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

LiDAR Surveys and Flood Mapping of Malambunga 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
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 MALAMBUNGA RIVER

Enrico C. Paringit, Dr. Eng. and Asst. Prof. Edwin Abucay

1.1 Background of the Phil-LiDAR 1 Program

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

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

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

1.2 Overview of the Malambunga River Basin

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

Malambunga River Basin is a 81,000-hectare watershed located in Palawan. It covers the barangays of Amas, Saraza and Tubtub in Brooke's Point municipality; and, Campong Ulay and Punta Baja in Rizal. The river basin is generally characterized by >50% slope. Sibul clay and rough mountain land (unclassified) can be found Malambunga River Basin. Closed canopy (mature trees covering <50%) dominates the basin area, followed by cultivated area mixed with brushland/grassland, cropland mixed with coconut plantation, open canopy (mature trees covering <50%) and mossy forests.

Malambunga River passes through Amas, Saraza and Tubtub in Brooke's Point municipality; and, Campong Ulay and Punta Baja in Rizal. The 2010 NSO Census of Population and Housing showed that Saraza in Brooke's Point, and Punta Baja in Rizal are the most populated barangays.

Based on the studies conducted by the Mines and Geosciences Bureau, only Punta Baja has a flood susceptibility range of low to high risk while other barangays have no flooding risk. The field surveys conducted by the PHIL-LiDAR 1 validation team found that two flooding events occurred in 2013 (Auring) and 2015 (heavy rainfall) affecting Punta Baja. As for landslide susceptibility, the other areas of Punta Baja have a range of low to high risk while others have moderate to high risk.

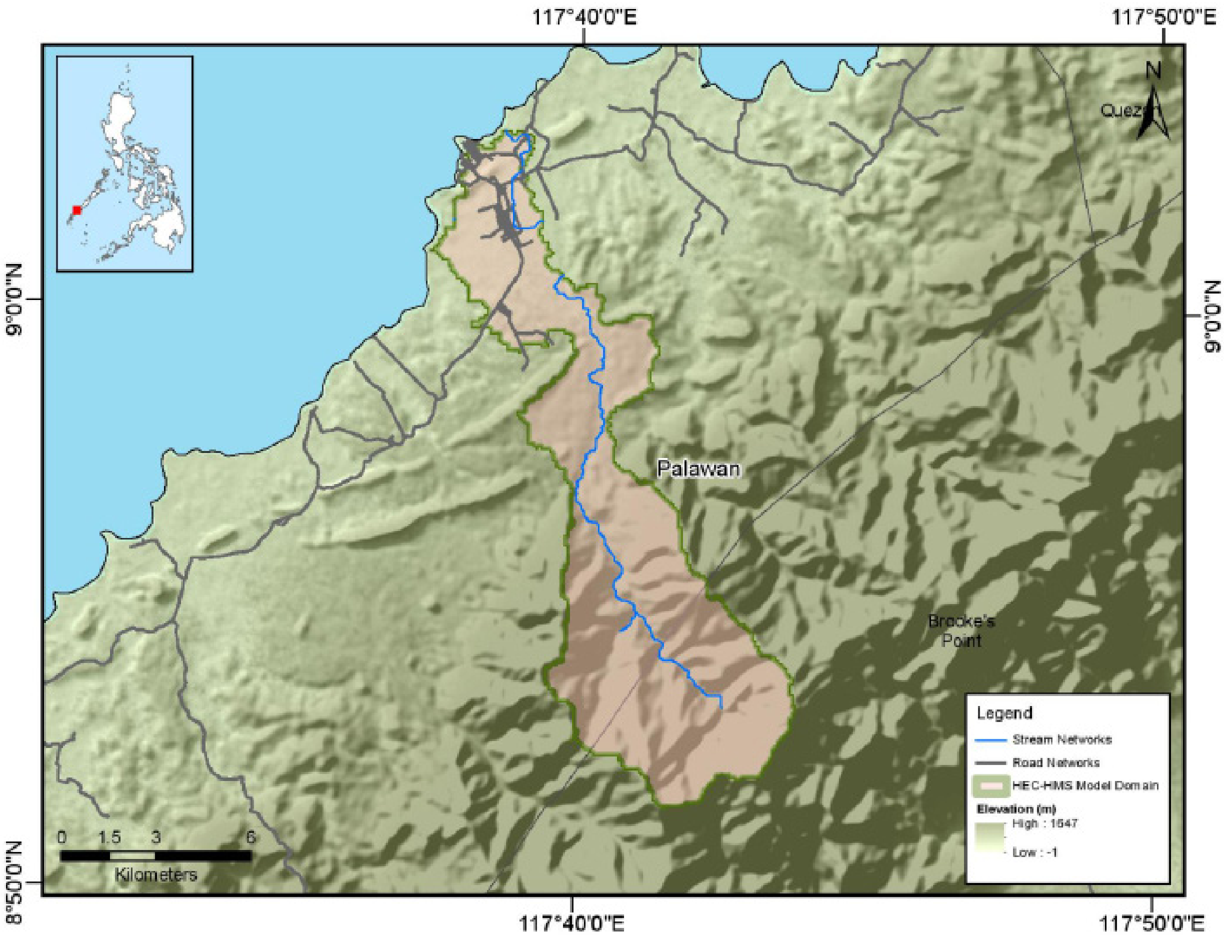

Figure 1. Map of the Malambunga River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MALAMBUNGA 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 Malambunga floodplain in Palawan. These missions were planned for 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 is found in Table 1. Figure 2 shows the flight plans and base stations used for Malambunga 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)
BLK42M	1200	30	50	200	30	130	5
BLK42N	1200	30	50	200	30	130	5
BLK42O	1200	30	50	200	30	130	5
BLK42P	1200	30	50	200	30	130	5
BLK42S	1200	30	50	200	30	130	5

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

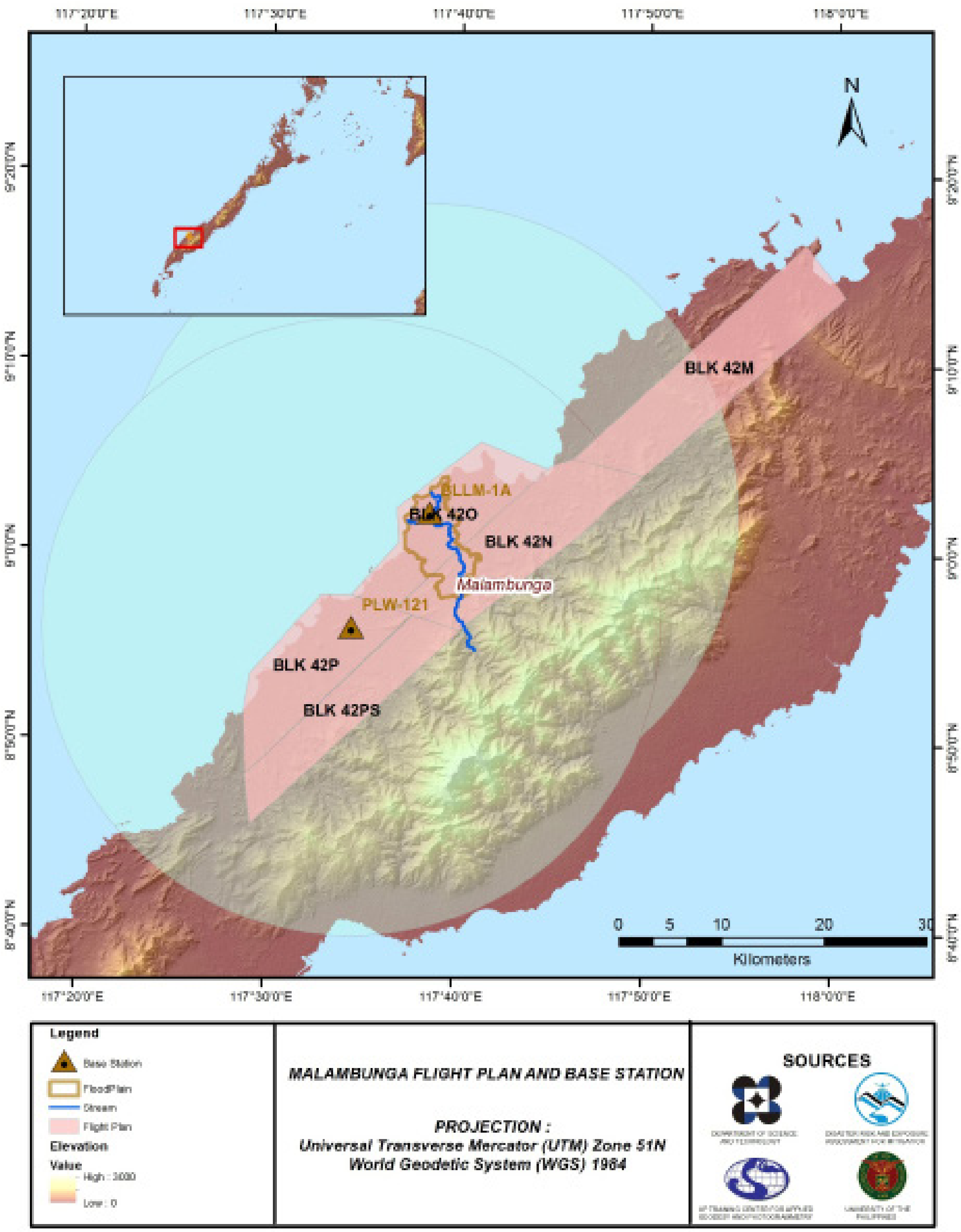

Figure 2. Flight Plan and base stations used for the Malambunga Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point: PLW-121 which is of second (2nd) order accuracy. The project team also established one (1) ground control point: BLLM-1. The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing report for the established ground control point is found in Annex 3. These were used as base stations during flight operation on July 11, 2015. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS[Iro, may SPS-R8 tayo ginamit?] 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Malambunga Floodplain are shown in Figure 2.

Figure 3 shows the recovered NAMRIA reference point within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations and established points while Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3. GPS set-up over PLW-121 as recovered within the vicinity of Cabkungan Elementary School in Brgy. Campong Ulay, Rizal, Palawan (a) and NAMRIA reference point PLW-121 (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point PLW-121 used as base station for the LiDAR acquisition

Station Name	PLW-121	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 56’ 1.71426” North 117° 34’ 23.99157” East 8.98036 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting Northing	398086.54 meters 987945.887 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 55’ 57.38325” North 117° 34’ 29.39124” East 58.05800 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting Northing	563030.26 meters 987521.12 meters

Table 3. Details of the established horizontal control point BLLM-1A used as base station for the LiDAR acquisition

Station Name	**BLLM-1A**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 02' 07.68639" North 117° 38' 28.10618" East -2.0700 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 02' 03.33580" North 117° 38' 33.49665" East 46.965 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting Northing	570465.682 meters 998772.489 meters

Table 4. Ground control points that were used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 11, 2015	3157P	1BLK42PO192A	PLW-121, BLLM-1A
July 11, 2015	3159P	1BLK42PO192B	PLW-121, BLLM-1A

2.3 Flight Missions

Two (2) missions were conducted to complete the LiDAR data acquisition in Malambunga Floodplain, for a total of seven hours and fifty-five minutes (7+35) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight missions for the LiDAR data acquisition of the Malambunga 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
July 11, 2015	3157P	546.67	445.38	39.94	405.44	538	4	23
July 11, 2015	3159P	385.73	231.17	29.40	201.77	1	3	12
TOTAL		932.4	676.55	69.34	607.21	539	7	35

Table 6. Actual parameters used during the LiDAR data acquisition of the Malambunga Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3157P	1200	30	50	200	25	130	5
3159P	1200	30	50	200	25	130	5

2.4 Survey Coverage

Malambunga Floodplain is situated within the municipality of Rizal in the province of Palawan. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Malambunga Floodplain is presented in Figure 4.

Table 8. List of municipalities and cities surveyed of the Malambunga Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Rizal	980.59	460.78	46.99%
	Quezon	917.97	52.71	5.74%
Total		**1898.56**	**513.49**	**26.37%**

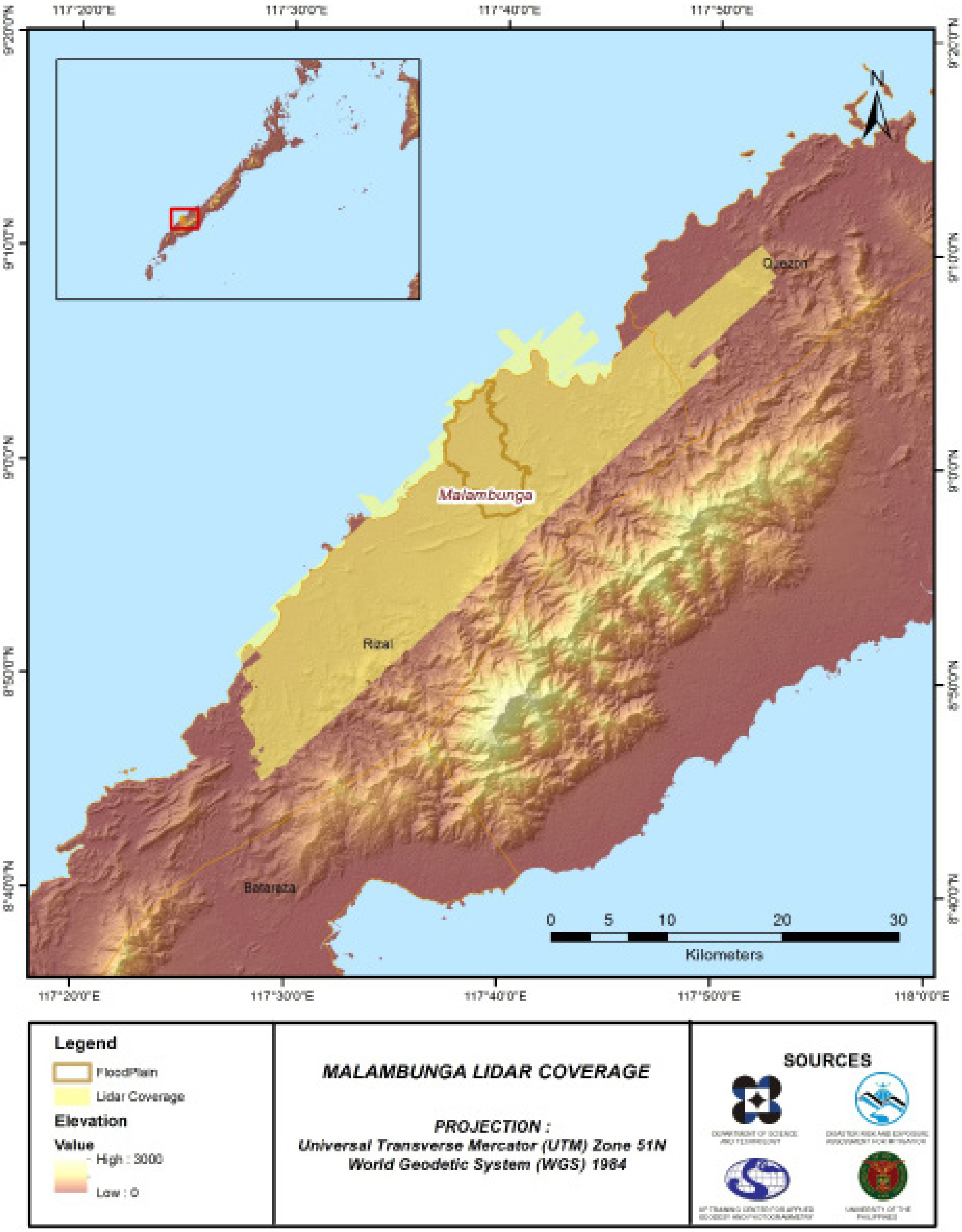

Figure 4. Actual LiDAR survey coverage of the Malambunga Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MALAMBUNGA 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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flow chart shown in Figure 5.

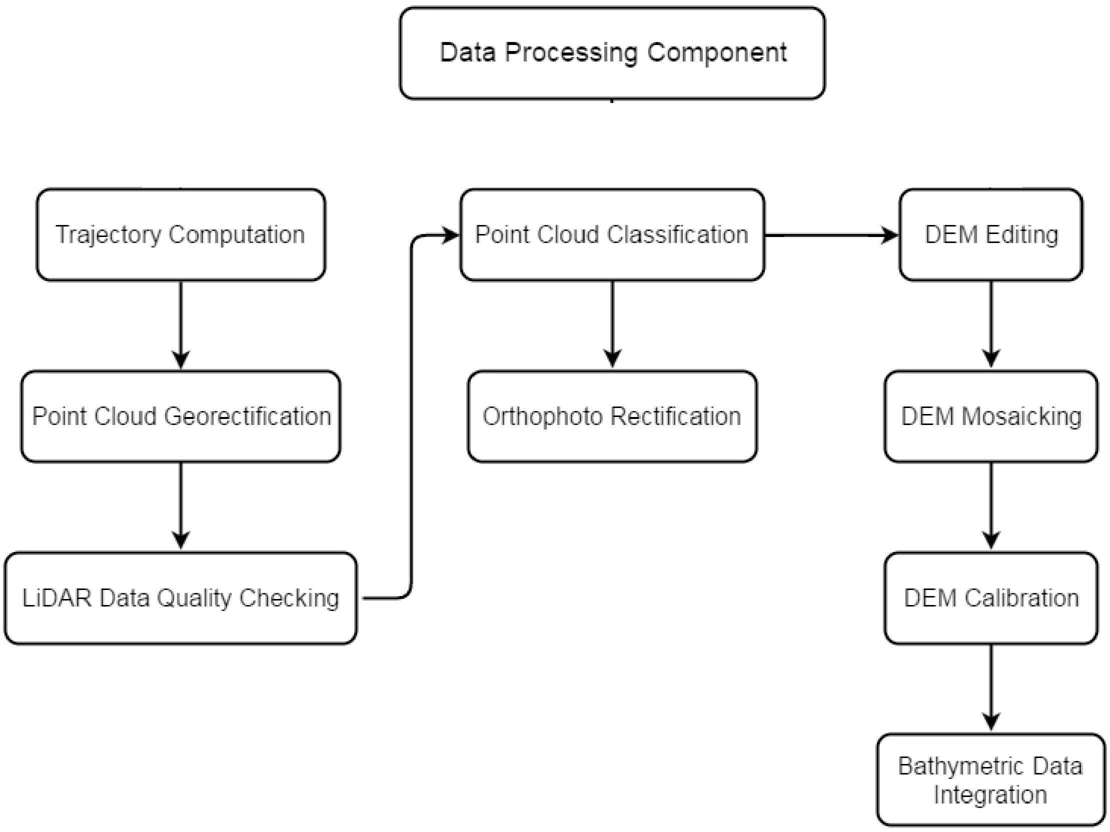


Figure 5. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Malambunga Floodplain can be found in Annex 5. Missions flown during the survey conducted on July 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Palawan. The Data Acquisition Component (DAC) transferred a total of 64.9 Gigabytes of Range data, 4.78 Gigabytes of POS data, 41.2 Megabytes of GPS base station data, and 90.7 Gigabytes of raw image data to the data server on July 11, 2015 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Malambunga was fully transferred on August 05, 2015, as indicated on the Data Transfer Sheets for Malambunga Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3159P, one of the Malambunga flights, which is the North, East, and Down position RMSE values are shown in Figure 6. 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 July 11, 2015 00:00PM. The y-axis is the RMSE value for that particular position.

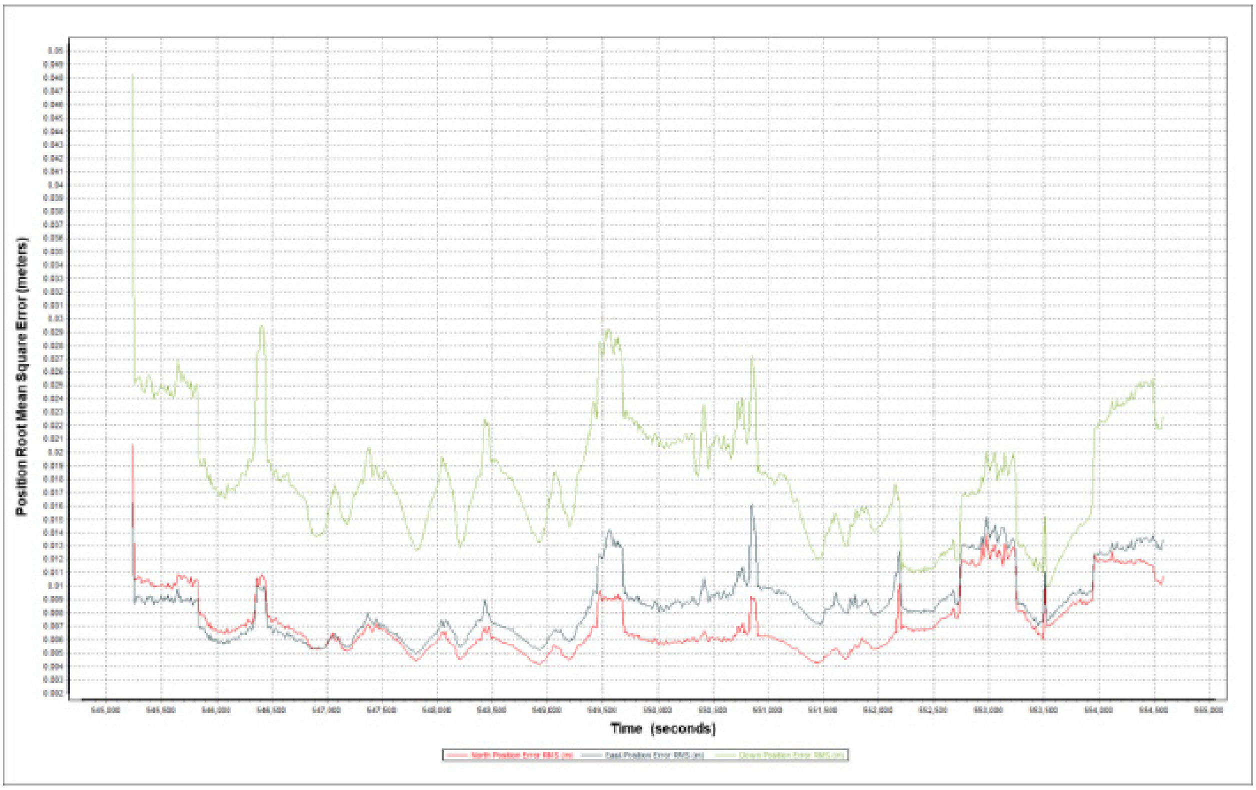


Figure 6. Smoothed Performance Metrics of Malambunga Flight 3159P.

The time of flight was from 545,000 seconds to 555,000 seconds, which corresponds to afternoon of July 11, 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 6 shows that the North position RMSE peaks at 1.40 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 0.30 centimeters, which are within the prescribed accuracies described in the methodology.

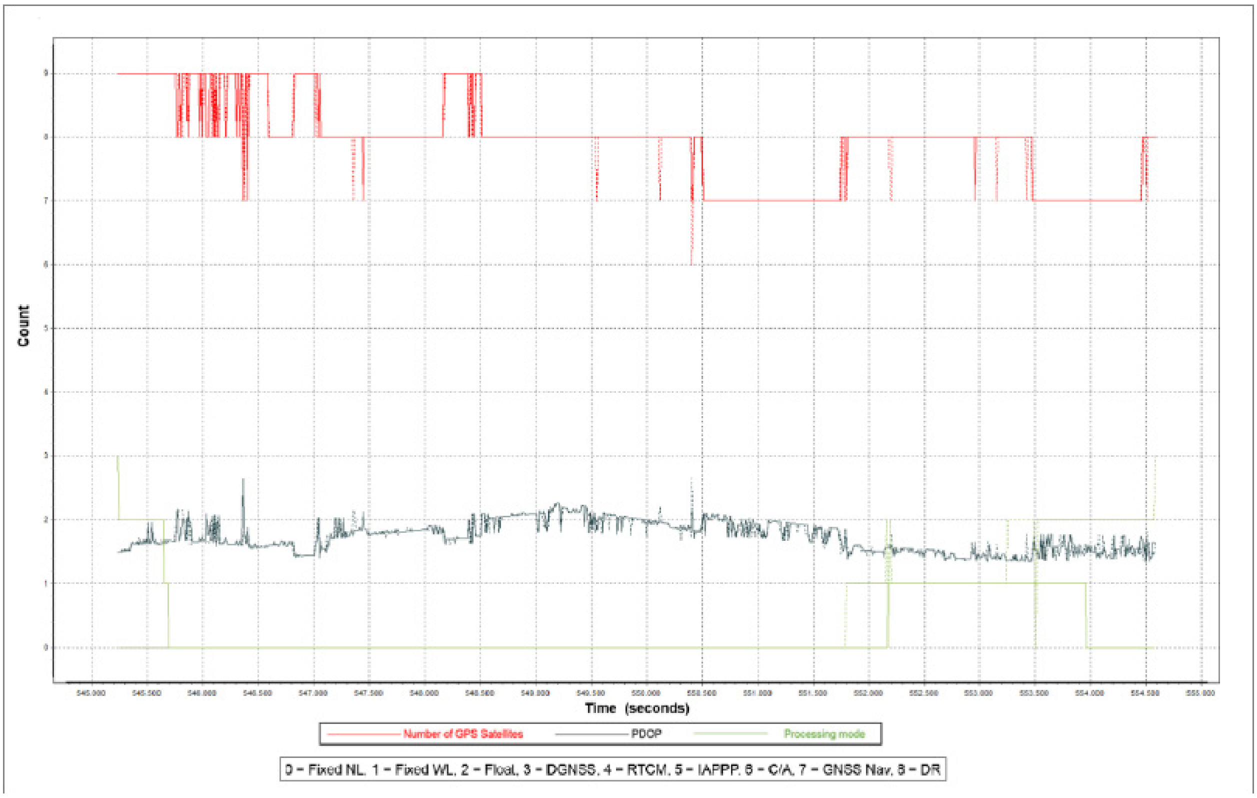


Figure 7. Solution Status Parameters of Malambunga Flight 3159P.

The Solution Status parameters of flight 3159P,one of the Malambunga flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 7. 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 9. 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 Malambunga flights is shown in Figure 8.

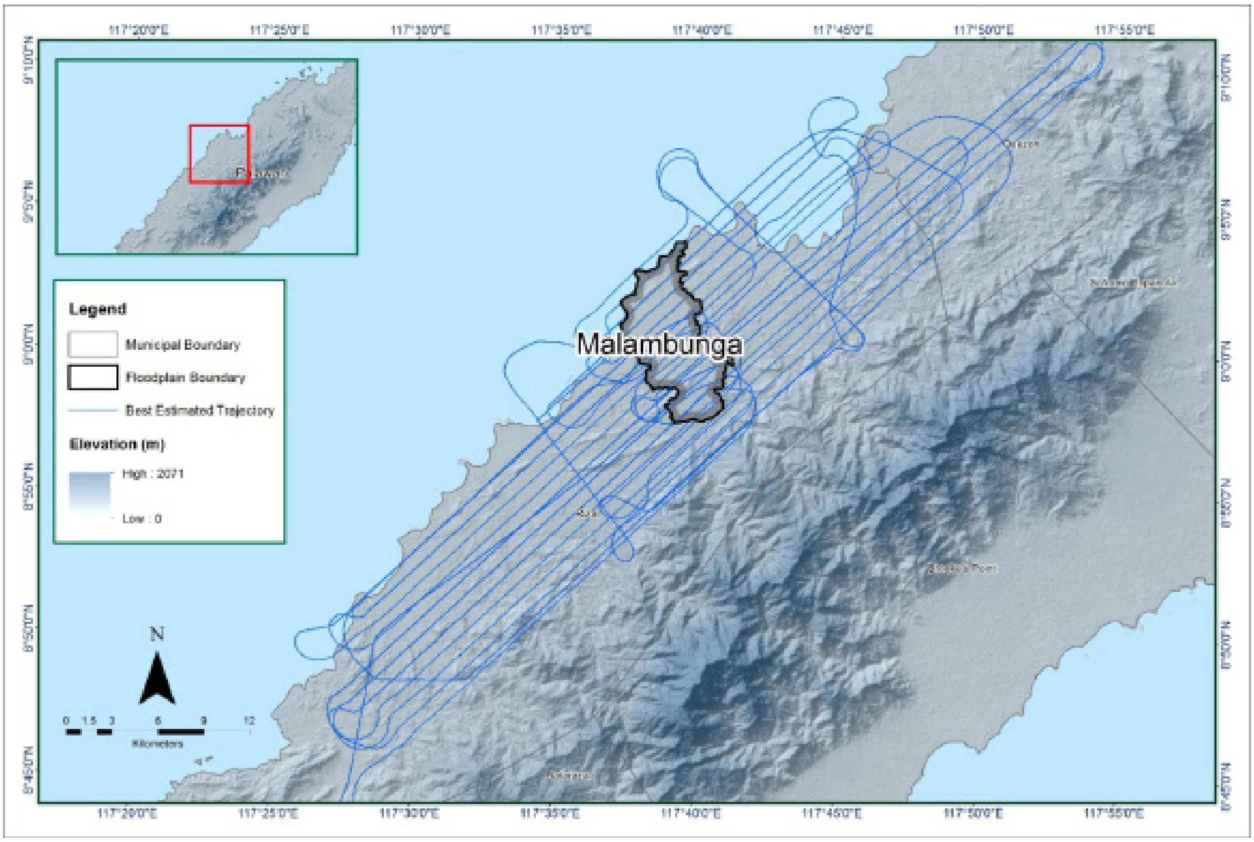


Figure 8. Best Estimated Trajectory of the LiDAR missions conducted over the Malambunga Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 24 flight lines, with each flight line containing two channels, since the Pegasus system contain two channels only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Malambunga Floodplain are given in Table 8.

Table 8. Self-calibration Results values for Malambunga flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000370
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000735
GPS Position Z-correction stdev	<0.01meters	0.0025

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Malambunga Floodplain is shown in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

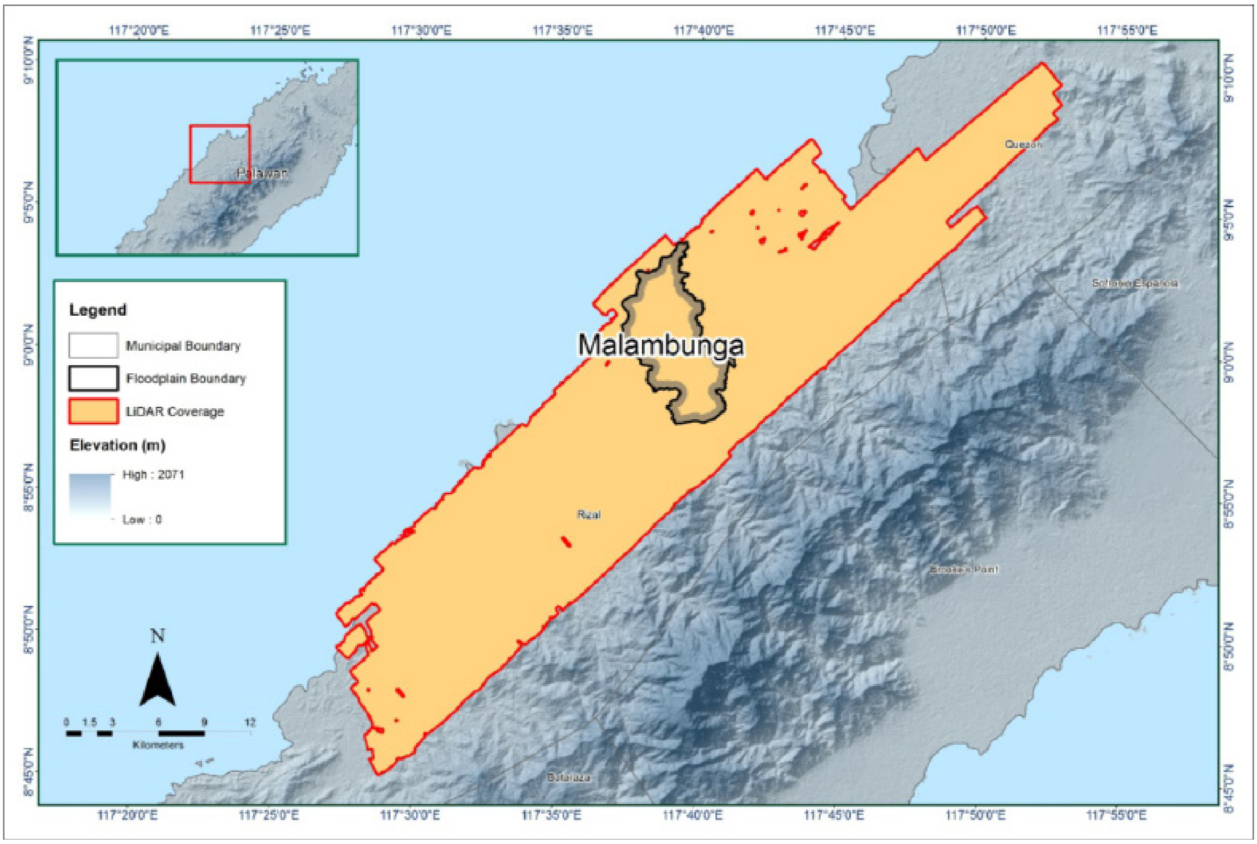


Figure 9. Boundary of the processed LiDAR data over Malambunga Floodplain

The total area covered by the Malambunga missions is 606.96 sq.km that is comprised of two (2) flight acquisitions grouped and merged into eight (3) blocks as shown in Table 9

Table 9. List of LiDAR blocks for Malambunga Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_Blk42N	3157P	189.40
	3159P	
Palawan_Blk42O	3157P	114.57
	3159P	
Palawan_Blk42P	3157P	307.61
	3159P	
TOTAL		606.96 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 10. Since the Pegasus system employs two channels, an average value of 2 (blue) for areas where there is limited overlap is expected, as well as a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

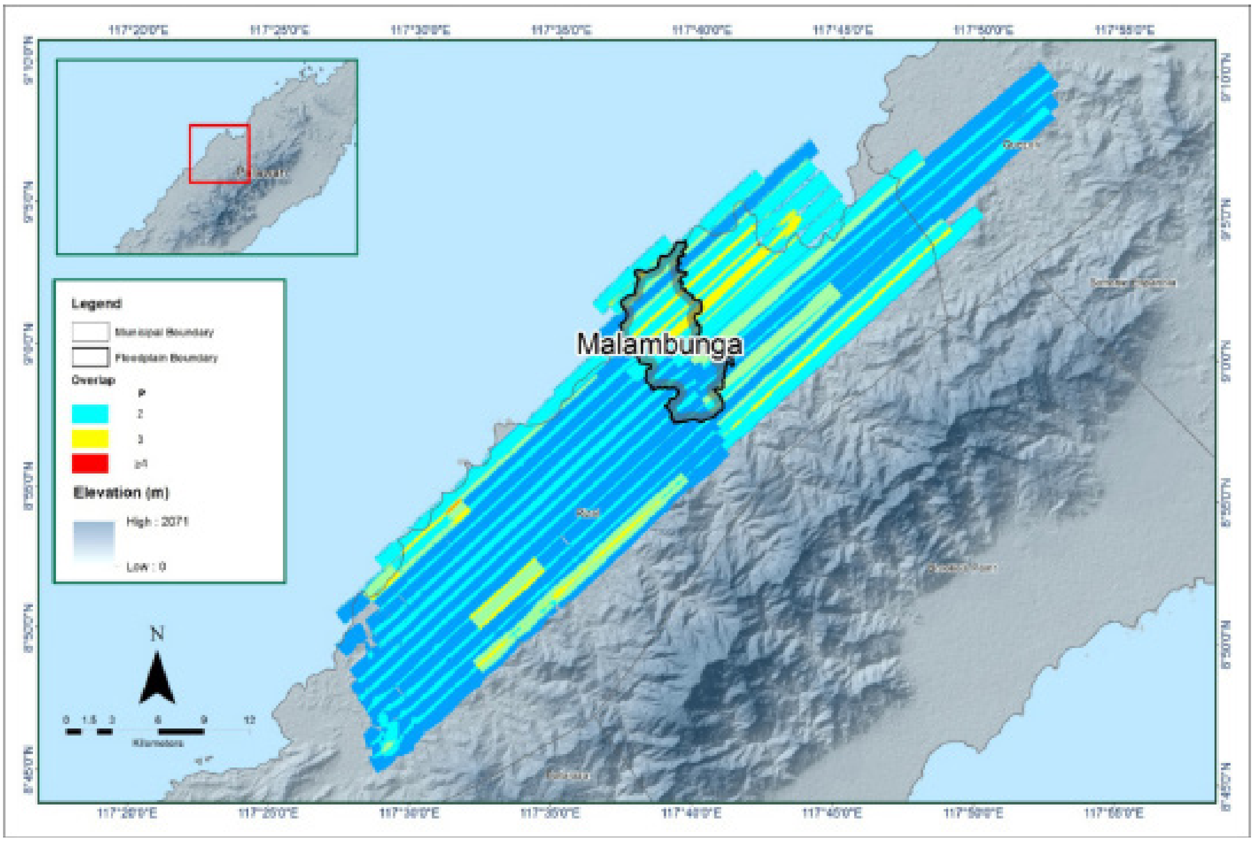


Figure 10. Image of data overlap for Malambunga Floodplain.

The overlap statistics per block for the Malambunga Floodplain can be found in Annex[Check annex number] One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 13.66% and 21.33% respectively.

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 11. It was determined that all LiDAR data for Malambunga Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.11 points per square meter.

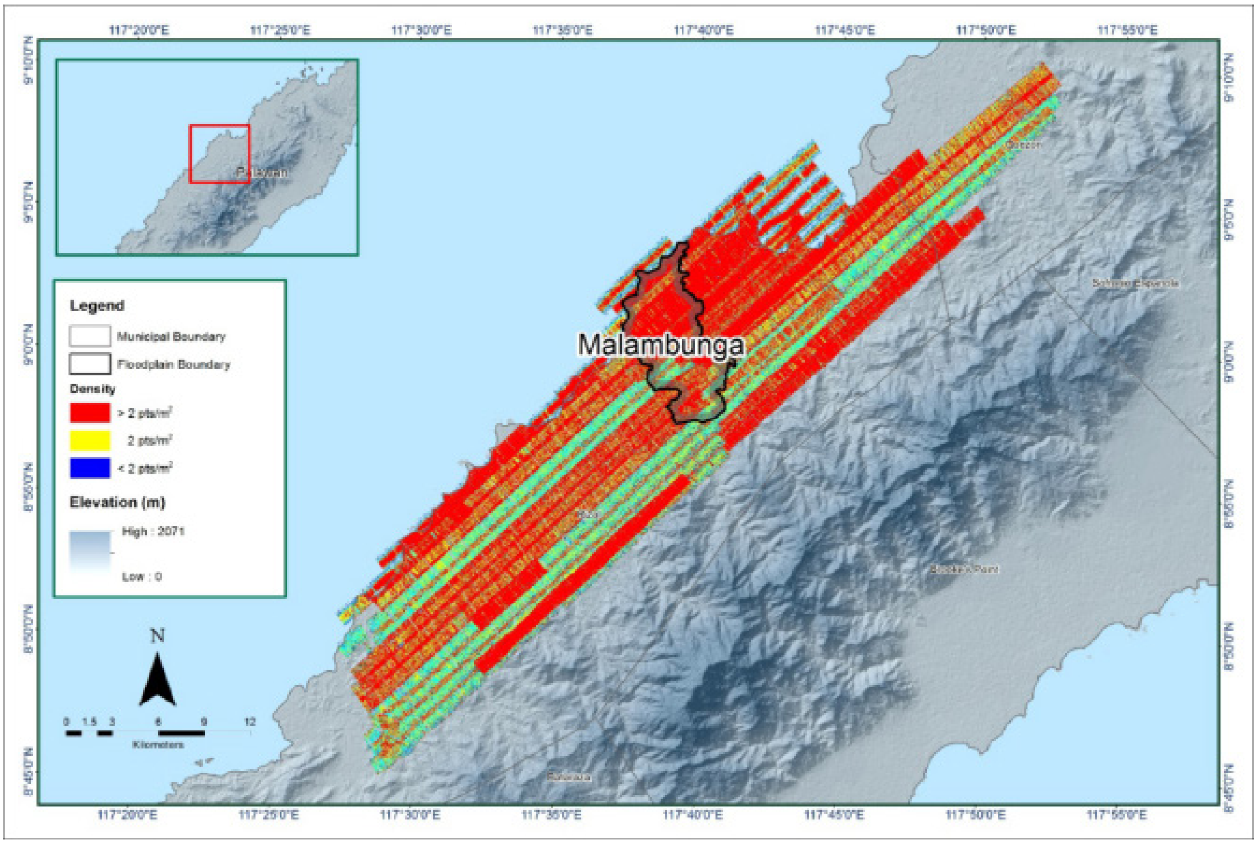


Figure 11. Pulse density map of merged LiDAR data for Malambunga Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 12. 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 0.20 m 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.

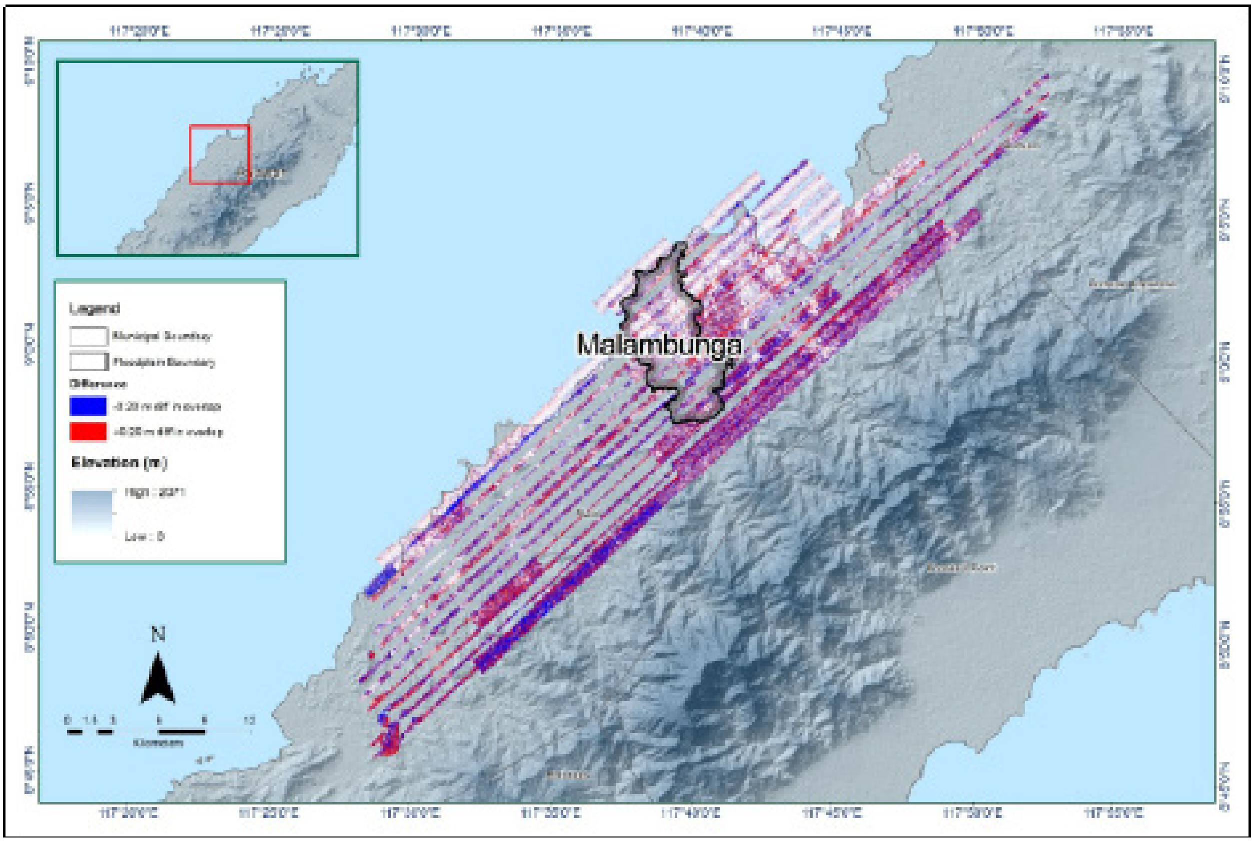


Figure 12. Elevation Difference Map between flight lines for Malambunga Floodplain Survey.

A screen capture of the processed LAS data from Malambunga flight 3159P loaded in QT Modeler is shown in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

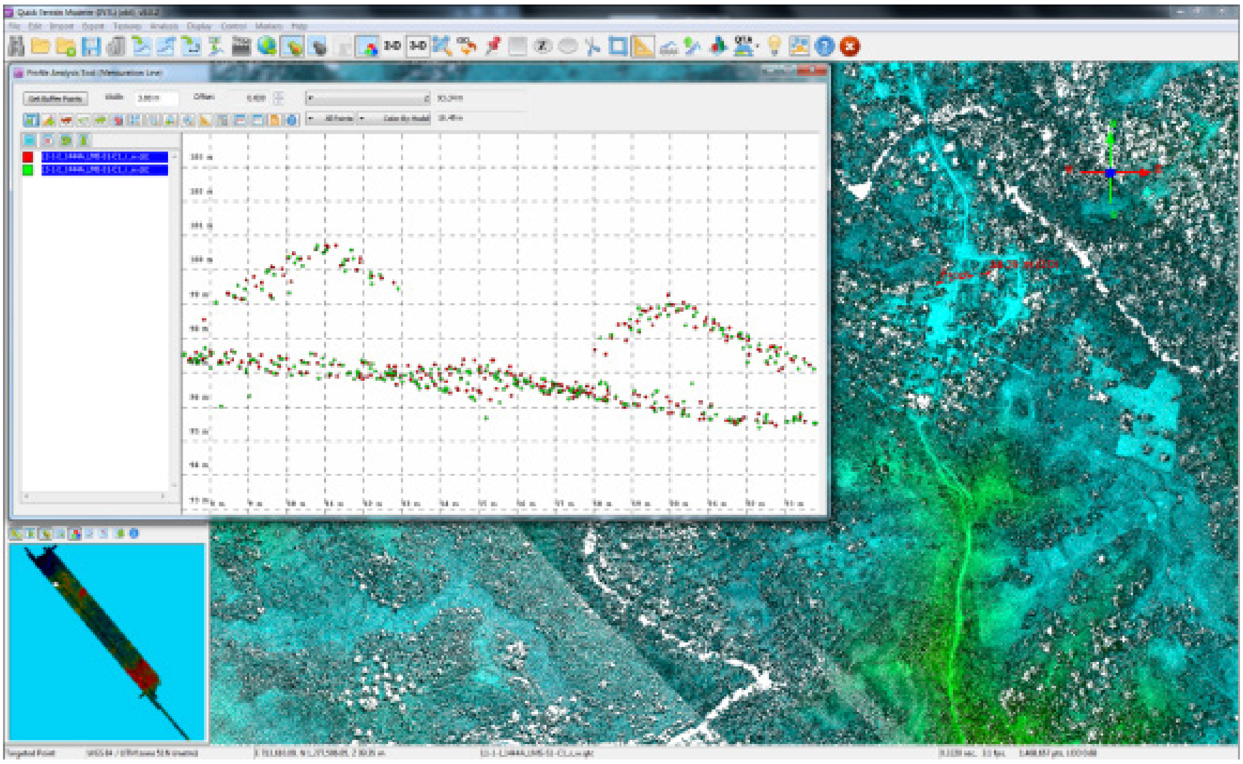


Figure 13. Quality checking for a Malambunga flight 2842P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Malambunga classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	321,923,768
Low Vegetation	207,171,454
Medium Vegetation	413,535,820
High Vegetation	1,457,324,855
Building	18,207,670

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Malambunga Floodplain is shown in Figure 14. A total of 785 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 760.06 meters and 40.13 meters respectively.

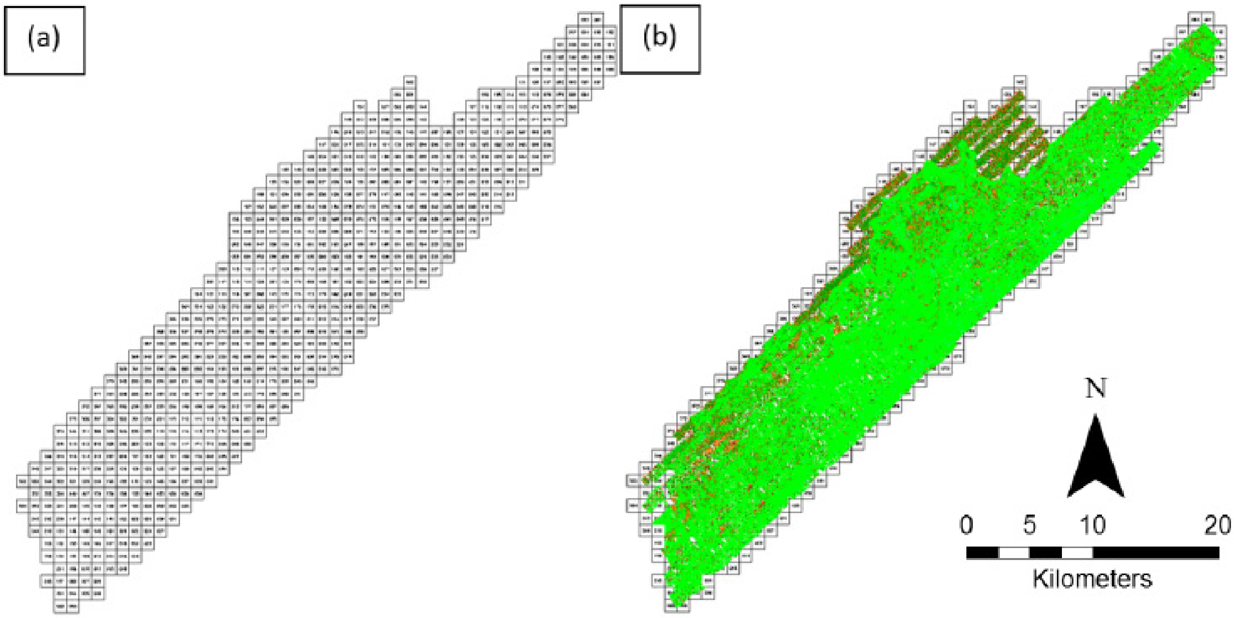


Figure 14. Tiles for Malambunga Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 15. 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.

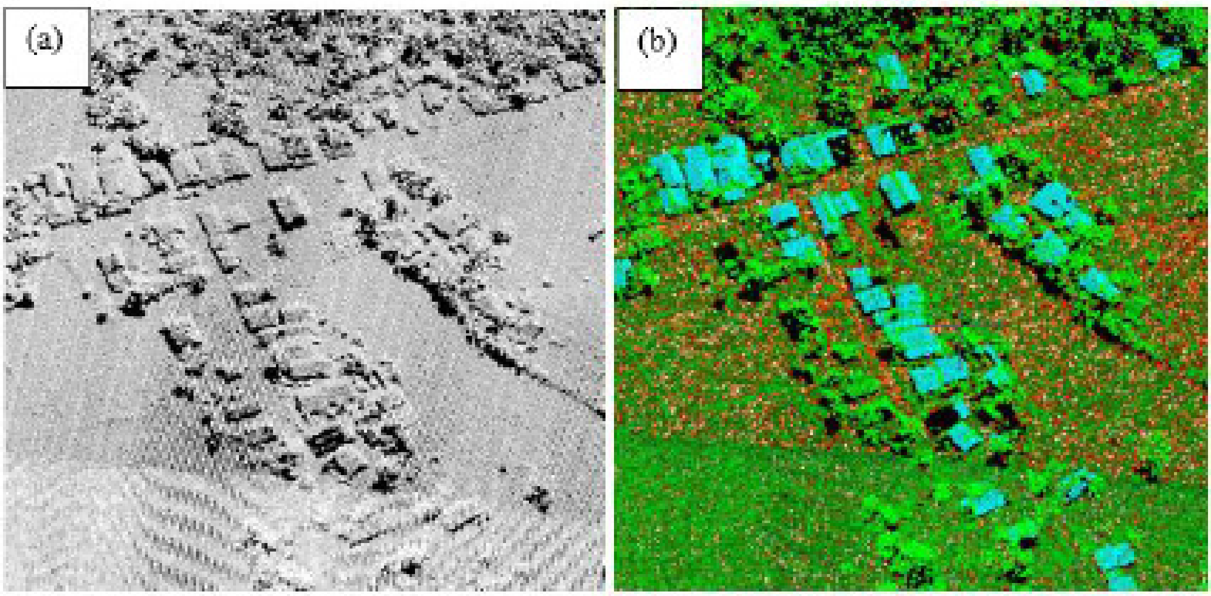


Figure 15. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 16. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

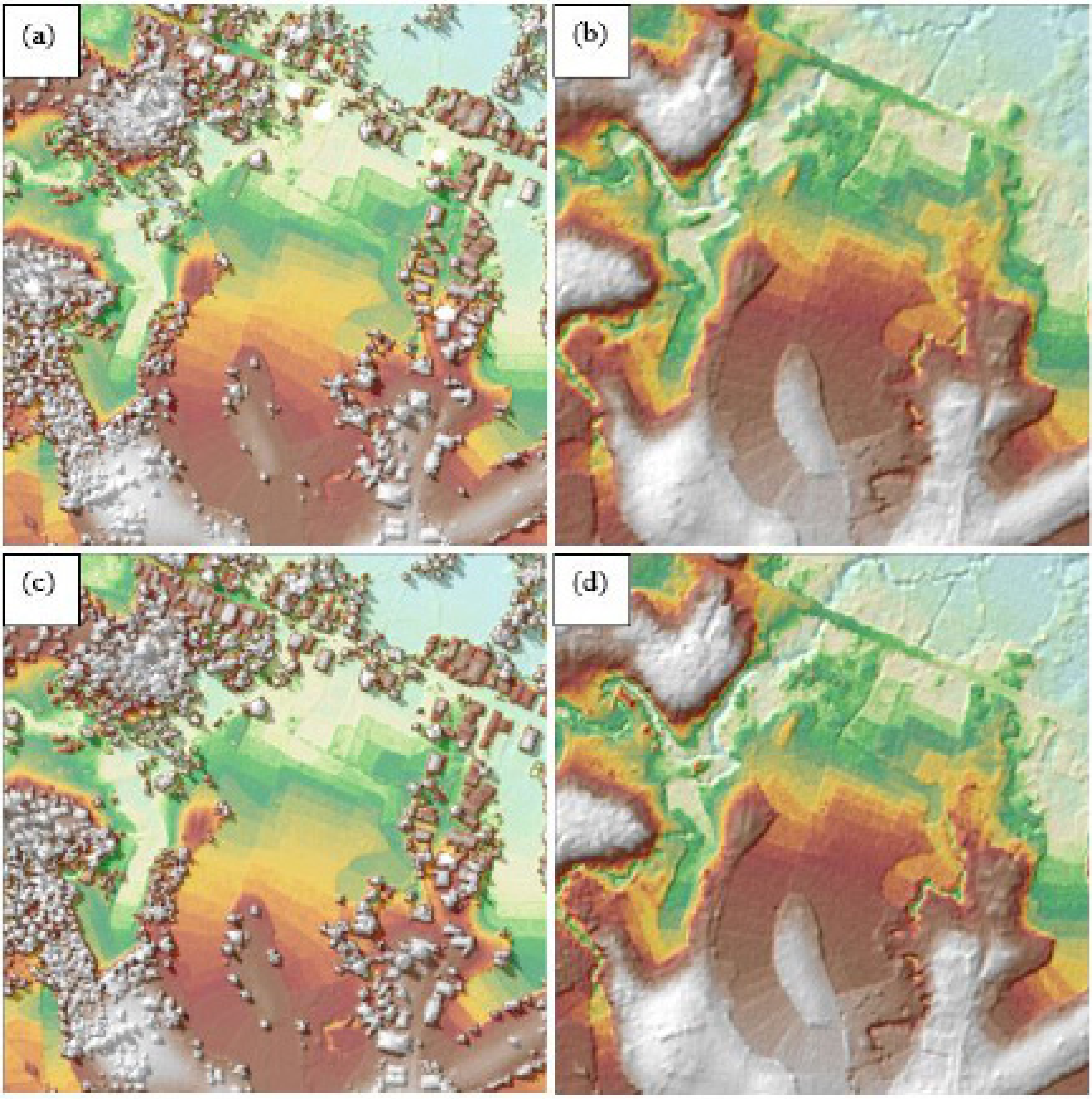


Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Malambunga Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 273 1km by 1km tiles area covered by Malambunga Floodplain is shown in Figure 17. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Malambunga Floodplain has a total of 153.14 sq.km orthophotogaph coverage comprised of303 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 18.

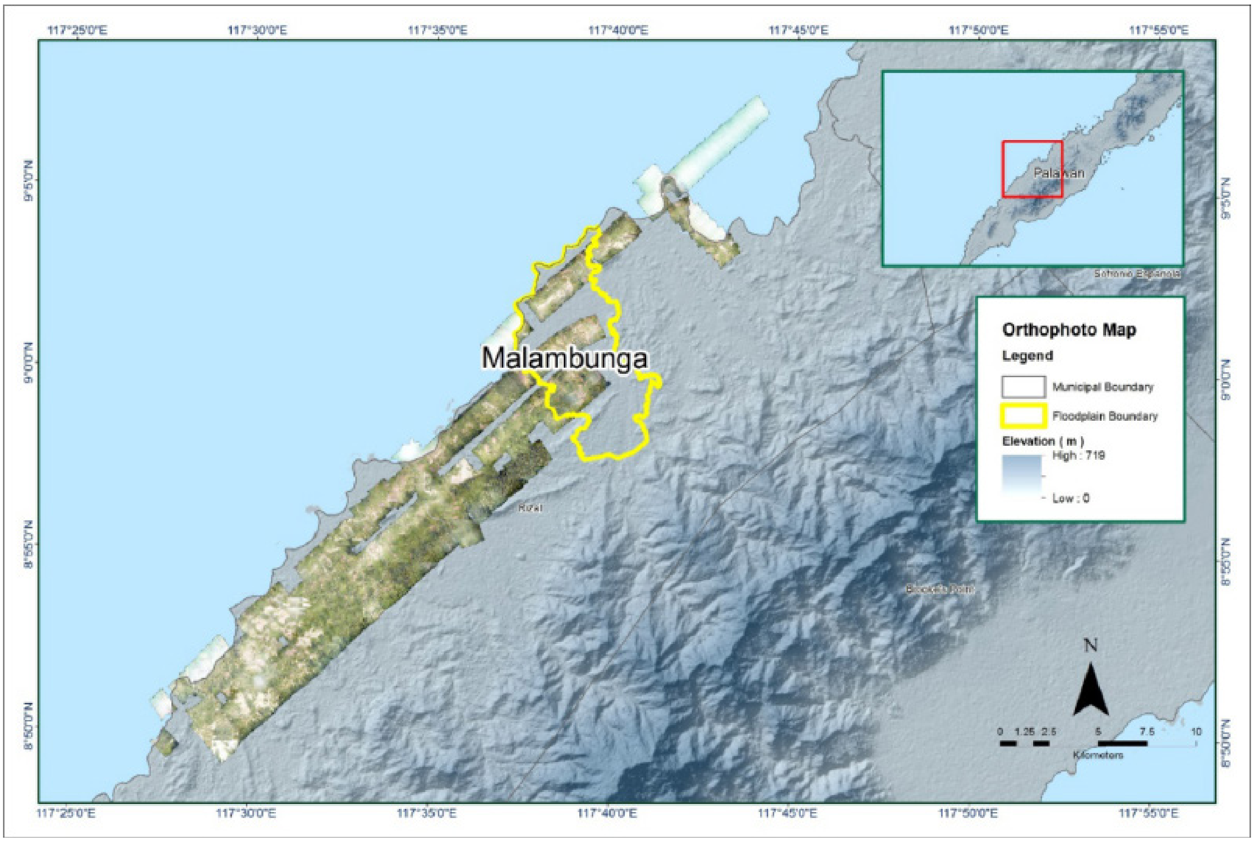


Figure 17. Malambunga Floodplain with available orthophotographs.

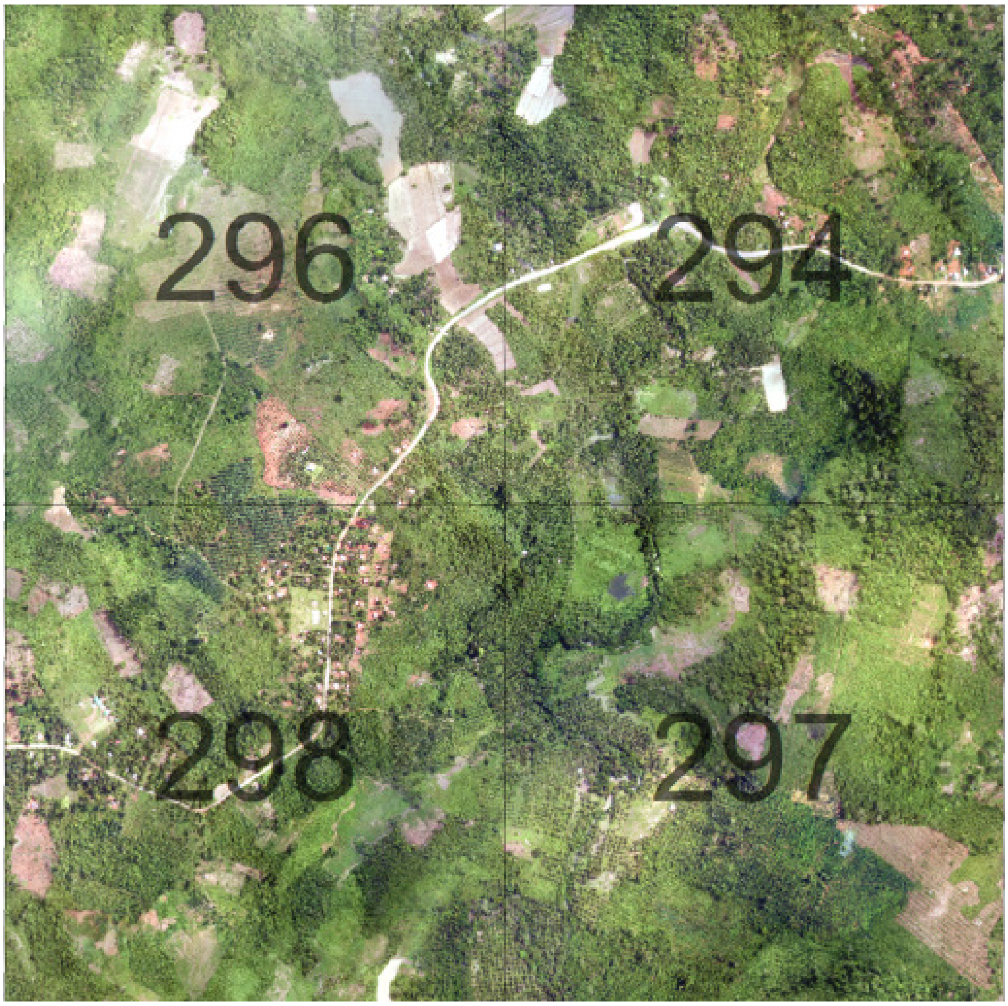


Figure 18. Sample orthophotograph tiles for Malambunga Floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Malambunga Floodplain. These blocks are composed of Palawan blocks with a total area of 606.96 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42N	188.81
Palawan_Blk42O	115.29
Palawan_Blk42P	302.86
TOTAL	606.96 sq.km

Portions of DTM before and after manual editing are shown in Figure 19. Data gaps (Figure 19a) were filled to complete the surface (Figure 19b) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 19c) and has to be removed through manual editing (Figure 19d).

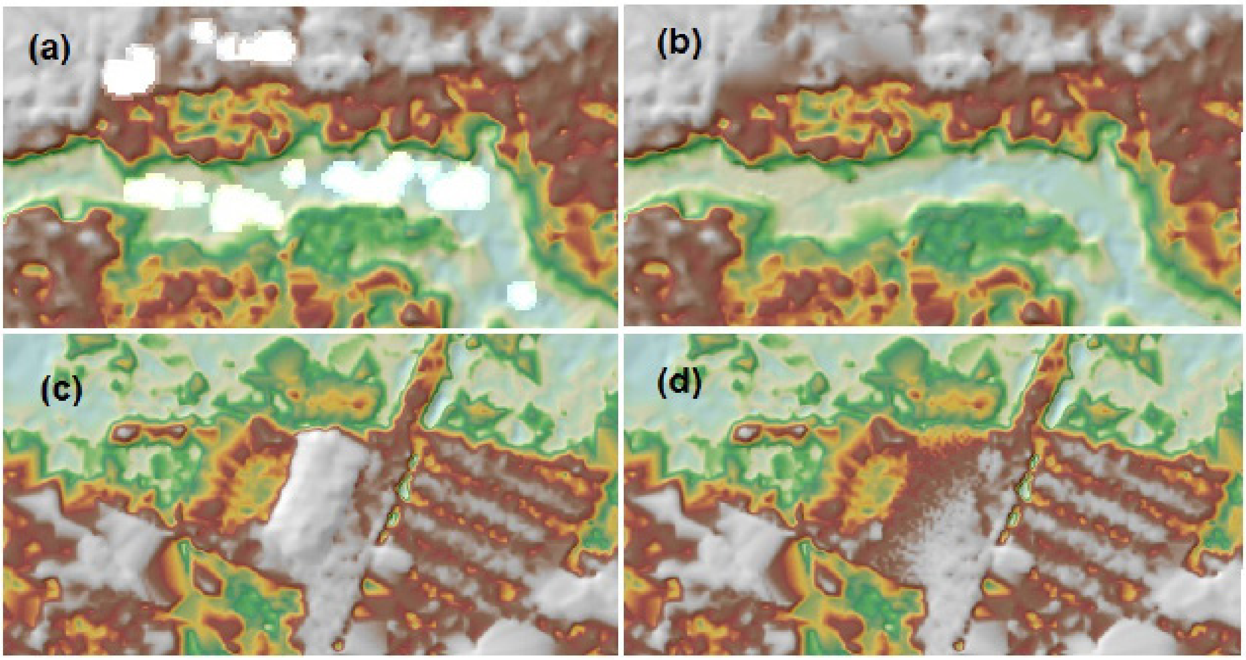


Figure 19. Portions in the DTM of Malambunga Floodplain – data gaps before (a) and after (b) filling; and a presence of a building before (c) and after (d) removal

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 Malambunga Floodplain, it was concluded that the elevation of all blocks for this river basin needed adjustment. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Malambunga floodplain is shown in Figure 20. It can be seen that the entire Malambunga Floodplain is 100% covered by LiDAR data.

Table 12. Shift values of each LiDAR block of Malambunga Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42N	0.00	0.00	6.49
Palawan_Blk42O	0.00	0.00	6.48
Palawan_Blk42P	0.00	0.00	6.55

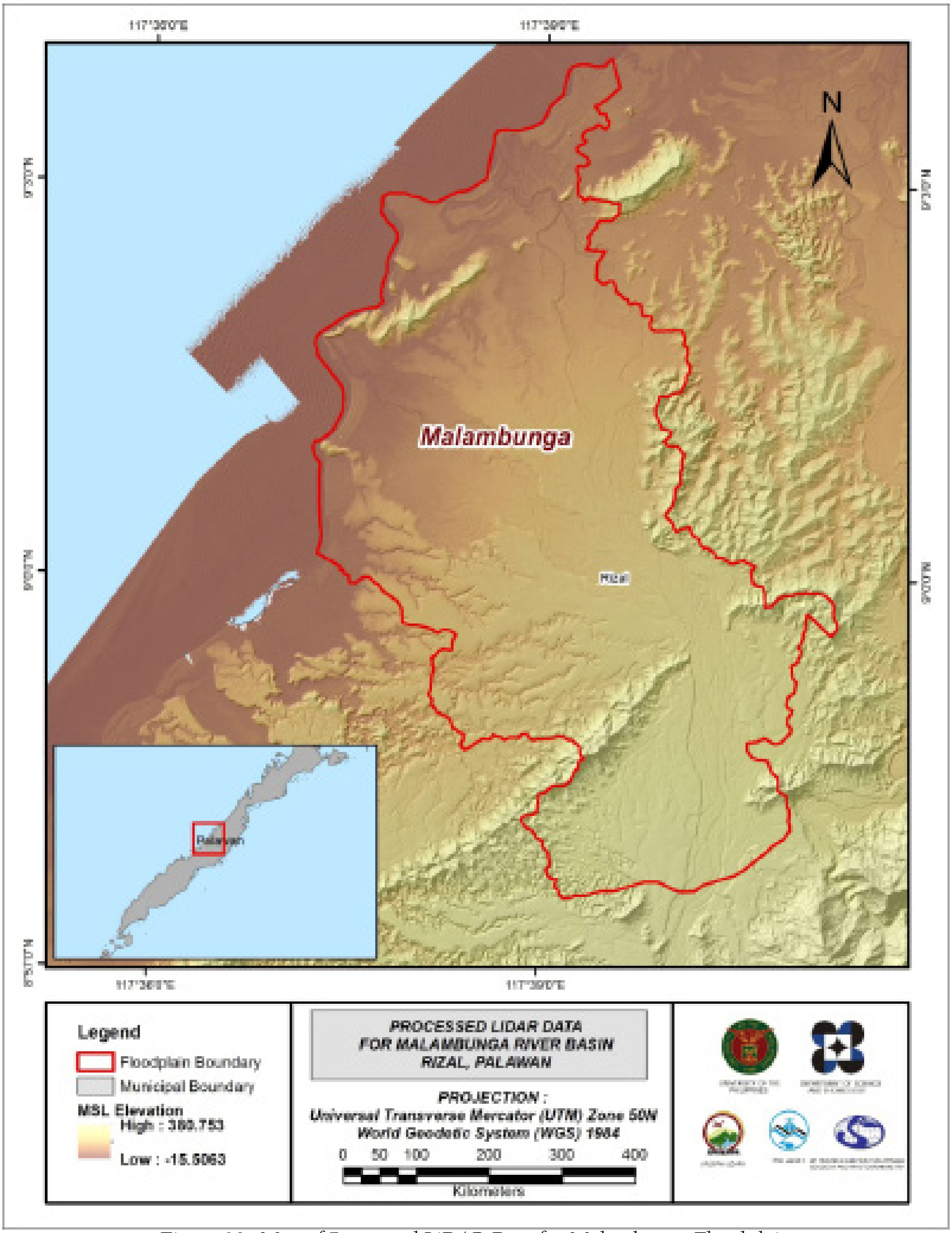


Figure 20 . Map of Processed LiDAR Data for Malambunga Floodplain.

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 Malambunga to collect points with which the LiDAR dataset was validated is shown in Figure 21. A total of 2,506 survey points were used for calibration and validation of Malambunga LiDAR data. Random selection of 80% of the survey points, resulting to 2,005 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 22. 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 14.31 meters with a standard deviation of 0.24 meters. Calibration of Malambunga LiDAR data was done by adding the height difference value, 14.31meters, to Malambunga mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

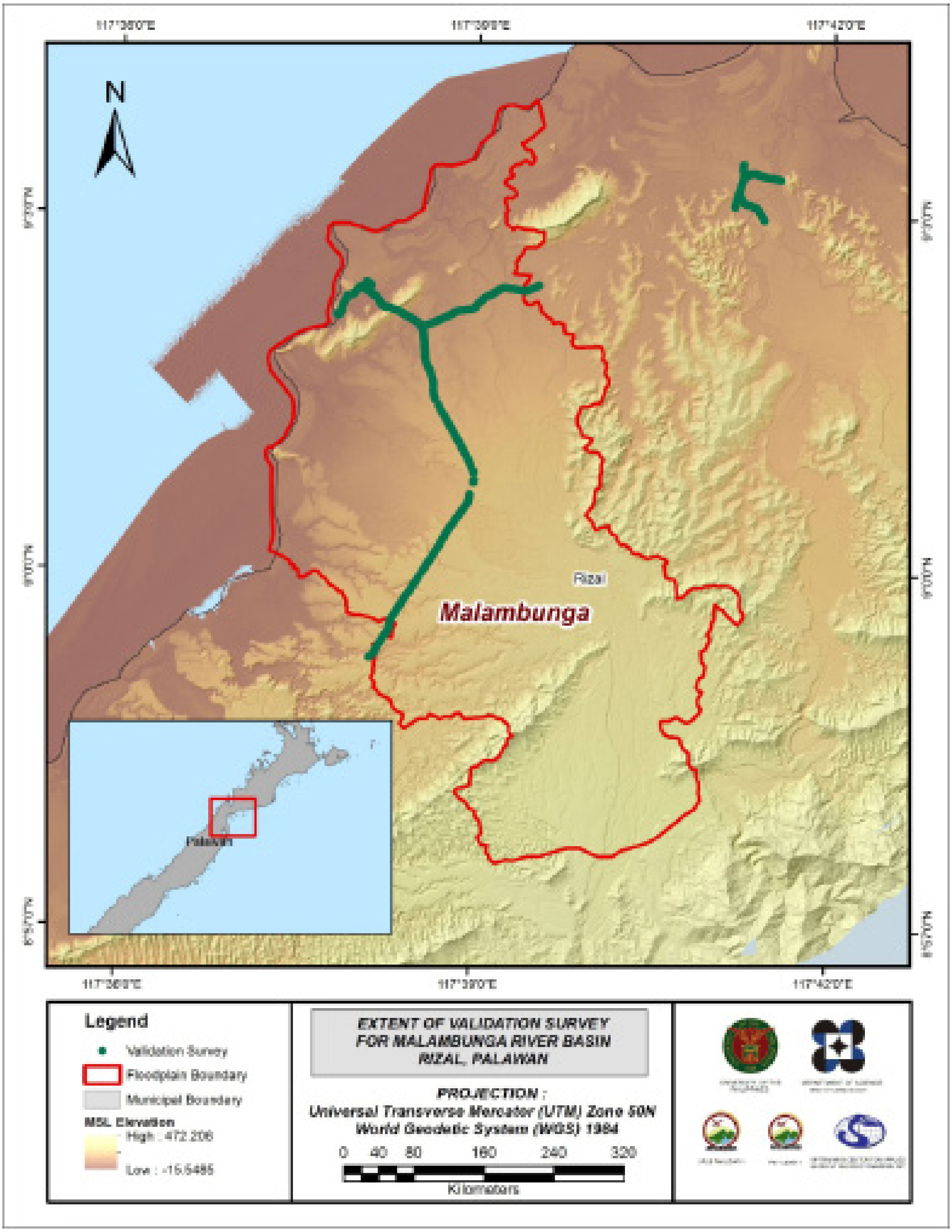


Figure 21. Map of Malambunga Floodplain with validation survey points in green.

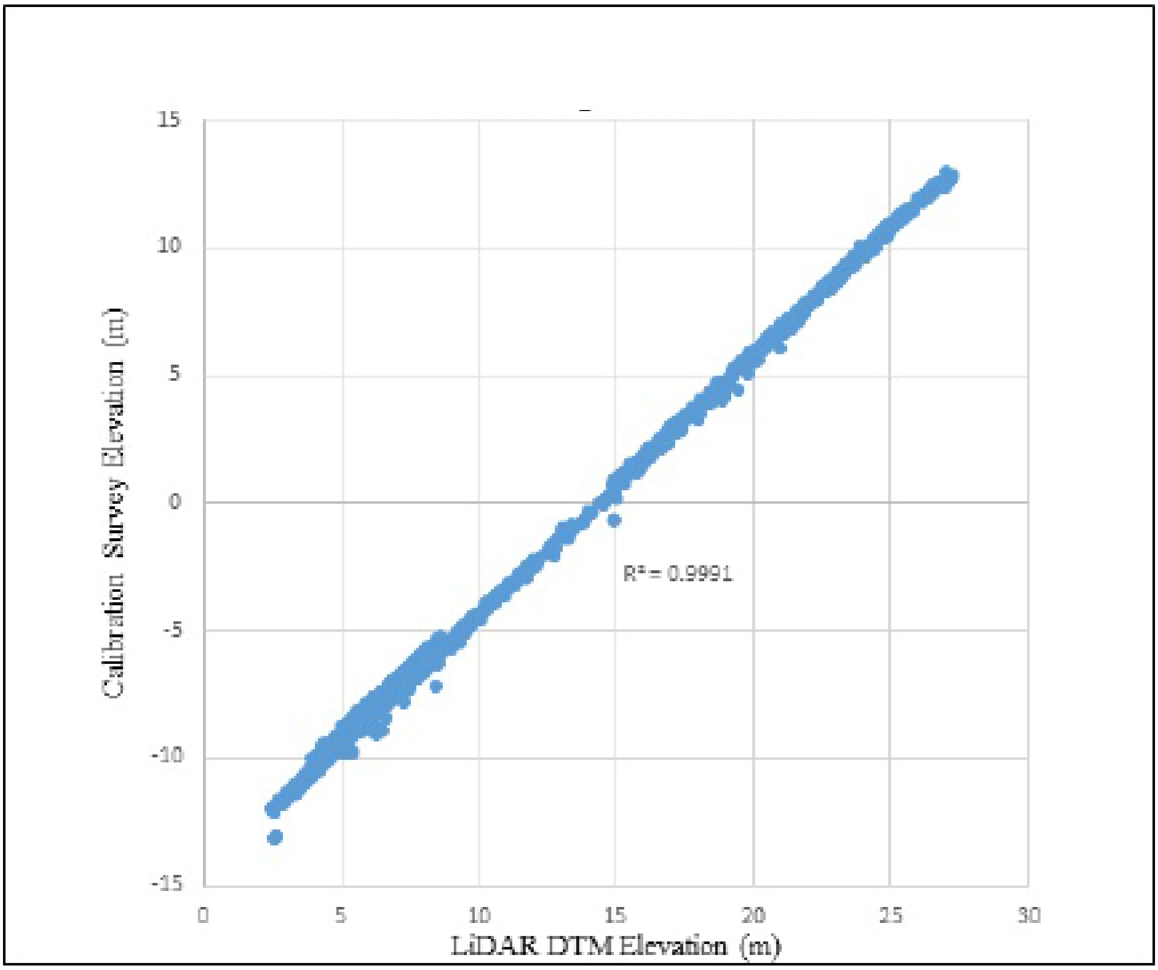


Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	14.31
Standard Deviation	0.24
Average	14.31
Minimum	13.84
Maximum	14.79

The remaining 20% of the total survey points, resulting to 501 points, were used for the validation of calibrated Malambunga 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.24meters with a standard deviation of 0.24meters, as shown in Table 14.

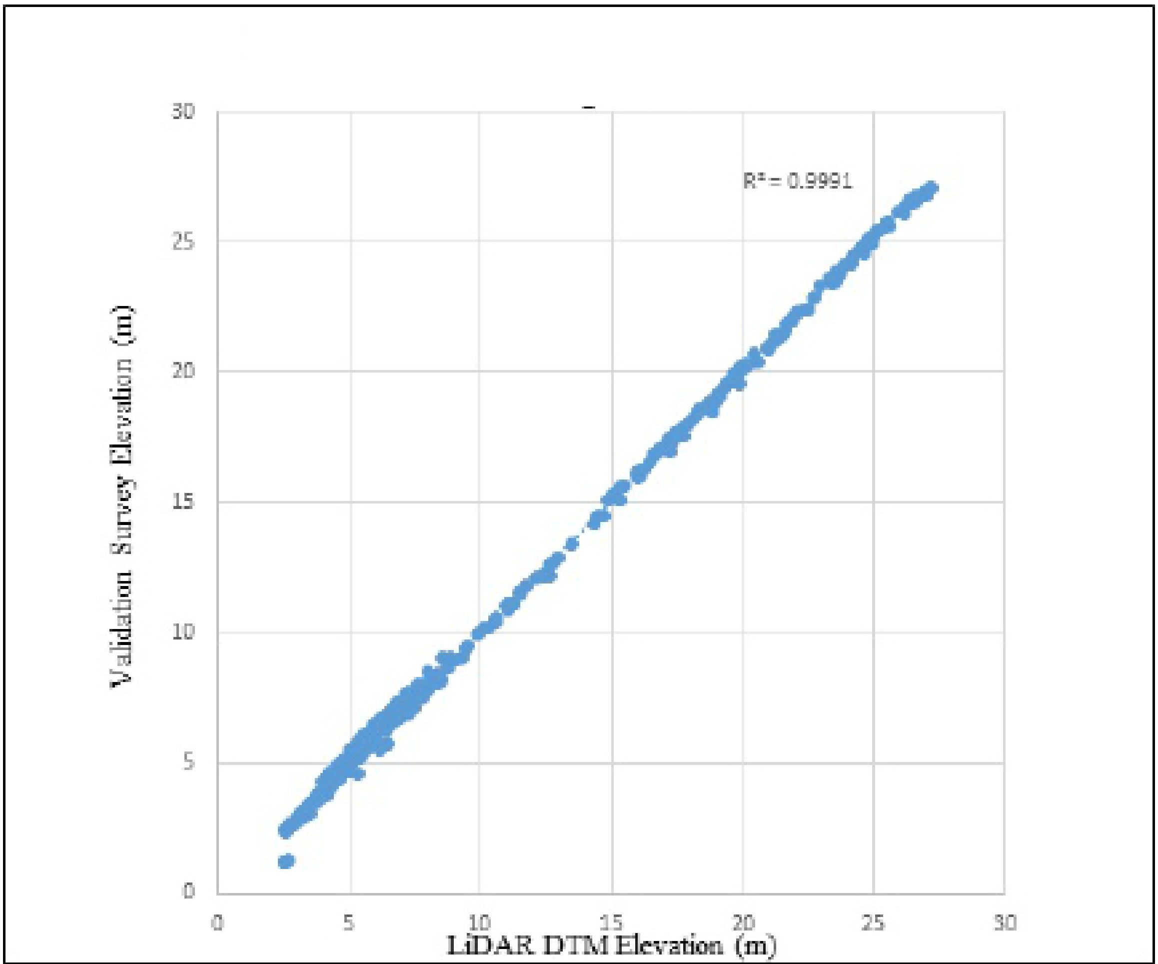


Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.24
Standard Deviation	0.24
Average	0.002
Minimum	-0.49
Maximum	0.49

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, zigzag, centerline, and cross section were available for Malambunga with 5,164 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.37 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Malambunga integrated with the processed LiDAR DEM is shown in Figure 24.

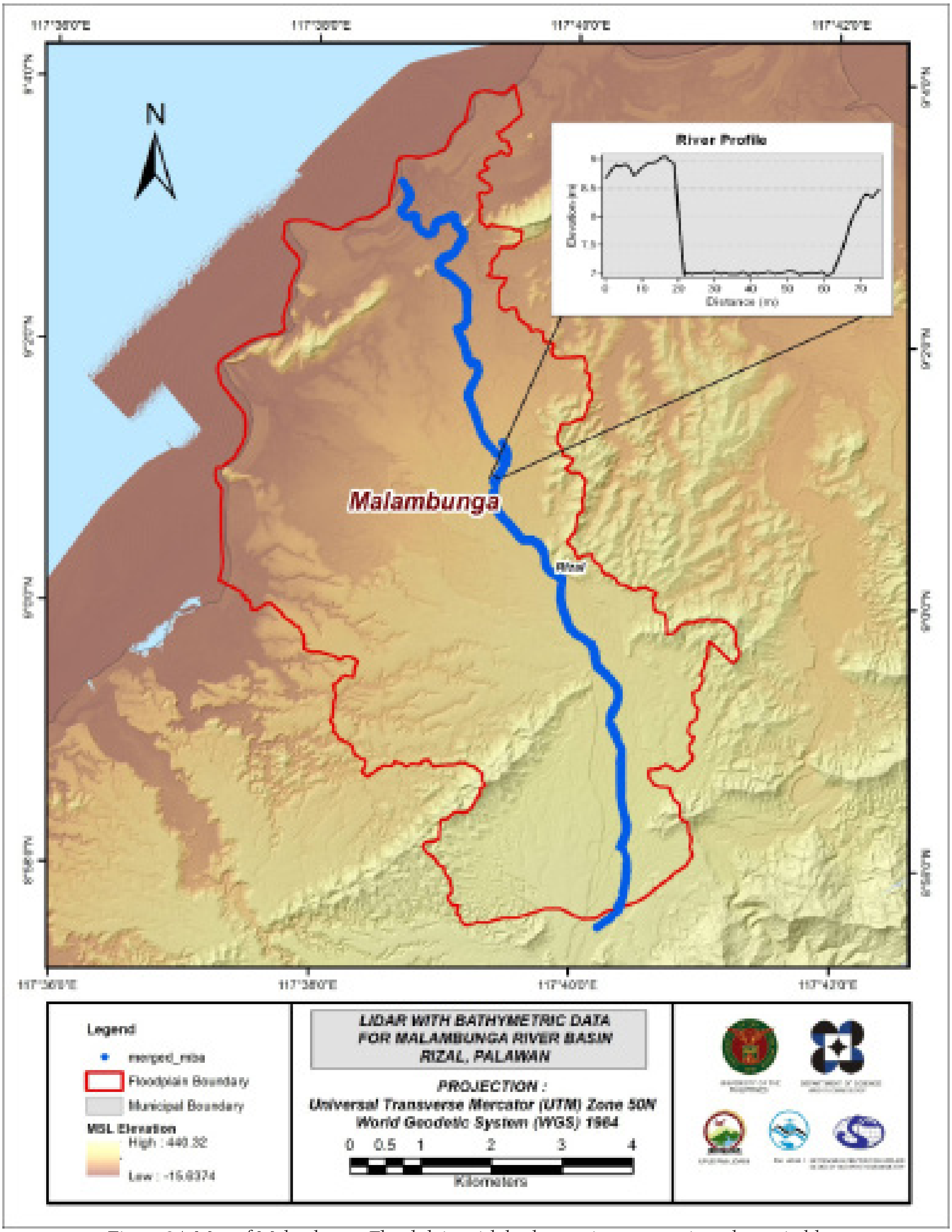


Figure 24. Map of Malambunga Floodplain with bathymetric survey points shown in blue.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, Vie Marie Paola M. Rivera

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

4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted a field survey in Malambunga River on December 4, 2015, January 20-22, 2016, and January 24-25, 2016 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Malambunga Bridge in Brgy. Punta Baja, Municipality of Rizal, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on August 16-28, 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 Malambunga River Basin area. The entire survey extent is illustrated in Figure 25..

Figure 25. Extent of the bathymetric survey (in blue line) in Malambunga River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Malambunga River is composed of one (1) loop established on August 19, 2016 occupying the following reference points: PLW-121 a second-order GCP, in Brgy. Ransang, Rizal, Palawan and PL-749, a first-order BM, in Brgy. Campong Ulay, Rizal, Palawan.

One (1) control point established in the area by ABSD was also occupied: UP_MAL-1, located beside the approach of Malambunga Bridge in Brgy. Punta Baja, Rizal, Province of Palawan.
The summary of reference and control points and its location is summarized in Table 15 while GNSS network established is illustrated in Figure 26.

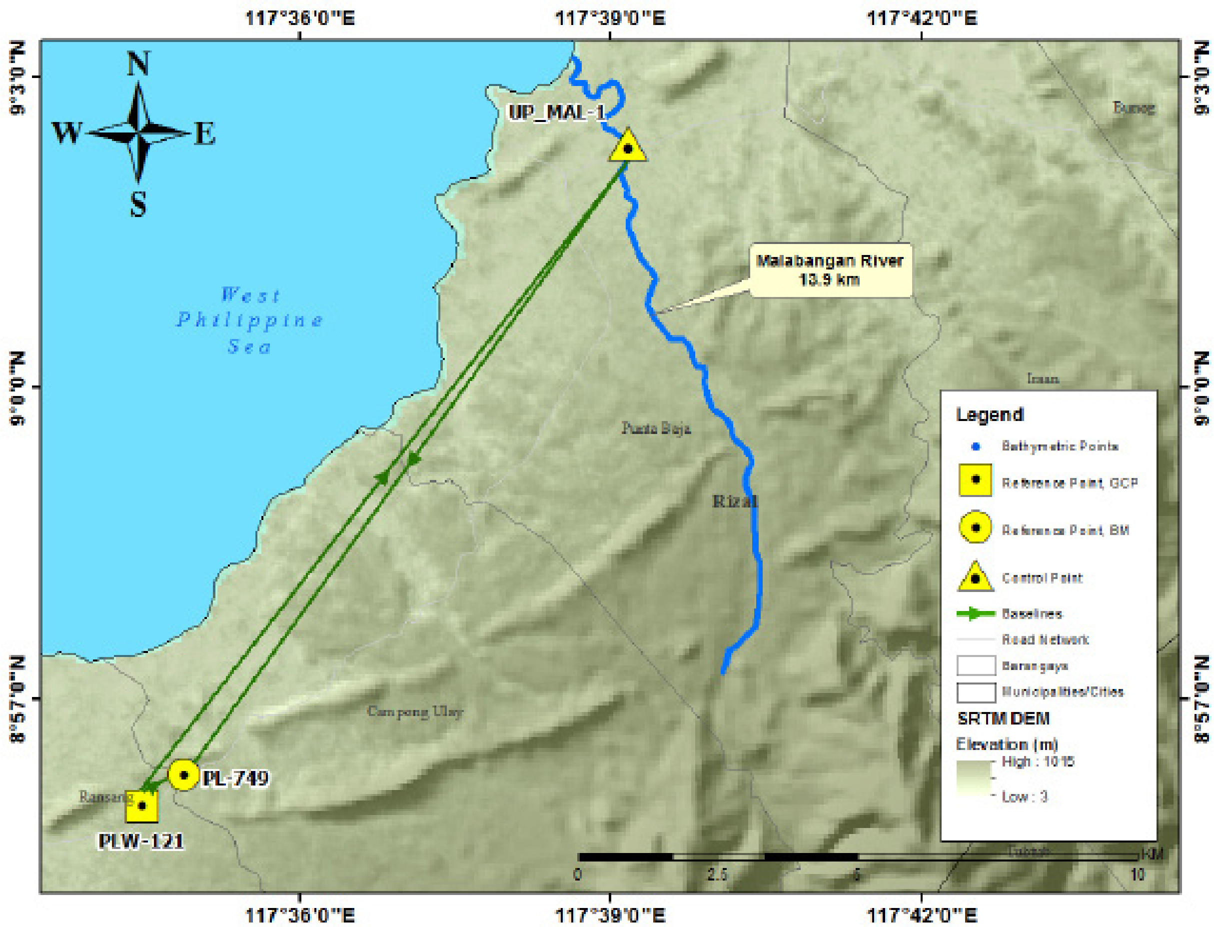


Figure 26. Malambunga River Basin Control Survey Extent

Table 15. List of Reference and Control Points occupied for Malambunga 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
PLW-121	2nd order, GCP	8°55'57.38325"N	117°34'29.39124"E	58.058	16.172	2007
PL-749	1st order, BM	8°56'16.45926"N	117°34'53.01226"E	62.444	20.529	2012
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	10.881	11-27-15

The GNSS set-ups on recovered reference points and established control points in Malambunga River are shown from Figure 27 to Figure 29.

Figure 27. GNSS base set-up, Trimble® SPS 852, at PLW-121, located along the basketball court inside Cabcungan Elementary School in Brgy. Ransang, Rizal, Province of Palawan

Figure 28. GNSS base set-up, Trimble® SPS 882, at PL-749, located in front of a monument near the approach of Ilog-Ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan

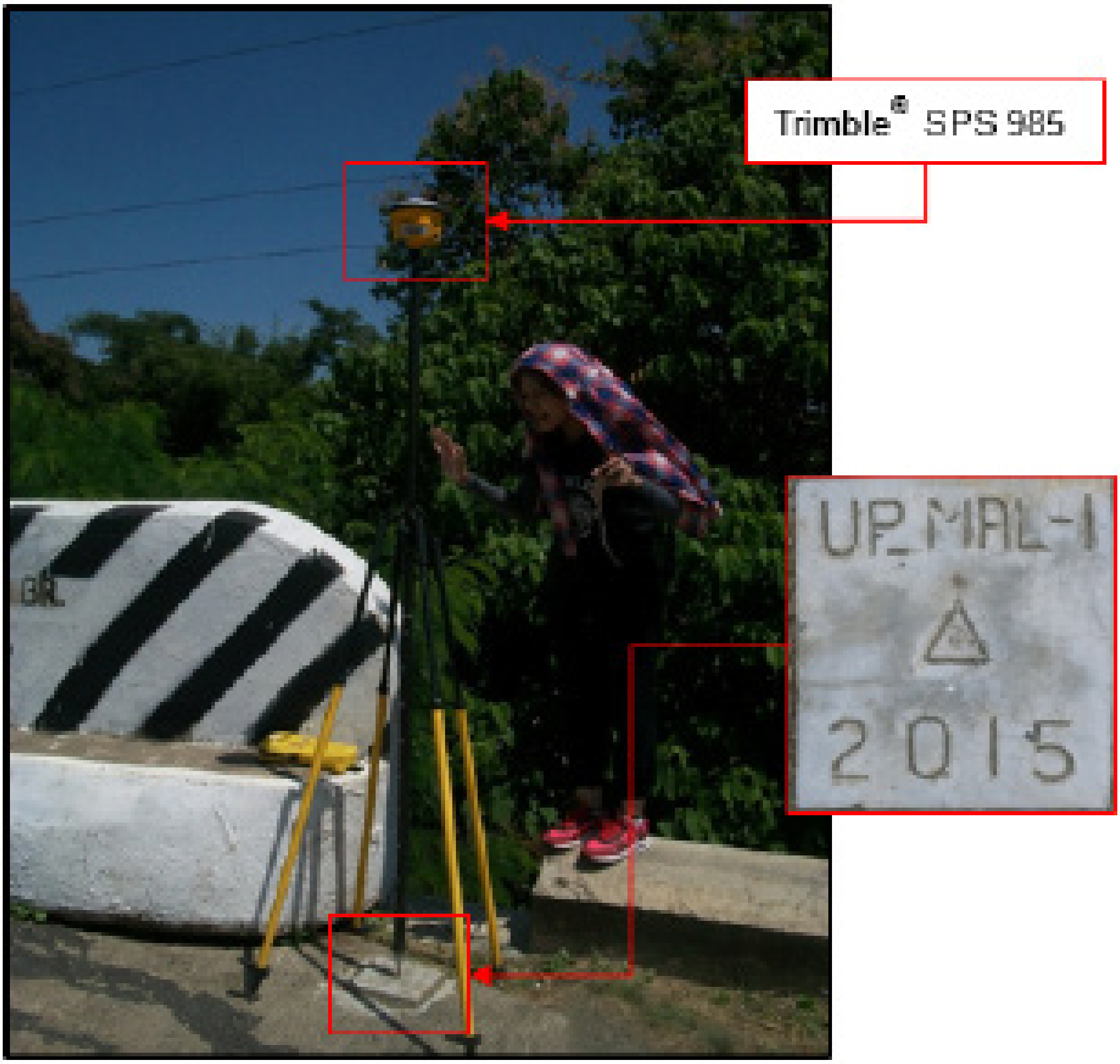


Figure 29. GNSS receiver set-up, Trimble® SPS 985, at UP_MAL-1, located beside the approach of Malambunga Bridge in Brgy. Punta Baja, Rizal, Province of Palawan

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 +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking was done by removing/masking portions of these baseline data using the same processing software. It was repeatedly processed until all baseline requirements were met. If the reiteration yielded out of the required accuracy, resurvey was initiated.

Baseline processing result of control points in Malambunga River Basin is summarized in Table 16 generated by TBC software.

Table 16. Baseline Processing Summary Report for Malambunga River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PLW-121 --- UP_MAL-1	8-19-2016	Fixed	0.004	0.013	36°02'30"	14584.808	-5.287
PLW-121 --- PL-749	8-19-2016	Fixed	0.004	0.005	50°55'02"	929.614	4.388
UP_MAL-1 --- PL-749	8-19-2016	Fixed	0.007	0.022	215°03'17"	13688.427	9.643

As shown Table 16, a total of three (3) baselines were processed with the coordinate and ellipsoidal height values of PLW-121 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 sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report shown from Table 17 to Table 19 for the complete details. Refer to Appendix [Check appendix number]for the computation for the accuracy of ABSD.

The three (3) control points, PLW-121, PL-749, and UP_MAL-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height value of PLW-121 were held fixed during the processing of the control points as presented in Table 17. Through this reference point, the coordinates and ellipsoidal height of the unknown control points were computed.

Table 17. 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-121	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Table 18. Adjusted grid coordinates for the control points used in the Malambunga River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PL-749	563915.056	0.004	988037.560	0.002	14.692	0.007	
PLW-121	563194.622	?	987450.572	?	10.335	?	LLh
UP_MAL-1	571754.477	0.004	999253.104	0.003	5.044	0.017	

With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

a.PLW-749

horizontal accuracy	=	$\sqrt{((0.4)^2 + (0.2)^2}$
	=	$\sqrt{(0.16 + 0.04)}$
	=	0.04< 20 cm
vertical accuracy	=	0.7< 10 cm

b.PLW-121

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

c.UP_MAL-1

horizontal accuracy	=	$\sqrt{((0.4)^2 + (0.3)^2}$
	=	$\sqrt{(0.16 + 0.09)}$
	=	0.5< 20 cm
vertical accuracy	=	1.7< 10 cm

Following the given formula, the horizontal and vertical accuracy result of the two (2) occupied control points are within the required precision.

Table 19. Adjusted geodetic coordinates for control points used in the Malambunga River Floodplain validation.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
PL-749	N8°56'16.45926"	E117°34'53.01226"	62.444	0.007	
PLW-121	N8°55'57.38325"	E117°34'29.39124"	58.058	?	LLh
UP_MAL-1	N9°02'21.21274"	E117°39'10.37109"	52.776	0.017	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 19. Based on the result of the computation, the equation was satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 20.

Table 20. The reference and control points utilized in the Malambunga River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
PLW-121	2nd order, GCP	8°55'57.38325"N	117°34'29.39124"E	58.058	987450.572	563194.622	16.172
PL-749	1st order, BM	8°56'16.45926"N	117°34'53.01226"E	62.444	988037.560	563915.056	20.529
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	999253.104	571754.477	10.881

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

Cross-section and as-built survey were conducted on June 19 and 20, 2016 at the downstream side of New Malambunga Bridge in Brgy. Masi, Municipality of Rizal, Palawan as shown in Figure 37. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique and a Total Station through Open Traverse Method was utilized for this survey.

Figure 30. Downstream side of Malambunga Bridge

Figure 31. As-built survey of Malambunga Bridge

The cross-sectional line of Malambunga Bridge is about 121 m with thirty-seven (37) cross-sectional points using the control points UP_MAL-1 and UP_MAL-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure 32 to Figure 34. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 20, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range was 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 signified a strong correlation between the vertical (elevation values) of the two datasets. The computed R2 values of 0.974 and 0.975 for the cross-section data and bridge points data, respectively, were 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 was 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 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the cross-section data and bridge points data, the computed values were 0.168 and 0.134, respectively. The computed RMSE value for the bridge points data was 0.174. The computed R2 and RMSE values are within the accuracy requirement of the program.

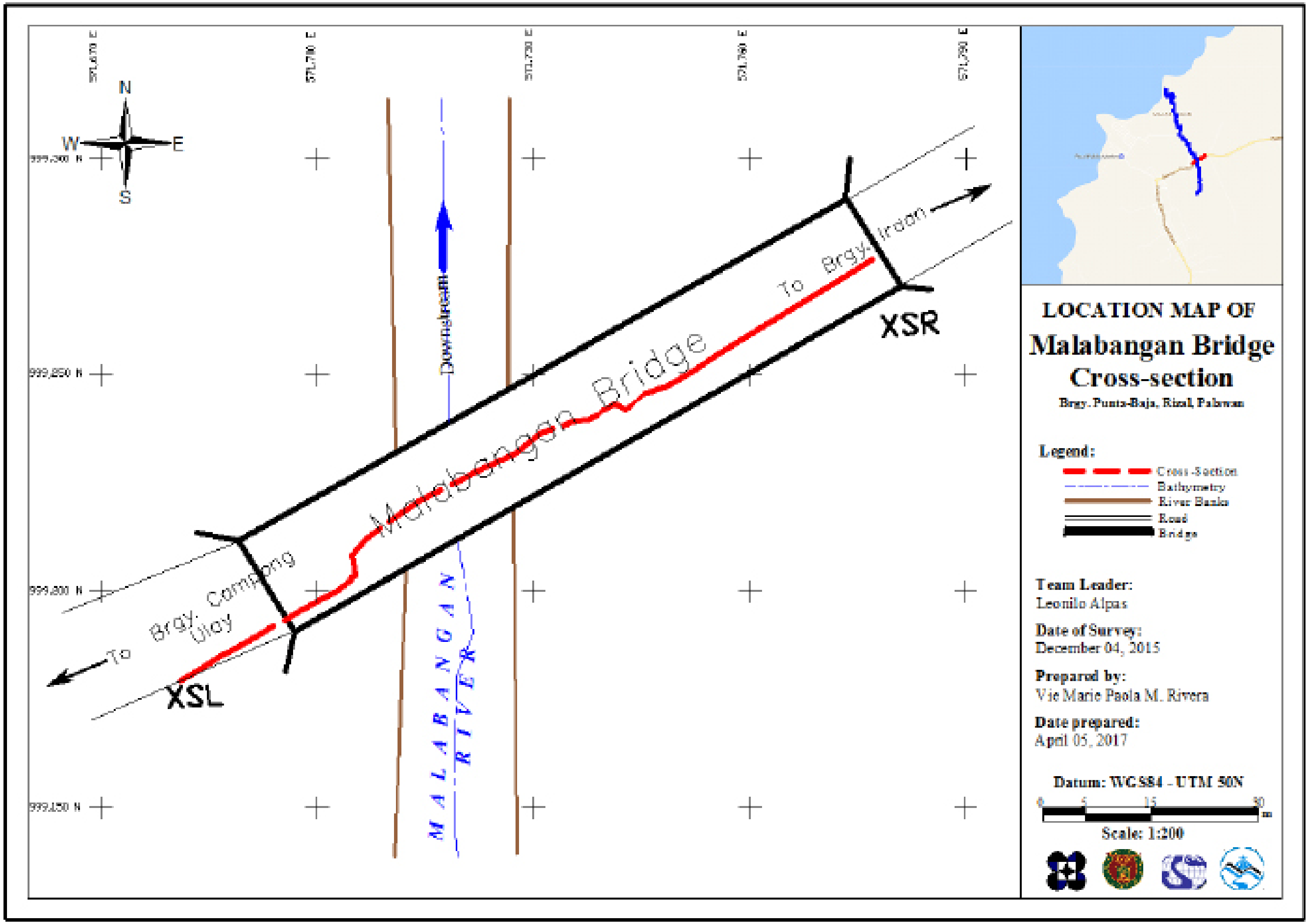


Figure 32. Malabangan (also known as Malambunga) Bridge Location Map

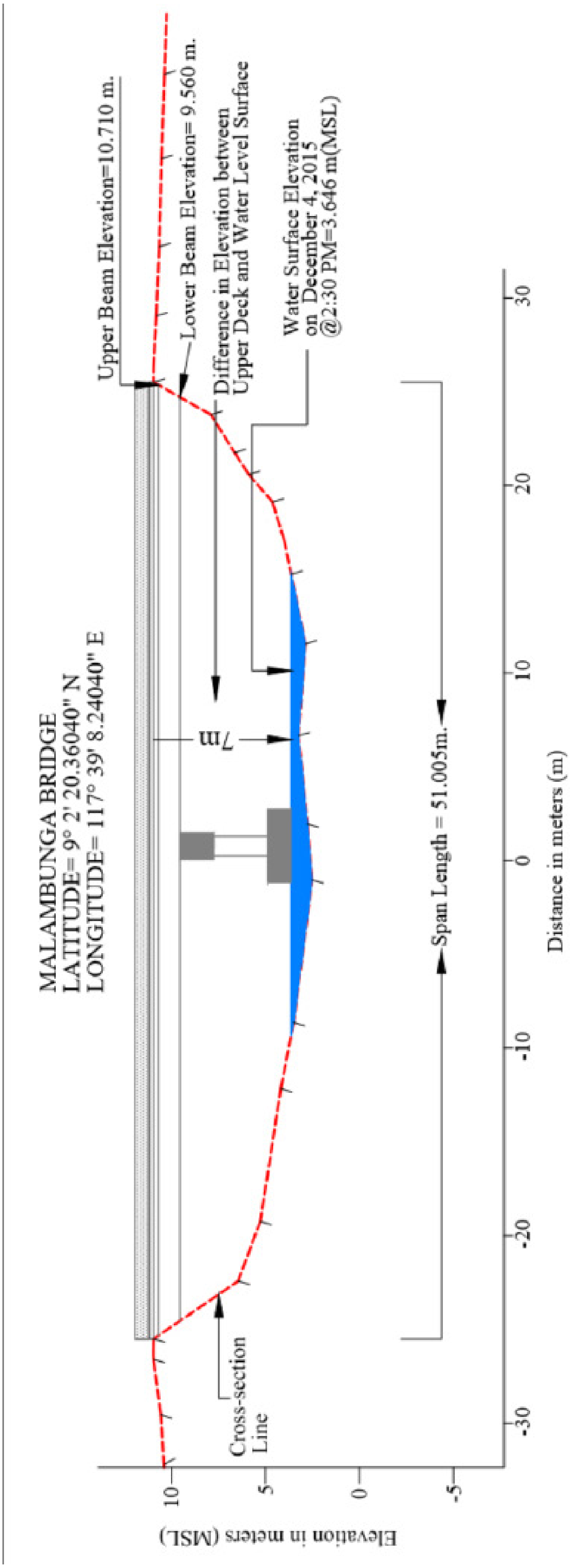


Figure 33. Malambunga Bridge cross-section diagram

Bridge Data Form

Bridge Name: Malambunga Bridge

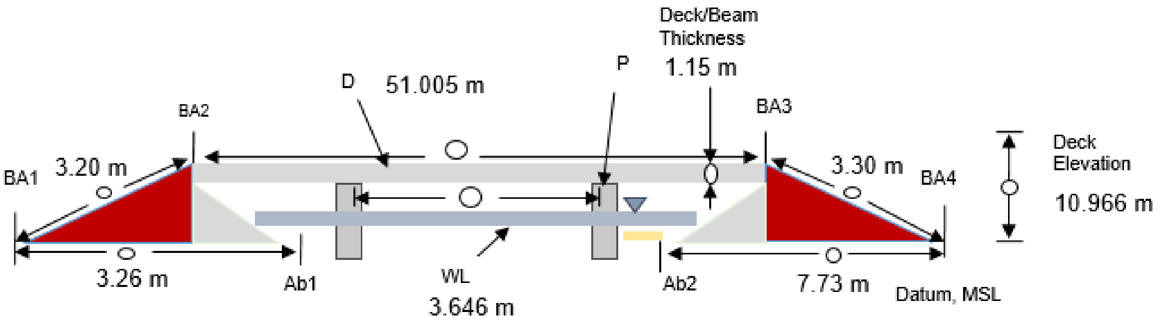
River Name: Malabangan River
Location (Brgy, City, Region): Brgy. Punta Baja, Rizal, Palawan

Survey Team: Nilo Alpas, Christorey dela Peña
Date and Time: December 4, 2015; 2:30 PM

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	3.20 m	
2. BA2-BA3	51.005 m	
3. BA3-BA4	3.30m	
4. BA1-Ab1	3.26 m	
5. Ab2-BA4	7.73 m	
6. Deck/beam thickness	1.15 m	
7. Deck elevation	10.966 m	

Note: Observer should be facing downstream

Figure 34. Malambunga Bridge Data Sheet

Water surface elevation of Malambunga River was determined by a Horizon® Total Station on December 4, 2015 at 2:30 PM at Malambunga Bridge area with a value of 3.646 m in MSL as shown in Figure 32. This was translated into marking on the bridge's pier as shown in Figure 35. The marking served as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Malambunga River, the University of the Philippines Los Baños.

Figure 35. Water-level markings on Malambunga Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC on August 19, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 36. 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 UP_MAL-1 occupied as the GNSS base station in the conduct of the survey.

Figure 36. Validation points acquisition survey set up along Malambunga River Basin

The survey started from Brgy. Iraan, Municipality of Rizal, Palawan going southwest along the national highway and ended in Brgy. Punta Baja, Municipality of Rizal, Palawan. The survey gathered a total of 346 points with approximate length of 15.71 km using UP_MAL-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 37. Approximately 50% of roads traversed were unpaved, hence no data was acquired along it.

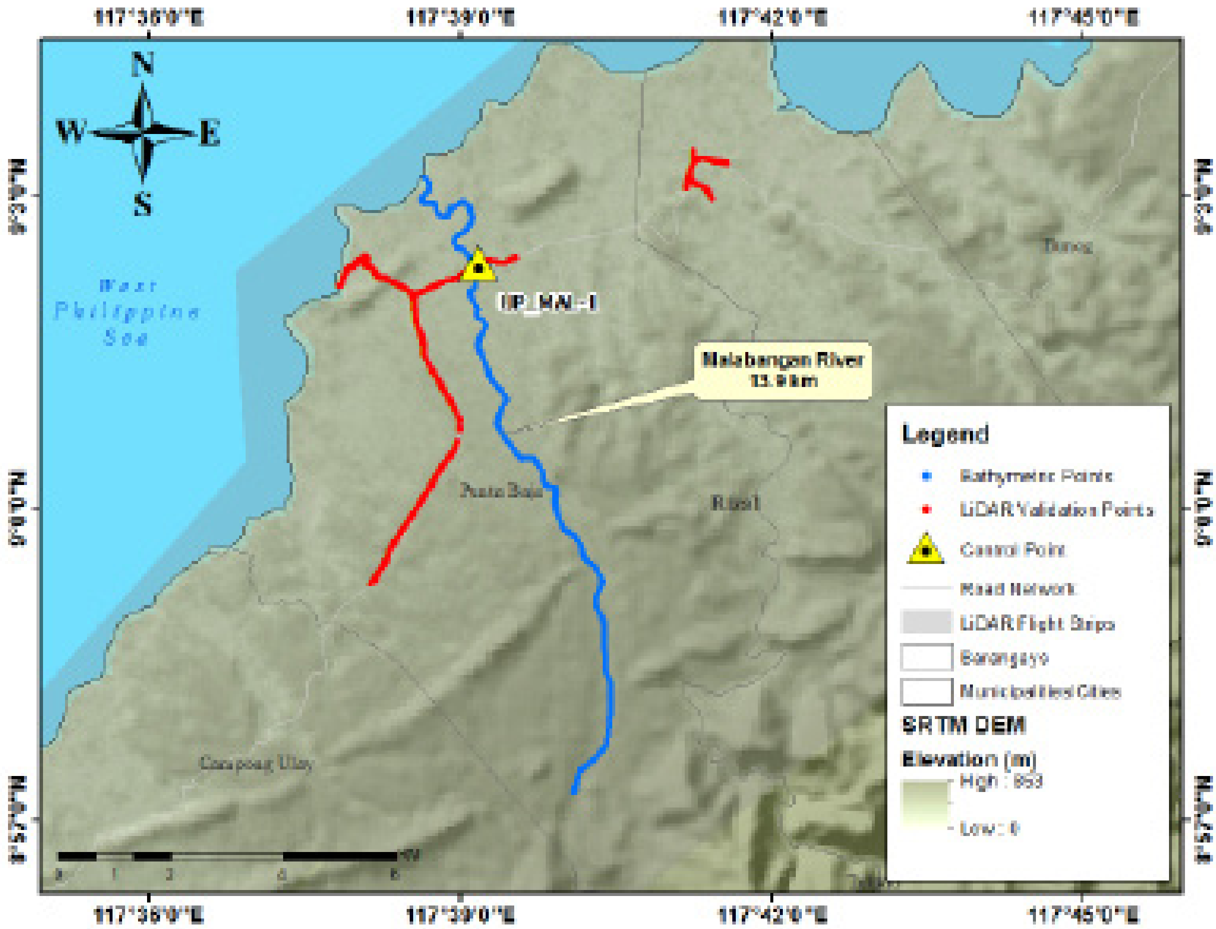


Figure 37. Validation point acquisition survey of Malambunga River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on January 20, 2016 using a Hi-Target™ Echo Sounder as illustrated in Figure 38 and Figure 39. The survey started in Brgy. Punta Baja, Municipality of Rizal, Palawan with coordinates 9° 2' 51.08788"N, 117° 38' 54.25979"E and ended at the mouth of the river in Brgy. Punta Baja, also in Municipality of Rizal, with coordinates 9° 3' 13.25050"N, 117° 38' 38.66812"E.

Figure 38. Bathymetric survey of ABSD at Malambunga River using a Hi-Target™ Echo Sounder

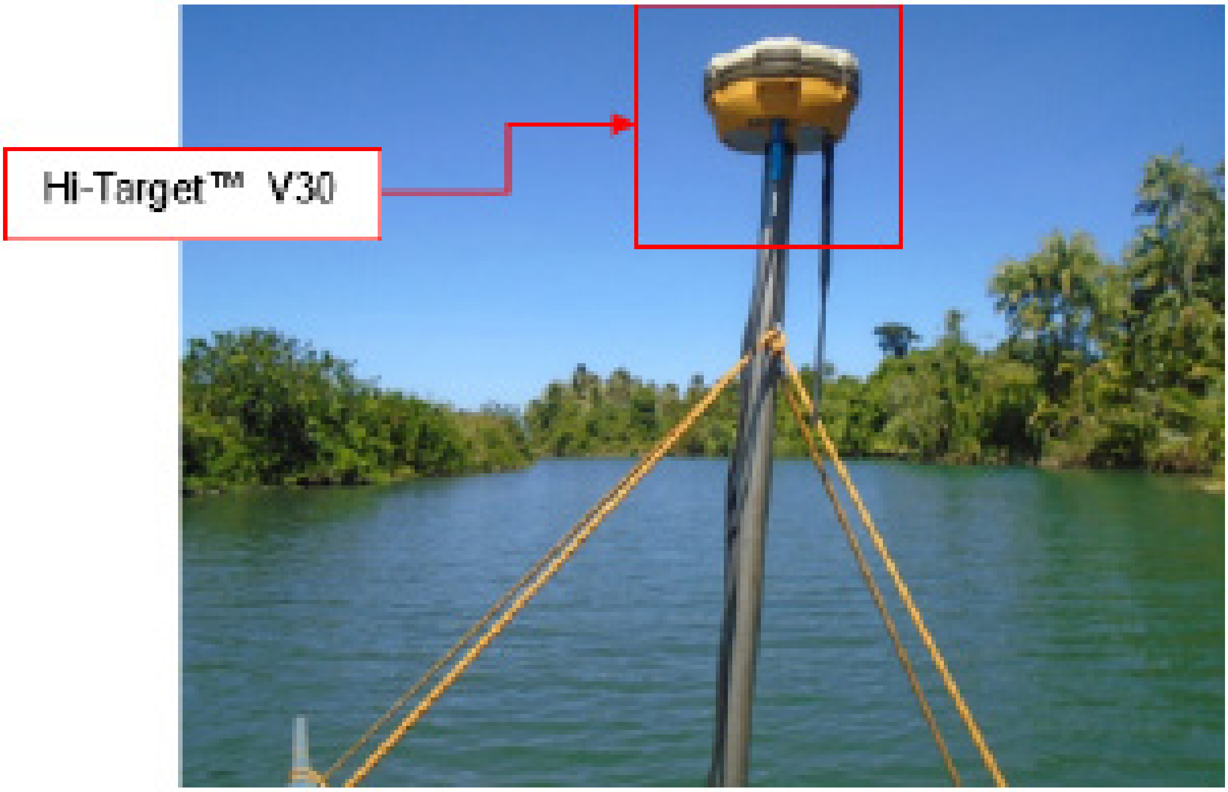


Figure 39. Bathymetric survey of ABSD at Malambunga River using a Hi-Target™ V30

Manual bathymetric survey was executed from January 20-22, 2016 and on January 24-25, 2016 using a Horizon® Total Station as illustrated in Figure 40. The survey started in Brgy. Punta Baja, Municipality of Rizal with coordinates 8° 57' 34.40144"N, 117° 40' 20.46381"E, traversing down the river and ended at the starting point of bathymetric survey using a boat in Brgy. Punta Baja, Municipality of Rizal. The control pointsUP_MAL-1 and UP_MAL-2 were used as GNSS base stations all throughout the entire survey.

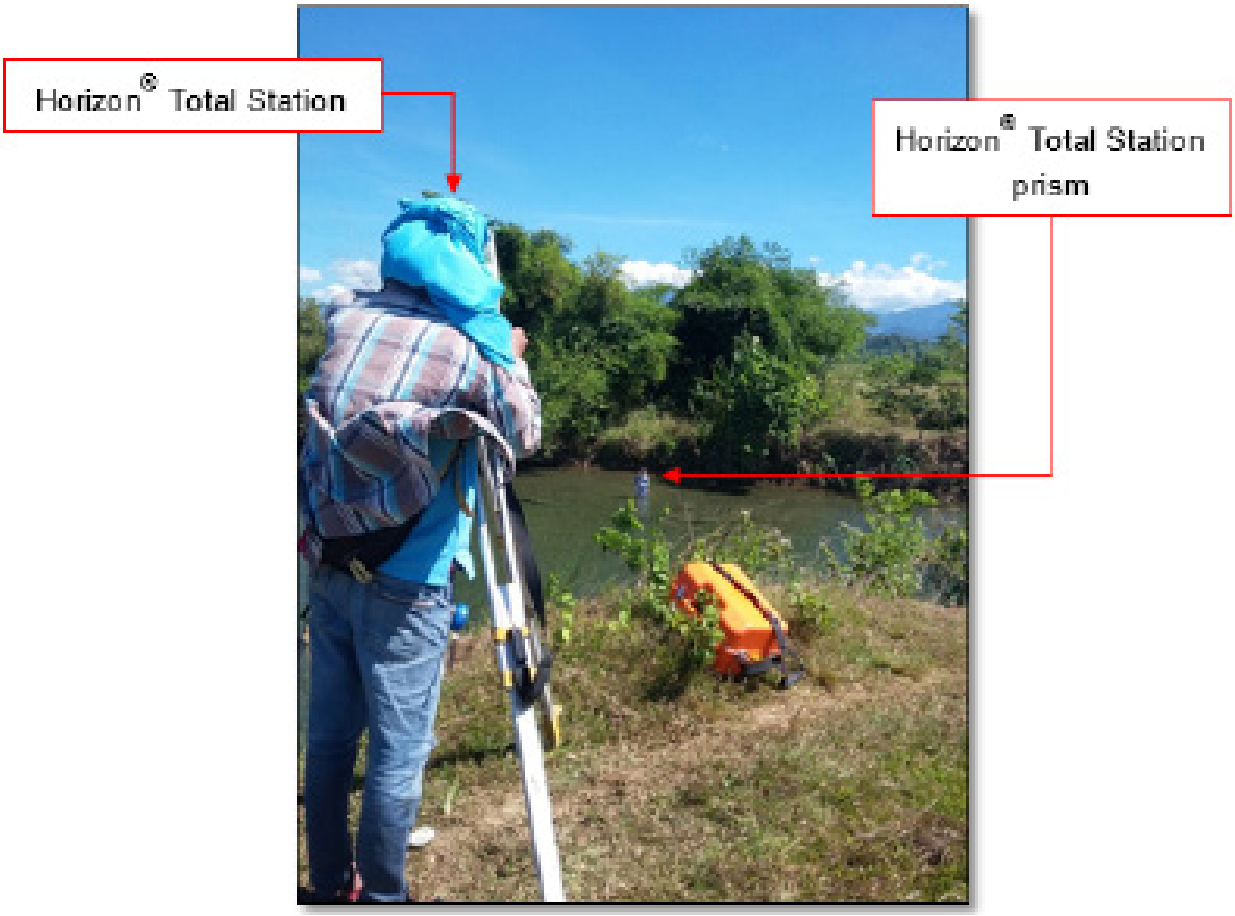


Figure 40. Manual bathymetric survey of ABSD along Malambunga River using a Horizon® Total Station

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 20, 2016 using a GNSS Rover receiver, Trimble® SPS 882 attached to a 2-m pole, see Figure 41. A map showing the DVBC bathymetric checking points is shown in Figure 43.

Figure 41. Gathering of bathymetric checking points along Malambunga River

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2value of 0.998 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.181 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

The bathymetric survey for Malambunga River gathered a total of 7,048 points covering 13.1 km of the river traversing Brgy. Punta Baja in the Municipality of Rizal. A CAD drawing was also produced to illustrate the riverbed profile of Malabunga River. As shown in Figure 44, the highest and lowest elevation has a 109-m difference. The highest elevation observed was 105.576 m above MSL while the lowest was -3.510 m below MSL, both located in Brgy. Punta Baja, Municipality of Rizal.

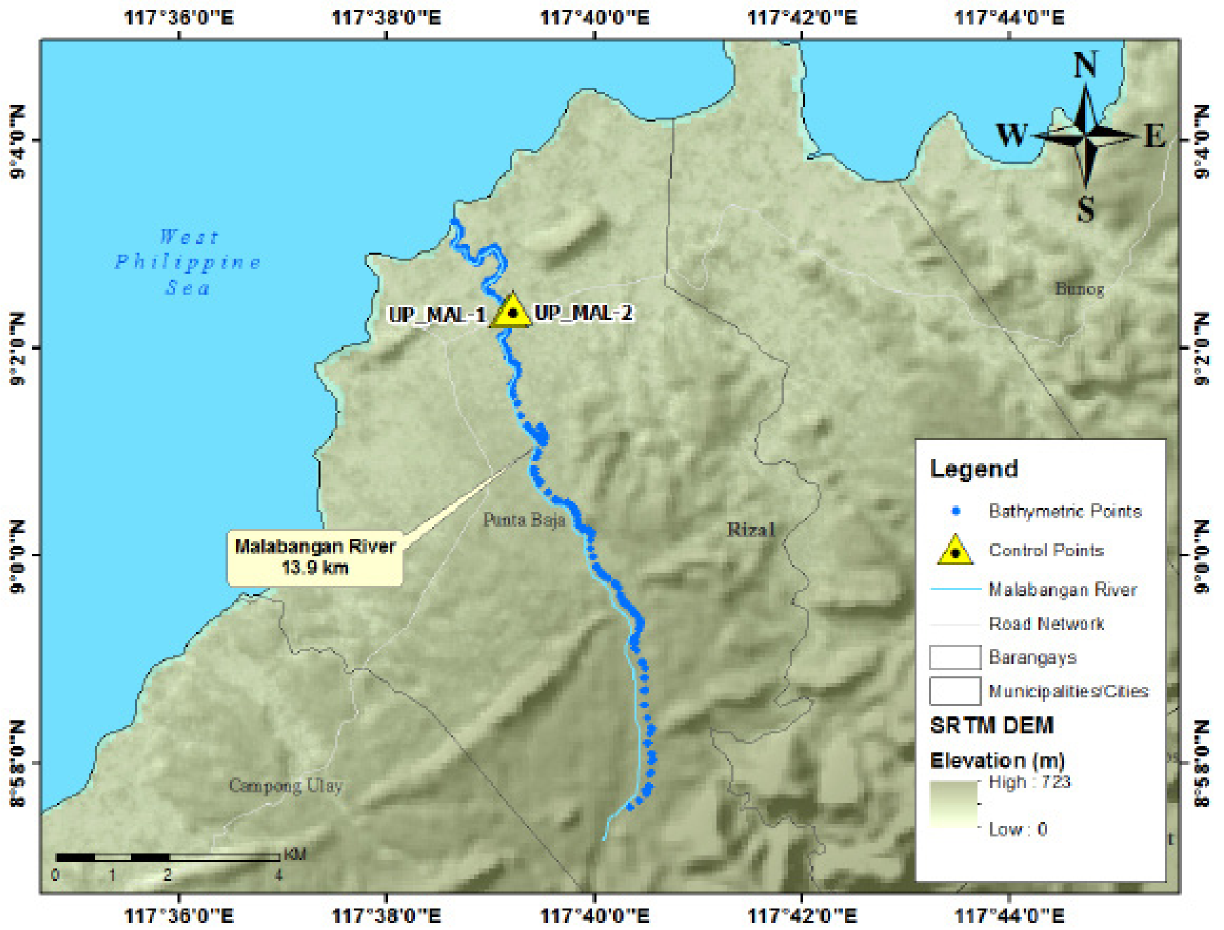


Figure 42. Gathering of bathymetric checking points along Malambunga River

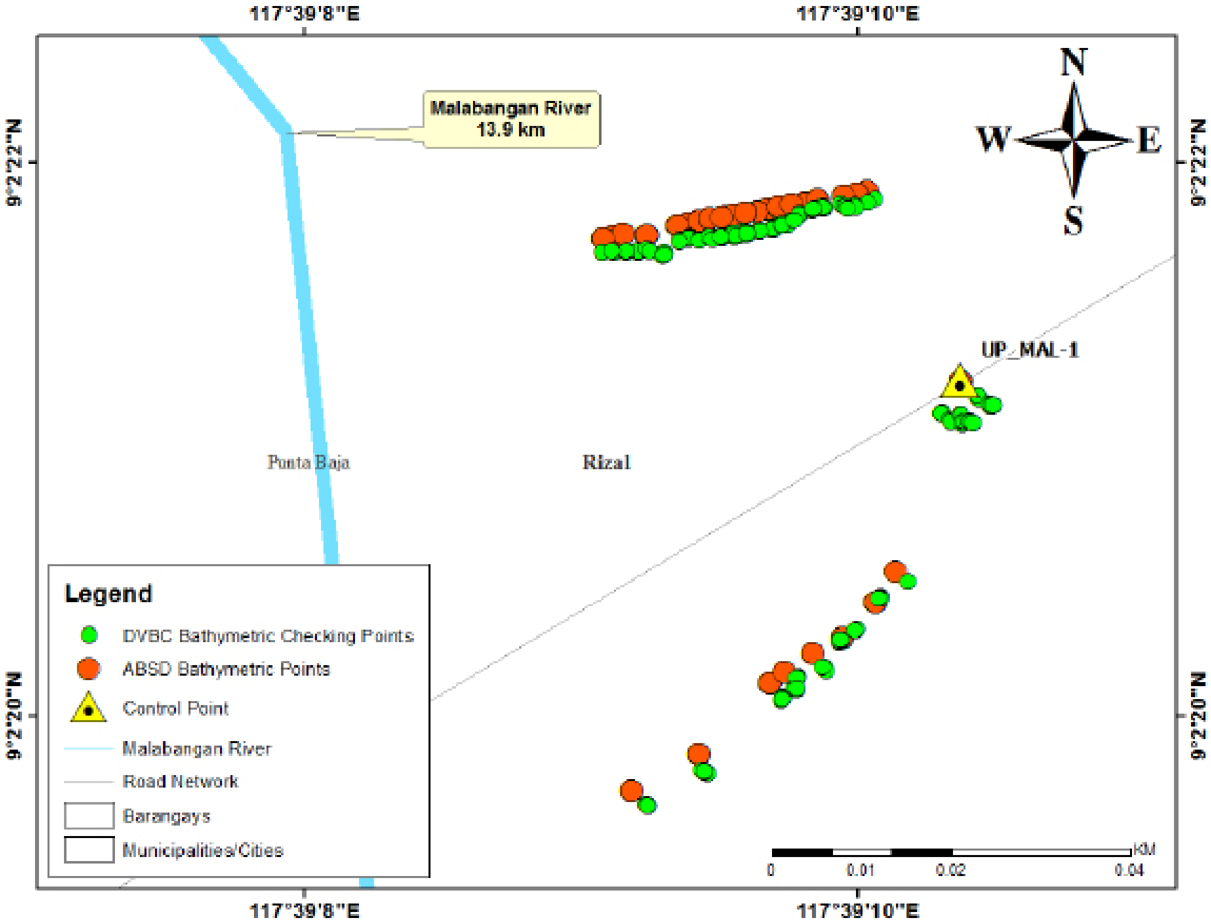


Figure 43. Quality checking points gathered along Malambunga River by DVBC
Quality checking points gathered along Malabangan River by DVBC

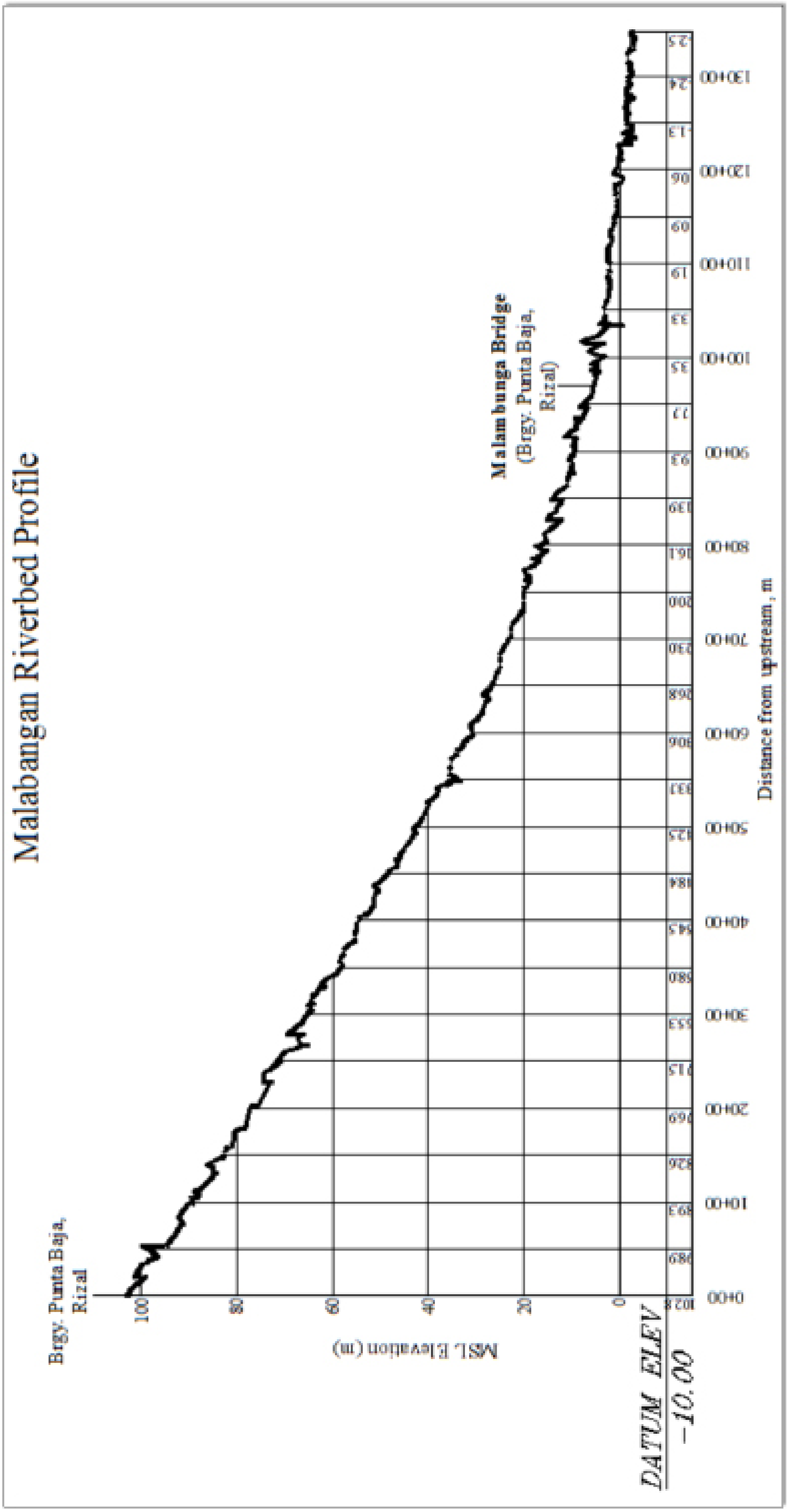


Figure 44. The Malambunga riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge deployed on a strategic location within the riverbasin (9.036632˚ N, 117.654386˚ E). The location of the rain gauge is seen in Figure 45.

The total precipitation for this event was 136.20 mm. It had a peak rainfall of 8.20 mm. on January 10, 2017 at 6:20 pm. The lag time between the peak rainfall and discharge was 15 hour and 5 minutes, as seen in Figure 48.

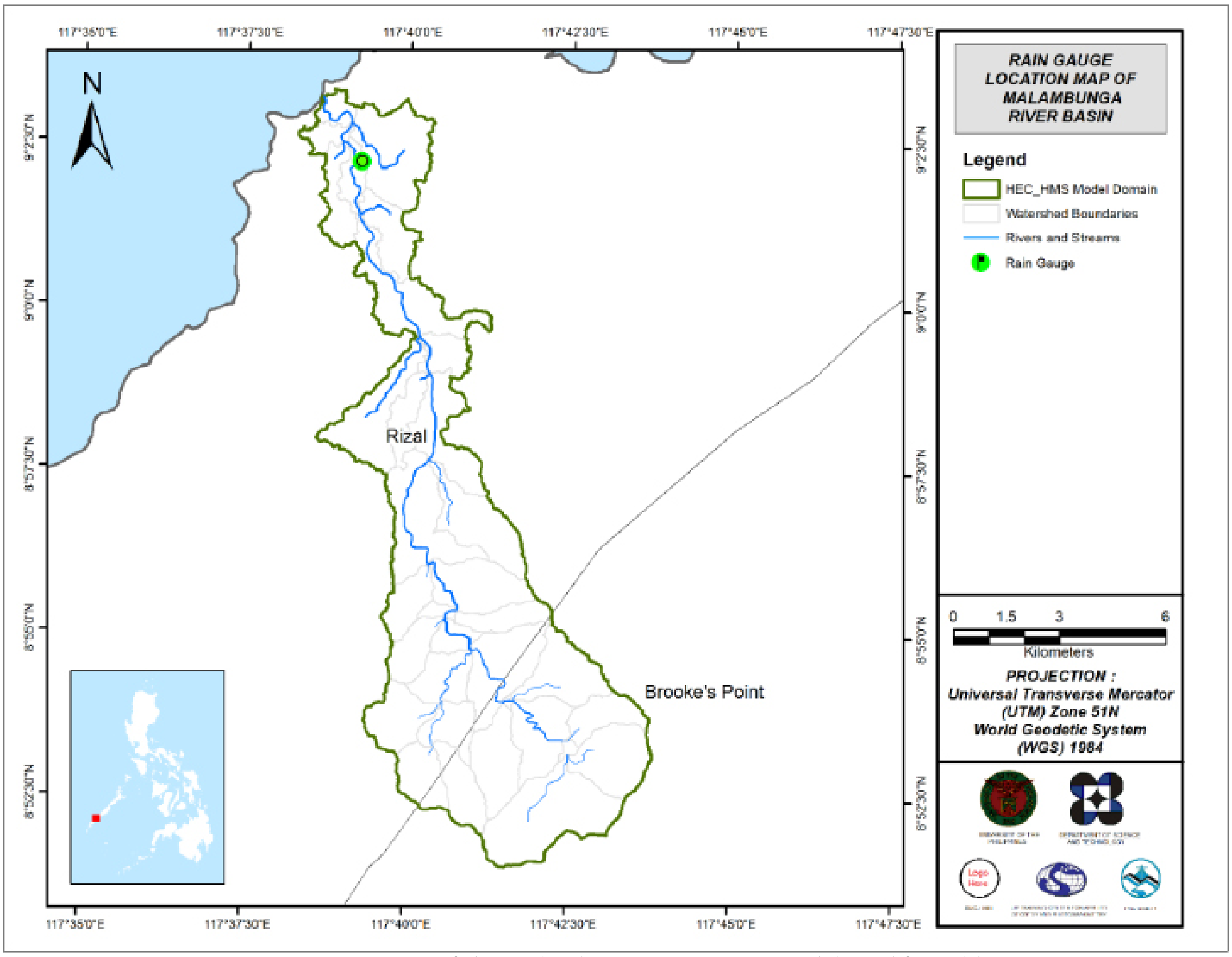


Figure 45. Location map of the Malambunga HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Malambunga Bridge, Rizal, Palawan (9.038779° N, 117.652399° E). It gives the relationship between the observed water levels from the Malambunga Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Malambunga Bridge, the rating curve is expressed as Q = 1.1683e0.450x as shown in Figure 47.

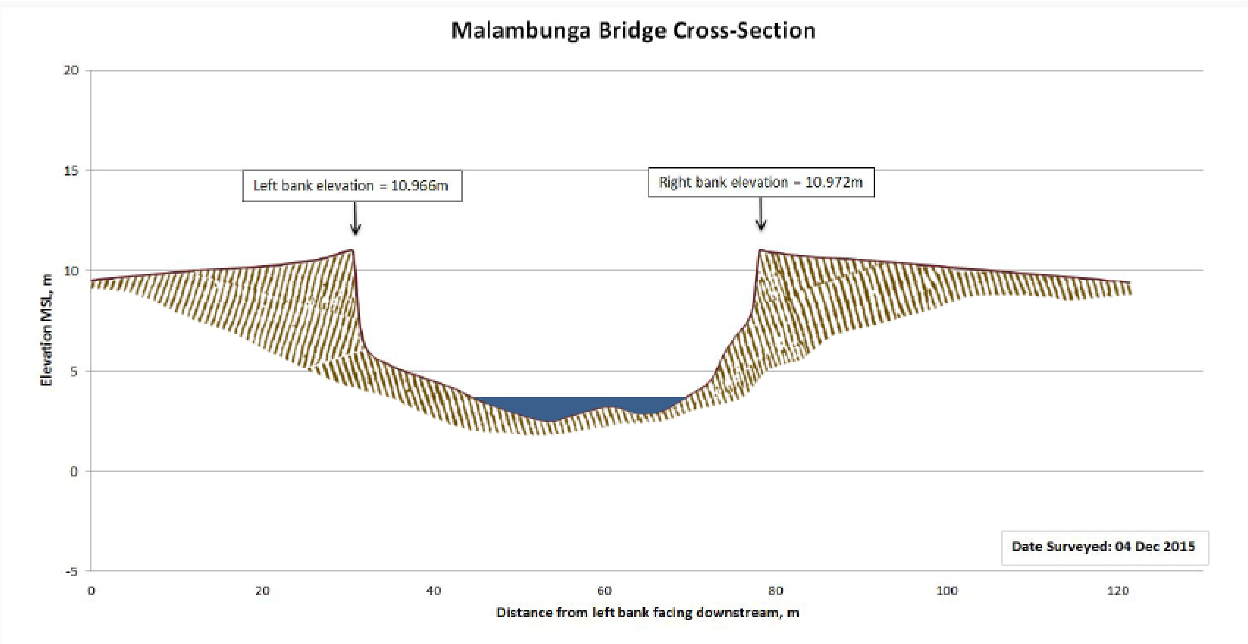


Figure 46. Cross-section plot of Malambunga Bridge

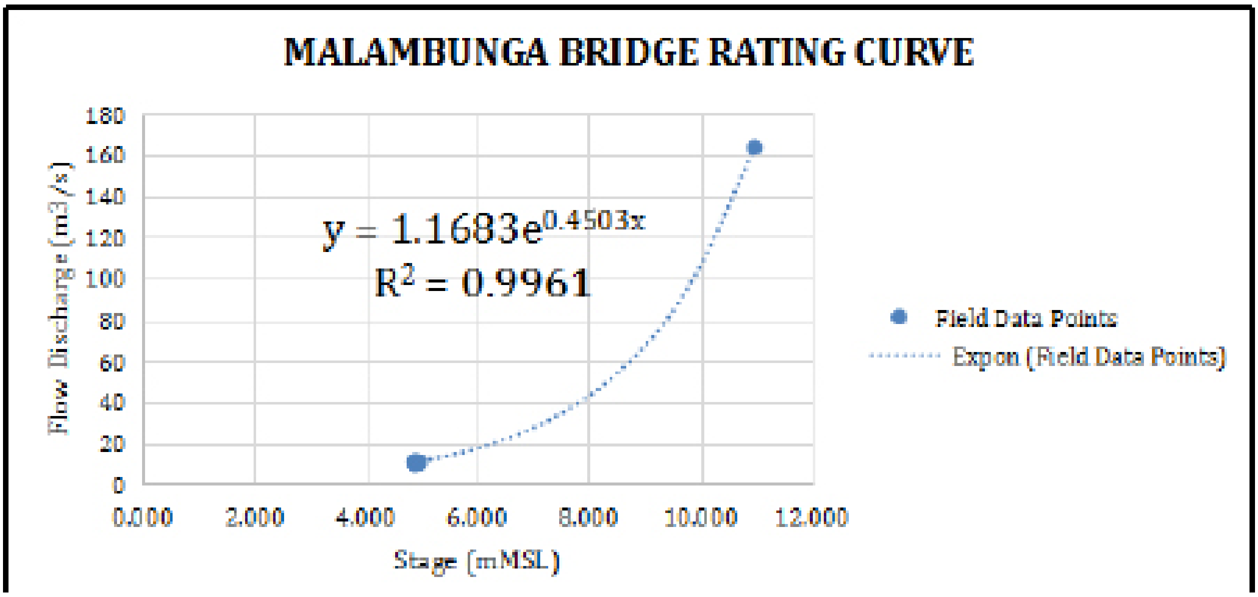


Figure 47. Rating Curve at Malambunga Bridge, Rizal,Palawan

For the calibration of the HEC-HMS model, shown in Figure 48, actual flow discharge during a rainfall event was collected in the Malambunga bridge. Peak discharge was 161.80 cu.m/s on January 11, 2017 at 8:45 am.

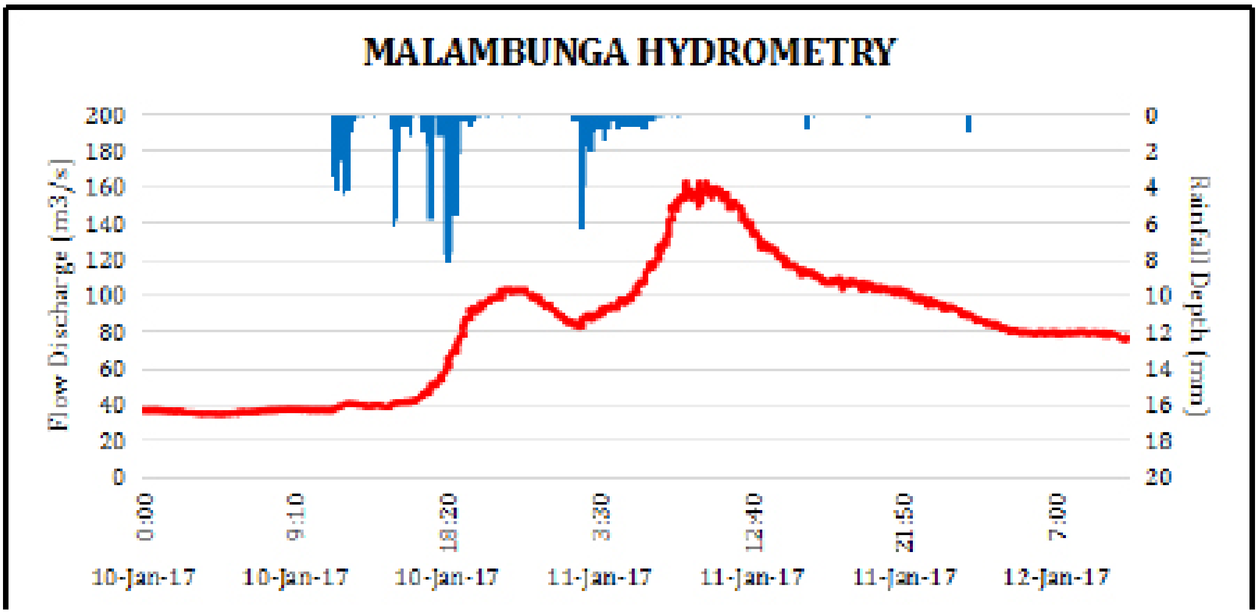


Figure 48. Rainfall and outflow data of Malambunga River Basin, which was used for modeling.

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 was attained at a certain time. This station was chosen based on its proximity to the Malambunga watershed. The extreme values for this watershed were computed based on a 58-year record.

Table 21. RIDF values for Aparri 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

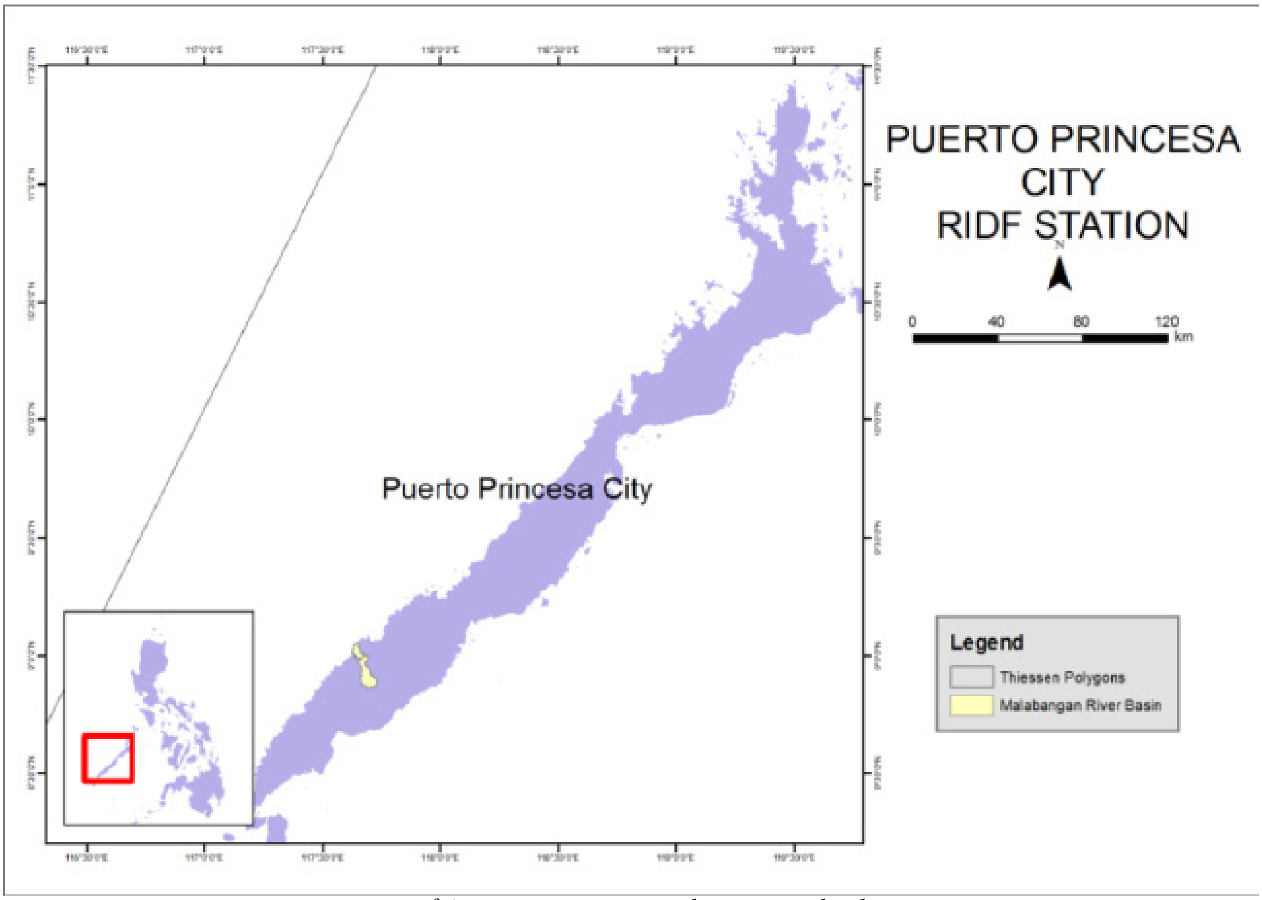


Figure 49. Location of Aparri RIDF Station relative to Malambunga River Basin

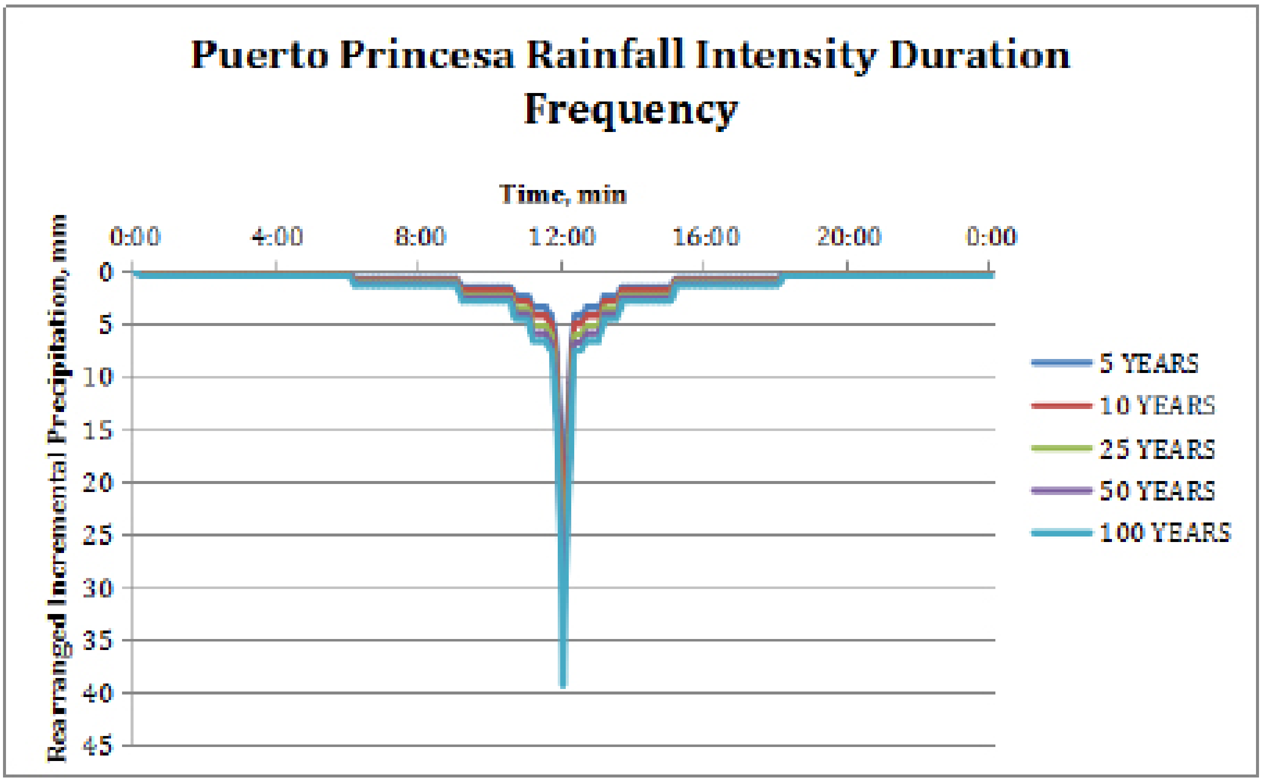


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA).

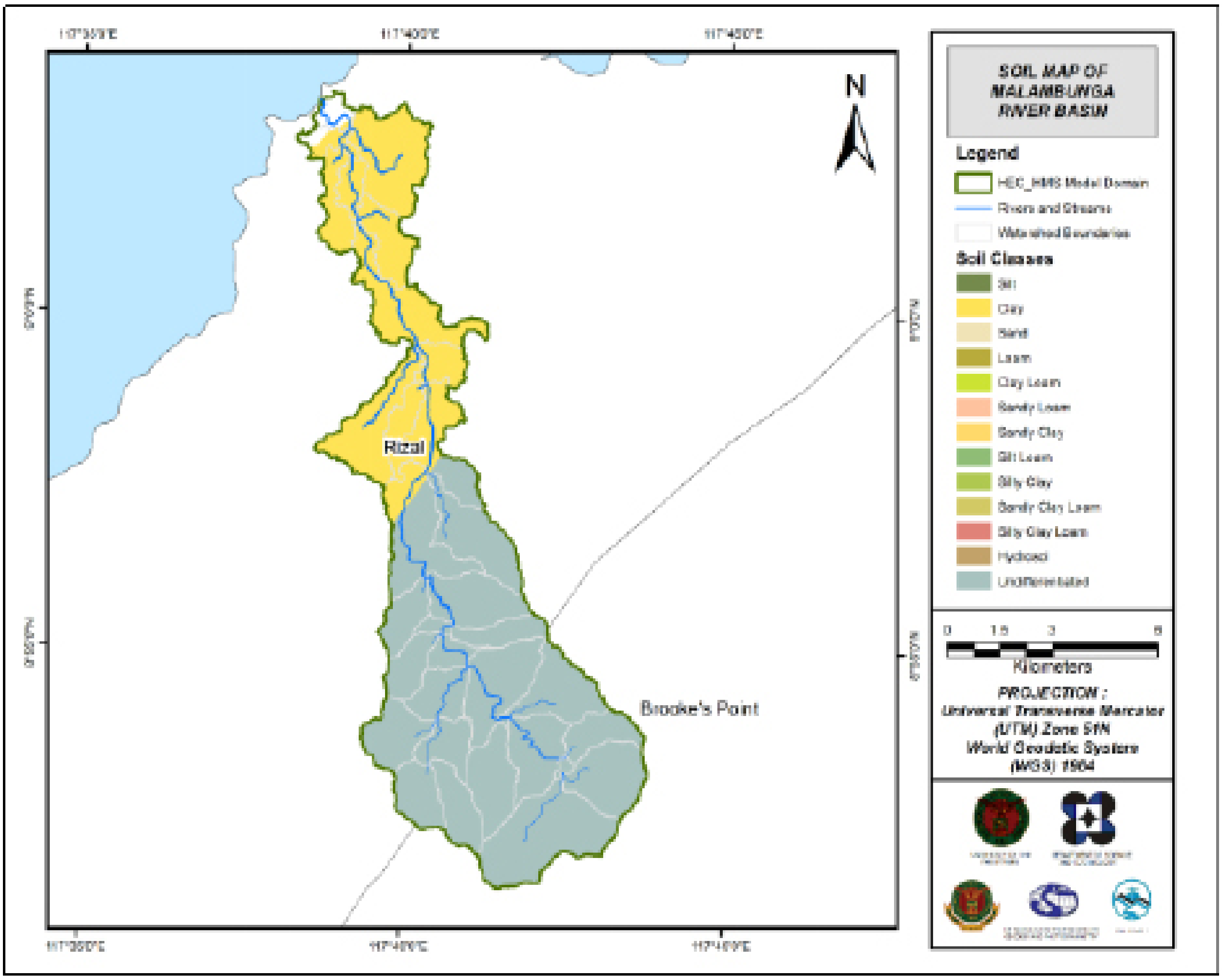


Figure 51. The soil map of the Malambunga River Basin used for the estimation of the CN parameter.

(Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

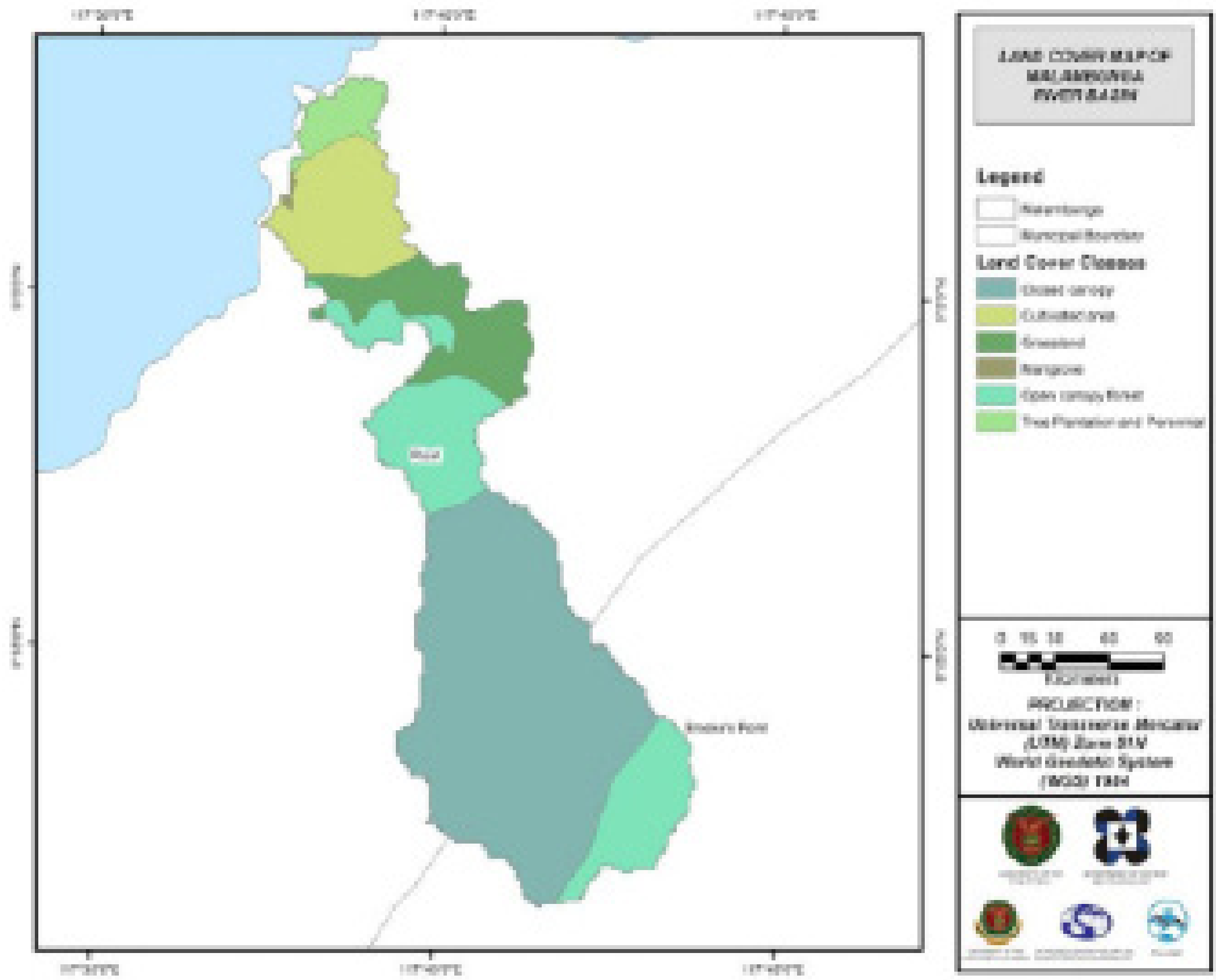


Figure 52. The land cover map of the Malambunga River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

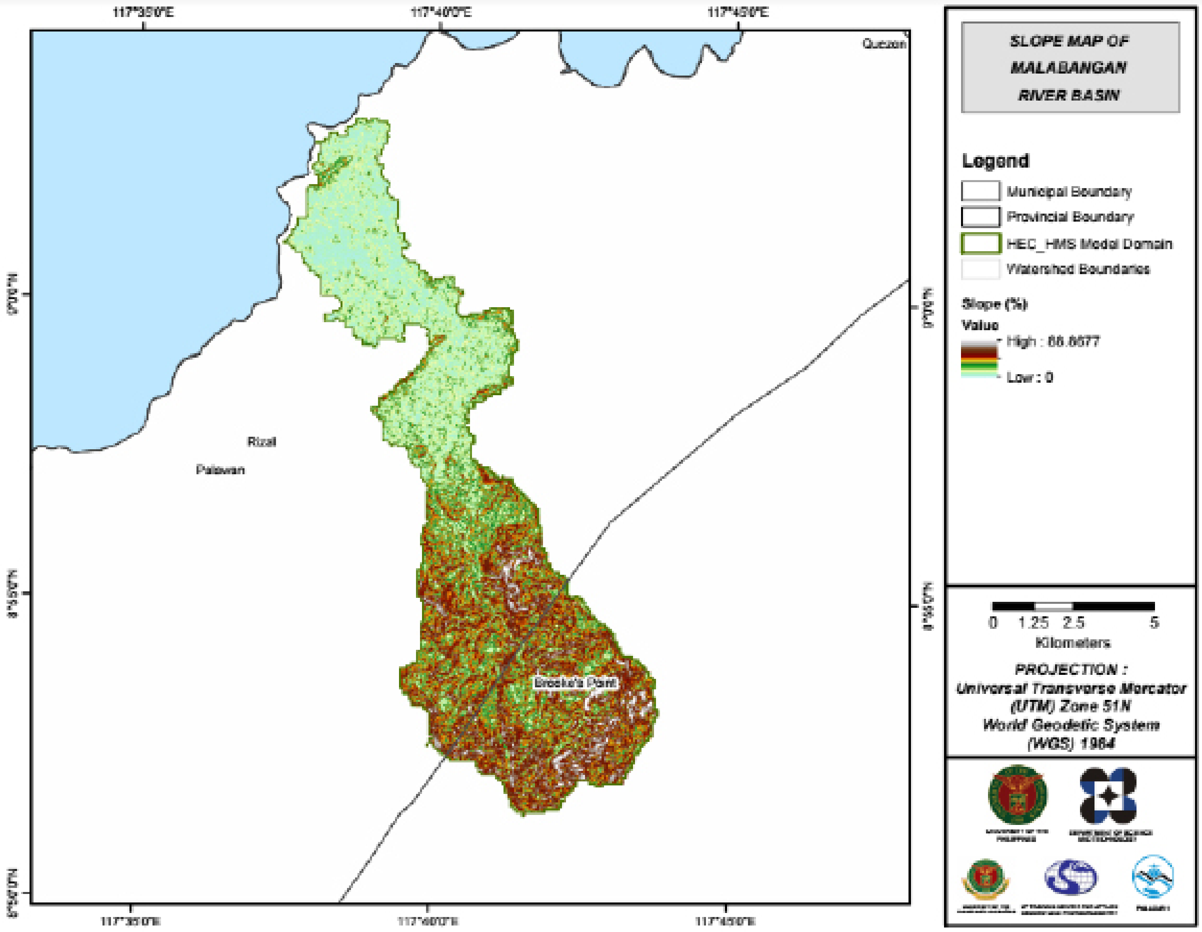


Figure 53. Slope Map of Malambunga River Basin

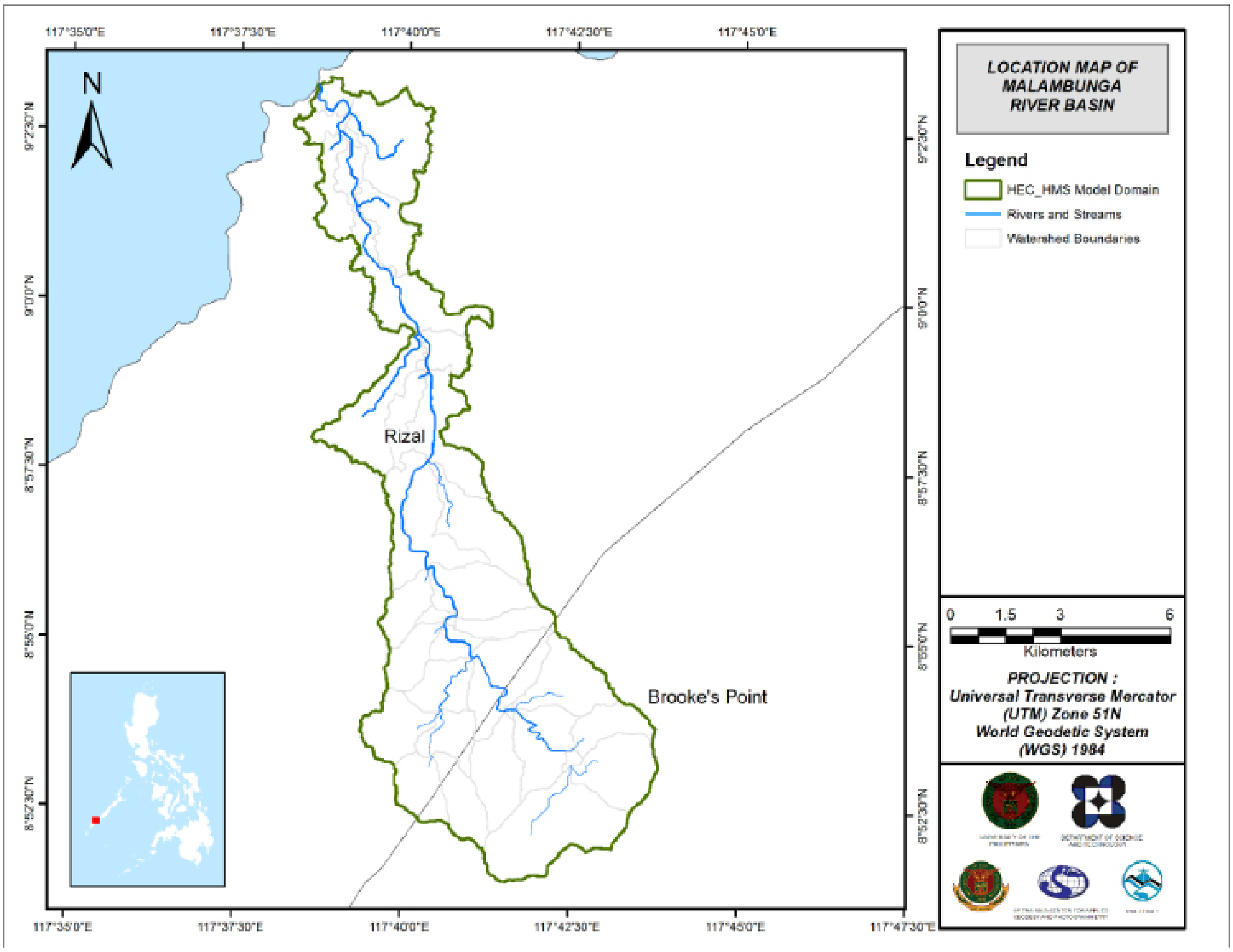


Figure 54. Stream Delineation Map of Malambunga River Basin

Using SAR-based DEM, the Malambunga basin was delineated and further subdivided into subbasins. The model consists of 34 sub basins, 17 reaches, and 17 junctions. The main outlet is labelled as 107. This basin model is illustrated in 55. 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 Malambunga Bridge.

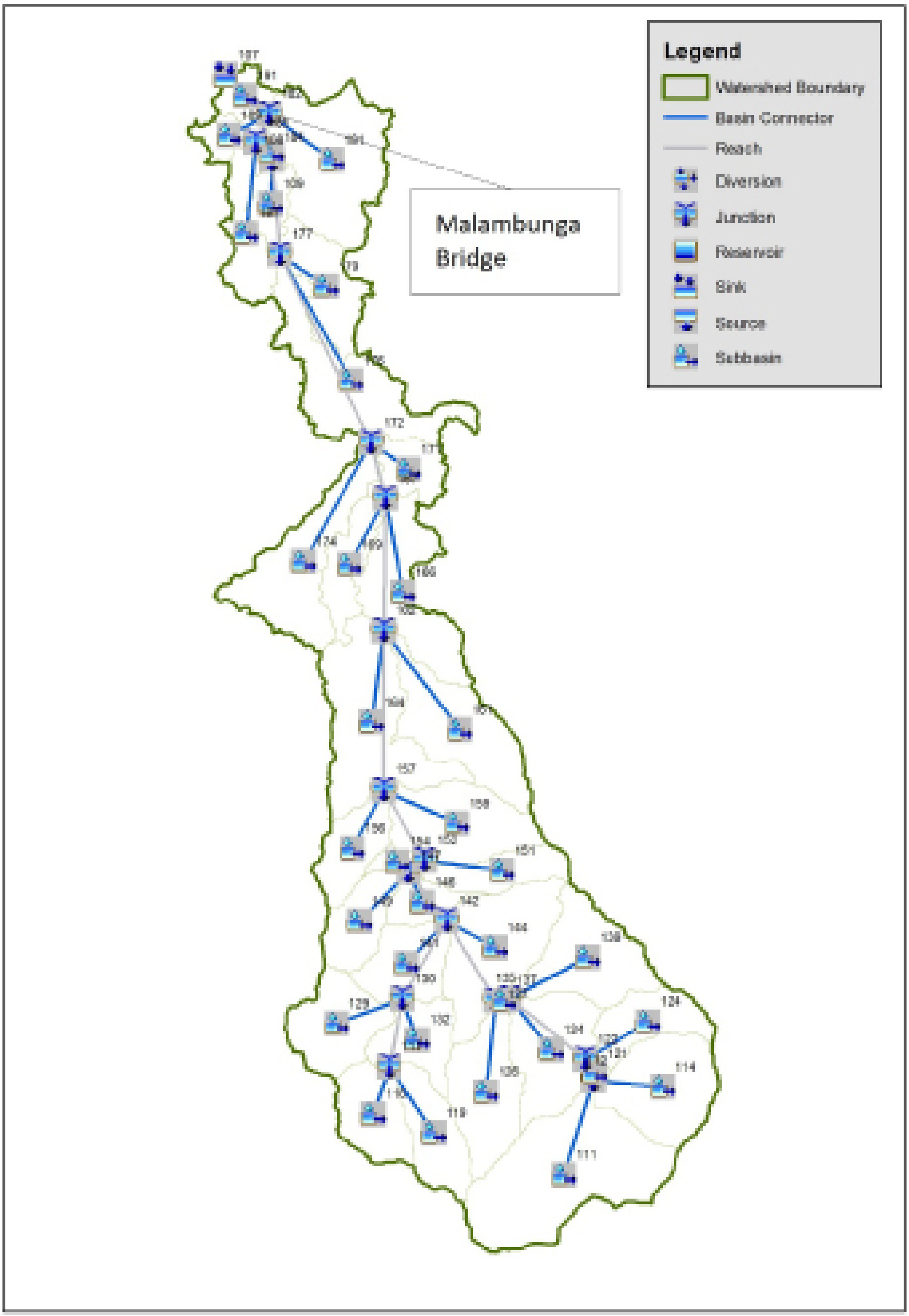


Figure 57. Malambunga River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model set-up. 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.

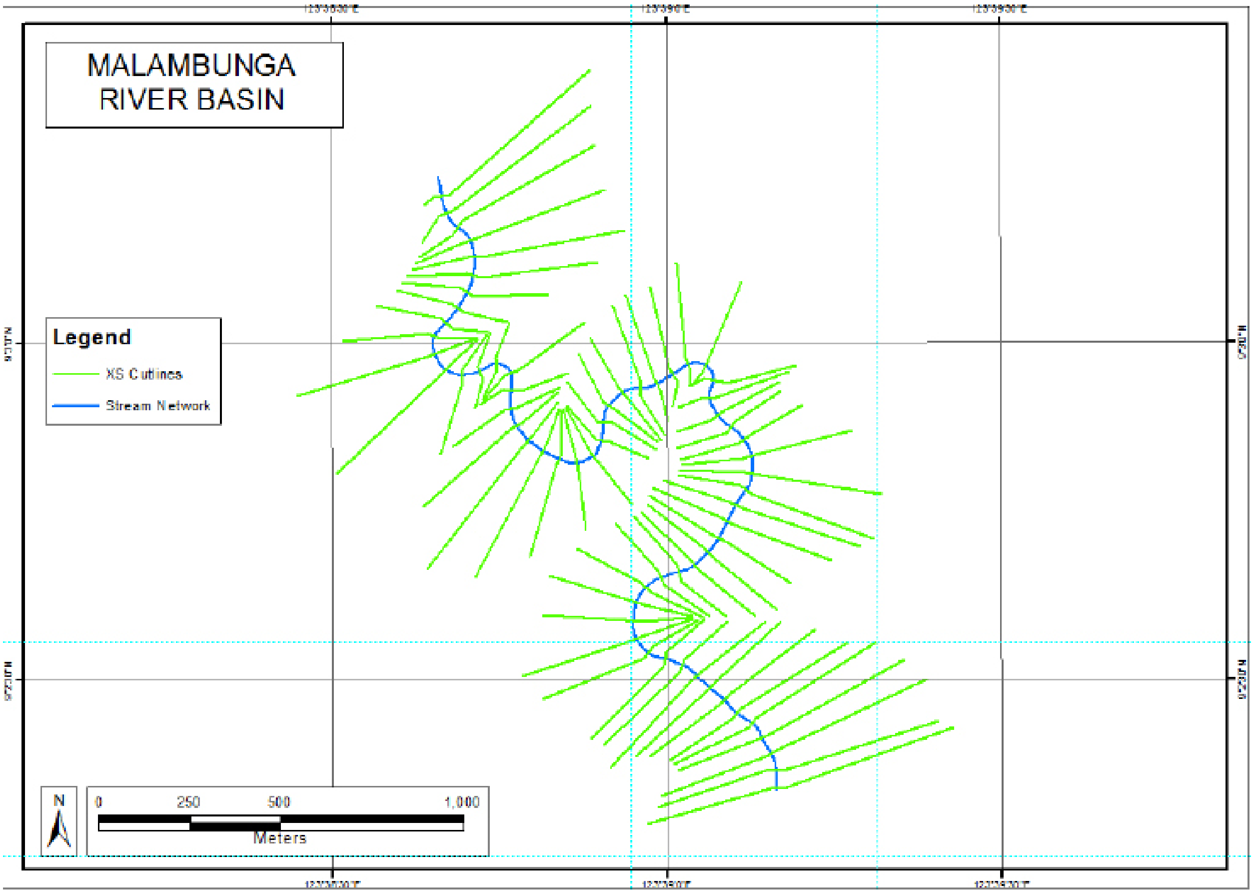


Figure 56. River cross-section of Malambunga River generated through Arcmap HEC GeoRAS tool

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

Figure 57. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 31.95605 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 80 183 700.00 m2.

There is a total of 36 447 348.62 m3 of water entering the model. Of this amount, 22 918 238.06 m3 is due to rainfall while 13 529 110.56 m3 is inflow from other areas outside the model. 7 005 949.50 m3 of this water is lost to infiltration and interception, while 4 475 535.98 m3 is stored by the flood plain. The rest, amounting up to 24 965 868.70 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Malambunga HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 58 shows the comparison between the two discharge data.

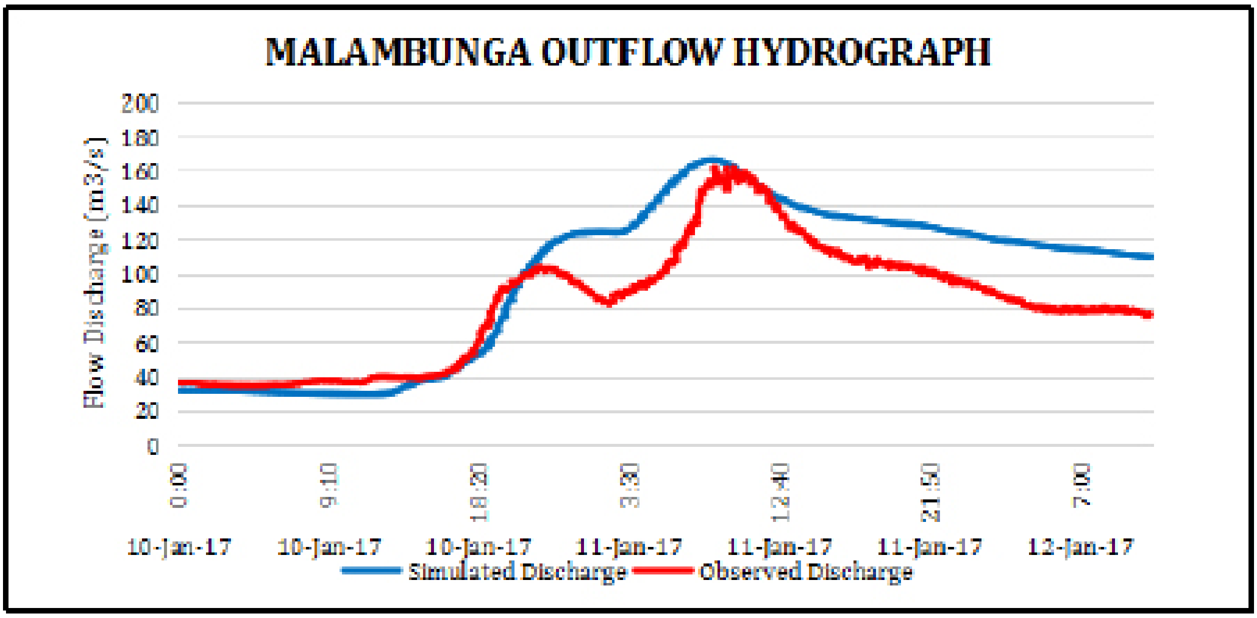


Figure 58. Outflow hydrograph of Malambunga produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 22 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 22. Range of calibrated values for the Malambunga River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.1 - 12
			Curve Number	35 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2 - 16
			Storage Coefficient (hr)	0.3 - 8
	Baseflow	Recession	Recession Constant	0.3 - 1
			Ratio to Peak	0.3 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.03 – 0.6

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.1 to 12mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 99 for curve number means that there is a diverse characteristic for this watershed depending on its subbasin.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 hours to 16 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. Same as the curve number, the characteristics of this watershed differs per reach.

Manning's roughness coefficient of 0.03 to 0.6 also indicates different characteristics of the river reaches

Table 23. Summary of the Efficiency Test of the Malambunga HMS Model

Accuracy measure	Value
RMSE	23.598
r2	0.936
NSE	0.554
PBIAS	-18.208
RSR	0.668

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 23.598.

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 0.936.

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 0.554.

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 -18.208.

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 0.668.

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 59) shows the Malambunga 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 revealed significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

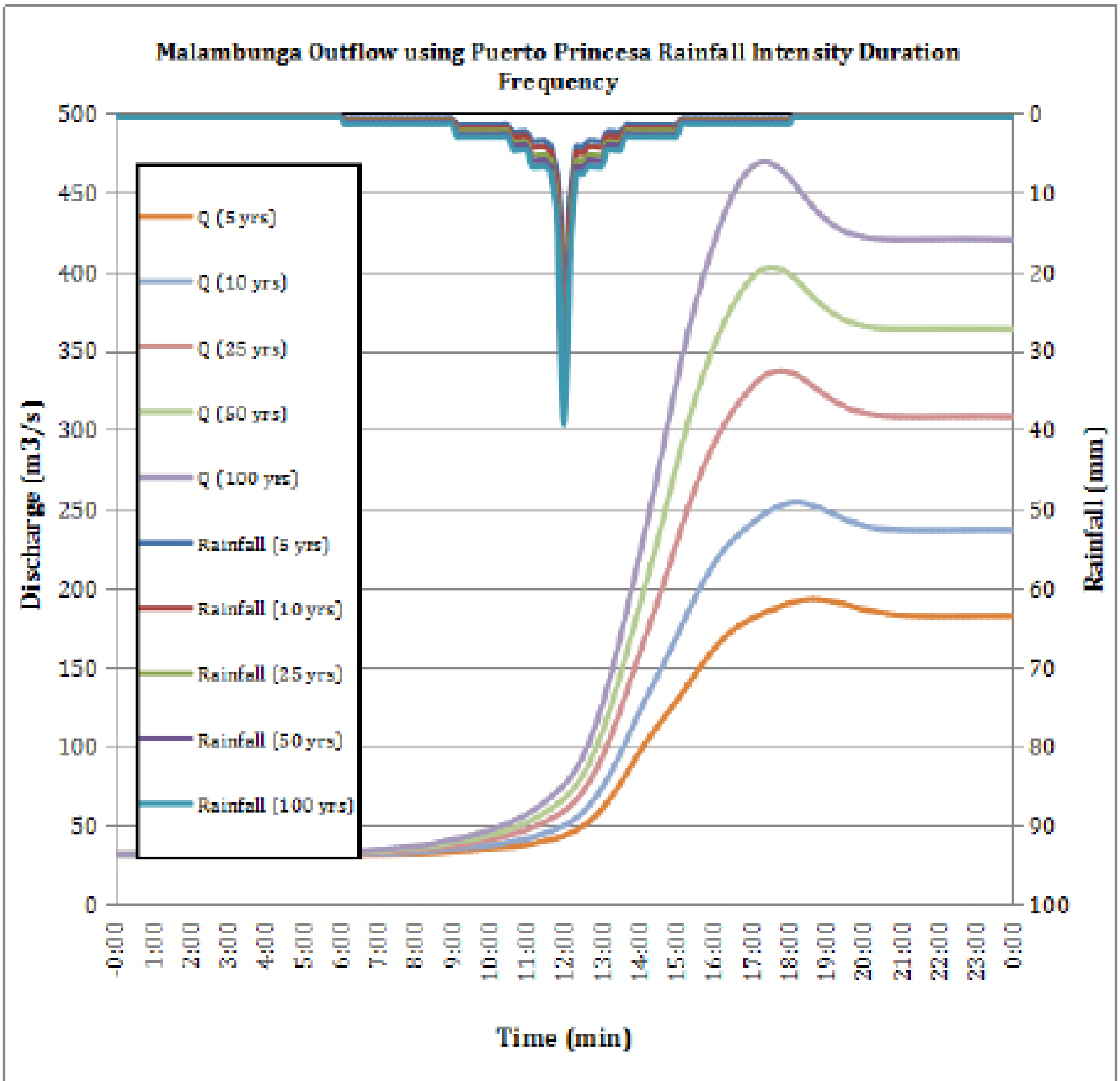


Figure 59. Outflow hydrograph at Malambunga Station generated using Puerto Princesa RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Malambunga discharge using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 24.

Table 24. Peak values of the Malambunga 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	192.998	6 hours 40 minutes
10-Year	191.1	25.60	254.286	6 hours 10 minutes
25-Year	234.90	31.10	337.537	5 hours 50 minutes
50-Year	267.30	35.20	402.619	5 hours 30 minutes
100-Year	299.60	39.20	469.450	5 hours 20 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Malambunga River using the HMS base flow is shown on Figure 60 below.

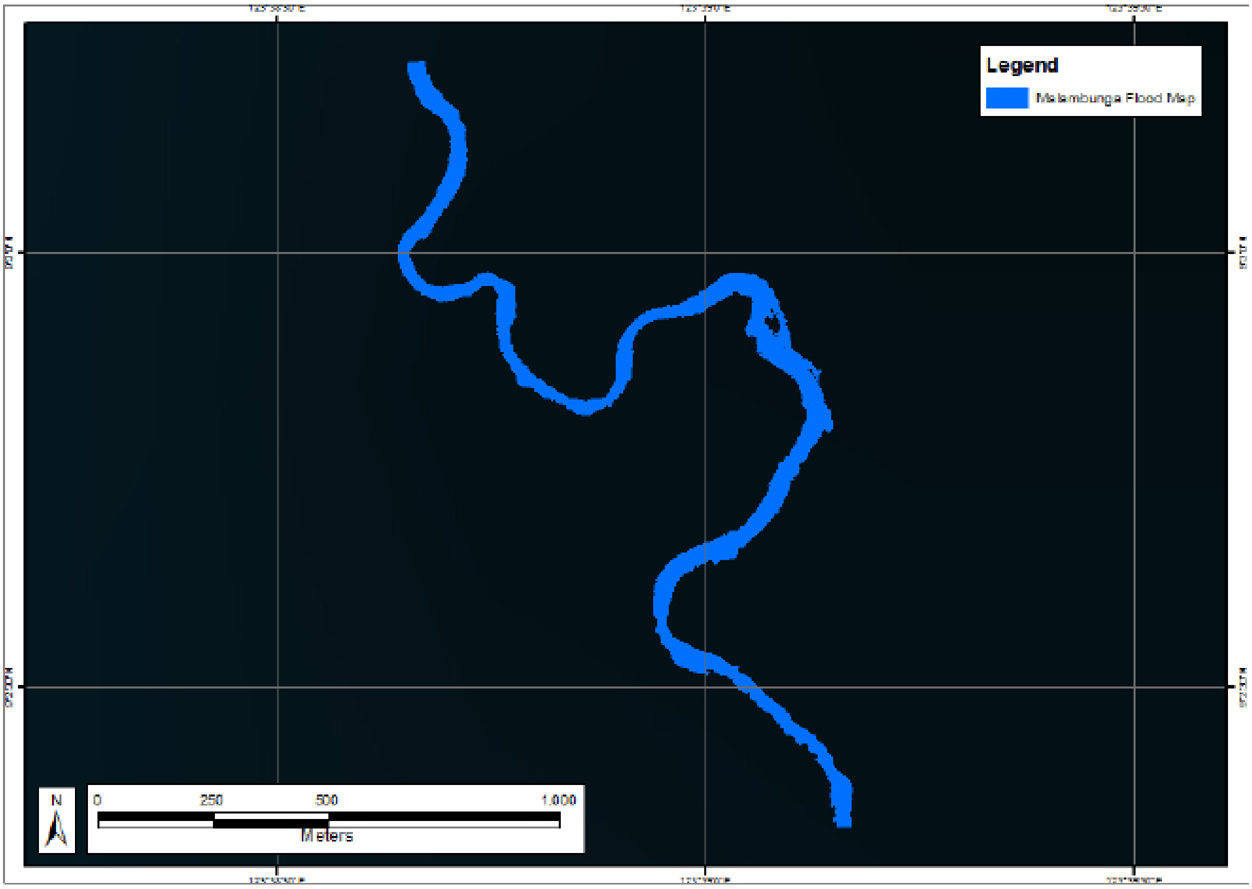


Figure 60. Sample output map of Malambunga RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Malambunga Floodplain are shown in Figure 17 to 21. The floodplain, with an area of 79.82 sq. km., covers onemunicipalitynamely Rizal. Table 25 shows the percentage of area affected by flooding per municipality.

Table 25. Municipalities affected in Malambunga Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Rizal	980.59	79.76	8.13

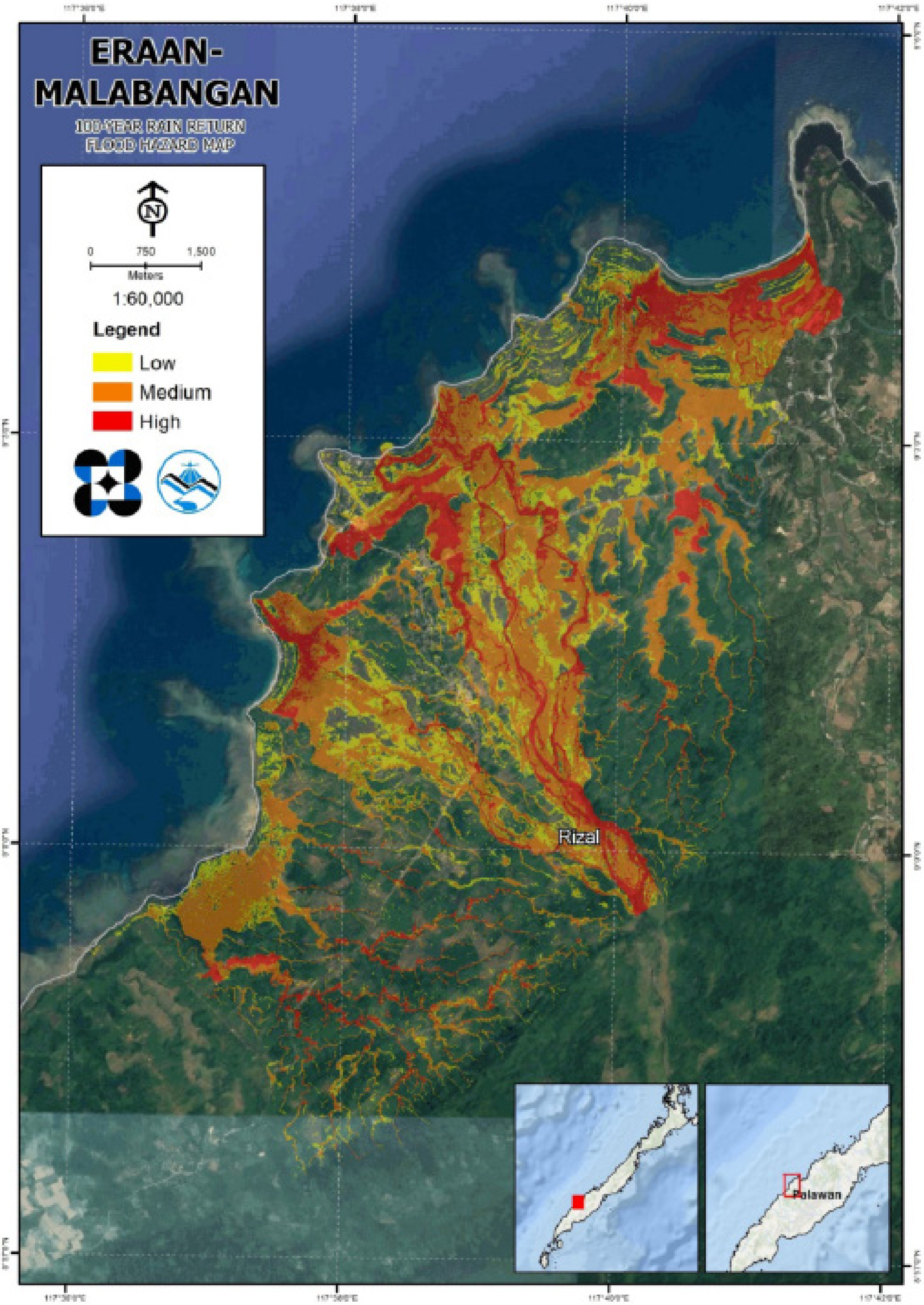


Figure 61. A 100-year flood hazard map for Eraan-Malabangan (also known as Iraan-Malambunga) Floodplain

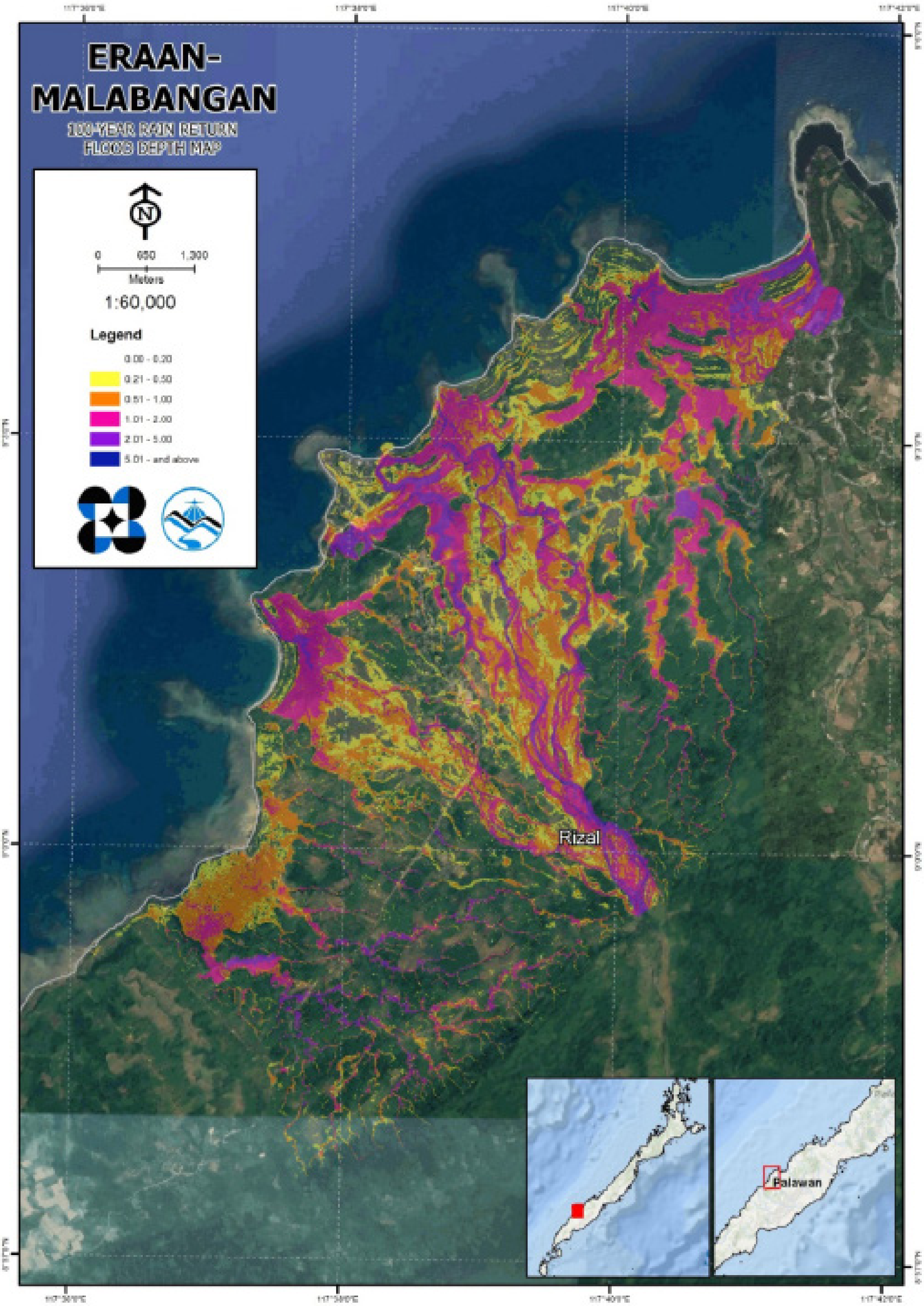


Figure 62. A 100-year Flow Depth Map for Eraan-Malabangan (also known as Iraan-Malambunga) Floodplain

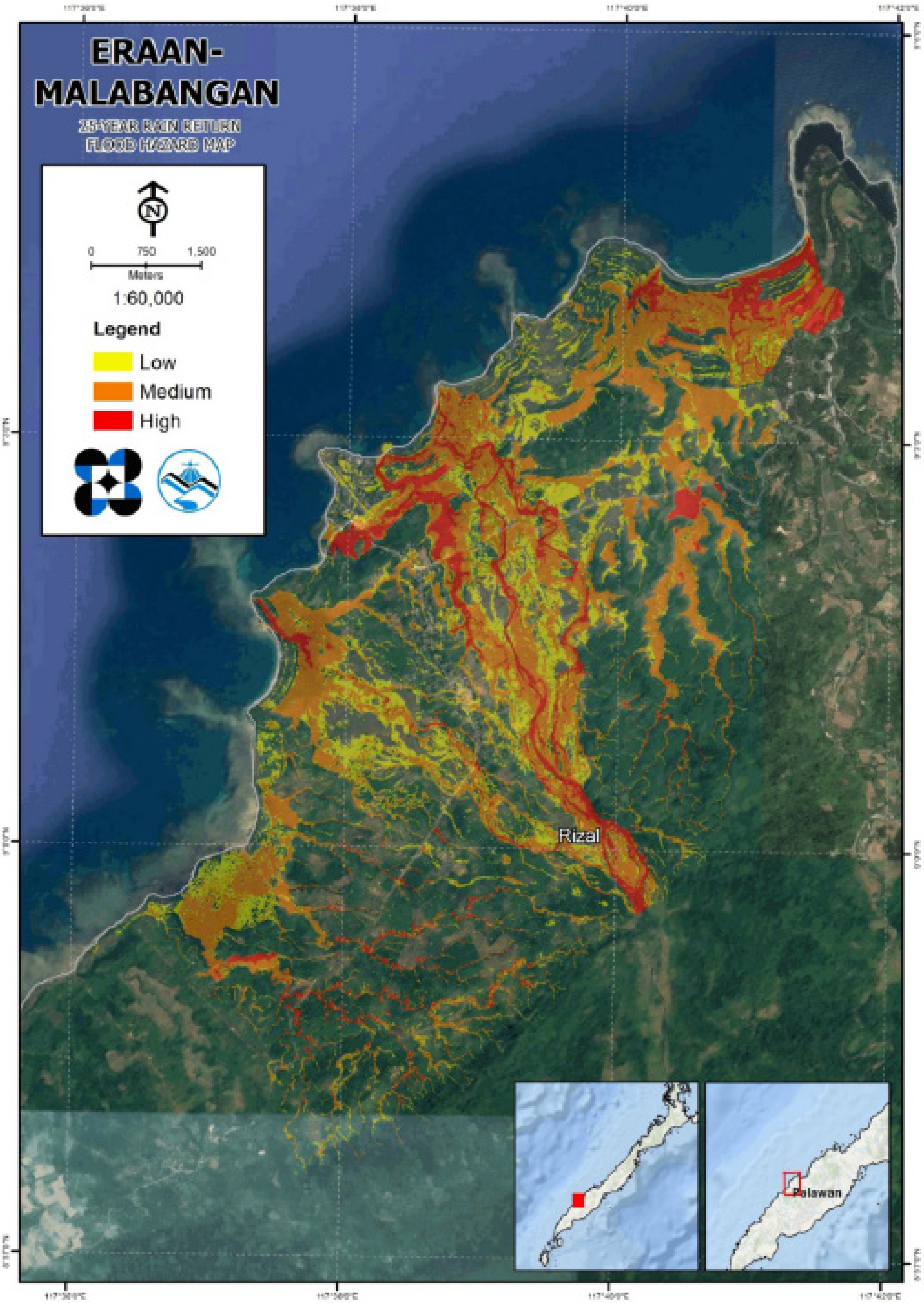


Figure 63. A 25-year Flood Hazard Map for Eraan-Malabangan (also known as Iraan-Malambunga) Floodplain

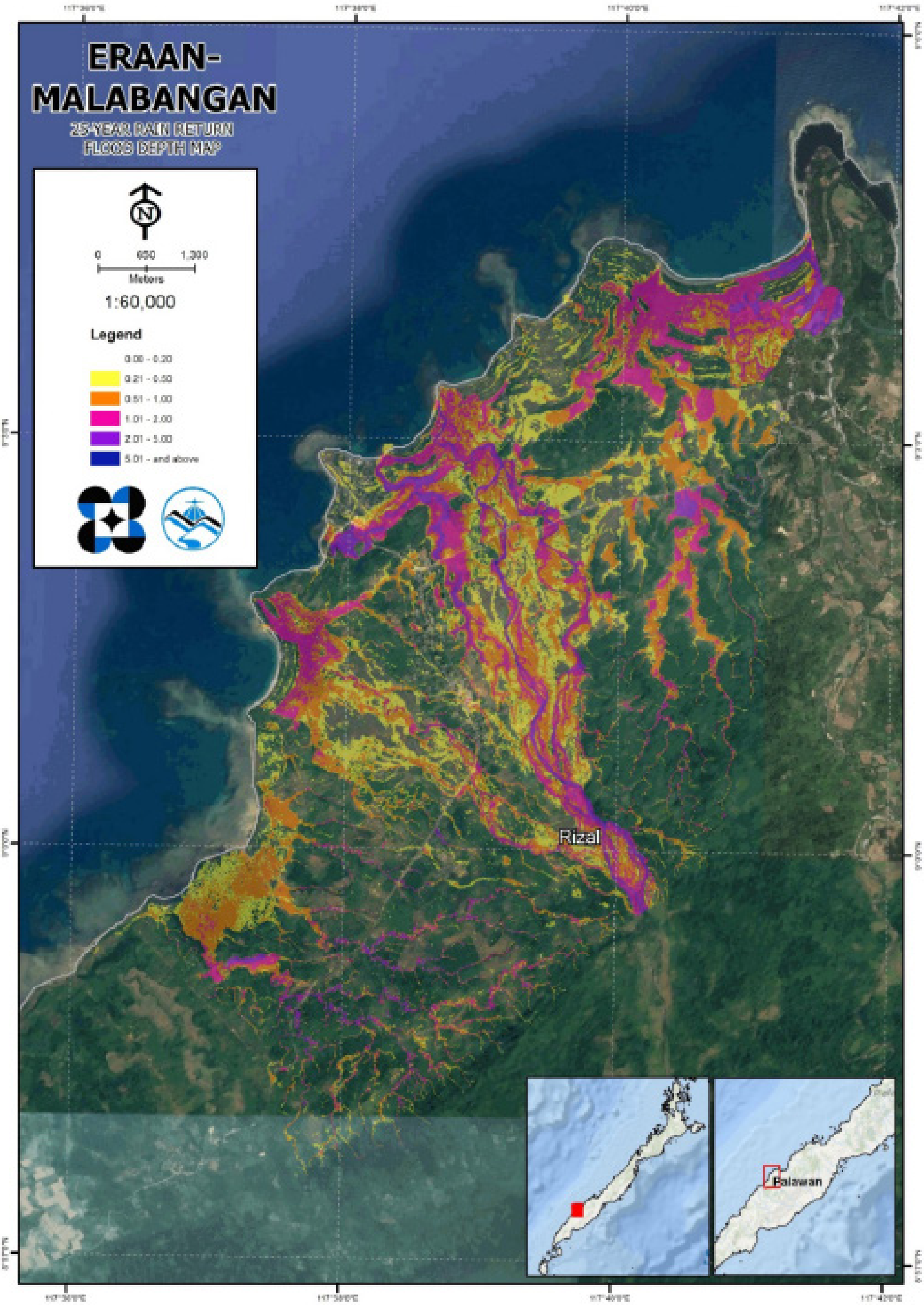


Figure 64. A 25-year Flow Depth Map for Eraan-Malabangan (also known as Iraan-Malambunga) Floodplain

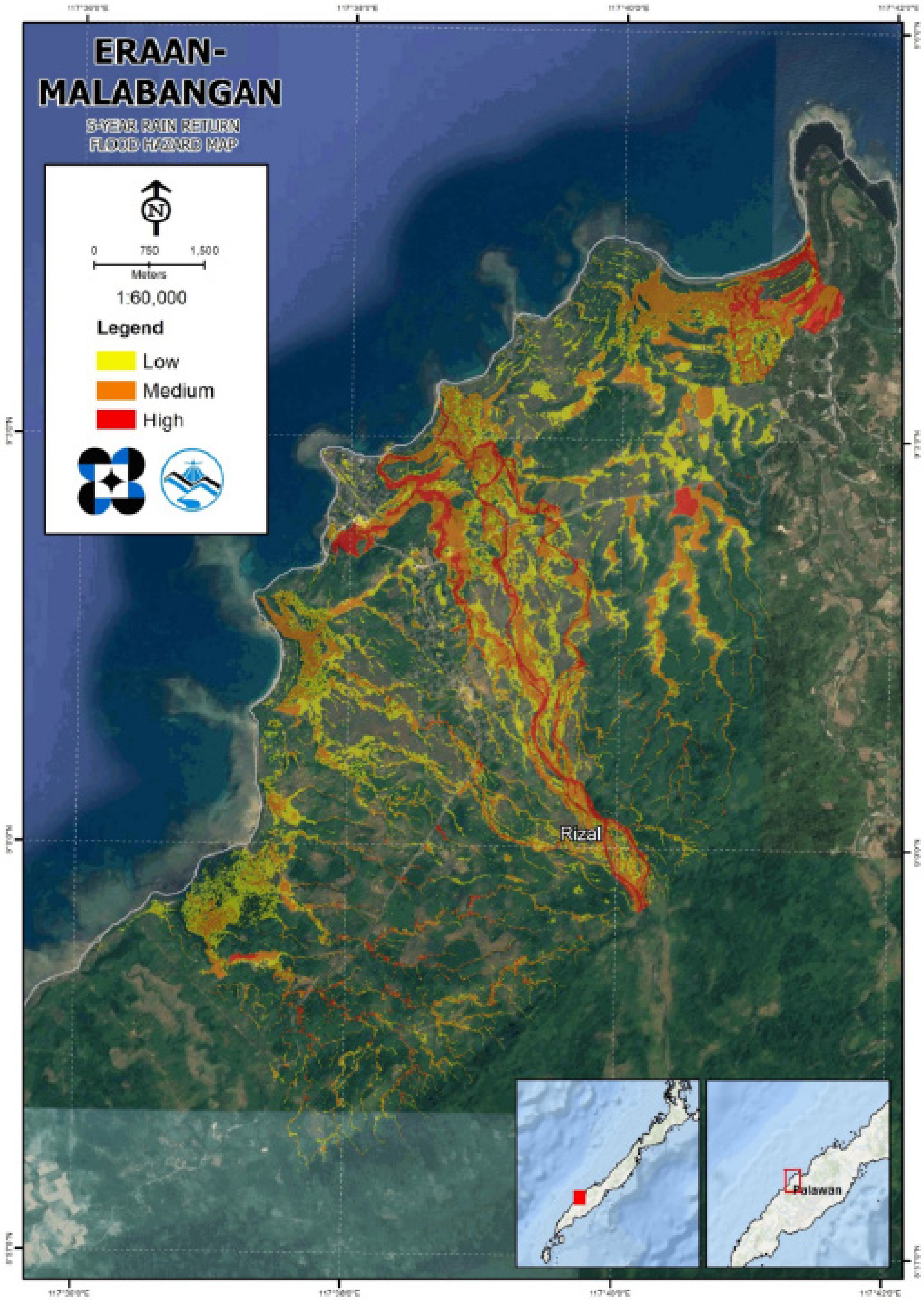


Figure 65. A 5-year Flood Hazard Map for Eraan-Malabangan (also known as Iraan-Malambunga) Floodplain

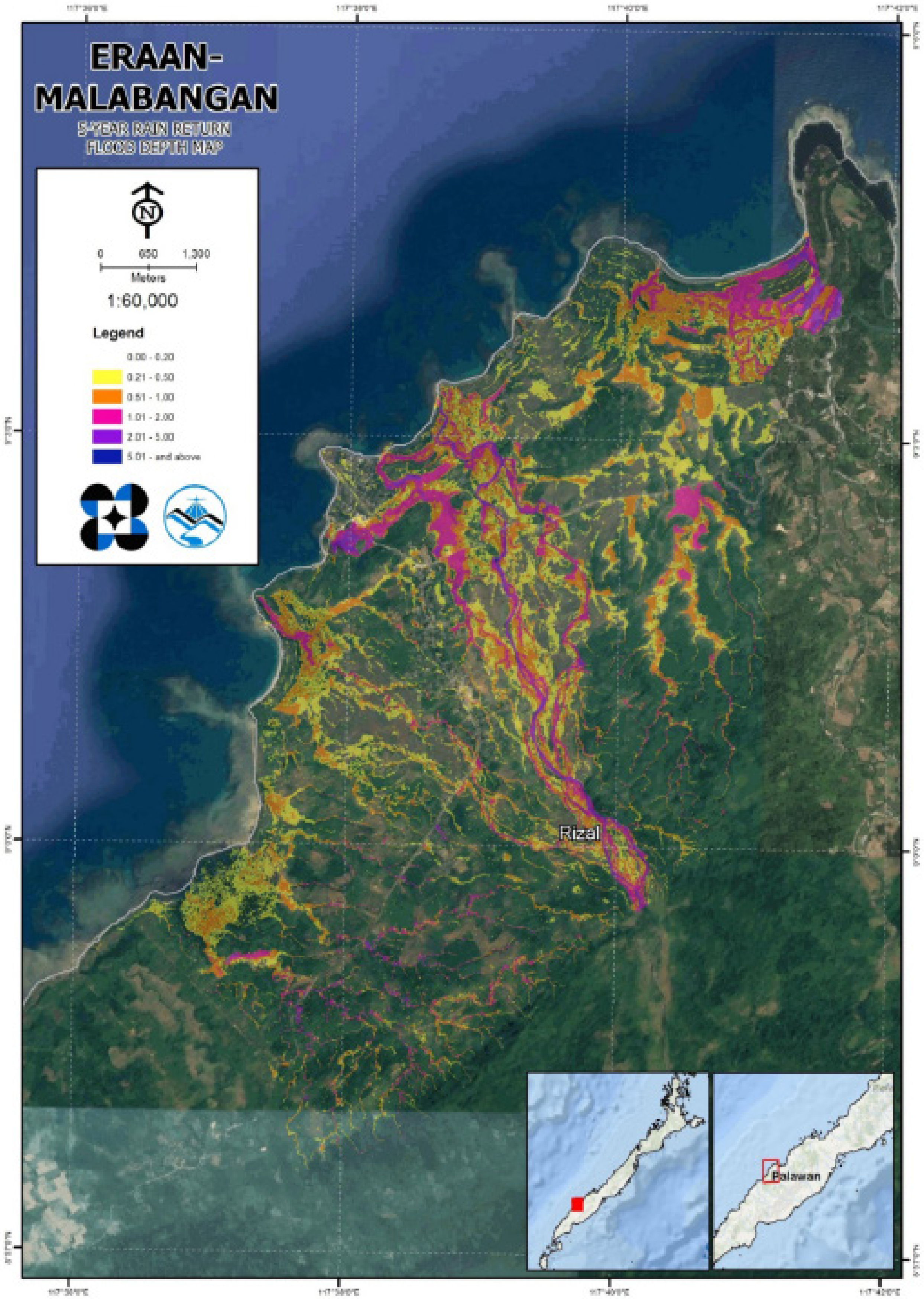


Figure 66. A 5-year Flow depth map for Eraan-Malabangan (also known as Iraan-Malambunga) Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Malambunga river basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 3 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 5.51% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.66%, 1.01%, 0.53%, and 0.00004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 26 are the affected areas in square kilometers by flood depth per barangay.

Table 26. Affected areas in Rizal, Palawan during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)		
	Bunog	Iraan	Punta Baja
0.03-0.20	20.26	25.91	7.87
0.21-0.50	1.09	2.41	0.36
0.51-1.00	1.21	4.85	0.43
1.01-2.00	1.84	7.19	0.91
2.01-5.00	0.44	3.68	1.13
> 5.00	0.0004	0	0

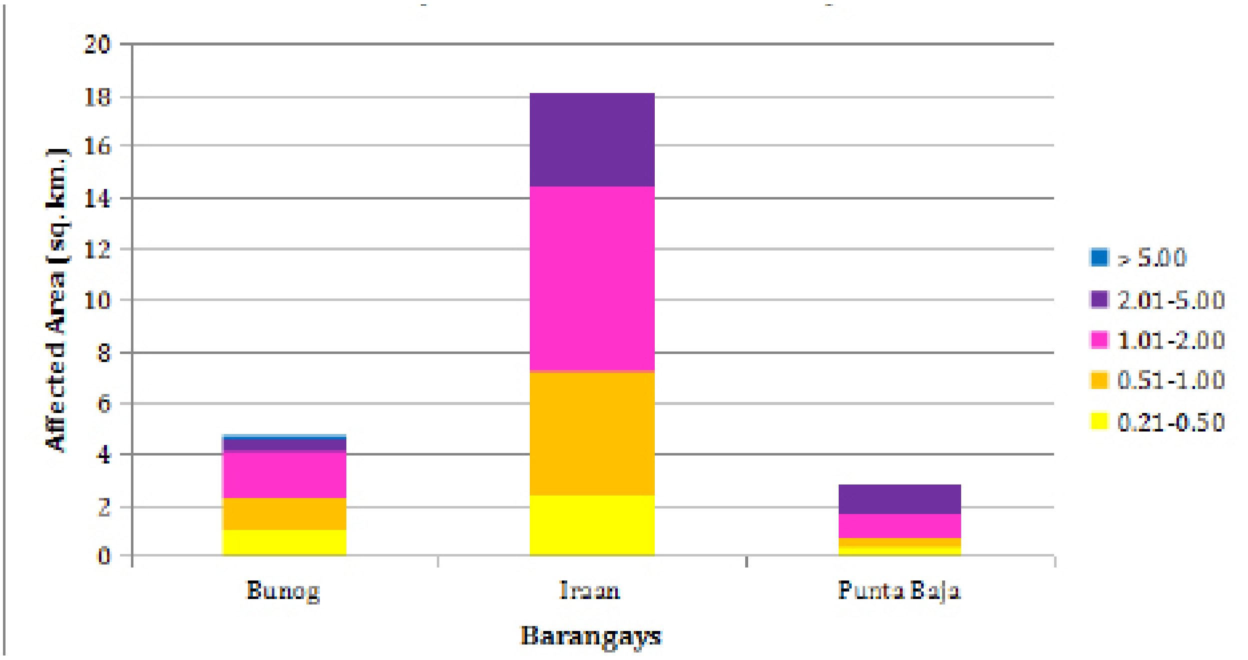


Figure 67. Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period

For the 25-year return period, 5.67% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 0.77%, 0.83%, 0.36%, and 0.008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meter, respectively. Listed in Table 27 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Rizal, Palawan during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Malambunga (in sq. km.)		
	Bunog	Iraan	Punta Baja
0.03-0.20	20.63	26.92	8
0.21-0.50	1.08	3.3	0.38
0.51-1.00	1.31	5.71	0.52
1.01-2.00	1.55	5.7	0.99
2.01-5.00	0.28	2.5	0.82
> 5.00	0.0002	0.079	0.0037

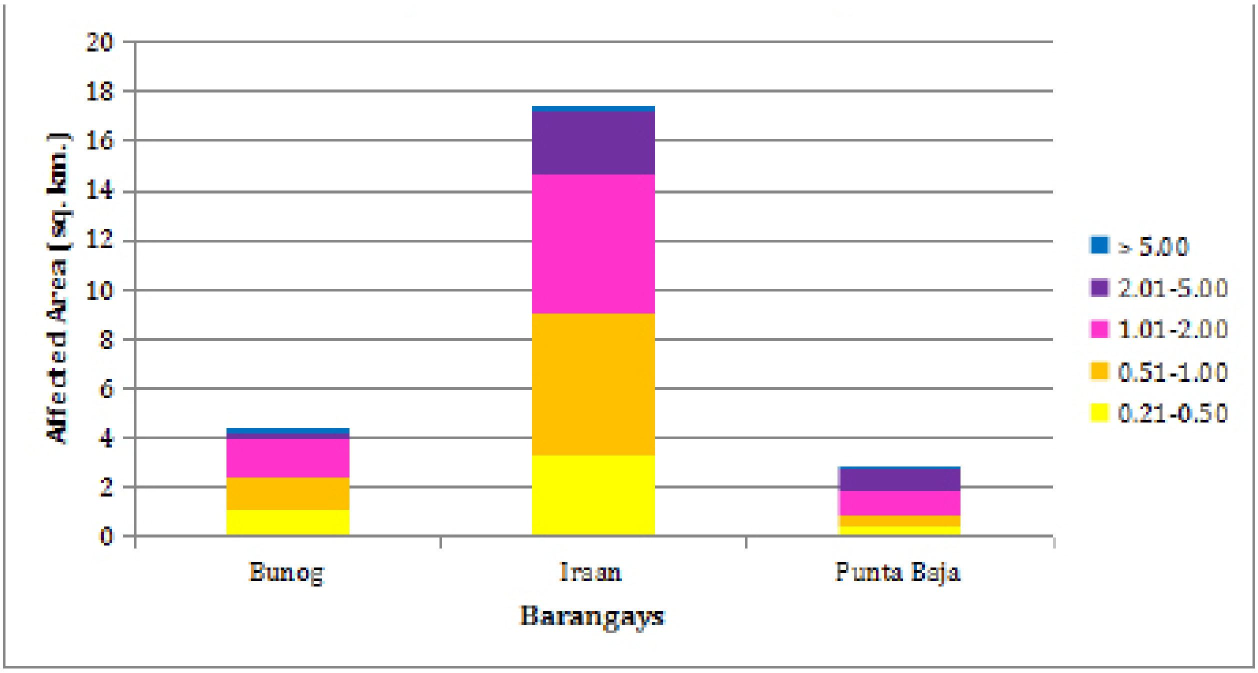


Figure 68. Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period

For the 100-year return period, 5.51% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.67%, 1.01%, 0.53%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 28 are the affected areas in square kilometers by flood depth per barangay.

Table 28. Affected areas in Rizal, Palawan during a 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)		
	Bunog	Iraan	Punta Baja
0.03-0.20	20.26	25.91	7.87
0.21-0.50	1.09	2.41	0.36
0.51-1.00	1.21	4.85	0.43
1.01-2.00	1.84	7.19	0.91
2.01-5.00	0.44	3.68	1.13
> 5.00	0.0004	0.16	0.0086

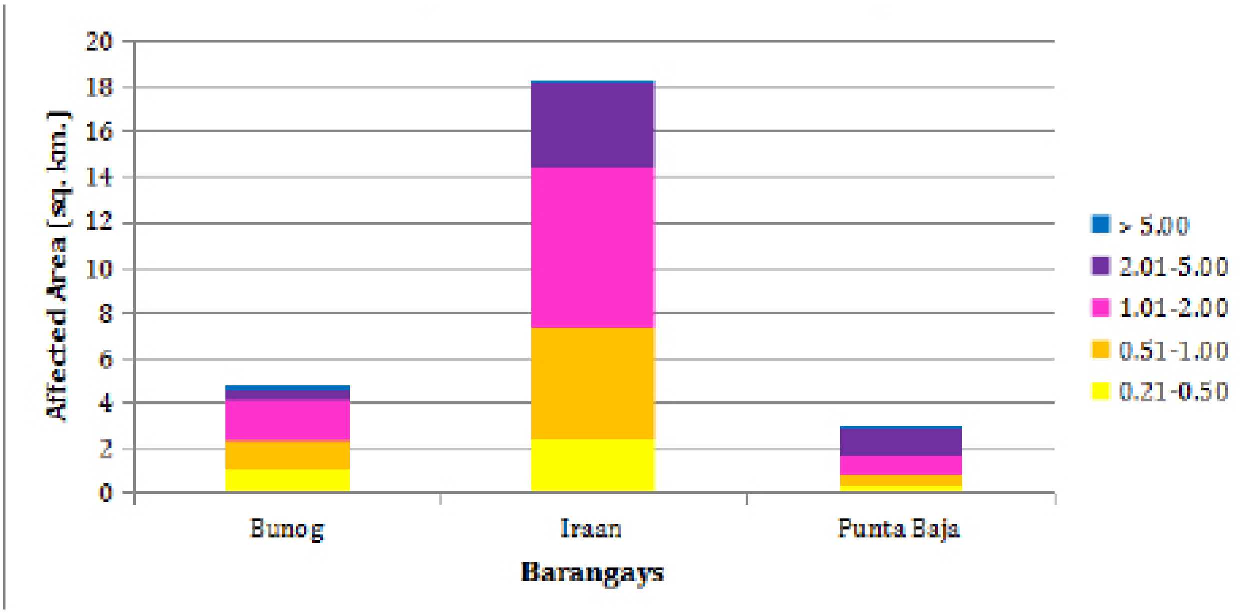


Figure 69. Affected Areas in Rizal, Palawan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Rizal, Iraan is projected to have the highest percentage of area that will experience flood levels at 4.50%. Meanwhile, Bunog posted the second highest percentage of area that may be affected by flood depths at 2.53%.

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 are identified for validation.

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 71.

The flood validation consists of 98 points randomly selected all over the Malambunga Floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.486m. Table 29 shows a contingency matrix of the comparison.

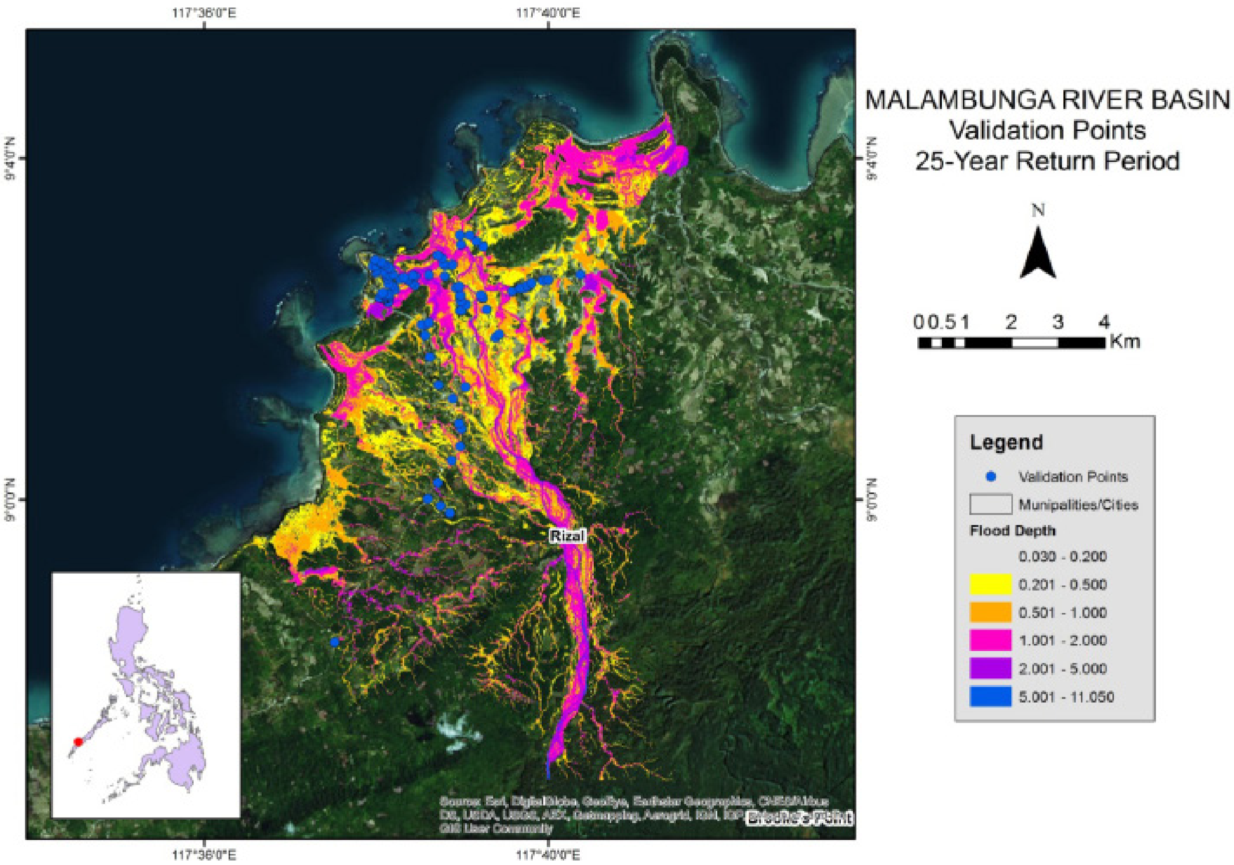


Figure 70. Validation points for 25-year Flood Depth Map of Malambunga Floodplain

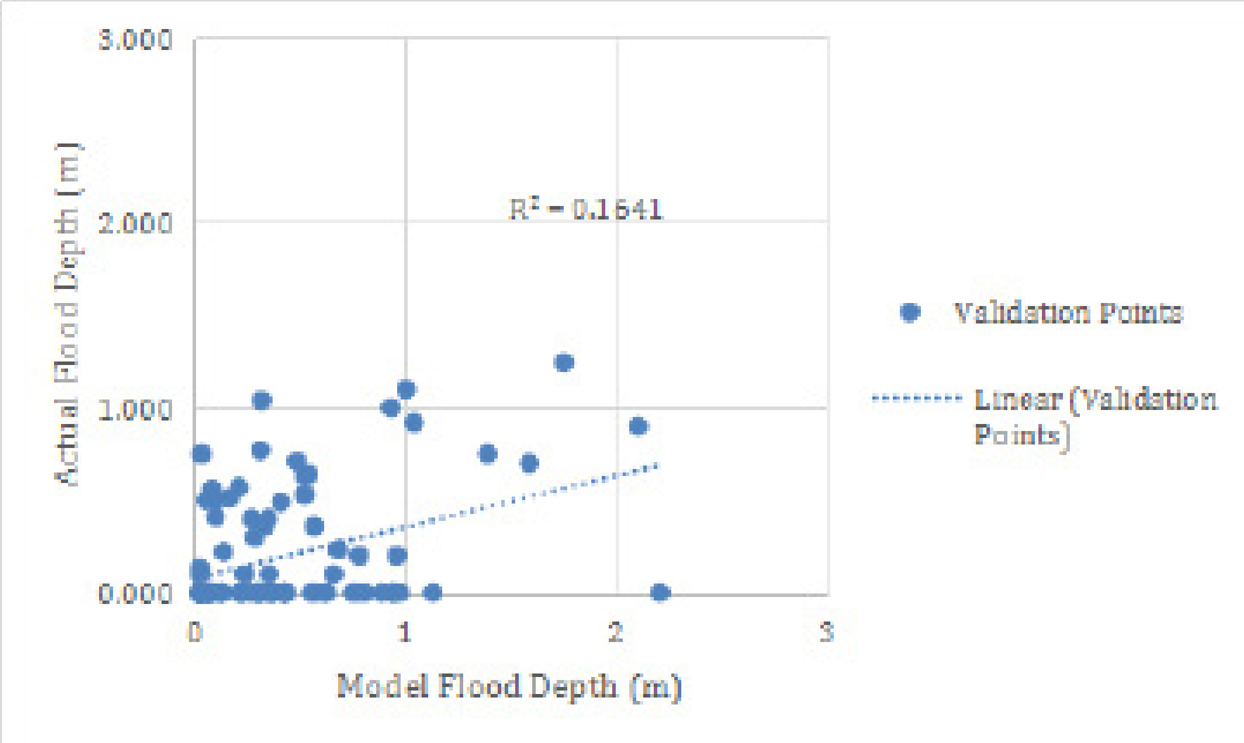


Figure 71. Flood map depth vs. actual flood depth

Table 29. Actual flood vs simulated flood depth at different levels in the Malambunga 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	35	17	15	2	1	0	70
0.21-0.50	4	5	2	0	0	0	11
0.51-1.00	3	3	4	3	1	0	14
1.01-2.00	0	1	0	2	0	0	3
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	42	26	21	7	2	0	98

The overall accuracy generated by the flood model is estimated at 46.94% with 46 points correctly matching the actual flood depths. In addition, there were 26 points estimated one level above and below the correct flood depths while there were 20 points and 3 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 11 points were underestimated in the modelled flood depths of Malambunga. Table 30 depicts the summary of the Accuracy Assessment in the Malambunga River Basin Survey.

Table 30. The summary of the Accuracy Assessment in the Malambunga River Basin Survey

	No. of Points	%
Correct	46	46.94
Overestimated	41	41.84
Underestimated	11	11.22
Total	98	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specification of the Pegasus Sensor

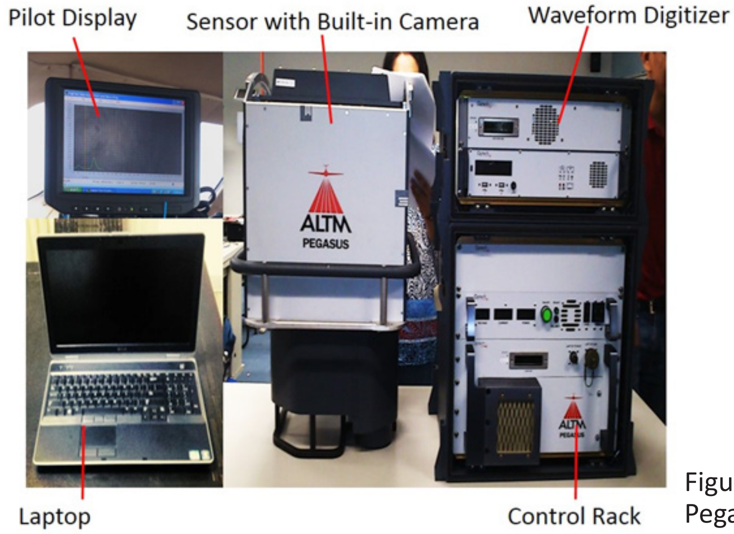


Figure A-1.1 The Pegasus sensor

Table A-1.1 Technical parameters and specifications of the Pegasus sensor

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

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 Certificates of Reference Points Used

1. PLW-121

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

July 21, 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-121**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **CAMPONG ULAY**	
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **8° 56' 1.71426"**	Longitude: **117° 34' 23.99157"**	Ellipsoidal Hgt: **8.98036 m.**
	WGS84 Coordinates	
Latitude: **8° 55' 57.38325"**	Longitude: **117° 34' 29.39124"**	Ellipsoidal Hgt: **58.05800 m.**
	PTM / PRS92 Coordinates	
Northing: **987945.887 m.**	Easting: **398086.54 m.**	Zone: **1A**
	UTM / PRS92 Coordinates	
Northing: **987,521.12**	Easting: **563,030.26**	Zone: **50**

Location Description

PLW-121
From poblacion Rizal travel S towards Brgy. Campong Ulay approximately 16 kms. up to Cabkungan Elem. School. Station is located in an open lot inside the school SW edge of the basketball court. Mark is the head of 4" copper nail flushed in a cement putty 30cm x 30cm x 120cm embedded 1m on the ground with inscriptions "PLW-121 2007 NAMRIA."

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8086767 I**
T.N.: **2015-1696**

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

9907212015170528

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-121

Annex 3. Baseline Processing Reports

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\PLW121-BLLM1.vce	Name:	UTM
		Datum:	PRS 92
Size:	189 KB	Zone:	50 North (117E)
Modified:	8/5/2015 5:59:19 PM (UTC:8)	Geoid:	EGMPH
Time zone:	Taipei Standard Time	Vertical datum:	
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PLW 121 --- BLLM1A (B2)	PLW 121	BLLM1A	Fixed	0.004	0.010	33°32'53"	13490.902	-11.050
PLW 121 --- BLLM1B (B1)	PLW 121	BLLM1B	Fixed	0.004	0.011	33°32'53"	13490.909	-11.052

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

PLW 121 - BLLM1A (7:49:14 AM-1:25:04 PM) (S2)

Baseline observation:	PLW 121 --- BLLM1A (B2)
Processed:	8/5/2015 6:01:20 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.010 m
RMS:	0.009 m
Maximum PDOP:	1.767
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	7/11/2015 7:49:34 AM (Local: UTC+8hr)
Processing stop time:	7/11/2015 1:25:04 PM (Local: UTC+8hr)
Processing duration:	05:35:30
Processing interval:	5 seconds

1

Figure A-3.1 Baseline Processing Report - A

Vector Components (Mark to Mark)

From:	PLW 121				
Grid		Local		Global	
Easting	563030.260 m	Latitude	N8°56'01.71425"	Latitude	N8°55'57.38325"
Northing	987521.114 m	Longitude	E117°34'23.99161"	Longitude	E117°34'29.39124"
Elevation	10.335 m	Height	8.980 m	Height	58.058 m

To:	BLLM1A				
Grid		Local		Global	
Easting	570465.682 m	Latitude	N9°02'07.68639"	Latitude	N9°02'03.33580"
Northing	998772.489 m	Longitude	E117°38'28.10618"	Longitude	E117°38'33.49665"
Elevation	-0.716 m	Height	-2.070 m	Height	46.965 m

Vector					
ΔEasting	7435.421 m	NS Fwd Azimuth	33°32'53"	ΔX	-5788.617 m
ΔNorthing	11251.375 m	Ellipsoid Dist.	13490.902 m	ΔY	-5020.895 m
ΔElevation	-11.052 m	ΔHeight	-11.050 m	ΔZ	11103.460 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	0.005 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000061683		
Y	-0.0000089563	0.0000212884	
Z	-0.0000018603	0.0000039102	0.0000013613

2

Figure A-3.2 Baseline Processing Report - B

Annex 4. The LiDAR Survey Team Composition

Table A-3.1 LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Associate (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ARIES TORNO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JUSTINE JOYA	AAC

Annex 5. Data Transfer Sheets for Malambunga Floodplain Flights

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

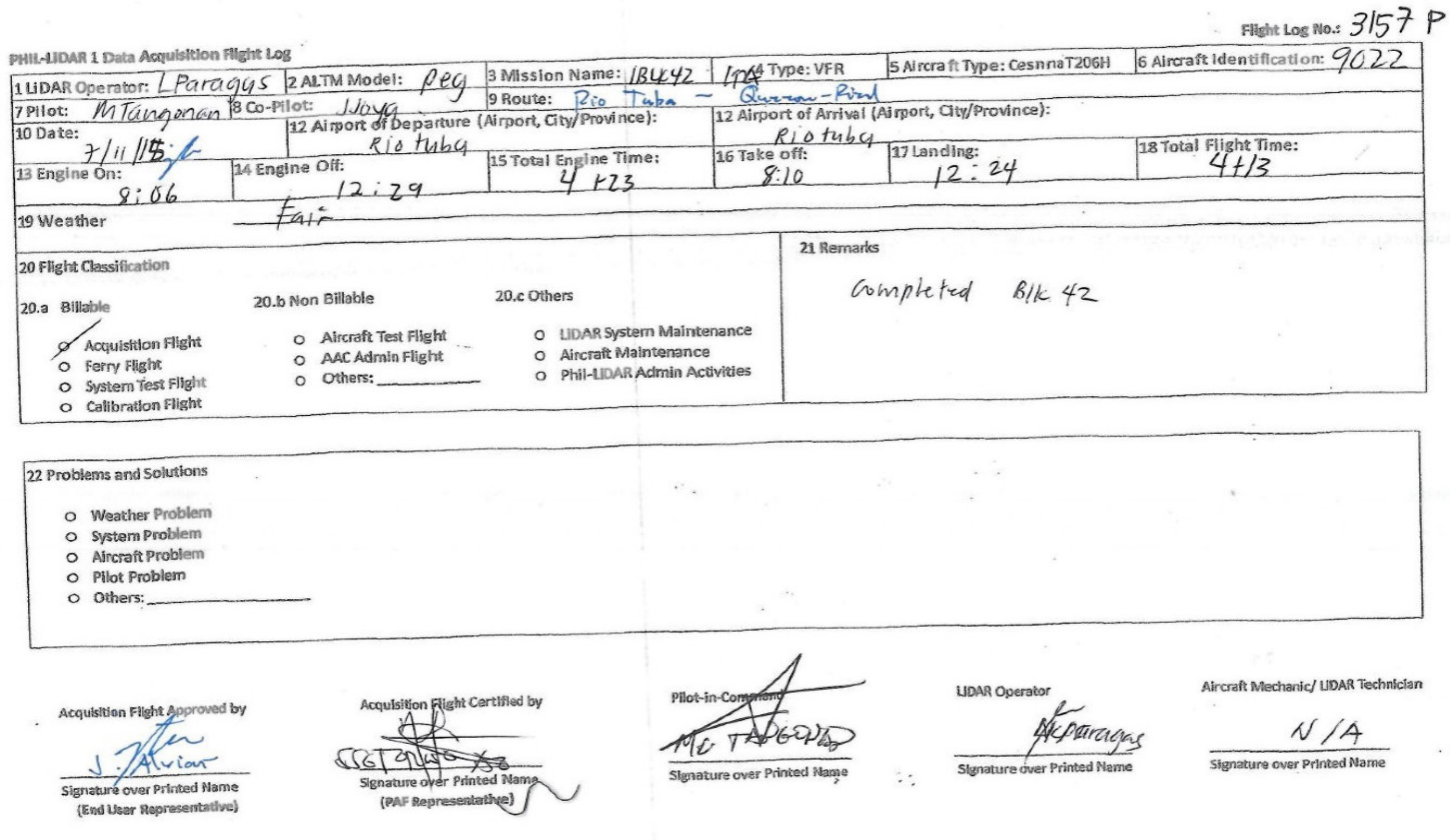
Received from
Name [signature]
Position FA
Signature [signature]

Received by
Name AC Bongat
Position SSRS
Signature [signature] 8/5/2015

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 3157P Mission



Flight Log No.: 3157 P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: L Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK42	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Joya	9 Route: Rio Tuba – Quezon - Rizal			
10 Date: 7/11/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 8:06	14 Engine Off: 12:29	15 Total Engine Time: 4+23	16 Take off: 8:10	17 Landing: 12:24	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 Blk 42

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

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

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

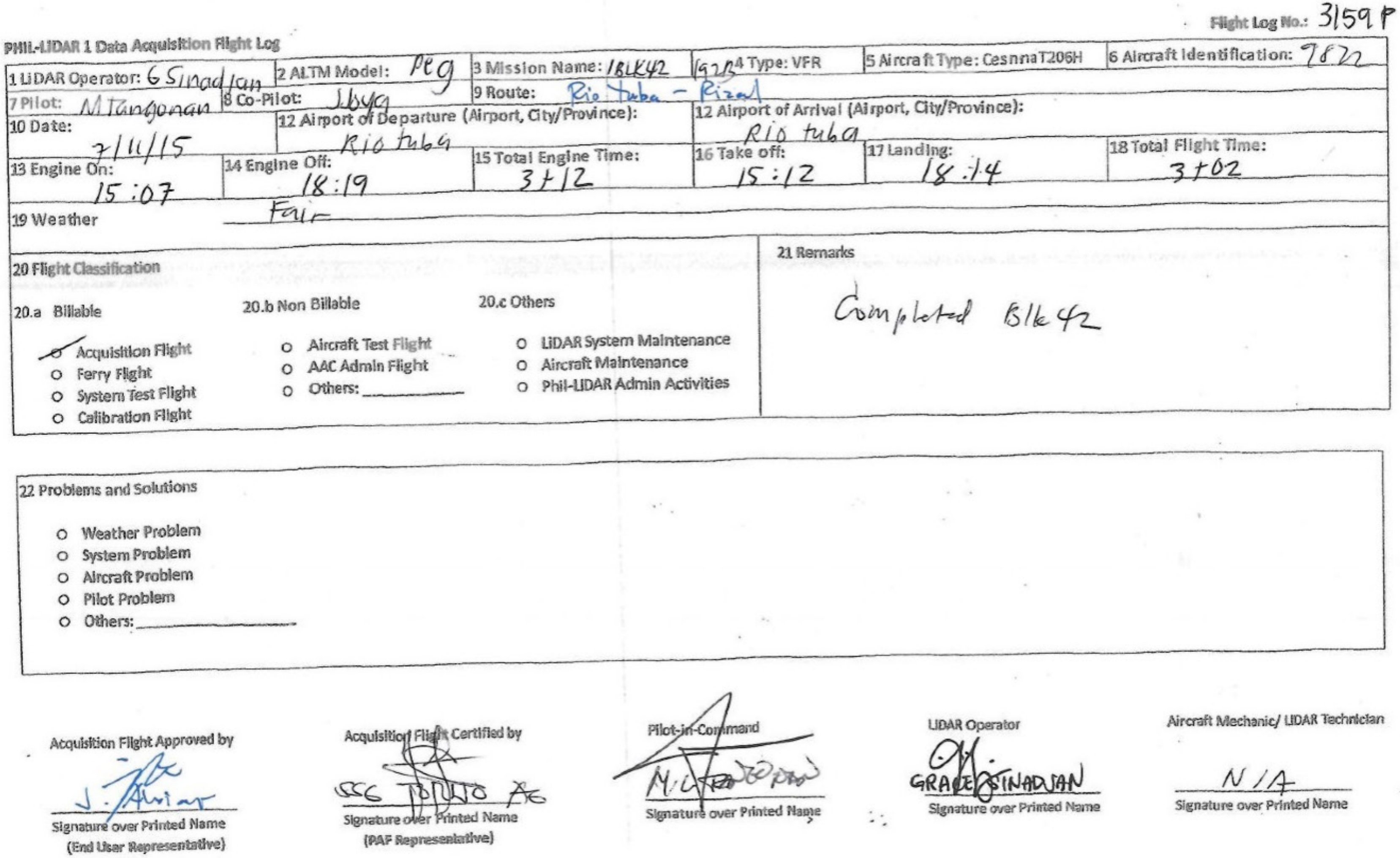
Pilot-in-Command: M. Tangonan — Signature over Printed Name

LIDAR Operator: L Paragas — Signature over Printed Name

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

Figure 6.1 Flight Log for Mission 3157P

2. Flight Log for 3159P Mission


Flight Log No.: 3159P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9822
7 Pilot: M Tangonan	8 Co-Pilot: Ibyg	9 Route: Rio Tuba - Rizal			
10 Date: 7/11/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 15:07	14 Engine Off: 18:19	15 Total Engine Time: 3+12	16 Take off: 15:12	17 Landing: 18:14	18 Total Flight Time: 3+02
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

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

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

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

Pilot-in-Command: M. [illegible] — Signature over Printed Name

LiDAR Operator: GRACE SINADJAN — Signature over Printed Name

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

Figure 6.2 Flight Log for Mission 3159P

Annex 7. Flight Status Reports

IRAAN-MALAMBUNGA FLOODPLAIN

(July 11-13, 2015)

Table 7.1 Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3157P	BLK 42P, PS, N, M	1BLK42PO192A	L. Paragas	July 11, 2015	Surveyed BLK 42P, PS, N, and parts of M
3159P	BLK 42O, N, P	1BLK42PO192B	G. Sinadjan	July 11, 2015	Surveyed BLK 42O, N, and gaps in BLK 42P

Flight No:	3157P
Mission Name:	1blk42po192a
Area:	BLOCK 42P, 42PS, 42N & 42M
Parameters:	Altitude: 1200 PRF: 200
	Scan Angle: 50 Overlap: 30

SWATH

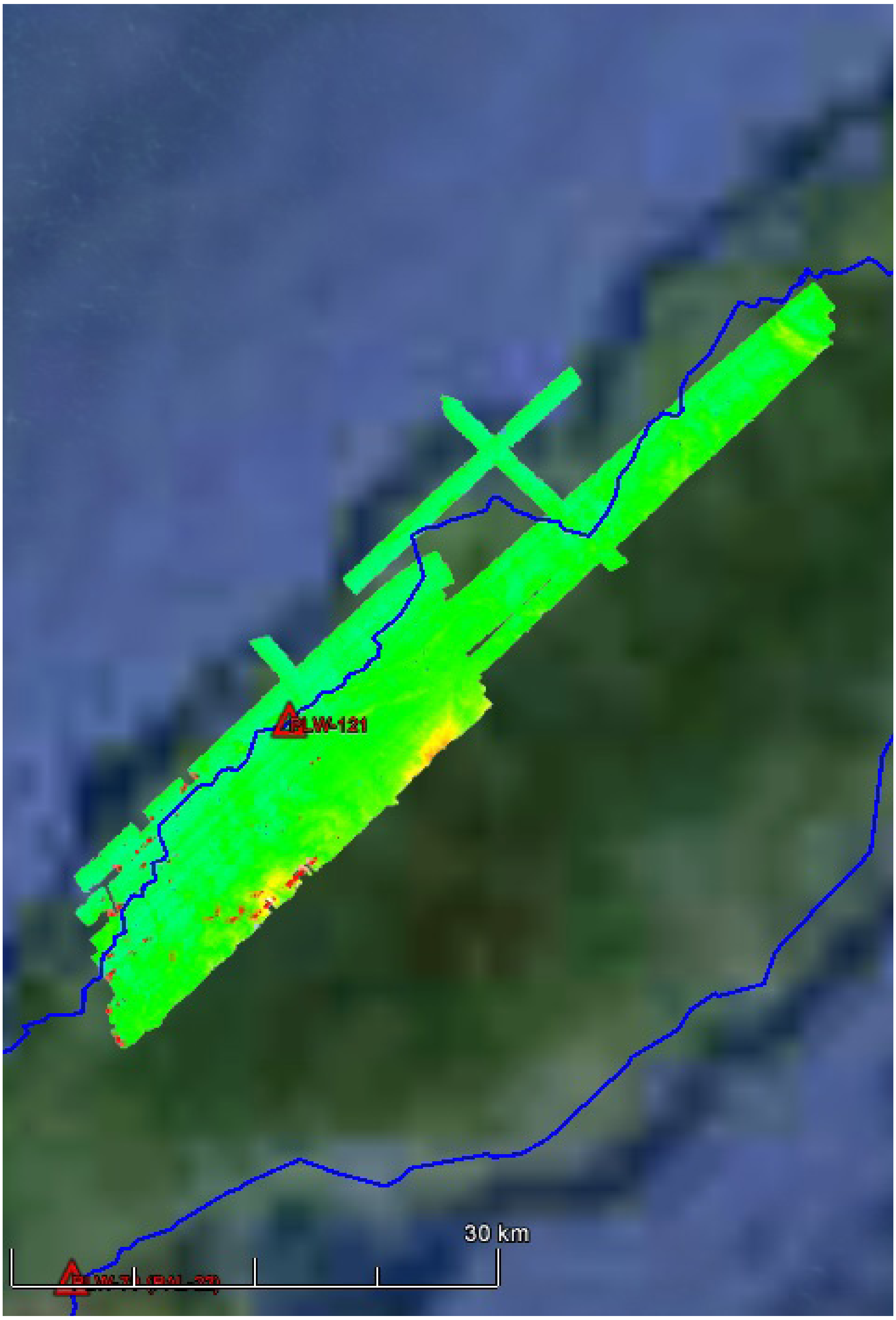


Figure 7.1 Swath for Flight No. 3157P

Flight No:	3157P	
Mission Name:	1BLK42PO192B	
Area:	BLOCK 42ONP	
Parameters:	Altitude: 1200	PRF: 200
	Scan Angle: 50	Overlap: 30

SWATH

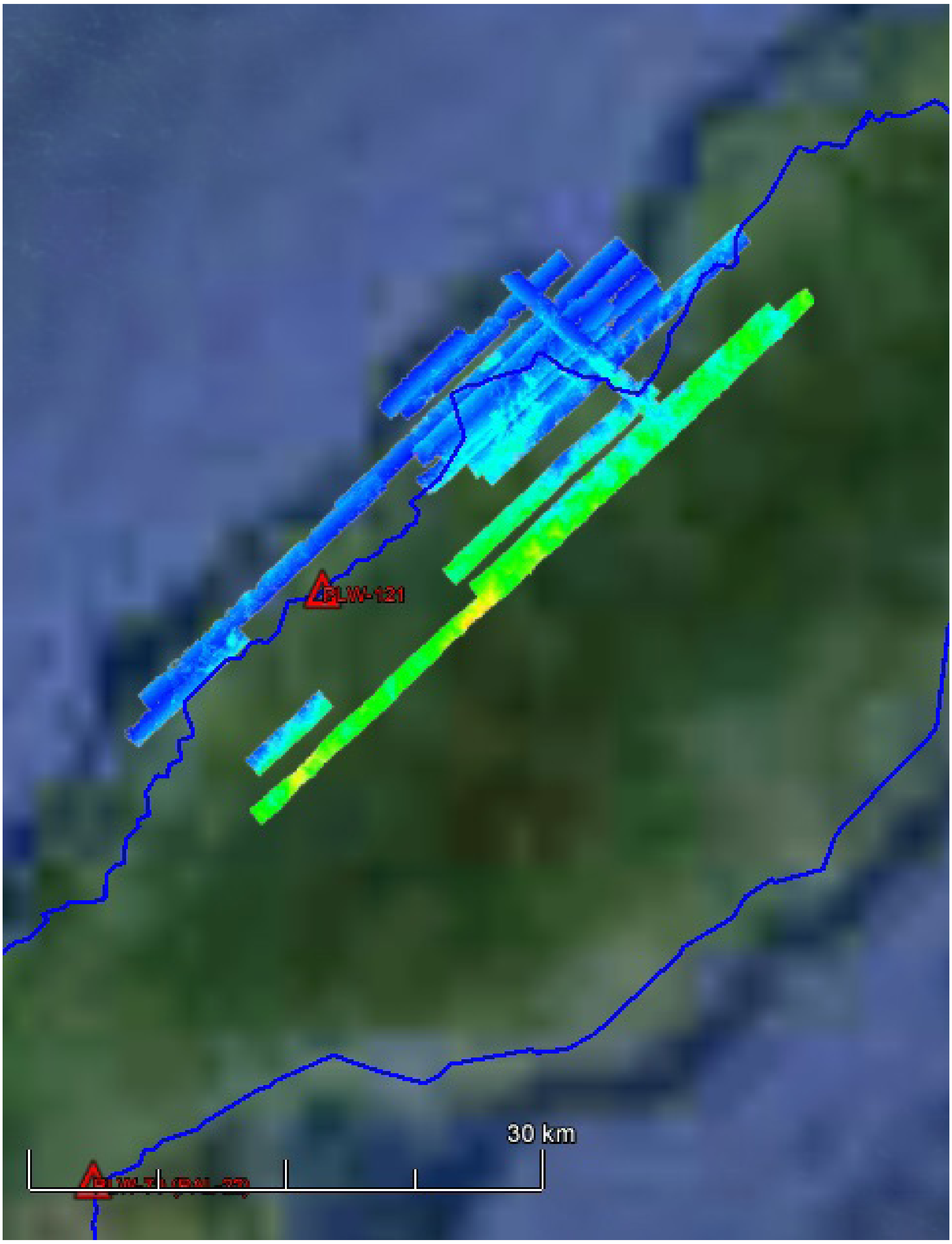


Figure 7.1 Swath for Flight No. 3157P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Block 42N

Flight Area	West Palawan
Mission Name	**Block 42N**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
POS	478MB
Image	90.70 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)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	18.19
Ave point cloud density per sq.m. (>2.0)	2.43
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	251
Maximum Height	658.32
Minimum Height	42.09
Classification (# of points)	
Ground	83015160
Low vegetation	50176090
Medium vegetation	153087772
High vegetation	599974416
Building	9903936
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. JovelleAnjeanette Canlas, Engr. Elainne Lopez

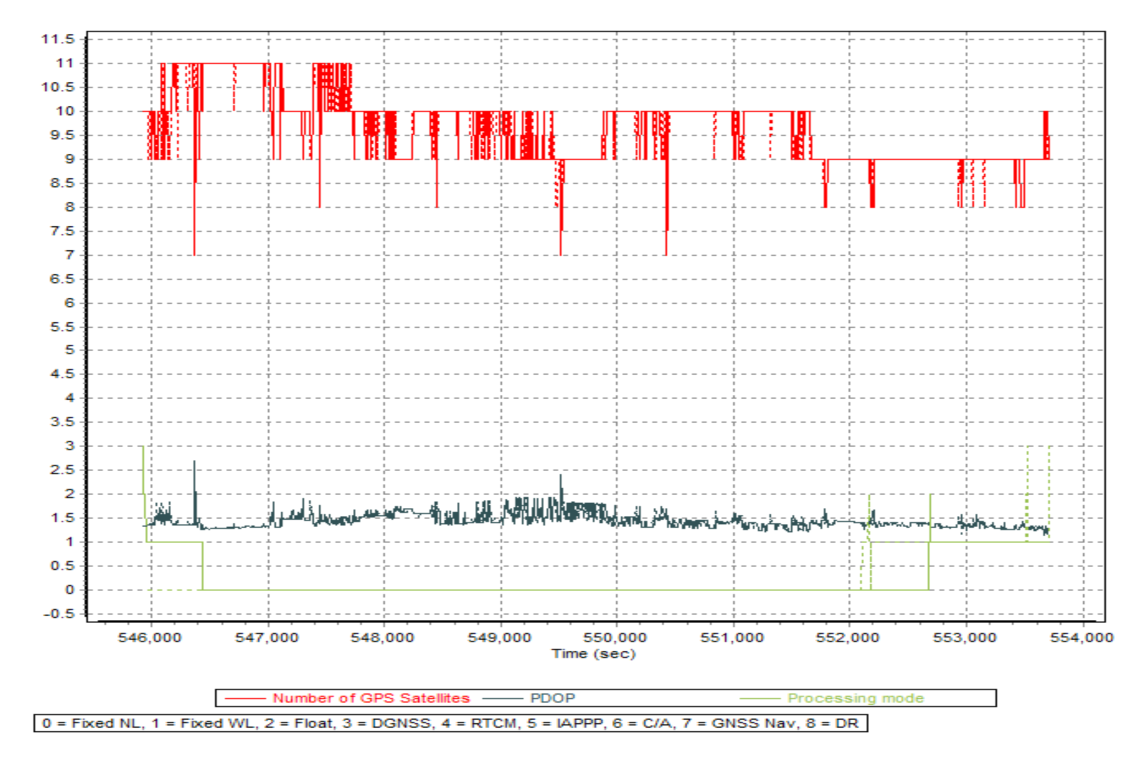


Figure A-8.1 Solution Status

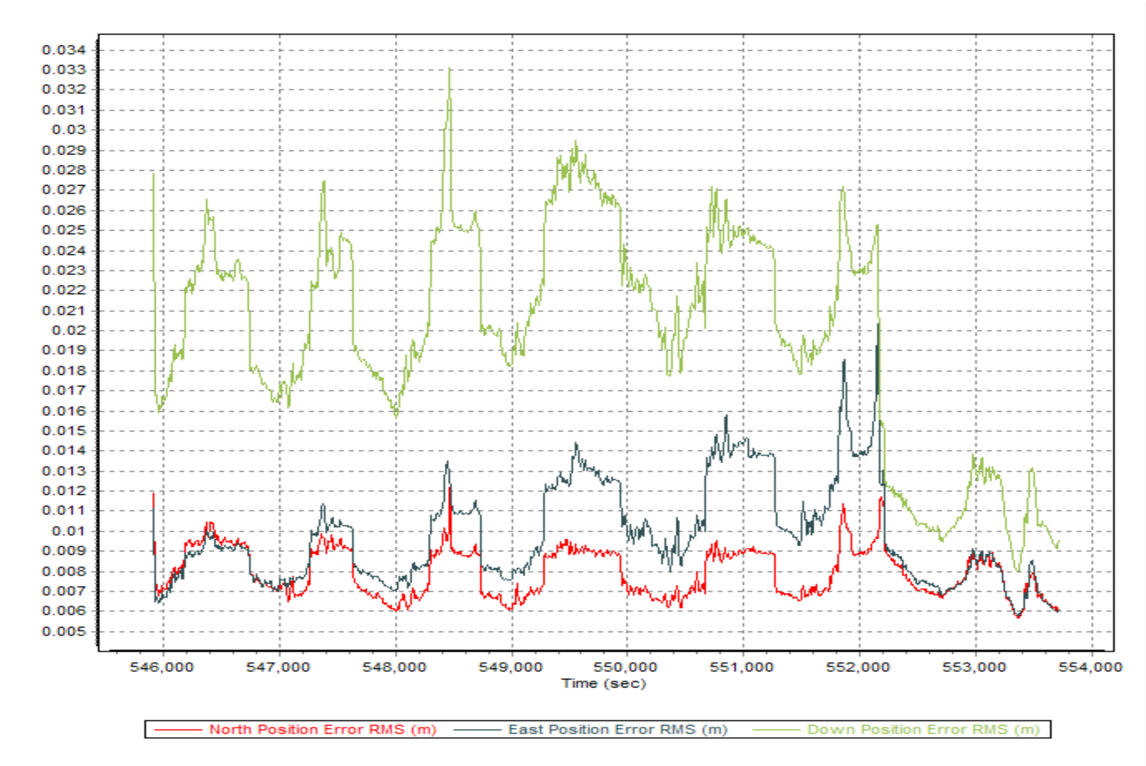


Figure A-8.2 Smoothed Performance Metric Parameters

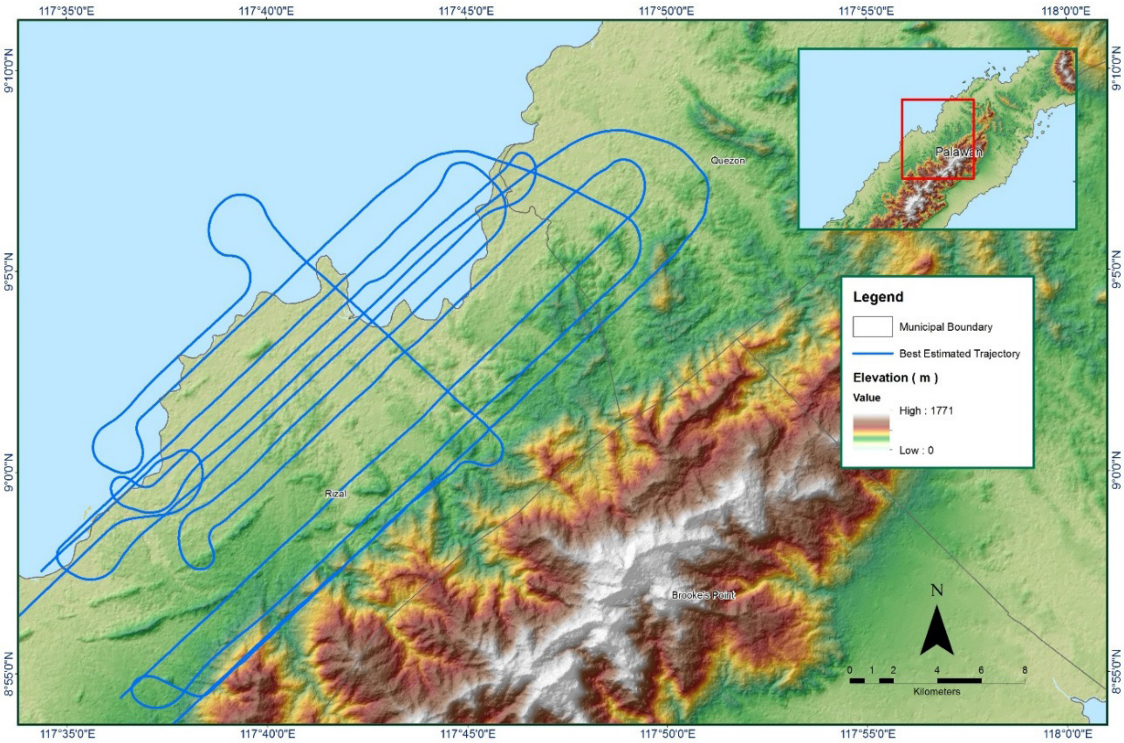


Figure A-8.3 *Best Estimated Trajectory*

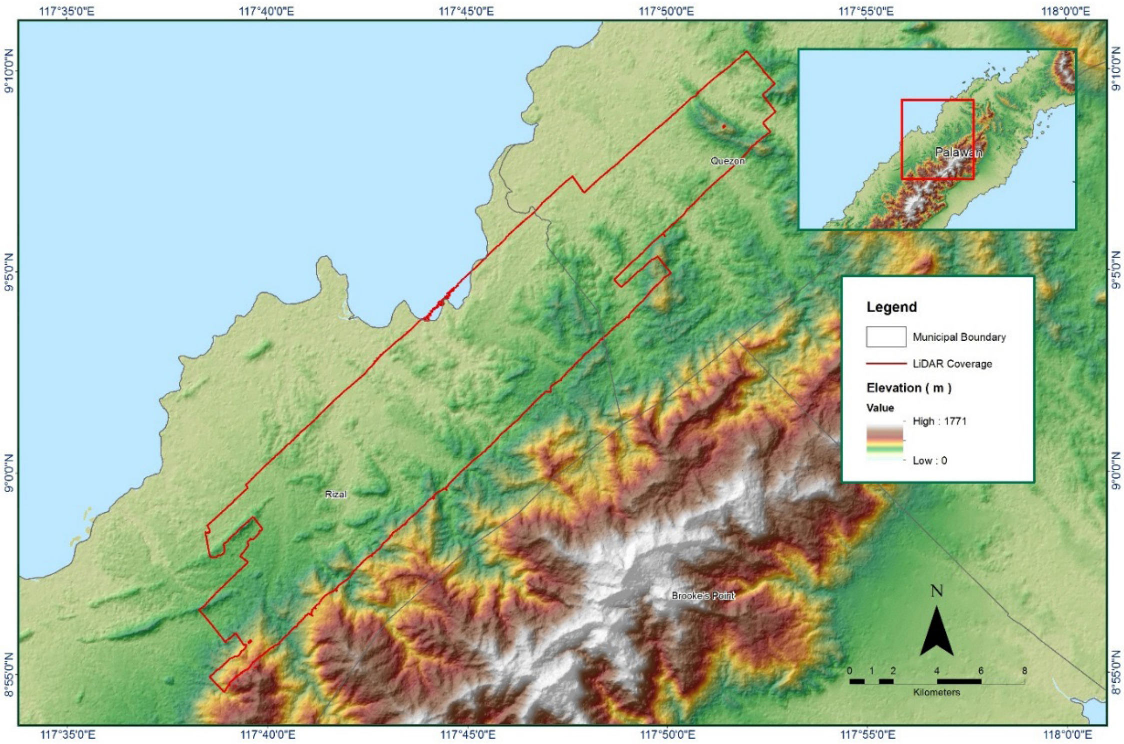


Figure A-8.4 Coverage of LiDAR data

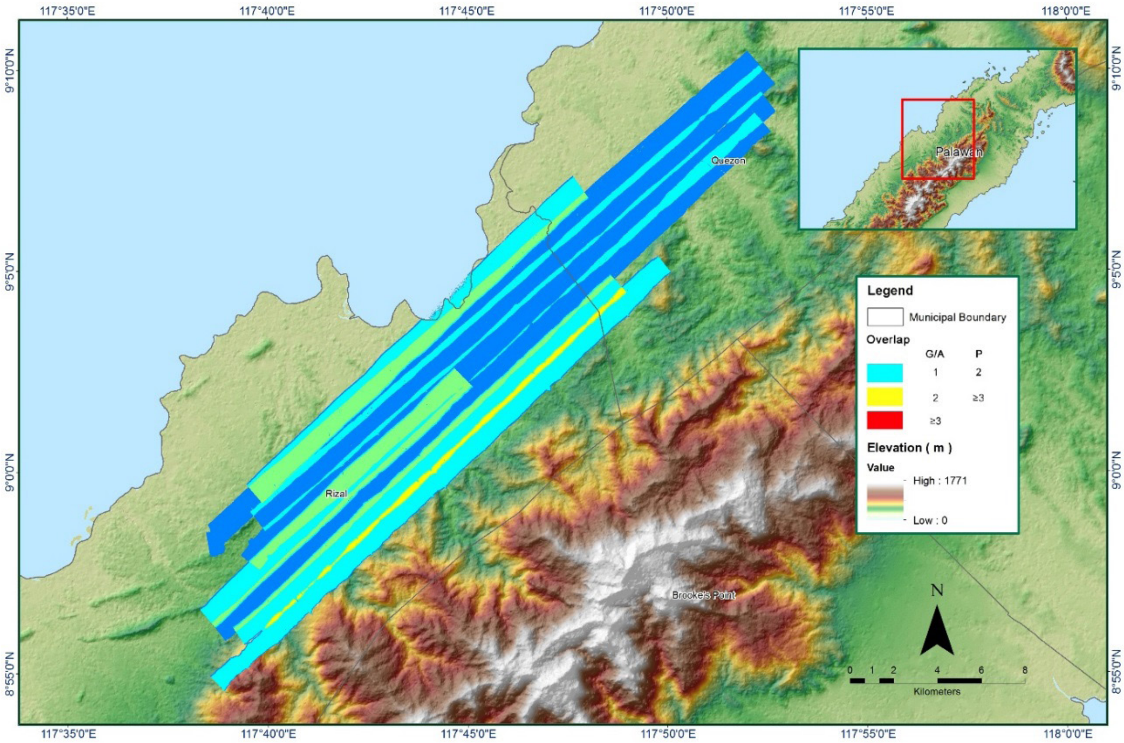


Figure A-8.5 Image of data overlap

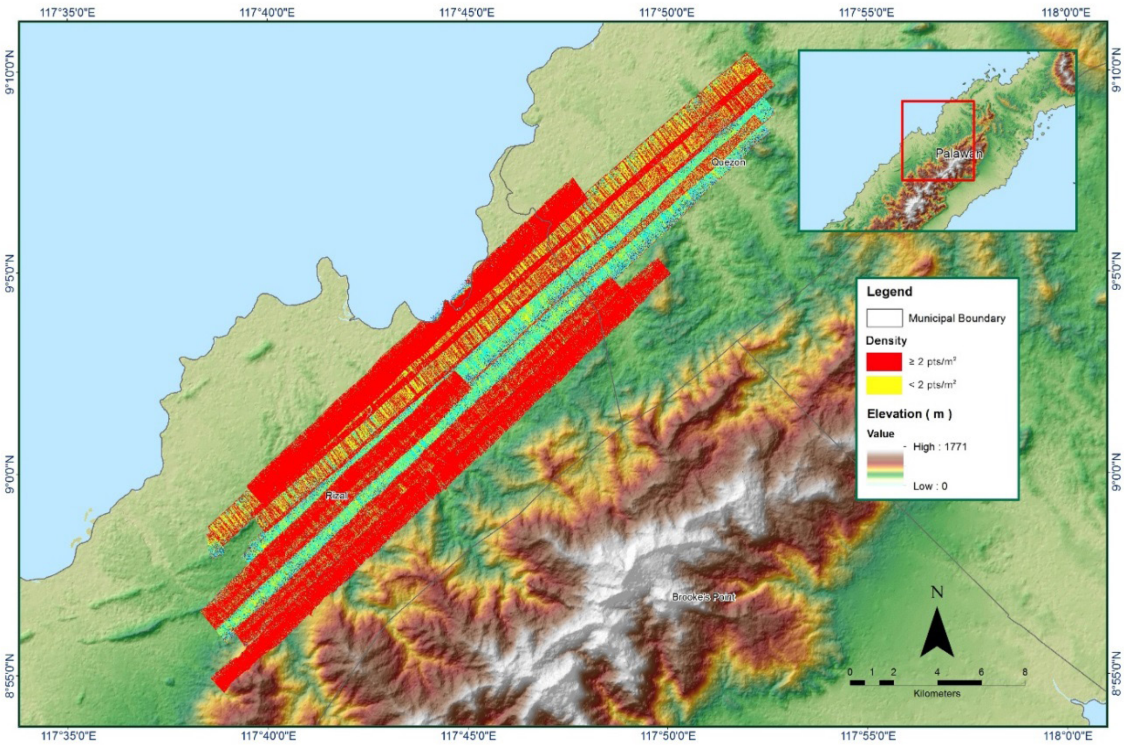


Figure A-8.6 *Density map of merged LiDAR data*

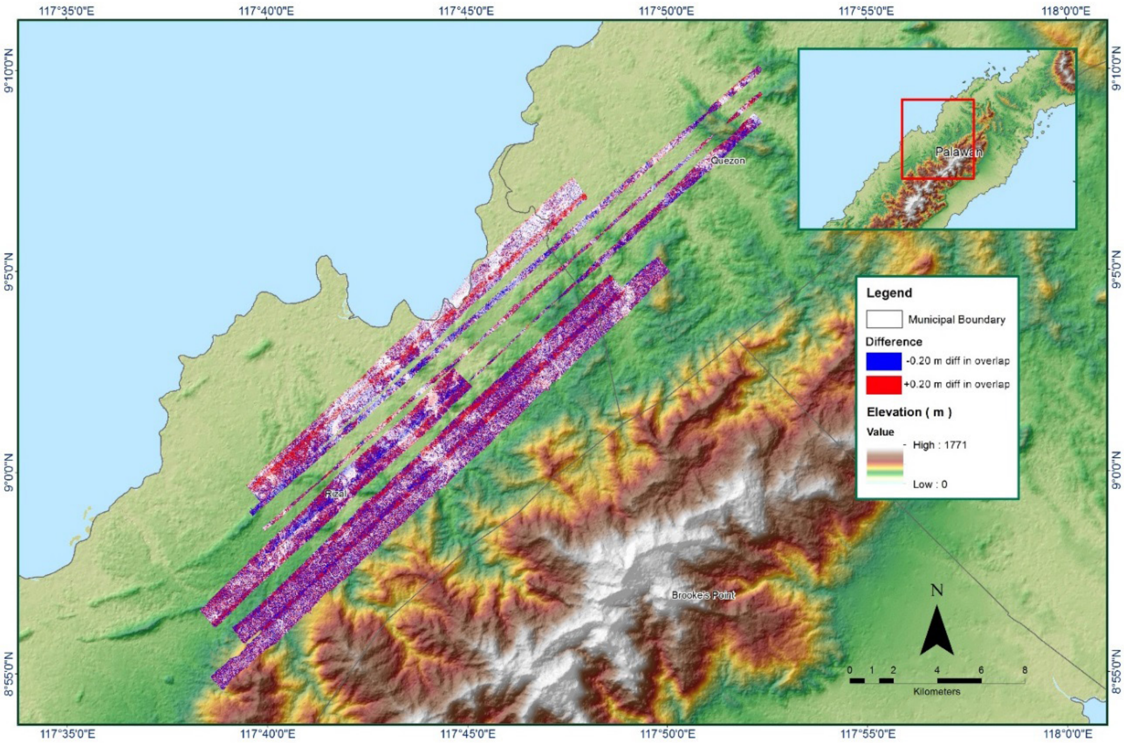


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Block 42O

Flight Area	**West Palawan**
Mission Name	**Block 42O**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
POS	478 MB
Image	90.70 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)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	21.33
Ave point cloud density per sq.m. (>2.0)	1.96
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	160
Maximum Height	178.72
Minimum Height	40.13
Classification (# of points)	
Ground	112805844
Low vegetation	95911890
Medium vegetation	80712706
High vegetation	142125592
Building	4713926
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Alex John Escobido

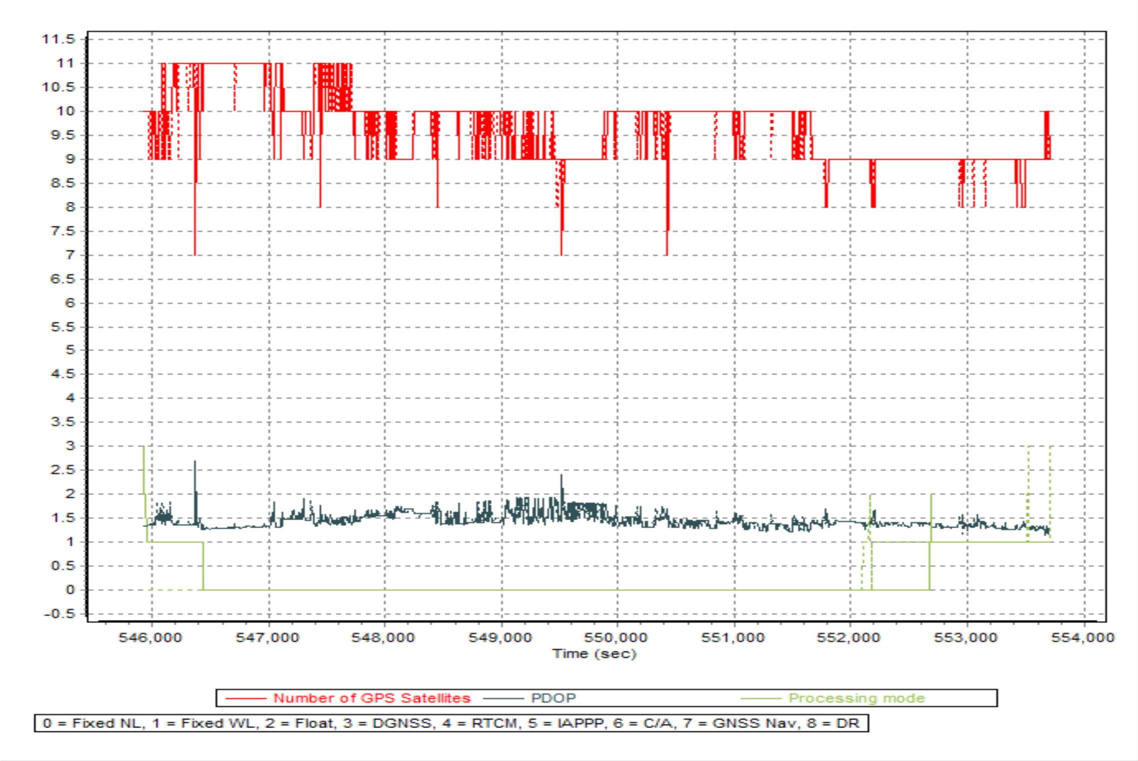


Figure A-8.8 Solution Status

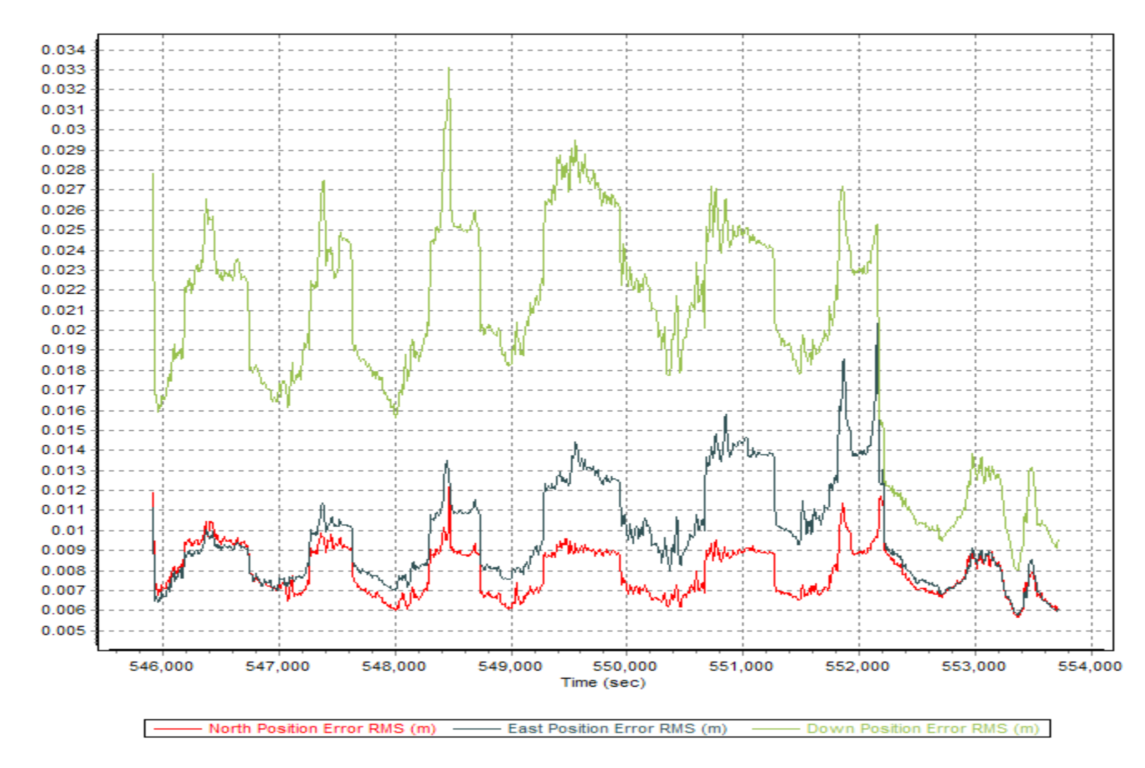


Figure A-8.9 Smoothed Performance Metric Parameters

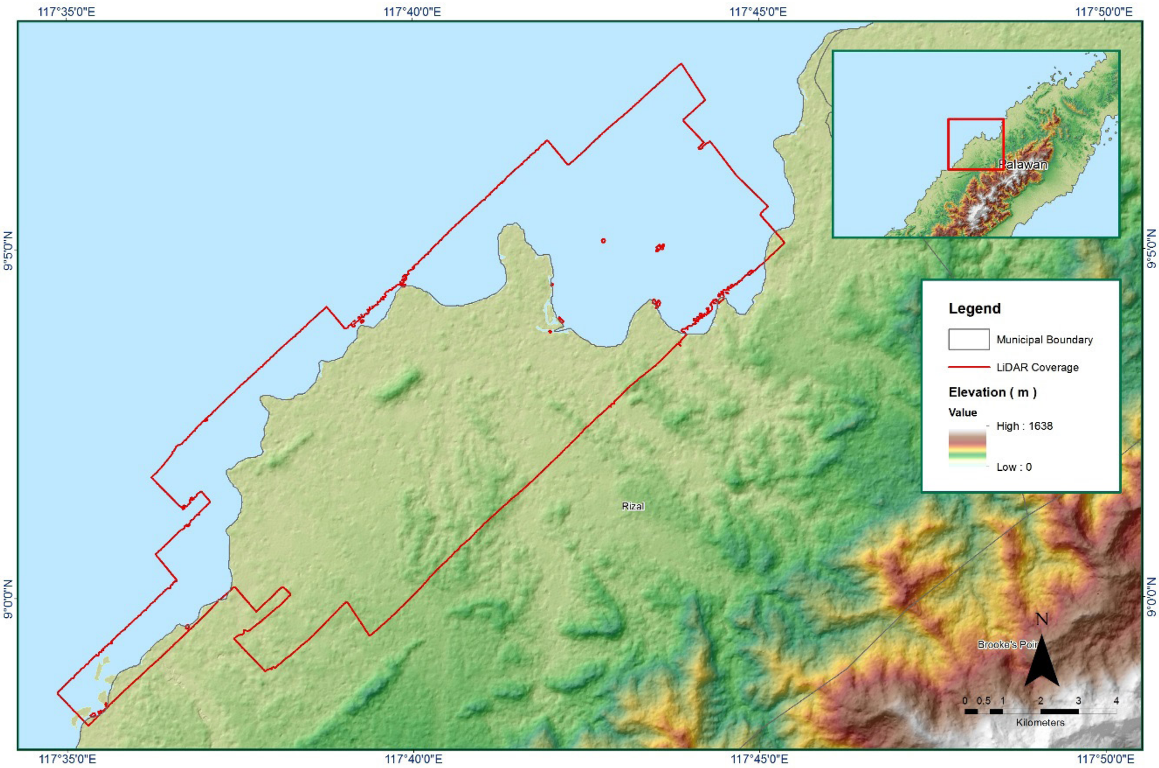


Figure A-8.10 Best Estimated Trajectory

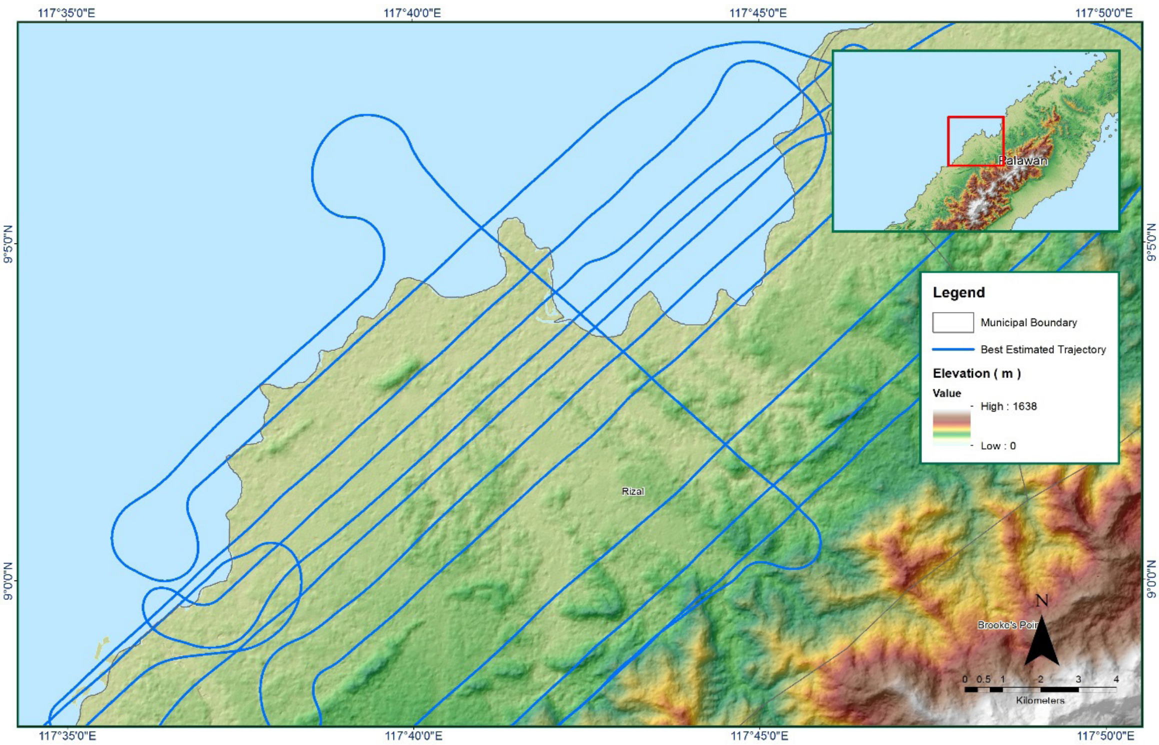


Figure A-8.11 Coverage of LiDAR data

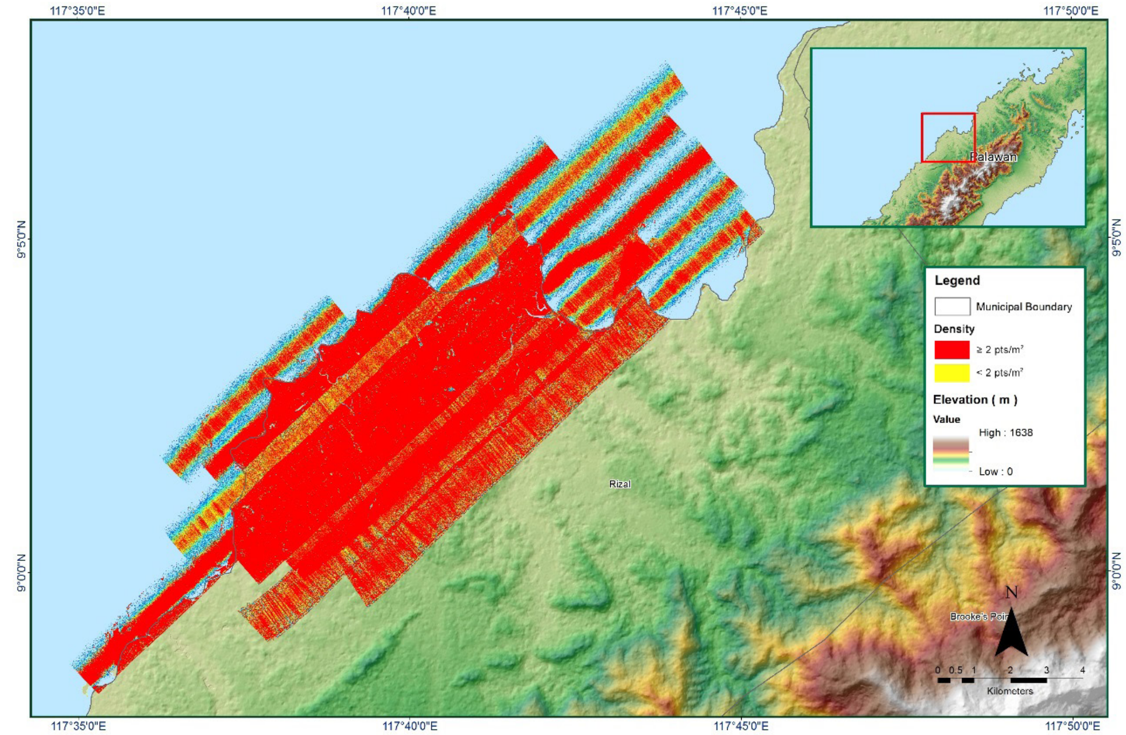


Figure A-8.12 Image of data overlap

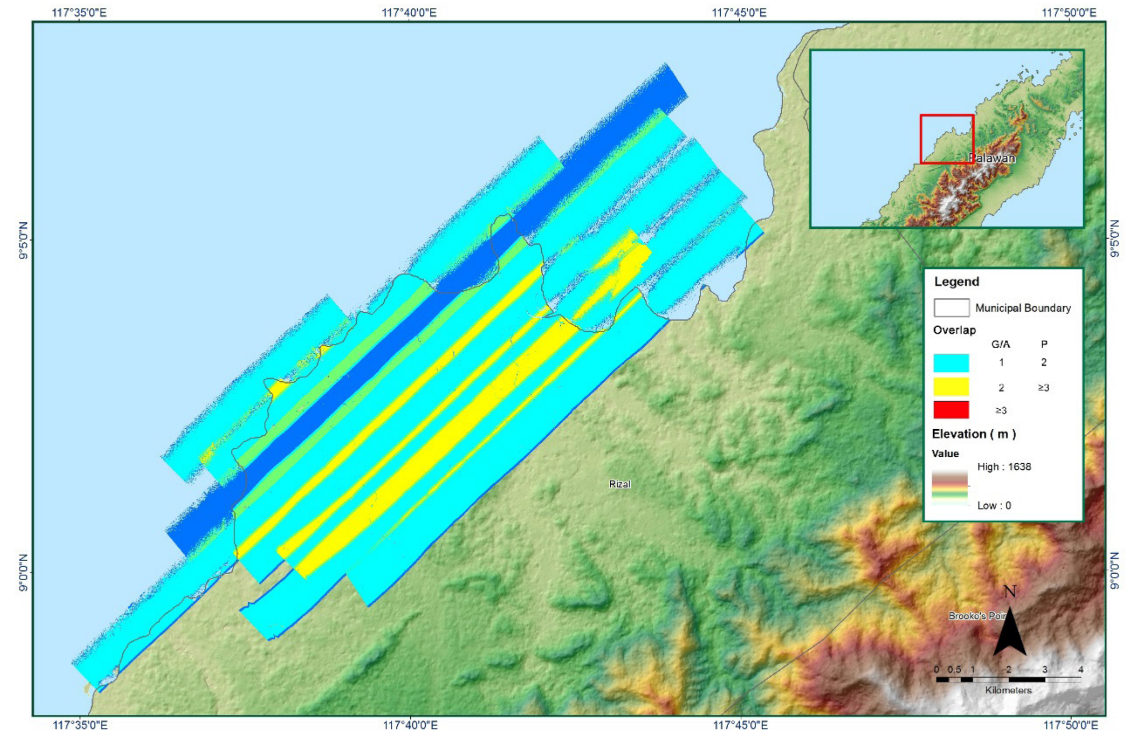


Figure A-8.13 *Density map of merged LiDAR data*

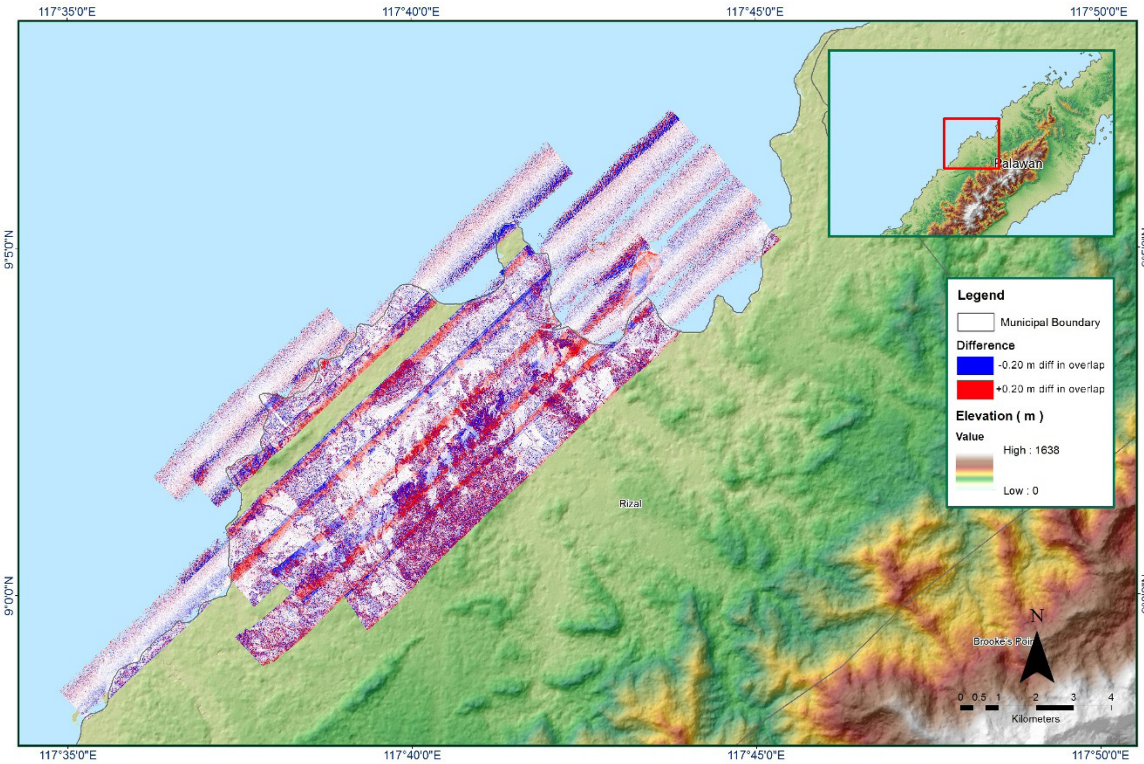


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Block 42P

Flight Area	West Palawan
Mission Name	**Block 42P**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
POS	478 MB
Image	90.70 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)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	13.66
Ave point cloud density per sq.m. (>2.0)	1.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	374
Maximum Height	760.06
Minimum Height	40.51
Classification (# of points)	
Ground	126102764
Low vegetation	61083474
Medium vegetation	179735342
High vegetation	715224847
Building	3589808
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista

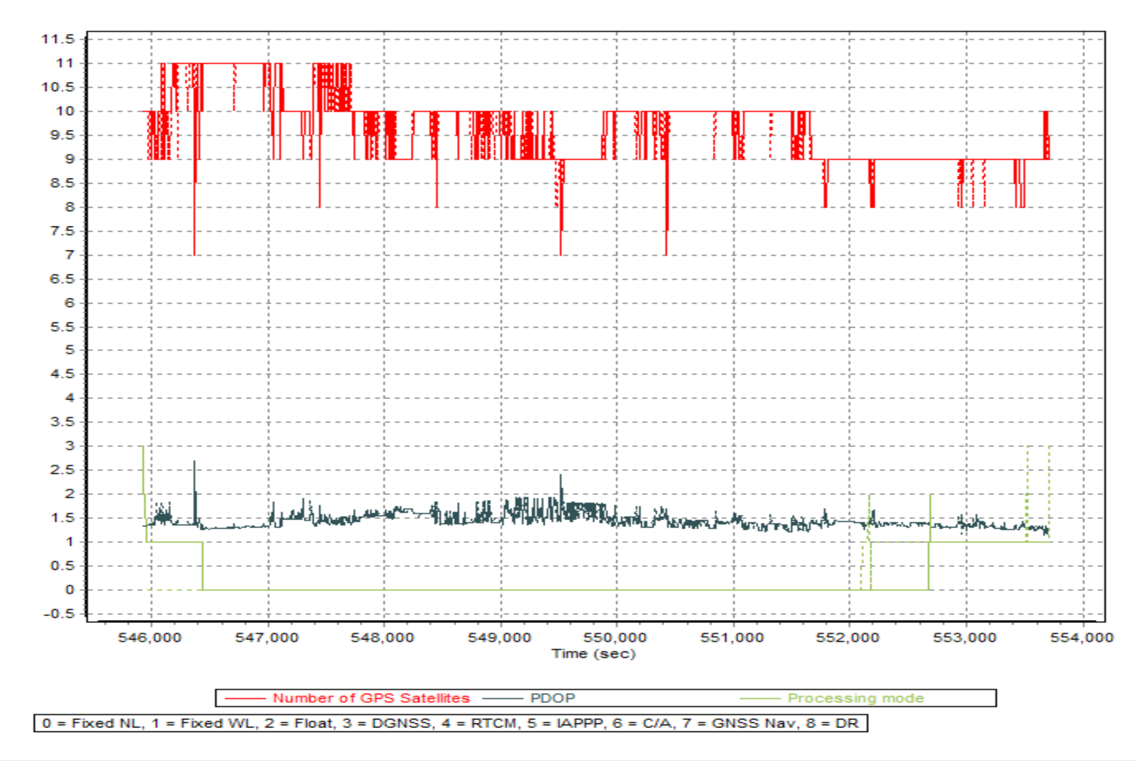


Figure A-8.15 Solution Status

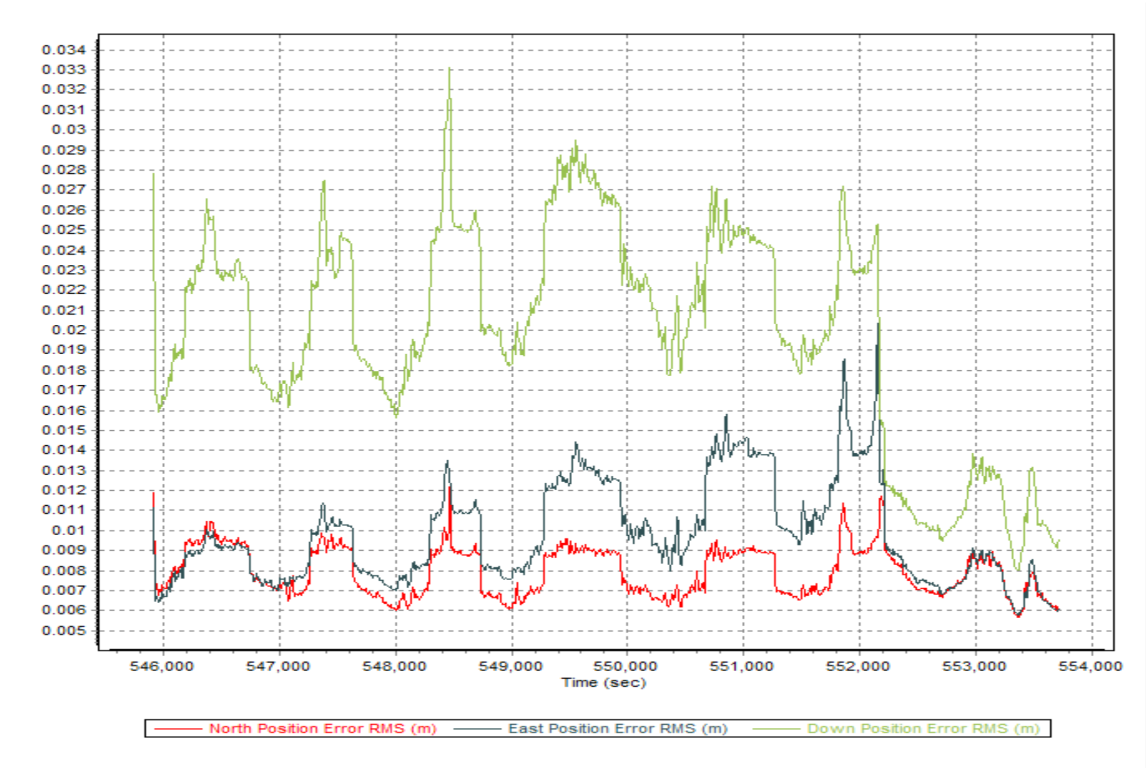


Figure A-8.16 Smoothed Performance Metric Parameters

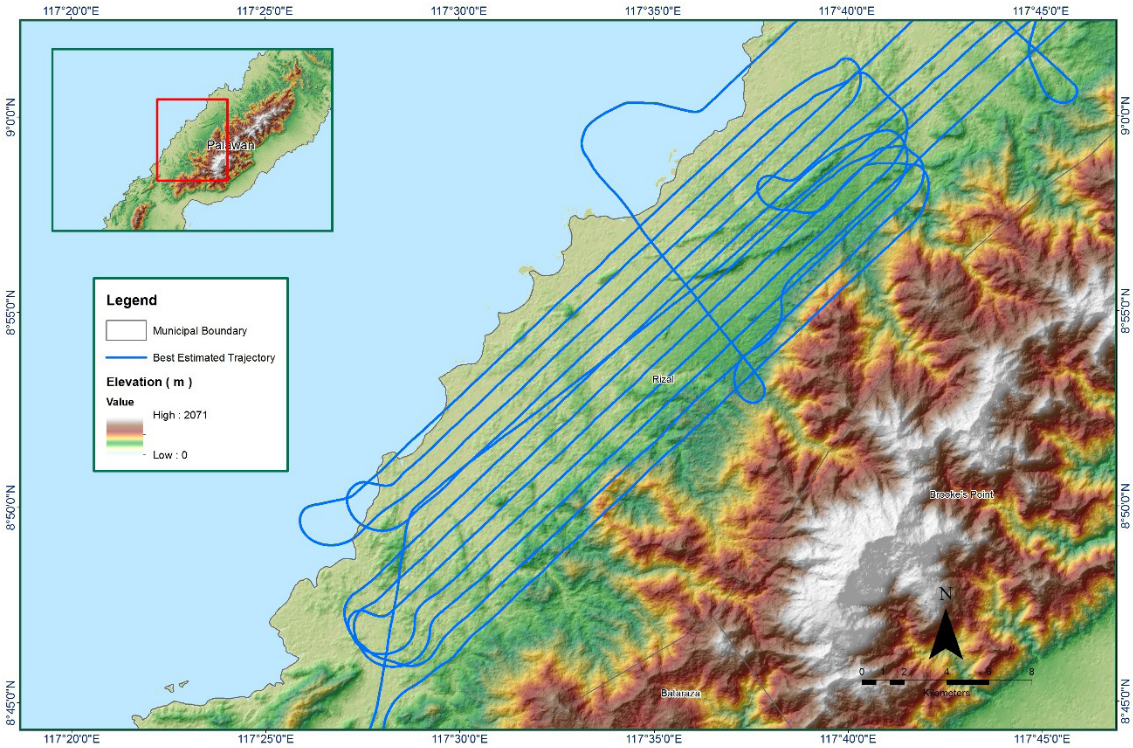


Figure A-8.17 Best Estimated Trajectory

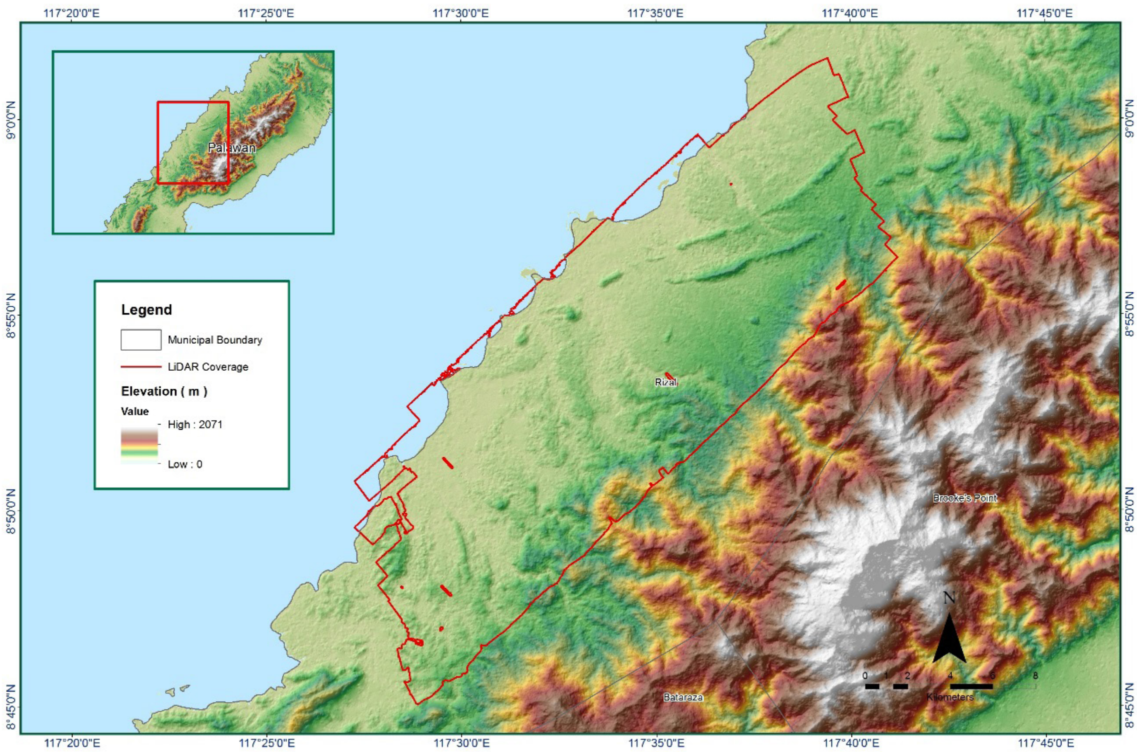


Figure A-8.18 Coverage of LiDAR data

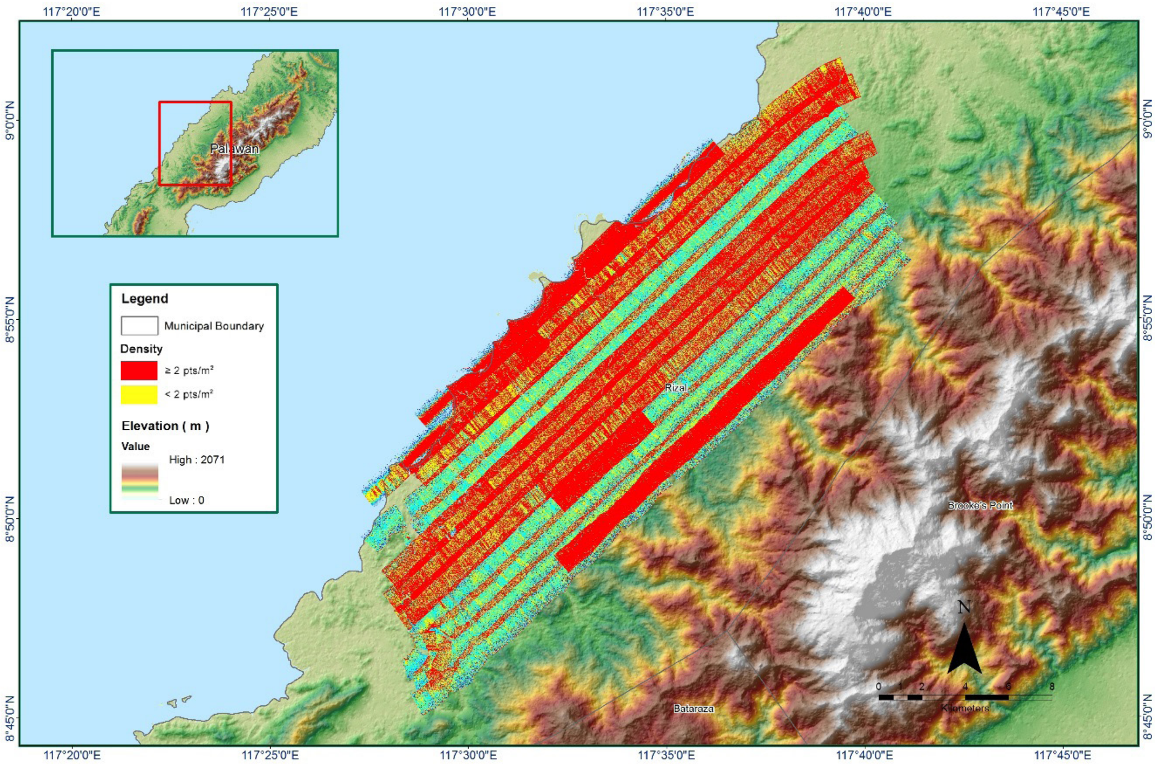


Figure A-8.19 Image of data overlap

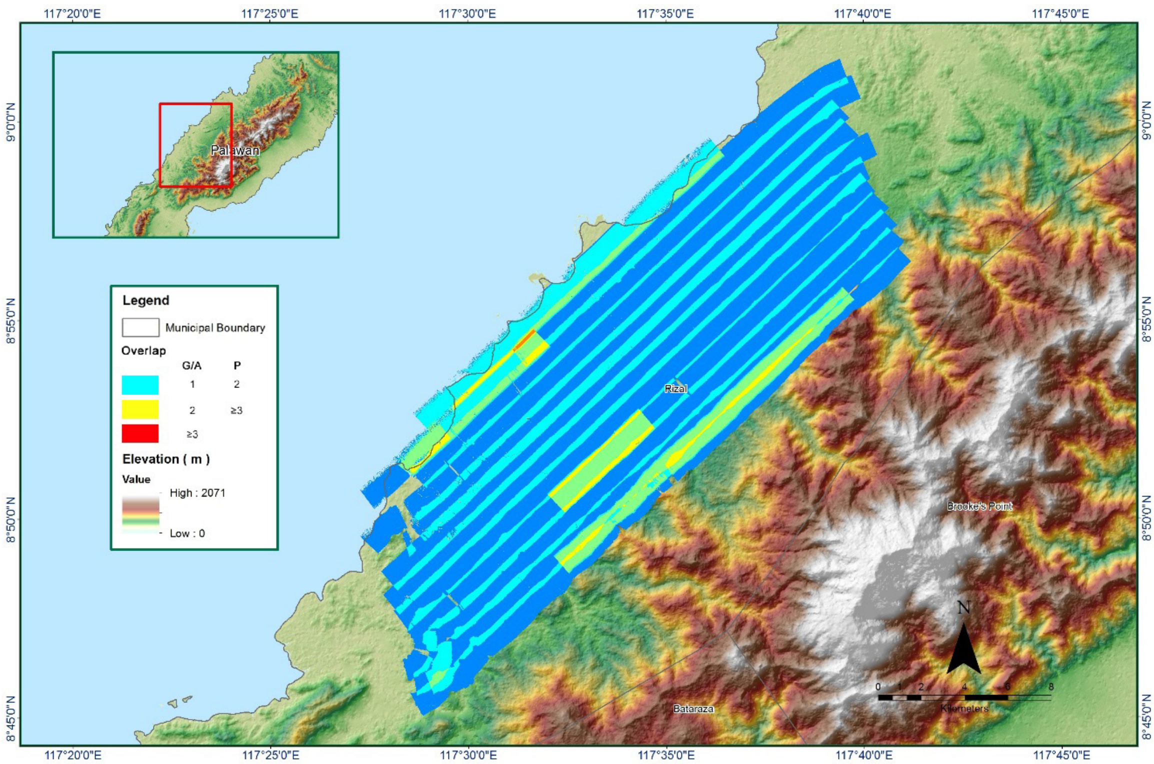


***Figure A-8.20** . Density map of merged LiDAR data*

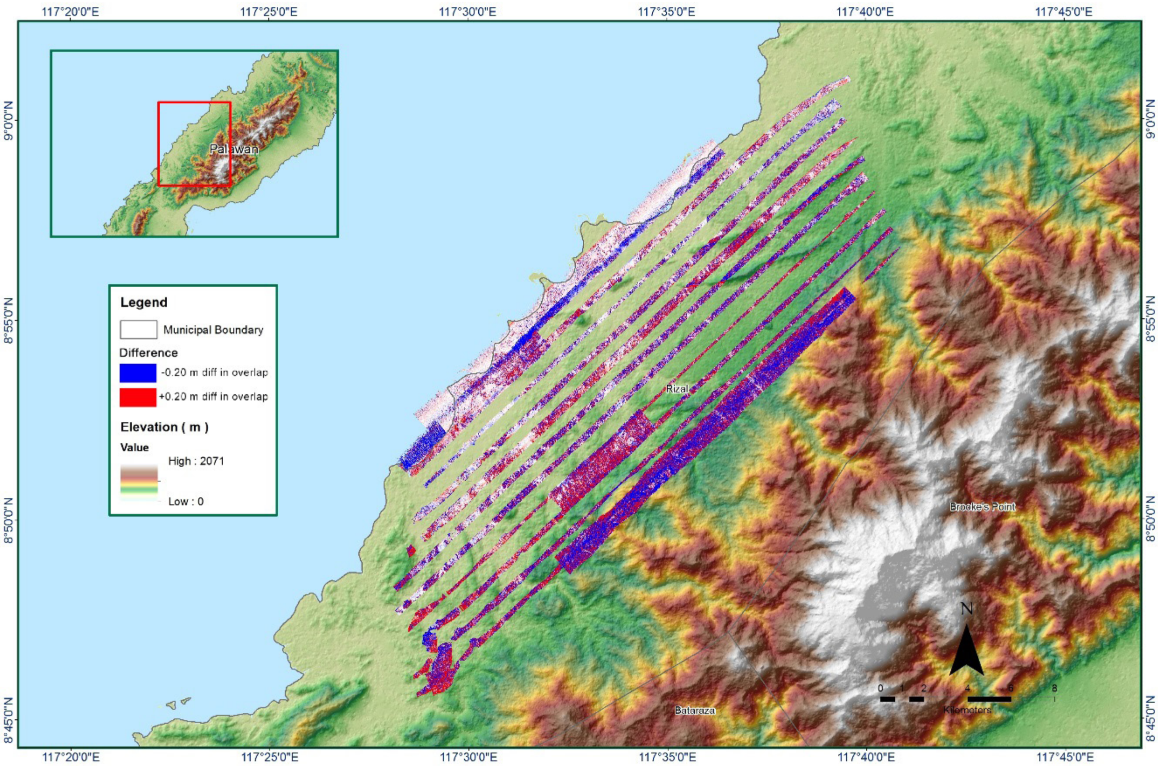


Figure A-8.21 Elevation difference between flight lines

Annex 9. Malambunga Model Basin Parameters

Table A-9.1 Malambunga Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W340	2.6	83	0.0	1.6203	2.6444	0.37032	1	0.5
W350	2.6	83	0.0	1.0994	1.7942	0.36686	1	0.5
W360	1.7999	87.587	0.0	2.7712	4.5226	0.80500	1	0.5
W380	1.7888	87.654	0.0	1.7412	0.83785	0.0723565	1	0.5
W390	1.719	88.078	0.0	2.006	2.8416	2.1839	1	0.5
W400	1.719	88.078	0.0	2.0066	1.8944	0.99897	1	0.5025
W410	2.4269	57.448	0.0	3.4078	1.2188	1.9657	0.62746	0.49749
W420	1.626	87.42	0.0	2.0152	1.7836	1.7726	0.62746	0.71166
W430	2.4269	87.436	0.0	2.271	1.6375	0.63238	0.62746	0.71624
W440	1.5856	56.311	0.0	4.4905	1.0535	0.70676	0.6013	0.74456
W450	1.0623	76.462	0.0	5.0637	1.1701	1.5705	0.57875	0.72972
W460	2.1499	72.656	0.0	4.932	1.1253	2.2554	0.36157	0.99604
W470	0.32231	52.868	0.0	2.8674	1.5738	1.6598	1	0.45107
W480	0.25846	75.537	0.0	0.82866	1.3935	1.5272	0.3335	0.48298
W490	3.4601	71.347	0.0	0.21077	2.5377	0.78460	0.40363	1
W500	0.2066	74.089	0.0	0.43982	1.2523	0.17024	0.58394	0.51876
W510	0.21278	47.774	0.0	1.6877	0.65143	0.68770	1	0.7499
W520	2.5462	38.679	0.0	1.1489	7.3707	0.76608	0.50509	0.67432
W530	0.15173	56.4	0.0	3.295	0.89818	0.44066	1	0.50581

W540	1.0183	85.09	0.0	15.983	7.6025	1.8167	1	0.33333
W550	5.317	55.424	0.0	12.989	5.2818	0.91583	1	0.2863
W560	2.3288	48.694	0.0	2.7401	0.80116	1.4788	1	0.74818
W570	3.4923	35.263	0.0	2.3472	1.2964	0.0362682	1	0.63406
W580	7.739	49.565	0.0	0.75071	7.8198	1.3904	1	1
W590	2.1074	53.3	0.0	1.8789	1.2703	0.78994	0.96259	0.61125
W600	1.0293	45.577	0.0	1.7125	1.5808	1.1357	1	0.68403
W610	0.71447	51.33	0.0	2.8154	0.31831	1.3558	1	1
W620	3.474	35.224	0.0	5.4887	5.0002	0.83336	1	1
W630	1.5992	95.262	0.0	15.992	3.9822	0.0825134	1	0.45196
W640	12.132	50.046	0.0	3.7727	8.3045	0.94625	0.882	1
W650	5.0554	79.206	0.0	13.7	5.4977	0.93960	0.66667	0.30877
W660	3.5106	54.375	0.0	2.5848	1.1304	1.5455	1	0.86247
W680	3.6526	75.134	0.0	13.484	5.5321	2.9596	1	0.51745
W690	0.15638	99	0.0	1.3521	3.6189	0.44978	0.57875	0.46017

Annex 10. Malambunga Model Reach Parameters

Table A-10.1 Malambunga Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	1852.2	0.0037676	0.04	Trapezoid	35	1
R110	Automatic Fixed Interval	2622.3	0.0103528	0.46591	Trapezoid	35	1
R130	Automatic Fixed Interval	3939.8	0.0195294	0.30295	Trapezoid	35	1
R150	Automatic Fixed Interval	1901.0	0.0139141	0.26445	Trapezoid	35	1
R170	Automatic Fixed Interval	463.85	0.0220342	0.0251321	Trapezoid	35	1
R190	Automatic Fixed Interval	1674.1	0.0092792	0.12053	Trapezoid	35	1
R20	Automatic Fixed Interval	748.41	0.0018042	0.04	Trapezoid	35	1
R210	Automatic Fixed Interval	2641.4	0.0428784	0.10819	Trapezoid	35	1
R220	Automatic Fixed Interval	2994.9	0.0352779	0.59945	Trapezoid	35	1
R230	Automatic Fixed Interval	306.57	0.0108348	0.12064	Trapezoid	35	1
R260	Automatic Fixed Interval	2959.4	0.0332614	0.45079	Trapezoid	35	1
R280	Automatic Fixed Interval	1896.6	0.0807550	0.0510904	Trapezoid	35	1
R290	Automatic Fixed Interval	510.71	0.23047	0.11671	Trapezoid	35	1
R50	Automatic Fixed Interval	493.55	0.000792595	0.04	Trapezoid	35	1
R70	Automatic Fixed Interval	4551.4	0.0108124	0.0486594	Trapezoid	35	1
R710	Automatic Fixed Interval	2072.7	0.0026811	0.24021	Trapezoid	35	1
R80	Automatic Fixed Interval	1240.5	0.0090219	0.050407	Trapezoid	35	1

Annex 11. Malambunga Field Validation Points

Table A-11.1 Malambunga Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Latitude	Longitude						
1	8.972181	117.6253	0.03	0	-0.03			25-Year
2	8.997459	117.6476	0.068	0	-0.068			25-Year
3	8.998876	117.6458	0.049	0	-0.049			25-Year
4	9.000211	117.6434	0.132	0	-0.132			25-Year
5	9.003353	117.6453	0.031	0	-0.031			25-Year
6	9.00773	117.648	0.268	0	-0.268			25-Year
7	9.010468	117.6497	2.209	0	-2.209			25-Year
8	9.013942	117.6498	0.053	0	-0.053			25-Year
9	9.014916	117.6494	0.034	0	-0.034			25-Year
10	9.01979	117.6482	0.056	0	-0.056			25-Year
11	9.022037	117.6506	0.946	0	-0.946			25-Year
12	9.022435	117.6454	0.03	0	-0.03			25-Year
13	9.027848	117.6438	0.03	0	-0.03			25-Year
14	9.031722	117.6564	0.105	0.41	0.305	Typhoon	Jan. 3, 2014	25-Year
15	9.032267	117.6572	0.087	0.56	0.473	Typhoon	Jan. 3, 2014	25-Year
16	9.032113	117.6428	0.03	0	-0.03			25-Year
17	9.034083	117.6427	0.306	0	-0.306			25-Year
18	9.034199	117.6422	0.03	0	-0.03			25-Year
19	9.034646	117.6436	0.03	0	-0.03			25-Year
20	9.036919	117.6497	0.138	0	-0.138			25-Year
21	9.037003	117.6499	0.03	0.13	0.1	Auring	Jan. 3, 2013	25-Year

22	9.037217	117.6547	0.29	0.3	0.01	Typhoon	Jan. 3, 2014	25-Year
23	9.038091	117.6508	0.383	0	-0.383			25-Year
24	9.038535	117.6356	2.106	0.9	-1.206			25-Year
25	9.03881	117.6498	0.572	0.36	-0.212	Auring	Jan. 3, 2013	25-Year
26	9.038633	117.6357	1.396	0.75	-0.646			25-Year
27	9.03942	117.6538	1.046	0.92	-0.126	Typhoon	Jan. 3, 2014	25-Year
28	9.039424	117.654	0.937	1	0.063	Typhoon	Jan. 3, 2014	25-Year
29	9.039288	117.6349	0.631	0	-0.631			25-Year
30	9.039356	117.6346	0.428	0	-0.428			25-Year
31	9.03937	117.6352	0.622	0	-0.622			25-Year
32	9.039442	117.6352	0.622	0	-0.622			25-Year
33	9.039521	117.6358	0.965	0.2	-0.765		2016	25-Year
34	9.03951	117.634	1.006	0	-1.006			25-Year
35	9.03955	117.6359	0.978	0	-0.978			25-Year
36	9.039597	117.6352	0.441	0	-0.441			25-Year
37	9.039825	117.6496	0.322	1.04	0.718			25-Year
38	9.03967	117.6358	0.785	0.2	-0.585			25-Year
39	9.039935	117.6536	0.038	0.75	0.712	Heavy Rain		25-Year
40	9.039906	117.6497	1.757	1.24	-0.517	Auring	Jan. 3, 2013	25-Year
41	9.039767	117.6352	0.434	0	-0.434			25-Year
42	9.039939	117.6359	0.334	0.36	0.026			25-Year
43	9.040037	117.6349	0.557	0	-0.557			25-Year
44	9.040168	117.6345	0.372	0	-0.372			25-Year
45	9.040262	117.6357	0.243	0.1	-0.143			25-Year
46	9.040716	117.6596	0.354	0.4	0.046			25-Year
47	9.040462	117.6346	0.03	0	-0.03			25-Year
48	9.041218	117.661	0.03	0	-0.03			25-Year
49	9.041344	117.6621	0.03	0	-0.03			25-Year

50	9.041008	117.6369	0.665	0.1	-0.565			25-Year
51	9.041371	117.6613	0.03	0	-0.03			25-Year
52	9.041386	117.6487	0.546	0.64	0.094	Auring	Jan. 3, 2013	25-Year
53	9.041671	117.6495	0.37	0	-0.37			25-Year
54	9.041896	117.6625	0.228	0	-0.228			25-Year
55	9.041641	117.6367	0.358	0.1	-0.258			25-Year
56	9.041878	117.6408	1.593	0.7	-0.893			25-Year
57	9.042284	117.6635	0.03	0	-0.03			25-Year
58	9.041919	117.6363	0.072	0	-0.072			25-Year
59	9.042238	117.6358	0.08	0	-0.08			25-Year
60	9.04236	117.6403	0.785	0	-0.785			25-Year
61	9.042777	117.6656	0.03	0	-0.03			25-Year
62	9.04294	117.6666	0.03	0	-0.03			25-Year
63	9.042779	117.6395	1.136	0	-1.136			25-Year
64	9.043045	117.6394	0.584	0	-0.584			25-Year
65	9.043131	117.638	0.03	0	-0.03			25-Year
66	9.04323	117.6356	0.03	0.1	0.07			25-Year
67	9.043426	117.6387	0.312	0	-0.312			25-Year
68	9.043977	117.6728	0.03	0	-0.03			25-Year
69	9.043665	117.6466	0.754	0	-0.754			25-Year
70	9.043679	117.6409	0.948	0	-0.948			25-Year
71	9.043811	117.6405	0.816	0	-0.816			25-Year
72	9.04393	117.6436	0.892	0	-0.892			25-Year
73	9.043846	117.6356	0.219	0	-0.219			25-Year
74	9.043981	117.6367	0.349	0	-0.349			25-Year
75	9.044162	117.6351	0.03	0	-0.03			25-Year
76	9.044294	117.6332	0.06	0.5	0.44			25-Year
77	9.04459	117.6348	0.306	0	-0.306			25-Year

78	9.044852	117.6334	0.426	0	-0.426			25-Year
79	9.04512	117.6361	0.078	0	-0.078			25-Year
80	9.045428	117.6357	0.03	0	-0.03			25-Year
81	9.045774	117.6467	0.17	0.51	0.34	Auring	Jan. 3, 2013	25-Year
82	9.045648	117.6327	0.03	0	-0.03			25-Year
83	9.045877	117.6481	0.276	0.4	0.124	Auring	Jan. 3, 2013	25-Year
84	9.045668	117.6334	0.103	0.5	0.397			25-Year
85	9.045887	117.635	0.03	0	-0.03			25-Year
86	9.046115	117.6464	0.527	0.53	0.003	Auring	Jan. 3, 2013	25-Year
87	9.046141	117.6346	0.098	0	-0.098			25-Year
88	9.046365	117.6342	0.072	0	-0.072			25-Year
89	9.046478	117.6343	0.126	0	-0.126			25-Year
90	9.046841	117.6331	0.229	0	-0.229			25-Year
91	9.047185	117.646	0.687	0.23	-0.457	Auring	Jan. 3, 2013	25-Year
92	9.047756	117.6451	0.491	0.71	0.219	Auring	Jan. 3, 2013	25-Year
93	9.04776	117.6453	0.216	0.57	0.354	Auring	Jan. 3, 2013	25-Year
94	9.049527	117.6541	0.529	0.63	0.101	Typhoon		25-Year
95	9.049879	117.6498	0.414	0.49	0.076	Heavy Rain		25-Year
96	9.050504	117.6528	0.142	0.22	0.078	Typhoon		25-Year
97	9.05164	117.6514	0.317	0.77	0.453	Typhoon		25-Year
98	9.05168	117.6496	1.008	1.1	0.092	Heavy Rain		25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

Project Leader
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