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

LiDAR Surveys and Flood Mapping of Bacungan River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA-BSWM	Department of Agriculture - Bureau of Soil and Water Management
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 BACUNGAN RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof.. Edwin R. Abucay, and Asst. Prof. Efraim D. Roxas

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) 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 described 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 Baños (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 forty-five (45) river basins in the Southern Luzon Region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Bacungan River Basin

The Bacungan River Basin is a 99,220-hectare watershed traversing the barangays of Bacungan, Bahile, Irawan, Santa Cruz and Santa Lourdes, all of which are in the City of Puerto Princesa in Palawan. The DENR River Basin Control Office (RBCO) states that the Bacungan River Basin has a drainage are of 96 km^2 and an estimated 154 cubic meter (MCM) annual run-off (RBCO, 2015).

The river basin experiences Climate Type I and III, which 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.

Meanwhile, the basin's topography is characterized with >50% slope. Moreover, two soil types (Malalag clay and Tapul clay loam) dominate the river basin. However, rough mountainous land (unclassified area) and hydrosol can also be found in the area. Cultivated area mixed with brushland/ grassland, closed canopy (mature trees covering >50%), grassland (grass covering >70%), mossy forest and open canopy (mature trees covering <50%) are the land cover types found in the river basin.

Its main stem, Bacungan River, passes through Bacungan, Bahile, Irawan, Santa Cruz and Santa Lourdes. The river is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner HEI, University of the Philippines Los Baños. According to the 2015 national census of the Philippine Statistics Authority (PSA), a total of 9,726 persons are residing in Brgy. Sta Lourdes and Brgy. Bacungan in the City of Palawan, which is within the immediate vicinity of the river. The economy of the province of Palawan largely rests on agriculture particularly fishing, tourism, trade, commerce, and mineral extraction (Palawan Knowledge Platform for Biodiversity and Sustainable Development, 2007).

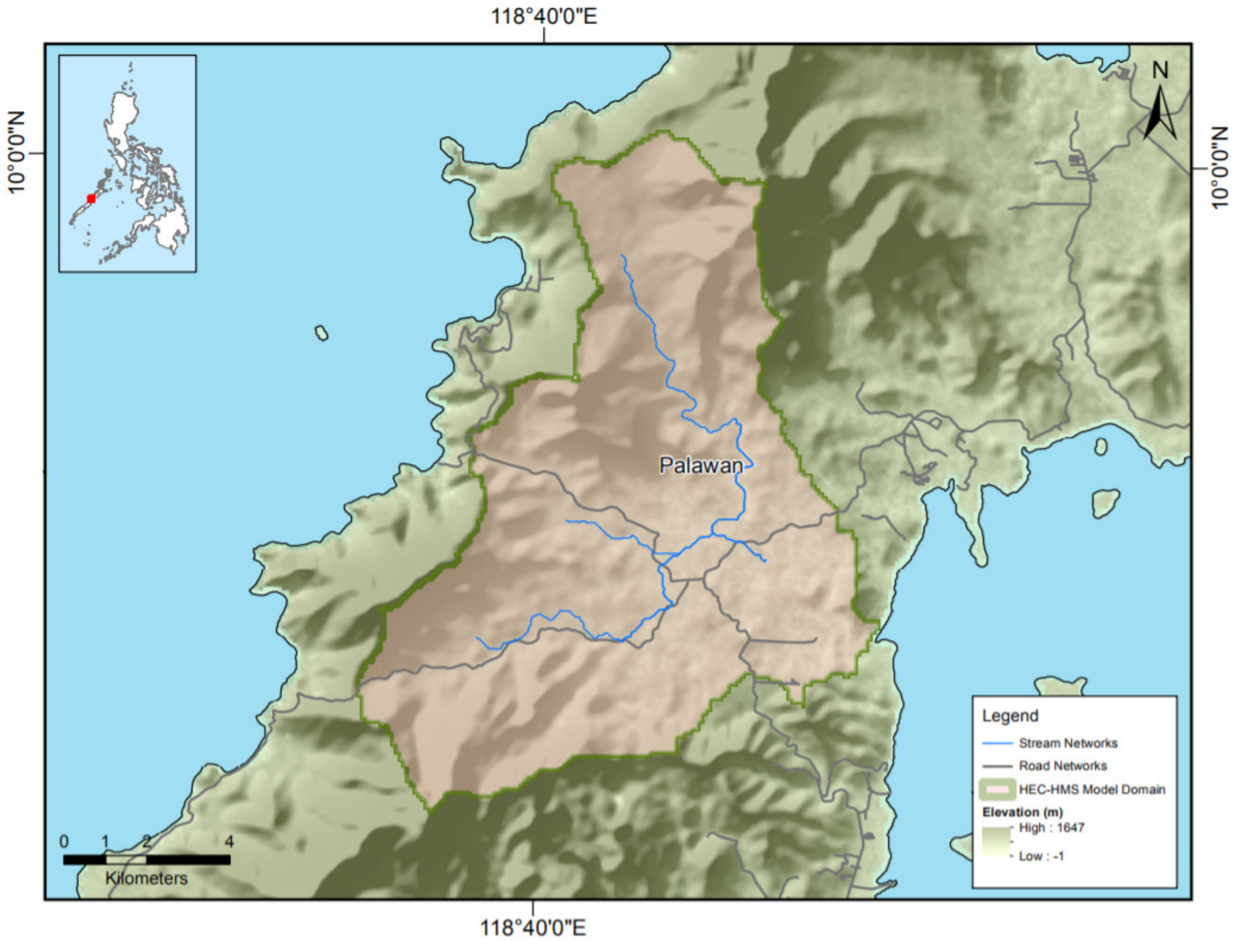

Figure 1. Map of Bacungan River Basin (in brown)

Based on the studies conducted by the Mines and Geosciences Bureau, only Bacungan has a flood susceptibility (low to high) while other barangays have no flood hazard at all. However, the field surveys conducted by the PHIL-LiDAR 1 validation team, showed that there were seven notable weather disturbance that caused flooding in 2008 (Frank), 2009 (Ondoy), 2013 (Yolanda), 2014 (Glenda), and 2016 (Karen, Lawin and Lando). On December 25, 2016, the National Disaster Risk Reduction and Management Council (NDRRMC) issued a flood advisory for Bacungan River and its tributaries due to the moderate to heavy rains brought Typhoon Nina affecting Southern Luzon, Visayas and Mindanao as per NDRRMC report (National Disaster Risk Reduction and Management Council, 2016). As for the landslide susceptibility, only Santa Cruz has a moderate to high risk while others have low to high risk range.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BACUNGAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Bacungan floodplain in Palawan. These missions were planned for ten (10) lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plans and base stations for Bacungan floodplain.

Table 1. 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)
BLK 42A	1000	30	50	200	30	130	5
BLK 42B	1000	30	50	200	30	130	5
BLK 42D	1000	30	50	200	30	130	5
BLK 42E	1100/1000	30	50	200	30	130	5
BLK 42F	1000	30	50	200	30	130	5

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

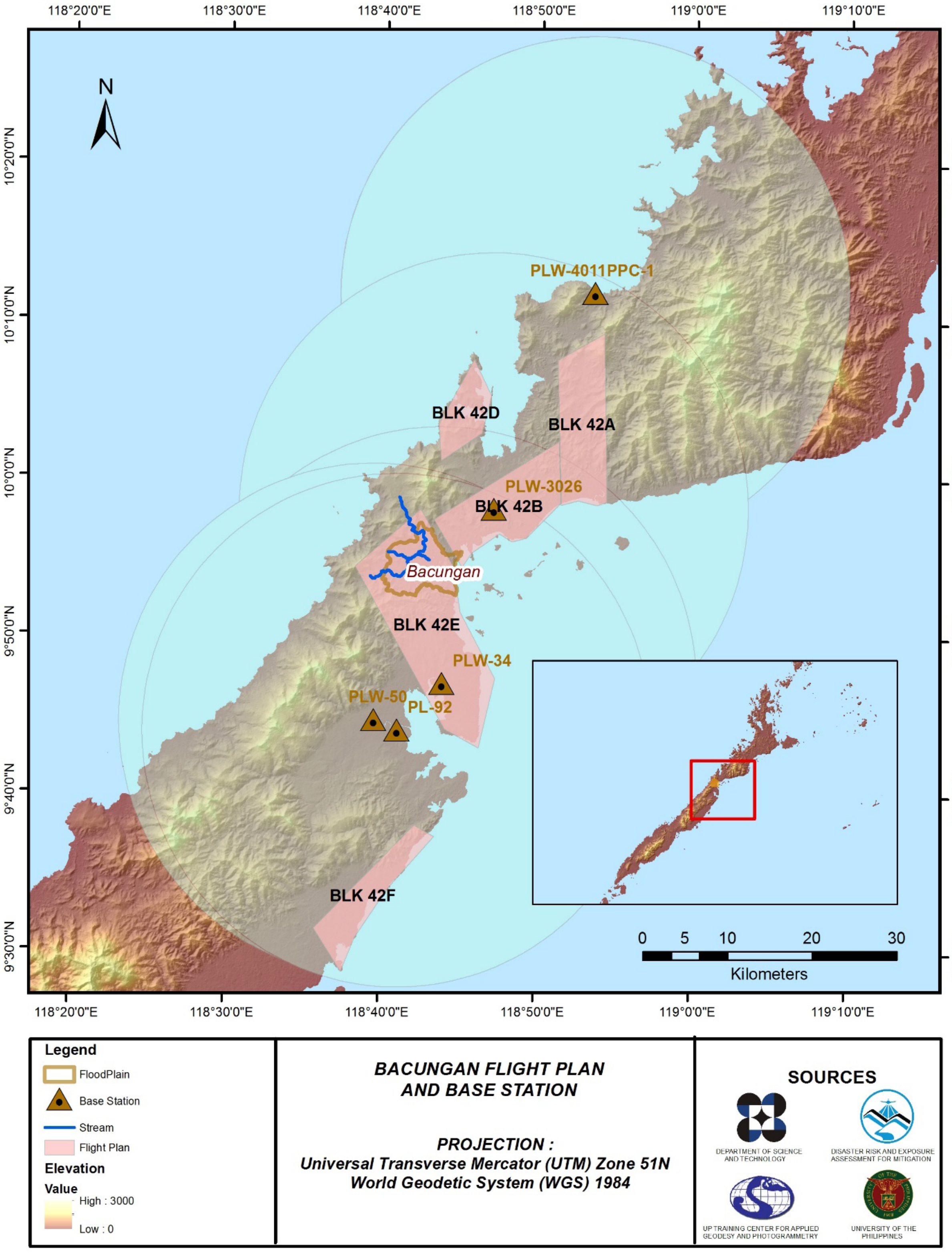

Figure 2. Flight Plan and base station used for the Bacungan Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA horizontal ground control points: PLW-34 and PLW-50 which are of first (1st) and second (2nd) order accuracy, respectively. The project team also re-processed ground control points: PLW-3026 and PLW-4011; and established (1) ground control point: PPC-1. One (1) NAMRIA benchmark was recovered, PL-92 which is of 2nd order accuracy. This benchmark was used as vertical reference point and was also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (May 30-June 20, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Bacungan floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. Table 2 to Table 7 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

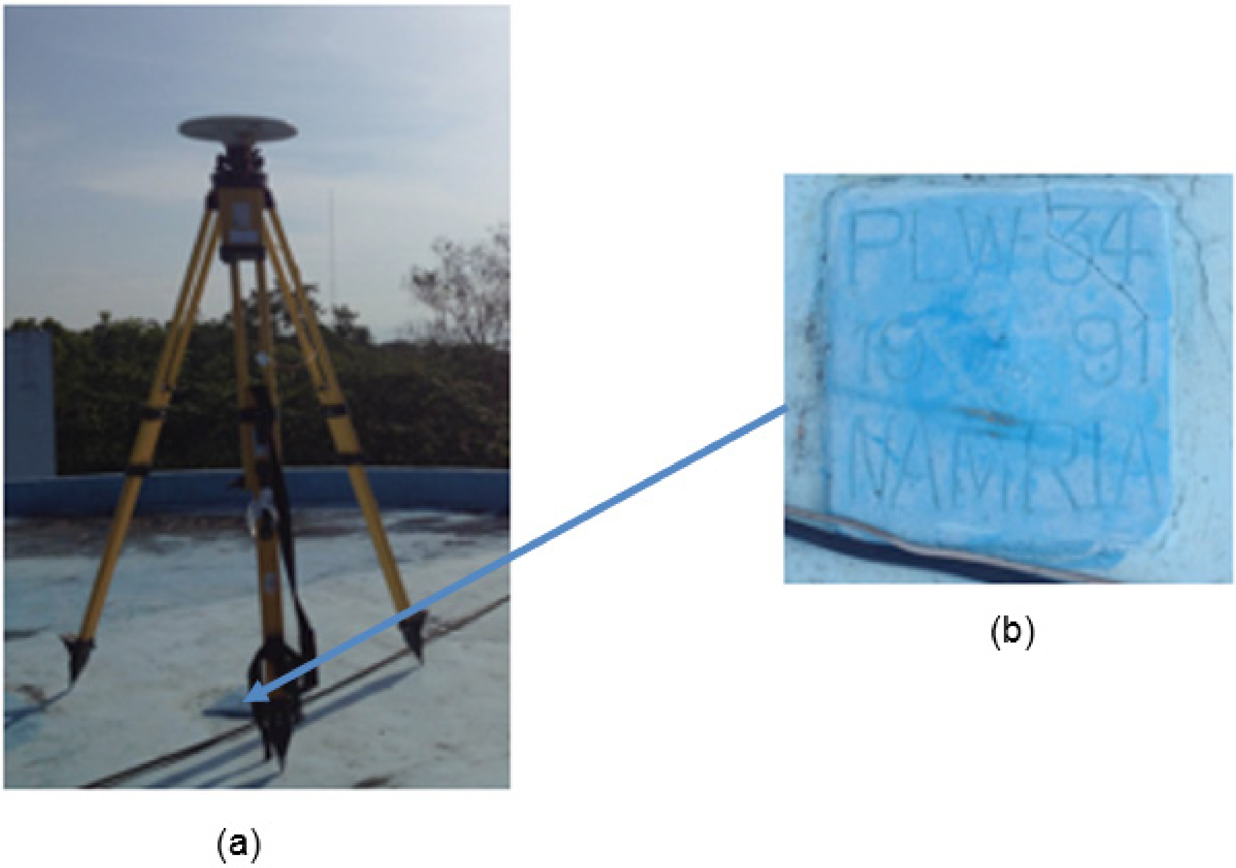

Figure 3. a) GPS set-up over PLW-34 located at the roof deck of the old city hall of Puerto Princesa, Brgy. Sta. Monica, Puerto Princesa City. b) NAMRIA reference point PLW-34 as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point PLW-34 used as base station for the LiDAR acquisition.

Station Name	**PLW-34**	
Order of Accuracy	**1st**	
Relative Error (Horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference Of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°47’4.34346” North 118°43’50.36738” East 53.76200 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	525304.737 m 1081910.004 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 46’59.90069” North 118° 43’ 55.68915” East 103.89600 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	689825.58 m 1082009.99 m

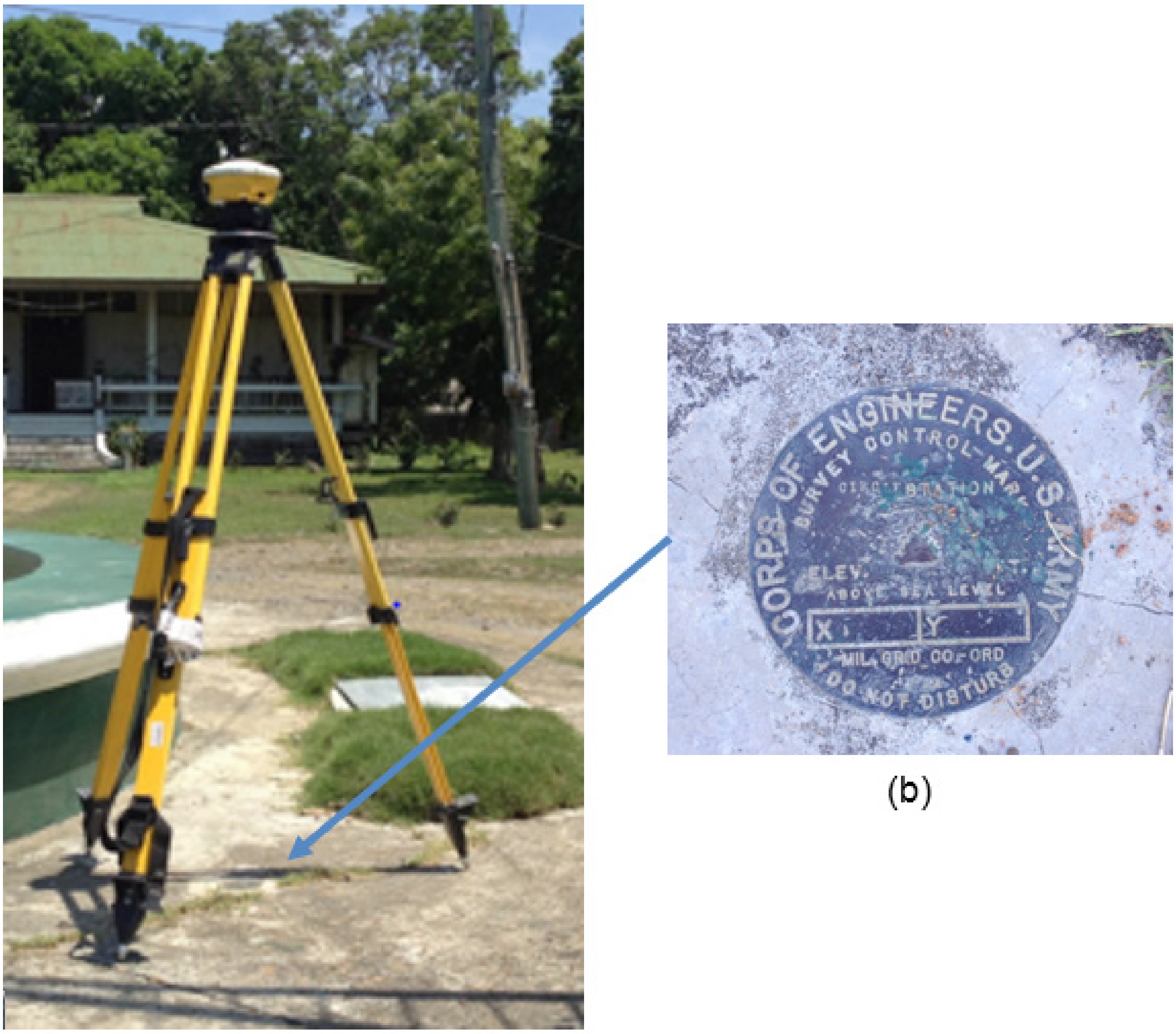

Figure 4. a) GPS set-up over PLW-50 located within the vicinity of Iwahig Prison and Penal Farm at the fountain in front of the supervisor's quarter (Quarter 1), Brgy. Iwahig, Puerto Princesa City. b) NAMRIA reference point PLW-50 as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point PLW-50 used as base station for the LiDAR acquisition.

Station Name	PLW-50	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°44'42.16318" North 118°29'28.02050" East 16.81300 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	517311.956 m 1077537.527 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 44'37.72390" North 118° 39' 33.34598" East 66.85300 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	681851.72 m 1077601.73 m

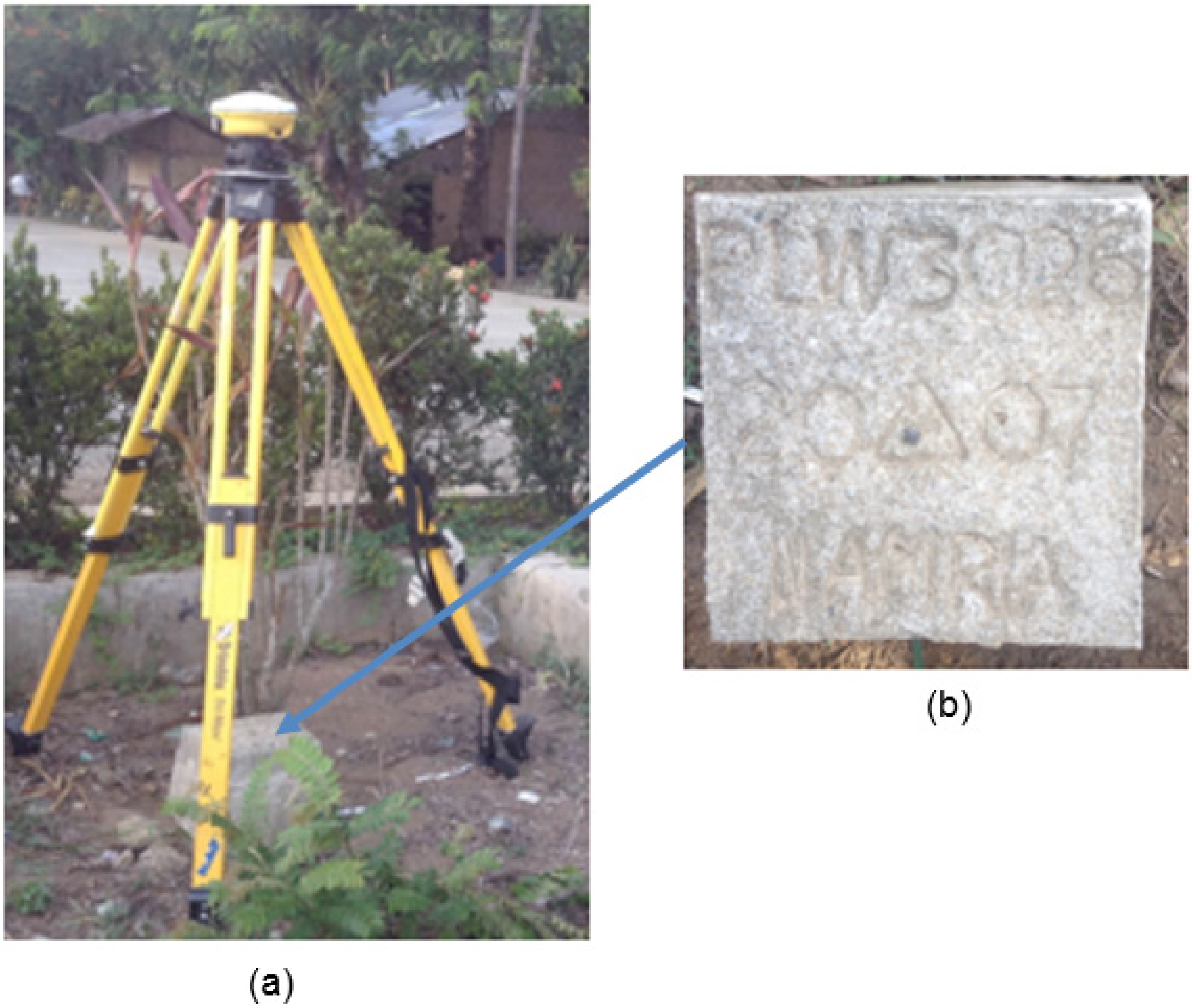

Figure 5. GPS set-up over PLW-3026 located at northeast corner of the center island in Salvacion junction, Brgy. Salvacion, Puerto Princesa City. b) NAMRIA reference point PLW-3026 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point PLW-3026 used as base station for the LiDAR acquisition.

Station Name	**PLW-3026**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°58’03.41442” North 118°47’09.05751” East 57.363 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°58’07.89863” North 118°47’03.75221” East 7.504 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 52N PRS 1992)	Easting Northing	695610.418 m 1102427.869 m

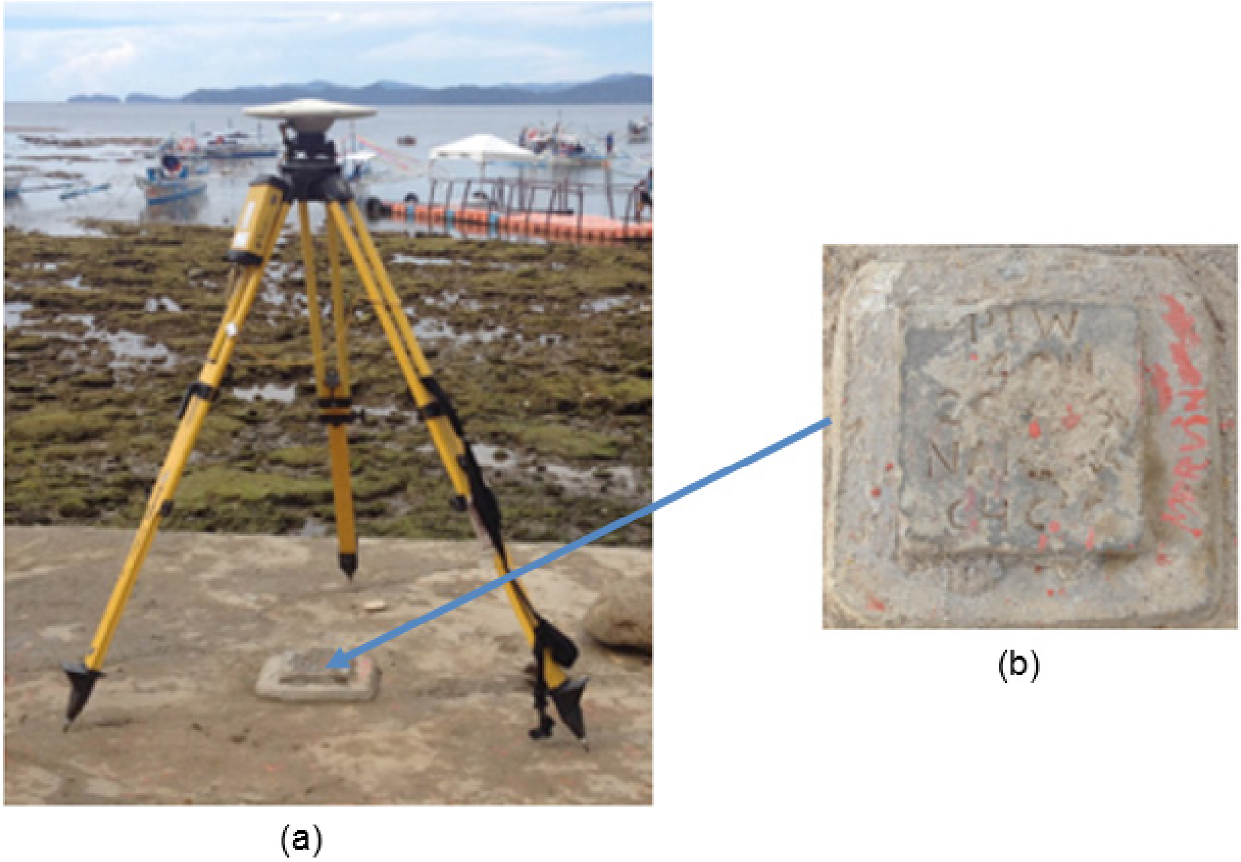

Figure 6. a) GPS set-up over PLW-4011 located infront of A. Susan's Store in Sabang Wharf, Sitio Sabang, Brgy. Cabacungan, Puerto Princesa City. b) NAMRIA reference point PLW-4011 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point PLW-4011 used as base station for the LiDAR acquisition.

Station Name	**PLW-4011**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°58'03.41442" North 118°47'09.05751" East 57.363 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°58'07.89863" North 118°47'03.75221" East 7.504 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 52N PRS 1992)	Easting Northing	695610.418 m 1102427.869 m

Table 6. Details of the recovered NAMRIA reference point PL-92 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	PL-92	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°44'04.01581" North 118°40'58.28065" East 8.218 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°43'59.58138" North 118°41'03.60701" East 58.344 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 52N PRS 1992)	Easting Northing	26049.752 m 1079008.192 m

Table 7. Details of the recovered NAMRIA horizontal control point PPC-1 used as base station for the LiDAR acquisition.

Station Name	PPC-1	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°11'54.83823" North 118°53'26.98215" East 4.002 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°11'50.30596" North 118°53'32.26682" East 53.609 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 52N PRS 1992)	Easting Northing	707137.228 m 1127901.415 m

Table 8. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 30, 2015	2898P	1BLK42E150A	PLW-34
June 6, 2015	3017P	1BLK42A157A	PLW-34 and PLW-3026
June 7, 2015	3021P	1BLK42BD158A	PLW-34 and PLW-3026
June 7, 2015	3023P	1BLK42BCAL158B	PLW-34 and PLW-3026
June 13, 2015	3045P	1BLK42BS164A	PLW-4011 and PPC-1
June 14, 2015	3049P	1BLK42S165A	PLW-50 and PL-92
June 20, 2015	3073P	1BLK42S171A	PLW-3026 and PLW-4011

2.3 Flight Missions

Seven (7) missions were conducted to complete LiDAR data acquisition in Bacungan Floodplain, for a total of twenty one hours and fifty six minutes (21+56) of flying time for RP-C9022. All missions were acquired using Pegasus system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for the LiDAR data acquisition in Bacungan 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
May 30, 2015	2989P	213.38	239.59	40.93	198.66	340	4	6
June 6, 2015	3017P	100.65	178.62	18.84	159.78	792	4	23
June 7, 2015	3021P	139.4	114.91	1.79	113.12	384	2	27
June 7, 2015	3023P	313.41	140.67	6.66	134.01	600	3	49
June 12, 2015	3041P	81.86	115.6	0	115.6	254	2	1
June 13, 2015	3045P	100.11	124.01	1.81	122.2	229	2	27
June 14, 2015	3049P	276.39	149.92	15.38	134.54	503	2	50
June 20, 2015	3073P	139.4	60.08	0	60.08	173	1	54
TOTAL		**1282.82**	**1007.8**	**91.6**	**916.2**	**3031**	**21**	**56**

Table 10. Actual parameters used during the LiDAR data acquisition of the Bacungan Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2989P	1100	30	50	200	30	140	5
3017P	1000	30	50	200	30	140	5
3021P	1000	30	50	200	30	140	5
3023P	1000	30	50	200	30	140	5
3045P	1000	30	50	200	30	140	5
3049P	1000	30	50	200	30	140	5
3073P	1000	30	50	200	30	140	5

2.4 Survey Coverage

Bacungan floodplain is located in the city of Puerto Princesa, Palawan. The survey covered mostly the city of Puerto Princesa, and municipality of Aborlan as shown in Table 11. The actual coverage of the LiDAR acquisition for Bacungan Floodplain is presented in Figure 7.

Table 11. List of municipalities and cities surveyed of the Bacungan Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Puerto Princesa	2186.36	577.34	26.41%
	Aborlan	645.11	16.63	2.58%
TOTAL		**2831.47**	**593.97**	**20.98%**

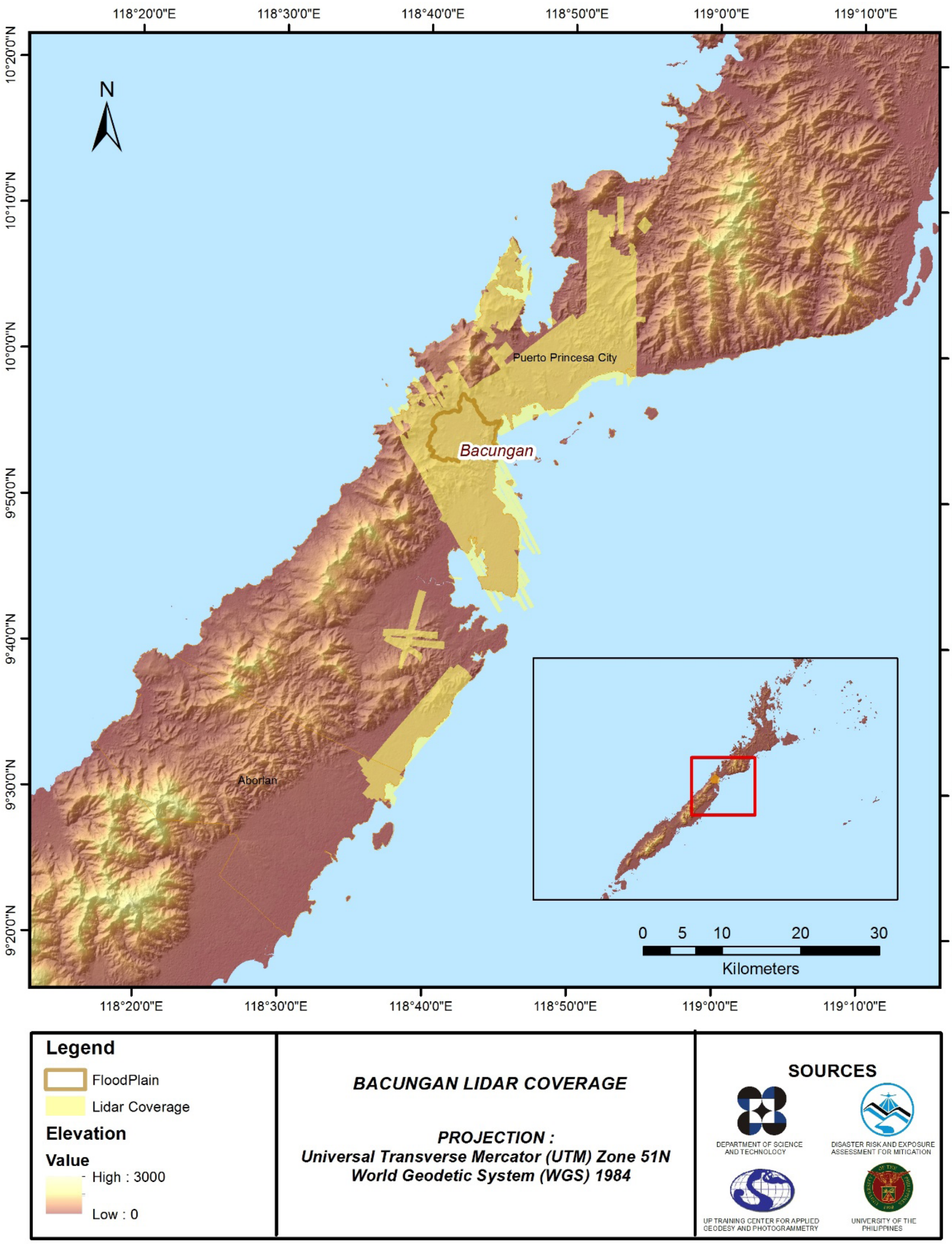

Figure 7. Actual LiDAR survey coverage of the Bacungan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BACUNGAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 8.

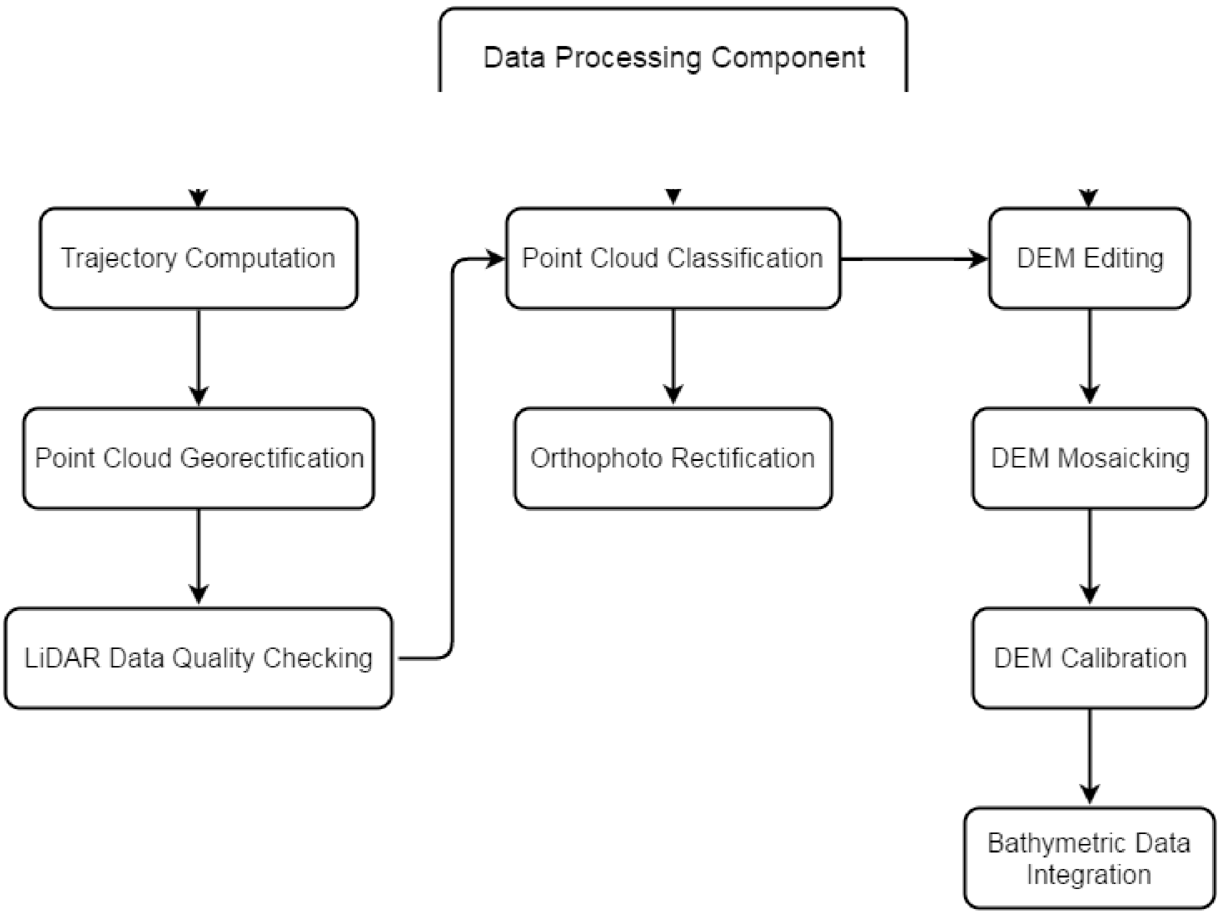

Figure 8. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Bacungan floodplain can be found in Annex 5. Missions flown during the survey conducted on May 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Puerto Princesa City, Palawan.

The Data Acquisition Component (DAC) transferred a total of 124.4 Gigabytes of Range data, 1.289 Gigabytes of POS data, 73.91 Megabytes of GPS base station data, and 231.9 Gigabytes of raw image data to the data server on August 3, 2015 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Bacungan was fully transferred on August 5, 2015, as indicated on the Data Transfer Sheets for Bacungan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3023P, one of the Bacungan flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on June 7, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

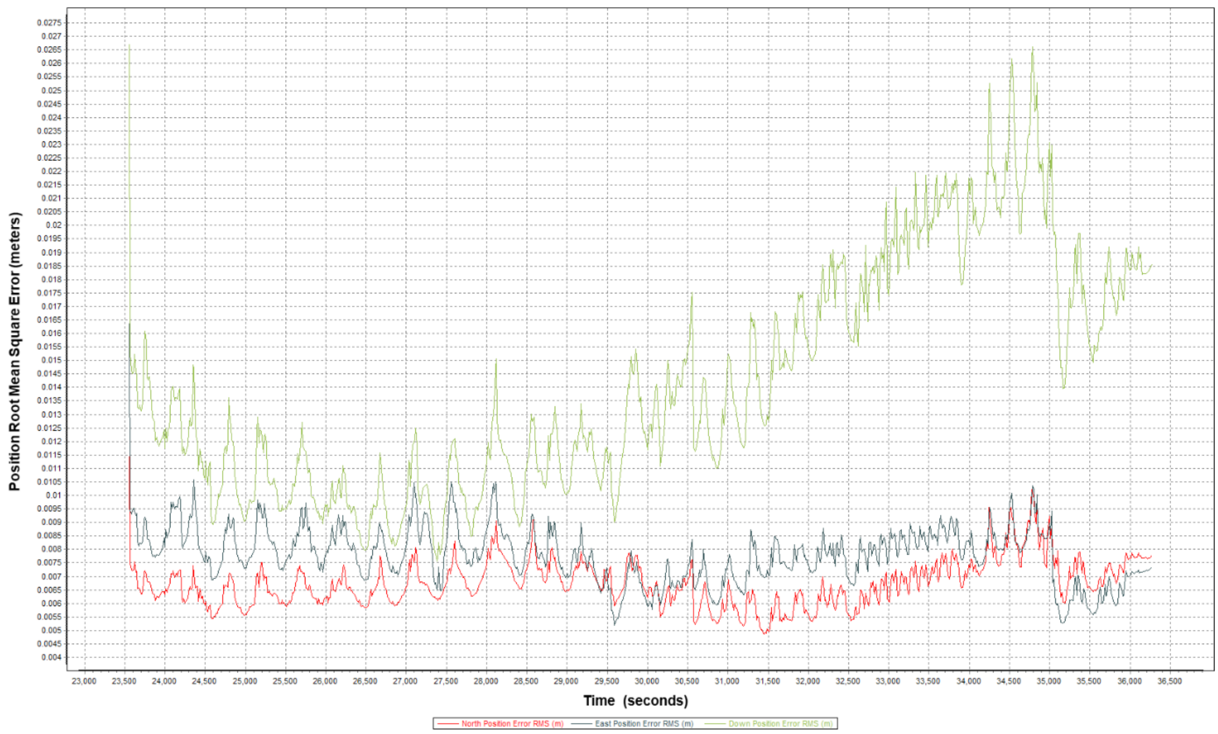

Figure 9. Smoothed Performance Metrics of Bacungan Flight 3023P

The time of flight was from 23500 seconds to 36250 seconds, which corresponds to afternoon of June 7, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 0.94 centimeters, the East position RMSE peaks at 1.05 centimeters, and the Down position RMSE peaks at 1.75 centimeters, which are within the prescribed accuracies described in the methodology.

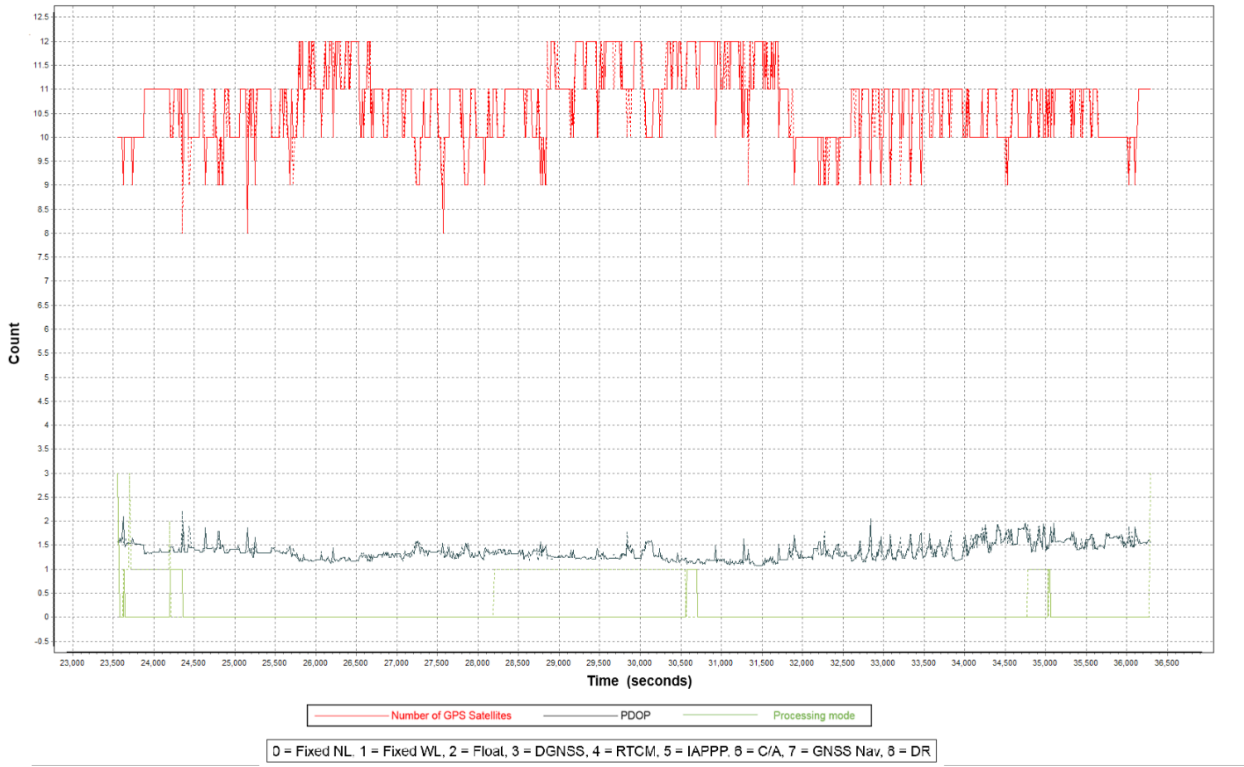

Figure 10. Solution Status Parameters of Bacungan Flight 3023P.

The Solution Status parameters of flight 3023P, one of the Bacungan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Bacungan flights is shown in Figure 11.

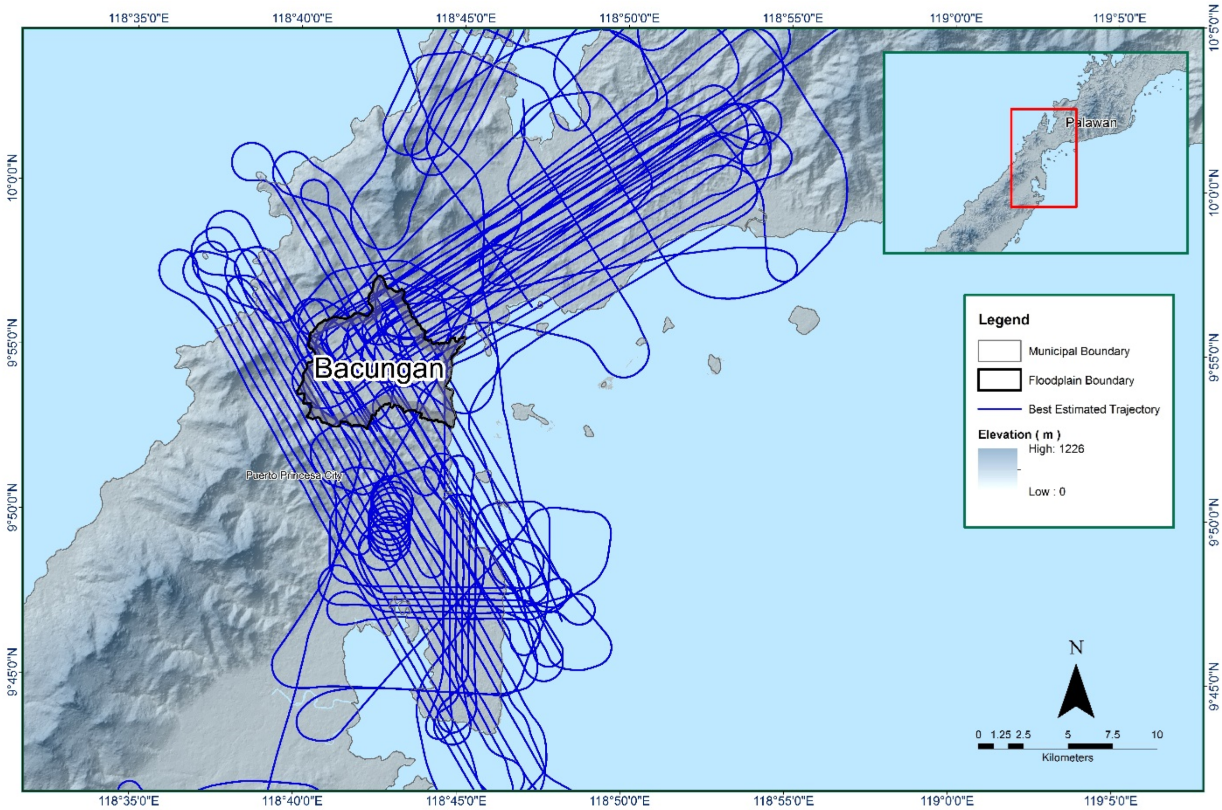

Figure 11. Best Estimated Trajectory of the LiDAR missions conducted over the Bacungan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 70 flight lines, with each flight line containing two channels, since the Pegasus system contains two. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Bacungan floodplain are given in Table 12.

Table 12. Self-calibration Results values for Bacungan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000249
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000905
GPS Position Z-correction stdev	<0.01meters	0.0099

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Bacungan Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

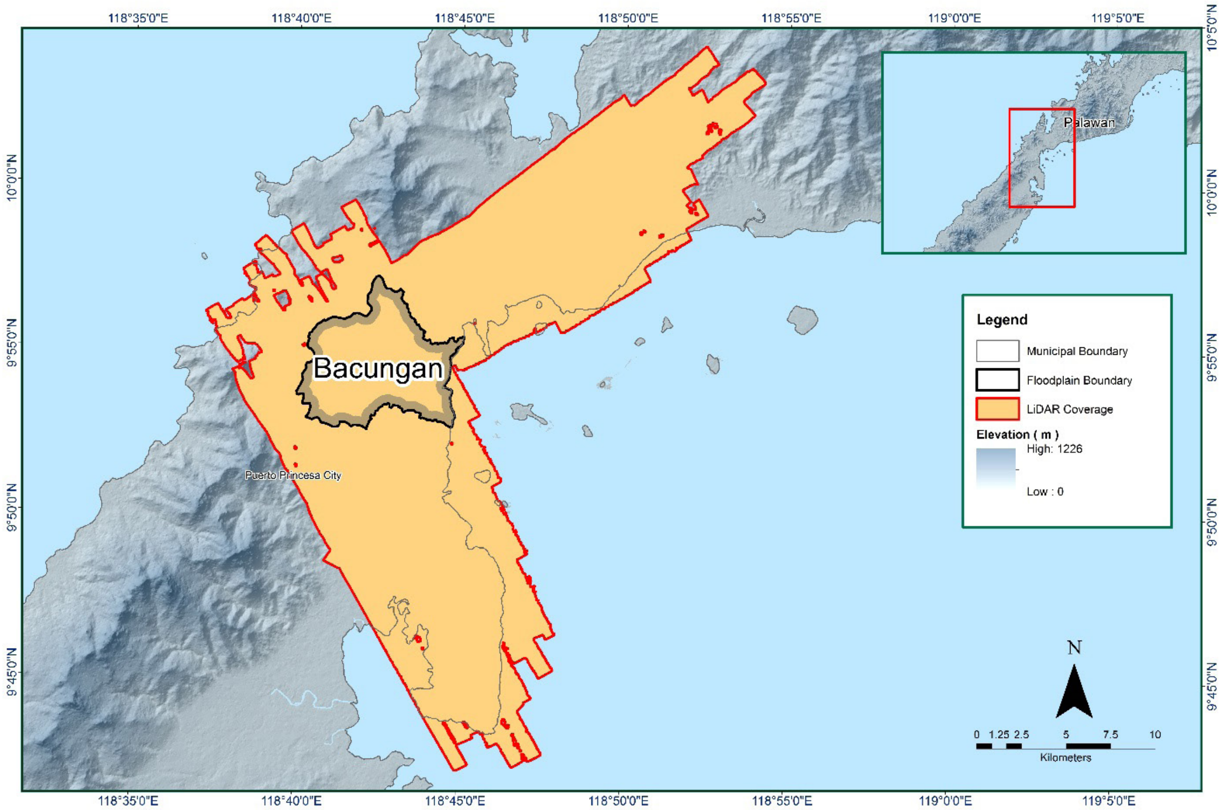

Figure 12. Boundary of the processed LiDAR data over Bacungan Floodplain

The total area covered by the Bacungan missions is 628.83 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into five (5) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Bacungan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_Blk42B	3021P	142.16
	3023P	
Palawan_Blk42B_additional	3073P	53.32
Palawan_Blk42B_supplement	3045P	115.88
Palawan_Blk42E	2989P	269.36
	3017P	
Palawan_Blk42E_additional2	3049P	48.11
TOTAL		**628.83 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

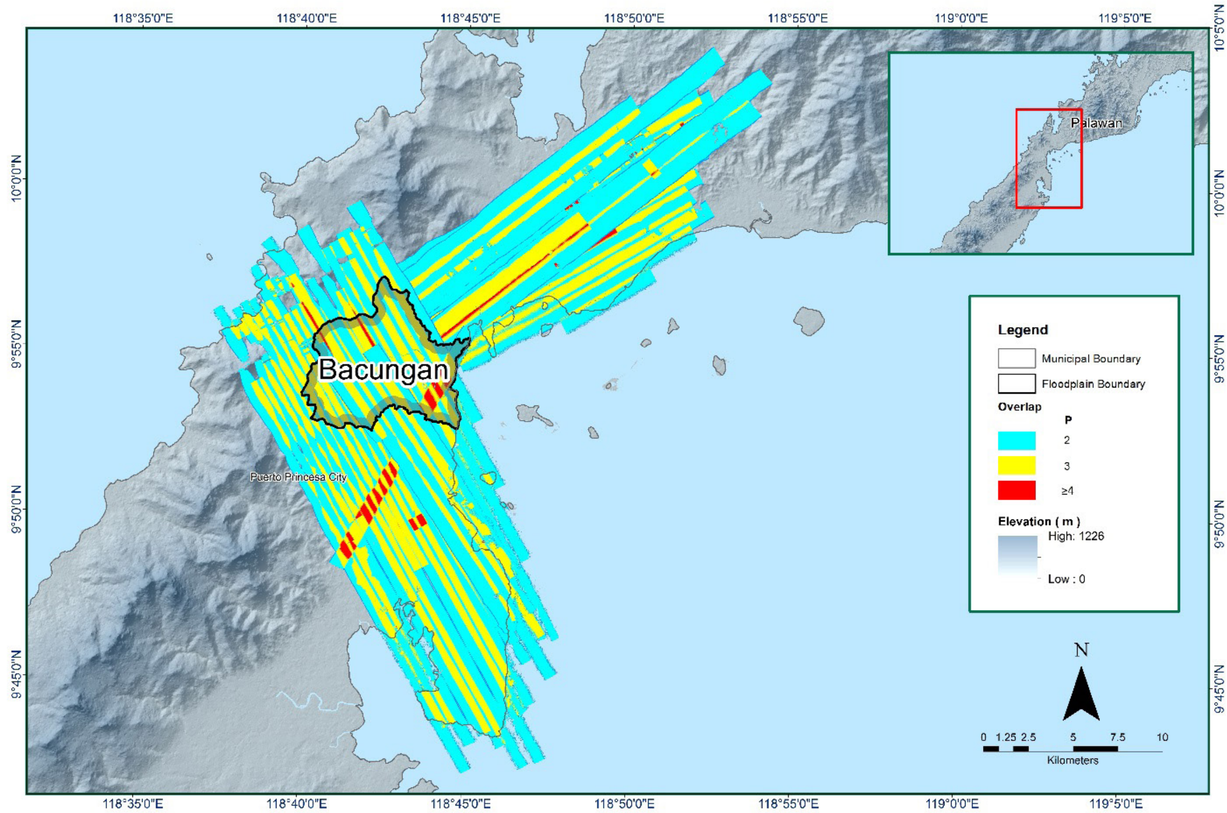

Figure 13. Image of data overlap for Bacungan Floodplain.

The overlap statistics per block for the Bacungan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.46% and 61.51% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Bacungan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.76 points per square meter.

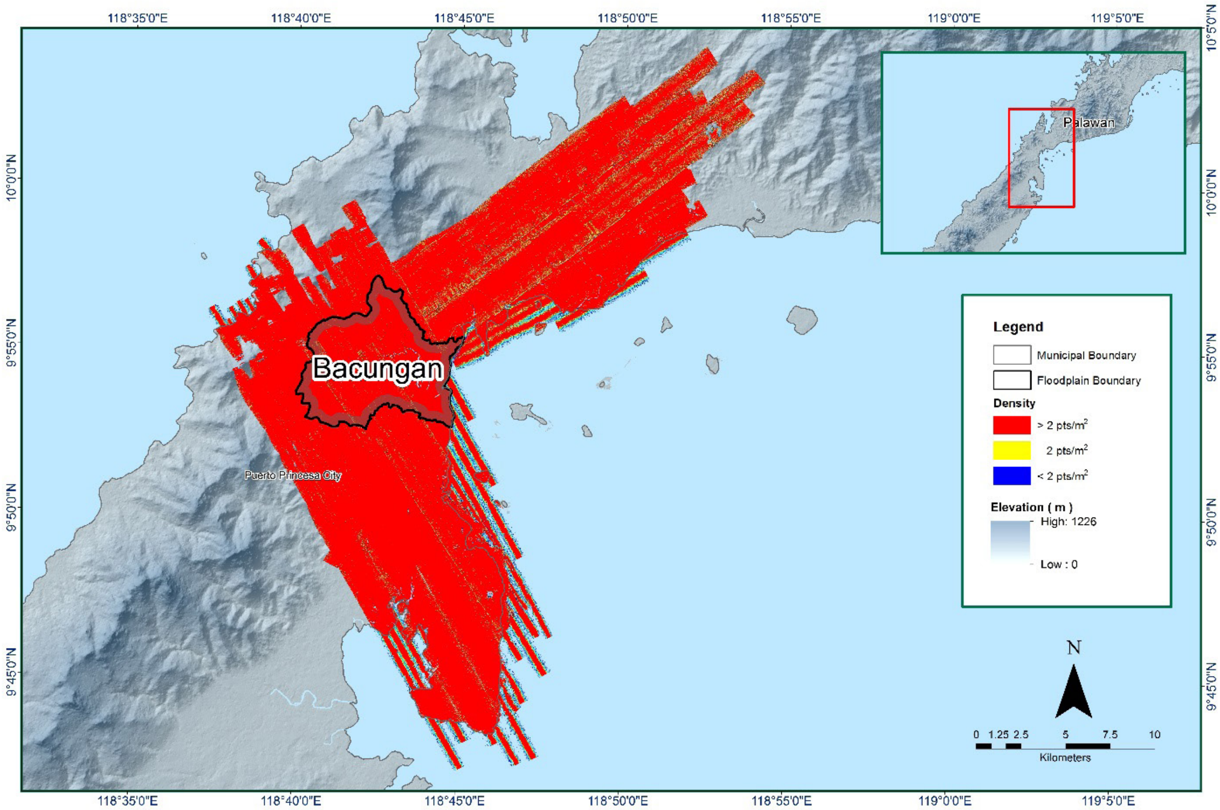

Figure 14. Pulse density map of merged LiDAR data for Bacungan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

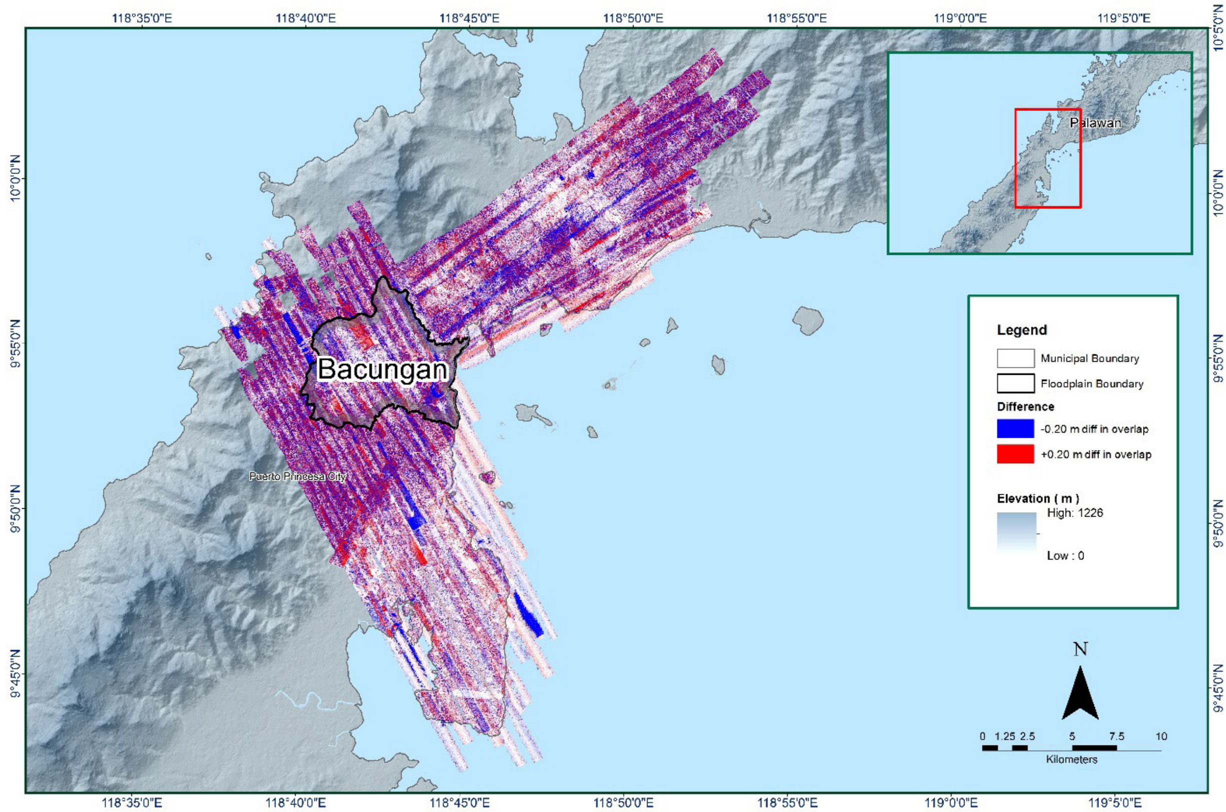

Figure 15. Elevation Difference Map between flight lines for Bacungan Floodplain Survey.

A screen capture of the processed LAS data from a Bacungan flight 3023P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

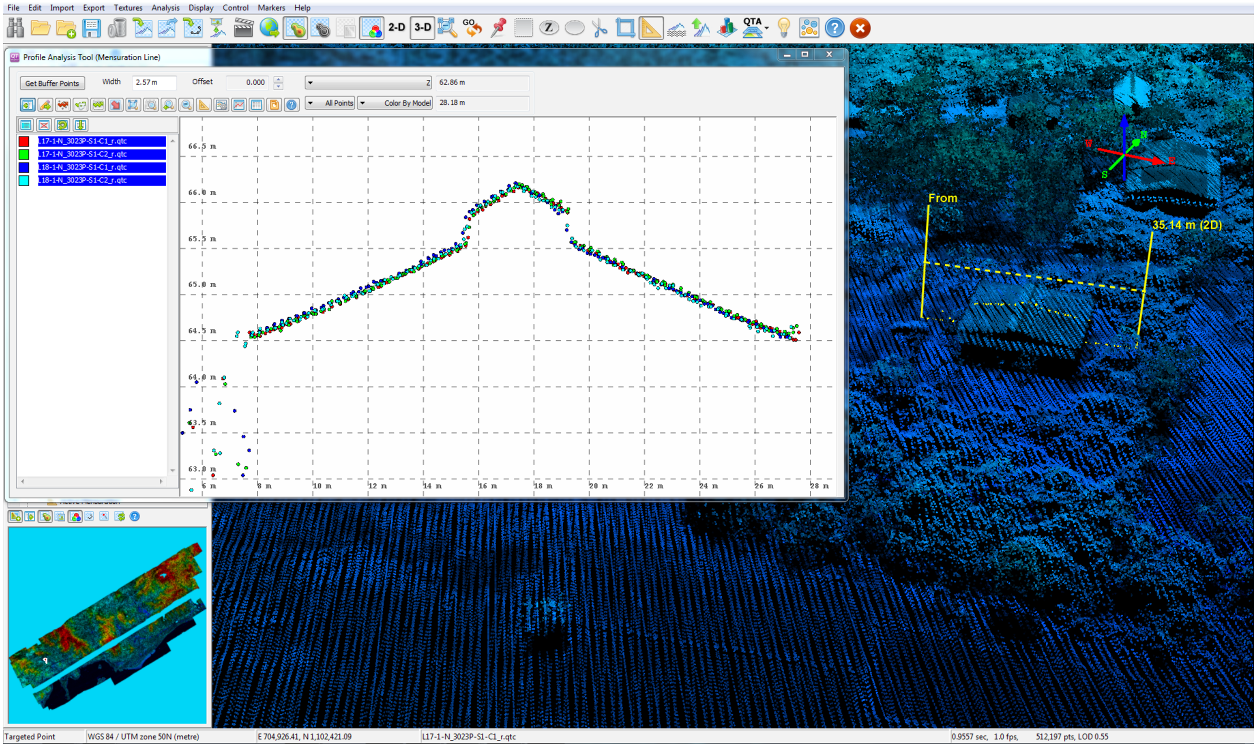

Figure 16. Quality checking for Bacungan Flight 3023P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Bacungan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	671,781,211
Low Vegetation	430,820,563
Medium Vegetation	944,124,406
High Vegetation	2,670,377,734
Building	46,186,598

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Bacungan floodplain is shown in Figure 17. A total of 896 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 531.87 meters and 31.32 meters respectively.

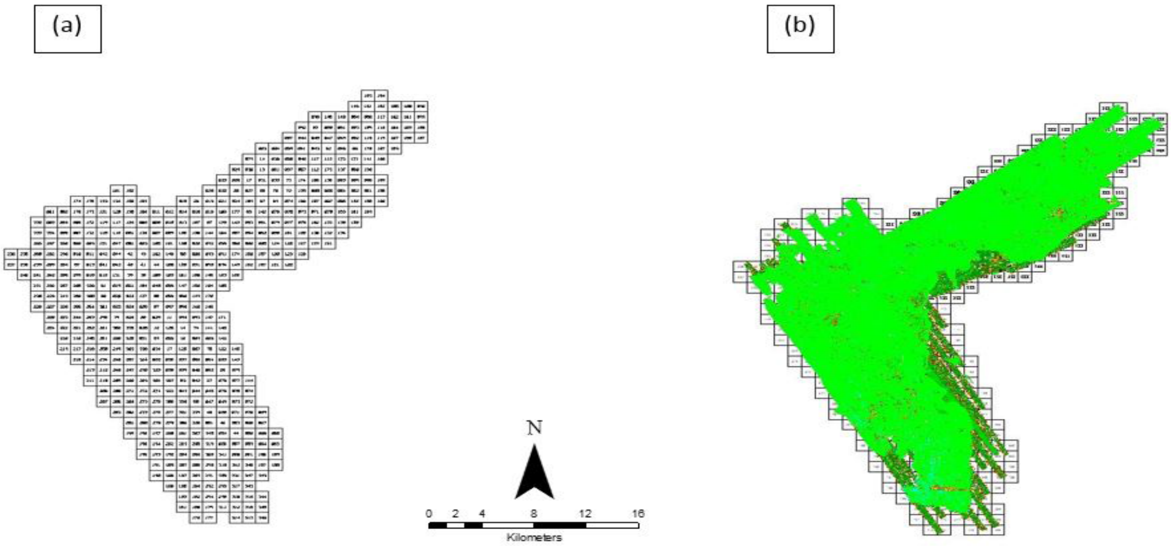

Figure 17. Tiles for Bacungan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

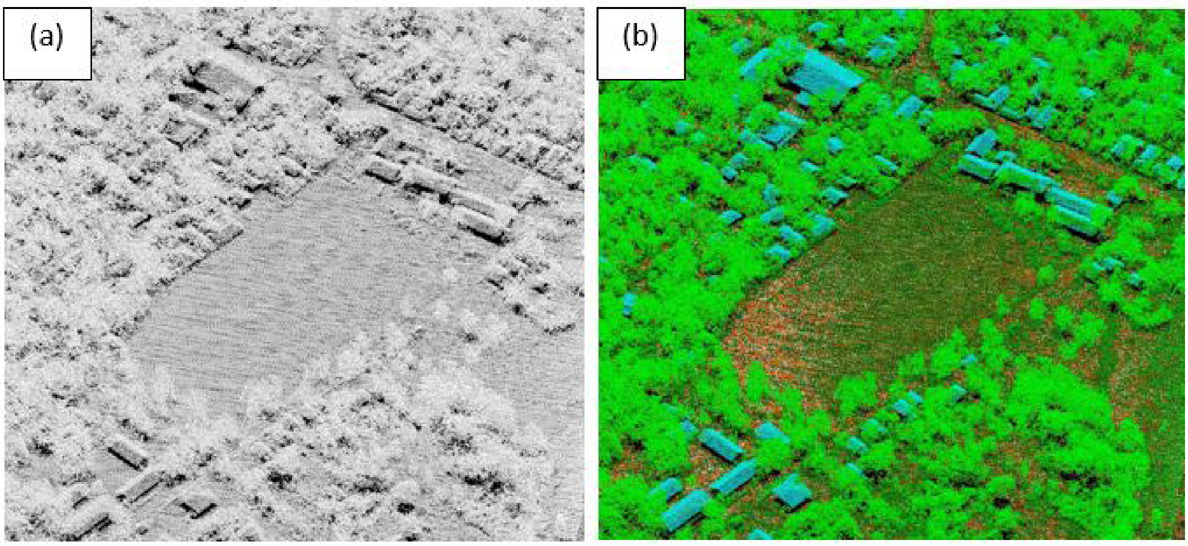

Figure 18. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

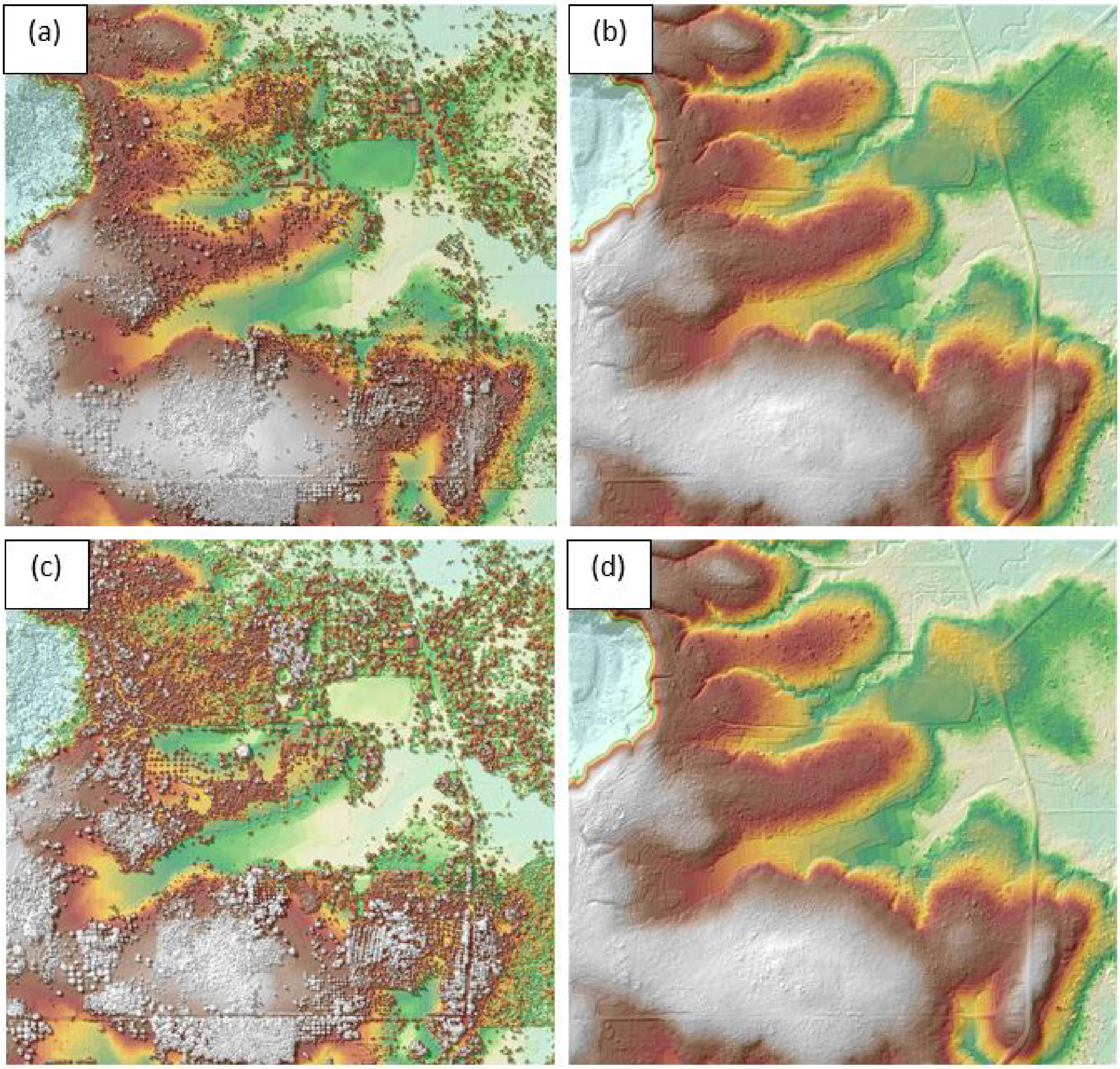

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Bacungan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 861 1km by 1km tiles area covered by Bacungan floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Bacungan floodplain has a total of 427 sq.km orthophotogaph coverage comprised of 2,118 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

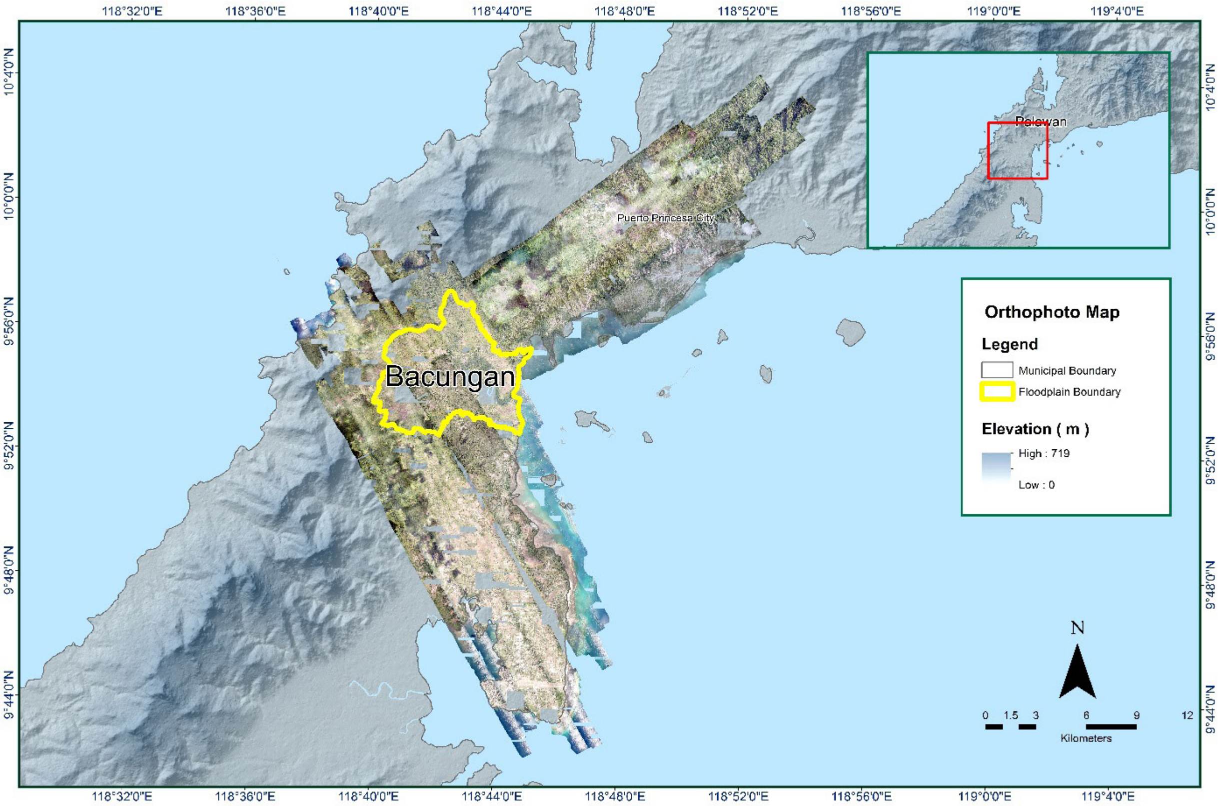

Figure 20. Bacungan Floodplain with available orthophotographs

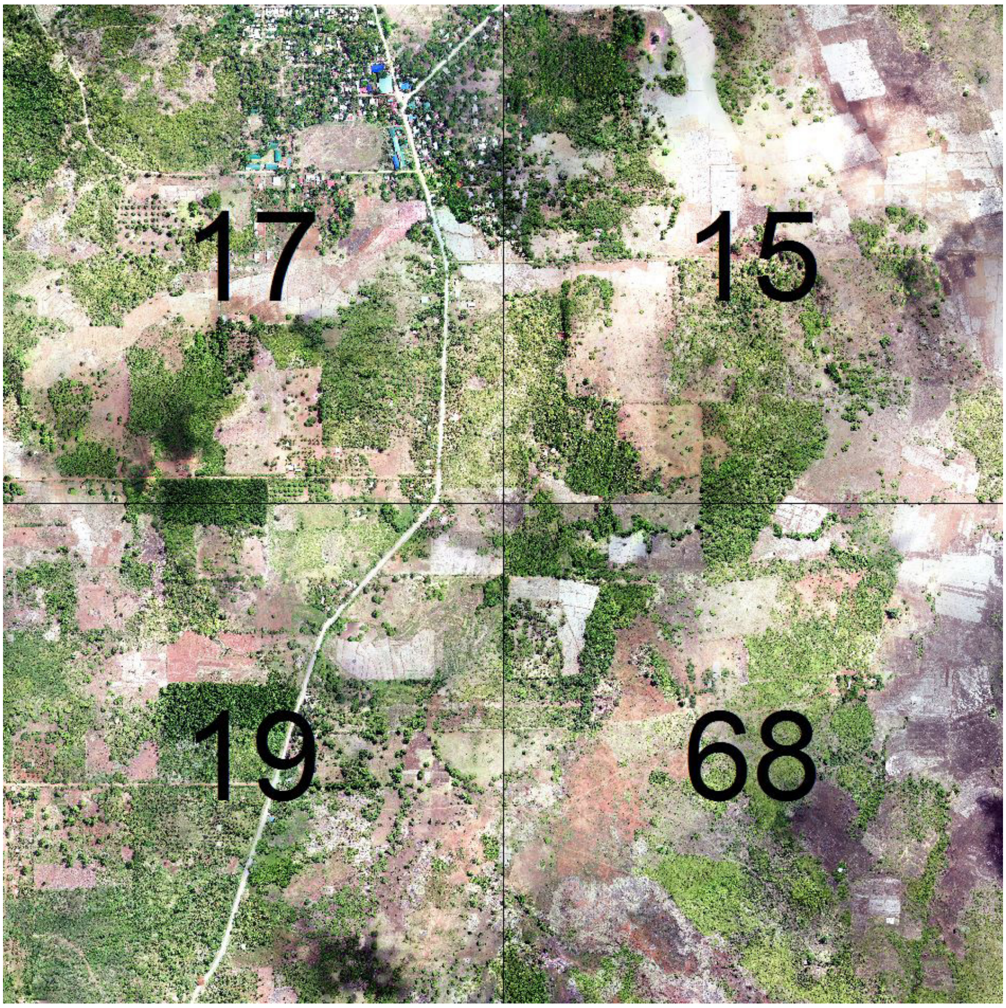

Figure 21. Sample orthophotograph tiles for Bacungan Floodplain

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Bacungan flood plain. These blocks are composed of Palawan blocks with a total area of 628.83 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42B	142.16
Palawan_Blk42B_additional	53.32
Palawan_Blk42B_supplement	115.88
Palawan_Blk42E	269.36
Palawan_Blk42E_additional2	48.11
TOTAL	**628.83 sq.km**

Portions of DTM before and after manual editing are shown in Figure 22. The bridge (Figure 22a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22b) in order to hydrologically correct the river. A part of the profile of the waterway (Figure 22c) was elevated and has to be interpolated (Figure 22d) to allow the correct flow of water.

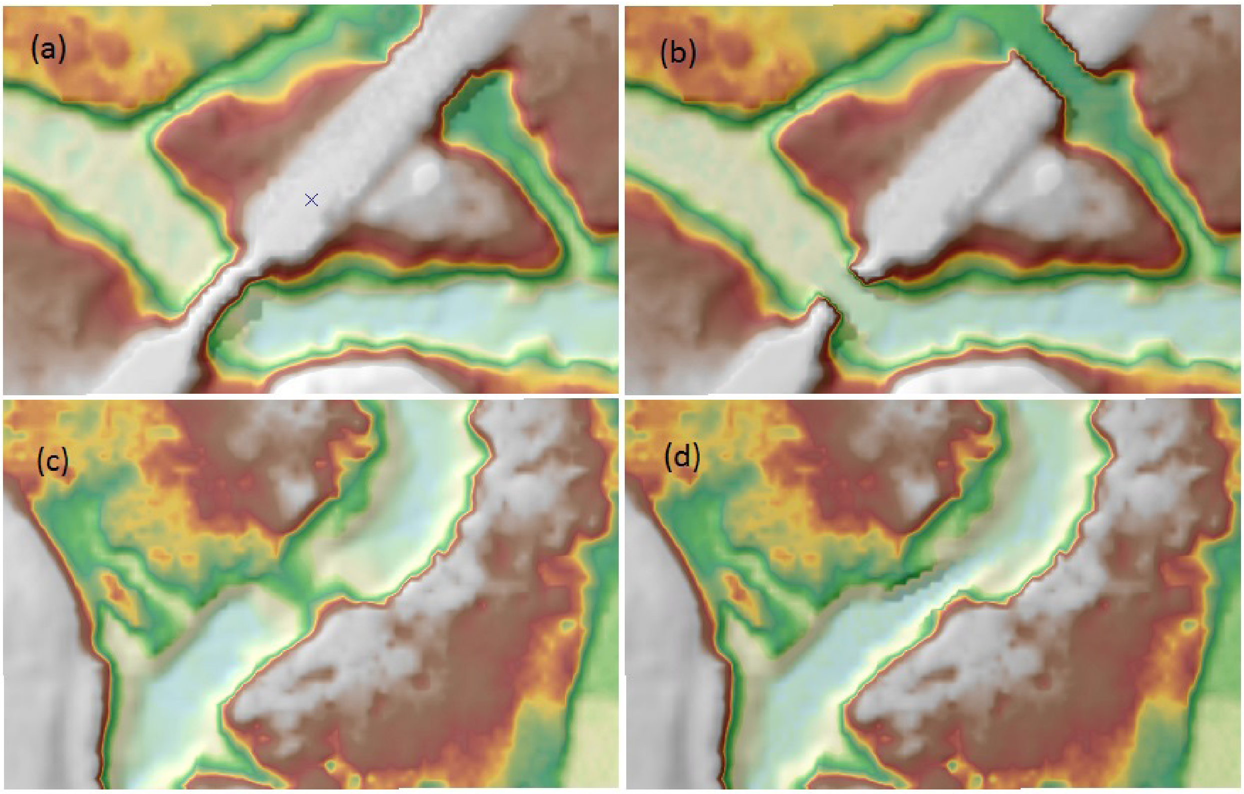

Figure 22. Portions in the DTM of Bacungan Floodplain – a bridge before (a) and after (b) manual editing; and an elevated area in the waterway before (c) and after (d) interpolation.

3.9 Mosaicking of Blocks

Palawan_Blk42Aa was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. Upon inspection of the blocks mosaicked for the Bacungan floodplain, it was concluded that the elevation of two blocks are in need to be adjusted before mosaicking the DTM. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Bacungan floodplain is shown in Figure 23. It can be seen that the entire Bacungan floodplain is 100% covered by LiDAR data.

Table 16. Shift values of each LiDAR block of Bacungan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42B	0.00	0.00	0.00
Palawan_Blk42B_additional	0.00	0.00	0.00
Palawan_Blk42B_supplement	0.00	0.00	0.00
Palawan_Blk42E	0.00	0.00	-0.13
Palawan_Blk42E_additional2	0.00	0.00	0.27

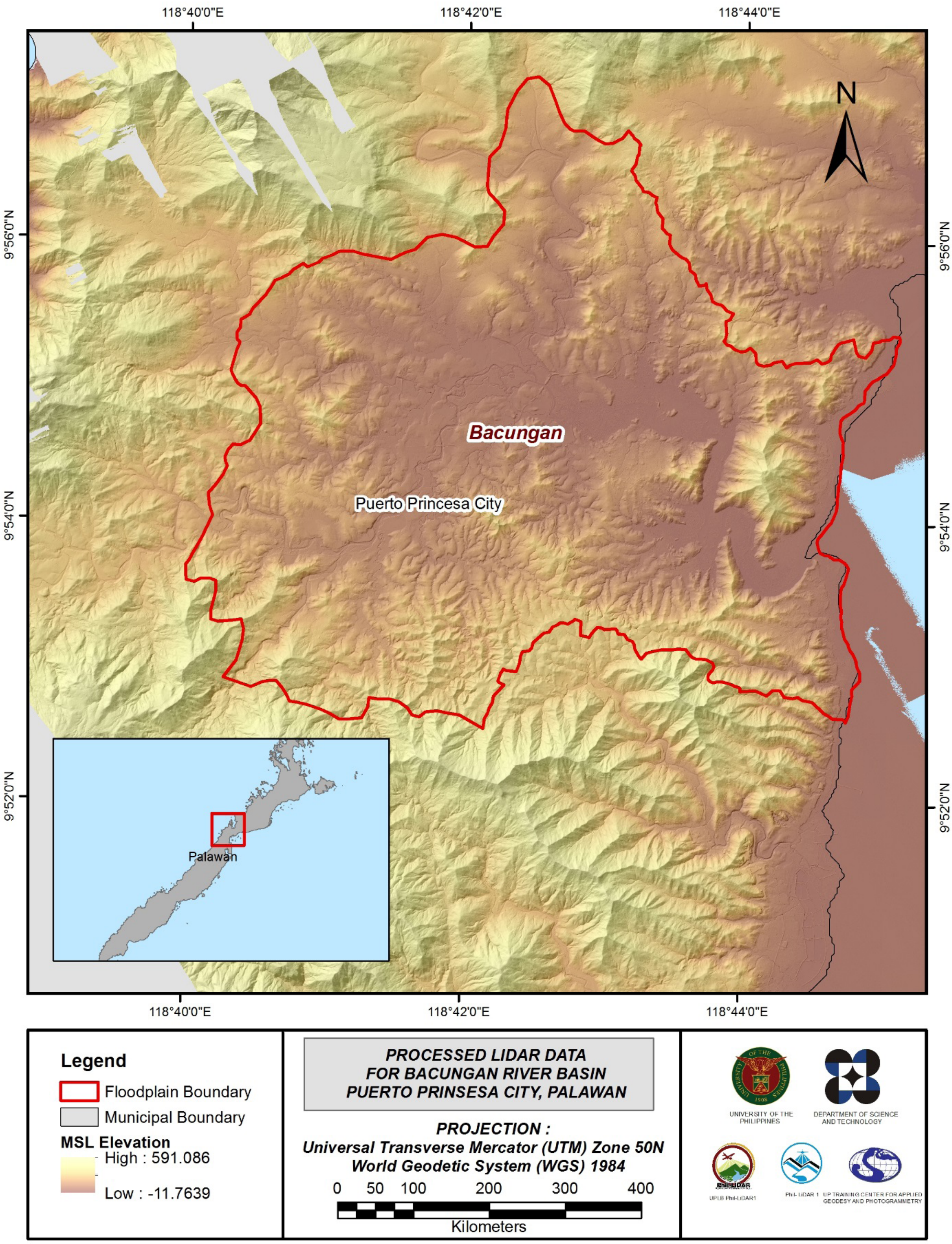

Figure 23. Map of Processed LiDAR Data for Bacungan Floodplain

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

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Bacungan to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 936 survey points were used for calibration and validation of Bacungan LiDAR data. Random selection of 80% of the survey points, resulting to 749 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 25. 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 0.20 meters with a standard deviation of 0.20 meters. Calibration of Bacungan LiDAR data was done by subtracting the height difference value, 0.20 meters, to Bacungan mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

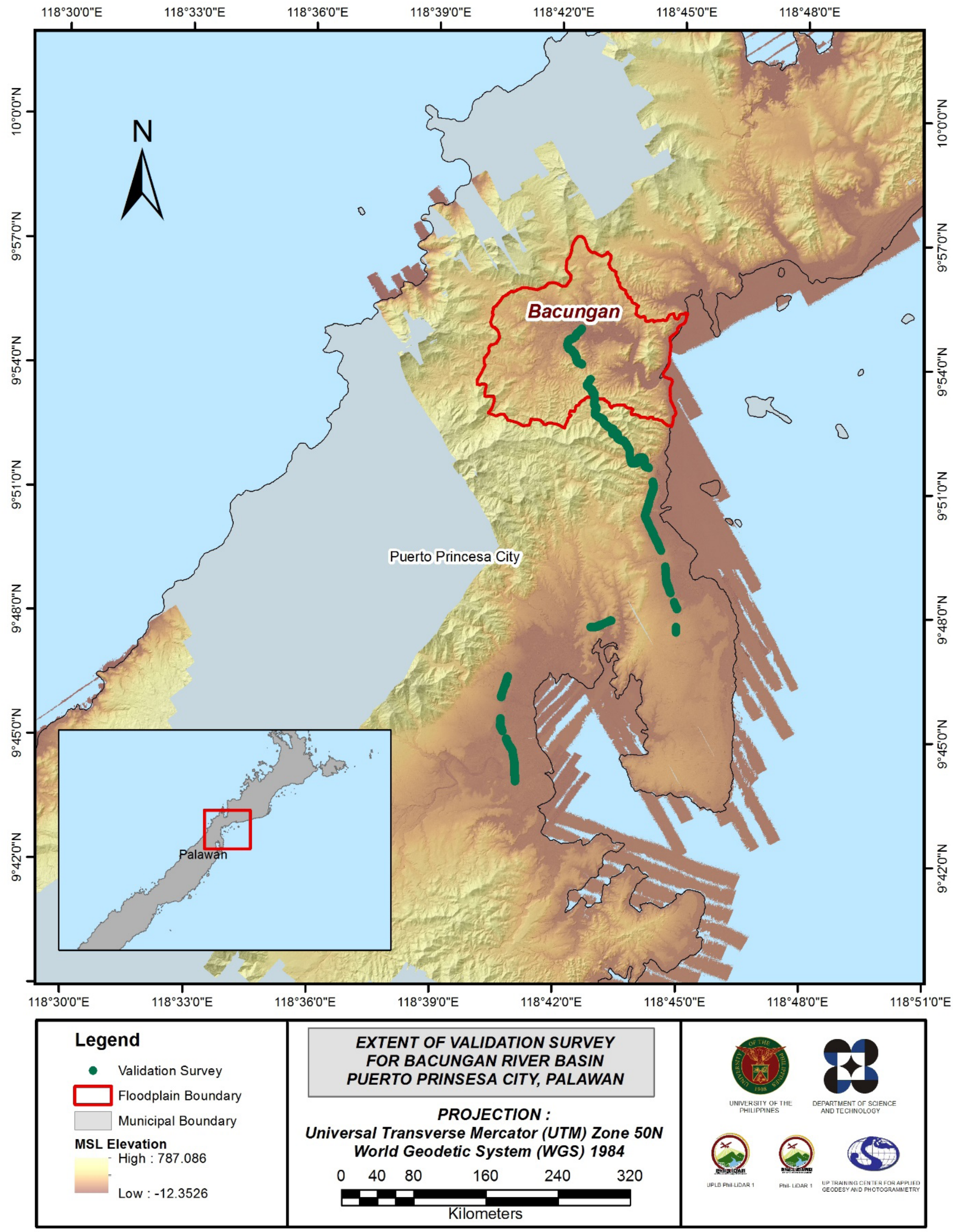

Figure 24. Map of Bacungan Floodplain with validation survey points in green.

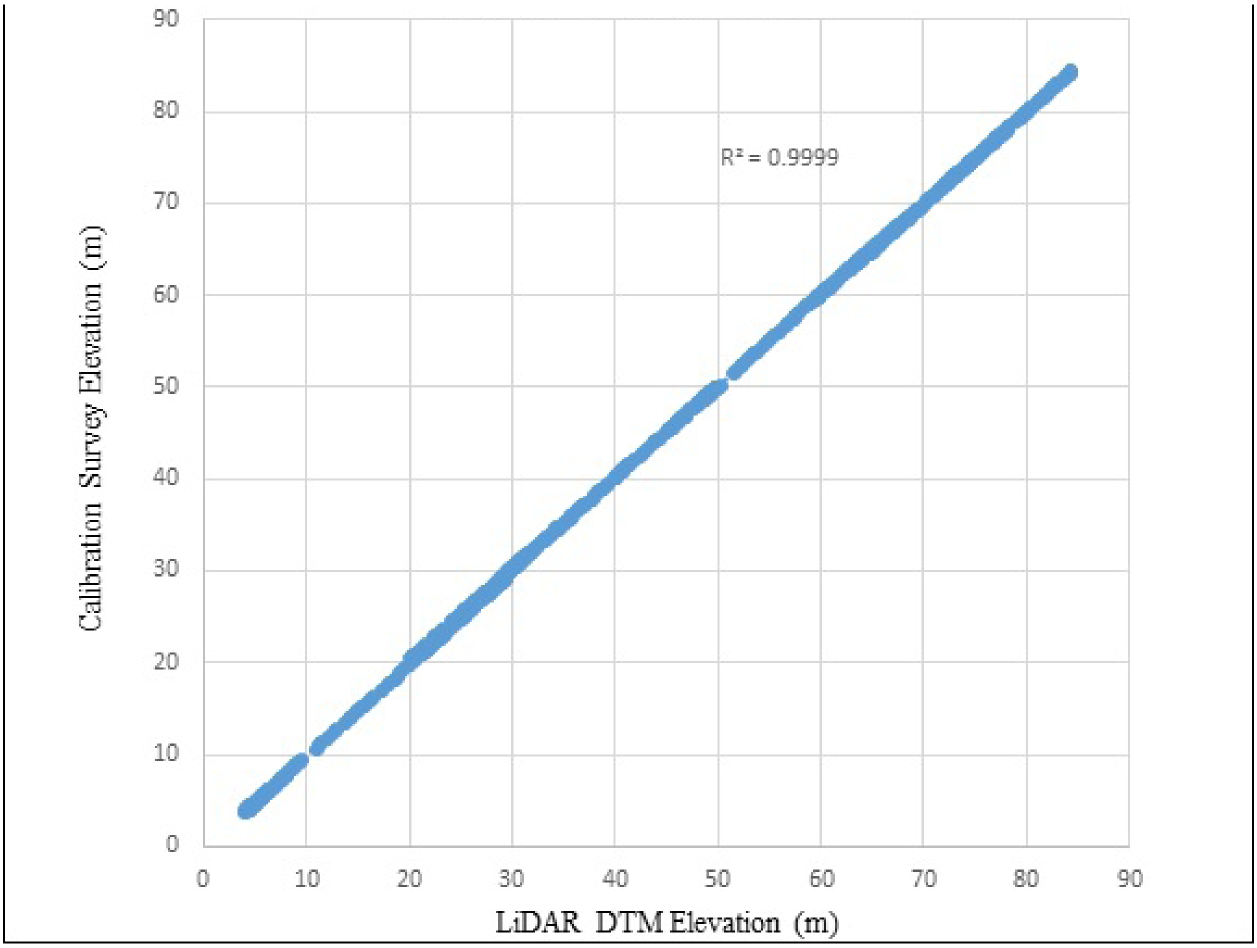

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.20
Standard Deviation	0.20
Average	-0.002
Minimum	-0.40
Maximum	0.40

The remaining 20% of the total survey points, resulting to 187 points, were used for the validation of calibrated Bacungan 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.20 meters, as shown in Table 17.

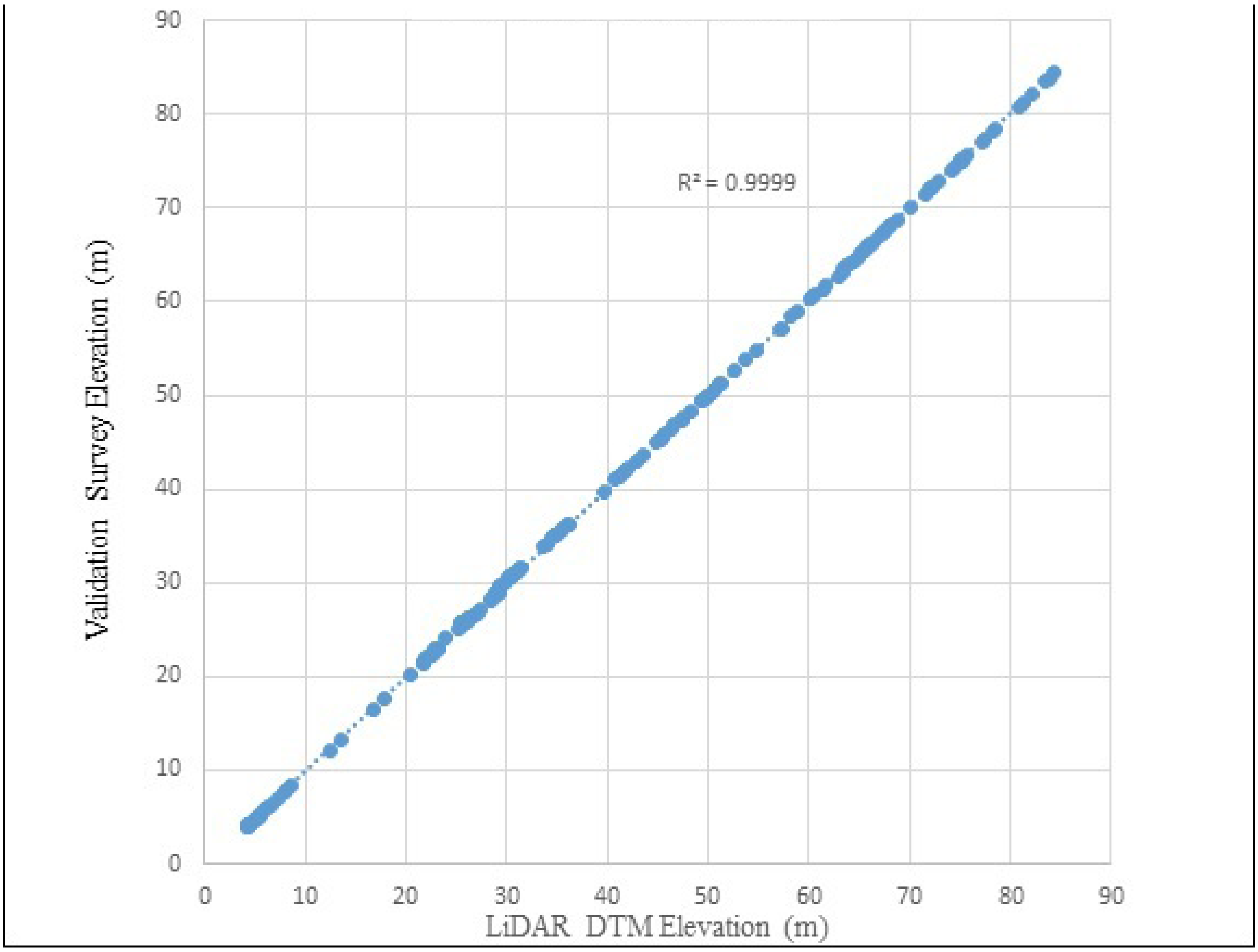

Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.20
Average	-0.0006
Minimum	-0.40
Maximum	0.40

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathymetric data integration, centerline and zigzag data were available for Bacungan with a total of 7,534 survey points and 2,431 points, respectively. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.47 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bacungan integrated with the processed LiDAR DEM is shown in Figure 27.

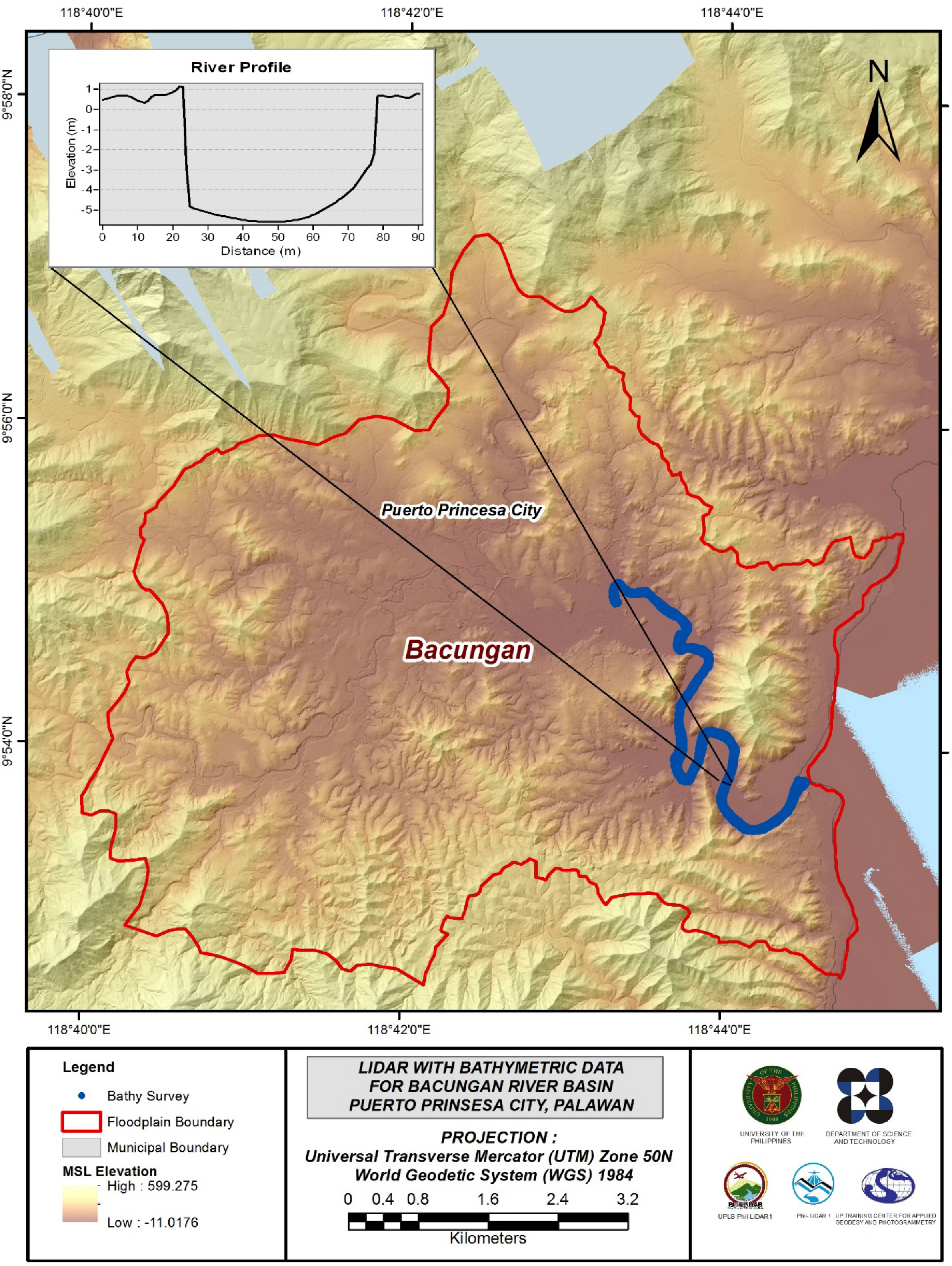

Figure 27. Map of Bacungan Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

AB Surveying and Development (ABSD) conducted a field survey in Bacungan River on November 26 and 30, 2015 and December 13, 2015 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Bacungan Bridge in Brgy. Bacungan, City of Puerto Princesa, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on August 27, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Bacungan River Basin area. The entire survey extent is illustrated in Figure 28.

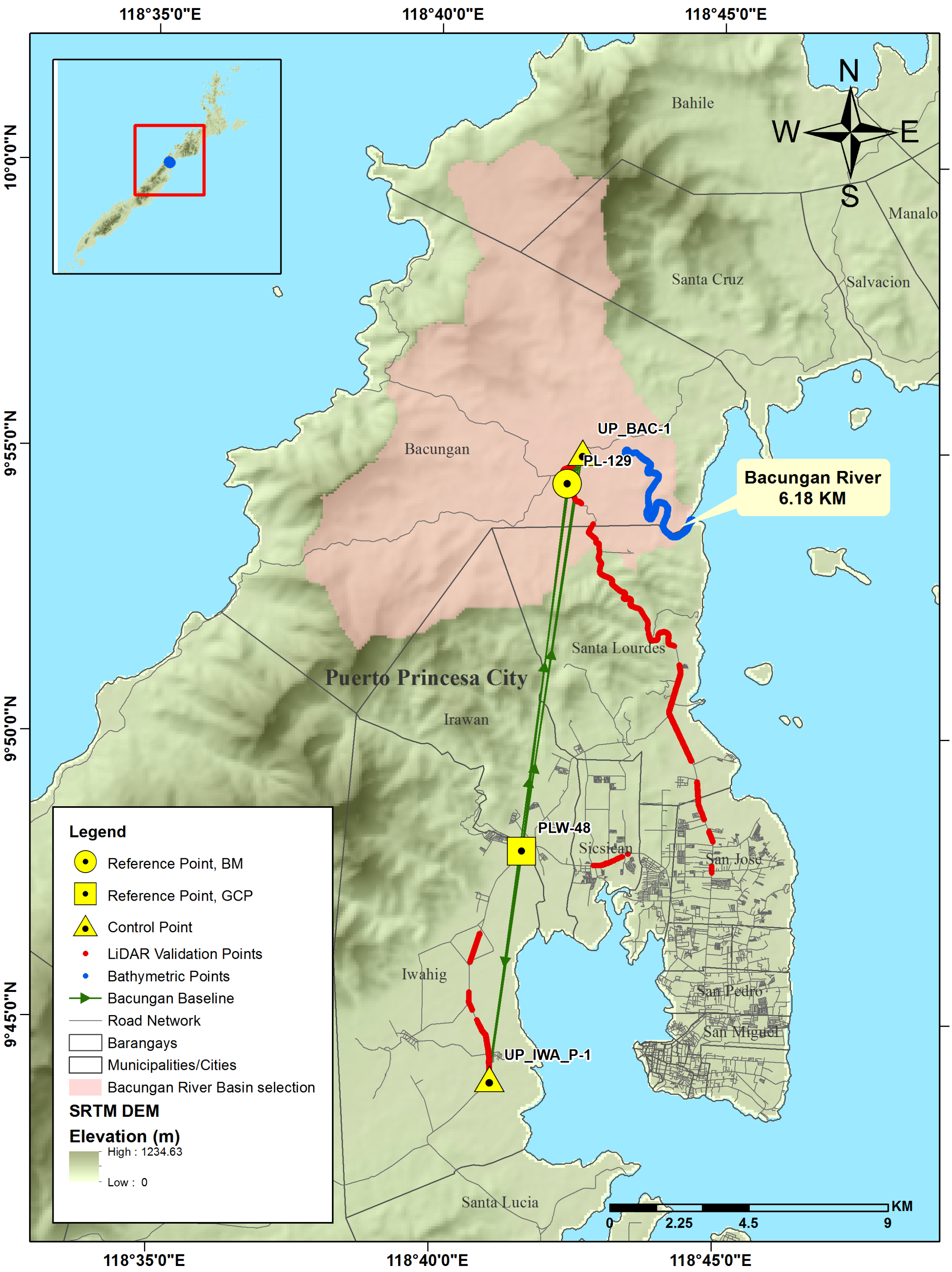


Figure 28. Extent of the bathymetric survey (in blue line) in Bacungan River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Bacungan River is composed of two (2) loops established on August 17, 2016 occupying the following reference points: PL-129, a first-order BM, in Brgy. Bacungan, Puerto Princesa City, Palawan; and PLW-48 a second-order GCP, in Brgy. Irawan, Puerto Princesa City, Palawan.

Two (2) control points established in the area by ABSD were also occupied: UP_BAC-1 at the approach of Bacungan Bridge in Brgy. Bacungan, Puerto Princesa City, Province of Palawan, and UP_IWA_P-1 located at the approach of Iwahig Penal Bridge in Brgy. Sta. Lucia, Puerto Princesa City, Palawan.

The summary of reference and control points and its location is summarized in Table 19 while GNSS network established is illustrated in Figure 29.

Table 19. List of Reference and Control Points occupied for Bacungan 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
PL-129	1st order, BM	9°54'24.25188 "N	118° 42' 18.11271"E	73.514	23.250	2008
PLW-48	2nd order, GCP	9°47' 58.27463"N	118° 41' 34.71781 "E	60.461	10.020	2004
UP_BAC-1	Established	9°16' 52.29568"N	118° 4' 23.41753"E	56.886	6.629	12-13-15
UP_IWA_P-1	Established	9°12' 21.10428"N	117° 56' 55.87963"E	55.531	5.046	11-25-15

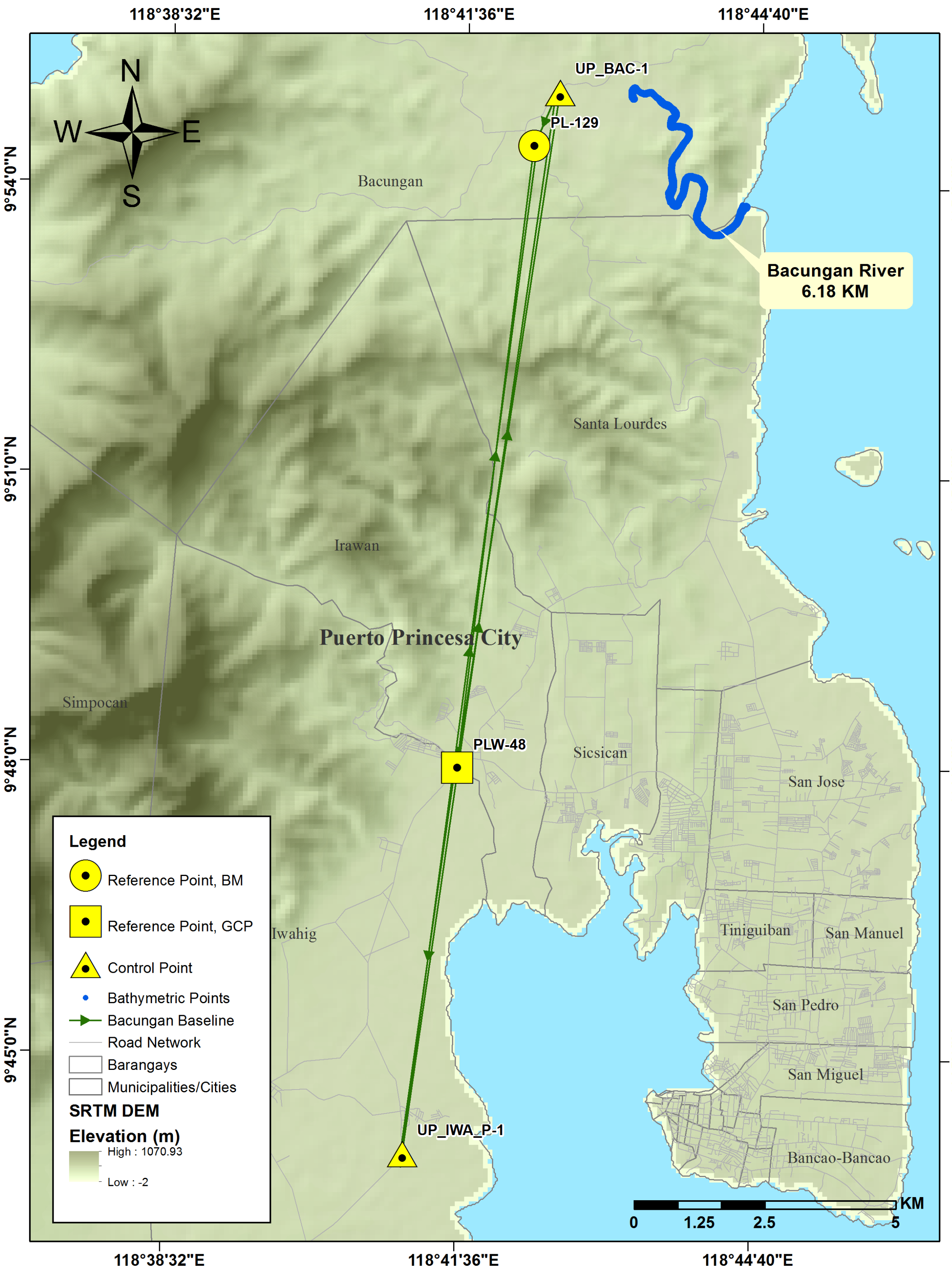


Figure 29. The GNSS Network established in the Bacungan River Survey.

The GNSS set-ups on recovered reference points and established control points in Bacungan River are shown from Figure 30 to Figure 33.

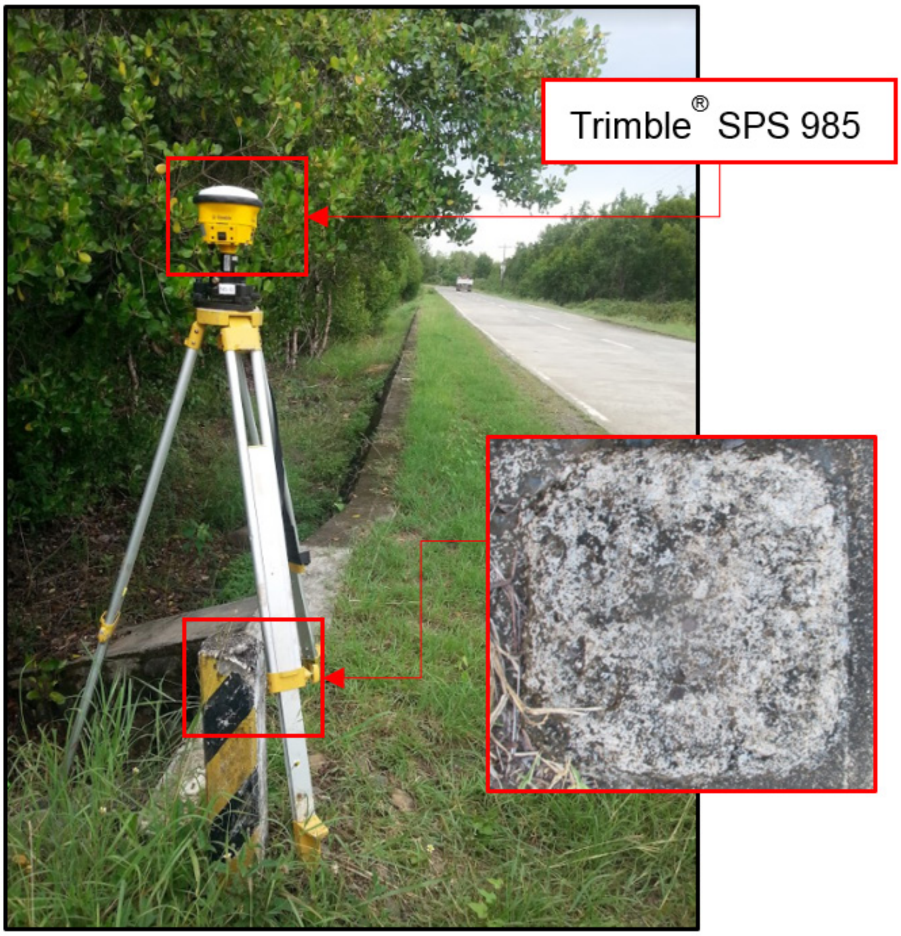


Figure 30. GNSS receiver set up, Trimble® SPS 882, at PL- 129, located along the National Highway. It is situated at the top of a concrete canal in Brgy. Sta. Lourdes, Puerto Princesa City, Palawan

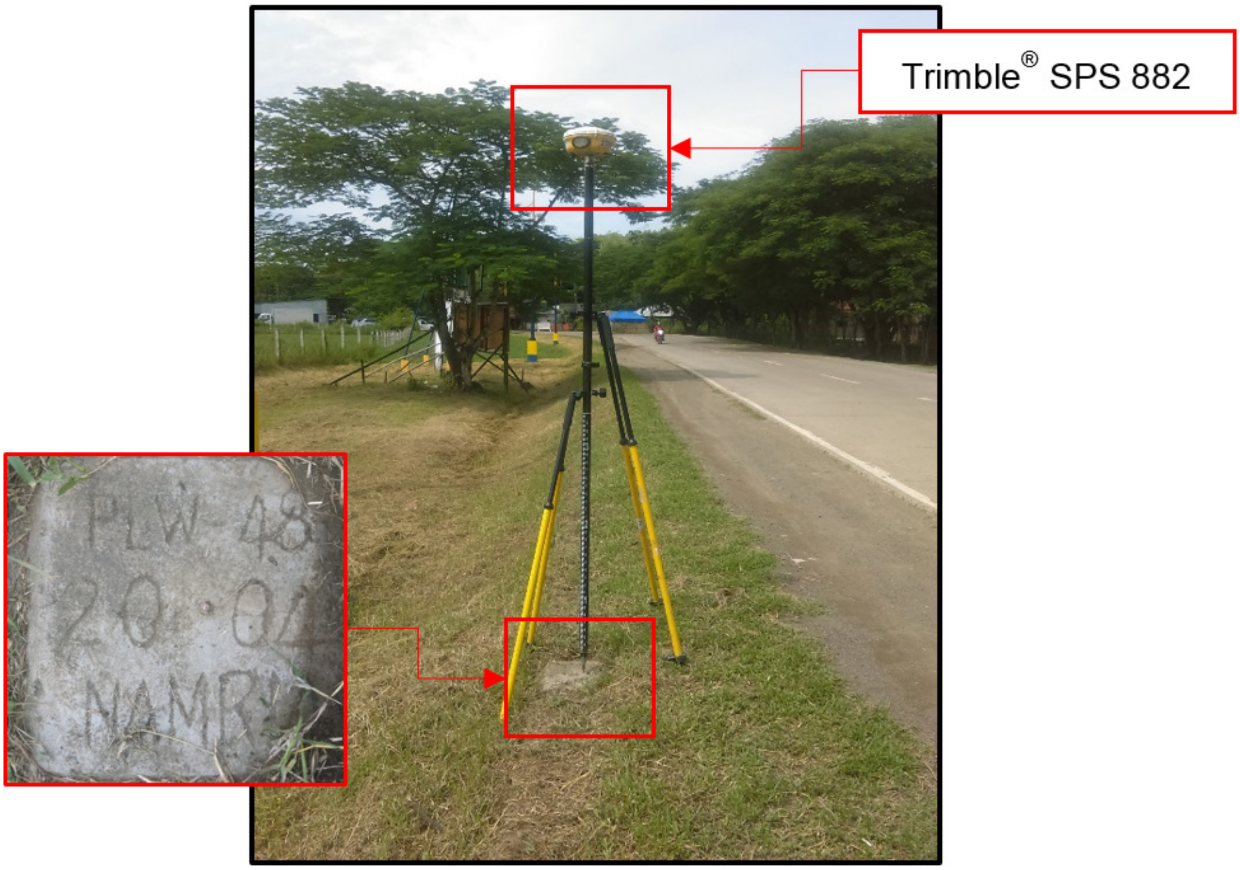


Figure 31. GNSS base set up, Trimble® SPS 882, at PLW-48, located at approximately 20 meters southwest from the gate of the Crocodile Farm in Brgy. Irawan, Puerto Princes City, Palawan. It is situated at approximately 5 meters west from the centerline of the highway

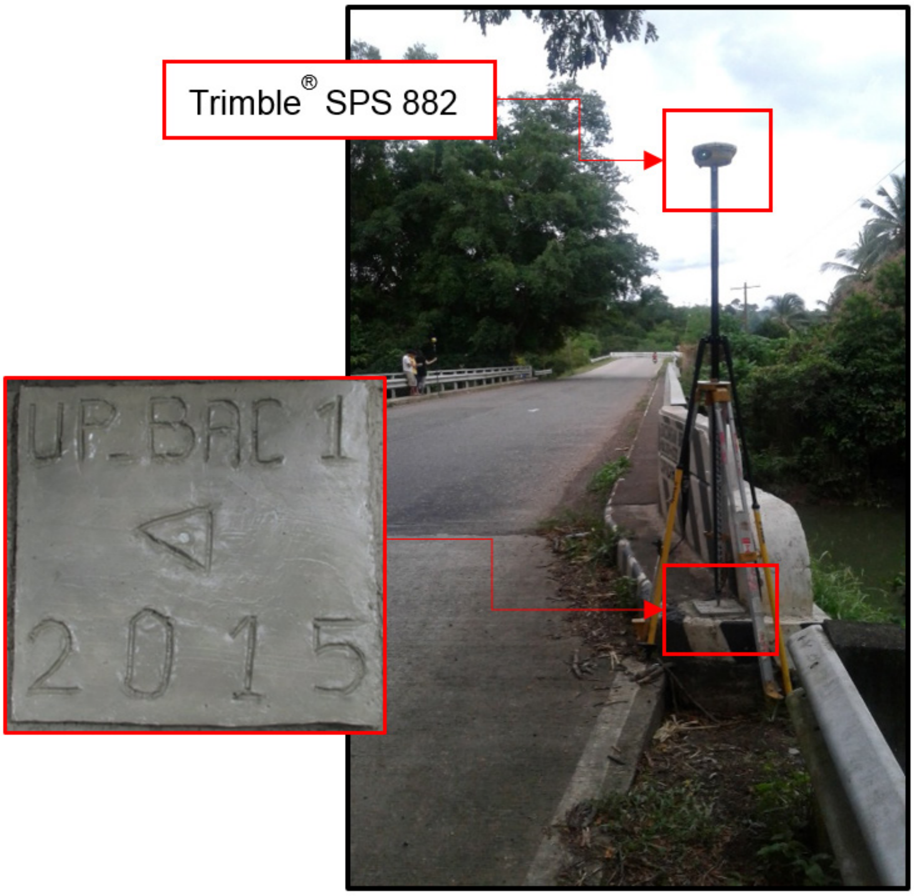


Figure 32. GNSS receiver set up, Trimble® SPS 985, at UP_BAC -1, located at the approach of Bacungan Bridge in Brgy. Bacungan, Quezon, Province of Palawan

Figure 33. GNSS receiver set up, Trimble® SPS 985, at UP_IWA_P-1, located on the approach of Iwahig Penal Bridge in Brgy. Sta. Lucia, Puerto Princesa City, Province of Palawan

4.3 Baseline Processing

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

Table 20. Baseline Processing Summary Report for Bacungan River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_IWA_P-1 --- PLW-48	9-16-2016	Fixed	0.004	0.021	187°20'14"	7431.037	-4.940
PLW-48 --- PL-129	9-16-2016	Fixed	0.004	0.022	6°21'39"	11935.262	13.077
PLW-48 --- UP_BAC-1	9-16-2016	Fixed	0.007	0.030	7°57'33"	13005.661	-3.587
UP_IWA_P-1 --- PL-129	9-16-2016	Fixed	0.003	0.024	6°44'03"	19362.644	18.001
UP_IWA_P-1 --- UP_BAC-1	8-17-2016	Fixed	0.006	0.040	7°43'53"	20436.423	1.310
UP_BAC-1 --- PL-129	8-17-2016	Fixed	0.004	0.006	205°07'03"	1128.235	16.626

As shown Table 20 a total of six (6) baselines were processed with coordinate and ellipsoidal height values of PLW- 48 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 21 to Table 23 for complete details.

The four (4) control points, PLW-48, PL-129, UP-BAC-1, and UP_IWA_P-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of PLW- 48 were held fixed during the processing of the control points as presented in Table 21. Through this reference point, the coordinates and ellipsoidal height of the unknown control points will be computed.

Table 21. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PLW-48	Global	Fixed	Fixed	FIxed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. All fixed control points have no values for grid errors and elevation error.

Table 22. Adjusted grid coordinates for the control points used in the Bacungan River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PL-129	686942.946	0.005	1095579.647	0.004	24.633	0.033	
PLW-48	685680.922	?	1083713.936	?	11.401	?	LLh
UP_BAC-1	687416.613	0.006	1096603.679	0.004	8.012	0.034	
UP_IWA_P-1	684768.852	0.005	1076338.886	0.004	6.427	0.036	

With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$ for horizontal and z_e<10 cm for the vertical; the computation for the accuracy are as follows:

a. **PL- 129**

horizontal accuracy	=	$\sqrt{((0.5)^2 + (0.4)^2}$
	=	$\sqrt{(0.25 + 0.16)}$
	=	0.41 < 20 cm
vertical accuracy	=	3.3 < 10 cm

b. **PLW- 48**

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

c. **UP_BAC-1**

horizontal accuracy	=	$\sqrt{((0.6)^2 + (0.4)^2}$
	=	$\sqrt{(0.36 + 0.16)}$
	=	0.52 < 20 cm
vertical accuracy	=	3.4 < 10 cm

d. **UP_IWA_P-1**

horizontal accuracy	=	$\sqrt{((0.5)^2 + (0.4)^2}$
	=	$\sqrt{(0.25 + 0.16)}$
	=	0.41 < 20 cm
vertical accuracy	=	3.6 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 23. Adjusted geodetic coordinates for control points used in the Bacungan River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
PL-129	N9°54'24.25168"	E118°42'18.11269"	74.898	0.033	
PLW-48	N9°47'58.27463"	E118°41'34.71781"	61.842	?	LLh
UP_BAC-1	N9°54'57.50085"	E118°42'33.83304"	58.270	0.034	
UP_IWA_P-1	N9°43'58.38961"	E118°41'03.58218"	56.912	0.036	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 23. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 24.

The summary of reference control points used is indicated in Table 24.

Table 24. The reference and control points utilized in the Bacungan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zome 50N)					
		Latitude	Longitude	Ellips-oidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
PL-129	1st order, BM	9°54'24.25168"N	118°42'18.11269"E	60.461	1083713.936	685680.922	10.020
PLW-48	2nd order, GCP	9°47'58.27463"N	118°41'34.71781"E	73.514	1095579.653	686942.946	23.250
UP_BAC-1	Established	9°54'57.50085"N	118°42'33.83304"E	56.886	1096603.686	687416.614	6.629
UP_IWA_P-1	Established	9°43'58.38961"N	118°41'03.58218"E	55.531	1076338.882	684768.851	5.046

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

Cross-section and as-built surveys were conducted on November 26, 2015 at the upstream side of Bacungan Bridge in Brgy. Bacungan, City of Puerto Princesa as shown in Figure 34. Horizon® Total Station was utilized for this survey as shown in Figure 35.

Figure 34. Upstream/downstream side of Bacungan Bridge

Figure 35. As-built survey of Bacungan Bridge

The cross-sectional line of Bacungan Bridge is about 146.125 m with thirty-eight (38) cross-sectional points using the control points UP_BAC-1 and UP_BAC-2 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 36 to Figure 38.

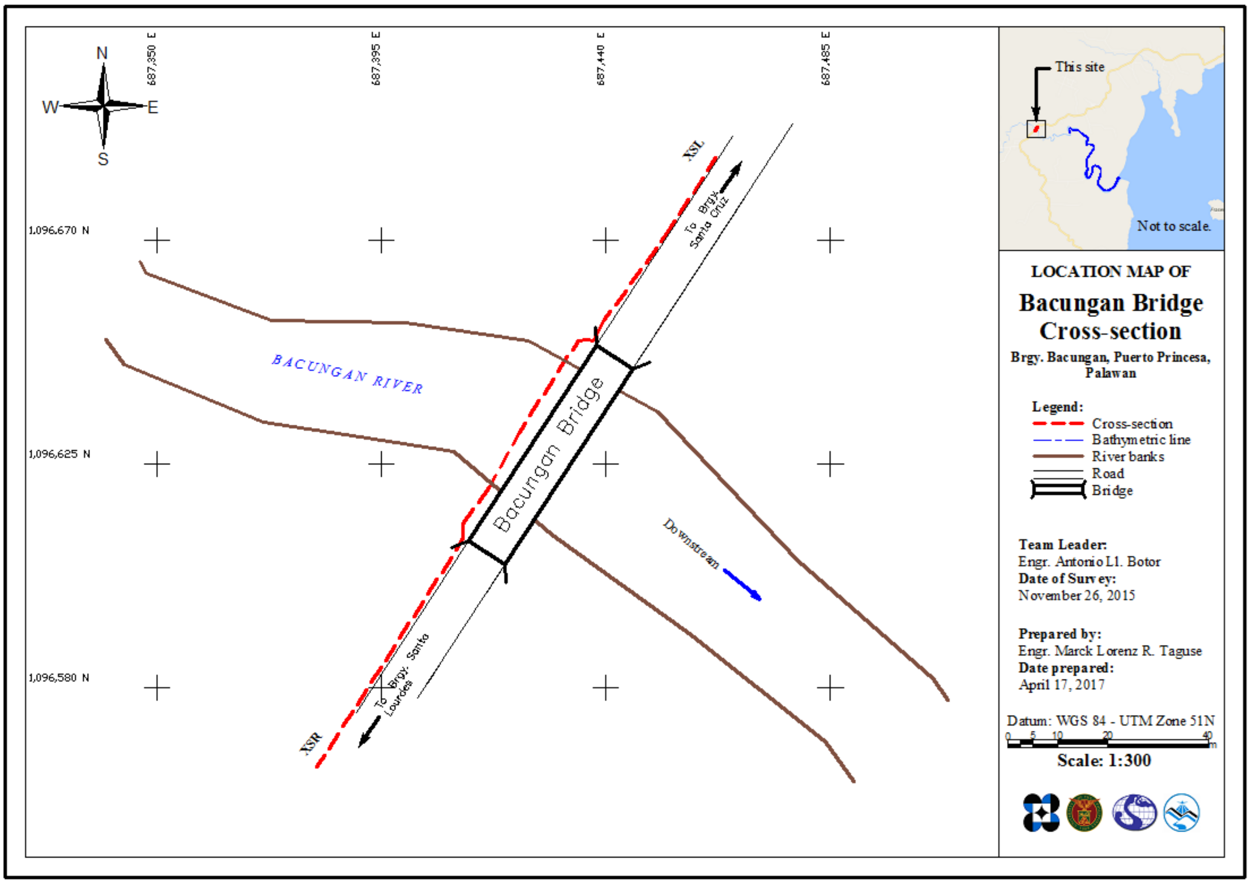


Figure 36. Upstream/downstream side of Bacungan Bridge

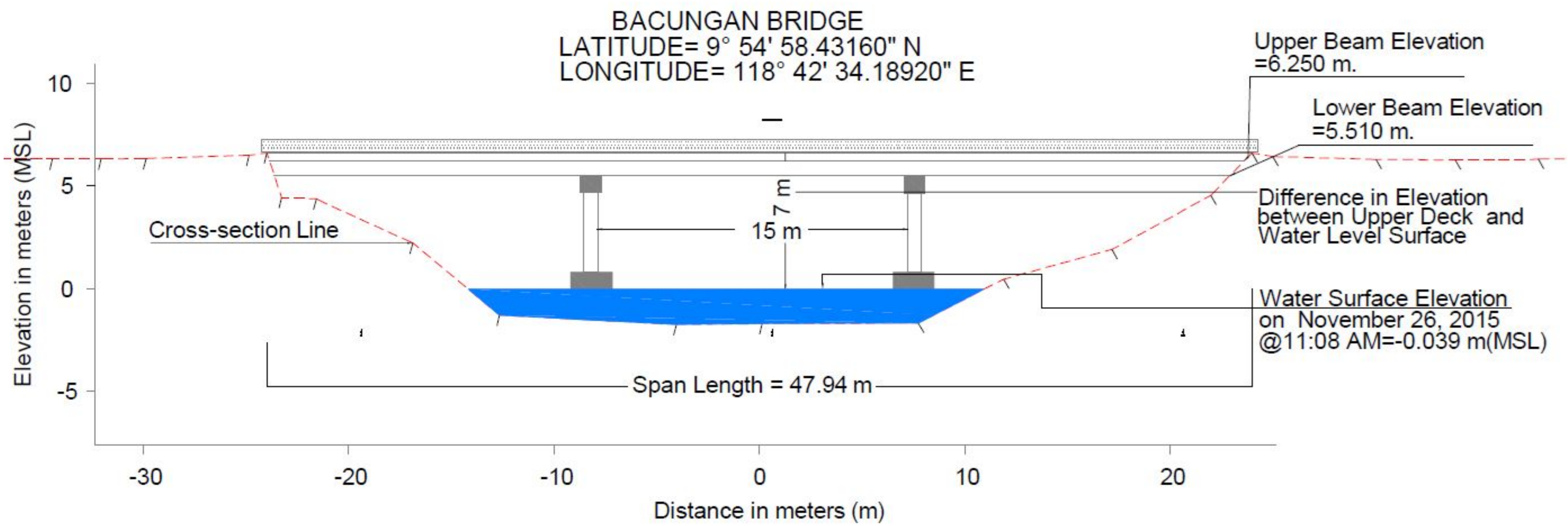


Figure 37. Bacungan Bridge cross-section diagram

Bridge Data Form

Bridge Name: BACUNGAN BRIDGE

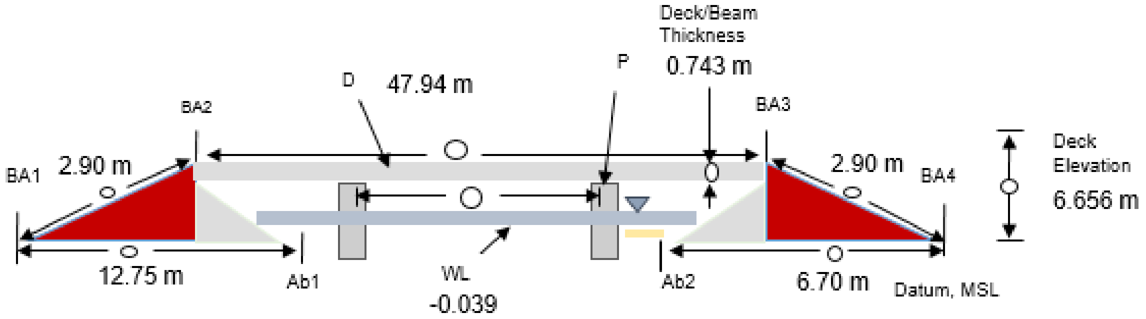
River Name: BACUNGAN RIVER
Location (Brgy, City, Region): Brgy. Bacungan, Puerto Princesa City, Palawan

Survey Team: Leonilo Alpas, Bernard Burcia
Date and Time: November 26, 2015; 11:08 A.M.

Flow Condition: low ✔normal high

Weather Condition: ✔fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	2.90 m	
2. BA2-BA3	47.94 m	
3. BA3-BA4	2.90 m	
4. BA1-Ab1	12.75 m	
5. Ab2-BA4	6.70 m	
6. Deck/beam thickness	0.743 m	
7. Deck elevation	6.656 m	

Note: Observer should be facing downstream

Figure 38. As-built survey of Bacungan Bridge

Water surface elevation of Bacungan River was determined by a Horizon® Total Station on November 26, 2015 at 11:08 AM at Bacungan Bridge area with a value of -0.039 m in MSL as shown in Figure 37. This was translated into marking on the bridge's pier as shown in Figure 39. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Bacungan River, the University of the Philippines Los Baños.

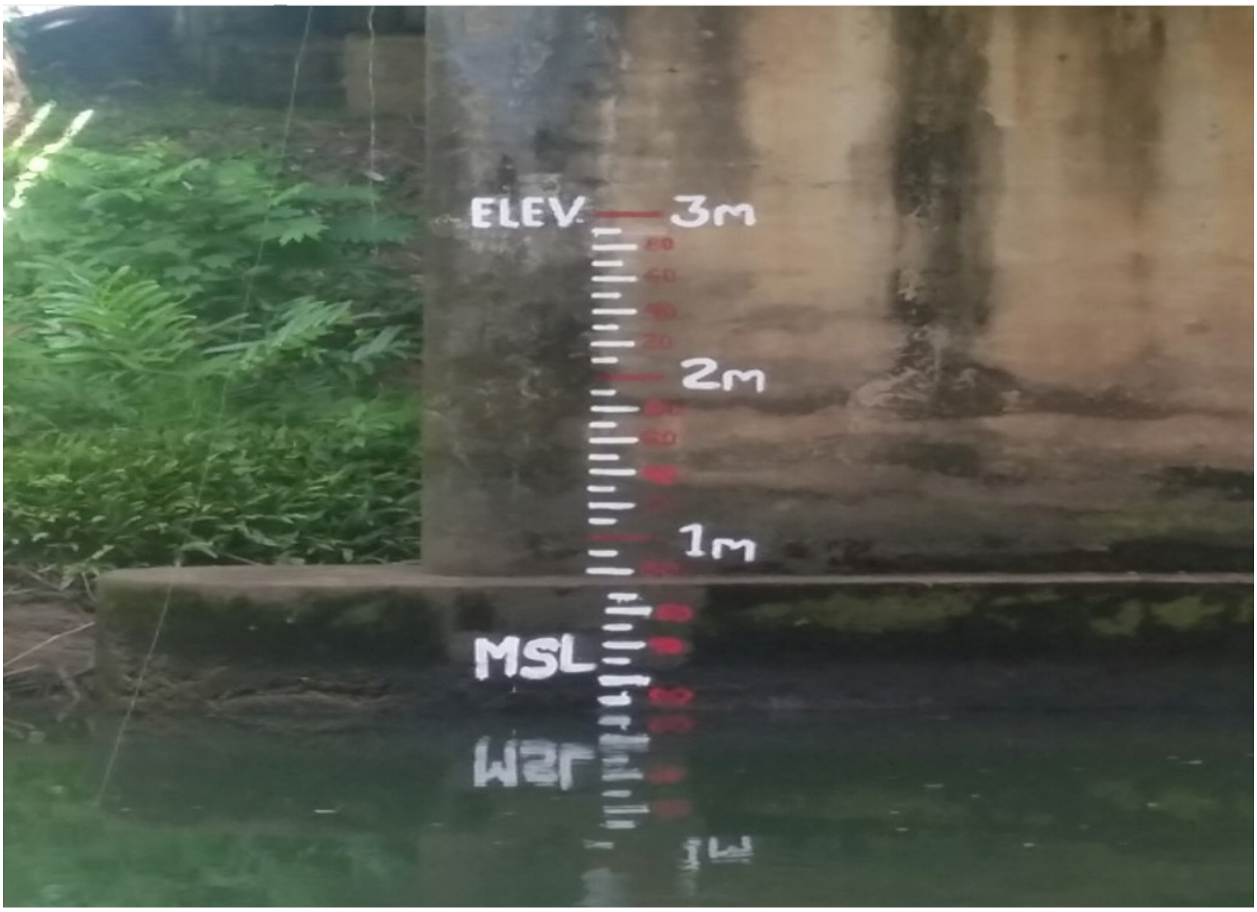


Figure 39. Water level markings on Bacungan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on August 27, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 40. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.560 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with PLW-48 occupied as the GNSS base station in the conduct of the survey.

Figure 40. Validation points acquisition survey set-up for Bacungan River

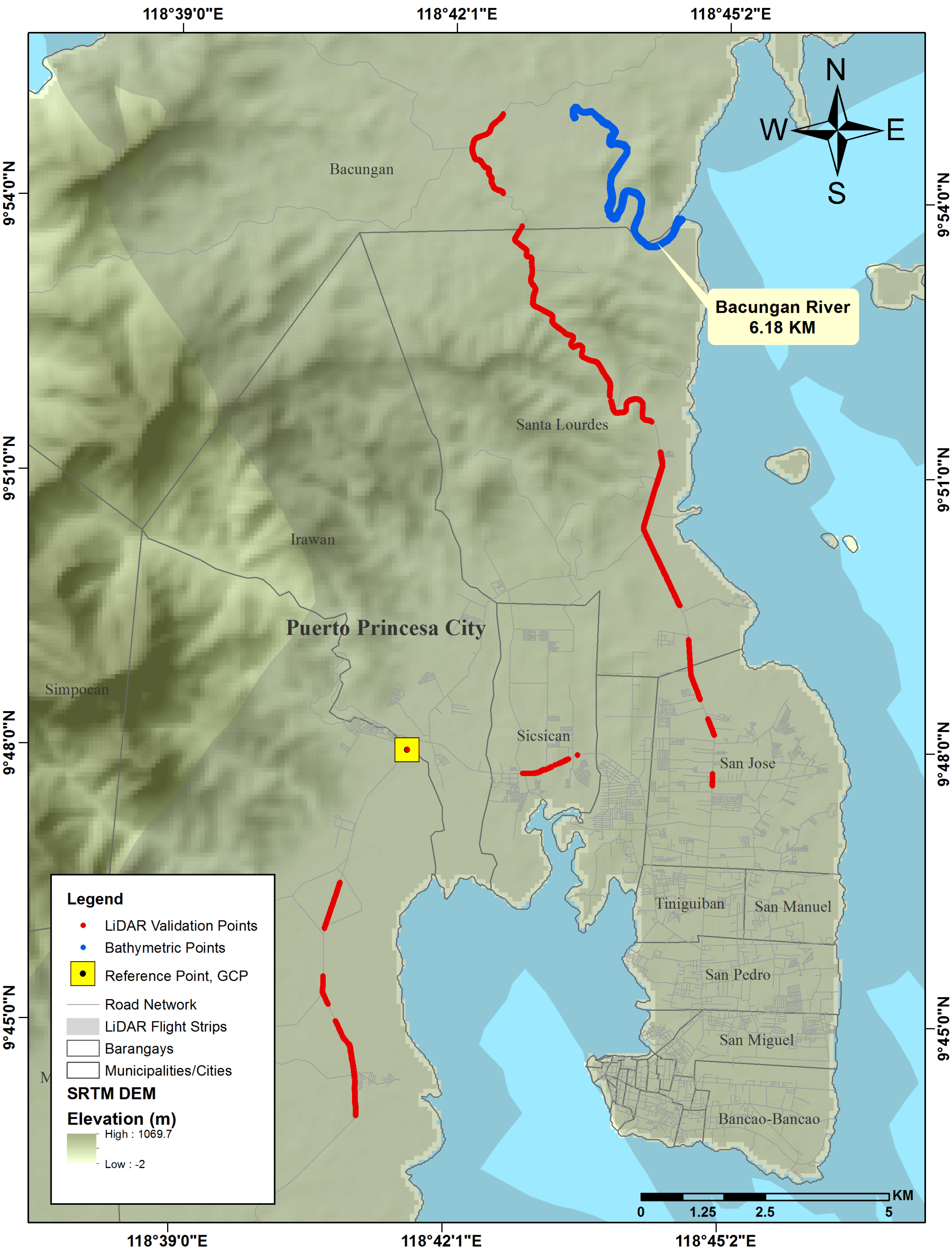


Figure 41. Validation point acquisition survey of Bacungan River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on November 29, 2015 using an echo sounder as illustrated in Figure 42. The survey started in Brgy. Bacungan, City of Puerto Palawan, Palawan with coordinates 9° 53' 48.08750"N, 118° 44' 31.88508"E and ended at the mouth of the river in Brgy. Sta. Lourdes, City of Puerto Princesa as well, with coordinates 9° 54' 54.12490"N, 118° 43' 19.36596"E. The control PLW-4001 was used as GNSS base station all throughout the entire survey.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 27, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique, see Figure 43. A map showing the DVBC bathymetric checking points is shown in Figure 44.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.968 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bathymetric data, a computed value of 0.357 was acquired. The computed R2 and RMSE values are within the accuracy requirement of the program.

Figure 42. Bathymetric survey of ABSD at Bacungan River using Hi-Target™ Echo Sounder

Figure 43. Gathering of random bathymetric points along Bacungan River

The bathymetric survey for Bacungan River gathered a total of 2,616 points covering 6.18 km of the river traversing Brgy. Bacungan in the City of Puerto Princesa. A CAD drawing was also produced to illustrate the riverbed profile of Bacungan River. As shown in Figure 46, the highest and lowest elevation has a 10-m difference. The highest elevation observed was -1.037 m below MSL while the lowest was -10.587 m below MSL located in Brgy. Sta. Lucia, City of Puerto Princesa.

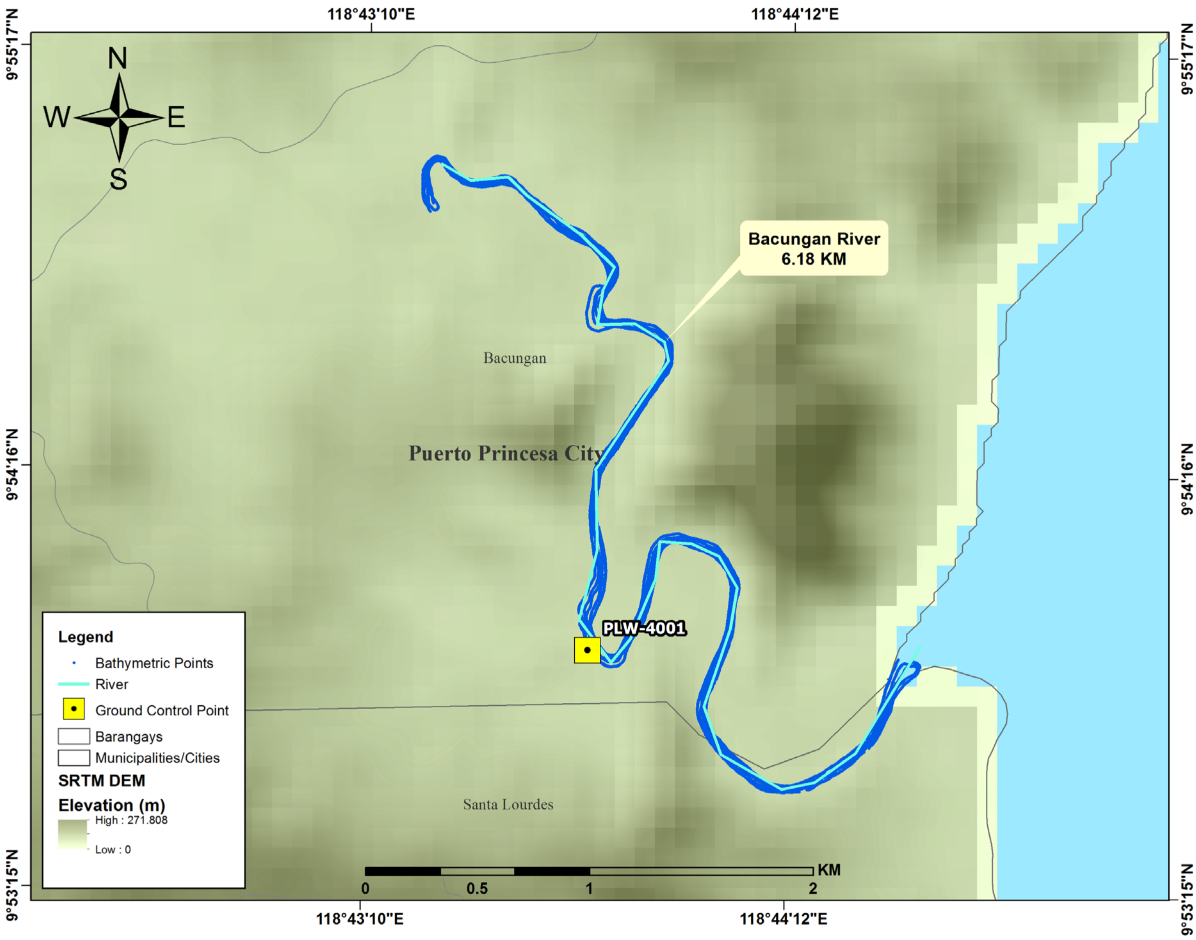


Figure 44. Extent of the Bacungan River Bathymetry Survey

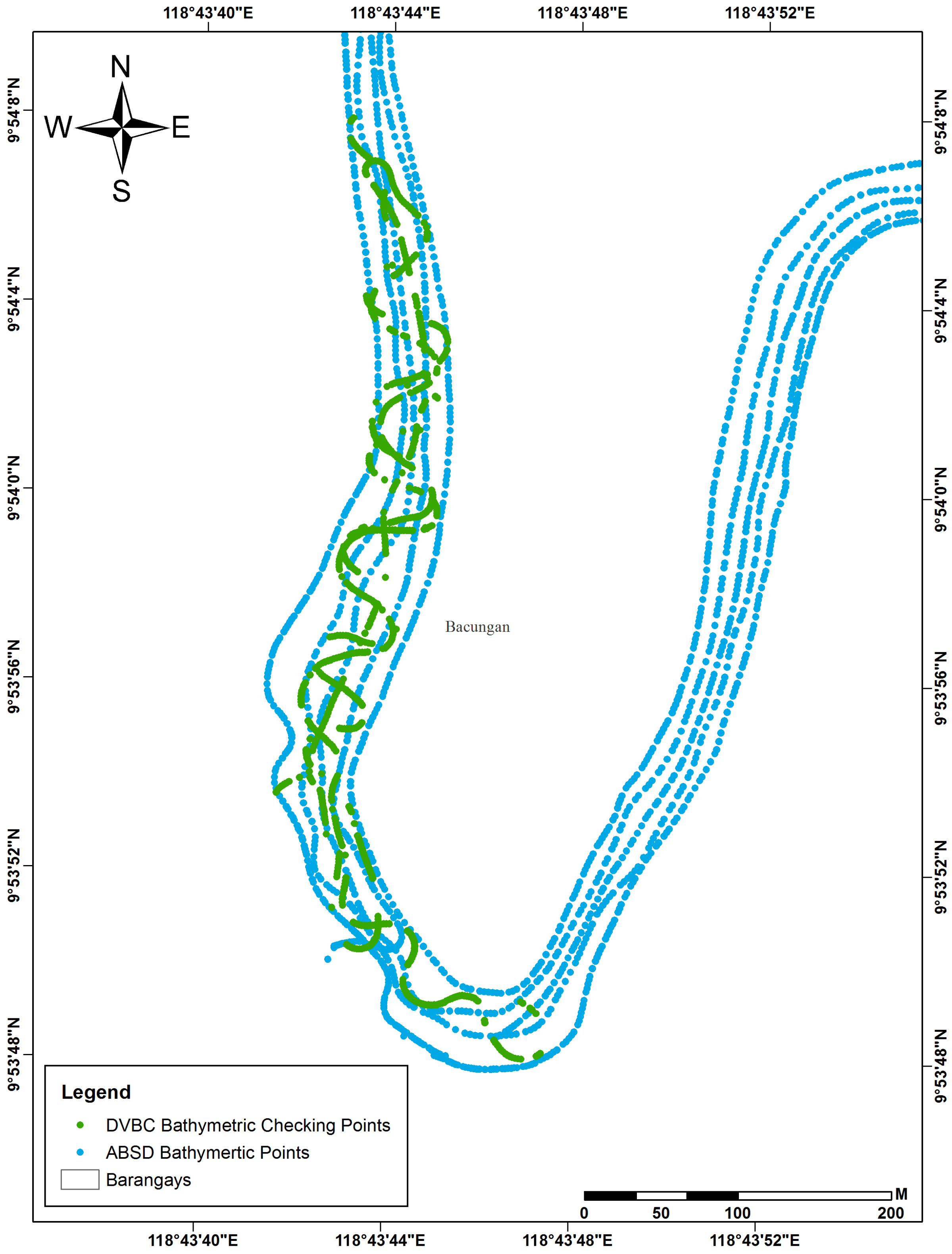


Figure 45. Quality checking points gathered along Bacungan River by DVBC

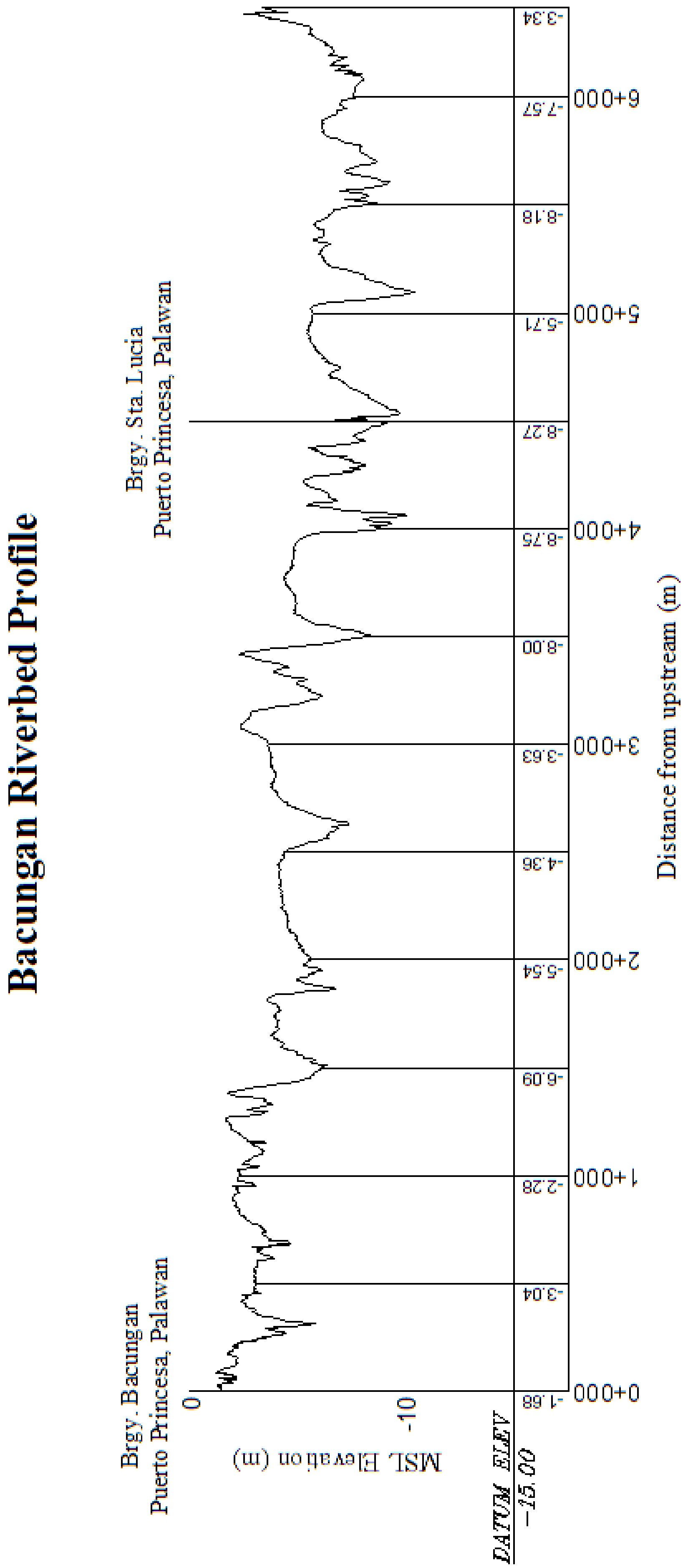


Figure 46. Bacungan riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable gauge deployed on a strategic location within the riverbasin (9.913920˚ N, 118.706500˚ E). The location of the rain gauge is seen in Figure 47.

The total precipitation for this event is 109.22 mm. It has a peak rainfall of 43.180 mm. on November, 26, 2016 at 1:15 am. The lag time between the peak rainfall and discharge is 2 hours and 45 minutes, as seen in Figure 50.

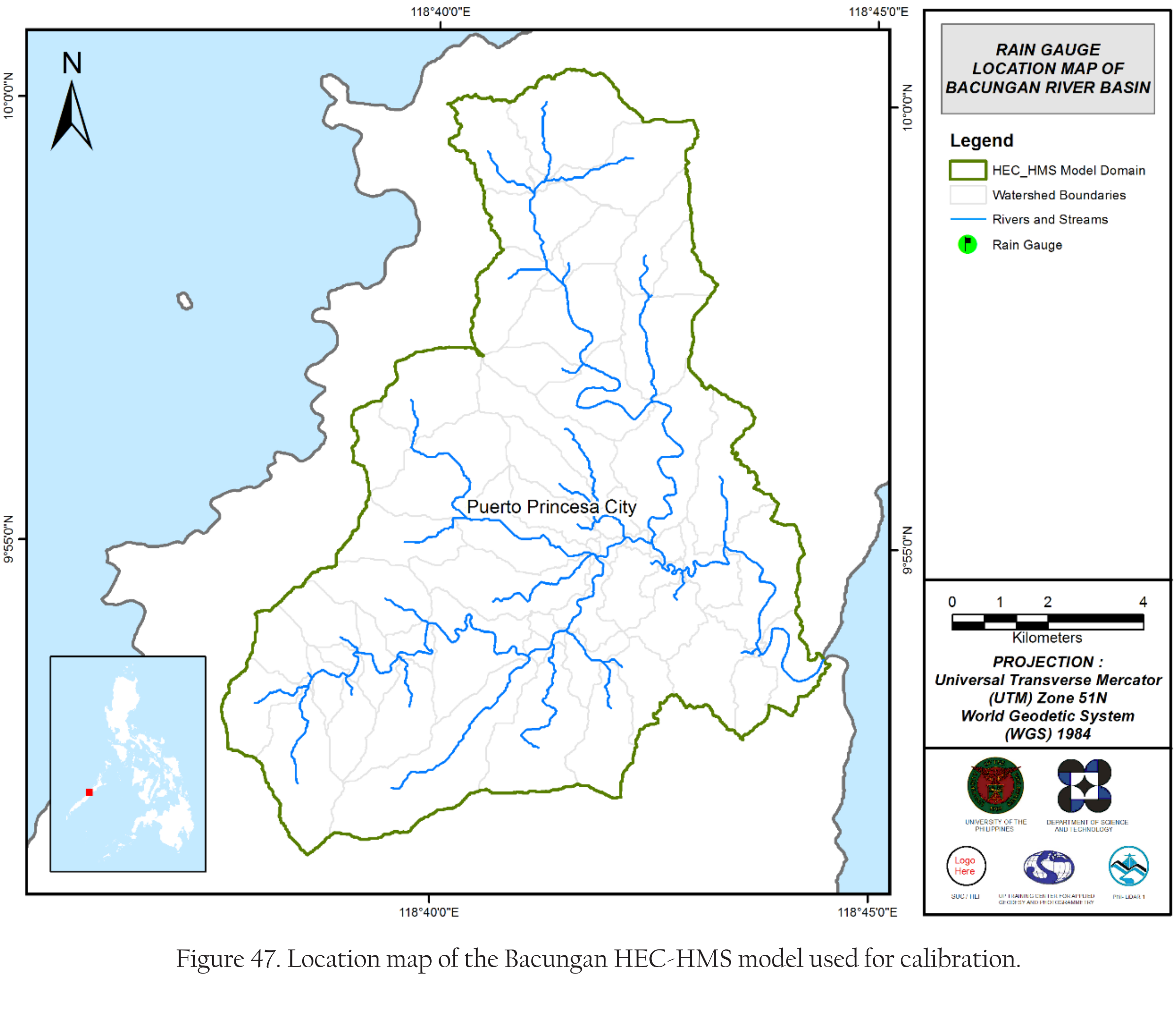


Figure 47. Location map of the Bacungan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Bacungan Bridge, Puerto Princesa, Palawan (9.916260° N, 118.709504° E). It gives the relationship between the observed water levels from the Bacungan Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

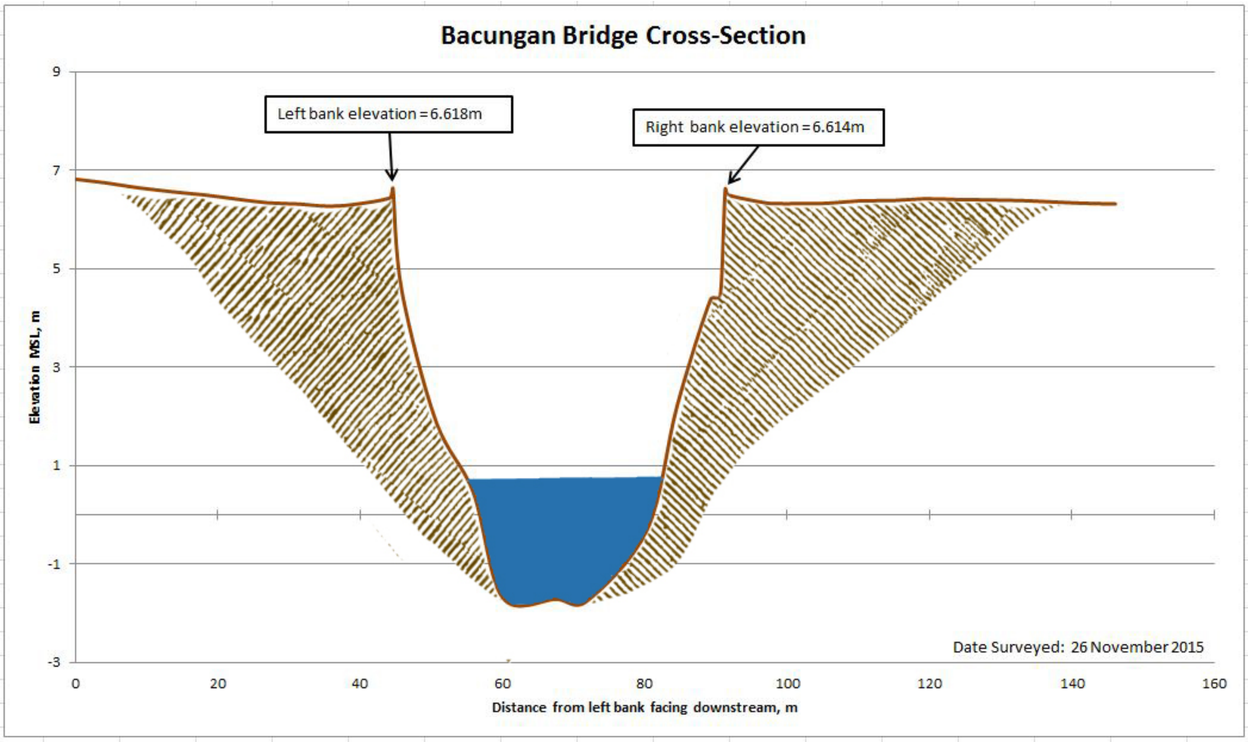


Figure 48. Cross-section plot of Bacungan Bridge

For Bacungan Bridge, the rating curve is expressed as Q = 37.037x2 +37.508x +9.2363 as shown in Figure 49.

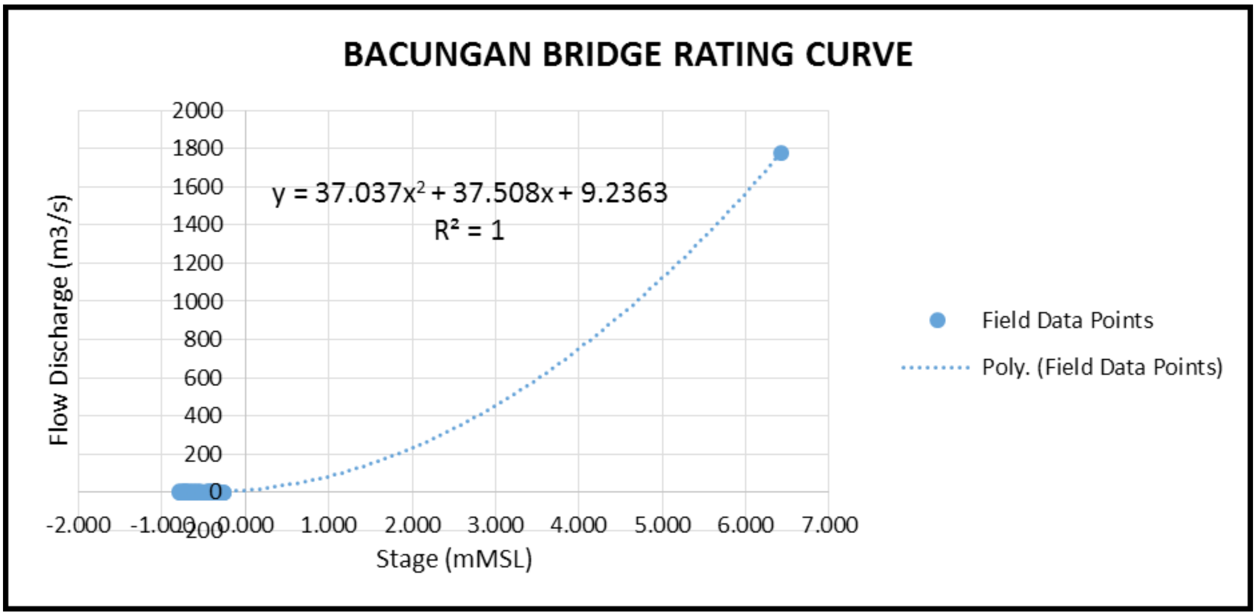


Figure 49. Rating curve at Bacungan Bridge, Puerto Princesa, Palawan

For the calibration of the HEC-HMS model, shown in Figure 50, actual flow discharge during a rainfall event was collected in the Bacungan bridge. Peak discharge is 124.10 cu.m/s on November 26, 2016 at 4:00 am.

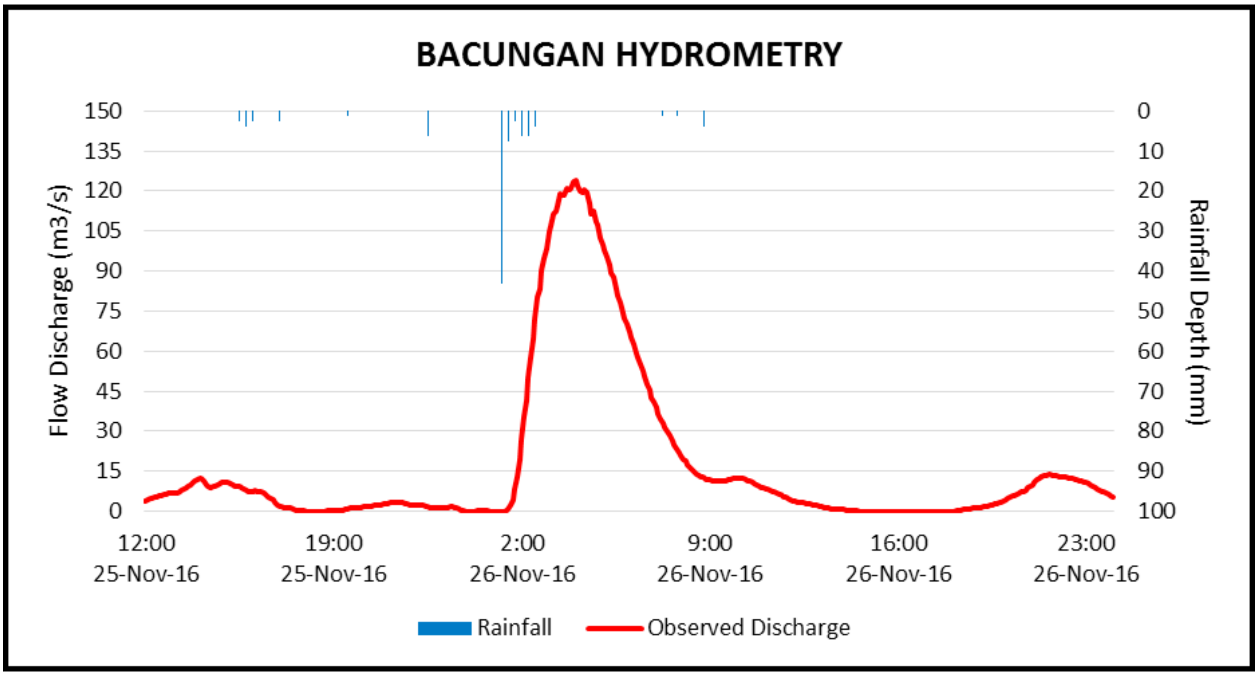


Figure 50. Rainfall and outflow data at Bacungan Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Bacungan watershed. The extreme values for this watershed were computed based on a 58-year record, with the computed extreme values shown in Table 25.

Table 25. RIDF values for Bacungan Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

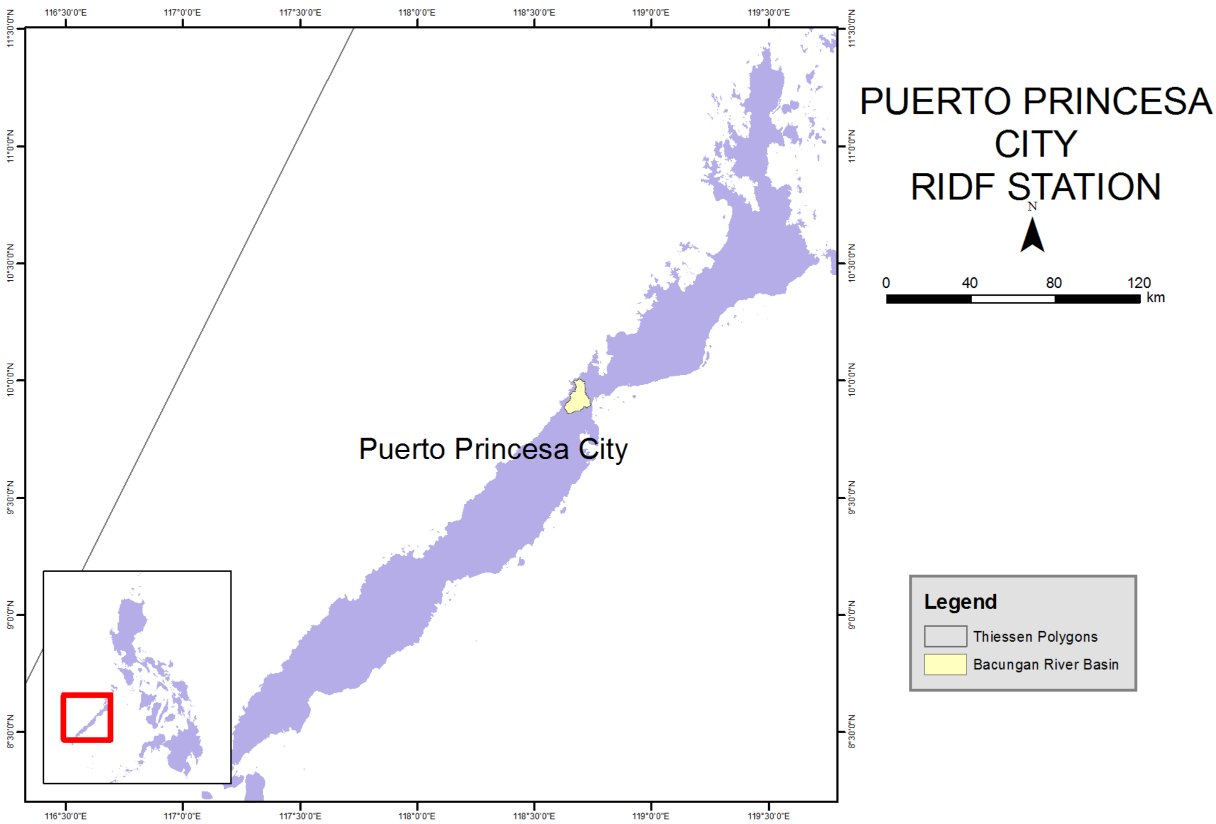


Figure 51. Location of Puerto Princesa RIDF Station relative to Bacungan River Basin

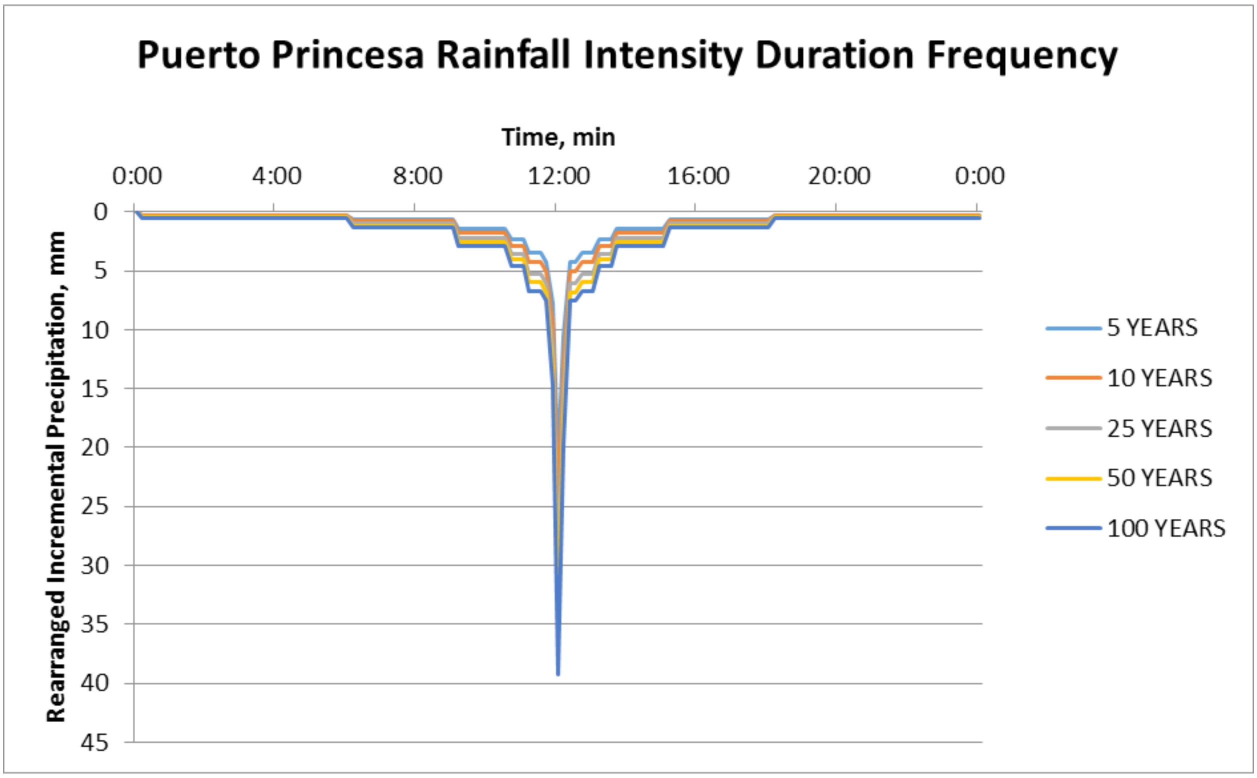


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

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

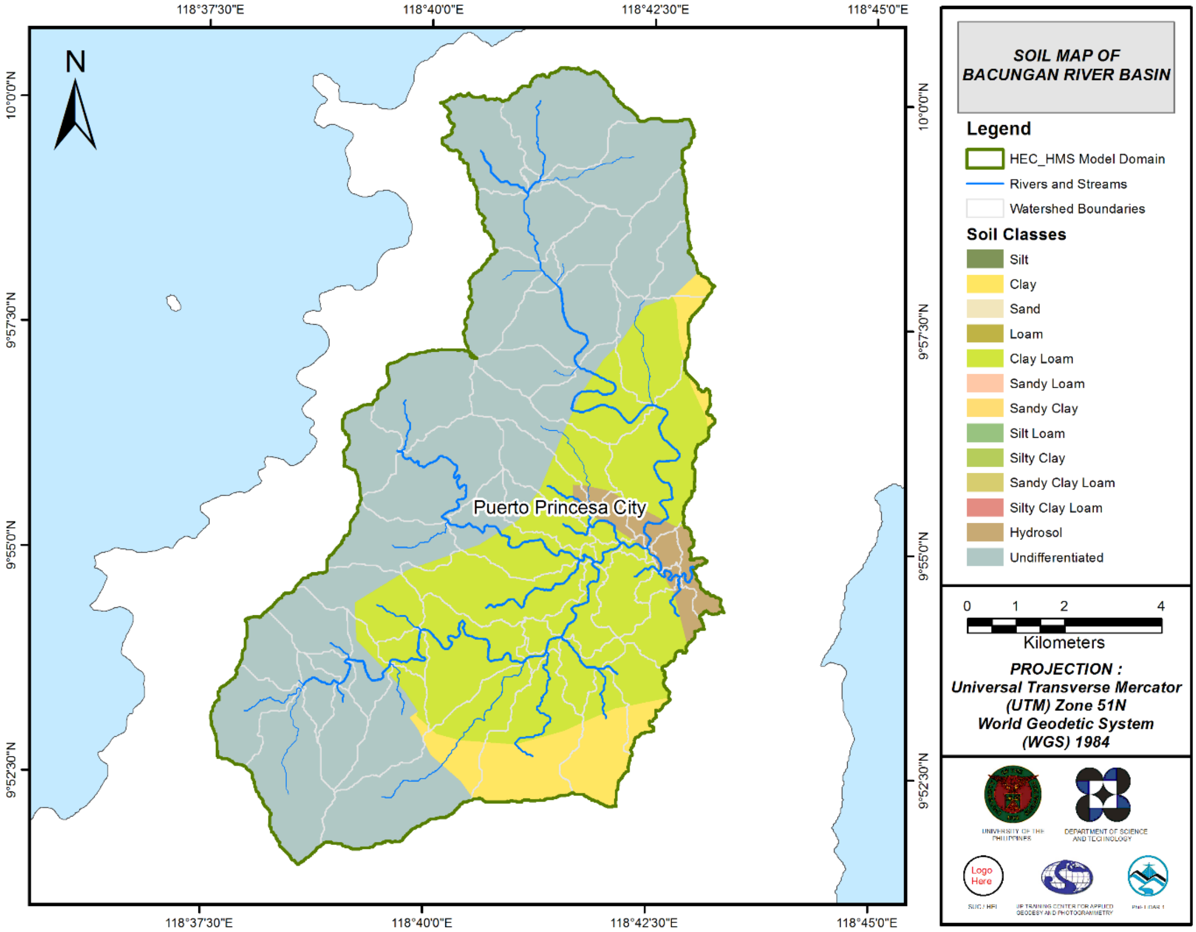


Figure 53. Soil Map of Bacungan River Basin used for the estimation of the CN parameter. (Source: DA)

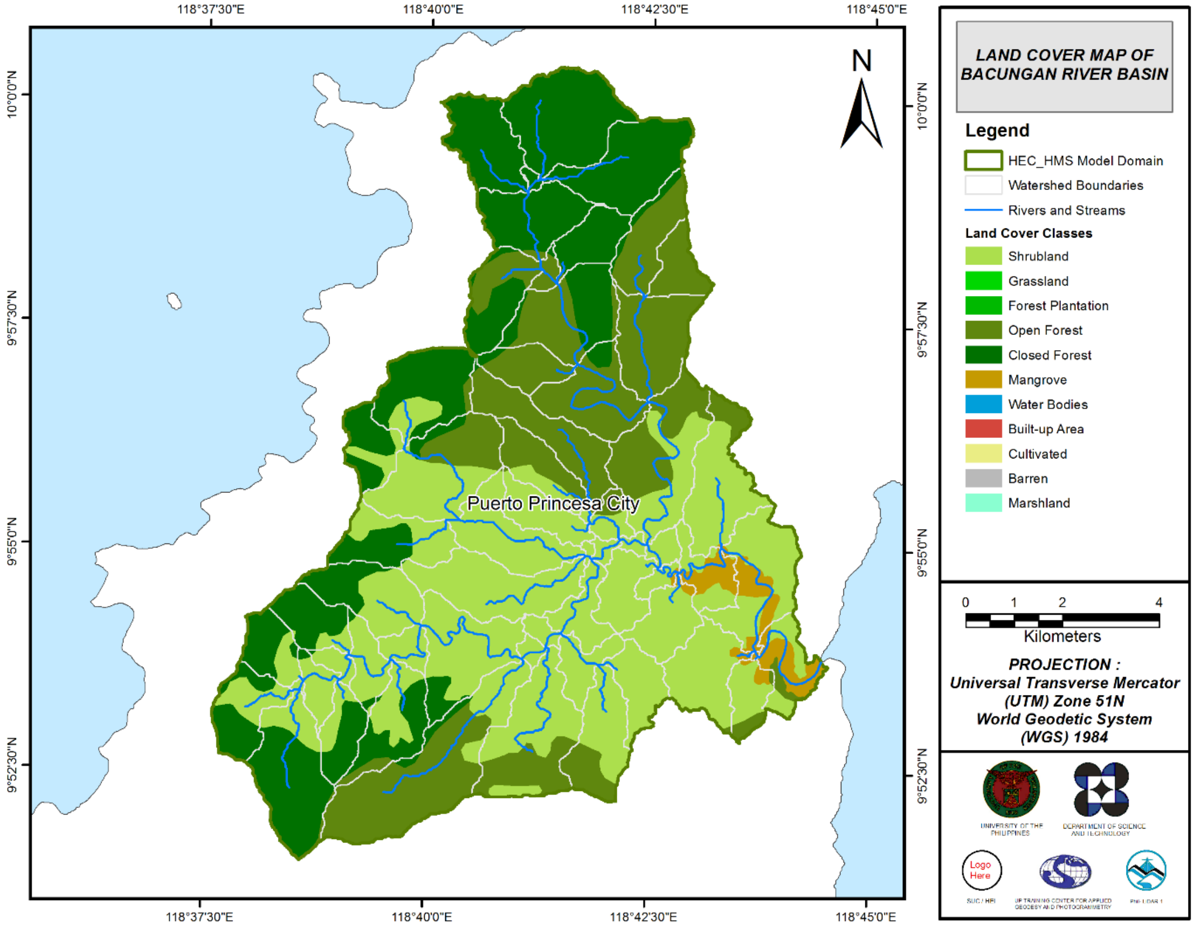


Figure 54. Land Cover Map of Bacungan River Basin used for the estimation of the Curve Number (CN) and the watershed lag parameters of the rainfall-runoff model.

For Bacungan river basin, the four (4) soil classes identified were clay loam, sandy clay and hydrosol, while the rest is undifferentiated. The four (4) land cover types identified were largely shrubland, open forest, closed forest, and mangrove.

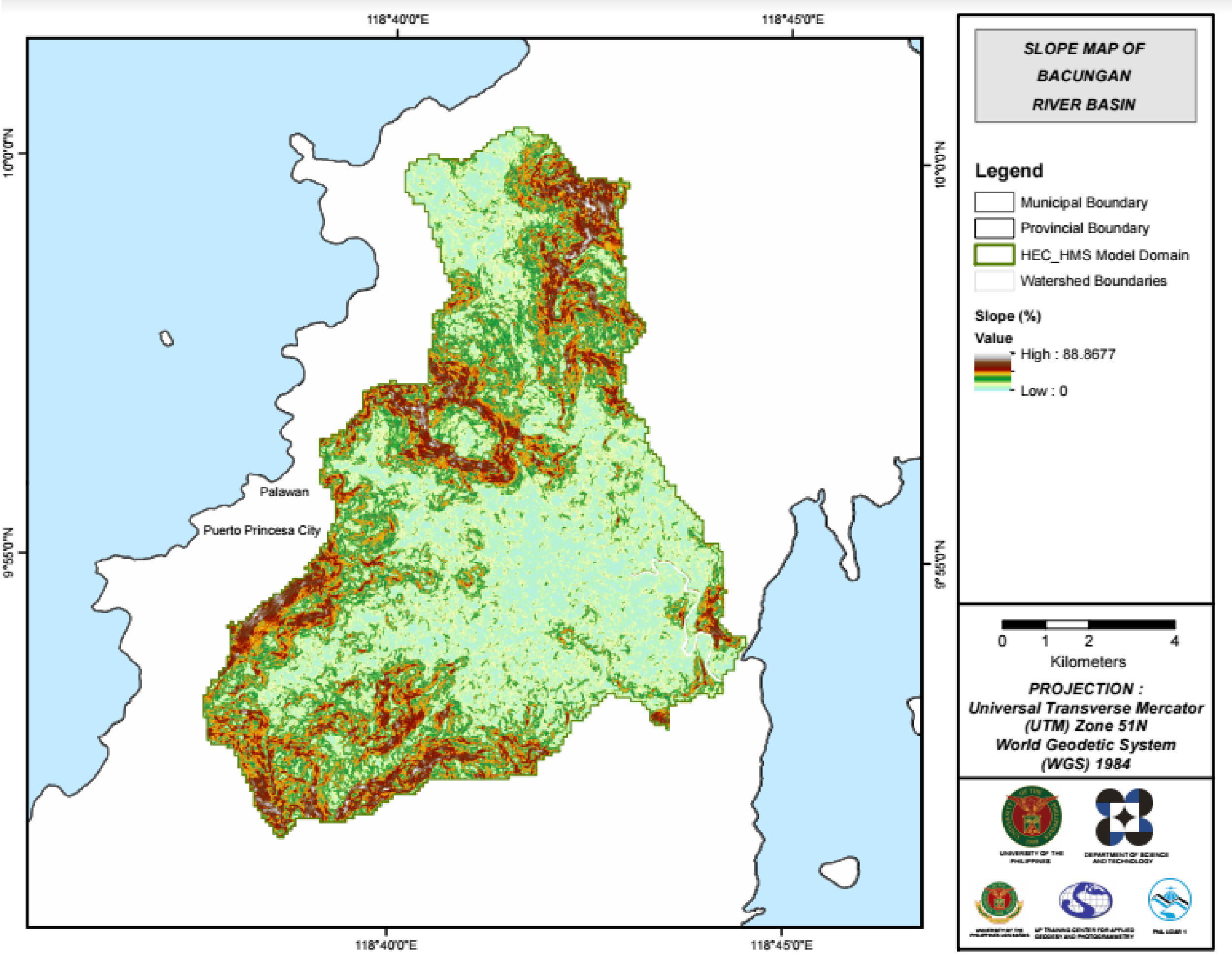


Figure 55. Slope Map of Bacungan River Basin

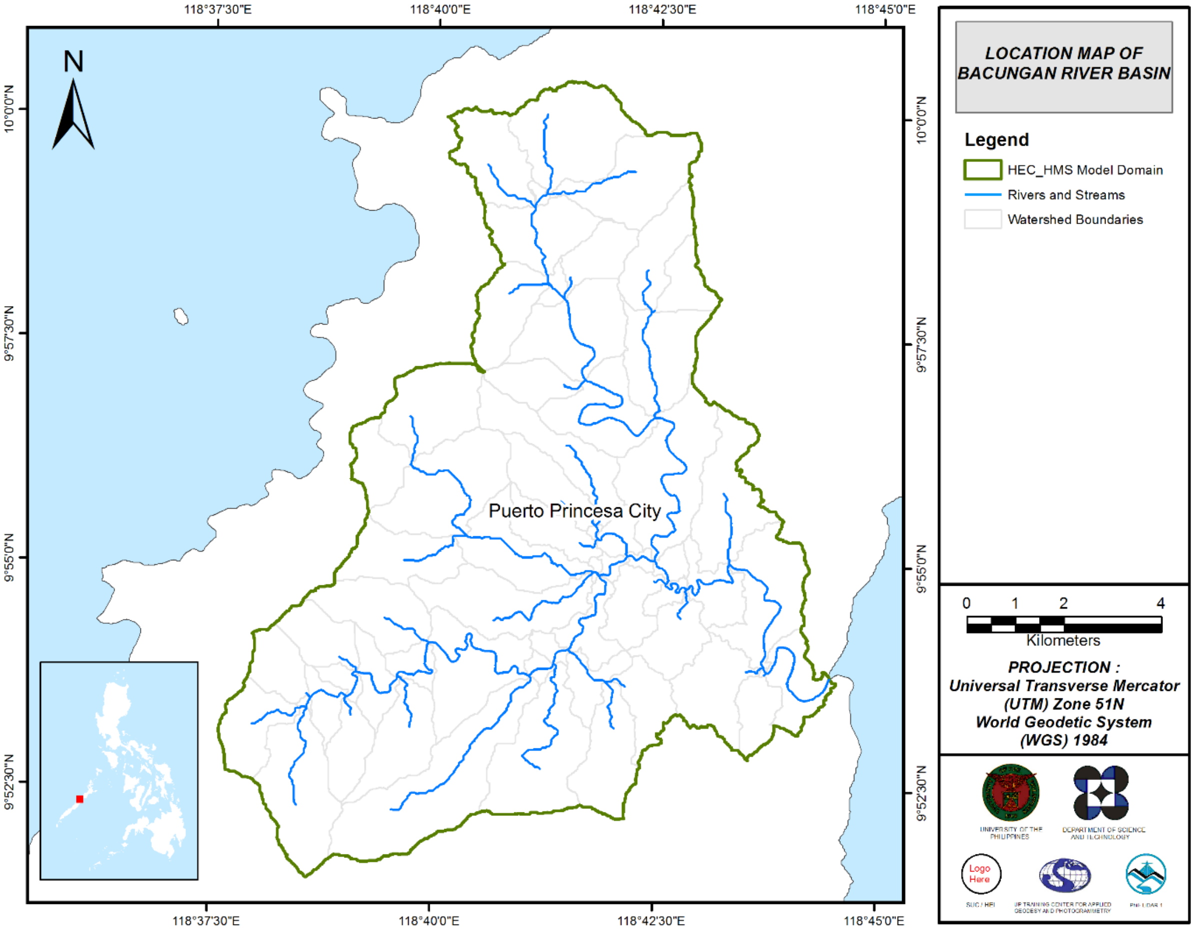


Figure 56. Stream Delineation Map of Bacungan River Basin

Using SAR-based DEM, the Bacungan basin was delineated and further subdivided into subbasins. The model consists of 56 sub basins, 28 reaches, and 28 junctions. The main outlet is labelled as 176. This basin model is illustrated in Figure 57. The basins were identified based on soil and land cover characteristics of the area. Precipitation was taken from the portable rain gauge set up by the Data Validation team of UPLB (DVC-UPLB) on a strategic point within the river basin. Finally, it was calibrated using the flow data collected from the Bacungan Bridge.

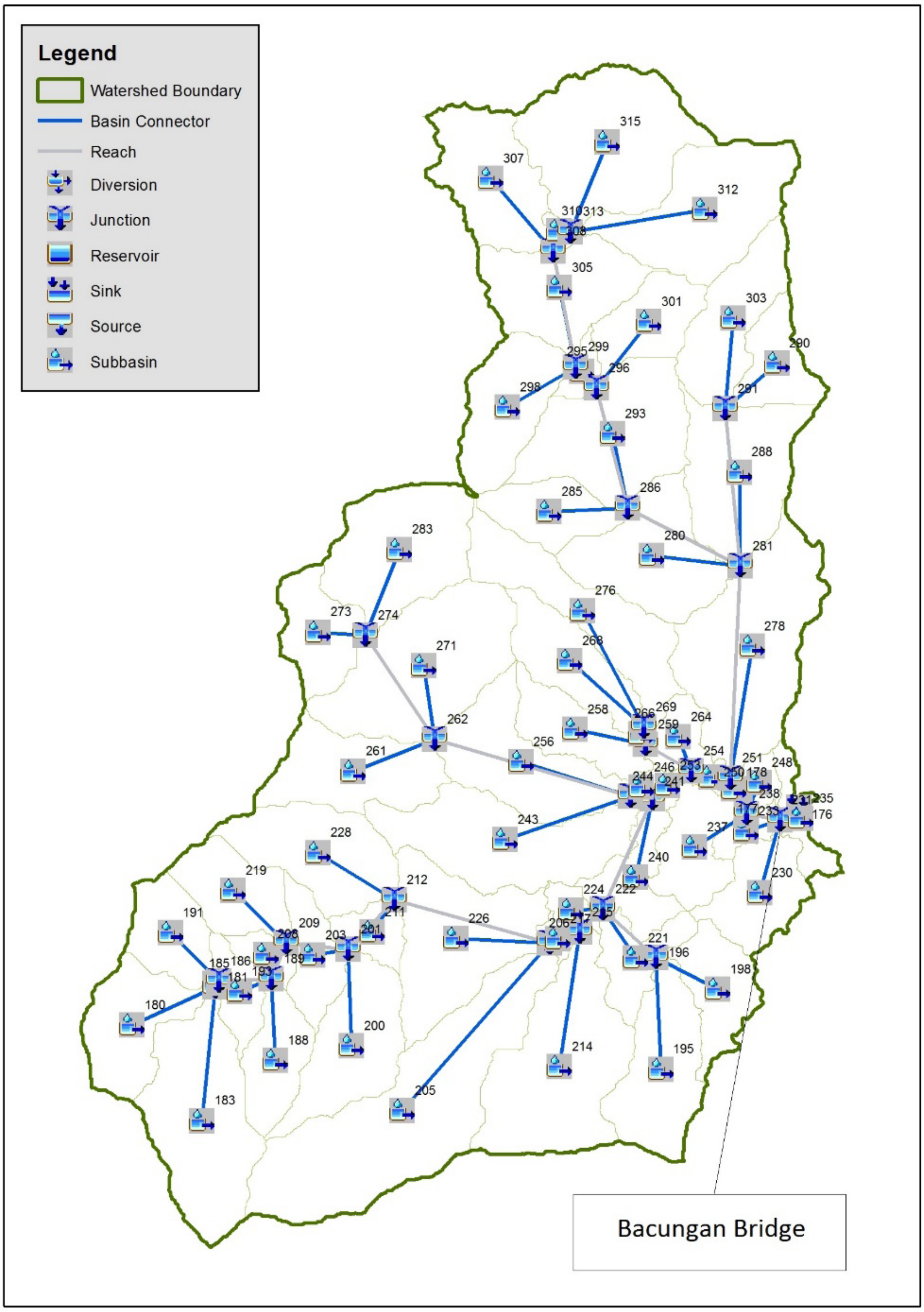


Figure 57. Bacungan River Basin model generated in HEC-HMS

5.4 Cross-section Data

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

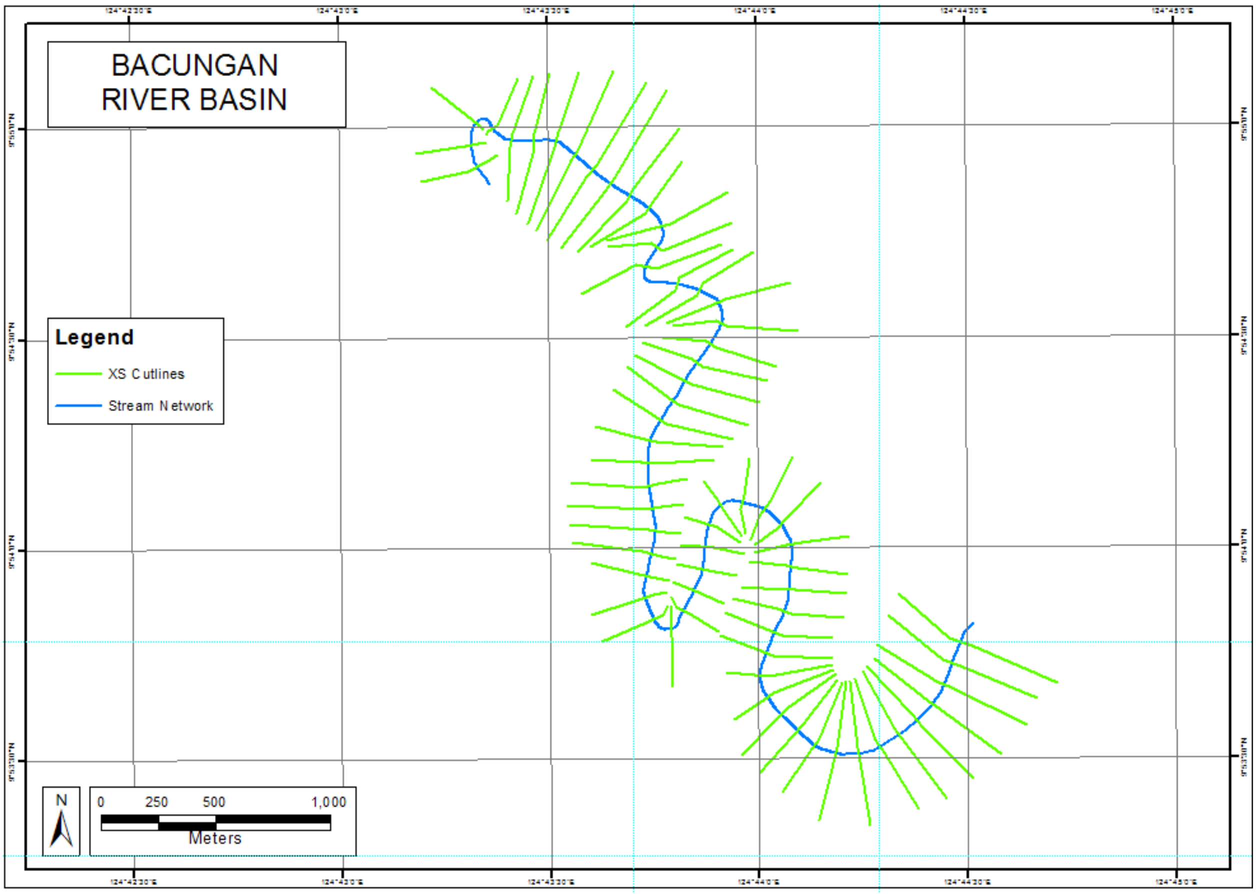


Figure 58. River cross-section of Bacungan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

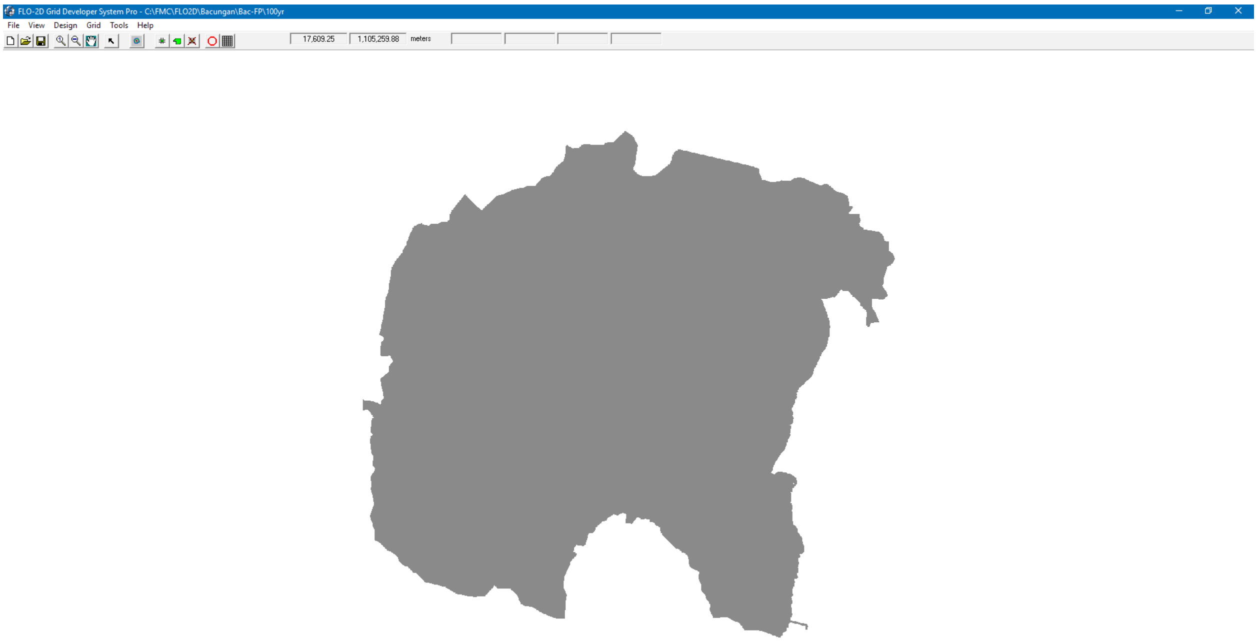


Figure 59. Screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 61.44043 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 73 211 712.00 m2.

There is a total of 36 527 447.05 cu.m. of water entering the model. Of this amount, 22 884 763.27 cu.m. is due to rainfall while 13 642 683.79 cu.m. is inflow from other areas outside the model. 6 566 641.50 m3 of this water is lost to infiltration and interception, while 17 082 008.09 cu.m. is stored by the floodplain. The rest, amounting up to 12 878 798.47 cu.m. is outflow.

5.6 Results of HMS Calibration

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

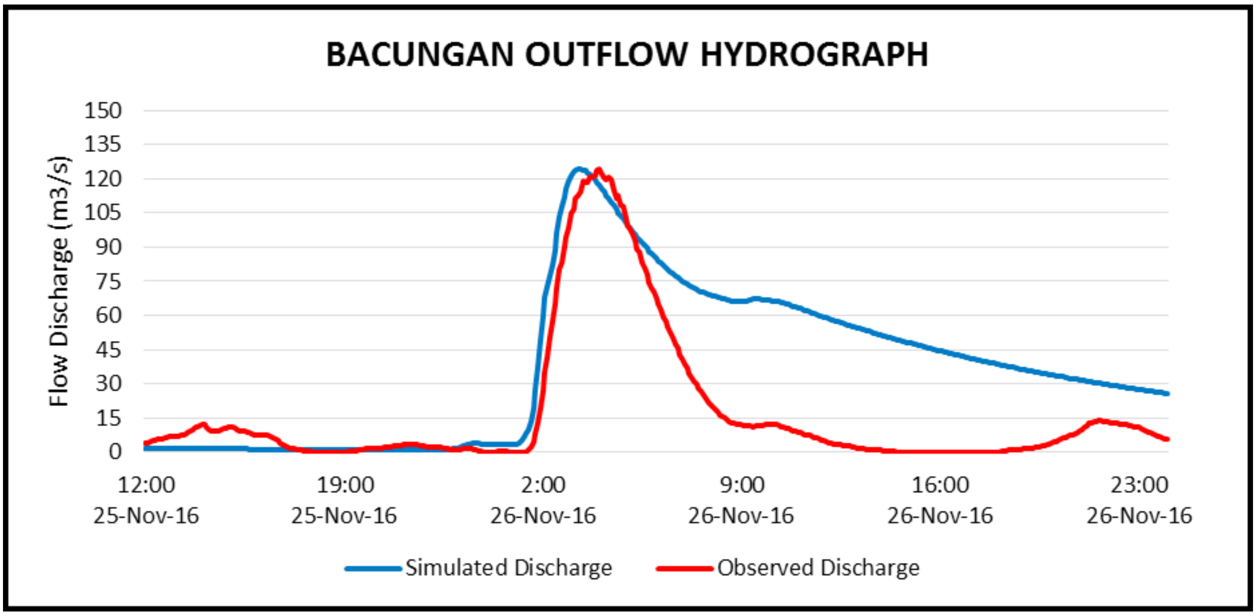


Figure 60. Outflow hydrograph of Balamban produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 26 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 26. Range of calibrated values for the Bacungan River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	8 - 98
			Curve Number	34 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 - 1
			Storage Coefficient (hr)	1 - 45
	Baseflow	Recession	Recession Constant	0.1 – 0.5
			Ratio to Peak	0.2 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.02

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 8 to 98mm means that there is a diverse amount of infiltration or rainfall interception by vegetation depending on the subbasin.

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.

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 0.02 hours to 45 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.1 to 0.5 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.2 to 0.5 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.02 is relatively low compared to the common roughness of watersheds (Brunner, 2010).

Table 27. Summary of the Efficiency Test of the Bacungan HMS Model

Accuracy measure	Value
RMSE	8.769
r2	0.976
NSE	0.924
PBIAS	-5.720
RSR	0.275

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 8.769.

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 0.976.

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 0.924.

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 -5.720.

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 0.275.

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 61) shows the Bacungan outflow using the Puerto Princesa 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.

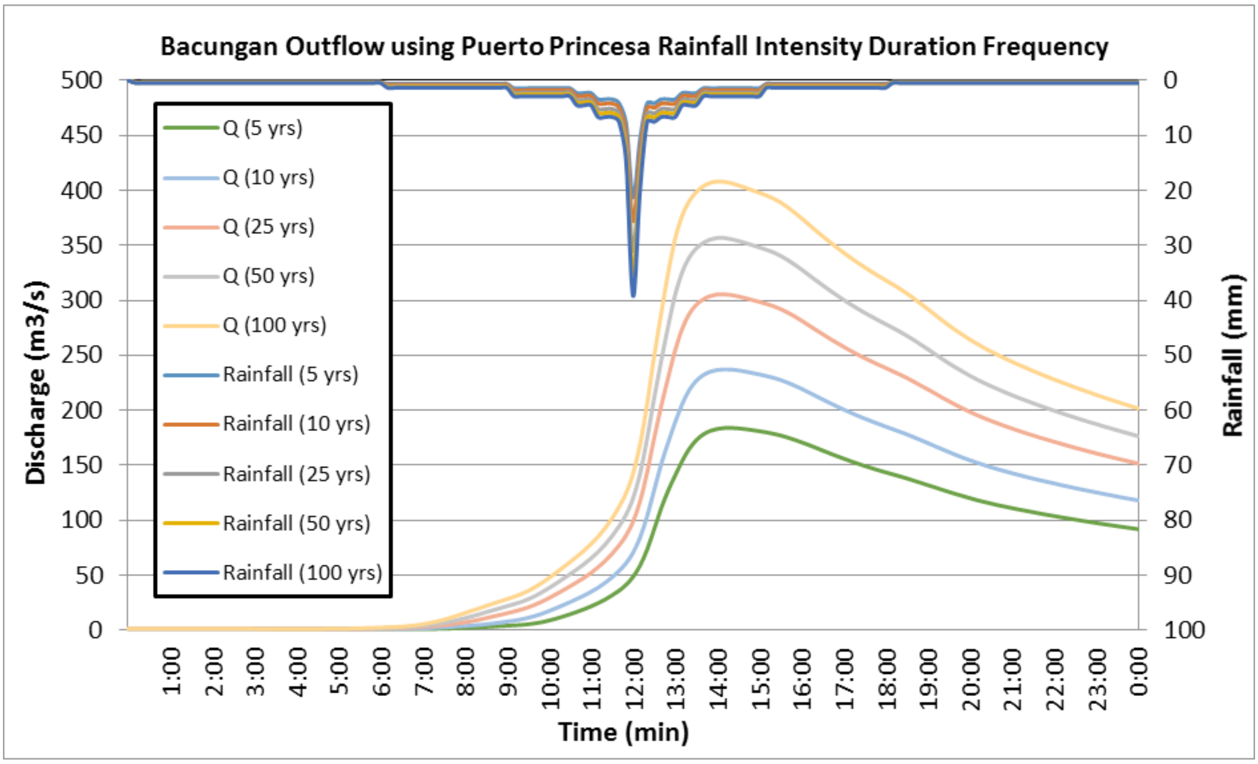


Figure 61. Outflow hydrograph at Bacungan Station generated using the Puerto Princesa RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Bacungan discharge using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 28.

Table 28. Peak values of the Bacungan HEC-HMS Model outflow using the Puerto Princesa RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	156.40	21.30	184.0	2 hours 20 minutes
10-Year	191.10	25.60	237.20	2 hours 10 minutes
25-Year	234.90	31.10	305.50	2 hours 10 minutes
50-Year	267.30	35.20	356.70	2 hours
100-Year	299.60	39.20	408.0	2 hours

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. The sample map of Bacungan River using the HMS base flow is shown on Figure 62.

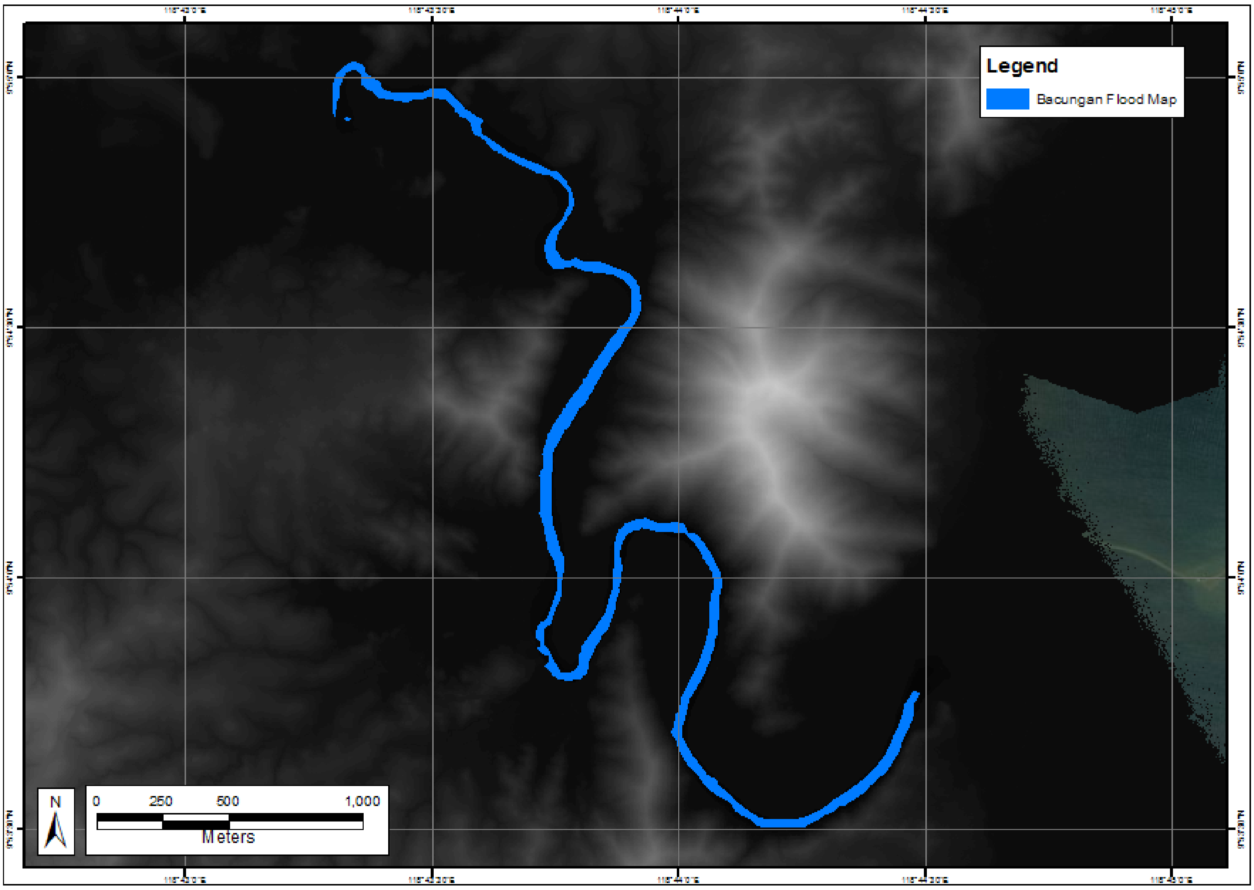


Figure 62. Sample output map of Bacungan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The generated flood hazard maps for the Bacungan Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr). The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Bacungan floodplain are shown Figure 63 to Figure 68. The floodplain, with an area of 73.16 sq. km., covers one city namely Puerto Princesa City. Table 29 show the percentage of area affected by flooding in Puerto Princesa City.

Table 31. Municipalities affected in Bacungan Floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Palawan	Puerto Princesa City	2186.36	73.10	3.34

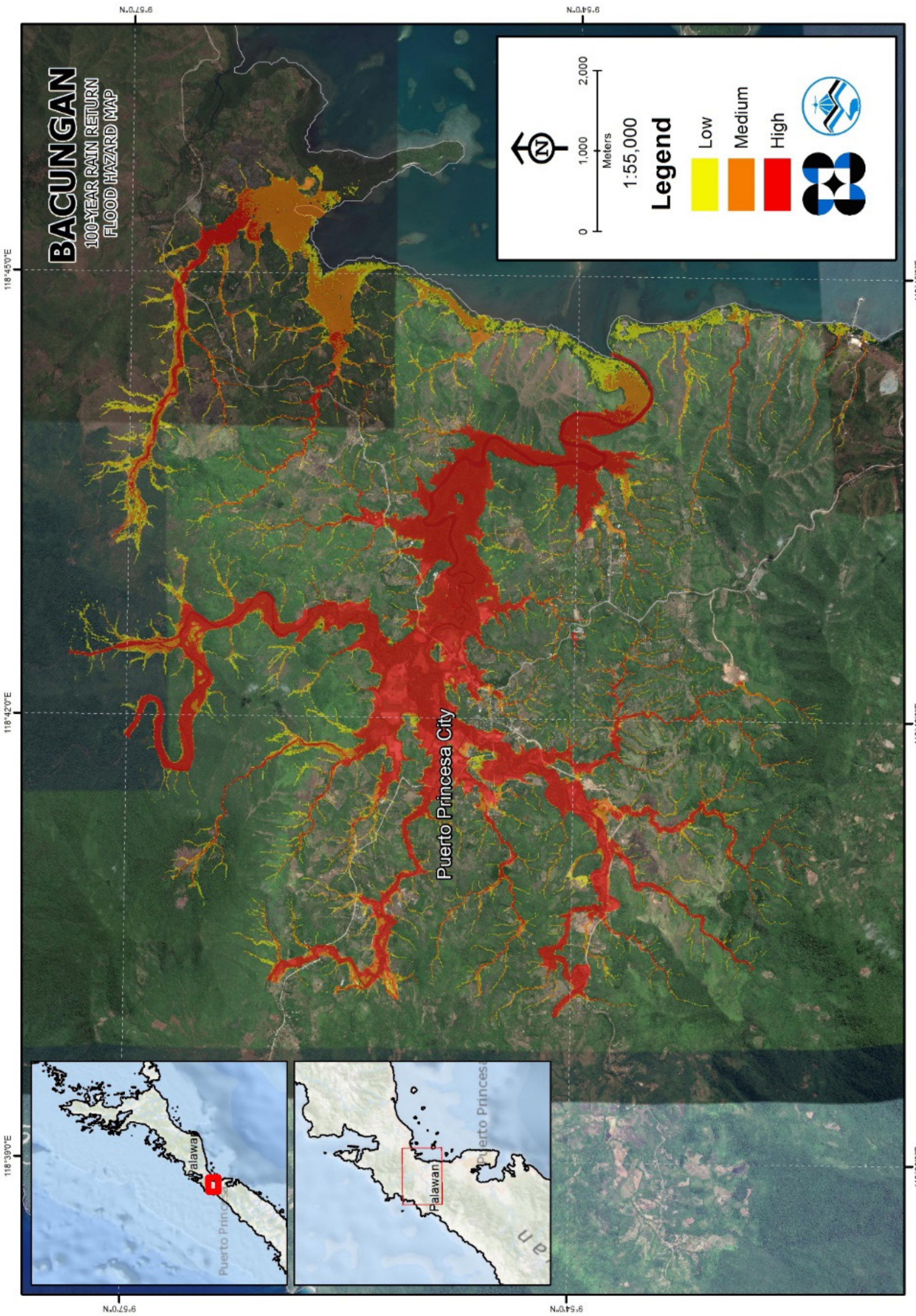


Figure 63. 100-year Flood Hazard Map for Bacungan Floodplain overlaid on Google Earth imagery

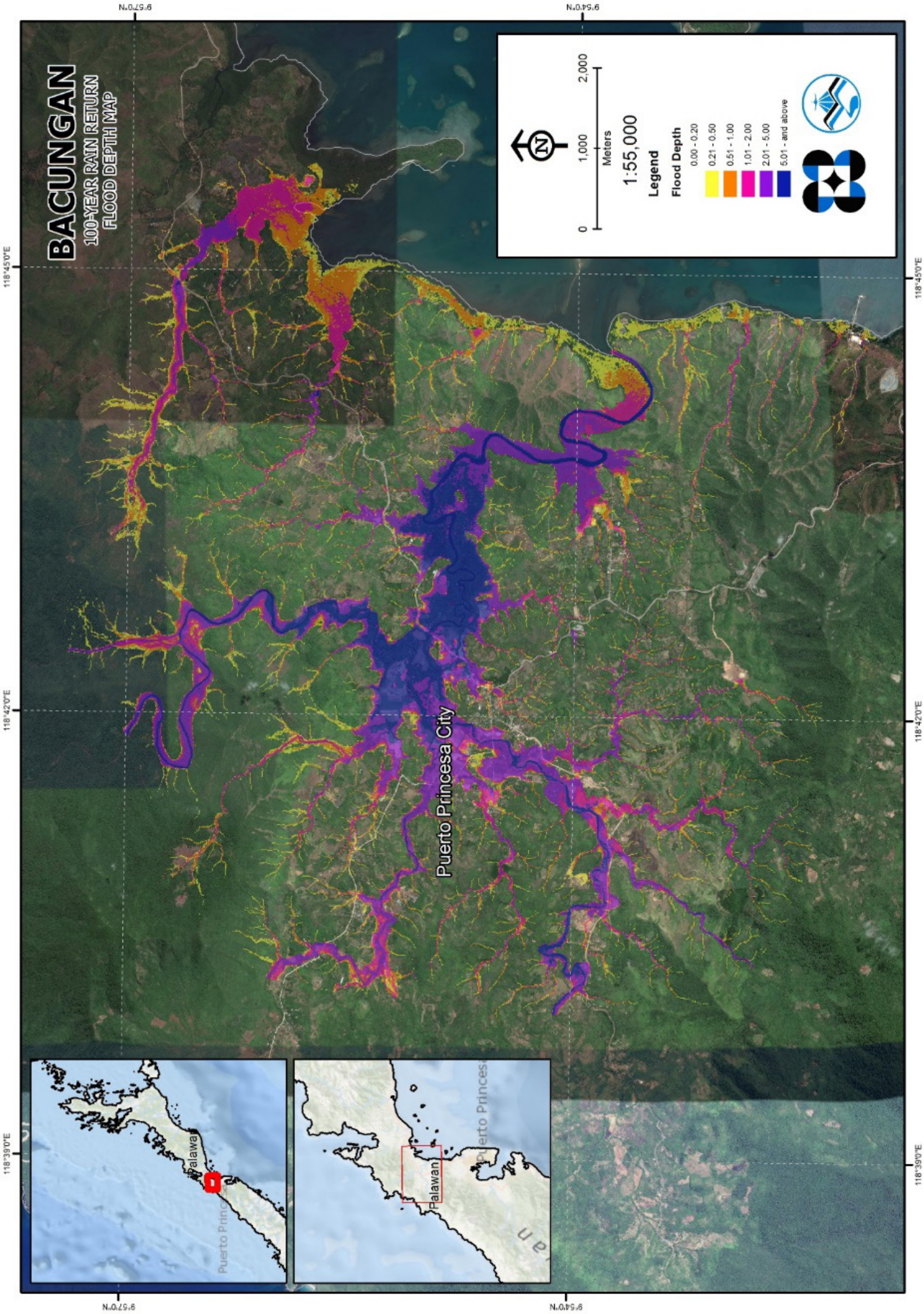


Figure 64. 100-year Flow Depth Map for Bacungan Floodplain overlaid on Google Earth imagery

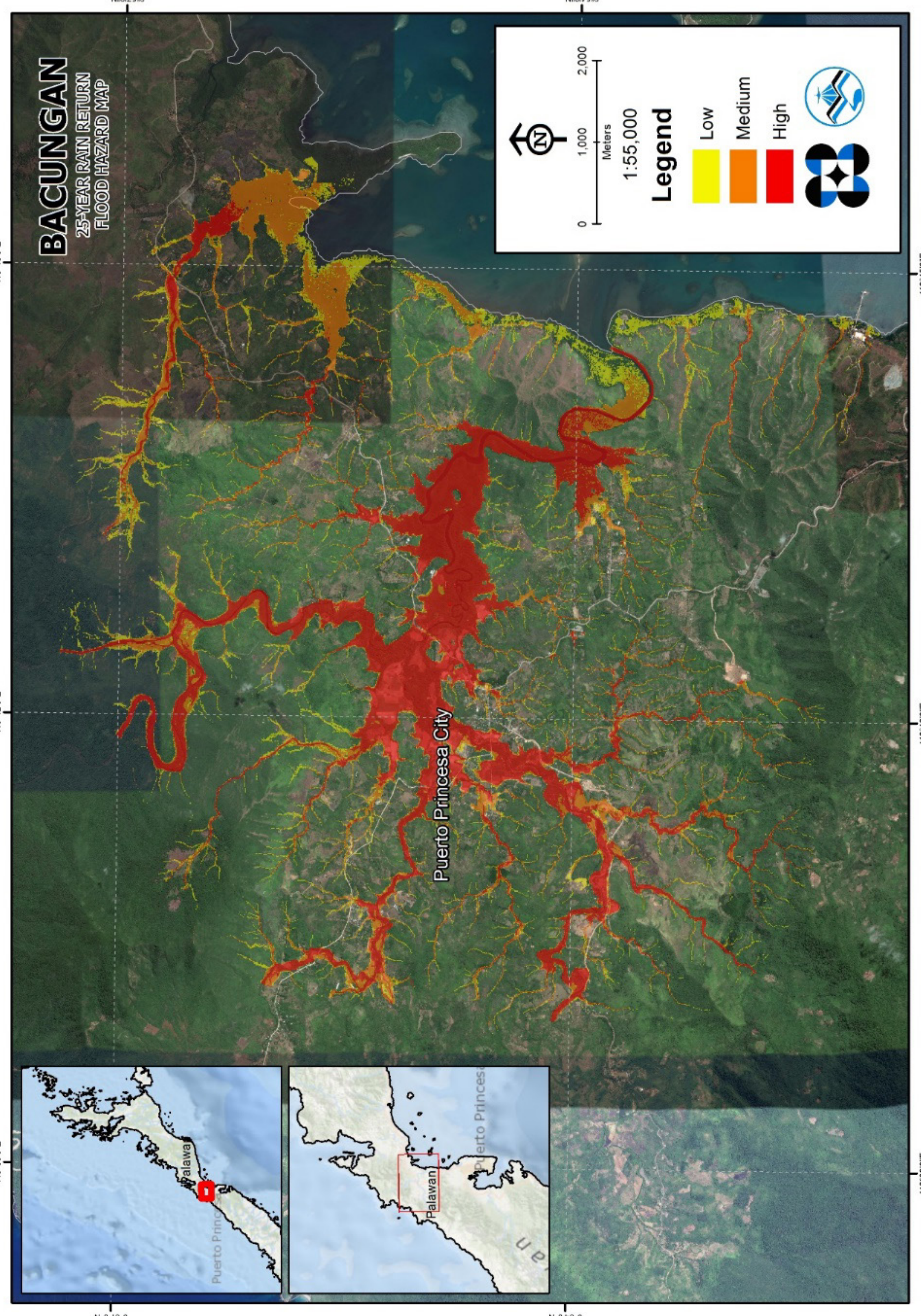


Figure 65. 25-year Flood Hazard Map for Bacungan Floodplain overlaid on Google Earth imagery

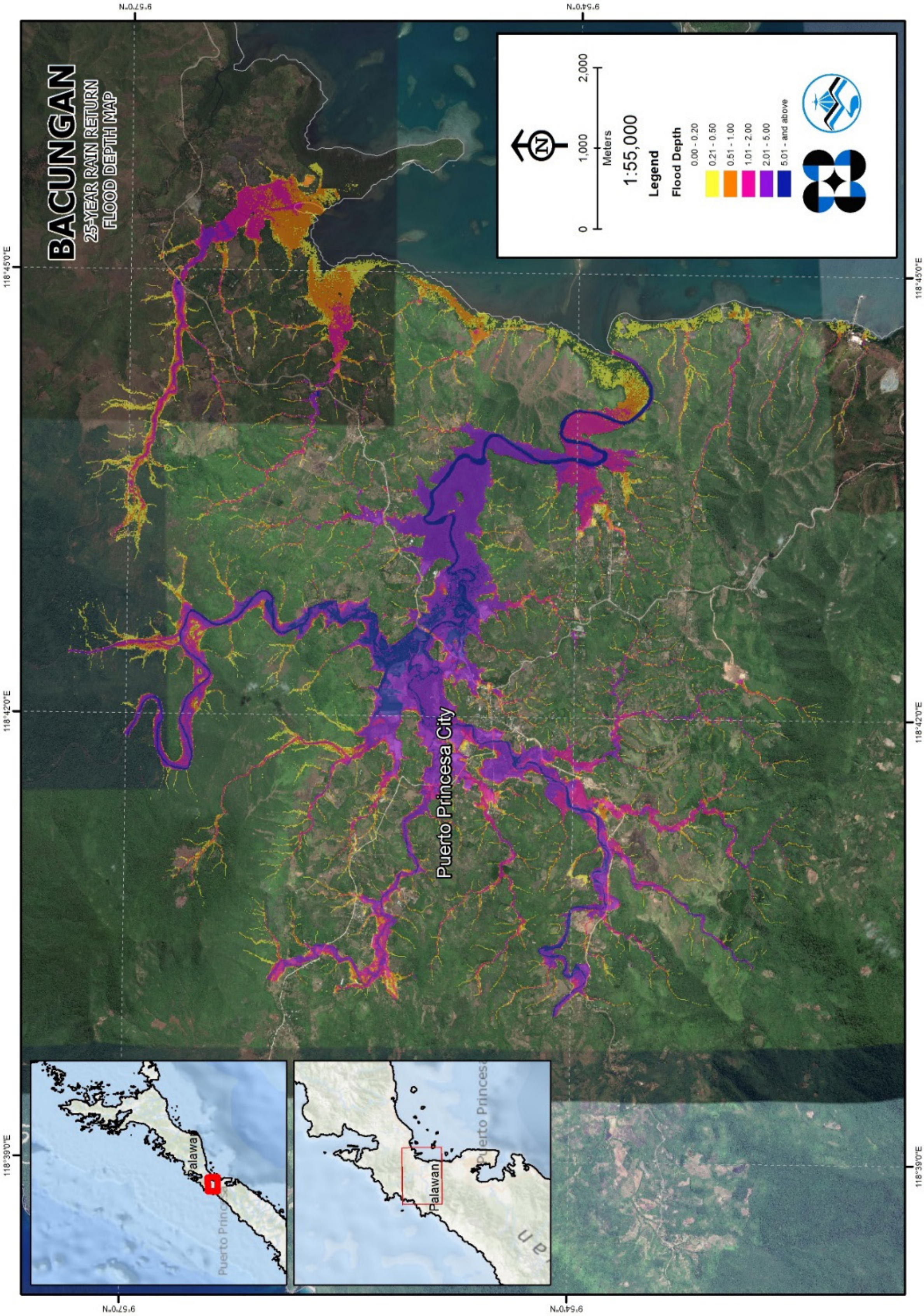


Figure 66. 25-year Flow Depth Map for Bacungan Floodplain overlaid on Google Earth imagery

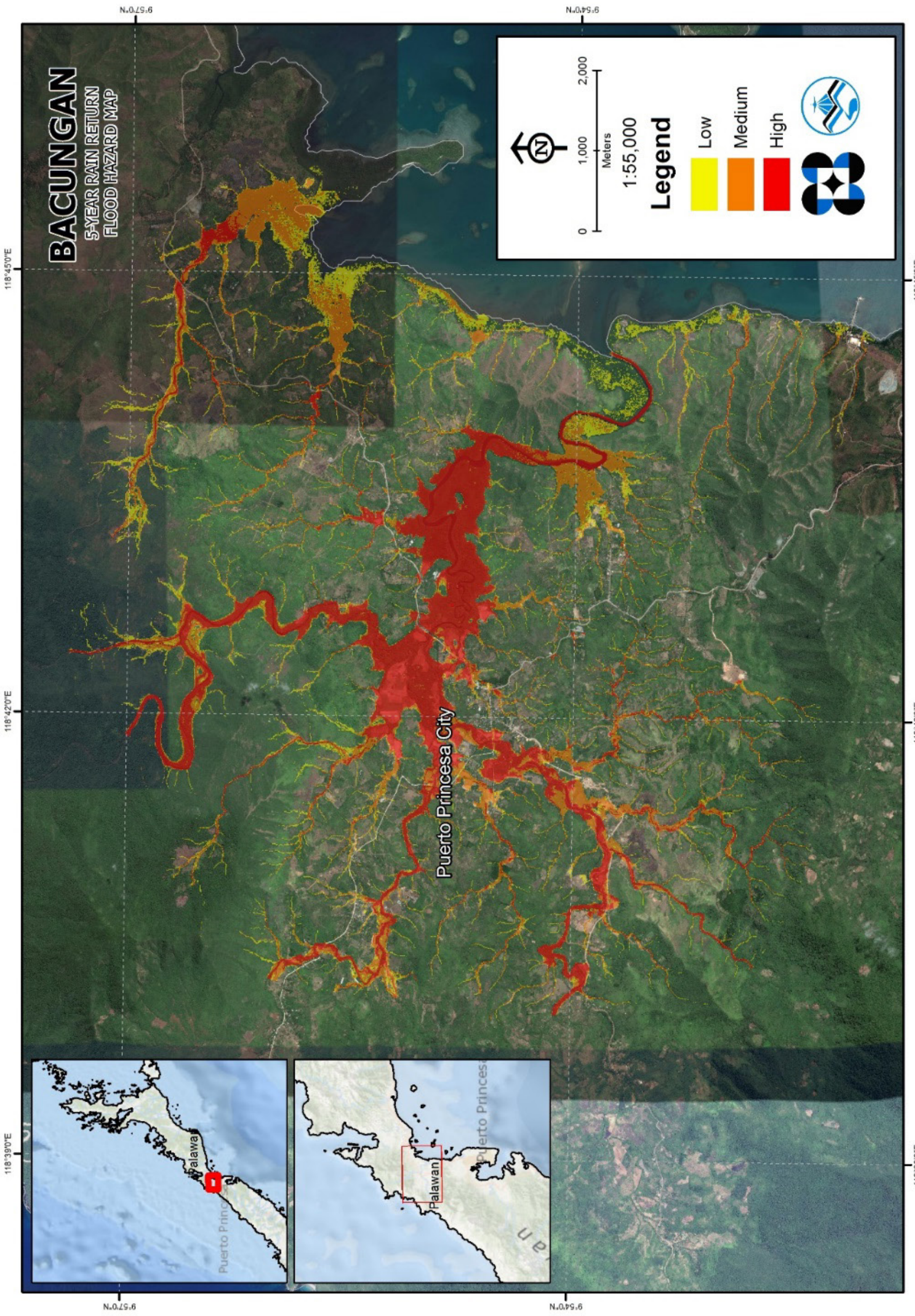


Figure 67. 5-year Flood Hazard Map for Bacungan Floodplain overlaid on Google Earth imagery

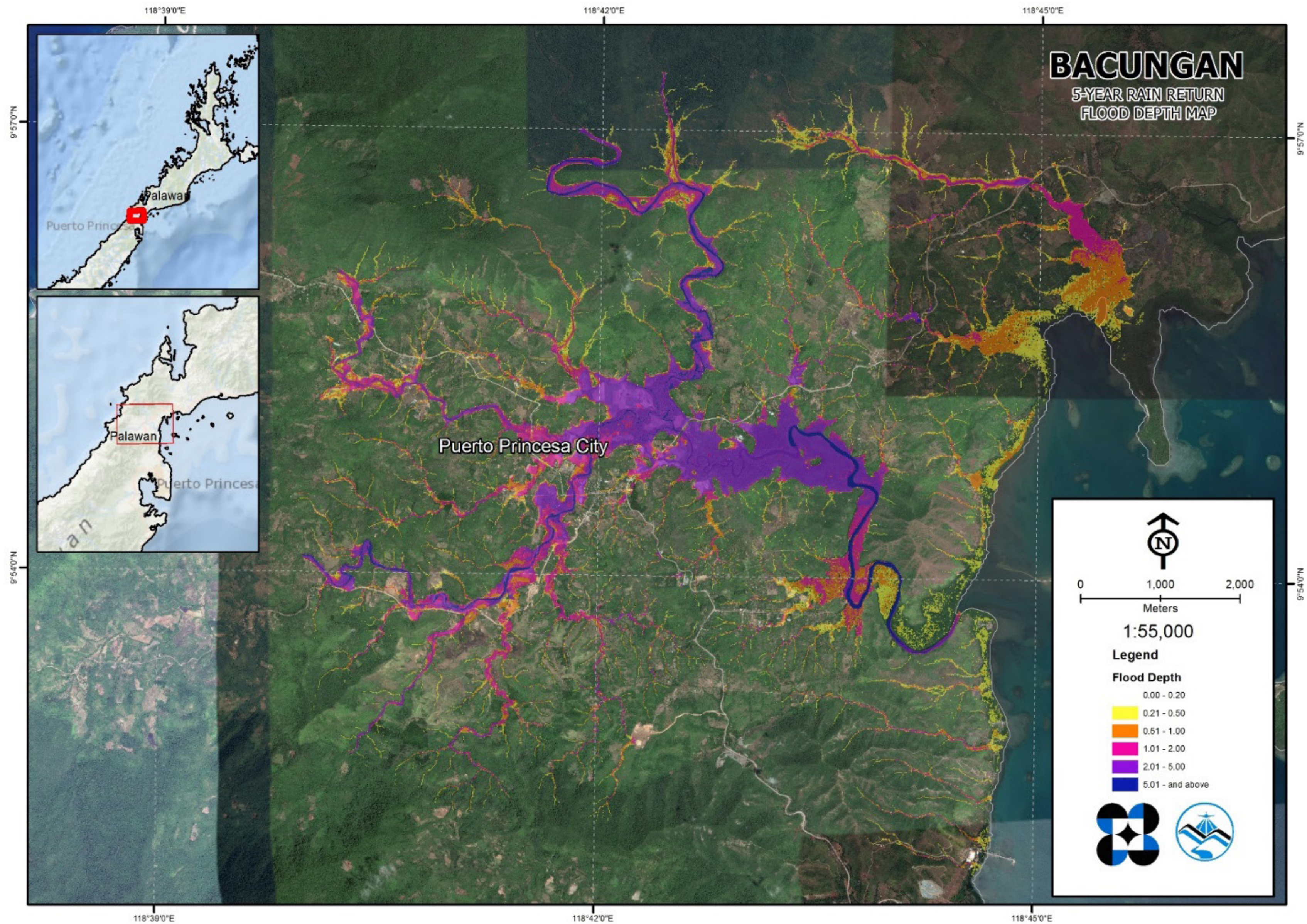


Figure 68. 5-year Flood Depth Map for Bacungan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Bacungan River Basin, grouped accordingly by municipality. For the said basin, one (1) municipality consisting of 4 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 2.73% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less 0.20 meters, while 0.14% of the area will experience flood levels of 0.21 to 0.50 meters; 0.13%, 0.14%, 0.18%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Listed in Table 30 and shown in Figure 69 are the affected areas in Puerto Princesa in square kilometres by flood depth per barangay.

Table 30. Affected areas in Puerto Princesa City, Palawan during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Puerto Princesa City (in sq. km.)			
	Bacungan	Irawan	Santa Cruz	Santa Lourdes
0.03-0.20	44.31	2.050	1.73	11.68
0.21-0.50	2.43	0.052	0.15	0.50
0.51-1.00	2.23	0.032	0.27	0.29
1.01-2.00	2.43	0.042	0.23	0.28
2.01-5.00	3.74	0.030	0.016	0.086
> 5.00	0.52	0.0002	0	0.0062

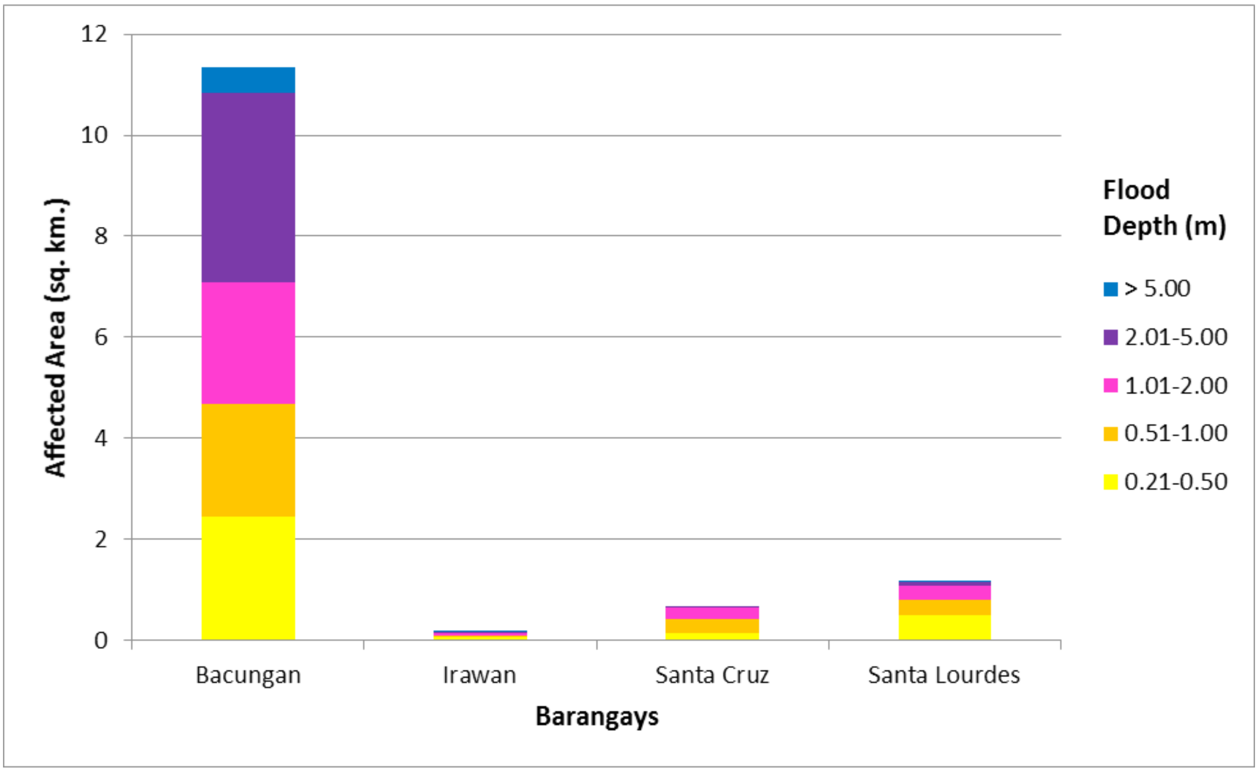


Figure 69. Affected Areas in Puerto Princesa City, Palawanl during 5-Year Rainfall Return Period

For the 25-year return period, 2.64% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less 0.20 meters, while 0.15% of the area will experience flood levels of 0.21 to 0.50 meters; 0.12%, 0.15%, 0.22%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Listed in Table 31 and shown in Figure 70 are the affected areas in square kilometres by flood depth per barangay.

Table 31. Affected areas in Puerto Princesa City, Palawan during a 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Puerto Princesa City (in sq. km.)			
	Bacungan	Irawan	Santa Cruz	Santa Lourdes
0.03-0.20	42.67	2.022	1.64	11.44
0.21-0.50	2.38	0.060	0.15	0.59
0.51-1.00	2.15	0.031	0.18	0.33
1.01-2.00	2.66	0.044	0.32	0.33
2.01-5.00	4.47	0.046	0.095	0.14
> 5.00	1.32	0.0033	0.0015	0.022

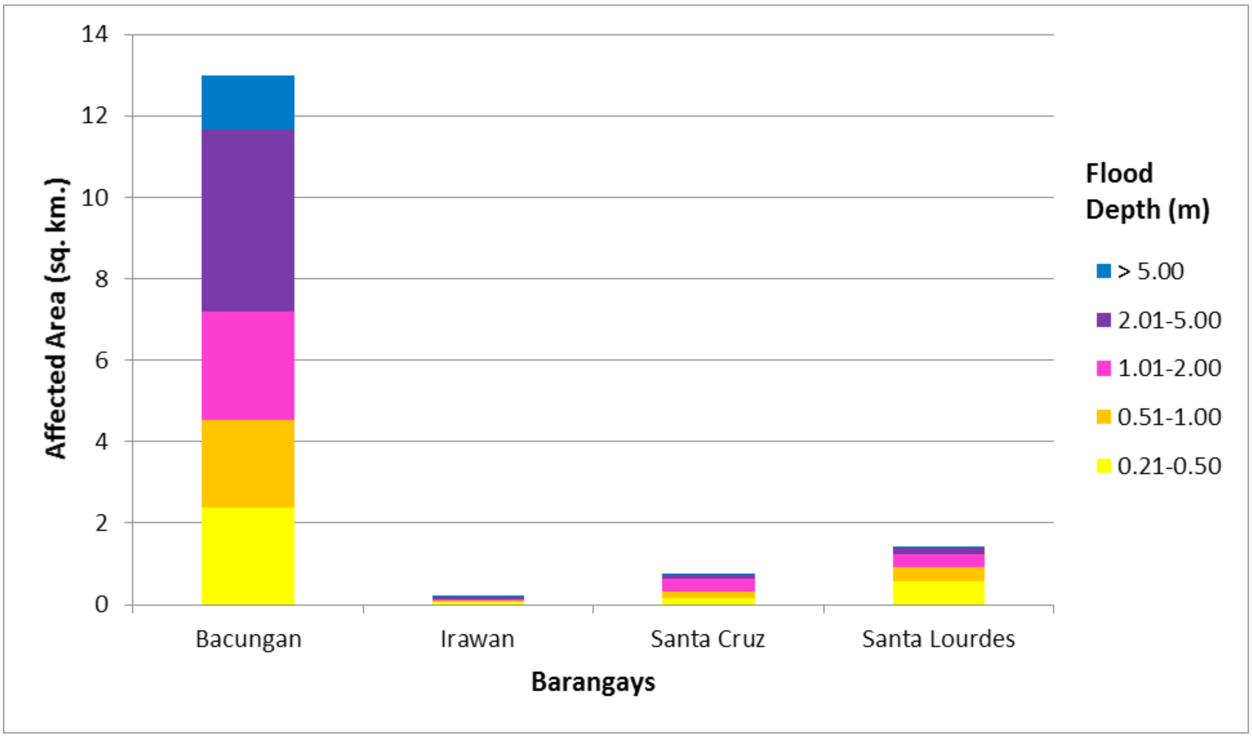


Figure 70. Affected Areas in Puerto Princesa City, Palawan during 25-Year Rainfall Return Period

For the 100-year return period, 2.58% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less 0.20 meters, while 0.15% of the area will experience flood levels of 0.21 to 0.50 meters; 0.12%, 0.15%, 0.21%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 t0 5 meters, and more than 5 meters respectively. Listed in Table 32 and shown in Figure 71 are the areas affected in Puerto Princesa City in square kilometers by flood depth per barangay.

Table 32. Affected areas in Puerto Princesa City, Palawan during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Puerto Princesa City (in sq. km.)			
	Bacungan	Irawan	Santa Cruz	Santa Lourdes
0.03-0.20	41.48	2.00071	1.59	11.28
0.21-0.50	2.48	0.068	0.16	0.61
0.51-1.00	2.13	0.032	0.15	0.38
1.01-2.00	2.48	0.039	0.34	0.34
2.01-5.00	4.15	0.062	0.15	0.21
> 5.00	2.93	0.0048	0.0025	0.029

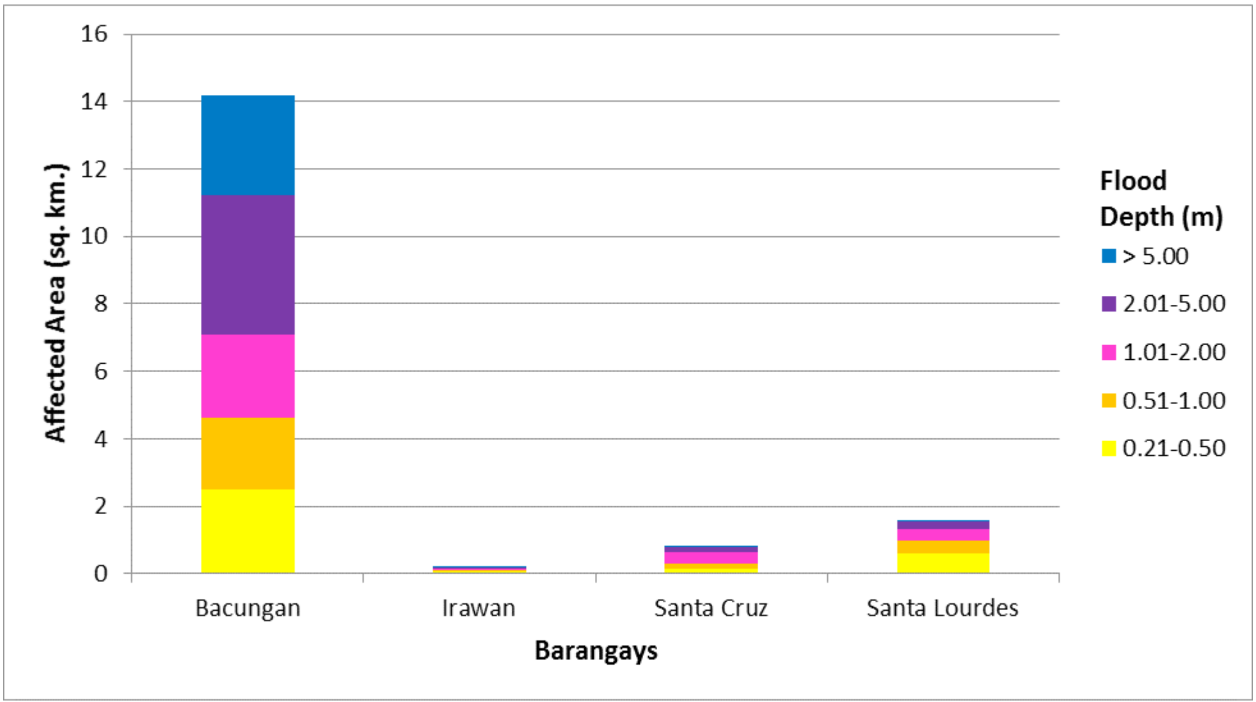


Figure 71. Affected Areas in Puerto Princesa City, Palawan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Puerto Princesa City, Bacungan is projected to have the highest percentage of area that will experience flood levels of at 2.55%. On the other hand, Santa Lourdes posted the percentage of area that may be affected by flood depths of at 0.59%.

5.11 Flood Validation

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

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

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 72.

The flood validation consisted of 137 points randomly selected all over the Bacungan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.05m (FIgure 73). Table 33 shows a contingency matrix of the comparison.

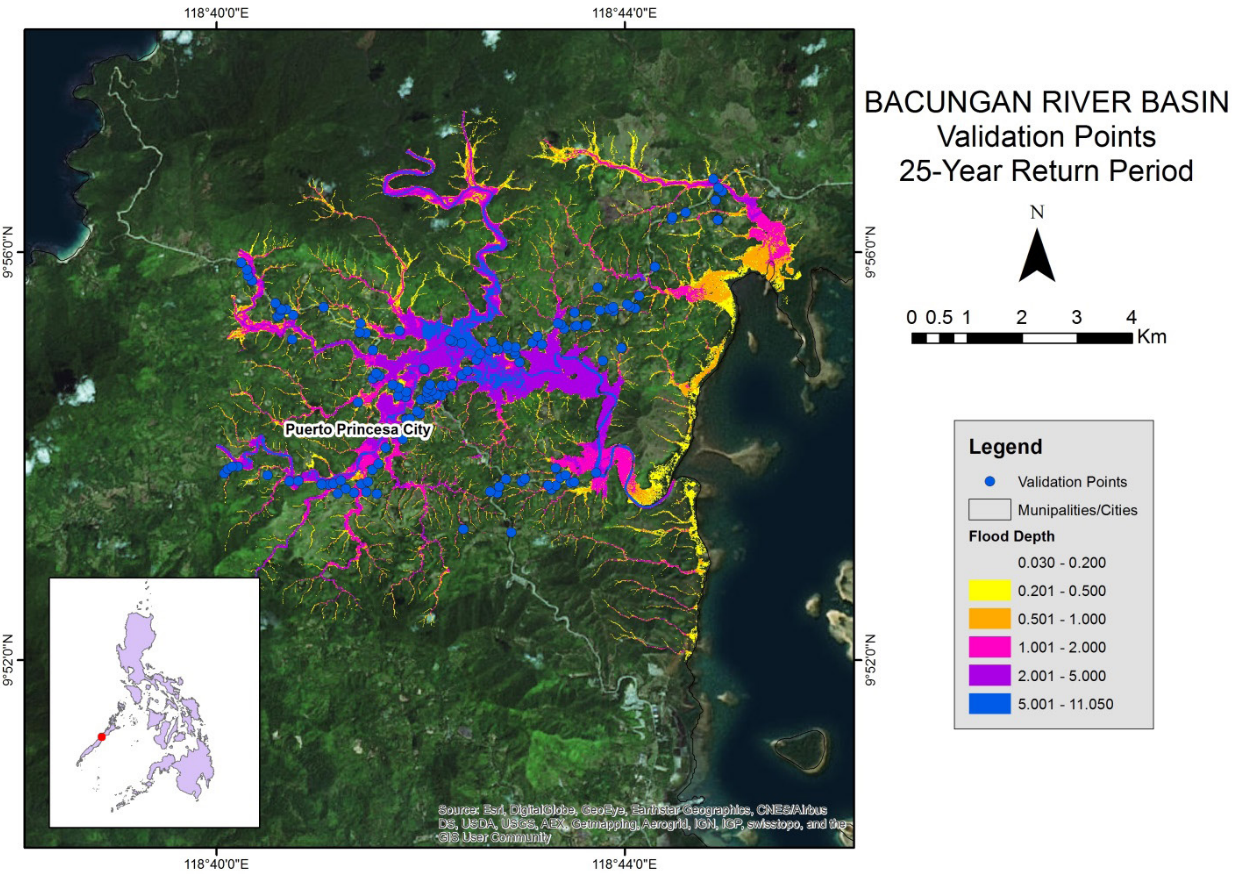


Figure 72. Validation points for 25-year Flood Depth Map of Bacungan Floodplain

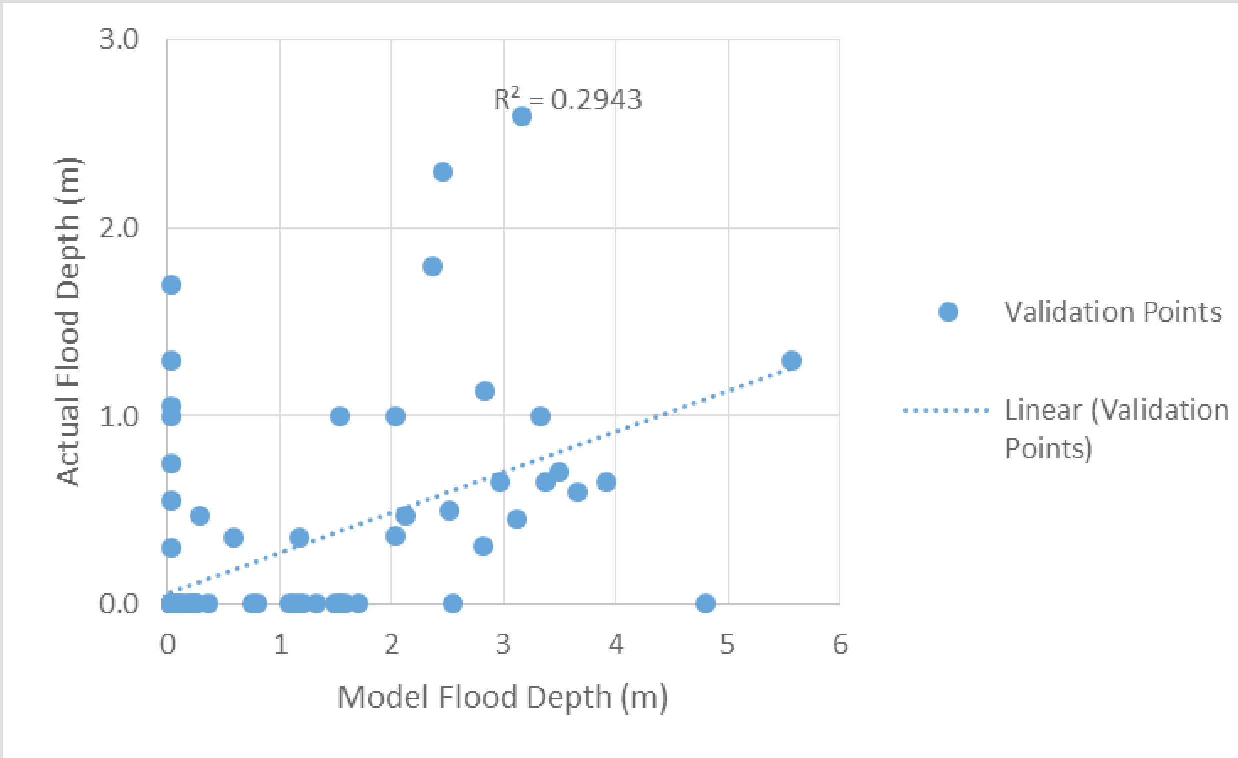


Figure 73. Flood map depth vs. actual flood depth

Table 33. Actual flood vs simulated flood depth at different levels in the Bacungan 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	91	4	2	10	2	0	109
0.21-0.50	1	1	1	1	5	0	9
0.51-1.00	3	0	0	1	7	0	11
1.01-2.00	3	0	0	0	2	1	6
2.01-5.00	0	0	0	0	2	0	2
> 5.00	0	0	0	0	0	0	0
Total	98	5	3	12	18	1	137

The overall accuracy generated by the flood model is estimated at 68.61% with 94 points correctly matching the actual flood depths. In addition, there were 9 points estimated one level above and below the correct flood depths while there were 14 points and 20 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 7 points were underestimated in the modelled flood depths of Bacungan. Table 34 depicts the summary of the Accuracy Assessment in the Bacungan River Basin Survey.

Table 34. Summary of the Accuracy Assessment in the Bacungan River Basin Survey

	No. of Points	%
Correct	94	68.61
Overestimated	36	26.28
Underestimated	7	5.11
Total	137	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor

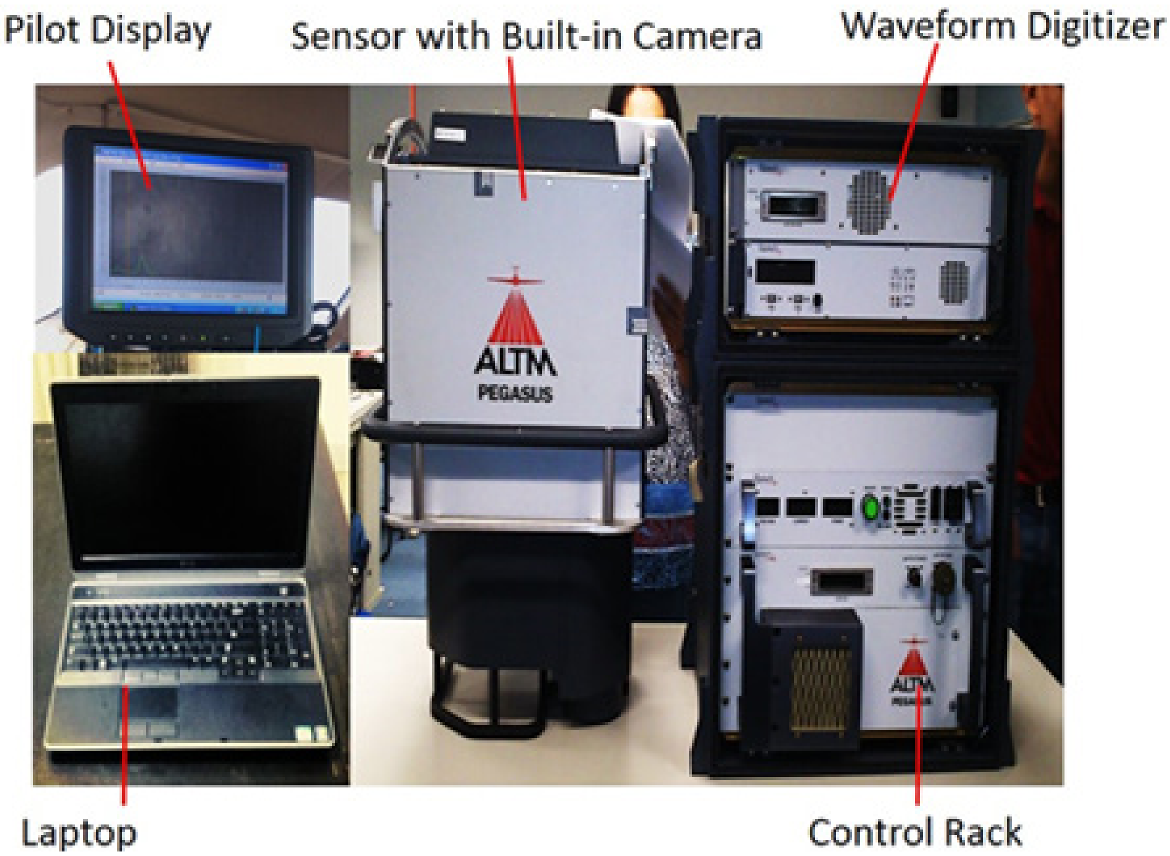


Figure A-1.1. Pegasus Sensor

Table A-1.1. Parameters and Specification of the Pegasus Sensor

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

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

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

1. PLW-34

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

June 15, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **PALAWAN**	
	Station Name: **PLW-34**	
	Order: **1st**	
Island: **LUZON**	Barangay: **STA. MONICA**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 47' 4.34346"**	Longitude: **118° 43' 50.36738"**	Ellipsoidal Hgt: **53.76200 m.**
	WGS84 Coordinates	
Latitude: **9° 46' 59.90069"**	Longitude: **118° 43' 55.68915"**	Ellipsoidal Hgt: **103.89600 m.**
	PTM / PRS92 Coordinates	
Northing: **1081910.004 m.**	Easting: **525304.737 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **1,082,009.99**	Easting: **689,825.58**	Zone: **50**

Location Description

PLW-34
From the wharf of Philippine Ports Authority in Puerto Princesa city, travel eastward on a 2 wheel drive vehicle, along Rizal street up to the National highway for 1.80 kilometers. Turn turn left, travel Northwest along the national highway for 5.50 kilometers up to the cemented road that leads to the City Hall. Turn left and travel alonf the cemented road for 0.75 kilometers up to the station. Station is located on top of the roof deck of the city Mayor's office. Station mark is 4" copper nail with cross cut on top centered in a 30 cm square cement patty, protruding about 1 cm on the semi-circle shaped concrete roofed deck of Puerto Princesa City Hall.

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8084005 I**
T.N.: **2015-1264**

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

9 9 0 6 1 5 2 0 1 5 1 3 2 3 0 3

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. PLW-34

2. PLW-50

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

June 23, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **PALAWAN**	
	Station Name: **PLW-50**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **IWAHIG**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 44' 42.16318"**	Longitude: **118° 39' 28.02050"**	Ellipsoidal Hgt: **16.81300 m.**
	WGS84 Coordinates	
Latitude: **9° 44' 37.72390"**	Longitude: **118° 39' 33.34598"**	Ellipsoidal Hgt: **66.85300 m.**
	PTM / PRS92 Coordinates	
Northing: **1077537.527 m.**	Easting: **517311.956 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **1,077,601.73**	Easting: **681,851.72**	Zone: **50**

Location Description

PLW-50
From Puerto Princesa City Proper, travel along the National Highway S bound, until reaching Iwahig Penal Farm at about 15 km. The station is located inside the vicinity of Iwahig Penal Farm, situated at the base of the fountain 20 m. NW of Administration Building and 50 m W of Iwahig Elem. School. Station mark is a brass plate 10" in diameter with inscription "Corps of Engineers, U.S. Army Survey control mark circle station".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8083538 I**
T.N.: **2015-1337**

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

9906232015114335

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. PLW-50

3. PLW-3026

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

June 23, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **PALAWAN**	
	Station Name: **PLW-3026**	
	Order: **3rd**	
Island: **LUZON**	Barangay: **SALVACION**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 58' 7.89691"**	Longitude: **118° 47' 3.75351"**	Ellipsoidal Hgt: **7.58909 m.**
	WGS84 Coordinates	
Latitude: **9° 58' 3.41268"**	Longitude: **118° 47' 9.05885"**	Ellipsoidal Hgt: **57.44800 m.**
	PTM / PRS92 Coordinates	
Northing: **1102299.607 m.**	Easting: **531180.701 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **1,102,427.82**	Easting: **695,610.46**	Zone: **50**

Location Description

PLW-3026
From Puerto Princesa, travel N via PPC-Roxas National Highway up to Sabang junction in Brgy. Salvacion. Station is located on the N corner of the center island. Mark is the head of 4" copper nail flushed in a cement putty 25cm x 25cm x 120cm embedded 1 m on the ground with inscriptions "PLW-3026 2007 NAMRIA."

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8083538 I**
T.N.: **2015-1338**

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

9906232015114420

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Figure A-2.3. PLW-3026

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

1. PLW-3026

Vector Components (Mark to Mark)

From:	PLW-34				
Grid		Local		Global	
Easting	689825.571 m	Latitude	N9°47'04.34346"	Latitude	N9°46'59.90069"
Northing	1082009.987 m	Longitude	E118°43'50.36738"	Longitude	E118°43'55.68915"
Elevation	53.466 m	Height	53.762 m	Height	103.896 m

To:	PLW-3026				
Grid		Local		Global	
Easting	695610.418 m	Latitude	N9°58'07.89863"	Latitude	N9°58'03.41442"
Northing	1102427.869 m	Longitude	E118°47'03.75221"	Longitude	E118°47'09.05751"
Elevation	7.024 m	Height	7.504 m	Height	57.363 m

Vector					
ΔEasting	5784.847 m	NS Fwd Azimuth	16°06'56"	ΔX	-3460.453 m
ΔNorthing	20417.882 m	Ellipsoid Dist.	21220.288 m	ΔY	-5939.795 m
ΔElevation	-46.442 m	ΔHeight	-46.258 m	ΔZ	20076.102 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Figure A-3.1. Baseline Processing Report - A

1. PLW-4011

Vector Components (Mark to Mark)

From:	PLW-34				
Grid		Local		Global	
Easting	689825.571 m	Latitude	N9°47'04.34346"	Latitude	N9°46'59.90069"
Northing	1082009.987 m	Longitude	E118°43'50.36738"	Longitude	E118°43'55.68915"
Elevation	53.466 m	Height	53.762 m	Height	103.896 m

To:	PLW-4011				
Grid		Local		Global	
Easting	707163.027 m	Latitude	N10°11'54.13011"	Latitude	N10°11'49.59791"
Northing	1127879.807 m	Longitude	E118°53'27.82551"	Longitude	E118°53'33.11019"
Elevation	3.616 m	Height	4.146 m	Height	53.754 m

Vector					
ΔEasting	17337.456 m	NS Fwd Azimuth	21°00'21"	ΔX	-11558.541 m
ΔNorthing	45869.821 m	Ellipsoid Dist.	49032.695 m	ΔY	-15476.070 m
ΔElevation	-49.850 m	ΔHeight	-49.616 m	ΔZ	45067.770 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Figure A-3.2. Baseline Processing Report - B

3. PL-92

Vector Components (Mark to Mark)

From:	PLW 50				
Grid		Local		Global	
Easting	23307.331 m	Latitude	N9°44'42.16318"	Latitude	N9°44'37.72390"
Northing	1080218.190 m	Longitude	E118°39'28.02050"	Longitude	E118°39'33.34598"
Elevation	16.338 m	Height	16.813 m	Height	66.853 m

To:	PL 92				
Grid		Local		Global	
Easting	26049.752 m	Latitude	N9°44'04.01581"	Latitude	N9°43'59.58138"
Northing	1079008.192 m	Longitude	E118°40'58.28065"	Longitude	E118°41'03.60701"
Elevation	7.859 m	Height	8.218 m	Height	58.344 m

Vector					
ΔEasting	2742.421 m	NS Fwd Azimuth	113°04'19"	ΔX	-2504.878 m
ΔNorthing	-1209.998 m	Ellipsoid Dist.	2990.326 m	ΔY	-1153.405 m
ΔElevation	-8.479 m	ΔHeight	-8.595 m	ΔZ	-1156.451 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.002 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Figure A-3.3. Baseline Processing Report - C

4. PPC-1

Vector Components (Mark to Mark)

From:	PLW-34				
Grid		Local		Global	
Easting	689825.571 m	Latitude	N9°47'04.34346"	Latitude	N9°46'59.90069"
Northing	1082009.987 m	Longitude	E118°43'50.36738"	Longitude	E118°43'55.68915"
Elevation	53.466 m	Height	53.762 m	Height	103.896 m

To:	PPC-1				
Grid		Local		Global	
Easting	707137.228 m	Latitude	N10°11'54.83823"	Latitude	N10°11'50.30596"
Northing	1127901.415 m	Longitude	E118°53'26.98215"	Longitude	E118°53'32.26682"
Elevation	3.473 m	Height	4.002 m	Height	53.609 m

Vector					
ΔEasting	17311.657 m	NS Fwd Azimuth	20°58'07"	ΔX	-11534.136 m
ΔNorthing	45891.429 m	Ellipsoid Dist.	49043.798 m	ΔY	-15467.164 m
ΔElevation	-49.993 m	ΔHeight	-49.760 m	ΔZ	45089.156 m

Standard Errors

Vector errors:					
σ ΔEasting	0.017 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.024 m
σ ΔNorthing	0.013 m	σ Ellipsoid Dist.	0.018 m	σ ΔY	0.010 m
σ ΔElevation	0.022 m	σ ΔHeight	0.022 m	σ ΔZ	0.017 m

Figure A-3.4. Baseline Processing Report - D

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, DR.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader - I</td><td>ENGR. LOUIE P. BALICANTA</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
</table>

FIELD TEAM

<table>
<tr><td rowspan="3">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>JASMINE ALVIAR</td><td>UP-TCAGP</td></tr>
<tr><td>Research Associate (RA)</td><td>ENGR. GRACE SINADJAN</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. LARAH KRISELLE PARAGAS</td><td>UP-TCAGP</td></tr>
<tr><td>Ground Survey, Data Download and Transfer</td><td>RA</td><td>JERIEL PAUL ALAMBAN, GEOL.</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="4">LiDAR Operation</td><td>Airborne Security</td><td>SSG PRADYUMNA DAS RAMIREZ</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="3">Pilot</td><td>CAPT. MARK LAWRENCE TANGONAN</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. JUSTIN JOYA</td><td>AAC</td></tr>
<tr><td>CAPT. RANDY LAGCO</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheet for Bacungan Floodplain

DATA TRANSFER SHEET
6/23/2015(West Palawan)

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	
30-May	2989P	1BLK42E150A	PEGASUS	2.9	NA	9.95	263	55	409	31.5	73.2	4.97	1KB	1KB	101/74/56/79/98/228	na	Z:\DAC\RAW DATA
4-Jun	3009P	1BLK42F155A	PEGASUS	1.63	1235	5.12	166	4.27/20.2	32/154	15.3	na	4.68	1KB	1KB	41/40/76/51	na	Z:\DAC\RAW DATA
6-Jun	3017A	1BLK42A157A	PEGASUS	1.17	334	9.56	256	55.8	400	23.2	na	14.2	1KB	1KB	41/72/40/76/51/37/61	na	Z:\DAC\RAW DATA
7-Jun	3021P	1BLK42BD158A	PEGASUS	580	1082	5.28	139	24.7	193	11.9	na	12.1	1KB	1KB	75/89/32	na	Z:\DAC\RAW DATA
7-Jun	3023P	1BLK42BCAL158B	PEGASUS	1.14	1368	9.2	249	37.4	303	21.9	na	15.1	1KB	1KB	32	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name JONMEK MEDINA
Position SENIOR SRS
Signature 6/23/2015

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

DATA TRANSFER SHEET
7/2/2015(palawan+catarman)

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	
8-Jun-15	3025P	1BLK42GH159A	Pegasus	1.04	1395	7.46	187	33.9	246	15.1	NA	7.06	1KB	1KB	14/28	na	Z:\DAC\RAW DATA
8-Jun-15	3027P	1BLK42FS159B	Pegasus	652	175	5.26	133	16.8	146	13.5	30.2	5.15	1KB	1KB	24	na	Z:\DAC\RAW DATA
11-Jun	3037P	1BLK42IJ162A	Pegasus	1.63	na	13.1	217	45.3	359	31.8	21.7	1.05	1KB	1KB	37/71	na	Z:\DAC\RAW DATA
11-Jun	3039P	1BLK42J162B	Pegasus	966	na	7.85	167	20.4	140/57	17.5	47.5	3.9	1KB	1KB	37/62/65/71	na	Z:\DAC\RAW DATA
12-Jun	3041P	1BLK42B163A	Pegasus	563	na	5.68	122	17	129	11.5	na	8.33	1KB	1KB	30	na	Z:\DAC\RAW DATA
13-Jun	3045P	1BLK42BS164A	Pegasus	589	na	6.01	144	15.7	116	10.5	na	7.09	1KB	1KB	32	na	Z:\DAC\RAW DATA
13-Jun	3047P	1BLK42Aa164B	Pegasus	1.4	na	10.9	221	53.5	434	19.6	73	3.69	1KB	1KB	114	na	Z:\DAC\RAW DATA
17-Jun	3061P	1BLK42Ab168A	Pegasus	1.3	na	10.7	205	39.9	105/152/54	24.4	na	5.03	1KB	1KB	59/66/55	na	Z:\DAC\RAW DATA
* 21-Feb	7814AC	3BLK331I052A	Aquarius	NA	34	81.5	55.1	9.53	31.1/72.5	1.68	na	3.66	1KB	1KB	4	NA	Z:\DAC\RAW DATA

* CATARMAN FLIGHT

Received from
Name: C. JOAQUIN
Position: RA
Signature:

Received by
Name: JOIDA PRIETO 7/13/15
Position: SSRS
Signature:

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

DATA TRANSFER SHEET
8/3/2015(palawan)

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	
14-Jun-15	3049P	1BLK42S165A	Pegasus	969	na	7	162	31	252	18.3	29.3	16.3	1KB	1KB	70/67	na	Z:\DAC\RAW DATA
20-Jun-15	3073P	1BLK42S171A	Pegasus	361	na	3.65	107	12.3	88	7.1	NA	4.15	1KB	1KB	92	na	Z:\DAC\RAW DATA
7-Jul	3141P	1BLK42QRT188A	Pegasus	1.84	na	11.6	256	2.11	15/20/9/1	35.5	108	8.43	1KB	1KB	95	na	Z:\DAC\RAW DATA
8-Jul	3145P	1BLK42QRT189A	Pegasus	752	na	5.41	124	184	101	14.8	NA	11.9	1KB	1KB	176/95	na	Z:\DAC\RAW DATA
11-Jul	3157P	1BLK42PO192A	Pegasus	2.29	na	13	279	35.2	369	43.3	113	20.6	1KB	1KB	206	na	Z:\DAC\RAW DATA
11-Jul	3159P	1BLK42PO192B	Pegasus	1.11	na	8.95	199	55.5	1	21.6	25.9	20.6	1KB	1KB	NA	na	Z:\DAC\RAW DATA
12-Jul	3161P	1BLK42LM193A	Pegasus	1.51	427/407	9.62	214	41.7	359	28.8	67.6	4.29	1KB	1KB	215	na	Z:\DAC\RAW DATA
13-Jul	3165P	1BLK42LM194A	Pegasus	1.5	na	10.5	255	36.4	295	28.9	na	11.5	1KB	1KB	na	na	Z:\DAC\RAW DATA
13-Jul	3167P	1BLK42JS194B	Pegasus	329	na	3.65	106	4.93	2	7.36	11	11.5	1KB	1KB	106/123	NA	Z:\DAC\RAW DATA
15-Jul	3173P	1BLK42KS196A	Pegasus	160	96/28	2.73	63.2	na	na	3.33	7.6	1.19	1KB	1KB	11	NA	Z:\DAC\RAW DATA

Received from

Name [illegible]
Position KA
Signature [illegible]

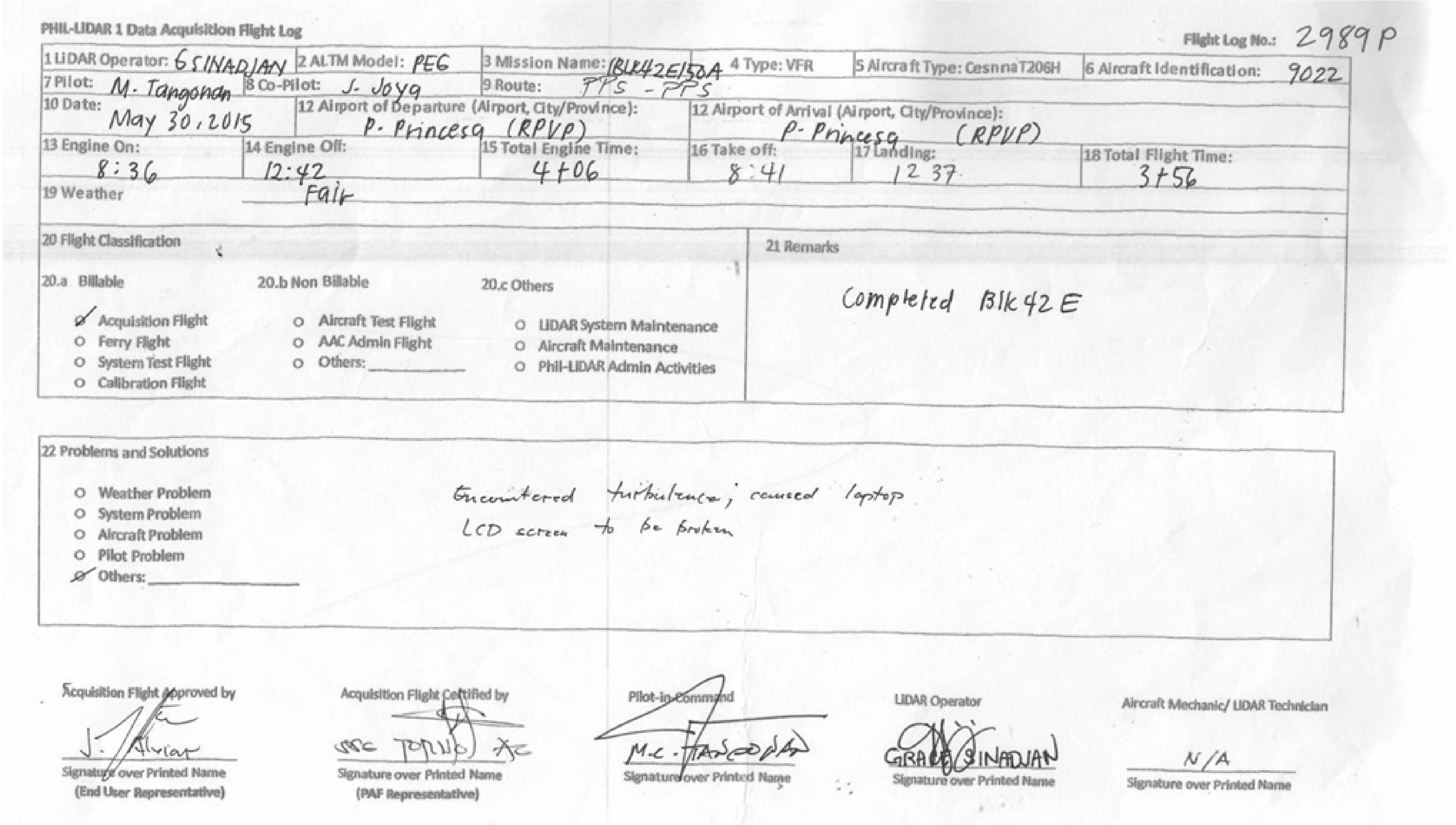
Received by

Name AC Bongat
Position SSRS
Signature [illegible] 8/5/2015

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 2989P


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2989P

1 LiDAR Operator: G SINADJAN	2 ALTM Model: PEG	3 Mission Name: 1BLK42E150A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Joya	9 Route: PPS - PPS			
10 Date: May 30, 2015	12 Airport of Departure (Airport, City/Province): P. Princesa (RPVP)		12 Airport of Arrival (Airport, City/Province): P. Princesa (RPVP)		
13 Engine On: 8:36	14 Engine Off: 12:42	15 Total Engine Time: 4+06	16 Take off: 8:41	17 Landing: 12 37	18 Total Flight Time: 3+56
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed Blk 42 E

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

Encountered turbulence; caused laptop LCD screen to be broken

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Alviar	[illegible]	M.C. Tangonan	GRACE SINADJAN	N/A
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-6.1. Flight Log for Mission 2989P

2. Flight Log for 3017P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3017P

1 LIDAR Operator: J. Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK42A157A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Joyo	9 Route:			
10 Date: 6-6-15	12 Airport of Departure (Airport, City/Province): RPVP		12 Airport of Arrival (Airport, City/Province): RPVP		
13 Engine On: 9:14	14 Engine Off: 1337	15 Total Engine Time: 4+23	16 Take off: 9:19	17 Landing: 13+32	18 Total Flight Time: 4+13
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed Blk42A

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

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

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

Pilot-in-Command: [signature] Signature over Printed Name

LIDAR Operator: [signature] Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: N/A Signature over Printed Name

Figure A-6.2. Flight Log for Mission 3017P

3. Flight Log for 3021P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3021P

1 LiDAR Operator: J.Alviar	2 ALTM Model: Peg	3 Mission Name: 1BLK42BD158A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M.Tangonan	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 6-7-15	12 Airport of Departure (Airport, City/Province): RPVP		12 Airport of Arrival (Airport, City/Province): RPVP		
13 Engine On: 6+52	14 Engine Off: 9+19	15 Total Engine Time: 2+27	16 Take off: 6+57	17 Landing: 9+14	18 Total Flight Time: 2+17
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

Completed BLK42B and BLK42D

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/ LIDAR Technician
Jasmine Alviar	SSG TOLUIO AG	M.L. TANGONAN	Jasmine Alviar	N/A
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-6.3. Flight Log for Mission 3021P

4. Flight Log for 3023P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3023P

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42BCAL158B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route:			
10 Date: 6-7-15	12 Airport of Departure (Airport, City/Province): RPVP		12 Airport of Arrival (Airport, City/Province): RPVP		
13 Engine On: 14+18	14 Engine Off: 18+7	15 Total Engine Time: 3+49	16 Take off: 14+23	17 Landing: 18+02	18 Total Flight Time: 3+39
19 Weather	Partly Cloudy				

20 Flight Classification

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

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

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

21 Remarks

Completed the rest of Blk42B, LMS and calibration of camera

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	SSC [illegible] Signature over Printed Name (PAF Representative)	M.L. TANGONAN Signature over Printed Name	GRACE SINADJAN Signature over Printed Name	N/A Signature over Printed Name

Figure A-6.4. Flight Log for Mission 3023P

5. Flight Log for 3045P Mission

Flight Log No.: 3045P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: J Almar
2 ALTM Model: PEG
3 Mission Name: 1BLK42BS164A
4 Type: VFR
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9022
7 Pilot: M Tangonan
8 Co-Pilot: J Joya
9 Route:
10 Date: 6-13-15
12 Airport of Departure (Airport, City/Province): RPVP
12 Airport of Arrival (Airport, City/Province): RPVP
13 Engine On: 6:30
14 Engine Off: 8:57
15 Total Engine Time: 2+27
16 Take off: 6:35
17 Landing: 8:52
18 Total Flight Time: 2+17
19 Weather: Cloudy

20 Flight Classification

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

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

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

21 Remarks

Supplementary flight for Blk 42B
No Digitizer Data

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

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

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

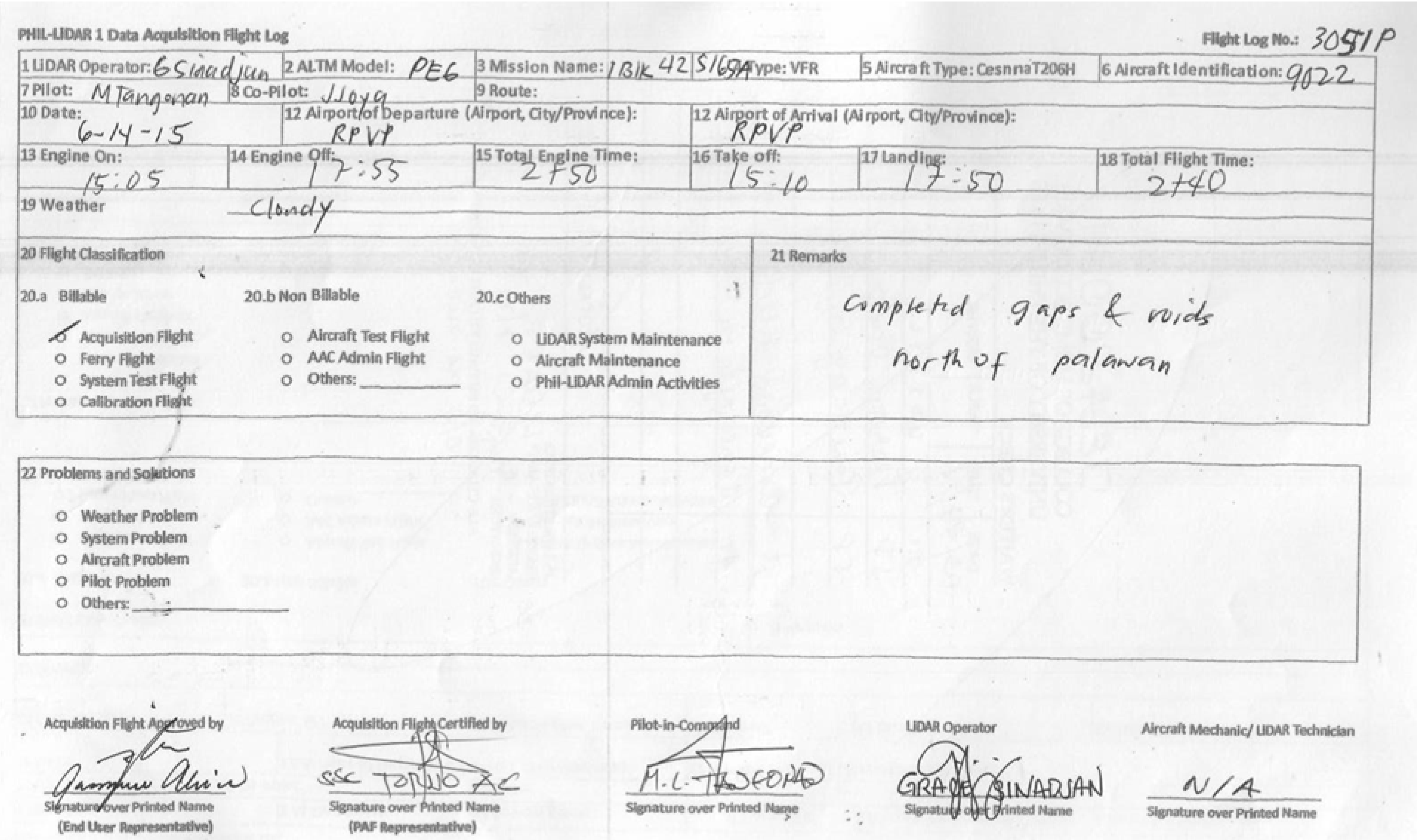
Pilot-in-Command: M.C. Tangonan — Signature over Printed Name

LIDAR Operator: Jasmine Alviar — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: N/A — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3045P

6. Flight Log for3051P Mission (For Mission 3049P)



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3051P

1 LiDAR Operator: G Sinadjan	2 ALTM Model: PEG	3 Mission Name: 1BLK42S169A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Loyo	9 Route:			
10 Date: 6-14-15	12 Airport of Departure (Airport, City/Province): RPVP		12 Airport of Arrival (Airport, City/Province): RPVP		
13 Engine On: 15:05	14 Engine Off: 17:55	15 Total Engine Time: 2+50	16 Take off: 15:10	17 Landing: 17:50	18 Total Flight Time: 2+40
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

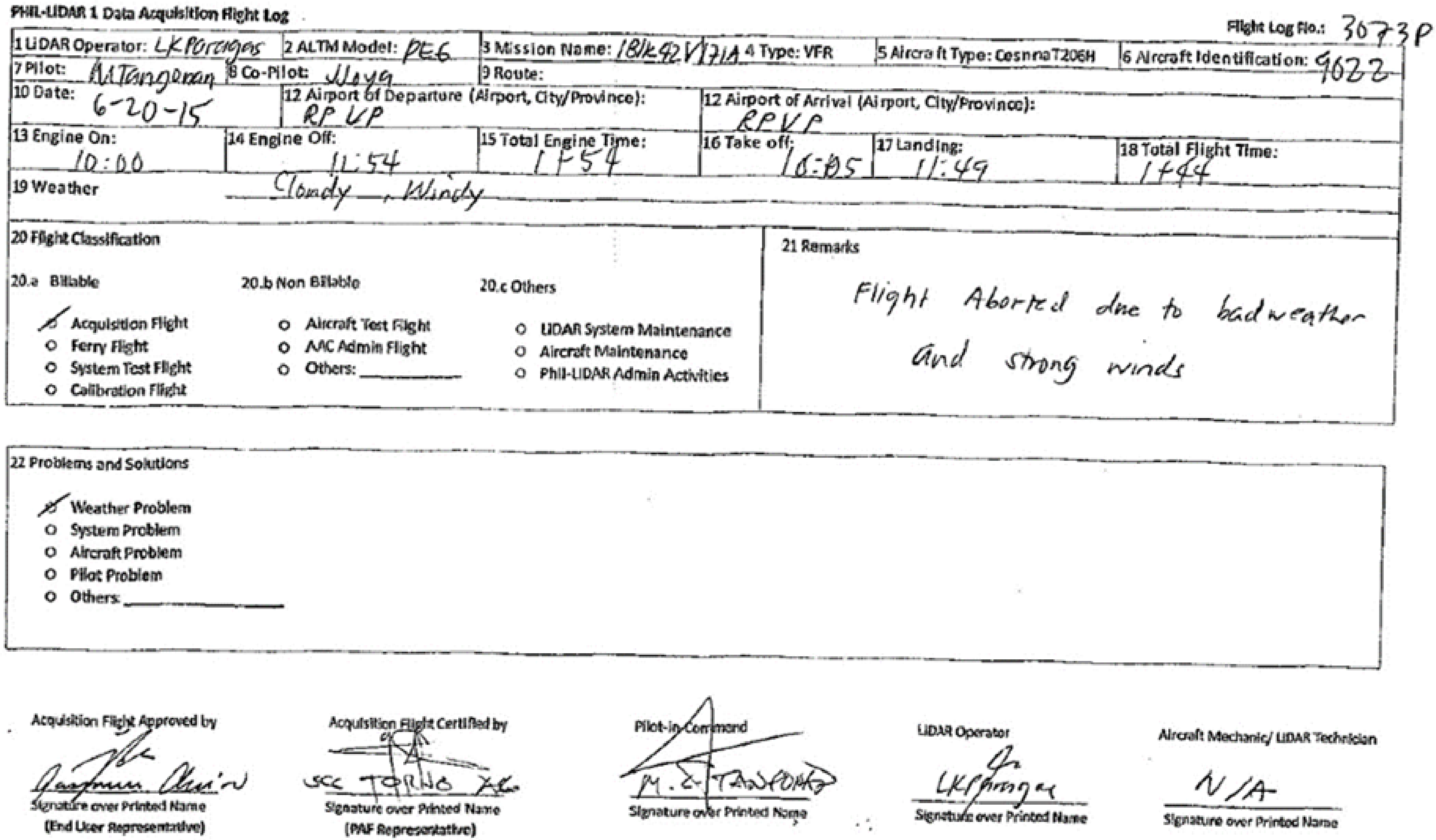
Completed gaps & voids north of palawan

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	SSC TORIJO AC	M.L. TANGONAN	GRACE SINADJAN	N/A
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-6.6. Flight Log for Mission 3051P (For Mission 3049P)

7. Flight Log for 3073P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3073P

1 LIDAR Operator: LK Paragas	2 ALTM Model: PEG	3 Mission Name: 1BLK42V171A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Maya	9 Route:			
10 Date: 6-20-15	12 Airport of Departure (Airport, City/Province): RPUP		12 Airport of Arrival (Airport, City/Province): RPVP		
13 Engine On: 10:00	14 Engine Off: 11:54	15 Total Engine Time: 1+54	16 Take off: 10:05	17 Landing: 11:49	18 Total Flight Time: 1+44
19 Weather	Cloudy, Windy				

20 Flight Classification

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

20.b Non Billable
- ○ Aircraft Test Flight
- ○ A/C Admin Flight
- ○ Others: ____________

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

21 Remarks

Flight Aborted due to bad weather and strong winds

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/ LIDAR Technician
[signature]	SSC TORNO XX	M. E. TANGONAN	LK Paragas	N/A
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-6.7. Flight Log for Mission 3073P

Annex 7. Flight Status Reports

PALAWAN
May 30, 2015 – June 20, 2015

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2989P	BLK 42E	1BLK42E150A	G. Sinadjan	May 30, 2015	Data Acquired In Blk 42E
3017P	BLK 42A	1BLK42A157A	J Alviar	June 6, 2015	Data acquired in blk 42a 175.55 sq.km
3021P	BLK 42BD	1BLK42BD158A	J Alviar	June 7, 2015	Data acquired; too cloudy in survey areas 118.57 sq.km
3023P	BLK 42BE	1BLK42BCAL158B	G Sinadjan	June 7, 2015	Mission completed; lms and camera calib also conducted 143.49 sq.km
3045P	BLK 42BS	1BLK42BS164A	J Alviar	June 13, 2015	Surveyed blk 42b voids, too cloudy 117.78 sq.km
3049P	BLK 42E, F	1BLK42S165A	G. Sinadjan	June 14, 2015	Covered Voids In Blk 42E And Blk 42F; Surveyed Inagauan Floodplain, East Coast
3073P	BLK 42B, D	1BLK42S171A	L Paragas	June 20, 2015	Surveyed voids in blk 42b and blk 42d; very cloudy 69.08 sq.km

LAS/SWATH PER FLIGHT MISSION

Flight No. :	2898P	
Area:	BLK 42E	
Mission Name:	1BLK42E150A	
Parameters:	Altitude: 1100	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

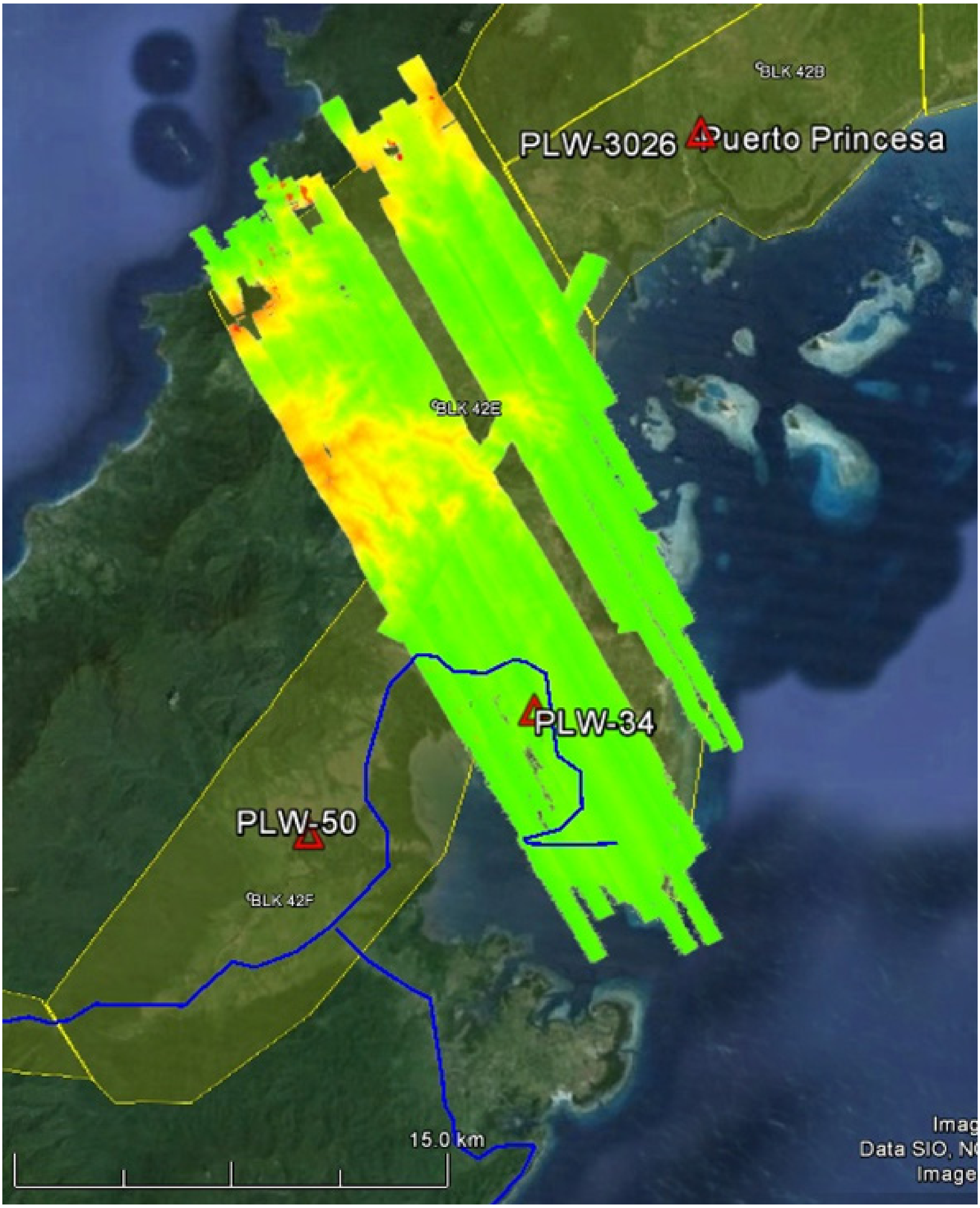


Figure A-7.1. Swath for Flight No. 2898P

Flight No. :	3017P	
Area:	BLK 42A	
Mission Name:	1BLK42A157A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

Figure A-7.2. Swath for Flight No. 3017P

Flight No. :	3021P	
Area:	BLK 42BD	
Mission Name:	1BLK42BD158A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

Figure A-7.3. Swath for Flight No. 3021P

Flight No. :	3023P	
Area:	BLK 42BE	
Mission Name:	1BLK42BCALIB158B	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

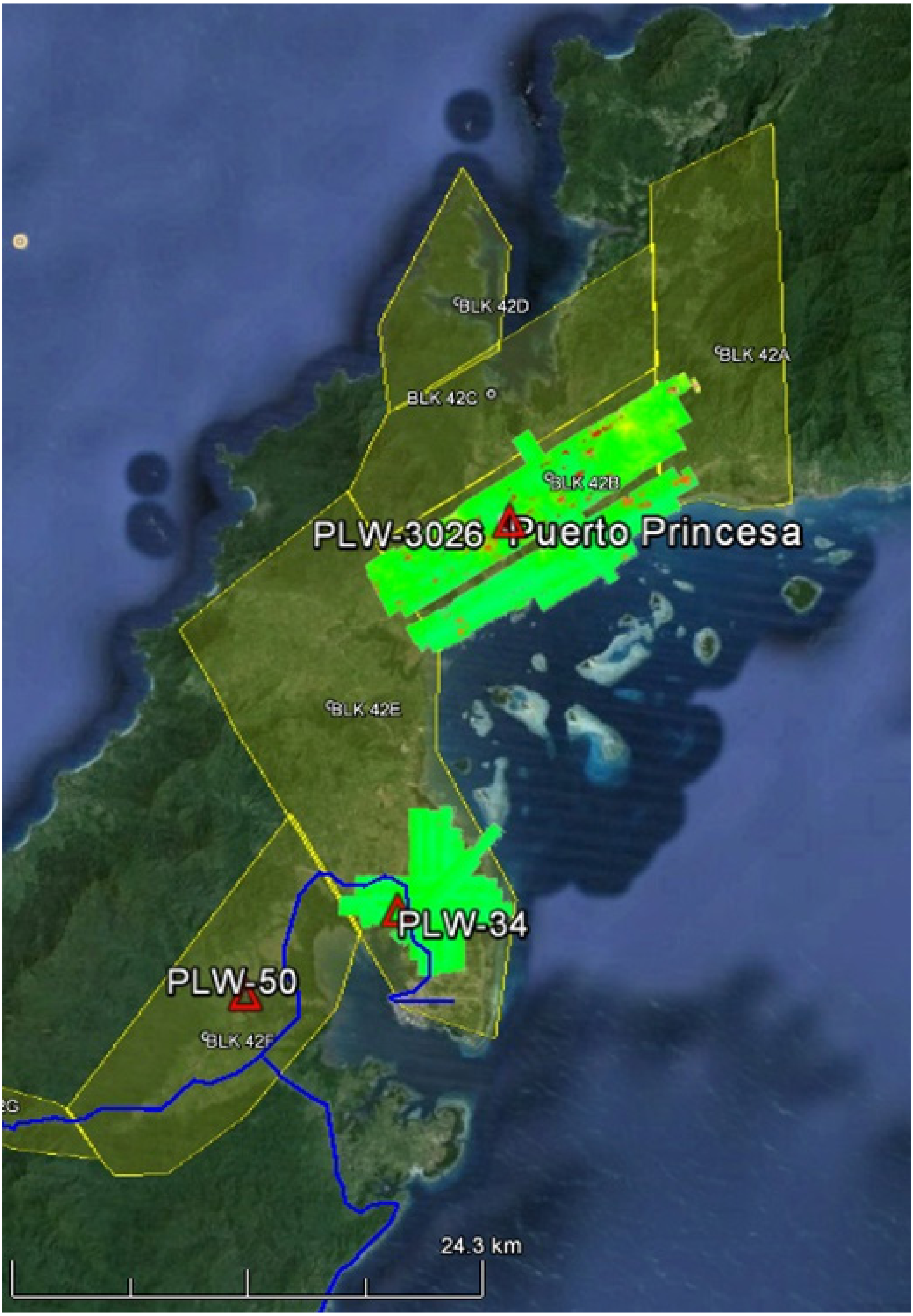


Figure A-7.4. Swath for Flight No. 3023P

Flight No. :	3045P	
Area:	BLK 42BS	
Mission Name:	1BLK42BS164A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

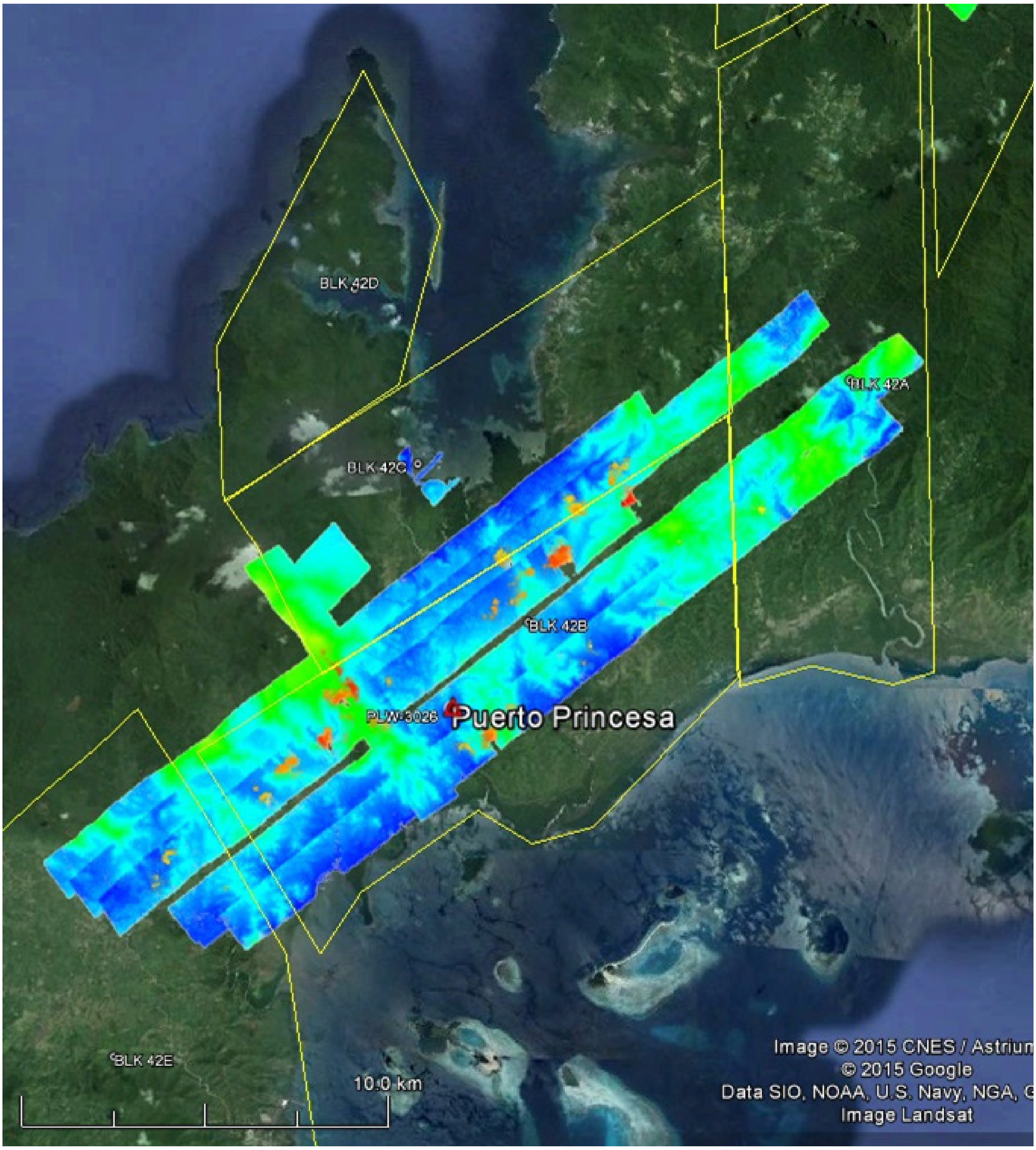


Figure A-7.5. Swath for Flight No. 3045P

Flight No. :	3049P	
Area:	BLK 42E and BLK 42F	
Mission Name:	1BLK42S165A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

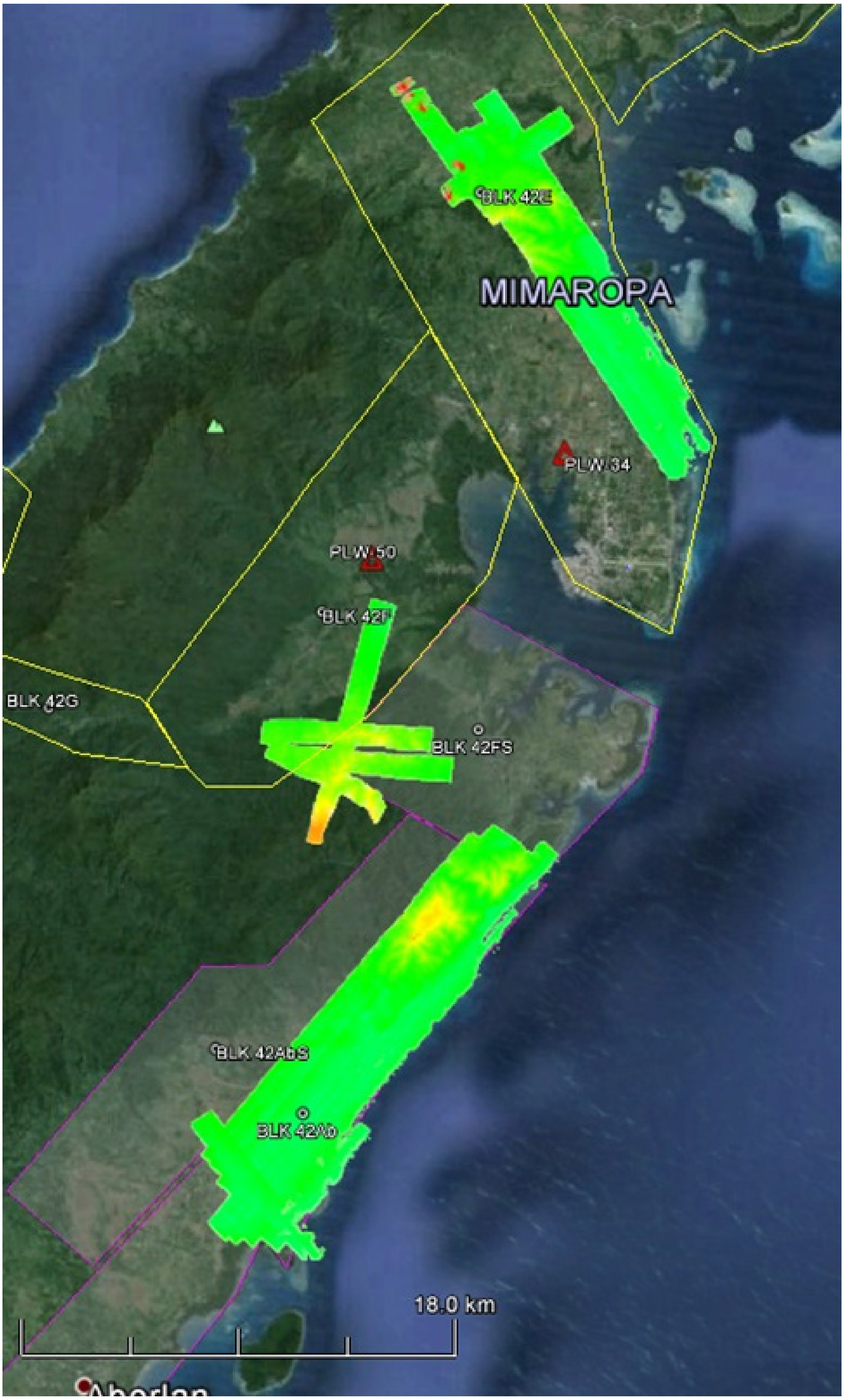


Figure A-7.6. Swath for Flight No. 3049P

Flight No. :	3073P	
Area:	BLK 42B, BLK 42D	
Mission Name:	1BLK42S171A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

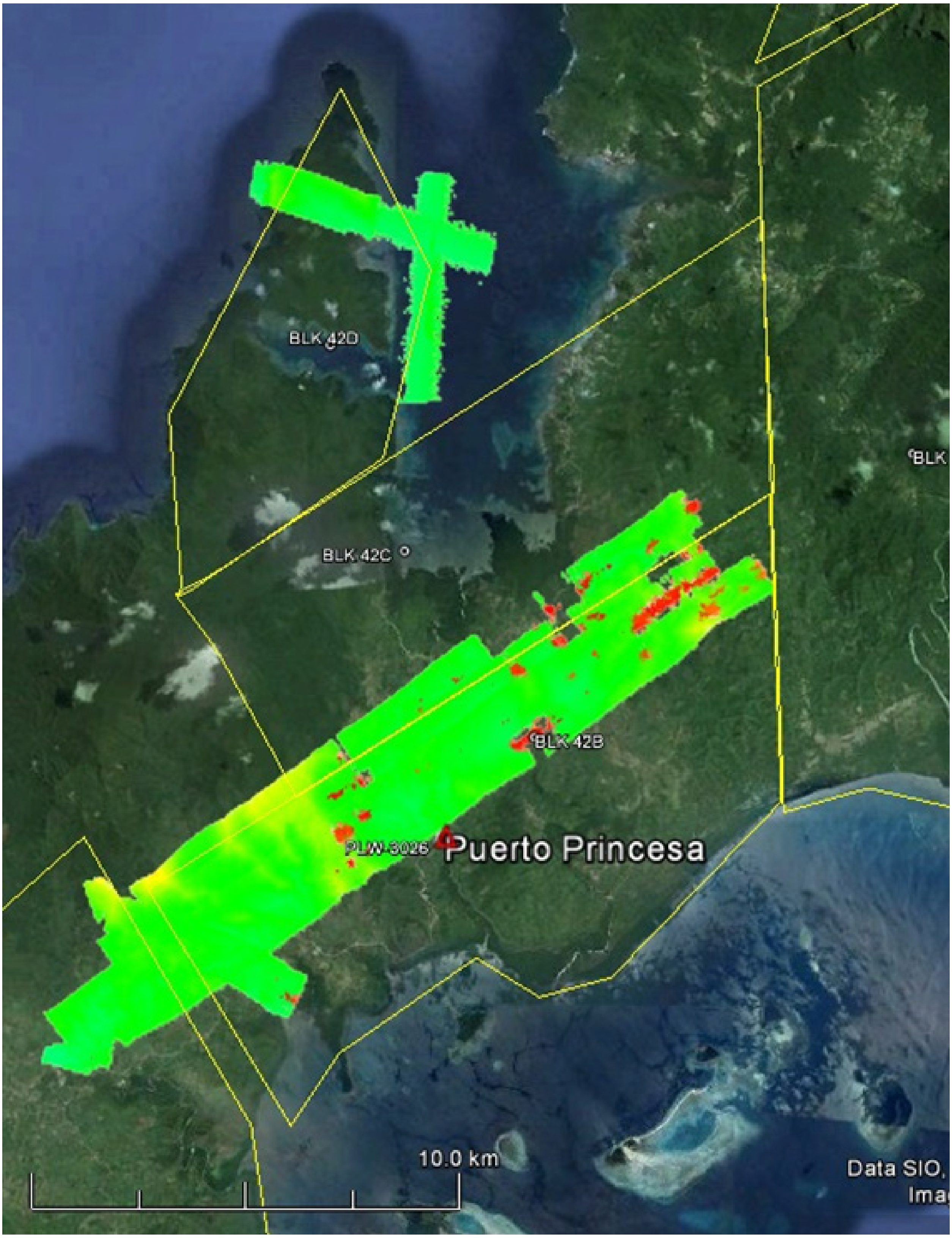


Figure A-7.7. Swath for Flight No. 3073P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk 42B

Flight Area	West Palawan
Mission Name	Blk 42B
Inclusive Flights	3021P & 3023P
Range data size	33.80 GB
POS	388 MB
Image	62.10 GB
Transfer date	June 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.15
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	2.70
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.0.003542
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	61.51
Ave point cloud density per sq.m. (>2.0)	4.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	187
Maximum Height	531.87 m
Minimum Height	51.45 m
Classification (# of points)	
Ground	127,193,781
Low vegetation	117,846,397
Medium vegetation	277,341,672
High vegetation	665,966,968
Building	3,365,152
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Jennifer Saguran, Aljon Rei Araneta, Engr. Mark Sueden Lyle Magtalas

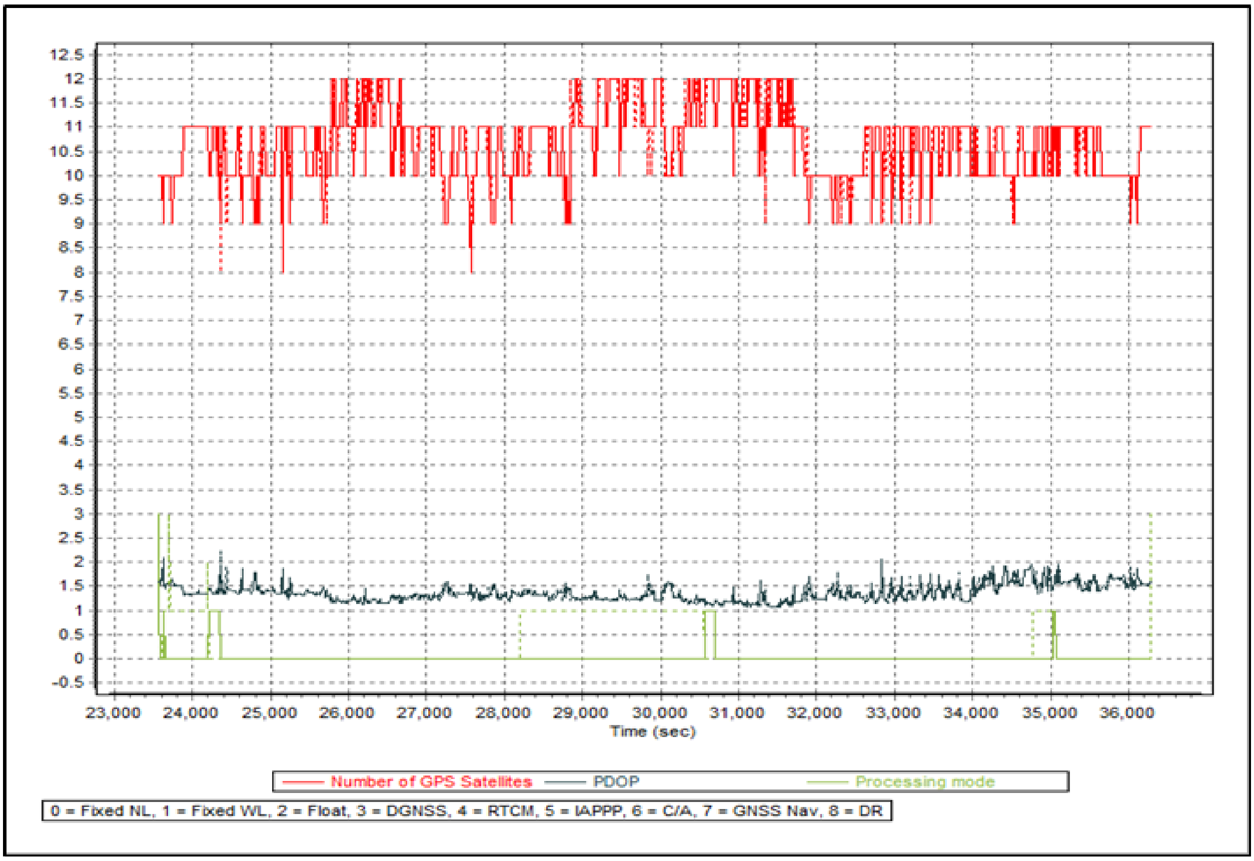


Figure A-8.1. Solution Status

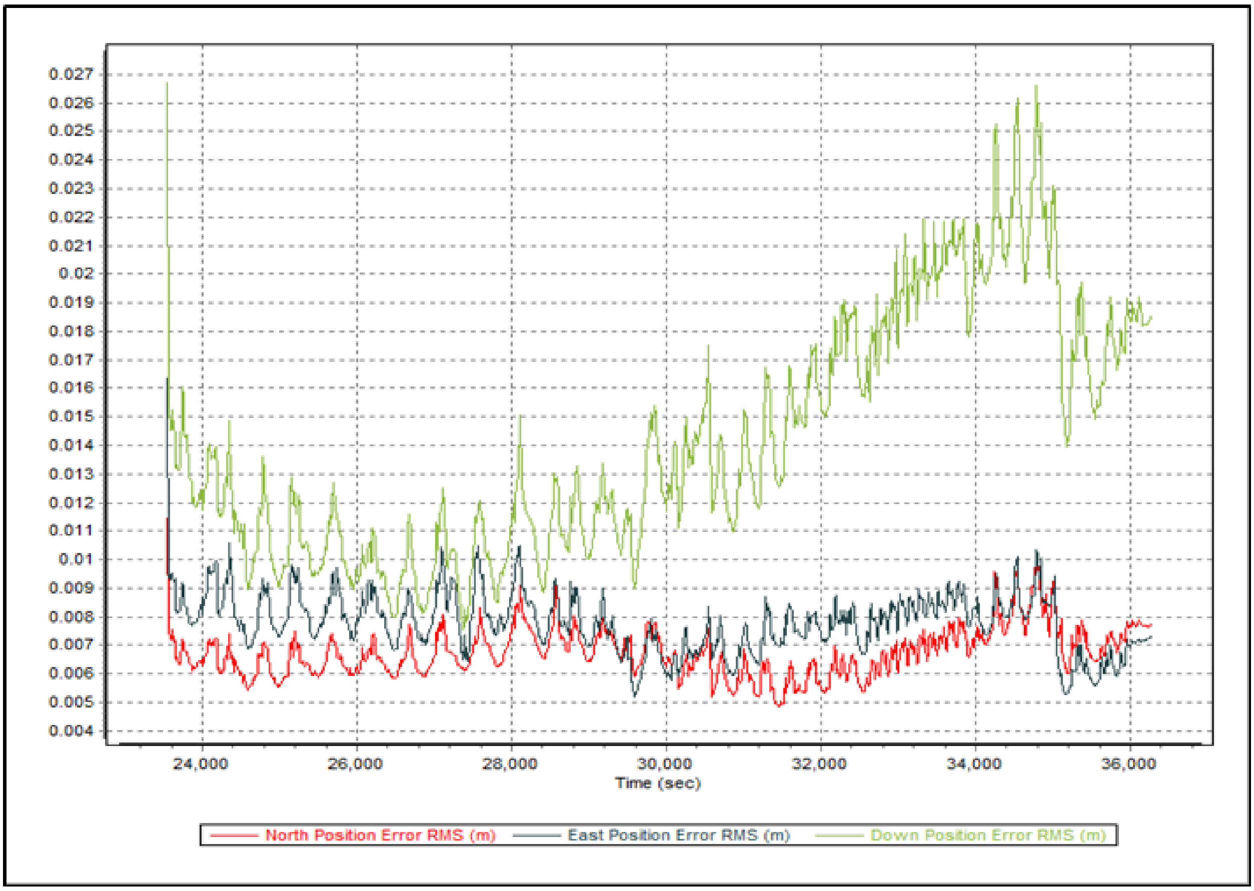


Figure A-8.2. Smoothed Performance Metrics Parameters

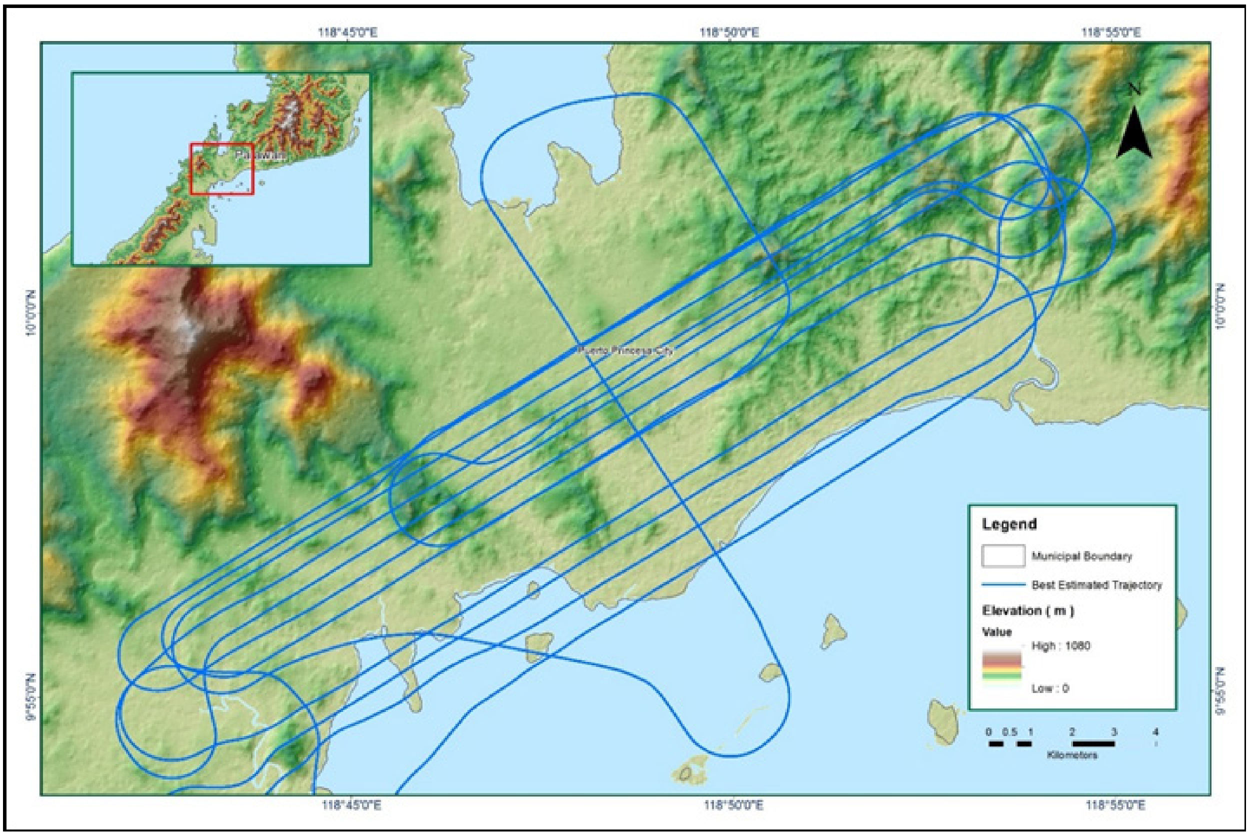


Figure A-8.3. Best Estimated Trajectory

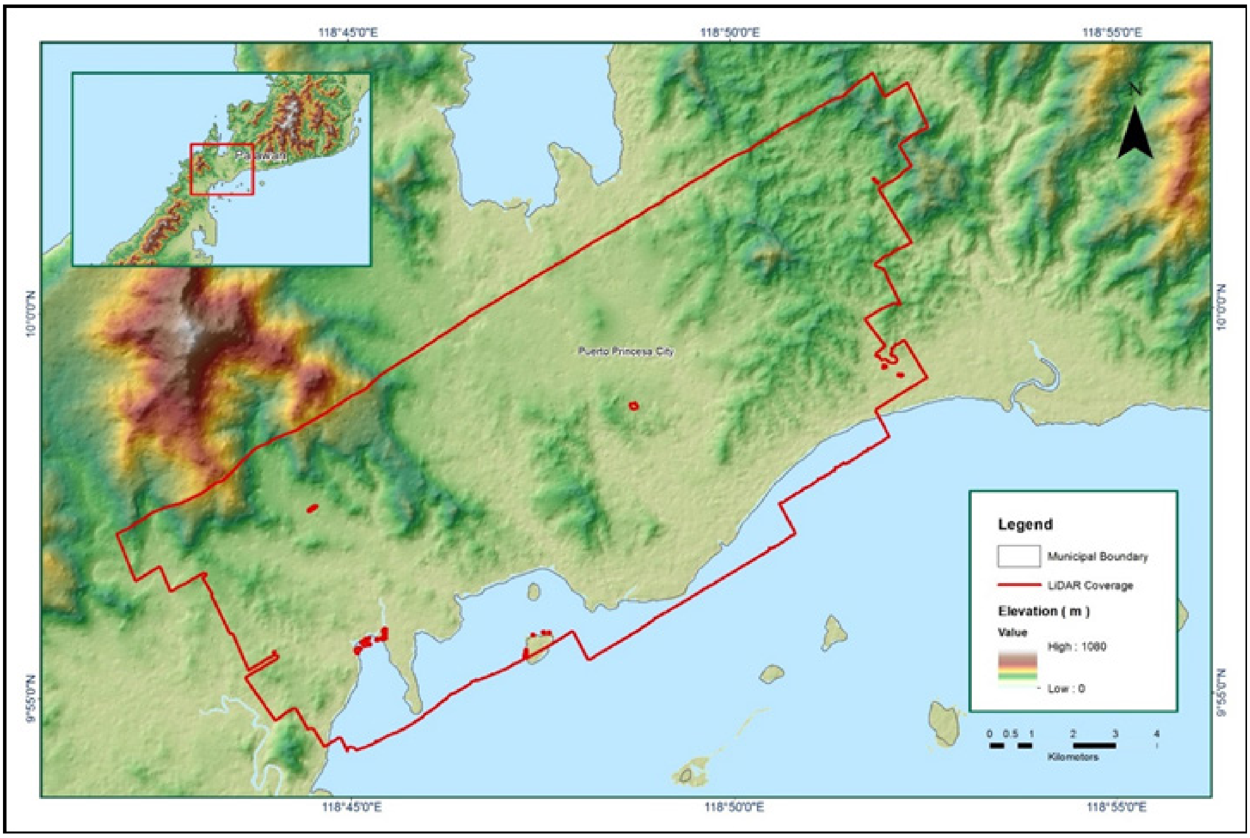


Figure A-8.4. Coverage of LiDAR data

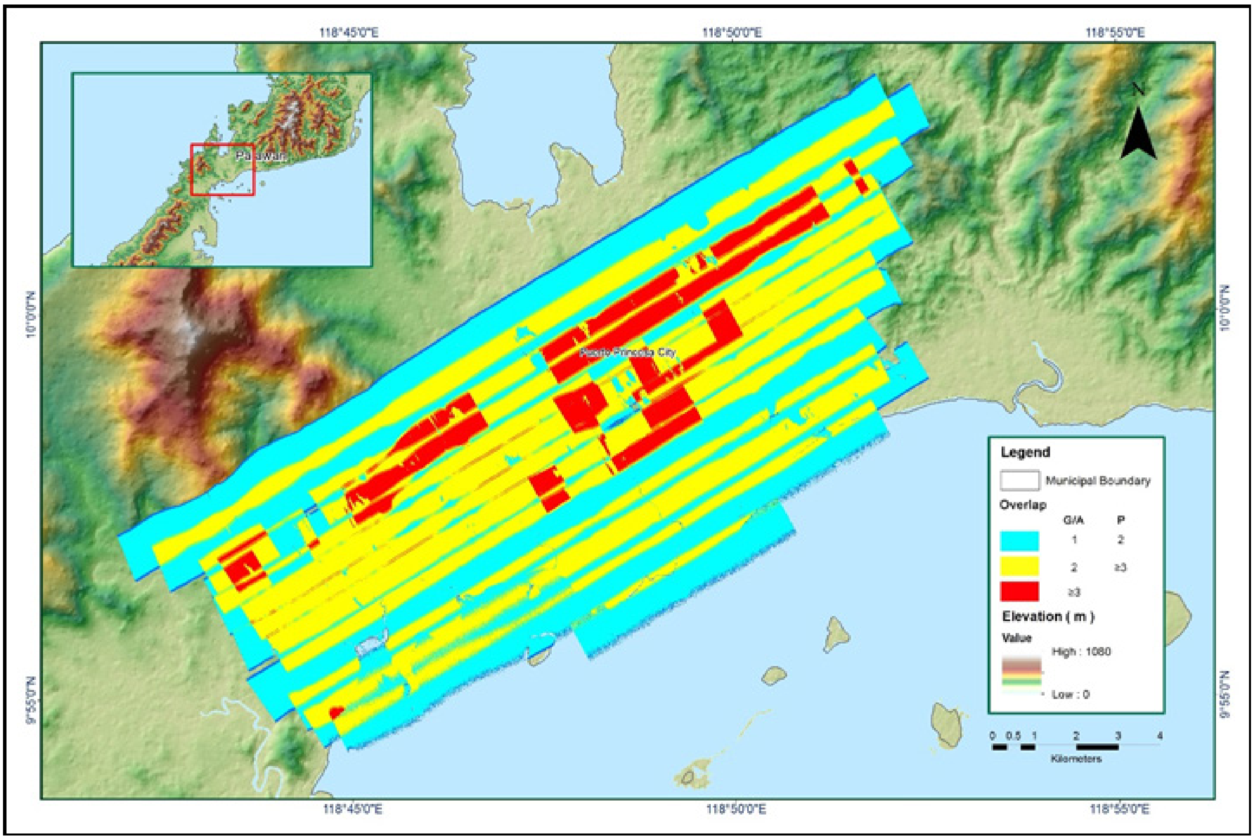


Figure A-8.5. Image of Data Overlap

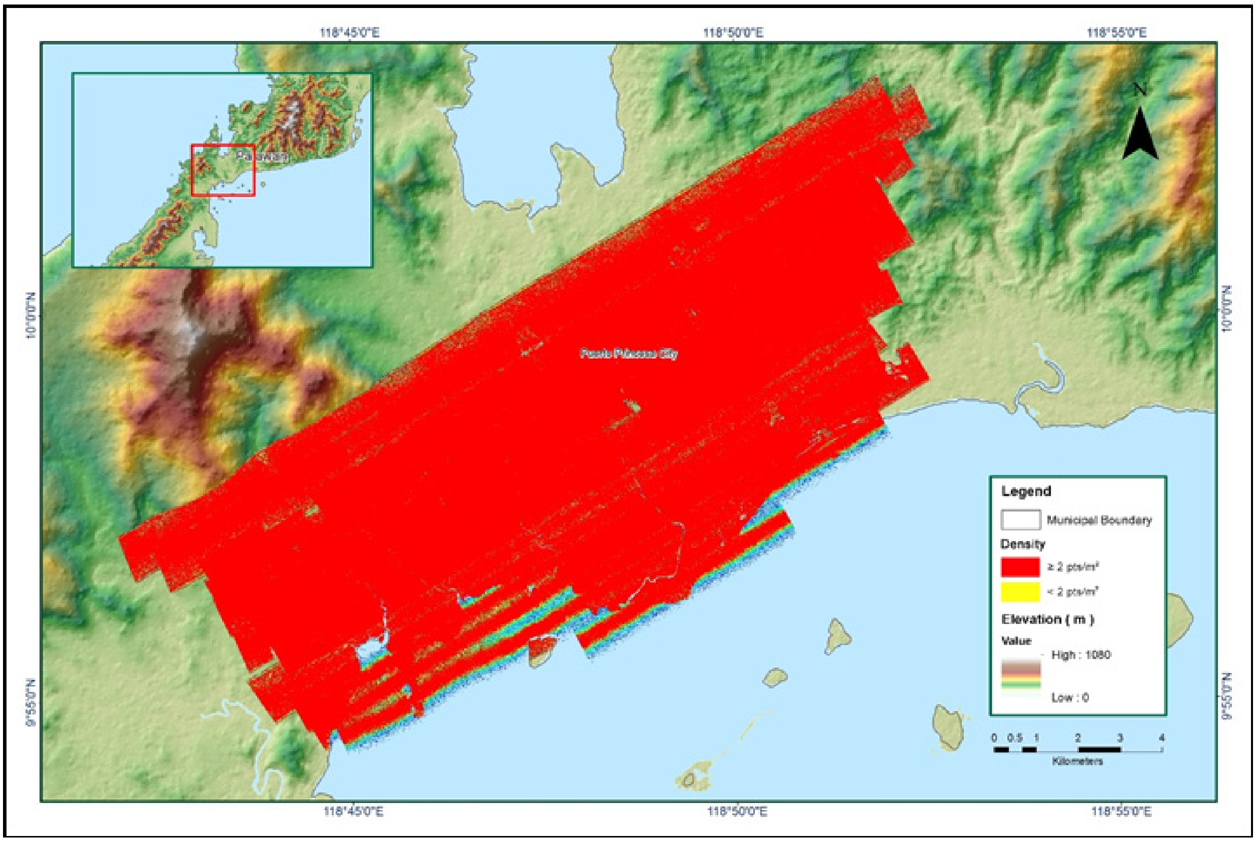


Figure A-8.6. Density map of merged LiDAR data

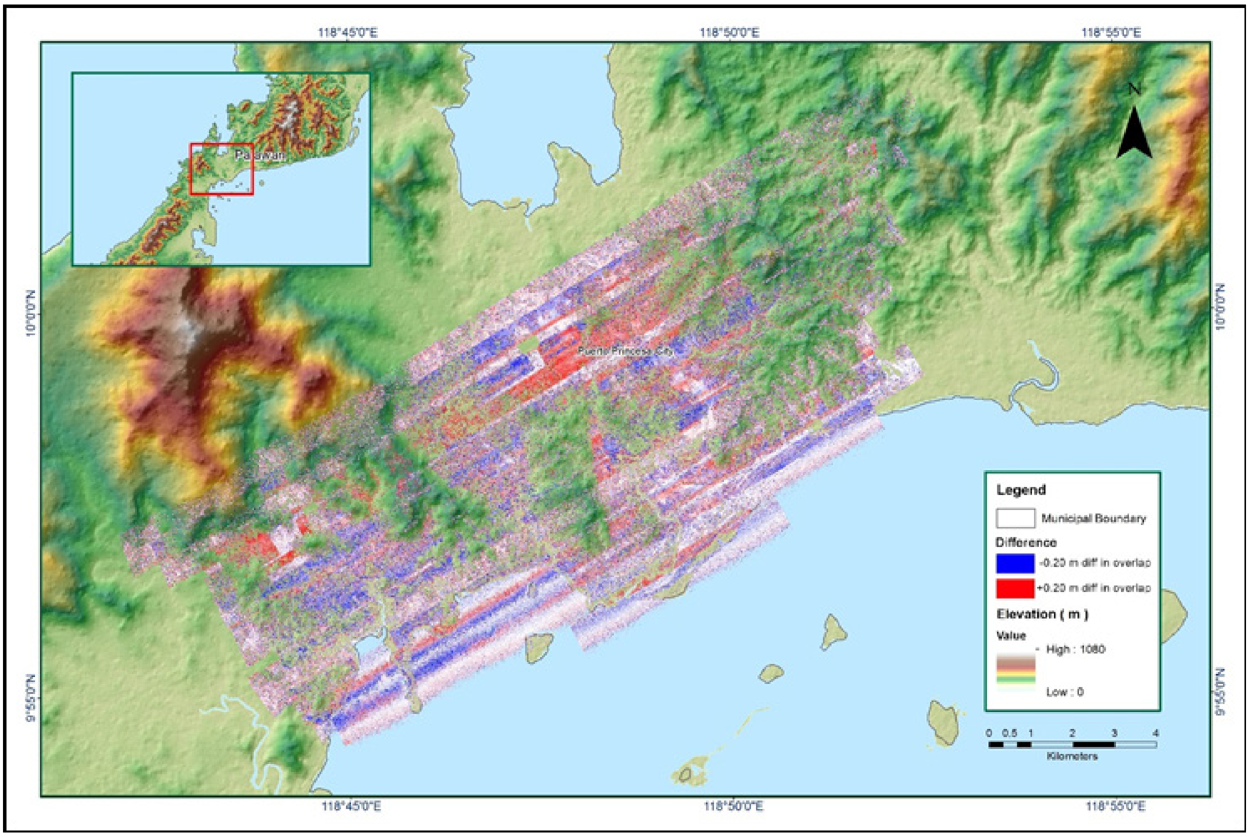


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk 42B Additional

Flight Area	West Palawan
Mission Name	Block 42B Additional
Inclusive Flights	3073P
Range data size	7.10 GB
POS	107 MB
Image	12.30 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.06
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	2.90
Boresight correction stdev (<0.001deg)	0.000070
IMU attitude correction stdev (<0.001deg)	0.0.003542
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	23.89
Ave point cloud density per sq.m. (>2.0)	3.56
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	92
Maximum Height	440.57 m
Minimum Height	52.38 m
Classification (# of points)	
Ground	41,429,226
Low vegetation	29,503,758
Medium vegetation	83,889,950
High vegetation	177,852,098
Building	1,986,175
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Velina Angela Bemida, Alex John EScobido

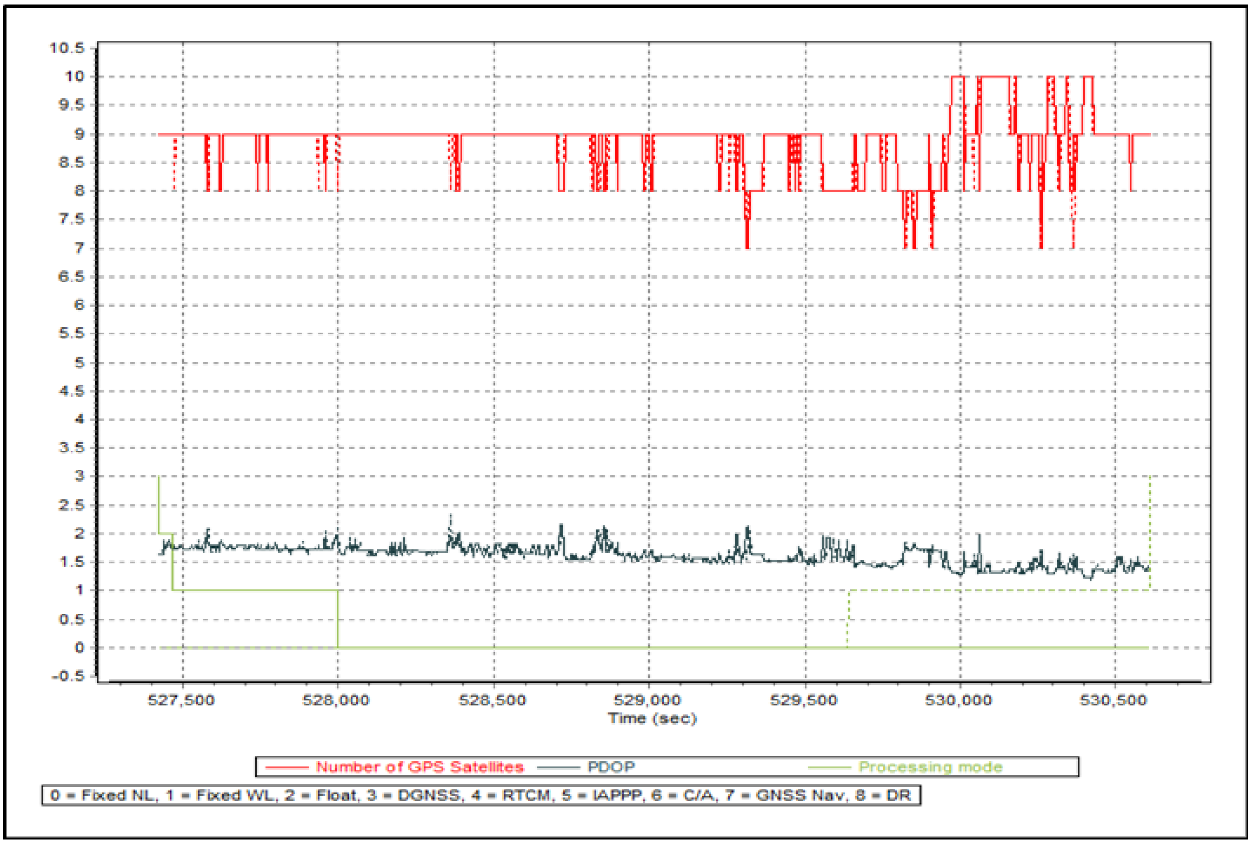


Figure A-8.8. Solution Status

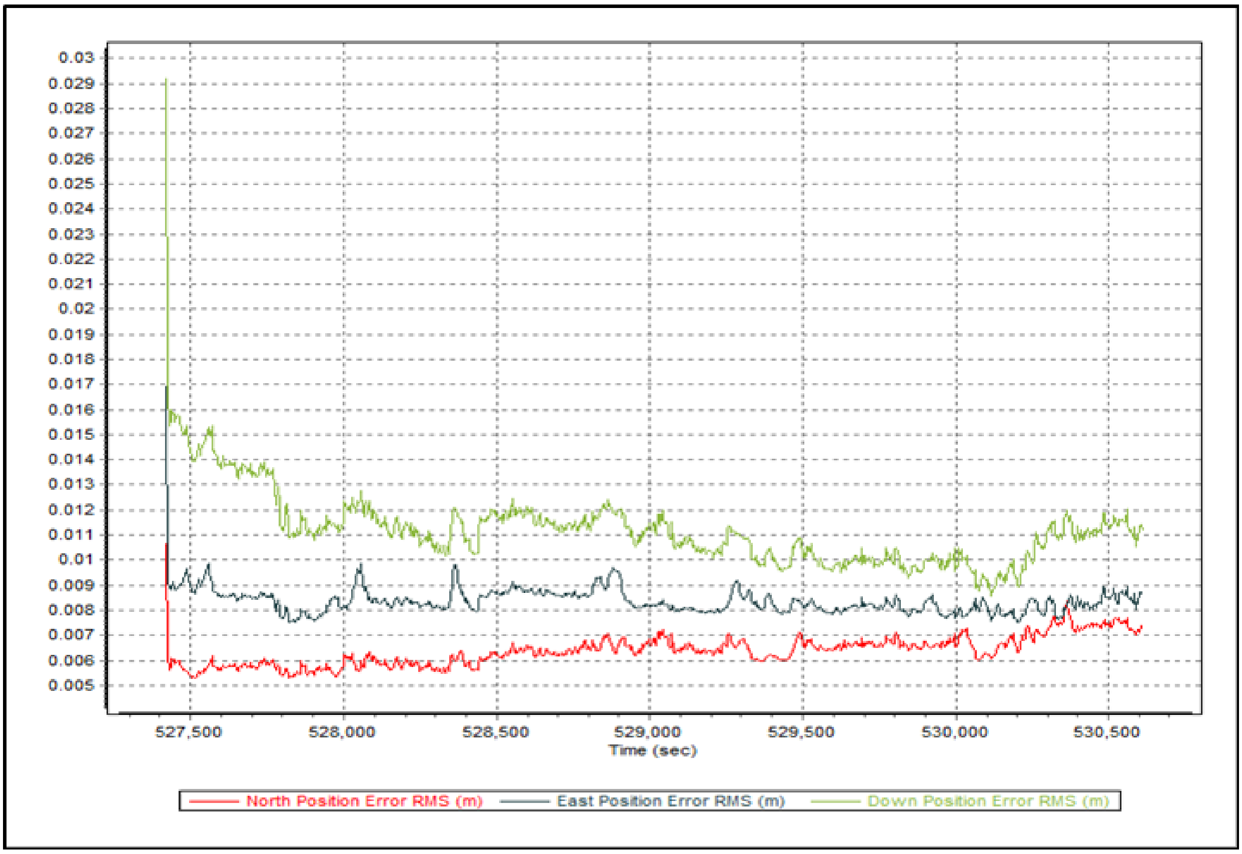


Figure A-8.9. Smoothed Performance Metrics Parameters

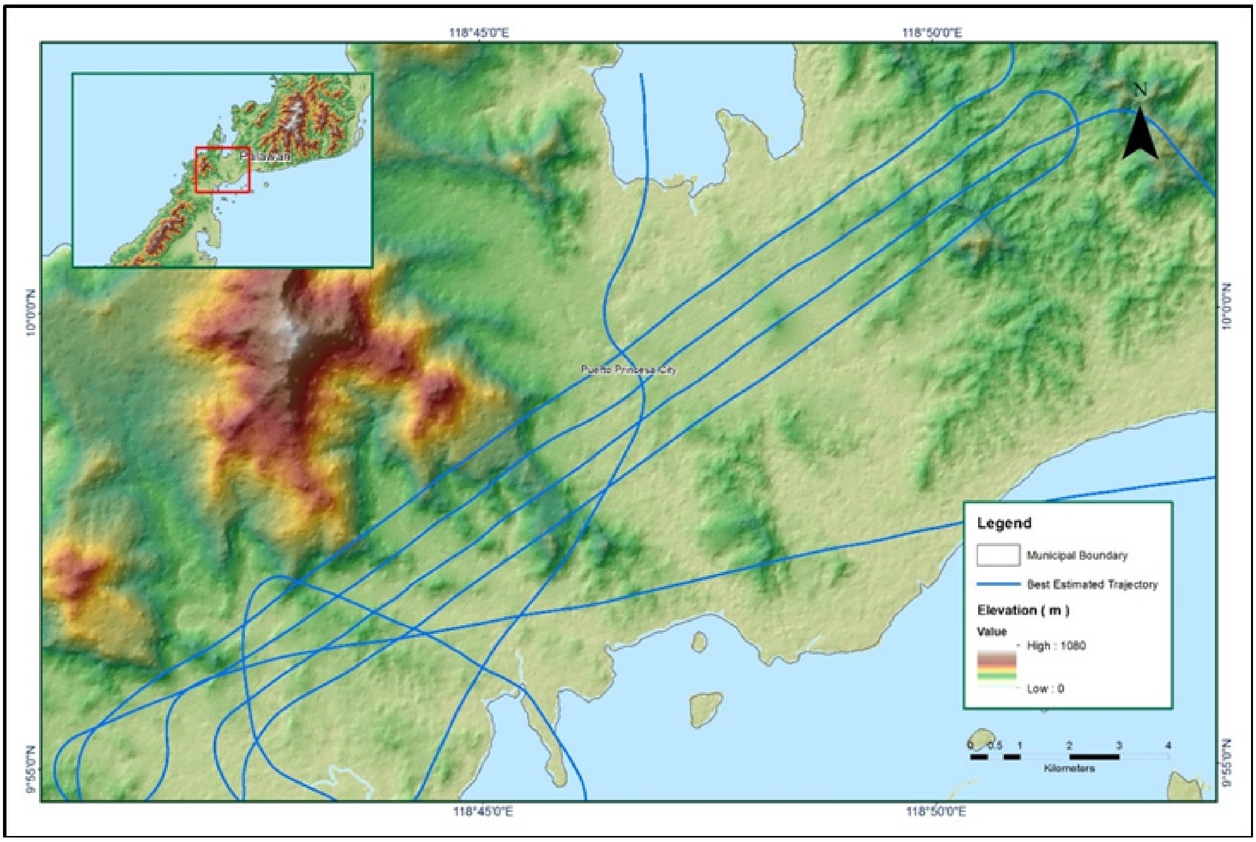


Figure A-8.10. Best Estimated Trajectory

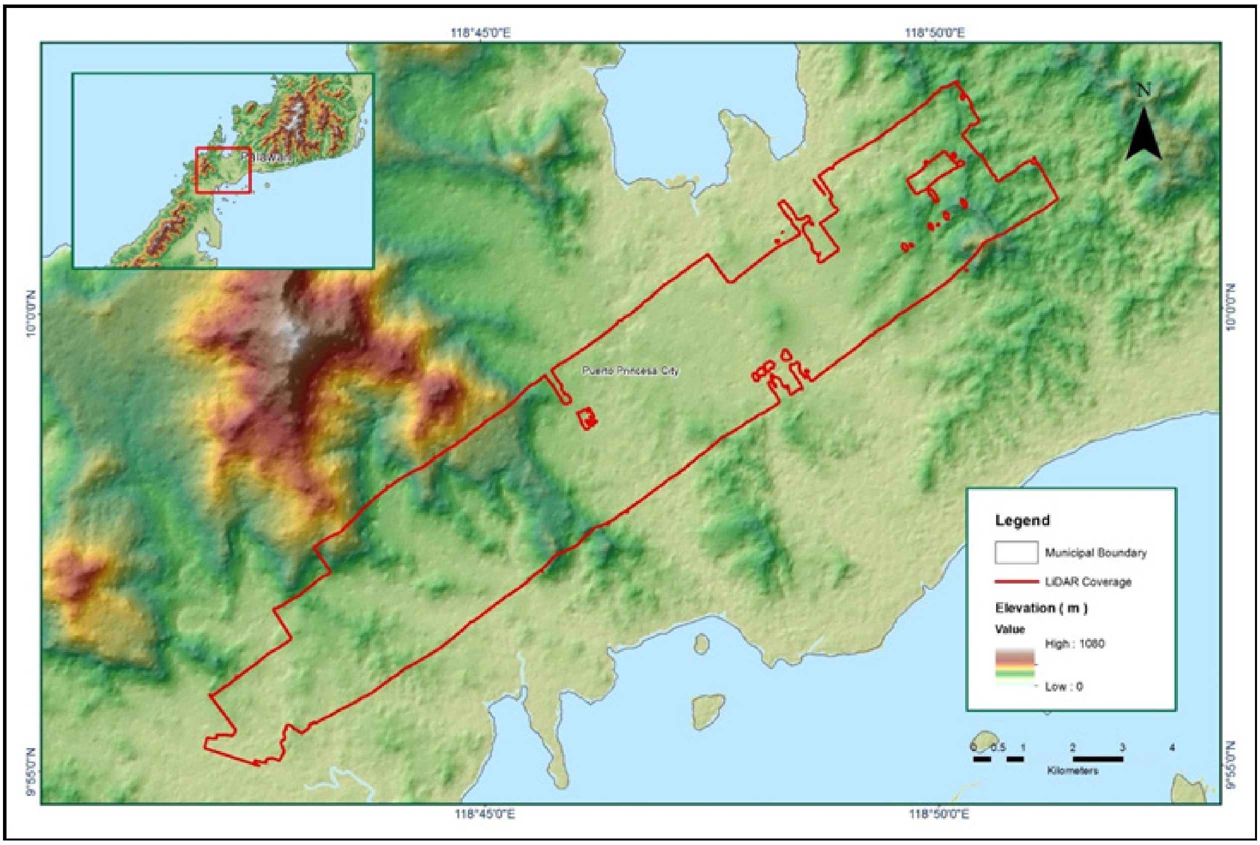


Figure A-8.11. Coverage of LiDAR data

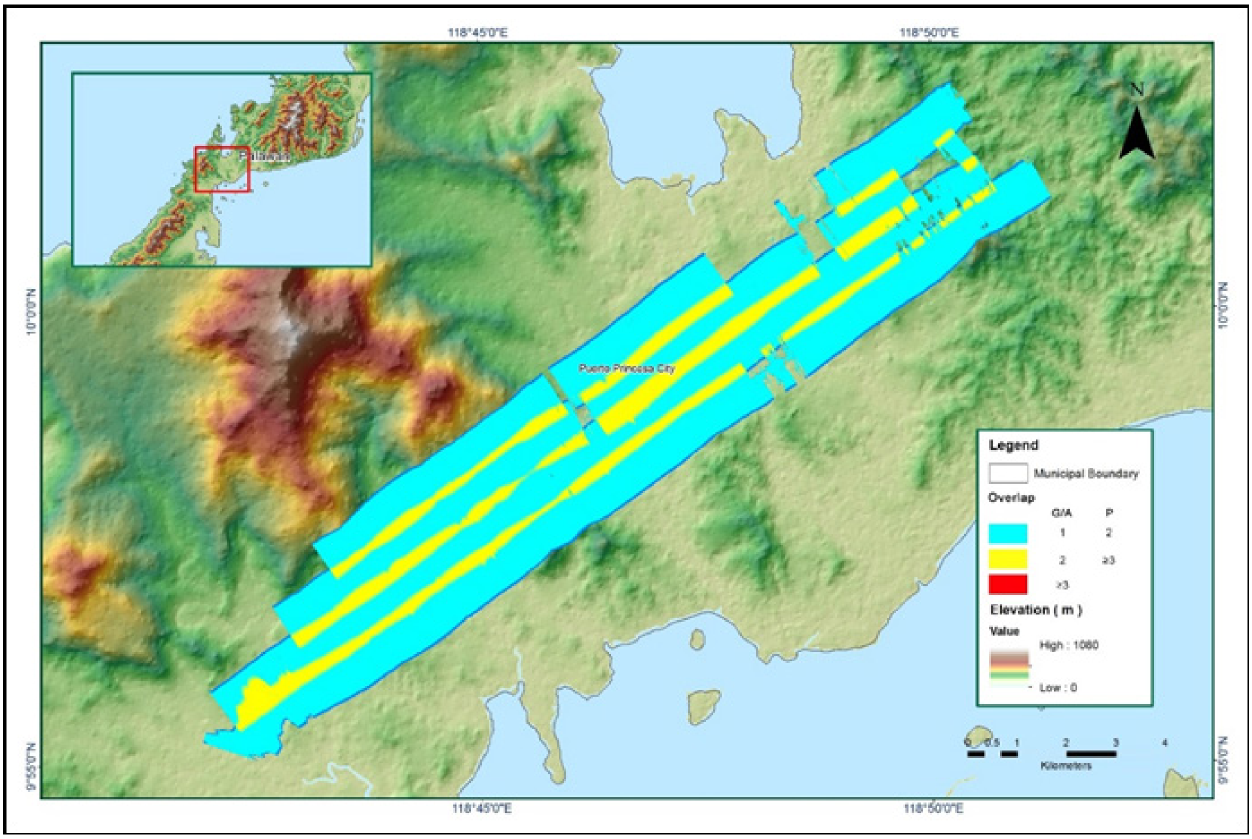


Figure A-8.12. Image of Data Overlap

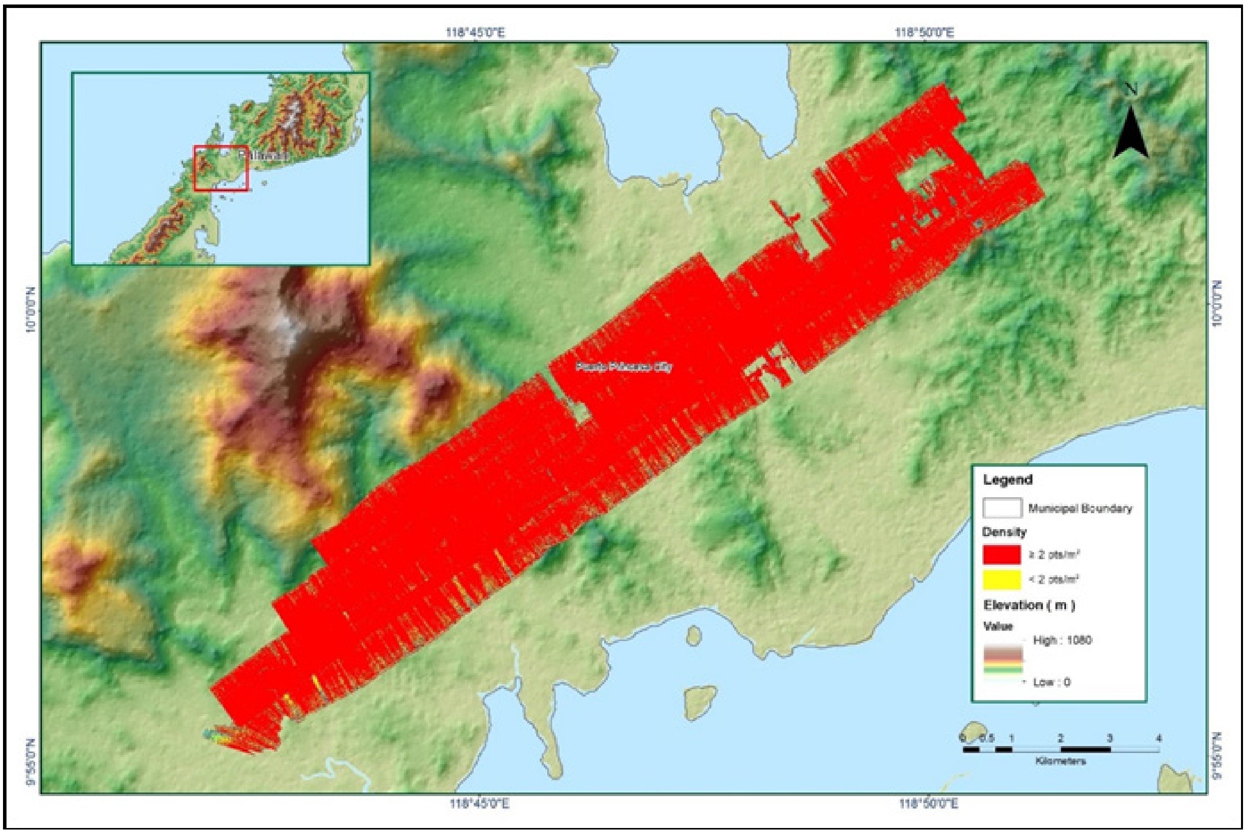


Figure A-8.13. Density map of merged LiDAR data

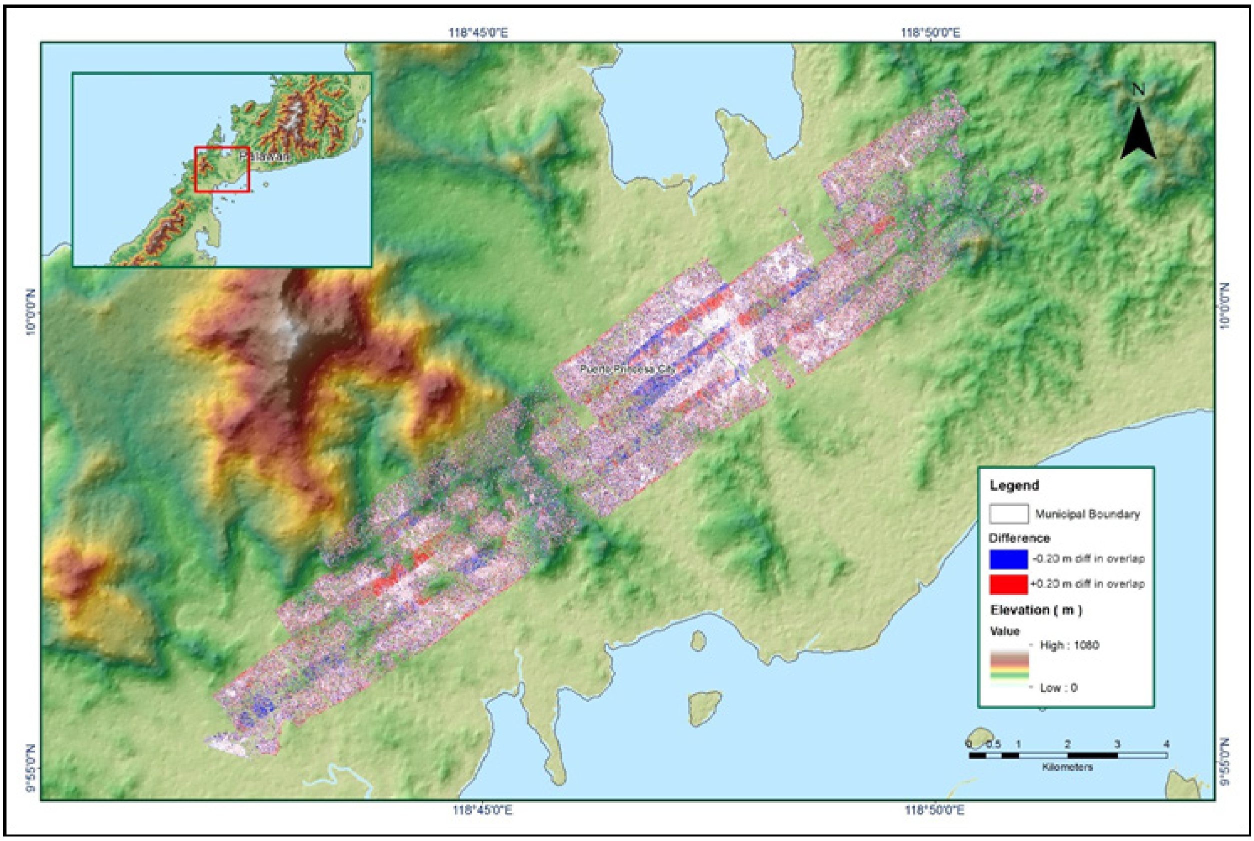


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk 42B supplement

Flight Area	West Palawan
Mission Name	Block 42B Supplement
Inclusive Flights	3045P
Range data size	10.50 GB
POS	144MB
Image	15.70 GB
Transfer date	June 13, 2015
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)	1.95
RMSE for East Position (<4.0 cm)	2.30
RMSE for Down Position (<8.0 cm)	3.70
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.0.003542
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	27.46
Ave point cloud density per sq.m. (>2.0)	2.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	177
Maximum Height	428.28 m
Minimum Height	42.45 m
Classification (# of points)	
Ground	92,670,052
Low vegetation	67,814,293
Medium vegetation	141,295,150
High vegetation	319,882,750
Building	4,546,105
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew Natino, Kathryn Claudyn Zarate

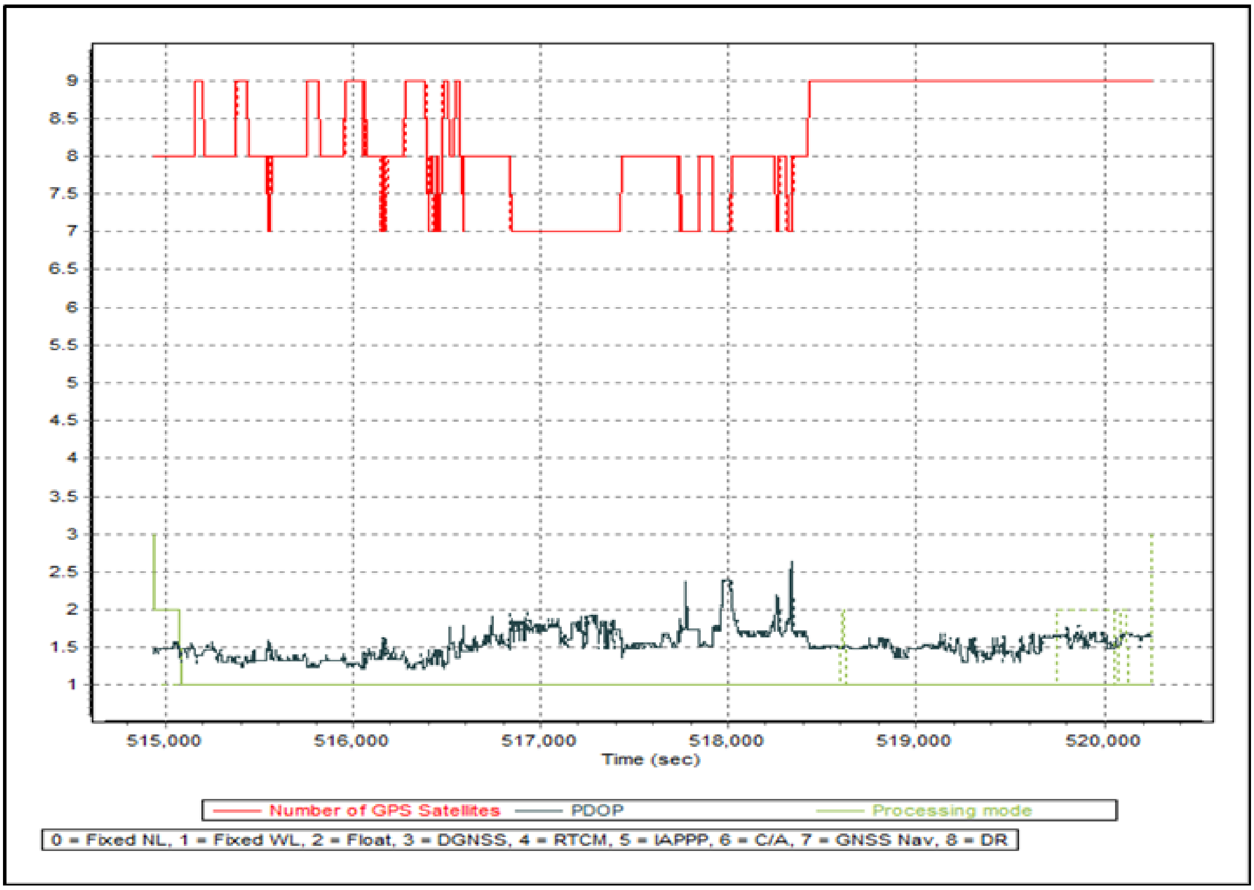


Figure A-8.15. Solution Status

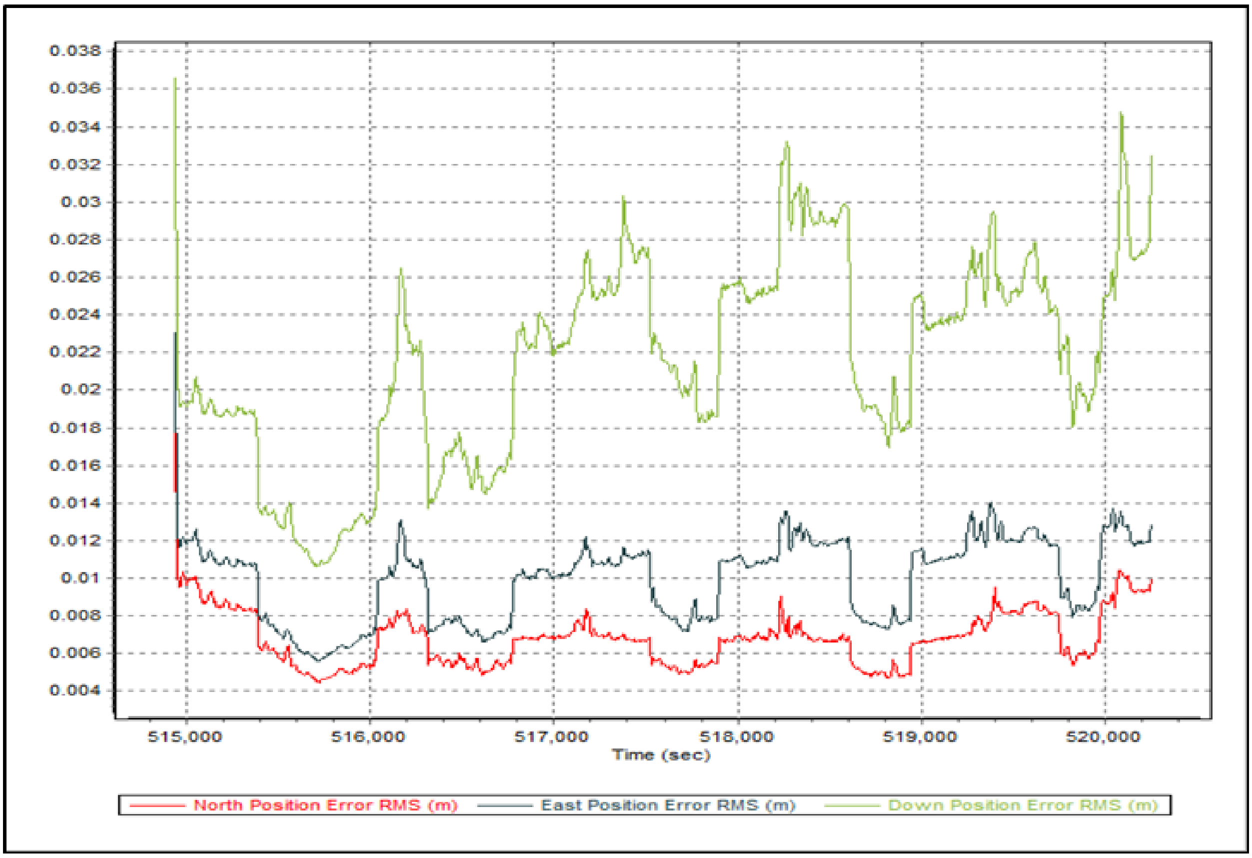


Figure A-8.16. Smoothed Performance Metrics Parameters

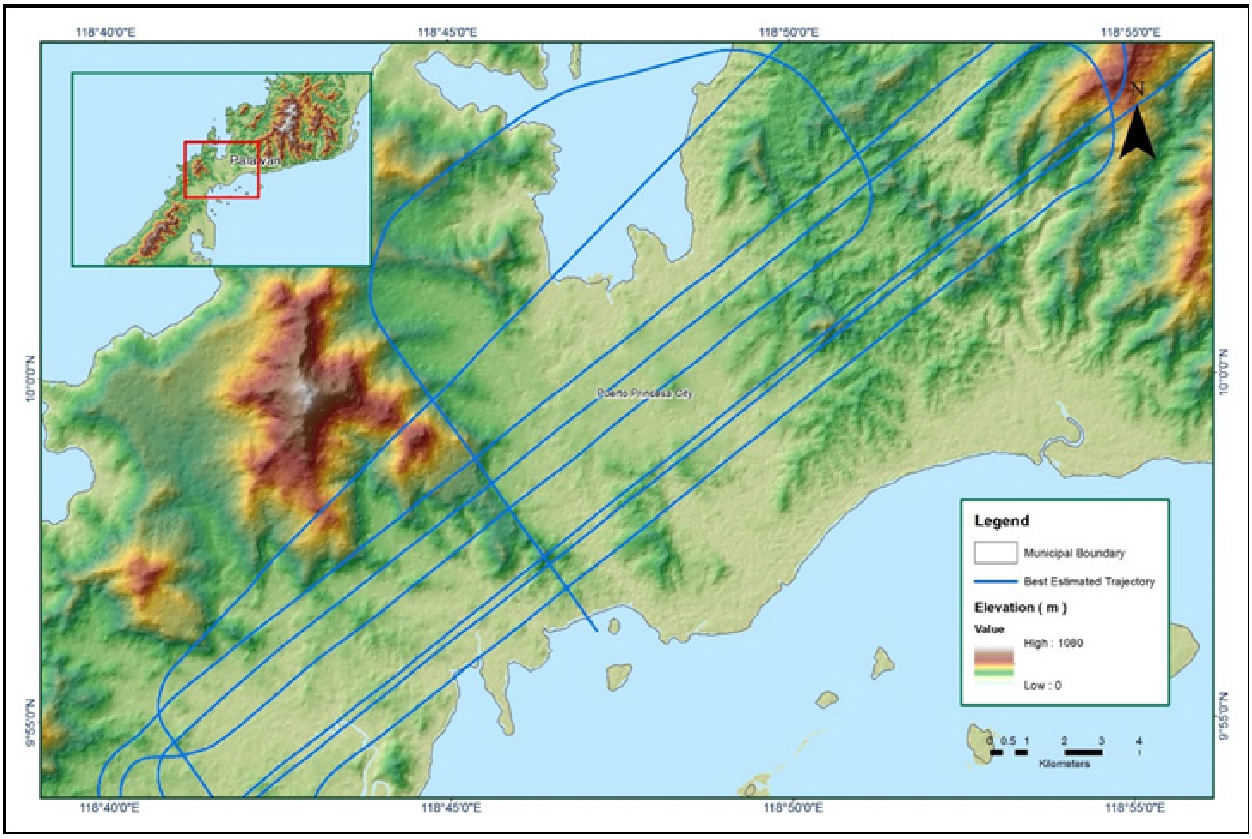


Figure A-8.17. Best Estimated Trajectory

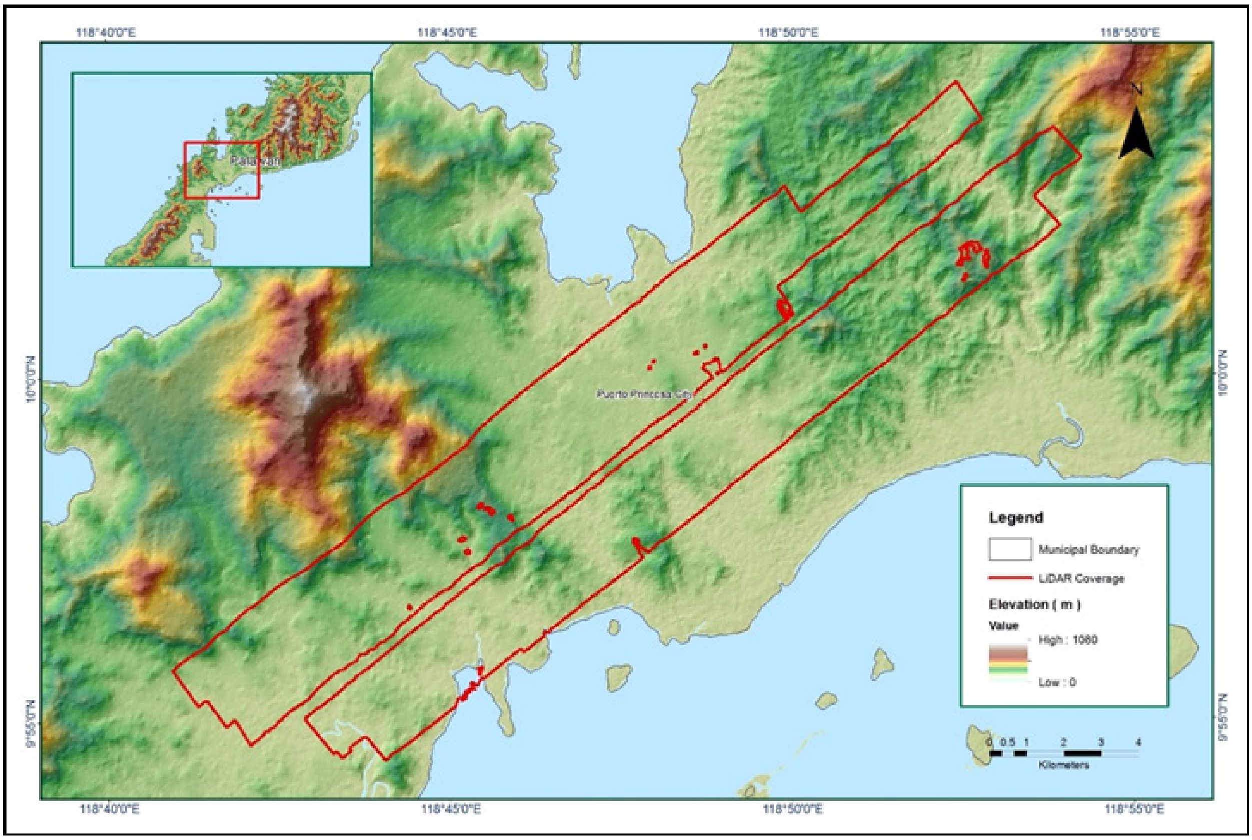


Figure A-8.18. Coverage of LiDAR data

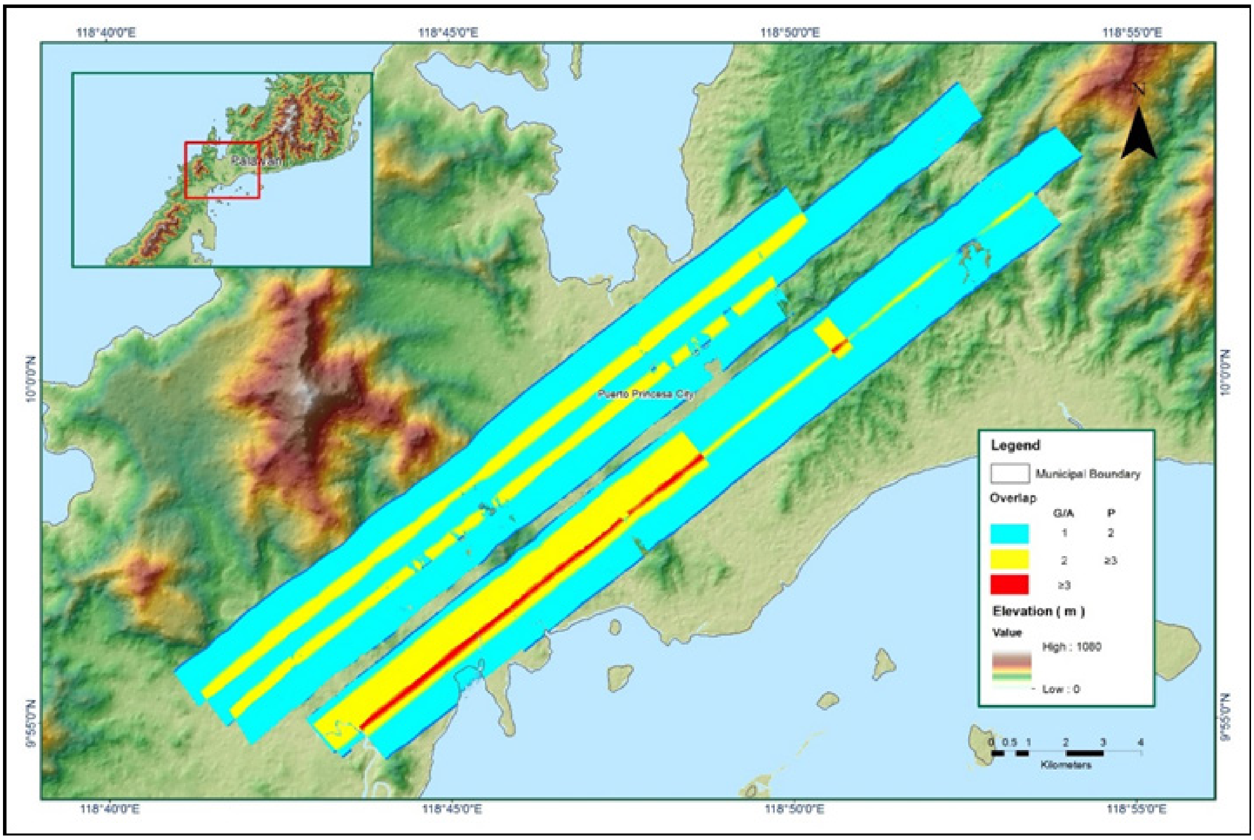


Figure A-8.19. Image of Data Overlap

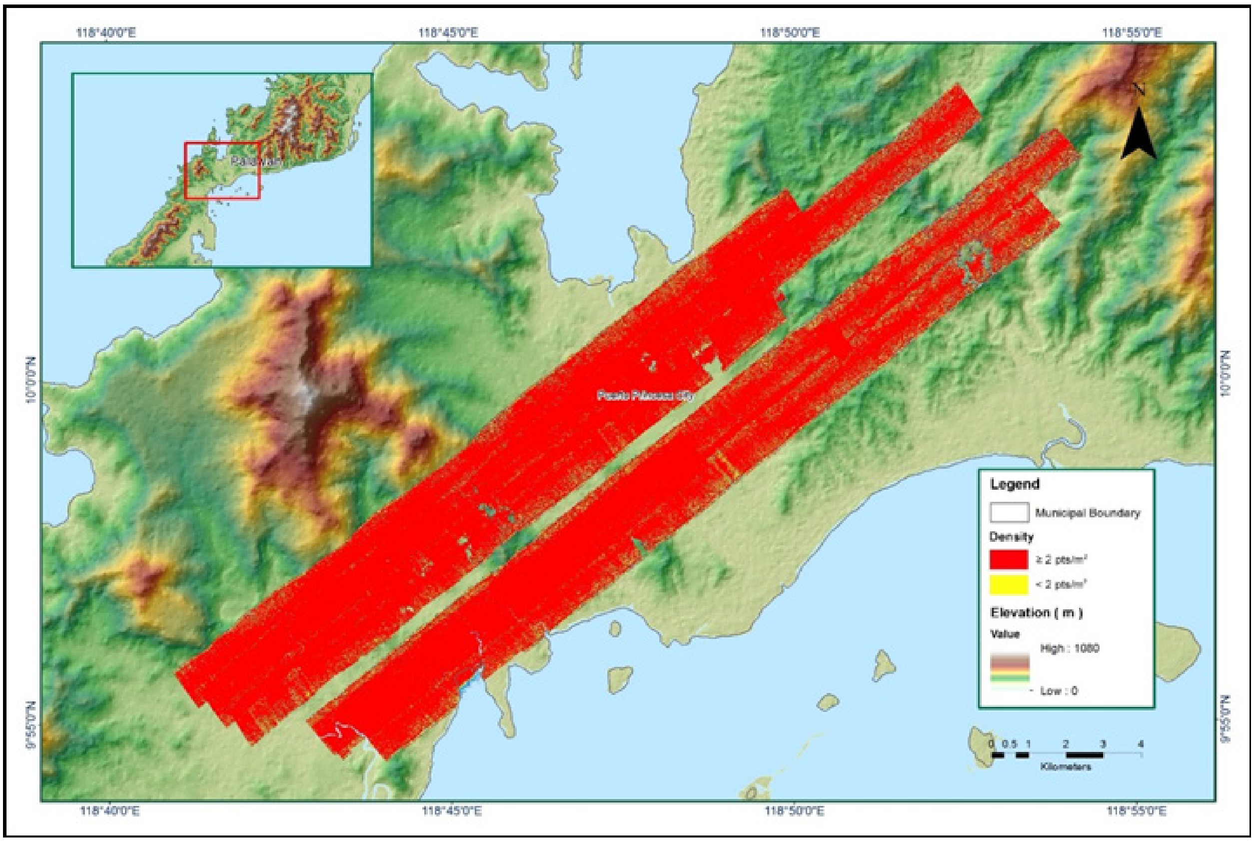


Figure A-8.20. Density map of merged LiDAR data

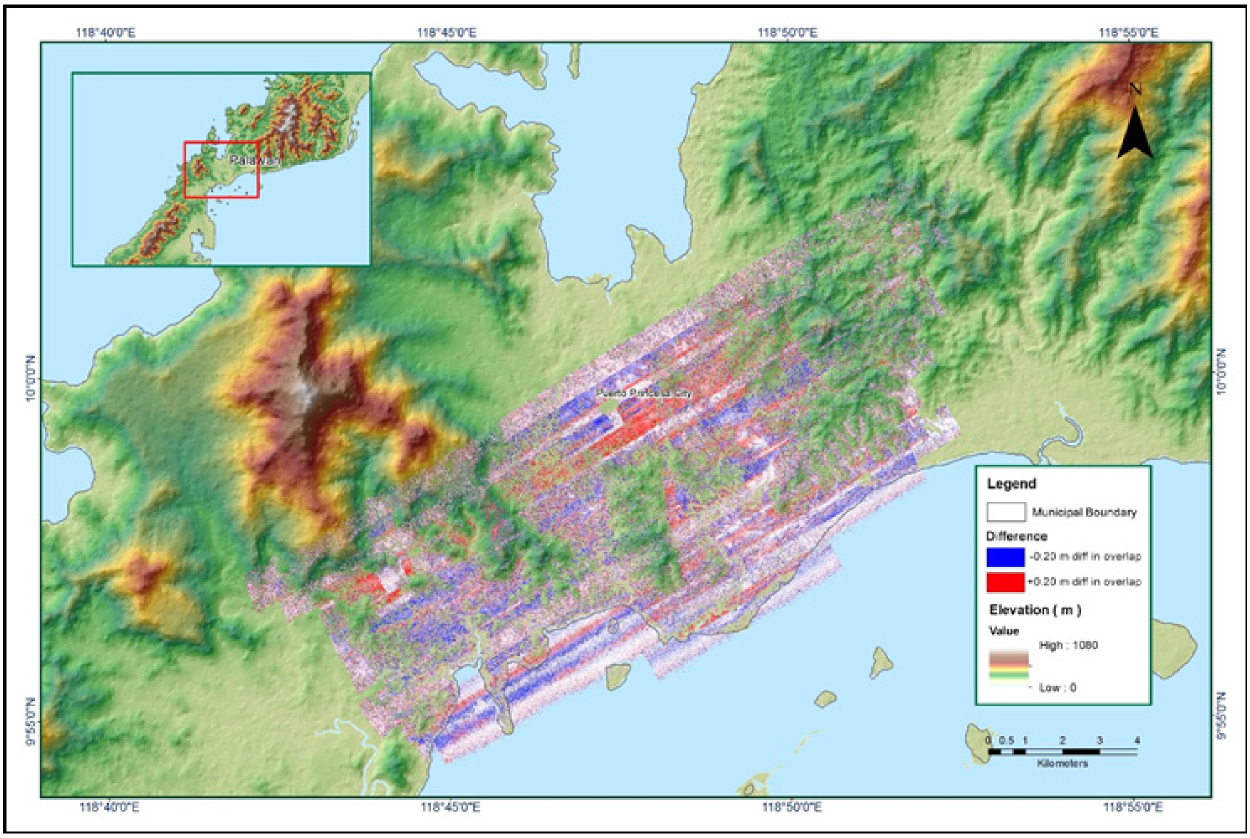


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk 42E

Flight Area	West Palawan
Mission Name	Blk 42E
Inclusive Flights	2989P & 3017P
Range data size	54.70 GB
POS	519 MB
Image	110.80 GB
Transfer date	June 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.60
RMSE for East Position (<4.0 cm)	2.60
RMSE for Down Position (<8.0 cm)	4.30
Boresight correction stdev (<0.001deg)	0.000203
IMU attitude correction stdev (<0.001deg)	0.147257
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	45.87
Ave point cloud density per sq.m. (>2.0)	4.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	353
Maximum Height	899.45 m
Minimum Height	49.6 m
Classification (# of points)	
Ground	364,978,265
Low vegetation	181,902,193
Medium vegetation	383,273,014
High vegetation	1,344,953,370
Building	33,880,796
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Abigail Ching, Engr. Chelou Prado, Engr. Ma. Ailyn Olanda, Engr. Krisha Marie Buatista

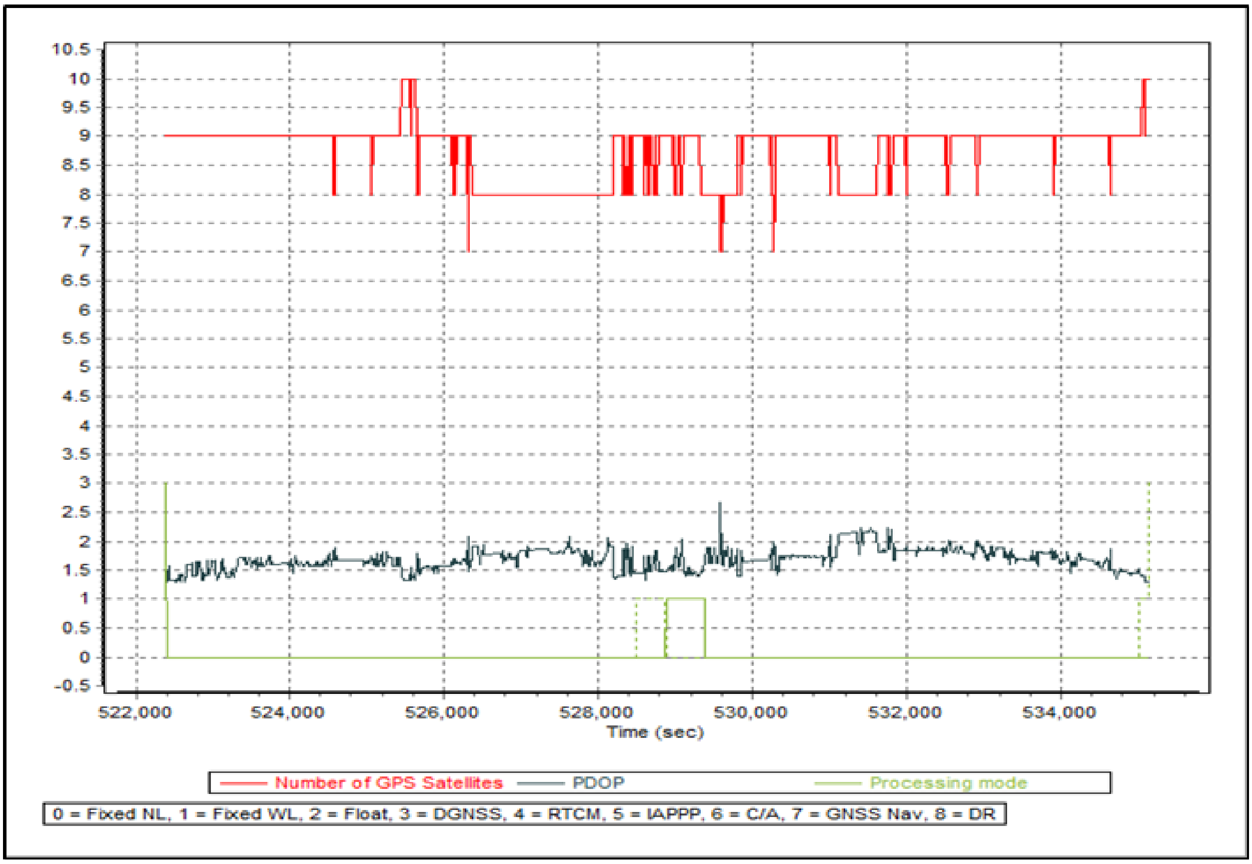


Figure A-8.22. Solution Status

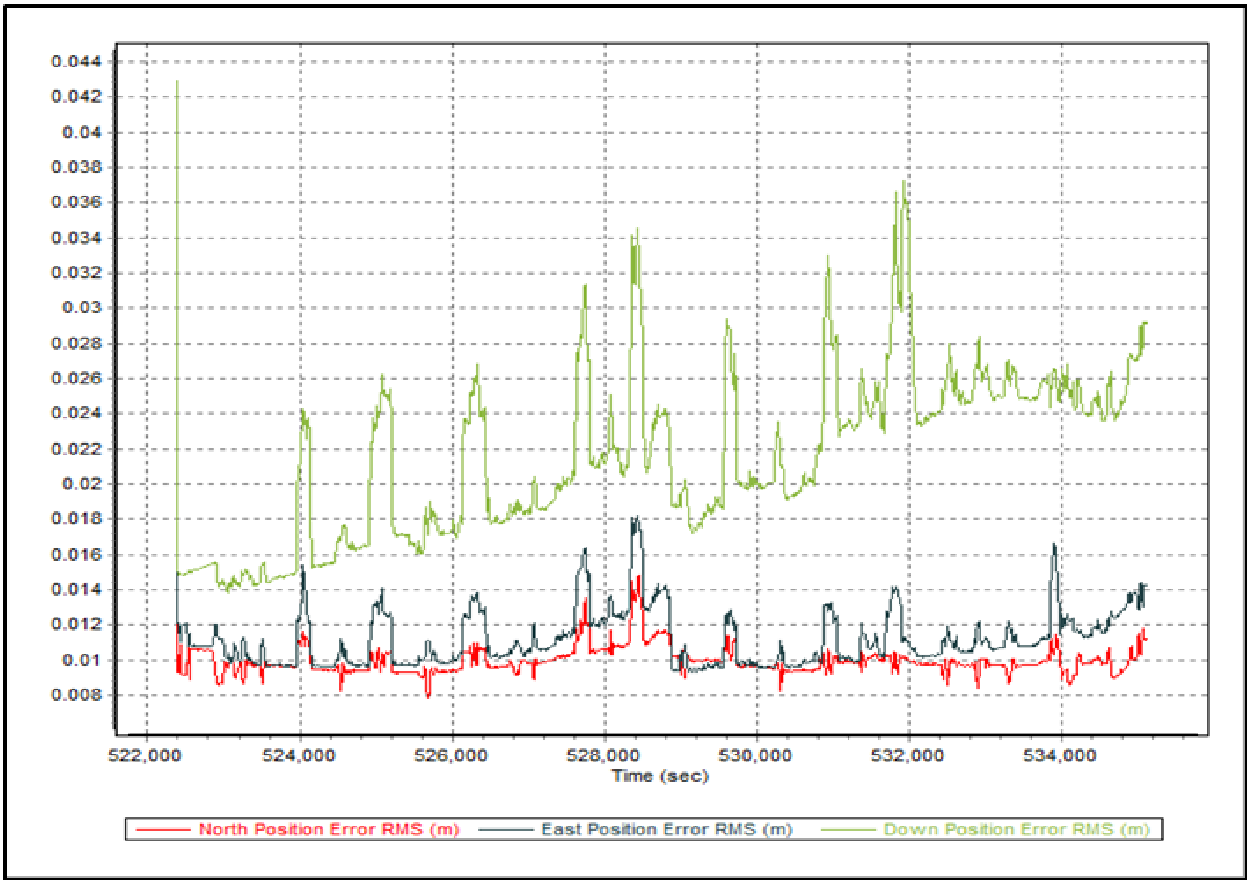


Figure A-8.23. Smoothed Performance Metric Parameters

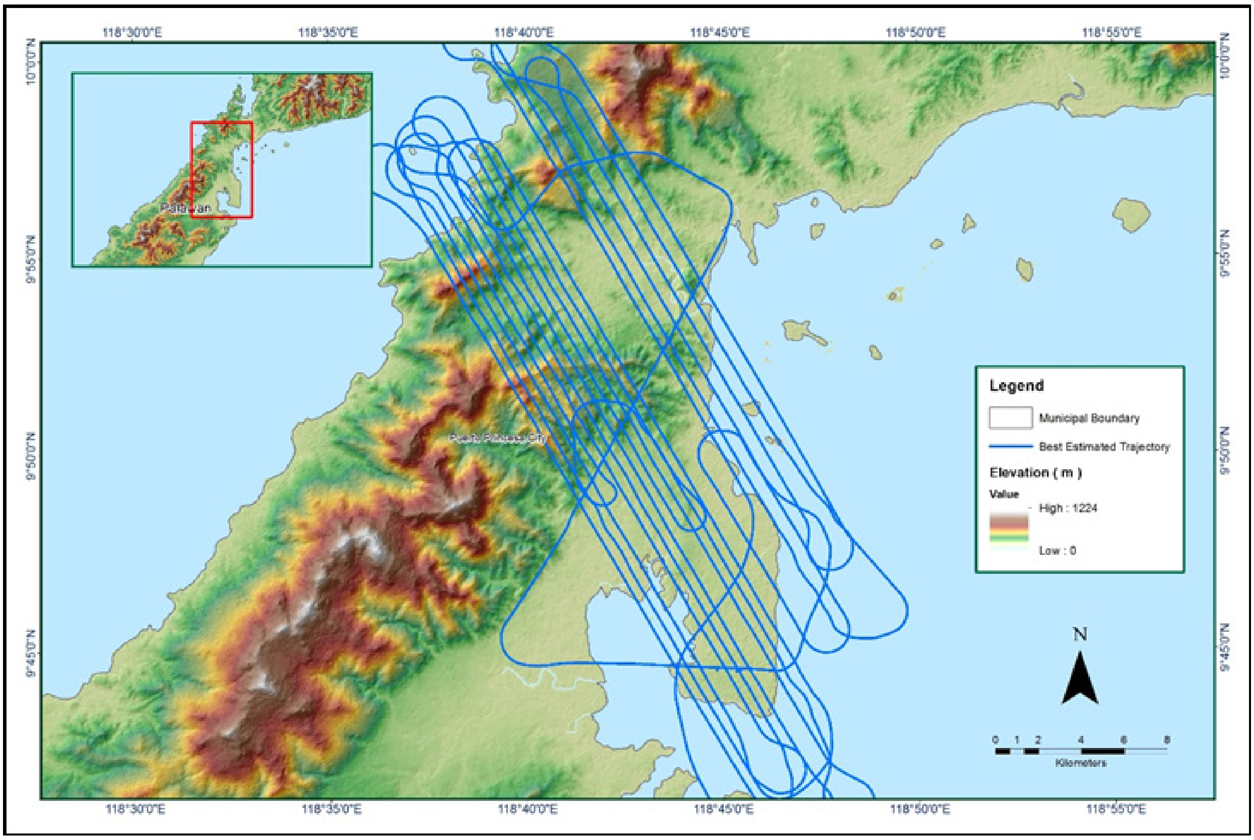


Figure A-8.24. Best Estimated Trajectory

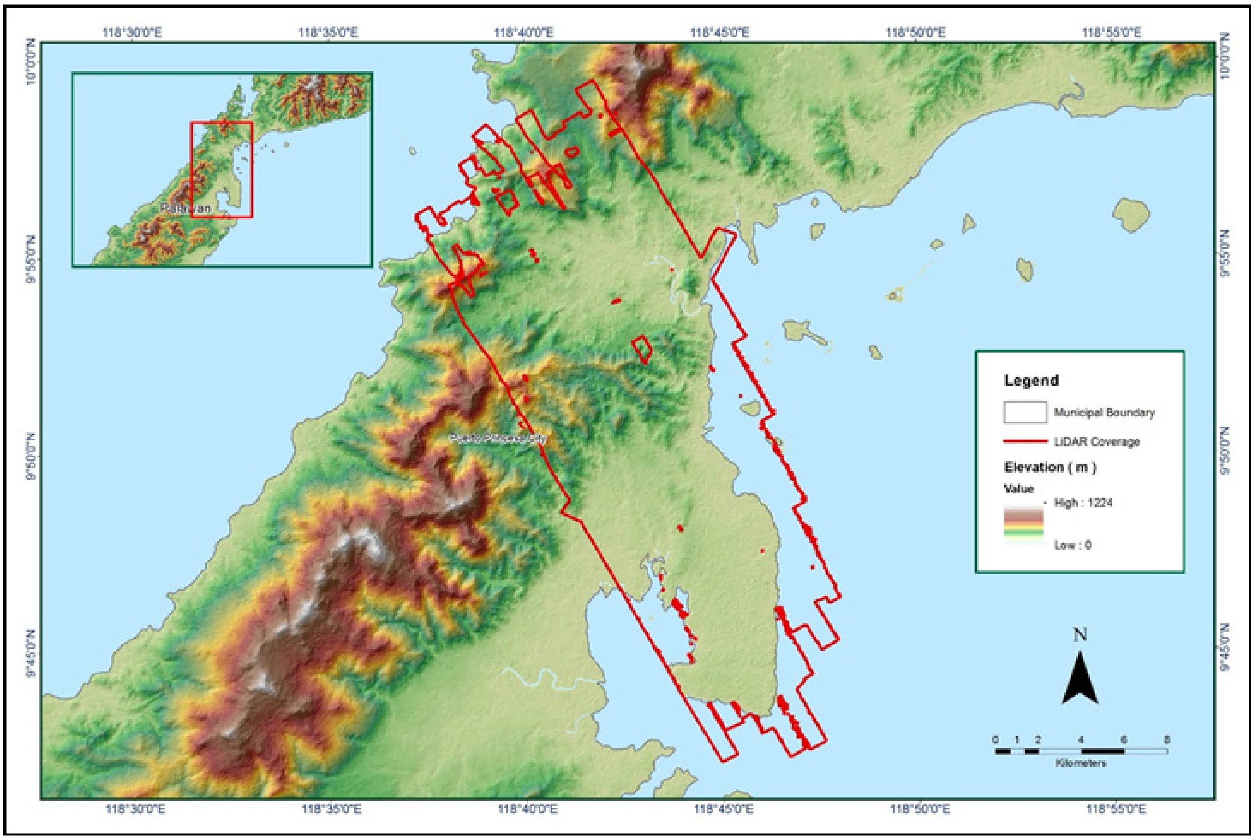


Figure A-8.25. Coverage of LiDAR data

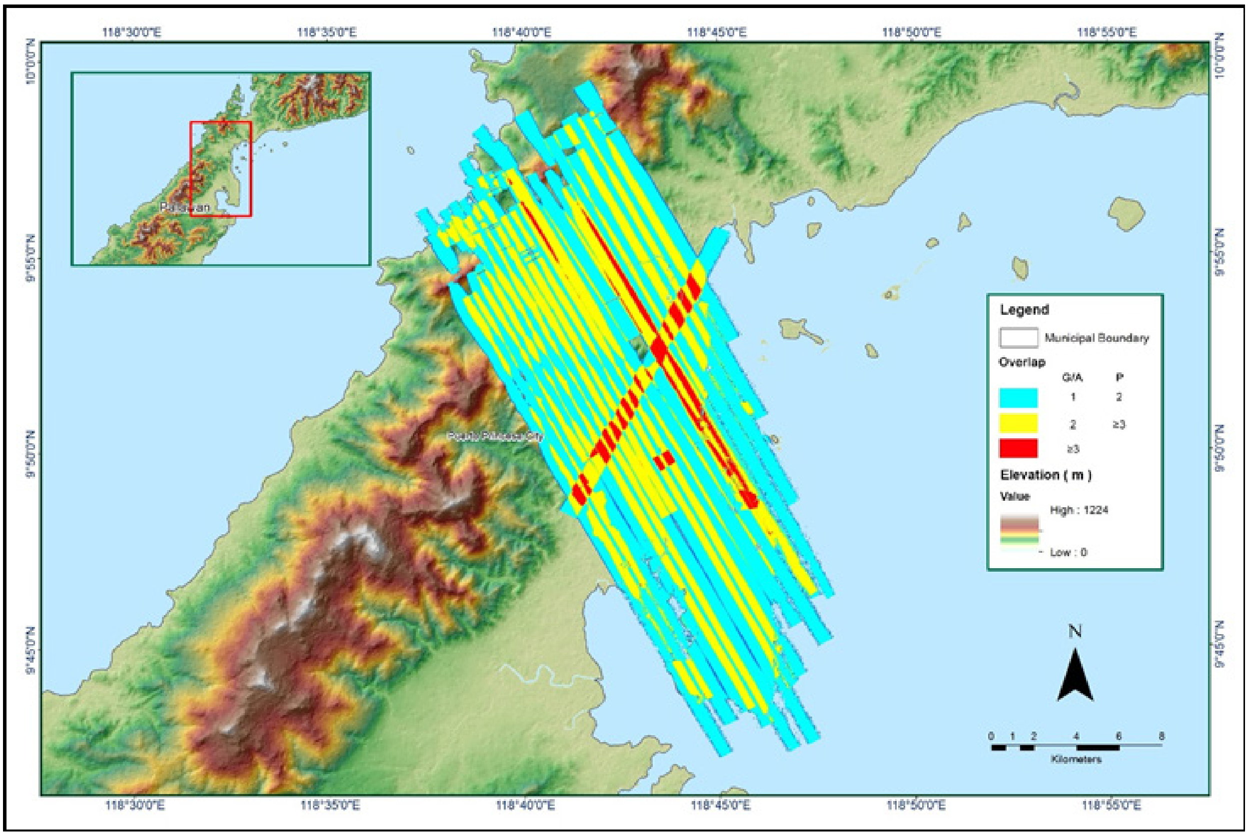


Figure A-8.26. Image of Data Overlap

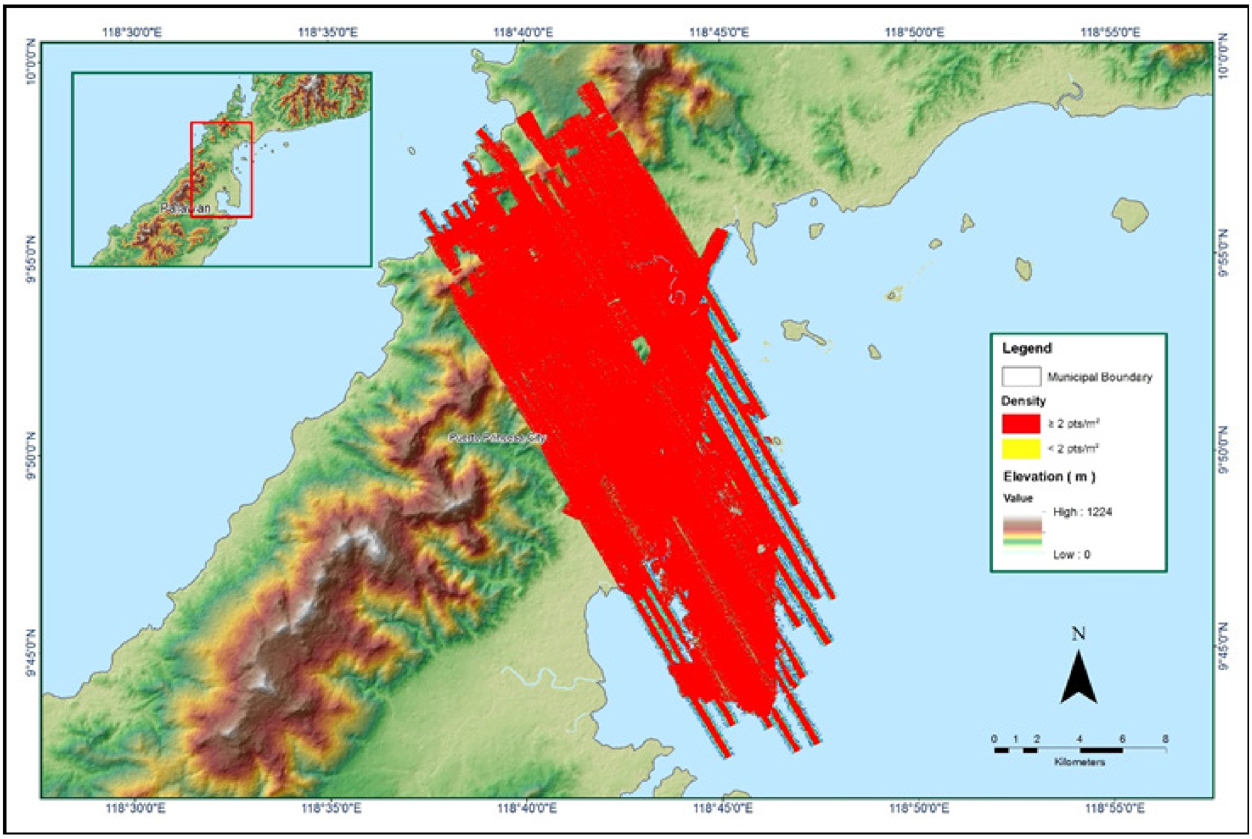


Figure A-8.27. Density map of merged LiDAR data

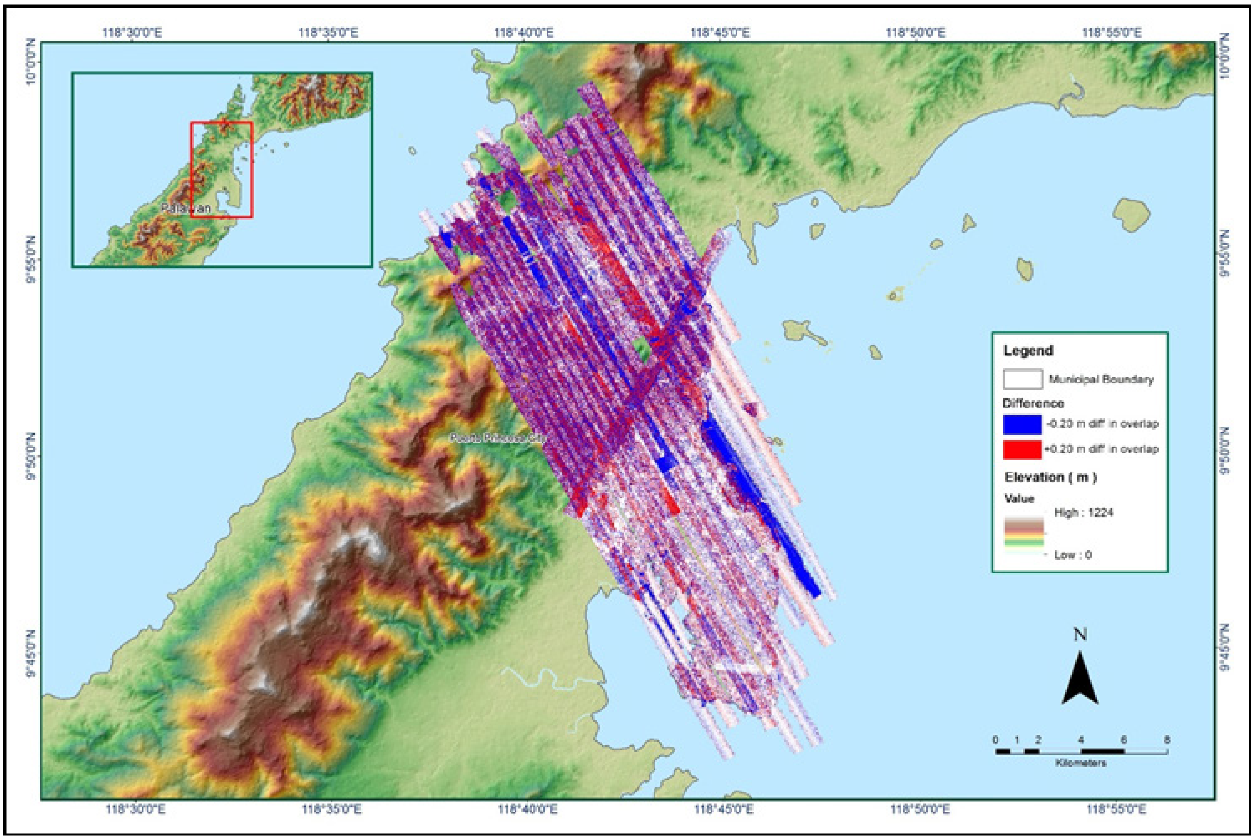


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk 42E additional 2

Flight Area	West Palawan
Mission Name	Block 42E additional 2
Inclusive Flights	3049P
Range data size	18.30 GB
POS	162 MB
Image	31 GB
Transfer date	August 5, 2015
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)	1.90
RMSE for East Position (<4.0 cm)	2.40
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000310
IMU attitude correction stdev (<0.001deg)	0.0.000769
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	36.67
Ave point cloud density per sq.m. (>2.0)	3.33
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	87
Maximum Height	437.23 m
Minimum Height	41.08 m
Classification (# of points)	
Ground	45,509,887
Low vegetation	33,753,922
Medium vegetation	58,324,620
High vegetation	161,722,548
Building	2,408,370
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Antonio Chua Jr., Jovy Narisma

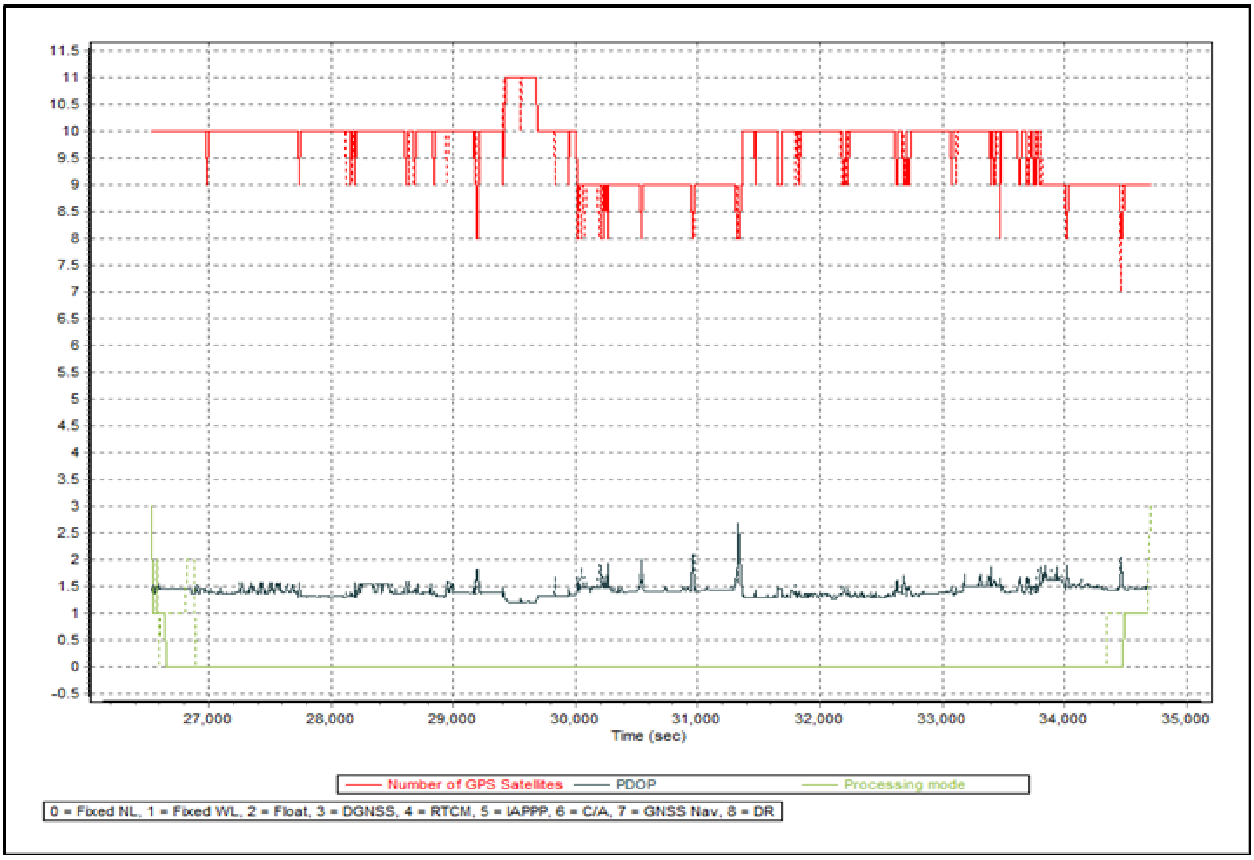


Figure A-8.29. Solution Status

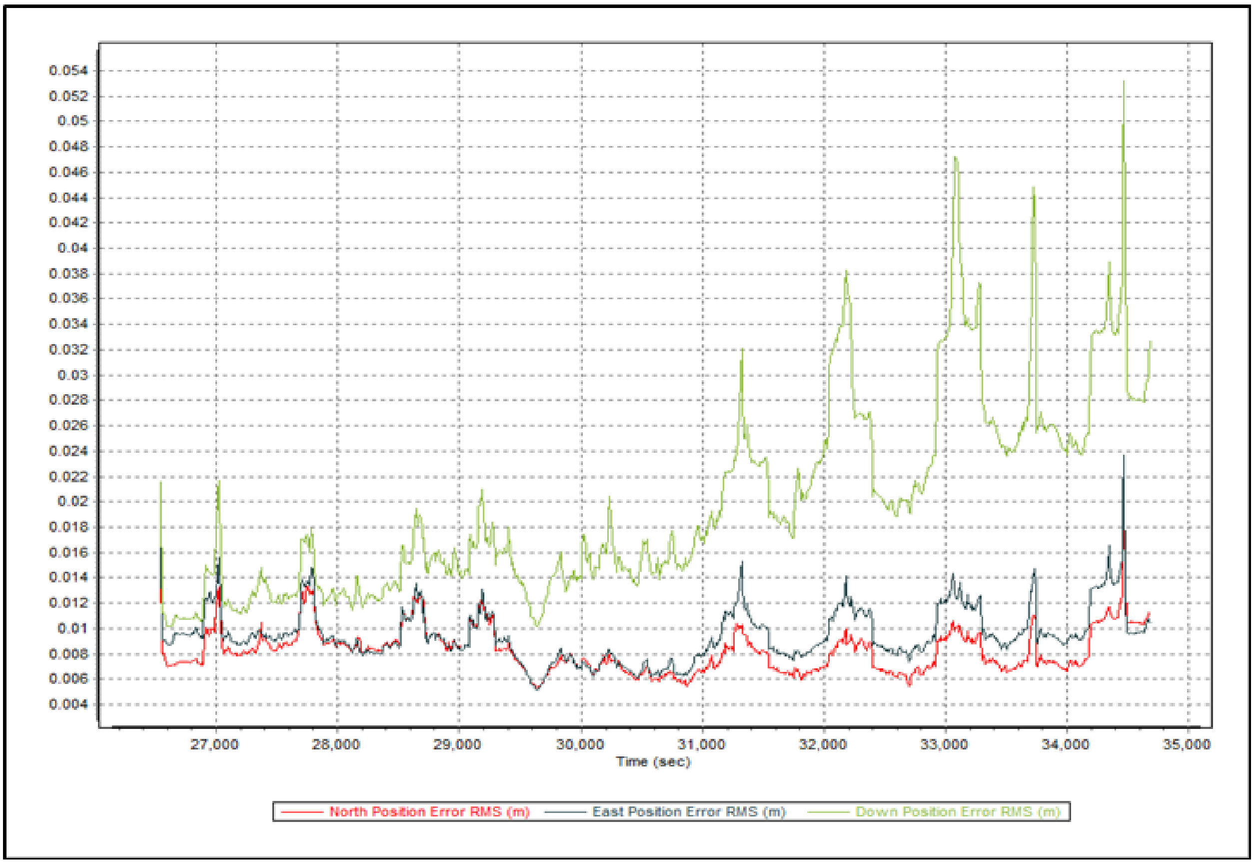


Figure A-8.30. Smoothed Performance Metric Parameters

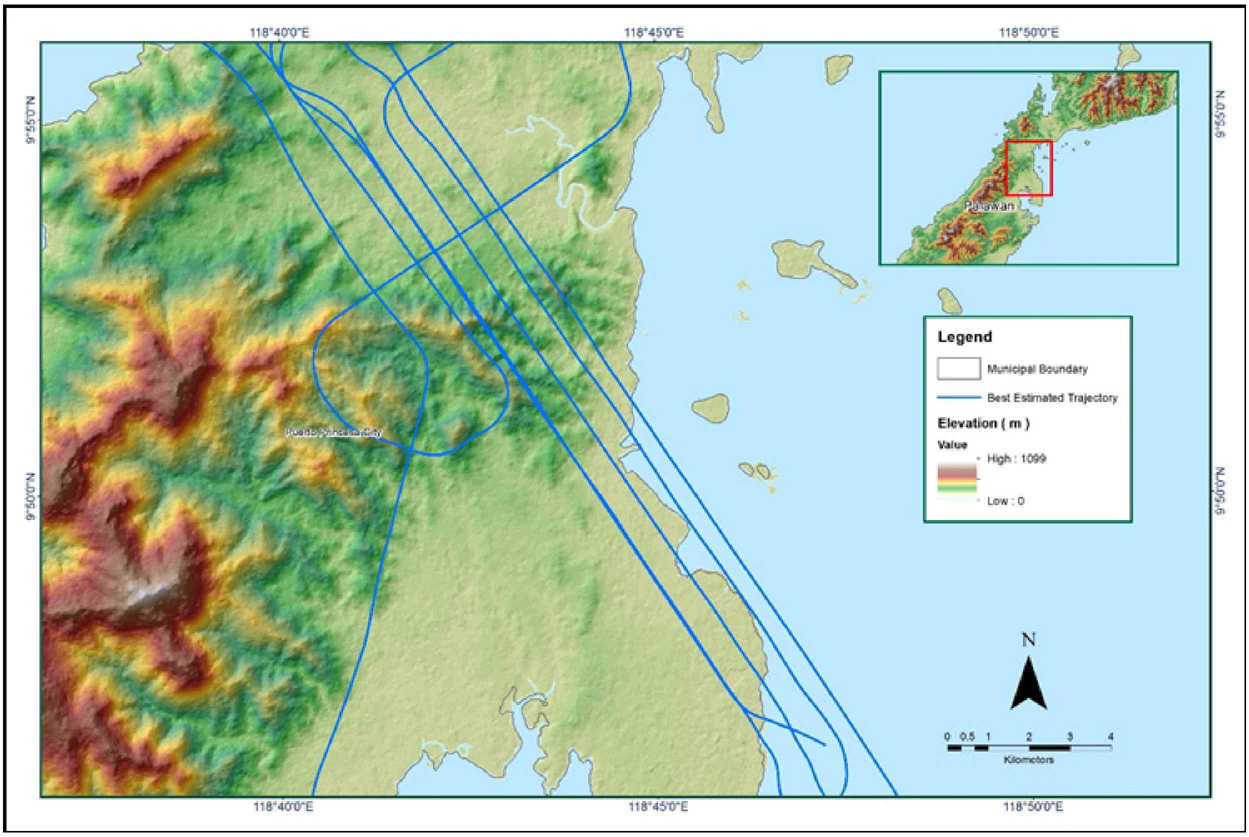


Figure A-8.31. Best Estimated Trajectory

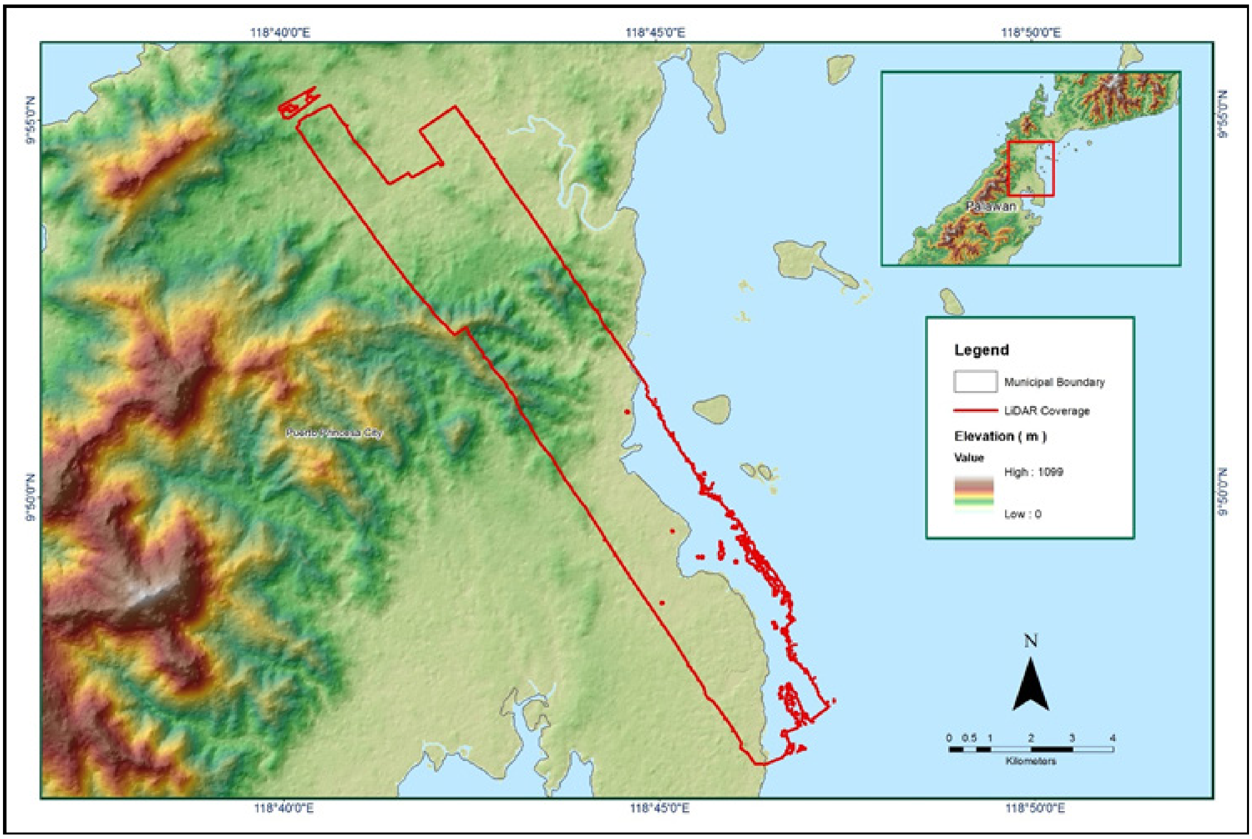


Figure A-8.32. Coverage of LiDAR data

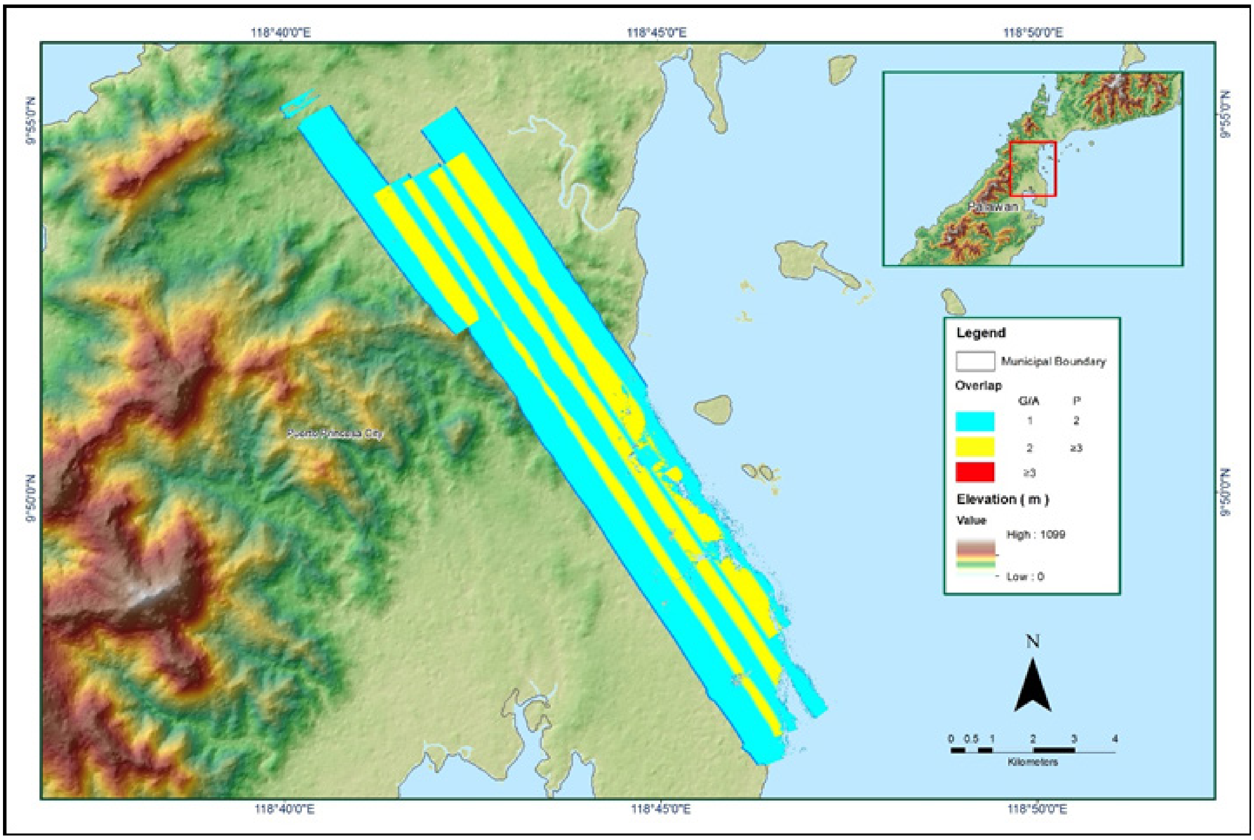


Figure A-8.33. Image of Data Overlap

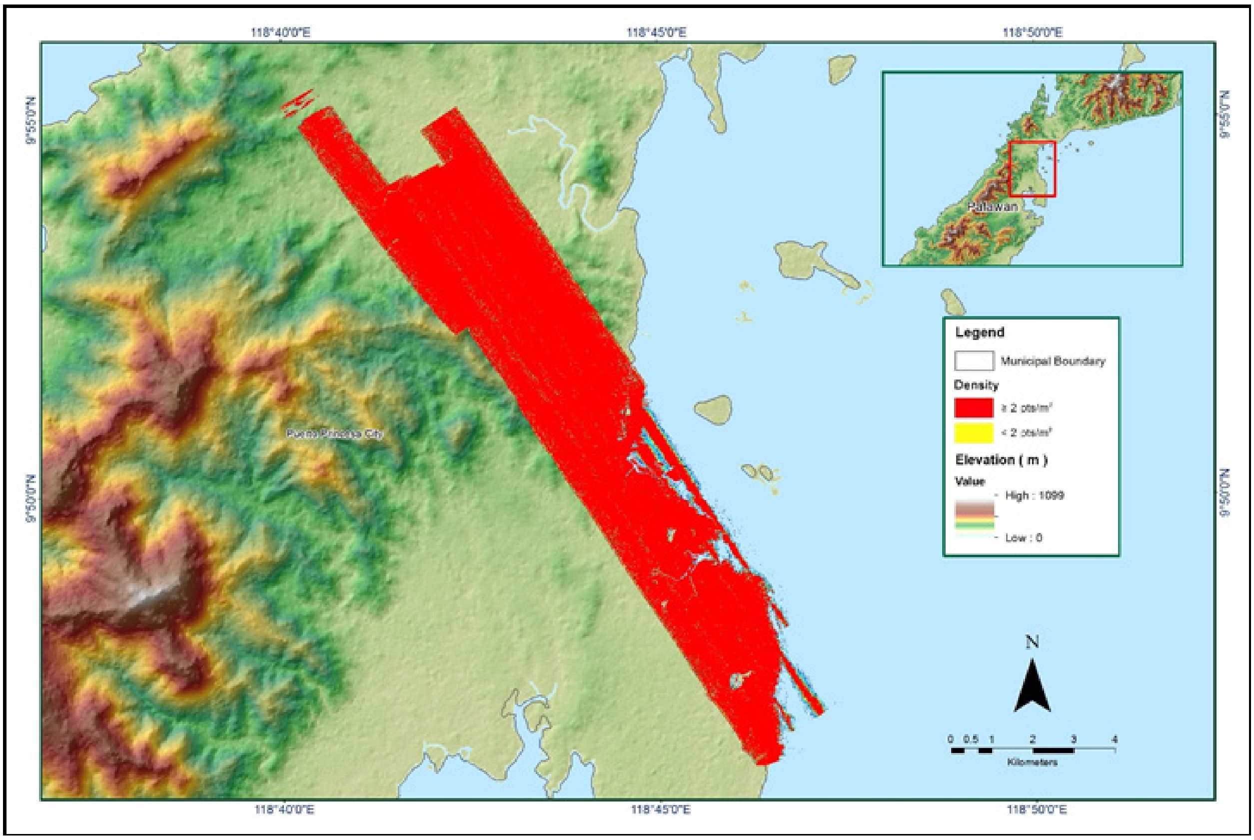


Figure A-8.34. Density map of merged LiDAR data

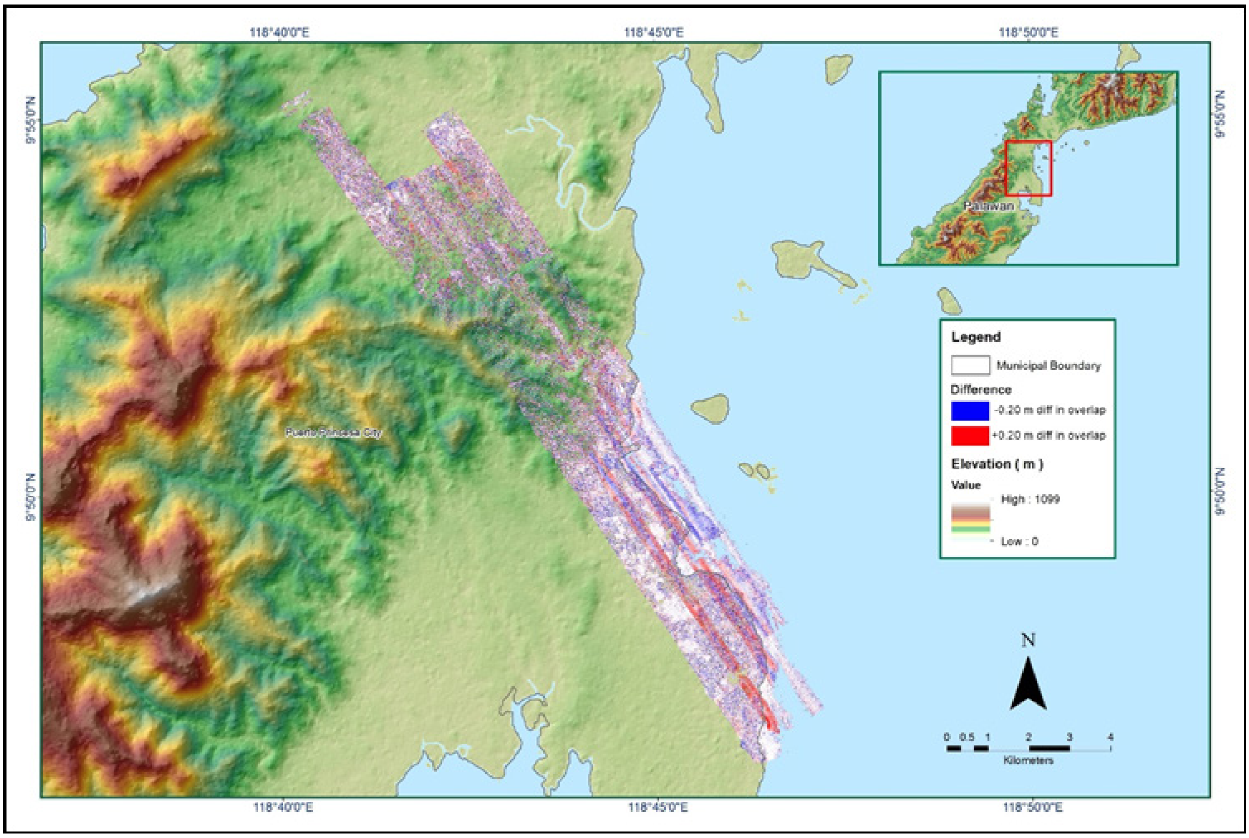


Figure A-8.35. Elevation difference between flight lines

Annex 9. Bacungan Model Basin Parameters

Table A-9.1. Bacungan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W1000	18.8570	99.0000	0.0	0.7581	7.6714	0.0909507	0.1489	0.4706
W1010	67.9120	99.0000	0.0	0.1463	16.1910	0.0168014	0.3217	0.4900
W1020	63.2370	99.0000	0.0	0.4035	29.5840	0.0351838	0.3217	0.4802
W1030	19.6940	99.0000	0.0	0.1346	6.7240	0.0217881	0.1489	0.4706
W1040	11.6600	43.1200	0.0	0.1100	3.5895	0.0366851	0.1489	0.4706
W1050	55.4900	50.6000	0.0	0.0812	3.9963	0.0117154	0.1492	0.4706
W1060	43.8870	66.0000	0.0	0.0167	4.0121	0.0203575	0.1489	0.4706
W1070	36.4360	44.1510	0.0	0.1456	23.6350	0.0200627	0.3217	0.4900
W1080	24.4280	99.0000	0.0	0.0550	1.1819	.00027378	0.1452	0.2178
W1090	47.1900	44.0000	0.0	0.2572	12.9910	0.0559369	0.1489	0.4706
W1100	69.8360	99.0000	0.0	0.1608	17.7970	0.0293682	0.2189	0.4802
W1120	49.8865	34.1883	0.0	0.4577	14.9410	0.0055042	0.5000	0.5000
W1130	19.1260	99.0000	0.0	0.0724	2.1557	.000740109	0.1489	0.2178
W560	98.2440	99.0000	0.0	0.2292	25.9630	0.0597909	0.3217	0.4900
W570	29.3720	44.0000	0.0	0.1438	4.6922	0.0495166	0.2189	0.4706
W580	28.5270	99.0000	0.0	0.1352	4.3133	0.0019811	0.1489	0.4706
W590	65.7930	99.0000	0.0	0.4040	45.4120	0.0359434	0.3217	0.5000
W600	19.0910	64.6800	0.0	0.2685	5.8717	0.0369107	0.1489	0.4706
W610	18.0930	99.0000	0.0	0.0899	4.3098	0.0302332	0.1489	0.4706
W620	18.5980	99.0000	0.0	0.1213	2.6240	0.0204628	0.1489	0.4706
W630	61.7030	64.9490	0.0	0.0926	15.3630	0.0316066	0.2189	0.4802
W640	23.5280	99.0000	0.0	0.1274	6.0154	0.0048453	0.1489	0.3201
W650	26.8650	44.0000	0.0	0.3816	19.5470	0.0493105	0.3217	0.4900

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W660	19.2000	99.0000	0.0	0.0795	5.8170	0.0174467	0.1489	0.4706
W670	10.7480	99.0000	0.0	0.0727	5.1270	0.0433084	0.1489	0.4706
W680	24.7530	99.0000	0.0	0.1226	5.0885	0.0193812	0.1489	0.3201
W690	45.7740	64.6800	0.0	0.1074	11.8350	0.0453317	0.2189	0.4802
W700	21.3110	99.0000	0.0	0.1104	18.4010	0.0406609	0.3217	0.4900
W710	26.2620	99.0000	0.0	0.1451	24.2130	0.0661721	0.3217	0.4900
W720	25.1980	99.0000	0.0	0.1641	4.9171	0.0395658	0.1489	0.4706
W730	29.5480	99.0000	0.0	0.1308	4.2697	0.0218588	0.1489	0.4706
W740	47.8140	99.0000	0.0	0.5475	27.6190	0.0594720	0.4729	0.5000
W750	12.6510	99.0000	0.0	0.3139	4.5760	0.0253081	0.1489	0.4706
W760	13.9420	99.0000	0.0	0.1017	3.3168	.000934162	0.1489	0.4706
W770	28.2290	99.0000	0.0	0.1960	5.6690	0.0102352	0.1489	0.4706
W780	31.9650	99.0000	0.0	0.1662	11.7140	0.0348122	0.1489	0.4706
W790	27.1380	99.0000	0.0	0.1826	5.4735	0.0211202	0.1489	0.4706
W800	32.4010	99.0000	0.0	1.0356	35.5110	0.0396380	0.4729	0.5000
W810	18.8400	99.0000	0.0	0.2642	5.1995	0.0032688	0.1489	0.4706
W820	23.7370	99.0000	0.0	0.1349	5.5141	0.0026897	0.1489	0.4706
W840	8.3022	99.0000	0.0	0.0922	2.9919	0.0015930	0.1489	0.3201
W850	13.4800	99.0000	0.0	0.2475	28.5130	0.0504042	0.3217	0.4900
W860	13.2740	99.0000	0.0	0.1555	6.5193	0.0184486	0.1489	0.4706
W870	17.4375	51.1000	0.0	0.3088	10.0790	0.0212074	0.5000	0.5000
W880	27.4610	44.3991	0.0	0.3857	12.5880	0.0096289	0.5000	0.5000
W890	24.8332	46.0093	0.0	0.4799	15.6620	0.0057193	0.5000	0.5000
W900	22.2265	47.7263	0.0	0.3877	12.6540	0.0237677	0.5000	0.5000
W910	18.0990	99.0000	0.0	0.1669	5.5335	0.0372311	0.1489	0.4706

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W920	13.1080	99.0000	0.0	0.0932	15.0610	0.0493632	0.2189	0.4802
W930	8.3735	99.0000	0.0	0.0829	4.7799	0.0060743	0.1489	0.4706
W940	18.8400	99.0000	0.0	0.2667	3.8768	0.0157664	0.1489	0.4706
W950	8.7446	99.0000	0.0	0.1385	4.5152	0.0228637	0.1489	0.4706
W960	8.3735	97.4800	0.0	0.0709	3.5766	0.0024129	0.1489	0.4706
W970	11.7740	97.2090	0.0	0.1105	5.3041	0.0620022	0.1489	0.4706
W980	13.2690	62.7200	0.0	0.1640	28.8860	0.0101509	0.2189	0.4802
W990	22.9500	99.0000	0.0	0.0865	6.6786	0.0061932	0.1489	0.4706

Annex 10. Bacungan Model Reach Parameters

Table A-10.1. Bacungan 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	2181.4	0.0158397	0.02	Trapezoid	40	1
R1140	Automatic Fixed Interval	237.28	0.0294399	0.02	Trapezoid	40	1
R130	Automatic Fixed Interval	2478.2	0.0696279	0.02	Trapezoid	40	1
R140	Automatic Fixed Interval	4387.6	0.0114757	0.02	Trapezoid	40	1
R190	Automatic Fixed Interval	3682.3	0.0090819	0.02	Trapezoid	40	1
R200	Automatic Fixed Interval	291.42	0.0050308	0.02	Trapezoid	40	1
R220	Automatic Fixed Interval	1069.1	0.0011576	0.02	Trapezoid	40	1
R240	Automatic Fixed Interval	655.98	0.0037033	0.02	Trapezoid	40	1
R250	Automatic Fixed Interval	4864.6	0.0048277	0.02	Trapezoid	40	1
R260	Automatic Fixed Interval	3745.8	0.0058359	0.02	Trapezoid	40	1
R270	Automatic Fixed Interval	509.41	0.0026210	0.02	Trapezoid	40	1
R280	Automatic Fixed Interval	821.84	0.0010244	0.02	Trapezoid	40	1
R290	Automatic Fixed Interval	430.42	0.0078706	0.004	Trapezoid	40	1
R310	Automatic Fixed Interval	973.26	0.0011080	0.004	Trapezoid	40	1
R320	Automatic Fixed Interval	823.05	0.0011080	0.004	Trapezoid	40	1
R360	Automatic Fixed Interval	2297.9	0.0020770	0.02	Trapezoid	40	1
R370	Automatic Fixed Interval	552.13	0.0037127	0.02	Trapezoid	40	1
R390	Automatic Fixed Interval	493.85	0.0153568	0.02	Trapezoid	40	1
R40	Automatic Fixed Interval	404.56	0.0013382	0.02	Trapezoid	40	1
R400	Automatic Fixed Interval	4046.5	0.0051451	0.02	Trapezoid	40	1
R410	Automatic Fixed Interval	1592.3	0.0091357	0.02	Trapezoid	40	1
R420	Automatic Fixed Interval	1130.5	0.0076201	0.02	Trapezoid	40	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R440	Automatic Fixed Interval	1427.1	0.0099449	0.02	Trapezoid	40	1
R450	Automatic Fixed Interval	760.12	0.0157952	0.02	Trapezoid	40	1
R470	Automatic Fixed Interval	925.69	0.0071733	0.02	Trapezoid	40	1
R480	Automatic Fixed Interval	100.71	0.0704455	0.02	Trapezoid	40	1
R50	Automatic Fixed Interval	1895.1	0.0347359	0.02	Trapezoid	40	1
R70	Automatic Fixed Interval	439.41	0.0301299	0.02	Trapezoid	40	1

Annex 11. Bacungan Field Validation Points

Table A-11.1. Bacungan Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
1	9.88759159000	118.71482210000	0.03	0	-0.03			25-Year
2	9.88812233300	118.70701440000	0.03	0	-0.03			25-Year
3	9.89397781100	118.71259200000	0.03	0	-0.03			25-Year
4	9.89388885700	118.69287670000	0.03	0	-0.03			25-Year
5	9.89420310600	118.71141540000	0.03	0	-0.03			25-Year
6	9.89393705200	118.68648390000	0.03	0	-0.03			25-Year
7	9.89406860000	118.68913000000	0.25	0	-0.25			25-Year
8	9.89417786300	118.69115490000	0.03	0	-0.03			25-Year
9	9.89457372600	118.72137540000	0.03	0	-0.03			25-Year
10	9.89470376800	118.68779000000	0.03	0	-0.03			25-Year
11	9.89506284900	118.71286530000	0.03	0	-0.03			25-Year
12	9.89521046800	118.72212640000	0.03	0	-0.03			25-Year
13	9.89529796100	118.72087520000	0.03	0	-0.03			25-Year
14	9.89571406100	118.72454660000	0.03	0	-0.03			25-Year
15	9.89578970000	118.72511000000	0.03	0	-0.03			25-Year
16	9.89537830000	118.68502000000	1.49	0	-1.49			25-Year
17	9.89545930000	118.69033000000	1.18	0.35	-0.83	Lawin	Oct. 2016	25-Year
18	9.89539050000	118.68381000000	0.03	0	-0.03			25-Year
19	9.89588576000	118.71654510000	0.03	0	-0.03			25-Year
20	9.89550802900	118.68573350000	1.53	0	-1.53			25-Year
21	9.89585810000	118.69143000000	0.03	0	-0.03			25-Year
22	9.89626160100	118.71395800000	0.03	0	-0.03			25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
23	9.89633243900	118.71706170000	0.03	0	-0.03			25-Year
24	9.89648130000	118.72286000000	0.8	0	-0.8			25-Year
25	9.89592570000	118.67859000000	1.16	0	-1.16			25-Year
26	9.89604910000	118.68696000000	1.09	0	-1.09			25-Year
27	9.89598240000	118.68003000000	1.53	0	-1.53			25-Year
28	9.89691980000	118.72374000000	0.59	0.35	-0.24	Lawin	Oct. 2016	25-Year
29	9.89734040000	118.72867000000	0.03	0	-0.03			25-Year
30	9.89694189100	118.67500280000	0.03	0	-0.03			25-Year
31	9.89719520000	118.66792000000	0.03	0	-0.03			25-Year
32	9.89810770000	118.72207000000	0.29	0.47	0.18	Karen	Oct. 2016	25-Year
33	9.89778679800	118.69212830000	0.03	0	-0.03			25-Year
34	9.89792030000	118.66850000000	0.03	0.3	0.27	Lawin	Oct. 2016	25-Year
35	9.89830800000	118.67018000000	1.33	0	-1.33			25-Year
36	9.89830885200	118.66921930000	0.03	0	-0.03			25-Year
37	9.89881006700	118.69311750000	0.03	0	-0.03			25-Year
38	9.90140190000	118.69426000000	0.03	0	-0.03			25-Year
39	9.90281132600	118.69710410000	0.03	0	-0.03			25-Year
40	9.90368840000	118.69564000000	2.13	0.47	-1.66		2015	25-Year
41	9.90600160000	118.69765000000	0.03	0	-0.03			25-Year
42	9.90615934300	118.69828740000	0.03	0	-0.03			25-Year
43	9.90693802400	118.69994230000	0.13	0	-0.13			25-Year
44	9.90736882200	118.69942370000	0.03	0	-0.03			25-Year
45	9.90880920000	118.68978000000	0.03	1	0.97			25-Year
46	9.90925020400	118.70005790000	0.06	0	-0.06			25-Year
47	9.90943795100	118.70166830000	0.04	0	-0.04			25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
48	9.90956719600	118.70104600000	0.05	0	-0.05			25-Year
49	9.90973240000	118.69758000000	2.54	0	-2.54			25-Year
50	9.90981460000	118.70140000000	0.03	0.55	0.52	Yolanda	Nov. 2013	25-Year
51	9.90986343400	118.70336950000	0.03	0	-0.03			25-Year
52	9.90986546800	118.69632020000	0.03	0	-0.03			25-Year
53	9.91007494500	118.70261210000	0.03	0	-0.03			25-Year
54	9.91046108200	118.70104720000	0.03	0	-0.03			25-Year
55	9.91055130000	118.69766000000	2.52	0.5	-2.02	Ondoy	Sept. 2009	25-Year
56	9.91077133700	118.70180510000	0.03	0	-0.03			25-Year
57	9.91110160000	118.70434000000	2.03	0.36	-1.67	Yolanda	Nov. 2013	25-Year
58	9.91106880300	118.70119530000	0.06	0	-0.06			25-Year
59	9.91120293500	118.69636800000	0.03	0	-0.03			25-Year
60	9.91131310000	118.70466000000	3.12	0.45	-2.67	Yolanda	Nov. 2013	25-Year
61	9.91136640000	118.70503000000	2.82	0.31	-2.51			25-Year
62	9.91149980000	118.70347000000	2.04	1	-1.04	Lando	Oct. 2015	25-Year
63	9.91154310000	118.70434000000	3.66	0.6	-3.06	Yolanda	Nov. 2013	25-Year
64	9.91173870000	118.70514000000	3.91	0.65	-3.26	Yolanda	Nov. 2013	25-Year
65	9.91173787500	118.70158530000	0.03	0	-0.03			25-Year
66	9.91171583200	118.69544540000	0.03	0	-0.03			25-Year
67	9.91268858900	118.69218150000	0.03	0	-0.03			25-Year
68	9.91328830000	118.70670000000	3.37	0.65	-2.72	Ondoy	Sept. 2009	25-Year
69	9.91313335700	118.69328620000	0.2	0	-0.2			25-Year
70	9.91356372700	118.69276730000	0.03	0	-0.03			25-Year
71	9.91398470000	118.70768000000	2.96	0.65	-2.31	Ondoy	Sept. 2009	25-Year
72	9.91428590000	118.70060000000	3.33	1	-2.33	Yolanda	Nov. 2013	25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
73	9.91539907300	118.71621810000	0.03	0	-0.03			25-Year
74	9.91561564200	118.72979930000	0.03	0	-0.03			25-Year
75	9.91573570000	118.70911000000	2.36	1.8	-0.56	Glenda	July 2014	25-Year
76	9.91663022700	118.71546640000	0.04	0	-0.04			25-Year
77	9.91671060000	118.70974000000	2.46	2.3	-0.16	Frank	June 2008	25-Year
78	9.91713350000	118.71532000000	0.03	1.05	1.02	Yolanda	Nov. 2013	25-Year
79	9.91736157000	118.71132230000	0.36	0	-0.36			25-Year
80	9.91769581400	118.73283300000	0.03	0	-0.03			25-Year
81	9.91745070000	118.71271000000	0.03	1.7	1.67	Glenda	July 2014	25-Year
82	9.91754649100	118.71424270000	0.03	0	-0.03			25-Year
83	9.91735370000	118.69225000000	0.03	1.3	1.27			25-Year
84	9.917729728	118.7121646	1.71	0	-1.71			25-Year
85	9.917811315	118.7155575	0.03	0	-0.03			25-Year
86	9.918076072	118.7141749	0.03	0	-0.03			25-Year
87	9.918303932	118.7198459	0.03	0	-0.03			25-Year
88	9.918571485	118.7183045	0.03	0	-0.03			25-Year
89	9.9184911	118.70672	5.57	1.3	-4.27	Lando	Oct. 2015	25-Year
90	9.918753577	118.7117567	0.03	0	-0.03			25-Year
91	9.918749	118.70529	3.49	0.7	-2.79	Lawin	Oct. 2016	25-Year
92	9.918767	118.70524	3.17	2.6	-0.57	Ondoy	Sept. 2009	25-Year
93	9.9189997	118.7048	2.83	1.13	-1.7	Ondoy	Sept. 2009	25-Year
94	9.919628076	118.7191141	0.26	0	-0.26			25-Year
95	9.91911533	118.6790555	0.03	0	-0.03			25-Year
96	9.920117569	118.6910732	0.05	0	-0.05			25-Year
97	9.920207719	118.6900343	0.03	0	-0.03			25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
98	9.92084838	118.7235193	0.03	0	-0.03			25-Year
99	9.920512	118.69659	1.54	1	-0.54	Heavy Rain		25-Year
100	9.921161138	118.7269511	0.06	0	-0.06			25-Year
101	9.921207548	118.7252589	0.24	0	-0.24			25-Year
102	9.921310985	118.7255436	0.76	0	-0.76			25-Year
103	9.921474366	118.7271847	0.03	0	-0.03			25-Year
104	9.92158215	118.7229681	1.12	0	-1.12			25-Year
105	9.921739421	118.7224131	4.8	0	-4.8			25-Year
106	9.9217252	118.69021	0.03	0.75	0.72	Yolanda	Nov. 2013	25-Year
107	9.922825927	118.6766556	0.03	0	-0.03			25-Year
108	9.923488201	118.7251808	0.03	0	-0.03			25-Year
109	9.923721321	118.7315631	0.05	0	-0.05			25-Year
110	9.923109853	118.6792426	1.59	0	-1.59			25-Year
111	9.923124994	118.6770572	0.03	0	-0.03			25-Year
112	9.923825932	118.729335	0.03	0	-0.03			25-Year
113	9.924053844	118.7309005	0.03	0	-0.03			25-Year
114	9.924175722	118.7351195	0.09	0	-0.09			25-Year
115	9.92434317	118.7315014	0.03	0	-0.03			25-Year
116	9.924496835	118.7342663	0.04	0	-0.04			25-Year
117	9.923824285	118.6771636	0.07	0	-0.07			25-Year
118	9.924040121	118.6780673	0.08	0	-0.08			25-Year
119	9.924037245	118.6772645	0.06	0	-0.06			25-Year
120	9.924836621	118.7337616	0.03	0	-0.03			25-Year
121	9.9243403	118.68419	0.03	0	-0.03			25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
122	9.925038148	118.6762729	0.06	0	-0.06			25-Year
123	9.926187082	118.7357826	0.03	0	-0.03			25-Year
124	9.927585388	118.7289646	0.03	0	-0.03			25-Year
125	9.9287066	118.67244	0.03	0	-0.03			25-Year
126	9.929511904	118.6718112	0.04	0	-0.04			25-Year
127	9.93095007	118.7383141	0.03	0	-0.03			25-Year
128	9.930508744	118.6716334	0.11	0	-0.11			25-Year
129	9.93168121	118.6706984	0.03	0	-0.03			25-Year
130	9.938630477	118.7485865	0.03	0	-0.03			25-Year
131	9.938675263	118.7410512	0.03	0	-0.03			25-Year
132	9.939114563	118.7412163	0.03	0	-0.03			25-Year
133	9.939876401	118.7433314	0.09	0	-0.09			25-Year
134	9.941810158	118.7482706	0.03	0	-0.03			25-Year
135	9.943288329	118.7493273	0.19	0	-0.19			25-Year
136	9.943862133	118.7486824	0.07	0	-0.07			25-Year
137	9.945339382	118.7478469	1.21	0	-1.21			25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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

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

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

Research Associates
Alfi Lorenz B. Cura
Angelica T. Magpantay
Gemmalyn E. Magnaye
Jayson L. Arizapa
Kevin M. Manalo
Leendel Jane D. Punzalan
Maria Michaela A. Gonzales
Paulo Joshua U. Quilao
Sarah Joy A. Acepcion
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Computer Programmers
Ivan Marc H. Escamos
Allen Roy C. Roberto

Information Systems Analyst
Jan Martin C. Magcale

Project Assistants
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Athena Mercado
Kaye Anne A. Matre
Randy P. Porciocula