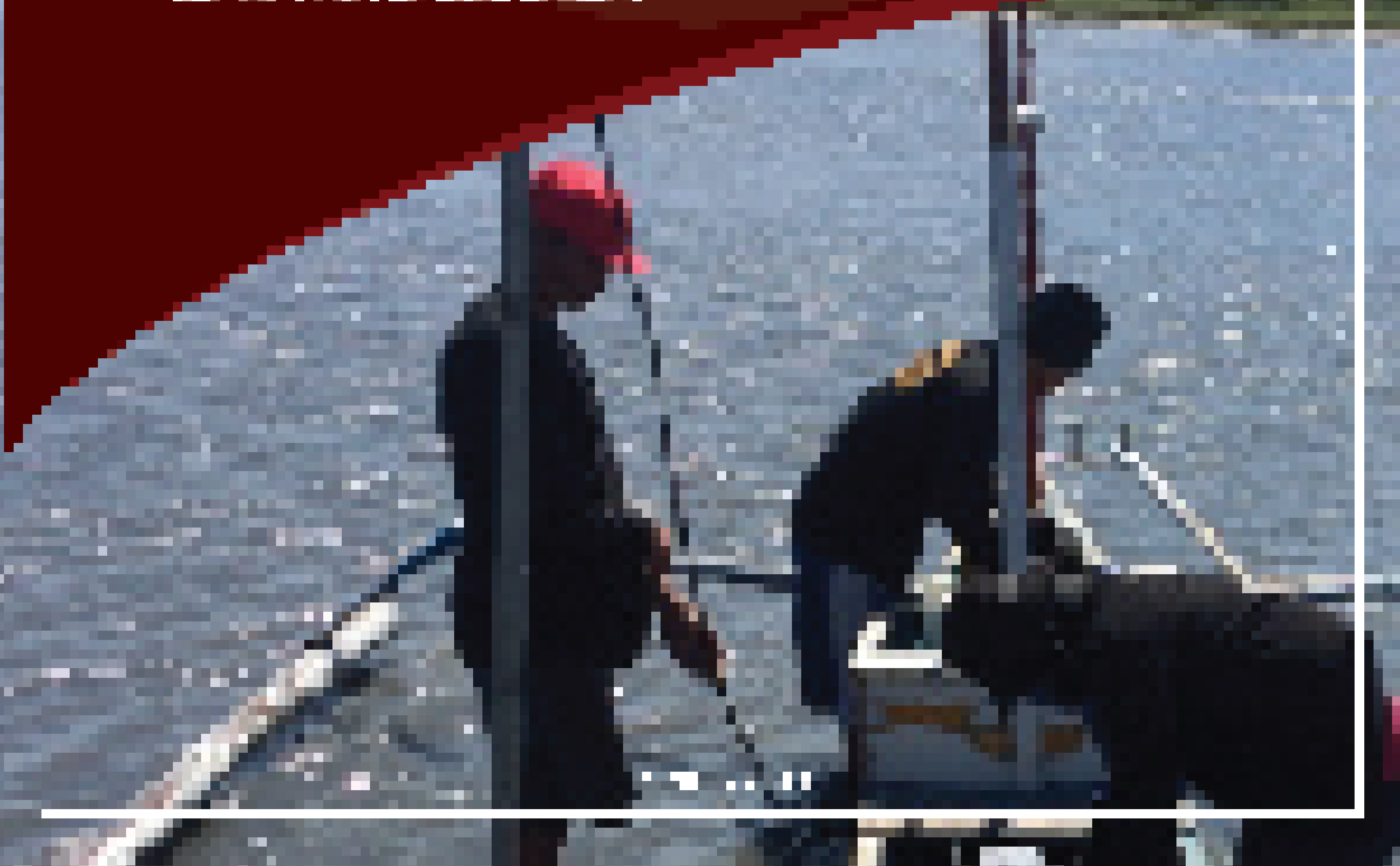
LiDAR Surveys and Flood Mapping of Amnay River



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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
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 AMNAY RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, 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 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

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 Tagalog region. The university is located in Los Baños City in the province of Laguna.

1.2 Overview of the Amnay River Basin

The Amnay River Basin, a 74,700-hectare watershed, covers some parts of Municipalities of Sablayan and Sta. Cruz in Occidental Mindoro. It covers the barangays of San Agustin, Batong Buhay, Claudio Salgad, Ibud, Ilvita, Lagnas, Malisbong, Paetan, Pag-asa, San Francisco, San Vicente, Tagumpay, and Victoria in the municipality of Sablayan; and Casague, Lumangbayan, and Pinagturilan in Santa Cruz. The DENR River Basin Control Office (RCBO) states that the Amnay River Basin has a drainage area of 466 km2 and an estimated 746 million cubic meter (MCM) annual run-off.

The basin area has five geological classifications including Basement Complex/ Pre-Jurassic as the most dominant type while the remaining are Paleocene-Eocene, Oligocene-Miocene, Oligocene and Cretaceous-Paleogene rocks. The river basin is also characterized to have more than 50% slope and elevation as high as 2,200 meters above mean sea level. Five soil types covers Amnay River which includes San Manuel sandy loam, Quingua clay loam, Faraon clay, Umingan loam and Banto clay loam. The river basin is also covered by cultivated areas mixed with brushland/grassland, grasslands, closed canopy with mature trees covering more than 50%, open canopy with mature trees covering less than 50%, mangrove forest, mossy forests, arable land with cereals and sugar as main crops, crop land mixed with coconut plantation and riverbeds.

Its main stem, Amnay river, is under the jurisdiction of the PHIL-LIDAR 1 partner, University of the Philippines, Los Baños. The Amnay river passes through laudio Salgad, Ilvita and Pagasa in Sablayan and Pinagturilan in Santa Cruz. A total of 19,643 people are residing within the immediate vicinity of the river, with Brgy. Pinagturilan being the most populated barangay having 7,168 residents as of 2010 according to National Statistics Office Census of Population and Housing.

As reported by the Mines and Geosciences Bureau, barangays dwelling nearby the Amnay River have a high risk to flooding. On the other hand, landslide susceptibility is none to very low.

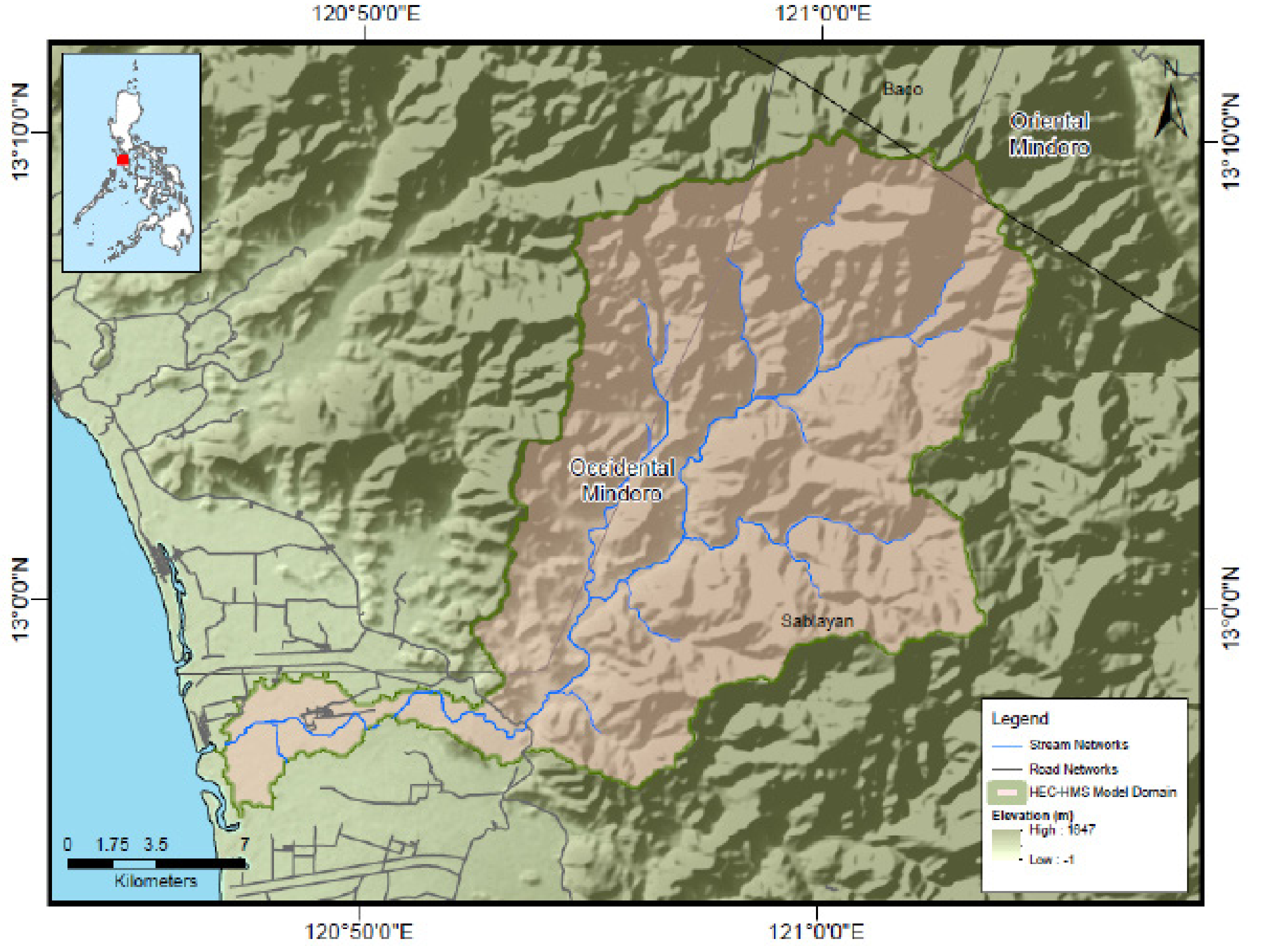

Figure 1. Map of the Amnay River Basin (in brown)

Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, there were eight notable weather disturbance that caused flooding in 2009 (Ondoy), 2011 (Pedring), 2013 (Yolanda), 2014 (Glenda), 2015 (Lando, Nona), and 2016 (Lawin and Nina). The most recent flooding event of the river was due to continuous heavy rain with thunderstorms in August 2011 as per NDRRMC report.

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

CHAPTER 2: LIDAR DATA ACQUISITION OF THE AMNAY FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Amnay floodplain Floodplain in Occidental Mindoro. These missions were planned for 15 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Amnay Floodplain.

Table 1. Flight planning parameters for the 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 the 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."

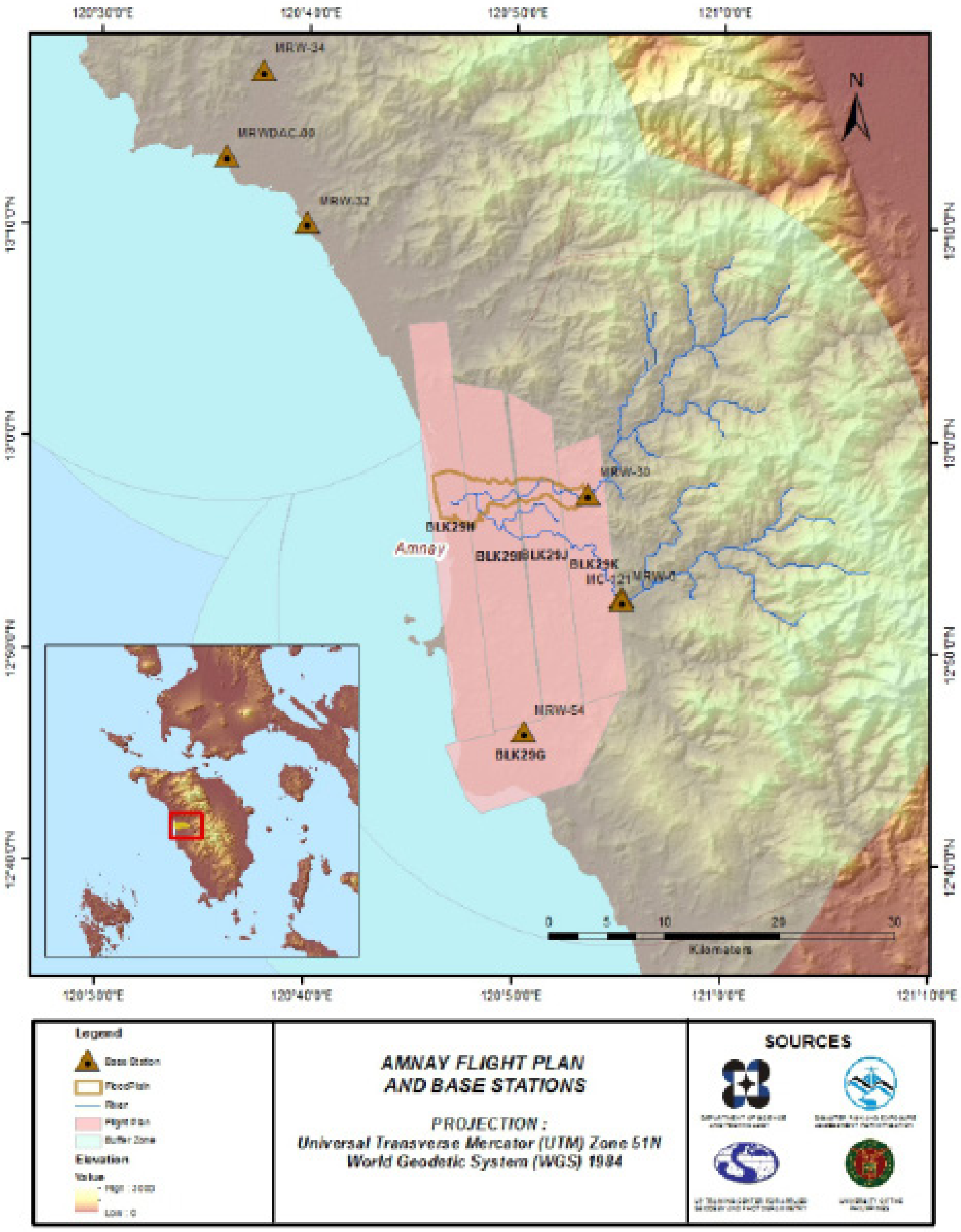


Figure 2. Flight Plan and base stations used for the Amnay Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover six (6) 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, MC-121, which areof first (1st)order accuracy, was also recovered. The benchmark was used as vertical reference points and was 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 A-2 while the baseline processing reports are found in Annex A-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 Amnay Floodplain floodplain are shown in Figure 2.

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 corresponding dates of survey.

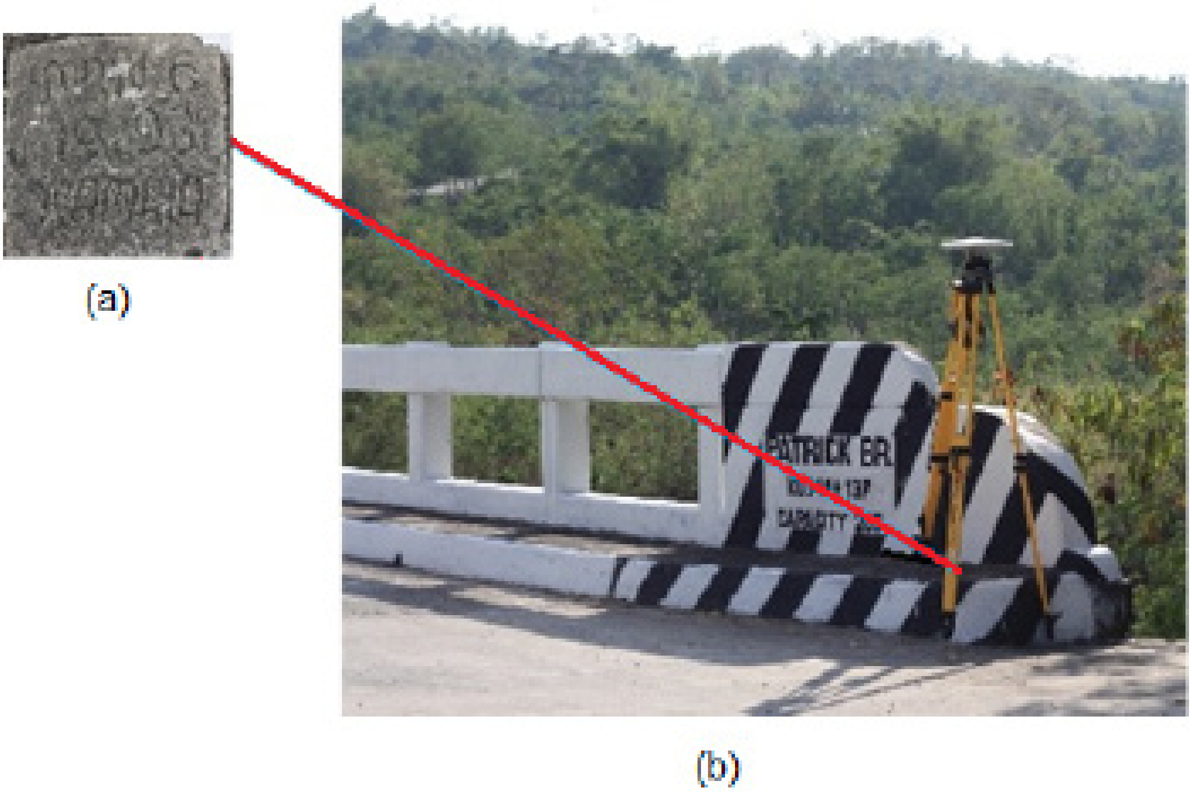


Figure 3. NAMRIA reference point MRW-6 (a) as recovered by the field team and GPS set-up over MRW-6 as recovered in Patrick Bridge in Brgy. Yabang, municipality of Sablayan, Occidental Mindoro (b).

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

Station Name	MRW-6	
Order of Accuracy	3rd	
Relative Error (Horizontal positioning)	1 in 20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude 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 Longitude 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

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

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

Station Name	MRW-30	
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°57'32.22950" North 120°53'28.50896" East 42.01300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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

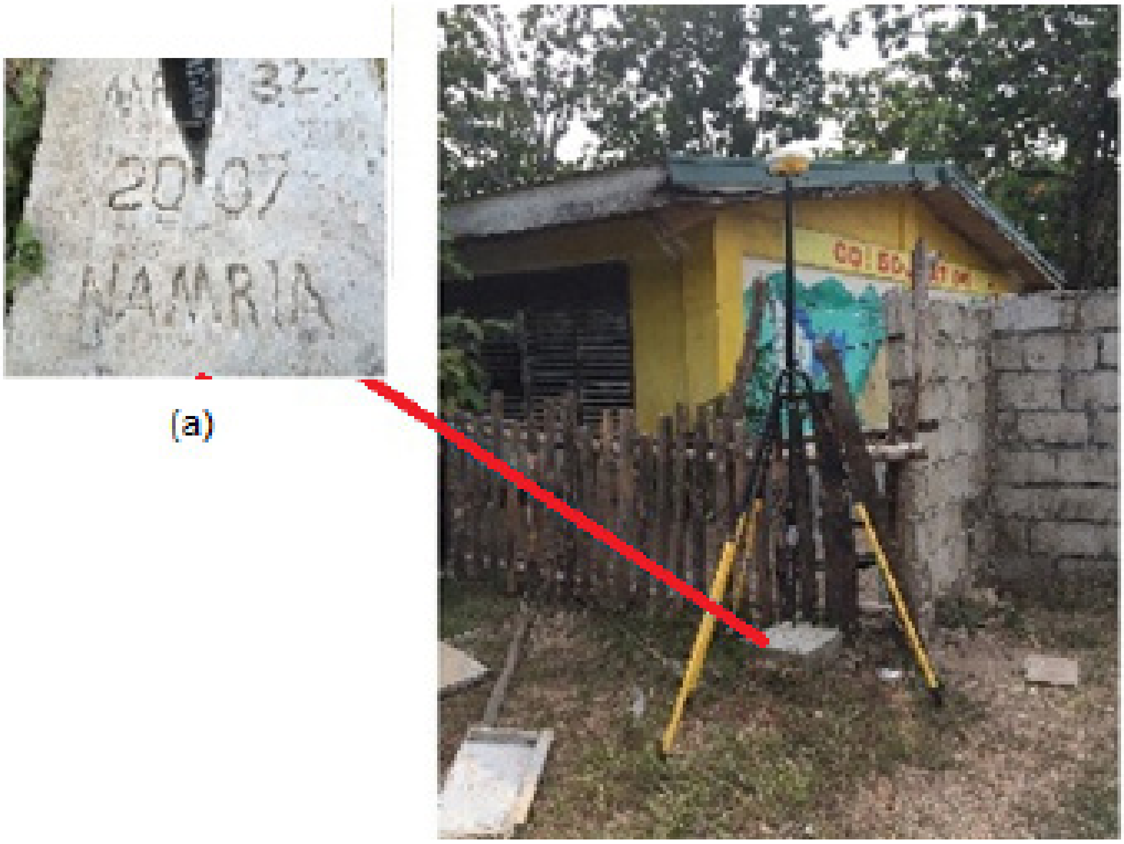


Figure 5. NAMRIA reference point MRW-32 (a) as recovered by the field team and GPS set-up over MRW-32 as recovered in the corner of a day care center in Brgy. Fatima, municipality of Mamburao, Occidental Mindoro (b).

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

Station Name	MRW-32	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°10'14.92094" North 120°39'52.29557" East 1.47400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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

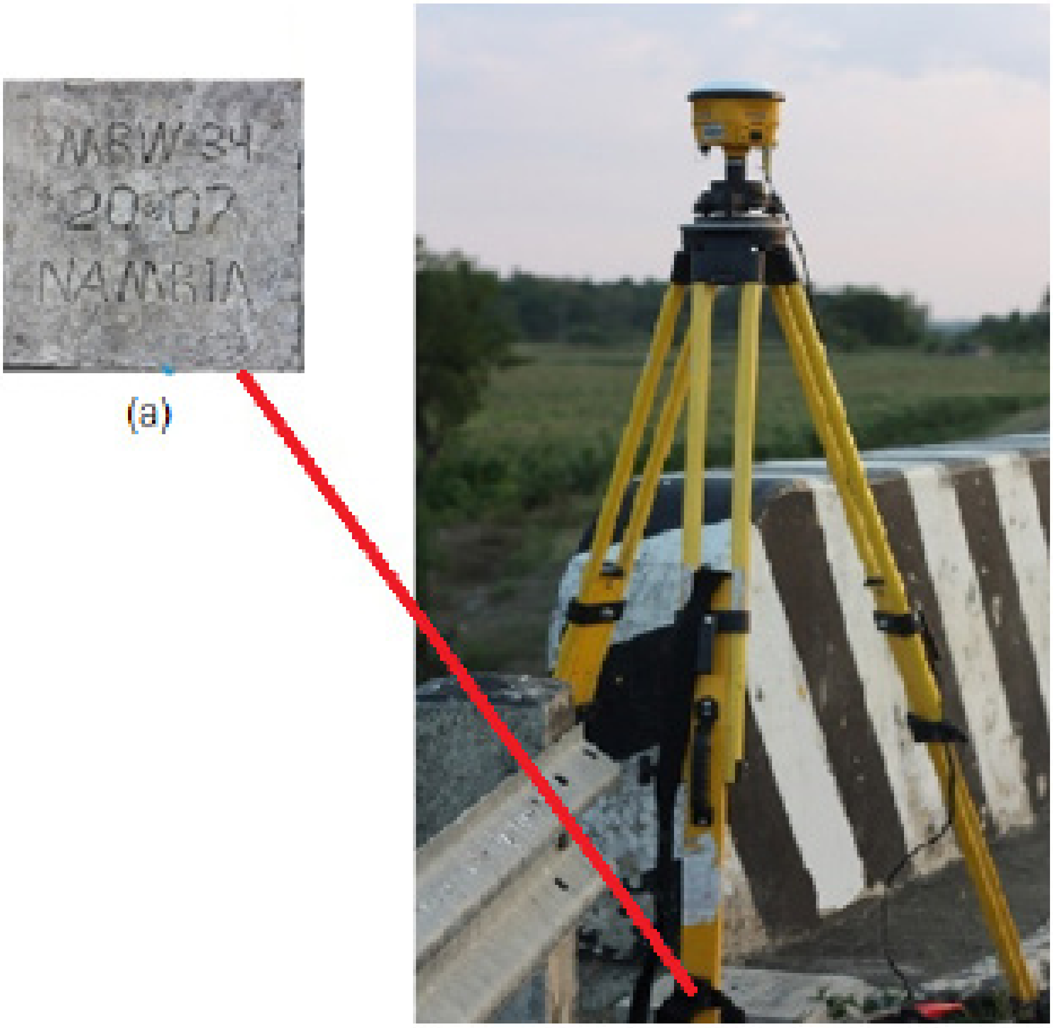


Figure 6. NAMRIA reference point MRW-34 (a) as recovered by the field team and GPS set-up over MRW-34 as recovered in Balibago Bridge in Brgy. Armado, municipality of Abra de Ilog, Occidental Mindoro (b).

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

Station Name	MRW-34	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°17'25.00981" North 120°37'41.53630" East 8.01600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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

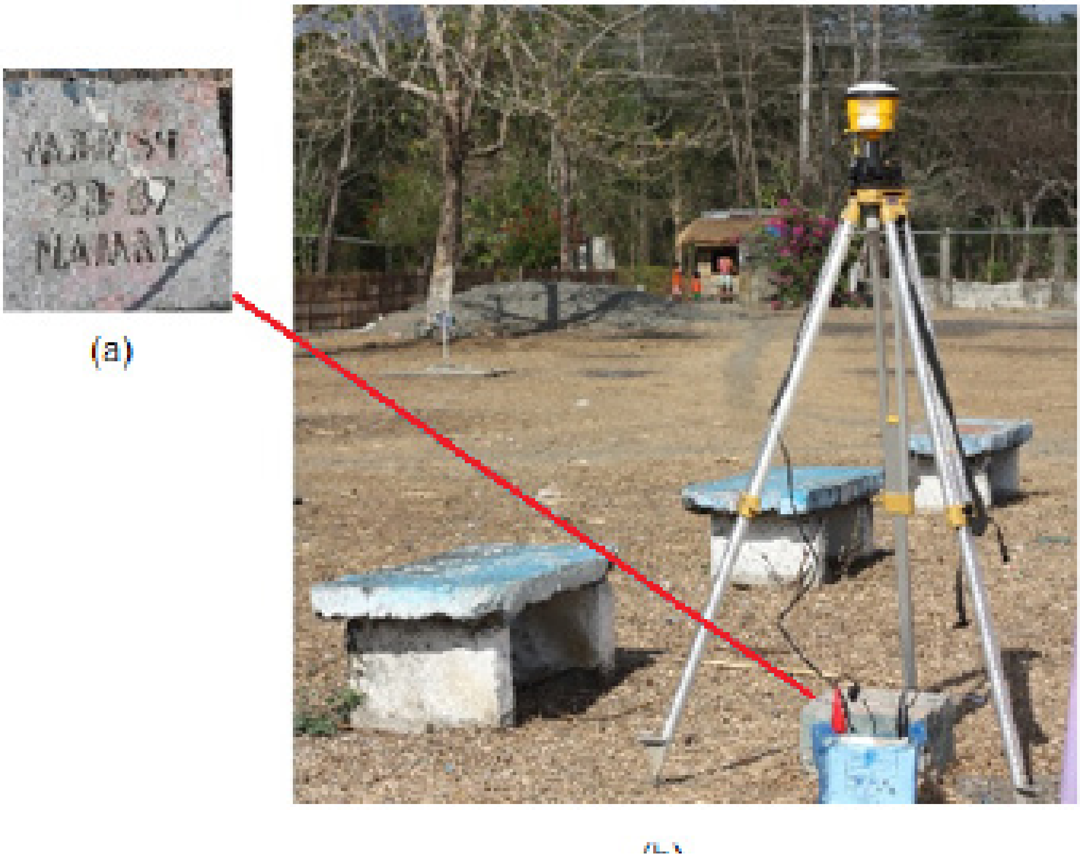


Figure 7. NAMRIA reference point MRW-54 (a) as recovered by the field team and GPS set-up over MRW-54 as recovered in near basketball open court in Brgy. Malisbong, municipality of Sablayan, Occidental Mindoro (b).

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

Station Name	MRW-54	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°46'18.56204" North 120°50'27.44152" East 28.20700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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 verticalreference point MC-121 used as base station for the LiDAR acquisition with established coordinates.

Station Name	MC-121	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1 in 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 3 (PTM Zone 3 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 established MRWDAC-00 used as base station for the LiDAR acquisition.

Station Name	MRWDAC-00	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°13'23.10541" 120°35'55.10583" 11.60100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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 Amnay Floodplainfloodplain, 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 systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for LiDAR data acquisition in Amnay 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	6.88	30.34	10	2	41
16-Feb-14	1110A	202.24	78.12	8.57	60.45	608	4	23
18-Feb-14	1116A	90.69	86.23	4.89	64.65	1056	4	23
18-Feb-14	1118A	111.55	59.60	3.75	48.56	734	3	35
21-Feb-14	1128A	117.38	116.66	12.93	94.61	99	4	35
22-Feb-14	1132A	248.63	120.42	13.37	96.04	610	4	41
23-Feb-14	1136A	131.25	69.06	0	69.06	1241	4	29
8-Dec-15	3068P	182.62	36.42	0	28.64	74	1	55
9-Dec-15	3070P	319.70	98.32	0	72.89	209	2	35
TOTAL		1515.62	700.42	32.12	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

Amnay Floodplain 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 Amnay Floodplain floodplain is presented in Figure 88.

Table 13. List of municipalities and cities surveyed during the Amnay 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	85.76	12.09%
TOTAL		**3342.30**	**508.15**	**15.20%**

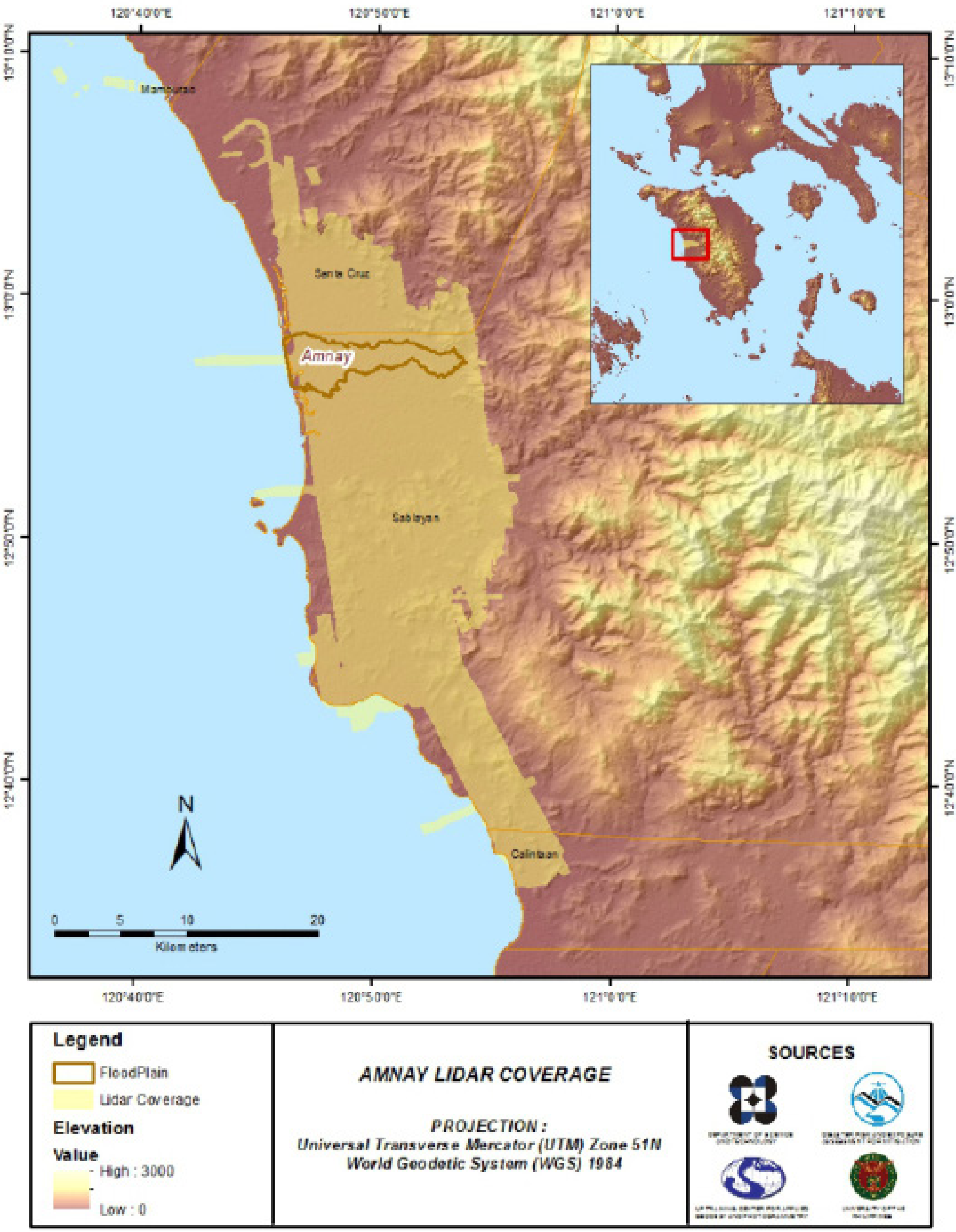


Figure 8. Actual LiDAR survey coverage for Amnay Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE AMNAY FLOODPLAIN

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

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

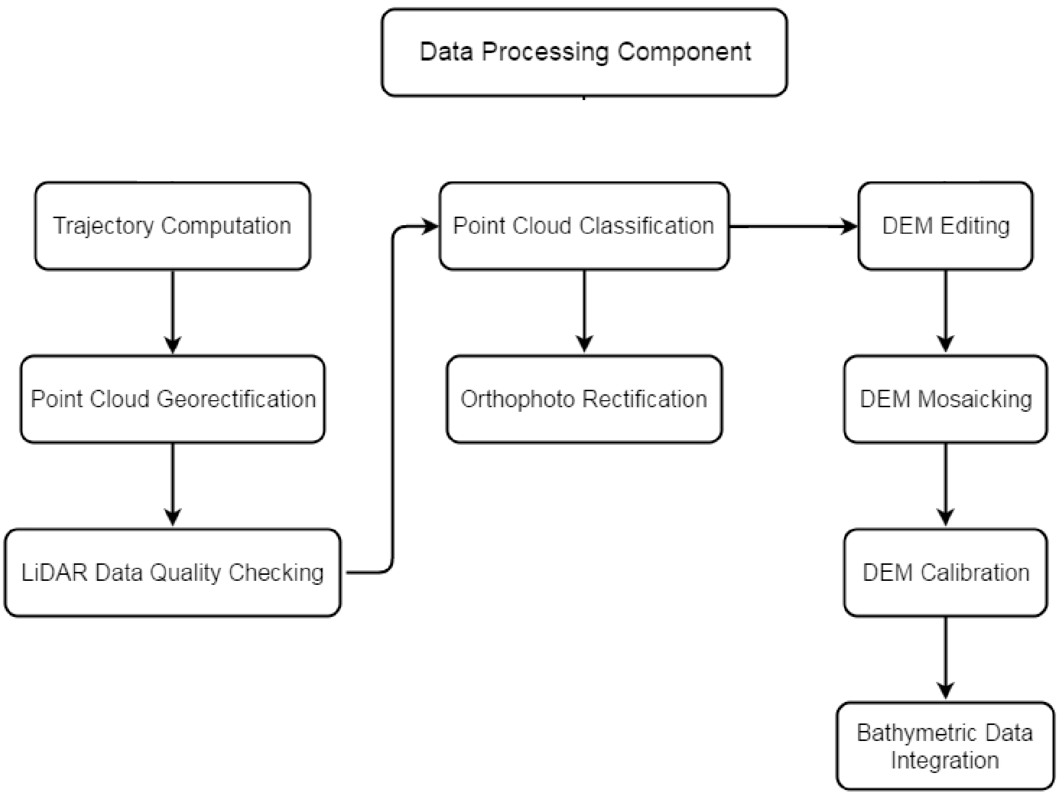


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Amnay Floodplain floodplain can be found in Annex A-5. Missions flown during the first survey conducted on in February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on in December 2016 5 were flown using Pegasus system over Sablayan, Occidental Mindoro. The Data Acquisition Component (DAC) transferred a total of 101.31 Gigabytes of Range data, 1.881 Gigabytes of POS data, 122.06 Megabytes of GPS base station data, and 286.149 Gigabytes of raw image data to the data server on March 19, 2014 for the first survey and January 15, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Amnay was fully transferred on January 15, 2016, as indicated on in the Data Transfer Sheets for Amnay Floodplain-floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1136A, one of the Amnay 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 23, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

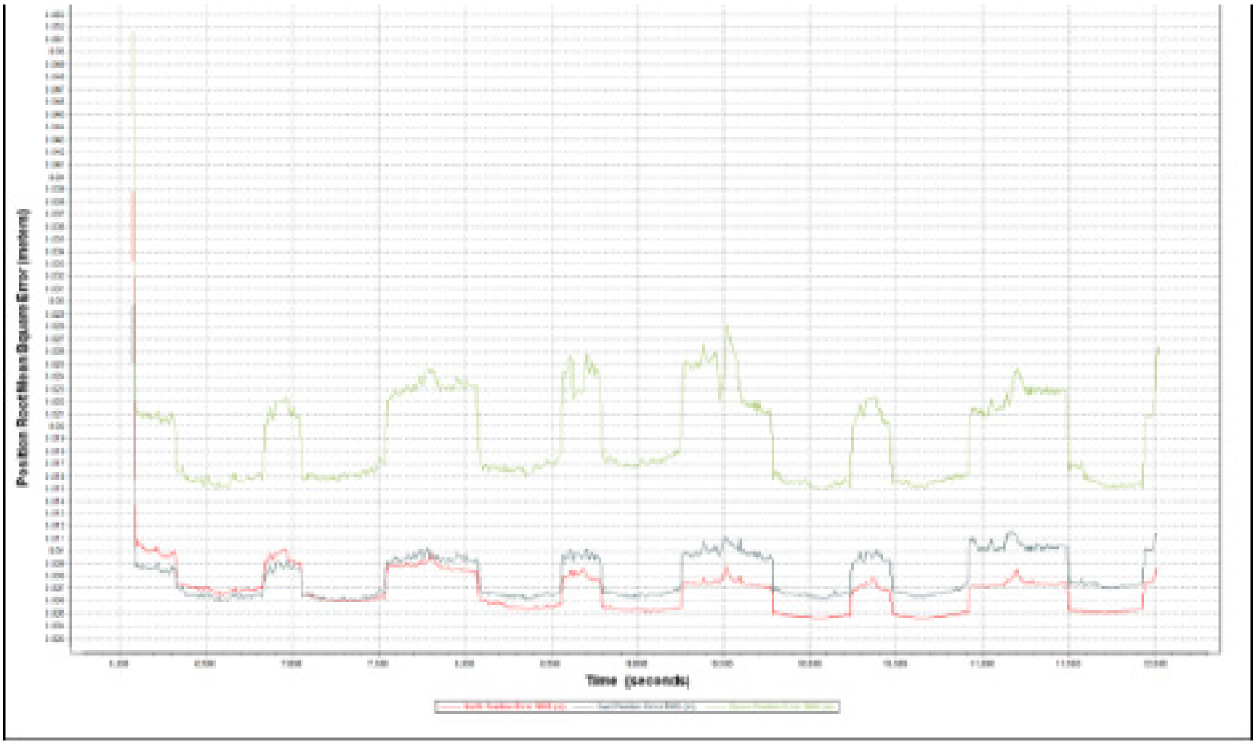


Figure 10. Smoothed Performance Metrics of Amnay Flight 1136A.

The time of flight was from 6100 seconds to 12000 seconds, which corresponds to morning of February 23, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.00 centimeters, the East position RMSE peaks at 1. 10 centimeters, and the Down position RMSE peaks at 2.80 centimeters, which are within the prescribed accuracies described in the methodology.

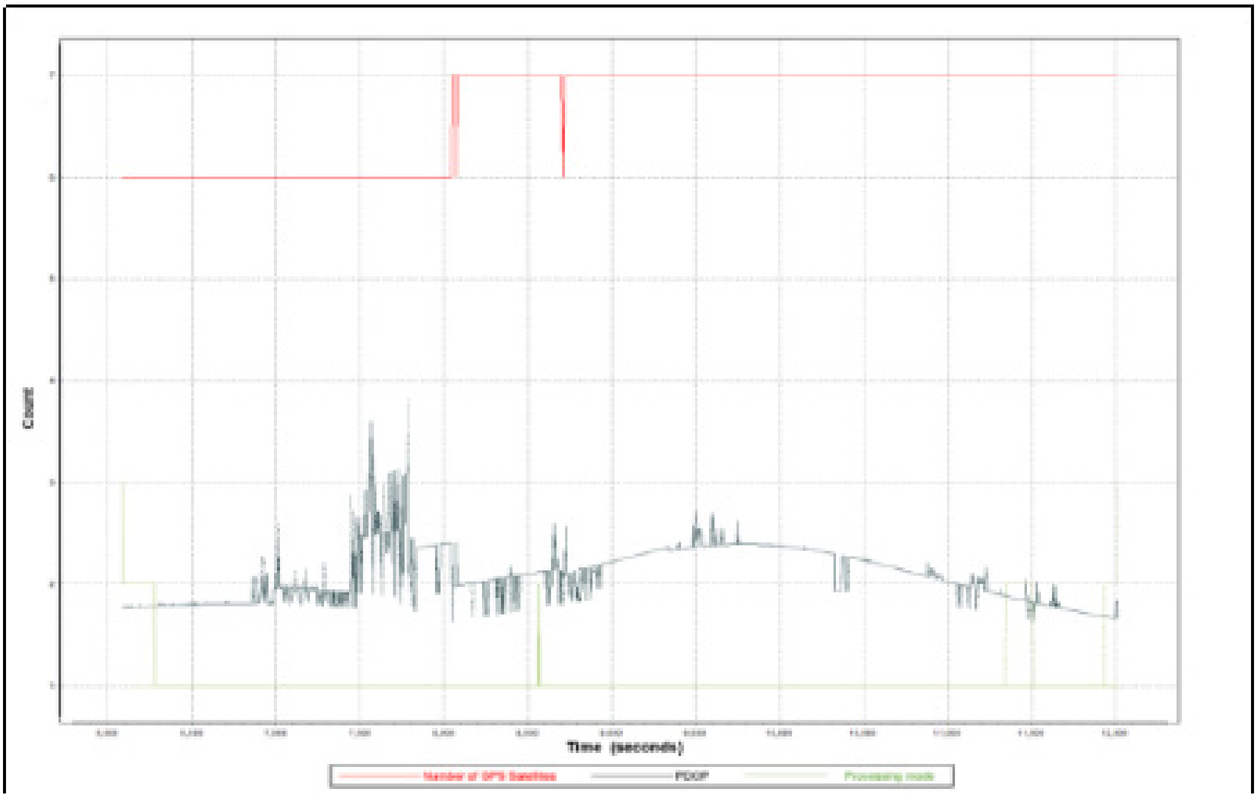


Figure 11. Solution Status Parameters of Amnay Flight 1136A.

The Solution Status parameters of flight 1136A, one of the Amnay flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), 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 to 6. Majority of the time, the number of satellites tracked was between 6 and 7. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Amnay flights is shown in Figure 12.

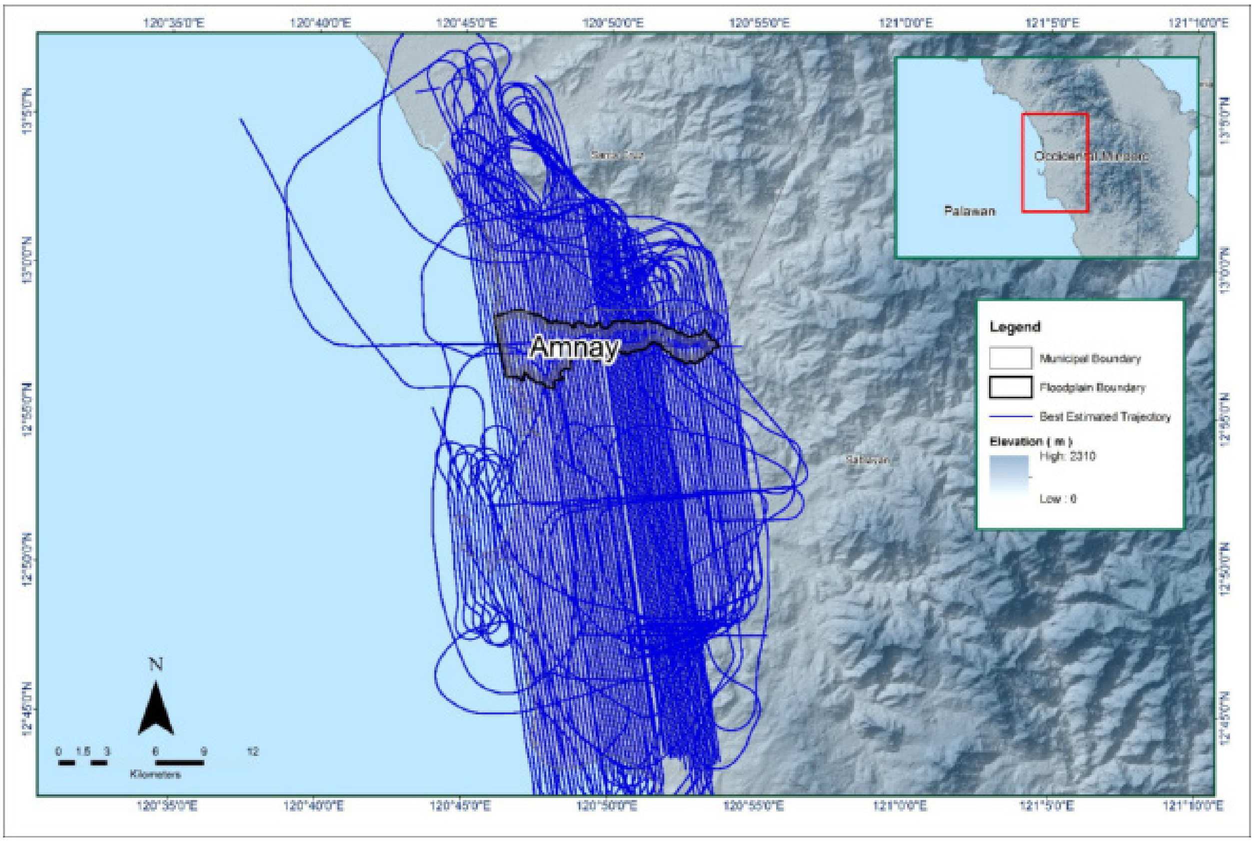


Figure 12. Best Estimated Trajectory for Amnay Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 97 flight lines, with some flight line containing one channel, since the Aquarius system contain one channel only and two channels for the Pegasus sytem. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Amnay Floodplain floodplain are given in Table 14.

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

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000270
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000746
GPS Position Z-correction stdev	<0.01meters	0.0093

The optimum accuracy is obtained for all Amnay flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex B-1. Mission Summary Reports8.

3.5 LiDAR Data Quality Checking

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

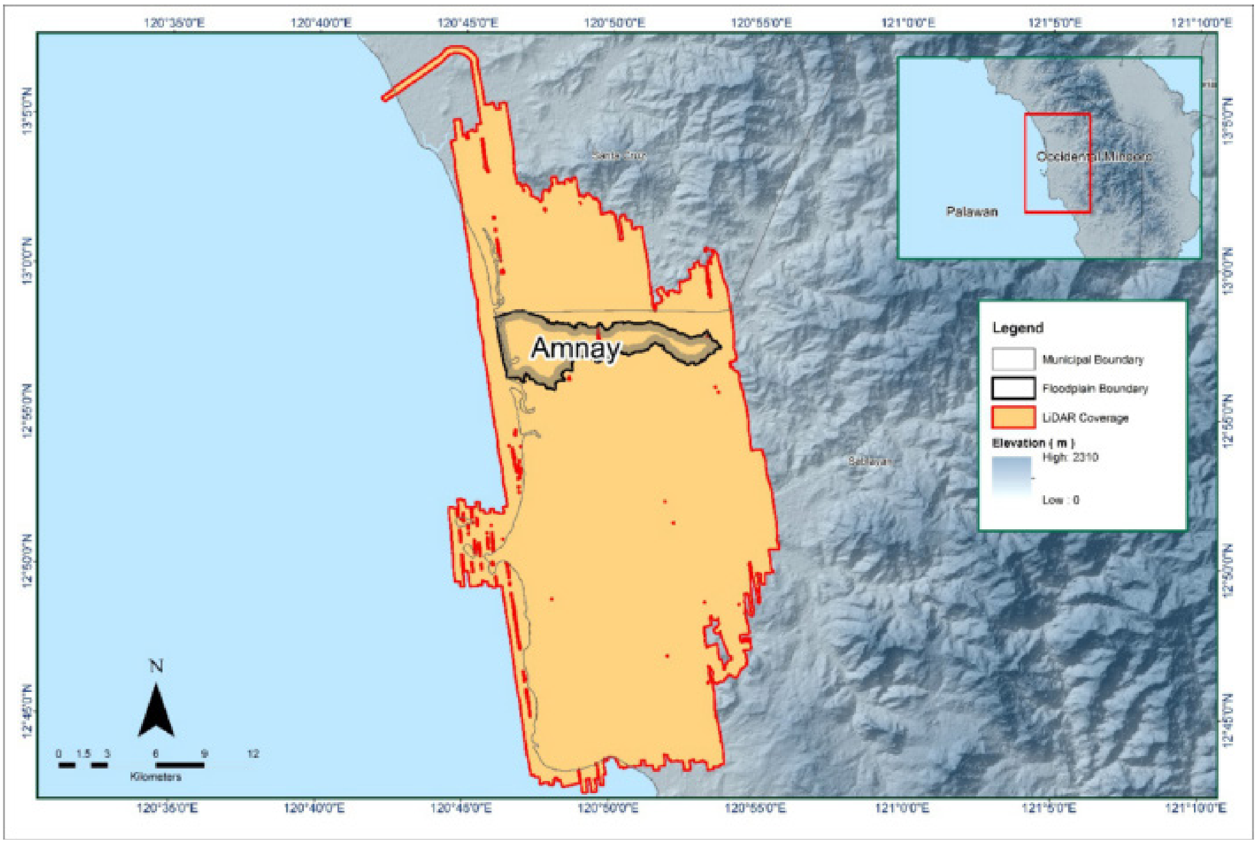


Figure 13. Boundary of the processed LiDAR data over Amnay Floodplain

The total area covered by the Amnay missions is 561.43 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into eight (6) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Amnay Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29H	1136A	102.41
OccidentalMindoro_Blk29HI_supplement	1132A	80.81
OccidentalMindoro_Blk29I	1128A	101.94
OccidentalMindoro_Blk29JK	1110A	133.64
	1118A	
	1108A	
OccidentalMindoro_Blk29K_supplement	1116A	82.45
OccidentalMindoro_Reflights_Blk29HI	3068P	60.18
	3070P	
TOTAL		561.43 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, 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 are expected. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines are expected.

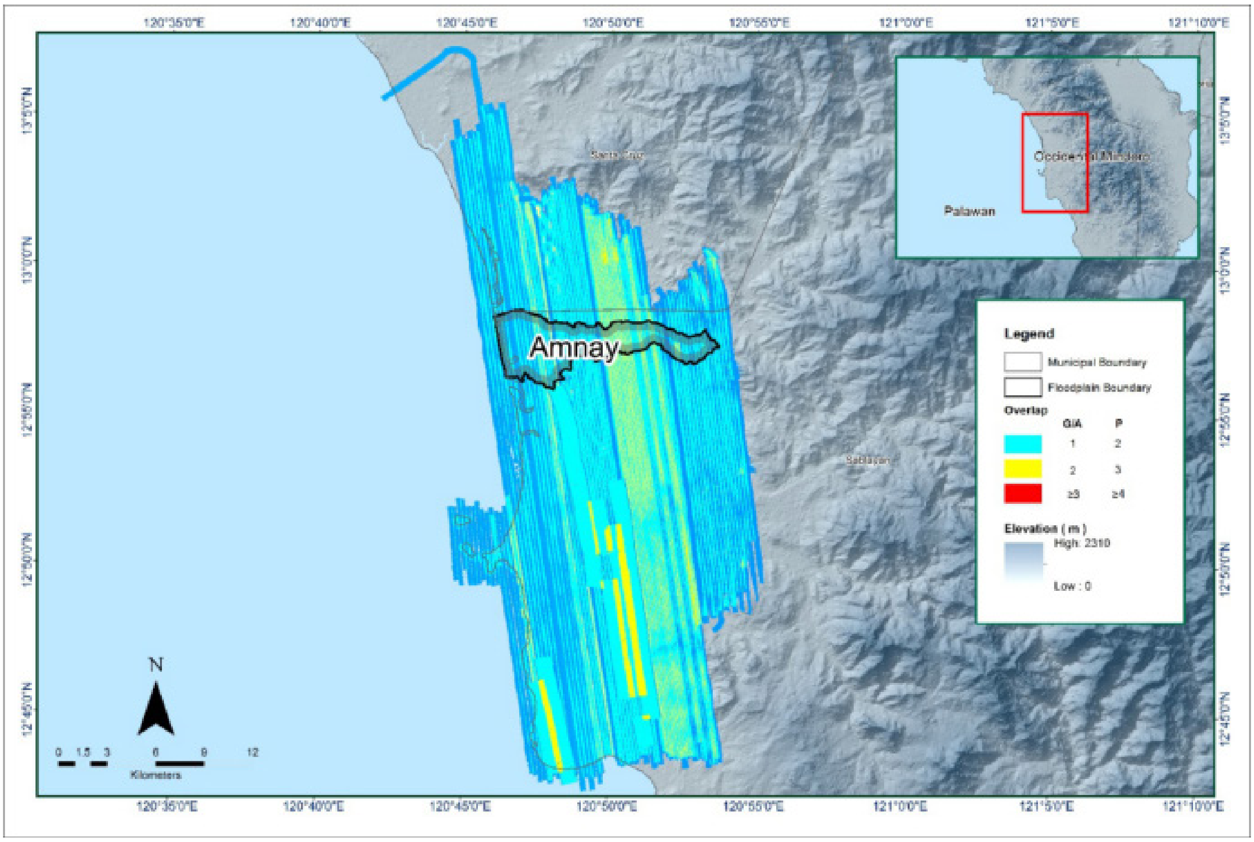


Figure 14. Image of data overlap for Amnay Floodplain.

The overlap statistics per block for the Amnay floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 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 Amnay Floodplain floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.64 points per square meter.

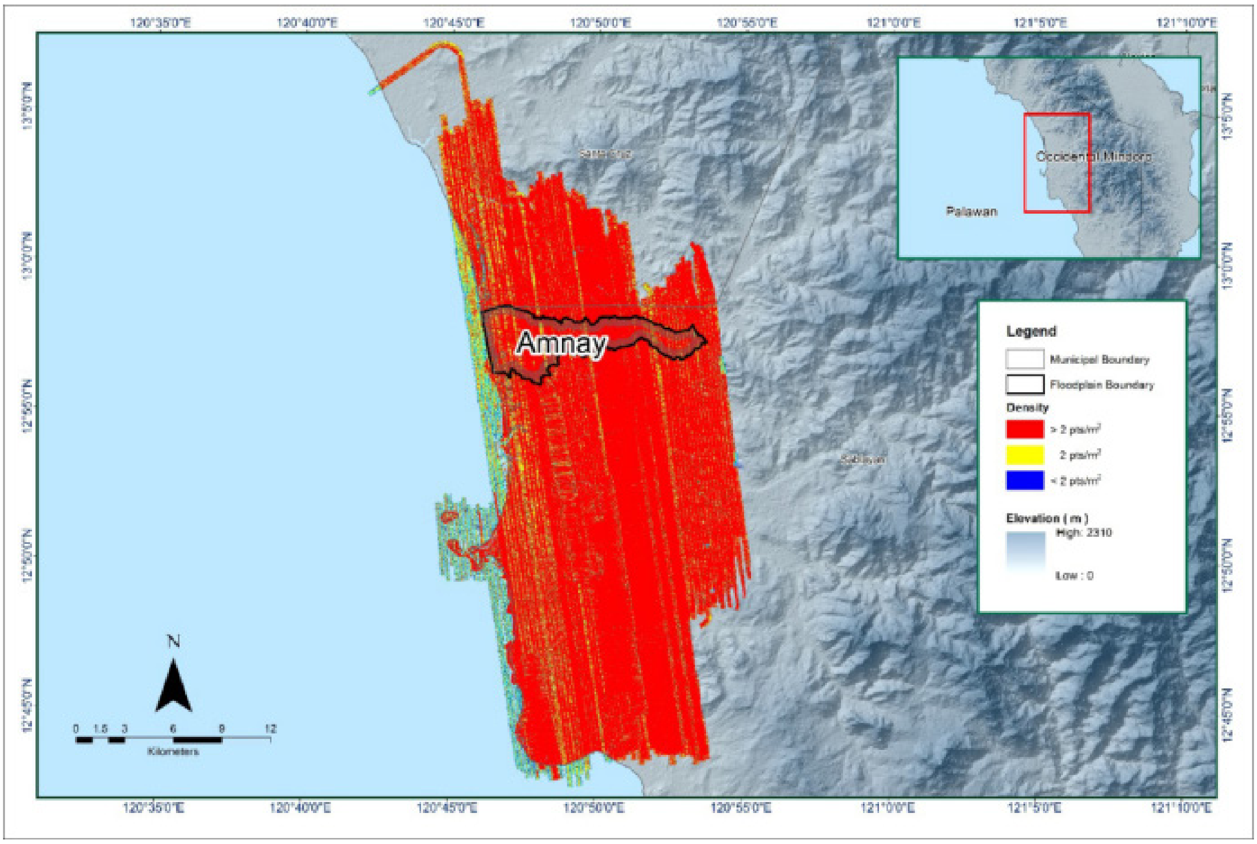


Figure 15. Pulse density map of merged LiDAR data for Amnay Floodplain.

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.

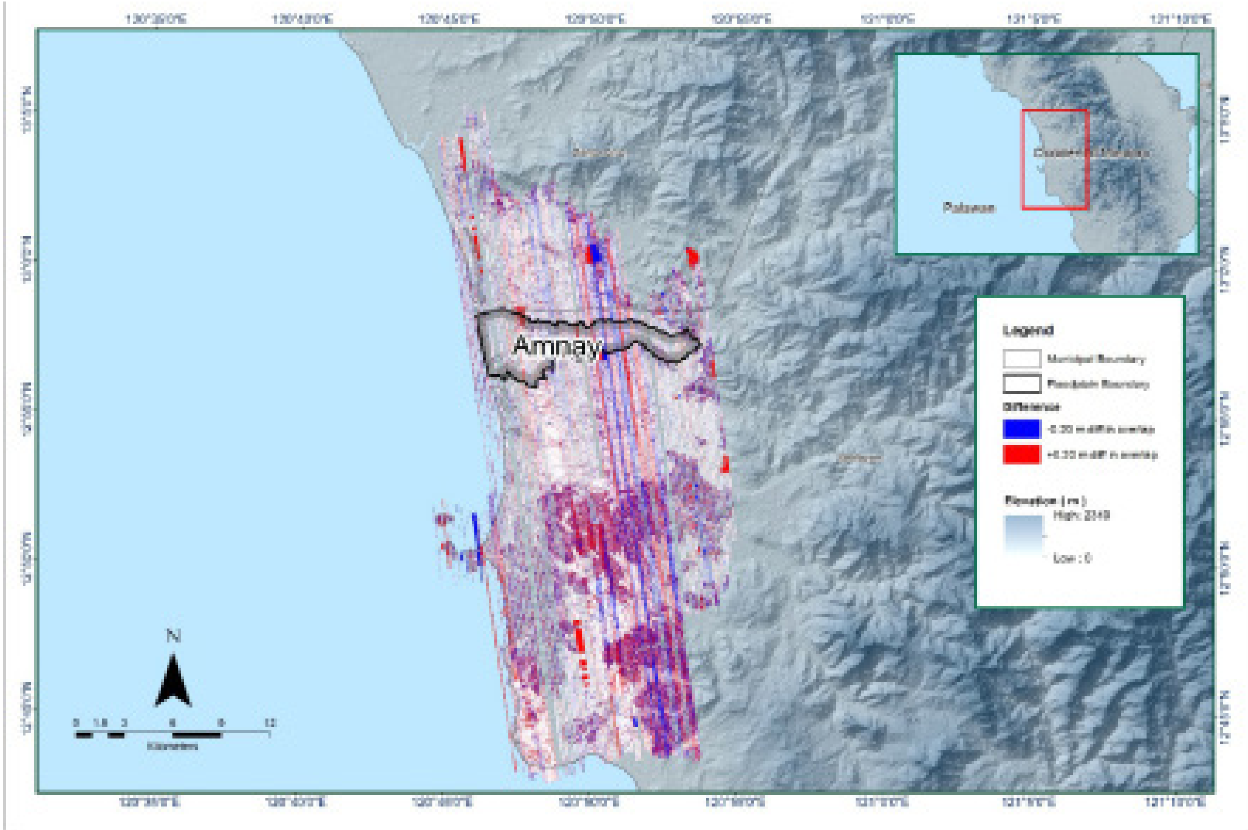


Figure 16. Elevation difference map between flight lines for Amnay Floodplain.

A screen capture of the processed LAS data from an Amnay flight 1136A 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.

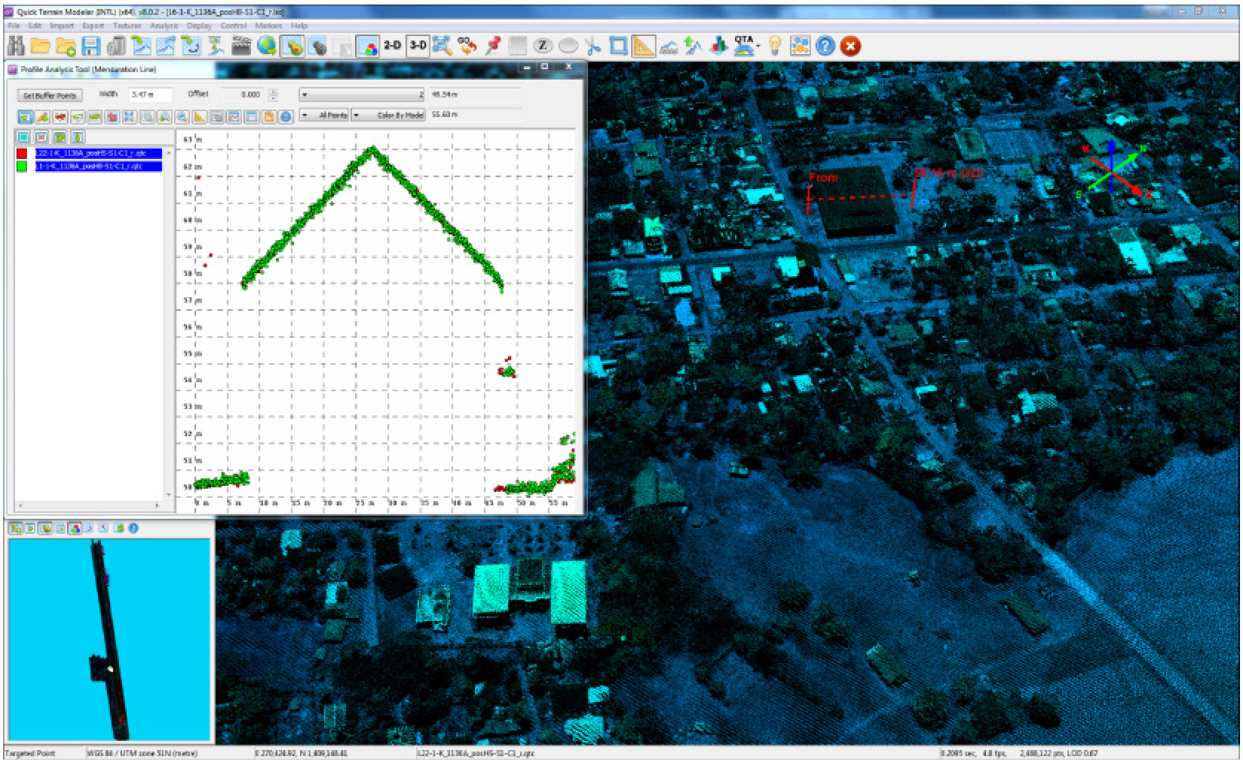


Figure 17. Quality checking for Amnay flight 1136A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Amnay classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	427,548,684
Low Vegetation	568,880,578
Medium Vegetation	606,064,647
High Vegetation	368,801,276
Building	12,236,871

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Amnay Floodplain floodplain is shown in Figure 18. A total of 907 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table B-316. The point cloud has a maximum and minimum height of 613.49 meters and 39.16 meters respectively.

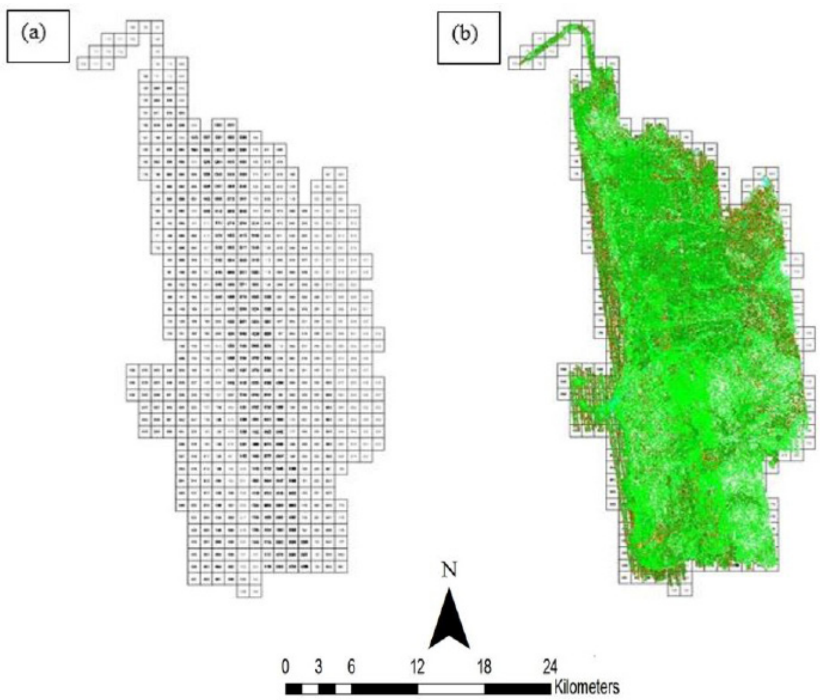


Figure 18. Tiles for Amnay Floodplain (a) and classification results (b) in TerraScan

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.

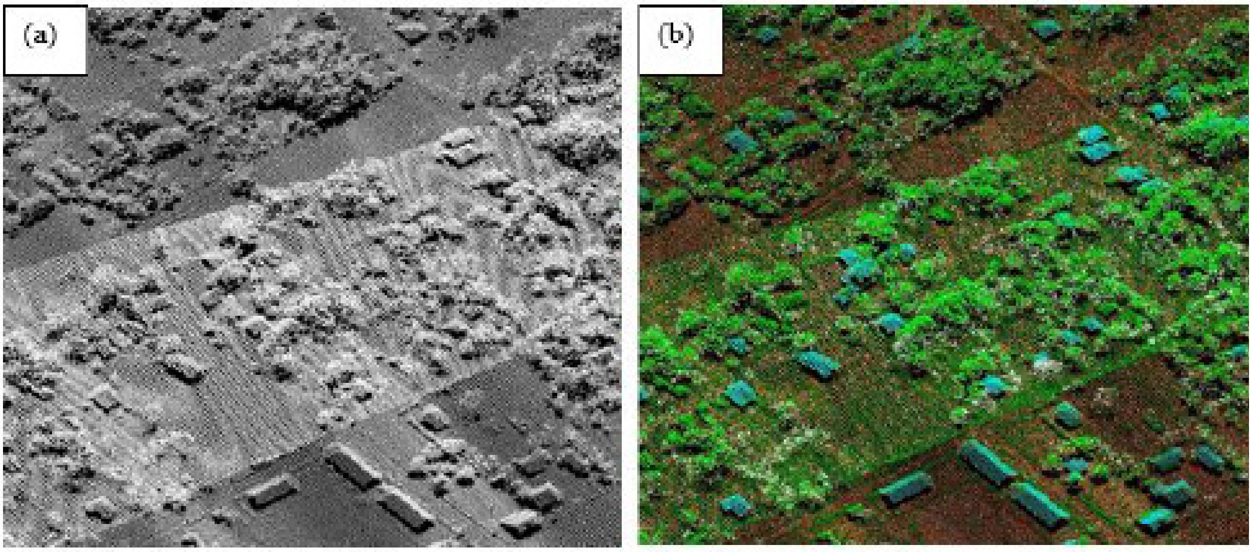


Figure 19. Point cloud before (a) and after (b) classification.

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

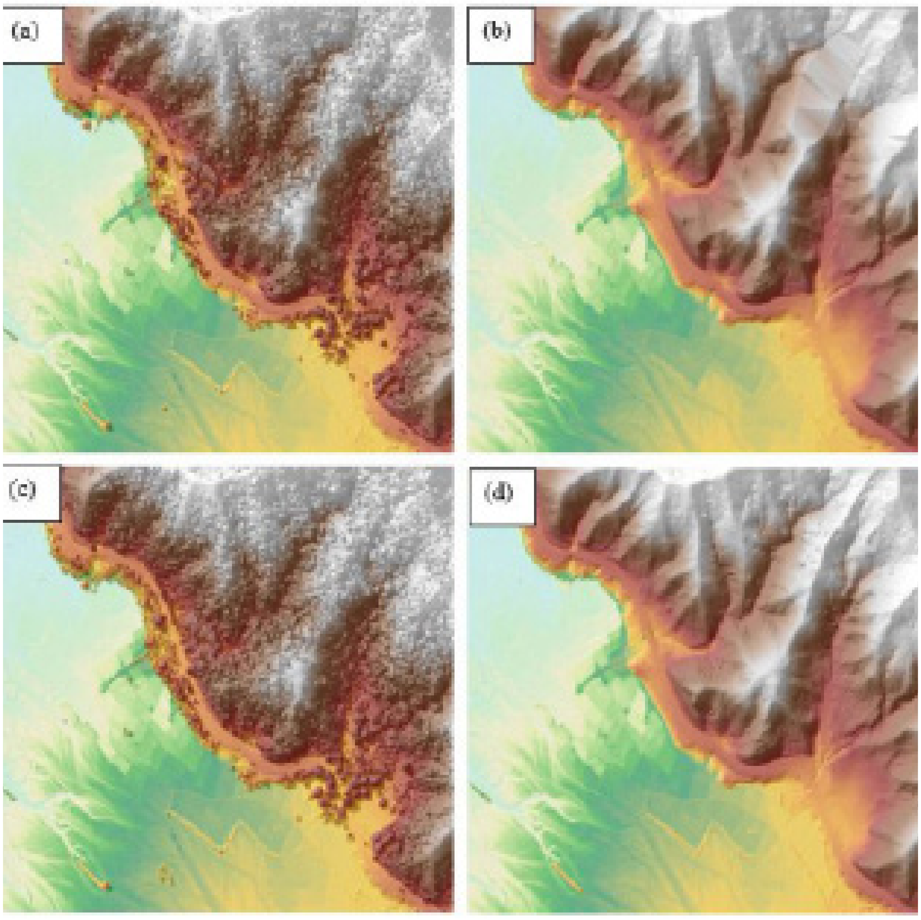


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Amnay Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 501 1km by 1km tiles area covered by Amnay Floodplain floodplain is shown in Figure B-1321. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Amnay Floodplain 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.

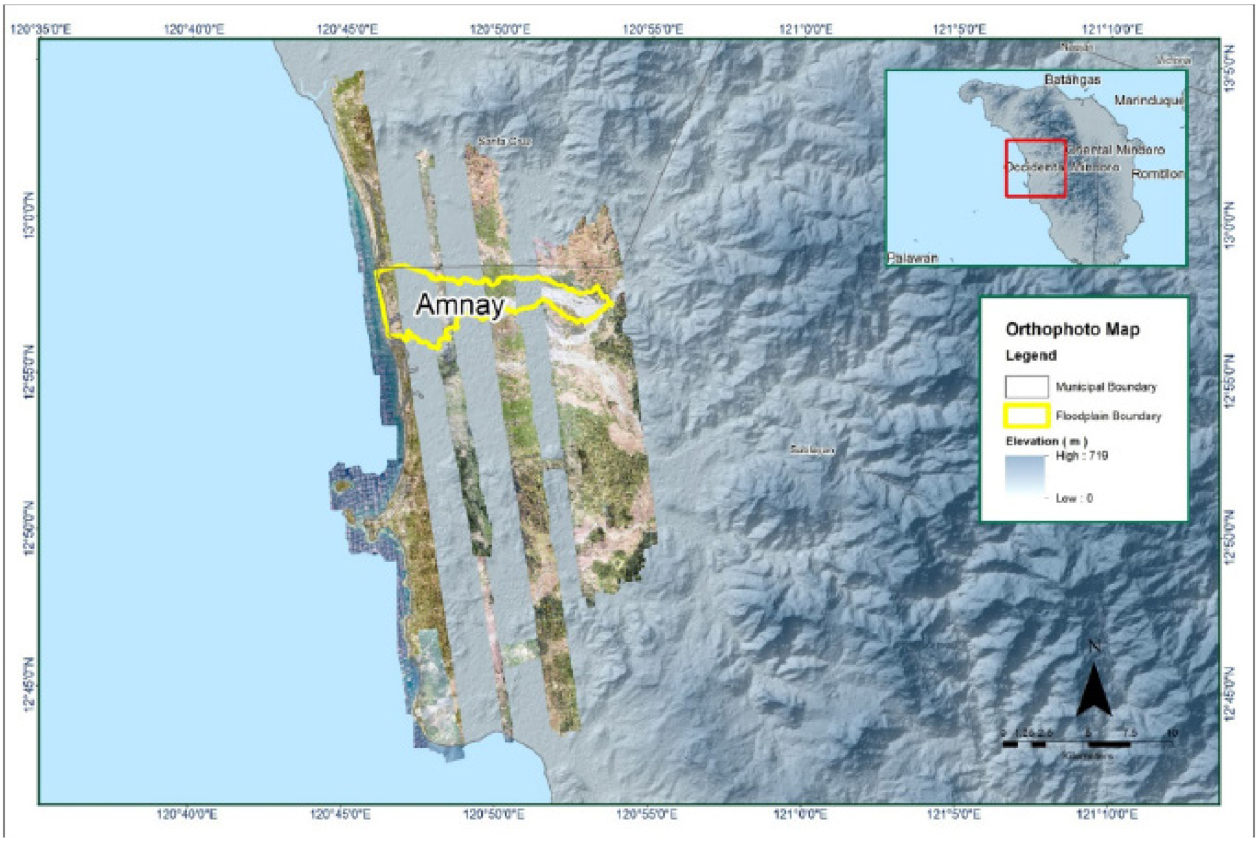


Figure 21. Amnay Floodplain with available orthophotographs.

Figure 22. Sample orthophotograph tiles for Amnay Floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Amnay floodplain. These blocks are composed of OccidentalMindoro and OccidentalMindoro_reflight blocks with a total area of 561.43 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	80.81
OccidentalMindoro_Blk29I	101.94
OccidentalMindoro_Blk29JK	133.64
OccidentalMindoro_Blk29K_supplement	82.45
OccidentalMindoro_reflights_Blk29HI	60.18
TOTAL	561.43 sq.km

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. Also, the mountain (Figure 23c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23d). Another example is a building that is still present in the DTM after classification (Figure 23e) and has to be removed through manual editing (Figure 23f).

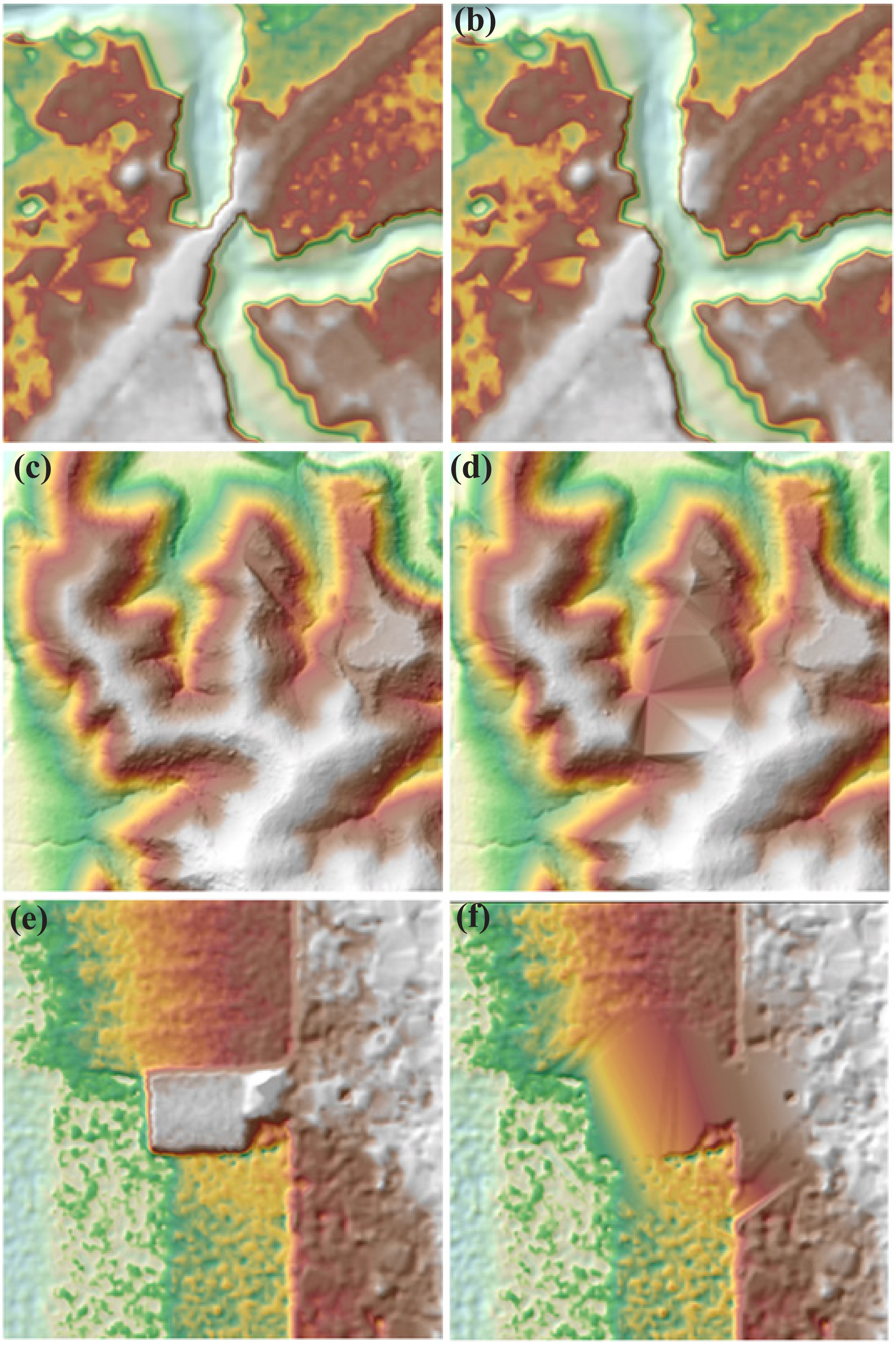


Figure 23. Portions in the DTM of Amnay Floodplain – a bridge before (a) and after (b) manual editing; a mountain (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing

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 Amnay Floodplain floodplain is shown in Figure 24. It can be seen that the entire Amnay Floodplain floodplain is 99.13% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 18. Shift Values of each LiDAR Block of Amnay 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

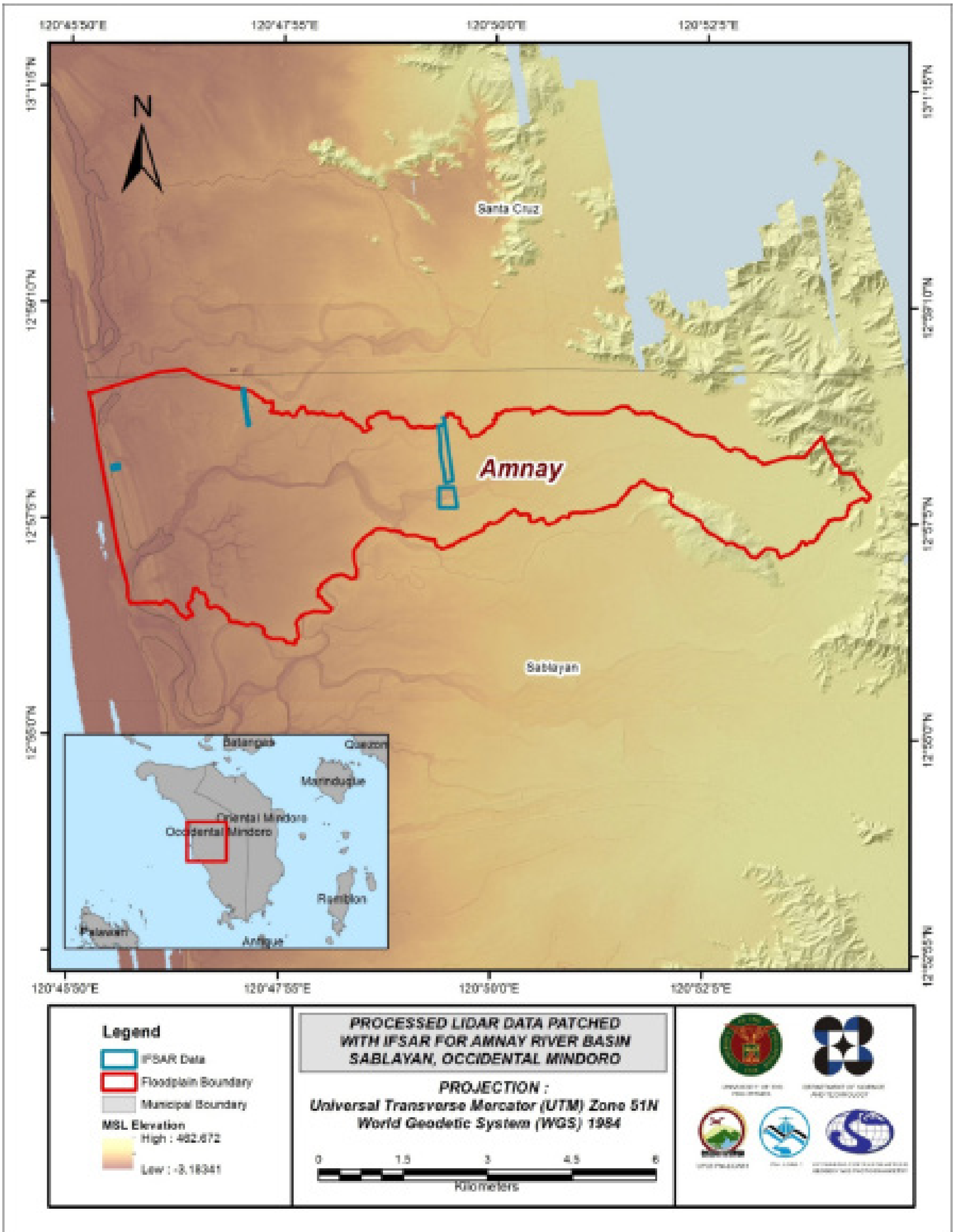


Figure 24. Map of Processed LiDAR Data for Amnay Floodplain.

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 Amnay 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 Amnay 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 Amnay LiDAR data was done by adding the height difference value, 0.23 meters, to Amnay mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

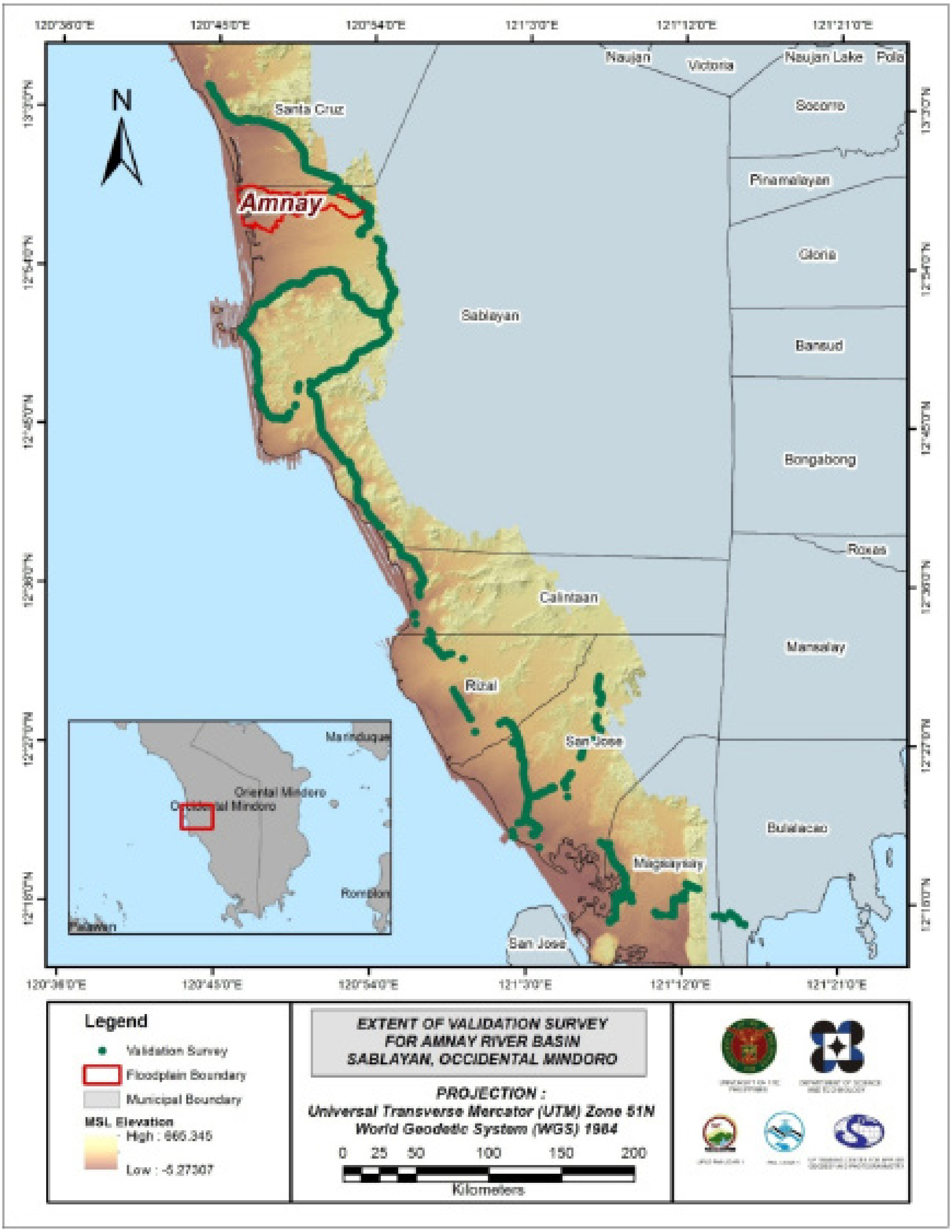


Figure 25. Map of Amnay Floodplain with validation survey points in green.

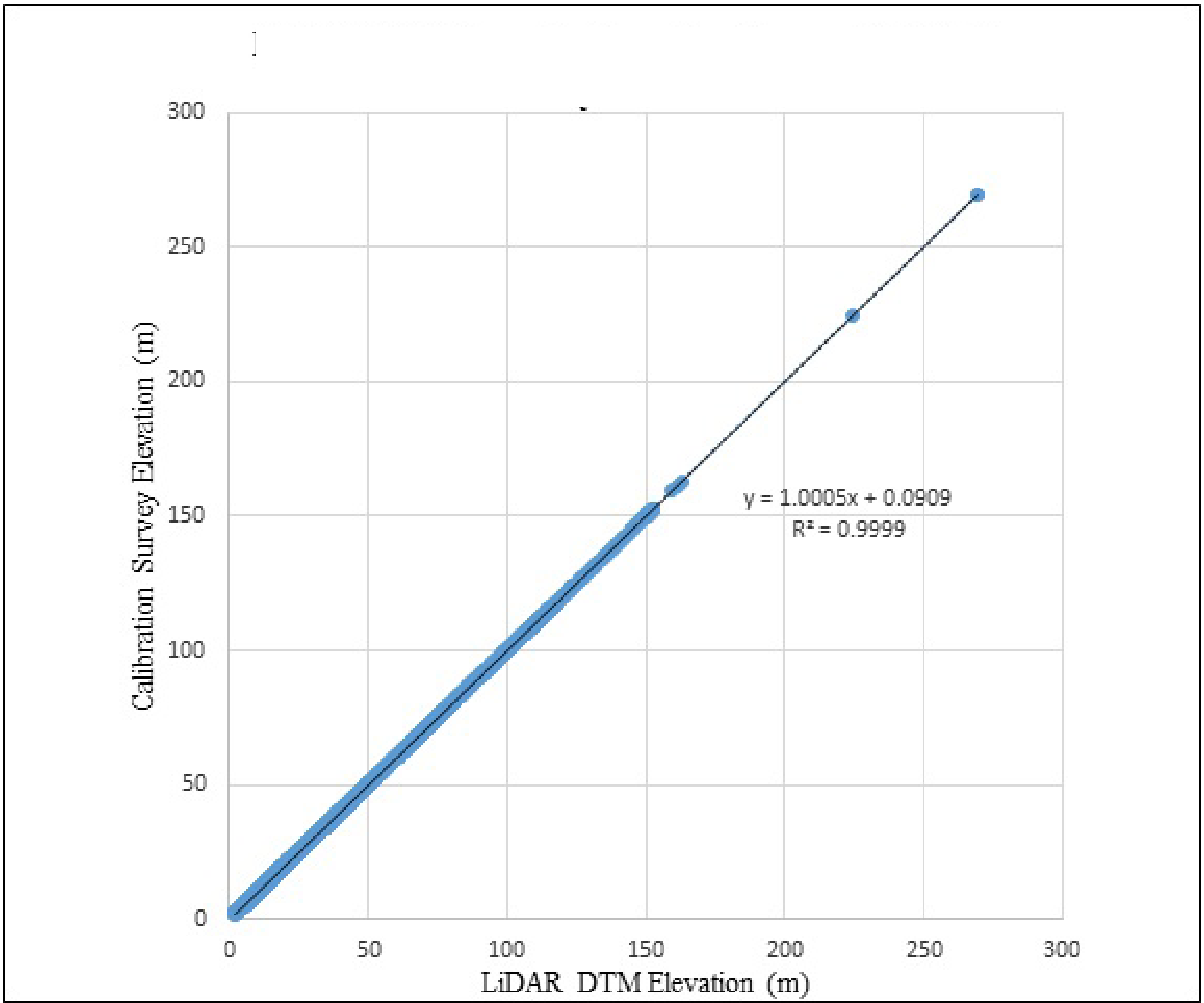


Figure 24. Correlation plot between calibration survey points and LiDAR data.

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 16 points. These were used for the validation of calibrated Amnay 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 0.17 meters with a standard deviation of 0.12 meters, as shown in Table 20.

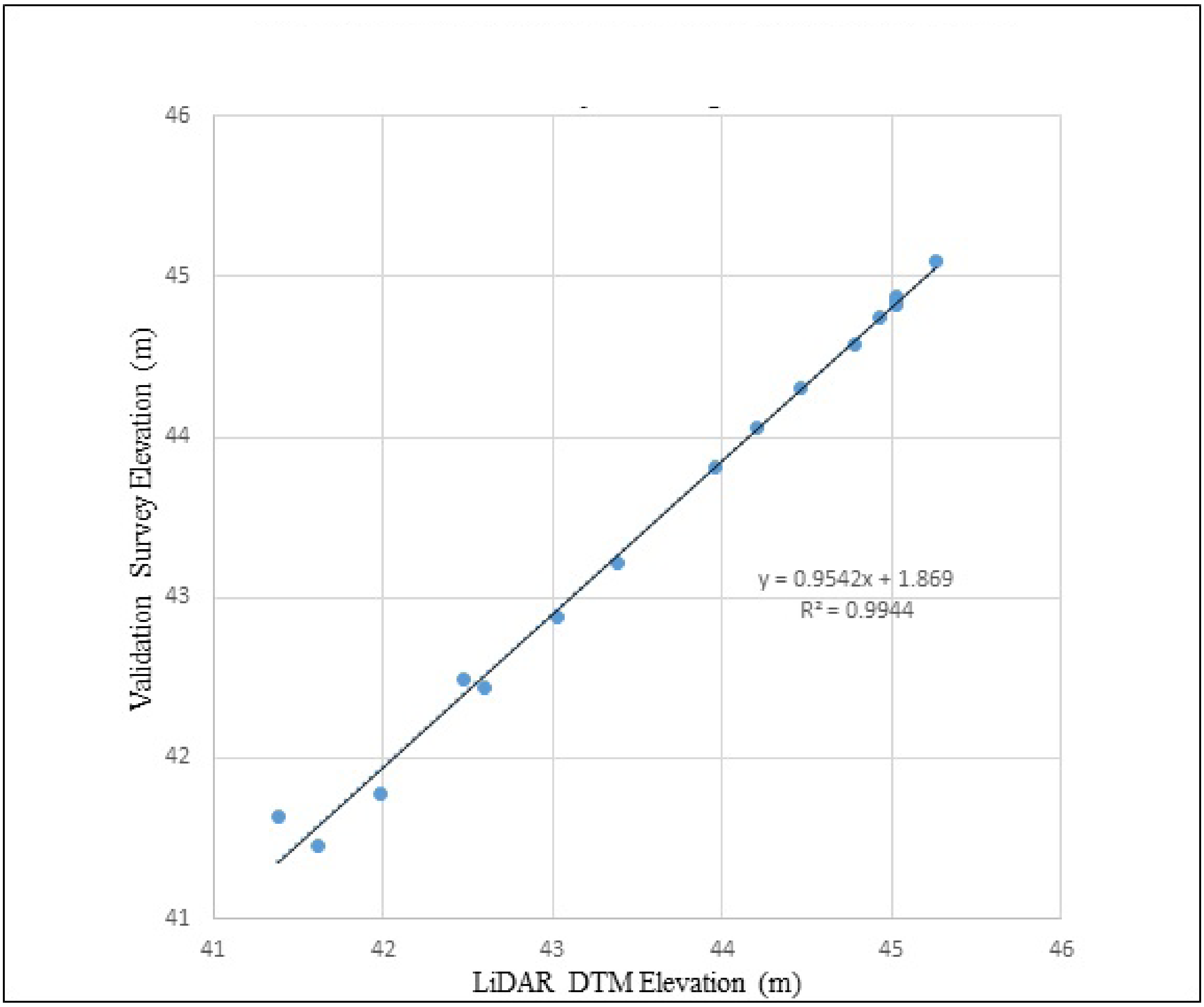


Figure 25. Correlation plot between validation survey points and LiDAR data.

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

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.12
Average	-0.12
Minimum	-0.20
Maximum	0.25

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Amnay with 10,537 and 4,831 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.

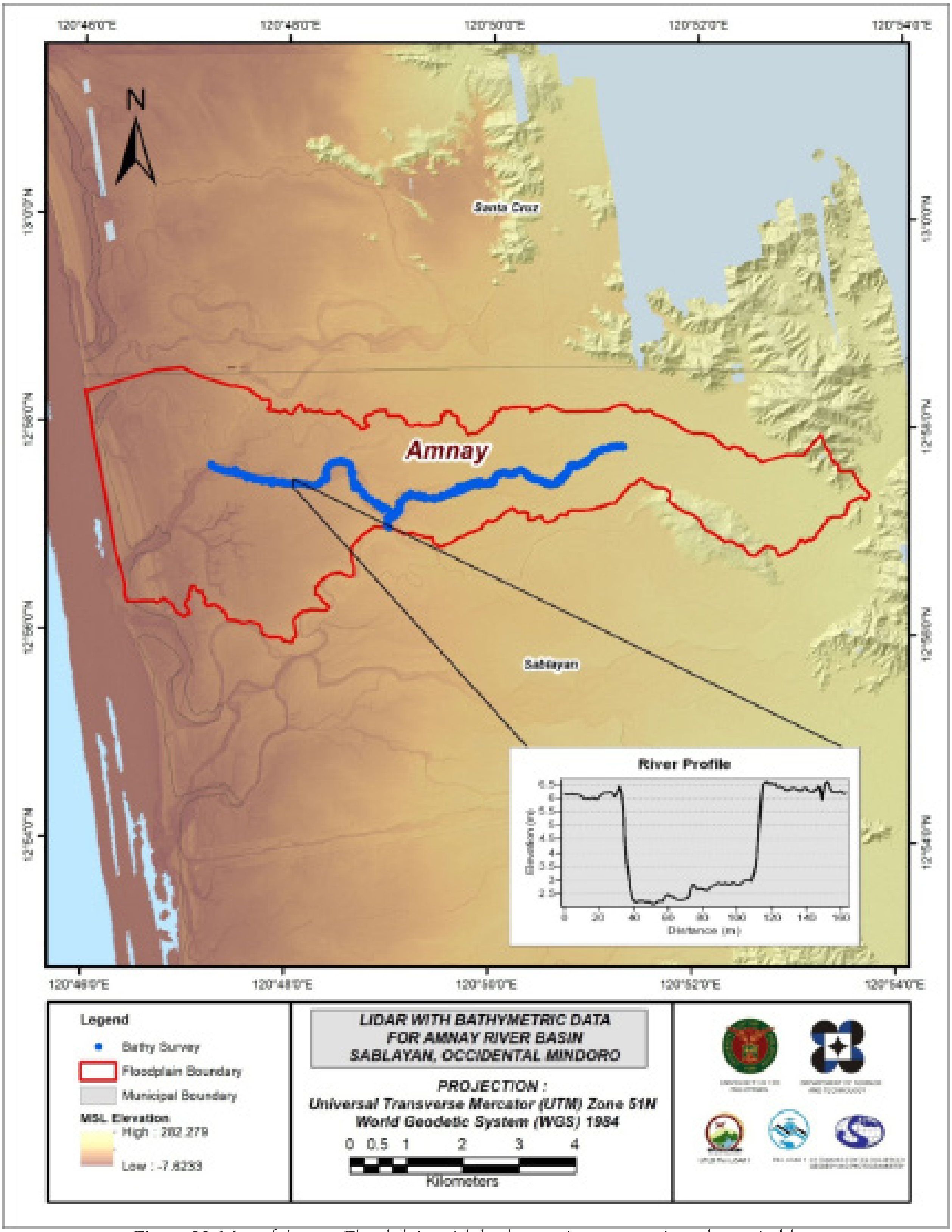


Figure 28. Map of Amnay Floodplain with bathymetric survey points shown in blue.

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

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

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 Amnay 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 Amnay Bridge; validation point acquisition in the province of Occidental Mindoro which covers Amnay River Basin; and bathymetric survey from the mouth of the river in Brgy. Claudio Salgado to part of Brgy. Pagasa, both in the Municipality of Sablayan using Trimble® GNSS PPK survey technique and a Hi-Target™ Echosounder. The extent of the bathymetric survey is shown in Figure 29.

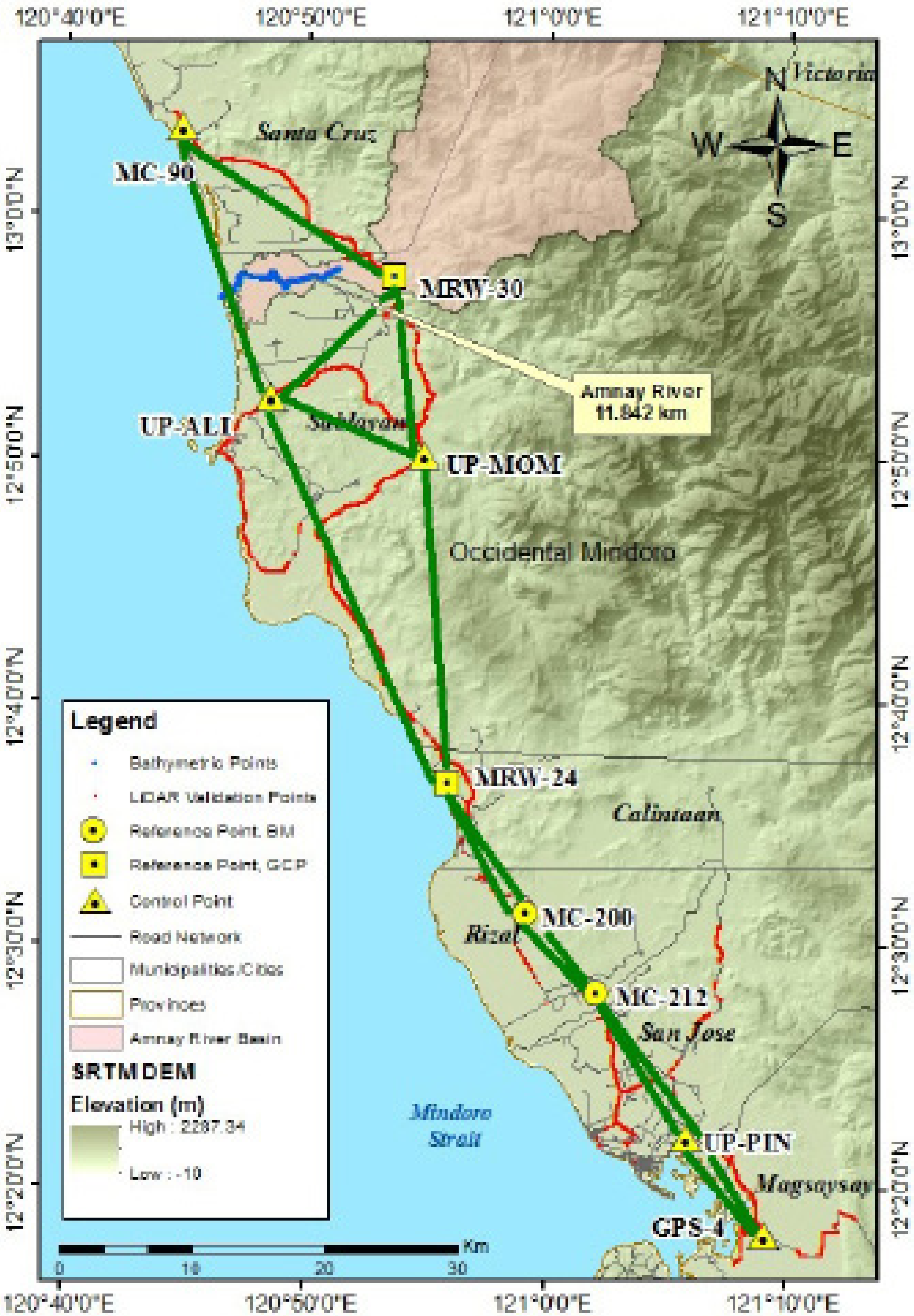


Figure 29. Amnay River survey Extent of the bathymetric survey (in blue) in Amnay River and the LiDAR data validation (in red)

4.2 Control Survey

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

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

The summary of reference and control points and its location is summarized in Table 25 while the GNSS network established is illustrated in Figure 30.

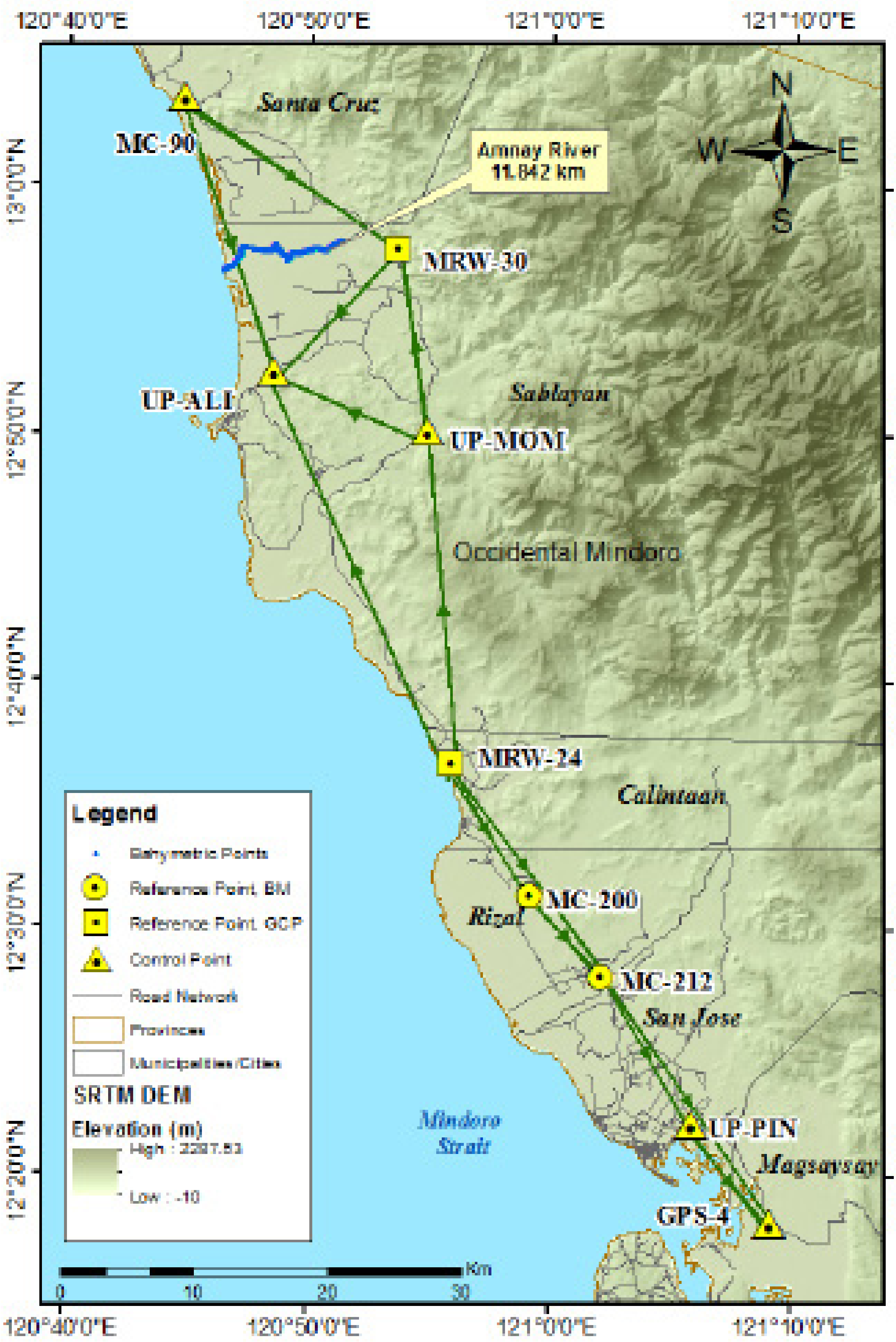


Figure 30. GNSS Network of Occidental Mindoro Field Survey

Table 25. List of reference and control points used during the survey in Amnay 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
MC-200	1st order, BM	-	-	83.225	-	2007
MC-212	1st order, BM	-	-	74.473	-	2007
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	4.746	2007
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	41.752	2007
MC-90	UP Established	-	-	-	-	2007
UP-ALI	UP Established	-	-	-	-	2015
UP-MOM	UP Established	-	-	-	-	2015
UP-PIN	UP Established	-	-	-	-	2015
GPS-4	DPWH Established	-	-	-	-	2013

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

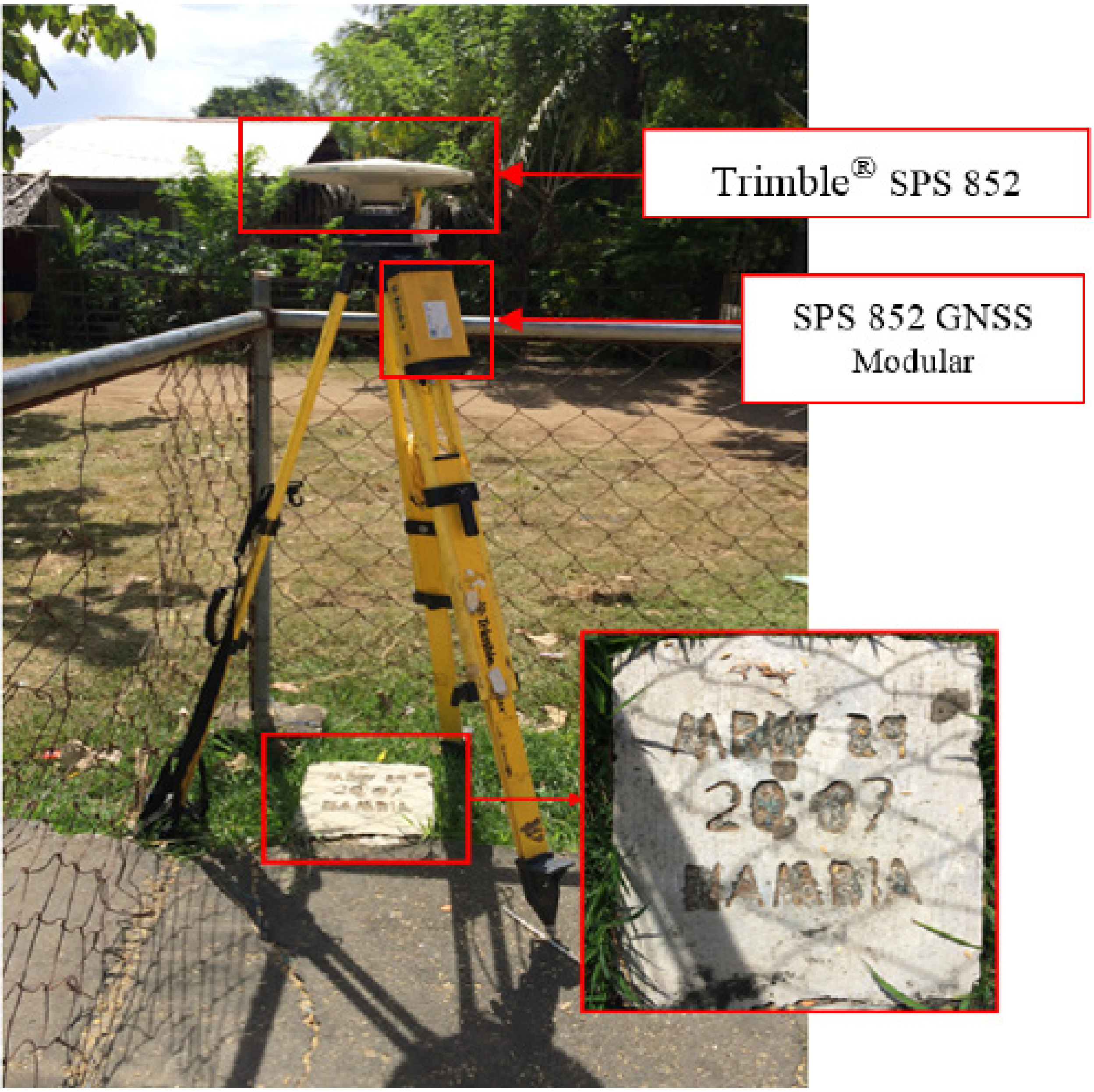


Figure 31. GNSS base set-up, Trimble® SPS 882, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

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

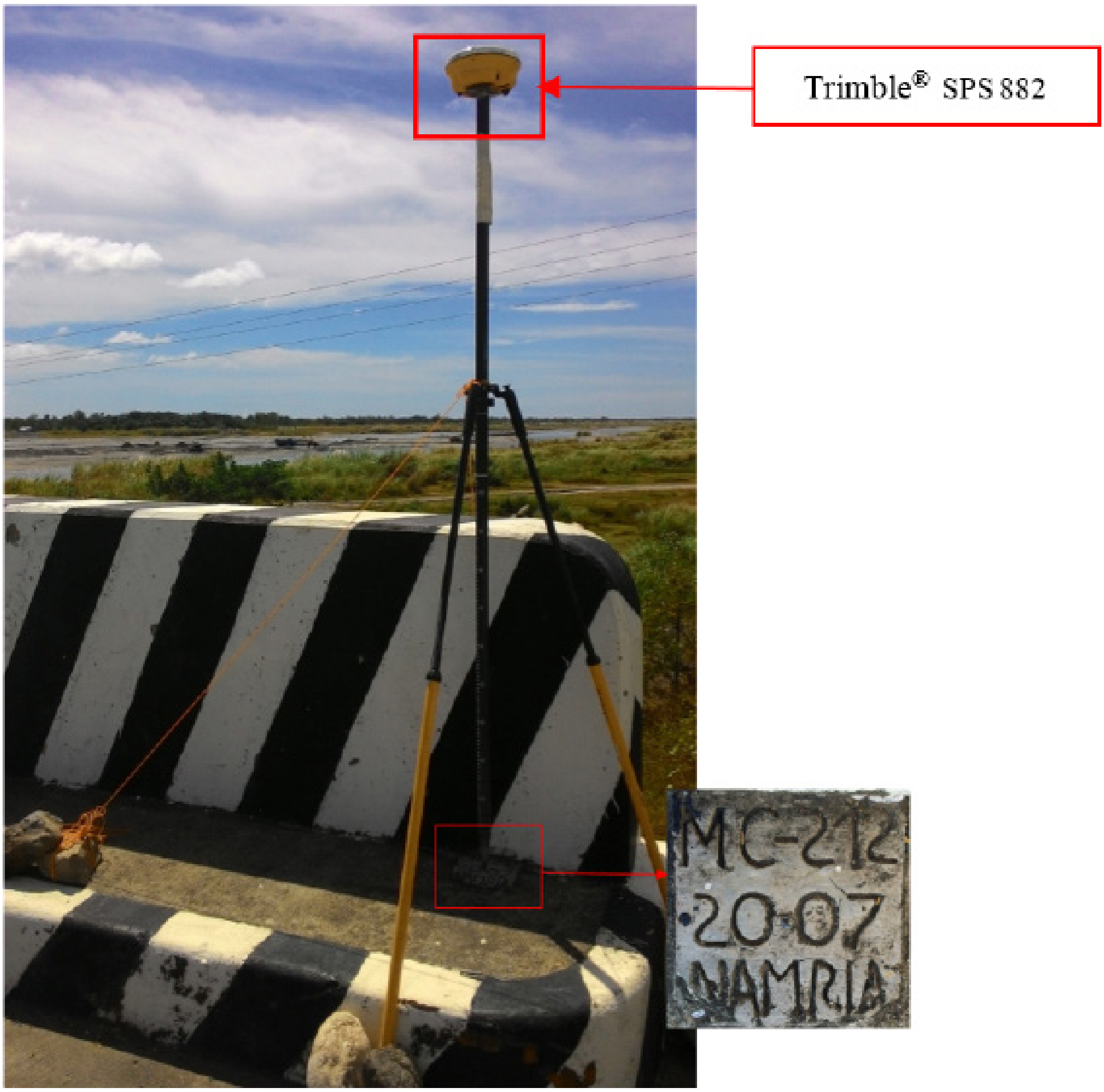


Figure 34. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

Figure 35. GNSS base, 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 +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Amnay River Basin is summarized in Table 26 generated TBC software.

Table 26. Baseline Processing Report for AMnay River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MC-212 --- GPS-4	11-05-2015	Fixed	0.003	0.015	145°21'06"	22241.566	-11.807
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.011	0.017	170°24'13"	13704.513	55.240
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.003	0.023	170°24'12"	13704.541	55.249
MRW-30 --- MC-90	11-17-2015	Fixed	0.010	0.018	305°24'12"	19473.086	-35.515
UP-PIN --- MC-212	11-05-2015	Fixed	0.003	0.007	328°11'40"	12856.399	14.631
UP-PIN --- GPS-4	11-05-2015	Fixed	0.003	0.006	141°30'11"	9422.221	2.872
MC-200 --- UP-PIN	11-05-2015	Fixed	0.003	0.022	144°37'57"	20841.368	-23.356
MC-200 --- UP-MOM	11-05-2015	Fixed	0.009	0.014	346°57'26"	35544.301	60.755

MC-200 --- UP-MOM	11-05-2015	Fixed	0.004	0.014	346°57'27"	35544.309	60.692
MC-200 --- MC-212	11-05-2015	Fixed	0.003	0.006	138°58'31"	8048.668	-8.741
UP-ALI --- UP-MOM	11-15-2015	Fixed	0.008	0.013	110°57'37"	12258.370	88.024
UP-MOM --- UP-ALI	11-15-2015	Fixed	0.004	0.036	110°57'37"	12258.373	88.139
UP-ALI --- MRW-30	11-17-2015	Fixed	0.009	0.012	45°05'52"	12929.488	32.865
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.017	45°05'52"	12929.476	32.850
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.007	45°05'51"	12929.529	32.747
MC-90 --- UP-ALI	11-17-2015	Fixed	0.004	0.008	341°46'30"	21480.592	-2.784
MRW-24 --- UP-PIN	11-05-2015	Fixed	0.003	0.006	145°50'52"	32317.096	6.413
MRW-24 --- MC-200	11-05-2015	Fixed	0.005	0.007	148°04'31"	11489.166	29.777
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.009	0.015	355°30'36"	24950.818	90.611
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.003	0.006	355°30'36"	24950.824	90.574
MRW-24 --- UP-ALI	11-15-2015	Fixed	0.006	0.007	335°24'00"	32186.124	2.579

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 form:

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

Where:

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

The nine (9) control points, MRW-24, MRW-30, MC-200, MC-212, MC-90, GPS-4, UP-PIN, UP-MOM, and UP-ALI were occupied and observed simultaneously to form a GNSS loop. All 14 baselines acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively as shown in Table 26.

Table 27. 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)					

Table 28. Adjusted Grid Coordinates

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

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 28. Below is the computation for accuracy that passed the required precision.

a.GPS-4

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

b.MC-200

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

c.MC-212

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

d.MC-90

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

e.MRW-24

Horizontal accuracy	=	Fixed
Vertical accuracy	=	4.5 cm < 10 cm

f.MRW-30

Horizontal accuracy	=	Fixed
Vertical accuracy	=	9.1 cm < 10 cm

g.UP-ALI

Horizontal accuracy	=	√ ((2.0) ² + (1.5) ²
	=	√(4.0 + 2.25)
	=	2.5 cm < 20 cm
Vertical accuracy	=	7.1 cm < 10 cm

h.UP-MOM

Horizontal accuracy	=	√ ((1.5) ² + (1.2) ²
	=	√(2.25 + 1.44)
	=	1.9 cm < 20 cm
Vertical accuracy	=	5.5 cm < 10 cm

i.UP-PIN

Horizontal accuracy	=	√ ((3.1) ² + (2.4) ²
	=	√(9.61 + 5.76)
	=	3.9 cm < 20 cm
Vertical accuracy	=	4.5 cm < 10 cm

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

Table 29. 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 C-5Table 29. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table C-6Table 30.

Table 30. 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)
	1st order, BM	12°31'20.68883"	120°59'15.31614"	83.225	1385155.121	281320.527	34.024
MC-212	1st order, BM	12°28'03.07504"	121°02'10.26310"	74.473	1379041.958	286558.124	24.884
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MC-90	UP Established	13°03'34.14426"	120°44'46.70845"	53.232	1444800.407	255607.924	8.195
UP-ALI	UP Established	12°52'30.24358"	120°48'29.69148"	55.998	1424334.041	262152.459	9.503
UP-MOM	UP Established	12°50'07.47192"	120°54'49.30854"	144.013	1419850.456	273564.872	96.192
UP-PIN	UP Established	12°22'07.55000"	121°05'54.64323"	59.843	1368066.413	293256.669	9.659
GPS-4	DPWH Established	12°18'07.55700"	121°09'08.74194"	62.706	1360649.962	299069.894	12.062

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

Cross-section and as-built survey were conducted on November 21, 2015 along the upstream side of Amnay Bridge located in Brgy. Pagasa, Municipality of Sablayan using Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 40.

Figure 40. Bridge cross-section acquisition along the upstream side of Amnay Bridge, Brgy. Pagasa, Municipality of Sablayan

A total of nine hundred and fifty-one (951) points with corresponding length of 444.11 meters were gathered from the survey of the bridge using the control point MRW-90 as base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 41 to Figure 43, respectively.

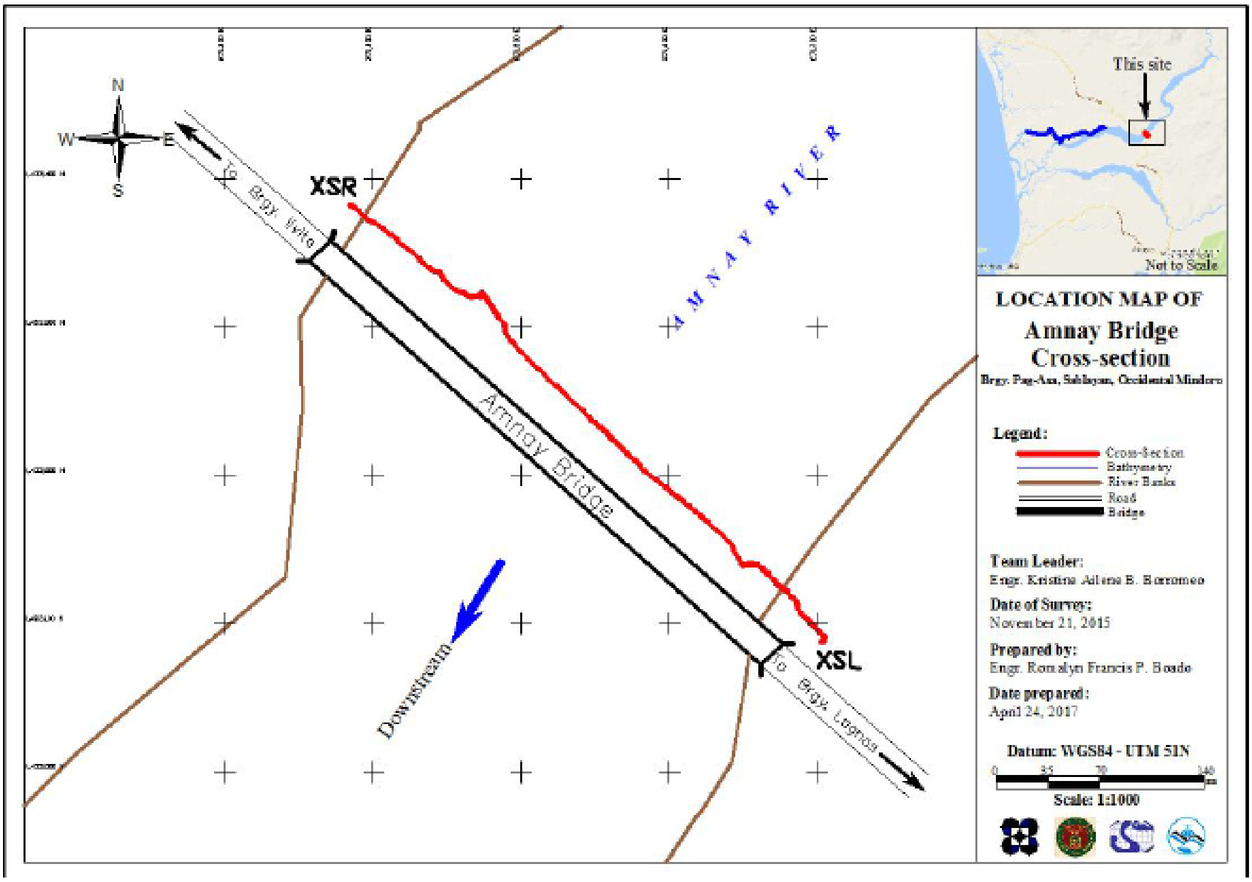


Figure 41. Amnay bridge cross-section location map

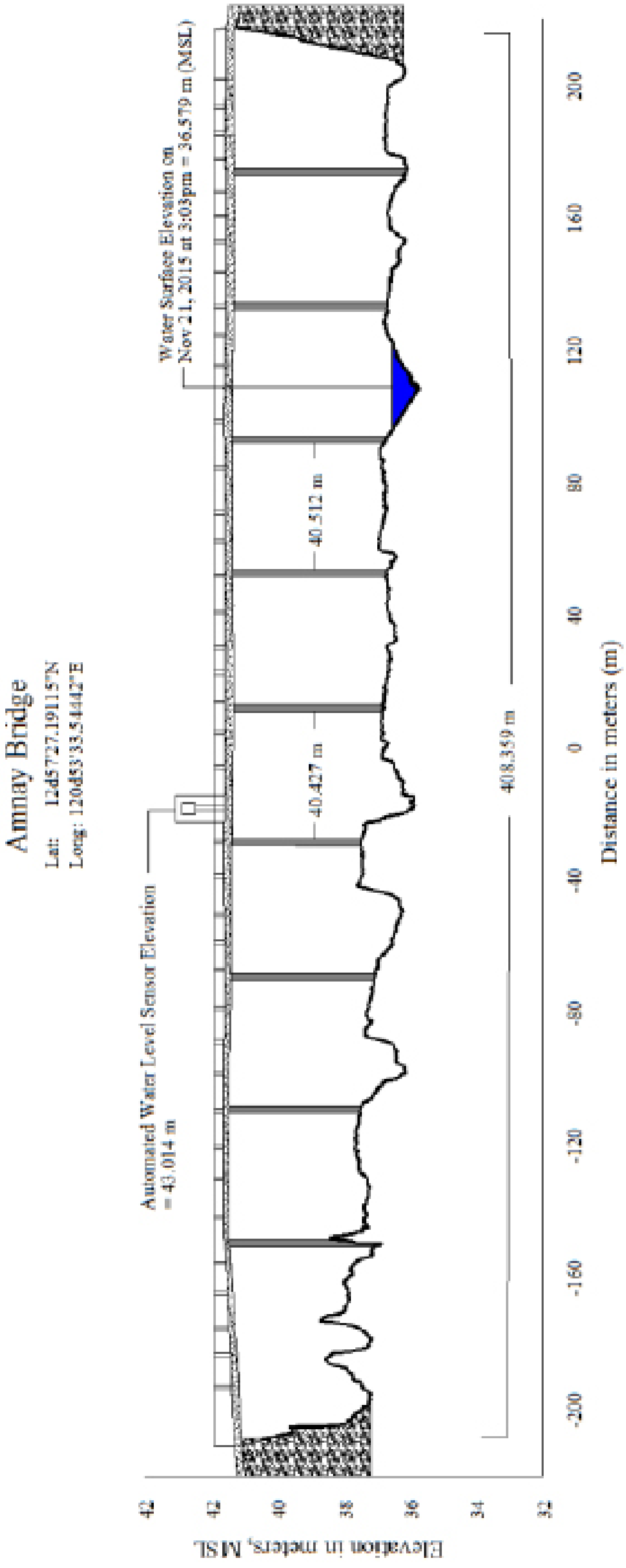


Figure 42. Amnay Bridge cross-section diagram

Bridge Data Form

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

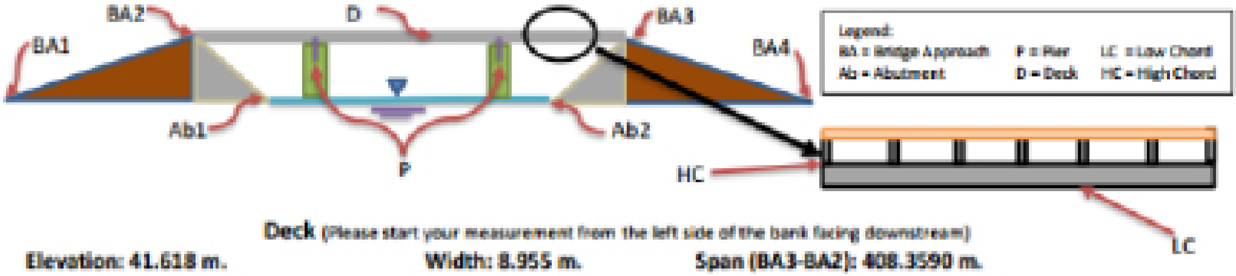
River Name: Amnay River **Time: 2:30 PM**

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°57'27.19115"N **Longitude:** 120°53'33.54442"E



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

Elevation: 41.618 m. **Width:** 8.955 m. **Span (BA3-BA2):** 408.3590 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	41.237	BA3	437.296	41.552
BA2	29.033	41.618	BA4	444.112	41.443

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

	Station (Distance from BA1)	Elevation
Ab1	NA	NA
Ab2	427.773	36.328

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

Shape: Cylindrical Number of Piers: 9 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	71.314	41.587	approx. 0.9 m.
Pier 2	111.596	41.617	approx. 0.9 m.
Pier 3	151.842	41.58	approx. 0.9 m.
Pier 4	192.411	41.609	approx. 0.9 m.
Pier 5	232.839	41.587	approx. 0.9 m.
Pier 6	273.597	41.569	approx. 0.9 m.
Pier 7	314.108	41.611	approx. 0.9 m.
Pier 8	354.500	41.557	approx. 0.9 m.
Pier 9	394.973	41.555	approx. 0.9 m.

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

Figure 43. Amnay Bridge Data Form

The water surface elevation of Amnay River was also acquired using Trimble® 882 GNSS PPK survey technique on November 21, 2015 at 3:03 p.m. The resulting water surface elevation at Amnay Bridge is 36.579 m above MSL. The water level marking for Amnay Bridge, shown in Figure 44, has an EGMOrtho value of 37.828 m which was then translated into a marking on the bridge's pier using digital level. This value shall bewas updated by UPLB PHIL-LiDAR 1 to its respective MSL value of 36.825 m to serve as reference for their flow data gathering and depth gauge deployment.

Figure 44. Water level marking at Amnay Bridge, Brgy. Pagasa, 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 is 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.

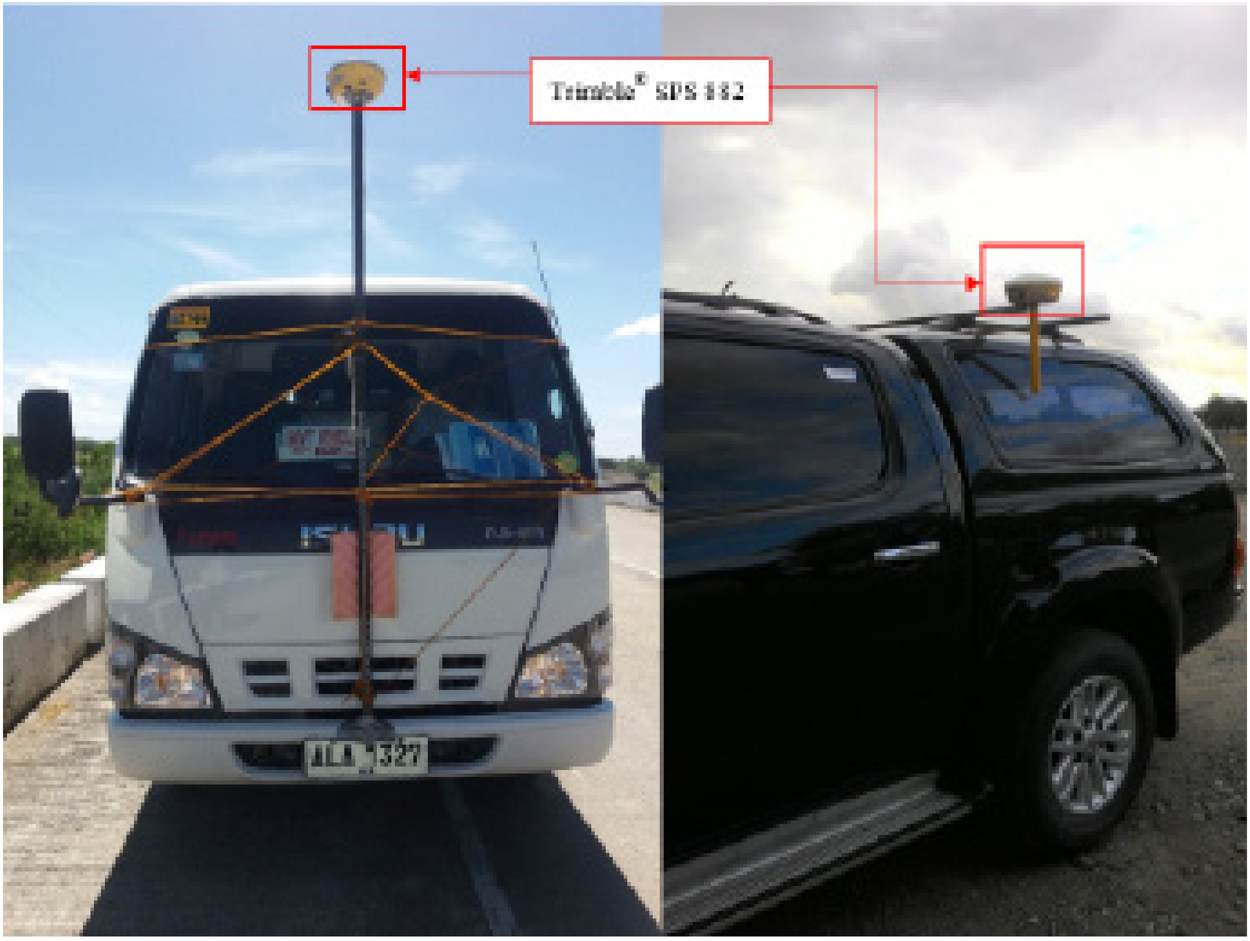


Figure 45. Validation points acquisition survey set-up

The validation points acquisition survey for the Amnay 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 point acquisition survey as shown in the map in Figure 46.

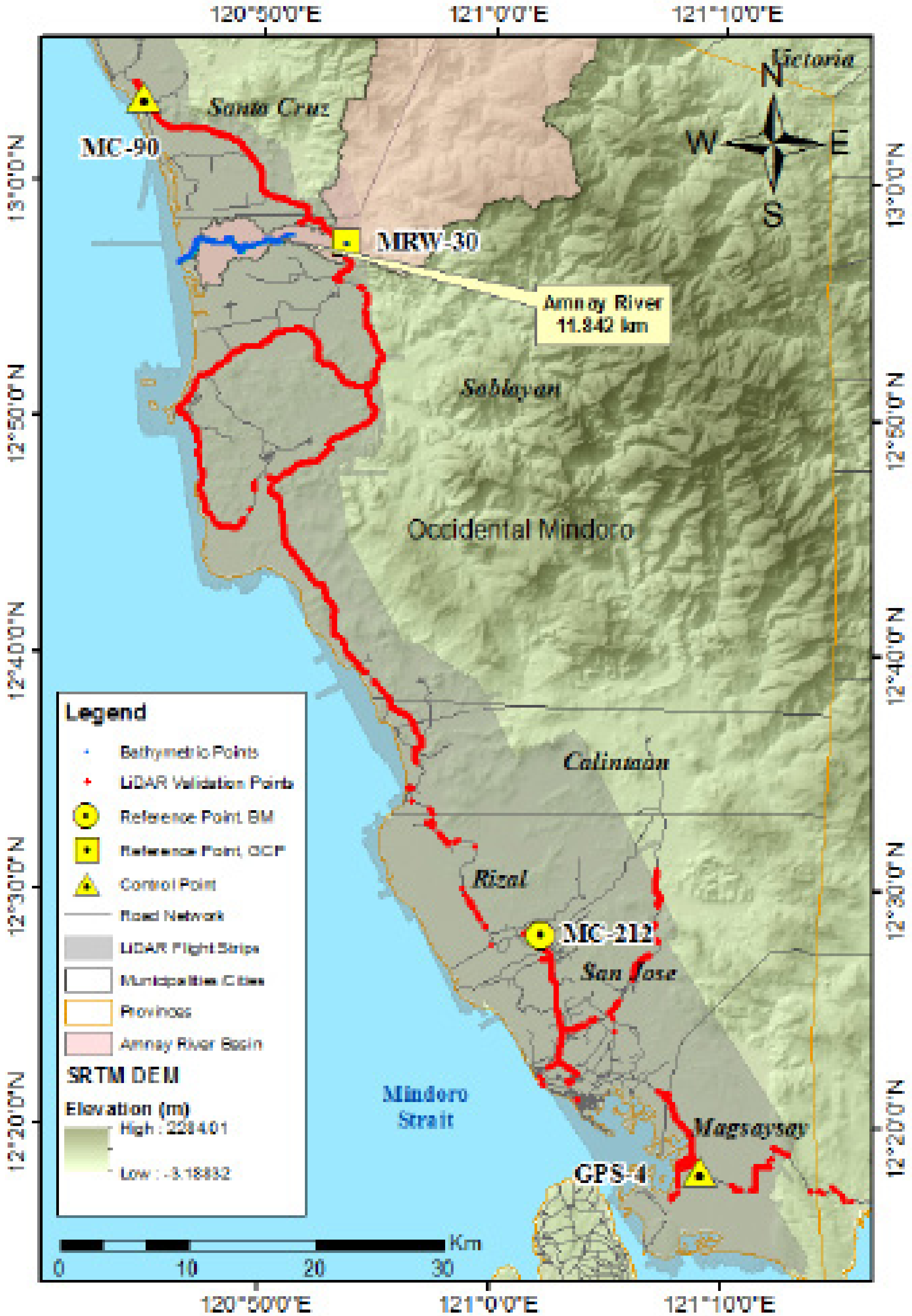


Figure 46. Validation Point Acquisition Survey for the Amnay River Survey Area

4.7 River Bathymetric Survey

Bathymetric survey using Hi-TargetTM echo sounder and a Trimble® SPS 882 attached to a pole secured on the side of the boat was executed on November 16 and 17, 2015 as shown in Figure 47. The survey began from approximately 2 km upstream the mouth of the river in Brgy, Claudio Salgado with coordinates 12 °57'33.85254"120°47'16.89625", and ended at the mouth of the river. Meanwhile, manual bathymetric survey was conducted on November 21, 2015 using a Trimble® SPS 882 GNSS PPK technique which started from the upstream portion of the river in Brgy. Ilvita with coordinates 12°57'47.74269"120°51'16.92794" and traversed by foot down to Brgy. Claudio Salgado at the starting point of the bathymetric survey using boat. The control point MRW-30 was used as base station for the whole bathymetric survey of the river.

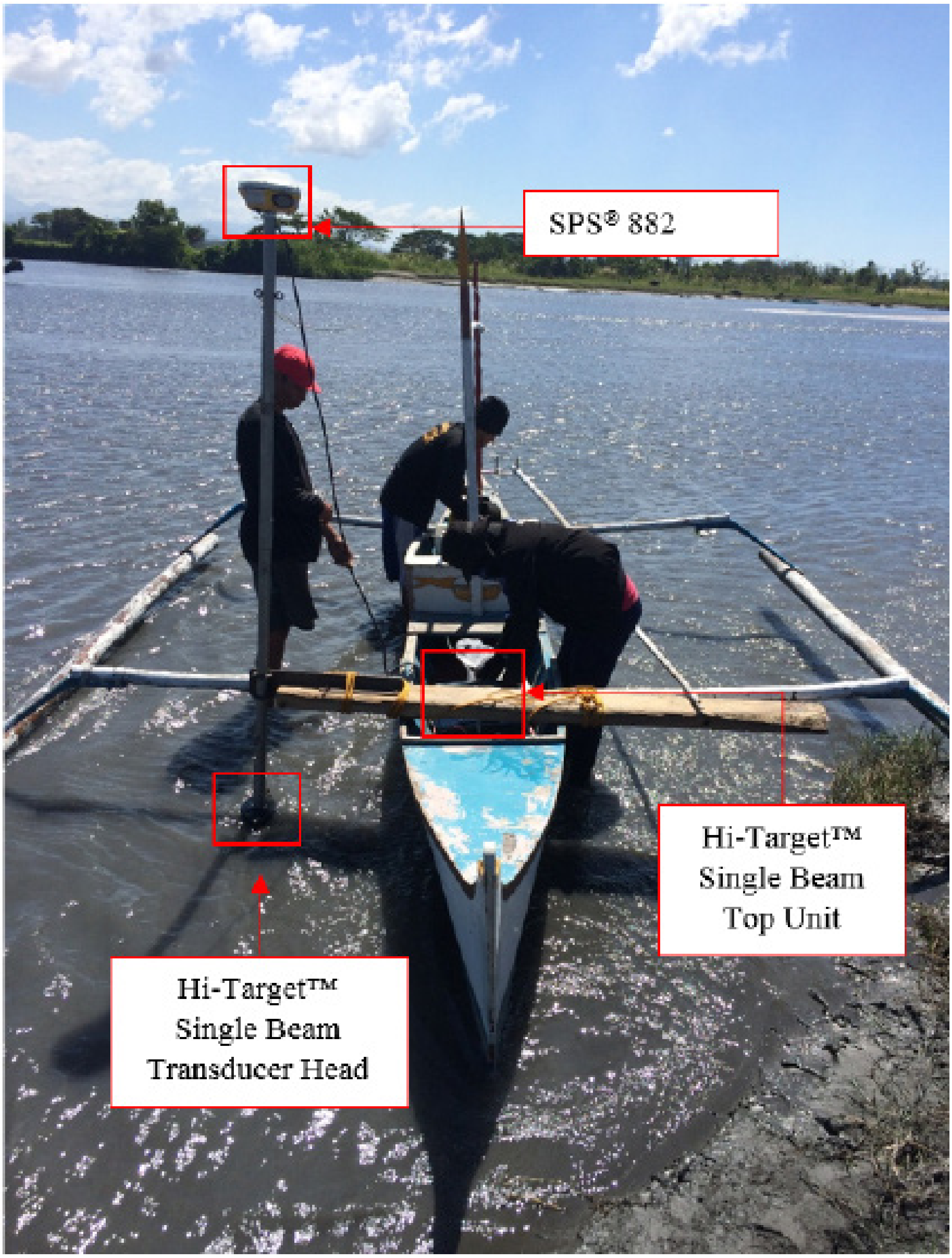


Figure 47. Bathymetry set-up and execution using Hi-Target™ for Amnay River.

The bathymetric survey coverage for Amnay river River is illustrated in Figure 48. Approximately 6 km of the delineated target bathymetric line was not covered due to absence of community in the upstream portion of the river.

Figure 48. Bathymetric points gathered from Amnay River

A CAD drawing was also produced to illustrate the Amnay riverbed centerline profile as shown in Figure 49. There is about a 20-m change in elevation observed within the 11.842-km bathymetric data from its upstream in Brgy. Ilvita down to the mouth of the river in Brgy. Claudio Salgado in Sablayan, Occidental Mindoro.

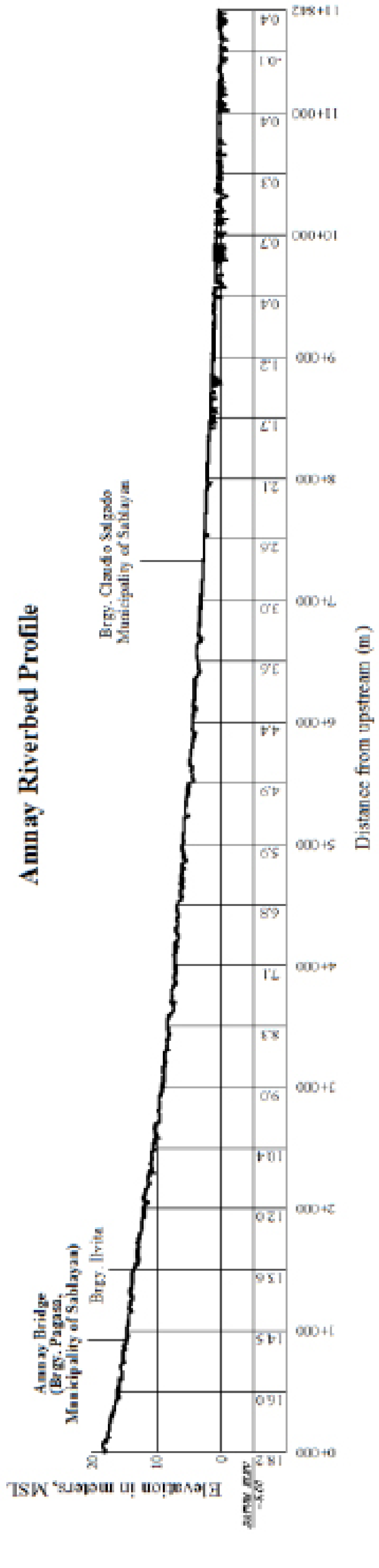


Figure 49. Amnay centerline riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

Components and data that affect the hydrologic cycle of the Amnay 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 Amnay River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an Automatic Rain Gauge (ARG) Station installed within the river basin (12.956910°N, 120.893270°E). The location of the rain gauge is seen in Figure 50.

The total precipitation for this event is 113.50 mm. It has a peak rainfall of 5.0 mm. on August 7, 2016 at 12:50 am.

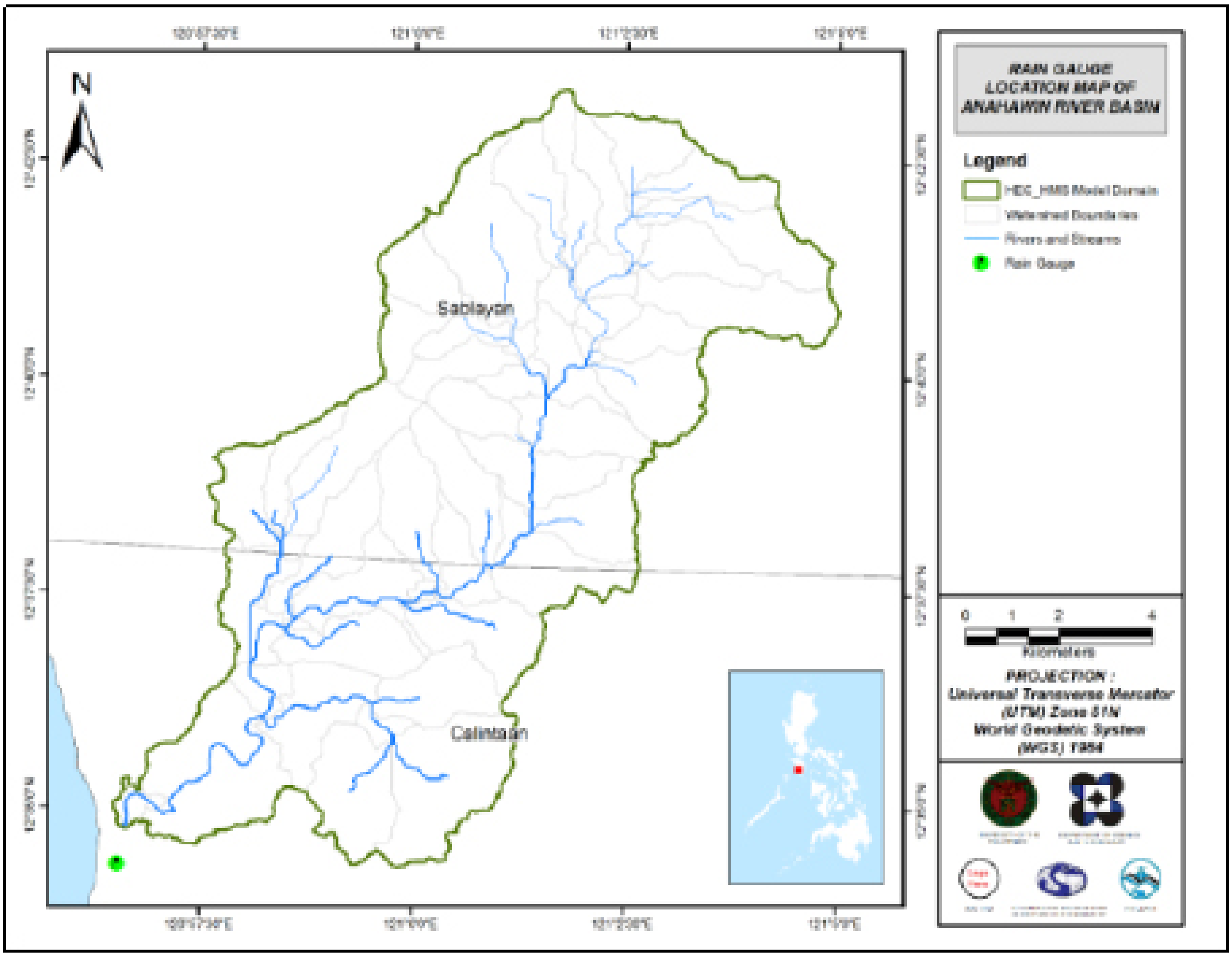


Figure 50. The location map of Amnay HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Pagasa Bridge (also known as Amnay Bridge), Occidental Mindoro (12.956910°N, 120.893270°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 Pagasa Bridge, the rating curve is expressed as Q = 9E-20e1.3237x as shown in Figure 53.

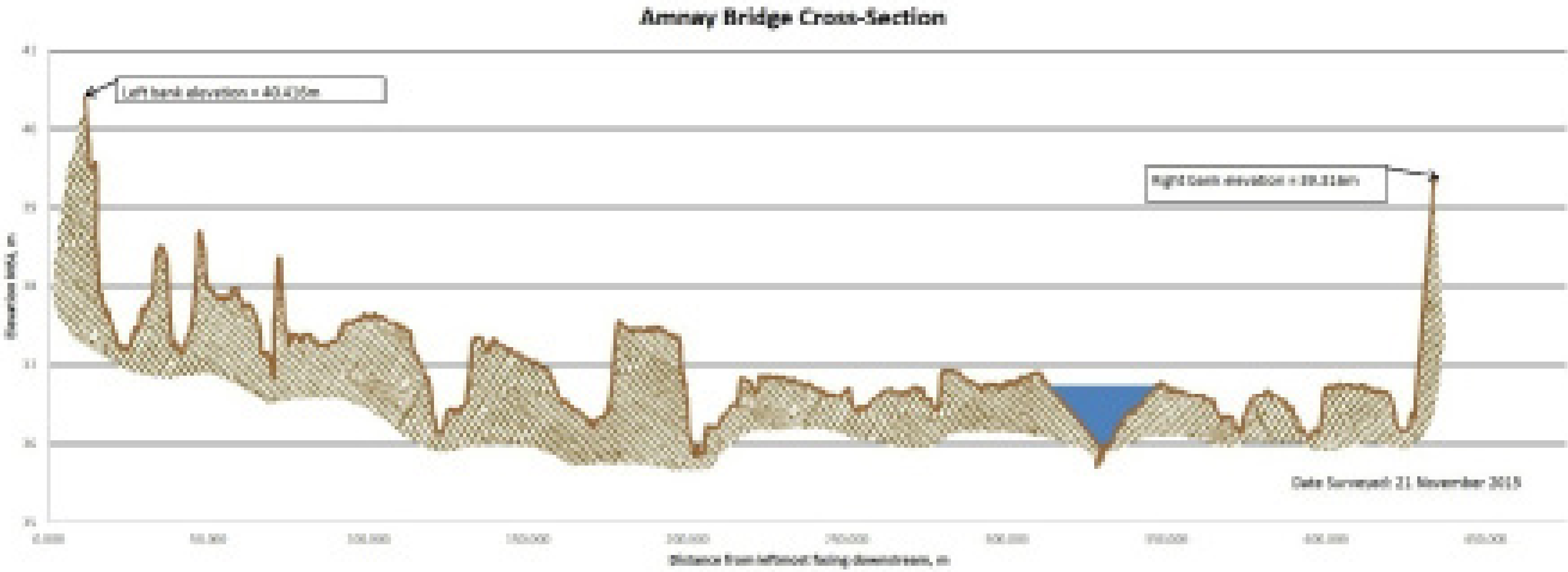


Figure 51. Cross-Section Plot of Pagasa (also known as Amnay) Bridge

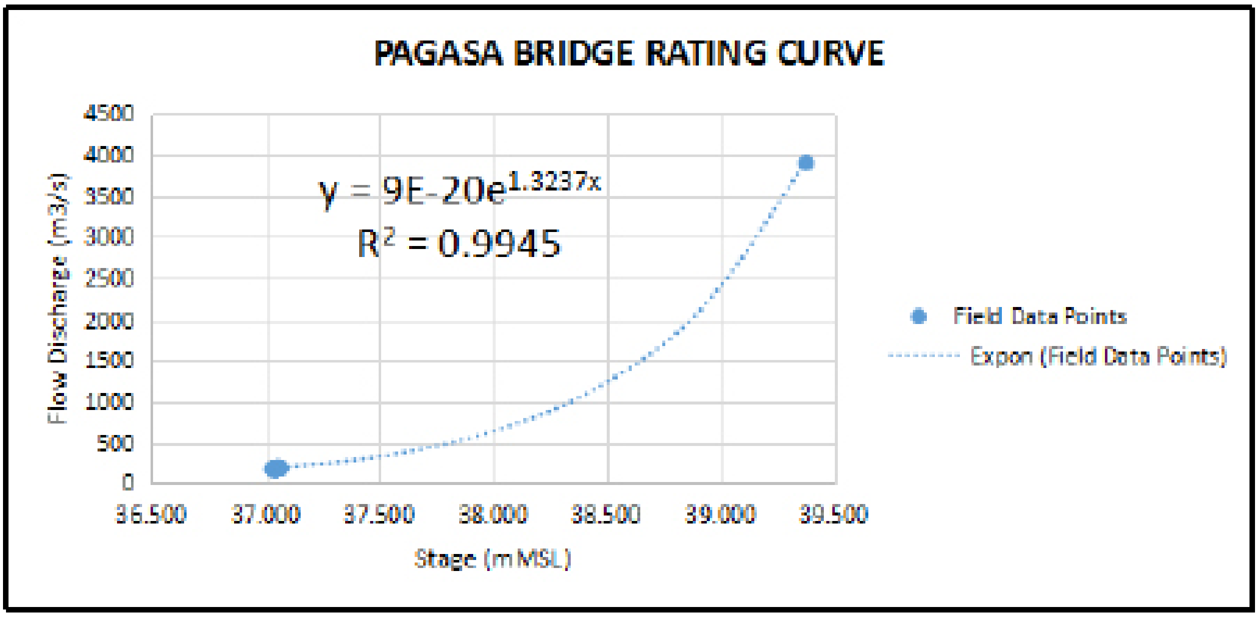


Figure 52. Rating Curve at Pagasa, Occidental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 53, actual flow discharge during a rainfall event was collected in the Pagasa bridge. Peak discharge is 264.50 cu.m/s on August 8, 2016 at 8:30 pm.

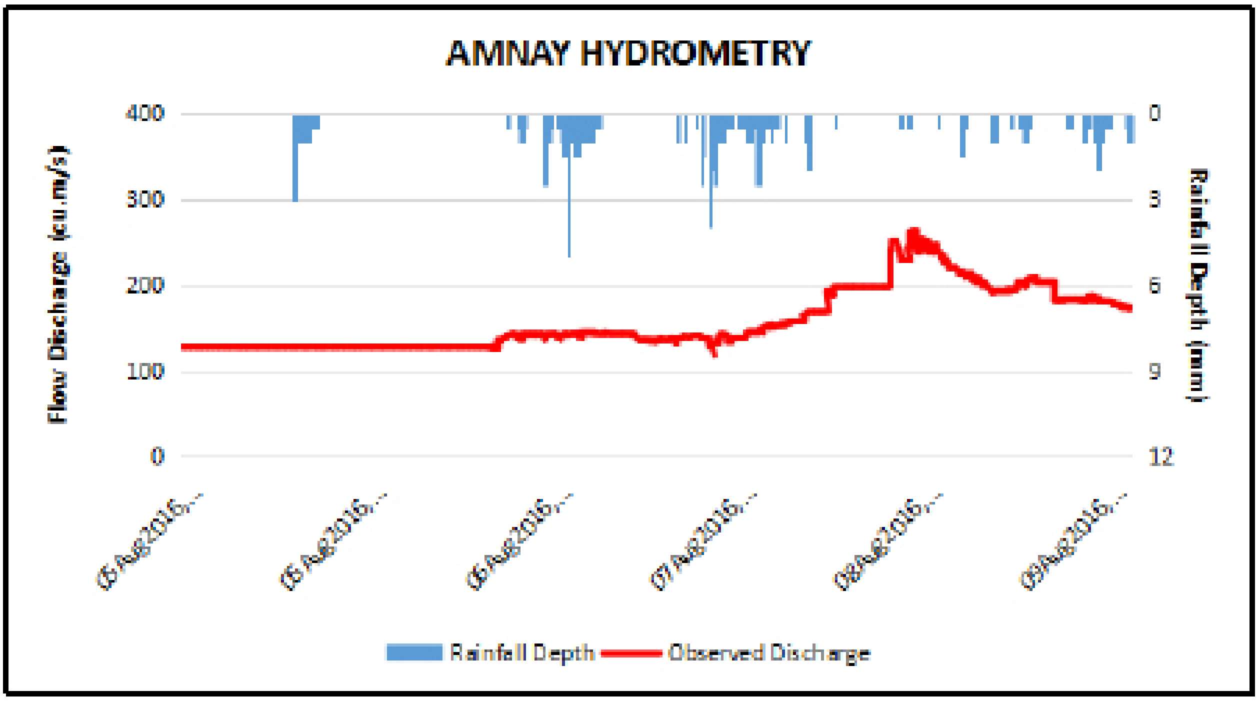


Figure 53. Rainfall and outflow data at Amnay used for modeling

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 was chosen based on its proximity to the Amnay watershed. The extreme values for this watershed were computed based on a 54-year record.

Table 31. 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

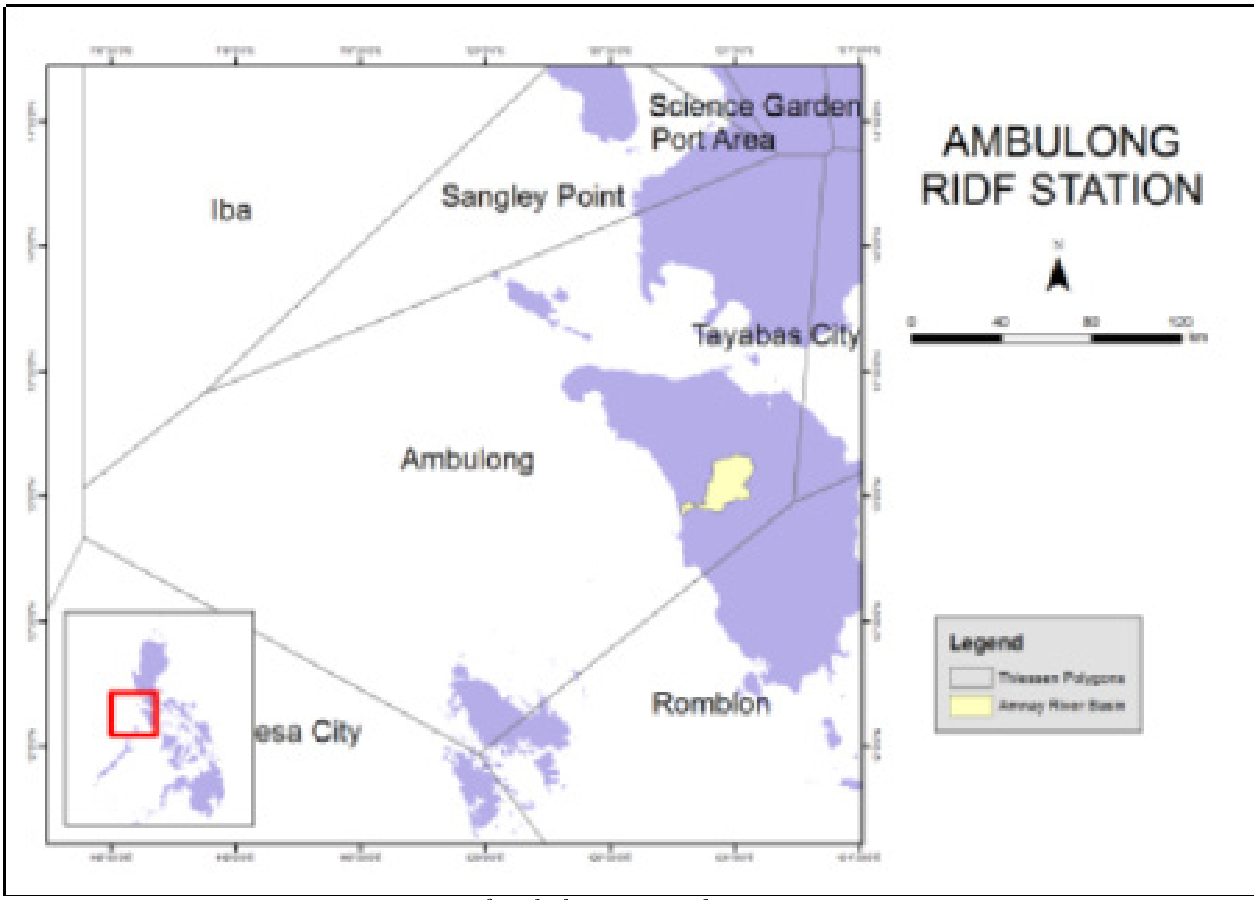


Figure 54. Location of Ambulong RIDF relative to Amnay River Basin

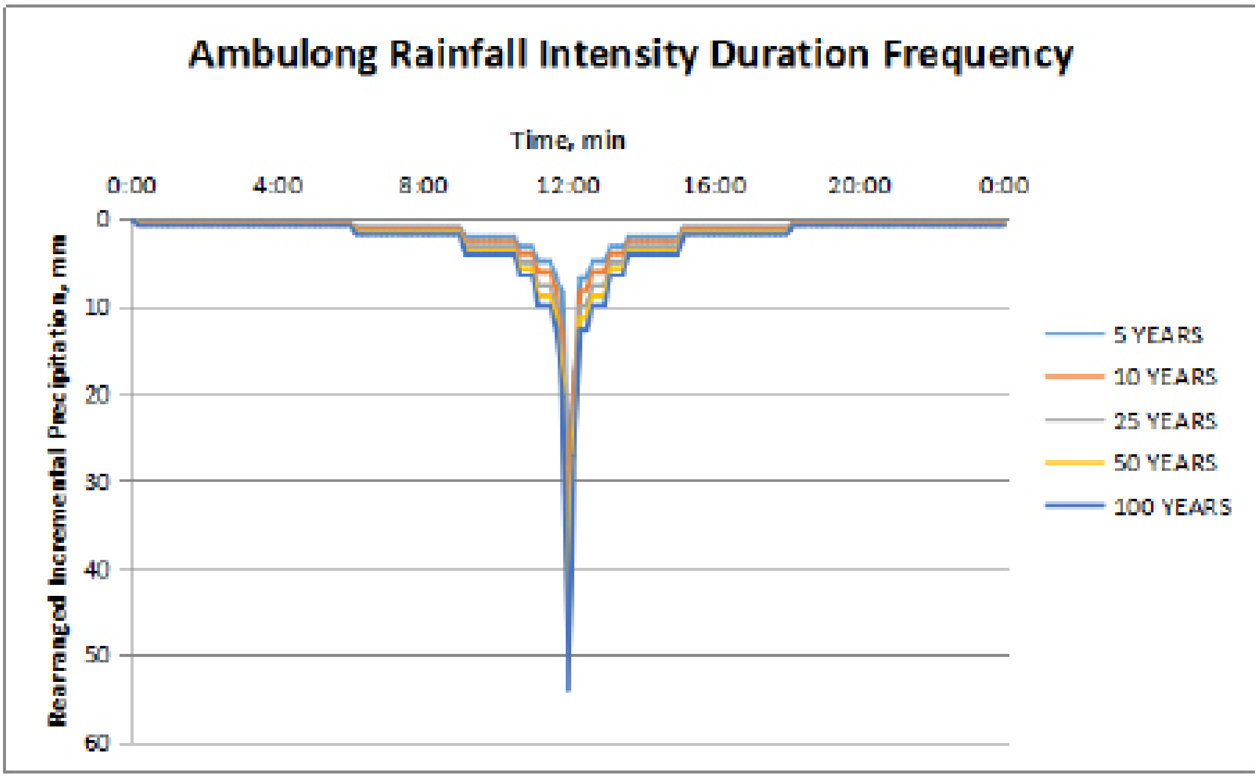


Figure 55. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Amnay River Basin are shown in Figure 56 and Figure 57, respectively.

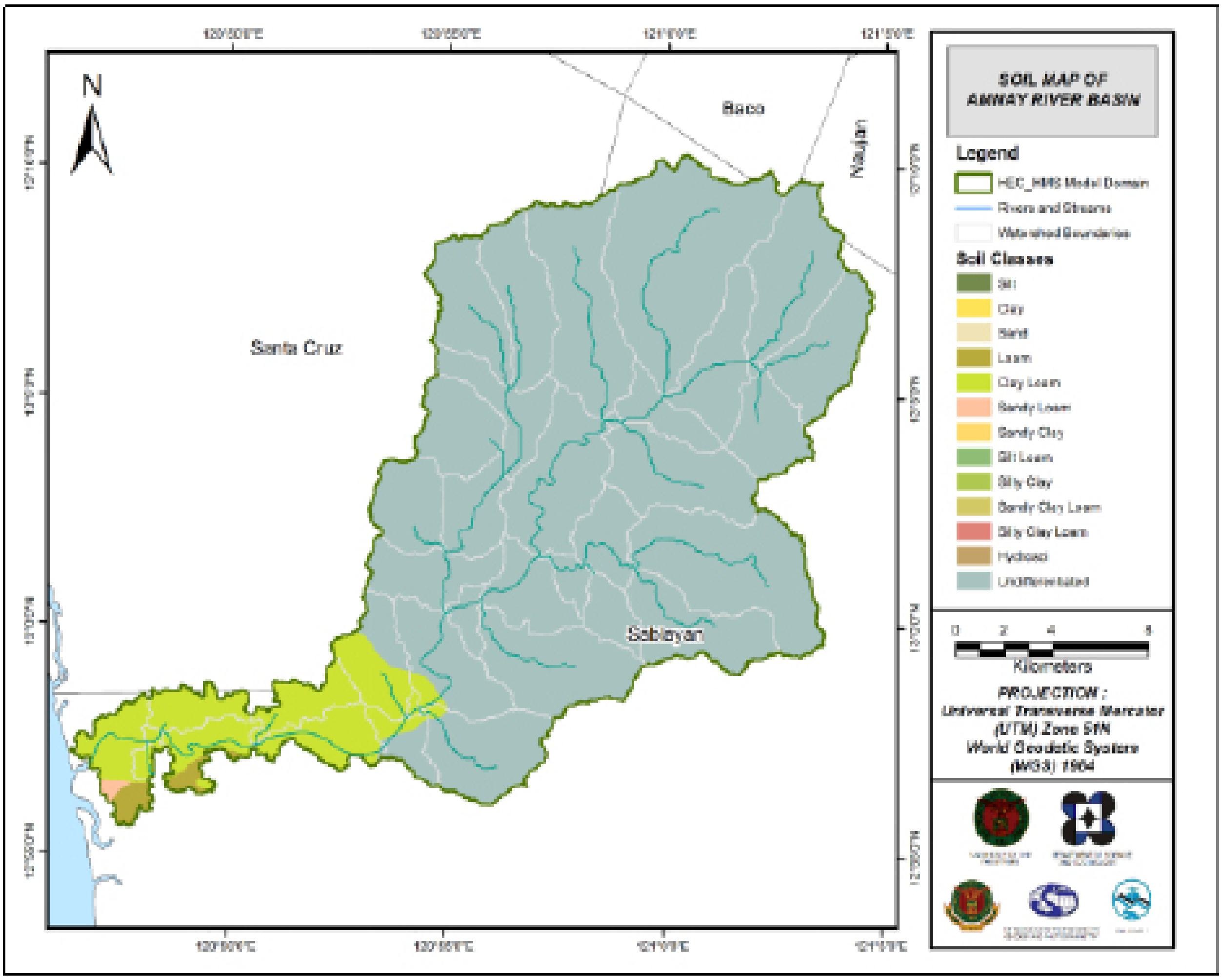


Figure 56. Soil map of the Amnay River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

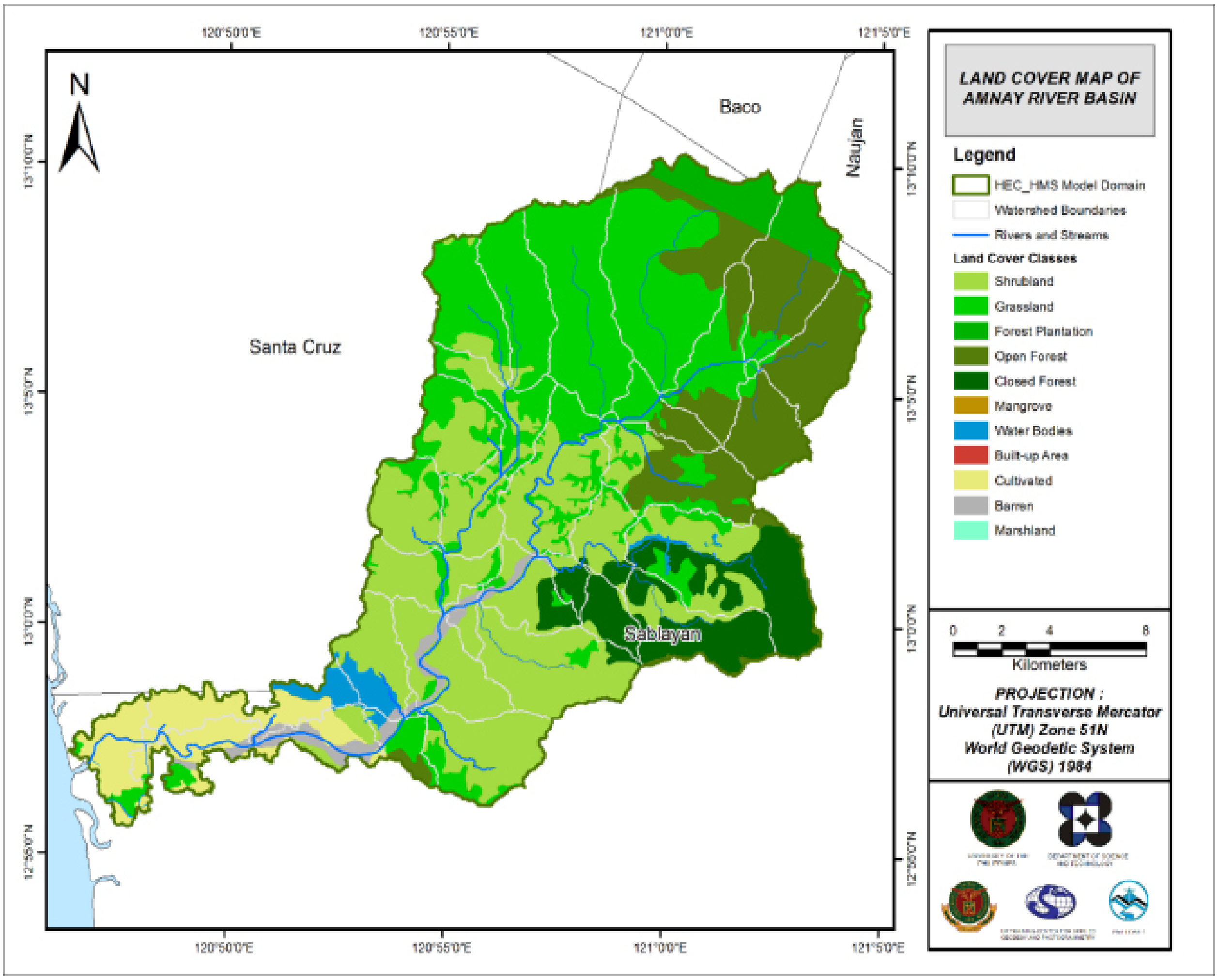


Figure 57. Land cover map of the Amnay River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

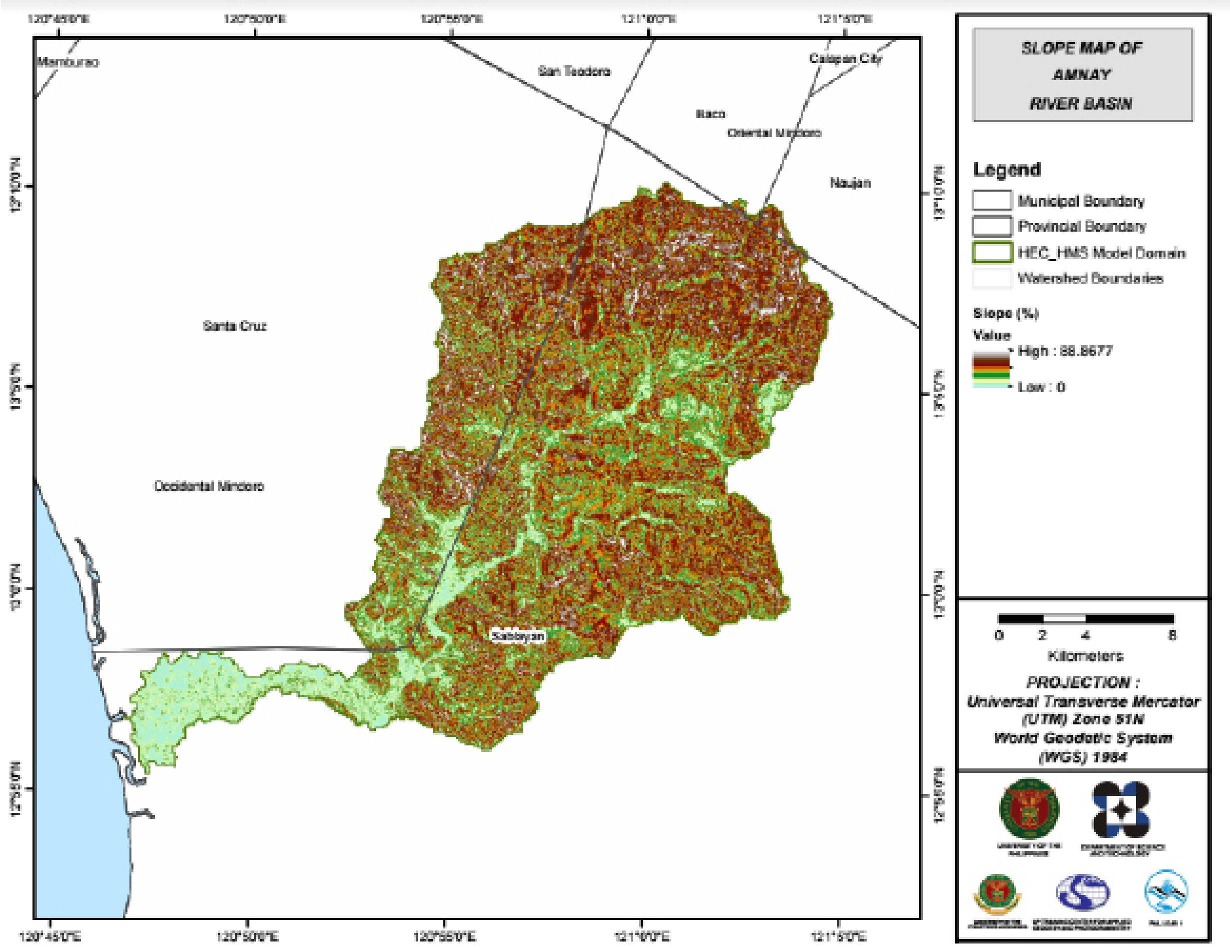


Figure 58. Slope Map of the Amnay River Basin

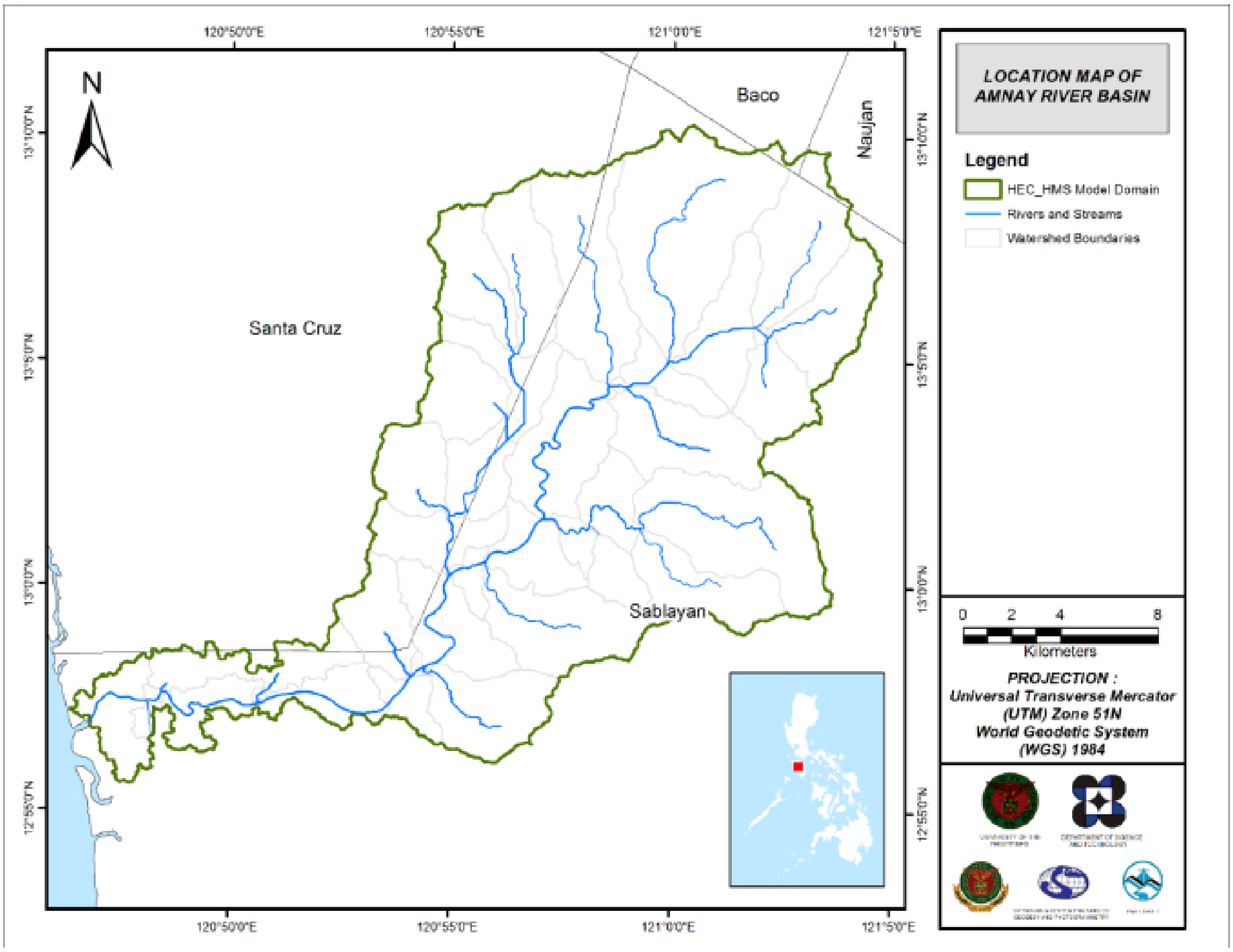


Figure 59. Stream Delineation Map of the Amnay River Basin

Using SAR-based DEM, the Amnay basin was delineated and further subdivided into subbasins. The model consists of 47 sub basins, 15 reaches, and 15 junctions. The Pagasa Bridge serves as the main outlet labelled as 95. 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 an Automatic Rain Gauge (ARG) Station installed on the bridge itself. Finally, it was calibrated using the data collected from the Automatic Water Level Sensor (AWLS) Station installed on the bridge itself (12.956910°N, 120.893270°E).

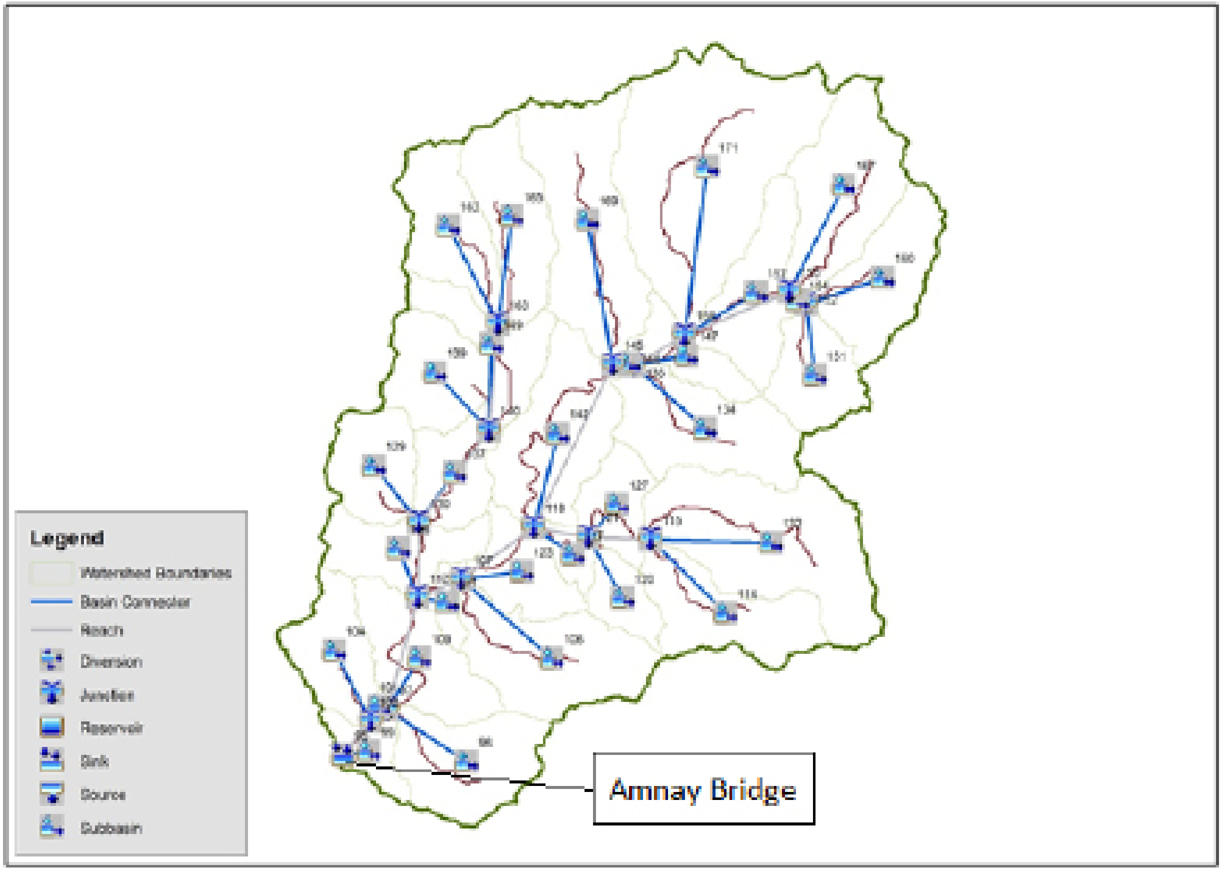


Figure 60. The Amnay River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

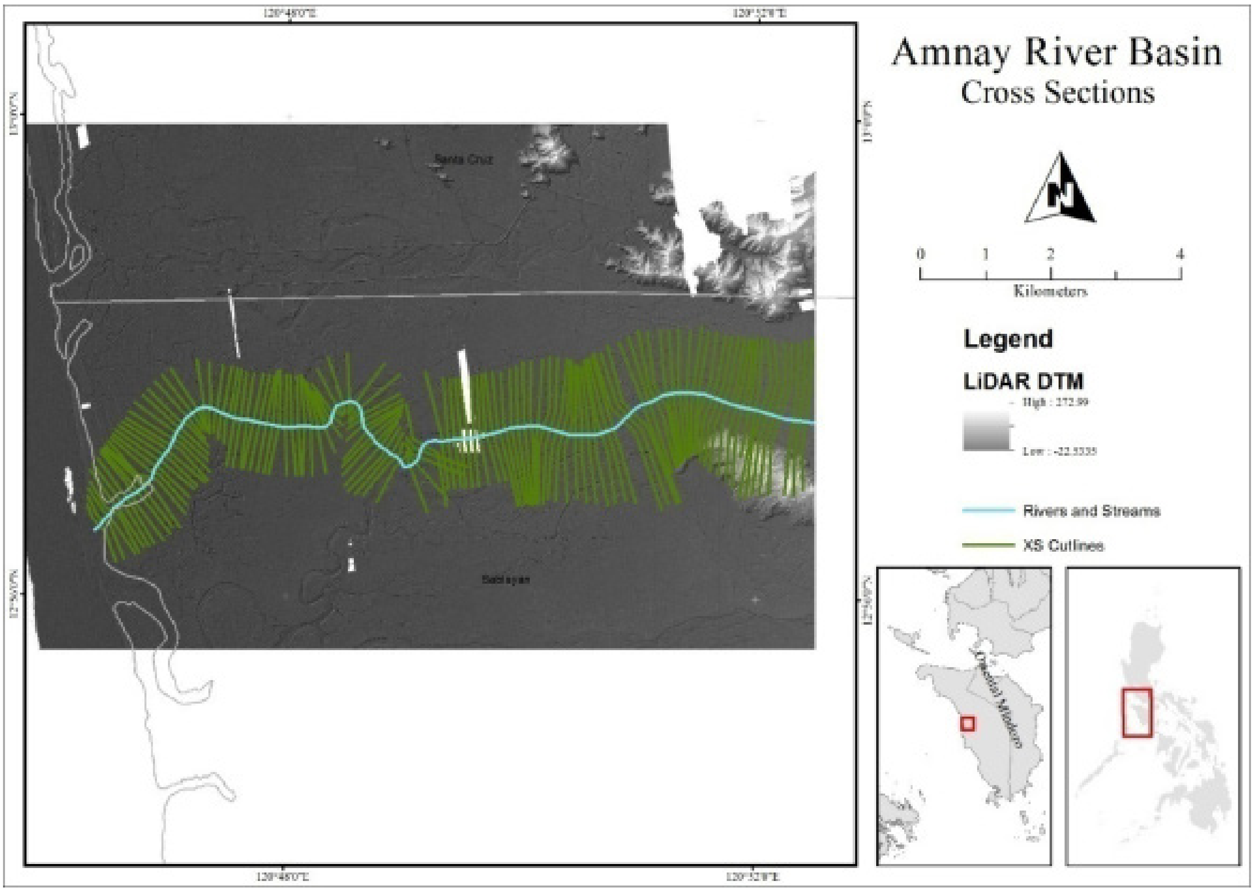


Figure 61. River cross-section of Amnay River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

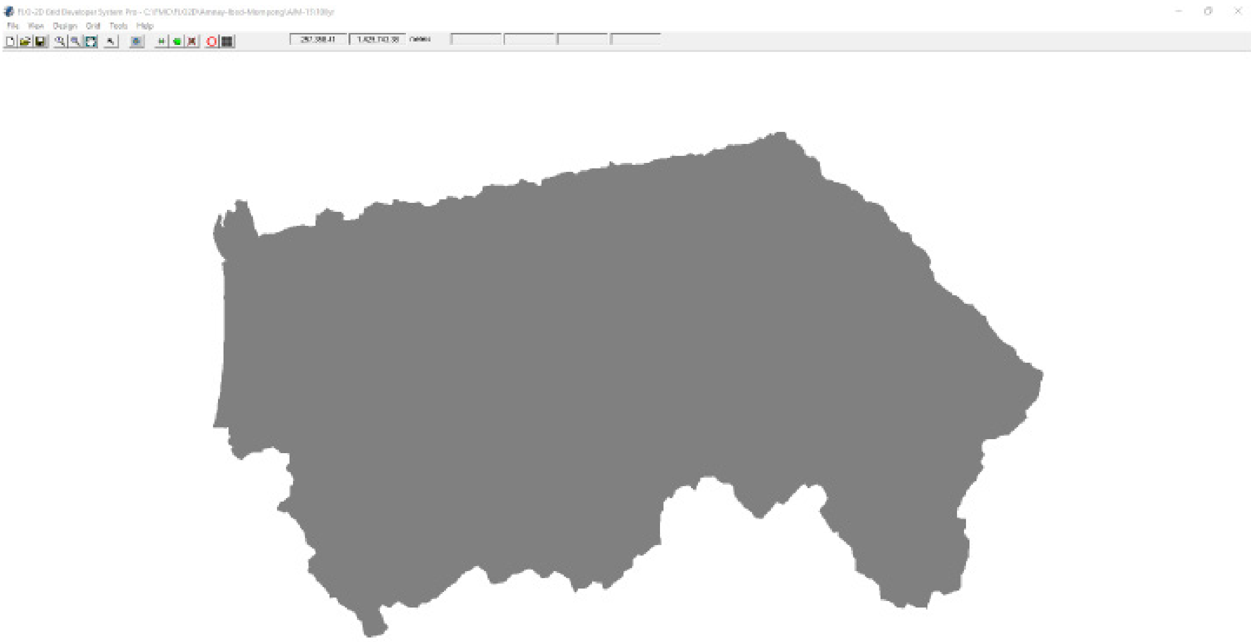


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is was 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 was 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 were 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 createds 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 was 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 Amnay HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

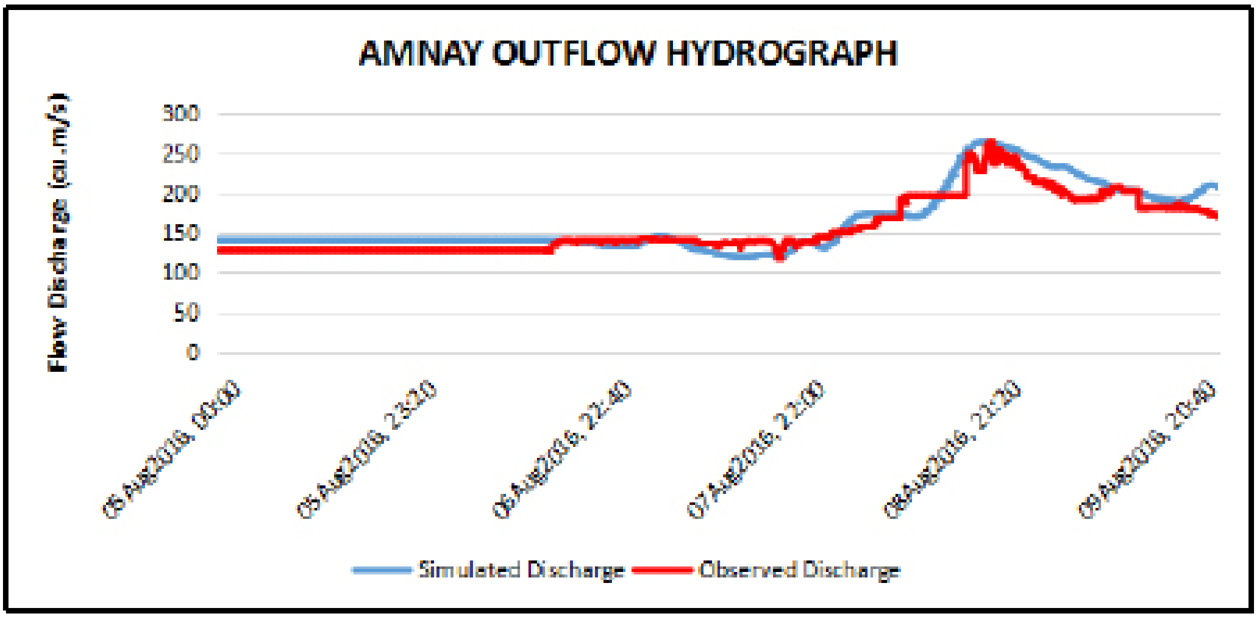


Figure 63. Outflow Hydrograph of Amnay produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model

Table 32. Range of Calibrated Values for Amnay

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3 - 13
			Curve Number	58 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2 - 9
			Storage Coefficient (hr)	0.2 - 4
	Baseflow	Recession	Recession Constant	0.4 – 0.5
			Ratio to Peak	0.5 – 0.8
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.6

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 13mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 58 to 99 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 9 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.4 to 0.5 indicates that the basin is likely to quickly go back to its original. Ratio to peak of 0.5 to 0.8 indicates a milder receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.6 is relatively high compared to the common roughness of watersheds.

Table 33. Summary of the Efficiency Test of Amnay HMS Model

Accuracy measure	Value
RMSE	16.732
r2	0.951
NSE	0.765
PBIAS	-2.768
RSR	0.485

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 16.732

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. A value of 0.951 was computed for this model.

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 0.765.

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 negative -2.768.

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 are quantified. The model has an RSR value of 0.485.

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 Amnay outflow using the Ambulong Rainfail Intensity-Duration-FrequencyRIDF 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.

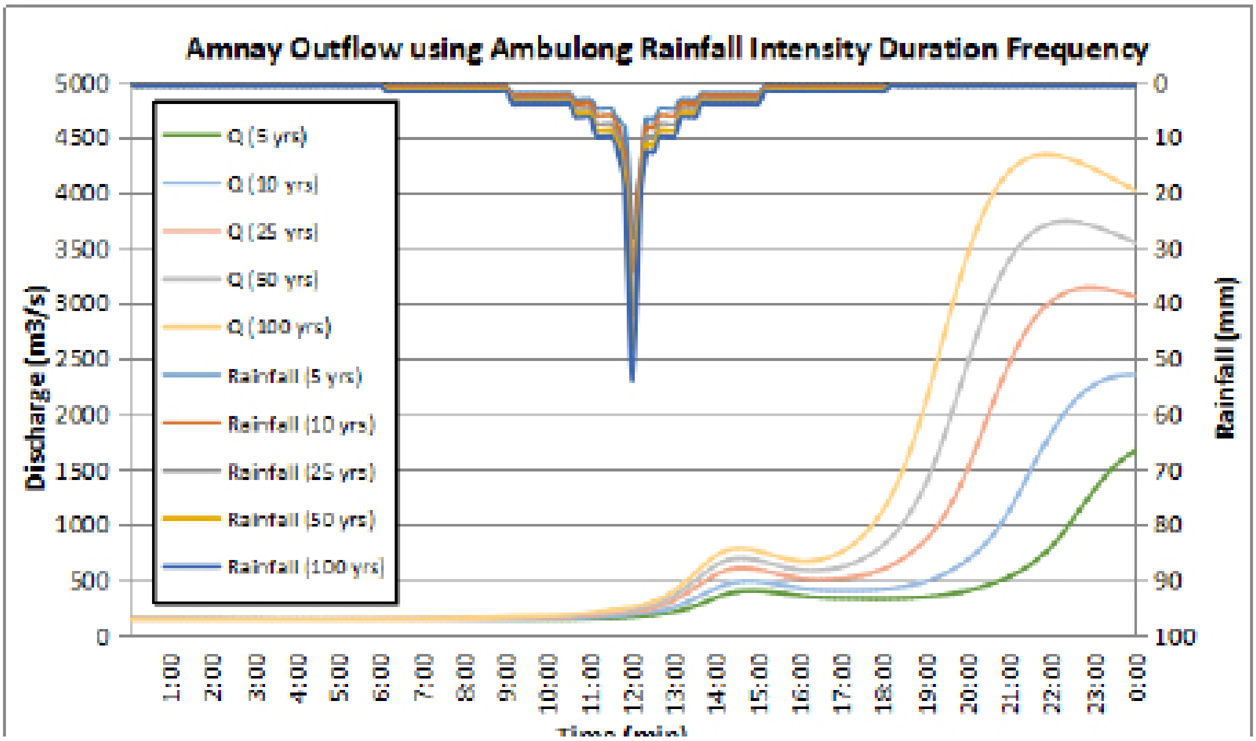


Figure 64. Outflow hydrograph at Amnay Station generated using Ambulong RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Amnay discharge using the Ambulong Rainfall Intensity-Duration-Frequency RIDF curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Amnay 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	1667.126	24 hours	12 hours
10-Year	276.90	34.20	2353.361	24 hours	12 hours
25-Year	340.40	42.20	3137.214	22 hours 50 minutes	10 hours 50 minutes
50-Year	387.50	48.10	3737.815	22 hours 20 minutes	10 hours 20 minutes
100-Year	434.30	54.0	4338.473	21 hours 50 minutes	9 hours 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 bewas used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Amnay River using the HMS base flow is shown on Figure 65 below.

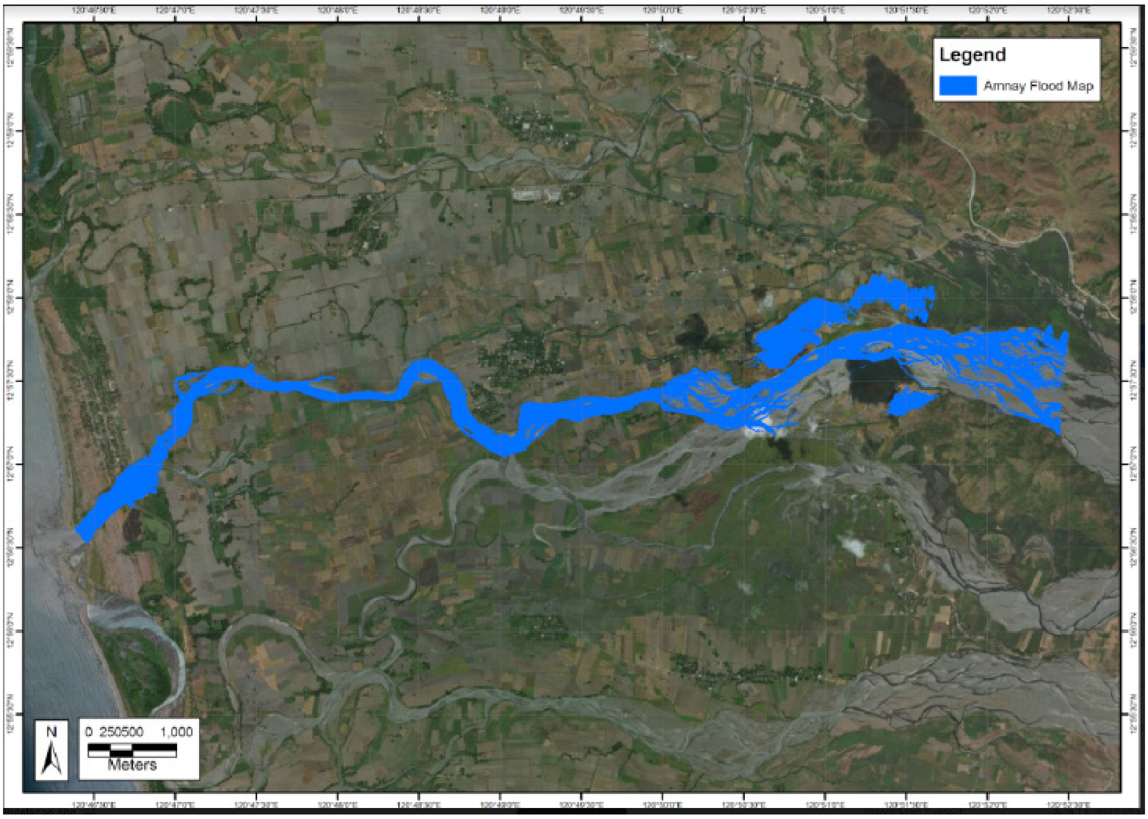


Figure 65. Amnay HEC-RAS Output

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Amnay 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 35 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Amnay Floodplain

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

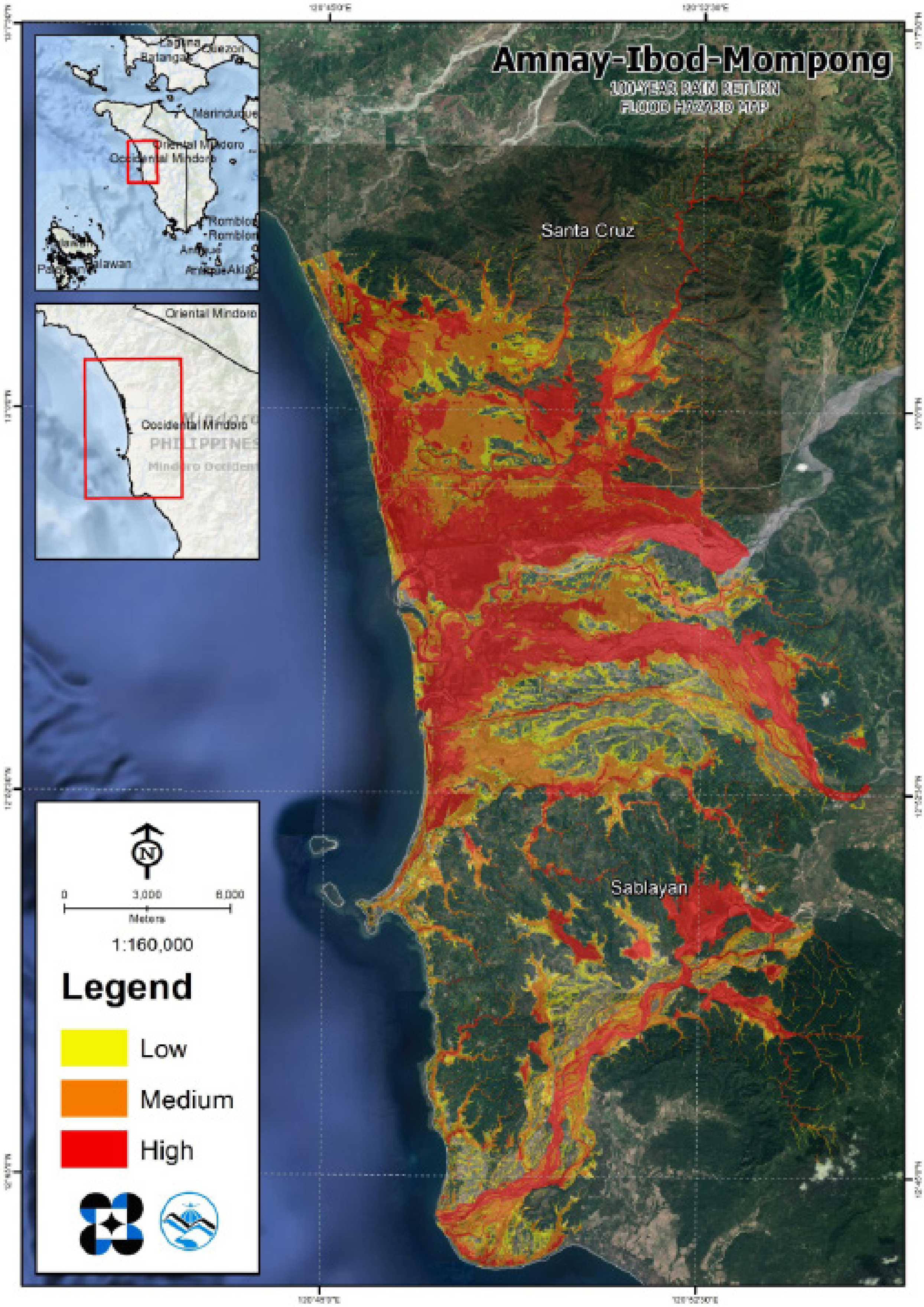


Figure 66. 100-year Rain Return Flood Hazard Map for Amnay-Ibod-Mompong Floodplain

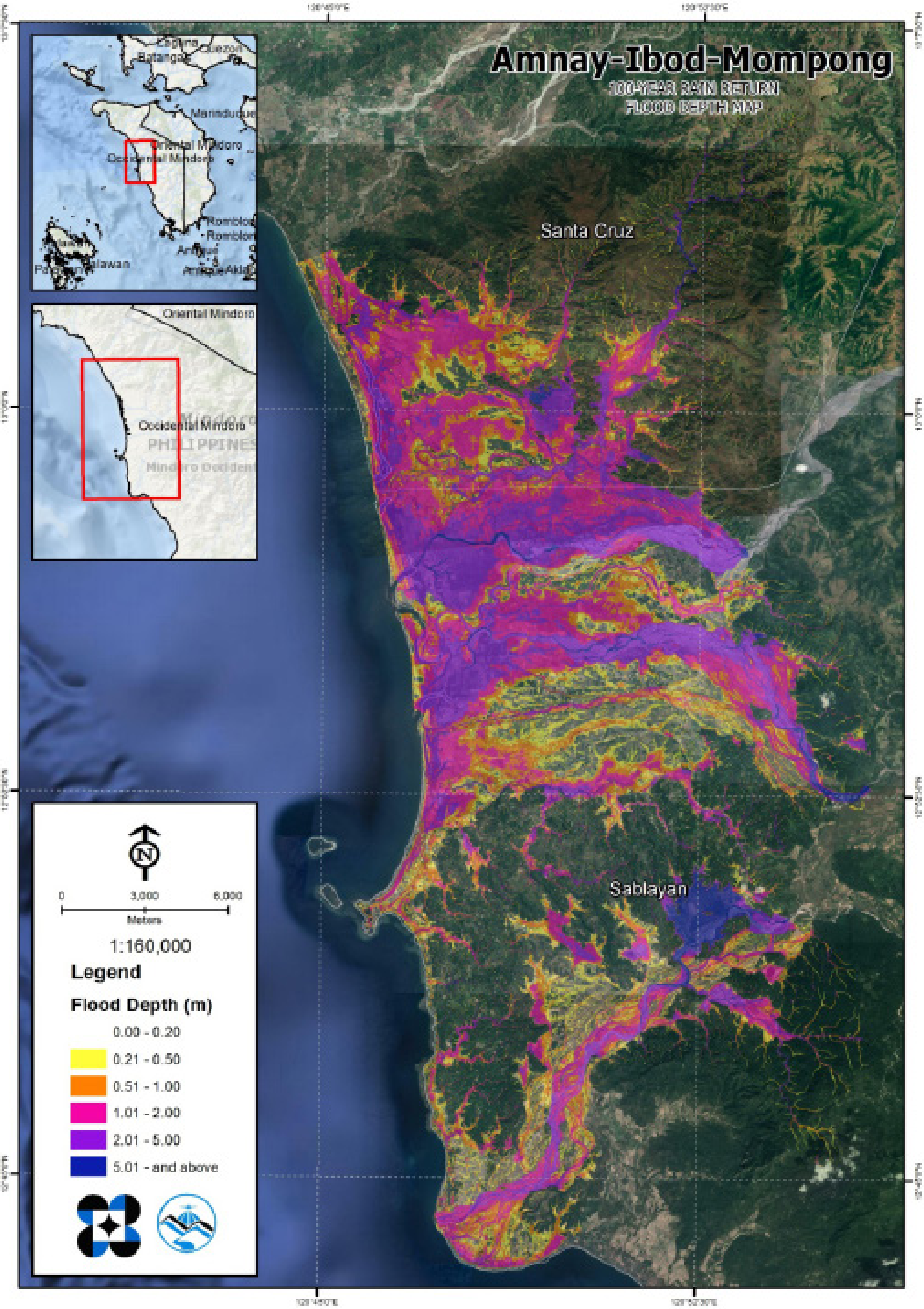


Figure 67. 100-year Rain Return Flood Depth Map for Amnay-Ibod-Mompong Floodplain

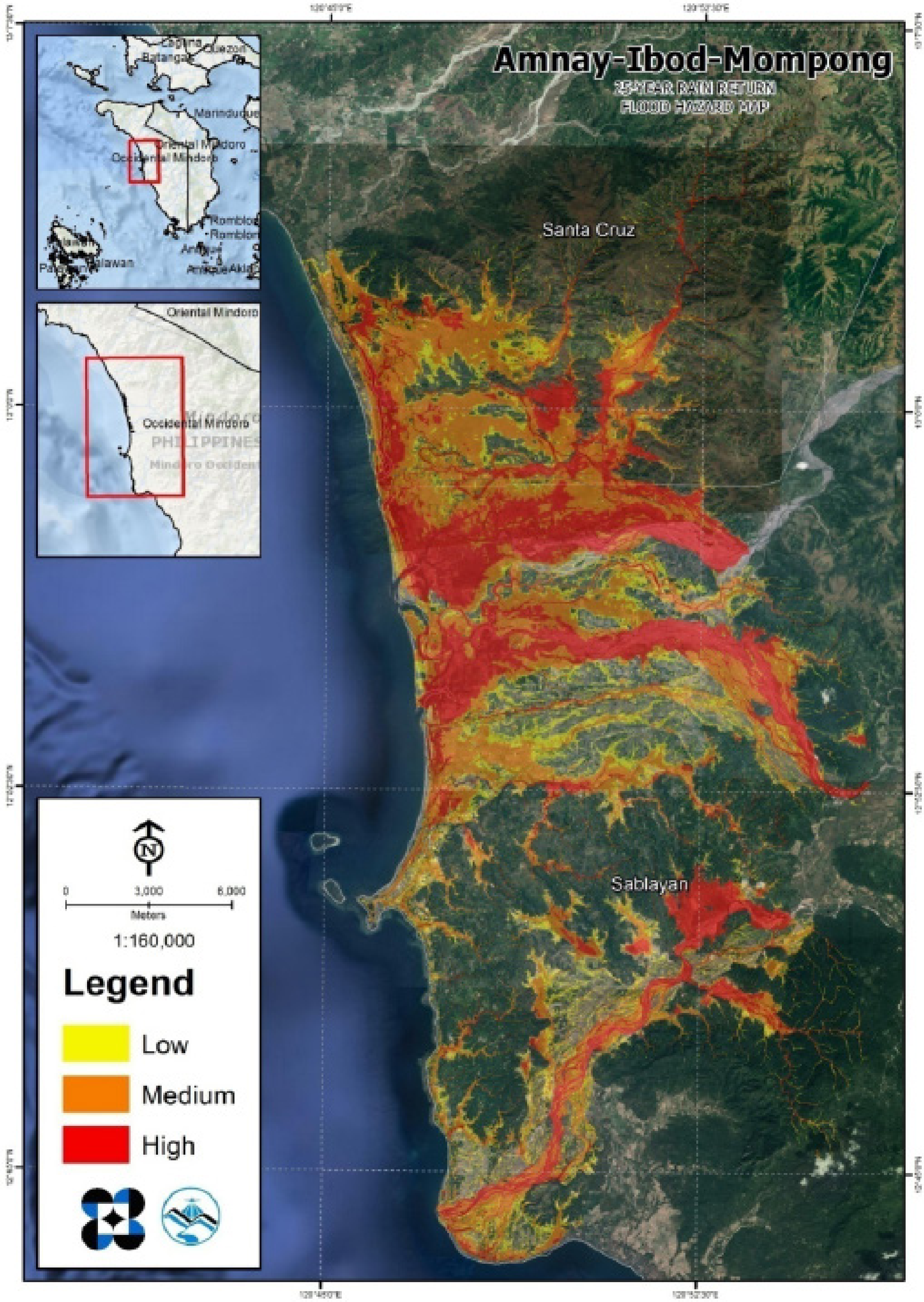


Figure 68. 25-year Rain Return Flood Hazard Map for Amnay-Ibod-Mompong Floodplain

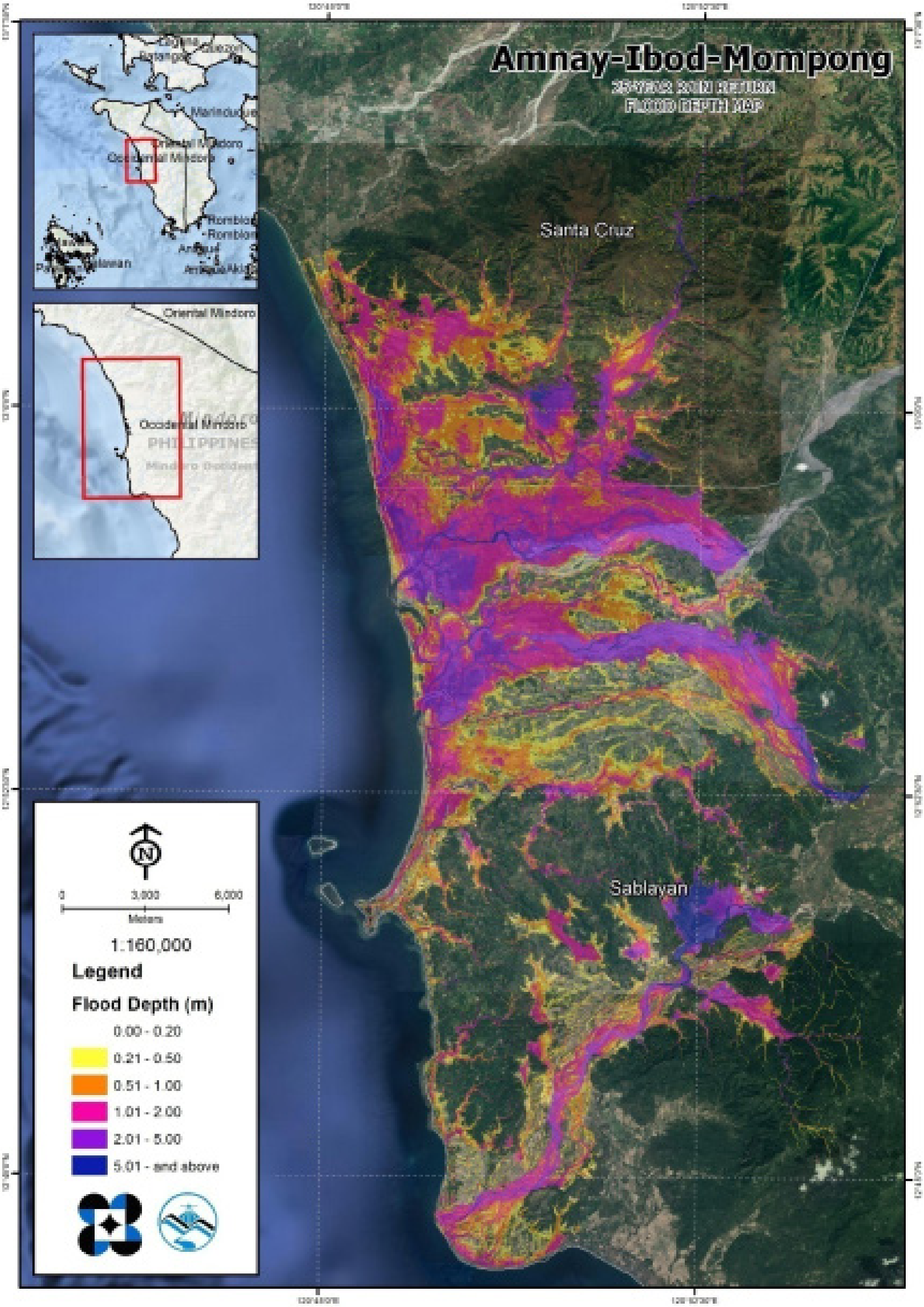


Figure 69. 25-year Rain Return Flood Depth Map for Amnay-Ibod-Mompng Floodplain

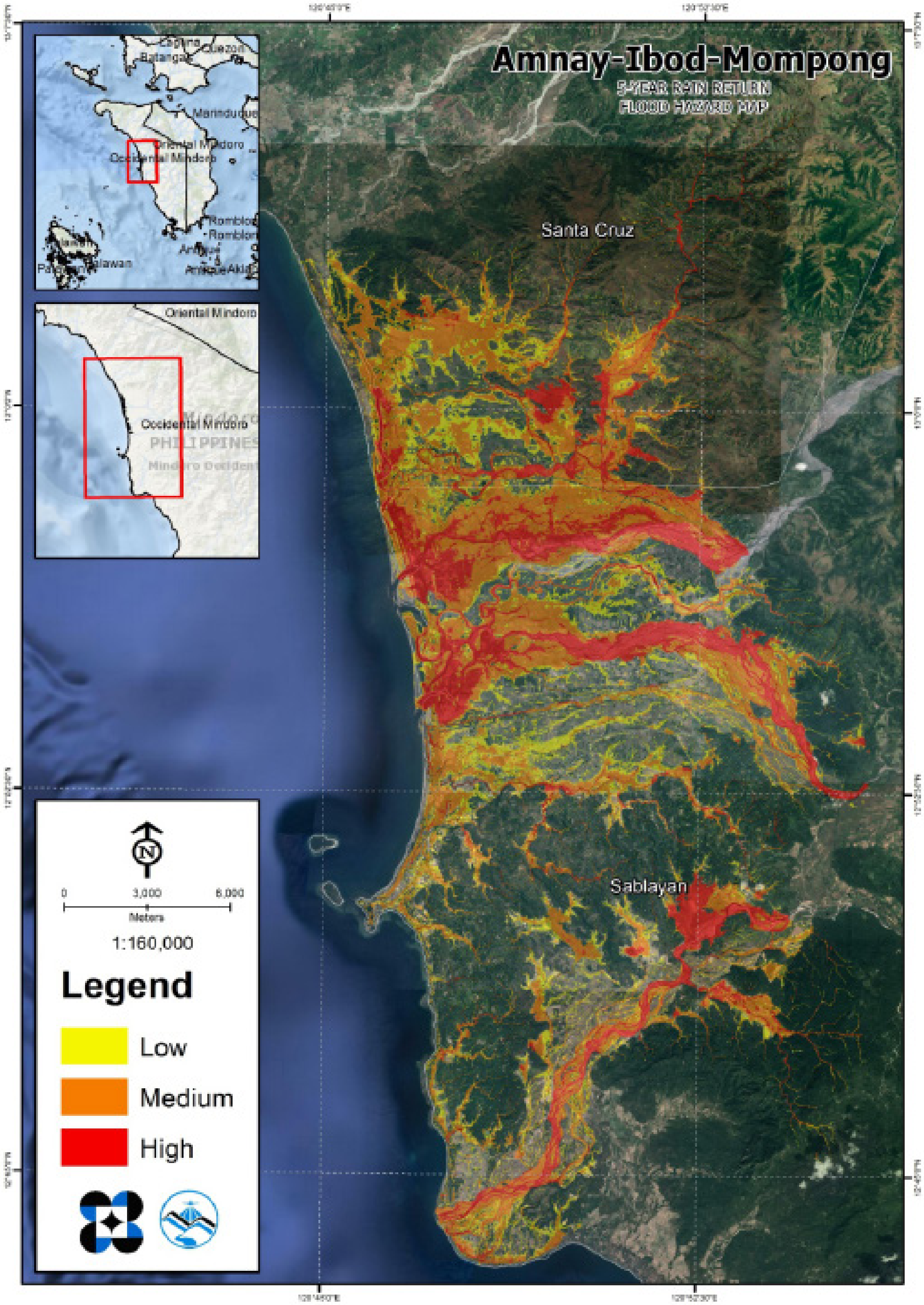


Figure 70. 5-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

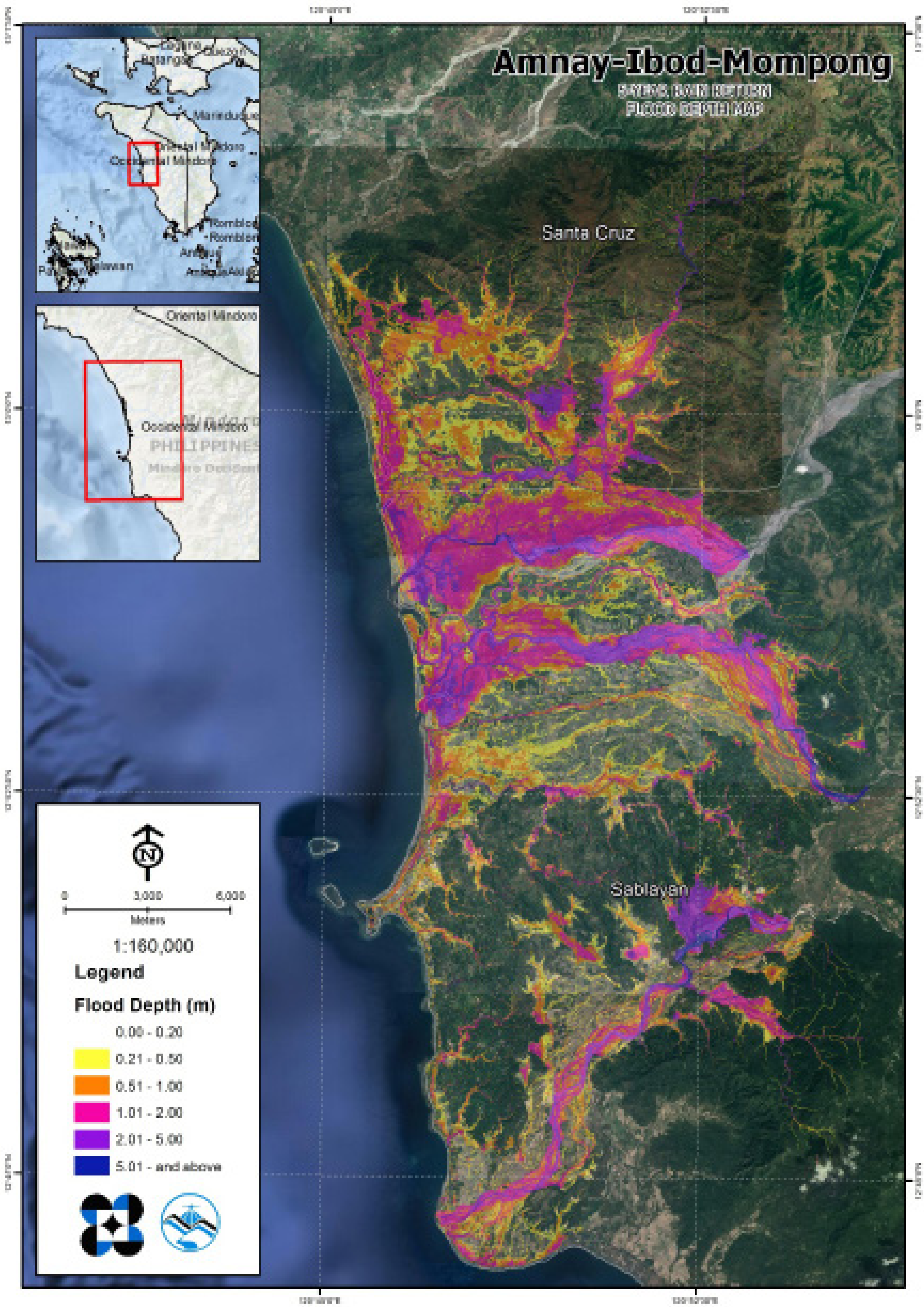


Figure 71. 5-year Rain Return Flood Depth Map for Amnay-Ibod-Mompong Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Amnay River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 20 barangays are expected to experience flooding when subjected to a 5-year 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 36 and shown in Figure 72 are the affected areas in Santa Cruz in square kilometres by flood depth per barangay.

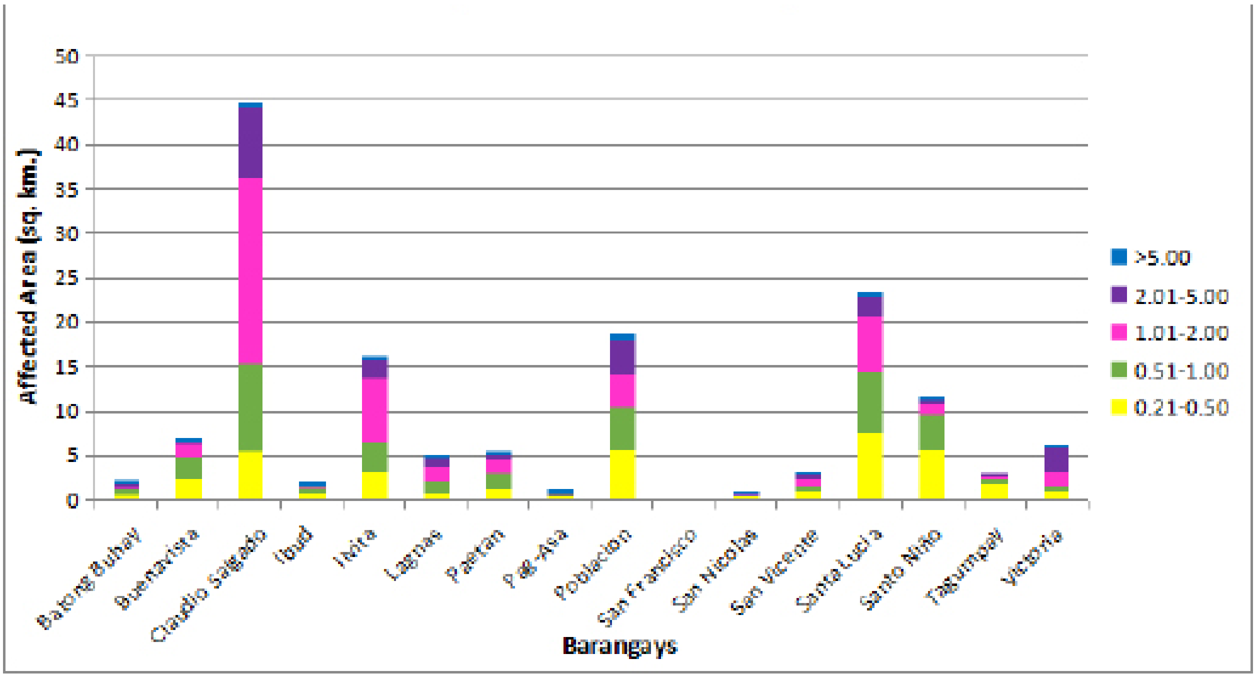


Figure 72. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

Table 36. 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

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

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 37 and shown in Figure 73 are the affected areas in square kilometres by flood depth per barangay.

Table 37. 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

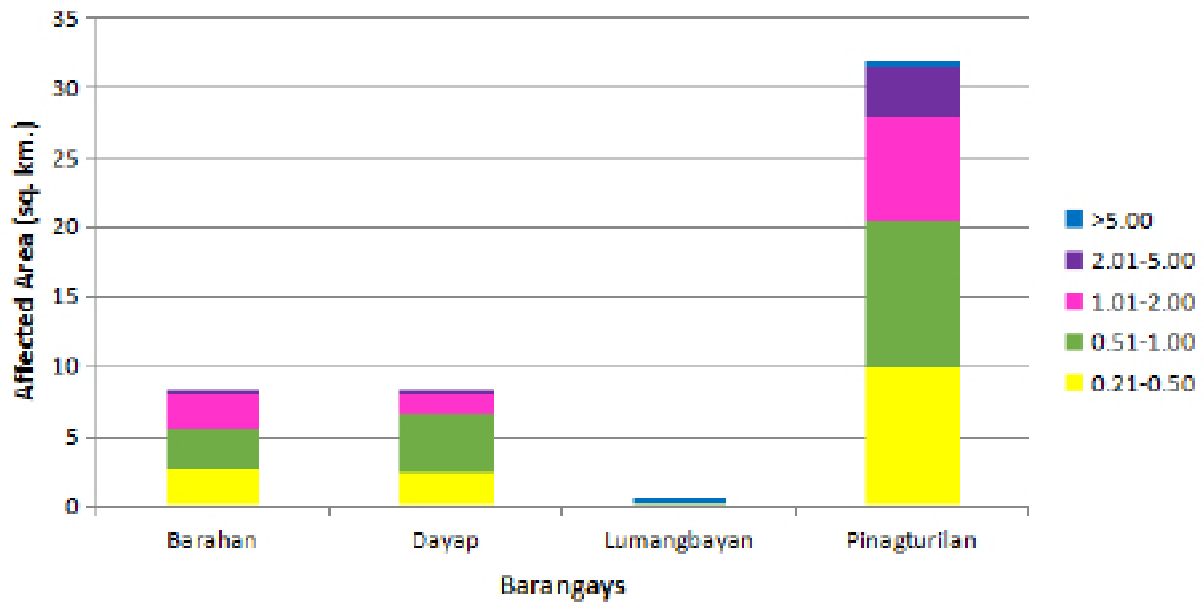


Figure 73. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

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 38 and shown in Figure 74 are the affected areas in square kilometres by flood depth per barangay.

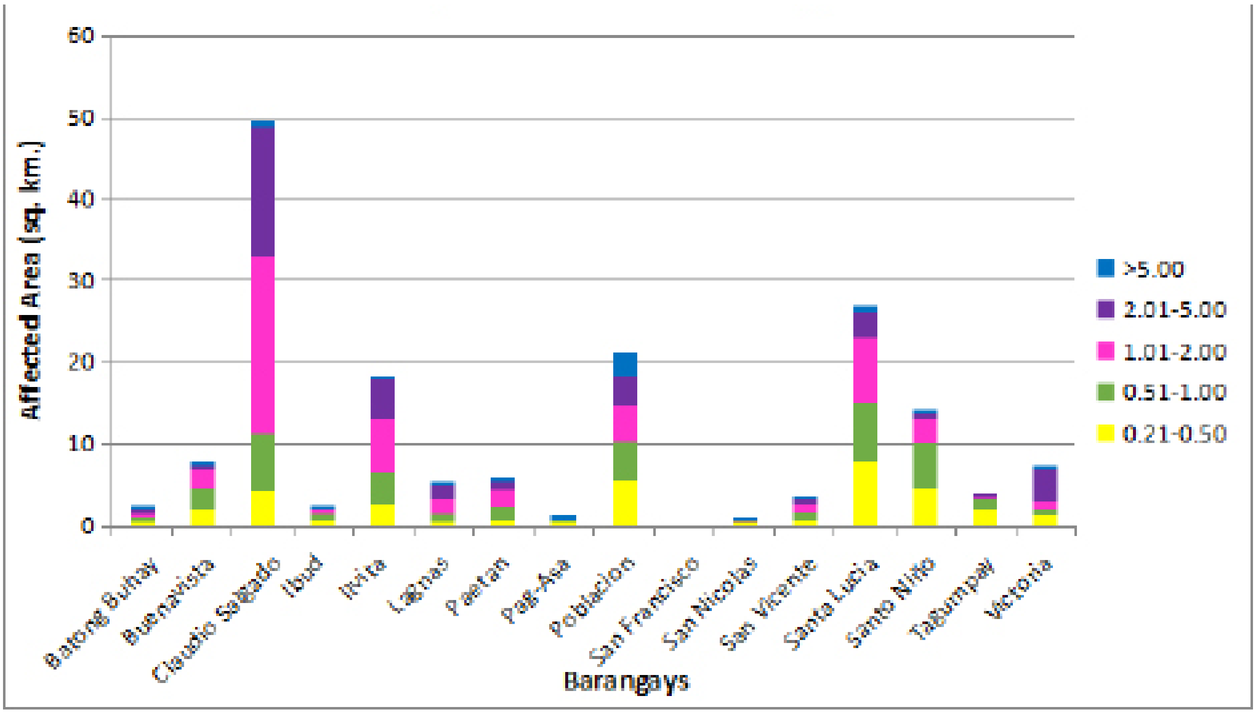


Figure 74. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

Table 38. 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

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

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 39 and Figure 75 are the affected areas in square kilometres by flood depth per barangay.

Table 39. 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

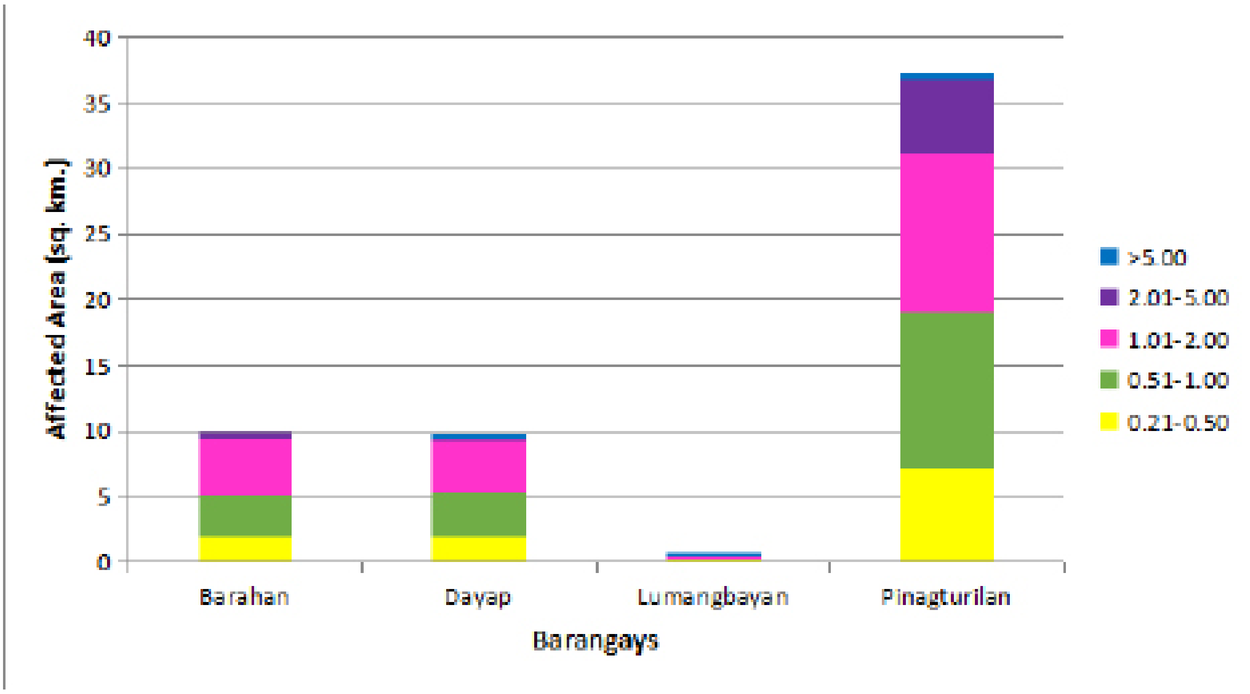


Figure 75. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

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 40 and Table 41, and shown in Figure 76 are the affected areas in square kilometres by flood depth per barangay.

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.)							
	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 41. 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

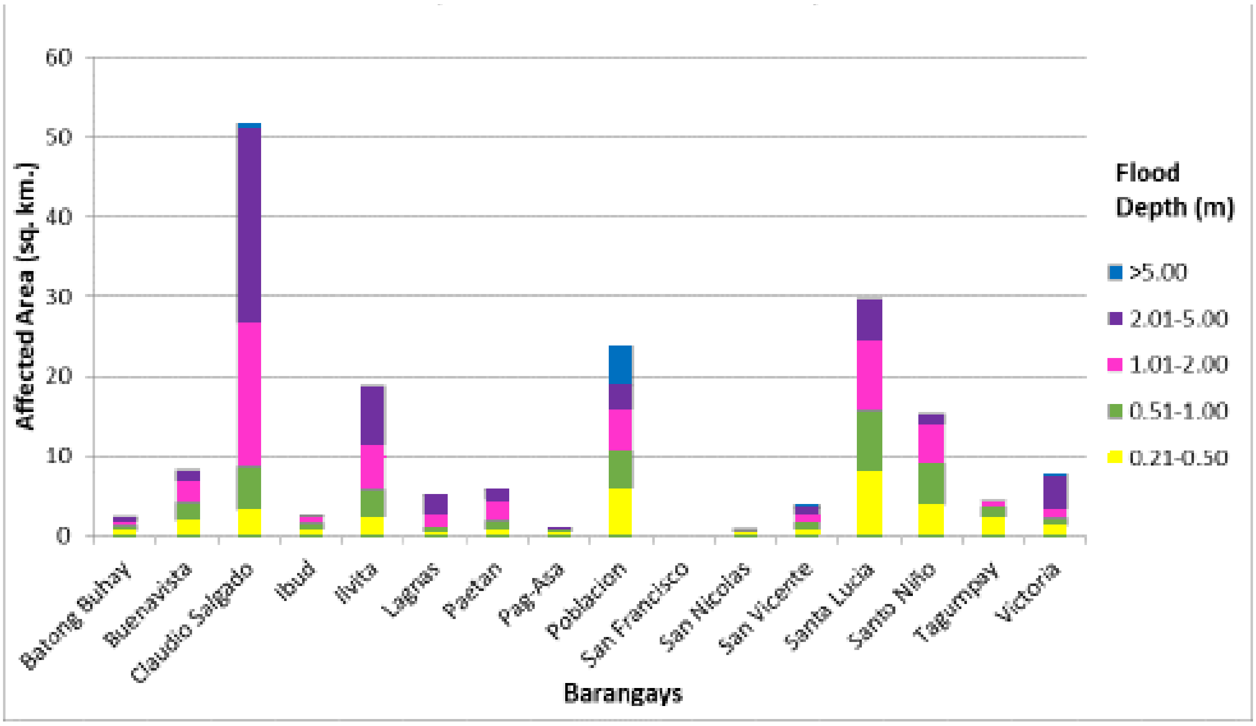


Figure 76. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

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 Figure 76 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Santa Cruz, Occidental Mindoro during 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

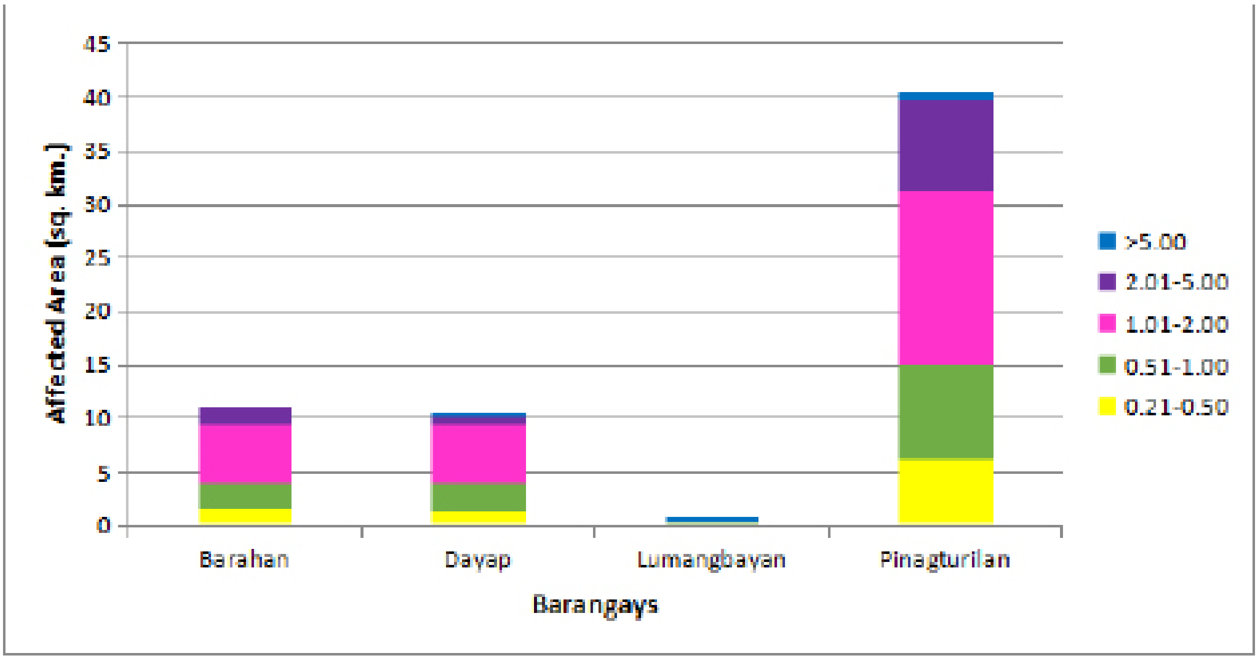


Figure 77. Affected Areas in Santa Cruz, Occidental Mindoro during 100-Year Rainfall Return Period

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 is a need to perform validation survey work. Field personnel gathered secondary data regarding flood occurrence in the area within the major river system in the Philippines.

From the Flood Depth Maps produced by Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios are 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 or interview some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 77.

The flood validation consists of 83 points randomly selected all over the Amnay floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.33m. Table 42 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

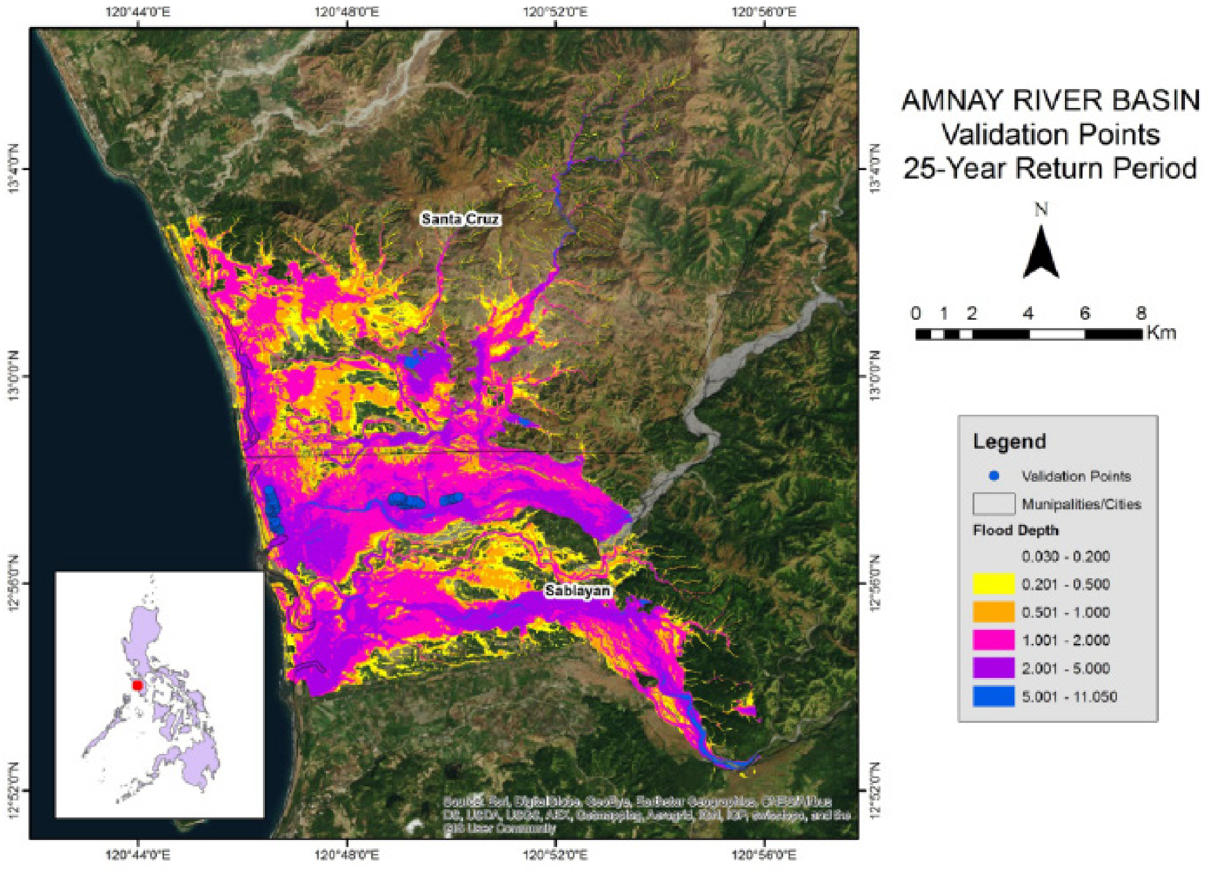


Figure 78. Validation points for 25-year Flood Depth Map of Amnay Floodplain

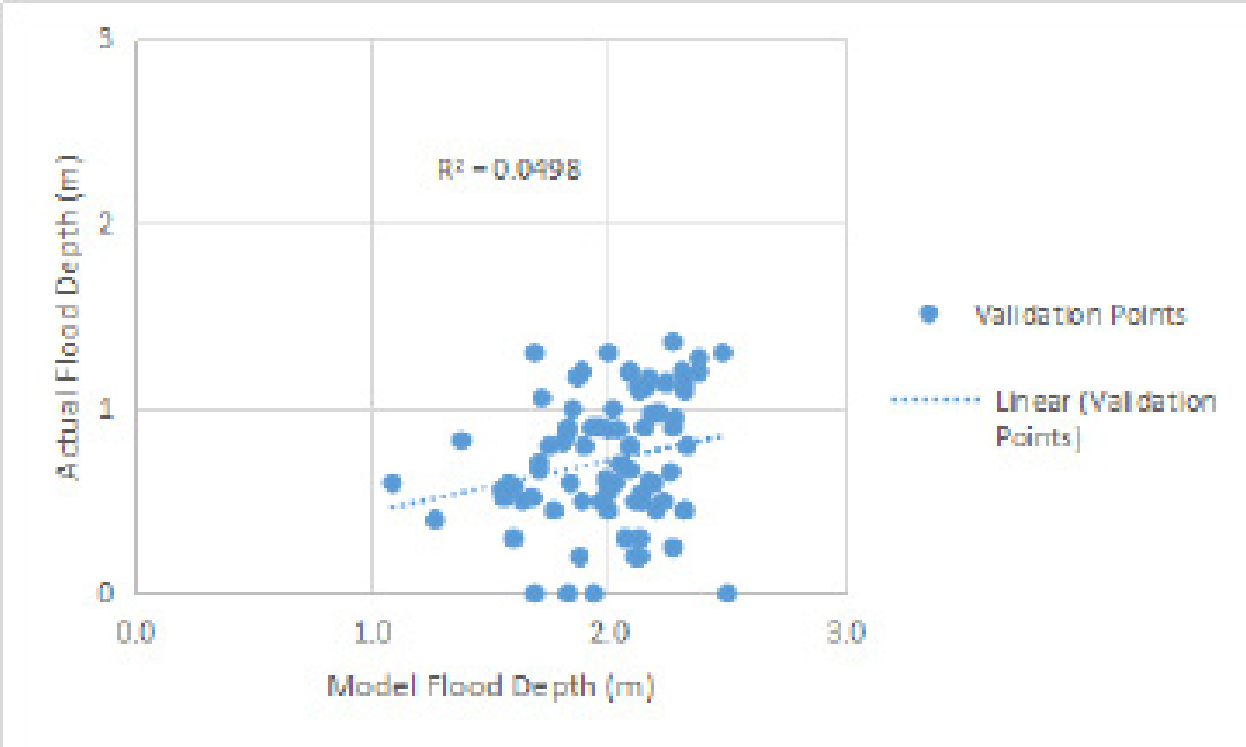


Figure 79. Flood map depth vs actual flood depth

Table 43. Actual flood vs simulated flood depth at different levels in the Amnay 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	0	0	0	4	3	0	7
0.21-0.50	0	0	0	9	10	0	19
0.51-1.00	0	0	0	23	16	0	39
1.01-2.00	0	0	0	5	13	0	18
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	0	0	0	41	42	0	83

The overall accuracy generated by the flood model is estimated at 6.02% with 5 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 25 points and 17 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 0 points were underestimated in the modelled flood depths of Amnay. Table 43 depicts shows the summary of the Accuracy Assessment in the Amnay River Basin Survey.

Table 44. Summary of the Accuracy Assessment in the Amnay River Basin Survey

	No. of Points	%
Correct	5	6.02
Overestimated	78	93.98
Underestimated	0	0.00
Total	83	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Aquarius Sensor

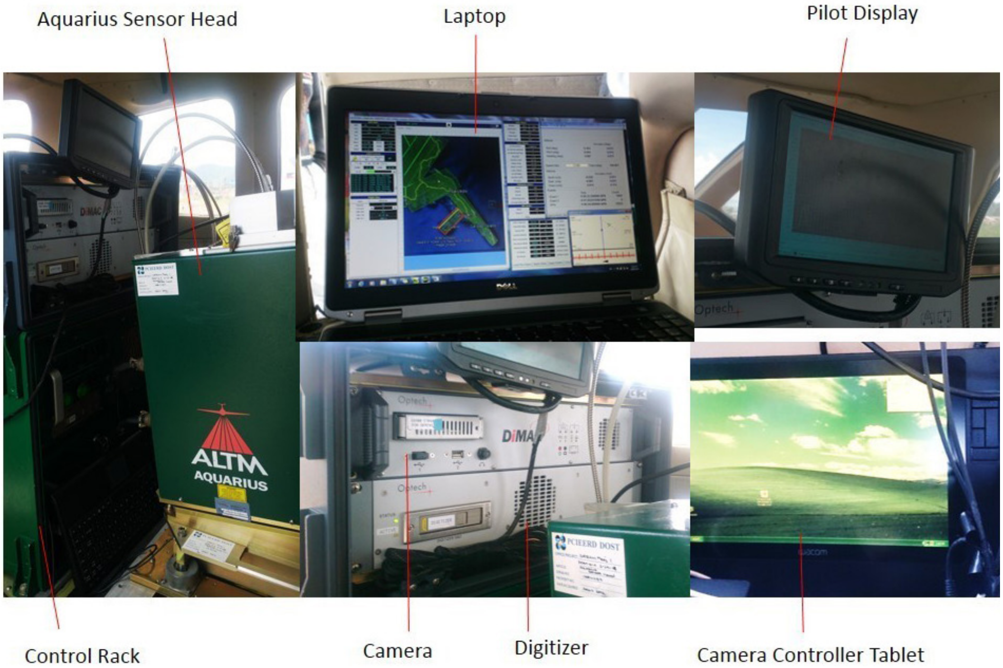


Figure A-1.1 Aquarius Sensor

Table A-1.1. Parameters and Specification of Aquarius Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	300-600 m AGL
Laser wavelength	33, 50. 70 kHz
Horizontal accuracy (2)	0-70 Hz
Elevation accuracy (2)	0 to ± 25 ˚
Effective laser repetition rate	30-60 cm
Position and orientation system	0 to > 10 m (for k < 0.1/m)
Scan width (FOV)	
Scan frequency (5)	300-2500
Sensor scan product	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Beam divergence	12-bit dynamic measurement range
Roll compensation	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Vertical target separation distance	Ruggedized removable SSD hard disk (SATA III)
Range capture	28 V, 900 W, 35 A
Intensity capture	5 MP interline camera (standard); 60 MP full frame (optional)
Image capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Full waveform capture	Sensor:250 x 430 x 320 mm; 30 kg;
Data storage	Control rack: 591 x 485 x 578 mm; 53 kg
Power requirements	0-35˚C
Dimensions and weight	0-95% no-condensing
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

Table A-1.2. Parameters and Specification of 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

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40˚ in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20˚
4 Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

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 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

9902192014141007

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Branch: 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

CIP/4701/12/09/814

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** 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 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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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

9902262014143552

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/13/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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www.namria.gov.ph

Figure A-2.3. MRW-32

3. 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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4731/12/09/814

Figure A-2.4 MRW-34

4. 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**		Barangay: **MALISBONG**
Municipality: **SABLAYAN**		
	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

5. 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**

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Director, Mapping And Geodesy Branch

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Figure A-2.6. MC-121

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

1. MC-121

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

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	196°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-3.1 MC-121

2. MRWDAC-00

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

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-3.2 MRWDAC-00

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist	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 Sheet for Amnay Floodplain

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	695MB	2/1/5/1KB	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	~~14.7GB~~ 39.7	1KB	13.3GB	43.6GB	14MB	1KB	1KB	48KB	N/A	X:\Airborne_Raw\1110A
18-2-14	1116A	3BLK29K349A	AQUARIUS	NA	659KB	4.08MB	245MB	71.7GB	32/165/253/5KB	12GB	61.6GB	15.3MB	1KB	1KB	46KB	N/A	X:\Airborne_Raw\1116A
18-2-14	1118A	3BLK29I349B	AQUARIUS	NA	540KB	1.04MB	204MB	48GB	1/372KB	11.3GB	50.2GB	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	352KB	N/A	X:\Airborne_Raw\1120A
19-2-14	1122A	3BLK29O50B	AQUARIUS	NA	166KB	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	3BLK29O53A	AQUARIUS	NA	308KB	1.34MB	248MB	~~[illegible]~~ 75.9GB	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	303KB	1.71MB	236MB	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 [signature]

Received by
Name JOIDA F. PRIETO
Position SRS
Signature [signature]

Figure A-5.1. Transfer Sheet for Amnay 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	1PAM9015A	PEGASUS	1.02MB	NA	5.85MB	165MB	NA	NA	9.2GB	N/A	11MB	1KB	1KB	NA	N/A	X:\Airborne_Raw\989P
Jan 21, 2014	1004A	3PNG1AB021A	AQUARIUS	NA	NA	920KB	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	8.78GB	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	3BLK29IS53A/3BLK29HS3A	AQUARIUS	NA	NA	1.62MB	276MB	34.3GB	251/1/328KB	16.1GB	83.7GB	13.4MB	1KB	1KB	432KB	383/508/320/384KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1132A
Feb 22, 2014	1134A	3BLK29MS53B/3BLK29MR53B	AQUARIUS	NA	NA	1.08MB	144MB	27.8GB	105/28/1/56/33/44KB	4.99GB	12.6GB	13.4MB	1KB	1KB	102KB	131KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1134A
Feb 23, 2014	1136A	3BLK29HS54A/3BLK29HBS4A	AQUARIUS	NA	NA	1.37MB	258MB	86.5GB	227/337/61KB	15GB	NA	15.6MB	1KB	1KB	268KB	265/265/529/36KB	(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	300KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1138A
Feb 24, 2014	1140A	3BLK29ES55A/3BLK29G55A	AQUARIUS	NA	NA	981KB	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	56/100KB	13.4GB	64.2GB	12.1MB	1KB	1KB	709KB	247KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1142A

Received from

Name CHRIS JOAQUIN
Position RA
Signature [signature]

Received by

Name JOIDA PRIETO
Position SSRS
Signature [signature]

Figure A-5.2. Transfer Sheet for Amnay 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	1.48	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	963	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	106	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

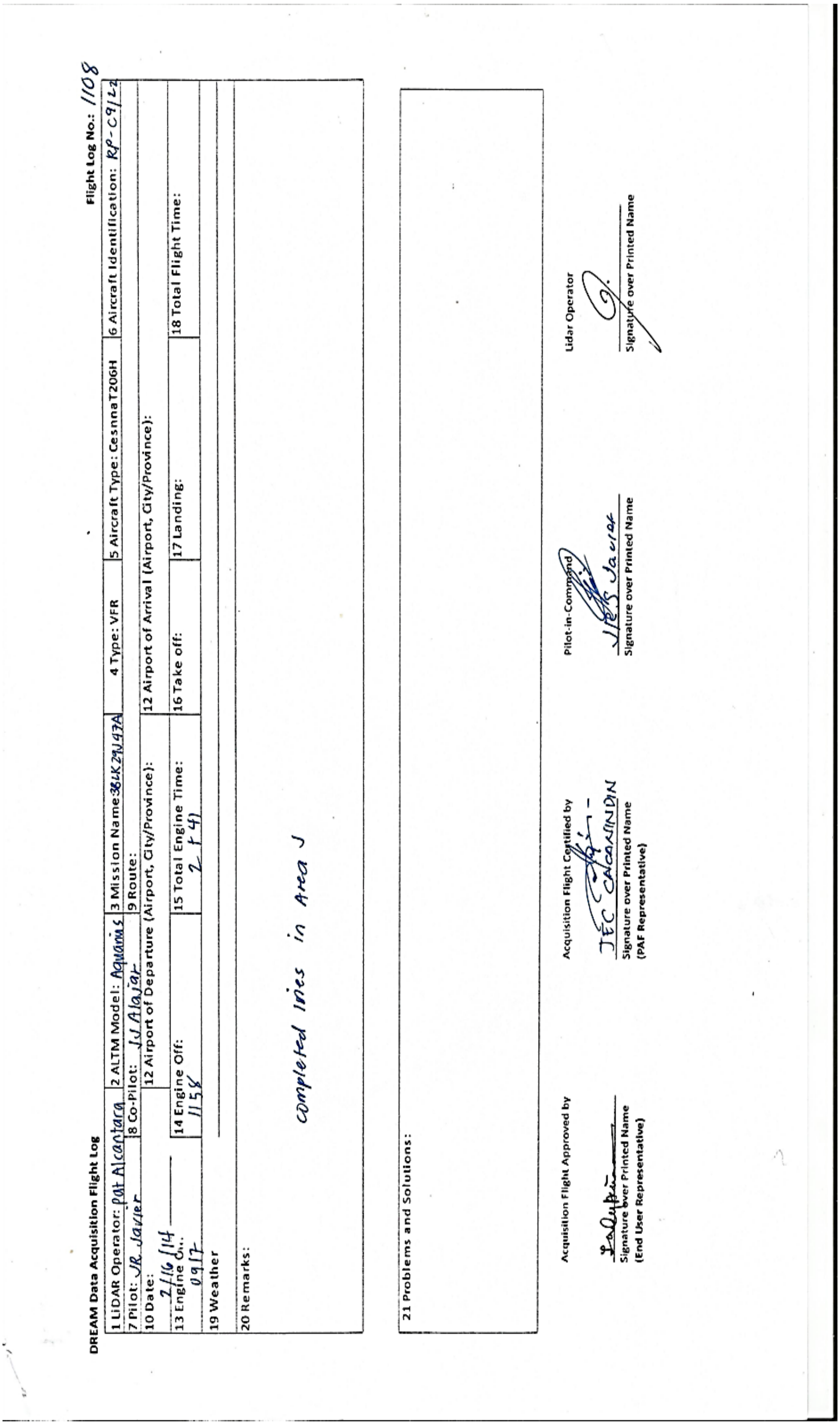
Received by

Name AC Bongat
Position SSRS
Signature 1/15/16

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

Annex 6. Flight Logs for the Flight Missions

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)

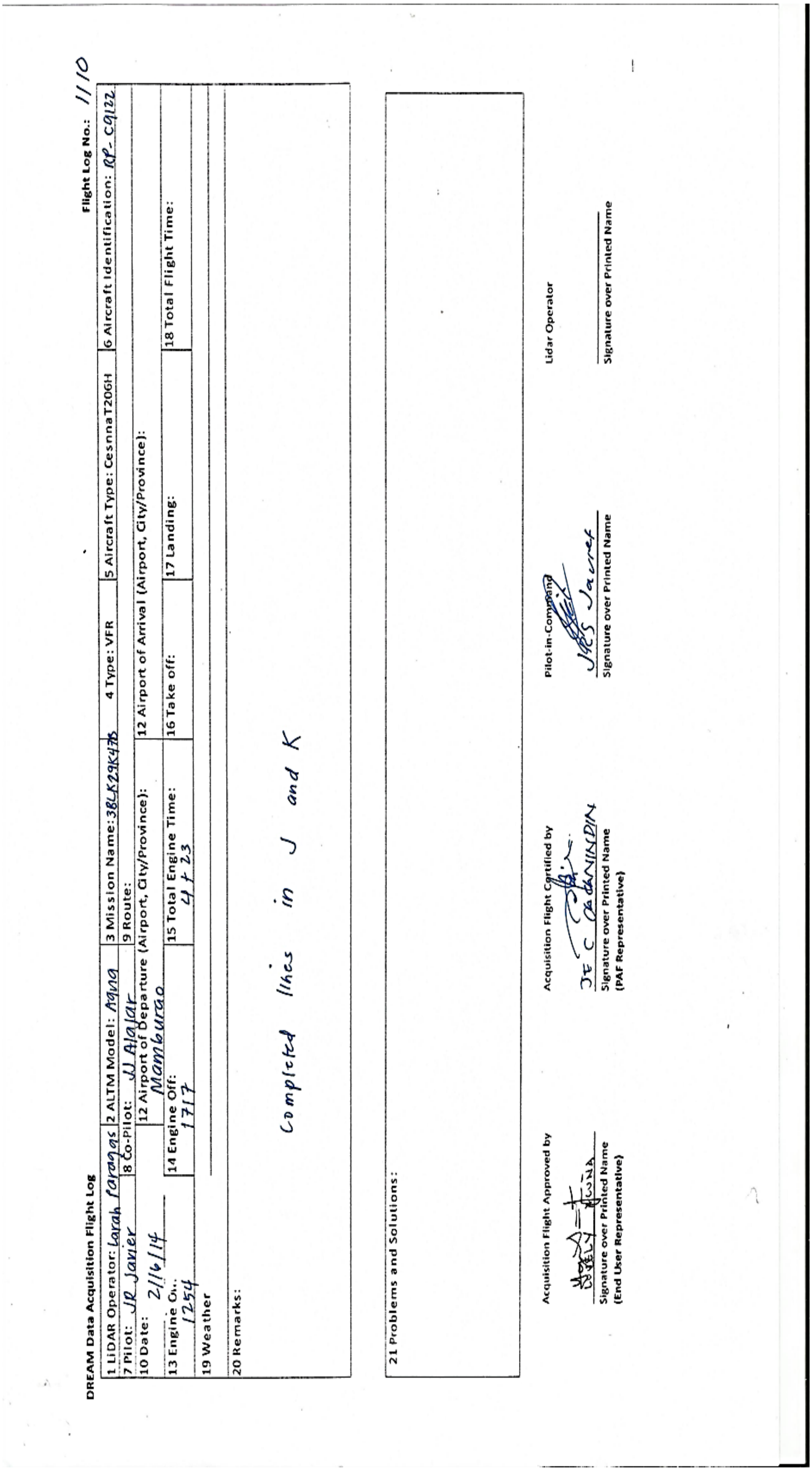
Acquisition Flight Certified by: JEC CACANINDIN — Signature over Printed Name (PAF Representative)

Pilot-in-Command: JRS Javier — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.1 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: Cesnna T206H	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 — Signature over Printed Name (End User Representative)

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

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

Lidar Operator — 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 Javier	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)

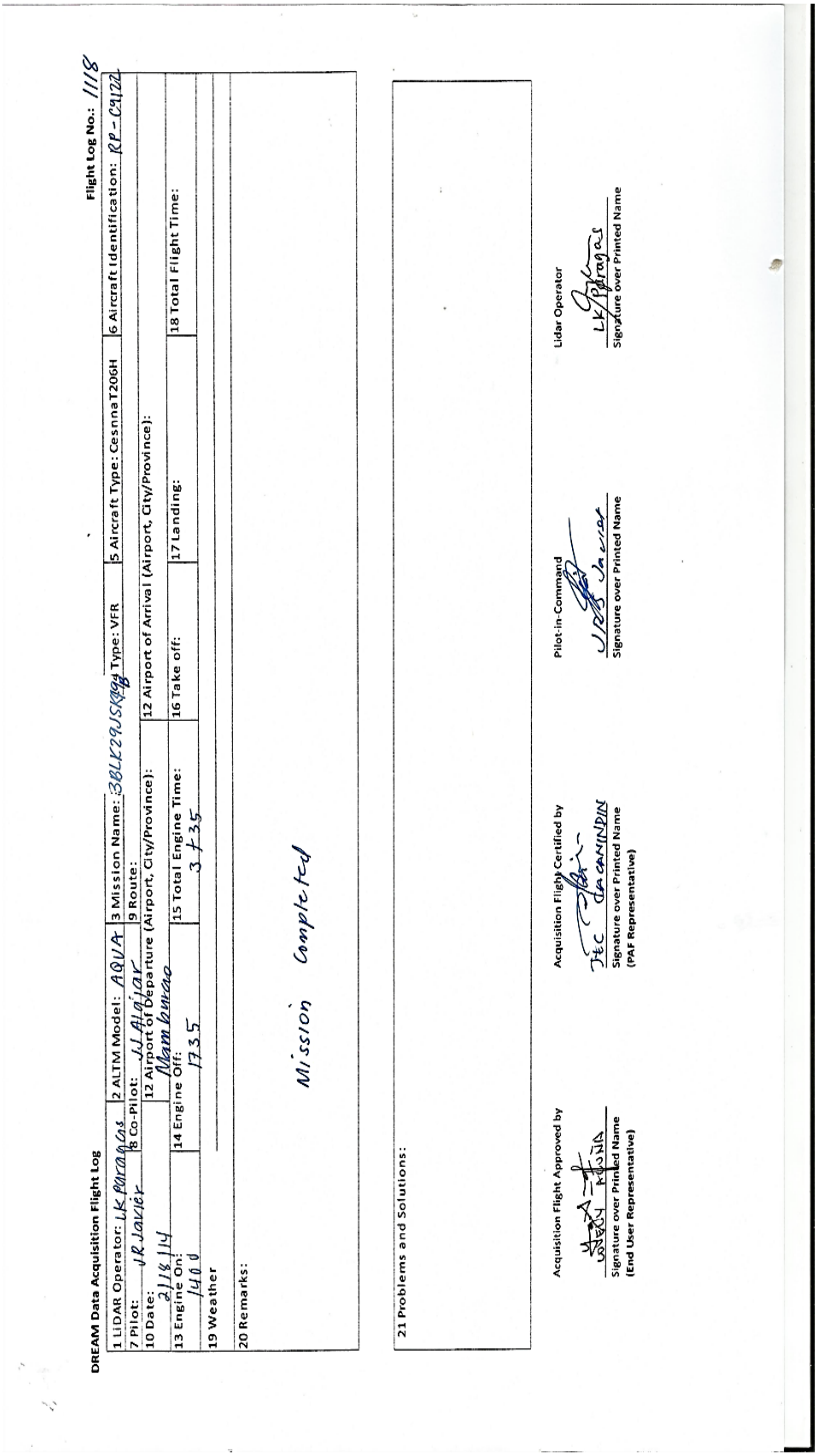
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.3. Flight Log for 3BLK29KS49A Mission

4. Flight Log for3BLK29JS49B 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: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajiar	9 Route:			
10 Date: 2/18/14	12 Airport of Departure (Airport, City/Province): Mambukao		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 — JEC Dacanindin — 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 for3BLK29JS49B Mission

5. Flight Log for3BLK29I52A 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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	[signature] TEC CACANINDIN	[signature] JRS Javier	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for3BLK29I52A Mission

6. Flight Log for3BLK29IS+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): Mamburao		12 Airport of Arrival (Airport, City/Province): Mamburao		
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:

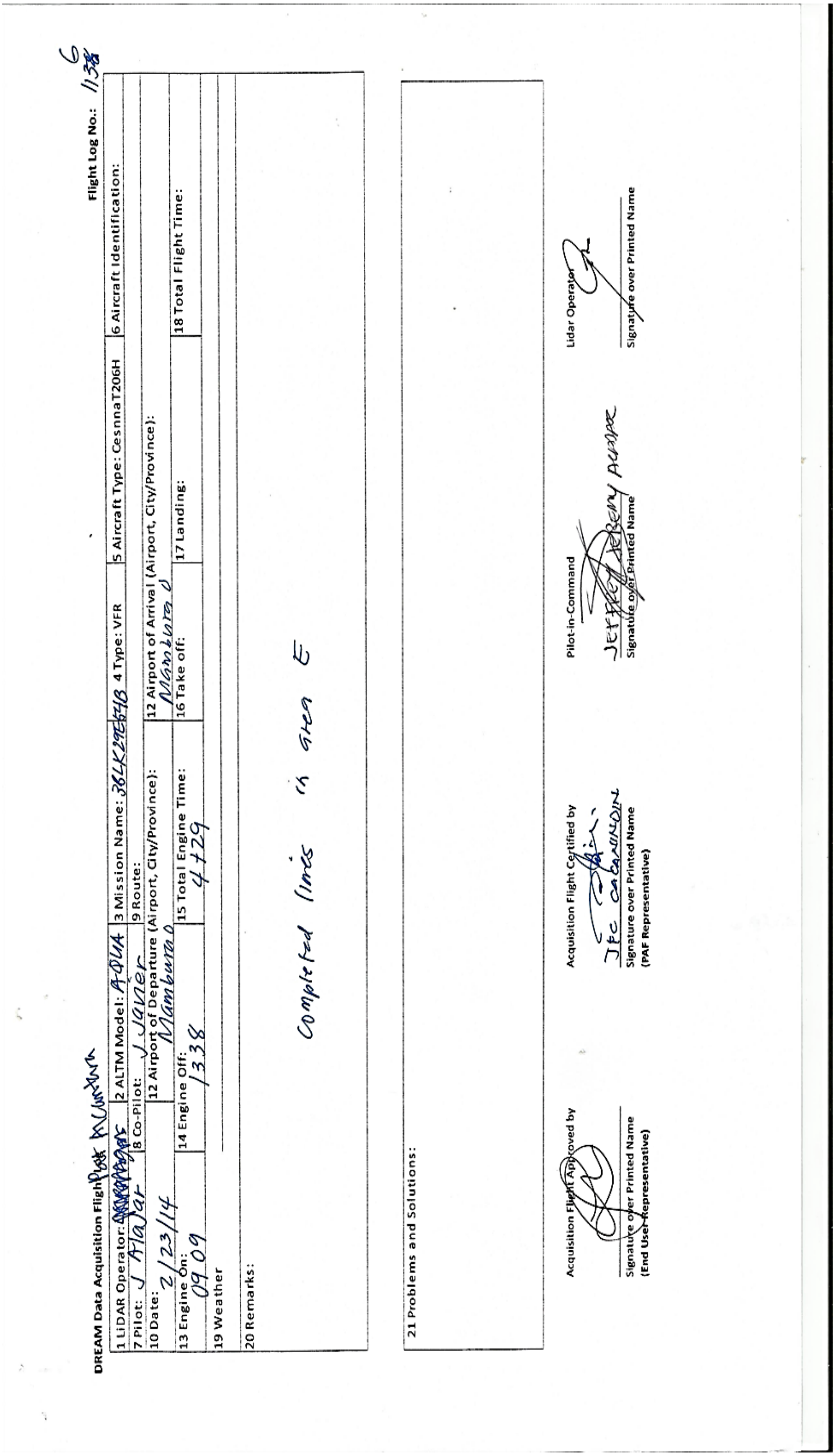
Mission I completed. 8 lines in area M

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 CACANINDIN Signature over Printed Name (PAF Representative)	JEFFREY JEREMY ALAJAR Signature over Printed Name	LK PARAGAS Signature over Printed Name

Figure A-6.6. Flight Log for3BLK29IS+H53A Mission

7. Flight Log for3BLK29HS54A/3BLK29HB54A Mission


DREAM Data Acquisition Flight Log — Flight Log No.: 1136

1 LiDAR Operator:	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)

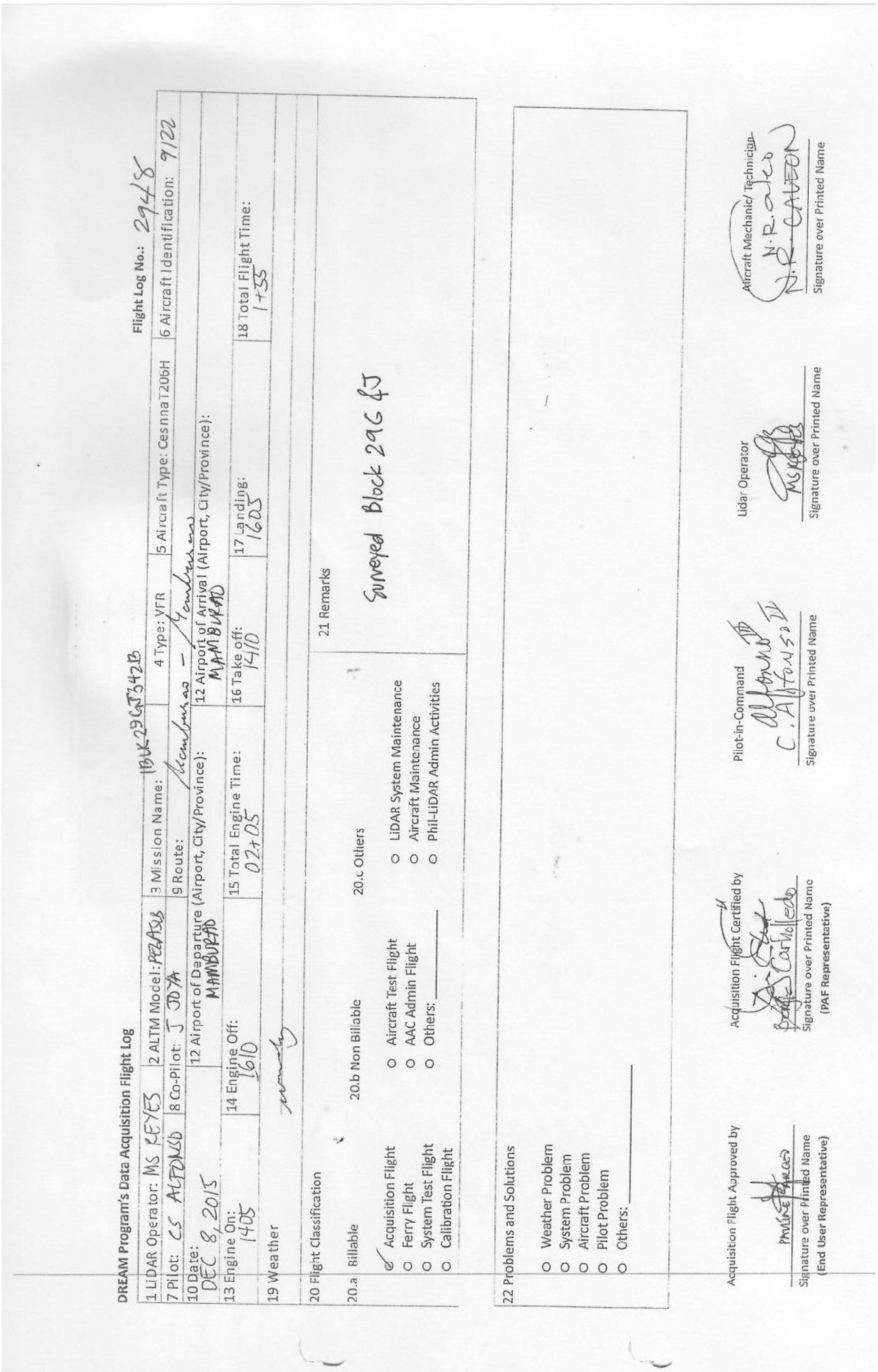
Acquisition Flight Certified by — JFC Cacanindin — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Jeffrey Jeremy Alajar — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.7. Flight Log for3BLK29HS54A/3BLK29HB54A Mission

8. Flight Log for1BLK29GJ342B 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 JOYA	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 GJ

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)

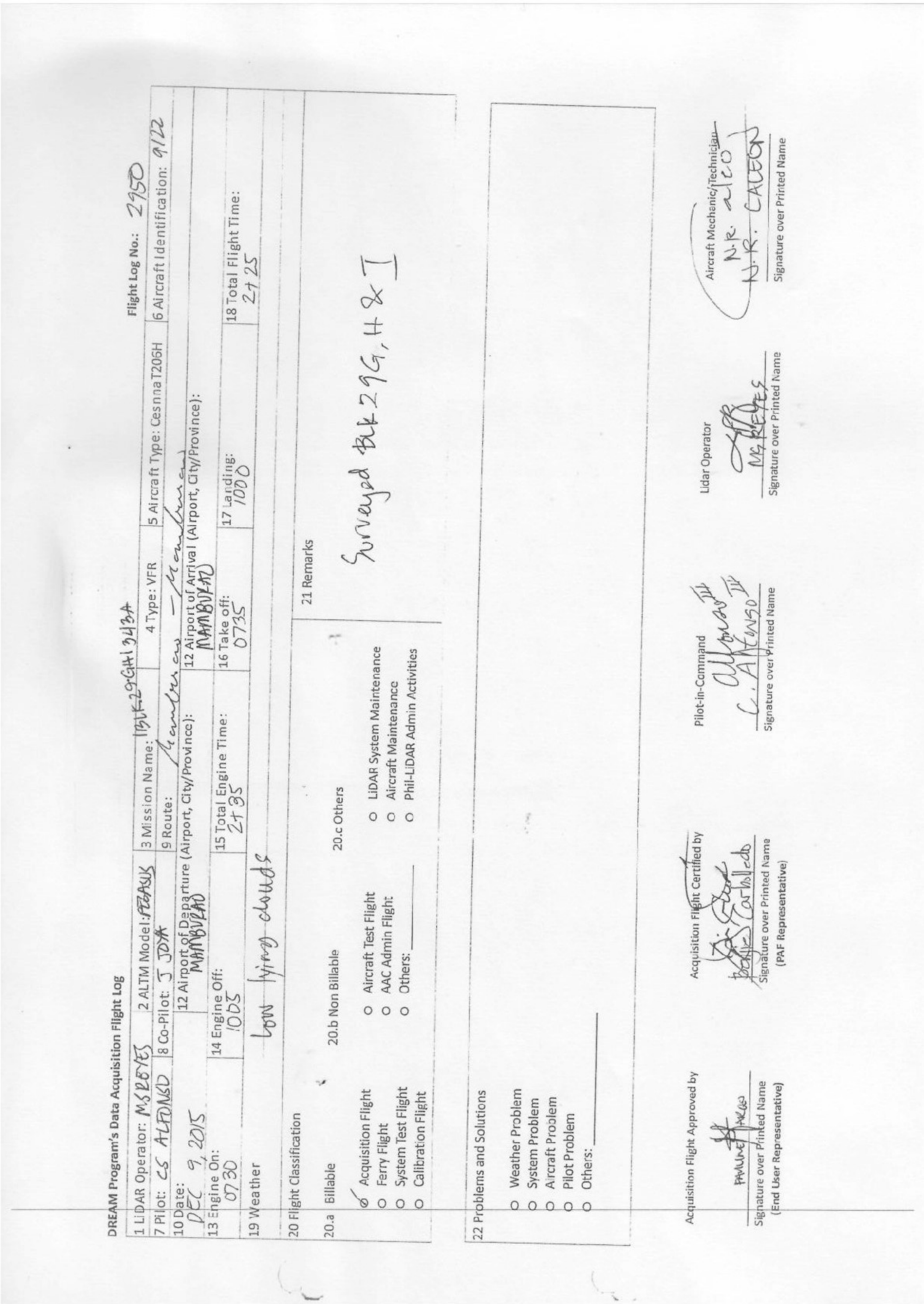
Pilot-in-Command: C. ALFONSO III — Signature over Printed Name

Lidar Operator: Signature over Printed Name

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

Figure A-6.8 Flight Log for1BLK29GJ342B Mission

9. Flight Log for1BLK29GHI343A 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: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao – Mamburao			
10 Date: DEC 9, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
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] 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-6.9 Flight Log for1BLK29GHI343A Mission

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

AMNAY 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

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 Coverage of Mission 3BLK29J47A

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

SURVEY COVERAGE:

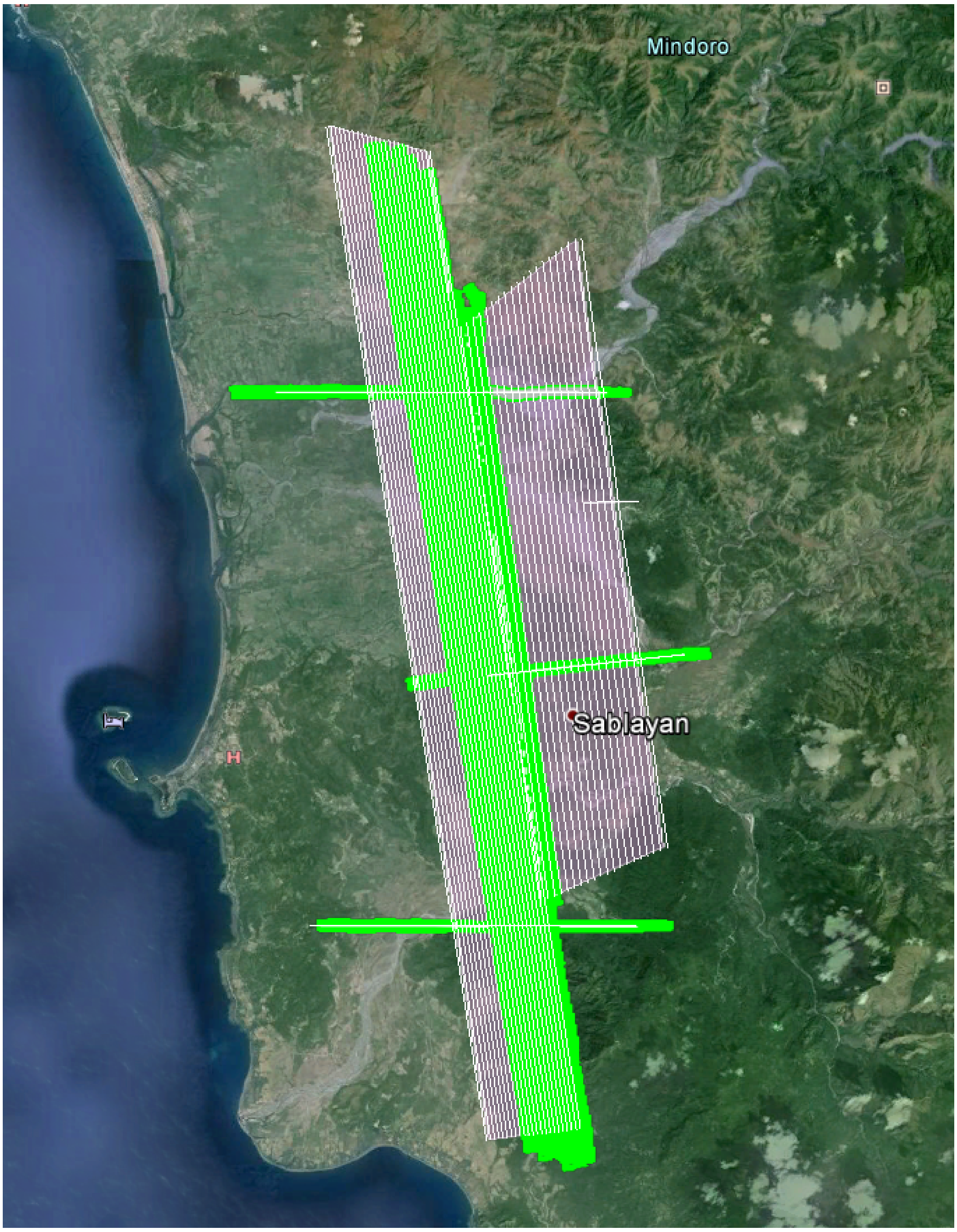


Figure A-7.2. Swath Coverage of Mission 3BLK29K+JS47B

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

SURVEY COVERAGE:

Figure A-7.3. Swath Coverage of Mission 3BLK29KS49A

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

SURVEY COVERAGE:

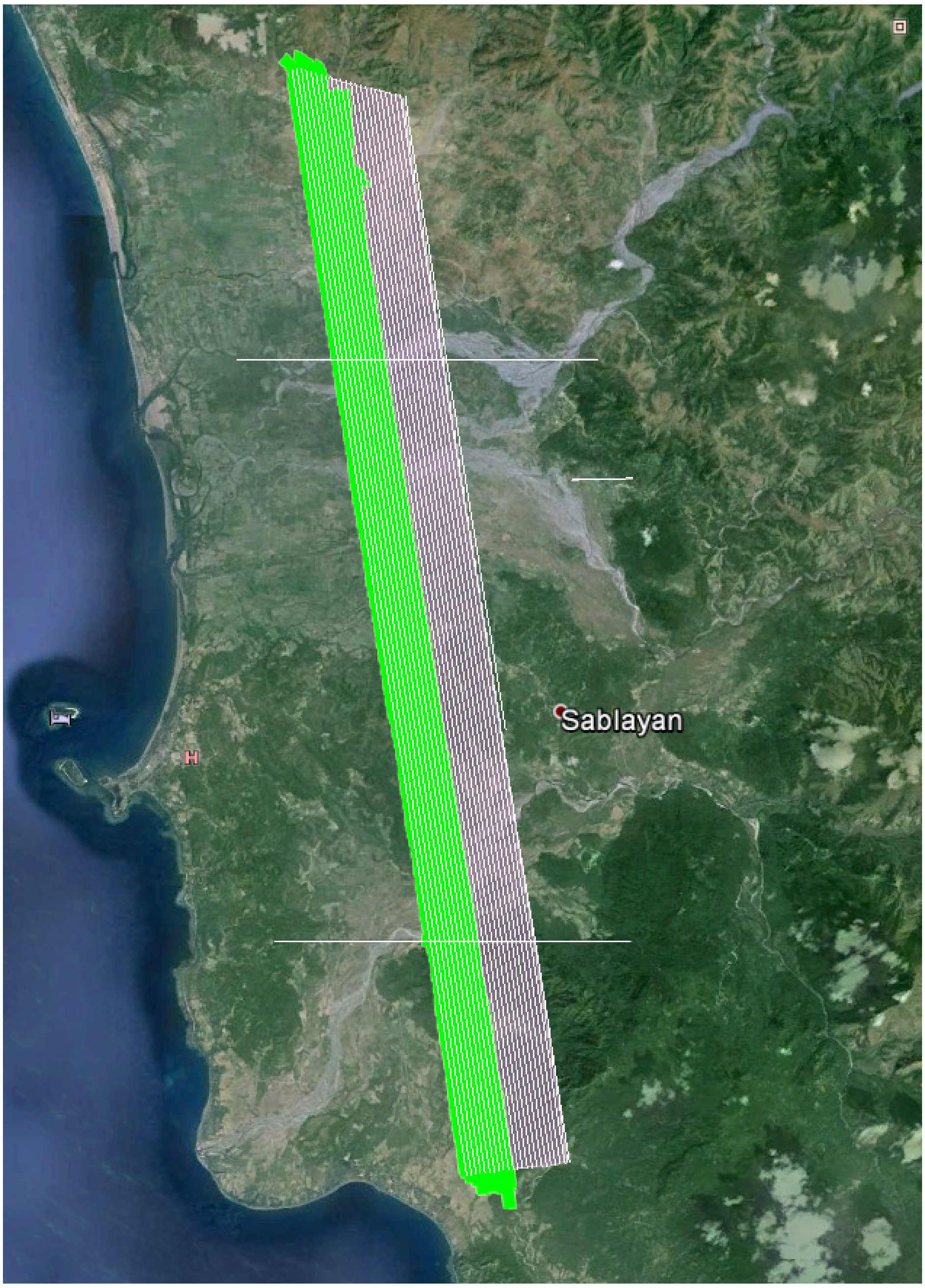


Figure A-7.4. Swath Coverage of Mission 3BLK29JS49B

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

SURVEY COVERAGE:

Figure A-7.5. Swath Coverage of Mission 3BLK29I52A

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

SURVEY COVERAGE:

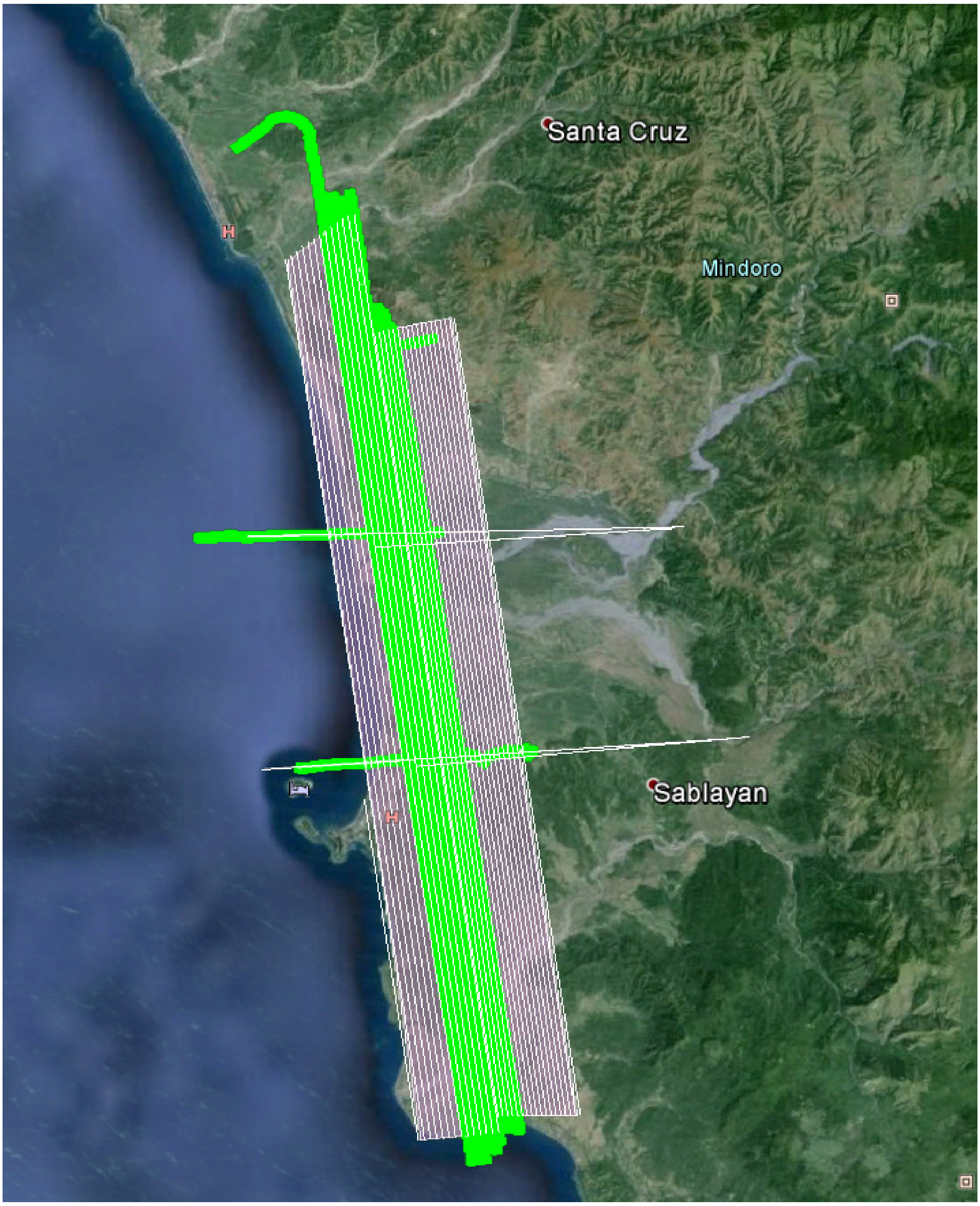


Figure A-7.7. Swath Coverage for 3BLK29IS+H53A Mission

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 Coverage for 3BLK29HS54A Mission

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

SURVEY COVERAGE:

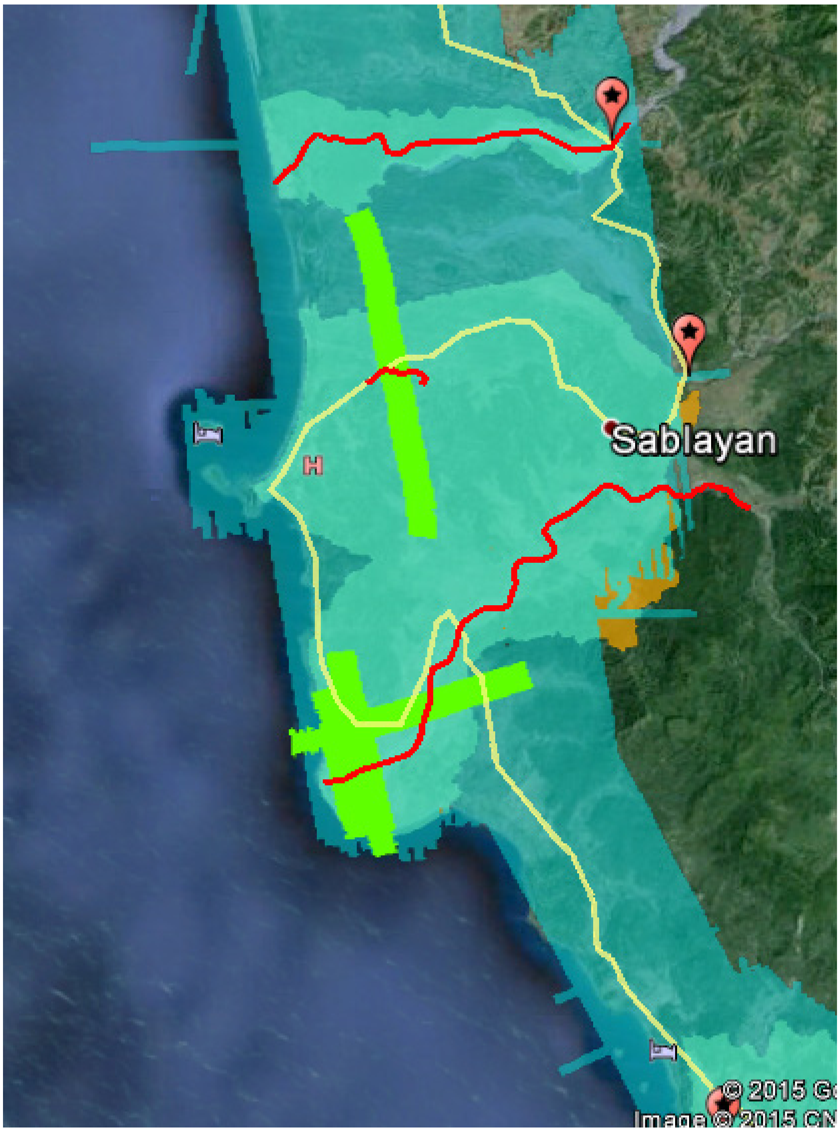


Figure A-7.9. Swath Coverage for 1BLK29GJ342B Mission

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

SURVEY COVERAGE:

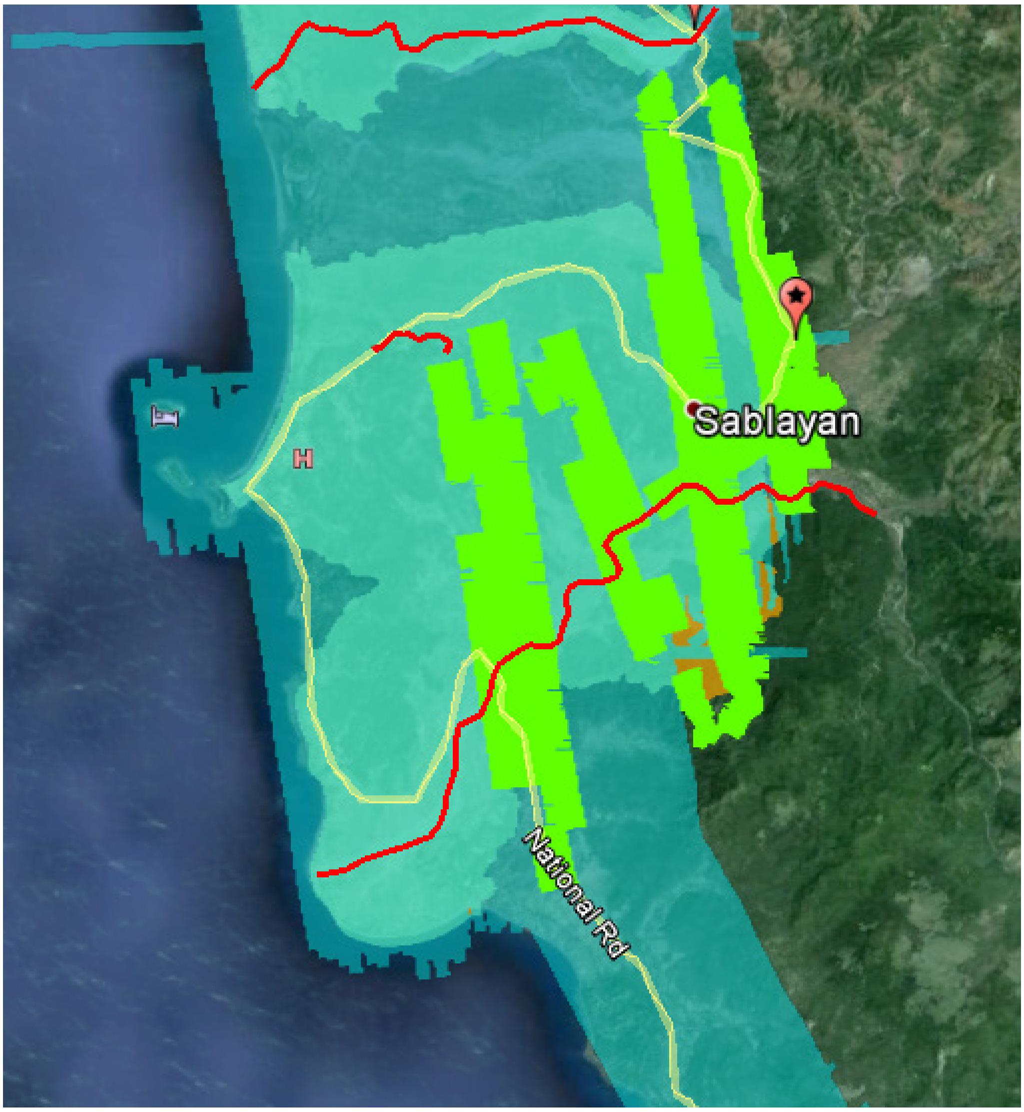


Figure A-7.10. Swath Coverage for 1BLK29GHI343A Mission

Annex 8. Mission Summary Reports

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

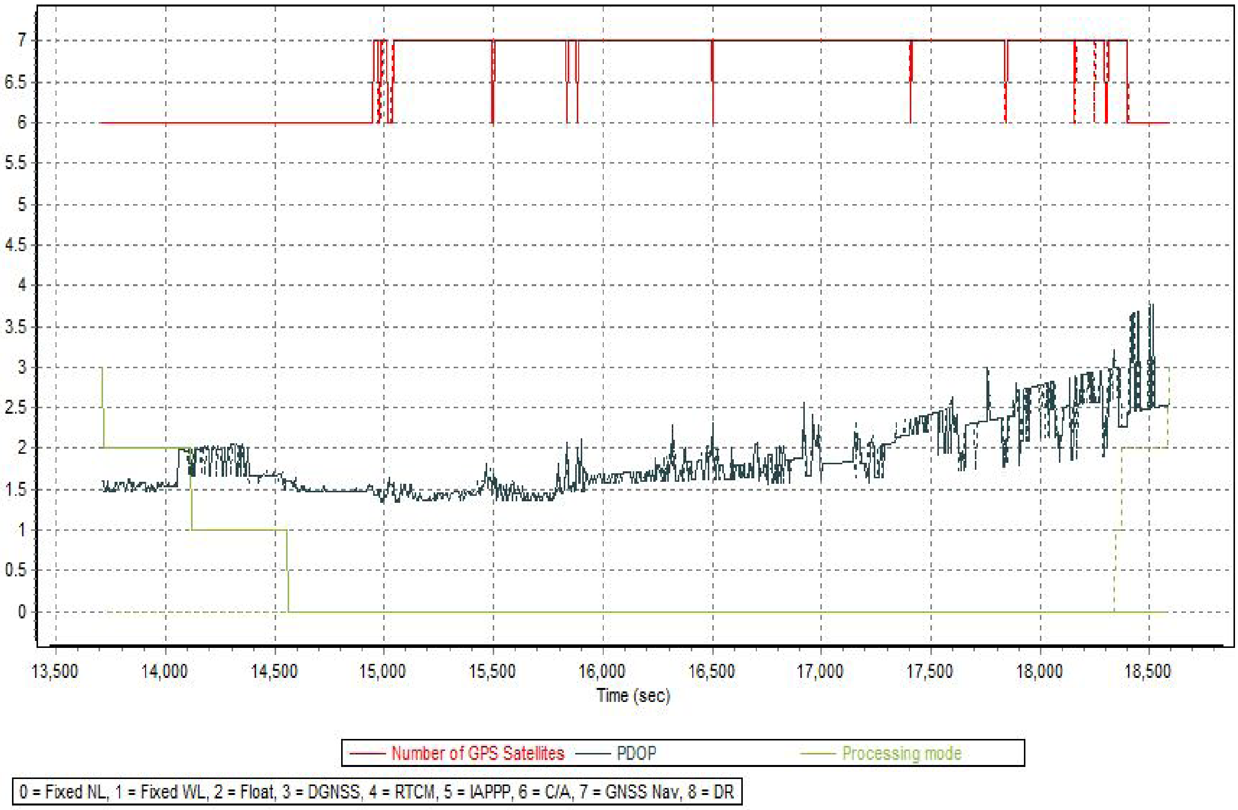


Figure A-8.1 Solution Status

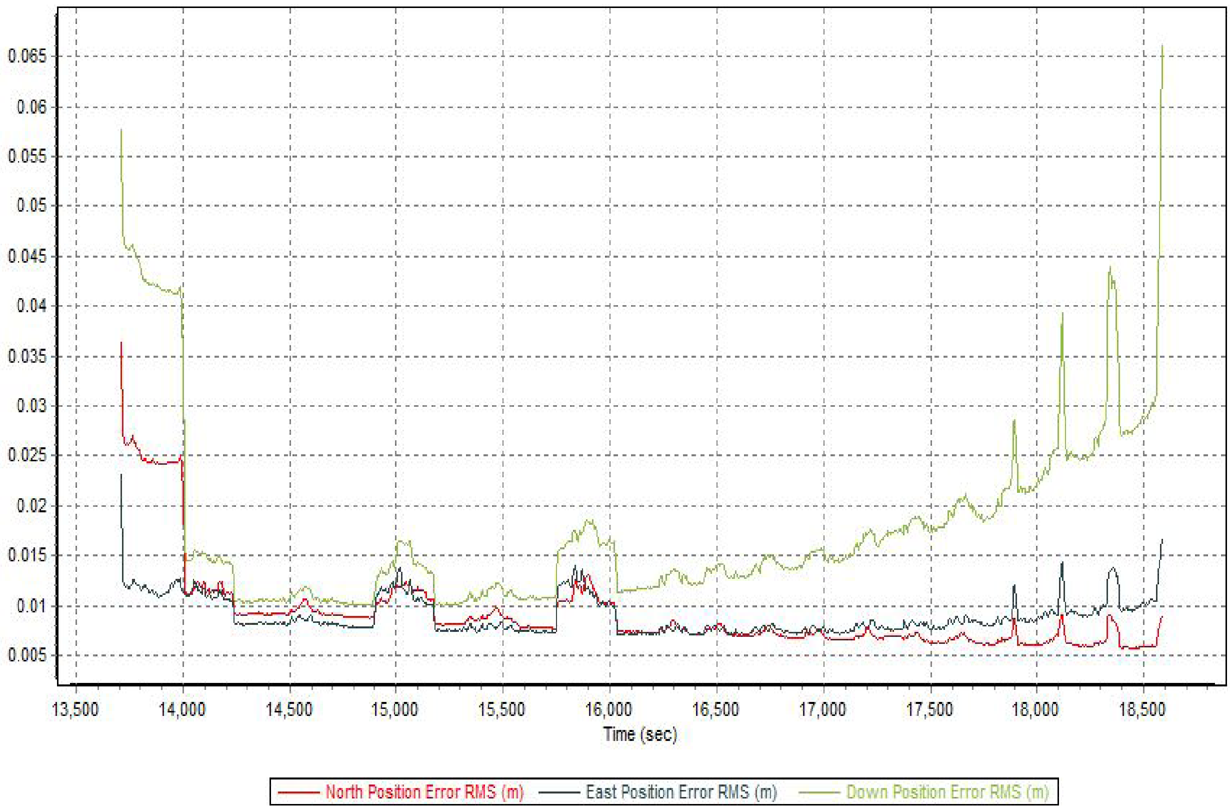


Figure A-8.2 Smoothed Performance Metrics Parameters

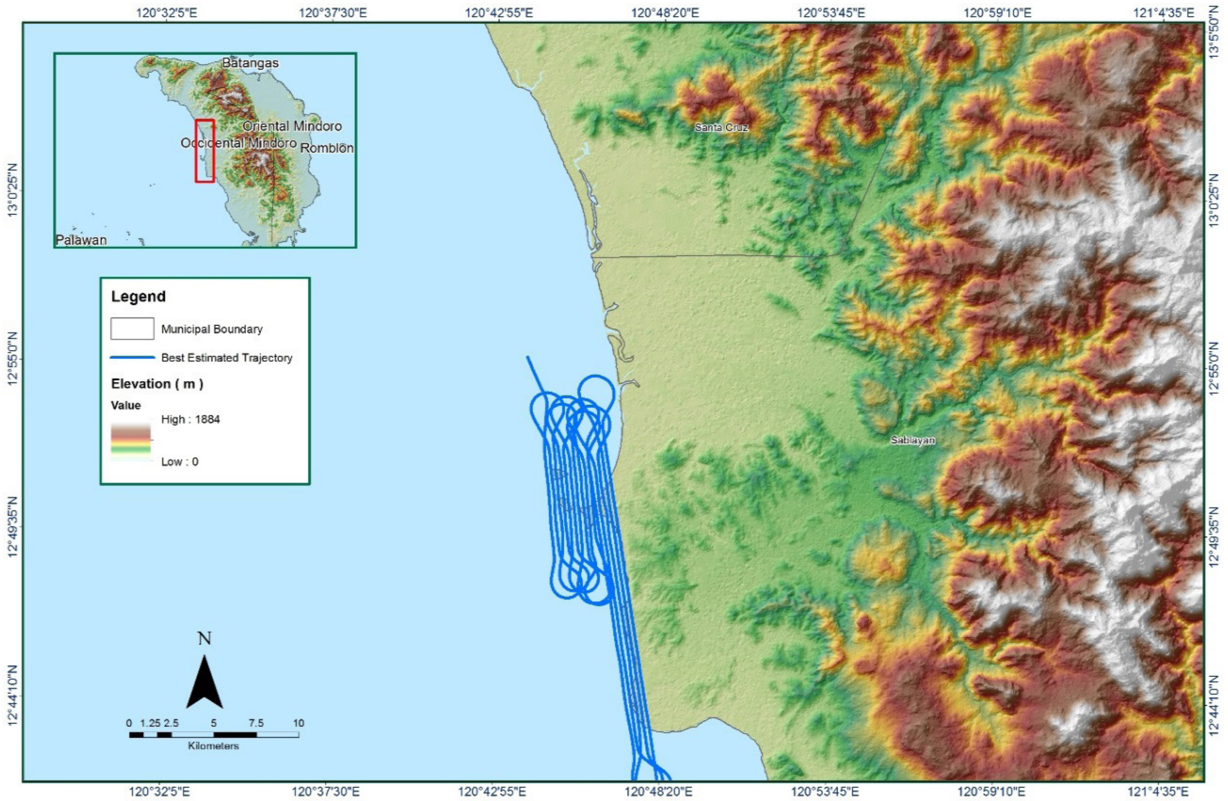


Figure A-8.3 Best Estimated Trajectory

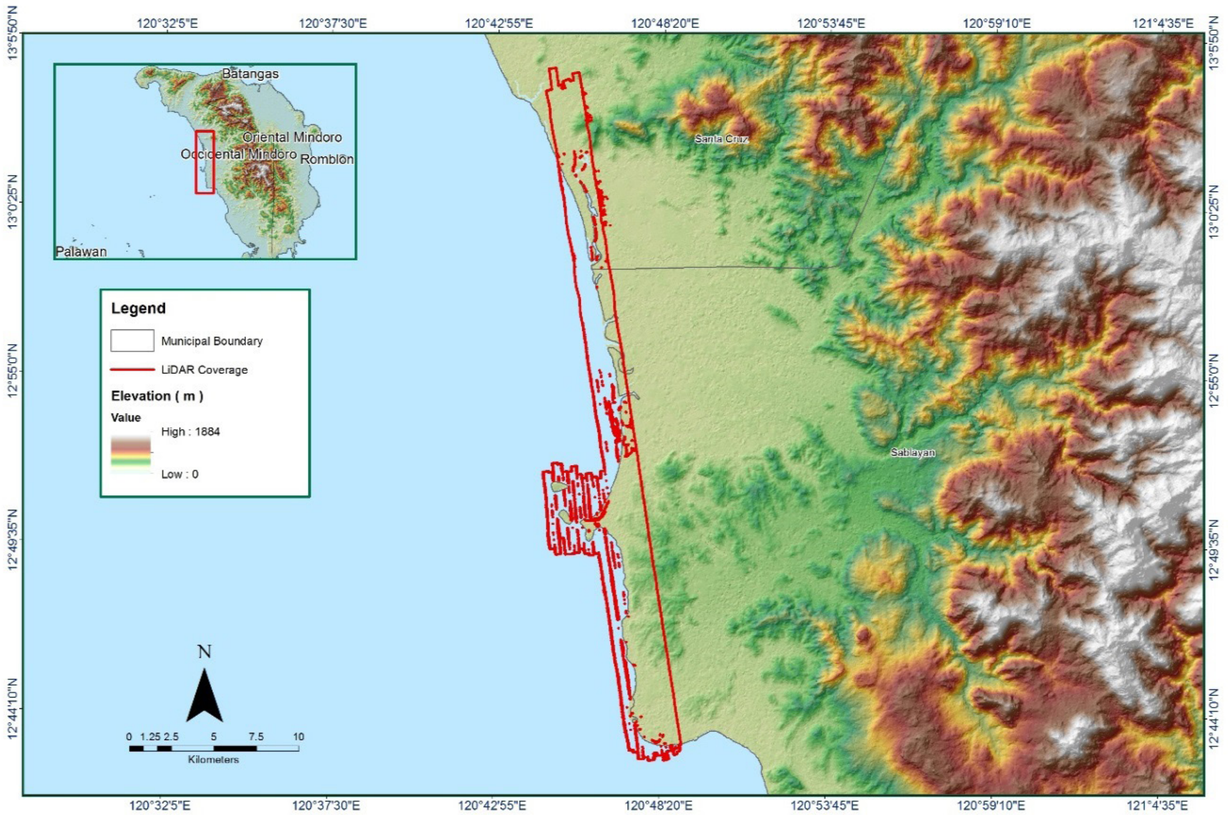


Figure A-8.4 Coverage of LiDAR data

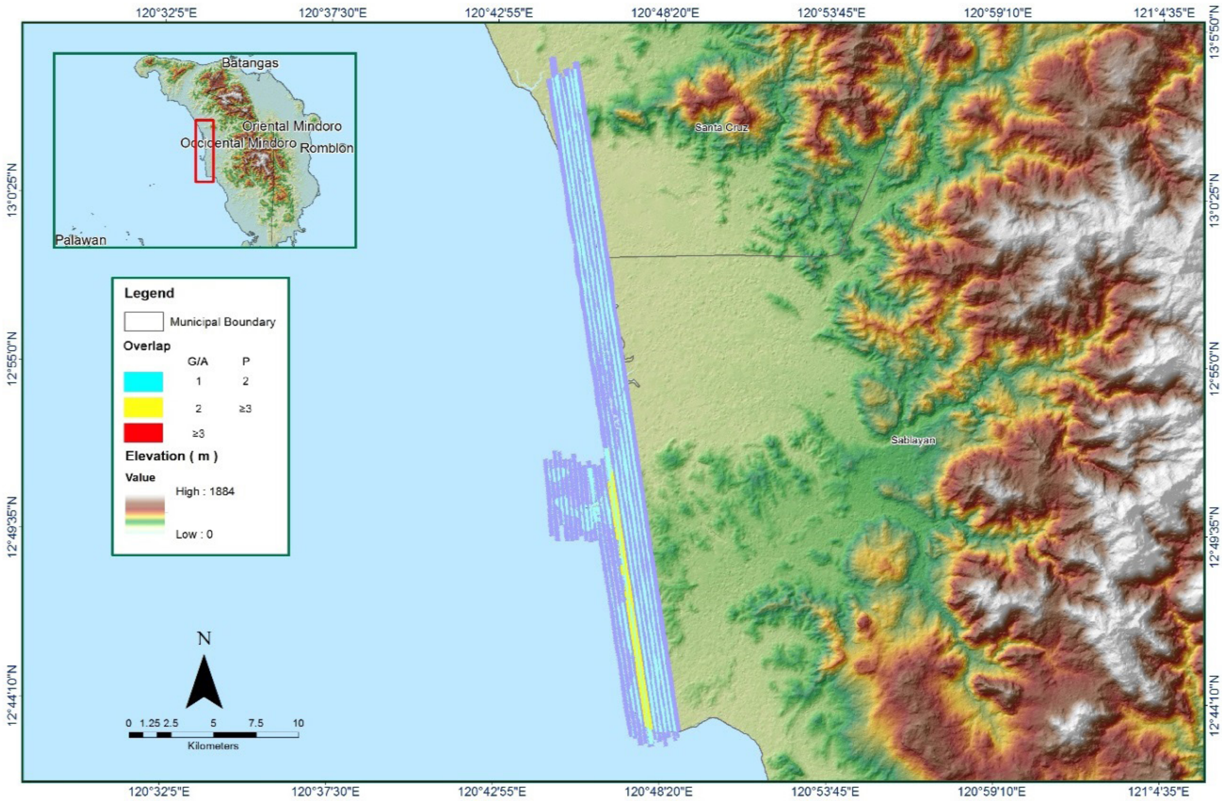


Figure A-8.5 Image of data overlap

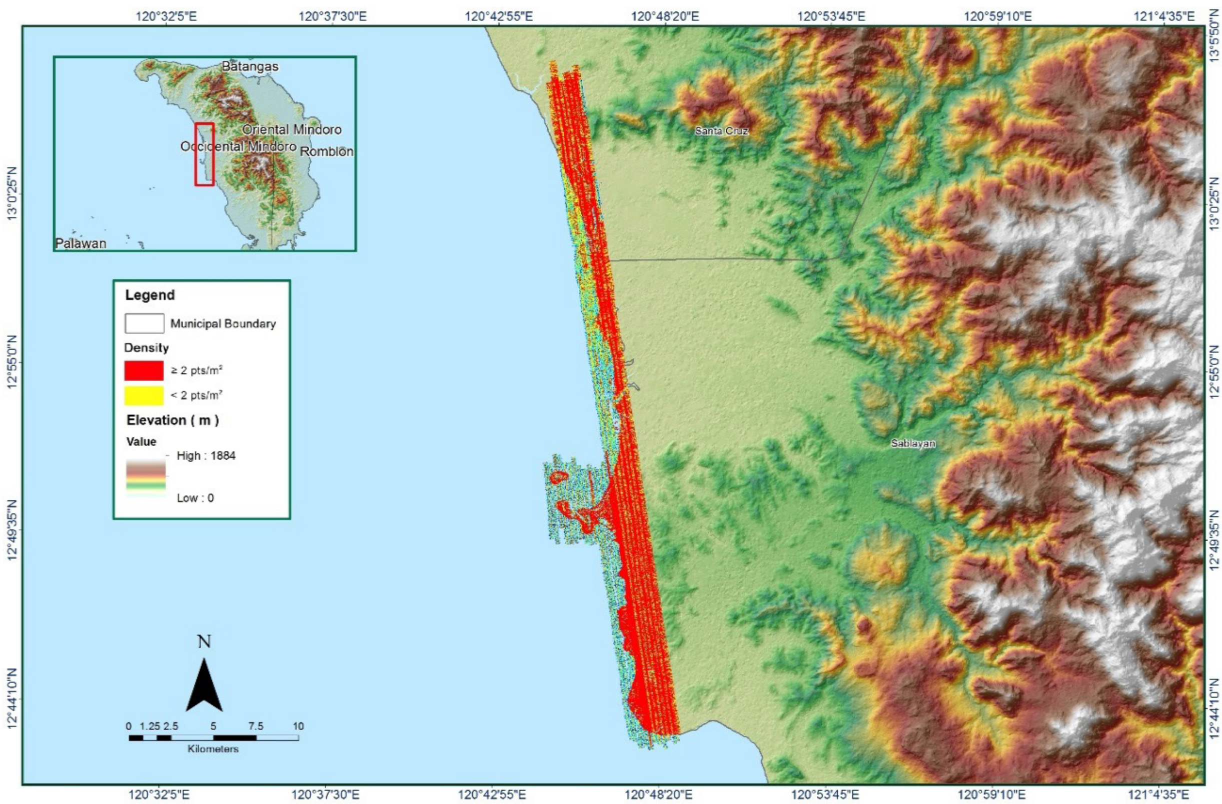


Figure A-8.6 Density map of merged LiDAR data

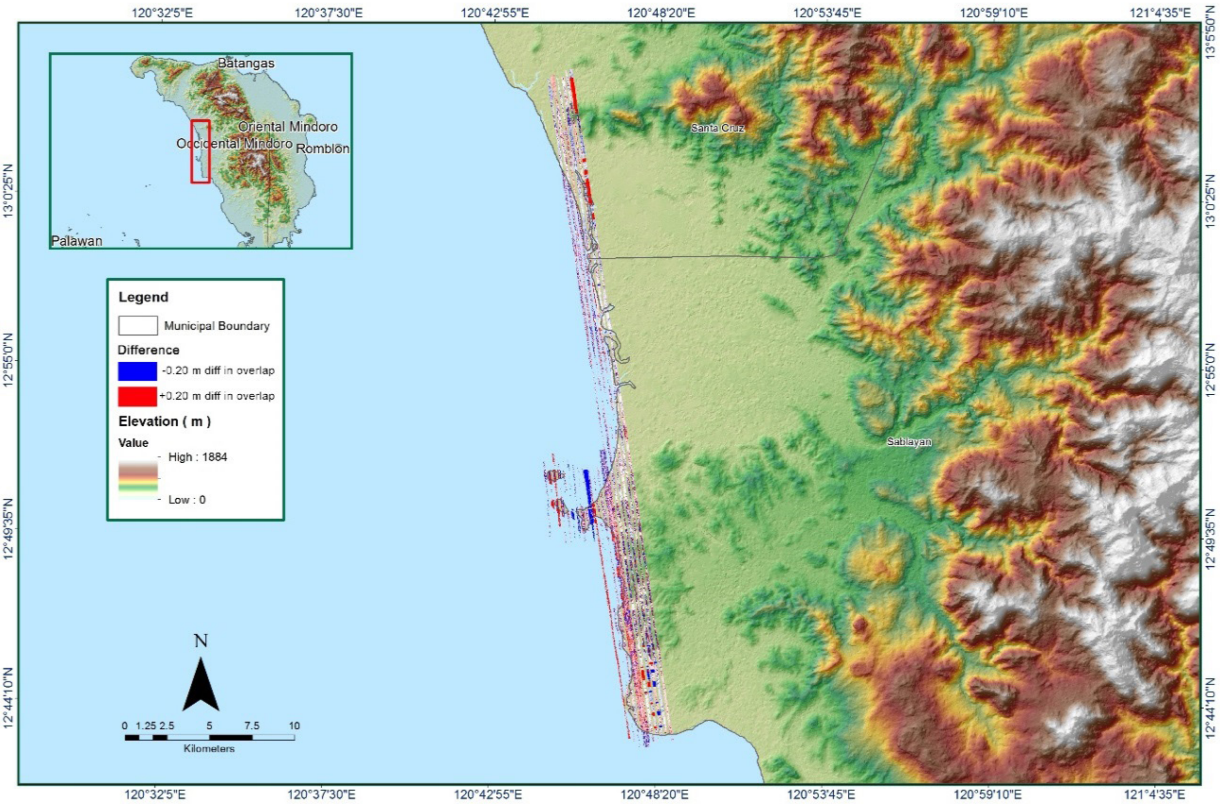


Figure A-8.7 Elevation difference between flight lines

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

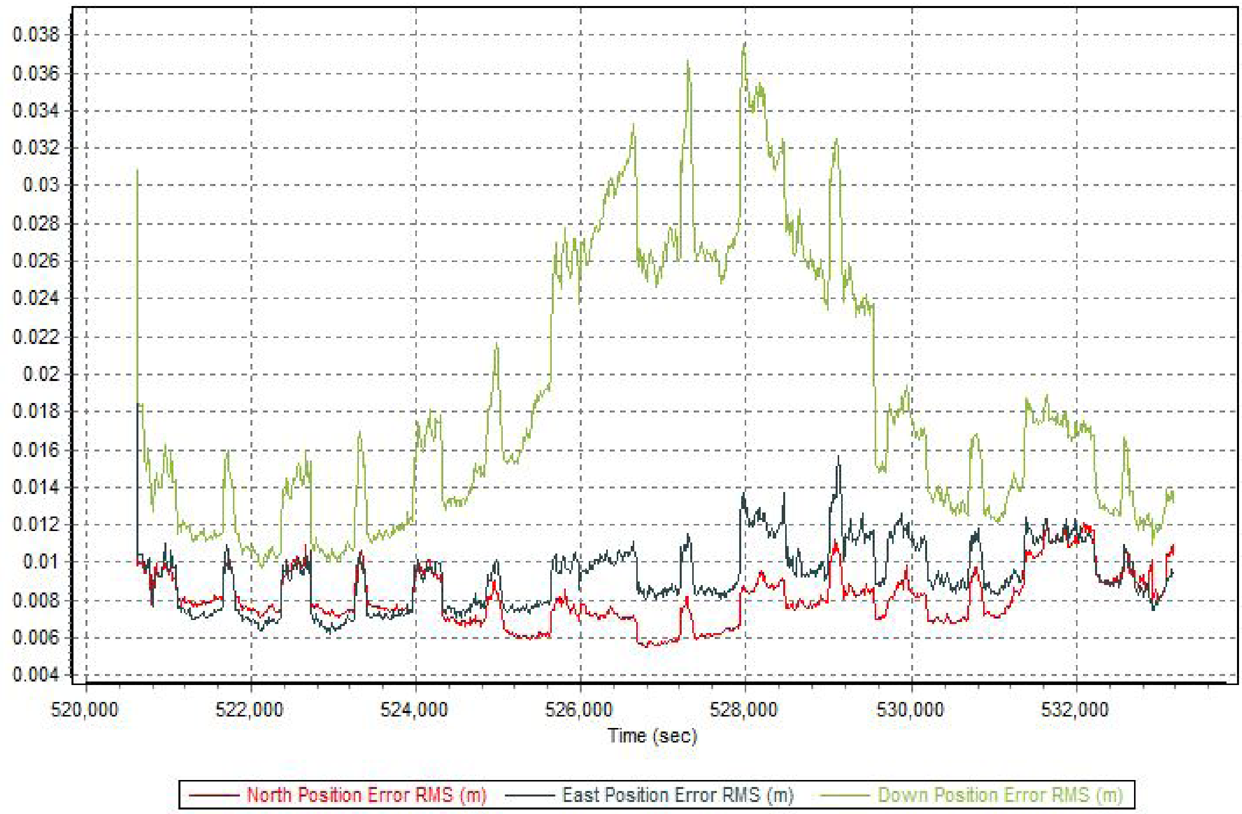


Figure A-8.9 Smoothed Performance Metrics Parameters

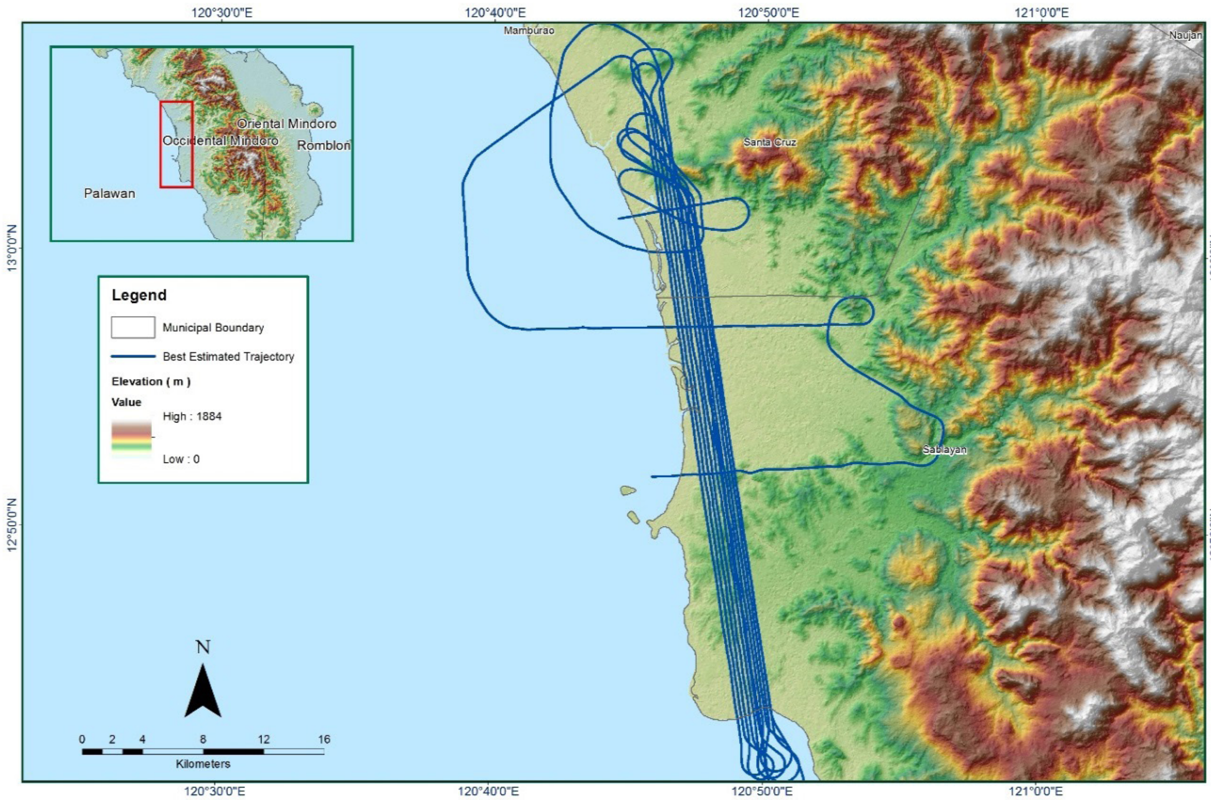


Figure A-8.10 Best Estimated Trajectory

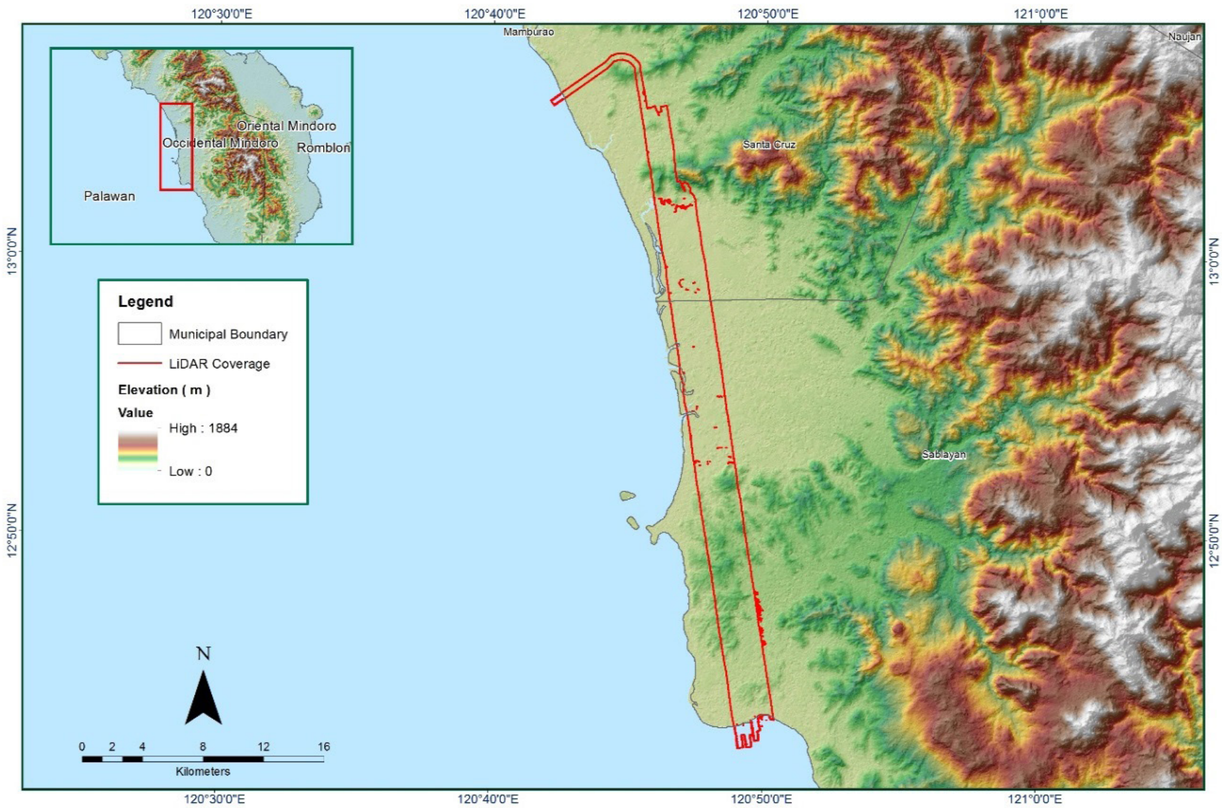


Figure A-8.11 Coverage of LiDAR data

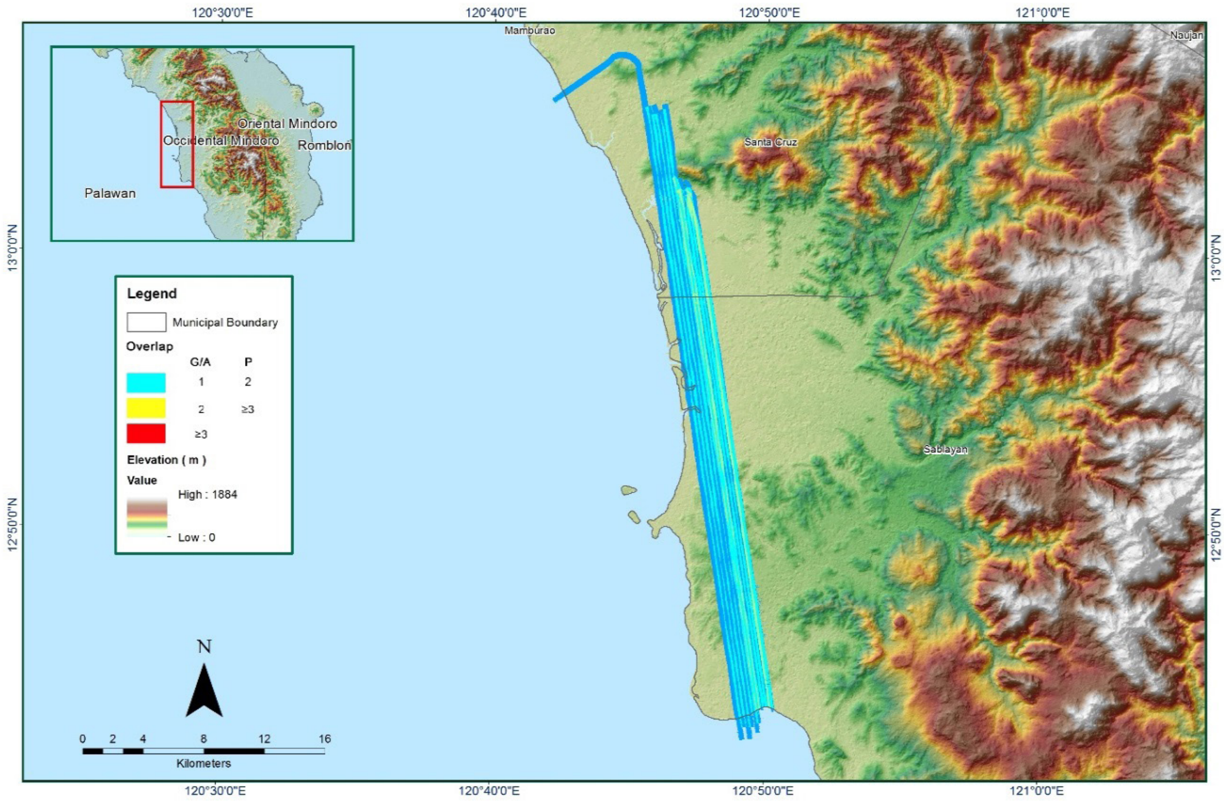


Figure A-8.12 Image of data overlap

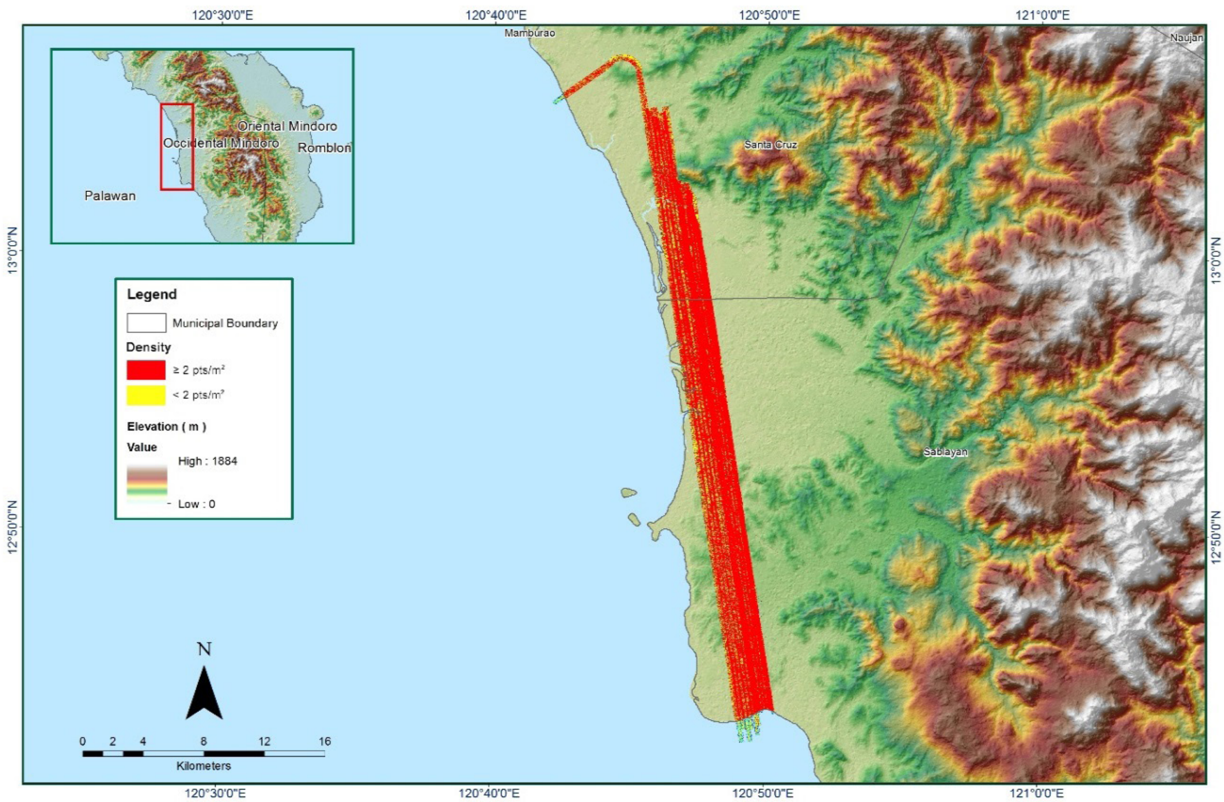


Figure A-8.13 Density map of merged LiDAR data

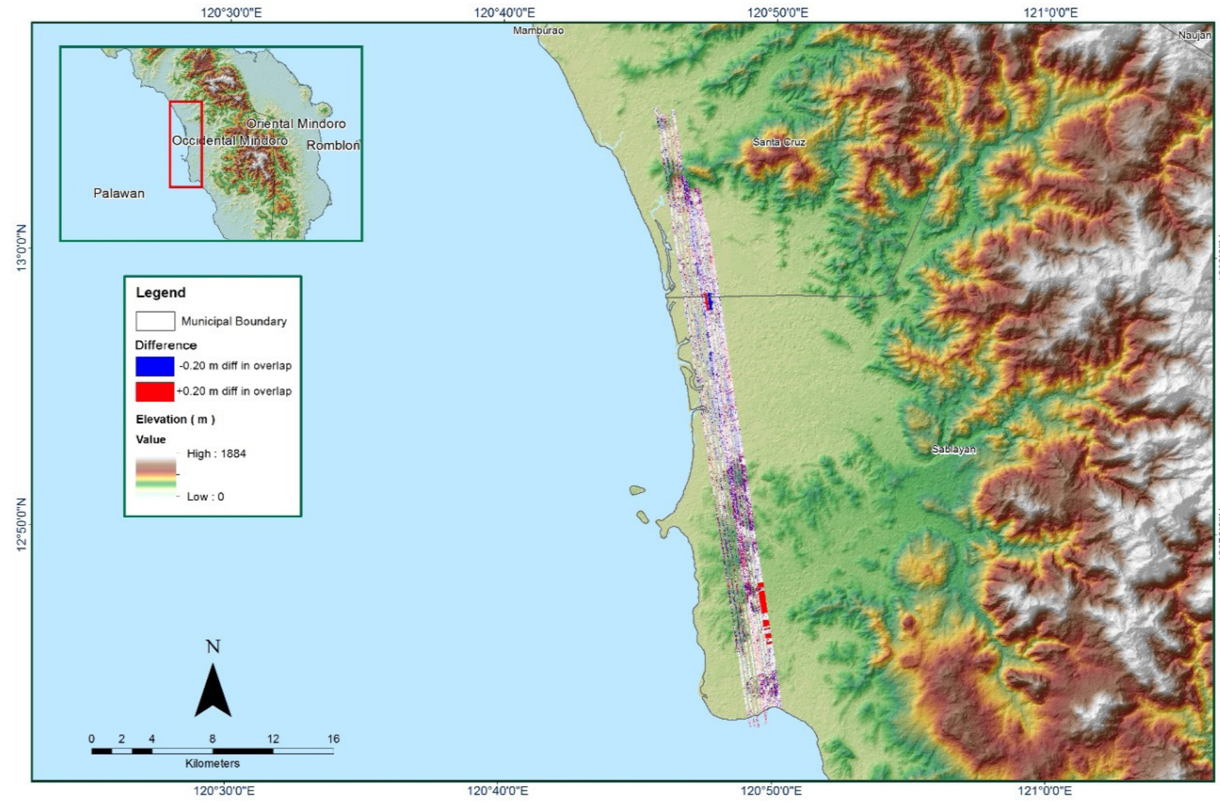


Figure A-8.14 Elevation difference between flight lines

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, Engr. Jeffrey Delica

Figure A-8.15 Solution Status

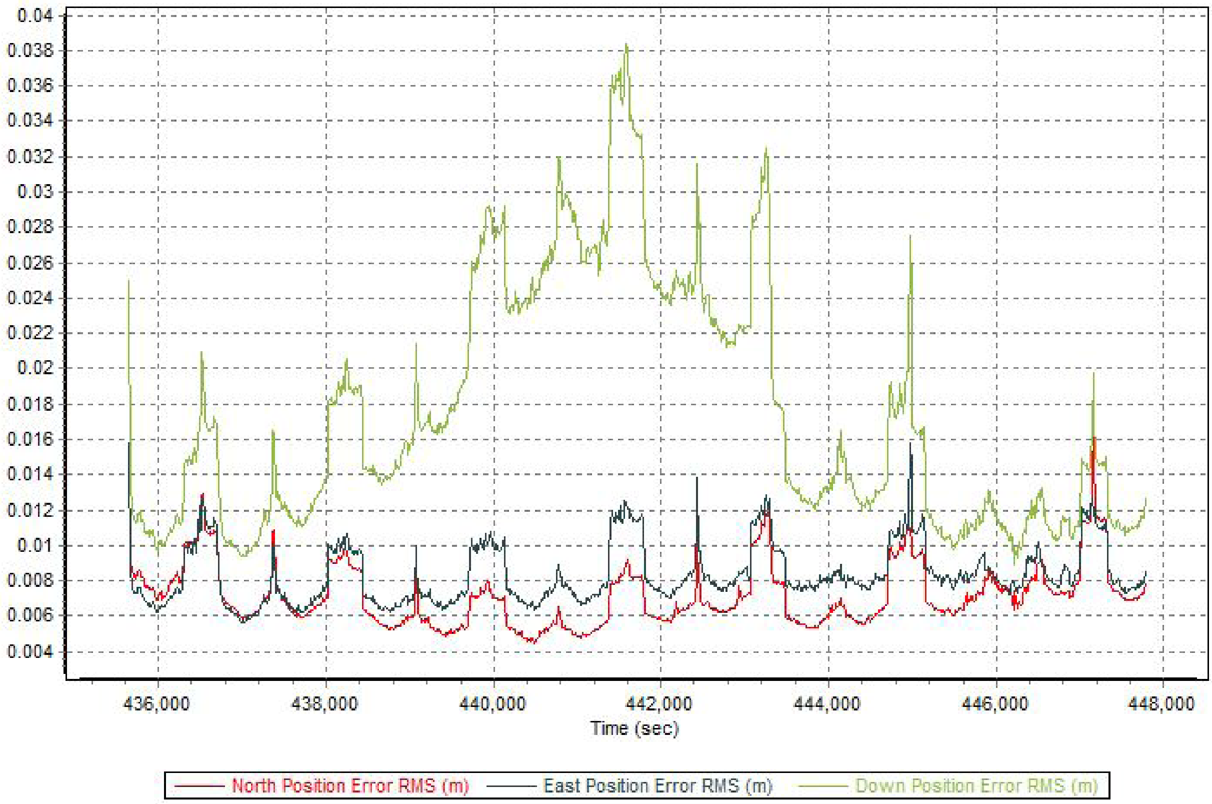


Figure A-8.16 Smoothed Performance Metrics Parameters

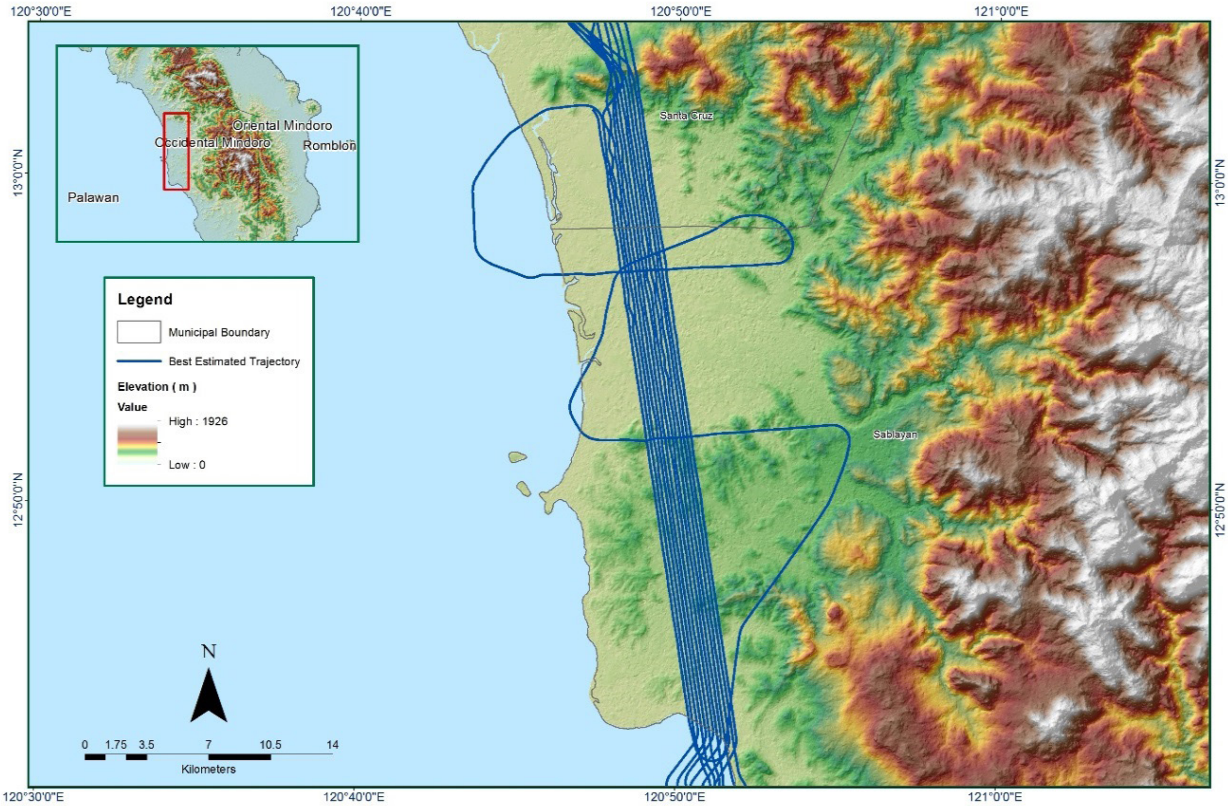


Figure A-8.17 Best Estimated Trajectory

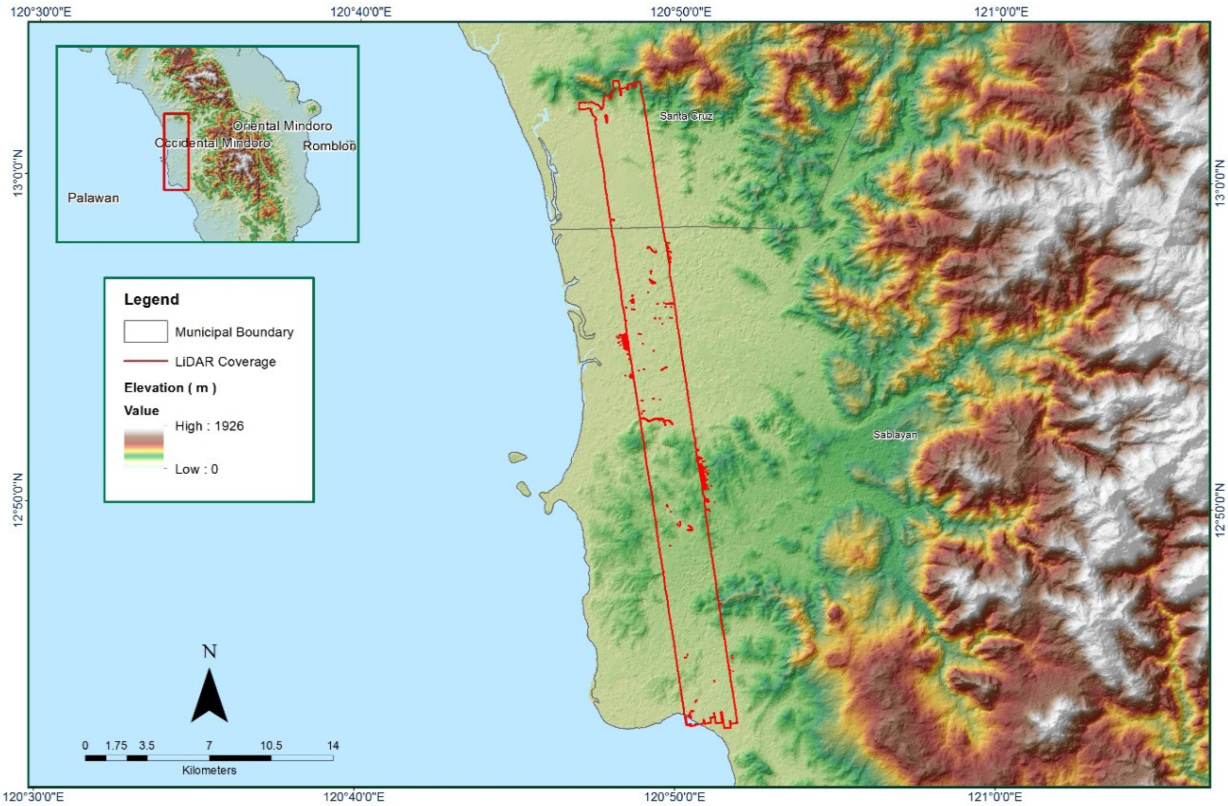


Figure A-8.18 Coverage of LiDAR data

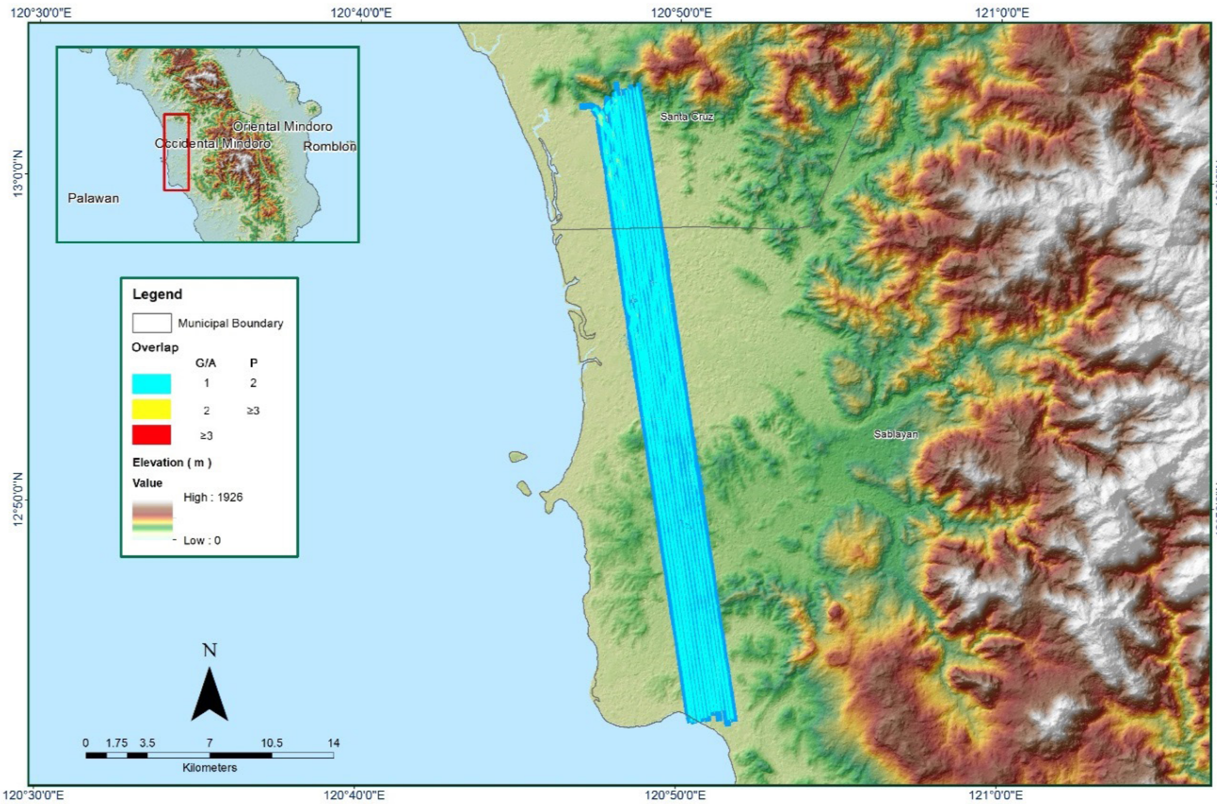


Figure A-8.19 Image of data overlap

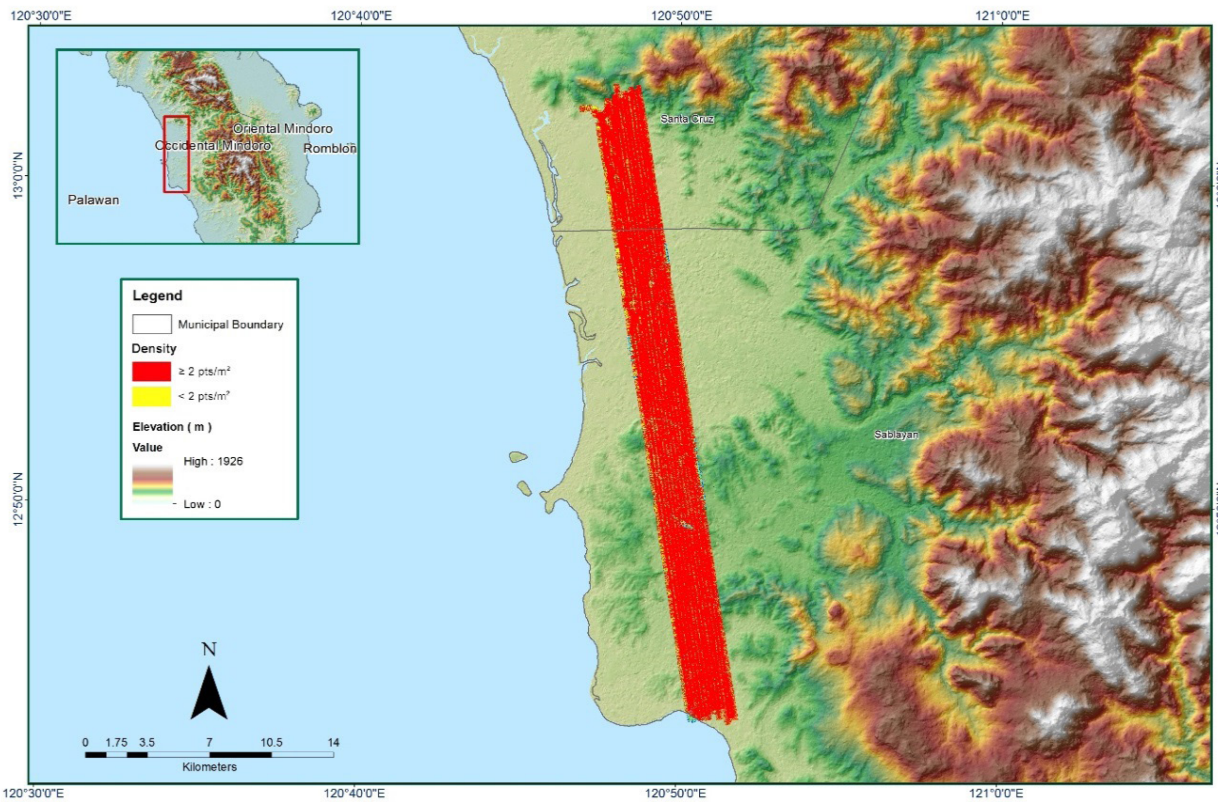


Figure A-8.20 Density map of merged LiDAR data

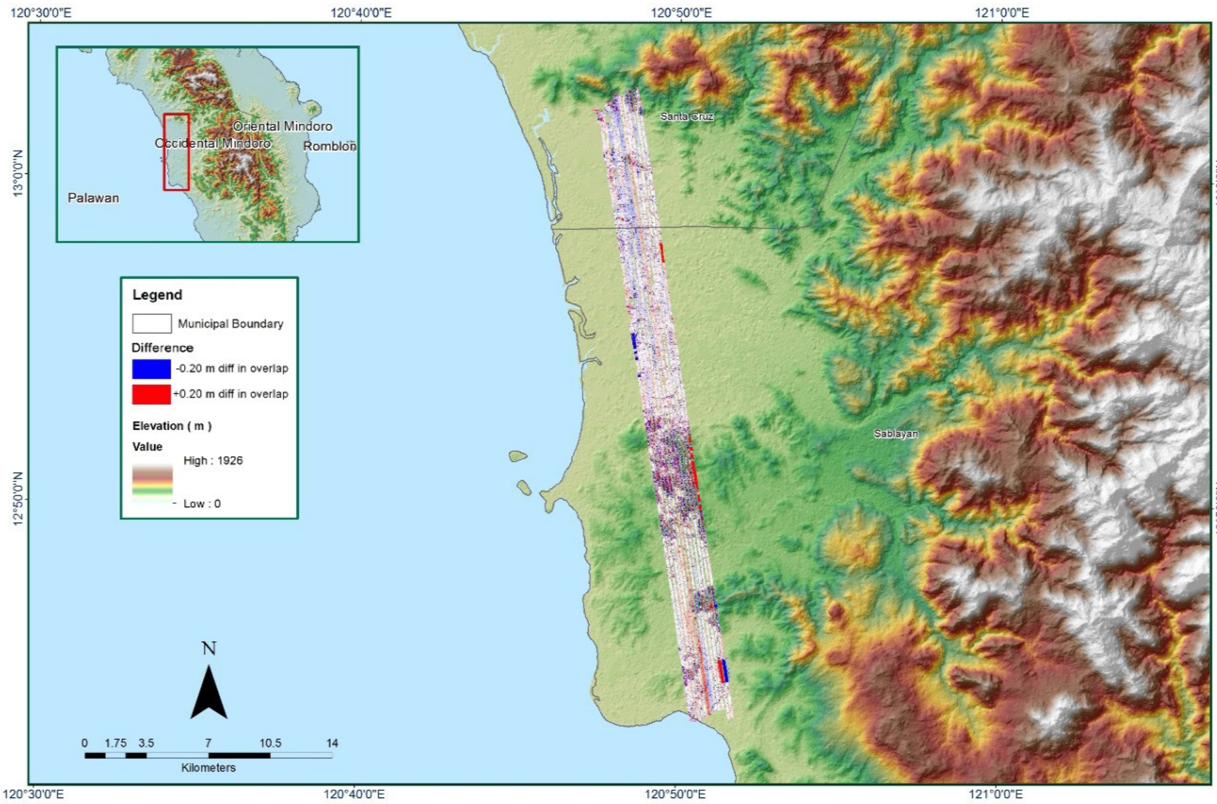


Figure A-8.21 Elevation difference between flight lines

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. Angelo Carlo Bongat, Engr. Carlyn Ann Ibanez, Engr. Christy Lubiano, Engr. Jeffrey Delica

Figure A-8.22 Solution Status

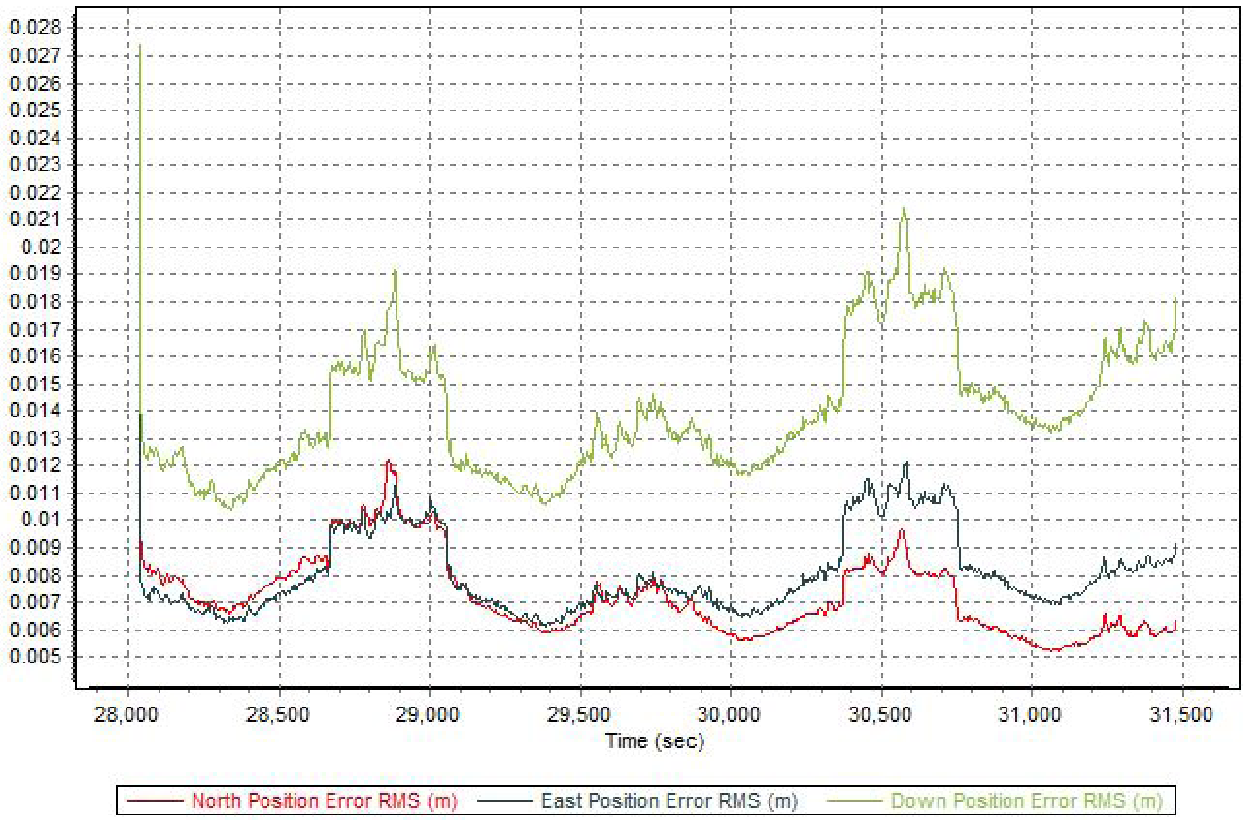


Figure A-8.23 Smoothed Performance Metrics Parameters

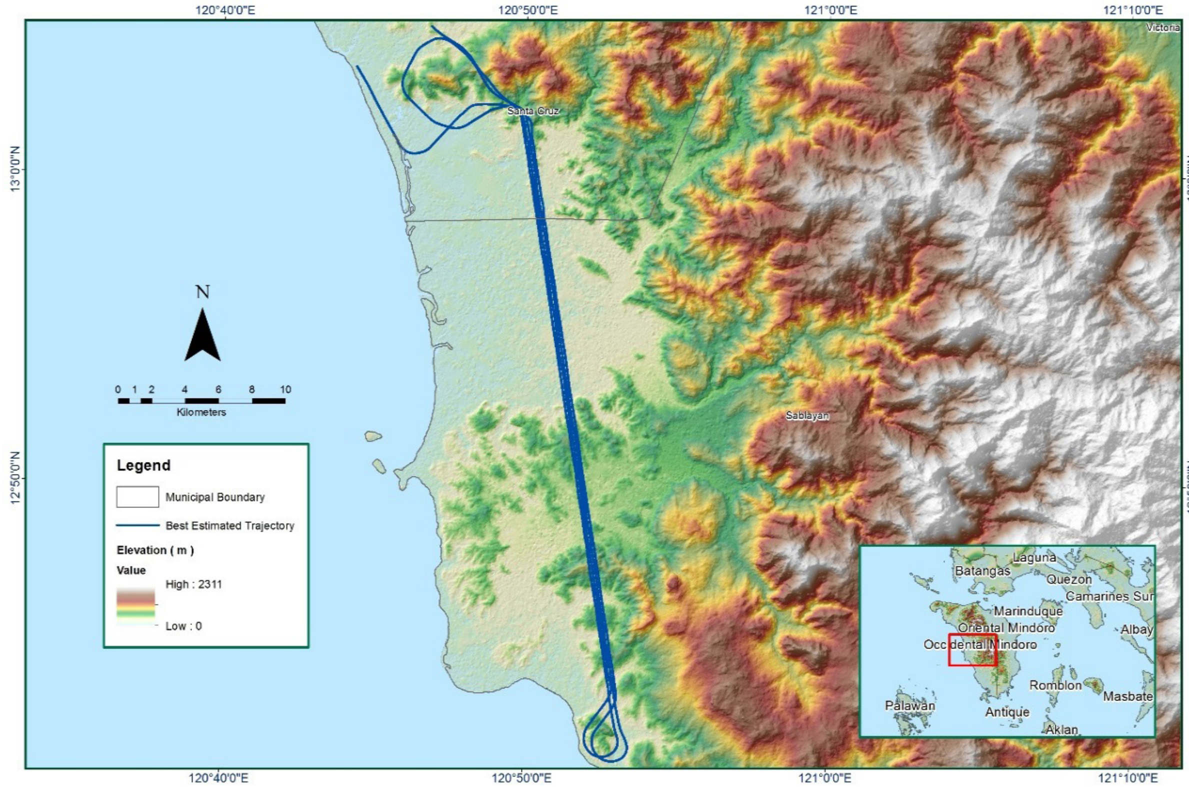


Figure A-8.24 Best Estimated Trajectory

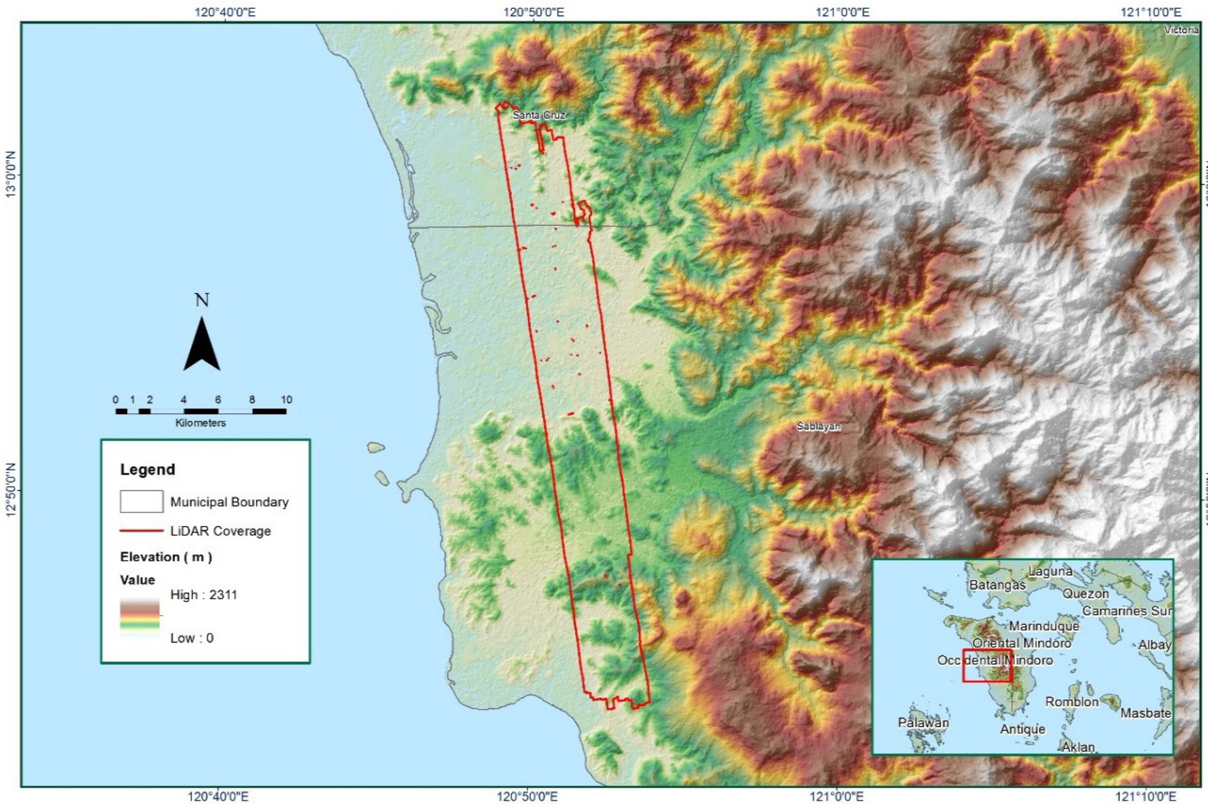


Figure A-8.25 Coverage of LiDAR data

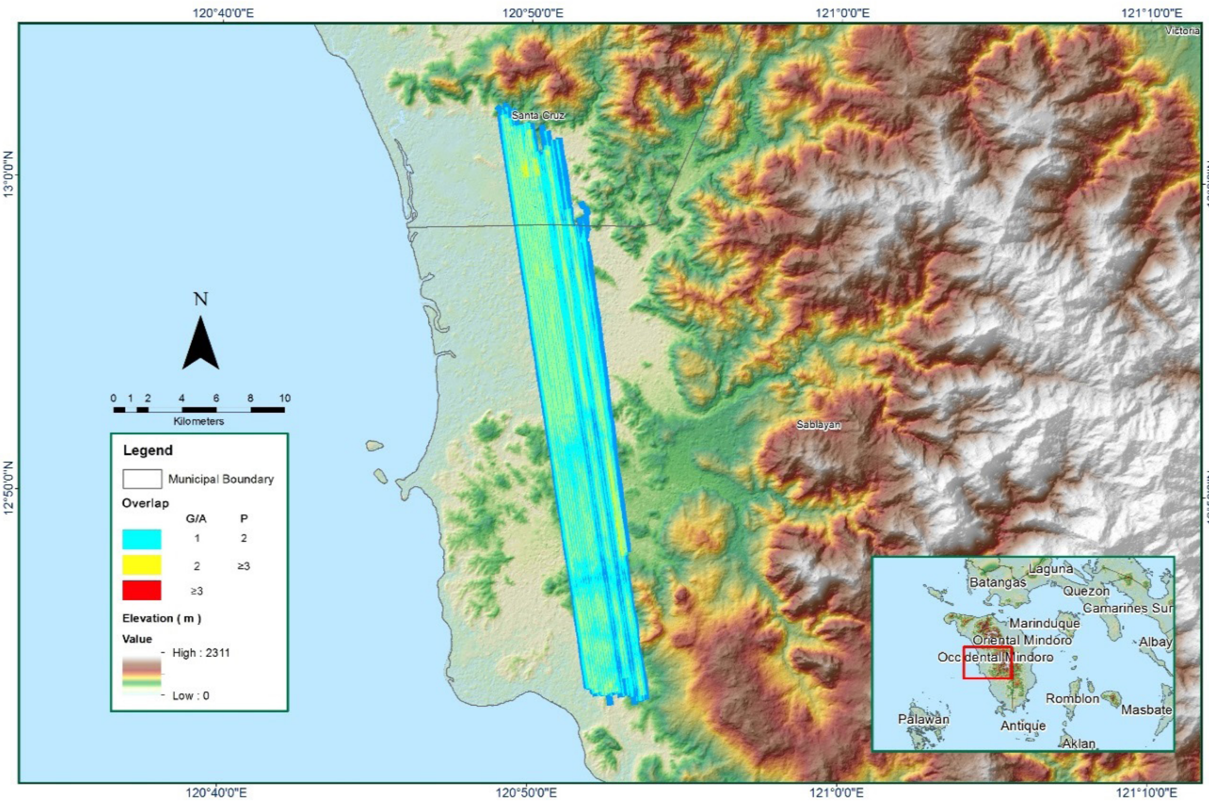


Figure A-8.26 Image of data overlap

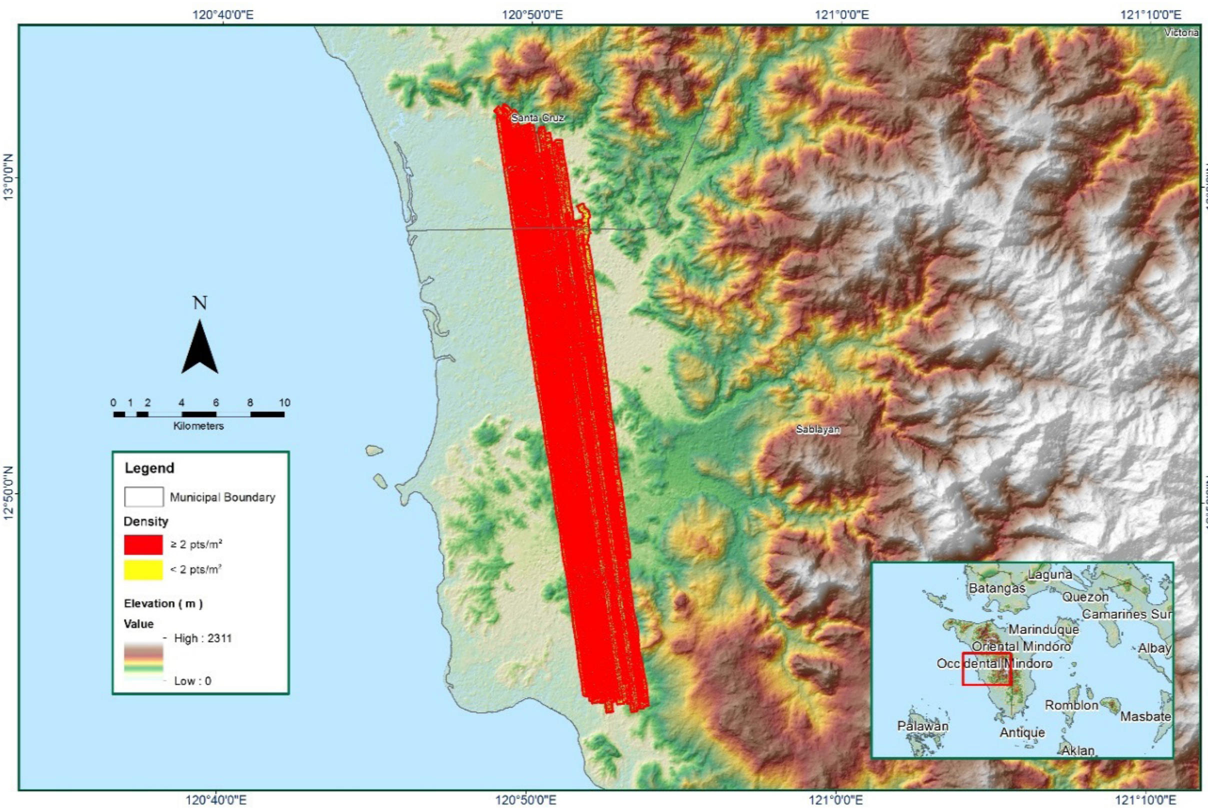


Figure A-8.27 Density map of merged LiDAR data

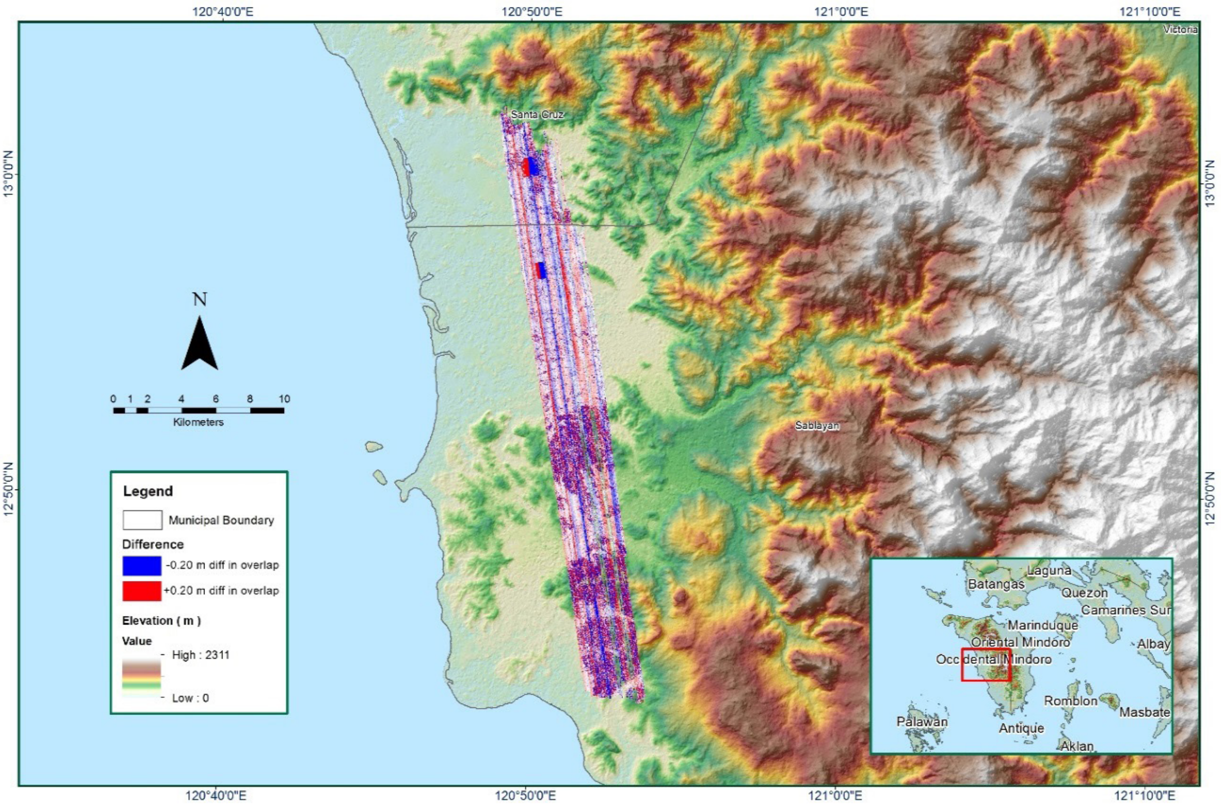


Figure A-8.28 Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission **Blk29K_supplement**

Flight Area	**Occidental Mindoro**
Mission Name	**Blk29K_supplement**
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. Melanie Hingpit, Engr. Mary Celine Vasquez

Figure A-8.29 Solution Status

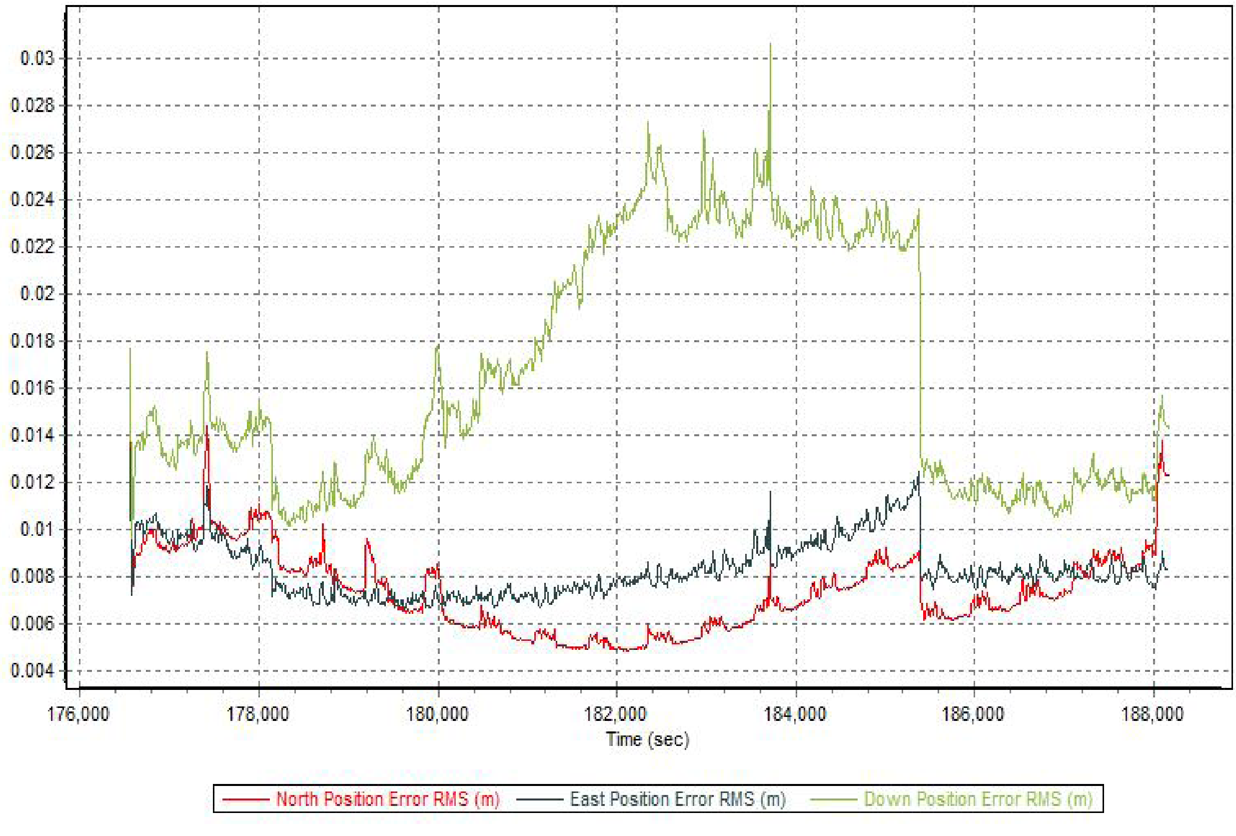


Figure A-8.30 Smoothed Performance Metrics Parameters

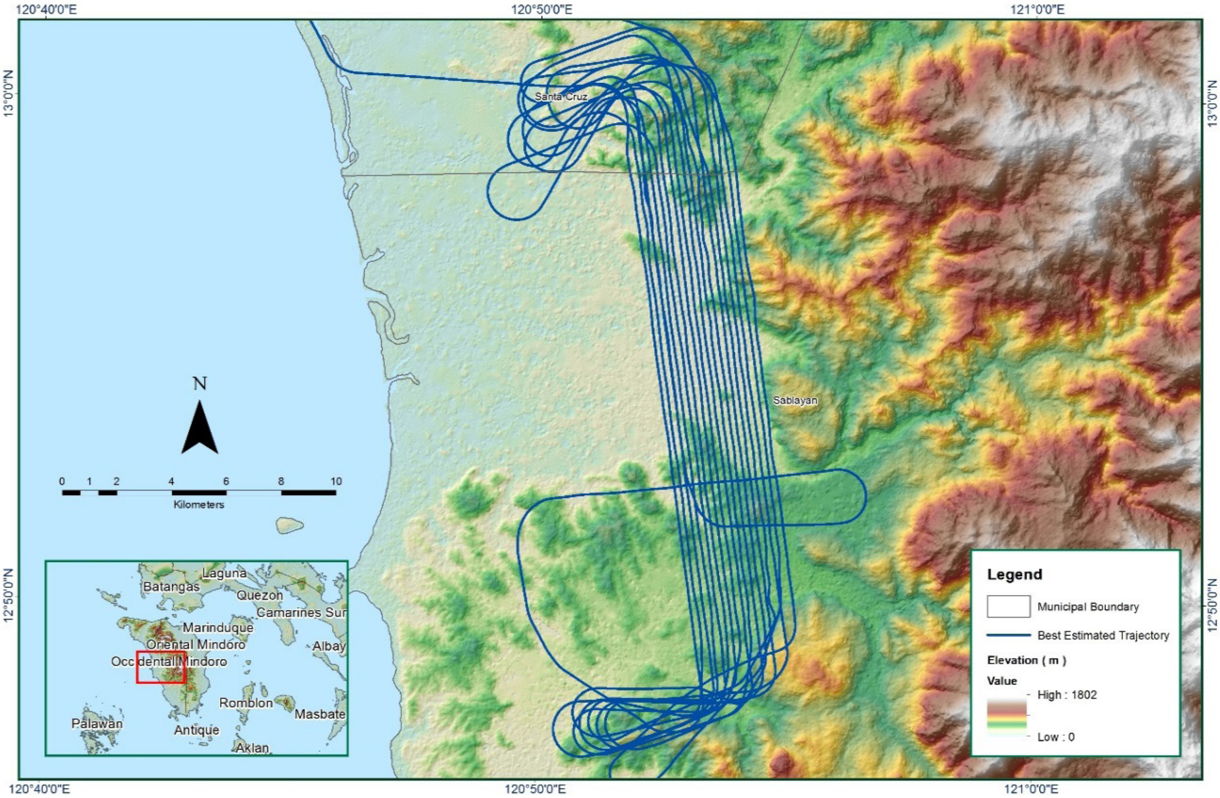


Figure A-8.31 Best Estimated Trajectory

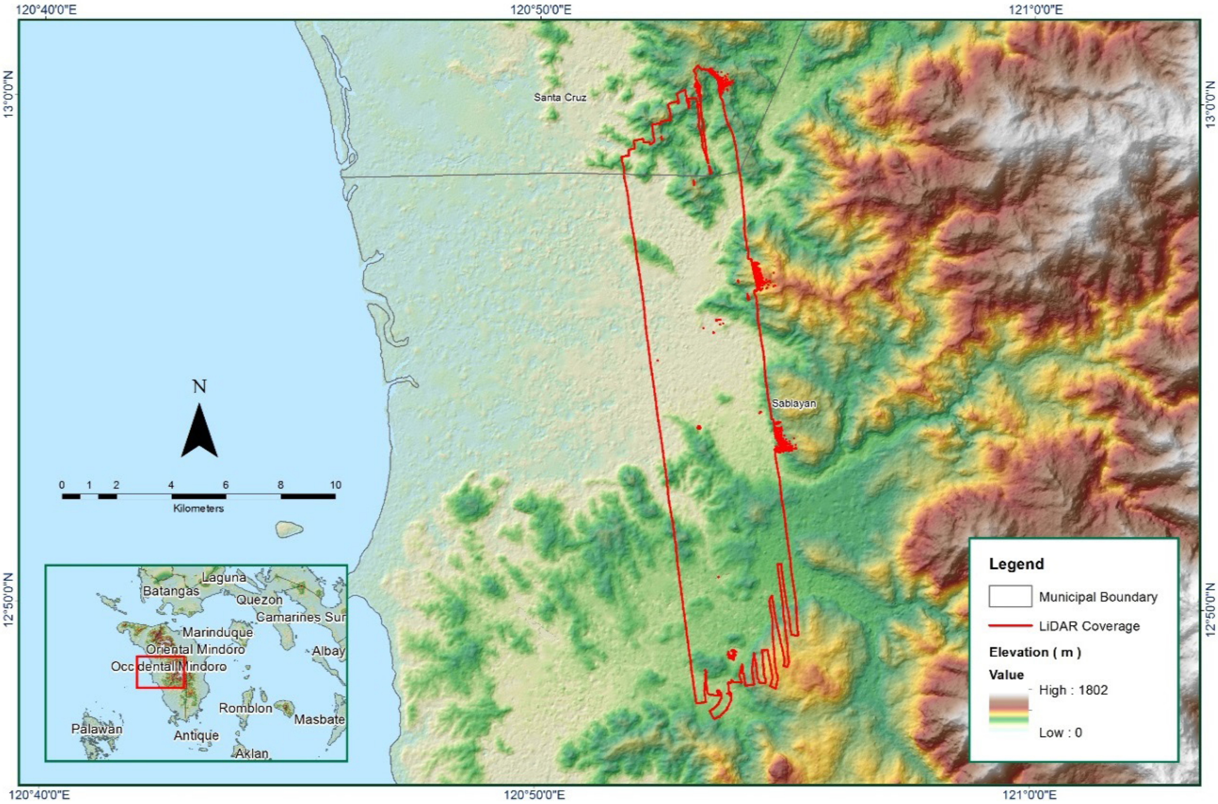


Figure A-8.32 Coverage of LiDAR data

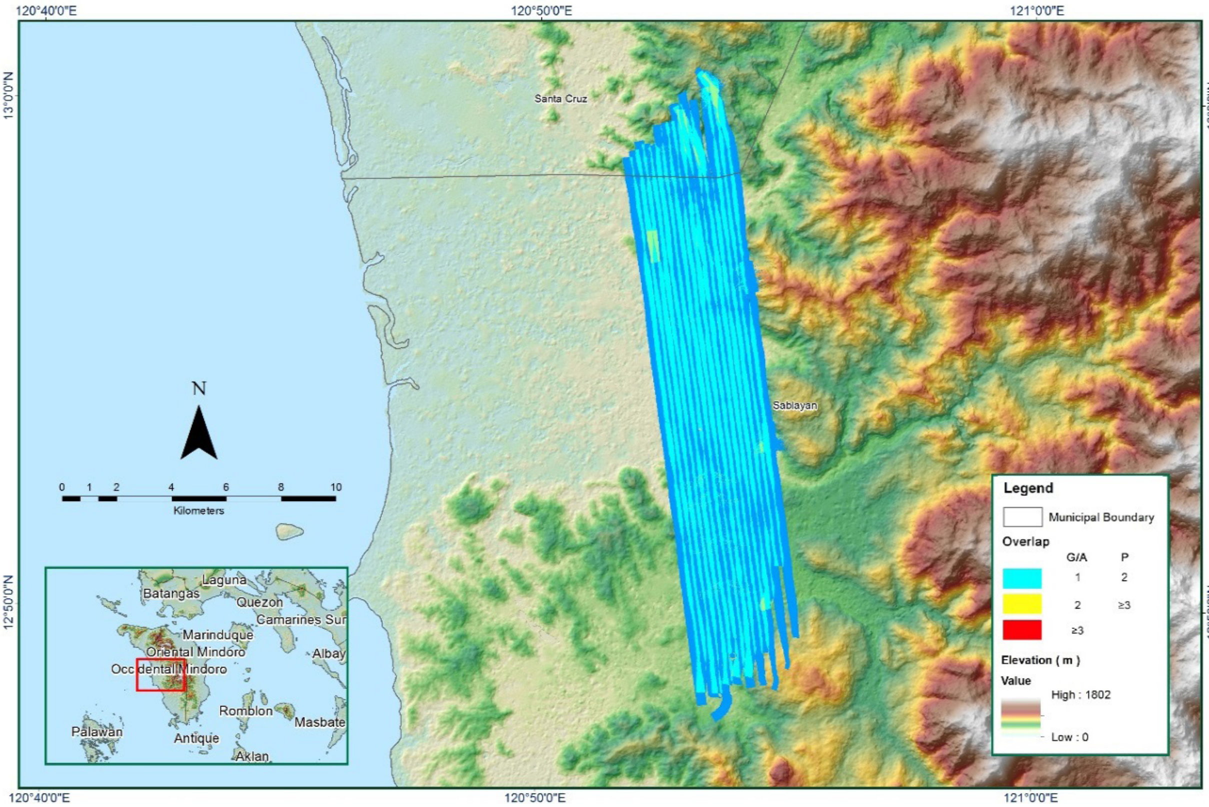


Figure A-8.33 Image of data overlap

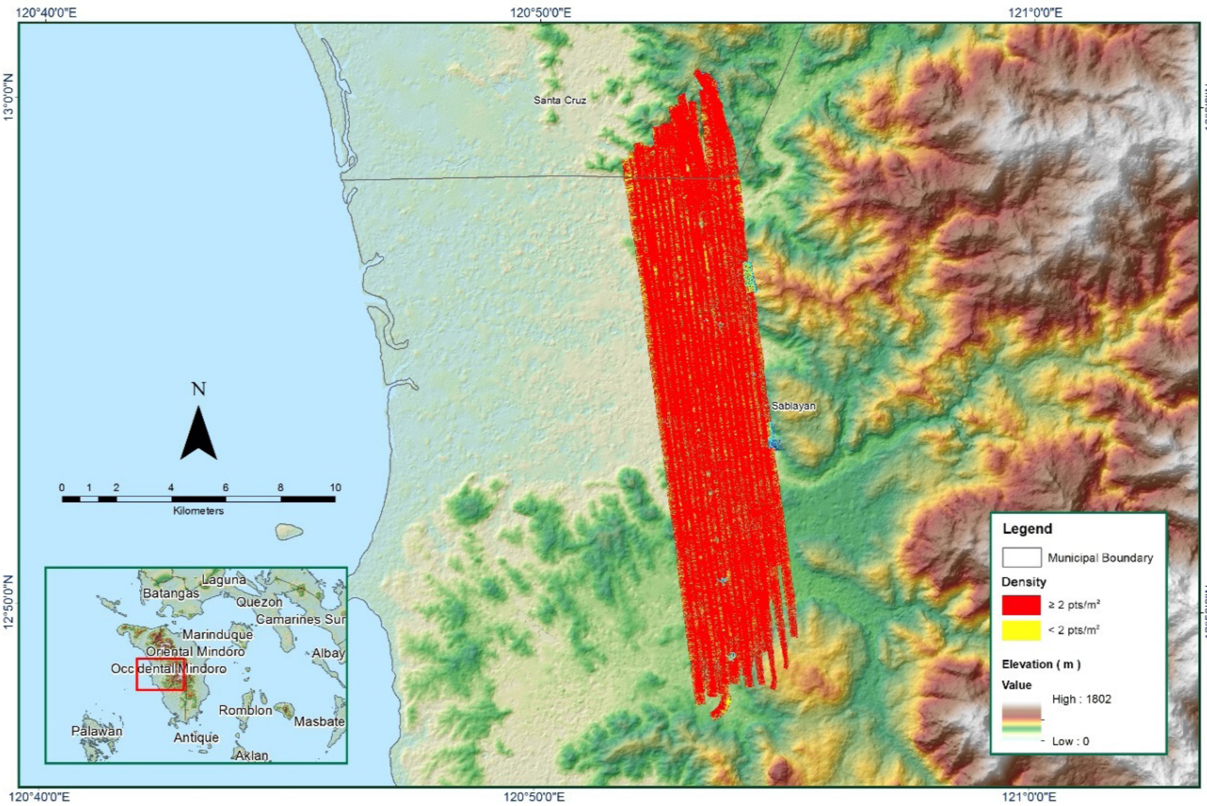


Figure A-8.34 Density map of merged LiDAR data

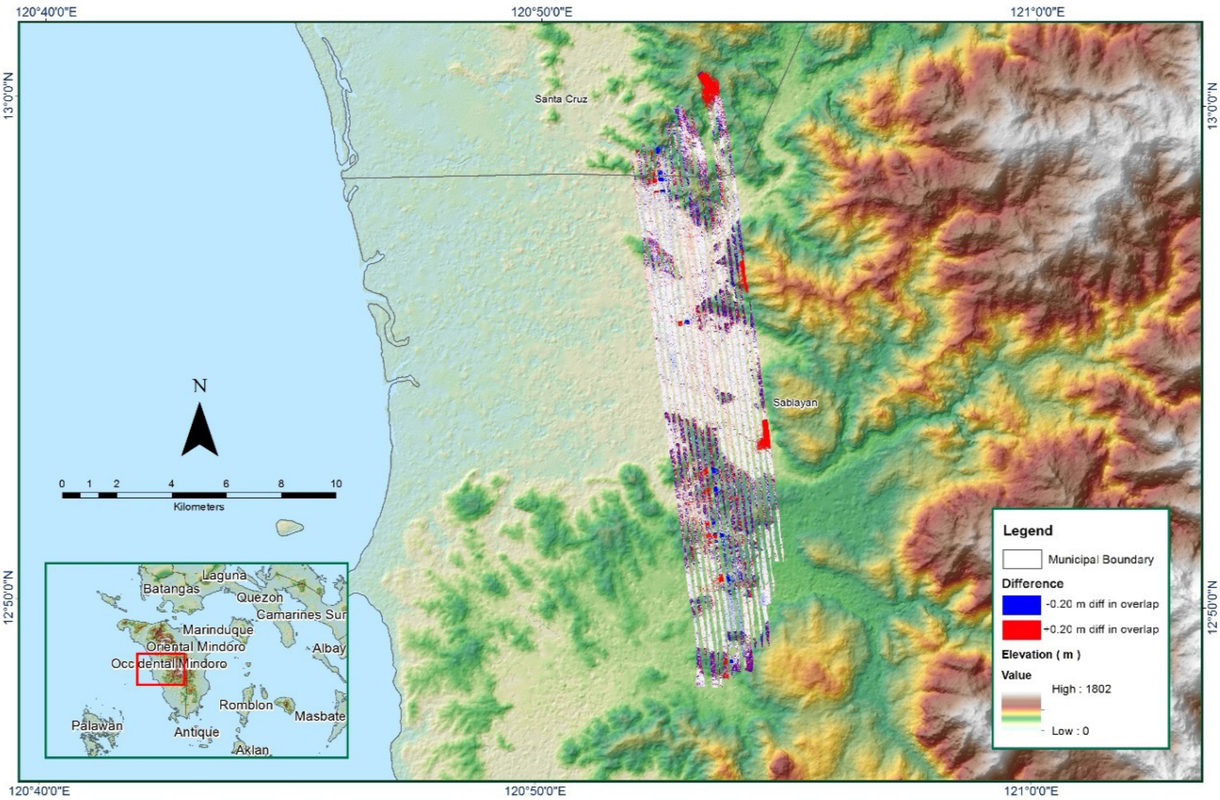


Figure A-8.35 Elevation difference between flight lines

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	257MB
Image	18.93MB
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

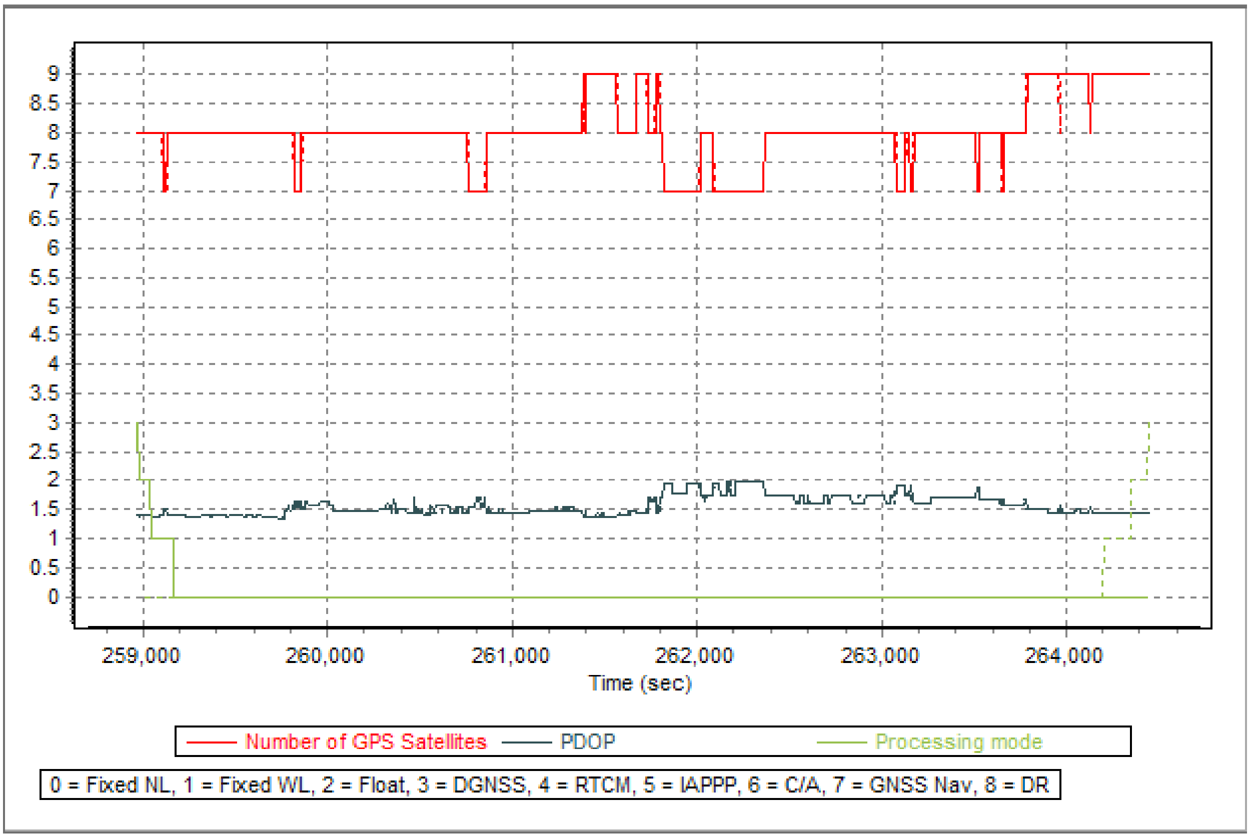


Figure A-8.36 Solution Status

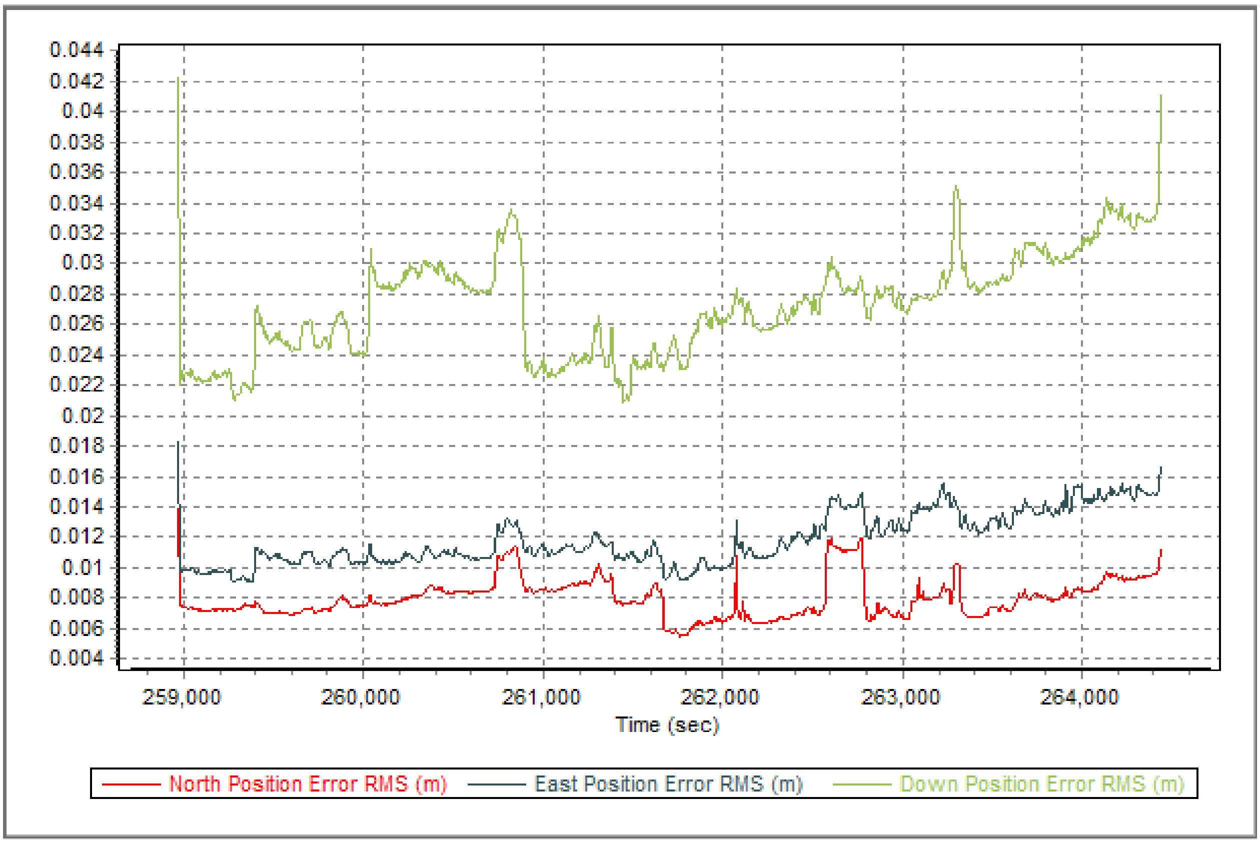


Figure A-8.37 Smoothed Performance Metric Parameters

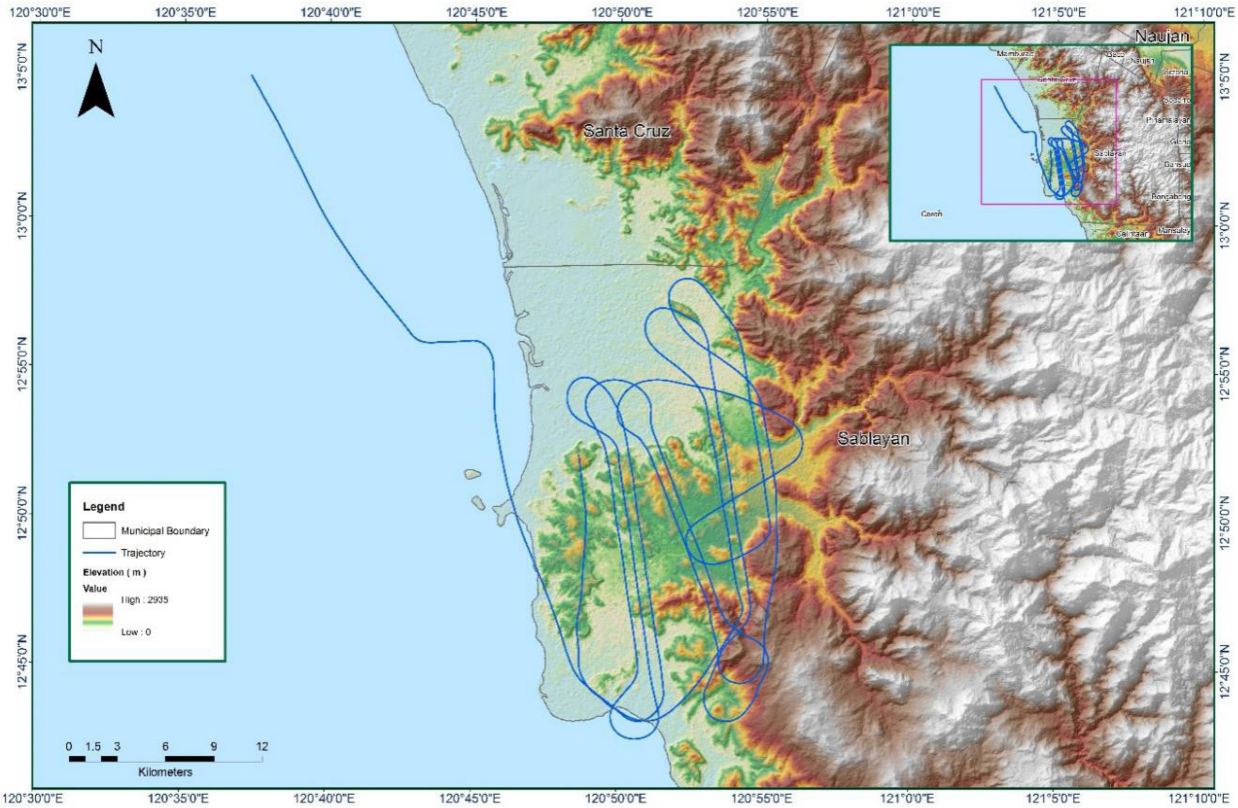


Figure A-8.38 ***Best Estimated Trajectory***

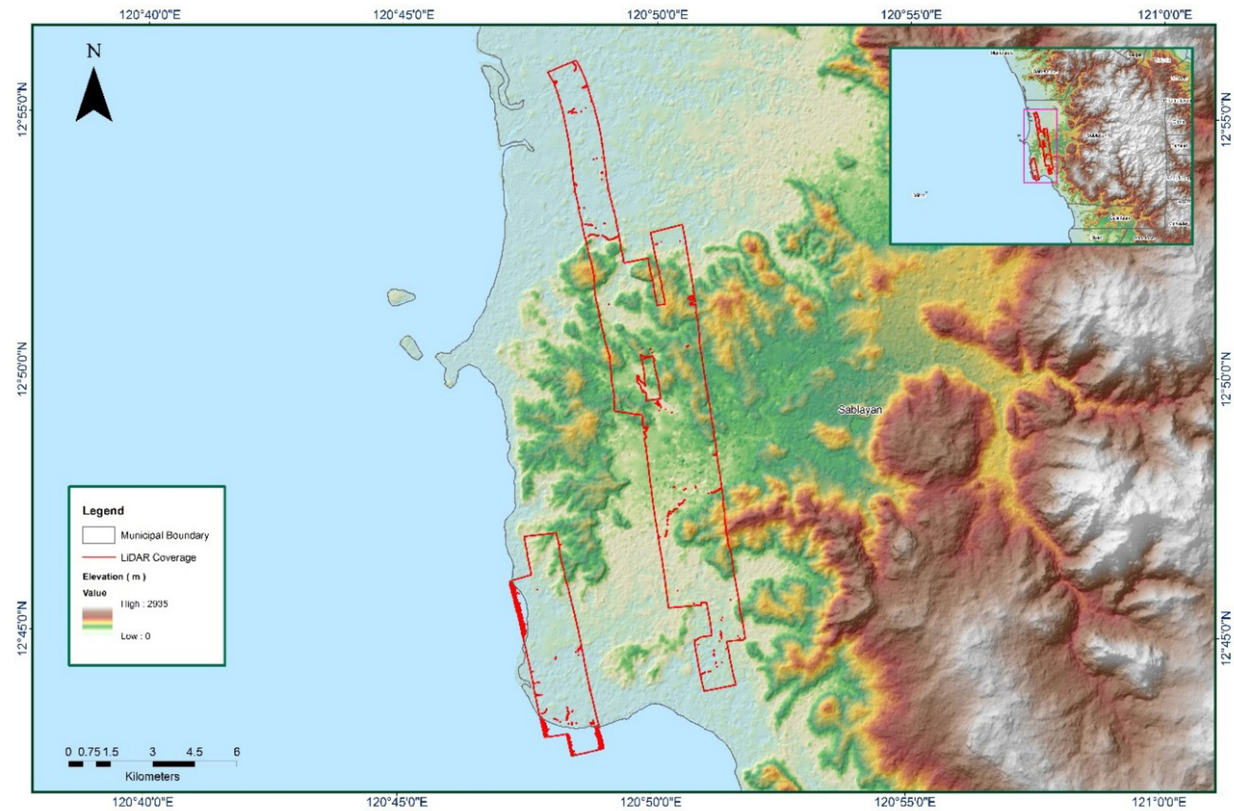


Figure A-8.39 Coverage of LiDAR Data

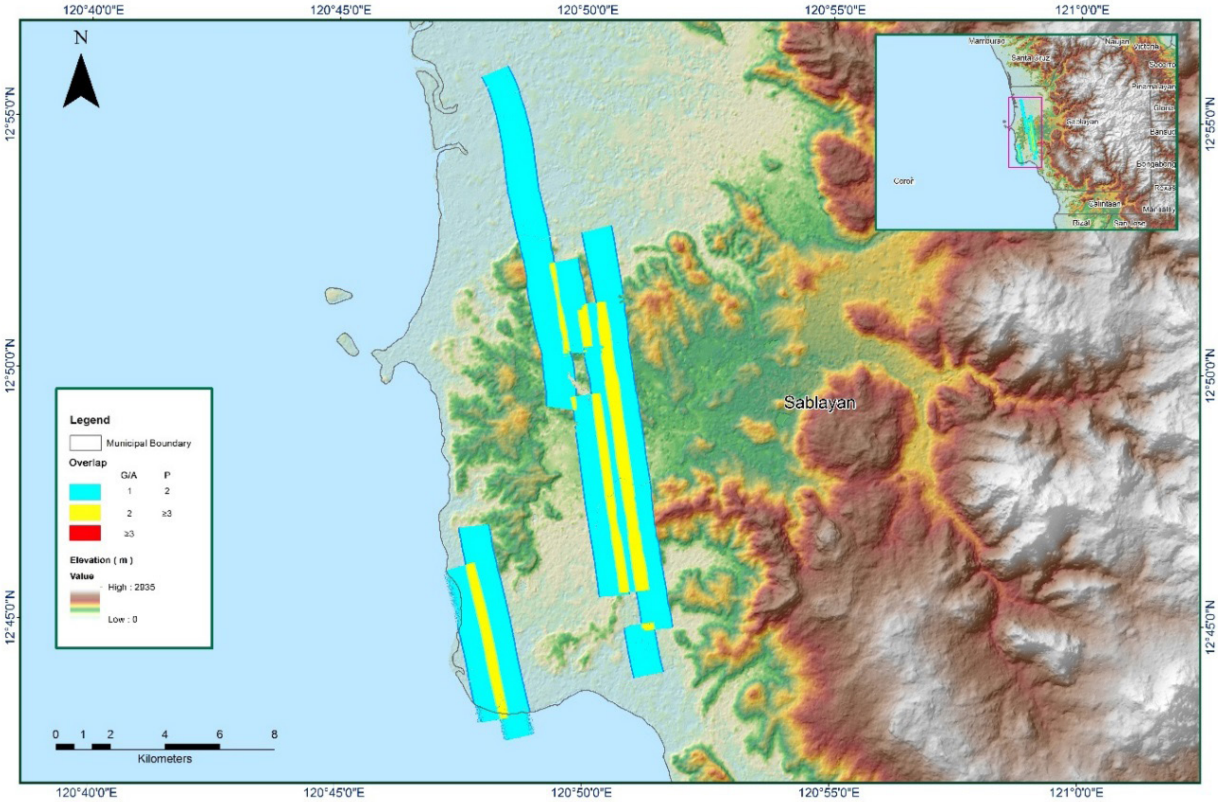


Figure A-8.40 Image of data overlap

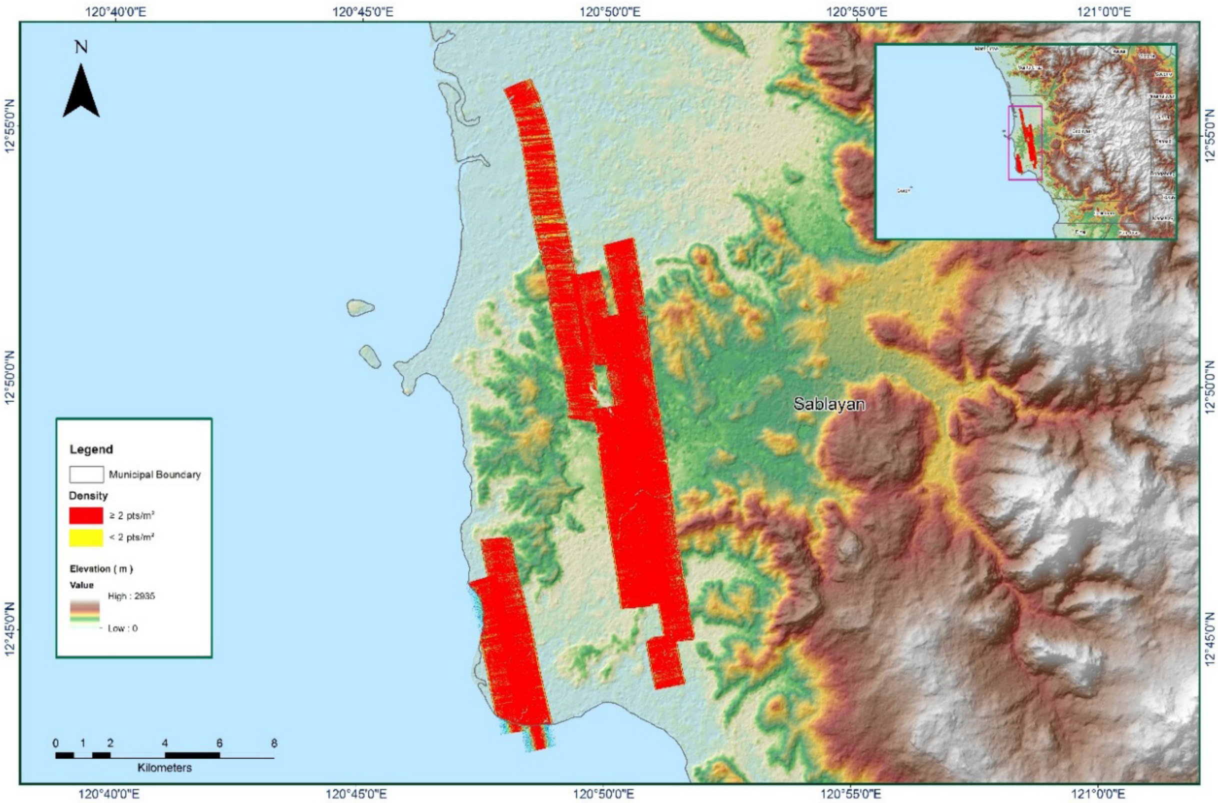


Figure A-8.41 ***Density map of merged LiDAR data***

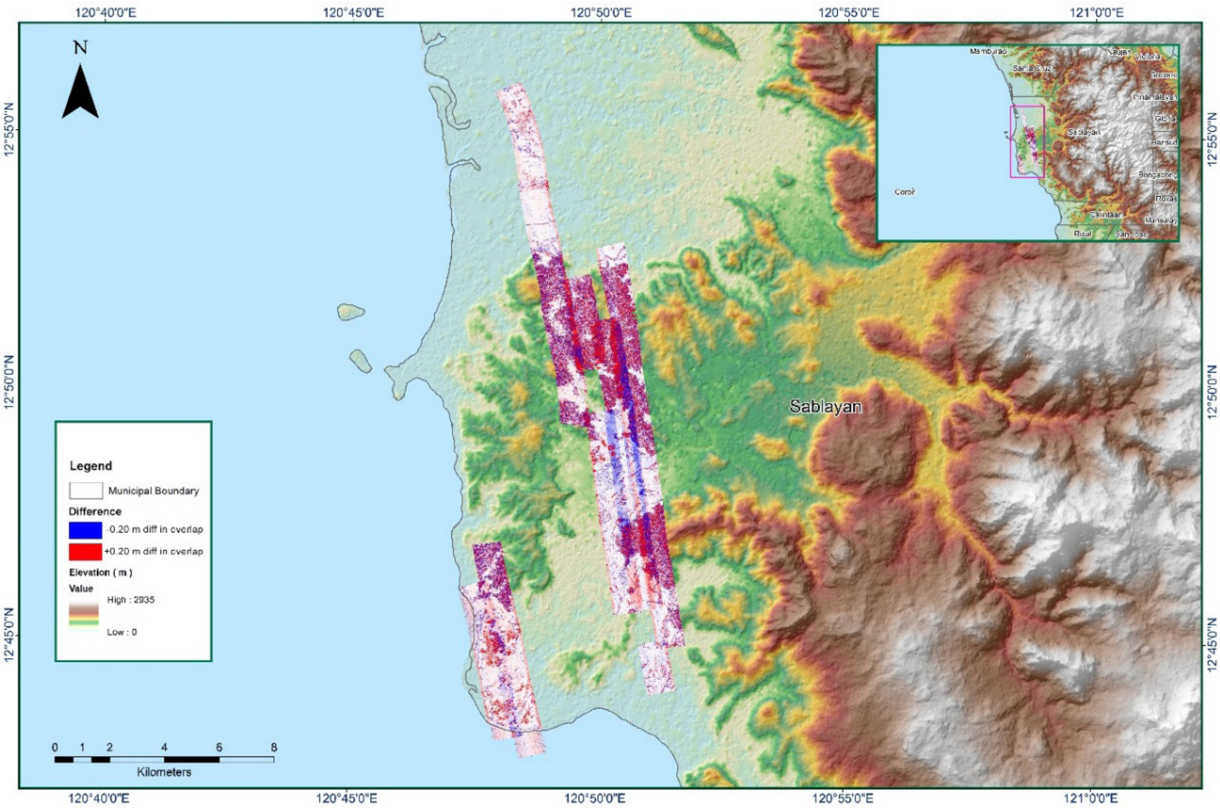


Figure A-8.42 Image of data overlap

Annex 9. Amnay Model Basin Parameters

Table A-9.1. Amnay 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
W320	8.5077	82.64	0.0	3.8689	3.1236	5.7515	0.5	0.4975
W330	9.1976	80.036	0.0	0.80027	0.65348	1.8057	0.5	0.825
W340	7.8048	72.838	0.0	0.21323	0.3832	0.15726	0.5	0.825
W350	9.4493	67.429	0.0	2.5724	1.4131	3.8782	0.5	0.75
W360	9.8636	65.984	0.0	2.5629	1.3956	7.0408	0.5	0.5
W370	8.4682	64.795	0.0	5.5487	2.0219	5.153	0.40194	0.5
W380	8.9038	70.543	0.0	0.56627	0.45282	1.0564	0.40198	0.575
W390	8.9995	99	0.0	3.3128	1.1974	5.4966	0.5	0.5
W400	8.5464	70.295	0.0	1.6483	0.60983	1.0598	0.5	0.49
W410	10.764	63.65	0.0	2.5724	1.3775	1.9599	0.40199	0.49
W420	8.89	69.236	0.0	3.2171	2.5727	3.513	0.40196	0.5
W430	9.1073	69.166	0.0	3.0468	1.5238	3.887	0.40197	0.5
W440	11.884	61.991	0.0	1.9874	0.71857	2.763	0.40199	0.49
W450	11.045	64.181	0.0	5.75	1.3831	3.7771	0.5	0.5
W460	12.663	60.088	0.0	4.4622	3.6023	10.949	0.5	0.5
W470	9.5186	68.591	0.0	1.4179	1.6668	6.4568	0.40198	0.49
W480	10.427	65.994	0.0	3.8832	2.1092	3.2939	0.40185	0.5
W490	12.606	60.223	0.0	3.6463	4.458	4.2204	0.402	0.49
W500	12.531	60.402	0.0	8.7171	3.0982	7.2008	0.40188	0.5
W510	12.892	59.55	0.0	1.3835	0.73338	0.13544	0.40197	0.5

W520	10.977	64.366	0.0	3.3321	1.8126	2.3751	0.5	0.5
W530	10.573	65.484	0.0	4.8387	2.5907	3.6603	0.5	0.5
W540	10.986	64.342	0.0	2.1248	1.1738	3.6861	0.5	0.5
W550	11.179	63.822	0.0	0.48462	0.17934	0.14112	0.5	0.75
W560	10.062	66.954	0.0	2.4887	2.0207	4.9275	0.5	0.5
W570	10.897	64.585	0.0	2.0701	0.76607	5.339	0.5	0.5
W580	13.259	58.708	0.0	3.1411	3.4432	4.8655	0.5	0.5
W590	5.0787	85.721	0.0	1.9119	1.0613	5.1769	0.40198	0.5
W600	3.5408	91.687	0.0	2.4563	1.3518	7.0591	0.5	0.5
W610	5.3595	84.388	0.0	5.7087	2.1179	9.3162	0.5	0.5
W620	12.229	61.135	0.0	4.3361	2.37	15.871	0.5	0.5

Annex 10. Amnay Model Reach Parameters

Table A-10.1. Amnay Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R100	Automatic Fixed Interval	772.13	0.0244898	0.57435	Trapezoid	400	1
R110	Automatic Fixed Interval	2169.4	.00018357	0.57624	Trapezoid	400	1
R130	Automatic Fixed Interval	4195.5	0.0120770	0.59066	Trapezoid	400	1
R160	Automatic Fixed Interval	4661.1	0.0225726	0.58883	Trapezoid	400	1
R170	Automatic Fixed Interval	9922.0	0.0081543	0.588	Trapezoid	400	1
R180	Automatic Fixed Interval	3734.0	0.0333219	0.588	Trapezoid	400	1
R190	Automatic Fixed Interval	2596.6	0.0200429	0.588	Trapezoid	400	1
R20	Automatic Fixed Interval	757.40	0.0650688	0.58967	Trapezoid	400	1
R220	Automatic Fixed Interval	3435.5	0.0096916	0.588	Trapezoid	400	1
R230	Automatic Fixed Interval	2849.7	0.0097816	0.588	Trapezoid	400	1
R240	Automatic Fixed Interval	1732.7	0.0035778	0.588	Trapezoid	400	1
R270	Automatic Fixed Interval	5907.0	0.0039390	0.588	Trapezoid	400	1
R290	Automatic Fixed Interval	733.26	0.0094455	0.588	Trapezoid	400	1
R300	Automatic Fixed Interval	1517.4	0.0094455	0.588	Trapezoid	400	1
R70	Automatic Fixed Interval	4235.8	0.0208034	0.588	Trapezoid	400	1

Annex 11. Amnay Field Validation

Table A-11.1. Amnay Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/Scenario
	Latitude	Longitude						
1	120.77843000000	12.95053000000	2.18	0.97	-1.21		2007	25-Year
2	120.77696000000	12.95118500000	1.27	0.4	-0.87		1999	25-Year
3	120.77796000000	12.95123700000	2.38	1.2	-1.18		2009	25-Year
4	120.77748000000	12.95155200000	1.83	0.88	-0.95		2007	25-Year
5	120.77691000000	12.95170500000	1.58	0.6	-0.98		2007	25-Year
6	120.77729000000	12.95187300000	1.64	0.5	-1.14		2007	25-Year
7	120.77665000000	12.95240700000	1.09	0.6	-0.49		2007	25-Year
8	120.77714000000	12.95264500000	1.75	0.8	-0.95	Yolanda		25-Year
9	120.77719000000	12.95297300000	1.95	0.9	-1.05		2011	25-Year
10	120.77735000000	12.95343600000	2.28	0.95	-1.33		2011	25-Year
11	120.77626000000	12.95437200000	1.55	0.56	-0.99		2007	25-Year
12	120.77595000000	12.95481400000	1.68	0.52	-1.16		2007	25-Year
13	120.77599580000	12.95581350000	2.26	0.66	-1.6	Nona	Dec. 2015	25-Year
14	120.77585150000	12.95597760000	2	0.45	-1.55	Nona	Dec. 2015	25-Year
15	120.77557510000	12.95600180000	1.38	0.83	-0.55	Ondoy	Sept. 2009	25-Year
16	120.77603080000	12.95601050000	2.32	0.45	-1.87	Nona	Dec. 2015	25-Year
17	120.77569380000	12.95602990000	1.6	0.3	-1.3	Ondoy	Sept. 2009	25-Year

18	120.77613000000	12.95646900000	2.16	1.12	-1.04		2011	25-Year
19	120.77557540000	12.95656180000	1.71	0.67	-1.04	Ondoy	Sept. 2009	25-Year
20	120.77598000000	12.95673000000	2.12	1.12	-1		2012	25-Year
21	120.77653000000	12.95673800000	2.24	1.14	-1.1		2007	25-Year
22	120.77741000000	12.95721300000	2.05	0.7	-1.35		2007	25-Year
23	120.77557630000	12.95728070000	2.15	0.9	-1.25	Yolanda	Nov. 2013	25-Year
24	120.77540870000	12.95734910000	2.21	0.98	-1.23	Yolanda	Nov. 2013	25-Year
25	120.77731000000	12.95749600000	2.14	0.5	-1.64		2009	25-Year
26	120.77612990000	12.95773530000	2.27	0.9	-1.37	Yolanda	Nov. 2013	25-Year
27	120.77705000000	12.95793300000	1.98	0.5	-1.48		2007	25-Year
28	120.77597970000	12.95812700000	2.48	1.3	-1.18	Yolanda	Nov. 2013	25-Year
29	120.81805260000	12.95864410000	2.13	0.3	-1.83	Nina	Dec. 2016	25-Year
30	120.81855220000	12.95867250000	2.14	0.55	-1.59	Ondoy	Sept. 2009	25-Year
31	120.81905540000	12.95868930000	2.19	0.6	-1.59	Ondoy	Sept. 2009	25-Year
32	120.81949900000	12.95873880000	2.09	1.2	-0.89	Ondoy	Sept. 2009	25-Year
33	120.81966660000	12.95879630000	2.13	0.2	-1.93	Ondoy	Sept. 2009	25-Year
34	120.82341670000	12.95888060000	2.02	1	-1.02	Ondoy	Sept. 2009	25-Year
35	120.82079600000	12.95888630000	1.97	0.5	-1.47	Ondoy	Sept. 2009	25-Year
36	120.82135130000	12.95892680000	2.11	0.5	-1.61	Ondoy	Sept. 2009	25-Year

37	120.82200260000	12.95897360000	1.69	0	-1.69	Ondoy	Sept. 2009	25-Year
38	120.82159790000	12.95898850000	1.94	0	-1.94	Ondoy	Sept. 2009	25-Year
39	120.82005590000	12.95899220000	2.11	0.2	-1.91	Ondoy	Sept. 2009	25-Year
40	120.77657960000	12.95866300000	1.89	0.5	-1.39		Oct. 2007	25-Year
41	120.82295700000	12.95911670000	1.89	1.2	-0.69	Ondoy	Sept. 2009	25-Year
42	120.77701000000	12.95883800000	2.33	0.8	-1.53		2007	25-Year
43	120.77674000000	12.95904400000	2.09	0.8	-1.29		2007	25-Year
44	120.82066000000	12.95959040000	2	1.3	-0.7	Yolanda	Nov. 2013	25-Year
45	120.82002230000	12.95965190000	1.85	1	-0.85	Yolanda	Nov. 2013	25-Year
46	120.77574960000	12.95930740000	2.32	0.45	-1.87	Nona	Dec. 2015	25-Year
47	120.82010000000	12.95974400000	1.81	0.82	-0.99	Yolanda		25-Year
48	120.82243690000	12.95978340000	1.88	0.2	-1.68	Nina	Dec. 2016	25-Year
49	120.82110400000	12.95979550000	1.83	0.9	-0.93	Yolanda	Nov. 2013	25-Year
50	120.83103000000	12.95992900000	1.71	0.71	-1		2010	25-Year
51	120.77640000000	12.95950100000	1.84	0.6	-1.24		2007	25-Year
52	120.81990350000	12.95993960000	1.83	0	-1.83	Nina	Dec. 2016	25-Year
53	120.81470000000	12.95995500000	2.27	1.36	-0.91		2010	25-Year
54	120.81602000000	12.95997000000	2.38	1.27	-1.11		2010	25-Year
55	120.77674720000	12.95965490000	2.2	0.45	-1.75	Yolanda	Nov. 2013	25-Year
56	120.81513000000	12.96001600000	2.13	1.1	-1.03		2010	25-Year

57	120.81772000000	12.96006100000	2.17	1.16	-1.01	Pedring		25-Year
58	120.81701000000	12.96020000000	2.32	1.13	-1.19		2013	25-Year
59	120.81661000000	12.96019800000	2.31	1.2	-1.11		2010	25-Year
60	120.83283310000	12.96036840000	1.6	0.58	-1.02	Lawin	Oct. 2016	25-Year
61	120.77598270000	12.95989860000	2.17	0.61	-1.56	Yolanda	Nov. 2013	25-Year
62	120.83355520000	12.96046140000	1.56	0.52	-1.04	Yolanda	Nov. 2013	25-Year
63	120.81586000000	12.96033300000	1.87	1.17	-0.7		2010	25-Year
64	120.77644410000	12.96007980000	2.07	0.3	-1.77	Nina	Dec. 2016	25-Year
65	120.83382000000	12.96061400000	1.57	0.55	-1.02		2010	25-Year
66	120.81755000000	12.96050100000	2.04	0.89	-1.15		2010	25-Year
67	120.83427880000	12.96071370000	1.77	0.45	-1.32	Yolanda	Nov. 2013	25-Year
68	120.81726000000	12.96062000000	2.32	1.1	-1.22		2010	25-Year
69	120.83471000000	12.96094800000	1.97	0.5	-1.47		2010	25-Year
70	120.81478000000	12.96084600000	2	0.89	-1.11		2010	25-Year
71	120.83546640000	12.96110070000	1.69	1.3	-0.39	Nina	Dec. 2016	25-Year
72	120.81560000000	12.96101600000	1.97	0.9	-1.07		2010	25-Year
73	120.81519000000	12.96102600000	2.09	0.67	-1.42		2010	25-Year
74	120.83560000000	12.96122000000	2.5	0	-2.5	Nina		25-Year
75	120.81748000000	12.96114900000	1.72	1.06	-0.66		2014	25-Year
76	120.81701000000	12.96122100000	1.99	0.62	-1.37		2010	25-Year
77	120.81616000000	12.96125200000	2.14	0.5	-1.64		2013	25-Year
78	120.77550310000	12.96108860000	2.23	0.5	-1.73	Yolanda	Nov. 2013	25-Year

79	120.77606470000	12.96115100000	1.93	0.9	-1.03	Glenda	July 2014	25-Year
80	120.77589980000	12.96172760000	2	0.55	-1.45	Glenda	July 2014	25-Year
81	120.77559800000	12.96210600000	2.03	0.6	-1.43	Nona	Dec. 2015	25-Year
82	120.77530520000	12.96294900000	2.27	0.25	-2.02	Lawin	Oct. 2016	25-Year
83	120.77526300000	12.96346720000	1.9	0.8	-1.1	Yolanda	Nov. 2013	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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