Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Binabang-Molino River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mapua Institute of Technology

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ASTI	Advanced Science and Technology Institute
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
BSWM	Bureau of Soils 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
MIT	Mapúa Institute of Technology
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
PSA	Philippine Statistics Authority
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RBCO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
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 BINABANG-MOLINO RIVER

Enrico C. Paringit, Dr. Eng., Dr. Francis Aldrine A. Uy, and Engr. Fibor Tan

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 a 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Mapúa Institute of Technology (MIT). MIT 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 twenty-six (26) river basins in the Southern Tagaog Region. The university is located in Manila City in Metropolitan Manila, or the National Capital Region (NCR).

1.2 Overview of the Binabang-Molino River Basin

The Binabang-Molino River Basin is a narrow watershed that covers portions of Bacoor and Dasmariñas in the province of Cavite, and Las Piñas in Metro Manila. It is one of the major river networks in the province of Cavite, and it serves as a boundary to the highly-urbanized cities of Bacoor and Las Piñas. The Department of Environment and Natural Resources – River Basin Control Office (DENR-RBCO) identified the basin to have an approximate land area of 108 square kilometers, with an estimated run-off of 173 million cubic meters (MCM) (River Basin Control Office, 2017).

The basin's main stem, the Binabang-Molino River, is among the twenty-five (25) rivers in the Southern Tagalog Region. The river delineation has an estimated length of 5.72 kilometers, which drains towards the Manila Bay.

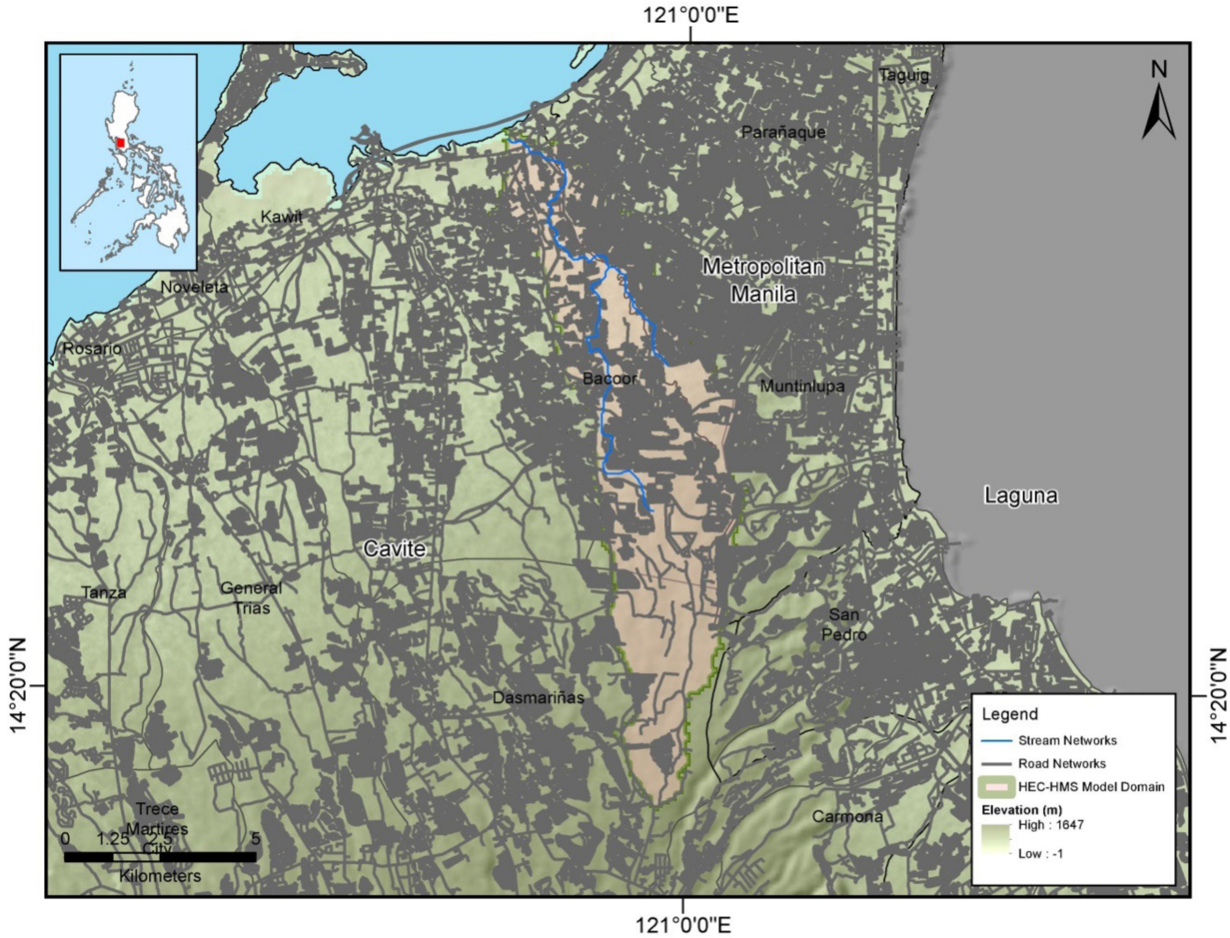

Figure 1. Location map of the Binabang-Molino River Basin (in brown)

According to the 2015 census of the Philippine Statistics Authority (PSA), the total population of residents living within the immediate vicinity of the river is 520, 216 people. The river also irrigates rice fields through the Molino Dam, which is a tourist destination featuring a floating bamboo restaurant.

The river was once a rich source of freshwater fish and edible snails, and served as a popular picnic destination for locals. Unfortunately, the rapid increase of population and commercial activity in the area significantly polluted the river, filling the water with domestic wastes and killing its once vigorous marine life.

Besides its poor water quality caused by extensive pollution, the Binabang-Molino River is also plagued by frequent severe typhoons. Since the river is a recurrent pathway of tropical storms, flooding has been a perennial problem in the surrounding cities and municipalities. Not only does this damage properties; more crucially, it endangers the lives of people due to the risk of drowning, and the exposure to diseases brought about by organisms thriving in the stagnant floodwaters.

Most recently, the landfall of Typhoon Maring in August 2013 caused the Binabang-Molino River to swell, and submerged almost half of Bacoor City in the province of Cavite. The flood inundated the barangays (villages) of Maliksi 1, 2 and 3; Talaba 1 and 2; Zapote 1, 2, 3, 4, and 5; Aniban 1 to 5; Niog 1 to 3; Panapaan 1 to 8; Talaba 1 to 7; Mambog 4 and 5; Ligas 1, Real 2, Banalo, Salinas, Tabing-dagat, Camposanto; and portions of Molino. The flooding damaged several properties and brought different kinds of diseases to the residents.

To prevent, or at least minimize, the impact of the flooding to the people and properties in the river basin, a combination of several technologies were employed by the Phil-LiDAR 1 Program in order to produce flood hazard maps. The first is Light Detection and Ranging (LiDAR), which primarily obtains data on elevation values in the floodplain. From these data, one can infer the presence of water bodies (e.g., rivers, streams, ponds, and lakes) and structures (e.g., roads, bridges, and buildings) in the covered area. Next, important data, such as discharge and rainfall events, gathered through fieldwork were used as input into the hydrologic model to generate hydrographs. The generated outputs, along with the LiDAR data, were then utilized to form the river hydraulic model. The final outputs for these processes were the flood hazard maps of the river basin, which shall aid the concerned local government units (LGUs) in disaster planning for the areas under their jurisdiction.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BINABANG-MOLINO FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Binabang-Molino floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Cavite. These missions were planned for eight (8) lines that ran for at most three and a half (3.5) hours, including take-off, landing, and turning time. The Pegasus LiDAR system was used for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the Pegasus system are found in Table 1. Figure 2 illustrates the flight plans for the Binabang-Molino floodplain survey.

Table 1. Flight planning parameters for the Pegasus 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)
BLK18B	1000	30	50	200	50	130	5
BLK18C	1000	30	50	200	50	130	5
BLK18D	1000	30	50	200	50	130	5
BLK18A	1000/1100	30	50	200	50	130	5
BLK18X	1200	30	50	200	50	130	5

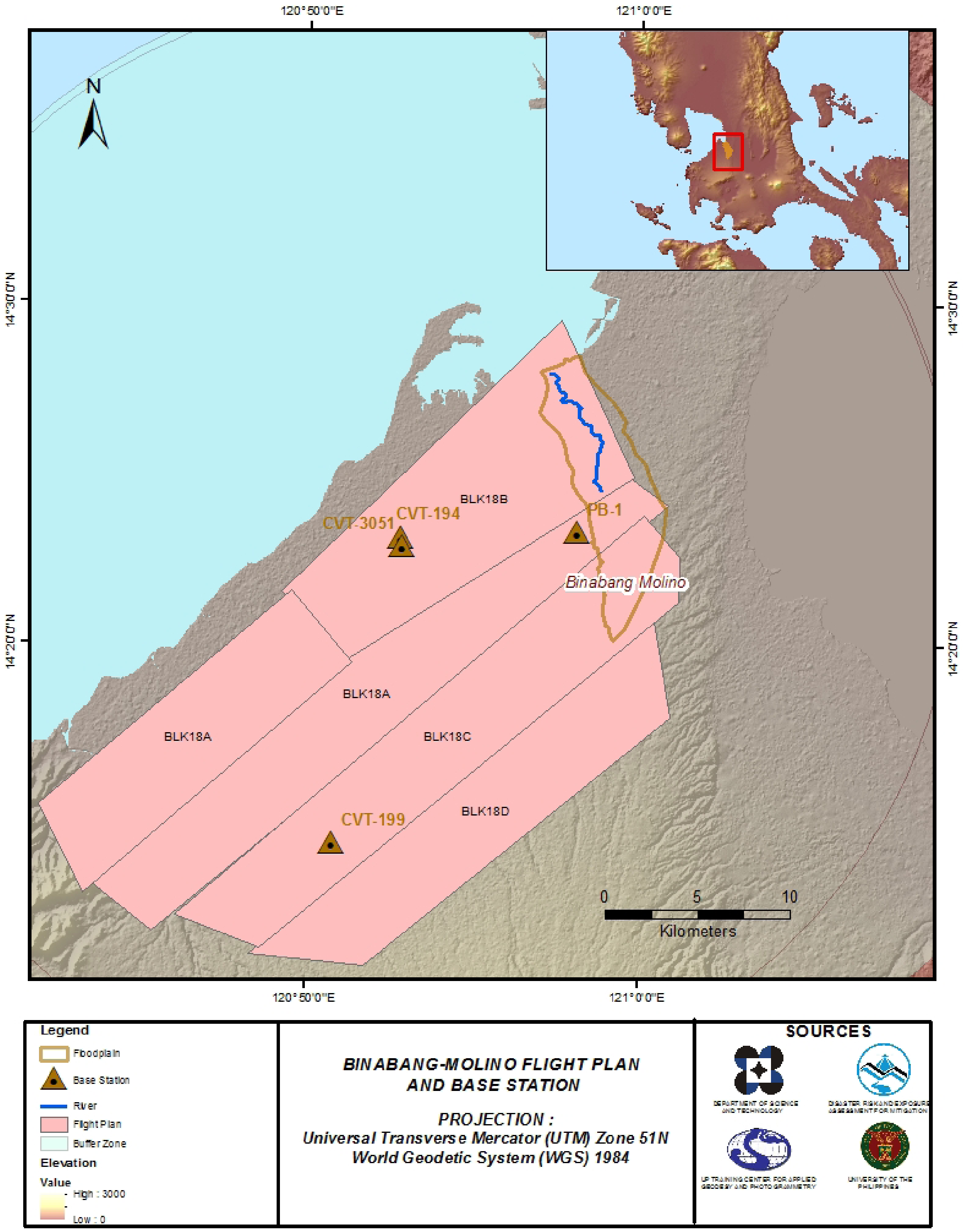
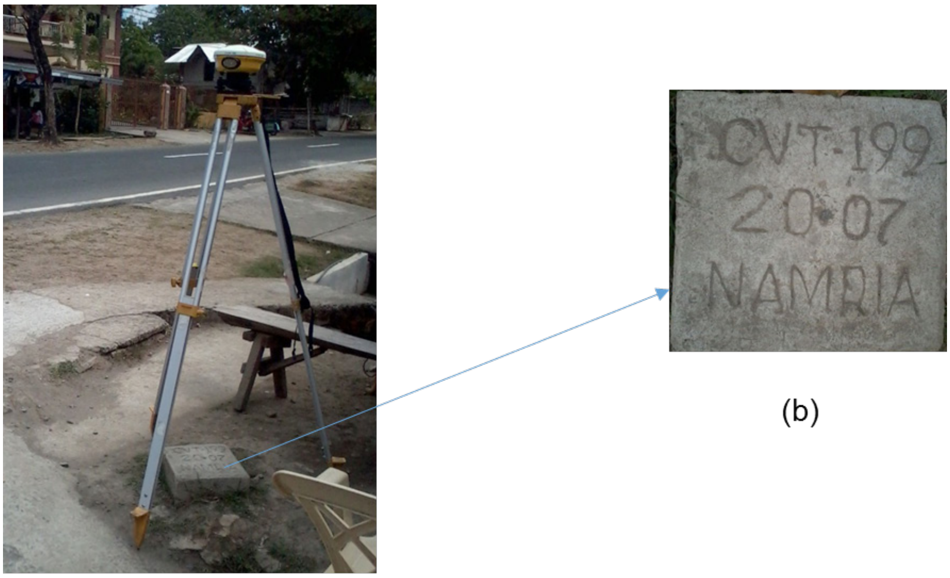


Figure 2. Flight plans and base stations used to cover the Binabang-Molino floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover three (3) NAMRIA ground control points: CVT-199, CVT-194, and BTG-45, which are of second (2^{nd}) order accuracy. The project team also established two (2) ground control points: PB-1 and BTG-45A; and re-processed one (1) NAMRIA reference point: CVT-3051. The certifications for the base stations are found in Annex 2; while the baseline processing reports for the re-processed ground control point and established points are found in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on January 26-February 28, 2014, and on August 18, 2015. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, TRIMBLE SPS 852, and TOPCON GR5. The flight plans and locations of base stations used during the aerial LiDAR acquisition in the Binabang-Molino floodplain are shown in Figure 2. The composition of the project team is given in Annex 4.

Figure 3 to Figure 7 exhibit the recovered NAMRIA reference points and established points within the area. Table 2 to Table 7 provide the details about the NAMRIA control stations. Table 8 lists all of the ground control points occupied during the acquisition, together with the dates of utilization.



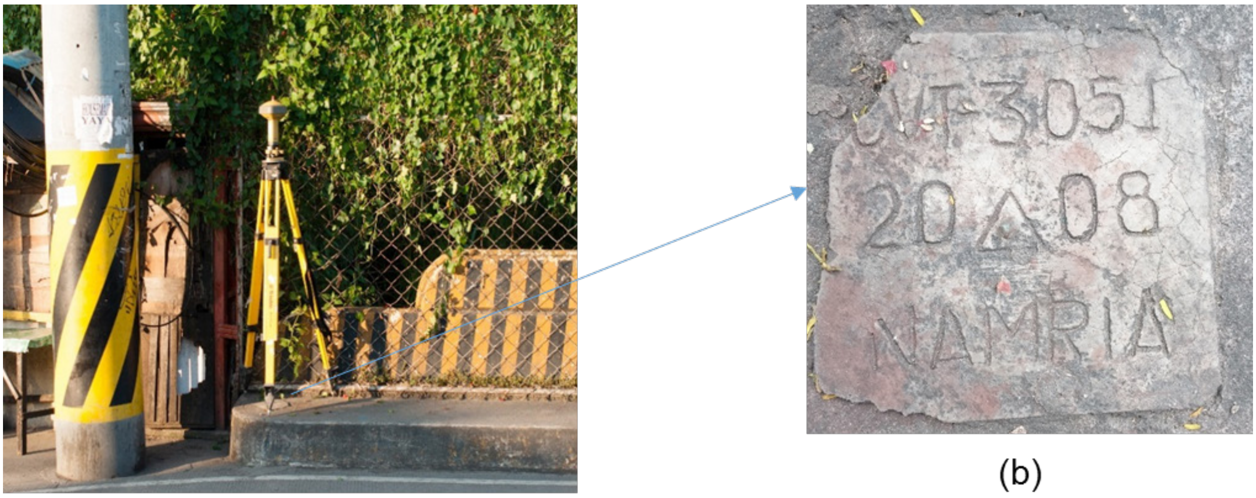
(b)

(a)

Figure 3. (a) GPS set-up over CVT-199 found near the basketball covered court of Barangay Calumpang Lejos; and (b) NAMRIA reference point CVT-199, as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point CVT-199, used as a base station for the LiDAR acquisition

Station Name	CVT-199	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 14’ 16.32329” North
	Longitude	120° 50’ 40.63536” East
	Ellipsoidal Height	166.20100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Northing	1574493.218 meters
	Easting	483231.789 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	14° 14’ 10.97763” North
	Longitude	120° 50’ 45.56096” East
	Ellipsoidal Height	210.38600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting	267, 428.74 meters
	Northing	1,575,012.80 meters

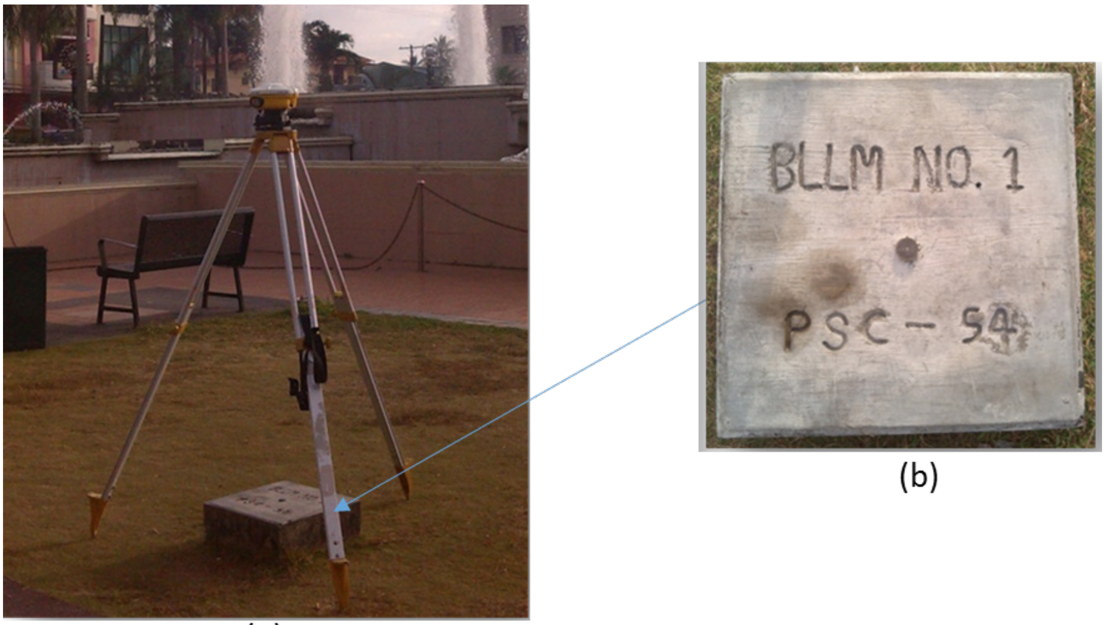


(a) (b)

Figure 4. (a) GPS set-up over CVT-3051 in a concrete bridge leading to Manggahan, 70 m SE of Jetti Gas Station and about 250 m from Gen. Trias Poblacion; and (b) NAMRIA reference point CVT-3051, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point CVT-3051 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	CVT-3051	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 22′ 58.33330″ North 120° 52′ 44.06059″East 21.122 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 22′52.95639″ North 120° 52′ 48.97372 East″ 64.983 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	271276.565 meters 1591024.612 meters

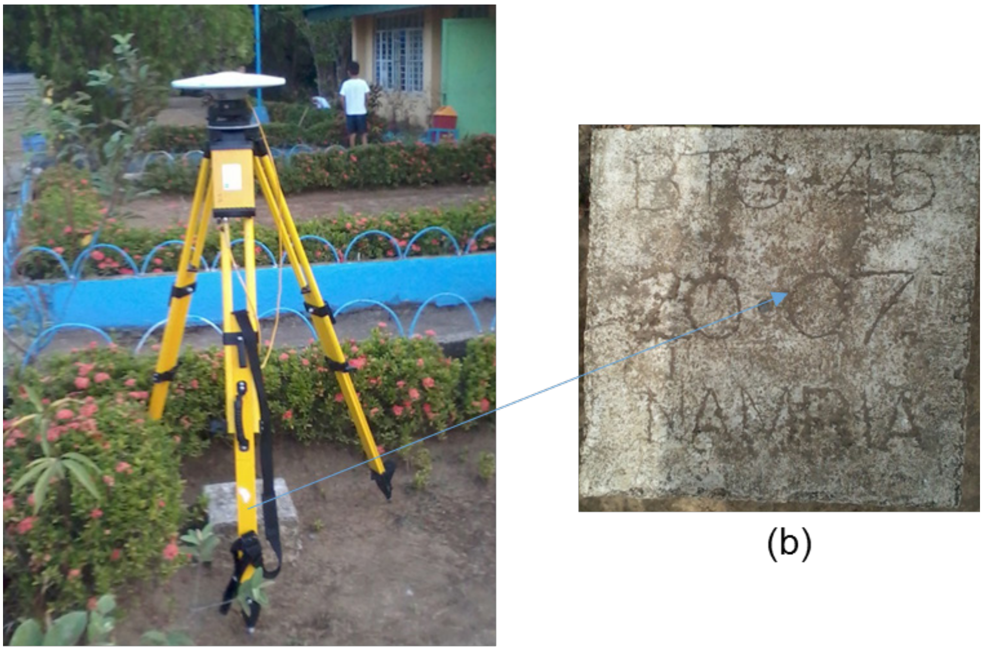


(a) (b)

Figure 5. (a) GPS set-up over CVT-194 (BLLM NO.1 PSC-94) near the Municipal Hall of Gen. Trias, Cavite; and (b) NAMRIA reference point CVT-194, as recovered by the field team

Table 4. Details of the recovered control point CVT-194, used as a base station for the LiDAR acquisition

Station Name	CVT-194	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 23’ 15.01186” North
	Longitude	120° 52’ 43.52184” East
	Ellipsoidal Height	18.337 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting	486924.253 meters
	Northing	1591045.311 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	14°23 ’9.63386” North
	Longitude	120° 52’ 48.43458” East
	Ellipsoidal Height	62.184 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	271265.13 meters
	Northing	1591537.44 meters



(a) (b)

Figure 6. (a) GPS set-up over BTG-45 inside Santiago De Guzman Elementary School in Barangay Malibu, Tuy, Batangas Province; and (b) NAMRIA reference point BTG-45, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point BTG-45, used as a base station for the LiDAR acquisition

Station Name	BTG-45	
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° 59’ 52.18294” North 120° 42’ 18.96476” East 48.43000 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	468159.677 meters 1547952.281 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 59’ 46.88216” North 120° 42’ 23.91169” East 92.94300 meters

(a) (b)

Figure 7. (a) GPS set-up over PB-1, as established in an elevated traffic island in Daang Hari Road, Imus, Cavite; and (b) reference point PB-1, as established by the field team

Table 6. Details of the established horizontal control point PB-1 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	PB-1	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 23’ 19.56635” North
	Longitude	120° 58’ 04.29835”East
	Ellipsoidal Height	87.568 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	14° 23’19.56635” North
	Longitude	120° 58’ 04.29835” East
	Ellipsoidal Height	87.568 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	280881.093 meters
	Northing	1591688.776 meters

Table 7. Details of the established control point BTG-45A with processed coordinates, used as a base station for the LiDAR acquisition

Station Name		BTG-45A
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° 59' 51.95603" North 120° 42' 18.98286 " East 49.08900 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Easting Northing	252126.100 meters 1548584.818 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 59' 46.65526" North 120° 42' 23.92980" East 93.60200 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
26 January 2014	1031P	1BLK18C026A	PB-1 and CVT-194
3 February 2014	1063P	1BLK18D034A	PB-1 and CVT-194
22 February 2014	1139P	1BLK18X53A	BTG-45 and BTG-45A
28 February 2014	1039P	1BLK18B028A	PB-1 and CVT-194
18 August 2015	3309P	1BLK18AsS230A	CVT-199 and CVT-3051

2.3 Flight Missions

A total of five (5) flight missions were conducted to complete the LiDAR data acquisition in the Binabang-Molino Floodplain, for a total of sixteen hours and forty-five minutes (16+45) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. The flight logs for the missions are provided in Annex 6. Table 9 indicates the total area of actual coverage and the corresponding flying hours per mission; while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for the LiDAR data acquisition in the Binabang-Molino 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
26 January 2014	1031P	124.00	124.01	3.10	120.91	NA	3	17
3 February 2014	1063P	601.14	190.00	19.41	170.59	348	2	59
22 February 2014	1139P	601.14	40.05	0.06	39.99	474	3	56
28 February 2014	1039P	601.14	82.85	NA	82.85	NA	3	17
18 August 2015	3309P	347.2	113.87	1.04	112.83	NA	3	16
TOTAL		2274.62	550.78	23.61	527.17	822	16	45

Table 10. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (AGL) (m)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1031P	1000	30	50	200	30	130	5
1063P	1000	30	50	200	30	130	5
1139P	1200	30	50	200	30	130	5
1039P	1000	30	50	200	30	130	5
3309P	1100	30	50	200	30	130	5

2.4 Survey Coverage

The Binabang-Molino floodplain is situated within the provinces of Batangas, Cavite, Laguna, and the NCR, with most of the floodplain located in Cavite. The City of Dasmariñas in Cavite was mostly covered during the survey. The municipalities and cities surveyed, with at least one (1) square kilometer coverage, are enumerated in Table 11. The actual coverage of the LiDAR acquisition for the Binabang-Molino floodplain is presented in Figure 8. See Annex 7 for the flight status reports.

Table 11. List of municipalities/cities surveyed during the Binabang-Molino floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Batangas	Nasugbu	266.83	3.42	1.28%
Cavite	Dasmariñas	84.01	66.76	89.99%
	General Trias	85.98	60.51	70.37%
	General Emilio Aguinaldo	39.39	23.18	58.86%
	Magallanes	69.07	32.34	46.82%
	Naic	76.11	34.52	45.36%
	Maragondon	147.39	65.04	44.13%
	Bacoor	47.43	17.77	37.48%
	Imus	56.81	19.56	34.43%
	Indang	88.65	26.57	29.97%
	Tanza	71.41	14.97	20.96%
	Amadeo	45.90	4.07	8.86%
	Silang	153.10	1.98	1.28%
Laguna	San Pedro	21.41	2.73	12.78%
NCR	Muntinlupa	38.52	7.26	18.86%
	Las Piñas	33.19	3.91	11.77%
Total		1325.2	384.59	33.33%

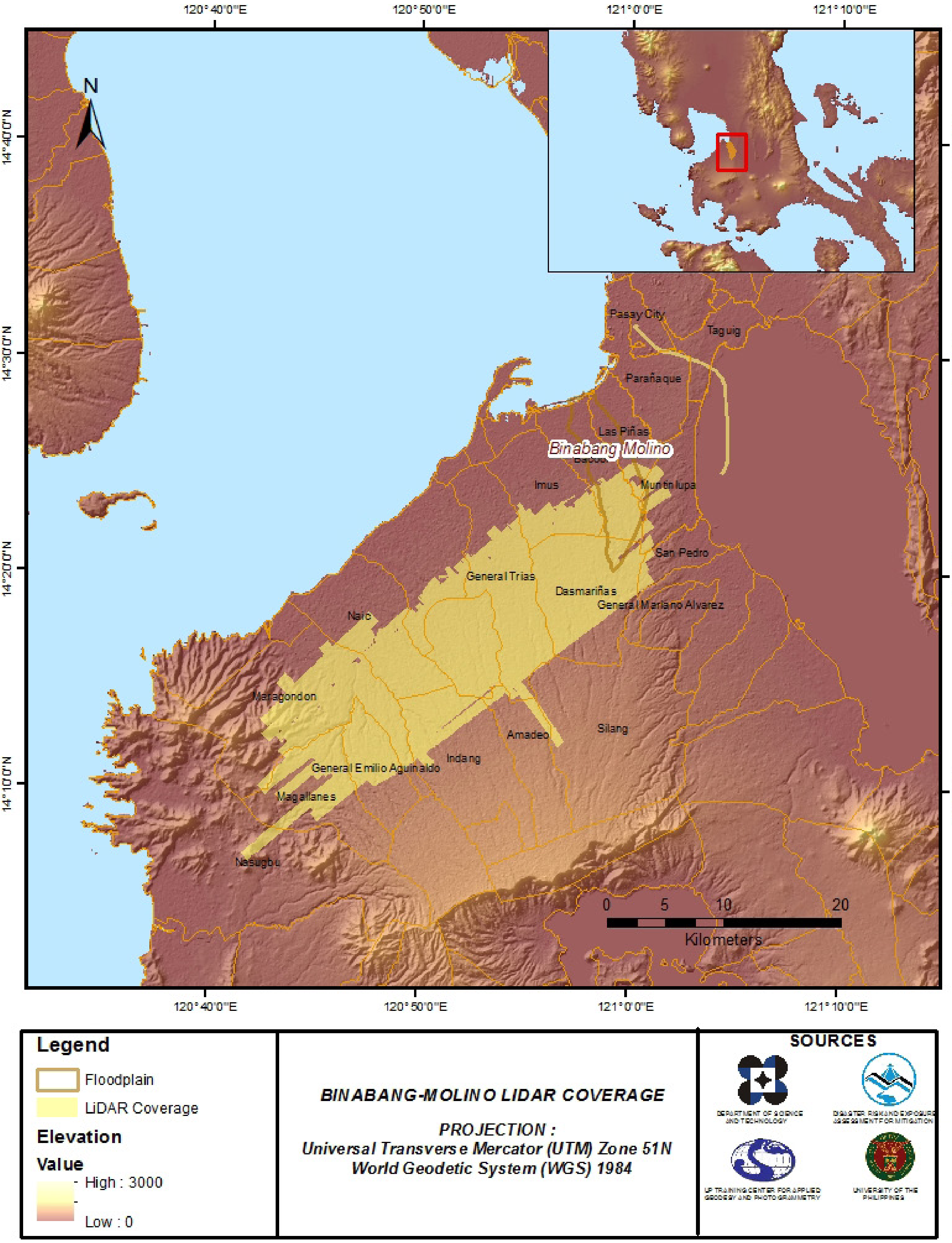


Figure 8. Actual LiDAR survey coverage of the Binabang-Molino floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BINABANG-MOLINO FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in diagram in Figure 9.

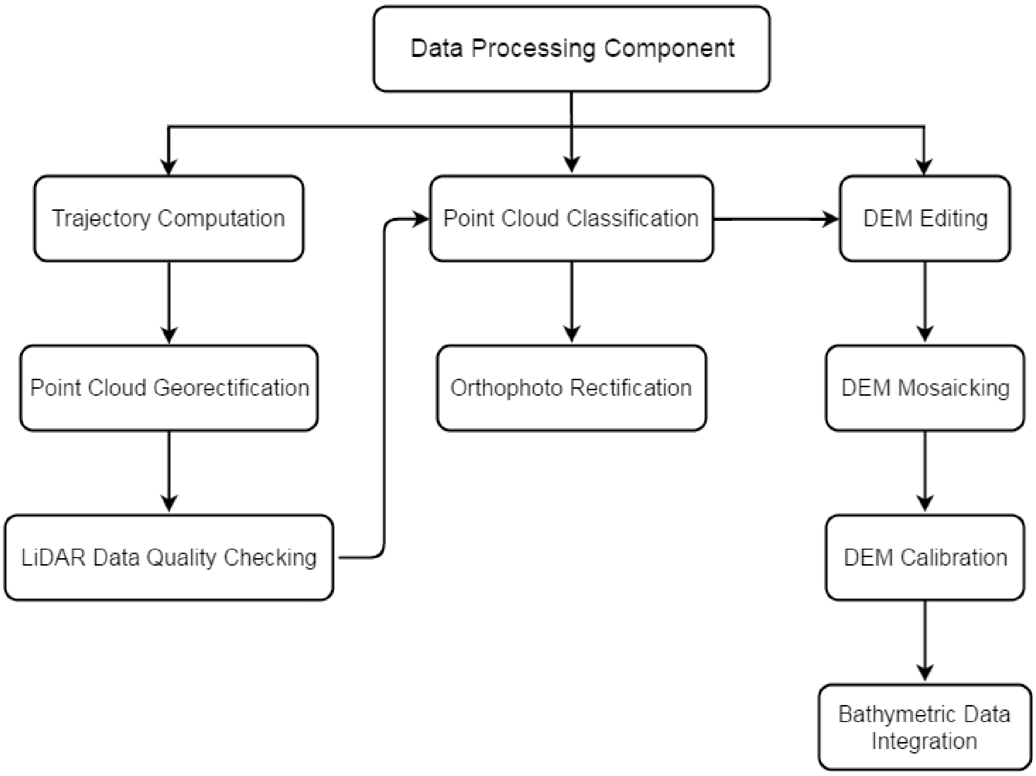


Figure 9. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Binabang-Molino floodplain are found in Annex 5. Missions flown over Bacoor, Cavite during the first survey conducted in November 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system. The DAC transferred a total of 99.70 Gigabytes of Range data, 1.15 Gigabytes of POS data, 54.26 Megabytes of GPS base station data, 55.65 Gigabytes of raw image data to the data server on September 11, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Binabang-Molino survey was fully transferred on February 29, 2016, as indicated on the data transfer sheets for the Binabang-Molino floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 3309P, one of the Binabang-Molino flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 10. 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 fell on August 19, 2015 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

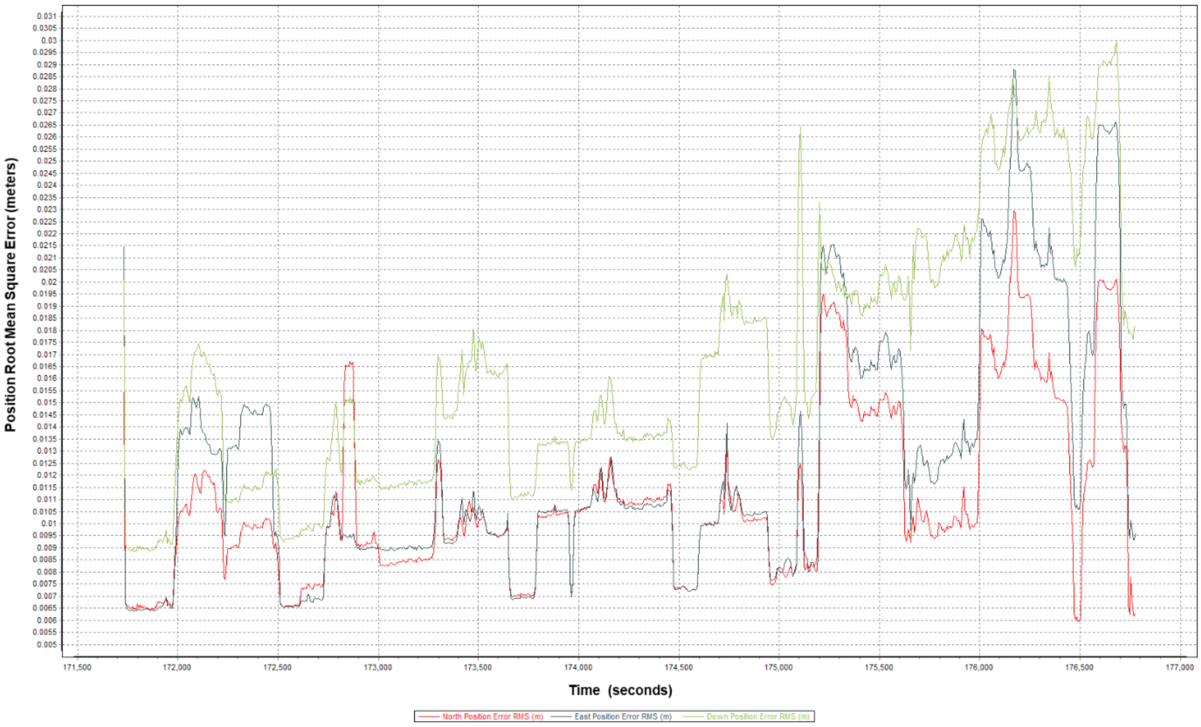


Figure 10. Smoothed Performance Metric Parameters of Binabang-Molino Flight 3309P

The time of flight was from 171500 seconds to 177000 seconds, which corresponds to the morning of August 18, 2015. The initial spike reflected on the data indicates the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute 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 set of RMSE values signifies the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 demonstrates that the North position RMSE peaked at 2.3 centimeters, the East position RMSE peaked at 2.8 centimeters, and the Down position RMSE peaked at 2.3 centimeters, which are within the prescribed accuracies described in the methodology.

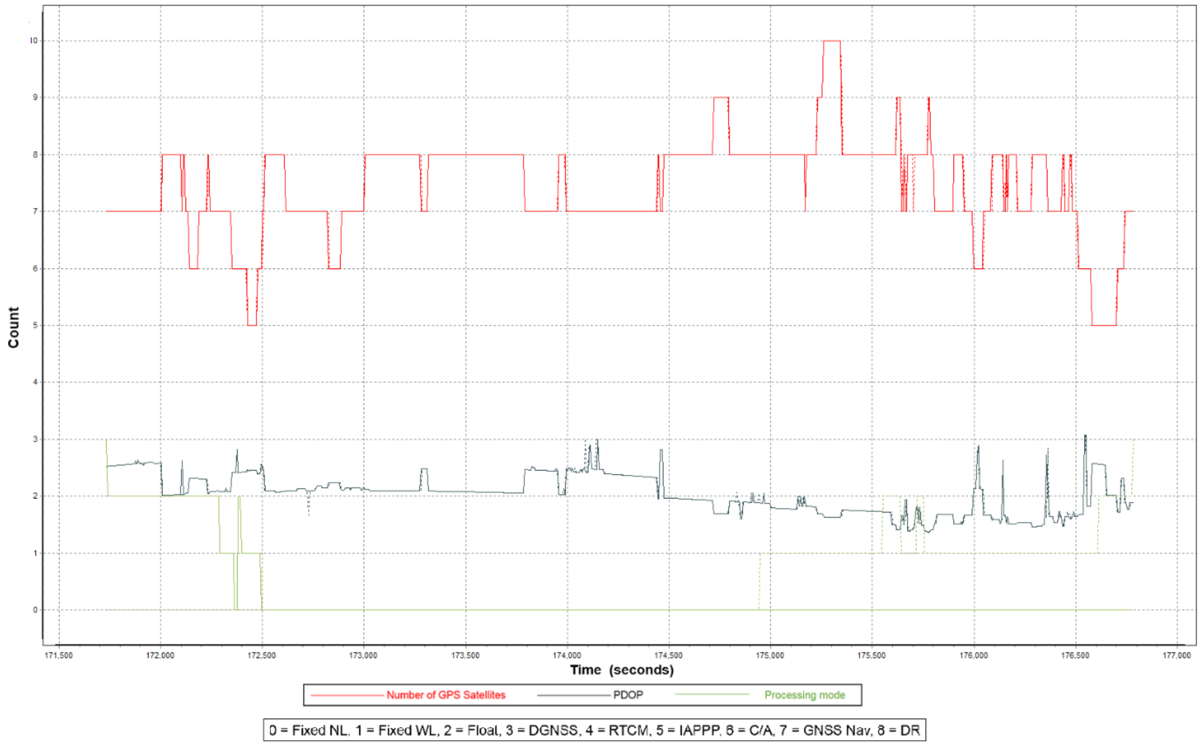


Figure 11. Solution Status Parameters of Binabang-Molino Flight 3309P

The Solution Status parameters of Flight 3309P, one of the Binabang-Molino flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are presented in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 5 and 10. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some peaks to up to 1, attributed to the turns performed by the aircraft. The value of 0 represents a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Binabang-Molino flights is exhibited in Figure 12.

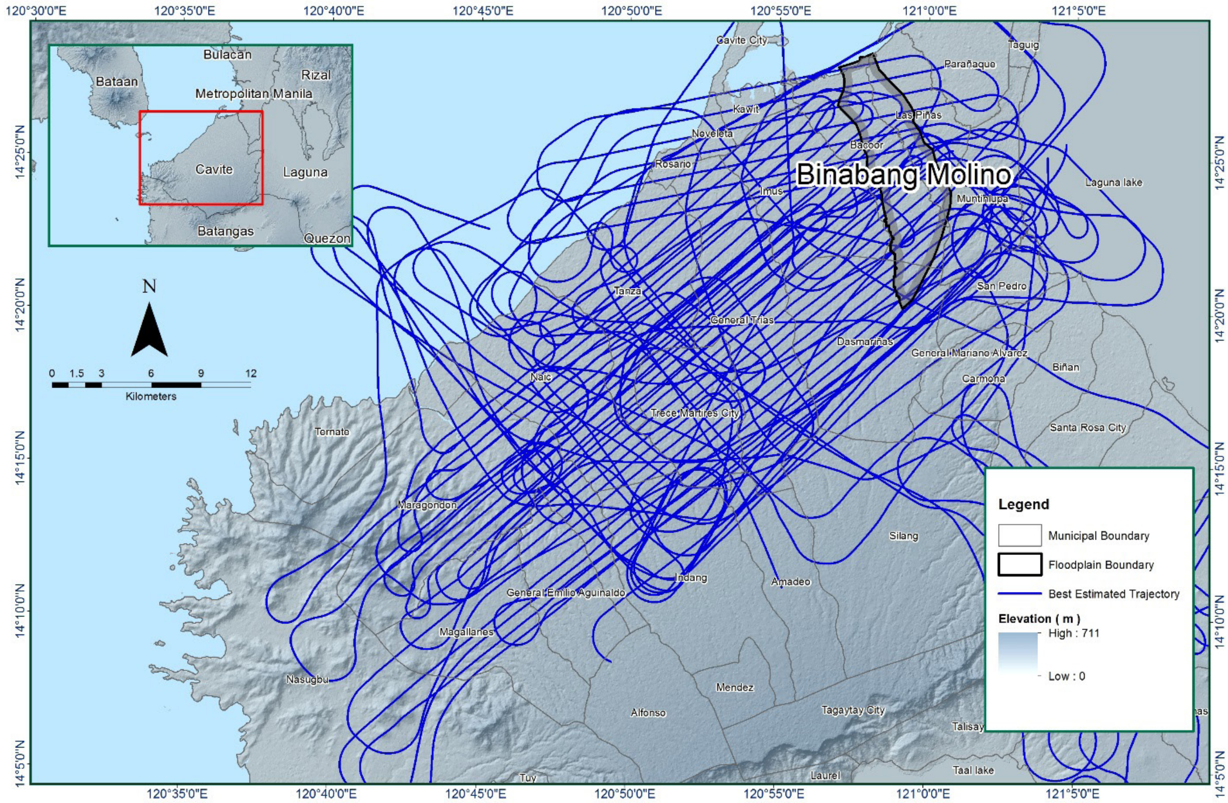


Figure 12. The best estimated trajectory conducted over the Binabang-Molino floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains forty-five (45) flight lines, with each flight line containing two (2) channels, since the Pegasus system consists of 2 (two) channels. The summary of the self-calibration results for all flights over the Binabang-Molino floodplain, obtained through LiDAR processing in LiDAR Mapping Suite (LMS) software, is given in Table 12.

Table 12. Self-calibration results for the Binabang-Molino flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000273
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000737
GPS Position Z-correction stdev	(<0.01meters)	0.0101

Optimum accuracy was obtained for all Binabang-Molino flights, based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for the individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Binabang-Molino floodplain are represented in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

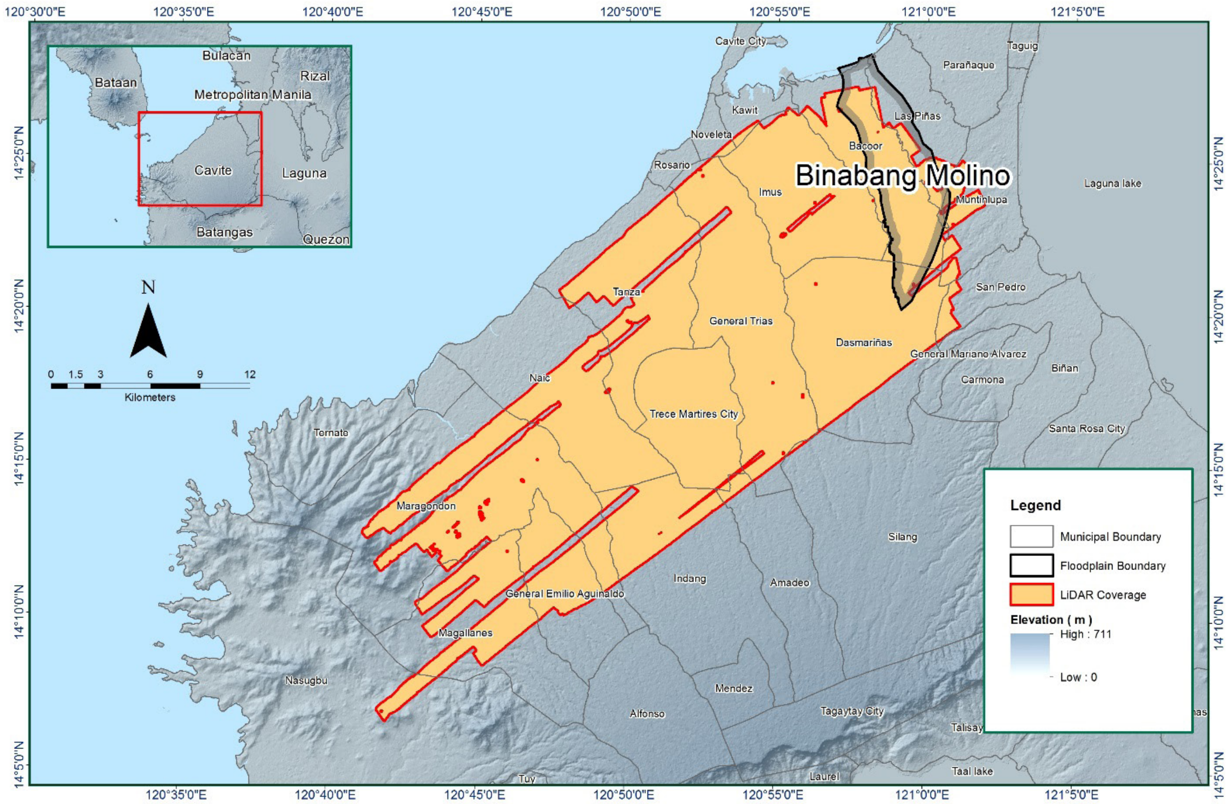


Figure 13. Boundaries of the processed LiDAR data over the Binabang-Molino floodplain

The total area covered by the Binabang-Molino missions is 680.53 square kilometers, comprised of six (6) flight acquisitions that are grouped and merged into five (5) blocks, as outlined in Table 13.

Table 13. List of LiDAR blocks for the Binabang-Molino floodplain

<table>
<tr><th>LiDAR Blocks</th><th>Flight Numbers</th><th>Area (sq. km)</th></tr>
<tr><td>CALABARZON_Blk18B_supplement</td><td>3309P</td><td>106.91</td></tr>
<tr><td>CALABARZON_reflights_Blk18B_supplement3</td><td>10321L</td><td>9.47</td></tr>
<tr><td>CALABARZON_reflights_Blk18B_supplement4</td><td>10321L</td><td>8.74</td></tr>
<tr><td rowspan="2">Cavite_Blk18AB</td><td>1031P</td><td rowspan="2">127.12</td></tr>
<tr><td>1027P</td></tr>
<tr><td>Cavite_Blk18C</td><td>1039P</td><td rowspan="2">117.91</td></tr>
<tr><td rowspan="2">Cavite_Blk18C_additional</td><td>1039P</td></tr>
<tr><td>1063P</td><td>210.76</td></tr>
<tr><td>Cavite_Blk18A_supplement2</td><td>1139P</td><td>99.62</td></tr>
<tr><td colspan="2">TOTAL</td><td>680.53 sq.km</td></tr>
</table>

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is depicted in Figure 14. Since the Pegasus system employs two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

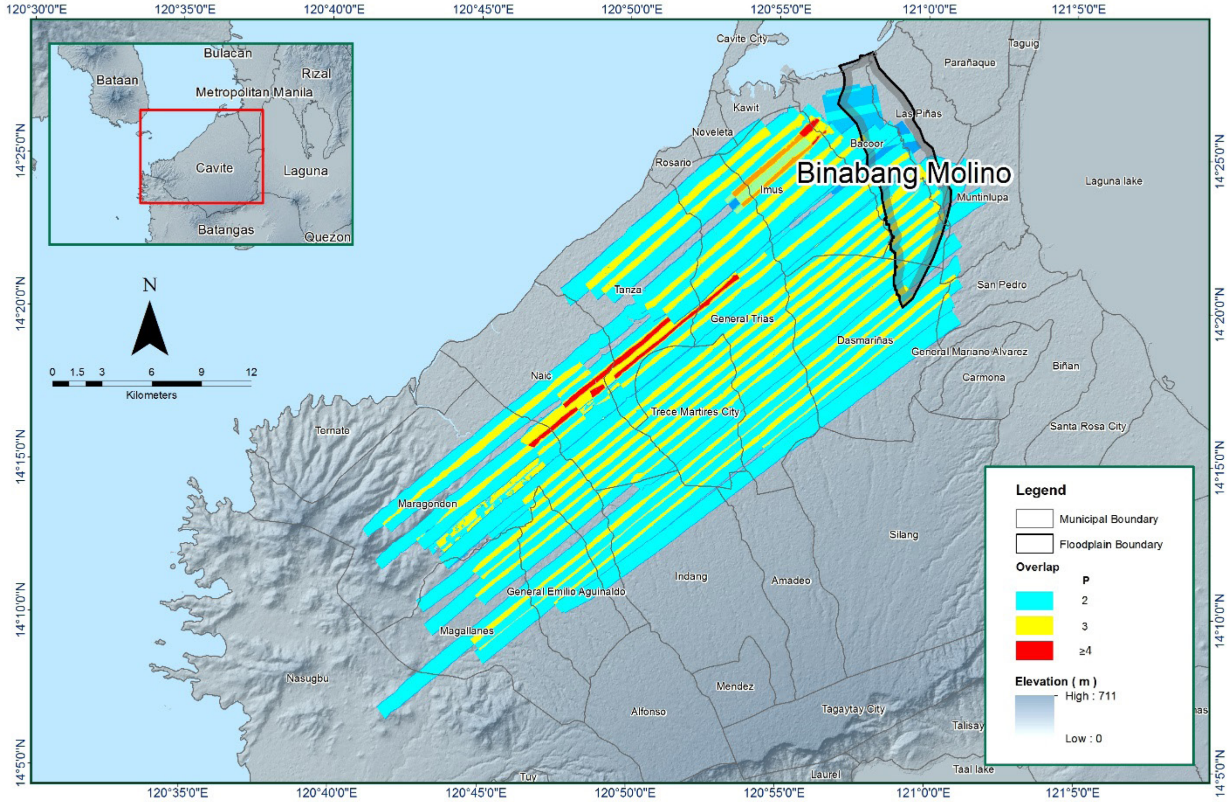


Figure 14. Image of data overlap for the Binabang-Molino floodplain

The overlap statistics per block for the Binabang-Molino floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap is 80.06%, which satisfied 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 two (2) points per square meter criterion, is illustrated in Figure 15. It was determined that all LiDAR data for the Binabang-Molino floodplain satisfy the point density requirement, and that the average density for the entire survey area is 2.32 points per square meter.

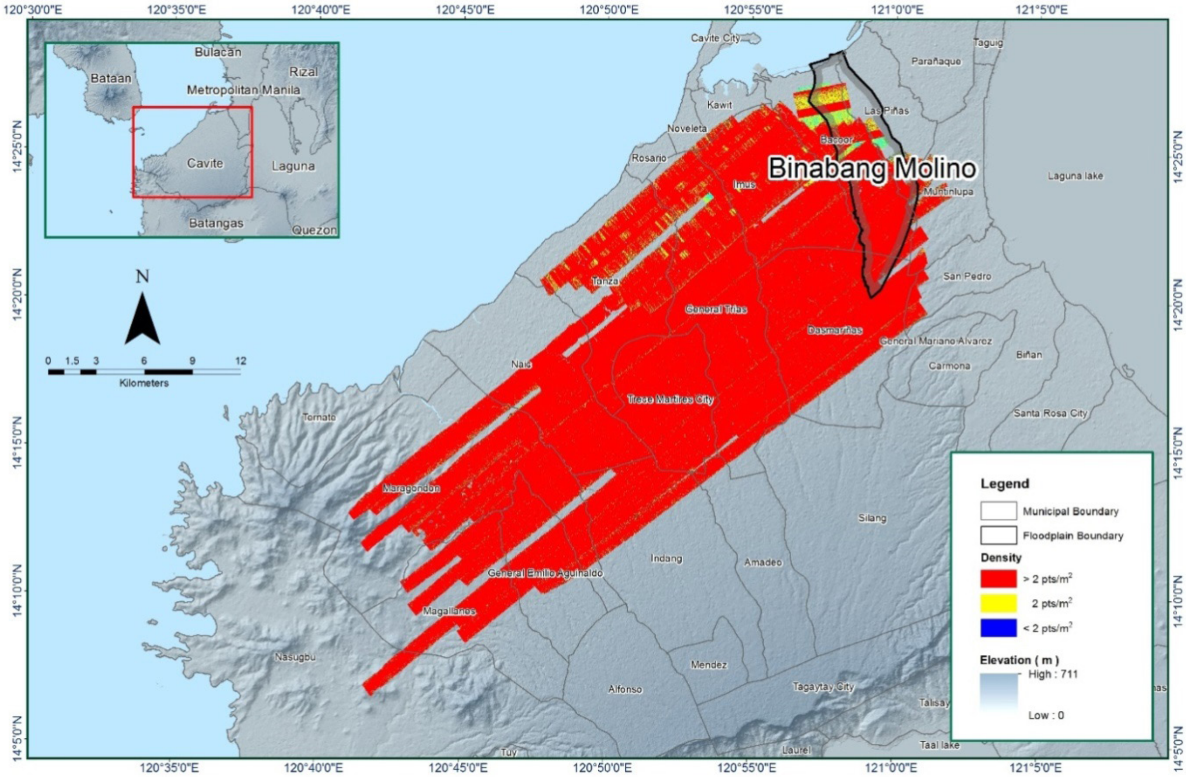


Figure 15. Pulse density map of merged LiDAR data for the Binabang-Molino floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red. Bright blue areas represent portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to the elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to the elevations of its adjacent flight line. Areas with bright red or bright blue colors were investigated further using the Quick Terrain (QT) Modeler software.

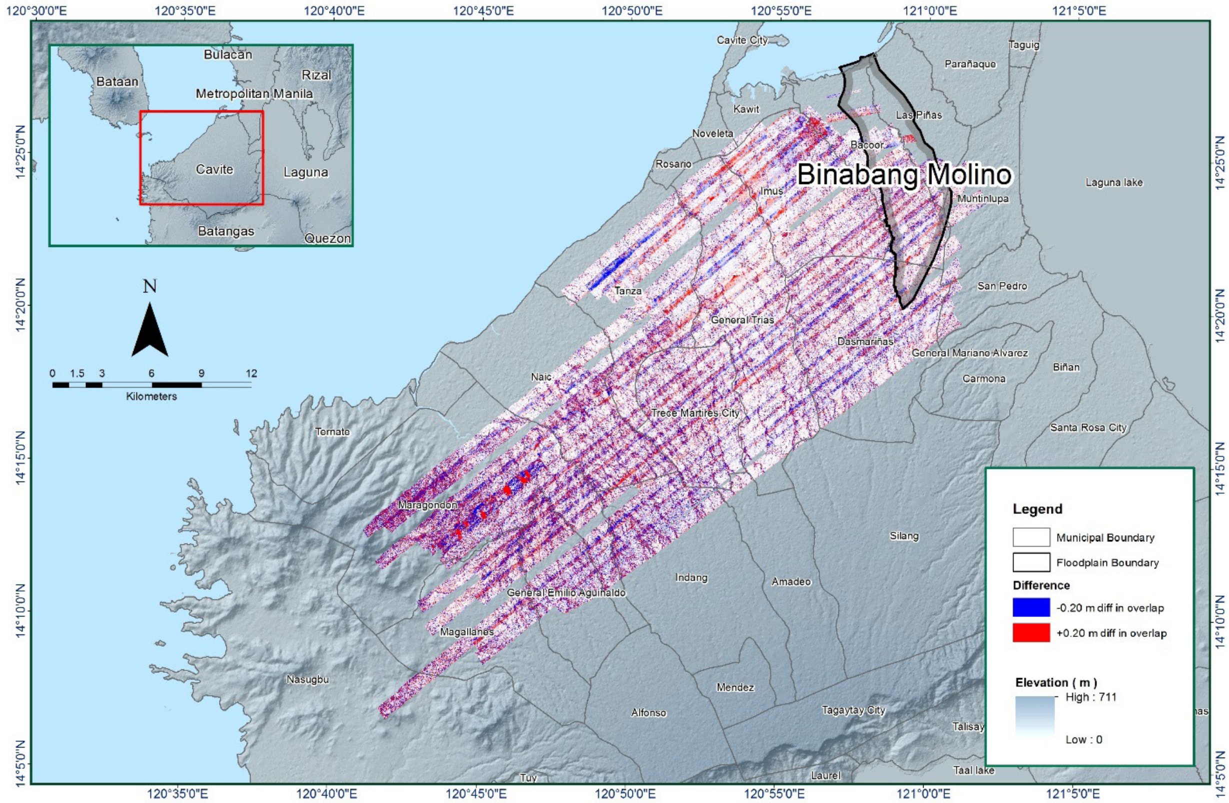


Figure 16. Elevation difference map between flight lines for the Binabang-Molino floodplain

A screen capture of the processed LAS data from Binabang-Molino Flight 3309P loaded in the QT Modeler is provided in Figure 17. The upper left image shows the elevations of the points from two (2) 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 were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

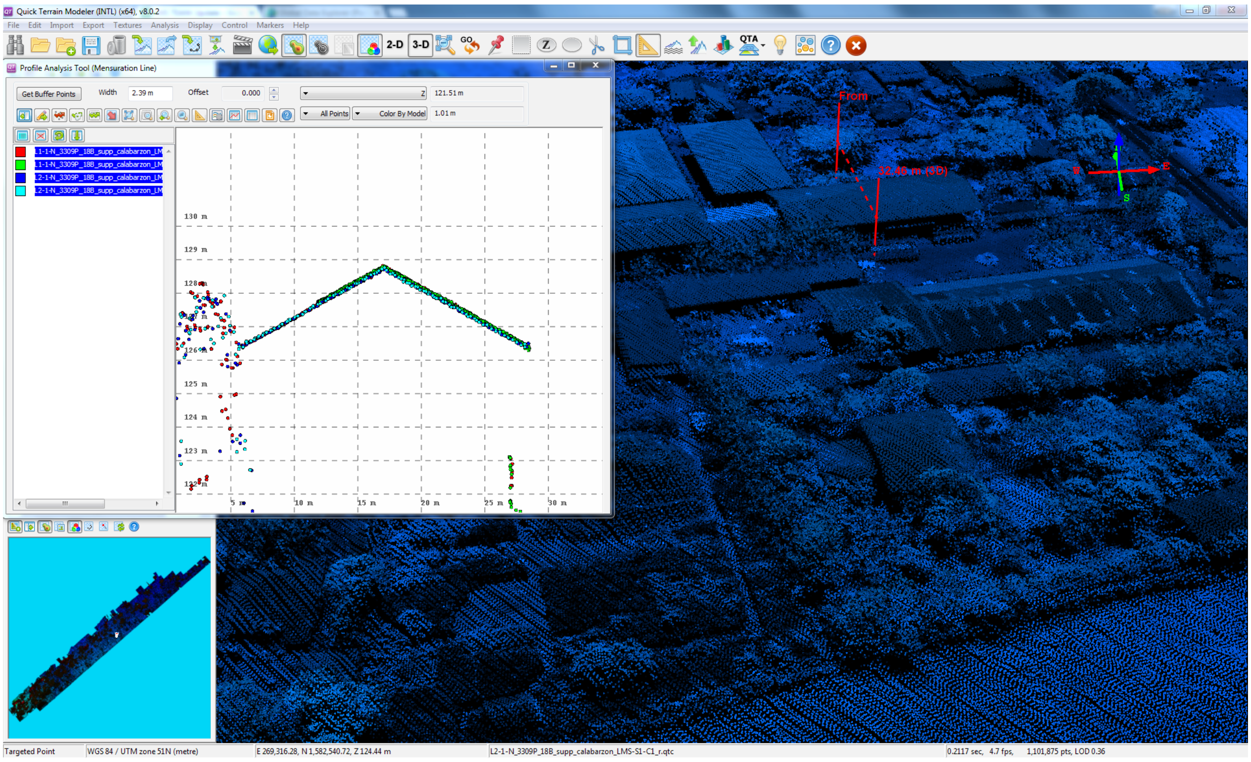


Figure 17. Quality checking for Binabang-Molino Flight 3309P, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Binabang-Molino classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	779,260,579
Low Vegetation	544,031,011
Medium Vegetation	632,776,944
High Vegetation	564,158,241
Building	189,522,144

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Binabang-Molino floodplain, are presented in Figure 18. A total of 1,067 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 14. The point cloud had a maximum and minimum height 603.46 meters and 45.01 meters, respectively.

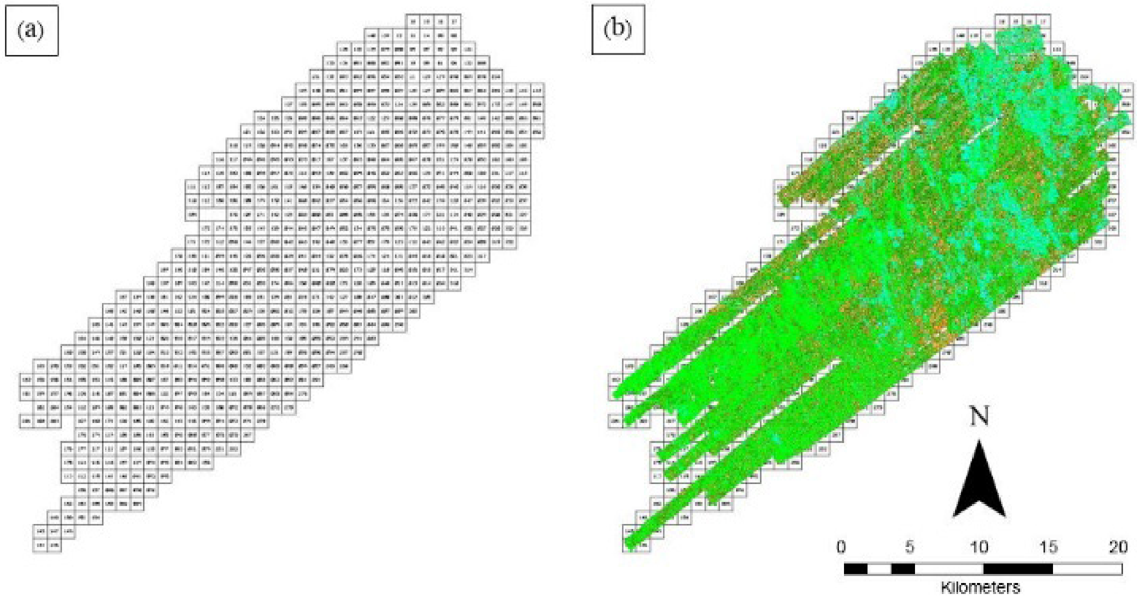


Figure 18. (a) Tiles for Binabang-Molino floodplain, and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

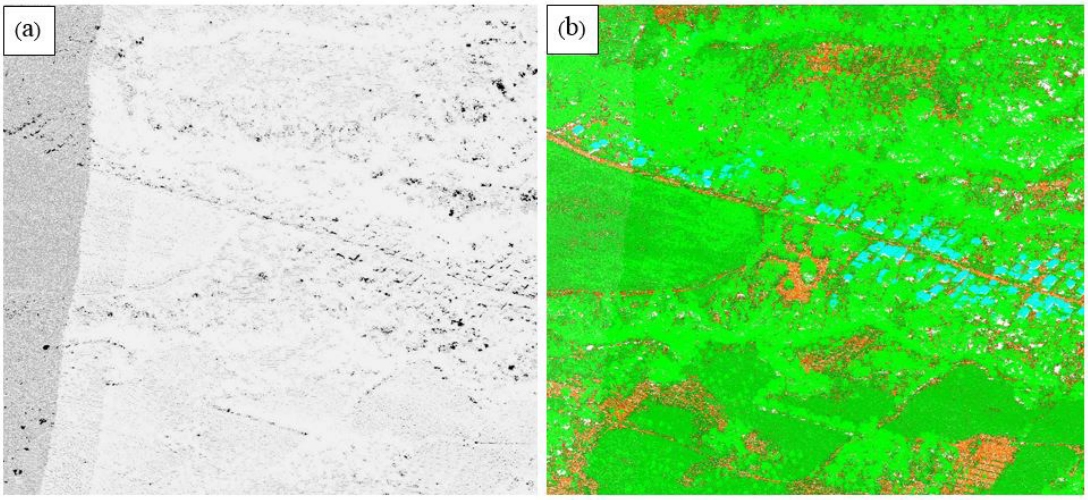


Figure 19. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 20, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

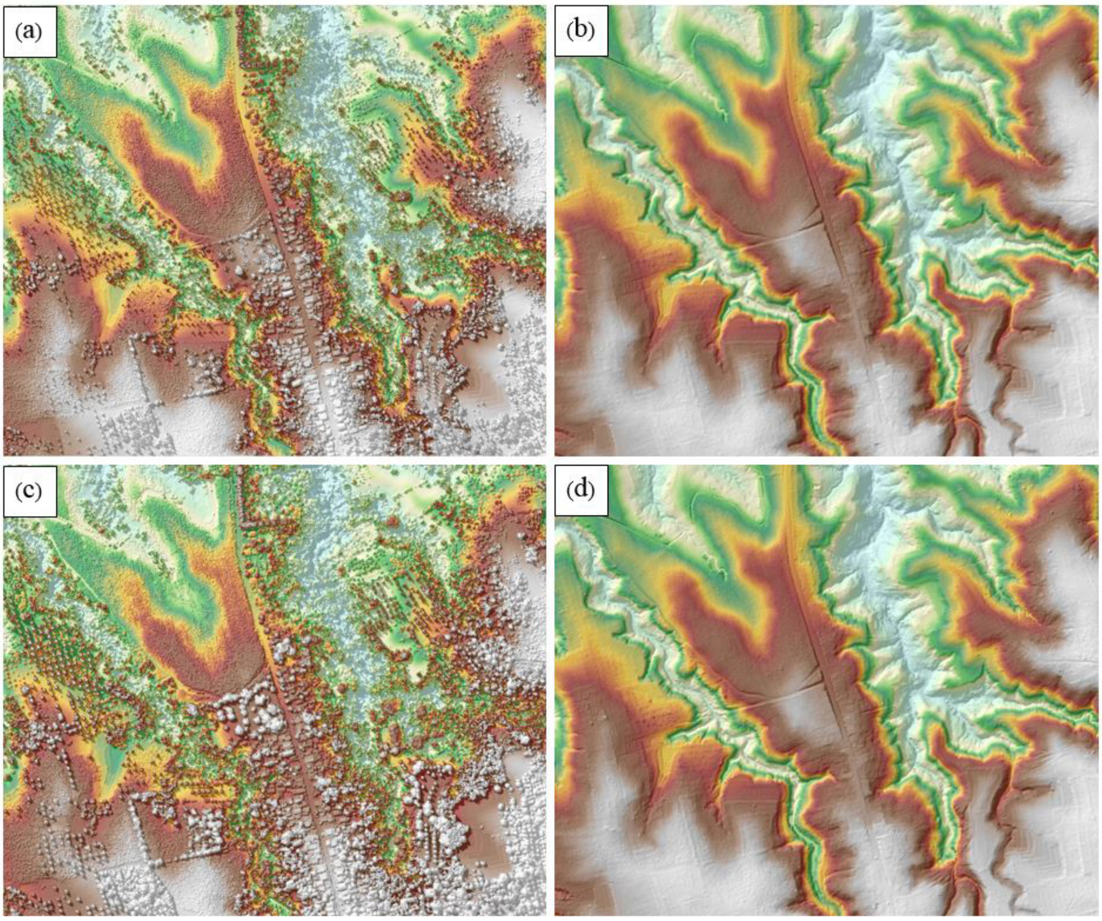


Figure 20. The production of (a) last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of Binabang-Molino floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 66 1km by 1km tiles of the block covering the Binabang-Molino floodplain is exhibited in Figure 21. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Binabang-Molino floodplain survey attained a total of 27.21 square kilometers in orthophotographic coverage, comprised of 49 images. However, the block does not have a complete set of orthophotographs, and the orthophotographs did not cover the area of the Binabang-Molino floodplain. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 22.

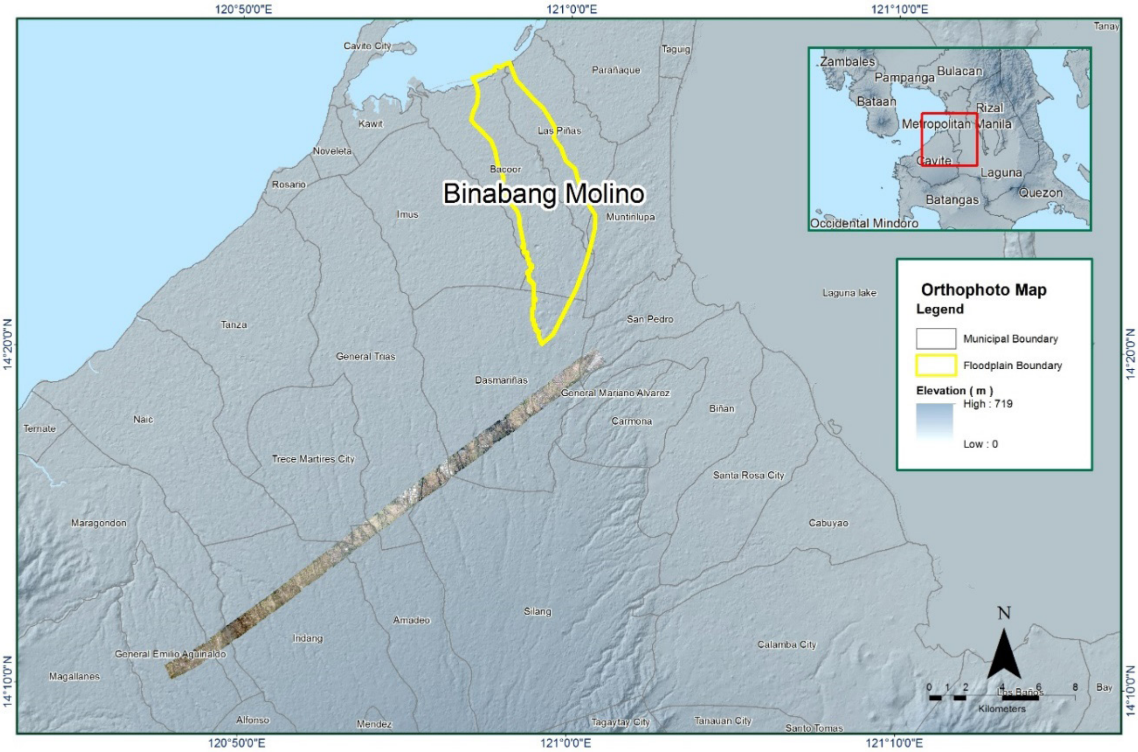


Figure 21. Available orthophotographs near the Binabang-Molino floodplain

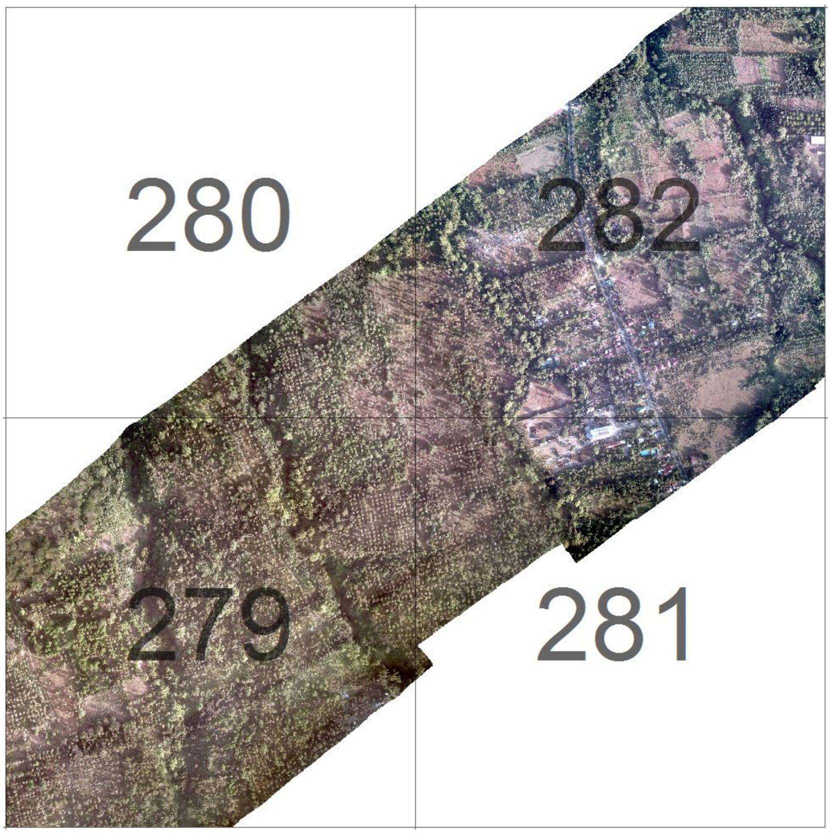


Figure 22. Sample orthophotograph tiles near the Binabang-Molino floodplain

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for the Binabang-Molino floodplain. These blocks are composed of CALABARZON, CALABARZON_reflights and Cavite blocks, with a total area of 680.53 square kilometers. Table 15 summarizes the names and corresponding areas of the blocks, in square kilometers.

Table 15. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
CALABARZON_Blk18B_supplement	106.91
CALABARZON_reflights_Blk18B_supplement3	9.47
CALABARZON_reflights_Blk18B_supplement4	8.74
Cavite_Blk18AB	127.12
Cavite_Blk18C	117.91
Cavite_Blk18C _additional	210.76
Cavite_Blk18A_supplement2	99.62
TOTAL	**680.53 sq.km**

Portions of the DTM before and after manual editing are exhibited in Figure 23. The bridge (Figure 23a) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 23b) in order to hydrologically correct the river. A ridge (Figure 23c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 23d) to allow for the correct flow of water. Another case was a building that was still present in the DTM after classification (Figure 23e), and had to be removed through manual editing (Figure 23f).

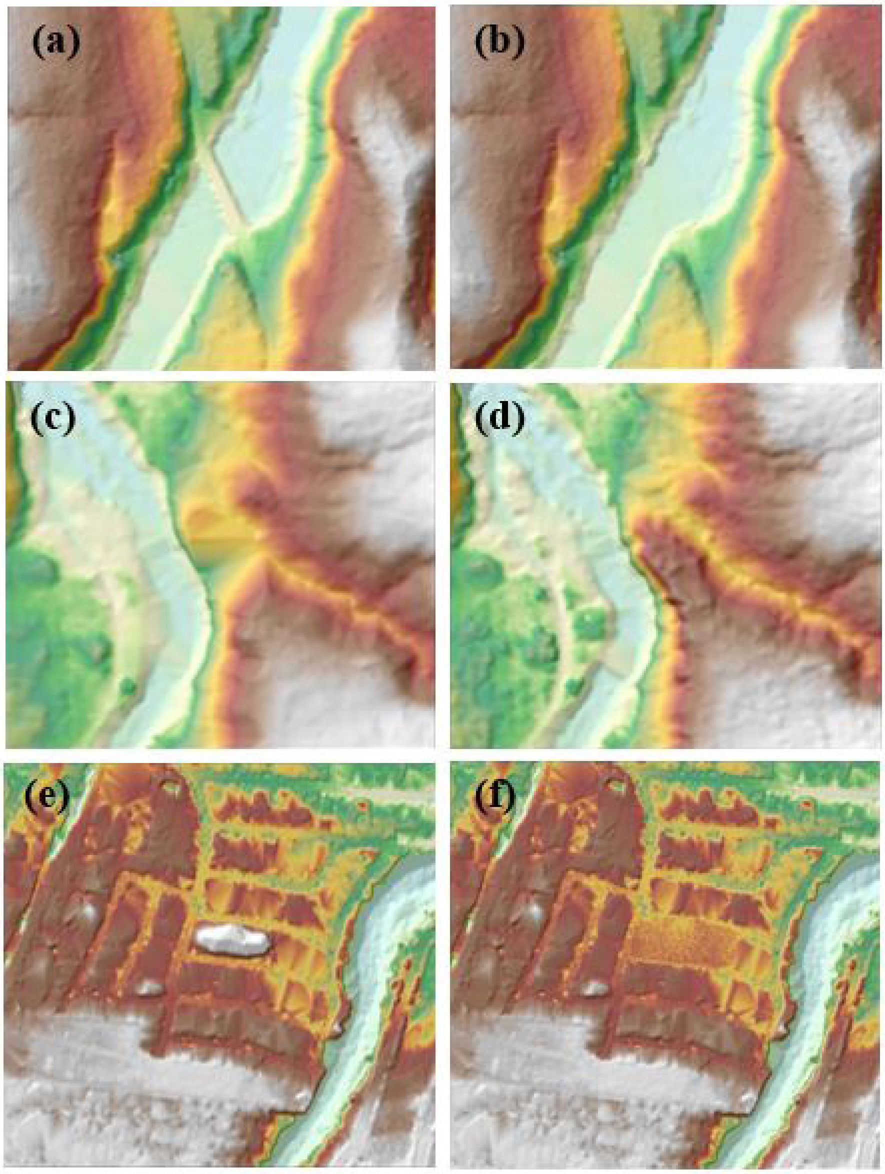


Figure 23. Portions in the DTM of the Binabang-Molino floodplain – a bridge (a) before and (b) after manual editing; a ridge (c) before and (d) after data retrieval; and a building (e) before and (f) after manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in the mosaicking process; because the identified reference for shifting was an existing calibrated CALABARZON DEM, overlapping with the blocks to be mosaicked. Table 16 specifies the shift values applied to each LiDAR block during mosaicking.

The mosaicked LiDAR DTM for the Binabang-Molino floodplain is presented in Figure 24. It demonstrates that the entire Binabang-Molino floodplain was 100% covered by LiDAR data.

Table 16. Shift values of each LiDAR block of the Binabang-Molino floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_Blk18B_supplement	0.00	0.00	0.00
CALABARZON_reflights_Blk18B_supplement3	0.00	0.00	0.00
CALABARZON_reflights_Blk18B_supplement4	-1.84	1.76	0.15
Cavite_Blk18AB	-1.80	1.13	-0.50
Cavite_Blk18C	-1.84	1.54	-0.45
Cavite_Blk18C _additional	-1.81	1.32	-0.50
Cavite_Blk18A_supplement2	-2.31	1.34	0.00

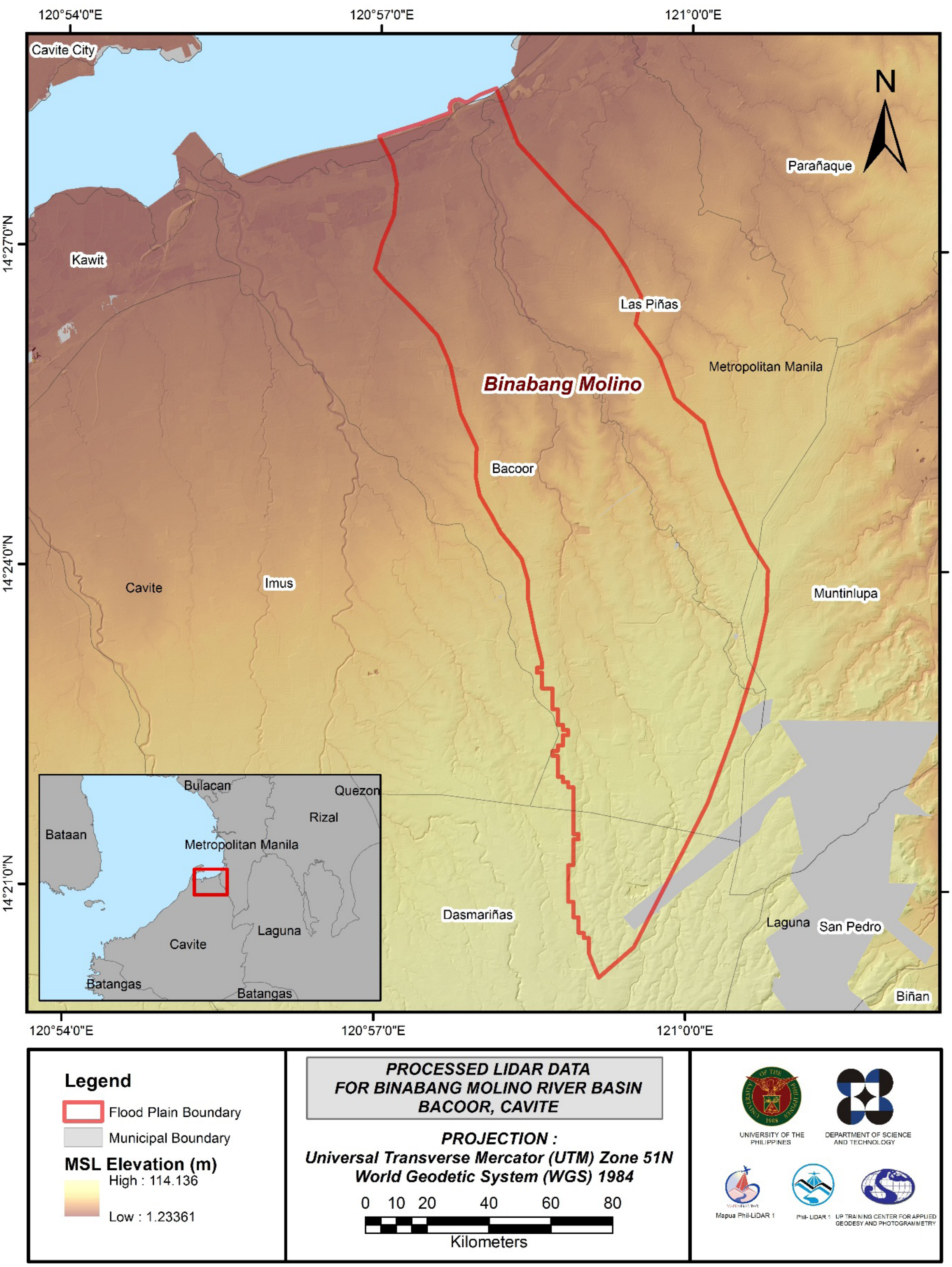


Figure 24. Map of processed LiDAR data for the Binabang-Molino floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Binabang Molino to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 24,251 survey points were gathered for all the flood plains within the provinces of CALABARZON wherein the Binabang Molino floodplain is located. Random selection of 80% of the survey points, resulting to 19,401 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 26. 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 points is 2.97 meters with a standard deviation of 0.20 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 2.97 meters, to the mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

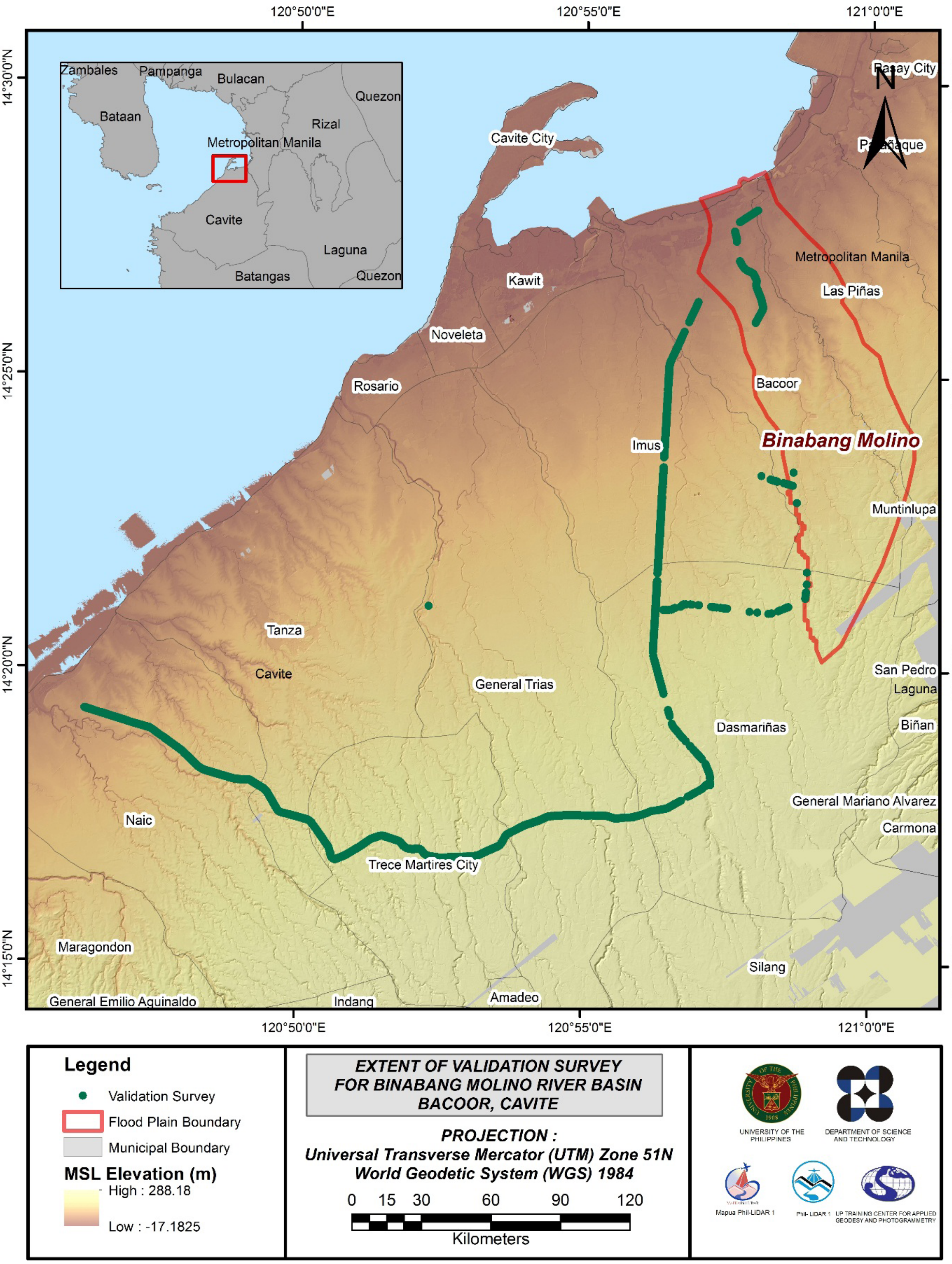


Figure 25. Map of the Binabang-Molino floodplain, with validation survey points in green

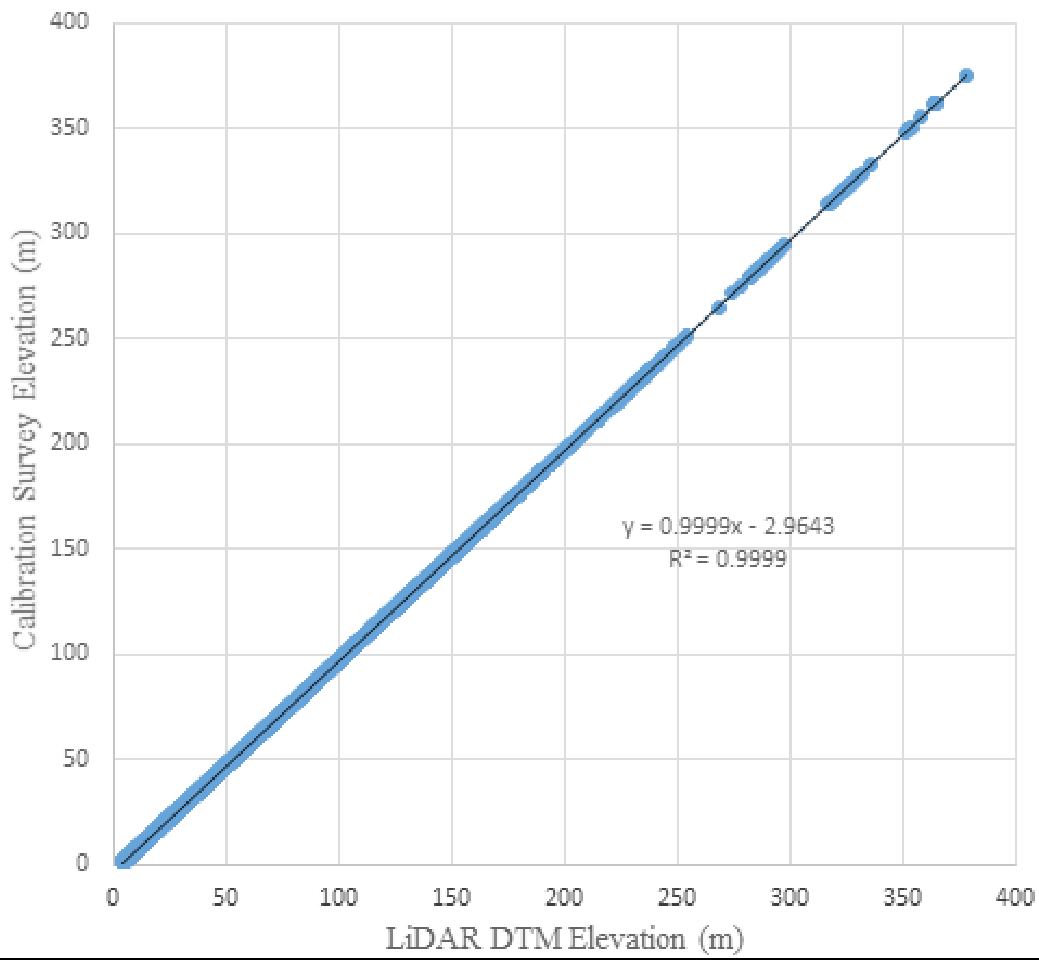


Figure 26. Correlation plot between the calibration survey points and the LiDAR data

Table 17. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.97
Standard Deviation	0.20
Average	-2.97
Minimum	-3.48
Maximum	-2.40

The remaining 20% of the total survey points that are near Binabang Molino flood plain, resulting to 362 points, were used for the validation of calibrated Binabang Molino 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.15 meters, as shown in Table 18.

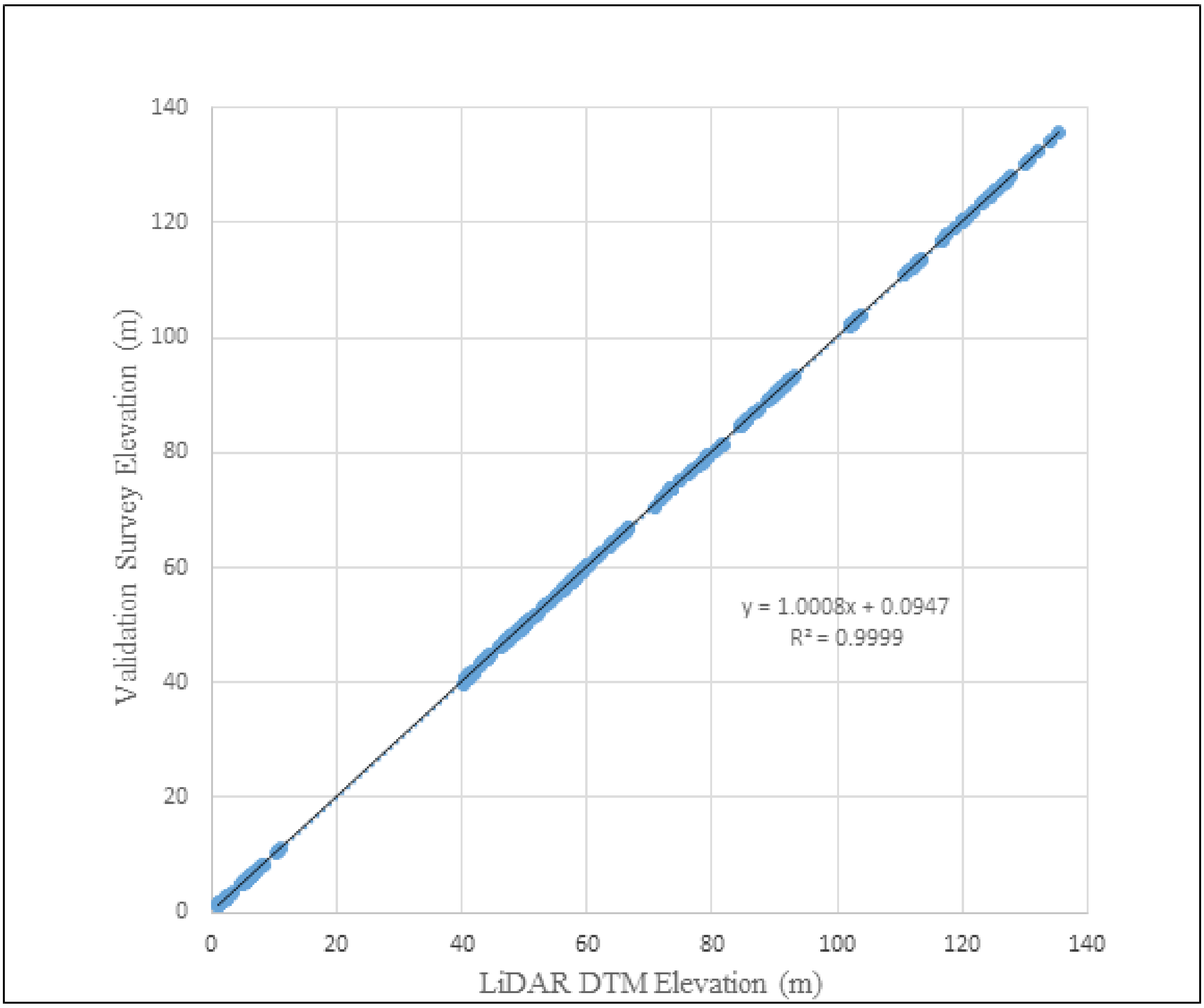


Figure 27. Correlation plot between the validation survey points and the LiDAR data

Table 18. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.15
Average	0.14
Minimum	-0.44
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Binabang-Molino, with 4,760 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.27 meters. The extent of the bathymetric survey done by the DVBC in the Binabang-Molino River, integrated with the processed LiDAR DEM, is illustrated in Figure 28.

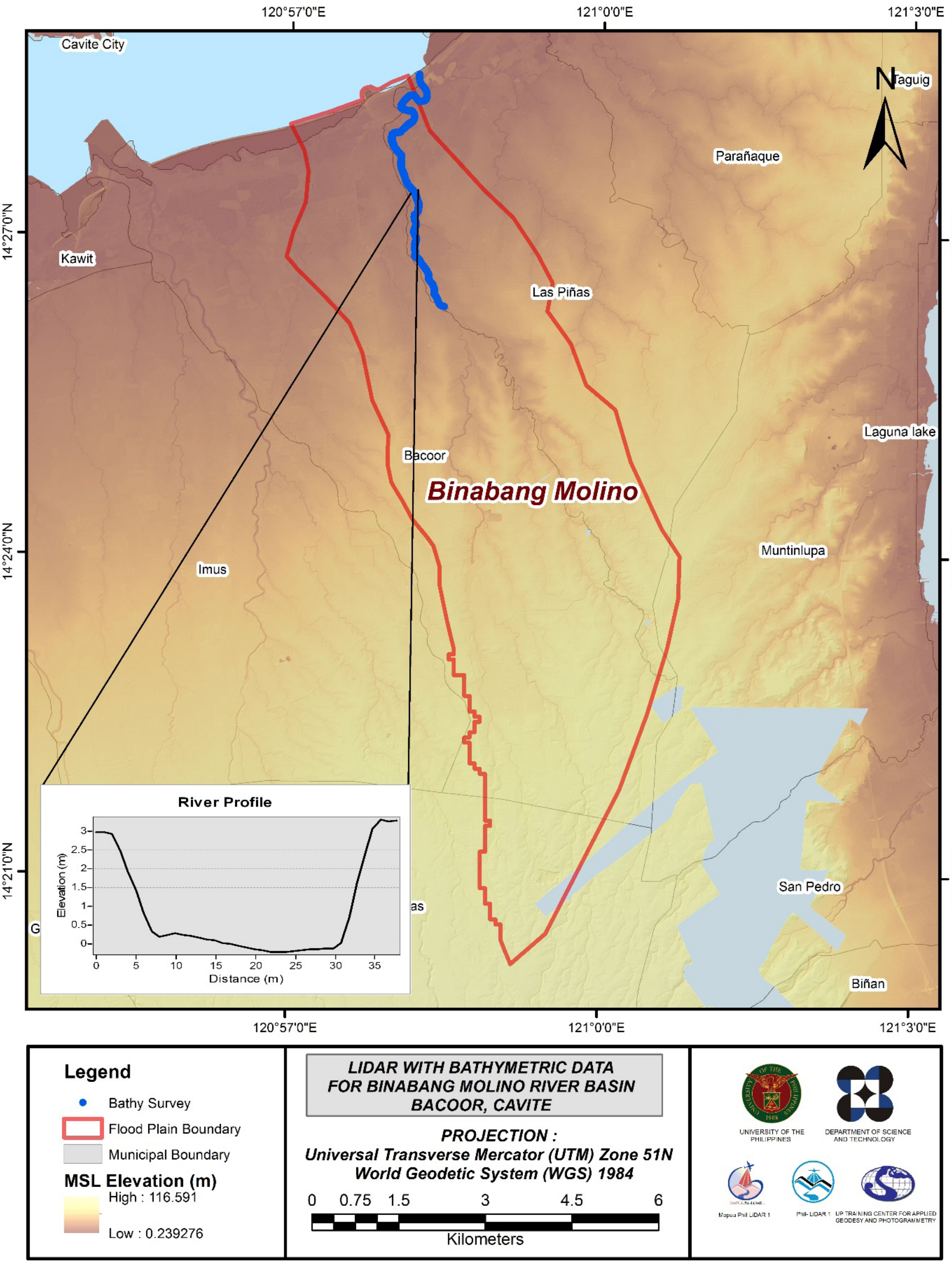


Figure 28. Map of the Binabang-Molino floodplain, with bathymetric survey points shown in blue

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area, with a 200-meters buffer zone. The mosaicked LiDAR DEM with a 1-meter resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Binabang-Molino floodplain, including its 200-meter buffer zone, has a total area of 54.76 square kilometers. For this area, a total of 5.0 square kilometers, corresponding to a total of 5,747 building features, were considered for quality checking (QC). Figure 29 displays the QC blocks for the Binabang-Molino floodplain.

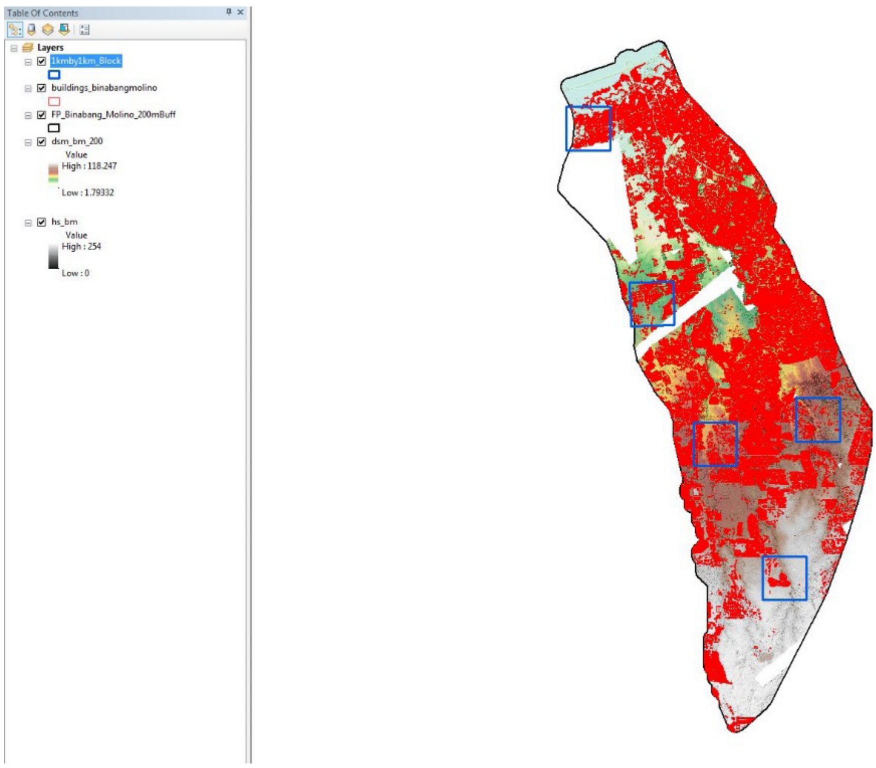


Figure 29. Blocks (in blue) of Binabang-Molino building features that were subjected to QC

Quality checking of the Binabang-Molino building features resulted in the ratings given in Table 19.

Table 19. Quality checking ratings for Binabang-Molino building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Binabang-Molino	99.40	99.71	96.17	PASSED

3.12.2 Height Extraction

Height extraction was done for 86,140 building features in the Binabang-Molino floodplain. Of these building features, 550 were filtered out after height extraction, resulting in 85,590 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 40.62 meters.

3.12.3 Feature Attribution

The attributes were obtained through field data gathering. GPS devices were used to determine the coordinates of important features. These points were uploaded and overlaid in ArcMap, and were then integrated with the shapefiles.

Table 20 summarizes the number of building features per type. Table 21 provides the total length of each road type, and Table 22 specifies the number of water features extracted per type.

Table 20. Building features extracted for the Binabang-Molino floodplain

Facility Type	No. of Features
Residential	85,081
School	167
Market	102
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	27
Barangay Hall	9
Military Institution	0
Sports Center/Gymnasium/Covered Court	9
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	3
Water Supply/Sewerage	6
Religious Institutions	14
Bank	2
Factory	0
Gas Station	8
Fire Station	1
Other Government Offices	7
Other Commercial Establishments	154
Total	85,590

Table 21.Total length of extracted roads for the Binabang-Molino floodplain

Floodplain	Road Network Length (km)					**Total**
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Binabang-Molino	651.57	25.90	23.61	8.42	0.00	**709.50**

Table 22. Number of extracted water bodies for the Binabang-Molino floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes / Ponds	Sea	Dam	Fish Pen	
Binabang-Molino	12	3	1	1	1	**18**

A total of thirty-five (35) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

Figure 30 represents the Digital Surface Model (DSM) of the Binabang-Molino floodplain, overlaid with its ground features.

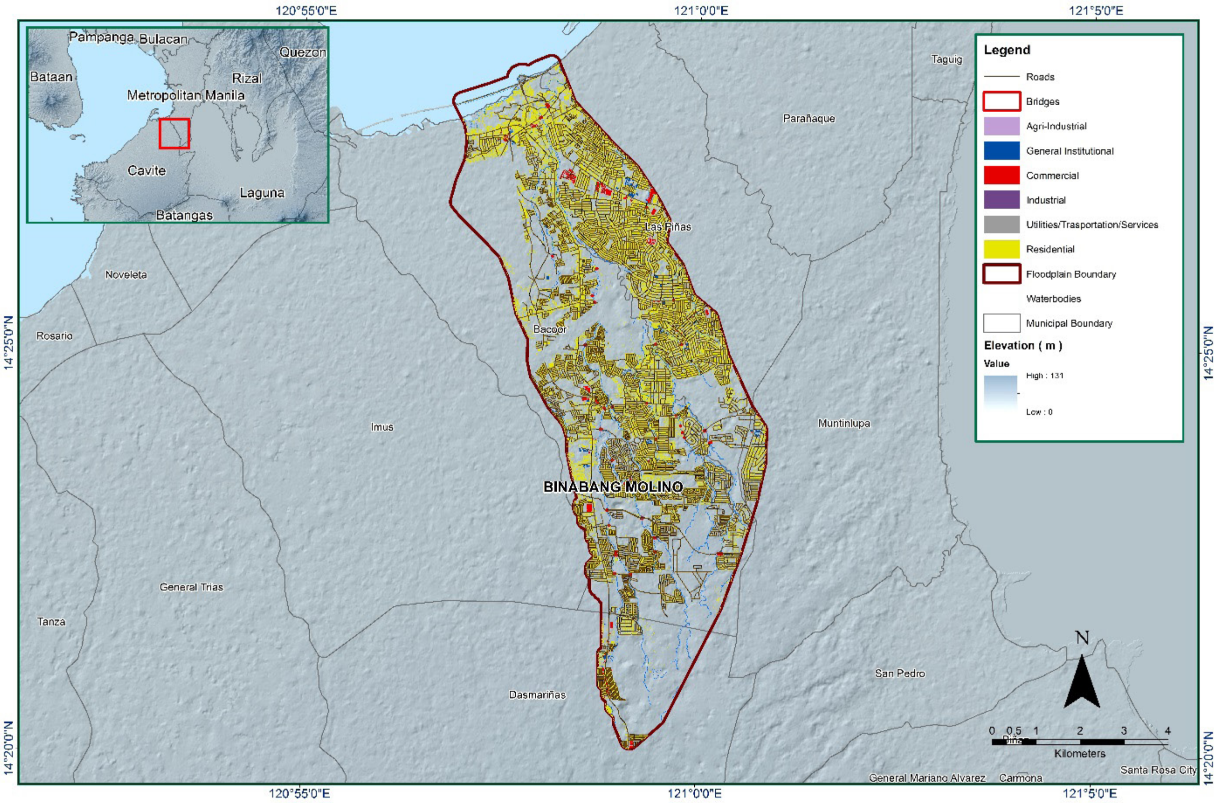


Figure 30. Extracted features for the Binabang-Molino floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BINABANG-MOLINO RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and 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 surveys in the Binabang-Molino River on September 13 - 25, 2015, in partnership with MIT Phil-LiDAR1 team. The scope of work was comprised of: (i.) initial reconnaissance to determine the viability of traversing the planned routes for the bathymetric survey; (ii.) courtesy calls with MIT and the Cavite LGUs; (iii.) control survey for the establishment of control point at the approach of the Zapote Bridge, with coordinates Latitude 14°27’51.21843”E and Longitude 120°57’59.22961”N occupied as base station for the GNSS surveys; (iv.) cross-section survey, bridge as-built features determination and water level marking; (v.) ground validation survey covering the Municipality of Bacoor along the Molino Paliparan Road, and the Municipality of Dasmariñas along the Governors Dr. Road, with an approximate distance of 22.8 kilometers. Lastly, (vi.) bathymetric survey covering the barangays of Talon Dos, Pamplona Dos, Pamplona Uno, Zapote, and Pulang Lupa Una, with an approximate length of 5.34 kilometers.

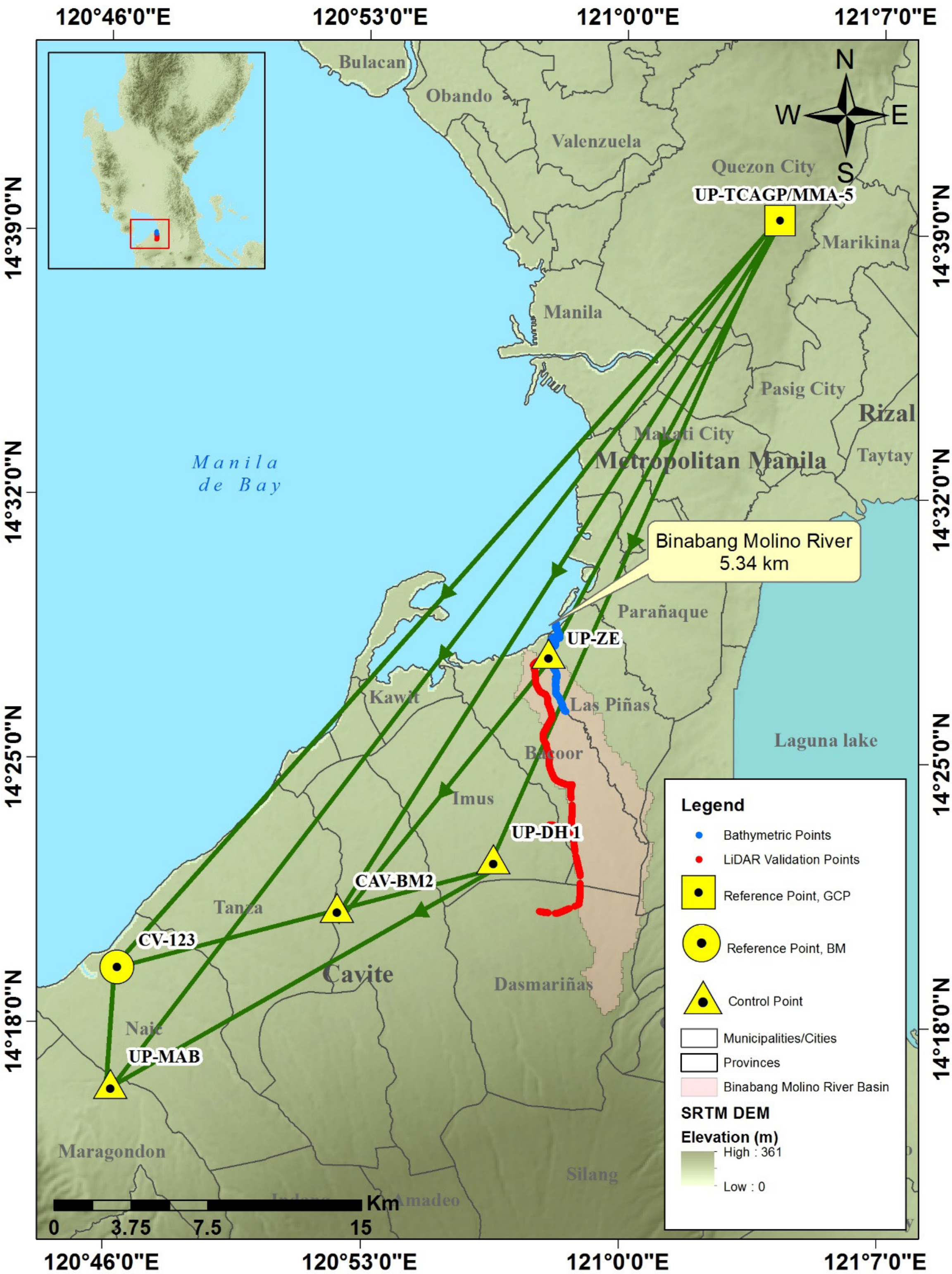


Figure 31. Extent of the bathymetric survey (in blue line) in the Binabang-Molino River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Binabang-Molino River Basin is composed of four (4) loops established on September 15 and 17, 2015 occupying the following reference points: (i.) MMA-5, a first-order GCP in the University of the Philippines, Diliman, Quezon City; and (ii.) CV-123, a first-order BM, located in front of an Iglesia ni Cristo church in Barangay Amaya, Municipality of Naic, Cavite.

Four (4) control points were established along the approach of the bridges, namely: (i.) UP-DH1, at the Daang Hari Bridge in Barangay Anabu II-A, Municipality of Imus, Cavite; (ii.) UP-MAB, located at the Mabacao Bridge in Barangay Bucal IV B, Municipality of Maragondon, Cavite; (iii.) UP-ZE at the right side of the Zapote Bridge in Barangay Zapote, Basa I, Las Piñas City; and (iv.) CAV-BM2, at the Cañas Bridge in Barangay Tapia, Municipality of General Trias, Cavite, which was also occupied as a marker during the survey.

The summary of the reference and control points and their locations is provided in Table 23; while the established GNSS network is illustrated in Figure 32.

Table 23. List of reference and control points occupied in the Binabang-Molino River survey (Source: NAMRIA and UP-TCAGP)

Control Point Name	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height, (m)	Elevation in MSL (m)	Date Established
MMA-5	2nd Order, GCP	14°39'22.97451"	121°04'11.14940"	133.379	-	1956
CV-123	1st Order, BM	-	-	52.071	9.314	2008
CAV-BM2	UP Established	-	-	-	-	Sept. 15, 2015
UP-DH1	UP Established	-	-	-	-	Sept. 15, 2015
UP-MAB	UP Established	-	-	-	-	Sept. 17, 2015
UP-ZE	UP Established	-	-	-	-	Sept. 17, 2015

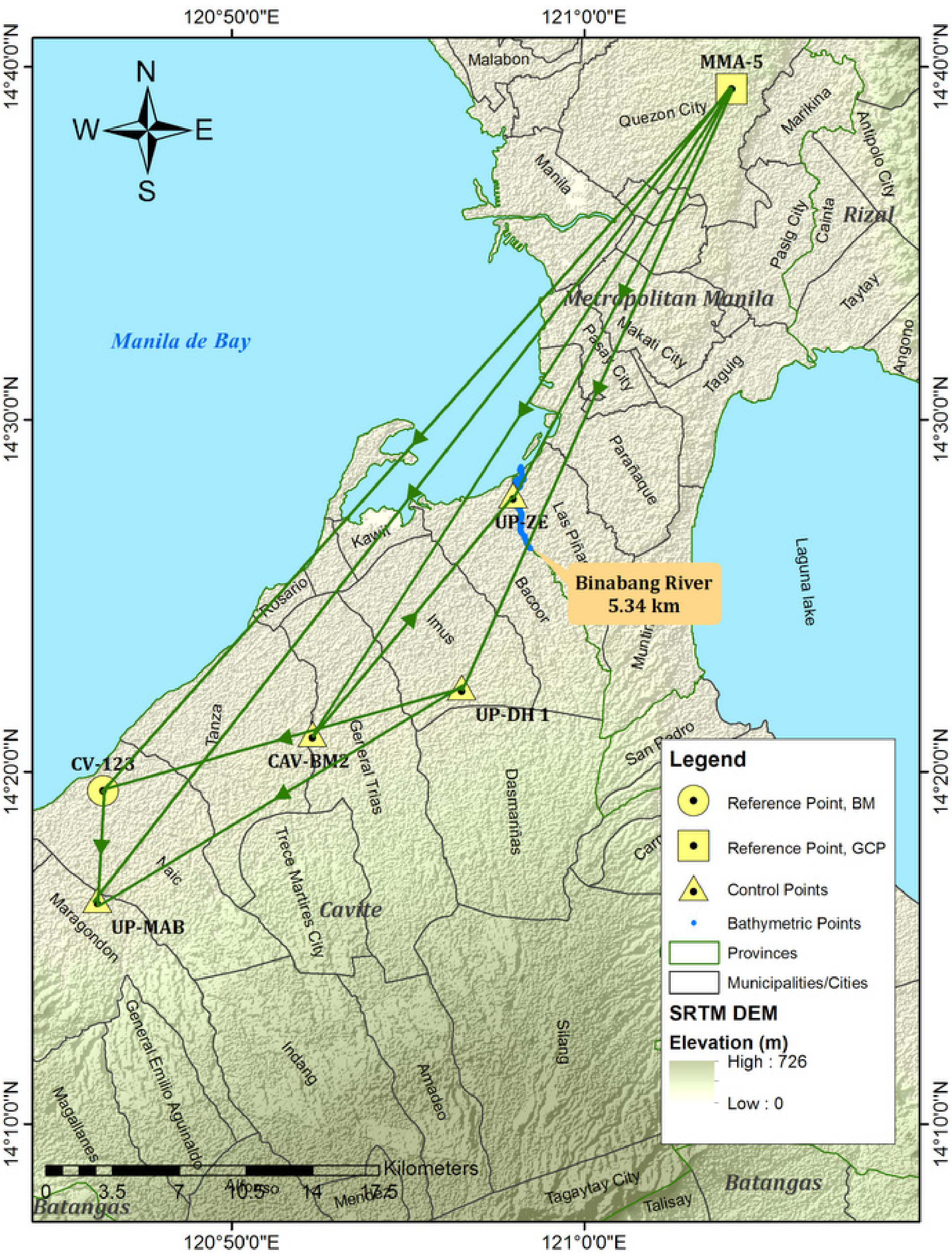


Figure 32. The GNSS network covering the Binabang-Molino River

The GNSS set-ups established in the locations of the reference and control points are exhibited in Figure 33 to Figure 38.

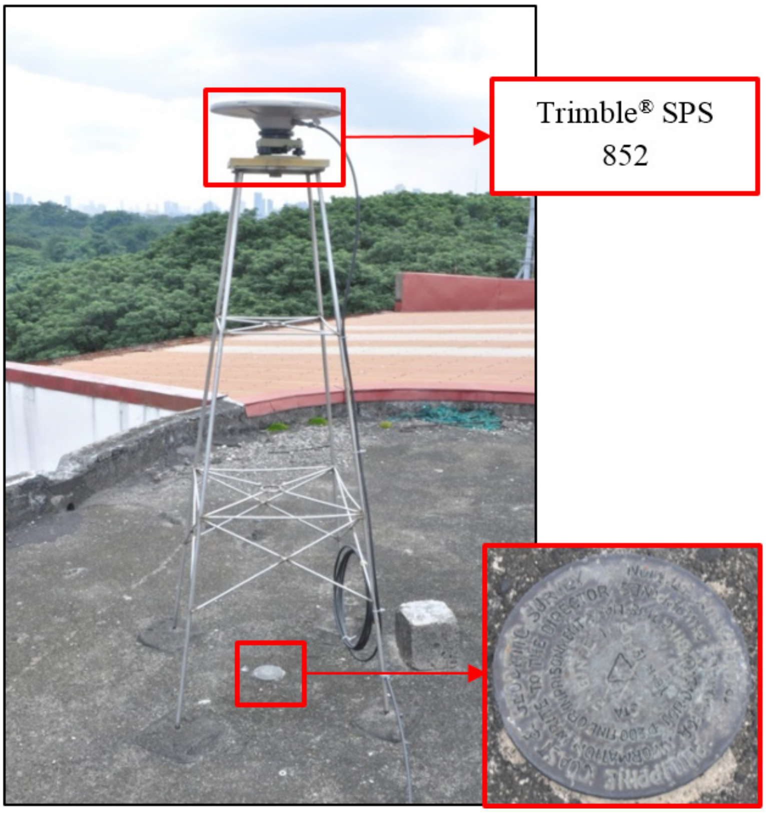


Figure 33. Trimble® SPS 852 set-up at MMA-5, located at the Melchor Hall, University of the Philippines, Diliman, Quezon City

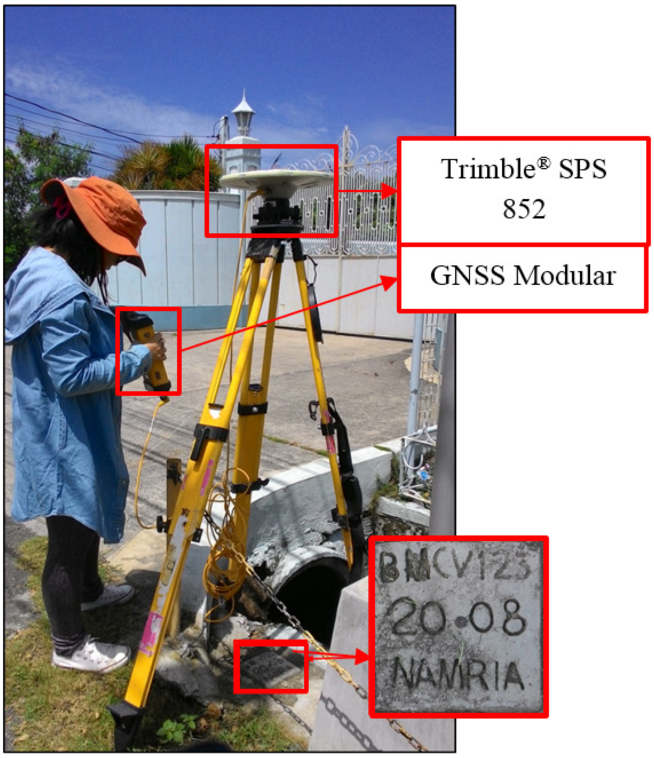


Figure 34. GPS set-up of Trimble® SPS 852 at CV-123, located in front of the Iglesia ni Cristo Chapel, Municipality of Naic, Cavite

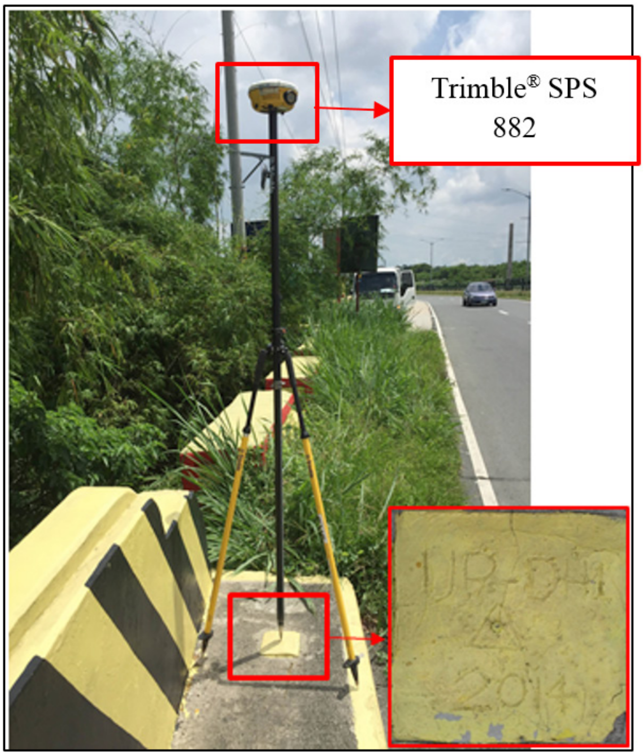


Figure 35. Trimble® SPS 882 set-up at UP-DH1, located at the Daang Hari Bridge in Barangay Anabu II-A, Municipality of Imus, Cavite

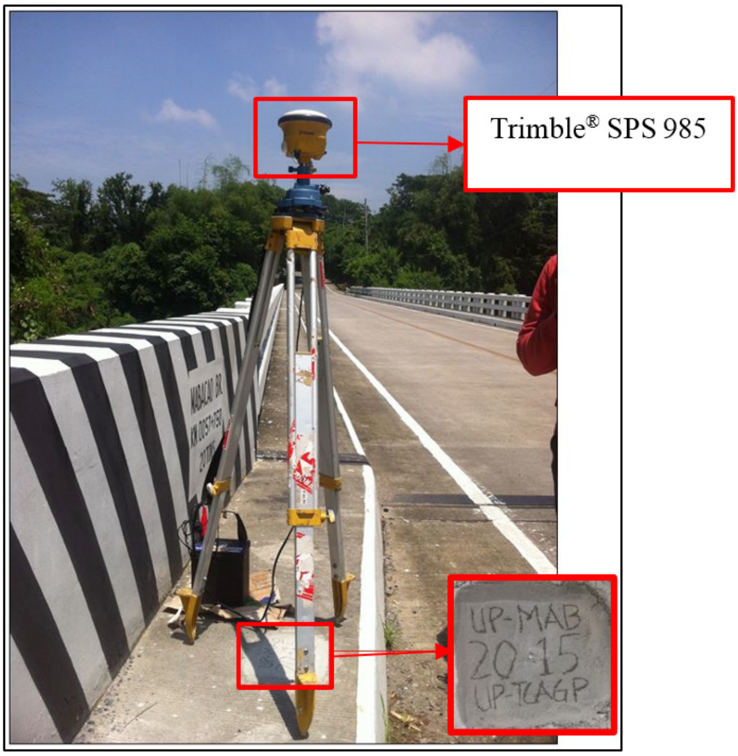


Figure 36. Trimble® SPS 985 set-up at UP-MAB, located at the approach of the Mabacao Bridge in Barangay Bucal IV B, Municipality of Maragondon, Cavite

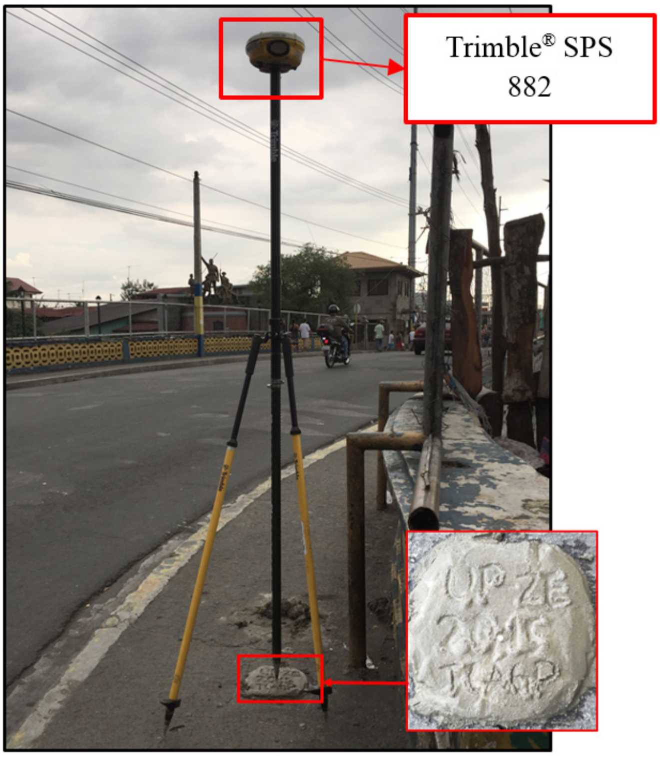


Figure 37. Trimble® SPS 882 set-up at UP-ZE, located at the Zapote Bridge in Barangay Zapote, Bacoor City, Cavite

Figure 38. GPS set-up of Trimble® SPS 852 at CAV-BM 2, located at the Cañas Bridge in Barangay Tapia, Municipality of General Trias, Cavite

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the +/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of the control points used in the Binabang-Molino River survey, generated by the TBC software, are summarized in Table 24.

Table 24. Baseline processing report used in the Binabang-Molino River Basin survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CV-123---UP-MAB	09-15-2015	Fixed	0.005	0.022	182°55’06”	5730.614	19.916
CV-123---UP-MAB	09-15-2015	Fixed	0.005	0.012	182°55’05”	5730.599	19.913
UP-DH1---UP-MAB	09-15-2015	Fixed	0.088	0.108	239°06’21”	21662.35	-9.875
UP-DH1---CV-123	09-15-2015	Fixed	0.006	0.034	253°33’16”	19073.15	-29.7
CAV-BM2---UP-ZE	09-17-2015	Fixed	0.005	0.022	39°14’40”	16153.02	-24.213
MMA-5---UP-DH1	09-15-2015	Fixed	0.006	0.014	203°41’56”	34213.76	-51.591
MMA-5---CV-123	09-15-2015	Fixed	0.023	0.021	221°06’52”	48736.51	-81.313
MMA-5---CV-123	09-15-2015	Fixed	0.023	0.025	221°06’52”	48736.48	-81.311
MMA-5---UP-ZE	09-17-2015	Fixed	0.005	0.018	207°38’44”	24003.52	-85.42
MMA-5—CAVBM2	09-17-2015	Fixed	0.004	0.014	212°19’39”	39957.2	-61.233

As shown in Table 24, a total of ten (10) baselines were processed, with reference point MMA-5 held fixed for coordinate values, and CV-123 held fixed for elevation values. All of the baselines satisfied the required accuracy set by the project.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was 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 centimeters, and z less than 10 centimeters, or in equation from:

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

Where:

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

The six (6) control points – MMA-5, CV-123, CAV-BM2, UP-DH1, UP-MAB, and UP-ZE – were occupied and observed simultaneously to form a GNSS loop. The coordinates of MMA-5 and the elevation values of CV-123 were held fixed during the processing of the control points, as presented in Table 25. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 25. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CV-123	Grid				Fixed
MMA-5	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 26. All fixed control points did not yield values for grid and elevation errors.

Table 26. Adjusted grid coordinates for the control points used in the Binabang-Molino floodplain survey

Point ID	X (Meter)	Easting Error (Meter)	Y (Meter)	Northing Error (Meter)	Z (Meter)	Elevation Error (Meter)	Constraint
MMA-5	292122.994	?	1621207.085	?	89.331	0.047	LL
CV-123	259759.978	0.023	1584752.533	0.010	9.314	?	e
CAV-BM2	270467.286	0.011	1587618.081	0.007	29.230	0.068	
UP-DH1	278104.989	0.018	1589990.469	0.007	38.572	0.055	
UP-MAB	259413.172	0.025	1579030.620	0.013	29.050	0.040	
UP-ZE	280803.732	0.012	1600035.582	0.009	4.798	0.076	

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

a. MMA-5

Horizontal Accuracy = Fixed

Vertical Accuracy = 4.7 cm < 10 cm

b. CV-123

Horizontal Accuracy = $\sqrt{((2.3)^2 + (1.0)^2)}$

	=	$\sqrt{(5.29 + 1)} < 20$ cm
	=	2.51 cm < 20 cm
Vertical Accuracy	=	Fixed

c. CAV-BM2

Horizontal Accuracy	=	$\sqrt{((1.1)^2 + (0.7)^2)}$
	=	$\sqrt{(1.21 + 0.49)} < 20$ cm
	=	1.30 cm < 20 cm
Vertical Accuracy	=	6.8 cm < 10 cm

d. UP-DH 1

Horizontal Accuracy	=	$\sqrt{((1.8)^2 + (0.7)^2)}$
	=	$\sqrt{((3.24 + 0.49)}$
	=	1.93 cm < 20 cm
Vertical Accuracy	=	5.5 cm < 10 cm

e. UP-MAB

Horizontal Accuracy	=	$\sqrt{((2.5)^2 + (1.3)^2)}$
	=	$\sqrt{(6.25 + 1.69)} < 20$ cm
	=	2.82 cm < 20 cm
Vertical Accuracy	=	4.0 cm < 10 cm

f. UP-ZE

Horizontal Accuracy	=	$\sqrt{((1.2)^2 + (0.9)^2)}$
	=	$\sqrt{(1.44 + 0.81)}$
	=	1.5 cm < 20 cm
Vertical Accuracy	=	7.6 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two occupied control points are within the required accuracy of the project.

Table 27. Adjusted geodetic coordinates for control points used in the Binabang-Molino River floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
MMA-5	N14°39’22.97451”	E121°04’11.14940”	133.379	0.047	LL
CV-123	N14°19’27.61225”	E120°46’21.72442”	52.071	?	e
CAV-BM2	N14°21’04.09862”	E120°52’18.03337”	72.153	0.068	
UP-DH1	N14°22’23.52073”	E120°56’32.16087”	81.814	0.055	
UP-MAB	N14°16’21.39512”	E120°46’11.99131”	71.979	0.040	
UP-ZE	N14°27’51.06089”	E120°57’59.25259”	47.954	0.076	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as reflected in Table 27. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Binabang-Molino River GNSS Static Survey are indicated in Table 28.

Table 28. Reference and control points used in the Binabang-Molino River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MMA-5	2nd Order, GCP	14°39’22.97451”	121°04’11.14940”	133.379	1621207.085	292122.994	89.331
CV-123	1st Order, BM	14°19’27.61225”	120°46’21.72442”	52.071	1584752.533	259759.978	9.314
CAV-BM2	UP Established	14°21’04.09862”	120°52’18.03337”	72.153	1587618.081	270467.286	29.230
UP-DH1	UP Established	14°22’23.52073”	120°56’32.16087”	81.814	1589990.469	278104.989	38.572
UP-MAB	UP Established	14°16’21.39512”	120°46’11.99131”	71.979	1579030.620	259413.172	29.050
UP-ZE	UP Established	14°27’51.06089”	120°57’59.25259”	47.954	1600035.582	280803.732	4.798

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

The cross-section and bridge as-built surveys were conducted on September 20, 2015 along the downstream side of the Zapote Bridge in Barangay using GNSS receiver Trimble® SPS 882 in PPK survey. The bridge as-built features determination was also performed to obtain the distance of piers and abutments from the bridge approach, as depicted in Figure 39. The bridge deck was measured to get the high chord and meter tapes to secure its low chord elevation. The established control point UP-ZE was used as the base station for the whole survey.

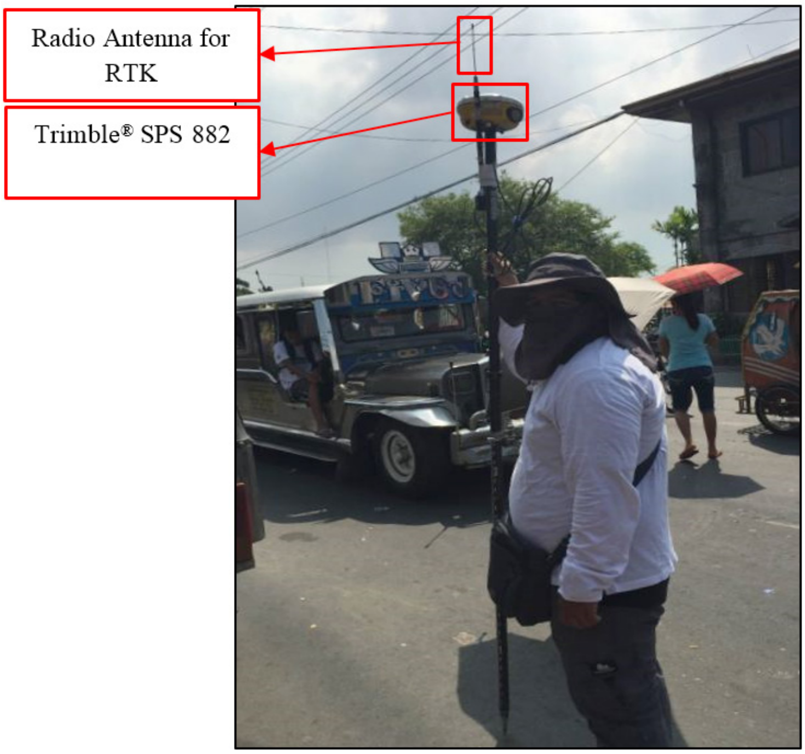


Figure 39. As-built and cross-section survey of the Zapote Bridge

The length of the cross-sectional line surveyed in the Zapote Bridge is about 179.53 meters, with fifty-one (51) cross-sectional points. Figure 40 to Figure 42 present the location map, cross-sectional diagram, and as-built bridge data form for the Zapote Bridge.

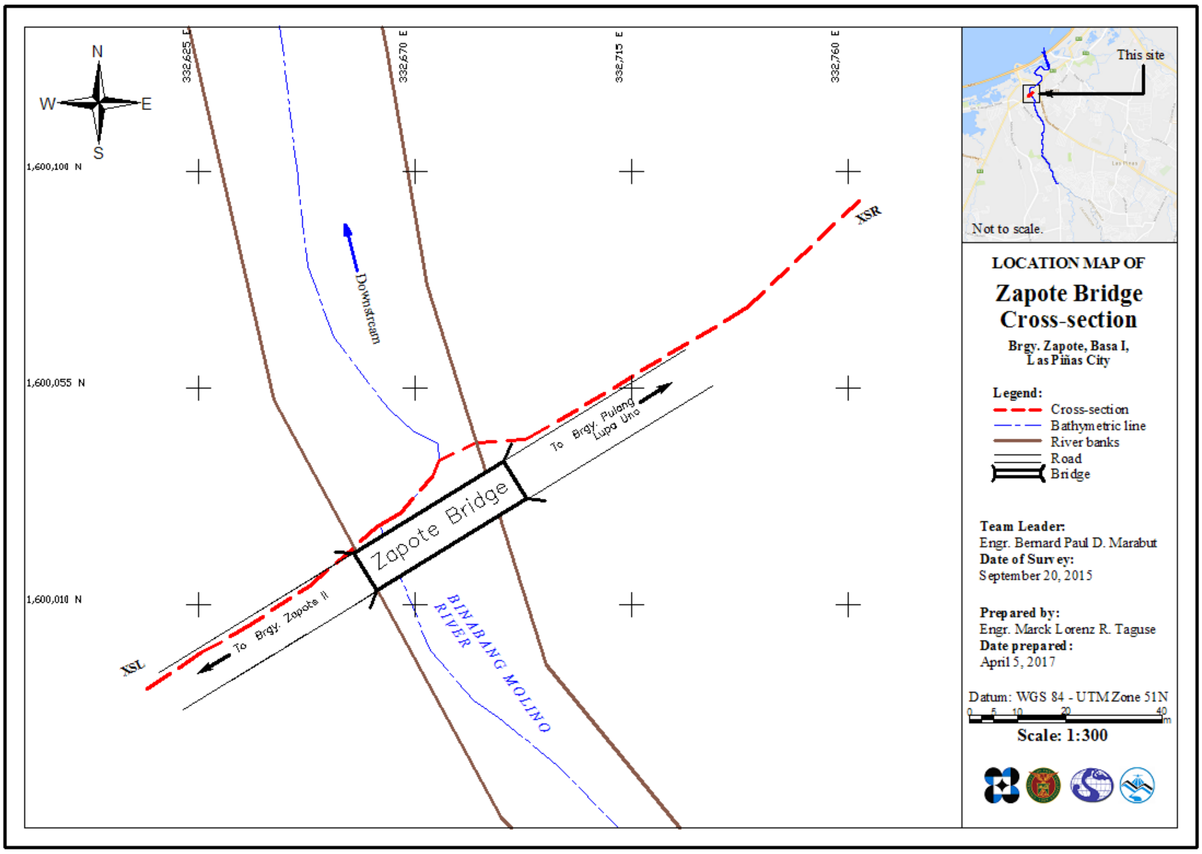


Figure 40. Zapote Bridge location map

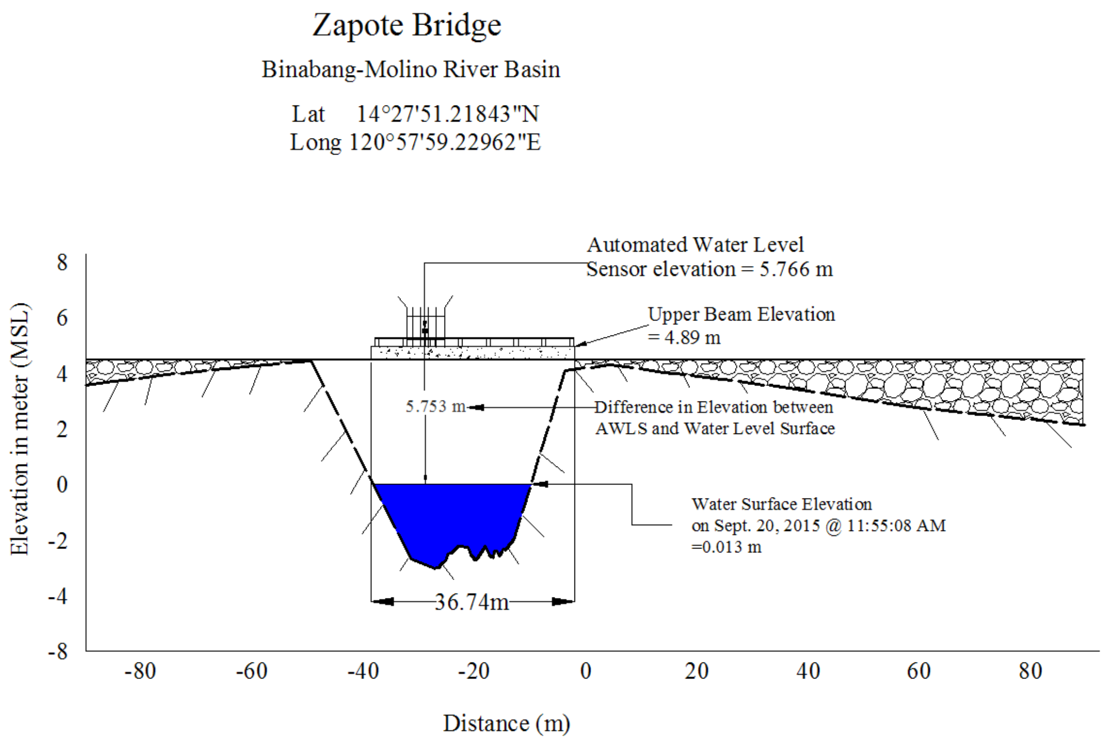


Figure 41. Zapote Bridge cross-sectional diagram

Bridge Data Form

Bridge Name: Zapote Bridge **Date:** Sept 20, 2015

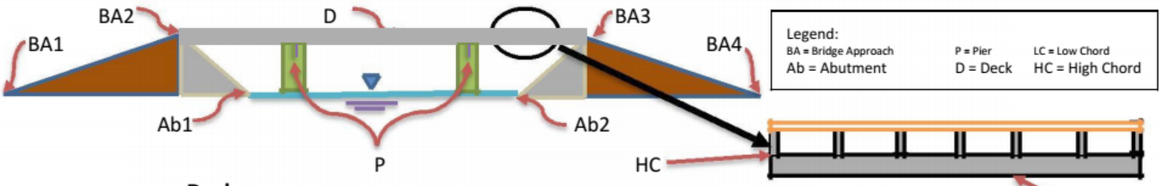
River Name: Binangbang Molino River **Time:** 9:45 AM

Location (Brgy, City,Region): Brgy. Zapote, Basa I, Las Piñas City

Survey Team:

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

Latitude: 14d27'51.21843" N **Longitude:** 120d57'59.22961" E



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

Elevation: 4.944 m **Width:** 11.50m **Span (BA3-BA2):** 36.74 m

	Station	High Chord Elevation	Low Chord Elevation
1			
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	3.55 m	BA3	87.98 m	4.89 m
BA2	51.25 m	5.60 m	BA4	106.42 m	2.119 m

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: NA Number of Piers: NA Height of column footing: NA

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 42. Zapote Bridge data form

Figure 43. Water level markings on the side of the pier of the Zapote Bridge

The water surface elevation of 0.013 meters in MSL in the Binabang-Molino River was determined using Trimble® SPS 882 in PPK mode technique on September 20, 2015 at 23:55 hrs. along the banks of the Zapote Bridge. The water surface elevation was translated into markings the bridge's abutment using a digital level system. The bridge's abutment was marked using red and white paint, as displayed in Figure 43. The marked pier served as a reference for flow data gathering and depth gauge deployment for the MIT Phil-LiDAR 1 team.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 20, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 985. The receiver was mounted on a pole that was attached in front of a vehicle, as demonstrated in Figure 44. It was secured with a cable tie to ensure that it is horizontally and vertically balanced. The antenna height of 2.36 meters was measured from the ground up to the bottom of the notch of the GNSS Rover receiver.

Figure 44. Validation points acquisition set-up for the Binabang-Molino River Basin

The survey was conducted using PPK technique set on a continuous topography mode, using UP-ZE as the base station. The survey began in Barangay Zapote Silangan, Las Piñas City, and traversed along the Molino Paliparan to Barangay Salawag, Dasmariñas City along the Governors Dr. Road, covering an approximate distance of 22.8 kilometers with 2,627 ground validation points gathered. The gaps in the validation line, as illustrated in Figure 45, were due to the difficulties in receiving satellite signals because of the presence of obstructions, such as dense canopies of trees along the roads.

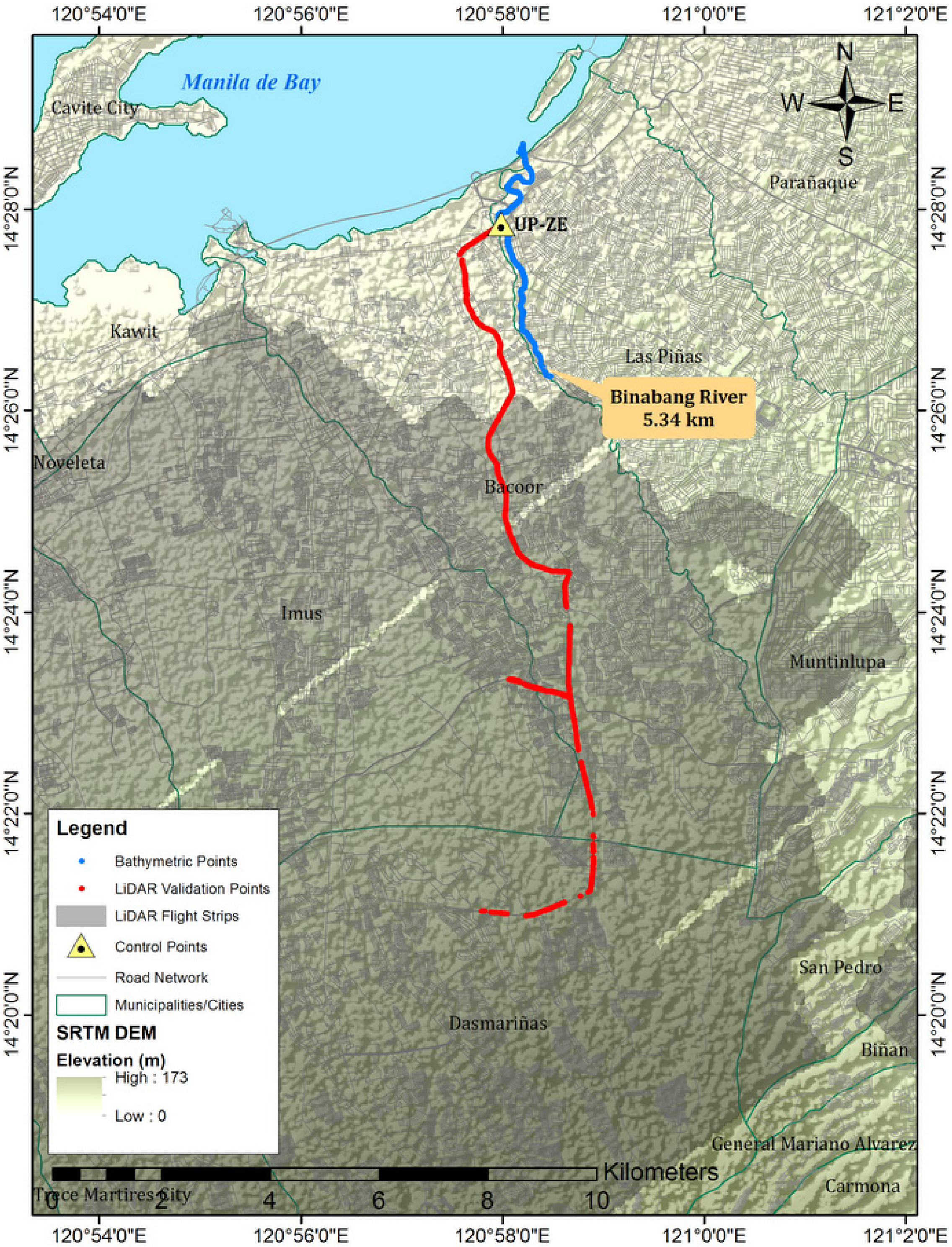


Figure 45. Extent of the LiDAR ground validation survey of the Binabang-Molino River Basin

4.7 Bathymetric Survey

A bathymetric survey of the Binabang-Molino River was conducted on September 19, 2015 using a GNSS Rover receiver, Trimble® SPS 882 in PPK survey technique mounted on top of a pole with an Ohmex™ single-beam echo sounder, as depicted in Figure 46. It started from the upstream side of the river in Barangay Talon Dos, Municipality of Las Piñas, with coordinates 14°26'20.30844" 120°58'28.20872"; down to the mouth of the river in Manila Bay located in Barangay Pulang Lupa I, also in Las Piñas, with coordinates 14°28'38.62738" 120°58'12.10312". The control point UP-ZE was used as the base station all throughout the survey.

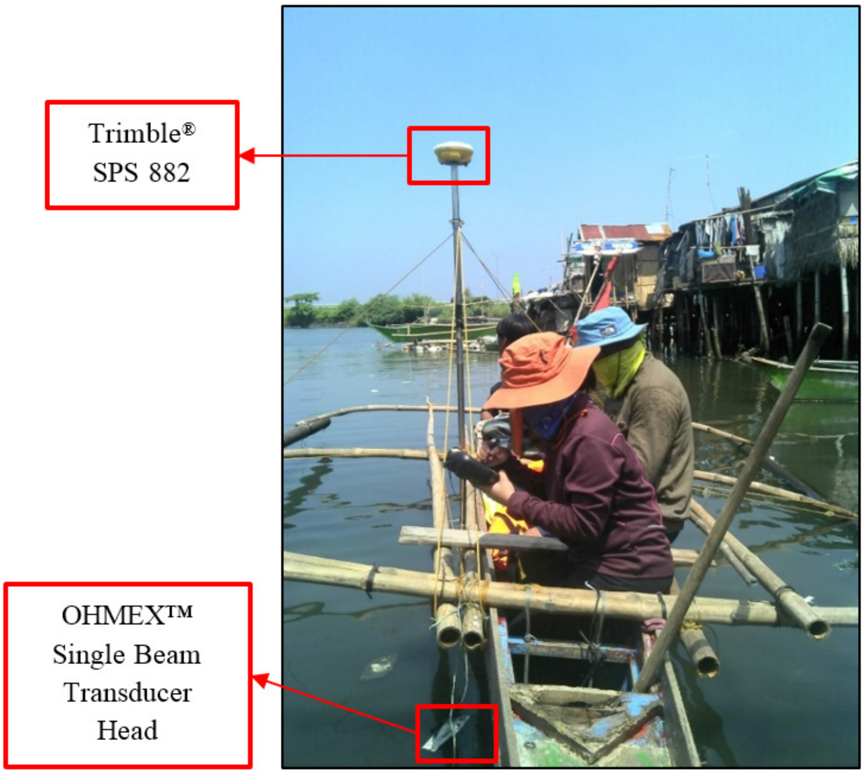


Figure 46. Bathymetric survey in the Binabang-Molino River

The entire bathymetric data coverage for the Binabang-Molino River is illustrated in Figure 47. A CAD drawing illustrating the Binabang-Molino riverbed profile is presented in Figure 48. An elevation rise of -0.6 meters with respect to MSL was observed within the approximated distance of 5.34 kilometers, with a total of 3,338 bathymetric points gathered. There was a 600-meter planned bathymetric line in the upstream part of Barangay Talon Dos that was not covered due to difficulties in navigating the boat in the narrower upstream part of the river. Additionally, the river was too deep to be traversed by foot.

Figure 47. Extent of the bathymetric survey of the Binabang-Molino River

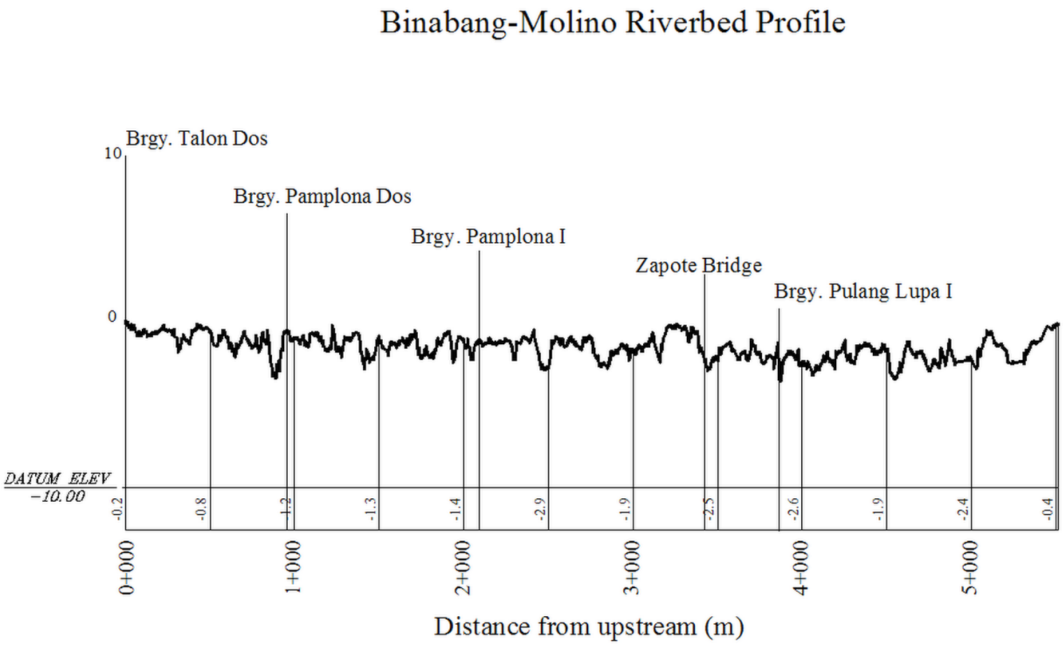


Figure 48. Riverbed profile of the Binabang-Molino River

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, and Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Rainfall, water level, and flow in a certain period of time, which are components and data that may affect the hydrologic cycle of the Binabang-Molino River Basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the DOST Bicutan Metro Manila ARG (14°29’22.78”N, 121° 3’8.17”E), located in Bicutan, Metro Manila (Figure 49). The precipitation data collection started on July 8, 2016 at 00:00 hrs. until July 8, 2016 at 23:45 hrs., with a 15-minute recording interval.

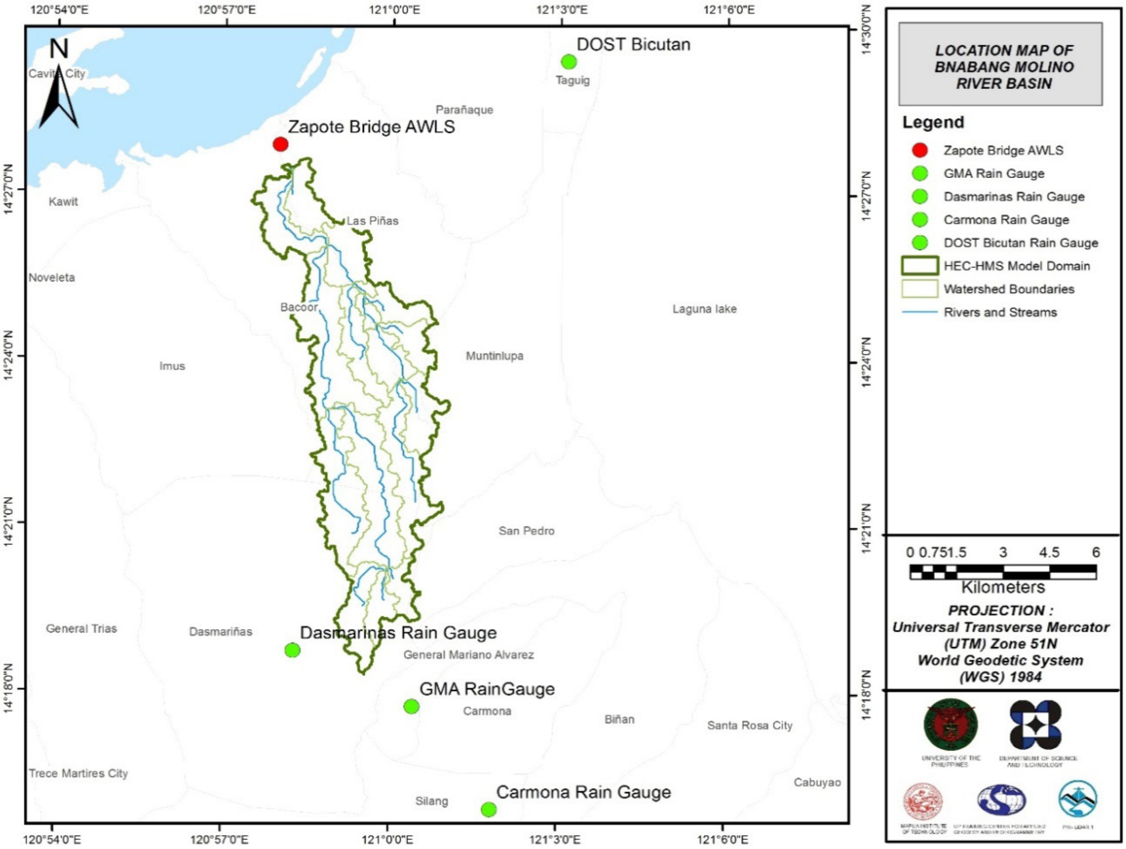


Figure 49. The location map of the rain gauge used for the calibration of the Binabang-Molino HEC-HMS model

The total rain for the event in the DOST Bicutan Gauge was 54.9 millimeters. Peak rain of 5.88 millimeters was recorded on May 15, 2016. The lag time between the peak rainfall and discharge was eight (8) hours. The other ARGs were not used, as no data were recorded from those gauges.

5.1.3 Rating Curves and River Outflow

A rating curve was computed at the prevailing cross-section (Figure 50) at the Zapote Bridge, Binabang-Molino, Cavite (14°27’50.87”N, 120°57’58.75”E). The curve establishes the relationship between the observed water levels (H) from the Zapote Bridge using depth gage, and the outflow of the watershed obtained from the flow meter at this location.

For the Zapote Bridge, the rating curve is expressed as $Q = 15.396e^{0.4263x}$, as depicted in Figure 51.

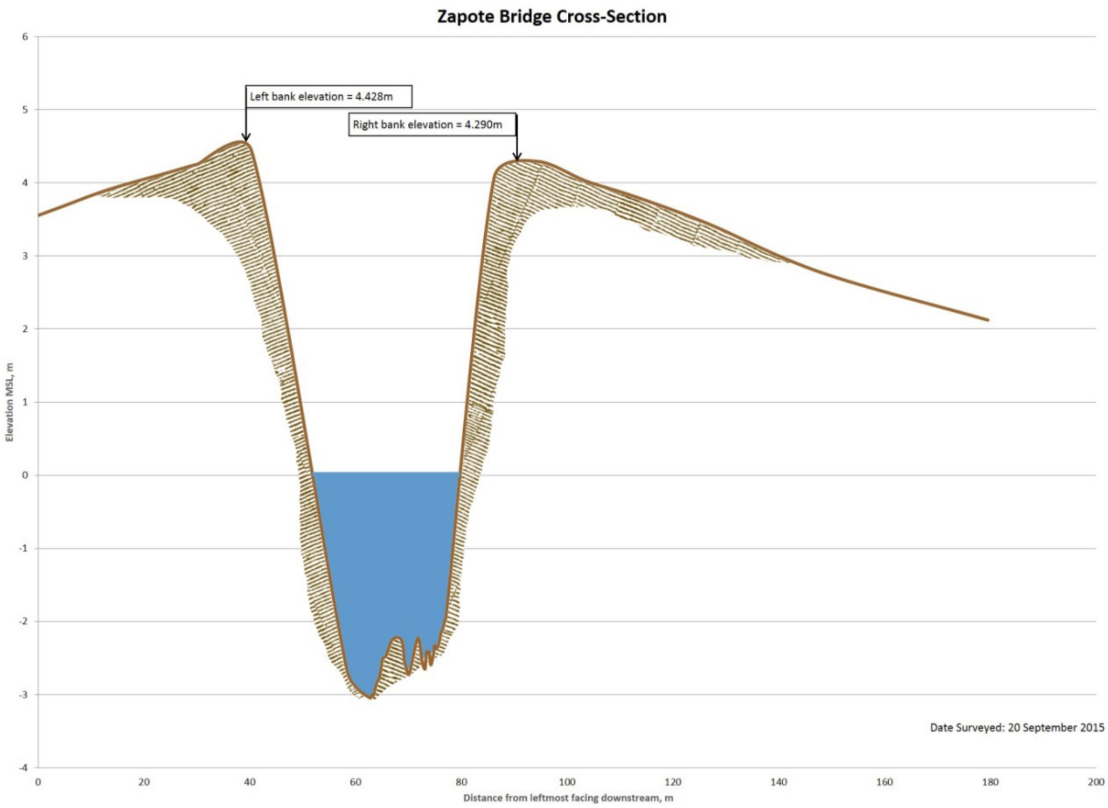


Figure 50. Cross-section plot of the Zapote Bridge

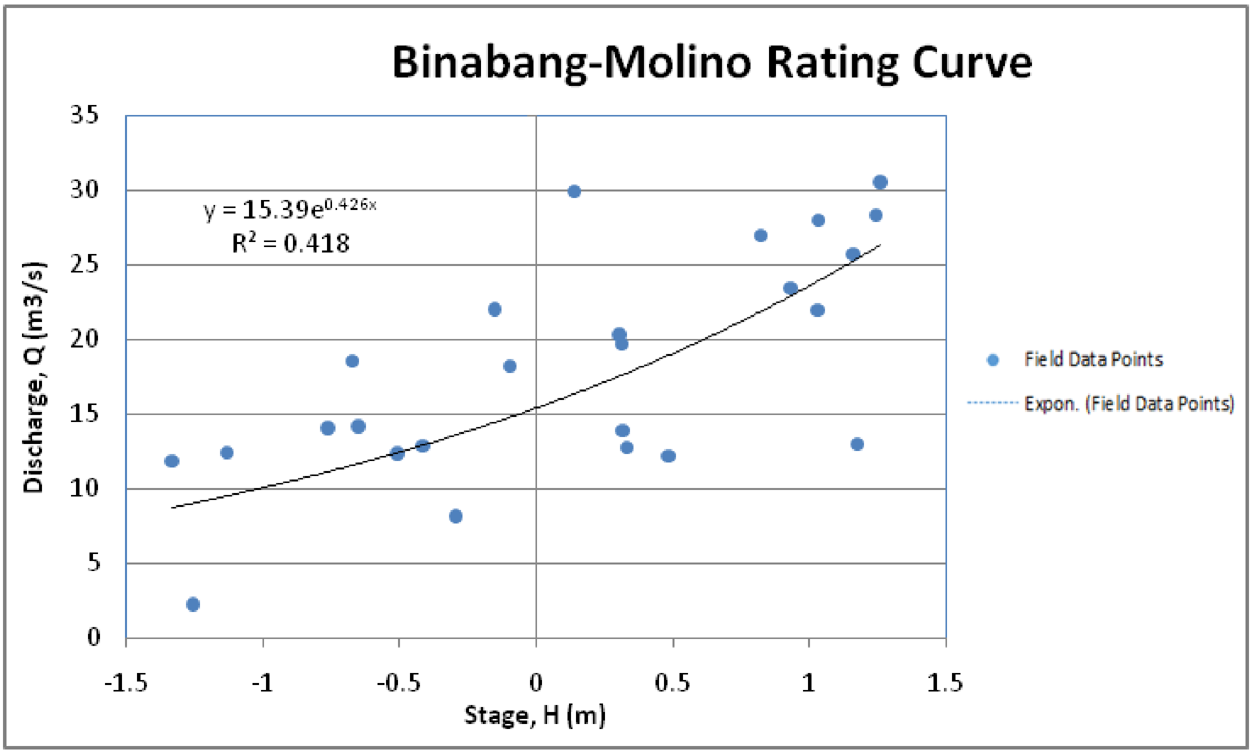


Figure 51. Rating curve at the Zapote Bridge, Binabang-Molino, Cavite

This rating curve equation was used to compute for the river outflow at the Zapote Bridge for the calibration of the HEC-HMS model presented in Figure 52. Peak discharge was 30.54 centimeters on July 8, 2016 at 12:40 hrs.

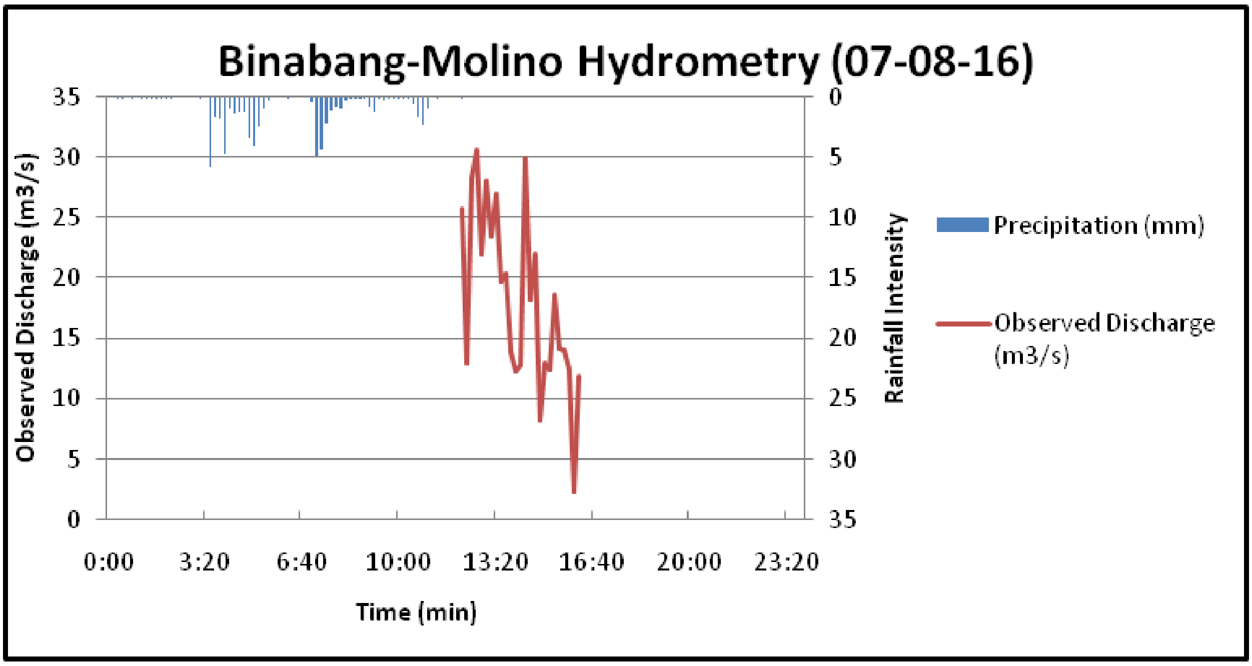


Figure 52. Rainfall and outflow data at Binabang-Molino, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Sangley Gauge (Table 29). This station was selected based on its proximity to the Binabang-Molino watershed (Figure 53). The extreme values for this watershed were computed based on a 54-year record.

Table 29. RIDF values for Sangley 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	22.7	35.5	36.3	50.2	68.2	80.1	104.1	125.7	150.8
5	27.9	45.5	53.8	74.2	103.4	122.5	159.7	192.9	226.7
10	34.2	52.1	65.4	90.1	126.7	150.6	196.5	237.3	276.9
15	37.8	57.4	71.9	99	139.8	166.4	217.3	262.4	305.3
20	40.3	61	76.5	105.3	149	177.5	231.9	280	325.1
25	42.2	63.9	80	110.1	156.1	186	243.1	293.5	340.4
50	48.1	72.6	90.9	125	178	212.3	277.6	335.2	387.5
100	54	81.2	101.6	139.8	199.7	238.4	311.8	376.6	434.3

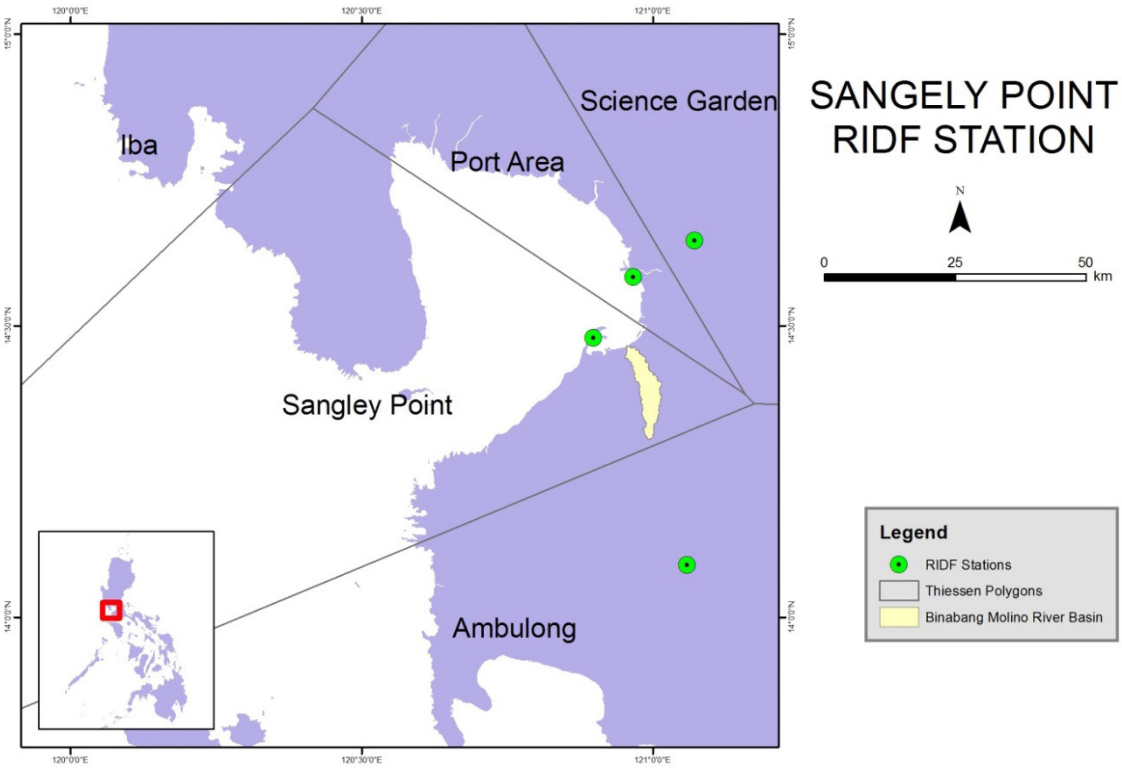


Figure 53. Sangley RIDF location relative to the Binabang-Molino River Basin

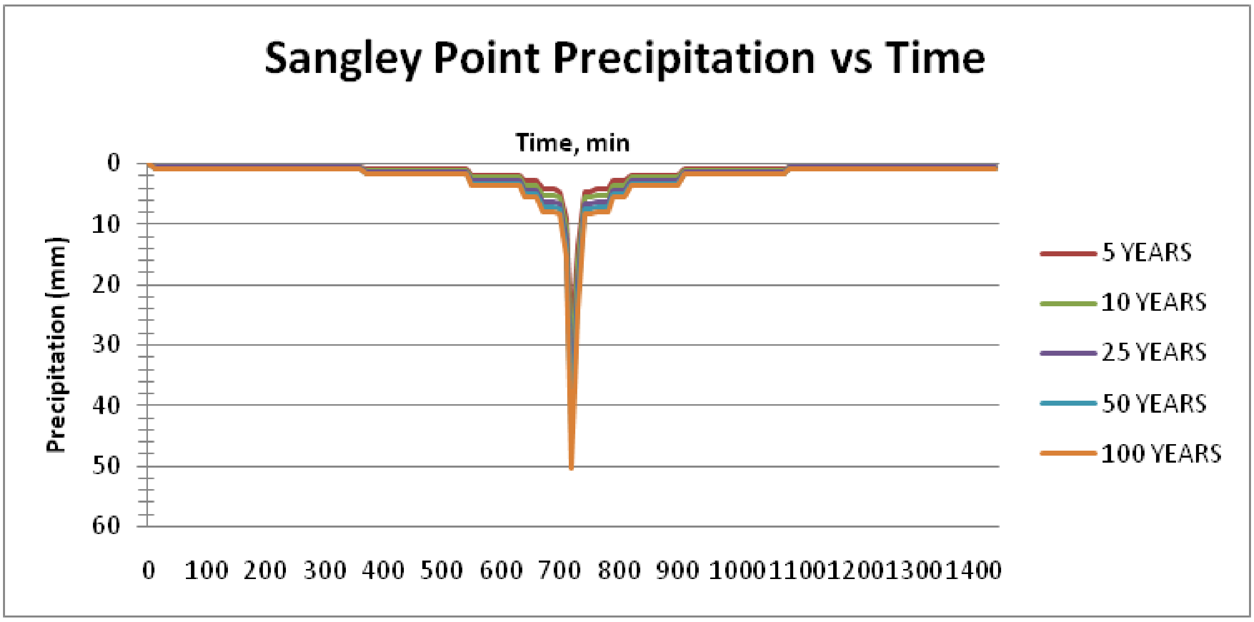


Figure 54. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken in 2004 from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover maps of the Binabang-Molino River Basin are exhibited in Figures 55 and 56, respectively.

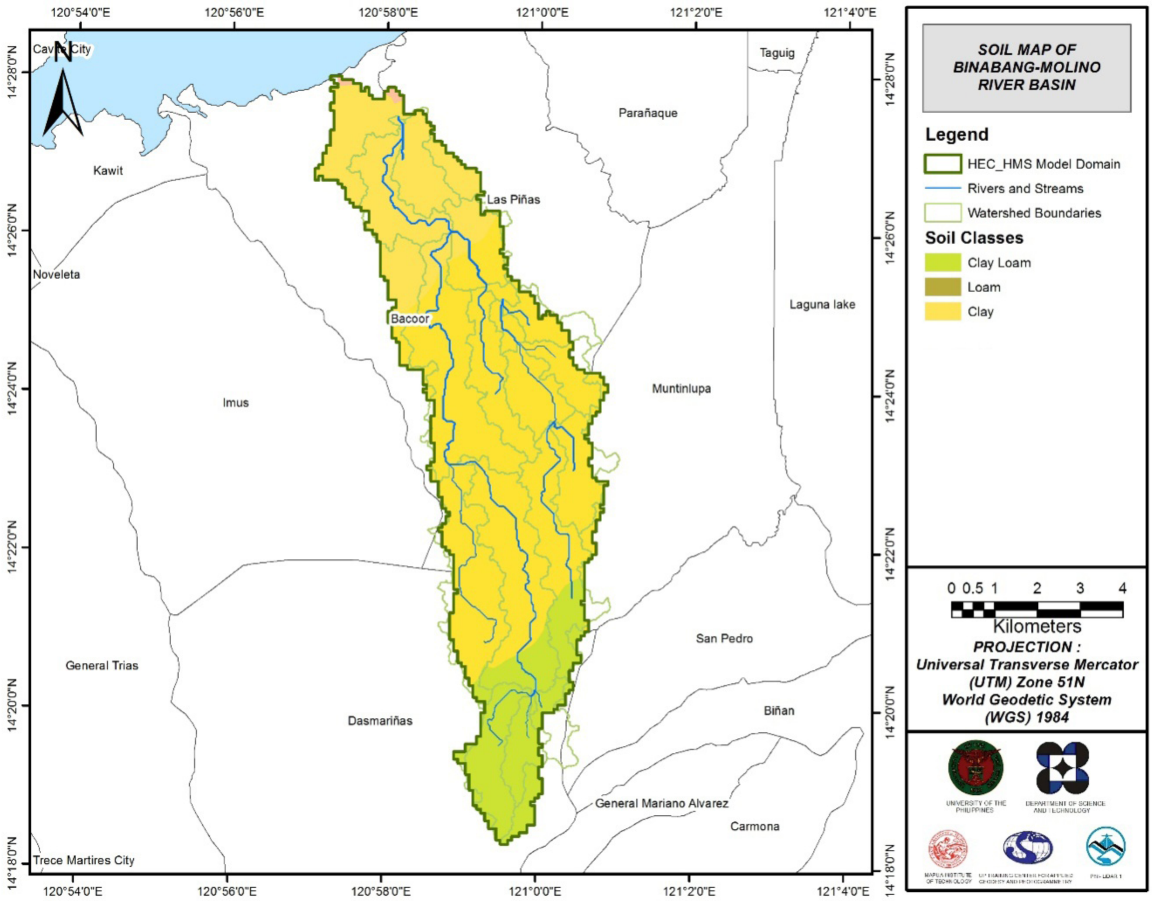


Figure 55. Soil map of the Binabang-Molino River Basin

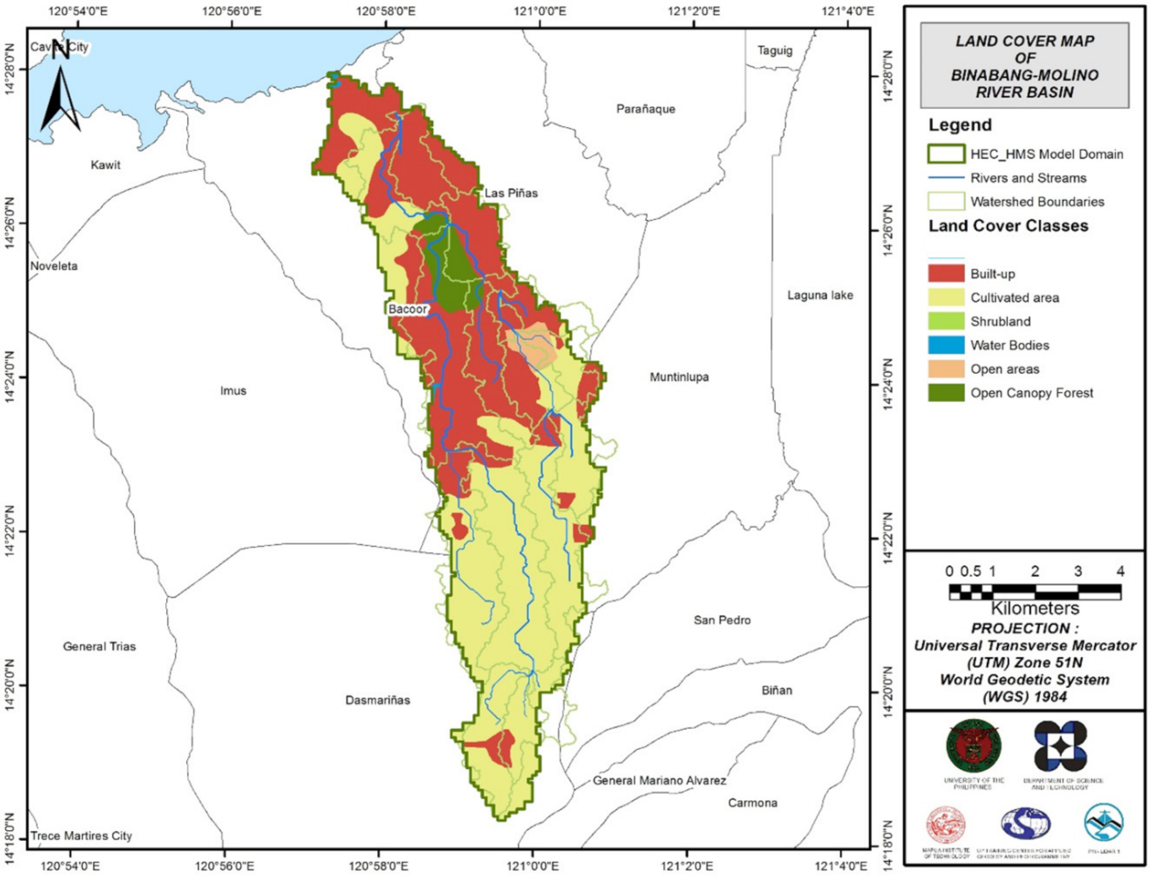


Figure 56. Land cover map of the Binabang-Molino River Basin

Three (3) soil classes were identified in the Binabang-Molino River Basin. These are clay loam, loam, and clay. Moreover, six (6) land cover classes were identified. These are built-up land, cultivated areas, shrub lands, water bodies, open areas, and open canopy forests.

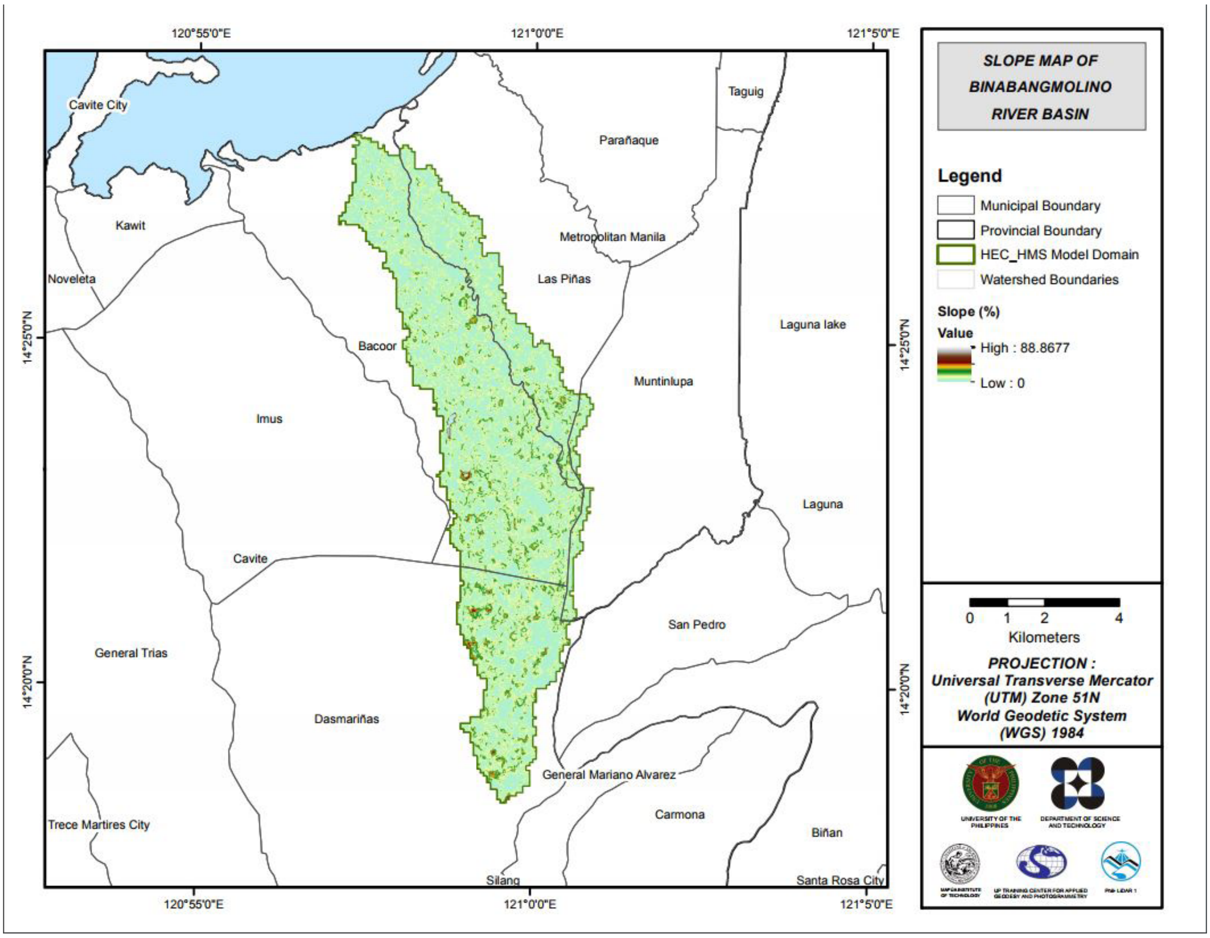


Figure 57. Slope map of the Binabang-Molino River Basin

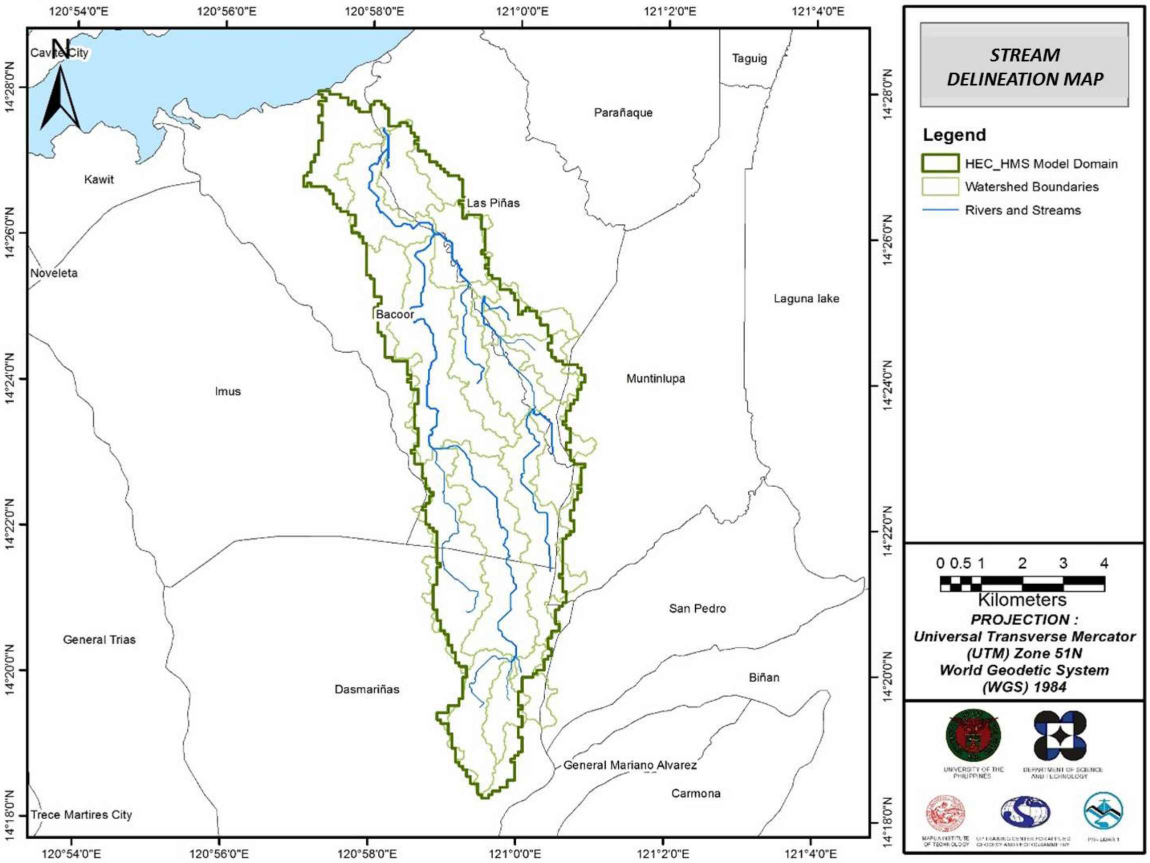


Figure 58. Stream delineation map of the Binabang-Molino River Basin

The Binabang-Molino basin model consists of nineteen (19) sub basins, nine (9) reaches, and nine (9) junctions. The main outlet is at the northernmost tip of the watershed. The basin model is illustrated in Figure 59. The basins were identified based on the soil and land cover characteristics of the area. Precipitation was taken from the DOST rain gauge. Finally, the model was calibrated using data from the Zapote Bridge. See Annex 10 for the Binabang-Molino Model Reach Parameters.

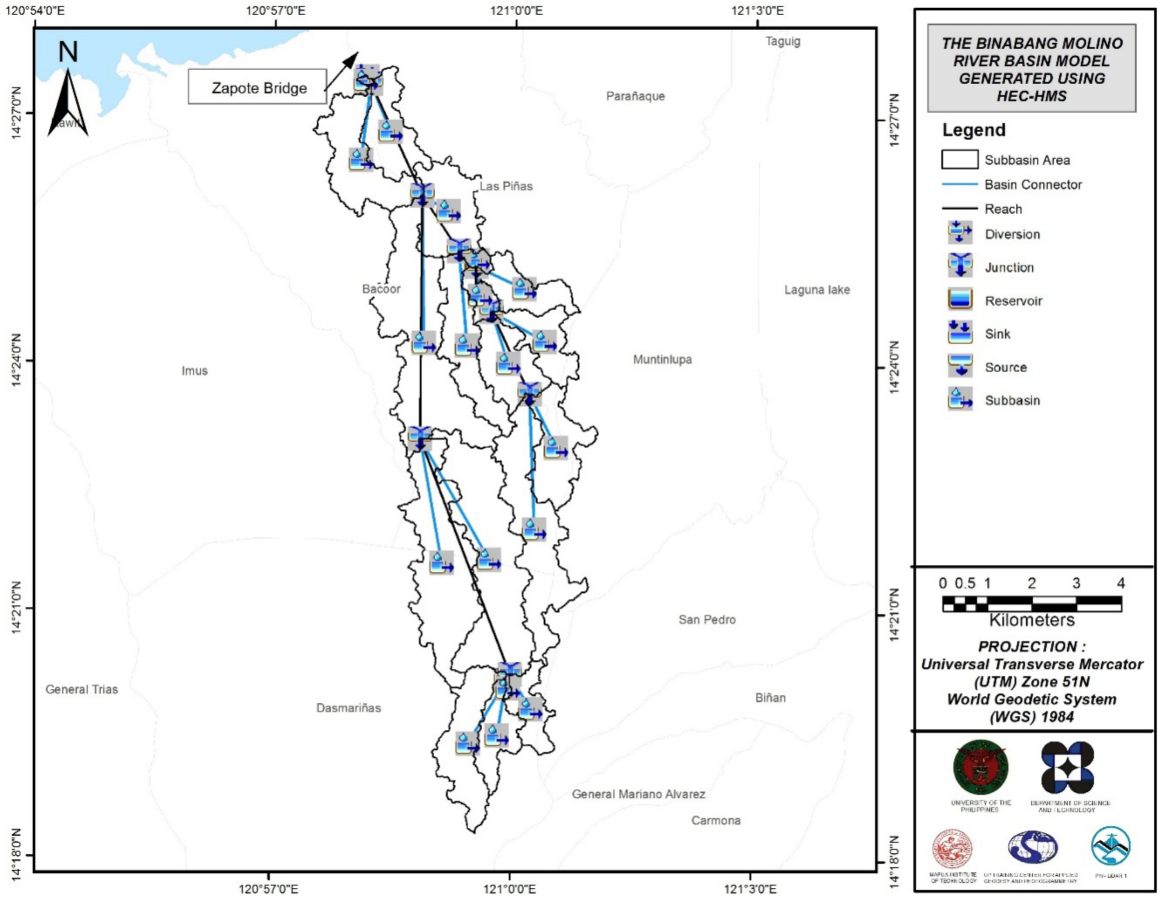


Figure 59. The Binabang-Molino River Basin model, generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 60).

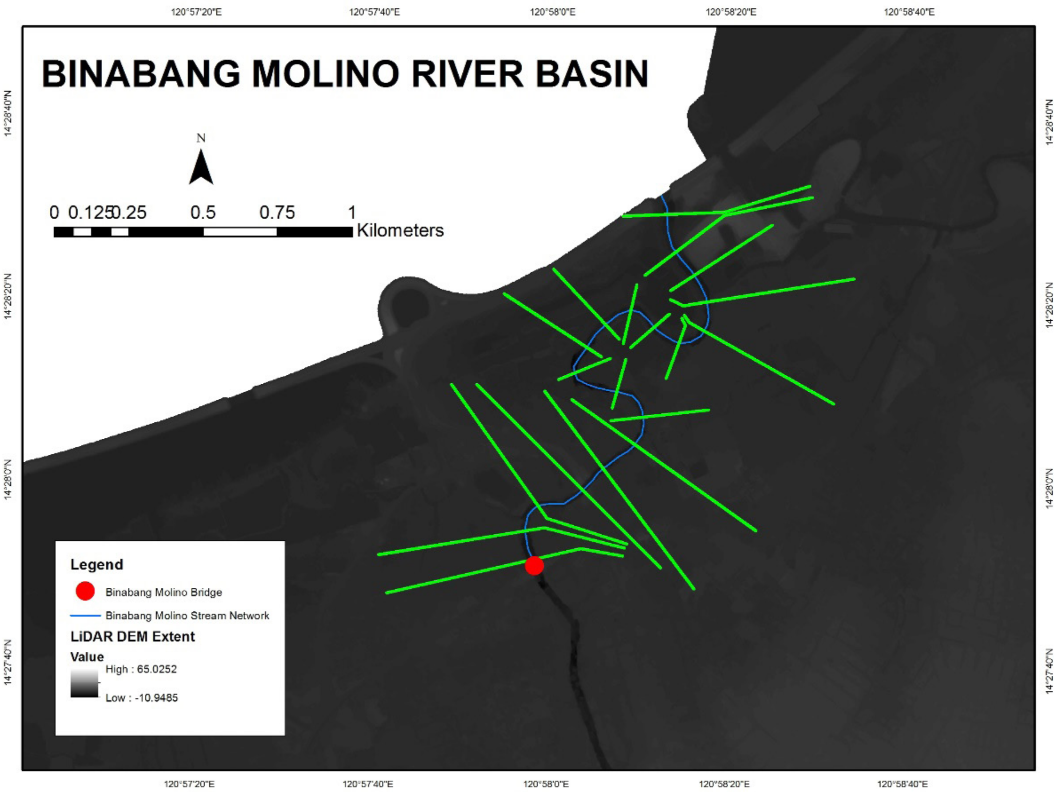


Figure 60. River cross-section of the Binabang-Molino River, generated through ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

[insert 2d report v4]

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

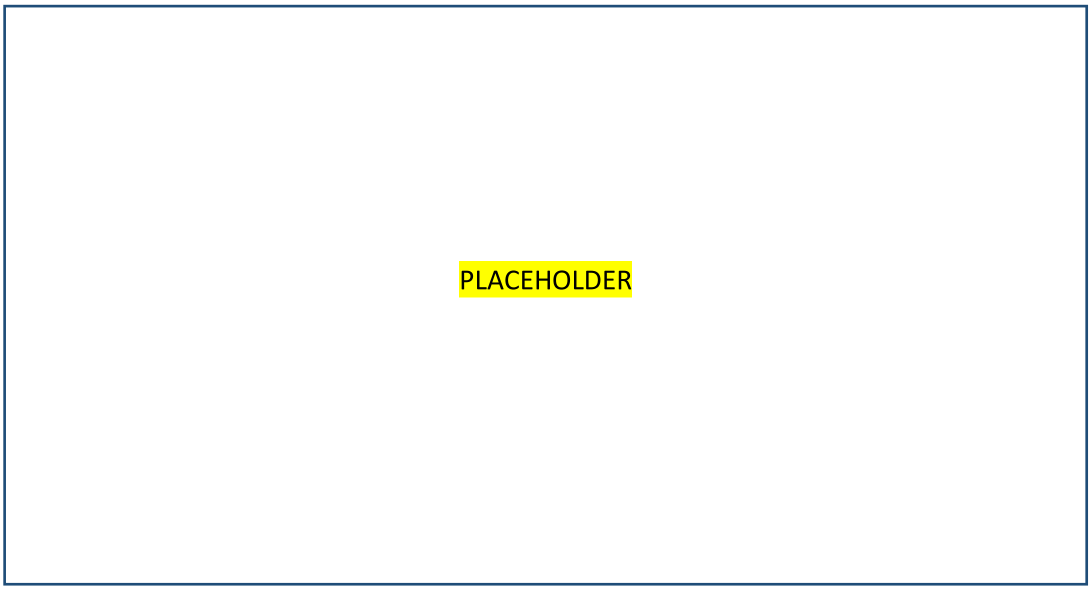


Figure 61. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

5.6 Results of HMS Calibration

After calibrating the Binabang-Molino HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 depicts the comparison between the two discharge data. The Binabang-Molino Model Basin Parameters are available in Annex 9.

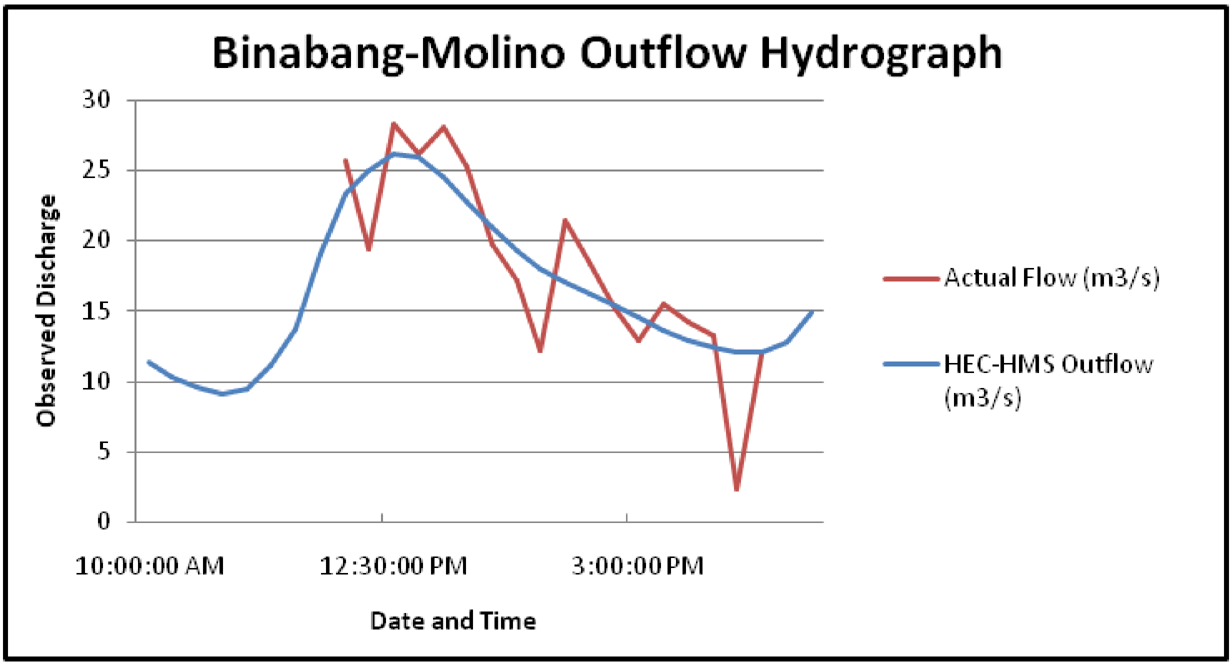


Figure 62. Outflow hydrograph of the Binabang-Molino produced by the HEC-HMS model, compared with observed outflow

Table 30 enumerates the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of calibrated values for the Binabang-Molino River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.16 – 36
			Curve Number	35 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.20 – 9.52
			Storage Coefficient (hr)	0.59 – 221
	Baseflow	Recession	Recession Constant	0.001 – 1
			Ratio to Peak	0.19 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.01 – 0.08

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values of 0.16 to 36 millimeters signifies that there is a minimal amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of the curve number for the Binabang-Molino River Basin is 35 to 99. The basin mostly consists of built-up and cultivated areas; and the soil mostly consists of clay and clay loam.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 hours to 9.52 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; while ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.001 - 1 implies that the basin is unlikely to quickly revert to its original discharge, and will be higher instead. A ratio to peak of 0.19 – 0.5 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.01 - 0.08 corresponds to the common roughness in Binabang-Molino watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 31. Efficiency Test of the Binabang-Molino HMS Model

Accuracy Measure	Value
r^2	0.7279
NSE	0.715
PBIAS	-1.567
RSR	0.534

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 3.551 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 represents an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.7279.

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 0.715.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -1.567.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained an RSR value of 0.534.

5.7 Calculated outflow hydrographys and Discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) depicts the Binabang-Molino outflow using the Sangley RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

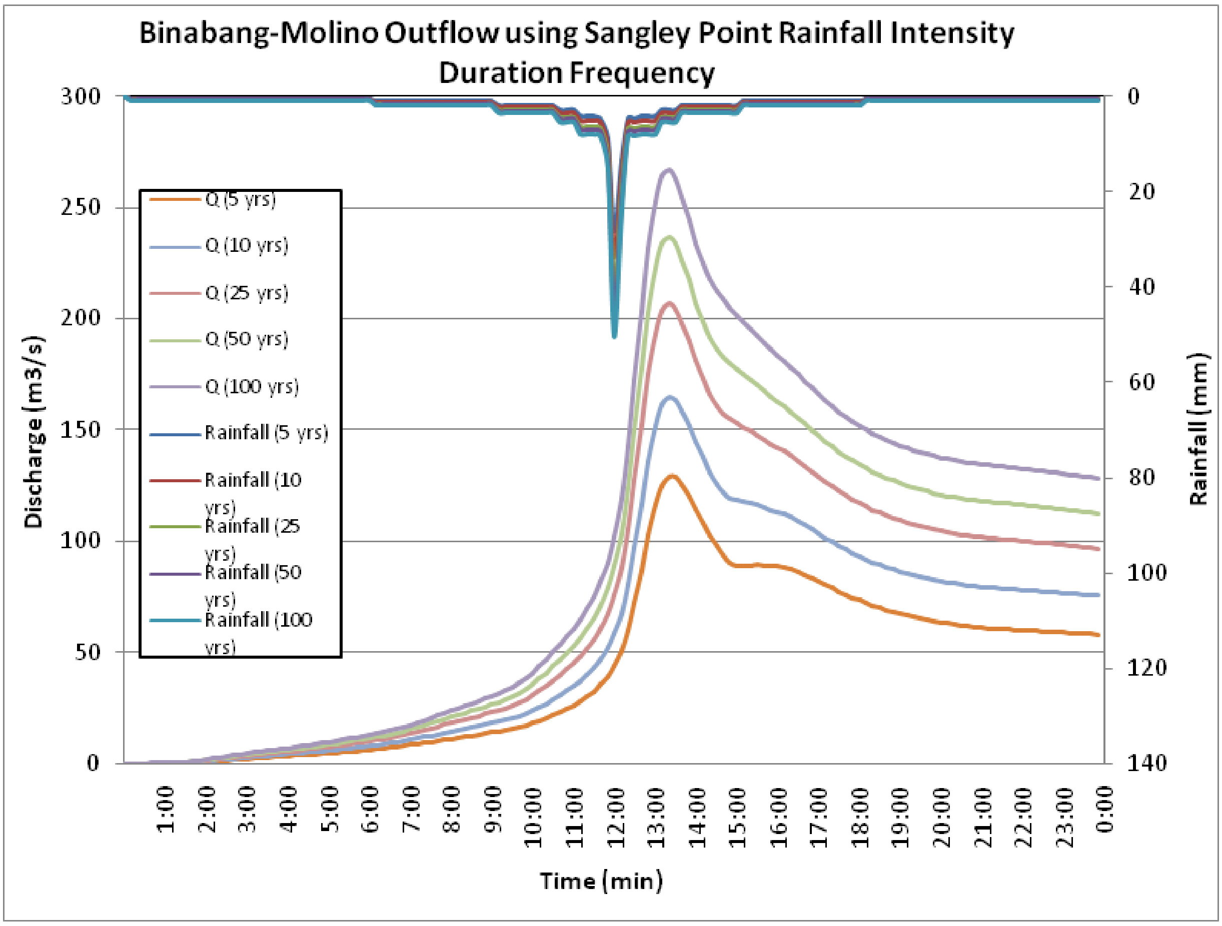


Figure 63. Outflow hydrograph at the Zapote Bridge generated using the Sangley RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Binabang-Molino River discharge using the Sangley RIDF curves in five (5) different return periods is outlined in Table 32.

Table 32. Peak values of the Binabang-Molino HEC-HMS Model outflow, using the Sangley RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	209.4	28.3	129	13 hours, 20minutes
10-Year	250.1	33.6	164.8	13 hours, 20minutes
25-Year	301.5	40.3	206.9	13 hours, 20minutes
50-Year	339.7	45.3	236.9	13 hours, 20minutes
100-Year	377.6	50.3	266.8	13 hours, 20minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map of the river is presented, since only the MIT Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of the Binabang-Molino River using the calibrated HMS base flow is shown in Figure 64.

Figure 64. Sample output map of the Binabang-Molino RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 65 to Figure 70 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Binabang-Molino floodplain. The floodplain, with an area of 76.52 square kilometers, covers five (5) municipalities, namely Bacoor, Dasmariñas, Imus, Las Piñas, and Muntinlupa. Table 33 enumerates the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in the Binabang-Molino floodplain

Municipality	Total Area	Area Flooded	% Flooded
Bacoor	47.43	38.23	81%
Dasmariñas	84.01	12.50	15%
Imus	56.81	0.00	0%
Las Piñas	33.19	24.89	75%
Muntinlupa	38.52	0.90	2.34%

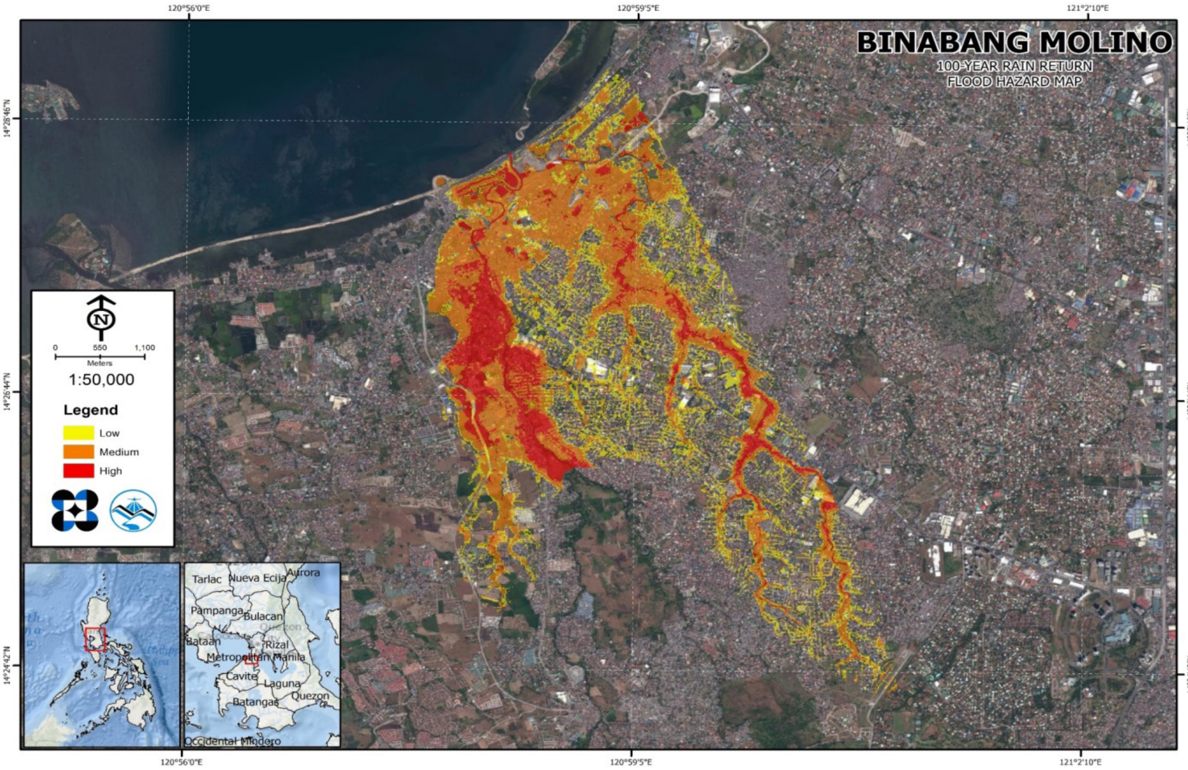


Figure 65. 100-year flood hazard map for the Binabang-Molino floodplain

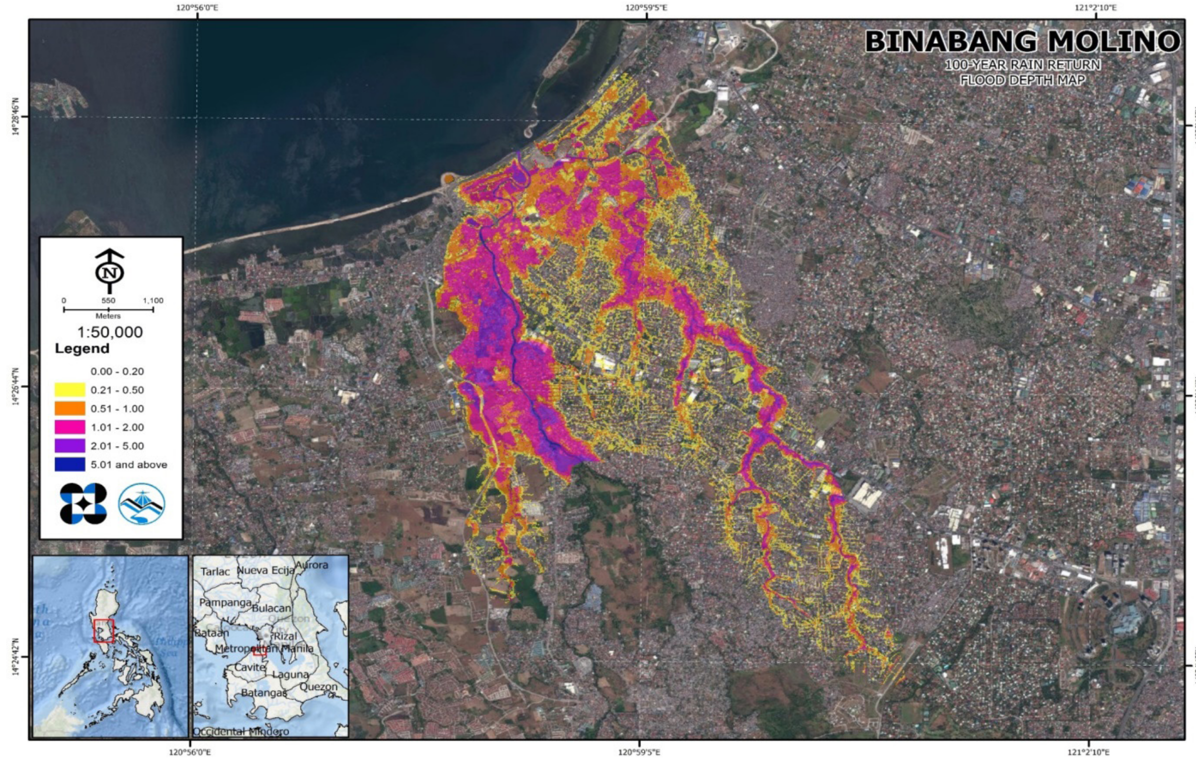


Figure 66. 100-year flow depth map for the Binabang-Molino floodplain

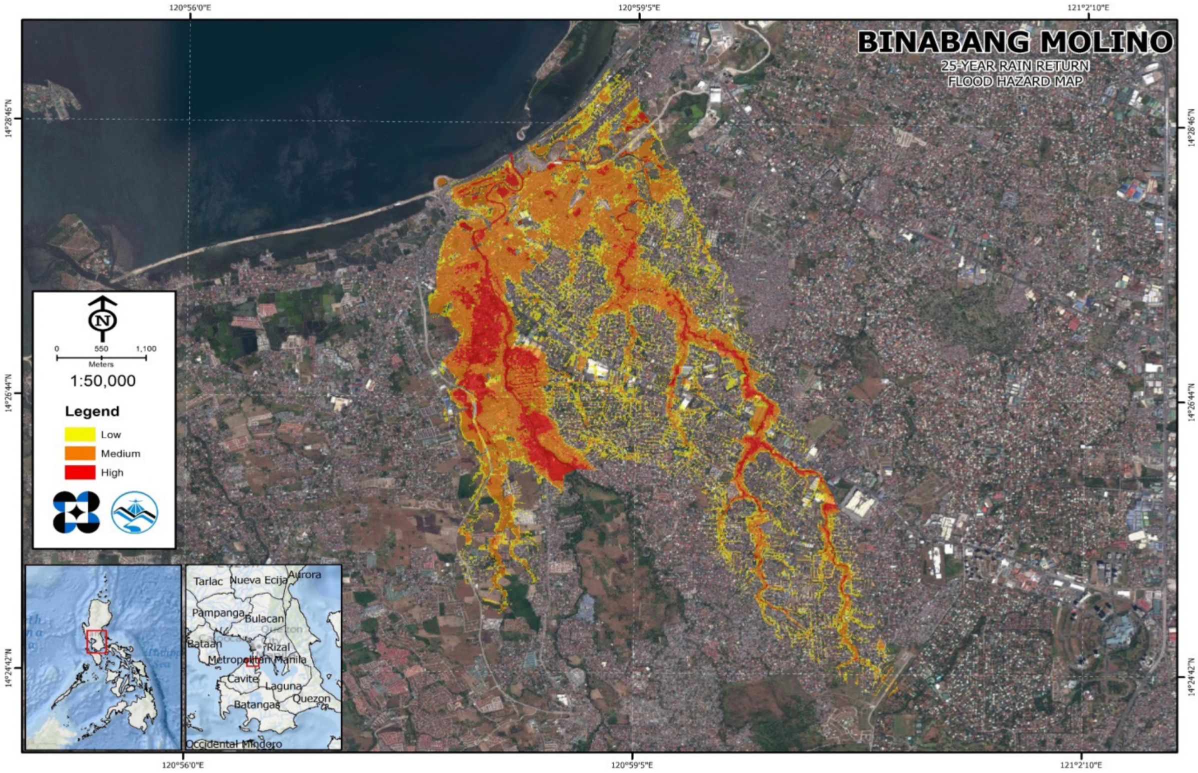


Figure 67. 25-year flood hazard map for the Binabang-Molino floodplain

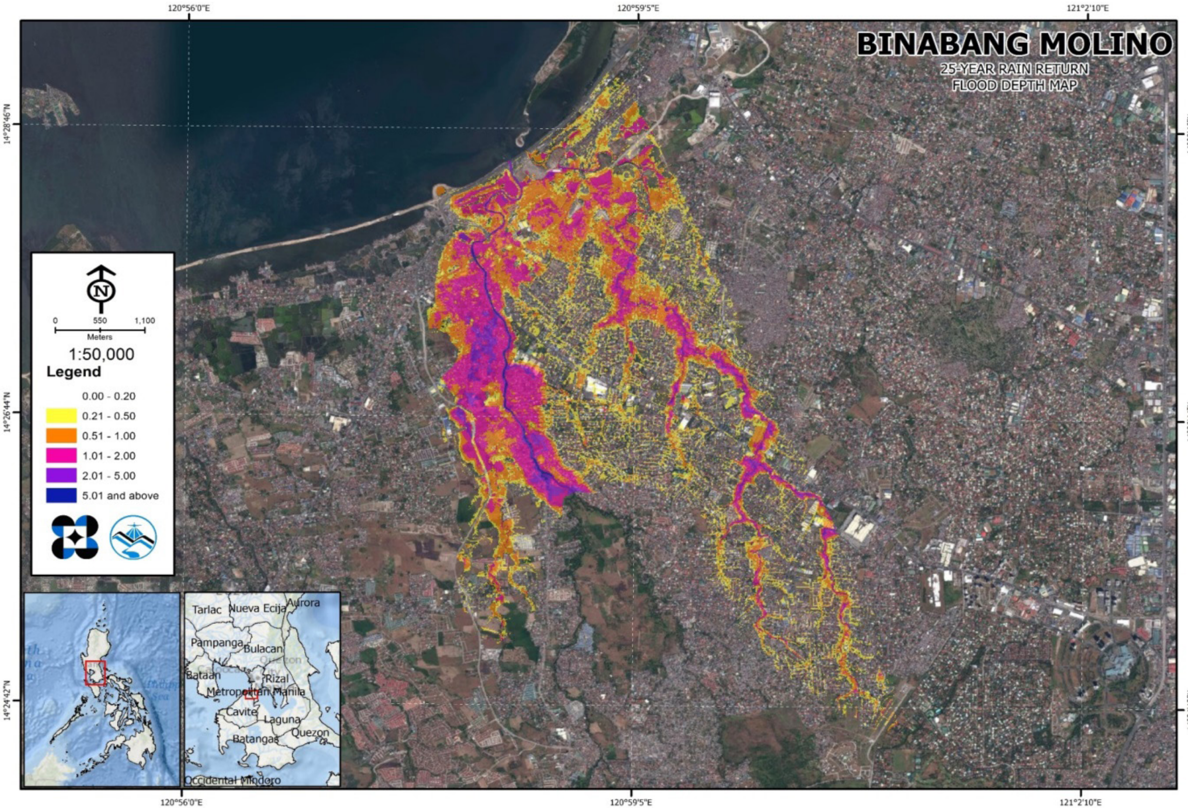


Figure 68. 25-year flow depth map for the Binabang-Molino floodplain

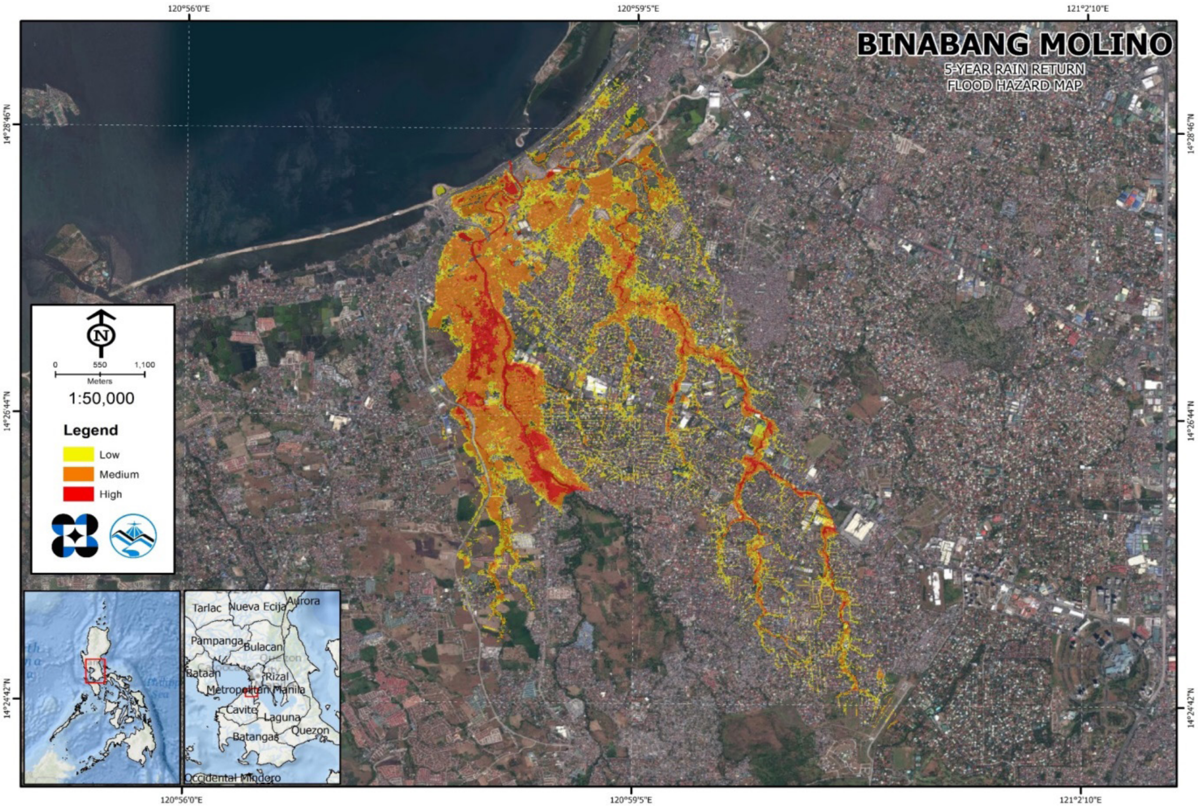


Figure 69. 5-year flood hazard map for the Binabang-Molino floodplain

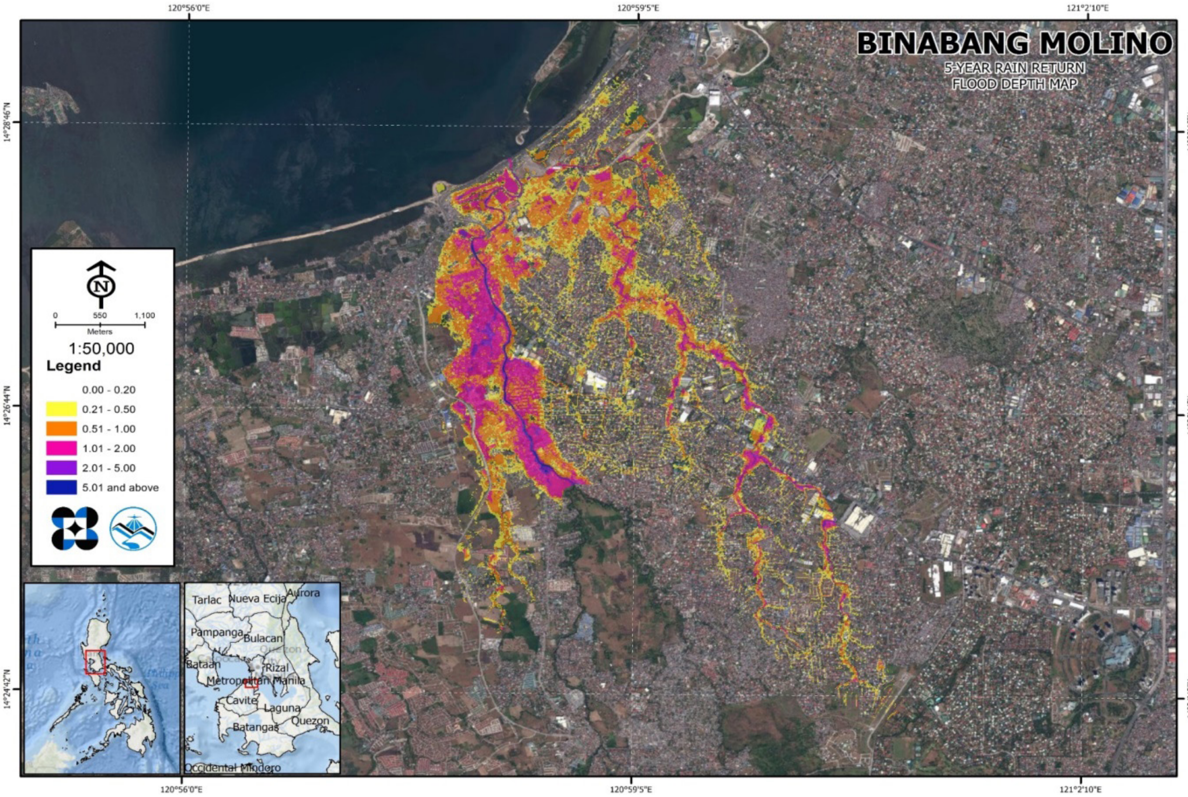


Figure 70. 5-year flow depth map for the Binabang-Molino floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in the Binabang-Molino River Basin, grouped by municipality, are listed below. For the said basin, five (5) municipalities consisting of sixty-three (63) barangays are expected to experience flooding when subjected to the 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 61.60% of the Municipality of Bacoor, with an area of 47.43 square kilometers, will experience flood levels of less than 0.20 meters. 9.16% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.33%, 3.25%, 1.28%, and 0.14% 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 34 are the affected areas, in square kilometers, by flood depth per barangay.

Table 34. Affected areas in Bacoor, Cavite during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Alima	Aniban I	Aniban II	Aniban III	Aniban IV	Aniban V	Banalo	Bayanan	Campo Santo	Daang Bukid	Digman
0.03-0.20	0.25	0.044	0.08	0.075	0.043	0.023	0.0043	2.32	0.17	0.24	0.03
0.21-0.50	0.023	0.016	0.0058	0.03	0.029	0.014	0.00079	0.31	0.038	0.24	0.073
0.51-1.00	0.0014	0.056	0.02	0.012	0.039	0.027	0	0.19	0.0048	0.23	0
1.01-2.00	0	0.075	0.081	0.031	0.042	0.038	0	0.032	0	0.0003	0
2.01-5.00	0	0.0026	0.01	0.018	0.017	0.0033	0	0.0001	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

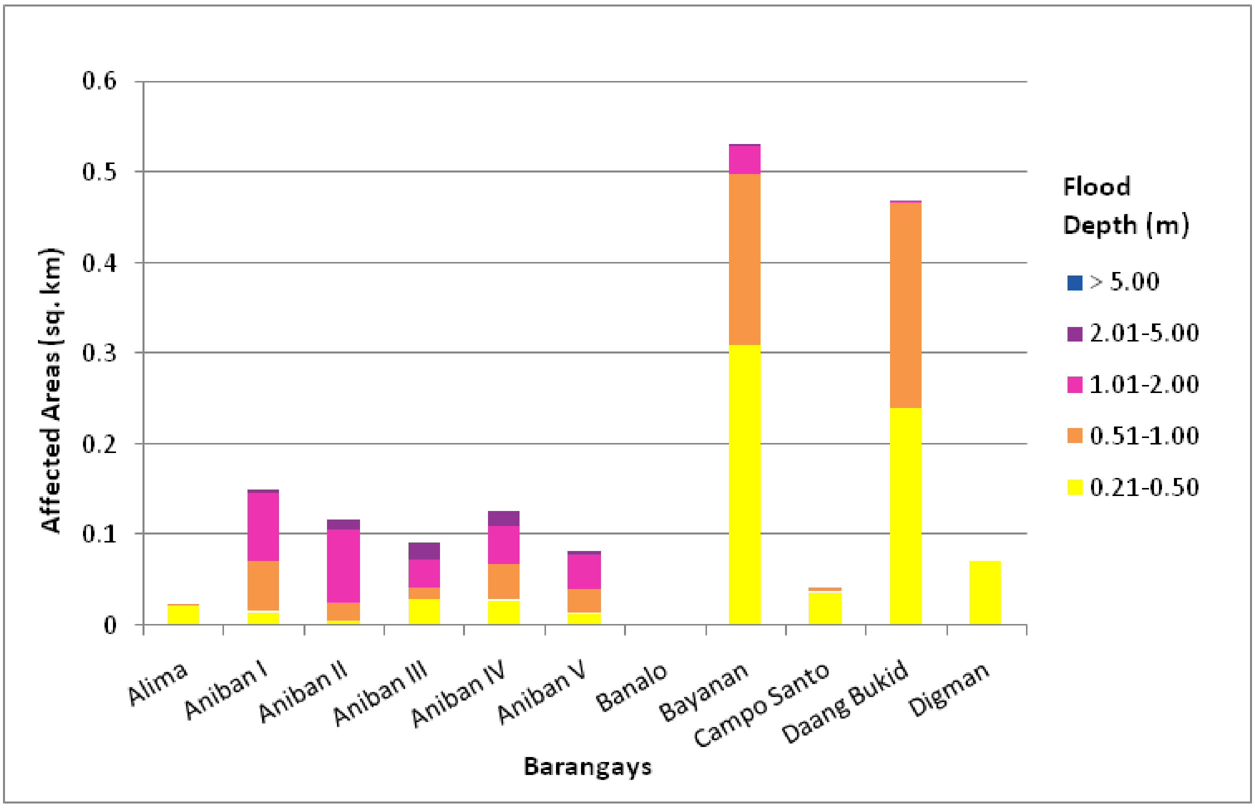
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Habay I	Habay II	Kaingin	Ligas I	Ligas II	Ligas III	Maliksi I	Maliksi II	Maliksi III	Mambog I	Mambog II
0.03-0.20	0.31	0.32	0.28	0.042	0.075	0.11	0.2	0.11	0.073	0.86	0.89
0.21-0.50	0.18	0.17	0.056	0.034	0.042	0.021	0.082	0.043	0.044	0.29	0.096
0.51-1.00	0.014	0.13	0.0019	0.056	0.12	0.028	0.018	0.0099	0.021	0.052	0.03
1.01-2.00	0.0012	0.0013	0	0.039	0.064	0.1	0	0	0	0.0029	0.0039
2.01-5.00	0	0	0	0.0001	0.0008	0.0063	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

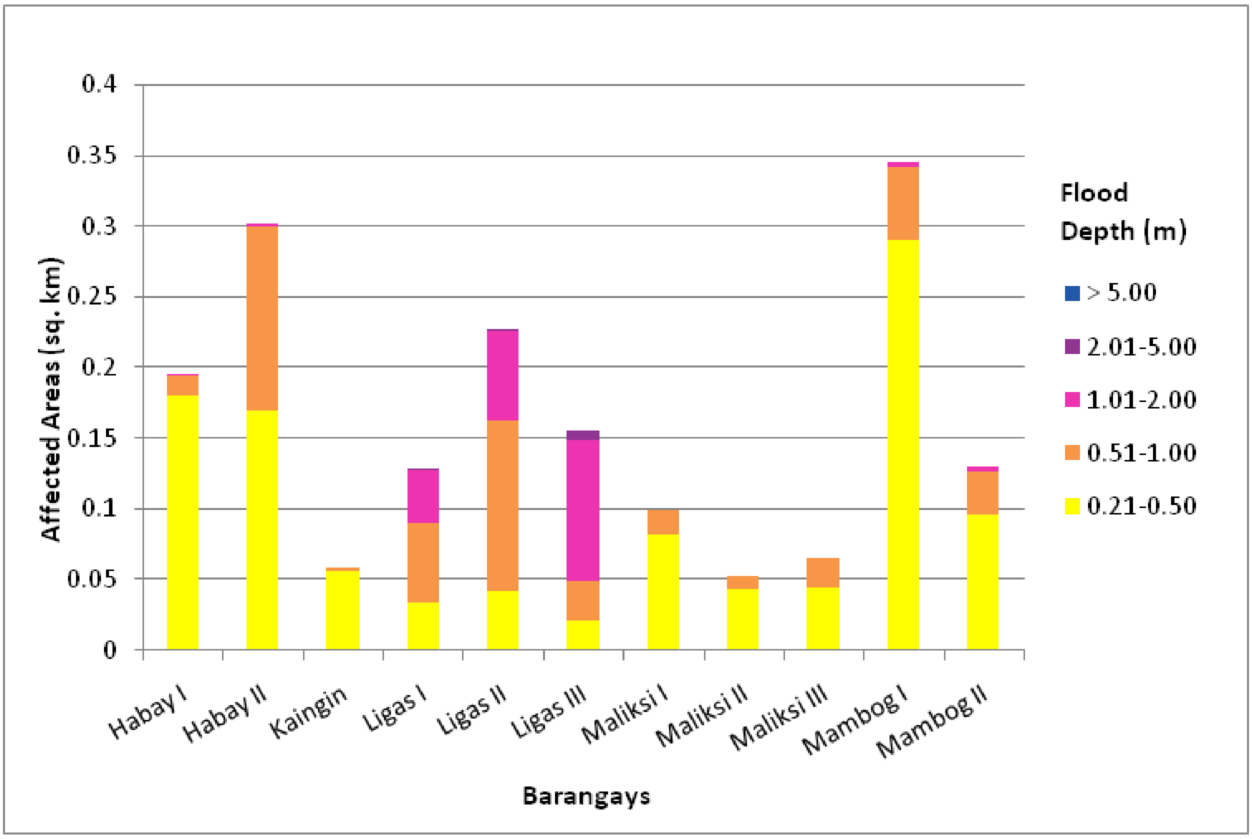
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Mambog III	Mambog IV	Mambog V	Molino I	Molino II	Molino III	Molino IV	Molino V	Molino VI	Molino VII	Niog I
0.03-0.20	0.88	0.31	0.027	6.58	0.79	0.95	0.39	0.9	1.74	0.36	0.8
0.21-0.50	0.088	0.15	0.076	0.38	0.016	0.08	0.0099	0.033	0.16	0.016	0.13
0.51-1.00	0.021	0.014	0.02	0.21	0.025	0.039	0.0059	0.0073	0.1	0.016	0.011
1.01-2.00	0.0049	0	0	0.17	0.046	0.053	0.01	0.0027	0.097	0.011	0
2.01-5.00	0.0002	0	0	0.12	0.0055	0.043	0.0016	0.0003	0.058	0.035	0
> 5.00	0	0	0	0.0009	0	0	0	0	0.016	0.012	0

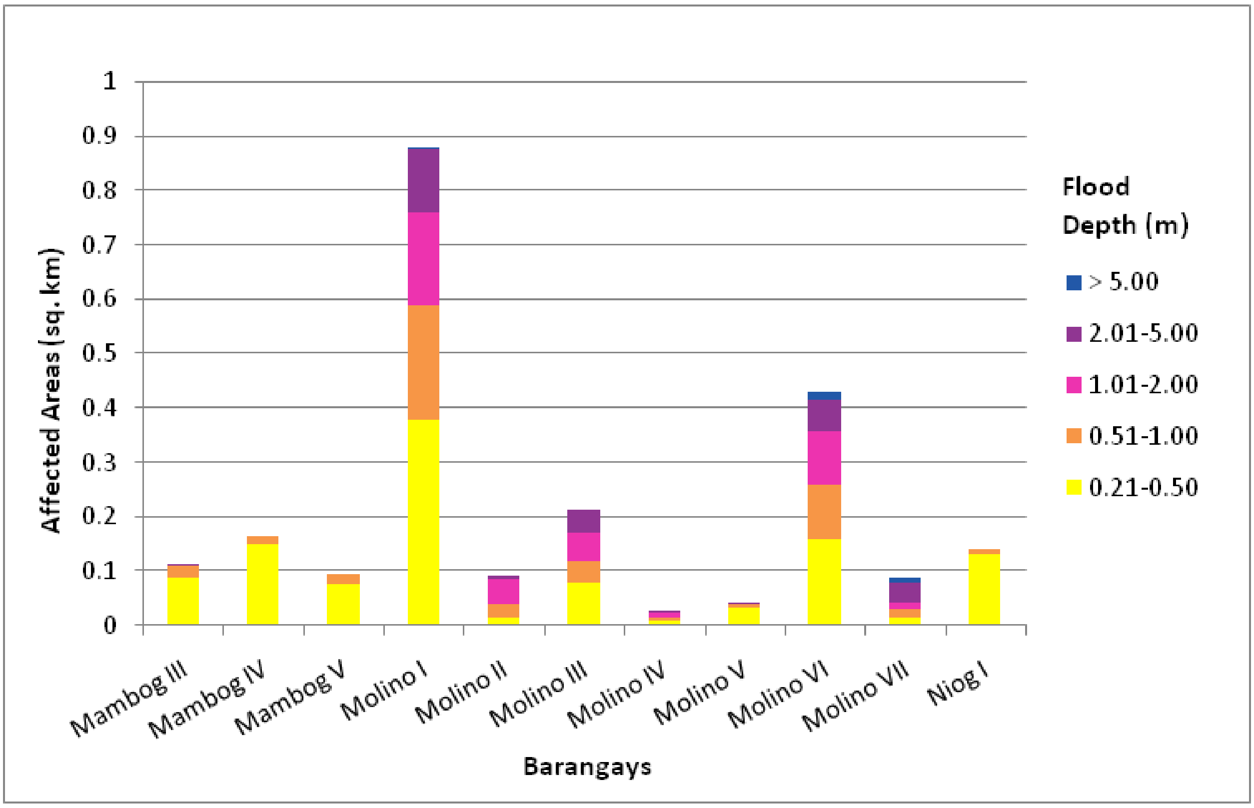
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Niog II	Niog III	P.F. Espiritu I	P.F. Espiritu II	P.F. Espiritu III	P.F. Espiritu IV	P.F. Espiritu V	P.F. Espiritu VI	P.F. Espiritu VII	P.F. Espiritu VIII	Queens Row Central
0.03-0.20	0.075	0.17	0.43	0.13	0.11	0.03	0.2	0.28	0.21	0.11	2.08
0.21-0.50	0.057	0.0086	0.012	0.12	0.032	0.12	0.022	0.023	0.0078	0.0016	0.2
0.51-1.00	0	0	0.002	7.1E-06	0.011	0.027	0	0.006	0.00098	0	0.16
1.01-2.00	0	0	0	0	0	0	0	0.0064	0	0	0.15
2.01-5.00	0	0	0	0	0	0	0	0	0	0	0.095
> 5.00	0	0	0	0	0	0	0	0	0	0	0.023

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)									
	Queens Row East	Queens Row West	Real I	San Nicolas I	San Nicolas II	San Nicolas III	Sineguelasan	Tabing Dagat	Talaba I	Talaba II
0.03-0.20	0.0025	2.67	0.031	0.84	0.73	0.35	0.074	0.059	0.14	0.069
0.21-0.50	0	0.11	0	0.088	0.066	0.08	0	0.011	0.042	0.049
0.51-1.00	0	0.073	0	0.053	0.04	0.094	0	0	0.057	0.067
1.01-2.00	0	0.081	0	0.034	0.031	0.12	0	0	0.029	0.02
2.01-5.00	0	0.042	0	0.055	0.051	0.034	0	0	0.0026	0.001
> 5.00	0	0	0	0.0096	0.0029	0.0016	0	0	0	0.00057

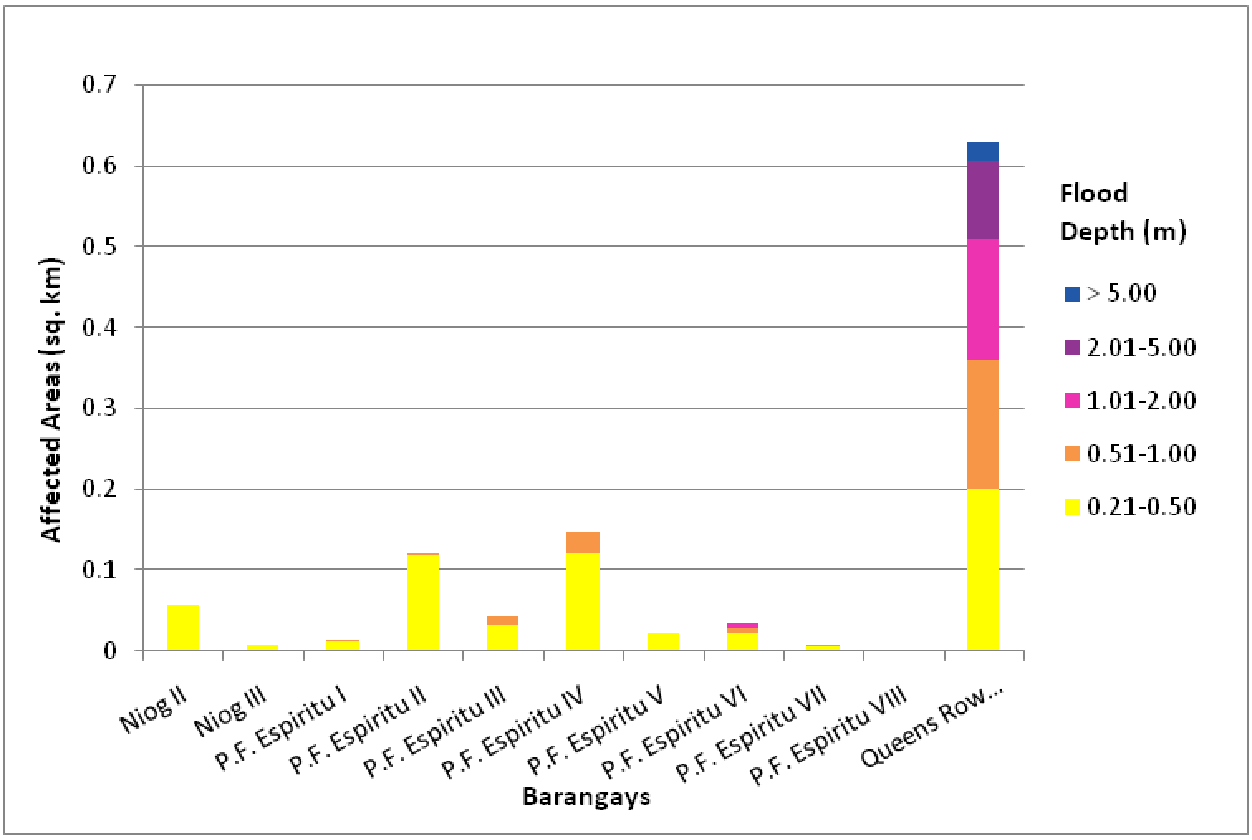
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)									
	Talaba III	Talaba IV	Talaba V	Talaba VI	Talaba VII	Zapote I	Zapote II	Zapote III	Zapote IV	Zapote V
0.03-0.20	0.041	0.0026	0.0043	0.0001	0.017	0.0075	0.0079	0.028	0.034	0.0063
0.21-0.50	0.027	0.023	0.019	0.038	0.02	0.042	0.016	0.021	0.046	0.064
0.51-1.00	0.024	0.014	0.034	0.02	0.025	0.083	0.059	0.075	0.034	0.04
1.01-2.00	0.004	0.000049	0	0	0.0023	0.011	0.061	0.082	0.0049	0
2.01-5.00	0	0	0	0	0	0.0011	0.0011	0.00034	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0


0.6
0.5
0.4
0.3
0.2
0.1
0
Affected Areas (sq. km)
Alima
Aniban I
Aniban II
Aniban III
Aniban IV
Aniban V
Banalo
Bayanan
Campo Santo
Daang Bukid
Digman
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50

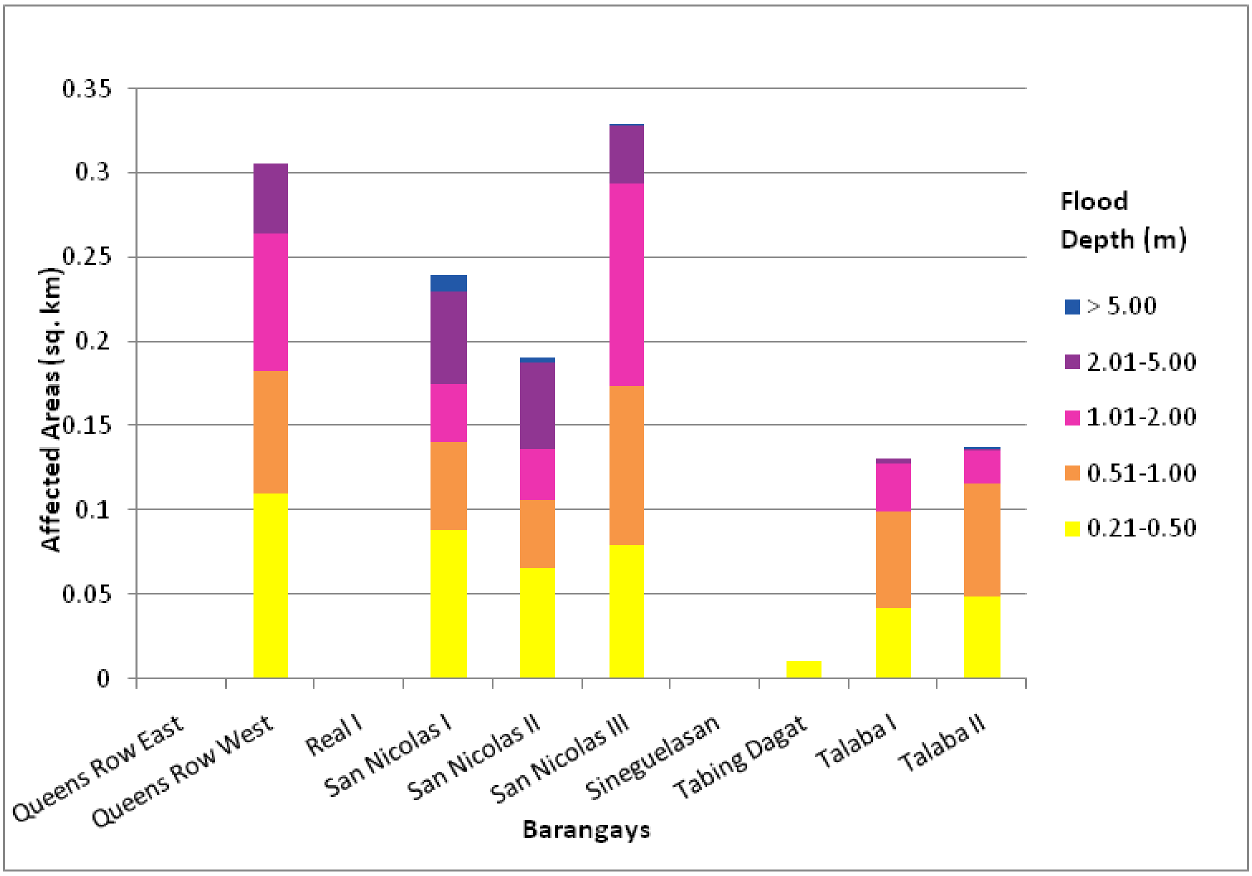

0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Affected Areas (sq. km)
Habay I
Habay II
Kaingin
Ligas I
Ligas II
Ligas III
Maliksi I
Maliksi II
Maliksi III
Mambog I
Mambog II
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50



Affected Areas (sq. km)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mambog III
Mambog IV
Mambog V
Molino I
Molino II
Molino III
Molino IV
Molino V
Molino VI
Molino VII
Niog I
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50



Affected Areas (sq. km)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Niog II
Niog III
P.F. Espiritu I
P.F. Espiritu II
P.F. Espiritu III
P.F. Espiritu IV
P.F. Espiritu V
P.F. Espiritu VI
P.F. Espiritu VII
P.F. Espiritu VIII
Queens Row...
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50



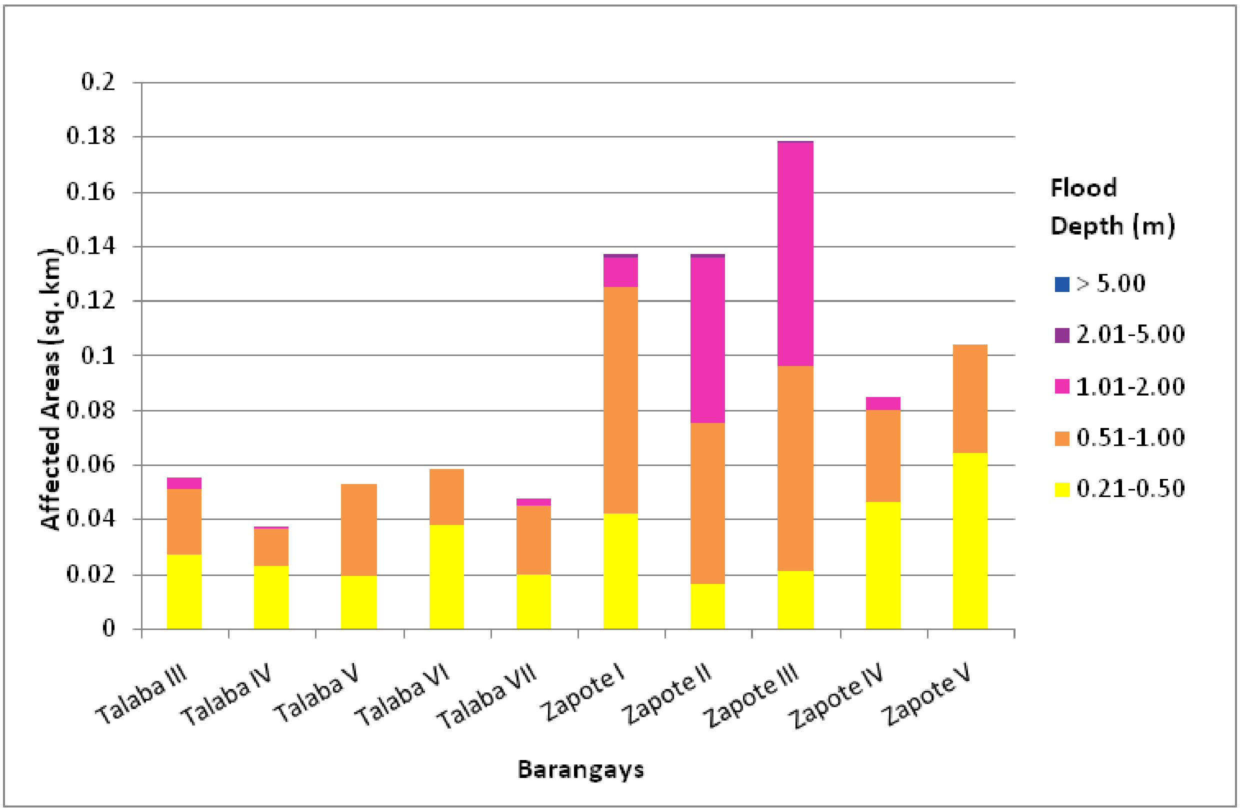


Figure 71. Affected areas in Bacoor, Cavite during a 5-year rainfall return period

For the 5-year return period, 13.15% of the Municipality of Dasmariñas, with an area of 84.01 square kilometers, will experience flood levels of less than 0.20 meters. 0.65% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.52%, 0.39%, 0.16%, and 0.01% 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 35 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected areas in Dasmariñas, Cavite during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dasmariñas (in sq. km)		
	Paliparan II	Paliparan III	Salawag
0.03-0.20	0.11	2	8.94
0.21-0.50	0.0037	0.11	0.43
0.51-1.00	0.0008	0.059	0.38
1.01-2.00	0	0.02	0.31
2.01-5.00	0	0.0004	0.13
> 5.00	0	0	0.0078

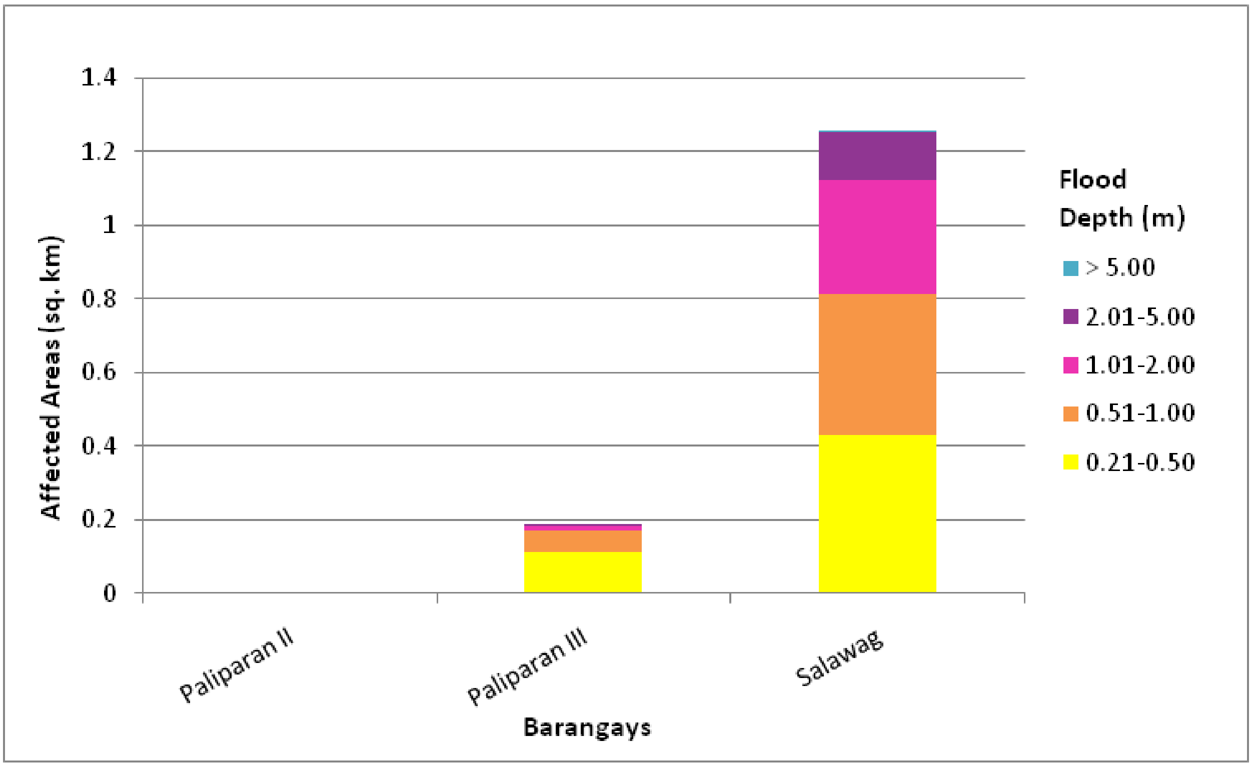


Figure 72. Affected areas in Dasmariñas, Cavite during a 5-year rainfall return period

For the 5-year return period, 0.00% of the Municipality of Imus, with an area of 56.81 square kilometers, will experience flood levels of less than 0.20 meters. 0.00% of the area will experience flood levels of 0.21 to 0.50 meters, and 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected areas in Imus, Cavite during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Imus (in sq. km)
	Tanzang Luma VI
0.03-0.20	0.000027
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

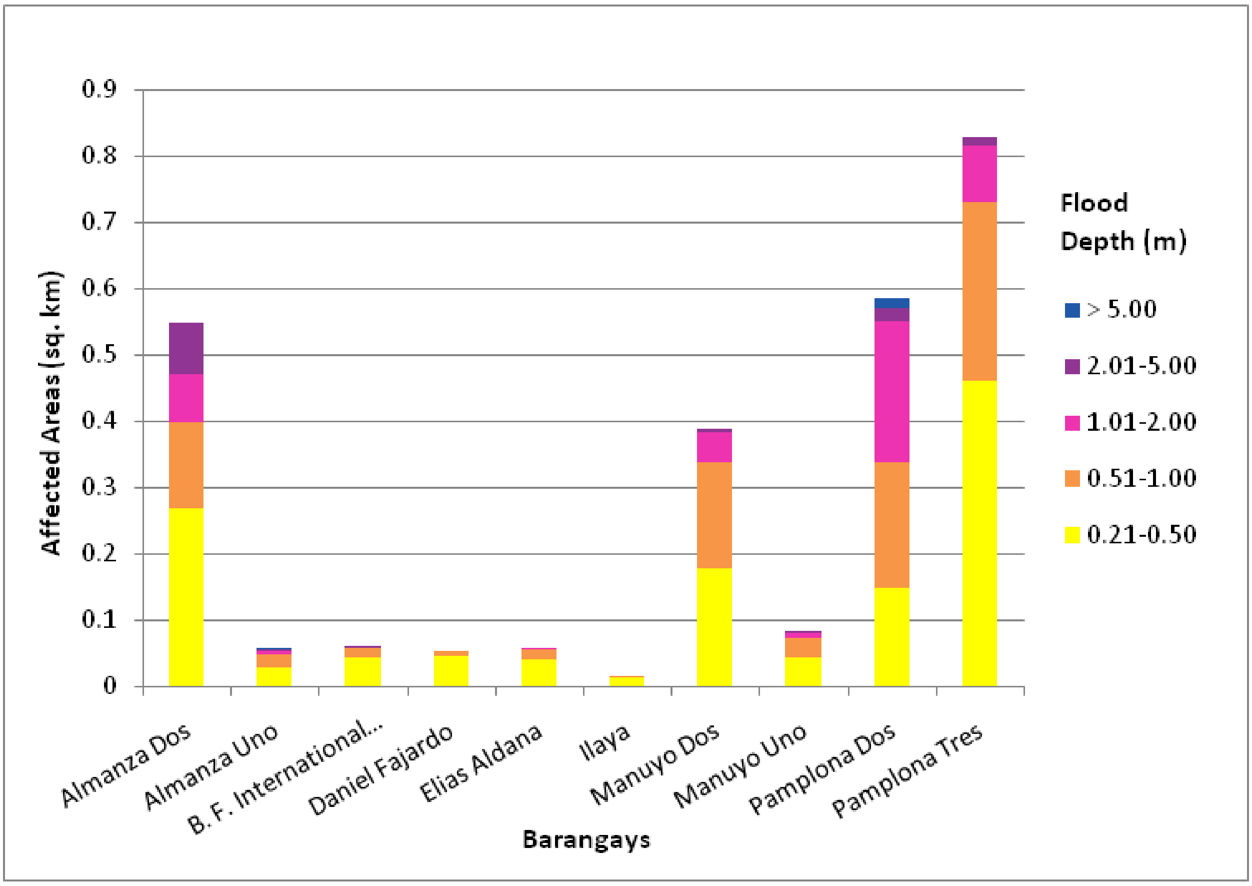
Figure 73. Affected areas in Imus, Cavite during a 5-year rainfall return period

For the 5-year return period, 51.41% of the City of Las Piñas, with an area of 33.19 square kilometers, will experience flood levels of less than 0.20 meters. 10.07% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 7.66%, 4.51%, 1.14%, and 0.17% 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 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Las Piñas City, Metropolitan Manila during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Las Piñas (in sq. km)									
	Almanza Dos	Almanza Uno	B. F. International Village	Daniel Fajardo	Elias Aldana	Ilaya	Manuyo Dos	Manuyo Uno	Pamplona Dos	Pamplona Tres
0.03-0.20	3.36	0.097	0.24	0.14	0.16	0.096	0.59	0.29	0.5	1.61
0.21-0.50	0.27	0.029	0.045	0.048	0.043	0.017	0.18	0.046	0.15	0.46
0.51-1.00	0.13	0.02	0.016	0.0068	0.017	0.00021	0.16	0.03	0.19	0.27
1.01-2.00	0.072	0.0062	0.0014	0	0.0004	0	0.043	0.0072	0.21	0.086
2.01-5.00	0.076	0.0041	0.0002	0	0	0	0.0053	0.0005	0.021	0.011
> 5.00	0	0.000095	0	0	0	0	0	0	0.014	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Las Piñas (in sq. km)									
	Pamplona Uno	Pilar	Pulang Lupa Dos	Pulang Lupa Uno	Talon Dos	Talon Kuatro	Talon Singko	Talon Tres	Talon Uno	Zapote
0.03-0.20	0.24	1.09	0.69	0.67	3.15	0.65	2.19	0.63	0.24	0.43
0.21-0.50	0.07	0.18	0.21	0.33	0.5	0.096	0.23	0.13	0.048	0.26
0.51-1.00	0.18	0.067	0.12	0.46	0.24	0.074	0.12	0.087	0.015	0.34
1.01-2.00	0.19	0.025	0.062	0.19	0.24	0.074	0.099	0.066	0.0058	0.12
2.01-5.00	0.021	0.013	0.01	0.017	0.1	0.021	0.046	0.019	0.0017	0.012
> 5.00	0.02	0.0001	0	0.0031	0.014	0	0	0	0	0.0063



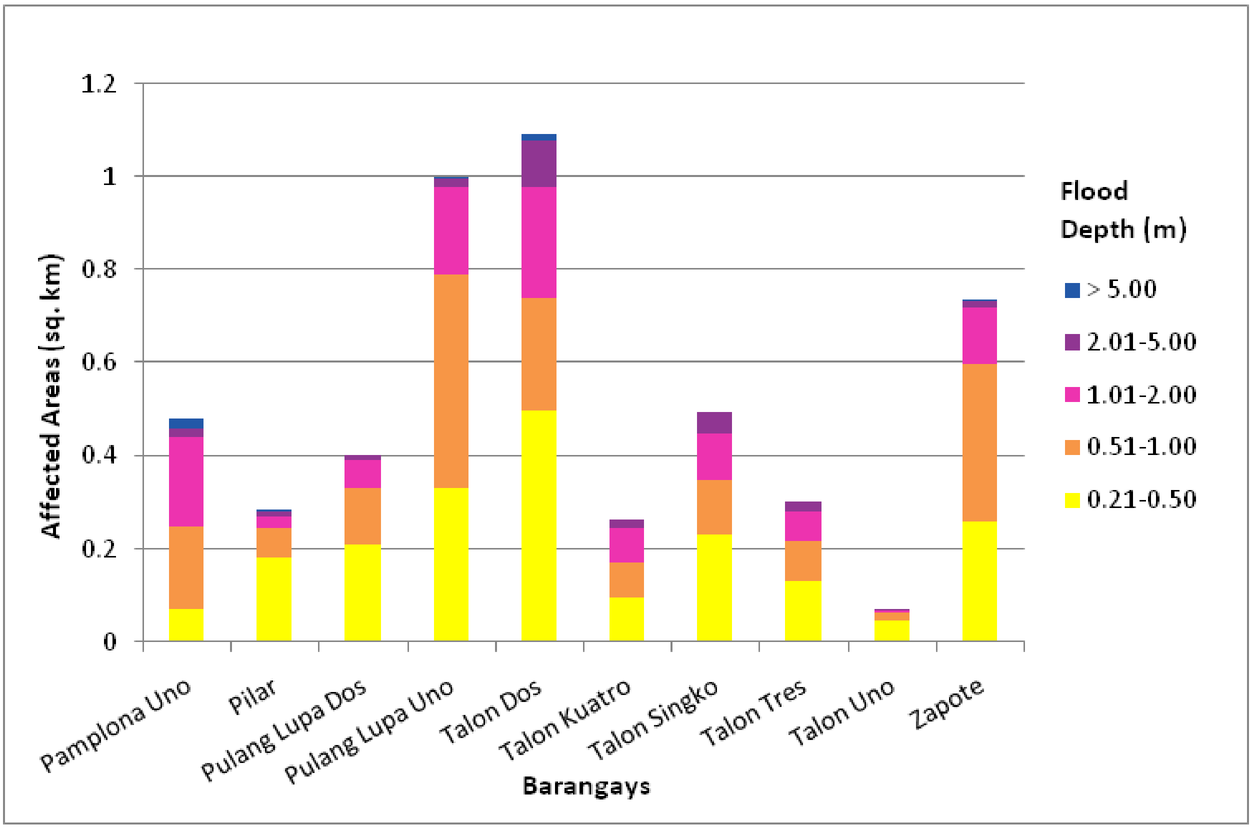


Figure 74. Affected areas in Las Piñas City, Metropolitan Manila during a 5-year rainfall return period

For the 5-year return period, 2.28% of the Municipality of Muntinlupa, with an area of 38.52 square kilometers, will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.01% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Muntinlupa City, Metropolitan Manila during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Muntinlupa (in sq. km)		
	New Alabang Village	Poblacion	Tunasan
0.03-0.20	0.27	0.33	0.28
0.21-0.50	0.013	0.0083	0.011
0.51-1.00	0.0029	0.0003	0.0023
1.01-2.00	0.0006	0	0.0005
2.01-5.00	0	0	0
> 5.00	0	0	0

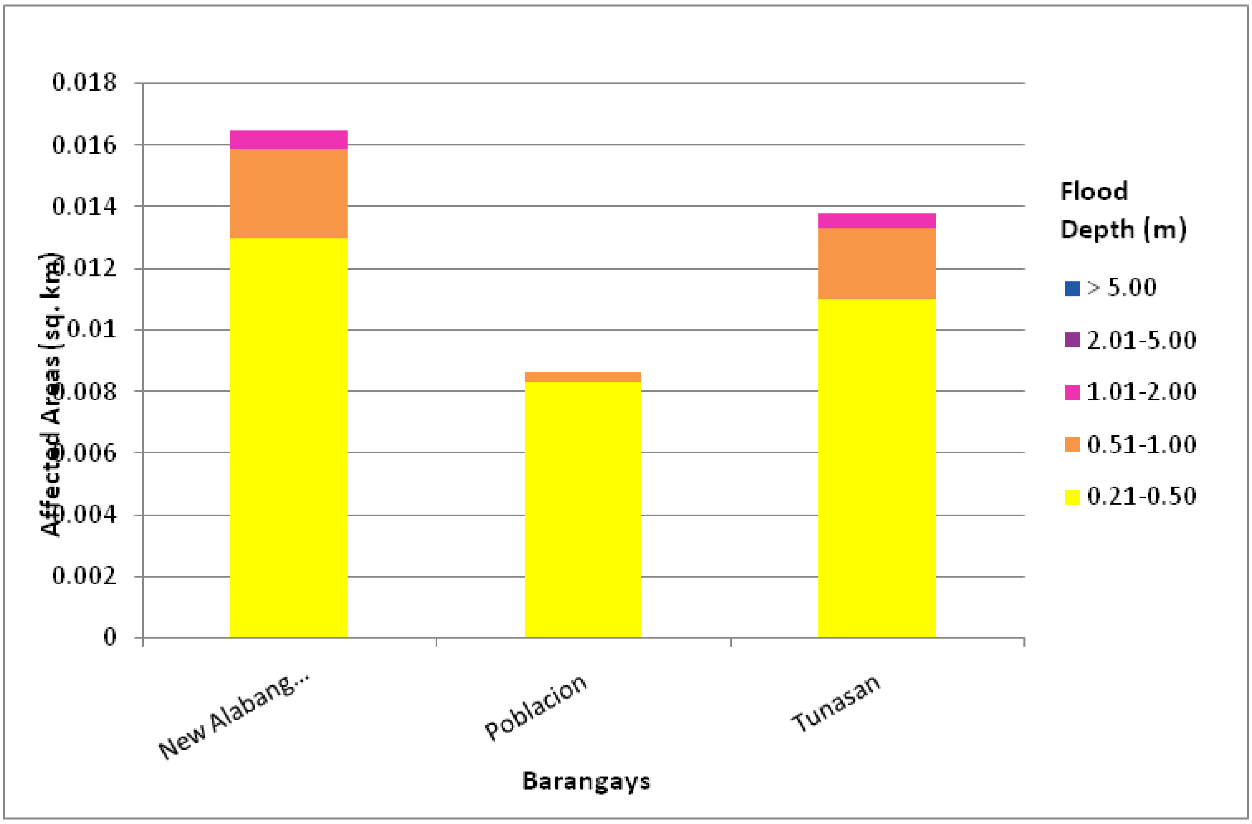


Figure 75. Affected areas in Muntinlupa City, Metropolitan Manila during a 5-year rainfall return period

For the 25-year return period, 55.27% of the Municipality of Bacoor, with an area of 47.43 square kilometers, will experience flood levels of less than 0.20 meters. 1.68% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.65%, 0.84%, and 0.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Bacoor, Cavite during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Alima	Aniban I	Aniban II	Aniban III	Aniban IV	Aniban V	Banalo	Bayanan	Campo Santo	Daang Bukid	Digman
0.03-0.20	0.23	0.034	0.079	0.058	0.034	0.0084	0.0042	2.14	0.13	0.15	0.012
0.21-0.50	0.034	0.0097	0.0022	0.029	0.019	0.015	0.00086	0.34	0.064	0.2	0.085
0.51-1.00	0.0028	0.026	0.0064	0.025	0.044	0.03	0	0.3	0.021	0.32	0.0068
1.01-2.00	0	0.11	0.077	0.018	0.039	0.039	0	0.074	0	0.043	0
2.01-5.00	0	0.013	0.032	0.035	0.034	0.012	0	0.0004	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

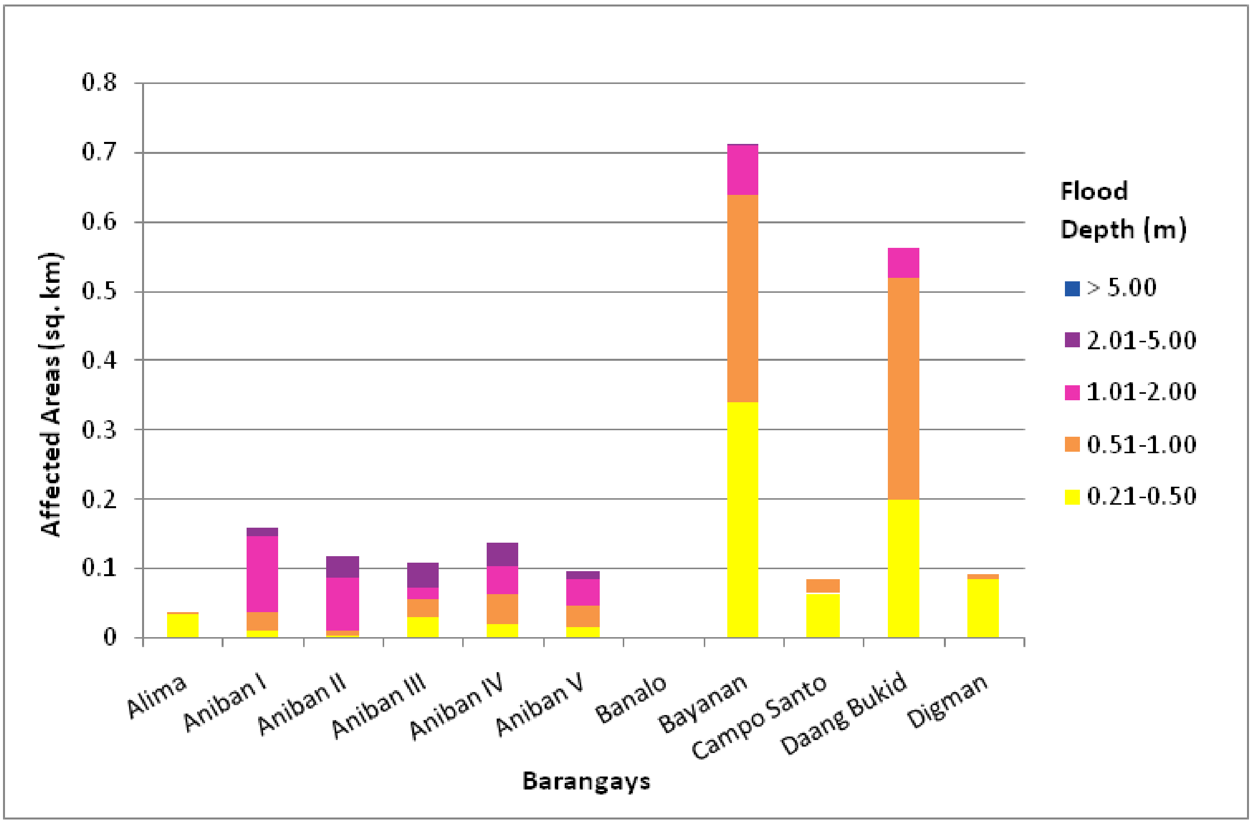
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Habay I	Habay II	Kaingin	Ligas I	Ligas II	Ligas III	Maliksi I	Maliksi II	Maliksi III	Mambog I	Mambog II
0.03-0.20	0.22	0.22	0.24	0.0098	0.039	0.073	0.12	0.063	0.023	0.75	0.78
0.21-0.50	0.23	0.22	0.083	0.029	0.018	0.021	0.12	0.07	0.064	0.32	0.19
0.51-1.00	0.04	0.18	0.019	0.058	0.093	0.035	0.06	0.034	0.05	0.13	0.041
1.01-2.00	0.0022	0.017	0	0.074	0.15	0.1	0.0008	0	0.0015	0.0069	0.0058
2.01-5.00	0	0	0	0.0008	0.0062	0.035	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

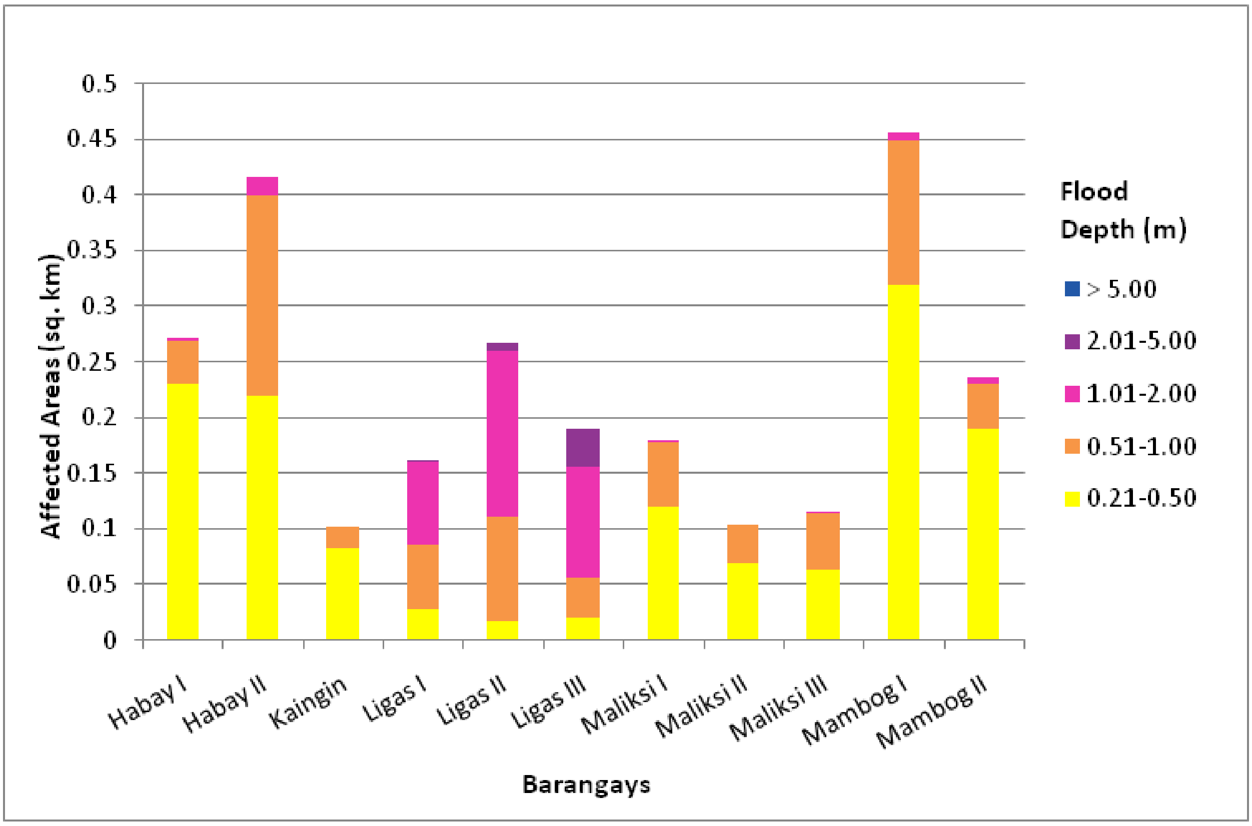
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Mambog III	Mambog IV	Mambog V	Molino I	Molino II	Molino III	Molino IV	Molino V	Molino VI	Molino VII	Niog I
0.03-0.20	0.83	0.26	0.016	6.33	0.77	0.86	0.39	0.85	1.61	0.33	0.73
0.21-0.50	0.12	0.18	0.043	0.46	0.021	0.11	0.012	0.08	0.19	0.018	0.19
0.51-1.00	0.036	0.034	0.063	0.25	0.022	0.056	0.0074	0.0097	0.13	0.014	0.024
1.01-2.00	0.0073	0	0.0001	0.21	0.045	0.066	0.011	0.0026	0.15	0.028	0
2.01-5.00	0.0007	0	0	0.19	0.029	0.061	0.0068	0.0007	0.08	0.038	0
> 5.00	0	0	0	0.0091	0	0.0053	0	0	0.025	0.024	0

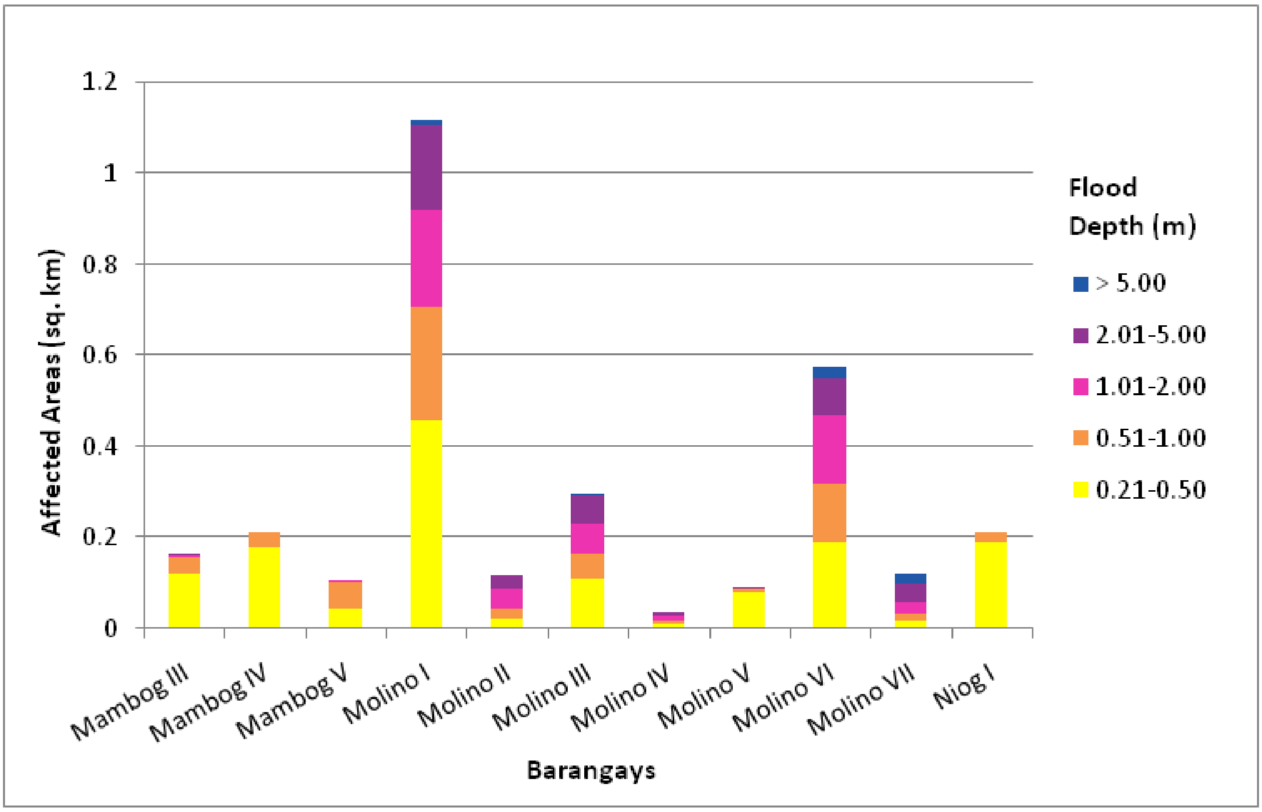
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Niog II	Niog III	P.F. Espiritu I	P.F. Espiritu II	P.F. Espiritu III	P.F. Espiritu IV	P.F. Espiritu V	P.F. Espiritu VI	P.F. Espiritu VII	P.F. Espiritu VIII	Queens Row Central
0.03-0.20	0.014	0.14	0.41	0.075	0.096	0.0094	0.16	0.23	0.17	0.069	1.89
0.21-0.50	0.12	0.039	0.02	0.17	0.033	0.11	0.064	0.073	0.046	0.045	0.2
0.51-1.00	0	0	0.0045	0.0077	0.022	0.058	0.00039	0.0081	0.0027	0	0.2
1.01-2.00	0	0	0	0	0	0.0007	0	0.0077	0	0	0.23
2.01-5.00	0	0	0	0	0	0	0	0	0	0	0.16
> 5.00	0	0	0	0	0	0	0	0	0	0	0.036

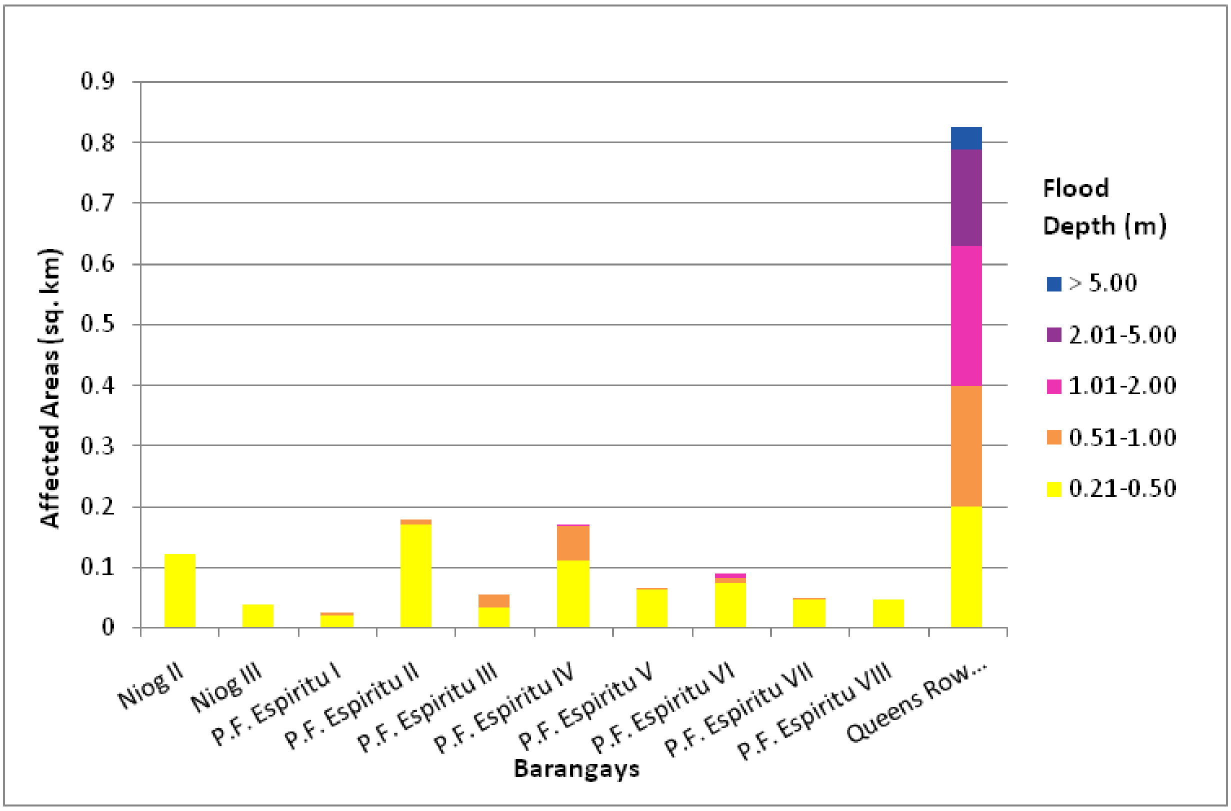
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)									
	Queens Row East	Queens Row West	Real I	San Nicolas I	San Nicolas II	San Nicolas III	Sineguelasan	Tabing Dagat	Talaba I	Talaba II
0.03-0.20	0.0025	2.58	0.031	0.72	0.62	0.26	0.073	0.04	0.12	0.053
0.21-0.50	0	0.14	0	0.092	0.092	0.077	0.00025	0.027	0.031	0.033
0.51-1.00	0	0.085	0	0.1	0.059	0.11	0	0.003	0.073	0.075
1.01-2.00	0	0.1	0	0.081	0.079	0.15	0	0	0.042	0.044
2.01-5.00	0	0.071	0	0.064	0.059	0.082	0	0	0.0031	0.0011
> 5.00	0	0.0028	0	0.026	0.012	0.0021	0	0	0	0.00057

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)									
	Talaba III	Talaba IV	Talaba V	Talaba VI	Talaba VII	Zapote I	Zapote II	Zapote III	Zapote IV	Zapote V
0.03-0.20	0.019	0	0.0011	0	0.012	0.0029	0.0022	0.011	0.011	0.00058
0.21-0.50	0.027	0.0073	0.0098	0.0091	0.011	0.02	0.012	0.022	0.029	0.017
0.51-1.00	0.04	0.031	0.027	0.047	0.028	0.096	0.047	0.05	0.068	0.092
1.01-2.00	0.01	0.0011	0.019	0.0022	0.013	0.023	0.079	0.12	0.011	0
2.01-5.00	0	0	0	0	0	0.0015	0.0053	0.0021	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Affected Areas (sq. km)
Alima
Aniban I
Aniban II
Aniban III
Aniban IV
Aniban V
Banalo
Bayanan
Campo Santo
Daang Bukid
Digman
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50


0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Affected Areas (sq. km)
Habay I
Habay II
Kaingin
Ligas I
Ligas II
Ligas III
Maliksi I
Maliksi II
Maliksi III
Mambog I
Mambog II
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50


Affected Areas (sq. km)
1.2
1
0.8
0.6
0.4
0.2
0
Mambog III
Mambog IV
Mambog V
Molino I
Molino II
Molino III
Molino IV
Molino V
Molino VI
Molino VII
Niog I
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50


Affected Areas (sq. km)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Niog II
Niog III
P.F. Espiritu I
P.F. Espiritu II
P.F. Espiritu III
P.F. Espiritu IV
P.F. Espiritu V
P.F. Espiritu VI
P.F. Espiritu VII
P.F. Espiritu VIII
Queens Row...
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50

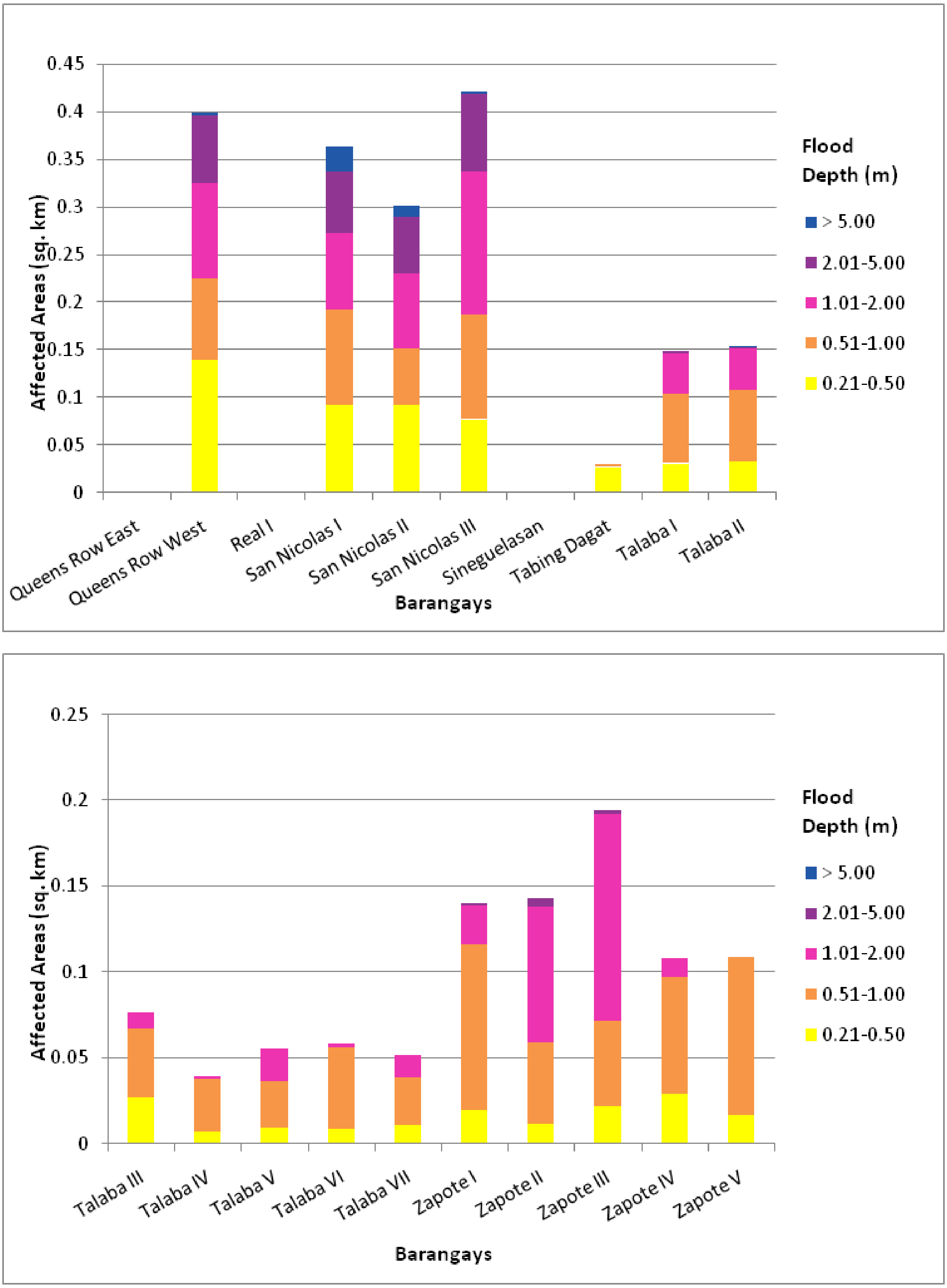


Figure 76. Affected areas in Bacoor, Cavite during a 25-year rainfall return period

For the 25-year return period, 12.78% of the Municipality of Dasmariñas, with an area of 84.01 square kilometers, will experience flood levels of less than 0.20 meters. 0.70% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.58%, 0.49%, 0.28%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Dasmariñas, Cavite during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dasmariñas (in sq. km)		
	Paliparan II	Paliparan III	Salawag
0.03-0.20	0.11	1.95	8.68
0.21-0.50	0.0047	0.12	0.46
0.51-1.00	0.0013	0.078	0.41
1.01-2.00	0	0.033	0.38
2.01-5.00	0	0.0022	0.23
> 5.00	0	0	0.022

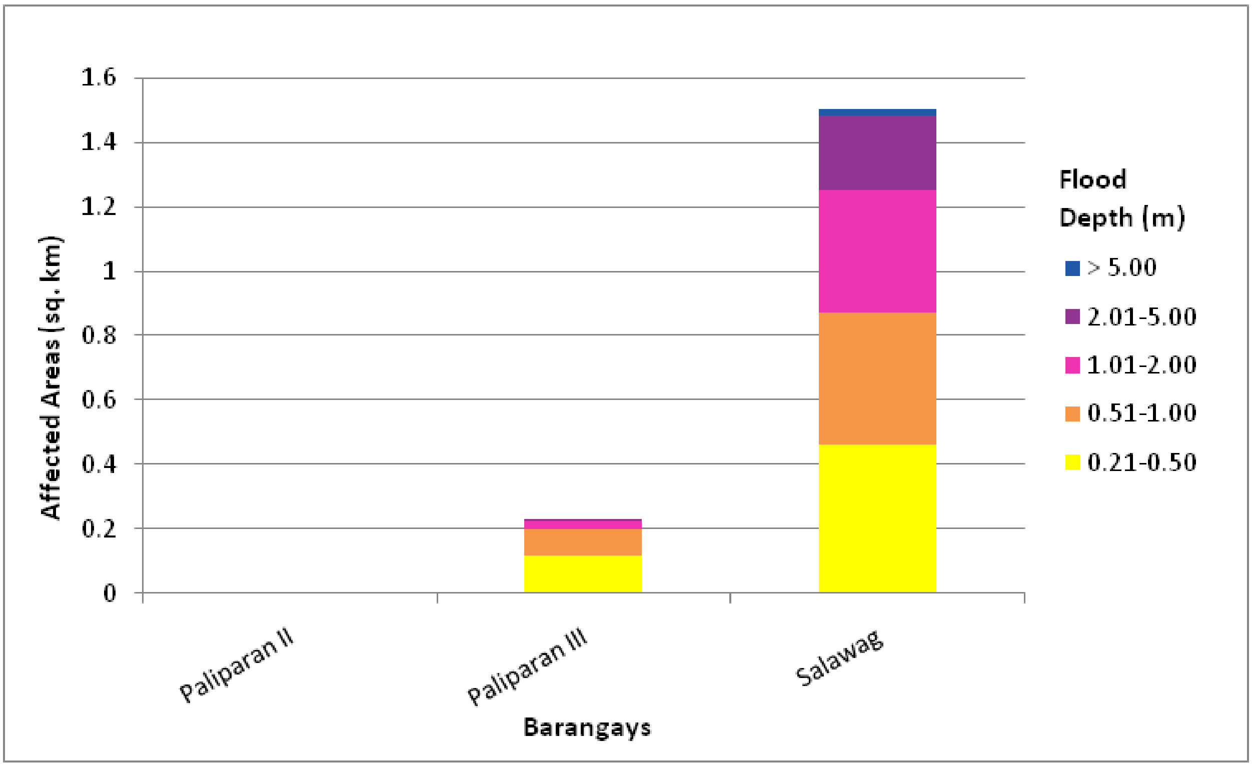


Figure 77. Affected areas in Dasmariñas, Cavite during a 25-year rainfall return period

For the 25-year return period, 0.00% of the Municipality of Imus, with an area of 56.81 square kilometers, will experience flood levels of less than 0.20 meters, 0.21 to 0.50 meters, and 0.51 to 1 meter. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Imus, Cavite during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Imus (in sq. km)
	Tanzang Luma VI
0.03-0.20	0.000027
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

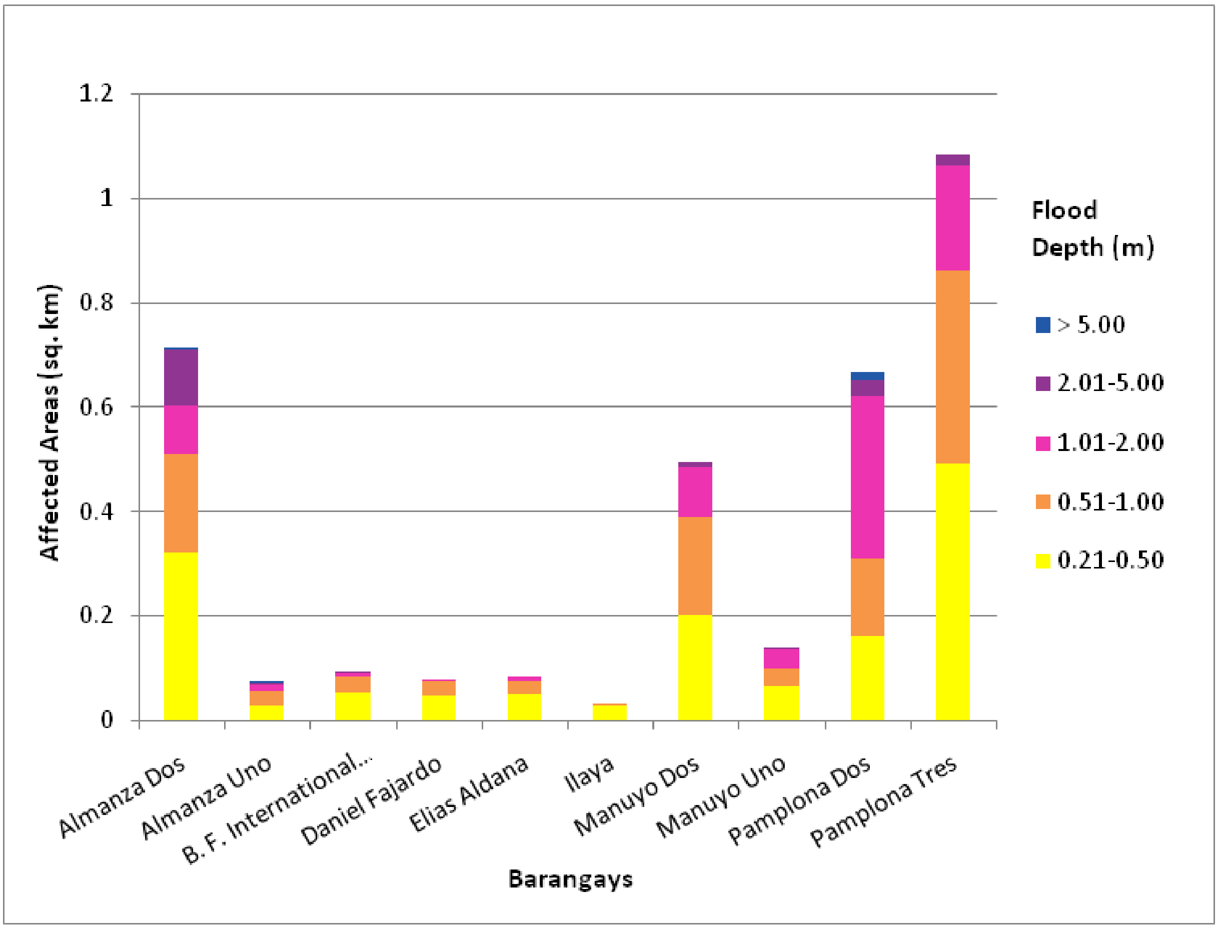
Figure 78. Affected areas in Imus, Cavite during a 25-year rainfall return period

For the 25-year return period, 45.09% of the City of Las Piñas, with an area of 33.19 square kilometers, will experience flood levels of less than 0.20 meters. 10.82% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 9.44%, 7.47%, 1.91%, and 0.19% 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 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in the City of Las Piñas, Metropolitan Manila during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Las Piñas (in sq. km)									
	Almanza Dos	Almanza Uno	B. F. International Village	Daniel Fajardo	Elias Aldana	Ilaya	Manuyo Dos	Manuyo Uno	Pamplona Dos	Pamplona Tres
0.03-0.20	3.19	0.082	0.2	0.12	0.14	0.082	0.48	0.24	0.42	1.34
0.21-0.50	0.32	0.028	0.052	0.046	0.05	0.03	0.2	0.065	0.16	0.49
0.51-1.00	0.19	0.029	0.03	0.029	0.025	0.0015	0.19	0.033	0.15	0.37
1.01-2.00	0.091	0.012	0.01	0.00075	0.0078	0	0.095	0.039	0.31	0.2
2.01-5.00	0.11	0.0049	0.00055	0	0	0	0.0085	0.002	0.032	0.023
> 5.00	0.0016	0.00036	0	0	0	0	0	0	0.015	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Las Piñas (in sq. km)									
	Pamplona Uno	Pilar	Pulang Lupa Dos	Pulang Lupa Uno	Talon Dos	Talon Kuatro	Talon Singko	Talon Tres	Talon Uno	Zapote
0.03-0.20	0.2	0.98	0.57	0.48	2.84	0.55	2.03	0.52	0.22	0.28
0.21-0.50	0.064	0.23	0.21	0.23	0.63	0.11	0.27	0.13	0.065	0.21
0.51-1.00	0.14	0.11	0.17	0.55	0.29	0.089	0.18	0.13	0.018	0.41
1.01-2.00	0.27	0.043	0.13	0.36	0.31	0.11	0.13	0.11	0.0096	0.24
2.01-5.00	0.035	0.017	0.022	0.037	0.16	0.045	0.083	0.038	0.0024	0.015
> 5.00	0.021	0.00024	0	0.0033	0.016	0	0	0.0001	0	0.0065



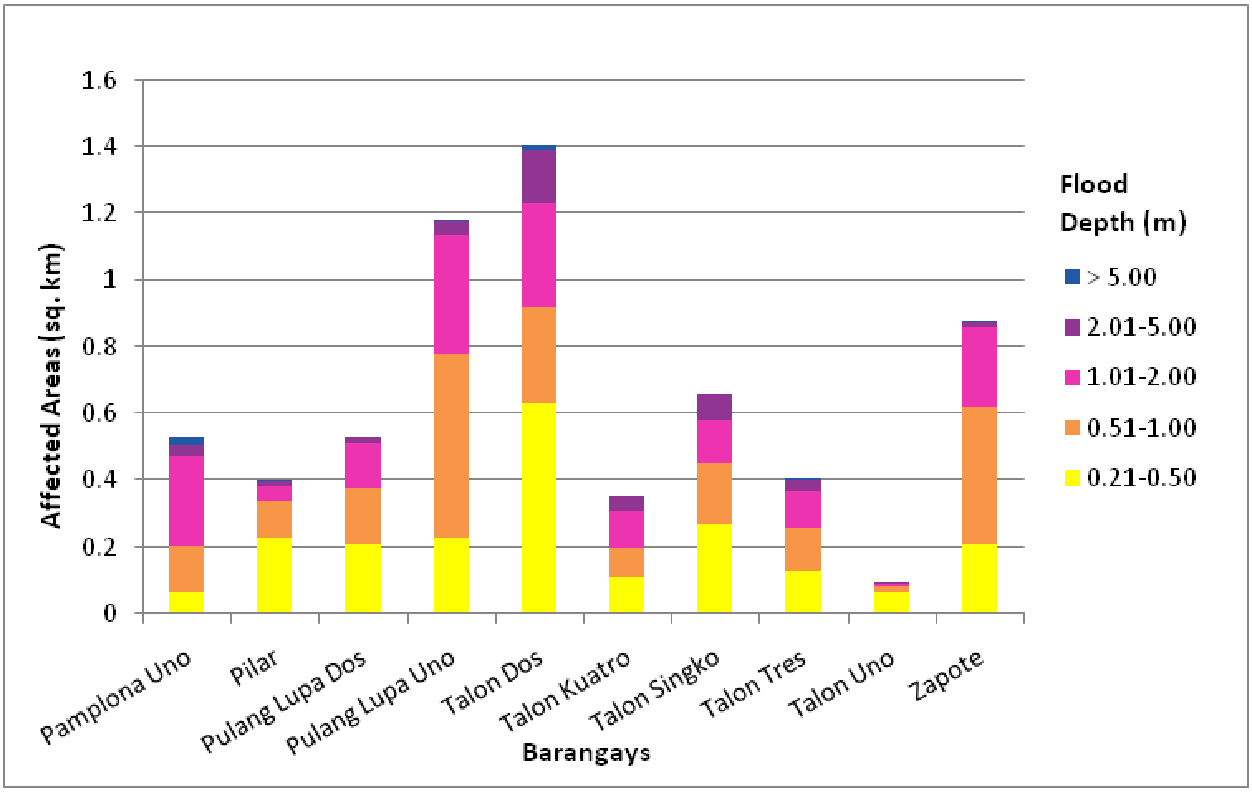


Figure 79. Affected areas in the City of Las Piñas, Metropolitan Manila during a 25-year rainfall return period

For the 25-year return period, 2.21% of the City of Muntinlupa, with an area of 38.52 square kilometers, will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.02% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Muntinlupa City, Metropolitan Manila during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Muntinlupa (in sq. km)		
	New Alabang Village	Poblacion	Tunasan
0.03-0.20	0.26	0.32	0.27
0.21-0.50	0.016	0.01	0.016
0.51-1.00	0.0057	0.0005	0.0028
1.01-2.00	0.0009	0	0.0007
2.01-5.00	0	0	0
> 5.00	0	0	0

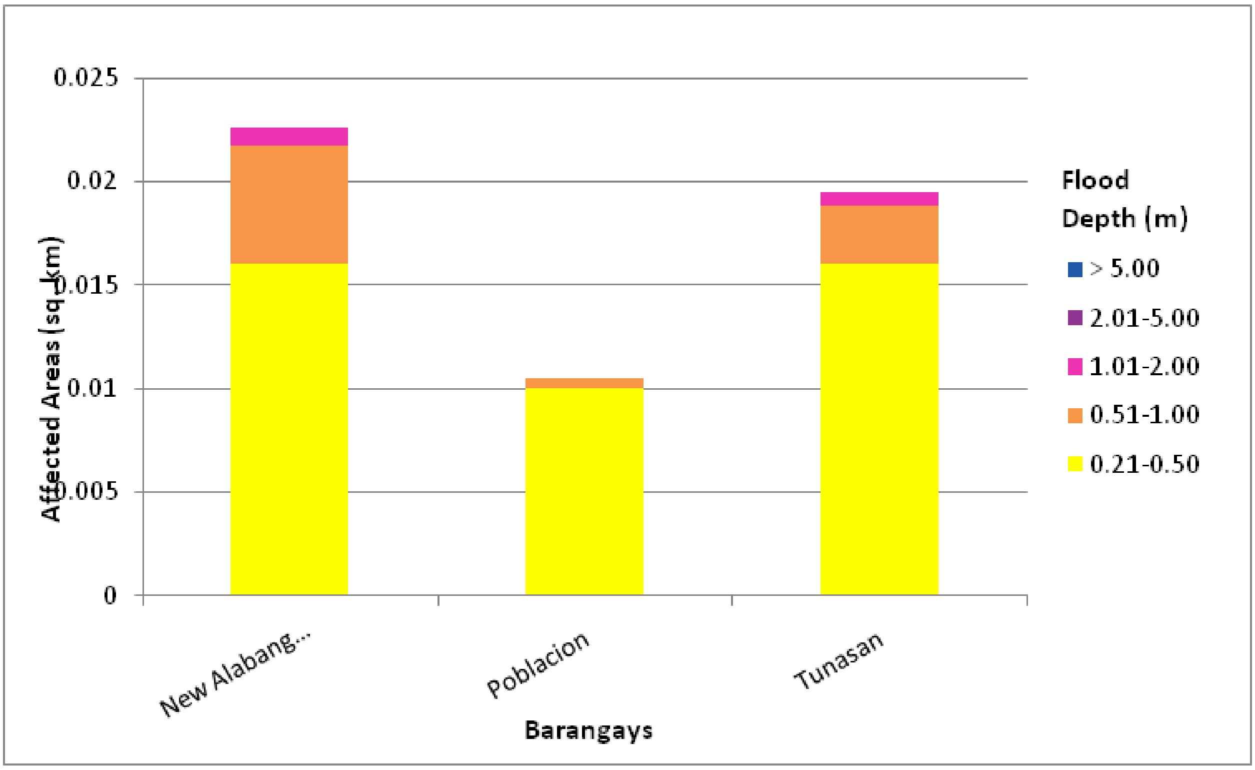


Figure 80. Affected areas in Muntinlupa City, Metropolitan Manila during a 25-year rainfall return period

For the 100-year return period, 48.05% of the Municipality of Bacoor, with an area of 47.43 square kilometers, will experience flood levels of less than 0.20 meters. 12.20% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 9.31%, 7.09%, 3.45%, and 0.56% 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 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Bacoor, Cavite during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Alima	Aniban I	Aniban II	Aniban III	Aniban IV	Aniban V	Banalo	Bayanan	Campo Santo	Daang Bukid	Digman
0.03-0.20	0.22	0.028	0.026	0.02	0.018	0.0013	0.0037	1.96	0.09	0.073	0.0059
0.21-0.50	0.043	0.0071	0.05	0.043	0.023	0.0086	0.0014	0.42	0.099	0.15	0.07
0.51-1.00	0.0059	0.016	0.0075	0.04	0.034	0.029	0	0.32	0.025	0.34	0.028
1.01-2.00	0	0.11	0.057	0.018	0.051	0.042	0	0.14	0	0.14	0
2.01-5.00	0	0.029	0.056	0.044	0.044	0.024	0	0.0017	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

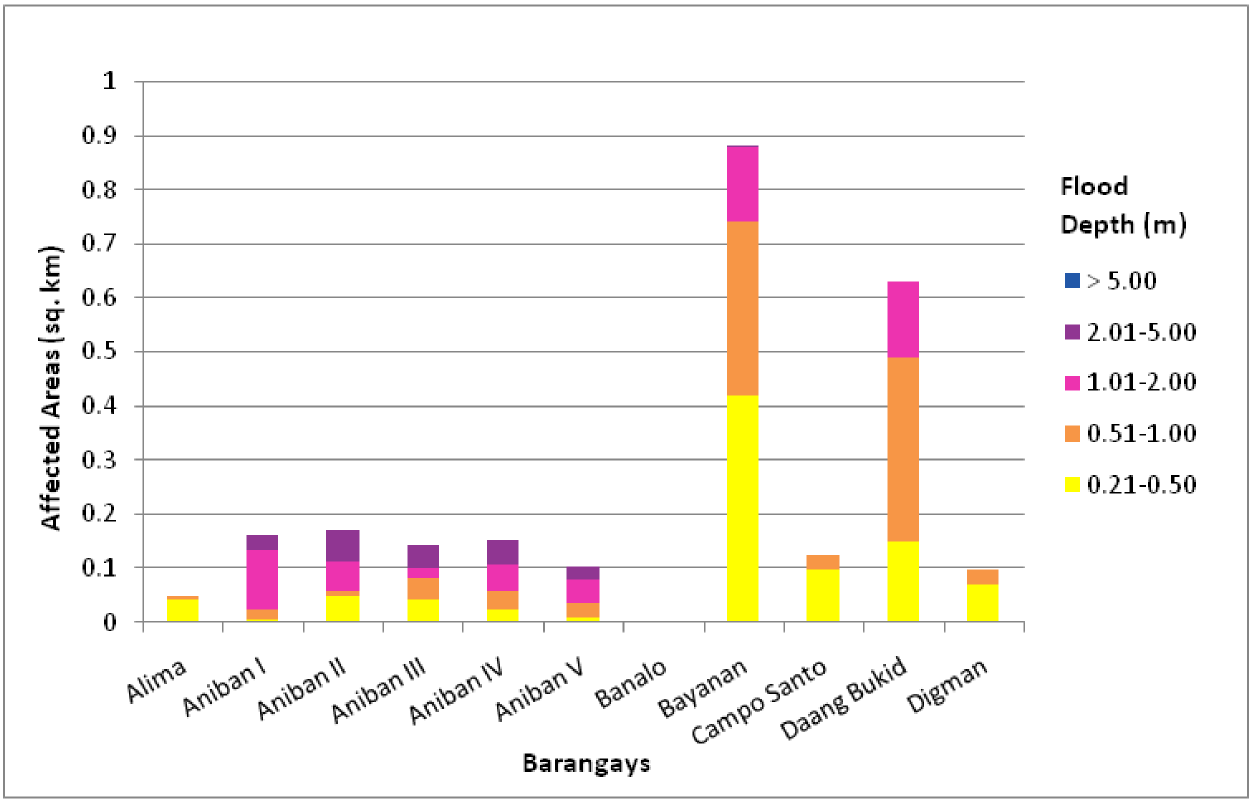
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Habay I	Habay II	Kaingin	Ligas I	Ligas II	Ligas III	Maliksi I	Maliksi II	Maliksi III	Mambog I	Mambog II
0.03-0.20	0.18	0.15	0.19	0.004	0.028	0.064	0.062	0.0017	0.0004	0.6	0.69
0.21-0.50	0.2	0.19	0.1	0.013	0.014	0.015	0.086	0.061	0.022	0.3	0.25
0.51-1.00	0.11	0.19	0.048	0.056	0.059	0.037	0.14	0.094	0.092	0.28	0.057
1.01-2.00	0.003	0.092	0.0003	0.096	0.19	0.083	0.015	0.01	0.024	0.018	0.013
2.01-5.00	0	0	0	0.002	0.016	0.068	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Mambog III	Mambog IV	Mambog V	Molino I	Molino II	Molino III	Molino IV	Molino V	Molino VI	Molino VII	Niog I
0.03-0.20	0.73	0.2	0.01	6.02	0.72	0.77	0.37	0.76	1.43	0.3	0.62
0.21-0.50	0.19	0.14	0.016	0.54	0.038	0.13	0.013	0.15	0.18	0.012	0.23
0.51-1.00	0.058	0.13	0.087	0.31	0.024	0.073	0.01	0.023	0.16	0.013	0.086
1.01-2.00	0.015	0.00077	0.0089	0.28	0.045	0.092	0.013	0.0032	0.23	0.03	0.00054
2.01-5.00	0.0015	0	0	0.26	0.055	0.091	0.014	0.0009	0.15	0.052	0
> 5.00	0	0	0	0.049	0	0.0096	0	0	0.034	0.041	0

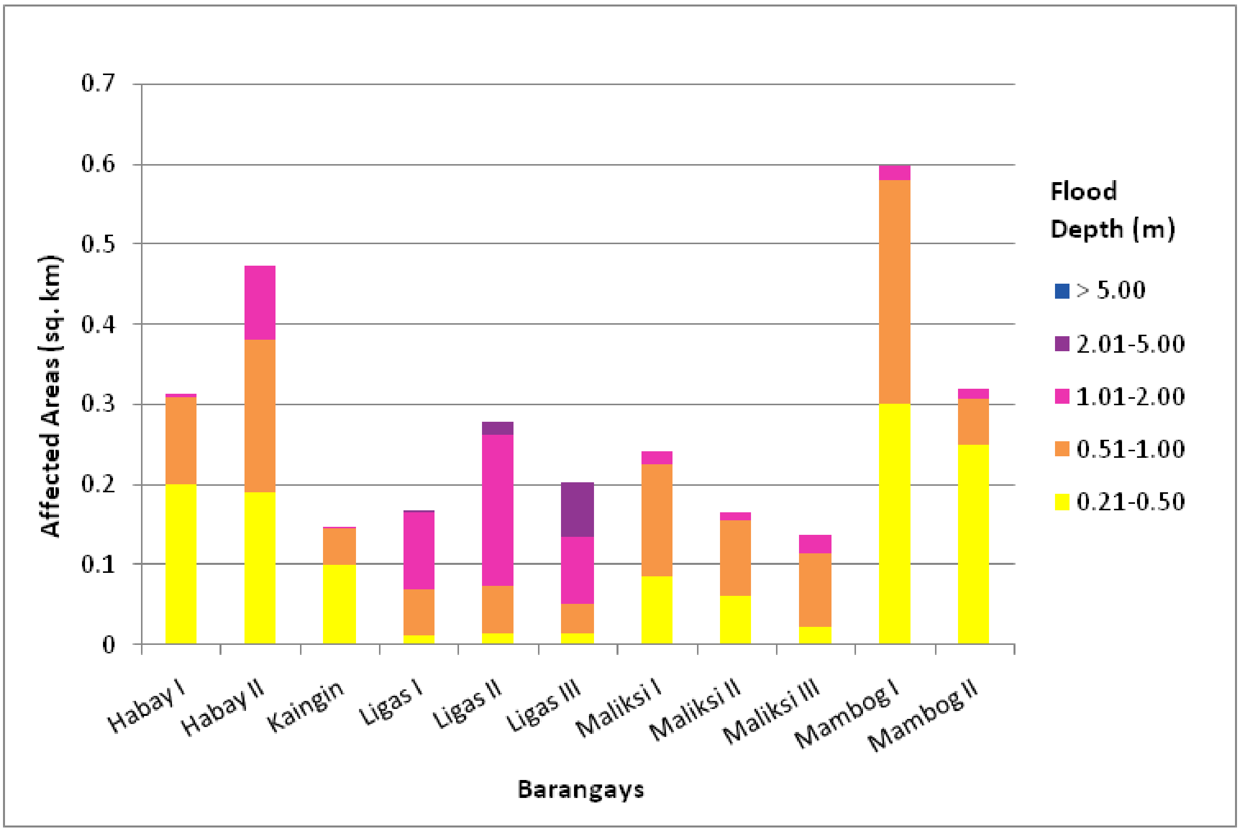
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)										
	Niog II	Niog III	P.F. Espiritu I	P.F. Espiritu II	P.F. Espiritu III	P.F. Espiritu IV	P.F. Espiritu V	P.F. Espiritu VI	P.F. Espiritu VII	P.F. Espiritu VIII	Queens Row Central
0.03-0.20	0	0.043	0.2	0.027	0.078	0.004	0.11	0.16	0.0066	0	1.7
0.21-0.50	0.13	0.12	0.23	0.16	0.04	0.044	0.099	0.14	0.2	0.11	0.2
0.51-1.00	0.0019	0.019	0.0086	0.059	0.033	0.13	0.012	0.011	0.0073	0.0018	0.2
1.01-2.00	0	0	0	0	0.0016	0.0047	0	0.007	0	0	0.28
2.01-5.00	0	0	0	0	0	0	0	0.002	0	0	0.26
> 5.00	0	0	0	0	0	0	0	0	0	0	0.061

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)									
	Queens Row East	Queens Row West	Real I	San Nicolas I	San Nicolas II	San Nicolas III	Sineguelasan	Tabing Dagat	Talaba I	Talaba II
0.03-0.20	0.0025	2.47	0.031	0.62	0.52	0.2	0.073	0.023	0.11	0.045
0.21-0.50	0	0.16	0.0002	0.069	0.079	0.042	0.00084	0.041	0.025	0.025
0.51-1.00	0	0.11	0	0.089	0.11	0.088	0	0.0058	0.059	0.05
1.01-2.00	0	0.11	0	0.16	0.11	0.22	0	0	0.069	0.086
2.01-5.00	0	0.12	0	0.1	0.085	0.13	0	0	0.0069	0.0012
> 5.00	0	0.011	0	0.038	0.019	0.0022	0	0	0	0.00057

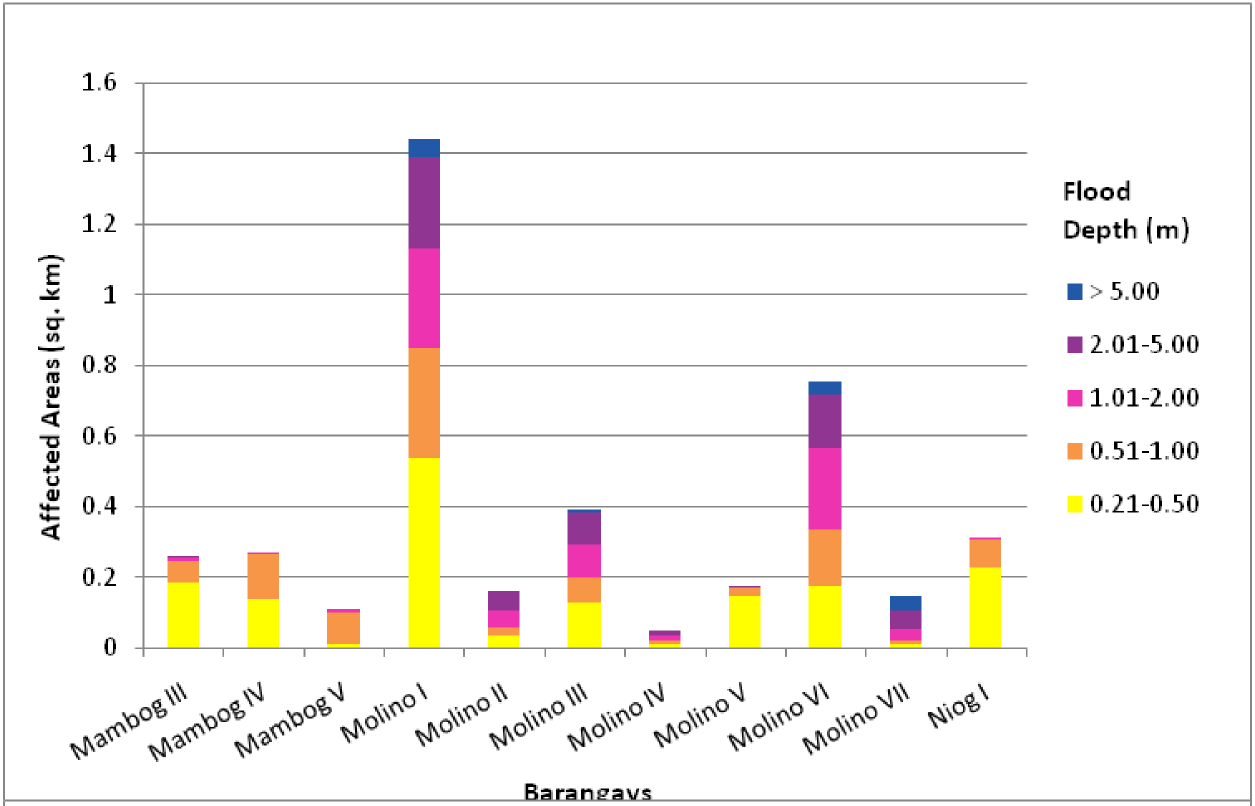
Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bacoor (in sq. km)									
	Talaba III	Talaba IV	Talaba V	Talaba VI	Talaba VII	Zapote I	Zapote II	Zapote III	Zapote IV	Zapote V
0.03-0.20	0.0094	0	0.0005	0	0.0086	0.0014	0.00076	0.0013	0.00018	0.0003
0.21-0.50	0.013	0	0.0006	0	0.0069	0.012	0.0078	0.013	0.013	0.00097
0.51-1.00	0.043	0.026	0.02	0.041	0.024	0.072	0.04	0.048	0.059	0.064
1.01-2.00	0.03	0.014	0.036	0.017	0.025	0.057	0.085	0.14	0.047	0.044
2.01-5.00	0	0	0	0	0	0.0015	0.011	0.0098	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0

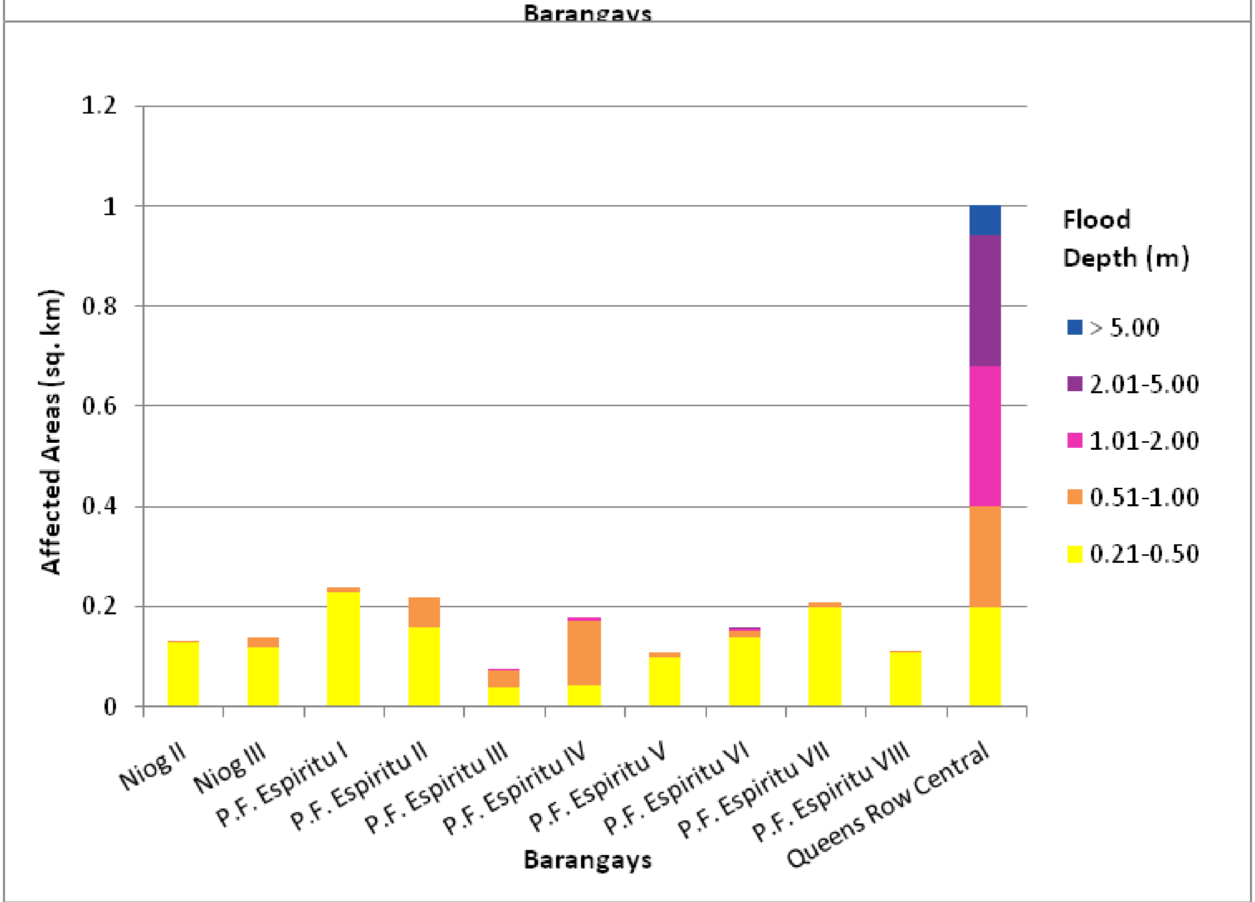


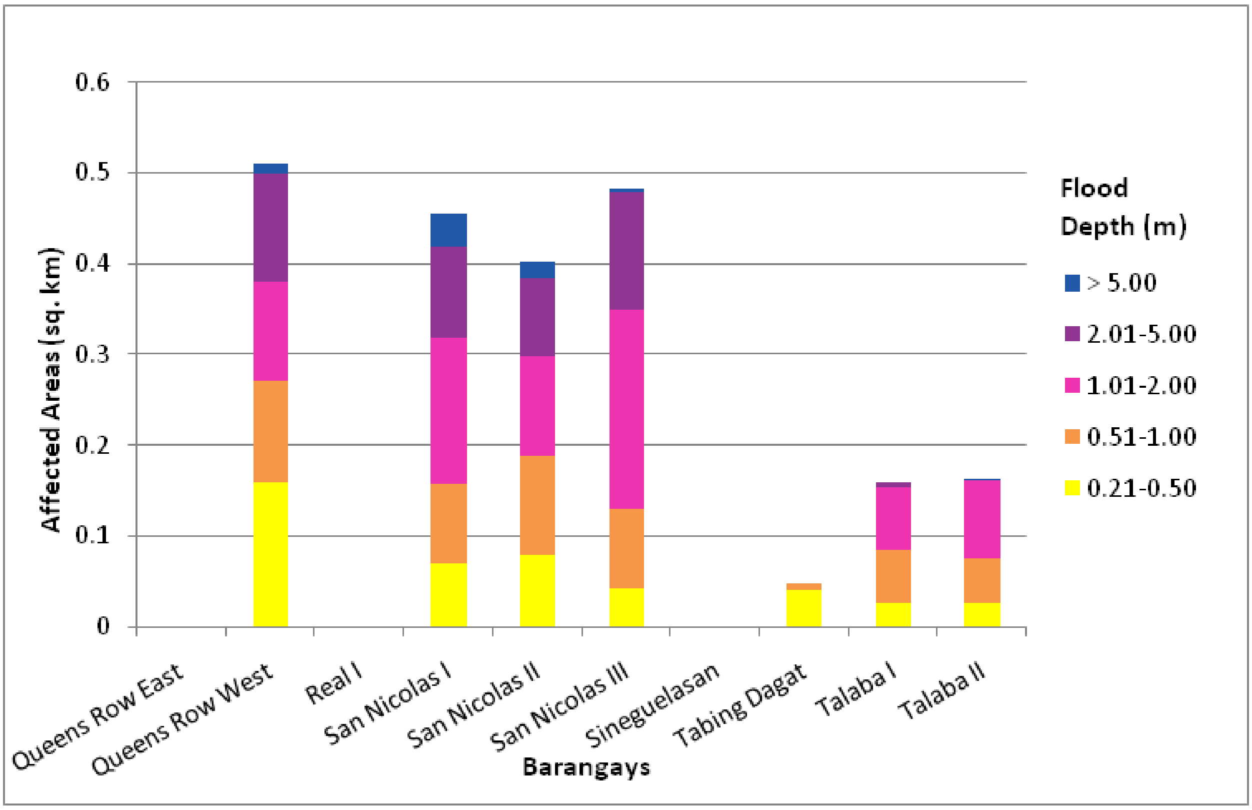
Affected Areas (sq. km)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Alima
Aniban I
Aniban II
Aniban III
Aniban IV
Aniban V
Banalo
Bayanan
Campo Santo
Daang Bukid
Digman
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50



Affected Areas (sq. km)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Habay I
Habay II
Kaingin
Ligas I
Ligas II
Ligas III
Maliksi I
Maliksi II
Maliksi III
Mambog I
Mambog II
Barangays
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50


Affected Areas (sq. km)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50
Mambog III
Mambog IV
Mambog V
Molino I
Molino II
Molino III
Molino IV
Molino V
Molino VI
Molino VII
Niog I
Barangays


Affected Areas (sq. km)
1.2
1
0.8
0.6
0.4
0.2
0
Flood Depth (m)
> 5.00
2.01-5.00
1.01-2.00
0.51-1.00
0.21-0.50
Niog II
Niog III
P.F. Espiritu I
P.F. Espiritu II
P.F. Espiritu III
P.F. Espiritu IV
P.F. Espiritu V
P.F. Espiritu VI
P.F. Espiritu VII
P.F. Espiritu VIII
Queens Row Central
Barangays



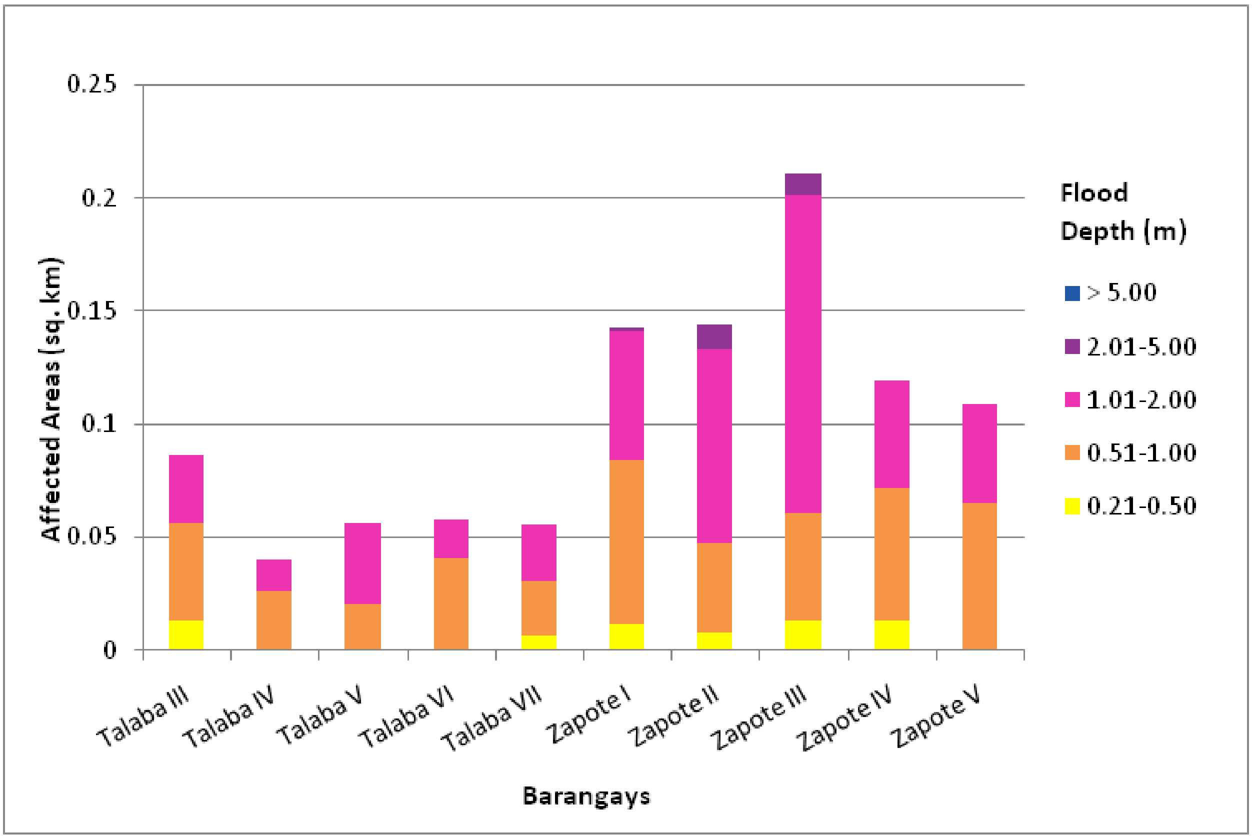


Figure 81. Affected areas in Bacoor, Cavite during a 100-year rainfall return period

For the 100-year return period, 12.36% of the Municipality of Dasmariñas, with an area of 84.01 square kilometers, will experience flood levels of less than 0.20 meters. 0.75% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.64%, 0.62%, 0.45%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Dasmariñas, Cavite during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Dasmariñas (in sq. km)		
	Paliparan II	Paliparan III	Salawag
0.03-0.20	0.11	1.89	8.38
0.21-0.50	0.0067	0.14	0.48
0.51-1.00	0.0016	0.089	0.45
1.01-2.00	7.3E-06	0.051	0.47
2.01-5.00	0	0.012	0.37
> 5.00	0	0	0.045

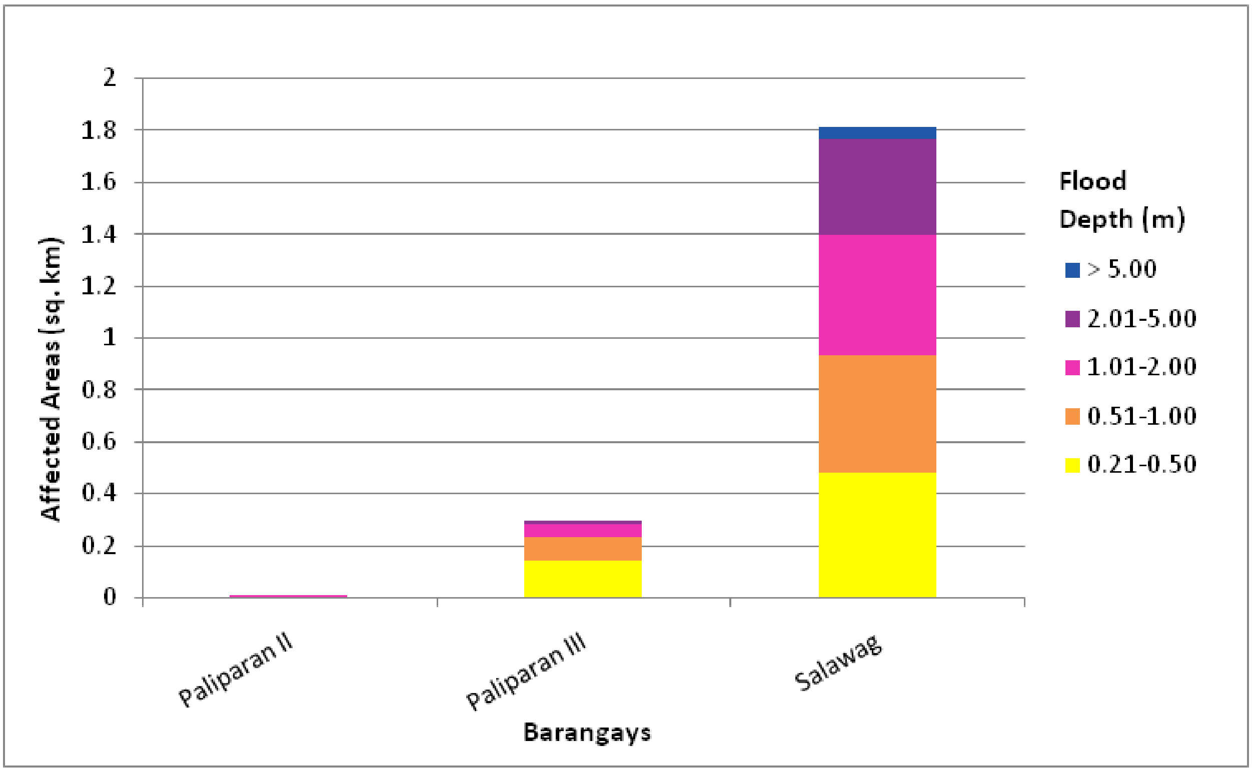


Figure 82. Affected areas in Dasmariñas, Cavite during a 100-year rainfall return period

For the 100-year return period, 0.00% of the Municipality of Imus, with an area of 56.81 square kilometers, will experience flood levels of less than 0.20 meters, 0.21 to 0.50 meters, and 0.51 to 1 meter. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Imus, Cavite during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Imus (in sq. km)
	Tanzang Luma VI
0.03-0.20	0.000027
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

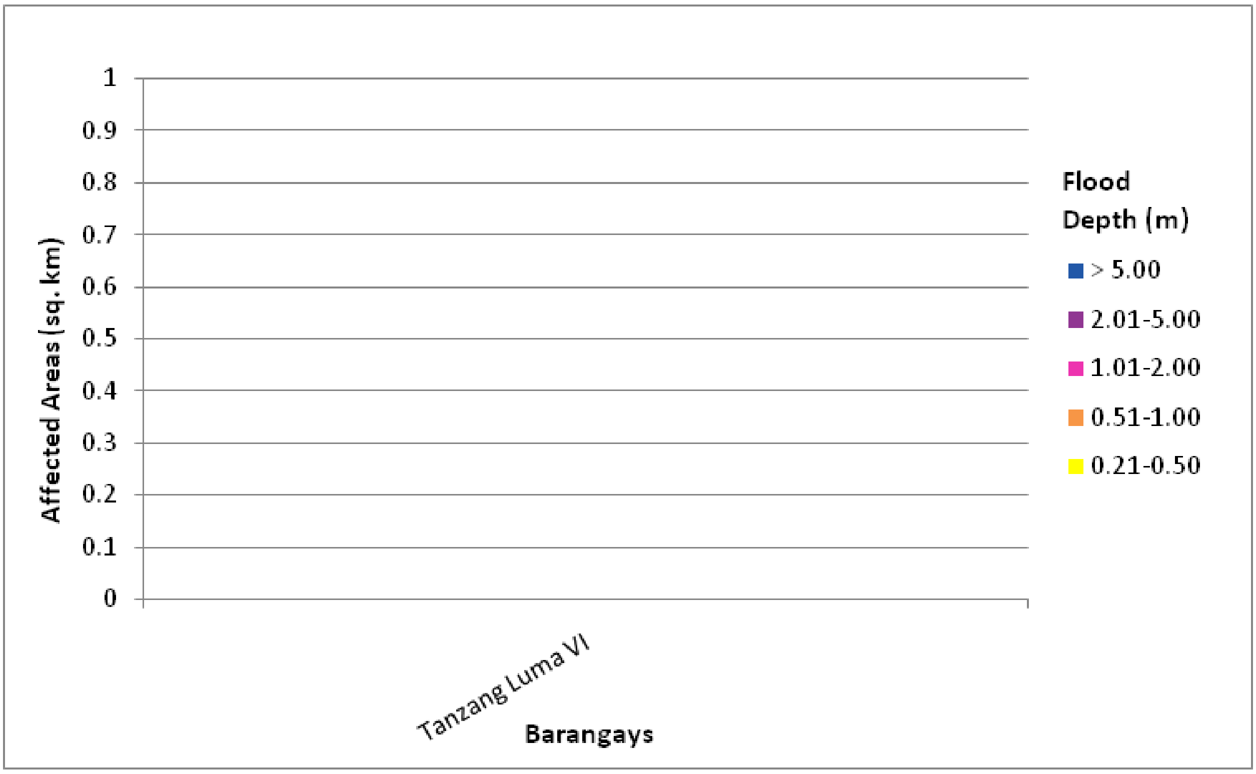


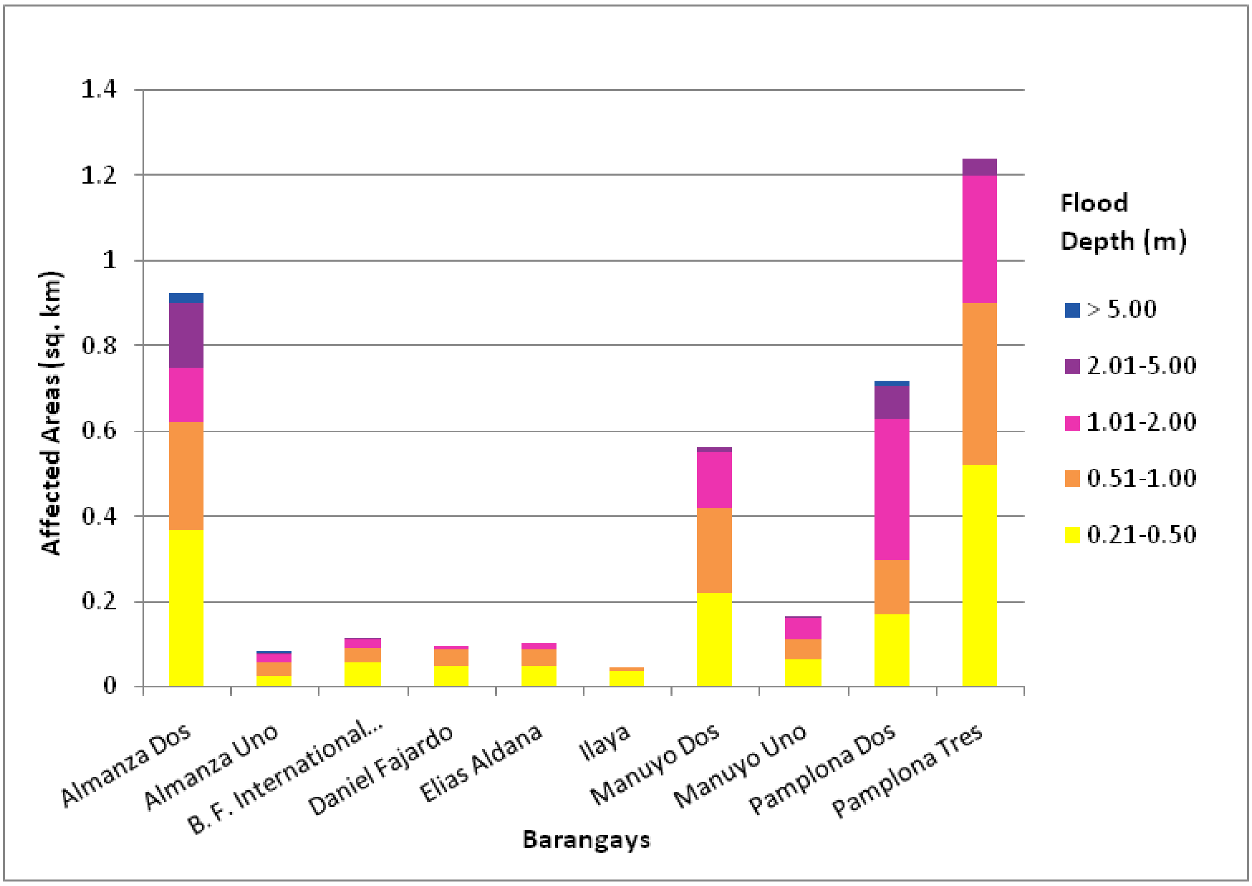
Figure 83. Affected areas in Imus, Cavite during a 100-year rainfall return period

For the 100-year return period, 40.74% of the City of Las Piñas, with an area of 33.19 square kilometers, will experience flood levels of less than 0.20 meters. 11.62% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 9.78%, 9.61%, 2.98%, and 0.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Las Piñas, Metropolitan Manila during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Las Piñas (in sq. km)									
	Almanza Dos	Almanza Uno	B. F. International Village	Daniel Fajardo	Elias Aldana	Ilaya	Manuyo Dos	Manuyo Uno	Pamplona Dos	Pamplona Tres
0.03-0.20	2.98	0.073	0.18	0.1	0.12	0.068	0.42	0.21	0.37	1.19
0.21-0.50	0.37	0.028	0.06	0.052	0.049	0.04	0.22	0.067	0.17	0.52
0.51-1.00	0.25	0.03	0.033	0.039	0.042	0.0056	0.2	0.045	0.13	0.38
1.01-2.00	0.13	0.019	0.022	0.0043	0.012	0	0.13	0.051	0.33	0.3
2.01-5.00	0.15	0.006	0.00096	0	0	0	0.011	0.0034	0.074	0.036
> 5.00	0.023	0.00059	0	0	0	0	0	0	0.015	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Las Piñas (in sq. km)									
	Pamplona Uno	Pilar	Pulang Lupa Dos	Pulang Lupa Uno	Talon Dos	Talon Kuatro	Talon Singko	Talon Tres	Talon Uno	Zapote
0.03-0.20	0.17	0.91	0.51	0.41	2.55	0.5	1.89	0.46	0.2	0.21
0.21-0.50	0.066	0.25	0.22	0.19	0.75	0.12	0.29	0.14	0.074	0.18
0.51-1.00	0.11	0.14	0.17	0.51	0.33	0.098	0.19	0.12	0.023	0.4
1.01-2.00	0.29	0.058	0.17	0.49	0.34	0.13	0.19	0.16	0.012	0.35
2.01-5.00	0.062	0.02	0.03	0.062	0.25	0.065	0.14	0.056	0.0031	0.019
> 5.00	0.022	0.00041	0	0.005	0.021	0	0	0.0001	0	0.0067



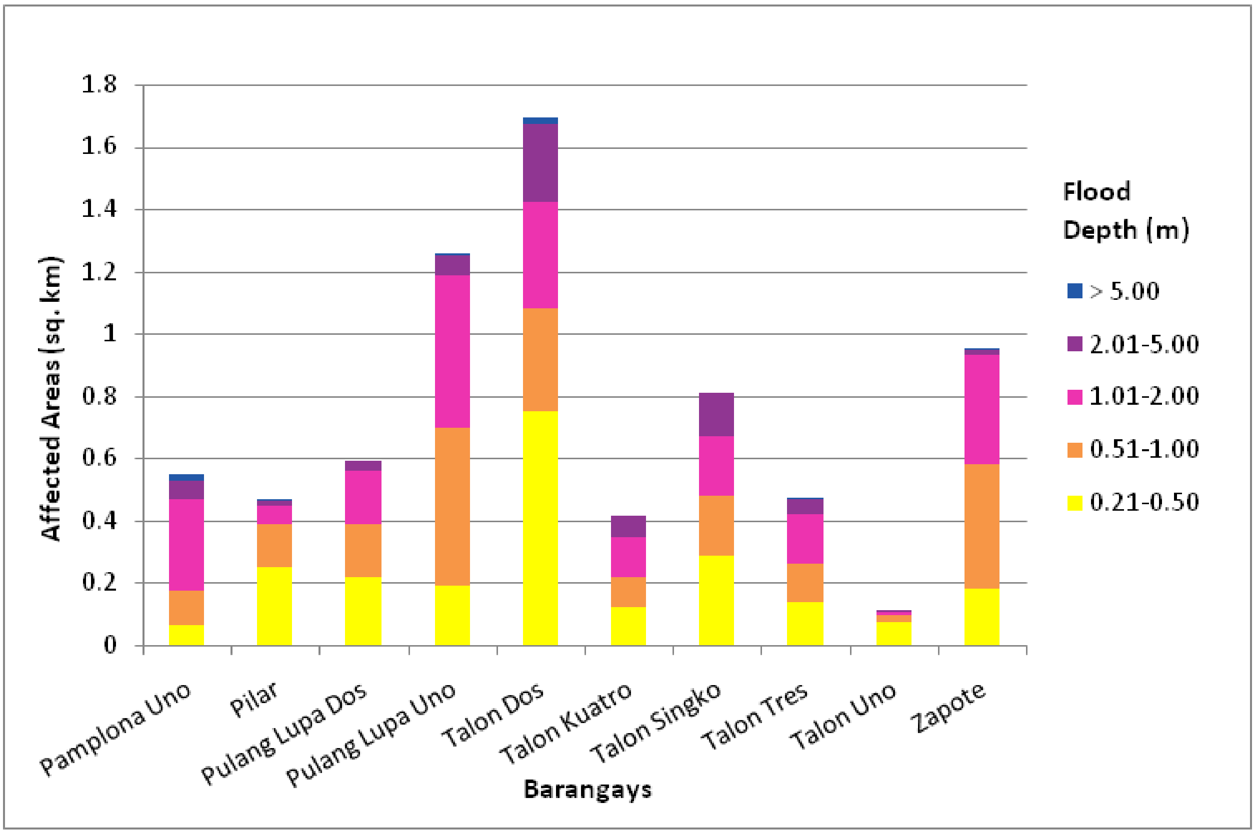


Figure 84. Affected areas in Las Piñas, Metropolitan Manila during a 100-year rainfall return period

For the 100-year return period, 2.15% of the Municipality of Muntinlupa, with an area of 38.52 square kilometers, will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Muntinlupa, Metropolitan Manila during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Muntinlupa (in sq. km)		
	New Alabang Village	Poblacion	Tunasan
0.03-0.20	0.25	0.32	0.26
0.21-0.50	0.021	0.013	0.023
0.51-1.00	0.0071	0.0015	0.0042
1.01-2.00	0.0013	0.000021	0.001
2.01-5.00	0	0	0
> 5.00	0	0	0

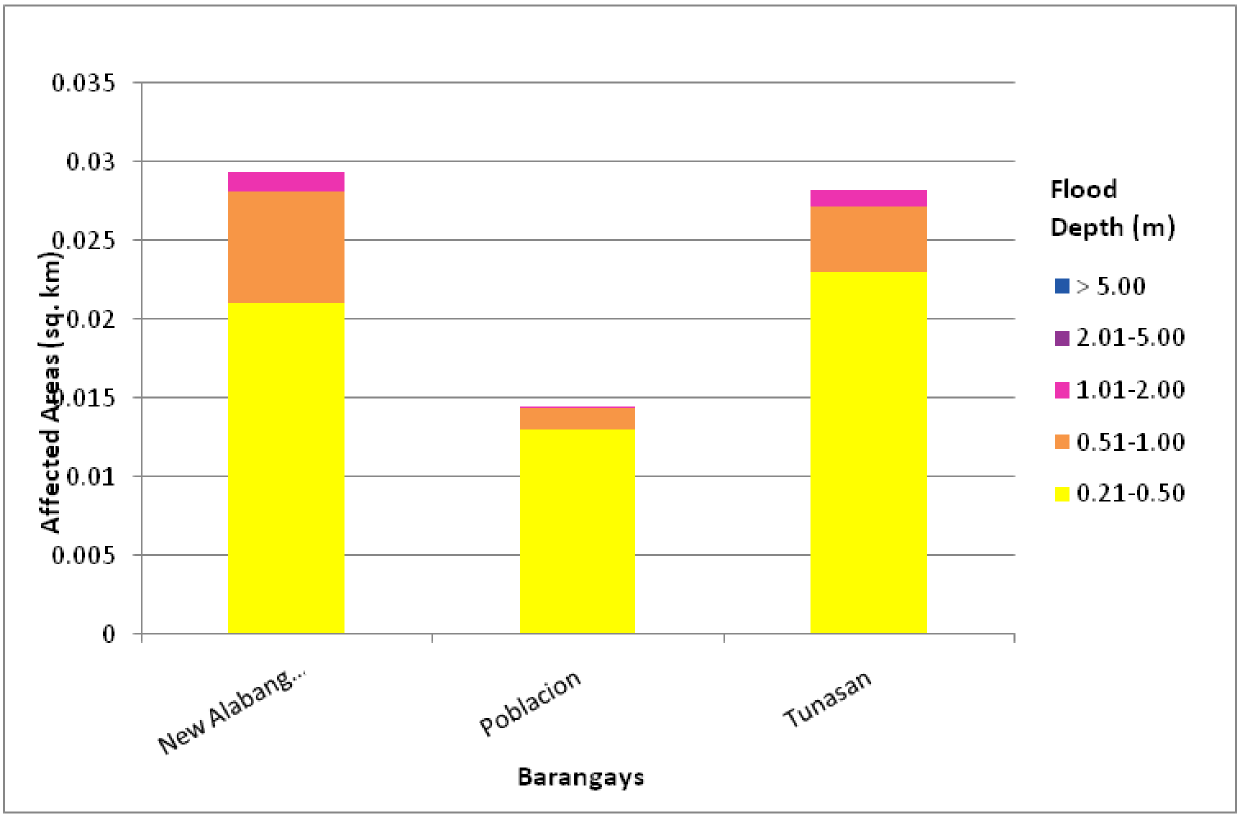


Figure 85. Affected areas in Muntinlupa, Metropolitan Manila during a 100-year rainfall return period

Among the barangays in the Municipality of Bacoor in Cavite, Molino I is projected to have the highest percentage of area that will experience flood levels, at 15.73%. Meanwhile, Queens Row West posted the second highest percentage of area that may be affected by flood depths, at 6.29%.

Among the barangays in the Municipality of Dasmariñas in Cavite, Salawag is projected to have the highest percentage of area that will experience flood levels, at 21.49%. Meanwhile, Paliparan III posted the second highest percentage of area that may be affected by flood depths, at 4.60%

.

Barangay Tanzang Luma VI is the only barangay affected in the Municipality of Imus in Cavite. The barangay is projected to experience flood in 0.00% of its area.

Among the barangays in the Municipality of Las Piñas in Metropolitan Manila, Talon Dos is projected to have the highest percentage of area that will experience flood levels, at 8.94%. Meanwhile, Almanza Dos posted the second highest percentage of area that may be affected by flood depths, at 8.23%.

Among the barangays in the Municipality of Muntinlupa in Metropolitan Manila, Poblacion is projected to have the highest percentage of area that will experience flood levels, at 0.71%. Meanwhile, Tunasan posted the second highest percentage of area that may be affected by flood depths, at 0.61%.

Table 49. Area covered by each warning level, with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5-year	25-year	100-year
Low	PLACEHOLDER		
Medium			
High			
TOTAL			

[insert warning level – feature extraction]

The generated flood hazard maps for the Binabang-Molino floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Annex 12 and Annex 13 present the educational and health institutions exposed to flooding, respectively.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in a river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 87.

The flood validation consists of one hundred and eighty-two (182) points, randomly selected all over the Binabang-Molino floodplain (Figure 86). Comparing the validation with the flood depth map of the nearest storm event, the map attained an RMSE value of 2.56 meters. Table 50 presents a contingency matrix of the comparison. The validation points are found in Annex 11.

PLACEHOLDER - validation points for 5-year Flood Depth Map of Binabang-Molino Floodplain

Figure 86. Validation points for 5-year Flood Depth Map of Binabang-Molino floodplain

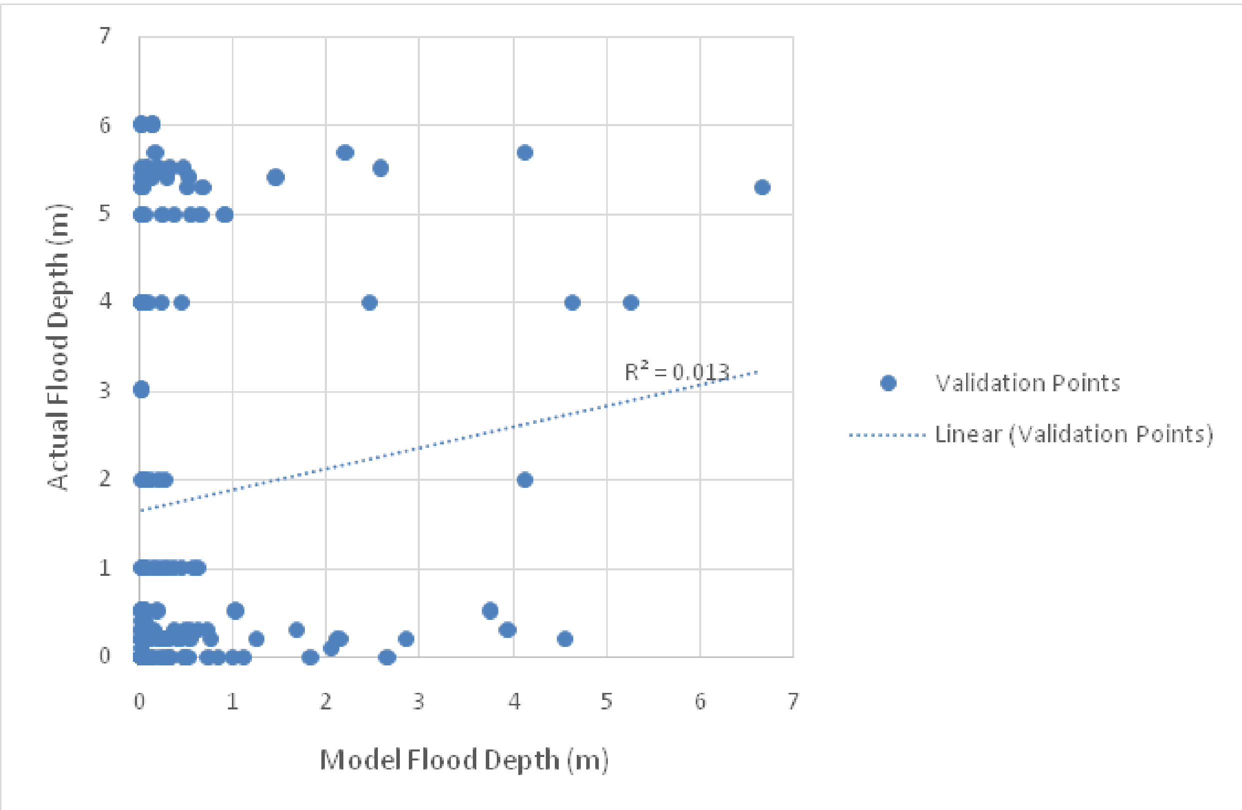


Figure 87. Model flood depth vs. actual flood depth

Table 50. Actual flood depth vs. simulated flood depth in the Binabang-Molino River Basin

BINABANG-MOLINO 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	42	14	6	3	6	0	71
	0.21-0.50	21	3	3	2	2	0	31
	0.51-1.00	8	5	2	0	0	0	15
	1.01-2.00	7	2	0	0	1	0	10
	2.01-5.00	18	4	4	0	2	1	29
	> 5.00	15	3	3	1	3	1	26
	Total	111	31	18	6	14	2	182

The overall accuracy generated by the flood model is estimated at 27.47%, with fifty (50) points correctly matching the actual flood depths. In addition, there were forty-three (43) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were twenty-three (23) points and sixty-one (61) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of ninety-four (94) points were underestimated in the modeled flood depths of Binabang-Molino.

Table 51. Summary of Accuracy Assessment in the Binabang-Molino River Basin model

No. of Points		%
Correct	50	**27.47**
Overestimated	38	**20.88**
Underestimated	94	**51.65**
Total	182	**100.00**

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ANNEXES

Annex 1. Technical Specifications of the Pegasus LiDAR Sensor used in the Binabang-Molino Floodplain Survey

Figure A-1.1. Pegasus Sensor

Table A-1.1. Technical specifications of the Pegasus 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. CVT-199

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

February 26, 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: **CAVITE**
Station Name: **CVT-199**
Order: **2nd**

Island:	**LUZON**			Barangay:	**CALUMPANG LEJOS**
Municipality:	**INDANG**				
		PRS92 Coordinates			
Latitude:	**14° 14' 16.32329"**	Longitude:	**120° 50' 40.63536"**	Ellipsoidal Hgt:	**166.20100 m.**
		WGS84 Coordinates			
Latitude:	**14° 14' 10.97763"**	Longitude:	**120° 50' 45.56096"**	Ellipsoidal Hgt:	**210.38600 m.**
		PTM Coordinates			
Northing:	**1574493.218 m.**	Easting:	**483231.789 m.**	Zone:	**3**
		UTM Coordinates			
Northing:	**1,575,012.80**	Easting:	**267,428.74**	Zone:	**51**

Location Description

CVT-199
To reach Brgy. Calumpang Lejos, take the nat'l. road from Indang Town Proper towards Naic for about 5 km. Station is located approx. 15 m. NW of the chapel, about 8 m. N of the basketball covered court. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. x 10 cm. concrete block, with inscriptions "CVT-199 2007 NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-391**

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

9 9 0 2 2 6 2 0 1 4 1 4 3 4 0 3

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. CVT-199

2. CVT-194

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: **CAVITE**
Station Name: **CVT-194 (BLLM-1)**
Order: **2nd**

Island: **LUZON**
Municipality: **GENERAL TRIAS**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **14° 23' 15.01186"**	Longitude: **120° 52' 43.52184"**	Ellipsoidal Hgt: **18.33700 m.**

WGS84 Coordinates

Latitude: **14° 23' 9.63386"**	Longitude: **120° 52' 48.43458"**	Ellipsoidal Hgt: **62.18400 m.**

PTM Coordinates

Northing: **1591045.311 m.**	Easting: **486924.253 m.**	Zone: **3**

UTM Coordinates

Northing: **1,591,537.44**	Easting: **271,265.13**	Zone: **51**

Location Description

CVT-194 (BLLM-1)
Is located inside the mun. park, about 100 m. SE from the Gen. Trias Mun. Hall. Mark is a brass rod centered and embedded on a concrete block, with inscriptions "BLLM No. 1 PSC-54".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-200**

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

9 9 0 2 0 4 2 0 1 4 1 3 0 0 1 6

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. CVT-194

3. BTG-45

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **BATANGAS**
Station Name: **BTG-45**
Order: **2nd**

Island: **LUZON**		Barangay: **MALIBU**
Municipality: **TUY**		
	PRS92 Coordinates	
Latitude: **13° 59' 52.18294"**	Longitude: **120° 42' 18.96476"**	Ellipsoidal Hgt: **48.43000 m.**
	WGS84 Coordinates	
Latitude: **13° 59' 46.88216"**	Longitude: **120° 42' 23.91169"**	Ellipsoidal Hgt: **92.94300 m.**
	PTM Coordinates	
Northing: **1547952.281 m.**	Easting: **468159.677 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,548,591.80**	Easting: **252,125.62**	Zone: **51**

Location Description

BTG-45
From Tuy Town Proper, travel S on the road going to Balayan, then turn right to the road going to Brgy. Malibu. Station is located on the NW side of a fenced garden and about 10 m. W of the school bldg. of Santiago De Guzman Elem. School. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "BTG-45 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-444**

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

9 9 0 3 0 4 2 0 1 4 1 6 0 1 1 4

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-2.3. BTG-45

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

1. CVT-3051

Table A-3.1. CVT-3051

Vector Components (Mark to Mark)

From:	CVT-199				
Grid		Local		Global	
Easting	267428.741 m	Latitude	N14°14'16.32329"	Latitude	N14°14'10.97763"
Northing	1575012.795 m	Longitude	E120°50'40.63536"	Longitude	E120°50'45.56096"
Elevation	167.120 m	Height	166.201 m	Height	210.386 m

To:	CVT-3051				
Grid		Local		Global	
Easting	271276.565 m	Latitude	N14°22'58.33330"	Latitude	N14°22'52.95639"
Northing	1591024.612 m	Longitude	E120°52'44.06059"	Longitude	E120°52'48.97372"
Elevation	22.137 m	Height	21.122 m	Height	64.983 m

Vector					
ΔEasting	3847.824 m	NS Fwd Azimuth	12°58'47"	ΔX	-1068.623 m
ΔNorthing	16011.817 m	Ellipsoid Dist.	16463.417 m	ΔY	-5421.802 m
ΔElevation	-144.982 m	ΔHeight	-145.079 m	ΔZ	15509.176 m

Standard Errors

Vector errors:					
σ ΔEasting	0.029 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.036 m
σ ΔNorthing	0.020 m	σ Ellipsoid Dist.	0.019 m	σ ΔY	0.058 m
σ ΔElevation	0.065 m	σ ΔHeight	0.065 m	σ ΔZ	0.029 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0012710639		
Y	-0.0011111494	0.0033830758	
Z	-0.0004897536	0.0012701754	0.0008644866

2. PB-1

Table A-3.2. PB-1

Vector Components (Mark to Mark)

From:	CVT-194				
Grid		Local		Global	
Easting	271413.844 m	Latitude	N14°23'09.63386"	Latitude	N14°23'09.63386"
Northing	1591468.703 m	Longitude	E120°52'48.43458"	Longitude	E120°52'48.43458"
Elevation	19.356 m	Height	62.184 m	Height	62.184 m

To:	PB-1				
Grid		Local		Global	
Easting	280881.093 m	Latitude	N14°23'19.56635"	Latitude	N14°23'19.56635"
Northing	1591688.776 m	Longitude	E120°58'04.29835"	Longitude	E120°58'04.29835"
Elevation	44.199 m	Height	87.568 m	Height	87.568 m

Vector					
ΔEasting	9467.249 m	NS Fwd Azimuth	88°08'29"	ΔX	-8091.412 m
ΔNorthing	220.073 m	Ellipsoid Dist.	9467.724 m	ΔY	-4906.972 m
ΔElevation	24.843 m	ΔHeight	25.384 m	ΔZ	302.003 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000191800		
Y	-0.0000293093	0.0000523957	
Z	-0.0000093650	0.0000161874	0.0000064708

2

3. BTG-45A

Table A-3.3. BTG-45A

Vector Components (Mark to Mark)

From:	BTG-45				
Grid		Local		Global	
Easting	252125.624 m	Latitude	N13°59'52.18294"	Latitude	N13°59'46.88216"
Northing	1548591.799 m	Longitude	E120°42'18.96476"	Longitude	E120°42'23.91169"
Elevation	49.818 m	Height	48.430 m	Height	92.943 m

To:	BTG-45A				
Grid		Local		Global	
Easting	252126.100 m	Latitude	N13°59'51.95603"	Latitude	N13°59'46.65526"
Northing	1548584.818 m	Longitude	E120°42'18.98286"	Longitude	E120°42'23.92980"
Elevation	50.478 m	Height	49.089 m	Height	93.602 m

Vector					
ΔEasting	0.476 m	NS Fwd Azimuth	175°32'41"	ΔX	-1.655 m
ΔNorthing	-6.981 m	Ellipsoid Dist.	6.995 m	ΔY	1.723 m
ΔElevation	0.659 m	ΔHeight	0.659 m	ΔZ	-6.607 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'12"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002866		
Y	-0.0000001658	0.0000003931	
Z	-0.0000000756	0.0000000861	0.0000001315

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-team	Designation	Name	Agency/Affiliation
Program Leader	Program Leader –I	ENRICO C. PARINGIT, D. Eng.	UP TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. CZAR JAKIRI S. SARMIENTO	UP TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. LOUIE P. BALICANTA	UP TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		ENGR. LOVELYN ASUNCION	UP TCAGP
		ENGR. GEROME HIPOLITO	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP TCAGP
	Research Associate	ENGR. LARAH PARAGAS	UP TCAGP
		PAULINE JOANNE ARCEO	UP TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP TCAGP
		FAITH JOY SABLE	UP TCAGP
		KRISTINE JOY ANDAYA	UP TCAGP
Ground Survey, Data Download and Transfer	Research Associate	ENGR. RENAN PUNTO	UP TCAGP
		MA. VERLINA TONGA	UP TCAGP
		ENGR. KENNETH QUISADO	UP TCAGP
LiDAR Operation/ Ground Survey	Research Associate	ENGR. RENAN PUNTO	UP TCAGP
		ENGR. DAN ALDOVINO	UP TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORP (AAC)
		CAPT. RAUL SAMAR	ASIAN AEROSPACE CORP (AAC)
		CAPT. FRANCO PEPITO	ASIAN AEROSPACE CORP (AAC)
		CAPT. CAESAR ALFONSO II	ASIAN AEROSPACE CORP (AAC)

Annex 5. Data Transfer Sheets for the Binabang-Molino Floodplain Flights

DATA TRANSFER SHEET
Apr 4, 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	
Jan 24, 2014	1023P	1BLK18B024A	PEGASUS	958MB	1.01MB	4.74MB	52.6MB	11.8GB	111KB	9.28GB	39.8GB	8.34MB	109B	245B	33.3KB	N/A	Z:\Airborne_Raw\1023P
Jan 25, 2014	1027P	1BLK18A025A	PEGASUS	1.51GB	1.62MB	5.69MB	194MB	7.11GB	83.9KB	14.3GB	N/A	6.71MB	112B	718B	105KB	N/A	Z:\Airborne_Raw\1027P
Jan 28, 2014	1031P	1BLK18C025A	PEGASUS	1.52GB	1.63MB	5.60MB	185MB	N/A	N/A	14.7GB	N/A	8.03MB	110B	62B	40.6KB	N/A	Z:\Airborne_Raw\1031P
Jan 29, 2014	1043P	1BLK18AS029A	PEGASUS	594MB	687KB	3.52MB	125MB	N/A	N/A	6.13GB	N/A	6.76MB	141B	352B	33.2KB	N/A	Z:\Airborne_Raw\1043P
Jan 31, 2014	1051P	1BLK18E031A	PEGASUS	1.28GB	1.60MB	5.47MB	189MB	14.4GB	154KB	13.3GB	N/A	2.28MB	217B	504B	76.5KB	N/A	Z:\Airborne_Raw\1051P
Feb 2, 2014	1059P	1BLK18F033A	PEGASUS	1.04GB	1.13MB	5.61MB	167MB	11.7GB	119KB	10.1GB	N/A	3MB	201B	421B	133KB	N/A	Z:\Airborne_Raw\1059P
Feb 3, 2014	1063P	1BLK18D034A	PEGASUS	1.18GB	853KB	5.17MB	144MB	19.2GB	174KB	18.5GB	N/A	5.95MB	191B	321B	28.3KB	N/A	Z:\Airborne_Raw\1063P
Feb 4, 2014	1067P	1BLK18H035A	PEGASUS	921MB	1.39MB	4.99MB	167MB	11.6GB	111KB	11.5GB	N/A	5.03MB	136B	333B	63.3KB	N/A	Z:\Airborne_Raw\1067P
Feb 5, 2014	1071P	1BLK18I036A	PEGASUS	1.62GB	1.81MB	4.91MB	157MB	16GB	157KB	15.4GB	N/A	2.50MN	193B	411B	95.2KB	N/A	Z:\Airborne_Raw\1071P
Feb 7, 2014	1079P	1BLKEFS038A	PEGASUS	451MB	603MB	3.17MB	132MB	4.97GB	55.8KB	5.51GB	N/A	3.01MB	194B	479B	69.9KB	N/A	Z:\Airborne_Raw\1079P
Feb 8, 2014	1083P	1BLK18J39A	PEGASUS	1.47GB	1.92MB	5.56MB	193MB	22.6GB	187KB	16.5GB	N/A	12.4MB	180B	604B	62.6KB	N/A	Z:\Airborne_Raw\1083P
Feb 9, 2014	1087P	1BLK18K40A	PEGASUS	1.28GB	1.77MB	5.19MB	183MB	16GB	139KB	14.8GB	N/A	10.7MB	185B	420B	32.6KB	N/A	Z:\Airborne_Raw\1087P
Feb 10, 2014	1091P	1BLK18W41A	PEGASUS	2.17GB	2.40MB	6.22MB	171MB	32.7GB	256KB	20.2GB	N/A	10.1MB	188B	428B	66.1KB	N/A	Z:\Airborne_Raw\1091P
Feb 11, 2014	1095P	1BLK18U42A	PEGASUS	1.15GB	1.53MB	7.92MB	235MB	96.9MB	1.61KB	14.9GB	N/A	11.4MB	205B	287B	76.7KB	N/A	Z:\Airborne_Raw\1095P
Feb 12, 2014	1099P	1BLK18US43A	PEGASUS	1.70GB	2.39MB	7.46MB	234MB	N/A	739B	20.7GB	N/A	11.4MB	205B	643B	95.2KB	N/A	Z:\Airborne_Raw\1099P
Feb 13, 2014	1103P	1BLK18VWS44A	PEGASUS	2.12GB	2.36MB	6.86MB	221MB	N/A	N/A	19.8GB	N/A	16.6MB	305B	429B	191KB	N/A	Z:\Airborne_Raw\1103P
Feb 13,2014	1105P	1BLK18T44B	PEGASUS	2.33GB	2.67MB	6.85MB	219MB	N/A	N/A	22.2GB	N/A	16.6MB	305B	394B	161KB	N/A	Z:\Airborne_Raw\1105P
Feb 14,2014	1107P	1BLK18CRS45A	PEGASUS	799MB	1.54MB	7.03MB	215MB	16.7GB	149KB	10.2GB	N/A	12MB	217B	N/A	N/A	N/A	Z:\Airborne_Raw\1107P
Feb 14,2014	1109P	1BLK18US45B	PEGASUS	N/A	1.87MB	5.61MB	183MB	N/A	N/A	15.9GB	N/A	12MB	217B	310B	196KB	N/A	Z:\Airborne_Raw\1109P

Figure A-5.1. Data Transfer Sheet for Binabang-Molino Floodplain – A

Feb 15,2014	1111P	1BLK18RS46A	PEGASUS	1.39GB	1.74MB	6.22MB	194MB	19.7GB	172KB	14.7GB	N/A	10.9MB	215B	569B	71KB	N/A	Z:\Airborne_Raw\1111P
Feb 17,2014	1119P	1BLK18O48A	PEGASUS	1.02GB	1.95MB	8.25MB	250MB	21.5GB	195KB	16.8GB	N/A	11.7MB	213MB	520B	41KB	N/A	Z:\Airborne_Raw\1119P
Feb 18, 2014	1123P	1BLK18OS49A	PEGASUS	1.38GB	1.81MB	6.46MB	193MB	N/A	N/A	14.7GB	N/A	12.5MB	213B	504B	43KB	N/A	Z:\Airborne_Raw\1123P
Feb 18,2014	1125P	1BLK18S49B	PEGASUS	374MB	665KB	4.21MB	144MB	N/A	N/A	5.57GB	N/A	12.6MB	213B	282B	79.7KB	N/A	Z:\Airborne_Raw\1125P
Feb 19, 2014	1127P	1BLK18G50A	PEGASUS	985MB	1.54MB	5.26MB	190MB	N/A	N/A	12.1GB	N/A	6.85MB	213B	507B	67.1KB	N/A	Z:\Airborne_Raw\1127P
Feb 20, 2014	1131P	1BLK18Z51A	PEGASUS	1.64GB	2.39MB	7.83MB	219MB	30.3GB	254KB	20GB	90.4GB	13.2MB	133B	310B	91.9KB	N/A	Z:\Airborne_Raw\1131P
Feb 20,2014	1133P	1BLK18Z51B	PEGASUS	1.06GB	1.41MB	4.71MB	169MB	18.9GB	140KB	12.1GB	N/A	13.2MB	133B	265B	91.5KB	N/A	Z:\Airborne_Raw\1133P
Feb 21, 2014	1135P	1BLK18Y52A	PEGASUS	1.54GB	2.04MB	7.95MB	235MB	7.41GB	117KB	17.4GB	33.9GB	7.52MB	133B	335B	91.9KB	N/A	Z:\Airborne_Raw\1135P
Feb 22,2014	1139P	1BLK18X53A	PEGASUS	2.19GB	2.45MB	7.52MB	233MB	29.3GB	238KB	21GB	N/A	6.71MB	133B	0B	147KB	N/A	Z:\Airborne_Raw\1139P
Feb 22, 2014	1141P	1BLK18S53B	PEGASUS	1.65GB	1.80MB	7.25MB	219MB	24GB	176KB	15.4GB	N/A	6.25MB	157B	410B	171KB	N/A	Z:\Airborne_Raw\1141P
28-Jan	1039P	1BLK18B028A	PEGASUS	2.06	36KB	11.8	185	NA	NA	19.1	NA	7.43	141B	242B	40.5	NA	Z:\Airborne_Raw\1039P

Received from
Name CHRIS
Position
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature

Figure A-5.2. Data Transfer Sheet for Binabang-Molino Floodplain – B

DATA TRANSFER SHEET
Calabarzon 9/10/15

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	
17-Aug	3307P	1BLK18JS229B	Pegasus	972	756	6.66	171	na	na	9.59	na	18.4	1KB	1KB	1/42	na	Z:\DAC\RAW DATA
18-Aug	3309P	1BLK18AsS230A	Pegasus	1.17	757	7.65	202	na	na	11.9	na	19.4	1KB	1KB	88	na	Z:\DAC\RAW DATA
3-Sep	3373P	1BLK18OS246A	Pegasus	1.81	2.06	9.59	212	na	na	18.2	na	7.67	1KB	1KB	1	na	Z:\DAC\RAW DATA
4-Sep	3377P	1BLK18JS247A	Pegasus	1.29	777	8.1	196	na	na	13.4	na	6.43	1KB	1KB	61.6	na	Z:\DAC\RAW DATA
5-Sep	3381P	1BLK18OS248A	Pegasus	2.12	1.54	10.3	256	na	na	20.6	na	9.05	1KB	1KB	59/59	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

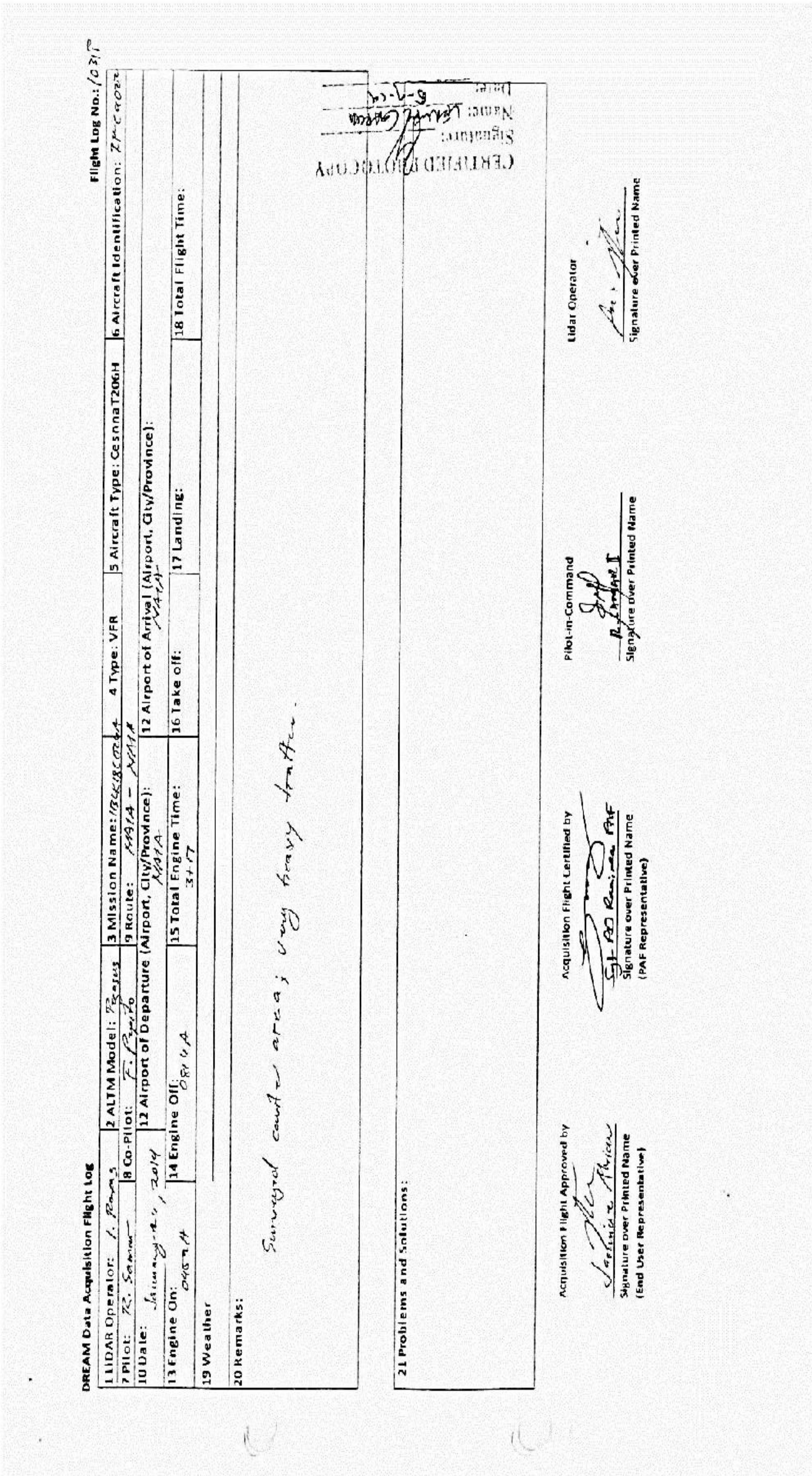
Received by

Name AC Bongat 9/11/15
Position SSRS
Signature

Figure A-5.3. Data Transfer Sheet for Binabang-Molino Floodplain – C

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1031P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1031P

1 LIDAR Operator: L. Paragas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK38C...	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samson	8 Co-Pilot: F. Pujado	9 Route: NAIA - NAIA			
10 Date: January ..., 2014	12 Airport of Departure (Airport, City/Province): NAIA	12 Airport of Arrival (Airport, City/Province): NAIA			
13 Engine On: 0457H	14 Engine Off: 0814H	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed control area; very heavy traffic.					
21 Problems and Solutions:					

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

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

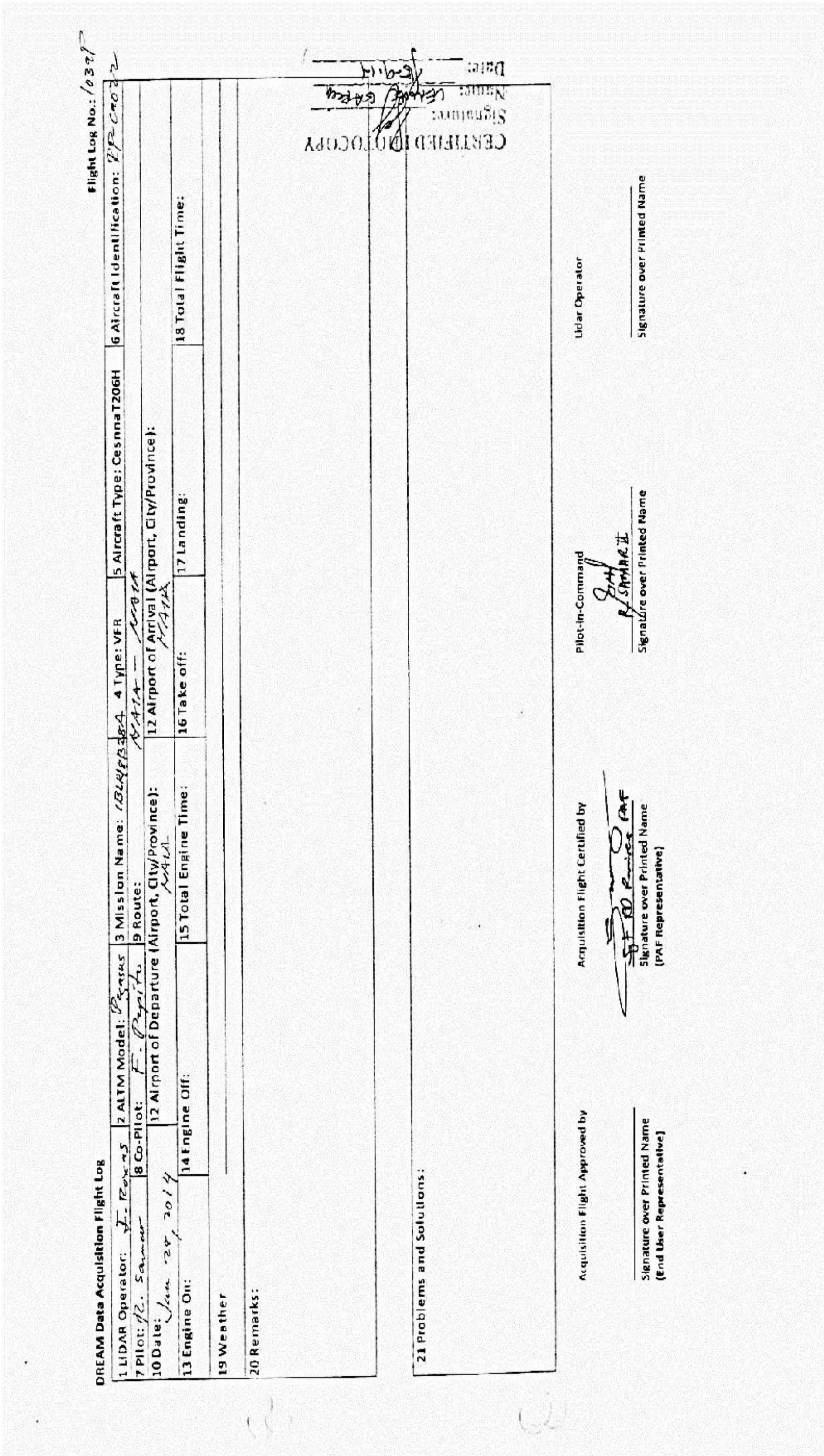
Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name:
Date:

Figure A-6.1. Flight Log for Mission 1031P

2. Flight Log for 1039P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1039P

1 LiDAR Operator: J. Rosas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18B384	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samar	8 Co-Pilot: F. Pepito	9 Route: MAIA – MAIA			
10 Date: Jan 28, 2014	12 Airport of Departure (Airport, City/Province): MAIA		12 Airport of Arrival (Airport, City/Province): MAIA		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					
21 Problems and Solutions:					

CERTIFIED PHOTOCOPY
Signature:
Name: Leonel Garcia
Date:

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

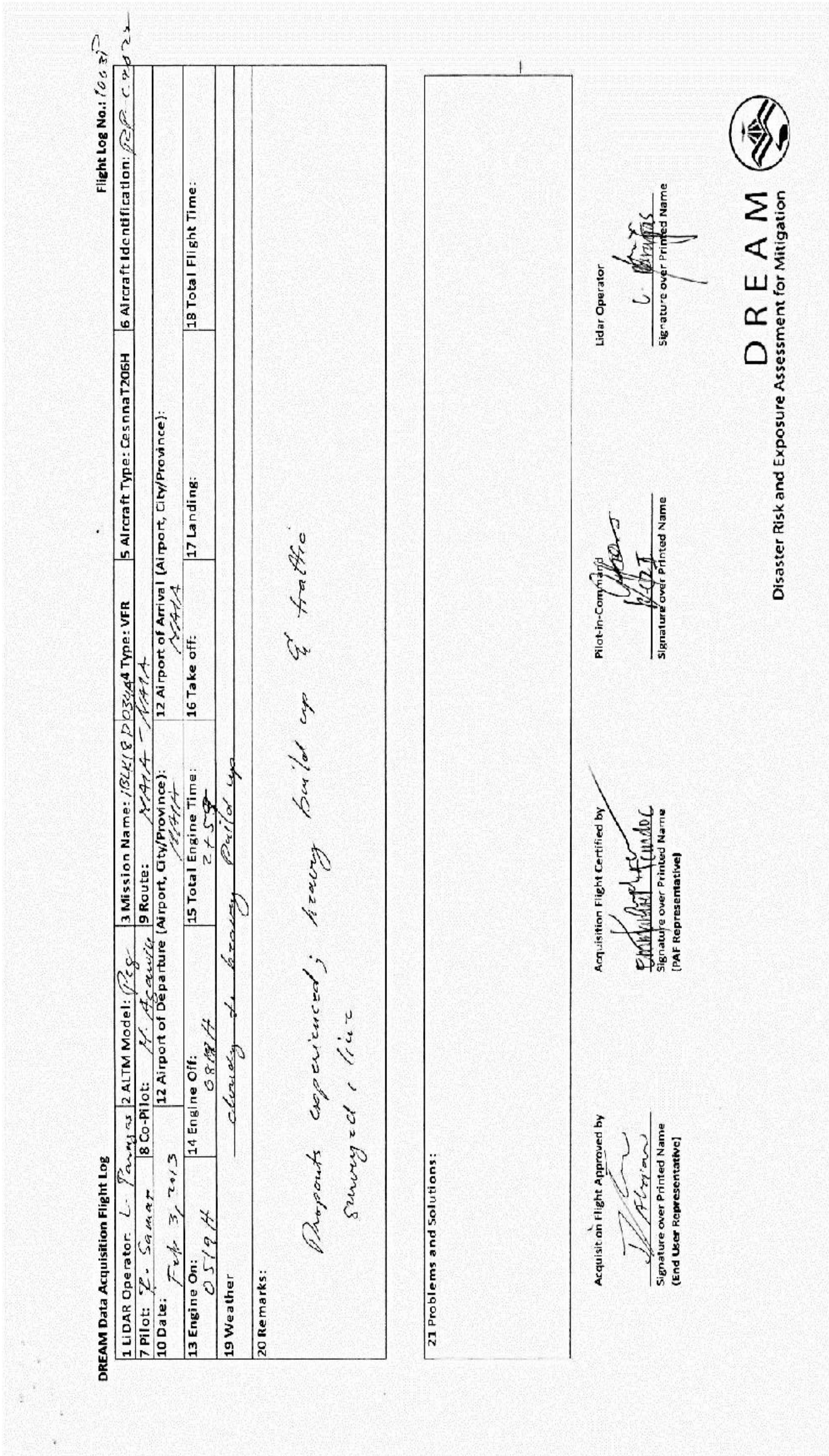
Acquisition Flight Certified by
SSgt MD Ramirez PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
R. Samar II
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1039P

3. Flight Log for 1063P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1063P

1 LIDAR Operator: L. Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK18D034A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samar	8 Co-Pilot: M. Acaucio	9 Route: NAIA - NAIA			
10 Date: Feb 3, 2013	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0519H	14 Engine Off: 0818H	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy to heavy build up				

20 Remarks:

Dropouts experienced; heavy build up & traffic surrounding line

21 Problems and Solutions:

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

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — L. Paragas — Signature over Printed Name

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3. Flight Log for Mission 1063P

4. Flight Log for 1139P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1139P

1 LiDAR Operator: J. ALVIAR	2 ALTM Model: PEG	3 Mission Name: 1BLK18XS53A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: C9022
7 Pilot: F. PEPITO	8 Co-Pilot: A. AGBAYANI	9 Route:			
10 Date: FEB. 22, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0550	14 Engine Off: 0546	15 Total Engine Time: 3+56	16 Take off:	17 Landing:	18 Total Flight Time: 3+42
19 Weather	cloudy				
20 Remarks: SUCCESSFUL FLIGHT					
21 Problems and Solutions:					

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

Acquisition Flight Certified by
Sgt. Dee Ramirez
Signature over Printed Name
(PAF Representative)

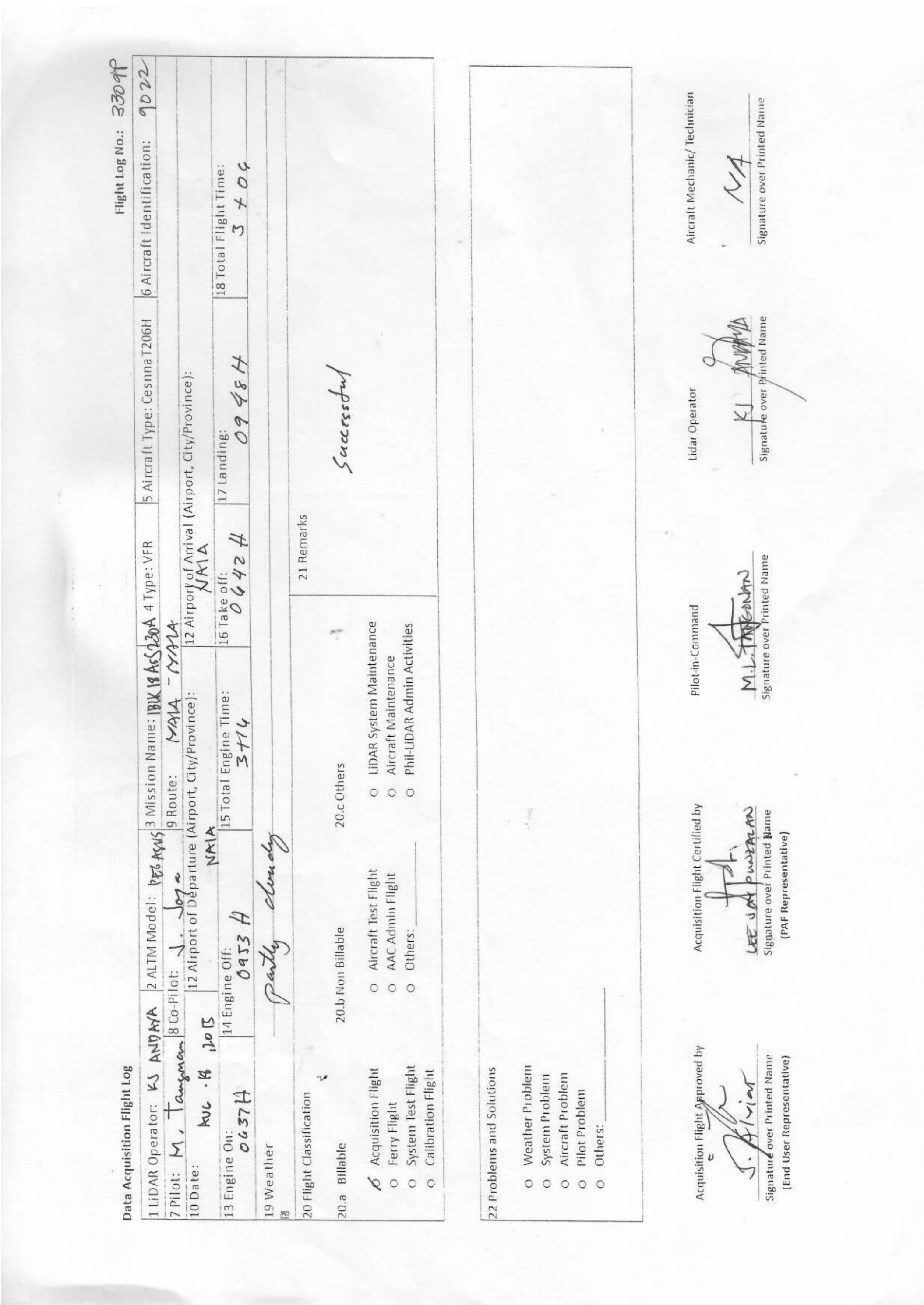
Pilot-in-Command
A. AGBAYANI
Signature over Printed Name

Lidar Operator
Jasmine Alviar
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4. Flight Log for Mission 1139P

5. Flight Log for 3309P Mission



Data Acquisition Flight Log — Flight Log No.: 3309P

1 LiDAR Operator: KJ ANDAYA	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18AS230A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Joya	9 Route: NAIA - NAIA			
10 Date: AUG. 18, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0637H	14 Engine Off: 0953H	15 Total Engine Time: 3+14	16 Take off: 0642H	17 Landing: 0948H	18 Total Flight Time: 3+04
19 Weather: Partly cloudy					

20 Flight Classification

20.a Billable
- [x] Acquisition Flight
- [ ] Ferry Flight
- [ ] System Test Flight
- [ ] Calibration Flight

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

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

21 Remarks: Successful

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

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

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

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

Lidar Operator: KJ Andaya — Signature over Printed Name

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

Figure A-6.5. Flight Log for Mission 3309P

Annex 7. Flight Status Reports

CALABARZON

(January 26-February 22, 2014 and August 18, 2015)

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1031P	BLK 18CD	1BLK18C026A	I. Roxas	26 Jan 2014	Acquired data at 1000m, broken lines and irregular survey pattern due to very heavy traffic and tower restrictions
1039P	BLK 18BC	1BLK18B028A		28 Jan 2014	Data acquired at 1000m AGL
1063P	BLK 18D	1BLK18D034A	L. Paragas	3 Feb 2014	Dropouts experienced, heavy build up and traffic, surveyed 1 line
1139P	BLK 18X & (ABCY)s	1BLK18X53A	J. Alviar	22 Feb 2014	Surveyed gaps in southern Cavite, voids in BLK 18Z and covered BLK 18X at 1200m flying height
3309P	BLK 18AsS	1BLK18AsS230A	KJ Andaya	18 Aug 2015	Voids due to low cloud cover, lines cut due to air traffic Without Digitizer and Camera

LAS BOUNDARIES PER FLIGHT

Flight No. :	1031P
Area:	BLK 18BC
Mission Name:	1BLK18B028A

LAS

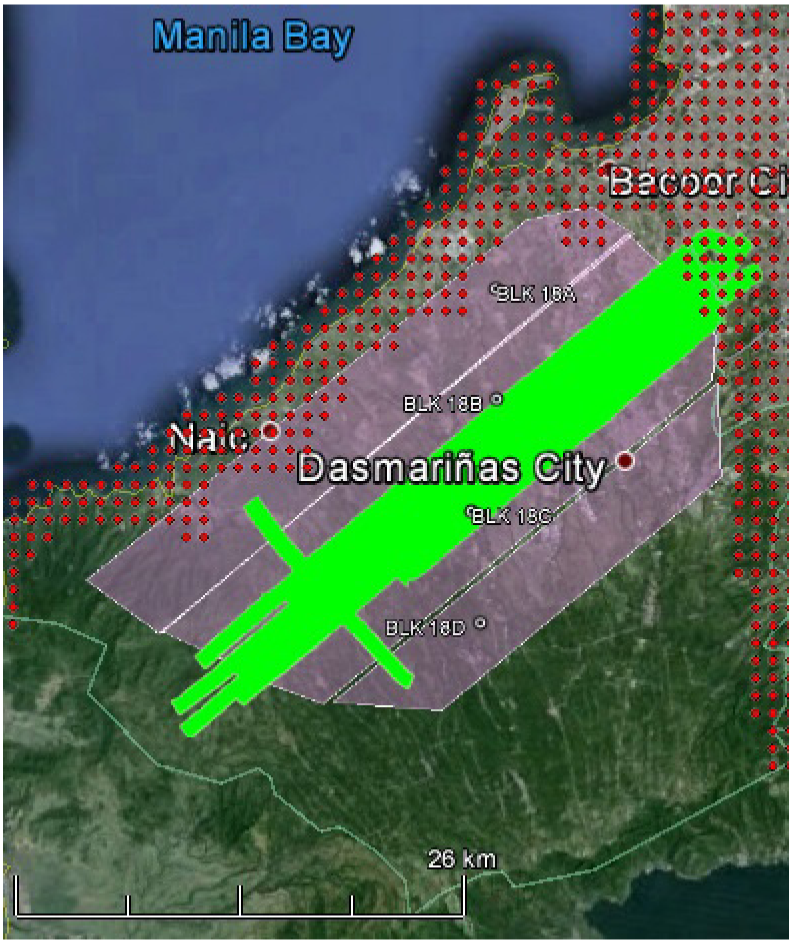


Figure A-7.1. Swath for Flight No. 1031P

Flight No. : 1039P
Area: BLK 18BC
Mission Name: 1BLK18B028A

LAS

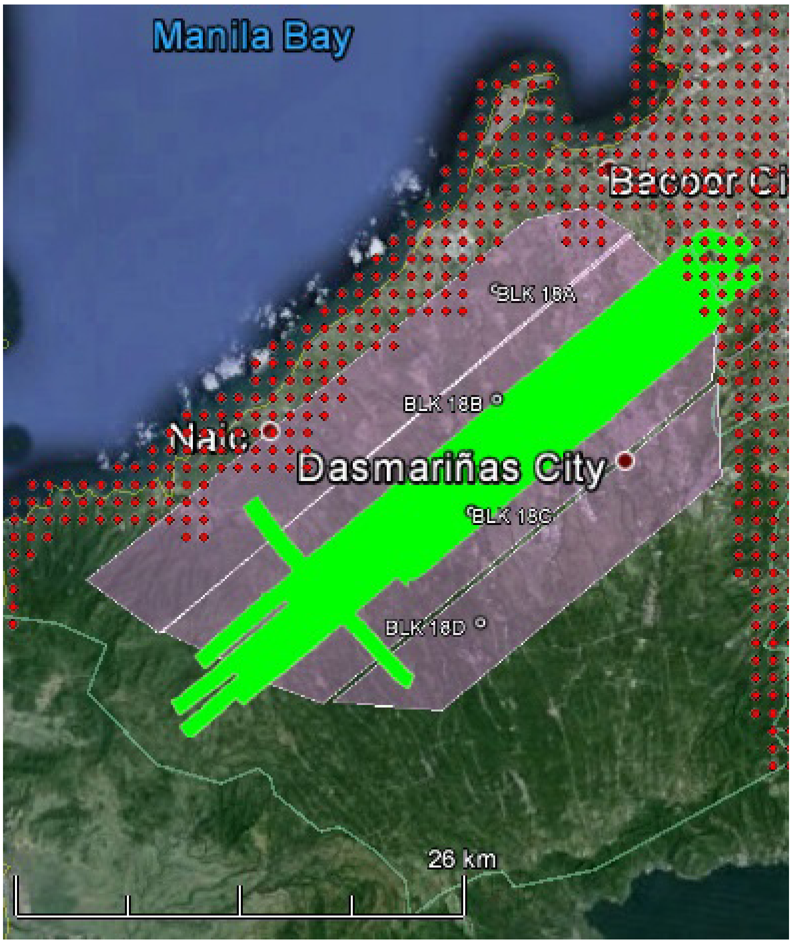


Figure A-7.2. Swath for Flight No. 1039P

Flight No. : 1063P
Area: BLK 18D
Mission Name: 1BLK18D034A

LAS

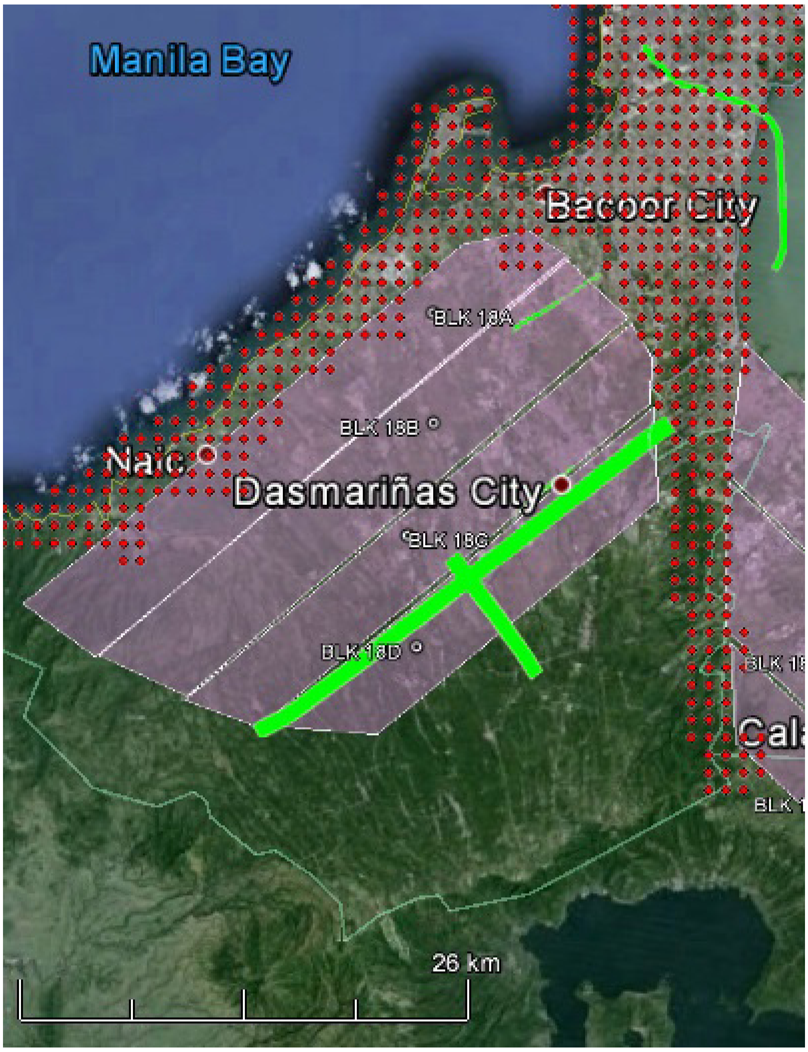


Figure A-7.3. Swath for Flight No. 1063P

Flight No. : 1139P (renamed from 1137P)
Area: BLK 18X & (ABCY)s
Mission Name: 1BLK18S53A

LAS

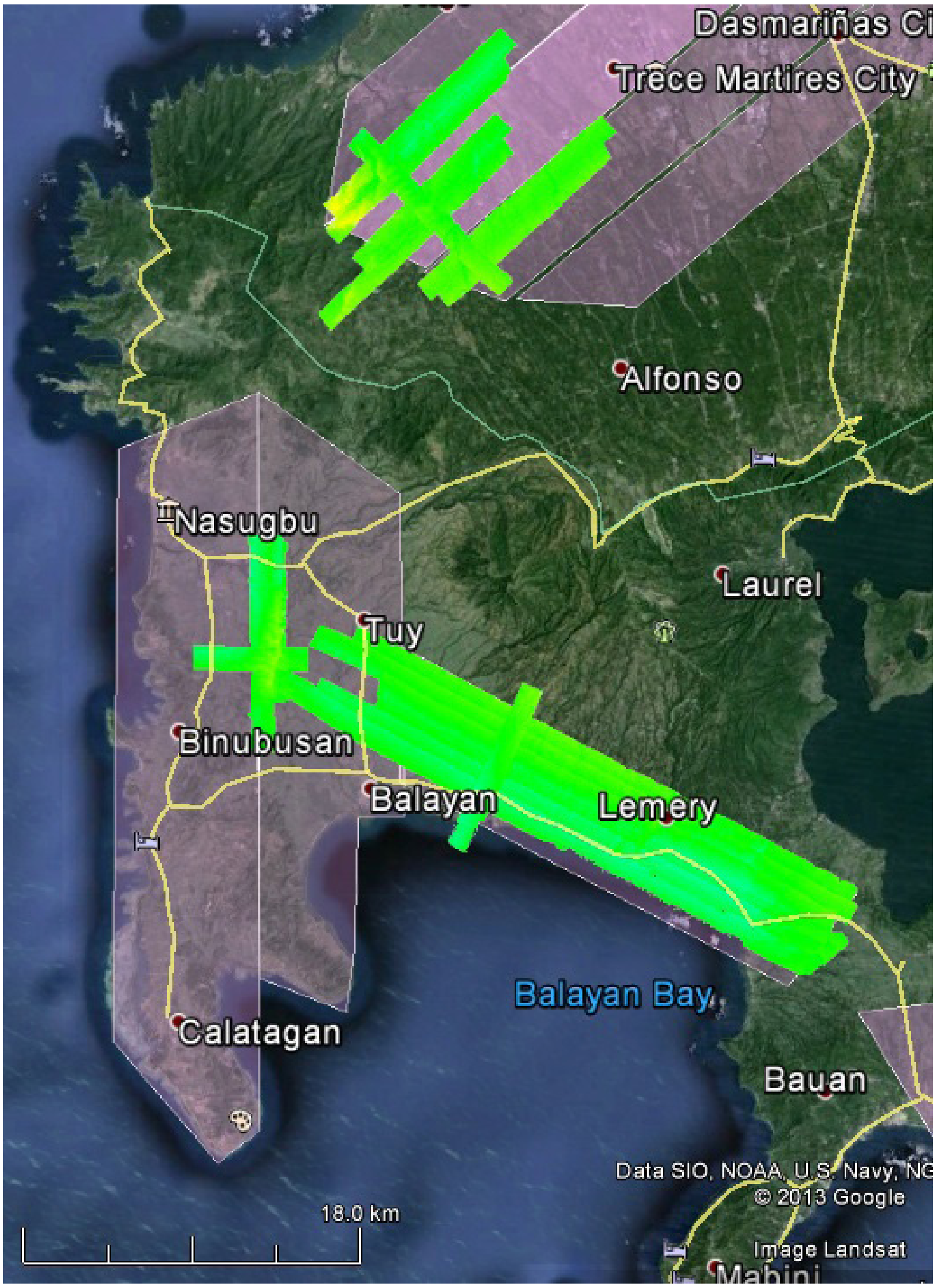


Figure A-7.4. Swath for Flight No. 1139P

Flight No. : 3309P
Area: BLK 18
Mission Name: 1BLK18AsS230A

LAS

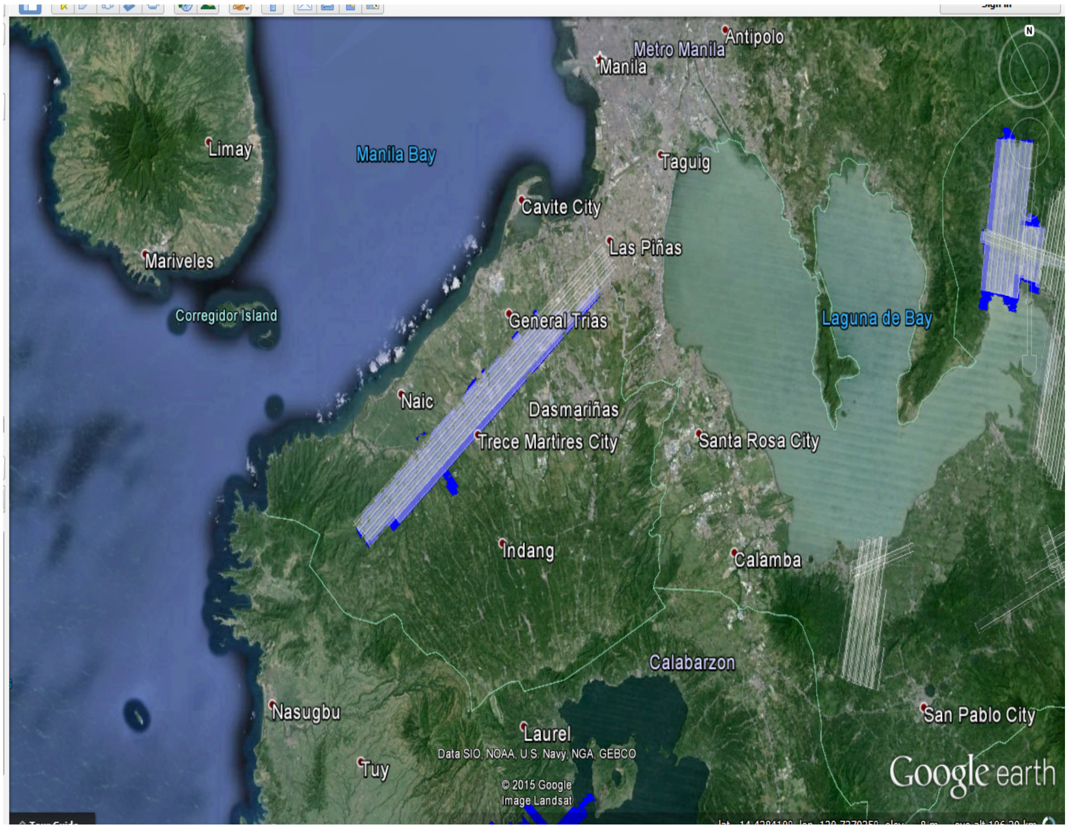


Figure A-7.5. Swath for Flight No. 3309P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk18B_supplement

Flight Area	**CALABARZON**
Mission Name	**Blk18B_supplement**
Inclusive Flights	3309P
Range data size	11.9GB
POS	202 MB
Image	N/A
Transfer date	09/11/2015
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)	2.3
RMSE for East Position (<4.0 cm)	2.9
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000273
IMU attitude correction stdev (<0.001deg)	0.000737
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	43.55%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	171
Maximum Height	426.11 m
Minimum Height	57.0 m
Classification (# of points)	
Ground	95,328,099
Low vegetation	65,505,303
Medium vegetation	120,204,321
High vegetation	132,825,937
Building	23,238,819
Orthophoto	No
Processed by	Engr. Analyn Naldo, Aljon Rie Araneta, Jovy Ann Narisma

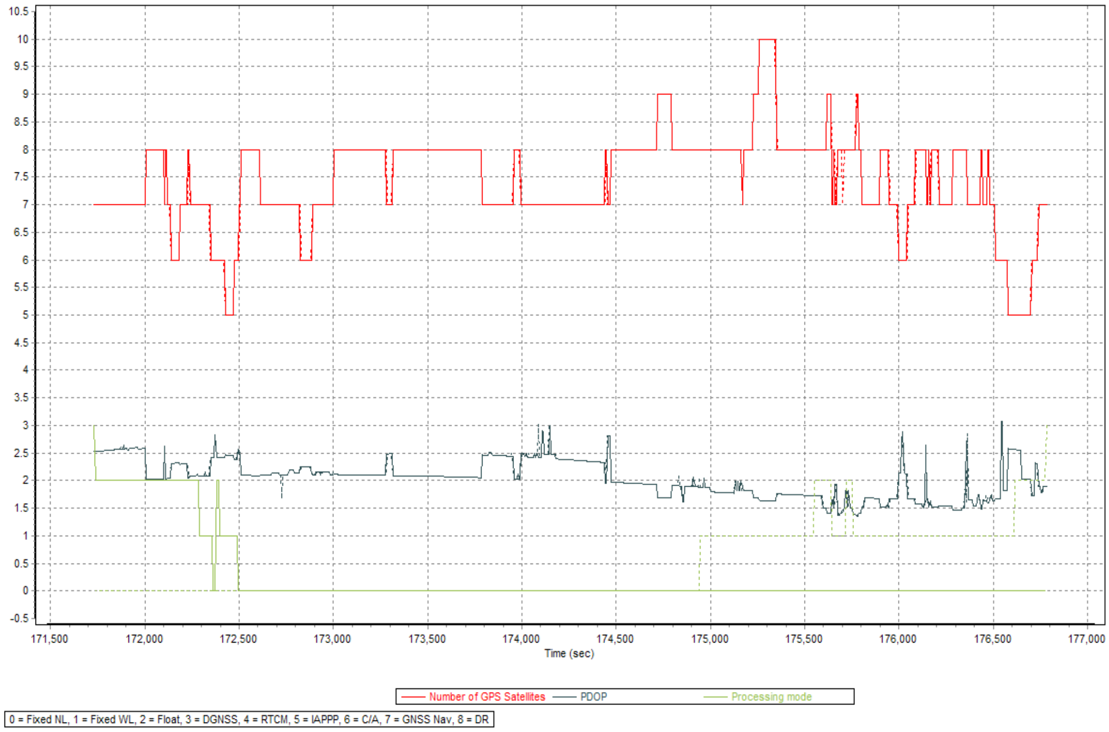


Figure A-8.1. Solution Status

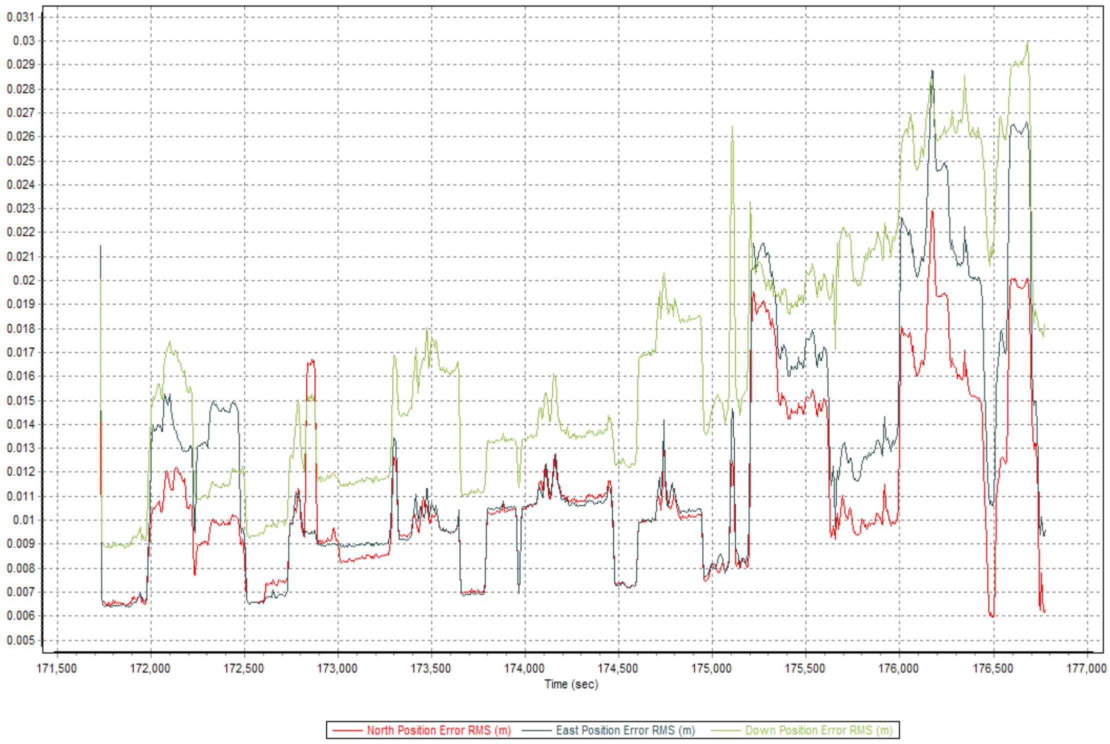


Figure A-8.2. Smoothed Performance Metrics Parameters

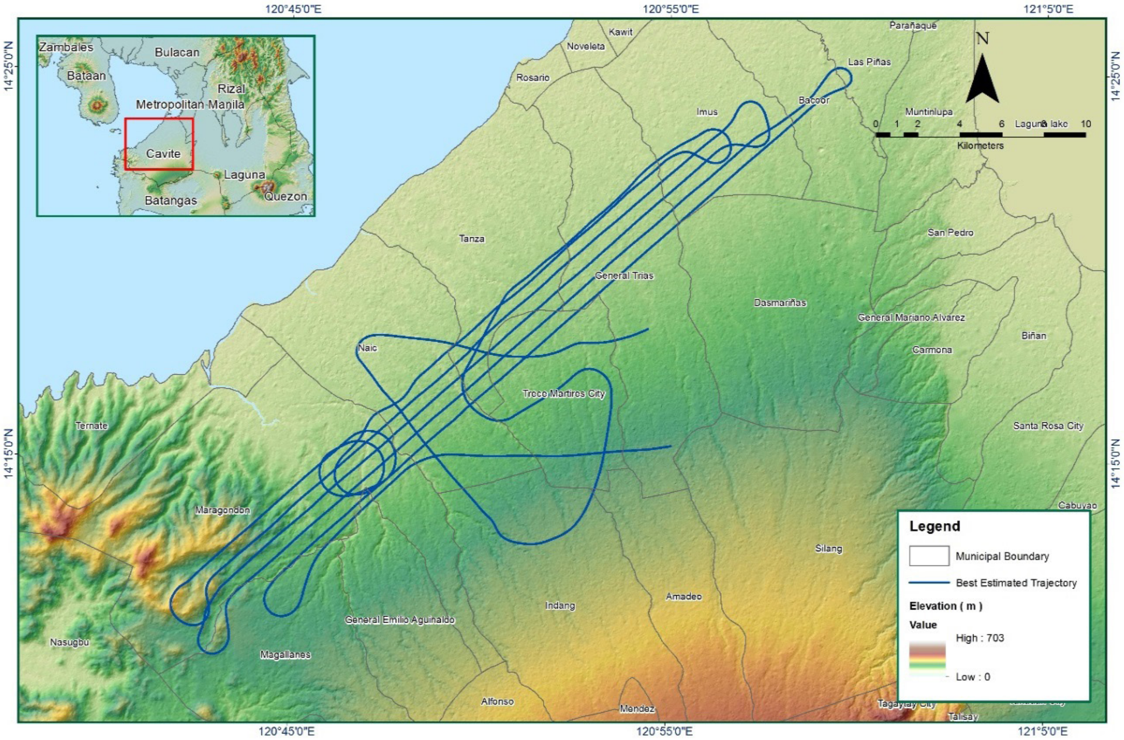


Figure A-8.3. Best Estimated Trajectory

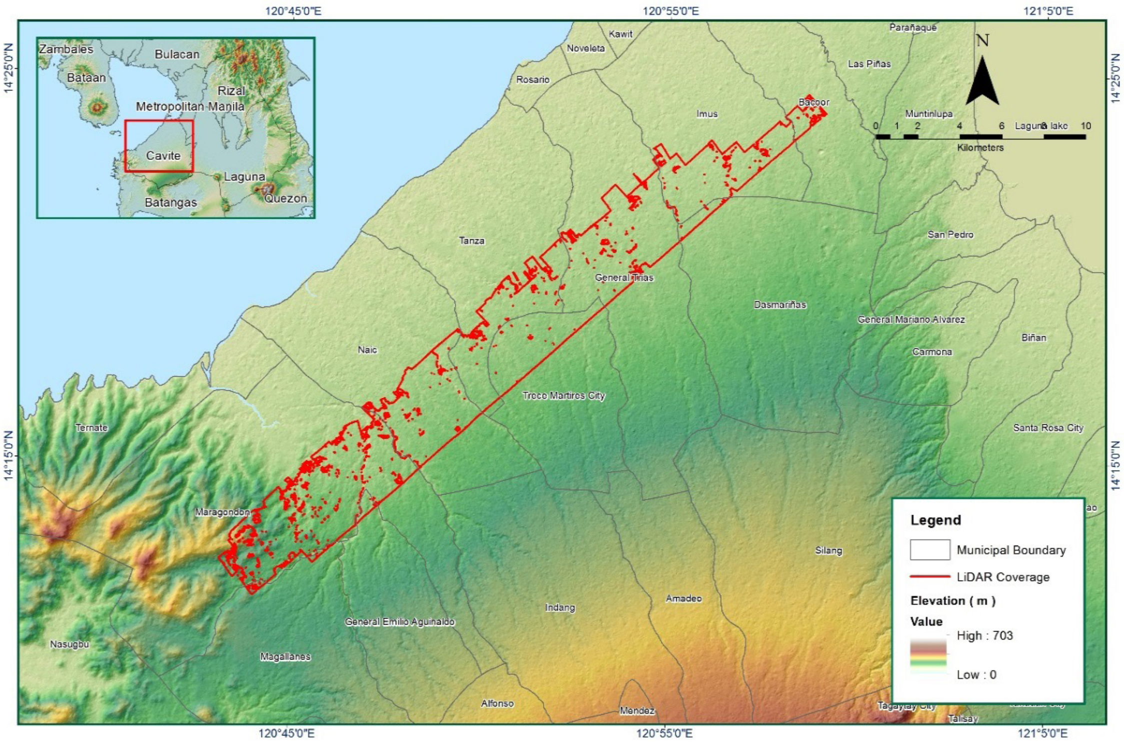


Figure A-8.4. Coverage of LiDAR data

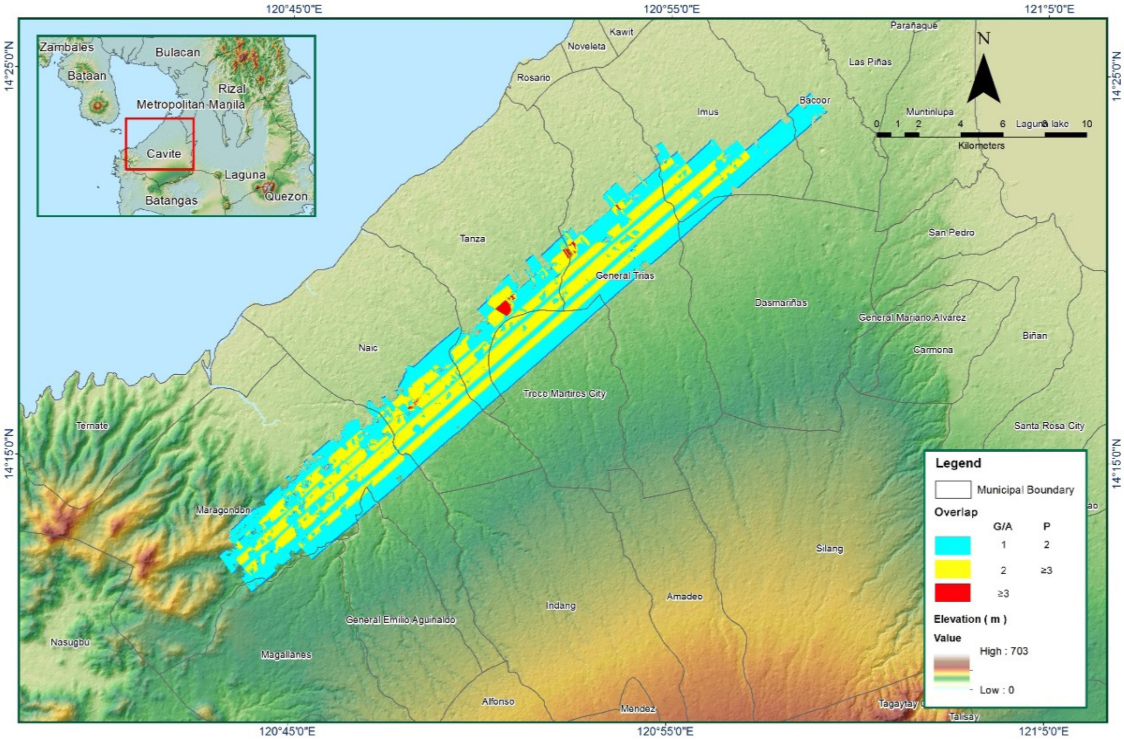


Figure A-8.5. Image of data overlap

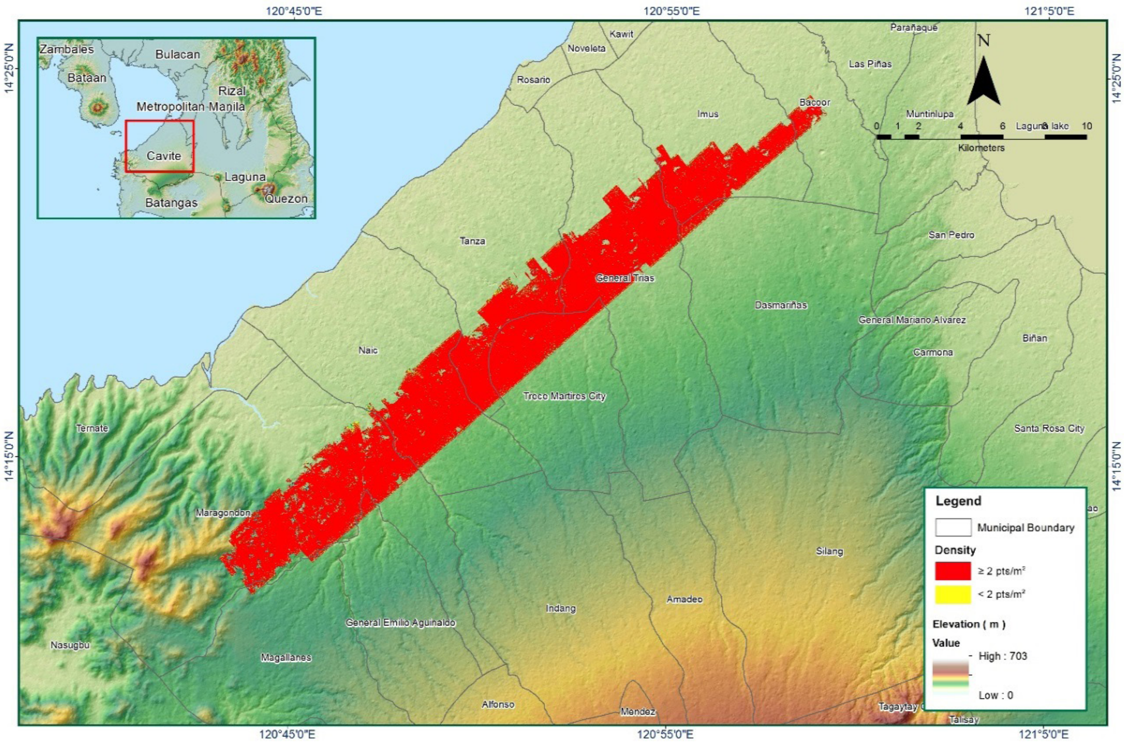
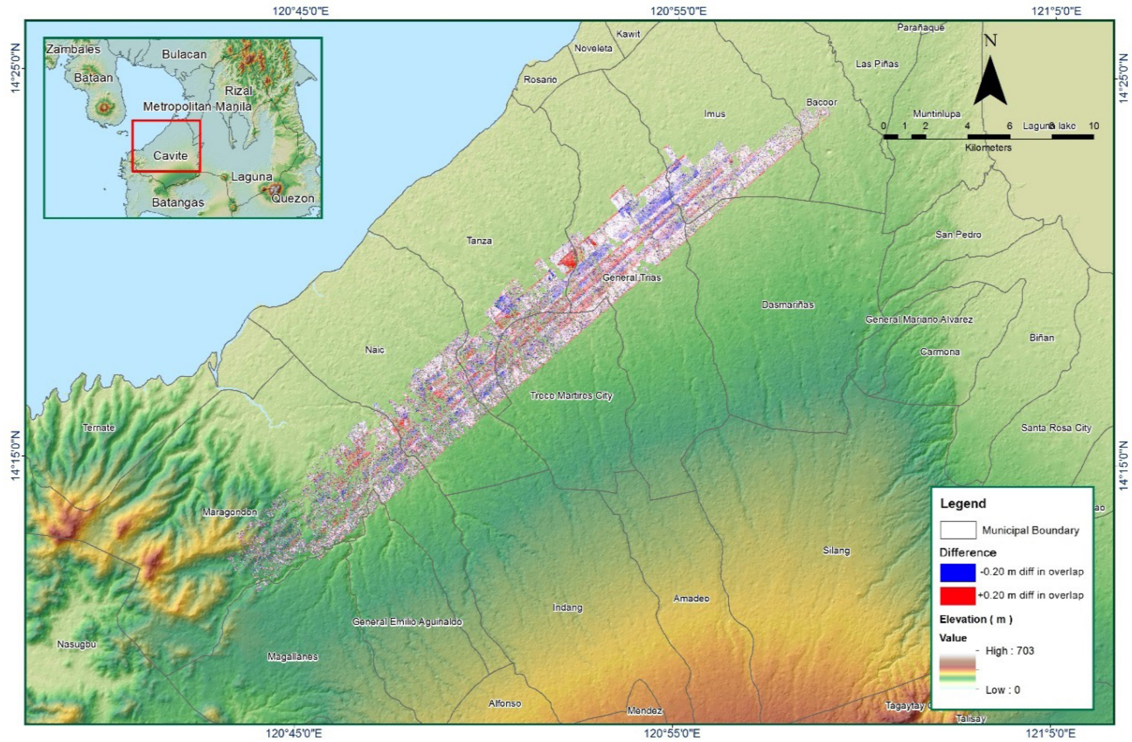


Figure A-8.6. Density map of merged LiDAR data



FigureA-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk18B_Supplement3

Flight Area	**CALABARZON Reflights**
Mission Name	**Blk18B_Supplement3**
Inclusive Flights	10321L
RawLaser	6.16 GB
GnssImu	329 MB
Image	7.32 GB
Transfer date	2/13/2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	No
Estimated Position Accuracy (in cm)	
Estimated Standard Deviation for North Position (<4.0 cm)	2.7
Estimated Standard Deviation for East Position (<4.0 cm)	3.2
Estimated Standard Deviation for Height Position (<8.0 cm)	3.5
Minimum % overlap (>25)	22.01%
Ave point cloud density per sq.m. (>2.0)	1.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	18
Maximum Height	103.706 m
Minimum Height	45.009 m
Classification (# of points)	
Ground	5339022
Low vegetation	1903203
Medium vegetation	3104416
High vegetation	4768776
Building	5270108
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

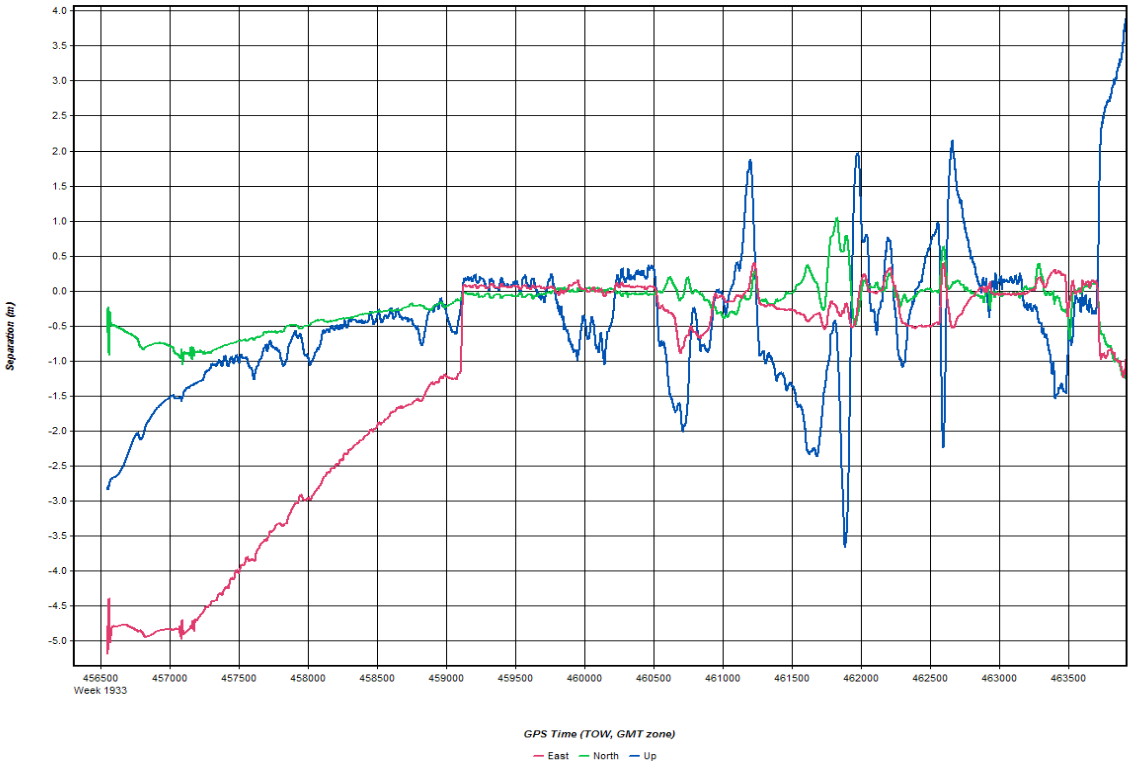


Figure A-8.8. Combined Separation

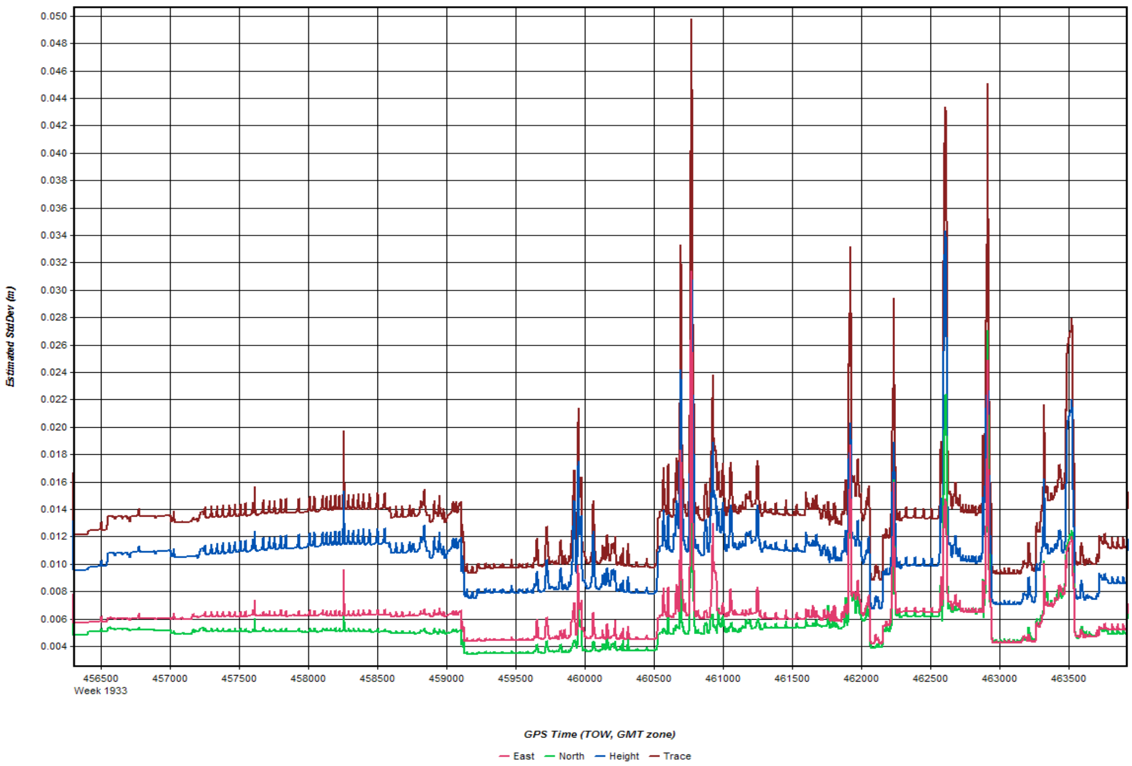


Figure A-8.9. Estimated Position of Accuracy

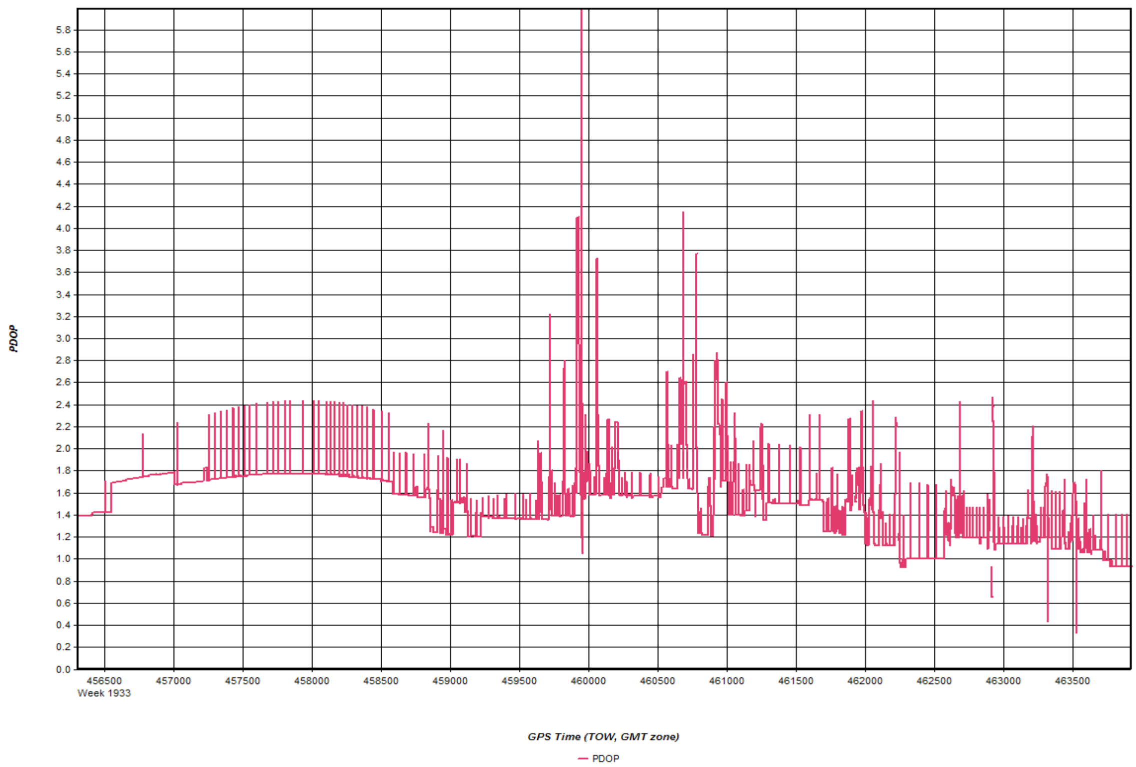


Figure A-8.10. PDOP

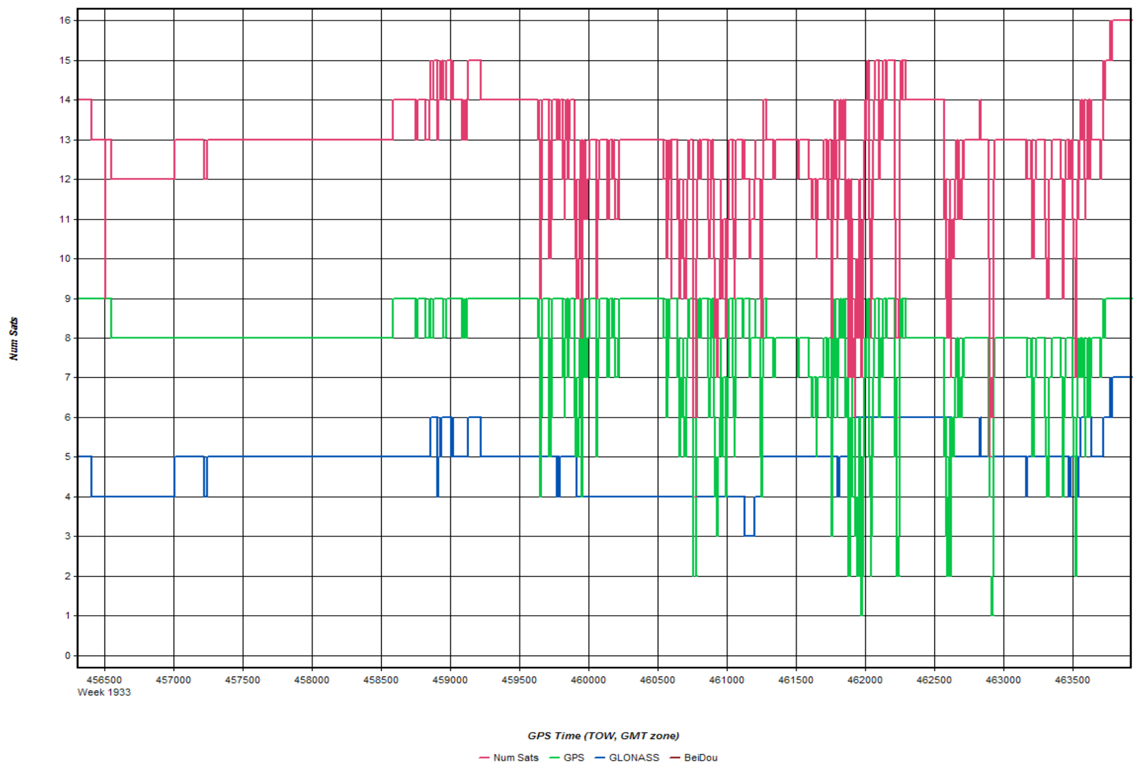


Figure A-8.11. Number of Satellites

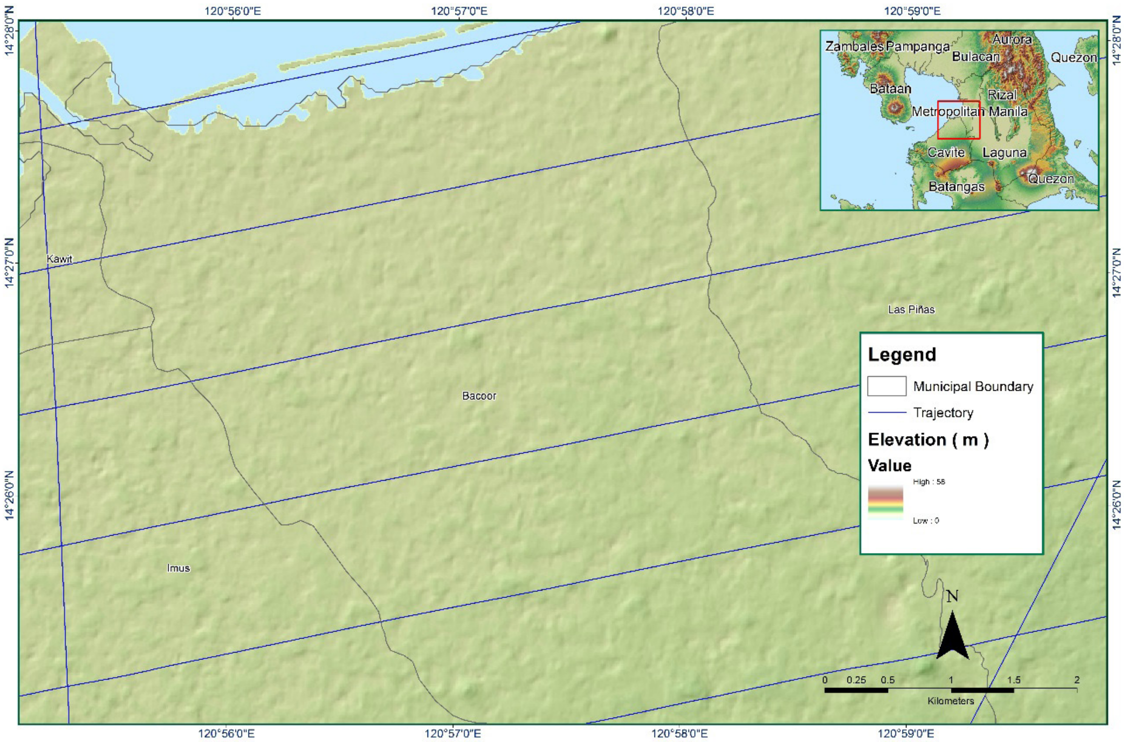


Figure A-8.12. Best Estimated Trajectory

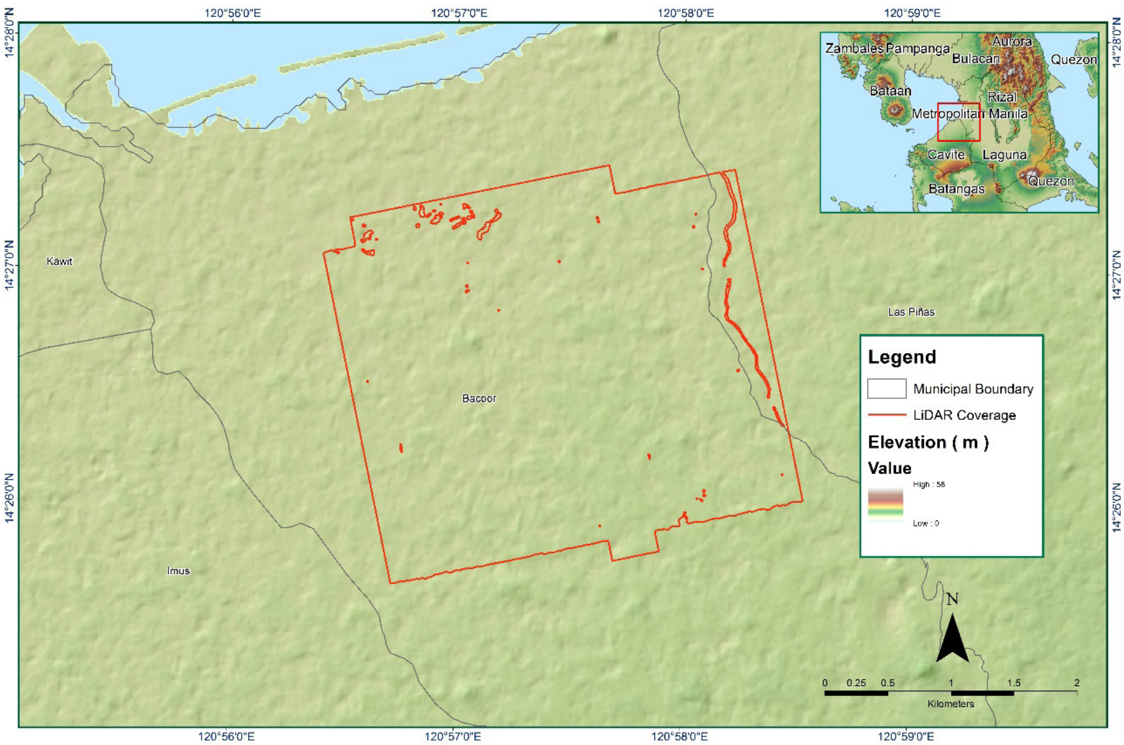


Figure A-8.13. Coverage of LiDAR data

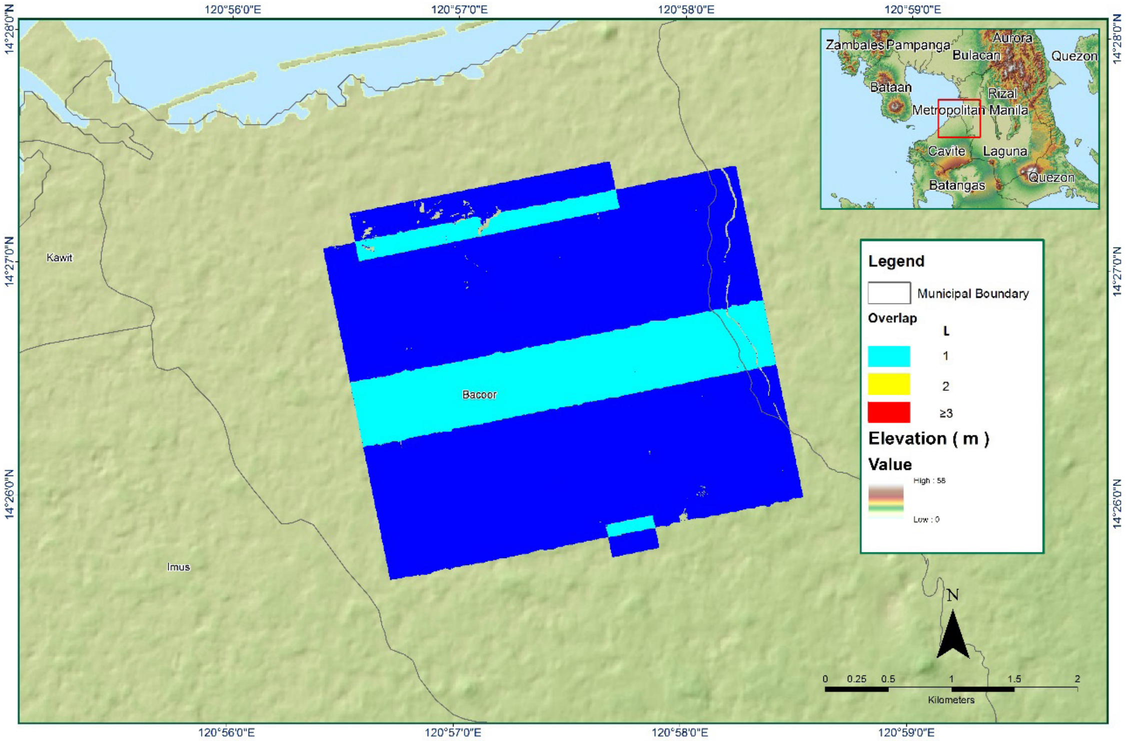


Figure A-8.14. Image of data overlap

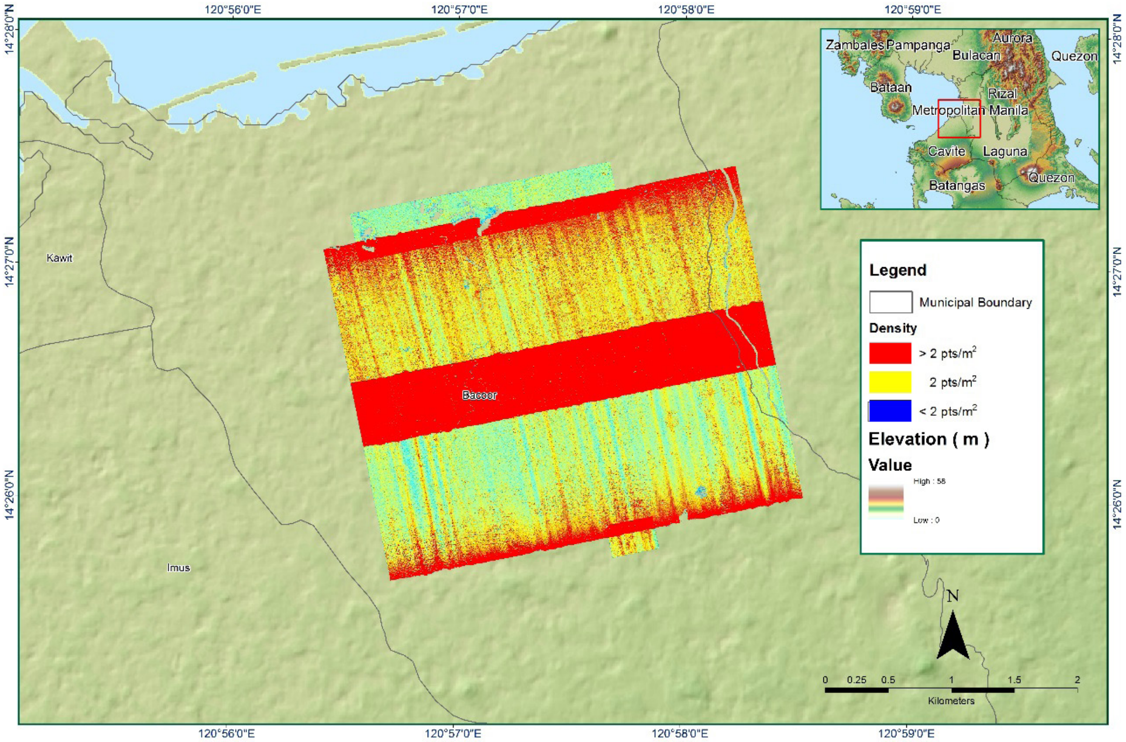


Figure A-8.15. Density map of merged LiDAR data

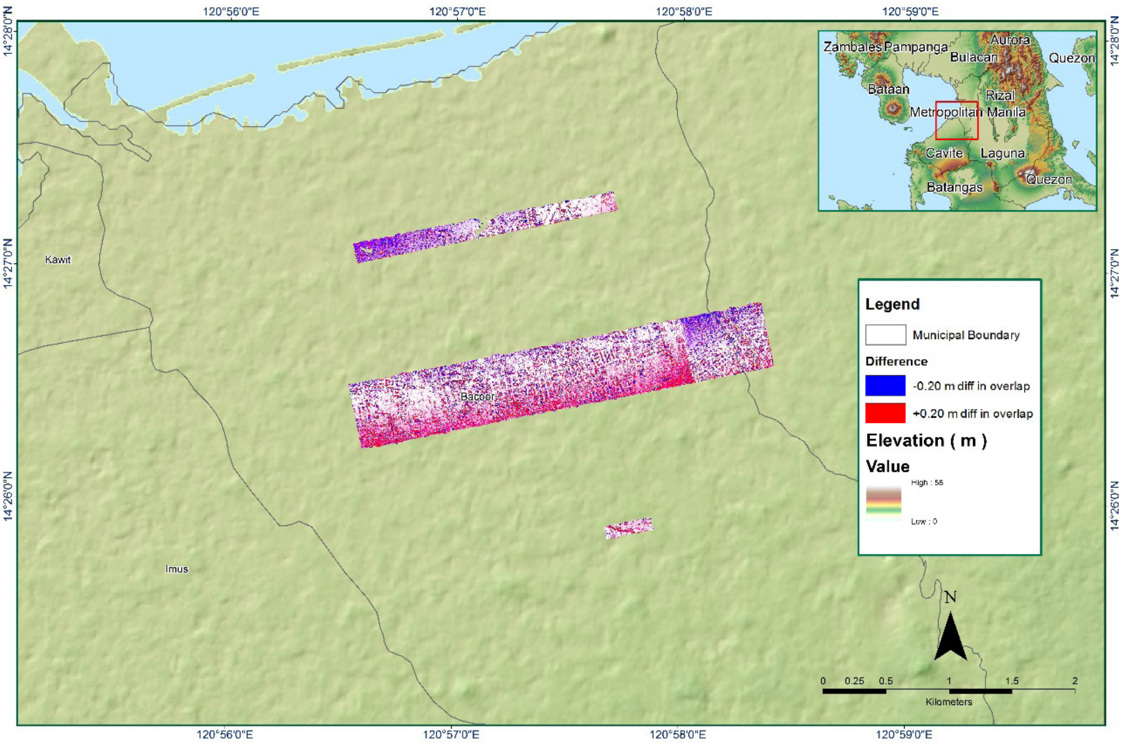


Figure A-8.16. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk18B_Supplement4

Flight Area	CALABARZON Reflights
Mission Name	**Blk18B_Supplement4**
Inclusive Flights	10321L
RawLaser	6.16 GB
GnssImu	329 MB
Image	7.32 GB
Transfer date	2/13/2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	No
Estimated Position Accuracy (in cm)	
Estimated Standard Deviation for North Position (<4.0 cm)	2.7
Estimated Standard Deviation for East Position (<4.0 cm)	3.2
Estimated Standard Deviation for Height Position (<8.0 cm)	3.5
Minimum % overlap (>25)	17.67%
Ave point cloud density per sq.m. (>2.0)	1.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	21
Maximum Height	98.84 m
Minimum Height	51.17 m
Classification (# of points)	
Ground	5,441,059
Low vegetation	2,034,291
Medium vegetation	2,580,434
High vegetation	4,410,883
Building	2,943,179
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

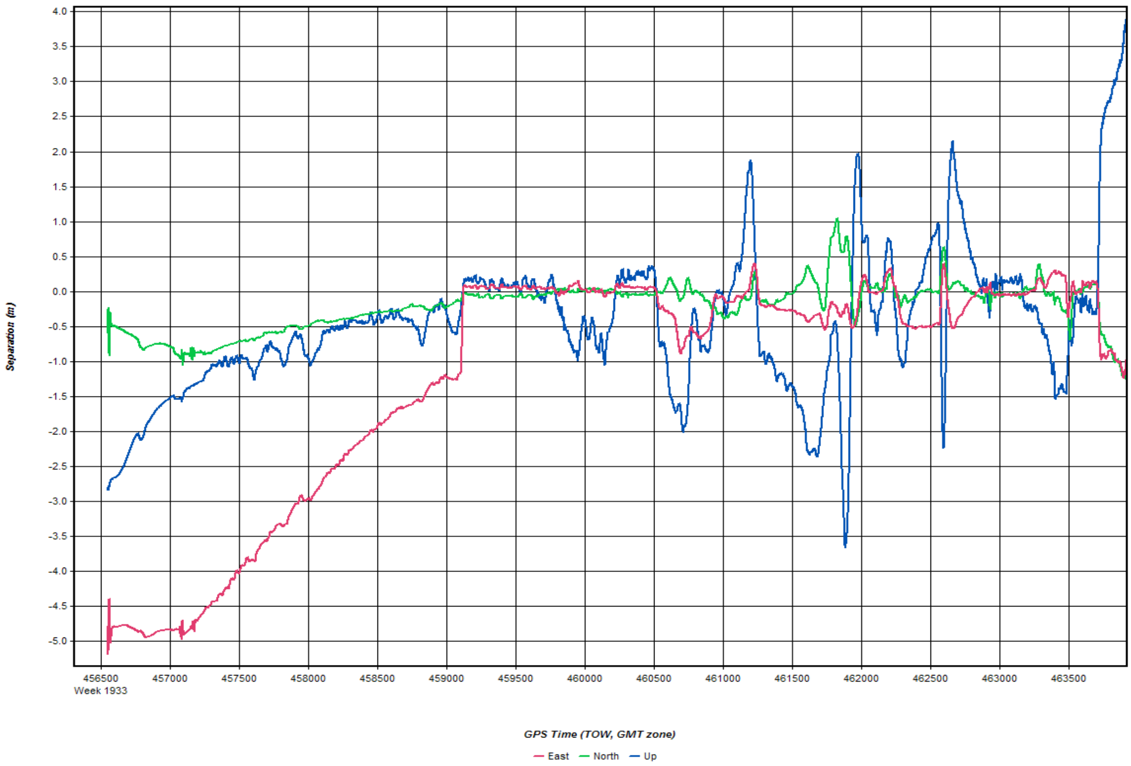


Figure A-8.17. Combined Separation

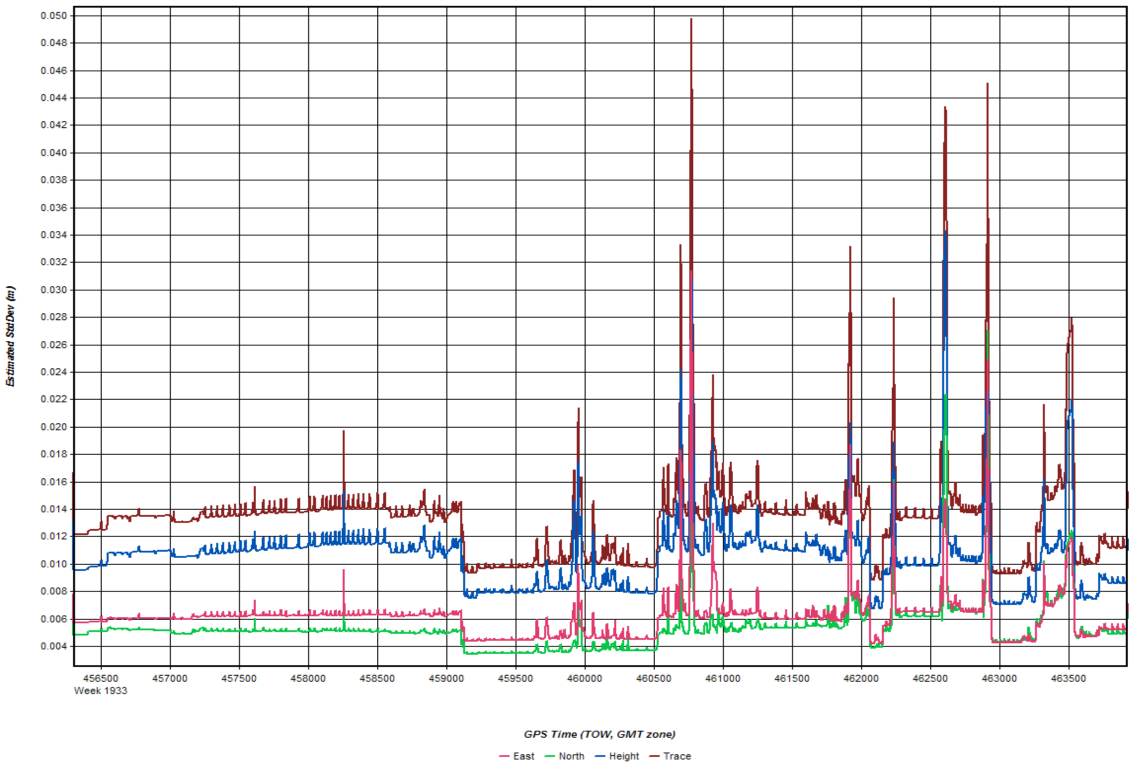


Figure A-8.18. Estimated Position of Accuracy

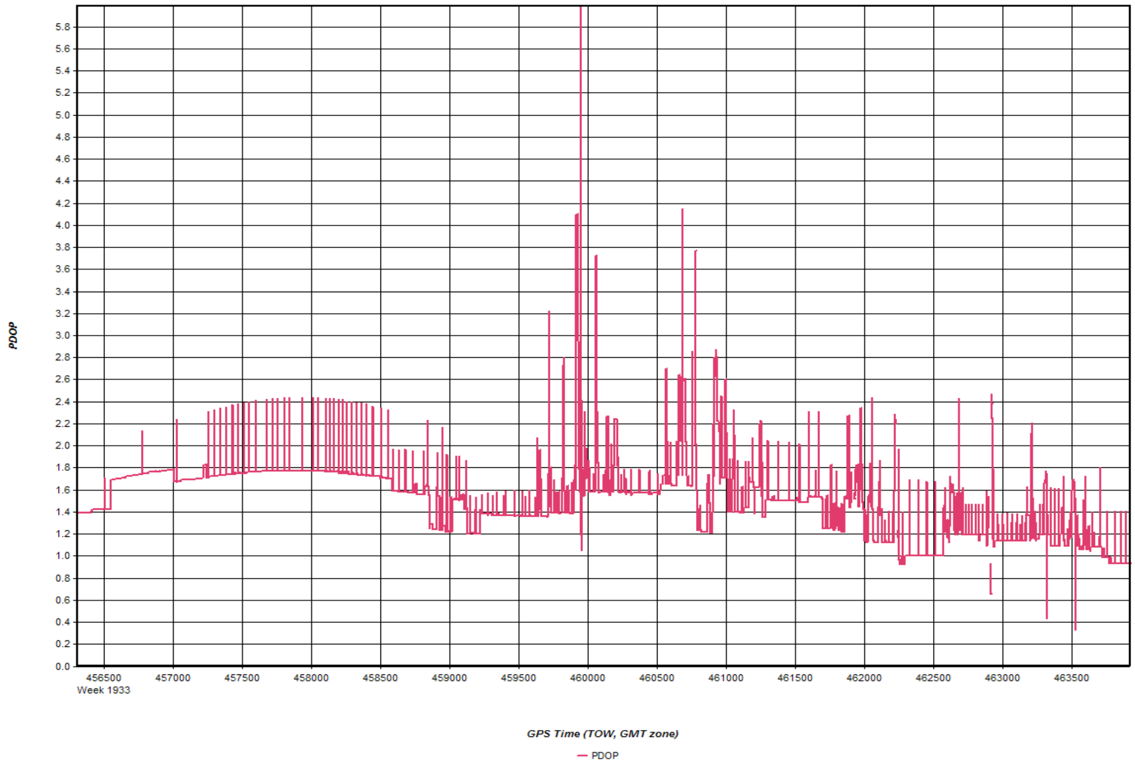


Figure A-8.19. PDOP

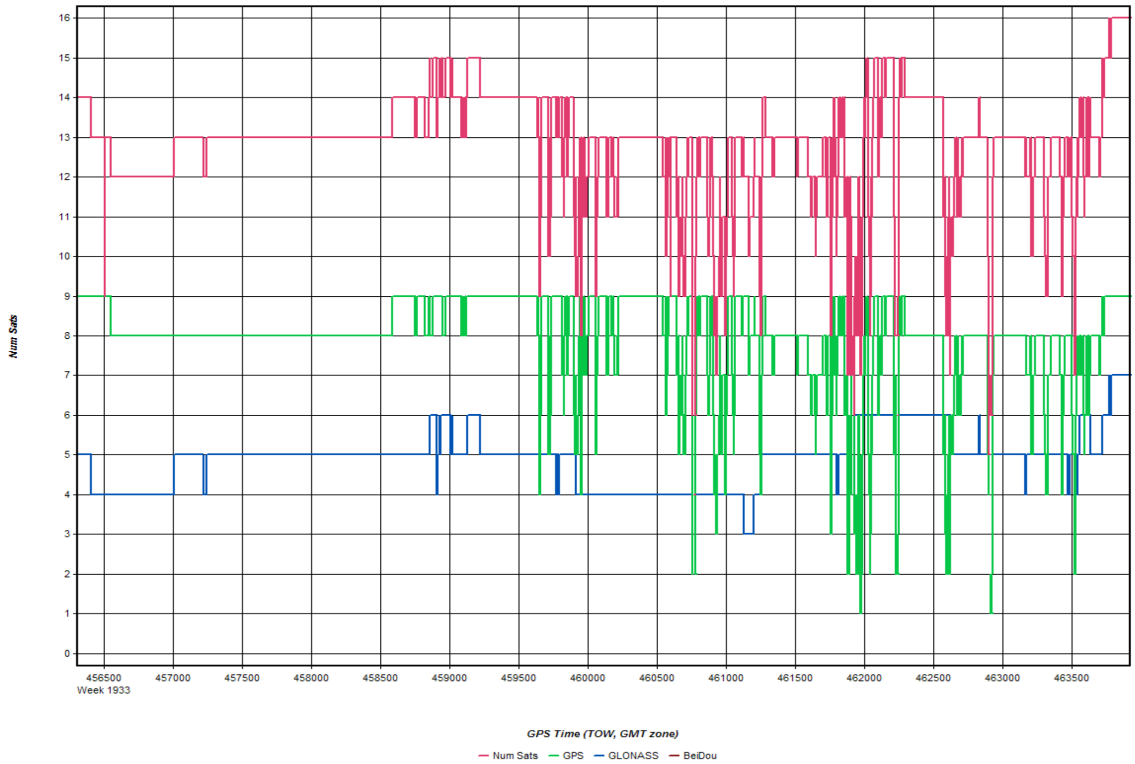


Figure A-8.20. Number of Satellites

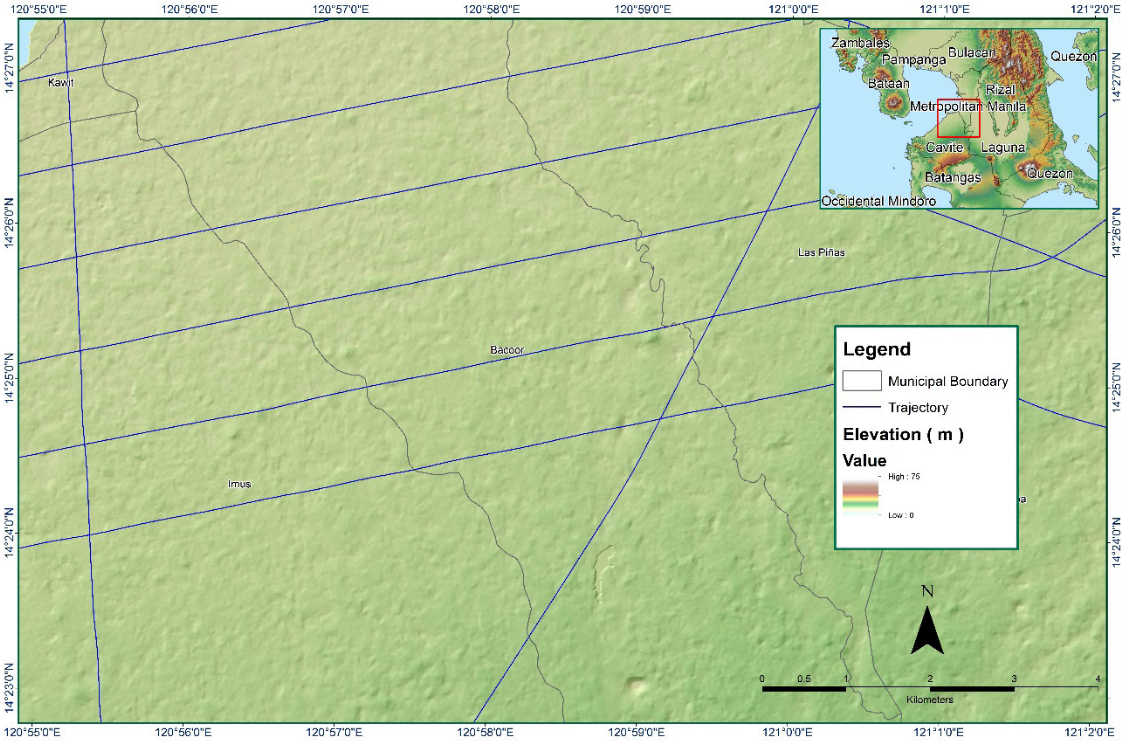


Figure A-8.21. Best Estimated Trajectory

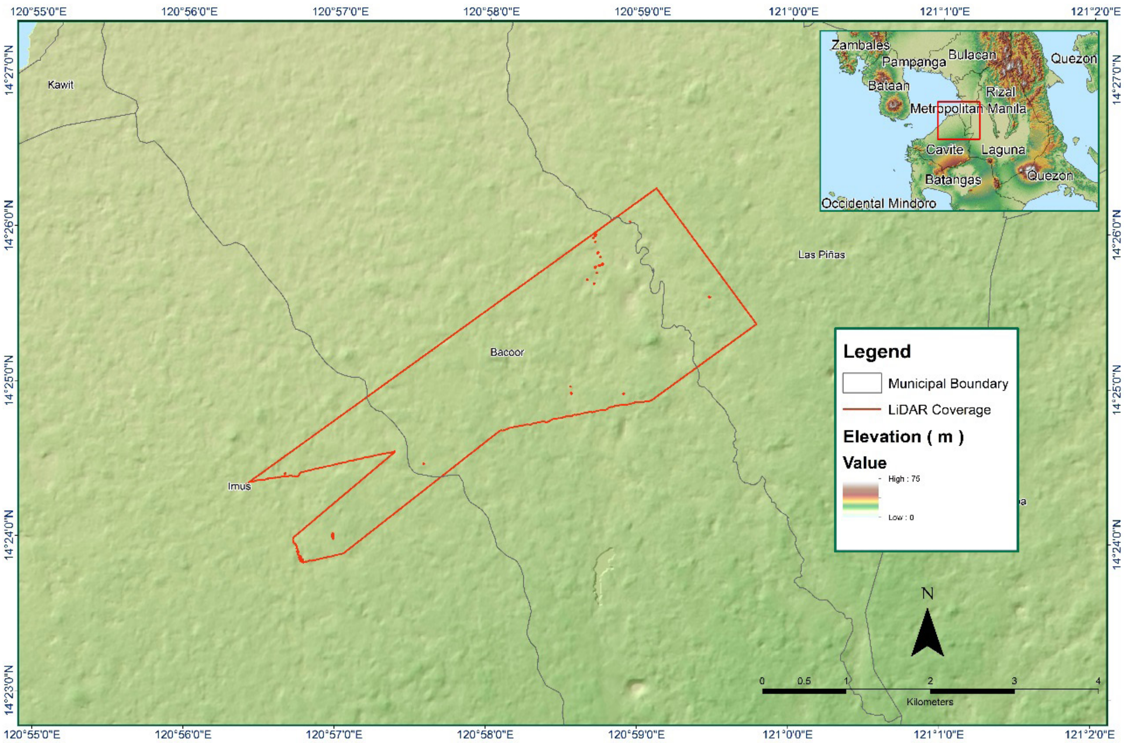


Figure A-8.22. Coverage of LiDAR data

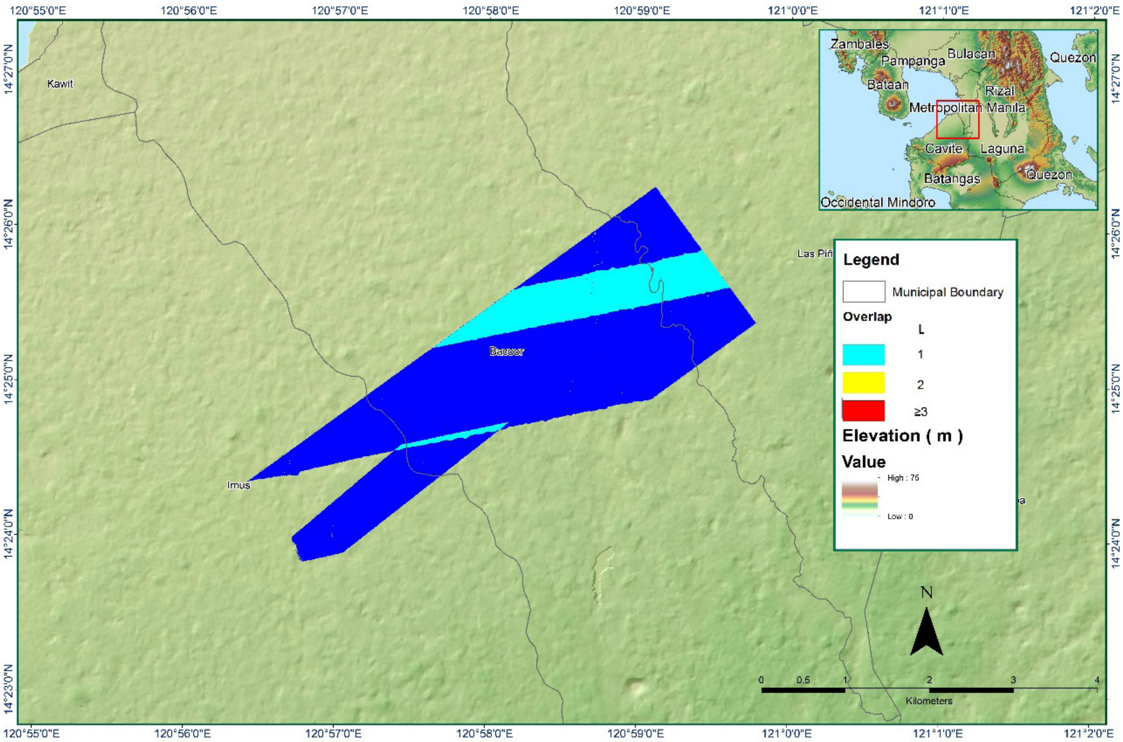


Figure A-8.23. Image of data overlap

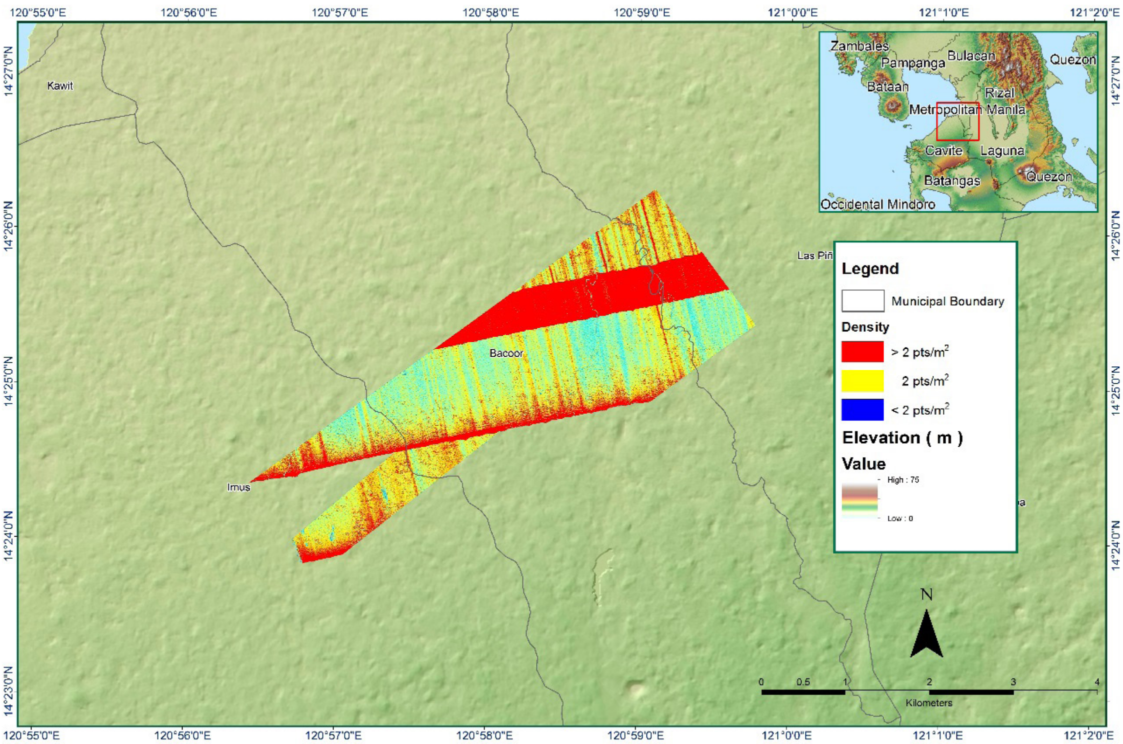


Figure A-8.24. Density map of merged LiDAR data

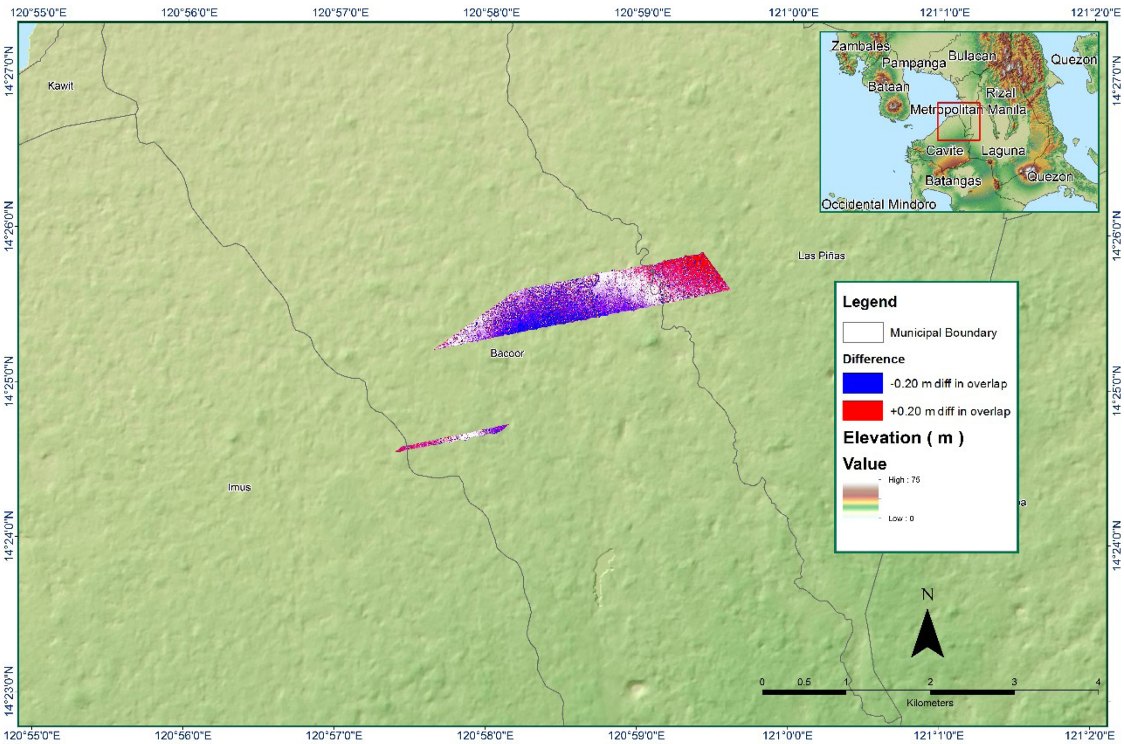


Figure A-8.25. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk18AB

Flight Area	CALABARZON
Mission Name	**Blk18AB**
Inclusive Flights	1031P, 1027P
Range data size	29.0 GB
POS	379 MB
Image	7.11 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000453
IMU attitude correction stdev (<0.001deg)	0.005473
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	28.57%
Ave point cloud density per sq.m. (>2.0)	3.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	204
Maximum Height	45.76 m
Minimum Height	603.46 m
Classification (# of points)	
Ground	175,046,421
Low vegetation	131,824,752
Medium vegetation	148,659,196
High vegetation	95,993,464
Building	30,587,801
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Celina Rosete, Engr. Gladys Mae Apat

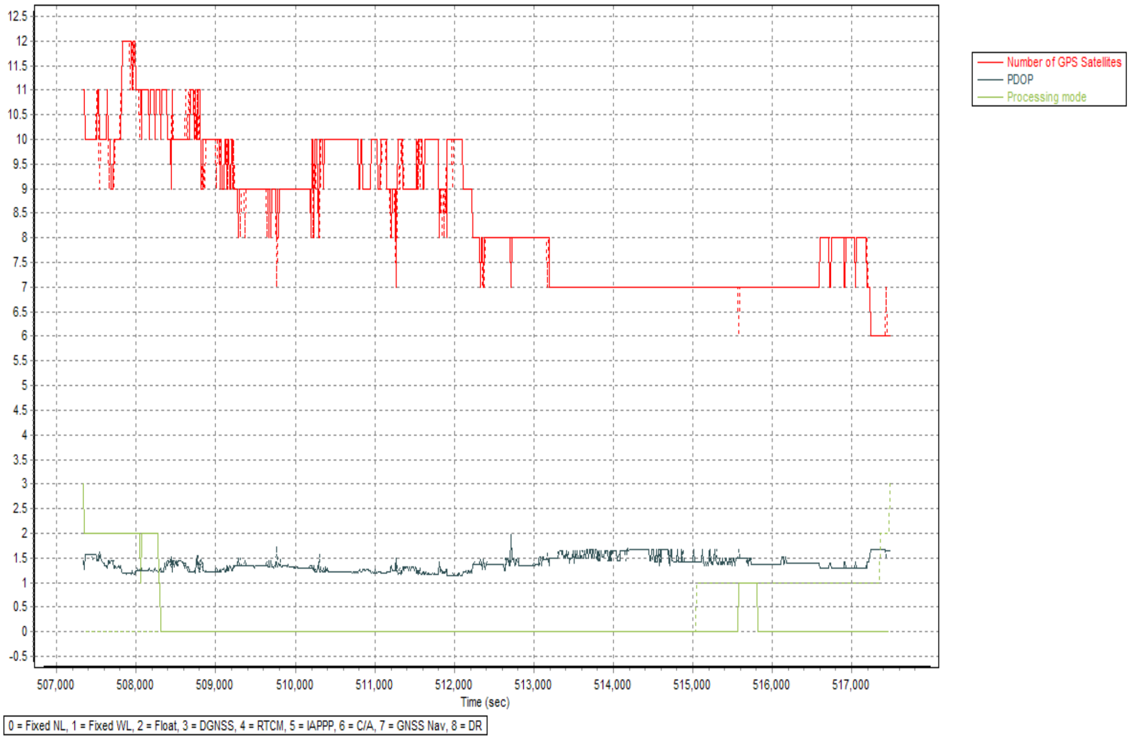


Figure A-8.26. Solution Status

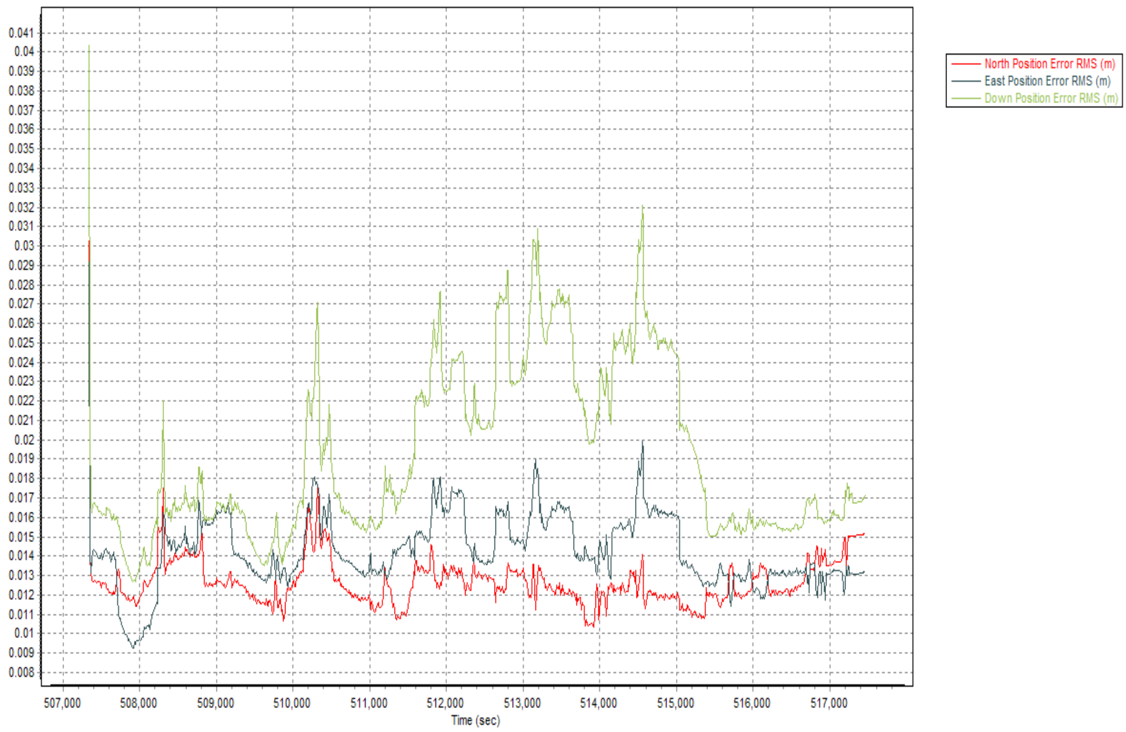


Figure A-8.27. Smoothed Performance Metrics Parameters

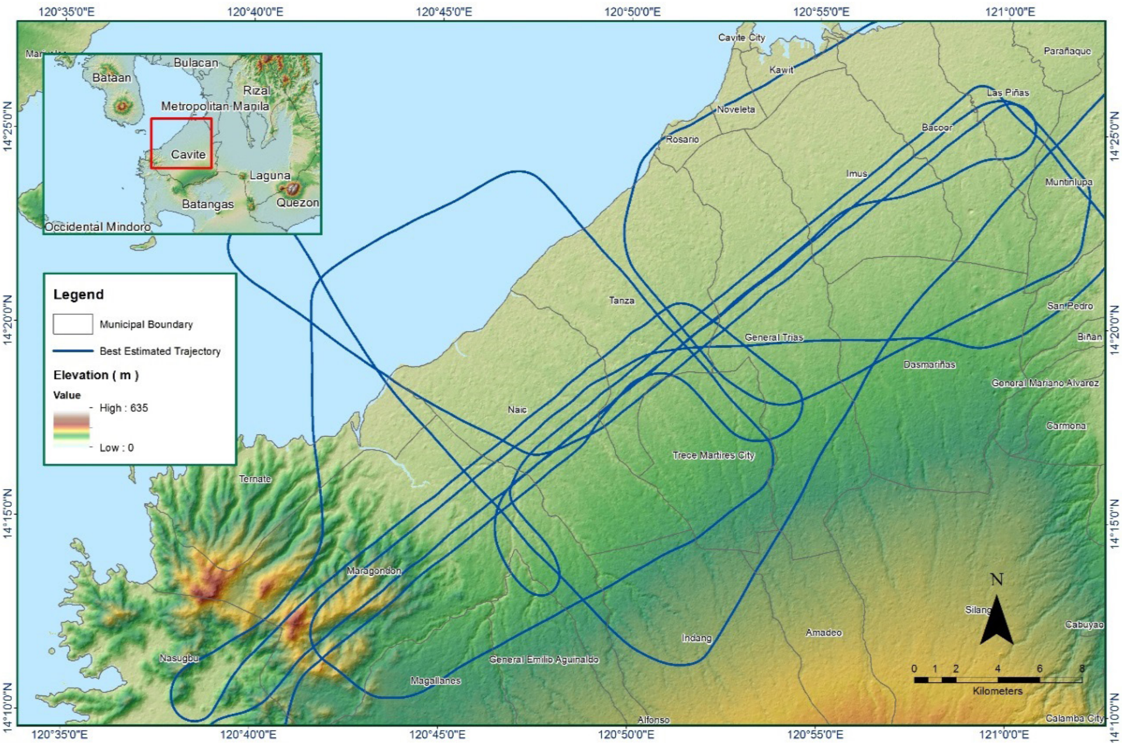


Figure A-8.28. Best Estimated Trajectory

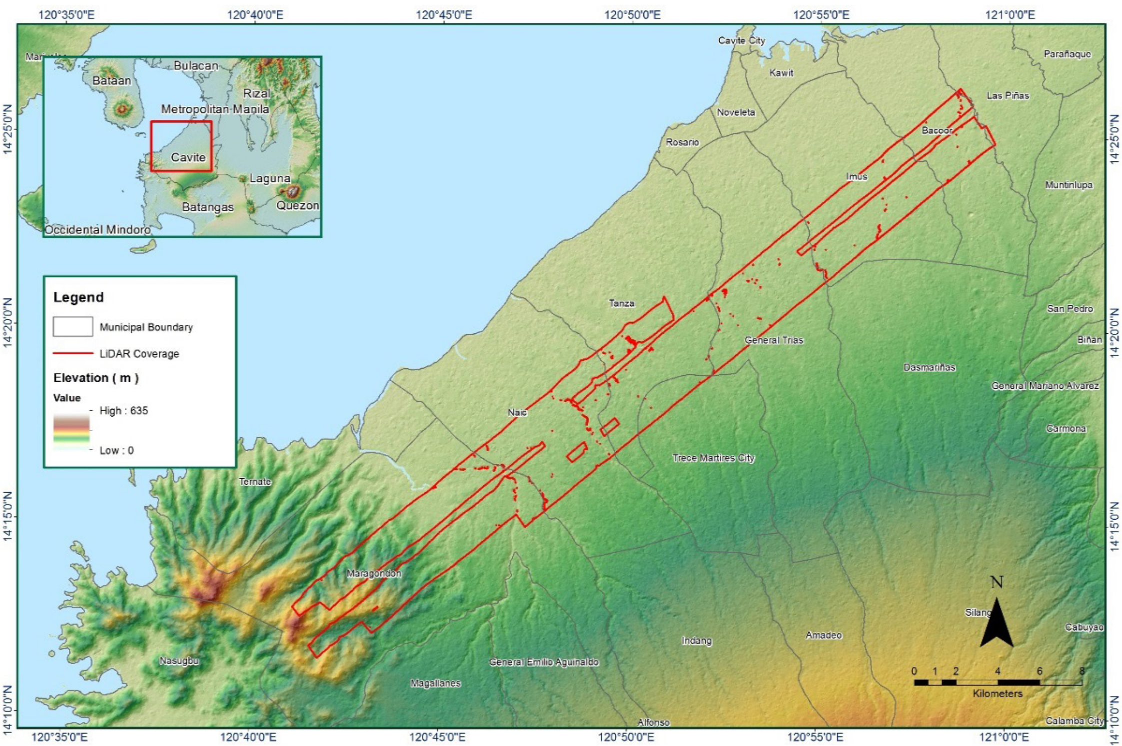


Figure A-8.29. Coverage of LiDAR data

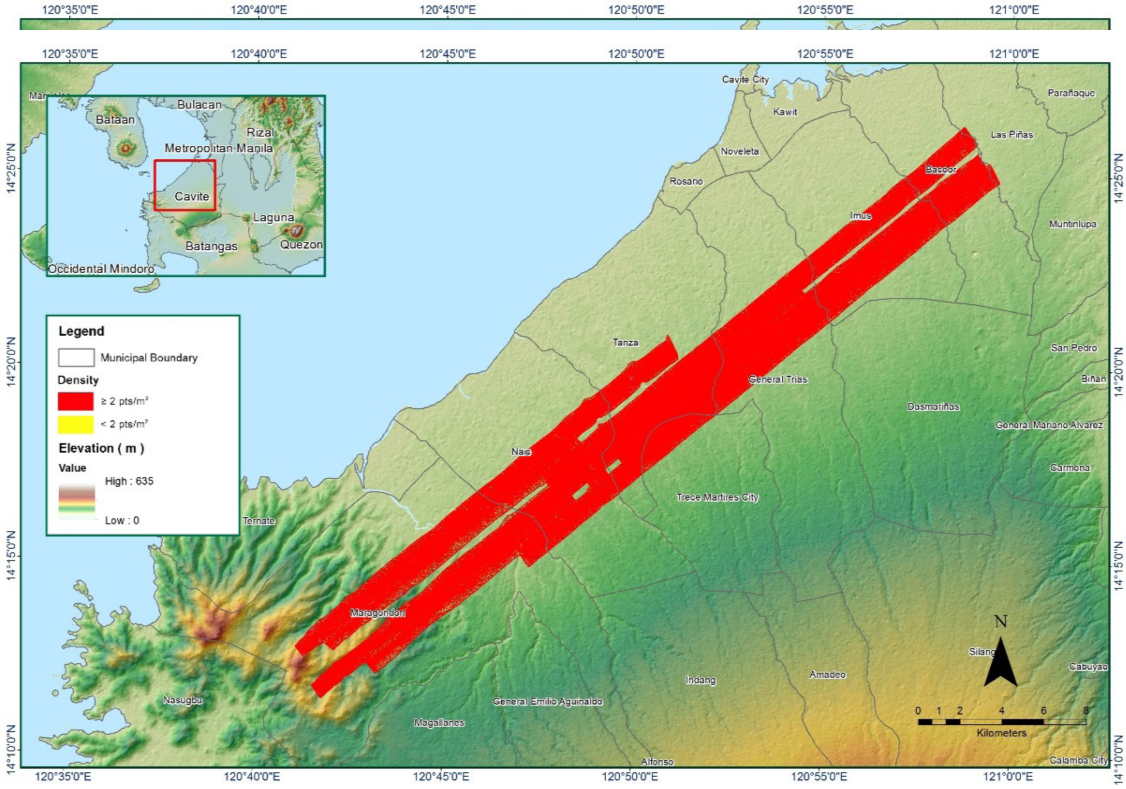


Figure A-8.30. Image of data overlap

Figure A-8.31. Density map of merged LiDAR data

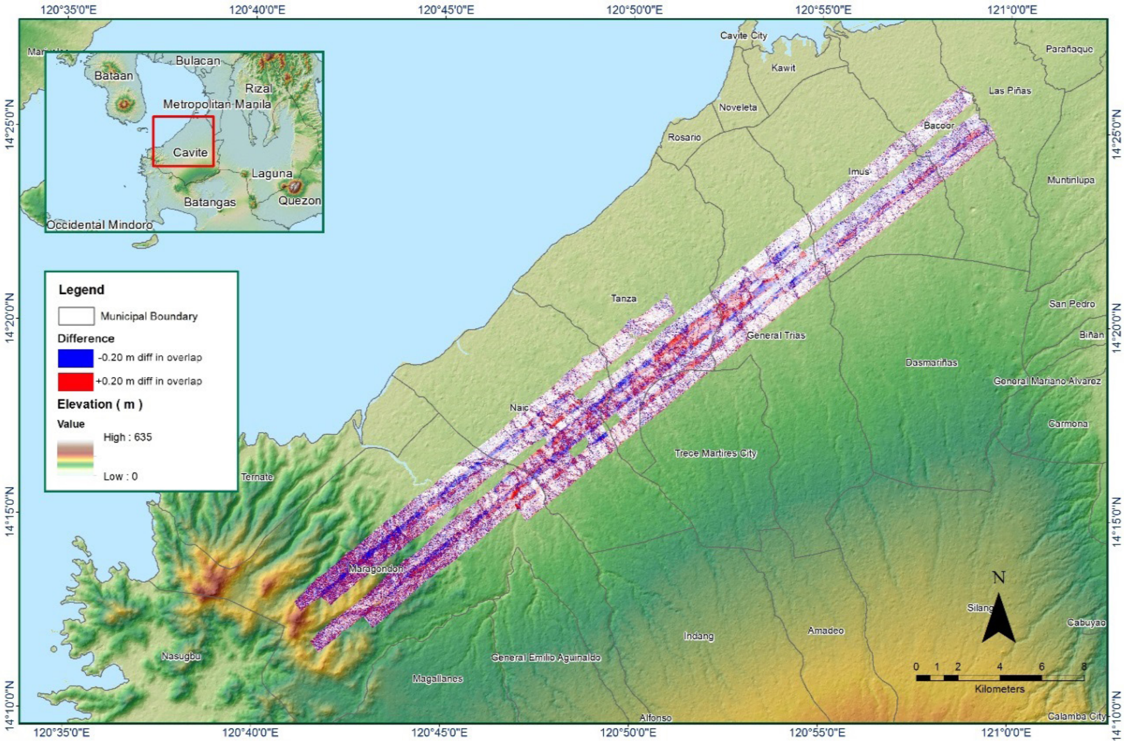


Figure A-8.32. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk18C

Flight Area	CALABARZON
Mission Name	**Blk18C**
Inclusive Flights	1031P
Range data size	14.7 GB
POS	185 MB
Image	N/A
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.4
Boresight correction stdev (<0.001deg)	0.000355
IMU attitude correction stdev (<0.001deg)	0.000702
GPS position stdev (<0.01m)	0.0113
Minimum % overlap (>25)	22.90%
Ave point cloud density per sq.m. (>2.0)	3.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	186
Maximum Height	404.02 m
Minimum Height	91.28 m
Classification (# of points)	
Ground	141,951,450
Low vegetation	94,479,716
Medium vegetation	142,100,182
High vegetation	100,785,000
Building	35,277,797
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. Jeffrey Delica

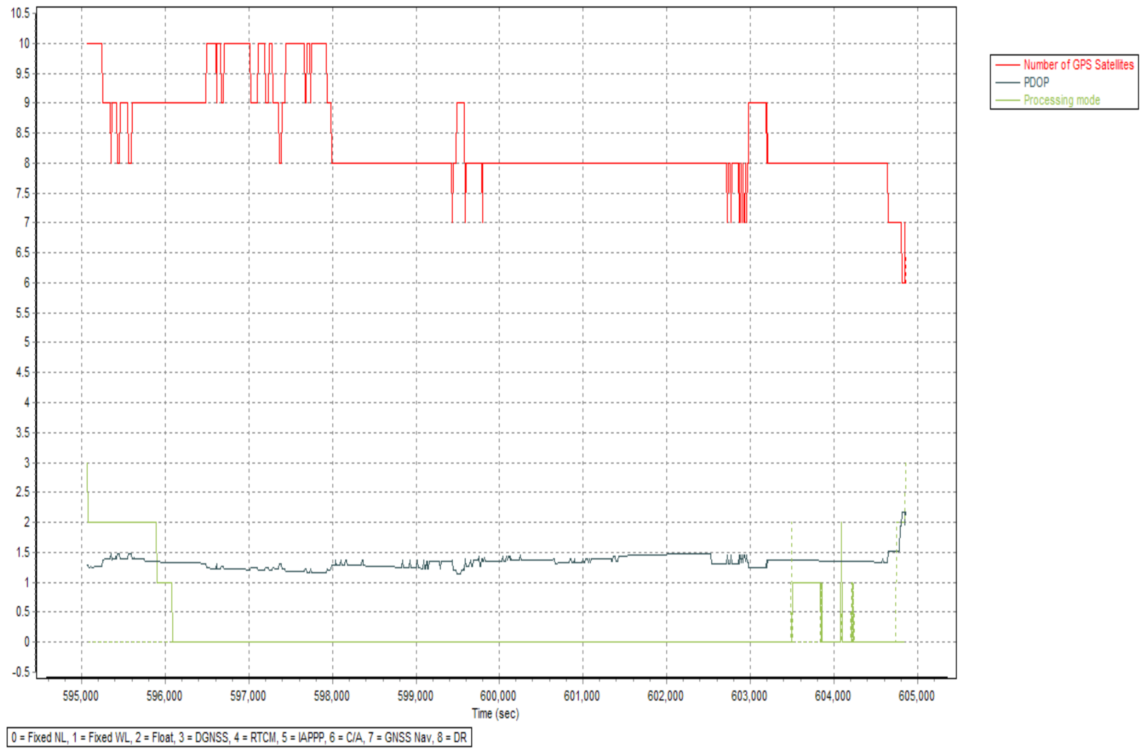


Figure A-8.33. Solution Status

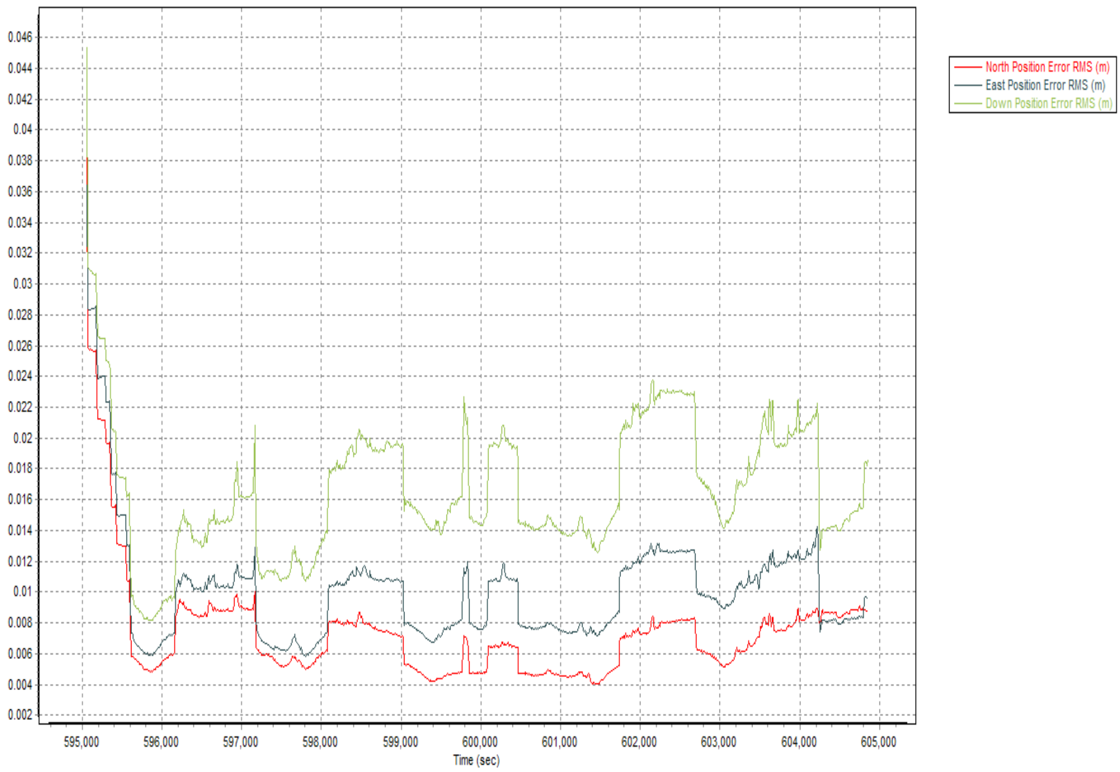


Figure A-8.34. Smoothed Performance Metrics Parameters

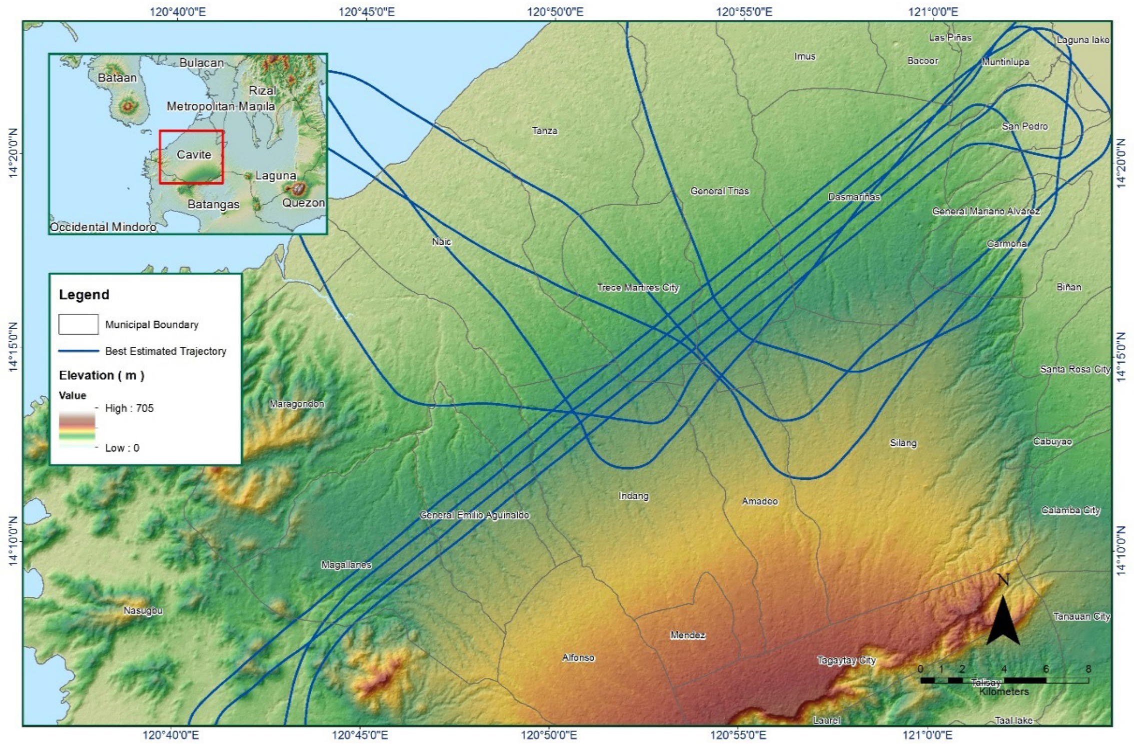


Figure A-8.35. Best Estimated Trajectory

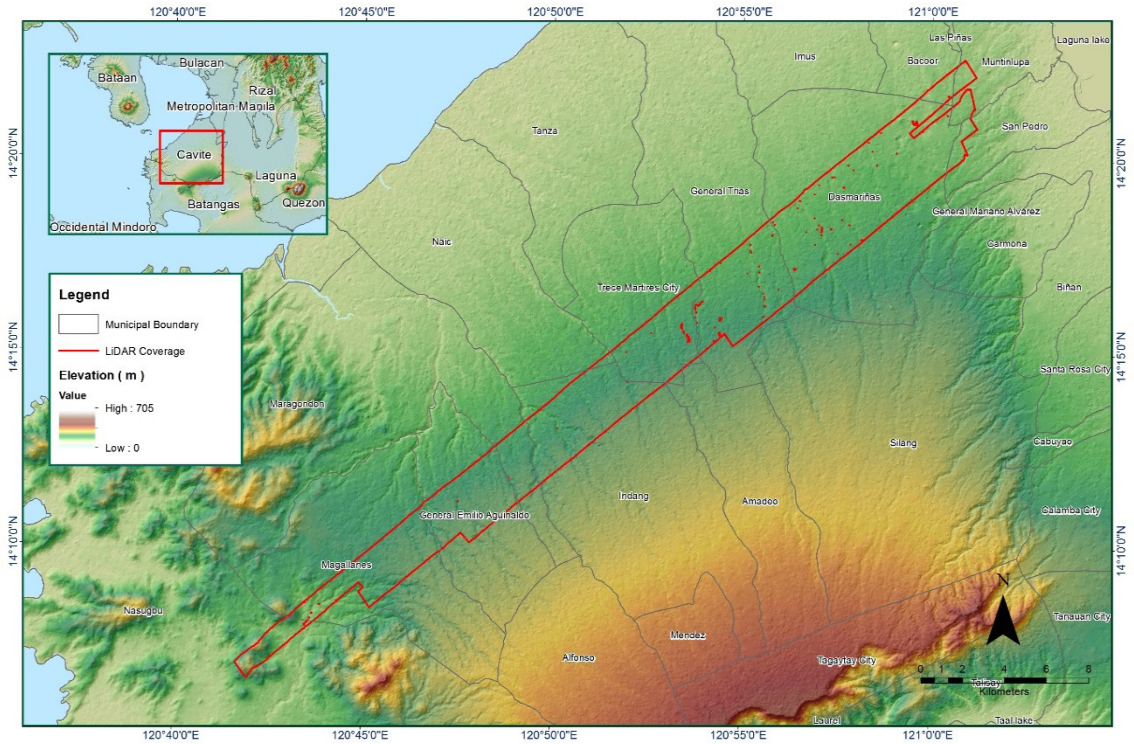


Figure A-8.36. Coverage of LiDAR data

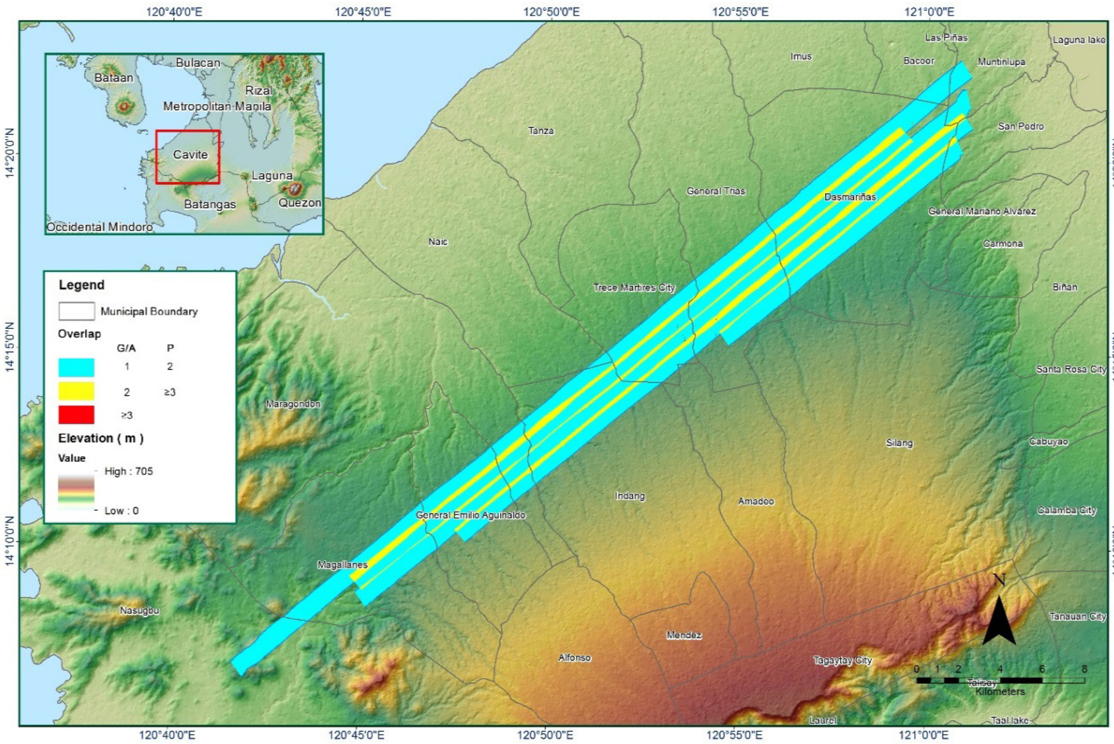


Figure A-8.37. Image of data overlap

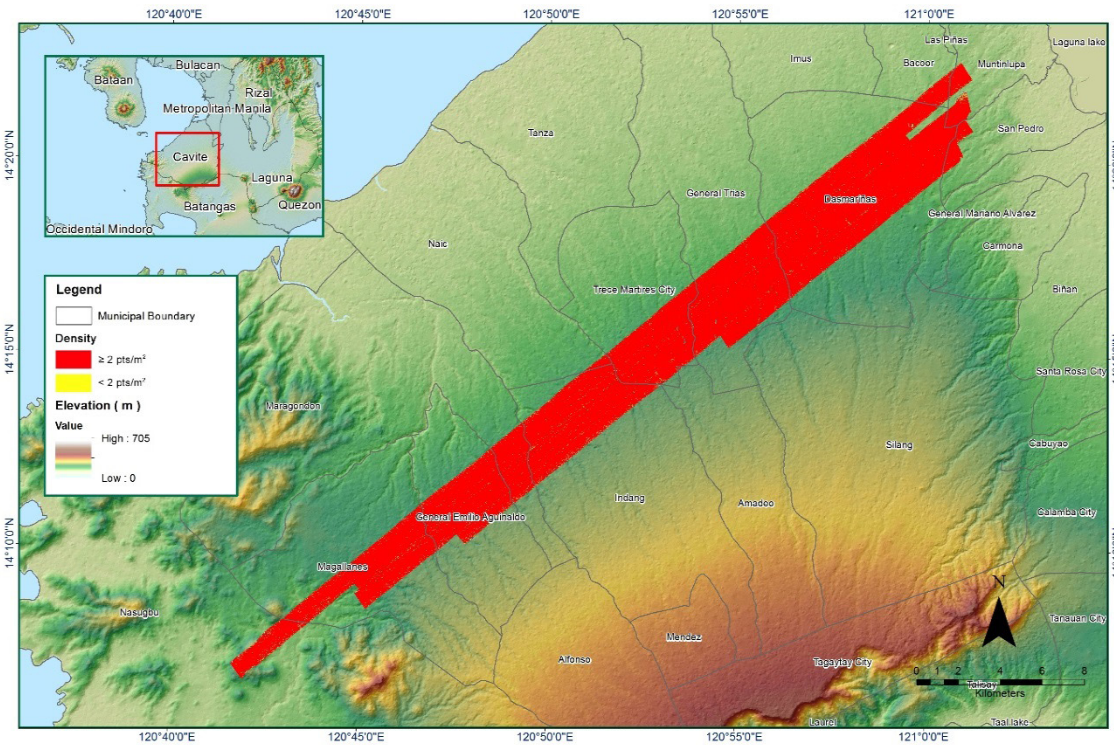


Figure A-8.38. Density map of merged LiDAR data

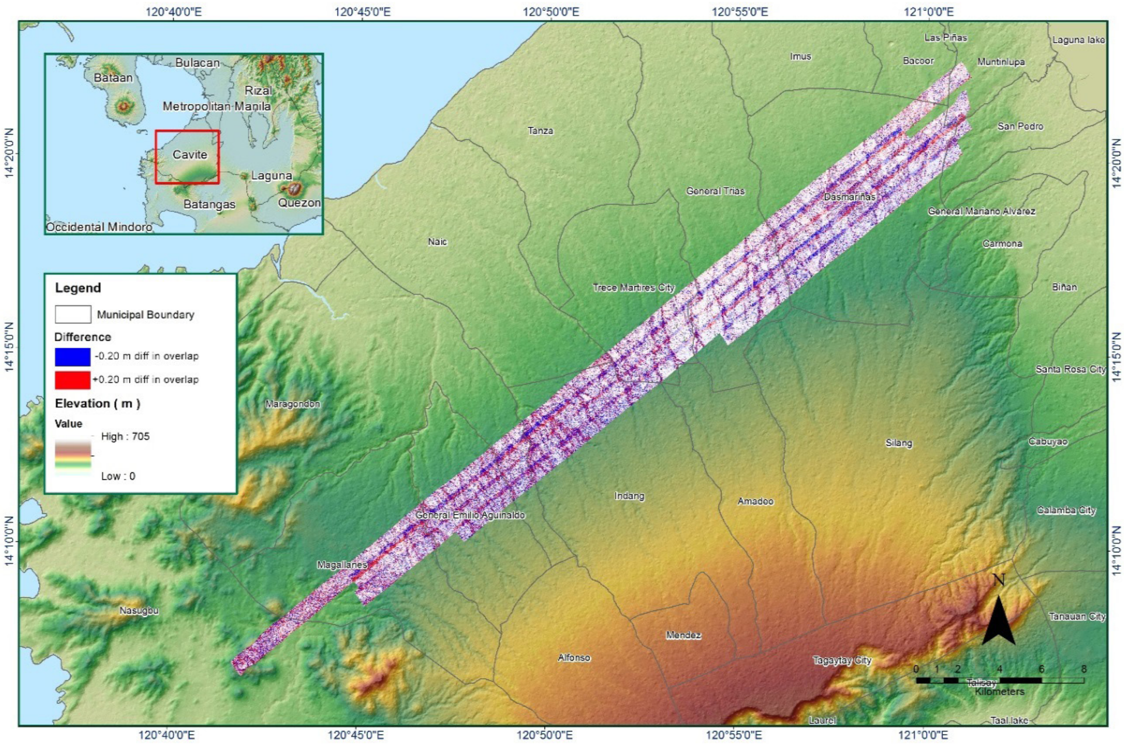


Figure A-8.39. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk18C_additional

Flight Area	CALABARZON
Mission Name	**Blk18C_additional**
Inclusive Flights	1031P; 1063P
Range data size	33.2 GB
POS	329 MB
Image	19.2 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000508
IMU attitude correction stdev (<0.001deg)	0.001492
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	29.92%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	327
Maximum Height	460.70 m
Minimum Height	60.39 m
Classification (# of points)	
Ground	187,497,140
Low vegetation	163,676,822
Medium vegetation	212,619,439
High vegetation	144,490,617
Building	59,922,956
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Merven Matthew Natino, Marie Joyce Ilagan

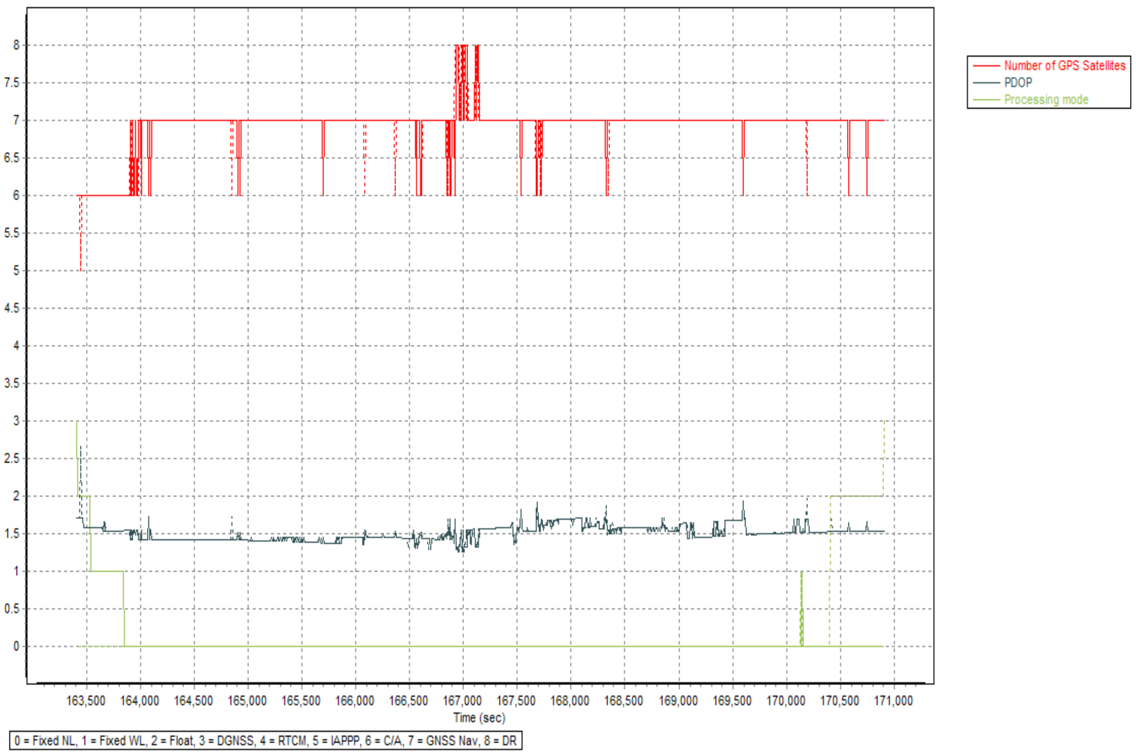


Figure A-8.40. Solution Status

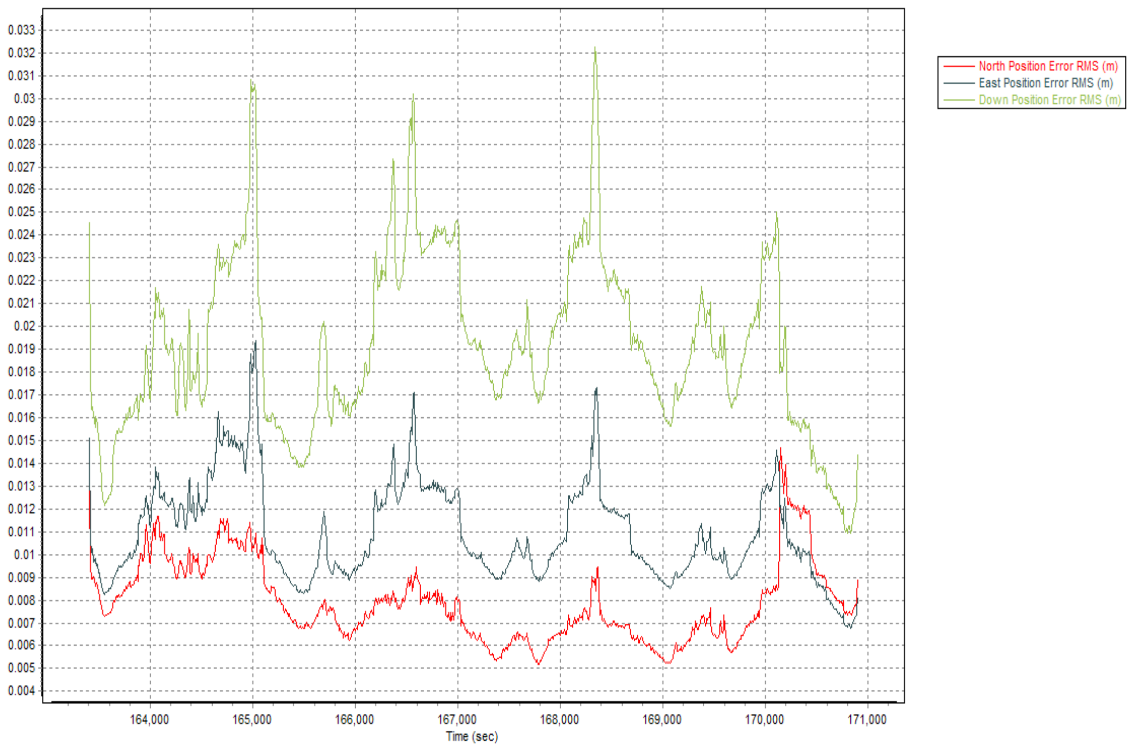


Figure A-8.41. Smoothed Performance Metrics Parameters

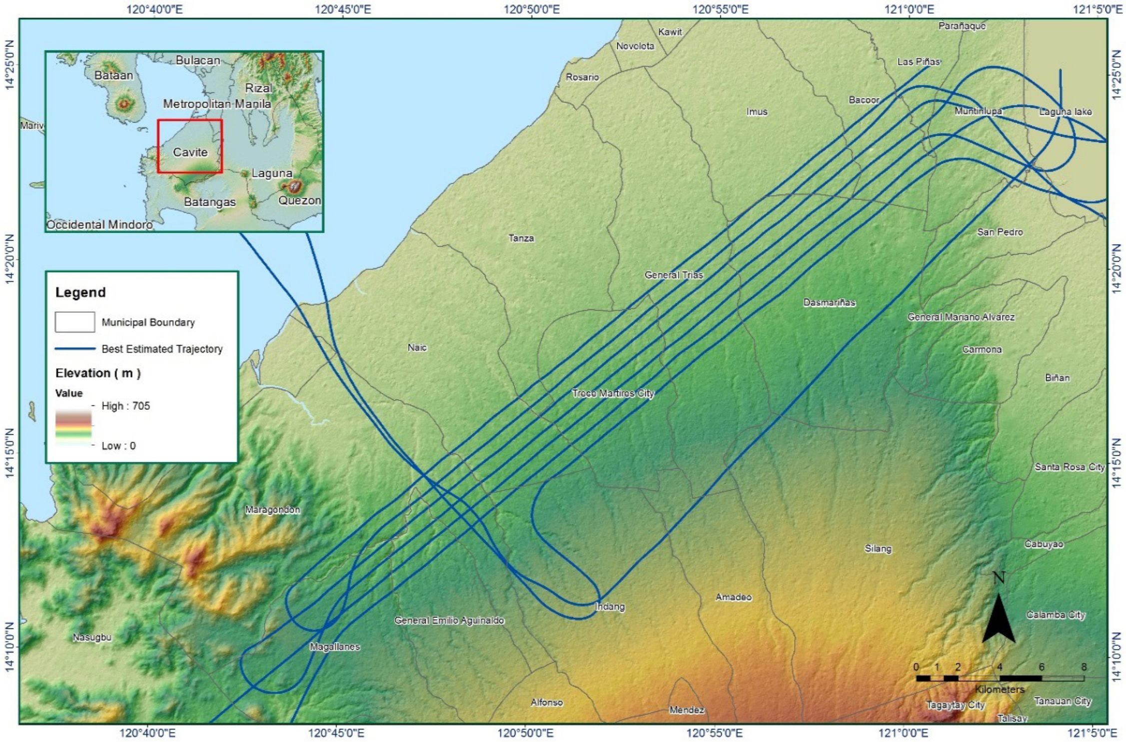


Figure A-8.42. Best Estimated Trajectory

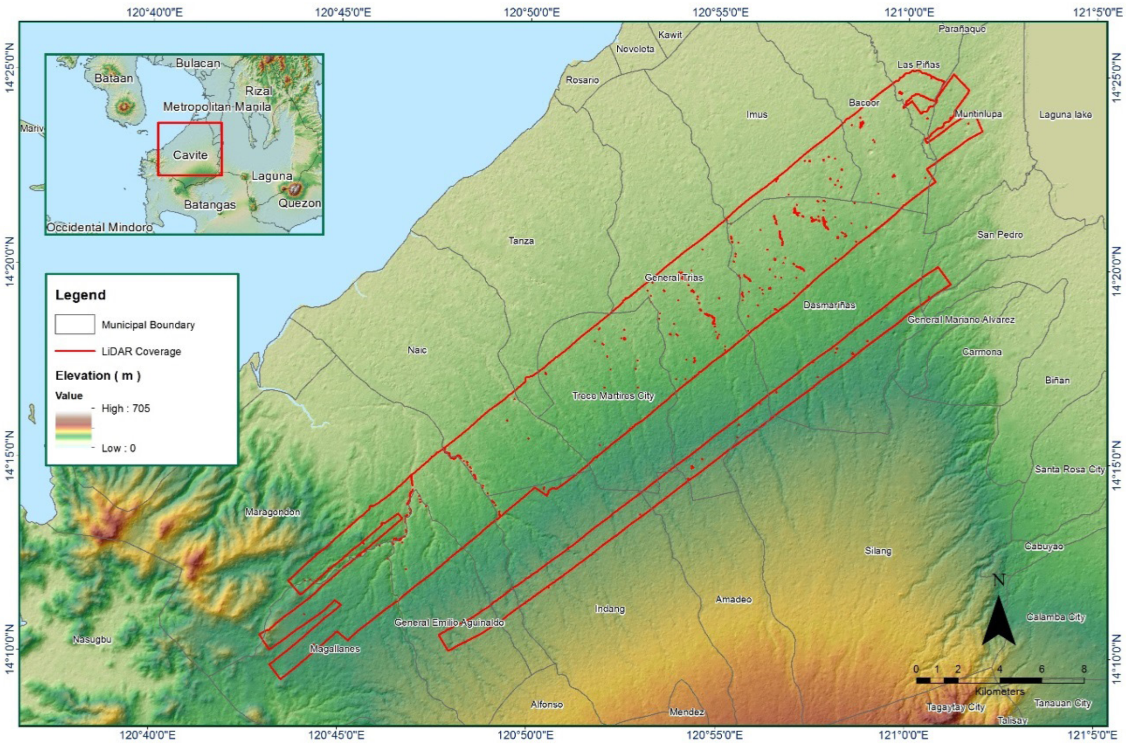


Figure A-8.43. Coverage of LiDAR data

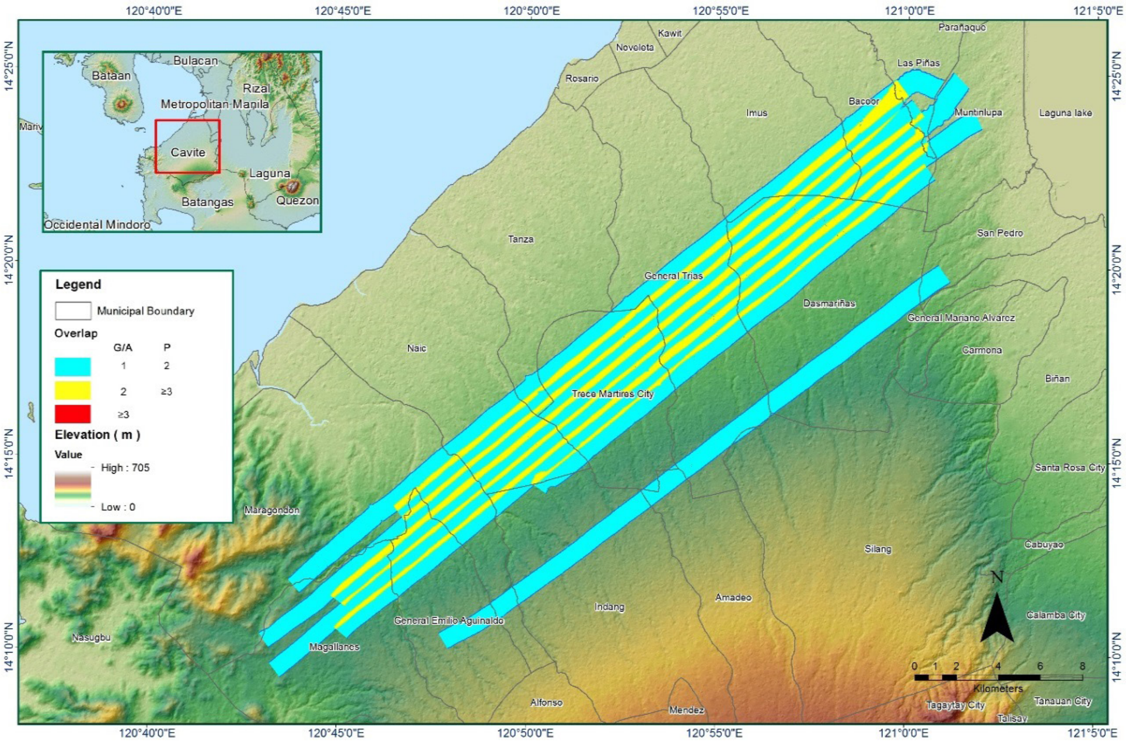


Figure A-8.44. Image of data overlap

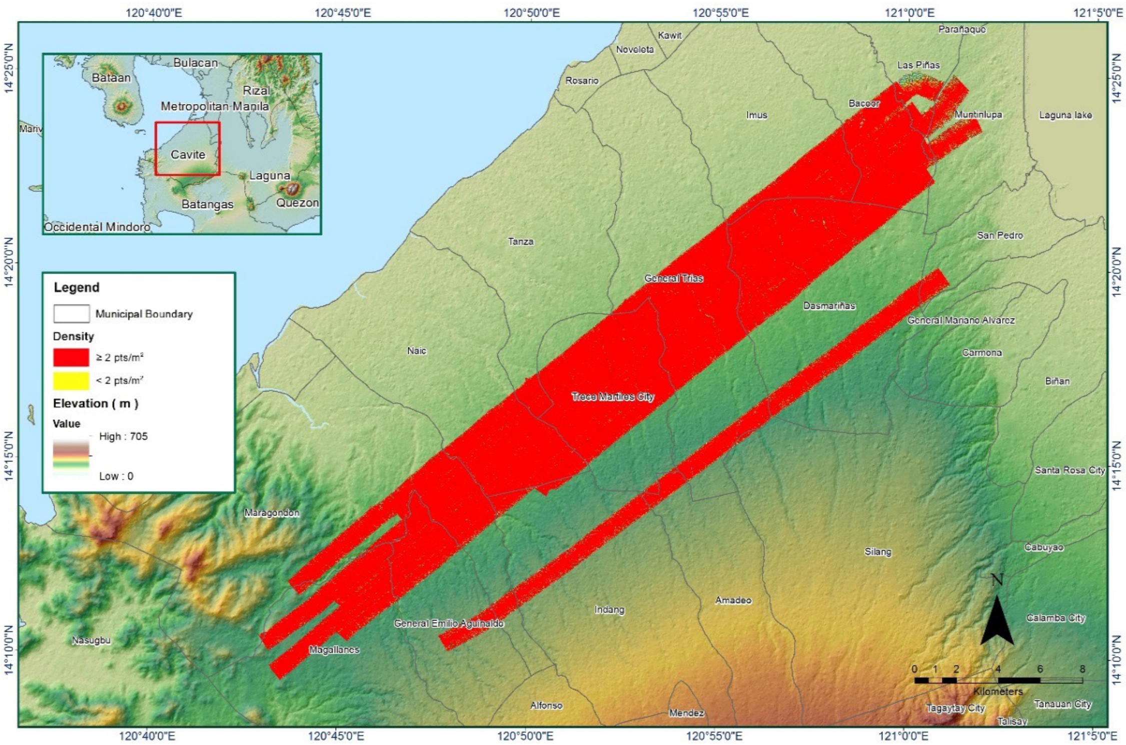


Figure A-8.45. Density map of merged LiDAR data

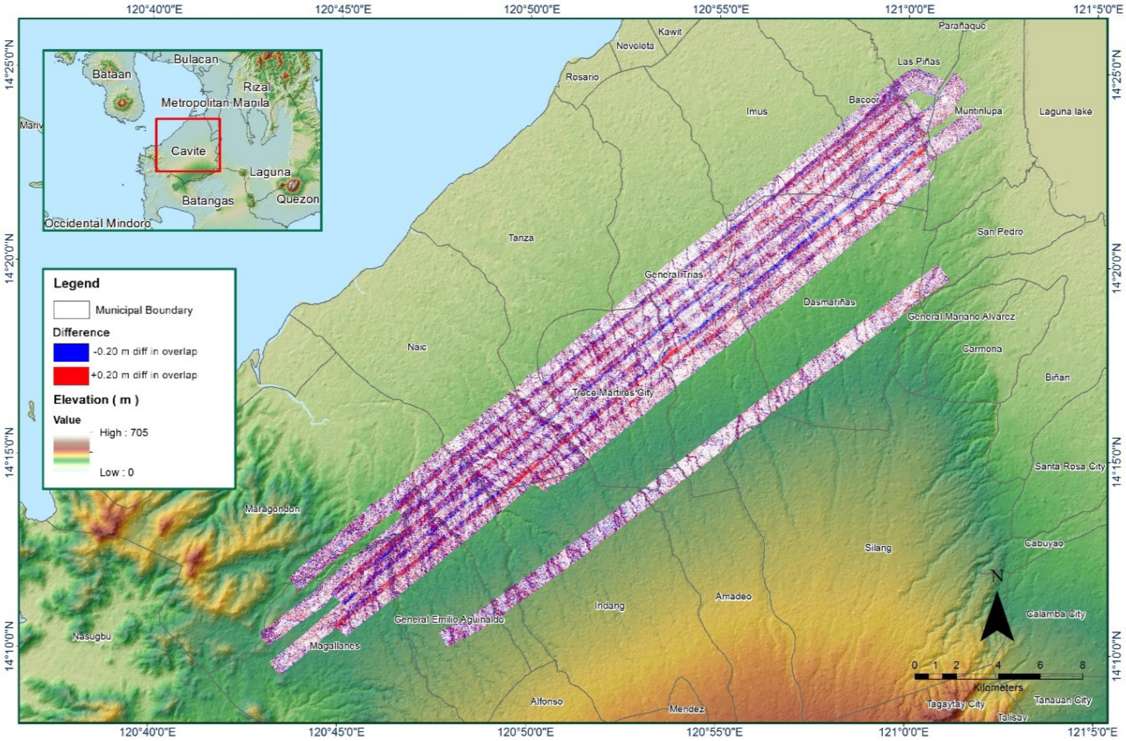


Figure A-8.46. Elevation difference between flight line

Table A-8.7. Mission Summary Report for Mission Blk18A_supplement2

Flight Area	CALABARZON
Mission Name	**Blk18A_supplement2**
Inclusive Flights	1141P (formerly 1139P)
Range data size	15.4 GB
POS	219 MB
Image	24 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000426
IMU attitude correction stdev (<0.001deg)	0.001019
GPS position stdev (<0.01m)	0.0155
Minimum % overlap (>25)	35.84%
Ave point cloud density per sq.m. (>2.0)	1.90
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	140
Maximum Height	133.73 m
Minimum Height	45.56 m
	133.73 m
Classification (# of points)	
Ground	104,162,308
Low vegetation	84,606,924
Medium vegetation	52,451,573
High vegetation	28,217,832
Building	1,102,474
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Engr. Jeffrey Delica

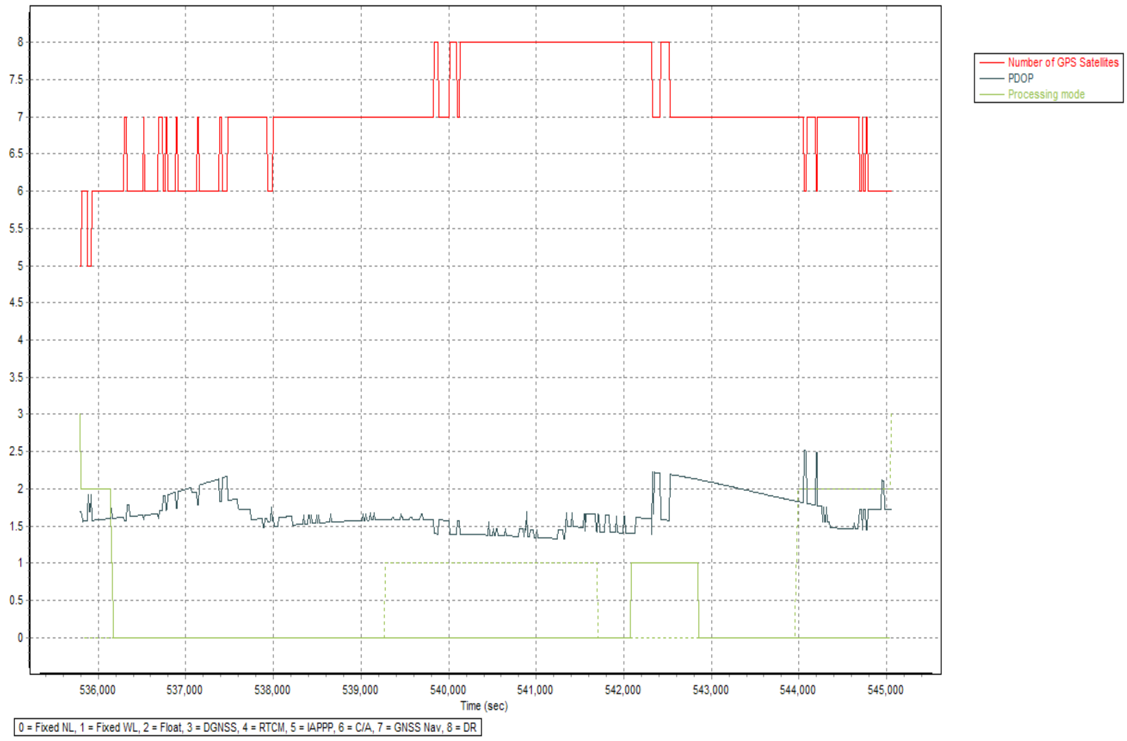


Figure A-8.47. Solution Status

Figure A-8.48. Smoothed Performance Metrics Parameters

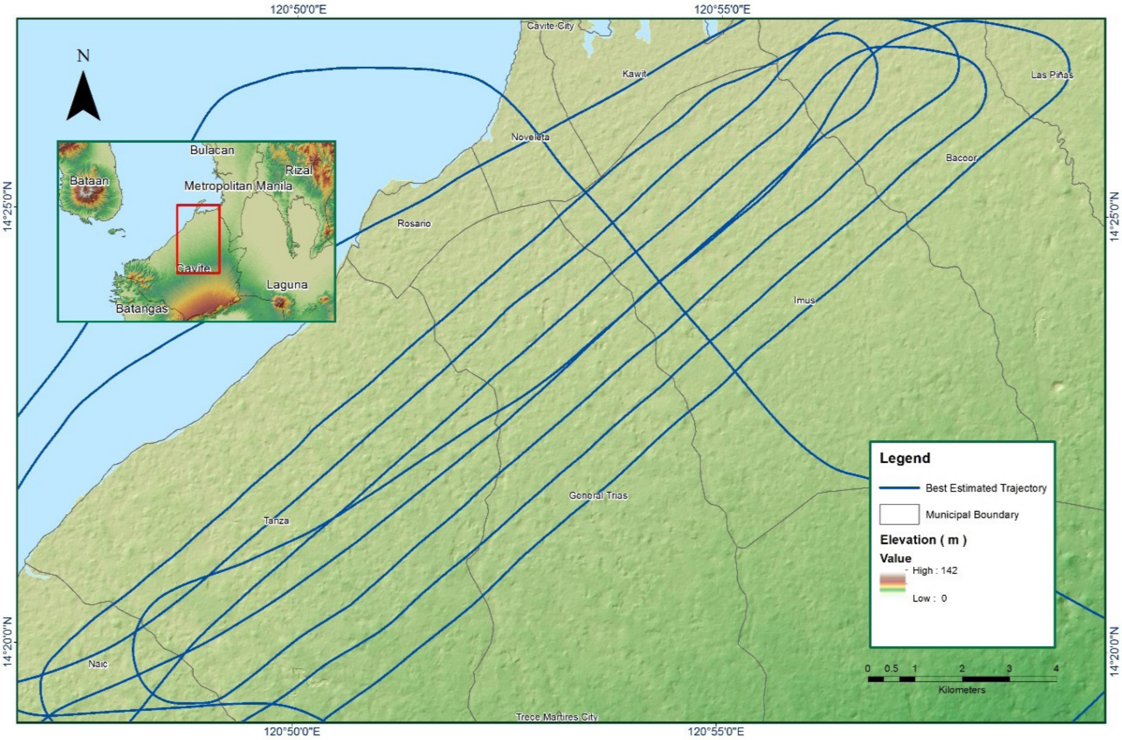


Figure A-8.49. Best Estimated Trajectory

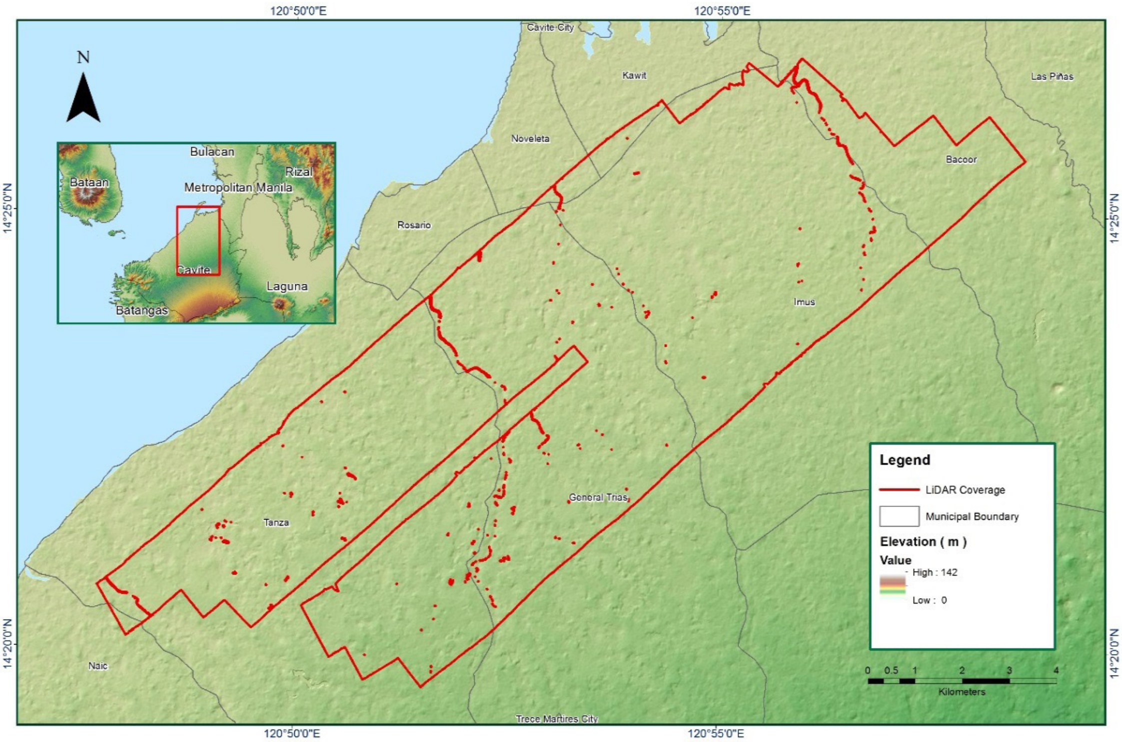


Figure A-8.50. Coverage of LiDAR data

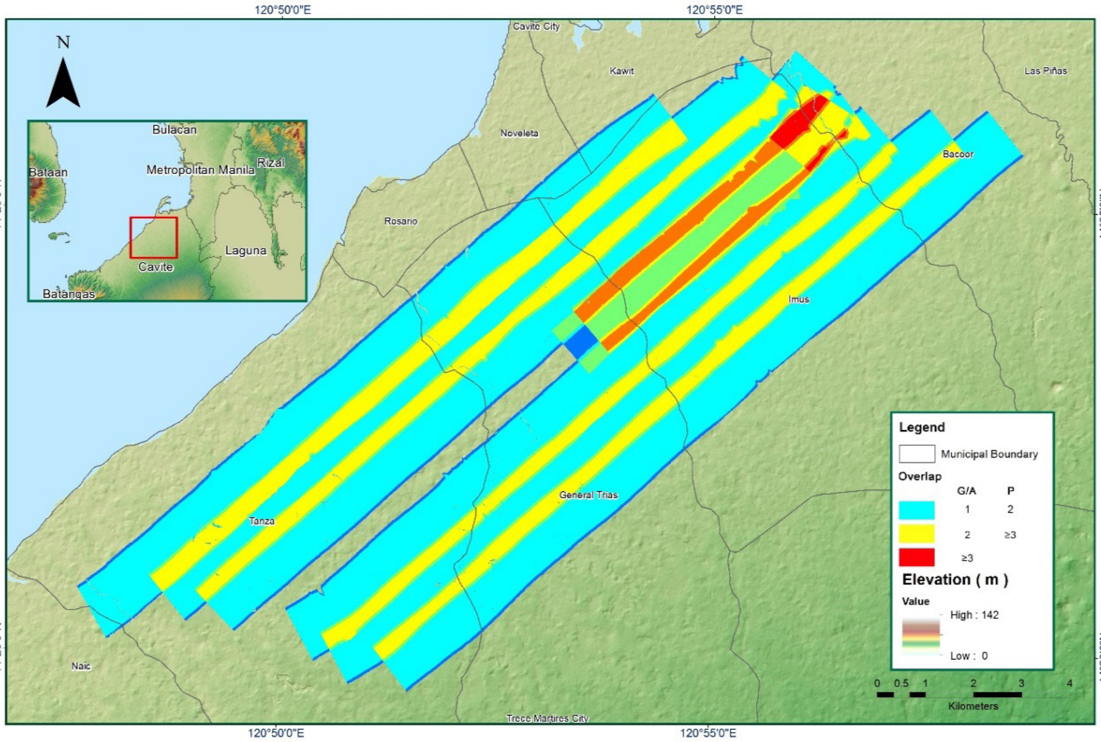


Figure A-8.51. Image of data overlap

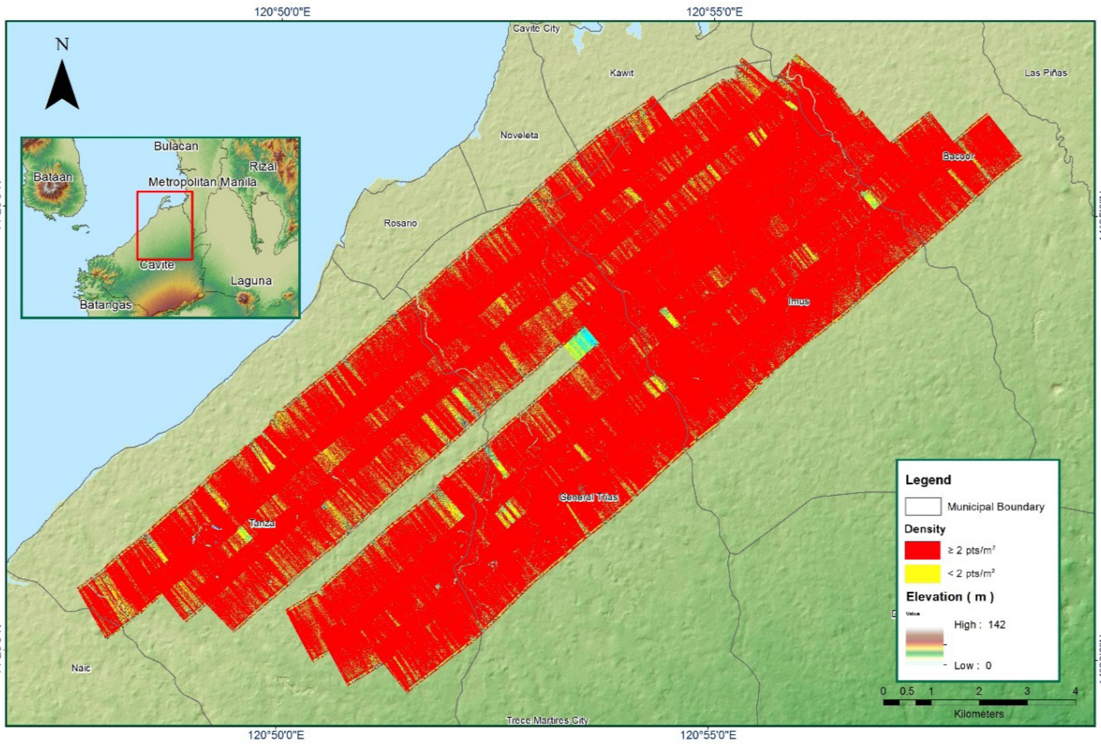


Figure A-8.52. Density map of merged LiDAR data

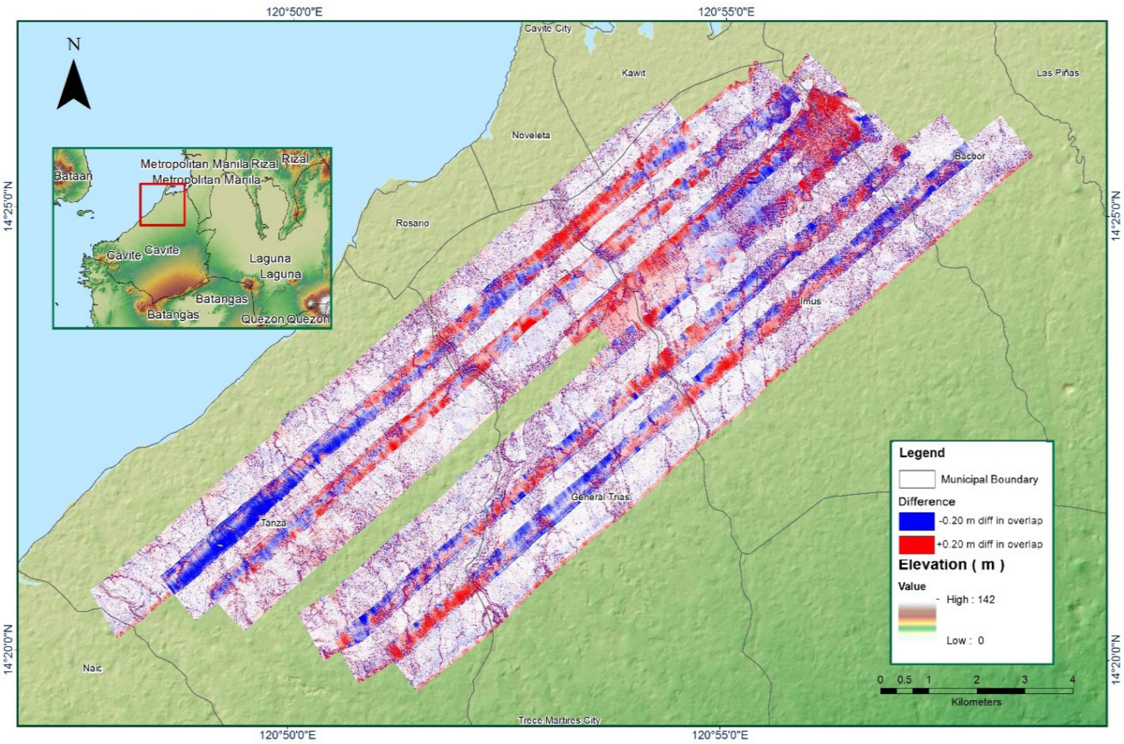


Figure A-8.53. Elevation difference between flight lines

Annex 9. Binabang-Molino Model Basin Parameters

Table A-9.1. Binabang-Molino Model Basin Parameters

Basin Number	SCS Curve Number Loss			Unit Hydrograph Tra		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W200	19.106	99	0	0.2468	2.3306	Discharge	0.000142967	0.0272984	Ratio to Peak	0.2211
W210	0.7996	99	0	1.3573	0.8014	Discharge	8.30E-03	0.87798	Ratio to Peak	0.2848
W220	0.7578	96.105	0	1.3412	1.605	Discharge	0.0058953	0.0025712	Ratio to Peak	0.192
W230	1.2221	35.282	0	14.557	10.213	Discharge	0.0186193	0.0686815	Ratio to Peak	0.5
W240	0.8815	87.035	0	0.4095	1.1833	Discharge	7.19E-03	1	Ratio to Peak	0.4517
W250	2.6742	48.733	0	5.7734	15.778	Discharge	0.0073351	0.0242255	Ratio to Peak	0.5
W260	1.7412	86.062	0	0.246	1.1788	Discharge	0.000715117	0.0018465	Ratio to Peak	0.4667
W270	0.5371	46.553	0	0.2448	1.057	Discharge	4.43E-03	0.0801071	Ratio to Peak	0.4254
W280	1.0445	99	0	0.3956	0.9074	Discharge	1.56E-03	1	Ratio to Peak	0.4732
W290	2.311	68.74	0	0.3928	1.1068	Discharge	0.0057899	0.25272	Ratio to Peak	0.456
W300	0.7662	95.997	0	0.2037	1.9995	Discharge	0.0045337	0.20969	Ratio to Peak	0.4534
W310	32.113	68.324	0	2.1025	220.75	Discharge	1.26E-02	0.37337	Ratio to Peak	0.5
W320	30.604	51.948	0	2.2978	111.89	Discharge	0.0066206	0.27426	Ratio to Peak	0.5
W330	1.117	40.617	0	9.5225	18.759	Discharge	0.0179395	0.19231	Ratio to Peak	0.5
W340	10.718	35.226	0	4.129	14.289	Discharge	0.0151748	0.17749	Ratio to Peak	0.5
W350	0.1604	35.504	0	1.191	18.419	Discharge	0.0075453	1.93E-01	Ratio to Peak	0.5
W360	35.587	35.114	0	2.3598	9.1995	Discharge	0.000167548	0.0373725	Ratio to Peak	0.0988
W370	0.4548	99	0	3.0554	0.5917	Discharge	0.0034216	0.0595887	Ratio to Peak	0.1891
W380	0.2633	99	0	2.5521	0.9064	Discharge	0.0040042	0.088877	Ratio to Peak	0.1929

Annex 10. Binabang-Molino Model Reach Parameters

Table A-10.1. Binabang-Molino Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	atic Fixed	204.35	0.0004	0.0405	Trapezoic	22	1
R100	atic Fixed	2284.5	0.0072	0.0631	Trapezoic	22	1
R110	atic Fixed	7160.9	0.0034	0.0266	Trapezoic	22	1
R150	atic Fixed	7374.5	0.0031	0.0411	Trapezoic	22	1
R160	atic Fixed	163.14	0.0055	0.0067	Trapezoic	22	1
R30	atic Fixed	4361.7	0.0071	0.054	Trapezoic	22	1
R40	atic Fixed	1737.5	0.0066	0.0787	Trapezoic	22	1
R50	atic Fixed	580.12	0.0103	0.045	Trapezoic	22	1
R70	atic Fixed	1259.1	0.0066	0.0306	Trapezoic	22	1

Annex 11. Binabang-Molino Field Validation Points

Table A-11.1. Binabang-Molino Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.727393	121.072898	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
2	13.731675	121.074500	0.34	0	-0.34	Glenda/ July 15, 2014	5 -Year
3	13.732275	121.073017	0.32	0	-0.32	Glenda/ July 15, 2014	5 -Year
4	13.733357	121.074602	1.00	0	-1.00	Glenda/ July 15, 2014	5 -Year
5	13.734289	121.072394	2.58	5.5	2.92	Glenda/ July 15, 2014	5 -Year
6	13.734818	121.073332	0.35	5.5	5.15	Glenda/ July 15, 2014	5 -Year
7	13.736704	121.071996	0.51	5.3	4.79	Glenda/ July 15, 2014	5 -Year
8	13.738276	121.071640	0.49	0.3	-0.19	Glenda/ July 15, 2014	5 -Year
9	13.740217	121.071228	0.38	0.3	-0.08	Glenda/ July 15, 2014	5 -Year
10	13.741518	121.070913	0.73	0.3	-0.43	Glenda/ July 15, 2014	5 -Year
11	13.747324	121.059655	0.46	4	3.54	Glenda/ July 15, 2014	5 -Year
12	13.747500	121.059359	0.05	4	3.95	Glenda/ July 15, 2014	5 -Year
13	13.747696	121.067302	0.05	0.3	0.25	Glenda/ July 15, 2014	5 -Year
14	13.747829	121.059660	0.63	1	0.37	Glenda/ July 15, 2014	5 -Year
15	13.748364	121.061092	0.03	3	2.97	Glenda/ July 15, 2014	5 -Year
16	13.748490	121.065140	0.05	2	1.95	Glenda/ July 15, 2014	5 -Year
17	13.748575	121.059634	0.06	1	0.94	Glenda/ July 15, 2014	5 -Year
18	13.748777	121.059349	0.09	0.3	0.21	Glenda/ July 15, 2014	5 -Year
19	13.748989	121.057976	0.06	4	3.94	Glenda/ July 15, 2014	5 -Year
20	13.748996	121.067755	2.05	0.1	-1.95	Glenda/ July 15, 2014	5 -Year
21	13.749423	121.061530	0.48	5.5	5.02	Glenda/ July 15, 2014	5 -Year
22	13.749496	121.061378	0.09	5.5	5.41	Glenda/ July 15, 2014	5 -Year
23	13.749822	121.059618	0.03	1	0.97	Glenda/ July 15, 2014	5 -Year
24	13.750051	121.060314	0.03	3	2.97	Glenda/ July 15, 2014	5 -Year
25	13.750149	121.059479	0.07	2	1.93	Glenda/ July 15, 2014	5 -Year
26	13.750174	121.058438	0.23	2	1.77	Glenda/ July 15, 2014	5 -Year
27	13.750197	121.058647	0.06	2	1.94	Glenda/ July 15, 2014	5 -Year
28	13.750341	121.059755	0.05	2	1.95	Glenda/ July 15, 2014	5 -Year
29	13.750354	121.057676	0.21	1	0.79	Glenda/ July 15, 2014	5 -Year
30	13.750354	121.064457	0.26	1	0.74	Glenda/ July 15, 2014	5 -Year
31	13.750753	121.058647	0.06	1	0.94	Glenda/ July 15, 2014	5 -Year
32	13.751425	121.056736	0.33	1	0.67	Glenda/ July 15, 2014	5 -Year
33	13.751932	121.069977	0.13	0.3	0.17	Glenda/ July 15, 2014	5 -Year
34	13.752289	121.044314	0.60	1	0.40	Glenda/ July 15, 2014	5 -Year
35	13.752367	121.064618	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
36	13.752870	121.055579	0.03	0.3	0.27	Glenda/ July 15, 2014	5 -Year
37	13.753052	121.043780	0.38	1	0.62	Glenda/ July 15, 2014	5 -Year
38	13.753327	121.070320	0.17	0.3	0.13	Glenda/ July 15, 2014	5 -Year
39	13.753620	121.067953	0.31	0.2	-0.11	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
40	13.754154	121.044694	0.05	1	0.95	Glenda/ July 15, 2014	5 -Year
41	13.754168	121.065340	0.30	5.4	5.10	Glenda/ July 15, 2014	5 -Year
42	13.754237	121.070429	1.69	0.3	-1.39	Glenda/ July 15, 2014	5 -Year
43	13.754331	121.064250	0.03	5.4	5.37	Glenda/ July 15, 2014	5 -Year
44	13.754373	121.047443	0.04	4	3.96	Glenda/ July 15, 2014	5 -Year
45	13.754406	121.055920	0.25	0	-0.25	Glenda/ July 15, 2014	5 -Year
46	13.754710	121.059690	0.03	0.2	0.17	Glenda/ July 15, 2014	5 -Year
47	13.754738	121.062223	0.53	5.4	4.87	Glenda/ July 15, 2014	5 -Year
48	13.754885	121.061580	0.20	5.5	5.30	Glenda/ July 15, 2014	5 -Year
49	13.754914	121.050339	0.12	0.2	0.08	Glenda/ July 15, 2014	5 -Year
50	13.754927	121.062337	0.15	5.4	5.25	Glenda/ July 15, 2014	5 -Year
51	13.755120	121.058733	0.03	0.2	0.17	Glenda/ July 15, 2014	5 -Year
52	13.755125	121.114721	0.03	5	4.97	Glenda/ July 15, 2014	5 -Year
53	13.755145	121.062406	1.48	5.4	3.92	Glenda/ July 15, 2014	5 -Year
54	13.755302	121.063697	5.25	4	-1.25	Glenda/ July 15, 2014	5 -Year
55	13.755359	121.062581	0.70	5.3	4.60	Glenda/ July 15, 2014	5 -Year
56	13.755391	121.052790	0.13	0.3	0.17	Glenda/ July 15, 2014	5 -Year
57	13.755538	121.061602	0.08	5.5	5.42	Glenda/ July 15, 2014	5 -Year
58	13.755549	121.056000	0.76	0	-0.76	Glenda/ July 15, 2014	5 -Year
59	13.755549	121.070726	0.03	0.3	0.27	Glenda/ July 15, 2014	5 -Year
60	13.755559	121.062518	6.66	5.3	-1.36	Glenda/ July 15, 2014	5 -Year
61	13.755593	121.062702	0.03	5.3	5.27	Glenda/ July 15, 2014	5 -Year
62	13.755935	121.062857	0.03	5.3	5.27	Glenda/ July 15, 2014	5 -Year
63	13.756049	121.062782	0.04	5.3	5.26	Glenda/ July 15, 2014	5 -Year
64	13.756085	121.062630	0.56	0.2	-0.36	Glenda/ July 15, 2014	5 -Year
65	13.756096	121.062871	0.93	5	4.07	Glenda/ July 15, 2014	5 -Year
66	13.756215	121.070734	0.06	0.3	0.24	Glenda/ July 15, 2014	5 -Year
67	13.756407	121.063073	0.92	5	4.08	Glenda/ July 15, 2014	5 -Year
68	13.756531	121.066151	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
69	13.756557	121.062846	2.22	5.7	3.48	Glenda/ July 15, 2014	5 -Year
70	13.756823	121.063203	0.19	5.7	5.51	Glenda/ July 15, 2014	5 -Year
71	13.756844	121.043143	0.44	0.2	-0.24	Glenda/ July 15, 2014	5 -Year
72	13.756999	121.063245	4.13	5.7	1.57	Glenda/ July 15, 2014	5 -Year
73	13.757125	121.063270	0.55	5	4.45	Glenda/ July 15, 2014	5 -Year
74	13.757230	121.060764	2.16	0.2	-1.96	Glenda/ July 15, 2014	5 -Year
75	13.757291	121.063325	0.27	5	4.73	Glenda/ July 15, 2014	5 -Year
76	13.757311	121.056461	0.33	0.2	-0.13	Glenda/ July 15, 2014	5 -Year
77	13.757320	121.070791	0.45	1	0.55	Glenda/ July 15, 2014	5 -Year
78	13.757359	121.055461	1.26	0.2	-1.06	Glenda/ July 15, 2014	5 -Year
79	13.757408	121.064950	0.05	4	3.95	Glenda/ July 15, 2014	5 -Year
80	13.757463	121.056183	0.06	0.2	0.14	Glenda/ July 15, 2014	5 -Year
81	13.757569	121.057345	2.85	0.2	-2.65	Glenda/ July 15, 2014	5 -Year
82	13.757624	121.063513	0.68	5	4.32	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
83	13.757645	121.059426	0.11	0.2	0.09	Glenda/ July 15, 2014	5 -Year
84	13.757656	121.057986	0.03	0.2	0.17	Glenda/ July 15, 2014	5 -Year
85	13.757812	121.063102	0.77	0.2	-0.57	Glenda/ July 15, 2014	5 -Year
86	13.757822	121.067054	4.63	4	-0.63	Glenda/ July 15, 2014	5 -Year
87	13.757923	121.063650	0.03	5	4.97	Glenda/ July 15, 2014	5 -Year
88	13.758200	121.062520	3.96	0.3	-3.66	Glenda/ July 15, 2014	5 -Year
89	13.758297	121.063841	0.07	5	4.93	Glenda/ July 15, 2014	5 -Year
90	13.758817	121.045185	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
91	13.759061	121.063047	0.33	0.2	-0.13	Glenda/ July 15, 2014	5 -Year
92	13.759219	121.074139	0.14	6	5.86	Glenda/ July 15, 2014	5 -Year
93	13.759447	121.072412	0.04	0.2	0.16	Glenda/ July 15, 2014	5 -Year
94	13.759641	121.060604	0.09	0.2	0.11	Glenda/ July 15, 2014	5 -Year
95	13.759800	121.073742	0.03	6	5.97	Glenda/ July 15, 2014	5 -Year
96	13.759836	121.068186	2.47	4	1.53	Glenda/ July 15, 2014	5 -Year
97	13.754885	121.061580	0.20	5.5	5.30	Glenda/ July 15, 2014	5 -Year
98	13.759844	121.067161	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
99	13.760034	121.062607	0.08	0.2	0.12	Glenda/ July 15, 2014	5 -Year
100	13.760151	121.069145	0.24	4	3.76	Glenda/ July 15, 2014	5 -Year
101	13.760153	121.061194	0.07	0.2	0.13	Glenda/ July 15, 2014	5 -Year
102	13.760266	121.047660	0.10	4	3.90	Glenda/ July 15, 2014	5 -Year
103	13.761035	121.073679	0.14	6	5.86	Glenda/ July 15, 2014	5 -Year
104	13.761503	121.050318	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
105	13.761511	121.075362	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
106	13.761877	121.076623	0.06	0	-0.06	Glenda/ July 15, 2014	5 -Year
107	13.762158	121.079028	0.54	0	-0.54	Glenda/ July 15, 2014	5 -Year
108	13.762205	121.051567	0.03	5.5	5.47	Glenda/ July 15, 2014	5 -Year
109	13.762412	121.081484	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
110	13.762450	121.080293	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
111	13.762470	121.064130	0.05	0.3	0.25	Glenda/ July 15, 2014	5 -Year
112	13.762500	121.073581	0.03	0.3	0.27	Glenda/ July 15, 2014	5 -Year
113	13.762652	121.083838	0.85	0	-0.85	Glenda/ July 15, 2014	5 -Year
114	13.762797	121.051747	0.14	1	0.86	Glenda/ July 15, 2014	5 -Year
115	13.762797	121.057625	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
116	13.762899	121.085857	0.05	0	-0.05	Glenda/ July 15, 2014	5 -Year
117	13.763066	121.056973	1.05	0.5	-0.55	Glenda/ July 15, 2014	5 -Year
118	13.763084	121.051750	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
119	13.763394	121.088799	0.13	0	-0.13	Glenda/ July 15, 2014	5 -Year
120	13.763538	121.058100	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
121	13.763614	121.090660	0.28	0	-0.28	Glenda/ July 15, 2014	5 -Year
122	13.763676	121.064475	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
123	13.763885	121.092710	2.67	0	-2.67	Glenda/ July 15, 2014	5 -Year
124	13.764045	121.072156	0.04	2	1.96	Glenda/ July 15, 2014	5 -Year
125	13.764125	121.080205	1.85	0	-1.85	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
126	13.764127	121.072344	0.28	2	1.72	Glenda/ July 15, 2014	5 -Year
127	13.764154	121.073288	1.12	0	-1.12	Glenda/ July 15, 2014	5 -Year
128	13.764163	121.072434	0.03	2	1.97	Glenda/ July 15, 2014	5 -Year
129	13.764268	121.072567	4.13	2	-2.13	Glenda/ July 15, 2014	5 -Year
130	13.764308	121.072703	0.12	2	1.88	Glenda/ July 15, 2014	5 -Year
131	13.764314	121.072838	0.03	0.5	0.47	Glenda/ July 15, 2014	5 -Year
132	13.764400	121.072905	3.75	0.5	-3.25	Glenda/ July 15, 2014	5 -Year
133	13.764470	121.072963	0.03	0.5	0.47	Glenda/ July 15, 2014	5 -Year
134	13.764585	121.098674	4.55	0.2	-4.35	Glenda/ July 15, 2014	5 -Year
135	13.764746	121.073160	0.21	0.5	0.29	Glenda/ July 15, 2014	5 -Year
136	13.764925	121.073173	0.03	6	5.97	Glenda/ July 15, 2014	5 -Year
137	13.765162	121.073124	0.03	5	4.97	Glenda/ July 15, 2014	5 -Year
138	13.765282	121.103365	2.12	0.2	-1.92	Glenda/ July 15, 2014	5 -Year
139	13.765384	121.072784	0.38	5	4.62	Glenda/ July 15, 2014	5 -Year
140	13.765389	121.050369	0.03	1	0.97	Glenda/ July 15, 2014	5 -Year
141	13.765573	121.105959	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
142	13.765676	121.072812	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
143	13.765851	121.080400	0.04	0.2	0.16	Glenda/ July 15, 2014	5 -Year
144	13.766112	121.064915	0.05	0	-0.05	Glenda/ July 15, 2014	5 -Year
145	13.766342	121.054608	0.07	0.3	0.23	Glenda/ July 15, 2014	5 -Year
146	13.766424	121.062208	0.63	0.3	-0.33	Glenda/ July 15, 2014	5 -Year
147	13.759844	121.067161	0.03	4	3.97	Glenda/ July 15, 2014	5 -Year
147	13.766513	121.049629	0.06	1	0.94	Glenda/ July 15, 2014	5 -Year
148	13.766579	121.072679	0.17	0	-0.17	Glenda/ July 15, 2014	5 -Year
149	13.766588	121.106272	0.03	0.2	0.17	Glenda/ July 15, 2014	5 -Year
150	13.767362	121.048213	0.56	0.3	-0.26	Glenda/ July 15, 2014	5 -Year
151	13.767473	121.080592	0.07	1	0.93	Glenda/ July 15, 2014	5 -Year
152	13.768361	121.071135	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
153	13.768373	121.106130	0.03	0.2	0.17	Glenda/ July 15, 2014	5 -Year
154	13.768540	121.065372	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
155	13.768924	121.068926	0.03	0.1	0.07	Glenda/ July 15, 2014	5 -Year
156	13.769012	121.105147	0.06	0	-0.06	Glenda/ July 15, 2014	5 -Year
157	13.769173	121.067627	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
158	13.769350	121.082014	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
159	13.769508	121.101663	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
160	13.769915	121.065531	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
161	13.770017	121.100847	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
162	13.770253	121.055683	0.03	0.5	0.47	Glenda/ July 15, 2014	5 -Year
163	13.770253	121.056972	0.03	0.5	0.47	Glenda/ July 15, 2014	5 -Year
164	13.770253	121.057194	0.06	0.5	0.44	Glenda/ July 15, 2014	5 -Year
165	13.770253	121.085381	0.50	0	-0.50	Glenda/ July 15, 2014	5 -Year
166	13.770357	121.049837	0.05	0.5	0.45	Glenda/ July 15, 2014	5 -Year
167	13.770384	121.065205	0.43	0.2	-0.23	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
168	13.770533	121.050769	0.07	0.5	0.43	Glenda/ July 15, 2014	5 -Year
169	13.771092	121.083208	0.47	0	-0.47	Glenda/ July 15, 2014	5 -Year
170	13.771293	121.050705	0.03	0.5	0.47	Glenda/ July 15, 2014	5 -Year
171	13.771884	121.089597	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
172	13.772039	121.092548	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
173	13.772051	121.098880	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
174	13.772111	121.095739	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
175	13.772343	121.085353	0.03	0	-0.03	Glenda/ July 15, 2014	5 -Year
176	13.772789	121.050769	0.07	0.4	0.33	Glenda/ July 15, 2014	5 -Year
177	13.772790	121.048856	0.03	0.4	0.37	Glenda/ July 15, 2014	5 -Year
178	13.774902	121.045792	0.26	0.2	-0.06	Glenda/ July 15, 2014	5 -Year
179	13.776175	121.044012	0.29	0.2	-0.09	Glenda/ July 15, 2014	5 -Year
180	13.778124	121.041045	0.42	0.2	-0.22	Glenda/ July 15, 2014	5 -Year
181	13.779179	121.039080	0.20	0.2	0.00	Glenda/ July 15, 2014	5 -Year

Annex 12. Educational Institutions Affected by Flooding in Binabang-Molino Floodplain

Table A-12.1 Educational Institutions Affected by Flooding in the Binabang-Molino Floodplain

Cavite				
Bacoor				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
STARFIELDS SCHOOL	Molino IV			
UNIVERSITY OF PERPETUAL HELP	Molino IV			
WOODRIDGE COLLEGE	Molino VI			
DAY CARE CENTER	Niog III			Low
STARFIELDS SCHOOL	Queens Row East			
UNIVERSITY OF PERPETUAL HELP	Queens Row East			
EASTERN BACOOR NATIONAL HIGH SCHOOL	Queens Row West			
QUEENS ROW ELEMENTARY SCHOOL	Queens Row West			
ANIBAN ELEMENTARY SCHOOL	Zapote II	High	High	High
SAINT DOMINIC COLLEGE OF ASIA	Zapote III		Low	Medium
SAINT DOMINIC COLLEGE OF ASIA	Zapote IV		Low	Medium
TALABA ELEMENTARY SCHOOL	Zapote IV	Low	Medium	Medium

Dasmariñas				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ANGEL OF PEACE LEARNING CENTER	Salawag			
CHILDREN OF MARY ACADEMY	Salawag			Low
ICC SALAWAG	Salawag			
LEGACY OF WISDOM ACADEMY OF DASMARINAS, INC.	Salawag			
LITTLE ROSE DAYCARE CENTER	Salawag	Medium	Medium	Medium
MIDLAND SCHOOL OF CAVITE	Salawag			
OXFORDIAN COLLEGES	Salawag			
RABBI CHRISTIAN INSTITUTE OF DASMARINAS	Salawag			
SALAWAG ELEMENTARY SCHOOL	Salawag			

Metropolitan Manila				
Las Piñas				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BLOOMFIELD ACADEMY	Talon Dos			
DAY CARE CENTER	Talon Dos	High	High	High
FR. ANGELICO LIPANI SCHOOL	Talon Dos			
LAS PIÑAS SCIENCE HIGH SCHOOL	Talon Dos		Medium	Medium
GOLDEN ACRES ELEMENTARY SCHOOL	Talon Singko			

GOLDEN ACRES NATIONAL HIGH SCHOOL	Talon Singko			
SCHOOL	Talon Singko			
WISHBONE KIDDIE CAMP	Talon Singko	Low	Low	Low
UNIVERSITY OF PERPETUAL HELP DALTA MEDICAL CENTER	Talon Uno			

Metropolitan Manila				
Muntinlupa				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
GCF SOUTH METRO CHRISTIAN SCHOOL	New Alabang Village			
PAREF WOODROSE	New Alabang Village			

Annex 13. Medical Institutions Affected by Flooding in Binabang-Molino Floodplain

Table A-13.1 Medical Institutions Affected by Flooding in the Binabang-Molino Floodplain

Cavite				
Bacoor				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BACOOR PEADITRIC CLINIC	Maliksi III		Low	Medium
MOLINO DOCTORS HOSPITAL	Molino V		Low	Low
SOUTHEAST ASIAN MEDICAL CENTER	Molino VII			
HEALTH CENTER	Niog III			Low
SAINT DOMINIC MEDICAL CENTER	Zapote IV		Low	Medium

Dasmariñas				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DASMARINAS CITY MEDICAL CENTER	Salawag			
DENTAL CLINIC	Salawag			
OPTICAL CLINIC	Salawag			
PARANAQUE ULTRASOUND DIAGNOSTIC CENTER, INC.	Salawag			
THE GENERICS PHARMACY	Salawag			
VIRATA MEDICAL CLINIC	Salawag			

Metropolitan Manila				
Las Piñas				
Building	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
TRIPLE Z OPTICAL CLINIC	Talon Dos			
AUDAR DENTAL CLINIC	Talon Singko	Low	Low	Low
CAVITE MATERNITY AND CHILDREN'S HOSPITAL	Talon Singko		Low	Low
DENTAL CLINIC	Talon Singko			