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

LiDAR Surveys and Flood Mapping of Ransang River

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

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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 RANSANG RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

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

1.2 Overview of the Ransang River Basin

The Ransang River Basin is a 94,170-hectare watershed covering two (2) municipalities in Palawan; namely, the municipalities of Bataraza and Rizal. Specifically, it covers the barangays of Malis, Salogon and Samareñana in Brook'es Point municipality and Ransang in Rizal The DENR River Basin Control Office (RBCO) states that the Ransang River Basin has a drainage are of 78 km² and an estimated 125 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Ransang River, is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner HEI, University of the Philippines Los Baños. The Ransang River passes through Malis, Salogon and Samareñana in Brookes Point municipality and Ransang in Rizal. According to the 2015 national census of PSA, a total of 4,983 persons are residing in Brgy. Ransang in the Municipality of Rizal, which is within the immediate vicinity of the river. The economy of the communities residing within the river basin, similar to the whole province of Palawan, largely rests on agriculture, particularly fishing, tourism, trade, commerce, and mineral extraction (Source: pkp.pcsd.gov.ph/images/ppcprofile/Economic%20Profile.pdf).

Based on the studies conducted by the Mines and Geosciences Bureau, only Brgy. Ransang has flood susceptibility (low to high) while other barangays have no flood hazard at all. The field surveys conducted by the PHIL-LiDAR 1 validation team found that heavy rains in 2013 (November) and 2016 (October) caused flooding affecting Ransang. In addition, on November 17, 2016, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) issued a flood advisory for Ransang River and its tributaries due to the moderate to heavy rains brought by the presence of a trough of low pressure area affecting Southern Luzon, Visayas and Mindanao as per NDRRMC report (Source: http://www.ndrrmc.gov.ph/attachments/article/3/General_ Flood_Advisories_as_of_17NOV016_1700H.pdf). As to landslide susceptibility, only Ransang has low to high susceptibility to landslides, while rest of the barangays have moderate to high susceptibility.

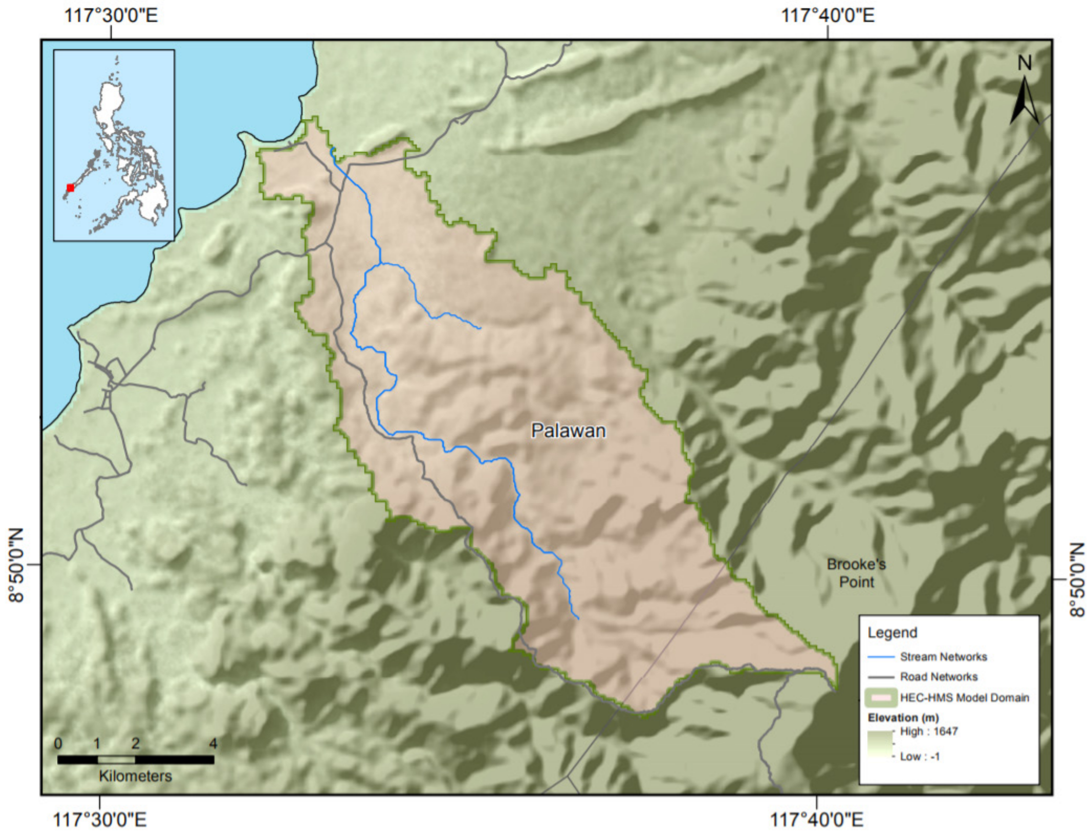

Figure 1. Map of Ransang River Basin (in brown)

With regards to climate, the Ransang River Basin lies within a tropical region. Climate Type I and III prevails in the Ransang River Basin, as well as in the larger MIMAROPA and Laguna areas, 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.

Moreover, in terms of geology, the river basin is characterized mostly by >50% slope. Sibul clay soil dominates the river basin. Closed canopy (mature trees covering >50%) land cover type can be mostly found in the area along with cultivated area mixed with brushland/grassland, cropland mixed with coconut plantation, open canopy (mature trees covering <50%) and mossy forest.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE RANSANG 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 Ransang 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 station used for Ransang floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Max. Field of View (θ)	Pulse Rate 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

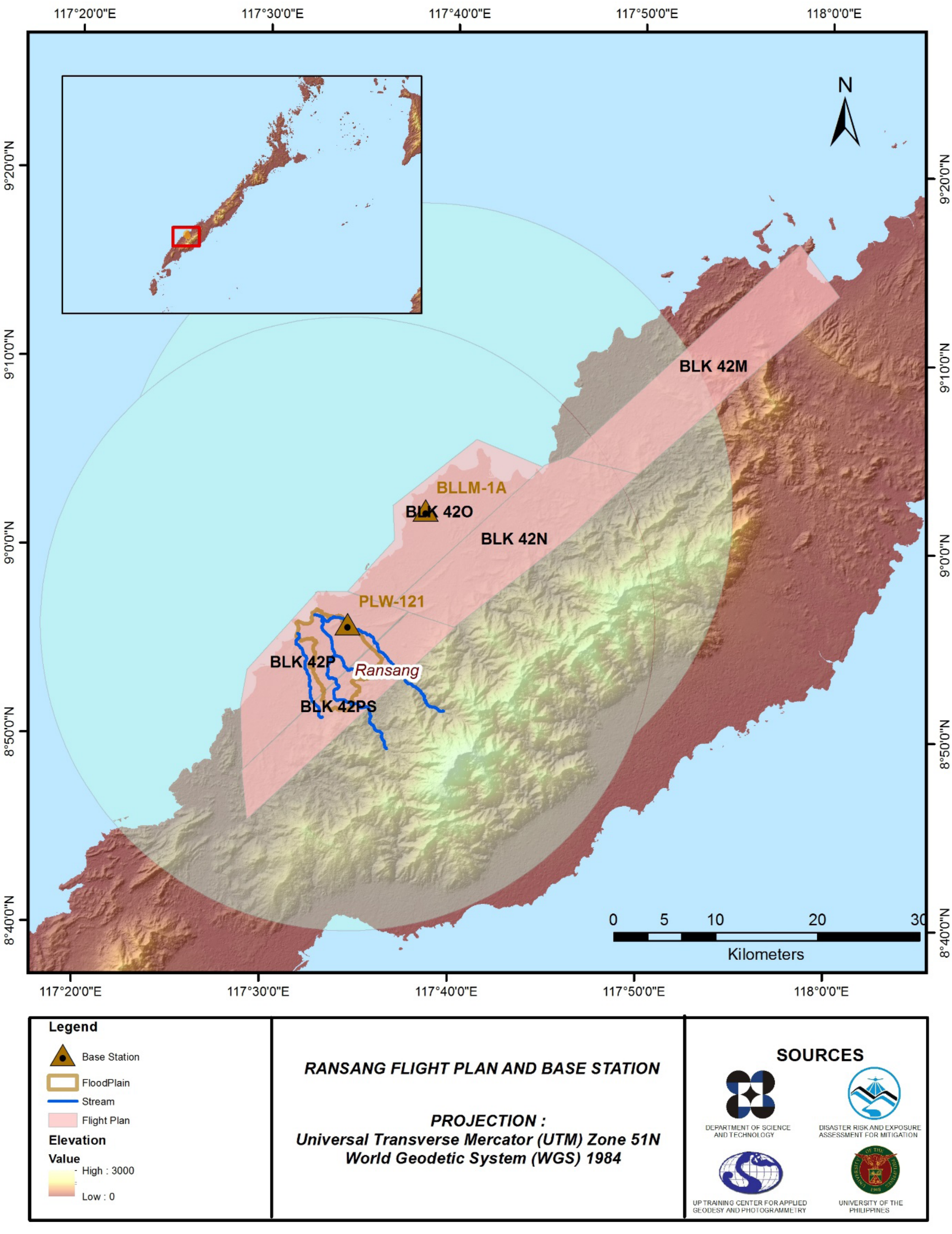

Figure 2. Flight plans and base stations used for Ransang Floodplain.

2.2 Ground Base Station

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 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ransang floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

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 station and established point while Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

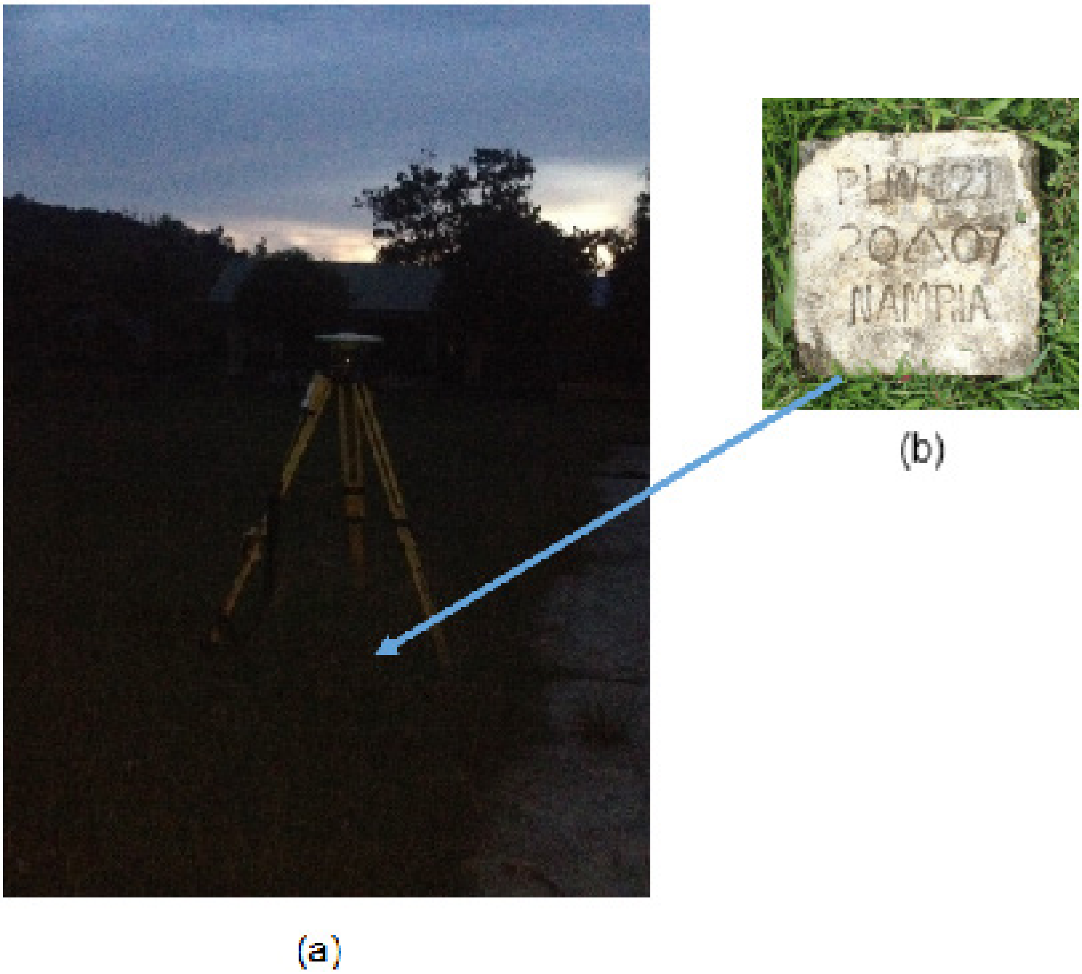

Figure 3. GPS set-up over PLW-121 as recovered within the vicinity of Cabkungan Elementary School in Brgy. Campong Ulay, Rizal, Palawan (a) and NAMRIA reference point PLW-121 (b) as recovered by the field team.

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	8° 56' 1.71426" North
	Longitude	117° 34' 23.99157" East
	Ellipsoidal Height	8.98036 meters
Grid Coordinates, Philippine Transverse Mercator Zone 1A (PTM Zone 1A PRS 92)	Easting	398086.54 meters
	Northing	987945.887 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	8° 55' 57.38325" North
	Longitude	117° 34' 29.39124" East
	Ellipsoidal Height	58.05800 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting	563030.26 meters
	Northing	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	9° 02' 07.68639" North
	Longitude	117° 38' 28.10618" East
	Ellipsoidal Height	-2.0700 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9° 02' 03.33580" North
	Longitude	117° 38' 33.49665" East
	Ellipsoidal Height	46.965 meters
Grid Coordinates, Universal Transverse Mercator Zone 50 North (UTM 50N PRS 92)	Easting	570465.682 meters
	Northing	998772.489 meters

Table 4. Ground control points used during 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 Ransang 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 LiDAR data acquisition in Ransang 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	445.38	39.94	538	4	23
July 11, 2015	3159P	385.73	231.17	231.17	29.4	1	3	12
TOTAL		932.4	676.55	676.55	69.34	539	7	35

Table 6. Actual parameters used during LiDAR data acquisition.

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

2.4. Survey Coverage

Ransang 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 Ransang floodplain is presented in Figure 4.

Table 7. List of municipalities and cities surveyed during Ransang Floodplain LiDAR survey.

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%

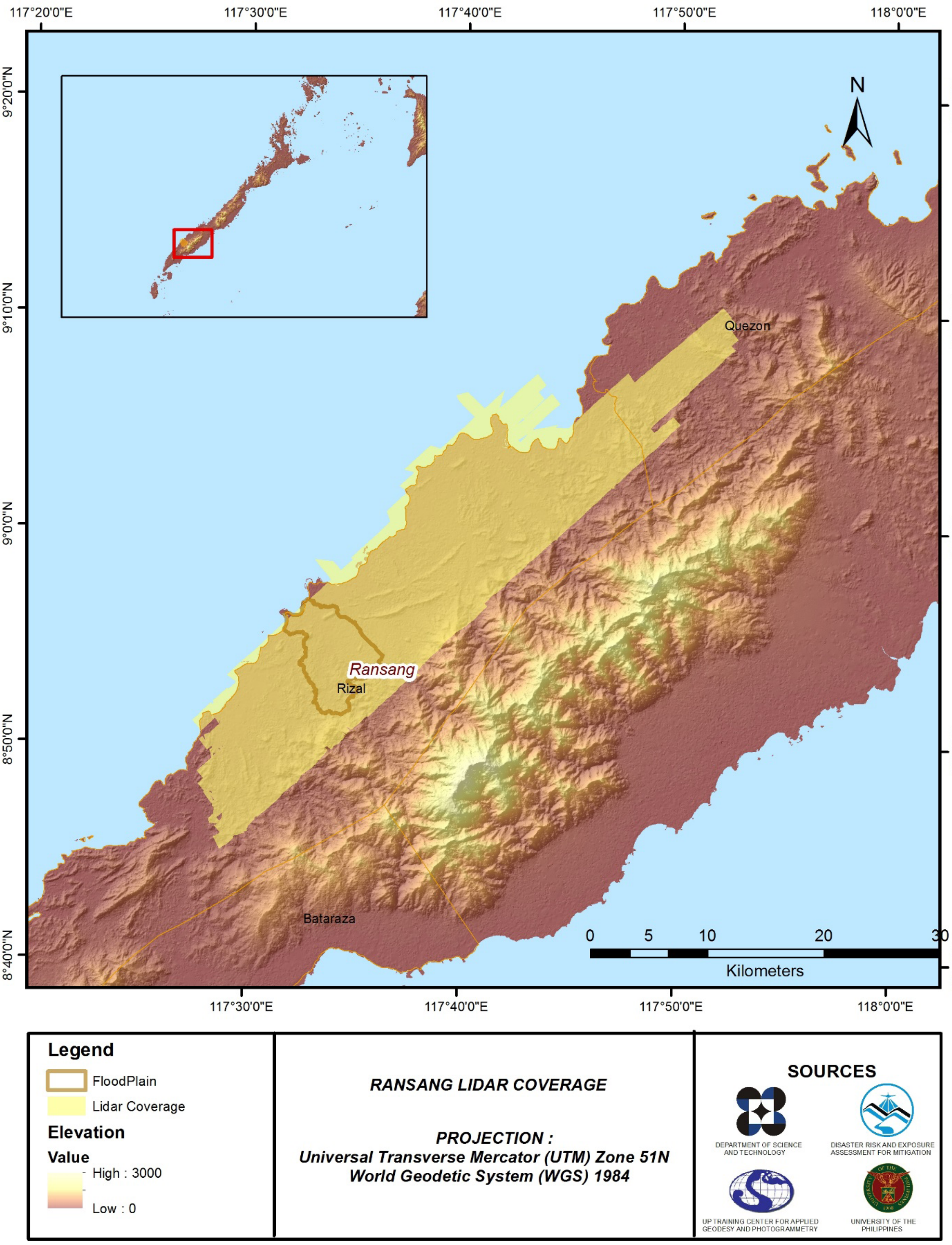

Figure 4. Actual LiDAR survey coverage for Ransang Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE RANSANG FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 5.

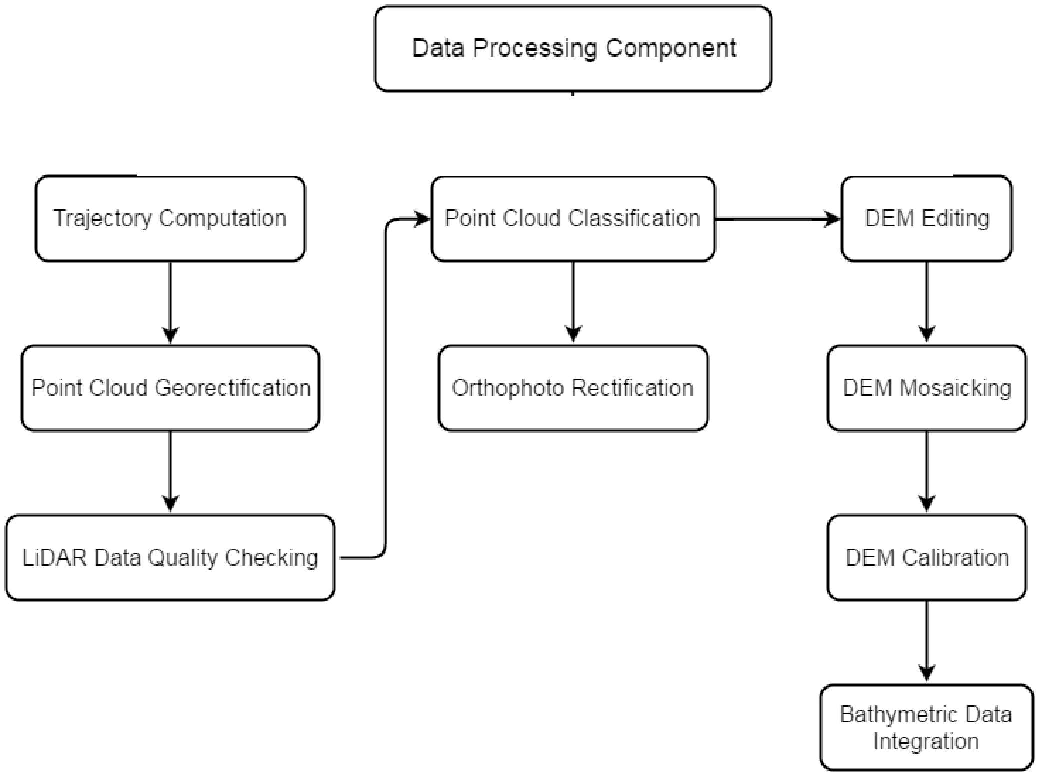

Figure 5. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ransang 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 Rizal, Palawan.

The Data Acquisition Component (DAC) transferred a total of 64.90 Gigabytes of Range data, 478 Megabytes of POS data, 41.20 Megabytes of GPS base station data, and 90.70 Gigabytes of raw image data to the data server on August 5, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ransang was fully transferred on August 5, 2015as indicated on the Data Transfer Sheets for Ransang floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 3159P, one of the Ransang 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 00:00AM. The y-axis is the RMSE value for that particular position.

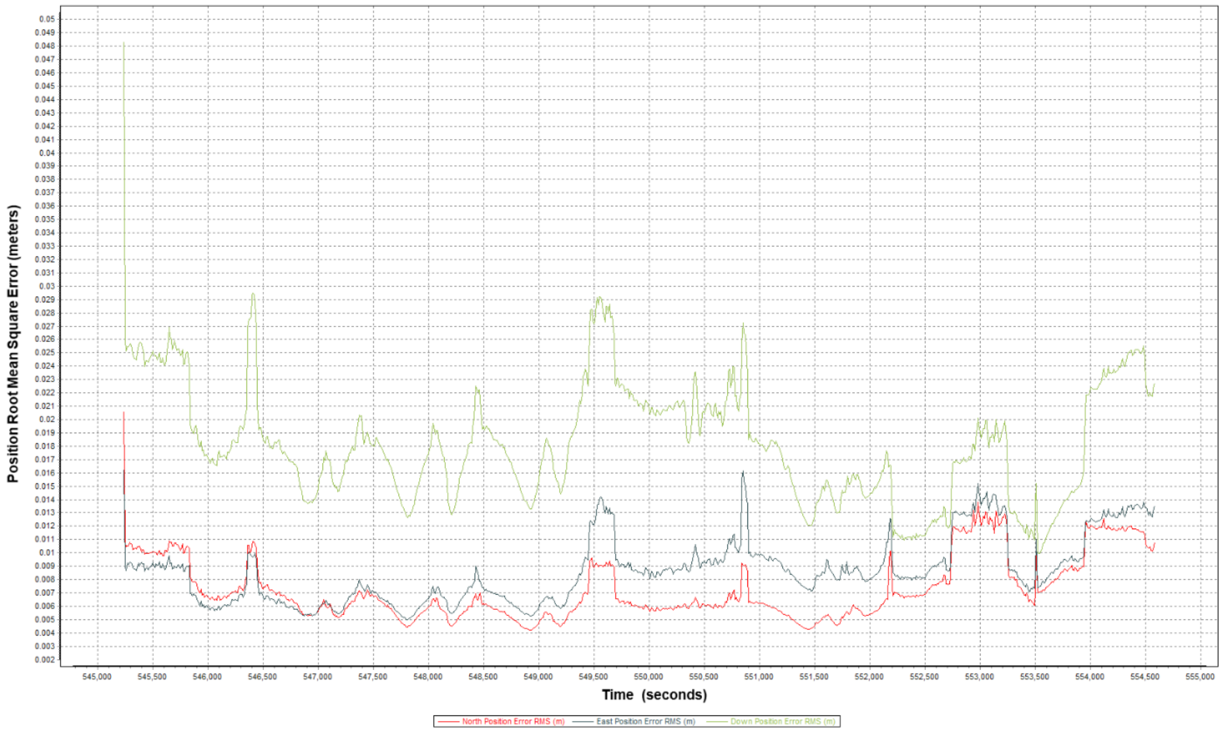

Figure 6. Smoothed Performance Metrics of Ransang Flight 3159P.

The time of flight was from 545200 seconds to 554600 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 2.00 centimeters, the East position RMSE peaks at 1. 60 centimeters, and the Down position RMSE peaks at 4.80 centimeters, which are within the prescribed accuracies described in the methodology.

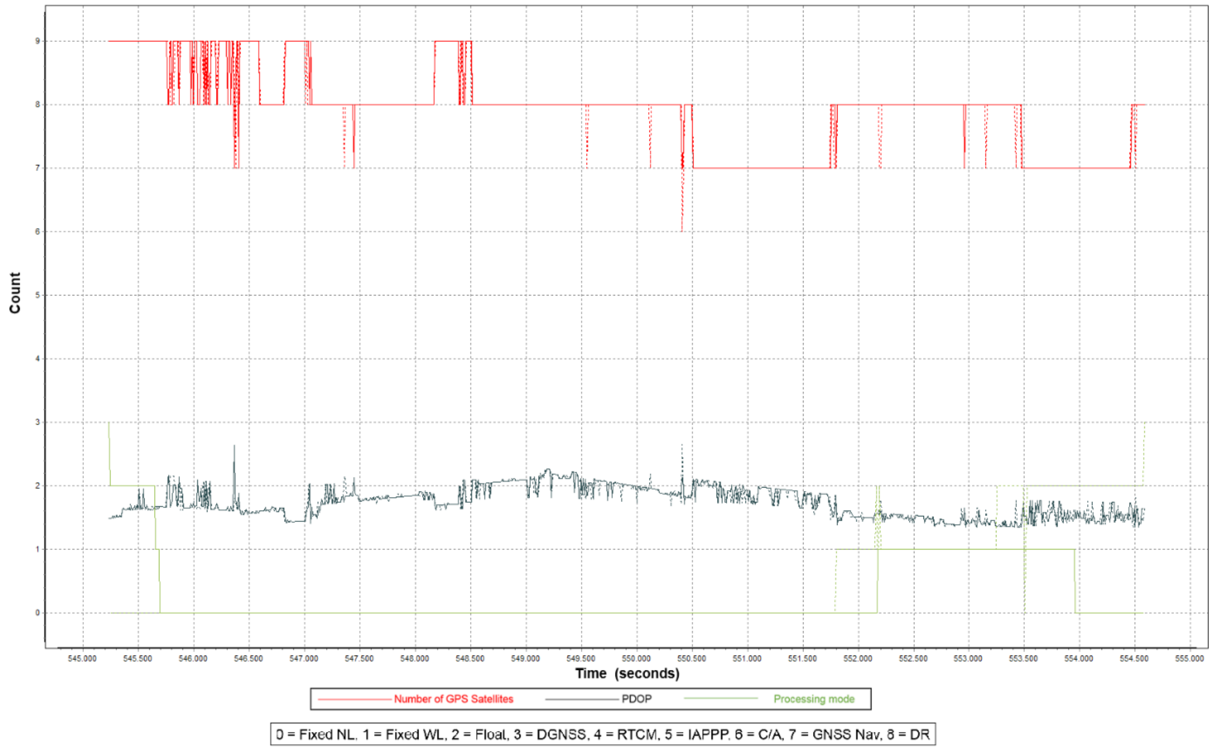

Figure 7. Solution Status Parameters of Ransang Flight 3159P.

The *Solution Status* parameters of flight 3159P, one of the Ransang 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 7 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 Ransang flights is shown in Figure 8.

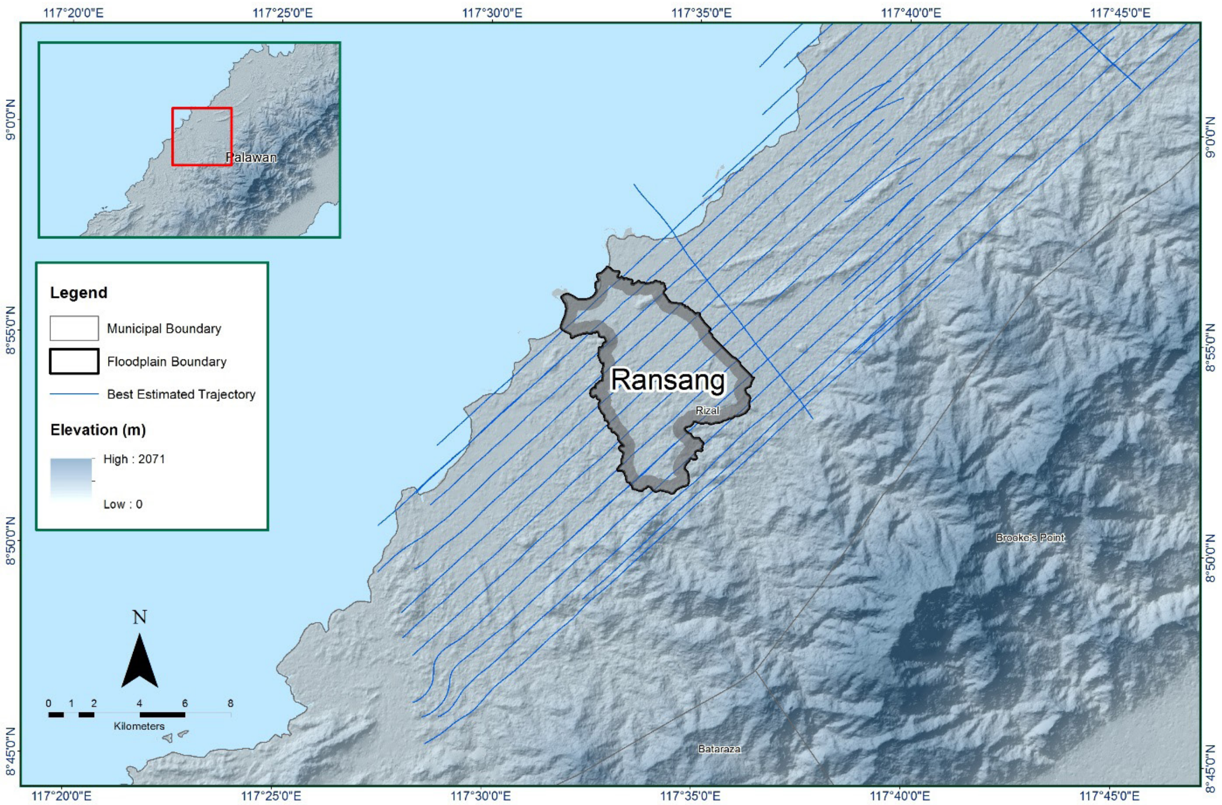

Figure 8. Best Estimated Trajectory for Ransang Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 10 flight lines, with each flight line containing two channels, since the Pegasus system contain two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ransang floodplain are given in Table 8.

Table 8. Self-Calibration Results values for Ransang flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000370
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000558
GPS Position Z-correction stdev	(<0.01meters)	0.0026

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

3.5 LiDAR Data Quality Checking

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

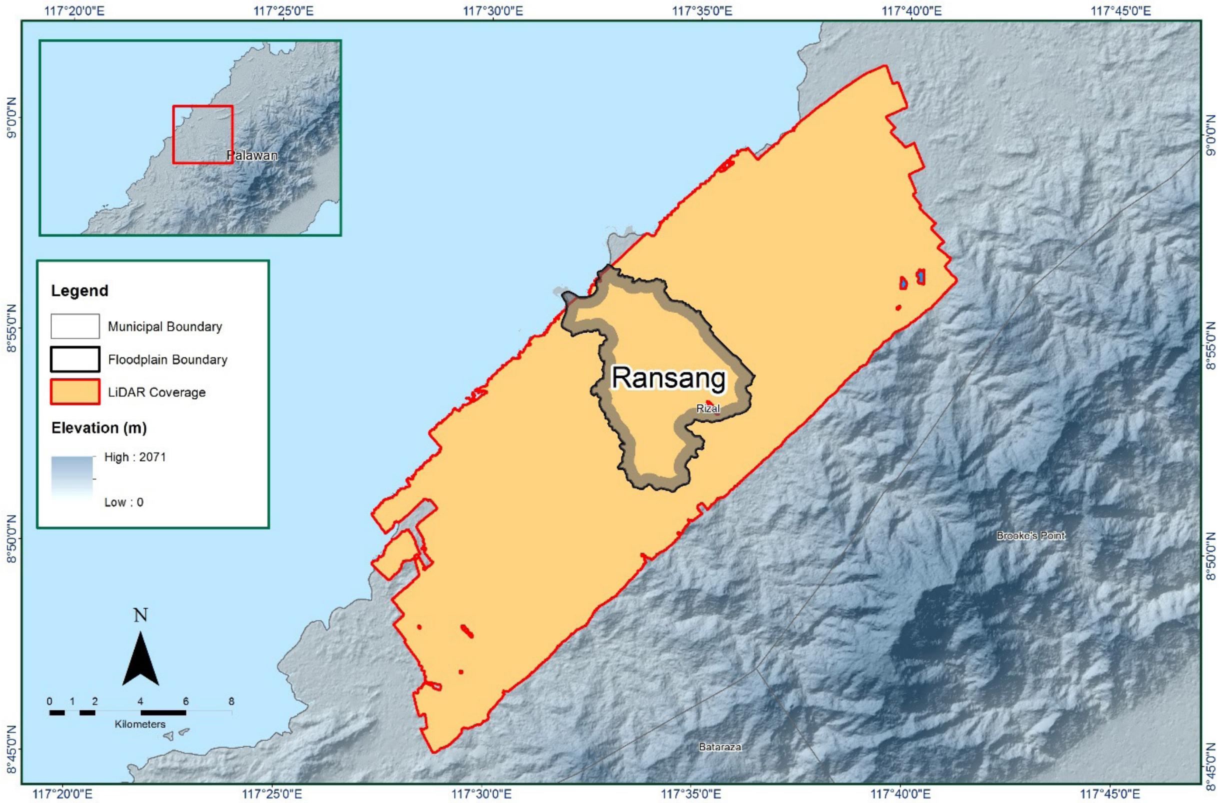

Figure 9. Boundary of the processed LiDAR data over Ransang Floodplain

The total area covered by the Ransang missions is 302.86 sq.km that is comprised of two (2) flight acquisitions grouped and merged into one (1) block only as shown in Table 9.

Table 9. List of LiDAR blocks for Ransang Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_Blk42P	3157P	302.86
	3159P	
TOTAL		**302.86 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 employ two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

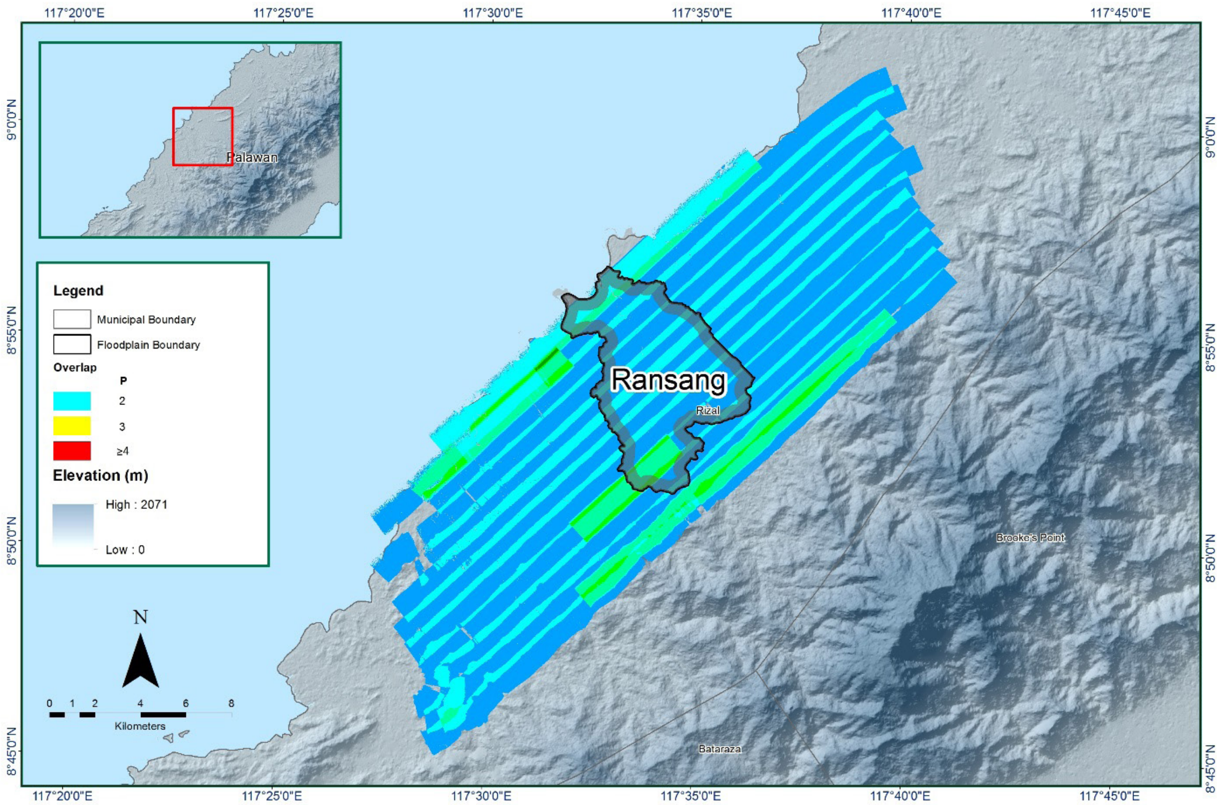

Figure 10. Image of data overlap for Ransang Floodplain.

The overlap statistics per block for the Ransang floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps is 13.66%.

The 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 Ransang floodplain satisfy the point density requirement, and the average density for the entire survey area is 1.95 points per square meter.

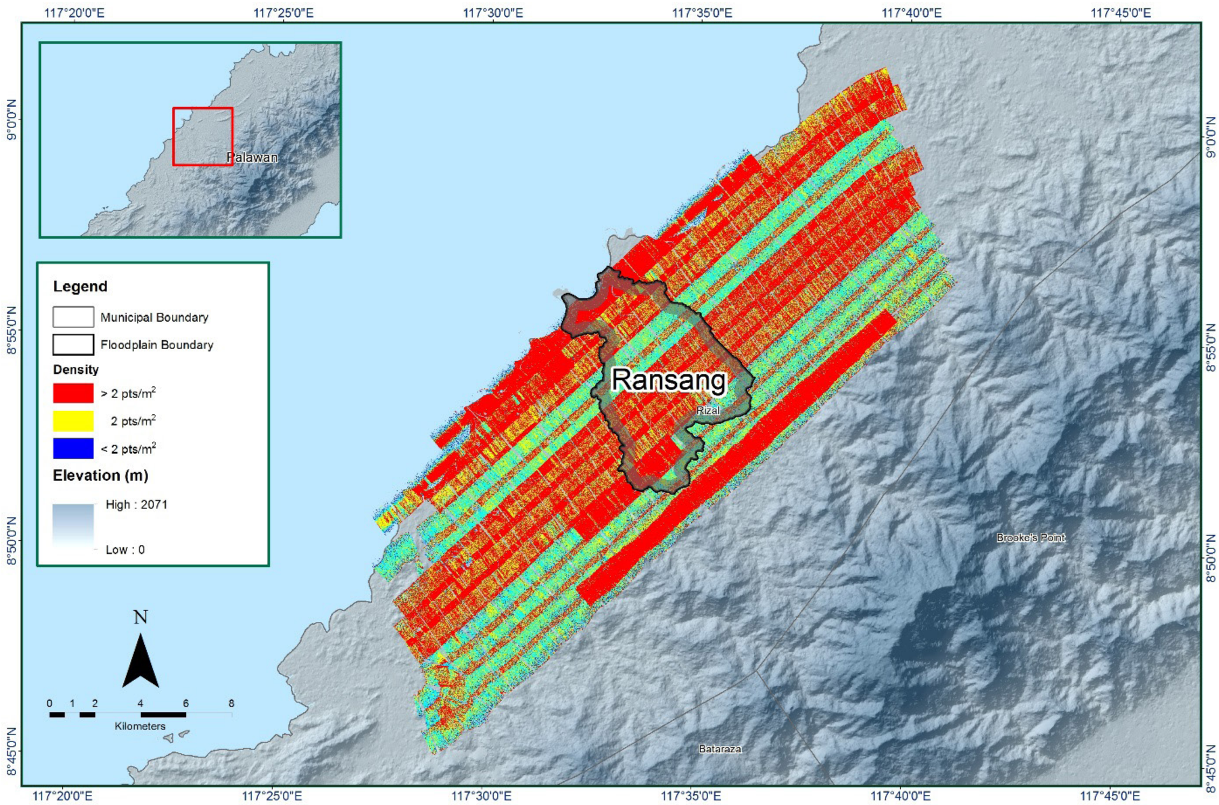

Figure 11. Pulse density map of merged LiDAR data for Ransang Floodplain.

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 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

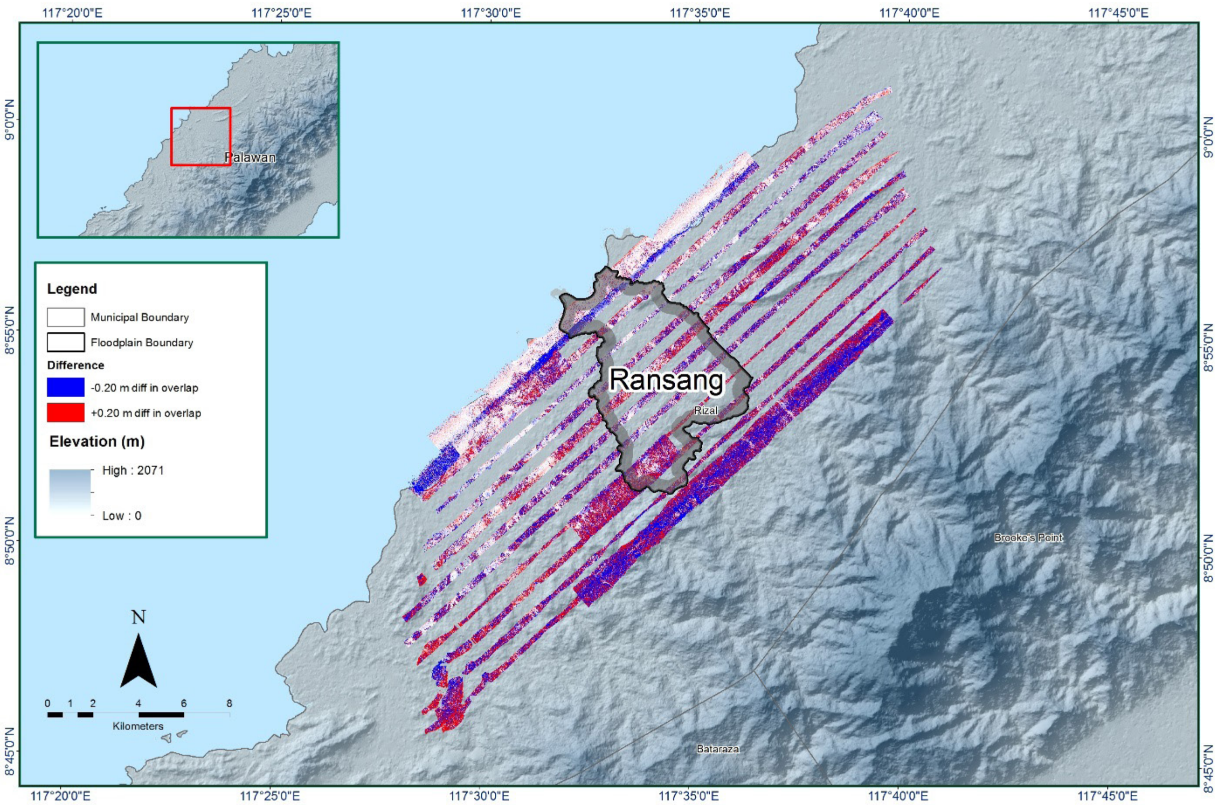

Figure 12. Elevation difference map between flight lines for Ransang Floodplain.

A screen capture of the processed LAS data from a Ransang 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.

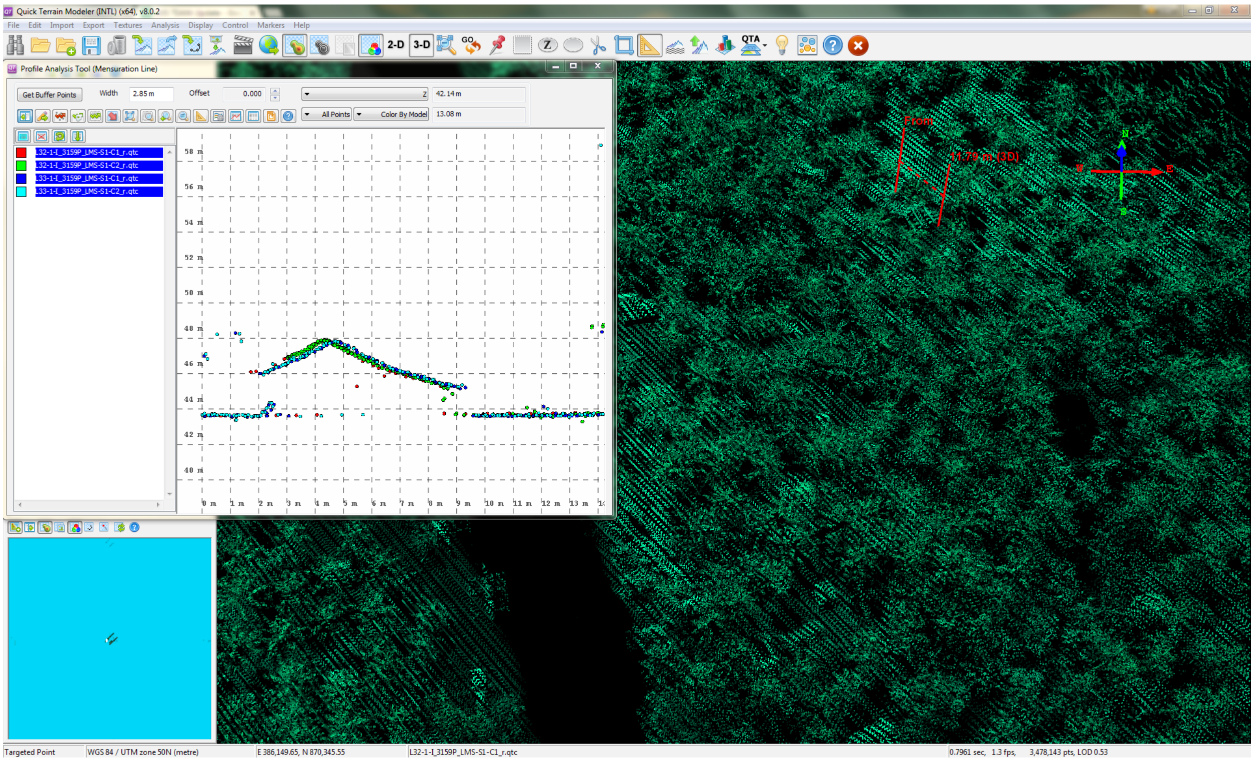

Figure 13. Quality checking for Ransang flight 3159P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10. Ransang classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	126,102,764
Low Vegetation	61,083,474
Medium Vegetation	179,735,342
High Vegetation	715,224,847
Building	3,589,808

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ransang floodplain is shown in Figure 14. A total of 374 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 40.51 meters respectively.

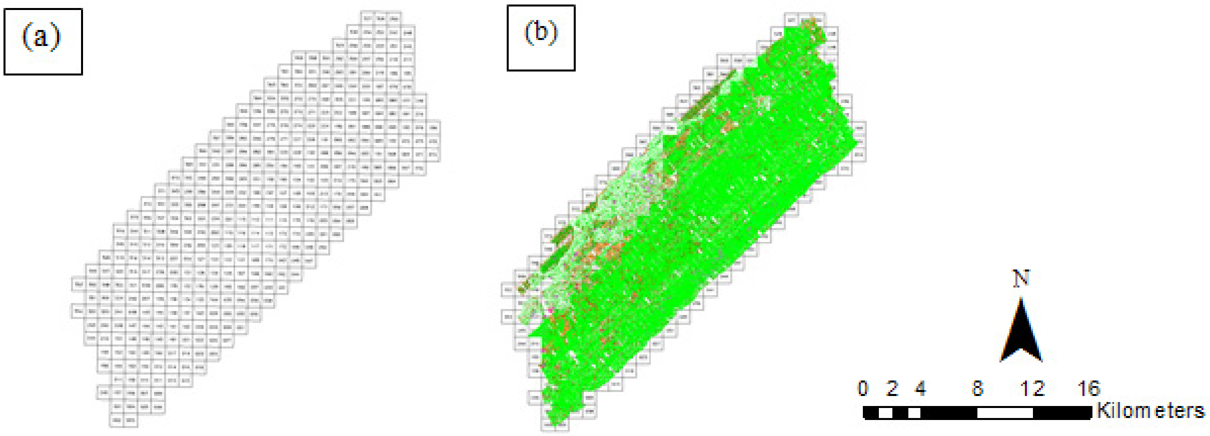

Figure 14. Tiles for Ransang Floodplain (a) and classification results (b) in TerraScan.

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.

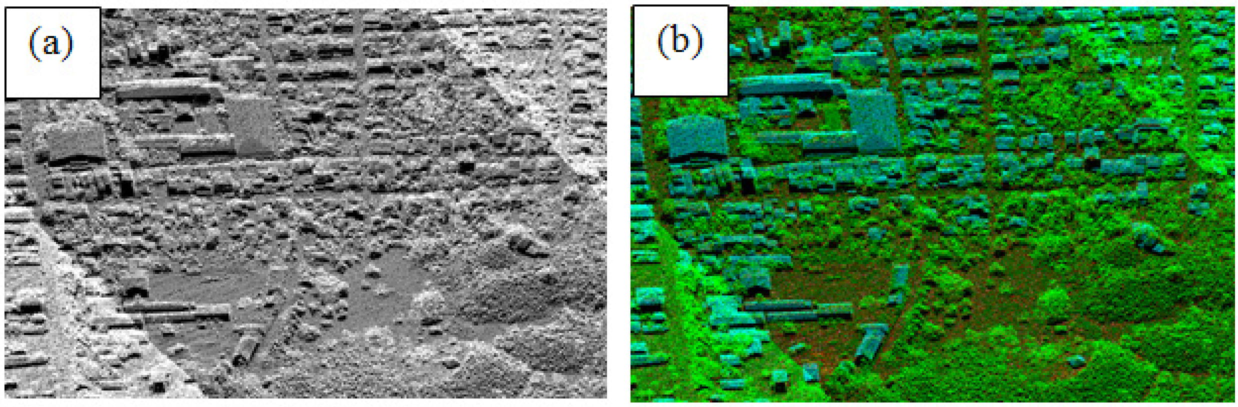

Figure 15. Point cloud before (a) and after (b) classification.

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.

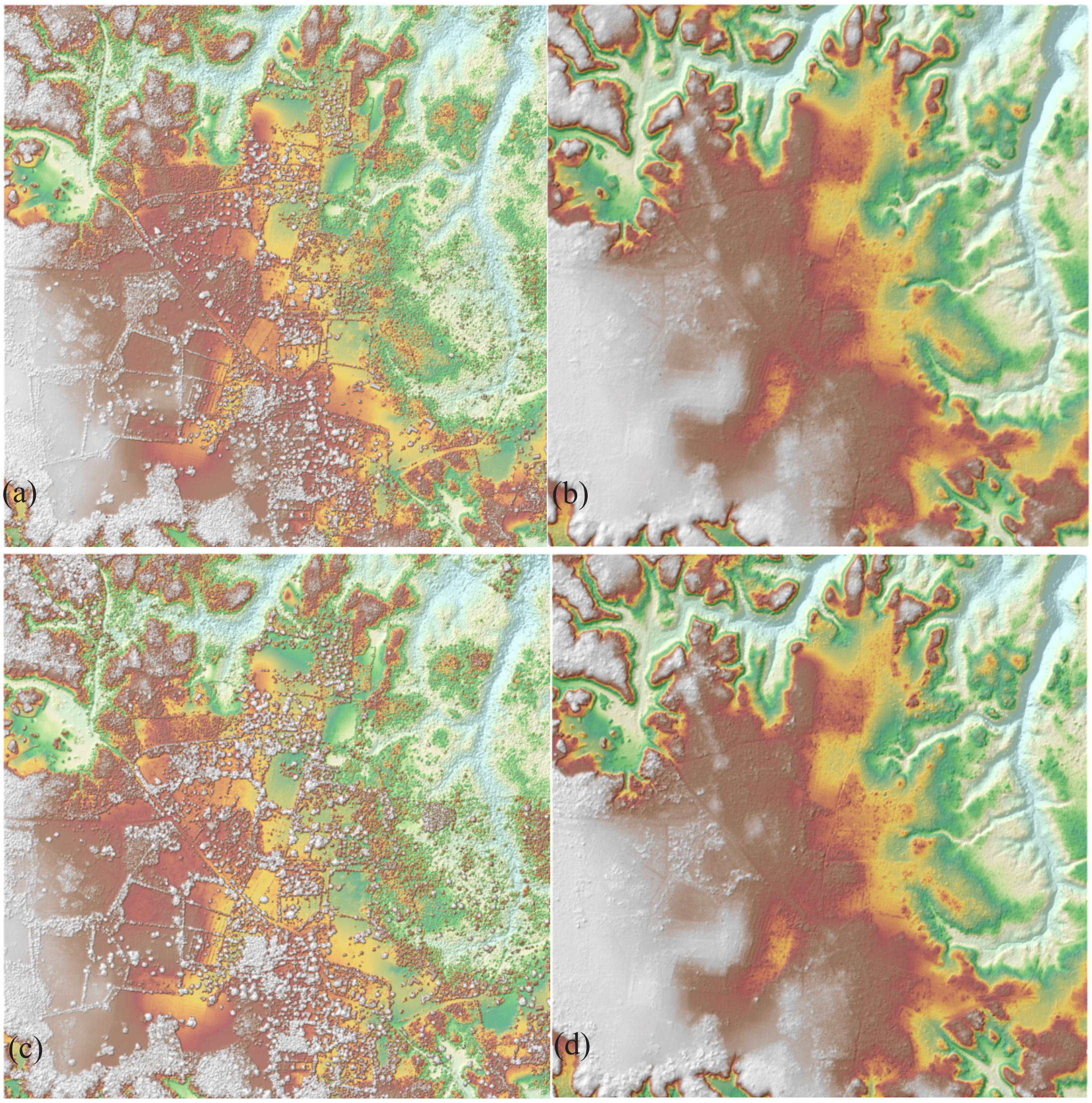

Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ransang Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 170 1km by 1km tiles area covered by Ransang 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 Ransang floodplain has a total of 123.03 sq.km orthophotograph coverage comprised of 217 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 18.

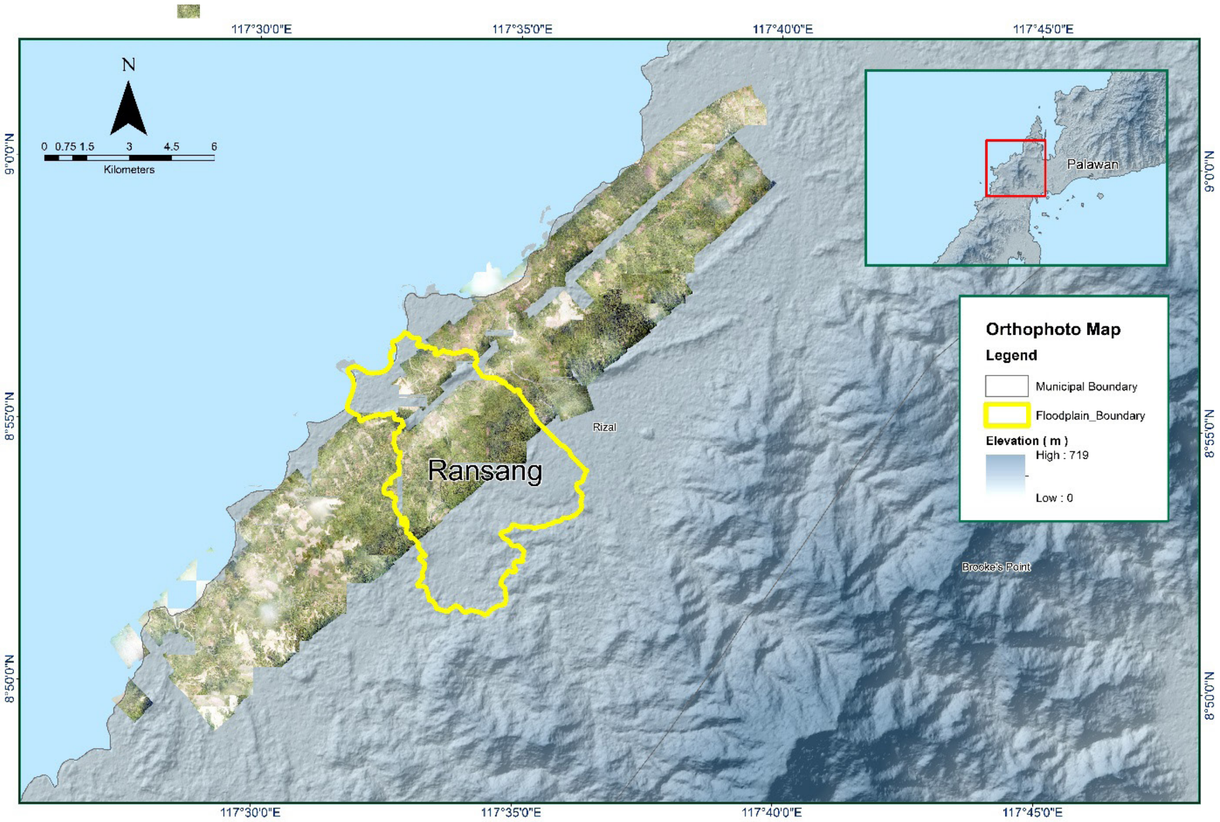

Figure 17. Ransang Floodplain with available orthophotographs

Figure 18. Sample orthophotograph tiles for Ransang Floodplain

3.8 DEM Editing and Hydro-Correction

One (1) mission block was processed for Ransang floodplain. The block is composed of a Palawan block with a total area of 302.86 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42P	302.86
TOTAL	**302.86 sq.km**

Portions of DTM before and after manual editing are shown in Figure 19. The bridge (Figure 19a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 19b) in order to hydrologically correct the river. The data gap (Figure 19c) has been filled to complete the surface (Figure 19d) to allow the correct flow of water.

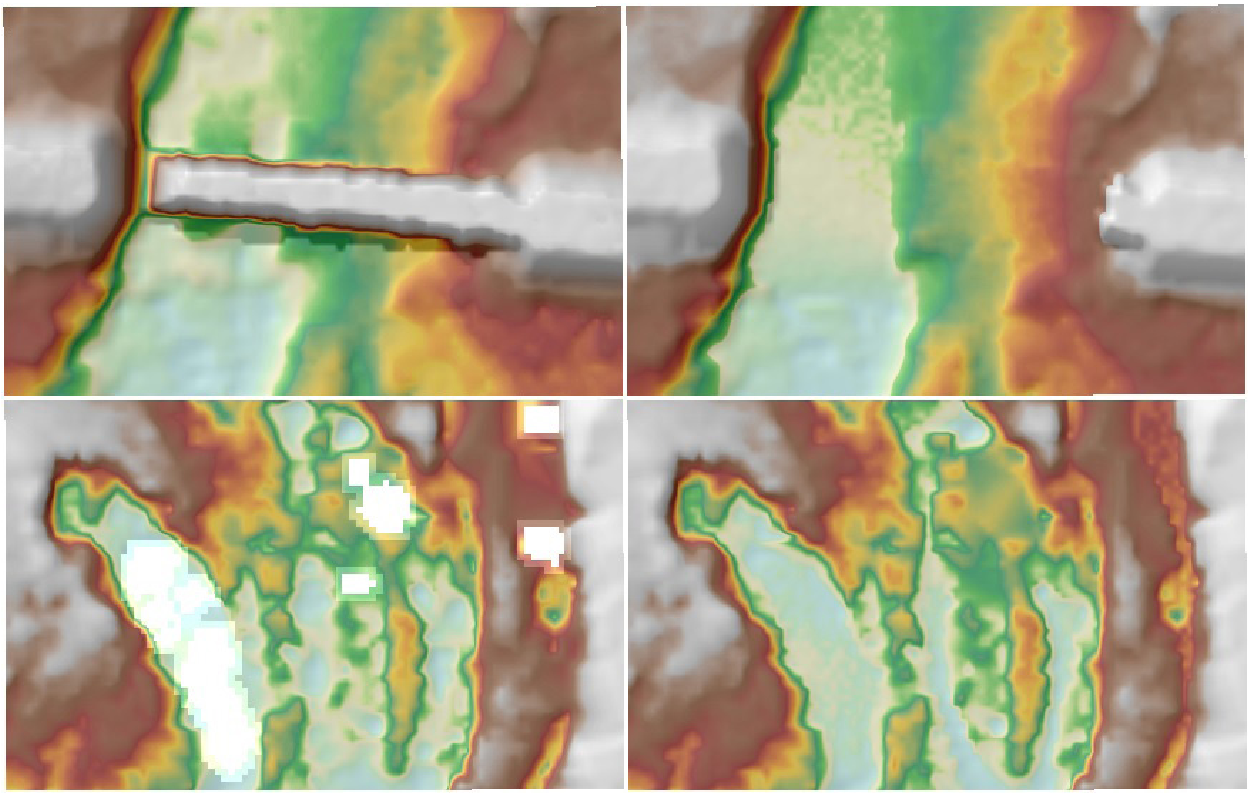

Figure 19. Portions in the DTM of Ransang Floodplain – a bridge before (a) and after (b) manual editing; and a data gap before (c) and after (d) filling.

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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 block mosaicked for the Ransang floodplain, it was concluded that the elevation of Palawan_Blk42P is in need to be adjusted before mosaicking the DTM.

Table 12. Shift Values of each LiDAR Block of Ransang Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42P	0.00	0.00	6.55

Mosaicked LiDAR DTM for Ransang floodplain is shown in Figure 20. It can be seen that the entire Ransang floodplain is 95% covered by LiDAR data.

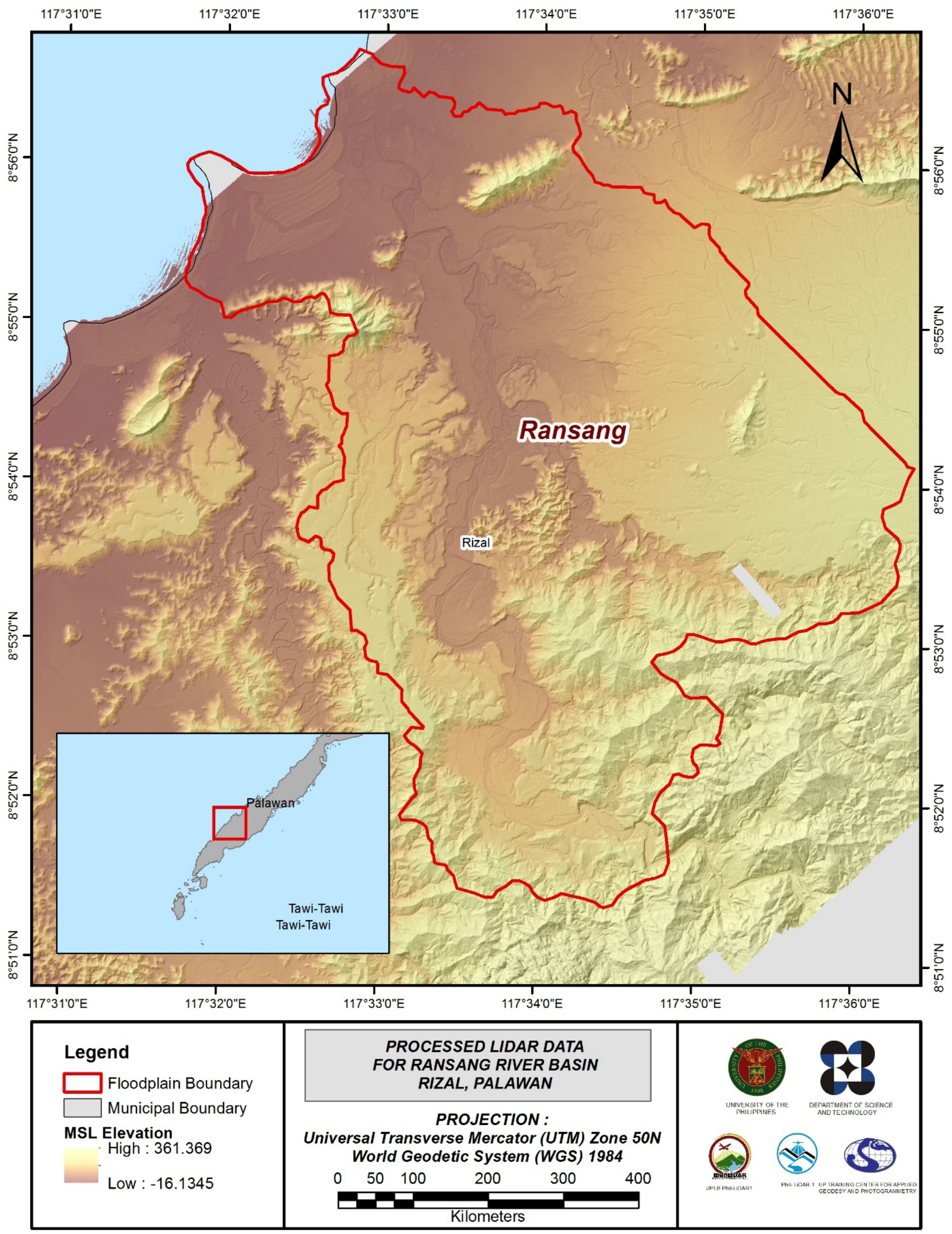


Figure 20. Map of Processed LiDAR Data for Ransang Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ransang to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 72 survey points were used for calibration and validation of Ransang LiDAR data. Random selection of 80% of the survey points, resulting to 58 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 14.63 meters with a standard deviation of 0.03 meters. Calibration of Ransang LiDAR data was done by adding the height difference value, 14.63 meters, to Ransang mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

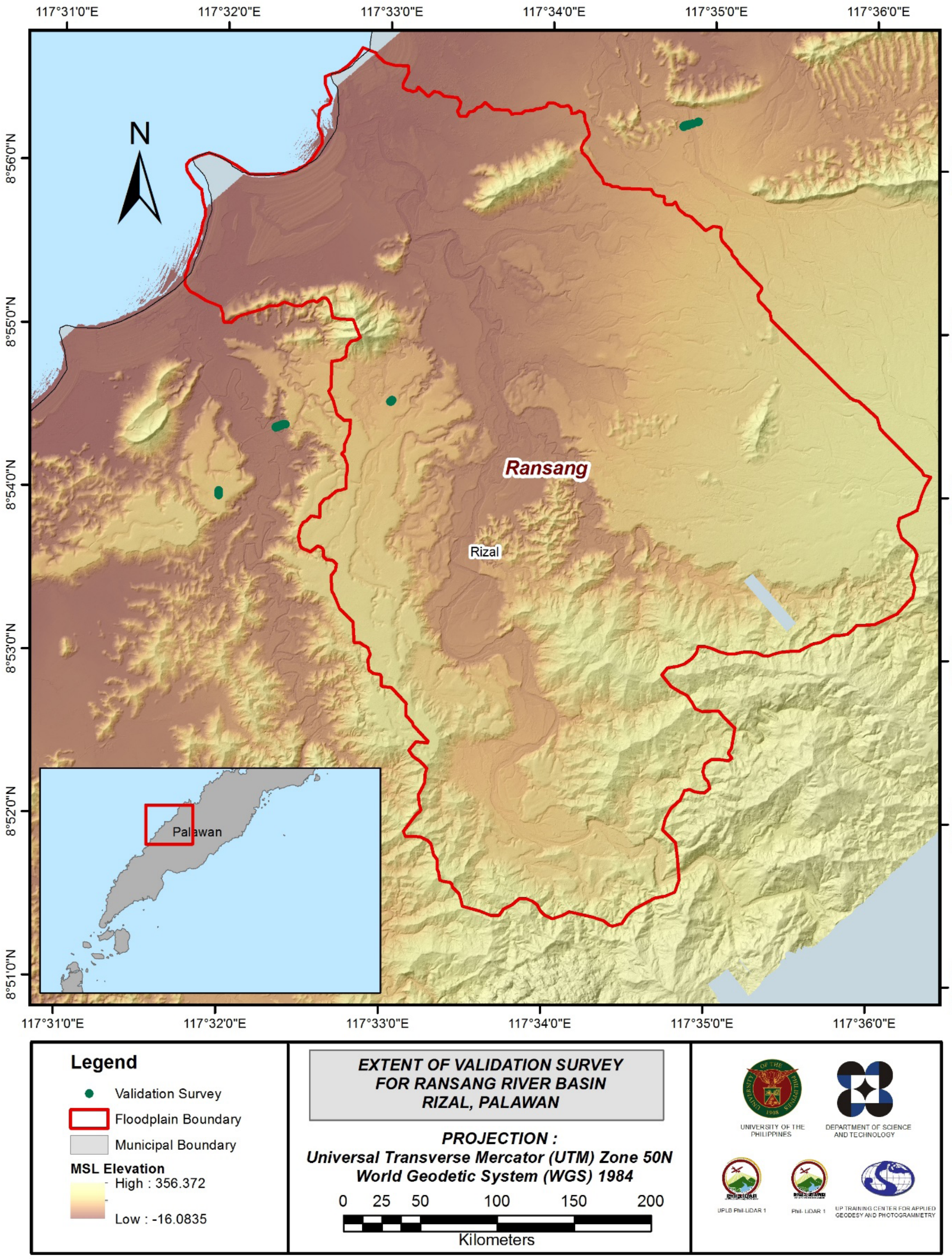


Figure 21. Map of Ransang Floodplain with validation survey points in green.

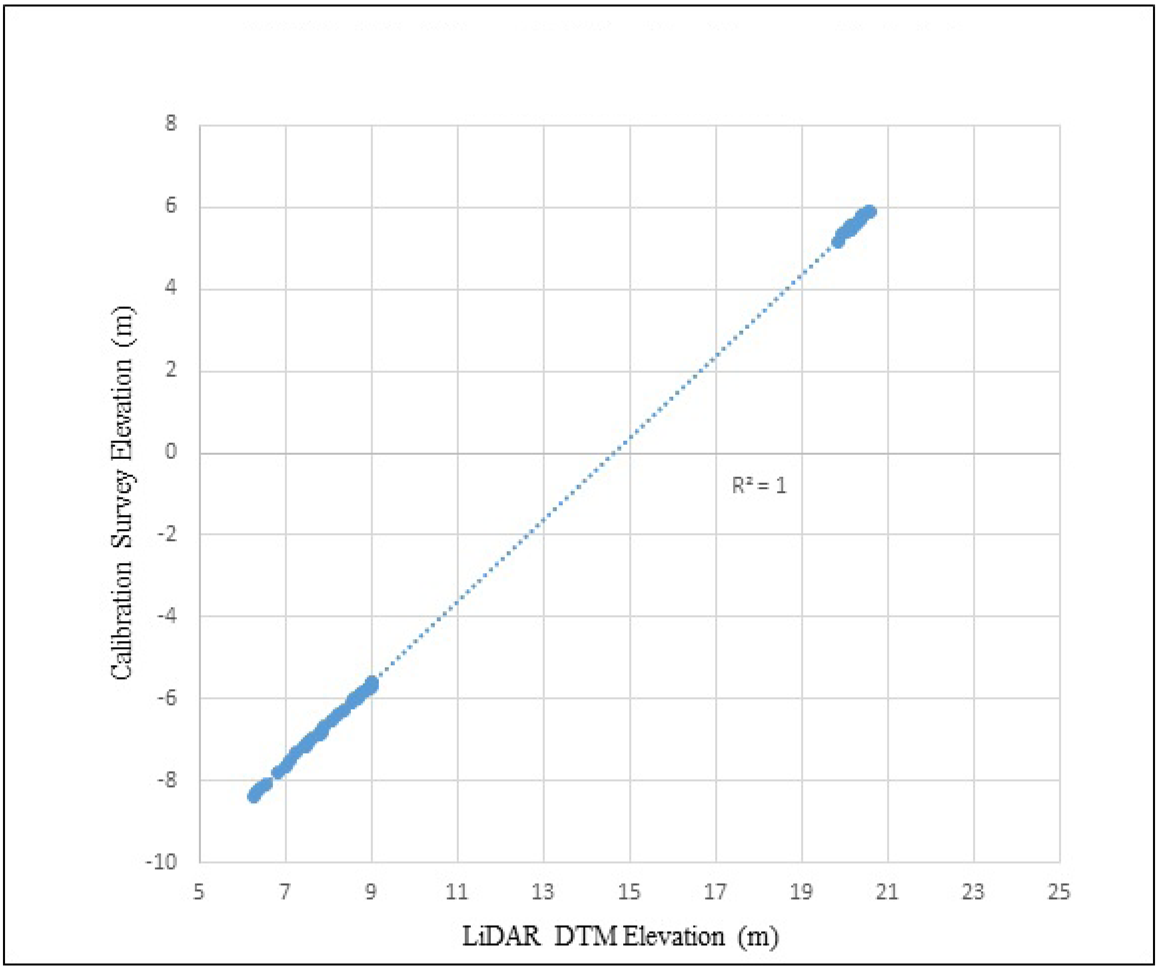


Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 13. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	14.63
Standard Deviation	0.03
Average	14.63
Minimum	14.58
Maximum	14.68

The remaining 20% of the total survey points, resulting to 14 points, were used for the validation of calibrated Ransang 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 0.03 meters with a standard deviation of 0.02 meters, as shown in Table 14.

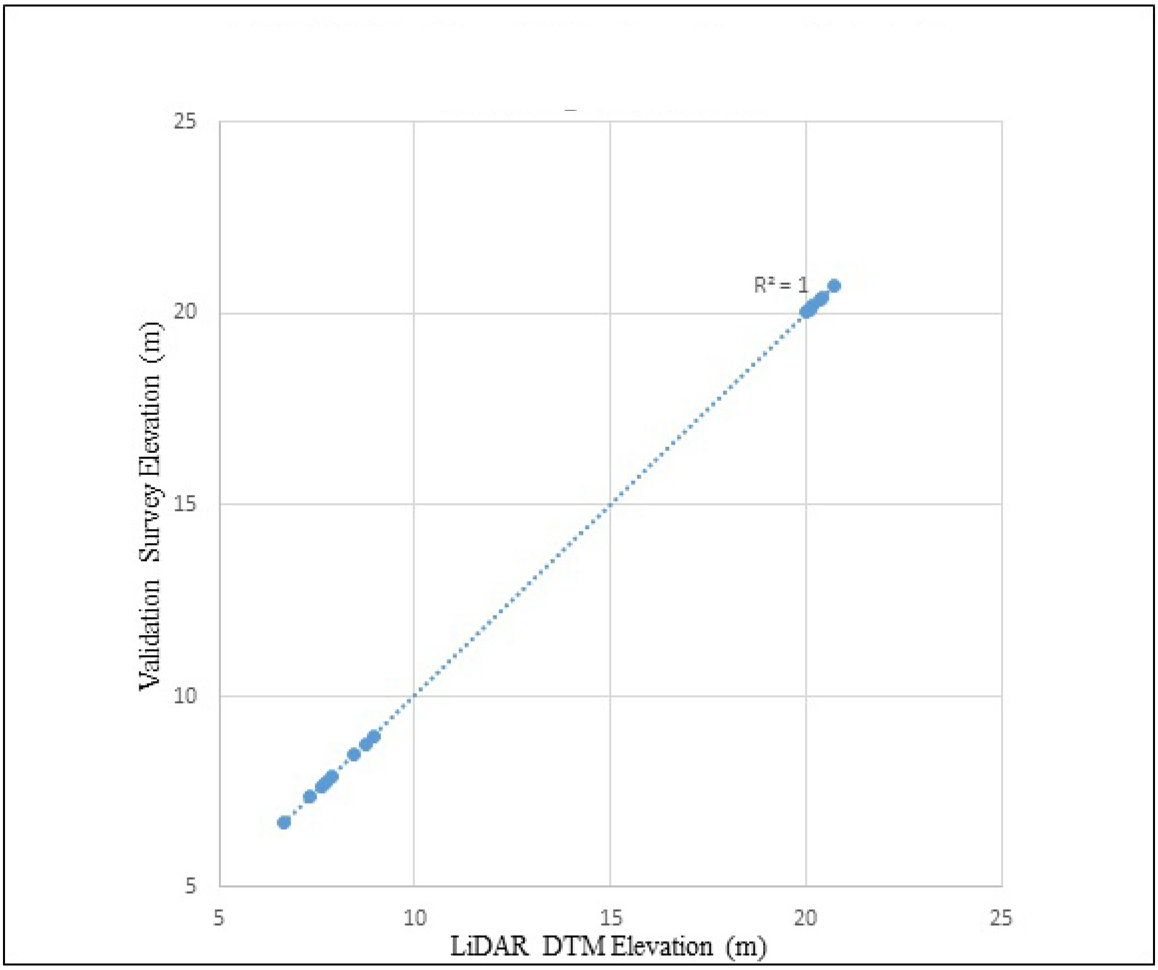


Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.03
Standard Deviation	0.02
Average	-0.02
Minimum	-0.07
Maximum	0.03

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathymetric data integration, zigzag and cross section were available, with 2,775 and 1,463 bathymetric points, respectively, resulting to a total of 4,238 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 0.43 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ransang integrated with the processed LiDAR DEM is shown in Figure 24.

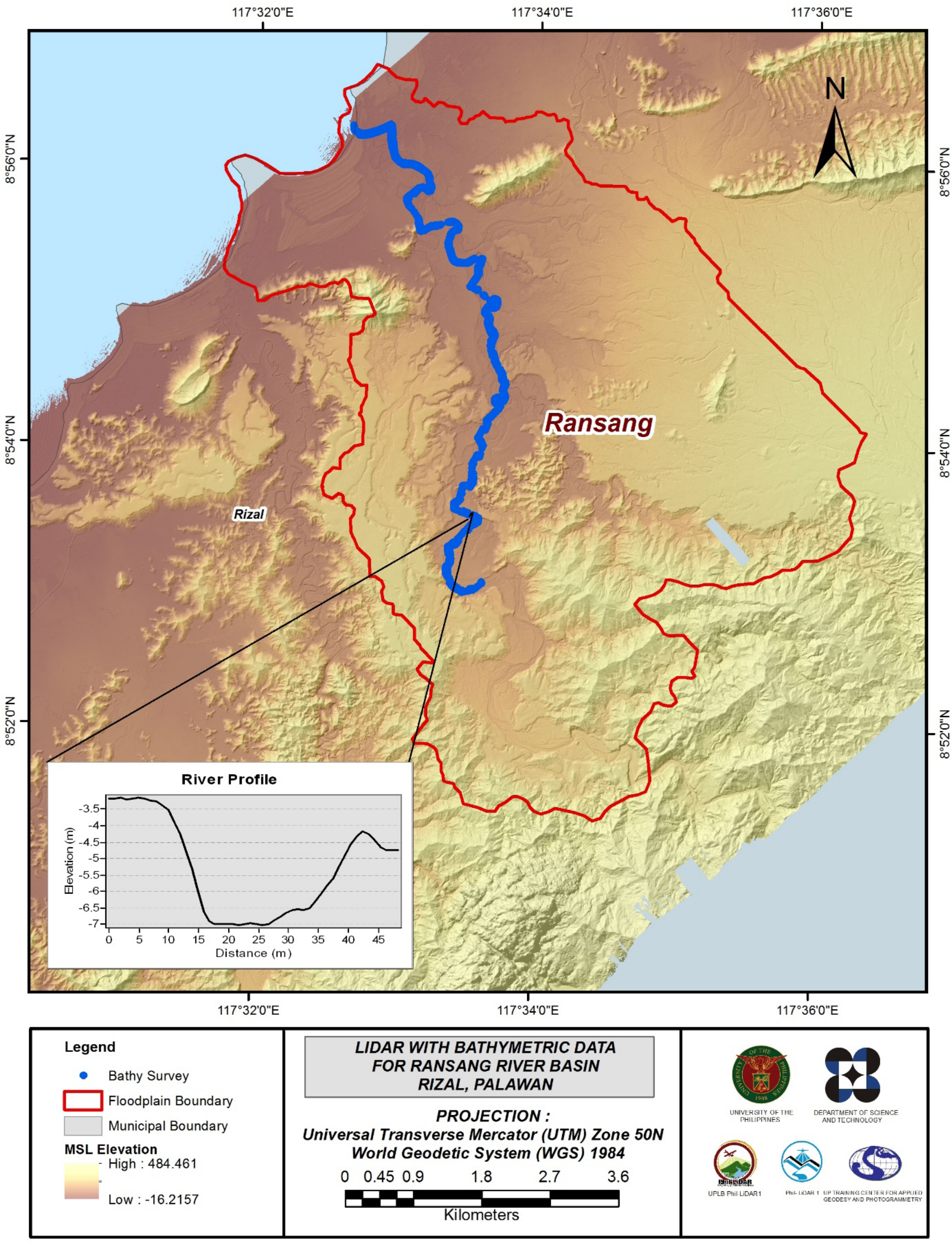


Figure 24. Map of Ransang Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF RANSANG 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

AB Surveying and Development (ABSD) conducted a field survey in Ransang River on December 5 and 28, 2015, and January 24, to 25, 2016 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Ransang Bridge in Brgy. Ransang, Municipality of Rizal, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVC 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 Ransang River Basin area. The entire survey extent is illustrated in Figure 25.

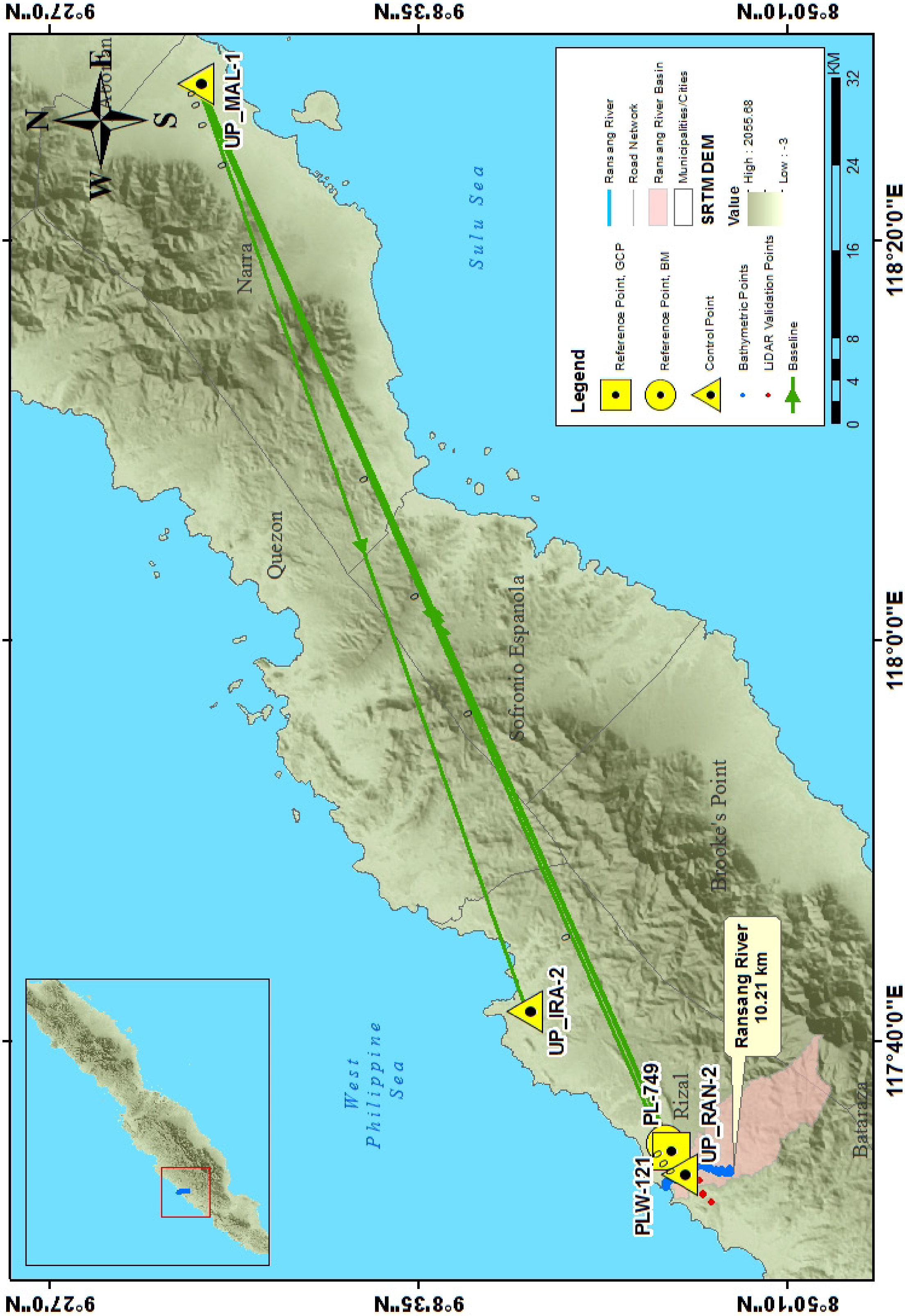


Figure 25. Ransang River Survey Extent

4.2 Control Survey

The GNSS network used for Ransang River is composed of two (2) loops established on occupying the following reference points: PLW-121, a second-order GCP, in Brgy. Ransang, Municipality of Rizal, Palawan; and PL-749, a first-order BM, in Brgy. Campong Ulay, Palawan.

Three (3) control points established in the area by ABSD were also occupied: UP_ILO-1 at the approach of Ilog-ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan, UP_MAL-1 at the approach of Malatgao Bridge in Brgy. Malatgao, Quezon, Palawan, and UP_RAN-2 located beside the riprap near Ransang Bridge in Brgy. Ransang, Municipality of Rizal, Province of Palawan.

The summary of reference and control points and its location is summarized in Table 15 while the GNSS network established is illustrated in Figure 26.

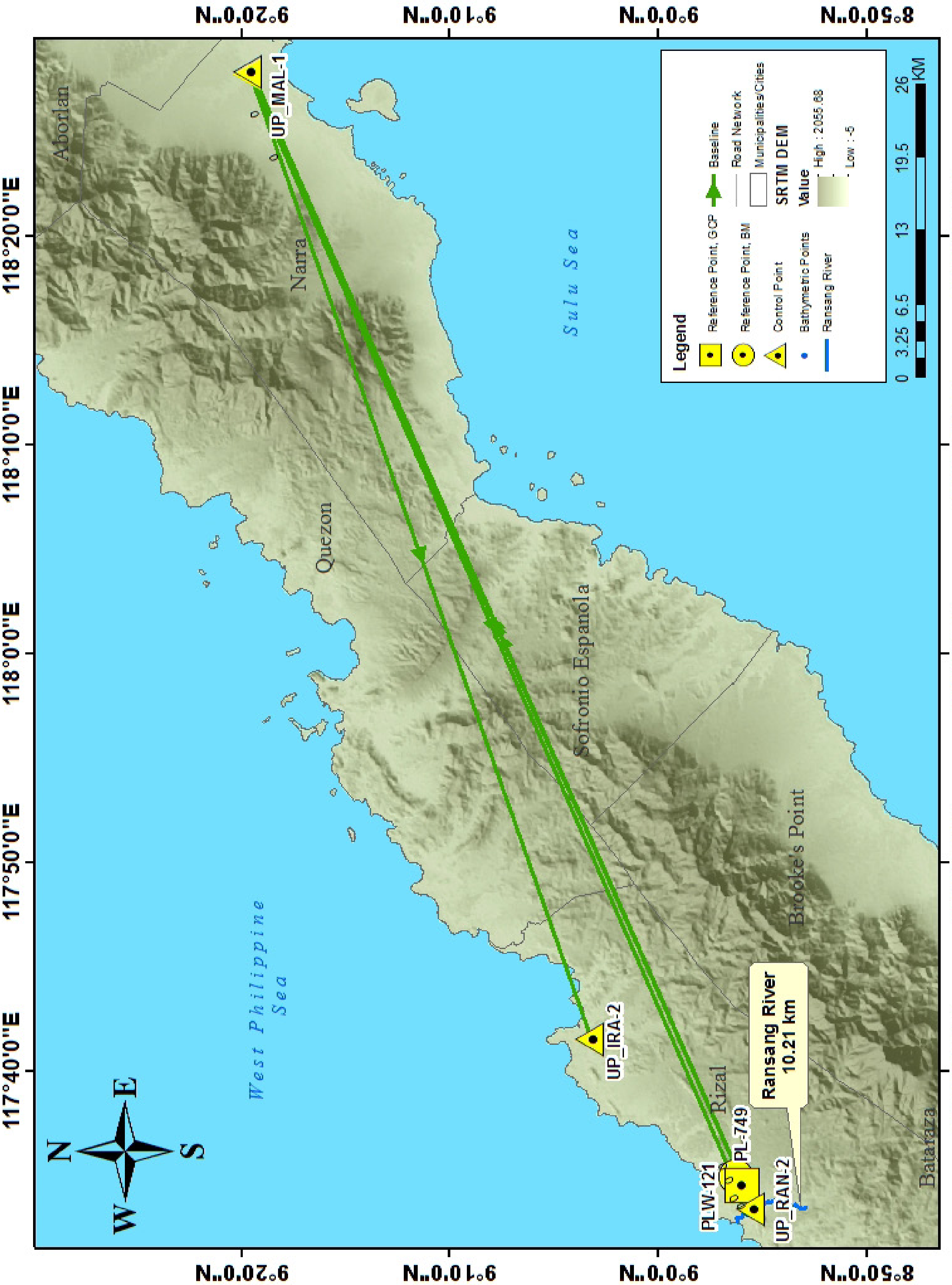


Figure 26. GNSS Network covering Ransang River

Table 15. List of reference and control points used during the survey in Ransang River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 50N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
PLW-121	2nd order, GCP	8°55'57.38325"N	117°34'29.39124"E	58.058	10.335	2007
PL-749	1st order, BM	8°56'16.45926"N	117°34'53.01226"E	62.444	14.692	2012
UP_ILO-1	Established	8°56'16.64151"N	117°34'53.41157"E	62.242	14.489	12-05-15
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	5.044	04-25-16
UP_RAN-2	Established	8°55'36.22496"N	117°33'21.55666"E	47.181	-0.406	12-05-15

The GNSS set-ups on recovered reference points and established control points in Ransang River are shown from Figure 27 to Figure 31.

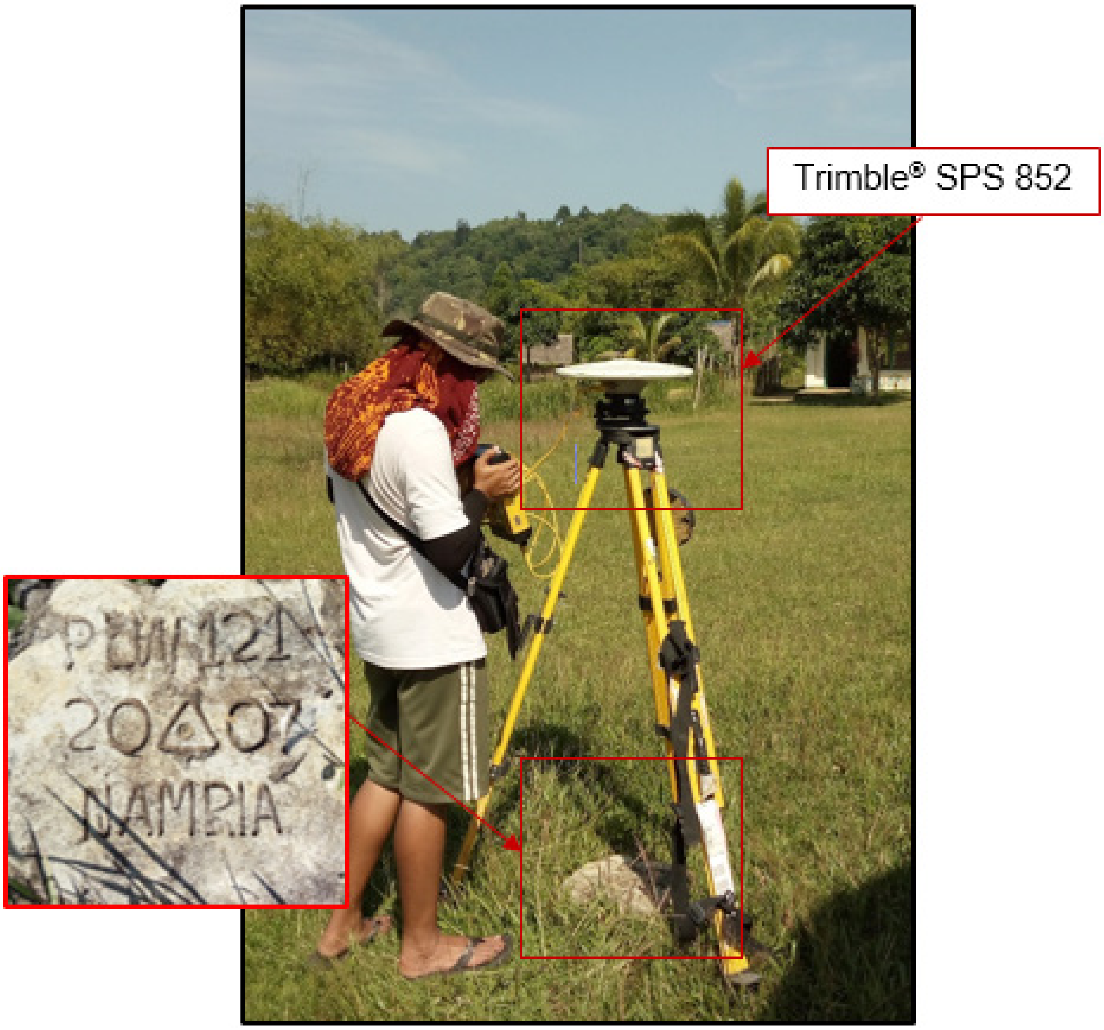


Figure 27. GNSS base set up, Trimble® SPS 852, at PLW-121, located along the edge of a basketball court inside Cabkungan Elementary School in Brgy. Ransang, Rizal, Province of Palawan

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

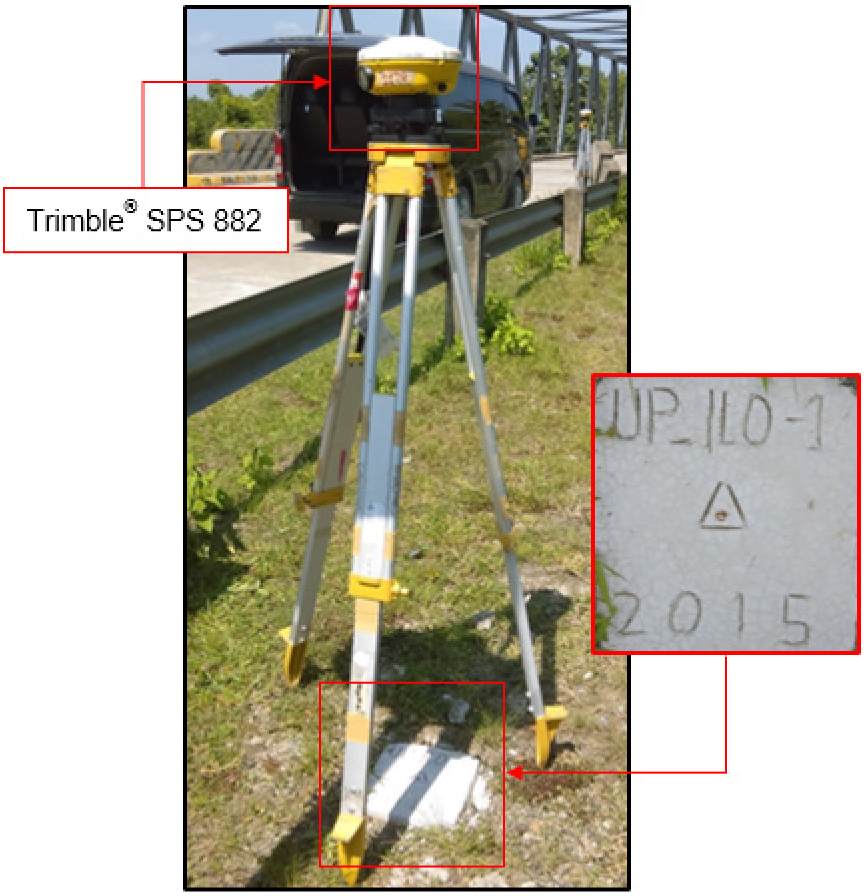


Figure 29. GNSS receiver set up, Trimble® SPS 882, at UP_ILO-1 near the approach of Ilog-Ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan

Figure 30. GNSS receiver set up, Trimble® SPS 985, at UP_MAL-1, Malambunga Bridge in Brgy. Punta Baja, Rizal, Province of Palawan

Figure 31. GNSS receiver set up, Trimble® SPS 882, at UP_RAN-2 beside the riprap near Ransang Bridge in Brgy. Ransang, 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 +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Ransang River Basin is summarized in Table C-2 generated by TBC software.

Table 16. Baseline Processing Report for Ransang River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
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
UP_ILO-1 --- UP_MAL-1	8-19-2016	Fixed	0.004	0.012	215°01'35"	13676.838	9.465
UP_MAL-1 -- UP_IRA-2	8-19-2016	Fixed	0.009	0.023	67°02'36	4630.420	-4.093
PLW-121 --- UP_ILO-1	8-19-2016	Fixed	0.002	0.002	231°07'17"	942.619	-4.184
PLW-121 --- UP_RAN-2	8-19-2016	Fixed	0.005	0.013	252°35'10"	2171.885	-10.878
PLW-121 --- UP_MAL-1	8-19-2016	Fixed	0.004	0.013	36°02'29"	14584.805	-5.289
UP_RAN-2 -- UP_ILO-1	8-19-2016	Fixed	0.005	0.015	66°07'44"	3068.568	15.065
UP_RAN-2 -- UP_MAL-1	8-19-2016	Fixed	0.006	0.018	40°34'00"	16380.815	5.587

As shown Table 16, a total of ten (10) baselines were processed with 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 from:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 17 to Table 19 for complete details.

The five (5) control points, PLW-121, PL-749, UP_ILO-1, UP_MAL-1, and UP-IRA-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of PLW-121 and UP_MAL-1 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 will be computed.

Table 17. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PLW-121	Global	Fixed	Fixed	Fixed	
UP_MAL-1	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 18.

Table 18. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PLW-121	563194.622	?	987450.572	?	10.335	?	LLh
PL-749	563915.056	0.004	988037.560	0.002	14.692	0.007	
UP_ILO-1	563927.242	0.001	988043.176	0.001	14.489	0.002	
UP_MAL-1	571754.477	?	999253.104	?	5.044	?	LLh
UP_RAN-2	561124.020	0.003	986797.593	0.002	-0.406	0.010	

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

a. **PLW-121**

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

b. **PL-749**

horizontal accuracy	=	√((0.4)² + (0.2)²
	=	√ (0.16 + 0.4)
	=	0.748 < 20 cm
vertical accuracy	=	0.7 < 10 cm

c. **UP_ILO-1**

horizontal accuracy	=	√((0.1)² + (0.1)²
	=	√ (0.01+ 0.01)
	=	0.141 < 20 cm
vertical accuracy	=	0.2 < 10 cm

d. **UP_MAL-1**

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

e. **UP_PAN-1**

horizontal accuracy	=	√((0.3)² + (0.2)²
	=	√ (0.09 + 0.04)
	=	0.36 < 20 cm
vertical accuracy	=	0.1 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required precision.

Table 19. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
PLW-121	8°55'57.38325"N	117°34'29.39124"E	58.058	?	LLh
PL-749	8°56'16.45926"N	117°34'53.01226"E	62.444	0.007	
UP_ILO-1	8°56'16.64151"N	117°34'53.41157"E	62.242	0.002	
UP_MAL-1	9°02'21.21274"N	117°39'10.37109"E	52.776	?	LLh
UP_RAN-2	8°55'36.22496"N	117°33'21.55666"E	47.181	0.010	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 20. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 21.

Table 20. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 50N)					
		Latitude	Longitude	Ellipsoidal Height (Meter)	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	10.335
PL-749	1st order, BM	8°56'16.45926"N	117°34'53.01226"E	62.444	988037.560	563915.056	14.692
UP_ILO-1	Established	8°56'16.64151"N	117°34'53.41157"E	62.242	988043.176	563927.242	14.489
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	999253.104	571754.477	5.044
UP_RAN-2	Established	8°55'36.22496"N	117°33'21.55666"E	47.181	986797.593	561124.020	-0.406

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

Cross-section and as-built surveys were conducted on November 29, 2015 at the upstream side of Ransang Bridge in Brgy. Ransang, Municipality of Rizal as shown in Figure 32. A Hi-Target™ Total Station was utilized for this survey as shown in Figure 33.

Figure 32. Ransang Bridge facing downstream

Figure 33. As-built survey of Ransang Bridge

The cross-sectional line of Ransang Bridge is about 125.944 m with thirty-nine (39) cross-sectional points using the control points UP_RAN-1 and UP_RAN-2 as the GNSS base stations. The location map, cross-section diagram, and the bridge data form are shown in Figure 34 to Figure 36.

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 (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R^2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.9972 was obtained was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. A computed value of 0.1313 for the bridge cross-section data with a radial maximum radial distance of 3.4086 was obtained, which is within the allowable 5 meters.

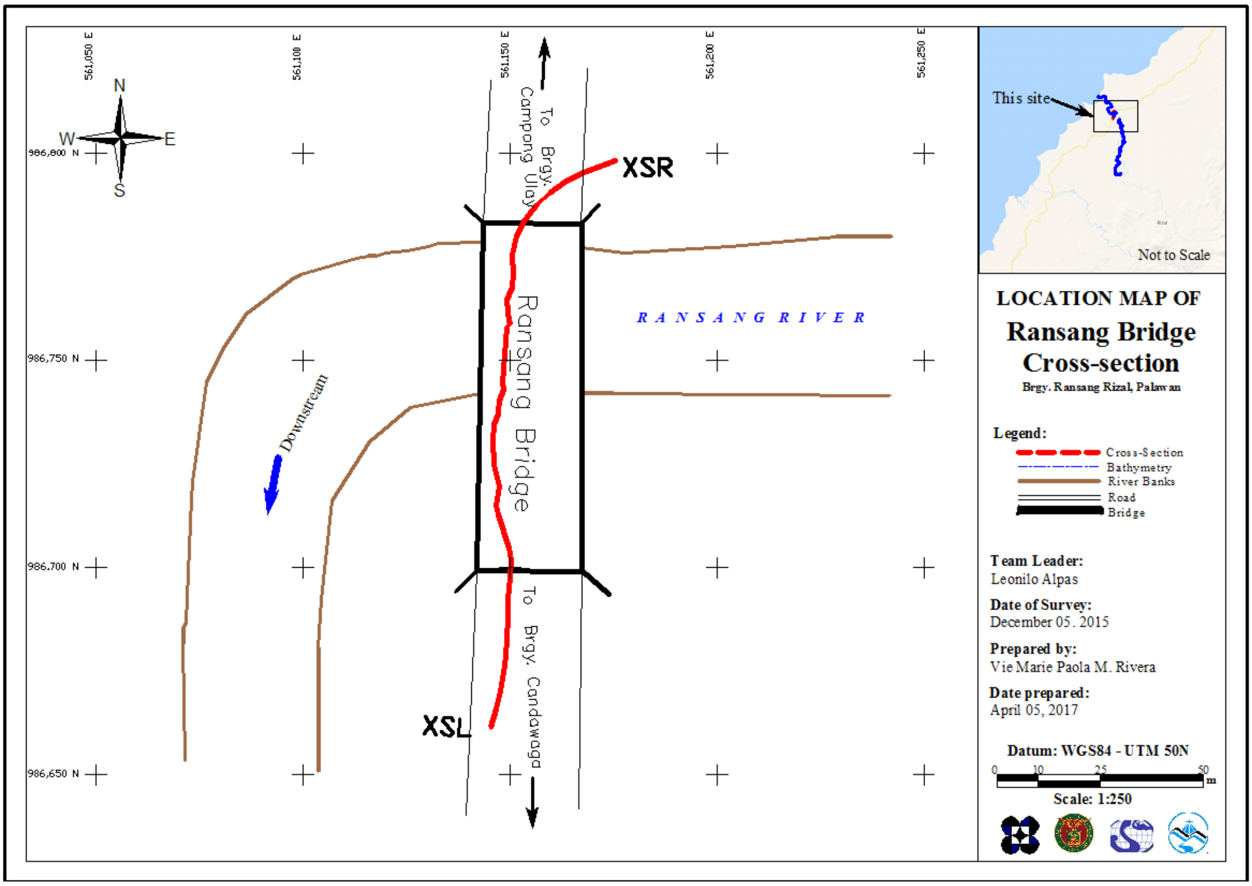


Figure 34. Location Map of Ransang Bridge River Cross-Section survey

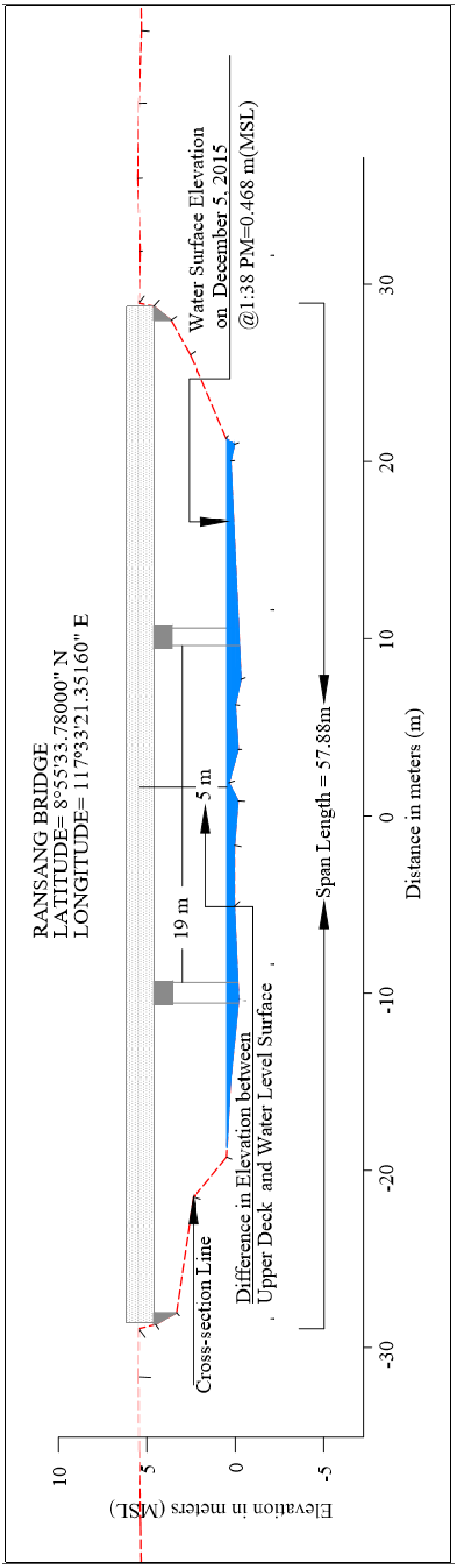


Figure 35. Ransang Bridge cross-section diagram

Bridge Data Form

Bridge Name: RANSANG BRIDGE

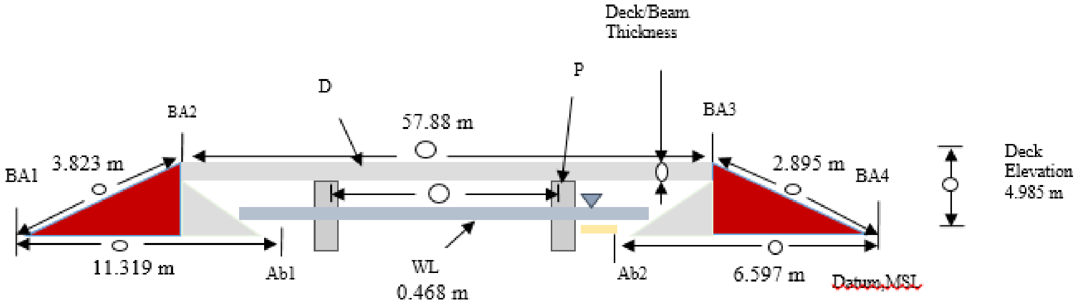
River Name: RANSANG RIVER
Location (Brgy,City,Region): Brgy. Ransang Rizal, Palawan

Survey Team: Nilo Alpas, Christorey Dela Peña
Date and Time: December 5, 2015 1:38 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	3.823 m	
2. BA2-BA3	57.88 m	
3. BA3-BA4	2.895 m	
4. BA1-Ab1	11.319 m	
5. Ab2-BA4	6.597 m	
6. Deck/beam thickness	N/A	No beam
7. Deck elevation	4.985 m	

Note: Observer should be facing downstream

Figure 36. Bridge as-built form of Ransang Bridge

Water surface elevation of Ransang River was determined by a Horizon® Total Station on December 5, 2015 at 1:28 PM at Ransang Bridge area with a value of 0.468 m in MSL as shown in Figure 35. This was translated into marking on the bridge's pier as shown in Figure 37. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Ransang River, the University of the Philippines Los Baños.

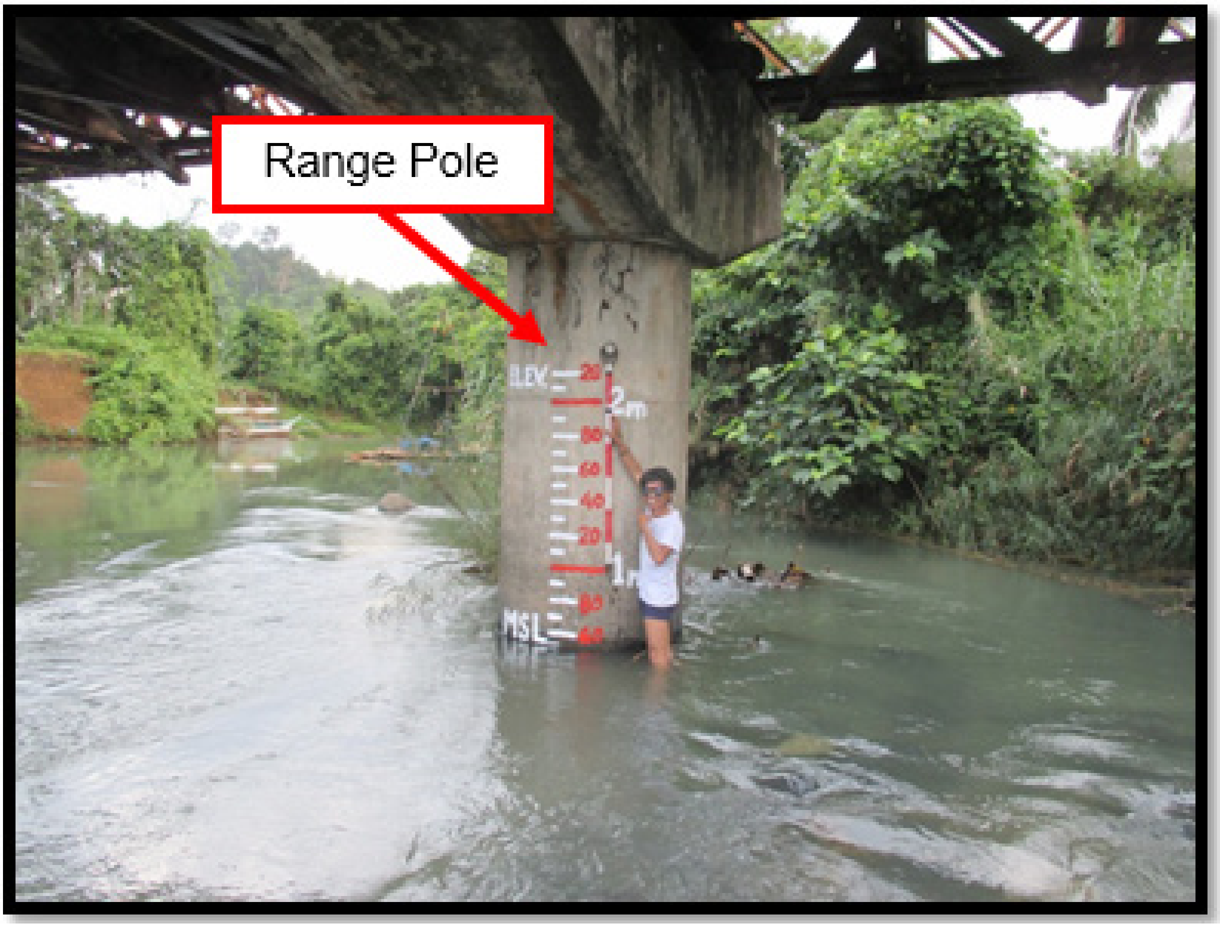


Figure 37. Water-level markings on Ransang Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 16-28, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 38. 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_ILO-1 occupied as the GNSS base station in the conduct of the survey.

Figure 38. Validation points acquisition survey set-up for Ransang River

The survey started from Brgy. Ransang, Municipality of Rizal, Palawan going north west along national high way covering two (2) barangays in the Municipality of Rizal, and ended in Brgy. Campong Ulay, Municipality of Rizal, Palawan. Concrete roads were very sparse along the Ransang River Basin, hence, few validation points were acquired. The survey gathered a total of 2,690 points with approximate length of 8.44 km using UP_ILO-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 39.

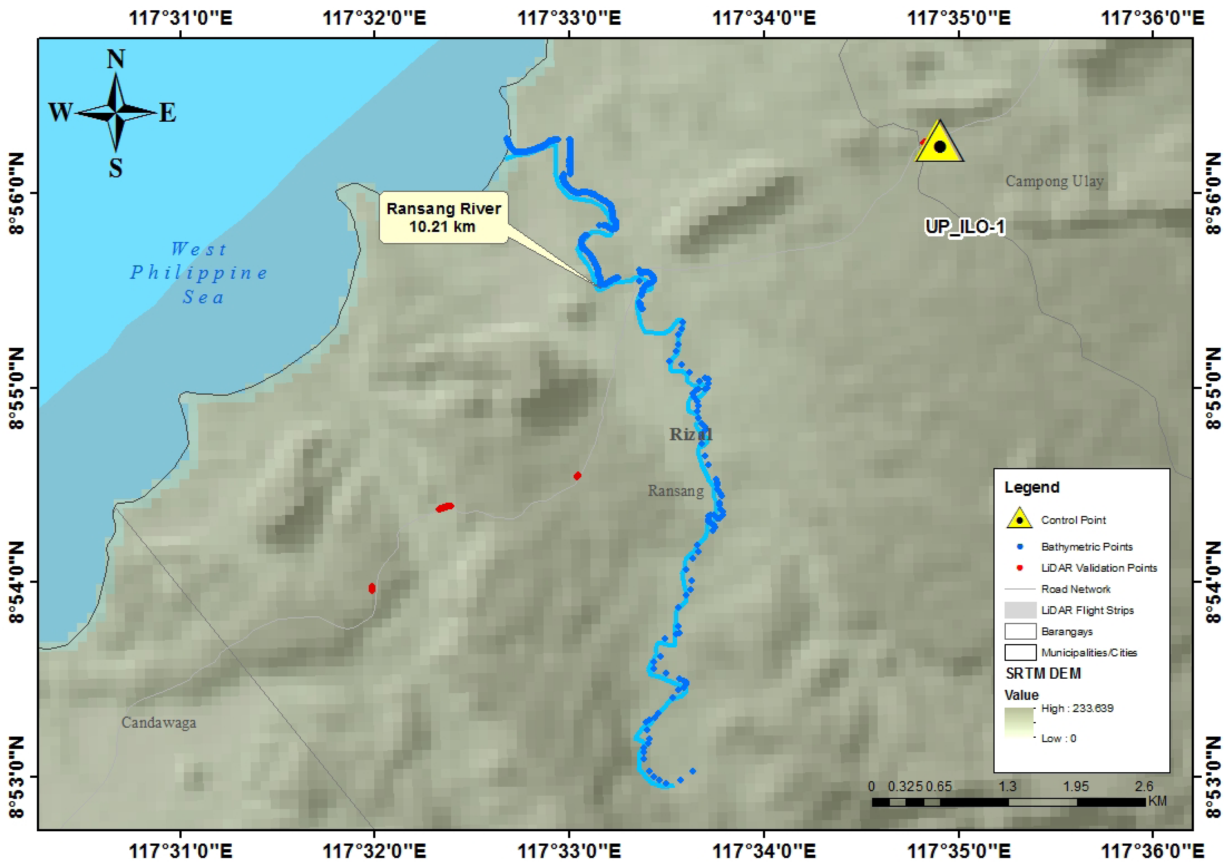


Figure 39. Validation point acquisition survey of Ransang River Basin

Figure 40. Terrain along Ransang River Basin

4.7 Bathymetric Survey

Bathymetric survey was executed on December 7, 2015 using an echo sounder as illustrated in Figure 41. The survey started in Brgy. Ransang, Municipality of Rizal, Palawan with coordinates 8°55'21.61287"N, 117°33'23.07996"E and ended at the mouth of the river in Brgy. Ransang, Municipality of Rizal as well, with coordinates 8°55'45.61501"N, 117°33'3.78324"E. The control points UP_RAN-1 and UP_RAN-2 were used as GNSS base stations all throughout the entire survey.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVC on August 20, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique, as shown in Figure 42. A map showing the DVC bathymetric checking points is shown in Figure 44.

Linear square correlation (R^2) and RMSE analysis were also performed on the two (2) datasets. The computed R^2 values of 0.947 and 0.985 for centerline and zigzag line bathymetry, respectively, which are within the required range for R^2, which is 0.85 to 1. Additionally, an RMSE value of 0.3092 was obtained. Both the computed R^2 and RMSE values are within the accuracy required by the program.

Figure 41. Bathymetric survey of ABSD at Ransang River using Hi-Target™ Echo Sounder (downstream)

Figure 42. Gathering of random bathymetric points along Ransang River

The bathymetric survey for Ransang River gathered a total of 4,672 points covering 7.59 km of the river traversing Brgy. Ransang in the Municipality of Rizal, as illustrated in Figure 43.

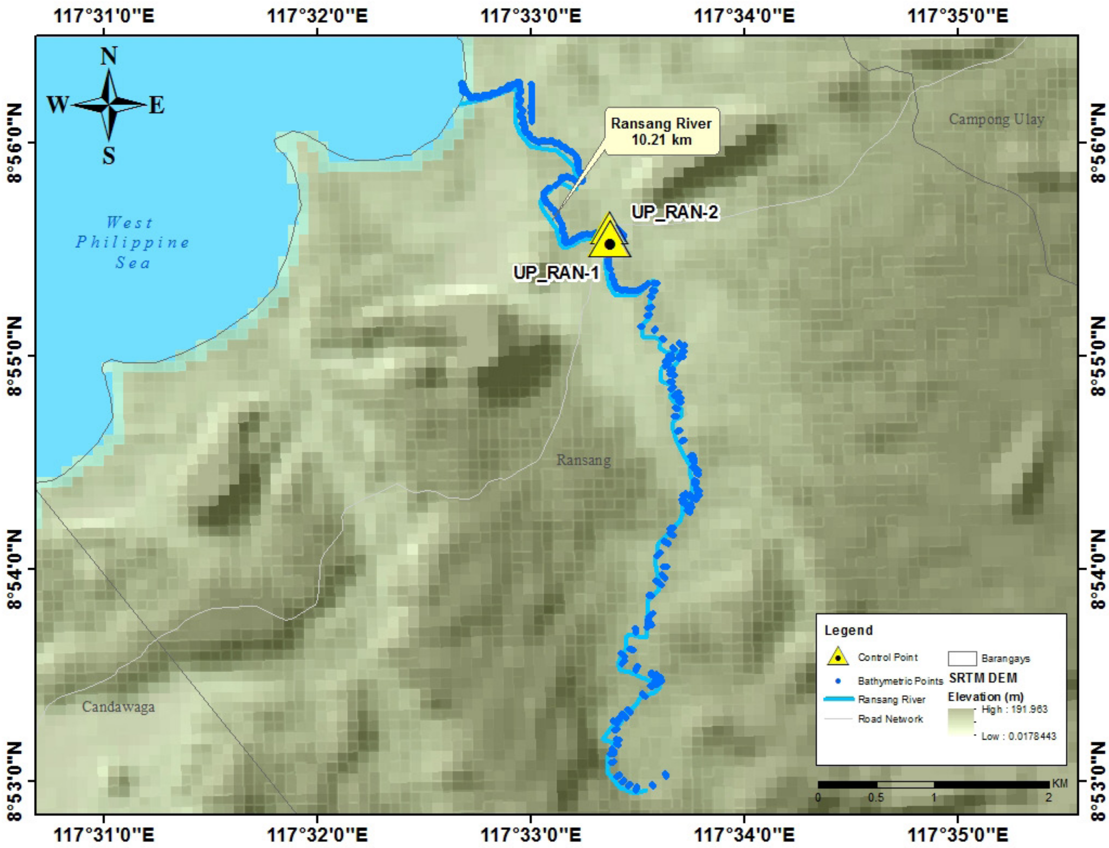


Figure 43. Bathymetric survey of Ransang River

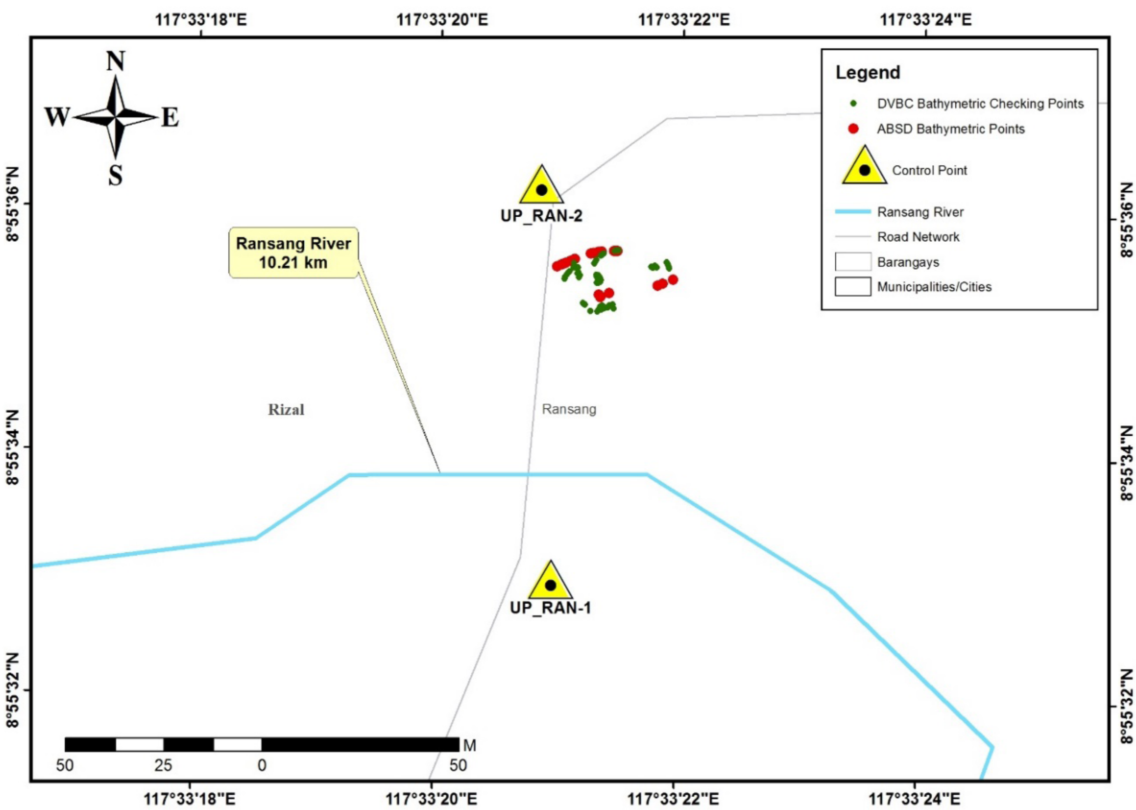


Figure 44. Quality checking points gathered along Ransang River by DVBC

A CAD drawing was also produced to illustrate the riverbed profile of Ransang River. As shown in Figure C-21, the highest and lowest elevation has a 5-m difference. The highest elevation observed was 0.990 m above MSL while the lowest was -4.671 m below MSL located in Brgy. Ransang, Municipality of Rizal.

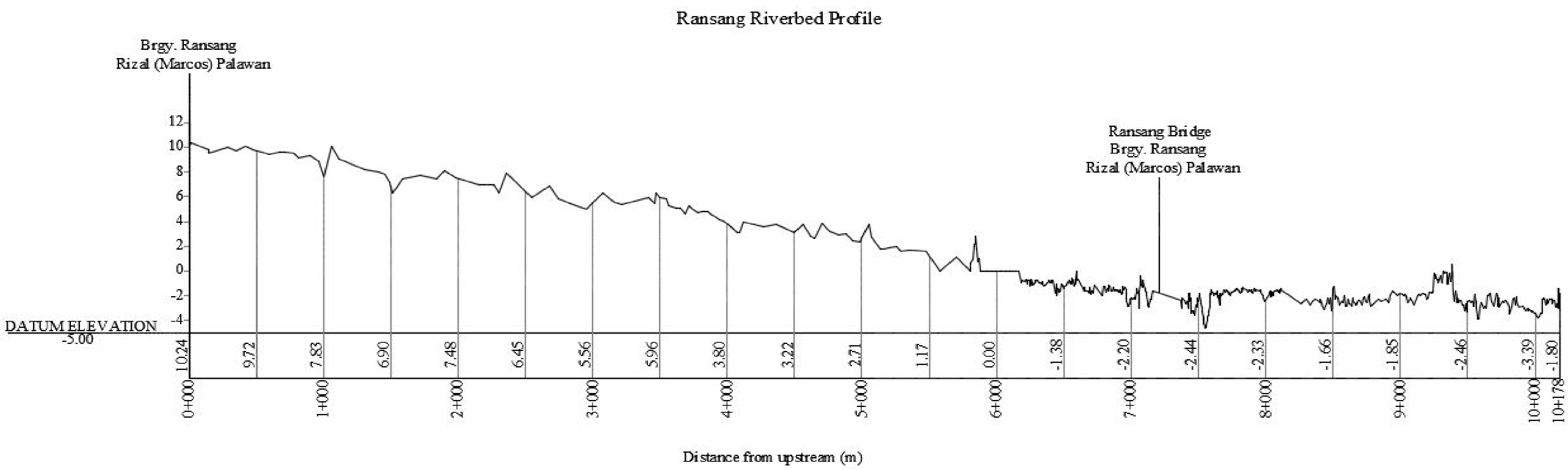


Figure 45. Ransang riverbed profile

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 in Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Ransang 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 Ransang 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 (8.925884˚ N, 117.555946˚ E). The location of the rain gauge is seen in Figure 46.

The total precipitation for this event is 38.0 mm. It has a peak rainfall of 4.0 mm on June 20, 2016 at 12:15 pm. The lag time between the peak rainfall and discharge is 4 hour and 50 minutes, as seen in Figure 49.

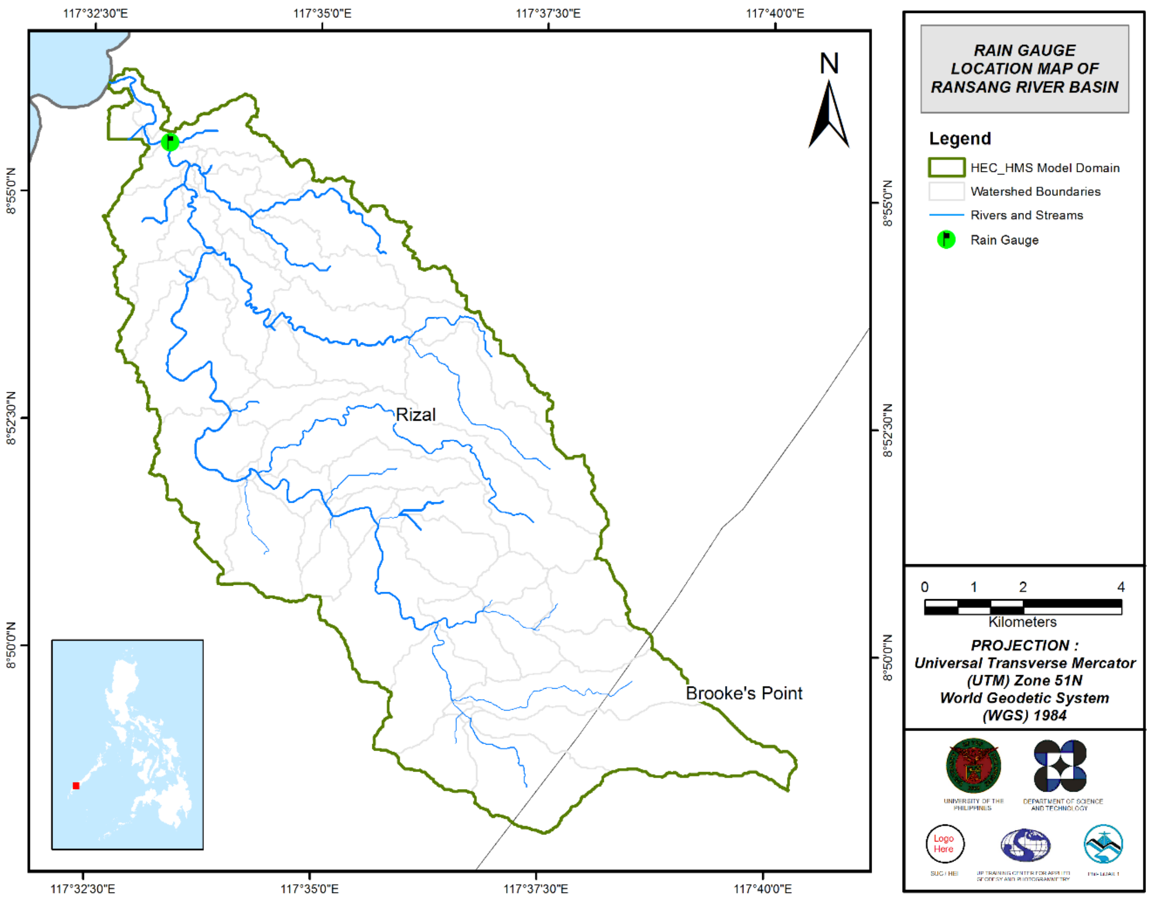


Figure 46. The location map of Ransang HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Ransang Bridge, Rizal, Palawan (8.926128°N, 117.555961°E). It gives the relationship between the observed water levels from the Ransang Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Ransang Bridge, the rating curve is expressed as $Q = 12.984e^{0.7079x}$ as shown in Figure 48.

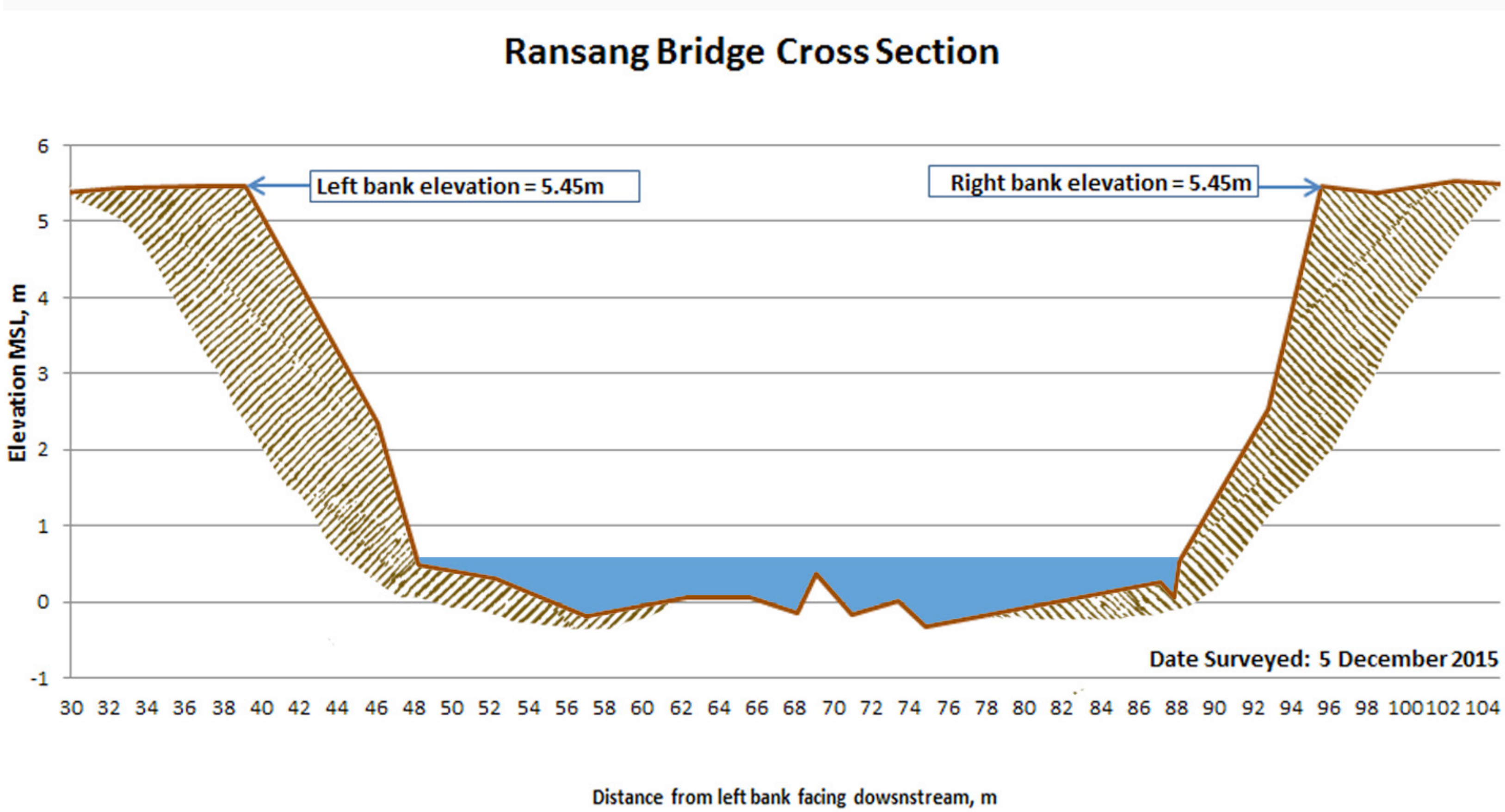


Figure 47. Cross-Section Plot of Ransang Bridge

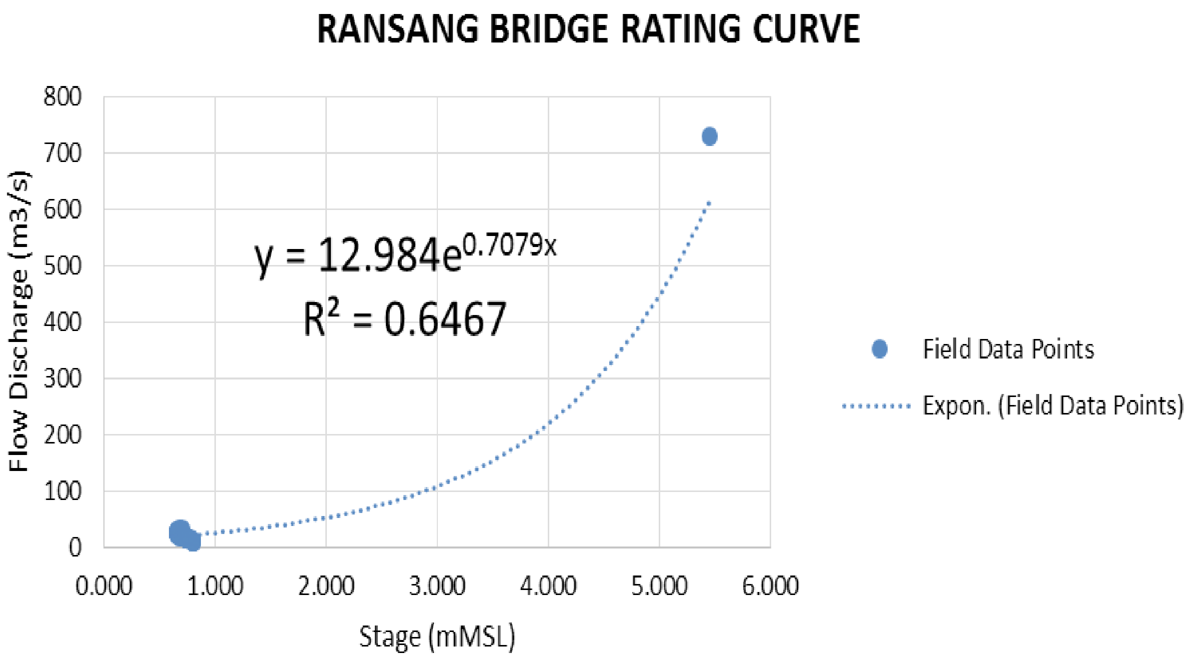


Figure 48. Rating Curve at Ransang Bridge, Rizal, Palawan

For the calibration of the HEC-HMS model, shown in Figure 49, actual flow discharge during a rainfall event was collected in the Ransang bridge. Peak discharge is 25.690 cu.m/s on June 20, 2016 at 5:05 pm.

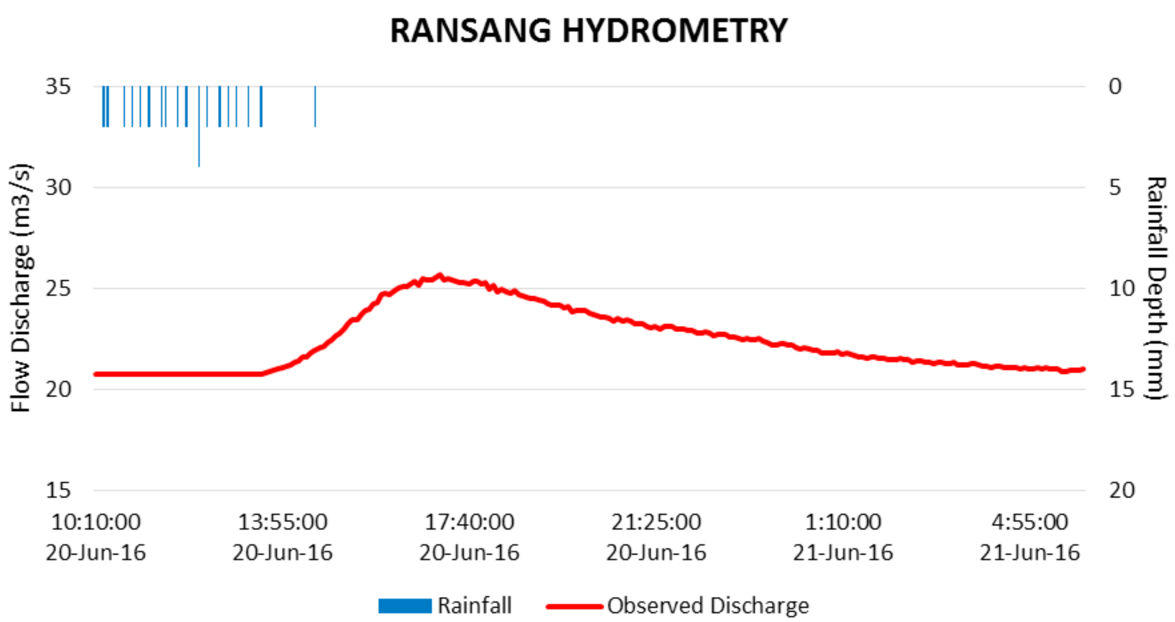


Figure 49. Rainfall and outflow data at Ransang used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Ransang watershed. The extreme values for this watershed were computed based on a 58-year record, as shown in Table 21.

Table 21. RIDF values for Puerto Princesa 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

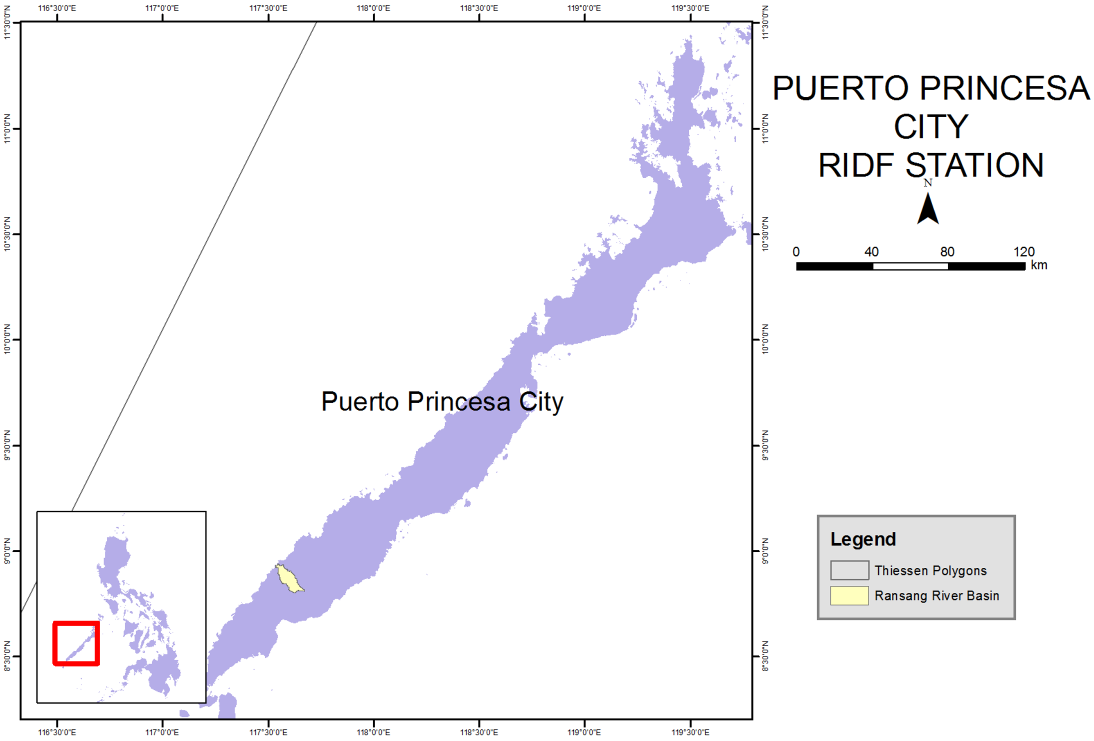


Figure 50. Location of Puerto Princesa RIDF relative to Ransang River Basin

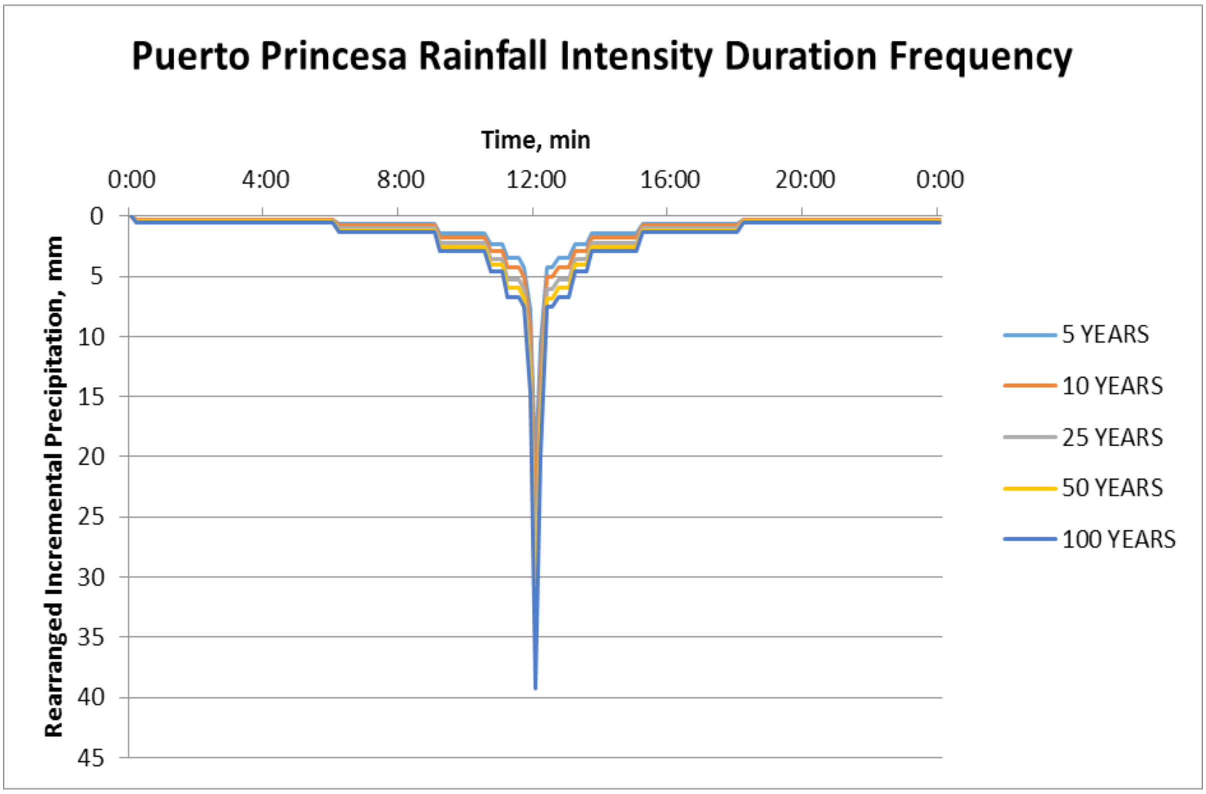


Figure 51. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Ransang River Basin are shown in Figure 52 and Figure 53, respectively.

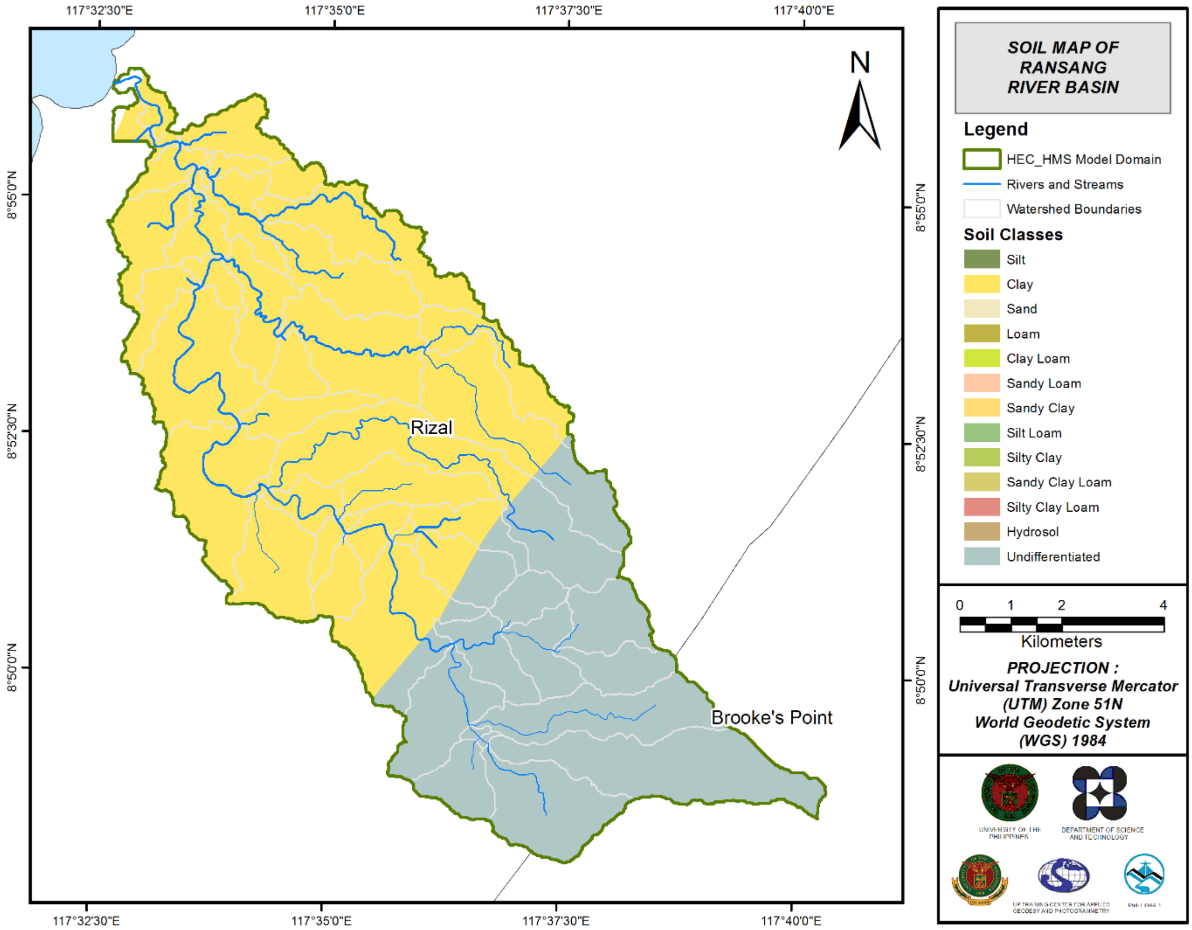


Figure 52. Soil map of Ransang River Basin used for the estimation of the CN parameter. (Source: DA)

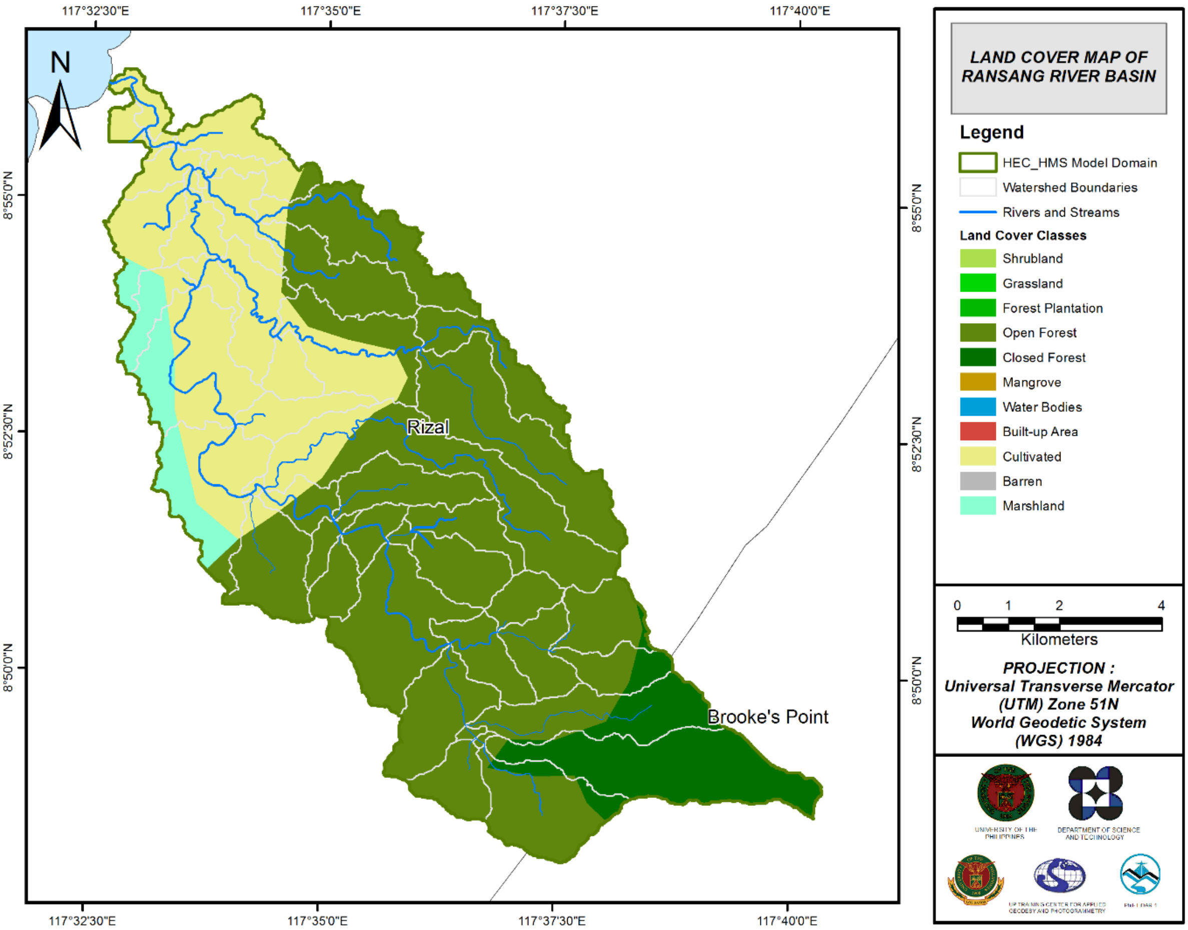


Figure 53. Land cover map of Ransang River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Ransang river basin, the two (2) soil classes identified were sandy clay and undifferentiated soil. The six (6) land cover types identified were largely open forest and cultivated area, with smaller portions of closed forest and marshland.

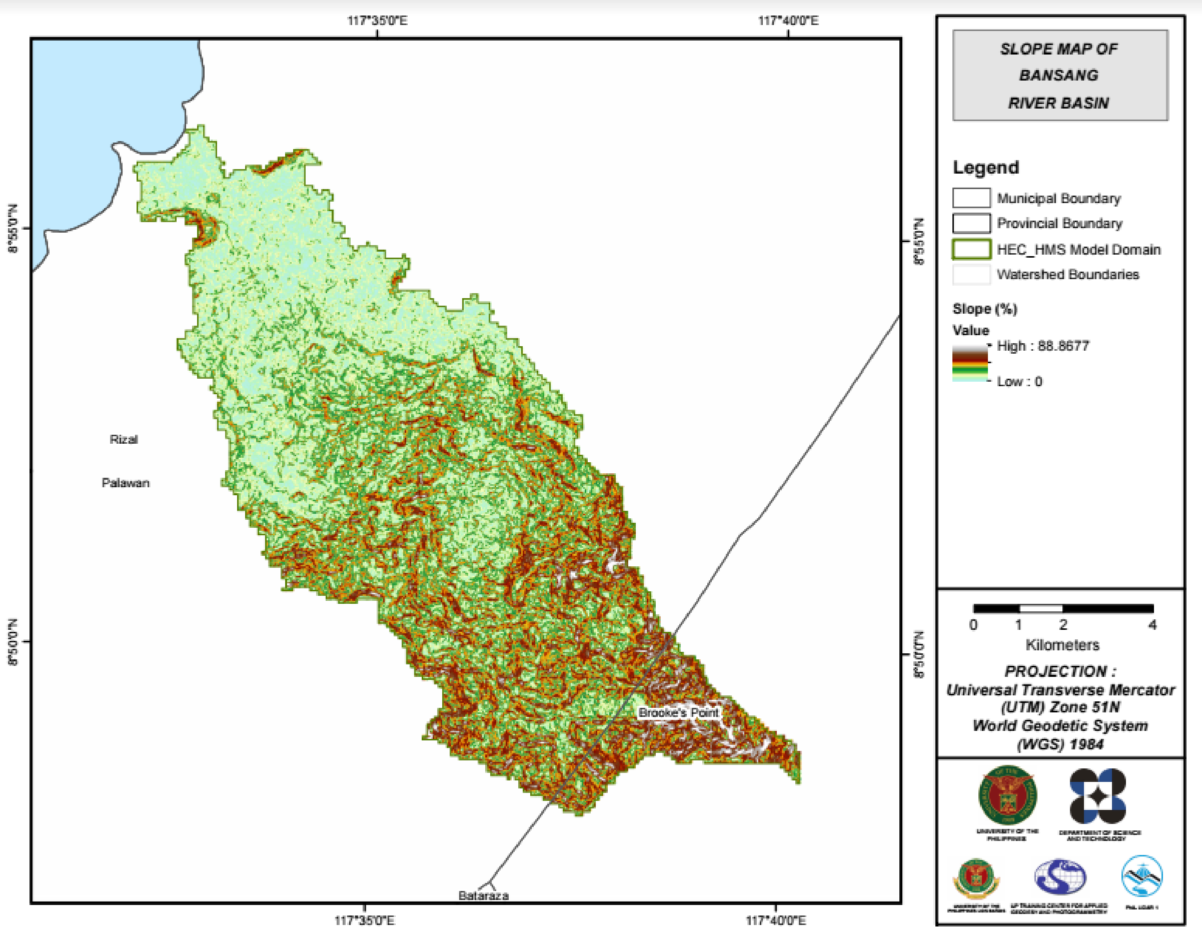


Figure 54. Slope map of Ransang River Basin

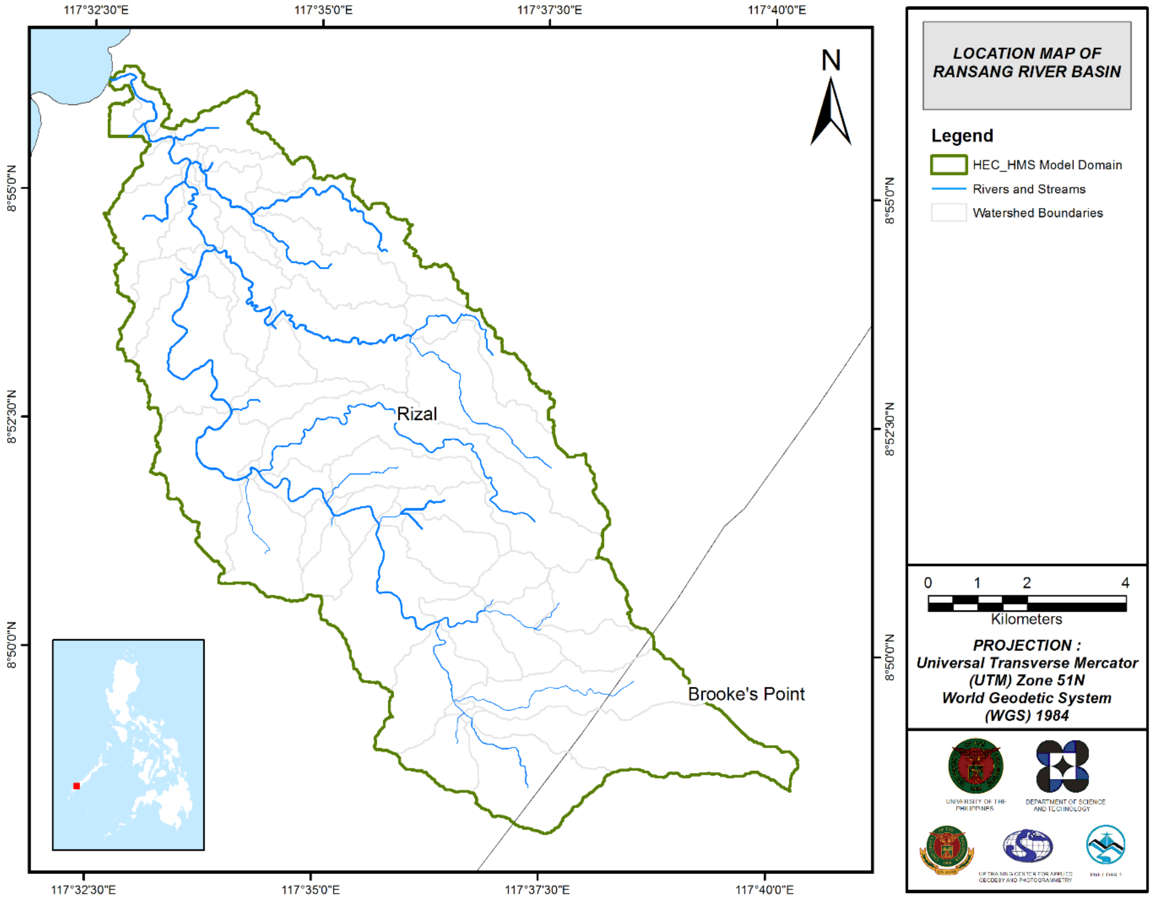


Figure 55. Stream delineation map of Ransang River Basin

Using SAR-based DEM, the Ransang basin was delineated and further subdivided into subbasins. The model consists of 48 sub basins, 24 reaches, and 24 junctions. The main outlet is labelled as 153. This basin model is illustrated in Figure 56. 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 Component of UPLB (DVC-UPLB) on a strategic point within the river basin. Finally, it was calibrated using the flow data collected from the Ransang Bridge.

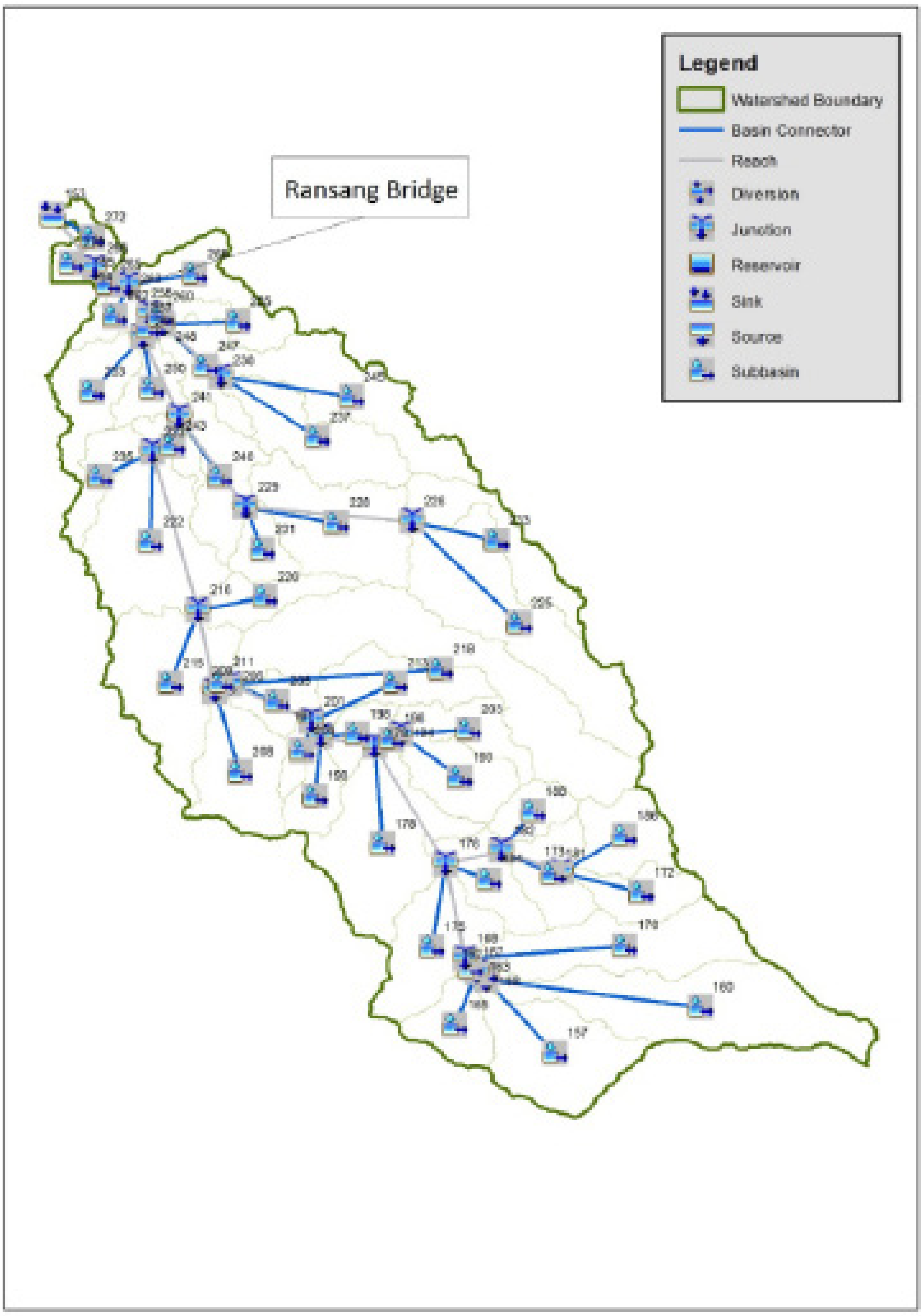


Figure 56. HEC-HMS generated Ransang River Basin Model.

5.4 Cross-section Data

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

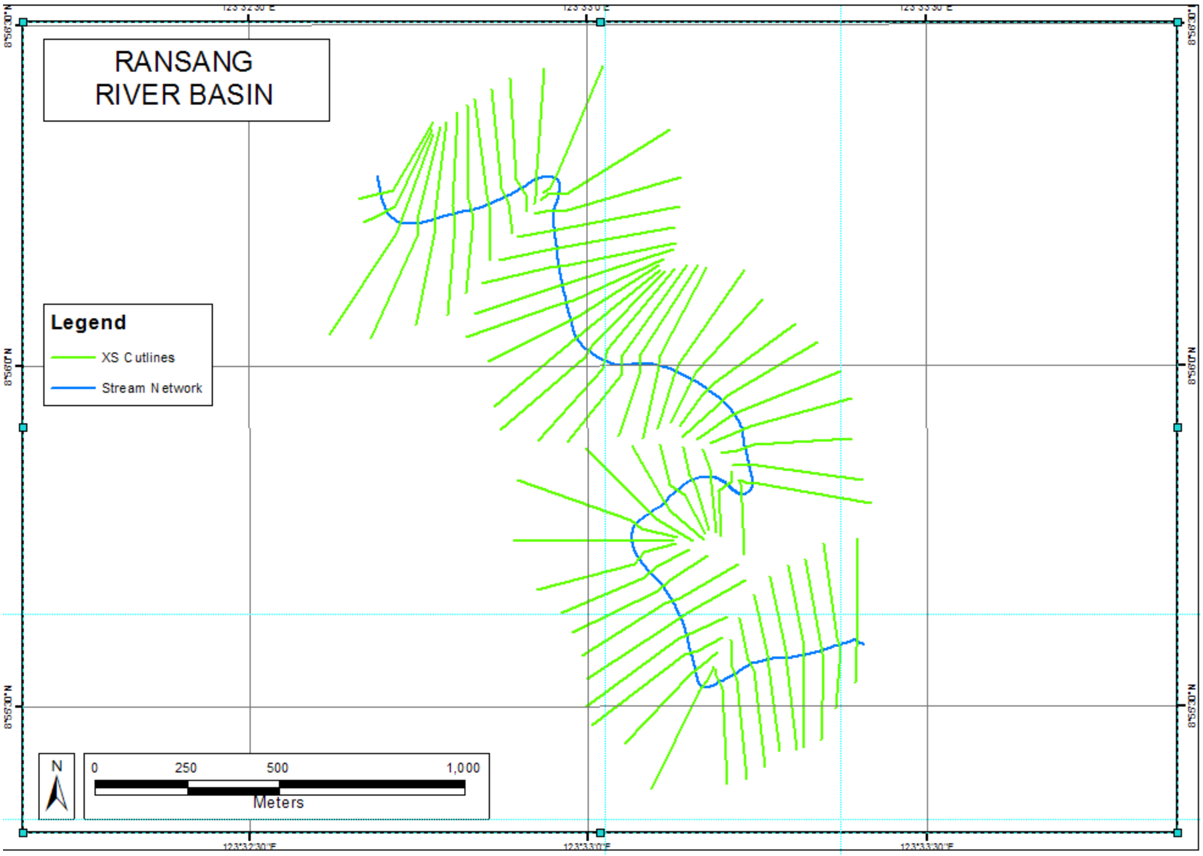


Figure 57. River cross-section of Ransang River generated through Arcmap HEC GeoRAS tool

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

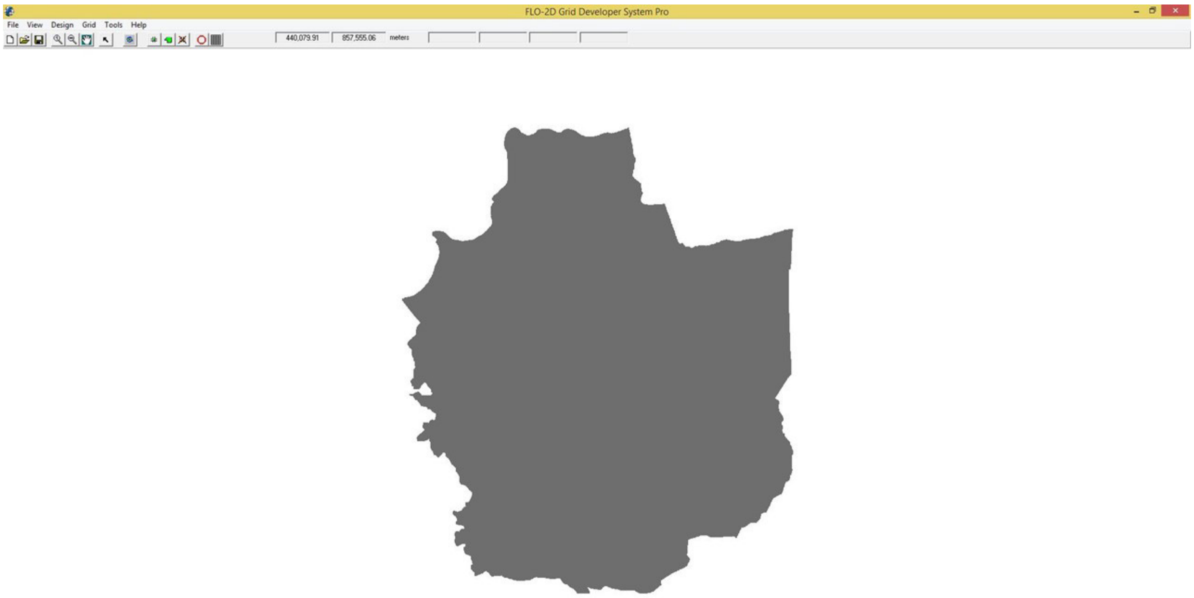


Figure 58. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 54.46680 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 m^2/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 87,073,248.00 m^2.

There is a total of 49,349,341.08 m^3 of water entering the model. Of this amount, 24,885,686.60 m^3 is due to rainfall while 24,463,654.48 m^3 is inflow from other areas outside the model. 9,103,592.00 m^3 of this water is lost to infiltration and interception, while 8,433,610.09 m^3 is stored by the flood plain. The rest, amounting up to 31,812,188.36 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Ransang HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

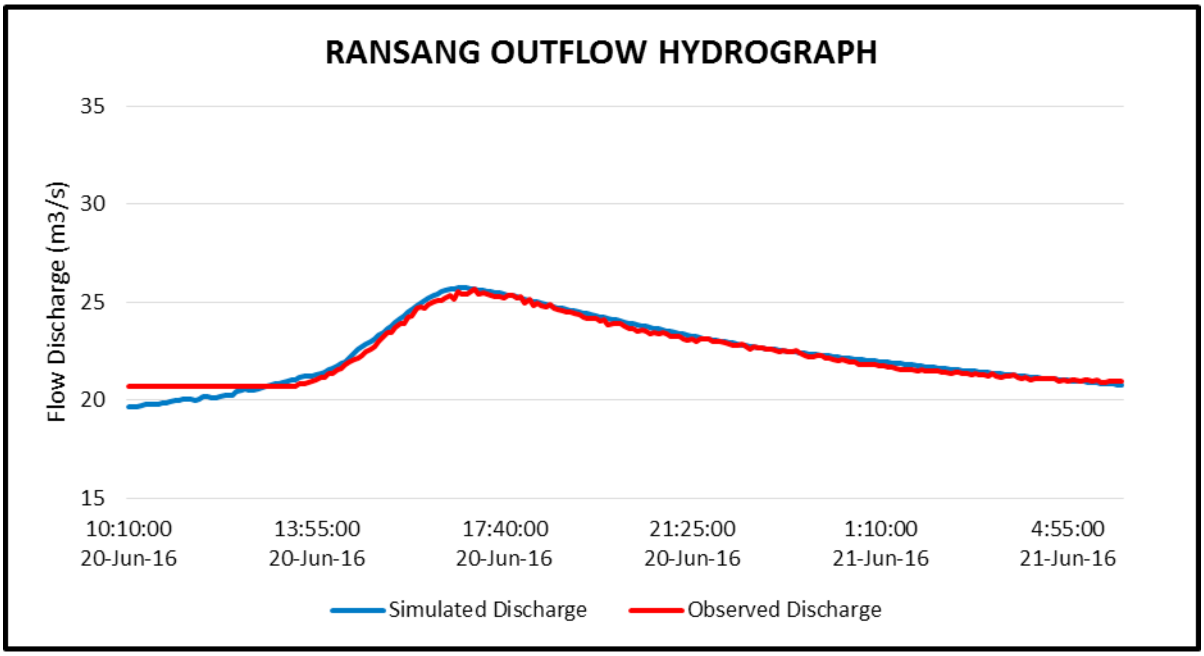


Figure 59. Outflow Hydrograph of Ransang produced by the HEC-HMS model compared with observed outflow.

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 Ransang River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.06 - 20
			Curve Number	35 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.05 - 10
			Storage Coefficient (hr)	0.1 - 25
	Baseflow	Recession	Recession Constant	0.3 - 1
			Ratio to Peak	0.5 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.003 – 0.09

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 0.06 to 20mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 39 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 0.05 hours to 25 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 0.003 to 0.09 also indicates different characteristics of the river reaches. (Brunner, 2010).

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

Accuracy measure	Value
RMSE	0.323
r^2	0.986
NSE	0.956
PBIAS	-0.180
RSR	0.210

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.323.

The Pearson correlation coefficient (r^2) 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 0.986.

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 0.956.

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 -0.180.

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 0.210.

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

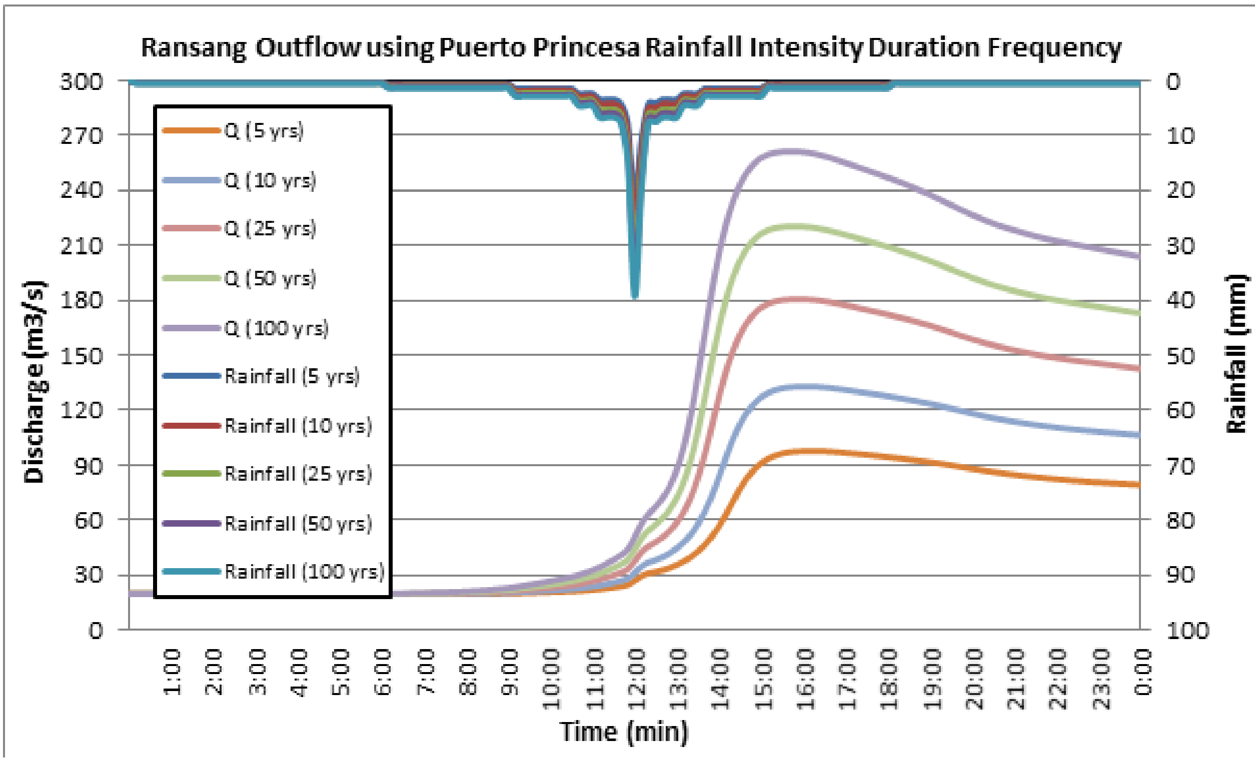


Figure 60. Outflow hydrograph at Ransang Station generated using Puerto Princesa RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Ransang 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 Ransang HECHMS Model outflow using the Puerto Princesa RIDF

RIDF PERIOD	Total Precipitation (mm)	Peak Rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak
5-yr	156.40	21.30	98.322	4 hours 10 minutes
10-yr	191.10	25.60	132.543	4 hours
25-yr	234.90	31.10	181.118	3 hours 50 minutes
50-yr	267.30	35.20	220.299	3 hours 50 minutes
100-yr	299.60	39.20	261.590	3 hours 40 minutes

5.8 River Analysis 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 Ransang River using the HMS base flow is shown on Figure 61 below.

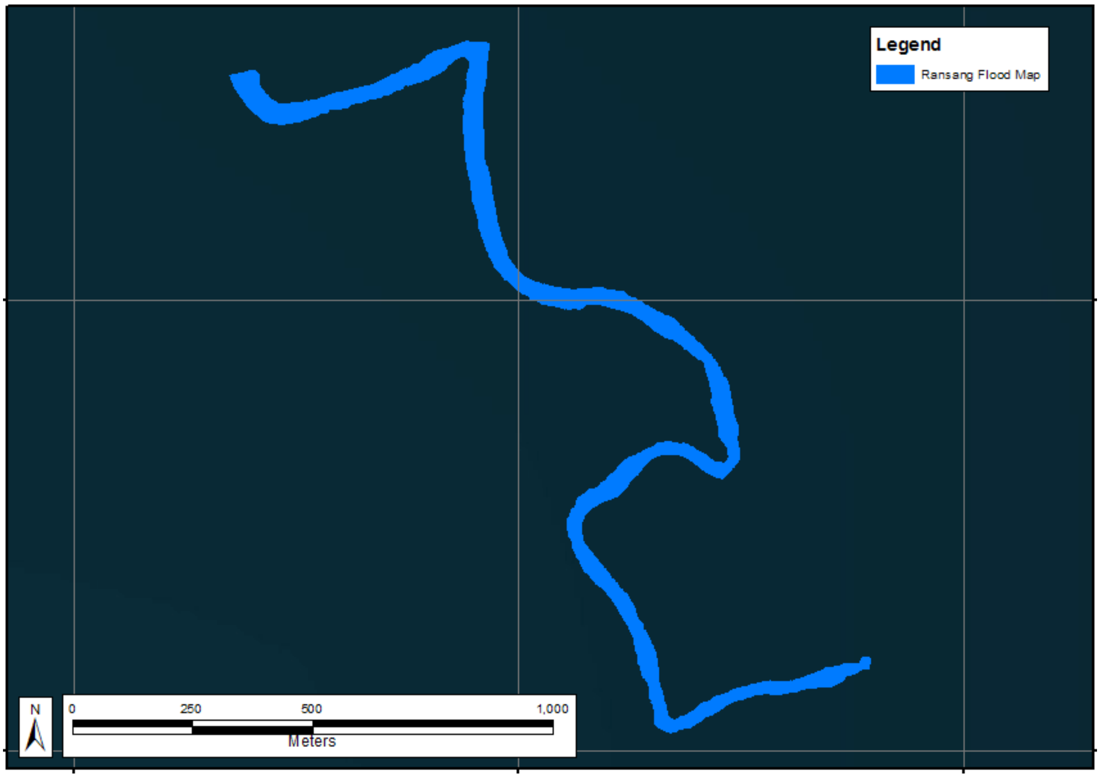


Figure 61. Sample output of Ransang RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Ransang floodplain are shown in to 21. The floodplain, with an area of 100.83 sq. km., covers one municipality namely Rizal. Table 25 shown the percentage of area affected by flooding per municipality.

Table 25. Municipalities affected in **Ransang** Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Rizal	980.59	100.77	10.28

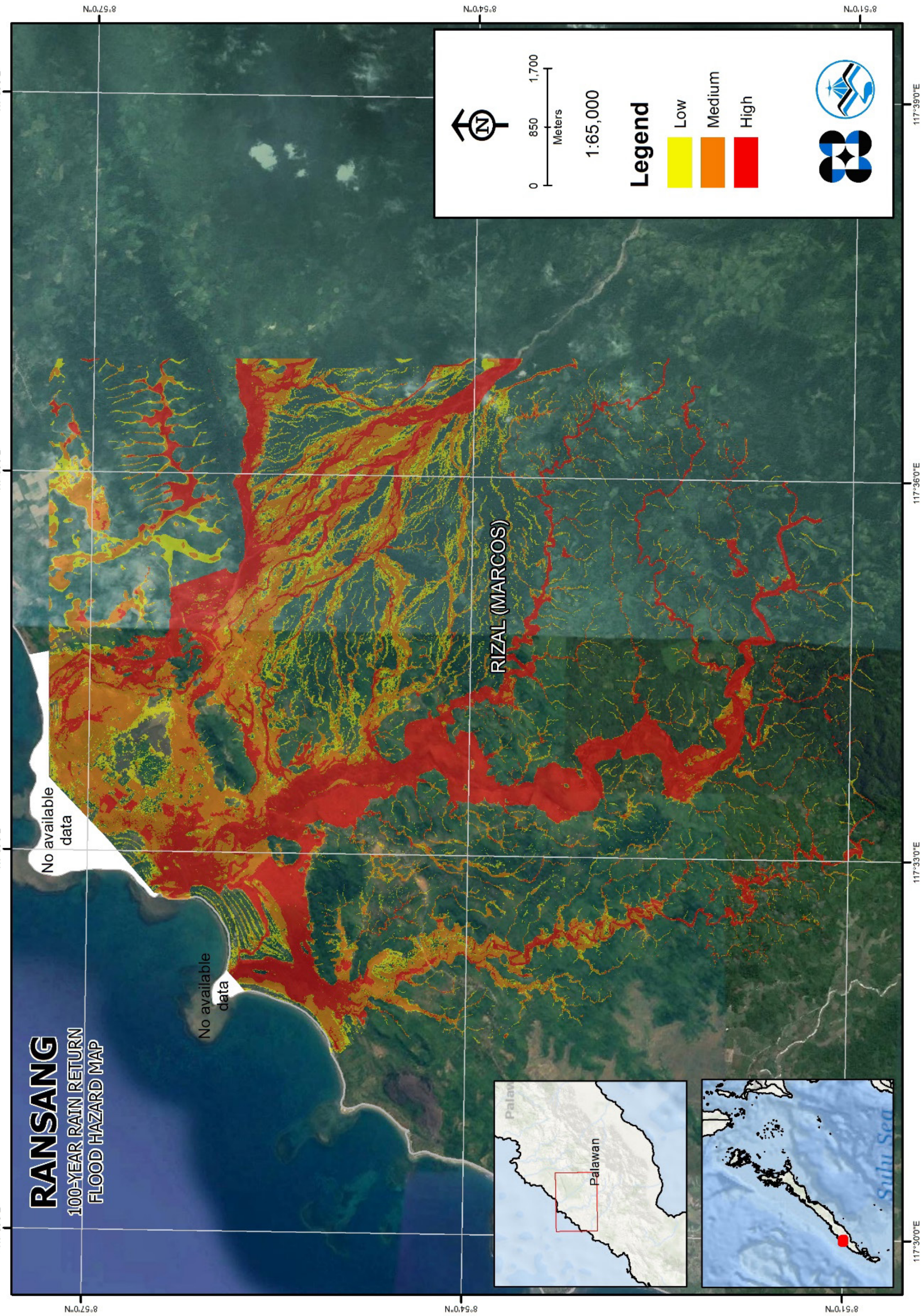


Figure 62. 100-year Flood Hazard Map for Ransang Floodplain overlaid on Google Earth imagery

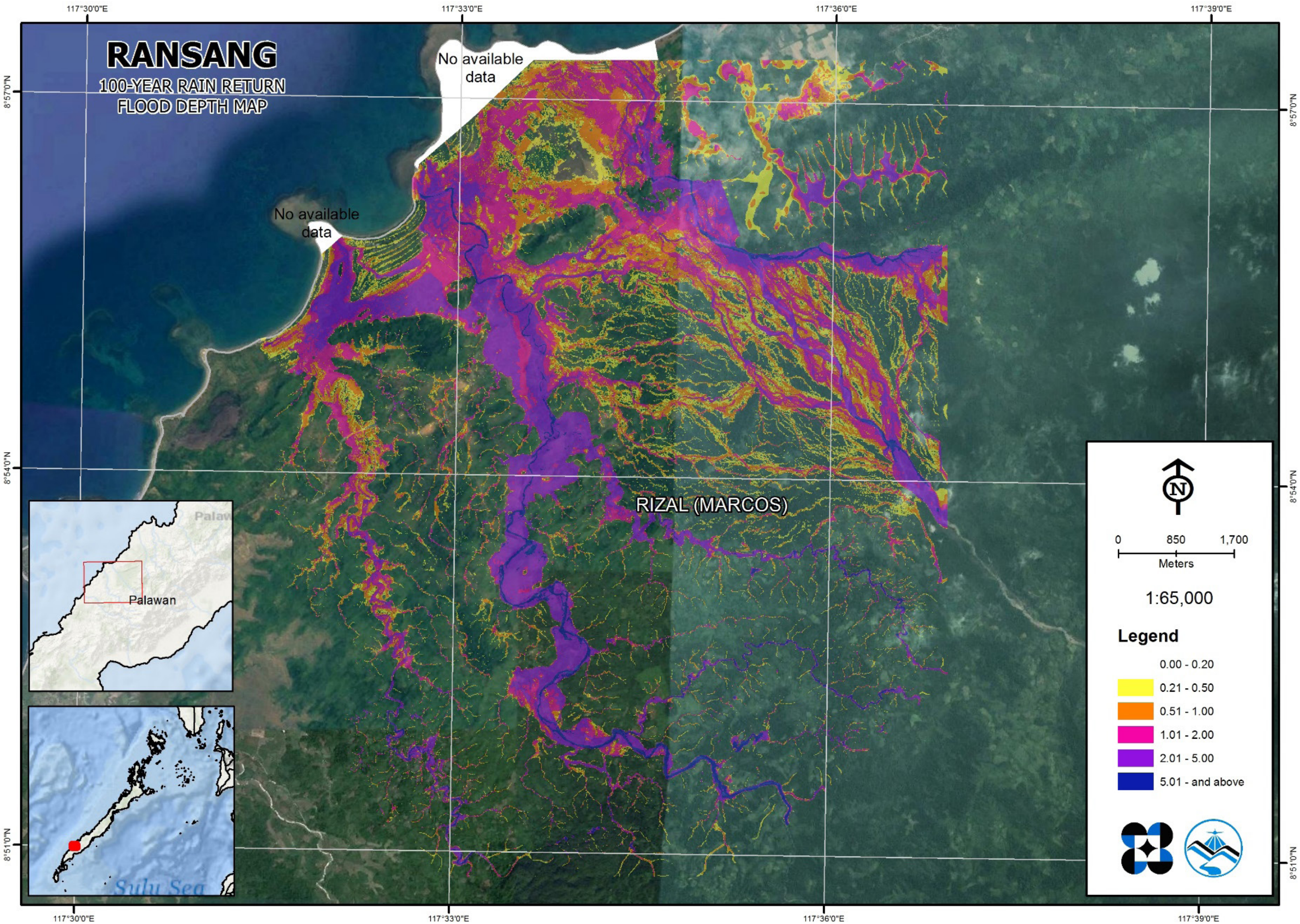


Figure 63. 100-year Flow Depth Map for Ransang Floodplain overlaid on Google Earth imagery

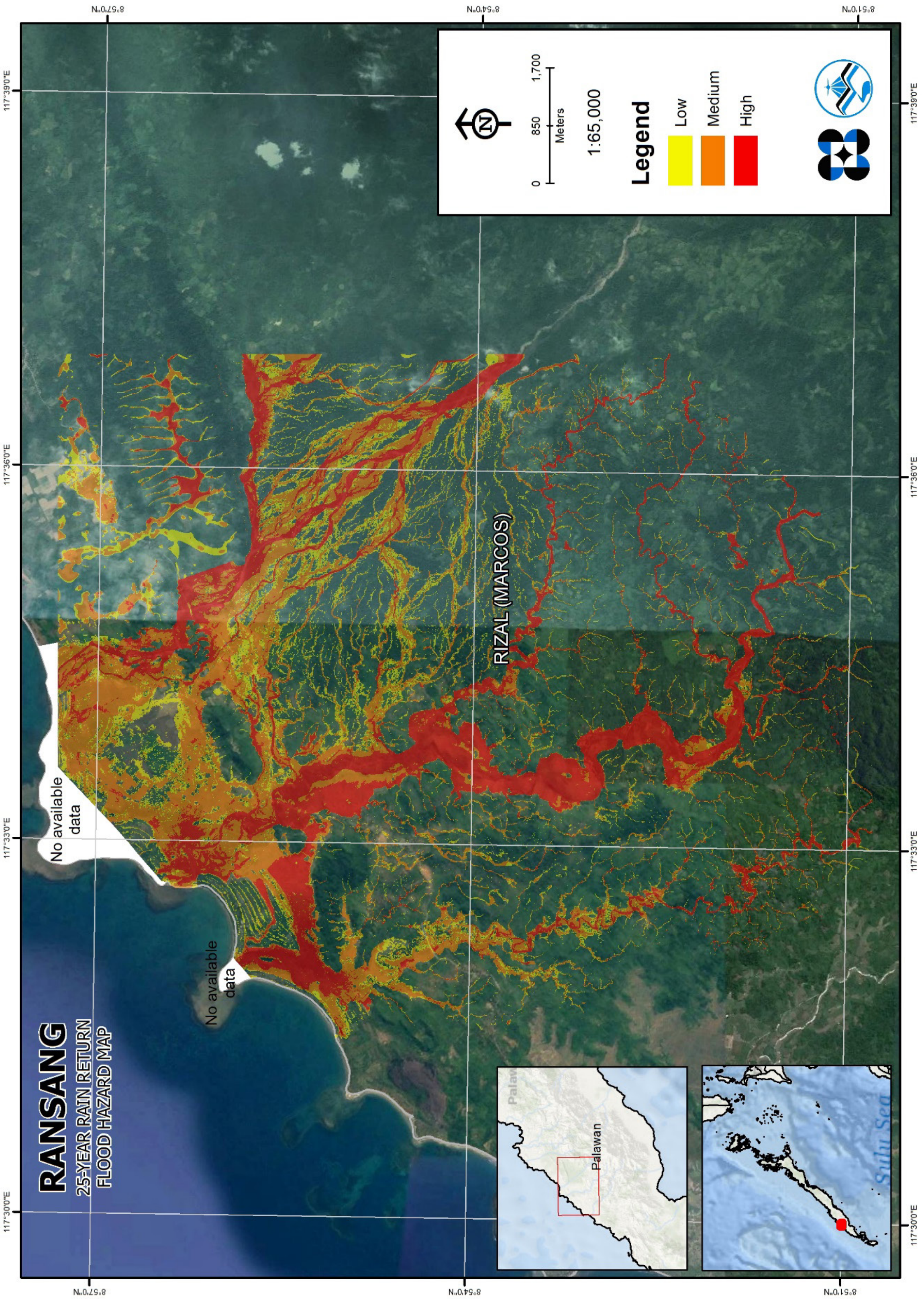


Figure 64. 25-year Flood Hazard Map for Ransang Floodplain overlaid on Google Earth imagery

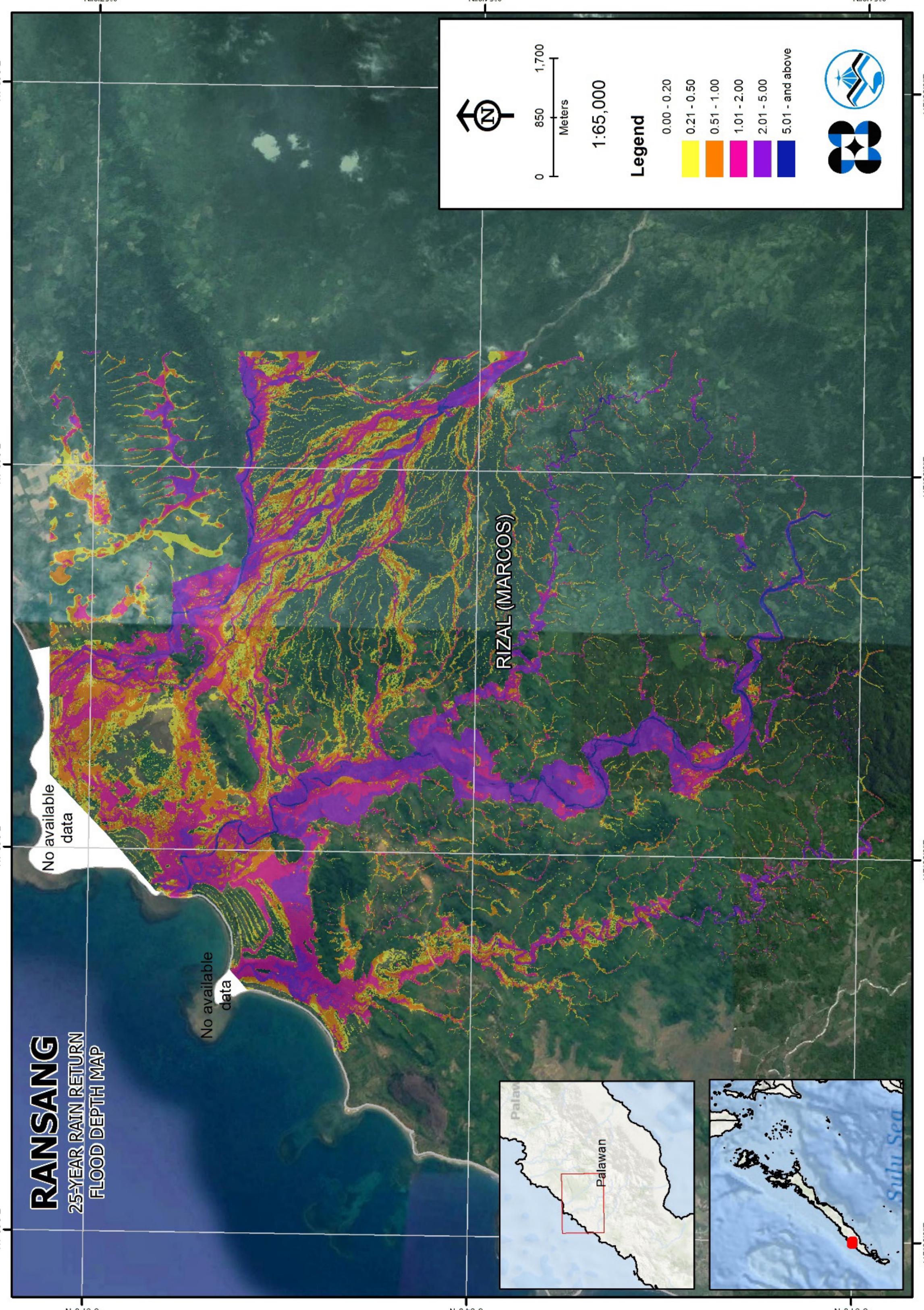


Figure 65. 25-year Flow Depth Map for Ransang Floodplain overlaid on Google Earth imagery

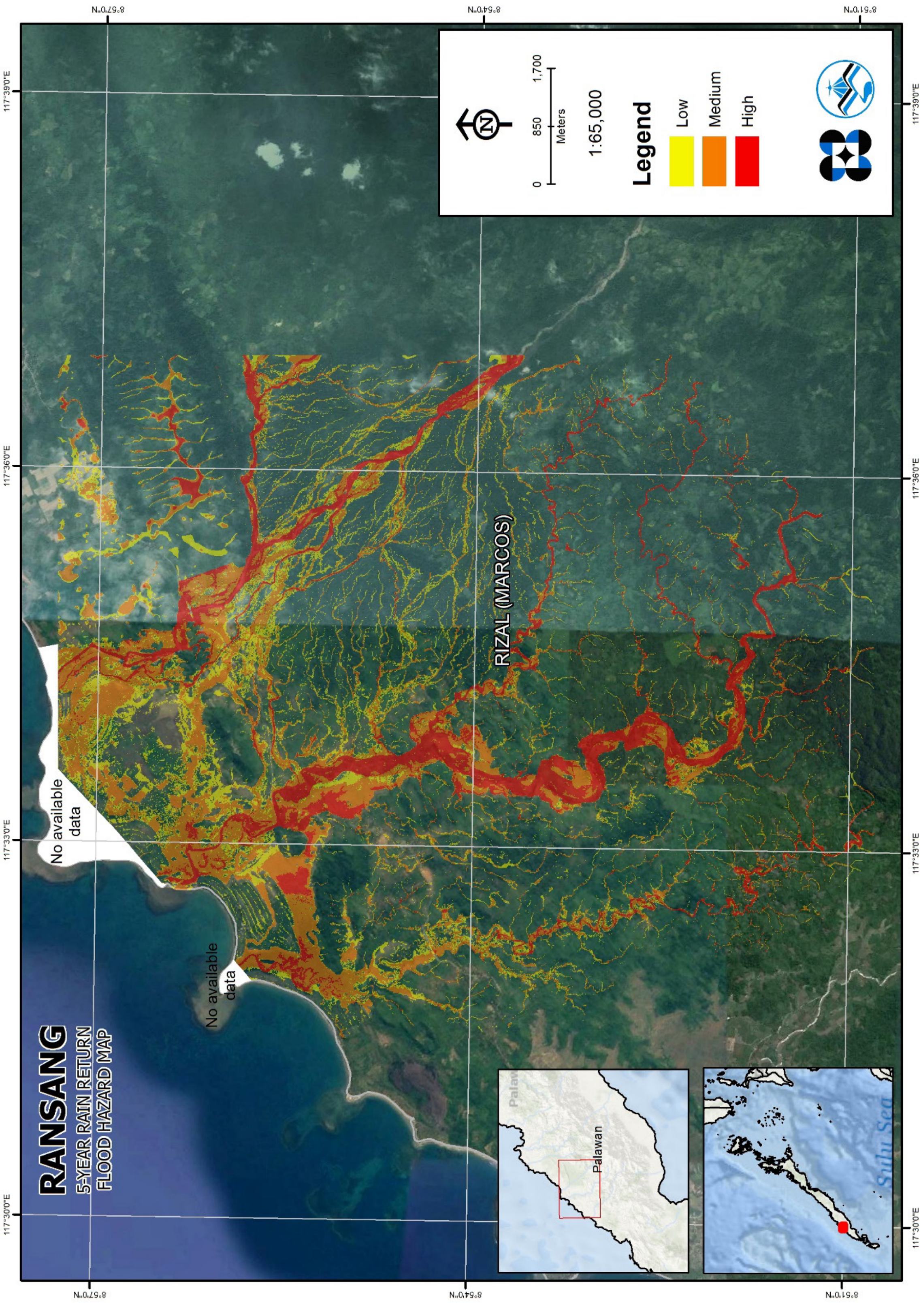


Figure 66. 5-year Flood Hazard Map for Ransang Floodplain overlaid on Google Earth imagery

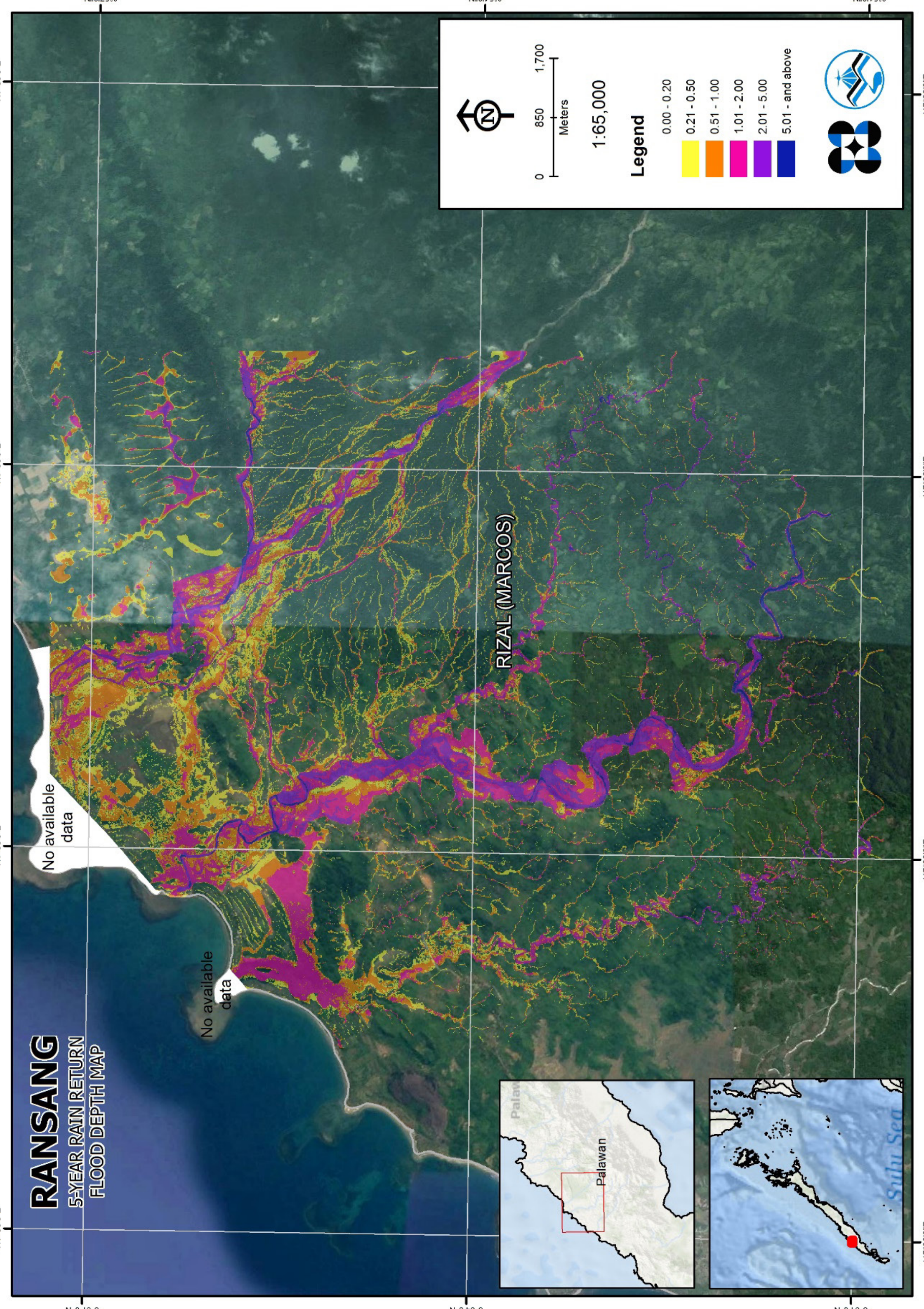


Figure 67. 5-year Flood Depth Map for Ransang Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Ransang 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, 5.85% of the municipality of Rizal with an area of 1281.59 sq. km. will experience flood levels of less 0.20 meters. 0.61% of the area will experience flood levels of 0.21 to 0.50 meters while 0.58%, 0.53%, 0.27%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 26 and Figure 68 are the affected areas in square kilometres by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)		
	Campong Ulay	Candawaga	Ransang
0.03-0.20	13.56	2.29	59.09
0.21-0.50	1.6	0.065	6.21
0.51-1.00	1.34	0.064	5.97
1.01-2.00	1.18	0.081	5.51
2.01-5.00	0.75	0.11	2.59
> 5.00	0.075	0.0093	0.31

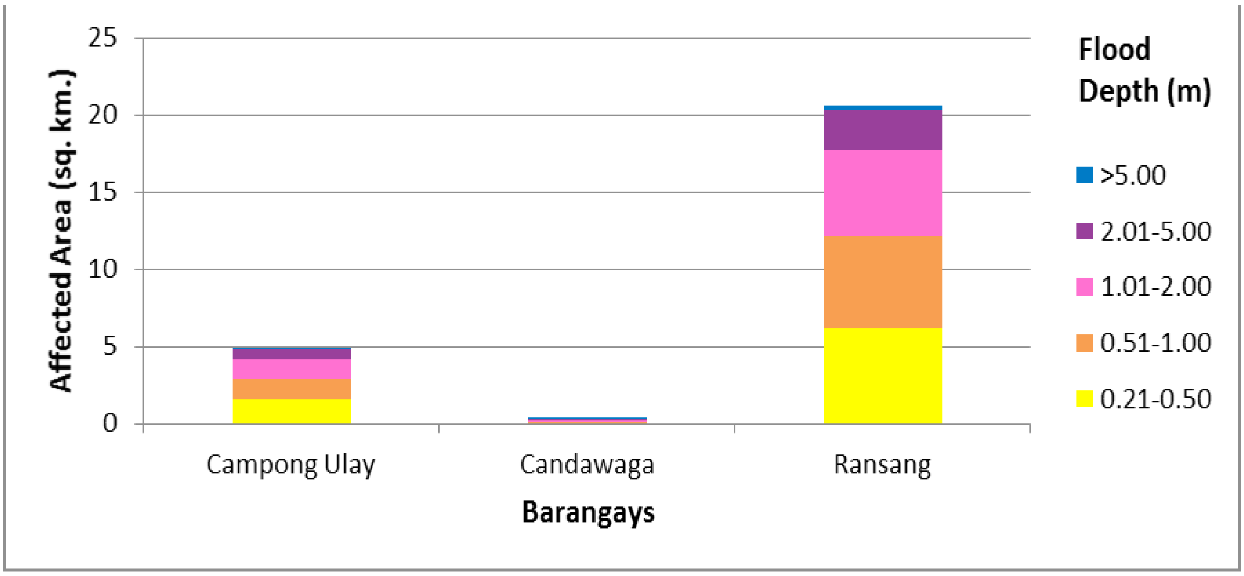


Figure 68. Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period

For the 25-year return period, 5.25% of the municipality of Rizal with an area of 1281.59 sq. km. will experience flood levels of less 0.20 meters. 0.6% of the area will experience flood levels of 0.21 to 0.50 meters while 0.68%, 0.74%, 0.54%, and 0.06% 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 27 and Figure 69 are the affected areas in square kilometres by flood depth per barangay.

Table 27. 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 Rizal (in sq. km.)		
	Campong Ulay	Candawaga	Ransang
0.03-0.20	11.4	2.23	53.62
0.21-0.50	1.84	0.063	5.74
0.51-1.00	1.8	0.06	6.87
1.01-2.00	1.95	0.098	7.44
2.01-5.00	1.39	0.14	5.43
> 5.00	0.14	0.028	0.59

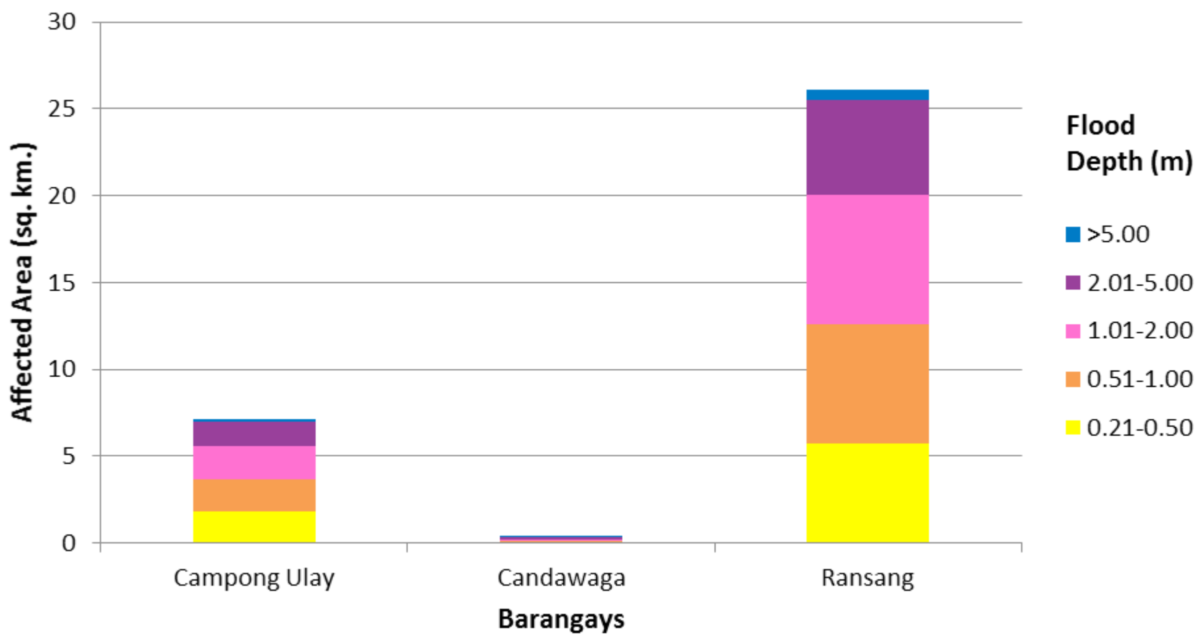


Figure 69. Affected Areas in Rizal, Palawan during 25-Year Rainfall Return Period

For the 100-year return period, 5.25% of the municipality of Rizal with an area of 1281.59 sq. km. will experience flood levels of less 0.20 meters. 0.6% of the area will experience flood levels of 0.21 to 0.50 meters while 0.68%, 0.74%, 0.54%, and 0.06% 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 and Figure 70 are the affected areas in square kilometres by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)		
	Campong Ulay	Candawaga	Ransang
0.03-0.20	10.39	2.18	50.64
0.21-0.50	1.82	0.064	5.38
0.51-1.00	1.92	0.064	6.75
1.01-2.00	2.23	0.096	8.49
2.01-5.00	1.94	0.16	7.5
> 5.00	0.23	0.054	0.92

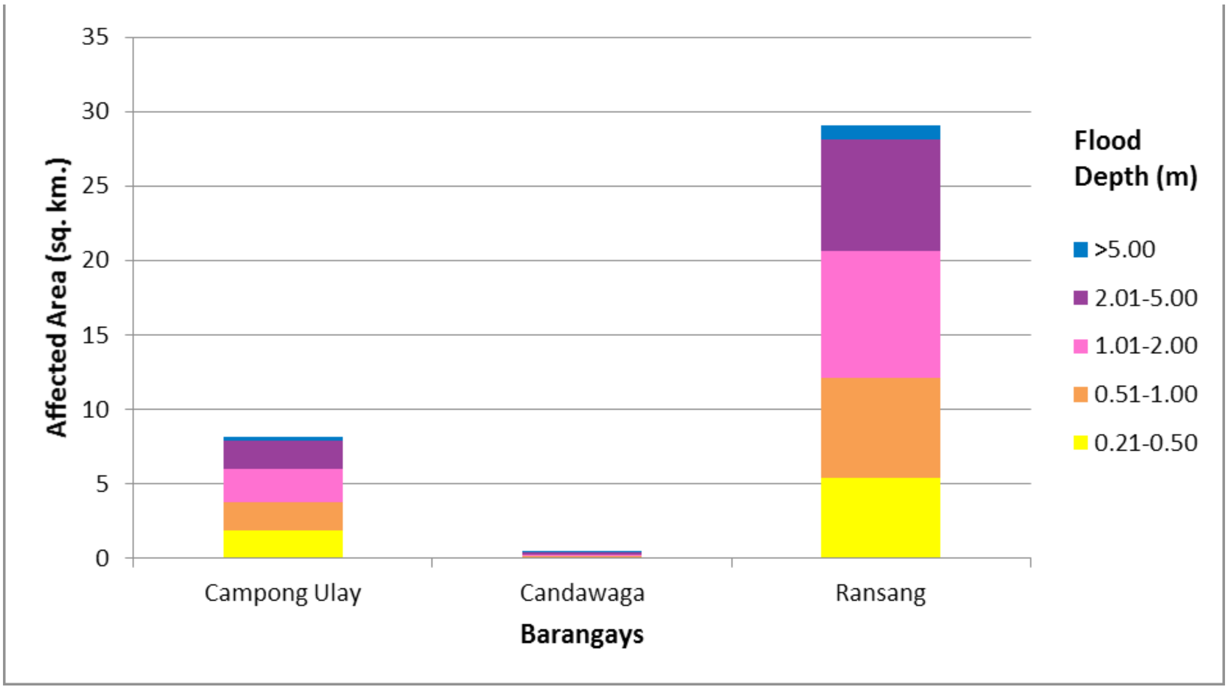


Figure 70. Affected Areas in Rizal, Palawan during 100-Year Rainfall Return Period

Among the barangays in the municipality of RIzal, Ransang is projected to have the highest percentage of area that will experience flood levels at 6.22%. Meanwhile, Campong Ulay posted the second highest percentage of area that may be affected by flood depths at 1.45%.

5.11 Flood Validation

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

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

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

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

The flood validation consisted of 41 points randomly selected all over the Ransang flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.39m. Table 29 shows a contingency matrix of the comparison.

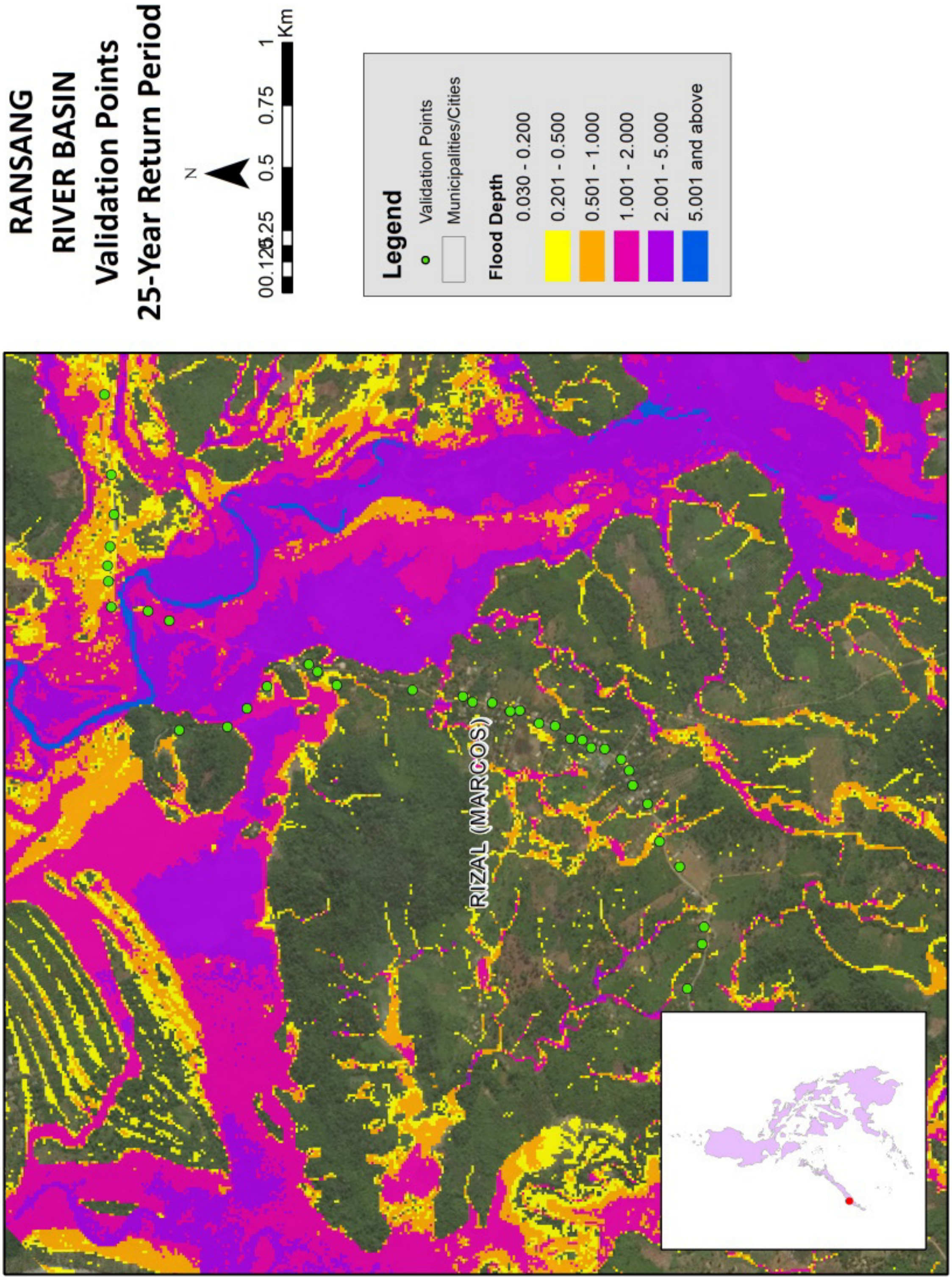


Figure 71. Validation points for 25-year Flood Depth Map of Ransang Floodplain

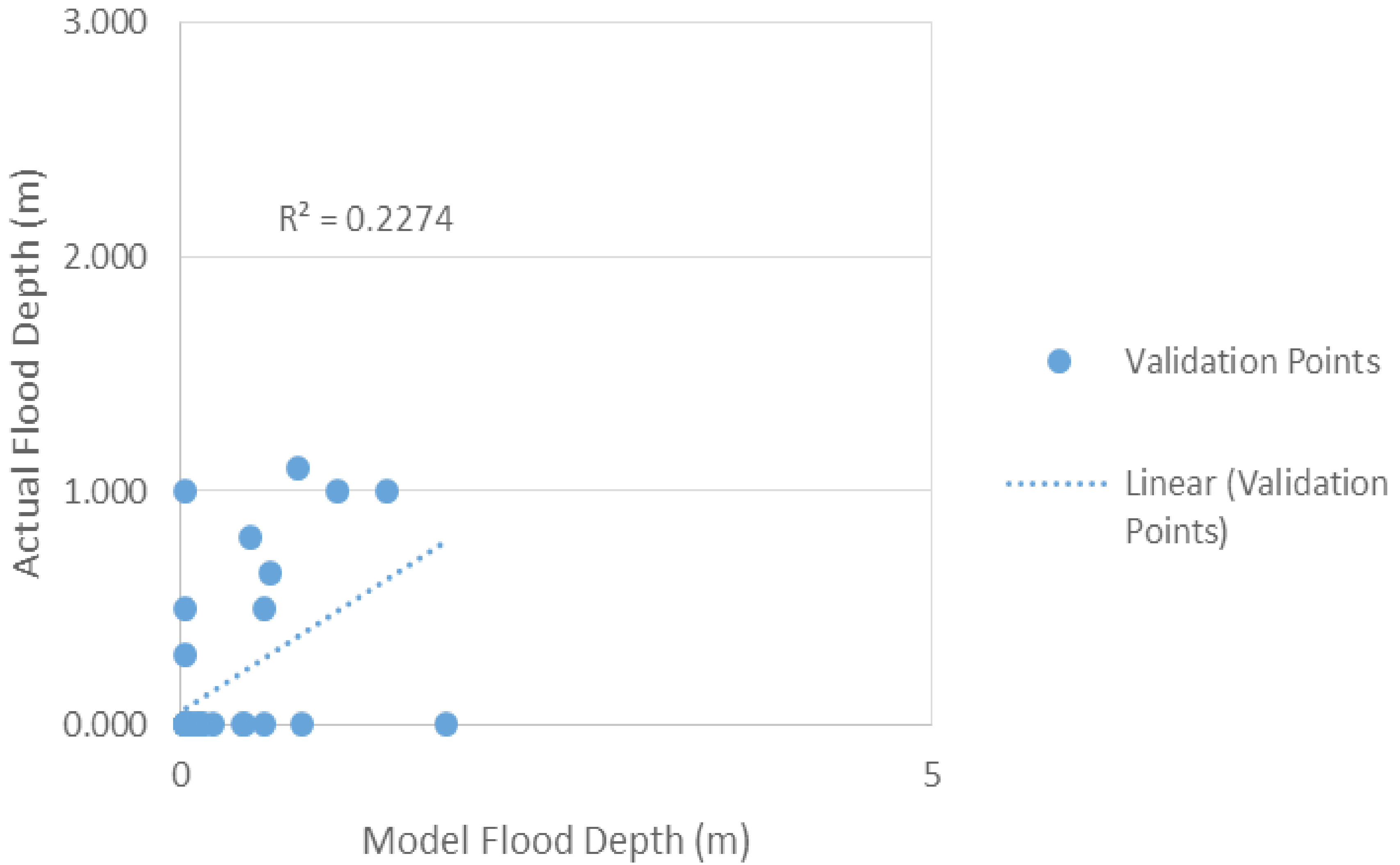


Figure 72. Flood map depth vs. actual flood depth

Table 29. Actual flood vs simulated flood depth at different levels in the Ransang 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	26	3	2	1	0	0	32
0.21-0.50	2	0	1	0	0	0	3
0.51-1.00	1	1	1	2	0	0	5
1.01-2.00	0	0	1	0	0	0	1
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	29	4	5	3	0	0	41

The overall accuracy generated by the flood model is estimated at 65.85% with 27 points correctly matching the actual flood depths. In addition, there were 9 points estimated one level above and below the correct flood depths while there were 3 points and 1 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 5 points were underestimated in the modelled flood depths of Ransang. Table 30 depicts the summary of the Accuracy Assessment in the Ransang River Basin Survey.

Table 30. Summary of the Accuracy Assessment in the Ransang River Basin Survey

	No. of Points	%
Correct	27	65.85
Overestimated	9	21.95
Underestimated	5	12.20
Total	41	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor

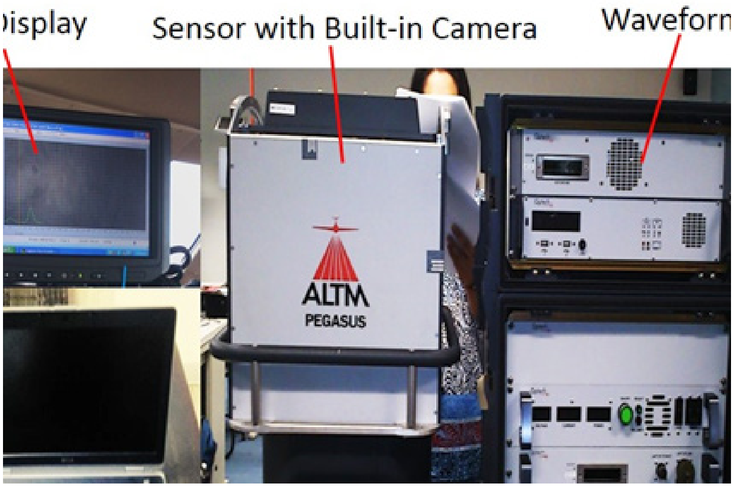


Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and 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**
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**
Barangay: **CAMPONG ULAY**
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

9 9 0 7 2 1 2 0 1 5 1 7 0 5 2 8

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 of Control Points used in the LIDAR Survey

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

Figure A-3.2. Baseline Processing Report – B

Annex 4. The LiDAR Survey Team Composition

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

DATA TRANSFER SHEET
8/3/2015(palawan)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Jun-15	3049P	1BLK42S165A	Pegasus	969	na	7	162	31	252	18.3	29.3	16.3	1KB	1KB	70/67	na	Z:\DAC\RAW DATA
20-Jun-15	3073P	1BLK42S171A	Pegasus	361	na	3.65	107	12.3	88	7.1	NA	4.15	1KB	1KB	92	na	Z:\DAC\RAW DATA
7-Jul	3141P	1BLK42QRT188A	Pegasus	1.84	na	11.6	256	2.11	15/20/9/1	35.5	108	8.43	1KB	1KB	95	na	Z:\DAC\RAW DATA
8-Jul	3145P	1BLK42QRT189A	Pegasus	752	na	5.41	124	184	101	14.8	NA	11.9	1KB	1KB	176/95	na	Z:\DAC\RAW DATA
11-Jul	3157P	1BLK42PO192A	Pegasus	2.29	na	13	279	35.2	369	43.3	113	20.6	1KB	1KB	206	na	Z:\DAC\RAW DATA
11-Jul	3159P	1BLK42PO192B	Pegasus	1.11	na	8.95	199	55.5	1	21.6	25.9	20.6	1KB	1KB	NA	na	Z:\DAC\RAW DATA
12-Jul	3161P	1BLK42LM193A	Pegasus	1.51	427/407	9.62	214	41.7	359	28.8	67.6	4.29	1KB	1KB	215	na	Z:\DAC\RAW DATA
13-Jul	3165P	1BLK42LM194A	Pegasus	1.5	na	10.5	255	36.4	295	28.9	na	11.5	1KB	1KB	na	na	Z:\DAC\RAW DATA
13-Jul	3167P	1BLK42JS194B	Pegasus	329	na	3.65	106	4.93	2	7.36	11	11.5	1KB	1KB	106/123	NA	Z:\DAC\RAW DATA
15-Jul	3173P	1BLK42KS196A	Pegasus	160	96/28	2.73	63.2	na	na	3.33	7.6	1.19	1KB	1KB	11	NA	Z:\DAC\RAW DATA

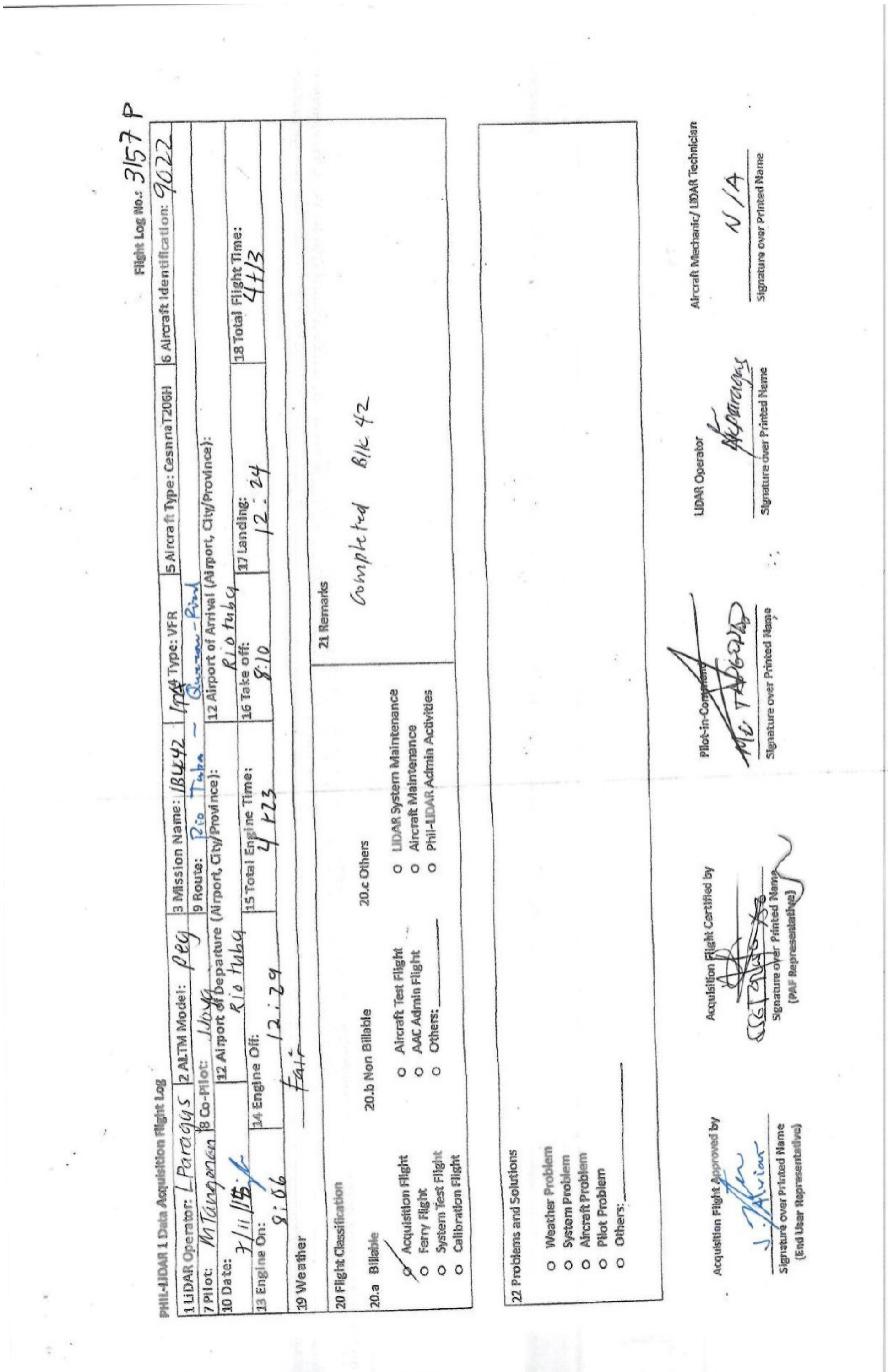
Received from
Name [illegible]
Position KA
Signature [illegible]

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

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

Annex 6. Flight Logs

1. Flight Log for 3157P Mission



Flight Log No.: 3157P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: L Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK42 [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Iloya	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
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

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

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

21 Remarks

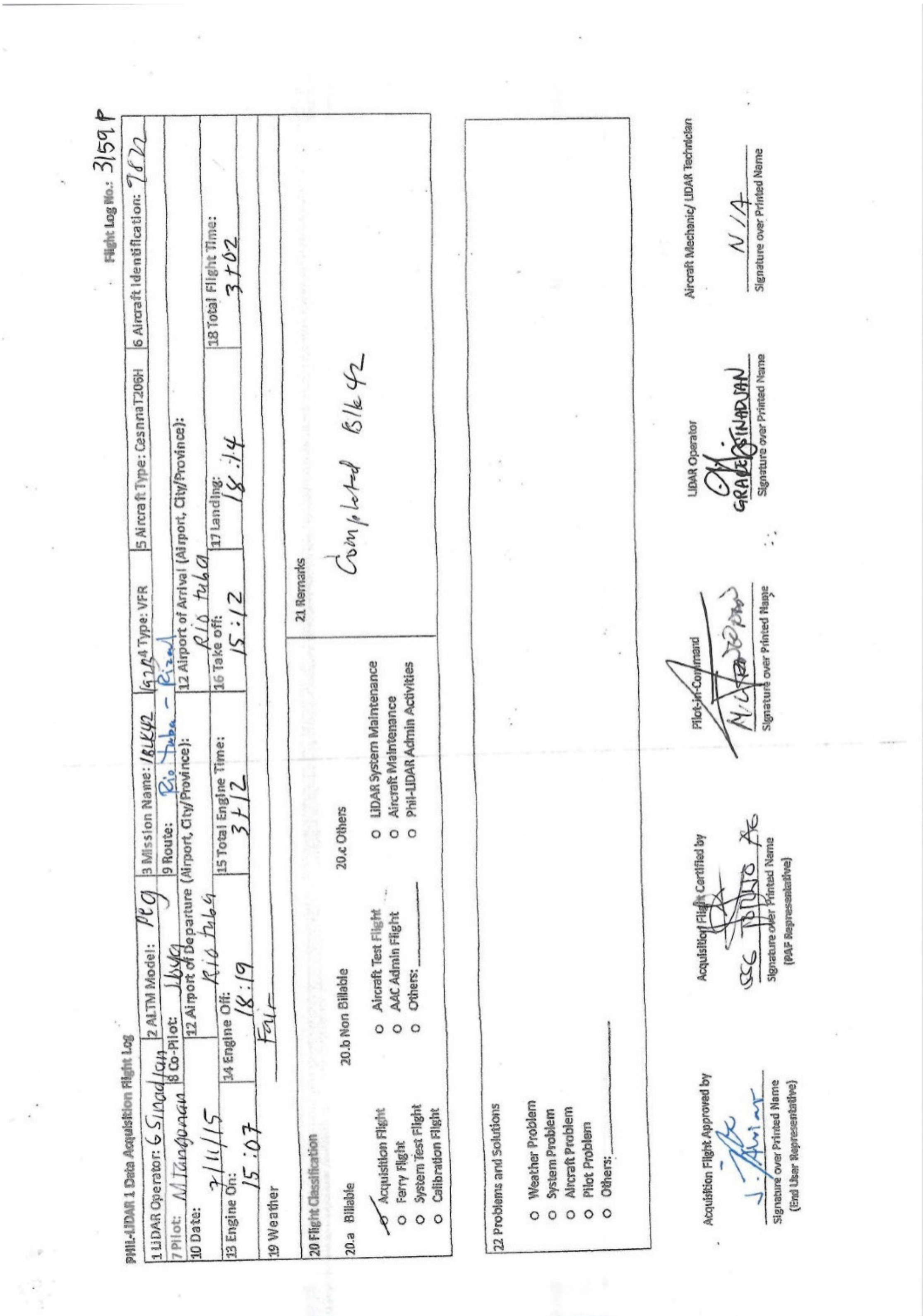
Completed Blk 42

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Alviar	[illegible]	M. Tangonan	L Paragas	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for 3157P Mission

2. Flight Log for 3159P Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3159P

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M Tangonan	8 Co-Pilot: J Ilyka	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	20.b Non Billable	20.c Others
✓ Acquisition Flight	o Aircraft Test Flight	o LiDAR System Maintenance
o Ferry Flight	o AAC Admin Flight	o Aircraft Maintenance
o System Test Flight	o Others: ____	o Phil-LiDAR Admin Activities
o Calibration Flight		

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	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Almirar	[illegible]	M. Tangonan	G. Sinadjan	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for 3159P Mission

Annex 7. Flight Status Report

ERAAN FLOODPLAIN
(July 11-13, 2015)

Table A-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

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

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

SWATH

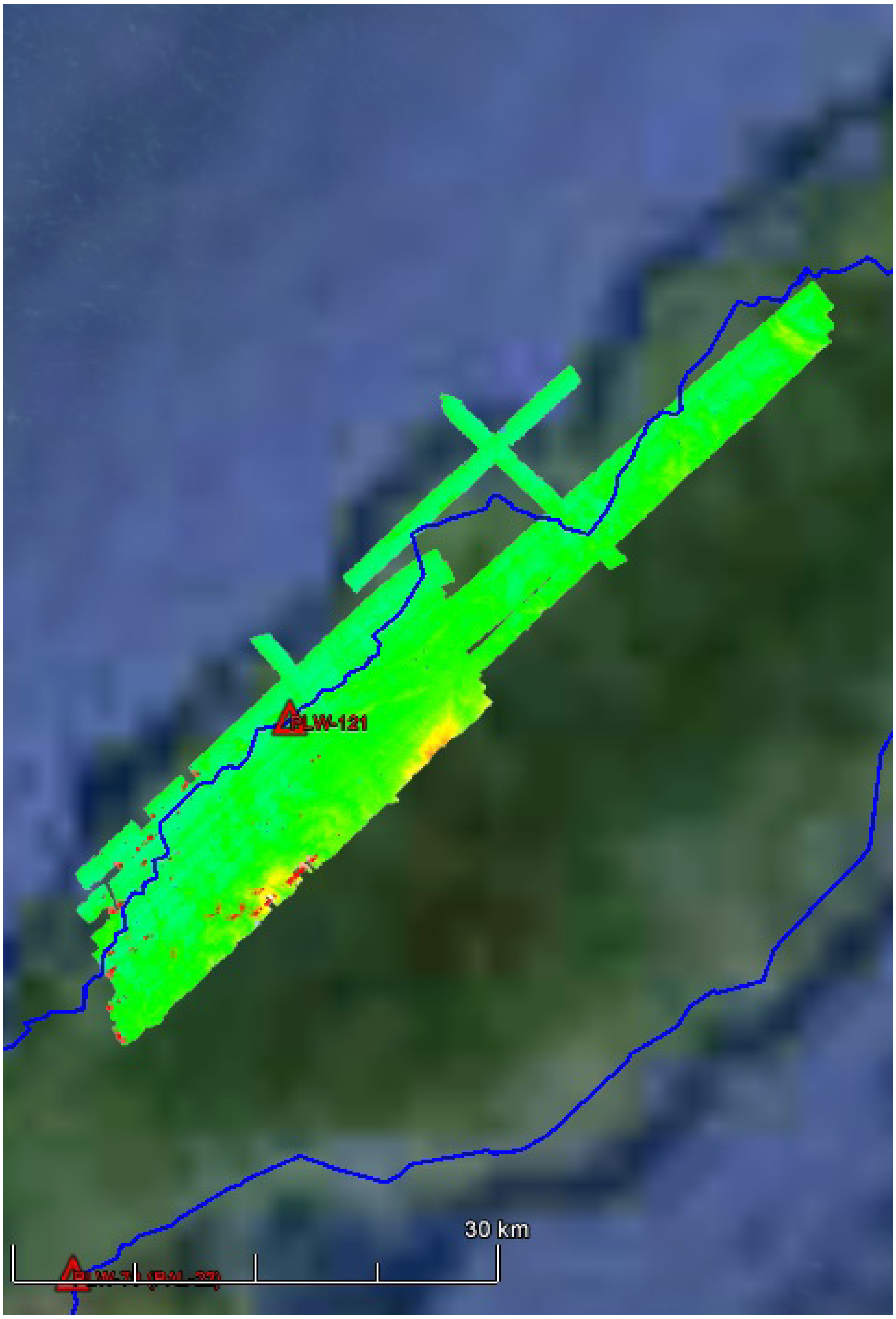


Figure A-7.1. Swath for Flight No. 3157P

Flight No:	3159P	
Mission Name:	1BLK42PO192B	
Area:	BLOCK 42ONP	
Parameters:	Altitude: 1200	PRF: 200
	Scan Angle: 50	Overlap: 30

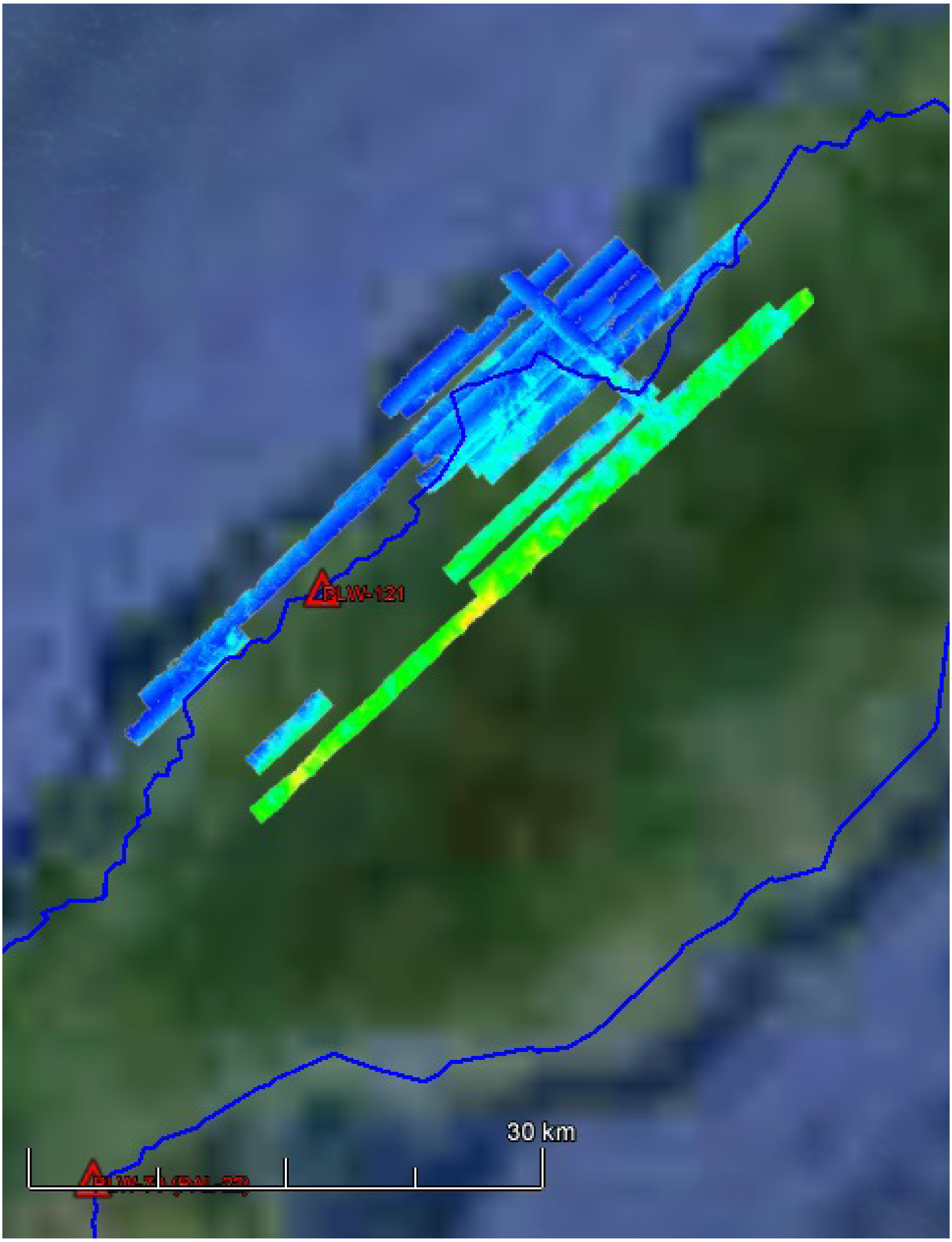


Figure A-7.2. Swath for Flight No. 3159P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk 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

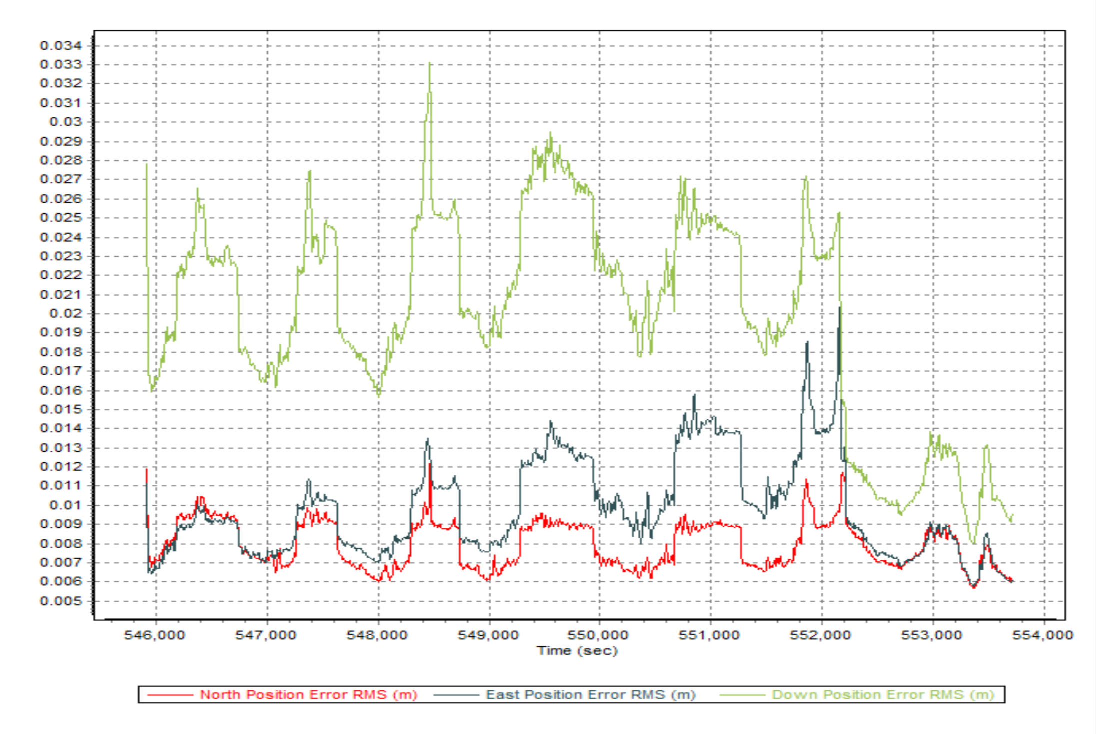


Figure A-8.1 Solution Status

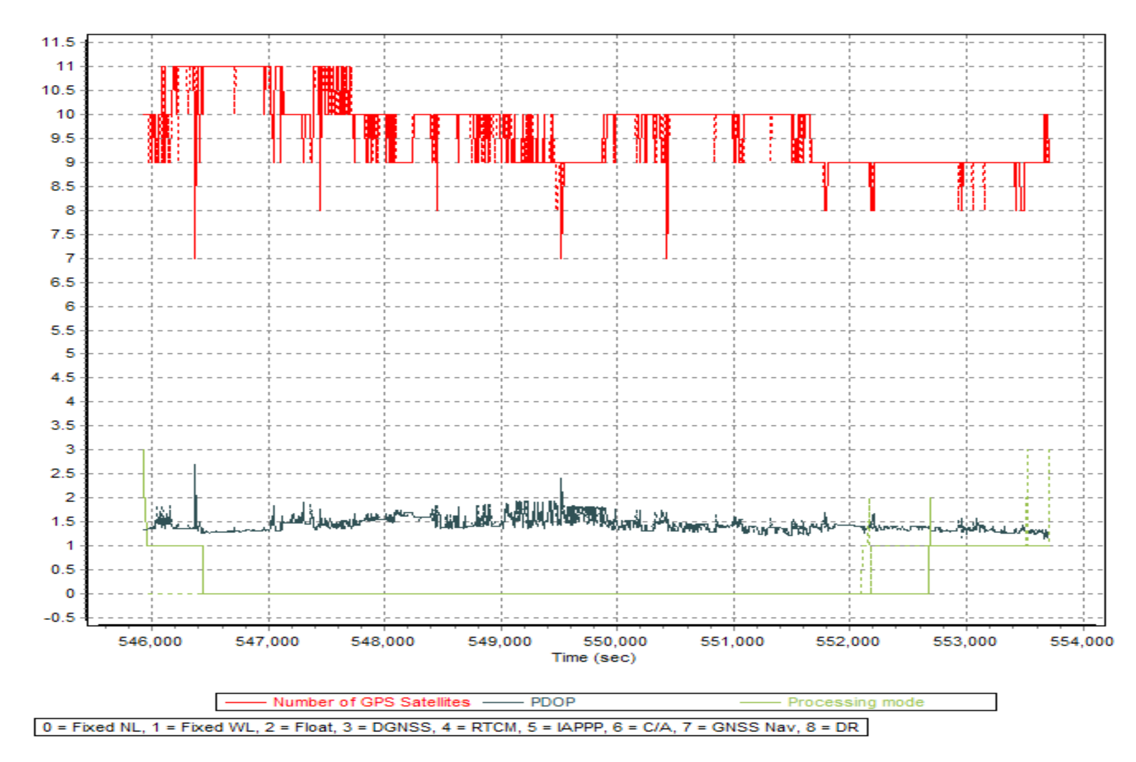


Figure A-8.2 Smoothed Performance Metrics Parameters

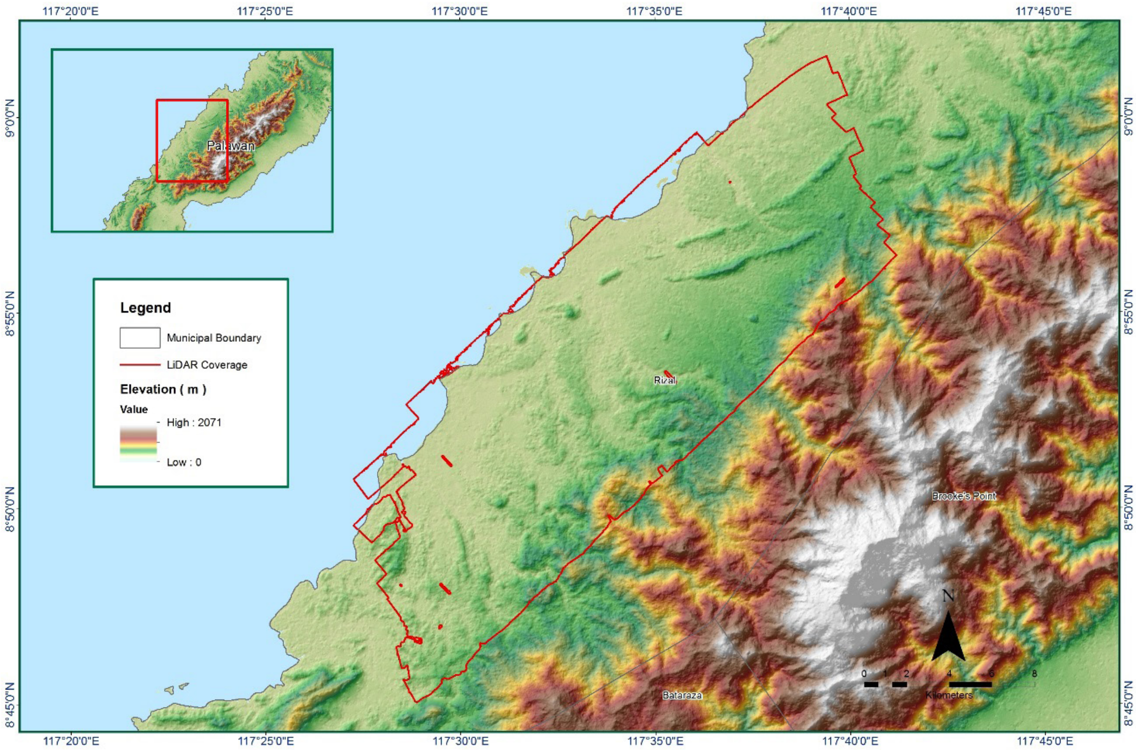


Figure A-8.3 Best Estimated Trajectory

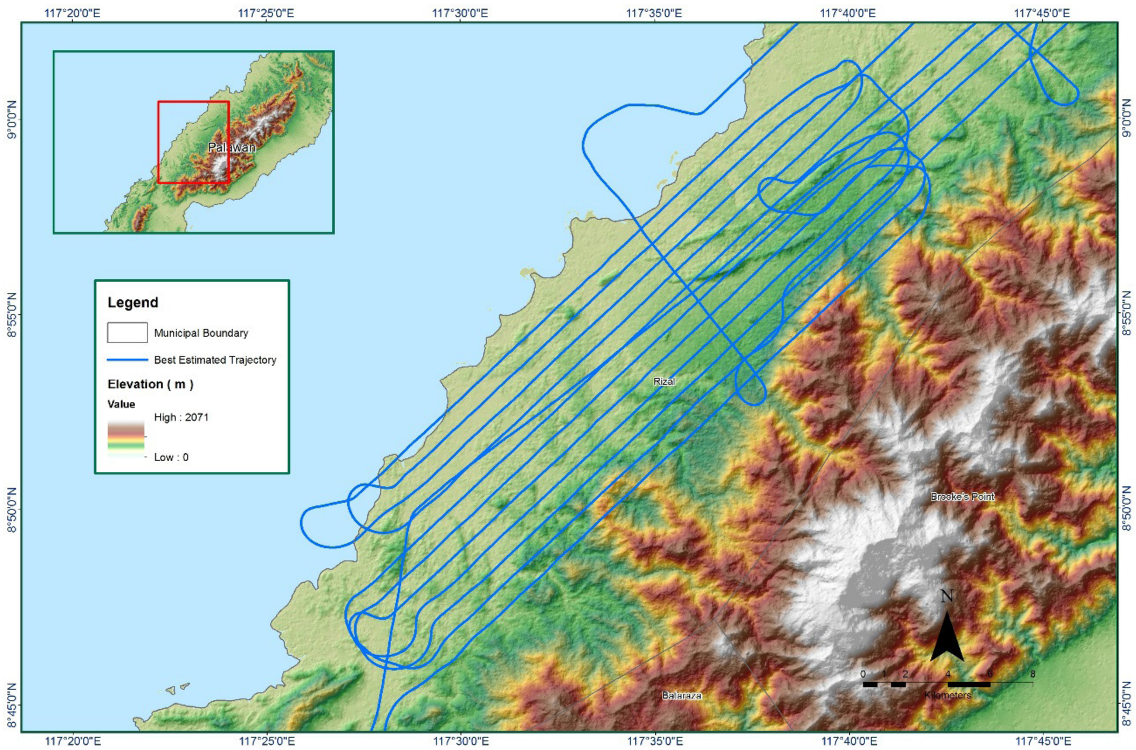


Figure A-8.4. Coverage of LiDAR data

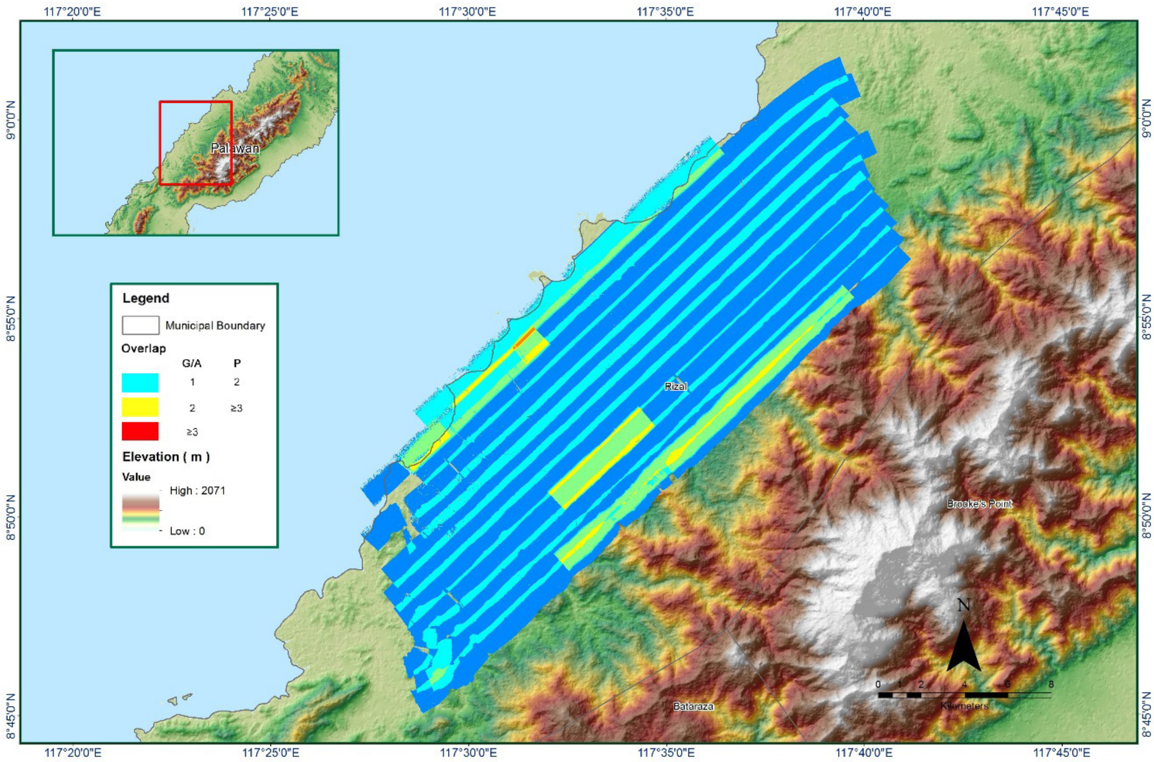


Figure A-8.5. Image of data overlap

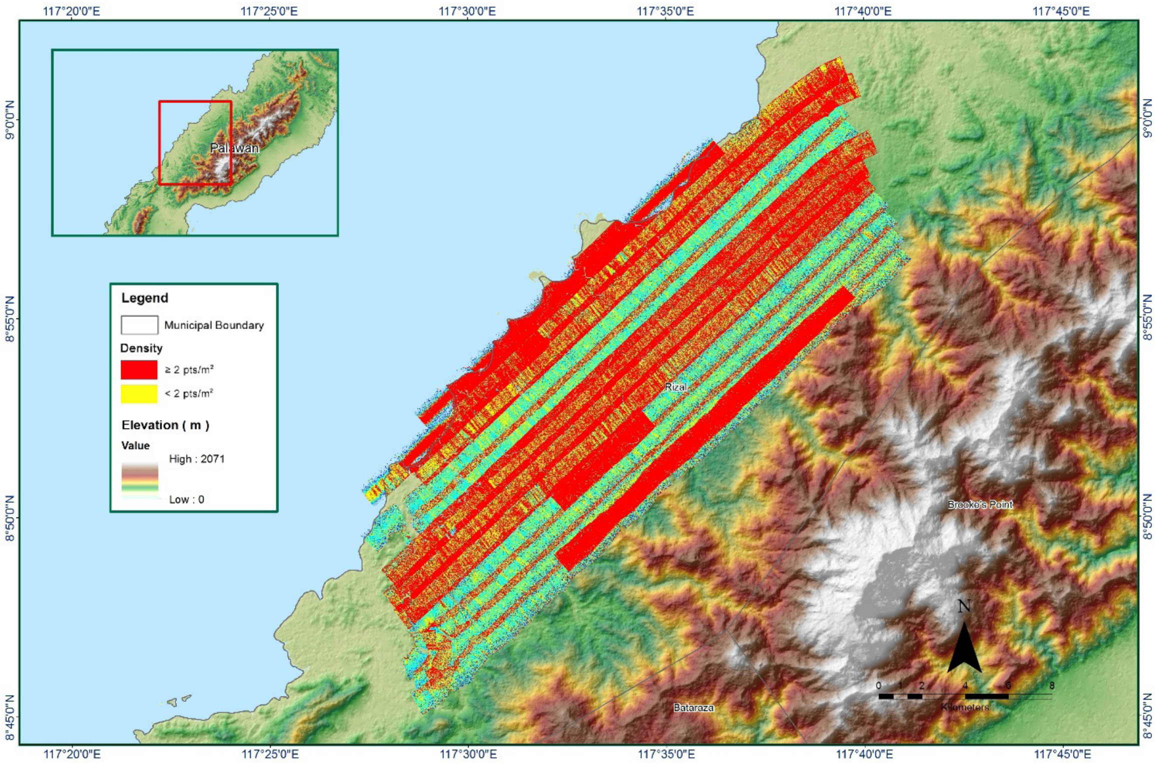


Figure A-8.6 Density of merged LiDAR data

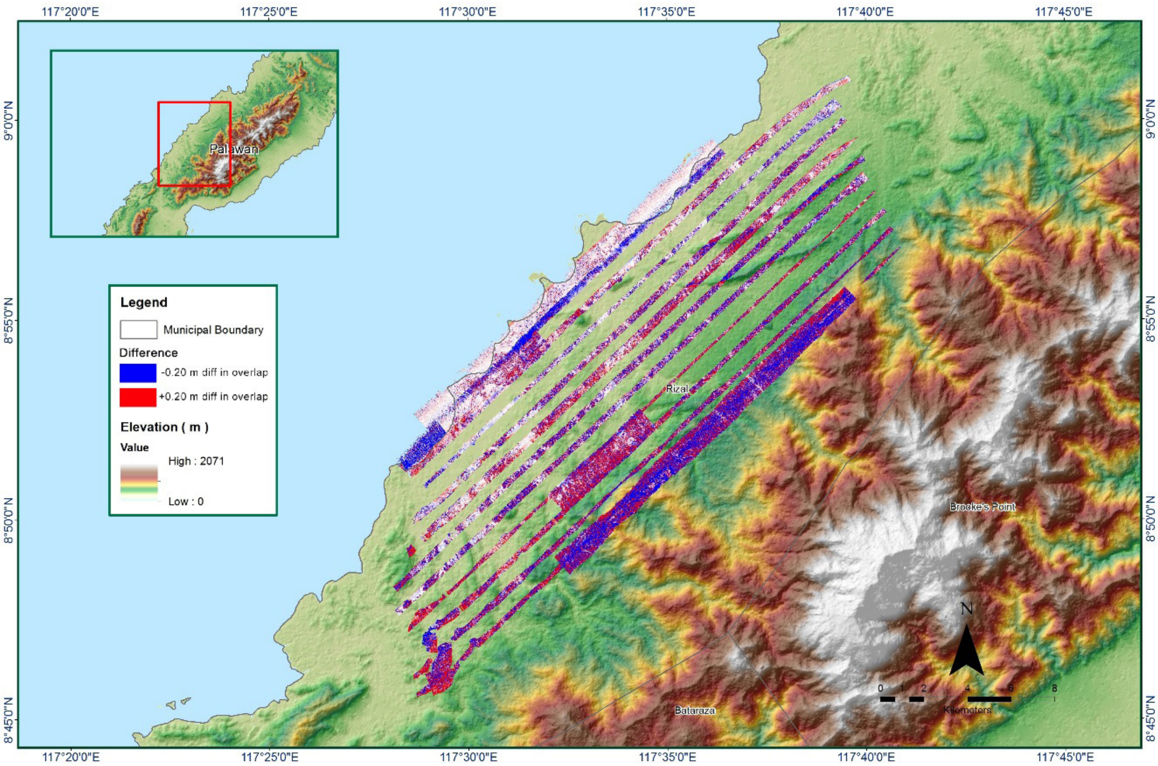


Figure A-8.7. Elevation difference between flight lines

Annex 9. Ransang Model Basin Parameters

Table A-9.1 Ransang 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
W480	1.55	89	0.0	1.463625	6.3698	0.15717	1	0.5
W490	1.55	89	0.0	0.815025	3.5468	0.0926837	1	0.5
W500	1.444	62.139	0.0	0.1098525	16.574	0.3323	0.44562	0.5
W520	0.42573	62.264	0.0	0.0551933	4.3493	0.0438026	0.30338	0.68349
W530	0.060478	99	0.0	0.0714071	0.29996	0.18024	0.44581	0.48285
W540	0.13608	64.036	0.0	0.125745	1.5021	0.0249988	0.30356	0.882
W550	1.5206	58.949	0.0	1.81515	4.0311	0.0236634	0.30346	0.46682
W560	1.3639	41.728	0.0	0.2572275	4.0155	0.24044	1	0.47167
W570	0.65814	63.635	0.0	0.0717534	17.681	0.45641	0.44521	0.5
W580	0.70276	41.579	0.0	0.0658341	24.54	0.2515	0.30321	0.50249
W590	3.2013	40.236	0.0	1.29555	6.6872	0.31231	0.6667	0.71594
W600	1.0489	40.606	0.0	0.0740608	18.146	0.83728	0.65158	0.5
W610	1.63	42.255	0.0	1.919625	7.3463	0.15448	0.45717	0.68739
W620	3.061	37.612	0.0	1.42275	13.458	0.46852	0.43974	1
W630	1.3815	42.651	0.0	1.572525	12.707	0.6459	0.66606	0.5
W640	3.3107	39.818	0.0	1.08225	9.2633	0.26533	0.45524	0.995
W650	1.6127	41.455	0.0	0.2114475	14.7	0.49006	0.66446	0.5
W660	2.3896	40.016	0.0	0.5319075	3.9643	0.2146128	0.68798	0.47702
W670	10.851	35.322	0.0	10.1865	10.668	0.87776	0.66478	0.5

W680	1.4922	41.384	0.0	1.6125	12.031	1.2552	1	0.5
W690	1.612	42.565	0.0	0.1616625	14.407	1.0057	1	0.5
W700	3.8988	35.512	0.0	1.9821	6.9615	0.30522	0.66759	0.99977
W710	1.4906	42.661	0.0	0.26922	12.932	1.6558	1	0.5
W720	3.3799	37.789	0.0	0.2748075	12.457	0.94536	1	0.5
W730	1.6125	94.238	0.0	0.0551000	13.364	0.47555	0.66549	0.5
W740	2.7286	38.786	0.0	1.584075	1.0947	0.0226565	1	0.47454
W750	1.9742	41.29	0.0	0.2717325	2.8361	0.61783	1	0.5
W760	6.7522	39.78	0.0	0.0845175	5.9499	0.2225371	0.45385	1
W770	3.3121	37.001	0.0	0.195915	16.129	0.33205	0.66719	0.5
W780	3.3024	38.606	0.0	0.4179225	1.8726	0.13274	0.44556	0.45382
W790	3.3091	83.779	0.0	0.0620248	1.6314	0.20124	0.45675	0.4706
W800	5.1039	48.566	0.0	0.2847375	1.256	0.0401688	1	0.47681
W810	3.3956	35.705	0.0	0.11031	20.767	0.42391	0.68184	0.5
W820	8.7195	41.692	0.0	0.1063275	5.0614	0.22943	1	0.5
W830	13.043	40.429	0.0	1.002825	10.996	0.2328	1	0.5
W840	8.5068	41.632	0.0	0.474525	6.3965	0.42382	1	0.5
W850	8.2252	41.87	0.0	1.5054	3.0227	0.36769	1	0.5
W860	3.9438	35.411	0.0	0.6301575	2.7227	0.36684	1	0.50003
W870	8.7742	39.066	0.0	5.179875	6.2275	1.0461	1	0.5
W880	13.477	40.699	0.0	1.0125	9.5409	0.64296	1	0.5
W890	8.9697	40.63	0.0	5.565525	4.2871	0.32588	1	1
W900	19.573	71.951	0.0	0.095685	9.7852	0.84374	1	0.5
W910	8.2221	42.732	0.0	1.042875	1.2831	0.0251958	1	0.45947
W920	19.576	71.956	0.0	0.18825	14.258	0.32763	1	0.5
W930	10.451	38.28	0.0	3.66555	2.7624	0.01517	1	0.49068
W940	20.443	39.126	0.0	8.22	10.531	1.3339	1	0.5
W960	1.55	89	0.0	0.4255875	3.401	0.81104	1	0.5
W970	0.20003	99	0.0	0.0532078	0.1284	0.0024079	1	0.45858

Annex 10. Ransang Model Reach Parameters

Table A-10.1 Ransang 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	2091.2	0.0023640	0.04	Trapezoid	35	1
R110	Automatic Fixed Interval	2190.4	0.0024388	0.0562679	Trapezoid	35	1
R150	Automatic Fixed Interval	874.26	0.0024388	0.0433093	Trapezoid	35	1
R160	Automatic Fixed Interval	3185.3	0.0034419	0.0400248	Trapezoid	35	1
R180	Automatic Fixed Interval	4048.6	0.0098741	0.017947	Trapezoid	35	1
R200	Automatic Fixed Interval	4980.9	0.0023815	0.0542741	Trapezoid	35	1
R230	Automatic Fixed Interval	428.70	0.0023815	0.0267199	Trapezoid	35	1
R240	Automatic Fixed Interval	2735.9	0.0071581	0.0377988	Trapezoid	35	1
R250	Automatic Fixed Interval	2377.6	0.0207882	0.017344	Trapezoid	35	1
R280	Automatic Fixed Interval	326.27	0.0143072	0.0390836	Trapezoid	35	1
R300	Automatic Fixed Interval	1229.1	0.0231732	0.0403304	Trapezoid	35	1
R310	Automatic Fixed Interval	566.27	0.10824	0.0154	Trapezoid	35	1

R360	Automatic Fixed Interval	1412.3	0.0289815	0.059754	Trapezoid	35	1
R370	Automatic Fixed Interval	1195.7	0.0817834	0.0399374	Trapezoid	35	1
R390	Automatic Fixed Interval	3418.4	0.0228802	0.0271442	Trapezoid	35	1
R40	Automatic Fixed Interval	865.27	0.13670	0.04	Trapezoid	35	1
R410	Automatic Fixed Interval	2119.9	0.0508996	0.0685625	Trapezoid	35	1
R430	Automatic Fixed Interval	328.70	0.10592	0.0261573	Trapezoid	35	1
R440	Automatic Fixed Interval	219.71	0.0686483	0.0263813	Trapezoid	35	1
R50	Automatic Fixed Interval	1007.4	0.0023640	0.0075883	Trapezoid	35	1
R60	Automatic Fixed Interval	444.56	0.0055643	0.085933	Trapezoid	35	1
R80	Automatic Fixed Interval	445.56	0.0021377	0.0169598	Trapezoid	35	1
R90	Automatic Fixed Interval	1630.2	0.0078443	0.039666	Trapezoid	35	1
R980	Automatic Fixed Interval	42.426	0.13670	0.0033726	Trapezoid	35	1

Annex 11. Ransang Flood Validation Data

Table A-11.1 Ransang Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Latitude	Longitude						
1	8.900433	117.5336	0.14	0	-0.14			25-Year
2	8.90258	117.5348	0.03	0	-0.03			25-Year
3	8.905577	117.5446	0.06	0	-0.06			25-Year
4	8.905653	117.544	0.03	0	-0.03			25-Year
5	8.905672	117.5368	0.81	0	-0.81			25-Year
6	8.905849	117.5342	0.03	0.5	0.47		2016	25-Year
7	8.90618	117.5424	0.03	0	-0.03			25-Year
8	8.906453	117.5468	0.21	0	-0.21			25-Year
9	8.907174	117.5477	0.04	0	-0.04			25-Year
10	8.907614	117.549	0.03	0	-0.03			25-Year
11	8.90814	117.5497	0.05	0	-0.05			25-Year
12	8.908278	117.5502	0.03	0	-0.03			25-Year
13	8.908561	117.5506	0.11	0	-0.11			25-Year

14	8.90916	117.551	0.03	0	-0.03			25-Year
15	8.909644	117.551	0.03	0	-0.03			25-Year
16	8.909955	117.5513	0.03	0	-0.03			25-Year
17	8.910394	117.5514	0.03	0	-0.03			25-Year
18	8.910949	117.5518	0.04	0	-0.04			25-Year
19	8.911516	117.5519	0.03	0	-0.03			25-Year
20	8.912214	117.5524	0.03	0	-0.03			25-Year
21	8.91256	117.5523	0.03	0	-0.03			25-Year
22	8.913211	117.5526	0.09	0	-0.09			25-Year
23	8.913918	117.5527	0.03	0	-0.03			25-Year
24	8.91426	117.5529	0.15	0	-0.15			25-Year
25	8.916076	117.5531	0.03	0	-0.03			25-Year
26	8.918797	117.5533	0.03	0	-0.03			25-Year
27	8.919491	117.5538	0.03	1	0.97		Jan. 2016	25-Year
28	8.919805	117.554	0.03	0	-0.03			25-Year
29	8.921301	117.5532	0.43	0	-0.43			25-Year
30	8.922023	117.5524	1.77	0	-1.77			25-Year
31	8.92274	117.5518	0.13	0	-0.13			25-Year
32	8.92447	117.5517	0.03	0	-0.03			25-Year

33	8.924826	117.5556	1.37	1	-0.37		Jan. 2016	25-Year
34	8.925583	117.5559	0.78	1.1	0.32		Jan. 2016	25-Year
35	8.926808	117.5594	0.03	0.3	0.27		Jan. 2013	25-Year
36	8.926922	117.5609	0.6	0.65	0.05		2016	25-Year
37	8.926921	117.5561	1.04	1	-0.04		Jan. 2013	25-Year
38	8.926956	117.5583	0.56	0.5	-0.06		Jan. 2013	25-Year
39	8.927015	117.557	0.41	0	-0.41			25-Year
40	8.927038	117.5576	0.46	0.8	0.34		Jan. 3, 2013	25-Year
41	8.92716	117.5637	0.55	0	-0.55			25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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