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

LiDAR Surveys and Flood Mapping of Baroc River

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

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For questions/queries regarding this report, contact:

Asst. Prof. Edwin R. Abucay
Project Leader, Phil-LiDAR 1 Program
University of the Philippines, Los Banos
Los Banos, Laguna, Philippines 4031
E-mail: erabucay@up.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LIDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

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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
BSWM	Bureau of Soil and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
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
NAMRIA	National Mapping and Resource Information Authority
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
RBCO	River Basin Control Office
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 BAROC RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, Asst. Prof. Joan Pauline P. Talubo

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 Baroc River Basin

The Baroc River Basin is a 15,800-hectare watershed situated in Oriental Mindoro covering the Municipalities of Mansalay and Roxas. It covers the barangays of B. Del Mundo, Balugo, Bonbon, Maliwanag, Panaytayan, Poblacion, Roma, Santa Brigida, Santa Maria, Santa Teresita, Villa Celestial, Wasig and Waygan in Mansalay municipality; and, Happy Valley, San Aquilino, San Isidro, San Mariano, San Miguel, San Rafael and San Vicente in Roxas. The river basin partially covers the south-eastern part of the island of Mindoro and is bounded east by Tablas Strait. The DENR River Basin Control Office identified it to has an approximate catchments area of 184 square kilometers and a 294 MCM estimated annual runoff (River Basin Control Office, 2017).

The river basin area has seven geological formation with Jurassic as the most dominant type while remaining include Recent, Basement Complex, Upper Miocene-Pliocene, Pliocene-Pleistocene, Oligocene and Oligocene-Miocene. The general area of the river basin is also characterized by 30-50% slope and elevation of 0-250 meters above mean sea level. Moreover, four soil types exists in the area including Maranlig gravelly sandy clay loam, Alaminos loam, San Manuel clay loam, Buguay loamy sand. Beach sand as well as rough mountain land (unclassified) can also be found in the area. Land cover in the area include perennial crop, annual crop, built-up, fishpond, grassland, inland water, mangrove forest, open forest, open/barren and shrubs.

Its main stem, the Baroc River is among the 45 river systems in the MIMAROPA Region. The Baroc River passes through B. Del Mundo, Balugo, Bonbon, Maliwanag, Panaytayan, Poblacion, Roma, Santa Brigida, Santa Maria, Santa Teresita, Villa Celestial, Wasig and Waygan in Mansalay; and, Happy Valley, San Aquilino, San Isidro, San Mariano, San Miguel, San Rafael and San Vicente in Roxas. Based on the 2015 National Census, a total of 6,479 people is residing within the immediate vicinity of the river distributed among three barangays namely: Barangay San Isidro in Municipality of Roxas, and Barangays Santa Brigida and Wasig in Municipality of Mansalay (Philippine Statistics Authority, 2016). An estimated distance of 4.42 km of Baroc River was delineated for bathymetric survey covering Brgy. San Isidro down to the mouth of the river at Tablas Strait.

Most of the areas encompassed by the river basin comprise of cultivated areas for agricultural sites and are made up of arable lands for coconut, cereal and sugar plantations, due to a conducive climate. Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

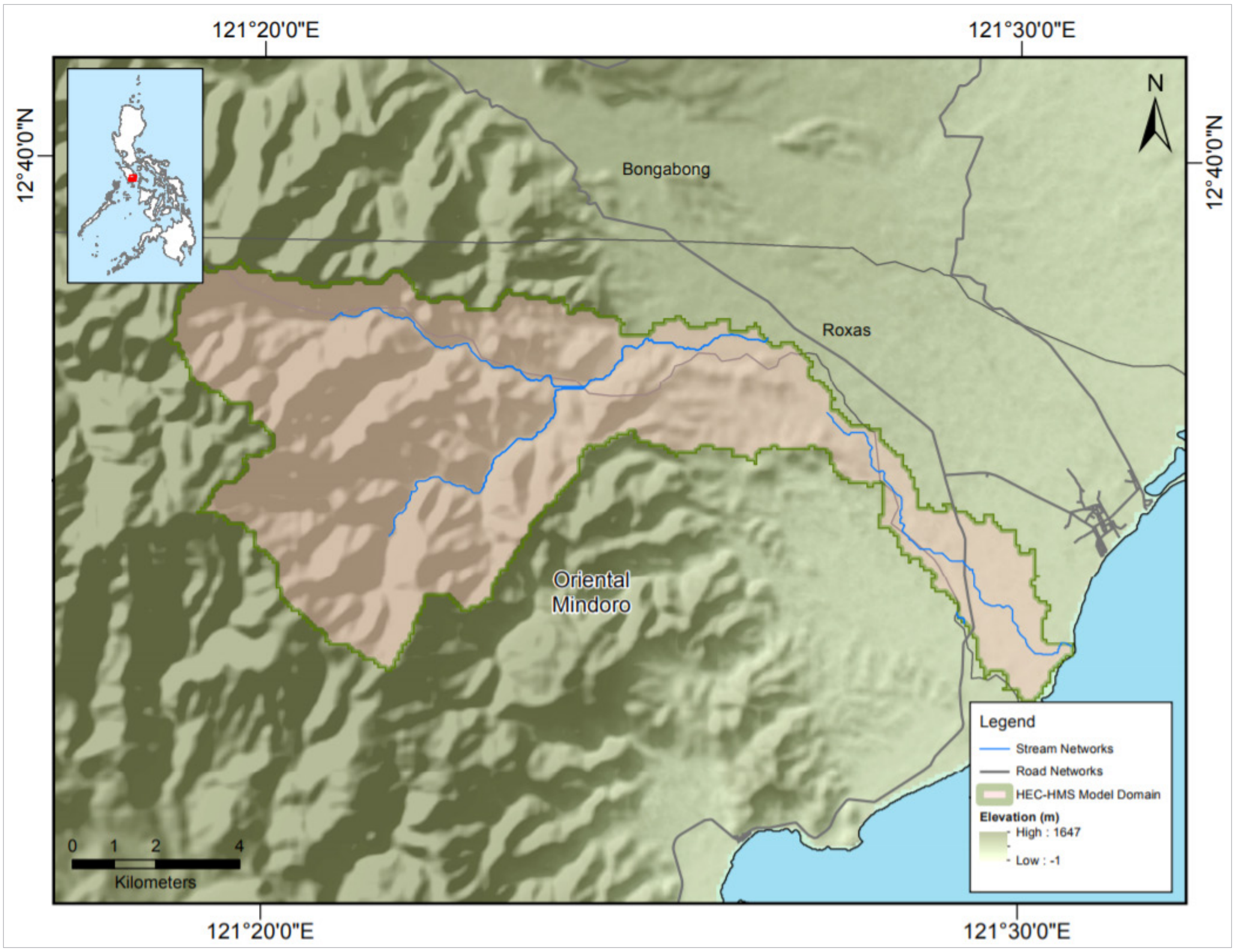


Figure 1. Map of Baroc River Basin (in brown)

Settlements in the area are in constant threat of flooding due to heavy rainfall. In addition, according to the Mines and Geoscience Bureau, Panaytayan of Mansalay and San Vicente of Roxas have high risk to landslide while the other barangays of each municipality has low to moderate risks. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, there were only four notable weather disturbance that caused flooding in 2004 (Unding), 2006 (Caloy), 2009 (Ondoy), and 2013 (Yolanda).

Flash floods occurred near the riverside last November 2–3, 2013 when Typhoon Haiyan hit most of Oriental Mindoro. The latest typhoon the hit Roxas is Typhoon Lando on October 2015 which resulted to the suspension of sea travels and 778 passengers had been stranded. (Delfin T. Mallari Jr., 2015).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BAROC FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Iro Niel D. Roxas, and Mr. Merlin A. Fernando

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 Baroc floodplain in Oriental Mindoro. These missions were planned for 21 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1 and Table 3. Figure 2 shows the flight plan and base stations for Baroc floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 28F	600	30	36	50	45	130	5
BLK 28G	600	30	36	50	45	130	5
BLK 28H	600	30	36	50	45	130	5
BLK 28I	600	30	36	50	45	130	5
BLK 28J	1000	30	36	50	45	130	5

Table 2. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK28J	1000	30	50	125	50	130	5

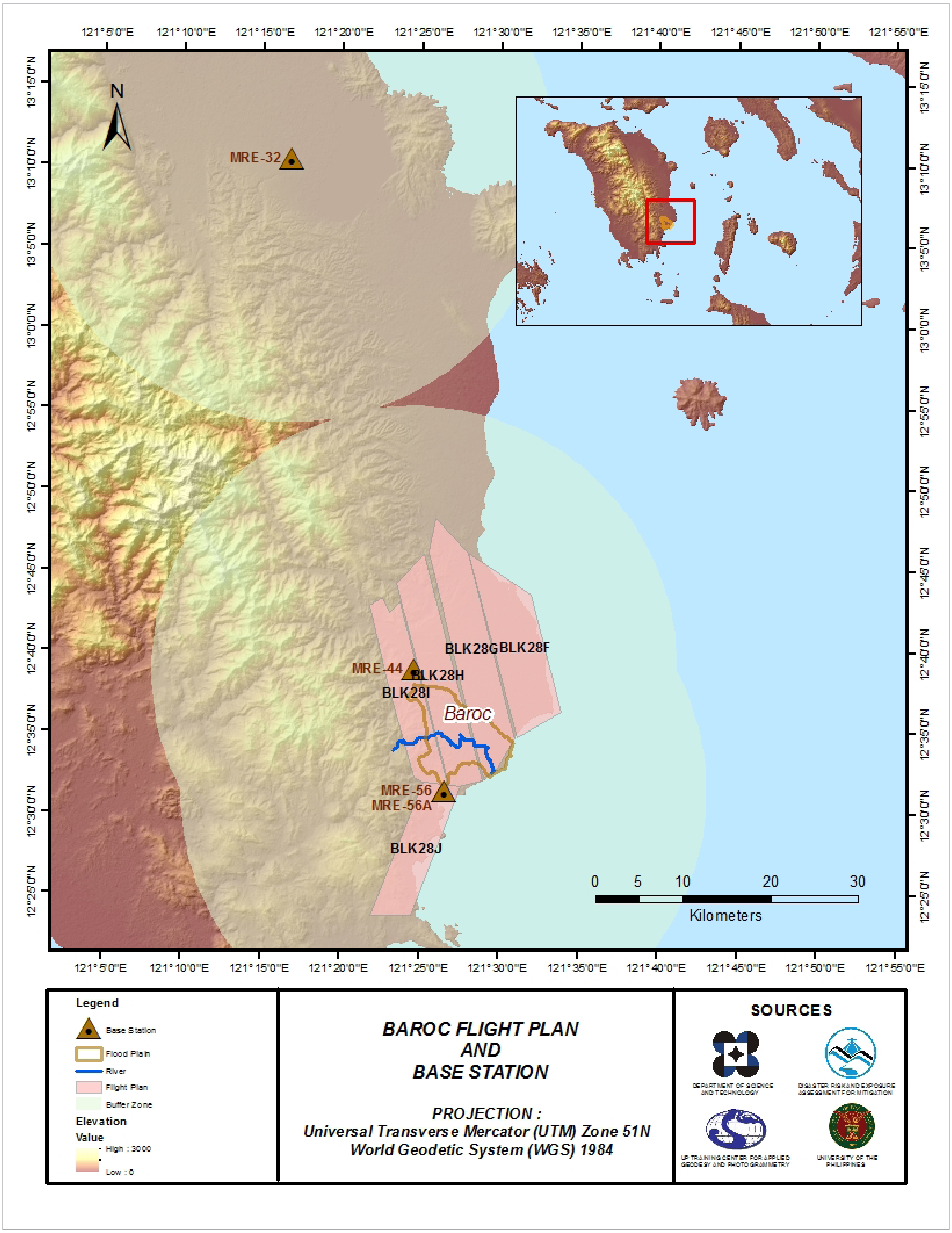


Figure 2. Flight plans and base stations used for Baroc Floodplain

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA ground control points: MRE-44, MRE-32 and MRE-56 which are of second (2nd) order accuracy. The project team also established one (1) ground control point MRE-56A. The certifications for the NAMRIA reference points are 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 operations for the entire duration of the survey (February 7-15, 2014; October 28, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Baroc floodplain are shown in Figure 2. The list of team members are shown in ANNEX 4.

Figure 2 shows the recovered NAMRIA reference point within the area. In addition, Table 3 to Table 8 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

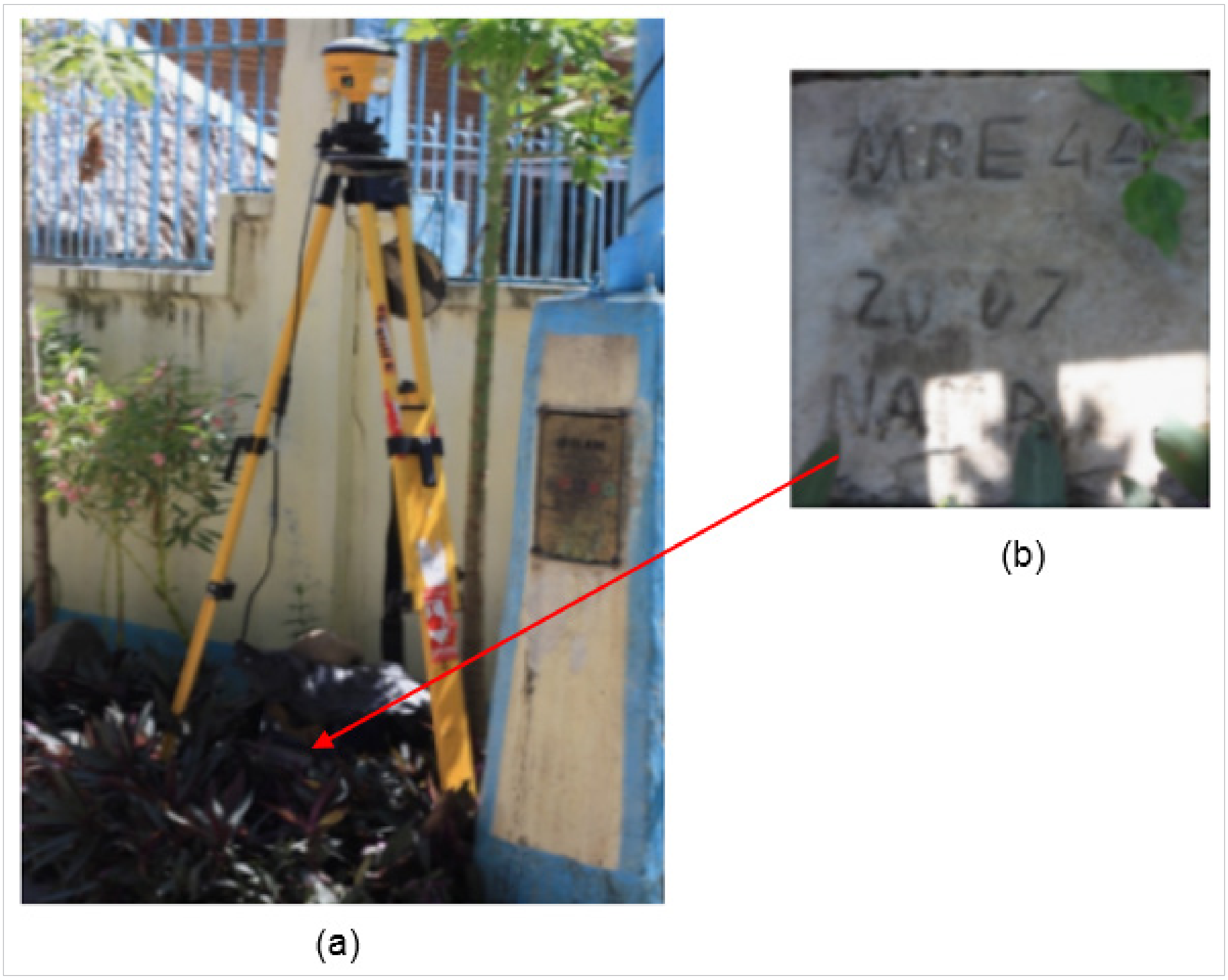


Figure 3. GPS set-up over MRE-44 just outside the compound of the barangay hall of Happy Valley, municipality of Roxas, Oriental Mindoro (a) and NAMRIA reference point MRE-44 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point MRE-44 used as base station for the LiDAR acquisition.

Station Name	MRE-44	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°38'59.03778" North 121°24'32.60444" East 87.94200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	544436.519 meters 1398838.995 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°38'54.11733" North 121°24'37.66392" East 137.80400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	327214.81 meters 1398840.08 meters

Table 4. Details of the recovered NAMRIA horizontal control point MRE-32 used as base station for the LiDAR acquisition.

Station Name	MRE-32	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°10'28.85064" North 121°16'38.44761" East 19.49300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	530065.679 meters 1456889.419 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°10'23.79251" North 121°16'43.46244" East 67.64700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	313296.85 meters 1457002.75 meters

Table 5. Details of the recovered NAMRIA horizontal control point MRE-56 used as base station for the LiDAR acquisition.

Station Name	MRE-56	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°31'25.76362'' North 121°26'25.21109'' East 7.8700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	547857.861 meters 1383916.657 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31'20.87629'' North 121°26'30.28143'' East 58.13600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	330530.08 meters 1384892.31 meters

Table 6. Details of the established ground control point MRE-56A used as base station for the LiDAR acquisition.

Station Name	MRE-56A	
Order of Accuracy	2nd (established)	
Relative Error (horizontal positioning)	1:50,000	
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31'20.59653'' North 121°26'30.40791'' East 57.601m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	330688.179 meters 1384818.639 meters

Table 7. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 7, 2014	1072A	3BLK28F038A	MRE-44
February 8, 2014	1076A	3BLK28G039A	MRE-44
February 8, 2014	1078A	3BLK28GSH039B	MRE-44
February 11, 2014	1088A	3BLK28HS042A	MRE-44
February 11, 2014	1090A	3BLK28J042B	MRE-44
February 13, 2014	1098A	3BLK28JSI044B	MRE-44, MRE-32
February 15, 2014	1104A	3BLK28JSI046A	MRE-44
October 8, 2015	8312G	2BLK28JKLS301A	MRE-56, MRE-56A

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR Data Acquisition in Baroc floodplain, for a total of thirty-one hours and twenty-one minutes (31+21) of flying time for RP-C9122 and RP-C9322. All missions were acquired using the Aquarius and Gemini LiDAR systems. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Baroc 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
7-Feb-14	1072A	100.27	106.58	NA	106.58	1143	4	23
8-Feb-14	1076A	118.33	100.75	15.56	85.19	1041	4	5
8-Feb-14	1078A	215.35	68.06	16.01	52.05	869	3	29
11-Feb-14	1088A	97.02	90.59	32.81	57.78	1235	4	29
11-Feb-14	1090A	69.40	28.77	1.76	27.01	319	2	47
13-Feb-14	1098A	103.26	76.86	15.85	61.01	909	3	59
15-Feb-14	1104A	144.96	125.50	3.50	122	771	4	41
28-Oct-15	8312G	69.40	75.52	NA	75.52	NA	3	28
TOTAL		**917.99**	**672.63**	**85.49**	**587.14**	**6287**	**31**	**21**

Table 9. 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)
1072A	600	30	36	50	45	130	5
1076A	600	30	36	50	45	130	5
1078A	600, 1000	30	36, 30, 20	50, 70	45	130	5
1088A	600	30	36	50	45	130	5
1090A	600	30	36	50	45	130	5
1098A	600	30	36	50	45	130	5
1104A	600, 1000	30	36, 30	50, 30, 40	45	130	5
8312G	1000	30	36	100	30	130	5

2.4 Survey Coverage

Baroc floodplain is located in the province of Oriental Mindoro, with majority of the floodplain situated within the municipality of Mansalay and Roxas. Municipalities of Roxas, Bongabong and Mansalay are mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Baroc floodplain is presented in Figure 4.

Table 10. List of municipalities and cities surveyed during the Baroc Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Oriental Mindoro	Roxas	90.14	76.2	85%
	Bongabong	493.74	226.48	46%
	Mansalay	477.24	132.56	28%
	Bulalacao	365.58	61.83	17%
	Bansud	196.99	5.66	3%
	Socorro	206.05	5.8	3%
	Gloria	327.28	5.49	2%
	Pinamalayan	206.87	2.66	1%
TOTAL		**2363.89**	**516.68**	**21.86%**

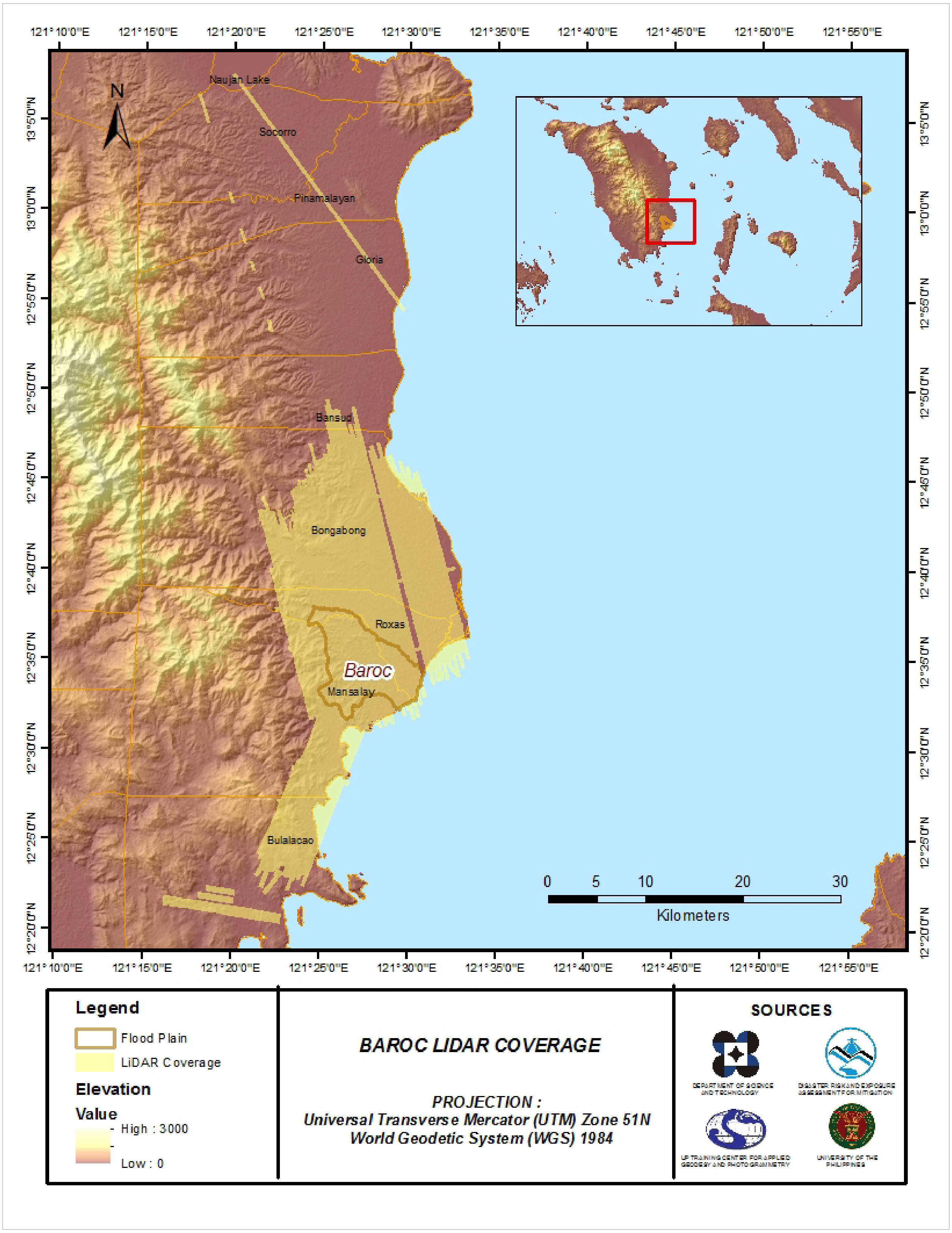


Figure 4. Actual LiDAR survey coverage for Baroc Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE BAROC FLOODPLAIN

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

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

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are 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.

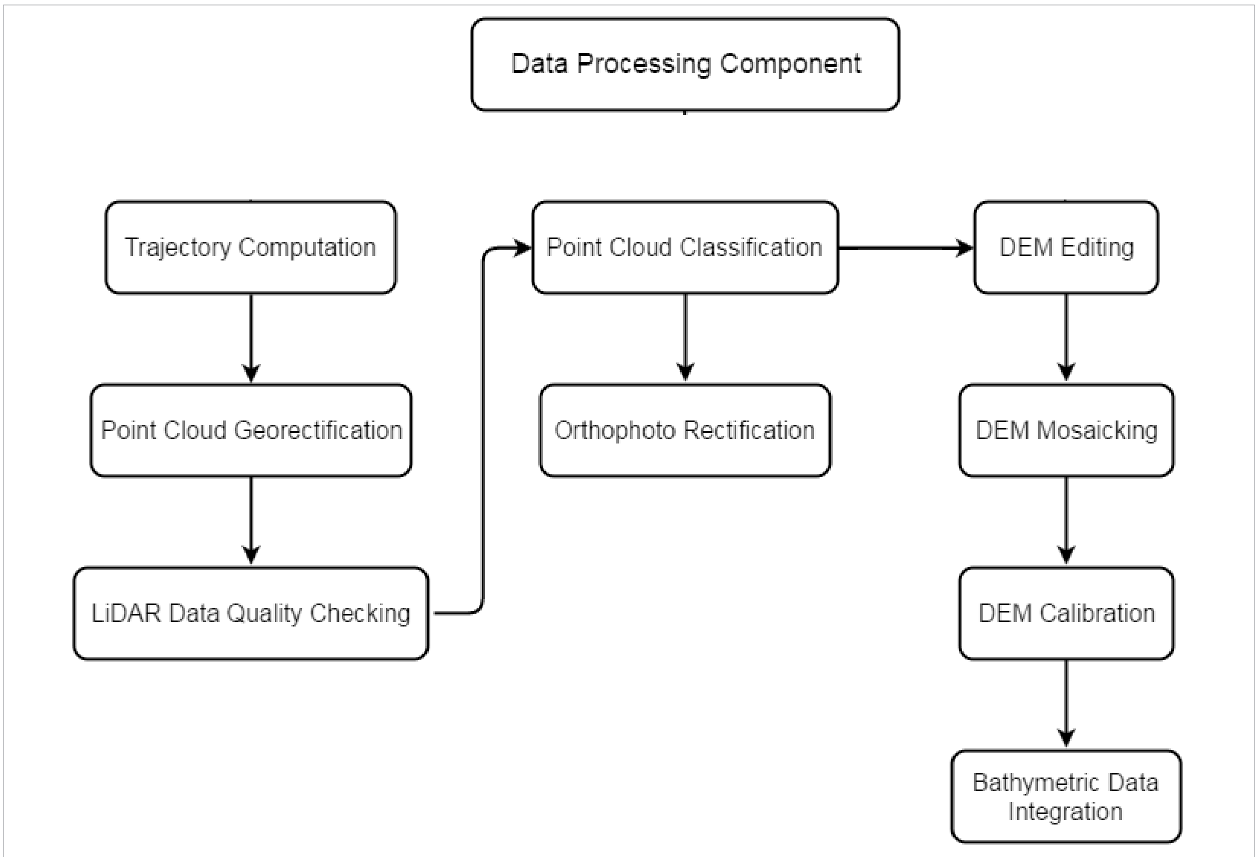


Figure 5. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Baroc floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on October 2015 were flown using the Gemini system over Mansalay, Oriental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 91.37 Gigabytes of Range data, 2.01 Gigabytes of POS data, 116.85 Megabytes of GPS base station data, and 428.96 Gigabytes of raw image data to the data server on February 21, 2014 for the first survey and October 12, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Baroc was fully transferred on October 12, 2015, as indicated on the Data Transfer Sheets for Baroc floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 1098A, one of the Baroc 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 February 13, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

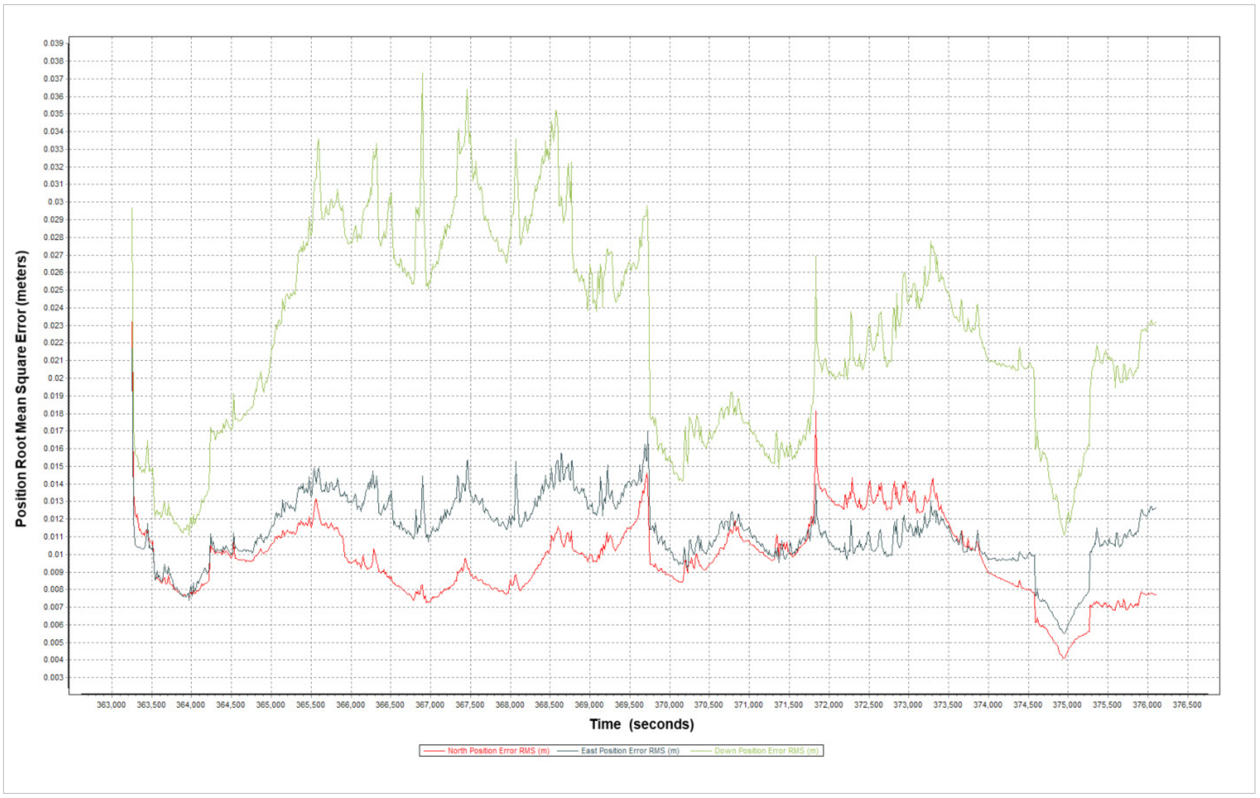


Figure 6. Smoothed Performance Metric Parameters of Baroc Flight 1098A.

The time of flight was from 363300 seconds to 376100 seconds, which corresponds to afternoon of February 13, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 6 shows that the North position RMSE peaks at 1.80 centimeters, the East position RMSE peaks at 1. 70 centimeters, and the Down position RMSE peaks at 3.80 centimeters, which are within the prescribed accuracies described in the methodology.

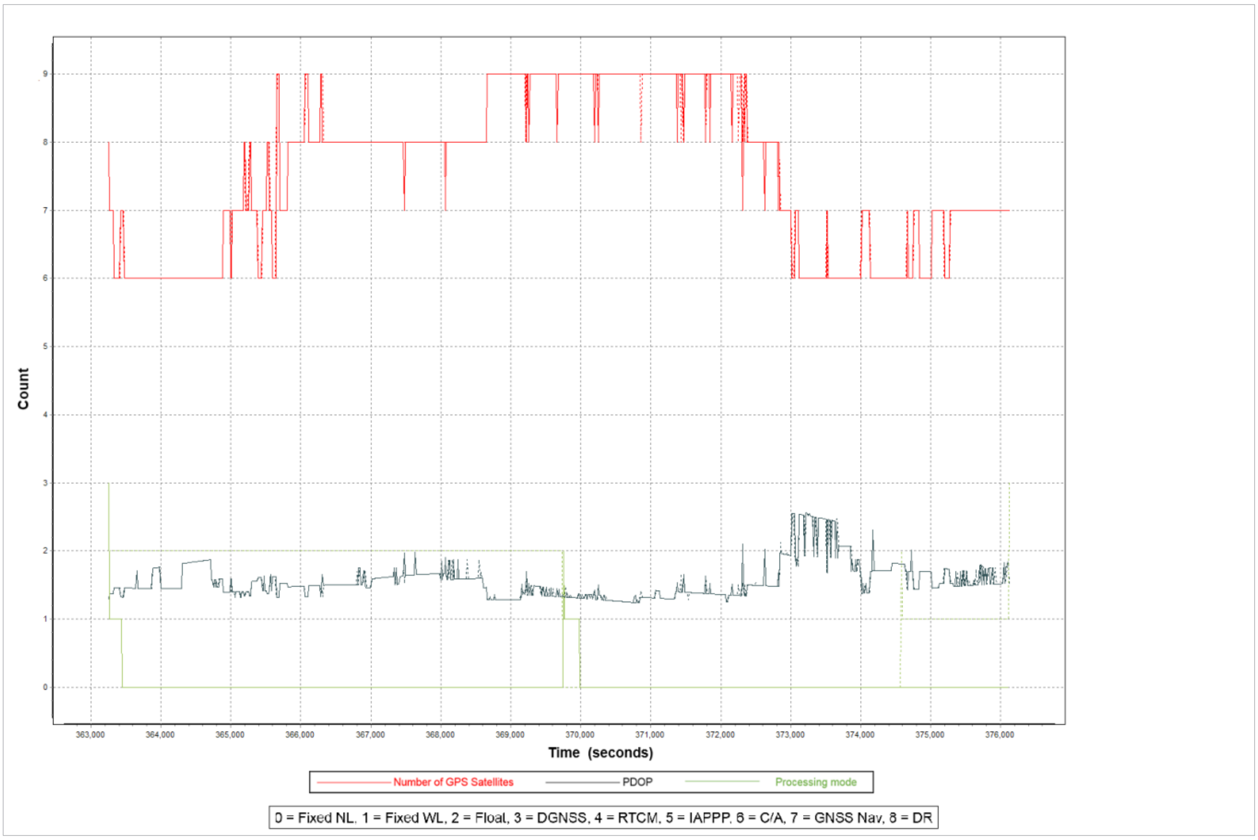


Figure 7. Solution Status Parameters of Baroc Flight 1098A.

The Solution Status parameters of flight 1098A, one of the Baroc flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 7. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Baroc flights is shown in Figure 8.

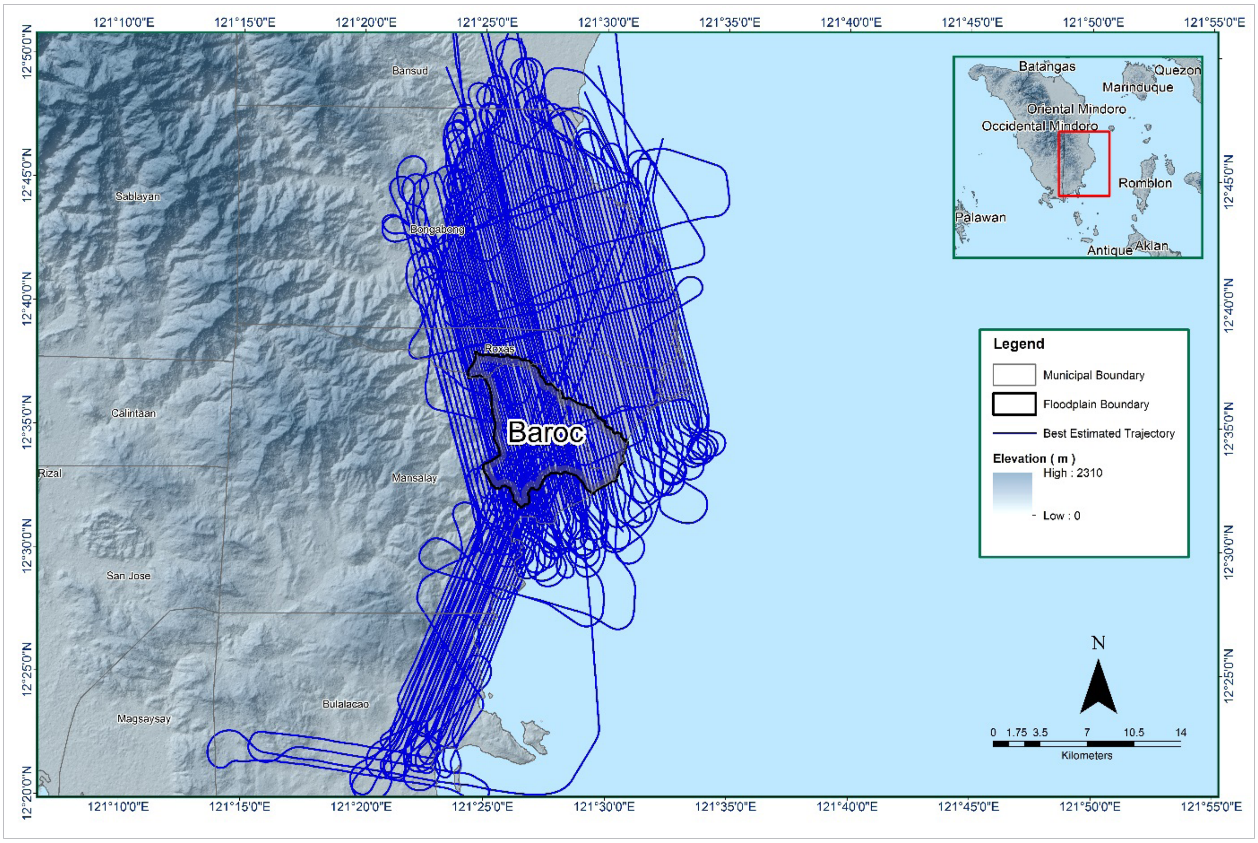


Figure 8. Best Estimated Trajectory for Baroc Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 114 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Baroc floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Baroc flights.

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000220
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000962
GPS Position Z-correction stdev	(<0.01meters)	0.0037

The optimum accuracy is obtained for all Baroc 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 Baroc Floodplain is shown in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

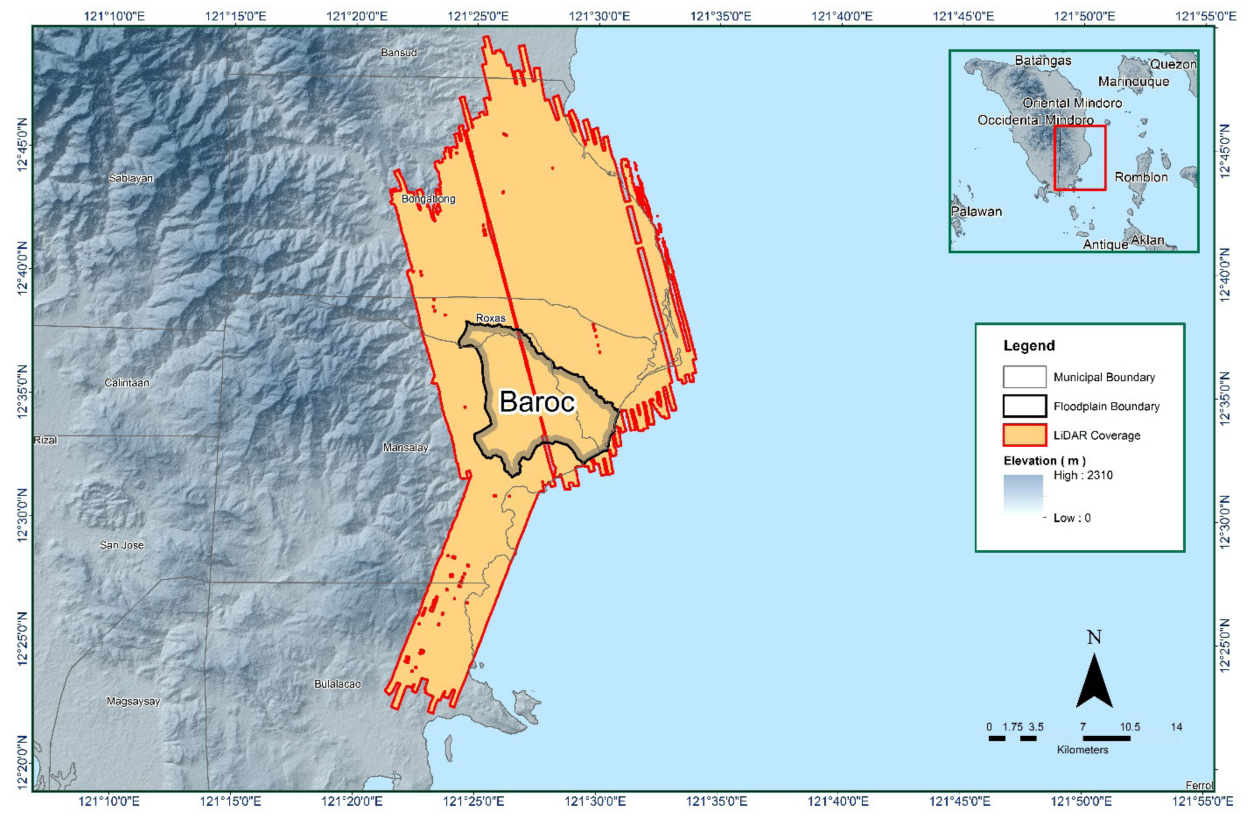


Figure 9. Boundary of the processed LiDAR data over Baroc Floodplain

The total area covered by the Baroc missions is 569.68 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into six (6) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Baroc Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Oriental_Mindoro_Blk28F	1072A	124.61
	1074A	
Oriental_Mindoro_Blk28G	1076A	95.35
Oriental_Mindoro_Blk28G_supplementH	1078A	62.40
Oriental_Mindoro_Blk28H_supplement	1088A	84.37
Oriental_Mindoro_Blk28I	1098A	97.92
	1104A	
Oriental_Mindoro_Blk28J	1090A	92.85
	1098A	
	1104A	
Oriental_Mindoro_Reflights_Blk28I	8312G	12.18
TOTAL		**569.68 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 Gemini and Aquarius systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

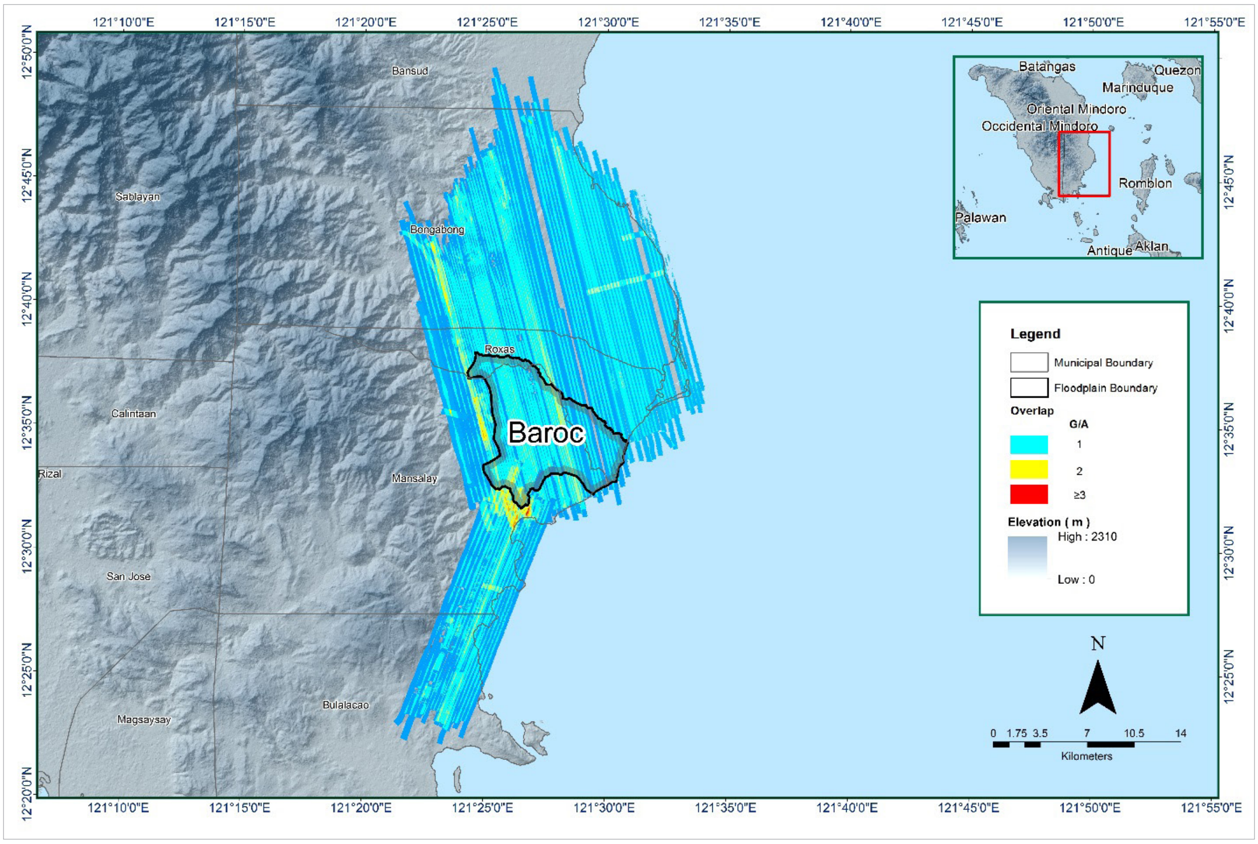


Figure 10. Image of data overlap for Baroc Floodplain.

The overlap statistics per block for the Baroc floodplain can be found in ANNEX 8 . One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 33.27% and 66.45% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 11. It was determined that all LiDAR data for Baroc floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.73 points per square meter.

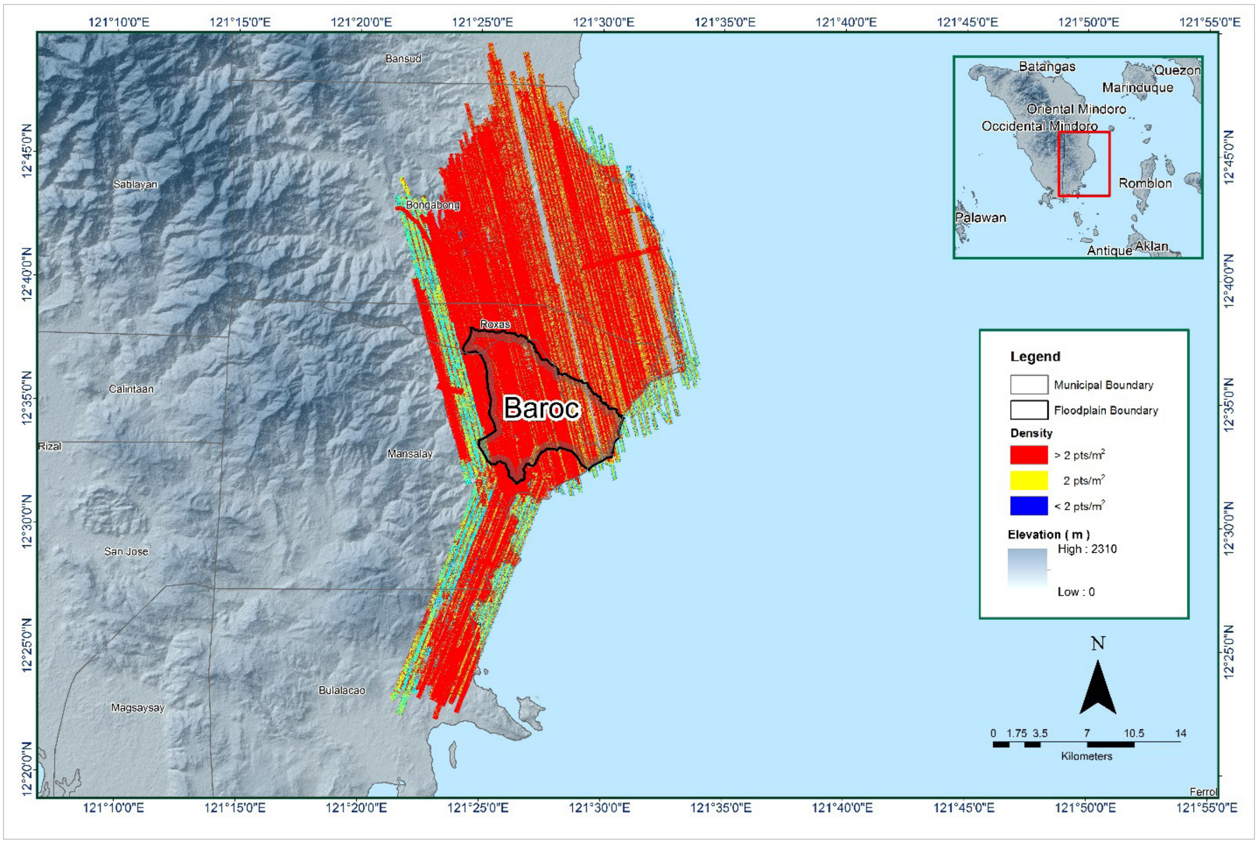


Figure 11. Pulse density map of merged LiDAR data for Baroc Floodplain.

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.

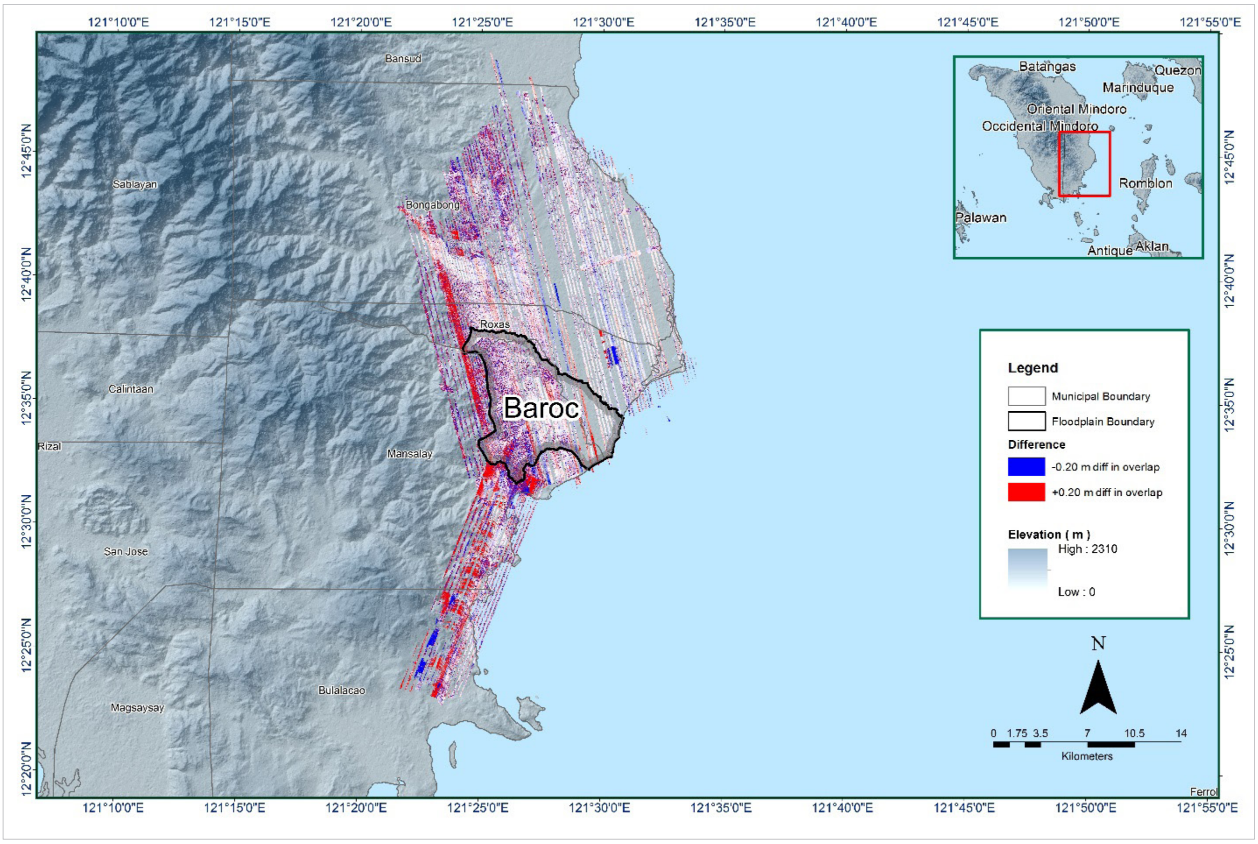


Figure 12. Elevation difference map between flight lines for Baroc Floodplain.

A screen capture of the processed LAS data from a Baroc flight 1098A 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.

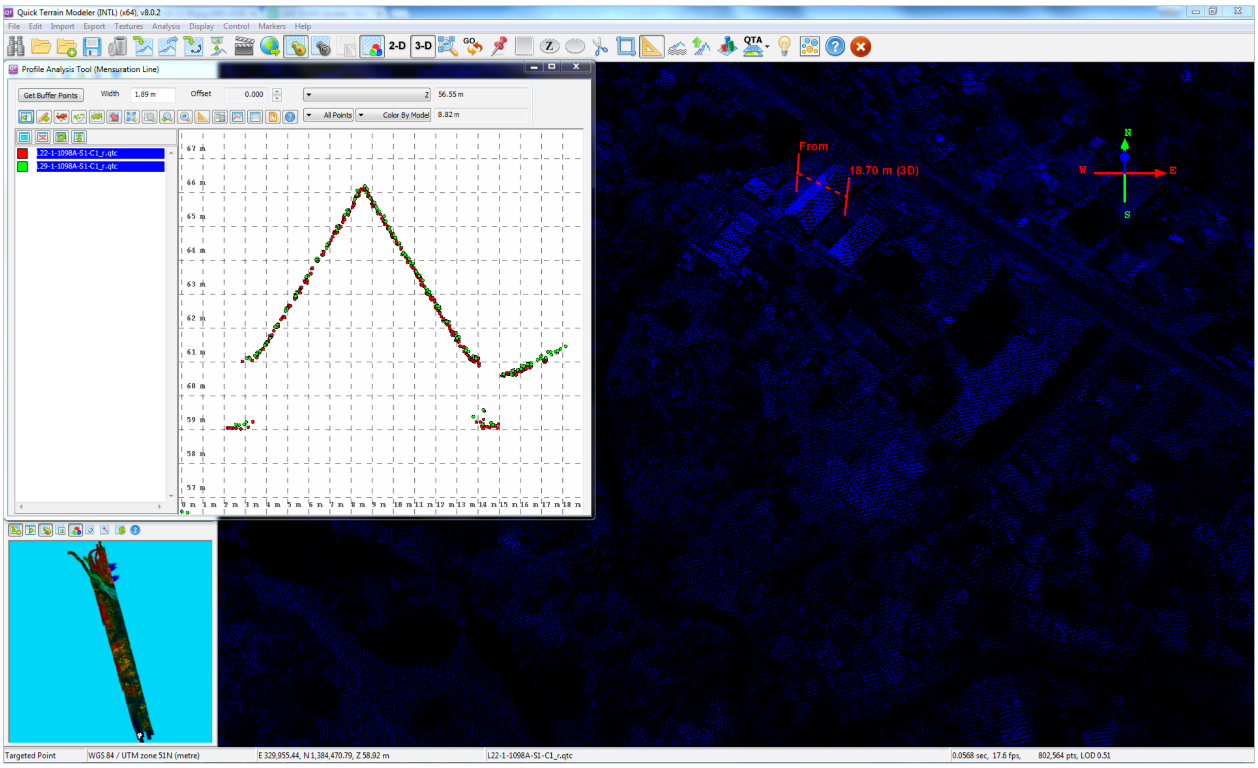


Figure 13. Quality checking for Baroc flight 1098A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Baroc classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	377,118,446
Low Vegetation	429,577,447
Medium Vegetation	394,980,848
High Vegetation	382,025,267
Building	14,151,903

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Baroc floodplain is shown in Figure 14. A total of 853 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 570.88 meters and 31.32 meters respectively.

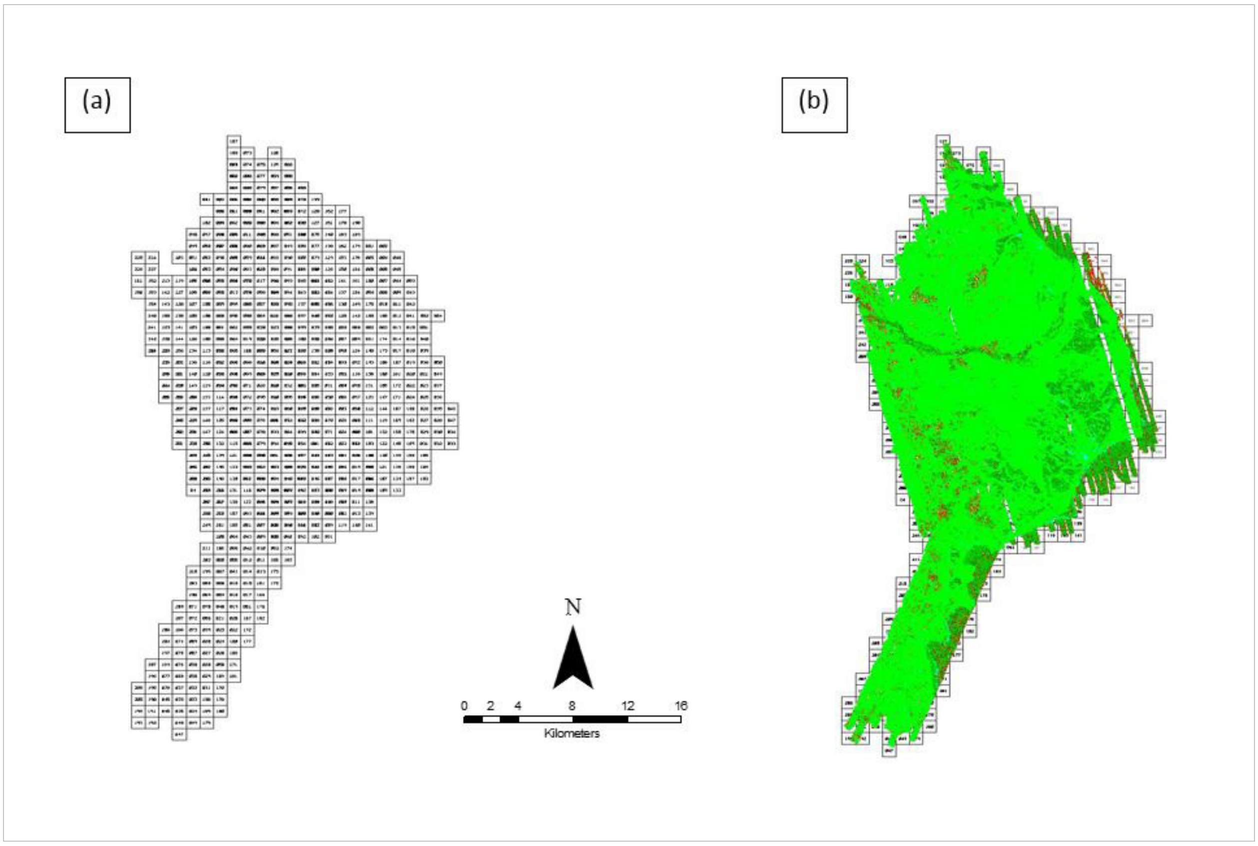


Figure 14. Tiles for Baroc Floodplain (a) and classification results (b) in TerraScan.

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.

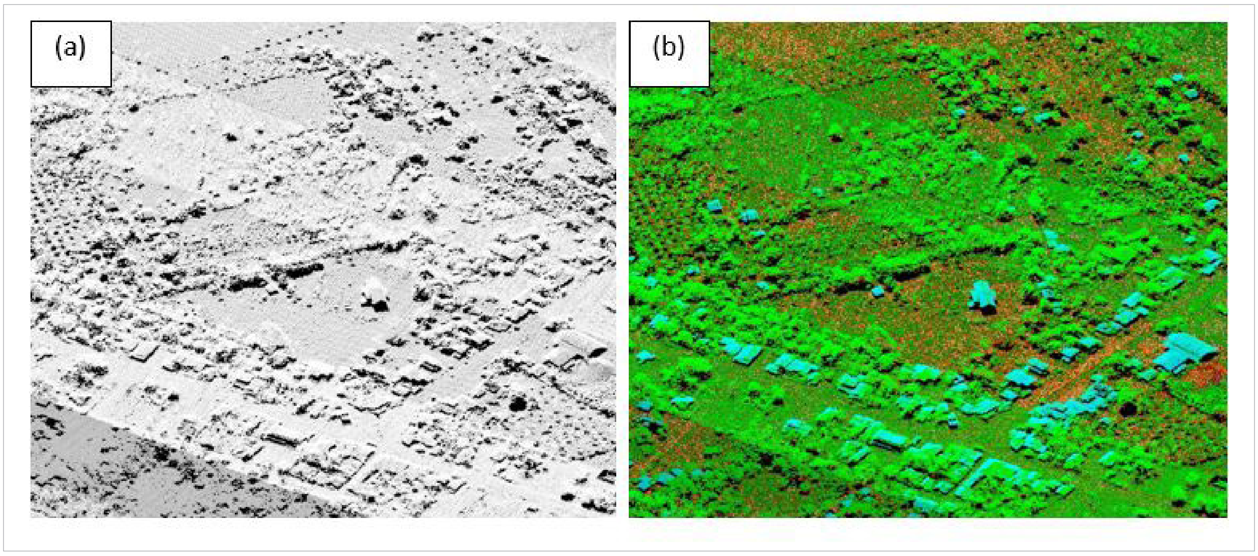


Figure 15. Point cloud before (a) and after (b) classification.

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.

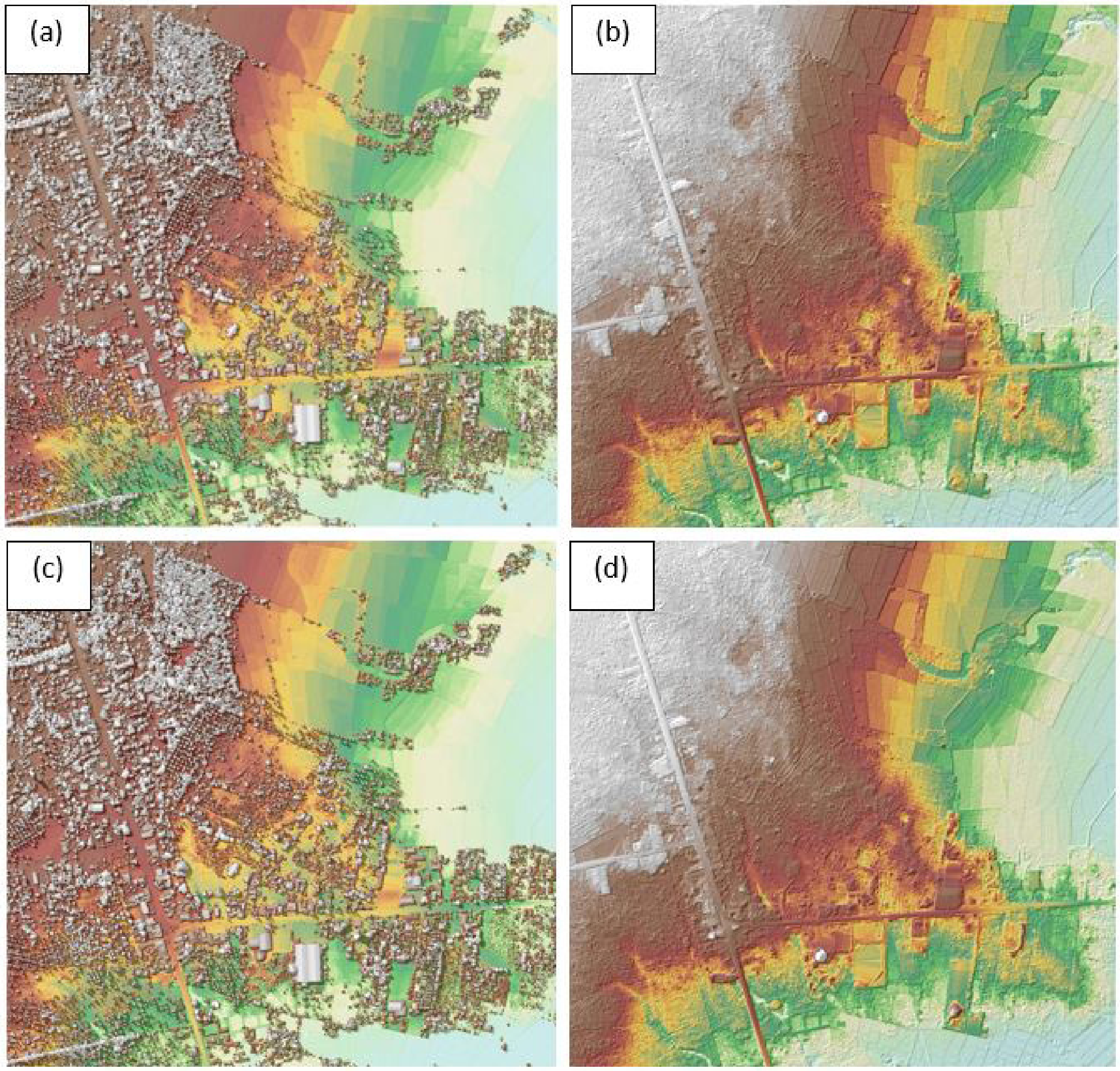


Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Baroc floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 670 1km by 1km tiles area covered by Baroc 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 Baroc floodplain has a total of 436.22 sq.km orthophotogaph coverage comprised of 4,615 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 18.

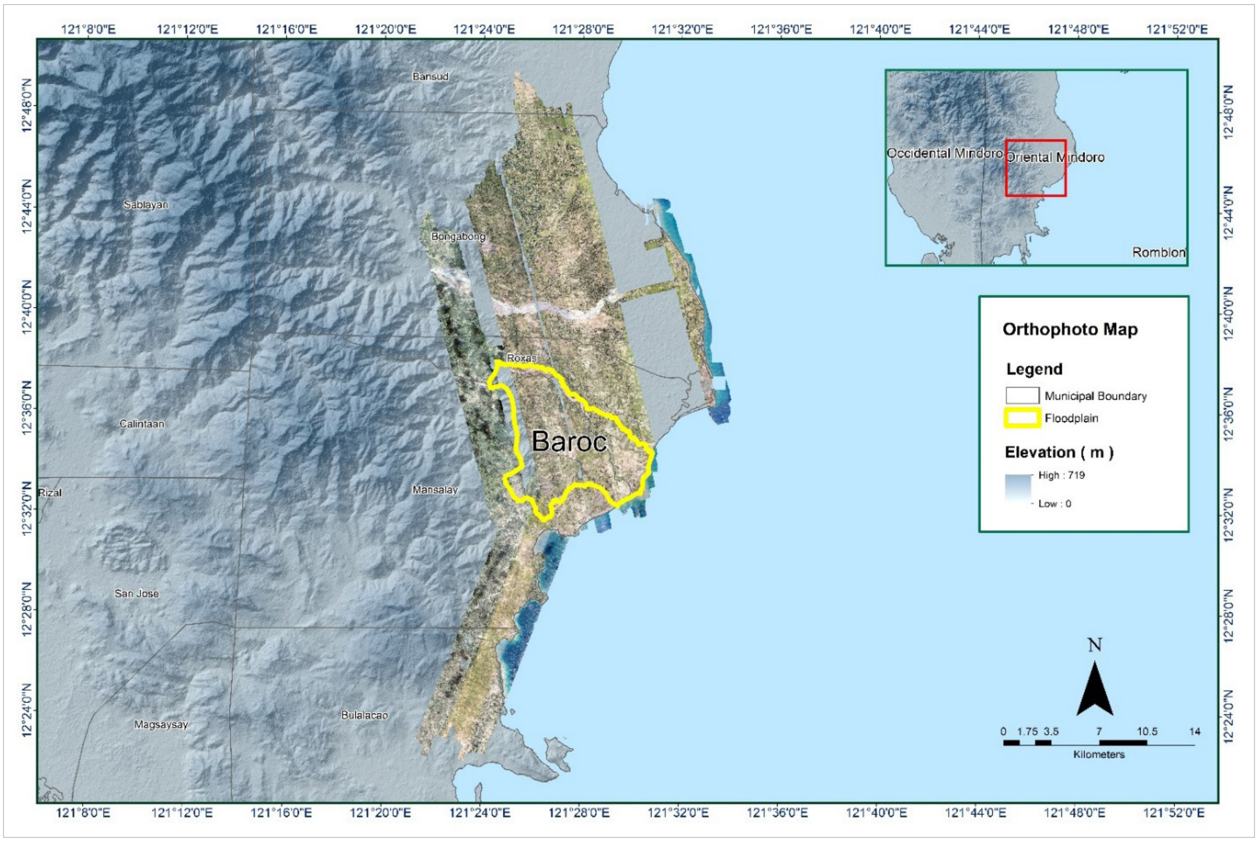


Figure 17. Baroc floodplain with available orthophotographs

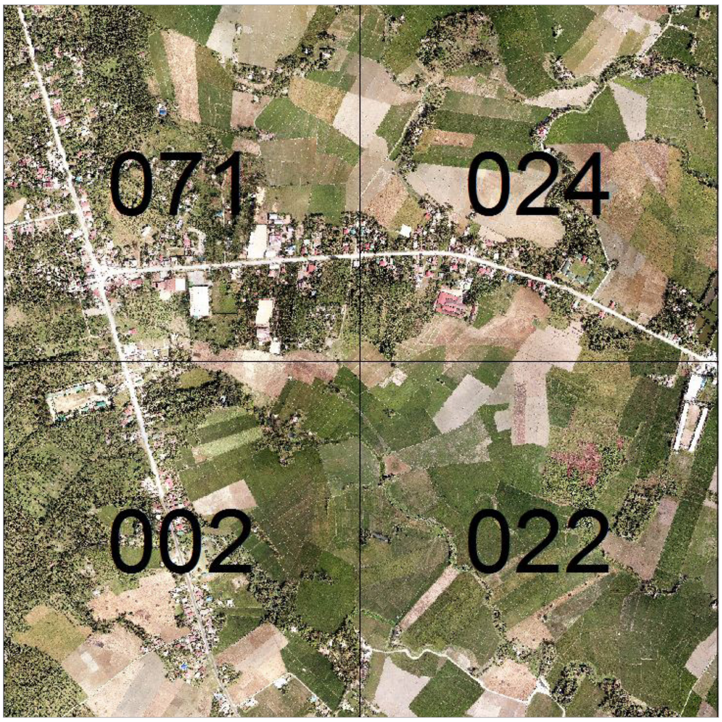


Figure 18. Sample orthophotograph tiles for Baroc Floodplain

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Baroc floodplain. These blocks are composed of Oriental Mindoro and Oriental Mindoro Reflights blocks with a total area of 569.68 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Oriental_Mindoro_Blk28F	124.61
Oriental_Mindoro_Blk28G	95.35
Oriental_Mindoro_Blk28G_supplementH	62.40
Oriental_Mindoro_Blk28H_supplement	84.37
Oriental_Mindoro_Blk28I	97.92
OrientalMindoro_Blk28J	92.85
Oriental_Mindoro_Reflights_Blk28I	12.18
TOTAL	**569.68 sq.km**

Portions of DTM before and after manual editing are shown in Figure 19. The bridge (Figure 19a) is also 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 embankment (Figure 19c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19d) to allow the correct flow of water. Also, the mountain (Figure 19e) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19f). Object retrieval uses the secondary DTM to fill in these areas.

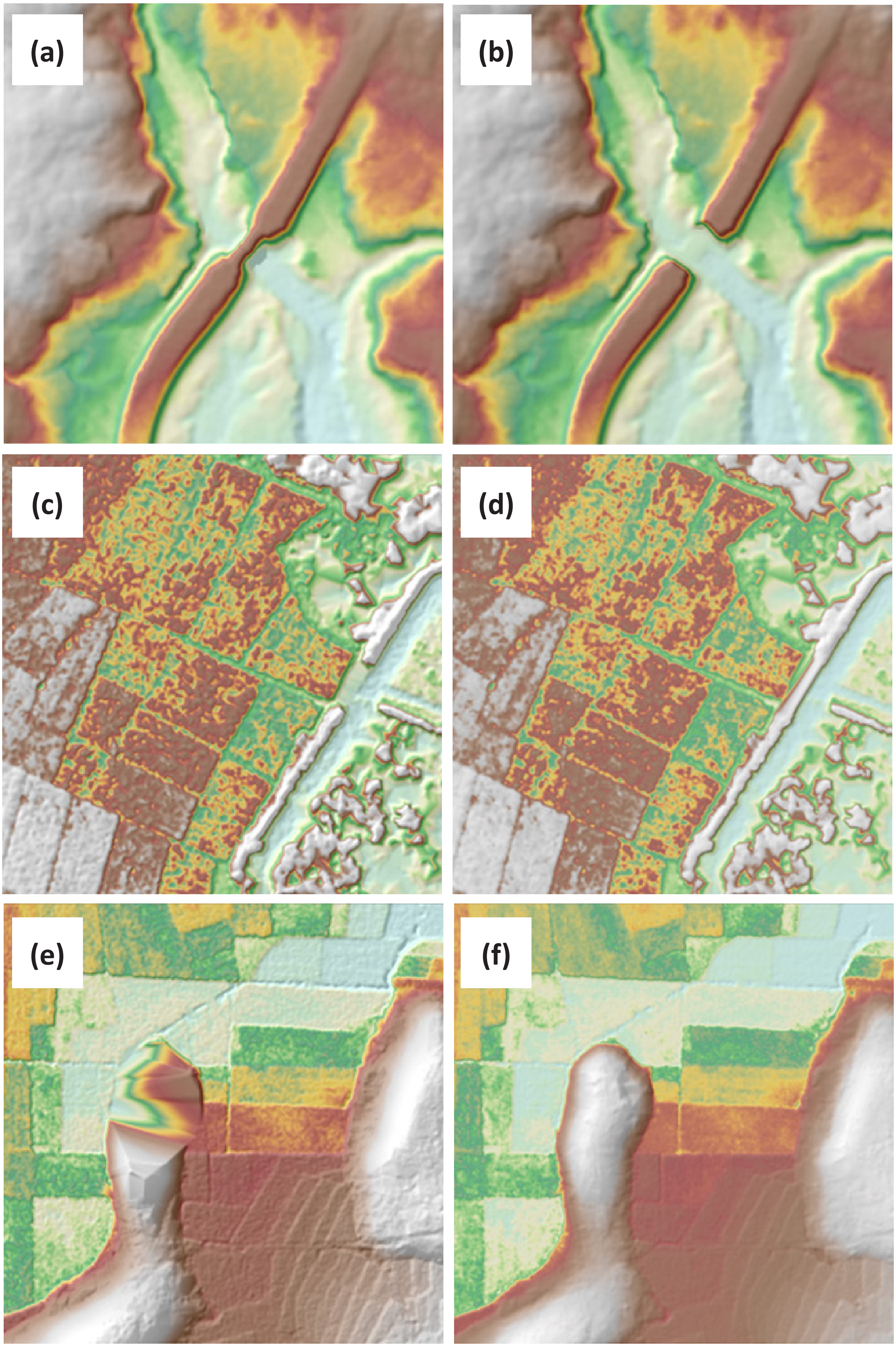


Figure 19. Portions in the DTM of Baroc floodplain – a bridge before (a) and after (b) manual editing; an embankment before (c) and after (d) data retrieval; and a mountain before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Mindoro_Blk29N was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy.

Table 15 shows the shift values applied to the LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Baroc floodplain is shown in Figure 20.

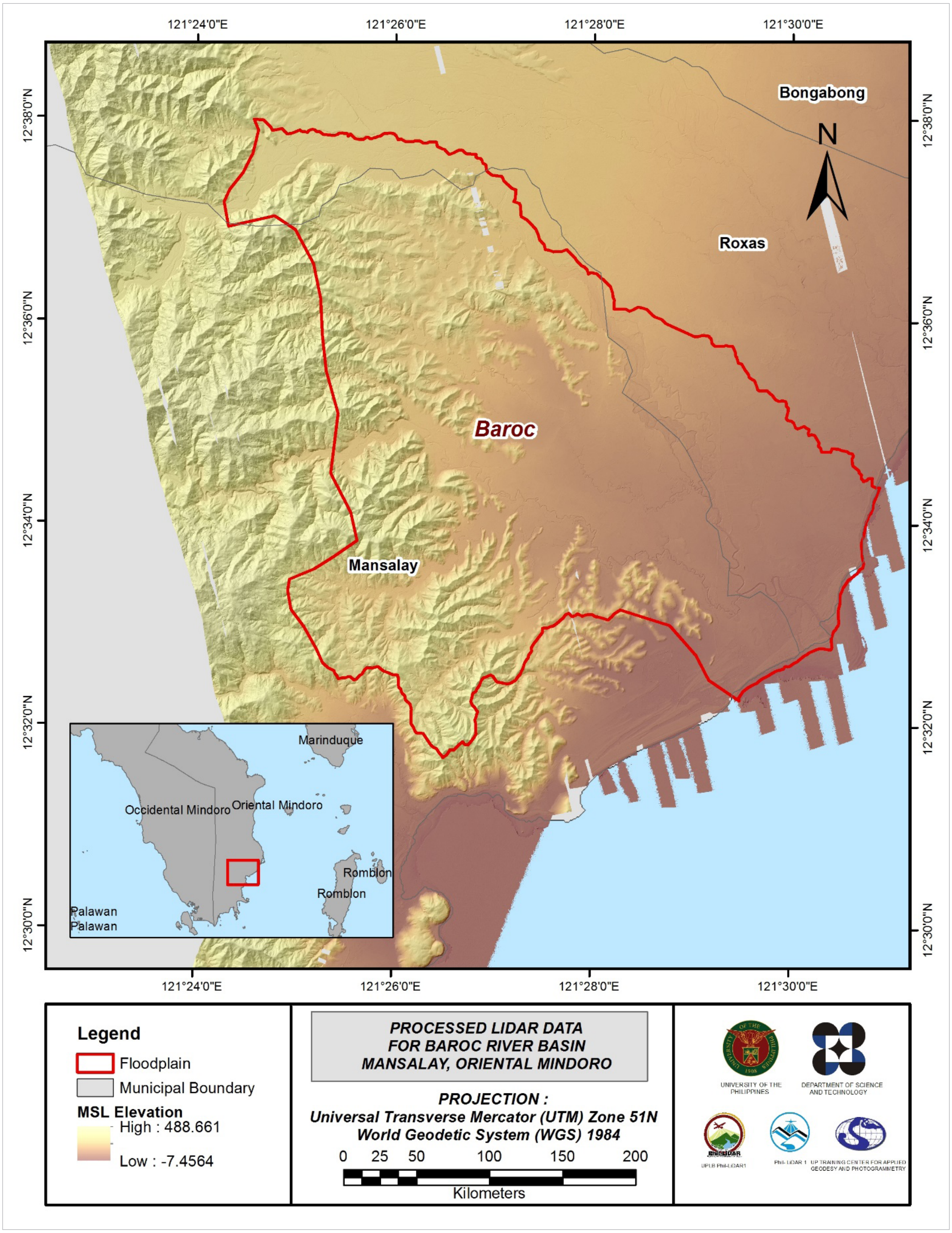


Figure 20. It can be seen that the entire Baroc floodplain is 99.80% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Baroc Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OrientalMindoro_Blk28F	0.00	0.00	0.84
OrientalMindoro_Blk28G	0.00	0.00	0.86
OrientalMindoro_Blk28G_supplementH	0.00	0.00	-0.08
OrientalMindoro_Blk28H_supplement	0.00	0.00	-0.29
OrientalMindoro_Blk28I	0.00	0.00	-0.20
OrientalMindoro_Blk28J	0.00	0.00	0.00
OrientalMindoro_Reflights_28I	0.00	0.00	-1.18

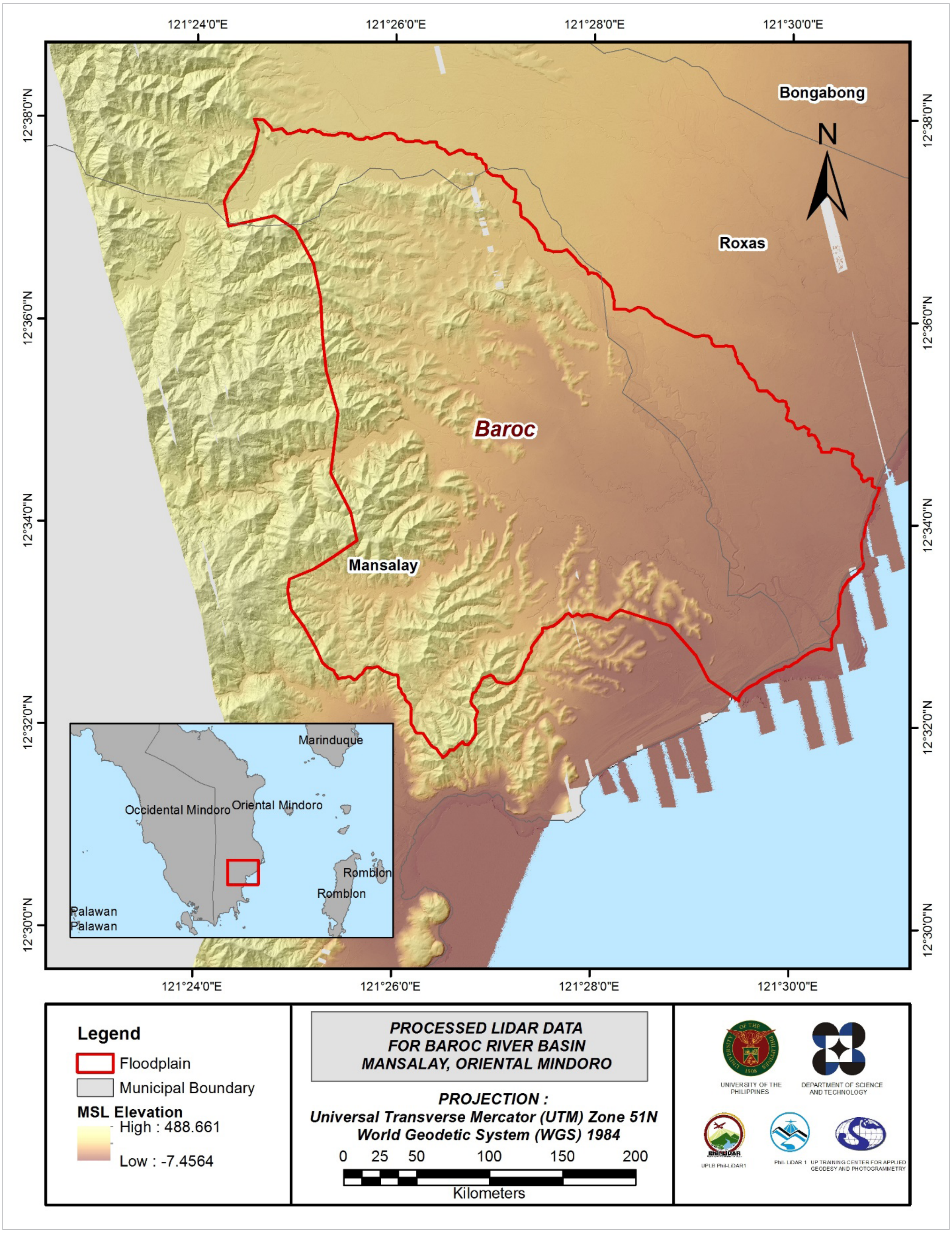


Figure 21. Map of Processed LiDAR Data for Baroc Floodplain.

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 Baroc to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 3,077 survey points were used for calibration and validation of Baroc LiDAR data. Random selection of 80% of the survey points, resulting to 2,465 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 2.64 meters with a standard deviation of 0.18 meters. Calibration of Baroc LiDAR data was done by adding the height difference value, 2.64 meters, to Baroc mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

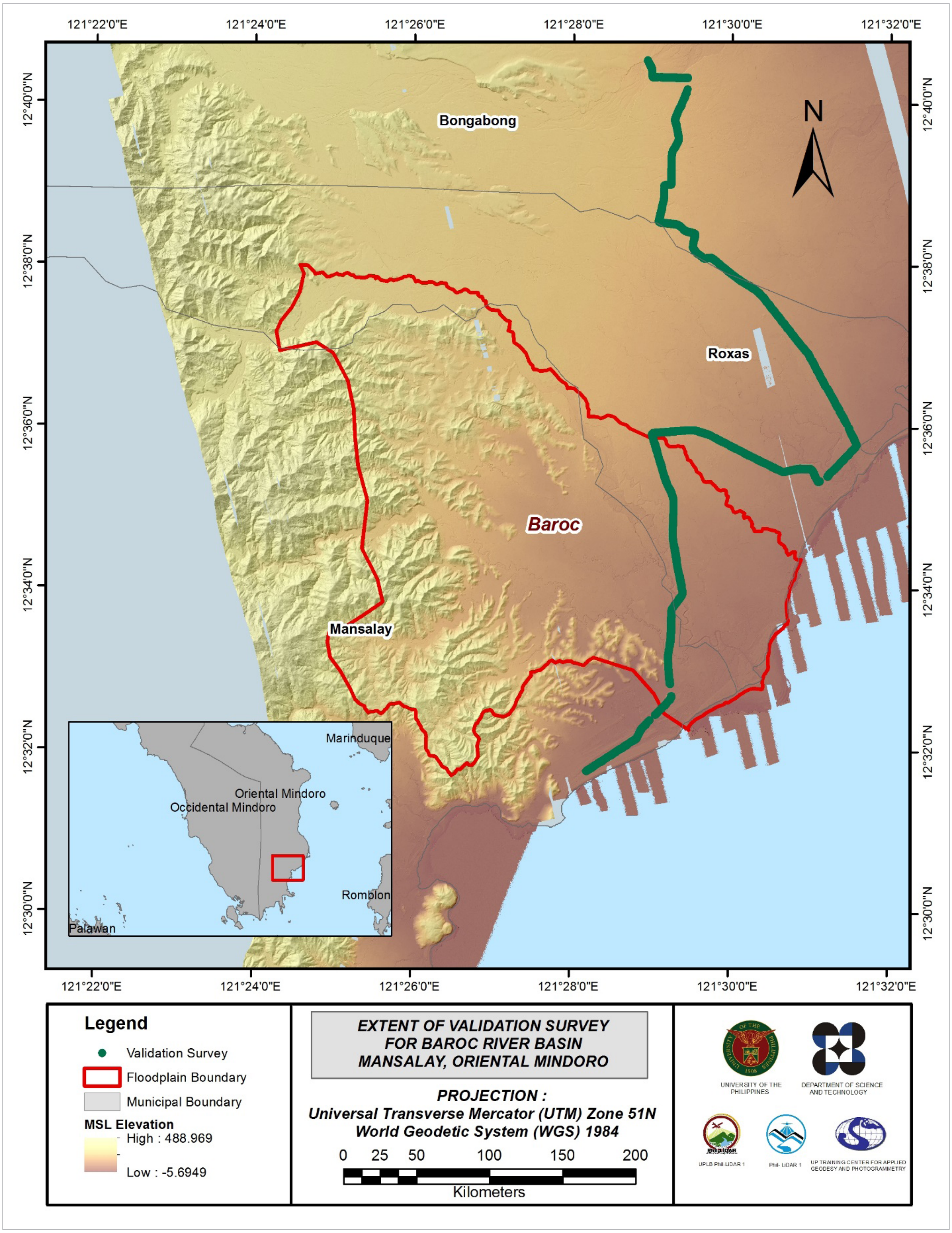


Figure 22. Map of Baroc Floodplain with validation survey points in green.

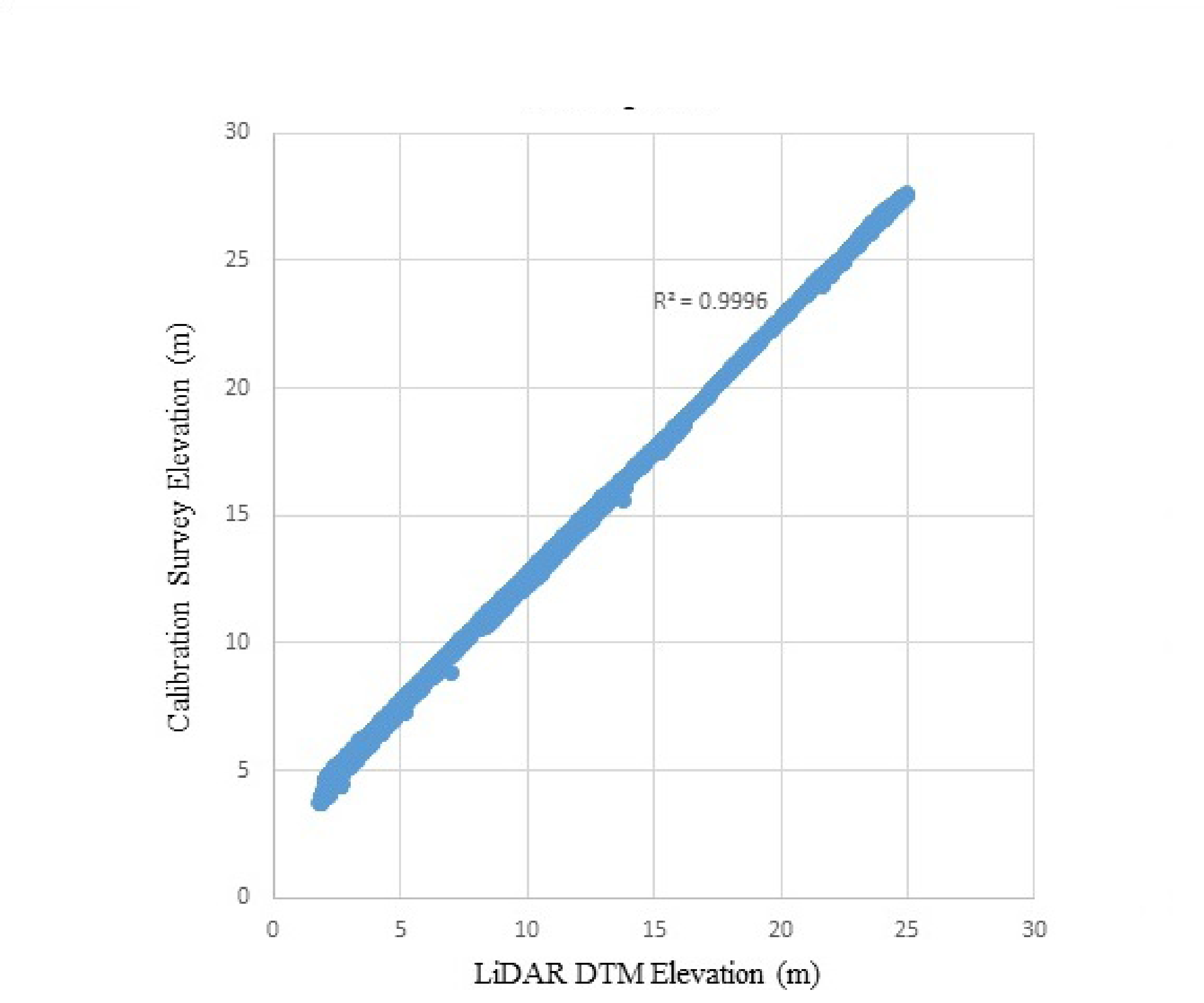


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.64
Standard Deviation	0.18
Average	2.63
Minimum	-2.99
Maximum	-2.28

The remaining 20% of the total survey points, resulting to 612 points, were used for the validation of calibrated Baroc 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 0.15 meters with a standard deviation of 0.15 meters, as shown in Table 17.

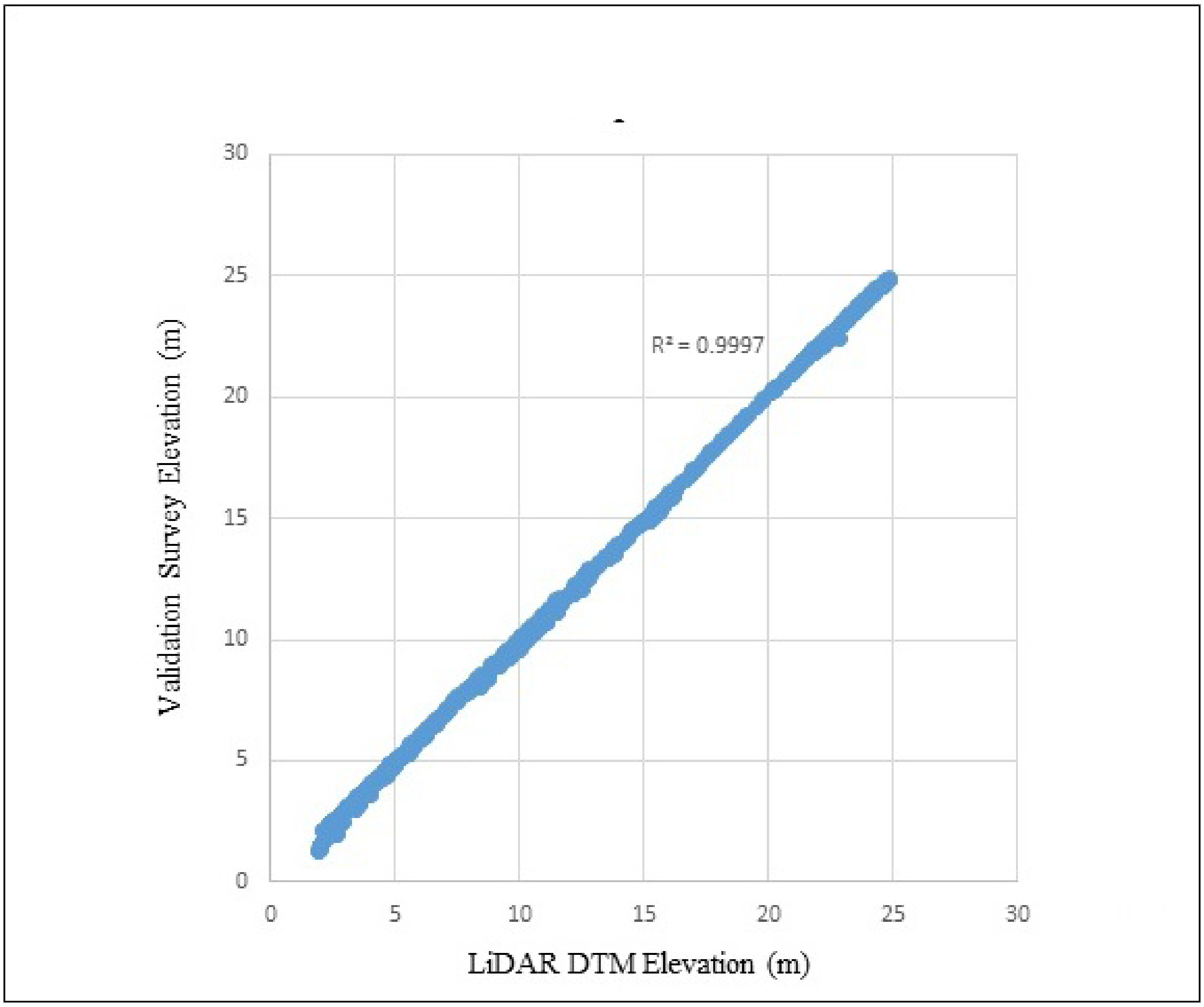


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.15
Standard Deviation	0.15
Average	-0.01
Minimum	-0.31
Maximum	1.20

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Baroc with 3,376bathymetric 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 0.063 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Baroc integrated with the processed LiDAR DEM is shown in Figure 24.

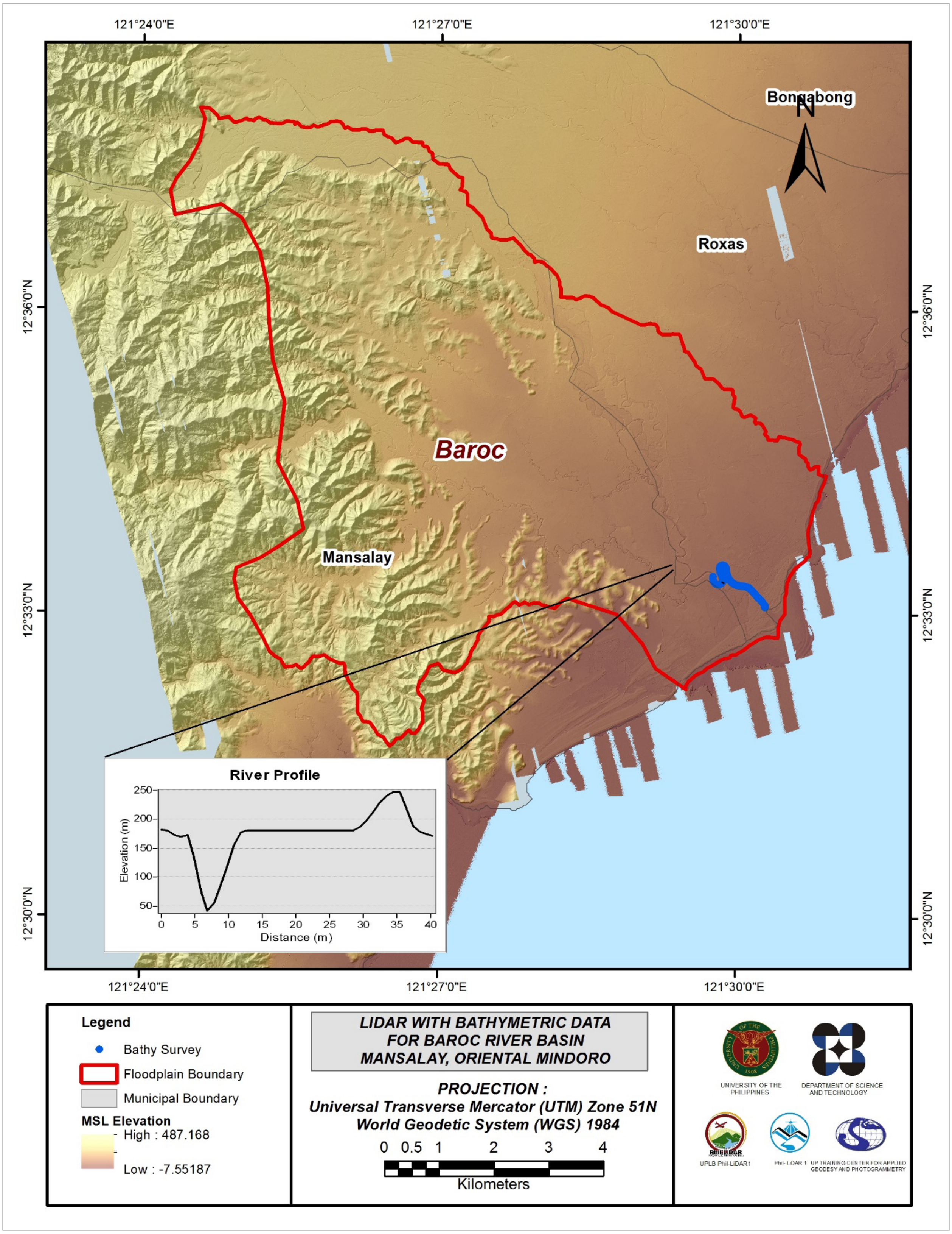


Figure 25. Map of Baroc Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF BAROC RIVER BASIN

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field survey in Baroc River last May 30, 2014 to June 11, 2014 with the following scope of work: courtesy call with LGU of Baroc; control survey for the establishment of control point at the approach of Barok Bridge to be occupied as base station for GNSS surveys; cross-section of the bridge with coordinates: Lat 12d33’52.65282” N and Long 121d29’21.90070” E; LiDAR acquired validation survey with estimated distance of 26.74 km; and manual bathymetric survey starting from the upstream from the bridge in Brgy. San Isidro down to the mouth of the river at Tablas Strait with estimated distance of 4.0 km. A follow up survey commenced on October 27, 2014 to November 3, 2014 with the following activities: courtesy call with same LGU and UPLB as partner SUC assigned for MIMAROPA and Laguna Regions; and bridge-as-built and water level marking of Baroc Bridge. The entire survey extent is illustrated in Figure 25.

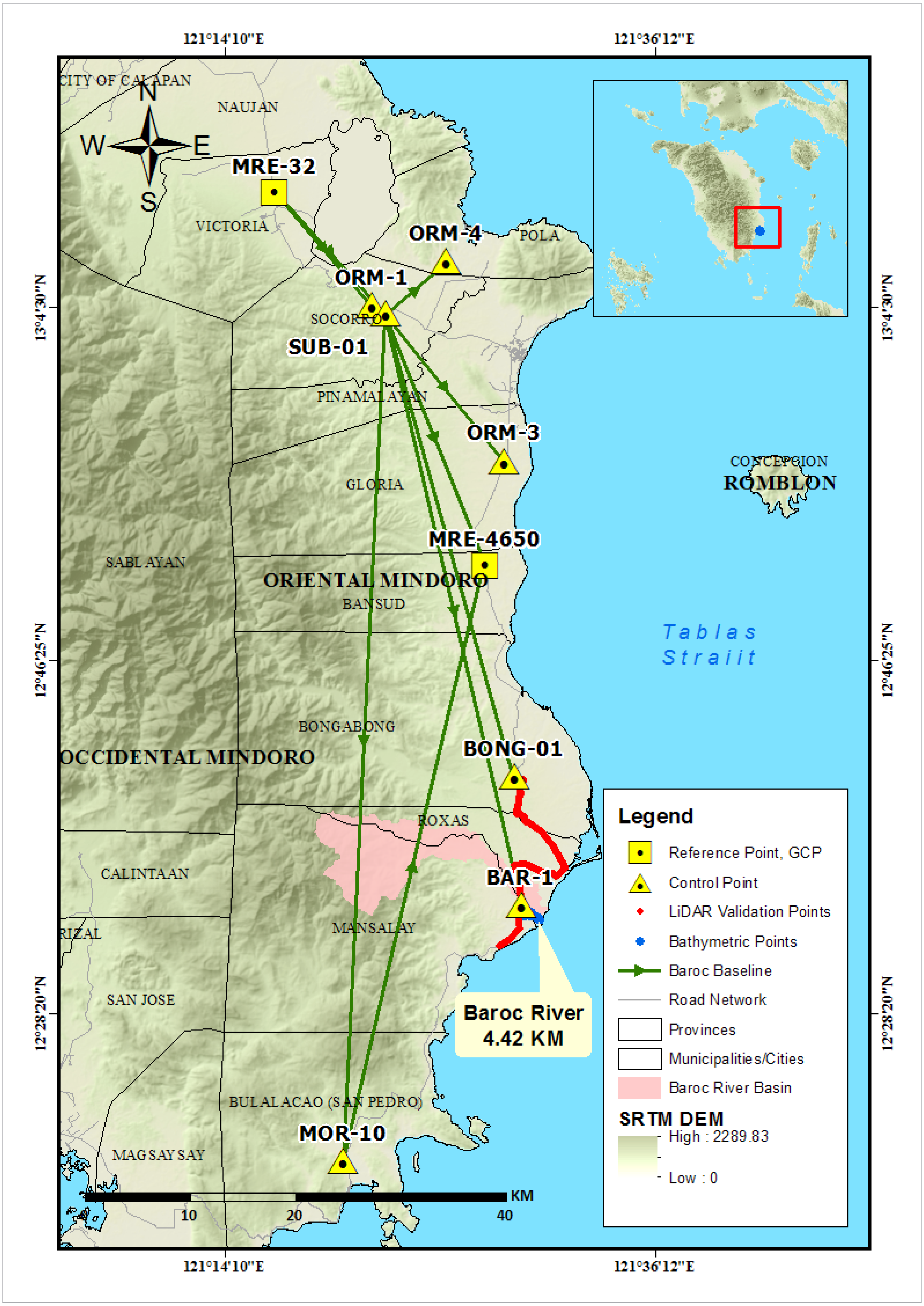


Figure 26. Baroc River Survey Extent

4.2 Control Survey

A GNSS network was established for previous PHIL-LiDAR fieldwork in Mindoro on February 28 – March 11, 2013 occupying MR-178, a first-order BM located at the approach of Panggalaan Bridge in Brgy. Bucayao, Calapan City, Oriental Mindoro; and MRE-32, a second order GCP in Brgy. Poblacion 1, Mun. of Victoria, Oriental Mindoro.

The GNSS network used for Baroc River Basin is composed of two (2) loops and four (4) baselines established on May 30 and May 31, 2014 occupying the reference point MRE-32, a second-order GCP fixed from the previous field survey in Mindoro Oriental for Mag Asawang Tubig river.

Seven (7) control points were established namely: BAR-1 located at the approach of Baroc Bridge in Brgy. San Isidro, Municipality of Mansalay; BONG-01 located near Bongabong Bridge in Brgy. San Isidro, Municipality of Luna; MOR-10, located at the approach of Cawacat Bridge in Brgy. Campaasan, Municipality of Bulalacao; ORM-1, located in Subaan Bridge in Barangay Subaan, Municipality of Socorro; ORM-3 located in Balete bridge in Brgy. Balete, Municipality of Gloria; ORM-4 in Pola Bridge, Brgy. Casiligan, Municipality of Pola; and SUB-01, located within the Maramot Residence in Brgy. Subaan, Municipality of Socorro. An LMS-established control point namely MRE-4650, located at Bansud Bridge, Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro was also occupied to use as marker in the survey.

The summary of references and control points and its location is summarized in Table 18 .while the GNSS network established is illustrated in Figure 26.

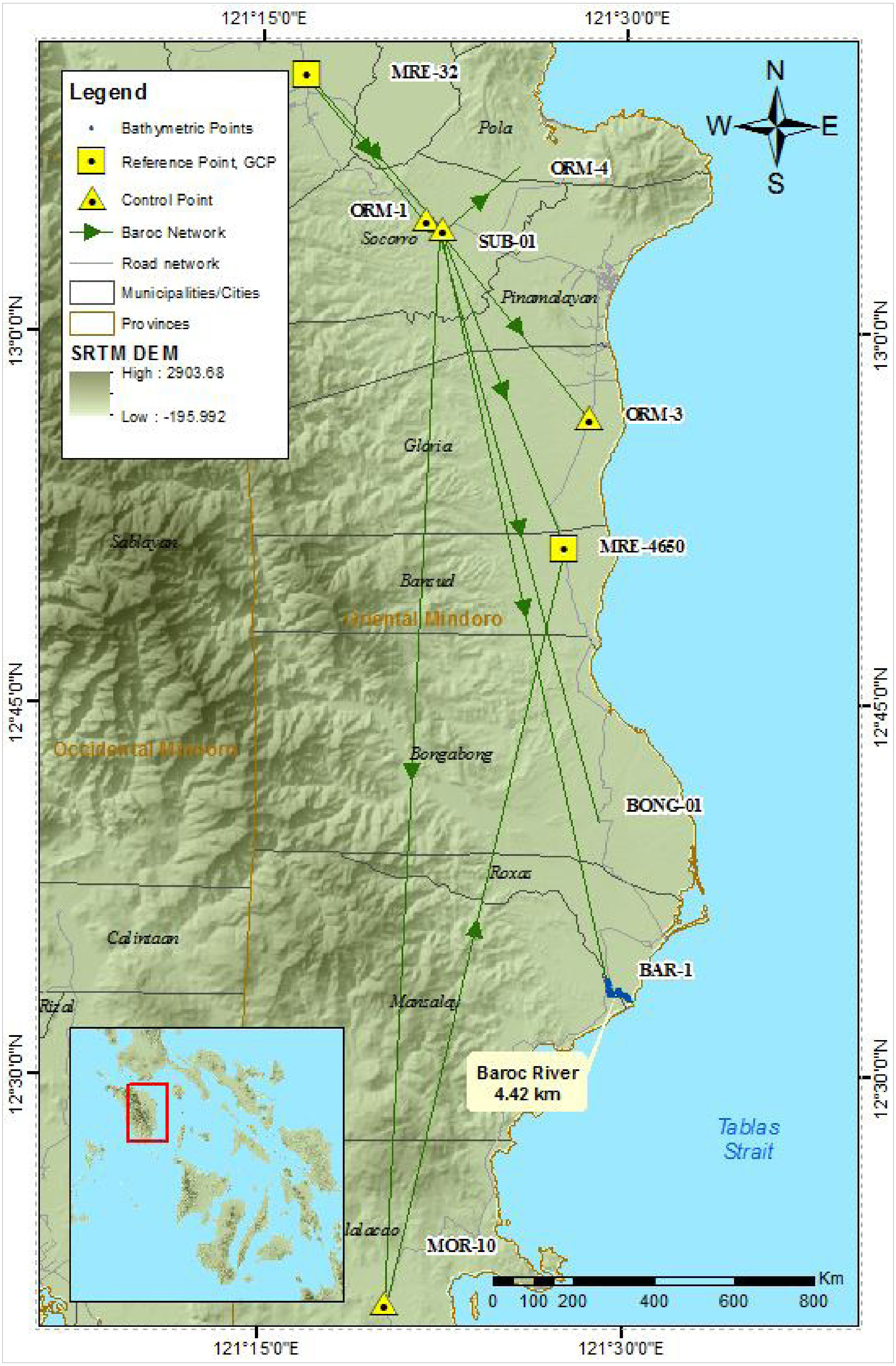


Figure 27. GNSS Network covering Baroc River

Table 18. List of reference and control points used during the survey in Baroc River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
MRE-32	2nd order, GCP	13°10'23.79251"	121°16'43.46244"	65.638	17.175	2007
MRE-4650	Used as marker	-		-	-	2011
BAR-1	UP Established	-	-	-	-	6-1-20014
BONG-01	UP Established	-	-	-	-	6-1-2014
MOR-10	UP Established	-	-	-	-	5-31-2014
ORM-1	UP Established	-	-	-	-	5-30-2014
ORM-3	UP Established	-	-	-	-	5-31-2014
ORM-4	UP Established	-	-	-	-	5-31-2014
SUB-01	UP Established	-	-	-	-	5-31-2014

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 27 to Figure 35.

Figure 28. GPS setup of Trimble® SPS 882 at MRE-32, located at the Municipal Park of Victoria, in Brgy. Poblacion 1, Oriental Mindoro

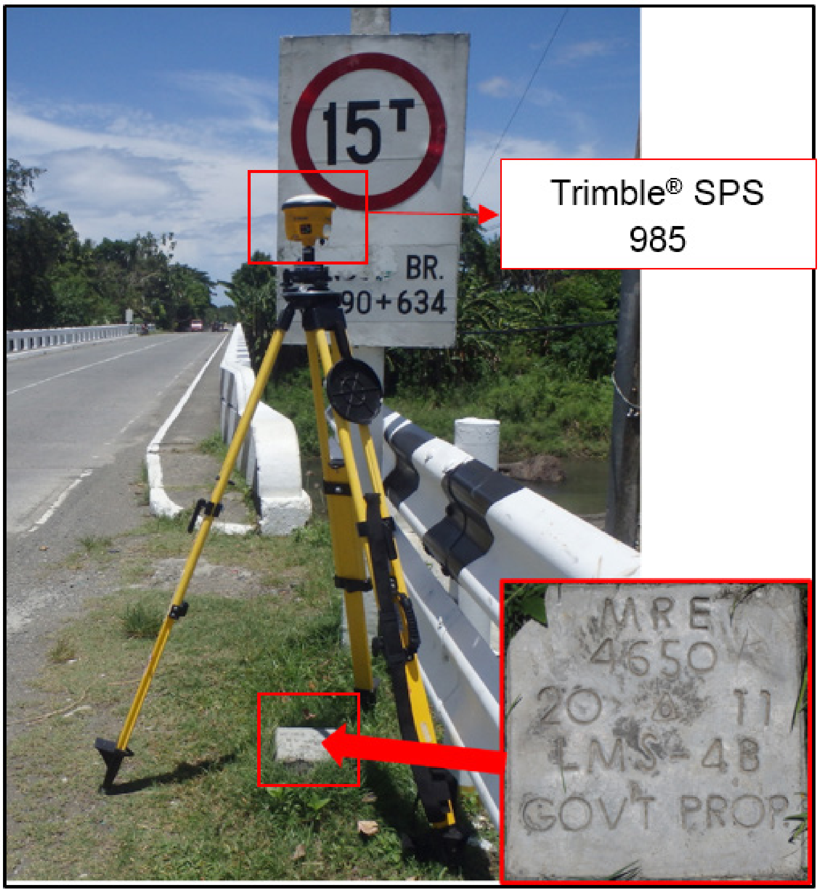


Figure 29. The GPS setup of Trimble® SPS 985 at MRE-4650, an LMS control point located at the approach of Bansud Bridge, in Brgy. Pagasa, Municipality of Bansud, Oriental Mindoro

Figure 30. GPS setup of Trimble® SPS 882 at BAR-1, an established control point located in Baroc Bridge, Brgy. San Isidro, Mansalay, Oriental Mindoro

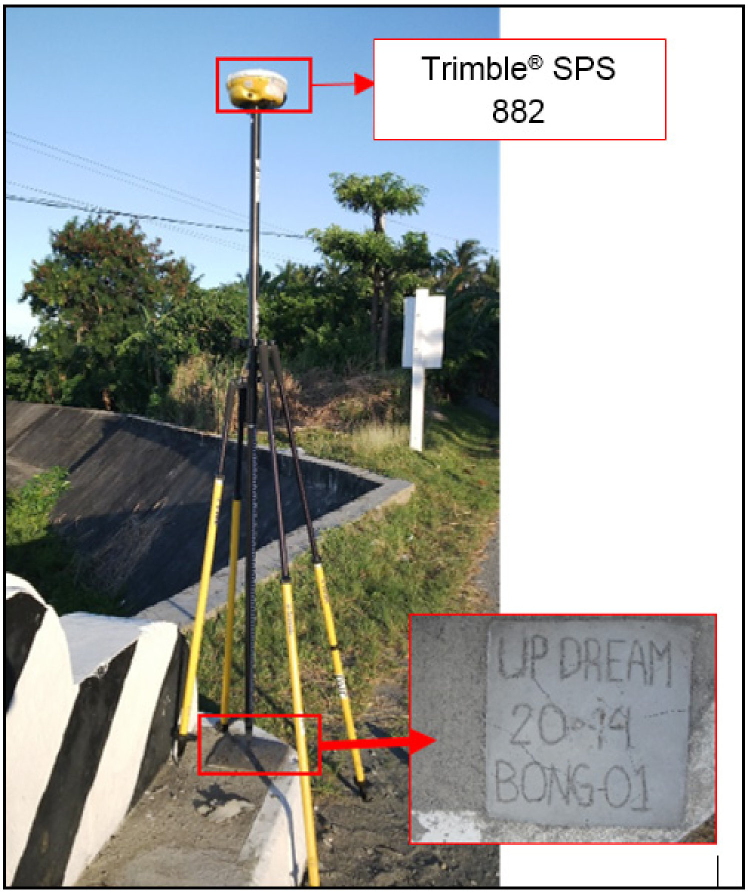


Figure 31. GNSS setup of Trimble® SPS 882 on BONG-01 in Brgy. San Isidro, Municipality of Bongabong, Oriental Mindoro

Figure 32. GPS setup of Trimble® SPS 852 at MOR-10, located in the approach of the Cawacat Bridge, in Bry. Campasaan, Municipality of Bulalacao, Oriental Mindoro

Figure 33. GPS setup of Trimble® SPS 852 at ORM-1, located on Subaan Bridge, Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

Figure 34. Trimble® SPS 985 setup at ORM-3 located at the approach of Balete Bridge, Brgy. Balete, Municipality of Gloria, Oriental Mindoro

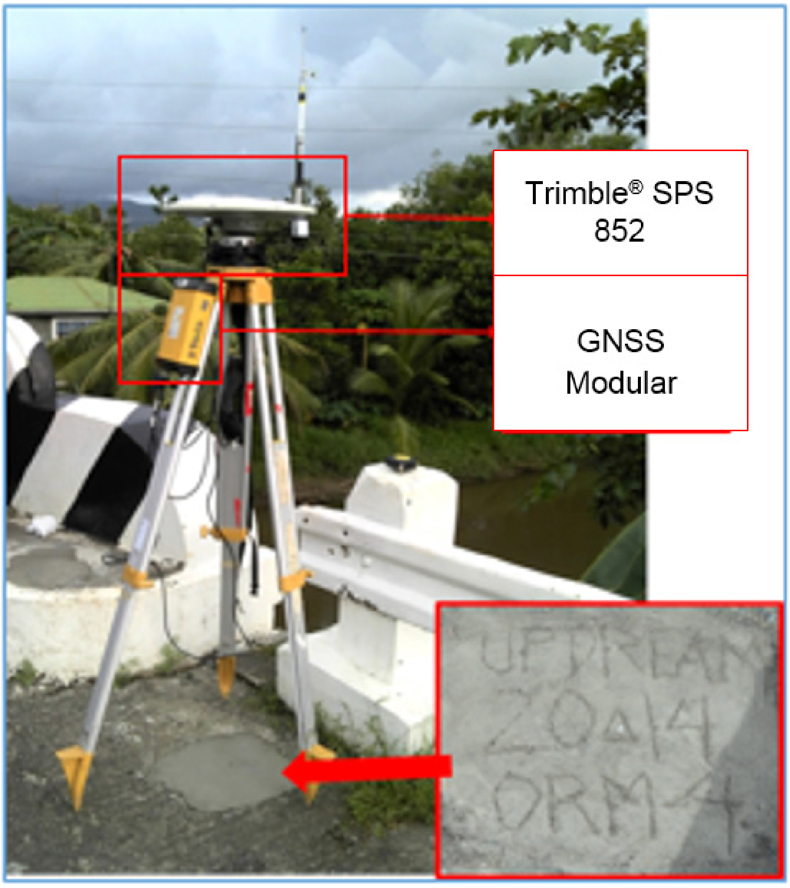


Figure 35. GNSS receiver Trimble® SPS 852 setup at ORM-4, located at the right side of the approach of Pola Bridge in Barangay Casiligan, Municipality of Pola, Oriental Mindoro

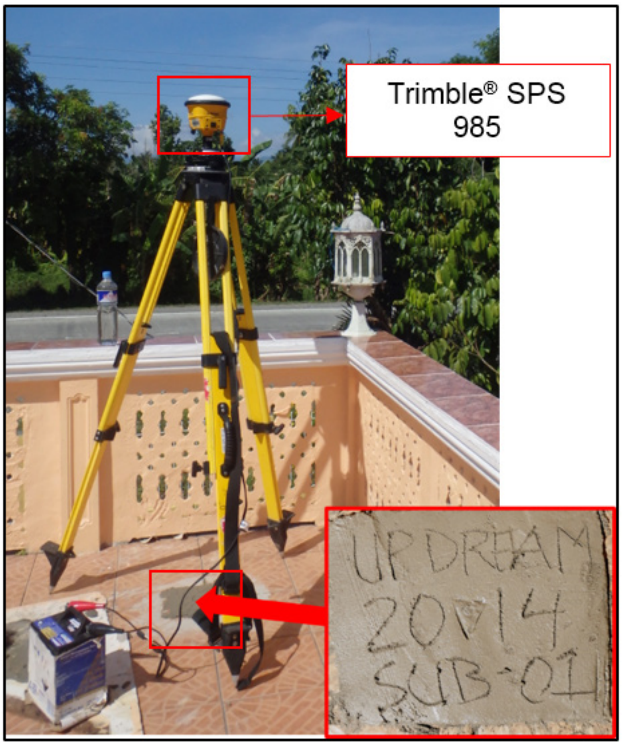


Figure 36. GPS setup of Trimble® SPS 985 at SUB-1, an established control point located at Maramot Residence in Brgy. Subaan, Municipality of Socorro, Oriental Mindoro

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is 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 Baroc River Basin is summarized in Table 19 generated by TBC software.

Table 19. Baseline Processing Report for Baroc River Static Survey (Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
ORM-1 --- SUB-01	05-30-2014	Fixed	0.004	0.006	301°40'27"	1466.251	4.823
SUB-01 --- MRE-32	05-30-2014	Fixed	0.010	0.031	318°11'52"	15342.18	-9.283
SUB-01 ---MOR-10	05-31-2014	Fixed	0.014	0.044	182°47'52"	80162.62	-16.502
SUB-01 --- MRE-4650	05-31-2014	Fixed	0.006	0.038	158°49'08"	25506.78	-9.971
SUB-01 --- ORM-3	5-31-2014	Fixed	0.007	0.028	141°48'05"	17755.532	-12.886
SUB-01 --- ORM-4	6-1-2014	Fixed	0.003	0.022	48°43'17"	7475.934	-19.149
SUB-01 --- BAR-1	6-1-2014	Fixed	0.024	0.107	167°15'17"	57308.832	-16.370
SUB-01 --- BONG-01	6-1-2014	Fixed	0.021	0.035	164°45'51"	45313.95	0.212
ORM-1 --- MRE 32	05-30-2014	Fixed	0.010	0.032	319°54'33"	13942.72	-14.146
MOR-10 --- MRE 4650	05-31-2014	Fixed	0.012	0.051	13°07'21"	57794.34	6.484

As shown in Table 19, a total of ten (10) baselines were processed and all of them passed the required accuracy set by the project.

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:

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

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 20 to Table 22 for complete details.

The five (5) control points, MRE-32, ORM-1, MOR-10, MRE-4650 and SUB-01 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of MRE-32 were held fixed during the processing of the control points as presented in Table 20. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 20. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
MRE-32	Grid	Fixed	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 21. All fixed control points have no values for grid and elevation errors.

Table 21. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MOR-10	319188.891	0.010	1365393.240	0.010	6.868	0.052	
MRE-32	313449.201	?	1456936.499	?	17.175	?	ENe
MRE-4650	332665.789	0.008	1421592.819	0.006	14.627	0.049	
ORM-1	322358.982	0.007	1446211.774	0.003	30.565	0.028	
SUB-01	323601.847	0.007	1445433.872	0.003	25.687	0.028	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 22.

Using the equation $\sqrt{((x_e)^2 + (y_e)^2)} < 20$ cm for horizontal and $z_e < 10$ cm for the vertical; below is the computation for accuracy that passed the required precision:

a. MRE-32

Horizontal accuracy = Fixed

Vertical accuracy = Fixed

b. MOR-10

Horizontal accuracy $= \sqrt{((1.0)^2 + (1.0)^2}$

$= \sqrt{(1.0 + 1.0)}$

$= 1.1$ cm < 20 cm

Vertical accuracy $= 1.4$ cm< 10 cm

c. MRE-4650

Horizontal accuracy $= \sqrt{((0.8)^2 + (0.6)^2}$

$= \sqrt{(0.64 + 0.36)}$

$= 1.0$ cm < 20 cm

Vertical accuracy $= 4.9$ cm < 10 cm

d. ORM-1

Horizontal accuracy $= \sqrt{((0.7)^2 + (0.3)^2}$

$= \sqrt{(0.49 + 0.90)}$

$= 1.2$ cm < 20 cm

Vertical accuracy $= 2.8$ cm < 10 cm

e. SUB-01

Horizontal accuracy $= \sqrt{((0.7)^2 + (0.3)^2}$

$= \sqrt{(0.49 + 0.90)}$

$= 1.2$ cm < 20 cm

Vertical accuracy $= 2.8$ cm < 10 cm

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

Table 22. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
MOR-10	N12°20'46.18547"	E121°20'13.54772"	58.186	0.052	
MRE-32	N13°10'23.79251"	E121°16'43.46244"	65.368	?	ENe
MRE-4650	N12°51'17.70515"	E121°27'28.71020"	64.693	0.049	
ORM-1	N13°04'36.74731"	E121°21'41.63863"	79.500	0.028	
SUB-01	N13°04'11.69491"	E121°22'23.06063"	74.676	0.028	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 22. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 23.

Table 23. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MRE-32	2nd order, GCP	13°10'23.79251"	121°16'43.46244"	65.368	1456936.499	313449.201	17.175
MRE-4650	Used as Marker	12°51'17.70515"	121°27'28.71020"	64.693	1421592.819	332665.789	14.627
BAR-1	UP Established	12°33'52.65149"	121°29'21.90040"	58.344	1389460.775	335892.131	6.953
BONG-01	UP Established	12°40'28.89755"	121°28'57.71173"	74.917	1401640.553	335232.485	23.974
MOR-10	UP Established	12°20'46.18547"	121°20'13.54772"	58.186	1365393.24	319188.891	6.868
ORM-1	UP Established	13°04'36.74731"	121°21'41.63863"	79.5	1446211.774	322358.982	30.565
ORM-3	UP Established	12°56'37.56304"	121°28'27.33712"	61.799	1431410.893	334491.821	12.031
ORM-4	UP Established	13°06'52.16736"	121°25'29.58456"	55.523	1450329.531	329251.554	6.585
SUB-01	UP Established	13°04'11.69491"	121°22'23.06063"	74.676	1445433.872	323601.847	25.687

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

Cross-section and As-built survey was conducted on May 31 and October 29, 2014, respectively using a GNSS receiver Trimble® SPS 882 in PPK survey technique along the downstream side of Baroc Bridge in Brgy. San Isidro, Oriental Mindoro as shown in Figure 36.

Figure 37. Baroc Bridge

The surveyed cross-sectional line is approximately 155.26 meters which gathered a total of 25 cross-section points using BAR-1 as the GNSS base station. The location map, cross-section diagram, and as-built data are shown in Figure 37 to Figure 39, respectively.

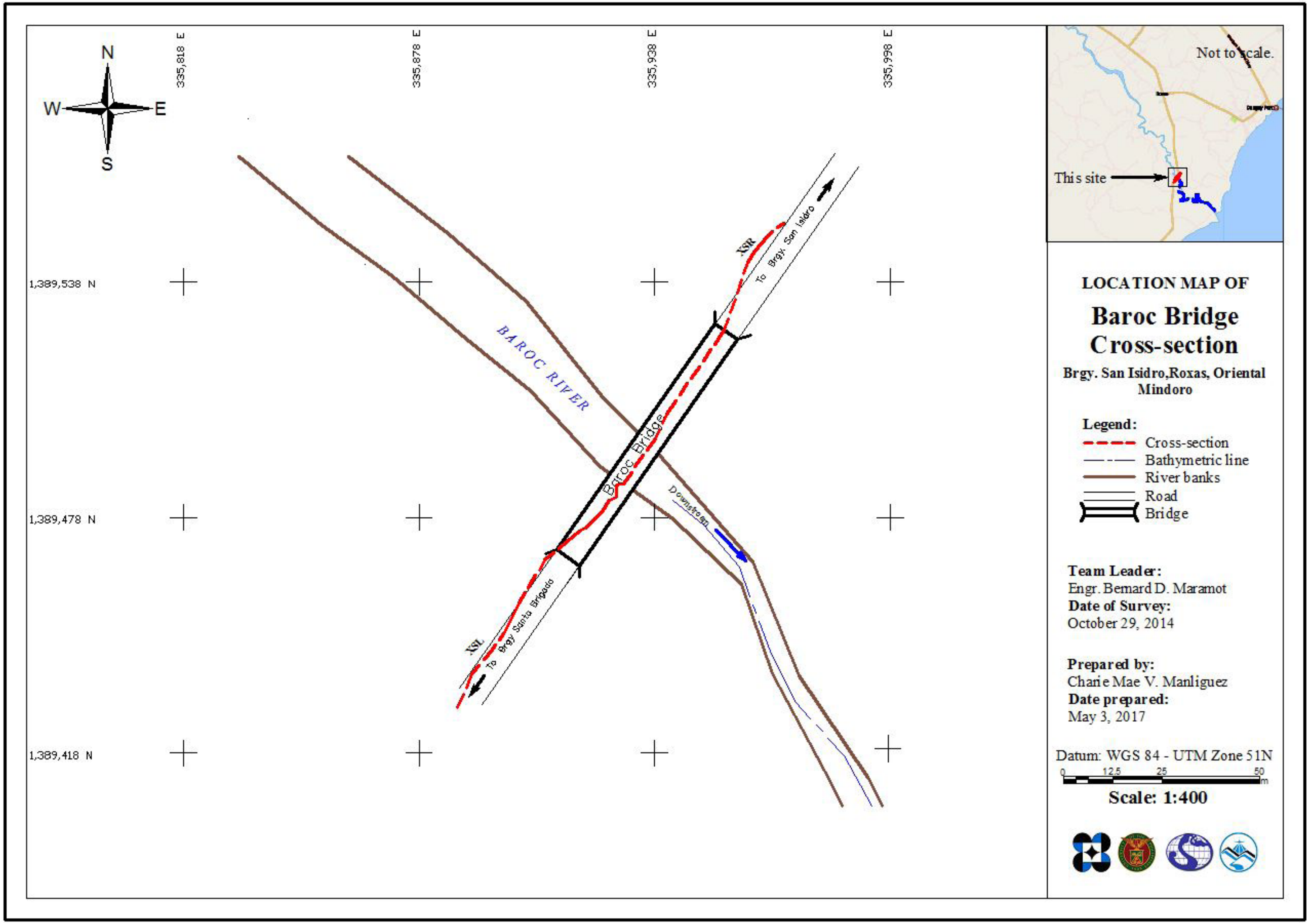


Figure 38. Location Map of Baroc Bridge River Cross-Section survey

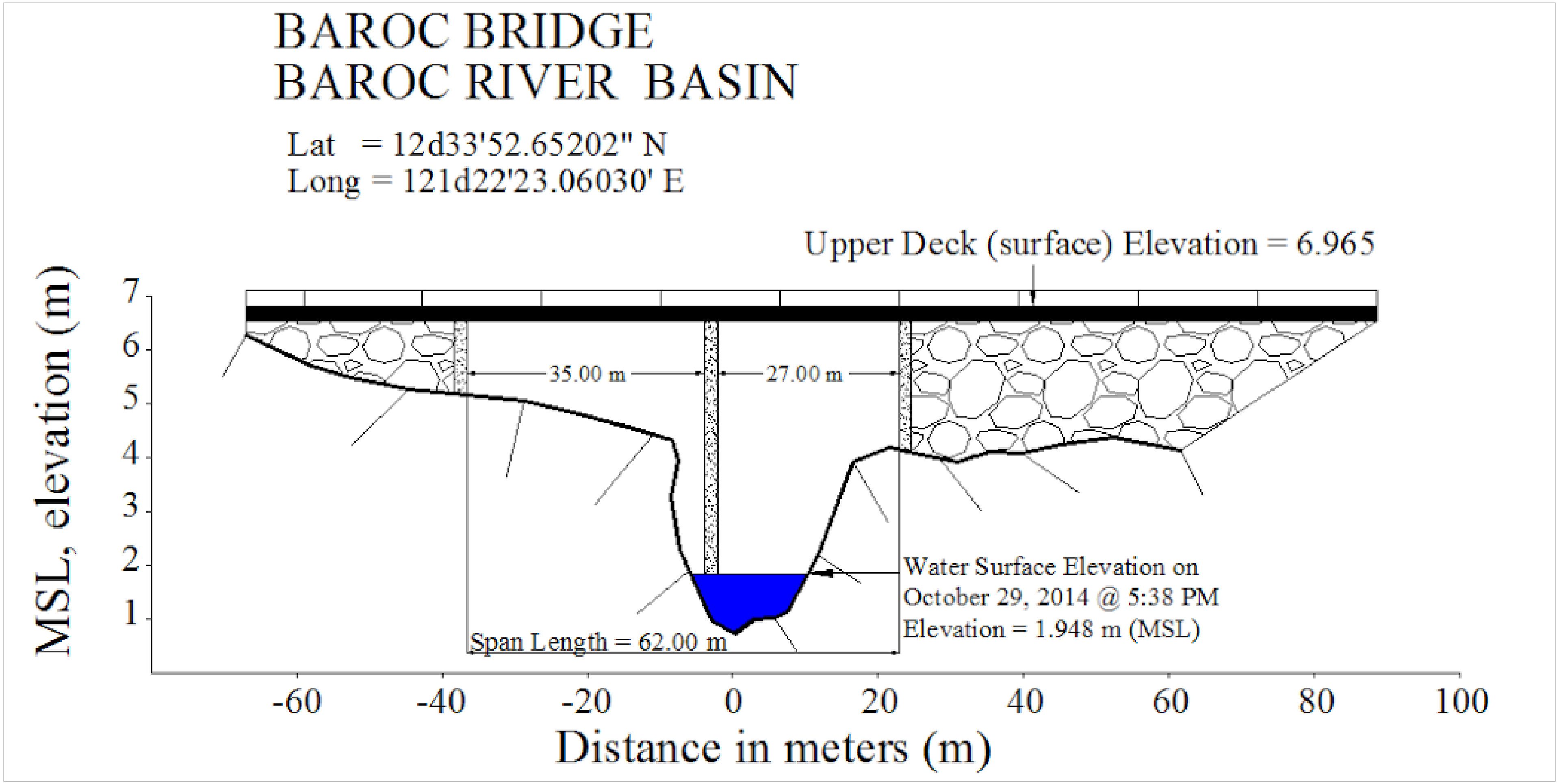


Figure 39. Baroc Bridge cross-section diagram

Bridge Data Form

Bridge Name: BAROC BRIDGE **Date:** October 29, 2014

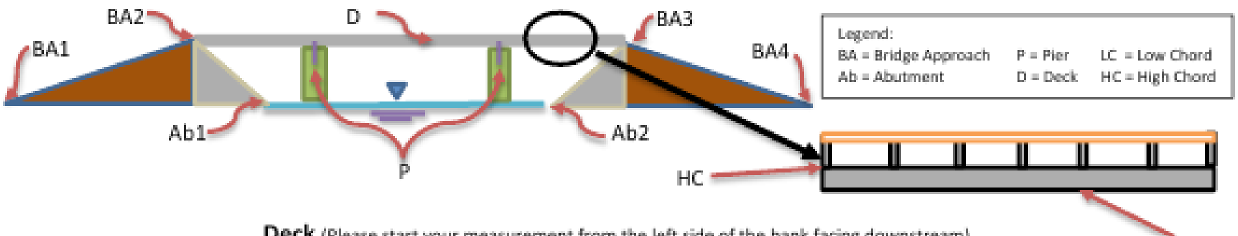
River Name: BAROC RIVER **Time:** 5:23 PM

Location (Brgy, City, Region): Brgy. San Isidro, Municipality of Roxas, Oriental Mindoro

Survey Team: Team Bernard

Flow condition: low normal high **Weather Condition:** fair rainy

Latitude: 12d33'52.65282"N **Longitude:** 121d29'21.90070"E



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

Elevation 6.967 m MSL **Width:** **Span (BA3-BA2):** 175.24 m

	Station	High Chord Elevation	Low Chord Elevation
1		7.201 m	5.084 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.290	**BA3**	175.370	6.958
BA2	0.154	5.281	**BA4**	253.893	4.787

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

	Station (Distance from BA1)	Elevation
Ab1	112.226	4.844
Ab2	172.058	4.787

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

Shape: Rectangular **Number of Piers:** 7 **Height of column footing:**

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	112.439	6.880	
Pier 2	141.738	6.965	
Pier 3	172.649	6.960	
Pier 4			
Pier 5			
Pier 6			
Pier 7			

Figure 40. Bridge as-built form of Baroc Bridge

Water surface elevation in MSL of Baroc River was determined using Trimble® SPS 882 in PPK mode survey on October 29, 2014 at 5:38 PM. The water surface elevation was translated onto marking the bridge's pier using a Digital Level. The marked pier, see Figure 40, shall serve as reference for water level elevation during flow data gathering and depth gauge deployment by the SUC, UPLB, who is responsible for monitoring Baroc River.

Figure 41. Water-level markings on the post of Baroc Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on June 4, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached in front of the vehicle as shown in Figure 41. It was secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.52m from the ground up to the bottom of notch of the GNSS Rover receiver. BAR-1 was occupied as based stations.

The survey was conducted using PPK technique on a continuous topography mode which started from Brgy. San Isidro traversing along the Strong Republic Nautical Highway to Western Nautical Highway and ended at Brgy. B. Del Mundo, Municipality of Mansalay, Oriental Mindoro. A total of 3,374 validation points were gathered covering an approximate distance of 26.74 kilometers. The gaps in the validation line as shown in Figure 42 are due to some difficulties in acquiring satellite signals caused by the presence of obstructions such as dense canopy cover of trees along the roads.

Figure 42. Trimble® SPS 882 setup for validation points acquisition survey for Baroc River

Figure 43. Validation point acquisition survey of Baroc River Basin

4.7 Bathymetric Survey

Bathymetric survey for Baroc River was conducted on June 4, 2014 using a Trimble® SPS 882 in GNSS PPK Survey technique as shown in Figure 43. The survey started at the upstream part of the river in Brgy. San Isidro, Municipality of Roxas with coordinates 12°33'52.65282" 121°29'21.90070", traversed down the river by foot and ended at the mouth of the river in the same barangay wit coordinates 12°33'04.04901" 121°30'16.93203". The control point BAR-01 was used as the GNSS base station all throughout the bathymetric survey.

Figure 44. Trimble® SPS 882 setup for validation points acquisition survey for Baroc River

There are 3,658 bathymetry points and an estimated total length of 4.47 km gathered starting from the bridge at Barangay San Isidro down to the mouth of the river at Tablas Strait as shown in Figure 44. A CAD drawing was also produced to illustrate the Baroc riverbed profile as shown in Figure 45. An elevation drop of 3.1 meters in MSL was observed within the approximate distance of 4 km. The highest elevation observed was 1.0262 m in MSL located at the upstream part of the river, while the lowest elevation value observed was -3.239 m below MSL located at the middle part of the river.

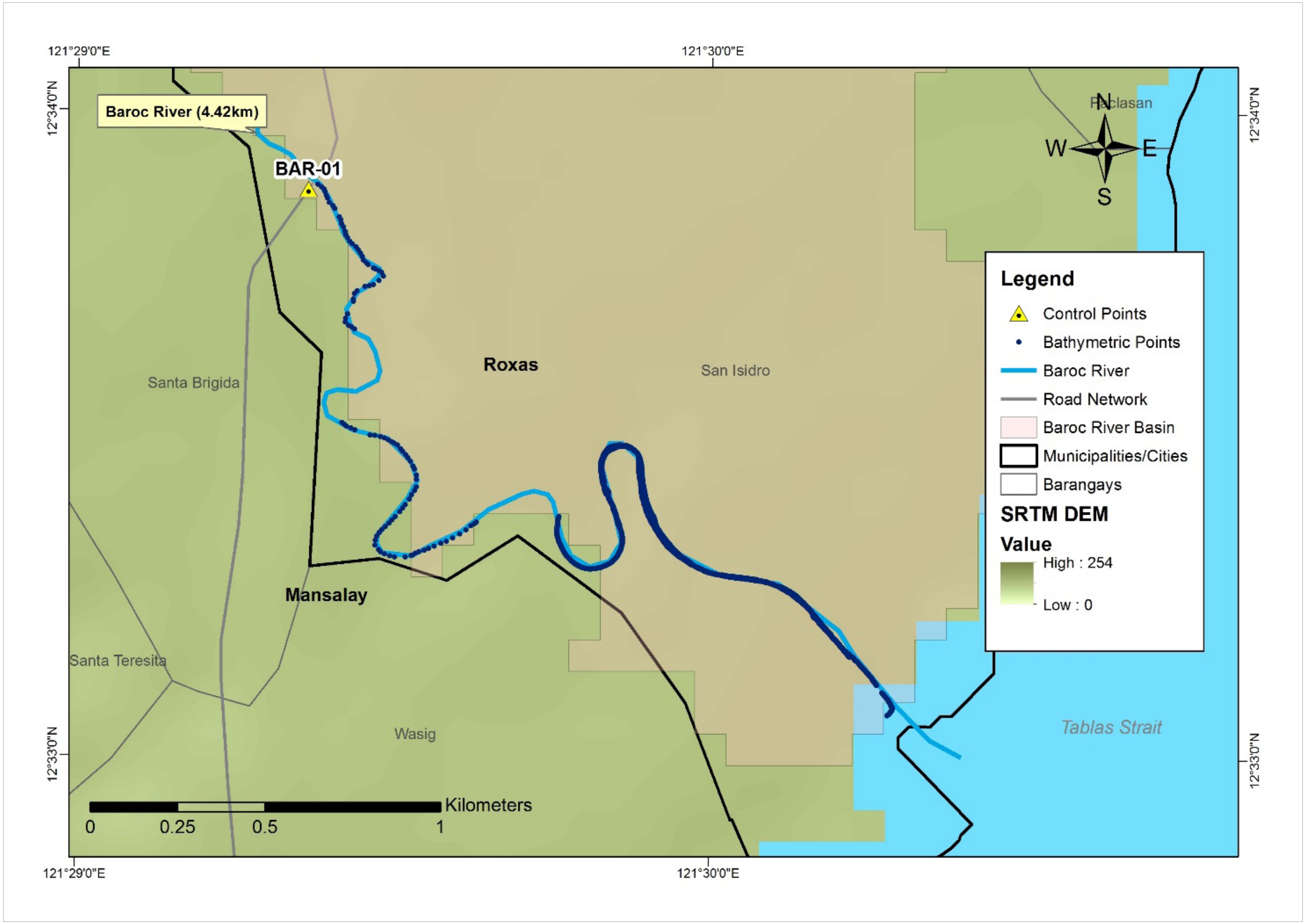


Figure 45. Bathymetric survey of Baroc River

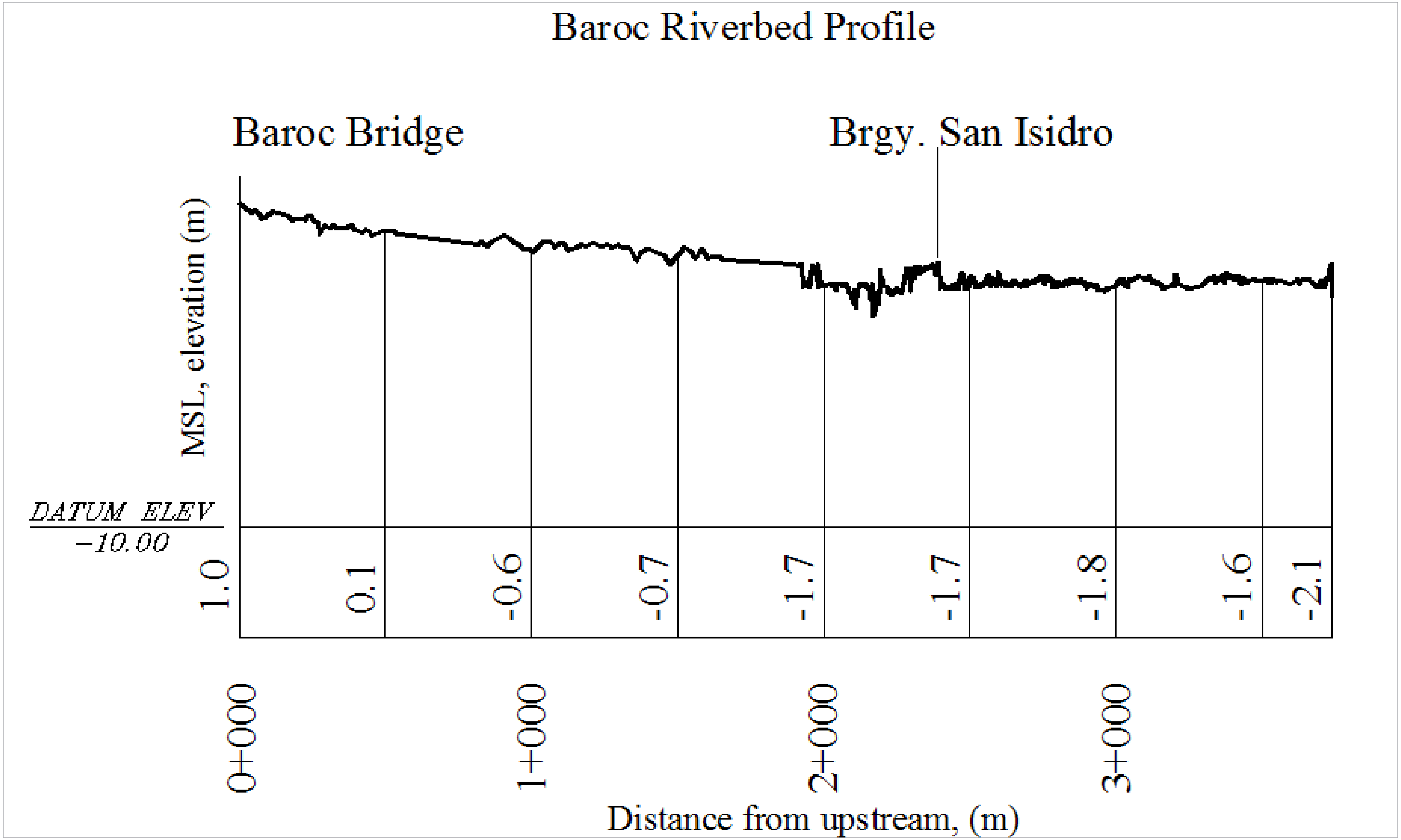


Figure 46. Baroc Riverbed Profile

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 Baroc 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 Baroc River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was measured using portable rain gauges installed on a strategic location within the watershed. The location of the rain gauges is seen in Figure 46.

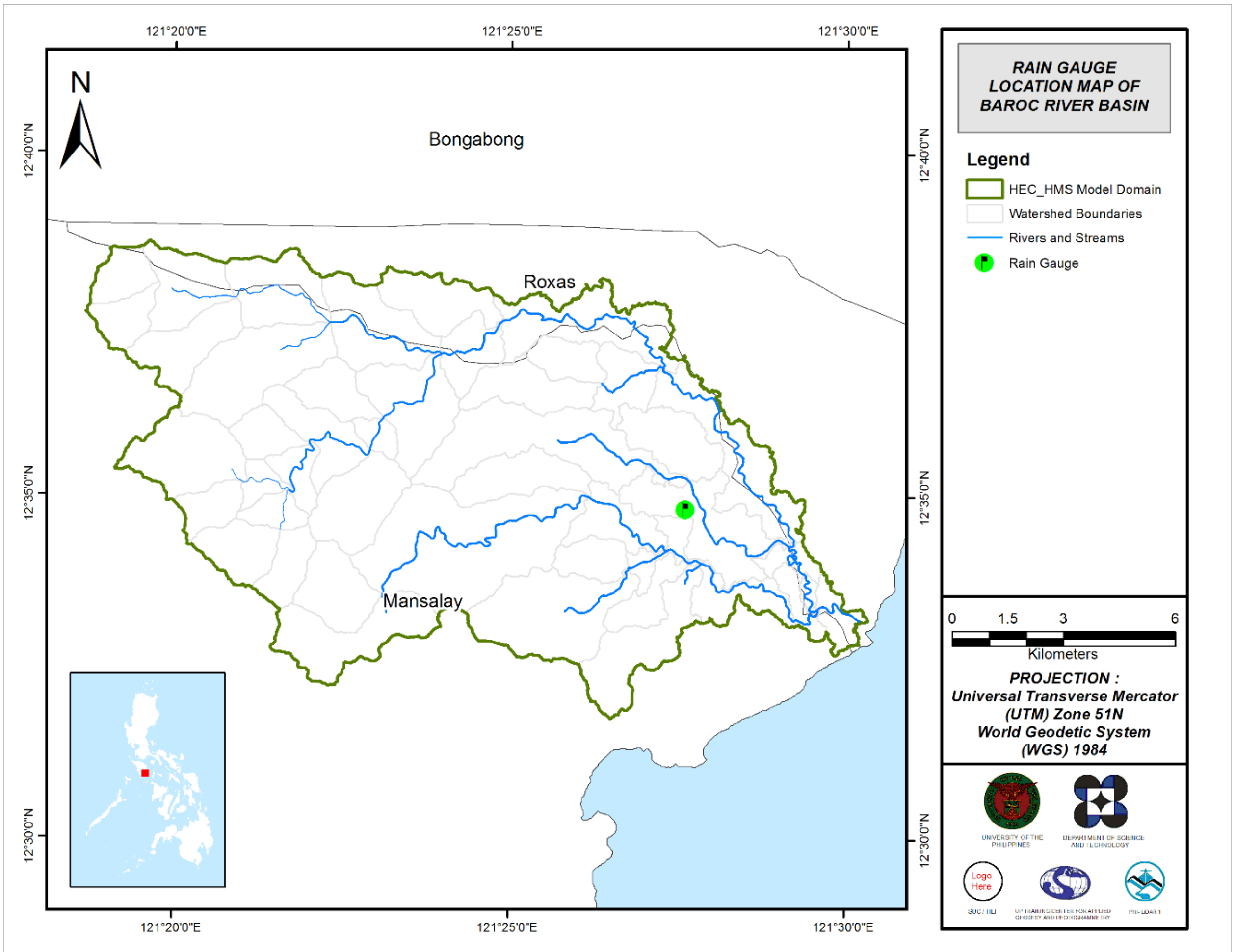


Figure 47. The location map of Baroc HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Baroc Bridge, Oriental Mindoro (12.564685° N, 121.489783° E) using Manning's Bankfull Method. It gives the relationship between the observed change in water and the outflow of the watershed at this location.

For Baroc Bridge, the rating curve is expressed as Q = 4.7899x -7.0005 as shown in Figure 48.

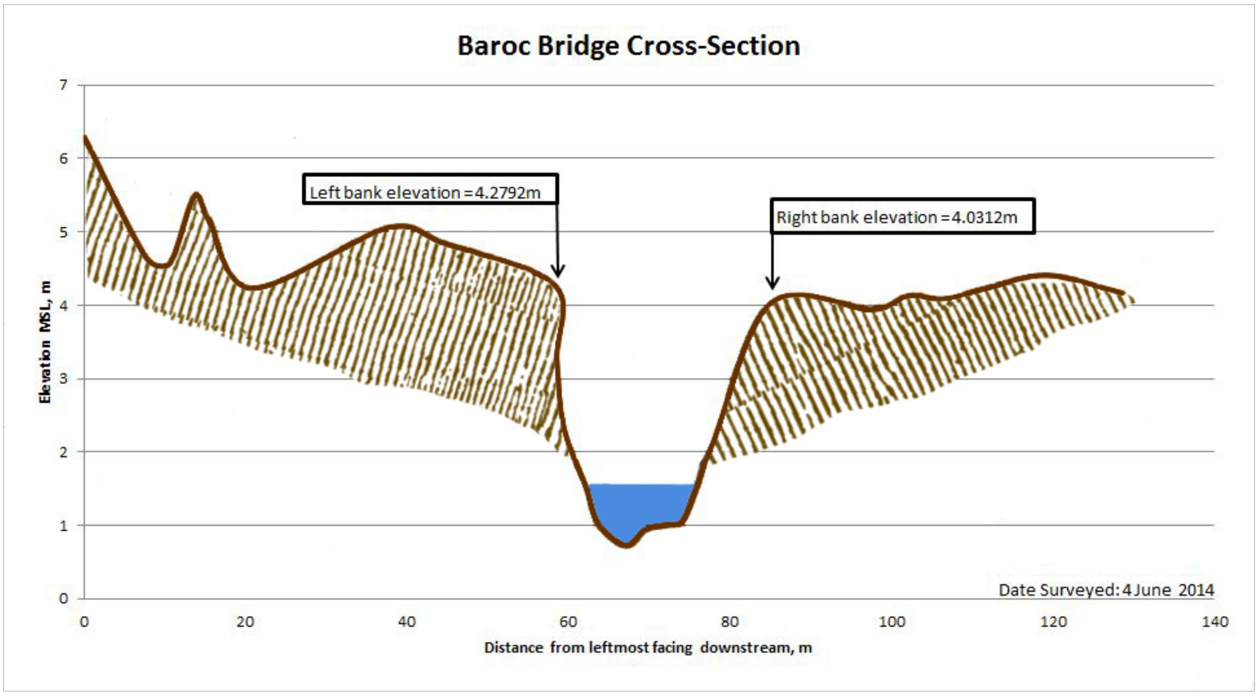


Figure 48. Cross-Section Plot of Baroc Bridge

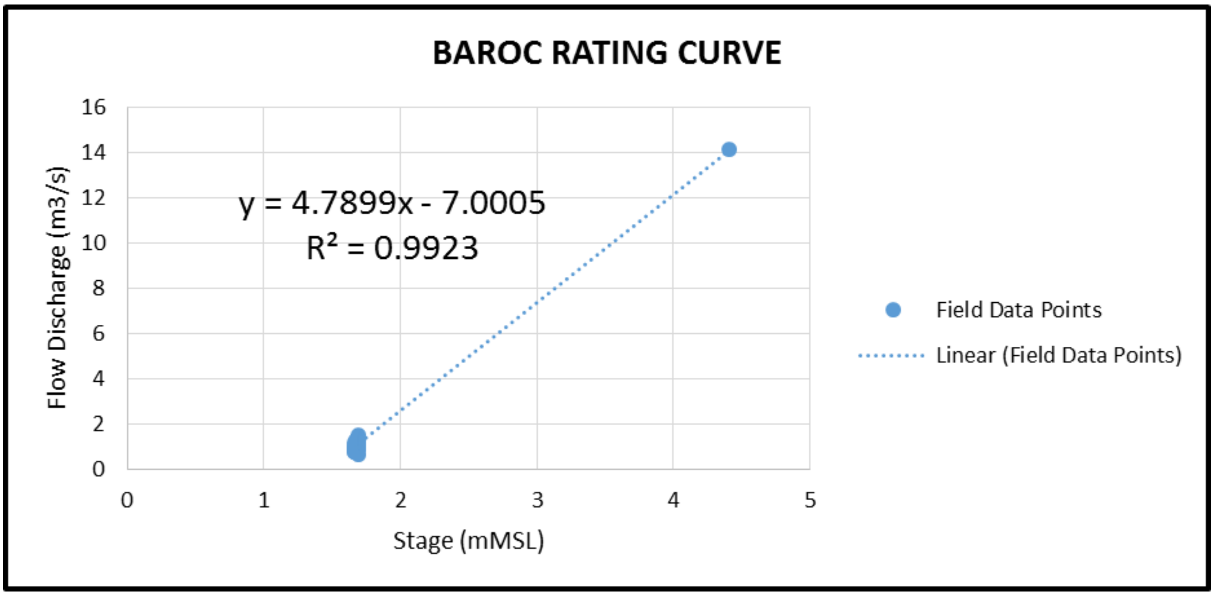


Figure 49. Rating curve at Baroc Bridge, Oriental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 49, actual flow discharge during a rainfall event was collected in the Baroc bridge. Peak discharge is 5.927 cu.m/s on January 11, 2017 at 1:25 pm.

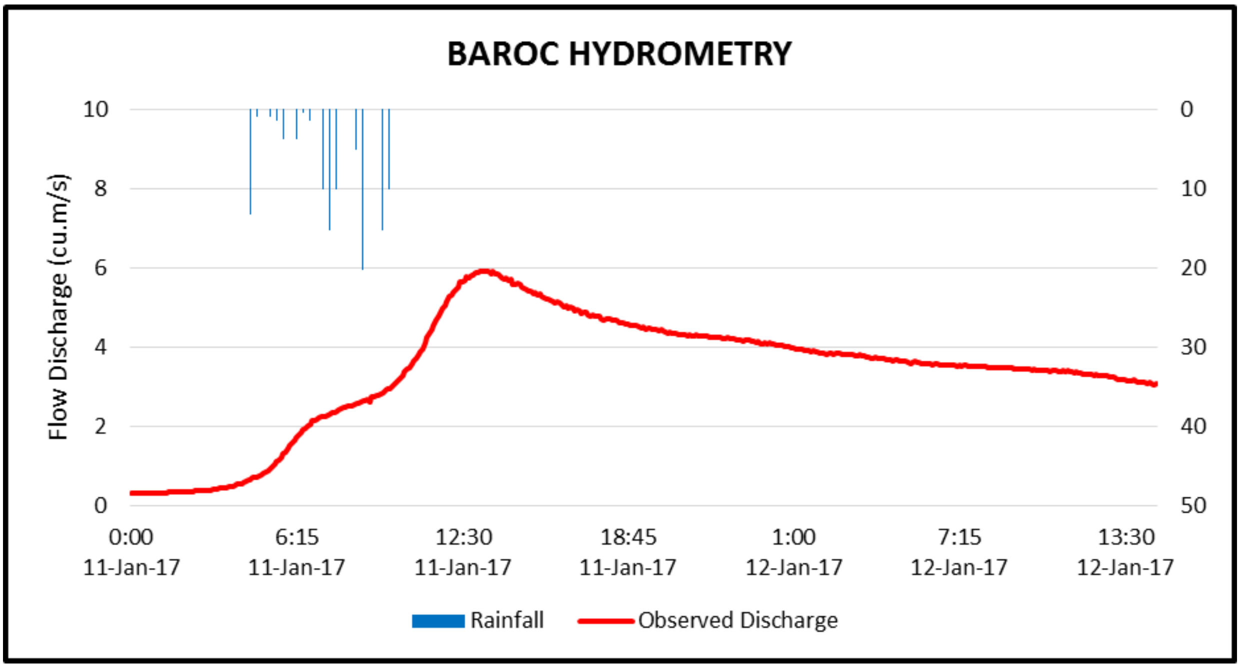


Figure 50. Rainfall and outflow data at Baroc River Basin used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Romblon 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 Baroc watershed. The extreme values for this watershed were computed based on a 48-year record, with the computed extreme values shown in Table 24.

Table 24. RIDF values for Baroc 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	18.2	27	33.5	44.3	59.5	70.4	89.5	107	119.8
5	26	37.7	46.5	60.7	82.2	97.6	125.5	152.9	171.6
10	31.1	44.8	55	71.5	97.3	115.7	149.3	183.4	205.9
15	34	48.8	59.9	77.7	105.8	125.8	162.8	200.5	225.2
20	36	51.6	63.3	82	111.8	133	172.2	212.6	238.8
25	37.6	53.8	65.9	85.3	116.4	138.4	179.4	221.8	249.2
50	42.4	60.4	74	95.4	130.5	155.3	201.8	250.3	281.4
100	47.2	67	81.9	105.5	144.5	172.1	223.9	278.6	313.3

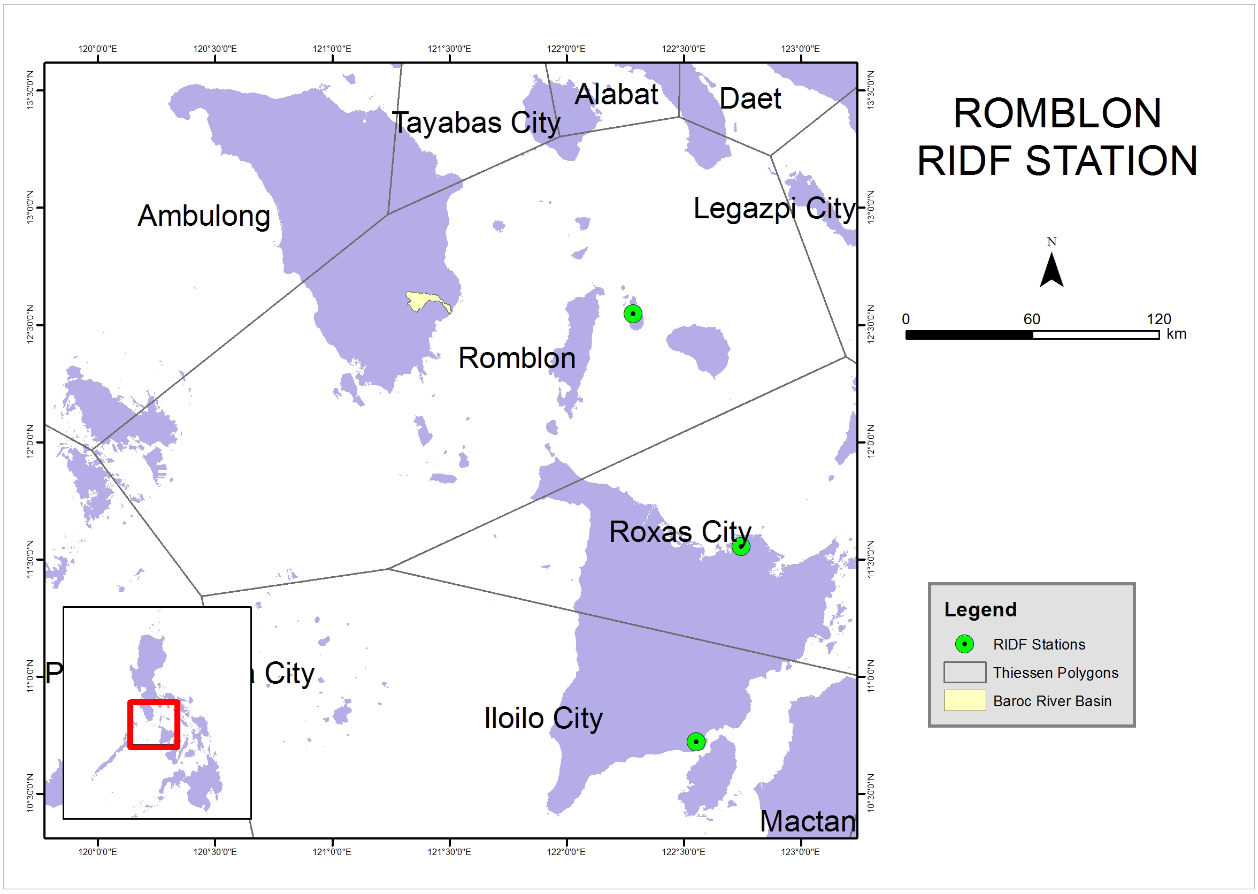


Figure 51. Location of Romblon RIDF relative to Baroc River Basin

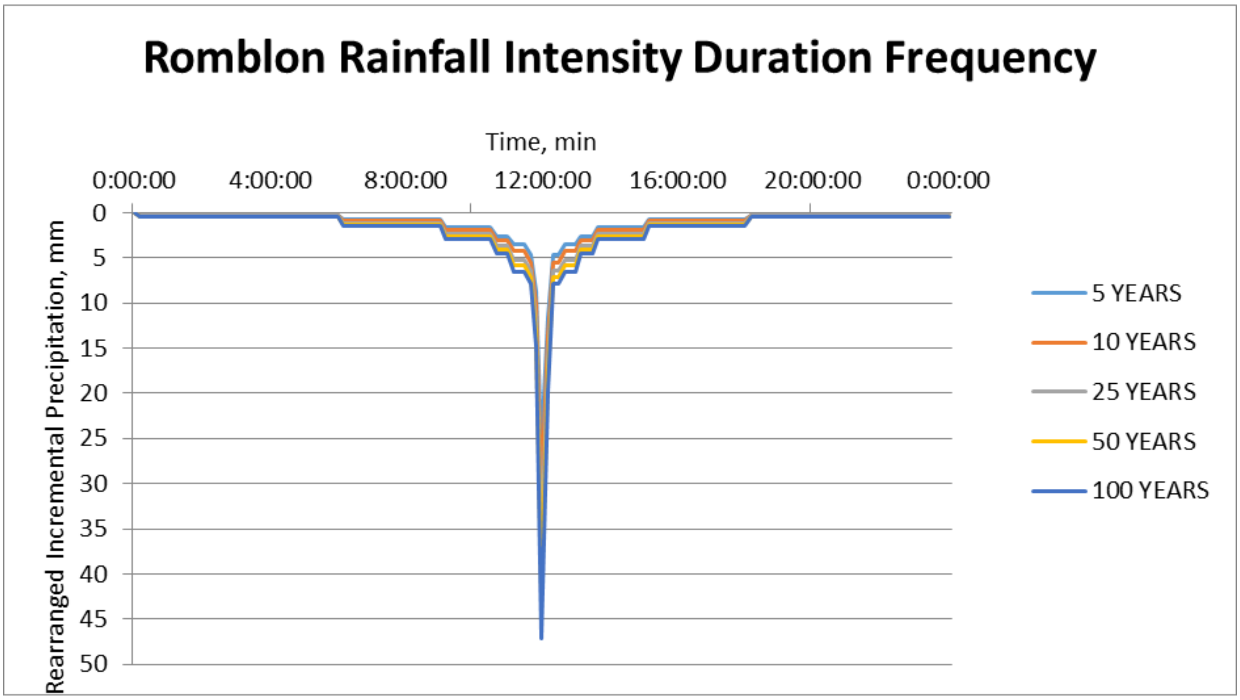


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

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

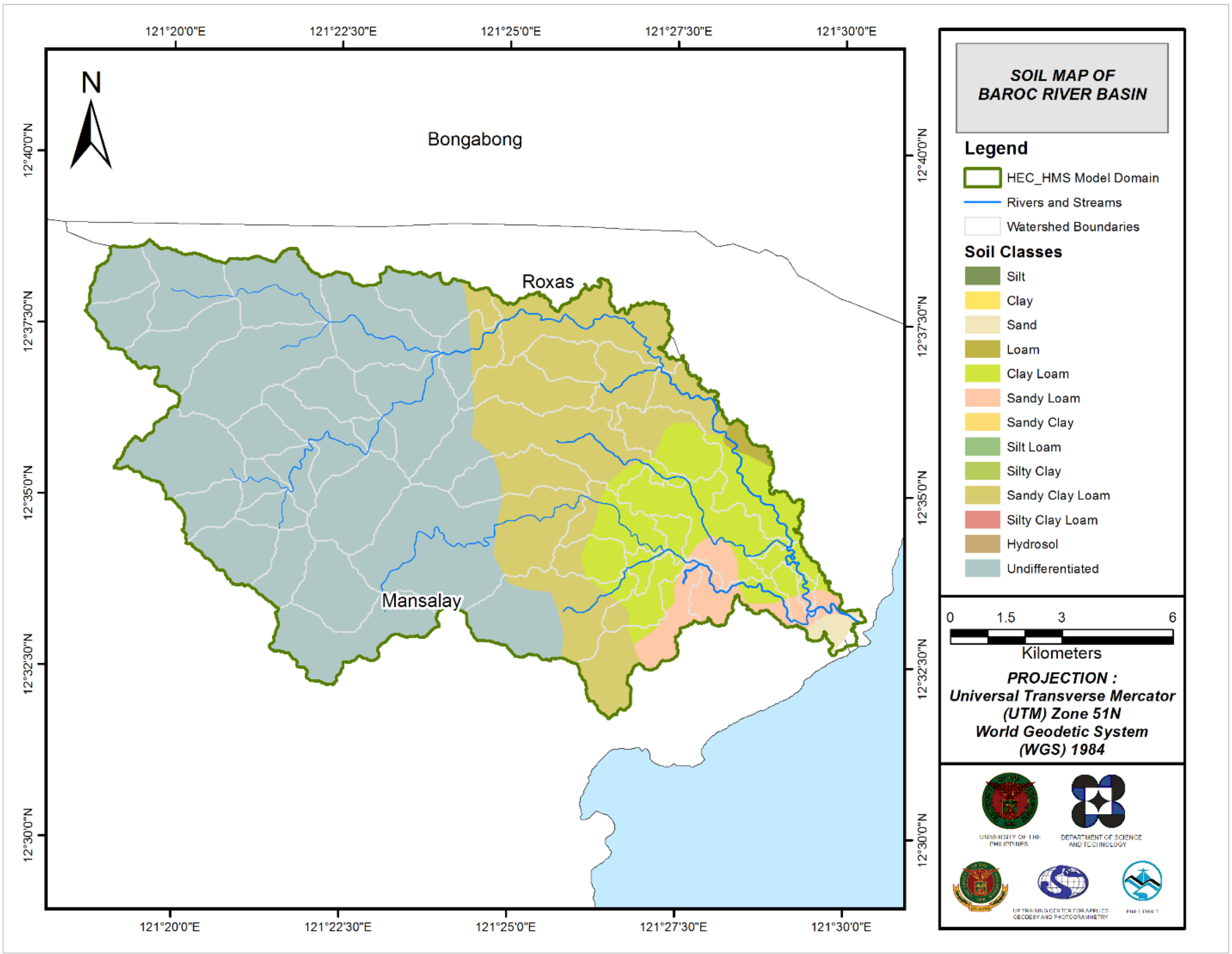


Figure 53. Soil map of Baroc River Basin used for the estimation of the CN parameter. (Source: DA)

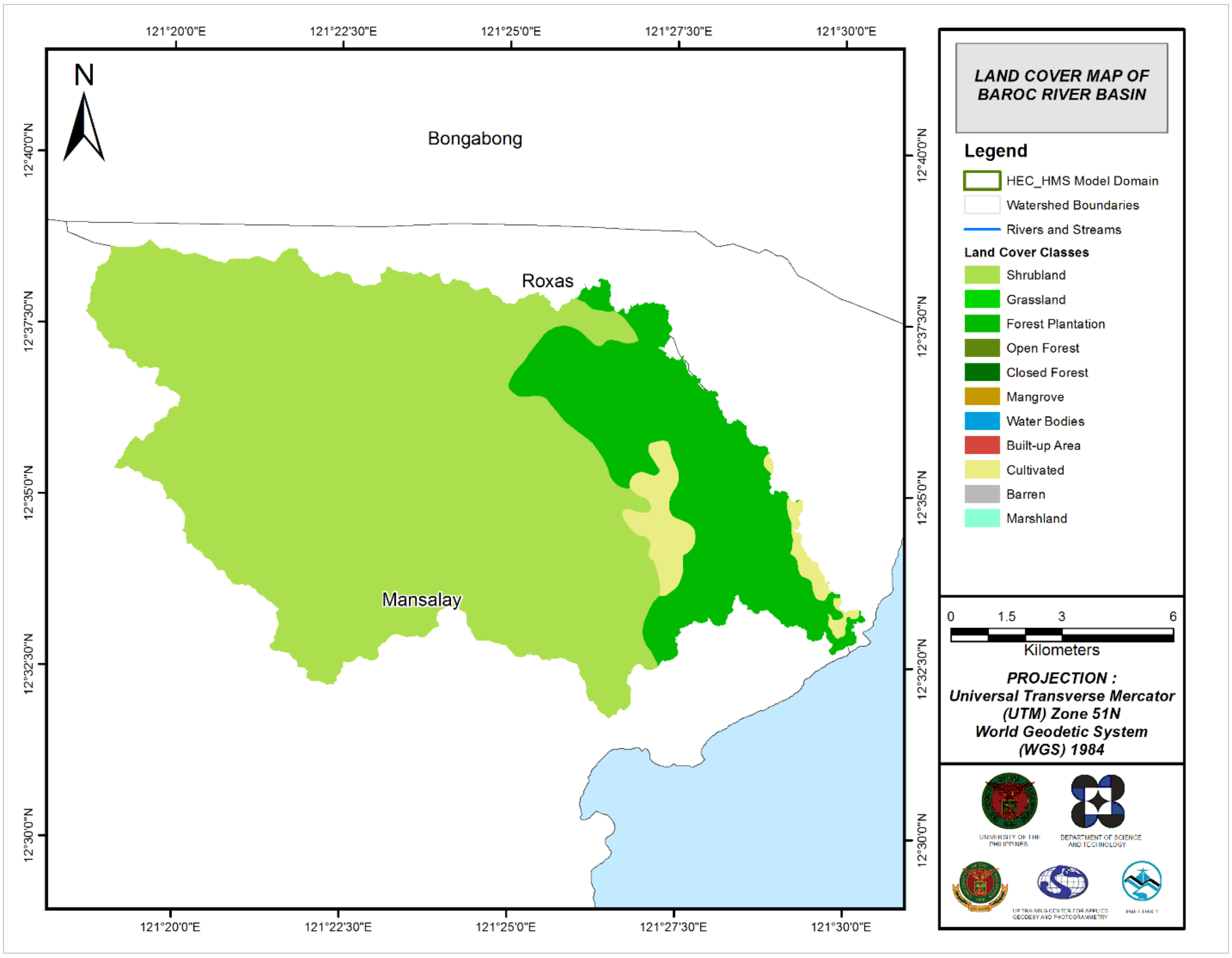


Figure 54. Land cover map of Baroc River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Baroc river basin, the four (4) soil classes identified were sand, sandy loam, clay loam, sandy clay loam, while the rest is undifferentiated. The three (3) land cover types identified were largely shrubland, with portions of forest plantation and cultivated land.

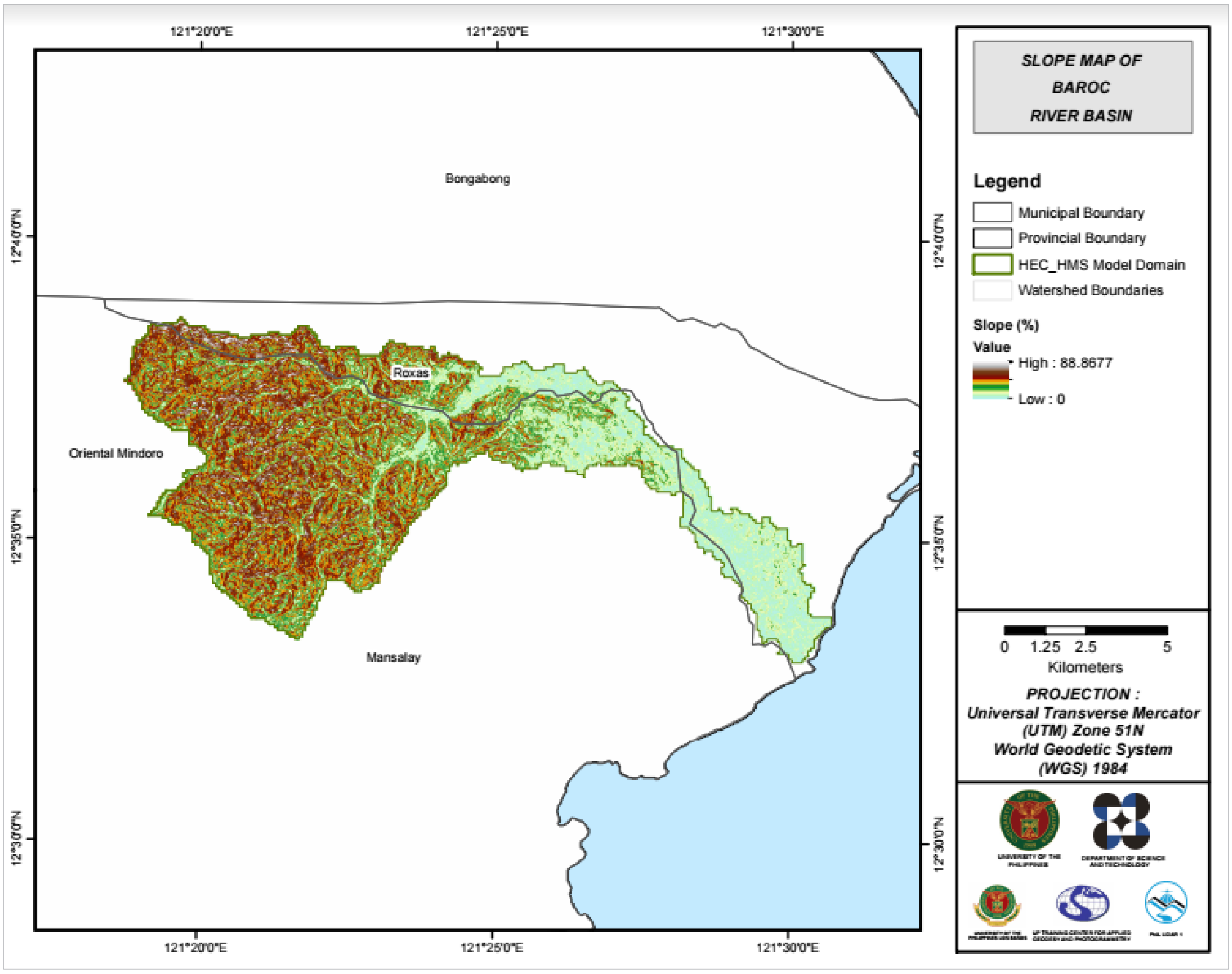


Figure 55. Slope map of Baroc River Basin

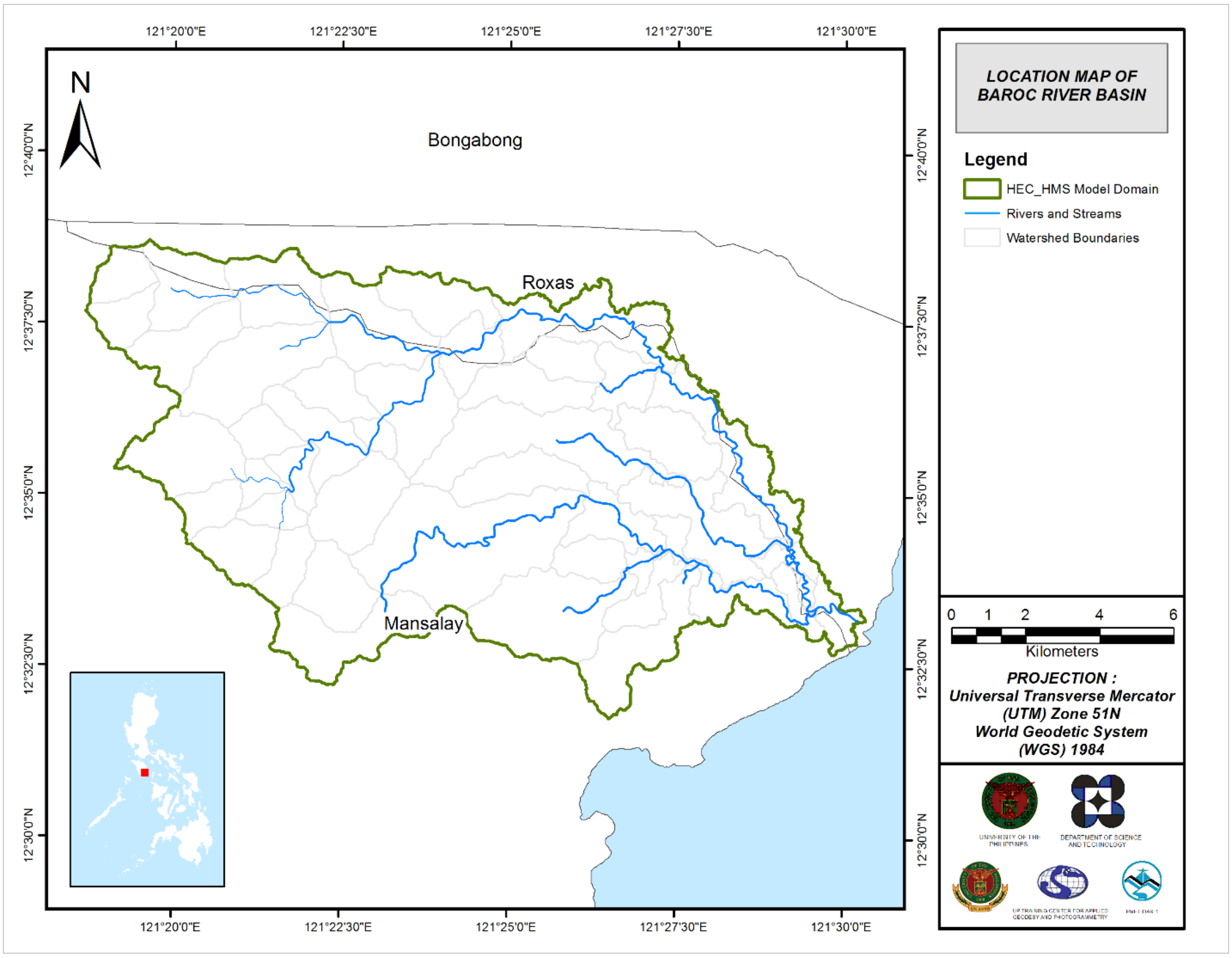


Figure 56. Stream delineation map of Baroc River Basin

Using SAR-based DEM, the Baroc basin was delineated and further subdivided into subbasins. The model consists of 19 sub basins, 10 reaches, and 10 junctions as shown in Figure 55. The main outlet is at Baroc Bridge.

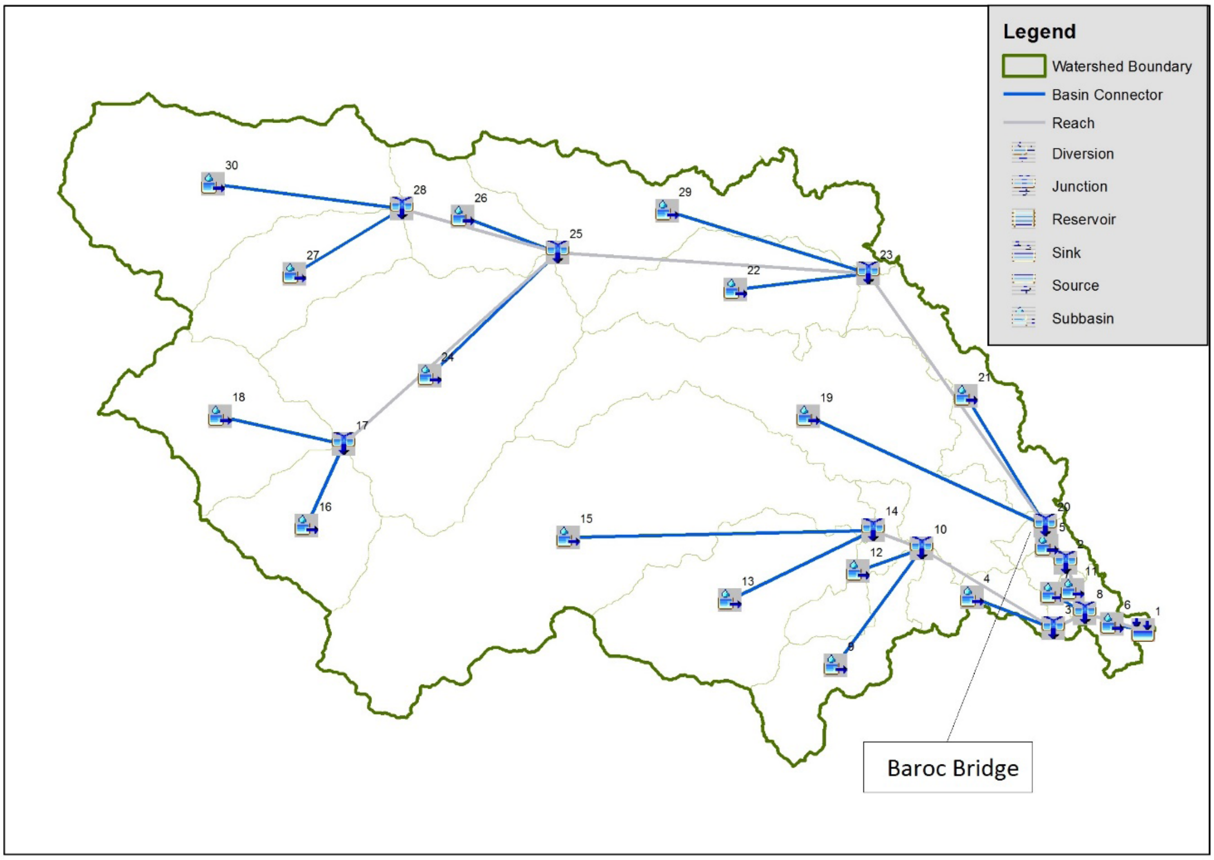


Figure 57. HEC-HMS generated Baroc River Basin Model.

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

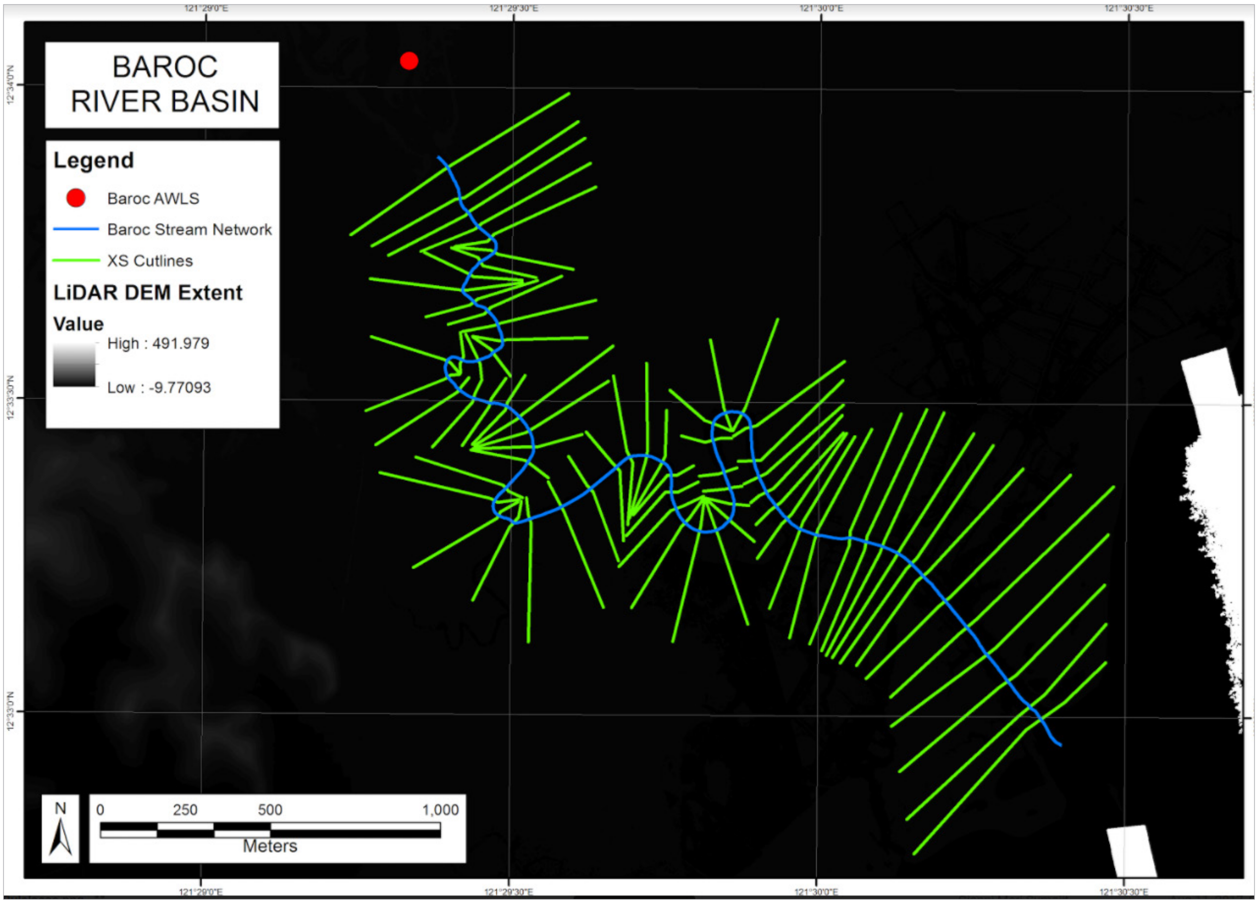


Figure 58. River cross-section of Baroc River generated through Arcmap HEC GeoRAS tool

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

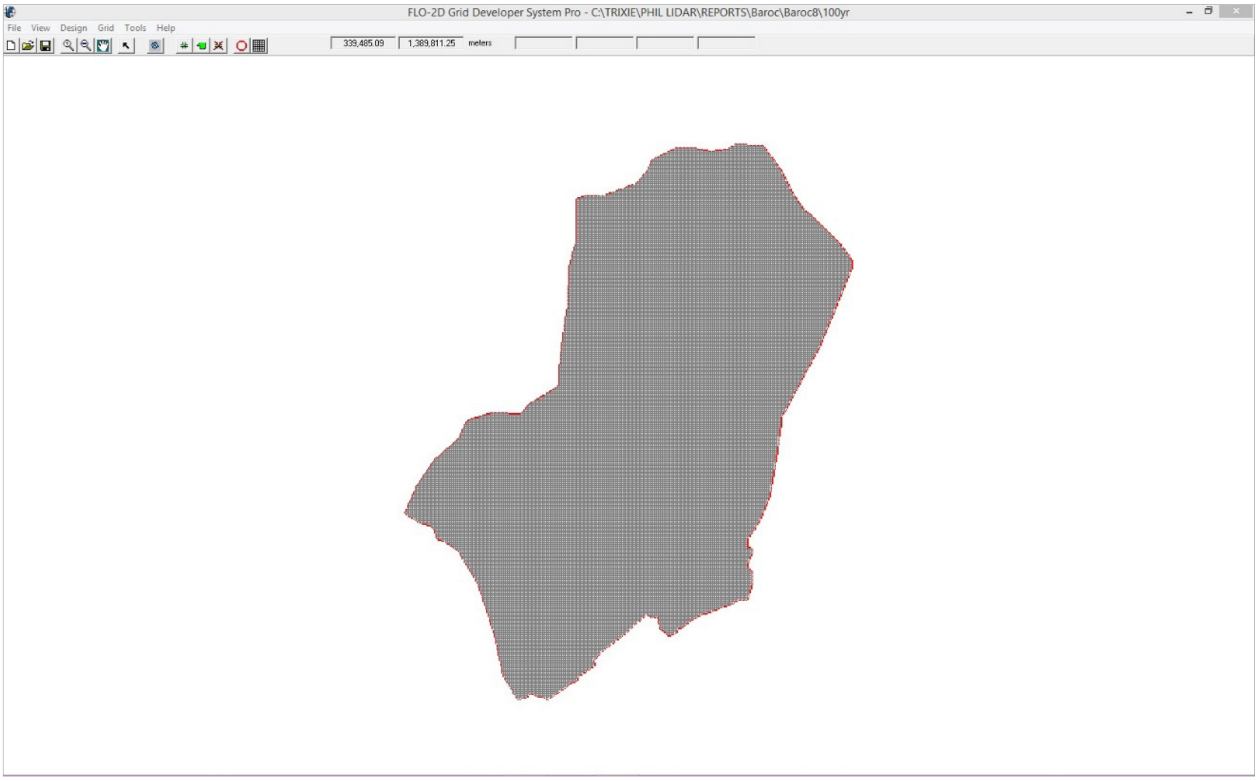


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 8.04590 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 23654800.00 m2.

There is a total of 24602839.22 m3 of water entering the model. Of this amount 7172345.46 m3 is due to rainfall while 17430493.75 m3 is inflow from other areas outside the model. 3143757.75 m3 of this water is lost to infiltration and interception, while 1184720.60 m3 is stored by the flood plain. The rest, amounting up to 17685662.82 m3, is outflow.

5.6 Results of HMS Calibration

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

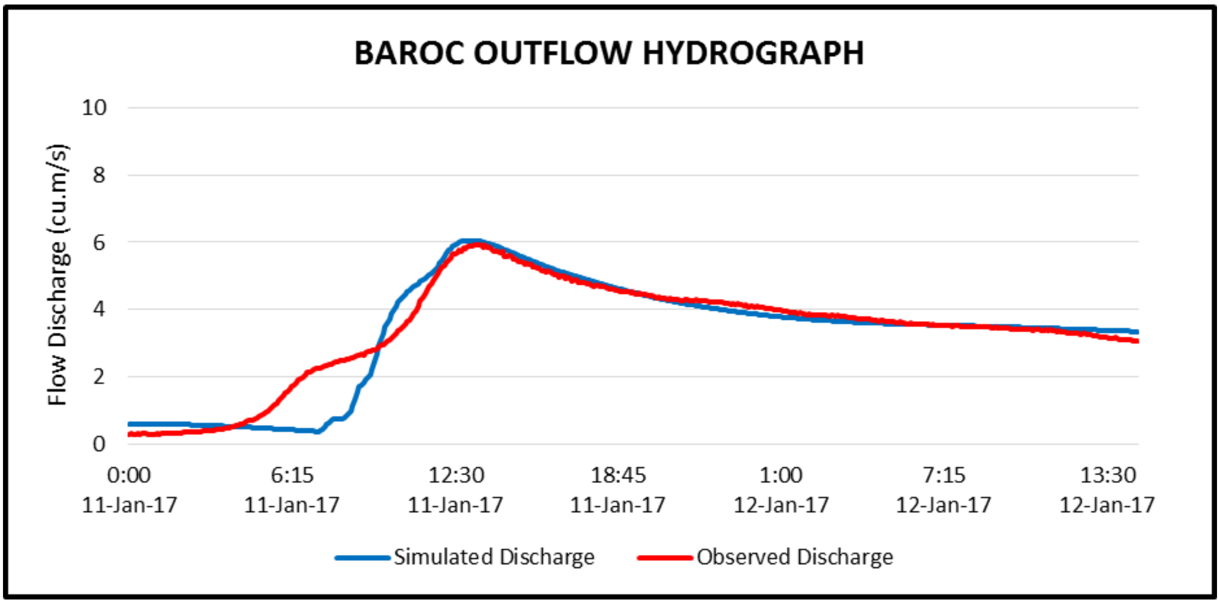


Figure 60. Outflow Hydrograph of Baroc produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 25 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 25. Range of calibrated values for Baroc River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	4 - 164
			Curve Number	41 - 84
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	.07 - 8
			Storage Coefficient (hr)	3 - 25
	Baseflow	Recession	Recession Constant	0.007 - 1
			Ratio to Peak	0 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.006 – 0.02

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 4mm to 164mm means that the subbasins have a diverse soil and land cover characteristics wherein there is average to high 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 41 to 84 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area. For Baroc, the soil cover mostly consists of sandy clay loam, clay loam, and sandy loam while land cover consists of shrubland, and forest plantation.

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 0.7 hours to 8 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.007 to 1 indicates that the subbasins react differently when the flow recedes. Ratio to peak from 0 to 0.5 indicates a steeper to normal receding limb of the outflow hydrograph.

Manning's roughness coefficient from 0.006 to 0.02 is low compared to the the common roughness of Philippine watersheds. This means that the riverbed is relatively smooth and water will most likely flow faster. (Brunner, 2010).

Table 26. Summary of the Efficiency Test of Baroc HMS Model

Accuracy Measure	Value
Root Mean Square Error (RMSE)	0.5614
Pearson Correlation Coefficient (r^2)	0.9480
Nash-Sutcliffe (E)	0.860
Percent Bias (PBIAS)	3.046
Observation Standard Deviation Ratio (RSR)	0.375

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.5614.

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 0.9480.

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 0.860.

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 3.046.

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 0.375.

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

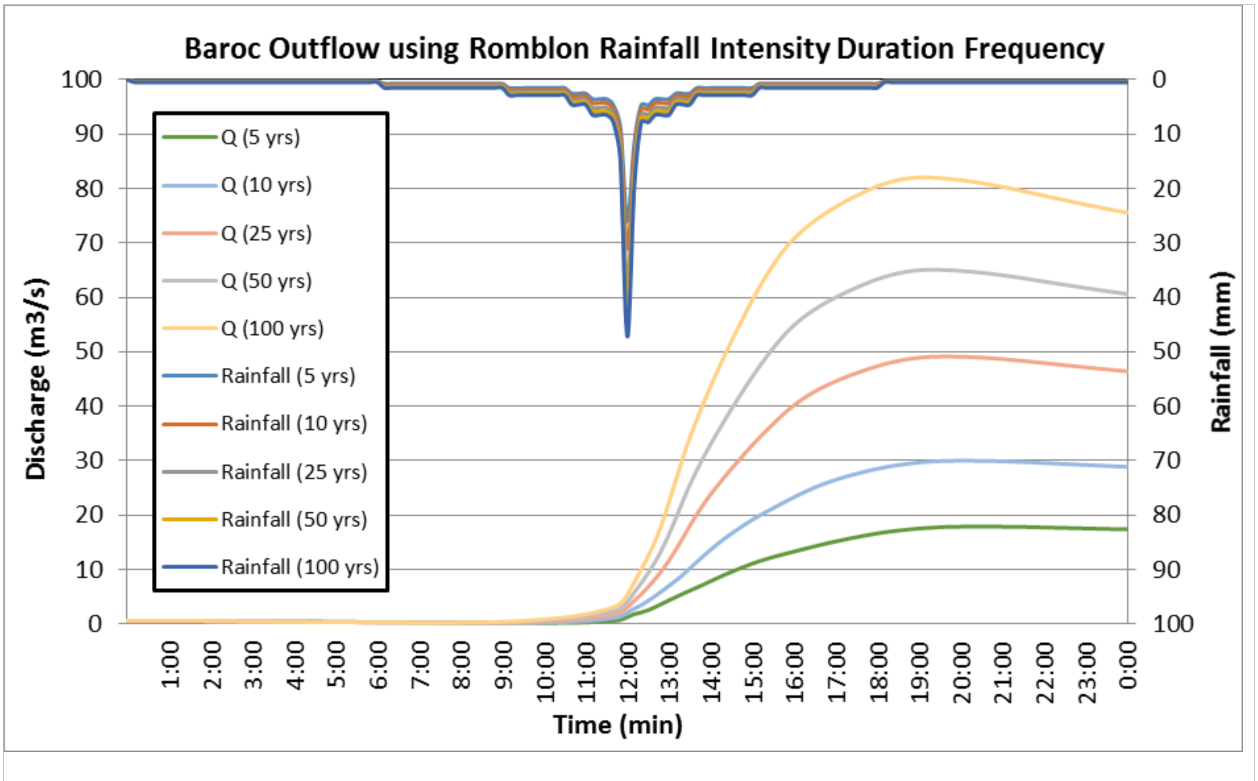


Figure 61. Outflow hydrograph at Baroc Station generated using Romblon RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Baroc discharge using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 27.

Table 27. Peak values of the Baroc HECHMS Model outflow using the Romblon RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak	Lag Time
5-yr	171.6	26	17.908	20 hours 30 minutes	8 hours 30 minutes
10-yr	205.9	31.1	29.991	20 hours 10 minutes	8 hours 10 minutes
25-yr	249.2	37.6	49.128	19 hours 40 minutes	7 hours 40 minutes
50-yr	281.4	42.4	65.057	19 hours 20 minutes	7 hours 20 minutes
100-yr	313.3	47.2	82.021	19 hours 10 minutes	7 hours 10 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/ Phil-LiDAR 1 website. The sample map of Baroc River using the HMS base flow is shown on Figure 61.

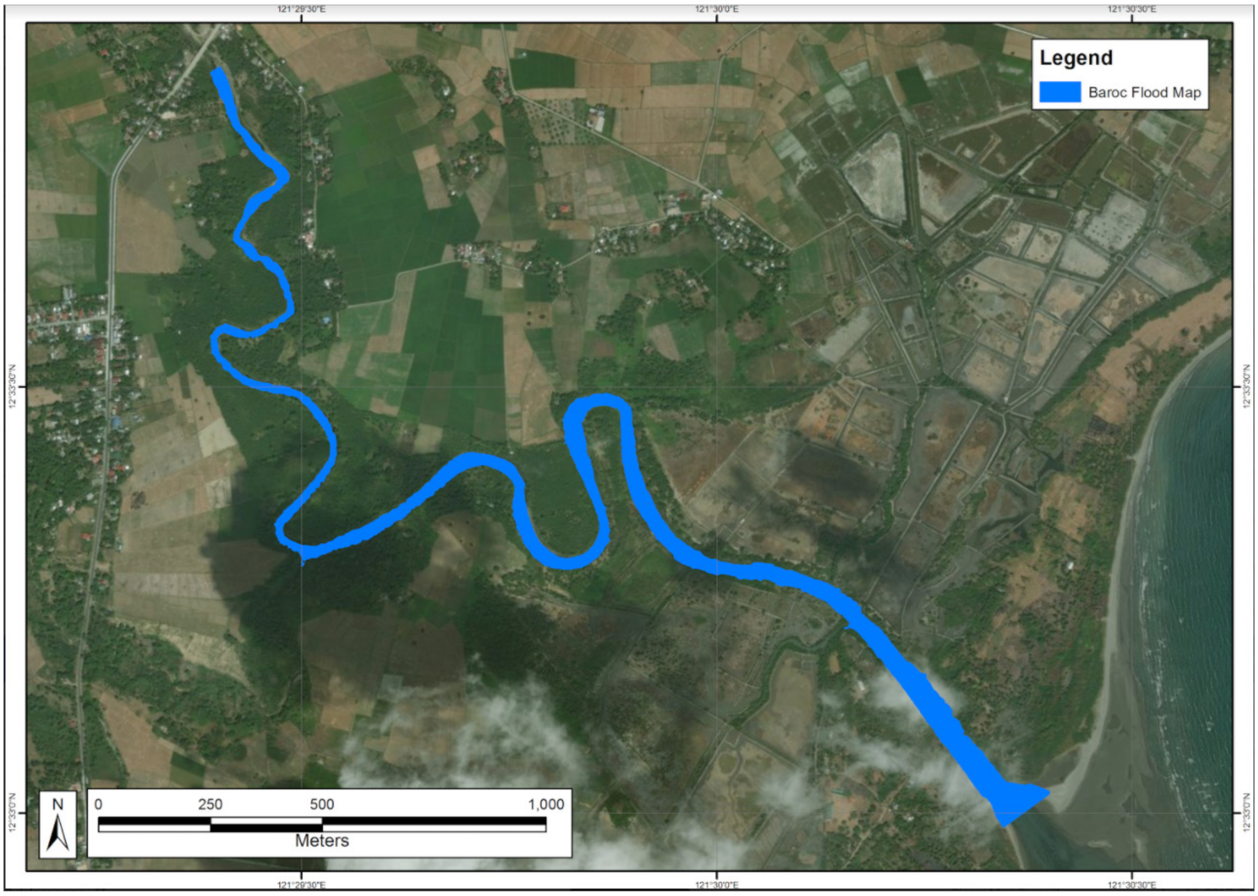


Figure 62. Sample output of Baroc RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. The generated flood hazard maps for the Tambang Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr). The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Baroc floodplain are shown in Figure 62 to Figure 67. The floodplain, with an area of 39.82 sq. km., covers two municipalities namely Mansalay, and Roxas. Table 28 shows the percentage of area affected by flooding per municipality.

Table 28. Municipalities affected in Baroc Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Mansalay	477.237	30.0876	6.304541
Roxas	90.1447	9.727181	10.79063

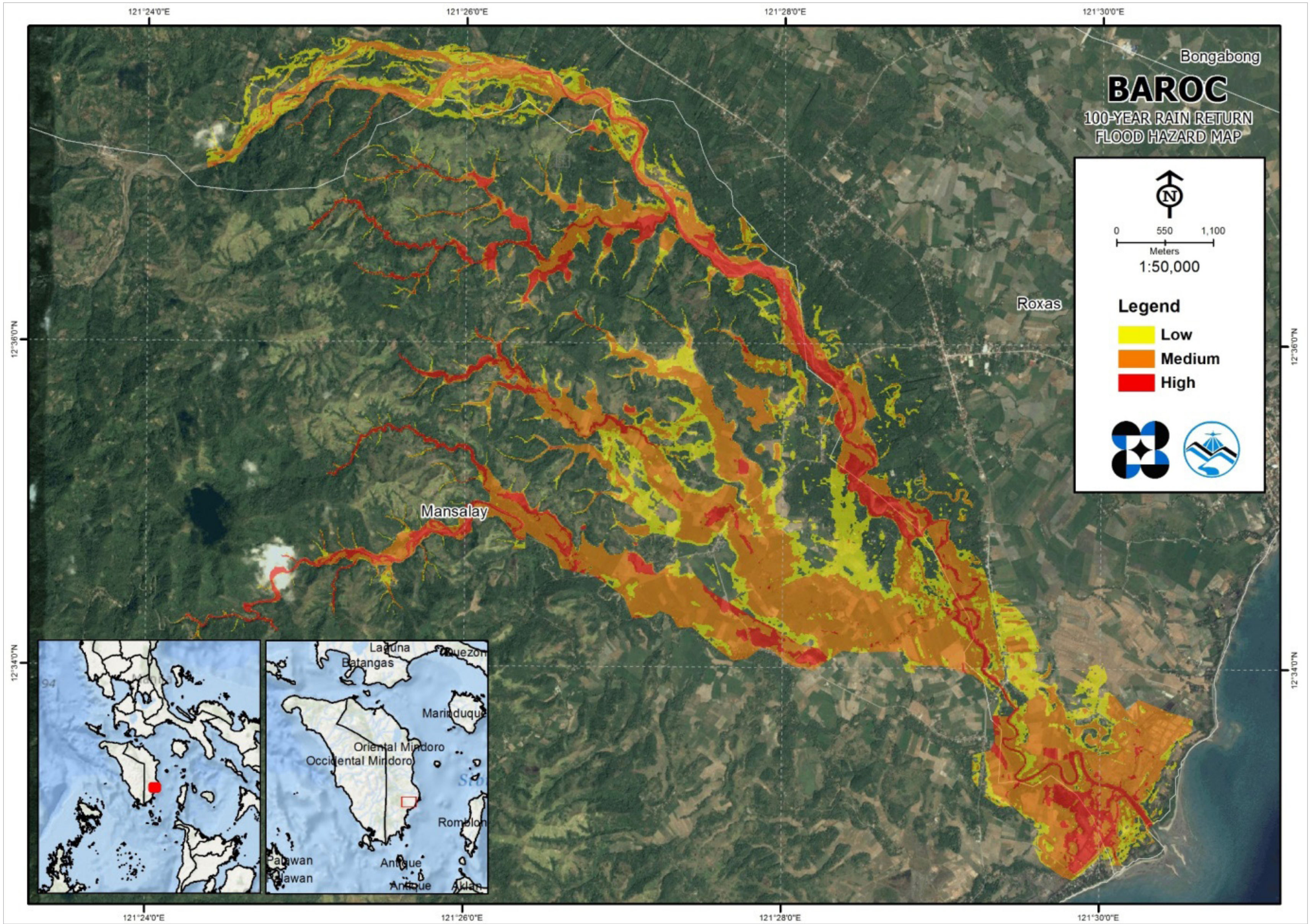


Figure 63. 100-year Flood Hazard Map for Baroc Floodplain overlaid on Google Earth imagery

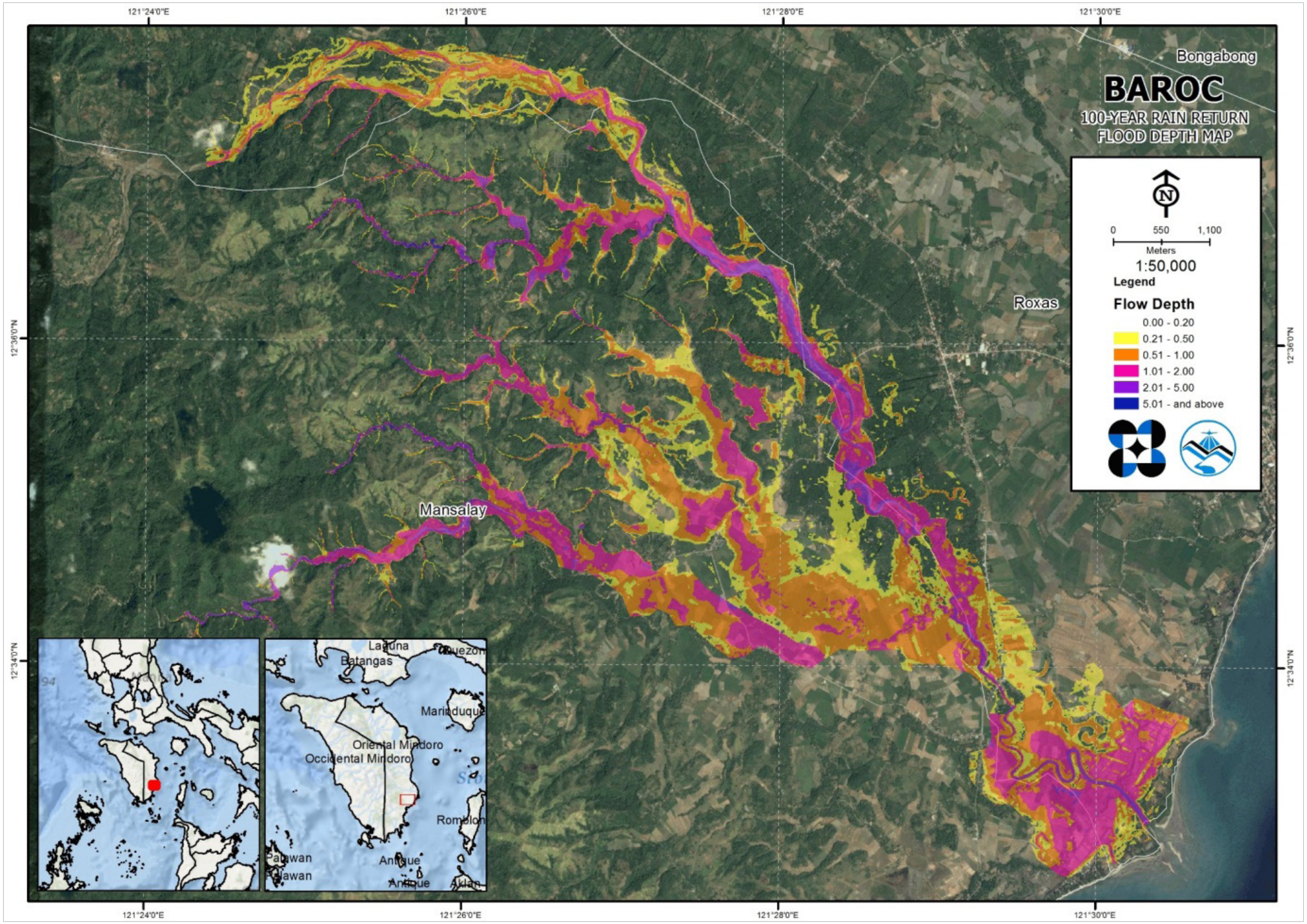


Figure 64. 100-year Flow Depth Map for Baroc Floodplain overlaid on Google Earth imagery

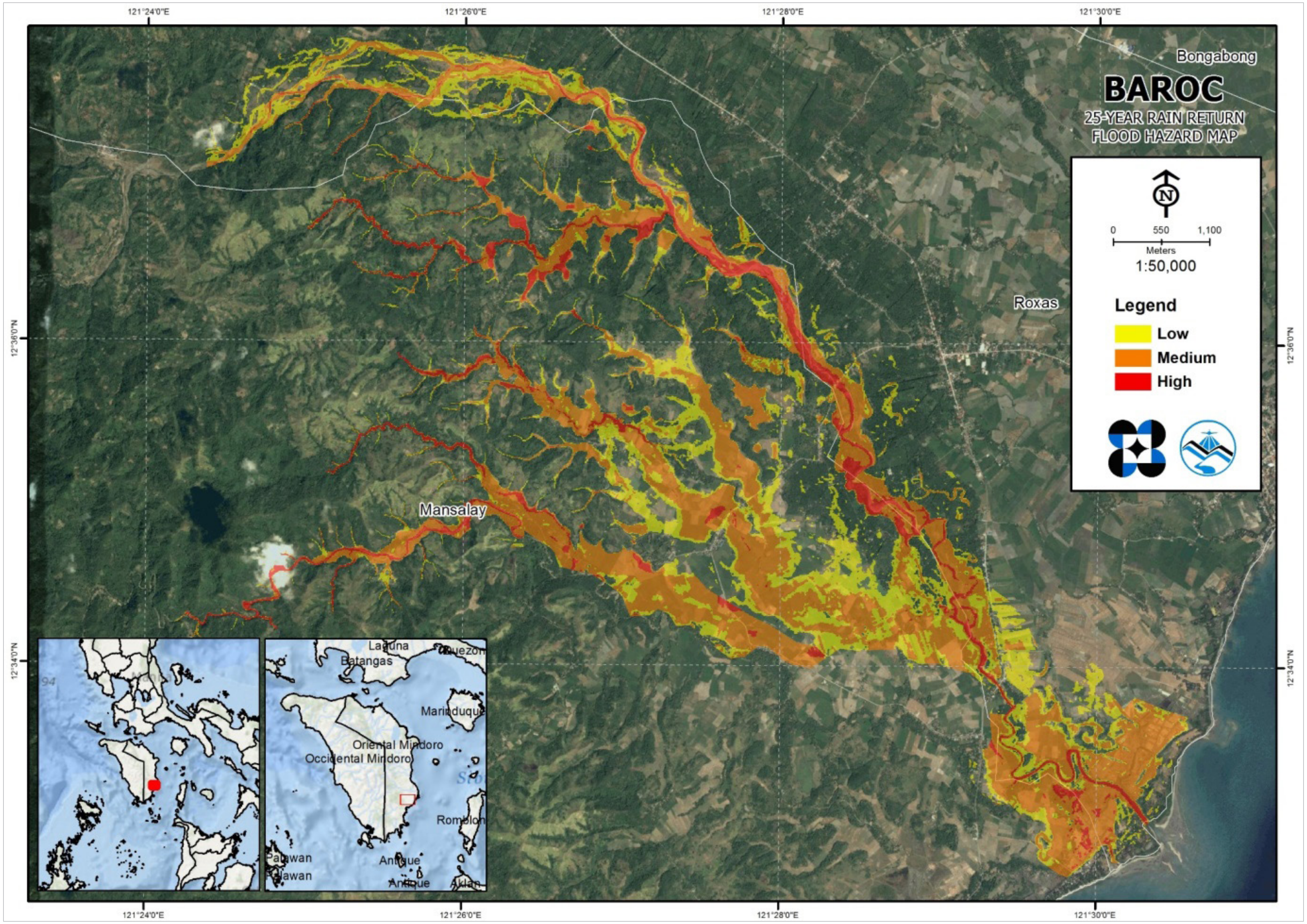


Figure 65. 25-year Flood Hazard Map for Baroc Floodplain overlaid on Google Earth imagery

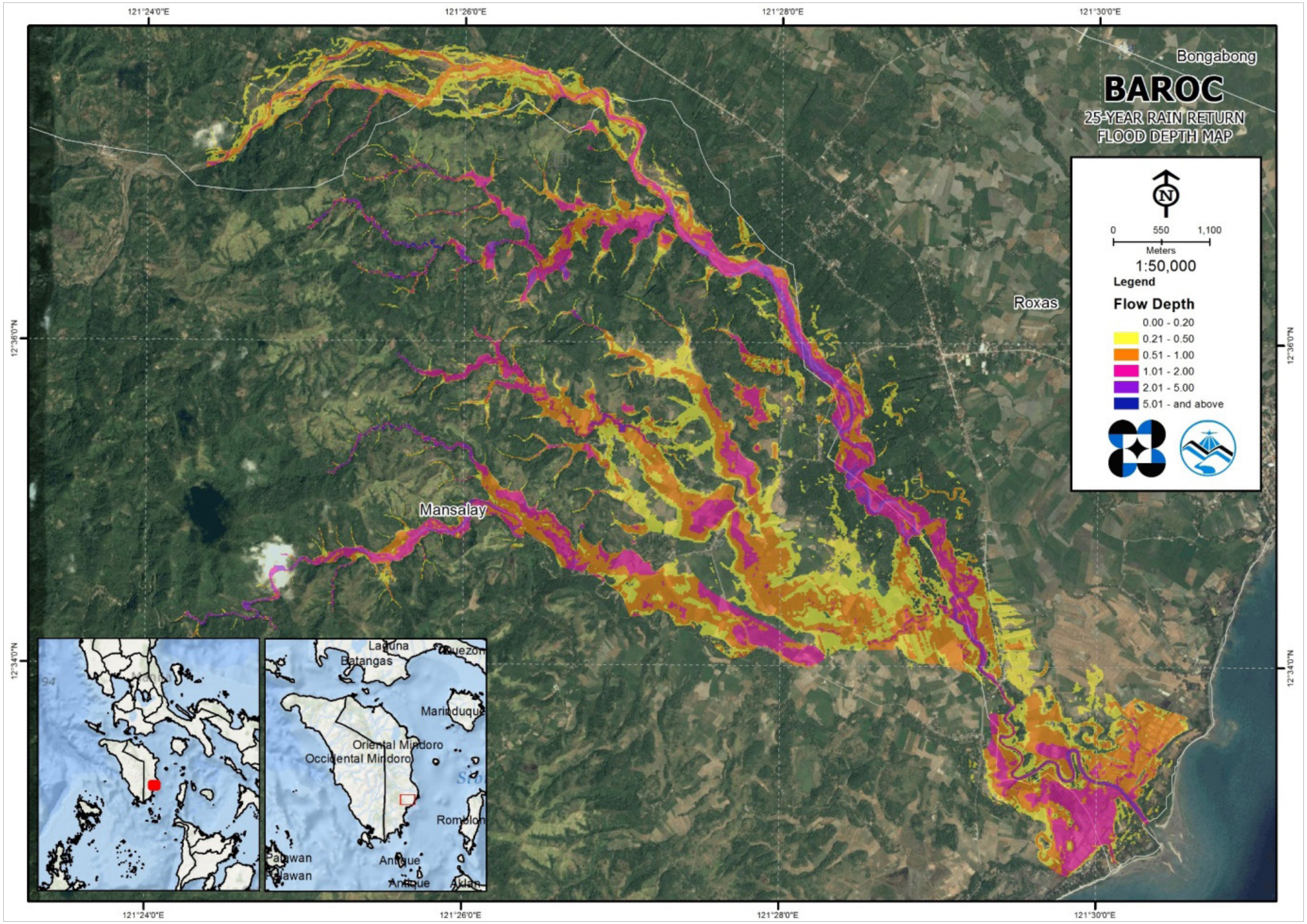


Figure 66. 25-year Flow Depth Map for Baroc Floodplain overlaid on Google Earth imagery

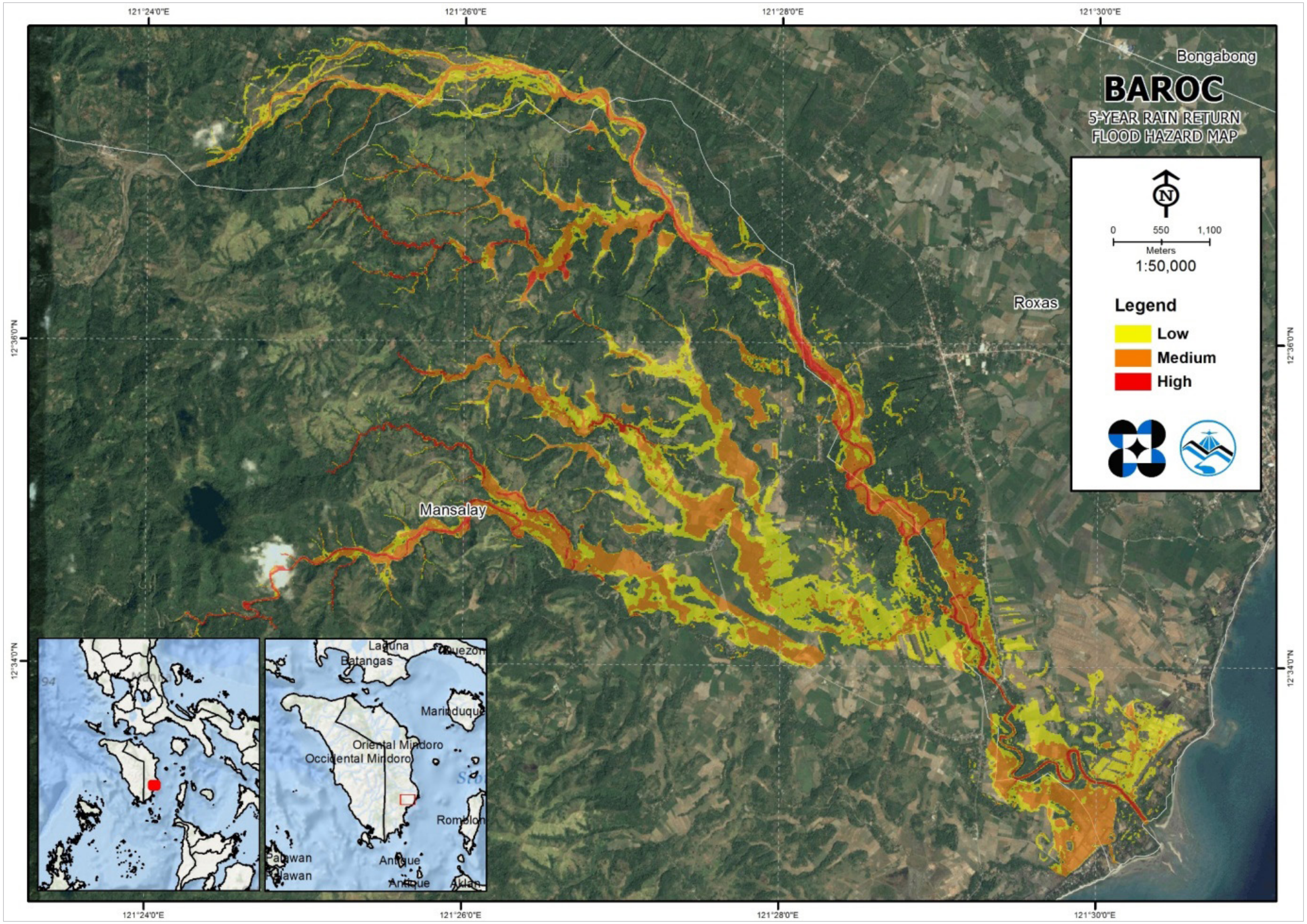


Figure 67. 5-year Flood Hazard Map for Baroc Floodplain overlaid on Google Earth imagery

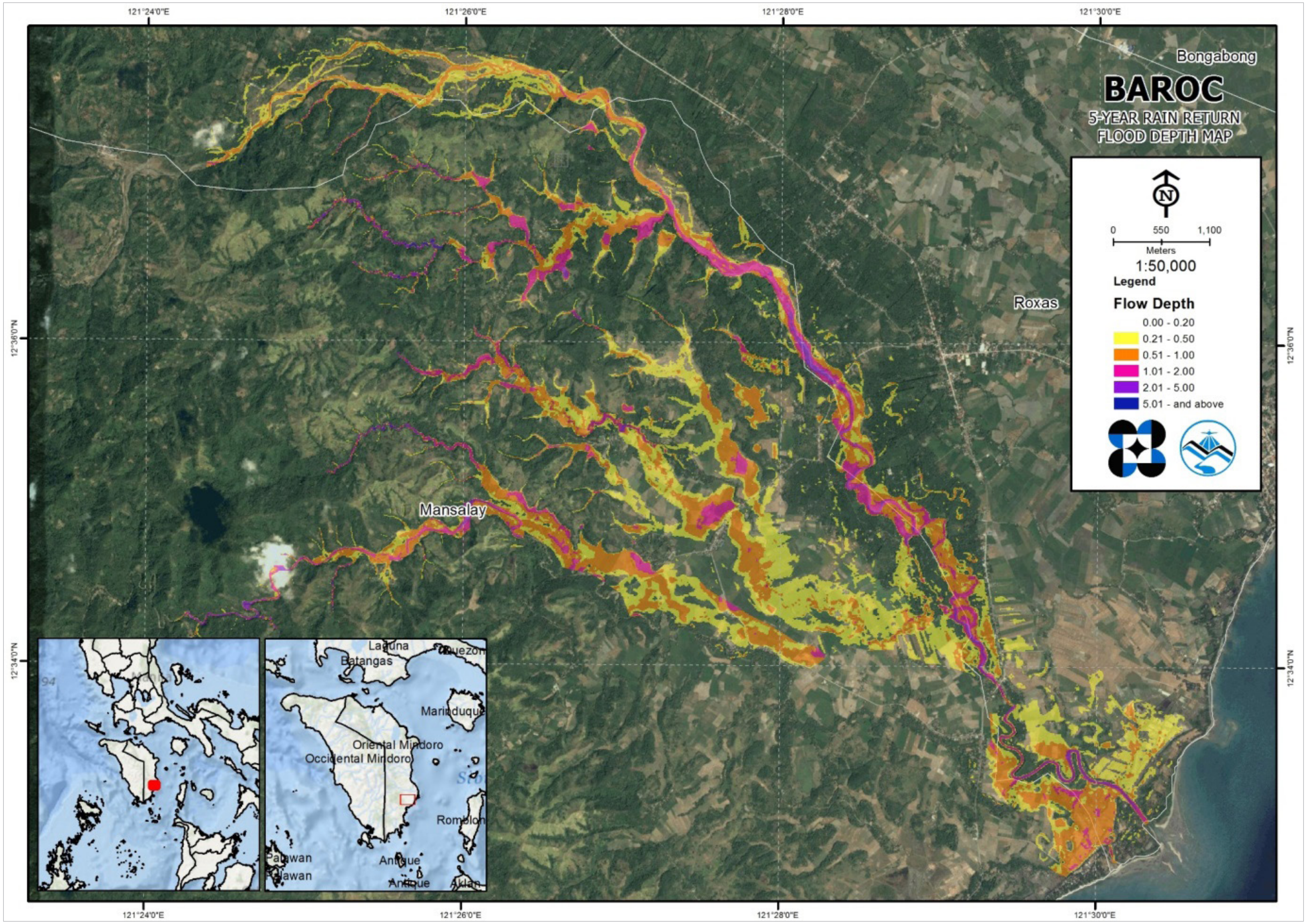


Figure 68. 5-year Flood Depth Map for Baroc Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Baroc river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 16 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 4.44% of the municipality of Mansalay with an area of 477.24 sq. km. will experience flood levels of less 0.20 meters. 0.89% of the area will experience flood levels of 0.21 to 0.50 meters while 0.69%, 0.26%, 0.03%, and 0.002% 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 29 and shown in Figure 68 are the affected areas in Mansalay in square kilometres by flood depth per barangay.

Table 29. Affected Areas in Mansalay, Oriental Mindoro during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mansalay (in sq. km.)								
	Balugo	Bonbon	Maliwanag	Roma	Santa Brigida	Santa Maria	Villa Celestial	Wasig	Waygan
0.03-0.20	3.42	10.33	0.37	2.87	1.09	0.41	0.21	0.24	2.23
0.21-0.50	1.2	0.94	0.015	0.45	1.06	0.032	0.21	0.17	0.17
0.51-1.00	1	0.78	0.01	0.4	0.31	0.029	0.14	0.36	0.27
1.01-2.00	0.25	0.52	0.011	0.19	0.056	0.018	0.0063	0.04	0.15
2.01-5.00	0.0097	0.052	0.0041	0.03	0.011	0.024	0	0	0.033
> 5.00	0	0.0061	0.0005	0	0	0.0006	0	0	0.0009

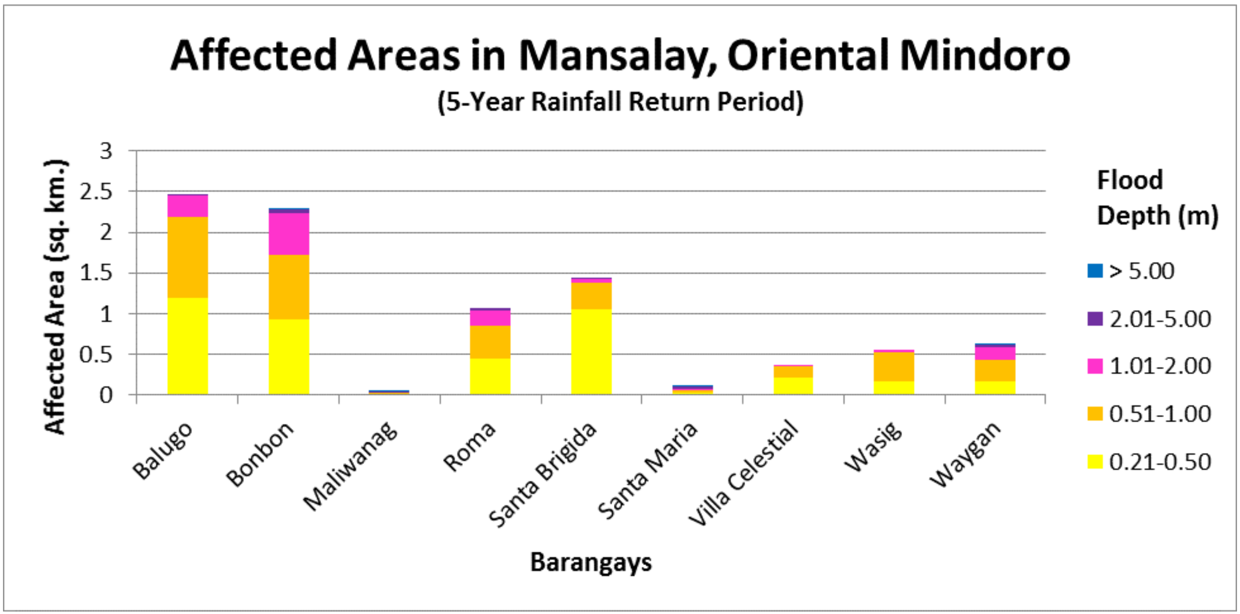


Figure 69. Affected Areas in Mansalay, Oriental Mindoro during 5-Year Rainfall Return Period

For the municipality of Roxas, with an area of 90.145 sq. km., 6.79% will experience flood levels of less 0.20 meters. 2.12% of the area will experience flood levels of 0.21 to 0.50 meters while 1.38%, 0.39%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 30 and shown in Figure 69 are the affected areas in square kilometres by flood depth per barangay.

Table 30. Affected Areas in Roxas, Oriental Mindoro during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mansalay (in sq. km.)						
	Happy Valley	San Aquilino	San Isidro	San Mariano	San Miguel	San Rafael	San Vicente
0.03-0.20	0.9	0.74	2.15	1.12	0.55	0.19	0.46
0.21-0.50	0.18	0.16	1.06	0.35	0.076	0.029	0.056
0.51-1.00	0.083	0.17	0.63	0.22	0.079	0.019	0.037
1.01-2.00	0.0095	0.091	0.18	0.01	0.054	0	0.0071
2.01-5.00	0	0.0088	0.059	0	0.042	0	0.0002
> 5.00	0	0	0	0	0	0	0

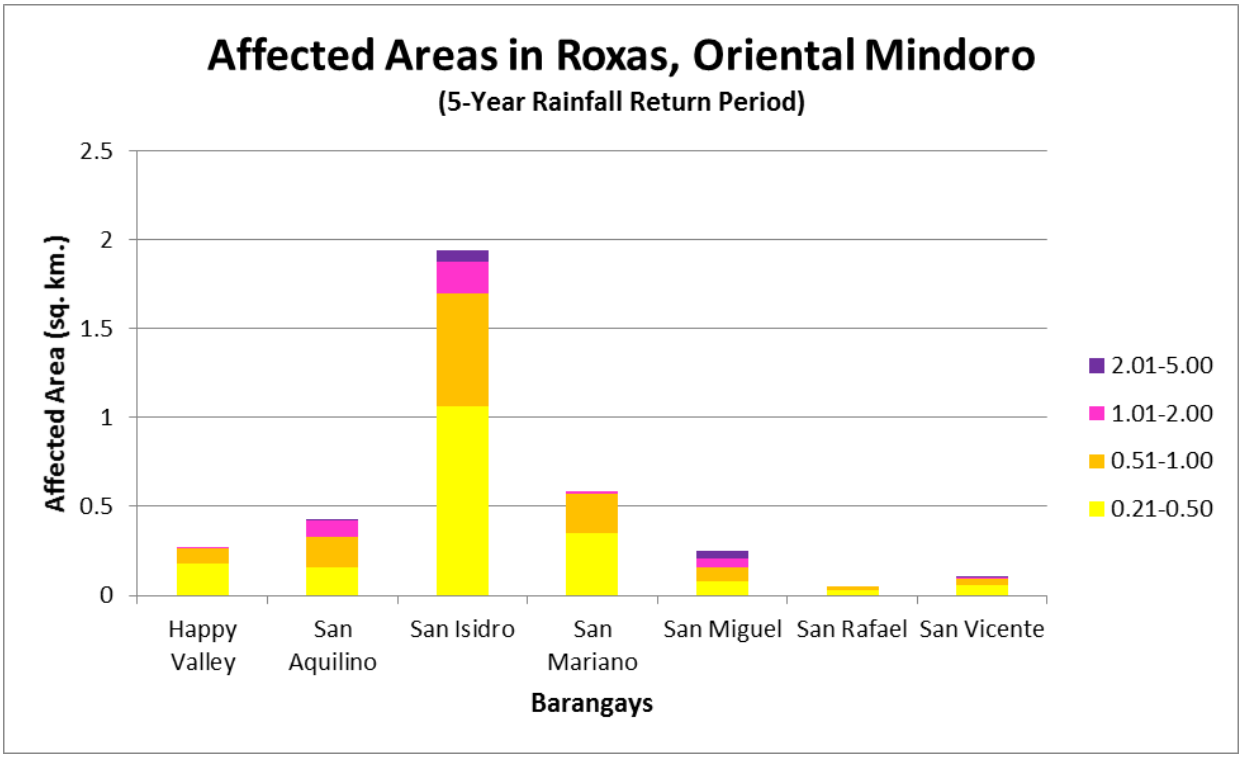


Figure 70. Affected Areas in Roxas, Oriental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 3.94% of the municipality of Mansalay with an area of 477.24 sq. km. will experience flood levels of less 0.20 meters. 0.76% of the area will experience flood levels of 0.21 to 0.50 meters while 0.90%, 0.61%, 0.10%, and 0.003% 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 31 and shown in Figure 70 are the areas affected in Mansalay in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Mansalay, Oriental Mindoro during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mansalay (in sq. km.)								
	Balugo	Bonbon	Maliwanag	Roma	Santa Brigida	Santa Maria	Villa Celestial	Wasig	Waygan
0.03-0.20	2.9	9.85	0.37	2.51	0.46	0.4	0.073	0.083	2.16
0.21-0.50	0.92	0.82	0.013	0.59	0.93	0.024	0.11	0.11	0.12
0.51-1.00	1.4	0.89	0.011	0.36	0.91	0.04	0.23	0.23	0.21
1.01-2.00	0.62	0.87	0.014	0.38	0.22	0.02	0.15	0.38	0.27
2.01-5.00	0.024	0.19	0.0082	0.1	0.016	0.033	0.001	0.000099	0.098
> 5.00	0	0.0089	0.0006	0	0	0.0011	0	0	0.0015

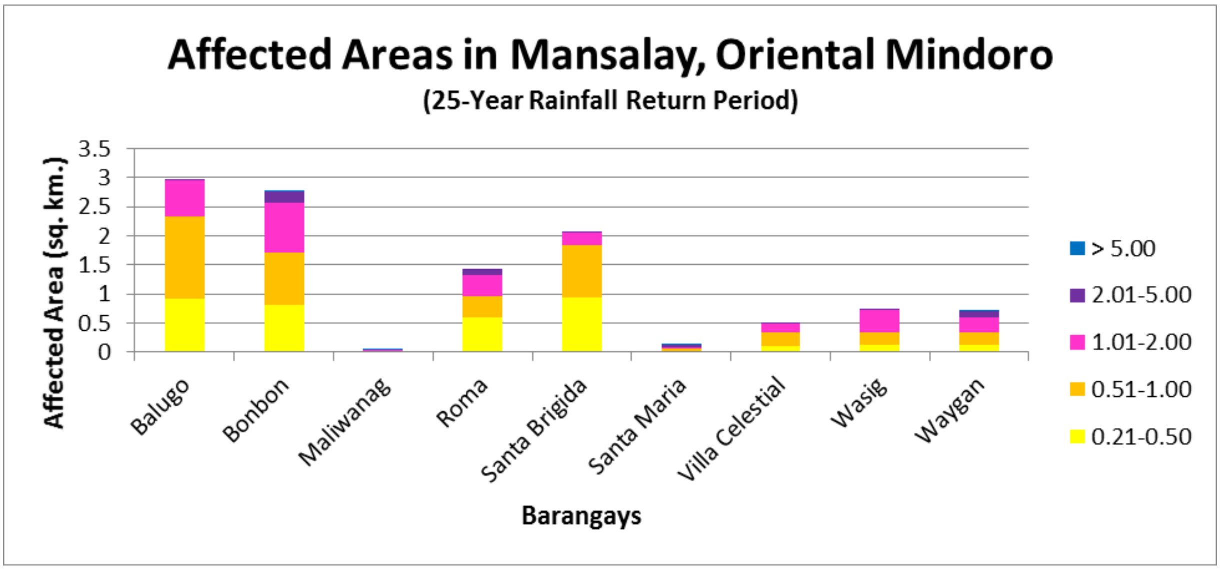


Figure 71. Affected areas in Mansalay, Oriental Mindoro during the 25-Year Rainfall Return Period

For the municipality of Roxas, with an area of 90.145 sq. km., 5.08% will experience flood levels of less 0.20 meters. 2.17% of the area will experience flood levels of 0.21 to 0.50 meters while 2.16%, 1.17%, and 0.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 32 and shown in Figure 71 are the affected areas in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Roxas, Oriental Mindoro during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Roxas (in sq. km.)								
	Happy Valley	San Aquilino	San Isidro	San Mariano	San Miguel	San Rafael	San Vicente	Wasig	Waygan
0.03-0.20	0.77	0.66	1.2	0.89	0.49	0.15	0.42	0.083	2.16
0.21-0.50	0.25	0.1	0.99	0.43	0.07	0.046	0.08	0.11	0.12
0.51-1.00	0.12	0.16	1.17	0.33	0.083	0.035	0.047	0.23	0.21
1.01-2.00	0.032	0.21	0.64	0.055	0.098	0.0044	0.016	0.38	0.27
2.01-5.00	0.0003	0.04	0.095	0	0.066	0	0.001	0.000099	0.098
> 5.00	0	0	0	0	0	0	0	0	0.0015

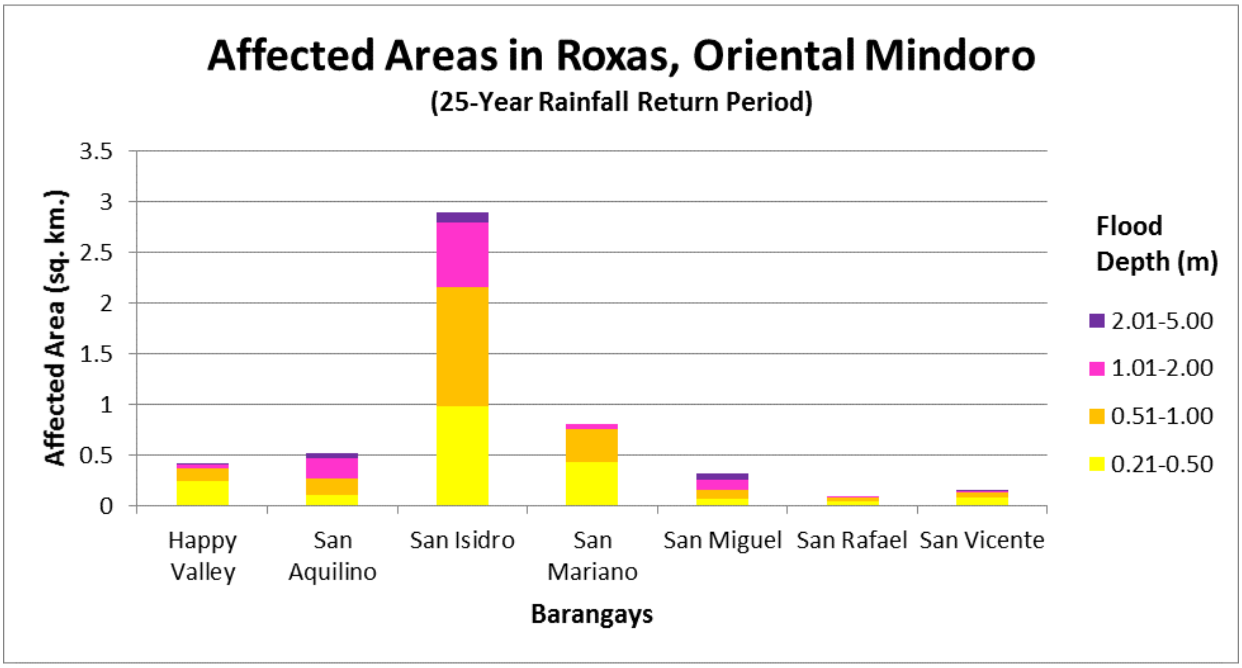


Figure 72. Affected Areas in Roxas, Oriental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 3.67% of the municipality of Mansalay with an area of 477.24 sq. km. will experience flood levels of less 0.20 meters. 0.67% of the area will experience flood levels of 0.21 to 0.50 meters while 0.97%, 0.82%, 0.17%, and 0.004% 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 33 and shown in Figure 72 are the affected areas in square kilometres by flood depth per barangay.

Table 33. Affected Areas in Mansalay, Oriental Mindoro during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mansalay (in sq. km.)								
	Balugo	Bonbon	Maliwanag	Roma	Santa Brigida	Santa Maria	Villa Celestial	Wasig	Waygan
0.03-0.20	2.66	9.57	0.36	2.17	0.22	0.39	0.015	0.022	2.11
0.21-0.50	0.81	0.82	0.013	0.76	0.52	0.02	0.075	0.081	0.11
0.51-1.00	1.39	0.88	0.012	0.39	1.36	0.04	0.24	0.2	0.14
1.01-2.00	0.97	0.99	0.015	0.47	0.41	0.023	0.23	0.49	0.33
2.01-5.00	0.055	0.36	0.012	0.15	0.022	0.039	0.004	0.013	0.16
> 5.00	0	0.012	0.0011	0	0	0.0052	0	0	0.0028

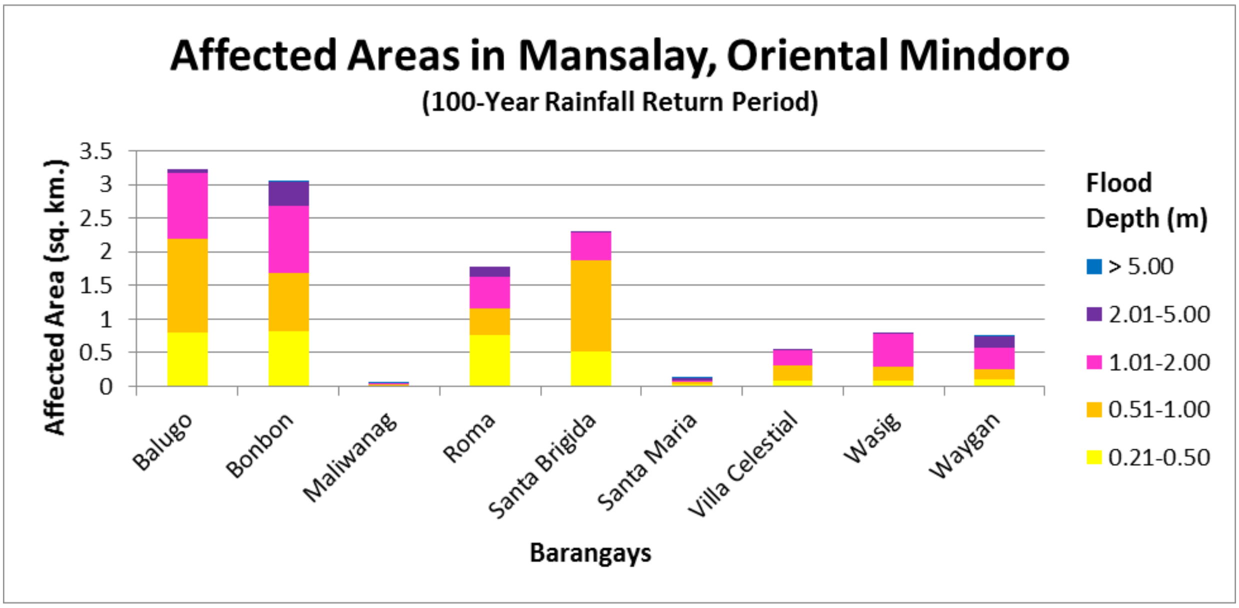


Figure 73. Affected Areas in Mansalay, Oriental Mindoro during 100-Year Rainfall Return Period

For the municipality of Roxas, with an area of 90.14 sq. km., 4.20% will experience flood levels of less 0.20 meters. 2.17% of the area will experience flood levels of 0.21 to 0.50 meters while 2.15%, 1.98%, and 0.31% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 34 and shown in Figure 73 are the areas affected in Roxas in square kilometers by flood depth per barangay.

Table 34. Affected areas in Roxas, Oriental Mindoro during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Roxas (in sq. km.)								
	Happy Valley	San Aquilino	San Isidro	San Mariano	San Miguel	San Rafael	San Vicente	Wasig	Waygan
0.03-0.20	0.7	0.63	0.71	0.78	0.44	0.13	0.39	0.083	2.16
0.21-0.50	0.27	0.11	0.94	0.42	0.082	0.045	0.09	0.11	0.12
0.51-1.00	0.15	0.11	1.12	0.41	0.053	0.043	0.057	0.23	0.21
1.01-2.00	0.054	0.26	1.2	0.099	0.14	0.011	0.023	0.38	0.27
2.01-5.00	0.001	0.066	0.12	0	0.087	0	0.0015	0.000099	0.098
> 5.00	0	0	0	0	0	0	0	0	0.0015

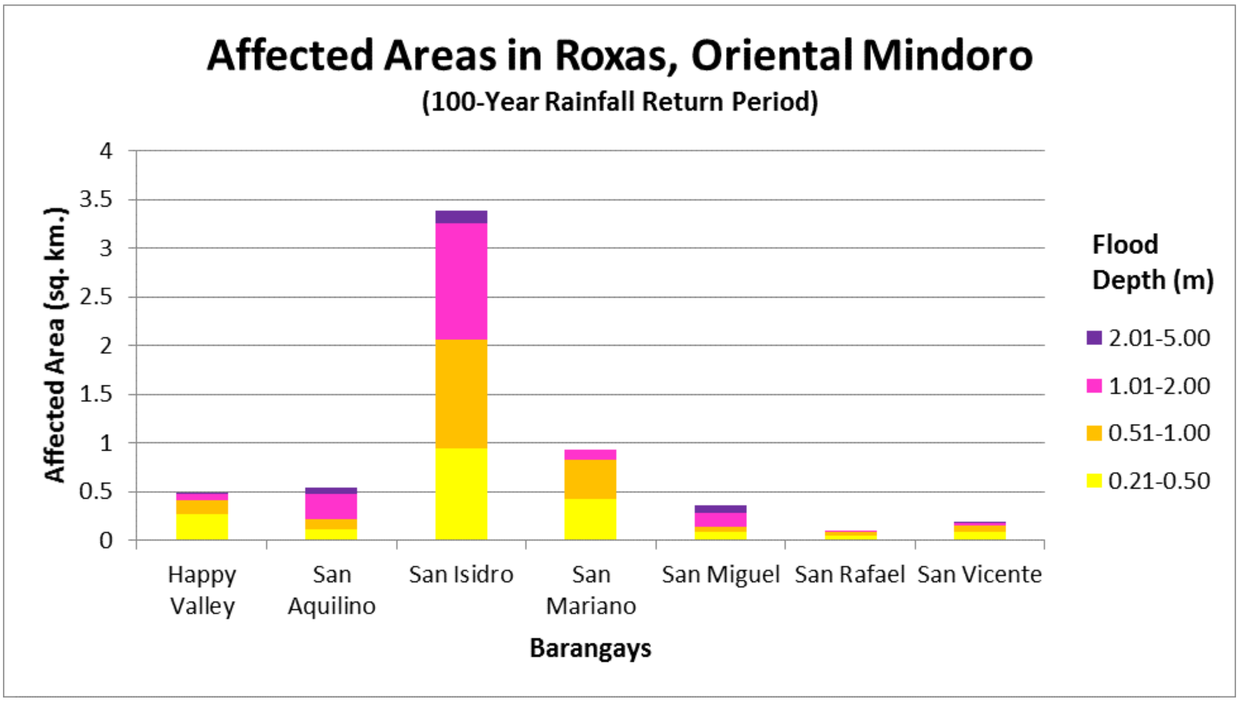


Figure 74. Affected areas in Roxas, Oriental Mindoro during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Mansalay, Bonbon is projected to have the highest percentage of area that will experience flood levels at 2.64%. Meanwhile, Balugo posted the second highest percentage of area that may be affected by flood depths at 1.23%.

Among the barangays in the municipality of Roxas, San Isidro is projected to have the highest percentage of area that will experience flood levels at 4.54%. Meanwhile, San Mariano posted the second highest percentage of area that may be affected by flood depths at 1.89%.

Moreover, the generated flood hazard maps for the Baroc floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - "Low", "Medium", and "High" - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

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 75.

The flood validation consists of 89 points randomly selected all over the Baroc flood plain. It has an RMSE value of 0.38. Table 35 shows a contingency matrix of the comparison.

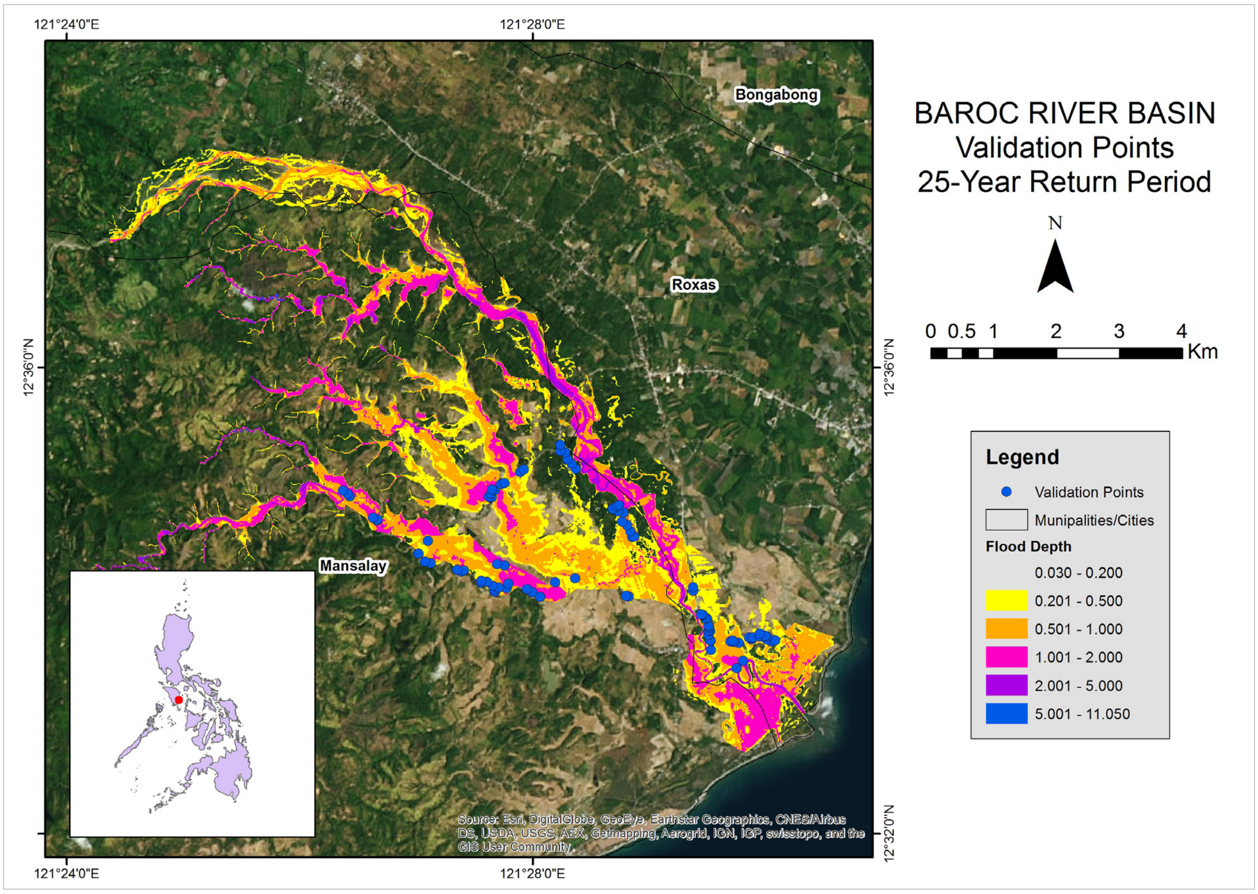


Figure 75. Validation points for 25-year Flood Depth Map of Baroc Floodplain

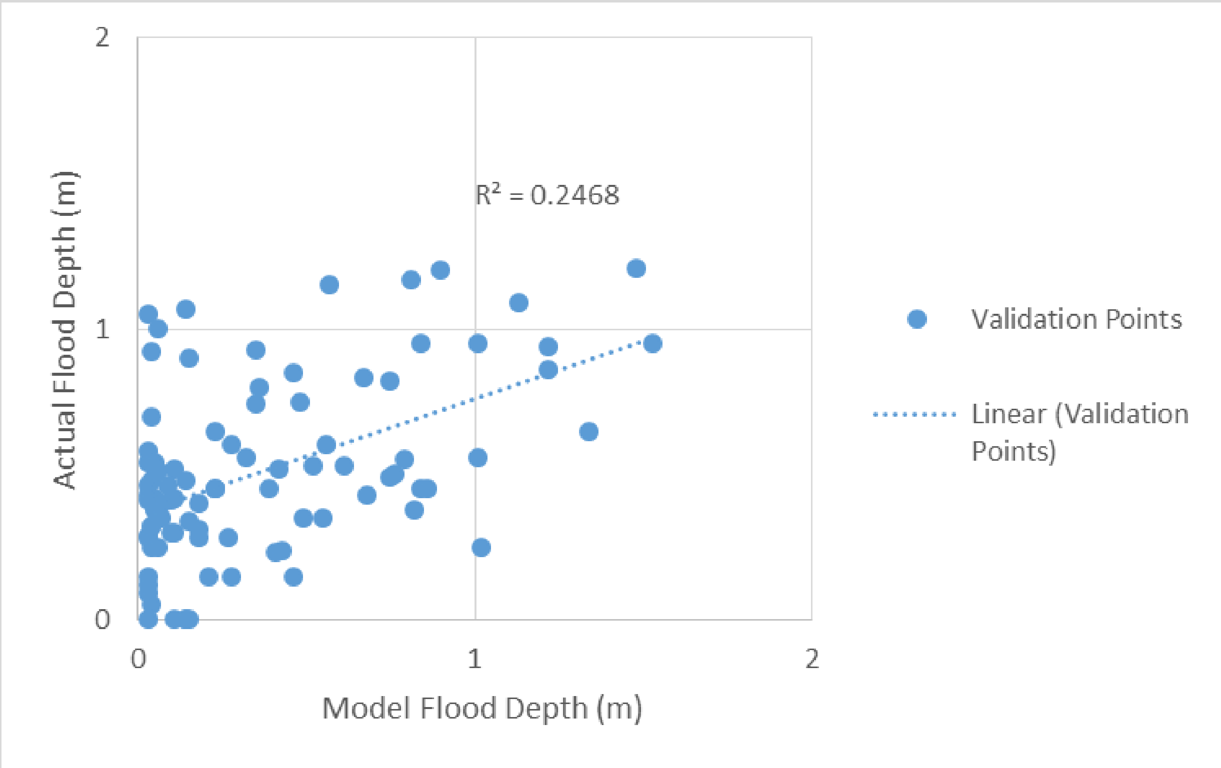


Figure 76. Flood map depth vs. actual flood depth

Table 35. Actual flood vs simulated flood depth at different levels in the Tawiran-Tagum River Basin.

BAROC BASIN		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
Actual Flood Depth (m)	0-0.20	9	3	0	0	0	0	**12**
	0.21-0.50	24	7	7	1	0	0	**39**
	0.51-1.00	9	9	7	6	0	0	**31**
	1.01-2.00	2	0	3	2	0	0	**7**
	2.01-5.00	0	0	0	0	0	0	**0**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**44**	**19**	**17**	**9**	**0**	**0**	**89**

The overall accuracy generated by the flood model is estimated at 28.09%, with 25 points correctly matching the actual flood depths. In addition, there were 52 points estimated one level above and below the correct flood depths while there were 10 points and 2 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 17 points were overestimated while a total of 47 points were underestimated in the modelled flood depths of Baroc. Table 36 depicts the summary of the Accuracy Assessment in the Baroc River Basin Survey.

Table 36. Summary of the Accuracy Assessment in the Baroc River Basin Survey

	No. of Points	%
Correct	25	28.09
Overestimated	17	19.10
Underestimated	47	52.81
Total	**89**	**100**

REFERENCES

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

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

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

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

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

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

ANNEX

ANNEX 1. Optech Technical Specification of the Aquarius and Gemini Sensors

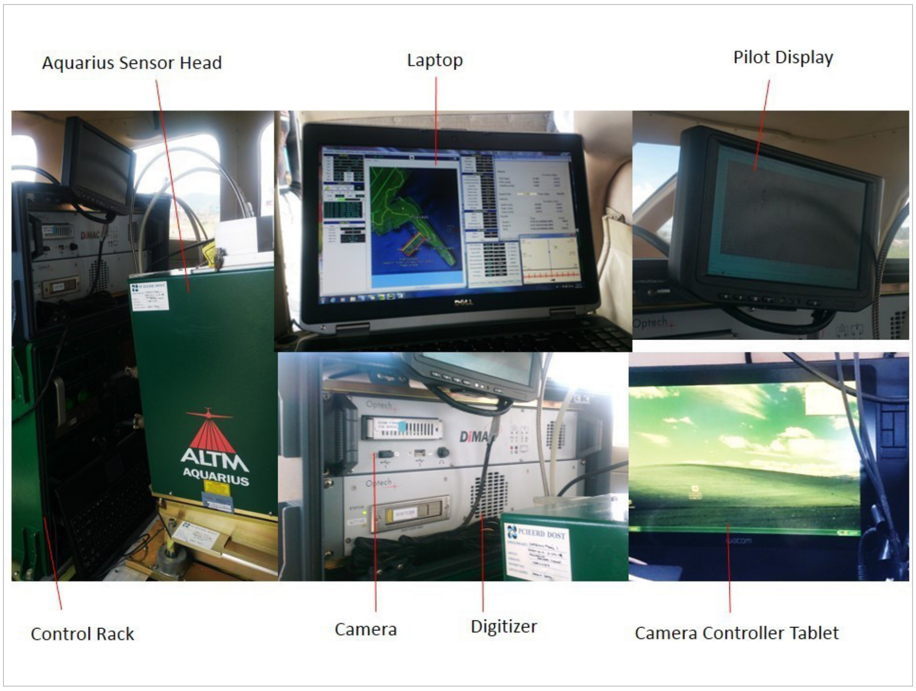


Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

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

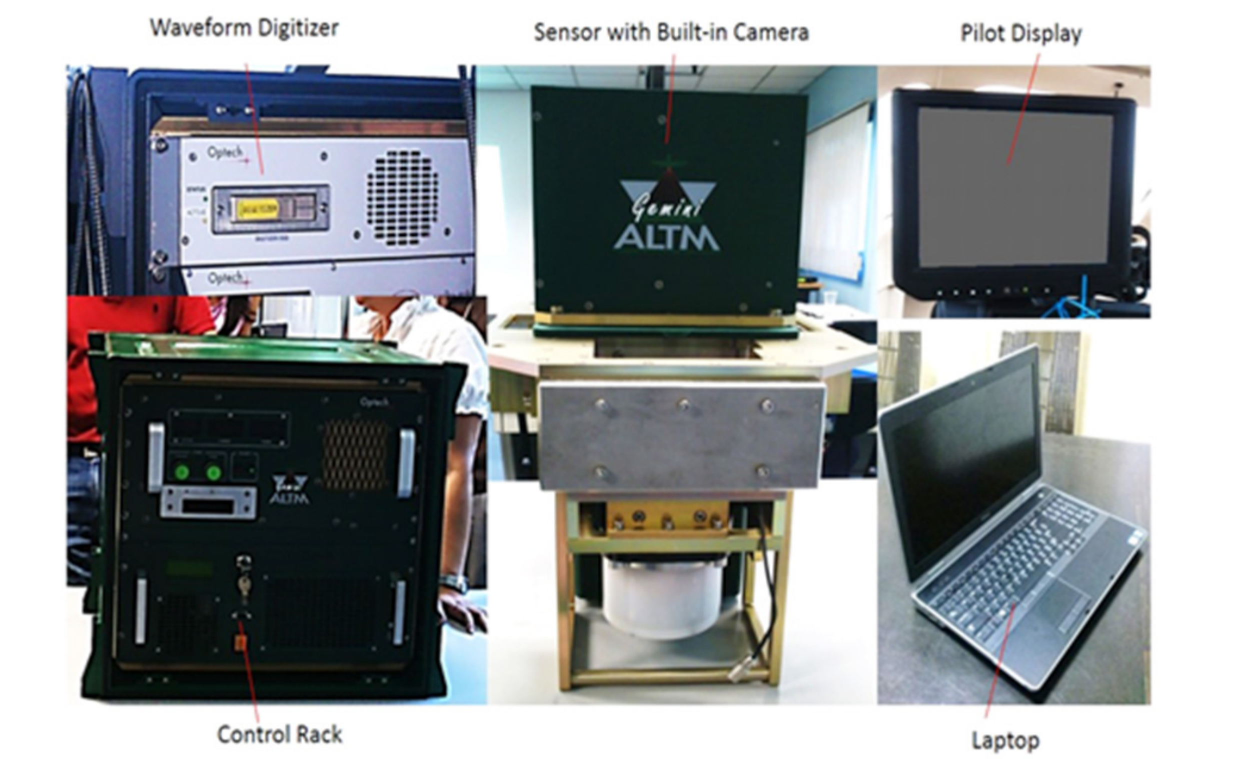


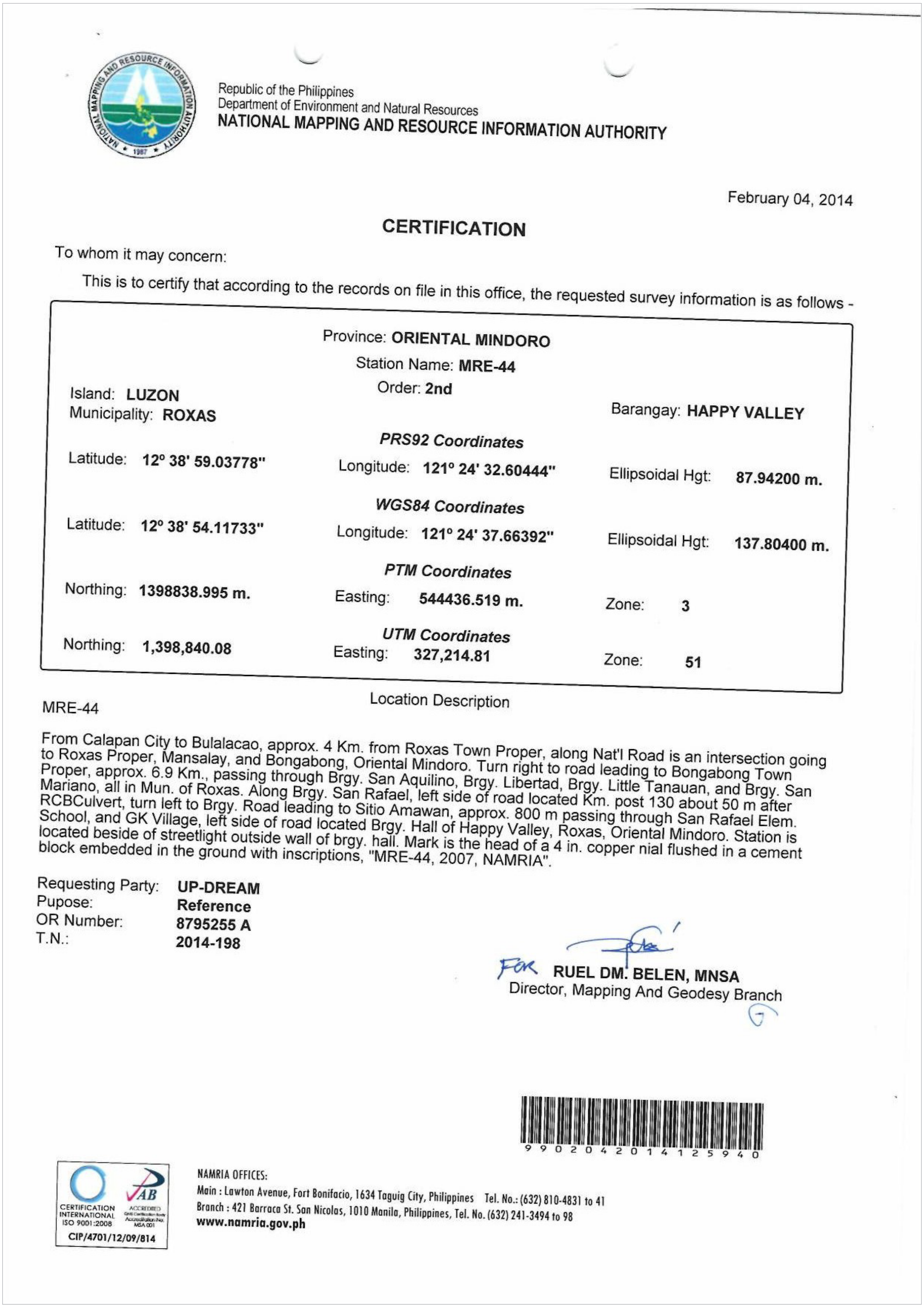
Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
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)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

ANNEX 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. MRE-44



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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-44**
Order: **2nd**

Island: **LUZON**		Barangay: **HAPPY VALLEY**
Municipality: **ROXAS**		
	PRS92 Coordinates	
Latitude: **12° 38' 59.03778"**	Longitude: **121° 24' 32.60444"**	Ellipsoidal Hgt: **87.94200 m.**
	WGS84 Coordinates	
Latitude: **12° 38' 54.11733"**	Longitude: **121° 24' 37.66392"**	Ellipsoidal Hgt: **137.80400 m.**
	PTM Coordinates	
Northing: **1398838.995 m.**	Easting: **544436.519 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,398,840.08**	Easting: **327,214.81**	Zone: **51**

MRE-44

Location Description

From Calapan City to Bulalacao, approx. 4 Km. from Roxas Town Proper, along Nat'l Road is an intersection going to Roxas Proper, Mansalay, and Bongabong, Oriental Mindoro. Turn right to road leading to Bongabong Town Proper, approx. 6.9 Km., passing through Brgy. San Aquilino, Brgy. Libertad, Brgy. Little Tanauan, and Brgy. San Mariano, all in Mun. of Roxas. Along Brgy. San Rafael, left side of road located Km. post 130 about 50 m after RCBCulvert, turn left to Brgy. Road leading to Sitio Amawan, approx. 800 m passing through San Rafael Elem. School, and GK Village, left side of road located Brgy. Hall of Happy Valley, Roxas, Oriental Mindoro. Station is located beside of streetlight outside wall of brgy. hall. Mark is the head of a 4 in. copper nial flushed in a cement block embedded in the ground with inscriptions, "MRE-44, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-198**

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

99020420141125940

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814

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

Figure A-2.1 MRE-44

2. MRE-32

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

April 05, 2013

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: **ORIENTAL MINDORO**
Station Name: **MRE-32**
Order: **2nd**

Island: **LUZON**
Municipality: **VICTORIA**
Barangay:

	PRS92 Coordinates	
Latitude: **13° 10' 28.85064"**	Longitude: **121° 16' 38.44761"**	Ellipsoidal Hgt: **19.49300 m.**
	WGS84 Coordinates	
Latitude: **13° 10' 23.79251"**	Longitude: **121° 16' 43.46244"**	Ellipsoidal Hgt: **67.64700 m.**
	PTM Coordinates	
Northing: **1456889.419 m.**	Easting: **530065.679 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,457,002.75**	Easting: **313,296.85**	Zone: **51**

Location Description

MRE-32

From Calapan City to Roxas, along Nat'l. Road approx. 34 Km. travel to Victoria Town Proper, 10 Km. from intersection of Naujan, left turn to Shell Gasoline Station, approx. 150 m, right side of road located Mun. Hall of Victoria, Oriental Mindoro. Station is located in Mun. Park in front of Former Mayor Statue, along corner of pathwalk. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRE-32, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943485 B**
T.N.: **2013-0270**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

9904052013155257

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/814

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

Figure A-2.2 MRE-32

3. MRE-56

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

October 28, 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: **ORIENTAL MINDORO**
Station Name: **MRE-56**
Order: **2nd**

Island: **LUZON**	Barangay:	
Municipality: **MANSALAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 31' 25.76362"**	Longitude: **121° 26' 25.21109"**	Ellipsoidal Hgt: **7.87000 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 20.87629"**	Longitude: **121° 26' 30.28143"**	Ellipsoidal Hgt: **58.13600 m.**
	PTM / PRS92 Coordinates	
Northing: **1384916.657 m.**	Easting: **547857.861 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,384,892.31**	Easting: **330,530.08**	Zone: **51**

Location Description

MRE-56

From Calapan City to Bulalacao, along Nat'l Road approx. 4 Km. from Roxas Proper is an intersection of Roxas, Mansalay, Bongabong Road, turn left, approx. 14 Km. travel, right side of Nat'l Road located Mun. Hall of Mansalay, Oriental Mindoro, in front of Mansalay Hospital. Station is located in corner wall of Mun. Park in front of Mun. Hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscritions, "MRE-56, 2007, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3523**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 8 1 7

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/07/814

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-2.3 MRE-56

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

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRE56 - 26 --- MRE56a - 26 (B1)	MRE56 - 26	MRE56a - 26	Fixed	0.001	0.002	-3.920	-0.909	-8.525	156°03'00"	9.407	-0.535

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

1

Figure A-3.1 Baseline Processing Report - A

MRE56 - 26 - MRE56a - 26 (6:52:03 AM-10:24:32 AM) (S1)

Baseline observation:	MRE56 - 26 --- MRE56a - 26 (B1)
Processed:	11/5/2015 5:05:12 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	12.356
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	10/26/2015 6:52:03 AM (Local: UTC+8hr)
Processing stop time:	10/26/2015 10:24:32 AM (Local: UTC+8hr)
Processing duration:	03:32:29
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	MRE56 - 26				
Grid		**Local**		**Global**	
Easting	330684.411 m	**Latitude**	N12°31'20.87629"	**Latitude**	N12°31'20.87629"
Northing	1384827.258 m	**Longitude**	E121°26'30.28143"	**Longitude**	E121°26'30.28143"
Elevation	7.925 m	**Height**	58.136 m	**Height**	58.136 m

To:	MRE56a - 26				
Grid		**Local**		**Global**	
Easting	330688.179 m	**Latitude**	N12°31'20.59653"	**Latitude**	N12°31'20.59653"
Northing	1384818.639 m	**Longitude**	E121°26'30.40791"	**Longitude**	E121°26'30.40791"
Elevation	7.390 m	**Height**	57.601 m	**Height**	57.601 m

Vector					
ΔEasting	3.768 m	**NS Fwd Azimuth**	156°03'00"	**ΔX**	-3.958 m
ΔNorthing	-8.619 m	**Ellipsoid Dist.**	9.407 m	**ΔY**	-0.847 m
ΔElevation	-0.535 m	**ΔHeight**	-0.535 m	**ΔZ**	-8.509 m

11/5/2015 5:06:23 PM		Business Center - HCE

2

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	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE BALIGUAS	
		ENGR. MILLIE SHANE REYES	
		ENGR. IRO NIEL ROXAS	
Ground Survey	RA	GRACE SINADJAN	
		ENGR. GEF SORIANO	
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	Philippine Air Force (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAAR	Asian Aerospace Corporation (AAC)
		CAPT. JACKSON JAVIER	

ANNEX 5. Data Transfer Sheets for the Baroc Floodplain Flights

DATA TRANSFER SHEET

Feb 18, 2014

DATE of Operation	FLIGHT NO.	SENSOR	MISSION NAME	RAW LAS (MB)	LOGS (KB)	POS (MB)	RAW IMAGES	MISSION LOG FILE	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S) (MB)	OPERATOR COMMENTS (DPC LOGS) (Bytes)	FLIGHT PLAN (KB)	SERVER LOCATION
2/7/2014	1072A	Aquarius	3BLK28F038A	703KB	1.16MB	256	81.4GB	563KB	12.5	174	14.1	767	13	\\FREENAS\geostorage3\Airborne_Raw\1072A
2/7/2014	1074A	Aquarius	3BLK28G038B	134 KB	968 KB	174	33.7GB	274KB	6.4	60.9	14.1	258	11 (28F)&12(28G)	\\FREENAS\geostorage3\Airborne_Raw\1074A
2/8/2014	1076A	Aquarius	3BLK28GS039A	643KB	1.21MB	233	76.8	308KB&218KB	11.5	101	14.3	357	12	\\FREENAS\geostorage3\Airborne_Raw\1076A
2/5/2014	1066A	Aquarius	3BLK28DS036A	360KB	1.38MB	203	73.9	311KB	11.7	N/A	14.5	414	11	\\FREENAS\geostorage3\Airborne_Raw\1066A
2/6/2014	1070A	Aquarius	3BLK28DSE037A	932KB	1.46MB	270	104	764KB	15.9	249	14.9	300	12	\\FREENAS\geostorage3\Airborne_Raw\1070A
2/8/2014	1078A	Aquarius	3BLK28GSH039B	530KB	892KB	197	56.8	442KB	9.71	N/A	14.3	738	12 (28G) & 12 (28H)	\\FREENAS\geostorage3\Airborne_Raw\1078A

Received from

Name/Signature Lovely Acuña
Position Supervising SRS
Date 02/19/2014

Received by

Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/2014

Verified by

Name/Signature JOIDA PRIETO
Position SSRS
Date 02/20/14

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

DATA TRANSFER SHEET

Feb 21, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
2/11/2014	1088A	3BLK28HS042A	AQUARIUS	N/A	781	1.23MB	269	80.7GB ~~25.4~~	565	14	N/A	14.7	143	506	6	12	\\FREENAS\geostorage3\Airborne_Raw\1088A
2/11/2014	1090A	3BLK28J042B	AQUARIUS	N/A	215	822KB	156	19.4	162	4.96	N/A	14.7	143	267	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1090A
2/12/2014	1092A	3BLK28ABES043A	AQUARIUS	N/A	1657	1.70MB	242	23.7	601	12.7	N/A	15.4	123	364	N/A	N/A	\\FREENAS\geostorage3\Airborne_Raw\1092A
2/12/2014	1094A	3BLK28BS043B	AQUARIUS	N/A	332	2.27MB	128	28.4GB ~~22.1~~	186	6.05	N/A	15.4	123	334	8	N/A	\\FREENAS\geostorage3\Airborne_Raw\1094A
2/13/2014	1096A	3BLK28NAJ044A	AQUARIUS	N/A	449	772KB	207	36.6	291	7.46	N/A	13.3	175	411	6	N/A	\\FREENAS\geostorage3\Airborne_Raw\1096A
2/13/2014	1098A	3BLK28JSI044B	AQUARIUS	N/A	582	954KB	235	23.9	291	11	N/A	13.3	175	725	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1098A
2/15/2014	1104A	3BLK28JSI046A	AQUARIUS	N/A	787	1.08MB	276	56.2	288KB&170KB	10.3	N/A	9.85	134	325	4	N/A	\\FREENAS\geostorage3\Airborne_Raw\1104A

Received from

Name Lovely Acuña / [signature]

Position Supervising SRS

Signature [signature] 02/21/2014

Received by

Name JOIDA F. PRIETO

Position SSRS

Signature [signature]

Verified by

Name JOIDA F. PRIETO

Position SSRS

Signature [signature]

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

DATA TRANSFER SHEET
Calapan 11/9/15

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	
Oct. 22, 2015	8300	2BLK28ABC295A	Gemini	na	400	675	236	28.5	214	18.2	247	15.6	1KB	1KB	24	na	Z:\DAC\RAW DATA
Oct. 22, 2015	8301	2BLK28CSD295B	Gemini	na	587	947	249	39.1/10.5	307/87	22.7	na	15.6	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 23, 2015	8302	2BLK28ASEHI296A	Gemini	na	343	593	228	28.2	223	14.5	na	11.5	1KB	1KB	22/24	na	Z:\DAC\RAW DATA
Oct. 24, 2015	8304	2BLK28FHS297A	Gemini	na	315	519	214	24.8	187	14.2	221	8.92	1KB	1KB	5/11/24/14/13	na	Z:\DAC\RAW DATA
Oct. 25, 2015	8306	2CALIBBLK28FSGS298A	Gemini	na	136	366	220	na	na	10.7	4.29	8.28	1KB	1KB	28/27	na	Z:\DAC\RAW DATA
Oct. 26, 2015	8308	2BLK28J299A	Gemini	na	312	356	235	na	na	14	153	8.39	1KB	1KB	7/5/2	na	Z:\DAC\RAW DATA
Oct. 28, 2015	8312	2BLK28JKLS301A	Gemini	na	40	292	215	na	na	11	427	7.5	1KB	1KB	7	270	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 11/12/15

15-20

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

ANNEX 6. FLIGHT LOGS

1. Flight Log for 3BLK28F038A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 107

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK28F038A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 7, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 805	14 Engine Off: 1228	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed 16/25 lines.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN ERIC CACANINDIN PAF	J. RS Javier	RJ ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for 3BLK28F038A Mission

2. Flight Log for 3BLK28G039A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 107

1 LiDAR Operator: ILO ROXAS	2 ALTM Model: AQUA	3 Mission Name: 3BLK28G039A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEB. 8, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8 25	14 Engine Off: 1230	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: finished 21/25 lines					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN ERIC CAMANINDIN PAF	JJ ALAJAR	I. ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Data Transfer Sheet for Baroc Floodplain - A

3. Flight Log for 3BLK28GSH039B Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1078

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK28GSH039B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEB. 8, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1308	14 Engine Off: 1637	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed mission BLK 28G and G12G lines from BLK 28H

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN ERIC CACANINDIN PAF	J.J. ALAJAR	RJ ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3 Flight Log for 3BLK28GSH039B Mission

4. Flight Log for 3BLK28HS042A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 108

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLK28H042A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEB. 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 851	14 Engine Off: 1320	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN ERL [illegible] PAF	JJ ALAJAR	LOVELY ACUNA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4 Flight Log for 3BLK28HS042A Mission

5. Flight Log for 3BLK28J042B Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1090

1 LiDAR Operator: I. Roxas	2 ALTM Model: AQUA	3 Mission Name: 3BLK28J042B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: J. Javier	9 Route:			
10 Date: FEB. 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1402	14 Engine Off: 1649	15 Total Engine Time: 2+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

FINISHED 5/13 LINES

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuña	SGT John Eric Caotanindin PAF	JJ Alajar	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for 3BLK28J042B Mission

6. Flight Log for 3BLK28JSI044B Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 1098

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: 3BLKJSI044B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: J. JAVIER	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: FEB. 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1239	14 Engine Off: 1638	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

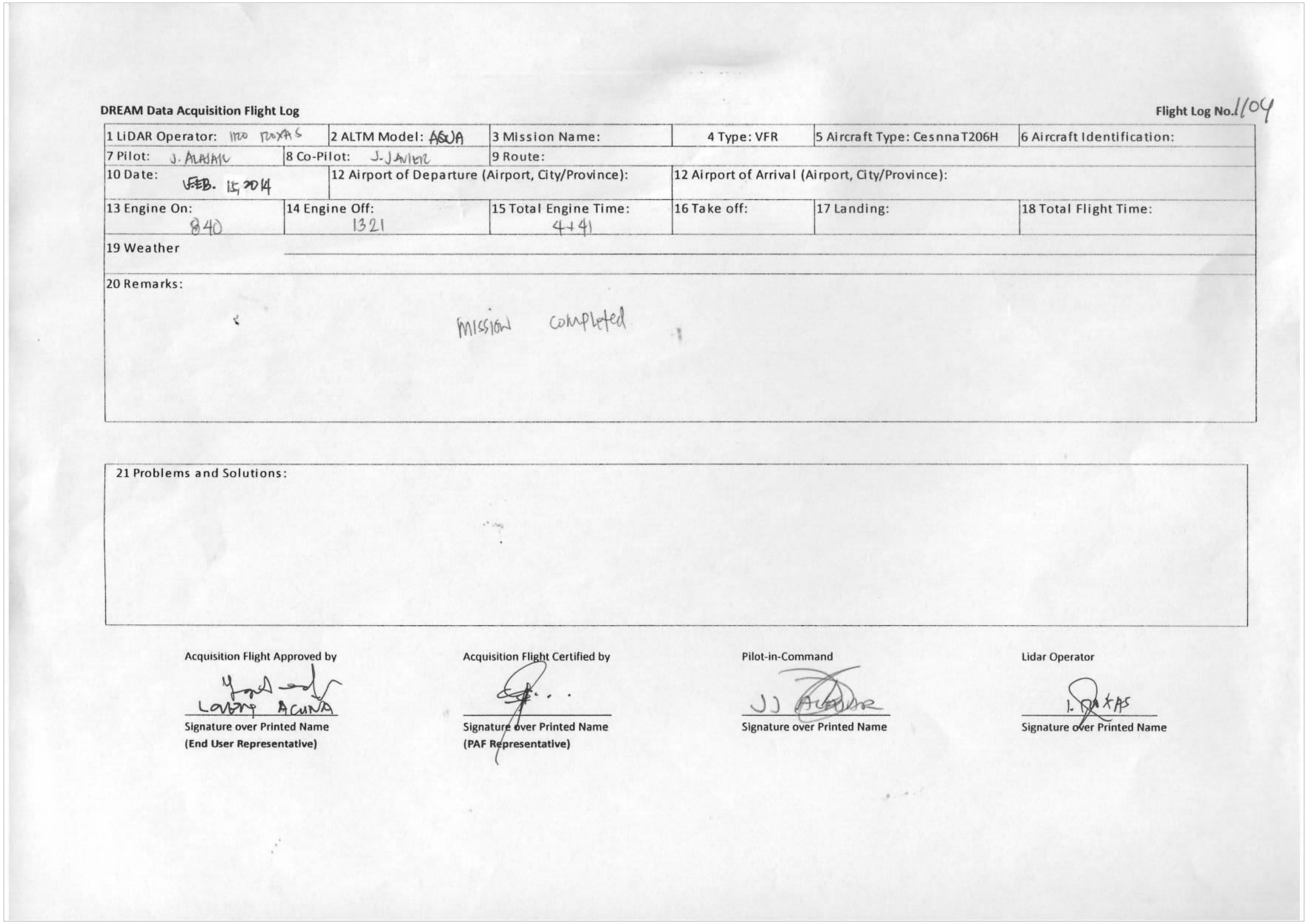
FINISHED 13/27 LINES.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	SGT JOHN RICCALANDIR PAF	J RS Javier	PJ ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6 Flight Log for 3BLK28JSI044B Mission

7. Flight Log for 3BLK28JSI046A Mission



DREAM Data Acquisition Flight Log — Flight Log No. 1104

1 LiDAR Operator: I. ROXAS	2 ALTM Model: AQUA	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JAVIER	9 Route:			
10 Date: FEB. 15, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 840	14 Engine Off: 1321	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: mission completed					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA		JJ ALAJAR	I. ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7 Flight Log for 3BLK28JSI046A Mission

8. Flight Log for 2BLK28JKLS301A Mission

Data Acquisition Flight Log

Flight Log No.: 83126

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: Gemini	3 Mission Name: 2BLK28JKLS 301A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: M TANGONAN	8 Co-Pilot: J MOONEY	9 Route: Calapan- Calapan			
10 Date: Oct. 28, 2015	12 Airport of Departure (Airport, City/Province): Calapan		12 Airport of Arrival (Airport, City/Province): Calapan		
13 Engine On: 0840	14 Engine Off: 1218	15 Total Engine Time: 3+38	16 Take off: 0845	17 Landing: 1213	18 Total Flight Time: 3+28
19 Weather: Cloudy					

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 Blk28J and covered additional areas

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
PJ ARCEO	AWIC CHARMAINE NAVARRO PAF	M.C. TANGONAN	[signature]	G. ANTONIO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.8 Flight Log for 2BLK28JKLS301A Mission

ANNEX 7. Flight Status Reports

BAROC FLOODPLAIN
February 7-15, 2014; October 28, 2015

Flight No	Area	Mission	Operator	Date Flown	Remarks
1072A	BLOCK 28F	3BLK28F038A	PAULINE ARCEO	FEB 7, 2014	Mission Complete
1076A	BLOCK 28G	3BLK28GS039A	IRO ROXAS	FEB 8, 2014	Mission Complete
1078A	BLOCK 28G & BLOCK 28H	3BLK28GSH039B	PAULINE ARCEO	FEB 8, 2014	Mission Complete
1088A	BLK 28H	3BLK28HS042A	IRO ROXAS	FEB 11, 2014	Mission Complete
1090A	BLK 28J	3BLK28J042B	PAU ARCEO	FEB 11, 2014	Mission Complete
1098A	BLK28J,I	3BLK28JSI044B	PAU ARCEO	FEB 13, 2014	Mission Complete
1104A	BLK28J,I	3BLK28JSI046A	IRO ROXAS	FEB 15, 2014	Mission Complete
8312G	BLK28J	2BLK28JKLS301A	C. BALIGUAS	28-Oct-15	Completed BLK28J and covered additional areas.

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO. 1072A
AREA: BLOCK 28F
MISSION NAME: 3BLK28F038A
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

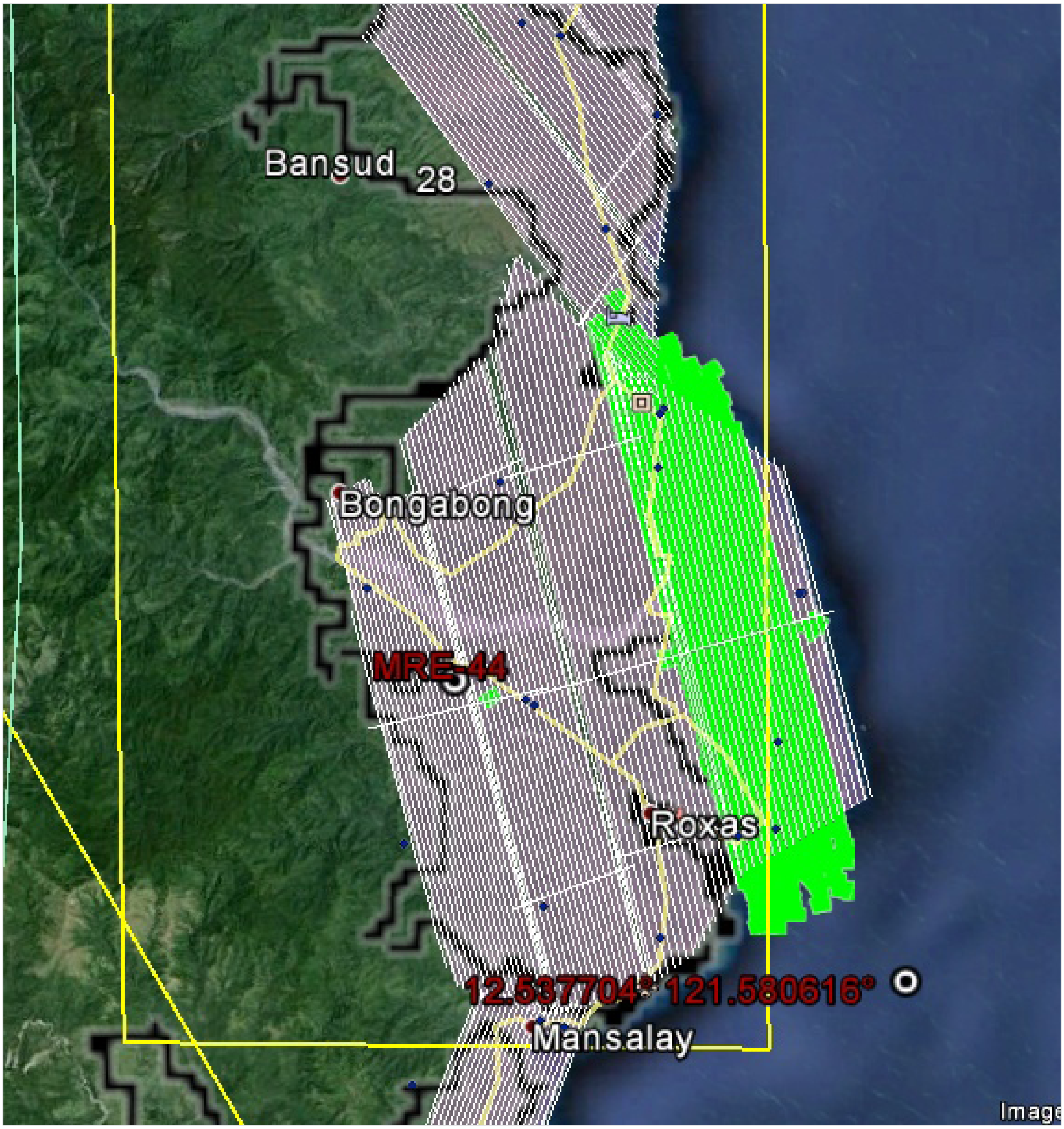


Figure A-7.1 Swath for Flight No. 1072A

FLIGHT LOG NO. 1076A
AREA: BLOCK 28G
MISSION NAME: 3BLK28G039A
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle:18deg
Alt: 600 m

Figure A-7.2 Swath for Flight No. 1076A

FLIGHT LOG NO. 1078A
AREA: BLOCK 28G, 28H
MISSION NAME: 3BLK28GSH039B
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

Figure A-7.3 Swath for Flight No. 1078A

FLIGHT LOG NO. 1088A
AREA: BLOCK 28H
MISSION NAME: 3BLK28HS042A
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

Figure A-7.4 Swath for Flight No. 1088A

FLIGHT LOG NO. 1090A
AREA: BLOCK 28J
MISSION NAME: 3BLK28HS042B
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

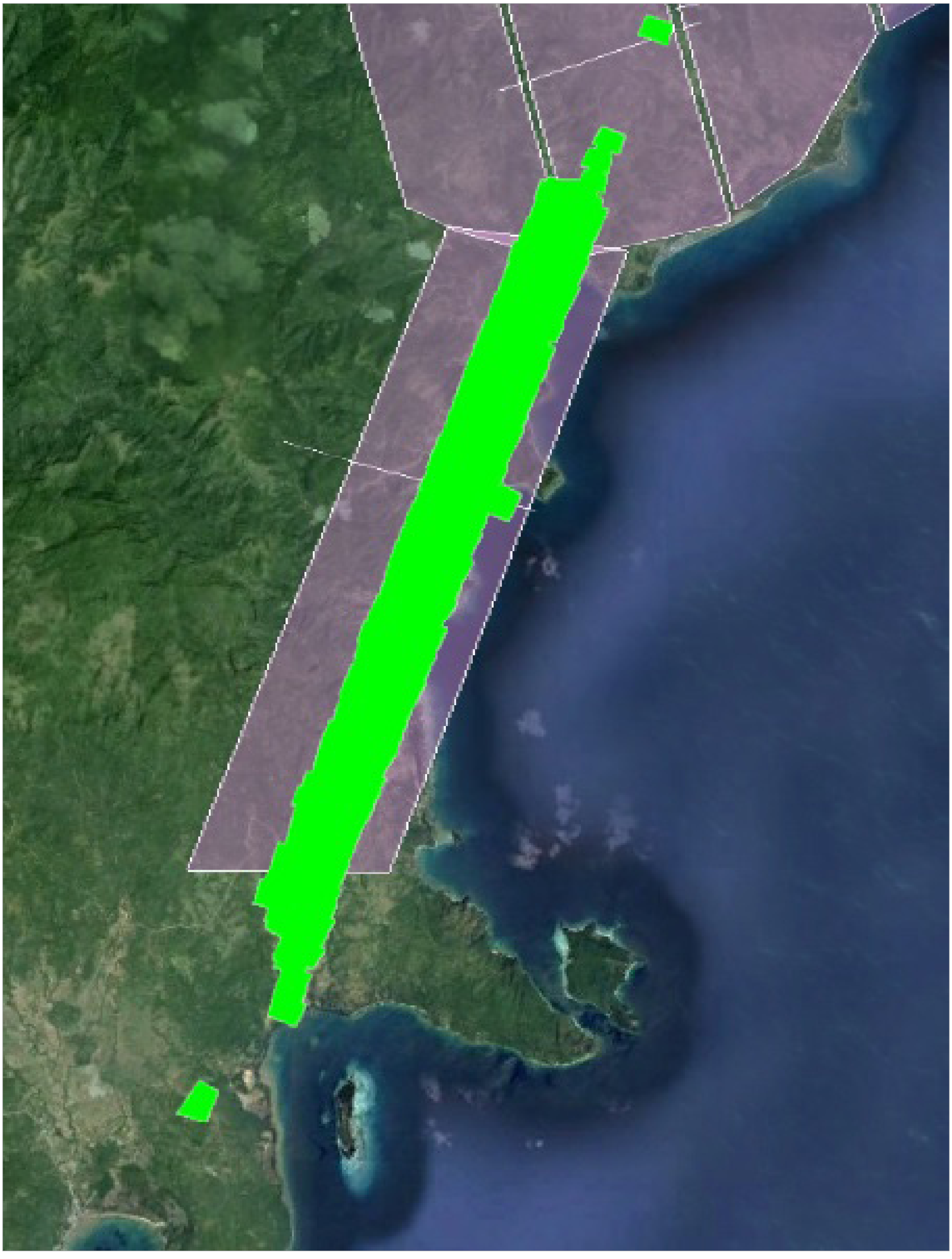


Figure A-7.5 Swath for Flight No. 1090A

FLIGHT LOG NO. 1098A
AREA: BLOCK 28JI
MISSION NAME: 3BLK28JSI044B
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 600 m

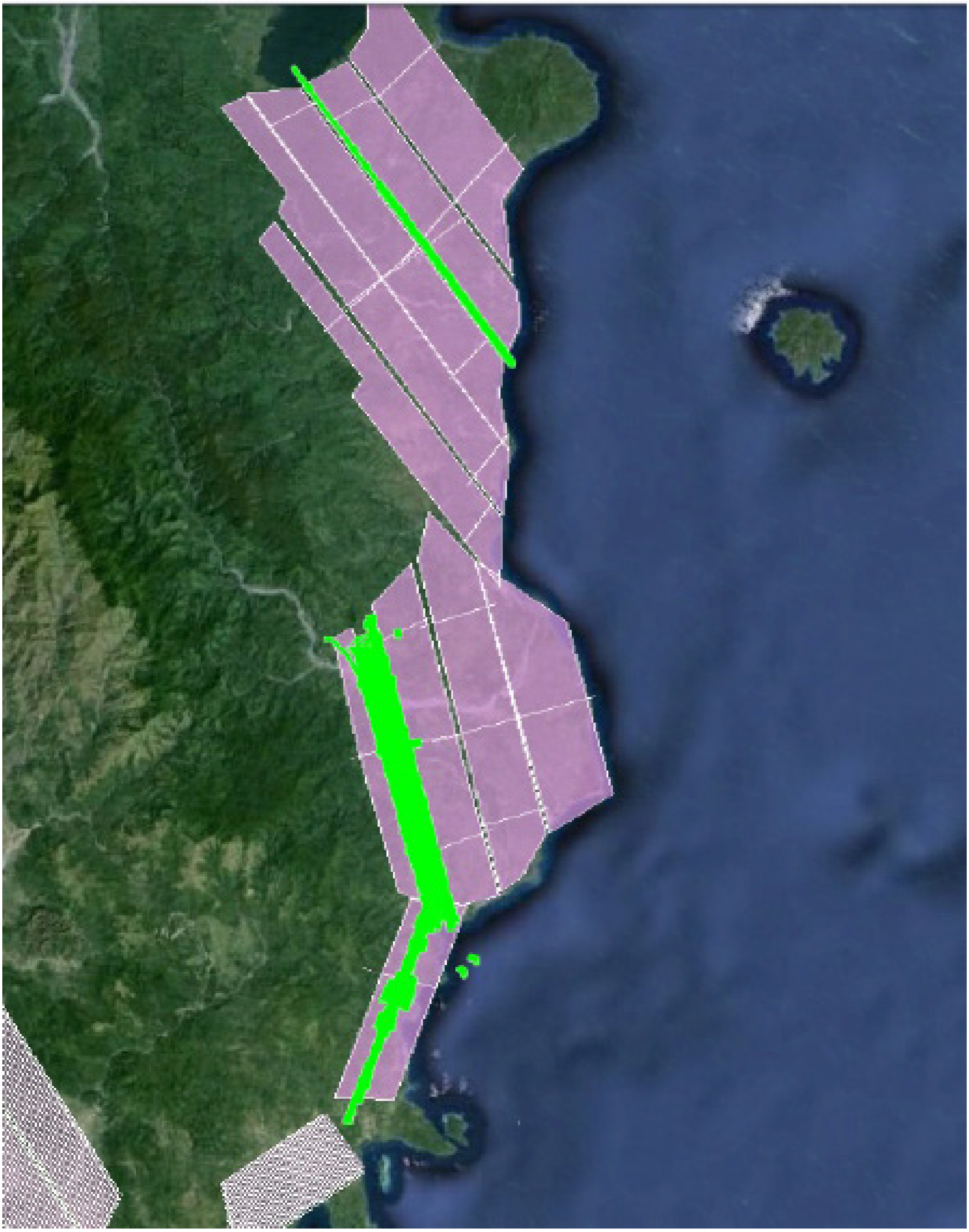


Figure A-7.6 Swath for Flight No. 1098A

FLIGHT LOG NO. 1104A
AREA: BLOCK 28JI
MISSION NAME: 3BLK28JSI046A
SURVEY COVERAGE:

Scan Freq: 45 kHz
Scan Angle: 18 deg
Alt: 1000 m

Figure A-7.7 Swath for Flight No. 1104A

FLIGHT LOG NO. 8312G
AREA: BLK28J
MISSION NAME: 2BLK28JKLS301A
SURVEY COVERAGE:

Scan Freq: 30 kHz
Scan Angle: 25 deg
Alt: 1000

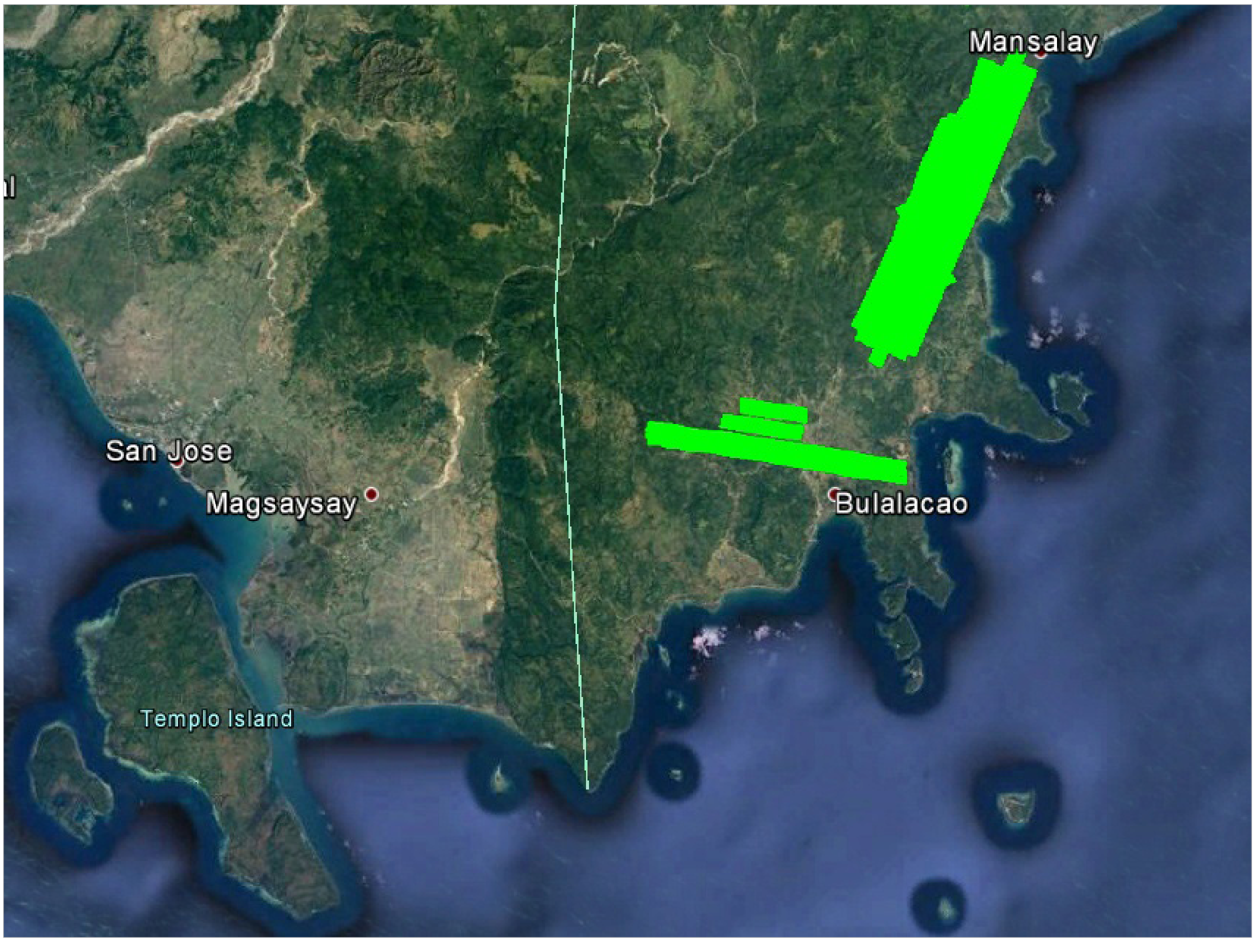


Figure A-7.8 Swath for Flight No. 8312G

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk28F

Flight Area	Oriental Mindoro
Mission Name	Blk28F
Inclusive Flights	1072A
Range data size	12.5 GB
POS	256 MB
Image	81.4 GB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000425
IMU attitude correction stdev (<0.001deg)	0.009525
GPS position stdev (<0.01m)	0.0318
Minimum % overlap (>25)	42.58%
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	190
Maximum Height	146.32 m
Minimum Height	31.32 m
Classification (# of points)	
Ground	83,396,476
Low vegetation	114,178,225
Medium vegetation	59,793,586
High vegetation	34,546,932
Building	3,692,979
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Antonio Chua Jr., Engr. Elainne Lopez

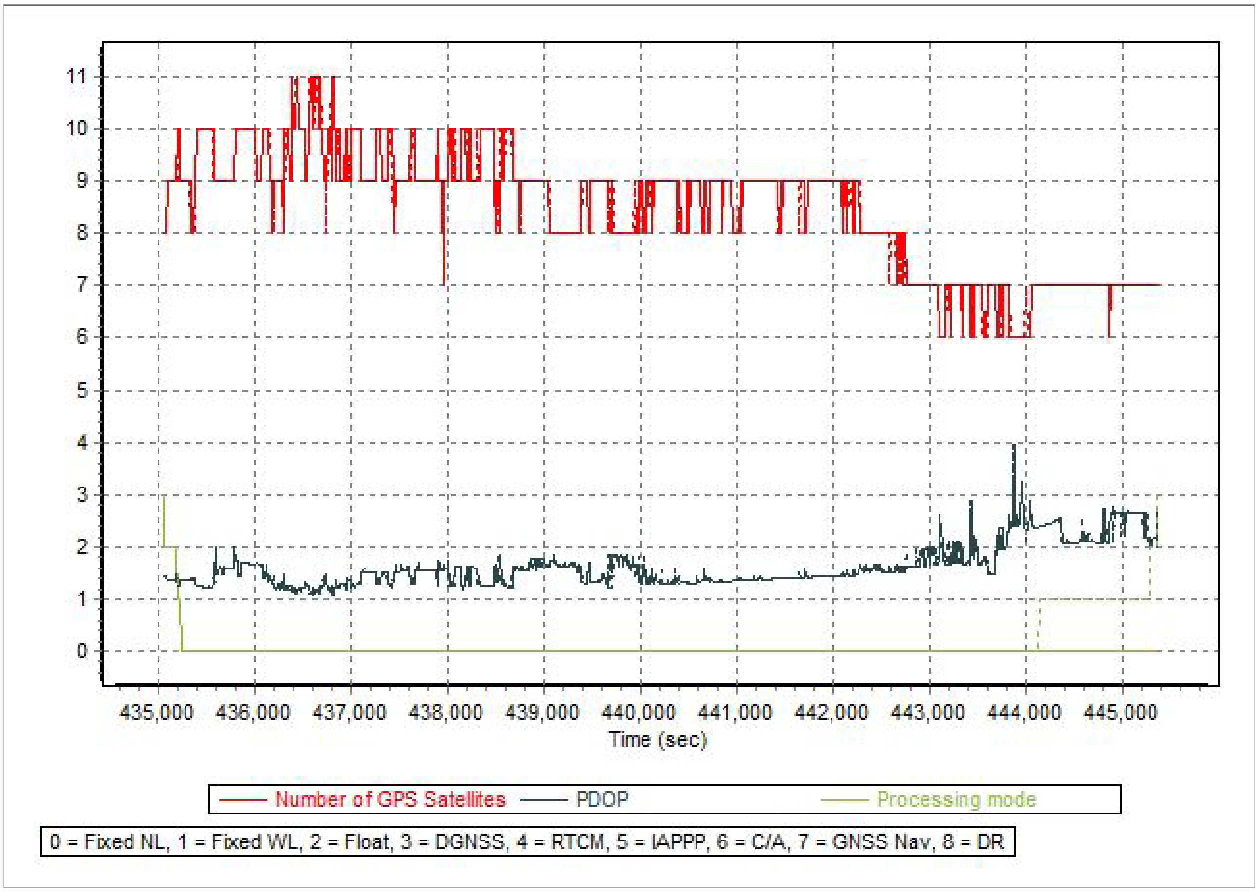


Figure A-8.1 Solution Status

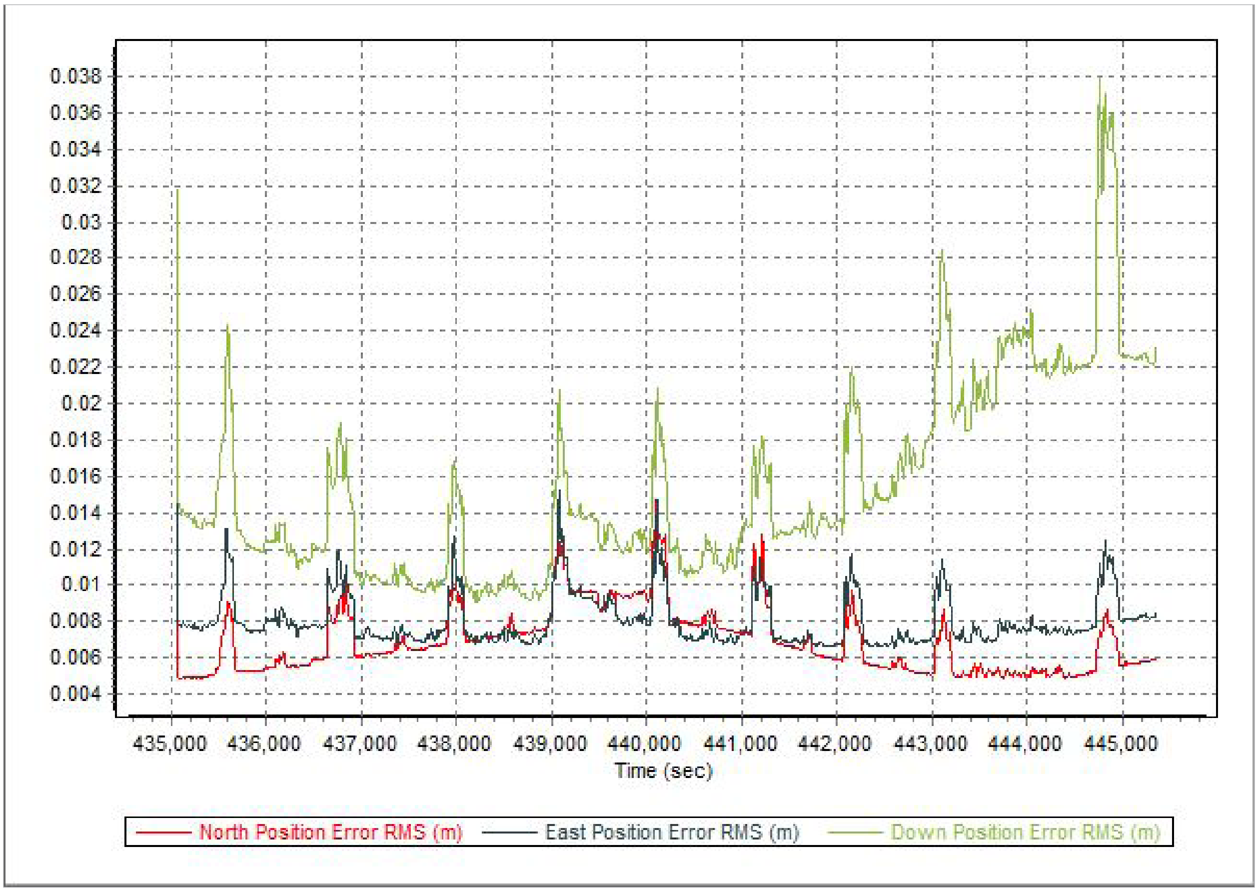


Figure A-8.2 Smoothed Performance Metric Parameters

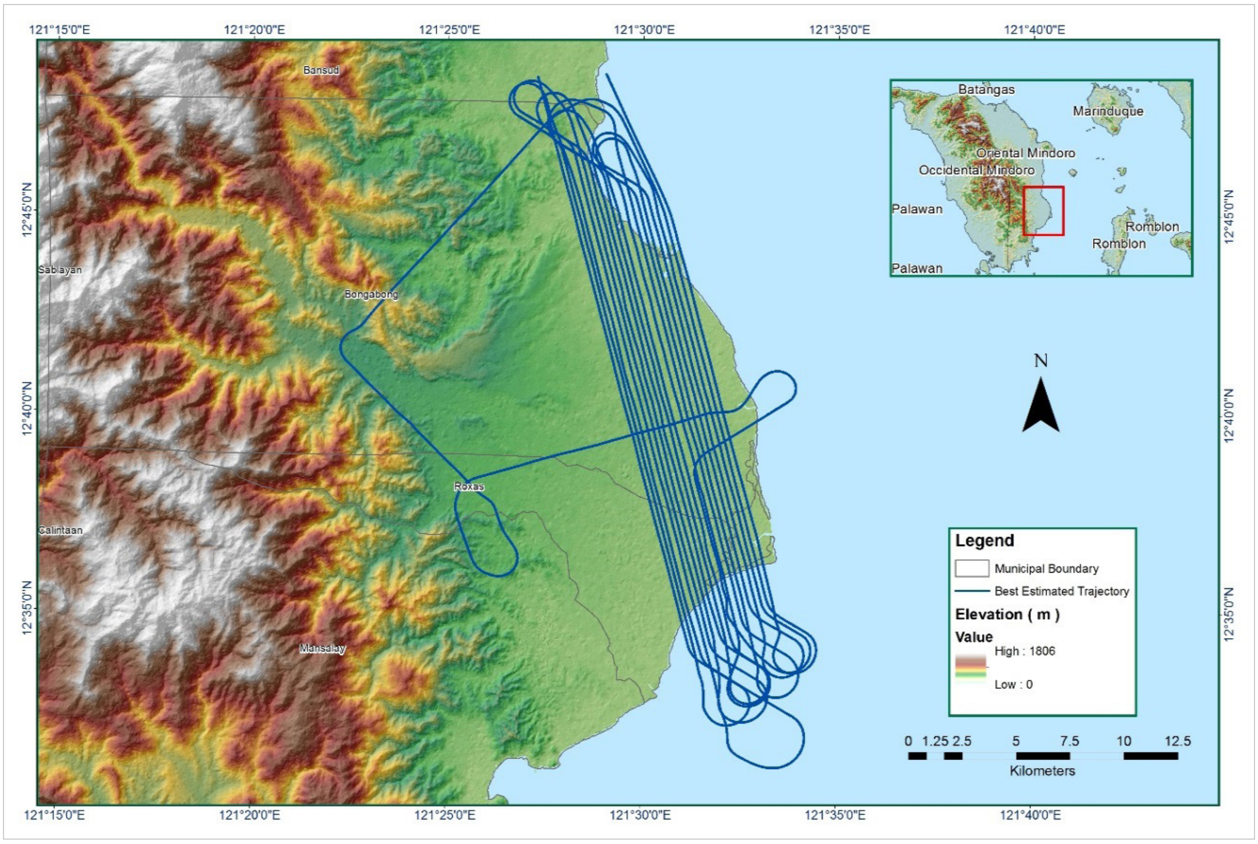


Figure A-8.3 Best Estimated Trajectory

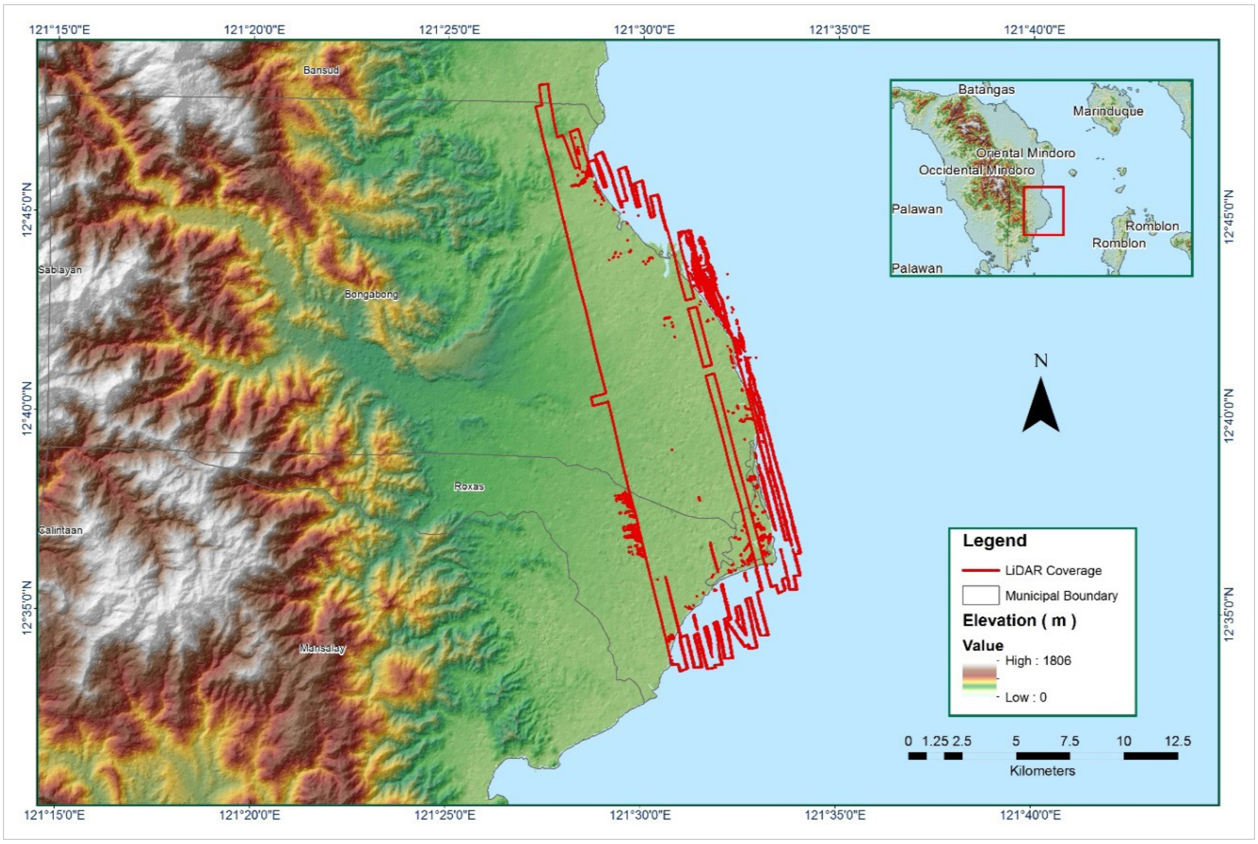


Figure A-8.4 Coverage of LiDAR data

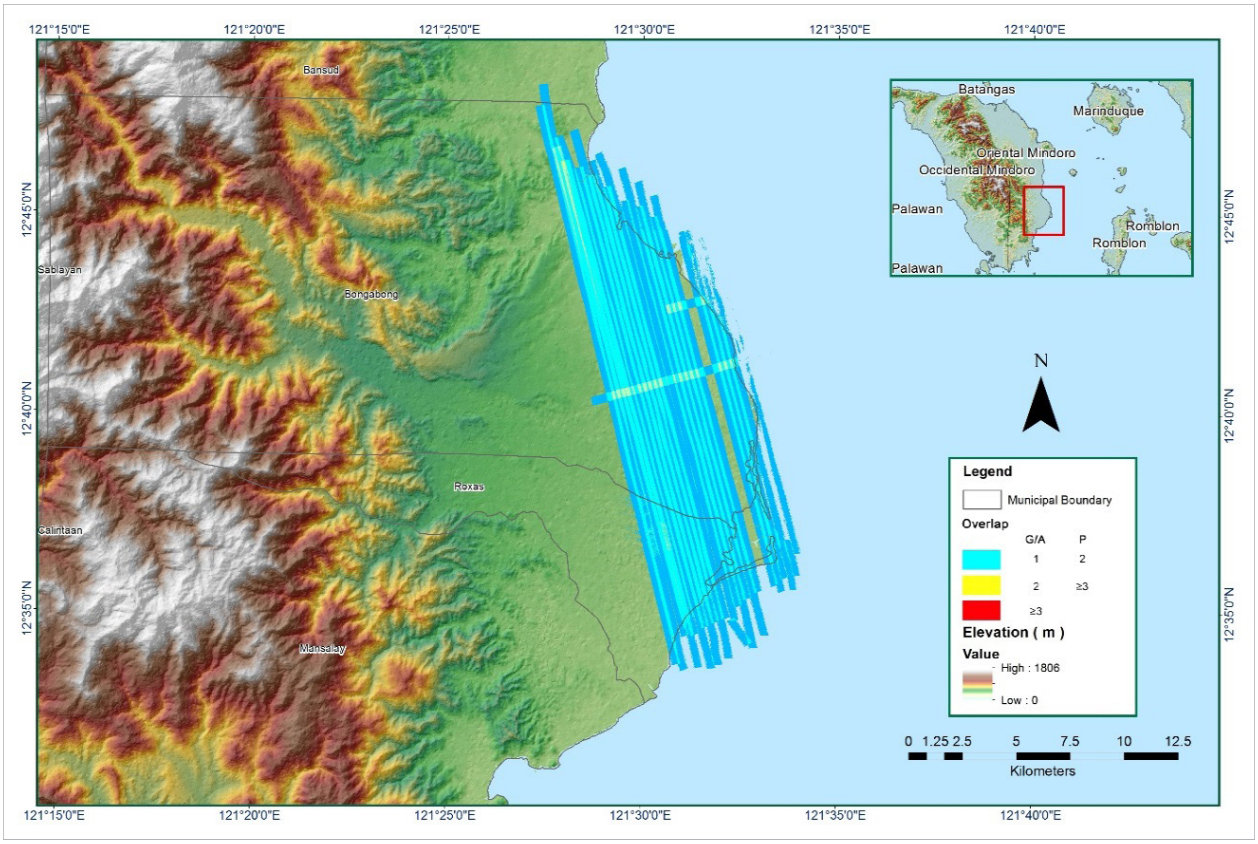


Figure A-8.5 Image of data overlap

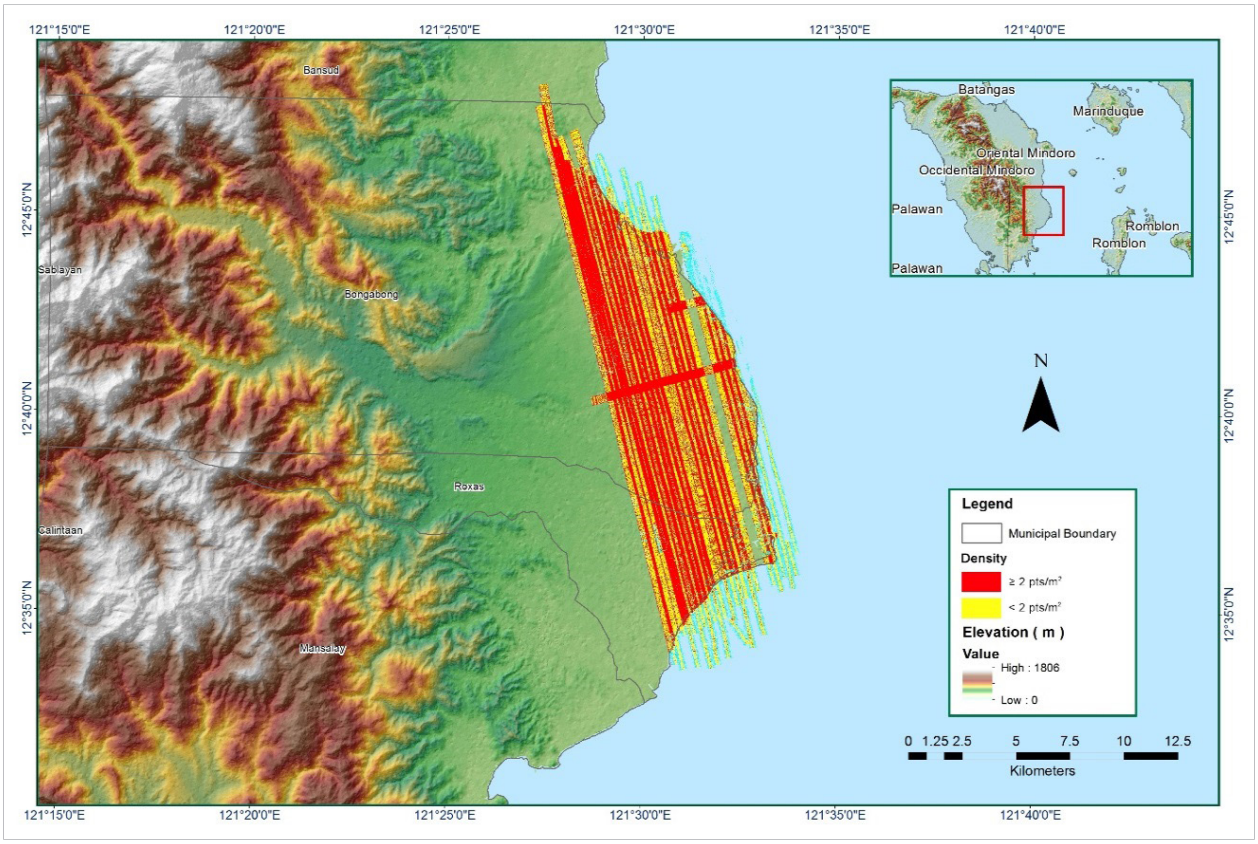


Figure A-8.6 Density map of merged LiDAR data

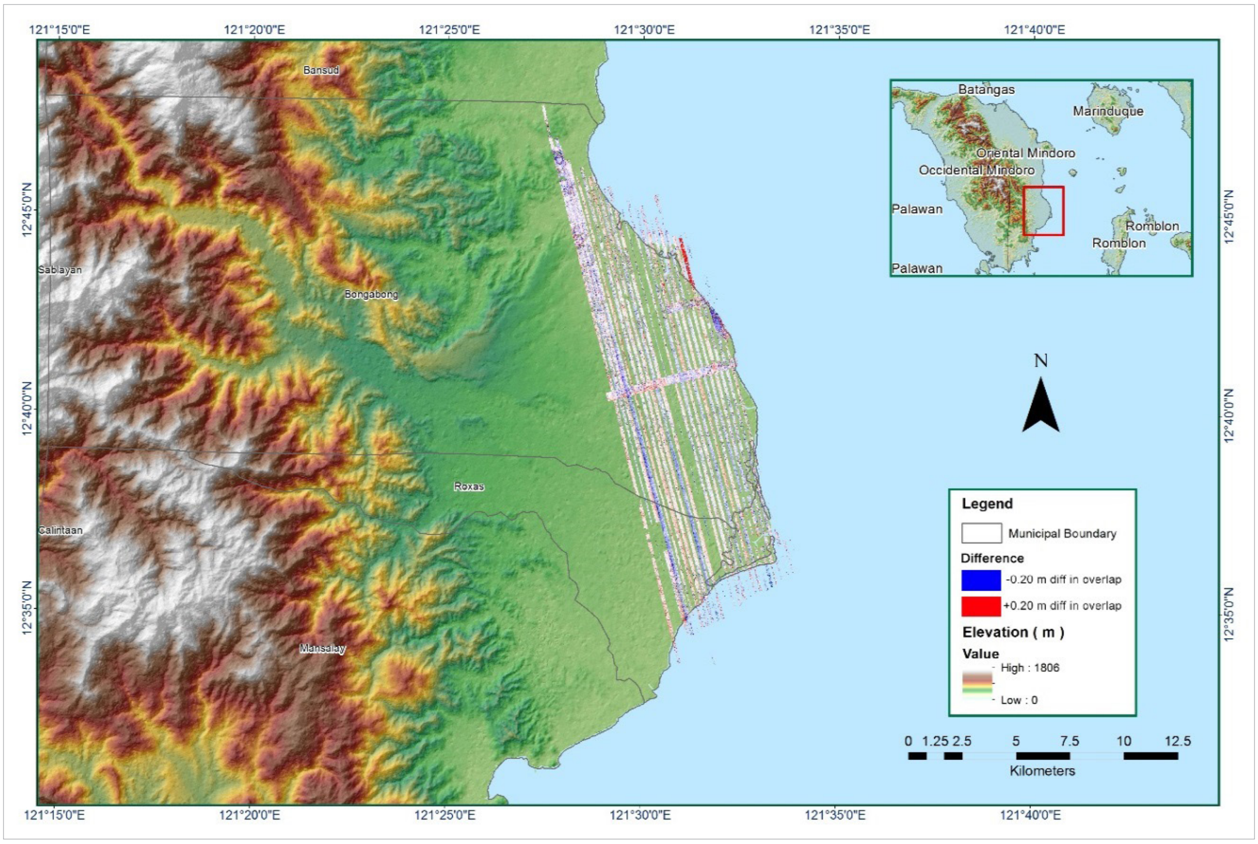


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk28G

Flight Area	Oriental Mindoro
Mission Name	Blk28G
Inclusive Flights	1076A
Range data size	11.5 GB
POS	233 MB
Image	76.8 GB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.8
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	8.6
Boresight correction stdev (<0.001deg)	0.000407
IMU attitude correction stdev (<0.001deg)	0.001355
GPS position stdev (<0.01m)	0.0097
Minimum % overlap (>25)	33.27%
Ave point cloud density per sq.m. (>2.0)	2.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	141
Maximum Height	216.76 m
Minimum Height	35.08 m
Classification (# of points)	
Ground	67,283,967
Low vegetation	77,300,272
Medium vegetation	51,202,535
High vegetation	45,765,772
Building	1,511,333
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. John Dill Macapagal

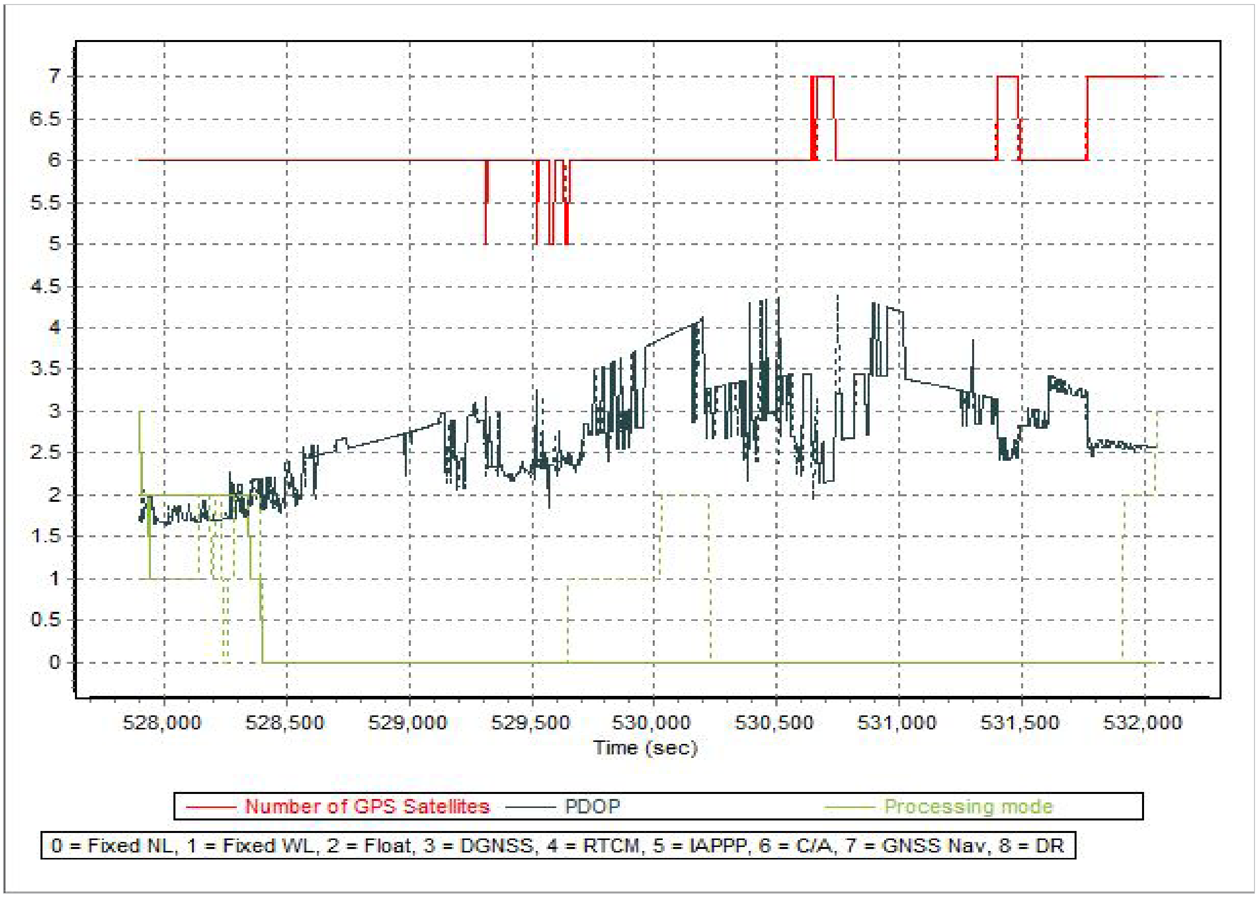


Figure A-8.8 Solution Status

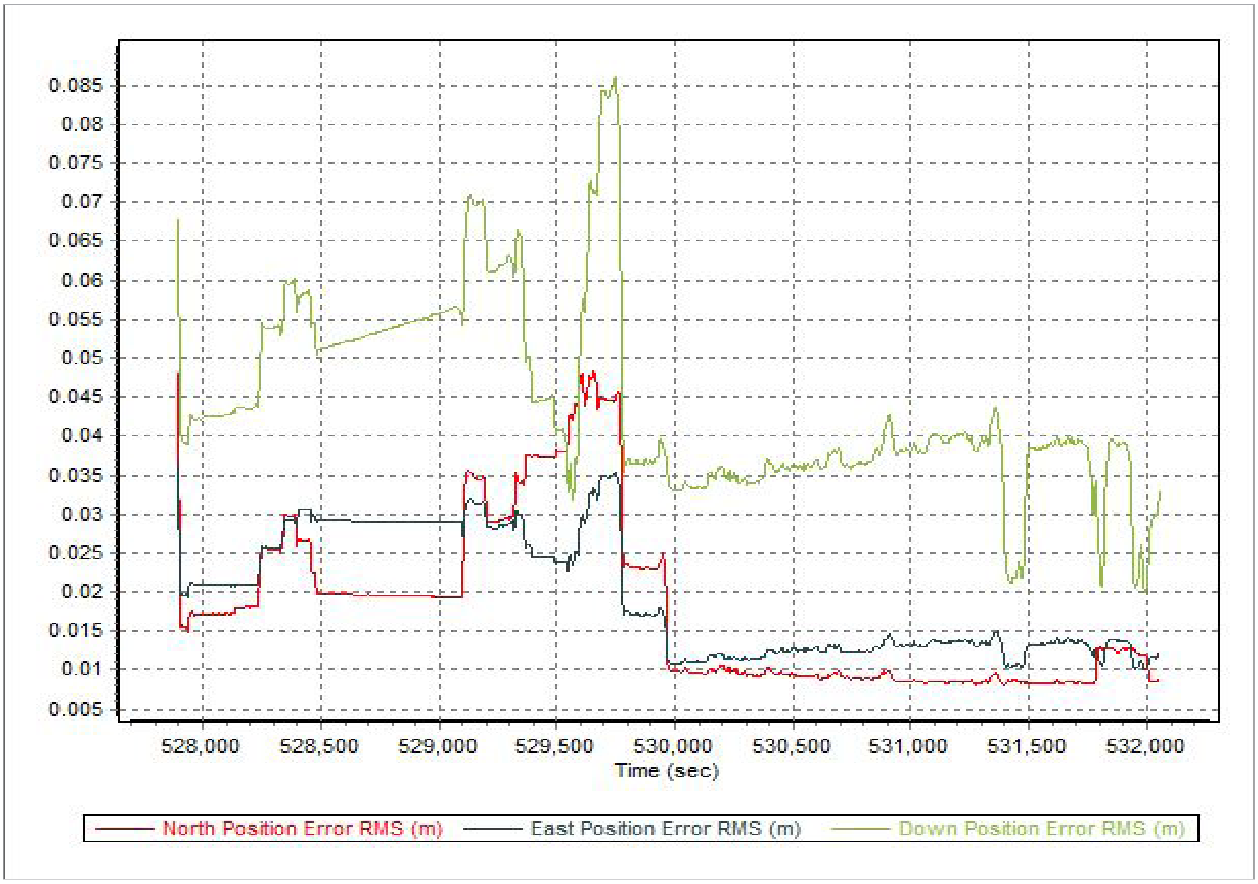


Figure A-8.9 Smoothed Performance Metric Parameters

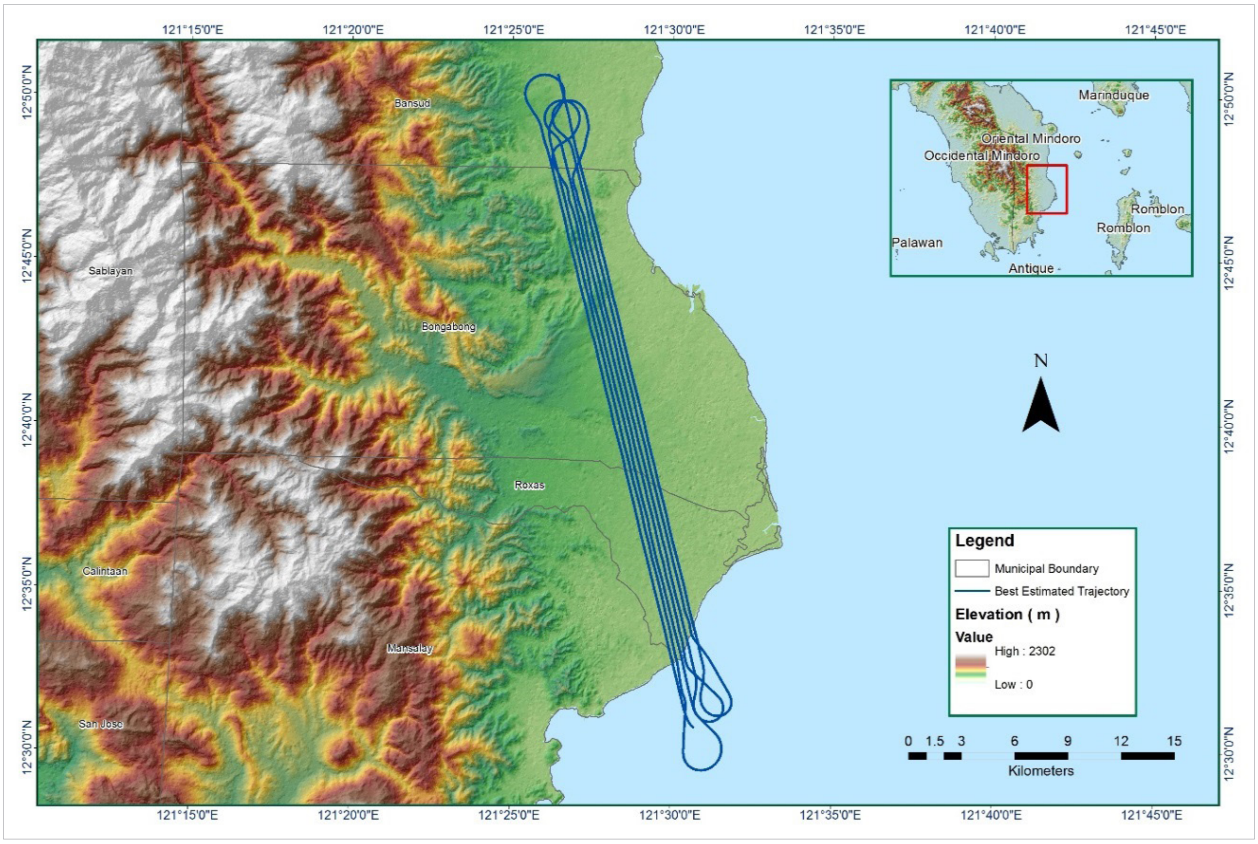


Figure A-8.10 Best Estimated Trajectory

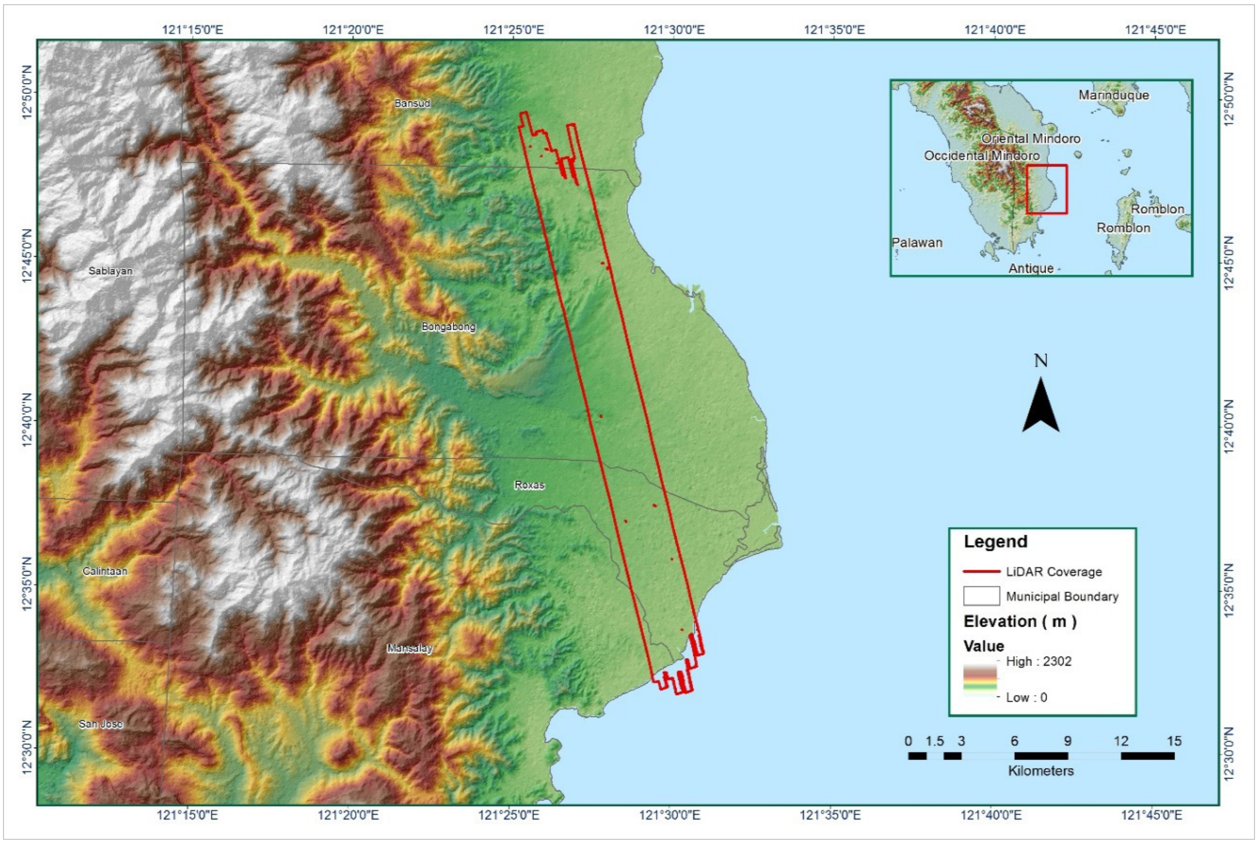


Figure A-8.11 Coverage of LiDAR data

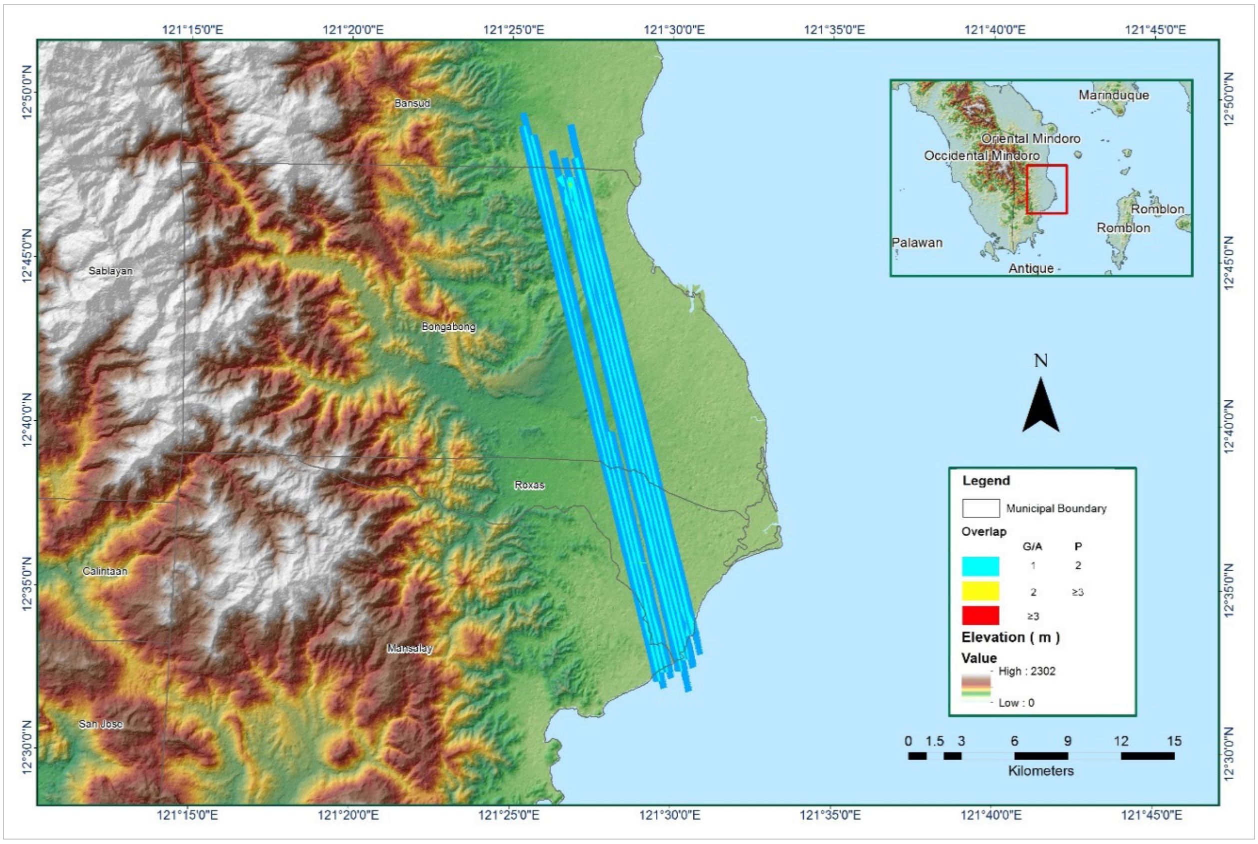


Figure A-8.12 Image of data overlap

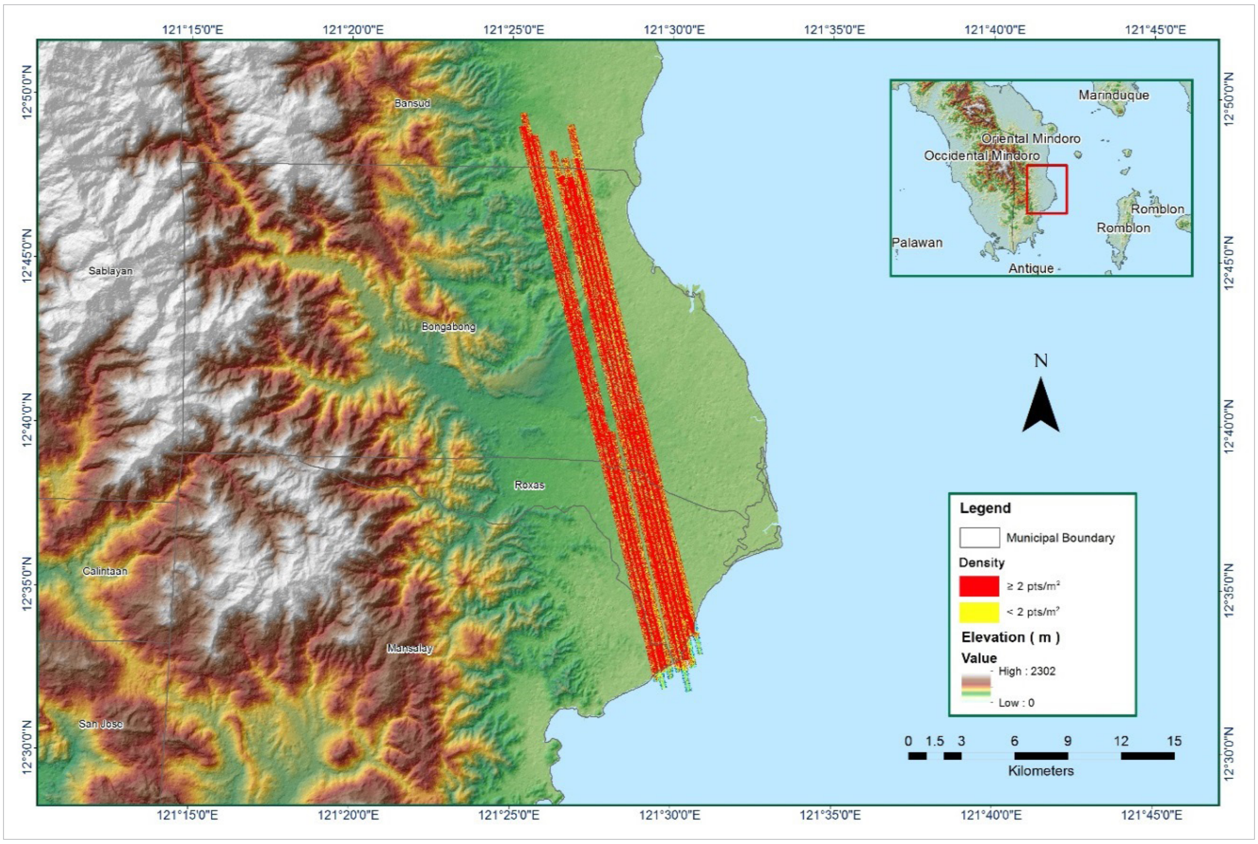


Figure A-8.13 Density map of merged LiDAR data

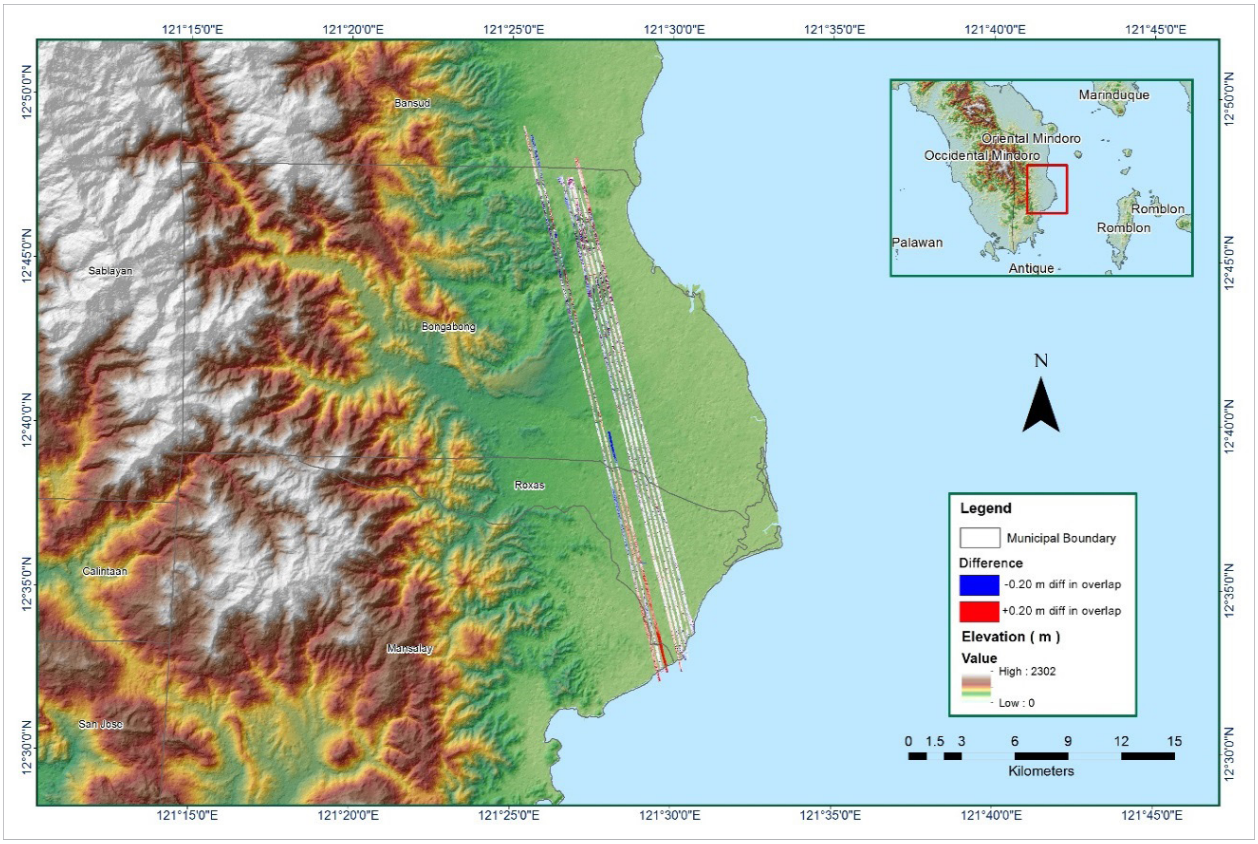


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk28GsH

Flight Area	Oriental Mindoro
Mission Name	Blk28GsH
Inclusive Flights	1078A
Range data size	9.71 GB
POS	197 MB
Image	56.8 GB
Transfer date	February 20, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.6
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	6.0
Boresight correction stdev (<0.001deg)	0.000552
IMU attitude correction stdev (<0.001deg)	0.004258
GPS position stdev (<0.01m)	0.0143
Minimum % overlap (>25)	58.5%
Ave point cloud density per sq.m. (>2.0)	4.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	107
Maximum Height	288.11 m
Minimum Height	48.43 m
Classification (# of points)	
Ground	46,444,727
Low vegetation	58,505,631
Medium vegetation	50,918,523
High vegetation	49,004,112
Building	1,332,080
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Celina Rosete, Engr. Elainne Lopez

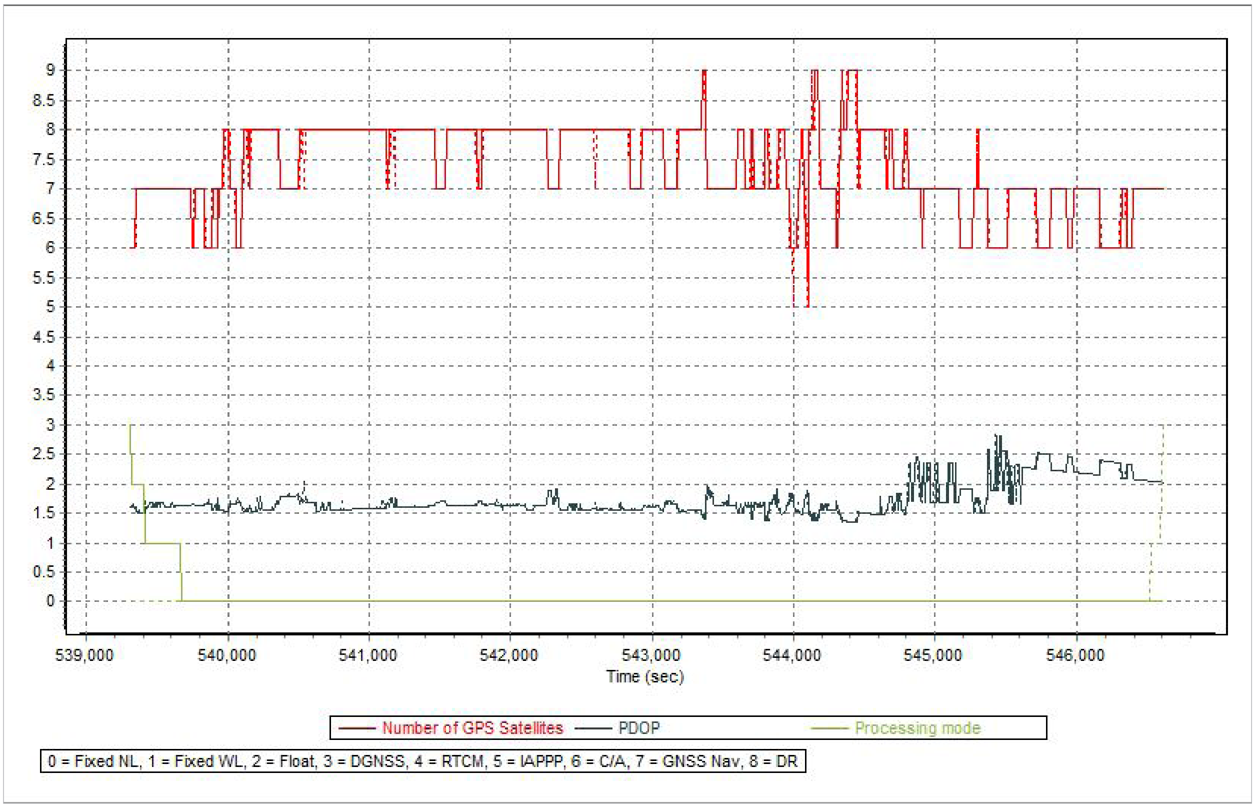


Figure A-8.15 Solution Status

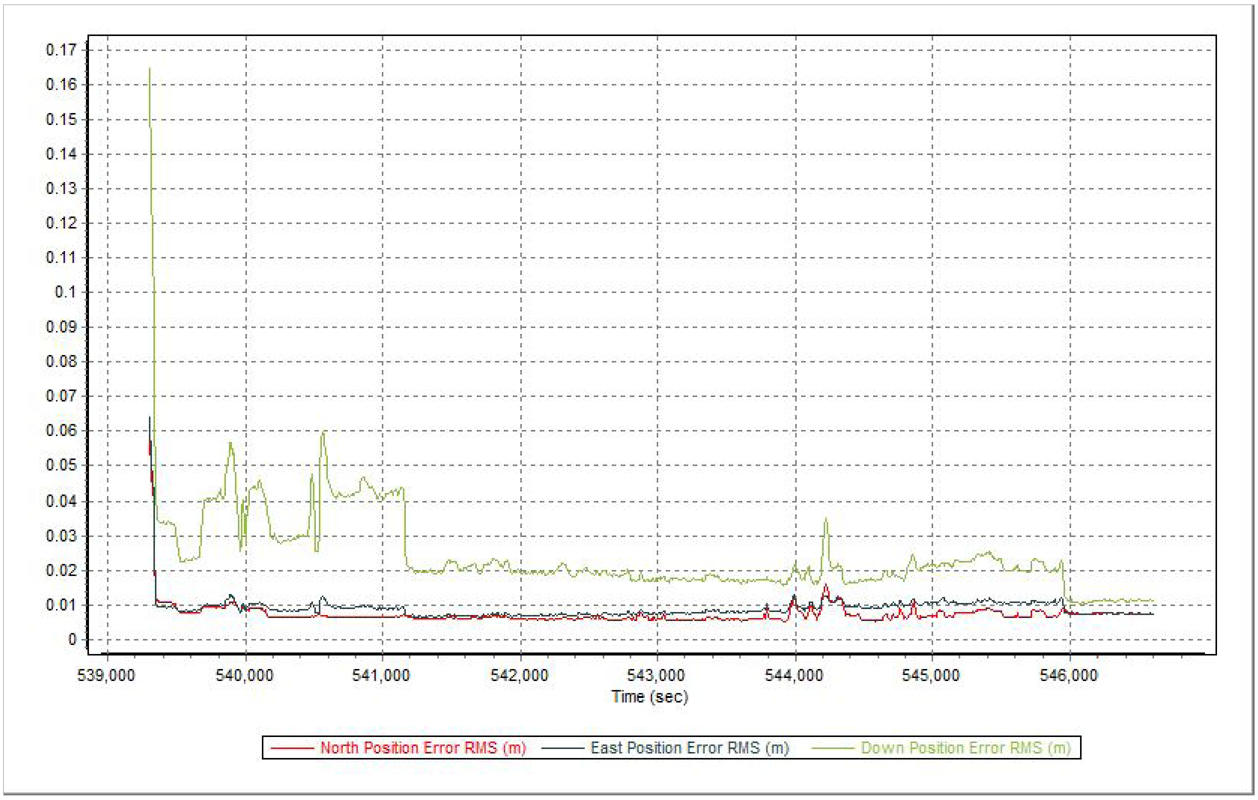


Figure A-8.16 Smoothed Performance Metric Parameters

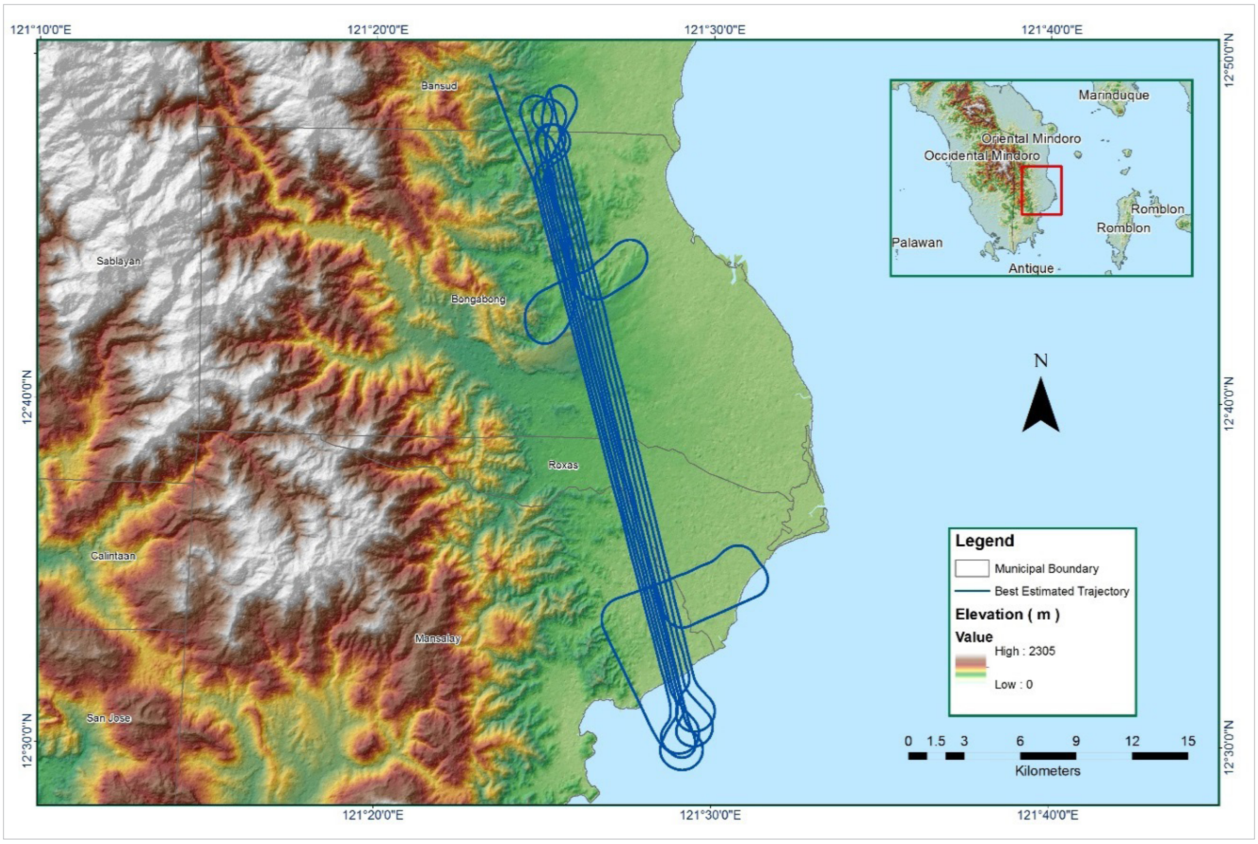


Figure A-8.17 Best Estimated Trajectory

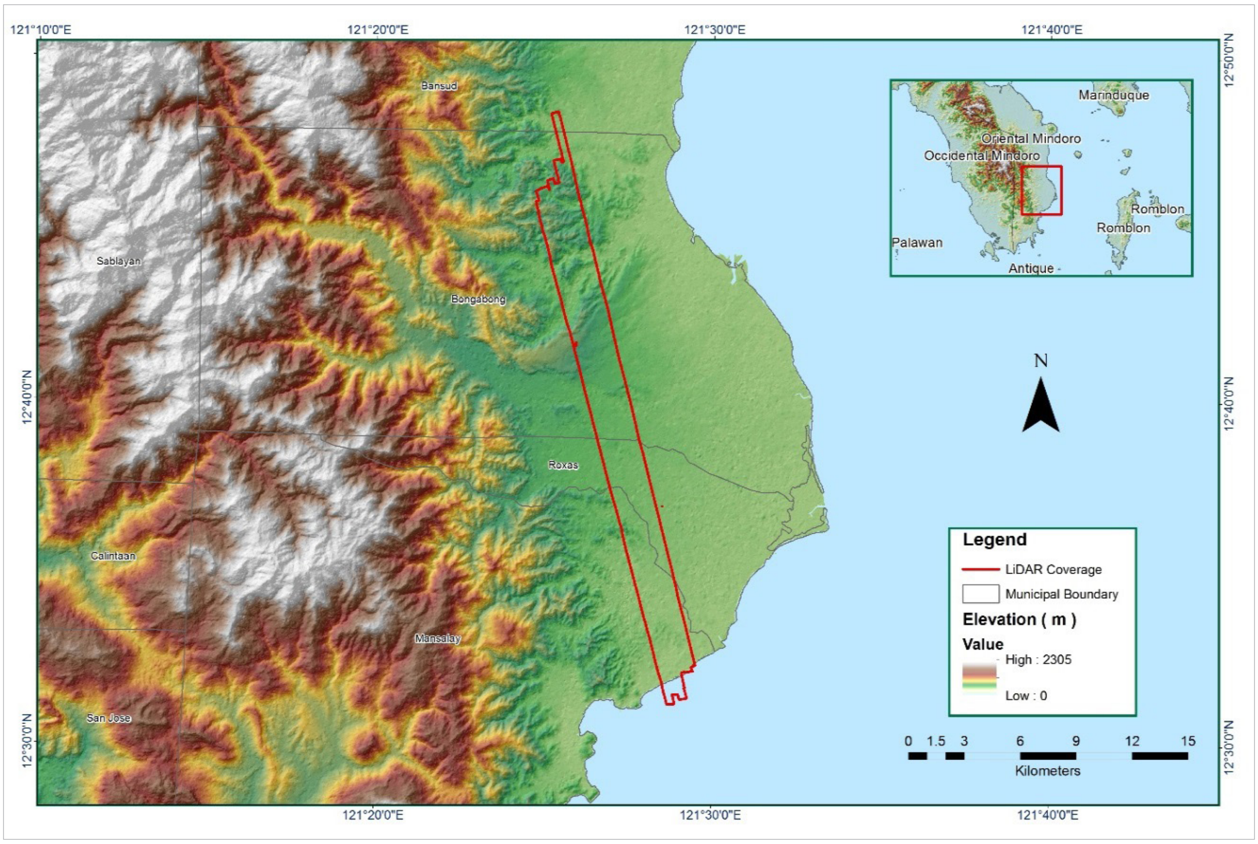


Figure A-8.18 Coverage of LiDAR data

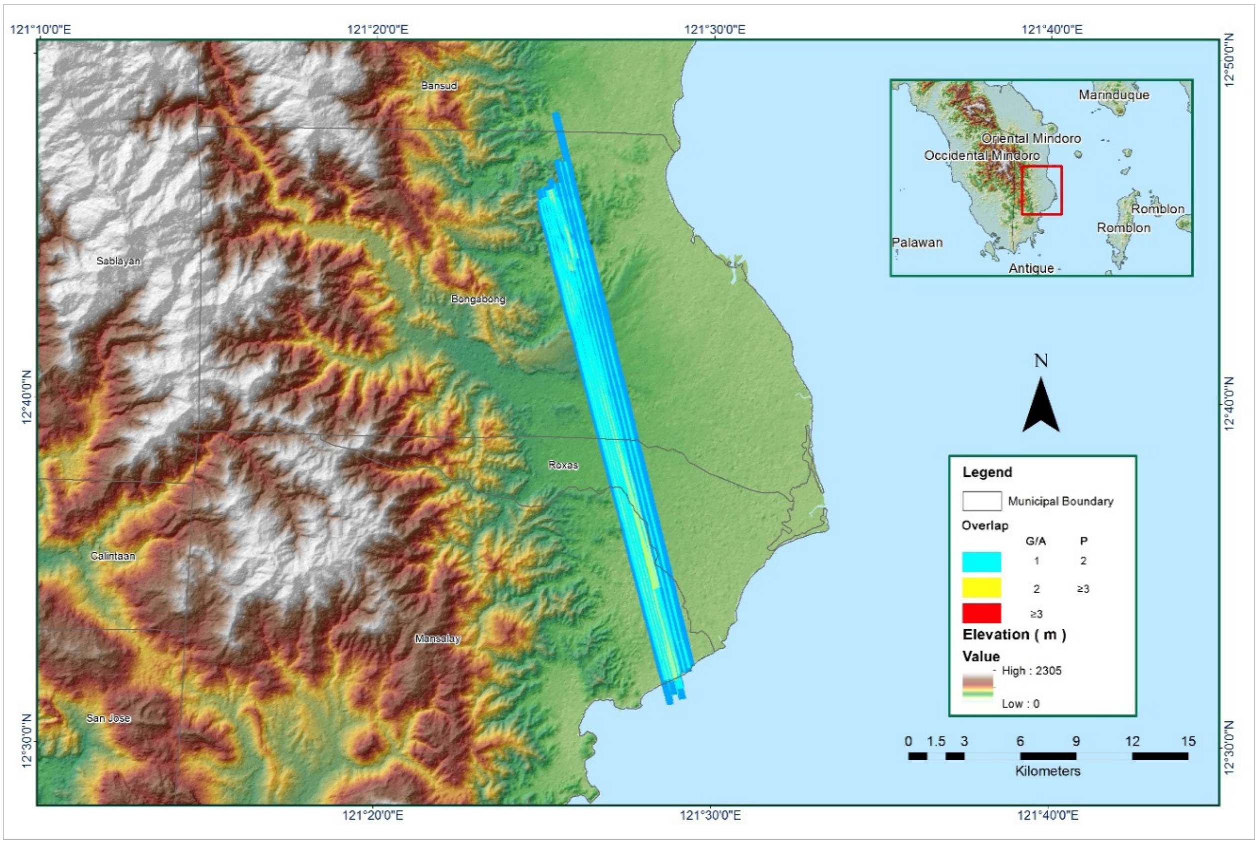


Figure A-8.19 Image of data overlap

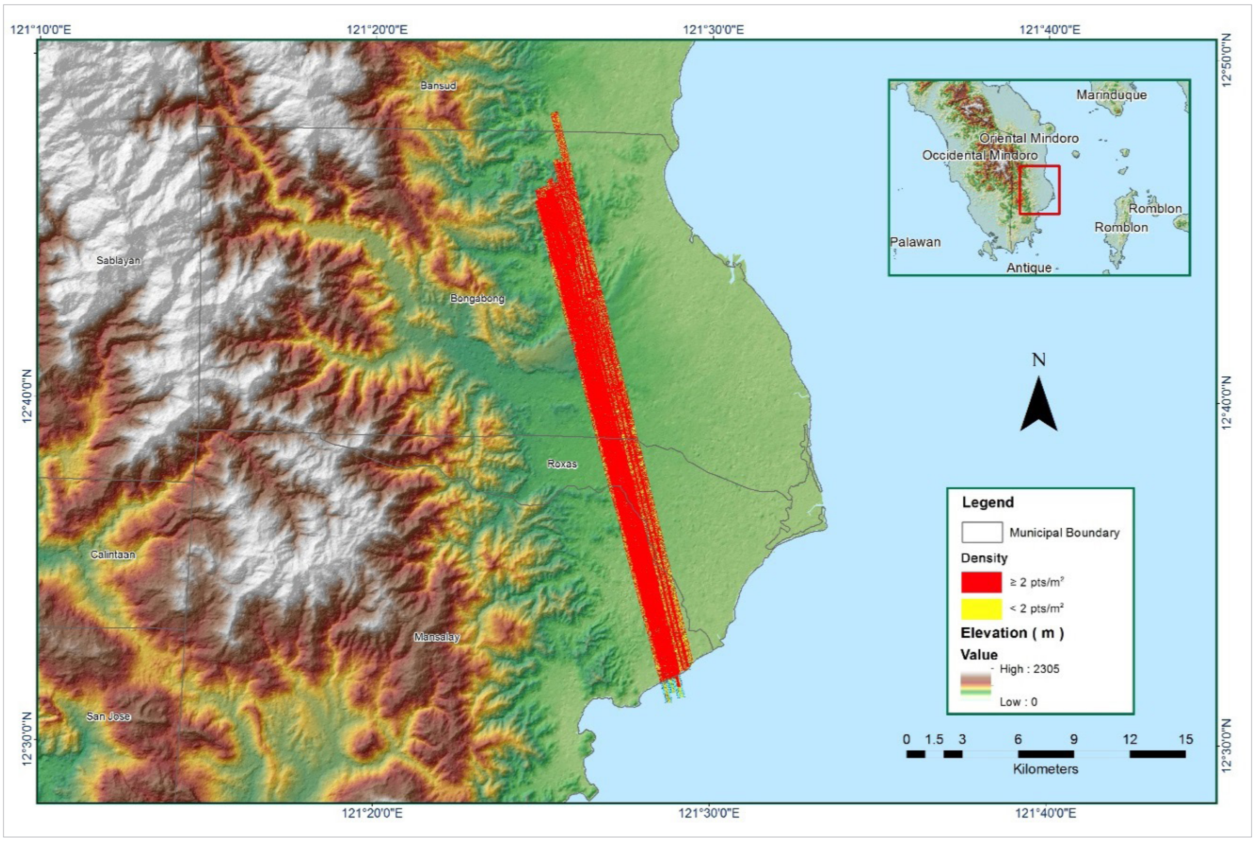


Figure A-8.20 Density map of merged LiDAR data

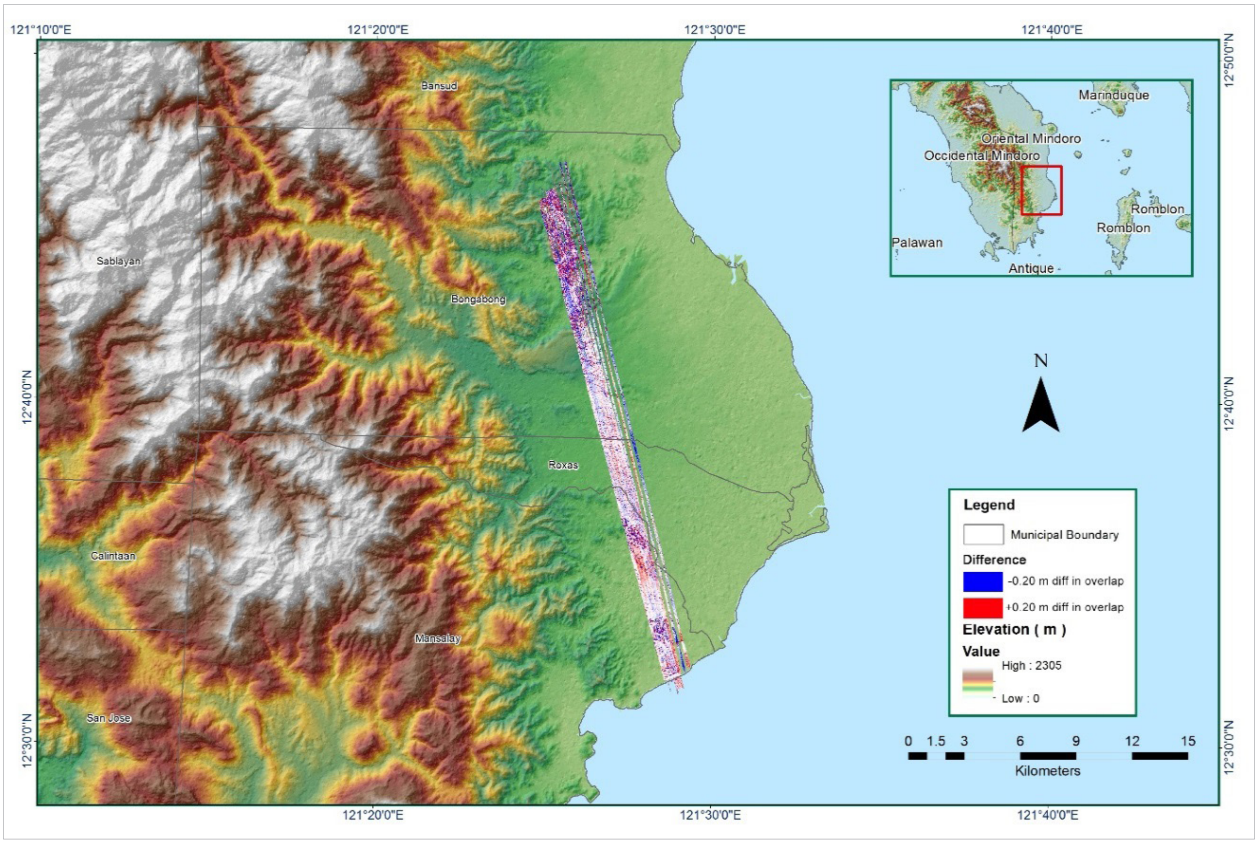


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk28Hs

Flight Area	Oriental Mindoro
Mission Name	Blk28Hs
Inclusive Flights	1088A
Range data size	14 GB
POS	269 MB
Image	80.7 GB
Transfer date	February 21, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.6
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	5.3
Boresight correction stdev (<0.001deg)	0.000304
IMU attitude correction stdev (<0.001deg)	0.000768
GPS position stdev (<0.01m)	0.0088
Minimum % overlap (>25)	66.45%
Ave point cloud density per sq.m. (>2.0)	4.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	418.58 m
Minimum Height	42.03 m
Classification (# of points)	
Ground	67,410,264
Low vegetation	78,245,475
Medium vegetation	73,011,298
High vegetation	74,100,895
Building	2,106,955
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Elyn Pama, Marie Joyce Ilagan

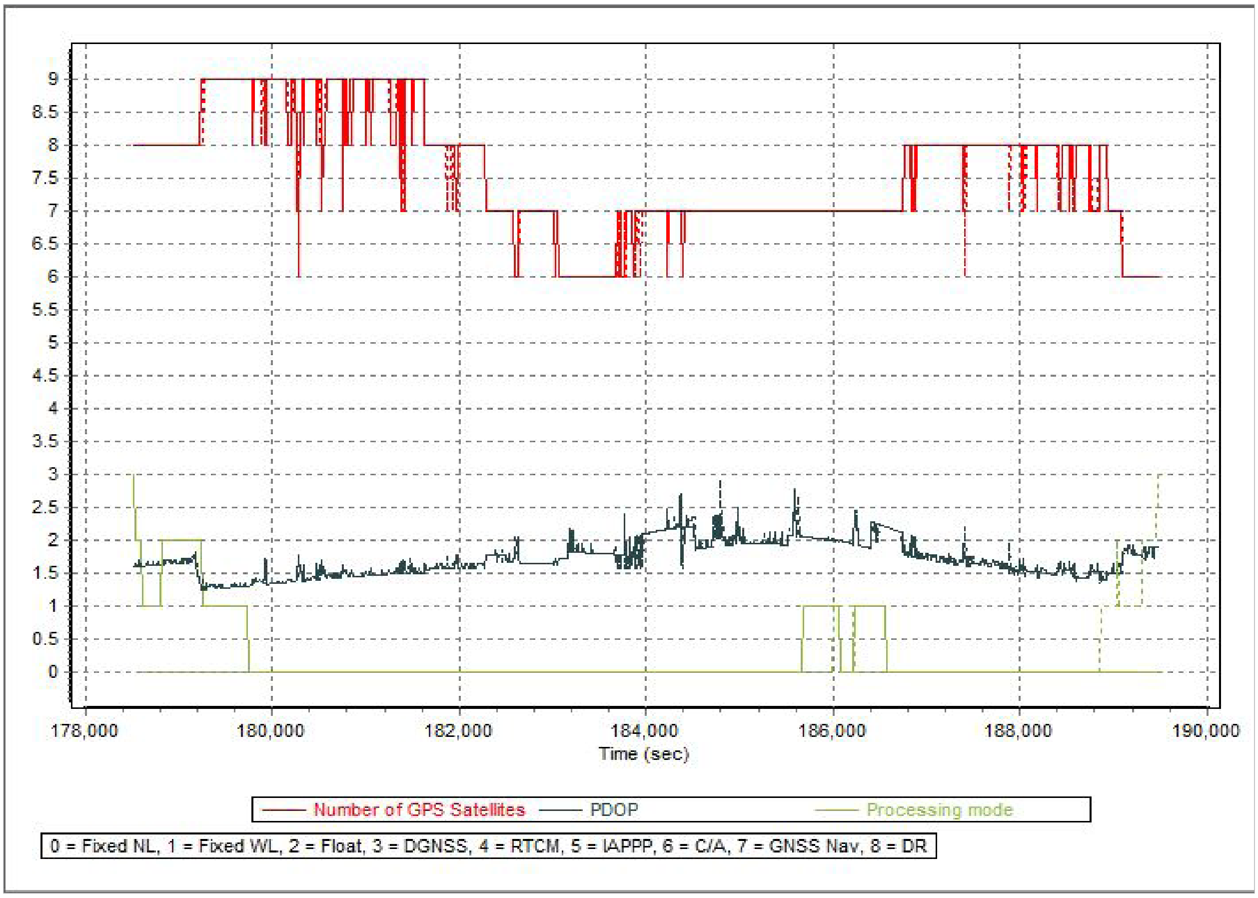


Figure A-8.22 Solution Status

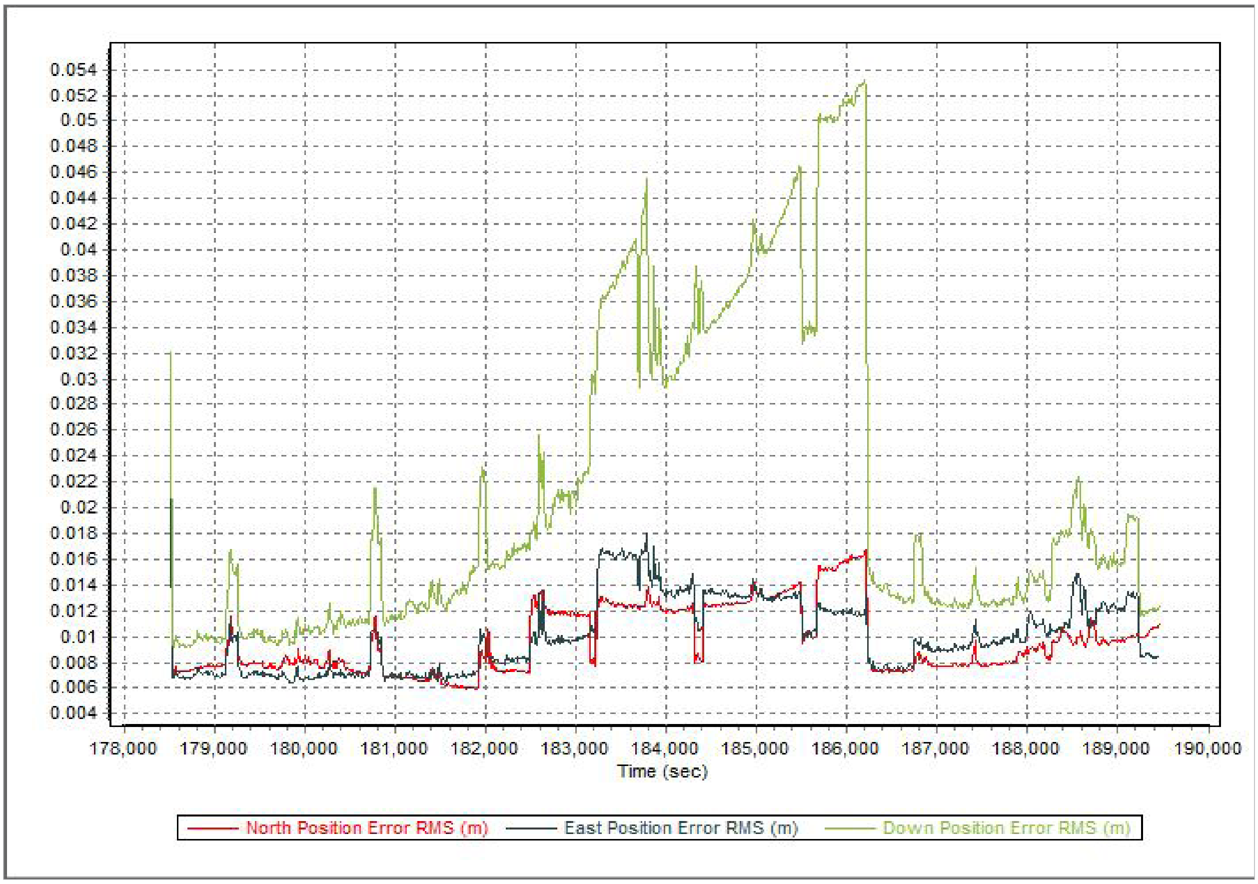


Figure A-8.23 Smoothed Performance Metric Parameters

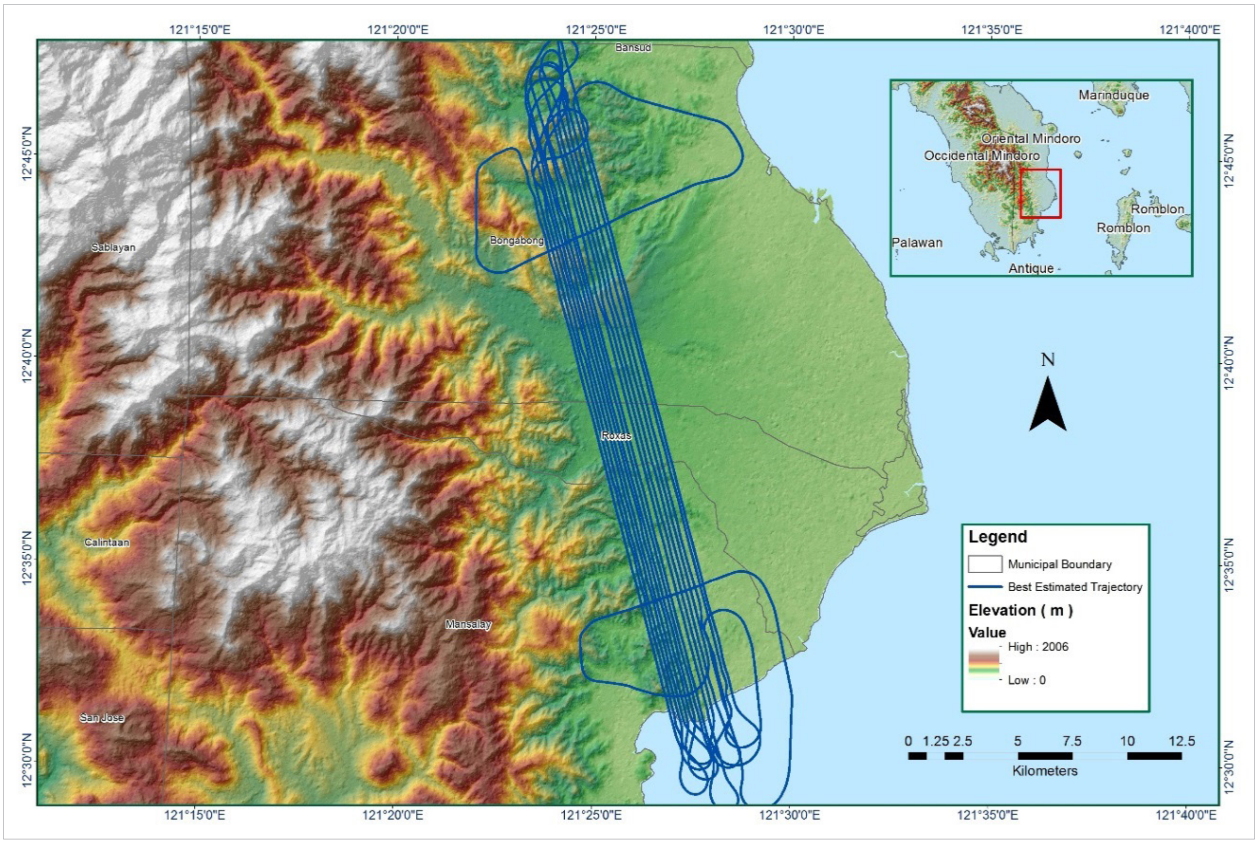


Figure A-8.24 Best Estimated Trajectory

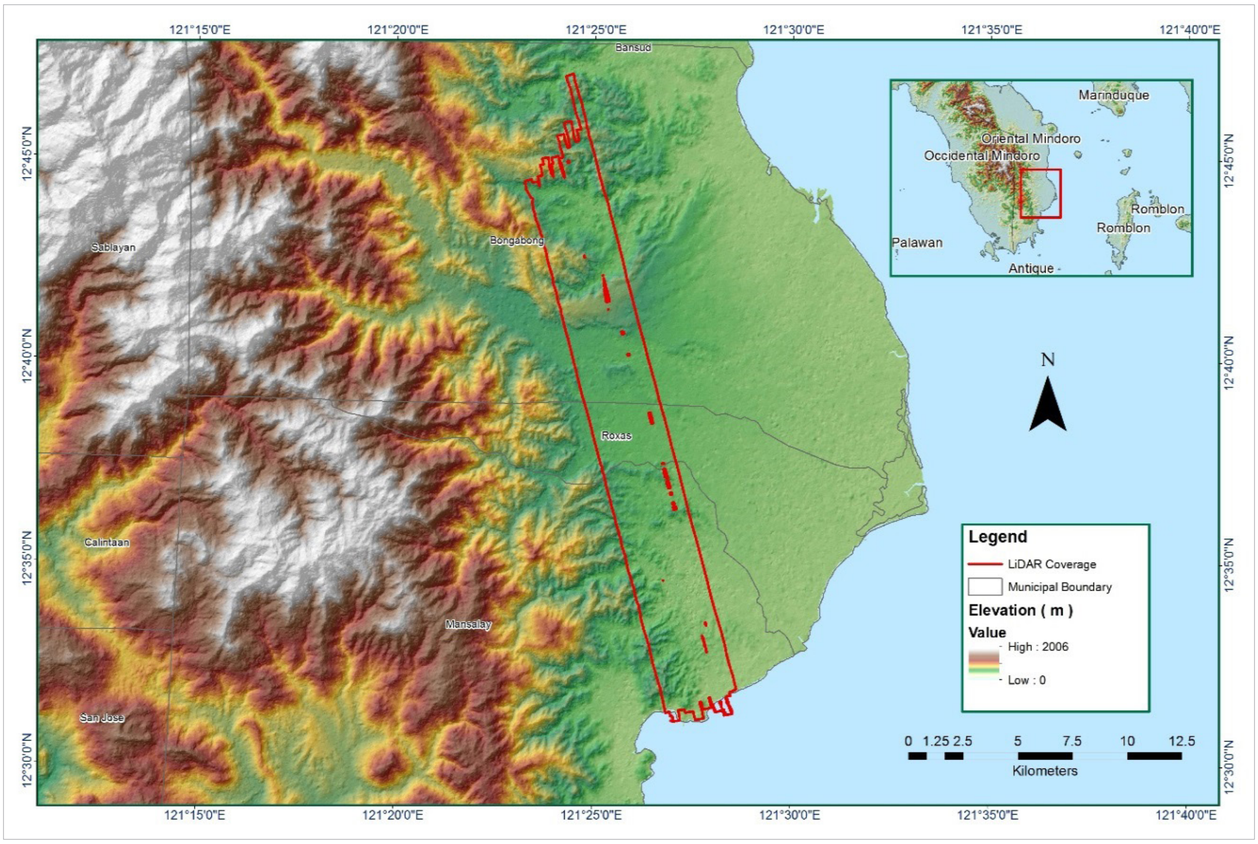


Figure A-8.25 Coverage of LiDAR data

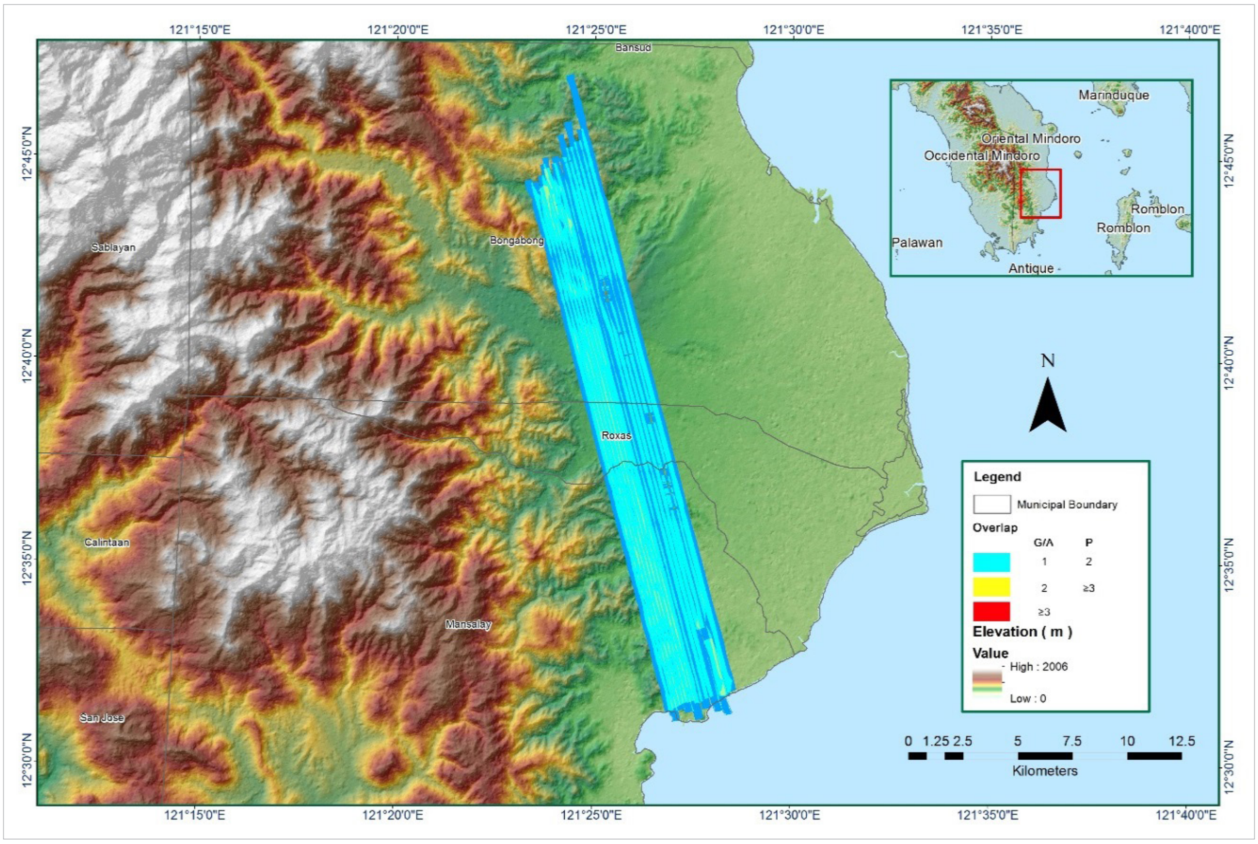


Figure A-8.26 Image of data overlap

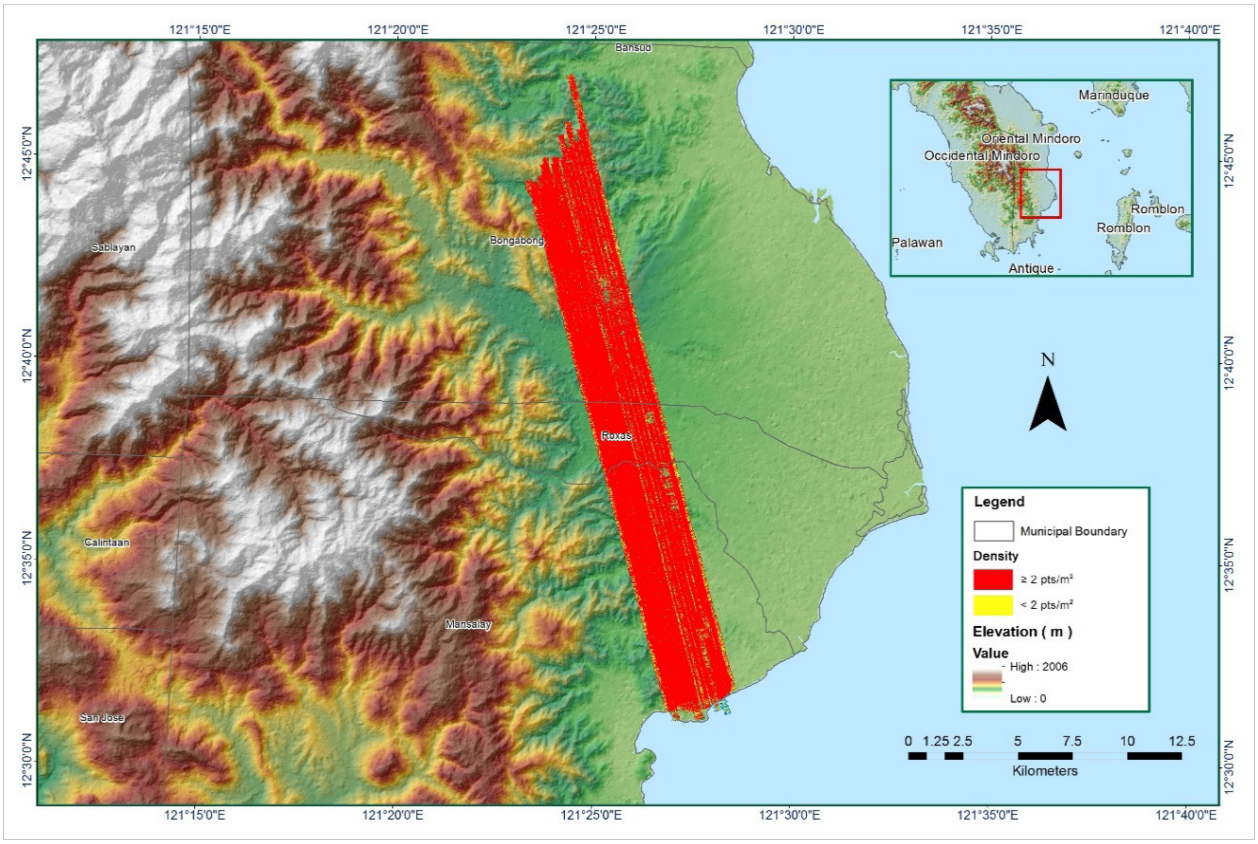


Figure A-8.27 Density map of merged LiDAR data

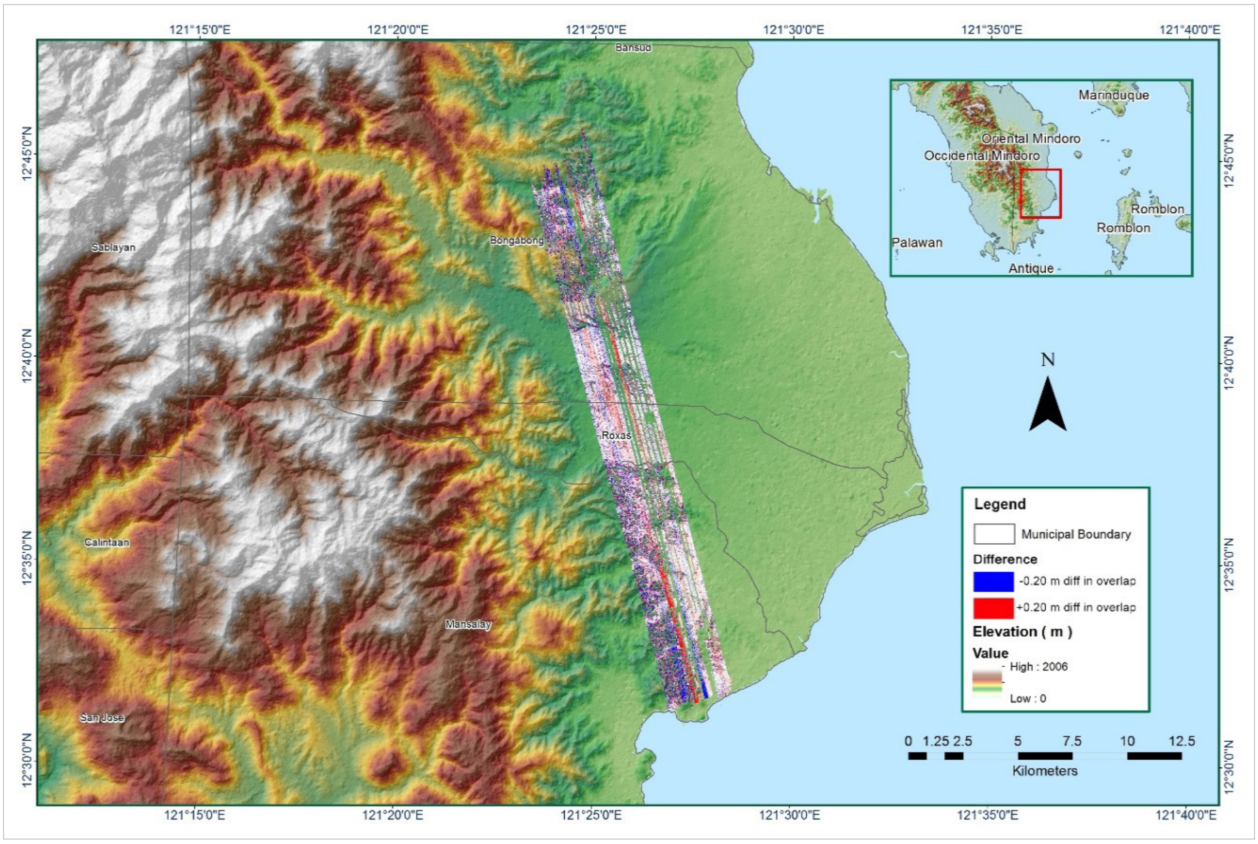


Figure A-8.28 Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk28IJ

Flight Area	Oriental Mindoro
Mission Name	Blk28IJ
Inclusive Flights	1104A
Range data size	10.3 GB
POS	276 MB
Image	56.2 GB
Transfer date	February 21, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.4
RMSE for East Position (<4.0 cm)	3.9
RMSE for Down Position (<8.0 cm)	1.1
Boresight correction stdev (<0.001deg)	0.000220
IMU attitude correction stdev (<0.001deg)	0.001457
GPS position stdev (<0.01m)	0.0037
Minimum % overlap (>25)	47.15%
Ave point cloud density per sq.m. (>2.0)	3.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	254
Maximum Height	570.88 m
Minimum Height	37.28 m
Classification (# of points)	
Ground	110,601,059
Low vegetation	99,664,631
Medium vegetation	142,219,461
High vegetation	131,163,224
Building	4,203,923
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

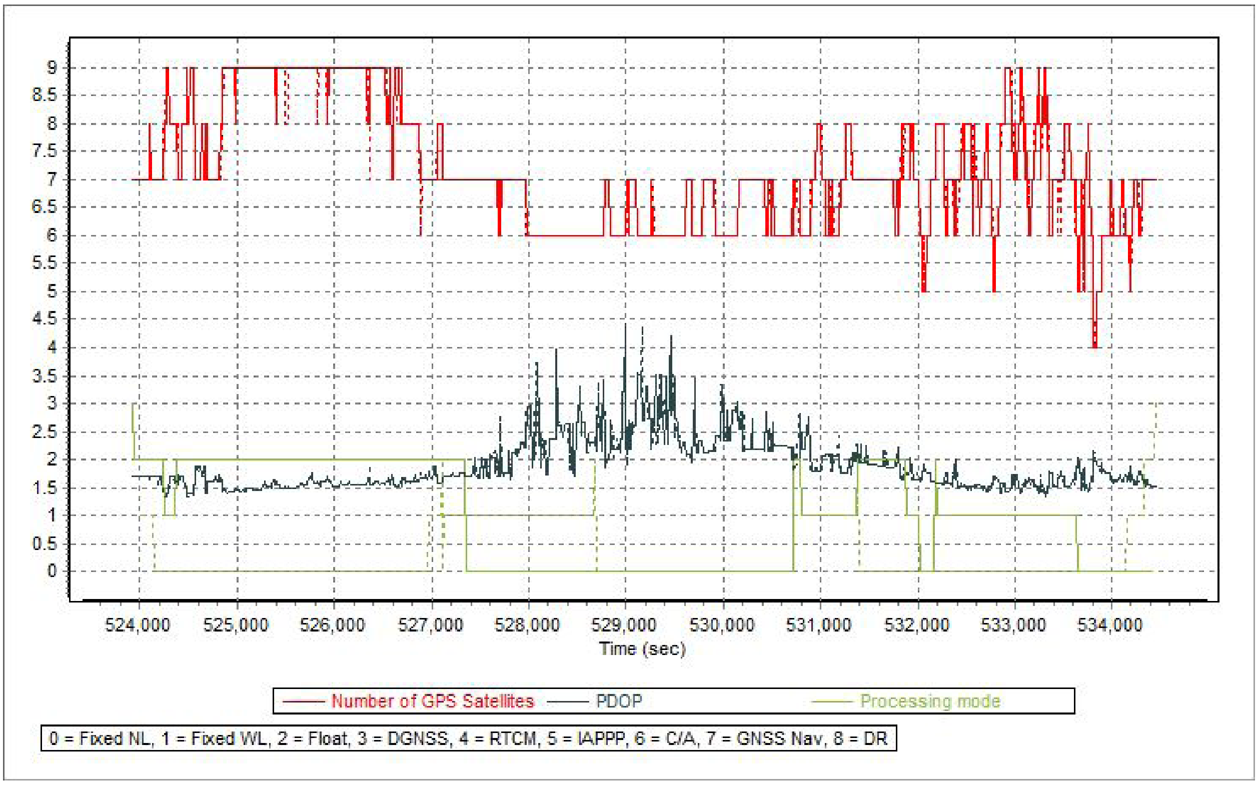


Figure A-8.29 Solution Status

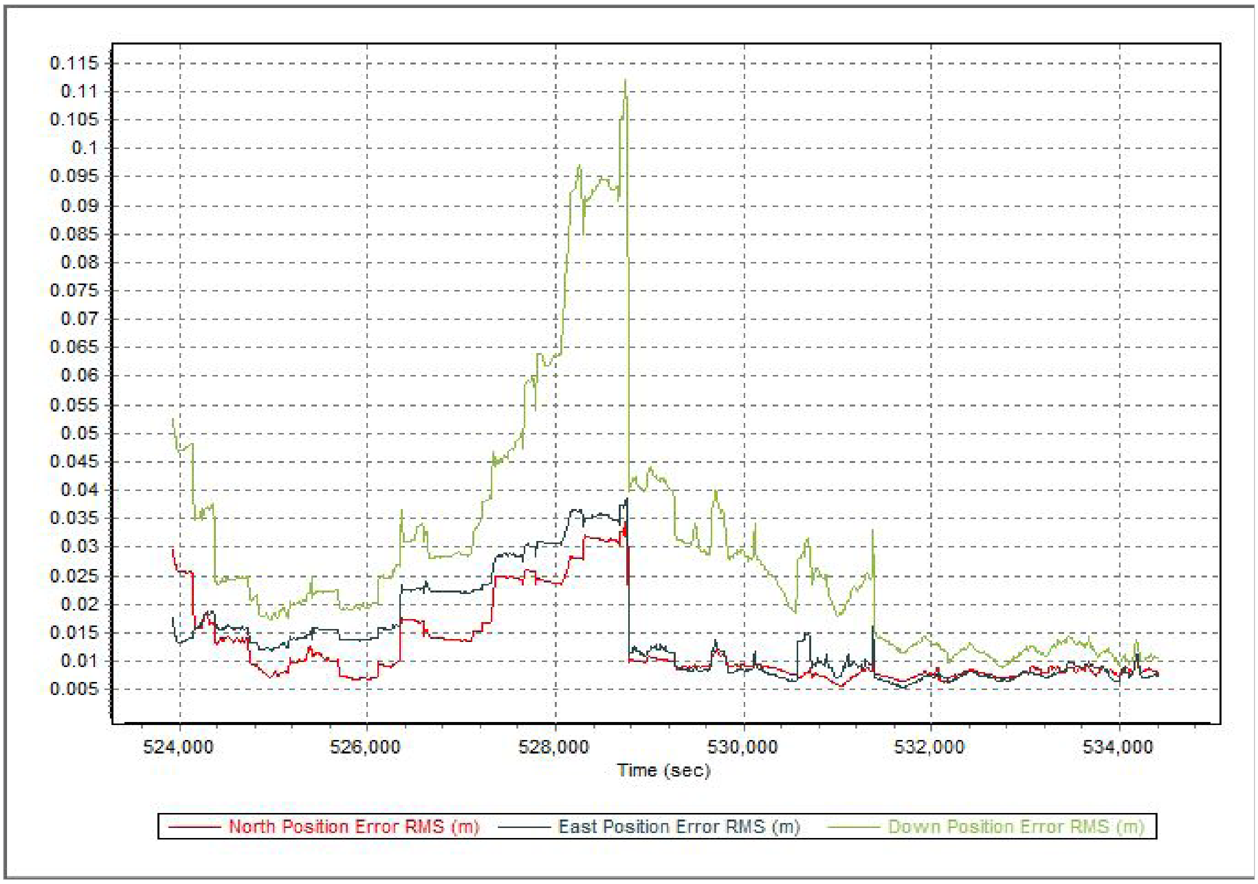


Figure A-8.30 Smoothed Performance Metric Parameters

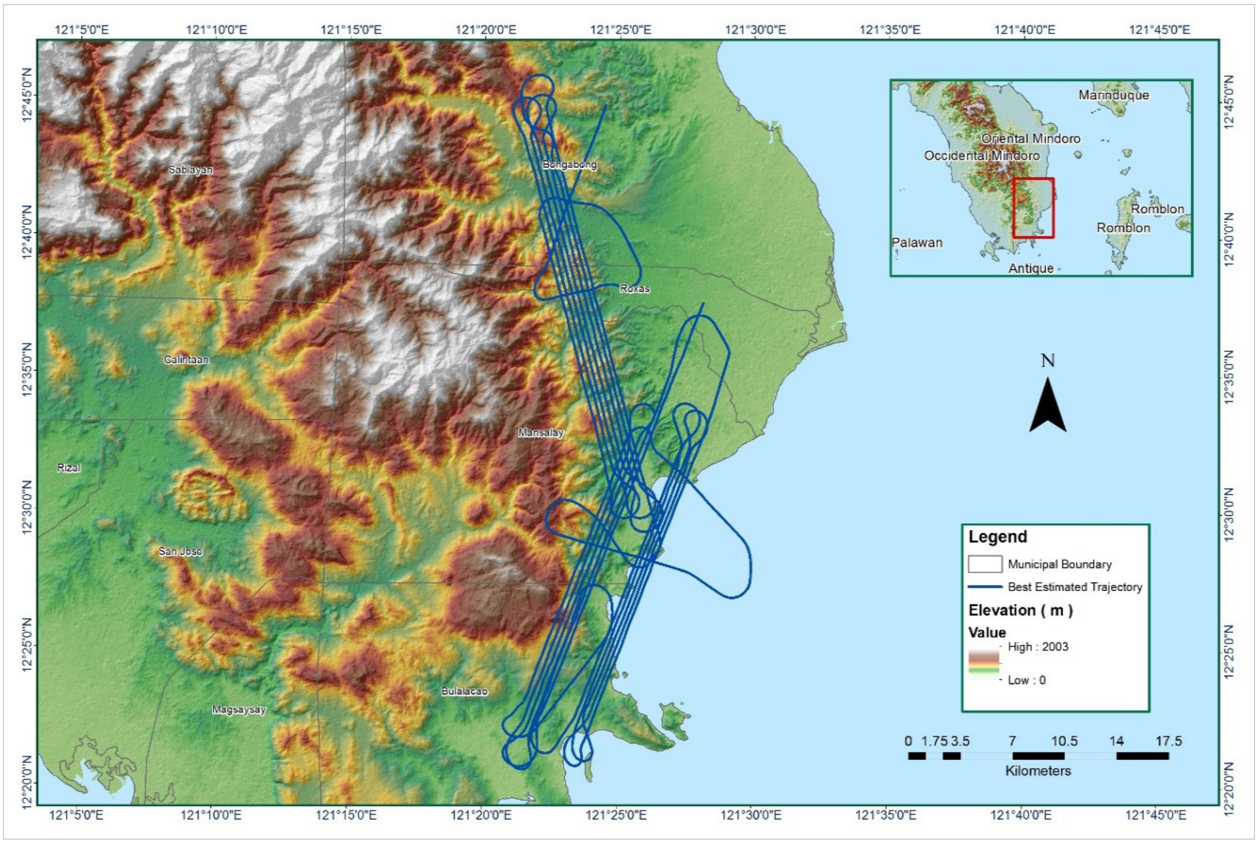


Figure A-8.31 Best Estimated Trajectory

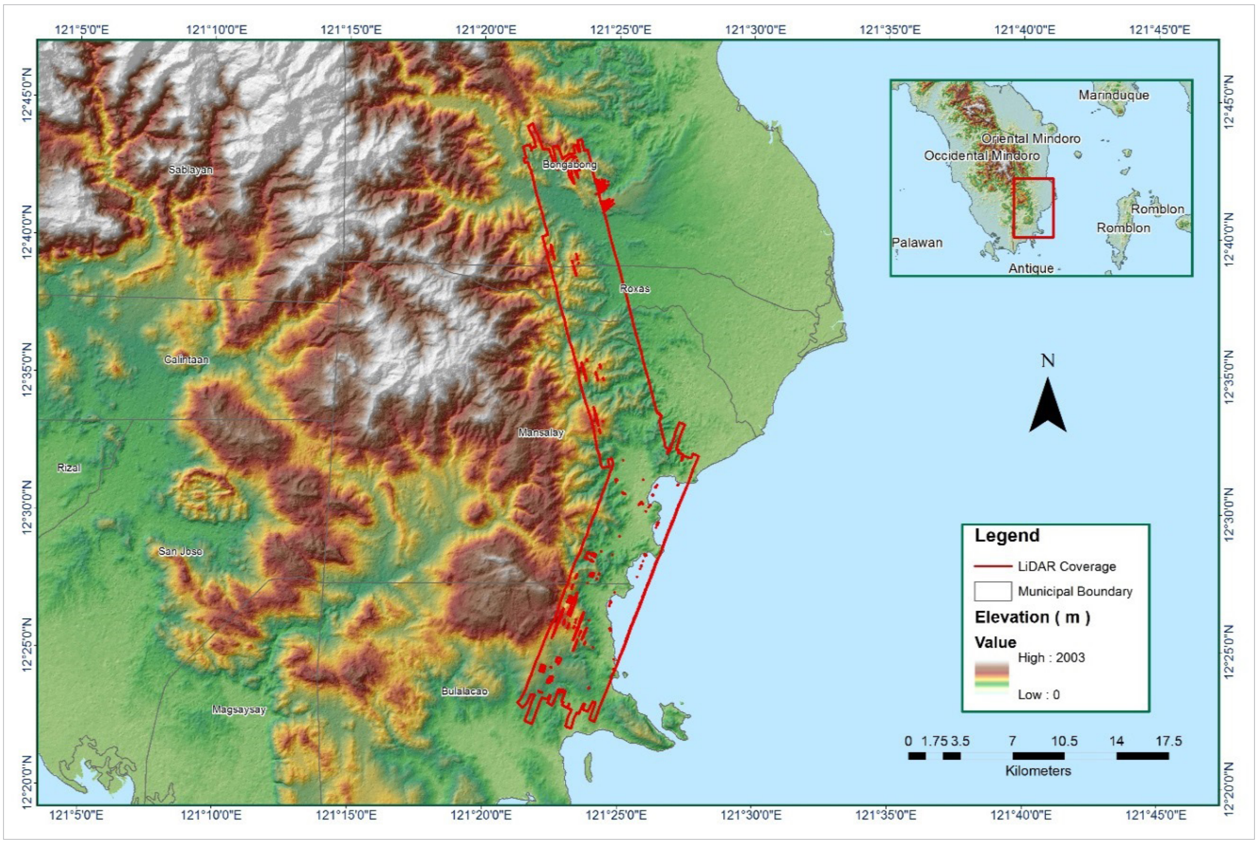


Figure A-8.32 Coverage of LiDAR data

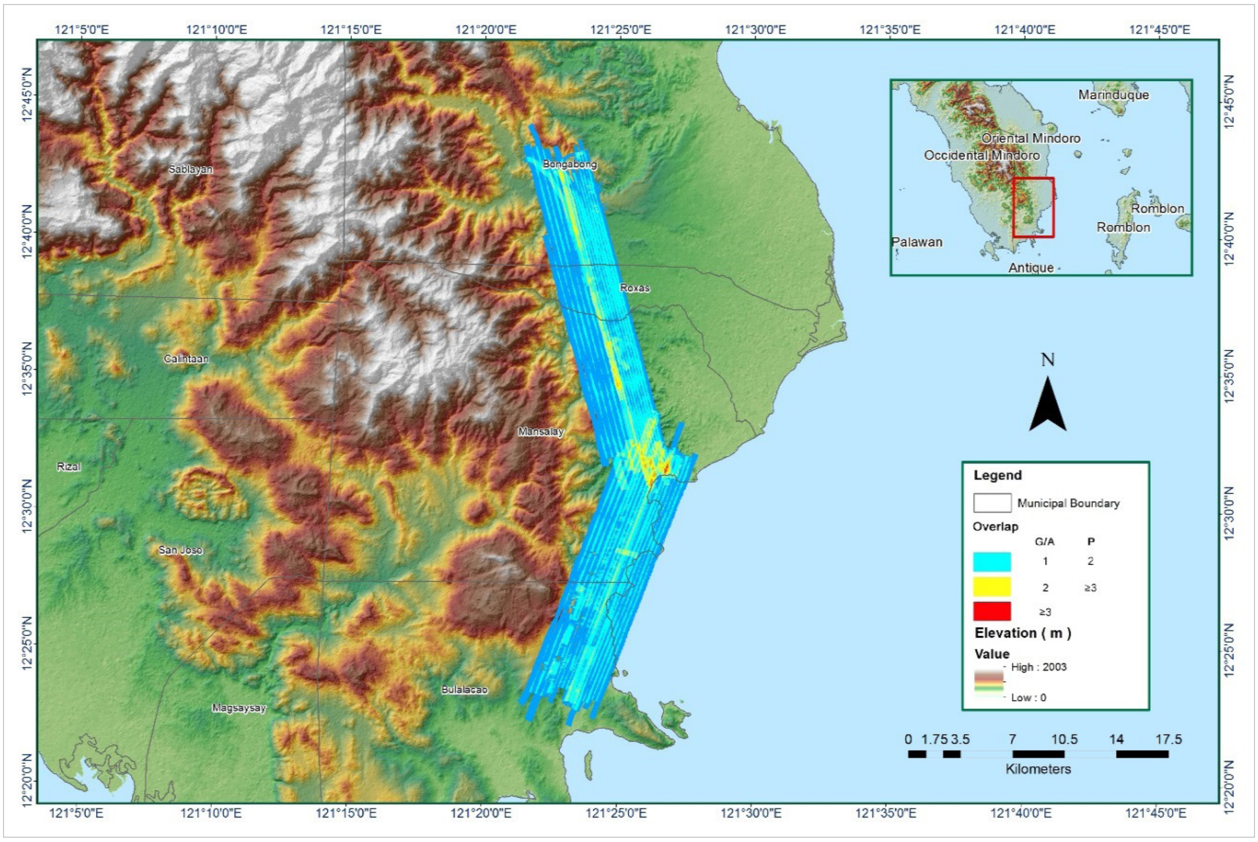


Figure A-8.33 Image of data overlap

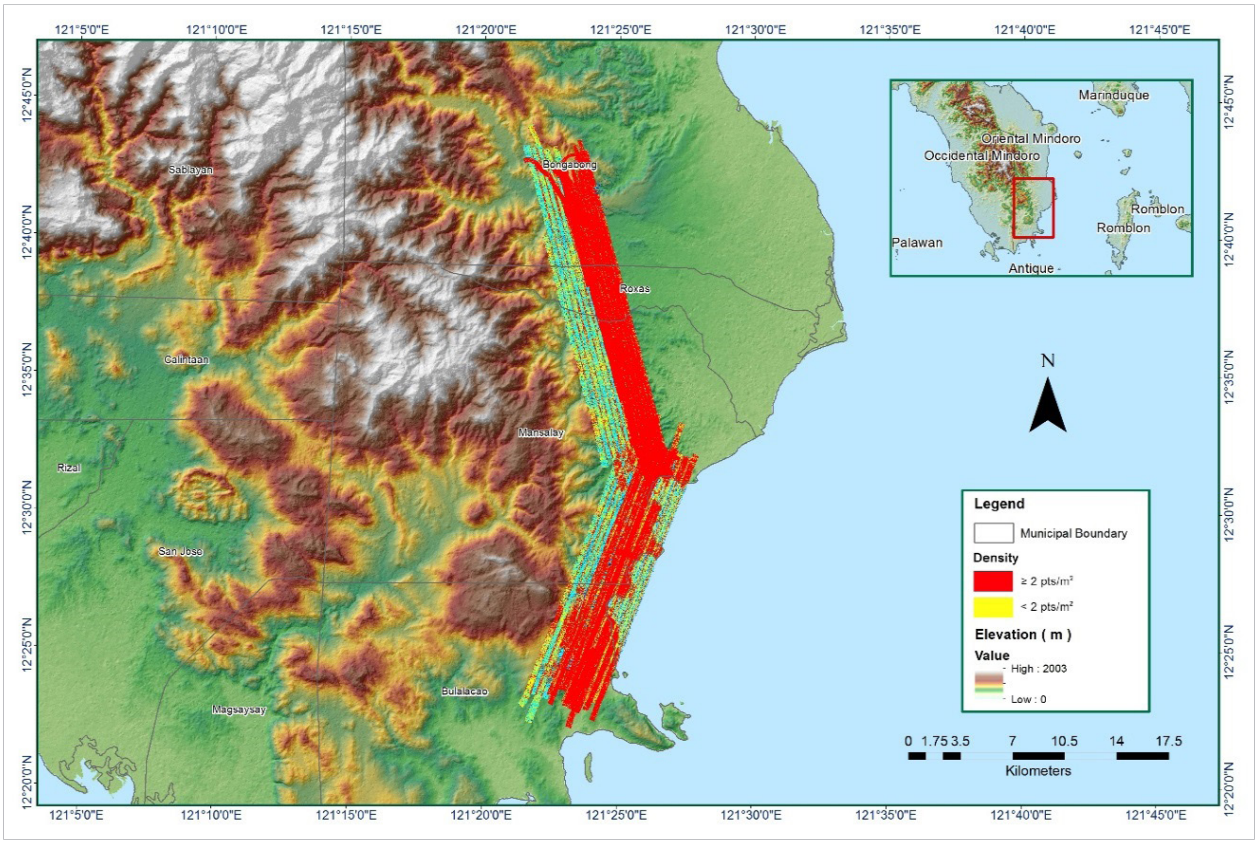


Figure A-8.34 Density map of merged LiDAR data

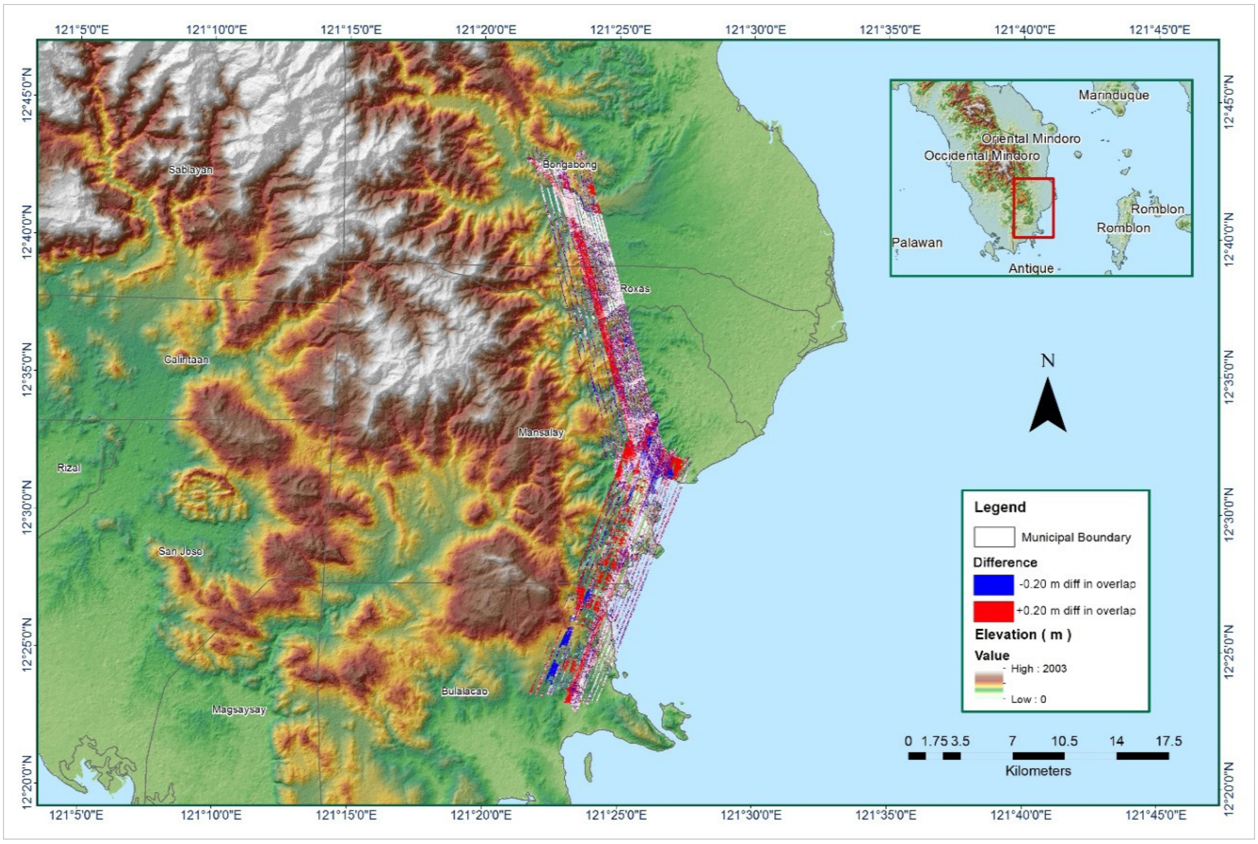


Figure A-8.35 Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk28I

Flight Area	**Oriental Mindoro Reflights**
Mission Name	Blk28I
Inclusive Flights	8312G
Range data size	11 GB
POS	215 MB
Image	NA
Transfer date	November 12, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.12
RMSE for East Position (<4.0 cm)	1.39
RMSE for Down Position (<8.0 cm)	3.39
Boresight correction stdev (<0.001deg)	0.001626
IMU attitude correction stdev (<0.001deg)	0.001230
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	21.53
Ave point cloud density per sq.m. (>2.0)	5.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	33
Maximum Height	557.48 m
Minimum Height	126.09 m
Classification (# of points)	
Ground	1,981,953
Low vegetation	1,683,213
Medium vegetation	17,835,445
High vegetation	47,444,332
Building	1,304,633
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Justine Francisco, Engr. Mark Sueden Lyle Magtalas

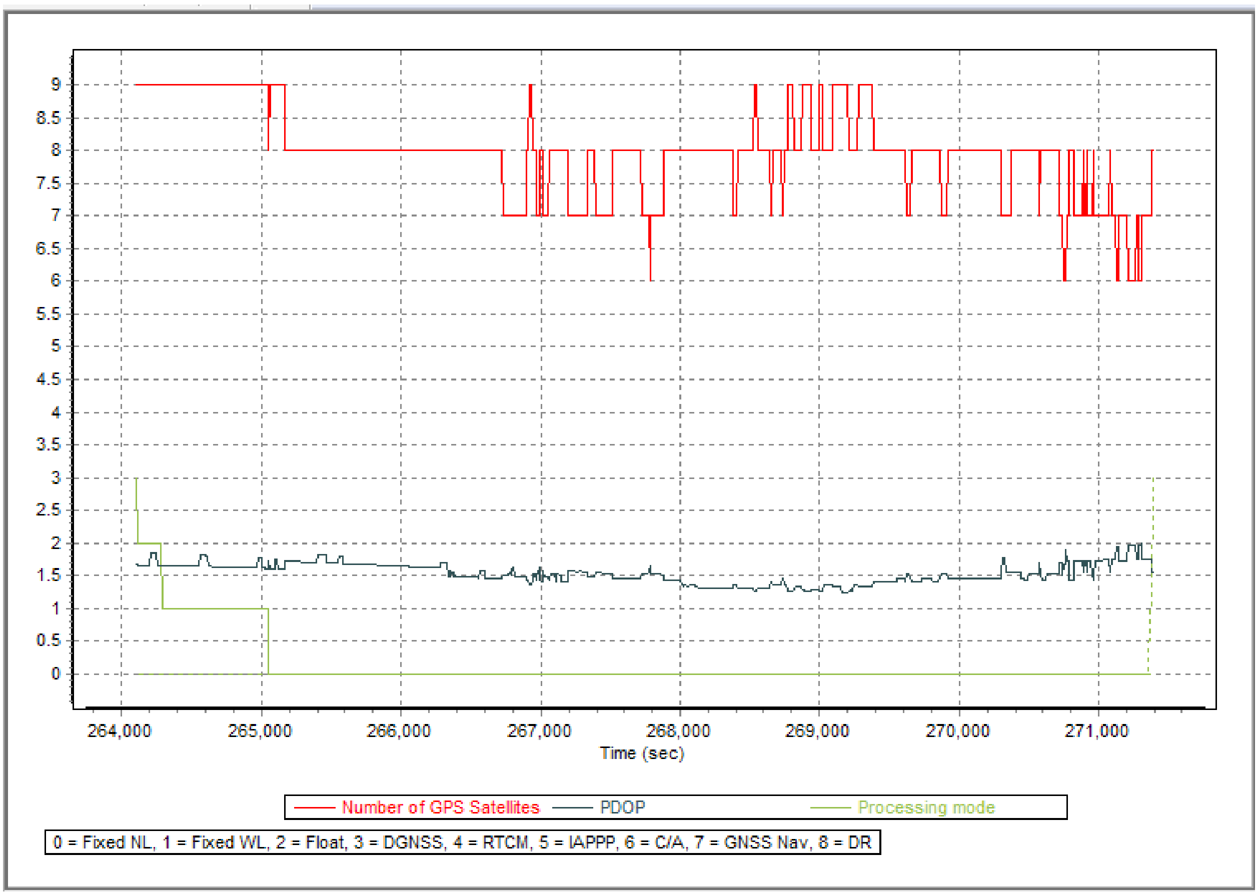


Figure A-8.36 Solution Status

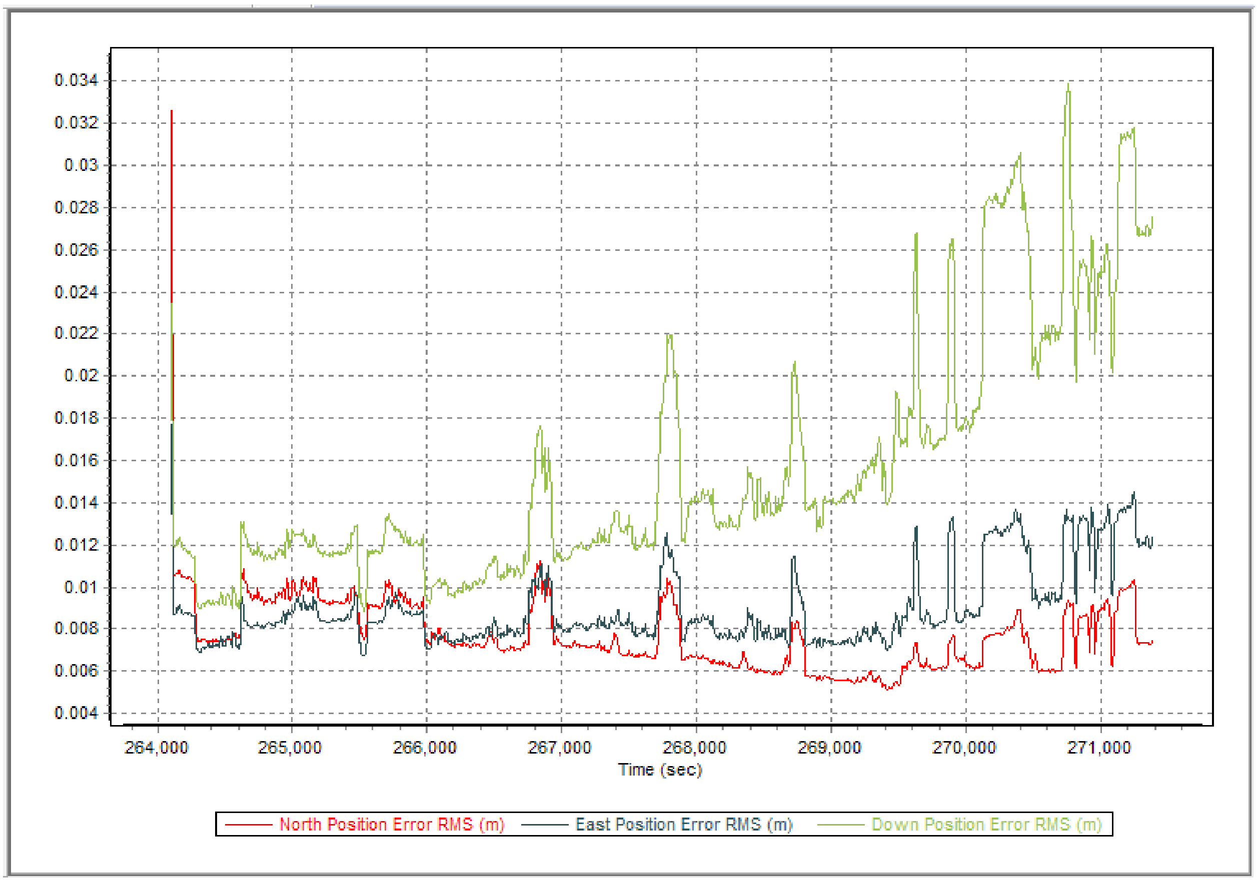


Figure A-8.37 Smoothed Performance Metric Parameters

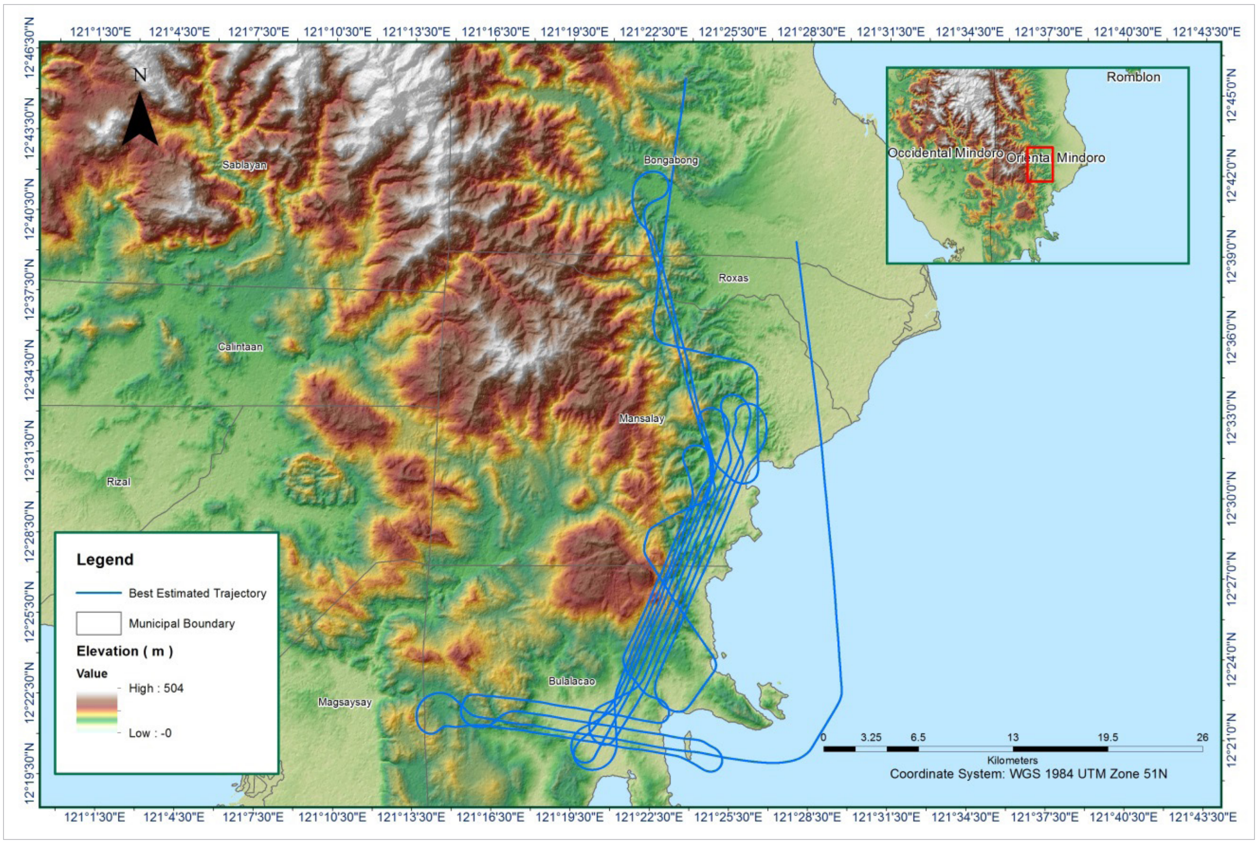


Figure A-8.38 Best Estimated Trajectory

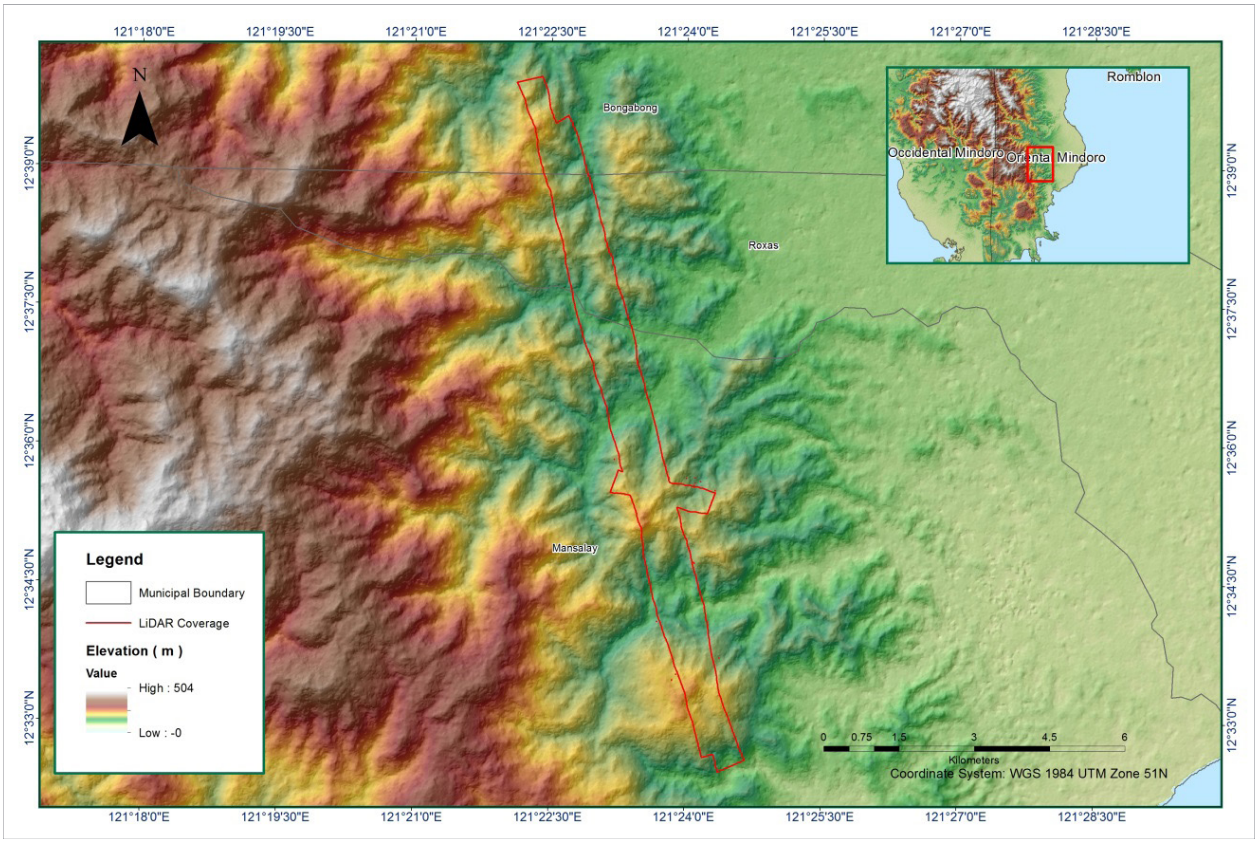


Figure A-8.39 Coverage of LiDAR data

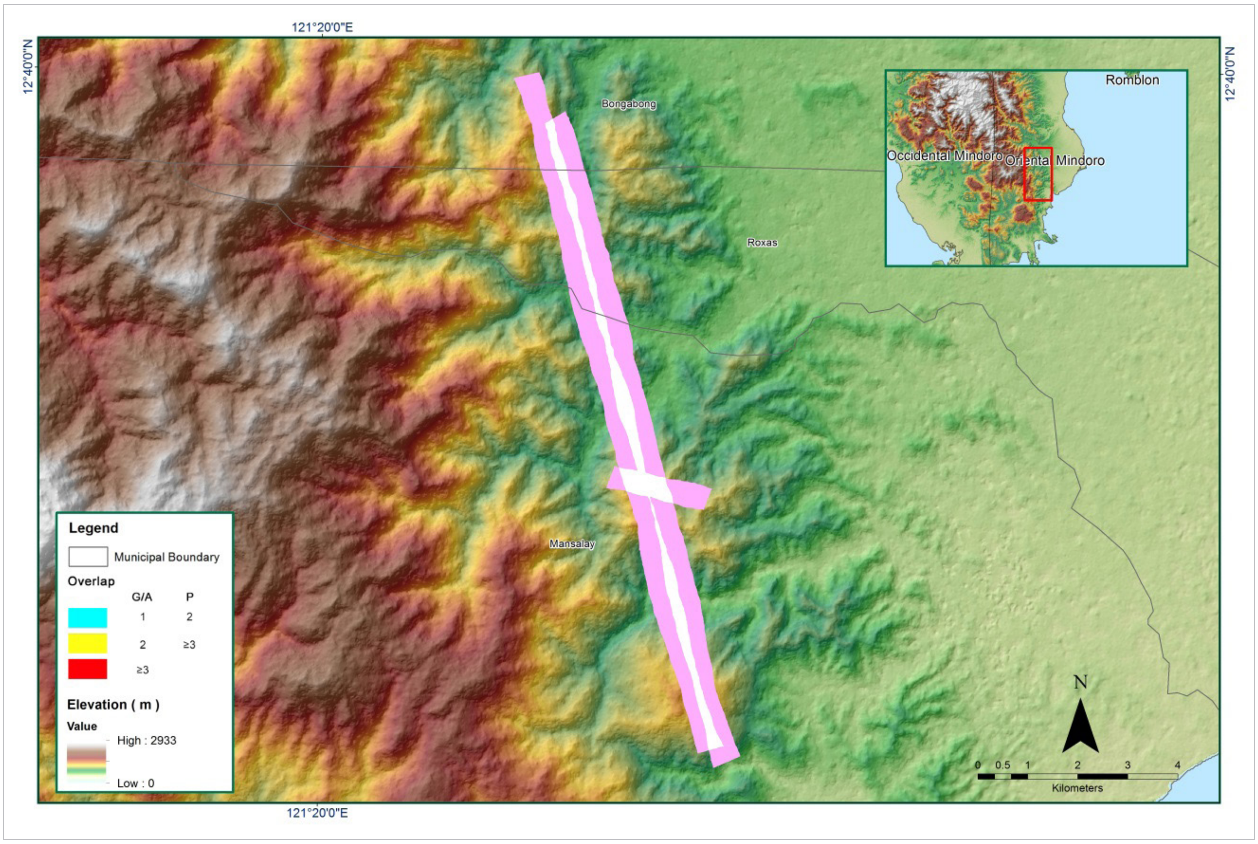


Figure A-8.40 Image of data overlap

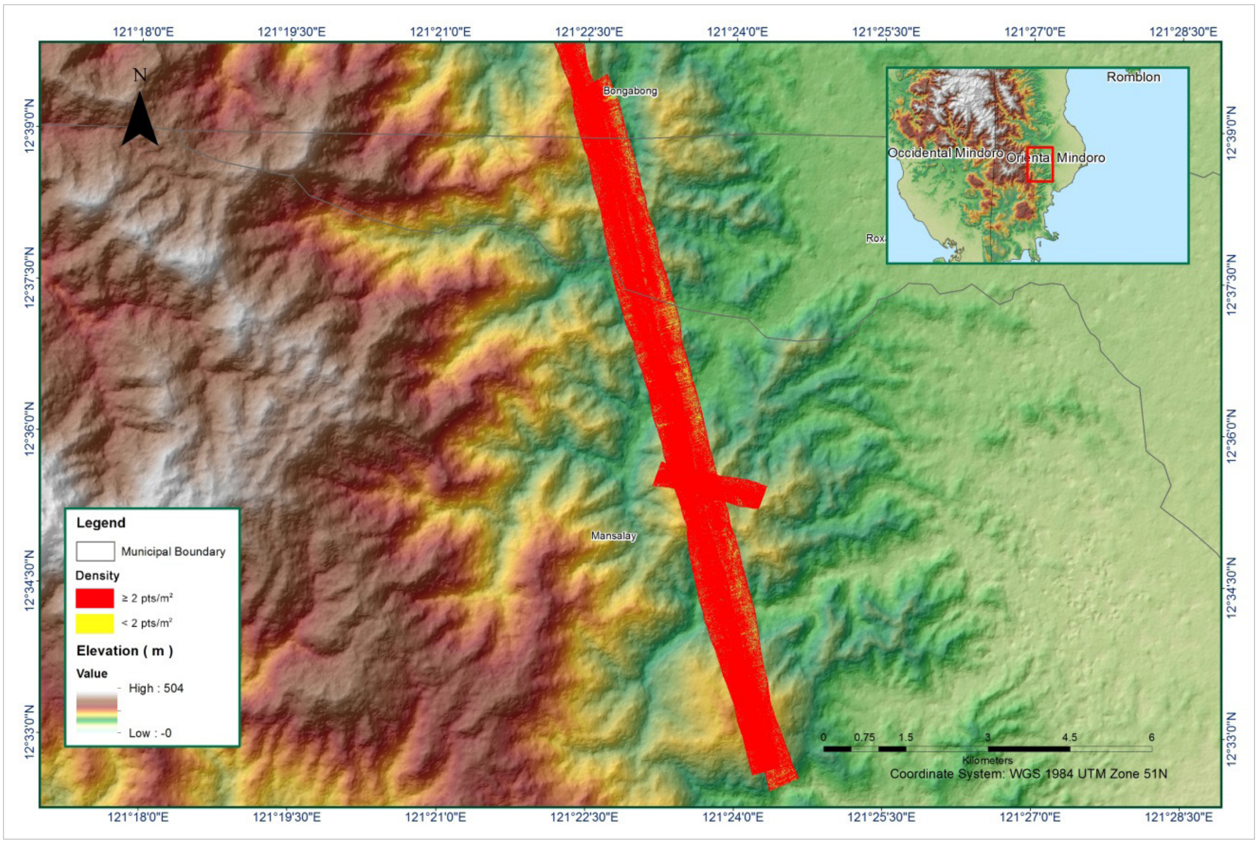


Figure A-8.41 Density map of merged LiDAR data

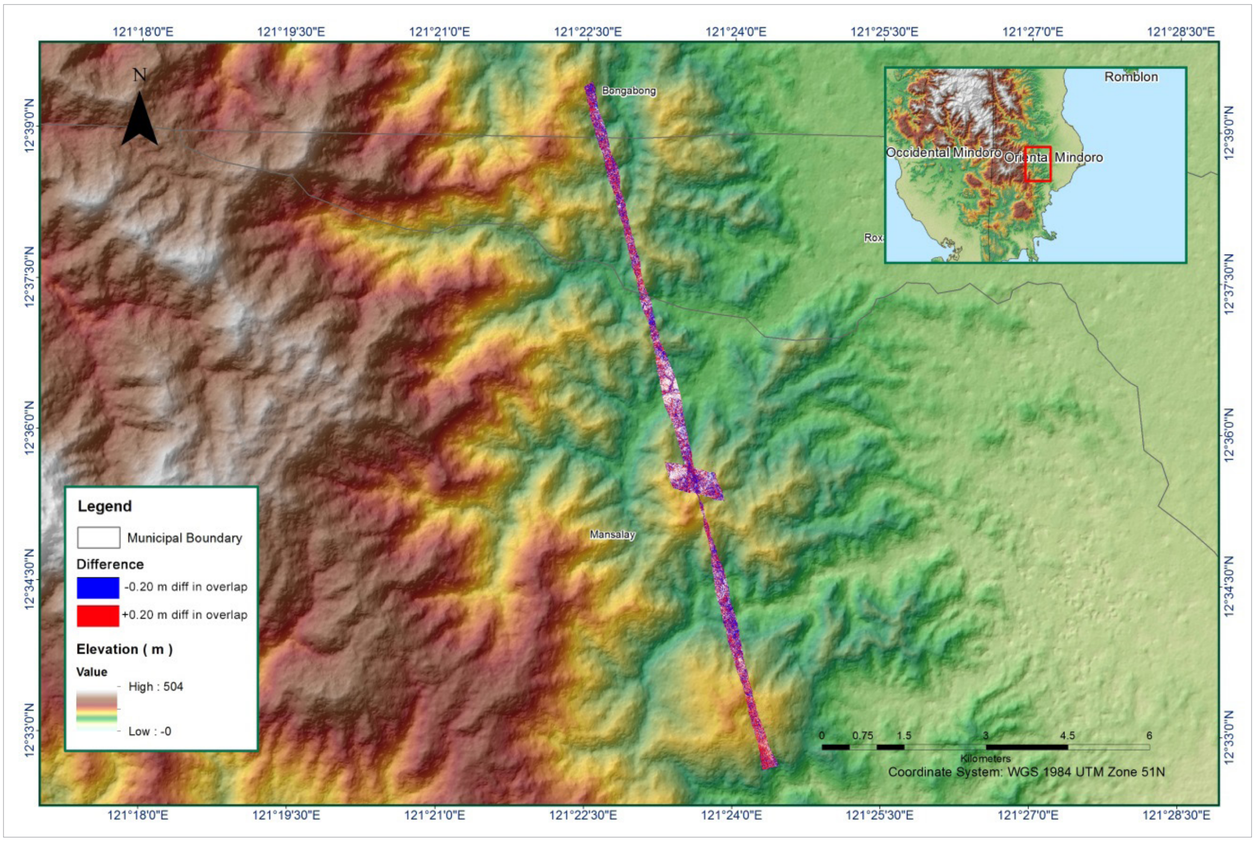


Figure A-8.42 Elevation difference between flight lines

ANNEX 9. Baroc Model Basin Parameters

Table A-9.1. Baroc Model Basin Parameters

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow		
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W180	97.445	57.894	0	0.22284	24.89	0.0877935	0.0146523	0.028937
W190	75.877	41.593	0	70.875	4.2733	0.0689929	0.0128978	0.05
W200	163.67	65.895	0	4.9397	13.701	0.0378764	0.010097	0.038451
W210	66.091	70.986	0	0.0717933	13.028	0.0288059	0.0213674	0
W220	83.763	41.483	0	139.04	3.7552	0.11125	0.055613	0.05
W230	48.629	50.999	0	0.22628	25.693	0.0437104	0.0101982	0.031373
W240	19.923	42.662	0	0.07228	10.393	0.0352833	0.0151357	0
W250	26.312	43.12	0	40.457	18.386	0.10460	0.0218044	0
W260	107.27	68.065	0	2.8733	9.6894	0.0453107	0.0402129	0.033333
W270	163.49	65.895	0	0.32371	24.407	0.0348884	0.0067662	0.019685
W280	10.74	54.18	0	8.296	13.53902647	0.16431	1	0.5
W290	8.2934	60.495	0	3.564	5.81646193	0.0579914	1	0.5
W300	3.7162	77.362	0	1.5959	2.604522207	0.0155103	1	0.5
W320	8.9599	58.634	0	4.2512	5.636745396	0.0021075	1	0.5
W340	10.144	55.596	0	3.2907	6.937916632	0.0280798	1	0.5
W360	7.5149	62.825	0	3.4539	7.525604316	0.0048867	1	0.5
W370	33.025	83.826	0	0.0719467	7.7313	0.0081718	0.0101988	0.032014
W410	6.6529	65.623	0	4.6113	3.519608021	0.0057750	1	0.5
W420	10.338	55.126	0	6.5612	10.70783714	0.0146537	1	0.5

ANNEX 10. Baroc Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	1169.5	0.004598	0.0096	Trapezoid	25	1
R140	Automatic Fixed Interval	1745.8	0.002305	0.0096	Trapezoid	25	1
R160	Automatic Fixed Interval	1681.2	0.004598	0.0096	Trapezoid	25	1
R170	Automatic Fixed Interval	1165.7	0.004587	0.0096	Trapezoid	25	1
R30	Automatic Fixed Interval	3821.6	0.02263	0.01568	Trapezoid	25	1
R390	Automatic Fixed Interval	1938.9	0.000159	0.0109066	Trapezoid	25	1
R40	Automatic Fixed Interval	8950.8	0.006341	0.007056	Trapezoid	25	1
R440	Automatic Fixed Interval	4219.6	0.000595	0.0096	Trapezoid	25	1
R70	Automatic Fixed Interval	8547.8	0.021024	0.006793	Trapezoid	25	1
R90	Automatic Fixed Interval	8085.8	0.002798	0.0063804	Trapezoid	25	1

ANNEX 11. Baroc Field Validation Points

Table A-11.1. Baroc Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
1	12.5570440	121.4958550	0.67	0.83	0.16	Yolanda / November 2013	25-Year
2	12.5581030	121.4967540	1.13	1.09	-0.04	Unding / November 2004	25-Year
3	12.5596150	121.4921910	0.18	0.28	0.10	Unding / November 2004	25-Year
4	12.5606300	121.4961310	0.10	0.41	0.31	Yolanda / November 2013	25-Year
5	12.5607840	121.4954640	0.14	0.00	-0.14		25-Year
6	12.5608390	121.5007830	0.05	0.38	0.33	Yolanda / November 2013	25-Year
7	12.5608780	121.4949590	0.11	0.42	0.31		25-Year
8	12.5609490	121.4952580	0.14	0.48	0.34	Unding / November 2004	25-Year
9	12.5610080	121.5013430	0.03	1.05	1.02	Unding / November 2004	25-Year
10	12.5609640	121.4921270	0.18	0.31	0.13	Yolanda / November 2013	25-Year
11	12.5611390	121.4980050	0.04	0.32	0.28	Unding / November 2004	25-Year
12	12.5611630	121.5001340	0.03	0.58	0.55	Unding / November 2004	25-Year
13	12.5613760	121.4978450	0.04	0.48	0.44	Yolanda / November 2013	25-Year
14	12.5613900	121.4976360	0.03	0.46	0.43	Yolanda / November 2013	25-Year
15	12.5614260	121.4981790	0.03	0.15	0.12		25-Year
16	12.5615240	121.5001560	0.03	0.29	0.26	Unding / November 2004	25-Year
17	12.5615650	121.4991360	0.06	0.51	0.45		25-Year
18	12.5616740	121.4999130	0.11	0.52	0.41	Unding / November 2004	25-Year
19	12.5617800	121.4918060	0.41	0.23	-0.18	Unding / November 2004	25-Year
20	12.5619650	121.4991690	0.09	0.46	0.37	Unding / November 2004	25-Year
21	12.5623390	121.4920600	0.23	0.65	0.42	Unding / November 2004	25-Year
22	12.5624220	121.4918450	0.35	0.74	0.39	Unding / November 2004	25-Year
23	12.5628550	121.4919240	0.03	0.28	0.25	Unding / November 2004	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
24	12.5628550	121.4919240	0.27	0.28	0.01	Unding / November 2004	25-Year
25	12.5630930	121.4918210	0.04	0.92	0.88	Unding / November 2004	25-Year
26	12.5641270	121.4916130	0.04	0.32	0.28	Ondoy / September 2009	25-Year
27	12.5642350	121.4913400	0.03	0.54	0.51	Yolanda / November 2013	25-Year
28	12.5645690	121.4909930	0.06	1.00	0.94	Atang / 2002	25-Year
29	12.5646180	121.4910720	0.05	0.42	0.37	Ondoy / September 2009	25-Year
30	12.5647460	121.4907720	0.05	0.54	0.49	Unding / November 2004	25-Year
31	12.5672580	121.4803810	0.10	0.30	0.20	Unding / November 2004	25-Year
32	12.5672140	121.4677310	0.84	0.45	-0.39	Unding / Nov. 2004	25-Year
33	12.5673640	121.4800130	0.03	0.09	0.06	Yolanda / November 2013	25-Year
34	12.5678810	121.4666050	0.68	0.43	-0.25	Yolanda / Nov. 8, 2013	25-Year
35	12.5680780	121.4896080	0.36	0.80	0.44	Yolanda / November 2013	25-Year
36	12.5679330	121.4612500	0.23	0.45	0.22	Unding / Nov. 2004	25-Year
37	12.5682790	121.4611340	0.18	0.40	0.22	Ondoy / Sept. 26, 2009	25-Year
38	12.5683680	121.4658800	1.02	0.25	-0.77	Unding / Nov. 2004	25-Year
39	12.5685910	121.4896430	0.14	1.07	0.93	Unding / November 2004	25-Year
40	12.5684400	121.4629680	0.79	0.55	-0.24	Unding / Nov. 2004	25-Year
41	12.5685530	121.4618250	0.46	0.15	-0.31	Ondoy / Sept. 26, 2009	25-Year
42	12.5688100	121.4609780	0.07	0.40	0.33	Ondoy / Sept. 26, 2009	25-Year
43	12.5691030	121.4632210	1.01	0.56	-0.45	Unding / Nov. 2004	25-Year
44	12.5692590	121.4593510	0.04	0.25	0.21	Unding / Nov. 2004	25-Year
45	12.5693230	121.4698630	0.06	0.25	0.19	Unding / Nov. 2004	25-Year
46	12.5693670	121.4601260	0.15	0.34	0.19	Yolanda / Nov. 8, 2013	25-Year
47	12.5695100	121.4593470	0.03	0.43	0.4	Unding / Nov. 2004	25-Year
48	12.5698920	121.4727240	0.56	0.60	0.04	Yolanda / Nov. 8, 2013	25-Year
49	12.5708460	121.4564510	0.35	0.93	0.58	Yolanda / Nov. 8, 2013	25-Year
50	12.5709780	121.4568200	0.52	0.53	0.01	Unding / Nov. 2004	25-Year
51	12.5710900	121.4558810	0.61	0.53	-0.08	Unding / Nov. 2004	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
52	12.5717200	121.4626290	0.86	0.45	-0.41	Yolanda / Nov. 8, 2013	25-Year
53	12.5719290	121.4615710	0.82	0.38	-0.44	Yolanda / Nov. 8, 2013	25-Year
54	12.5720080	121.4520860	0.28	0.60	0.32	Oct. 2014	25-Year
55	12.5722560	121.4512940	0.49	0.35	-0.14	Oct. 2014	25-Year
56	12.5734090	121.4503390	0.42	0.52	0.1	Yolanda / Nov. 8, 2013	25-Year
57	12.5752360	121.4516640	0.39	0.45	0.06	Unding / Nov. 2004	25-Year
58	12.5758030	121.4809240	0.43	0.24	-0.19	Yolanda / Nov. 8, 2013	25-Year
59	12.5758610	121.4811880	0.23	0.45	0.22	Yolanda / Nov. 8, 2013	25-Year
60	12.5766120	121.4806260	0.46	0.85	0.39	Caloy / May, 2006	25-Year
61	12.5774720	121.4802100	0.57	1.15	0.58	Unding / Nov. 2004	25-Year
62	12.5779920	121.4794820	0.75	0.49	-0.26	Yolanda / Nov. 8, 2013	25-Year
63	12.5781460	121.4443890	1.22	0.94	-0.28	Unding / Nov. 2004	25-Year
64	12.5783180	121.4444930	1.34	0.65	-0.69	Oct. 2014	25-Year
65	12.5785570	121.4438120	1.53	0.95	-0.58	Oct. 2014	25-Year
66	12.5792670	121.4796770	0.75	0.82	0.07	Caloy / May, 2006	25-Year
67	12.5794590	121.4789290	0.28	0.15	-0.13	Caloy / May, 2006	25-Year
68	12.5798350	121.4781490	0.04	0.05	0.01	Unding / Nov. 2004	25-Year
69	12.5801200	121.4786640	0.11	0.00	-0.11	Unding / Nov. 2004	25-Year
70	12.5803330	121.4790060	0.03	0.12	0.09	Unding / Nov. 2004	25-Year
71	12.5814080	121.4605990	0.55	0.35	-0.2	Oct. 2014	25-Year
72	12.5814590	121.4608160	0.32	0.56	0.24	Unding / Nov. 2004	25-Year
73	12.5815690	121.4603820	0.90	1.20	0.3	Yolanda / Nov. 8, 2013	25-Year
74	12.5815930	121.4405190	0.76	0.50	-0.26	Oct. 2014	25-Year
75	12.5819560	121.4607280	0.81	1.17	0.36	Yolanda / Nov. 8, 2013	25-Year
76	12.5819610	121.4402280	1.22	0.86	-0.36	Oct. 2014	25-Year
77	12.5824820	121.4612240	0.84	0.95	0.11	Oct. 2014	25-Year
78	12.5824060	121.4395180	1.01	0.95	-0.06	Oct. 2014	25-Year
79	12.5825840	121.4608700	1.48	1.21	-0.27	Oct. 2014	25-Year
80	12.5833650	121.4621100	0.48	0.75	0.27	Ondoy / Sept. 26, 2009	25-Year
81	12.5835020	121.4626530	0.04	0.70	0.66	Unding / Nov. 2004	25-Year
82	12.5850870	121.4648940	0.15	0.90	0.75	Ondoy / Sept. 26, 2009	25-Year
83	12.5854430	121.4653800	0.11	0.30	0.19	Ondoy / Sept. 26, 2009	25-Year
84	12.5855280	121.4728500	0.15	0.00	-0.15	Caloy / May, 2006	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Rain Return/ Scenario
	Lat	Long					
85	12.5862540	121.4722590	0.21	0.15	-0.06	Caloy / May, 2006	25-Year
86	12.5869050	121.4716770	0.14	0.00	-0.14	Yolanda / Nov. 8, 2013	25-Year
87	12.5878570	121.4713750	0.07	0.35	0.28	Ondoy / Sept. 26, 2009	25-Year
88	12.5880630	121.4706610	0.03	0.41	0.38	Unding / Nov. 2004	25-Year
89	12.5889750	121.4706330	0.03	0.00	-0.03	Unding / Nov. 2004	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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

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

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

Research Associates
Alfi Lorenz B. Cura
Angelica T. Magpantay
Gemmalyn E. Magnaye
Jayson L. Arizapa
Kevin M. Manalo
Leendel Jane D. Punzalan
Maria Michaela A. Gonzales
Paulo Joshua U. Quilao
Sarah Joy A. Acepcion
Ralphael P. Gonzales

Computer Programmers
Ivan Marc H. Escamos
Allen Roy C. Roberto

Information Systems Analyst
Jan Martin C. Magcale

Project Assistants
Daisili Ann V. Pelegrina
Athena Mercado
Kaye Anne A. Matre
Randy P. Porciocula