240	5.8564	68.44	0.0	0.6741	1.1001	0.0546003	1	0.1125
W250	11.893	51.64	0.0	4.5946	7.4984	0.0384222	0.99419	0.05
W290	6.3532	66.655	0.0	2.9599	4.8306	0.24871	0.99677	0.05
W300	26.771	58.732	0.0	1.8453	0.27014	0.84016	1	0.05

Annex 10. Ibod Model Reach Parameters

Table A-10.1 Ibod Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R110	Automatic Fixed Interval	1460.7	0.0015244	0.04	Trapezoid	25	1
R20	Automatic Fixed Interval	2907.4	0.0087309	0.10453	Trapezoid	25	1
R30	Automatic Fixed Interval	891.84	0.0087309	0.1568	Trapezoid	25	1
R310	Automatic Fixed Interval	1881.7	2.3910735	0.24116	Trapezoid	25	1
R50	Automatic Fixed Interval	4965.6	0.0023167	0.04	Trapezoid	25	1
R60	Automatic Fixed Interval	362.13	.00097790	0.04	Trapezoid	25	1
R90	Automatic Fixed Interval	2080.4	0.0015244	0.04	Trapezoid	25	1

Annex 11. Ibod Flood Validation Data

Table A-11.1 Ibod Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Latitude	Longitude						
1	120.77428000000	12.83658200000	0.680	0.000	-0.680			25-Year
2	120.77354000000	12.83673800000	0.490	0.000	-0.490			25-Year
3	120.77261670000	12.83699470000	0.560	0.000	-0.560			25-Year
4	120.77231000000	12.83736900000	0.250	0.000	-0.250			25-Year
5	120.77205000000	12.83779000000	0.930	0.000	-0.930			25-Year
6	120.77336000000	12.83788650000	0.850	0.000	-0.850			25-Year
7	120.77409180000	12.83853080000	0.670	0.000	-0.670			25-Year
8	120.77526270000	12.83957460000	0.420	0.200	-0.220	Habagat	Aug. 2016	25-Year
9	120.77662500000	12.84112510000	0.430	0.000	-0.430			25-Year
10	120.77756490000	12.84173600000	0.210	0.000	-0.210			25-Year
11	120.77515000000	12.84216800000	0.090	0.000	-0.090			25-Year
12	120.77586000000	12.84257900000	0.030	0.000	-0.030			25-Year
13	120.77857910000	12.84273620000	0.290	0.000	-0.290			25-Year
14	120.77870850000	12.84286840000	0.110	0.300	0.190	Habagat	Aug. 2016	25-Year
15	120.77593000000	12.84325000000	0.030	0.000	-0.030			25-Year
16	120.77974000000	12.84373400000	0.440	0.250	-0.190	Habagat	Aug. 2016	25-Year
17	120.77654000000	12.84372700000	0.030	0.000	-0.030			25-Year
18	120.77822740000	12.84412600000	0.300	0.000	-0.300			25-Year
19	120.77765000000	12.84442200000	0.030	0.000	-0.030			25-Year
20	120.77639000000	12.84444200000	0.060	0.000	-0.060			25-Year
21	120.77689000000	12.84445600000	0.100	0.000	-0.100			25-Year

22	120.77832000000	12.84496600000	0.210	0.000	-0.210			25-Year
23	120.77859340000	12.84500910000	0.280	0.000	-0.280			25-Year
24	120.77713000000	12.84544500000	0.220	0.000	-0.220			25-Year
25	120.77887000000	12.84552100000	0.090	0.000	-0.090			25-Year
26	120.77949250000	12.84586280000	0.260	0.000	-0.260			25-Year
27	120.77760000000	12.84592000000	0.100	0.000	-0.100			25-Year
28	120.77948000000	12.84675800000	0.110	0.000	-0.110			25-Year
29	120.77877170000	12.85077420000	0.450	0.330	-0.120	Marce	Nov. 2016	25-Year
30	120.77833330000	12.85089210000	0.440	0.800	0.360	Habagat	Aug. 2016	25-Year
31	120.77833330000	12.85089210000	0.440	0.800	0.360	Habagat	Aug. 2016	25-Year
32	120.77845000000	12.85112600000	0.480	0.200	-0.280	Habagat	Aug. 2016	25-Year
33	120.78113140000	12.85125190000	1.150	0.000	-1.150			25-Year
34	120.77869000000	12.85142300000	0.240	0.300	0.060		Sept. 2015	25-Year
35	120.77883000000	12.85172100000	0.380	0.300	-0.080	Habagat	Aug. 2016	25-Year
36	120.77991000000	12.85178000000	0.210	0.100	-0.110	Habagat	Aug. 2016	25-Year
37	120.77874000000	12.85185100000	0.480	0.800	0.320	Habagat	Aug. 2016	25-Year
38	120.78011000000	12.85188700000	0.030	0.000	-0.030			25-Year
39	120.78049000000	12.85194800000	0.350	0.000	-0.350			25-Year
40	120.78108700000	12.85199050000	0.960	0.250	-0.710	Habagat	Aug. 2016	25-Year
41	120.78141330000	12.85201980000	0.670	1.300	0.630	Habagat	Aug. 2016	25-Year
42	120.77894000000	12.85199900000	0.330	0.100	-0.230	Habagat	Aug. 2016	25-Year
43	120.78099000000	12.85220600000	1.300	0.500	-0.800	Habagat	Aug. 2016	25-Year
44	120.78056670000	12.85247490000	0.150	0.330	0.180	Habagat	Aug. 2016	25-Year
45	120.78131000000	12.85249100000	0.060	0.000	-0.060			25-Year

46	120.78075000000	12.85258700000	0.540	0.400	-0.140	Habagat	Aug. 2016	25-Year
47	120.77926020000	12.85268150000	0.500	0.330	-0.170			25-Year
48	120.78065000000	12.85299000000	1.130	0.000	-1.130			25-Year
49	120.78119970000	12.85310860000	0.540	0.550	0.010			25-Year
50	120.78340000000	12.85801300000	0.130	0.000	-0.130			25-Year
51	120.78344000000	12.85875700000	0.070	1.300	1.230		Jun. 2014	25-Year
52	120.78415430000	12.85921260000	0.180	0.300	0.120			25-Year
53	120.78380000000	12.85943400000	0.030	0.000	-0.030			25-Year
54	120.78401000000	12.85958880000	0.030	0.400	0.370	Marce	Nov. 2016	25-Year
55	120.78305470000	12.85978670000	0.330	0.000	-0.330			25-Year
56	120.78932370000	12.86258440000	0.070	0.950	0.880	Nina	Dec. 2016	25-Year
57	120.78932370000	12.86258440000	0.070	0.950	0.880	Nina	Dec. 2016	25-Year
58	120.83739700000	12.87379030000	0.200	0.900	0.700	Nina	Dec. 2016	25-Year
59	120.83700000000	12.87378800000	0.030	0.000	-0.030			25-Year
60	120.83777000000	12.87385200000	0.310	0.000	-0.310			25-Year
61	120.83975280000	12.87396970000	0.130	0.290	0.160	Lando	Oct. 2015	25-Year
62	120.84042000000	12.87413200000	0.040	0.000	-0.040			25-Year
63	120.83699860000	12.87430190000	0.050	0.450	0.400	Nina	Dec. 2016	25-Year
64	120.84214220000	12.87459650000	0.080	0.650	0.570	Lando	Oct. 2015	25-Year
65	120.85463000000	12.87566100000	0.030	0.500	0.470	Lando	Oct. 2015	25-Year
66	120.80811790000	12.87545350000	0.400	0.320	-0.080	Nona	Dec. 2015	25-Year
67	120.80815760000	12.87613110000	0.430	0.300	-0.130			25-Year
68	120.80853720000	12.87658780000	0.330	0.000	-0.330			25-Year
69	120.80881170000	12.87668030000	0.500	0.500	0.000			25-Year
70	120.85712000000	12.87709400000	1.140	0.600	-0.540	Nina	Dec. 2016	25-Year

71	120.85848000000	12.87801200000	0.660	0.460	-0.200	Nina	Dec. 2016	25-Year
72	120.81021370000	12.87809570000	0.070	0.000	-0.070			25-Year
73	120.81048210000	12.87822350000	0.180	0.580	0.400	Ruby	Dec. 2014	25-Year
74	120.83363000000	12.87881600000	0.560	0.000	-0.560			25-Year
75	120.81171380000	12.87880950000	0.120	0.980	0.860	Nina	Dec. 2016	25-Year
76	120.81243400000	12.87907710000	0.030	1.300	1.270	Nina	Dec. 2016	25-Year
77	120.85933000000	12.87957200000	0.670	0.500	-0.170	Lando	Oct. 2015	25-Year
78	120.81308370000	12.87923580000	0.060	0.950	0.890	Nina	Dec. 2016	25-Year
79	120.83215000000	12.88082600000	0.030	0.000	-0.030			25-Year
80	120.83219210000	12.88108100000	0.050	0.000	-0.050			25-Year
81	120.80864000000	12.88127100000	0.030	0.000	-0.030			25-Year
82	120.86390340000	12.88188180000	0.300	0.000	-0.300			25-Year
83	120.8315551	12.8819232	0.130	0.000	-0.130			25-Year
84	120.83126	12.882114	0.130	0.000	-0.130			25-Year
85	120.864	12.88284	0.620	0.000	-0.620			25-Year
86	120.83068	12.882642	0.090	0.000	-0.090			25-Year
87	120.8310908	12.8831408	0.030	0.000	-0.030			25-Year
88	120.79057	12.884875	1.800	0.500	-1.300	Habagat	Aug. 2016	25-Year
89	120.79065	12.886123	1.180	0.450	-0.730	Habagat	Aug. 2016	25-Year
90	120.79025	12.88787	1.230	0.400	-0.830	Habagat	Aug. 2016	25-Year
91	120.78762	12.887962	1.880	0.400	-1.480	Habagat	Aug. 2016	25-Year
92	120.79018	12.888004	1.030	0.380	-0.650	Habagat	Aug. 2016	25-Year
93	120.78936	12.888291	1.340	0.300	-1.040	Habagat	Aug. 2016	25-Year
94	120.87311	12.889269	0.310	0.090	-0.220	Nina	Dec. 2016	25-Year
95	120.86659	12.889827	0.030	0.000	-0.030			25-Year

96	120.87257	12.890424	0.060	0.000	-0.060			25-Year
97	120.79072	12.891026	0.680	0.450	-0.230	Habagat	Aug. 2016	25-Year
98	120.87324	12.89205	0.100	0.000	-0.100			25-Year
99	120.79458	12.891519	0.510	0.000	-0.510	Habagat	Aug. 2016	25-Year
100	120.86724	12.892189	0.030	0.000	-0.030			25-Year
101	120.80141	12.892437	0.680	0.300	-0.380	Habagat	Aug. 2016	25-Year
102	120.87057	12.893027	0.130	0.000	-0.130			25-Year
103	120.80081	12.89278	0.680	0.200	-0.480	Habagat	Aug. 2016	25-Year
104	120.86766	12.893501	0.030	0.000	-0.030			25-Year
105	120.79792	12.893678	0.290	0.200	-0.090	Habagat	Aug. 2016	25-Year
106	120.86816	12.895334	0.05	0	-0.05			25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

Project Leader
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