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

LiDAR Surveys and Flood Mapping of Anahawin River

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

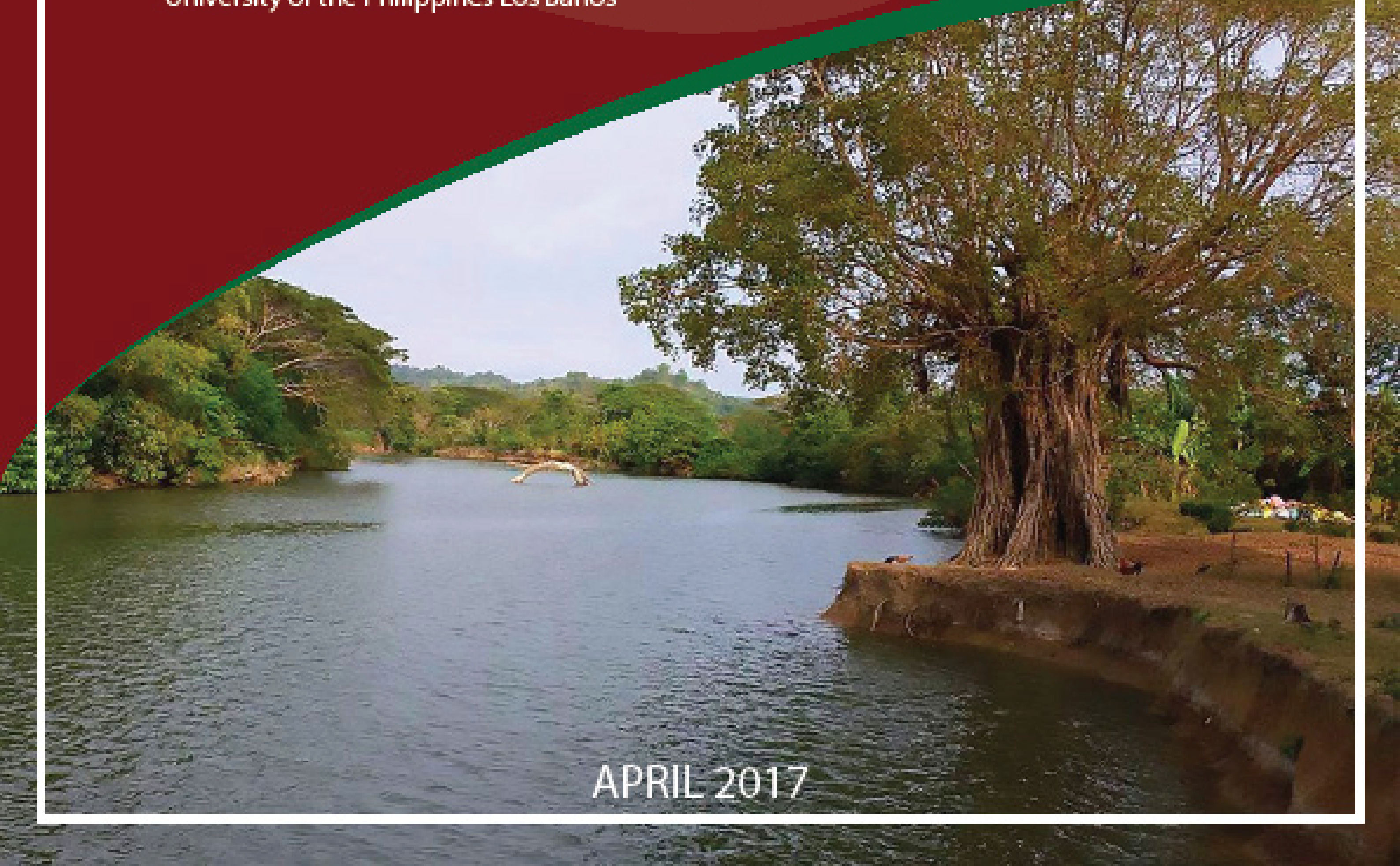

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

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

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "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 Banos (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 45 river basins in the MIMAROPA Region. The university is located at Los Baños, Laguna.

1.2 Overview of the Anahawin River Basin

The Anahawin River Basin is a 11,800-hectare watershed located in Occidental Mindoro. It covers the barangays: San Agustin, San Francisco, San Nicolas, San Vicente, Lagnas, Malisbong, Batong Buhay, Buenavista, Burgos, Ligaya, Poblacion, Santa Lucia, Santo Niño, Tagumpay, Victoria, Tusban, Gen. Emilio Aguinaldo, Claudio Salgado, Ibud, Invita, Paetan and Pag-asa in Sablayan municipality; and, Concepcion, Iriron, Malpapon, New Dagupan, Poblacion, Poypoy and Tanyag in Calintaan municipality. The basin area has seven geological classifications with Oligocene-Miocene as the most dominant type while others are Oligocene, Paleocene-Eocene, Pliocene-Pleistocene, and Upper Miocene-Pliocene.

Majority of the river basin is characterized by 30-50% slope and elevation of 11-2,200 meters above mean sea level. Anahawin River Basin is comprised of eight soil classes. Among them, Maranlig gravelly sandy clay loam is the most dominant, others include Rough Mountainous Land, Beach Sand, Quiangua Silt Loam, Quiangua Loam, Quiangua Clay Loam, Bantog Clay and San Manuel Sandy Loam. The river basin is dominated by grassland land cover while other areas are classified as arable land with cereals and sugar as main crops, crop land mixed with coconut plantation, cultivated area mixed with brushland/ grassland and open canopy.

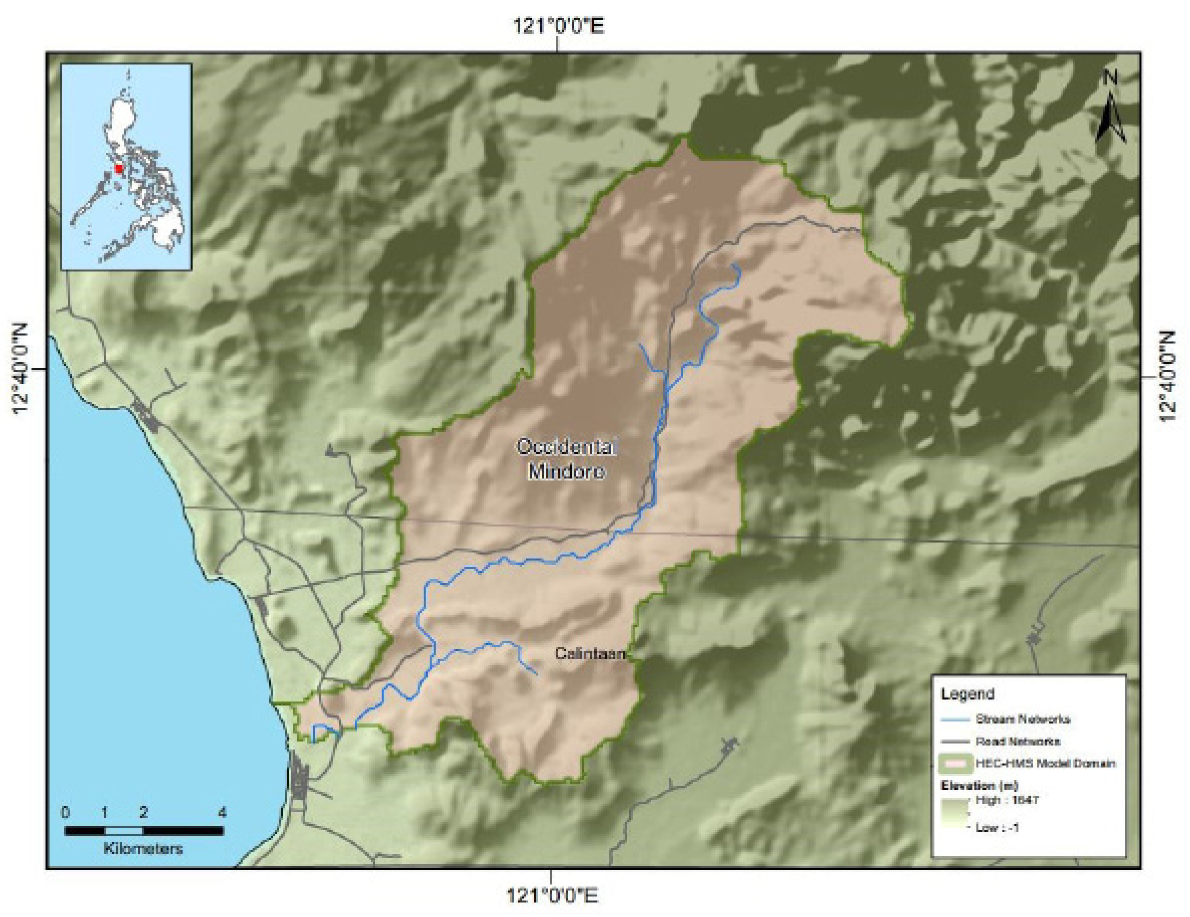

Figure 1. Map of Anahawin River Basin

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

Anahawin River passes through Ligaya, Burgos and Tuban in the municipality of Sablyan; and Malpalon, Poypoy and Poblacion in the municipality of Calintaan. As recorded in the 2010 NSO Census of Population and Housing, among the barangays in Sablayan, Brgy. Ligaya is the most populated while Brgy. Poblacion in Calintaan.

According to the studies conducted by the Mines and Geosciences Bureau, generally, Sablayan has moderate to high risk to flooding while Calintaan has a low to high risk to flooding. On the other hand, both has a low to high risk due to landslide. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, about six notable weather disturbance caused flooding in 2009 (Ondoy), 2013 (Yolanda), 2014 (Glenda, Mario), and 2015 (Lando, Nona). Heavy rainfall in August 2016 attributed to habagat also caused flooding in barangay Iriron, Calintaan.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE ANAHAWIN FLOODPLAIN

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The methods applied in this Chapter were based on the 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 Anahawin floodplain in Oriental Mindoro. These missions were planned for 17 lines that run for at most four (4) hours including take-off, landing and turning time. The flight planning parameters for Aquarius and Gemini LiDAR systems are found in Error! Reference source not found. and Table 2, respectively. Error! Reference source not found. shows the flight plan for Anahawin 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)
BLK29A	600	30	36	125	40	130	5
BLK29D	600	30	36	125	40	130	5
BLK29E	600	30	36	125	40	130	5
BLK29F	600	30	36	125	40	130	5
BLK29G	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)
BLK29O	1100	30	50	125	50	130	5

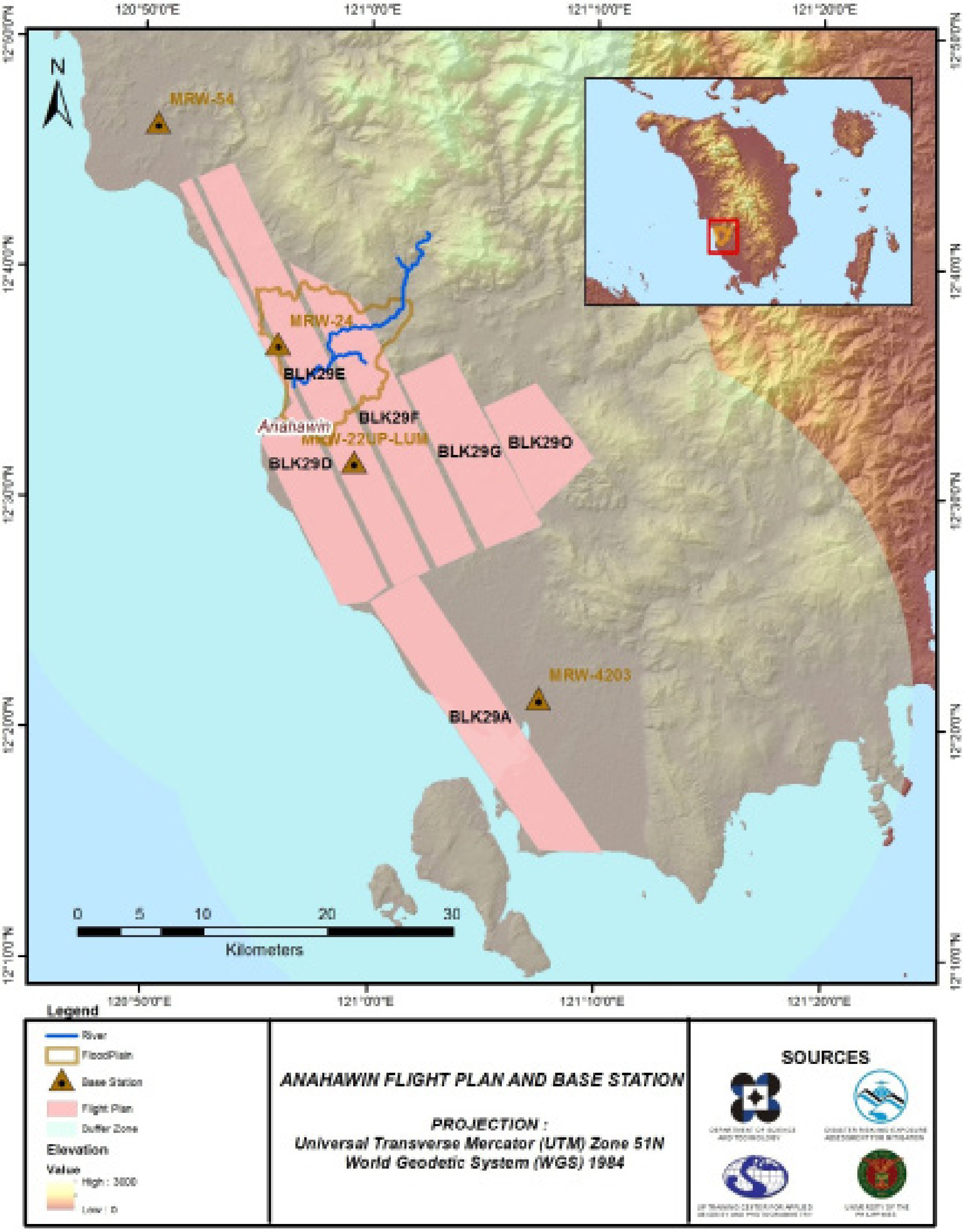

Figure 2. Flight Plan and base stations used for the Anahawin Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover four (5) NAMRIA ground control points: MRW-6, MRW-22, MRW-24, MRW-54 which are of second (2nd) order accuracy and MRW-4203 which is of third (3rd) order accuracy. The project team also established one (1) ground control point UP-LUM.

The certifications for the base stations are found in Annex 2 while the baseline processing report for established point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from February 16 - March 3, 2014 and December 10, 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 Anahawin floodplain are shown in Error! Reference source not found..

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Anahawin Floodplain LiDAR Survey. Figure 3 to Figure 8 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 3 to Table 8 show the details about the following NAMRIA control stations and established points. Table 9, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

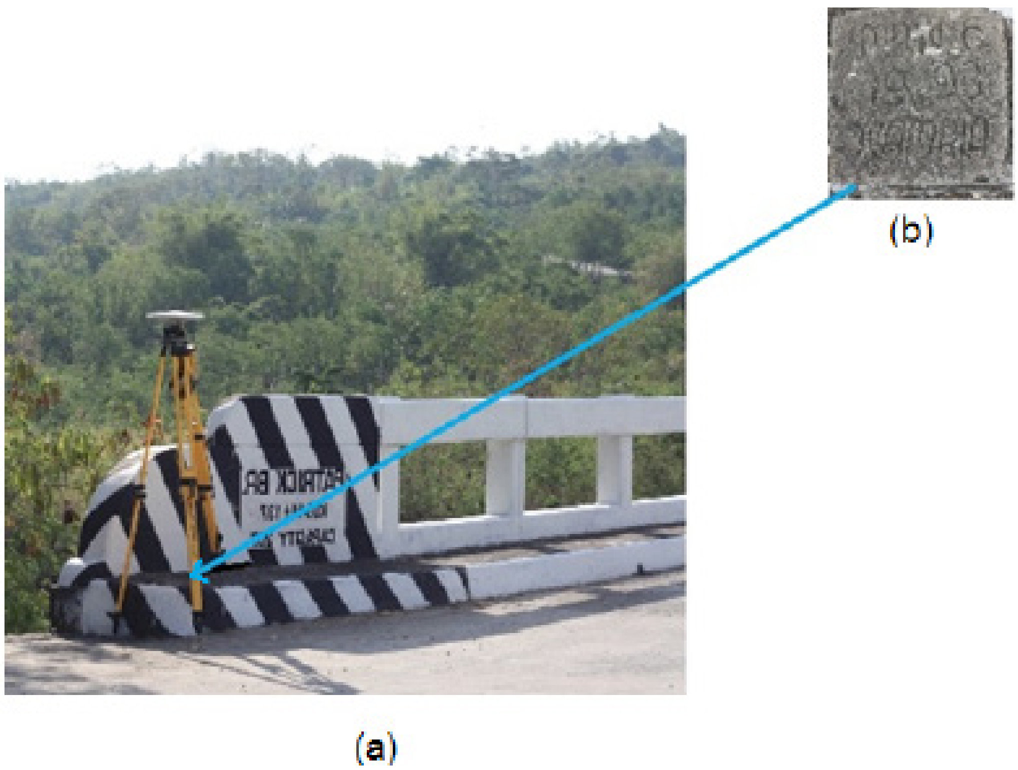

Figure 3. NAMRIA reference point MRW-6 (a) as recovered by the field team and GPS set-up over MRW-6 as recovered in Patrick Bridge in Brgy. Yabang, municipality of Sablayan, Occidental Mindoro (b).

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

Station Name	MRW-6	
Order of Accuracy	3rd	
Relative Error (Horizontal positioning)	1 : 20,000	
Geographic Coordinates, Philippine Reference 0f 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 3 (PTM Zone 3 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, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	274116.83 meters 1424453.14 meters

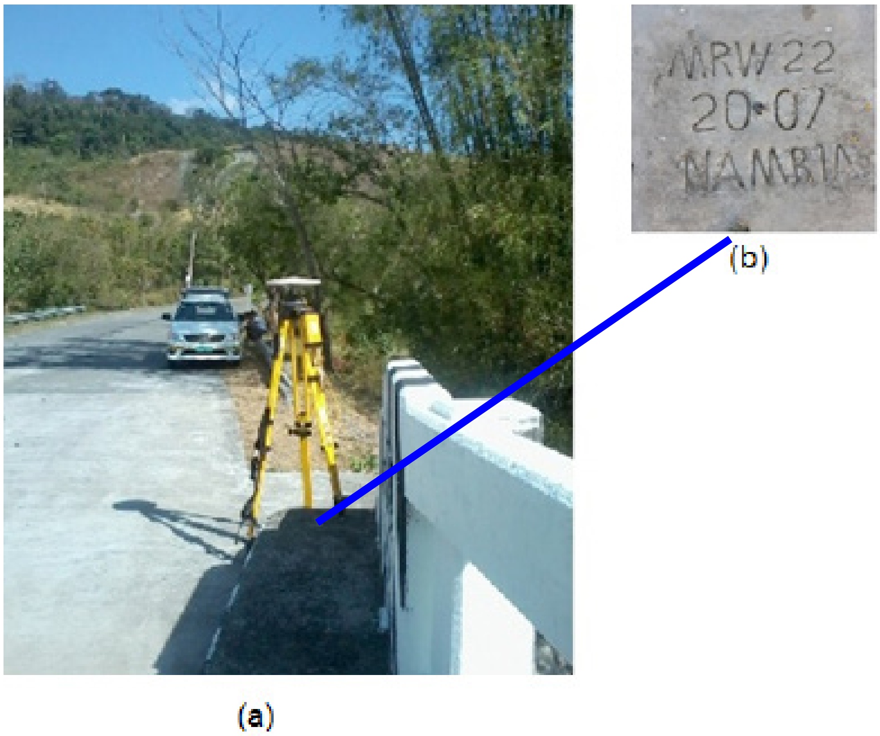

Figure 4. GPS set-up over MRW-22 in Lumintao Bridge in Brgy. Tanyag, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-22 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRW-22 used as base station for the LiDAR acquisition.

Station Name	**MRW-22**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31’36.76881” North 120°59’13.46492” East 35.12700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	498595.125 meters 1385214.96 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31’31.84278” North 120°59’18.53734” East 84.27100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	281265.62 meters 1385563.72 meters

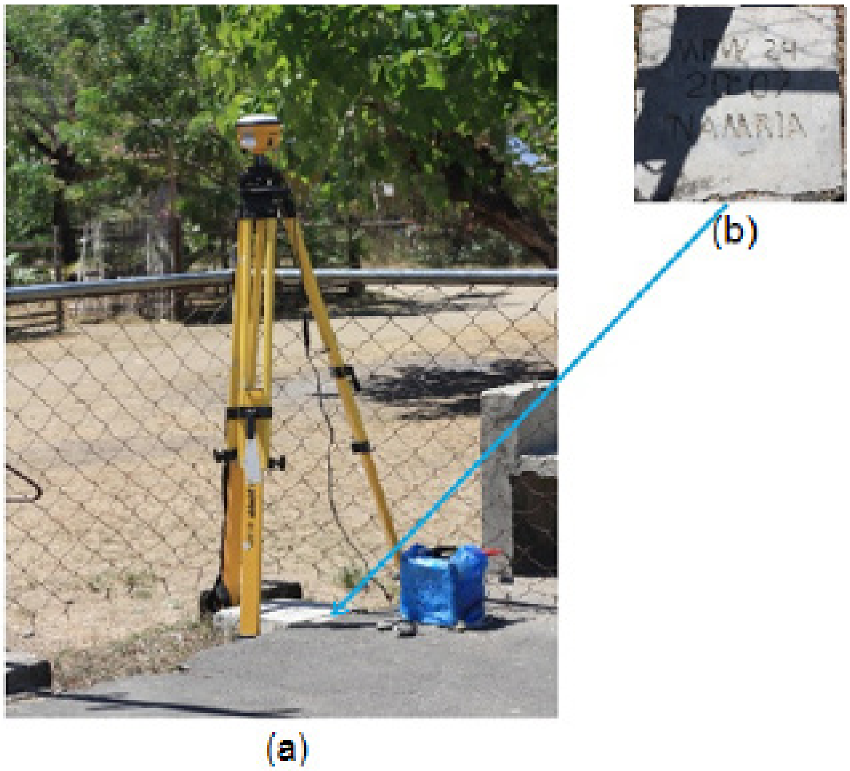

Figure 5. GPS set-up over MRW-24 in the basketball court in Brgy. Iriron, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-24 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRW-24 used as base station for the LiDAR acquisition.

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

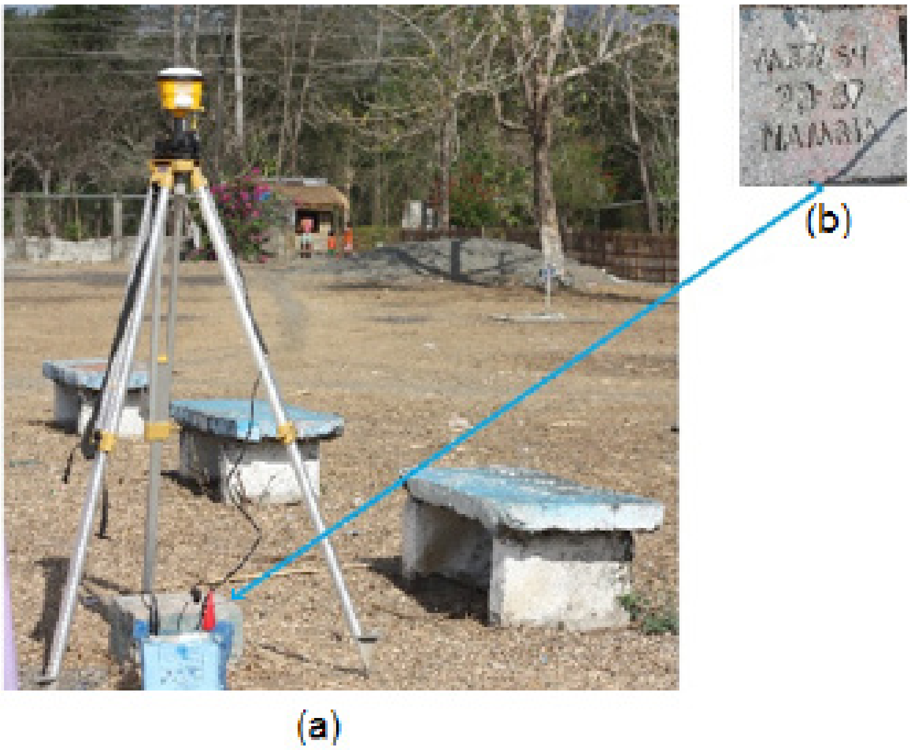

Figure 6. NAMRIA reference point MRW-54 (a) as recovered by the field team and GPS set-up over MRW-54 as recovered in near basketball open court in Brgy. Malisbong, municipality of Sablayan, Occidental Mindoro (b).

Table 6. Details of the recovered NAMRIA horizontal control point MRW-54 used as base station for the LiDAR acquisition.

Station Name	**MRW-54**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 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 1992)	Easting Northing	265604.90 meters 1412791.69 meters

Figure 7. GPS set-up over MRW-4203 in front of the barangay hall of Brgy. Mapaya, municipality of San Jose, Occidental Mindoro (a) and NAMRIA reference point MRW-4203 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point MRW-4203 used as base station for the LiDAR acquisition.

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

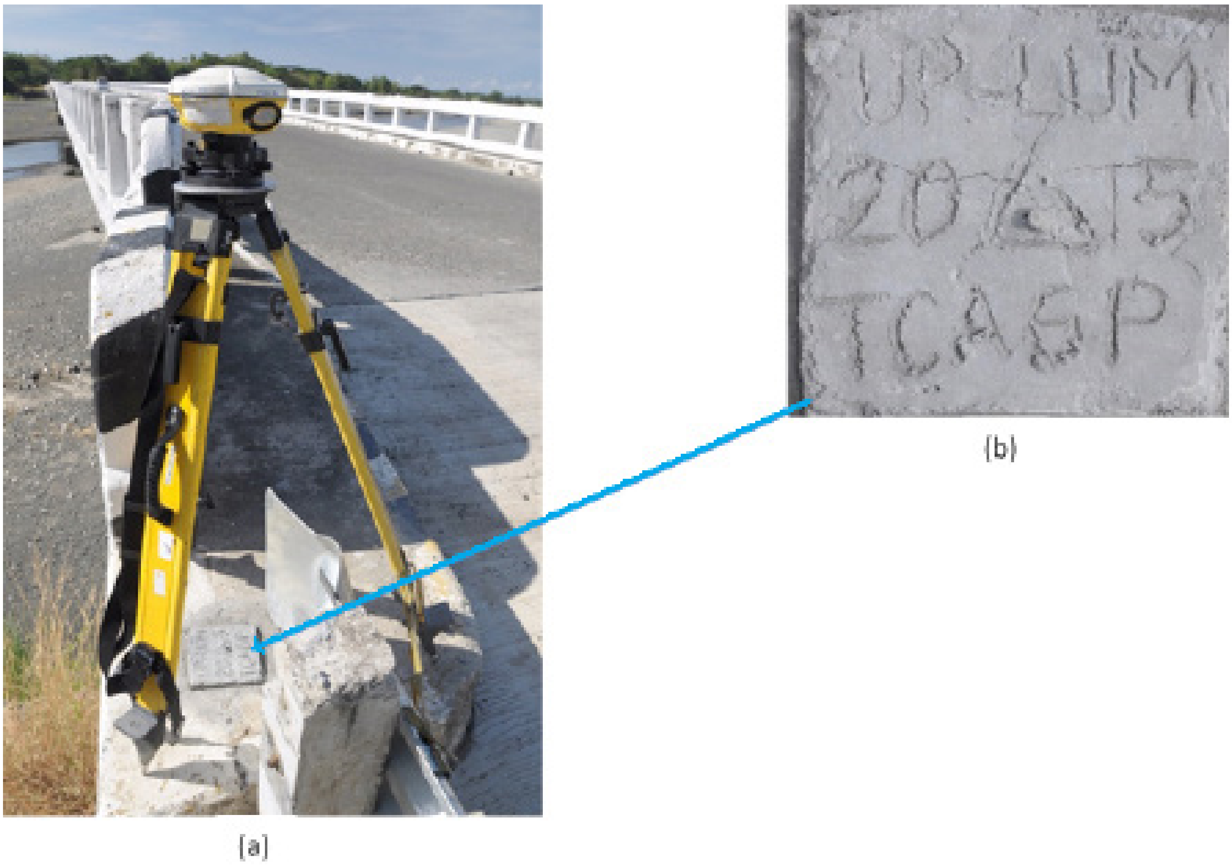

Figure 8. GPS set-up over UP-LUM in the municipality of Rizal, Occidental Mindoro (a) and reference point UP-LUM (b) as established by the field team.

Table 8. Details of the established control point UP-LUM used as base station for the LiDAR acquisition.

Station Name	UP-LUM	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31’36.65200” North 120°59’13.78049” East 35.185 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31’31.72599” North 120°59’18.85291” East 84.296 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	281275.130 meters 1385560.055 meters

Table 9. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
23-Feb-14	1138A	3BLK29E54B	MRW-54, MRW-6
24-Feb-14	1140A	3BLK29ES55A (3BLK29ES+G55A)	MRW-22, MRW-24
24-Feb-14	1142A	3BLK29P55B	MRW-22, MRW-24
27-Feb-14	1152A	3BLK29GSD58A (3BLK29D+GS58A)	MRW-22, MRW-24
27-Feb-14	1154A	3BLK29DS58B	MRW-22, MRW-24
28-Feb-14	1156A	3BLK29F59A	MRW-22, MRW-24
01-Mar-14	1162A	3BLK29AS60B (3BLK29AS+DV60B)	MRW-22, MRW-4205
10-Dec-15	3074P	1BLK29KLMO344A	MRW-24, UP-LUM
January 30, 2016	3729G	2BLK34HJ030A	SMR-53 and LYT-104
February 5, 2016	3753G	2BLK34K33AB036A	SMR-58 and SM-309
February 6, 2016	3757G	2BLK34K037A	SMR-58 and SM-309

2.3 Flight Missions

A total of eight (8) missions were conducted to complete the LiDAR data acquisition in Anahawin floodplain, for a total of thirty three hours and ten minutes (33+10) of flying time for RP-C9122. All missions were acquired using the Aquarius and Pegasus LiDAR systems. As shown below, the total area of actual coverage and the corresponding flying hours per mission are depicted in Table 10, while the actual parameters used during the LiDAR data acquisition are presented in Table 11.

Table 10. Flight missions for the LiDAR data acquisition of the Anahawin Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 23, 2014	1138A	115.31	69.06	19.92	49.14	813	4	29
February 24, 2014	1140A	189.5	72.50	1.02	71.48	796	4	11
February 24, 2014	1142A	89.72	110.31	39.14	71.17	1061	3	59
February 27, 2014	1152A	155.58	89.81	0.13	89.68	1077	4	23
February 27, 2014	1154A	81.39	78.54	8.64	69.9	617	3	53
February 28, 2014	1156A	89.72	114.55	36.09	78.46	1312	4	29
March 01, 2014	1162A	191.43	87.17	0	87.17	593	3	41
December 10, 2015	3074P	47.18	85.00	4.23	80.77	454	4	5
TOTAL		959.83	706.94	109.17	597.77	6723	33	10

Table 11. Actual parameters used during the LiDAR data acquisition of the Anahawin Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1138A	600	30	36	125	40	130	5
1140A	600	30	36	125	40	130	5
1142A	600	30	36	125	40	130	5
1152A	600	30	36	125	40	130	5
1154A	600	30	36	125	40	130	5
1156A	600	30	36	125	40	130	5
1162A	600	30	36	125	40	130	5
3074P	1100	30	50	200	30	130	5

2.4 Survey Coverage

Anahawin floodplain is located in the province of Occidental Mindoro with majority of the floodplain situated within the municipalities of Calintaan, Rizal and Sablayan. Municipality of Rizal is mostly covered by the survey (Annex 7). The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Anahawin floodplain is presented in Figure 9.

Table 12. The list of municipalities and cities surveyed of the Anahawin Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Occidental Mindoro	Rizal	184.98	183.00	99%
	Calintaan	282.31	139.93	50%
	San Jose	449.82	132.50	29%
	Magsaysay	256.56	17.49	7%
	Sablayan	2350.46	83	4%

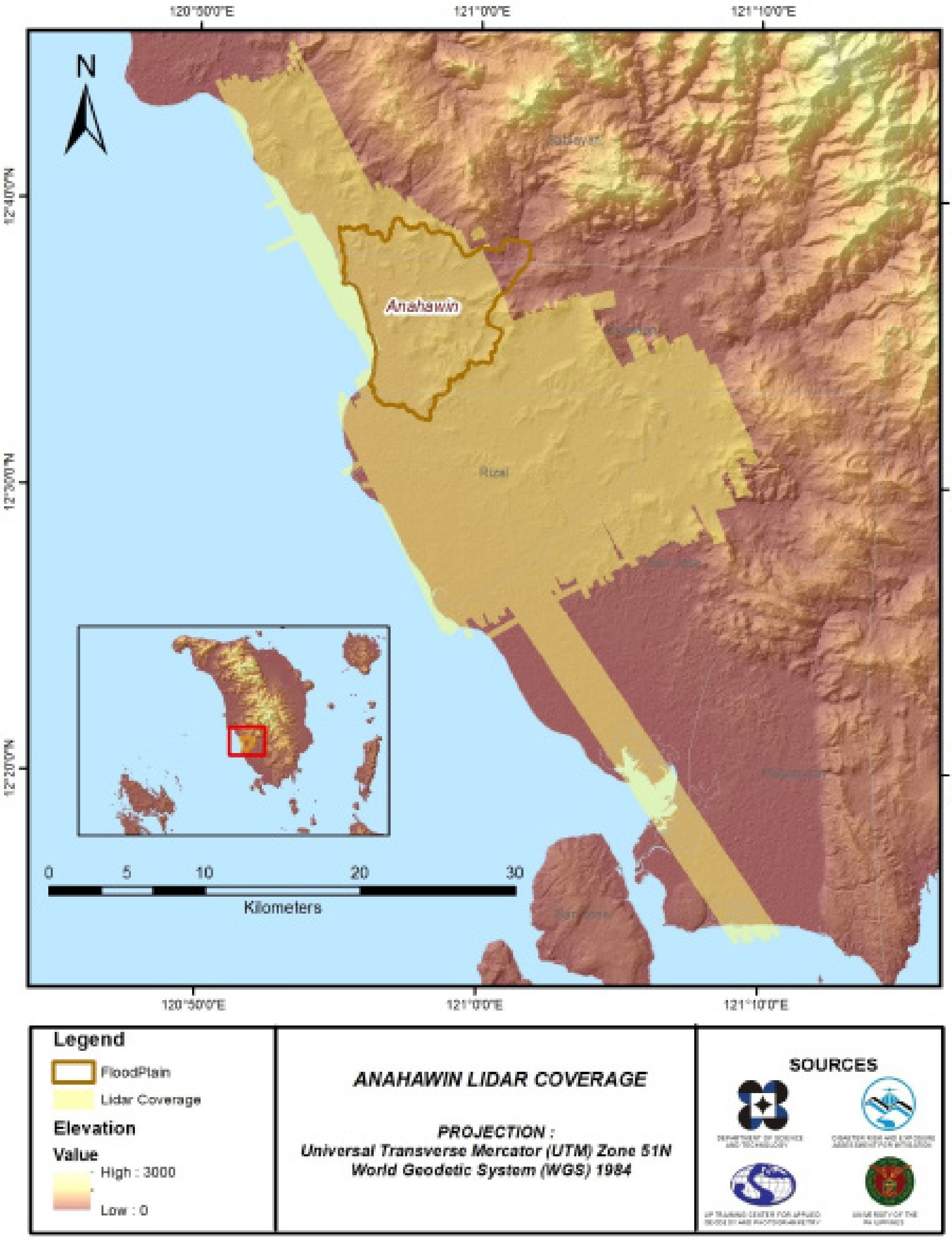

Figure 9 . Actual LiDAR survey coverage of the Anahawin Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE ANAHAWIN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

After the acquisition of LiDAR data, the latter is transmitted to the DPPC. Upon acceptance of the field data, the DPPC checks it for completeness and accuracy based on the list of raw files needed to proceed with its pre-processing. After which, the flight trajectory is georeferenced to obtain the exact location of the LiDAR sensor when the laser was shot.

Subsequently, the point cloud georectification is performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds are then subjected to a quality check to ensure that the required accuracies of the program, namely the minimum point density and vertical and horizontal accuracies, are met. These point clouds are then classified into various classes, which are integral in the generation of Digital Elevation Models (DEMs) such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

After this, the LiDAR-derived digital models are calibrated using the elevation of points gathered in the field. Parts of the river basin that were barely penetrated by the LiDAR system are then replaced by the actual river geometry measured from the field by the DVBC. Temporally acquired LiDAR data are then mosaicked to completely cover the target river systems in the Philippines. Images acquired from the field are orthorectified simultaneously with the LiDAR data through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in Figure 10.

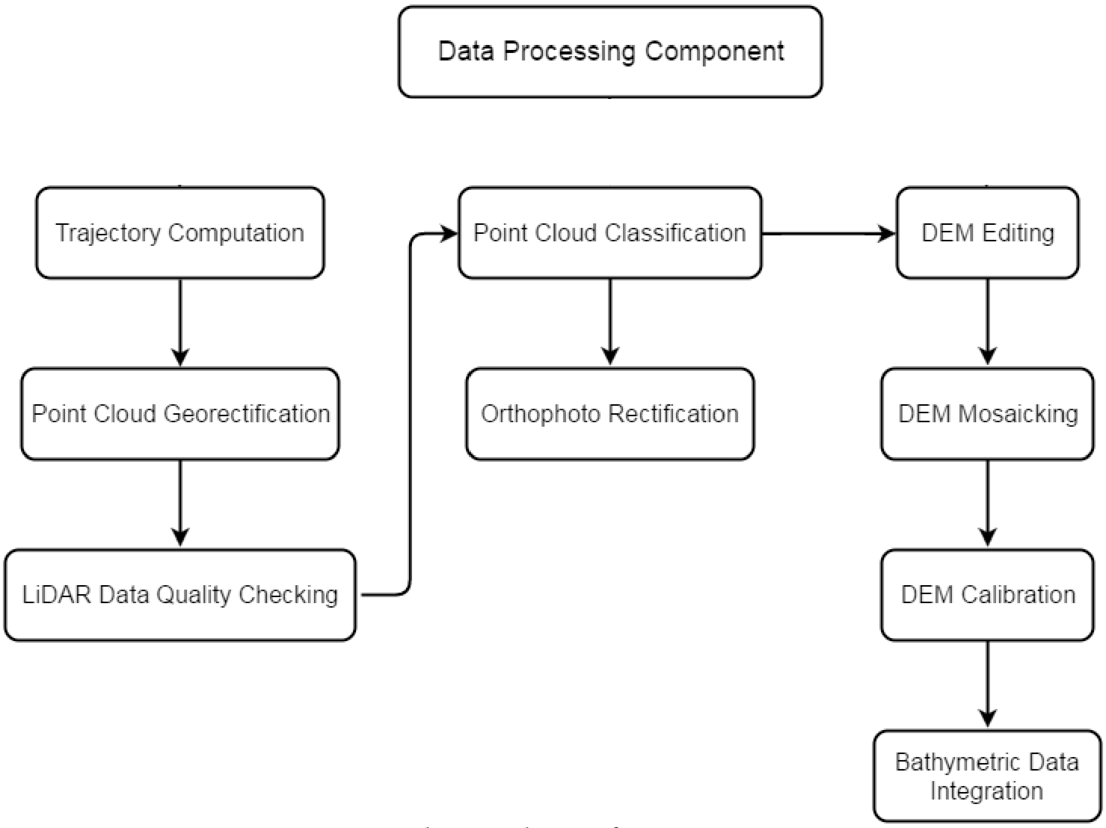

Figure 10. Schematic diagram for Data Pre-processing

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions of the Anahawin Floodplain can be found in Annex 5. The missions flown during the conduct of the first survey in February 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system, while the missions flown during the conduct of the second survey in December 2015 utilized the Pegasus system. Both were flown over the municipality of Calintaan, Occidental Mindoro.

In total, the DAC transferred 132.92 Gigabytes of Range data, 1.826 Gigabytes of POS data, 120.80 Megabytes of GPS base station data, and 413.30 Gigabytes of raw image data to the data server on January 13, 2016, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Anahawin Floodplain was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for the Anahawin Floodplain Survey.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 1156A, one of the Anahawin flights, are shown in Figure 11. It demonstrates that the Root Mean Square Error (RMSE) values are North, East, and Down positions. The x-axis corresponds to the time of the flight, which was measured by the number of seconds from the midnight of the start of the GPS week, which fell on the date and time of February 23, 2014, 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

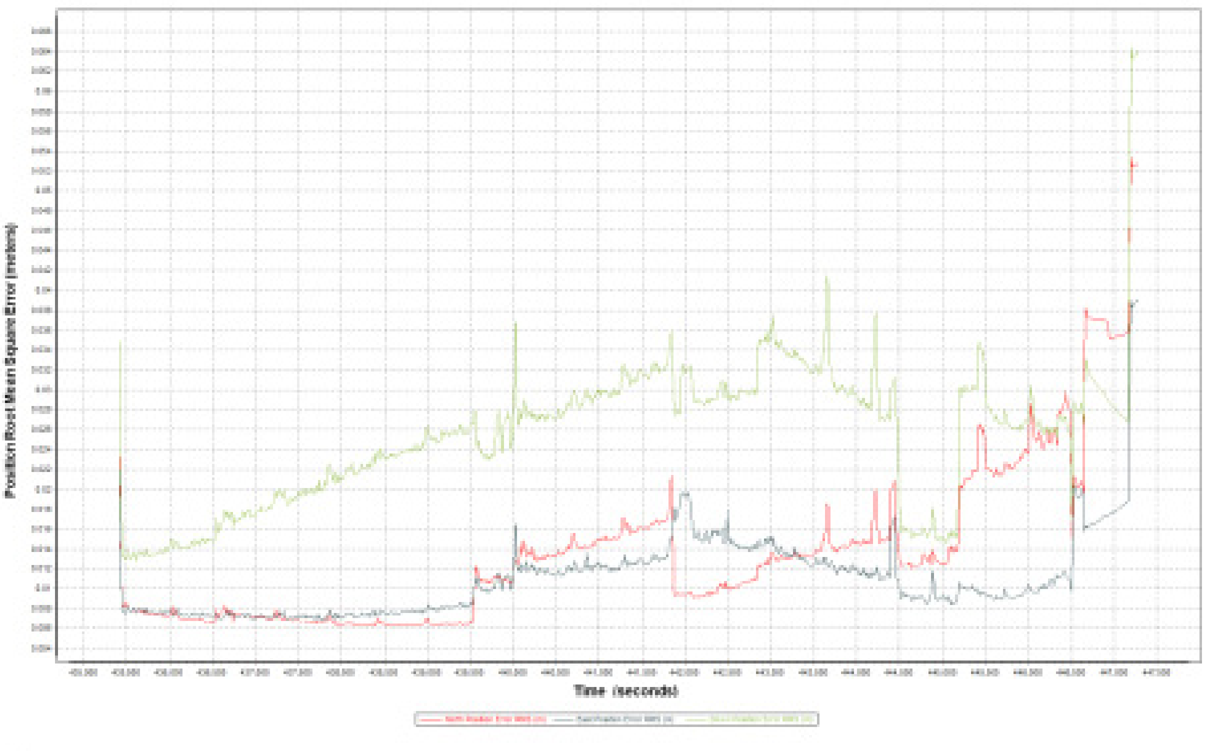

Figure 11. The Smoothed Performance Metrics of Anahawin Flight 1156A.

The time of flight was from 435,000 seconds to 447,500 seconds, which corresponds to morning of February 28, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 3.00 centimeters, the East position RMSE peaks at 2.05 centimeters, and the Down position RMSE peaks at 4.18 centimeters, which are within the prescribed accuracies described in the methodology.

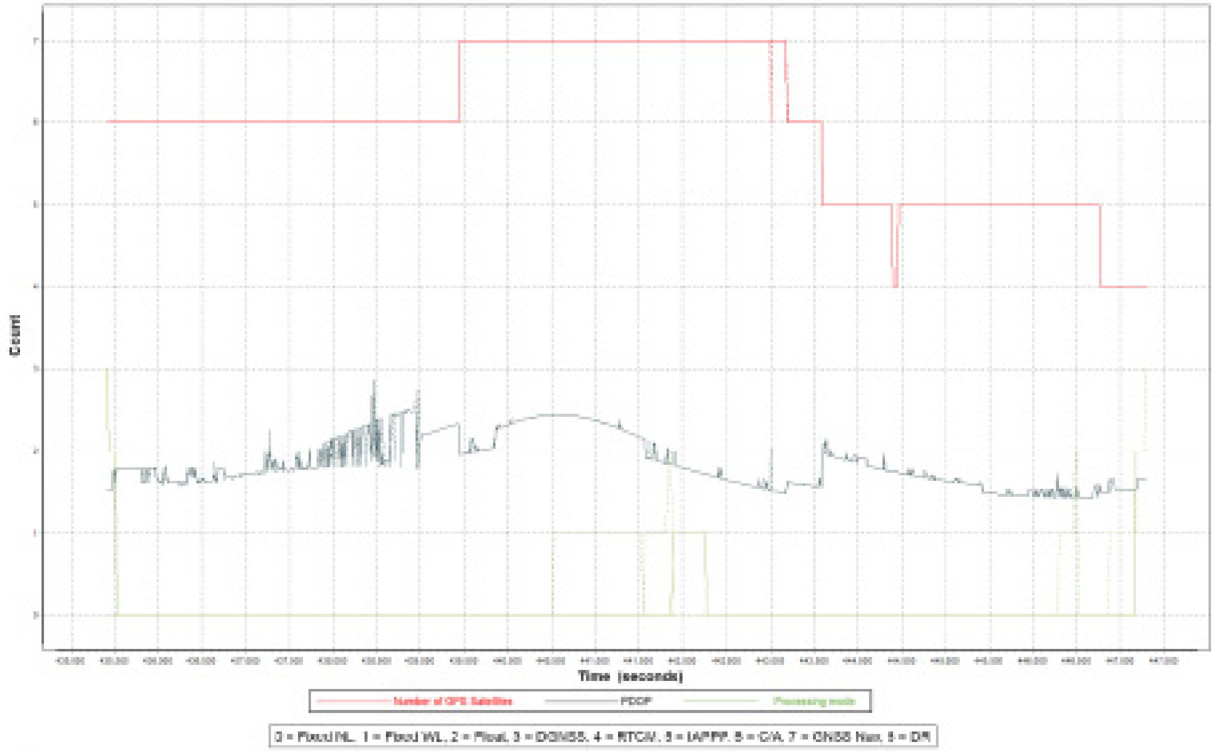

Figure 12. The Solution Status Parameters of Anahawin Flight 1156A.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Anahawin Flight 1156A are shown in Figure 12. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 5 and 7, not going lower than 4. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also stayed at the value of 0 for the majority of the survey, with some observed peaks of up to 2, which were 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 the POSPAC MMS. Fundamentally, 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 Anahawin flights is shown in Figure 13.

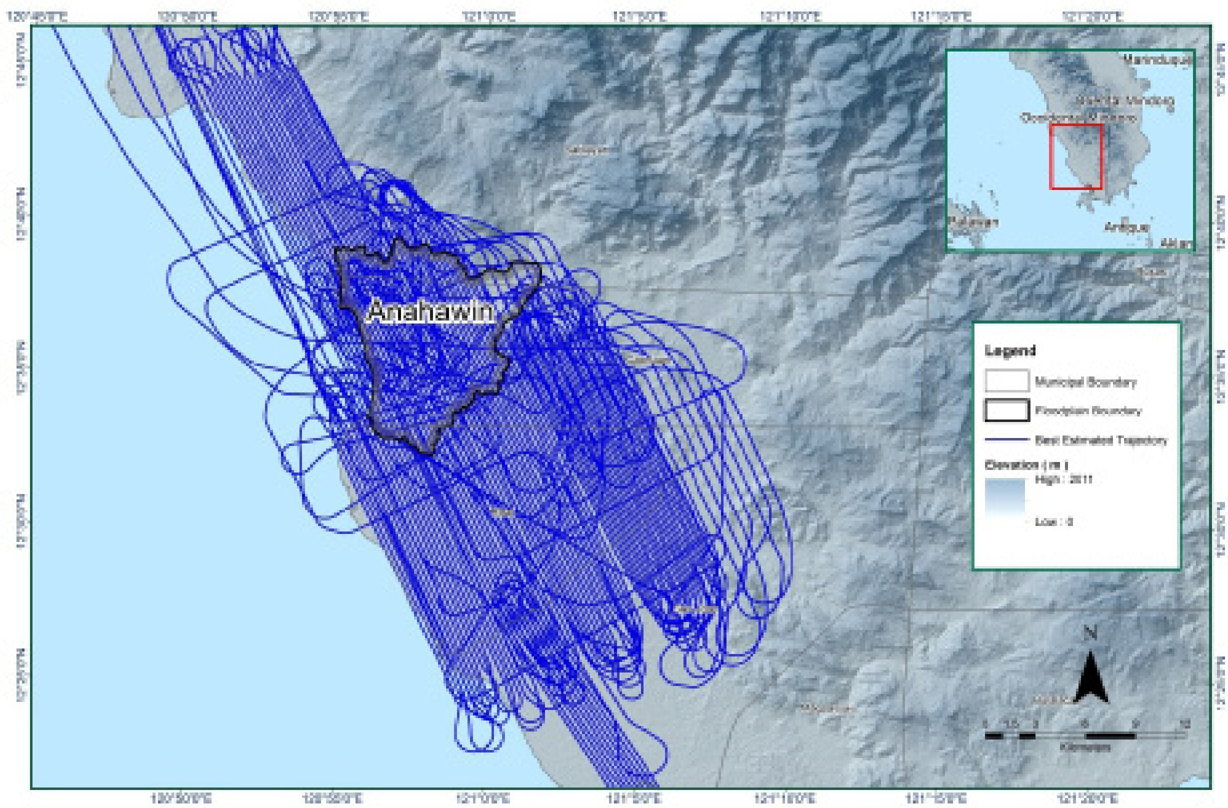

Figure 13. The Best Estimated Trajectory of LiDAR missions conducted over the Anahawin Floodplain.

3.4 LiDAR Point Cloud Computation

The data generated in LAS contains 82 flight lines, 74 of these flight lines contains one channel, since the Aquarius system contains only one channel and 8 of these flight lines contains two channels, since the Pegasus system contains two channels. Illustrated in Table 13 is the summary of the Self-Calibration Results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Anahawin Floodplain.

Table 13. Self-calibration values for all Anahawin Floodplain flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000557
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000902
GPS Position Z-correction stdev)	<0.01meters	0.0027

The optimum accuracy values for all Anahawin flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (0).

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of the SAR Elevation Data over the Anahawin Floodplain are depicted in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

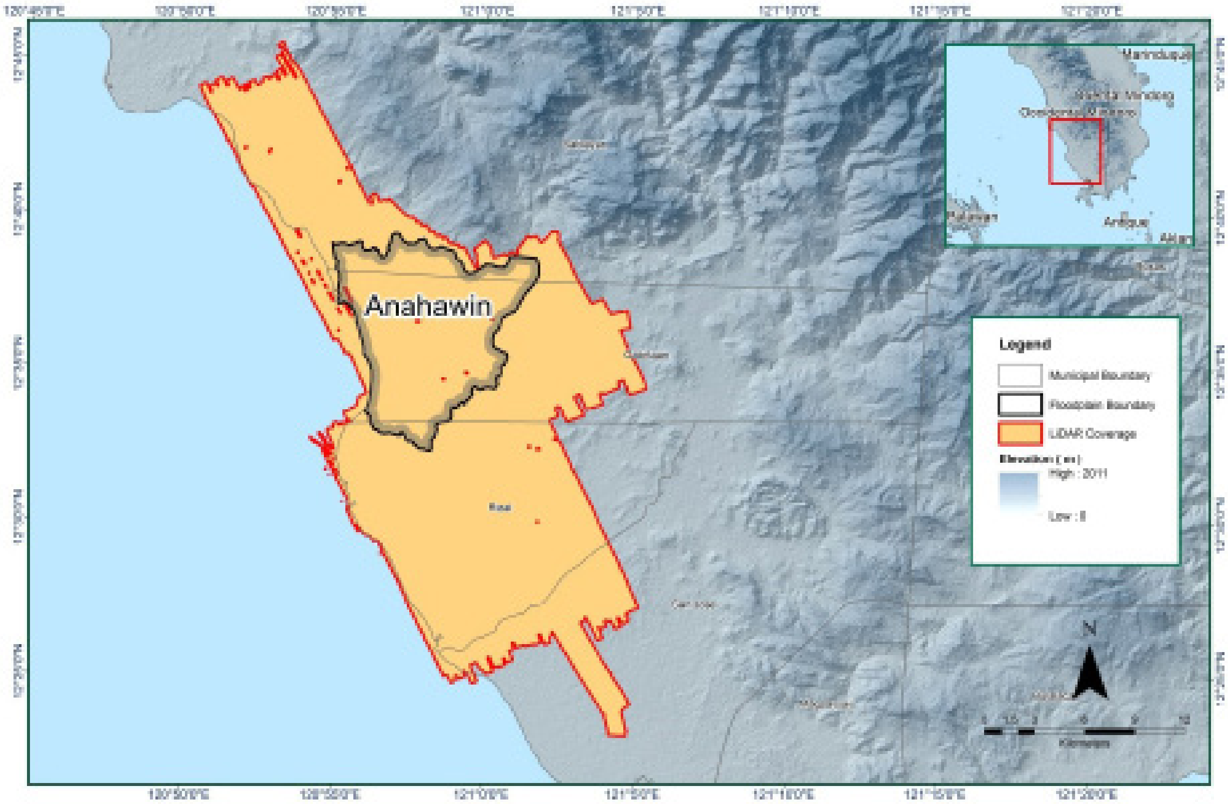

Figure 14. The boundaries of the processed LiDAR data over the Anahawin Floodplain.

A total area of 529.16 square kilometers (sq. kms.) were covered by the Anahawin flight missions as a result of eight (8) flight acquisitions, which were grouped and merged into six (6) blocks accordingly, as portrayed in Table 14.

Table 14. List of LiDAR blocks for the Anahawin Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29D	1152A	89.07
	1154A	
	1162A	
OccidentalMindoro_Blk29E	1138A	65.74
OccidentalMindoro_Blk29E_supplement	1140A	31.98
OccidentalMindoro_Blk29F	1156A	112.31
OccidentalMindoro_Blk29P	1142A	106.52
OccidentalMindoro_Reflights_Blk29G_additional	3074P	123.54
TOTAL		**529.16**

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

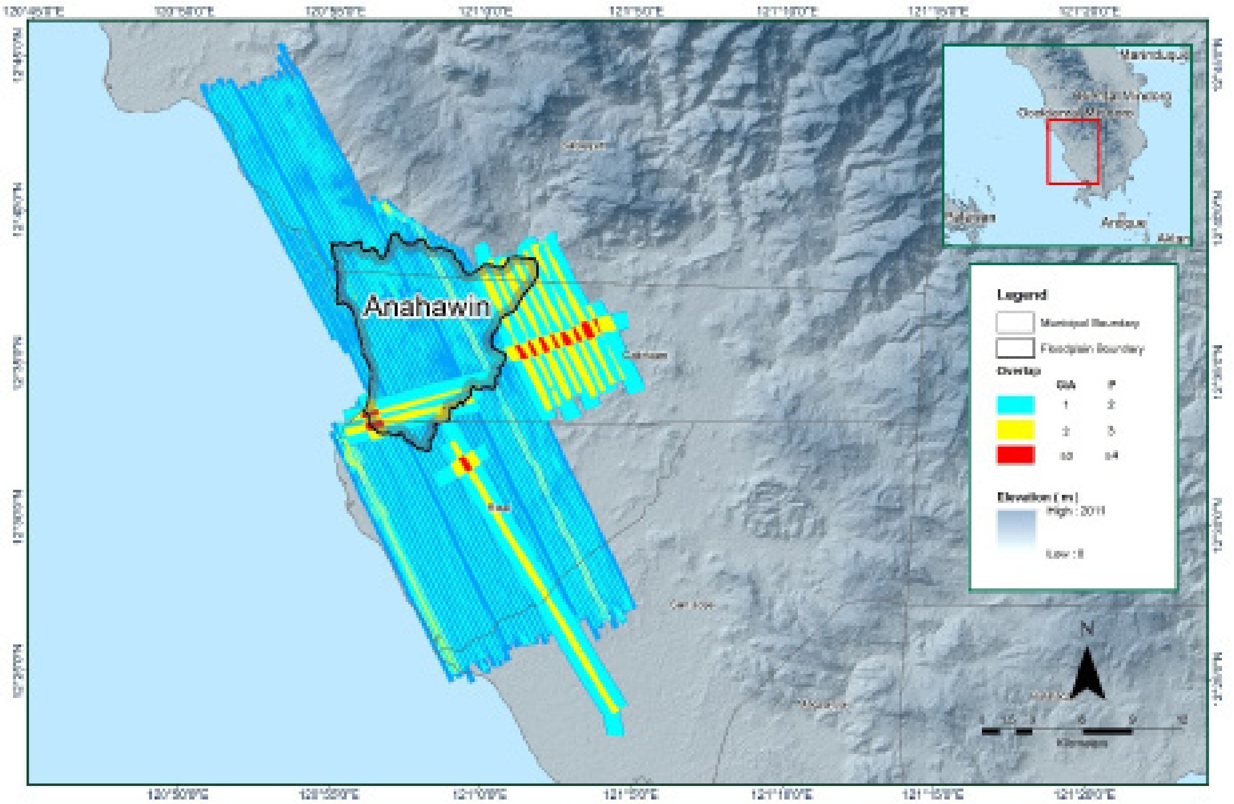

Figure 15. Data overlap between missions and flight lines for the Anahawin River Floodplain Survey.

The overlap statistics per block for the Anahawin Floodplain Survey can be found in Annex 8: Mission Summary Reports. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.26% and 51.63% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data is shown in Figure 16, where portions of the data that satisfy the two (2) points per square meter criterion are highlighted in red. As seen in the figure below, it was determined that all LiDAR data for the Anahawin Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.28 points per square meter.

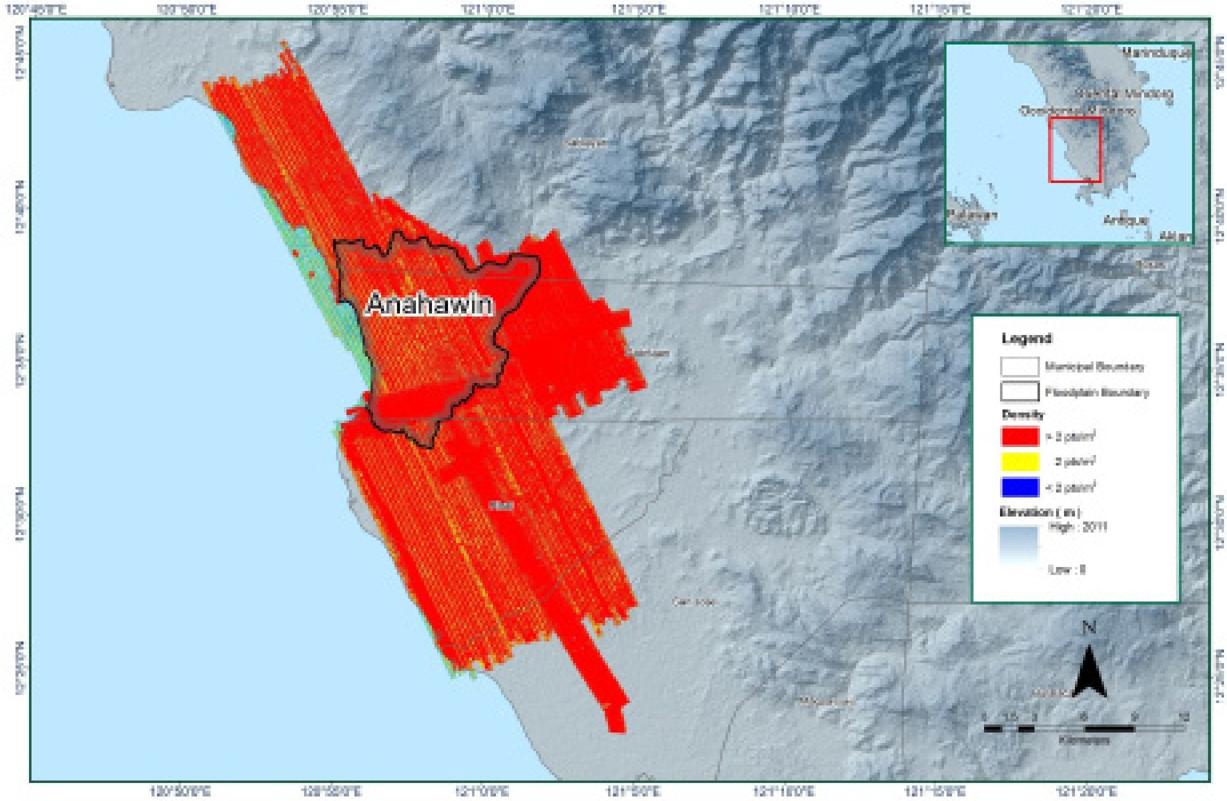

Figure 16. Pulse density map of the merged LiDAR data for the Anahawin Floodplain Survey.

The elevation difference between overlaps of adjacent flight lines in shown in Figure 17. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which are relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

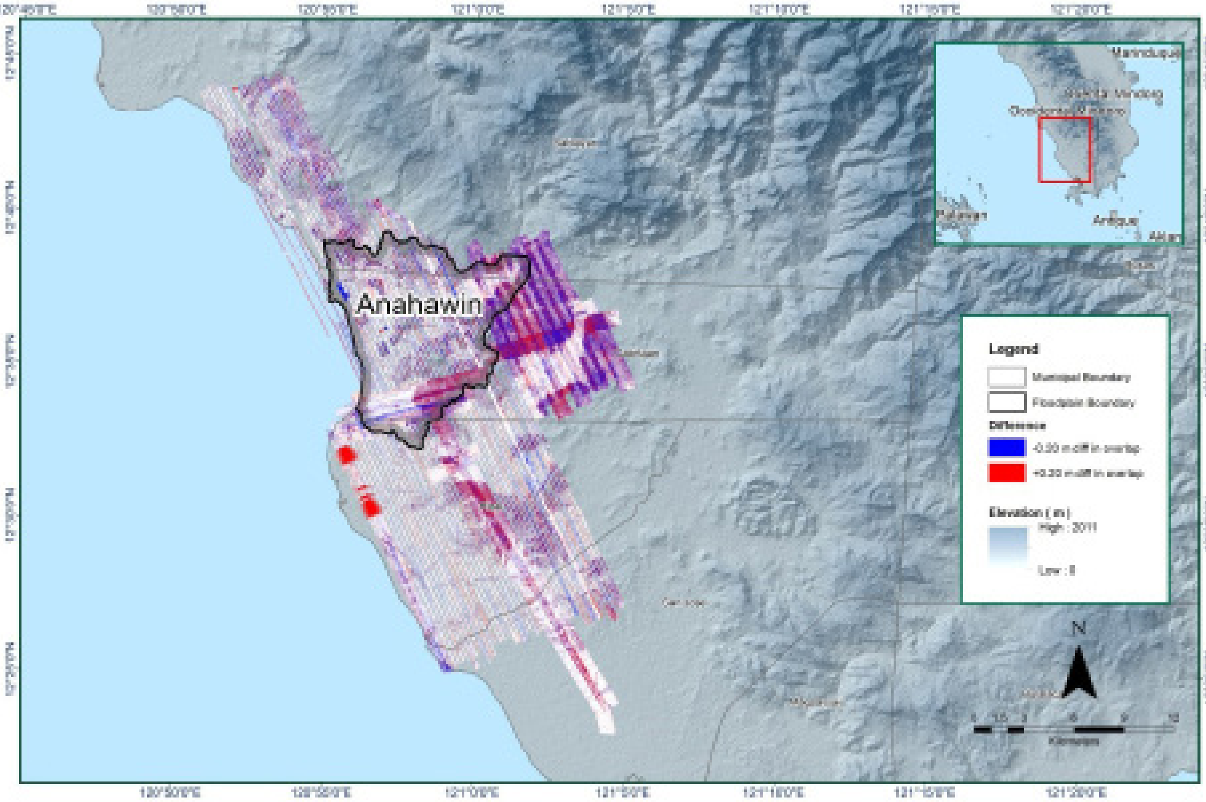

Figure 17. Map of elevation difference Map between flight lines for the Anahawin Floodplain Survey.

The screen-capture of the processed LAS data from Anahawin Flight 1156A loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

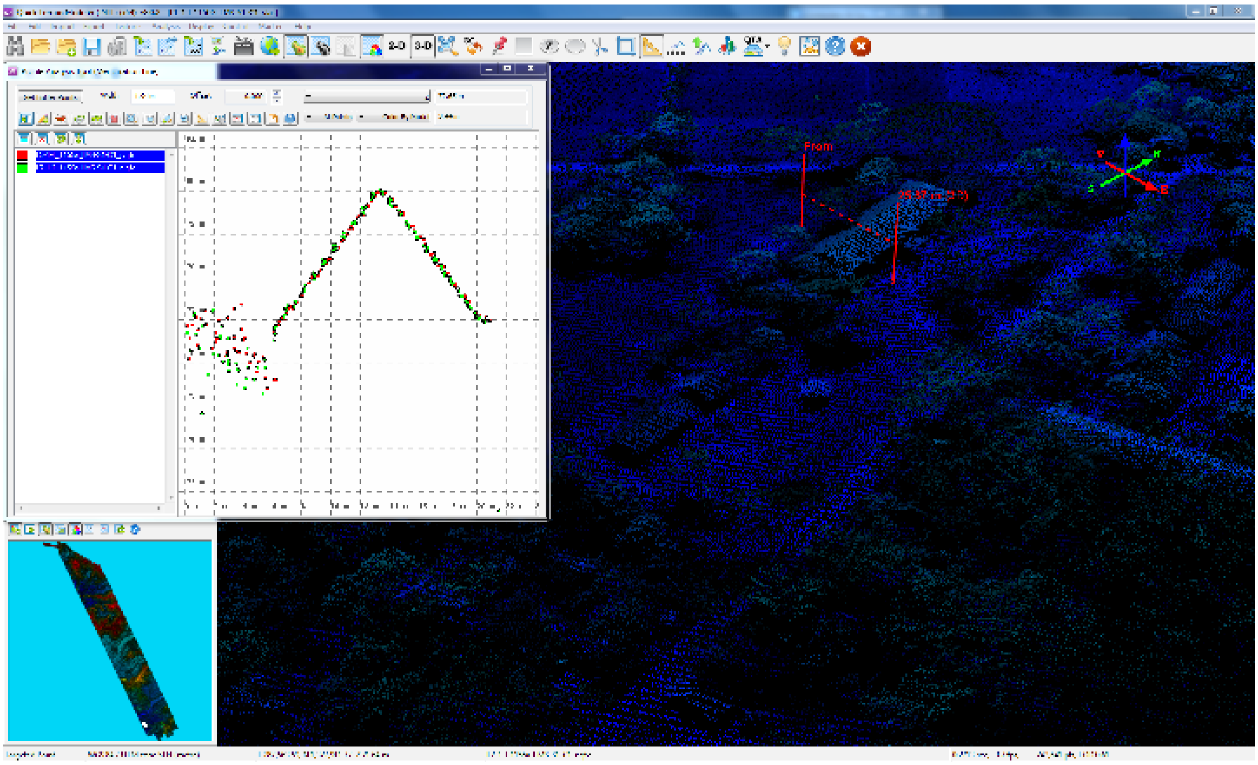

Figure 18. Screen-capture of the quality checking for Anahawin Flight 1156A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Summary of point cloud classification results in TerraScan for Anahawin River Floodplain.

Pertinent Class	Total Number of Points
Ground	435,987,559
Low Vegetation	458,889,143
Medium Vegetation	390,666,975
High Vegetation	694,566,509
Building	16,172,085

Figure 19 shows the tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Anahawin Floodplain Survey. As shown in the figure, a total of 798 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 15 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 544.26 meters and 41.75 meters respectively.

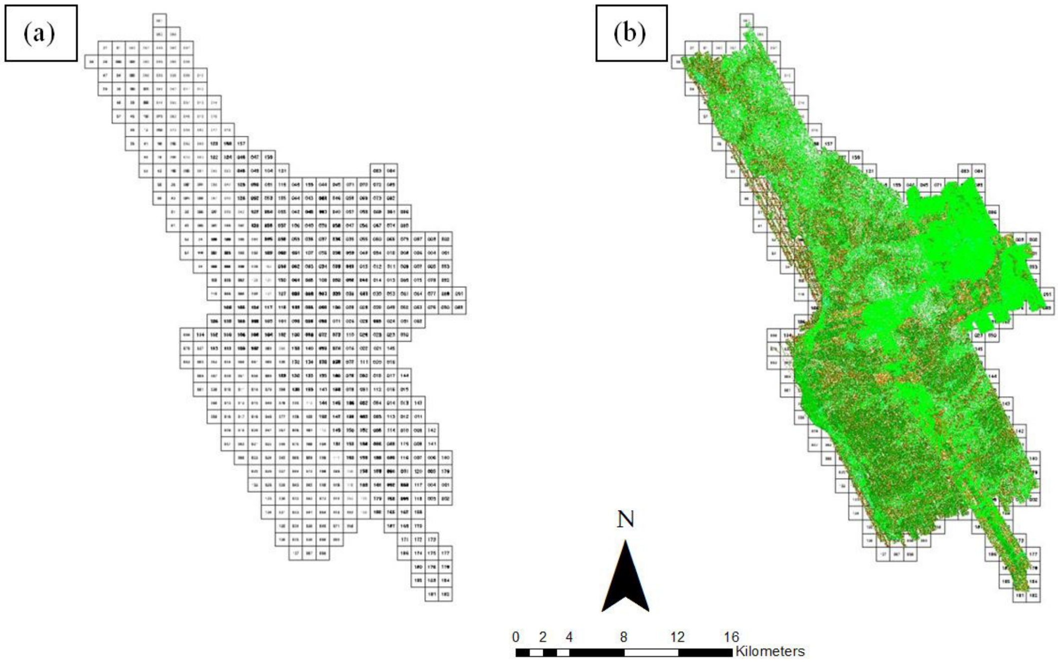

Figure 19. The coverage of the Anahawin Floodplain Survey(a) the tile system (b) depicts the classification results in TerraScan.

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

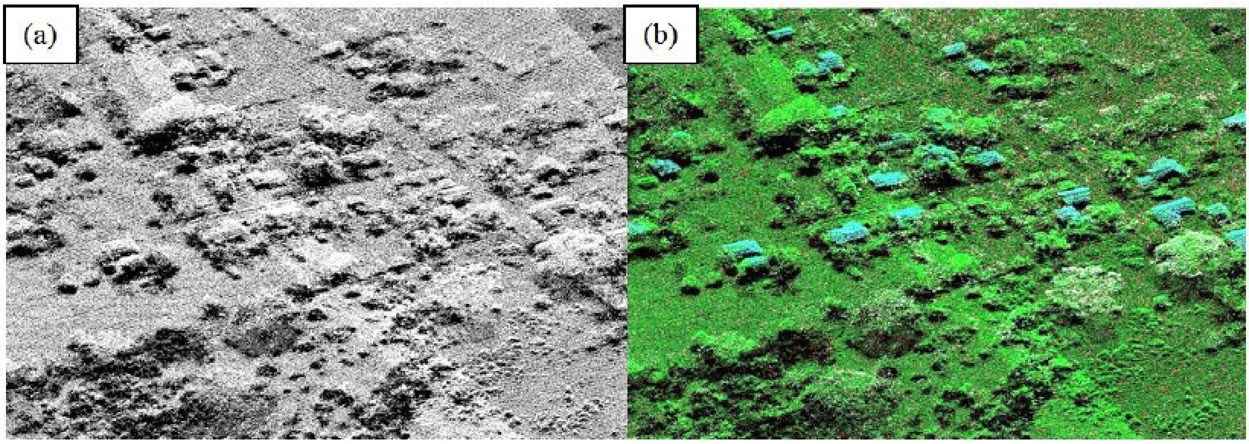

Figure 20. The images before (a) and after (b) undertaking classification.

Correspondingly, Figure 21 shows the production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display. As seen in the figure, the DTMs represent the bare earth, while all other features, such as buildings and vegetation, are present in the DSMs.

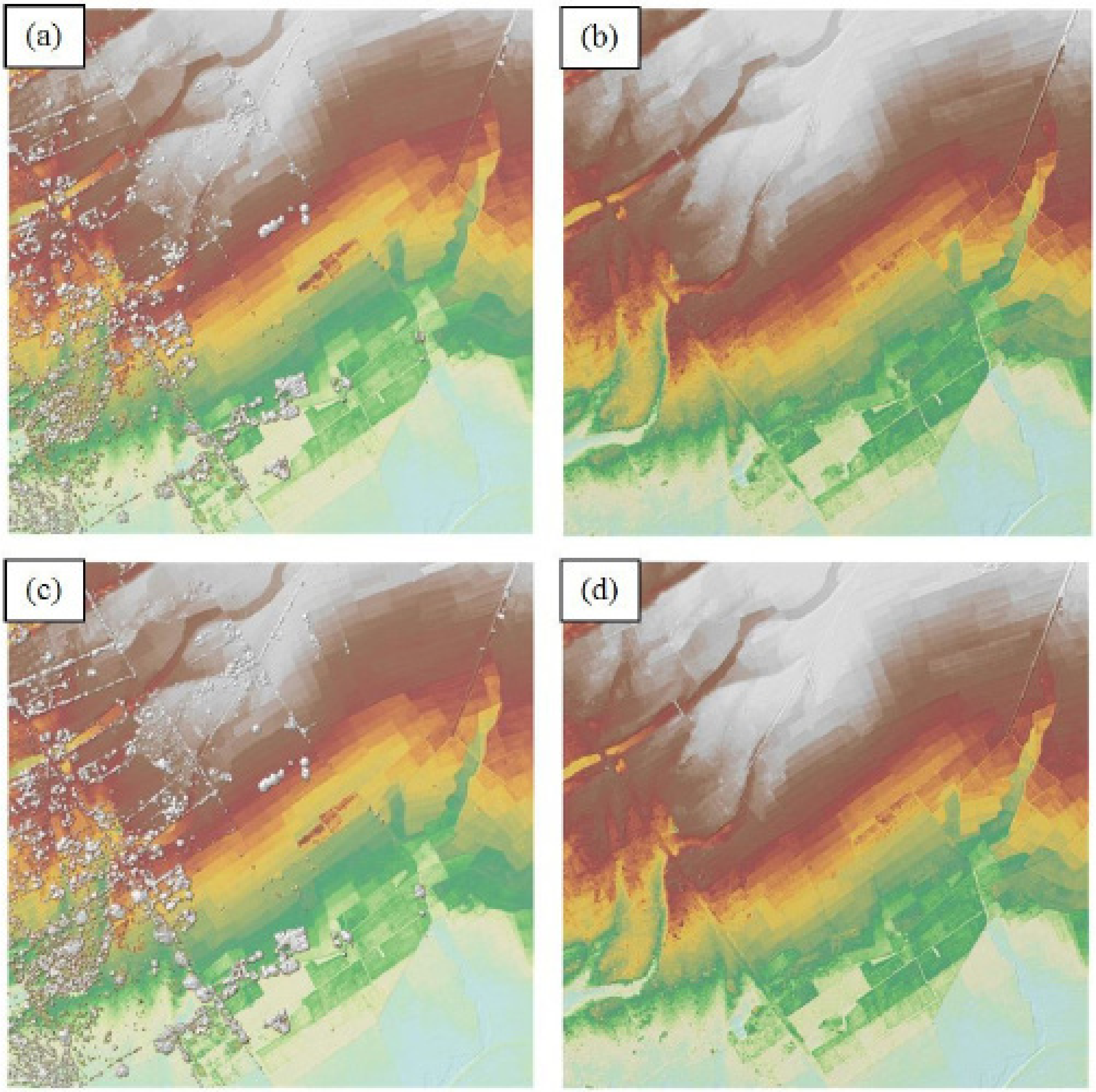

Figure 21. Photo (A) features the production of the last return DSM; (B) depicts the production of the DTM; (C) portrays the production of the first return DSM; and (D) presents the generation of the secondary DTM in some portions of the Anahawin Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

To fix photo misalignments, a tie point selection was done. Color points were then added to smooth out any visual inconsistencies along the seam lines where photos overlap. The Anahawin floodplain furvey attained a total of 402.23 sq. kms. in orthophotograph coverage, comprised of 3,748 images. Figure 22 shows the area covered by the Anahawin Floodplain Survey featuring 798 1 km. X 1 km. tiles. Figure 23 on the other hand, depicts a zoomed-in version of sample orthophotographs named in reference to its tile number.

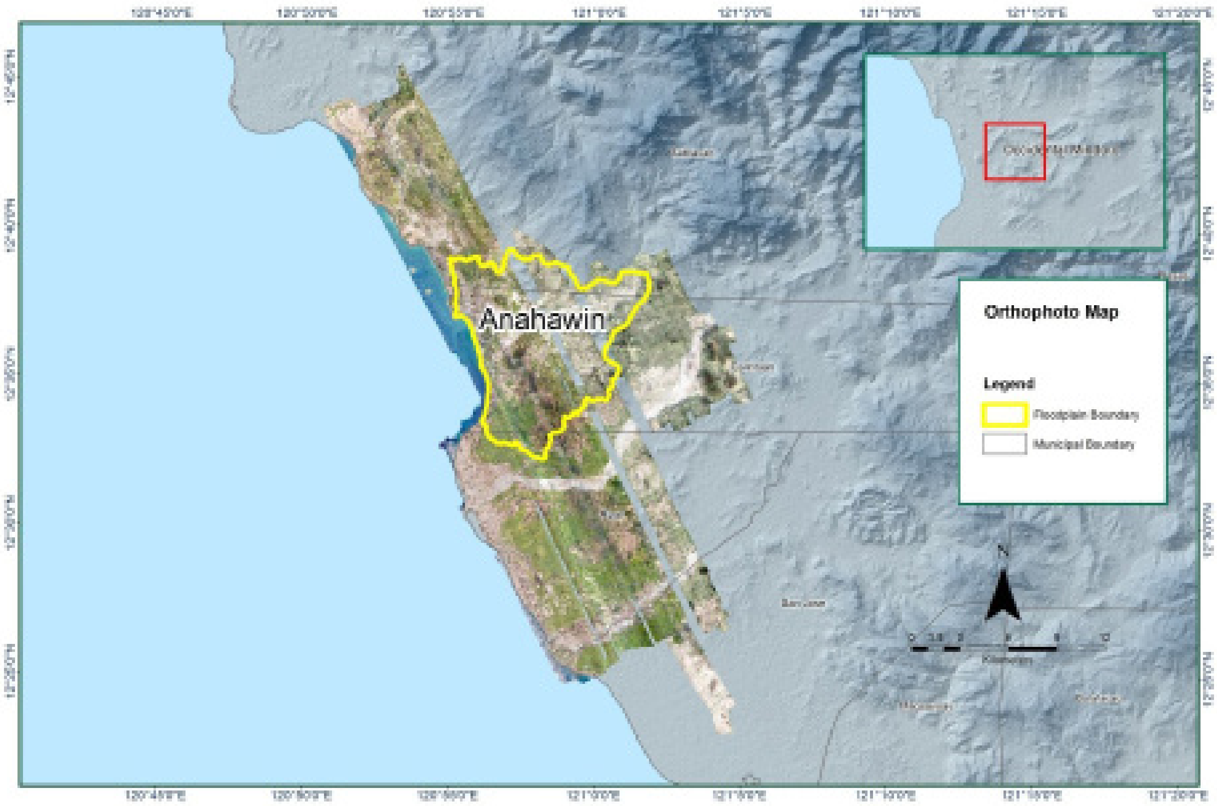

Figure 22. The Anahawin Floodplain with the available orthophotographs.

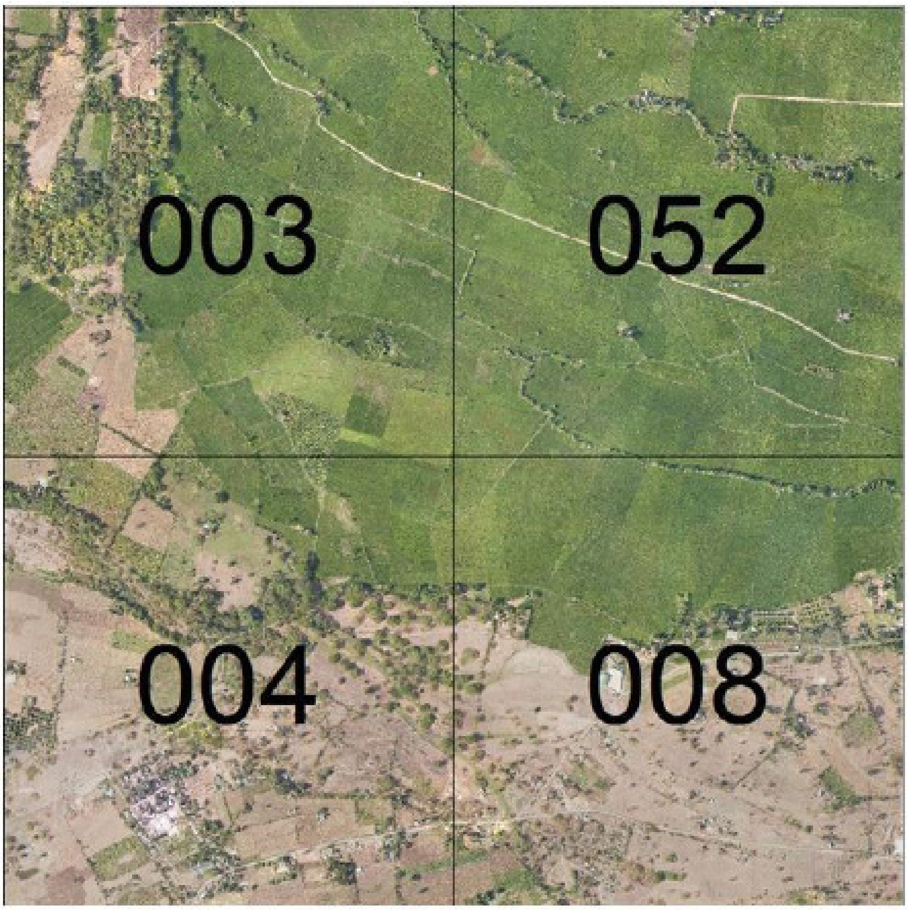

Figure 23. Sample orthophotograph tiles for the Anahawin Floodplain.

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for the Anahawin Floodplain Survey. Essentially, these blocks are composed of 'Occidental Mindoro' and 'Occidental Mindoro Reflight' blocks, which arrive at a total area of 529.16 sq. kms. As listed in Table 16, the name and corresponding area of each block are measured out in square kilometers (sq. kms.).

Table 16. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq. km.)
OccidentalMindoro_Blk29D	89.07
OccidentalMindoro_Blk29E	65.74
OccidentalMindoro_Blk29E_supplement	31.98
OccidentalMindoro_Blk29F	112.31
OccidentalMindoro_Blk29P	106.52
OccidentalMindoro_Reflights_Blk29G_ additional	123.54
TOTAL	**529.16 sq.km**

Figure 24 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 24a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 24b). Likewise, the pit (Figure 24c) was misclassified and removed during the classification process. To complete the surface, the pit (Figure 24d) was retrieved and reclassified through manual editing to allow the correct water flow. As well, a lone building (Figure 24e) was still present in the DTM after the classification process. To correct this, the building was removed through manual editing (Figure 24f).

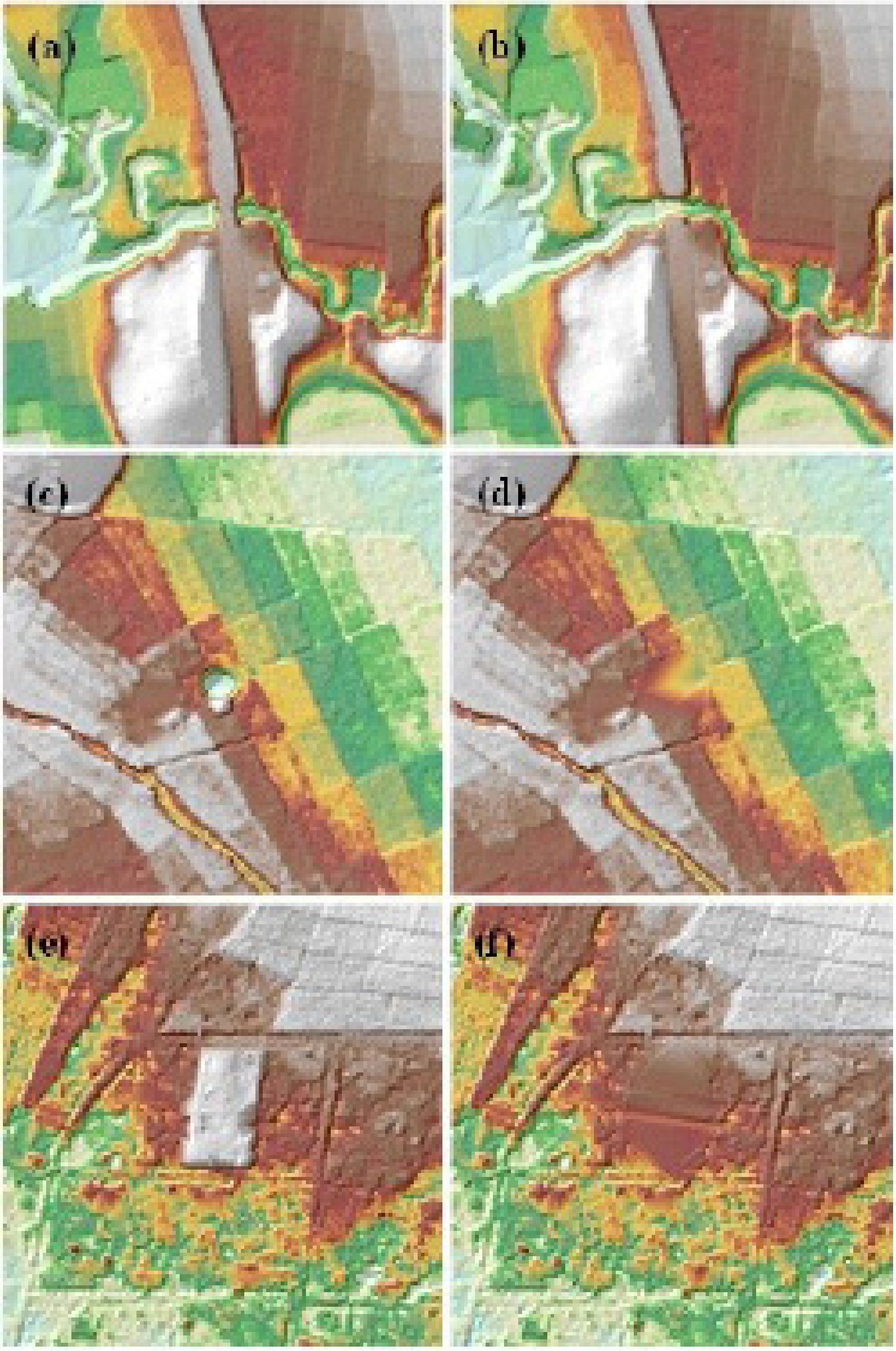

Figure 24. Portions in the DTM of the Anahawin Floodplain showing (a) a bridge before undergoing manual editing, while (b) after manual editing; (c) shows a pitfield before manual editing; (d) pit after data retrieval; (e) a building before manual editing, while (f) after manual editing.

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. Correspondingly, Table 17 shows the shifts in values applied to each LiDAR block during mosaicking. Figure 25 shows the mosaicked LiDAR DTM for the Anahawin Floodplain, which further elucidated that the LiDAR Acquisition was able to cover 99.8% of the Anahawin Floodplain.

Table 17. Shift values of each LiDAR block of Anahawin Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29D	0.00	0.00	-0.76
OccidentalMindoro_Blk29E	0.00	0.00	-1.18
OccidentalMindoro_Blk29E_supplement	0.00	0.00	-0.48
OccidentalMindoro_Blk29F	0.00	0.00	-0.55
OccidentalMindoro_Blk29P	0.00	0.00	-0.65
OccidentalMindoro_Reflights_Blk29G_additional	0.00	0.00	-1.51

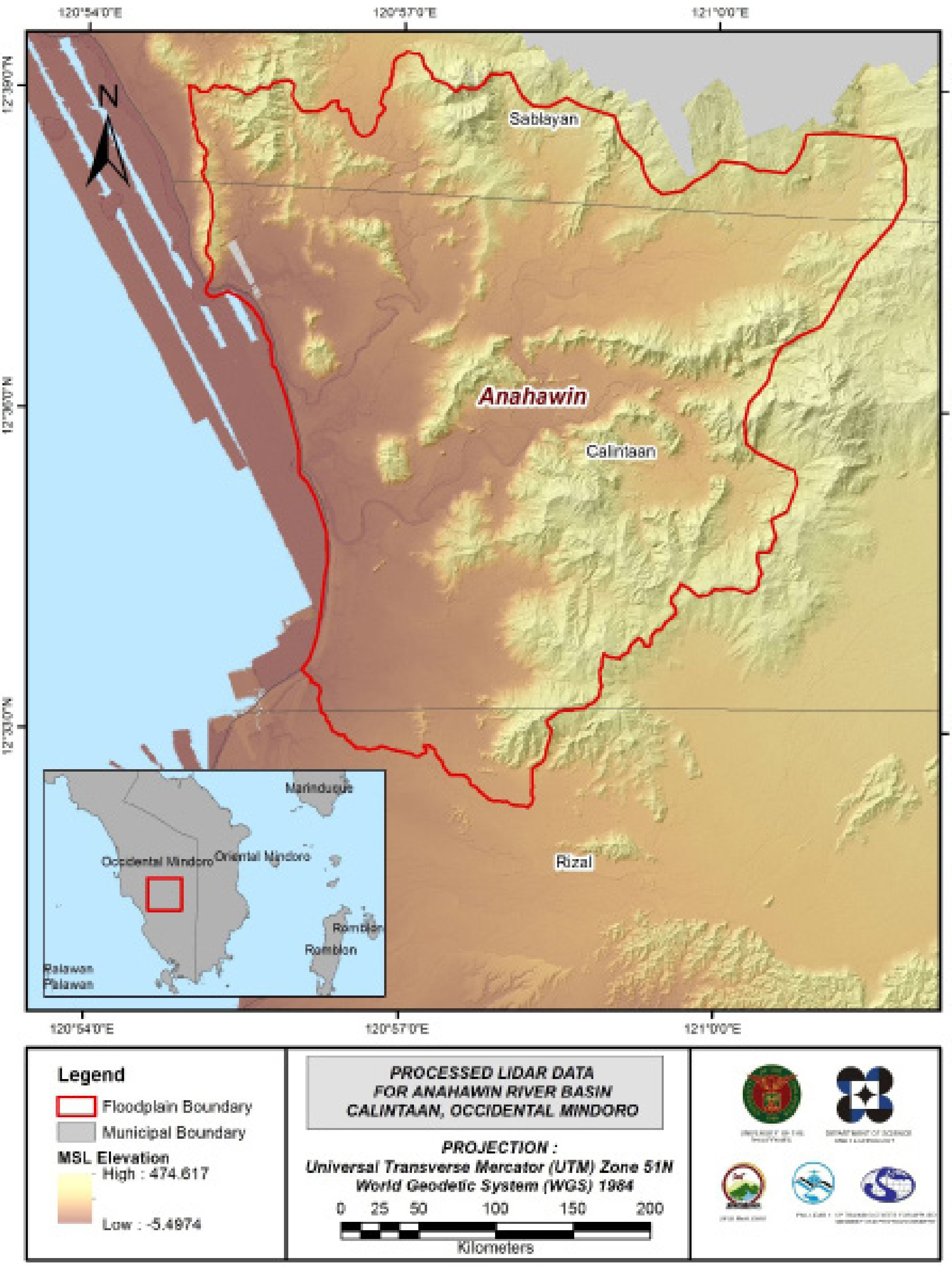

Figure 25 . Map of processed LiDAR data for the Anahawin Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Anahawin to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 28,494 survey points were gathered for all the flood plains within Occidental Mindoro wherein the Anahawin 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 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Anahawin LiDAR data was done by adding the height difference value, 0.23 meters, to Anahawin mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

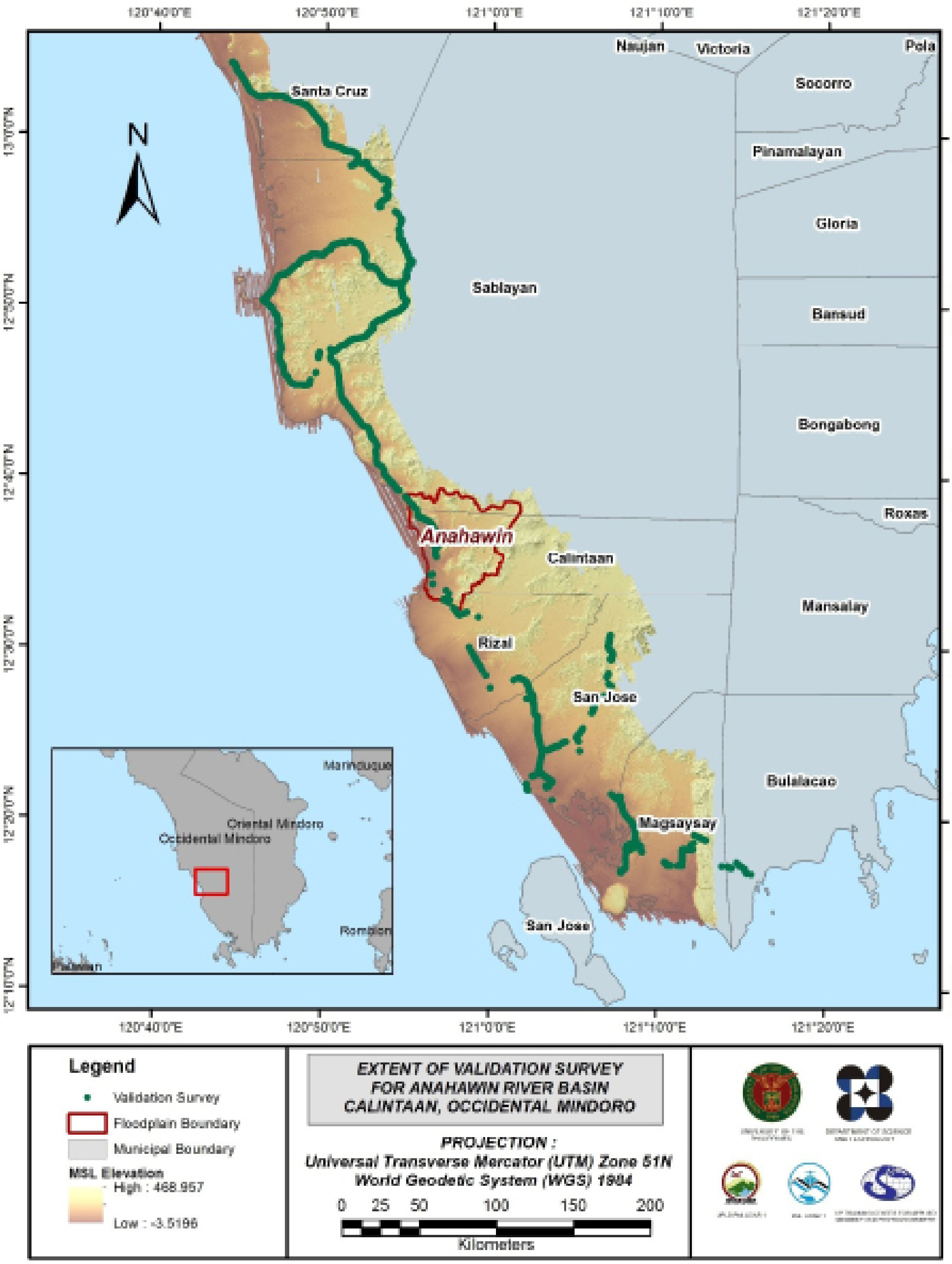

Figure 26. Map of Anahawin Floodplain with validation survey points in green.

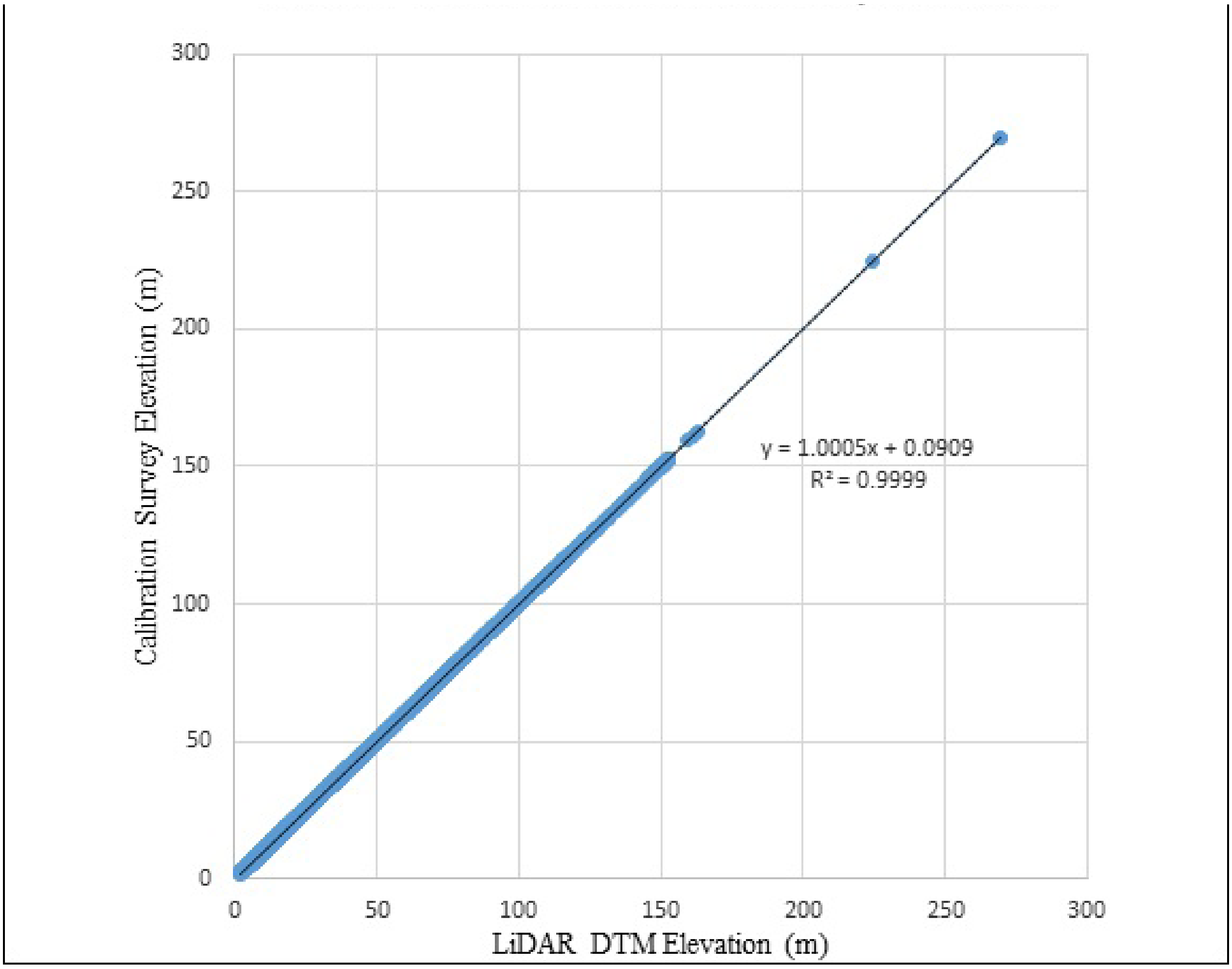

Figure 27. The correlation plot between calibration survey points and LiDAR data.

Table 18. The calibration statistical measures of the compared elevation values between the Anahawin LiDAR data and the calibration data.

Calibration Statistical Measures	Value (meters)
Height Difference	0.18
Standard Deviation	0.18
Average	0.02
Minimum	-0.34
Maximum	0.38

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 141 points. These were used for the validation of calibrated Anahawin DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.16 meters, as shown in Table 19.

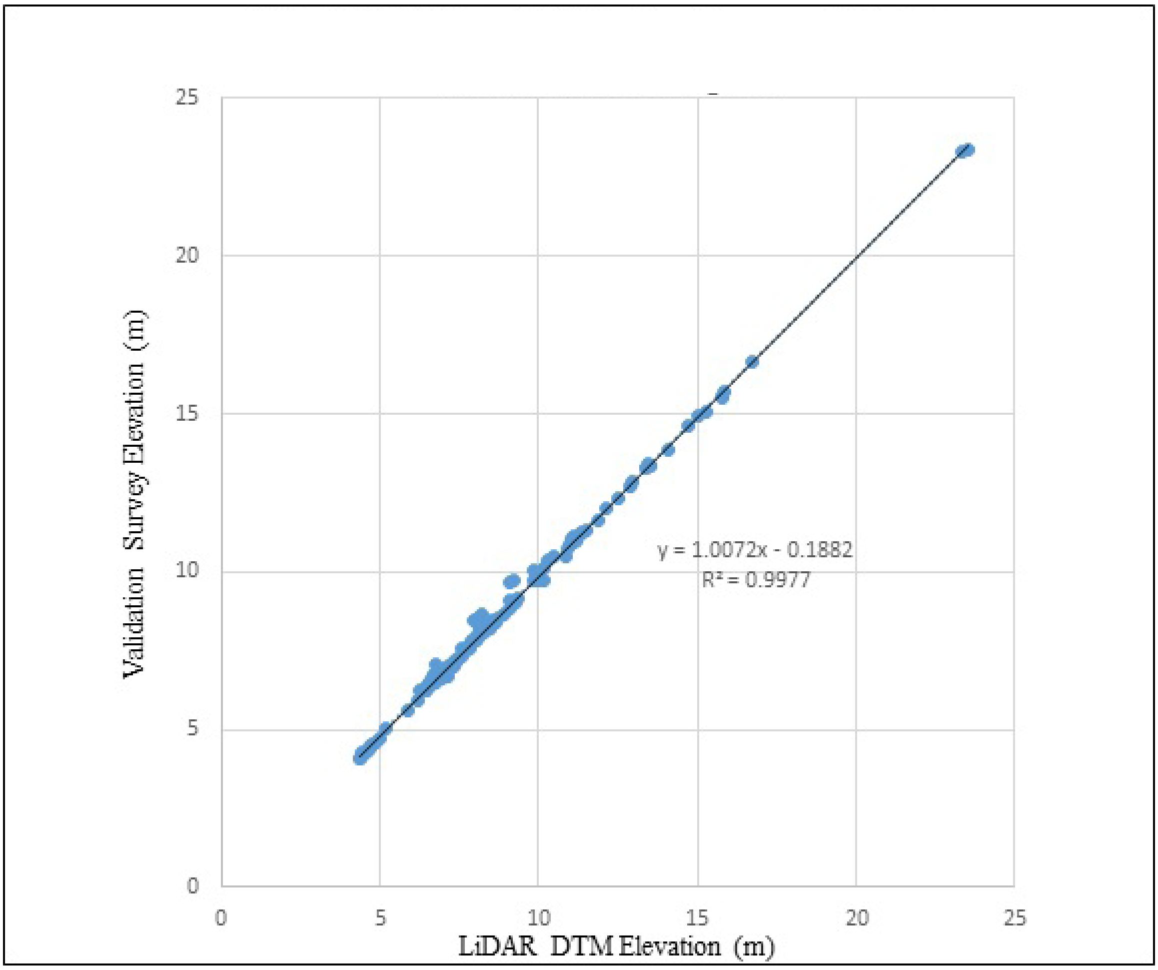

Figure 28. Correlation plot between the validation survey points and the LiDAR data.

Table 19. Statistical measures for the Anahawin River Basin DTM validation.s

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.16
Average	-0.12
Minimum	-0.44
Maximum	0.55

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathymetric data integration, centerline and zigzag data were available for Anahawin with a total of 6,976 survey points and 1,531 points, respectively. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.38 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Anahawin integrated with the processed LiDAR DEM is shown in Figure 29.

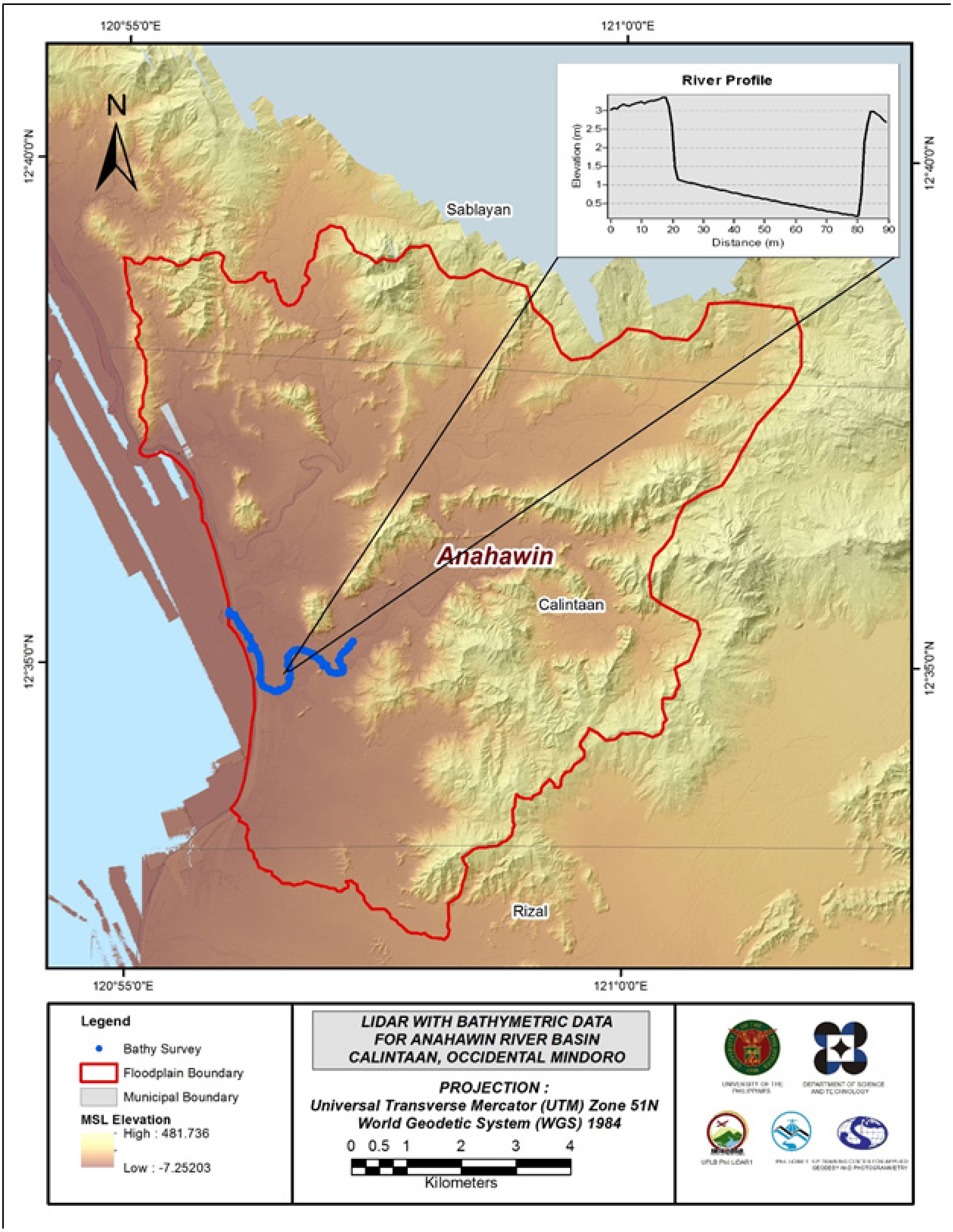

Figure 29. Map of Anahawin Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field survey in Anahawin River on November 3-24, 2015 with the following scope of work: reconnaissance to determine the viability of traversing the planned routes for bathymetric survey; courtesy call with UPLB, Rizal and Calintaan LGUs and MDRRMC; control survey; cross-section survey at the upstream with coordinates Lat 12d34’57.99417” N and Long 120d57’03.08663”E, and downstream with coordinates Lat 12d34’59.56130” N and Long 120d57’01.47479”E of Anahawin Bridge; ground validation survey along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate distance of 191 km. Lastly, bathymetric survey from Brgy. Poypoy down to the mouth of the river in Brgy. Iriron, with an approximate length of 4.611 km using GNSS PPK survey technique.

Figure 30. Extent of the bathymetric survey (in blue line) in Anahawin River and the LiDAR data validation survey (red).

4.2 Control Survey

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

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

Table 20 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Anahawin River Survey.

Figure 31. The GNSS Network established in the Anahawin River Survey.

Table 20. References used and control points established in the Anahawin River Survey (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

Figure 32 to Figure 40 depict the setup of the GNSS on recovered reference points and established control points in the Occidental Mindoro Survey.

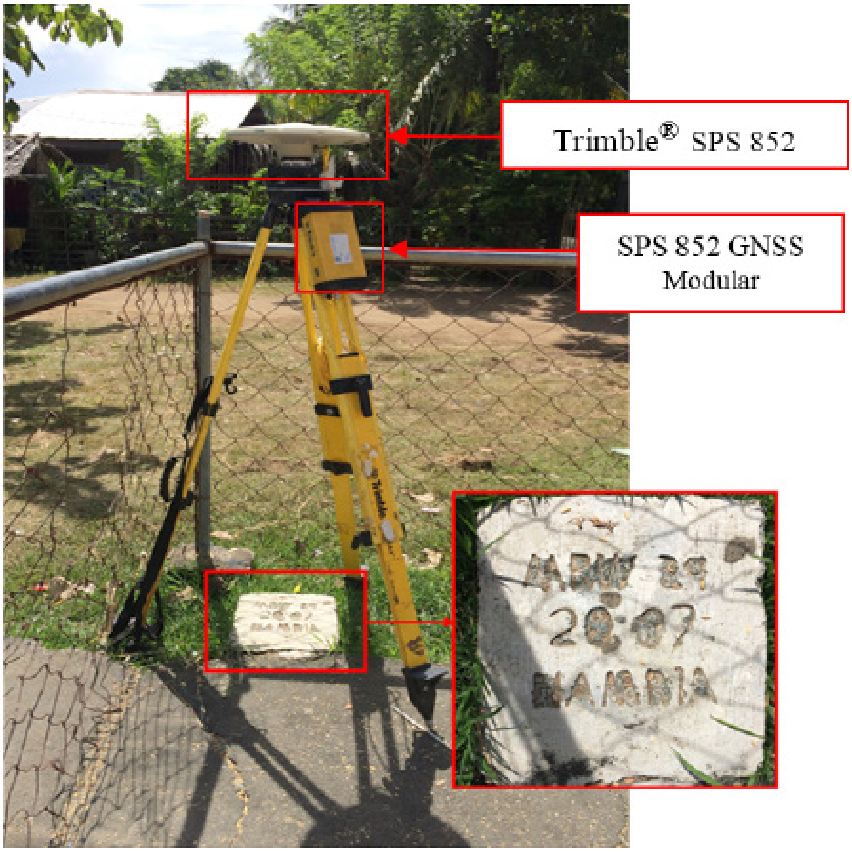

Figure 32. The GNSS base receiver setup, Trimble® SPS 852, at MRW-24, located in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro.

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

Figure 34. The GNSS (Trimble® SPS 882) receiver occupation, at MC-200 30 located at the approach of Lumintao Bridge in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

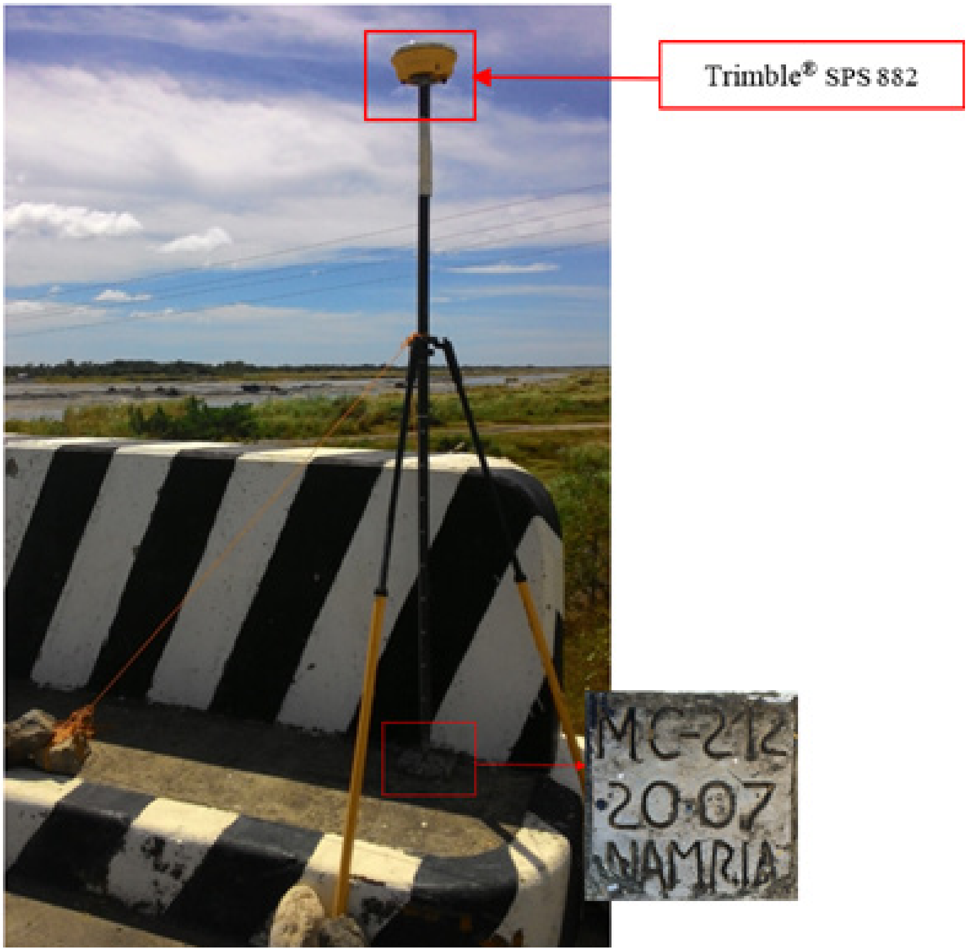

Figure 35. The GNSS (Trimble® SPS 852) base occupation at MC-212, located at the approach of Busuanga Bridge in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

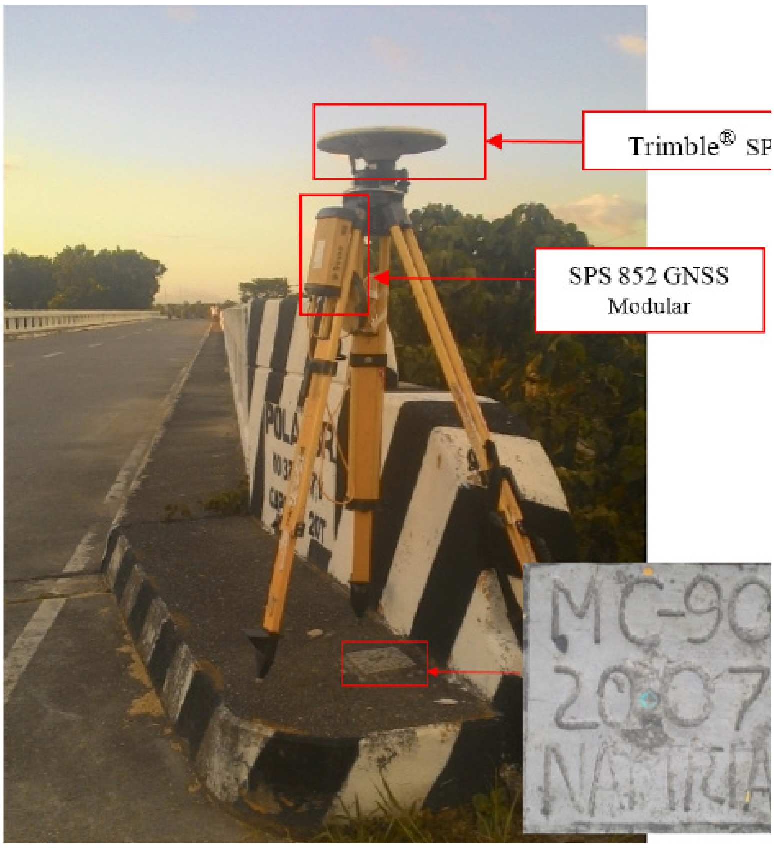

Figure 36. The GNSS (Trimble® SPS 852) base occupation at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

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

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

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

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

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 25 presents the baseline processing results of control points in the Anahawin River Basin, as generated by the TBC software.

Table 21. The Baseline processing report for the Anahawin River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec.	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

As shown in Table 21, a total of twenty-one (21) baselines were processed with the coordinates of MRW-24 and MRW-30, and the elevation value of reference points MC-200 and MC-212 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. 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 for each control point; or in equation form:

$$\sqrt{((Xe)^2+(Ye)^2)} < 20cm \text{ and } Ze < 10\ cm$$

where:

Xe is the Easting Error,
Ye is the Northing Error, and
Ze is the Elevation Error

For complete details, see the Network Adjustment Report shown in Table 26 to Table 29.

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 21.

Table 22. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SE-85	Grid				Fixed
SME-18	Local	Fixed	Fixed		
MRW-24	Global	Fixed	Fixed		
MRW-30	Global	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

Likewise, the list of adjusted grid coordinates (i.e. Northing, Easting, Elevation, and computed standard errors of the control points in the network) is indicated in Table 23. All fixed control points have no values for grid and elevation errors.

Table 23. Adjusted grid coordinates for the control points used in the Anahawin River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SE-49	776407.626	0.007	1240340.446	0.005	3.779	0.050	
SE-85	777079.164	0.006	1262825.941	0.004	6.310	?	e
SM-33S	741264.593	0.010	1230815.204	0.007	3.951	0.061	
SME-12	757572.894	0.007	1230490.556	0.005	2.721	0.051	
SME18	784907.431	?	1257282.043	?	17.660	0.032	LL
SMR-3322	731377.313	0.009	1249392.087	0.007	6.636	0.060	
UP-CNG	766068.484	0.005	1282999.389	0.004	6.035	0.036	

The results of the computation for accuracy are as follows:

a. GPS-4

Horizontal accuracy	=	$\sqrt{((3.9)^{2} + (3.2)^{2}}$
	=	$\sqrt{(15.21 + 10.24)}$
	=	5.0 cm < 20 cm
Vertical accuracy	=	6.8 cm < 10 cm

b. MC-200

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

c. MC-212

Horizontal accuracy	=	$\sqrt{((2.8)^{2} + (2.2)^{2}}$
	=	$\sqrt{(7.84+ 4.84)}$
	=	3.6 cm < 20 cm
Vertical accuracy	=	Fixed

d. MC-90

Horizontal accuracy	=	$\sqrt{((3.9)^{2} + (2.3)^{2}}$
	=	$\sqrt{(15.21 + 5.29)}$
	=	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	=	$\sqrt{((2.0)^{2} + (1.5)^{2}}$
	=	$\sqrt{(4.0 + 2.25)}$
	=	2.5 cm < 20 cm
Vertical accuracy	=	7.1 cm < 10 cm

h. UP-MOM

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

i. UP-PIN

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

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

Table 24. Adjusted geodetic coordinates for control points used in the Anahawin River Floodplain validation.

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-CNG	N11°35'44.92939"	E125°26'23.62776	78.217	0.032	
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 24. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Anahawin River GNSS Static Survey are seen in Table 25.

Table 25. The reference and control points utilized in the Anahawin River Static Survey, with their corresponding locations (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)
MC-200	1st order, BM	12°31'20.68883"	120°59'15.31614"	83.225	1385155.121	281320.527	34.024
MC-212	1st order, BM	12°28'03.07504"	121°02'10.26310"	74.473	1379041.958	286558.124	24.884
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MC-90	UP Established	13°03'34.14426"	120°44'46.70845"	53.232	1444800.407	255607.924	8.195
UP-ALI	UP Established	12°52'30.24358"	120°48'29.69148"	55.998	1424334.041	262152.459	9.503
UP-MOM	UP Established	12°50'07.47192"	120°54'49.30854"	144.013	1419850.456	273564.872	96.192
UP-PIN	UP Established	12°22'07.55000"	121°05'54.64323"	59.843	1368066.413	293256.669	9.659
GPS-4	DPWH Established	12°18’07.55700”	121°09’08.74194”	62.706	1360649.962	299069.894	12.062

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

The bridge cross-section survey was conducted on November 19, 2015 at the upstream and downstream side of Anahawin Bridge in Brgy. Poblacion, Municipality of Calintaan using GNSS receiver Trimble® SPS 882 in PPK Survey Technique (Figure 41). Bridge As-built and water level marking cannot be executed due to the on-going Anahawin Bridge construction during the survey.

Figure 41. The Cross-section survey conducted at the downstream side of Anahawin Bridge, Brgy.Poblacion, Municipality of Calintaan

The length of the cross-sectional line surveyed in Anahawin River is about 68.084 meters with ninety-four (94) cross-sectional points at the upstream side while 80.182 meters with 121 cross-sectional points on the downstream side using MRW-24 as the GNSS base station. The cross-section diagram and planimetric map are shown in Figure 42 to Figure 44. An automated water level sensor is found installed in the bridge.

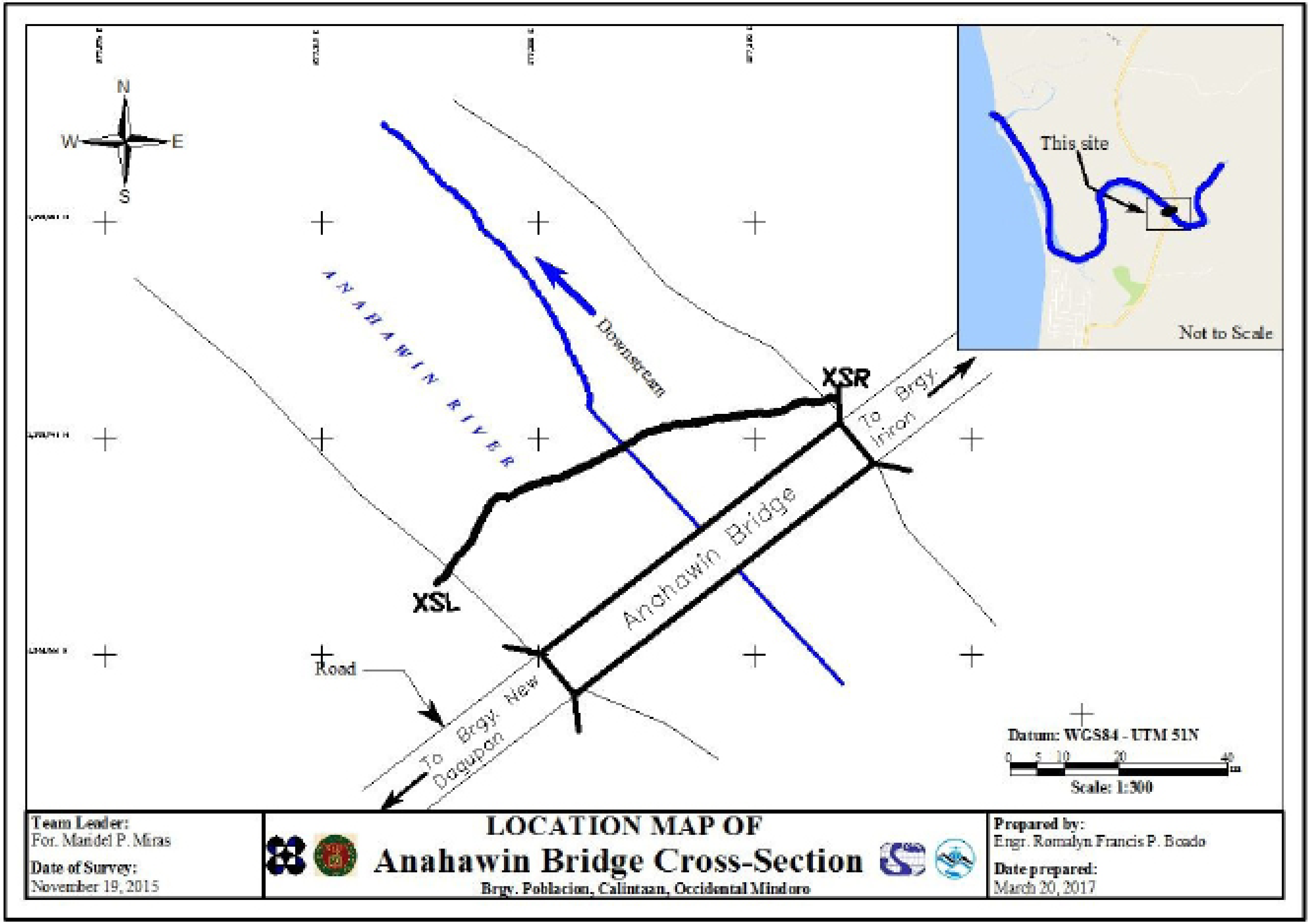

Figure 42. Location map of the Anahawin Bridge cross-section survey.

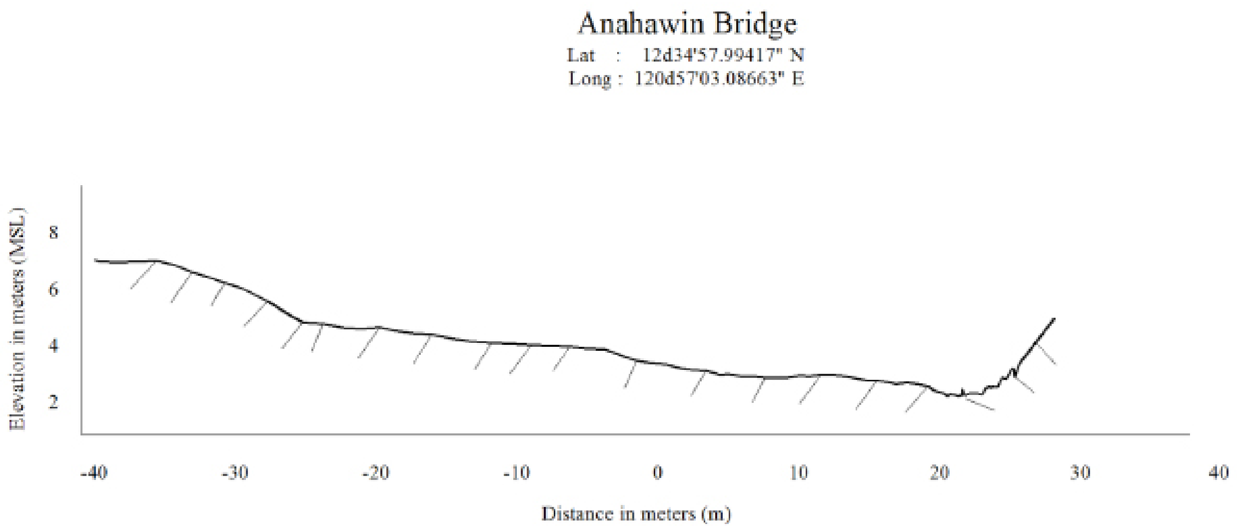

Figure 43. The upstream side of the Anahawin Bridge cross-section survey drawn to scale

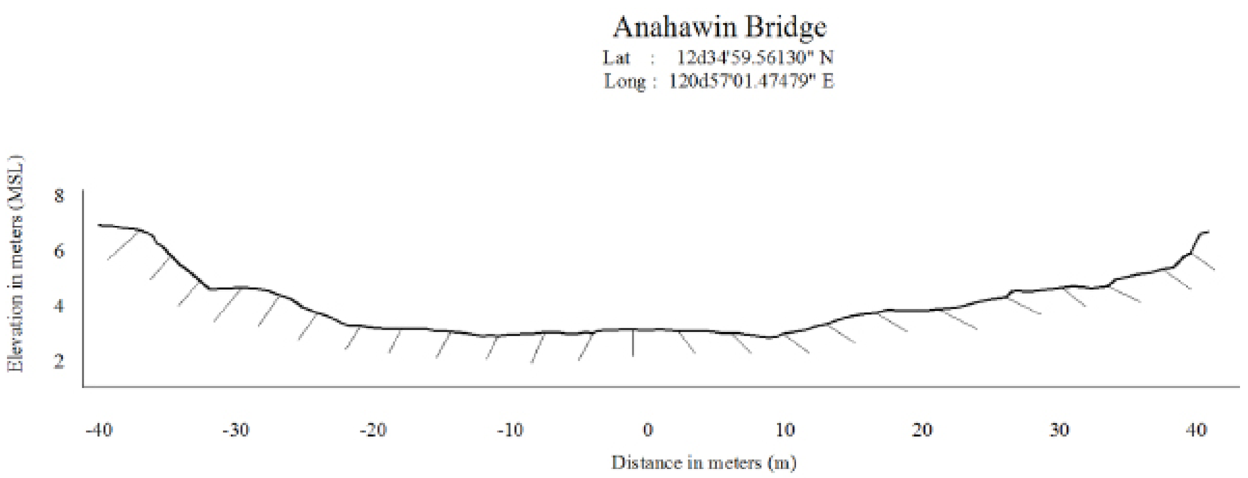

Figure 44. The downstream side of the Anahawin Bridge cross-section survey drawn to scale

4.6 Validation Points Acquisition Survey

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

Figure 45. Painting of water level markings on Anahawin Bridge

The survey was along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate length of 191 km with 26,449 validation points gathered. The gaps in the validation line as shown in Figure 46 were due to road construction and difficulties in receiving satellite signals because of the presence of obstructions such as dense canopy cover of trees along the roads.

Figure 46. The extent of the LiDAR ground validation survey for Anahawin River Basin

4.7 River Bathymetric Survey

A manual bathymetric survey was performed on November 19, 2015 by carrying a Trimble bag with installed Trimble® SPS 882 using the control point MRW-24 as base station. The survey started at the upstream portion of the river in Brgy. Poypoy with coordinates 12°35'13.74524" 120°57'17.04959", traversed down by foot down to the mouth of the river in Brgy. Poblacion and ended at the mouth of the river in Brgy. Iriron, Municipality of Calintaan with coordinates 12°35'30.67006" 120°56'02.14152". The set-up of manual bathymetry is shown on Figure 47.

Figure 47. Setup for the manual Bathymetric Survey along Anahawin River

The entire bathymetric data coverage for Anahawin River is illustrated in the map in Figure 48. A CAD diagram was also produced to illustrate the Anahawin riverbed profile as shown in Figure 49. An elevation drop of 3.723 meters in MSL was observed within the approximate distance of 4.611 km with a total of 8,514 bathymetric points gathered. Gradual change in elevation can also be seen in the illustration with an average change elevation of about 0.24 m for every 500-meter interval.

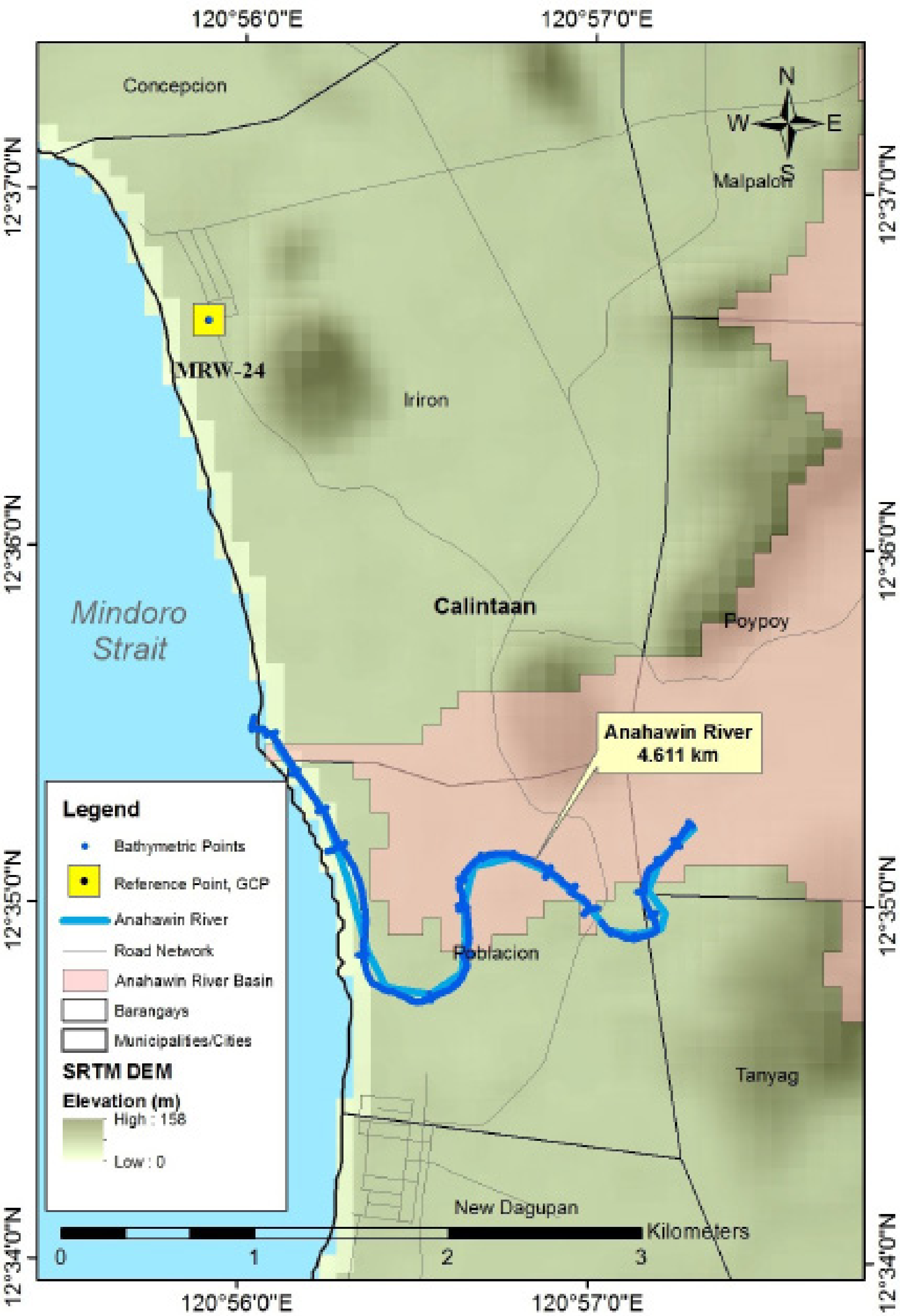

Figure 48. The extent of the Anahawin River Bathymetry Survey

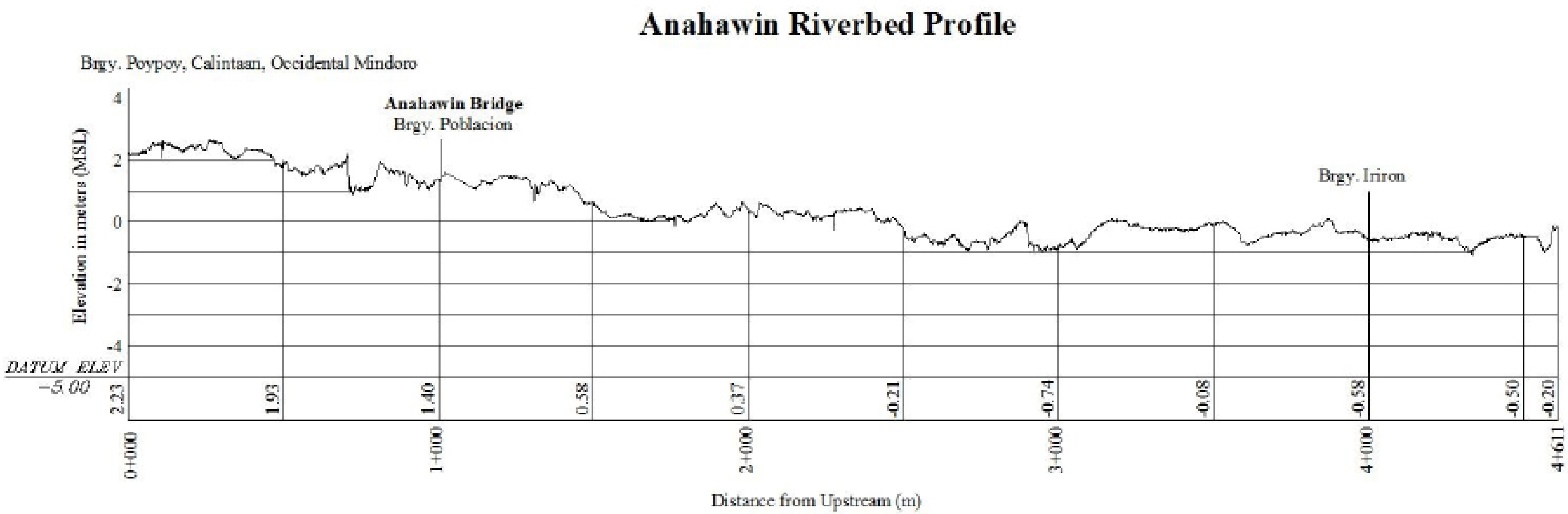

Figure 49. The Anahawin river bed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was measured using portable rain gauges installed on a strategic location within the watershed. The location of the rain gauges is seen in Figure 50.

The total amount of rainfall recorded for this event was 36.83 mm. It has a peak rainfall of 17.272 mm on September 8, 2016 at 3:00 pm. The lag time between the peak rainfall and discharge is 2 hours and 5 minutes.

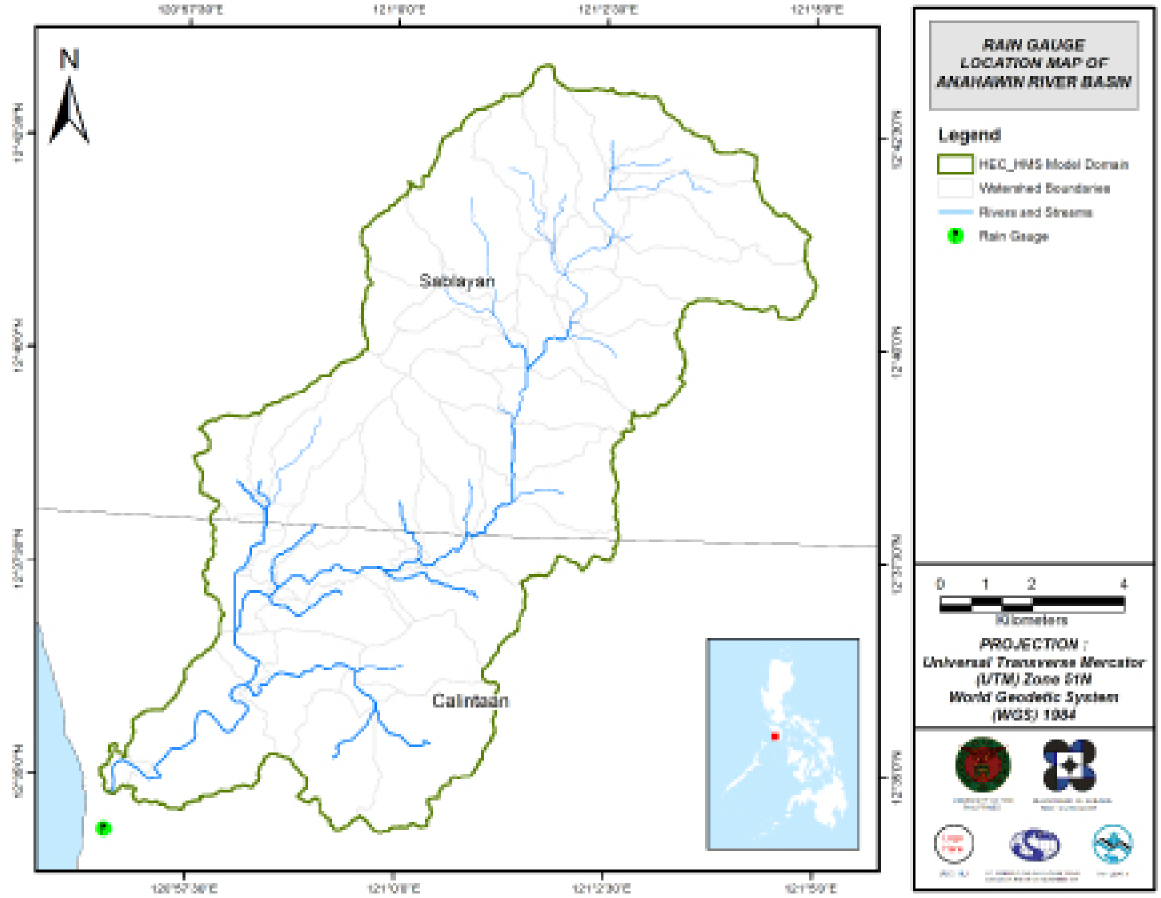

Figure 50. Location Map of the Anahawin HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Anahawin Bridge, Anahawin, Occidental Mindoro (12.582785° N, 120.950271° E) using Manning's Bankfull Method. It gives the relationship between the observed change in water and the outflow of the watershed at this location.

For Anahawin Bridge, the rating curve is expressed as Q = 1.567e1.0369x as shown in Figure 52 .

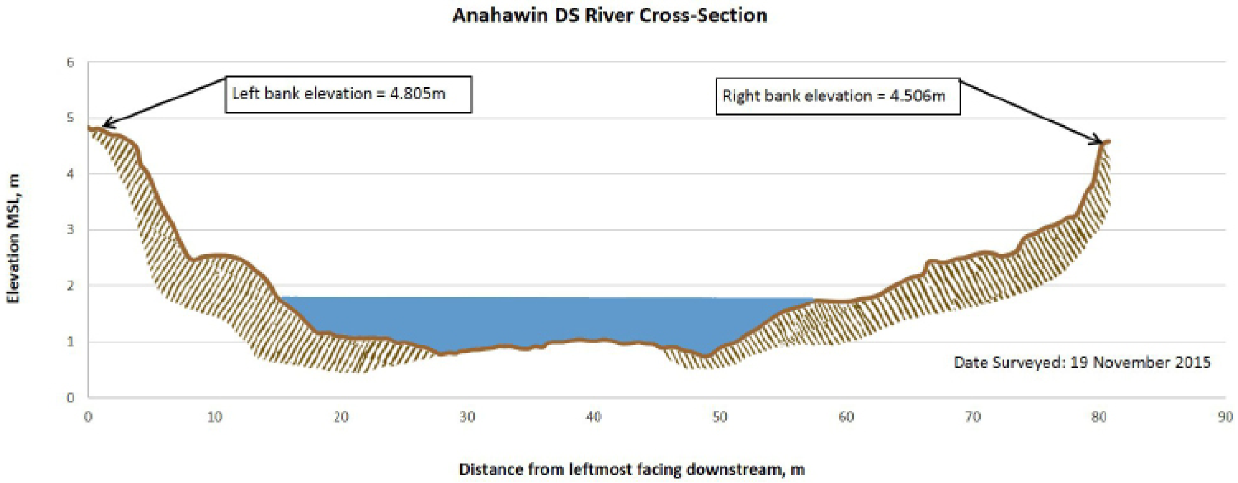

Figure 51. The cross-section plot of the Anahawin Bridge

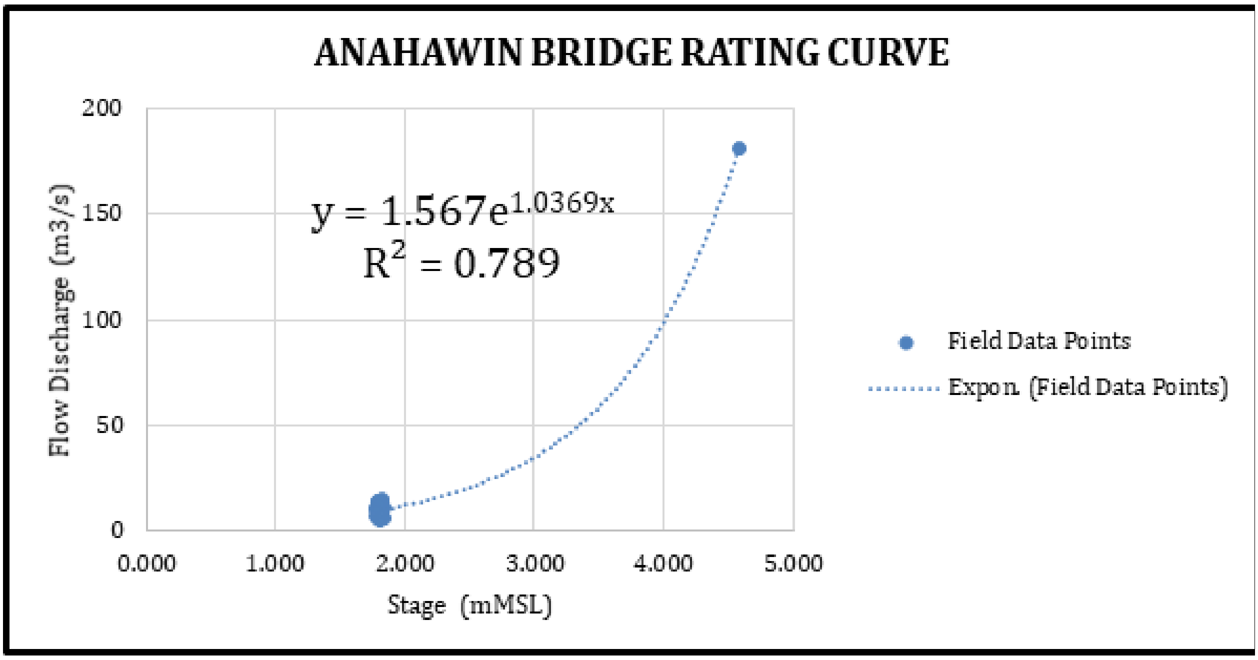

Figure 52. The rating curve of the Anahawin Bridge in Anahawin, Occidental Mindoro.

This rating curve equation was used to compute the river outflow at Anahawin Bridge for the calibration of the HEC-HMS model shown in Figure 53. The peak discharge is 80.34 m3 at 5:05 in the afternoon, September 8, 2016.

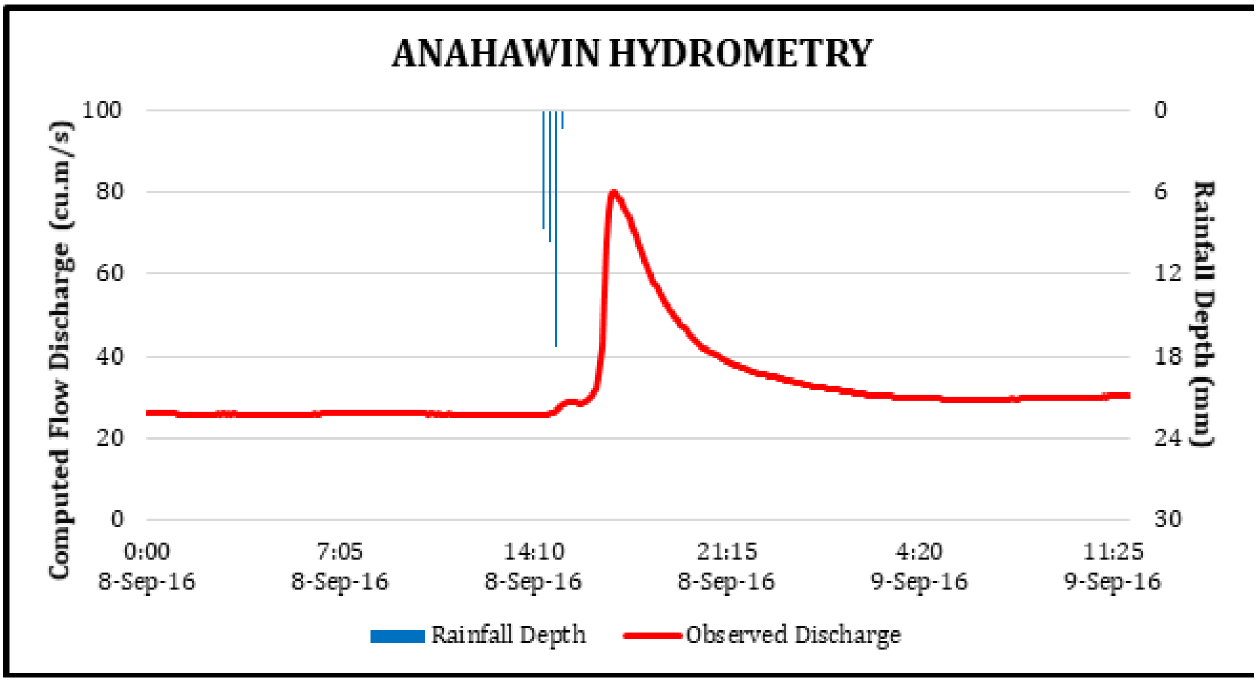

Figure 53. Rainfall and outflow data of the Anahawin River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Romblon Rain Gauge (Table 30). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Table 30). This station was selected based on its proximity to the Anahawin watershed. The extreme values for this watershed were computed based on a 48-year record.

Table 30. RIDF values for the Romblon Rain Gauge, as computed by PAGASA

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

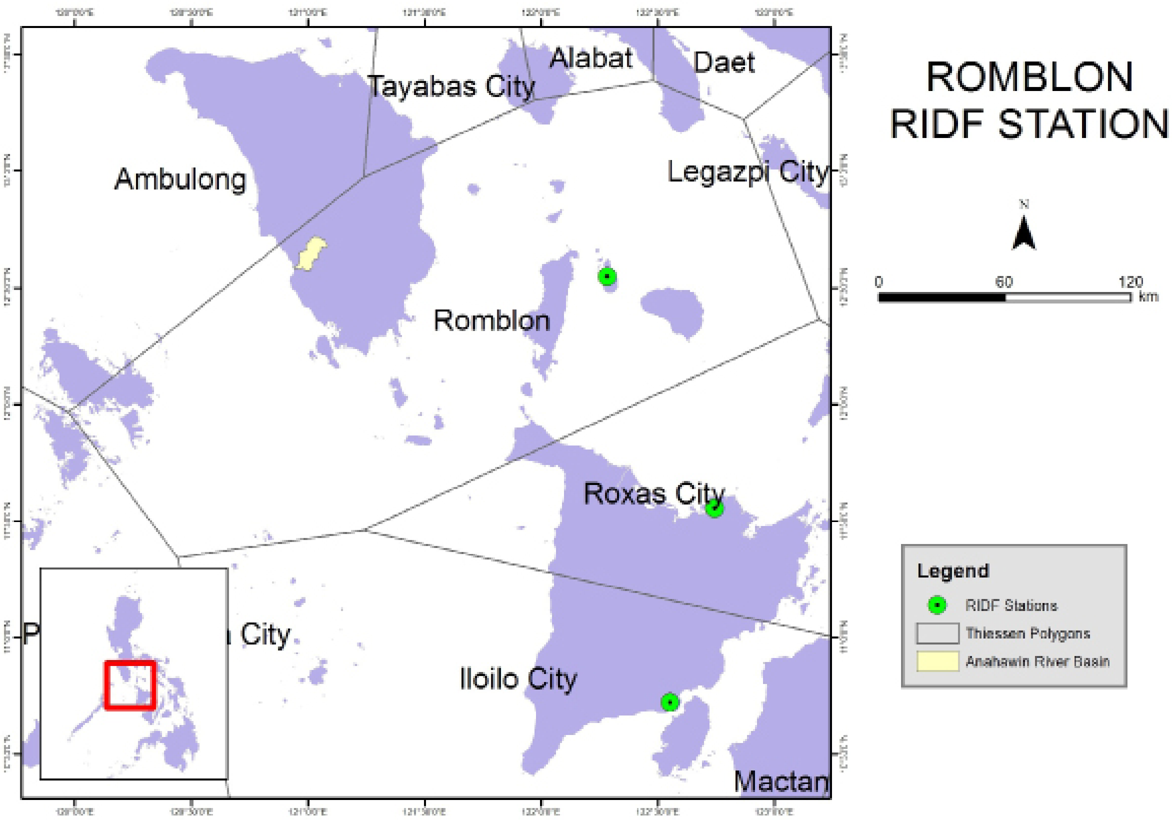

Figure 54. The location of the Romblon RIDF station relative to the Anahawin River Basin.

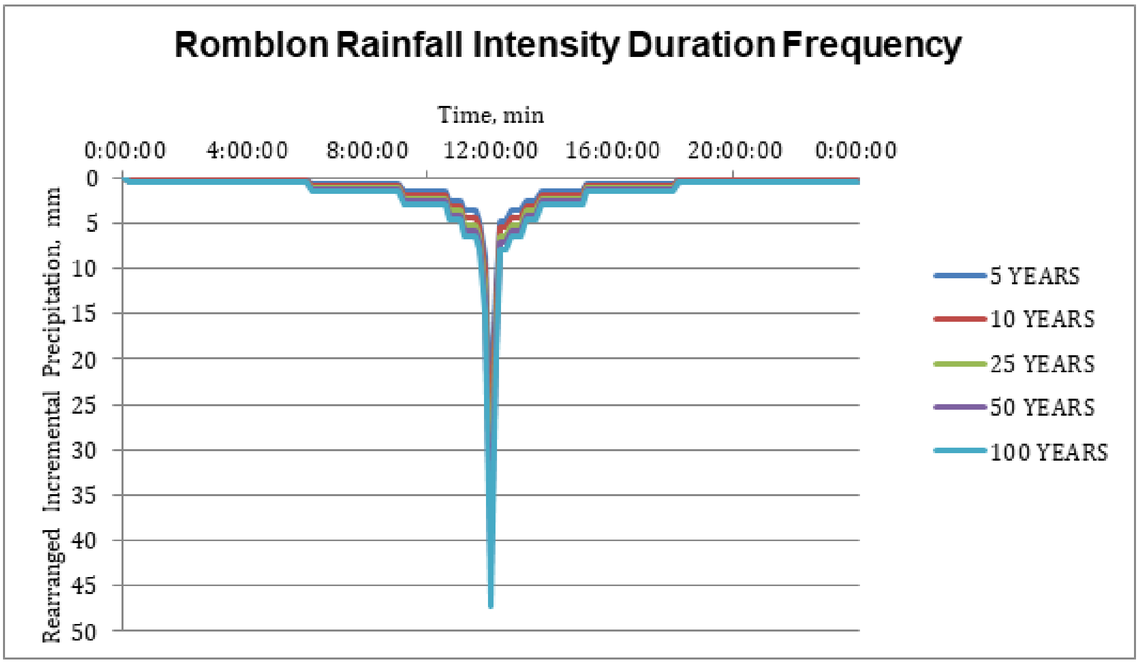

Figure 55. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Anahawin River Basin are shown in Figure 56 and Figure 57, respectively.

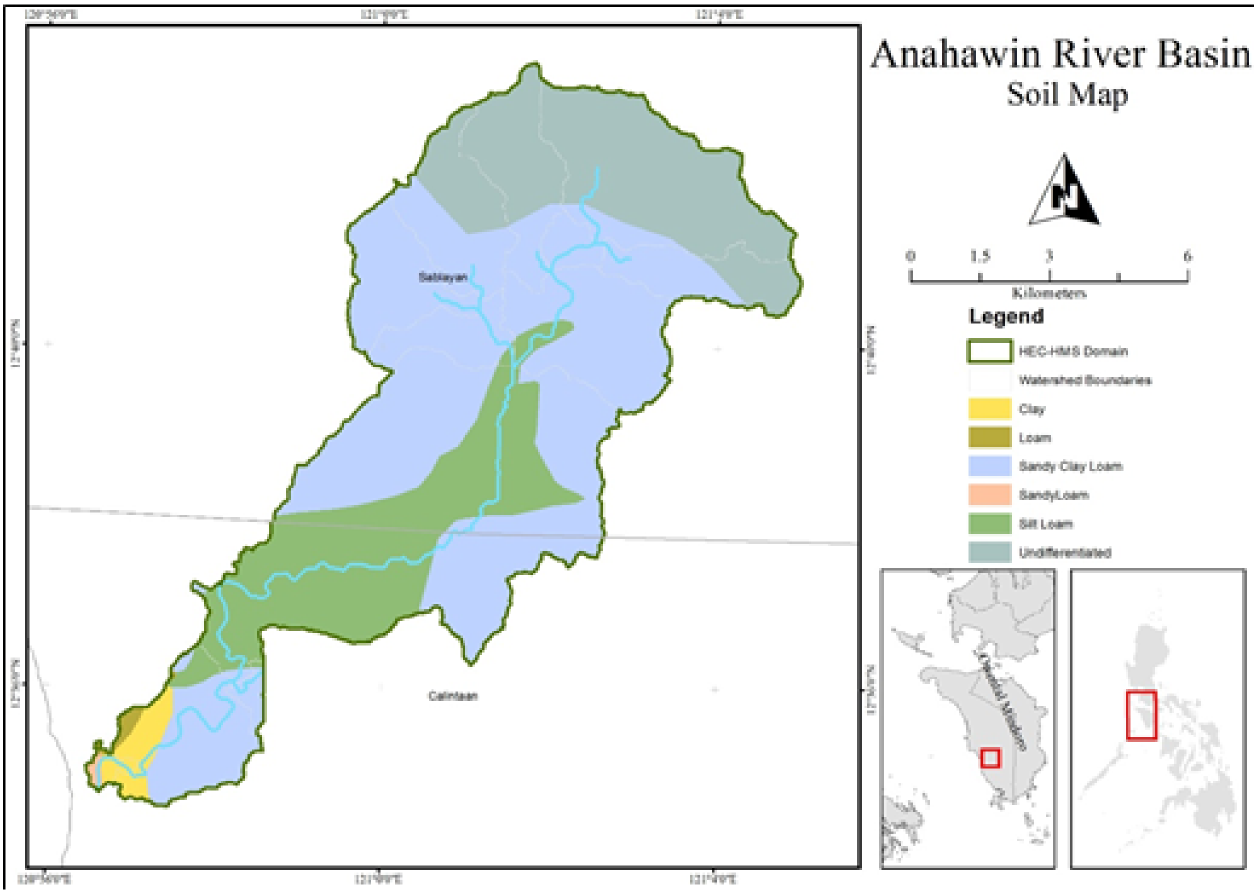

Figure 56. Soil Map of Anahawin River Basin.

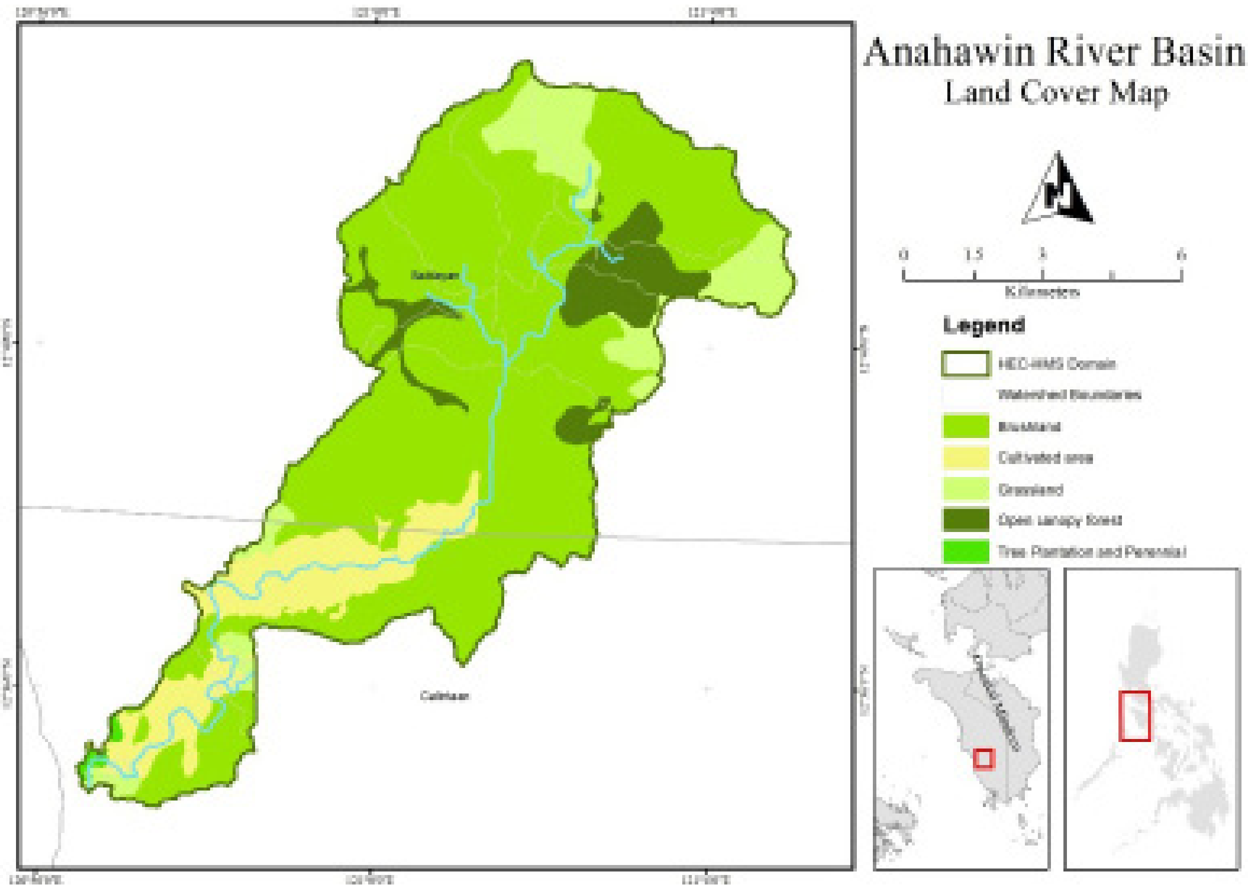

Figure 57. Land Cover Map of Anahawin River Basin

For Anahawin, six soil classes were identified. These are clay, loam, sandy clay loam, sandy loam, silt loam and undifferentiated soil. Moreover, six land cover classes were identified. These are brushland, cultivated areas, grassland, open canopy forest, tree plantations and perrenials.

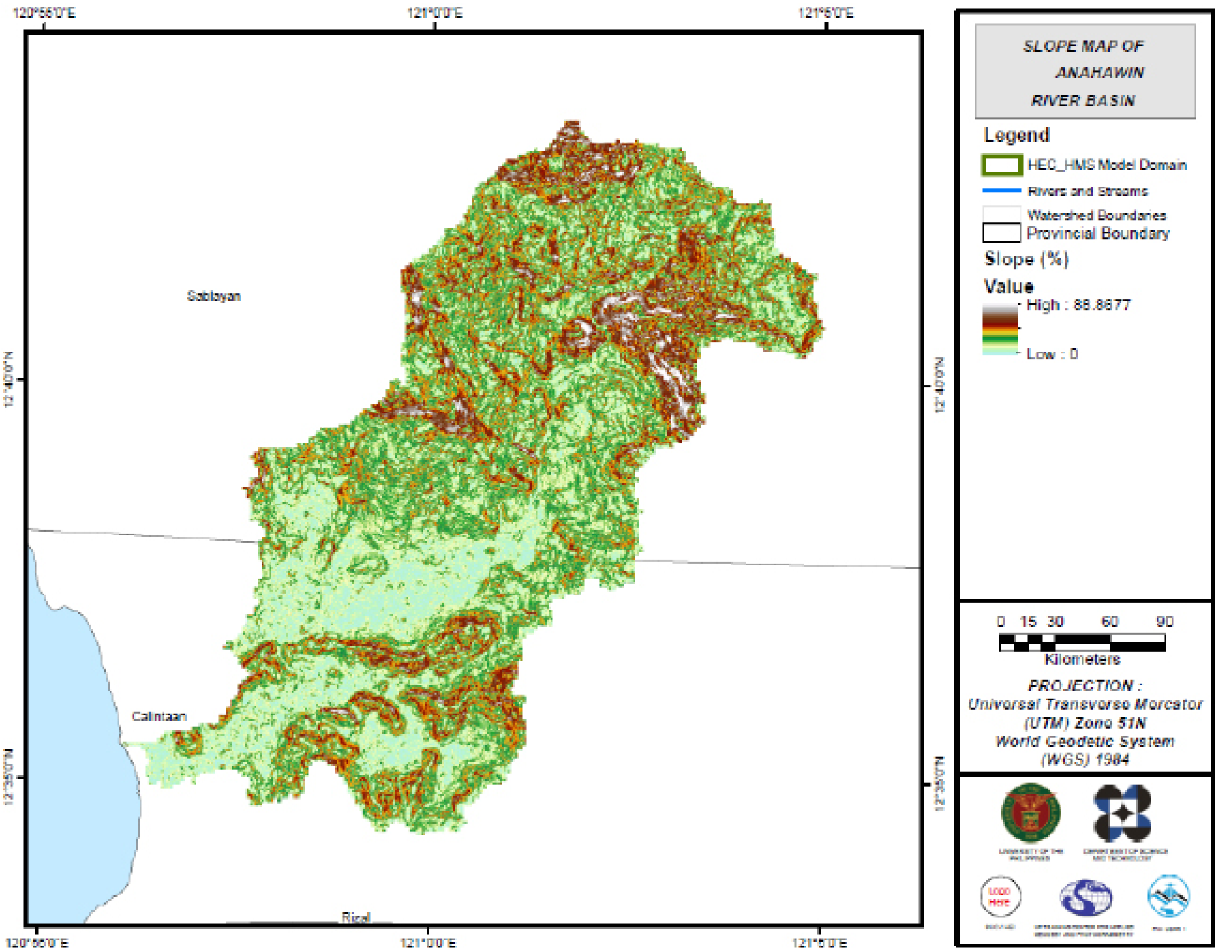

Figure 58. Slope Map of the Anahawin River Basin.

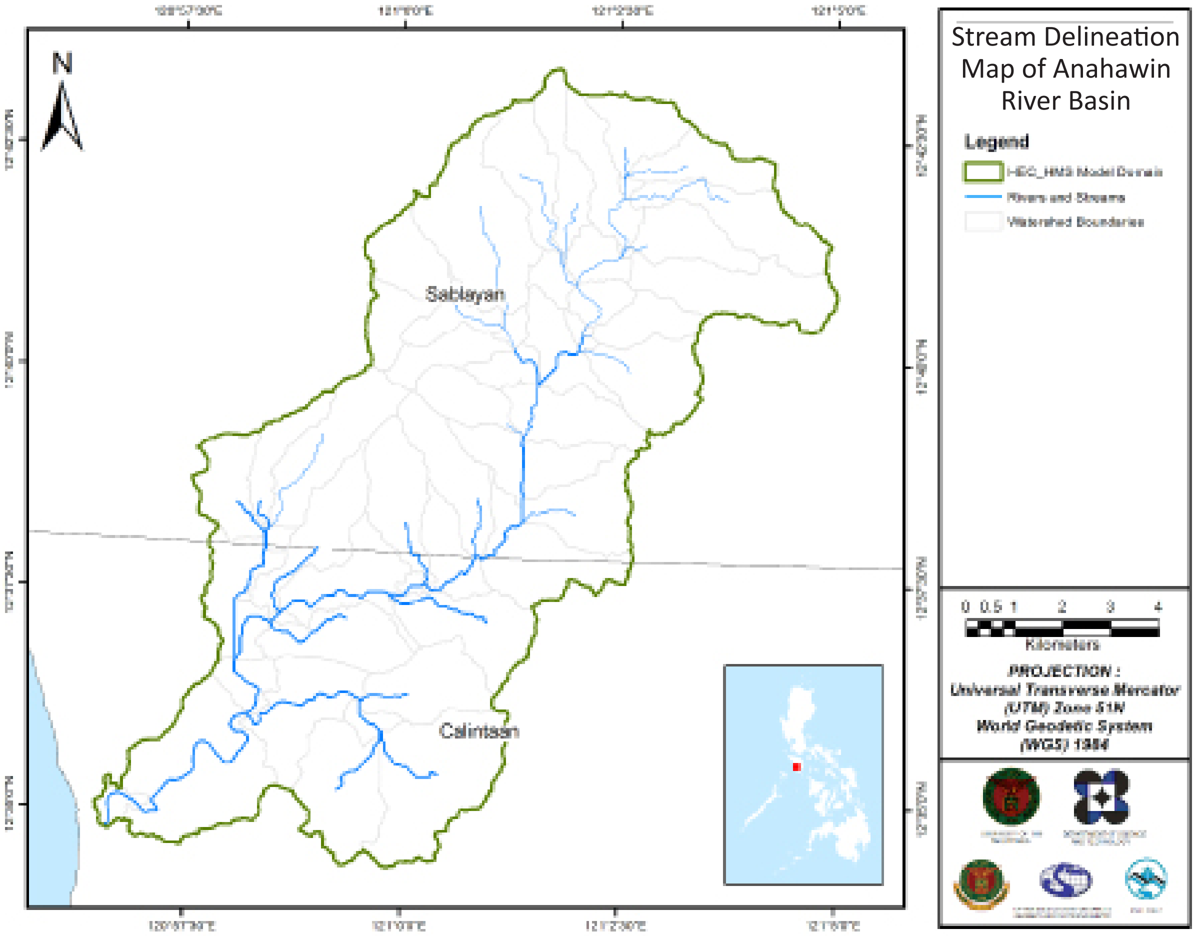

Figure 59. Stream Delineation Map of Anahawin River Basin

Using the SAR-based DEM, the Anahawin basin was delineated and further subdivided into subbasins (Annex 10). The model consists of 12 sub basins, 6 reaches, and 6 junctions as shown in Figure 60. The main outlet is at Anahawin Bridge.

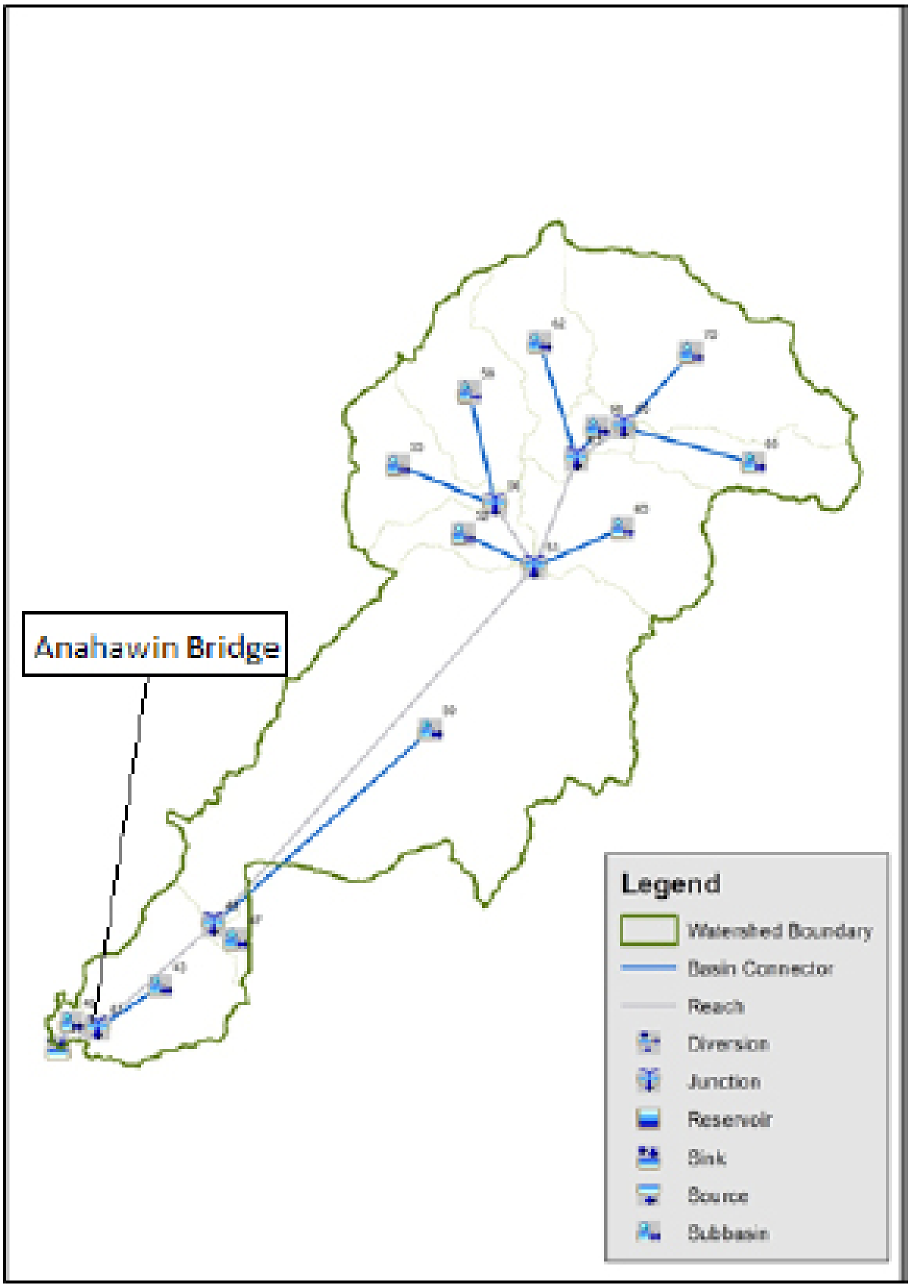

Figure 60. The Anahawin river basin model generated using HEC-HMS

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS.

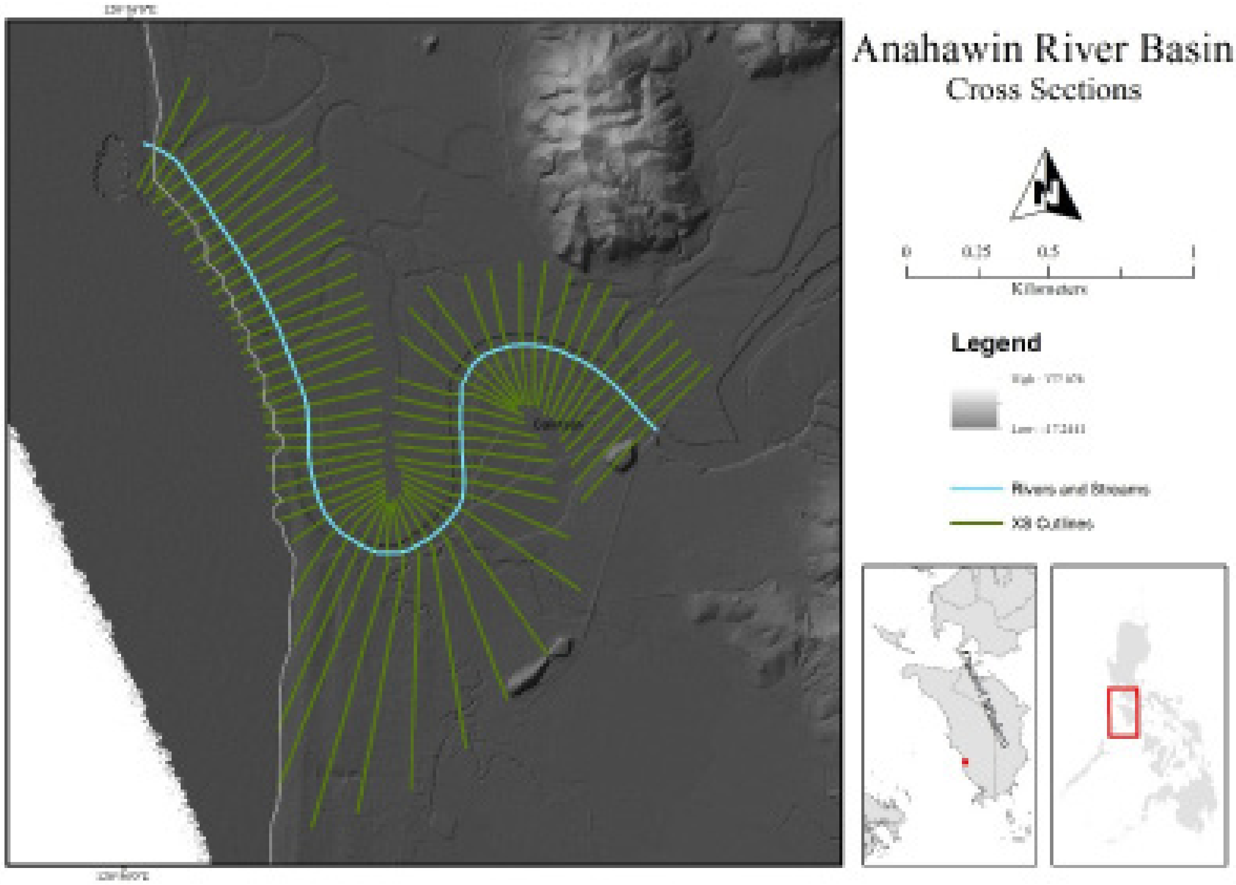

Figure 61. River cross-section of the Anahawin River through the ArcMap HEC GeoRas tool

5.5 Flo 2D Model

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

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

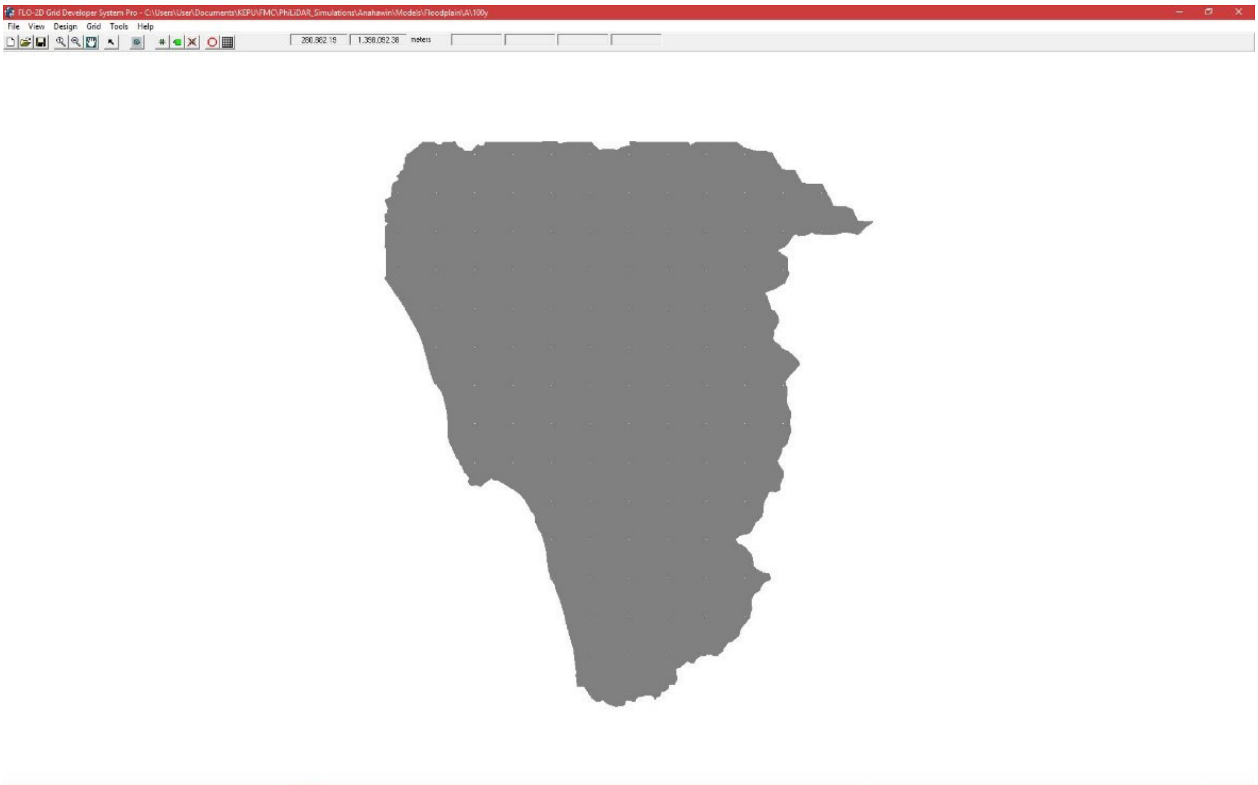

Figure 62. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 55.22119 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Anahawin are in Figure 69, 71 and 73.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 38003900.00 m2. The gen-erated flood depth maps for Anahawin are in Figure 70, 72 and 74.

There is a total of 20784401.11 m3 of water entering the model. Of this amount, 13549895.69 m3 is due to rainfall while 7234505.41 m3 is inflow from other areas outside the model 3545082.75 m3 of this water is lost to infiltration and interception, while 2382891.11 m3 is stored by the flood plain. The rest, amounting up to 14856453.19 m3, is outflow.

5.6 Results of HMS Calibration

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

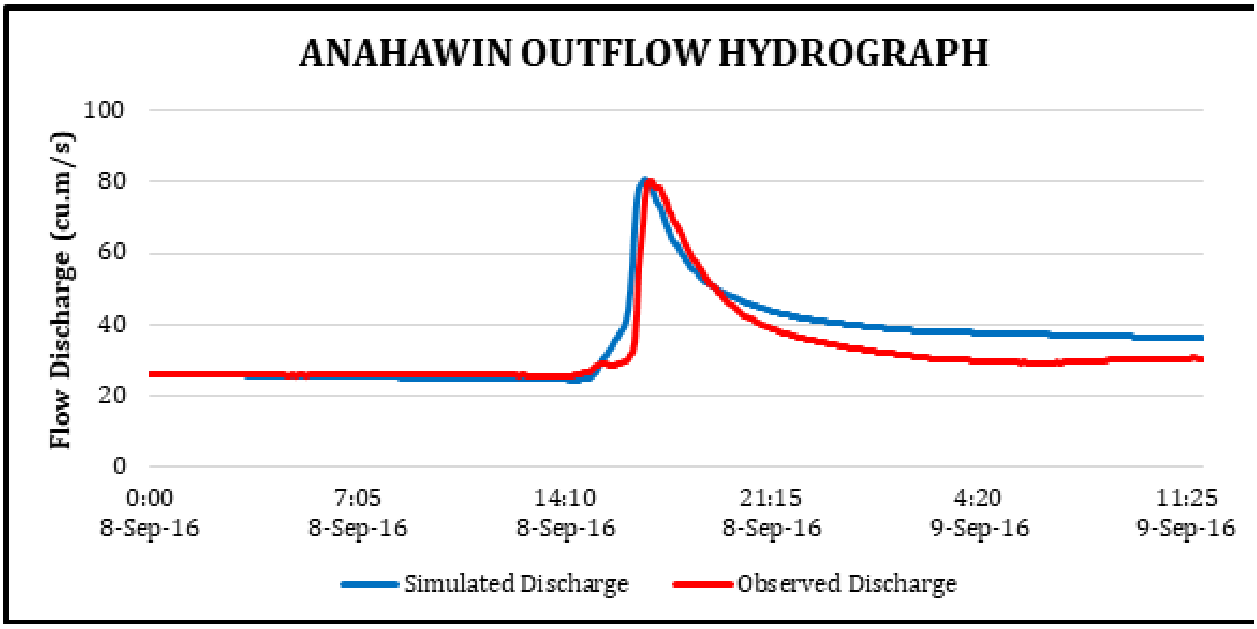

Figure 63. Outflow Hydrograph of Anahawin produced by the HEC-HMS model compared with observed outflow

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

Table 31. Range of calibrated values for the Anahawin River Basin.

Basin/ Reach Characteristic	Method	Parameter	Range of Calibrated Values
Loss	SCS Curve number	Initial Abstraction (mm)	2 - 10
		Curve Number	40 - 75
Transform	Clark Unit Hydro-graph	Time of Concentration (hr)	0.5 - 2
		Storage Coefficient (hr)	0.8 – 3.7
Baseflow	Recession	Recession Constant	0.5 - 1
		Ratio to Peak	0.3 – 0.6
Routing	Muskingum-Cunge	Slope	0.002 – 0.03
		Manning's Coefficient	0.003 – 0.03

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 2 to 10mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The 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 40 to 75 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Anahawin, the basin mostly consists of brushlands and the soil consists of shrublands and soil consists of sandy clay loam and silt loam.

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 0.5 to 2 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.5 to 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.3 to 0.6 indicates an average steepness of the receding limb of the outflow hydrograph. Anahawin model basin parameters are presented in Annex 9.

Manning's roughness coefficient of 0.003 to 0.03 deviates more on the lower value with respect to the common roughness of Philippine watersheds, which indicates that water flows relatively faster in Anahawin than other rivers.

Table 32. Summary of the Efficiency Test of the Anahawin HMS Model

Accuracy measure	Value
RMSE	5.641
r2	0.909
NSE	0.726
PBIAS	-9.300
RSR	0.523

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 5.641.

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.909.

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 0.726.

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 -9.300.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.523.

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

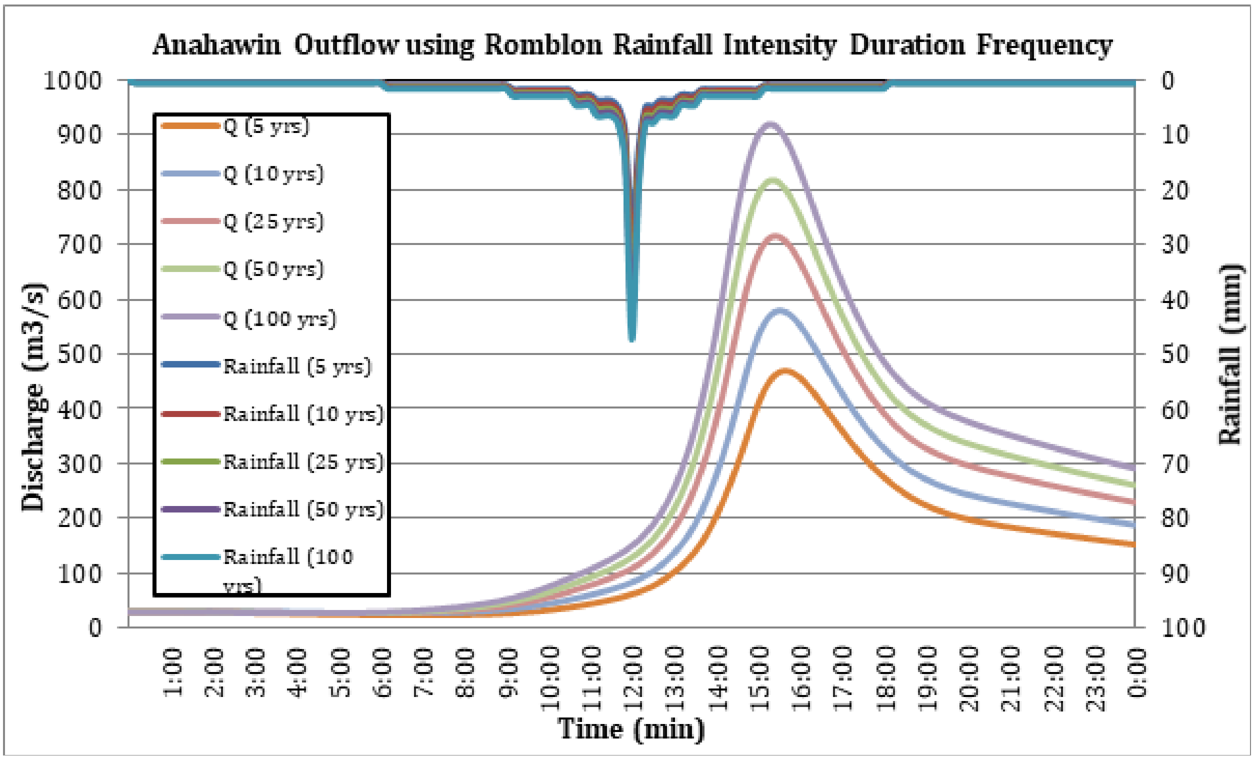

Figure 64. The Outflow hydrograph at the Anahawin Station, generated using the Romblon RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Anahawin discharge using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. The peak values of the Anahawin HEC-HMS Model outflow using the Romblon RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak	Lag Time
5-Year	171.60	26.0	420.092	13 hours 50 minutes	1 hour 50 minutes
10-Year	205.90	31.1	533.547	13 hours 50 minutes	1 hour 50 minutes
25-Year	249.20	37.6	681.173	13 hours 50 minutes	1 hour 50 minutes
50-Year	281.40	42.4	793.633	13 hours 40 minutes	1 hour 40 minutes
100-Year	313.30	47.2	908.347	13 hours 40 minutes	1 hour 40 minutes

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

The river discharges for the three rivers entering the floodplain are shown in Figure 65 to Figure 67 and the peak values are summarized in Table 34 to Table 36.

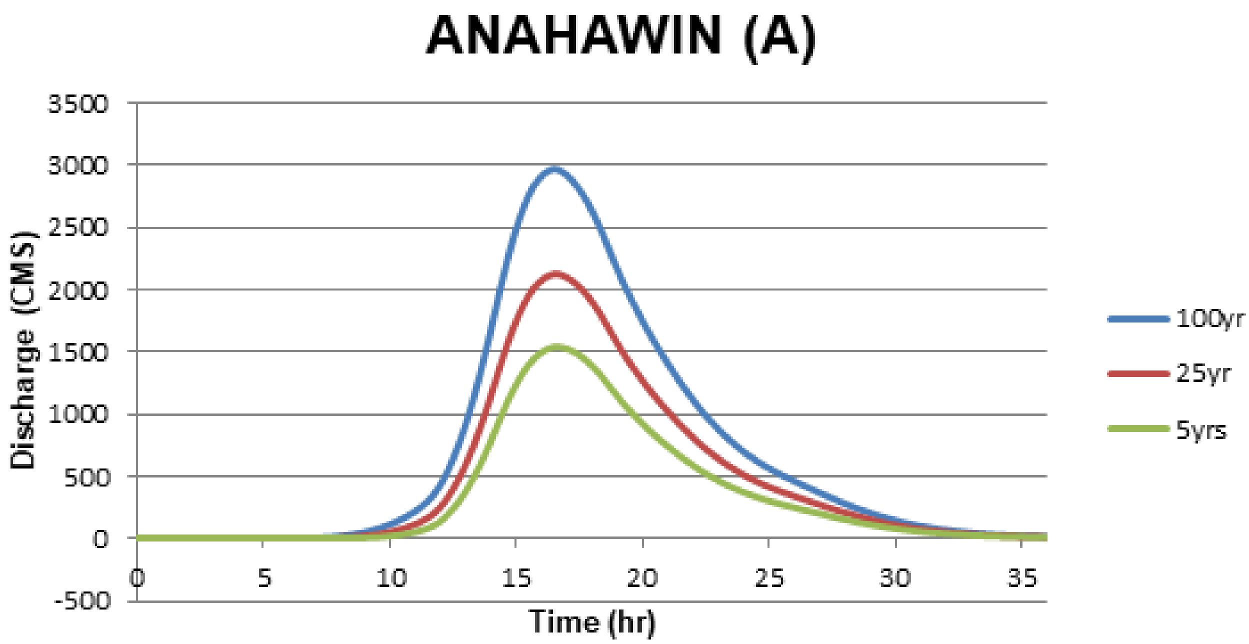

Figure 65. Anahawin river (A) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

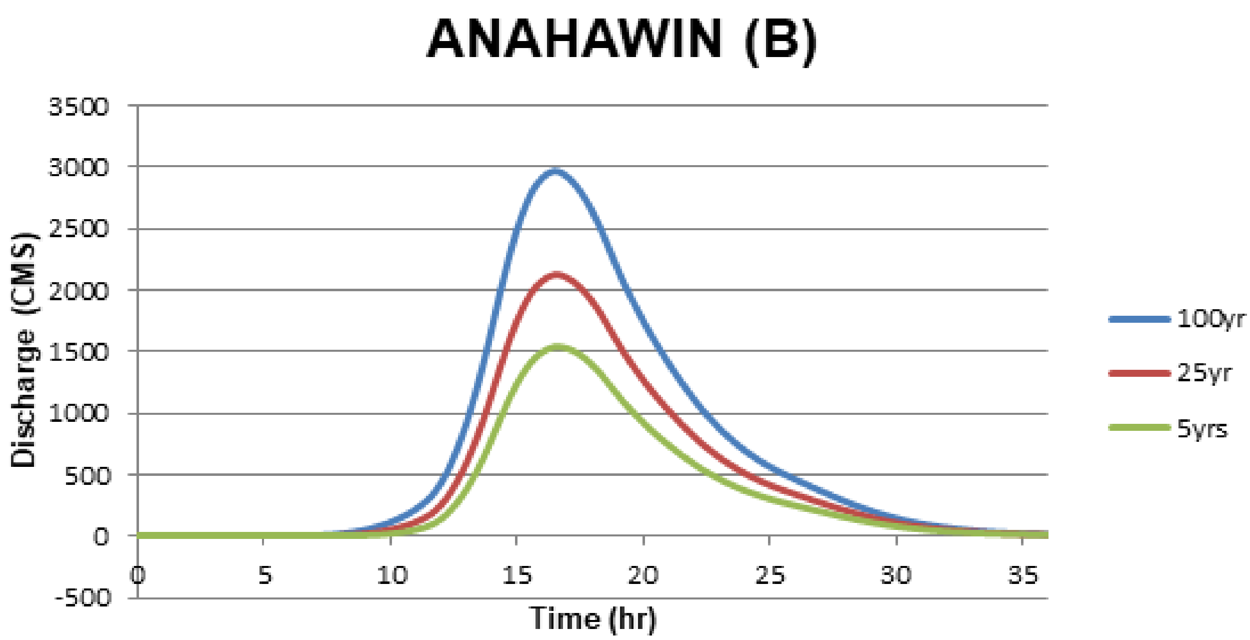

Figure 66. Anahawin river (B) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

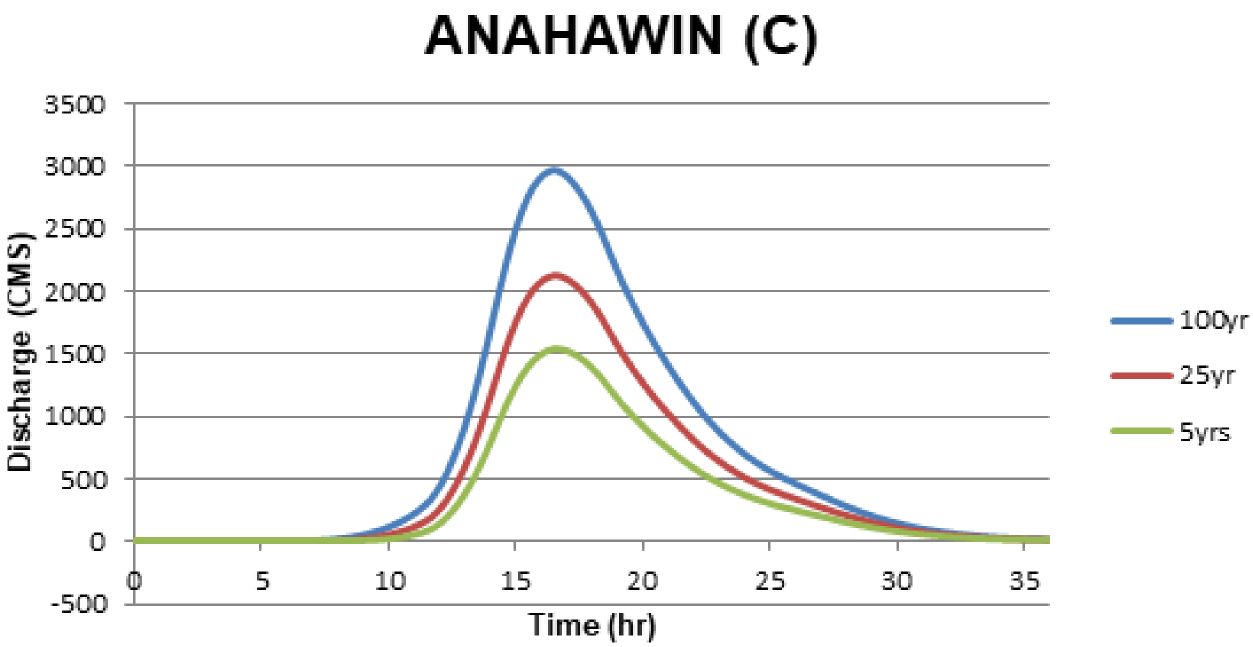

Figure 67. Anahawin river (B) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 34. Summary of Anahawin river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	622.2	12 hours, 40 minutes
25-Year	438.3	12 hours, 50 minutes
5-Year	314.8	12 hours, 50 minutes

Table 35. Summary of Anahawin river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1306.8	13 hours, 30 minutes
25-Year	938.5	13 hours, 30 minutes
5-Year	686.3	13 hours, 30 minutes

Table 36. Summary of Anahawin river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2958.8	16 hours, 30 minutes
25-Year	2119.7	16 hours, 30 minutes
5-Year	1543.7	16 hours, 40 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 37.

Table 37. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Anahawin (A)	277.024	440.811	268.591	Pass	Pass
Anahawin (B)	603.944	632.078	527.286	Pass	Pass
Anahawin (C)	1358.456	2051.435	1234.387	Pass	Pass

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

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. Figure 68 shows a generated sample map of the Anahawin River using the calibrated HMS base flow.

Figure 68. The sample output map of the Anahawin RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 69 to Figure 74 shows the 5-, 25-, and 100-year rain return scenarios of the Anahawin floodplain. The floodplain, with an area of 152.12 sq. km., covers three municipalites namely Calintaan, Rizal and Sablayan. Table 38 shows the percentage of area affected by flooding per municipality.

Table 38. Municipalities affected in Anahawin Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Calintaan	282.31	90.08	31.90%
Rizal	1165.56	34.36	2.94%
Sablayan	2350.46	27.61	1.17%

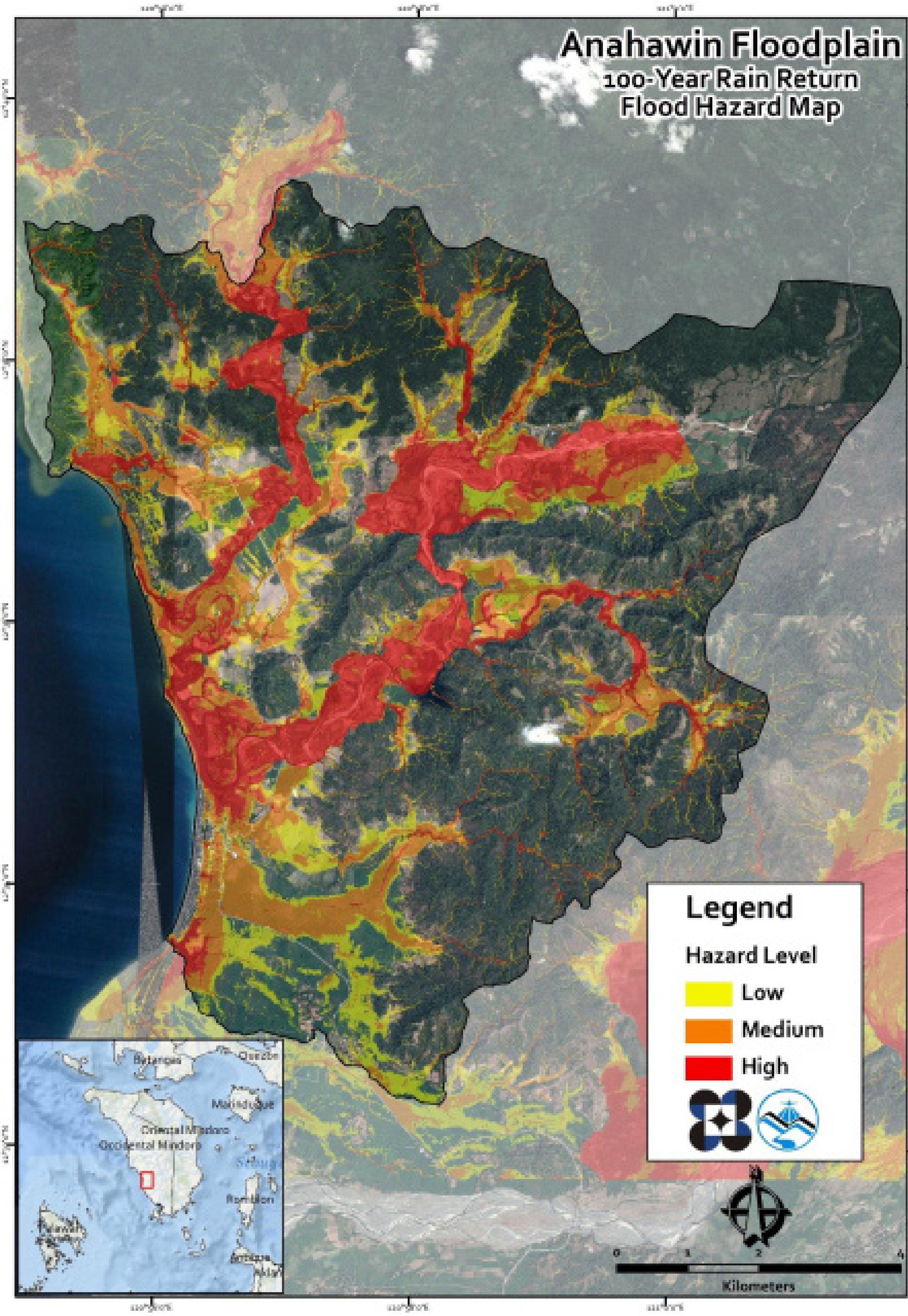

Figure 69. A 100-year flood hazard map for the Anahawin floodplain overlaid on Google Earth imagery

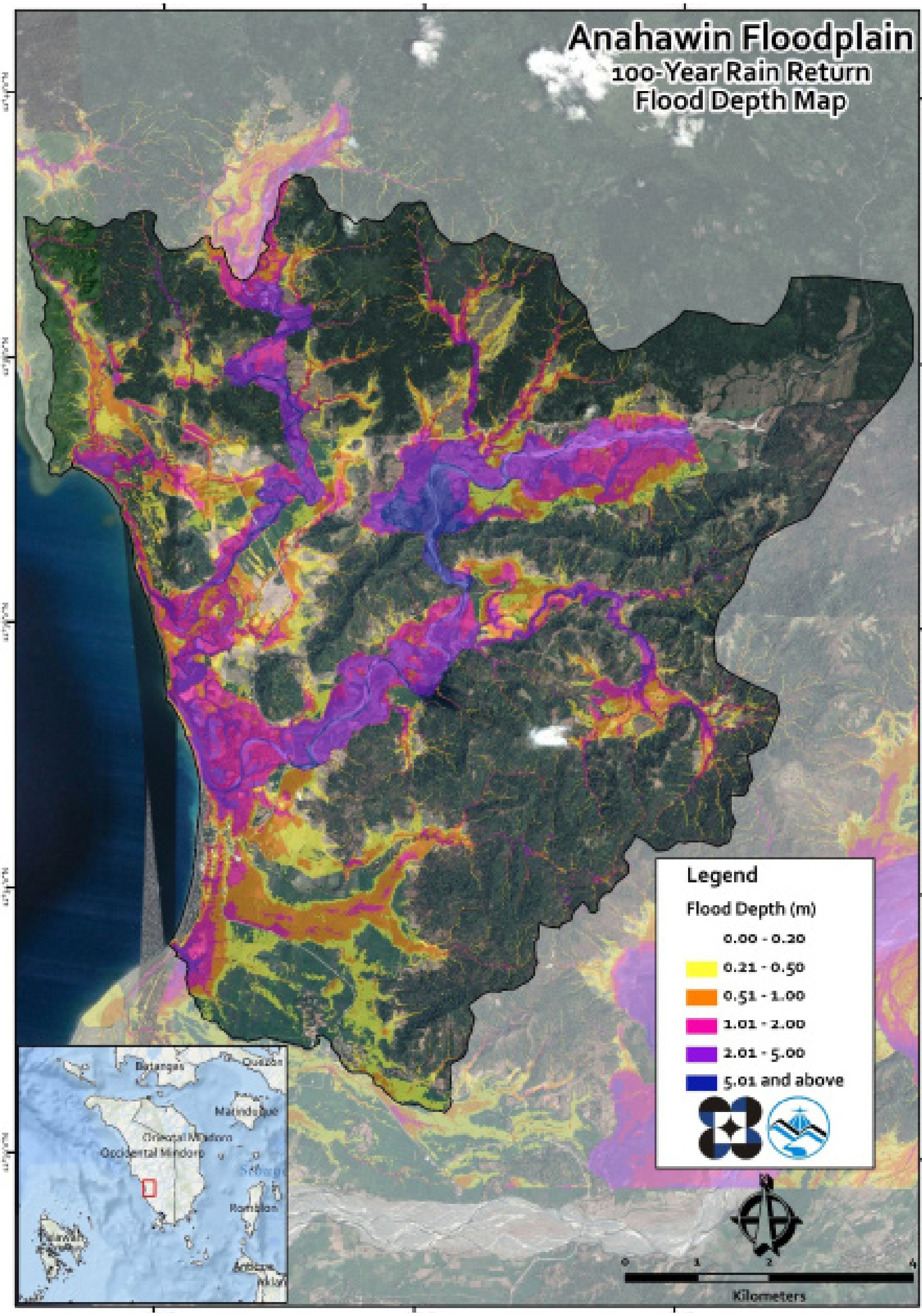

Figure 70. A 100-year Flow Depth Map for the Anahawin Floodplain overlaid on Google Earth imagery

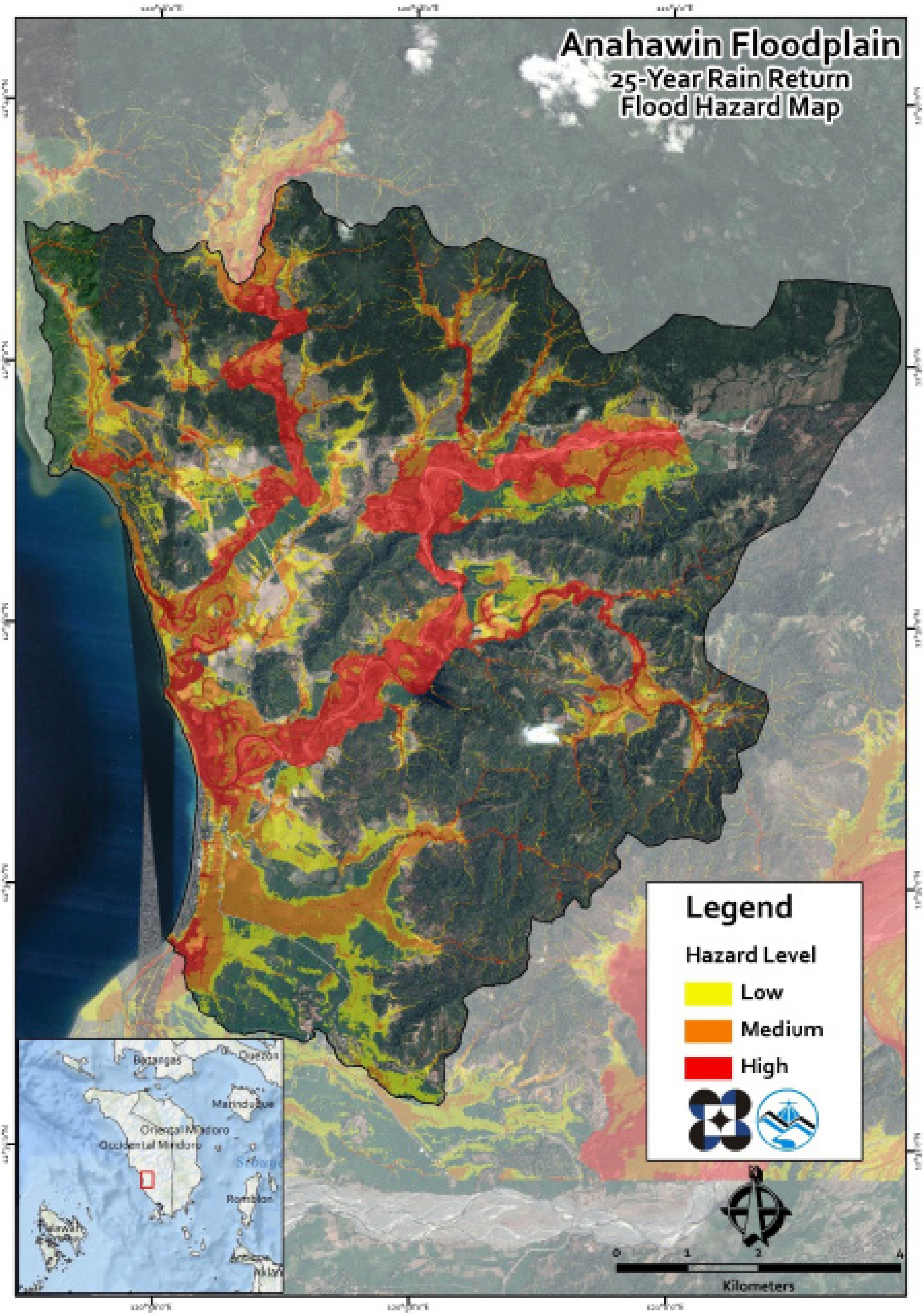

Figure 71. A 25-year flood hazard map for the Anahawin floodplain overlaid on Google Earth imagery

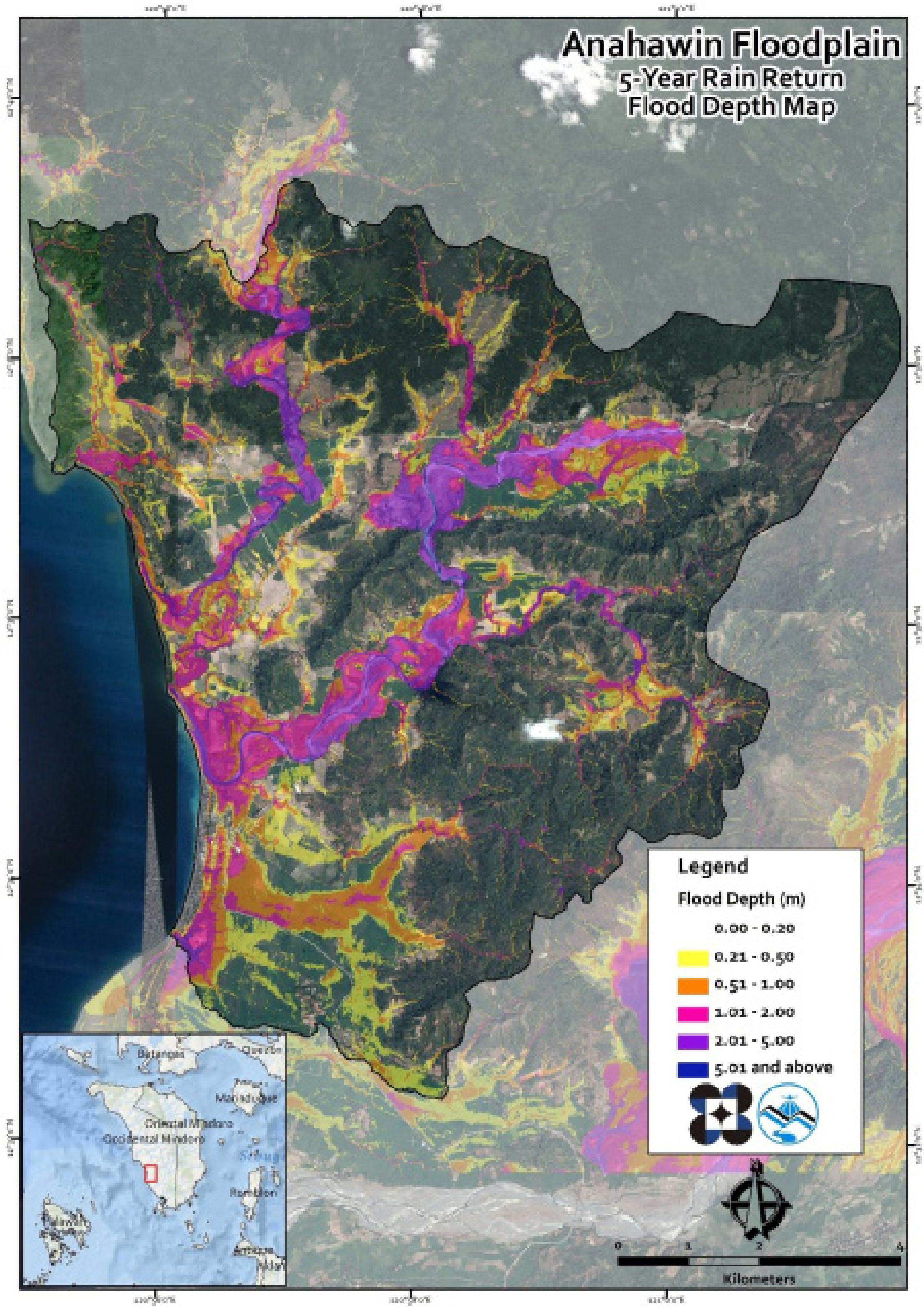

Figure 72. A 25-year Flow Depth Map for the Anahawin Floodplain overlaid on Google Earth imagery

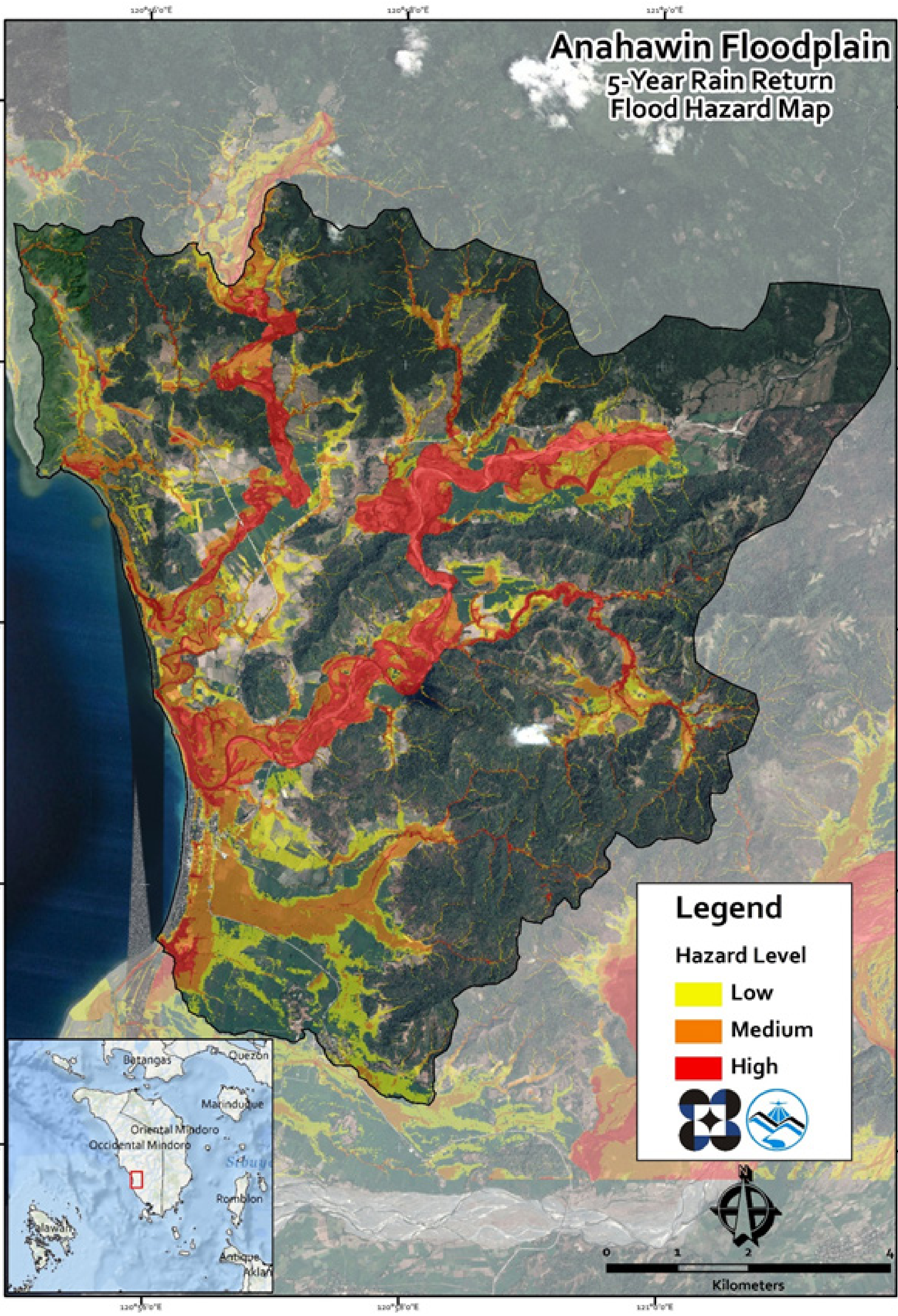

Figure 73. A 5-year flood hazard map for the Anahawin floodplain overlaid on Google Earth imagery

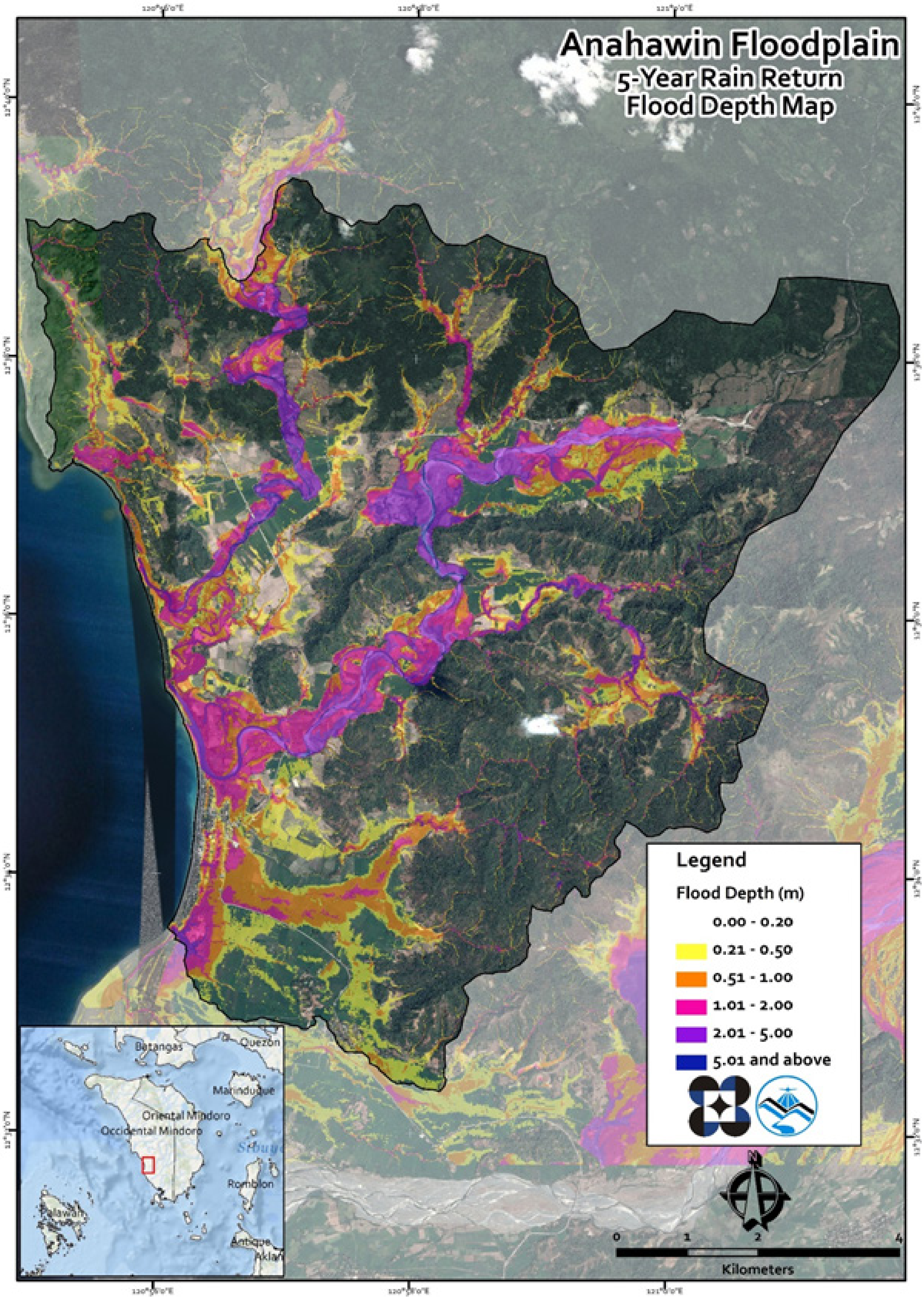

Figure 74. A 5-year Flow Depth Map for the Anahawin Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Anahawin River Basin, grouped accordingly by municipality. For the said basin, four municipalities consisting of 12 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 20.68% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters. 3.23% of the area will experience flood levels of 0.21 to 0.50 meters while 2.82%, 3.1%, 2.001%, and 0.10% 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. Table 39 depicts the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected areas in Calintaan, Occidental Mindoro during a 5-Year Rainfall Return Period

Affected area (vsq. km.) by flood depth (in m.)	Affected Barangays in Calintaan						
	Concepcion	Iriron	MalAnahawinn	New Dagupan	Poblacion	Poypoy	Tanyag
0.03-0.20	3.72	5.24	8.22	2.21	0.85	18.07	20.06
0.21-0.50	0.58	1.17	1.4	1.17	0.44	1.91	2.44
0.51-1.00	0.34	0.96	1.19	1.27	0.44	1.32	2.44
1.01-2.00	0.44	0.87	1.17	0.71	1.08	1.4	3.08
2.01-5.00	0.12	0.46	1.88	0.14	0.3	1.26	1.49
> 5.00	0.0077	0.077	0.11	0	0.0038	0.081	0.0074

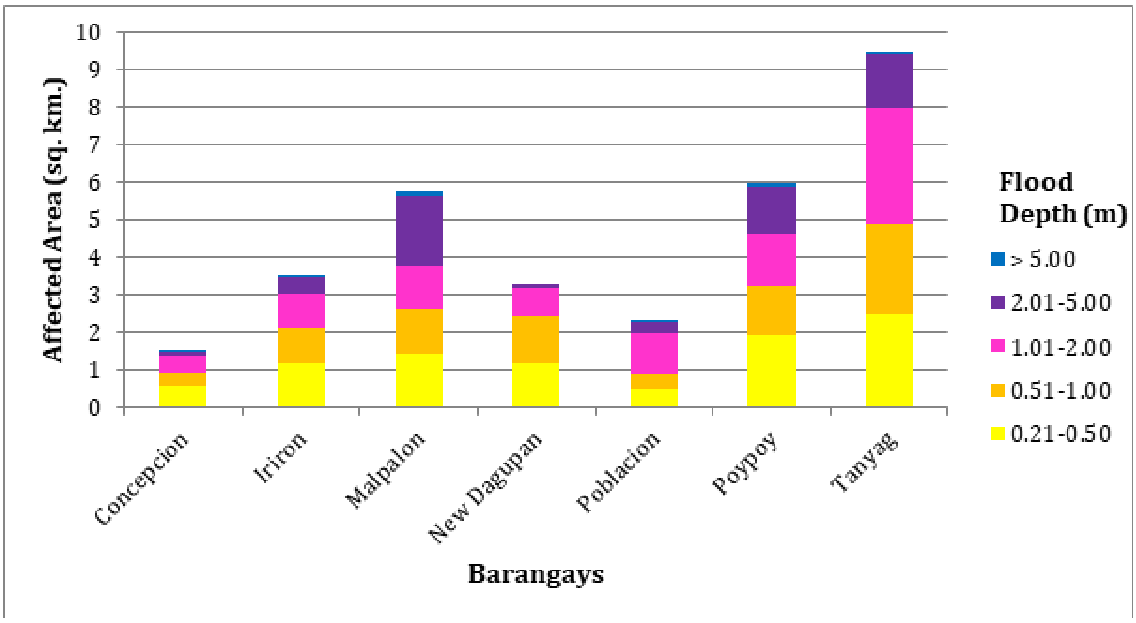

Figure 75. Affected areas in Calintaan, Occidental Mindoro during a 5-Year Rainfall Return Period.

For the municipality of Rizal, with an area of 184.98 sq. km., 10.17% will experience flood levels of less 0.20 meters. 3.35% of the area will experience flood levels of 0.21 to 0.50 meters while 2.56%, 1.91%, 0.59%, and 0.0002% 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. Table 40 depicts the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Rizal, Occidental Mindoro during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)			
	Magsikap	Mala-waan	Manoot	Rizal
0.03-0.20	5.02	9.76	0.065	3.98
0.21-0.50	1.06	3.4	0.012	1.72
0.51-1.00	0.74	1.04	0.0037	2.96
1.01-2.00	0.92	0.19	0	2.42
2.01-5.00	0.63	0.011	0	0.44
> 5.00	0.0003	0	0	0.0001

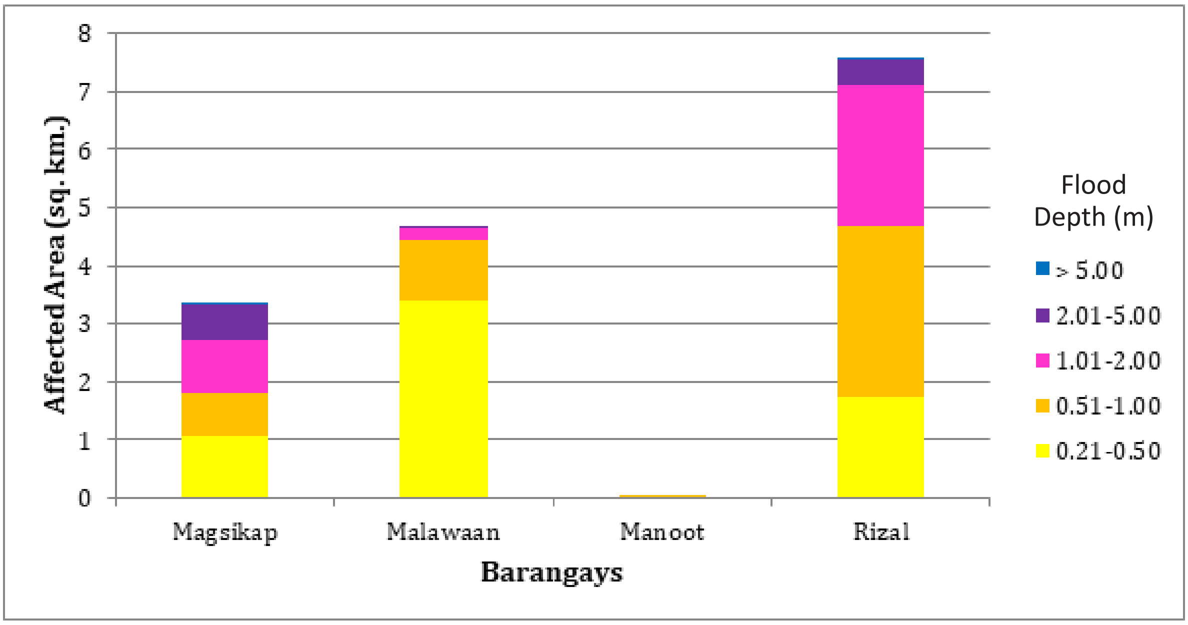

Figure 76. Areas affected by flooding in Rizal, Occidental Mindoro for a 5-Year Return Period rainfall event.

For the municipality of Sablayan, with an area of 2350.46 sq. km., 22.44% will experience flood levels of less 0.20 meters. 2.15% of the area will experience flood levels of 0.21 to 0.50 meters while 1.52%, 1.001%, 0.50%, 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. Illustrated in Table 41 are the affected areas in square

Table 41. Affected areas in Sablayan, Occidental Mindoro during a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Sablayan
	Burgos
0.03-0.20	22.44
0.21-0.50	2.15
0.51-1.00	1.52
1.01-2.00	1
2.01-5.00	0.5
> 5.00	0.017

Among the barangays in the municipality of Villareal, Inasudlan is projected to have the highest percentage of area that will experience flood levels of at 2.41%. On the other hand, Igot posted the percentage of area that may be affected by flood depths of at 1.0%.

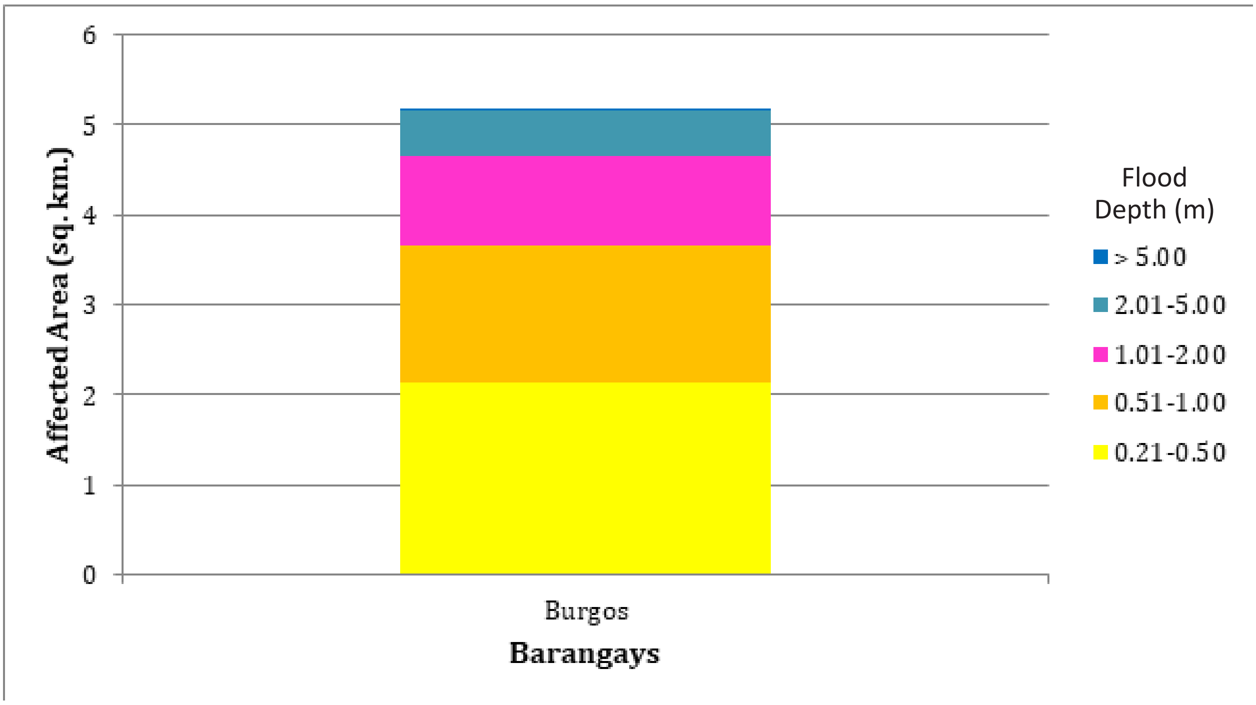

Figure 77. The specifically affected areas in Sablayan, Occidental Mindoro during a 5-Year Rainfall Return Period.

For the 25-year return period, 19.48% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters. 3.31% of the area will experience flood levels of 0.21 to 0.50 meters while 2.89%, 3.20%, 2.81%, and 0.20% 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. Outlined in Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Calintaan, Occidental Mindoro during a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan						
	Concepcion	Iriron	Malpalon	New Dagupan	Poblacion	Poypoy	Tanyag
0.03-0.20	3.45	4.54	7.47	2.18	0.63	17.31	19.43
0.21-0.50	0.65	1.32	1.39	1.18	0.49	2	2.33
0.51-1.00	0.43	1.07	1.18	1.29	0.34	1.58	2.28
1.01-2.00	0.48	1.14	1.44	0.71	1.16	1.28	2.82
2.01-5.00	0.19	0.61	2.24	0.14	0.46	1.72	2.64
> 5.00	0.014	0.097	0.25	0	0.013	0.16	0.019

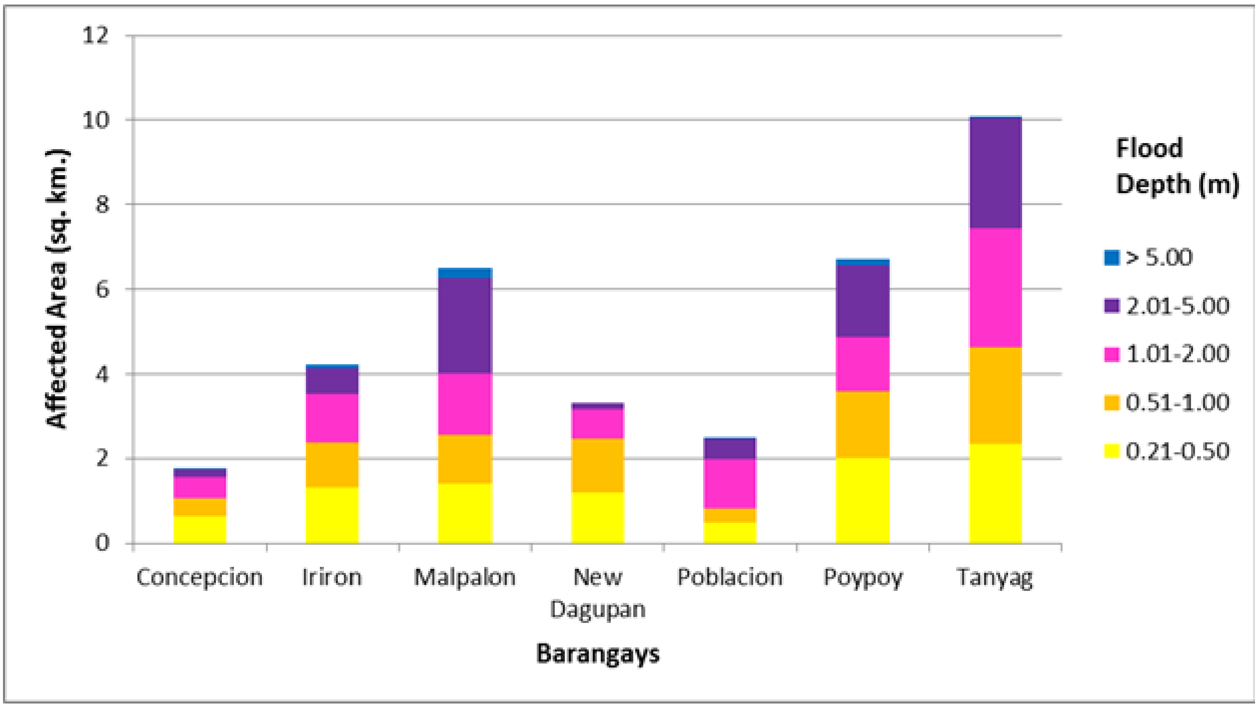

Figure 78. The specifically affected areas in Calintaan, Occidental Mindoro during a 25-Year Rainfall Return Period.

For the municipality of Rizal, with an area of 184.98 sq. km., 9.77% will experience flood levels of less 0.20 meters. 3.25% of the area will experience flood levels of 0.21 to 0.50 meters while 2.26%, 2.35%, 0.95% and 0.0009% 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. Outlined in Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 43 Affected Areas in Rizal, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)			
	Magsikap	Mala-waan	Manoot	Rizal
0.03-0.20	4.98	9.76	0.039	3.3
0.21-0.50	1.03	3.4	0.029	1.54
0.51-1.00	0.46	1.04	0.012	2.66
1.01-2.00	0.89	0.19	0	3.27
2.01-5.00	0.99	0.011	0	0.76
> 5.00	0.0016	0	0	0.0002

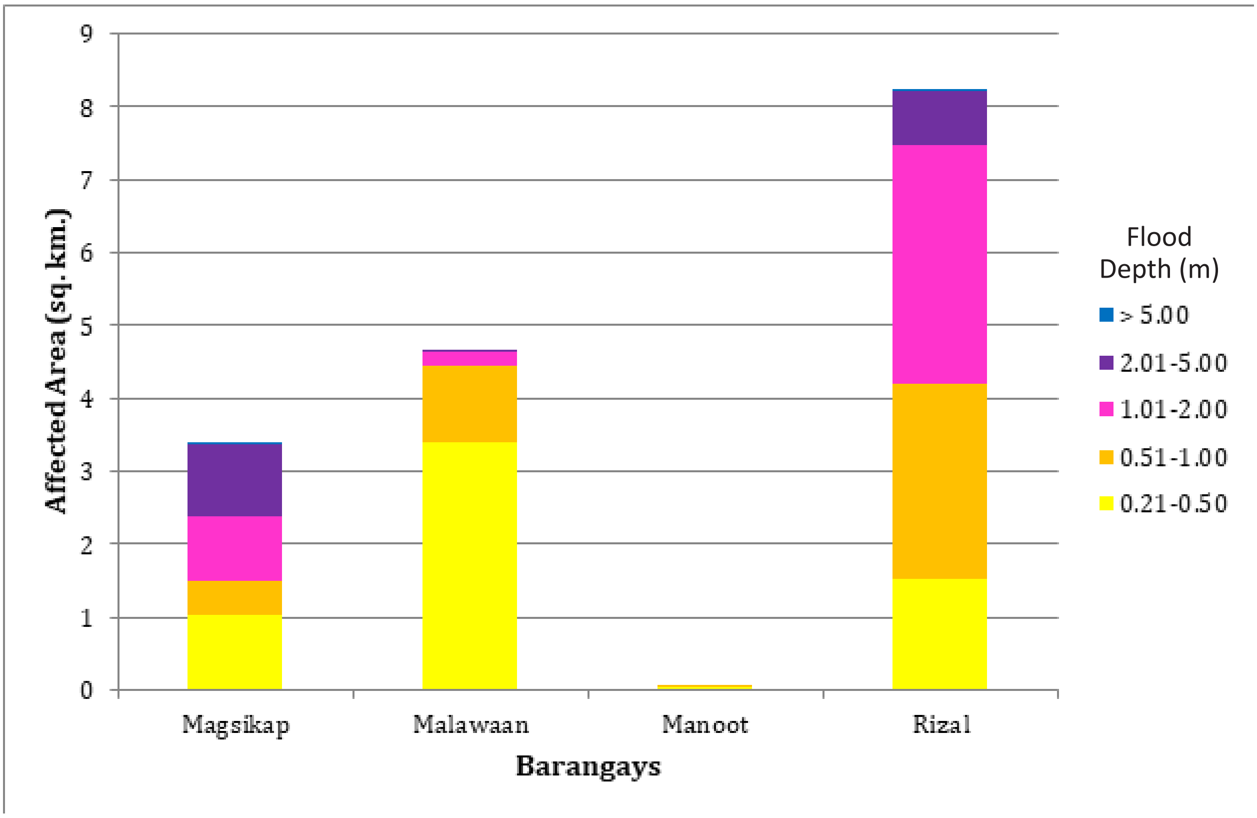

Figure 79. Affected Areas in Rizal, Occidental Mindoro during 25-Year Rainfall Return Period

For the municipality of Sablayan, with an area of 2350.46 sq. km., 21.63% will experience flood levels of less 0.20 meters. 2.19% of the area will experience flood levels of 0.21 to 0.50 meters while 1.82%, 1.27%, 0.68% and 0.03% 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. Outlined in Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 44. 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 Sablayan (in sq.km.)
	Burgos
0.03-0.20	21.63
0.21-0.50	2.19
0.51-1.00	1.82
1.01-2.00	1.27
2.01-5.00	0.68
> 5.00	0.03

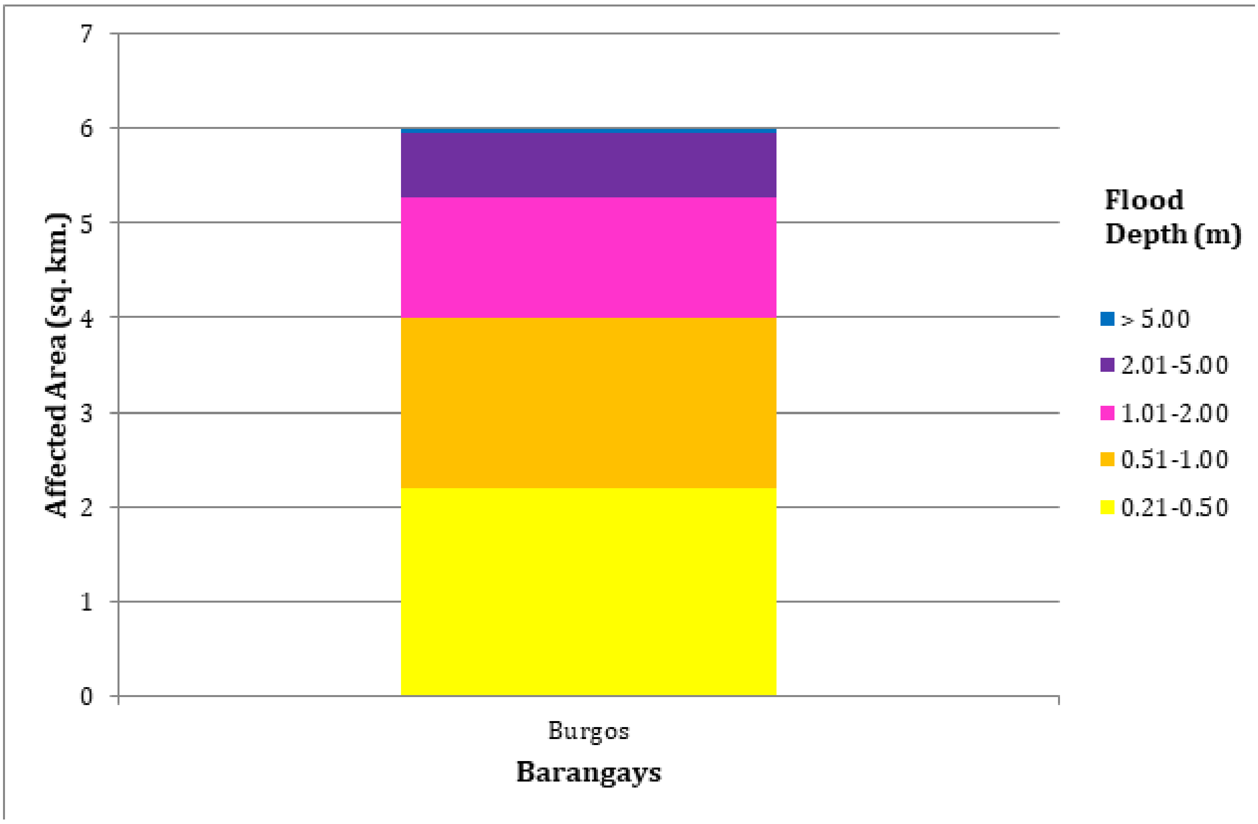

Figure 80. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 18.24% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters. 3.20% of the area will experience flood levels of 0.21 to 0.50 meters while 3.14%, 3.23%, 3.65%, and 0.47% 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 45 are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected Areas in Calintaan, Occidental Mindoro during 100-Year Rainfall Return Period

Affected Area (sq. km.) by Flood Depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)						
	Concepcion	Iriron	Malpalon	New Dagupan	Poblacion	Poypoy	Tanyag
0.03-0.20	3.18	3.73	6.57	2.15	0.5	16.53	18.83
0.21-0.50	0.68	1.28	1.38	1.17	0.33	1.98	2.22
0.51-1.00	0.54	1.32	1.18	1.33	0.47	1.78	2.24
1.01-2.00	0.45	1.44	1.61	0.71	0.99	1.36	2.55
2.01-5.00	0.35	0.88	2.42	0.14	0.78	2.09	3.66
> 5.00	0.024	0.12	0.81	0	0.025	0.29	0.038

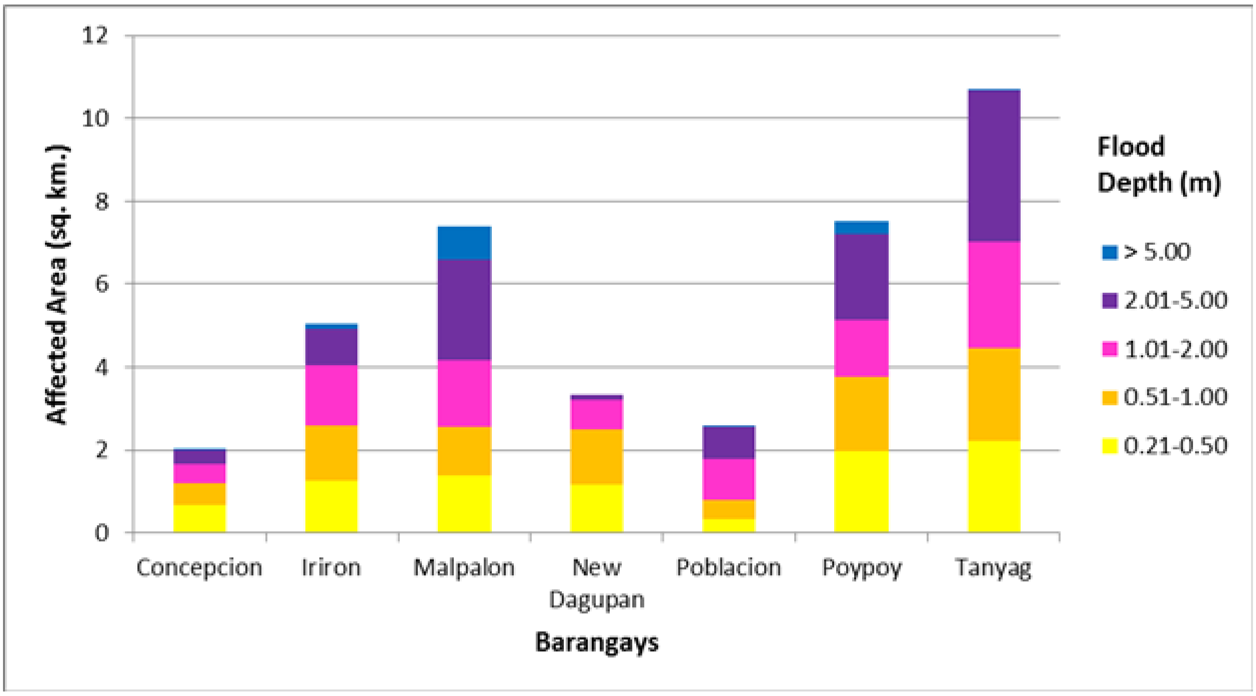

Figure 81. Affected Areas in Calintaan, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of Rizal, with an area of 184.98 sq. km., 9.27% will experience flood levels of less 0.20 meters. 3.18% of the area will experience flood levels of 0.21 to 0.50 meters while 1.95%, 2.63%, 1.54%, 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 46 are the affected areas in square kilometres by flood depth per barangay.

Table 46. Affected Areas in Rizal, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal			
	Magsikap	Malawaan	Manoot	Rizal
0.03-0.20	4.95	9.76	0.0067	2.43
0.21-0.50	1.02	3.4	0.037	1.43
0.51-1.00	0.36	1.04	0.028	2.18
1.01-2.00	0.65	0.19	0.009	4.01
2.01-5.00	1.36	0.011	0	1.47
> 5.00	0.022	0	0	0.0007

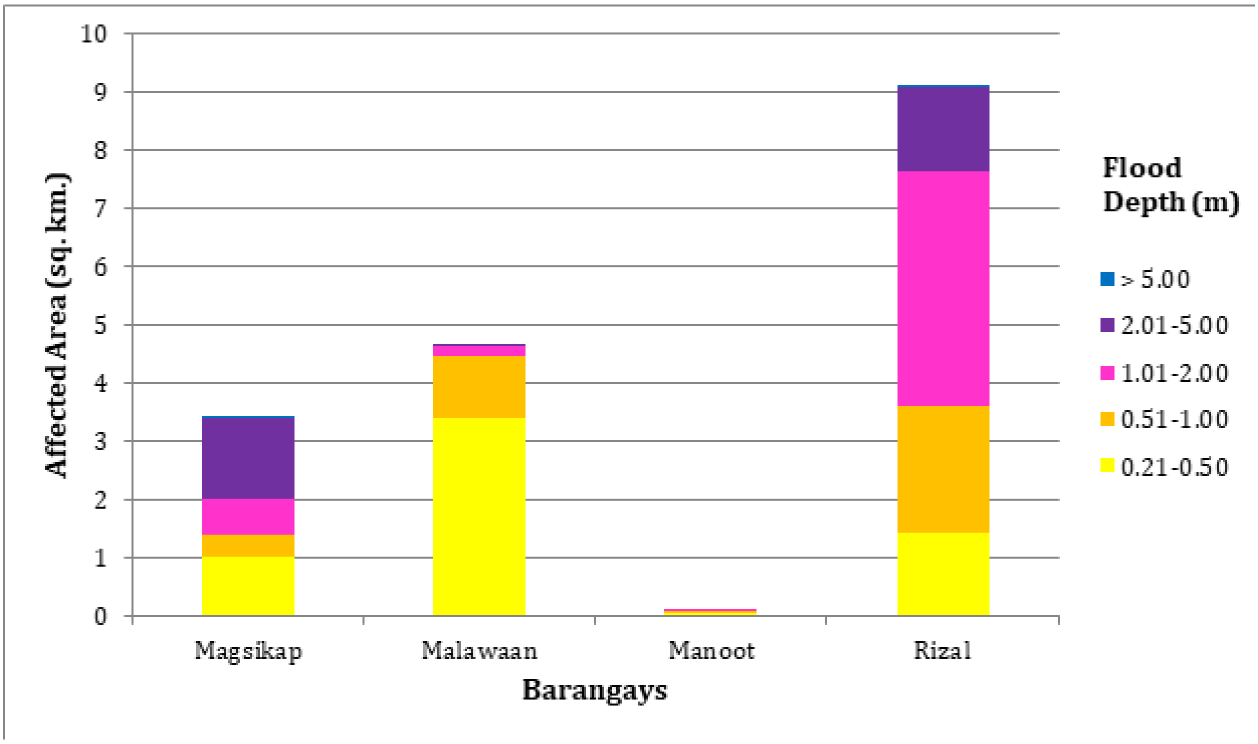

Figure 82. Affected Areas in Rizal, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of Sablayan, with an area of 2350.46 sq. km., 20.78% 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 1.97%, 1.67%, 0.92%, and 0.05% 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 47 are the affected areas in square kilometres by flood depth per barangay.

Table 47. 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
	Burgos
0.03-0.20	20.78
0.21-0.50	2.22
0.51-1.00	1.97
1.01-2.00	1.67
2.01-5.00	0.92
> 5.00	0.047

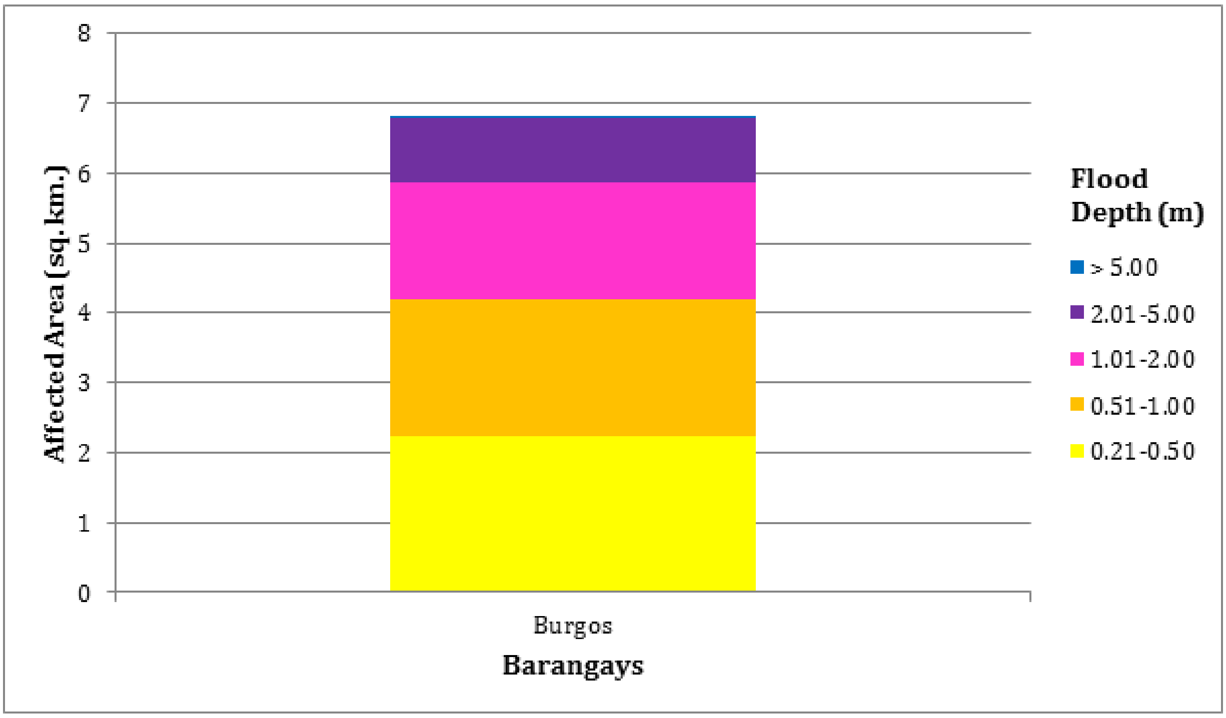

Figure 83. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

Among the barangays in the municipality of Calintaan, Tanyag is projected to have the highest percentage of area that will experience flood levels at 10.45%. Meanwhile, Poypoy posted the second highest percentage of area that may be affected by flood depths at 8.52%.

Among the barangays in the municipality of Rizal, Malawaan is projected to have the highest percentage of area that will experience flood levels at 7.79%. Meanwhile, Rizal posted the second highest percentage of area that may be affected by flood depths at 6.23%.

Among the barangays in the municipality of Sablayan, Burgos is projected to have the highest percentage of area that will experience flood levels at 1.17%.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and through interviews of 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 the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 85.

The flood validation consisted of 92 points randomly selected all over the Anahawin floodplain (Figure 84). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.63m. Figure 83 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

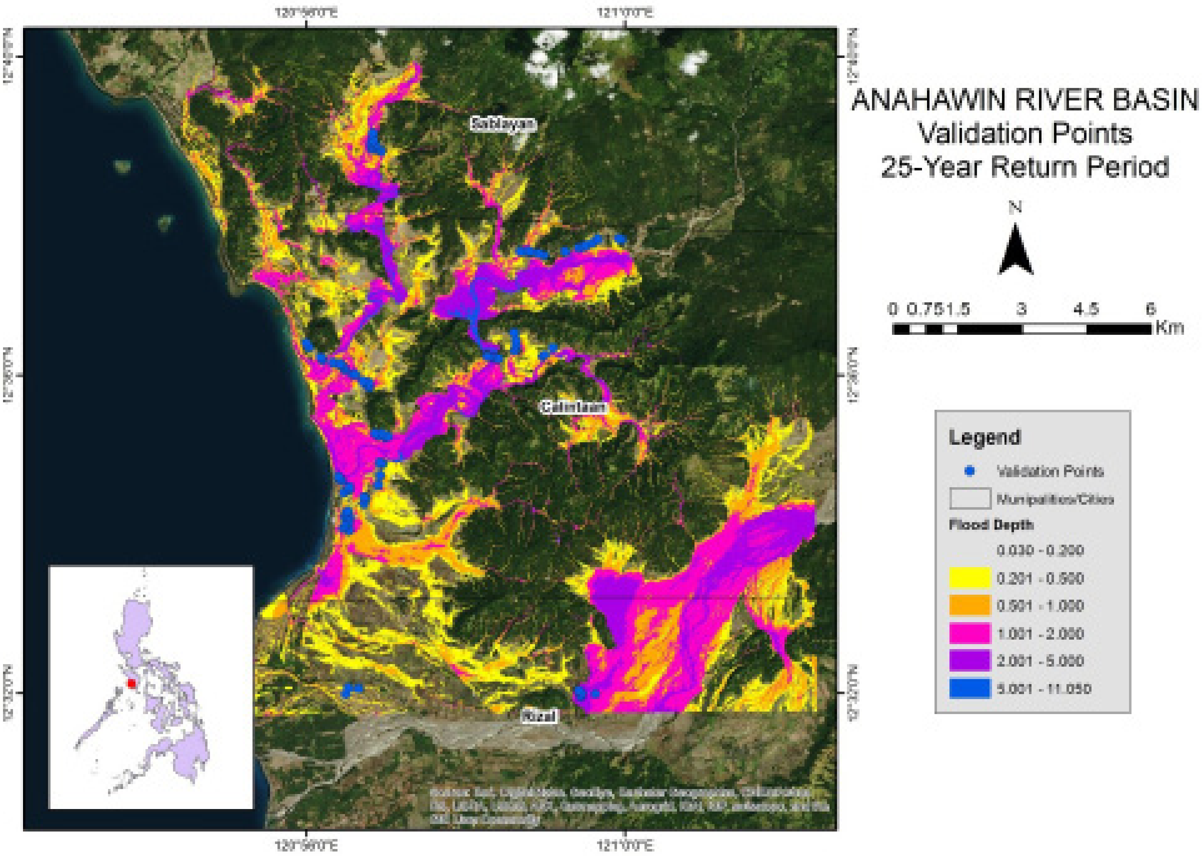

Figure 84. The Validation Points for a 5-year Flood Depth Map of the Anahawin Floodplain.

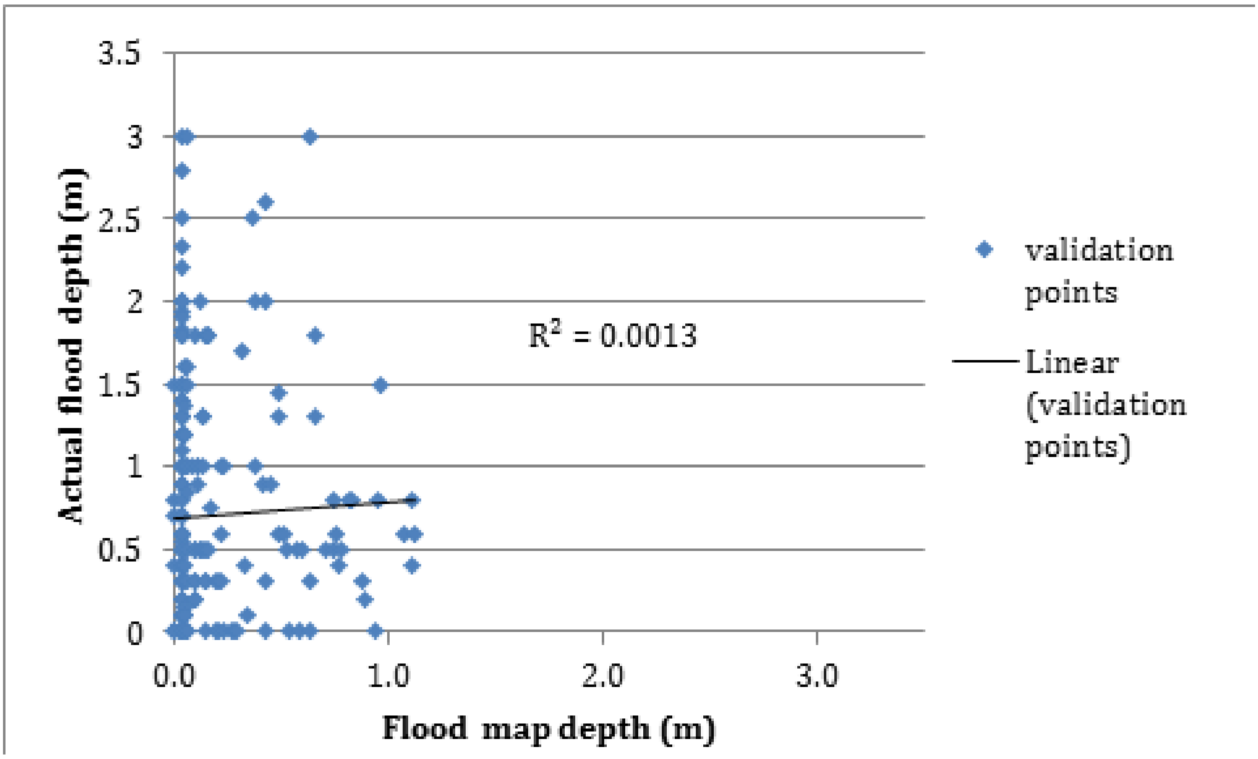

Figure 85. Flood map depth vs actual flood depth

Table 44. Actual Flood Depth vs Simulated Flood Depth in the Anahawin 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	19	3	2	2	0	0	26
0.21-0.50	6	6	7	2	0	0	21
0.51-1.00	9	6	6	7	0	0	28
1.01-2.00	3	0	5	3	6	0	17
2.01-5.00	0	0	0	0	0	0	9
Total	37	15	20	14	6	0	92

On the whole, the overall accuracy generated by the flood model is estimated at 36.96%, with 34 points correctly matching the actual flood depths. In addition, there were 40 points estimated one level above and below the correct flood depths while there were 13 points and 5 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 29 points were overestimated while a total of 29 points were underestimated in the modelled flood depths of Anahawin. Table 45 depicts the summary of the Accuracy Assessment in the Anahawin River Basin Flood Depth Map.

Table 45. The summary of the Accuracy Assessment in the Anahawin River Basin Survey

	No. of Points	%
Correct	34	36.96
Overestimated	29	31.52
Underestimated	29	31.52
Total	92	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Anahawin Floodplain Survey

Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

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

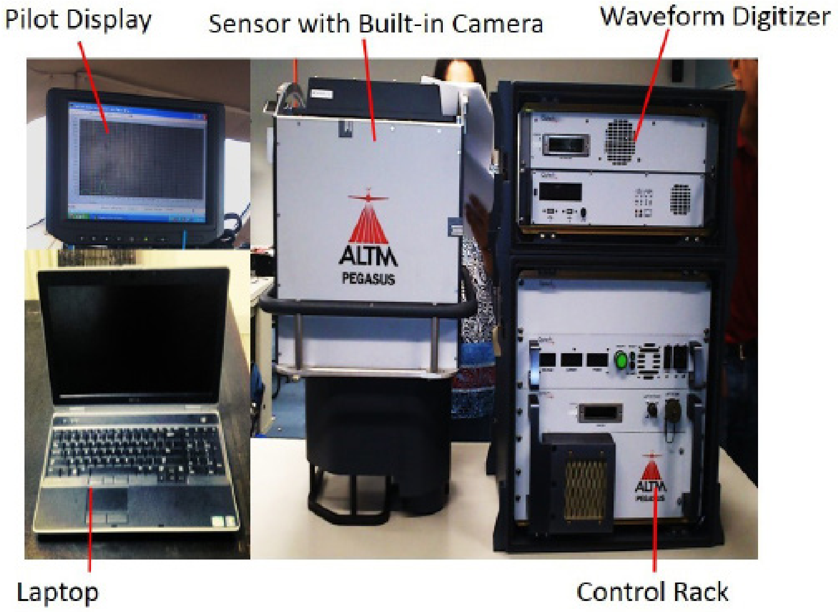

Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 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 (WOV)	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	Compatible with full Optech camera line (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% no-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 footprint

5 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

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

CP/4701/12/09/614

Figure A-2.1 MRW-6

2. MRW-22

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-22**
Order: **2nd**

Island: **LUZON**
Municipality: **CALINTAAN**
Barangay: **TANYAG**

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

Location Description

MRW-22

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

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

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

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

Figure A-2.2 MRW-22

3. MRW-24

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-24**
Order: **2nd**

Island: **LUZON**		Barangay: **IRIRON**
Municipality: **CALINTAAN**		
	PRS92 Coordinates	
Latitude: **12° 36' 42.98691"**	Longitude: **120° 55' 49.01762"**	Ellipsoidal Hgt: **5.69500 m.**
	WGS84 Coordinates	
Latitude: **12° 36' 38.03549"**	Longitude: **120° 55' 54.08296"**	Ellipsoidal Hgt: **54.47900 m.**
	PTM Coordinates	
Northing: **1394624.897 m.**	Easting: **492425.435 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,395,022.71**	Easting: **275,166.05**	Zone: **51**

Location Description

MRW-24

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

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

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

9903042014160207

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

Figure A-2.3 MRW-24

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**
Municipality: **SABLAYAN**
Barangay: **MALISBONG**

PRS92 Coordinates

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

WGS84 Coordinates

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

PTM Coordinates

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

UTM Coordinates

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

Location Description

MRW-54

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

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

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

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

Figure A-2.4 MRW-54

5. MRW-4203

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

March 25, 2014

CERTIFICATION

To whom it may concern:

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

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

Island: **LUZON**		Barangay: **MAPAYA**
Municipality: **SAN JOSE**		
	PRS92 Coordinates	
Latitude: **12° 21' 24.45294"**	Longitude: **121° 7' 26.82407"**	Ellipsoidal Hgt: **7.40100 m.**
	WGS84 Coordinates	
Latitude: **12° 21' 19.57973"**	Longitude: **121° 7' 32.01059"**	Ellipsoidal Hgt: **57.32000 m.**
	PTM Coordinates	
Northing: **1366404.003 m.**	Easting: **513501.246 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,366,637.32**	Easting: **296,032.79**	Zone: **51**

Location Description

MRW-4203

From San Jose Town Proper to Brgy. Mapaya, approx. 7.8 Km. travel to reach brgy. hall. The station is located inside the compound of brgy. plaza, beside the gate post, left side fronting brgy. hall about 40 m NE of brgy. hall, 200 m NW of post Km. post 223, along Nat'l Road, 7 Km. to San Jose. Station is located in Brgy. Mapaya, San Jose, Occ., Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4203, 2007, NAMRIA"

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

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

NAMRIA OFFICES:
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

1. UP-LUM-2015

Table A-3.1 Baseline Processing Report - A

VECTOR COMPONENTS (Mark to Mark)

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

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

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

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000207579		
Y	-0.0000318186	0.0000636236	
Z	-0.0000092702	0.0000183702	0.0000069466

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

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

Annex 5. Data Transfer Sheet for Anahawin Floodplain

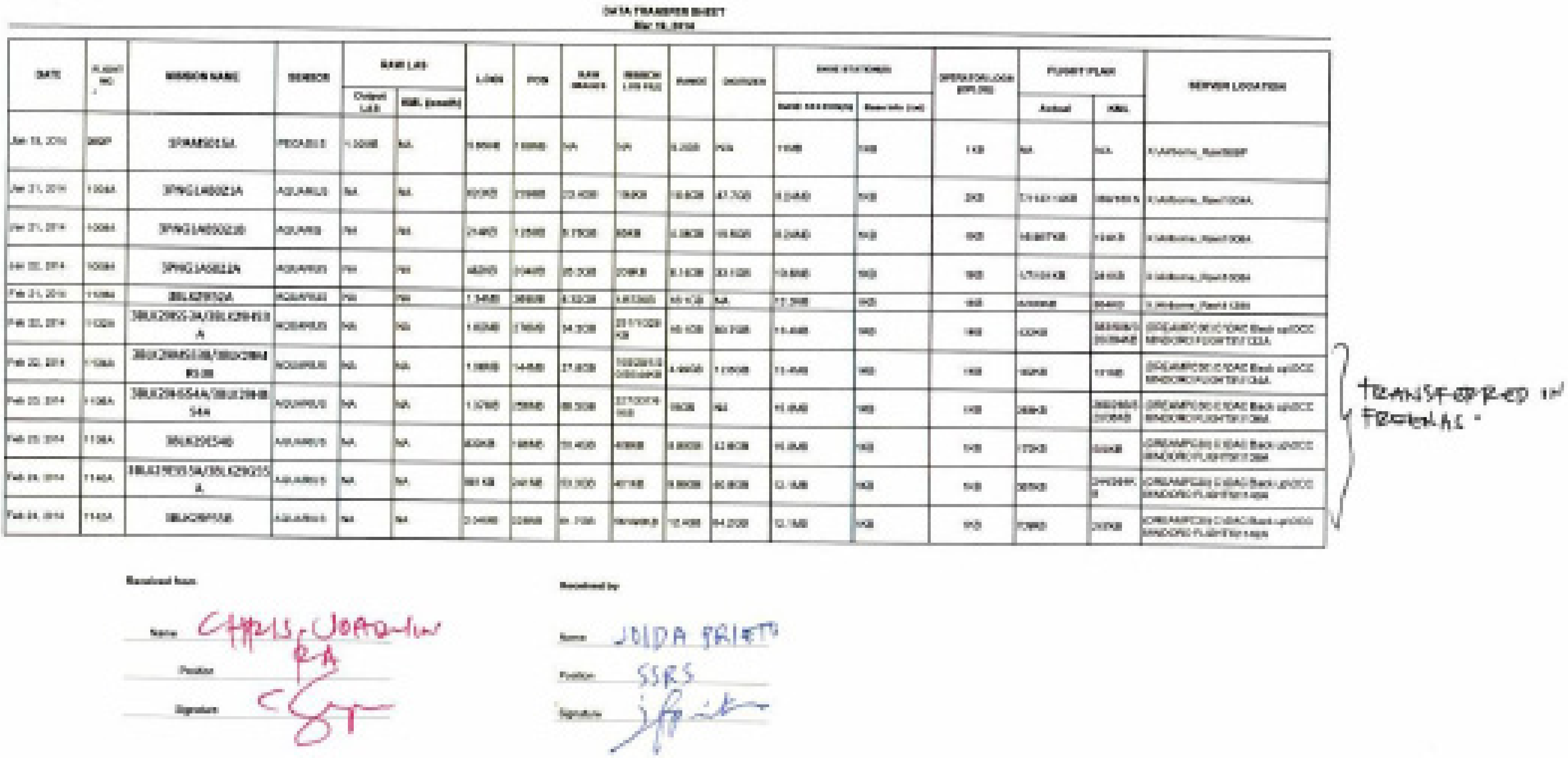


Figure A-5.1 Data Transfer Sheet for Anahawin Floodplain - A

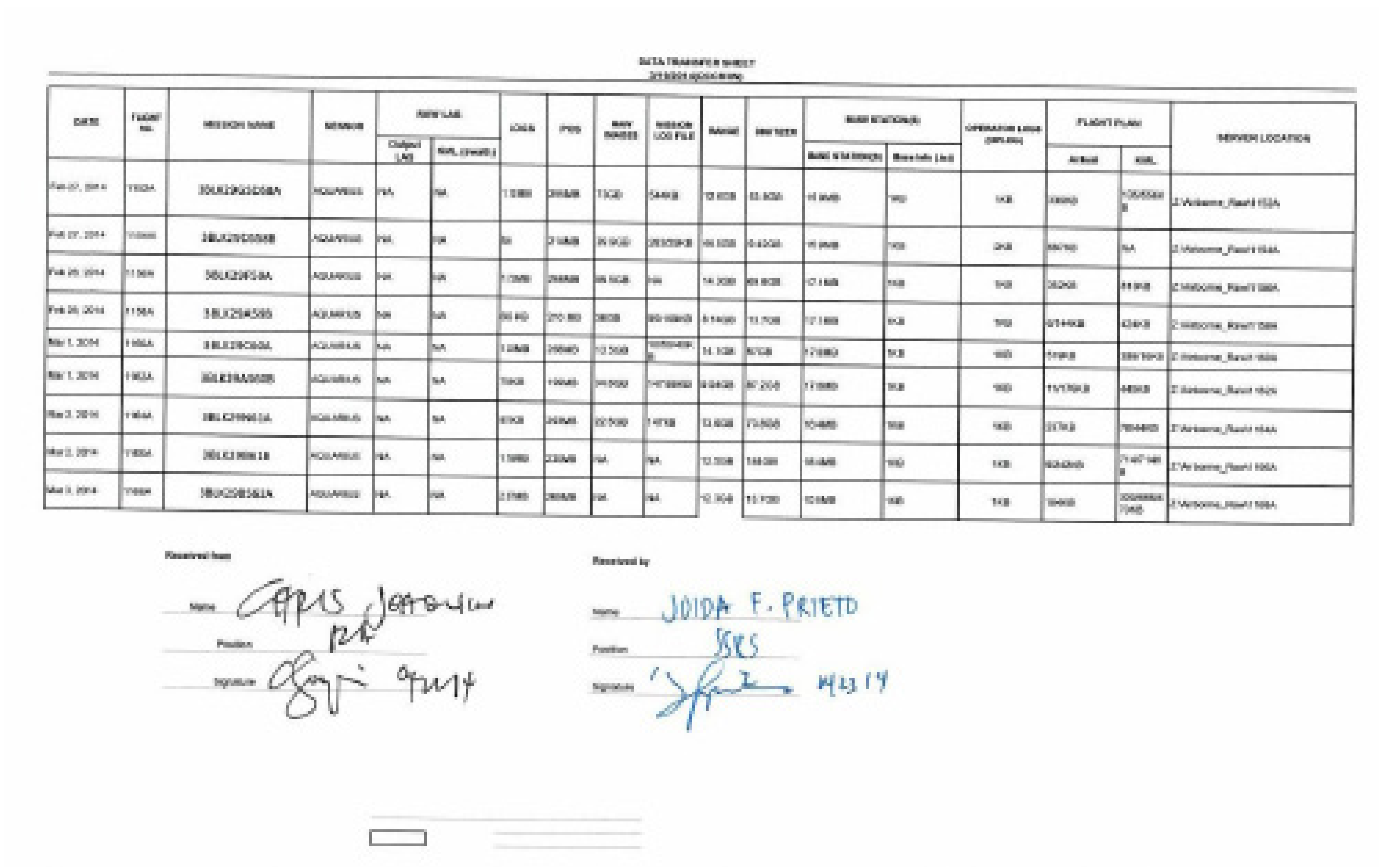


Figure A-5.2 Data Transfer Sheet for Anahawin Floodplain - B

DATA TRANSFER SHEET
Dec. Missions 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	702	189	5.89	120	8.79	74	7.56	na	15.4	1KB	1KB	48	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	394/94/258	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.46	400	9.18	208	28.6	192	14.4	na	7.81	1KB	1KB	130/89/85	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACD342A	pegasus	552	279	7.18	177	17	121	9.79	na	16	1KB	1KB	146/155	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	0	87	2.7	114	4.83	37	2.77	na	16	1KB	1KB	146/155	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	853	217	5.7	143	14.3	na	9.37	na	5.98	1KB	1KB	146/155	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.89	212	9.12	228	38.9	224	28.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	258	75	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	385/318/295/313/140/158	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	551	171	5.23	157	12.9	105	8.2	na	7.02	1KB	1KB	47/39/40/48/13/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29RO346A	pegasus	932	208	6.85	174	13.1	93	9.22	na	7.81	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

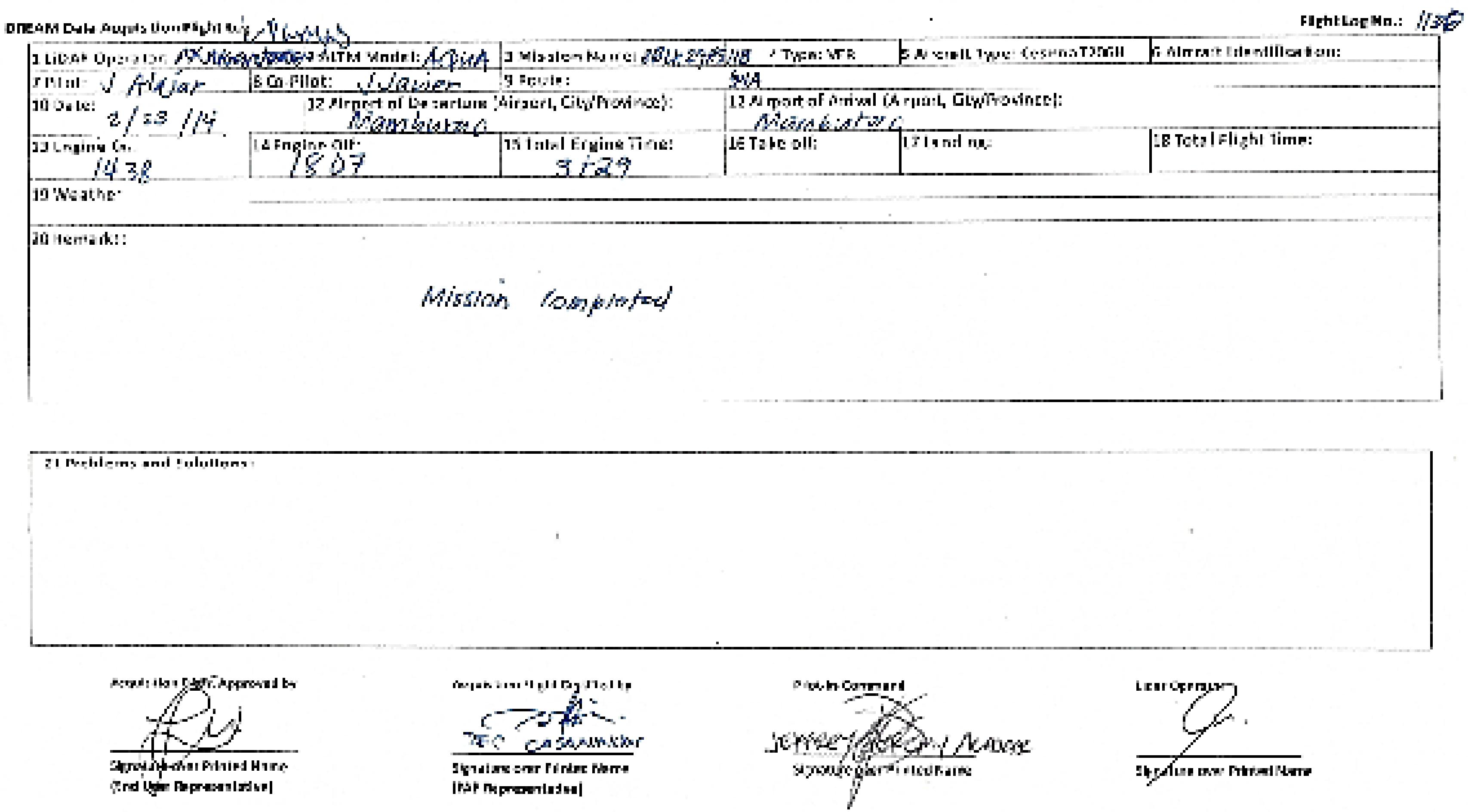
Received by

Name AC Bongat
Position SSRS
Signature 1/13/16

Figure A-5.3 Data Transfer Sheet for Anahawin Floodplain - C

Annex 6. Flight logs for the flight missions

1. Flight Log for 1138A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1138

1 LiDAR Operator:	2 ALTM Model: Aquia	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	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):		13 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1438	14 Engine Off: 1807	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

LiDAR Operator — Signature over Printed Name

Figure A-6.1 Flight Log for Mission 1138A

2. Flight Log for 1140A Mission

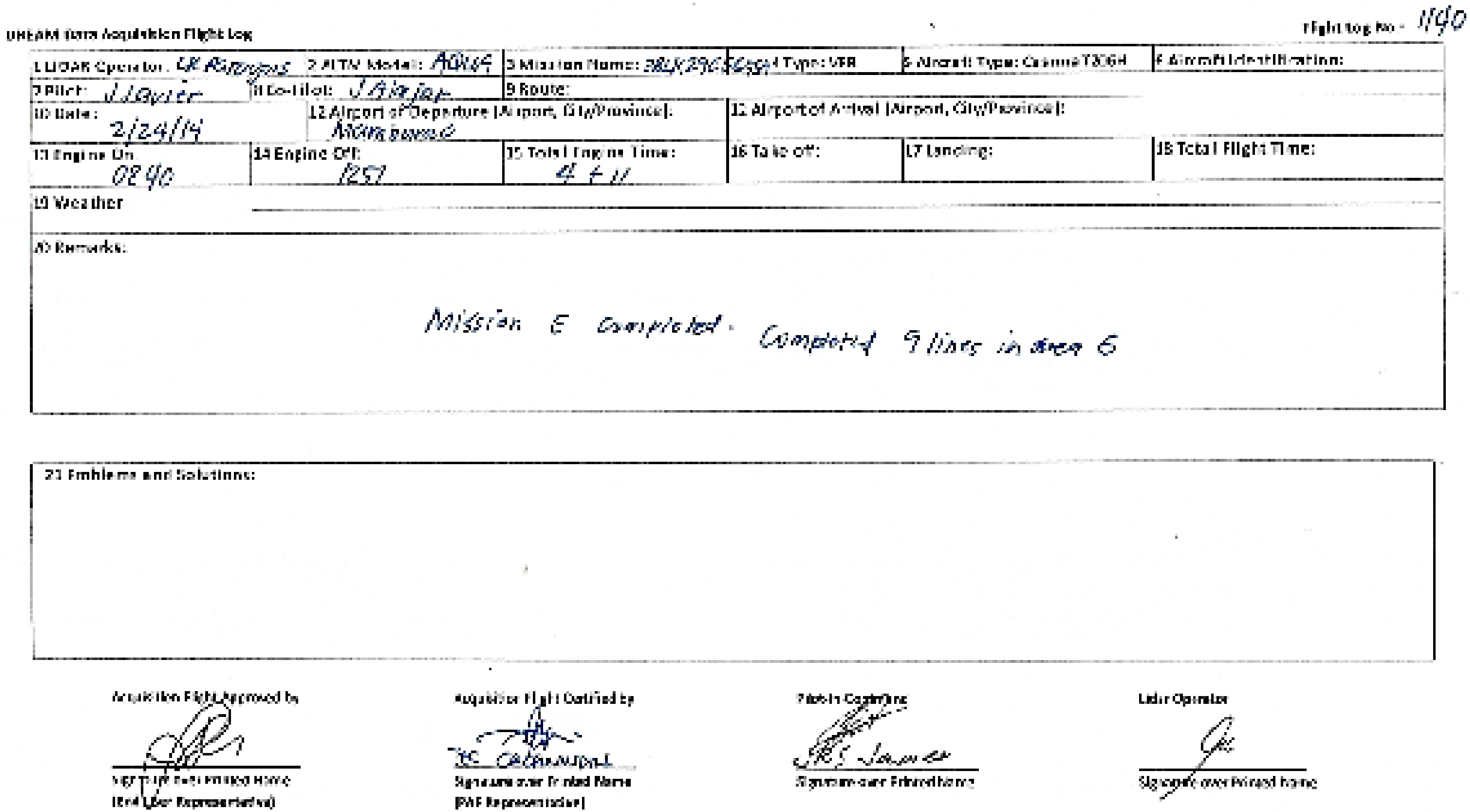
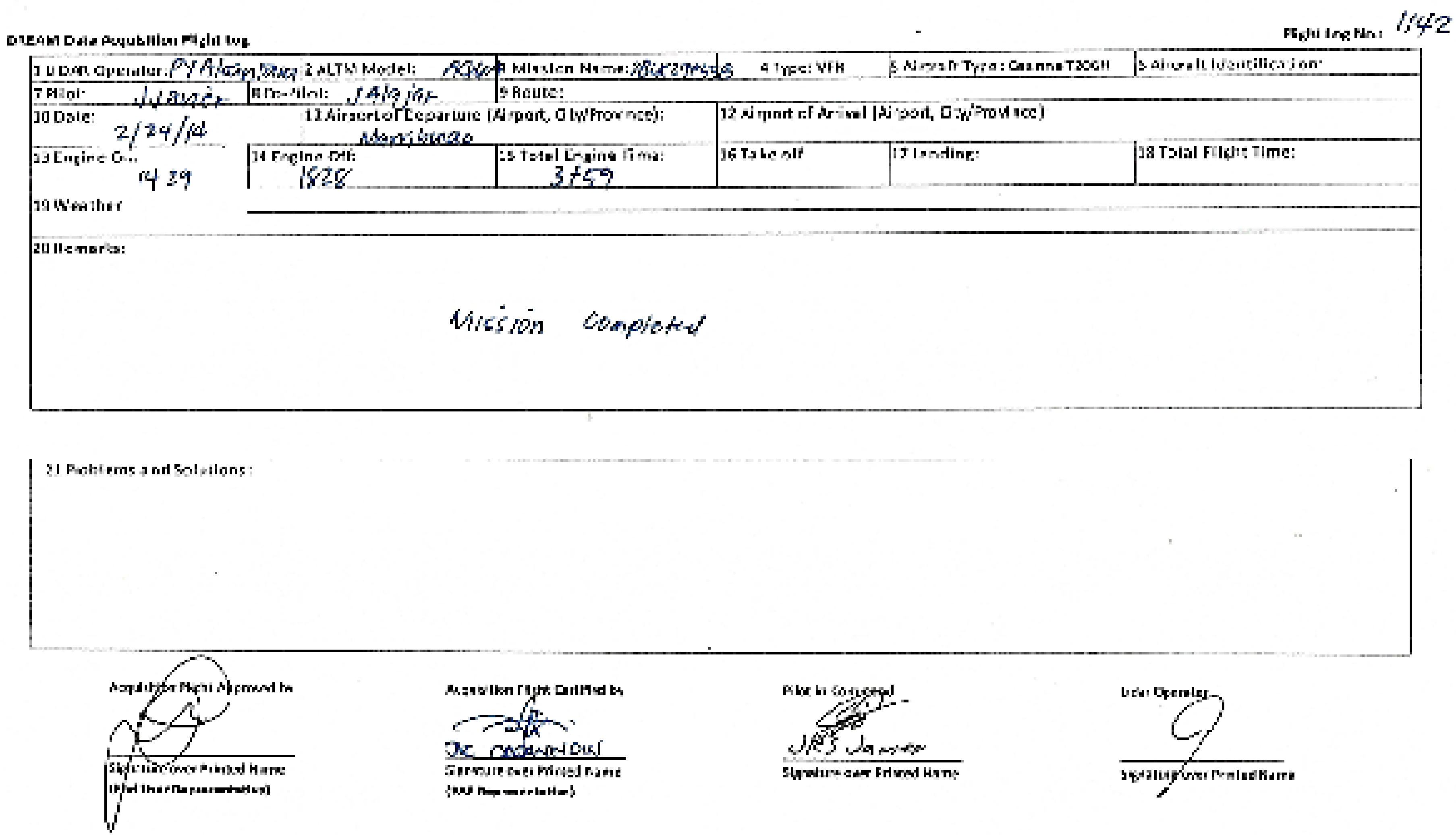


Figure A-6.2 Flight Log for Mission 1140A

3. Flight Log for 1142A Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1142

1 LiDAR Operator:	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: 2/24/14	11 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province)		
13 Engine On: 1439	14 Engine Off: 1828	15 Total Engine Time: 3+59	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 Mission 1142A

4. Flight Log for 1152A Mission

DREAM Data Acquisition Flight Log Flight Log No.: 1152

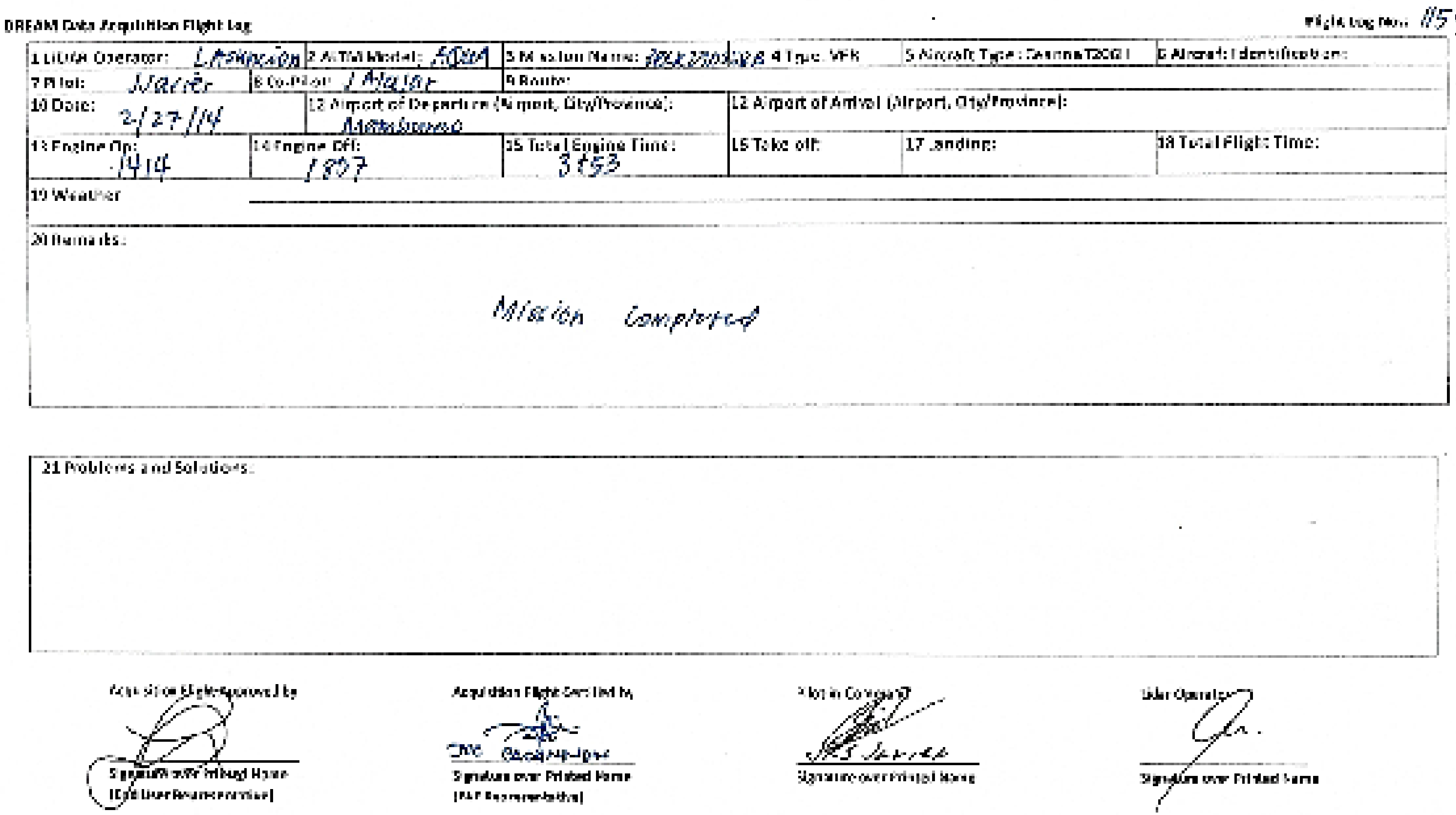
1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29650S8A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/27/14	12 Airport of Departure (Airport, City/Province): Namburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0841	14 Engine Off: 1304	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission 6 Completed. Completed 5 lines in area D					

21 Problems and Solutions:

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

Figure A-6.4 Flight Log for Mission 1152A

5. Flight Log for 1154A Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1159

1 LiDAR Operator: L Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK28...	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Alajar	8 Co-Pilot: J. Alajar	9 Route:			
10 Date: 2/27/14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1414	14 Engine Off: 1807	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission Completed

21 Problems and Solutions:

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.5 Flight Log for Mission 1154A

6. Flight Log for 1156A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1156

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK38A59A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J Major	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/28/14	12 Airport of Departure (Airport, City/Province): Ubambuco		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 819	14 Engine Off: 1248	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.6 Flight Log for Mission 1156A

7. Flight Log for 1162A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1162

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

20 Remarks:

Mission completed

21 Problems and Solutions:

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

Figure A-6.7 Flight Log for Mission 1162A

8. Flight Log for 3074P Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 3074P

1 LIDAR Operator: G.S/MADJAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29KLM0344A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao			
10 Date: DEC 10, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0752	14 Engine Off: 1157	15 Total Engine Time: 4+05	16 Take off: 0757	17 Landing: 1152	18 Total Flight Time: 3+55
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

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

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[signature]	[signature]	C. Alfonso III	Gerome Sinadjan	N.R. Caleon
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.8 Flight Log for Mission 3074P

Annex 7. Flight status reports

Table A-7.1 Flight Status Report

February 16 - March 3, 2014 and December 10, 2015

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1138A	BLK29E	3BLK29E54B	LK PARAGAS	23-Feb-14	Completed 18 lines of Area E. Repeated lines 20, 21 & 22 to cover the voids
1140A	BLK29E & BLK29G	3BLK29ES55A (3BLK29ES+G55A)	LK PARAGAS	24-Feb-14	Completed the rest of area E and 5 lines of area G. 30 percent dropouts in line 20 of area G.
1142A	BLK29F	3BLK29P55B	PY ALCANTARA	24-Feb-14	Mission completed. Camera error in line 16, 100% dropouts in line 15
	BLK33F BLK33G	3BLK34OSP130B	I. ROXAS	May 10, 2014	Completed 15 lines over BLK33G.
1152A	BLK29D & BLK29G	3BLK29GSD58A (3BLK29D+GS58A)	L. PARAGAS	27-Feb-14	Completed the rest of BLK29G and 5 lines of BLK29D.
1154A	BLK29D	3BLK29DS58B	L. ASUNCION	27-Feb-14	Completed the rest of BLK29D. Experienced dropouts over water. Camera assertion failed in line 15, restarted the camera. Also, cam error in line 18.
1156A	BLK29F	3BLK29F59A	L. PARAGAS	28-Feb-14	Mission completed. No camera mission logs.
1162A	BLK29A & BLK29D	3BLK29AS60B (3BLK29AS+DV60B)	L. ASUNCION	01-Mar-14	Mission completed. Continuation of BLK29A and covered voids in BLK29D. Restarted the system due to high system temperature. Camera hanged in line 3, no images for half of the line while manually for the rest of the line and entire line 8 while no images for lines 1, 4 and 7.
3074P	BLK 29O	1BLK29KLMO344A	G. Sinadjan	December 10, 2015	Surveyed BLK 29K, L, M and O

SWATH PER FLIGHT MISSION

Flight No. : 1138A
Area: BLK29E
MISSION NAME: 3BLK29E54B
SURVEY COVERAGE:

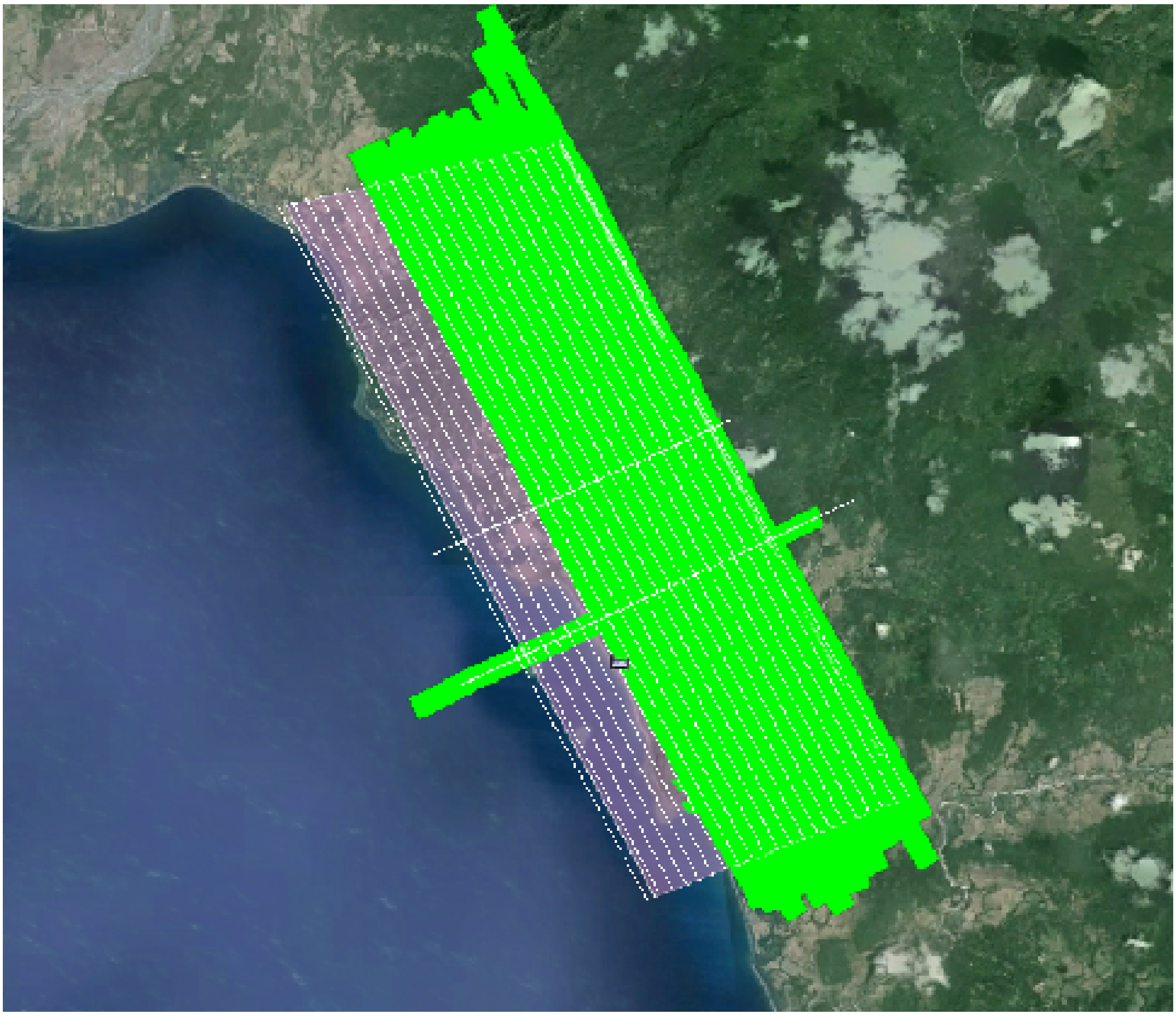


Figure A-7.1 Swath for Flight No. 1138A

Flight No. : 1140A
Area: BLK29E AND BLK29G
Mission Name: 3BLK29ES55A (3BLK29ES+G55A)
SURVEY COVERAGE:

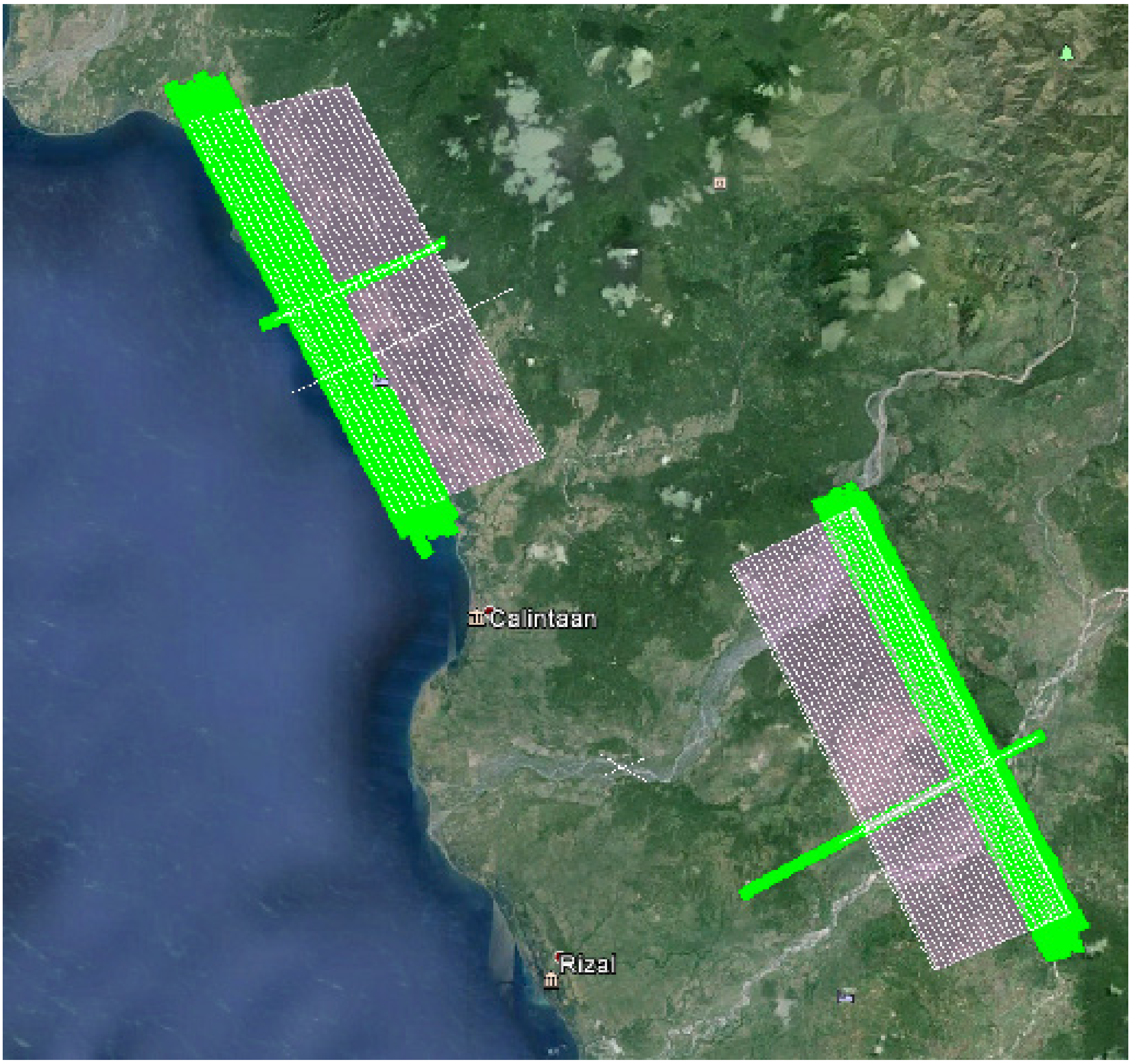


Figure A-7.2 Swath for Flight No. 1140A

Flight No. :	1142A
Area:	BLK29P
Mission Name:	3BLK29P55B
SURVEY COVERAGE:	

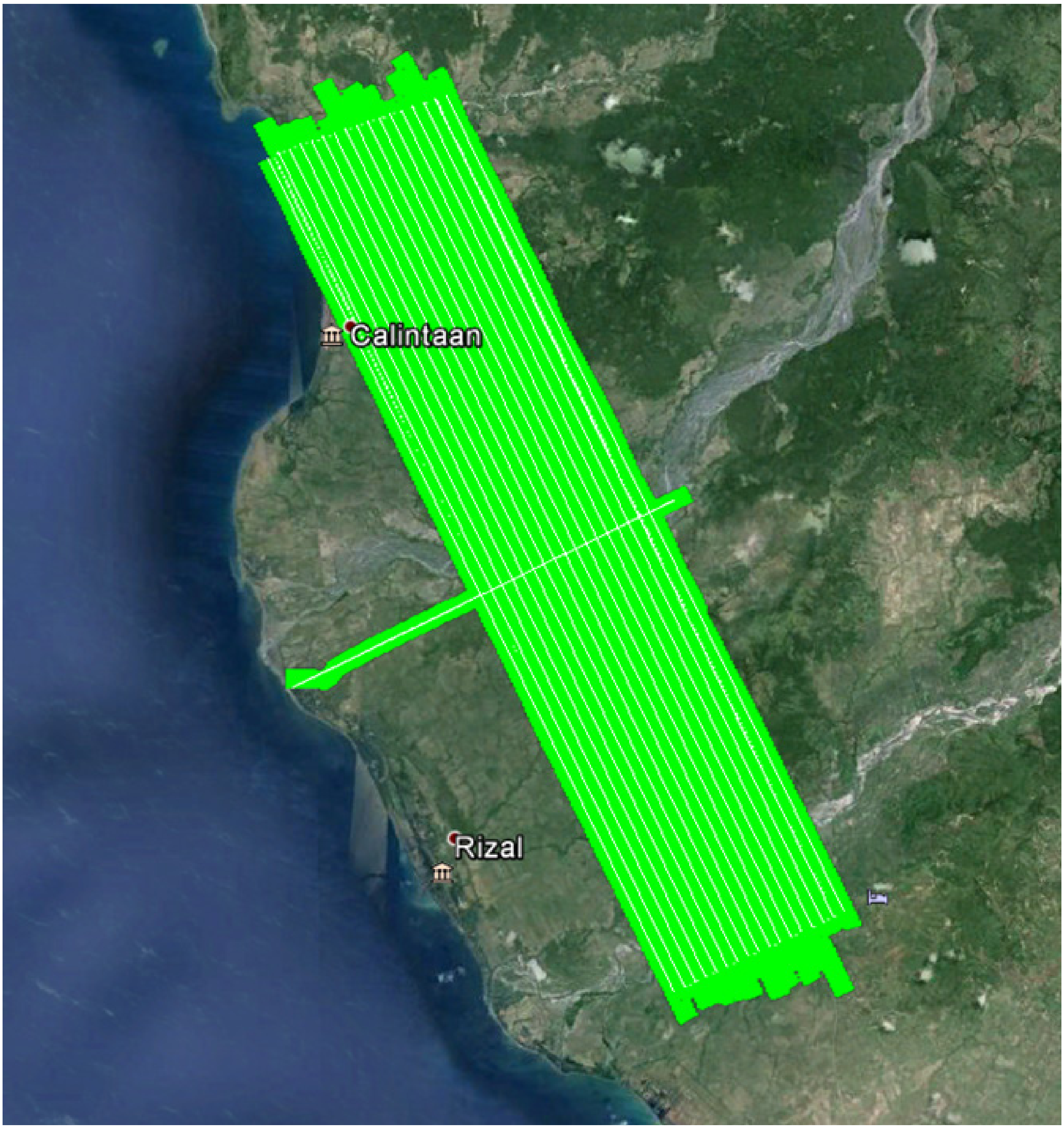


Figure A-7.3 Swath for Flight No. 1142A

Flight No. :	1152A
Area:	BLK29D AND BLK29G
Mission Name:	3BLK29GSD58A (3BLK29D+GS58A)
SURVEY COVERAGE:	

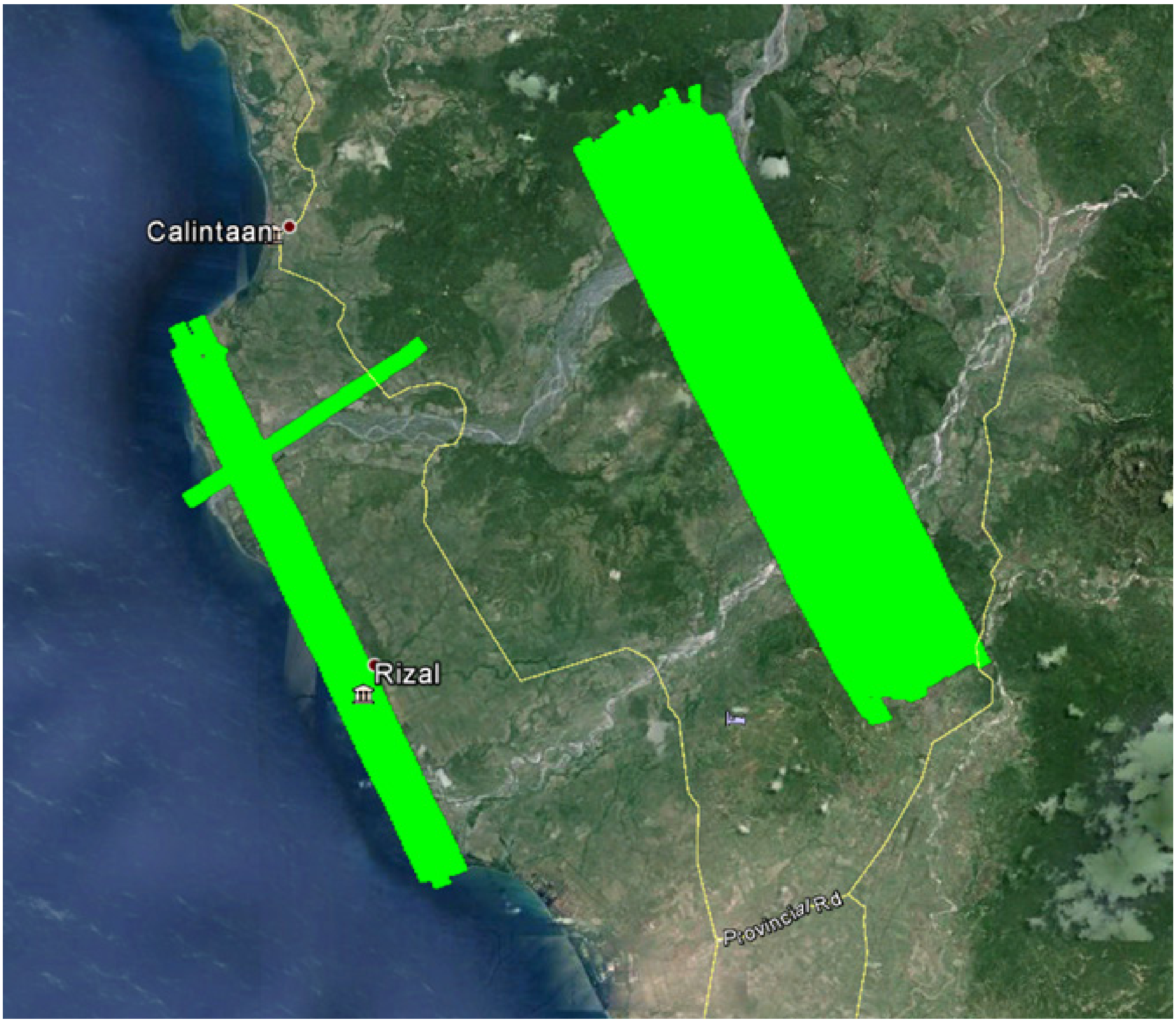


Figure A-7.4 Swath for Flight No. 1152A

Flight No. : 1154A
Area: BLK29D
Mission Name: 3BLK29DS58B
SURVEY COVERAGE:

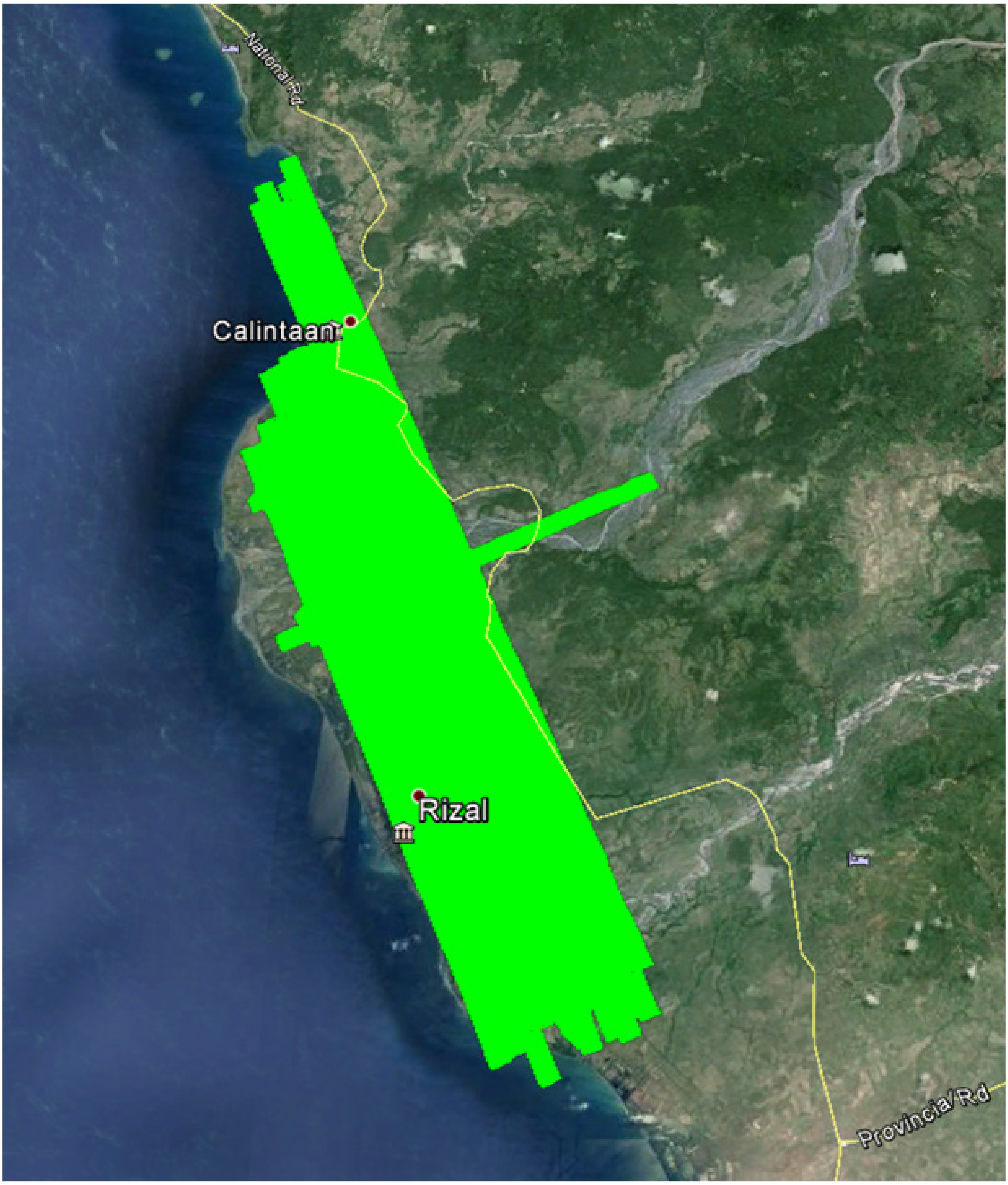


Figure A-7.5 Swath for Flight No. 1154A

Flight No. :	1156A
Area:	BLK29F
Total Area:	3BLK29F59A
SURVEY COVERAGE:	

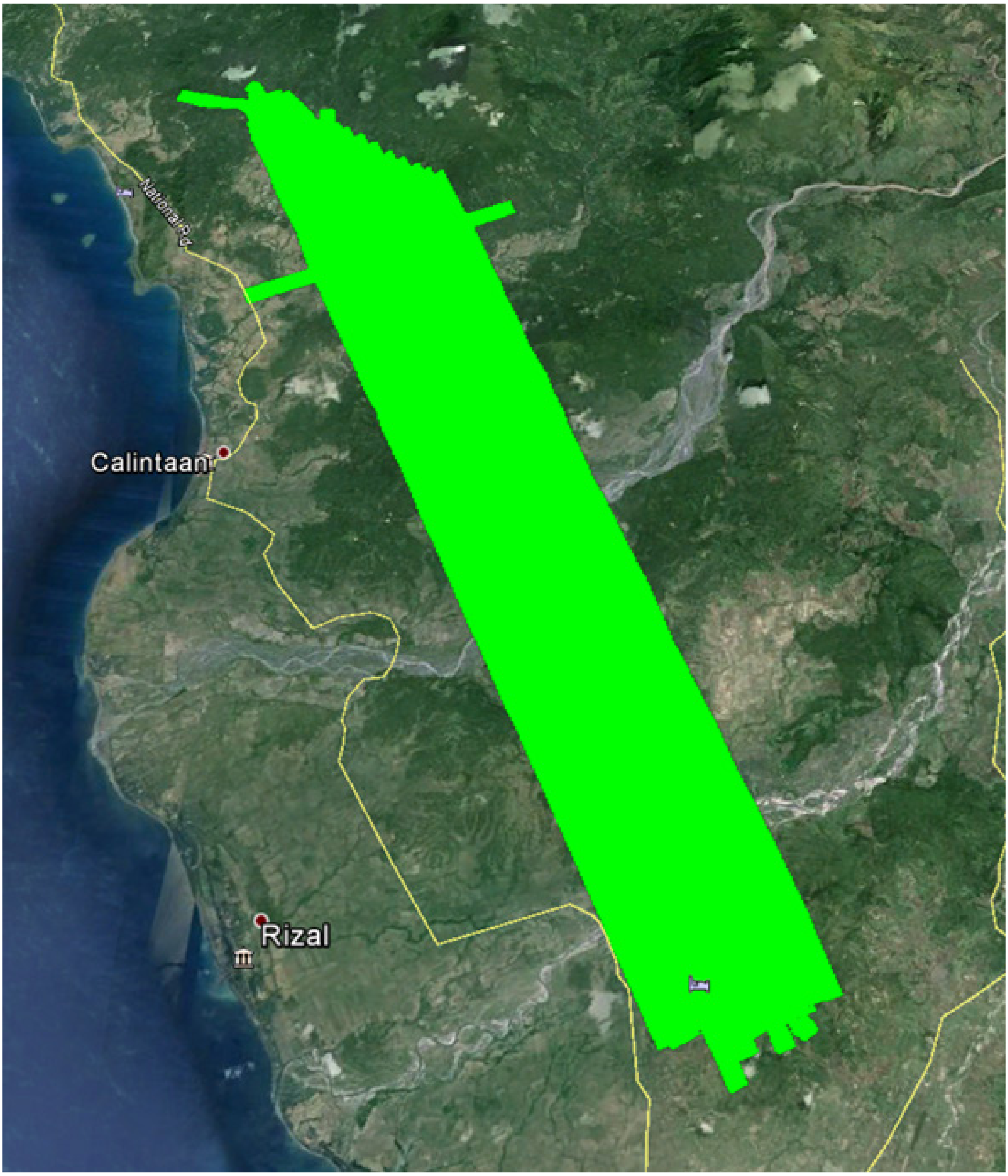


Figure A-7.6 Swath for Flight No. 1156A

Flight No. : 1162A
Area: BLK29A AND BLK29D
Total Area: 3BLK29AS60B (3BLK29AS+DV60B)
SURVEY COVERAGE:

Figure A-7.7 Swath for Flight No. 1162A

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

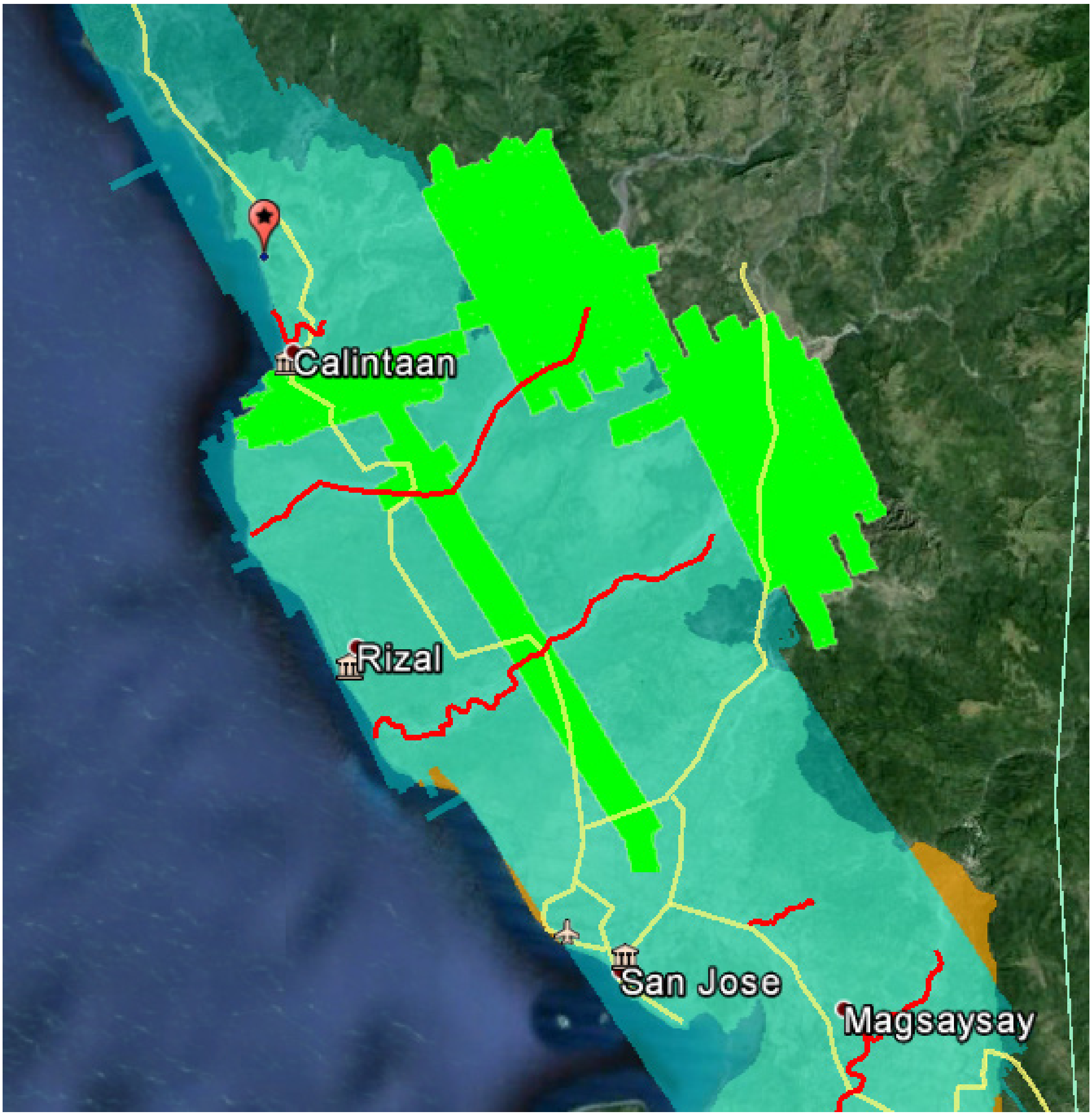


Figure A-7.8 Swath for Flight No. 3074P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Blk29D

Flight Area	Occidental Mindoro
Mission Name	Blk29D
Inclusive Flights	1152A, 1154A, 1162A
Range data size	91.7 GB
POS data size	668 MB
Image	122.4 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.7
Boresight correction stdev (<0.001deg)	0.000443
IMU attitude correction stdev (<0.001deg)	0.001081
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	51.63%
Ave point cloud density per sq.m. (>2.0)	3.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	137
Maximum Height	342.94 m
Minimum Height	44.17 m
Classification (# of points)	
Ground	74,678,234
Low vegetation	114,713,757
Medium vegetation	46,923,753
High vegetation	14,006,770
Building	1,753,112
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat

Figure A-8.1. Solution Status

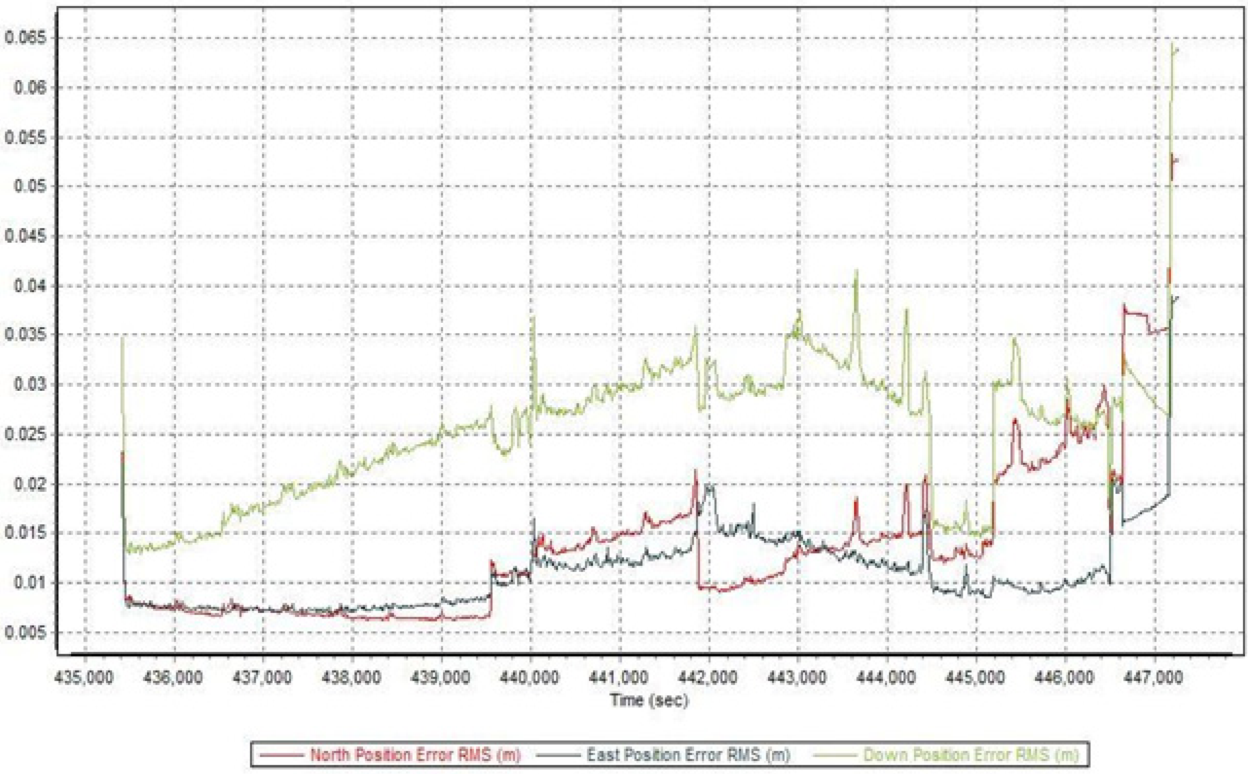


Figure A-8.2. Smoothed Performance Metrics Parameters

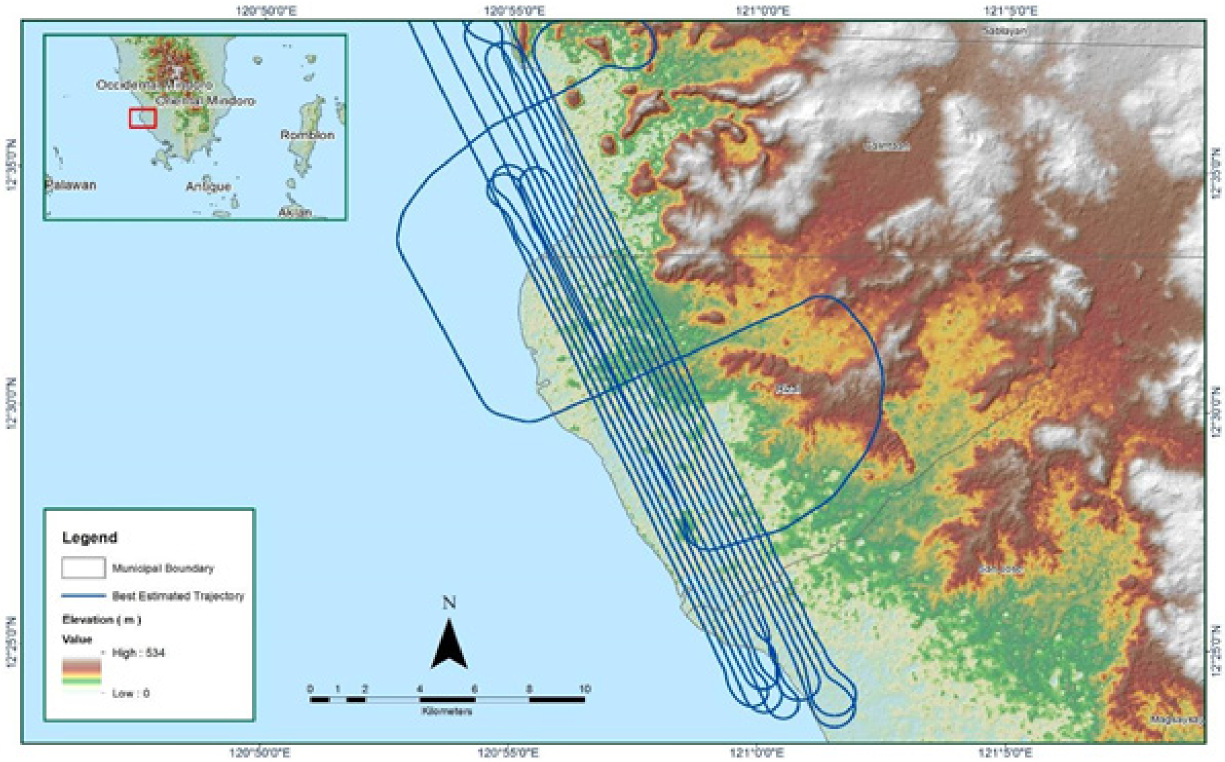


Figure A-8.3. Best estimated trajectory of LiDAR missions conducted over the Anahawin Floodplain.

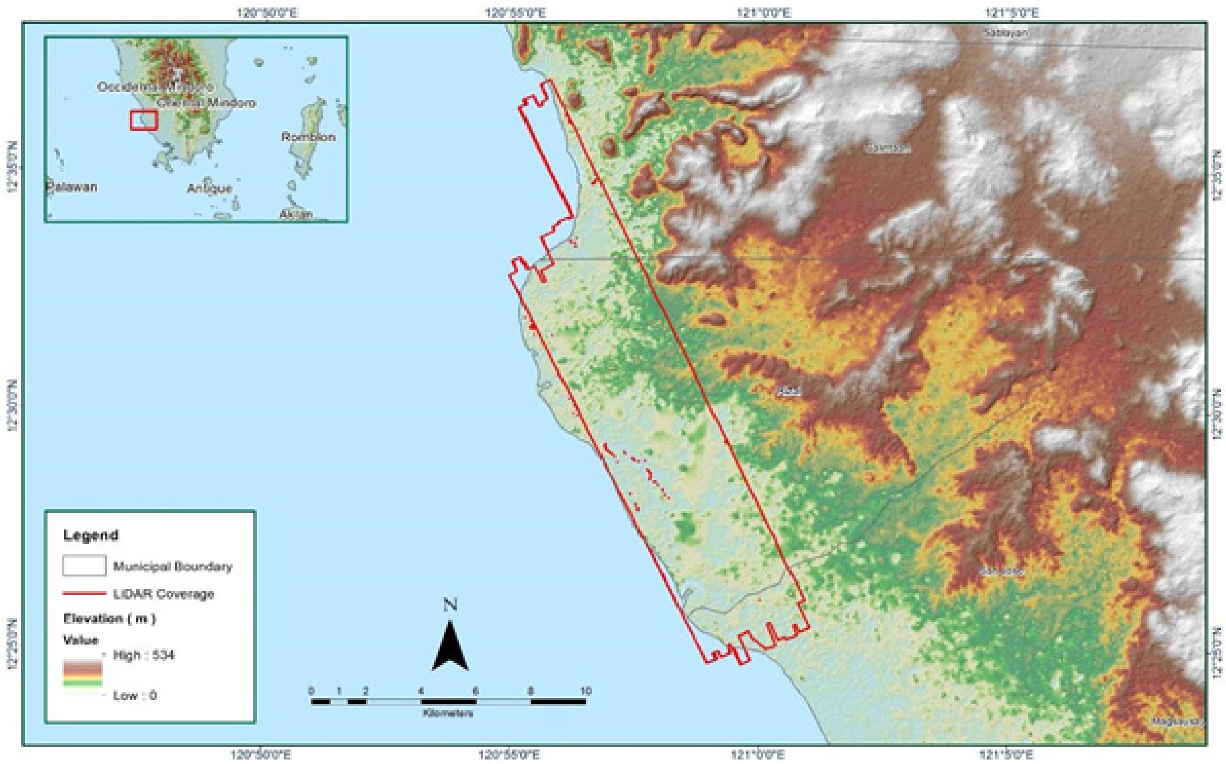


Figure A-8.4. Coverage of LiDAR data

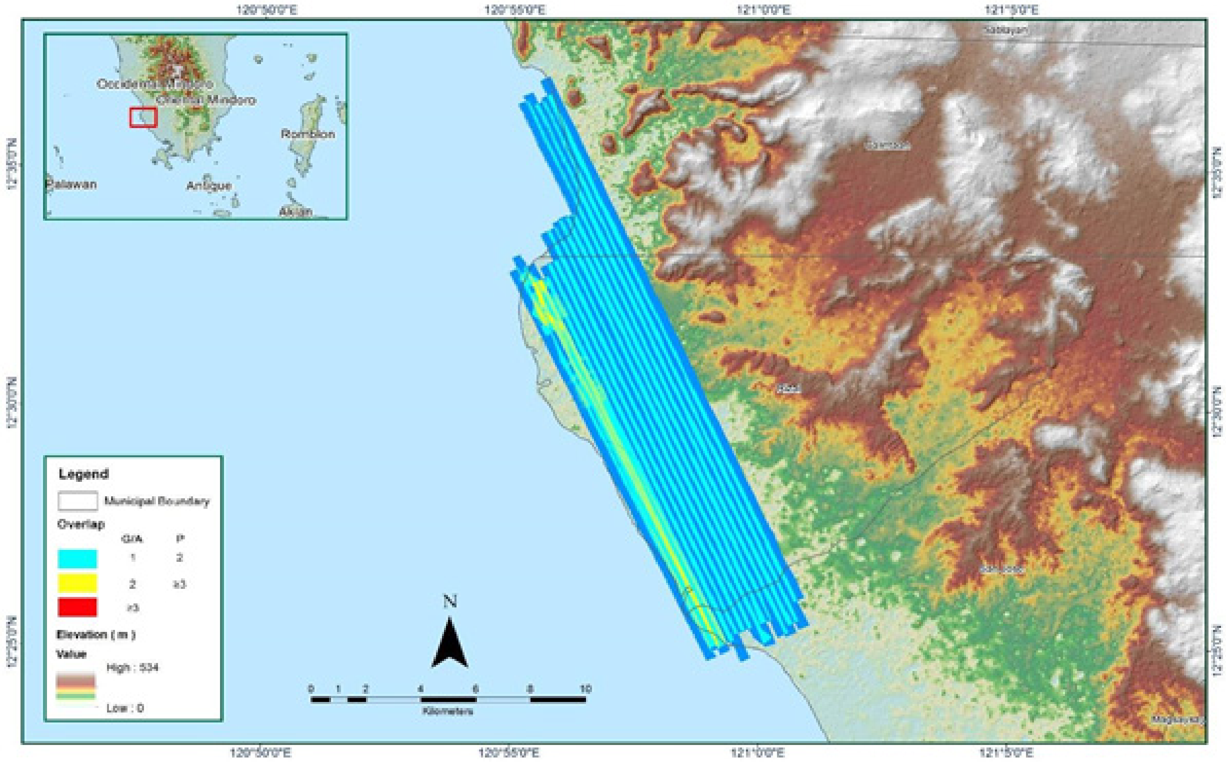


Figure A-8.5. Image of data overlap

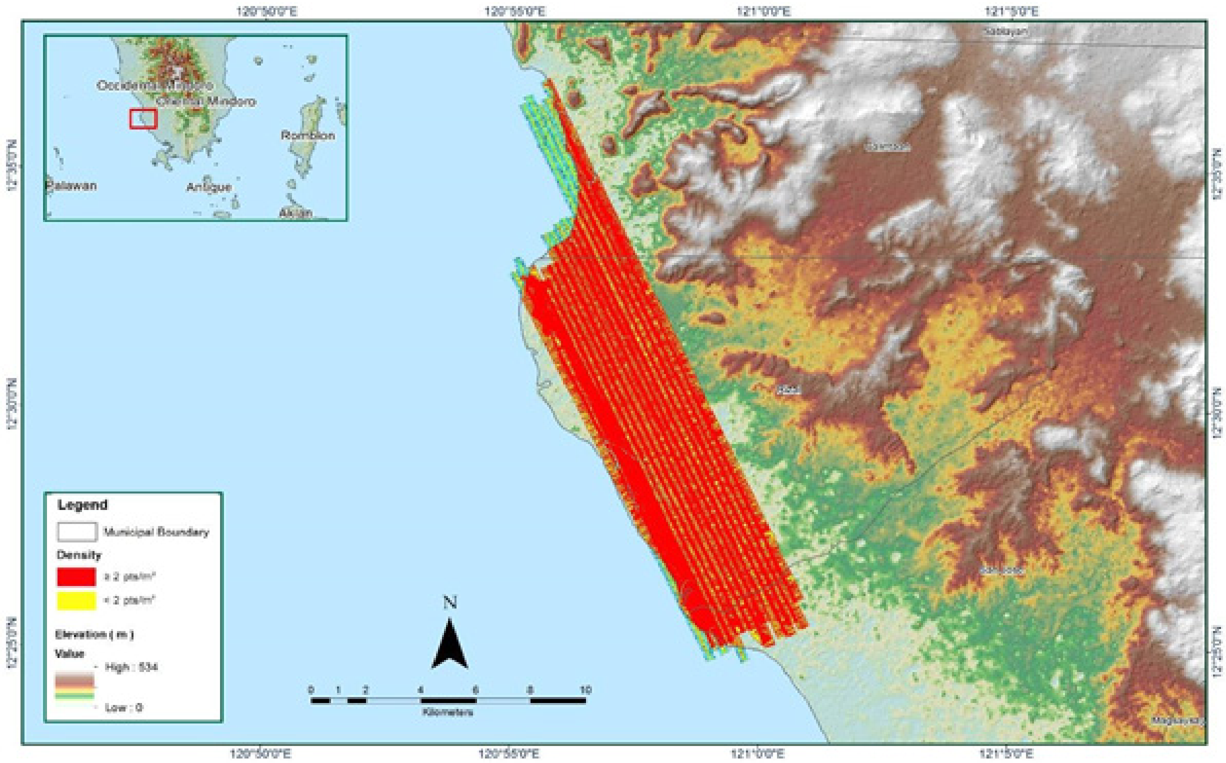


Figure A-8.6. Density map of merged LiDAR data

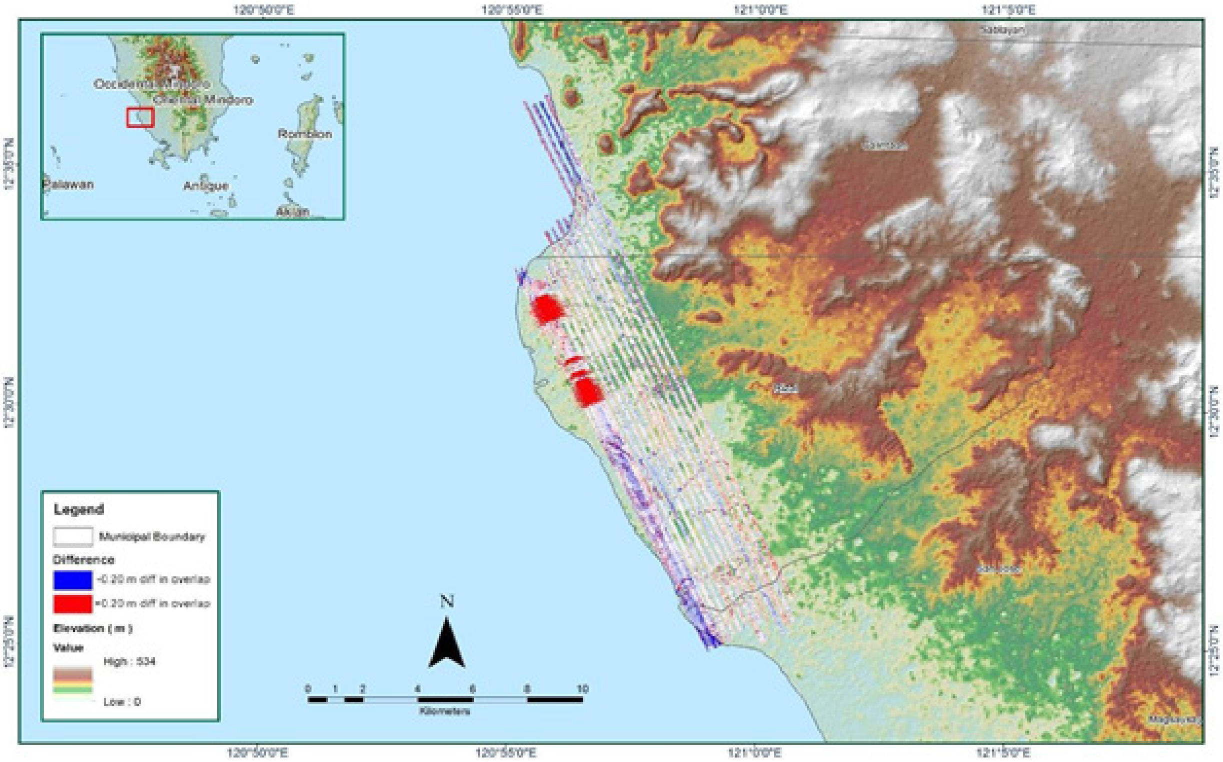


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Blk29E

Flight Area	Occidental Mindoro
Mission Name	Blk29E
Inclusive Flights	1138A
Range data size	8.89 GB
POS	196 MB
Image	50.4
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)	1.7
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000336
IMU attitude correction stdev (<0.001deg)	0.000997
GPS position stdev (<0.01m)	0.0075
Minimum % overlap (>25)	45.17%
Ave point cloud density per sq.m. (>2.0)	3.55
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	100
Maximum Height	438.43 m
Minimum Height	46.76 m
Classification (# of points)	
Ground	42,446,887
Low vegetation	40,569,753
Medium vegetation	49,197,063
High vegetation	55,377,868
Building	907,347
Orthophoto	Yes
Processed by	Engr. Benjamin Jonah Magallon, Engr. Christy Lubiano, Engr. Roa Shalemar Redo

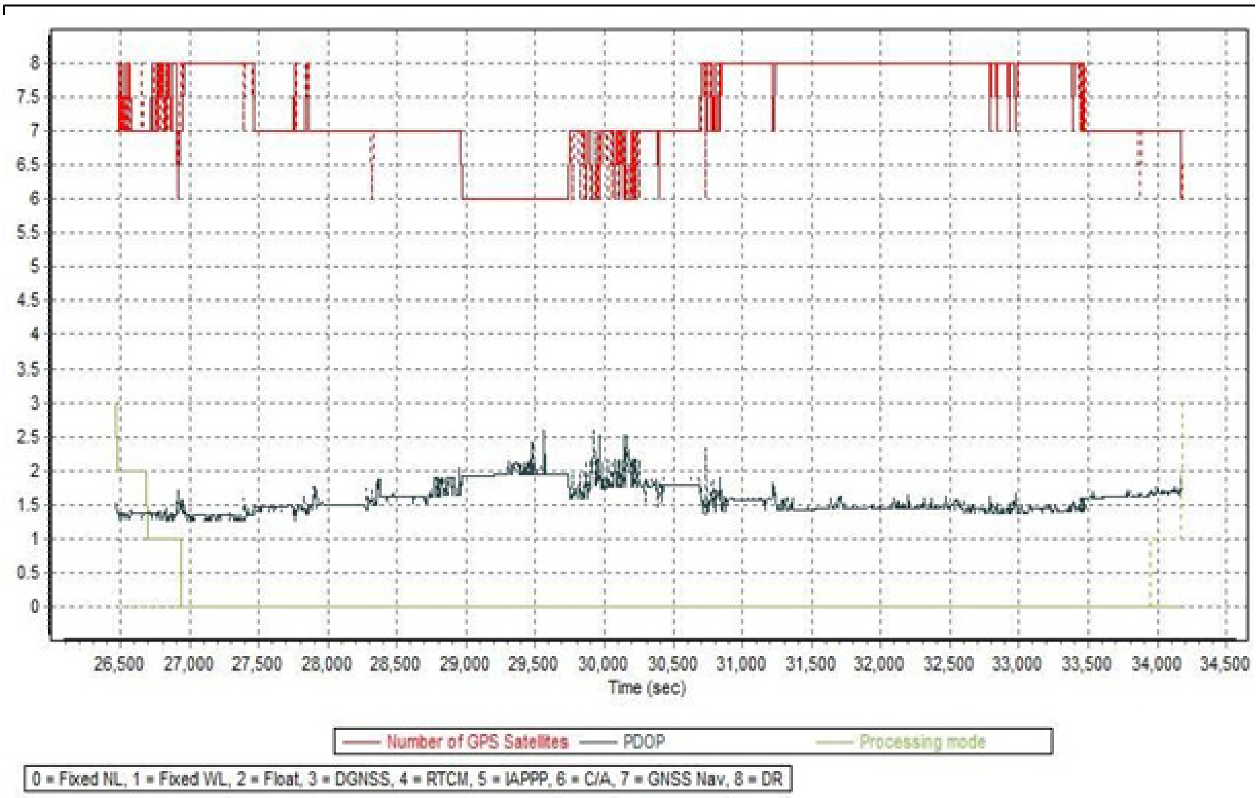


Figure A-8.8. Solution Status

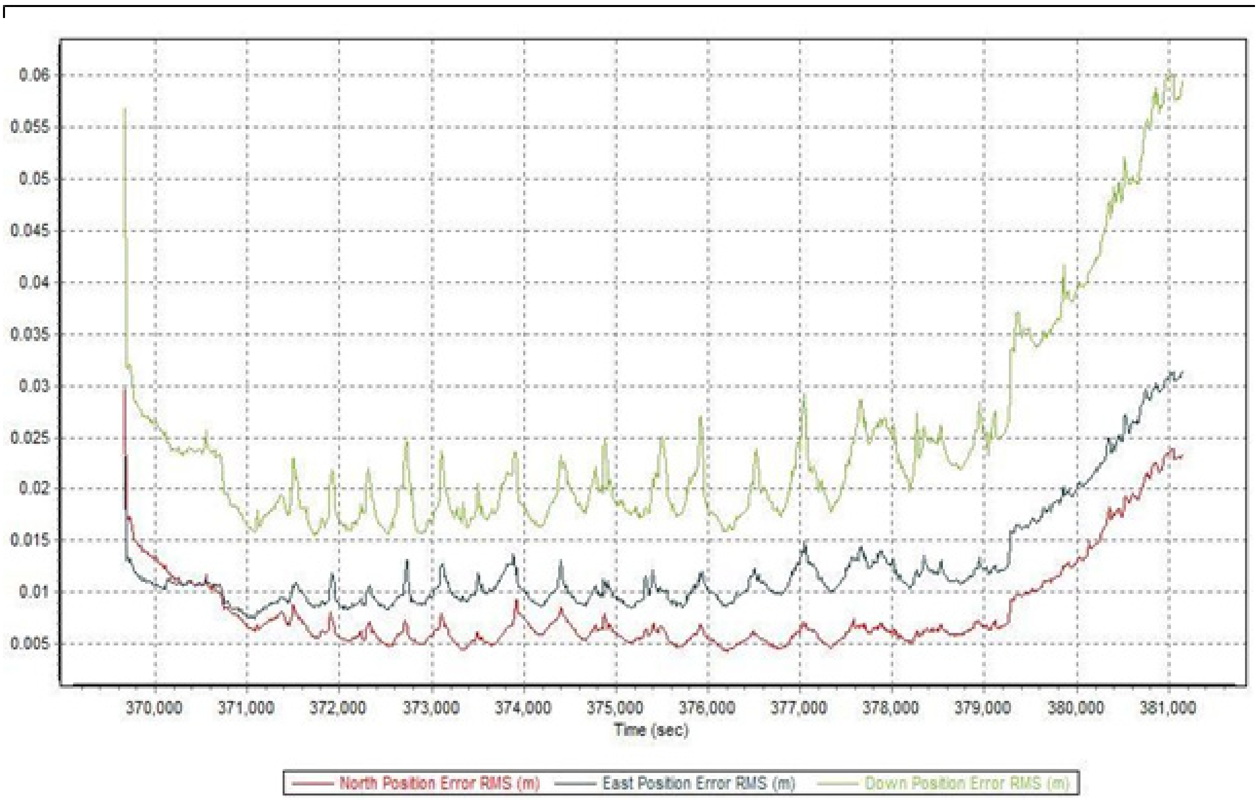


Figure A-8.9. Smoothed Performance Metrics Parameters

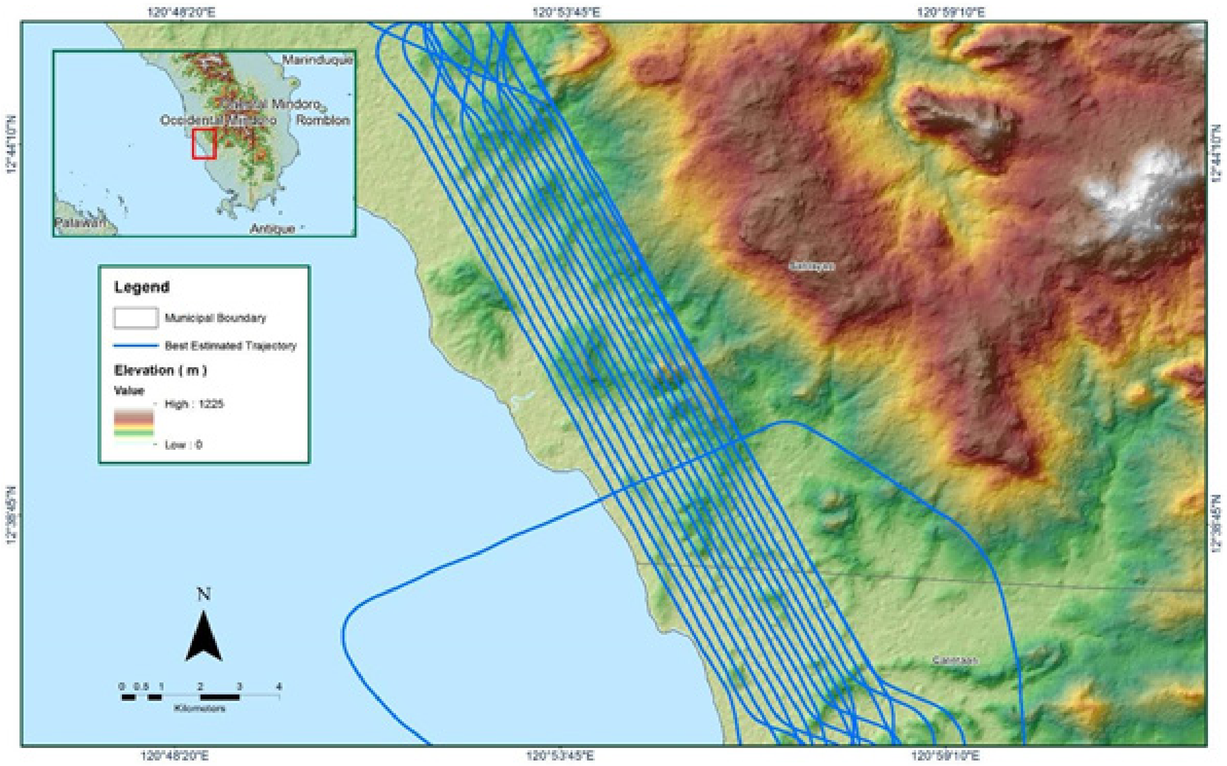


Figure A-8.10.Best estimated trajectory of LiDAR missions conducted over the Anahawin Floodplain.

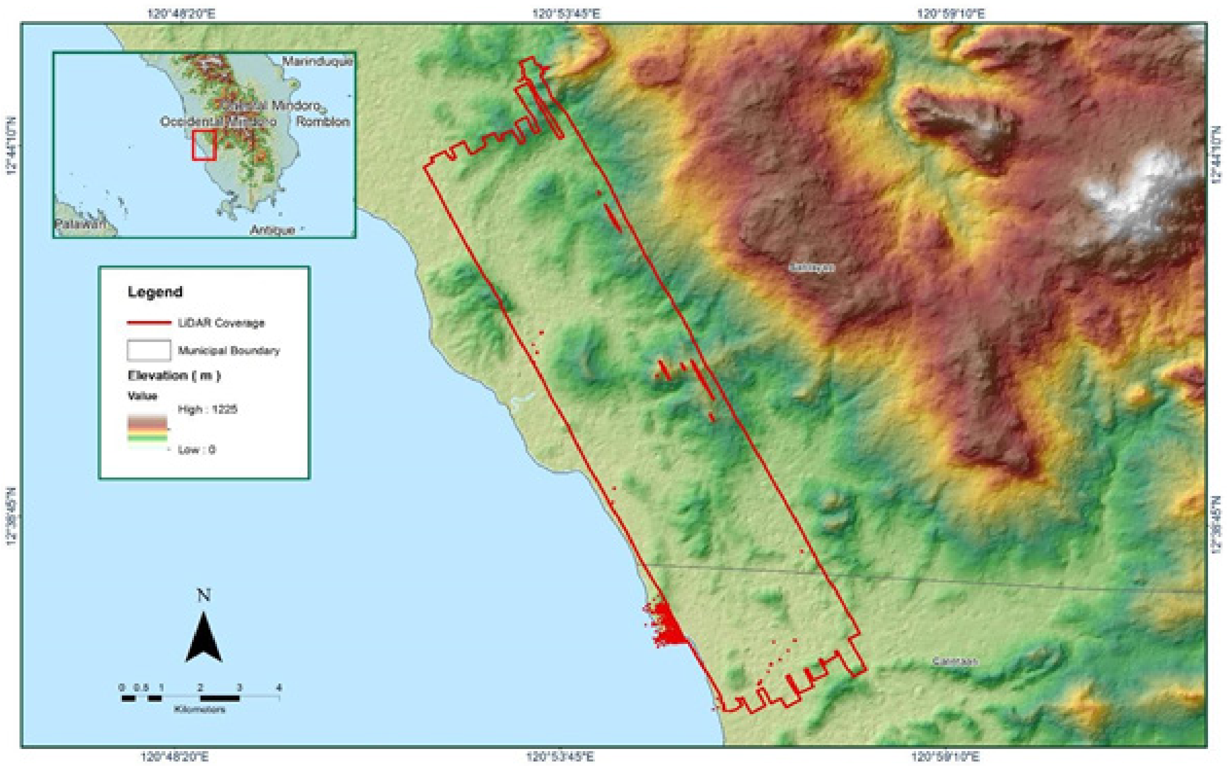


Figure A-8.11. Coverage of LiDAR data

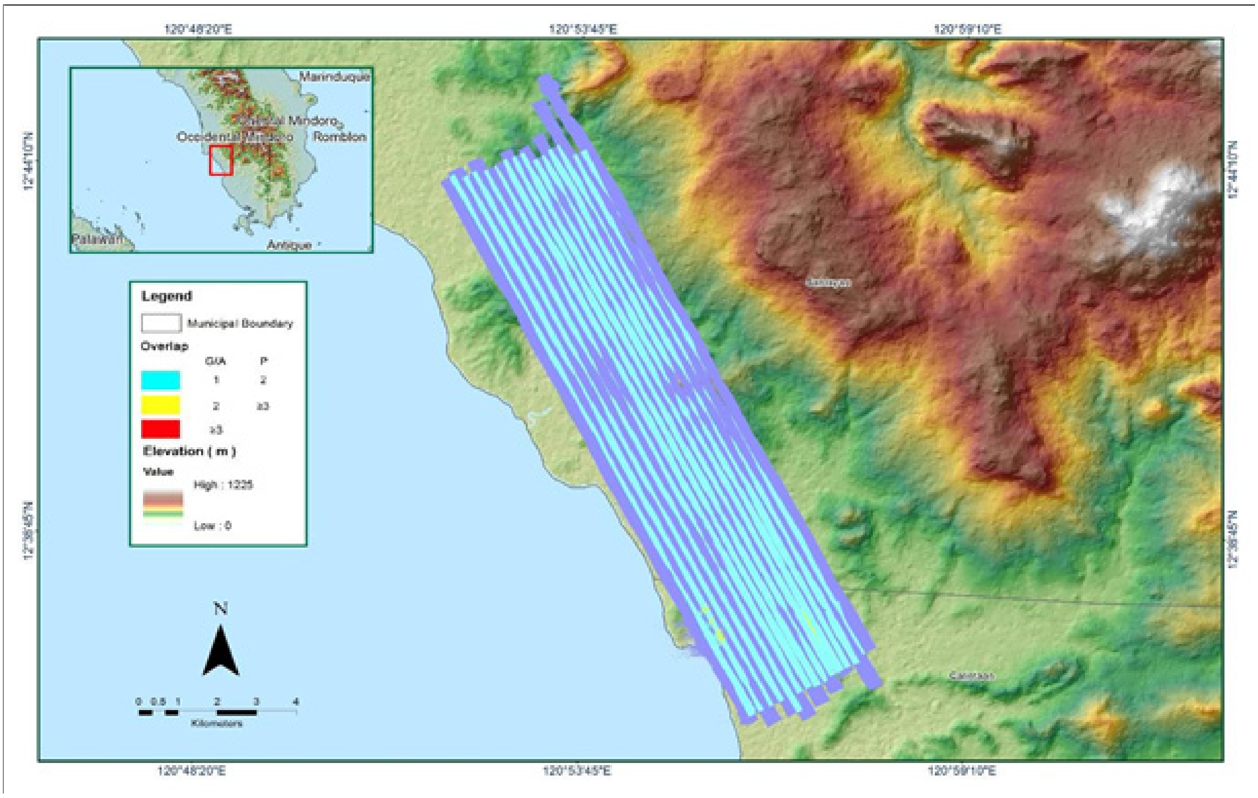


Figure A-8.12. Image of data overlap

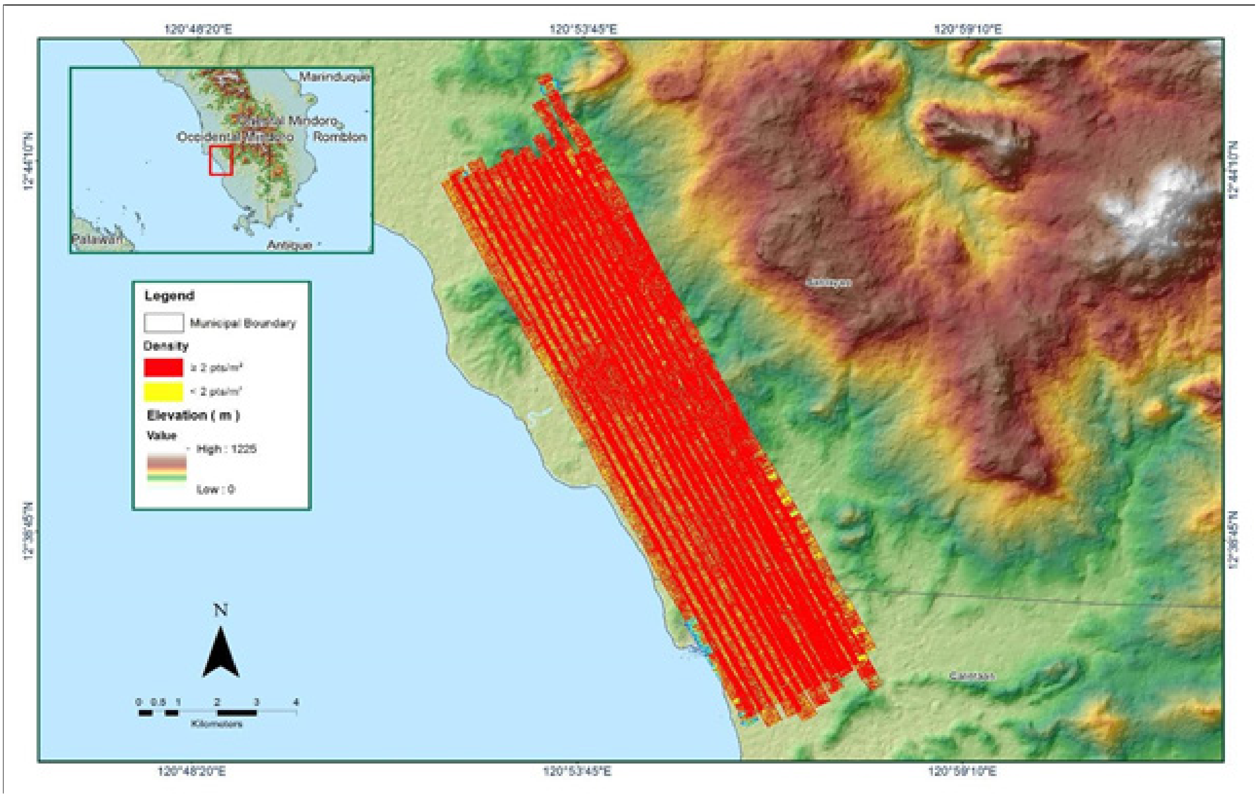


Figure A-8.13. Density map of merged LiDAR data

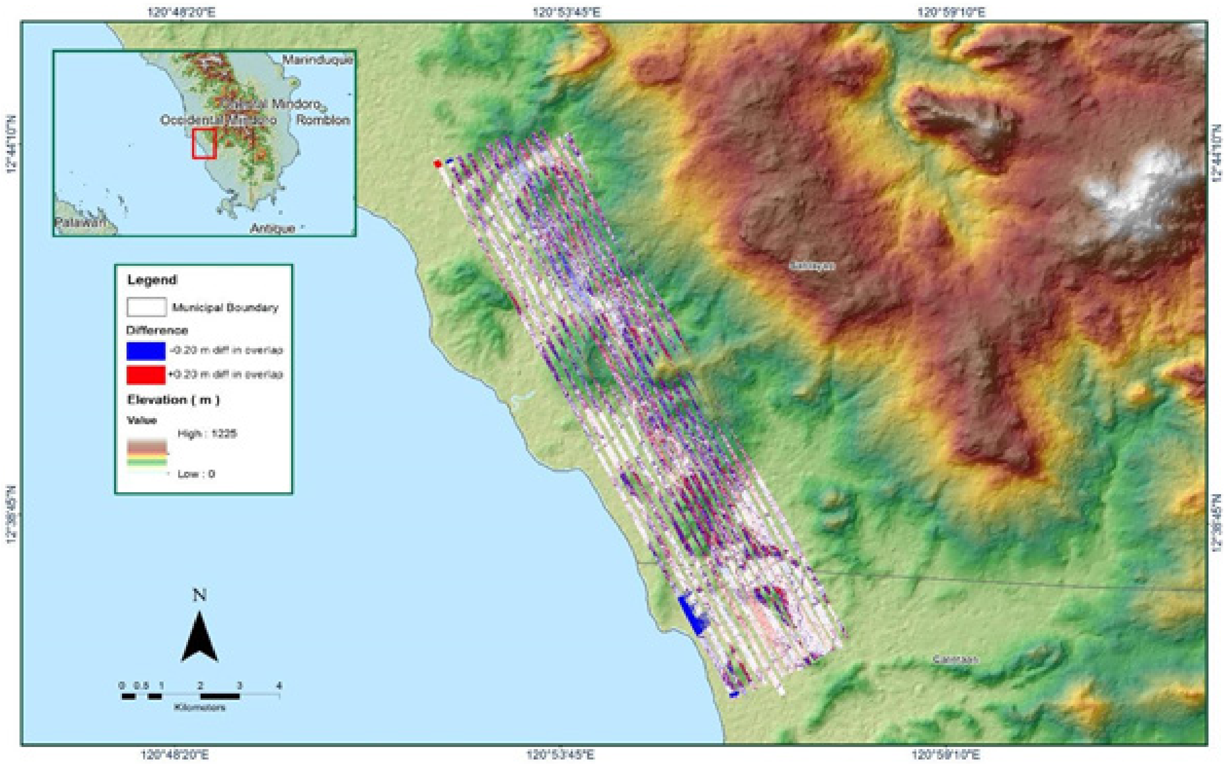


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Blk29Es

Flight Area	Occidental Mindoro
Mission Name	Blk29Es
Inclusive Flights	1140A
Range data size	9.99 GB
POS	241 MB
Image	53.3 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.9
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	4.5
Boresight correction stdev (<0.001deg)	0.000536
IMU attitude correction stdev (<0.001deg)	0.001360
GPS position stdev (<0.01m)	0.0162
Minimum % overlap (>25)	30.26%
Ave point cloud density per sq.m. (>2.0)	2.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	62
Maximum Height	336.48 m
Minimum Height	41.75 m
Classification (# of points)	
Ground	19,043,185
Low vegetation	17,745,800
Medium vegetation	11,136,132
High vegetation	11,997,445
Building	733,066
Orthophoto	Yes
Processed by	Engr. Benjamin Jonah Magallon, Engr. Christy Lubiano, Engr. Gladys Mae Apat

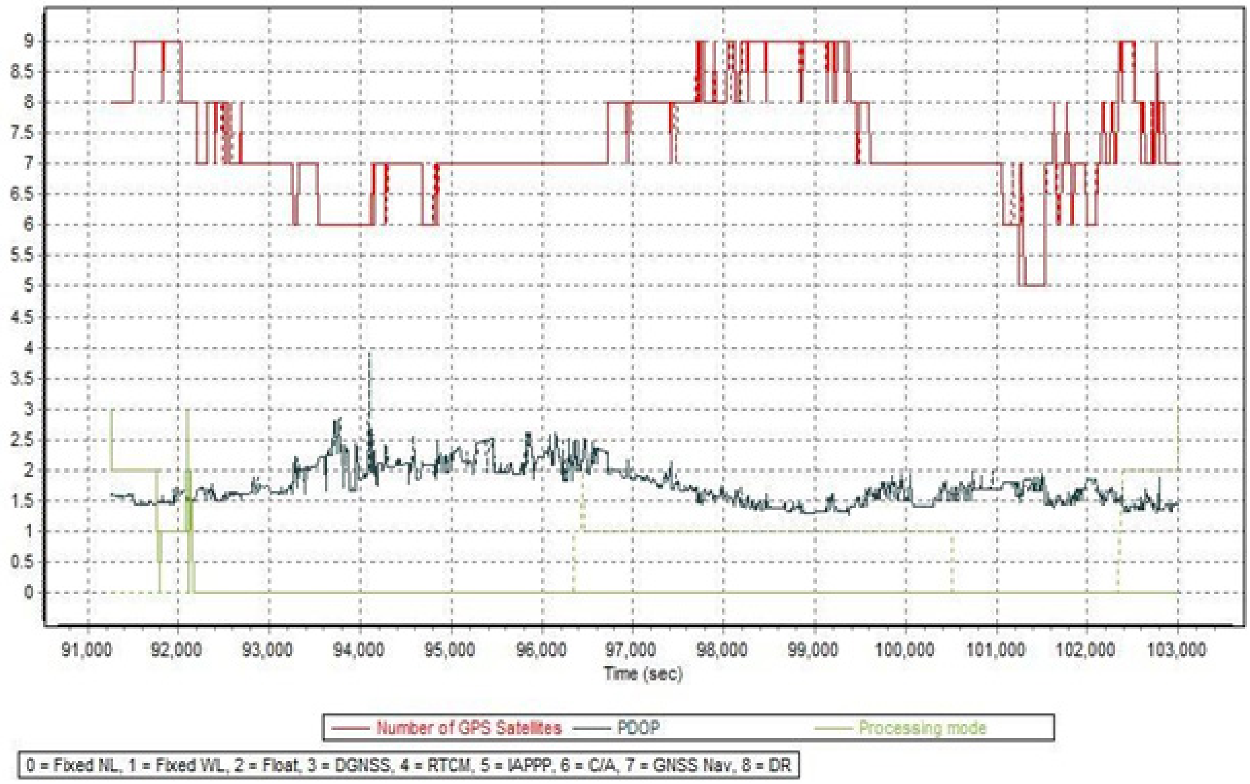


Figure A-8.15. Solution Status

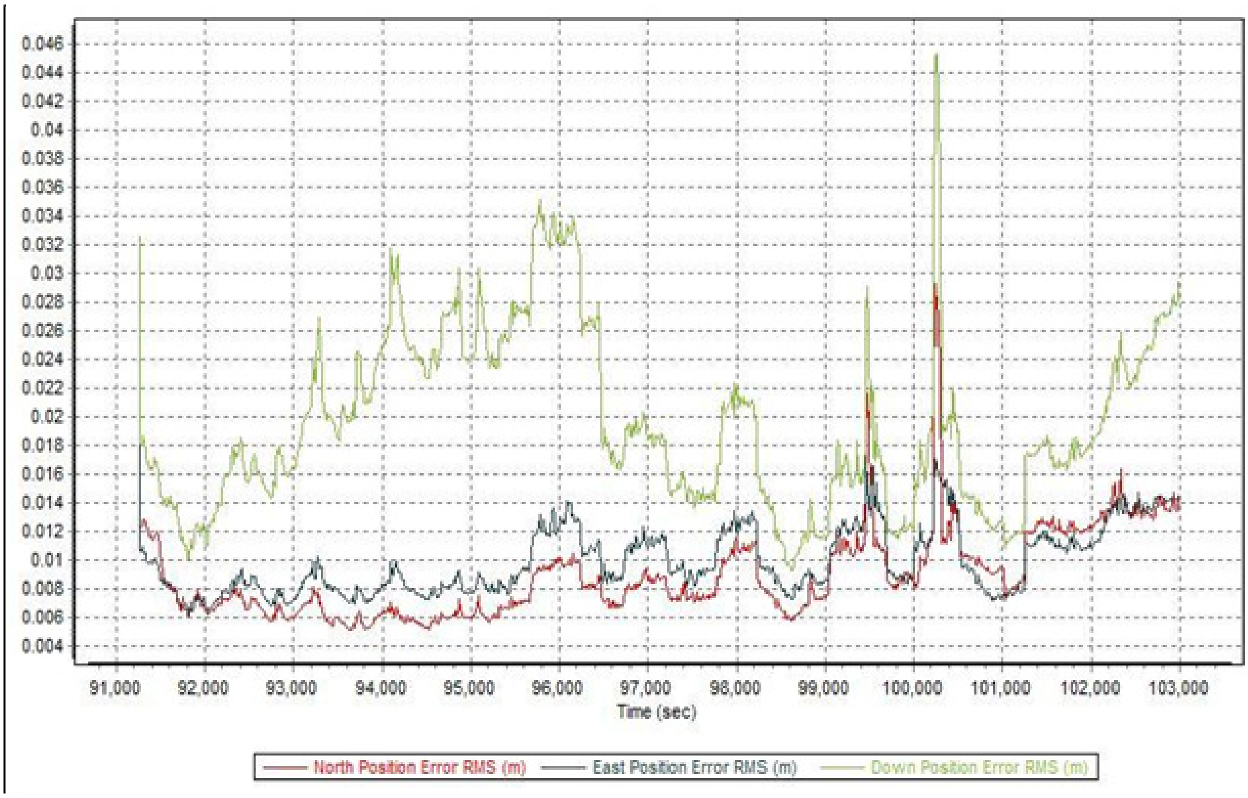


Figure A-8.16. Smoothed Performance Metrics Parameters

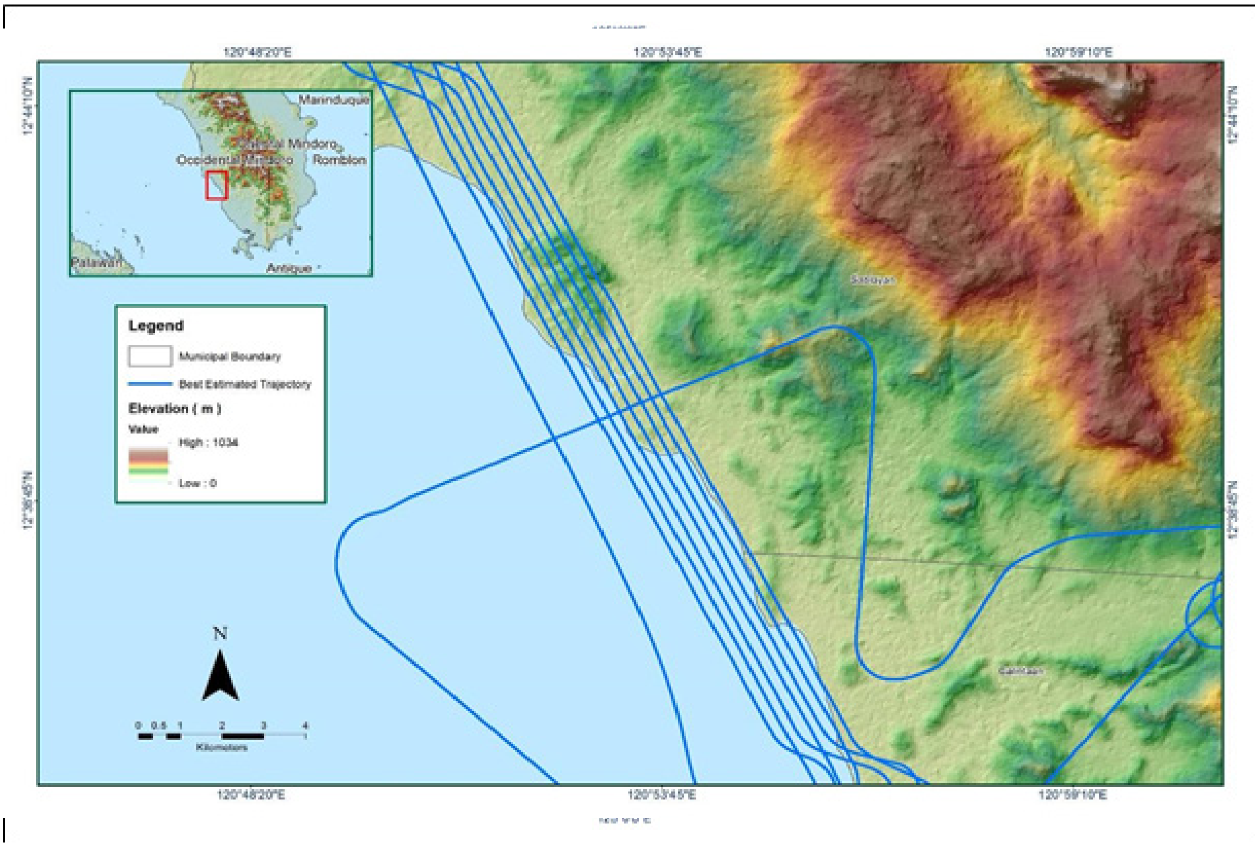


Figure A-8.17. Best estimated trajectory of LiDAR missions conducted over the Anahawin Floodplain.

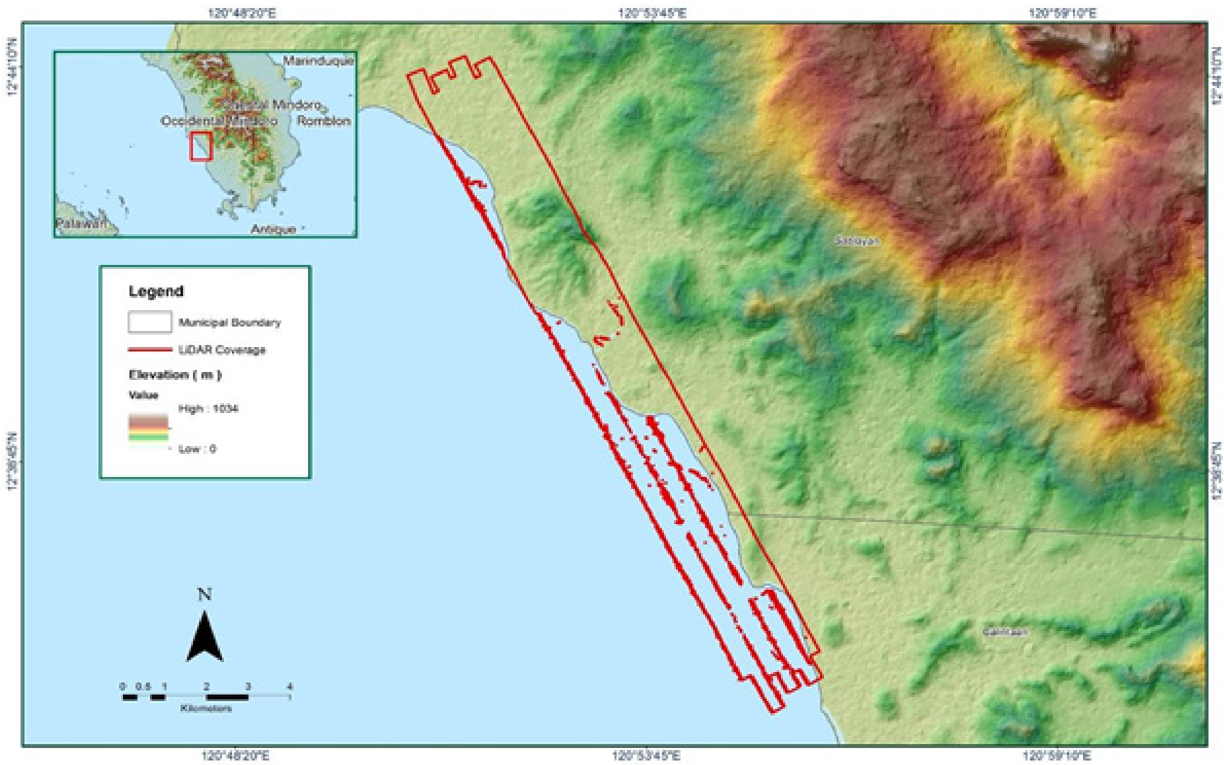


Figure A-8.18. Coverage of LiDAR data

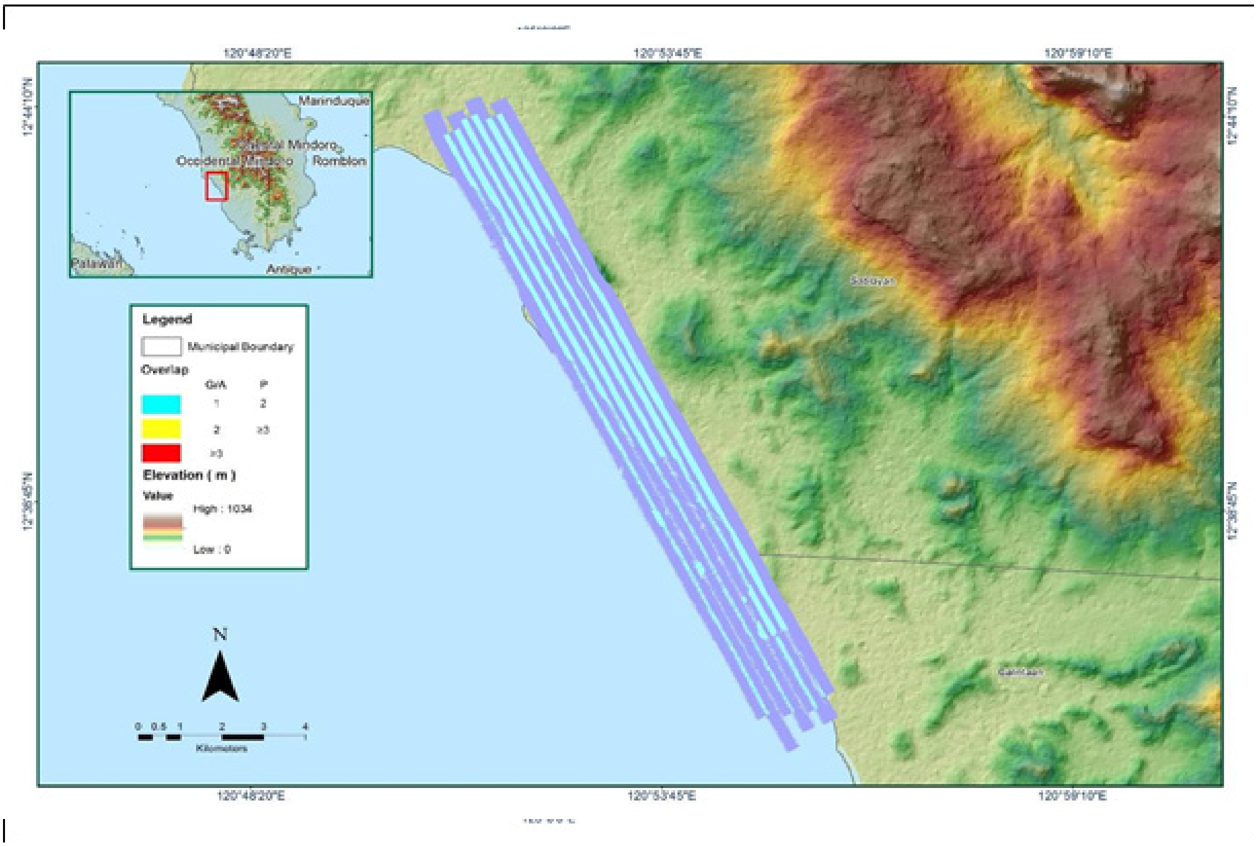


Figure A-8.19. Image of data overlap

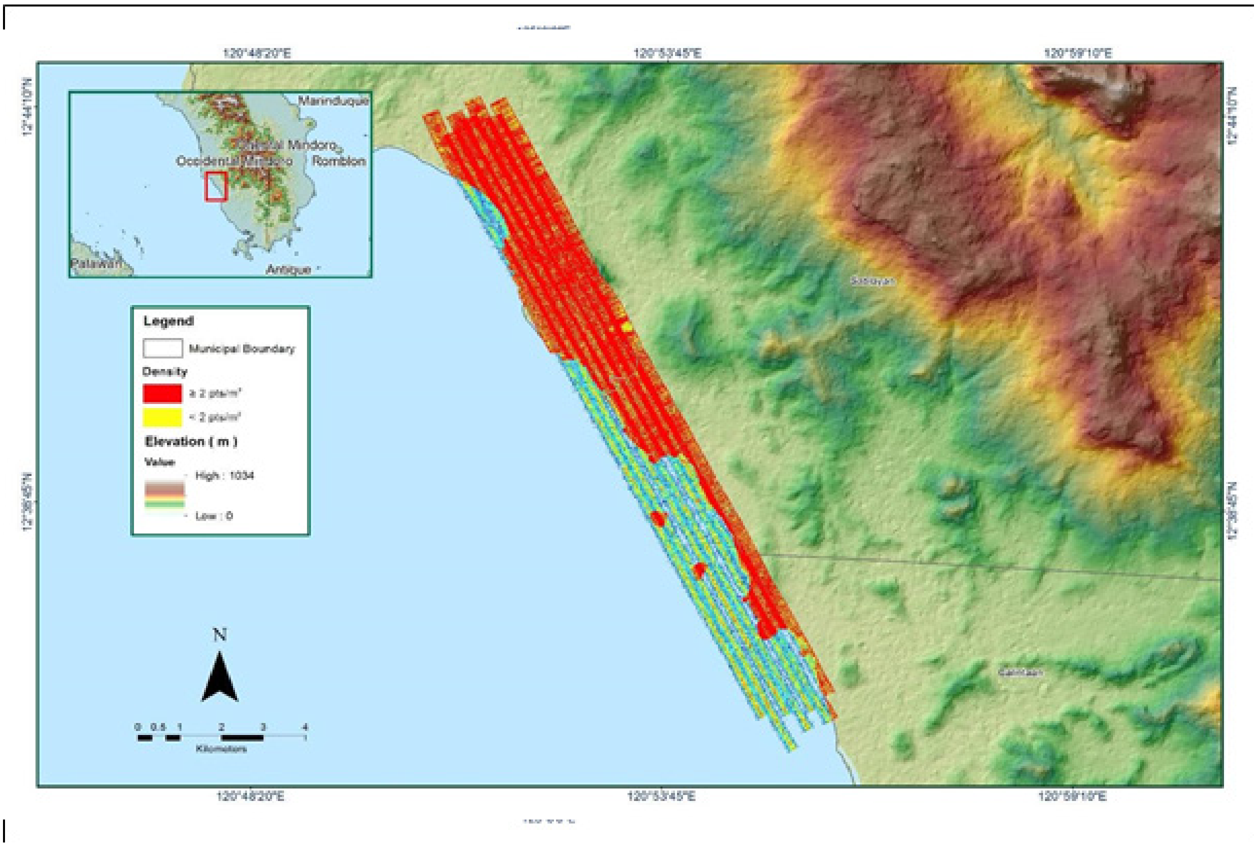


Figure A-8.20. Density map of merged LiDAR data

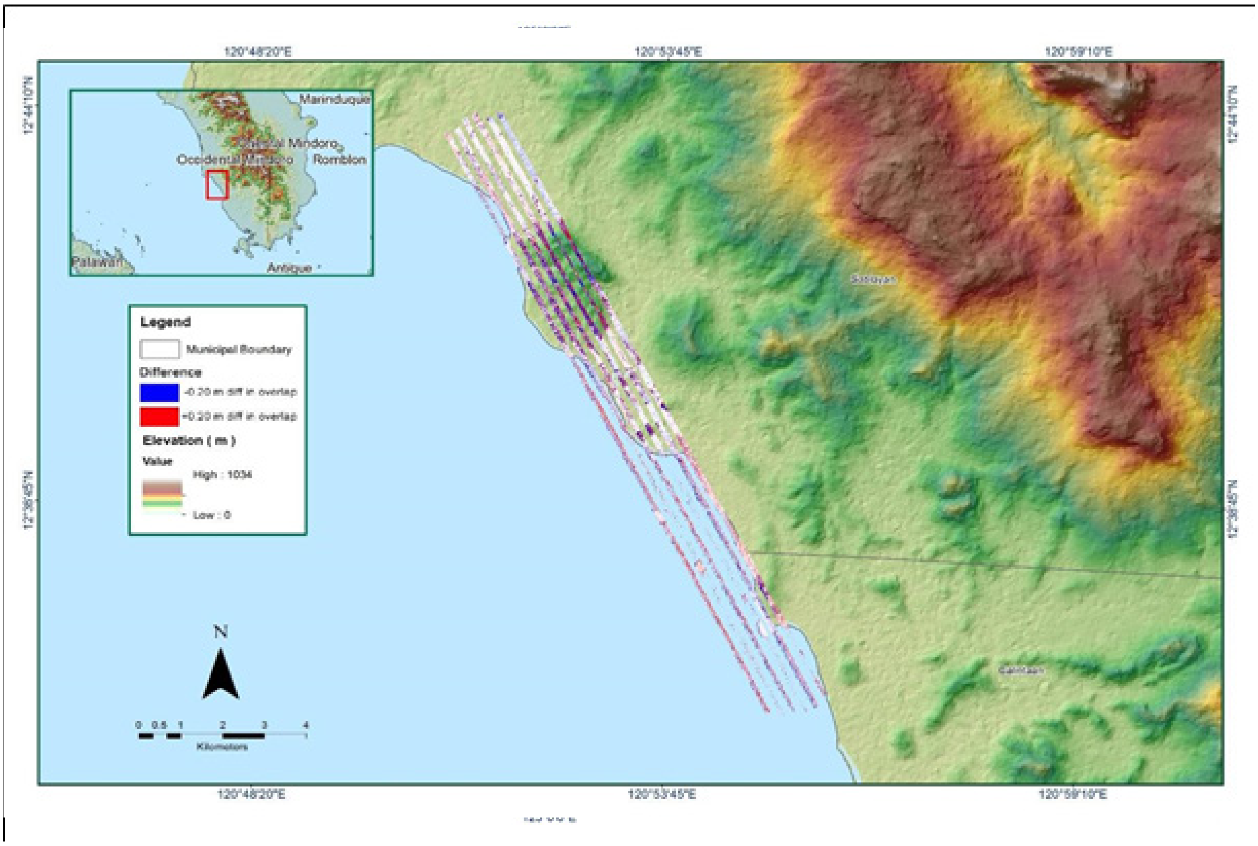


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Blk29F

Flight Area	Occidental Mindoro
Mission Name	Blk29F
Inclusive Flights	1156A
Range data size	14.3 G
POS	268 MB
Image	89.5 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.8
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000557
IMU attitude correction stdev (<0.001deg)	0.001546
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	48.39%
Ave point cloud density per sq.m. (>2.0)	3.79
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	159
Maximum Height	471.05 m
Minimum Height	54.39 m
Classification (# of points)	
Ground	81,694,493
Low vegetation	98,359,773
Medium vegetation	85,774,483
High vegetation	77,521,690
Building	2,203,415
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Ryan Nicholai Dizon

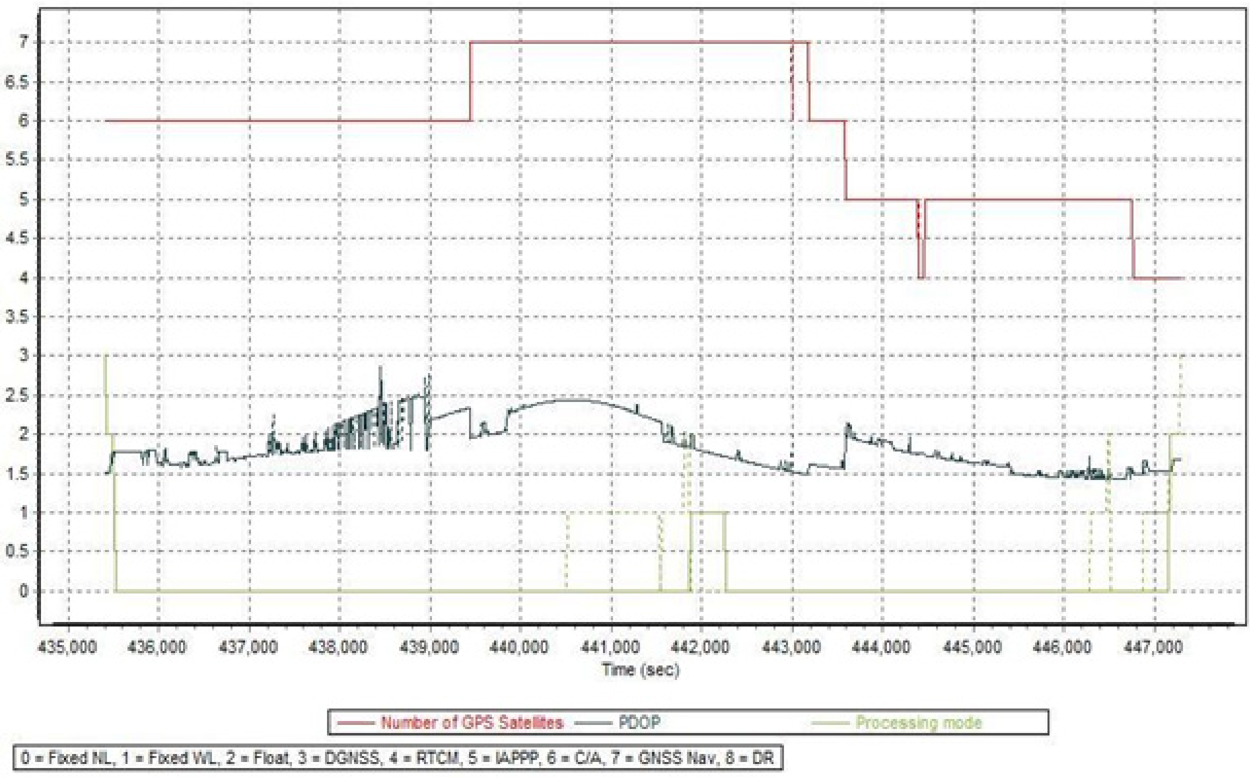


Figure A-8.22. Solution Status

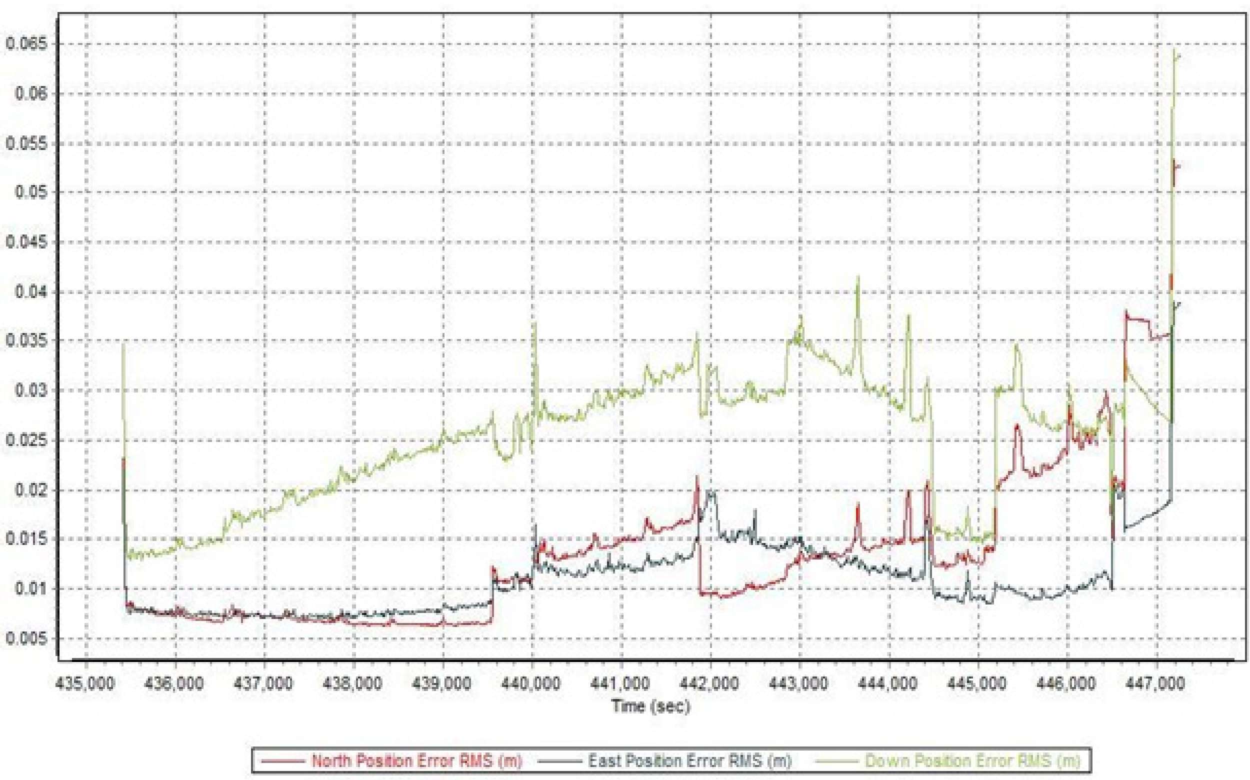


Figure A-8.23. Smoothed Performance Metrics Parameters

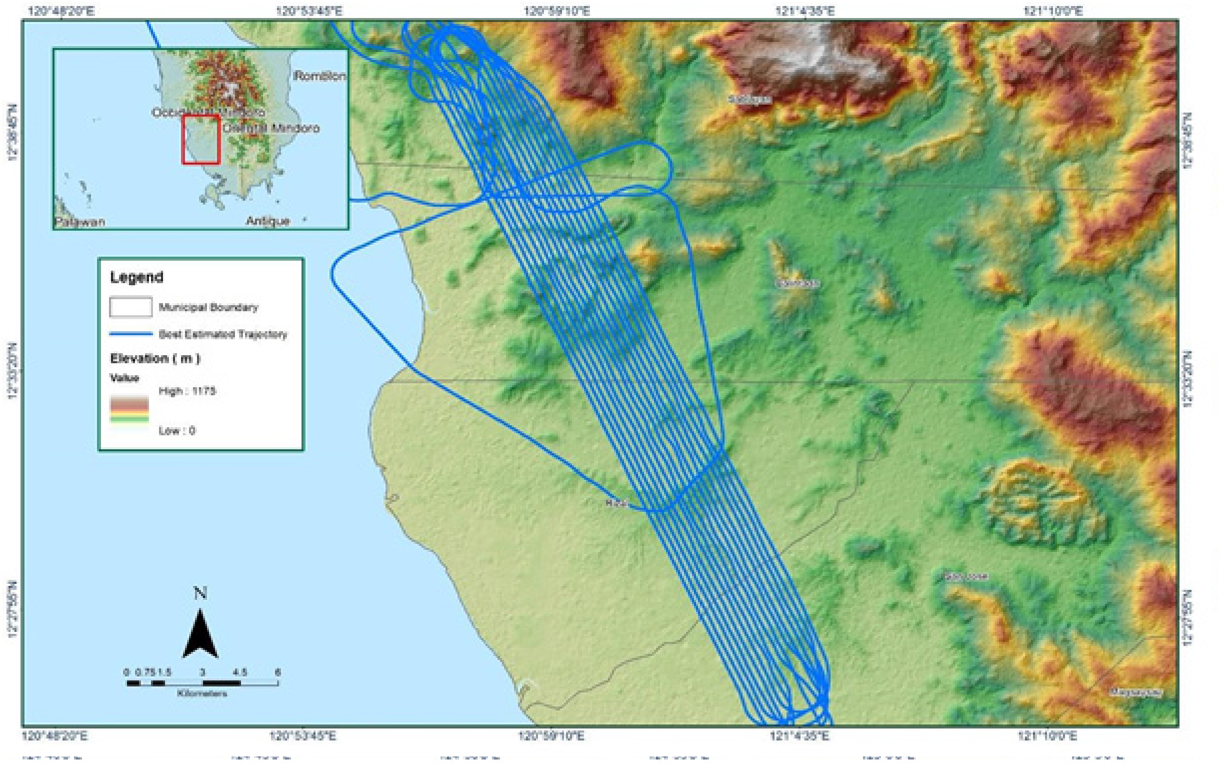


Figure A-8.24. Best Estimated Trajectory

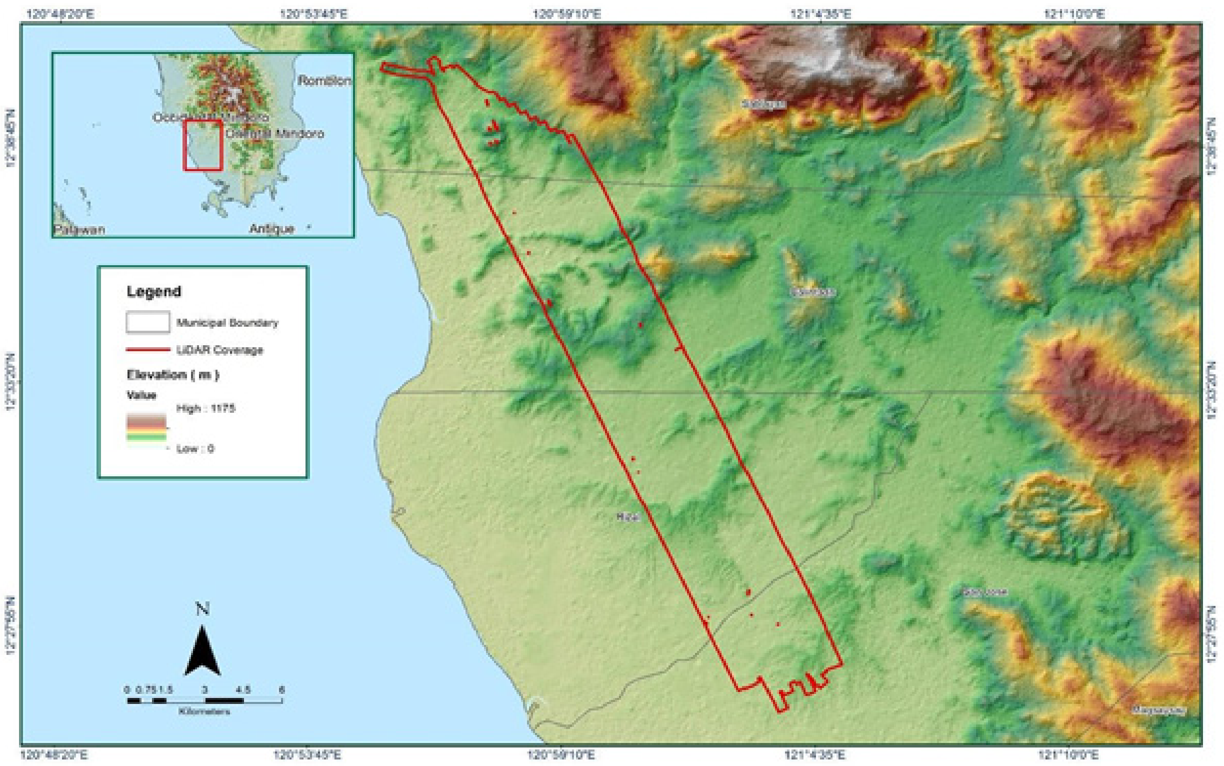


Figure A-8.25. Coverage of LiDAR data

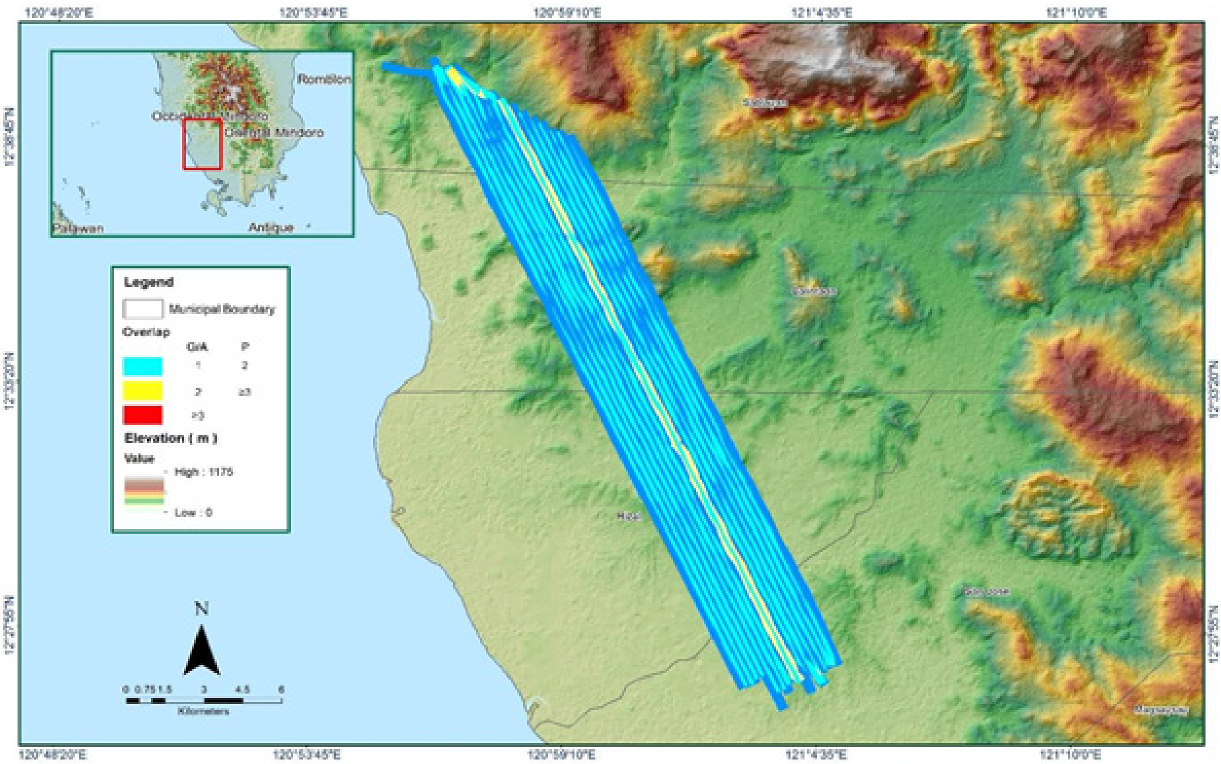


Figure A-8.26. Image of data overlap

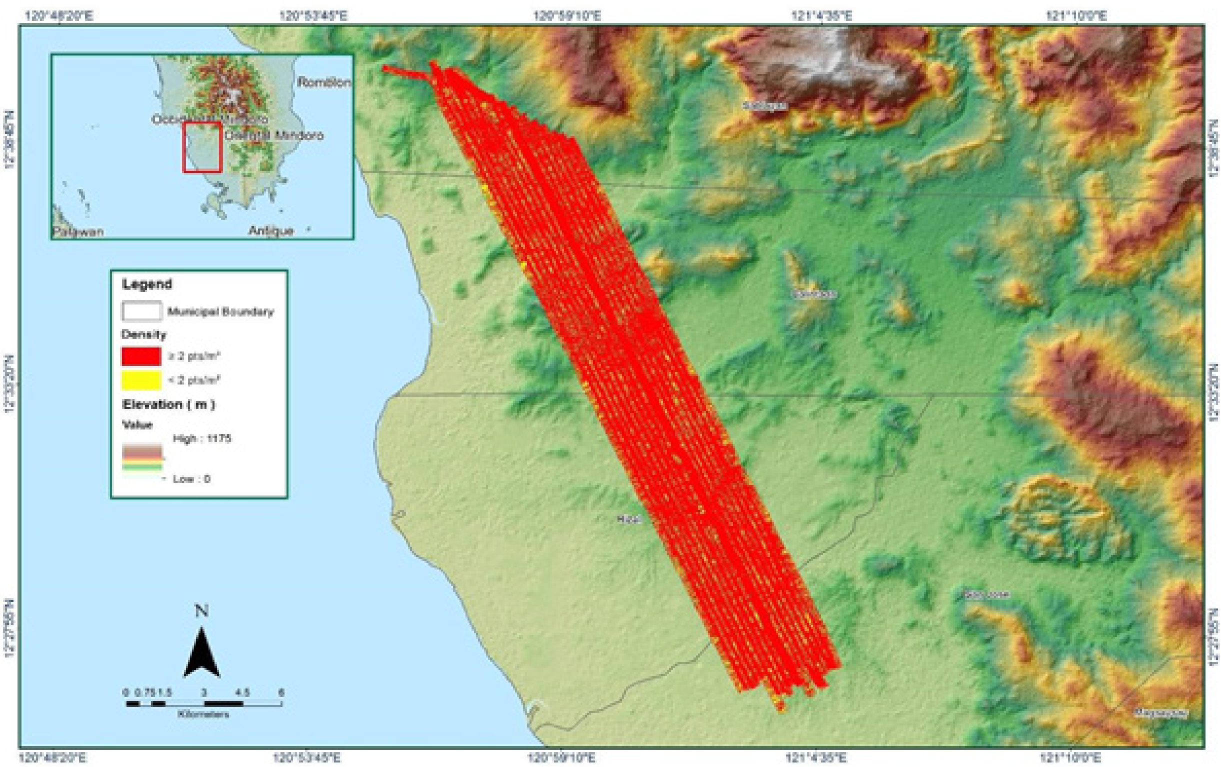


Figure A-8.27. Density map of merged LiDAR data

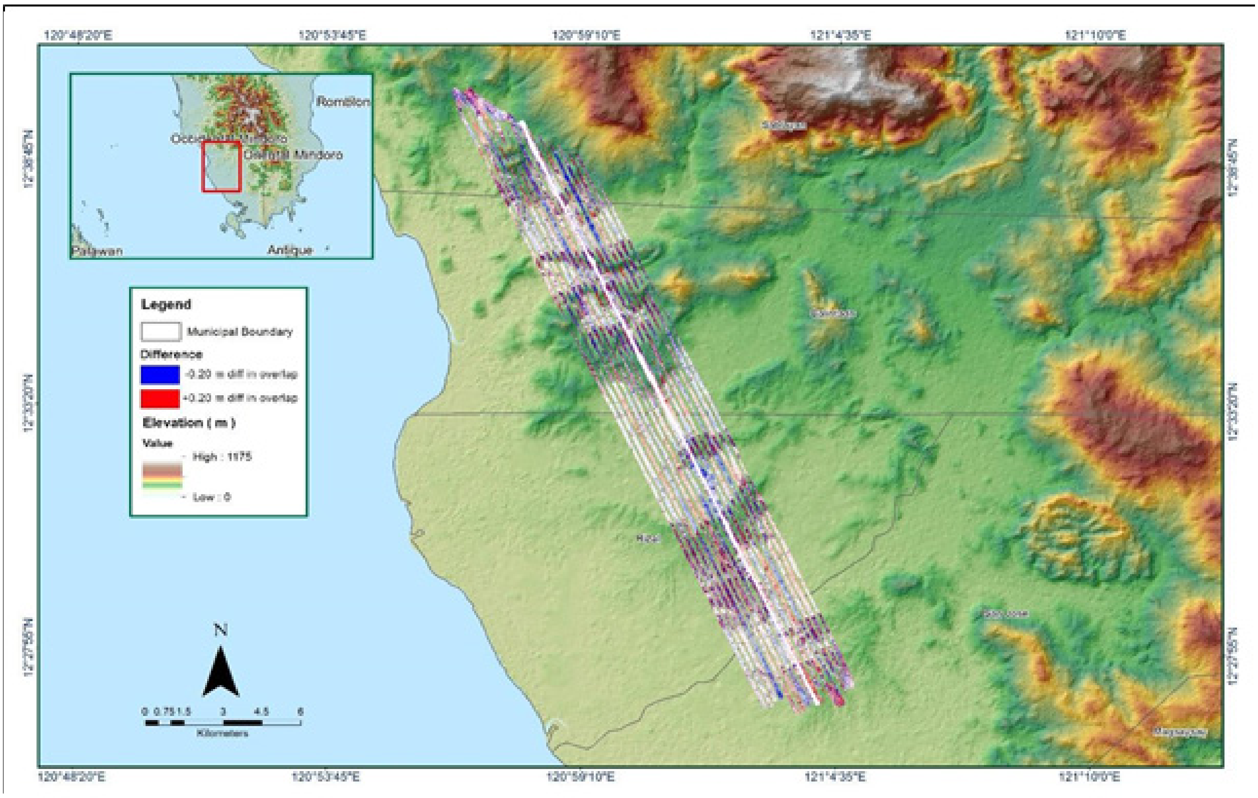


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Blk29P

Flight Area	Occidental Mindoro
Mission Name	Blk29P
Inclusive Flights	1142A
Range data size	12.40 GB
POS	228 MB
Image	61.70 GB
Transfer date	March 19, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.9
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000355
IMU attitude correction stdev (<0.001deg)	0.001037
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	40.97%
Ave point cloud density per sq.m. (>2.0)	3.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	147
Maximum Height	340.73 m
Minimum Height	44.92 m
Classification (# of points)	
Ground	81,422,256
Low vegetation	95,863,036
Medium vegetation	50,474,492
High vegetation	47,671,724
Building	1,625,539
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

Figure A-8.29. Solution Status

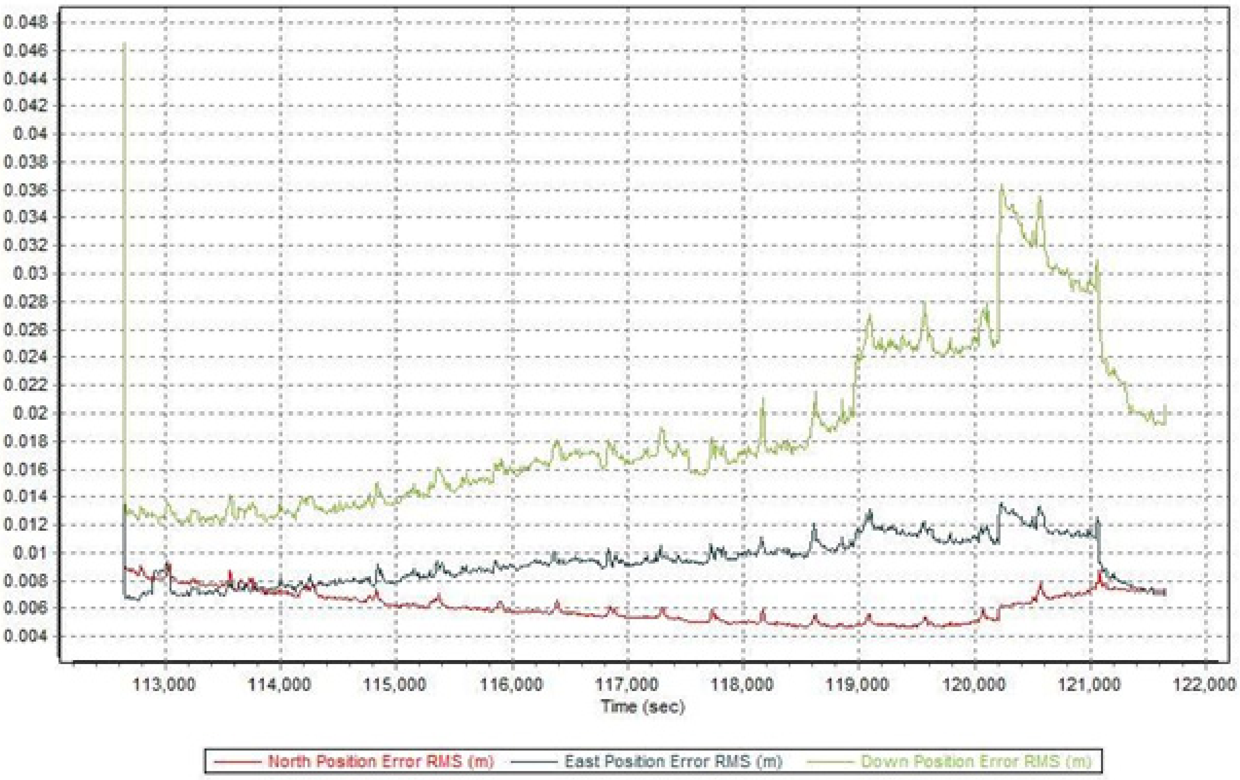


Figure A-8.30. Smoothed Performance Metrics Parameters

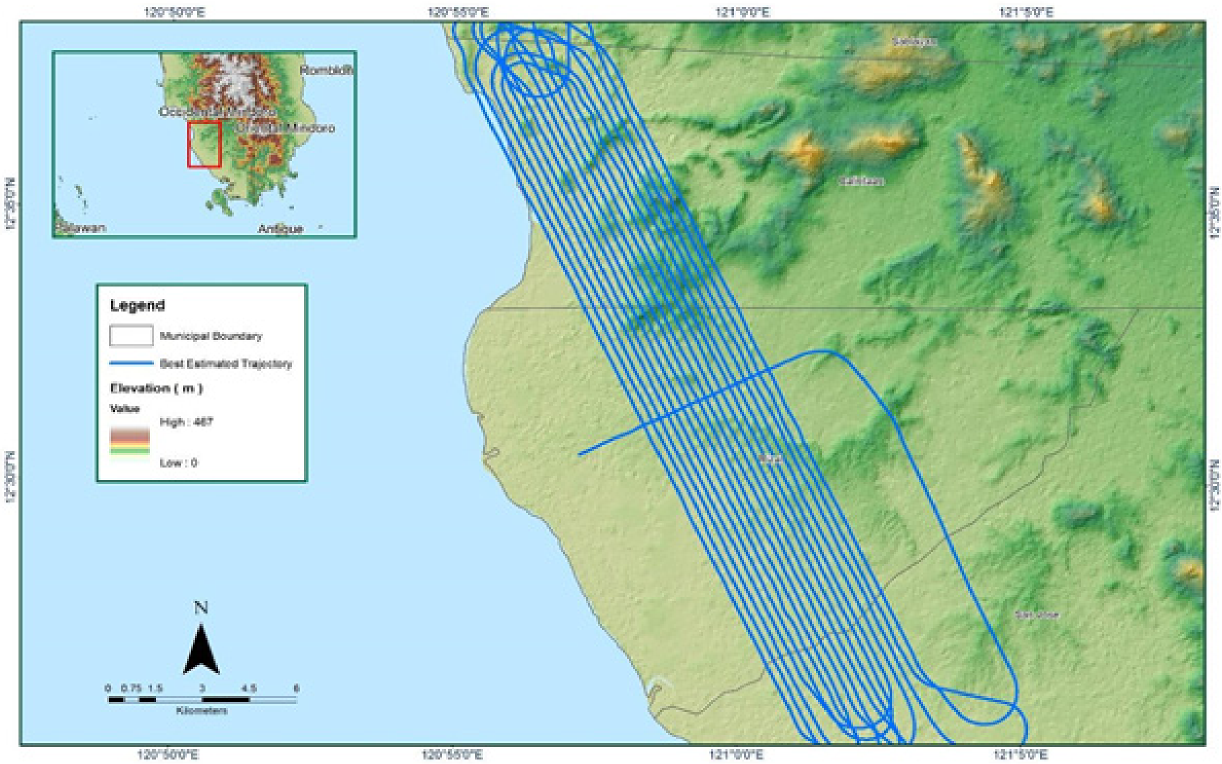


Figure A-8.31. Best Estimated Trajectory

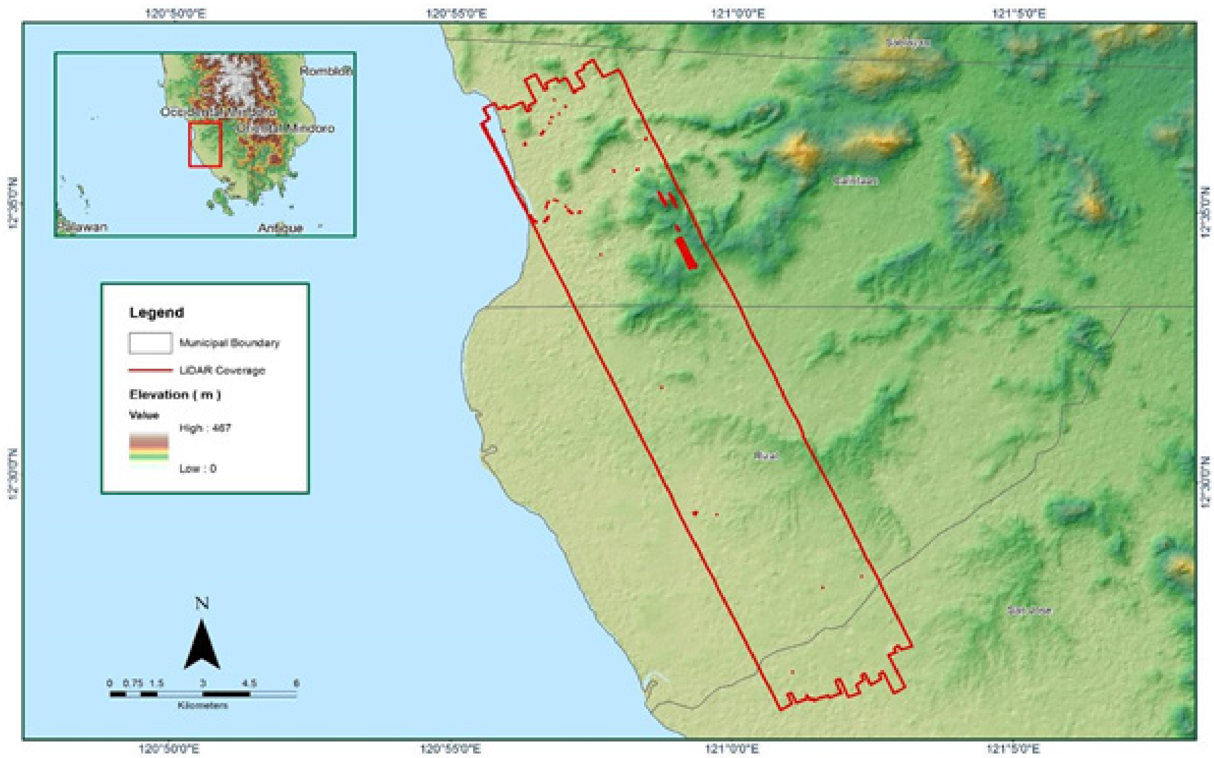


Figure A-8.32. Coverage of LiDAR data

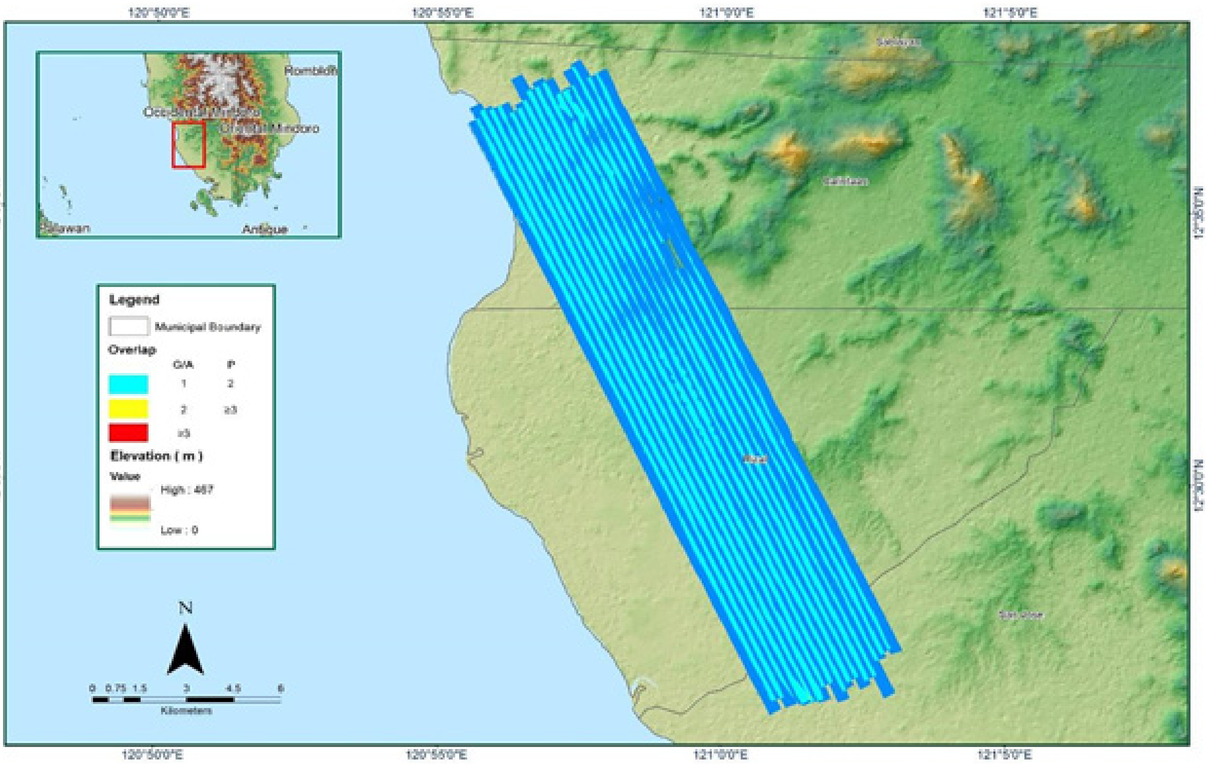


Figure A-8.33. Image of data overlap

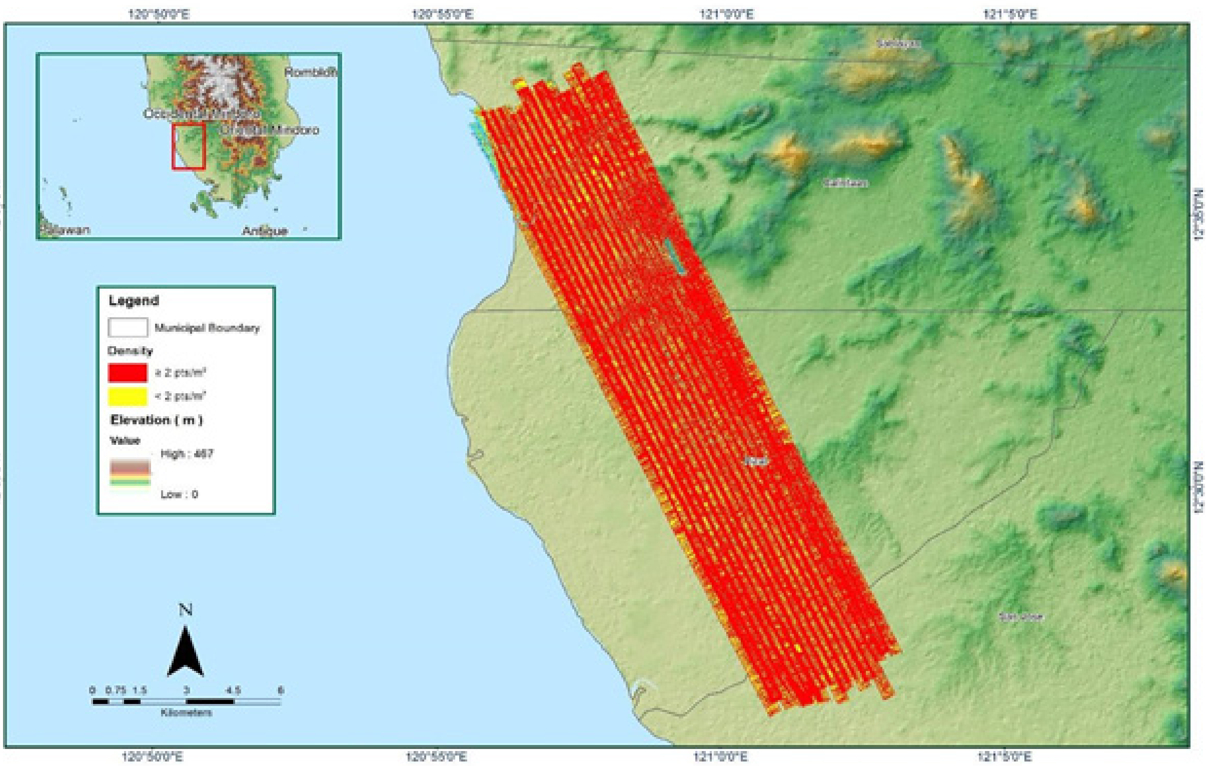


Figure A-8.34. Density map of merged LiDAR data

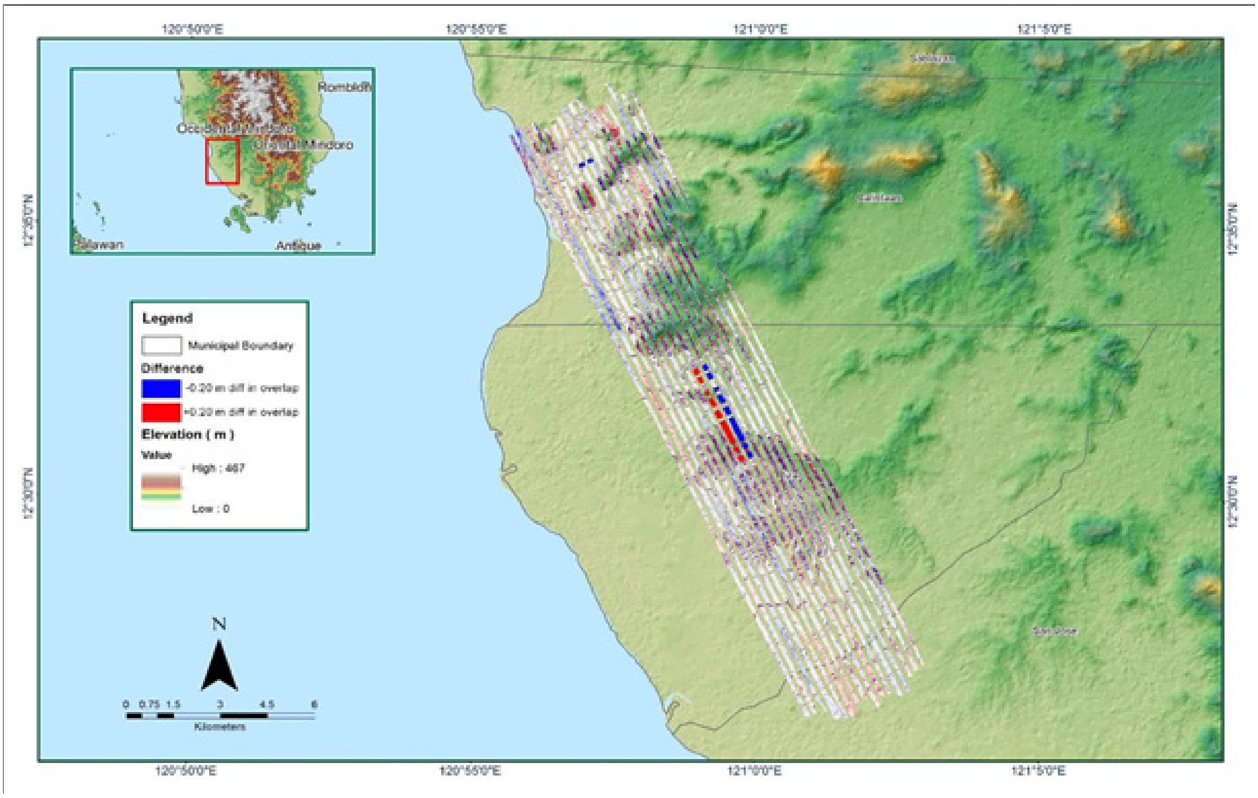


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Blk29G_additional

Flight Area	Occidental Mindoro Reflights
Mission Name	Blk29G_additional
Inclusive Flights	3074P
Range data size	20.7GB
Base data size	14.1MB
POS	225MB
Image	30.9MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.27
RMSE for East Position (<4.0 cm)	1.03
RMSE for Down Position (<8.0 cm)	2.94
Boresight correction stdev (<0.001deg)	0.000280
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0009
Minimum % overlap (>25)	39.69%
Ave point cloud density per sq.m. (>2.0)	3.72
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	193
Maximum Height	544.26 m
Minimum Height	50.35 m
Classification (# of points)	
Ground	136,702,504
Low vegetation	91,637,024
Medium vegetation	147,161,052
High vegetation	487,991,012
Building	8,949,606
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Merven Matthew Natino, Engr. Vincent Louise Azucena

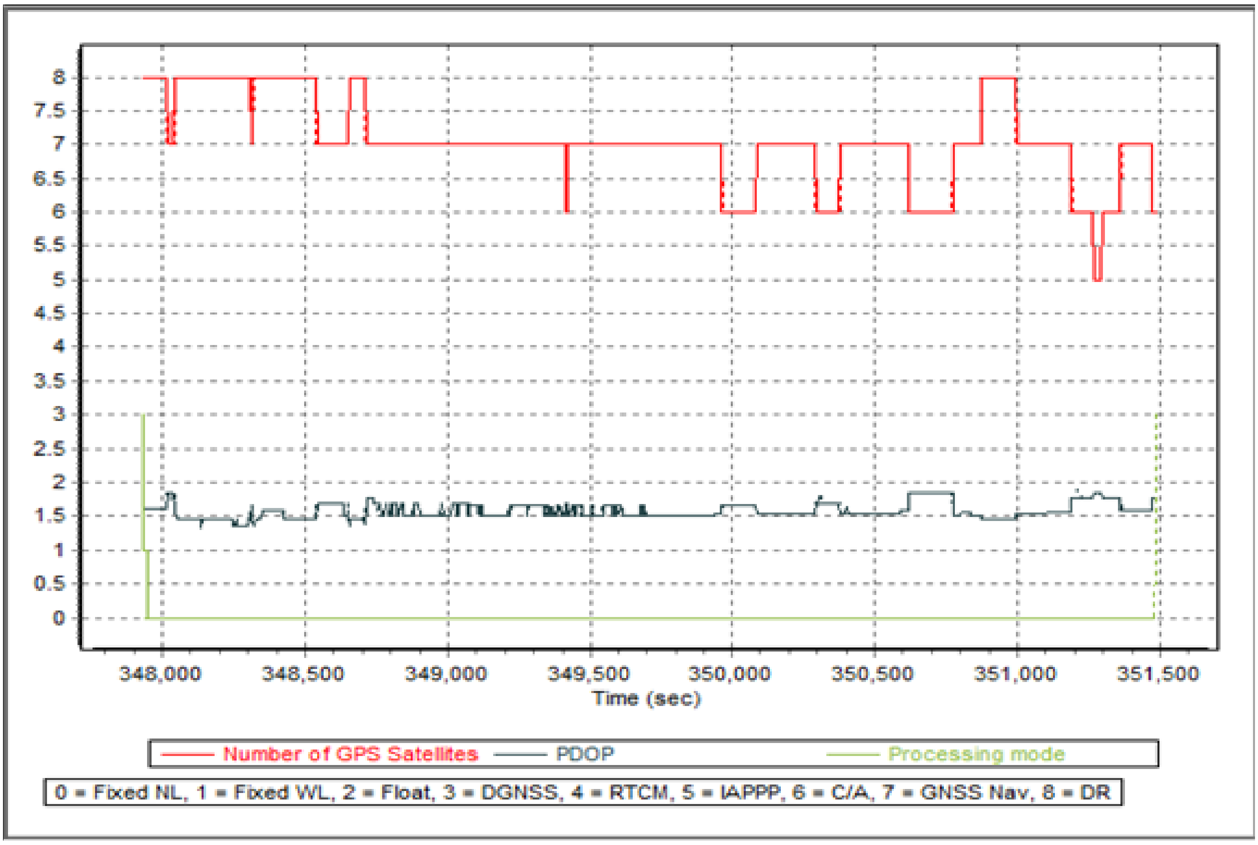


Figure A-8.36. Solution Status

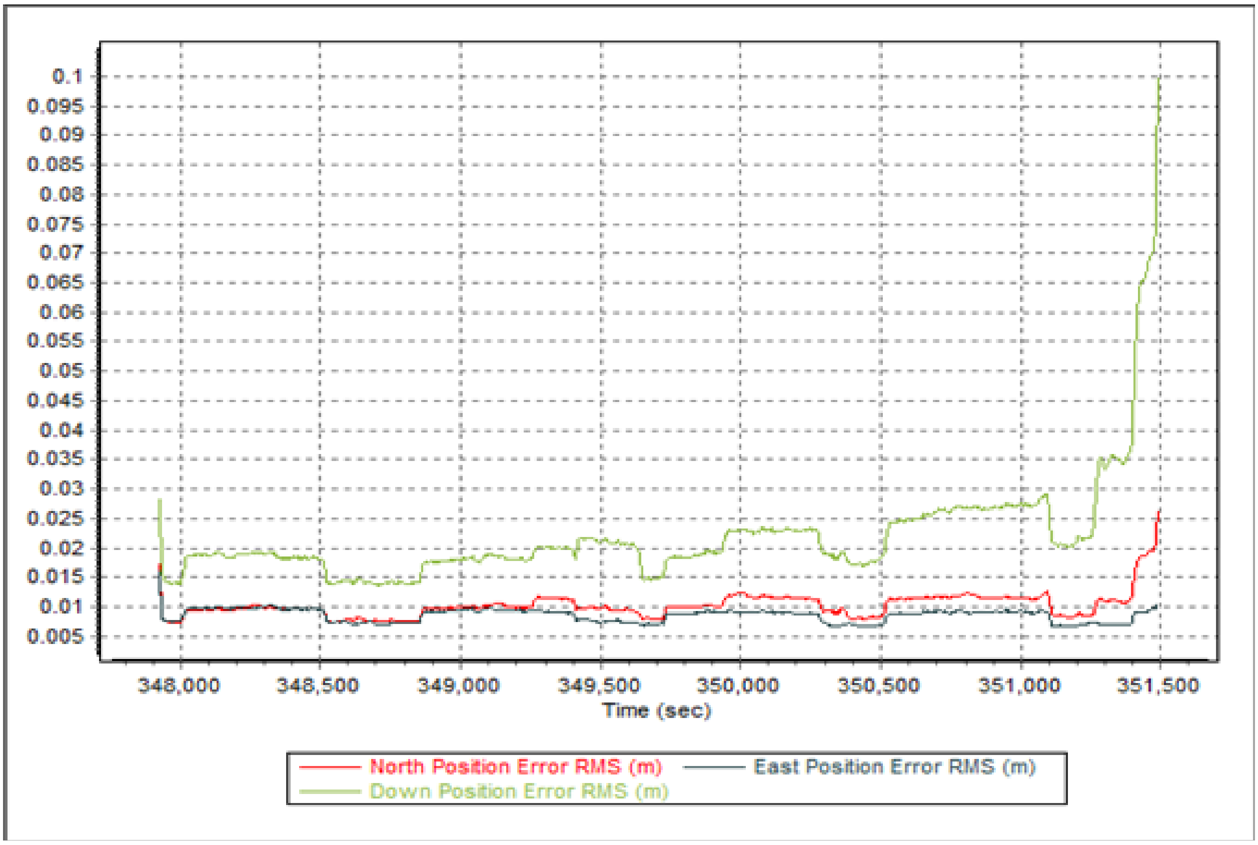


Figure A-8.37. Smoothed Performance Metric Parameters

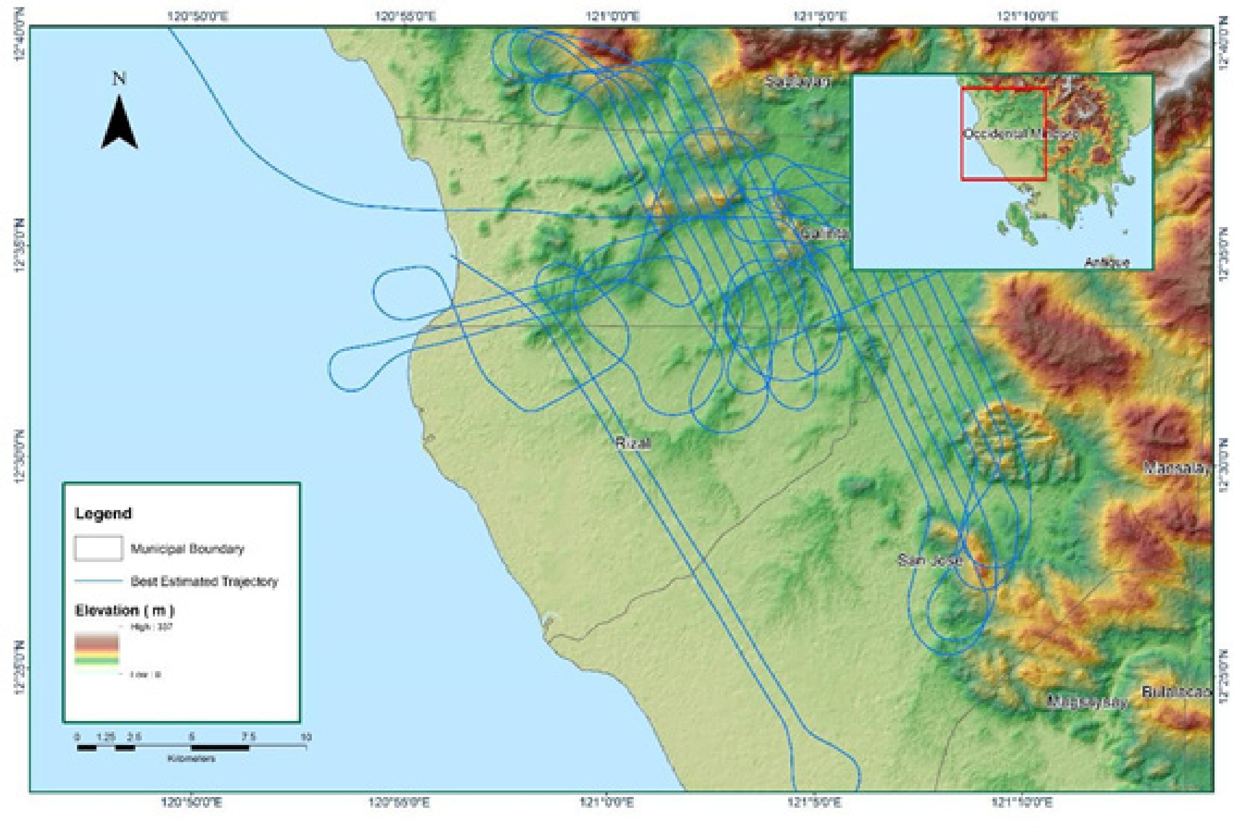


Figure A-8.38. Best Estimated Trajectory

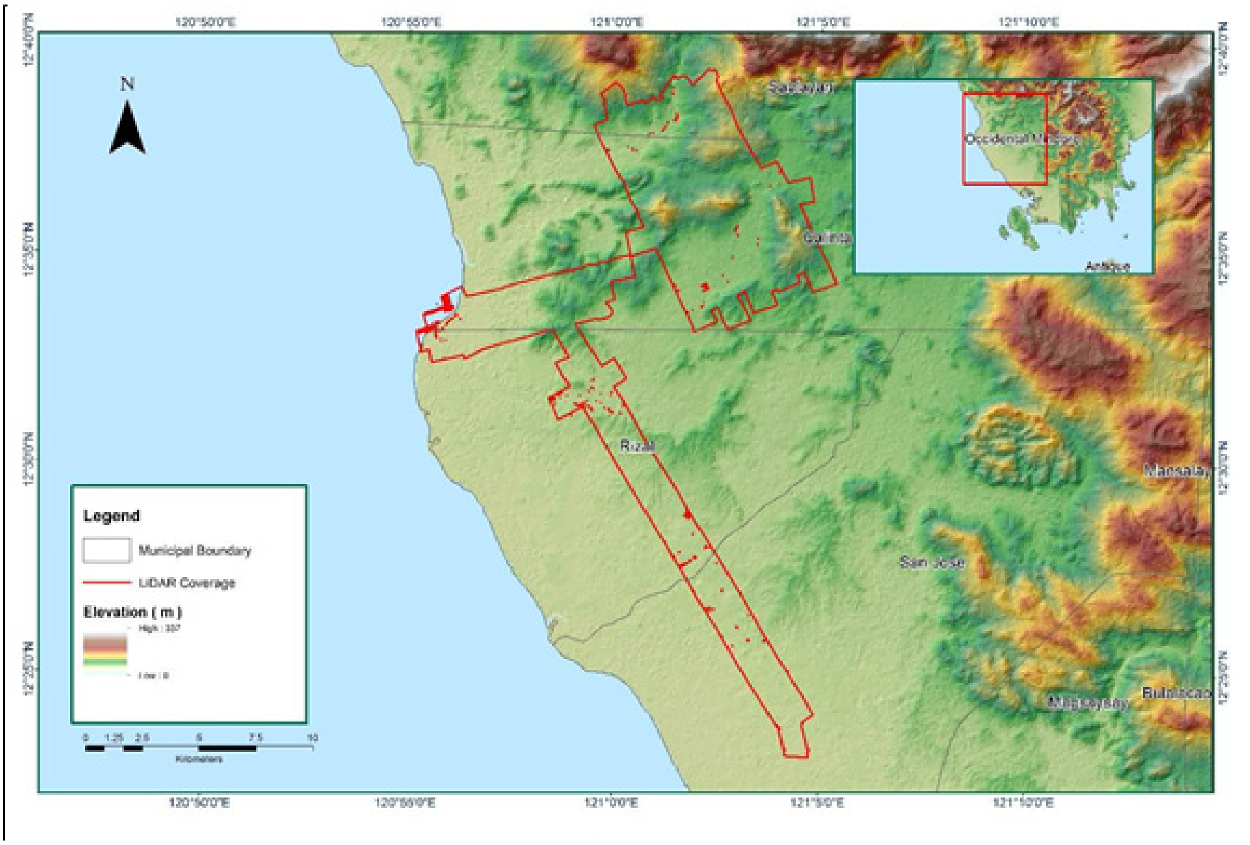


Figure A-8.39. Coverage of LiDAR Data

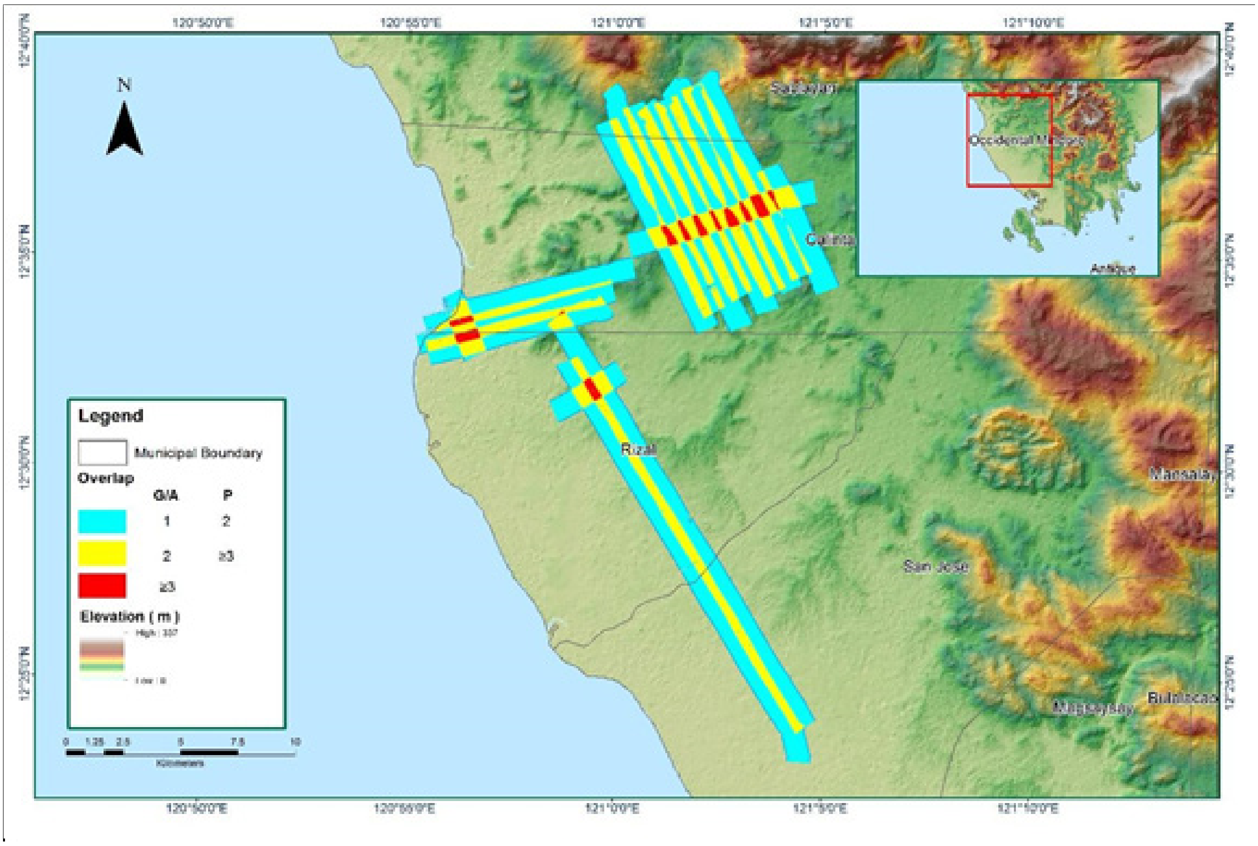


Figure A-8.40. Image of data overlap

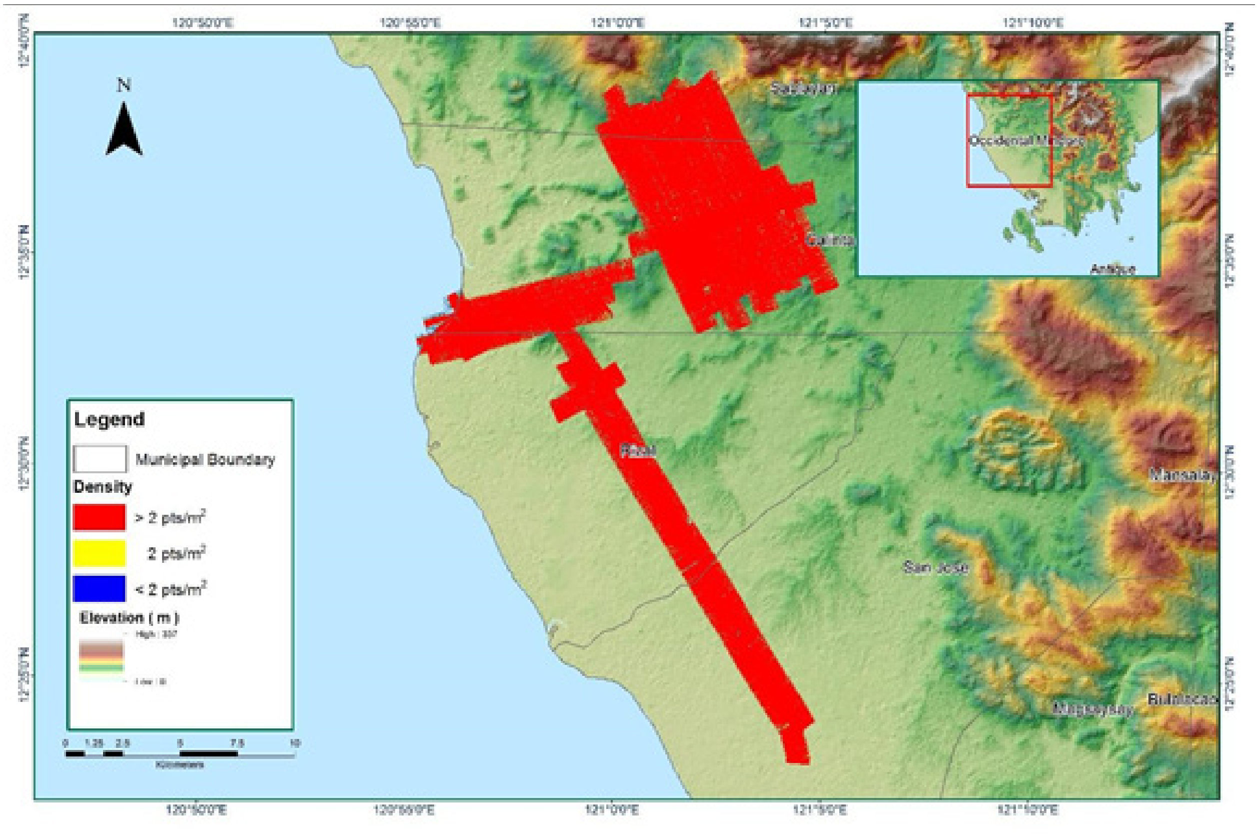


Figure A-8.41. Density map of merged LiDAR data

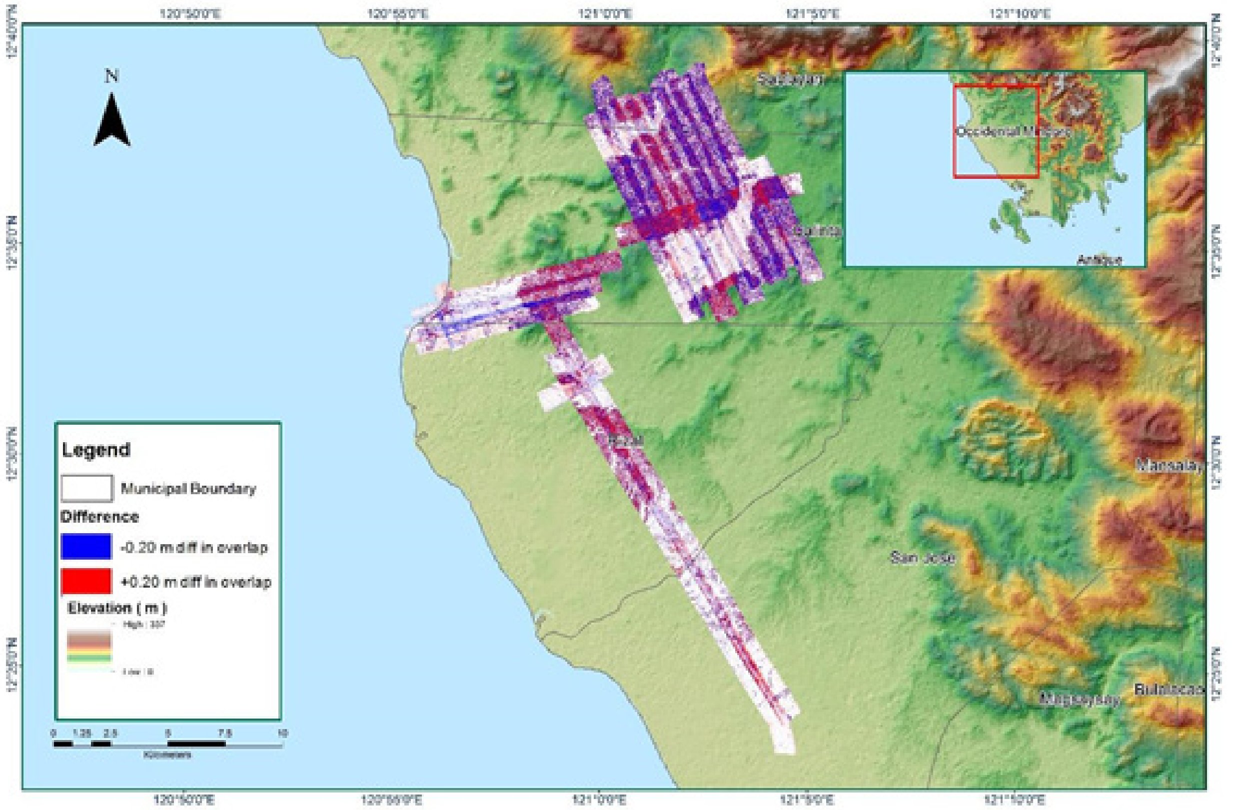


Figure A-8.42. Elevation difference between flight lines

Annex 9. Anahawin Model Basin Parameters

Table A-9.1 Anahawin Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W120	6.2421	70.172	0	1.0406	1.1612	Discharge	3.8233	0.5762	Ratio to Peak	0.66439
W130	4.3623	41.427	0	0.7052	0.79606	Discharge	0.48056	1	Ratio to Peak	0.4612
W140	5.0452	71.172	0	0.5441	2.0975	Discharge	2.6771	0.9	Ratio to Peak	0.4612
W150	10.492	57.751	0	0.9603	1.7838	Discharge	0.65898	1	Ratio to Peak	0.4612
W160	3.4452	64.382	0	1.2545	1.2641	Discharge	1.5851	1	Ratio to Peak	0.4612
W170	2.8958	57.328	0	0.6624	1.6274	Discharge	1.707	0.76693	Ratio to Peak	0.2965
W180	4.1172	74.594	0	0.7415	1.8998	Discharge	1.7654	0.9836	Ratio to Peak	0.30743
W190	4.4876	65.389	0	1.0602	1.3838	Discharge	0.55788	1	Ratio to Peak	0.4612
W200	2.7861	65.997	0	2.1929	3.6705	Discharge	10.388	0.9958	Ratio to Peak	0.4612
W210	2.5015	72.293	0	0.5548	0.4356	Discharge	0.26025	0.6667	Ratio to Peak	0.4728
W240	5.4619	69.9260	0	2.1384	3.4899	Discharge	0.1647678	1	Ratio to Peak	0.5
W250	2.7649	73.615	0	1.8508	2.0779	Discharge	2.0129	1	Ratio to Peak	0.4612

Annex 10. Anahawin Model Reach Parameters

Table A-10.1 Anahawin Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	5018.1	0.0017515	0.03	Trapezoid	45.287	1
R270	Automatic Fixed Interval	659.41	0.0017515	0.0066318	Trapezoid	45.287	1
R40	Automatic Fixed Interval	1323	0.0751231	0.00742125	Trapezoid	45.287	1
R70	Automatic Fixed Interval	1433.7	0.0444538	0.003296025	Trapezoid	45.287	1
R80	Automatic Fixed Interval	1469.2	0.0343105	0.007610625	Trapezoid	45.287	1
R90	Automatic Fixed Interval	559.41	0.0083219	0.014634225	Trapezoid	45.287	1

Annex 11. Anahawin Field Validation Points

Table A-11.1 Anahawin Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	12.532712	120.99069	3.19	1.25	-1.94	Glenda / July 2014	25-Year
2	12.533116	120.99075	3.19	1.34	-1.85	Glenda / July 2014	25-Year
3	12.53332	120.99376	1.62	0.49	-1.13	Yolanda / Nov. 2013	25-Year
4	12.533556	120.9909	2.96	1.13	-1.83	Yolanda / Nov. 2013	25-Year
5	12.533296	120.9416	0.11	0.96	0.85	Yolanda / Nov. 2013	25-Year
6	12.53406	120.99032	3.16	1.01	-2.15	Glenda / July 2014	25-Year
7	12.534458	120.9443	0.03	0.10	0.07	Glenda / July 2014	25-Year
8	12.534634	120.94217	0.03	0.17	0.14	Yolanda / Nov. 2013	25-Year
9	12.567645	120.94226	1.13	0.93	-0.20	Glenda / July 2014	25-Year
10	12.56807	120.94109	1.08	1.08	0.00	Glenda / July 2014	25-Year
11	12.568547	120.94166	0.91	0.77	-0.14	Glenda / July 2014	25-Year
12	12.56914	120.94223	0.32	0.77	0.45	Glenda / July 2014	25-Year
13	12.569316	120.94173	0.83	0.53	-0.30	Glenda / July 2014	25-Year
14	12.570223	120.9424	0.31	0.59	0.28	Lando	25-Year
15	12.570472	120.94139	1.08	1.22	0.14	Glenda / July 2014	25-Year
16	12.570559	120.94192	0.39	0.56	0.17	Glenda / July 2014	25-Year
17	12.571256	120.94168	0.64	0.46	-0.18	Glenda / July 2014	25-Year
18	12.57149	120.94203	0.53	0.21	-0.32	Glenda / July 2014	25-Year
19	12.573112	120.945348	0.47	0.29	-0.18	Glenda / July 2014	25-Year
20	12.574181	120.945758	0.56	0.75	0.19	Glenda / July 2014	25-Year
21	12.574586	120.945397	0.24	0.45	0.21	Glenda / July 2014	25-Year
22	12.575517	120.94128	1.6	0.83	-0.77	Glenda / July 2014	25-Year
23	12.576119	120.942285	0.96	0.46	-0.50	Glenda / July 2014	25-Year
24	12.576662	120.942347	2.06	1.70	-0.36	Glenda / July 2014	25-Year
25	12.5771	120.9483	0.03	0.46	0.43	Glenda / July 2014	25-Year
26	12.577983	120.940762	1.05	0.00	-1.05	Glenda / July 2014	25-Year
27	12.578231	120.940449	0.99	0.33	-0.66	Glenda / July 2014	25-Year
28	12.578749	120.940085	0.43	0.15	-0.28	Glenda / July 2014	25-Year
29	12.5791	120.9488	0.03	1.22	1.19	Glenda / July 2014	25-Year
30	12.581461	120.949011	0.05	0.00	-0.05	Glenda / July 2014	25-Year
31	12.581516	120.949284	0.03	0.69	0.66	Glenda / July 2014	25-Year
32	12.5817	120.9486	0.06	1.13	1.07	Glenda / July 2014	25-Year
33	12.587032	120.94992	1.11	0.95	-0.16	Yolanda / Nov. 2013	25-Year
34	12.587193	120.94966	0.63	0.10	-0.53	Mario / Sept. 2014	25-Year
35	12.587253	120.95043	1.92	0.84	-1.08	Habagat / August 2016	25-Year
36	12.587446	120.94839	0.06	0.00	-0.06		25-Year
37	12.587829	120.94904	0.04	0.27	0.23	Habagat / August 2016	25-Year
38	12.58783	120.94763	0.03	0.00	-0.03		25-Year
39	12.597482	120.94644	0.04	0.76	0.72	Glenda / July 2014	25-Year
40	12.597822	120.94617	0.14	0.58	0.44	Glenda / July 2014	25-Year
41	12.598475	120.94556	0.12	0.57	0.45	Yolanda / Nov. 2013	25-Year
42	12.598488	120.94634	0.87	1.29	0.42	Glenda / July 2014	25-Year
43	12.598799	120.94518	0.28	0.66	0.38	Yolanda / Nov. 2013	25-Year
44	12.600142	120.9431	0.03	0.87	0.84	Glenda / July 2014	25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
45	12.600177	120.94353	0.04	0.25	0.21	Glenda / July 2014	25-Year
46	12.601206	120.94142	0.03	0.00	-0.03		25-Year
47	12.60158	120.94113	0.03	0.00	-0.03		25-Year
48	12.602143	120.94067	0.09	0.20	0.11	Mario / Sept. 2014	25-Year
49	12.602362	120.93984	0.63	0.60	-0.03	Mario / Sept. 2014	25-Year
50	12.602369	120.94043	0.86	1.15	0.29	Mario / Sept. 2014	25-Year
51	12.602576	120.93887	0.33	0.22	-0.11	Mario / July 2015	25-Year
52	12.60335	120.973258	0.47	0.30	-0.17	Glenda / July 2014	25-Year
53	12.603147	120.93664	0.6	0.76	0.16	Nona / Dec. 2015	25-Year
54	12.603498	120.973374	0.06	0.72	0.66	Glenda / July 2014	25-Year
55	12.603809	120.971934	1.47	0.00	-1.47	Glenda / July 2014	25-Year
56	12.603973	120.982704	0.99	0.34	-0.65	Glenda / July 2014	25-Year
57	12.60391	120.971557	0.03	0.62	0.59	Glenda / July 2014	25-Year
58	12.603917	120.971105	0.03	0.00	-0.03	Yolanda / Nov. 2013	25-Year
59	12.603788	120.93628	0.55	0.10	-0.45	Mario / Sept. 2014	25-Year
60	12.604255	120.983135	2.05	1.10	-0.95	Glenda / July 2014	25-Year
61	12.605277	120.976854	0.03	0.00	-0.03	Glenda / July 2014	25-Year
62	12.605775	120.984825	0.23	0.00	-0.23	Glenda / July 2014	25-Year
63	12.605916	120.93388	0.04	0.00	-0.04		25-Year
64	12.606315	120.977045	0.58	0.40	-0.18	Ondoy / Sept. 2009	25-Year
65	12.606715	120.93336	0.05	0.39	0.34	Mario	25-Year
66	12.607351	120.977043	0.03	0.23	0.2	Ondoy / Sept. 2009	25-Year
67	12.608851	120.976723	0.06	0.00	-0.06	Glenda / July 2014	25-Year
68	12.625	120.982955	0.06	0.00	-0.06	Glenda / July 2014	25-Year
69	12.625476	120.981824	0.17	0.00	-0.17	Glenda / July 2014	25-Year
70	12.625772	120.980088	0.03	0.94	0.91	Glenda / July 2014	25-Year
71	12.62578	120.980342	0.03	1.30	1.27	Ondoy / Sept. 2009	25-Year
72	12.625856	120.978513	0.61	0.30	-0.31	Glenda / July 2014	25-Year
73	12.625938	120.987392	0.03	0.00	-0.03	Glenda / July 2014	25-Year
74	12.625945	120.97801	0.07	0.43	0.36	Glenda / July 2014	25-Year
75	12.625975	120.979844	0.34	0.80	0.46	Glenda / July 2014	25-Year
76	12.626647	120.990333	0.05	0.00	-0.05	Glenda / July 2014	25-Year
77	12.62685	120.99123	0.37	0.52	0.15	Glenda / July 2014	25-Year
78	12.627157	120.991845	0.27	0.33	0.06	Glenda / July 2014	25-Year
79	12.62763	120.99317	0.19	0	-0.19	Glenda / July 2014	25-Year
80	12.628377	120.9994	0.03	0	-0.03		25-Year
81	12.628487	120.994287	0.23	0	-0.23	Glenda / July 2014	25-Year
82	12.628576	120.99863	0.11	0	-0.11		25-Year
83	12.646895	120.94897	0.31	0.3	-0.01	Mario / Sept. 2014	25-Year
84	12.647267	120.94811	0.78	0.8	0.02	Mario / Sept. 2014	25-Year
85	12.647413	120.94731	1.02	0.6	-0.42	Mario / Sept. 2014	25-Year
86	12.647452	120.947	0.83	1.03	0.2	Mario / Sept. 2014	25-Year
87	12.647843	120.94719	1.05	0.66	-0.39	Mario / Sept. 2014	25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
88	12.648264	120.9477	0.78	1.07	0.29	Mario / Sept. 2014	25-Year
89	12.648547	120.94691	1.28	1.04	-0.24	Mario / Sept. 2014	25-Year
90	12.6488	120.94727	0.98	1.01	0.03	Mario / Sept. 2014	25-Year
91	12.649344	120.94729	1.25	0.59	-0.66	Mario / Sept. 2014	25-Year
92	12.65064	120.94718	1.3	0.45	-0.85	Mario / Sept. 2014	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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