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

LiDAR Surveys and Flood Mapping of Calumpang River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mapua Institute of University (MIT)

APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid (GIA) Program and is to be cited as:

E. C. Paringit and F. A. Uy (eds.) (2017), LiDAR Surveys and Flood Mapping of Calumpang River, Quezon City: University of the Philippines Training Center on Applied Geodesy and Photogrammetry-244pp.

For questions/queries regarding this report, contact:

Dr. Aldrine Francis A. Uy
Project Leader, PHIL LIDAR 1 Program
MAPUA Institute of Technology
Intramuros, Philippines 1002
E-mail: faauy@mapua.edu.ph

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

National Library of the Philippines
ISBN: 978-621-430-046-4

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MIT	Mapua 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
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
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 SILONGIN RIVER

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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled *Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods* (Paringit et al., 2017).

The implementing partner university for the Phil-LiDAR 1 Program is the Mapua 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 25 river basins in the Southern Tagalog Region. The university is located in Intramuros in the City of Manila.

1.2 Overview of the Calumpang River Basin

The Calumpang River Basin is a perennial body of water located in Batangas province. It serves as a catchment basin for the areas of Ibaan, San Jose, Taysan, Rosario, Batangas City and a portion of Lipa City. It drains into Batangas Bay, and its mouth is located in Batangas City. The Calumpang River serves as its main channel.

The river basin is often visited by typhoons every year, which causes flood in its low-lying areas. It results in damage to surrounding infrastructures and loss of life among the people living nearby. In 2014, Typhoon Glenda devastated the municipalities and cities covered by the river basin. Batangas City, located at the river basin's mouth, experienced flooding on its barangays situated along the riverbank. Due to the high discharge of the river, Calumpang River swelled up, leading to the collapse of Calumpang Bridge that crosses its mouth. Historically, this is not the first time that Batangas City experienced flash flood. In October 2009, during Typhoon Santi, the Bridge of Promise, which also crosses the Calumpang River, went down due to high volume of water rushing through the river. There was also another incident sometime in the 1920s when 200 people died and major properties damaged due to the Calumpang River overflowing.

These casualties brought by flooding only demonstrate the need of an accurate and reliable flood forecasting system. With the advancement of technology, Light Detection and Ranging (LiDAR), a technology which allows the production of highly accurate digital elevation models (DEMs) of the earth, can be applied in flood modeling to produced high resolution flood hazard maps that for use by the local government units in planning, development, and disaster preparedness.

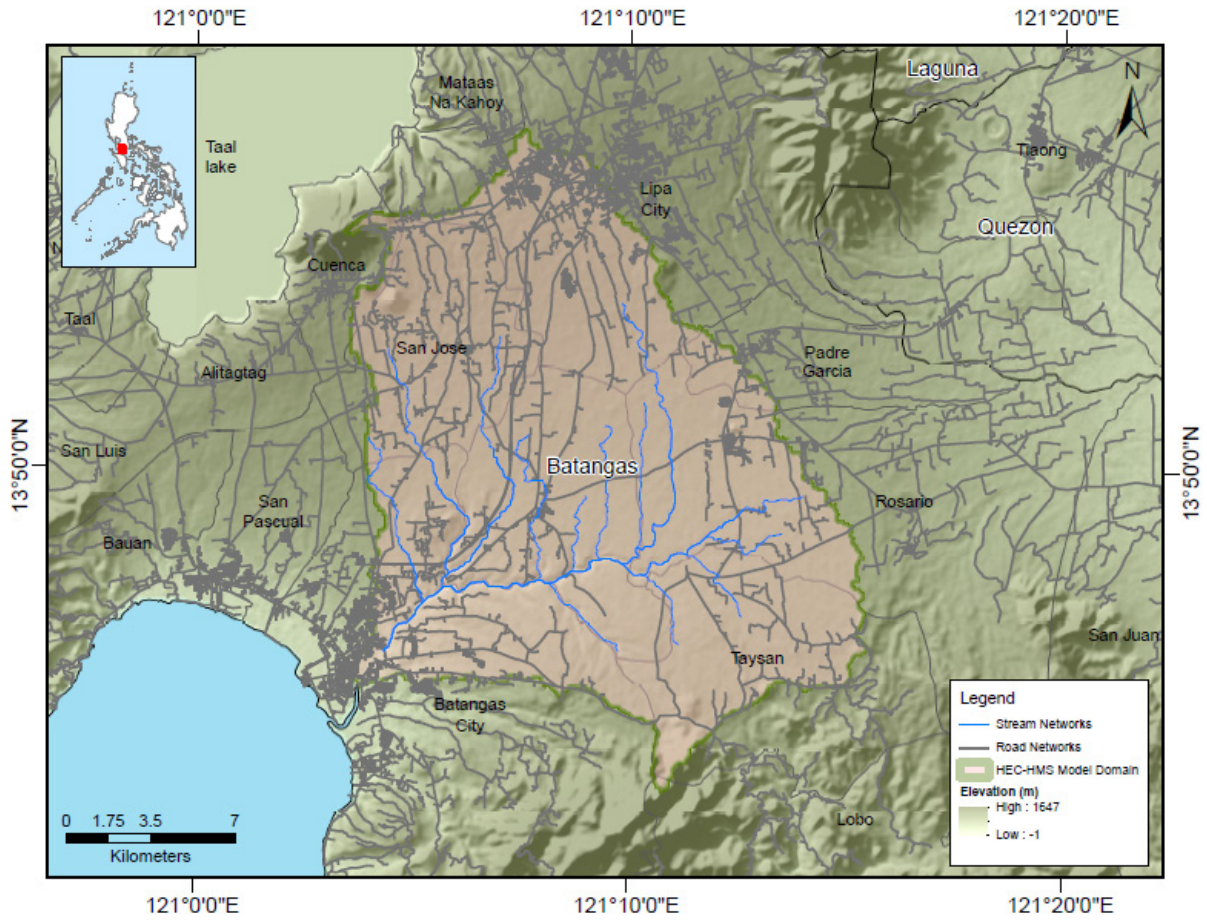


Figure 1. Map of the Calumpang River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN CALUMPANG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Ms. Jonalyn S. Gonzales

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Calumpang floodplain in Batangas .These missions were planned for 12 lines that run for at most three (3) hours including take-off, landing, and turning time. The flight planning parameters for Gemini and Pegasus LiDAR systems are found in Table 1 and Table 2, respectively. Figure 2 shows the flight plan for Calumpang Floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK18KDBEF	1000	30	40	125	50	130	5
BLK18SG	1000	30	40	125	50	130	5
BLK18SF	1000	30	40	125	50	130	5
BLK18SAB	1000	30	40	125	50	130	5
BLK18KLB	850	40	50	125	40	120	5
BLK18SAB	600	40	40	125	20	130	5
BLK18SBC	1000	30	40	125	50	130	5
BLK18SC	850	40	50	125	40	130	5

Table 2. Flight planning parameters for 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)
BLK18SAB	1000	15	50	200	30	130	5
BLK18SABEK	1000	15	50	200	30	130	5

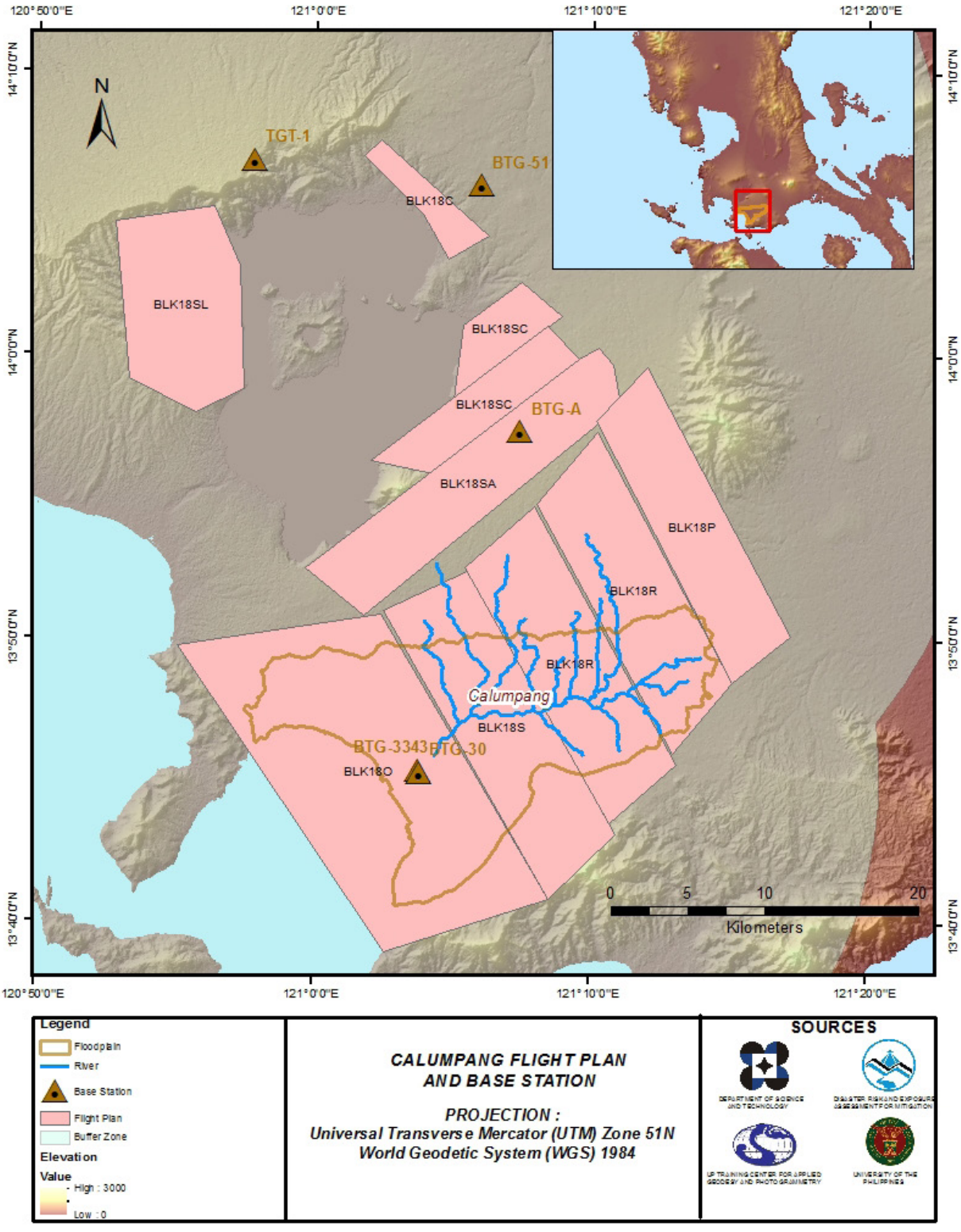


Figure 2. Flight plan and base stations for Calumpang Floodplain

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA reference points, BTG-51 and QZN-21, which are of second (2nd)-order accuracy, and BTG-3343, which is of fourth (4th)-order accuracy. The project team also established two (2) ground control points, BTG-A and TGT-1. The certifications for the base stations are found in ANNEX 2 while the baseline processing reports for the established ground control points are found in ANNEX 3. These points were used as base stations during flight operations for the entire duration of the survey (December 21, 2016–January 16, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Calumpang Floodplain are shown in Figure 2.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 7 show the details about the following NAMRIA reference points and established points, while Table 8 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

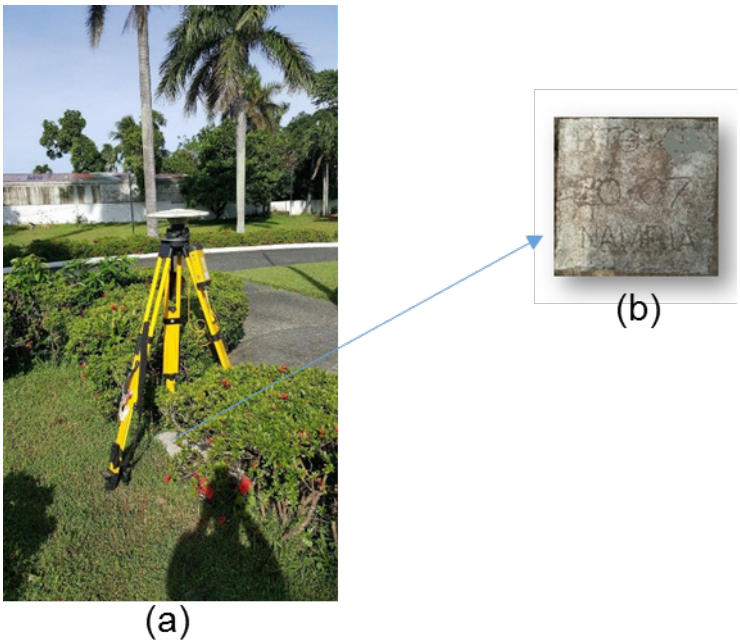


Figure 3. GPS set-up over BTG-51 inside the vicinity of Mabini Shrine in Brgy, Talaga, Tanuan City, Batangas (a) NAMRIA reference point BTG-51 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point BTG-51 used as base station for the LiDAR acquisition

Station Name	BTG-51	
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° 06’ 8.57112” North 121° 05’ 52.31002 ”East 152.36900 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Easting Northing	510567.544 meters 1559501.067 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 06’ 3.27790” North 121° 05’ 57.24592” East 197.55100 meters

Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	1559783.81 meters 294641.94 meters

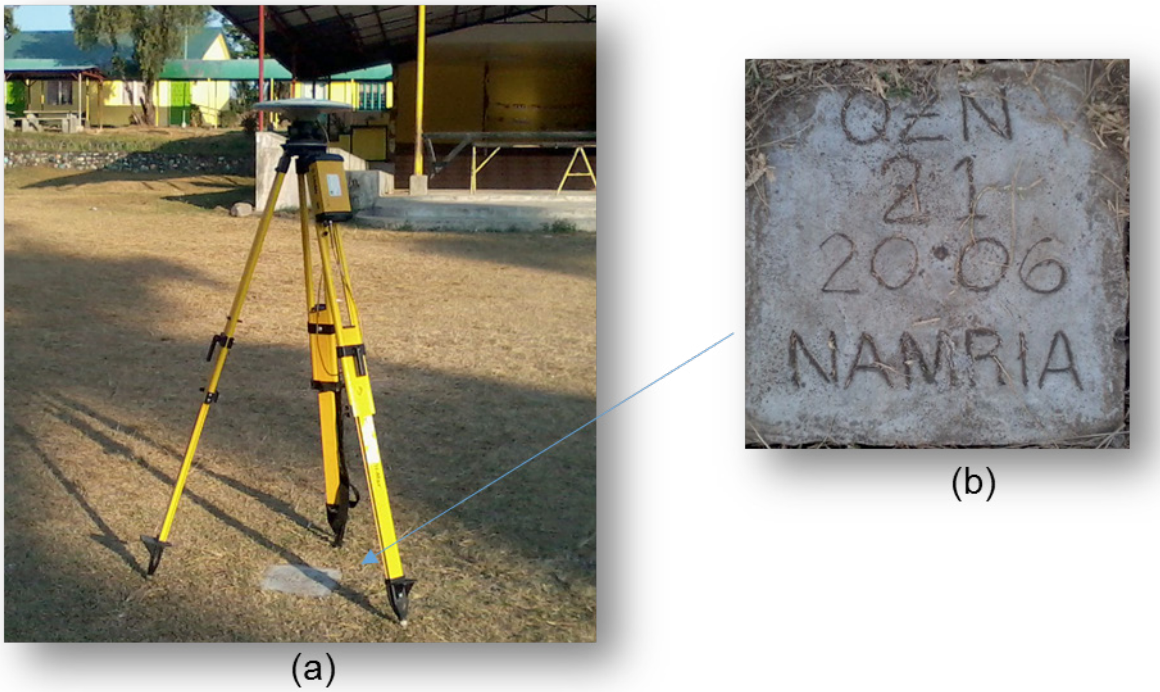


Figure 4. GPS set-up over QZN-21 inside Paaralang Elementarya ng Silangang Tiaong of Brgy. Poblacion III, Tiaong, Quezon Province (a) and NAMRIA reference point QZN-21 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point QZN-21 used as base station for the LiDAR acquisition

Station Name	QZN-21	
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° 57’ 44.31576” North 121° 19’ 27.34822” East 51.25800 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	535036.042 meters 1544027.063 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 57’ 39.07397” North 121° 19’ 32.29499” East 97.38200 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	318981.12 meters 1544101.56 meters

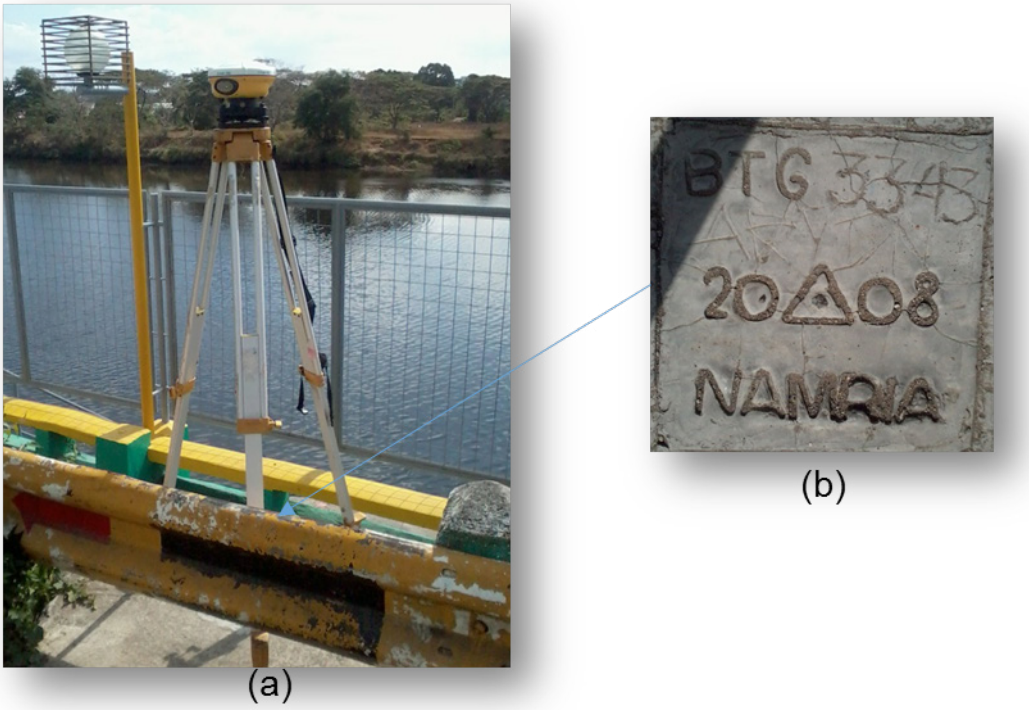


Figure 5. GPS set-up over BTG-3343 near the corner of Rizal and P. Herrera St. of Brgy. Pallocan, Batangas City, Batangas Province (a) and NAMRIA reference point BTG-3343 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point BTG-3343 used as base station for the LiDAR acquisition

Station Name	BTG-3343	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1:10,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 45’ 28.66051” North 121° 03’ 42.01826” East 9.01500 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	506669.312 meters 1521397.691 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°45 ’23.44551” North 121° 03’ 46.98401” East 55.06100 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	290422.78 meters 1521707.64 meters

Table 6. Details of the established reference point BTG-A with processed coordinates used as base station for the LiDAR acquisition

Station Name	BTG-A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude	13° 59' 51.95603" North
	Longitude	120° 42' 18.98286 " East
	Ellipsoidal Height	49.08900 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Easting	252126.100 meters
	Northing	1548584.818 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 59' 46.65526" North
	Longitude	120° 42' 23.92980" East
	Ellipsoidal Height	93.60200 meters

Table 7. Details of the established reference point TGT-1 with processed coordinates used as base station for the LiDAR acquisition

Station Name	TGT-1	
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° 07' 00.06528" North 120° 57' 38.31871 " East 613.37000 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Easting Northing	279835.821 meters 1561490.819 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 06' 54.75787" North 120° 57' 43.25375" East 93.60200 meters

Table 8. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
14 Feb 2014	1107P	1BLK18QRS45A	QZN-21 and QZN-21A
15 Feb 2014	1111P	1BLK18QRS46A	QZN-21 and QZN-21A
17 Feb 2014	1119P	1BLK18O48A	BTG-30 and BTG-3433
18 Feb 2014	1123P	1BLK18OS49A	BTG-30 and BTG-3433
18 Feb 2014	1125P	1BLK18S49B	BTG-30 and BTG-3433
21 Dec 2015	3000P	1BLK18SB355A	BTG-51 and BTG-A
21 Dec 2015	3002P	1BLK18S356A	BTG-51 and BTG-A
9 Jan 2016	3689G	2BLK18SV009A	BTG-51 and BTG-A
30 Dec 2015	3673G	2BLK18S363A	BTG-51 and BTG-A
9 Jan 2016	3691G	2BLK18SVV009B	BTG-51 and BTG-A
29 Dec 2015	3669G	2BLK18SBC363A	BTG-51 and BTG-A
29 Dec 2015	3671G	2BLK18BC363B	BTG-51 and BTG-A
16 Jan 2016	3693G	2BLK18SCB016A	BTG-51 and TGT-1

2.3 Flight Missions

Thirteen (13) missions were conducted to complete the LiDAR data acquisition in Calumpang Floodplain, for a total of forty two hours and twenty four minutes (42+24) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus and Gemini LiDAR systems. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for LiDAR data acquisition in Calumpang Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
14 Feb 2014	1107P	567.95	161.35	73.11	88.24	300	3	35
15 Feb 2014	1111P	567.95	177.52	56.24	121.28	346	3	47
17 Feb 2014	1119P	567.95	175.38	111.49	63.89	392	4	11
18 Feb 2014	1123P	567.95	181.32	109.93	71.39	NA	3	53
18 Feb 2014	1125P	567.95	63.60	50.16	13.44	NA	3	29
21 Dec 2015	3000P	525.1	69.21	4.32E-04	69.20	173	2	21
21 Dec 2015	3002P	710.1	280.85	2.19	278.66	614	3	21
9 Jan 2016	3689G	358.19	144.36	NA	144.36	NA	3	47
30 Dec 2015	3673G	358.19	149.22	NA	149.22	NA	3	29
9 Jan 2016	3691G	29.10	4.8	NA	4.8	NA	2	23
29 Dec 2015	3669G	342.93	144.41	NA	144.41	NA	2	47
29 Dec 2015	3671G	342.93	68.37	NA	68.37	NA	1	58
16 Jan 2016	3693G	85.40	49.1	NA	49.1	NA	3	23
TOTAL		5591.69	1669.49	403.12	1266.36	1825	42	24

Table 10. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1119P	1000	30	50	200	30	130	5
1123P	1000	30	50	200	30	130	5
1107P	1000	30	50	200	30	130	5
1111P	1000	30	50	200	30	130	5
1125P	1000	30	50	200	30	130	5
3000P	1000	15	50	200	30	130	5
3002P	1000	15	50	200	30	130	5
3689G	1000	30	40	125	50	130	5
3673G	1000	30	40	125	50	130	5
3691G	850	40	50	125	40	120	5
3669G	600	40	40	125	20	130	5
3671G	1000	30	40	125	50	130	5
3693G	850	40	50	125	40	130	5

2.4 Survey Coverage

Calumpang Floodplain is located along the provinces of Batangas, Cavite, Laguna, and Quezon with majority of the floodplain situated within the municipalities of Batangas. The municipality of San Jose in Batangas was fully covered during the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Calumpang Floodplain is presented in Figure 6.

Table 11. List of municipalities/cities surveyed during Calumpang Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Batangas	San Jose	60.70	60.70	100%
	Lipa City	202.80	179.45	88.49%
	Cuenca	21.91	22.87	81.96%
	Alitagtag	27.03	19.72	72.96%
	Laurel	69.53	49.31	70.91%
	Tanauan City	111.77	72.13	64.53%
	Batangas City	274.48	175.66	64.00%
	Bauan	51.31	30.37	59.19%
	Agoncillo	39.54	22.70	57.41%
	Rosario	197.03	86.45	43.88%
	Taysan	91.03	35.26	38.73%
	Santo Tomas	92.08	34.76	37.75%
	Lemery	82.32	16.71	20.29%
	San Luis	42.04	6.21	14.77%
Cavite	Tagaytay City	61.41	7.54	12.28%
Laguna	Calamba City	130.68	18.63	14.26%
Quezon	San Antonio	60.34	12.67	20.99%
Total		1616.00	851.14	50.73%

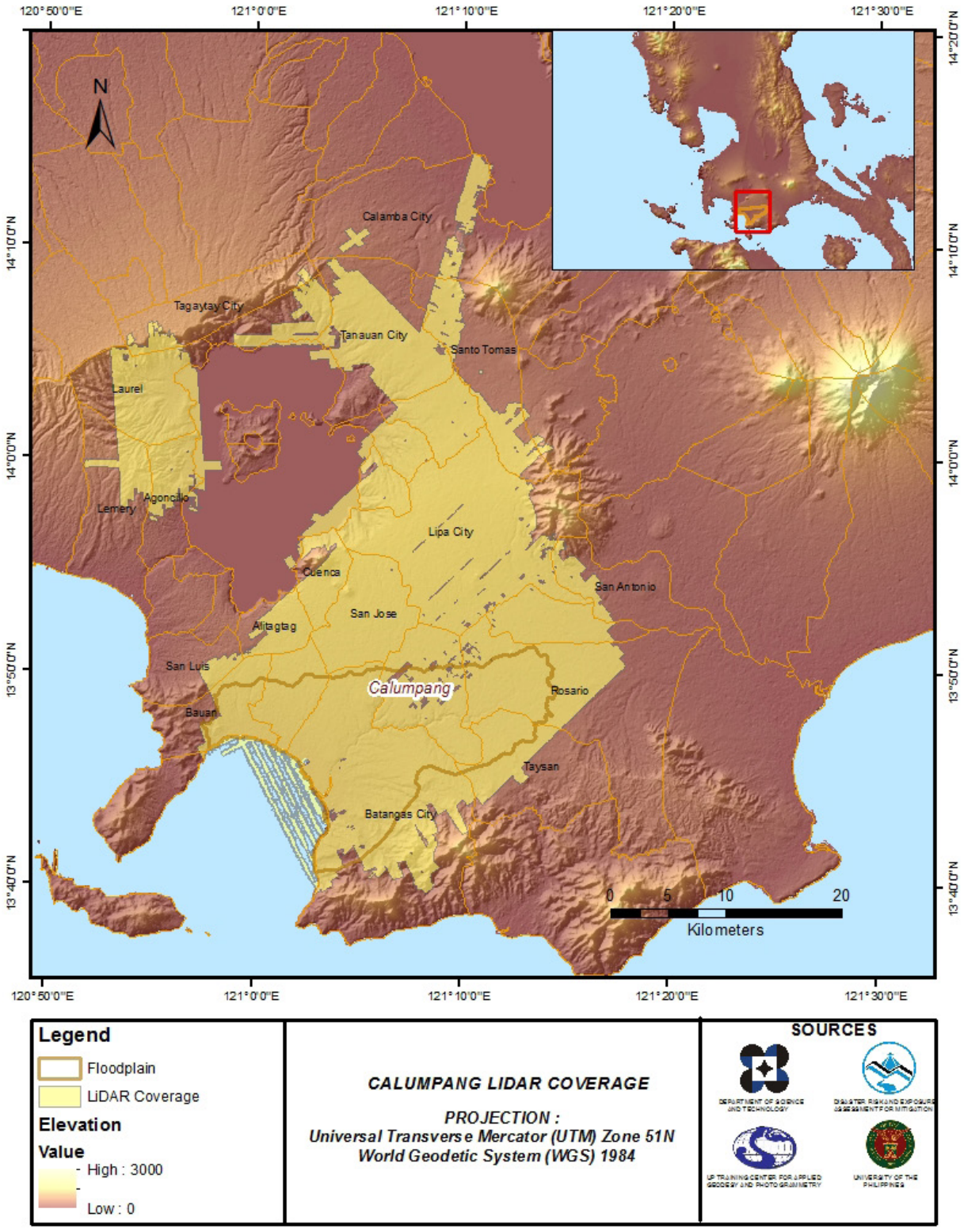


Figure 6. Actual LiDAR survey coverage for Calumpang Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR CALUMPANG FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Joida F. Prieto, Engr. Melissa F. Fernandez, Engr. Ma. Ailyn L. Olanda, Engr. Sheila-Maye F. Santillan, Aljon Rie V. Araneta, Engr. Ezzo Marc C. Hibionada, Ziarre Anne P. Mariposa

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 7.

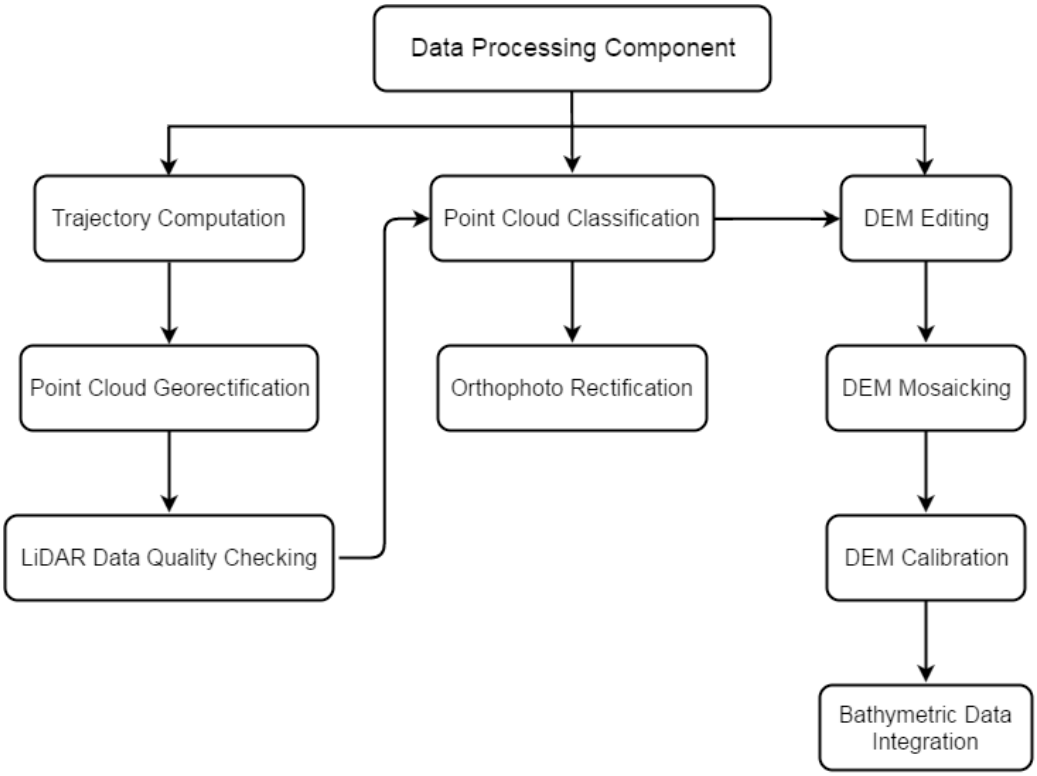


Figure 7. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Calumpang Floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on February 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on December 2015 were flown using the Gemini system over Batangas City. The Data Acquisition Component (DAC) transferred a total of 163.68 Gigabytes of Range data, 2.097 Gigabytes of POS data, 158.96 Megabytes of GPS base station data, and 110.76 Gigabytes of raw image data to the data server on April 23, 2014 for the first survey and January15, 2016 for the second survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Calumpang was fully transferred on January 20, 2016, as indicated on the data transfer sheets for Calumpang Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3669G, one of the Calumpang flights, which is the North, East, and Down position RMSE values, are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on December 29, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

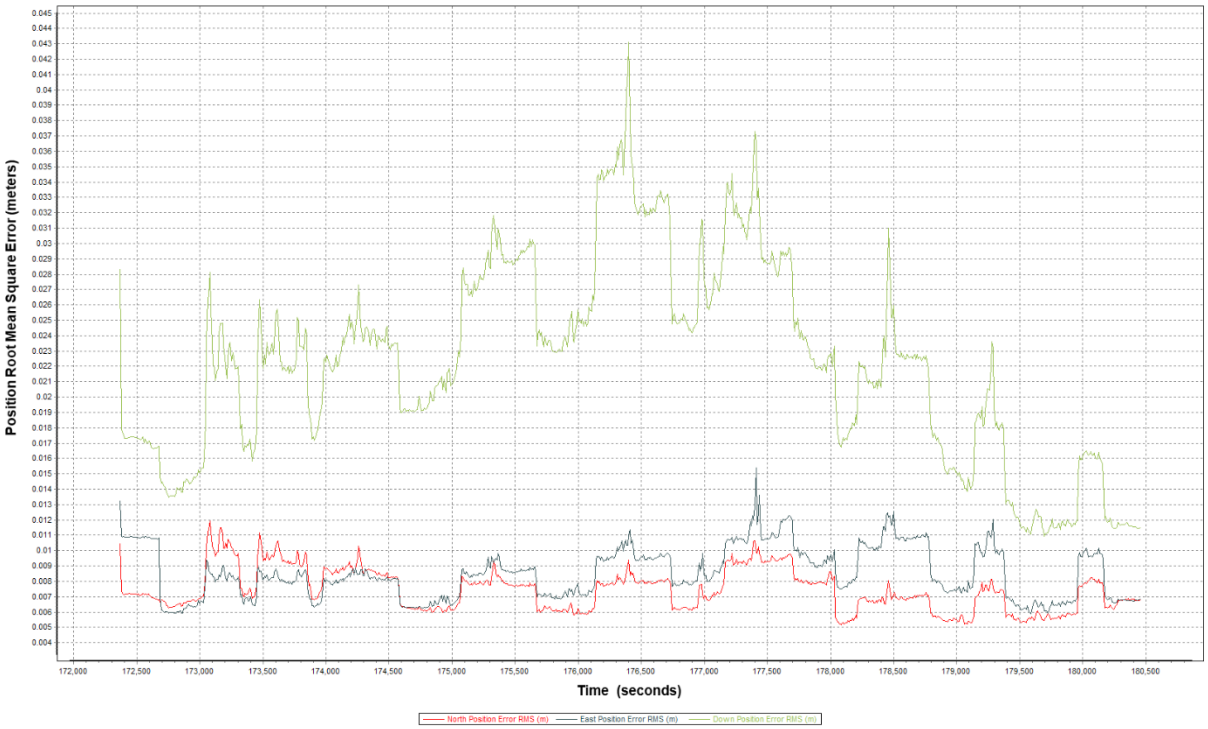


Figure 8. Smoothed Performance Metric Parameters of a Calumpang Flight 3669G.

The time of flight was from 172250 seconds to 180500 seconds, which corresponds to morning of December 29, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the time the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.06 centimeters, the East position RMSE peaks at 1.55 centimeters, and the Down position RMSE peaks at 4.31 centimeters, which are within the prescribed accuracies described in the methodology.

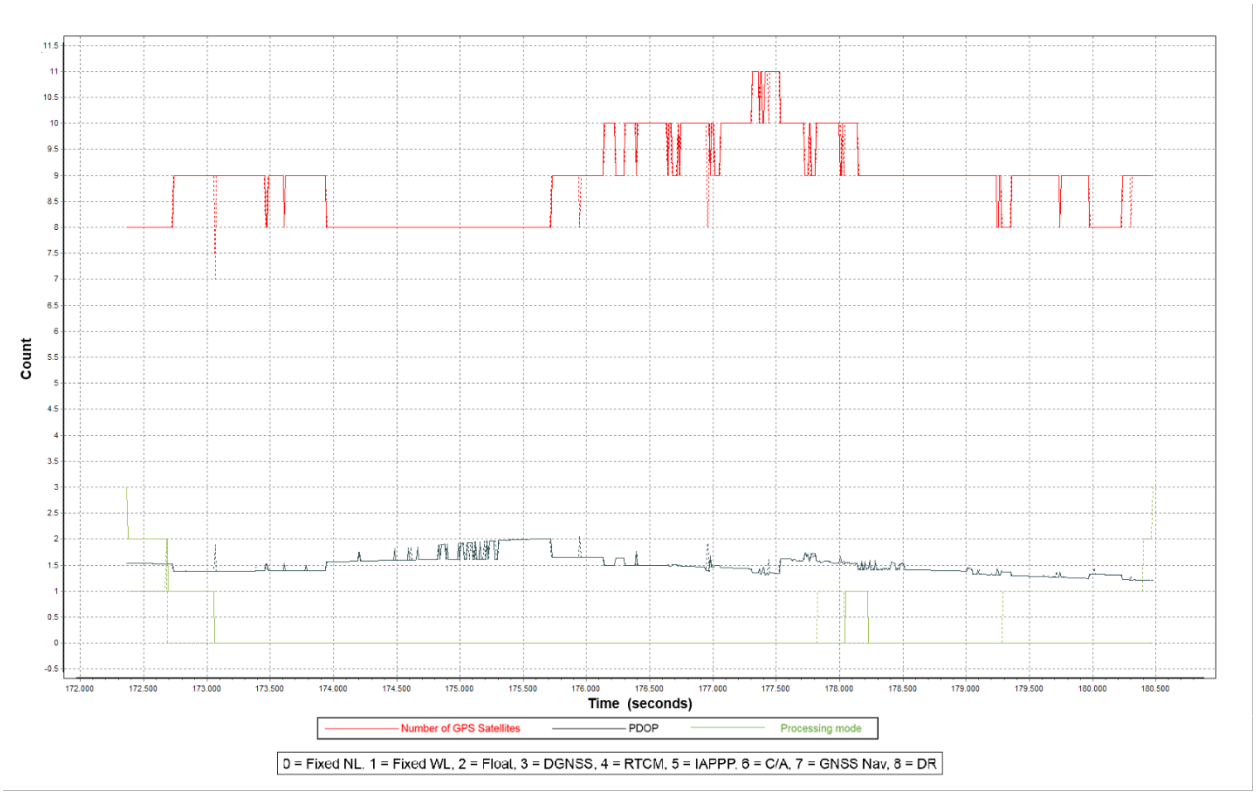


Figure 9. Solution Status Parameters of Calumpang Flight 3669G.

The Solution Status parameters of flight 3669G,one of the Calumpang flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Calumpang flights is shown in Figure 10.

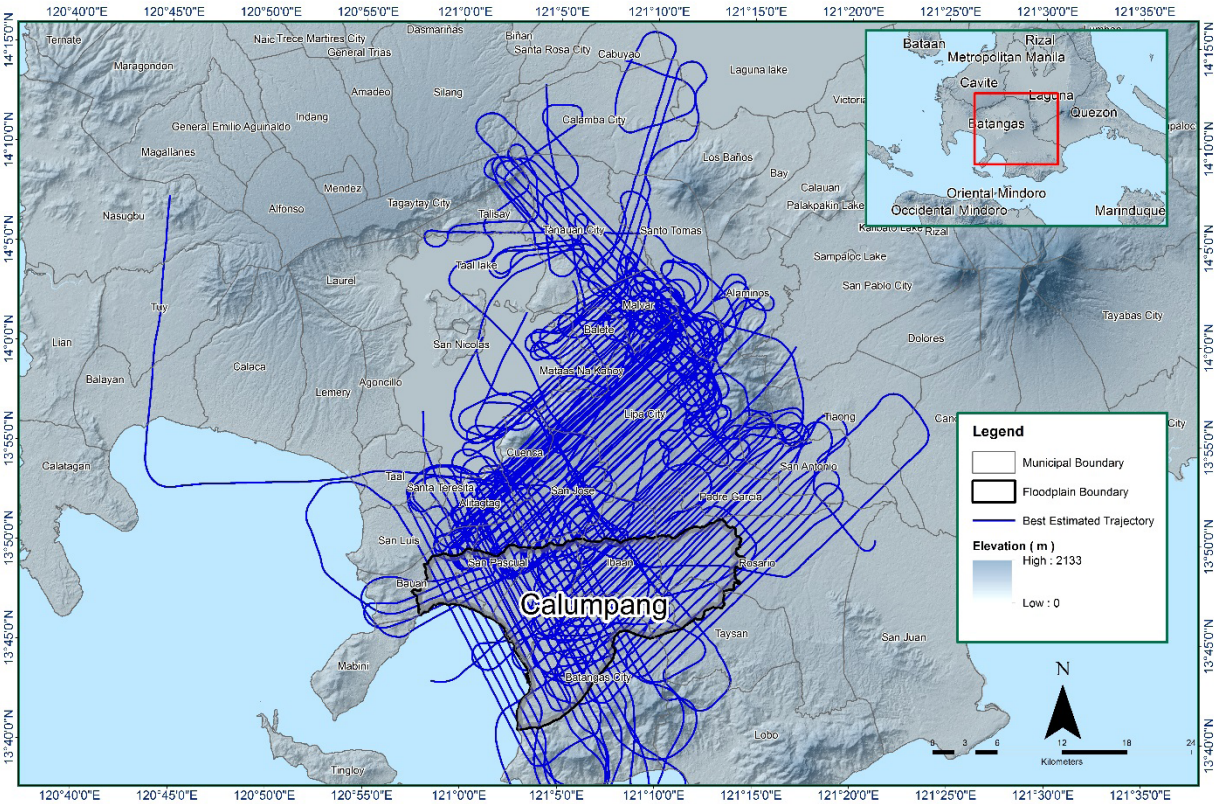


Figure 10. Best estimated trajectory of the LiDAR missions conducted over Calumpang Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 126 flight lines, with some of the flight lines containing two channels, since the Pegasus system contains two channels while Gemini system contains only one. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Calumpang Floodplain are given in Table 12.

Table 12. Self-calibration results values for Calumpang flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000395
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000938
GPS Position Z-correction stdev	(<0.01meters)	0.0017

The optimum accuracy is obtained for all Calumpang flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in ANNEX 8.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Calumpang Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

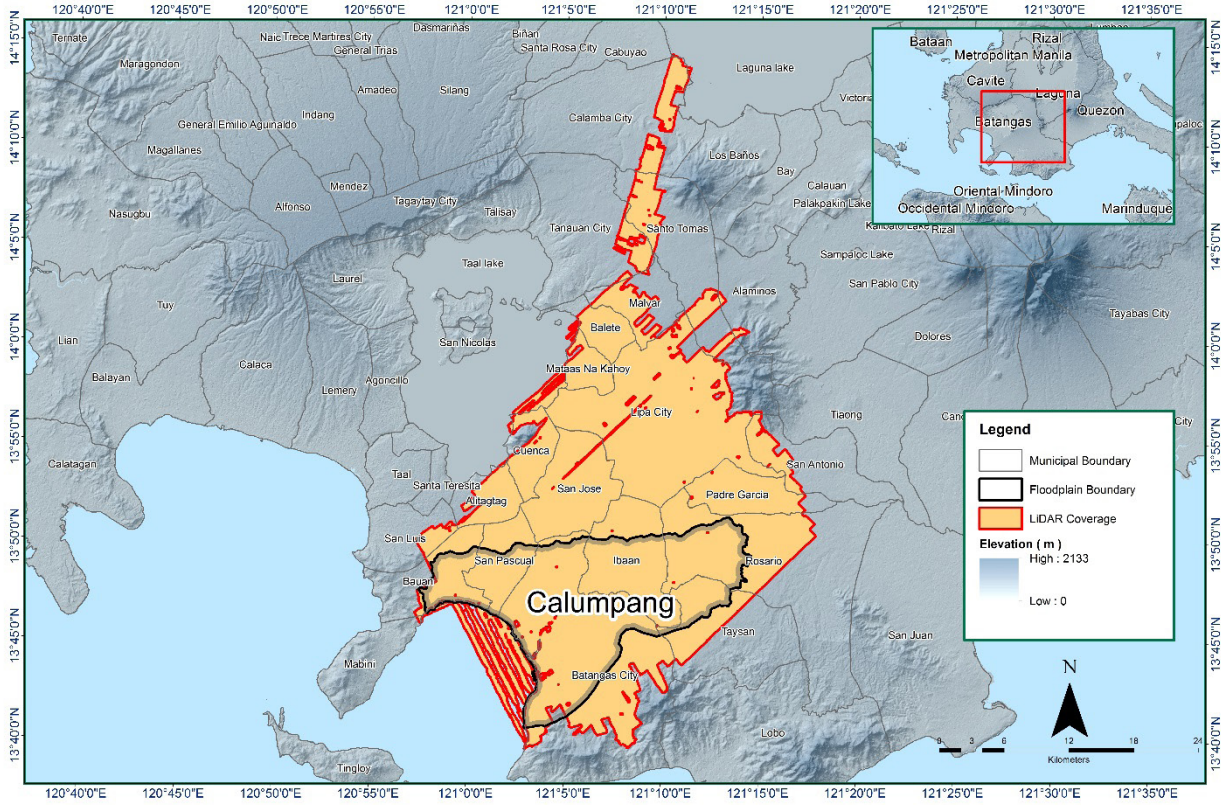


Figure 11. Boundary of the processed LiDAR data over Calumpang Floodplain

The total area covered by the Calumpang missions is 1,317.73 sq km comprised of thirteen (13) flight acquisitions grouped and merged into twelve (12) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Calumpang Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
Batangas_Blk18SA	3000P	88.34
	3002P	
Batangas_Blk18SA_additional	3689G	6.91
Batangas_Blk18SB	3002P	120.42
	3673G	
	3689G	
Batangas_Blk18SB_additional	3691G	4.76
Batangas_Blk18SB_supplement	3669G	139.71
Batangas_Blk18SC	3671G	65.98
Batangas_Blk18SC_supplement	3693G	41.1
Batangas_Blk18O	1119P	184.86
	1123P	
Batangas_Blk18O_supplement2	1123P	175.12
Batangas_Blk18QR	1111P	161.47
	1125P	

Batangas_Blk18QR_supplement1	1107P	158.88
Laguna_Blk18EFG_supplement	1111P	170.18
TOTAL		1,317.73 sq km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Gemini system employs one channel and Pegasus system employs two channels an average value of 1 (blue) would be expected for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

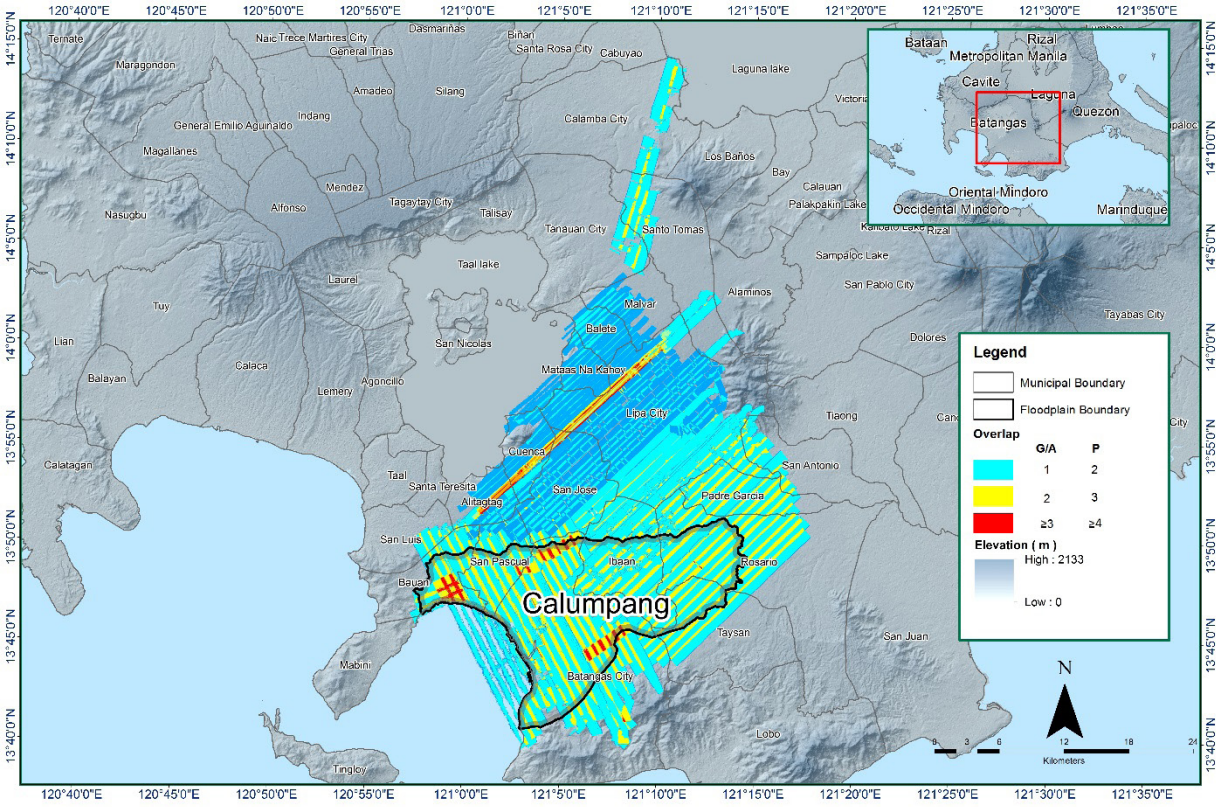


Figure 12. Image of data overlap for Calumpang Floodplain

The overlap statistics per block for the Calumpang Floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 29.57% and 96.27%, respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion, is shown in Figure 13. It was determined that all LiDAR data for Calumpang Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.42 points per square meter.

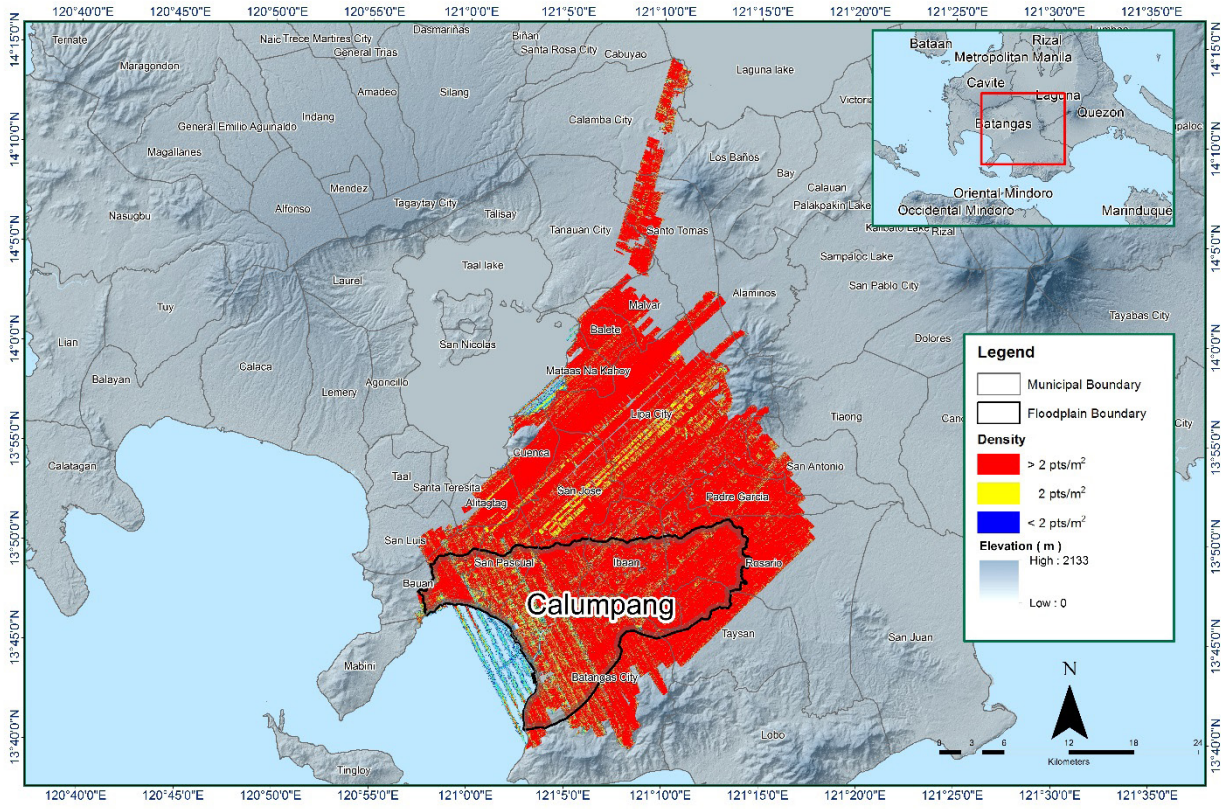


Figure 13. Pulse density map of merged LiDAR data for Calumpang Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, in which bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.2 0m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

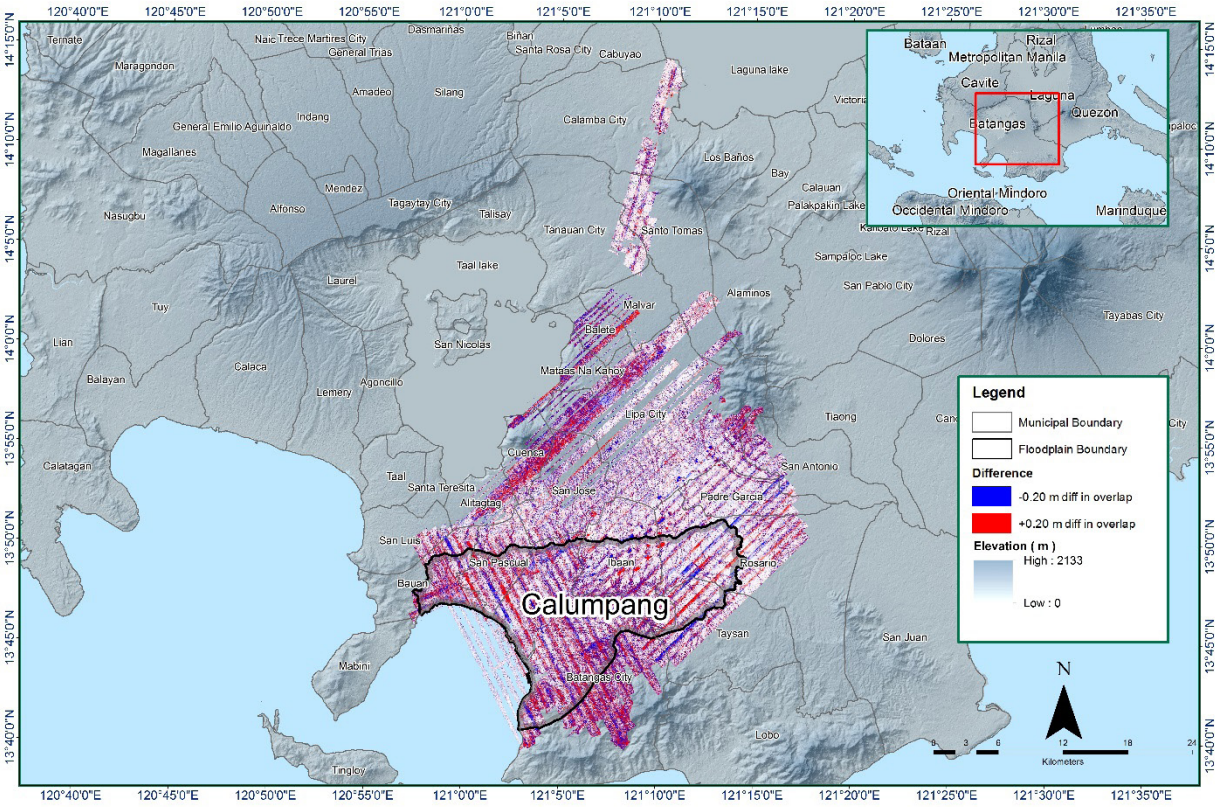


Figure 14. Elevation difference map between flight lines for Calumpang Floodplain

A screen capture of the processed LAS data from a Calumpang flight 3669G loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

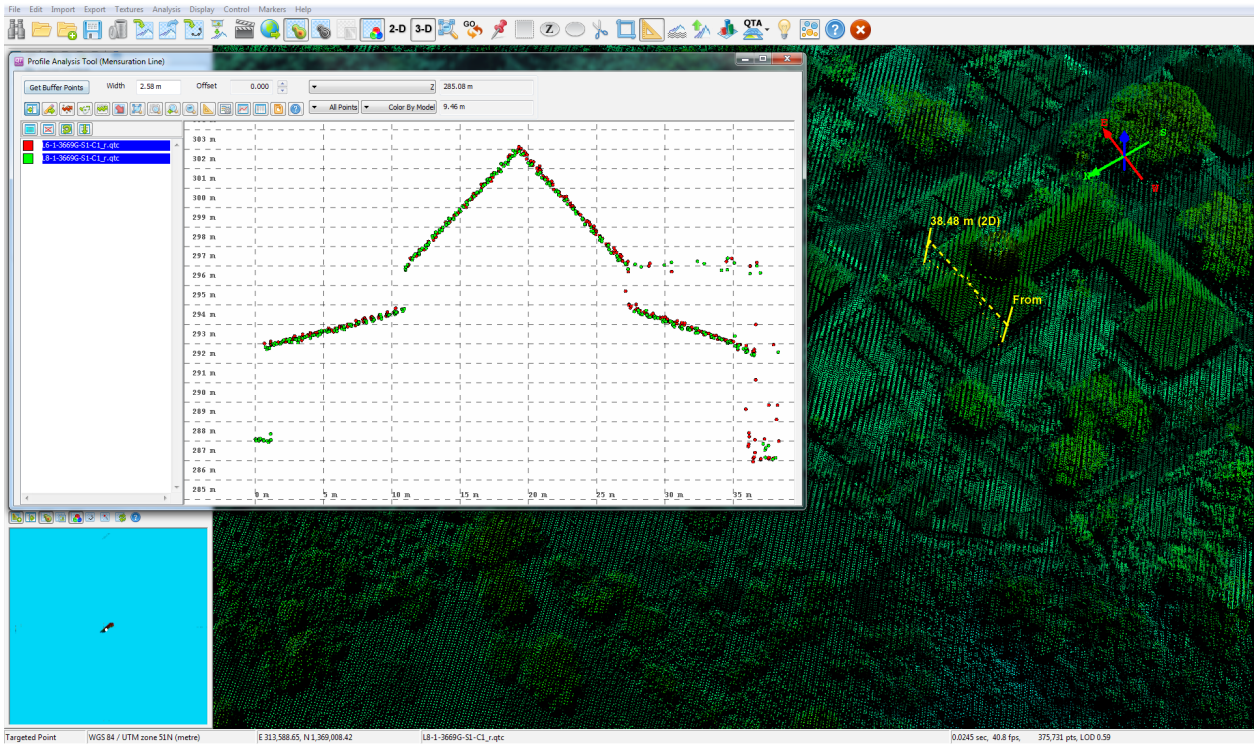


Figure 15. Quality checking for a Calumpang flight 3669G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Calumpang classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	784,972,363
Low Vegetation	748,520,741
Medium Vegetation	1,122,996,120
High Vegetation	1,709,758,858
Building	156,178,800

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Calumpang Floodplain is shown in Figure 16. A total of 1,707 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 858.77 meters and 28.87 meters, respectively.

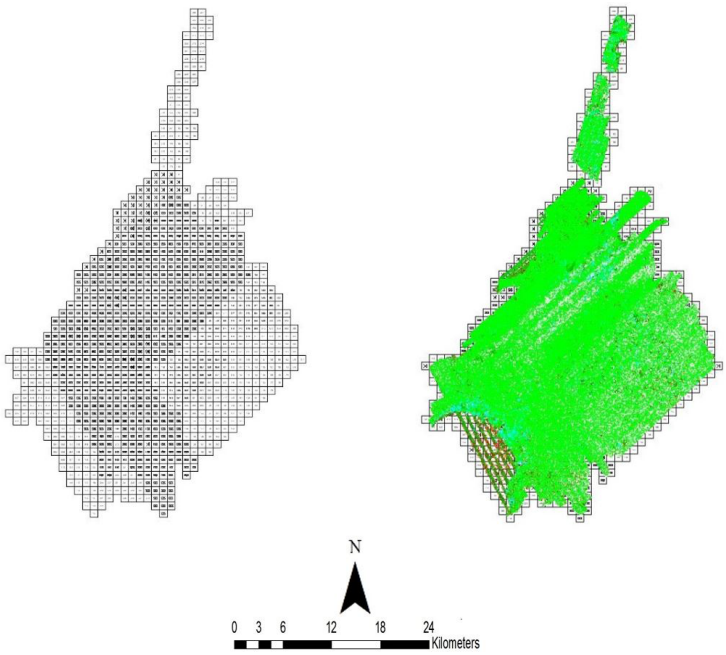


Figure 16. Tiles for Calumpang Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly due to the density of the LiDAR data.

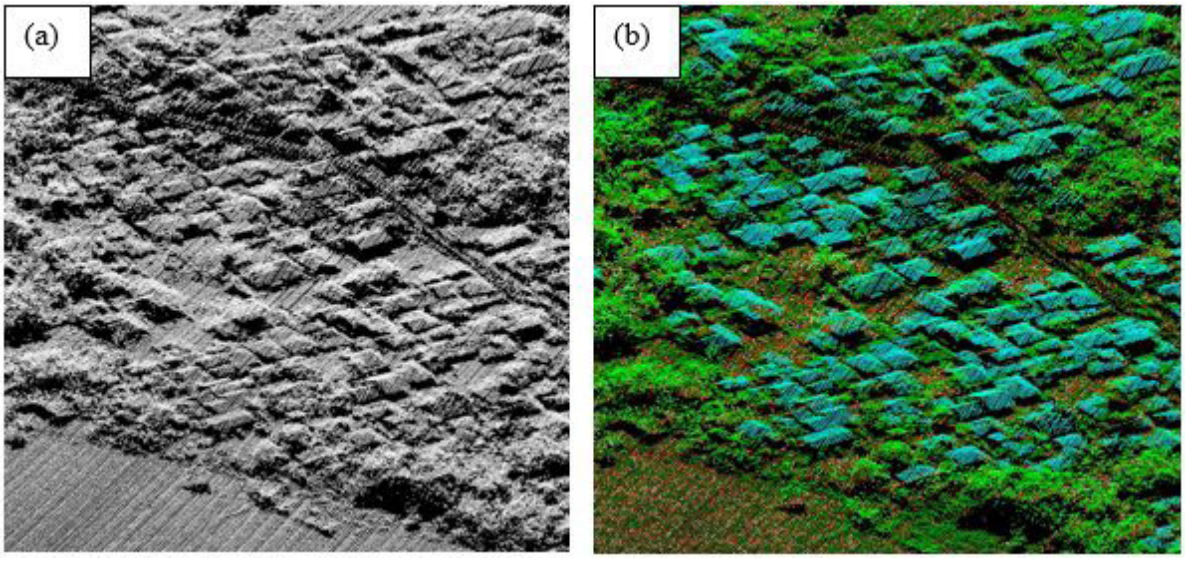


Figure 17. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 18. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

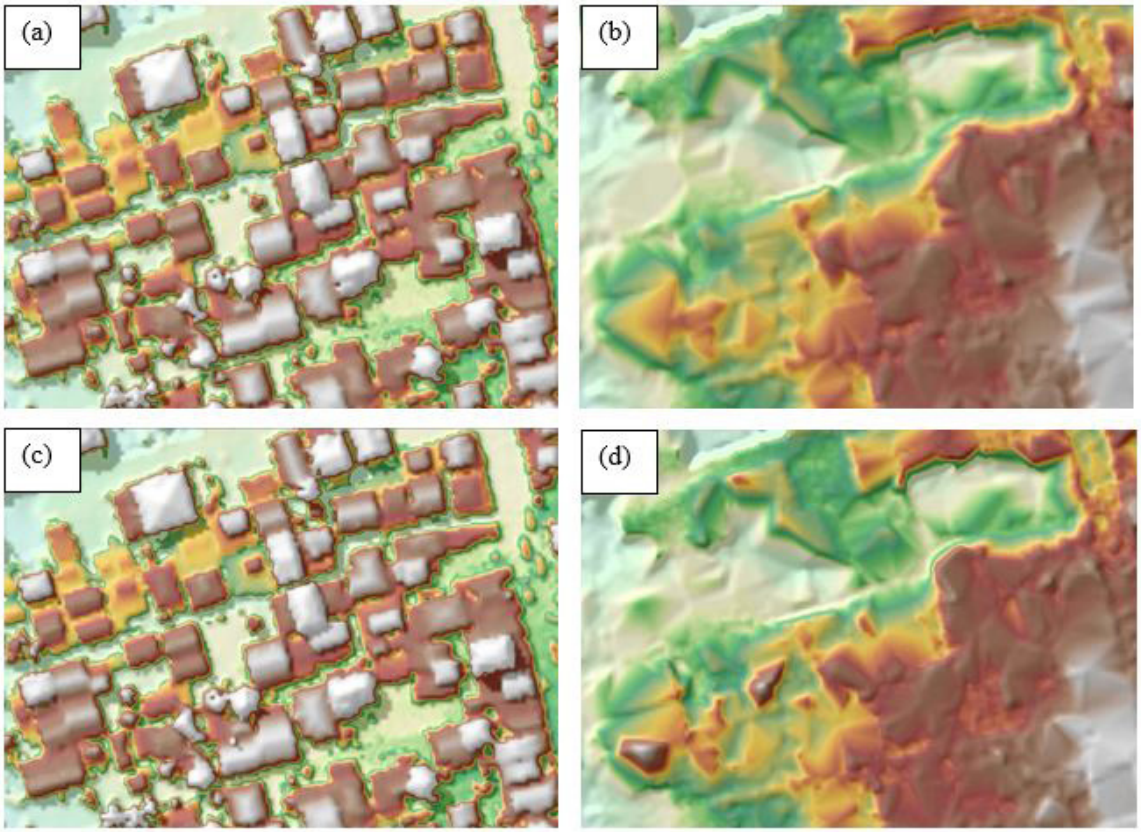


Figure 18. The production of last return DSM (a) and DTM (b); first return DSM (c) and secondary DTM (d) in some portion of Calumpang Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 915 1 km by 1 km tiles area covered by Calumpang Floodplain is shown in Figure 19. After tie-point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Calumpang Floodplain attained a total of 640.89 sq km in orthophotogaph coverage comprised of 1,354 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

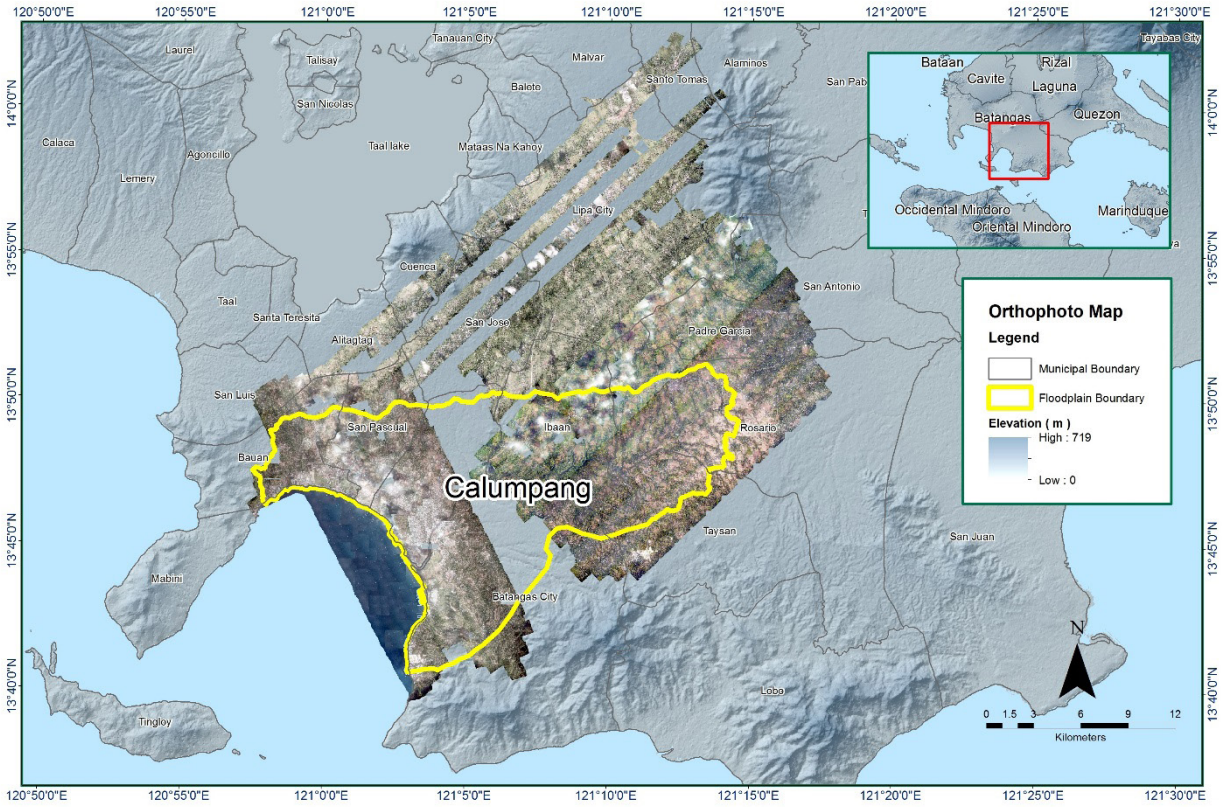


Figure 19. Calumpang Floodplain with available orthophotographs

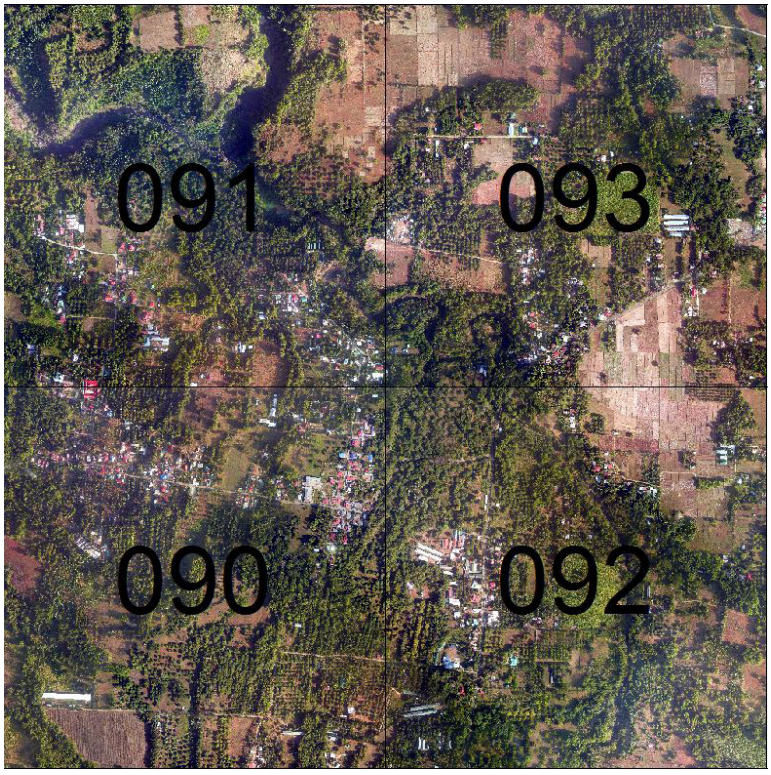


Figure 20. Sample orthophotograph tiles for Calumpang Floodplain

3.8 DEM Editing and Hydro-Correction

Twelve (12) mission blocks were processed for Calumpang Floodplain. These blocks are composed of Batangas and Laguna blocks with a total area of 1,317.73 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with their corresponding area

LiDAR Blocks	Area (sq km)
Batangas_Blk18SA	88.34
Batangas_Blk18SA_additional	6.91
Batangas_Blk18SB	120.42
Batangas_Blk18SB_additional	4.76
Batangas_Blk18SB_supplement	139.71
Batangas_Blk18SC	65.98
Batangas_Blk18SC_supplement	41.10
Batangas_Blk18O	184.86
Batangas_Blk18O_supplement2	175.12
Batangas_Blk18QR_supplement1	158.88
Batangas_Blk18QR	161.47
Laguna_Blk18EFG_supplement	170.18
TOTAL	1,317.73 sq km

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) was also considered to be an impedance to the flow of water along the river and had to be removed (Figure 21b) in order to hydrologically correct the river. The river embankment Figure 21c) had been misclassified and removed during classification process and had to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water. Another example is a building that was still present in the DTM after classification (Figure 21e) and had to be removed through manual editing (Figure 21f).

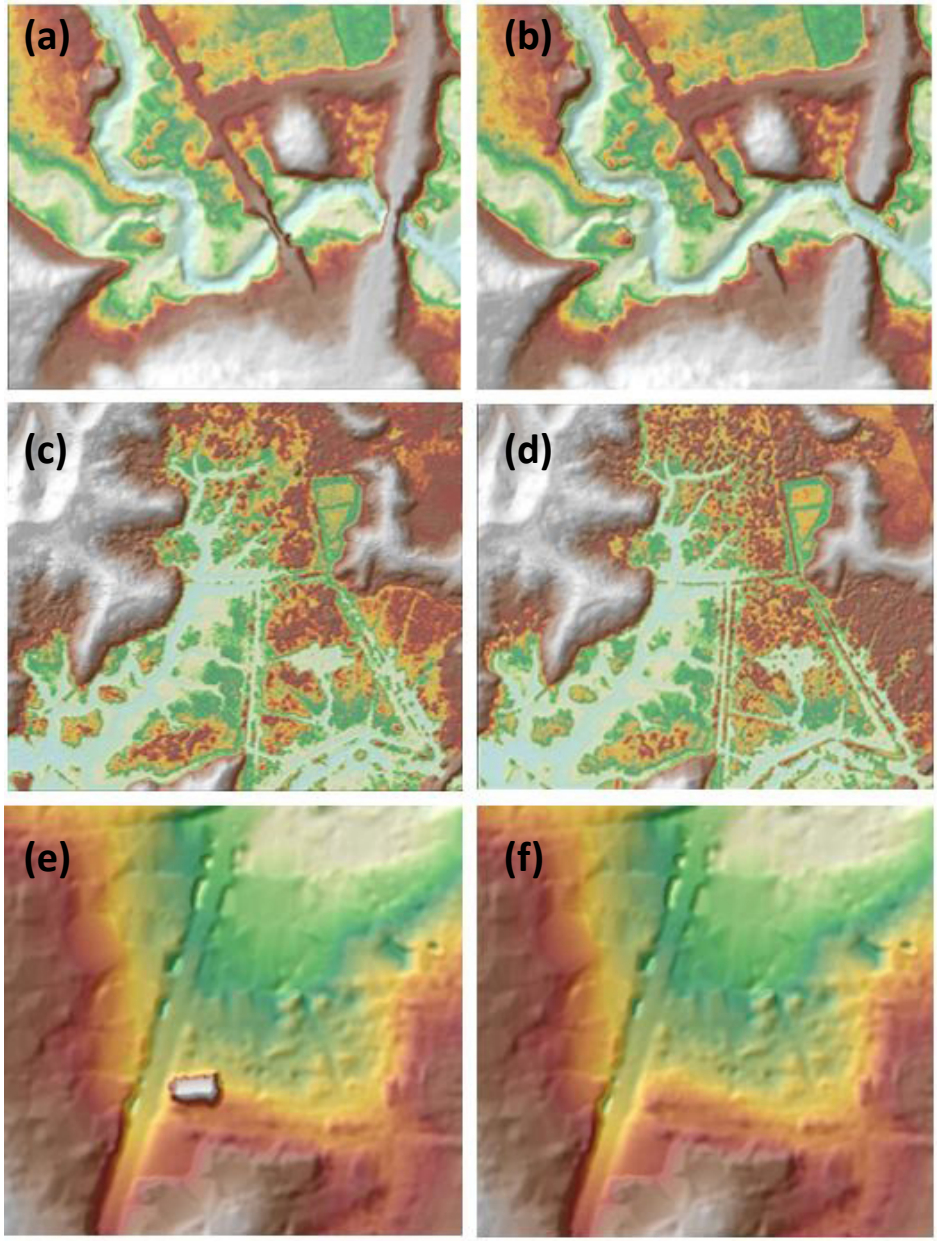


Figure 21. Portions in the DTM of Calumpang Floodplain—a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing

3.9 Mosaicking of Blocks

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

Table 16. Shift values of each LiDAR Block of Calumpang Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Batangas_Blk18SA	0.00	0.00	0.00
Batangas_Blk18SA_additional	0.00	0.00	0.00
Batangas_Blk18SB	0.00	0.00	0.00
Batangas_Blk18SB_additional	0.00	0.00	0.00
Batangas_Blk18SB_supplement	0.00	0.00	0.00
Batangas_Blk18SC	0.00	0.00	0.00
Batangas_Blk18SC_supplement	0.00	0.00	0.00
Batangas_Blk18O	0.00	0.00	0.00
Batangas_Blk18O_supplement2	0.00	0.00	0.02
Batangas_Blk18QR_supplement1	0.00	0.00	-0.12
Batangas_Blk18QR	0.00	0.00	-0.05
Laguna_Blk18EFG_supplement	0.00	0.00	-0.27

Mosaicked LiDAR DTM for Calumpang Floodplain is shown in Figure 22. It can be seen that the entire Calumpang Floodplain is 100% covered by LiDAR data.

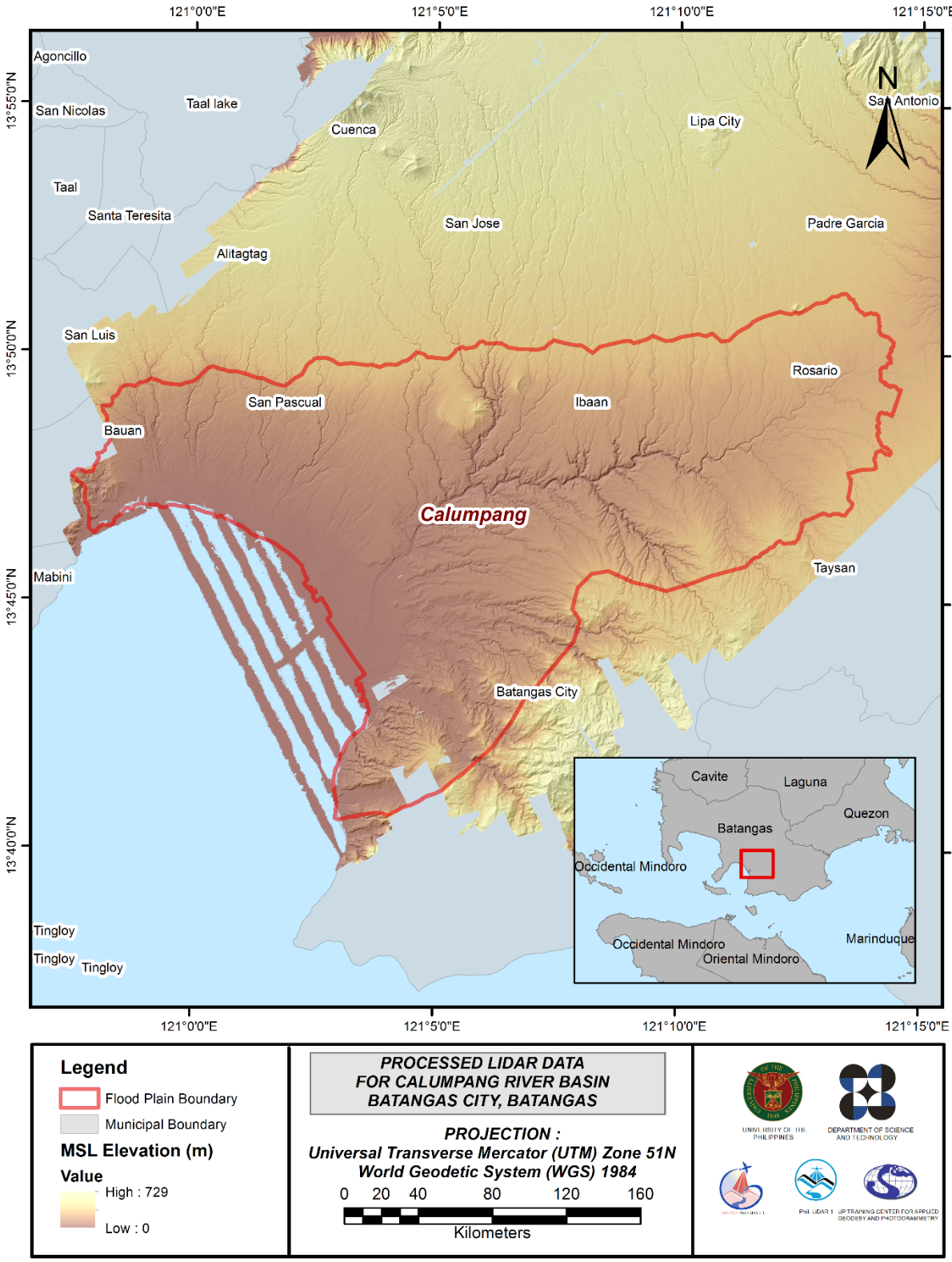


Figure 22. Map of Processed LiDAR Data for Calumpang Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Calumpang to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 24,251 survey points were gathered for all the flood plains within the provinces of CALABARZON wherein the Calumpang 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 24. 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.

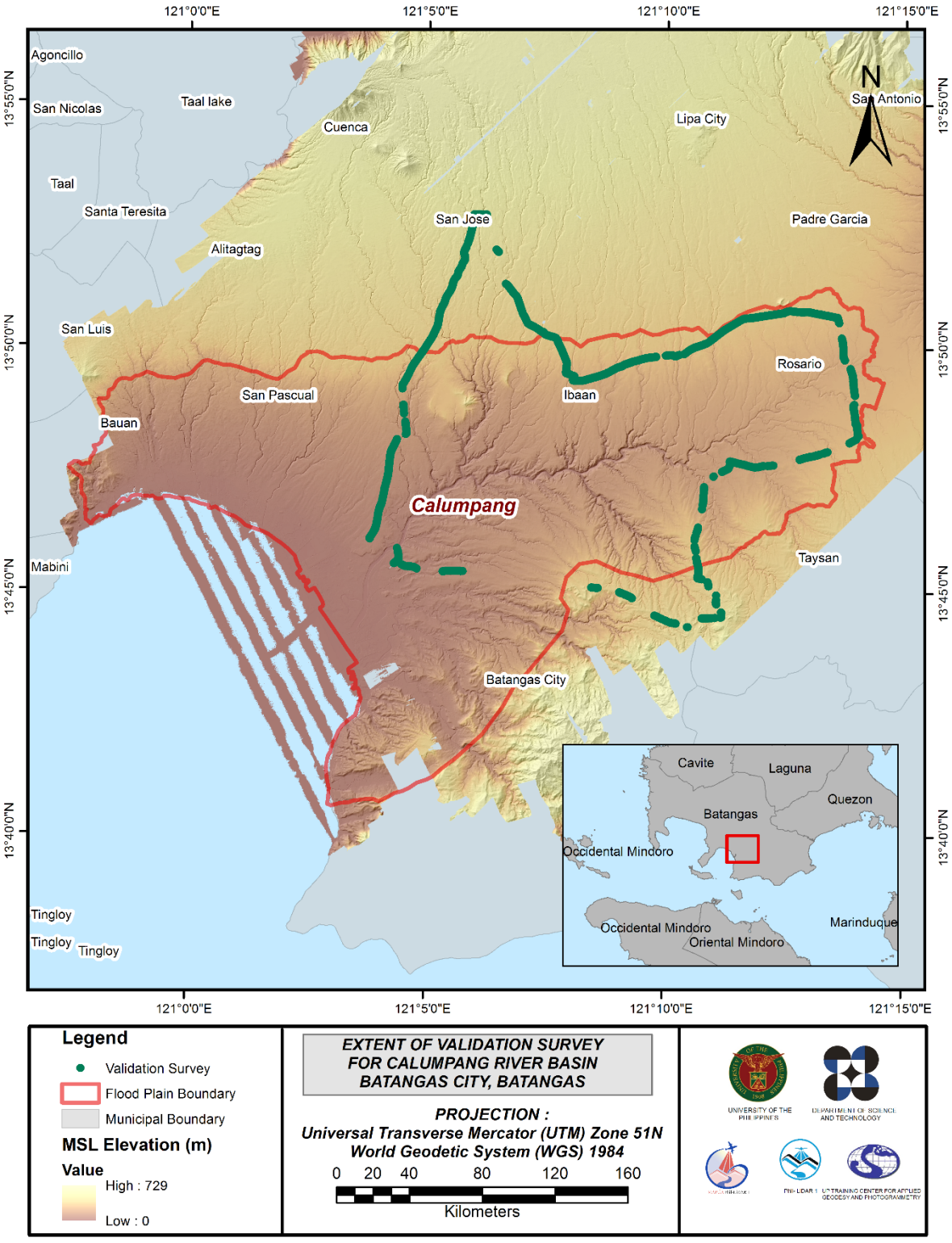


Figure 23. Map of Calumpang Floodplain with validation survey points in green

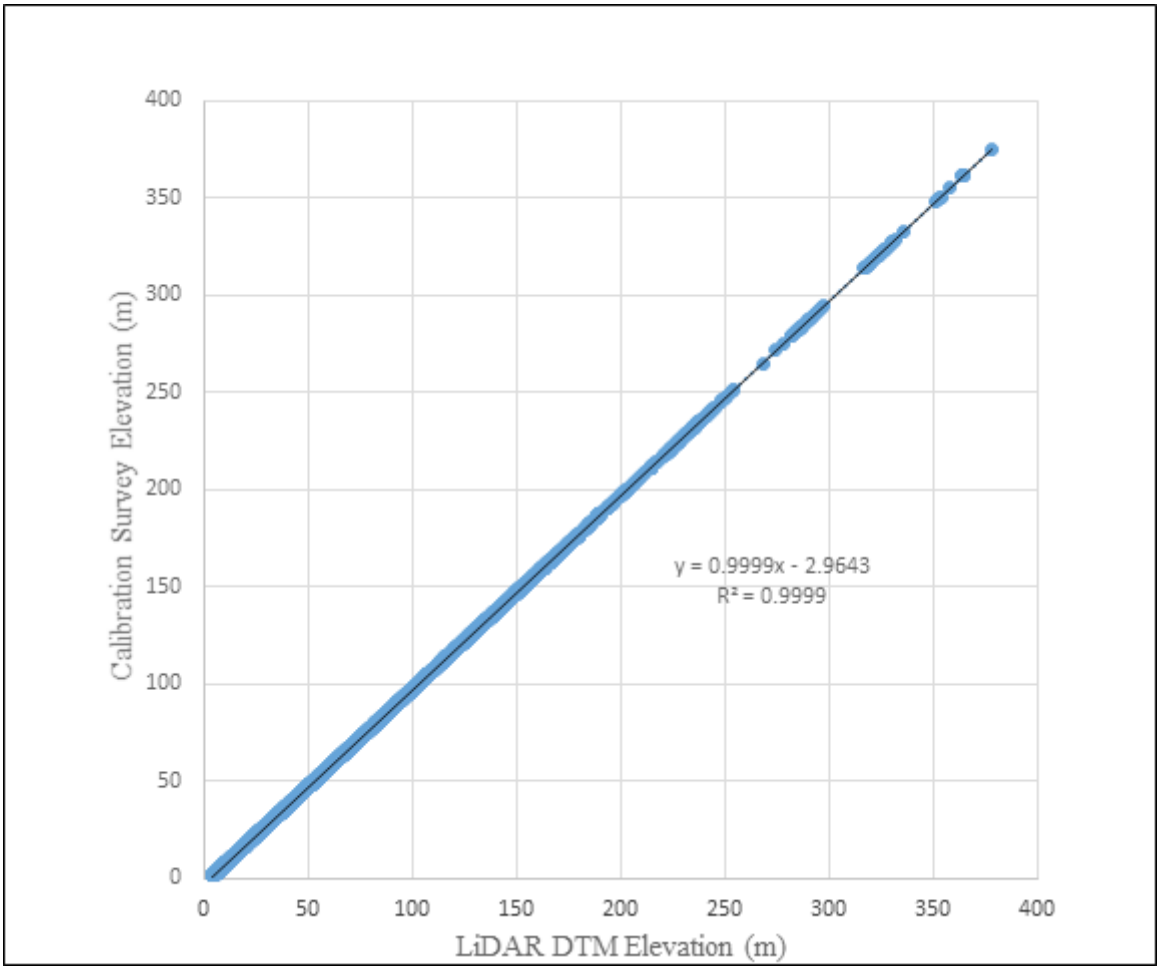


Figure 24. Correlation plot between calibration survey points and LiDAR data

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, resulting in 256 points, were used for the validation of calibrated Calumpang 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.15 meters with a standard deviation of 0.14 meters, as shown in Table 18.

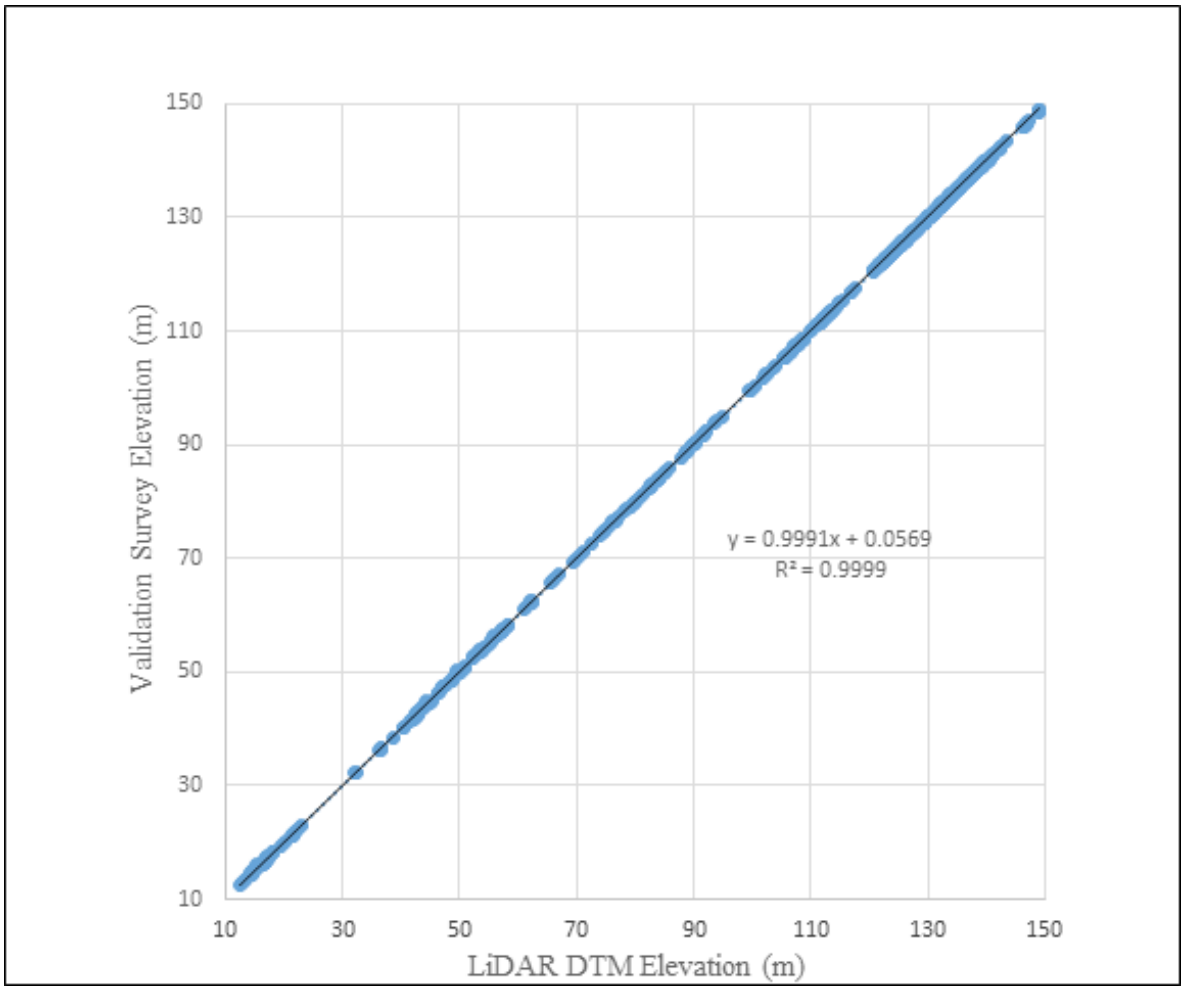


Figure 25. Correlation plot between validation survey points and LiDAR data

Table 18. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.14
Standard Deviation	0.14
Average	-0.03
Minimum	-0.51
Maximum	0.57

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Calumpang with 5,724 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface was represented by the computed RMSE value of 0.80 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Calumpang integrated with the processed LiDAR DEM is shown in Figure 26.

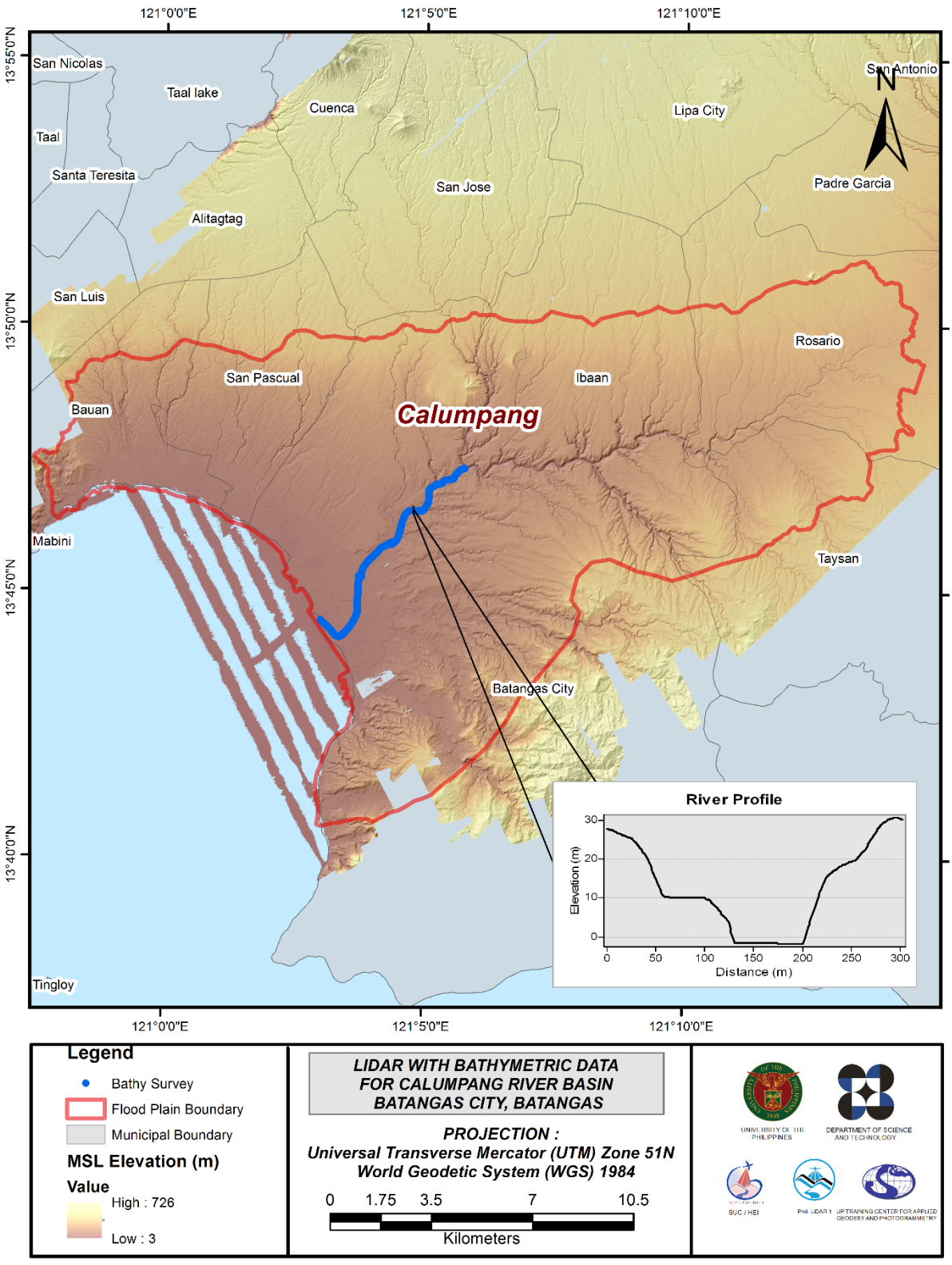


Figure 26. Map of Calumpang Floodplain with bathymetric survey points shown in blue

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 200 m buffer zone. Mosaicked LiDAR DEM with 1 m 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 comprise of main thoroughfares such as highways and municipal and barangay roads essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Calumpang Floodplain, including its 200 m buffer, has a total area of 297.76 sq km. For this area, a total of 9.0 sq km, corresponding to a total of 4,824 building features, are considered for QC. Figure 27 shows the QC blocks for Calumpang Floodplain.

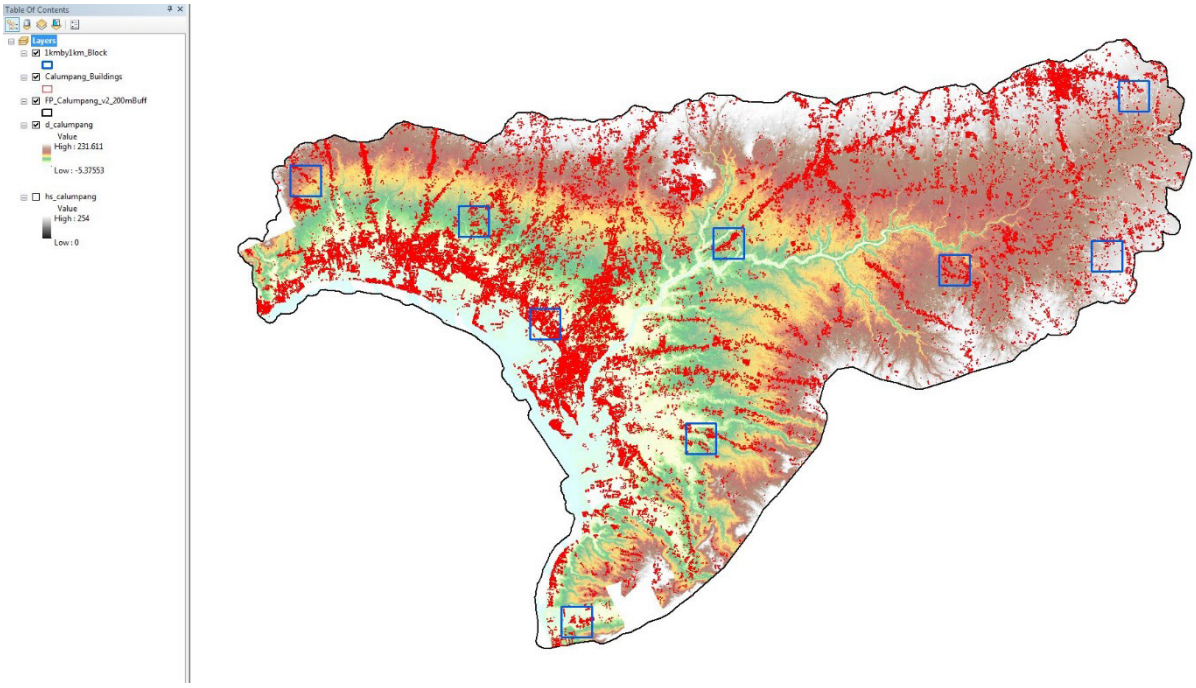


Figure 27. Blocks (in blue) of Calumpang building features subjected to QC

Quality checking of Calumpang building features resulted in the ratings shown in Table 19.

Table 19. Quality checking ratings for Calumpang building features

Floodplain	Completeness	Correctness	Quality	Remarks
Calumpang	97.09	99.05	89.05	PASSED

3.12.2 Height Extraction

Height extraction was done for 110,338 building features in Calumpang Floodplain. Of these building features, 7,796 was filtered out after height extraction, resulting in 102.542 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 17.37 m.

3.12.3 Feature Attribution

The attributes were obtained by 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. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Building features extracted for Calumpang Floodplain

Facility Type	No. of Features
Residential	99,264
School	1,180
Market	151
Agricultural/Agro-Industrial Facilities	17
Medical Institutions	116
Barangay Hall	97
Military Institution	0
Sports Center/Gymnasium/Covered Court	31
Telecommunication Facilities	4
Transport Terminal	12
Warehouse	163
Power Plant/Substation	44
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	29
Religious Institutions	194
Bank	46
Factory	381
Gas Station	34
Fire Station	1
Other Government Offices	117
Other Commercial Establishments	659
Total	102,542

Table 21. Total length of extracted roads for Calumpang Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Calumpang	68.87	298.32	580.50	35.58	0.00	983.27

Table 22. Number of extracted water bodies for Calumpang Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Calumpang	24	0	1	0	0	25

A total of 148 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 28 shows the Digital Surface Model (DSM) ofCalumpang Floodplain overlaid with its ground features.

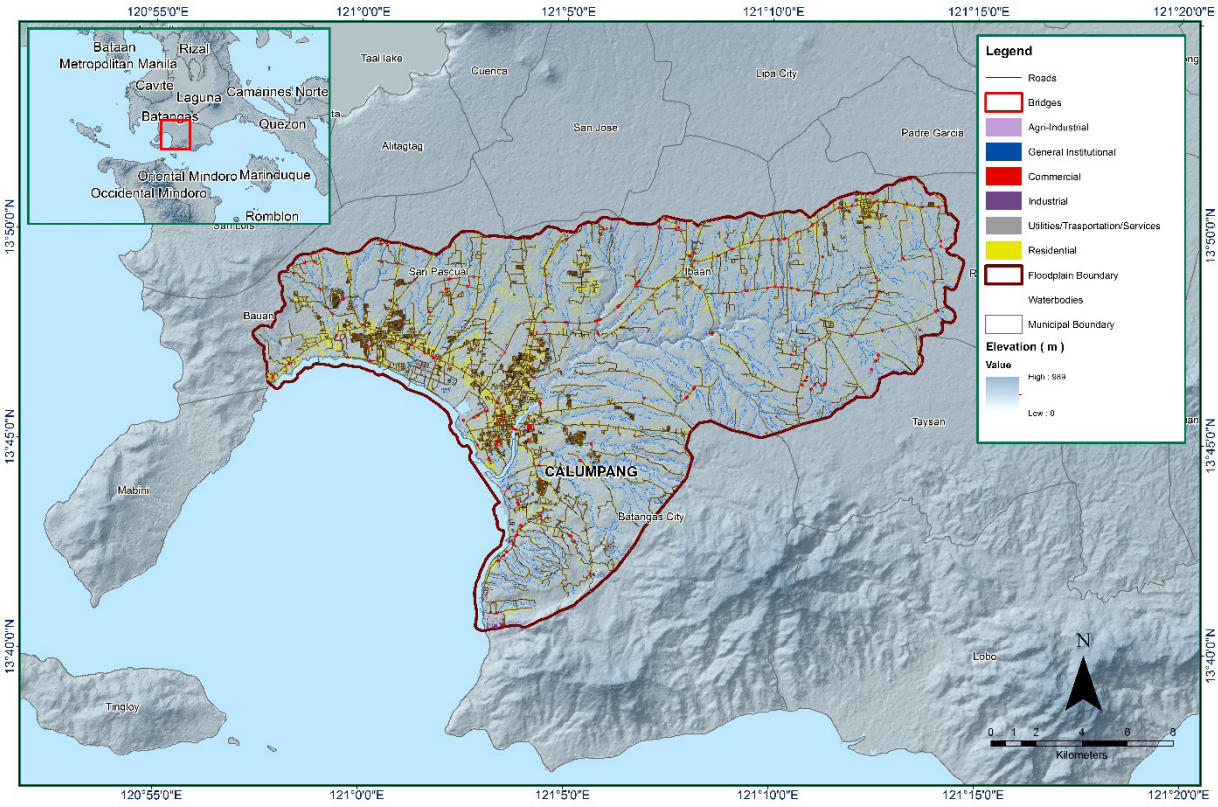


Figure 28. Extracted features for Calumpang Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE CALUMPANG RIVER BASIN

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

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

4.1 Summary of Activities

In line with this, field surveys were conducted from May 14 to 22, 2014 for control survey and bridge cross-section. On August 26 to 30, 2014, bathymetric survey for 9.11 km, bridge as-built, features determination, and water level elevation marking were done using an Ohmex™ single-beam echo sounder and a GNSS PPK survey technique.

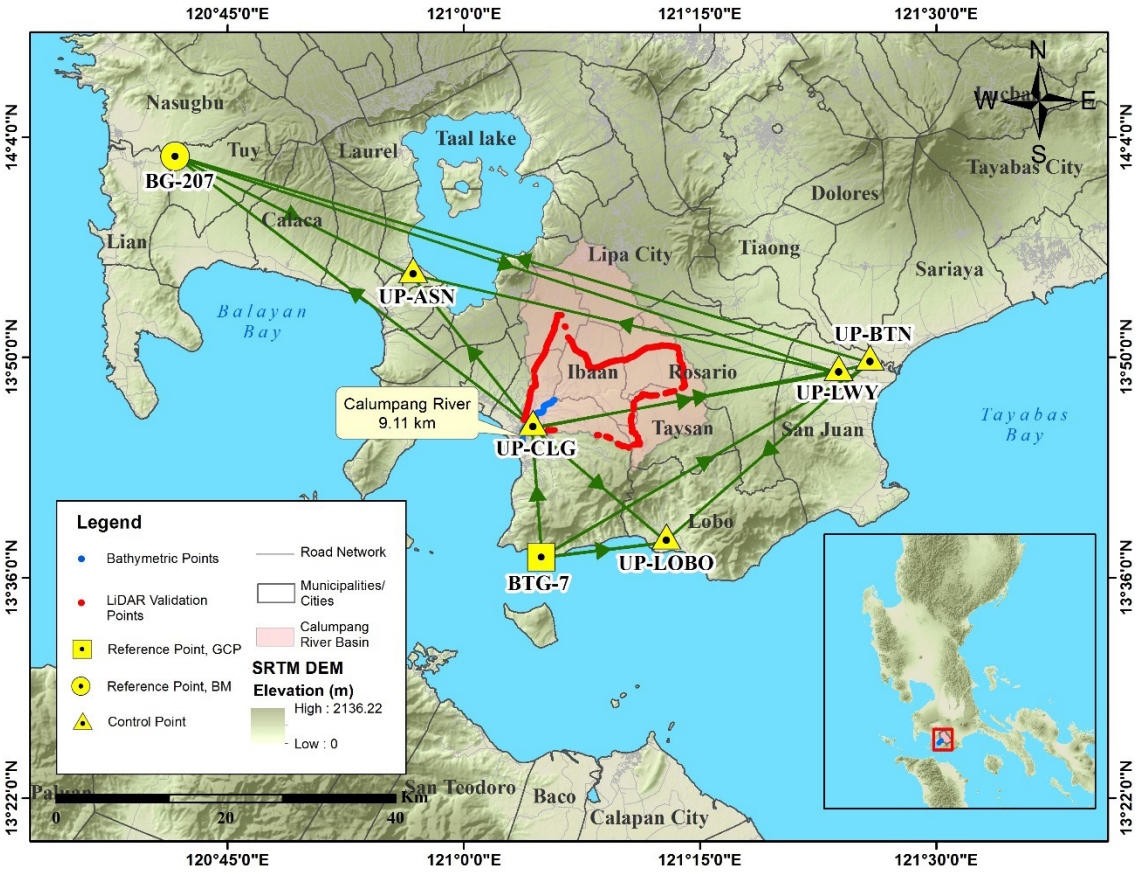


Figure 29. Extent of the bathymetric survey (in blue) in Calumpang River Basin and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network for this survey is composed of six (6) loops established on May 14–22, 2016 occupying the following reference points: BG-207, a first order BM in Brgy. Sabang, Municipality of Tuy; and BTG-7, a first order GCP located in Brgy. Dela Paz, Batangas City.

Five (5) control points were established at the approach of bridges namely UP-BTN at Bantilan Bridge in Brgy. UP-LOBO at Lobo Bridge in Brgy. Lagadlarin, Municipality of Lobo; UP-ASN at San Nicholas Bridge in Brgy. Poblacion, Municipality of San Nicholas; UP-CLG at Calumpang Bridge in Brgy. Kumintang Ibaba, Batangas City; and UP-LWY at Lawaye Bridge in Brgy. Calitcalit, Municipality of San Juan.

The summary of reference and control points and their location is summarized in Table 23 while the GNSS network established is illustrated in Figure 30.

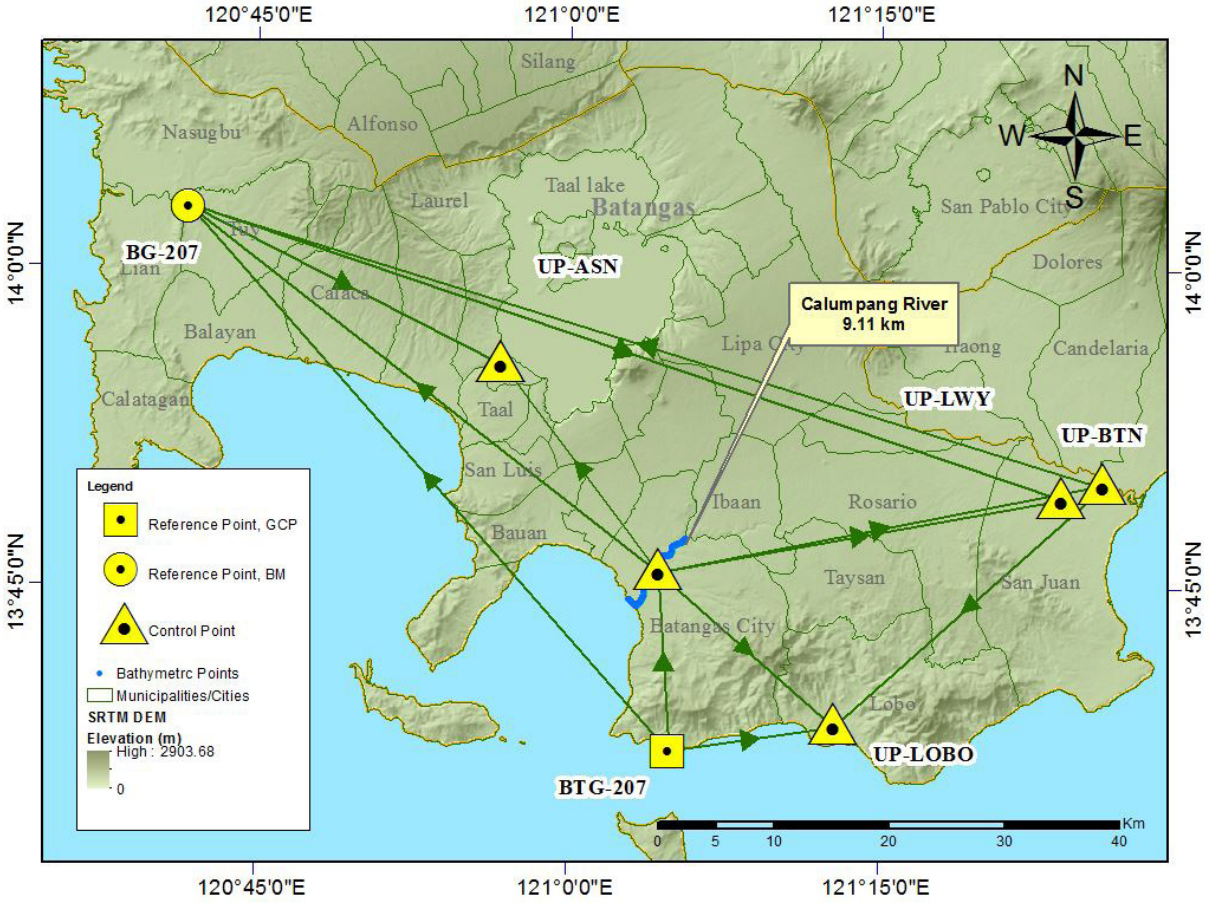


Figure 30. GNSS Network of Calumpang River field survey

Table 23. List of reference and control points used in Cavite-Batangas Region survey (*Source: NAMRIA, UP-TCAGP)*

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
BG207	1st Order	-	-	65.606	22.502	2008
BTG-7	1st Order	13°37'19.49611"	121°04'56.32756"	66.192	-	1992
UP-ASN	UP Established	-	-	-	-	5-22-2014
UP-BTN	UP Established	-	-	-	-	5-21-2014

UP-CLG1	UP Established	-	-	-	-	5-21-2014
UP-LOBO	UP Established	-	-	-	-	5-21-2014
UP-LWY1	UP Established					5-22-2014

The GNSS set-up on reference and established control points in Batangas are shown on Figure 31 to Figure 37.

Figure 31. GNSS receiver, Trimble® SPS 985, set-up at BG-207 at Palico Bridge, Brgy. Luntal, Nasugbu, Batangas

Figure 32. GNSS receiver, Trimble® SPS 985, set-up at BTG-7 in Dela Paz Lighthouse in Brgy. Dela Paz, Batangas City, Batangas

Figure 33. GNSS receiver, Trimble® SPS 882, set-up at UP-ASN at San Nicholas Bridge, Brgy. Poblacion, San Nicholas, Batangas

Figure 34. GNSS base receiver, Trimble® SPS 852, set-up at UP-BTN at Bantilan Bridge, Brgy. Manggalang Banitilan, Sariaya, Quezon

Figure 35. GNSS base receiver, Trimble® SPS 852, set-up at UP-CLG1 in Calumpang Bridge, Brgy. Cumintang Ibaba, Batangas City, Batangas

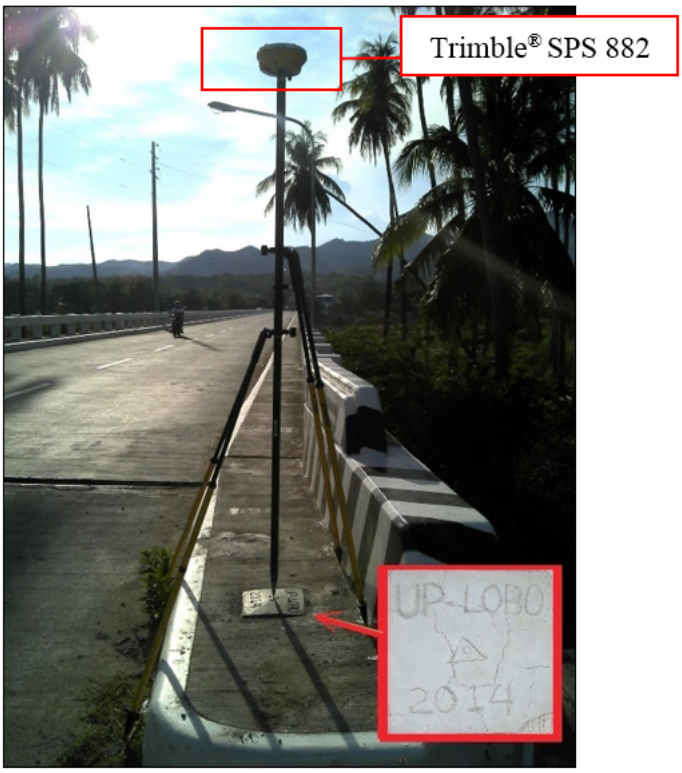


Figure 36. GNSS base receiver, Trimble® SPS 882, set-up at UP-LOBO, in Lobo Bridge, Brgy. Lagadlarin, Lobo, Batangas

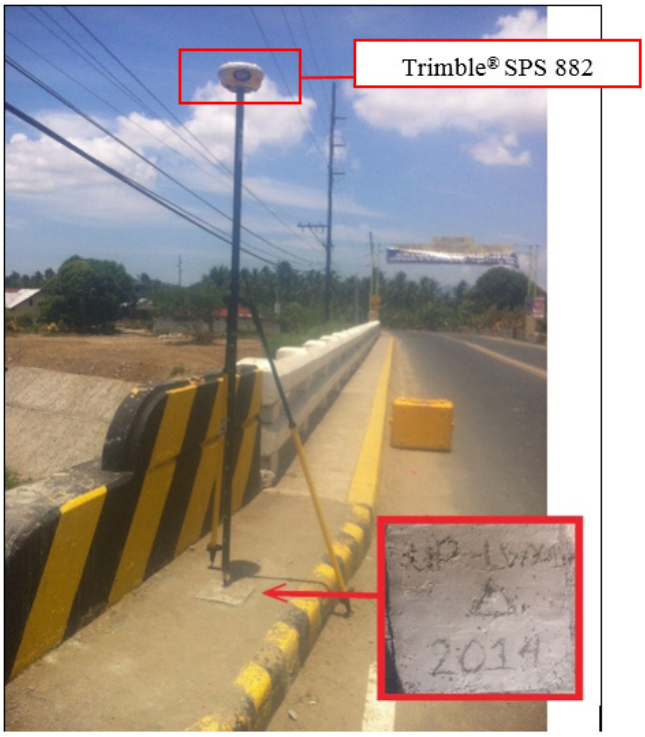


Figure 37. GNSS receiver, Trimble® SPS 882, set-up at UP-LWY1 at Lawaye Bridge, Brgy. Calitcalit-Mabalanoy, San Juan, Batangas

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Calumpang River Basin is summarized in Table 24 generated by TBC software.

Table 24. Baseline processing report for Calumpang River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UPCLG --- BTG7 (B11)	5-22-2014	Fixed	0.003	0.013	356°25'22"	15777.353	-8.962
BTG7 --- UPLOBO (B14)	5-22-2014	Fixed	0.008	0.037	80°16'20"	14501.810	-9.895
UPCLG --- UPBTN (B8)	5-21-2014	Fixed	0.004	0.018	78°44'11"	39325.812	-1.938
UPCLG --- UPBTN (B10)	5-22-2014	Fixed	0.023	0.082	78°44'11"	39325.931	-1.993
UPCLG --- UPBTN (B9)	5-21-2014	Fixed	0.018	0.032	78°44'11"	39326.011	-1.988
UPCLG --- BMBG207 (B7)	5-21-2014	Fixed	0.008	0.021	307°20'38"	51500.583	8.348
UPCLG --- UPLWY (B15)	5-22-2014	Fixed	0.004	0.015	79°31'48"	35577.341	6.690
UPCLG --- UPASN (B6)	5-21-2014	Fixed	0.005	0.020	322°34'54"	22553.641	-5.613
UPCLG --- UPLOBO (B12)	5-22-2014	Fixed	0.006	0.026	131°01'52"	20253.372	-0.954
UPBTN --- BMBG207 (B2)	5-21-2014	Fixed	0.066	0.086	286°35'24"	82928.558	10.191
BTG7 --- UPBTN (B5)	5-21-2014	Fixed	0.004	0.018	58°03'54"	44287.329	-10.884
BTG7 --- UPBTN (B3)	5-21-2014	Fixed	0.017	0.070	58°03'54"	44287.367	-10.925
BTG7 --- UPBTN (B4)	5-21-2014	Fixed	0.011	0.024	58°03'54"	44287.360	-10.823
UPBTN --- UPLOBO (B13)	5-22-2014	Fixed	0.011	0.045	228°04'35"	31344.157	0.983
BMBG207 --- UPLWY (B17)	5-22-2014	Fixed	0.015	0.033	107°58'47"	79868.067	-1.689
BMBG207 --- UPASN (B1)	5-21-2014	Fixed	0.005	0.022	115°58'50"	30324.834	-14.030
UPLWY --- UPASN (B16)	5-22-2014	Fixed	0.011	0.021	283°18'29"	50016.834	-12.285

As shown in Table 24, a total of seventeen (17) baselines were processed with reference elevation of point BG-207 and coordinates of BTG-7 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates (Table 26) of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 25 to Table 27 for the complete details.

The seven (7) control points, BG-207, BTG-7, UP-ASN, UP-BTN, UP-CLG, UP-LOBO, and UP-LWY were occupied and observed simultaneously to form a GNSS loop. Coordinates of point BTG-7 and elevation value of BG-207 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points would be computed.

Table 25. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
BG-207	Grid				Fixed
BTG-7	Global	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. The fixed control points, BG-207 and BTG-7, have no values for standard elevation and coordinates error, respectively.

Table 26. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MBG207	250979.768	0.014	1554083.399	0.009	22.502	?	e
BTG7	292538.897	?	1506749.028	?	20.801	0.072	LL
UPASN	278117.299	0.013	1540530.569	0.008	7.619	0.060	
UPBTN	330309.700	0.008	1529876.941	0.006	9.361	0.075	
UPCLG	291679.224	0.007	1522505.093	0.005	12.287	0.058	
UPLOBO	306852.492	0.014	1509086.720	0.008	10.498	0.094	
UPLWY	326716.786	0.013	1528689.759	0.008	18.019	0.064	

The network was fixed at reference points BG-207 and BTG-7 for elevation and coordinate values, respectively. With the mentioned equation , for horizontal; and for the vertical; the computation for the accuracy for the controls are as follows:

BG-207

horizontal accuracy = $\sqrt{((1.4)^2 + (0.9)^2}$
= $\sqrt{(1.96 + 0.81)}$
= 1.66 cm < 20 cm
vertical accuracy = Fixed

BTG-7

horizontal accuracy = Fixed
vertical accuracy = 7.2 cm

UP-ASN

horizontal accuracy = $\sqrt{((1.3)^2 + (0.8)^2}$
= $\sqrt{(1.69 + 0.64)}$
= 1.53 cm < 20 cm
vertical accuracy = 6.0 cm

UP-BTN

horizontal accuracy = $\sqrt{((0.8)^2 + (0.6)^2}$
= $\sqrt{(0.64 + 0.36)}$
= 1.0 cm < 20 cm
vertical accuracy = 7.5 cm

UP-CLG

horizontal accuracy = $\sqrt{((0.7)^2 + (0.5)^2}$
= $\sqrt{(0.49 + 0.25)}$
= 0.86 cm < 20 cm
vertical accuracy = 5.8 cm

UP-LOB

horizontal accuracy = $\sqrt{((1.4)^2 + (0.8)^2}$
= $\sqrt{(1.96 + 0.64)}$
= 1.48 cm < 20 cm
vertical accuracy = 9.4 cm

UP-LWY

horizontal accuracy = $\sqrt{((1.3)^2 + (0.8)^2}$
= $\sqrt{(1.69 + 0.64)}$
= 1.52 cm < 20 cm
vertical accuracy = 6.4 cm

Following the given formula, the horizontal and vertical accuracy result of the seven occupied control points are within the required precision of the program

Table 27. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height	Height Error (Meter)	Constraint
BMBG207	N14°02'47.32674"	E120°41'38.93608"	65.606	?	e
BTG7	N13°37'19.49611"	E121°04'56.32756"	66.192	0.072	LL
UPASN	N13°55'34.60792"	E120°56'47.03882"	51.610	0.060	
UPBTN	N13°50'00.87917"	E121°25'47.84870"	55.321	0.075	
UPCLG	N13°45'51.87502"	E121°04'23.55781"	57.236	0.058	
UPLOBO	N13°38'39.10157"	E121°12'51.89916"	56.291	0.094	
UPLWY	N13°49'21.47536"	E121°23'48.47095"	63.917	0.064	

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

The summary of reference and control points used is indicated in Table 28.

Table 28. Reference and control points and their location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	Elevation in MSL (m)
BG207	1st Order	14°02'47.32674"	120°41'38.93608"	65.606	1554083	250979.8	22.502
BTG-7	1st Order	13°37'19.49611"	121°04'56.32756"	66.192	1506749	292538.9	20.801
UP-ASN	UP Established	13°55'34.60792"	120°56'47.03882"	51.61	1540531	278117.3	7.619
UP-BTN	UP Established	13°50'00.87917"	121°25'47.84870"	55.321	1529877	330309.7	9.361
UP-CLG1	UP Established	13°45'51.87502"	121°04'23.55781"	57.236	1522505	291679.2	12.287
UP-LOBO	UP Established	13°38'39.10157"	121°12'51.89916"	56.291	1509087	306852.5	10.498
UP-LWY1	UP Established	13°49'21.47536"	121°23'48.47095"	63.917	1528690	326716.8	18.019

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

Cross-section and as-built survey were done on May 20, 2014 and August 27, 2014, respectively, at the downstream side of Bridge of Promise in Brgy Cumintang Ibaba, Batangas City as shown in Figure 38. A Trimble® SPS 882 in GNSS PPK survey technique was used during the survey.

Figure 38. Bridge of Promise Panorama

A total of 72 points with an approximate length of 335.59 m were gathered for Bridge of Promise using the control point UP-CLG as the GNSS base station. The planimetric map, cross-sectional diagram, and bridge as-built form are shown in Figure 39 to Figure 41.

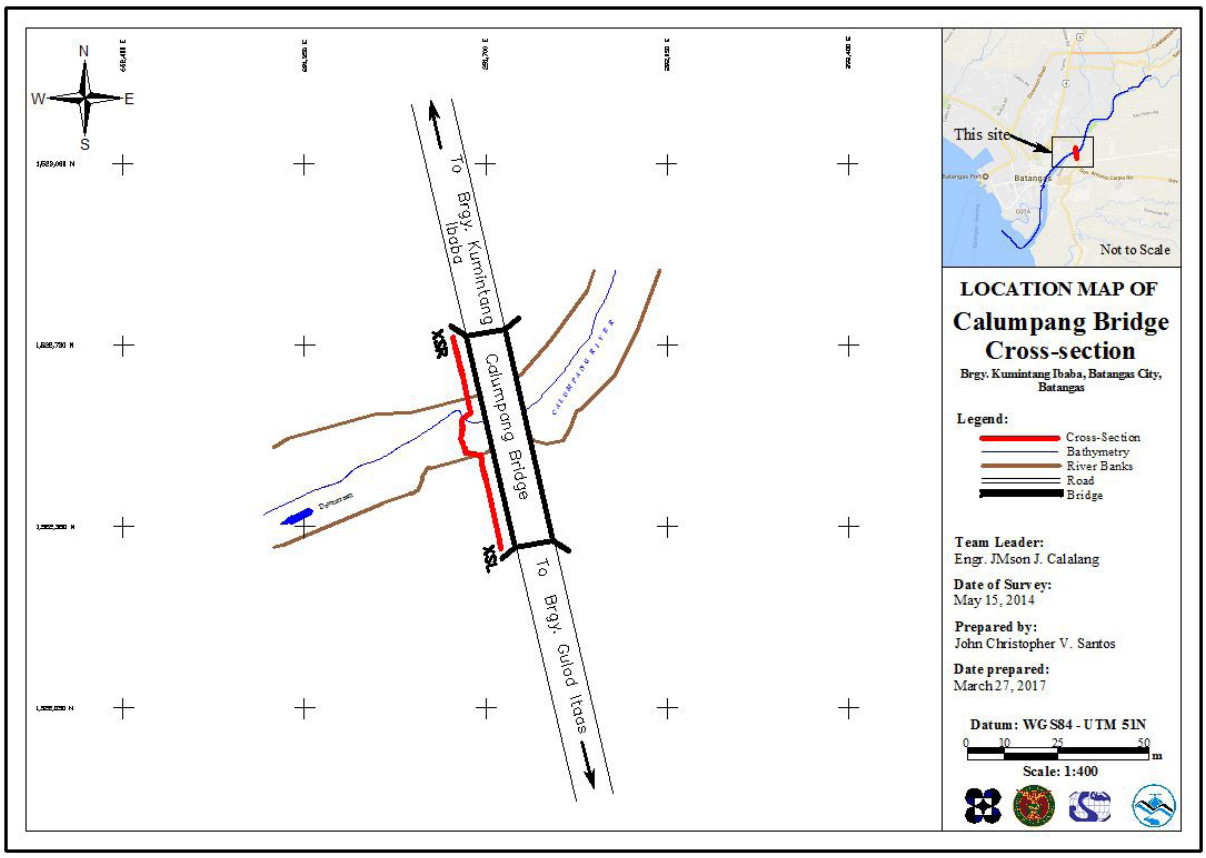


Figure 39. Calumpang bridge cross-section location map

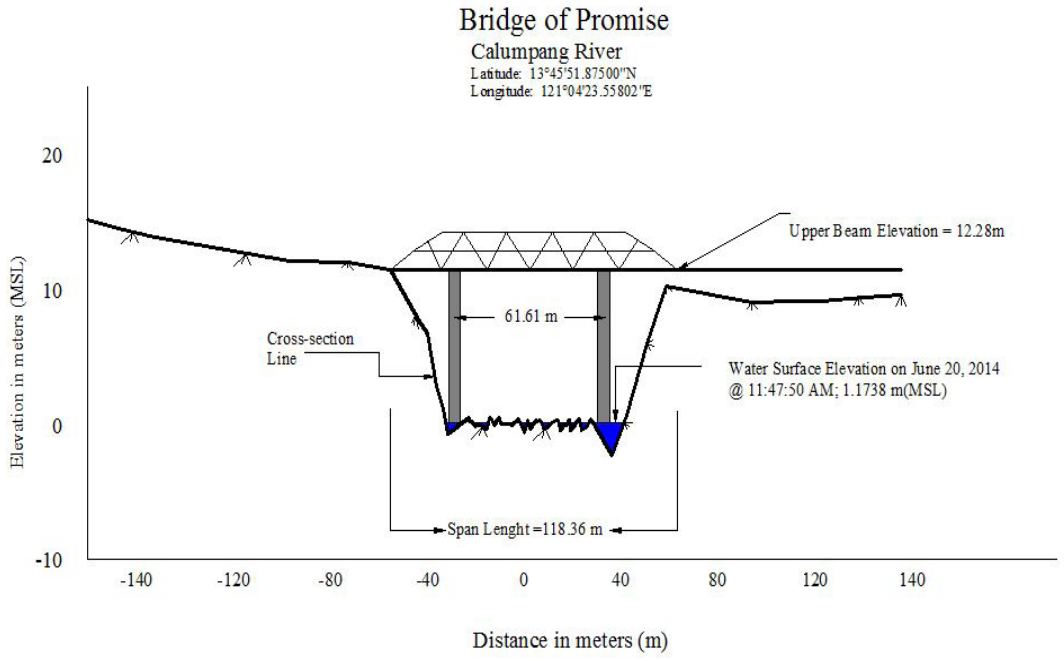


Figure 40. Bridge of Promise cross-section diagram

Bridge Name: Bridge of Promise **Date:** August 27, 2014

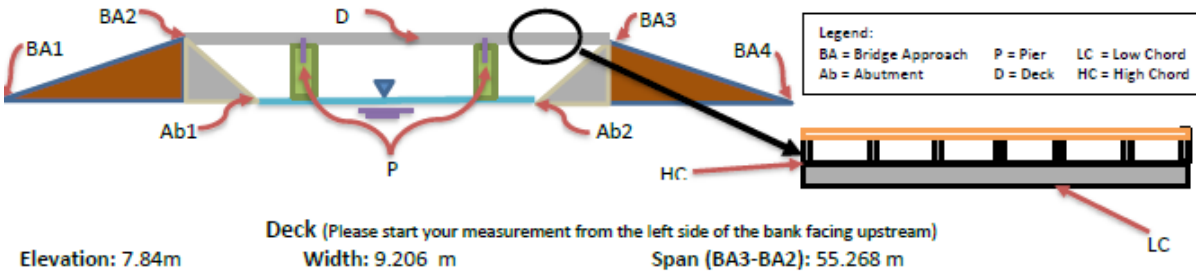
River Name: Calumpang River **Time:** 11: 30 AM

Location (Brgy, City,Region): Barangay Kumintang Ibaba, Batangas City

Survey Team: DVBC Batangas Survey Team

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

Latitude: 13°45'51.87500"N **Longitude:** 121°04'23.55802"E



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

Elevation: 7.84m **Width:** 9.206 m **Span (BA3-BA2):** 55.268 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	12.275	
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	12.271 m	BA3	164.560	12.555 m
BA2	46.203	12.253 m	BA4	249.58 m	12.395 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 downsteam)

Shape: cylinder **Number of Piers:** 2 **Height of column footing:** _____

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	74.413	12.275	
Pier 2	136.025	12.198	
Pier 3			
Pier 4			
Pier 5			
Pier 6			

Figure 41. Bridge of Promise bridge data form

The water marking was done on the pier of the Bridge of Promise in Brgy. Kumintang Ibaba, Batangas City using a Trimble® SPS 882 PPK survey technique GNSS point observation. The water surface elevation of Calumpang River was acquired on August 27, 2014 at 2:49 PM. The resulting water surface elevation data is 0.541 m in MSL. This value was translated onto the bridge's pier which would serve as reference for the partner HEI, MIT.

Figure 42. Determination of water surface elevation at the river banks of the Bridge of Promise

Figure 43. Marking of MSL-based elevation on the right side of a pier in Bridge of Promise

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 8, 2014 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the top of the vehicle as shown in Figure 44. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 2.09 m measured from the ground up to the bottom of notch of the GNSS rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-CLG occupied as the GNSS base station all throughout the conduct of the survey.

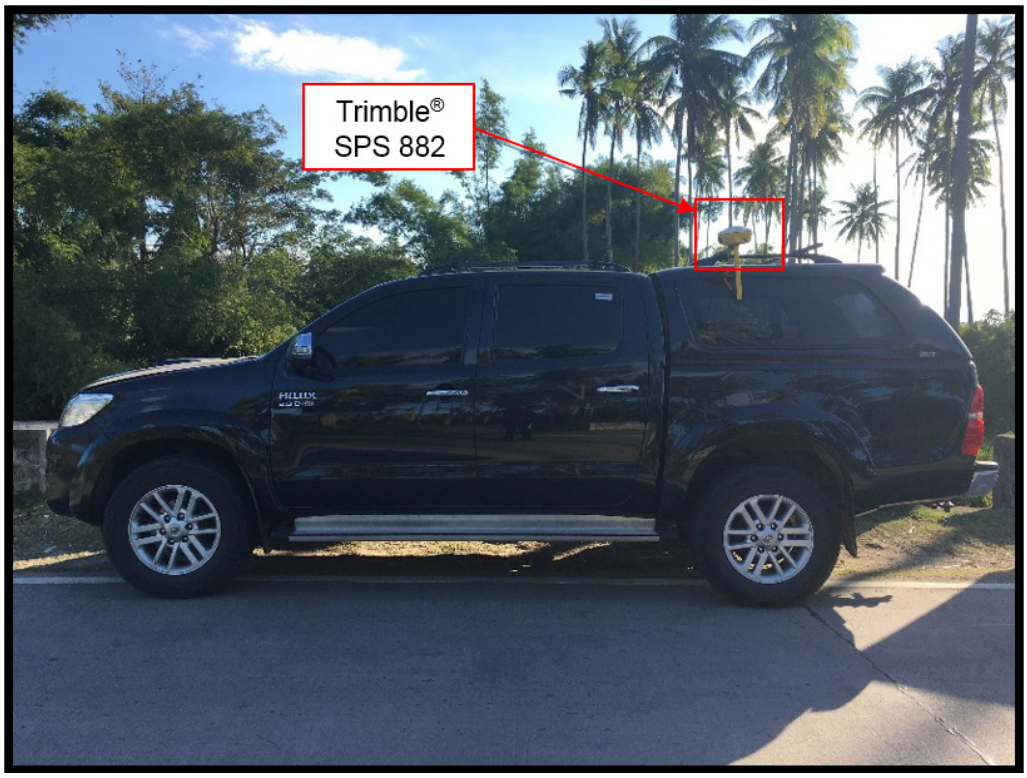


Figure 44. Ground Validation set up in Calumpang Survey

The validation points acquisition survey for the Calumpang River Basin traversed the Municipality of San Jose, Ibaan, Rosario, Taysan, and Batangas City. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 4,470 points with an approximate length of 60 km was acquired for the validation point acquisition survey as shown in the map in Figure 45.

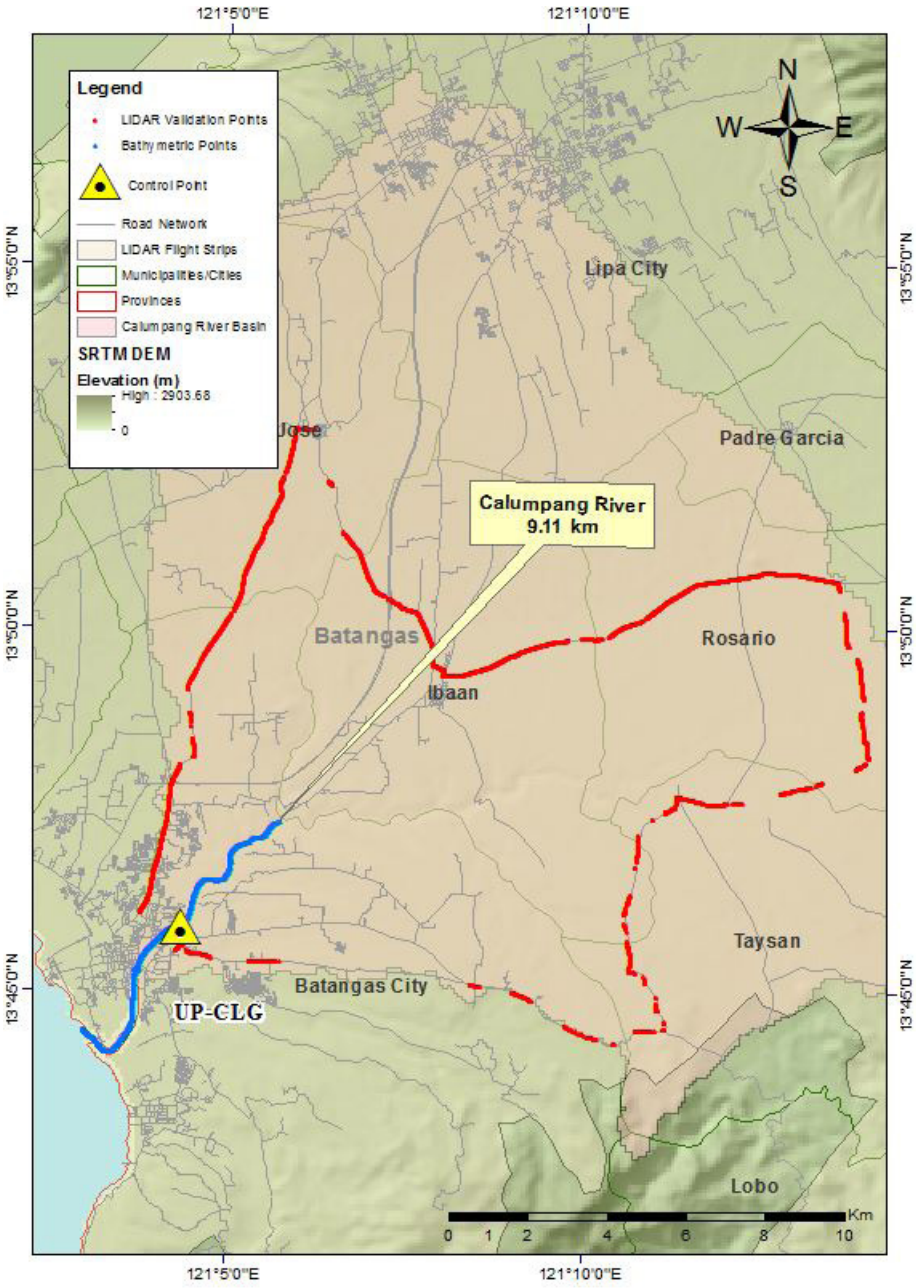


Figure 45. Calumpang Ground validation survey

4.7 River Bathymetric Survey

The bathymetric survey was conducted on August 27, 2014 using an Ohmex™ single-beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 46. The survey started from Brgy. Tinga Itaas, Batangas City with coordinates 13°47'18.44423"121°05'45.18162", down to the mouth of the river in Brgy. Wawa, Batangas City with coordinates 13°44'27.26237"121°03'01.09411".

Figure 46. OHMEX™ single-beam echo sounder set-up on a rubber for the Calumpang River bathymetric survey

Bathymetric line length surveyed is 9.11 km with a total of 5,642 points acquired using UP-CLG. The coverage of the bathymetric survey is shown in the map in Figure 47. A CAD drawing was produced to illustrate the Calumpang Riverbed profile. As shown in Figure 48, the difference in elevation from upstream in Brgy. Tinga Itaas down to Brgy. Wawa (mouth of the river) is 0.17 m. The deepest portion or the lowest elevation recorded is about 11.40 m (MSL) which is located near the Bridge of Promise.

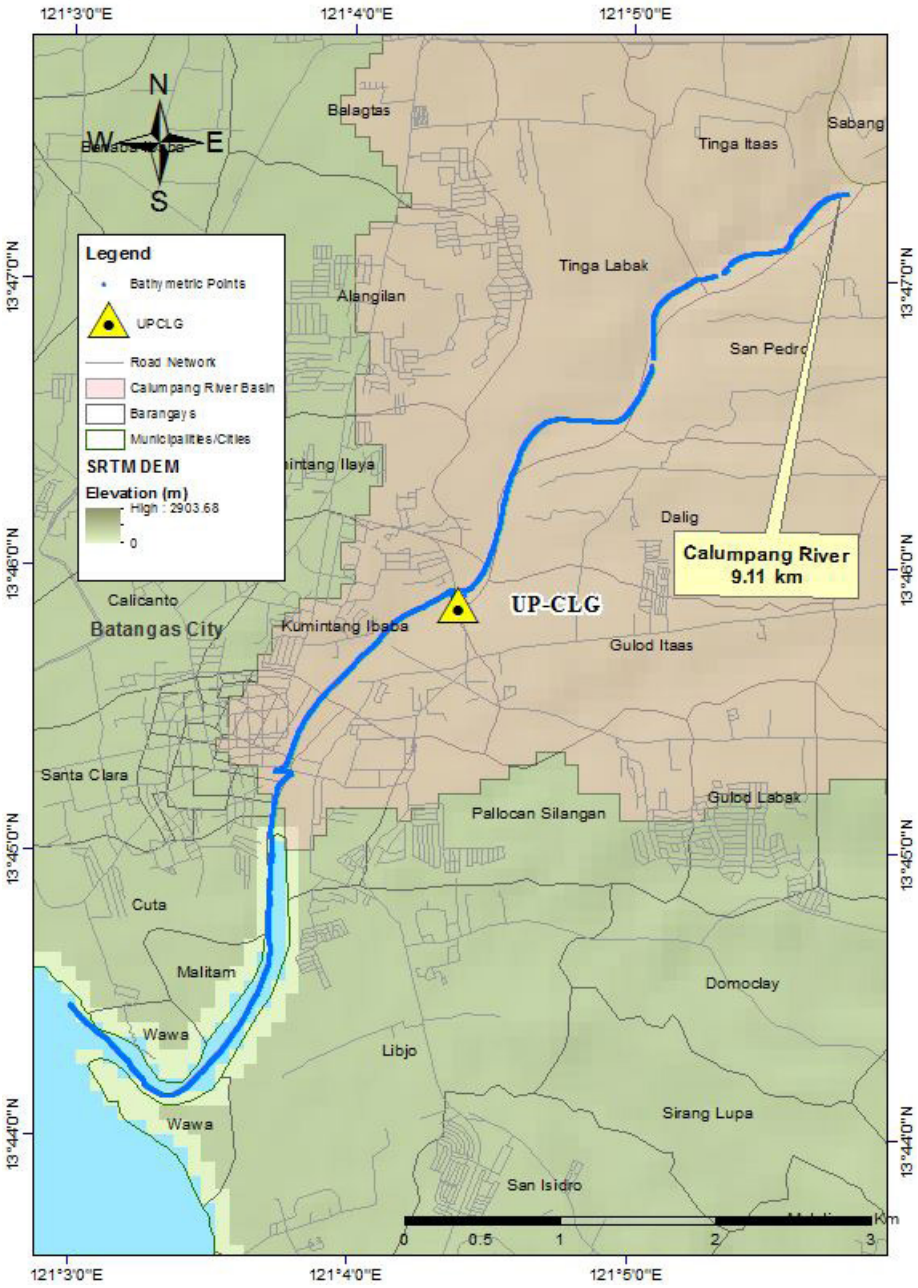


Figure 47. Bathymetric points gathered along Calumpang River

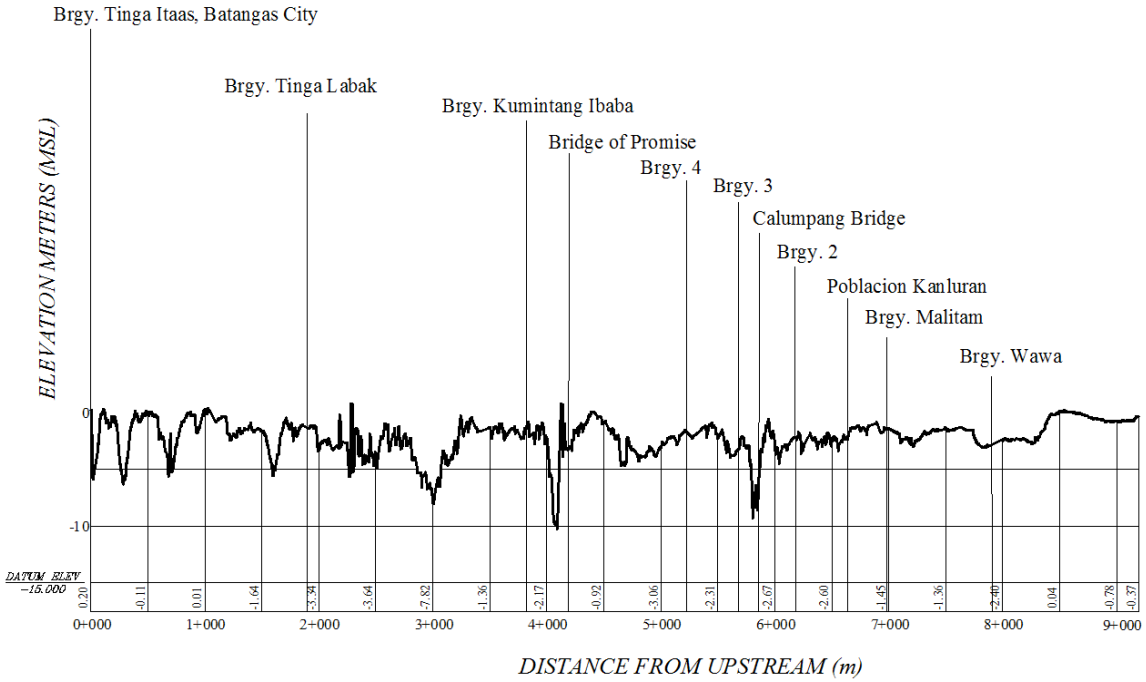


Figure 48. Riverbed profile of Calumpang River

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, 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 may affect the hydrologic cycle of the Calumpang River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from two automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The locations of the ARGs are Padre Garcia and Pina. The Location of the rain gauge is as shown in Figure 49.

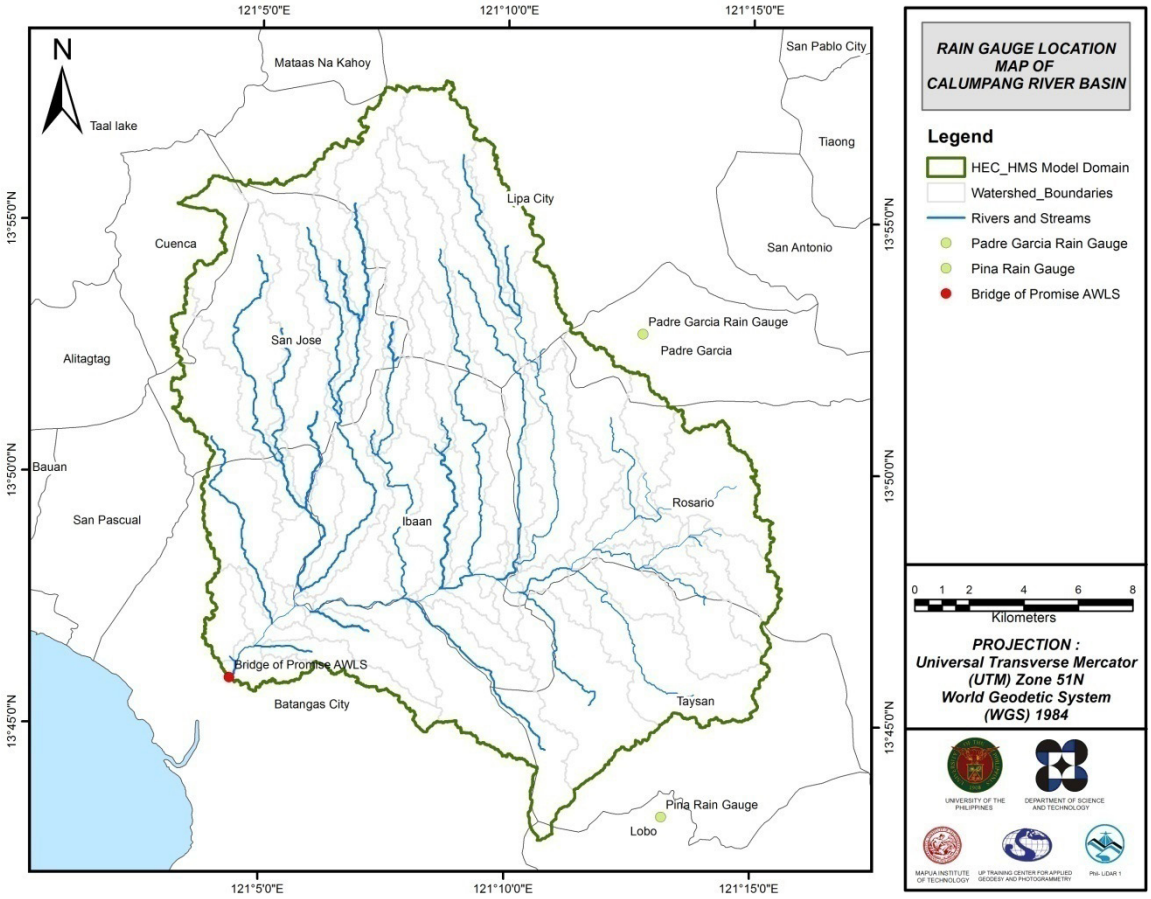


Figure 49. Location map of rain gauges used for the calibration of the Calumpang HEC-HMS Model.

For Pina Rain Gauge, total rain for the event is 6.5 mm. Peak rain of 1.5 mm was recorded on June 26, 2016. The lag time between the peak rainfall and discharge is 1hour and 19 minutes, as seen in Figure 52.

For Padre Garcia, the total recorded rain is 5.8 mm. It peaked at 1.6 mm at 14:30, June 26, 2016. The lag time between the peak rainfall and discharge is 3 hours as seen in Figure 52.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Bridge of Promise, Batangas City, Batangas (13°45'54.85"N, 121° 4'22.93"E). It gives the relationship between the observed water levels and outflow of the watershed at this location. It is expressed in the form of the following equation:

$Q=a^{nh}$

where, Q : Discharge (m^3/s),

h : Gauge height (reading from deployed depth gage at Bridge of Promise), and a and n: Constants.

For Bridge of Promise, the rating curve is expressed $y = 437.27e^{9.0259x}$ as shown in Figure 51.

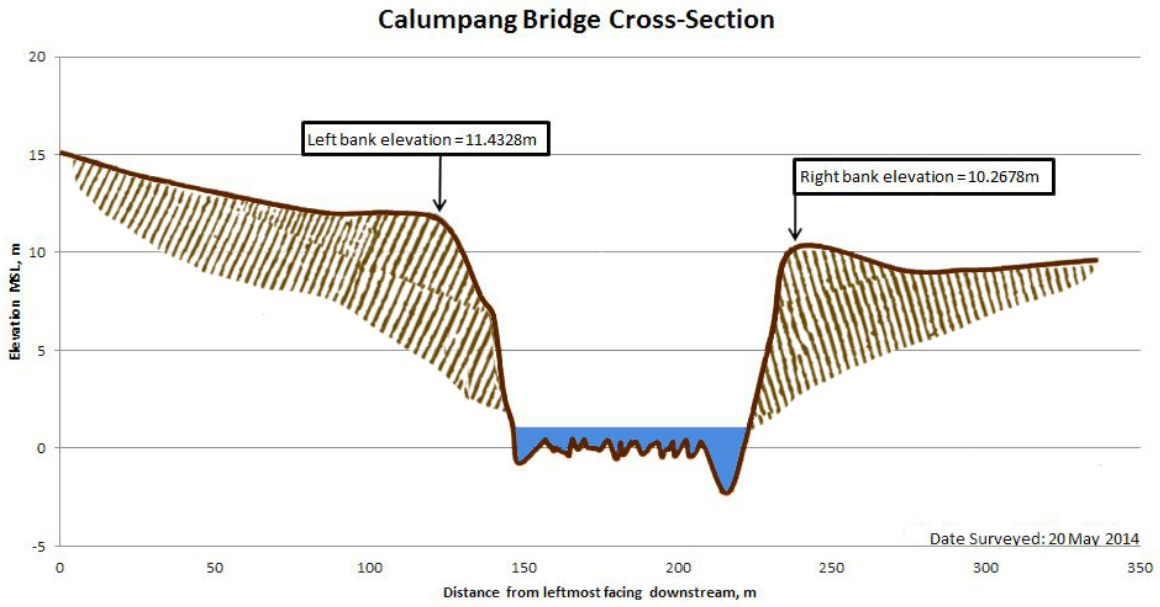


Figure 50. Cross-section plot of Bridge of Promise

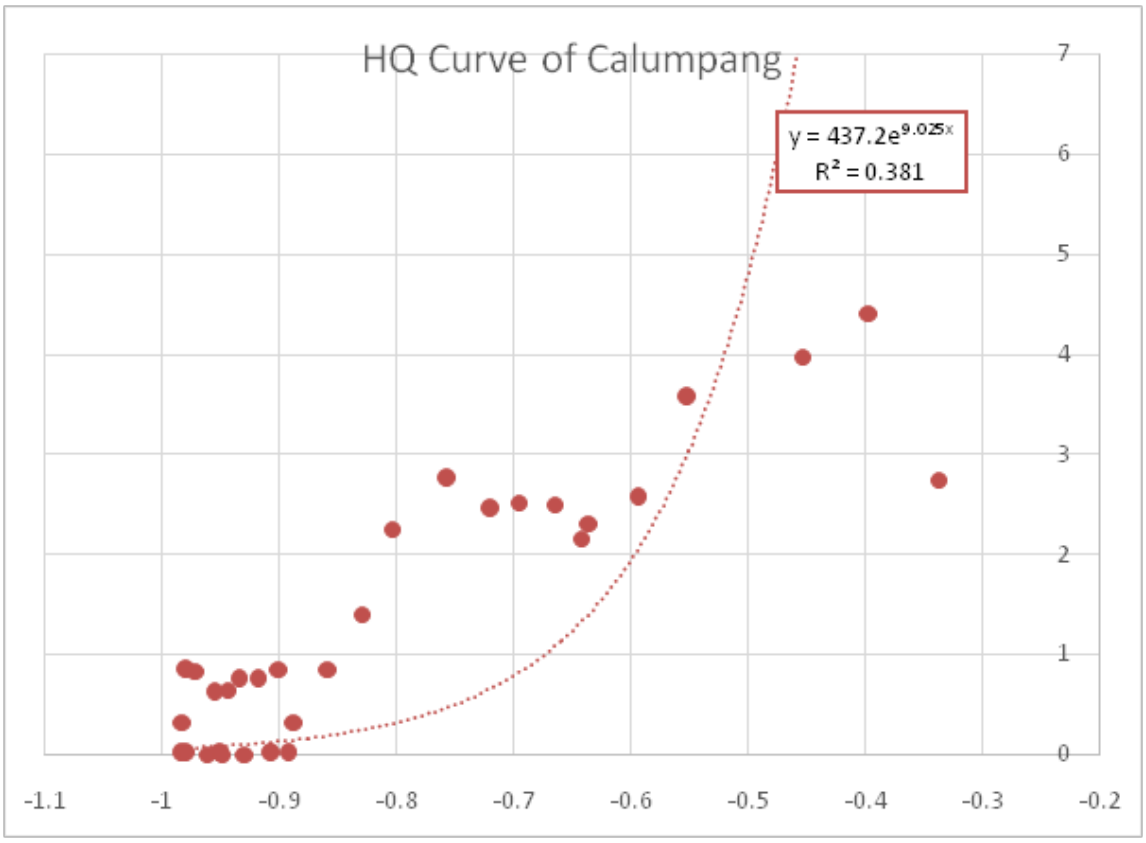


Figure 51. Rating curve at Bridge of Promise, Batangas City, Batangas Province

This rating curve equation was used to compute the river outflow at the Bridge of Promise for the calibration of the HEC-HMS model shown in Figure 52. Peak discharge is 4.409872 m^3/s at 17:30, June 26, 2016.

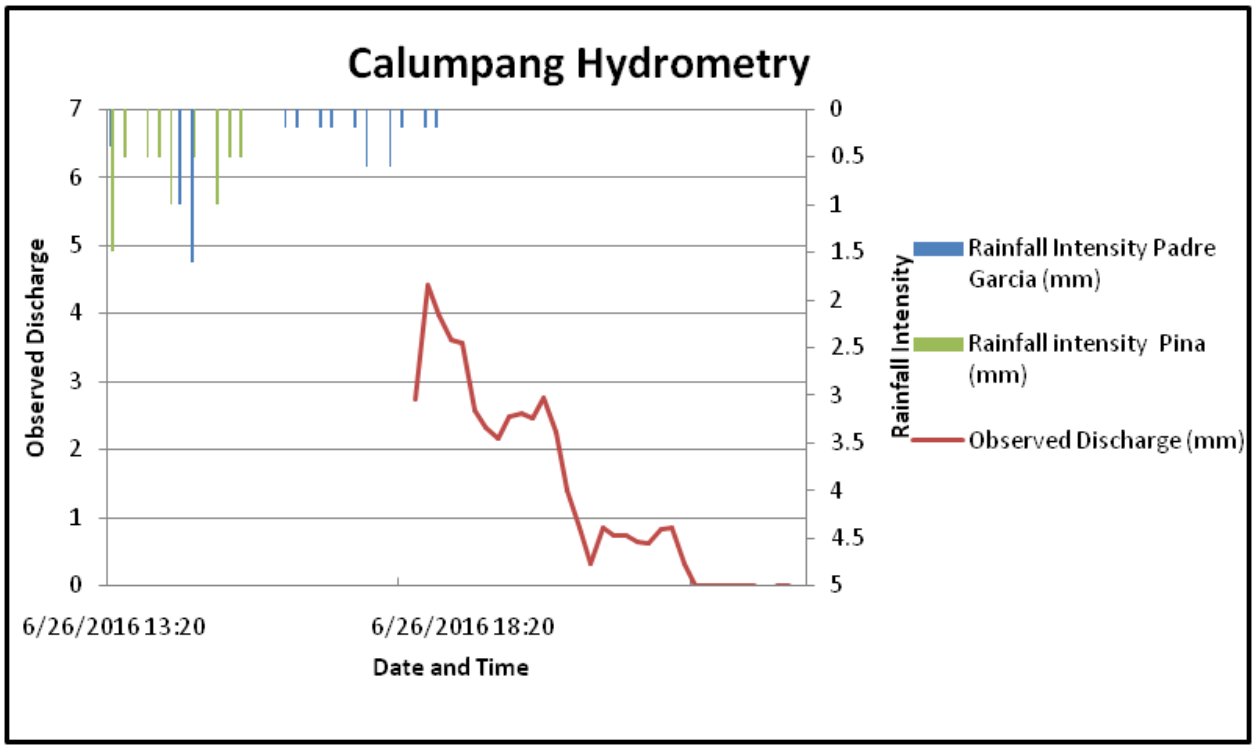


Figure 52. Rainfall and outflow data at Calumpang used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Ambulong Gauge. This station was chosen based on its proximity to the Calumpang watershed. The extreme values for this watershed were computed based on a 54-year record.

Table 29. RIDF values for Ambulong 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

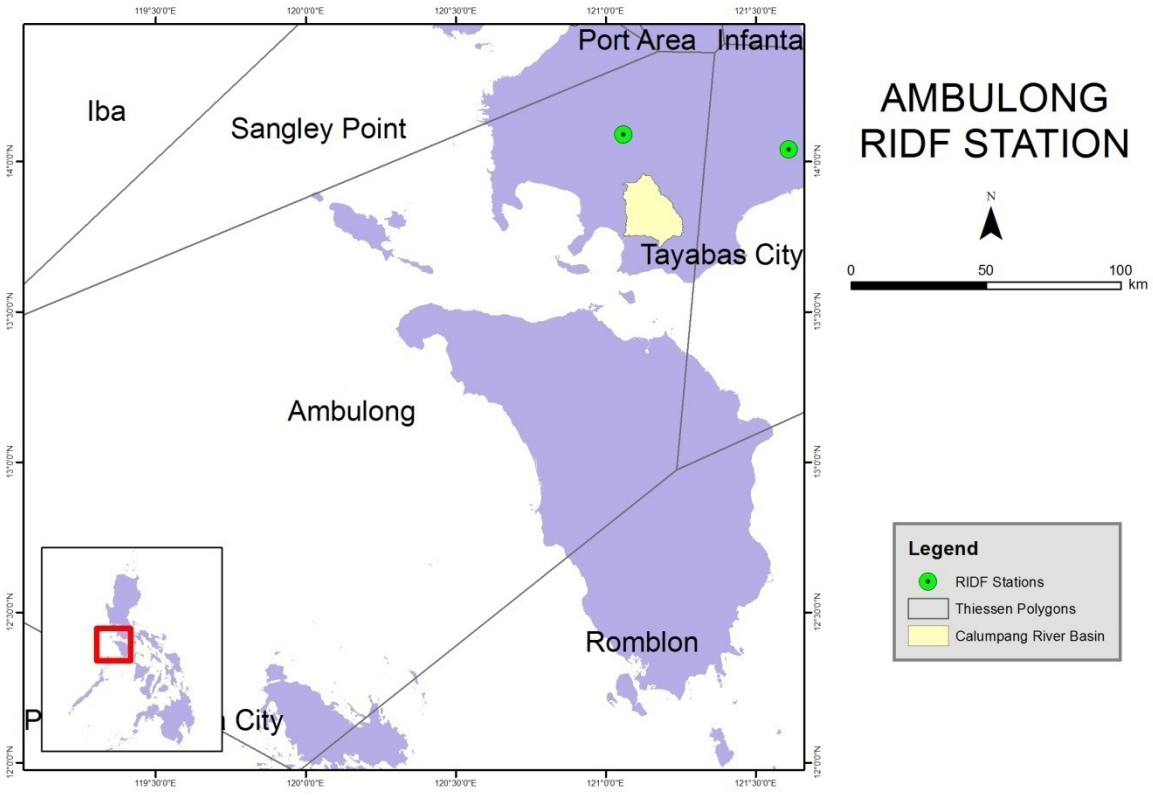


Figure 53. Ambulong RIDF location relative to Calumpang River Basin

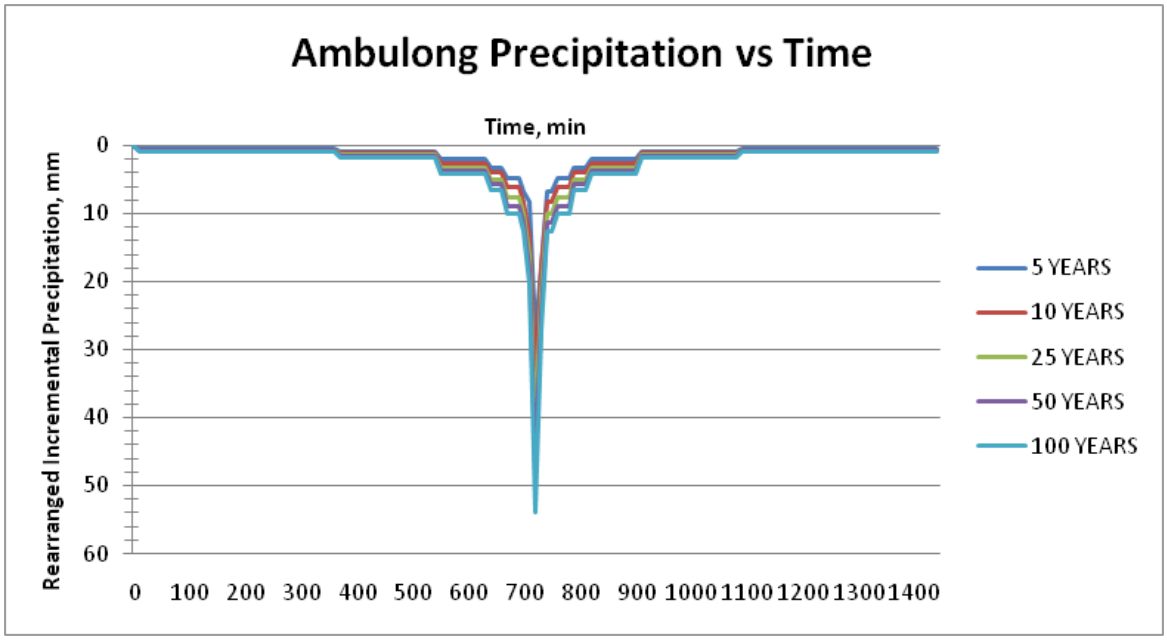


Figure 54. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Calumpang River Basin are shown in Figure 55 and Figure 56, respectively.

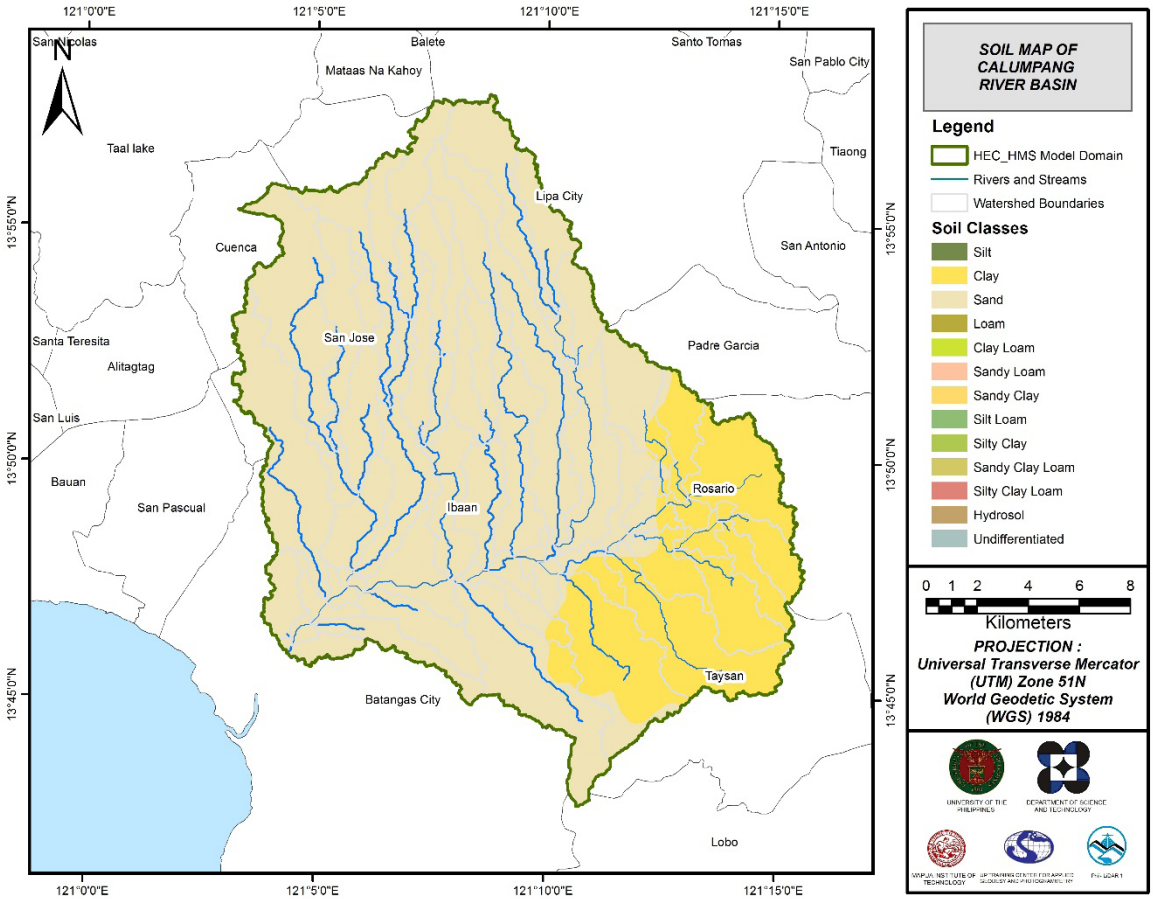


Figure 55. Soil map of Calumpang River Basin

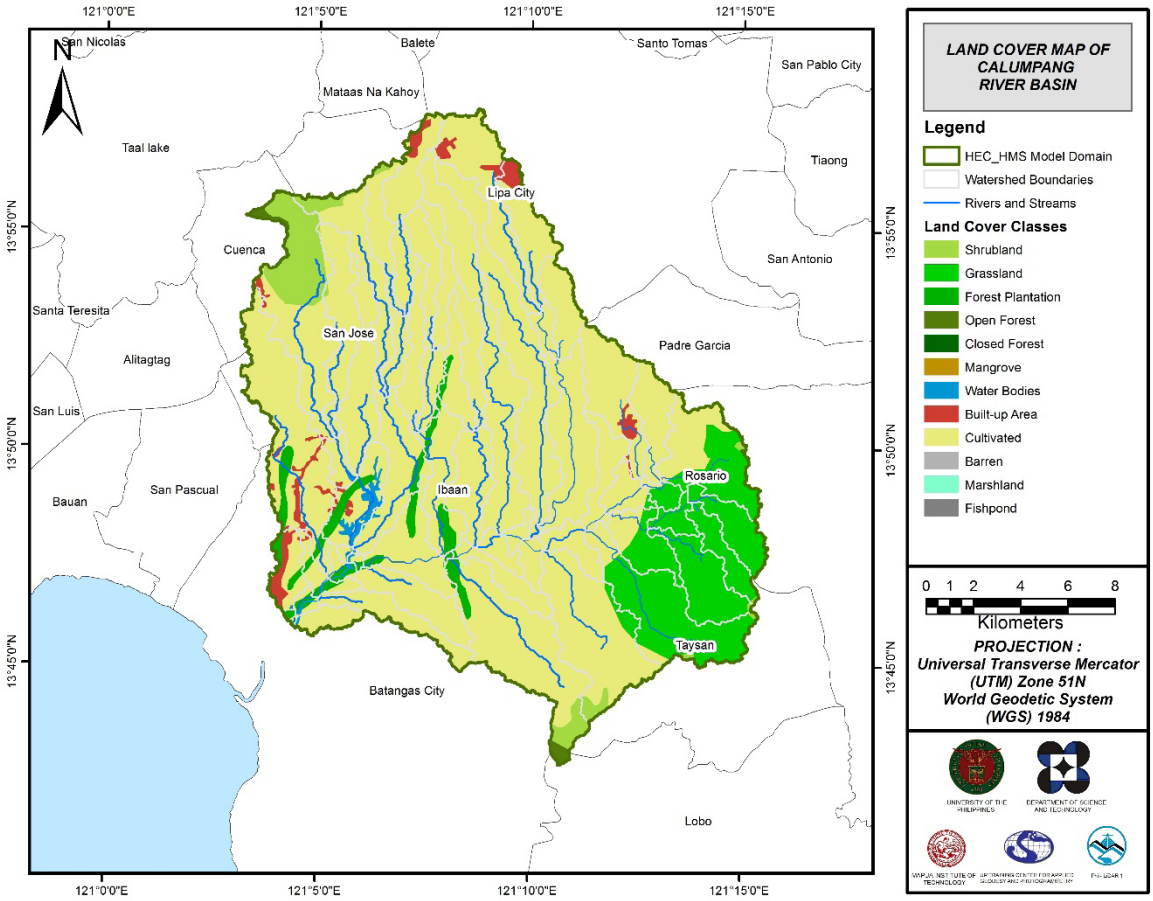


Figure 56. Land cover map of Calumpang River Basin

For Calumpang, the soil classes identified were clay and sand. The land cover types identified were built-up areas, cultivated areas, inland water, shrubland, and grassland.

[insert Slope Map]

Figure 57. Slope map of Calumpang River Basin

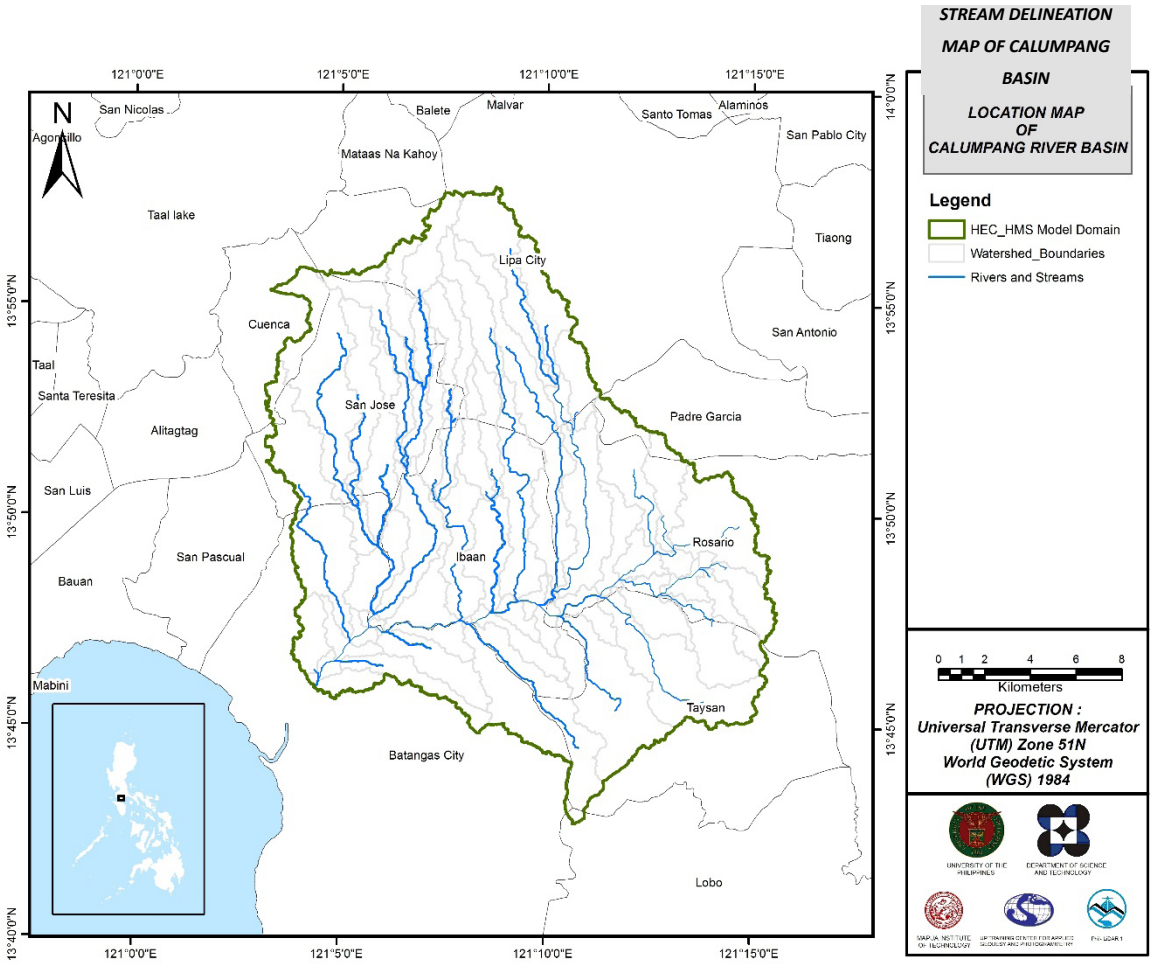


Figure 58. Stream delineation map of Calumpang River Basin

The Calumpang Basin model comprises 57 subbasins, 28 reaches, and 28 junctions. The main outlet is outlet 2. The basins were identified based on soil and land cover characteristic of the area. It was calibrated using the data from actual discharge flow gathered in the Bridge of Promise.

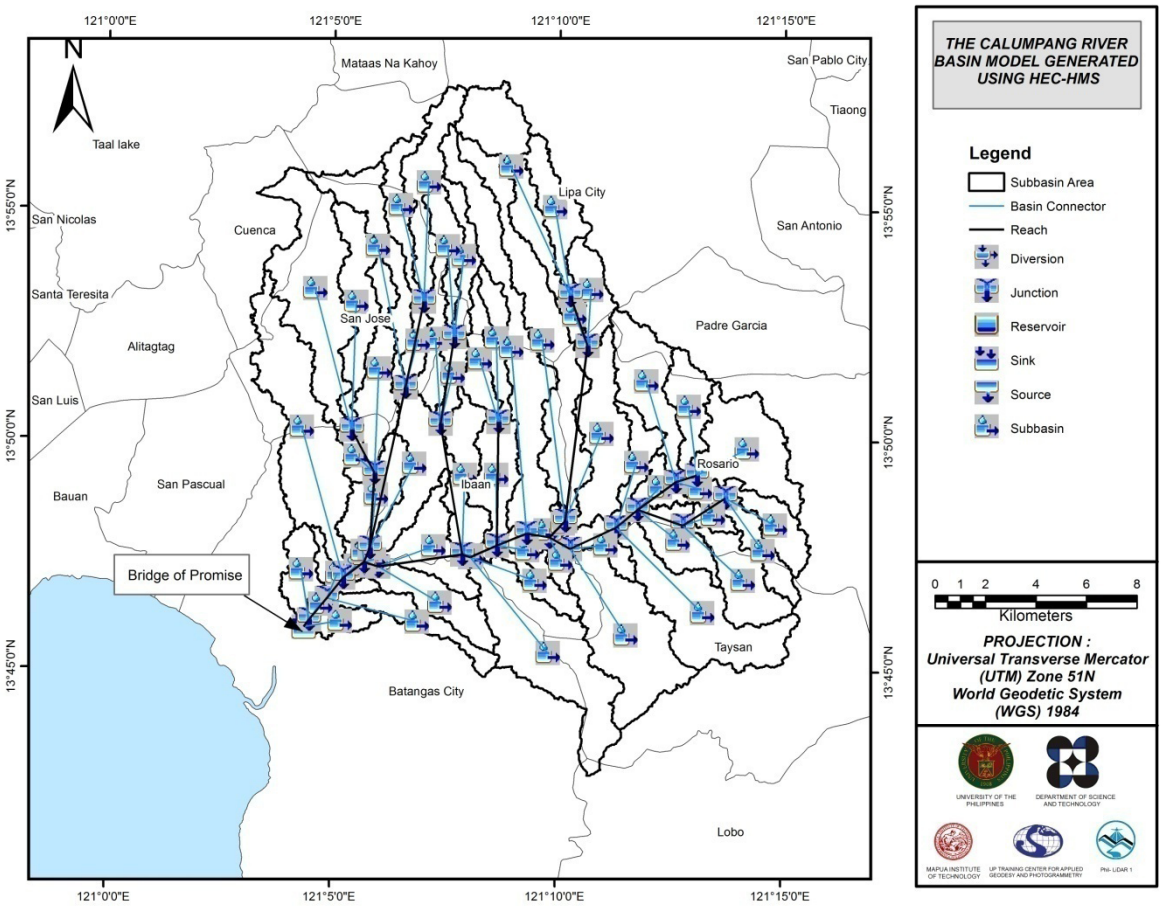


Figure 59. Calumpang River Basin Model Domain generated by HEC-HMS

5.4 Cross-Section Data

Riverbed cross-sections of the watershed are 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.

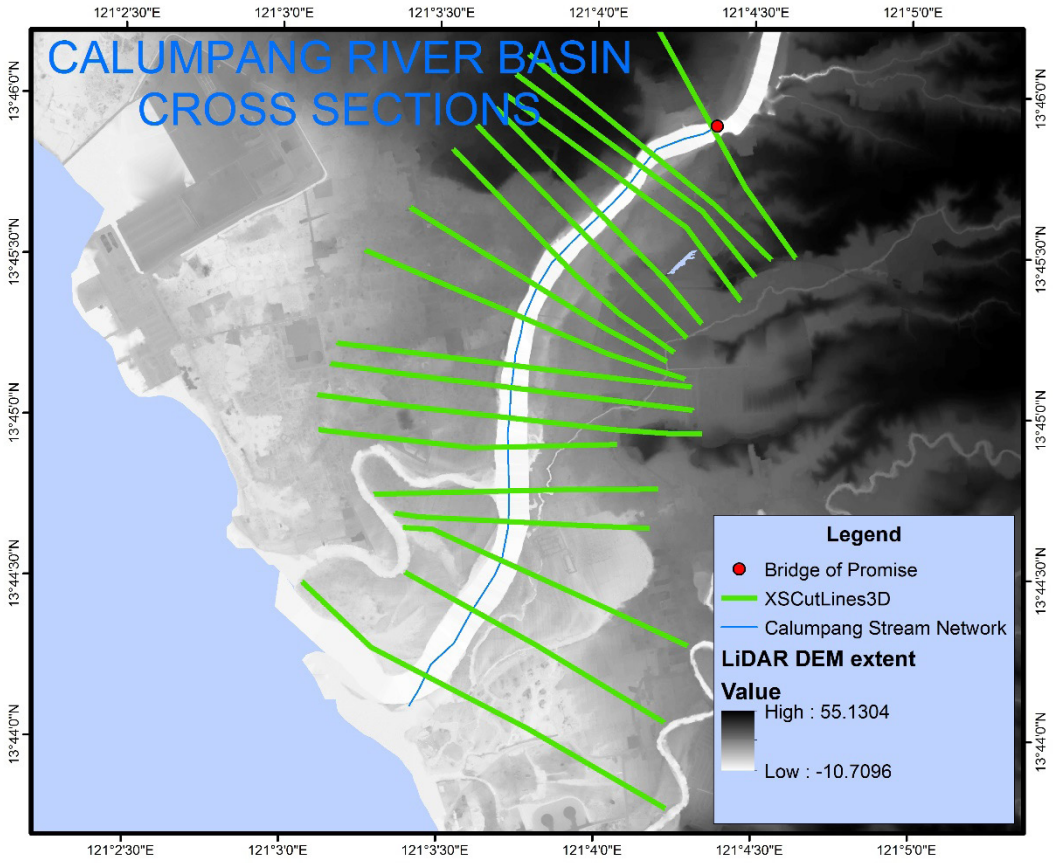


Figure 60. River cross-section of Calumpang River generated through Arcmap HEC GeoRAS tool

5.4.1 Manning's n

The Manning's n is a constant value that depends on the nature of the channel and its surface. Determining the roughness coefficient of the channel is important in determining the water flow. Appropriate selection of Manning's n values is based on the land cover type of the watershed area.

A look-up table was derived to have a standardized Manning's n value for the HEC-RAS model.

Table 30. Look-up table for Manning's n values (Source: Brunner, 2010)

Land-cover Class	Corresponding Manning's *n* Class	Manning's *n*
Barren Land	Cultivated areas, no crop	0.030
Built-up Area	Concrete, float finished	0.015
Cultivated land, annual crop	Cultivated areas, mature field crops	0.040
Cultivated land, perennial crop	Cultivated areas, mature row crops	0.035
Fishpond	Excavated, earth, straight and uniform	0.018
Inland Water	Main channel, clean, straight, no rifts or deep pools	0.030
Grassland	Pasture, no brush, short grass	0.030
Mangrove Forest	Trees, heavy stand, flow into branches	0.120
Shrub land	Medium to dense brush	0.100

5.5 Flo 2D Model

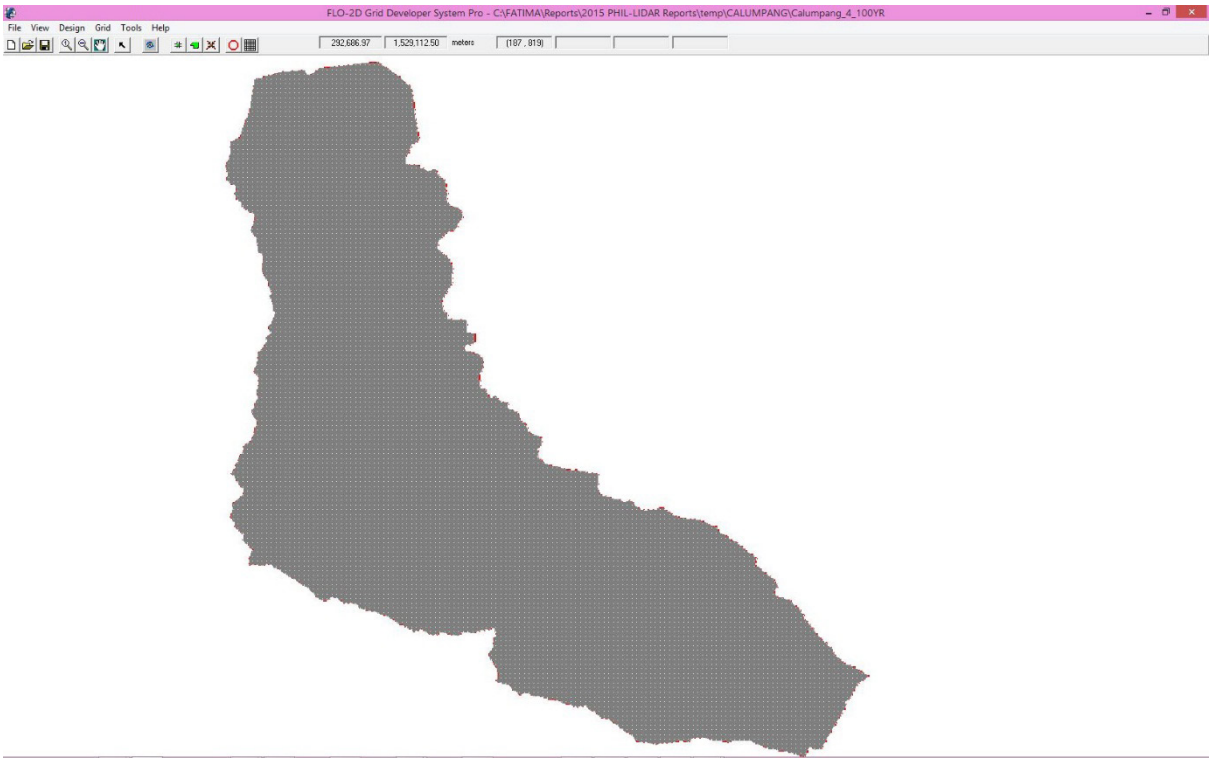


Figure 61. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

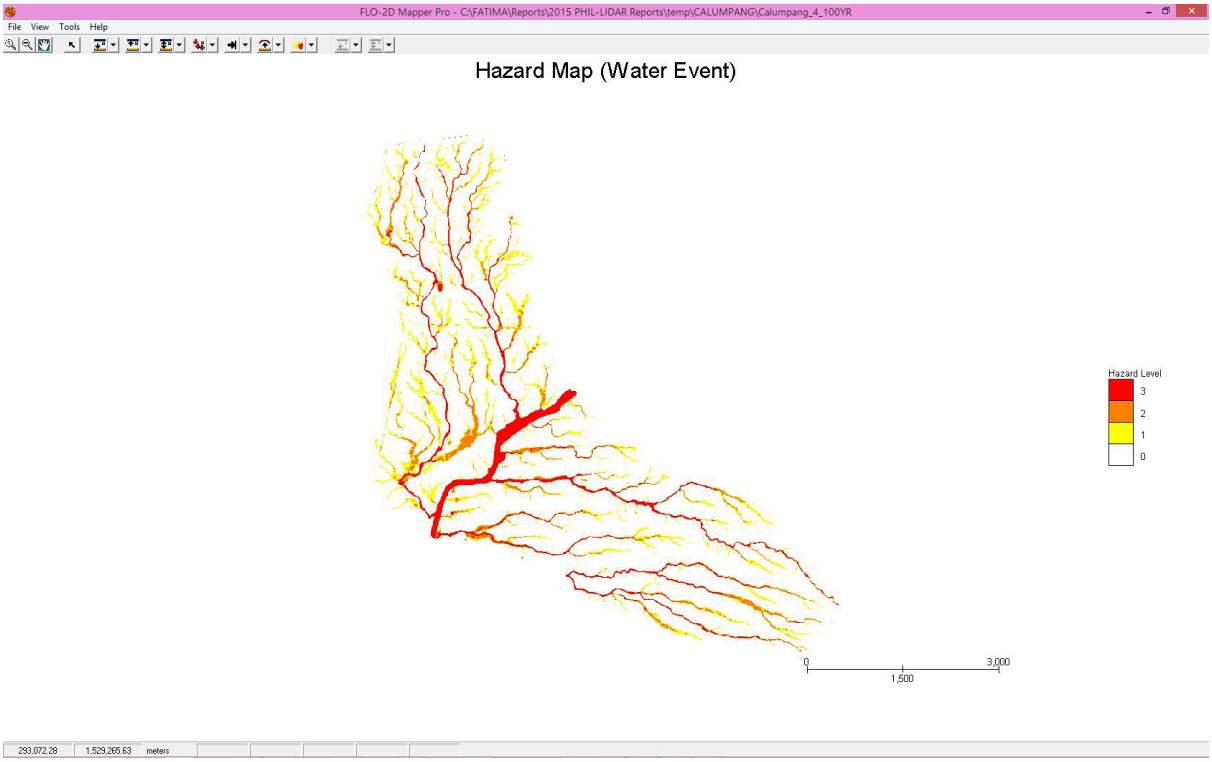


Figure 62. Generated 100-year rain return hazard map from FLO-2D Mapper

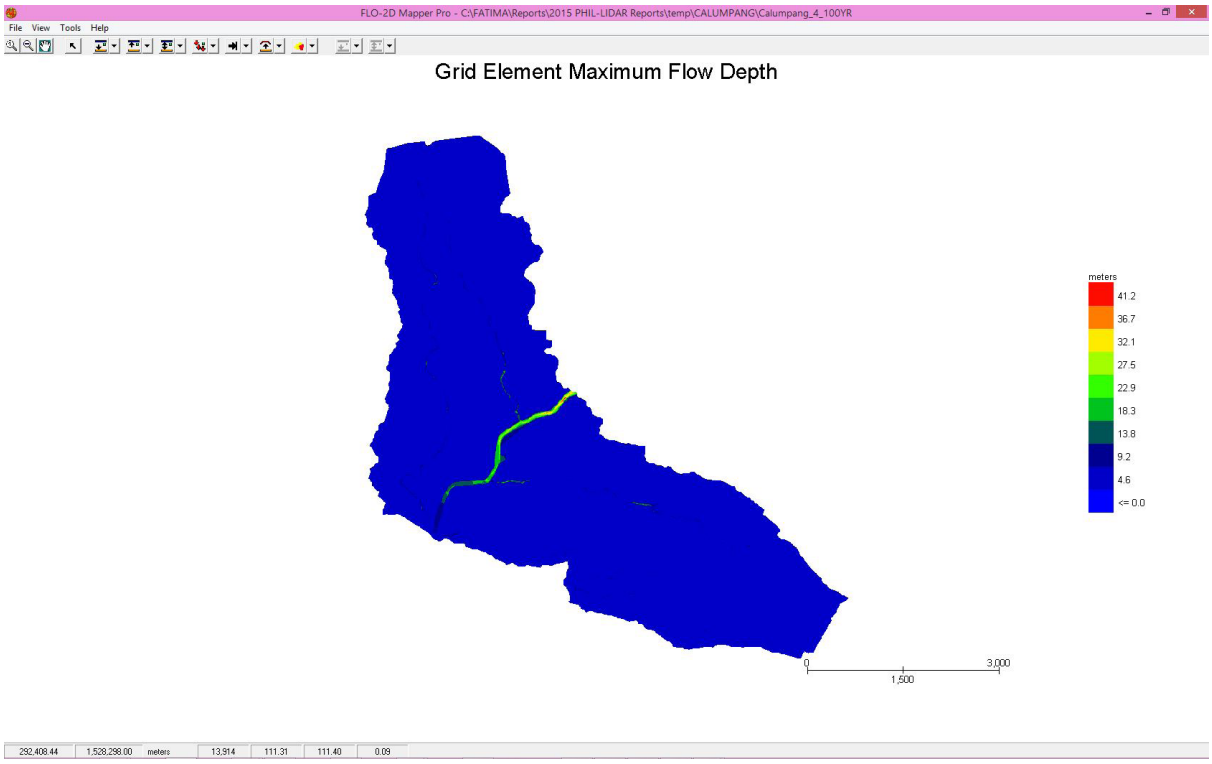


Figure 63. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

After calibrating the Calumpang HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 64 shows the comparison between the two discharge data.

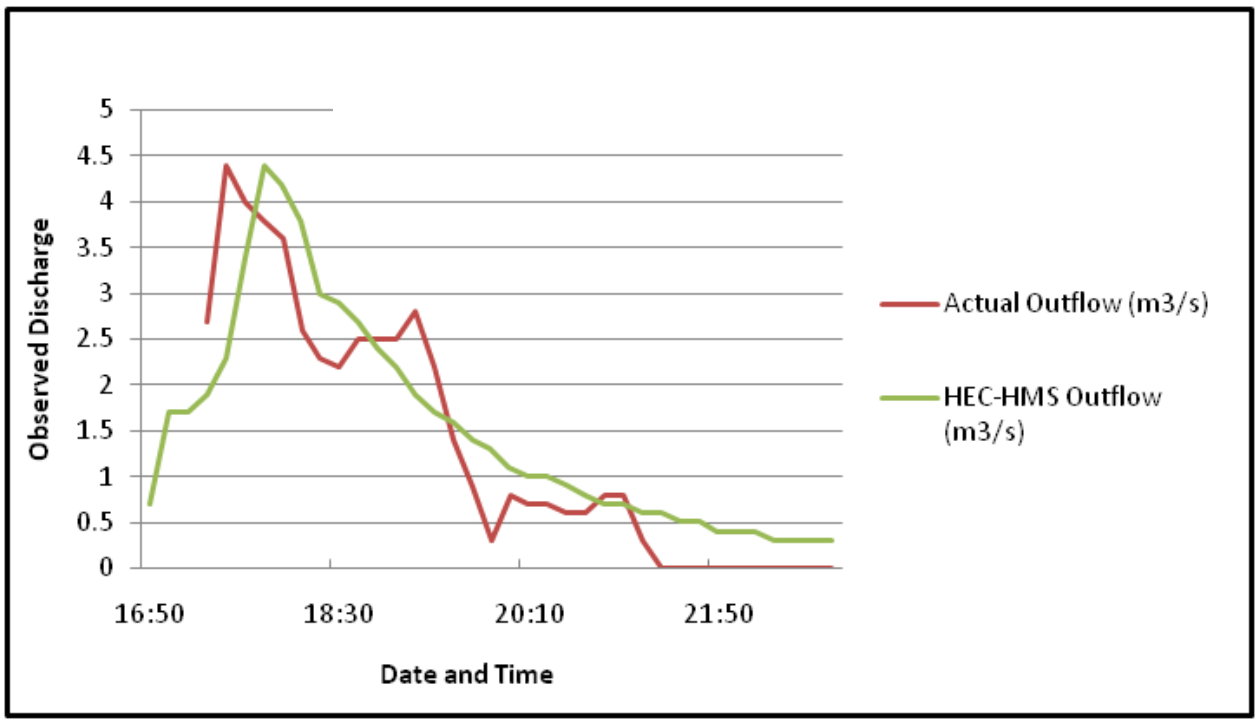


Figure 64. Outflow hydrograph of Calumpang produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of calibrated values for Calumpang

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.18 – 12.39
			Curve Number	35.21 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.17 – 352.95
			Storage Coefficient (hr)	0.17 - 995
	Baseflow	Recession	Recession Constant	0.00001 – 0.9
			Ratio to Peak	0.0055 – 0.75
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0055 – 0.75

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.18 mm to 12.39 mm means that there is a minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of curve number values for the basin range from 35.21 and 99.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.17 hours to 995 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.00001 to 0.9 and Ratio to Peak of 0.0055–0.75 represents a large variation of values among the subbasins of the watershed.

Manning's roughness coefficient of 0.0055 to 0.75 corresponds to the roughness values in Calumpang watershed.

Table 32. Summary of the efficiency test of Calumpang HMS Model

RMSE	0.71
r^2	0.7622
NSE	0.72
PBIAS	-17.845
RSR	0.53

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.71 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.7622.

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 0.72.

.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -17.845.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.53.

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 65) shows the Calumpang outflow using the Ambulong RIDF in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

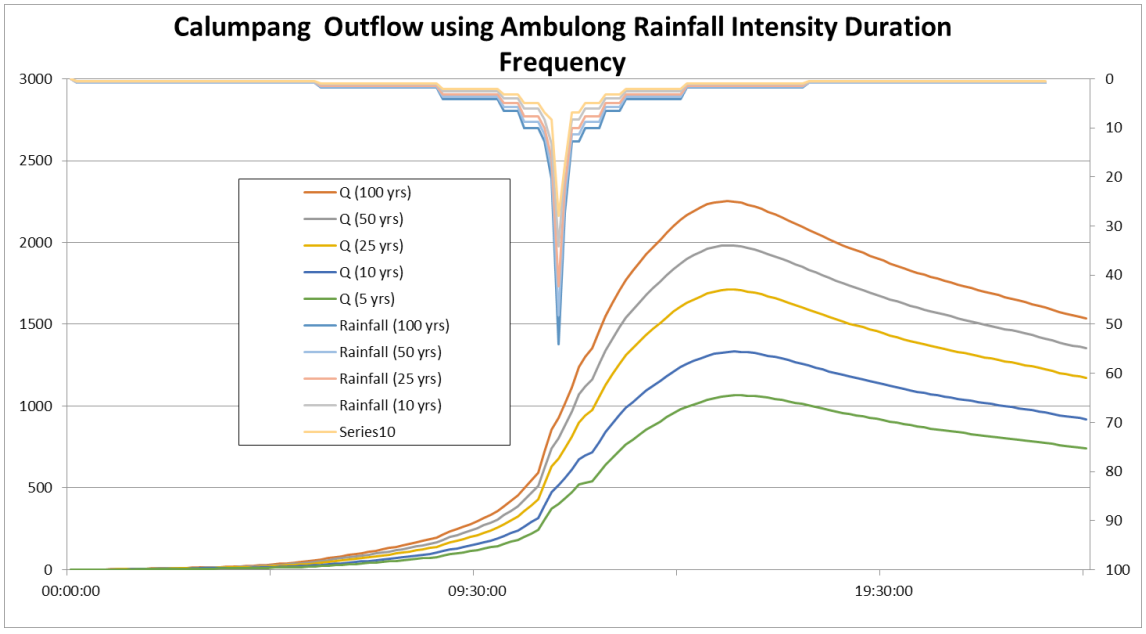


Figure 65. Outflow hydrograph at Bridge of Promise generated using Ambulong RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Calumpang River discharge using the Ambulong RIDF curves in five different return periods is shown in Table 33.

Table 33. Peak values of the Calumpang HEC-HMS Model outflow using the Ambulong RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	226.7	27.9	1065.4	16 hours, 30 minutes
10-Year	276.9	34.2	1333.3	16 hours, 20 minutes
25-Year	340.4	42.2	1711.2	16 hours, 10 minutes
50-Year	387.5	48.1	1982.4	16 hours, 10 minutes
100-Year	434.3	54	2252	16 hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river will be shown, since only the Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of Calumpang River using the calibrated HMS base flow is shown in Figure 66.

Figure 66. Sample output of Calumpang RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figure 67 to Figure 72 shows the 100-, 25-, and 5-year rain return scenarios of the Calumpang Floodplain.

Table 34. Municipalities affected in Calumpang Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Batangas City	274.44	97.44	35.50%
Rosario	199.04	16.85	8.46%
Ibaan	70.33	38.21	54.33%
Taysan	92.55	10.36	11.22%

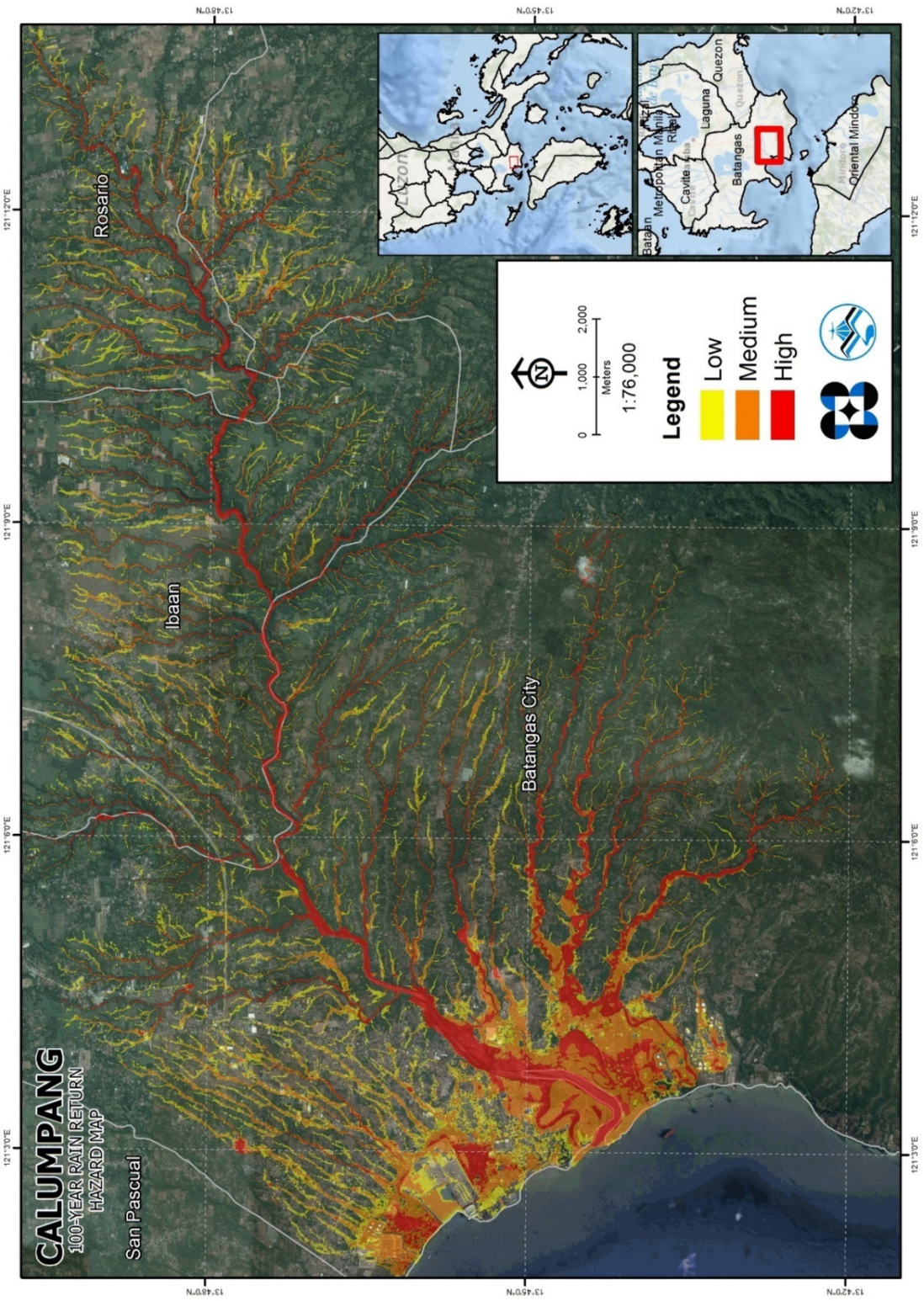


Figure 67. 100-year flood hazard map for Calumpang Floodplain

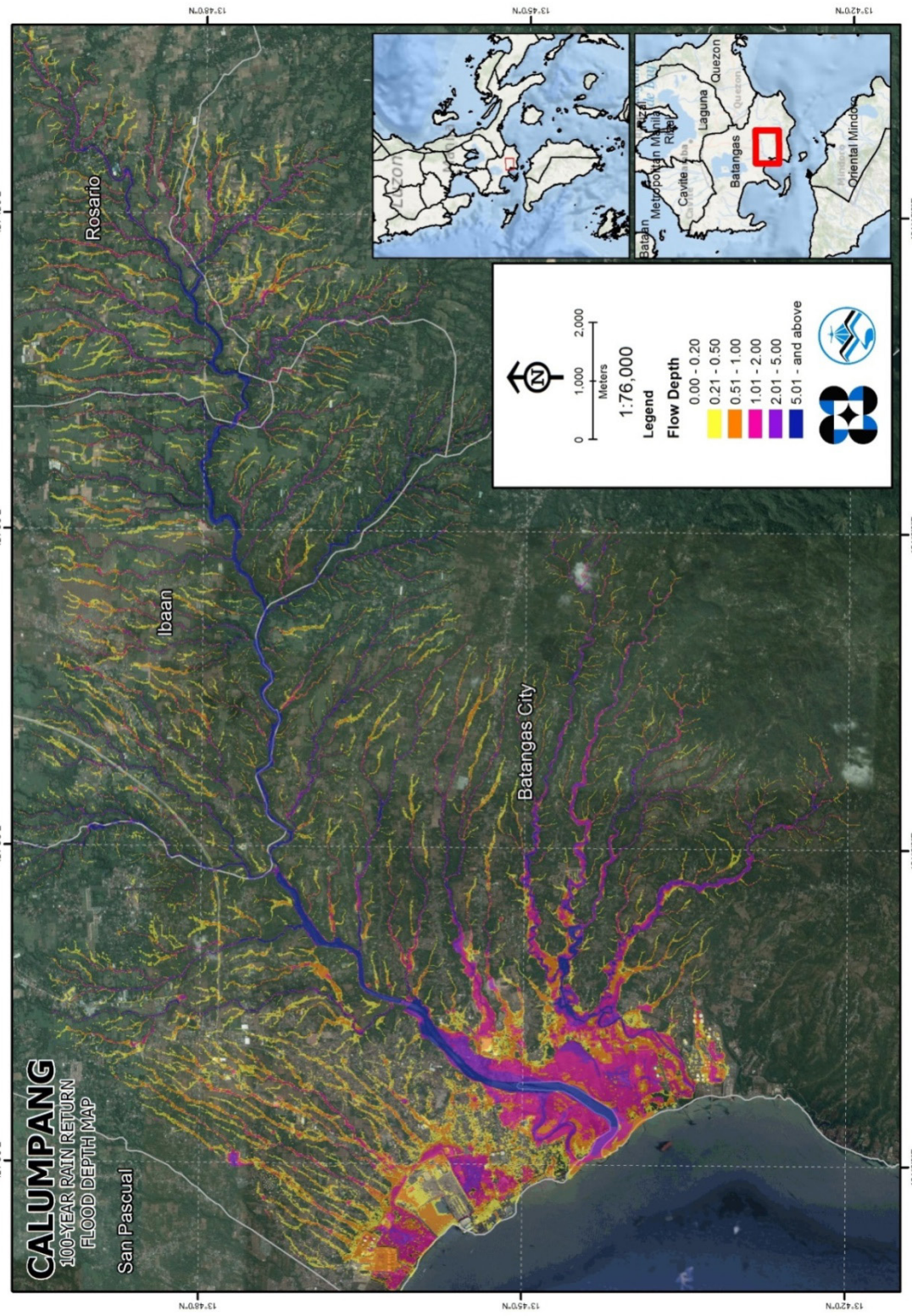


Figure 68. 100-year flow depth map for Calumpang Floodplain

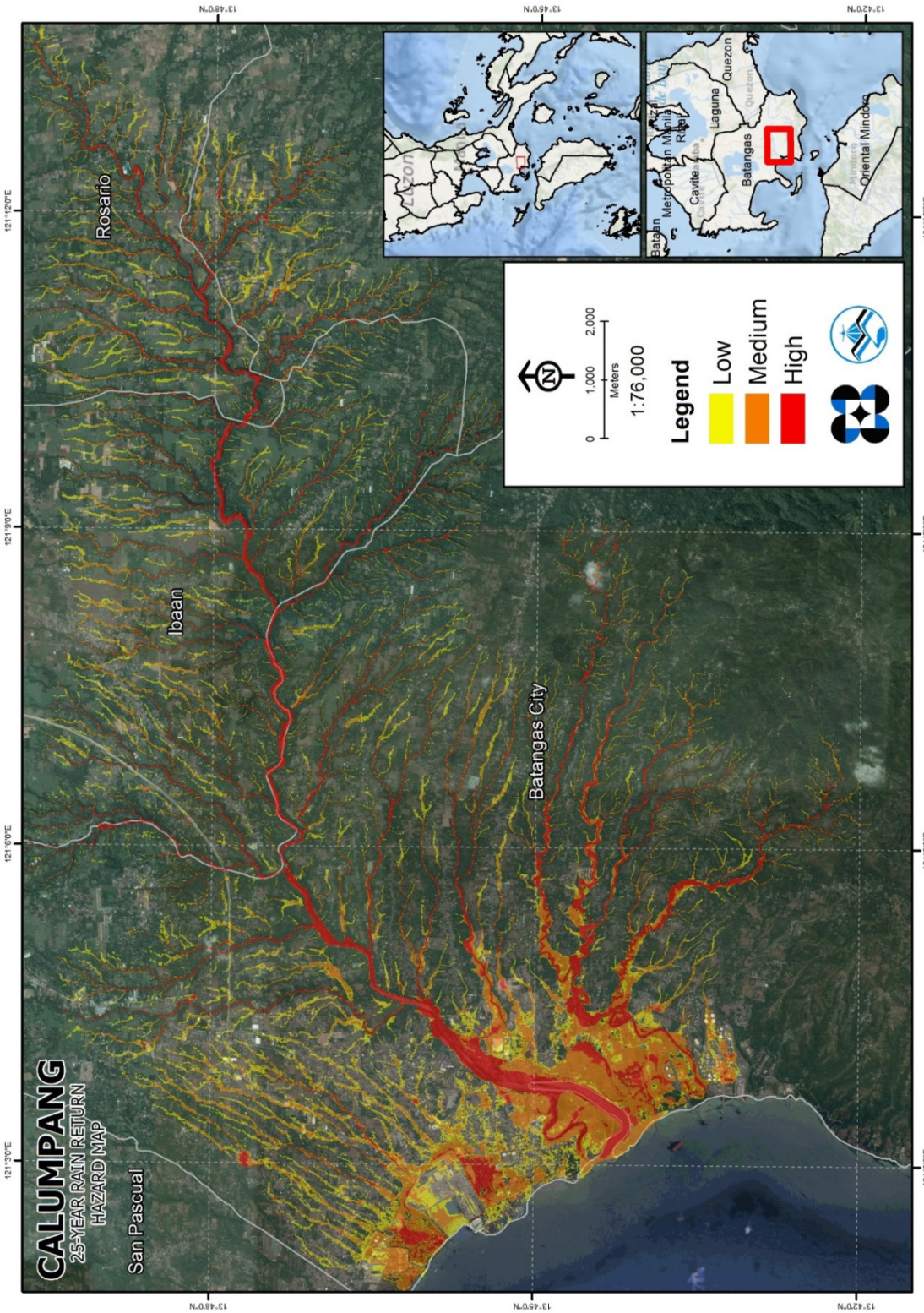


Figure 69. 25-year flood hazard map for Calumpang Floodplain

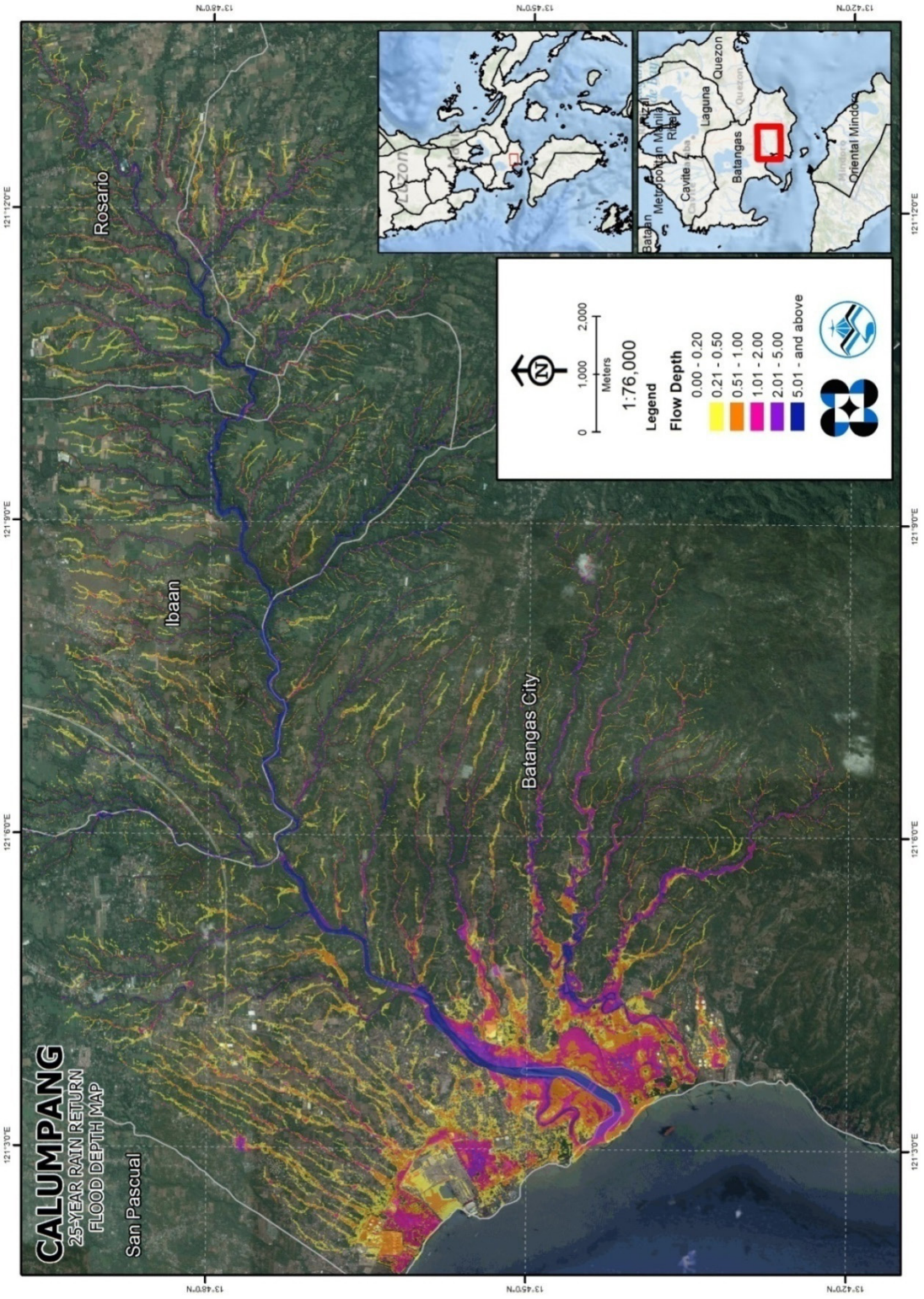


Figure 70. 25-year flow depth map for Calumpang Floodplain

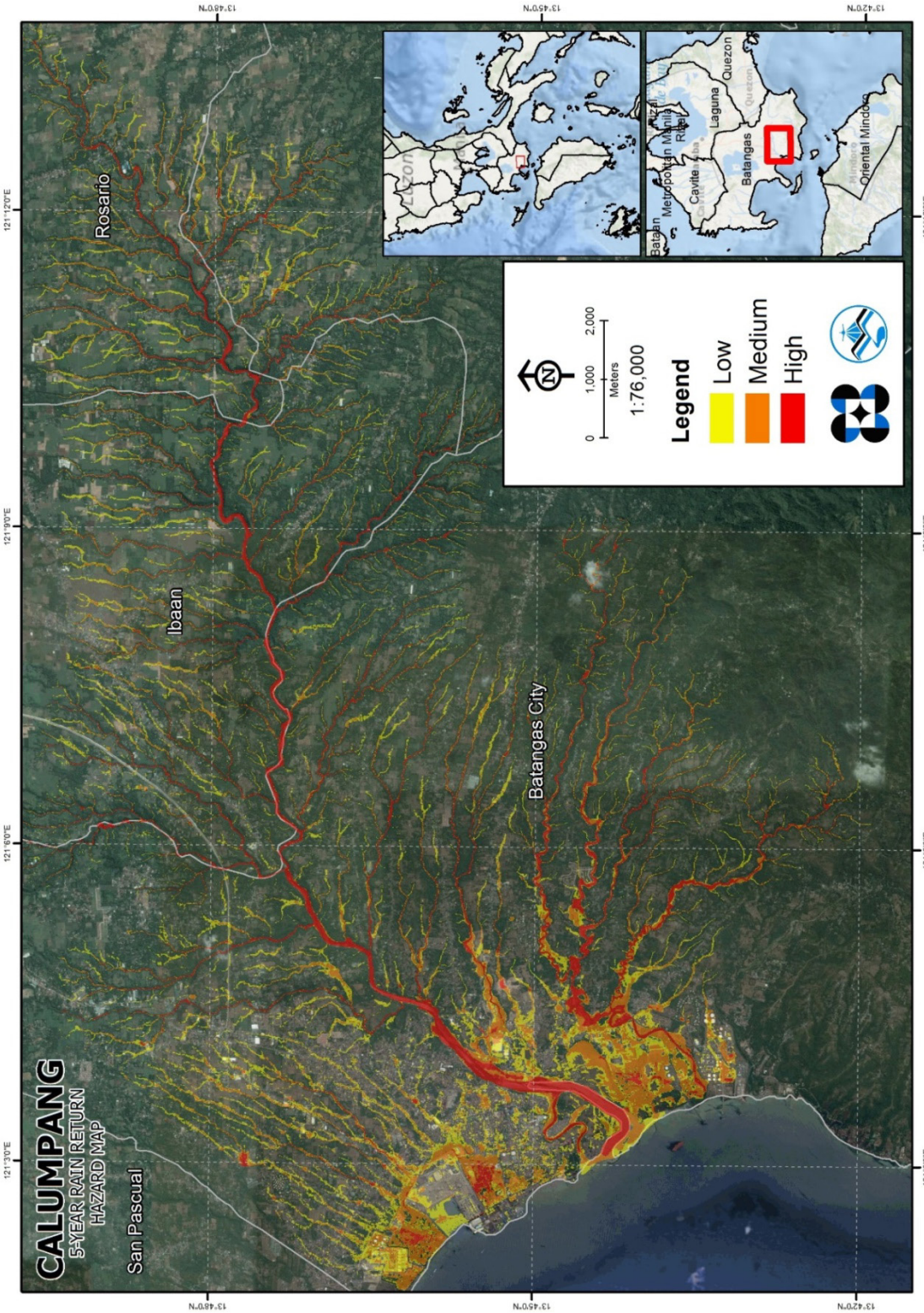


Figure 71. 5-year flood hazard map for Calumpang Floodplain

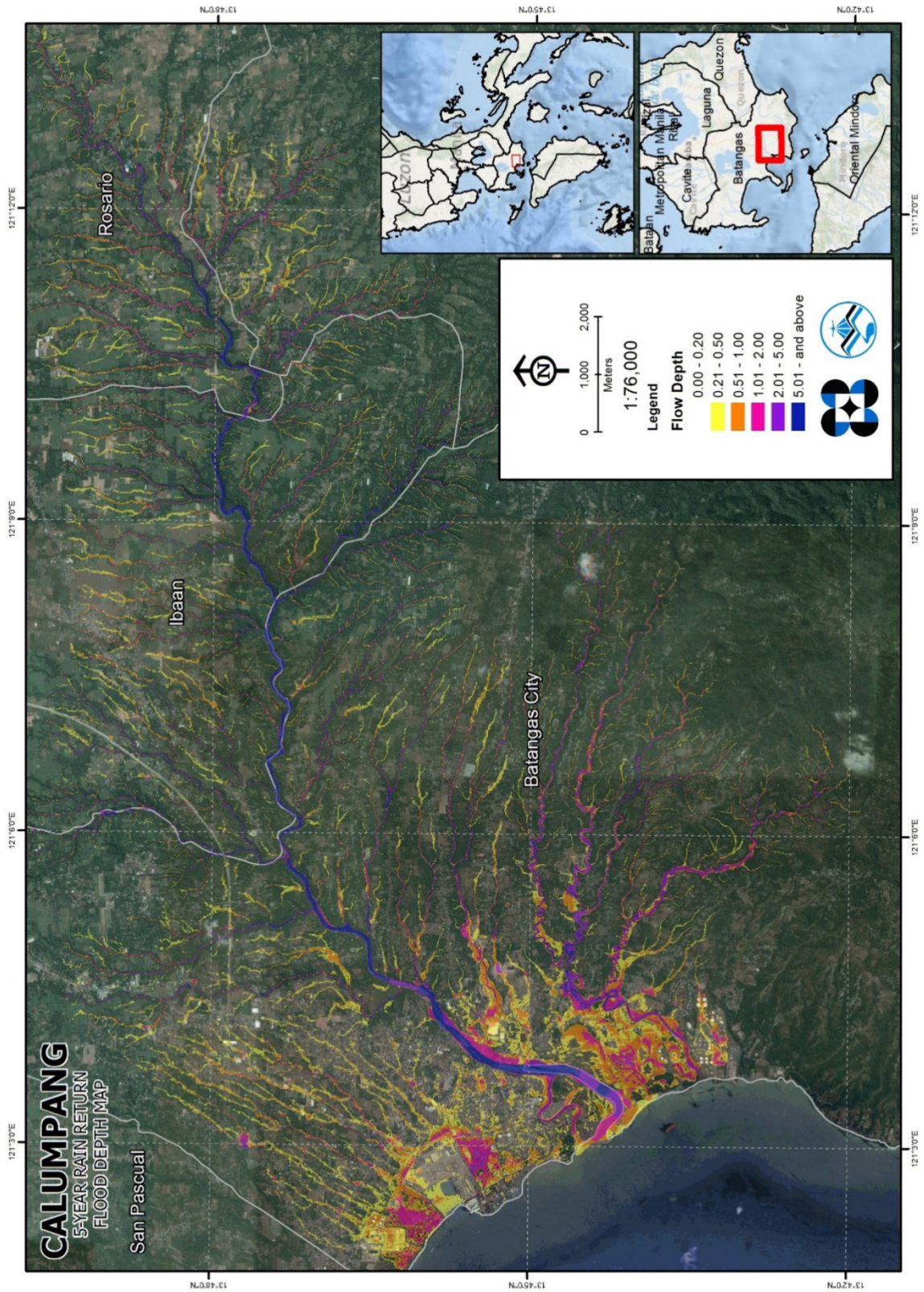


Figure 72. 5-year flow depth map for Calumpang Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Listed below are the barangays affected by the Calumpang River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of 117 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 29.36% of the municipality of Batangas City with an area of 274.44 sq km will experience flood levels of less than 0.20 meters; 2.62% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.60%, 0.99%, 0.61%, and 0.31% 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 to Table 41 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Alangilan	Balagtas	Balete	Banaba Center	Banaba Ibaba	Banaba Kanluran	Banaba Silangan	Barangay 1	Barangay 10	Barangay 11	Barangay 12
Affected Area (sq. km.)	1	2.36	2.1	0.38	1.1	1.06	1.08	0.31	0.053	0.014	0.011	0.01
	2	0.31	0.25	0.019	0.15	0.15	0.094	0.046	0.0077	0.0016	0.0014	0.0027
	3	0.088	0.061	0.0052	0.054	0.063	0.032	0.021	0.0005	0	0.0006	0
	4	0.023	0.0085	0.0026	0.0041	0.013	0.016	0.023	0.0016	0	0	0
	5	0.018	0.0058	0.0035	0.0001	0.0017	0.0074	0.016	0.0011	0	0	0.0001
	6	0.002	0.0033	0.00041	0	0	0.0004	0.0002	0.0036	0	0	0

Table 36. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Barangay 13	Barangay 14	Barangay 15	Barangay 16	Barangay 17	Barangay 18	Barangay 19	Barangay 2	Barangay 20	Barangay 21	Barangay 22
Affected Area (sq. km.)	1	0.0099	0.011	0.024	0.047	0.039	0.042	0.038	0.022	0.049	0.043	0.039
	2	0.0031	0.0044	0.0027	0.005	0.0018	0.017	0.0055	0.0039	0.0039	0.0098	0.01
	3	0.0002	0.0012	0.00027	0	0.000002	0.0043	0	0.0064	0	0.0001	0.000003
	4	0	0.0001	0	0	0	0	0	0.0045	0	0	0
	5	0	0	0	0	0	0	0	0.00075	0	0	0
	6	0	0	0	0	0	0	0	0.0079	0	0	0

Table 37. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Barangay 23	Barangay 24	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Bilogo	Bolbok
Affected Area (sq. km.)	1	0.021	0.012	0.053	0.0096	0.039	0.046	0.021	0.013	0.008	1.27	1.83
	2	0.0028	0.0027	0.014	0.00073	0.0078	0.0076	0.0077	0.0066	0.0053	0.031	0.43
	3	0	0.000095	0.0053	0.00055	0.00045	0.0042	0.0036	0.0065	0.013	0.026	0.26
	4	0	0	0.0005	0.017	0.000013	0.00023	0.0001	0.0035	0.00042	0.021	0.076
	5	0	0	0.00053	0.0073	0	0.000001	0	0	0	0.015	0.012
	6	0	0	0.015	0.053	0	0	0	0	0	0.0025	0

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

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Bukal	Calicanto	Catandala	Conde Itaas	Conde Labak	Cuta	Dalig	Domoclay	Gulod Itaas	Gulod Labak	Kumintang Ibaba
Affected Area (sq. km.)	1	0.69	1	4.68	2.98	1.14	0.87	1.88	2.54	1.53	0.97	1.32
	2	0.014	0.3	0.18	0.096	0.025	0.2	0.088	0.16	0.099	0.06	0.19
	3	0.008	0.18	0.065	0.077	0.021	0.13	0.064	0.13	0.12	0.041	0.076
	4	0.011	0.17	0.053	0.078	0.015	0.069	0.054	0.11	0.057	0.023	0.074
	5	0.01	0.033	0.052	0.065	0.0033	0.045	0.058	0.22	0.037	0.025	0.054
	6	0.0015	0	0.057	0.01	0	0.021	0.011	0.028	0.0031	0.0083	0.14

Table 39. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Kumintang Ilaya	Libjo	Maapas	Mahabang Dahilig	Mahabang Parang	Mahacot Kanluran	Mahacot Silangan	Malalim	Malitam	Paharang Silangan	Sampaga
Affected Area (sq. km.)	1	0.96	1.62	1.4	0.43	1.11	2.32	1.92	1.88	0.19	1.51	2.06
	2	0.092	0.82	0.035	0.0086	0.05	0.1	0.068	0.081	0.047	0.04	0.12
	3	0.02	0.99	0.025	0.0051	0.018	0.034	0.044	0.052	0.035	0.027	0.047
	4	0.004	0.5	0.022	0.0017	0.012	0.032	0.031	0.072	0.027	0.028	0.042
	5	0.0052	0.23	0.026	0.0006	0.0076	0.044	0.037	0.065	0.019	0.022	0.053
	6	0.002	0.045	0.0086	0	0.0019	0.019	0.025	0.0006	0.00062	0.0013	0.0095

Table 40. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		San Isidro	San Jose Sico	San Miguel	San Pedro	Santa Clara	Santa Rita Aplaya	Santa Rita Karsada	Santo Niño	Sirang Lupa	Sorosoro Ibaba	Sorosoro Ilaya
Affected Area (sq. km.)	1	2.24	0.62	4.22	4.23	1.03	0.21	2.45	0.55	1.49	1.25	0.64
	2	0.22	0.013	0.12	0.15	0.4	0.2	0.49	0.014	0.095	0.033	0.014
	3	0.13	0.0089	0.078	0.095	0.25	0.17	0.14	0.0093	0.067	0.016	0.0063
	4	0.052	0.0092	0.06	0.074	0.22	0.17	0.028	0.0059	0.067	0.011	0.0063
	5	0.021	0.011	0.042	0.076	0.0037	0	0.0012	0.0025	0.064	0.0078	0.0093
	6	0.0018	0.0009	0.0025	0.14	0	0	0	0	0.0057	0.0029	0.0095

Table 41. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)							
		Sorosoro Karsada	Tabangao Ambulong	Tabangao Aplaya	Talumpok Kanluran	Tinga Itaas	Tinga Labak	Tulo	Wawa
Affected Area (sq. km.)	1	2.17	0.37	0.063	2.61	2.59	2.54	3.97	0.18
	2	0.091	0.093	0.017	0.072	0.16	0.19	0.16	0.18
	3	0.031	0.065	0.016	0.054	0.048	0.097	0.094	0.15
	4	0.037	0.033	0.019	0.061	0.033	0.025	0.063	0.054
	5	0.042	0.0002	0.0019	0.02	0.048	0.046	0.071	0.0081
	6	0.0067	0	0	0.00012	0.095	0.11	0.0047	0.00045

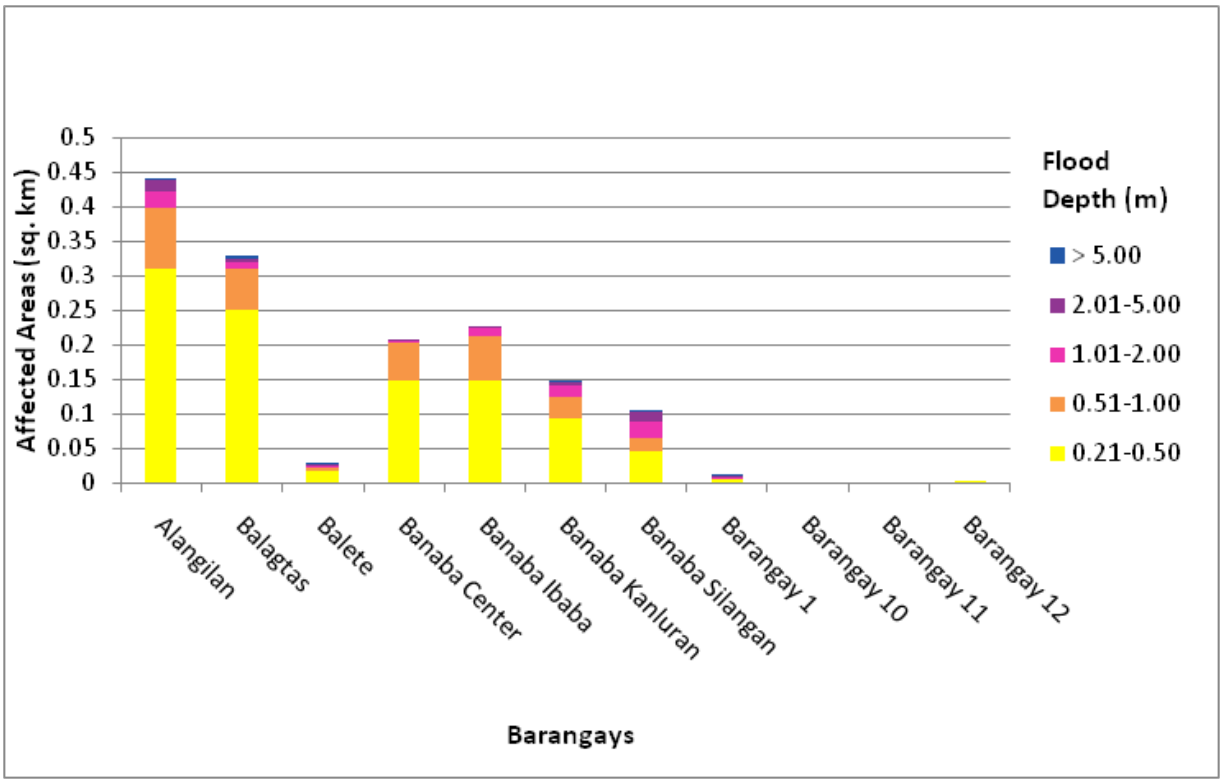


Figure 73. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

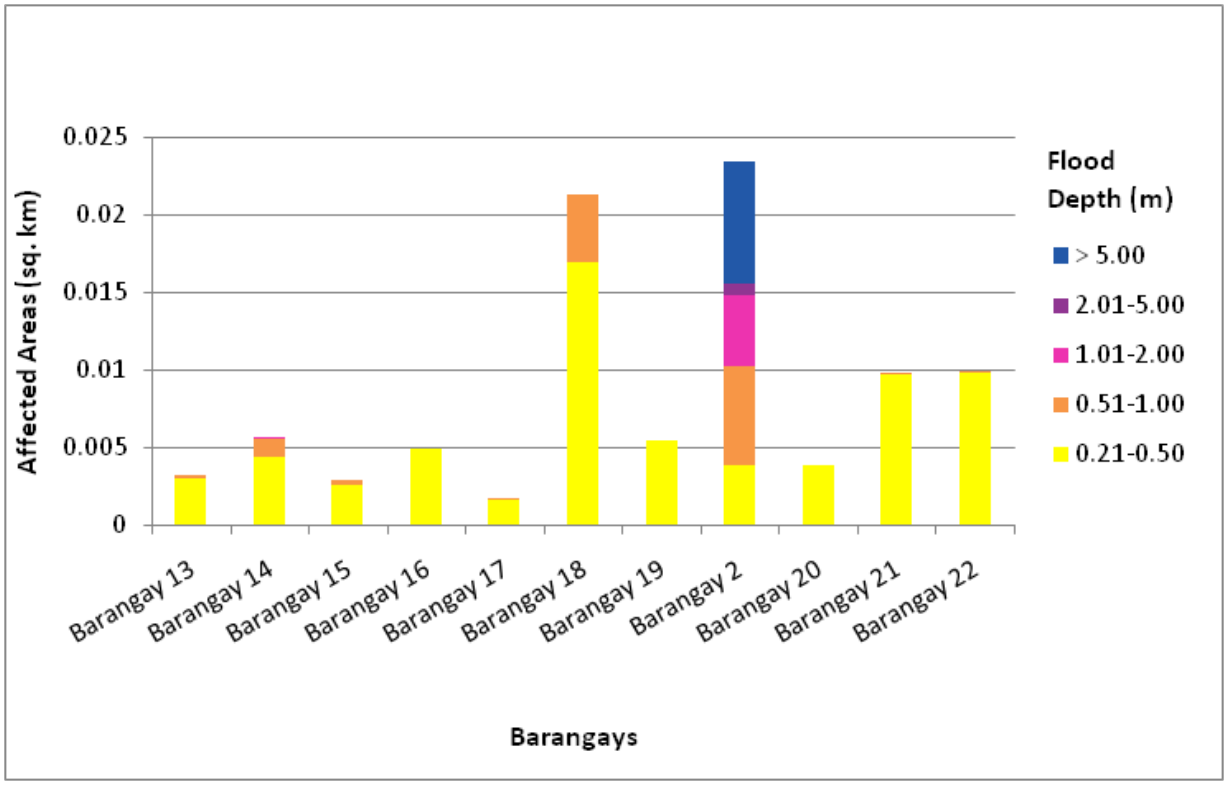


Figure 74. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

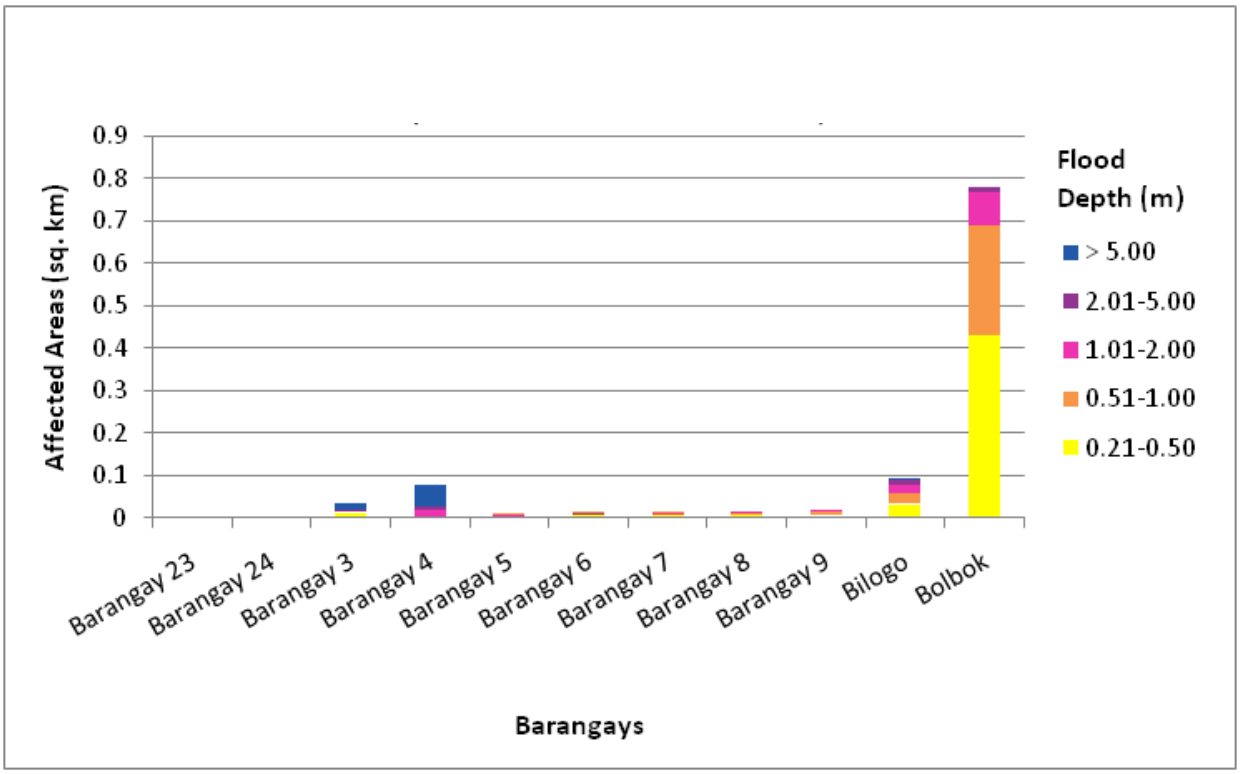


Figure 75. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

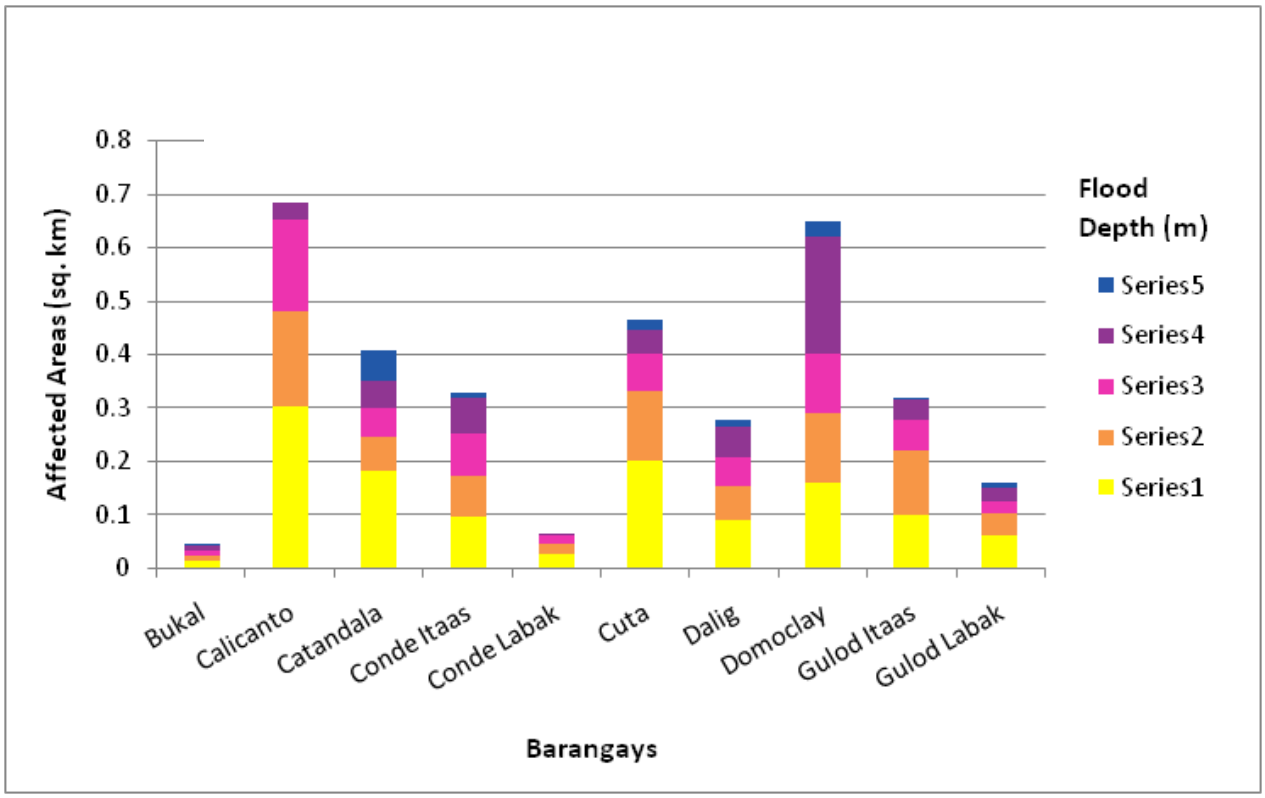


Figure 76. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

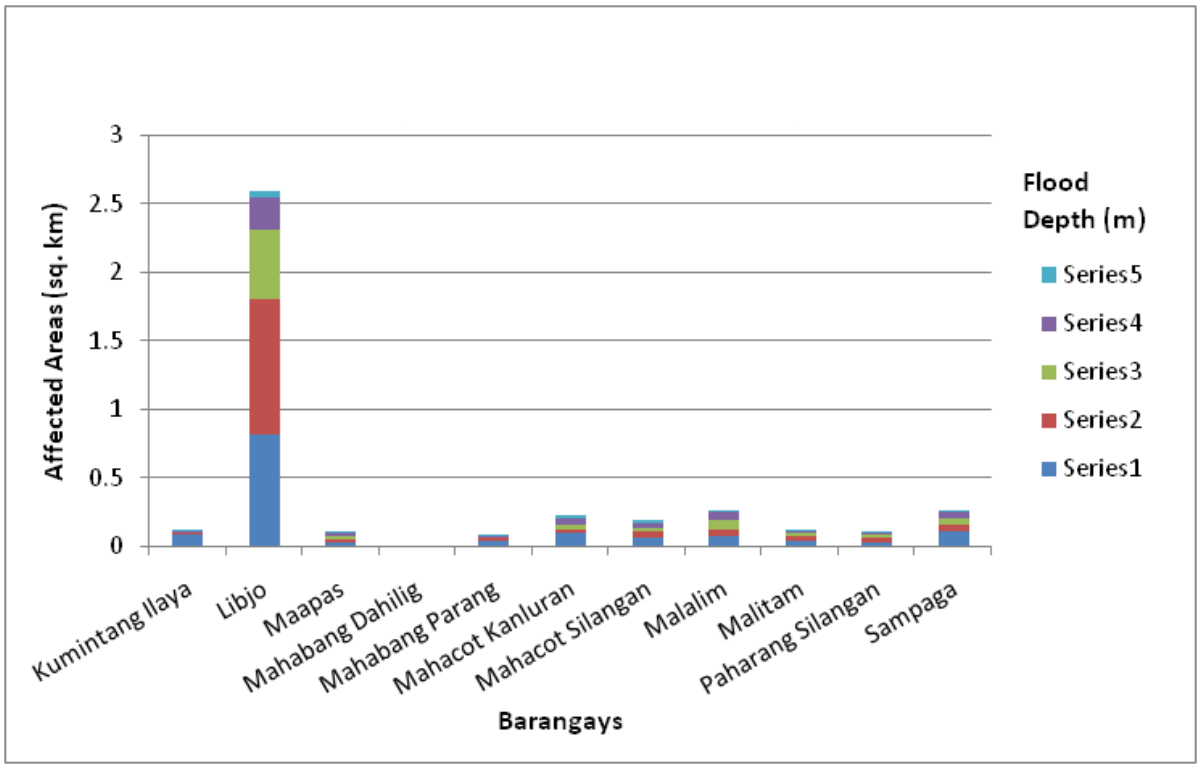


Figure 77. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

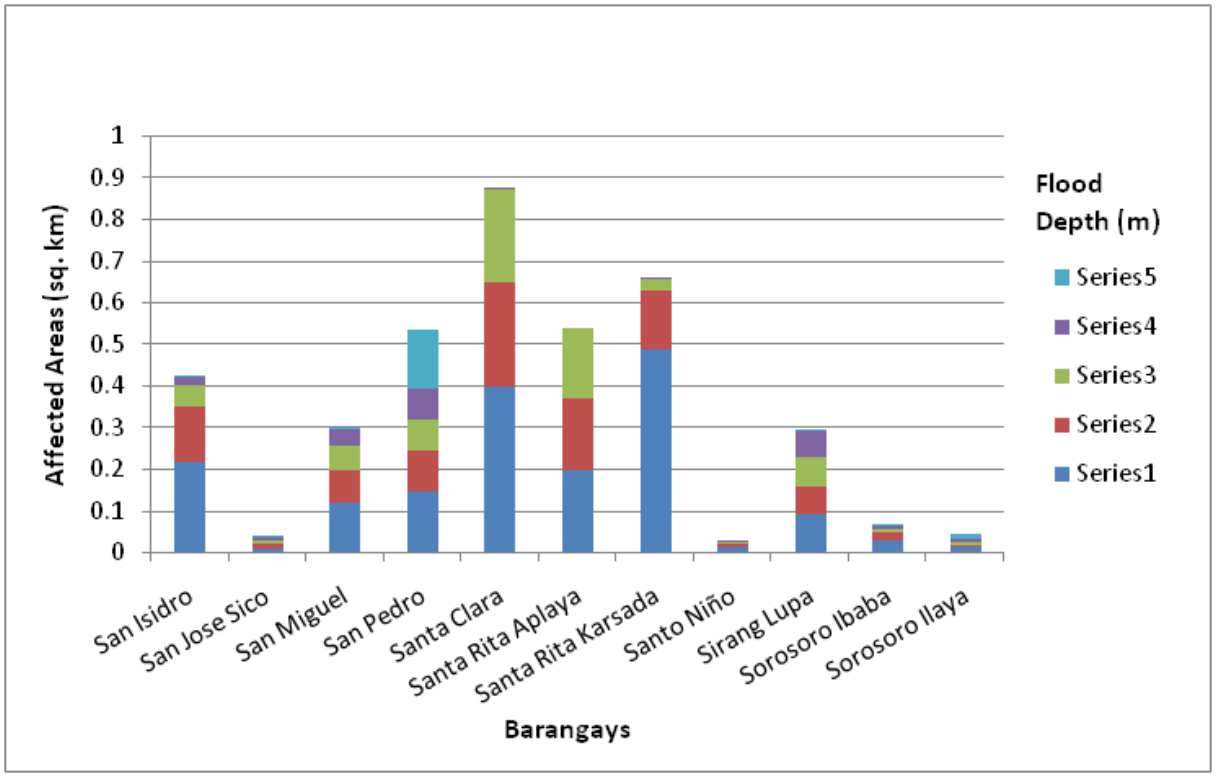


Figure 78. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

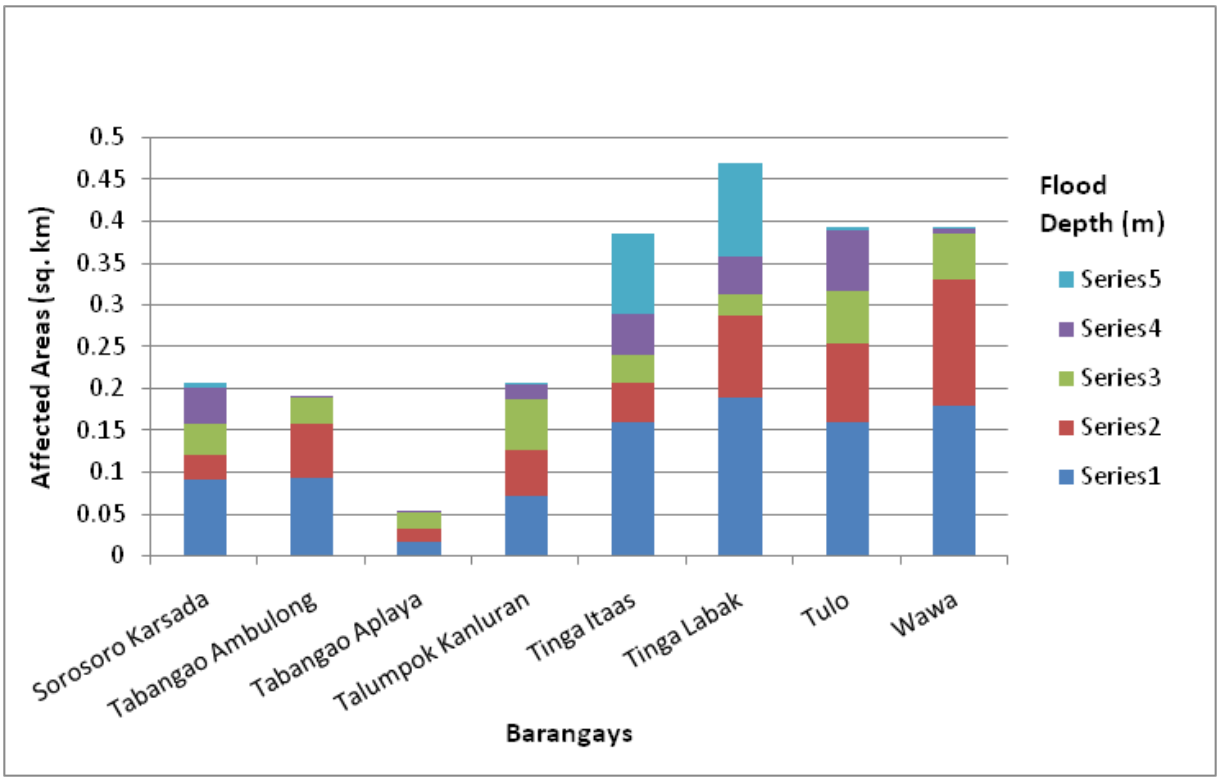


Figure 79. Affected areas in Batangas City, Batangas during a 5-year rainfall return period

For the 5-year return period, 7.51% of the municipality of Rosario with an area of 199.037 sq km will experience flood levels of less than 0.20 meters; 0.40% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.21%, 0.17%, 0.10%, and 0.08% 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 and Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected areas in Rosario, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Rosario (in sq. km.)							
		Bagong Pook	Bulihan	Colongan	Itlugan	Maalas-As	Malaya	Mavalor	Namuco
Affected Area (sq. km.)	1	0.82	0.11	3.7	2.41	2.07	0.67	0.66	0.14
	2	0.049	0.0041	0.23	0.1	0.11	0.04	0.033	0.0054
	3	0.029	0.0013	0.09	0.072	0.06	0.02	0.0093	0.0028
	4	0.017	0.0002	0.075	0.067	0.046	0.0033	0.008	0.00066
	5	0.012	0	0.065	0.062	0.014	0.0001	0.002	0
	6	0	0	0.08	0.024	0.0017	0	0	0

Table 43. Affected areas in Rosario, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Rosario (in sq. km.)		
		San Ignacio	Timbugan	Tiquiwan
Affected Area (sq. km.)	1	0.075	4.28	0.013
	2	0.0042	0.22	0.00077
	3	0.00076	0.13	0.0008
	4	0	0.12	0
	5	0	0.051	0
	6	0	0.046	0

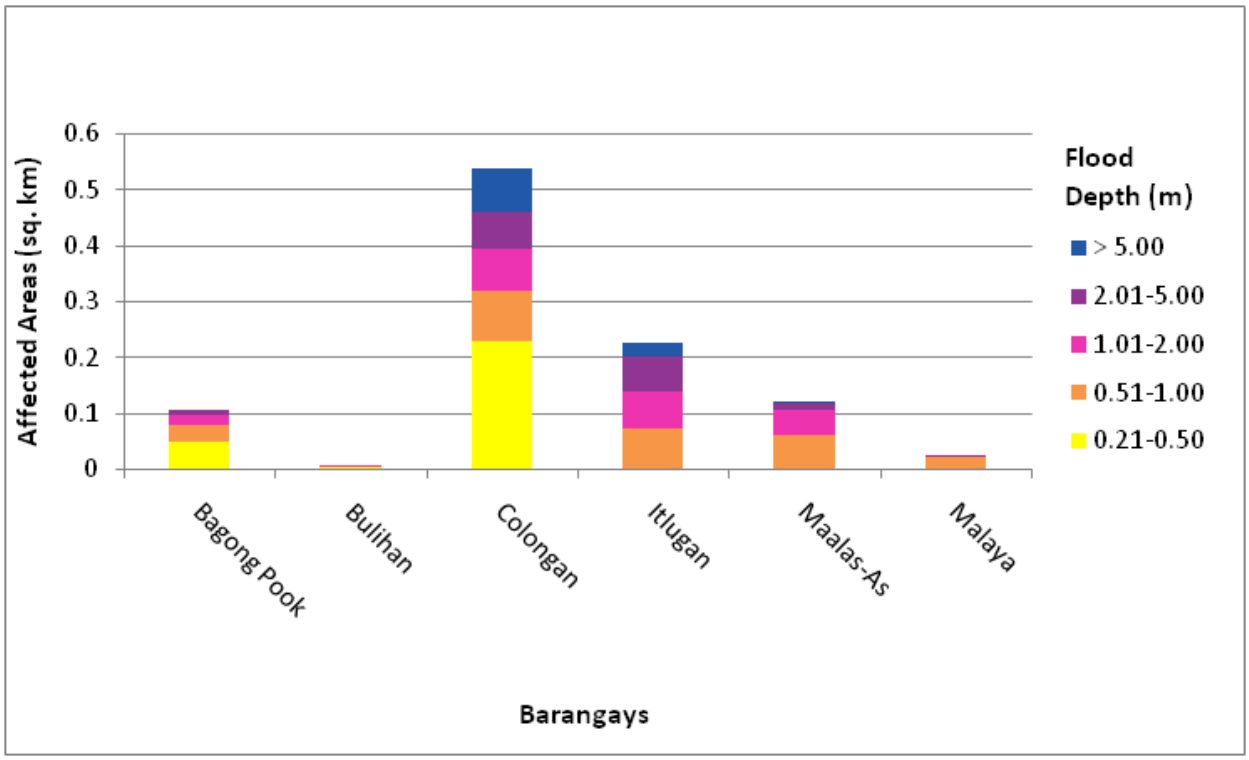


Figure 80. Affected areas in Rosario, Batangas during a 5-year rainfall return period

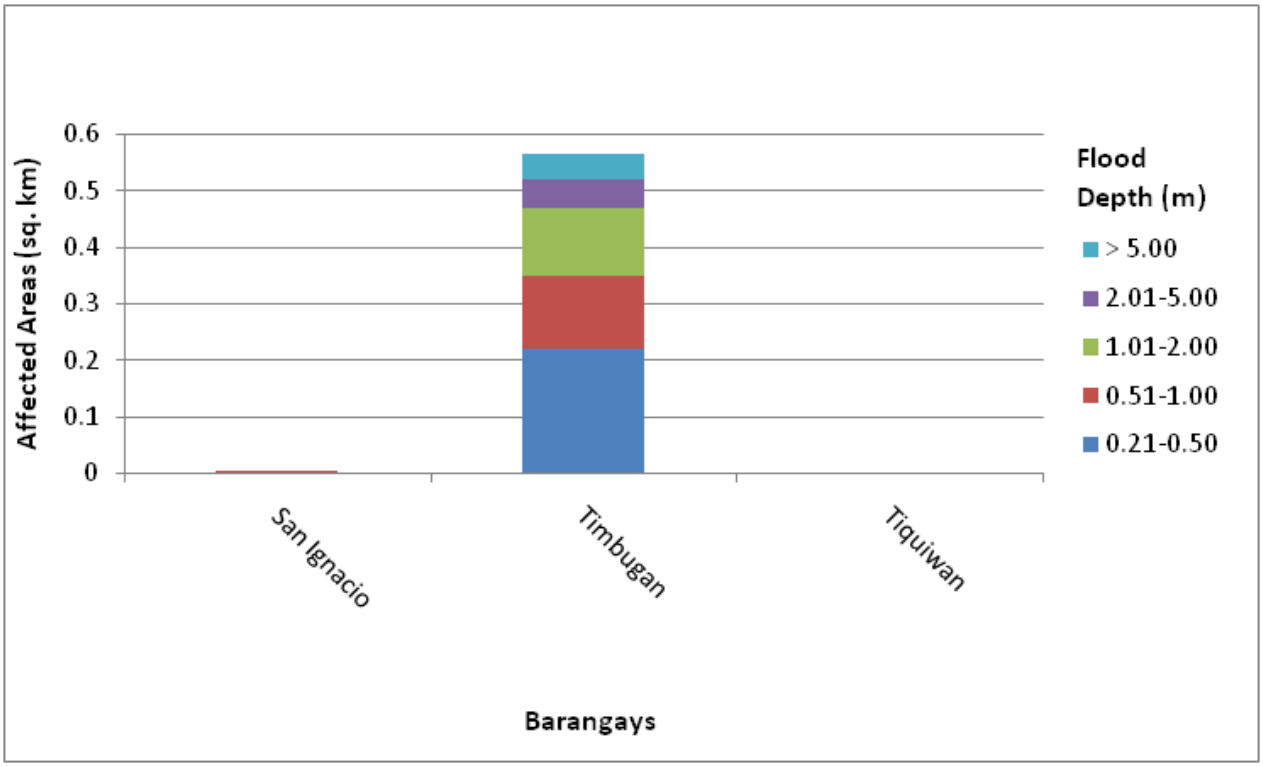


Figure 81. Affected areas in Rosario, Batangas during a 5-year rainfall return period

For the 5-year return period, 49.03% of the municipality of Ibaan with an area of 70.33 sq km will experience flood levels of less than 0.20 meters; 2.34% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.02%, 0.72%, 0.61%, and 0.63% 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 and Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 44. Affected areas in Ibaan, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ibaan (in sq. km.)									
		Bago	Bala-nga	Bunga-han	Catan-dala	Coliat	Daya-pan	Luc-suhin	Maba-lor	Mala-inin	Matala
Affec-ted Area (sq. km.)	1	1.06	2.06	3.38	3.33	1.32	2.24	2.88	4.44	0.49	0.56
	2	0.079	0.084	0.17	0.12	0.11	0.14	0.12	0.17	0.026	0.032
	3	0.034	0.038	0.077	0.069	0.031	0.054	0.071	0.08	0.008	0.0072
	4	0.017	0.028	0.044	0.056	0.02	0.034	0.066	0.061	0.0025	0.0049
	5	0.015	0.034	0.041	0.04	0.0082	0.031	0.051	0.04	0.0017	0.0005
	6	0.0001	0.064	0.077	0.036	0.0005	0.075	0.064	0.024	0.0002	0

Table 45. Affected areas in Ibaan, Batangas during a 5-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ibaan (in sq. km.)							
		Palindan	Pangao	Panghayaan	Poblacion	Quilo	Sabang	San Agustin	Sandalan
Affected Area (sq. km.)	1	0.45	1.61	2.07	0.46	2.94	3.58	0.57	1.04
	2	0.022	0.12	0.075	0.032	0.12	0.14	0.037	0.049
	3	0.0076	0.048	0.049	0.018	0.042	0.041	0.0088	0.035
	4	0.0041	0.024	0.029	0.0066	0.038	0.037	0.0038	0.029
	5	0.0006	0.0058	0.019	0.0014	0.055	0.072	0	0.013
	6	0	0	0.0022	0	0.015	0.084	0	0.0006

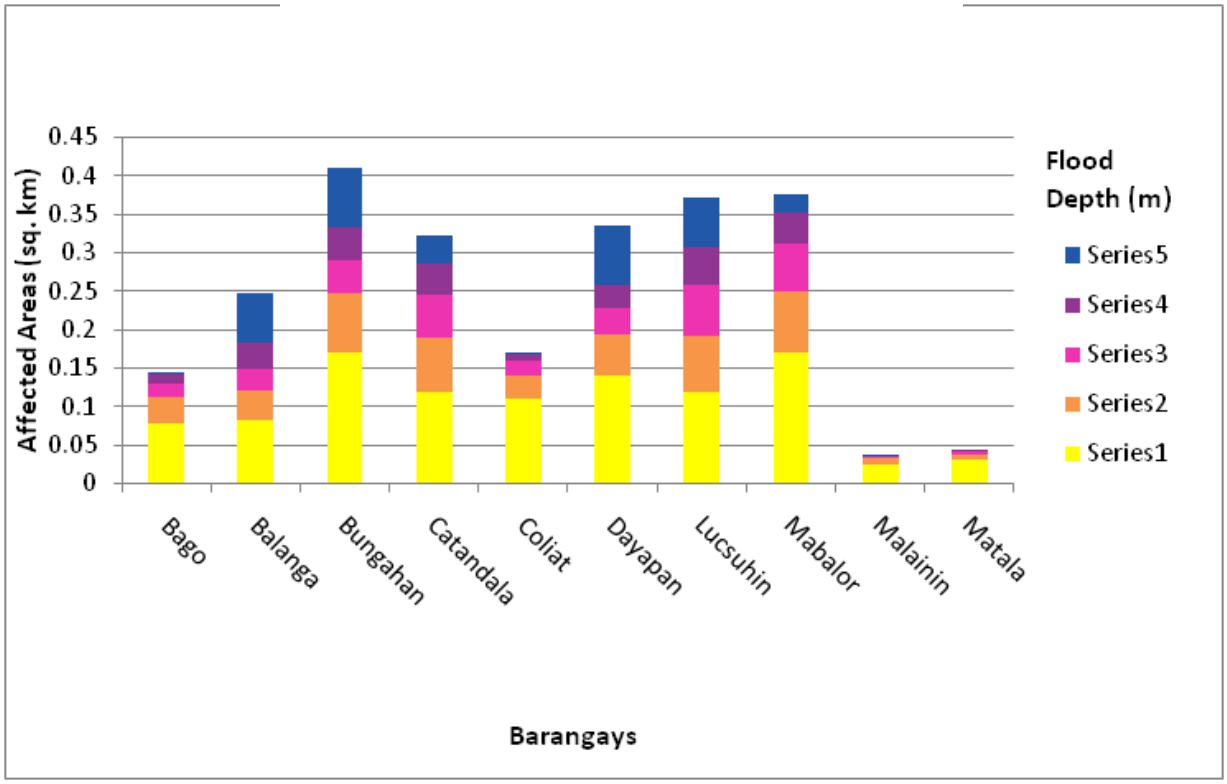


Figure 82. Affected areas in Ibaan, Batangas during a 5-year rainfall return period

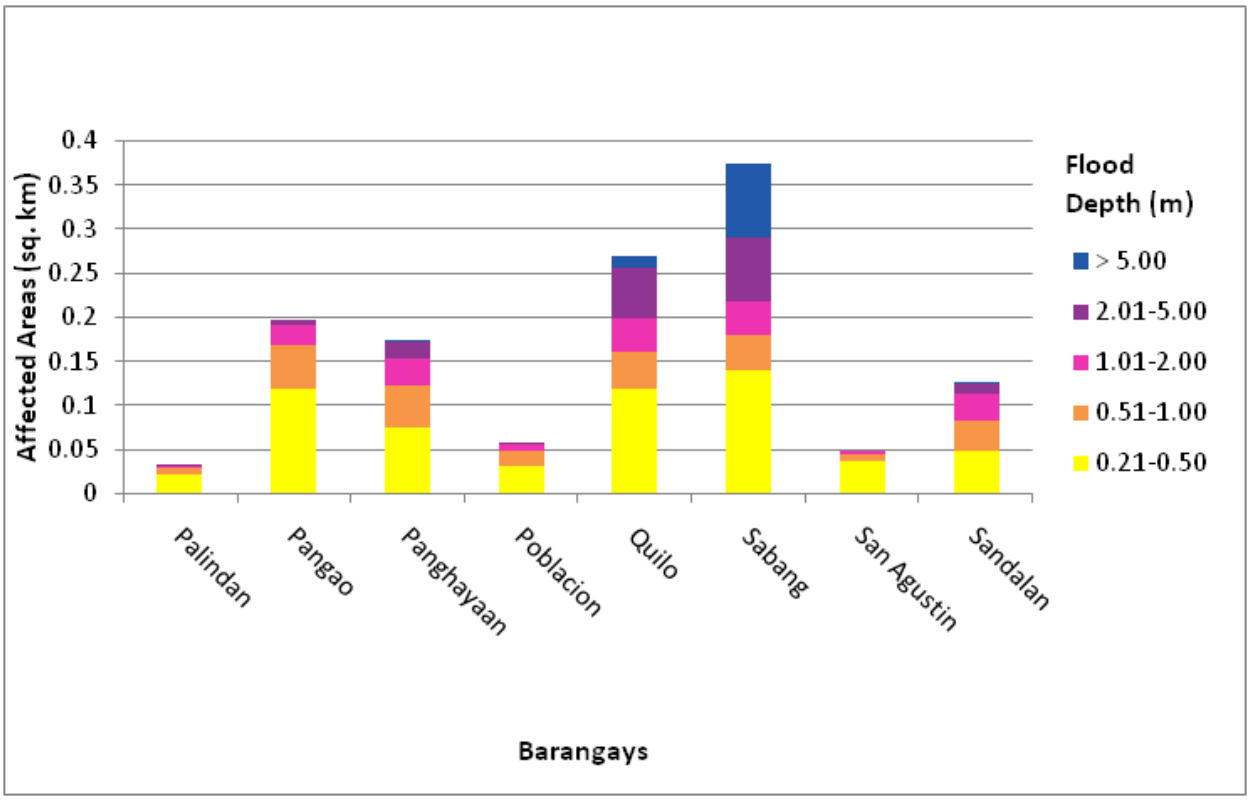


Figure 83. Affected areas in Ibaan, Batangas during a 5-year rainfall return period

For the municipality of Santa Rita, with an area of 250.37 sq km., 45.63% will experience flood levels of less 0.20 meters; 3.44% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.33%, 2.40%, 0.68%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Outlined in Table 46 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected areas in Taysan, Batangas during a 5-year rainfall return period

Affec-ted Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Taysan (in sq. km.)								
		Bilogo	Bukal	Maba-yabas	Mahana-diong	Mataas Na Lupa	Pag-Asa	Pang-hayaan	Pobla-cion East	Tilam-bo
Affec-ted Area (sq. km.)	1	0.57	0.18	3.42	1.67	0.1	1.76	1.05	0.35	0.08
	2	0.013	0.0059	0.26	0.14	0.0038	0.089	0.045	0.047	0.001
	3	0.014	0.0056	0.13	0.049	0.0024	0.032	0.028	0.022	0
	4	0.012	0.0045	0.098	0.012	0.0015	0.039	0.03	0.009	0
	5	0.0066	0.0019	0.053	0.0007	0.0002	0.041	0.0081	0.0059	0
	6	0.0008	0	0.004	0	0	0.002	0	0	0

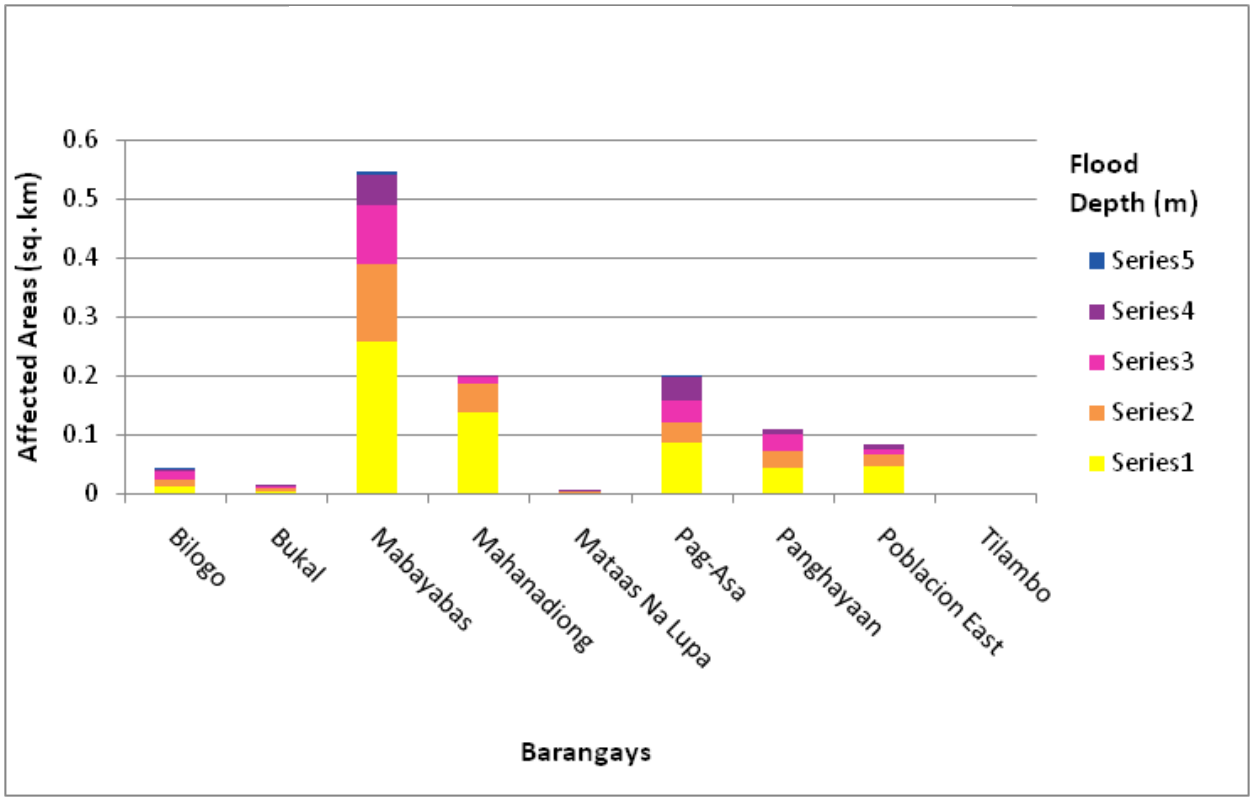


Figure 84. Affected Areas in Taysan, Batangas during a 5-year rainfall return period

For the 25-year return period, 27.48% of the municipality of Batangas City with an area of 274.44 sq km will experience flood levels of less than 0.20 meters; 2.76% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.29%, 1.65%, 0.88%, and 0.46% 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 the Table 47 to Table 53 are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Alangilan	Balagtas	Balete	Banaba Center	Banaba Ibaba	Banaba Kanluran	Banaba Silangan	Barangay 1	Barangay 10	Barangay 11	Barangay 12
Affected Area (sq. km.)	1	2.22	1.98	0.37	1.04	0.99	1.03	0.29	0.0024	0.013	0.01	0.0087
	2	0.37	0.32	0.026	0.17	0.17	0.11	0.047	0.0092	0.0027	0.002	0.004
	3	0.15	0.097	0.0087	0.091	0.097	0.044	0.033	0.044	0	0.0006	0.0001
	4	0.035	0.016	0.0025	0.0066	0.028	0.021	0.024	0.0051	0	0	0
	5	0.024	0.0067	0.0048	0.0004	0.0031	0.011	0.022	0.0028	0	0	0.0001
	6	0.0044	0.0051	0.00071	0	0	0.0023	0.0007	0.0039	0	0	0

Table 48. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Barangay 13	Barangay 14	Barangay 15	Barangay 16	Barangay 17	Barangay 18	Barangay 19	Barangay 2	Barangay 20	Barangay 21	Barangay 22
Affected Area (sq. km.)	1	0.0077	0.0081	0.022	0.042	0.033	0.029	0.011	0.0028	0.043	0.037	0.033
	2	0.0047	0.0052	0.0049	0.0086	0.003	0.0069	0.0043	0.0027	0.0087	0.016	0.015
	3	0.00081	0.0029	0.00088	0.0011	0.0041	0.015	0.029	0.014	0.0039	0.0004	0.00078
	4	0	0.0002	0	0	0.00065	0.015	0.00041	0.013	0	0	0
	5	0	0	0	0	0	0	0	0.0049	0	0	0
	6	0	0	0	0	0	0	0	0.0083	0	0	0

Table 49. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Barangay 23	Barangay 24	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Bilogo	Bolbok
Affected Area (sq. km.)	1	0.017	0.011	0.025	0.004	0.034	0.04	0.019	0.0087	0.0067	1.26	1.6
	2	0.0066	0.0036	0.019	0.0017	0.011	0.0094	0.0078	0.0075	0.0029	0.034	0.47
	3	0	0.00047	0.0076	0.0026	0.0014	0.006	0.0053	0.0083	0.016	0.027	0.37
	4	0	0	0.021	0.0023	0.00025	0.0015	0.0004	0.0048	0.0018	0.026	0.15
	5	0	0	0.0011	0.021	0.000068	0.00017	0	0	0	0.02	0.017
	6	0	0	0.015	0.057	0	0	0	0	0	0.0037	0.0001

Table 50. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Bukal	Calicanto	Catandala	Conde Itaas	Conde Labak	Cuta	Dalig	Domoclay	Gulod Itaas	Gulod Labak	Kumintang Ibaba
Affected Area (sq. km.)	1	0.68	0.85	4.58	2.92	1.13	0.39	1.82	2.35	1.47	0.93	1.12
	2	0.017	0.31	0.22	0.11	0.035	0.25	0.1	0.17	0.086	0.057	0.22
	3	0.0093	0.25	0.088	0.075	0.022	0.37	0.072	0.18	0.098	0.055	0.089
	4	0.012	0.21	0.063	0.097	0.019	0.2	0.067	0.15	0.12	0.045	0.098
	5	0.013	0.069	0.061	0.093	0.0056	0.1	0.061	0.23	0.062	0.028	0.15
	6	0.0021	0	0.073	0.016	0	0.024	0.029	0.1	0.011	0.014	0.18

Table 51. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Kumintang Ilaya	Libjo	Maapas	Mahabang Dahilig	Mahabang Parang	Mahacot Kanluran	Mahacot Silangan	Malalim	Malitam	Paharang Silangan	Sampaga
Affected Area (sq. km.)	1	0.89	0.91	1.38	0.42	1.08	2.26	1.87	1.79	0.0013	1.49	1.98
	2	0.14	0.49	0.04	0.011	0.075	0.12	0.082	0.1	0.012	0.046	0.14
	3	0.033	1.18	0.029	0.0055	0.021	0.047	0.054	0.056	0.16	0.032	0.067
	4	0.0065	1.23	0.026	0.0025	0.014	0.034	0.041	0.07	0.099	0.027	0.048
	5	0.0062	0.31	0.032	0.001	0.01	0.056	0.046	0.12	0.041	0.033	0.071
	6	0.0042	0.084	0.012	0	0.0031	0.031	0.036	0.0084	0.0016	0.003	0.024

Table 52. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		San Isidro	San Jose Sico	San Miguel	San Pedro	Santa Clara	Santa Rita Aplaya	Santa Rita Karsada	Santo Niño	Sirang Lupa	Sorosoro Ibaba	Sorosoro Ilaya
Affected Area (sq. km.)	1	2.17	0.61	4.15	4.1	0.78	0.17	2.2	0.55	1.41	1.23	0.63
	2	0.22	0.015	0.14	0.18	0.43	0.079	0.59	0.014	0.1	0.051	0.018
	3	0.17	0.0097	0.086	0.11	0.36	0.26	0.27	0.012	0.097	0.018	0.0067
	4	0.083	0.011	0.073	0.095	0.32	0.23	0.05	0.0069	0.087	0.012	0.0057
	5	0.026	0.013	0.062	0.11	0.019	0.0029	0.003	0.0038	0.081	0.011	0.012
	6	0.0026	0.0016	0.0049	0.17	0	0	0	0	0.01	0.0042	0.013

Table 53. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)							
		Sorosoro Karsada	Tabangao Ambulong	Tabangao Aplaya	Talumpok Kanluran	Tinga Itaas	Tinga Labak	Tulo	Wawa
Affected Area (sq. km.)	1	2.1	0.32	0.05	2.57	2.48	2.42	3.88	0.032
	2	0.14	0.096	0.019	0.08	0.21	0.22	0.18	0.07
	3	0.034	0.091	0.022	0.06	0.069	0.14	0.12	0.27
	4	0.039	0.053	0.019	0.071	0.031	0.031	0.073	0.19
	5	0.055	0.001	0.0064	0.04	0.058	0.064	0.099	0.016
	6	0.013	0	0	0.00015	0.13	0.14	0.01	0.0035

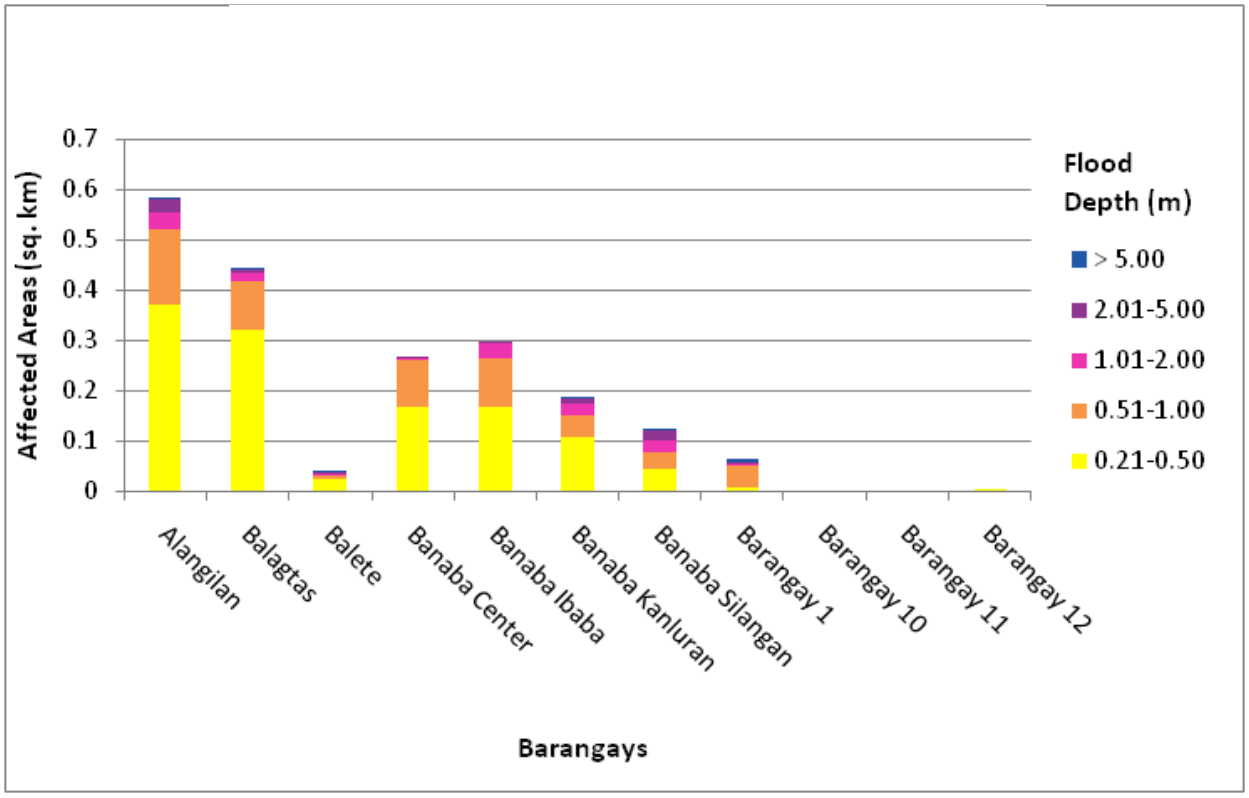


Figure 85. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

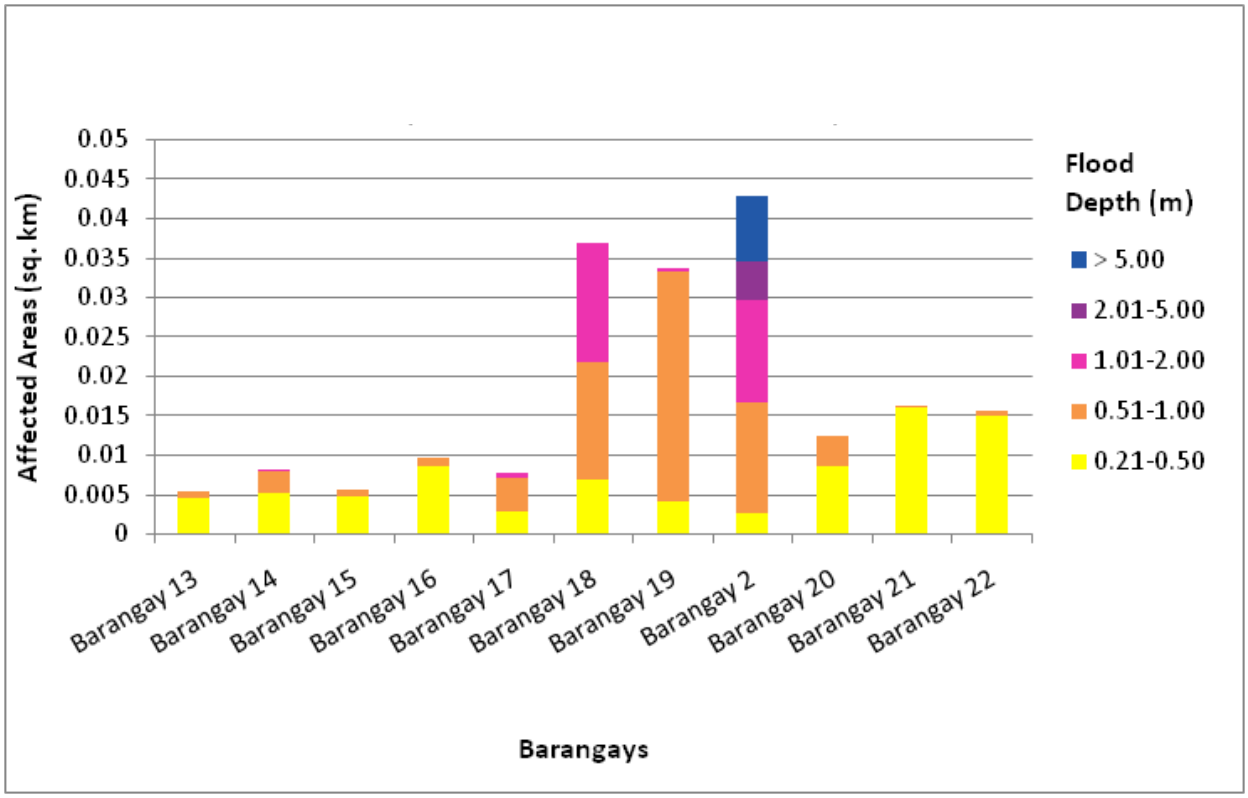


Figure 86. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

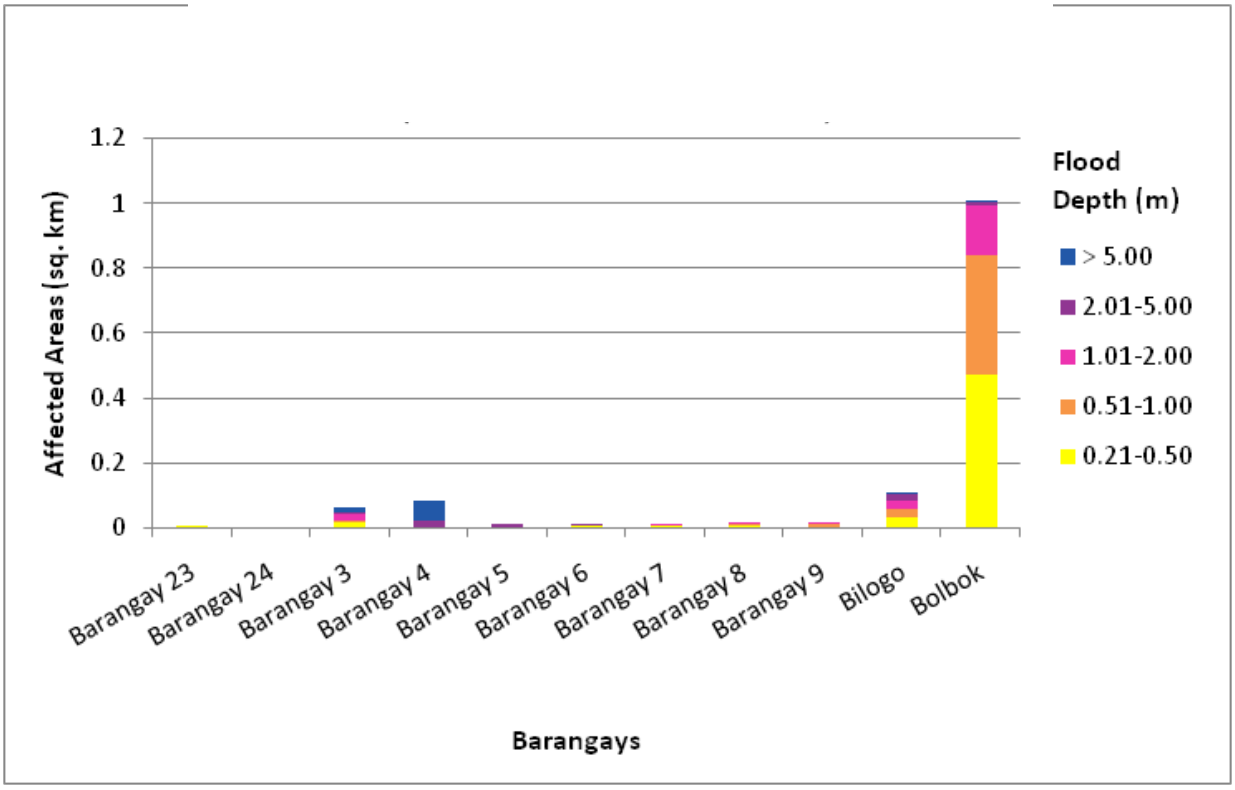


Figure 87. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

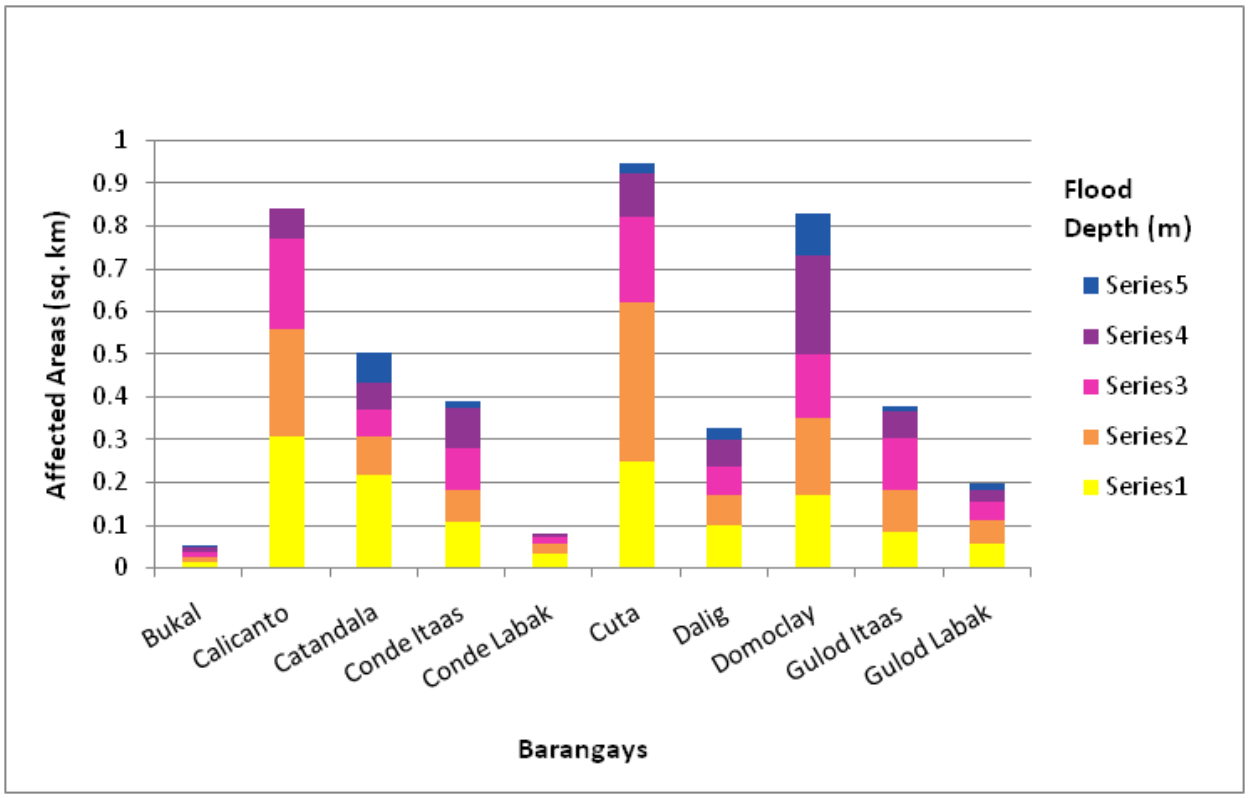


Figure 88. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

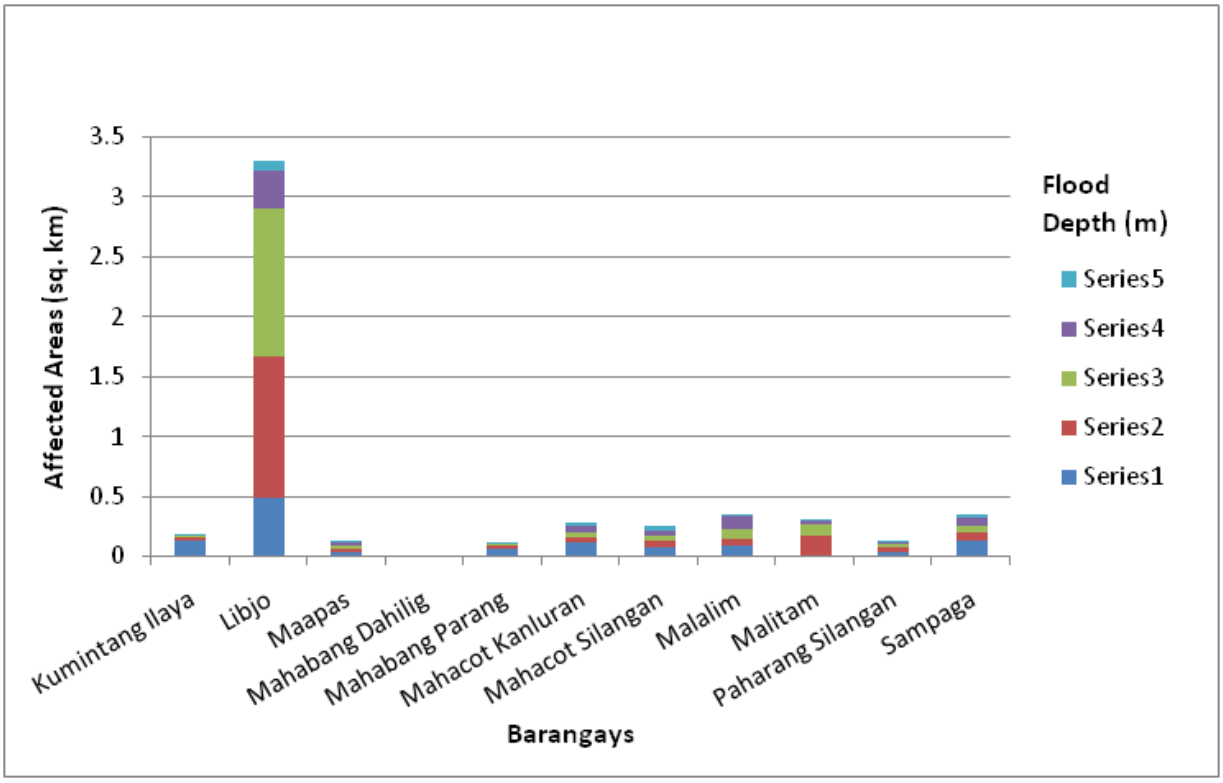


Figure 89. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

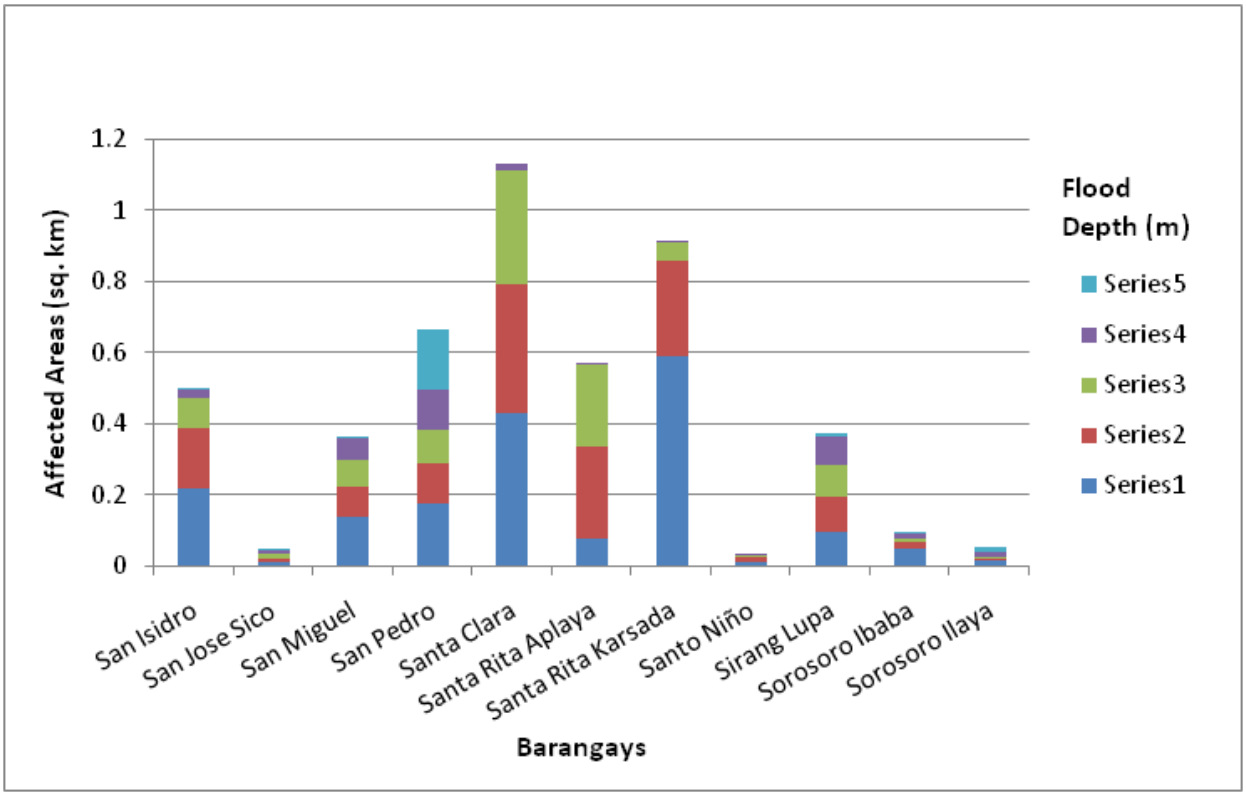


Figure 90. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

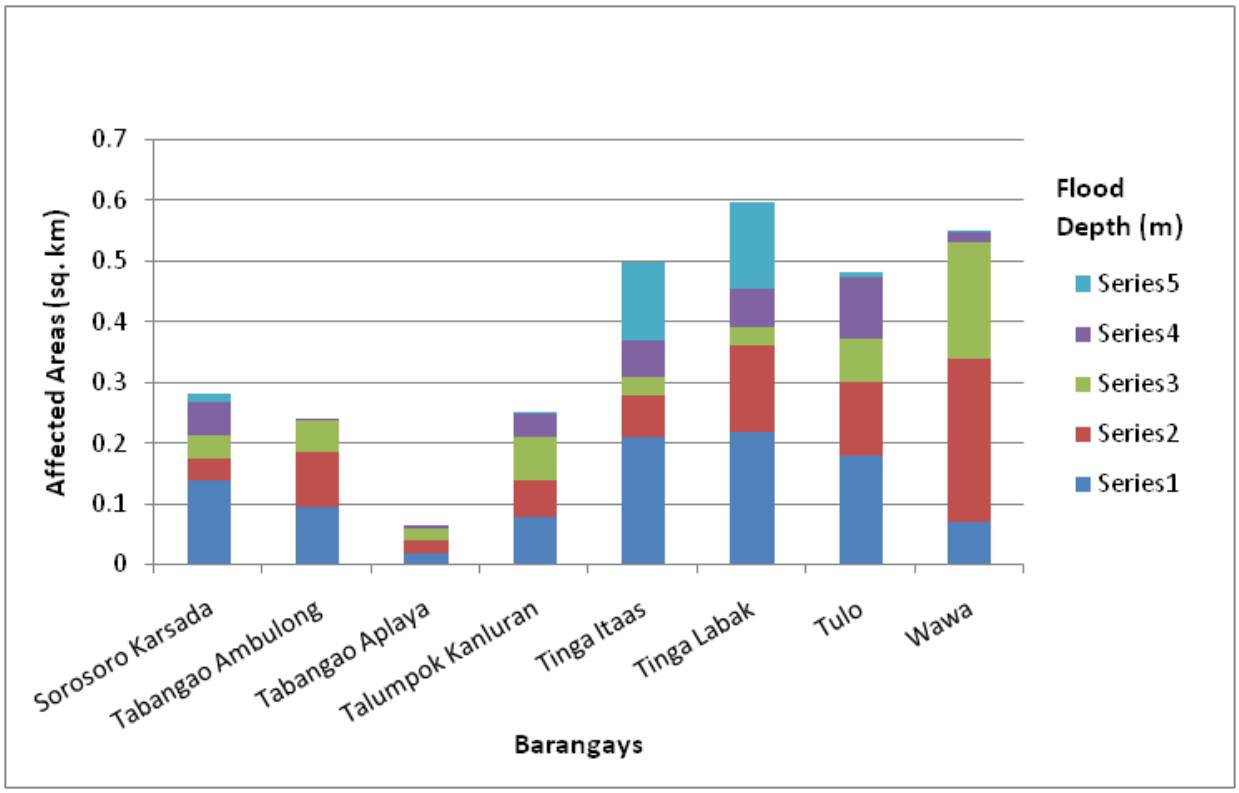


Figure 91. Affected areas in Batangas City, Batangas during a 25-year rainfall return period

For the 25-year return period, 7.21% of the municipality of Rosario with an area of 199.037 sq km will experience flood levels of less than 0.20 meters; 0.52% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.25%, 0.21%, 0.14%, and 0.13% 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 54 and Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected areas in Rosario, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Rosario (in sq. km.)							
		Bagong Pook	Bulihan	Colongan	Itlugan	Maalas-As	Malaya	Mavalor	Namuco
Affected Area (sq. km.)	1	0.79	0.1	3.55	2.31	2	0.64	0.65	0.14
	2	0.065	0.007	0.3	0.13	0.13	0.048	0.04	0.0076
	3	0.033	0.0014	0.11	0.083	0.074	0.03	0.014	0.0039
	4	0.023	0.0004	0.088	0.084	0.061	0.0046	0.0096	0.0011
	5	0.019	0	0.082	0.074	0.021	0.0011	0.0042	0
	6	0	0	0.12	0.047	0.0067	0	0	0

Table 55. Affected areas in Rosario, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Rosario (in sq. km.)		
		San Ignacio	Timbugan	Tiquiwan
Affected Area (sq. km.)	1	0.073	4.08	0.013
	2	0.0062	0.3	0.00082
	3	0.0011	0.15	0.0011
	4	0	0.15	0
	5	0	0.08	0
	6	0	0.087	0

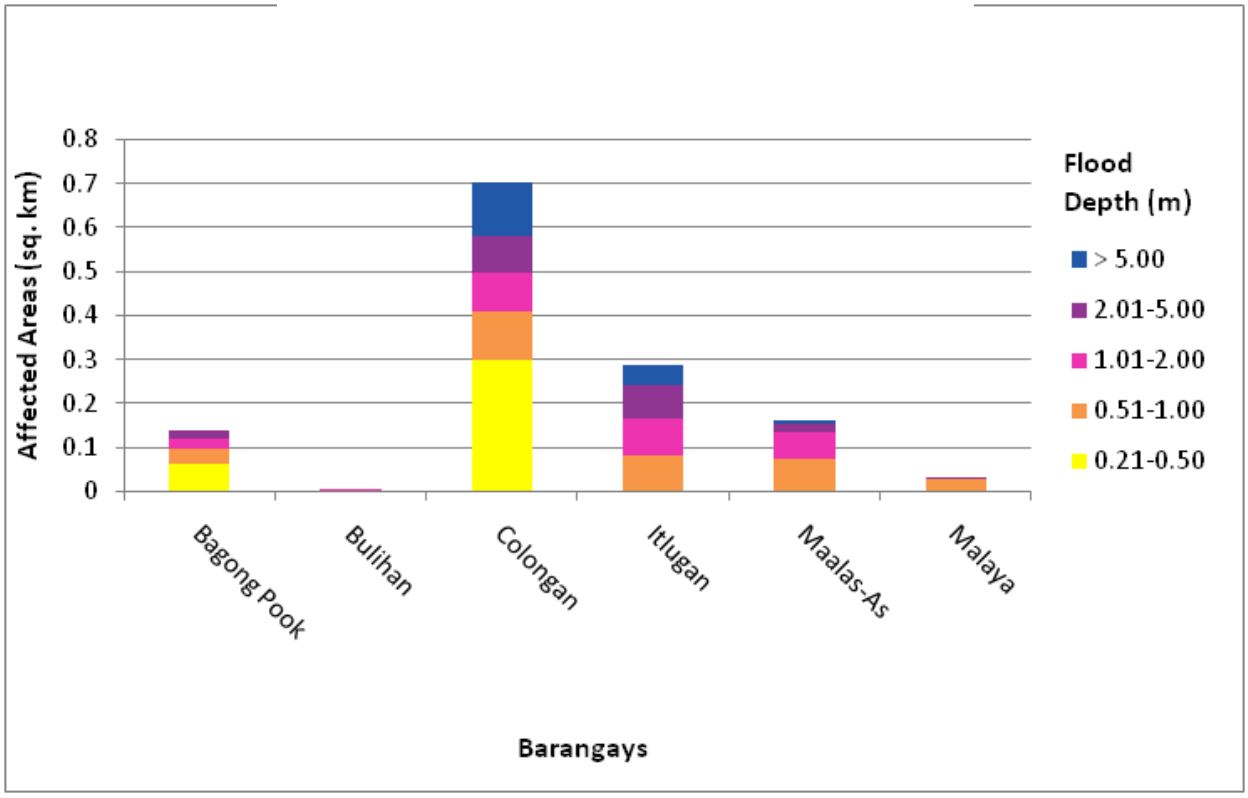


Figure 92. Affected areas in Rosario, Batangas during a 25-year rainfall return period

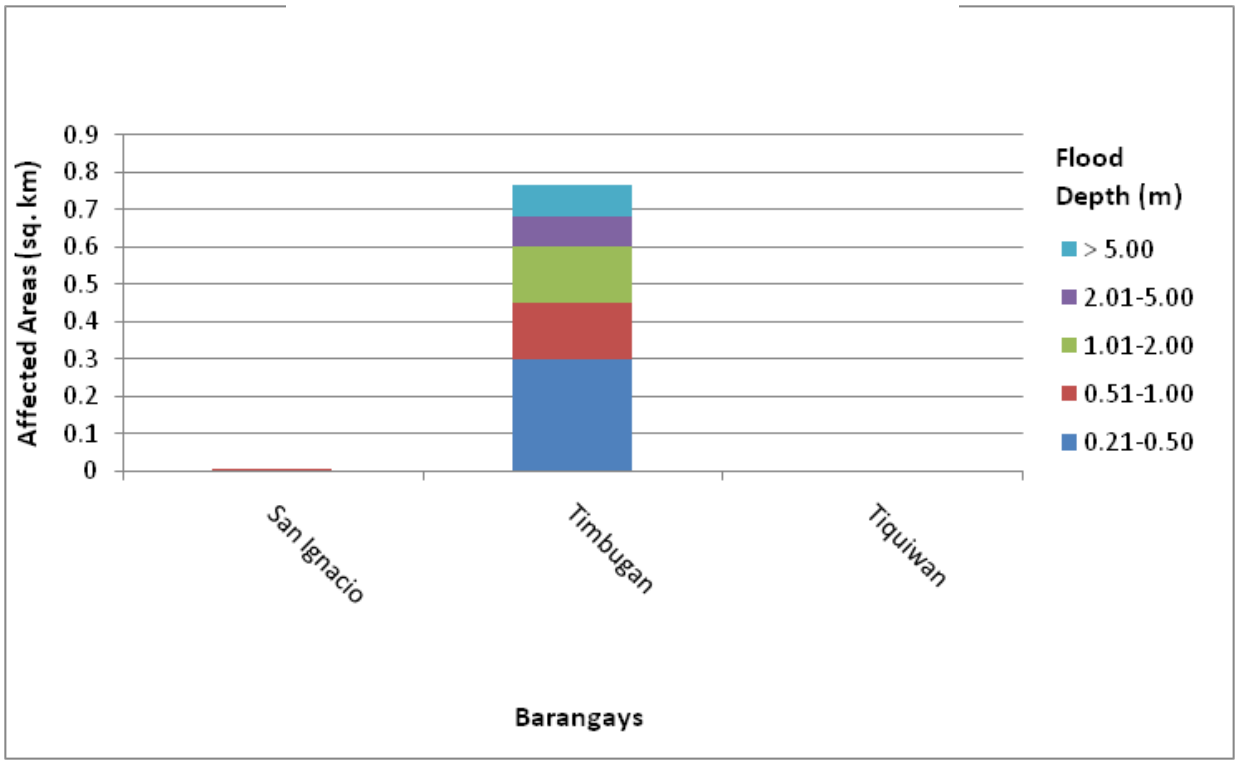


Figure 93. Affected areas in Rosario, Batangas during a 25-year rainfall return period

For the municipality of Ibaan, with an area of 130.22 sq km, 3.02% will experience flood levels of less 0.20 meters; 0.10% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.13%, 0.16%, and 0.014% 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 56 and Table 57 are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected areas in Ibaan, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ibaan (in sq. km.)									
		Bago	Bala-nga	Bunga-han	Catan-dala	Coliat	Daya-pan	Lucsu-hin	Maba-lor	Mala-inin	Mata-la
Affec-ted Area (sq. km.)	1	1.02	2	3.28	3.25	1.26	2.16	2.8	4.33	0.47	0.55
	2	0.094	0.11	0.21	0.15	0.14	0.16	0.15	0.23	0.034	0.04
	3	0.047	0.042	0.11	0.086	0.045	0.083	0.079	0.095	0.012	0.012
	4	0.025	0.034	0.051	0.065	0.027	0.037	0.077	0.076	0.0041	0.0068
	5	0.022	0.041	0.053	0.056	0.014	0.039	0.066	0.054	0.0024	0.0008
	6	0.0004	0.083	0.095	0.053	0.0009	0.095	0.091	0.035	0.0002	0

Table 57. Affected areas in Ibaan, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ibaan (in sq. km.)							
		Palindan	Pangao	Pangha-yaan	Pobla-cion	Quilo	Sabang	San Agustin	Sanda-lan
Affected Area (sq. km.)	1	0.44	1.55	2.03	0.44	2.86	3.47	0.56	1.01
	2	0.031	0.14	0.085	0.036	0.17	0.18	0.048	0.059
	3	0.01	0.069	0.063	0.023	0.051	0.059	0.012	0.04
	4	0.0054	0.031	0.035	0.012	0.041	0.042	0.005	0.035
	5	0.001	0.012	0.027	0.0019	0.066	0.08	0.0004	0.02
	6	0	0	0.0037	0	0.027	0.11	0	0.0014

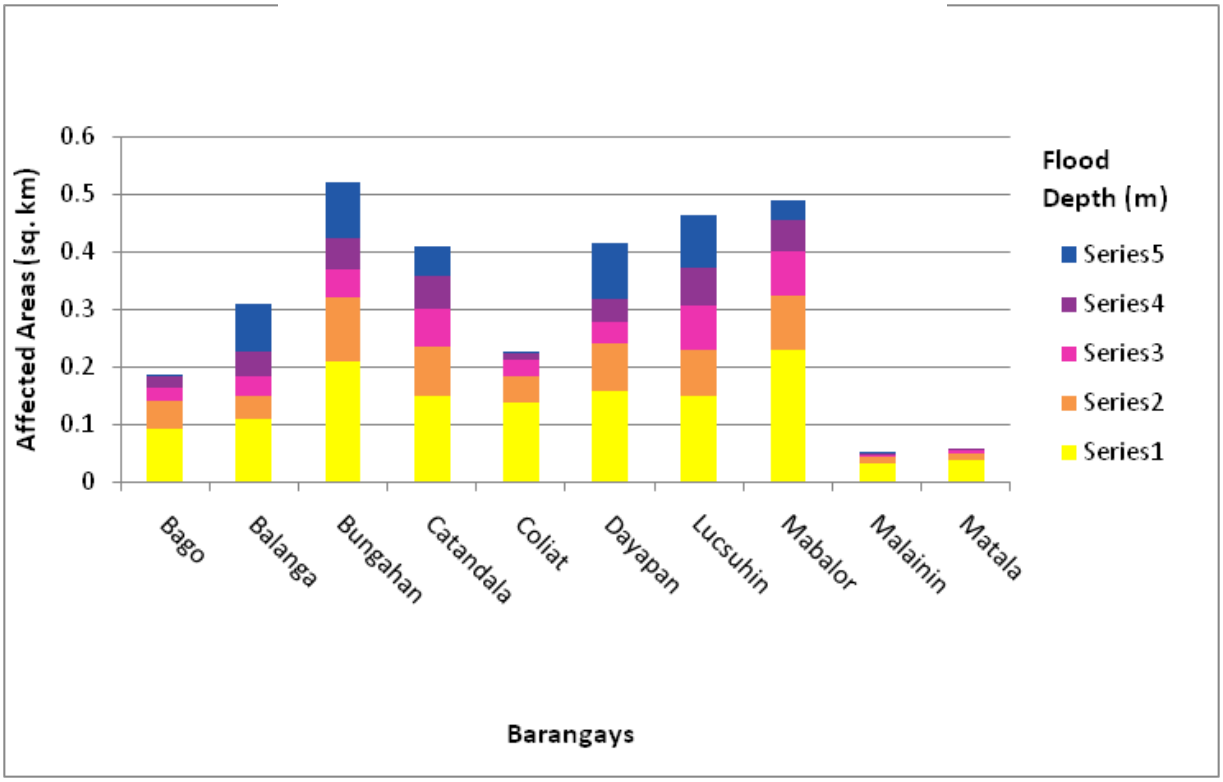


Figure 94. Affected areas in Ibaan, Batangas during a 25-year rainfall return period

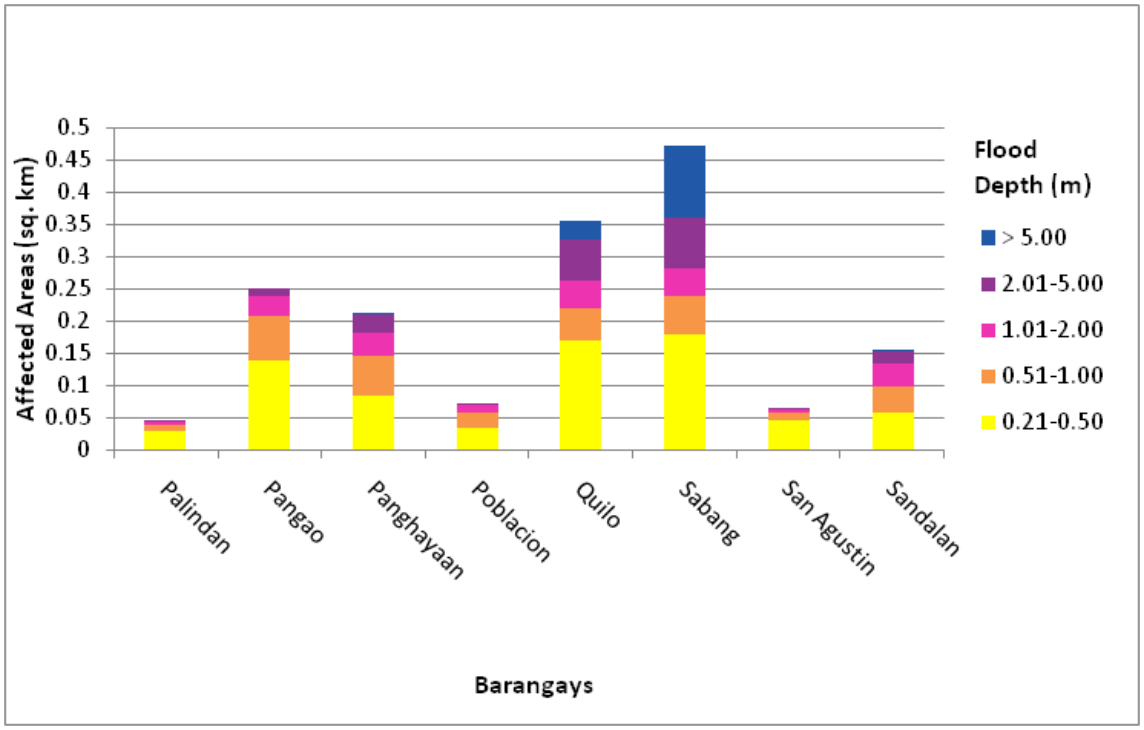


Figure 95. Affected areas in Ibaan, Batangas during a 25-year rainfall return period

For the 25-year return period, 9.52% of the municipality of Taysan with an area of 92.55 sq km will experience flood levels of less than 0.20 meters; 0.78% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.42%, 0.27%, 0.22%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 58 are the affected areas in square kilometers by flood depth per barangay.

Table 58. Affected areas in Taysan, Batangas during a 25-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Taysan (in sq. km.)								
		Bilogo	Bukal	Maba-yabas	Mahana-diong	Mataas Na Lupa	Pag-Asa	Pang-hayaan	Pobla-cion East	Tilam-bo
Affec-ted Area (sq. km.)	1	0.56	0.17	3.26	1.6	0.1	1.69	1.02	0.33	0.079
	2	0.016	0.0048	0.31	0.16	0.0036	0.12	0.056	0.052	0.0025
	3	0.014	0.0068	0.17	0.082	0.0035	0.048	0.032	0.034	0
	4	0.013	0.0059	0.12	0.02	0.0016	0.04	0.033	0.014	0
	5	0.011	0.0031	0.096	0.002	0.0003	0.059	0.02	0.0093	0
	6	0.0011	0	0.013	0	0	0.0088	0	0	0

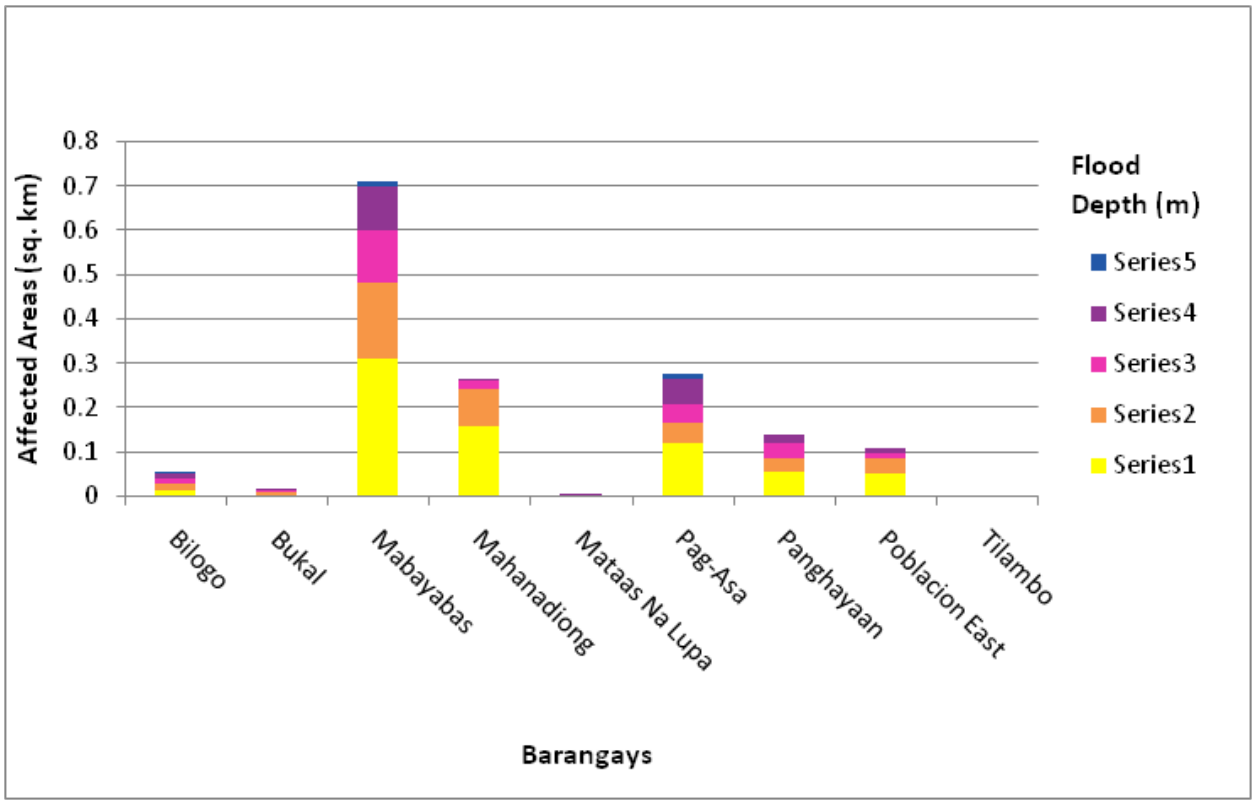


Figure 96. Affected Areas in Taysan, Batangas during 25-Year Rainfall Return Period

For the 100-year return period, 26.54% of the municipality of Batangas City with an area of 274.44 sq km will experience flood levels of less than 0.20 meters; 2.85% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.30%, 2.13%, 1.13%, and 0.55% 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 59 to Table 65 are the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Alangi-lan	Balag-tas	Balete	Bana-ba Center	Bana-ba Ibaba	Bana-ba Kan-luran	Bana-ba Sila-ngan	Bara-ngay 1	Bara-ngay 10	Bara-ngay 11	Bara-ngay 12
Affec-ted Area (sq. km.)	1	2.12	1.9	0.36	1	0.95	1	0.27	0.0005	0.012	0.0095	0.0077
	2	0.41	0.36	0.031	0.18	0.18	0.13	0.047	0.0017	0.0037	0.0026	0.0047
	3	0.19	0.12	0.011	0.11	0.12	0.055	0.041	0.019	0.00024	0.00076	0.00048
	4	0.044	0.025	0.0031	0.012	0.042	0.026	0.024	0.039	0	0	0
	5	0.028	0.0074	0.0053	0.0007	0.0041	0.013	0.027	0.0028	0	0	0.0001
	6	0.0064	0.0063	0.00078	0	0	0.003	0.0009	0.004	0	0	0

Table 60. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Barangay 13	Barangay 14	Barangay 15	Barangay 16	Barangay 17	Barangay 18	Barangay 19	Barangay 2	Barangay 20	Barangay 21	Barangay 22
Affected Area (sq. km.)	1	0.0061	0.0061	0.019	0.031	0.027	0.026	0.011	0.0011	0.041	0.028	0.028
	2	0.0061	0.0063	0.0069	0.014	0.0046	0.005	0.00085	0.0015	0.0089	0.022	0.02
	3	0.001	0.0037	0.001	0.0058	0.0048	0.0074	0.01	0.0056	0.0047	0.0028	0.0014
	4	0	0.00033	0.00013	0.00022	0.004	0.027	0.023	0.02	0.0016	0	0
	5	0	0	0	0	0	0	0	0.0088	0	0	0
	6	0	0	0	0	0	0	0	0.0084	0	0	0

Table 61. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Barangay 23	Barangay 24	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Bilogo	Bolbok
Affected Area (sq. km.)	1	0.012	0.01	0.012	0.003	0.029	0.036	0.018	0.0071	0.0062	1.24	1.46
	2	0.011	0.0038	0.012	0.0011	0.013	0.012	0.0067	0.0068	0.0021	0.036	0.46
	3	0.0006	0.001	0.024	0.0027	0.0054	0.0067	0.0069	0.01	0.016	0.029	0.46
	4	0	0	0.02	0.0039	0.00076	0.0025	0.00086	0.0053	0.0029	0.029	0.2
	5	0	0	0.0057	0.02	0.00014	0.00056	0	0	0	0.025	0.025
	6	0	0	0.015	0.059	0	0	0	0	0	0.005	0.0005

Table 62. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Bukal	Calicanto	Catandala	Conde Itaas	Conde Labak	Cuta	Dalig	Domoclay	Gulod Itaas	Gulod Labak	Kumintang Ibaba
Affected Area (sq. km.)	1	0.67	0.75	4.51	2.88	1.11	0.31	1.78	2.25	1.43	0.9	1.05
	2	0.022	0.32	0.25	0.12	0.041	0.23	0.11	0.18	0.083	0.059	0.22
	3	0.0087	0.29	0.11	0.078	0.022	0.27	0.078	0.18	0.072	0.057	0.11
	4	0.012	0.21	0.068	0.1	0.021	0.39	0.08	0.21	0.15	0.065	0.082
	5	0.015	0.11	0.071	0.12	0.009	0.13	0.057	0.24	0.089	0.032	0.19
	6	0.0028	0	0.076	0.021	0	0.025	0.049	0.13	0.016	0.015	0.21

Table 63. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		Kumintang Ilaya	Libjo	Maapas	Mahabang Dahilig	Mahabang Parang	Mahacot Kanluran	Mahacot Silangan	Malalim	Malitam	Paharang Silangan	Sampaga
Affected Area (sq. km.)	1	0.85	0.72	1.36	0.42	1.05	2.23	1.85	1.77	0.0003	1.47	1.93
	2	0.16	0.34	0.041	0.012	0.089	0.13	0.092	0.12	0.001	0.049	0.15
	3	0.05	0.91	0.031	0.0062	0.024	0.057	0.056	0.06	0.05	0.032	0.079
	4	0.01	1.64	0.028	0.0029	0.014	0.035	0.047	0.061	0.21	0.03	0.053
	5	0.0065	0.49	0.037	0.0011	0.013	0.065	0.052	0.14	0.058	0.04	0.085
	6	0.0056	0.1	0.019	0	0.0042	0.035	0.038	0.0068	0.0033	0.0055	0.032

Table 64. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)										
		San Isidro	San Jose Sico	San Miguel	San Pedro	Santa Clara	Santa Rita Aplaya	Santa Rita Karsada	Santo Niño	Sirang Lupa	Sorosoro Ibaba	Sorosoro Ilaya
Affected Area (sq. km.)	1	2.11	0.6	4.11	4.02	0.6	0.15	2.06	0.54	1.36	1.2	0.62
	2	0.22	0.016	0.15	0.2	0.45	0.051	0.62	0.014	0.087	0.07	0.022
	3	0.18	0.011	0.092	0.13	0.43	0.27	0.36	0.013	0.11	0.018	0.0079
	4	0.12	0.011	0.079	0.1	0.38	0.23	0.071	0.0078	0.11	0.014	0.0051
	5	0.034	0.015	0.077	0.13	0.052	0.043	0.0077	0.0052	0.099	0.012	0.012
	6	0.0029	0.0024	0.0076	0.19	0	0	0	0	0.014	0.0061	0.016

Table 65. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Batangas (in sq. km.)							
		Sorosoro Karsada	Tabangao Ambulong	Tabangao Aplaya	Talumpok Kanluran	Tinga Itaas	Tinga Labak	Tulo	Wawa
Affected Area (sq. km.)	1	2.04	0.28	0.044	2.54	2.4	2.34	3.83	0.011
	2	0.16	0.11	0.019	0.087	0.24	0.24	0.18	0.046
	3	0.048	0.098	0.023	0.061	0.084	0.15	0.14	0.19
	4	0.038	0.068	0.022	0.074	0.034	0.045	0.08	0.29
	5	0.065	0.0016	0.0086	0.059	0.061	0.064	0.11	0.027
	6	0.02	0	0	0.00049	0.15	0.17	0.017	0.004

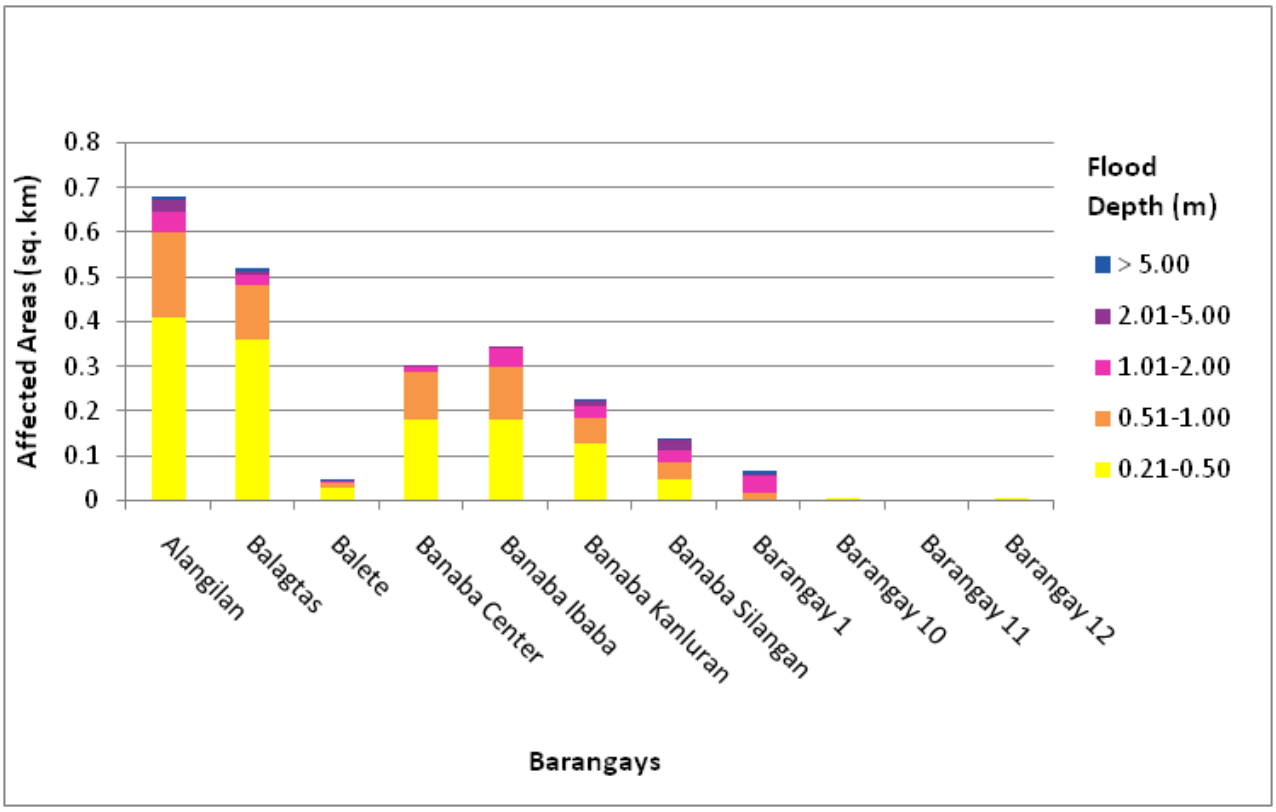


Figure 97. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

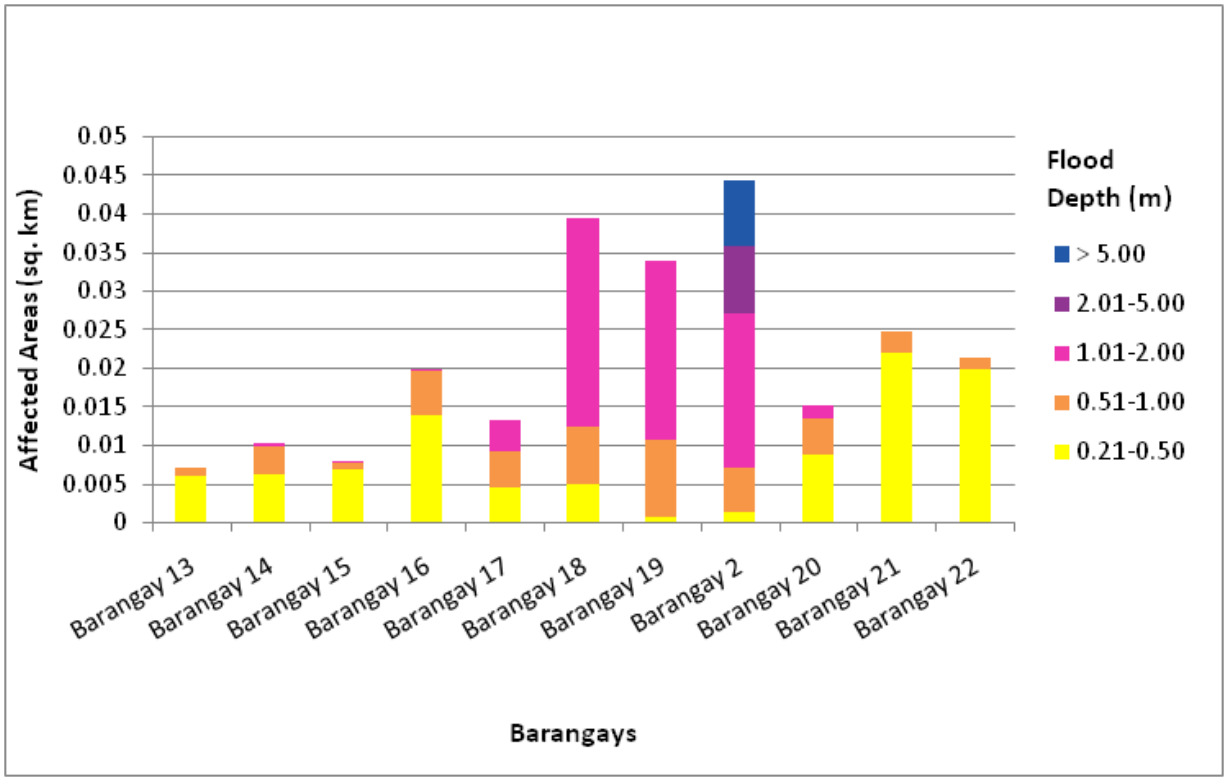


Figure 98. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

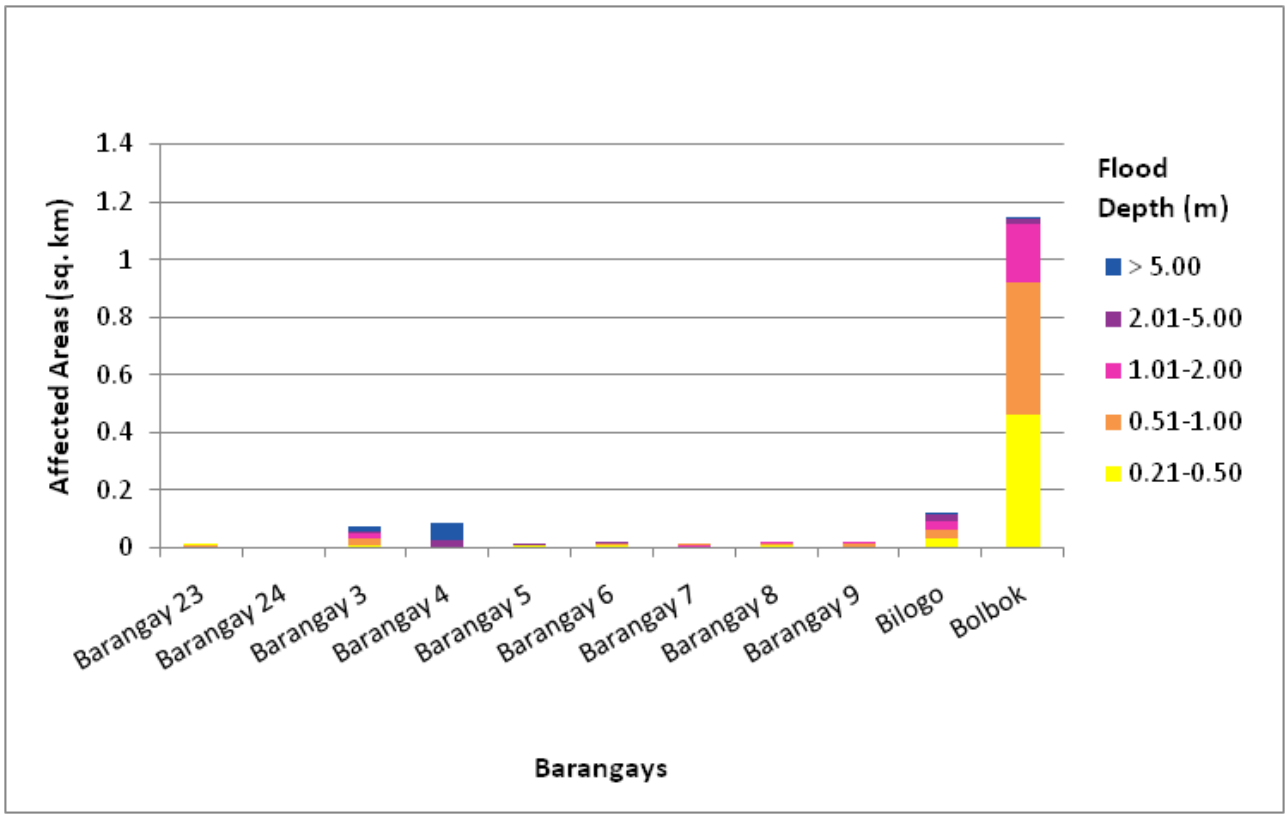


Figure 99. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

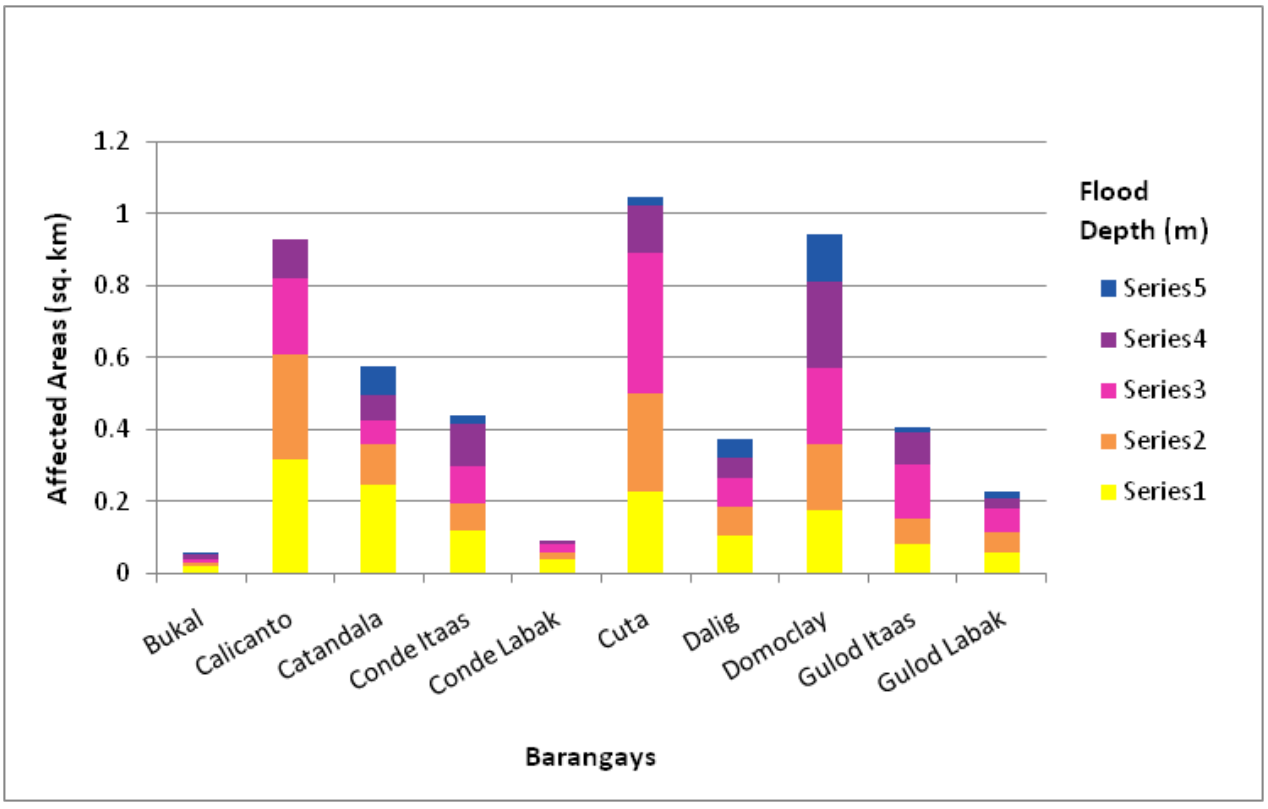


Figure 100. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

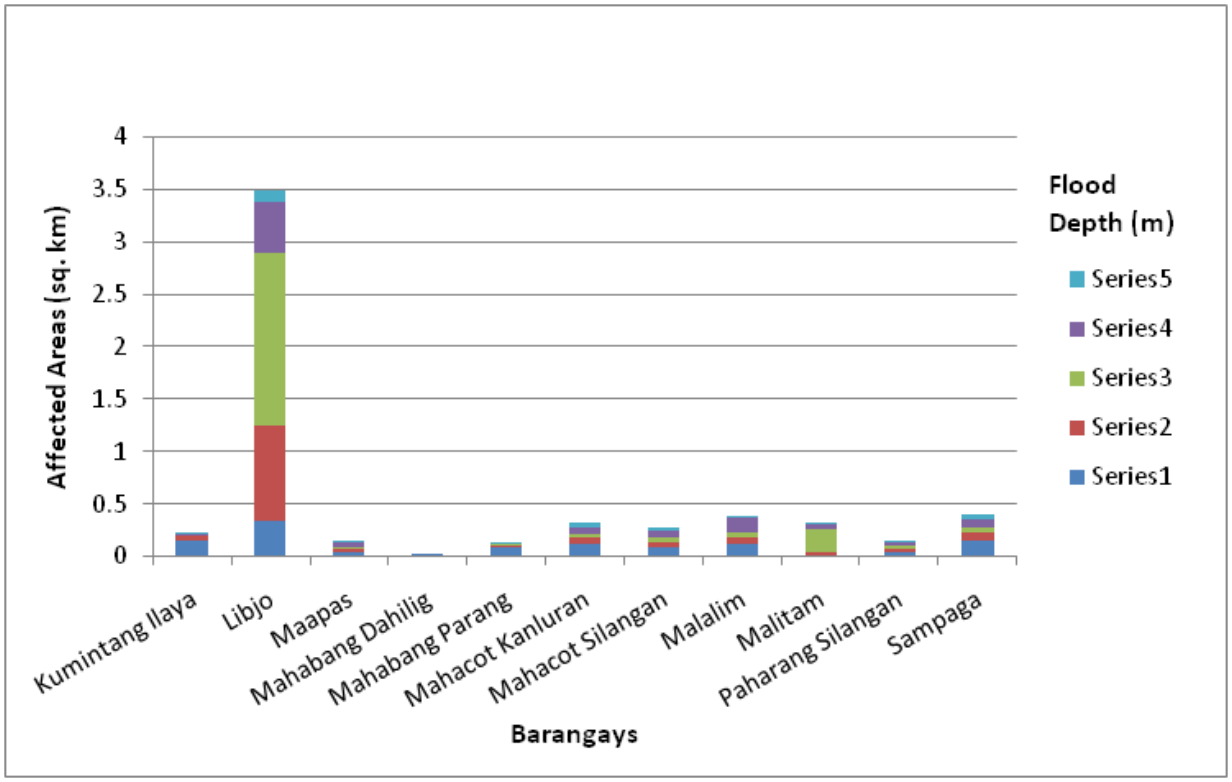


Figure 101. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

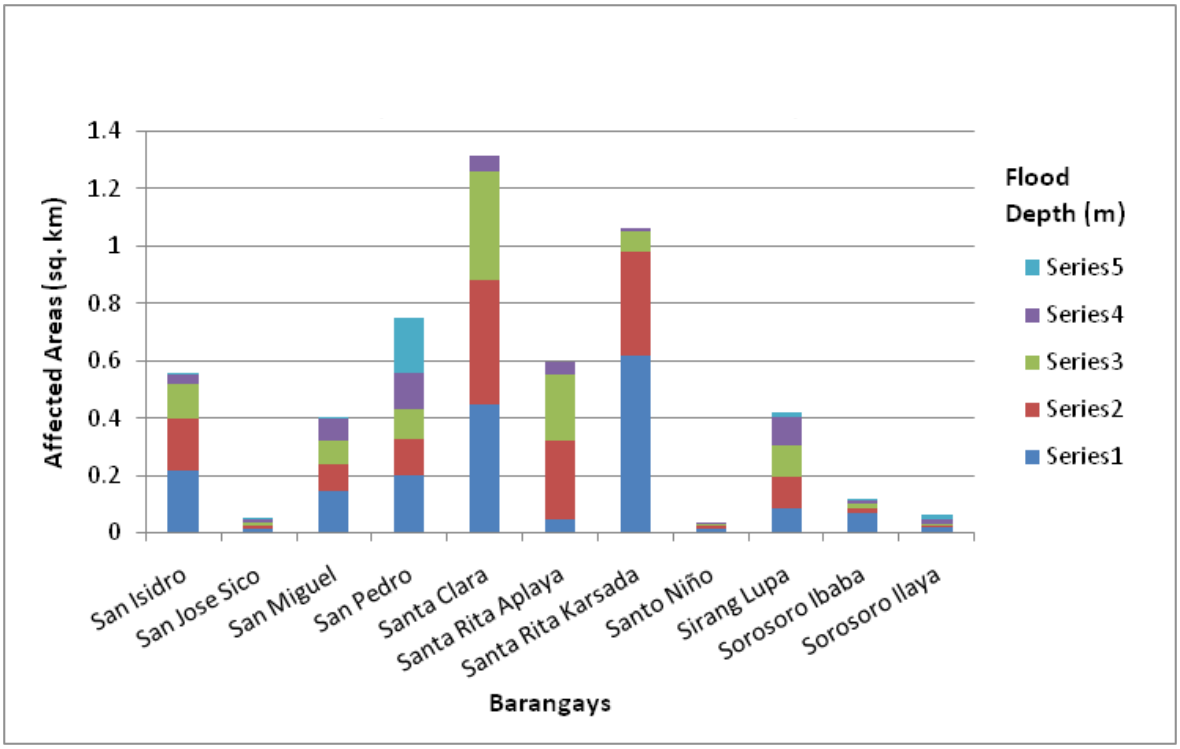


Figure 102. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

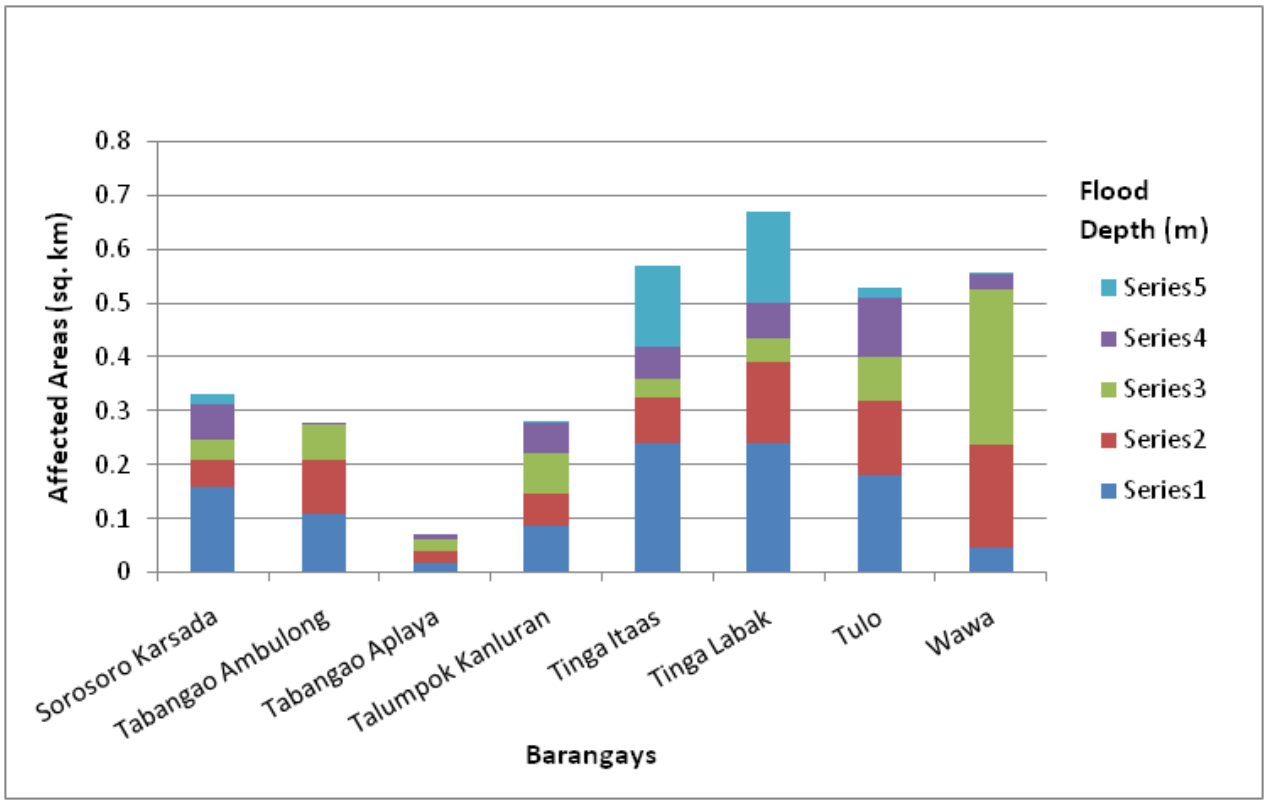


Figure 103. Affected areas in Batangas City, Batangas during a 100-year rainfall return period

For the 100-year return period, 7.00% of the municipality of Rosario with an area of 199.037 sq km will experience flood levels of less than 0.20 meters; 0.60% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.29%, 0.23%, 0.18%, and 0.16% 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 66 and Table 67 are the affected areas in square kilometers by flood depth per barangay.

Table 66. Affected areas in Rosario, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Rosario (in sq. km.)							
		Bagong Pook	Bulihan	Colongan	Itlugan	Maalas-As	Malaya	Mavalor	Namuco
Affected Area (sq. km.)	1	0.77	0.1	3.44	2.24	1.95	0.63	0.63	0.14
	2	0.073	0.0079	0.34	0.15	0.16	0.057	0.047	0.0087
	3	0.038	0.0017	0.14	0.093	0.082	0.036	0.018	0.0046
	4	0.027	0.0009	0.096	0.093	0.071	0.0069	0.011	0.0015
	5	0.023	0	0.098	0.088	0.029	0.0019	0.0059	0
	6	0	0	0.13	0.064	0.0091	0	0	0

Table 67. Affected areas in Rosario, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Rosario (in sq. km.)		
		San Ignacio	Timbugan	Tiquiwan
Affected Area (sq. km.)	1	0.072	3.94	0.012
	2	0.0068	0.35	0.0013
	3	0.0019	0.17	0.0013
	4	0	0.16	0
	5	0	0.11	0
	6	0	0.11	0

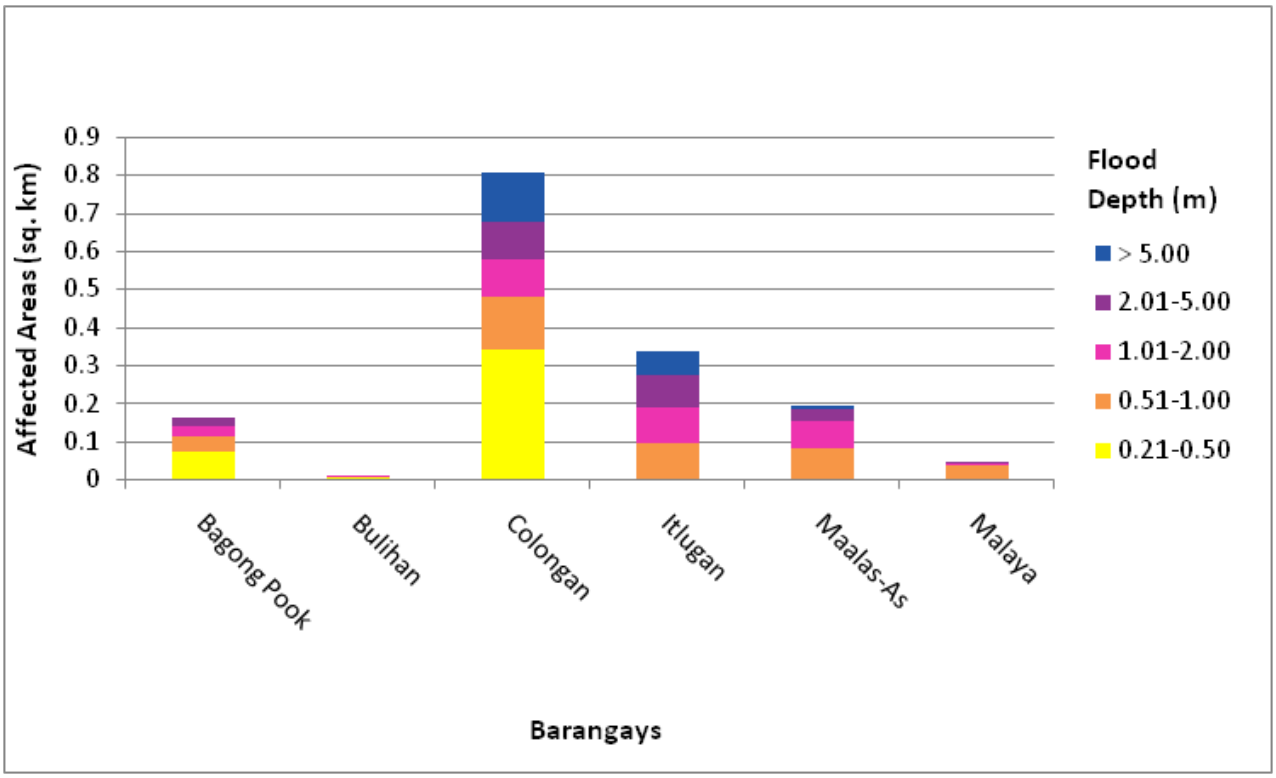


Figure 104. Affected areas in Rosario, Batangas during a 100-year rainfall return period

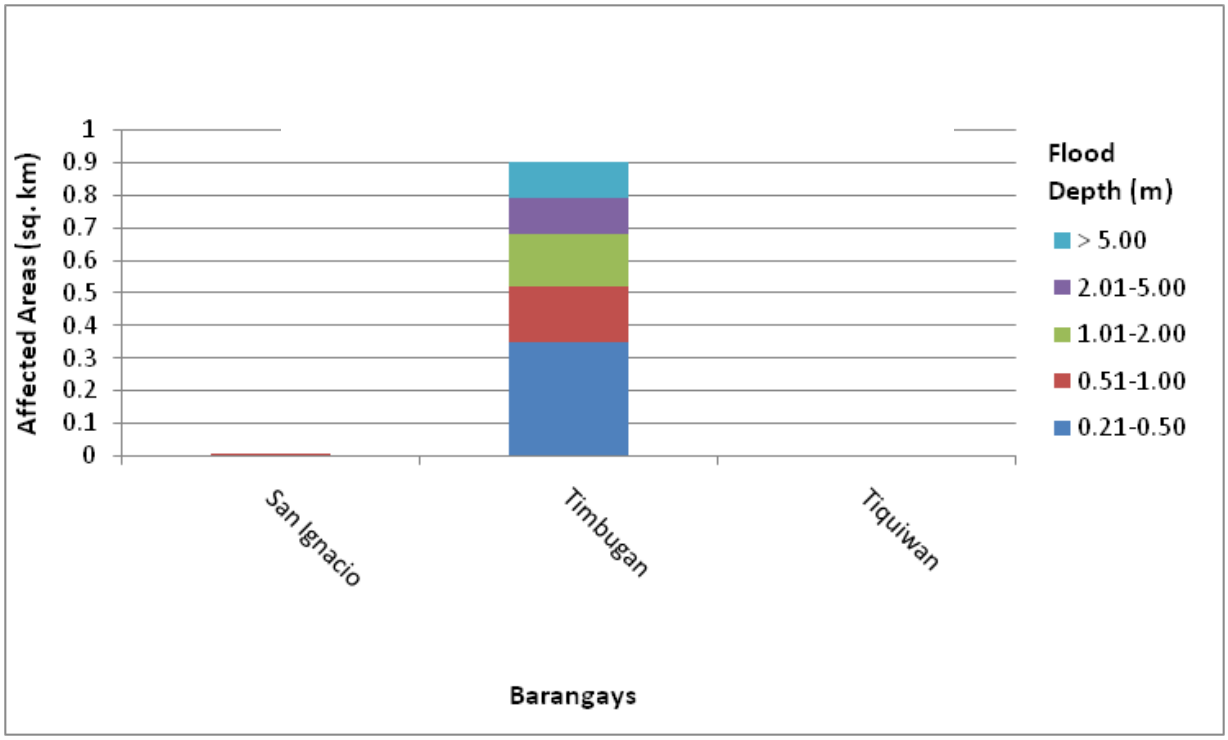


Figure 105. Affected areas in Rosario, Batangas during a 100-year rainfall return period

For the 100-year return period, 46.58% of the municipality of Ibaan with an area of 70.33 sq km will experience flood levels of less than 0.20 meters; 3.34% of the area will experience flood levels of 0.21 to 0.50 meters; while 1.54%, 0.99%, 0.91%, and 0.97% 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 68 and Table 69 are the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected areas in Ibaan, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ibaan (in sq. km.)									
		Bago	Bala-nga	Bunga-han	Catan-dala	Coliat	Daya-pan	Lucsu-hin	Maba-lor	Mala-inin	Mata-la
Affec-ted Area (sq. km.)	1	0.98	1.96	3.22	3.19	1.22	2.11	2.73	4.25	0.46	0.54
	2	0.11	0.13	0.24	0.17	0.15	0.17	0.17	0.27	0.039	0.045
	3	0.056	0.048	0.13	0.097	0.059	0.099	0.081	0.1	0.015	0.016
	4	0.031	0.038	0.058	0.073	0.033	0.045	0.085	0.087	0.0049	0.0072
	5	0.025	0.044	0.063	0.066	0.017	0.045	0.08	0.067	0.0028	0.0016
	6	0.0021	0.089	0.092	0.063	0.0013	0.11	0.1	0.041	0.0002	0

Table 69. Affected areas in Ibaan, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Ibaan (in sq. km.)							
		Palindan	Pangao	Pangha-yaan	Pobla-cion	Quilo	Sabang	San Agustin	Sanda-lan
Affected Area (sq. km.)	1	0.43	1.51	2	0.43	2.8	3.4	0.55	0.98
	2	0.037	0.15	0.097	0.038	0.2	0.21	0.053	0.067
	3	0.011	0.084	0.068	0.026	0.061	0.072	0.016	0.045
	4	0.0066	0.038	0.043	0.015	0.047	0.043	0.0058	0.036
	5	0.0013	0.016	0.032	0.0025	0.068	0.083	0.0008	0.028
	6	0	0	0.0045	0	0.037	0.14	0	0.0029

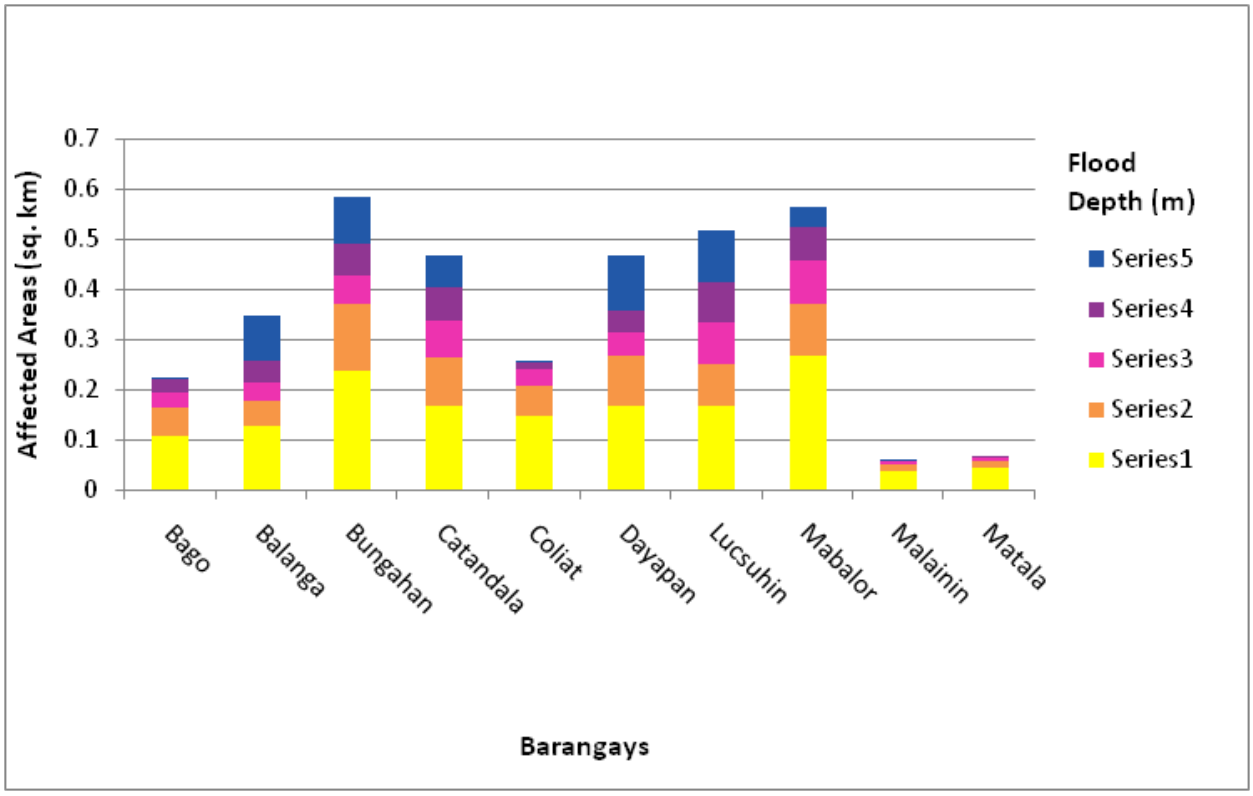


Figure 106. Affected areas in Ibaan, Batangas during a 100-year rainfall return period

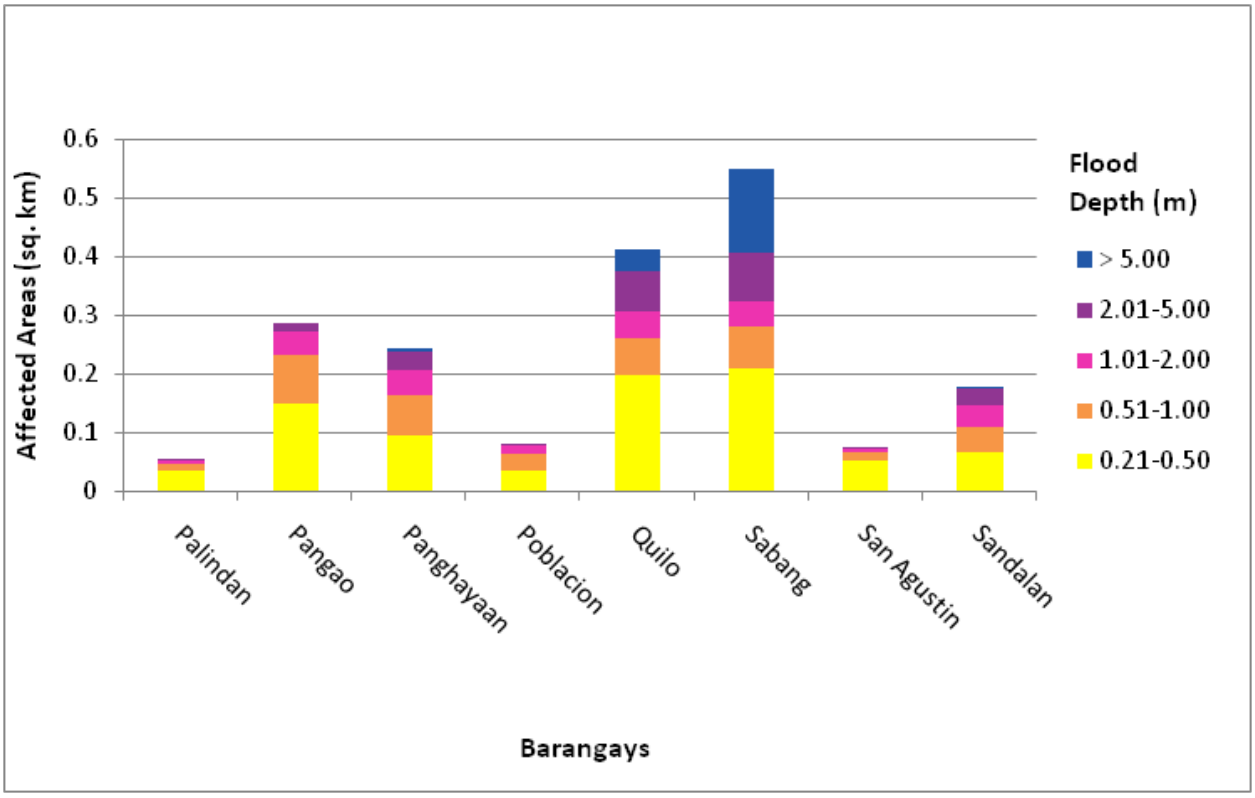


Figure 107. Affected areas in Ibaan, Batangas during a 100-year rainfall return period

For the 100-year return period, 9.22% of the municipality of Taysan with an area of 92.55 sq km will experience flood levels of less than 0.20 meters; 0.88% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.51%, 0.30%, 0.27%, and 0.04% 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 70 are the affected areas in square kilometers by flood depth per barangay.

Table 70. Affected areas in Taysan, Batangas during a 100-year rainfall return period

Affected Area (sq. km.) by flood depth (in m.)		Area of affected barangays in Taysan (in sq. km.)								
		Bilo-go	Bukal	Maba-yabas	Mahana-diong	Mataas Na Lupa	Pag-Asa	Pangha-yaan	Pobla-cion East	Tilam-bo
Affec-ted Area (sq. km.)	1	0.56	0.17	3.13	1.55	0.1	1.64	1	0.31	0.077
	2	0.017	0.0064	0.35	0.18	0.0043	0.13	0.065	0.055	0.0039
	3	0.016	0.0073	0.2	0.11	0.0036	0.061	0.035	0.042	0
	4	0.013	0.0058	0.13	0.027	0.0017	0.046	0.034	0.018	0
	5	0.013	0.004	0.12	0.0031	0.0005	0.066	0.027	0.012	0
	6	0.0014	0	0.022	0	0	0.017	0.00079	0	0

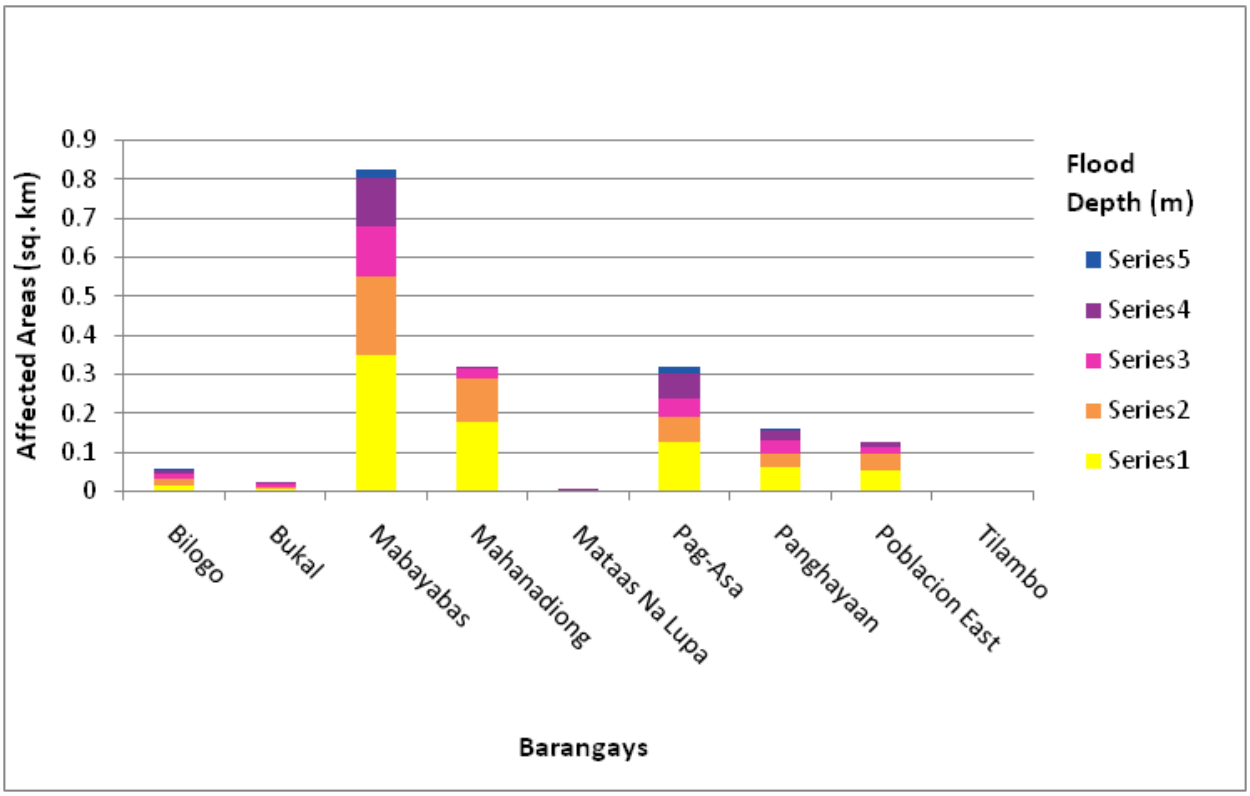


Figure 108. Affected Areas in Taysan, Batangas during 100-Year Rainfall Return Period

Moreover, the generated flood hazard maps for the Calumpang Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps ("Low," "Medium," and "High"), the affected institutions were given their individual assessment for each flood hazard scenario (5-year, 25-year, and 10-year).

Table 71. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq km.		
	5 year	25 year	100 year
Low	11.13	12.26	12.84
Medium	8.63	12.40	13.76
High	6.22	8.92	10.92
TOTAL	8.66	33.58	37.51

Of the 215 identified educational institutions in Calumpang Floodplain, 20 schools were discovered exposed to low-level flooding during a 5-year scenario, while 12 schools were found exposed to medium-level flooding in the same scenario.

In the 25-year scenario, 21 schools were found exposed to low-level flooding, while 23 schools were discovered exposed to medium-level flooding, and 1 to high-level flooding.

For the 100-year scenario, 22 schools were discovered exposed to low-level flooding , while 27 schools were exposed to medium-level flooding. In the same scenario, 2 schools were found exposed to high-level flooding.

Apart from this, 88 health institutions were identified in the Calumpang Floodplain. For the 5-year scenario, 3 were exposed to low-level flooding while 1 was exposed to medium-level flooding. For the 25-year scenario, 8 were exposed to low-level flooding and 2 to medium-level flooding. For the 100-year scenario, 12 were exposed to low- and 3 to medium-level flooding.

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. Field personnel gathered secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed.

The flood validation consists of 181 points randomly selected all over the Calumpang Floodplain. It has an RMSE value of 2.56.

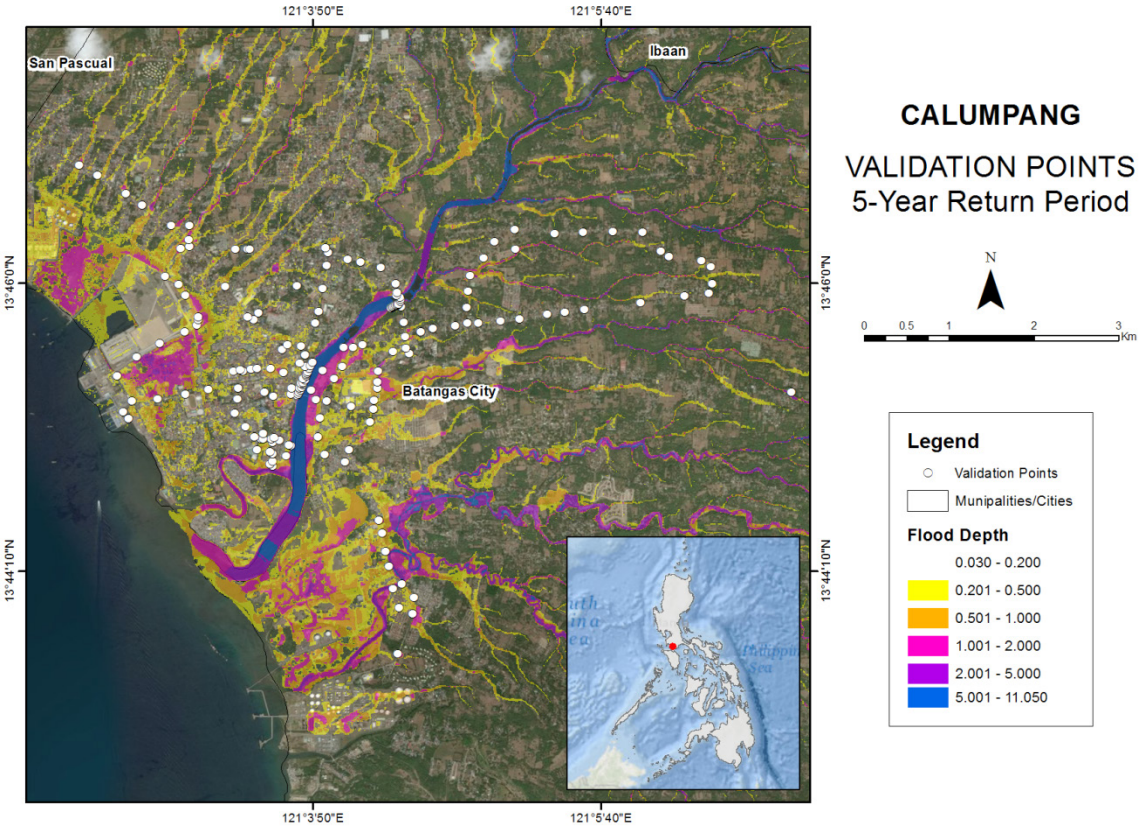


Figure 109. Flood validation points of Calumpang River Basin

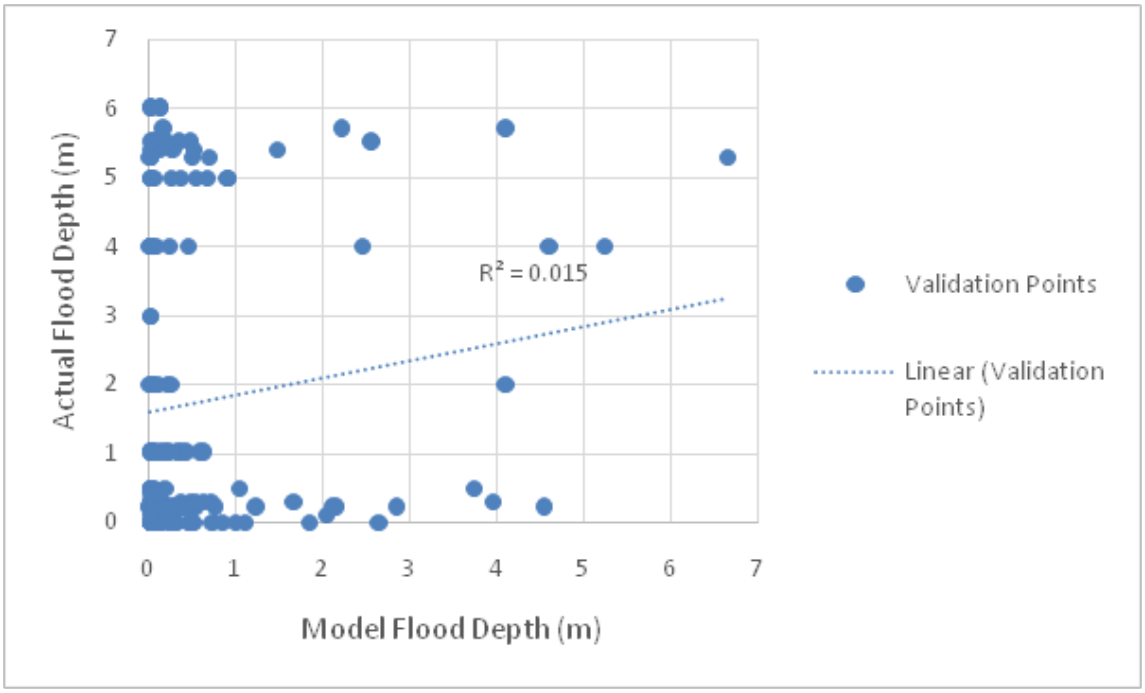


Figure 110. Flood map depth vs. actual flood depth

Table 72. Actual flood depth vs. simulated flood depth in Calumpang

Actual Flood Depth	Modeled Flood Depth (m)						
(m)	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	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	17	4	4	0	2	1	28
> 5.00	14	3	3	1	3	1	25
Total	109	31	18	6	14	2	180

The overall accuracy generated by the flood model is estimated at 27.78% with 50 points correctly matching the actual flood depths. In addition, there were 43 points estimated one level above and below the correct flood depths while there were 23 points and 59 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 92 points were underestimated in the modeled flood depths of Calumpang.

Table 73. Summary of accuracy assessment in the Calumpang River Basin Survey

	No. of Points	%
Correct	50	**27.78**
Overestimated	38	**21.11**
Underestimated	92	**51.11**
Total	180	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. OPTECH Technical Specification

PEGASUS

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

GEMINI SENSOR

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

Annex 2. NAMRIA Certificates of Reference Points Used in the LiDAR Survey

BTG-51

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

January 05, 2016

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-51**
Order: **2nd**

Island: **LUZON** Barangay: **TALAGA**
Municipality: **TANAUAN** MSL Elevation:

PRS92 Coordinates

Latitude: **14° 6' 8.57112"** Longitude: **121° 5' 52.31002"** Ellipsoidal Hgt: **152.36900 m.**

WGS84 Coordinates

Latitude: **14° 6' 3.27790"** Longitude: **121° 5' 57.24592"** Ellipsoidal Hgt: **197.55100 m.**

PTM / PRS92 Coordinates

Northing: **1559501.067 m.** Easting: **510567.544 m.** Zone: **3**

UTM / PRS92 Coordinates

Northing: **1,559,783.81** Easting: **294,641.94** Zone: **51**

Location Description

BTG-51
From Star Expressway Exit, Tanauan City, turn right to Talisay and continue traveling W until reaching the Y-road. Station is located inside the Mabini Shrine, approx. 100 m. from the right side of the road. It is situated approx. 2 m. S of the flagpole, about 15 m. N from the gate of the said shrine. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. concrete block flushed on the ground, with inscriptions "BTG-51 2007 NAMRIA".

Requesting Party: **DOST-PCIEERD**
Purpose: **Reference**
OR Number: **8089513 I**
T.N.: **2016-0018**

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

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

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
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

BTG-3343

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

February 19, 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-3343**
Order: **4th**

Island: **LUZON**
Municipality: **BATANGAS CITY (CAPITAL)**
Barangay: **BARANGAY 3 (POB.)**

PRS92 Coordinates

Latitude: **13° 45' 28.66051"** Longitude: **121° 3' 42.01826"** Ellipsoidal Hgt: **9.01500 m.**

WGS84 Coordinates

Latitude: **13° 45' 23.44551"** Longitude: **121° 3' 46.98401"** Ellipsoidal Hgt: **55.06100 m.**

PTM Coordinates

Northing: **1521397.691 m.** Easting: **506669.312 m.** Zone: **3**

UTM Coordinates

Northing: **1,521,707.64** Easting: **290,422.78** Zone: **51**

Location Description

BTG-3343

From Batangas City Hall, travel E along M.H. Del Pilar St. approx. 450 m towards Calumpang Bridge and turn left before the bridge. Follow the street and turn right at Rizal Avenue (3rd corner) and continue until the end of the road to the corner of Rizal and P. Herrera St. The station is beside the stairs leading to the dike. Station is located in Brgy. Pallocan, Batangas City, Batangas. Mark is the head of a 4 in. copper nail centered on a 20 cm x 20 cm cement putty with inscriptions, "BTG-3343, 2008, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795394 A**
T.N.: **2014-355**

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

9902192014140928

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

QZN-21

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

February 13, 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: **QUEZON**
Station Name: **QZN-21**
Order: **2nd**

Island: **LUZON**
Municipality: **TIAONG**
Barangay: **POBLACION III**

PRS92 Coordinates

Latitude: **13° 57' 44.31576"** Longitude: **121° 19' 27.34822"** Ellipsoidal Hgt: **51.25800 m.**

WGS84 Coordinates

Latitude: **13° 57' 39.07397"** Longitude: **121° 19' 32.29499"** Ellipsoidal Hgt: **97.38200 m.**

PTM Coordinates

Northing: **1544027.063 m.** Easting: **535036.042 m.** Zone: **3**

UTM Coordinates

Northing: **1,544,101.56** Easting: **318,981.12** Zone: **51**

Location Description

QZN-21
From Tiaong Municipal Hall, travel along the highway going to Lucena, then turn left to Dia St. until reaching Paaralang Elementarya ng Silangang Tiaong. Station is located on the open ground of the said school, 30 m. NE from the entrance gate. It is approx. 21 m. WNW from the NW corner post in front of the stage and 13.4 m. ESE from the concrete wall of the school. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. concrete monument flushed on the ground, with inscriptions "QZN-21 2006 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8795355 A**
T.N.: **2014-320**

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

9902132014164652

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

Annex 3. Baseline Processing Reports of Reference Points Used in the LiDAR Survey

BTG-A and TGT-1

Project Information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
BTG-51 --- BTG-A (B1)	BTG-51	BTG-A	Fixed	0.003	0.013	170°48'36"	16216.677	221.457
BTG-51 --- BTG-A (B2)	BTG-51	BTG-A	Fixed	0.004	0.017	170°48'36"	16216.637	221.577
BTG-51 --- BTG-A (B3)	BTG-51	BTG-A	Fixed	0.003	0.012	170°48'36"	16216.621	221.544
TGT-1 --- BTG-A (B4)	BTG-A	TGT-1	Fixed	0.008	0.017	315°18'50"	24750.750	239.384
BTG-51 --- TGT-1 (B5)	BTG-51	TGT-1	Fixed	0.009	0.018	276°06'46"	14901.801	460.990
BTG-A --- TGT-1 (B6)	BTG-A	TGT-1	Fixed	0.005	0.019	315°18'50"	24750.733	239.429
BTG-51 --- TGT-1 (B7)	BTG-51	TGT-1	Fixed	0.005	0.017	276°06'46"	14901.814	461.001
TGT-2 --- TGT-1 (B8)	TGT-2	TGT-1	Fixed	0.005	0.008	183°02'45"	3.316	0.124
BTG-A --- TGT-2 (B9)	TGT-2	BTG-A	Fixed	0.006	0.017	135°16'50"	24752.968	-239.298
BTG-51 --- TGT-2 (B10)	BTG-51	TGT-2	Fixed	0.007	0.017	276°07'32"	14901.989	460.964
TGT-1 --- TGT-2 (B11)	TGT-2	TGT-1	Fixed	0.003	0.004	182°17'41"	3.293	0.187
BTG-A --- TGT-2 (B12)	TGT-2	BTG-A	Fixed	0.004	0.017	135°16'50"	24752.942	-239.320
BTG-51 --- TGT-2 (B13)	BTG-51	TGT-2	Fixed	0.005	0.017	276°07'32"	14901.994	460.970
BTG-51 --- BTG-A (B14)	BTG-51	BTG-A	Fixed	0.020	0.025	170°48'36"	16216.661	221.703
TGT-2 --- BTG-A (B15)	TGT-2	BTG-A	Fixed	0.065	0.038	135°16'50"	24753.003	-239.177
BTG-51 --- TGT-2 (B16)	BTG-51	TGT-2	Fixed	0.004	0.013	276°07'31"	14901.990	460.994

1

Acceptance Summary

Processed	Passed	Flag	Fail
16	16	0	0

BTG-51 - BTG-A (10:17:13 AM-4:00:13 PM) (S1)

Baseline observation:	BTG-51 --- BTG-A (B1)
Processed:	1/6/2016 4:11:57 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.013 m
RMS:	0.003 m
Maximum PDOP:	1.859
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/21/2015 10:17:33 AM (Local: UTC+8hr)
Processing stop time:	12/21/2015 4:00:13 PM (Local: UTC+8hr)
Processing duration:	05:42:40
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BTG-51				
Grid		**Local**		**Global**	
Easting	294641.947 m	**Latitude**	N14°06'08.57113"	**Latitude**	N14°06'03.27790"
Northing	1559783.810 m	**Longitude**	E121°05'52.31001"	**Longitude**	E121°05'57.24592"
Elevation	152.867 m	**Height**	152.369 m	**Height**	197.551 m

To:	BTG-A				
Grid		**Local**		**Global**	
Easting	297103.192 m	**Latitude**	N13°57'27.65020"	**Latitude**	N13°57'22.39320"
Northing	1543753.102 m	**Longitude**	E121°07'18.59698"	**Longitude**	E121°07'23.54499"
Elevation	374.449 m	**Height**	373.826 m	**Height**	419.468 m

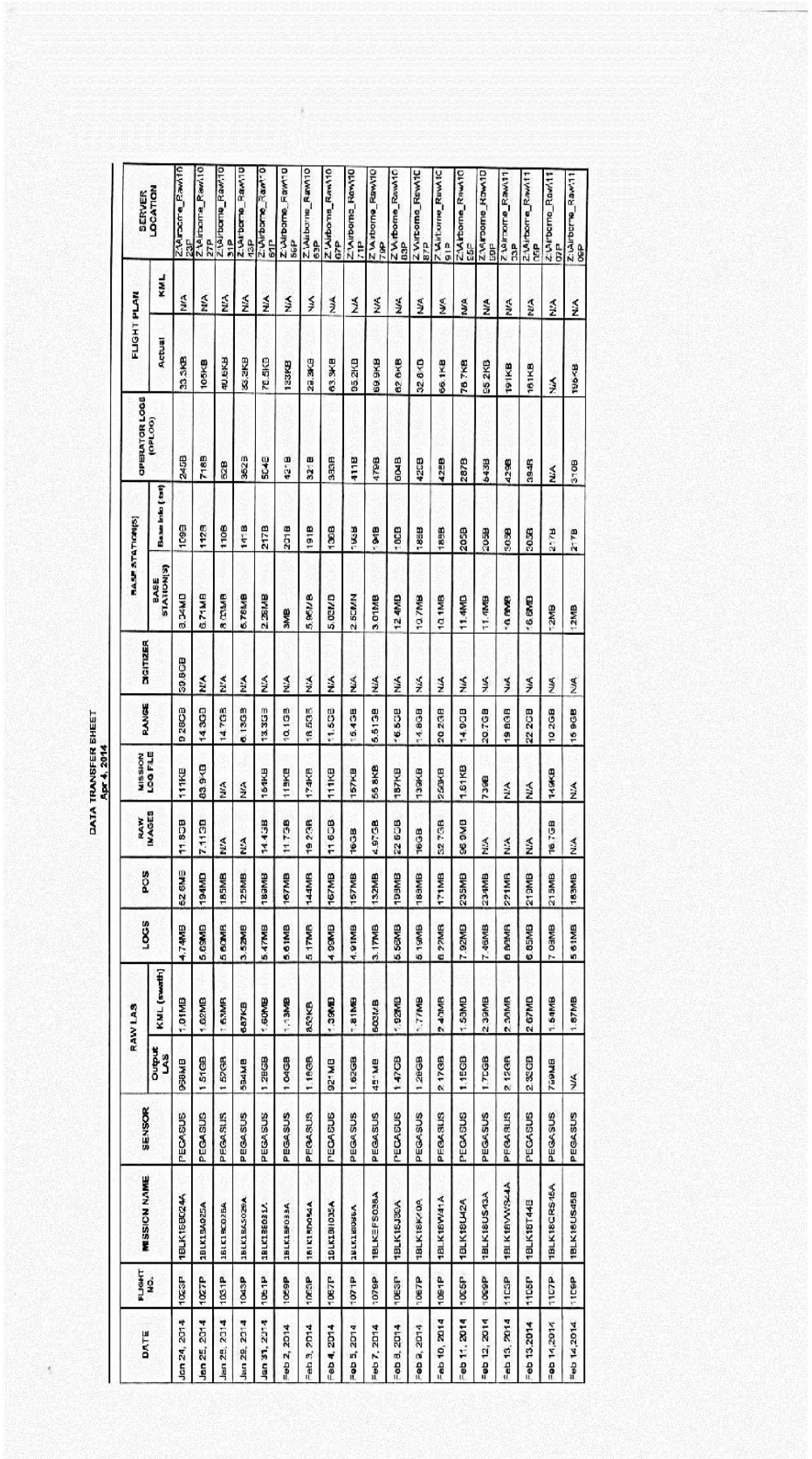
Vector					
ΔEasting	2461.246 m	**NS Fwd Azimuth**	170°48'36"	**ΔX**	-4333.540 m
ΔNorthing	-16030.708 m	**Ellipsoid Dist.**	16216.677 m	**ΔY**	2168.834 m
ΔElevation	221.582 m	**ΔHeight**	221.457 m	**ΔZ**	-15477.964 m

2

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-team	**Designation**	**Name**	**Agency/Affiliation**
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. CZAR JAKIRI S. SARMIENTO	UP TCAGP
		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
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP TCAGP
		JULIE PEARL MARS	UP TCAGP
	Research Associate	JONALYN GONZALES	UP TCAGP
		ENGR. IRO NIEL ROXAS	
		ENGR. LARAH KRISELLE PARAGAS	UP TCAGP
		KRISTINE JOY ANDAYA	UP TCAGP
		FAITH JOY SABLE	UP TCAGP
		PAULINE JOANNE ARCEO	
Ground Survey, Data Download and Transfer	Research Associate	ENGR. CHRISTOPHER JOAQUIN	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	TSG. JULIUS RENDON	PHILIPPINE AIR FORCE (PAF)
		TSG. BENJIE CARBOLLEDO	PHILIPPINE AIR FORCE (PAF)
		SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORP (AAC)
		CAPT. RAUL SAMAR	ASIAN AEROSPACE CORP (AAC)
		CAPT. FRANCO PEPITO	ASIAN AEROSPACE CORP (AAC)
		CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORP (AAC)
		CAPT. ALBERT PAUL LIM	ASIAN AEROSPACE CORP (AAC)
		CAPT. RANDY LAGCO	ASIAN AEROSPACE CORP (AAC)

Annex 5. Data Transfer Sheet for Calumpang Floodplain



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	1063P	1BLK16BG24A	PEGASUS	958MB	1.01MB	4.74MB	62.6MB	11.8GB	111KB	9.28GB	30.8GB	8.24MB	109B	24GB	33.3KB	N/A	Z:\Airborne_Raw\10 23P
Jan 25, 2014	1027P	1BLK19A025A	PEGASUS	1.51GB	1.62MB	5.63MB	194MB	7.11GB	83.9KB	14.3GB	N/A	8.71MB	112B	71KB	105KB	N/A	Z:\Airborne_Raw\10 27P
Jan 28, 2014	1051P	1BLK19C075A	PEGASUS	1.52GB	1.63MB	5.63MB	185MB	N/A	N/A	14.7GB	N/A	8.75MB	110B	5GB	40.6KB	N/A	Z:\Airborne_Raw\10 31P
Jan 29, 2014	1043P	1BLK18A502EA	PEGASUS	994MB	687KB	3.52MB	125MB	N/A	N/A	6.13GB	N/A	5.76MB	141B	362B	35.2KB	N/A	Z:\Airborne_Raw\10 43P
Jan 31, 2014	1061P	1BLK18E081A	PEGASUS	1.28GB	1.60MB	5.47MB	189MB	14.4GB	154KB	13.3GB	N/A	2.26MB	217B	5C4B	76.5KB	N/A	Z:\Airborne_Raw\10 61P
Feb 2, 2014	1059P	1BLK1BF033A	PEGASUS	1.04GB	1.13MB	5.61MB	167MB	11.7GB	113KB	10.1GB	N/A	3MB	231B	42B	133KB	N/A	Z:\Airborne_Raw\10 59P
Feb 3, 2014	1053P	1BLK1BN044A	PEGASUS	1.16GB	855KB	5.17MB	144MB	19.2GB	174KB	18.8GB	N/A	5.85MB	191B	32B	29.3KB	N/A	Z:\Airborne_Raw\10 53P
Feb 4, 2014	1067P	1BLK1BI035A	PEGASUS	921MB	1.33MB	4.93MB	167MB	11.6GB	111KB	11.5GB	N/A	5.02MB	136B	33B	83.3KB	N/A	Z:\Airborne_Raw\10 67P
Feb 5, 2014	1071P	1BLK1BI094A	PEGASUS	1.62GB	1.81MB	4.91MB	157MB	16GB	157KB	15.4GB	N/A	2.52MB	194B	411B	95.2KB	N/A	Z:\Airborne_Raw\10 71P
Feb 7, 2014	1079P	1BLKEFS039A	PEGASUS	451MB	503KB	3.17MB	132MB	4.57GB	55.8KB	5.51GB	N/A	3.01MB	9MB	479B	69.9KB	N/A	Z:\Airborne_Raw\10 79P
Feb 8, 2014	1083P	1BLK16J36A	PEGASUS	1.47GB	1.92MB	5.58MB	193MB	22.6GB	187KB	16.5GB	N/A	12.4MB	10CB	604B	67.6KB	N/A	Z:\Airborne_Raw\10 83P
Feb 9, 2014	1087P	1BLK16K10A	PEGASUS	1.28GB	1.77MB	5.13MB	183MB	16GB	139KB	14.8GB	N/A	10.7MB	188B	42CB	32.8KB	N/A	Z:\Airborne_Raw\10 87P
Feb 10, 2014	1061P	1BLK16W41A	PEGASUS	2.17GB	2.42MB	6.27MB	171MB	33.7GB	256KB	20.2GB	N/A	10.1MB	188B	423B	56.1KB	N/A	Z:\Airborne_Raw\10 61P
Feb 11, 2014	1065P	1BLK16U42A	PEGASUS	1.15GB	1.53MB	7.92MB	235MB	56.9MB	1.61KB	14.9GB	N/A	11.4MB	205B	287B	76.7KB	N/A	Z:\Airborne_Raw\10 65P
Feb 12, 2014	1069P	1BLK16U543A	PEGASUS	1.7GB	2.39MB	7.49MB	234MB	N/A	739B	20.7GB	N/A	11.4MB	205B	643B	95.2KB	N/A	Z:\Airborne_Raw\10 69P
Feb 13, 2014	1105P	1BLK16VVX544A	PEGASUS	2.12GB	2.36MB	6.88MB	221MB	N/A	N/A	19.8GB	N/A	16.8MB	303B	429B	191KB	N/A	Z:\Airborne_Raw\11 05P
Feb 13,2014	1113P	1BLK16T144B	PEGASUS	2.3GB	2.67MB	6.85MB	213MB	N/A	N/A	22.2GB	N/A	16.8MB	303B	384B	161KB	N/A	Z:\Airborne_Raw\11 13P
Feb 14,2014	1107P	1BLK16CR515A	PEGASUS	739MB	1.54MB	7.03MB	213MB	16.7GB	145KB	10.2GB	N/A	12MB	217B	N/A	N/A	N/A	Z:\Airborne_Raw\11 07P
Feb 14,2014	1109P	1BLK16US45B	PEGASUS	N/A	1.87MB	5.61MB	183MB	N/A	N/A	15.9GB	N/A	12MB	217B	310B	195KB	N/A	Z:\Airborne_Raw\11 09P

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\11 11P
Feb 17,2014	1119P	1BLK18C48A	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\11 19P
Feb 18, 2014	1123P	1BLK18QB49A	PEGASUS	1.3GB	1.81MB	6.46MB	193MB	N/A	N/A	14.7GB	N/A	12.5MB	213B	504B	43KB	N/A	Z:\Airborne_Raw\11 23P
Feb 16,2014	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\11 25P
Feb 19, 2014	1127P	1BLK18G50A	PEGASUS	985MB	1.54MB	5.26MB	150MB	N/A	N/A	12.1GB	N/A	6.85MB	213B	507B	67.1KB	N/A	Z:\Airborne_Raw\11 27P
Feb 20, 2014	1131P	1BLK18Z51A	PEGASUS	1.84GB	2.39MB	7.83MB	219MB	30.3GB	254KB	20GB	90.4GB	13.2MB	133B	310B	91.9KB	N/A	Z:\Airborne_Raw\11 31P
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\11 33P
Feb 21, 2014	1135P	1BLK18Y52A	PEGASUS	1.84GB	2.04MB	7.95MB	238MB	7.41GB	117KB	17.4GB	33.9GB	7.52MB	133B	335B	91.9KB	N/A	Z:\Airborne_Raw\11 35P
Feb 22,2014	1139P	1BLK18X53A	PEGASUS	2.19GB	2.45MB	7.52MB	238MB	29.3GB	238KB	21GB	N/A	6.71MB	133B	0B	147KB	N/A	Z:\Airborne_Raw\11 39P
Feb 22, 2014	1141P	1BLK18S53B	PEGASUS	1.05GB	1.80MB	7.26MB	219MB	24GB	176KB	15.4GB	N/A	6.25MB	157B	410B	174KB	N/A	Z:\Airborne_Raw\11 41P
28-Jan	1039P	1BLK18B028A	PEGASUS	2.05	38KB	11.8	155	NA	NA	19.1	NA	7.43	141B	242B	40.5	NA	Z:\Airborne_Raw\10 39P

Received from

Name CHRIS SOBREVINAS
Position
Signature 8/23/14

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

DATA TRANSFER SHEET

01/06/2016 Batangas

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	
12/22/2015	3002P	1BLK18SB356A	PEGASUS	2.71	1195	10.6	185	41.7	310	25.3	NA	27.5	1KB	1KB	137/134	NA	Z:\DAC\RAWDATA
12/29/2015	3669G	2BLK18SBC363A	GEMINI	NA	198	861	151	NA	NA	14.9	NA	7.42	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
12/29/2015	3671G	2BLK18SBC363B	GEMINI	NA	96	473	85	NA	NA	7.41	NA	7.42	1KB	1KB	11	NA	Z:\DAC\RAWDATA
12/30/2015	3673G	2BLK18S364A	GEMINI	NA	221	1.28	195	NA	NA	16.6	NA	11.4	1KB	1KB	17	NA	Z:\DAC\RAWDATA

Received from

Name: Kristine Andaya
Position: RA
Signature:

Received by

Name: JOIDA F. PRIETO
Position: SupSRS
Signature:

01/06/2016

3002P

16-02

DATA TRANSFER SHEET

01/06/2016 Batangas

	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	
13	1/16/2016	3693G	2BLK18SCB106A	GEMINI	NA	88	1.6	82.9	NA	NA	7.98	NA	8.36	1KB	1KB	4	NA	Z:\DAC\RAWDATA

Received from

Name K. LAPAYA

Position KA

Signature

Received by

Name AC Bongat

Position SPT

Signature 11/20/16

16-03

DATA TRANSFER SHEET
Batangas 1/13/16

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	
21-Dec 1	3000P	1BLK18SB355A	pegasus	736	656	3.8	107	11.1	85	7.11	na	11.1	1KB	1KB	100	na	Z:\DAC\RAW DATA
6-Jan 6	3677G	2BLK18SK006A	GEMINI	NA	322	699	157	NA	NA	38.7	na	27.2	0KB	1KB	11	na	Z:\DAC\RAW DATA
6-Jan 7	3679G	2BLK18SDG006B	GEMINI	NA	60	401	131	NA	NA	12.8	na	27.2	0KB	1KB	5/3	na	Z:\DAC\RAW DATA
7-Jan 8	3681G	2BLK18SM007A	GEMINI	NA	226	0	209	NA	NA	24	na	18.5	0KB	1KB	NA	na	Z:\DAC\RAW DATA
8-Jan 9	3685G	2BLK18SF008A	GEMINI	NA	99	786	185	NA	NA	24.4	na	20.9	0KB	1KB	4/2	na	Z:\DAC\RAW DATA
8-Jan 10	3687G	2BLK18SGS008B	GEMINI	NA	214	0	172	NA	NA	17.2	na	20.9	0KB	1KB	4/20	na	Z:\DAC\RAW DATA
9-Jan 11	3689G	2BLK18SV009A	GEMINI	NA	201	1.54	219	NA	NA	16.3	na	12.9	0KB	1KB	23	na	Z:\DAC\RAW DATA
9-Jan 12	3691G	2BLK18SVV009B	GEMINI	NA	12.8	440	124	NA	NA	6.93	na	12.9	0KB	1KB	10	na	Z:\DAC\RAW DATA

Received from

Name C. Jaraula
Position
Signature

Received by

Name ACBongat
Position SPO
Signature ACBongat 1/15/16

16-05

Annex 6. Flight Logs for the Flight Missions

Flight log for 1107P Mission

Flight Log No.: 1107P

DREAM Data Acquisition Flight Log

1 LIDAR Operator: R. Punto	2 ALTM Model: Peg	3 Mission Name: 1BLK18Q RS 4	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: M. Tangonan	8 Co-Pilot: F. Pujante	9 Route: NAIA - NAIA			
10 Date: Feb 19, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0615H	14 Engine Off: 0950H	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					
20 Remarks: Mission completed; changed orientation of flight lines to avoid PAF base restriction in Lipa					
21 Problems and Solutions:					

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

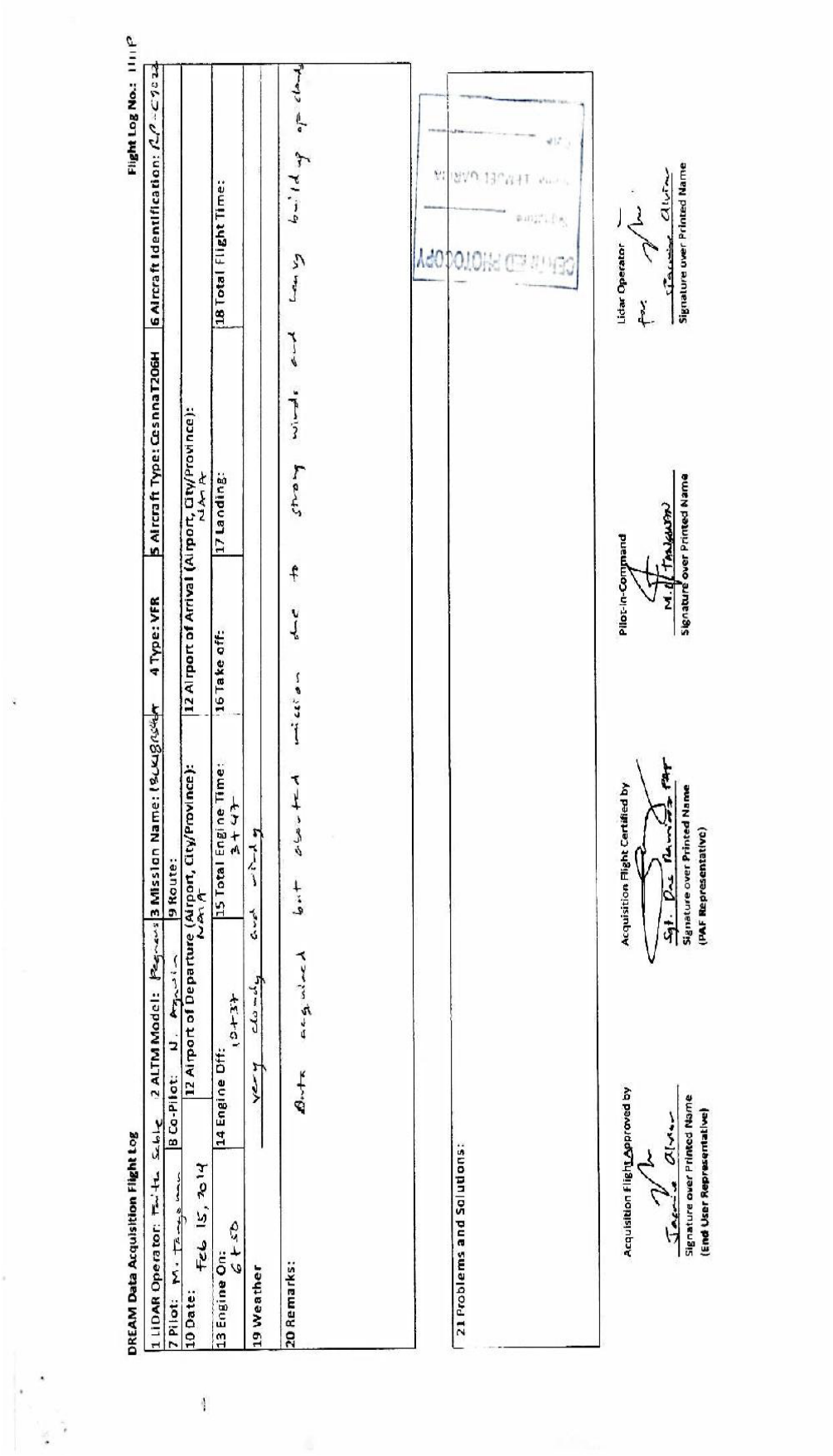
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

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

Lidar Operator: Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Flight log for 1111P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1111P

1 LiDAR Operator: [illegible]	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification: RP-C9032
7 Pilot: M. [illegible]	8 Co-Pilot: N. [illegible]	9 Route:			
10 Date: Feb 15, 2014	11 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 6:50	14 Engine Off: 10:37	15 Total Engine Time: 3:47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	very cloudy and windy				
20 Remarks:	Data acquired but system issue due to strong winds and low build up clouds				
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

Flight Log for 1113P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1113P

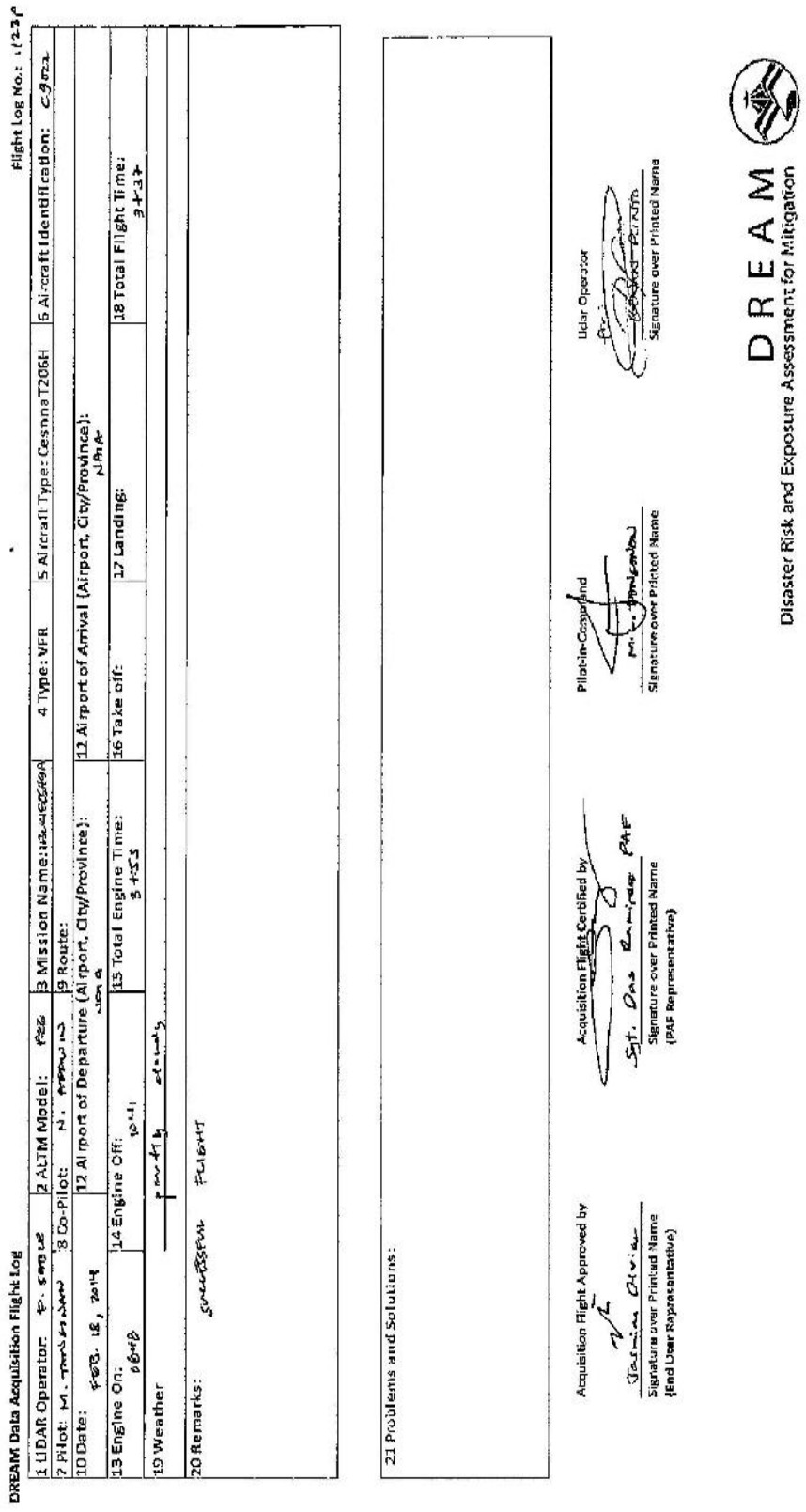
1 LIDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18O46A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Aborin	9 Route:			
10 Date: Feb. 17, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0627	14 Engine Off: 1038	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time: 4+00
19 Weather: cloudy					
20 Remarks: Successful Flight					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Sgt. Lie Ramirez PAF	M. L. Tangonan	R. Punto
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Flight log for 1123P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1123P

1 LiDAR Operator: [illegible]	2 ALTM Model: [illegible]	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	5 Aircraft Identification: [illegible]
7 Pilot: [illegible]	8 Co-Pilot: [illegible]	9 Route:			
10 Date: [illegible]	12 Airport of Departure (Airport, City/Province): [illegible]		12 Airport of Arrival (Airport, City/Province): [illegible]		
13 Engine On: [illegible]	14 Engine Off: [illegible]	15 Total Engine Time: [illegible]	16 Take off:	17 Landing:	18 Total Flight Time: [illegible]
19 Weather	[illegible]				
20 Remarks: [illegible] FLIGHT					

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

DREAM

Disaster Risk and Exposure Assessment for Mitigation

Flight log for 1125P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1125P

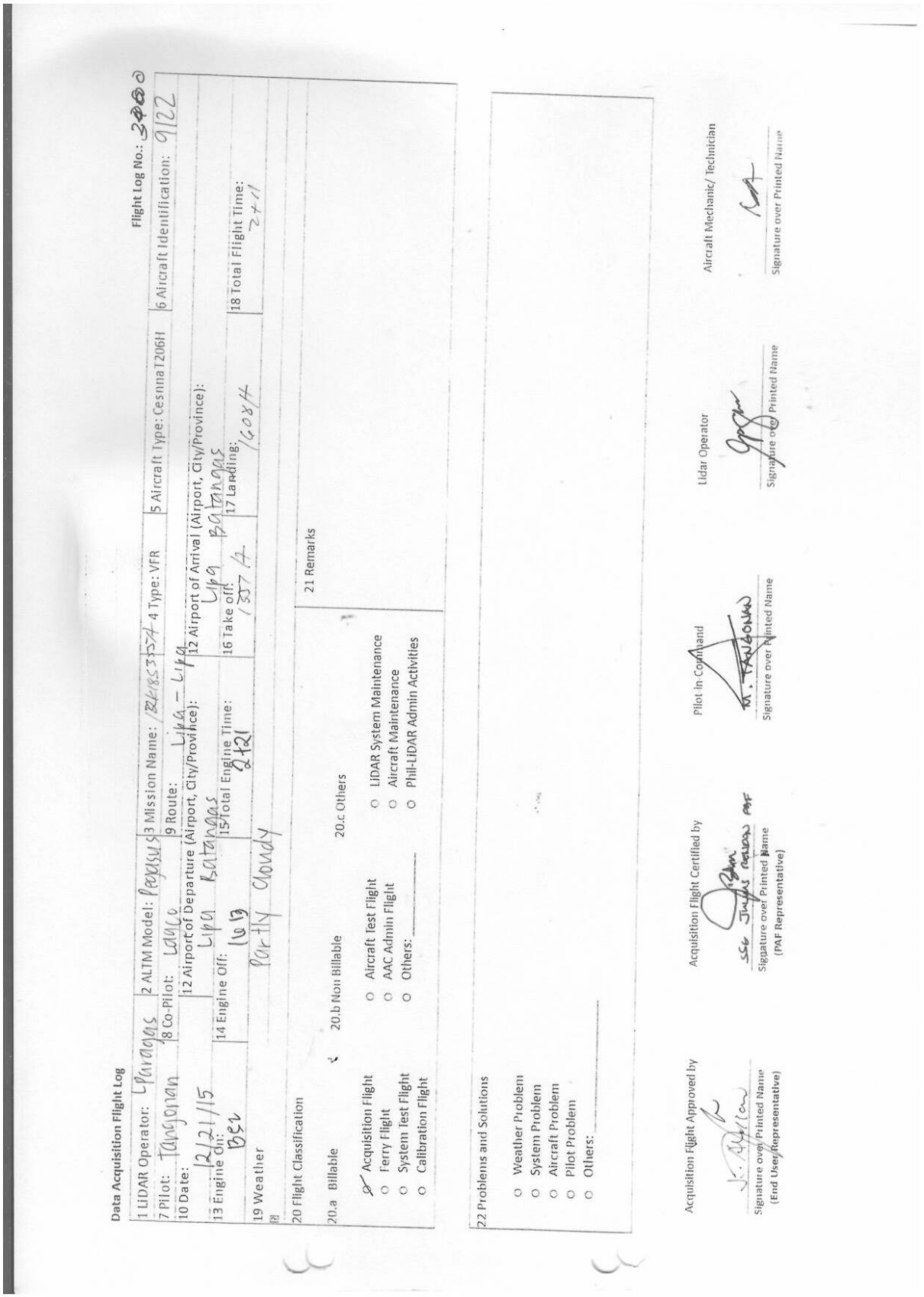
1 LIDAR Operator: E. Punto	2 ALTM Model: PEG	3 Mission Name: 1BLK18S49B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: FEB. 18, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 1324	14 Engine Off: 1553	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time: 2+21
19 Weather: partly cloudy					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Sgt. Dac Ramirez PAF	M. L. Tangonan	E. Punto
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Flight log for 3000P Mission



Data Acquisition Flight Log

Flight Log No.: 3000

1 LiDAR Operator: Lidar Surveys	2 ALTM Model: Pegasus	3 Mission Name: Blk85357A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: Tangonan	8 Co-Pilot: Lamug	9 Route: Lipa – Lipa			
10 Date: 12/21/15	11 Airport of Departure (Airport, City/Province): Lipa Batangas		12 Airport of Arrival (Airport, City/Province): Lipa Batangas		
13 Engine On: 0821	14 Engine Off: 1013	15 Total Engine Time: 2.12	16 Take off: 1357.4	17 Landing: 1608.4	18 Total Flight Time: 2.41
19 Weather: Partly cloudy					

20 Flight Classification

20.a Billable

- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: _____

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

SSG JAMES AGUDO PAF

Signature over Printed Name (PAF Representative)

Pilot In Command

Signature over Printed Name

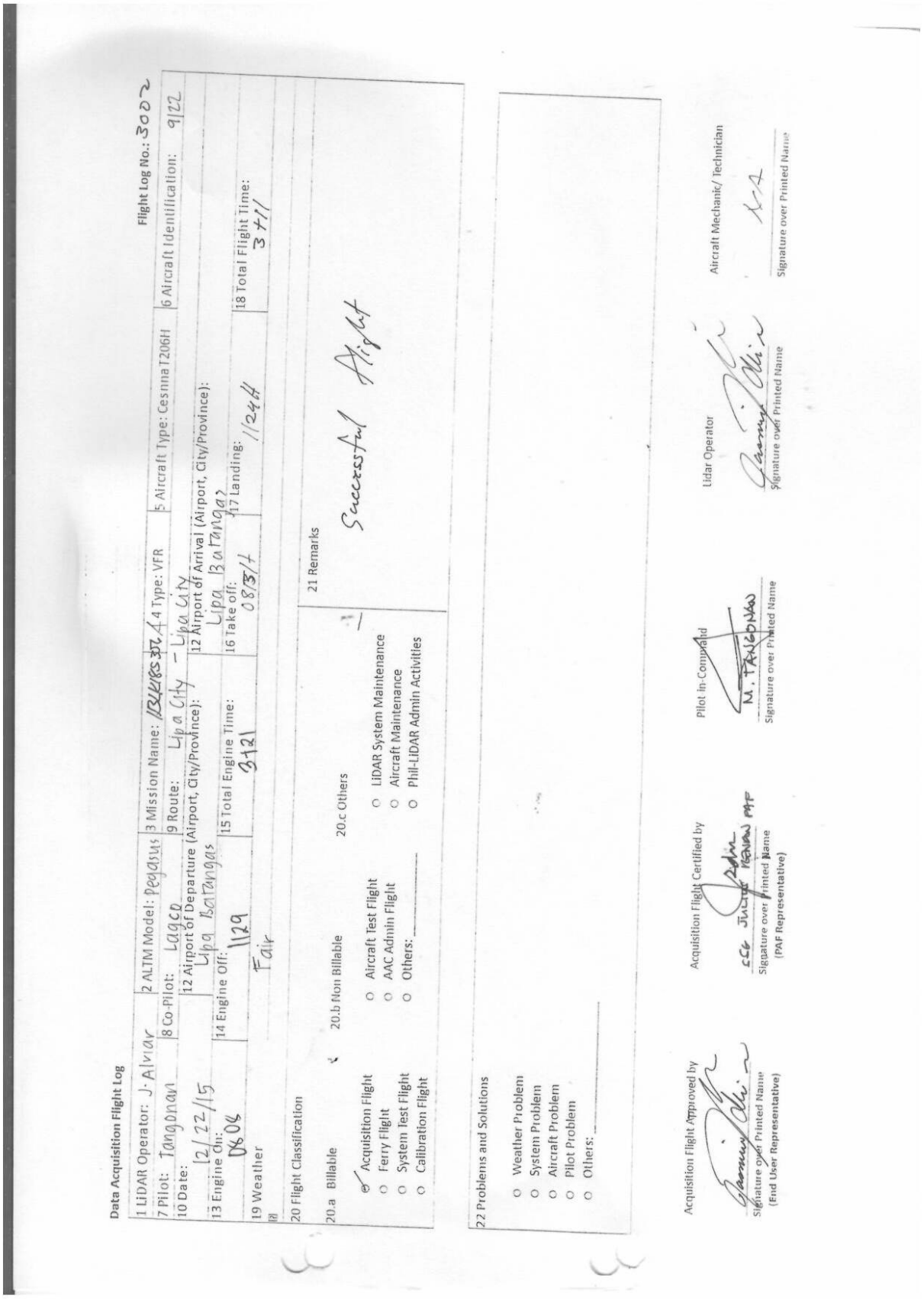
Lidar Operator

Signature over Printed Name

Aircraft Mechanic/ Technician

Signature over Printed Name

Flight Log for 3002P Mission



Data Acquisition Flight Log

Flight Log No.: 3002

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: [illegible] 4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: Tangonan	8 Co-Pilot: Lagco	9 Route: Lipa City – Lipa City		
10 Date: 12/22/15	11 Airport of Departure (Airport, City/Province): Lipa Batangas		12 Airport of Arrival (Airport, City/Province): Lipa Batangas	
13 Engine On: 0804	14 Engine Off: 1129	15 Total Engine Time: 3121	16 Take off: 0835/1	17 Landing: 1244
19 Weather: Fair				18 Total Flight Time: 3+1

20 Flight Classification

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

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

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

21 Remarks: Successful Flight

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

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

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

Pilot In-Command
M. TANGONAN
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Aircraft Mechanic/ Technician
Signature over Printed Name

Flight Log for 3689G Mission

Data Acquisition Flight Log

Flight Log No.: 3689

1 LiDAR Operator: Marc	2 ALTM Model: Gemini	3 Mission Name: 2BLK18SVV009A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: Lim	8 Co-Pilot: Lagao	9 Route: Lipa - Lipa			
10 Date: Jun. 9, 2016	12 Airport of Departure (Airport, City/Province): Lipa		12 Airport of Arrival (Airport, City/Province): Lipa		
13 Engine On: 0707	14 Engine Off: 1054	15 Total Engine Time: 3+47	16 Take off: 0712H	17 Landing: 1049H	18 Total Flight Time: 3+37
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

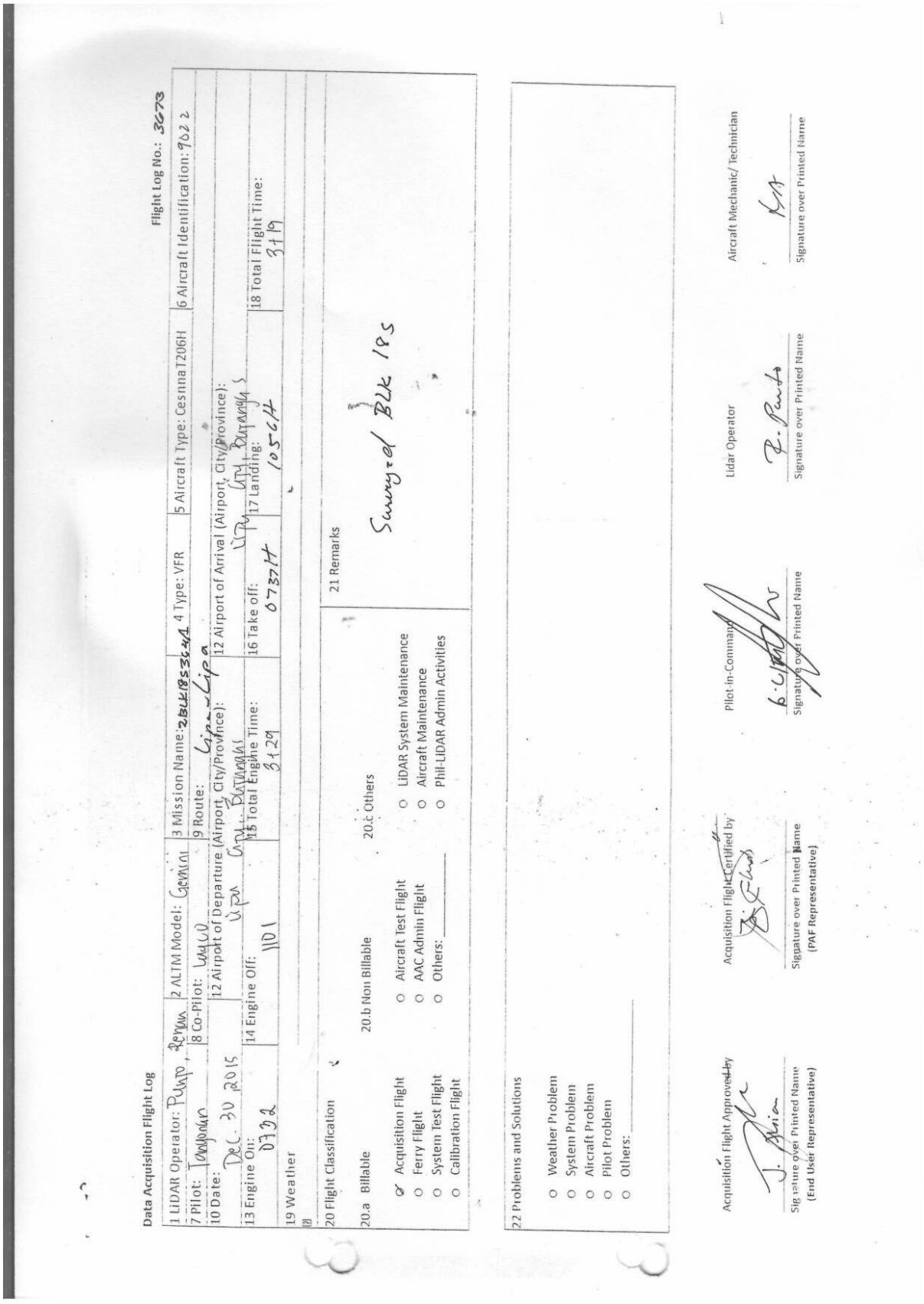
Surveyed BLK18S

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	NA Signature over Printed Name

Flight Log for 3673G Mission



Data Acquisition Flight Log

Flight Log No.: 3673

1 LiDAR Operator: Pamp, Reyan	2 ALTM Model: Gemini	3 Mission Name: 2BLK18S364A 4 Type: VFR	5 Aircraft Type: Cessna T206H
7 Pilot: Tamayo	8 Co-Pilot: Lucio	9 Route: Lipa-Clip-a	6 Aircraft Identification: 962 2
10 Date: Dec. 30 2015	12 Airport of Departure (Airport, City/Province): Lipa City, Batangas	12 Airport of Arrival (Airport, City/Province): Lipa City, Batangas	
13 Engine On: 0732	14 Engine Off: 1101	15 Total Engine Time: 3+29	16 Take off: 0732H / 17 Landing: 1056H
			18 Total Flight Time: 3+19

19 Weather

[0]

20 Flight Classification

20.a Billable

- ☒ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LIDAR Admin Activities

21 Remarks

Survey of BLK 18S

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: _____

Acquisition Flight Approved by

J. Blanco

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

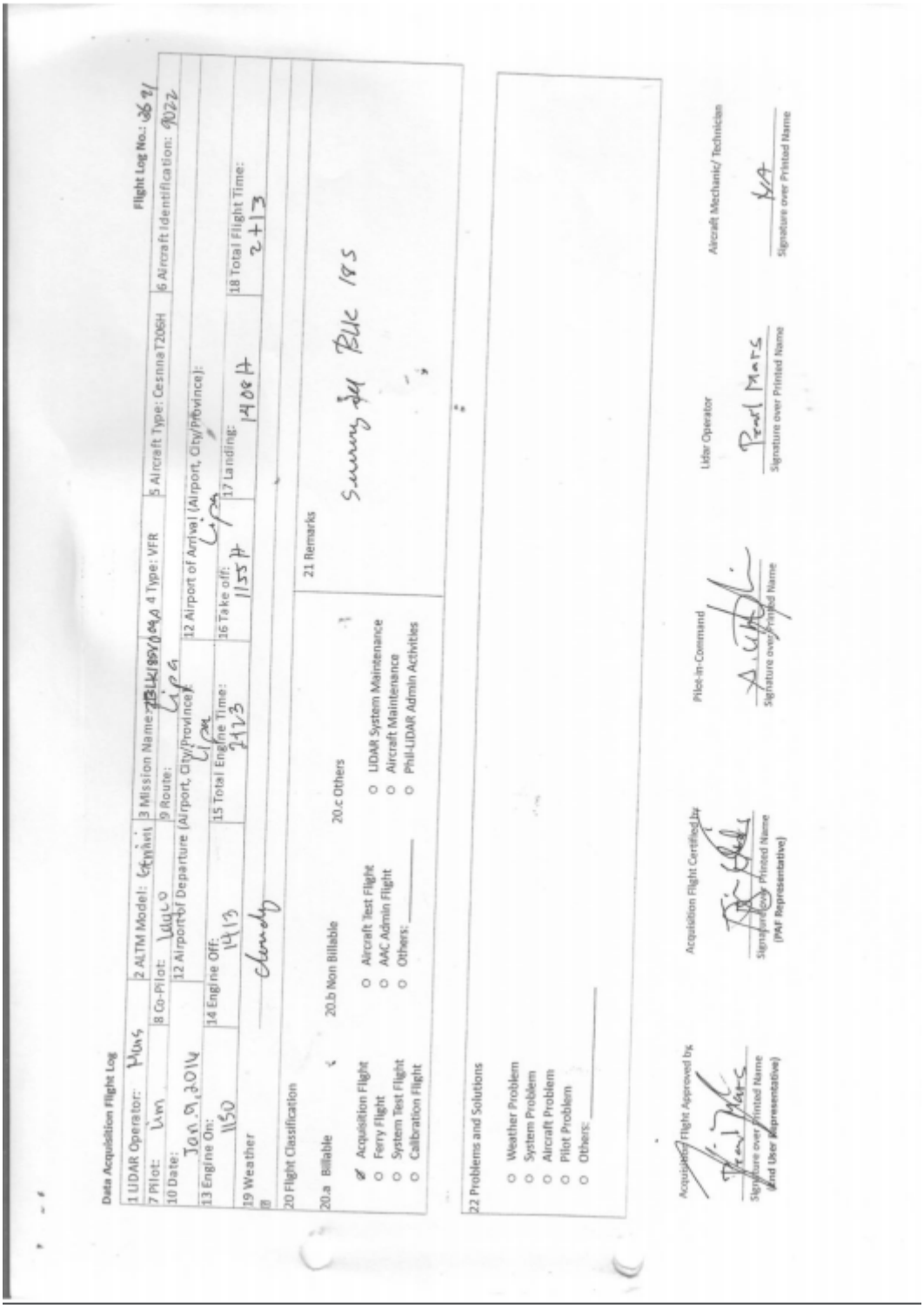
E. Pamp

Signature over Printed Name

Aircraft Mechanic/ Technician

Signature over Printed Name

Flight Log for 3671G Mission



Data Acquisition Flight Log

Flight Log No.: 36 91

1 LiDAR Operator: Phils	2 ALTM Model: Optech	3 Mission Name: [illegible]	4 Type: VFR
5 Aircraft Type: CessnaT206H	6 Aircraft Identification: 9022		
7 Pilot: Lim	8 Co-Pilot: Lugo	9 Route: Lipa	
10 Date: Jan. 9, 2014	11 Airport of Departure (Airport, City/Province): Lipa	12 Airport of Arrival (Airport, City/Province): Lipa	
13 Engine On: 1150	14 Engine Off: 1413	15 Total Engine Time: 2123	16 Take off: 1155 H
17 Landing: 1405 H	18 Total Flight Time: 2+13		
19 Weather: Cloudy			

20 Flight Classification

20.a Billable ✓ 20.b Non Billable 20.c Others

- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____
- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks: Sunny sky Blue ips

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: _____

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

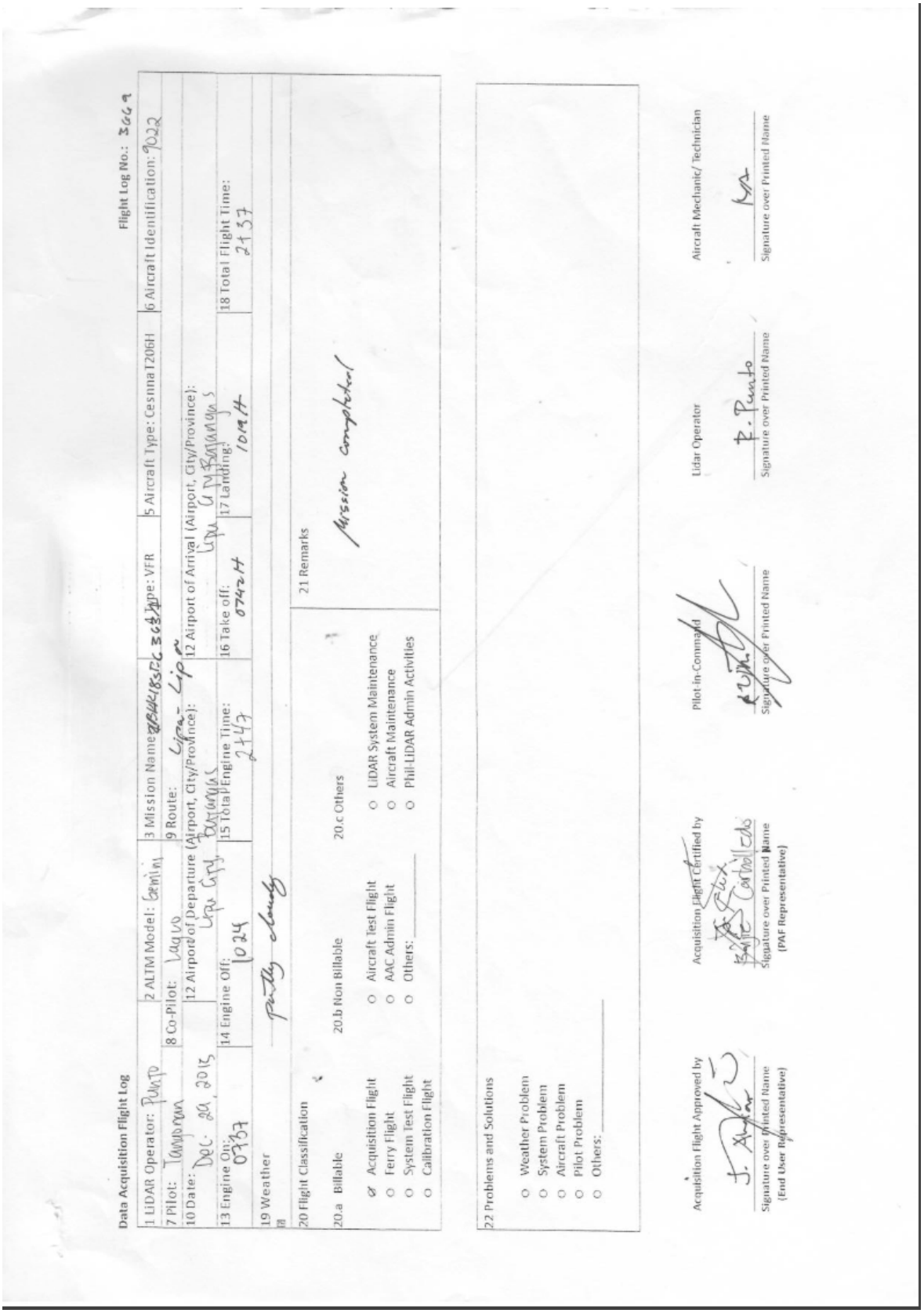
Acquisition Flight Certified by: Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: Signature over Printed Name

Flight Log for 3669G Mission



Data Acquisition Flight Log

Flight Log No.: 3669

1 LiDAR Operator: Rimto	2 ALTM Model: Gemini	3 Mission Name: [illegible] Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: Tamboran	8 Co-Pilot: Laguo	9 Route: Cipac Lipa		
10 Date: Dec. 20, 2015	11 Airport of Departure (Airport, City/Province): Lipa City Batangas		12 Airport of Arrival (Airport, City/Province): Lipa CLMP Batangas	
13 Engine On: 0737	14 Engine Off: 1024	15 Total Engine Time: 2.4.7	16 Take off: 0742H	17 Landing: 1049H	18 Total Flight Time: 2.1.7

19 Weather: partly cloudy

20 Flight Classification

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

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

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

21 Remarks: Mission completed

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

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
E. Punto
Signature over Printed Name

Aircraft Mechanic/ Technician
Signature over Printed Name

Data Acquisition Flight Log — Flight Log No.: 3671

1 LiDAR Operator: Gonzales J.	2 ALTM Model: Gemini	3 Mission Name: BLK18BC3691B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: Tangonan	8 Co-Pilot: Lagle	9 Route: Lipa – Lipa			
10 Date: Dec. 29, 2015	12 Airport of Departure (Airport, City/Province): Lipa City, Batangas		12 Airport of Arrival (Airport, City/Province): Lipa City, Batangas		
13 Engine On: 1509	14 Engine Off: 1707	15 Total Engine Time: 1+58	16 Take off: 1514H	17 Landing: 1702H	18 Total Flight Time: 1+48
19 Weather: Partly cloudy					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
ø Acquisition Flight	o Aircraft Test Flight	o LiDAR System Maintenance
o Ferry Flight	o AAC Admin Flight	o Aircraft Maintenance
o System Test Flight	o Others: _____	o Phil-LiDAR Admin Activities
o Calibration Flight		

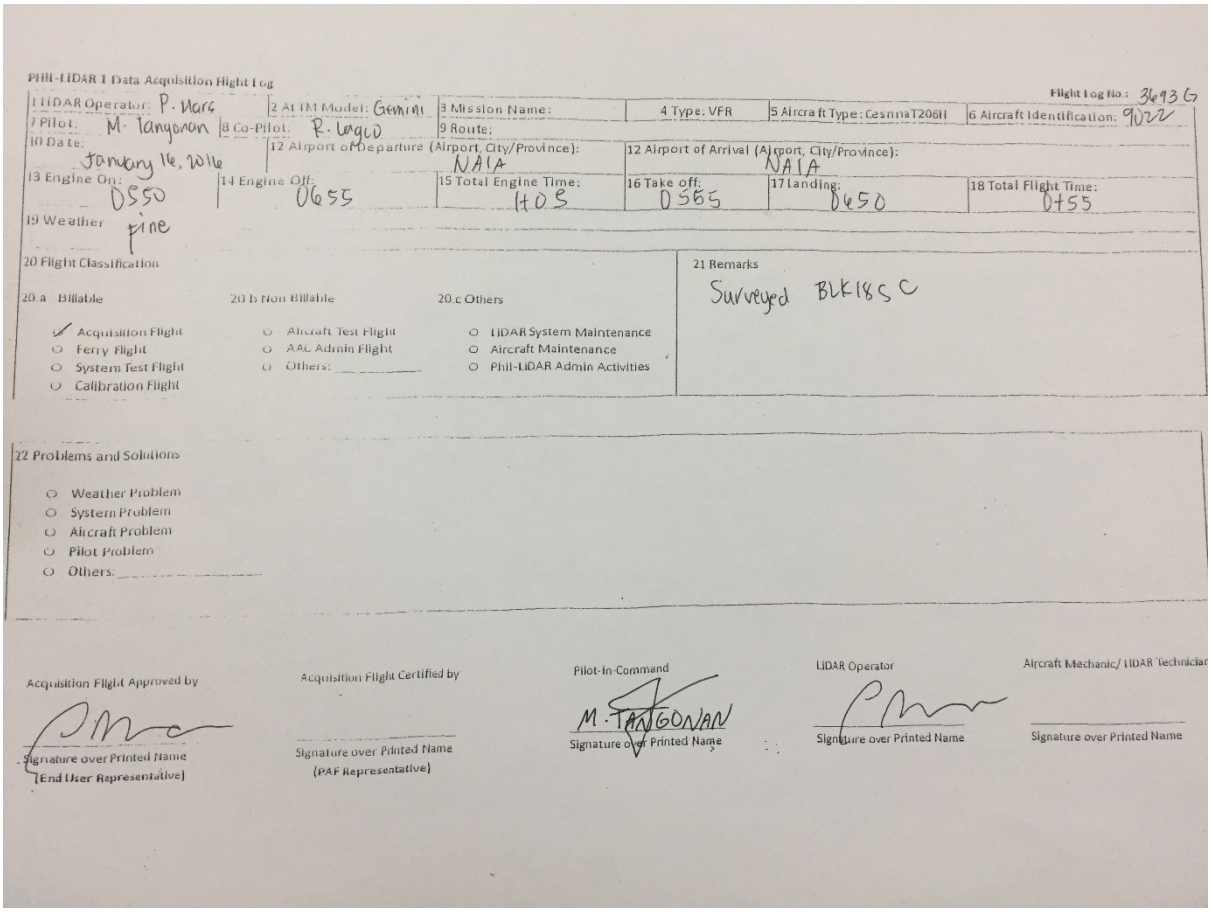
21 Remarks: Surveyed BLK18BC

22 Problems and Solutions

- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: _____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 3693GMission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3693G

1 LiDAR Operator: P. Marc	2 ALTM Model: Gemini	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: R. Legco	9 Route:			
10 Date: January 16, 2016	11 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0550	14 Engine Off: 0655	15 Total Engine Time: 1+05	16 Take off: 0565	17 Landing: 0650	18 Total Flight Time: 0+55

19 Weather: fine

20 Flight Classification

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

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

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

21 Remarks: Surveyed BLK18SC

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	M. TANGONAN Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

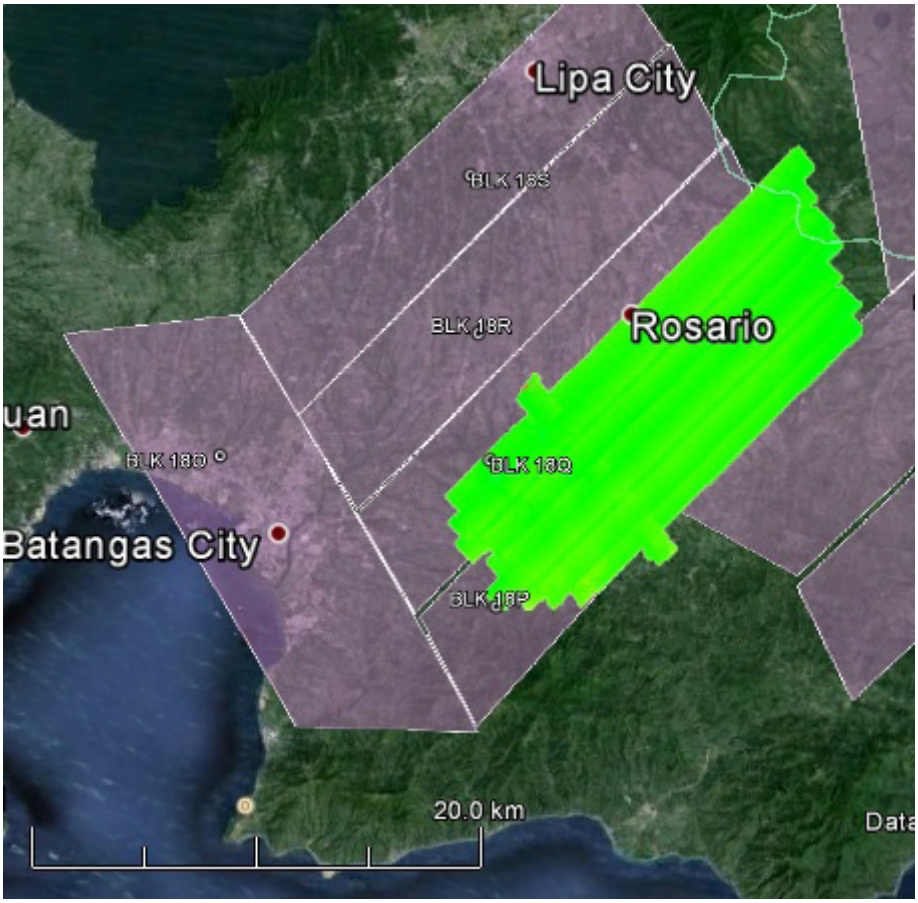
Annex 7. Flight Status Reports

CALABARZON					
(DECEMBER 21-22, 2015 DECEMBER 29-30, 2015, JANUARY 9, 2016 and JANUARY 16, 2016)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
14-Feb-14	1107P	1BLK18QRS45A	R. Punto	14-Feb	Mission completed; changed orientation of flight plan to avoid PAF base restriction in Lipa; 1200m flying height
15-Feb-14	1111P	1BLK18QRS46A	F. Sable	15-Feb	Data acquired but aborted mission due to strong wind, heavy build up and traffic especially in Laguna area; 1200m flying height
17-Feb-14	1119P	1BLK18O48A	R. Punto	17-Feb	Data acquired but with major voids due to clouds
18-Feb-14	1123P	1BLK18OS49A	F. Sable	18-Feb	Mission completed at 1200 flying height
18-Feb-14	1125P	1BLK18S49B	R. Punto	18-Feb	Data acquired at 1200m flying height
3000P	BLK 18SAB LIPA, SAN JOSE	1BLK18SB355A	LK PARAGAS	21-Dec	SURVEYED BLK 18SAB 60.04 SQ KM
3002P	BLK 18SABEK TANAUAN, MALVAR, TALISAY	1BLK18S356A	J ALVIAR	22-Dec	SURVEYED BLK 18SABEK 304.12 SQ KM
3689G	GAPS IN BLK 18KDBEF	2BLK18SV009A	P.MARS	9-Jan	SURVEYED GAPS IN BLK 18KDBEF 77.45 SQ KM.
3673G	BLK 18SG, 18SB LAUREL, LIPA, CUENCA	2BLK18S363A	R PUNTO	30-Dec	SURVEYED BLK 18SG, GAPS IN BLK 18SB 156.04 SQ KM
3691G	GAPS IN BLK18KLB	2BLK18SVV009B	P.MARS	9-Jan	SURVEYED IN GAPS IN BLK18SKL 45.86 SQ KM.
3669G	BLK 18SAB LIPA, SAN JOSE	2BLK18SBC363A	R PUNTO	29-Dec	SURVEYED BLK 21AB; 144.41 SQ KM
3671G	BLK 18SBC CUENCA	2BLK18BC363B	J GONZALES	29-Dec	SURVEYED BLK 18SBC 71.61 SQ KM
3693G	BLK18SC	2BLK18SCB016A	P.MARS	16-Jan	SURVEYED IN BLK18SC 33.941 SQ KM.

LAS/SWATH BOUNDARIES PER FLIGHT

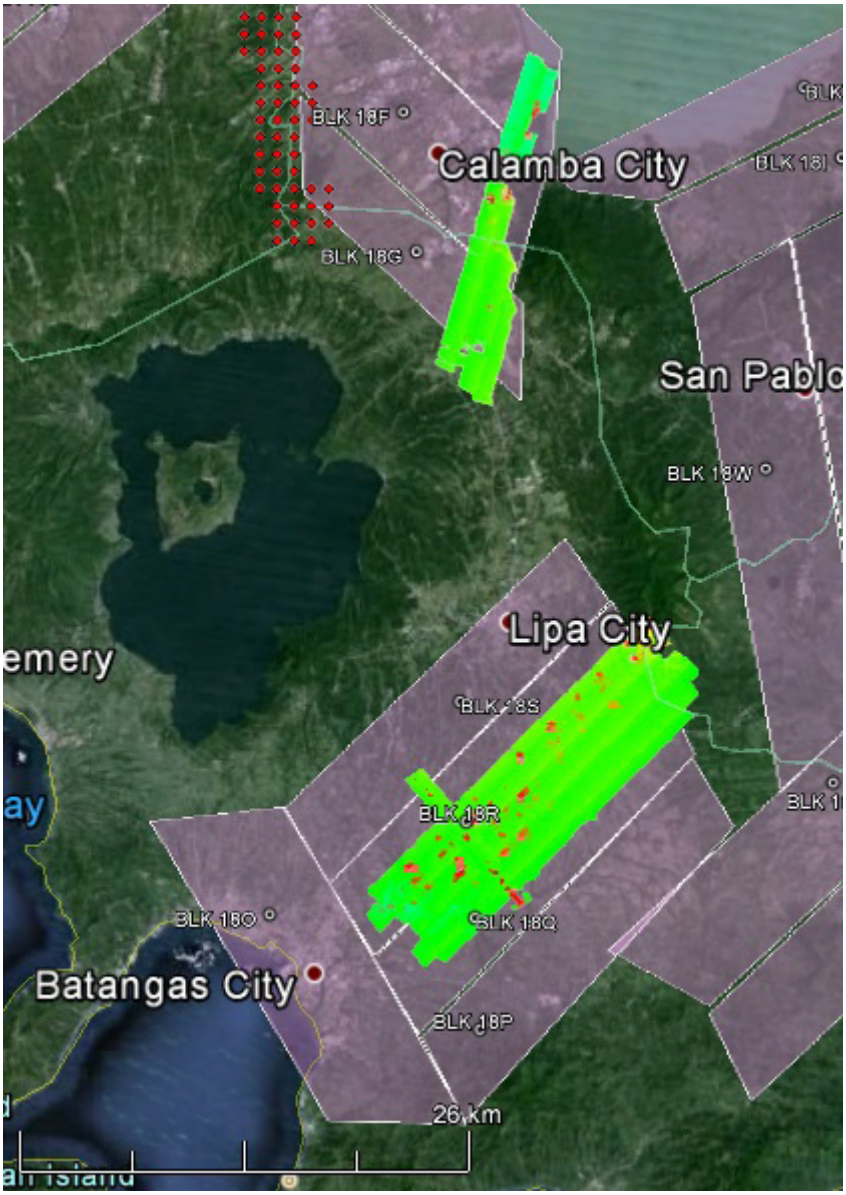
Flight No. : 1107P
Area: BLK 18PQ
Mission Name: 1BLK18QRS45A
Parameters: PRF 200 SF 30 FOV 50

LAS



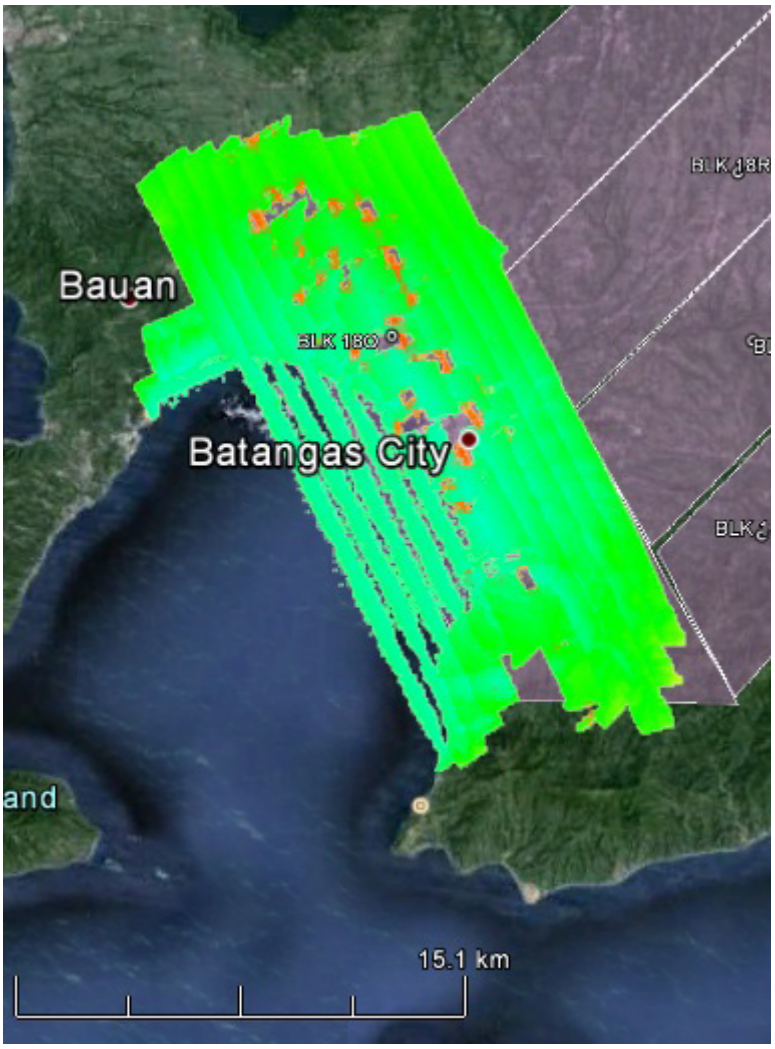
Flight No. : 1111P
Area: BLK 18RS AND BLK 18ES
Mission Name: 1BLK18RS46A
Parameters: PRF 200 SF 30 FOV 50

LAS



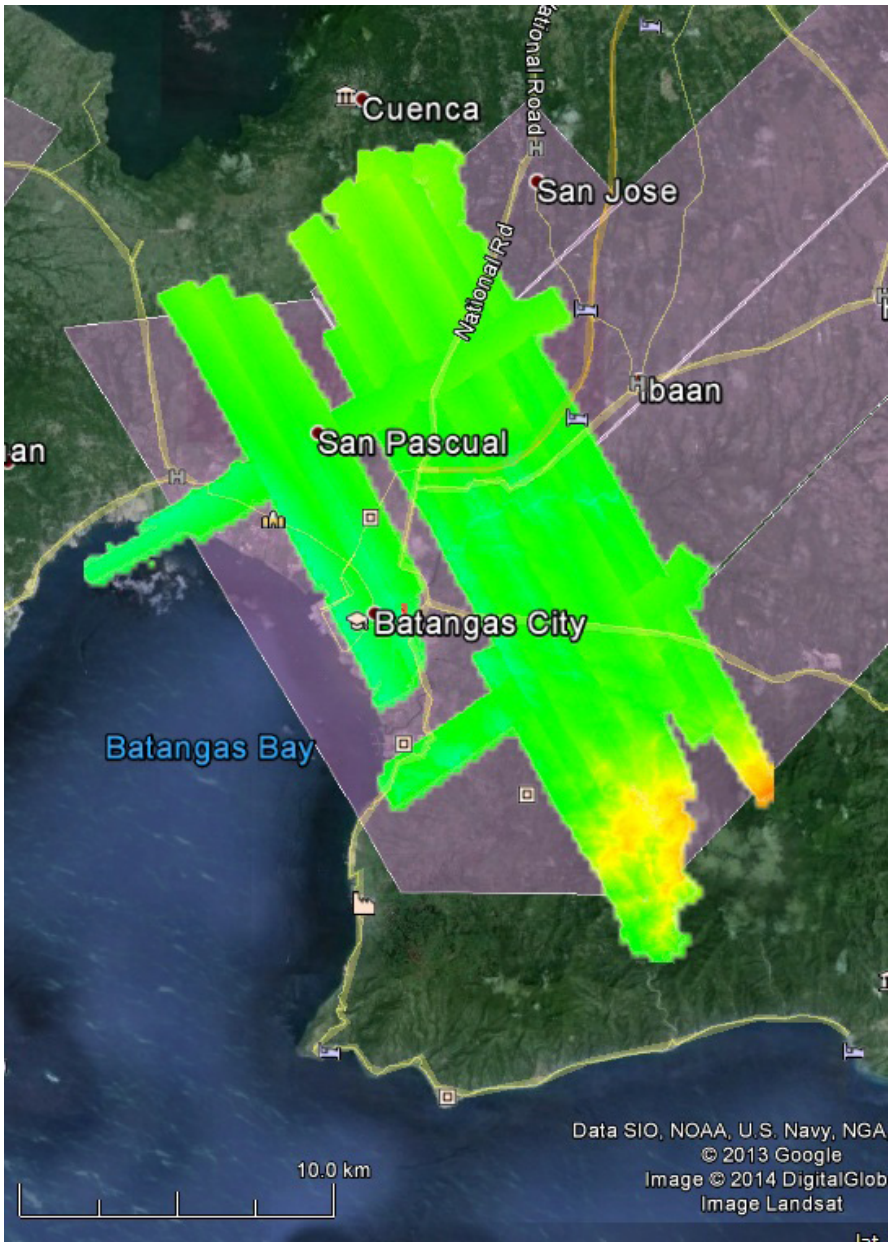
Flight No. : 1119P
Area: BLK 18O
Mission Name: 1BLK18048A
Parameters: PRF 200 SF 30 FOV 50

LAS



Flight No. : 1123P (renamed from 1121P)
Area: BLK 18OPQRS
Mission Name: 1BLK18OS49A
Parameters: PRF 200 SF 30 FOV 50

LAS

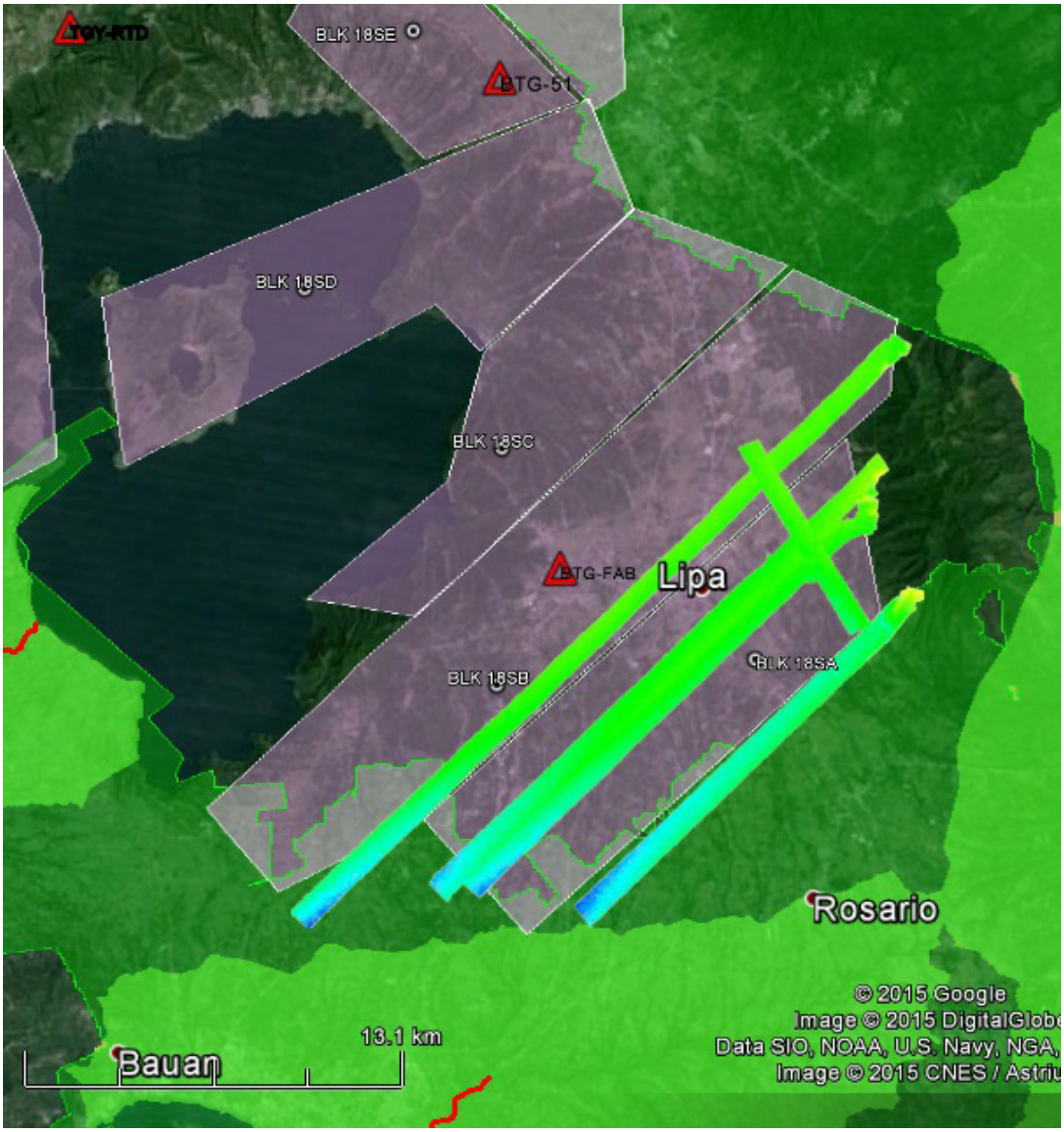


Flight No. : 1125P (renamed from 1123P)
Area: BLK 18Os
Mission Name: 1BLK18OS49B
Parameters: PRF 200 SF 30 FOV 50

LAS

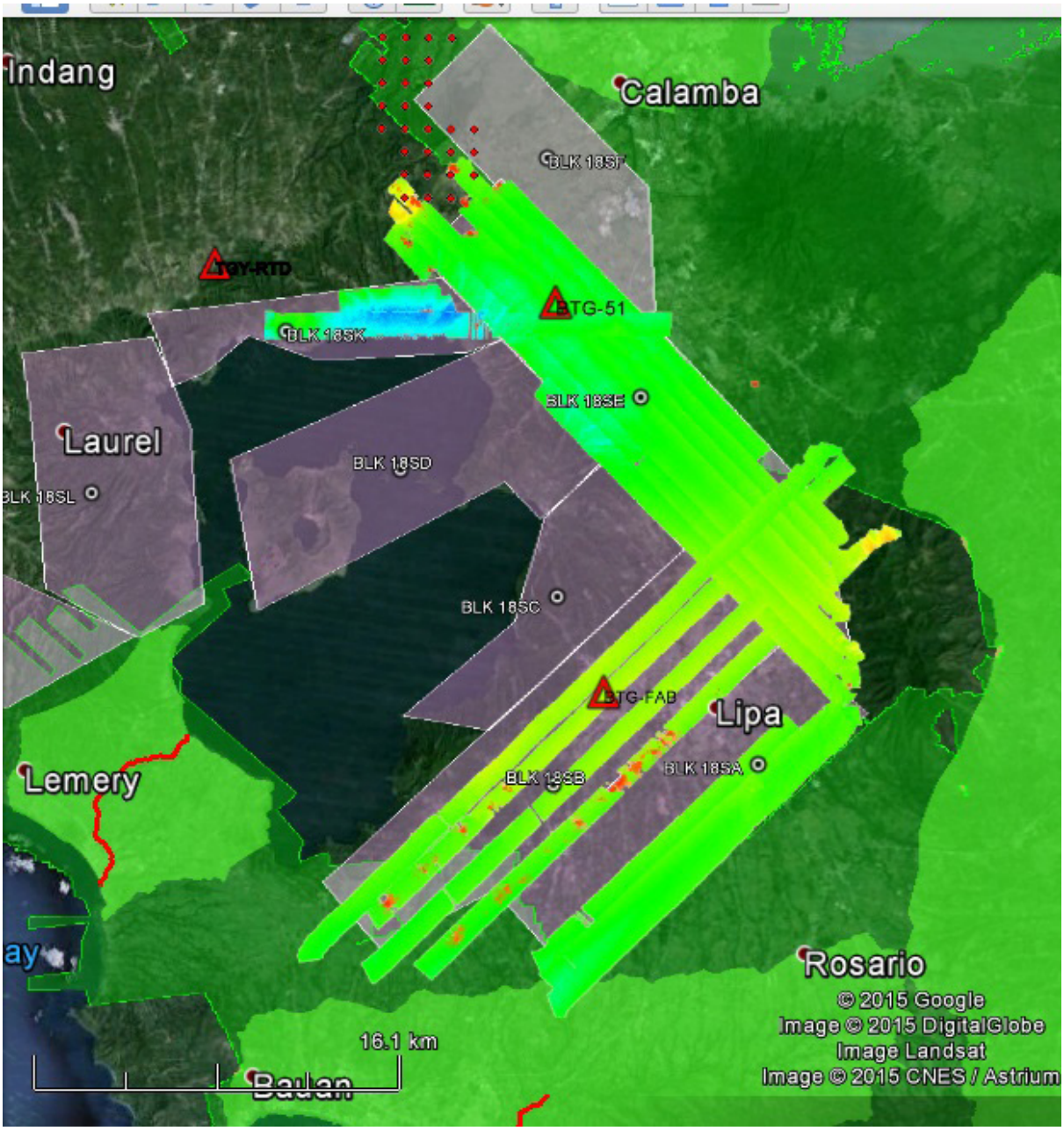
Flight No. : 3000P
Area: BLK 18SAB
Mission Name: 1BLK18SB355A
Parameters: PRF 200 SF 30 FOV 50

LAS



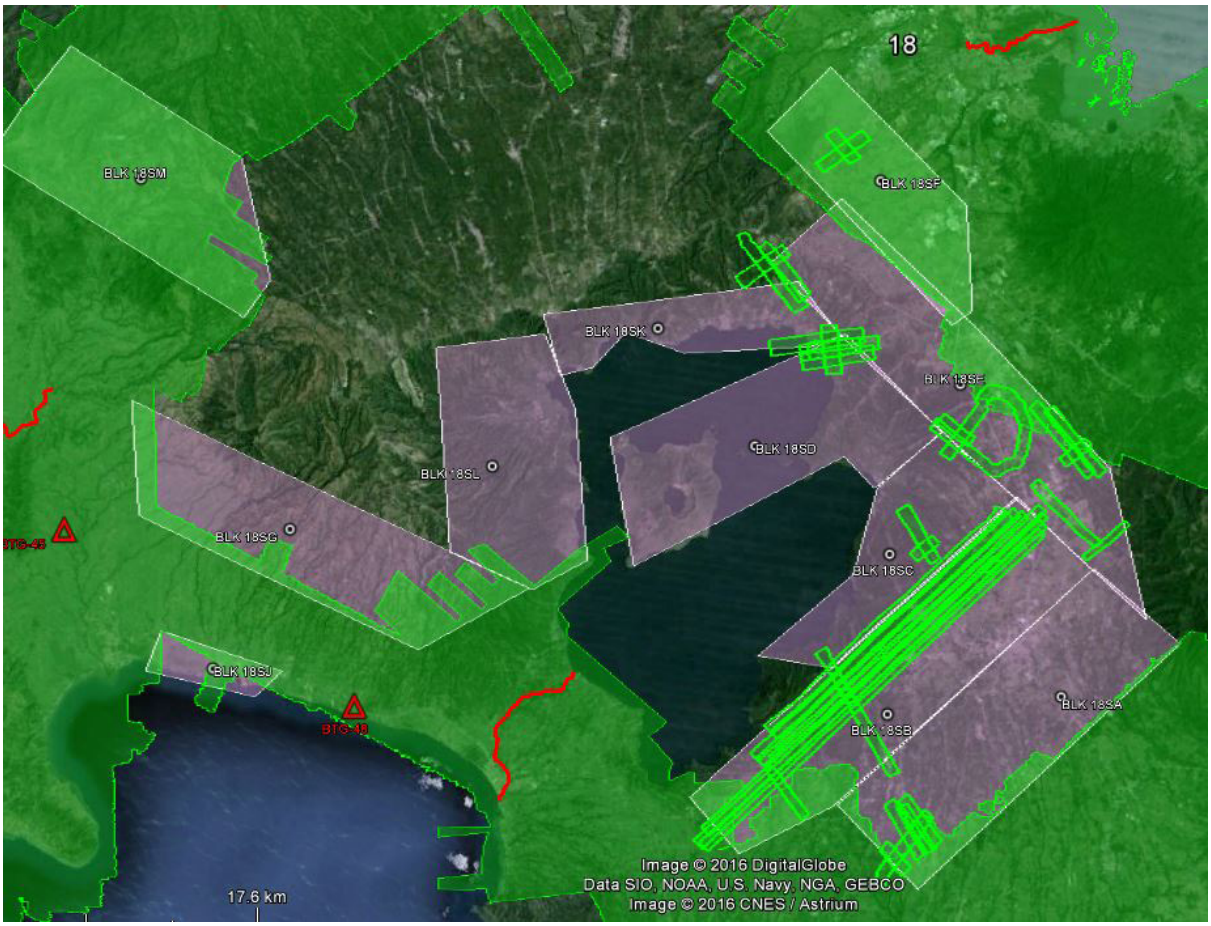
Flight No. : 3002P
Area: BLK 18SABEK
Mission Name: 1BLK18S356A
Parameters: PRF 200 SF 30 FOV 50

LAS



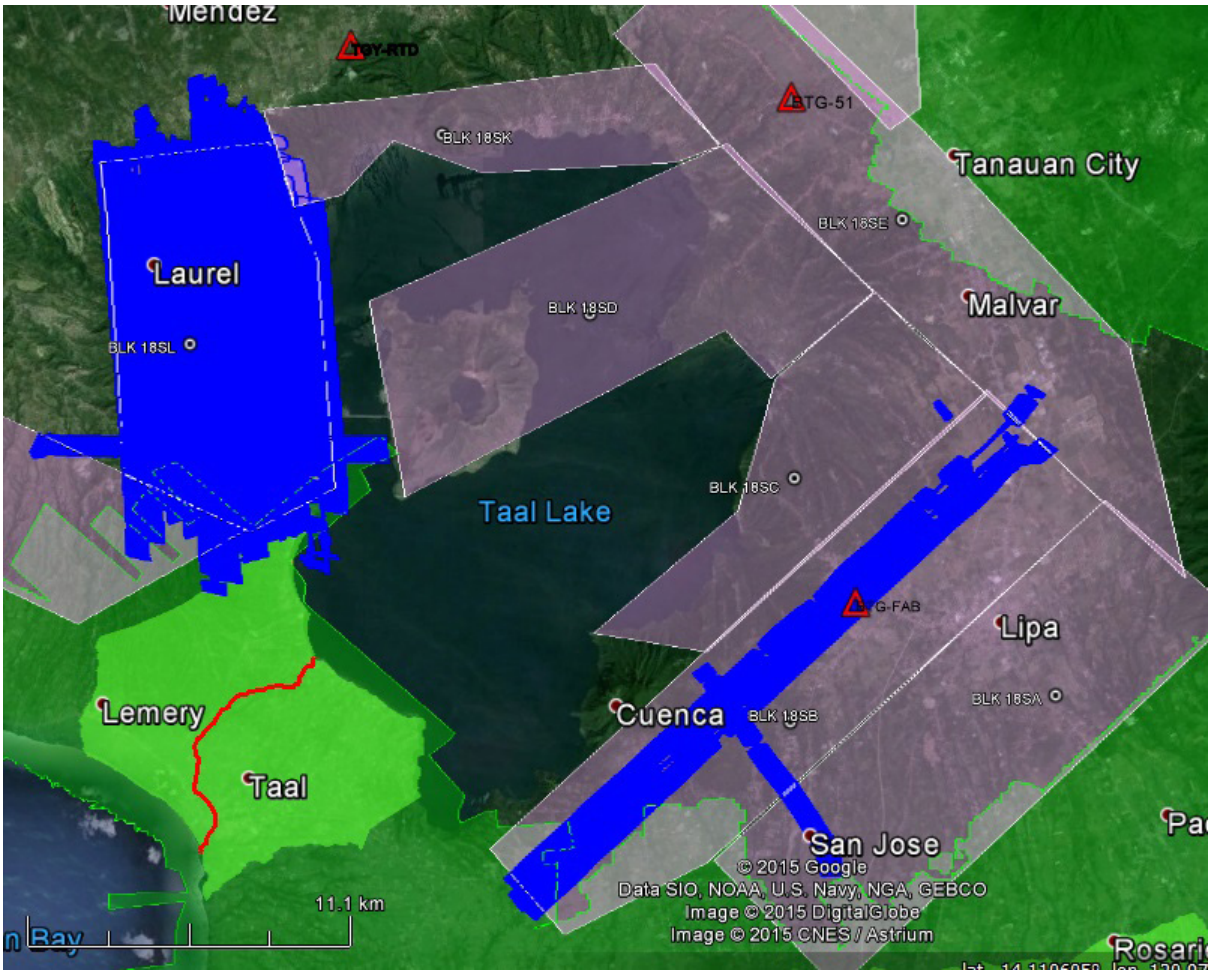
Flight No. : 3689G
Area: GAPS IN BLK 18KDBEF
Mission Name: 2BLK18SV009A
Parameters: PRF 142 SF 40 FOV 50

SWATH



Flight No. : 3673G
Area: BLK 18SG, 18SBS
Mission Name: 1BLK18S364A
Parameters: PRF 100 SF 20 FOV 40

SWATH

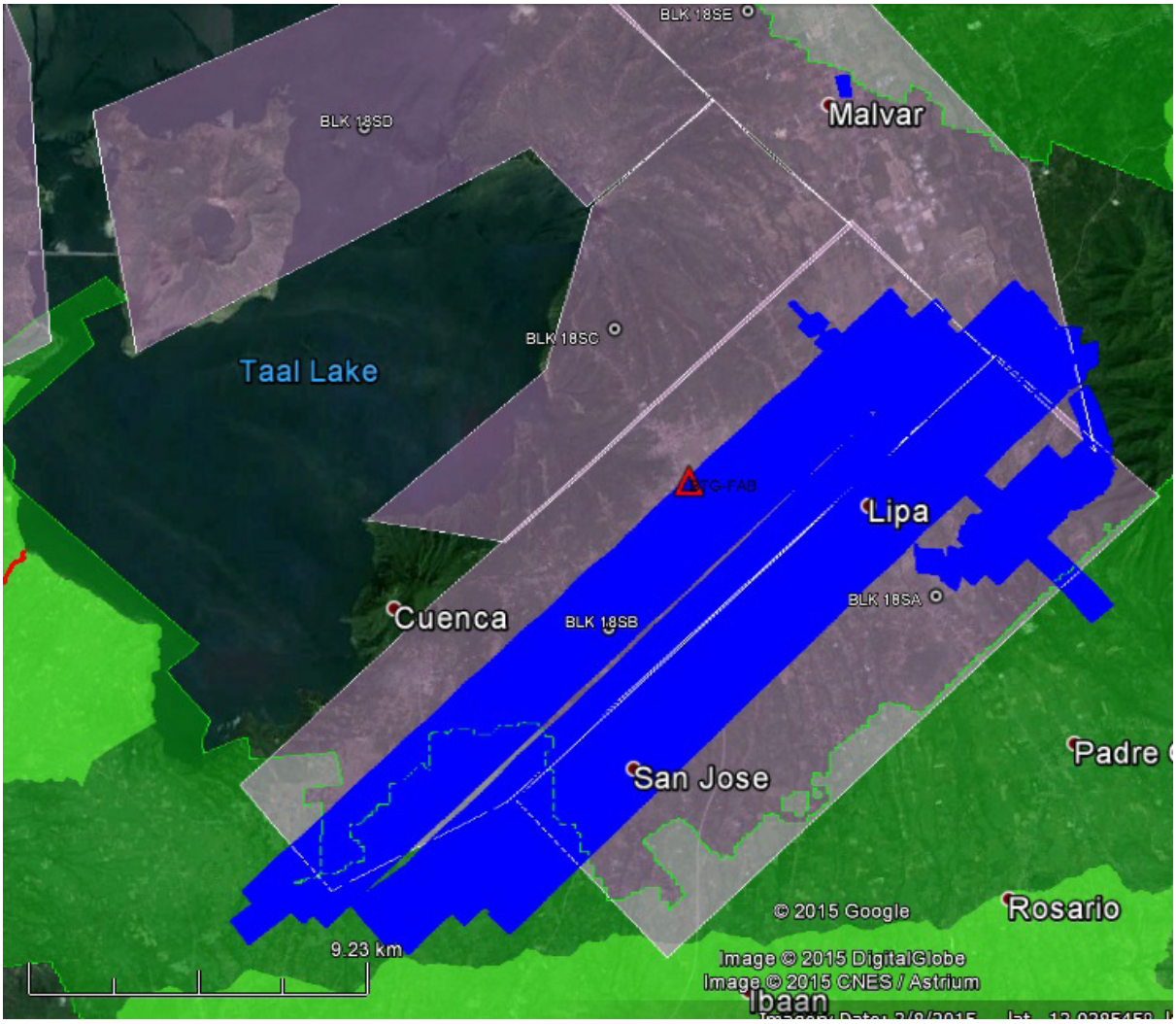


Flight No. : 3691G
Area: BLK 18SG, SF
Mission Name: 2BLK18SVV009B
Parameters: PRF 142 SF 40 FOV 50

SWATH

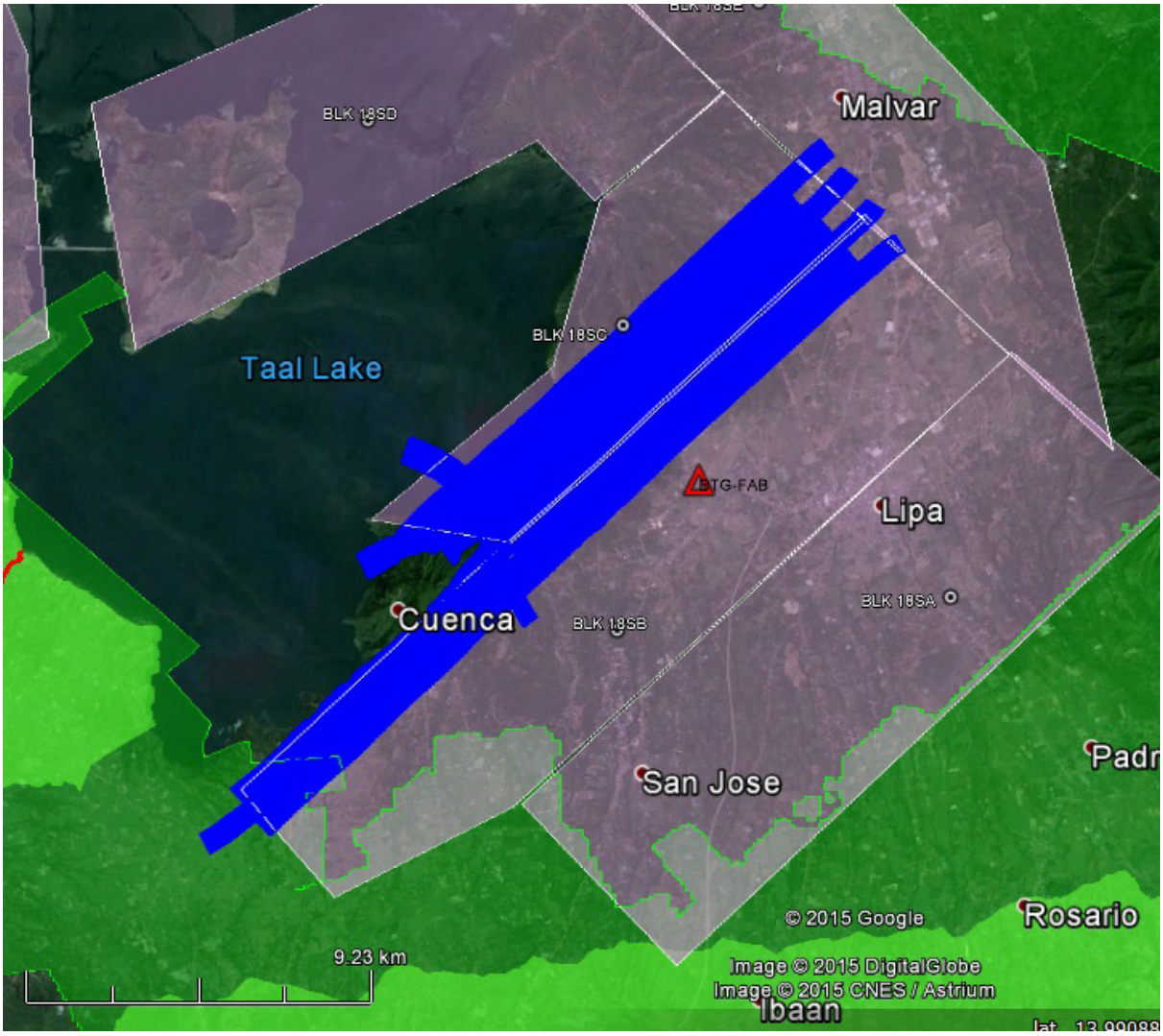
Flight No. : 3669G
Area: BLK 18SAB
Mission Name: 1BLK18SBC363A
Parameters: PRF 100 SF 20 FOV 40

SWATH



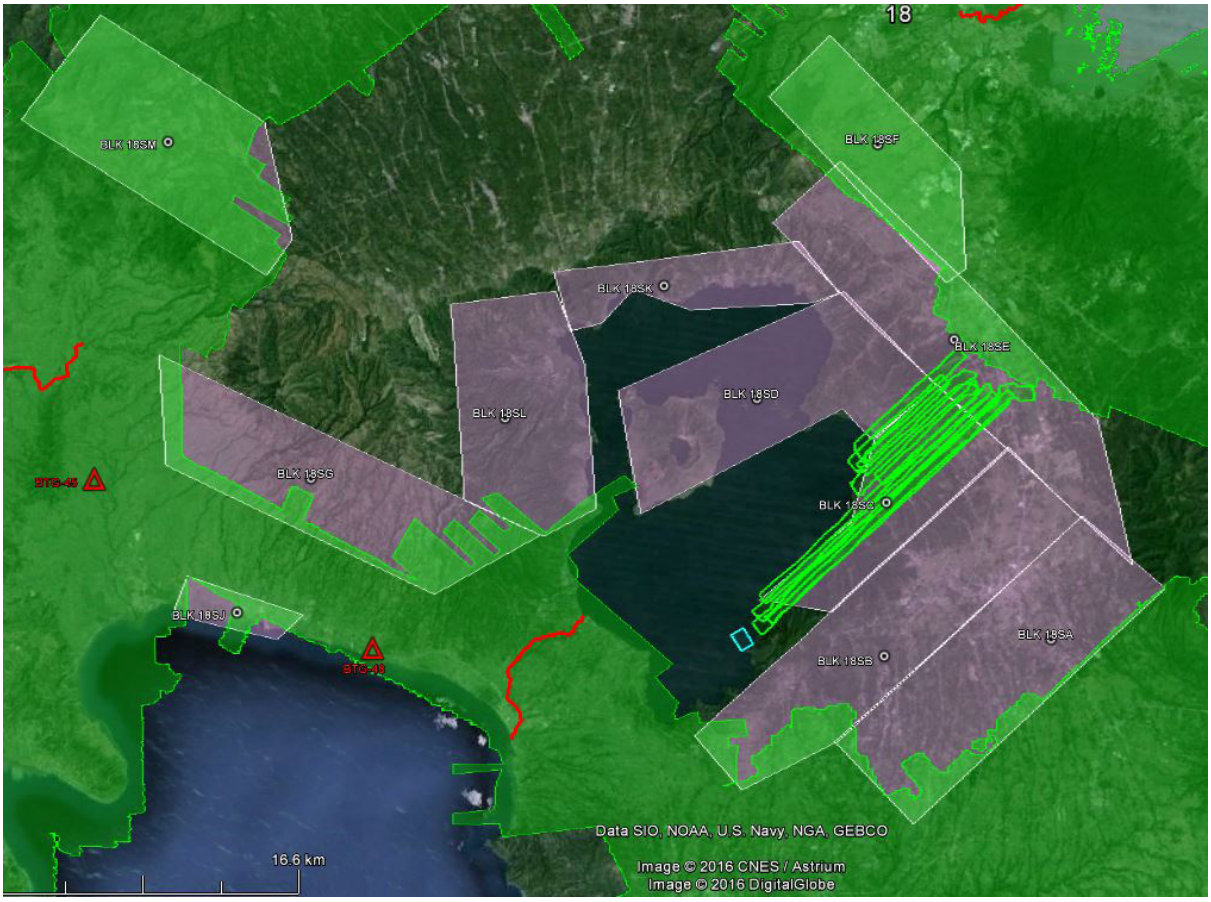
Flight No. : 3671G
Area: BLK 18SBC
Mission Name: 1BLK18SBC363B
Parameters: PRF 100 SF 20 FOV 40

SWATH



Flight No. : 3693G
Area: BLK 18SC
Mission Name: 2BLK18SCB016a
Parameters: PRF 142 SF 40 FOV 50

SWATH



Annex 8. Mission Summary Reports

Flight Area	**Batangas**
Mission Name	**Blk18SA**
Inclusive Flights	3000P, 3002P
Range data size	32.41 GB
POS data size	292 MB
Base data size	38.6 MB
Image	52.8 GB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2698
RMSE for East Position (<4.0 cm)	1.0579
RMSE for Down Position (<8.0 cm)	1.8439
Boresight correction stdev (<0.001deg)	0.000239
IMU attitude correction stdev (<0.001deg)	0.000238
GPS position stdev (<0.01m)	0.001200
Minimum % overlap (>25)	6.79
Ave point cloud density per sq.m. (>2.0)	2.94
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	130
Maximum Height	620.36 m
Minimum Height	102.31 m
Classification (# of points)	
Ground	85,591,089
Low vegetation	58,169,445
Medium vegetation	119,088,921
High vegetation	217,682,240
Building	15,032,211
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Merven Matthew Natino. KathlynClaudyn Zarate

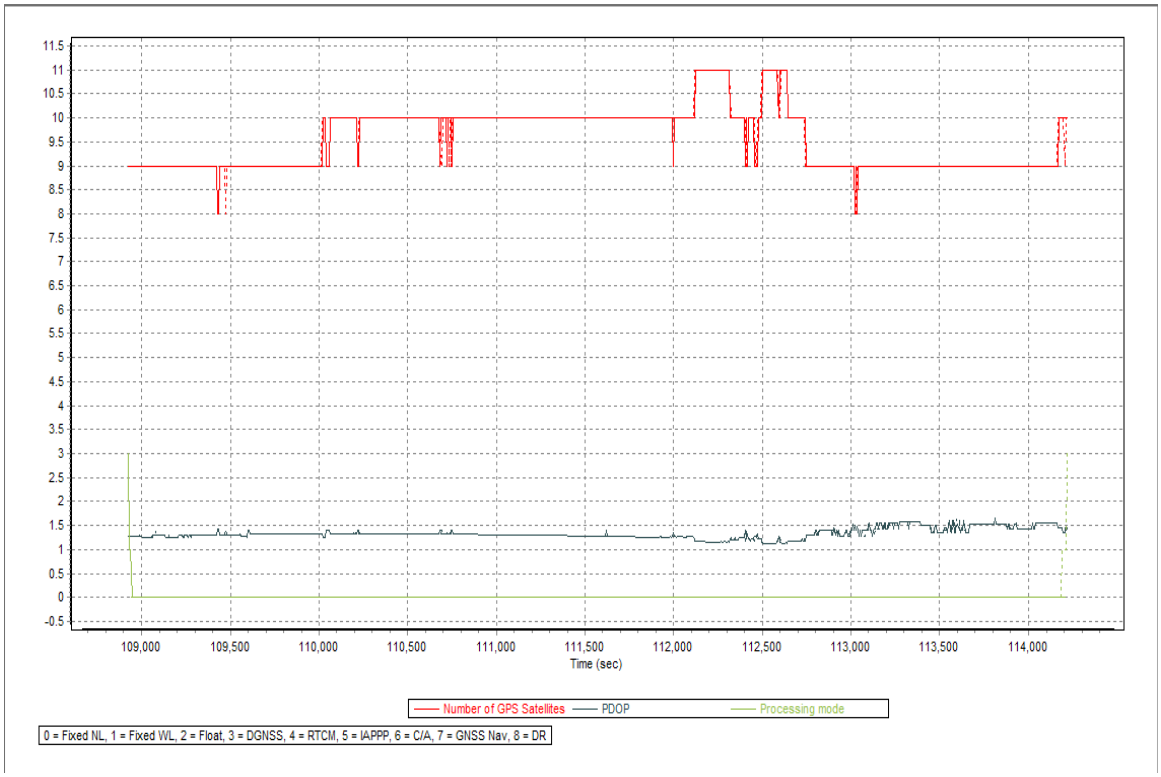


Figure 1.1.1. Solution Status

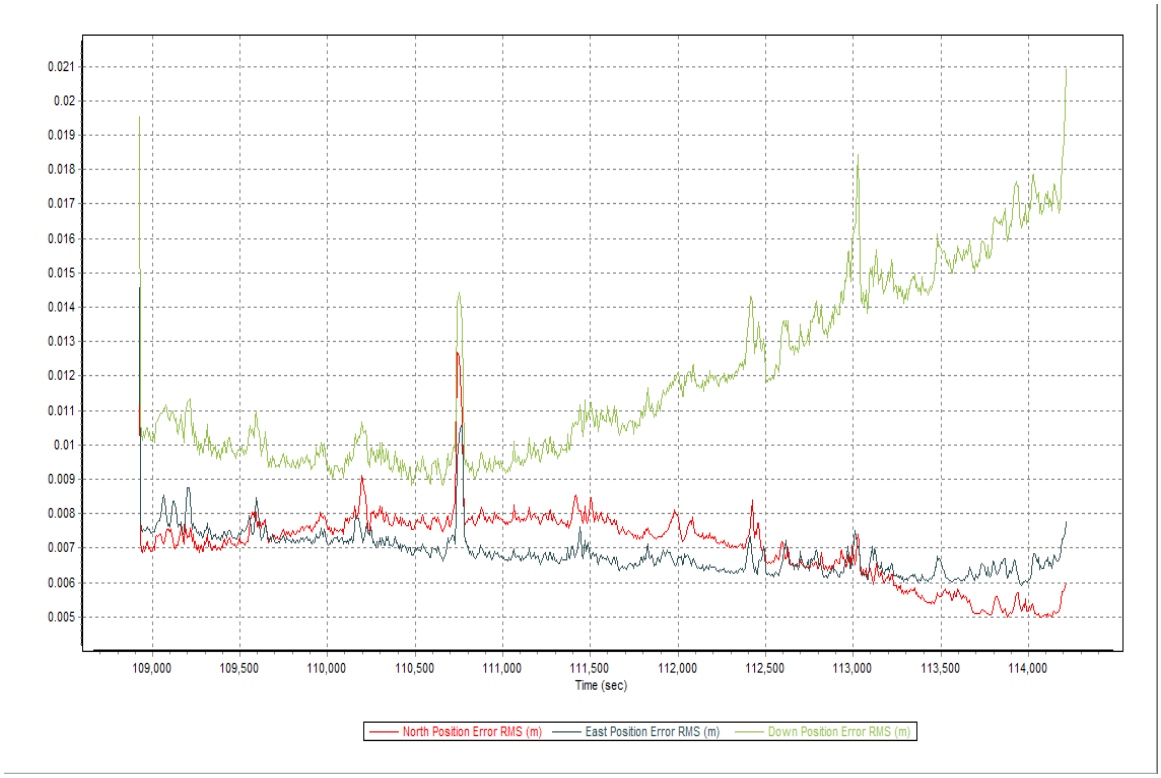


Figure 1.1.2. Smoothed Performance Metric Parameters

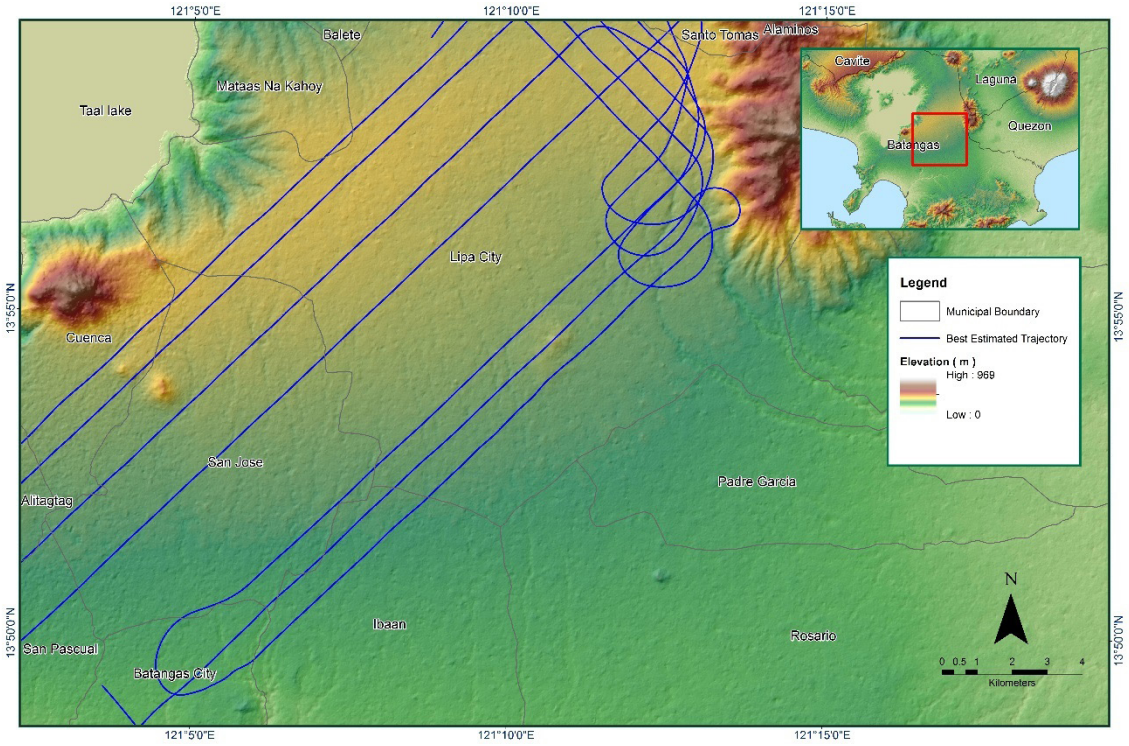


Figure 1.1.3. Best Estimated Trajectory

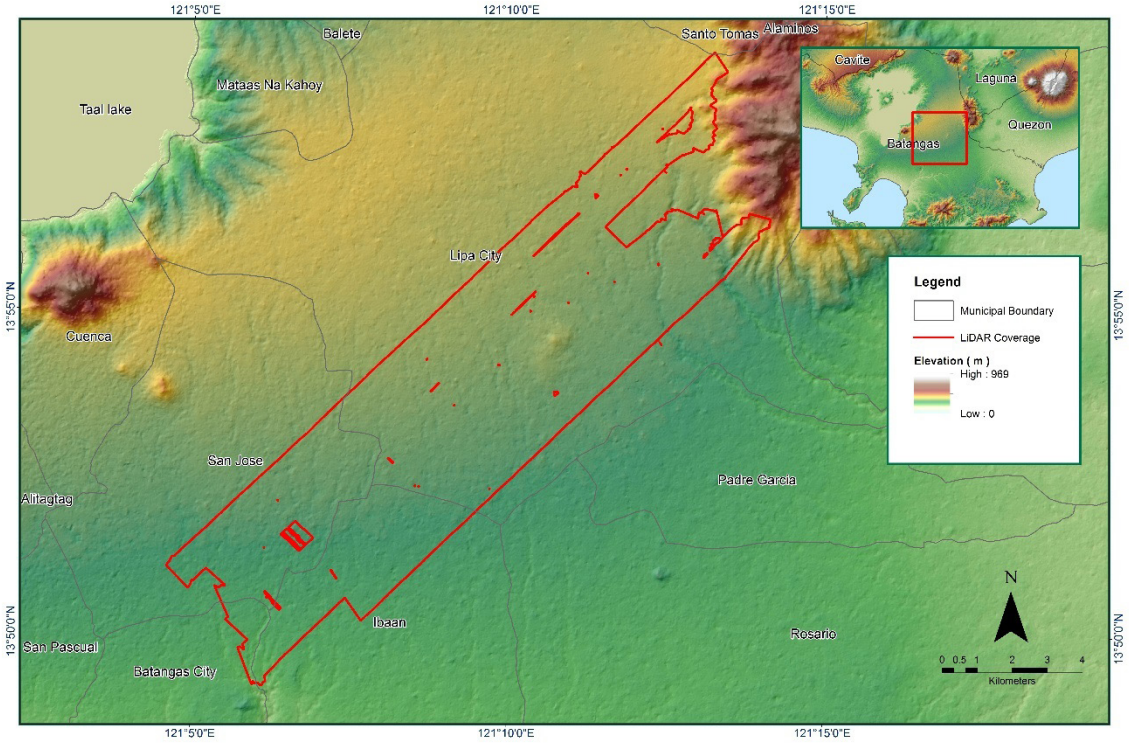


Figure 1.1.4. Coverage of LiDAR Data

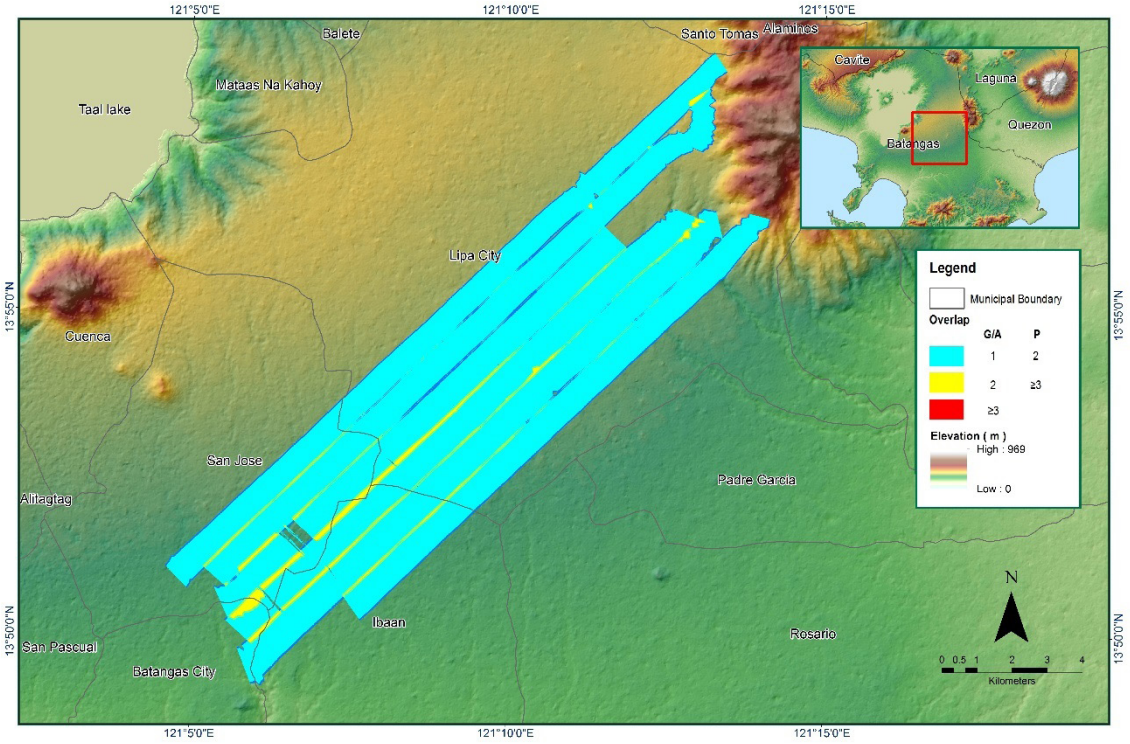


Figure 1.1.5. Image of data overlap

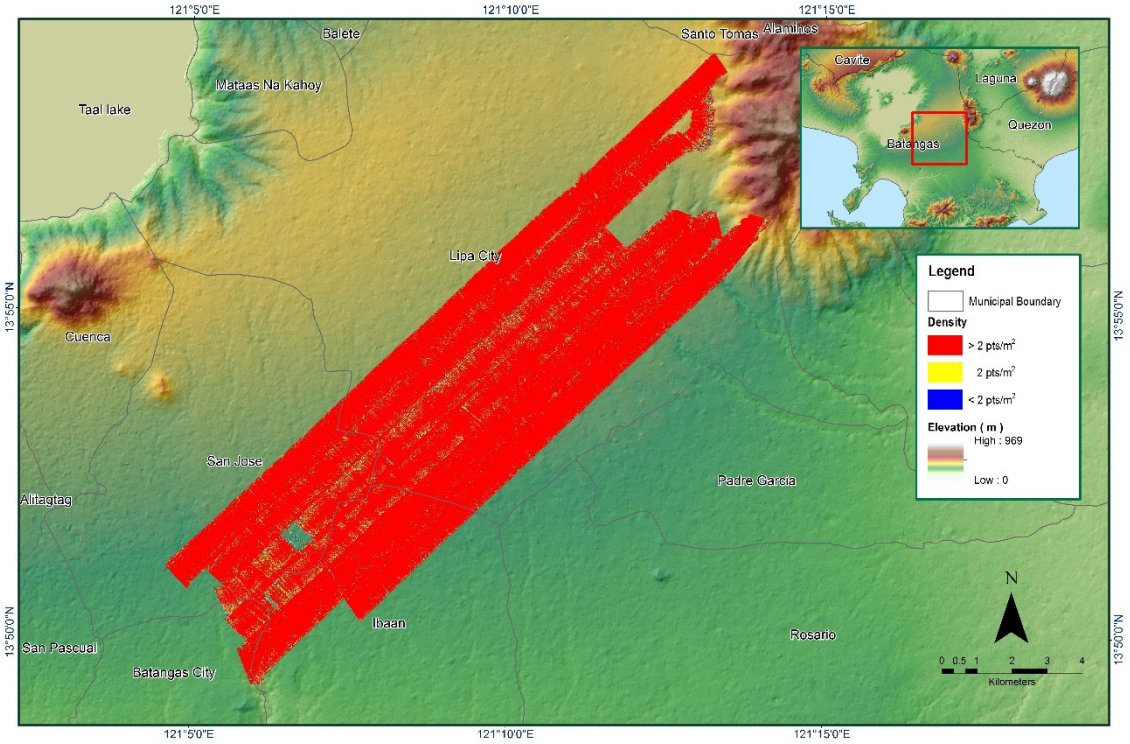


Figure 1.1.6. Density map of merged LiDAR data

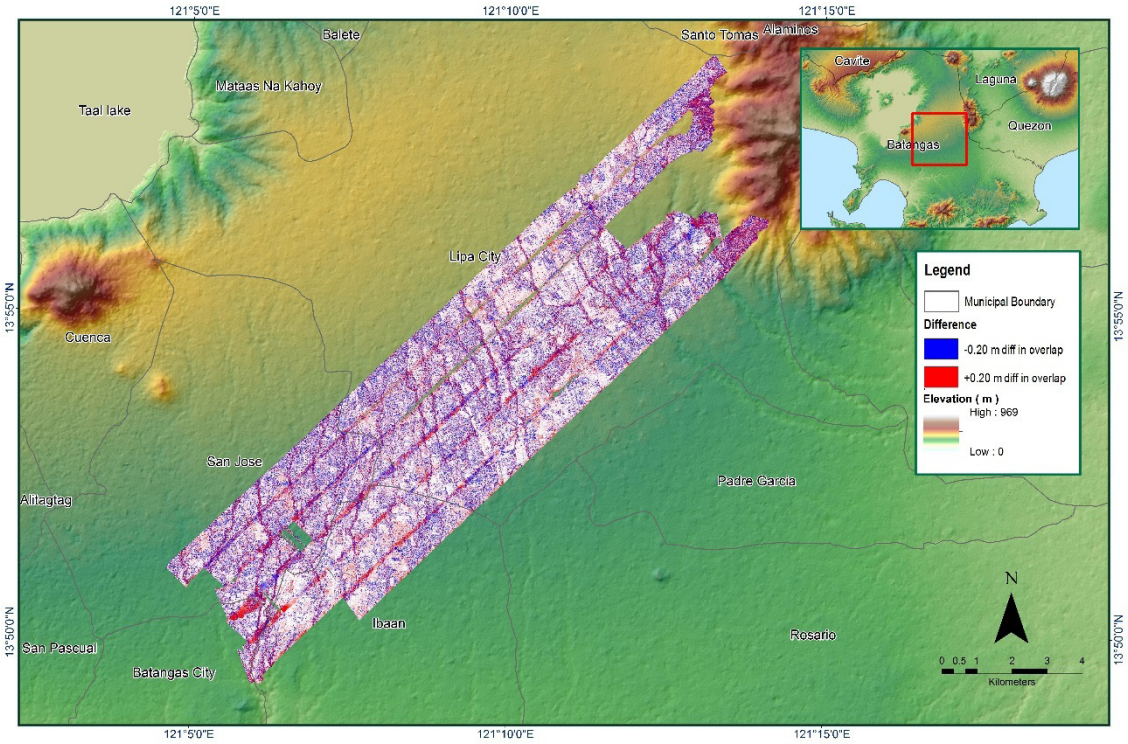


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	Blk18SA_additional
Inclusive Flights	3689G
Range data size	16.3 GB
POS data size	219 MB
Base data size	12.9 MB
Image	n/a
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.9595
RMSE for East Position (<4.0 cm)	1.1895
RMSE for Down Position (<8.0 cm)	3.2216
Boresight correction stdev (<0.001deg)	0.000865
IMU attitude correction stdev (<0.001deg)	0.001788
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	96.27
Ave point cloud density per sq.m. (>2.0)	5.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	17
Maximum Height	291.37 m
Minimum Height	171.27 m
Classification (# of points)	
Ground	2,017,754
Low vegetation	2,246,486
Medium vegetation	18,378,369
High vegetation	17,092,659
Building	144,595
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga Jr., Marie Denise Bueno

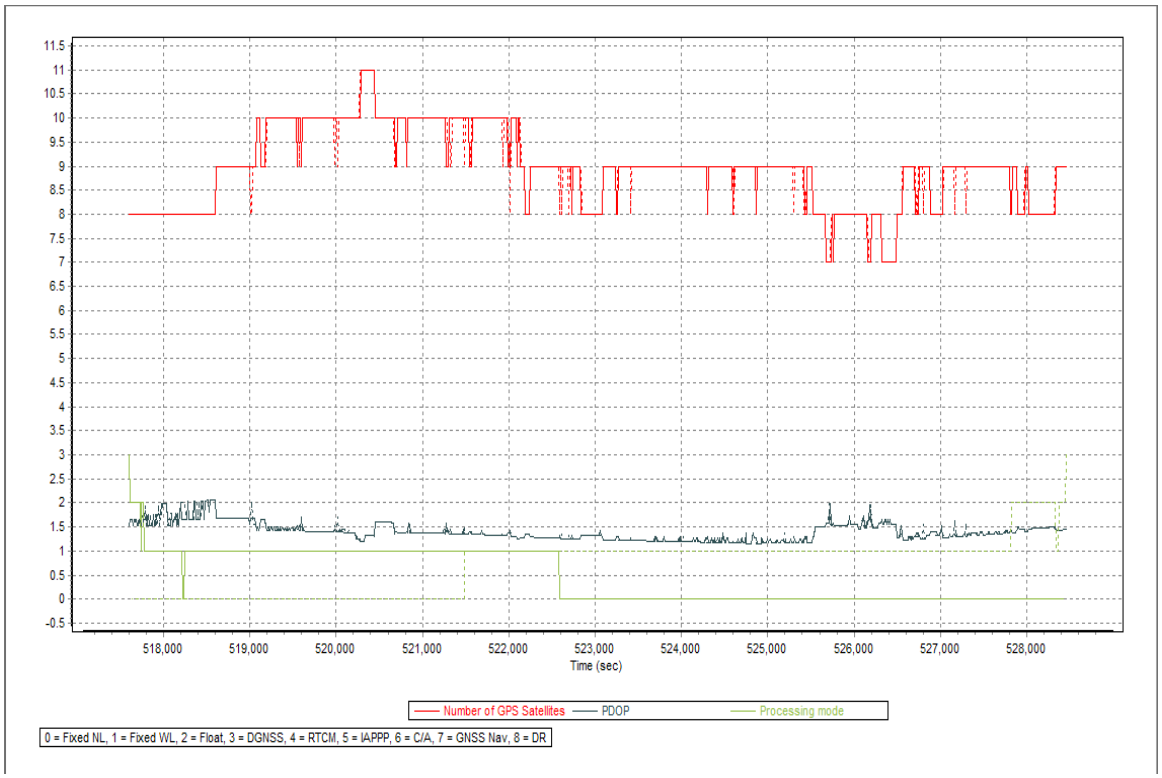


Figure 1.2.1. Solution Status

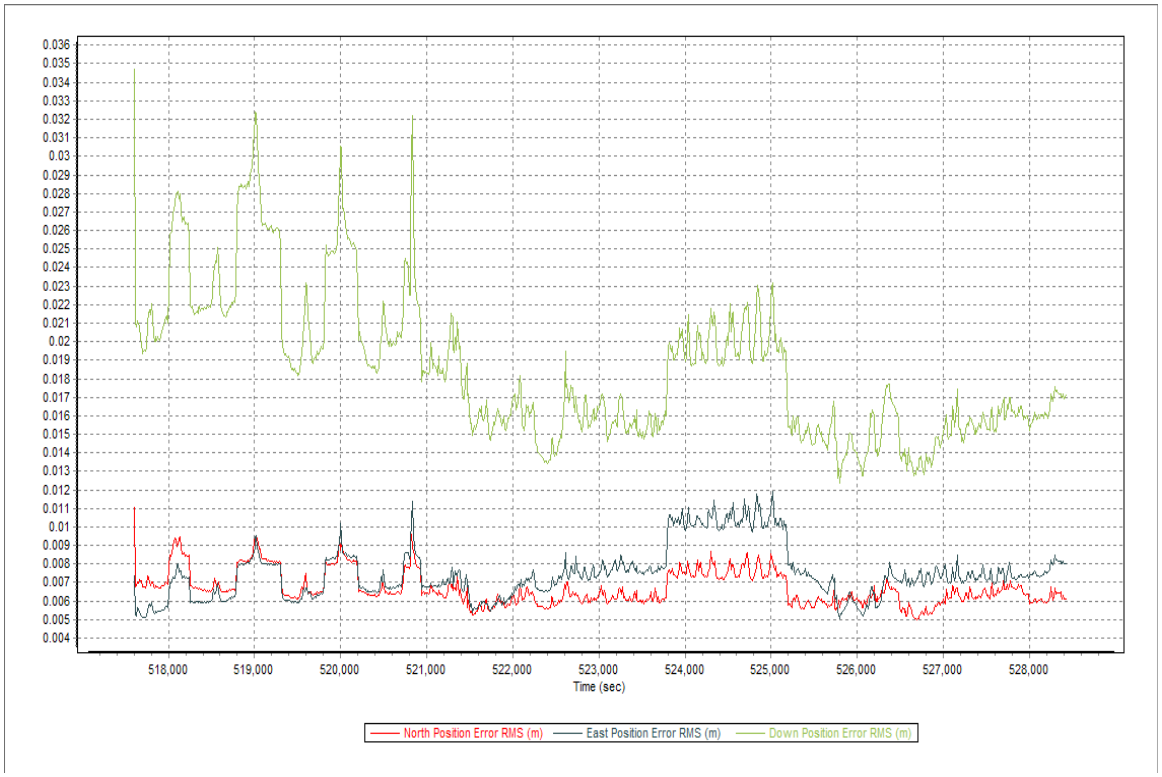


Figure 1.2.2. Smoothed Performance Metric Parameters

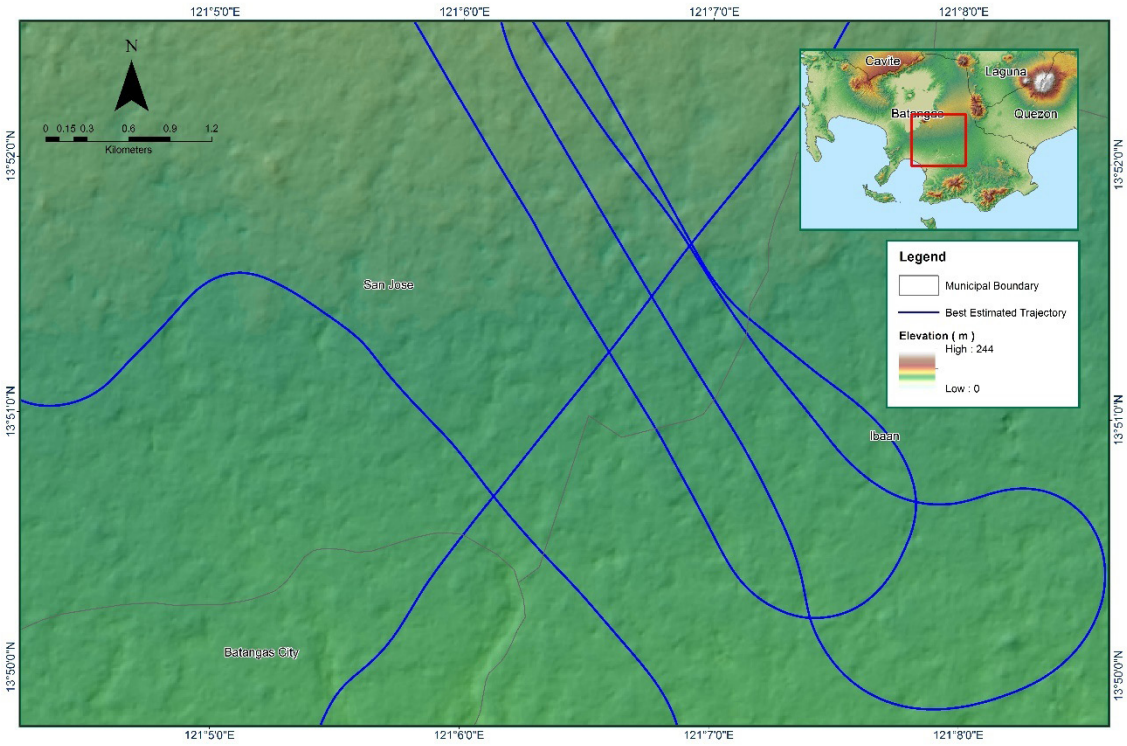


Figure 1.2.3. Best Estimated Trajectory

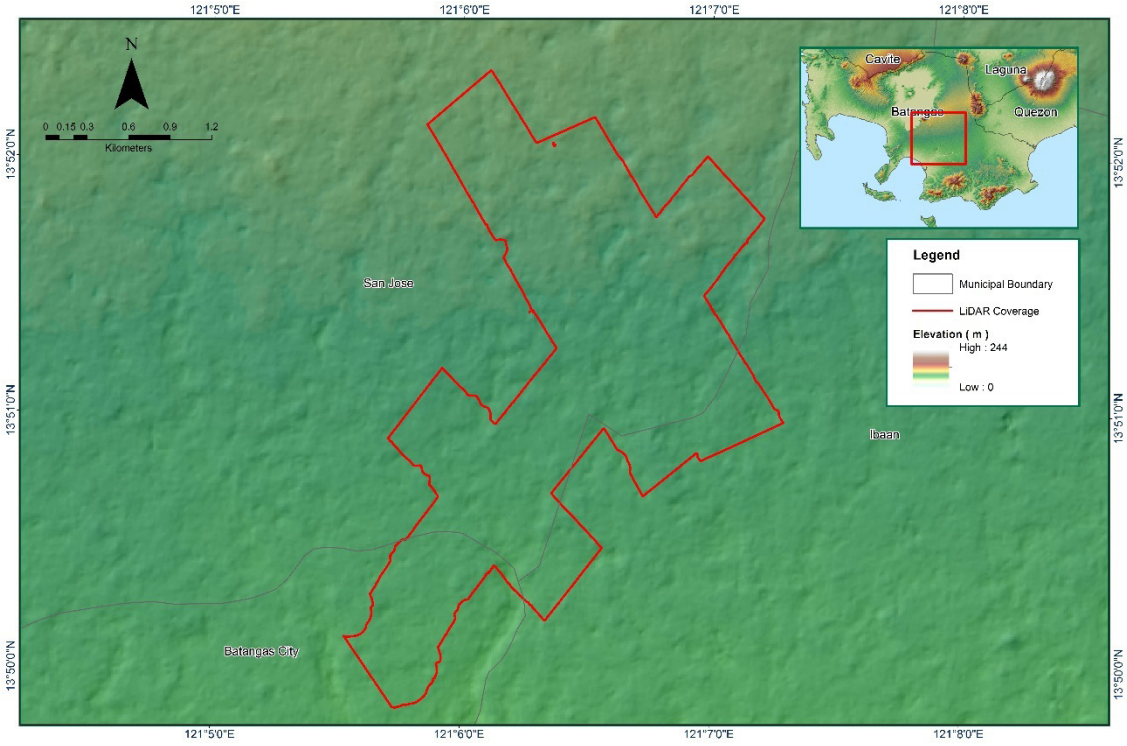


Figure 1.2.4. Coverage of LiDAR Data

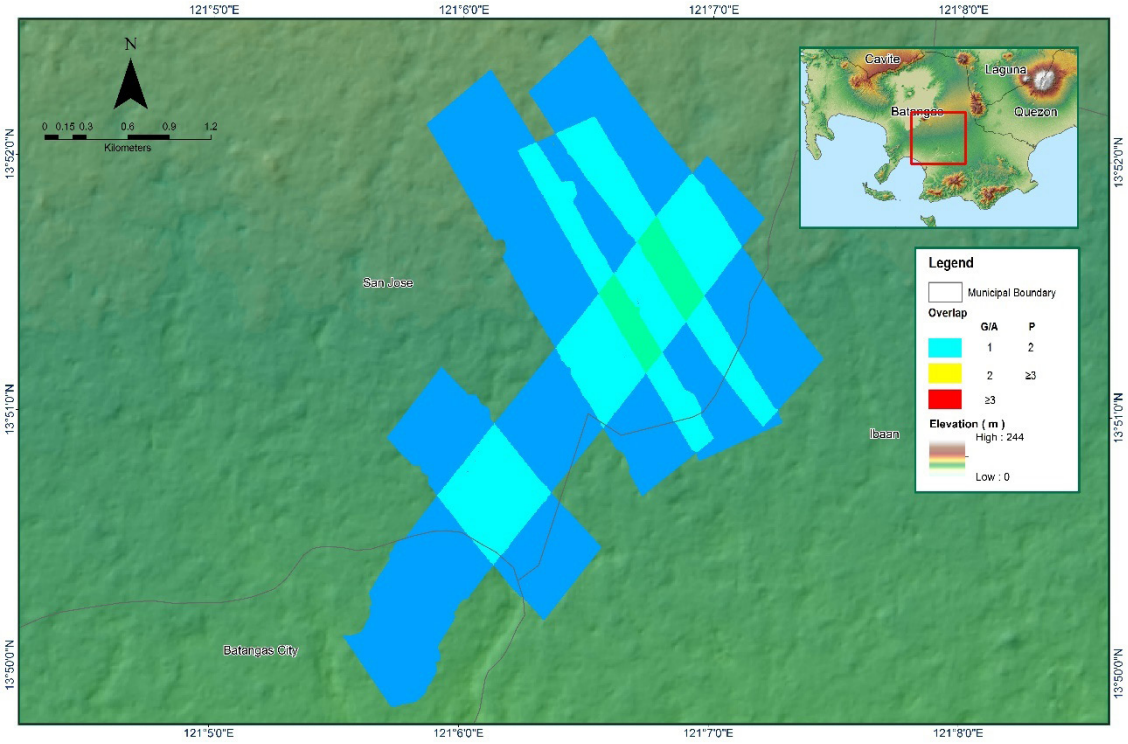


Figure 1.2.5. Image of data overlap

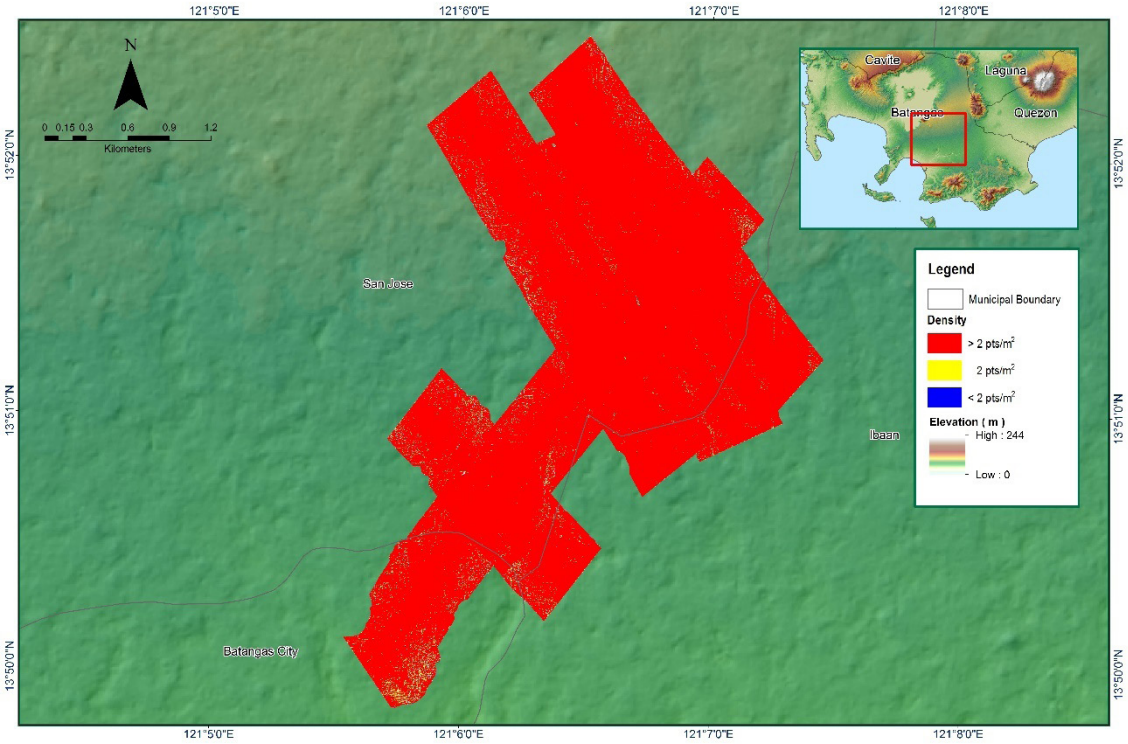


Figure 1.2.6. Density map of merged LiDAR data

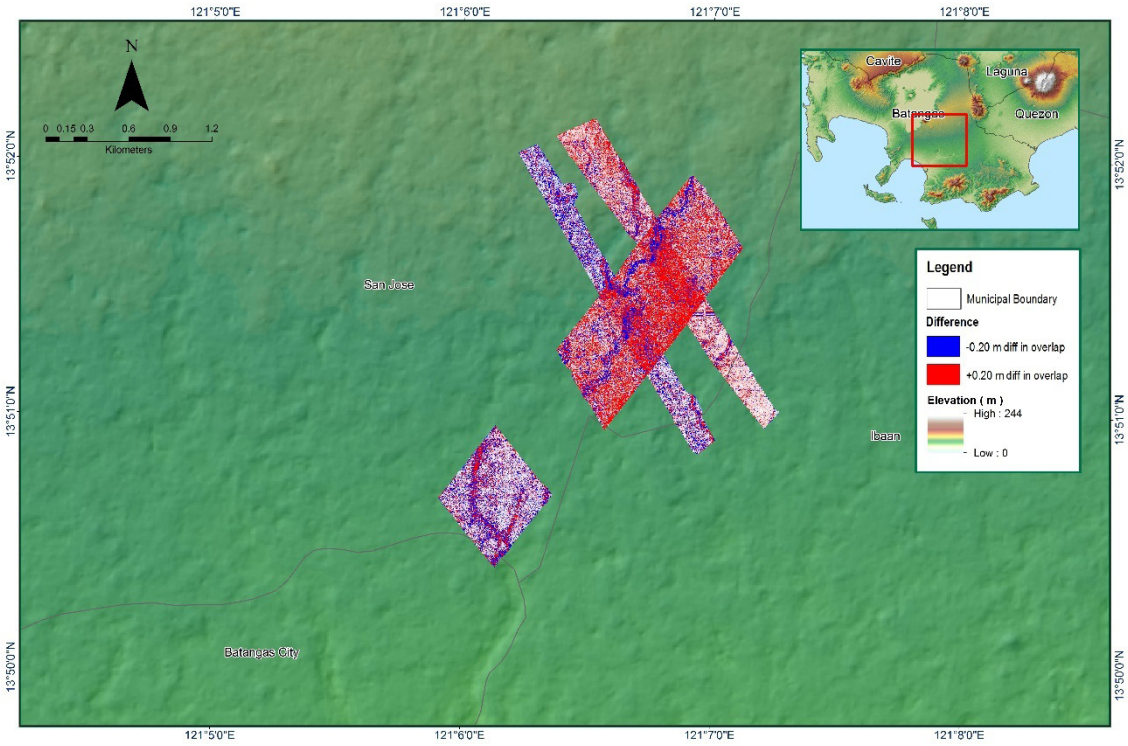


Figure 1.2.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	**Blk18SB**
Inclusive Flights	3002P, 3673G, 3689G
Range data size	58.2 GB
POS data size	599 MB
Base data size	51.8 MB
Image	41.7 GB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1457
RMSE for East Position (<4.0 cm)	1.0991
RMSE for Down Position (<8.0 cm)	3.2627
Boresight correction stdev (<0.001deg)	0.000395
IMU attitude correction stdev (<0.001deg)	0.003896
GPS position stdev (<0.01m)	0.002300
Minimum % overlap (>25)	30.66
Ave point cloud density per sq.m. (>2.0)	4.16
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	216
Maximum Height	766.11 m
Minimum Height	28.87 m
Classification (# of points)	
Ground	110,887,488
Low vegetation	116,871,073
Medium vegetation	284,484,416
High vegetation	427,490,155
Building	44,511,337
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Kenneth Solidum, Engr. JovelleAnjeannette Canlas, Marie Denise Bueno

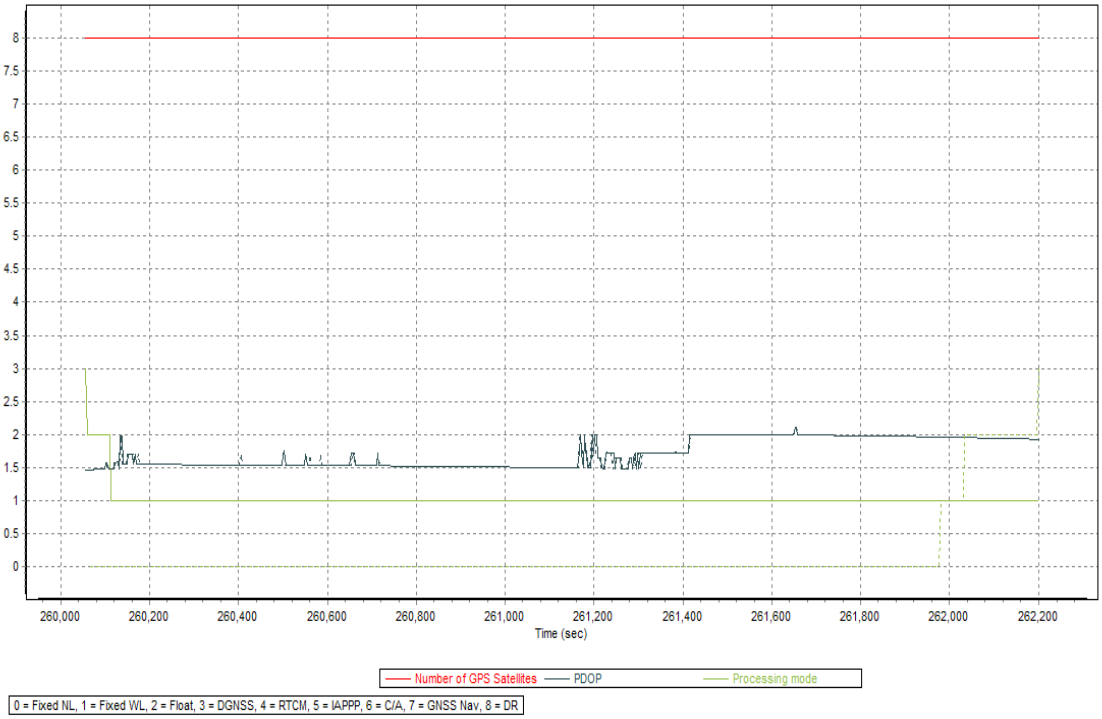


Figure 1.3.1. Solution Status

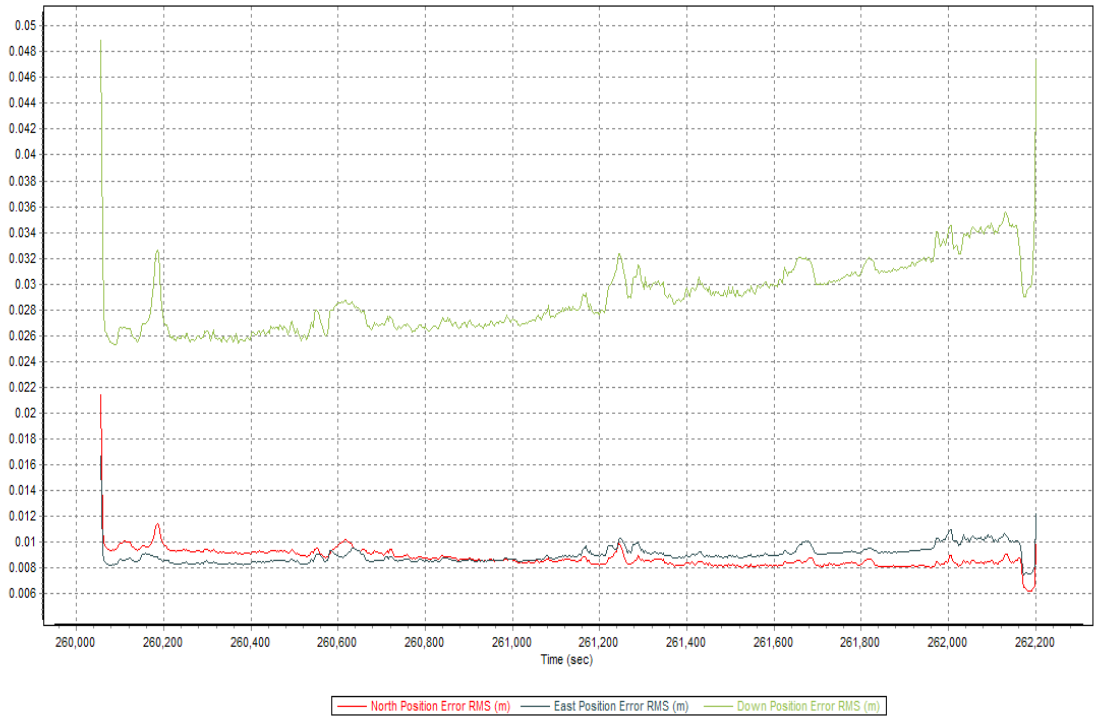


Figure 1.3.2. Smoothed Performance Metric Parameters

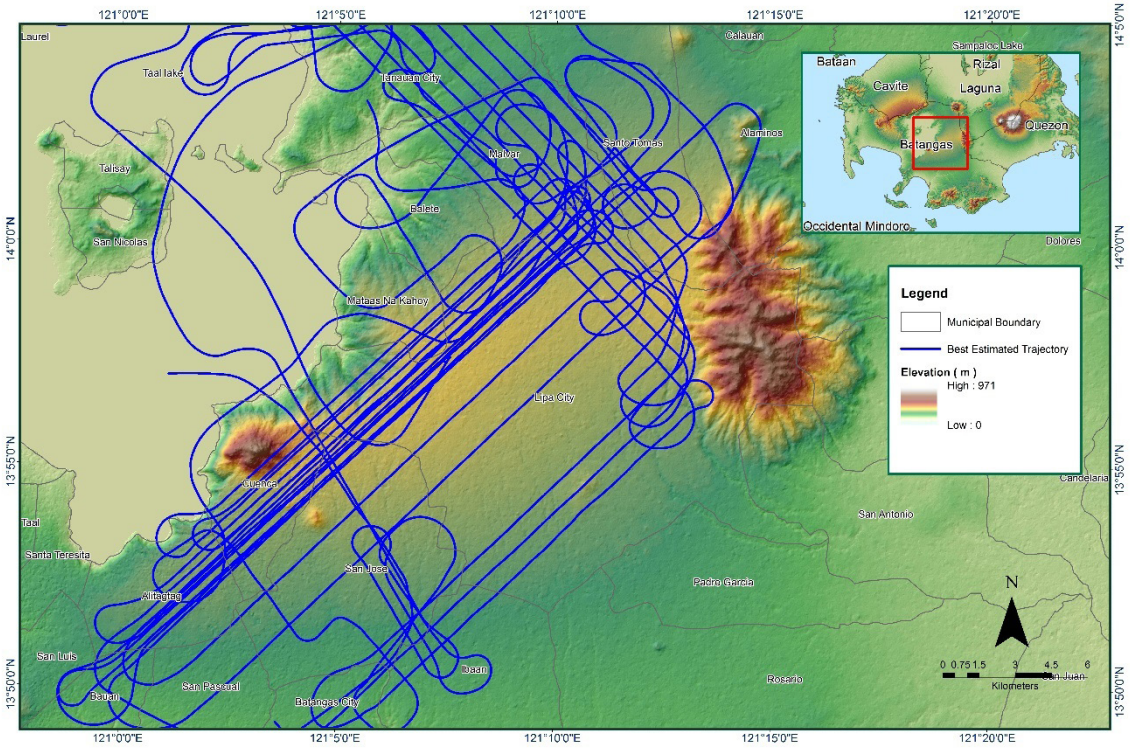


Figure 1.3.3. Best Estimated Trajectory

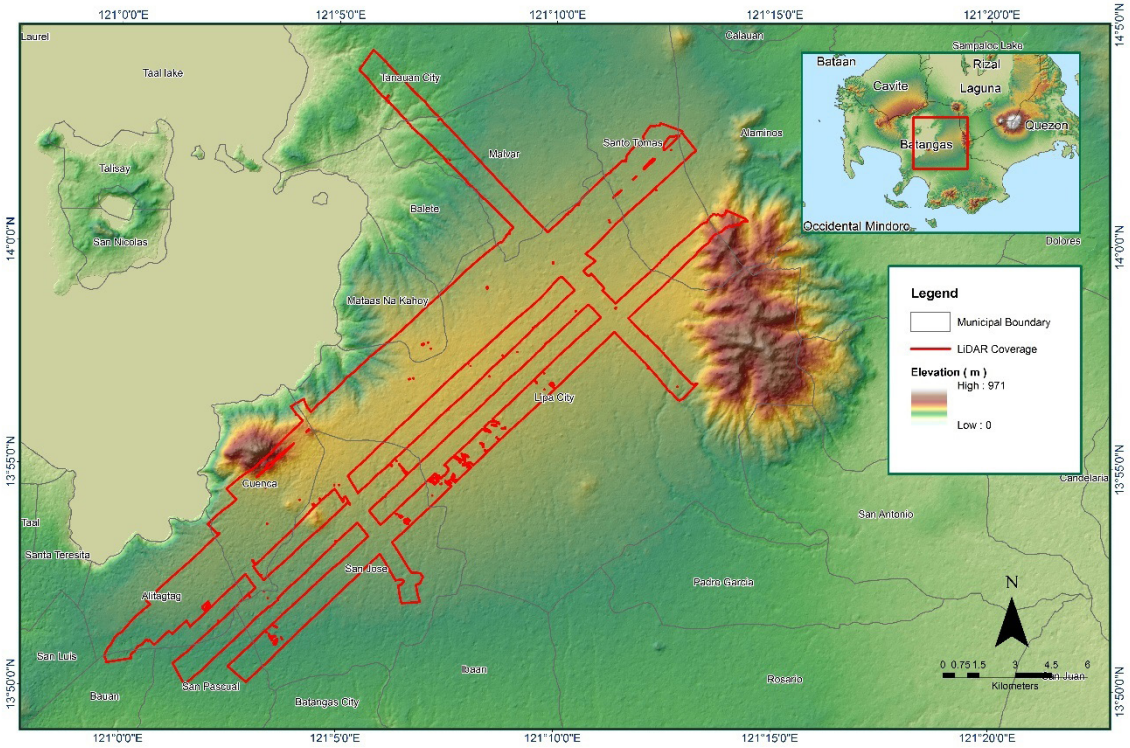


Figure 1.3.4. Coverage of LiDAR Data

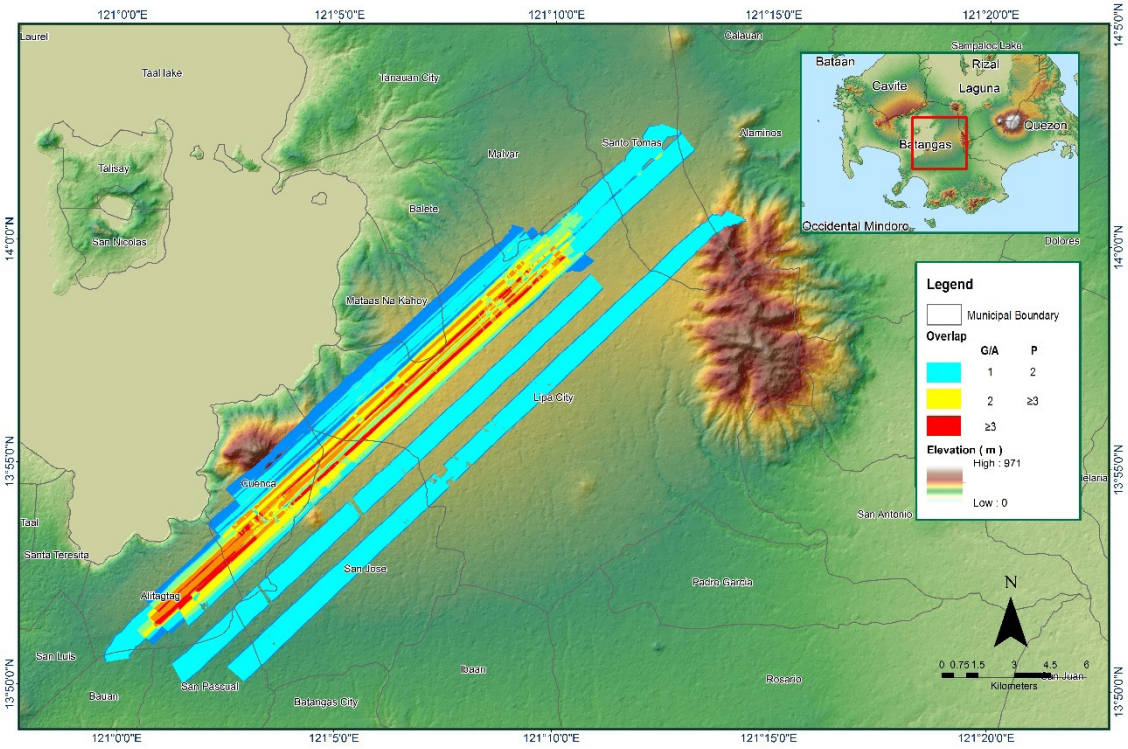


Figure 1.3.5. Image of data overlap

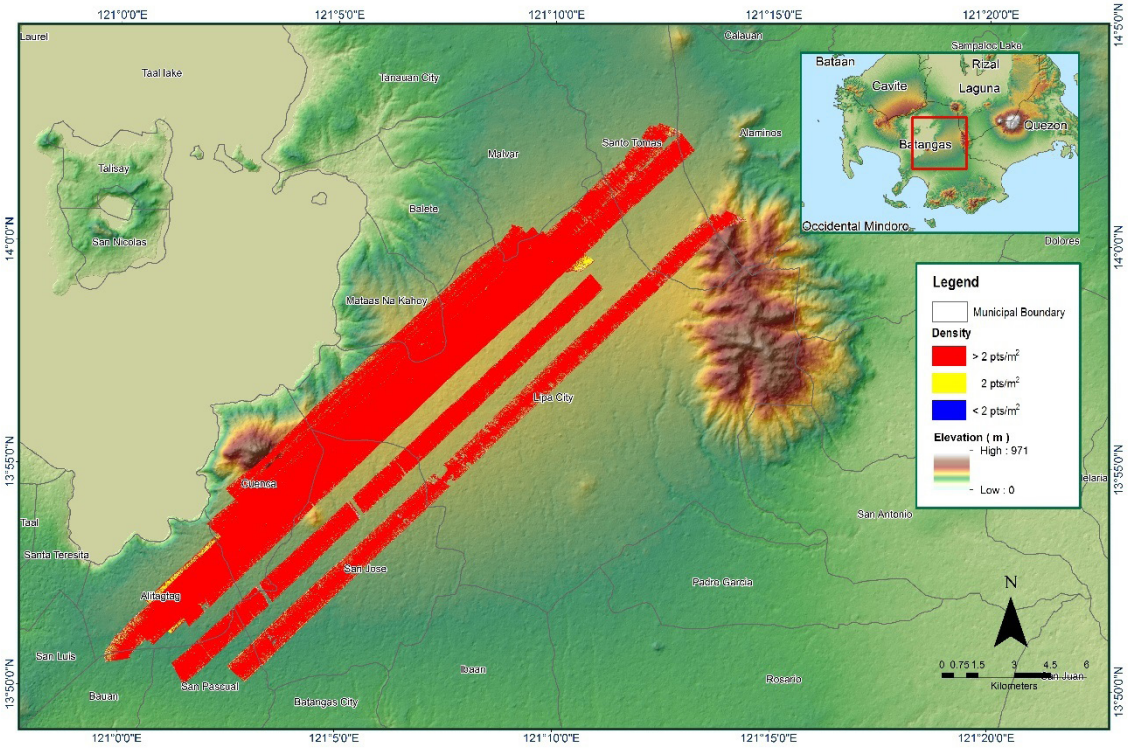


Figure 1.3.6. Density map of merged LiDAR data

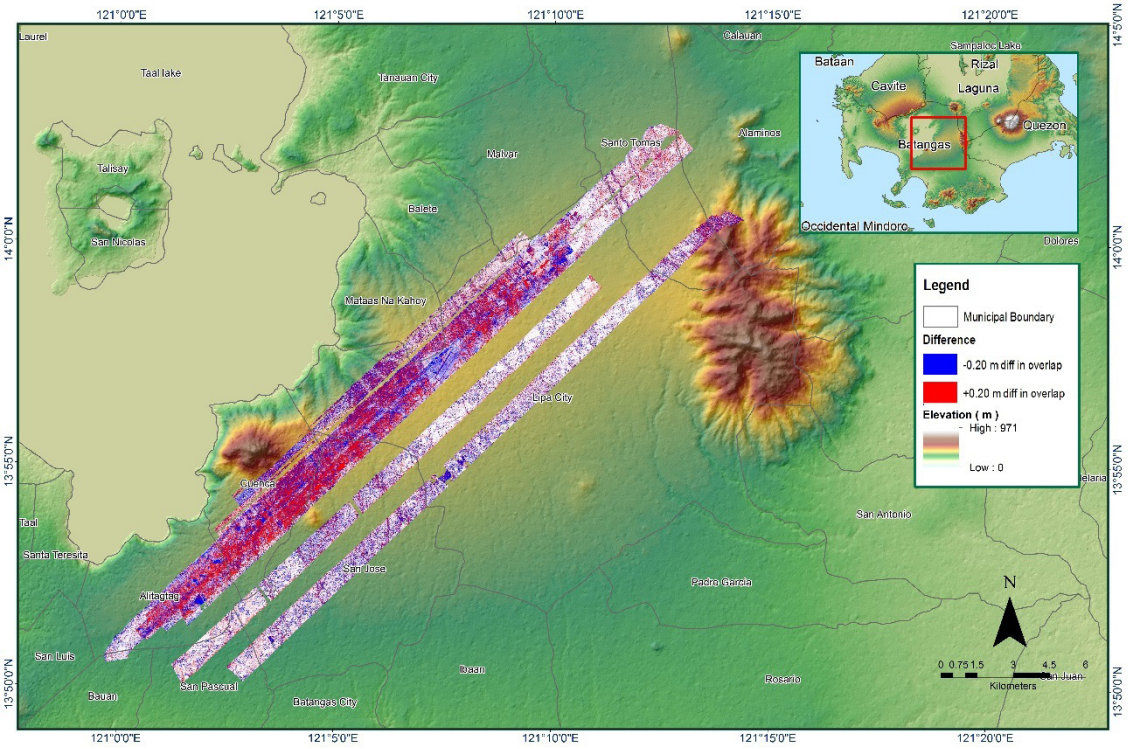


Figure 1.3.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	**Blk18SB_additional**
Inclusive Flights	3691G
Range data size	6.93 GB
POS data size	124 MB
Base data size	12.9 MB
Image	n/a
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1374
RMSE for East Position (<4.0 cm)	1.3443
RMSE for Down Position (<8.0 cm)	2.1918
Boresight correction stdev (<0.001deg)	0.002622
IMU attitude correction stdev (<0.001deg)	0.001037
GPS position stdev (<0.01m)	0.001500
Minimum % overlap (>25)	56.86
Ave point cloud density per sq.m. (>2.0)	6.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	18
Maximum Height	443.07 m
Minimum Height	290.06 m
Classification (# of points)	
Ground	3,697,480
Low vegetation	2,978,689
Medium vegetation	7,394,117
High vegetation	15,180,500
Building	516,231
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga Jr., Marie Denise Bueno

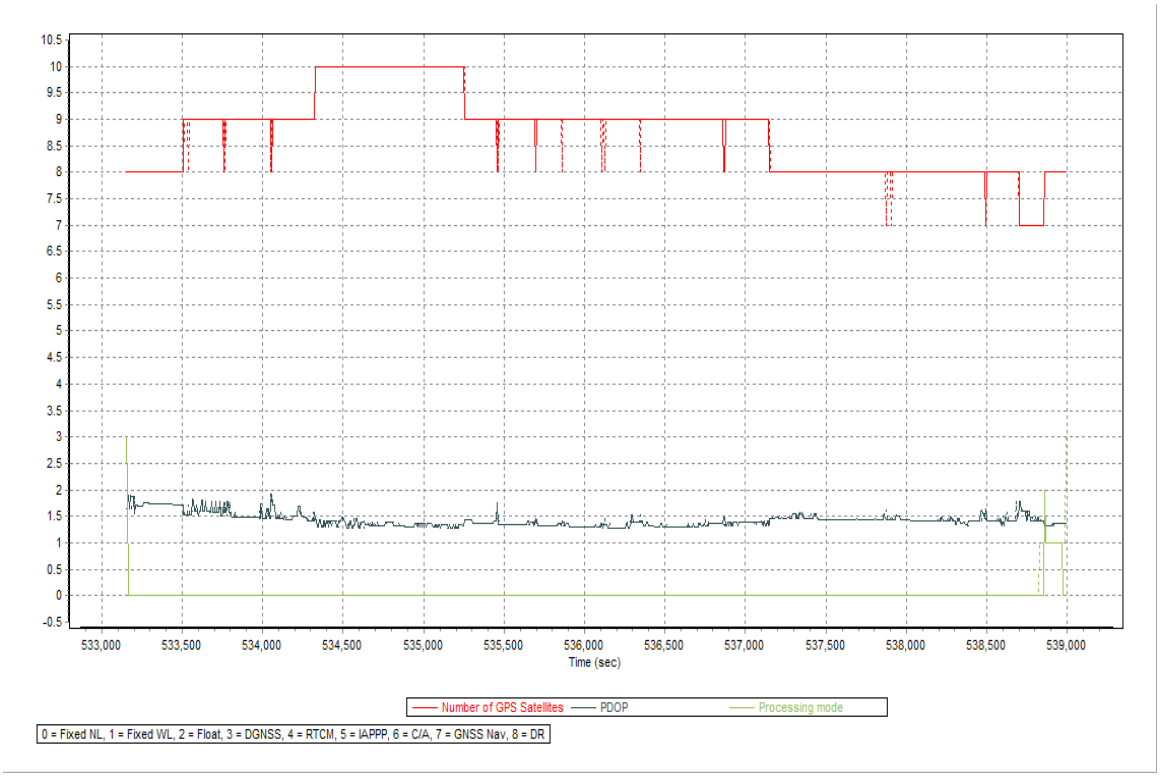


Figure 1.4.1. Solution Status

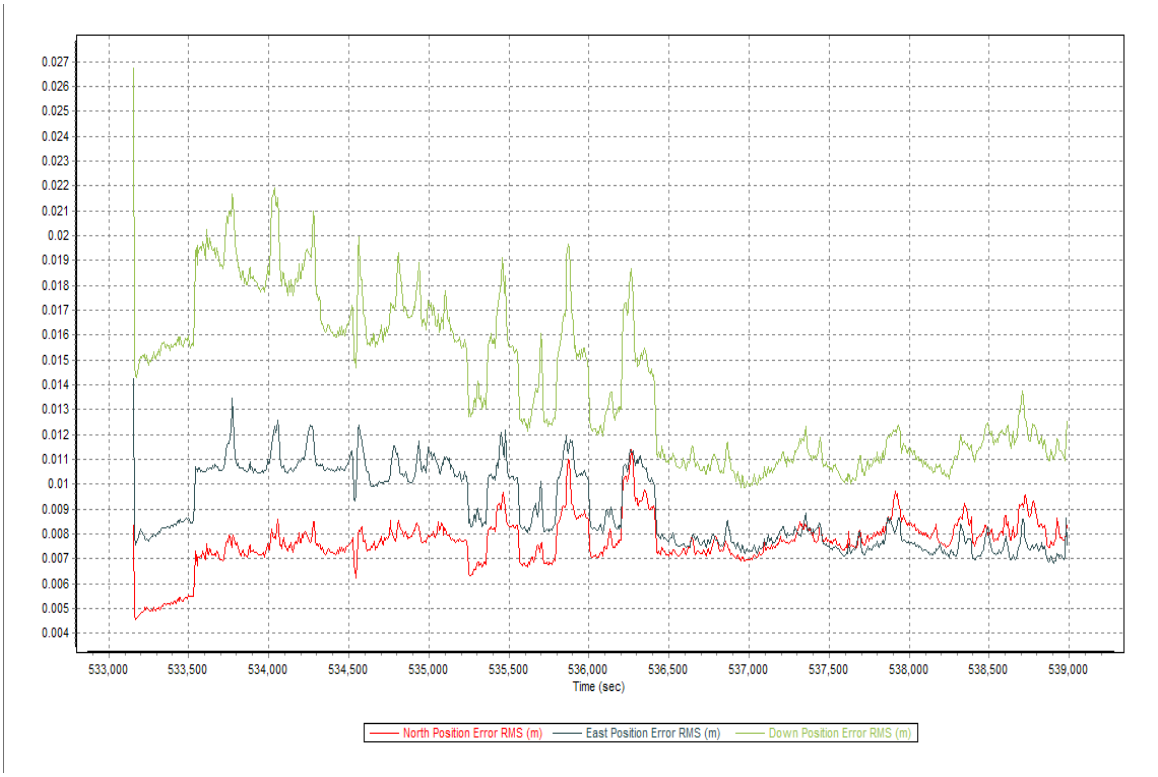


Figure 1.4.2. Smoothed Performance Metric Parameters

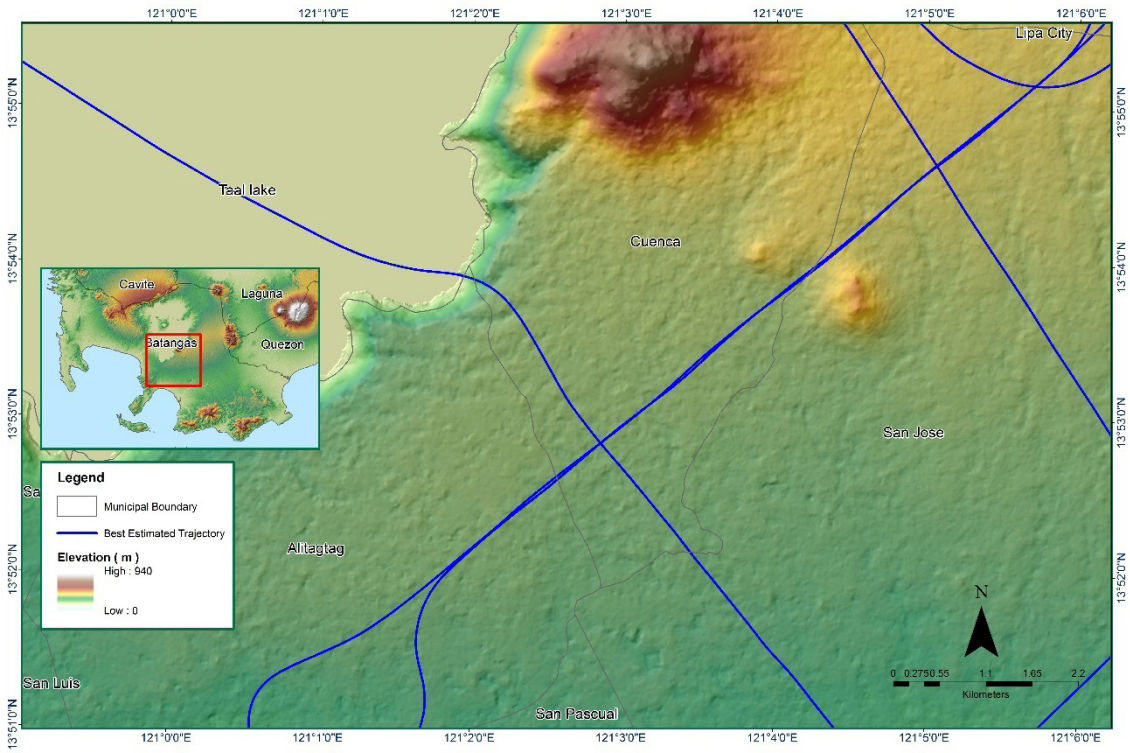


Figure 1.4.3. Best Estimated Trajectory

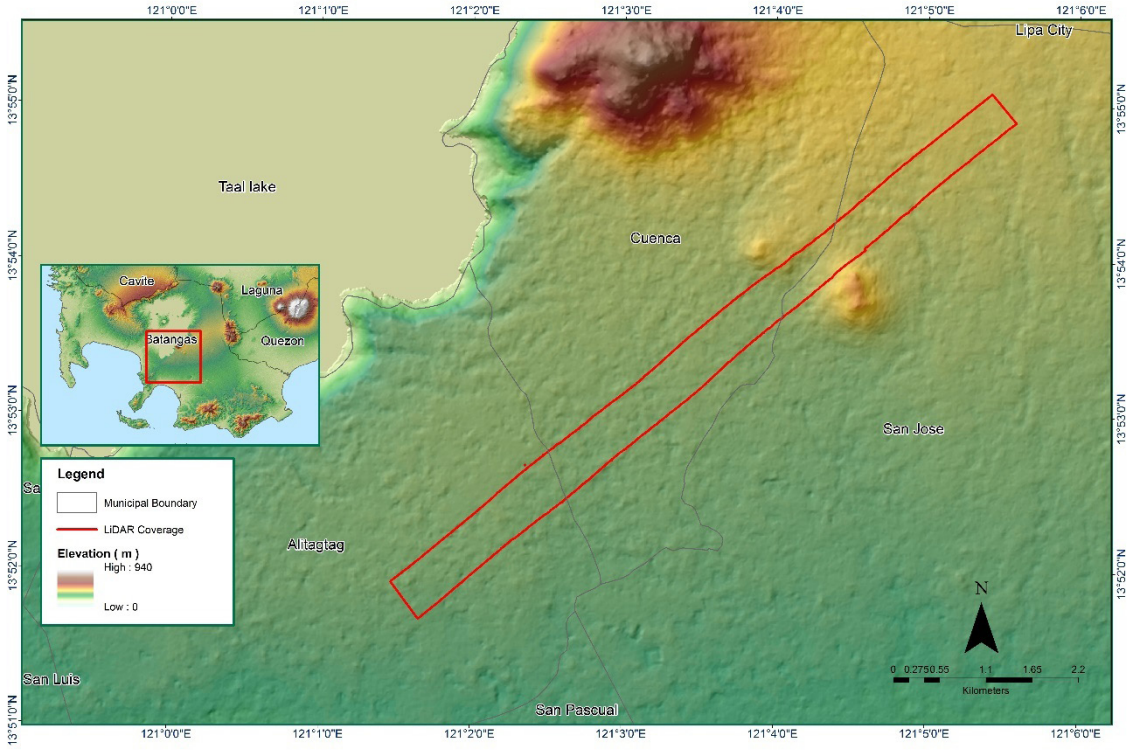


Figure 1.4.4. Coverage of LiDAR Data

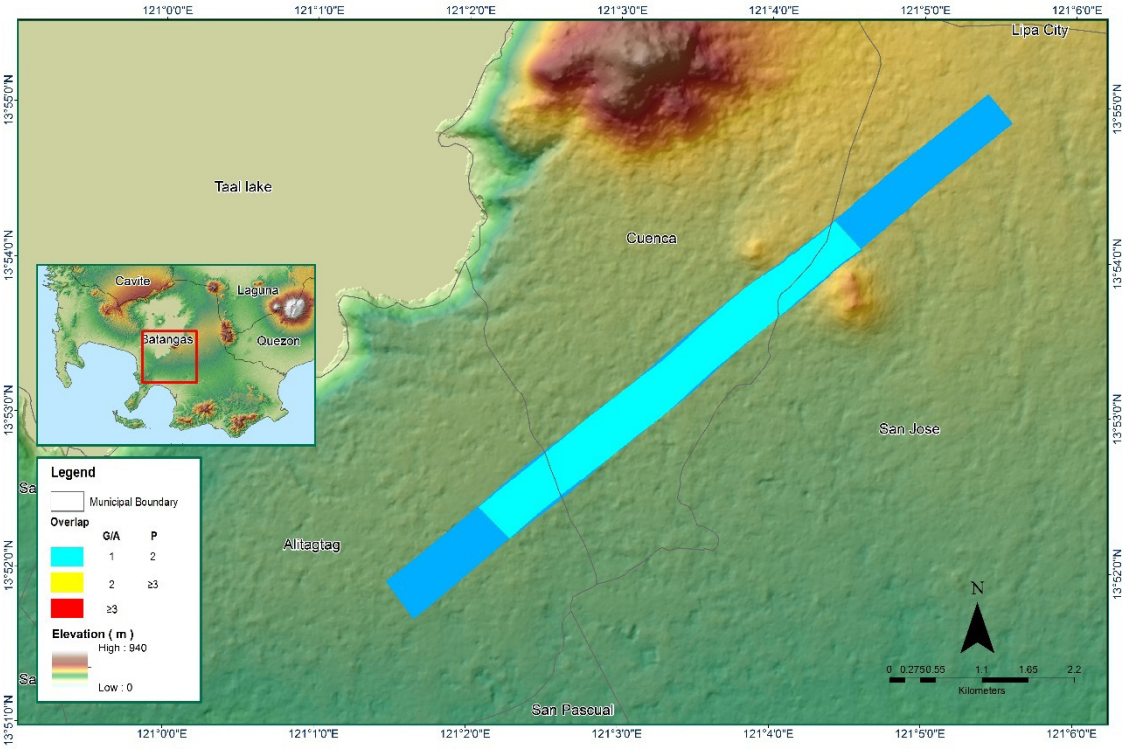


Figure 1.4.5. Image of data overlap

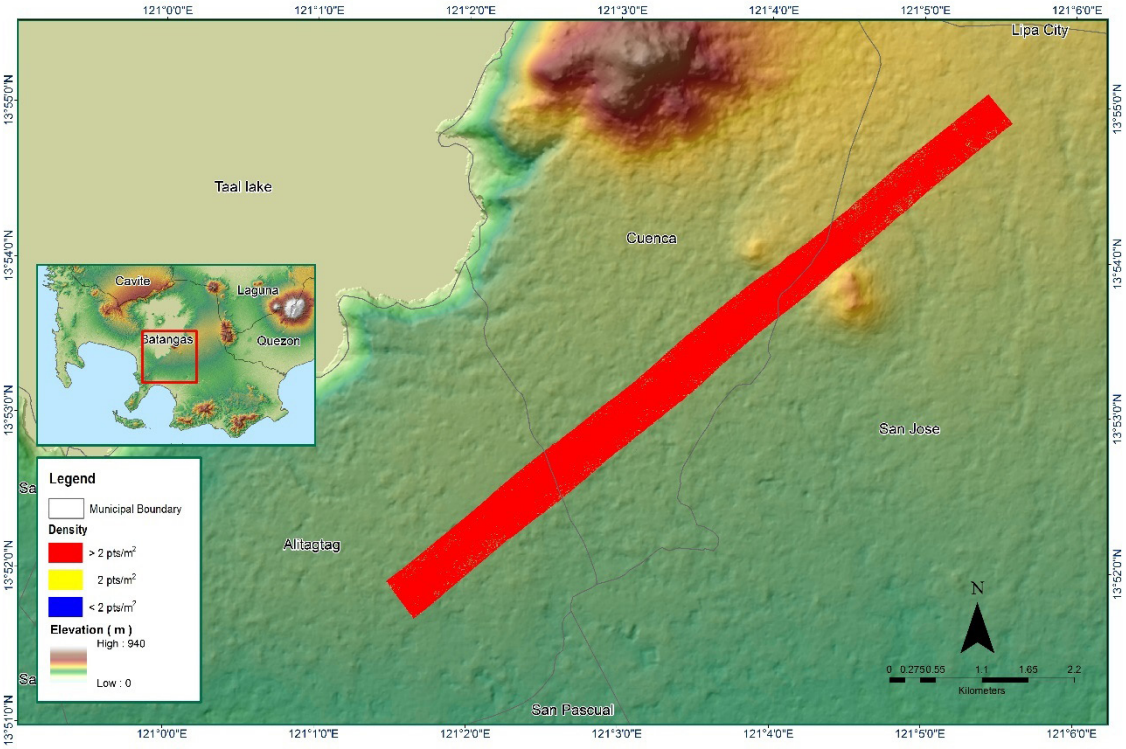


Figure 1.4.6. Density map of merged LiDAR data

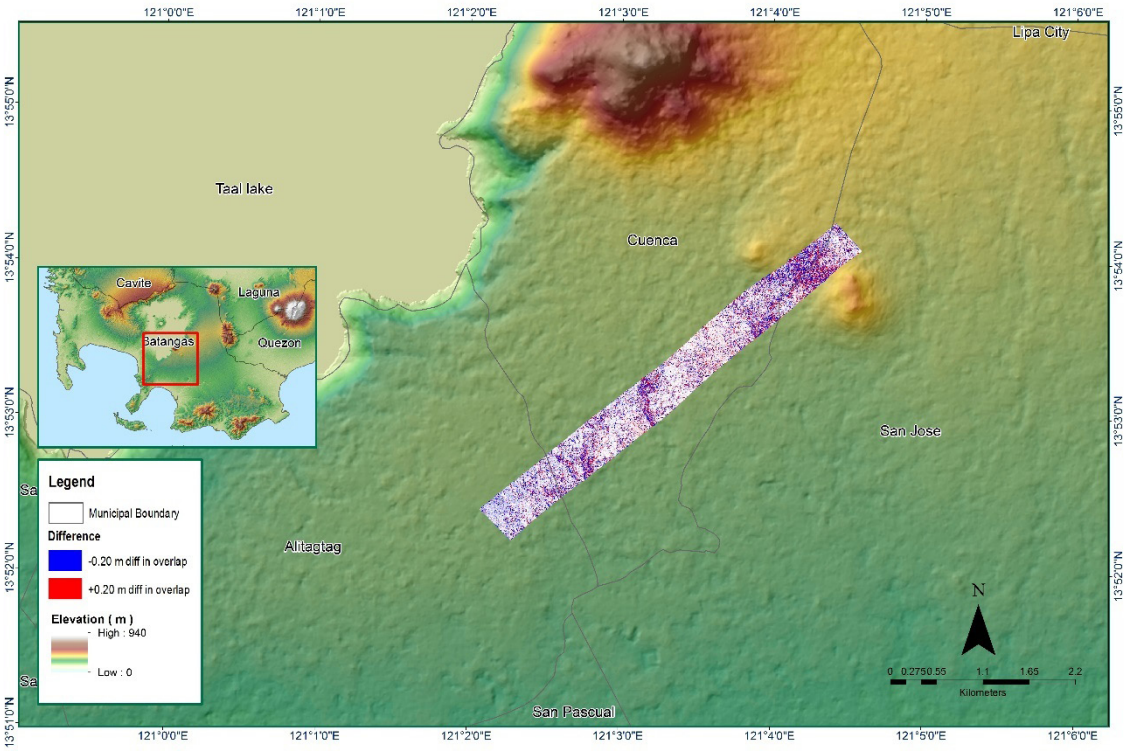


Figure 1.4.7. Elevation difference between flight lines

Flight Area	**Batangas**
Mission Name	**Blk18SB_supplement**
Inclusive Flights	3669G
Range data size	14.9 GB
POS data size	151 MB
Base data size	7.42 MB
Image	N/A
Transfer date	January 06, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.19
RMSE for East Position (<4.0 cm)	1.54
RMSE for Down Position (<8.0 cm)	4.31
Boresight correction stdev (<0.001deg)	0.000524
IMU attitude correction stdev (<0.001deg)	0.004882
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	24.09 %
Ave point cloud density per sq.m. (>2.0)	3.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	196
Maximum Height	601.68 m
Minimum Height	175.82 m
Classification (# of points)	
Ground	54,649,078
Low vegetation	61,016,989
Medium vegetation	136,361,089
High vegetation	165,308,687
Building	19,226,341
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Ma. Joanne Balaga, Engr. Elainne Lopez

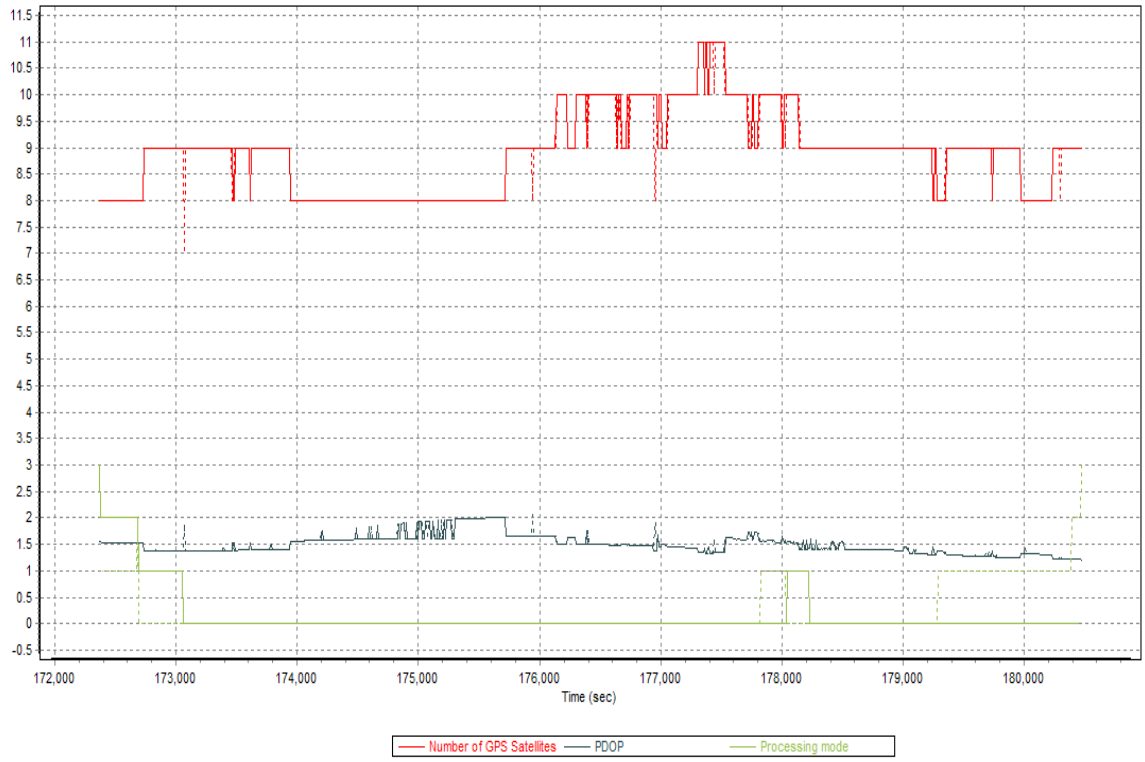


Figure 1.5.1. Solution Status

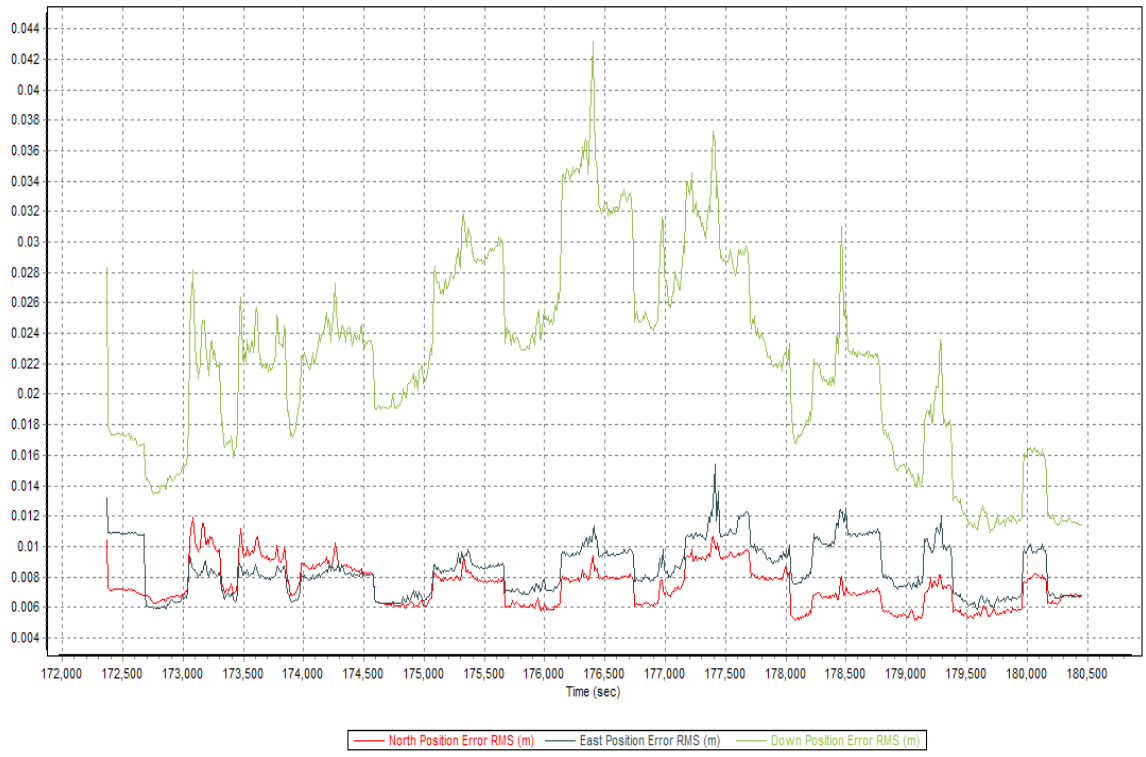


Figure 1.5.2. Smoothed Performance Metric Parameters

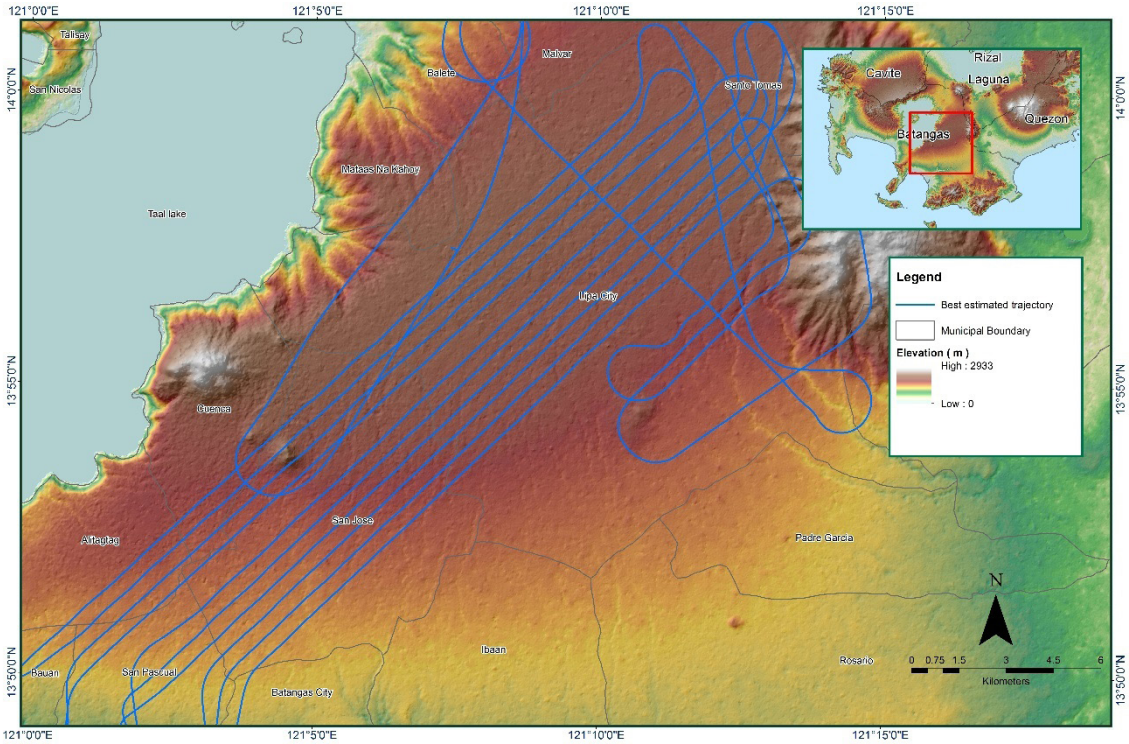


Figure 1.5.3. Best Estimated Trajectory

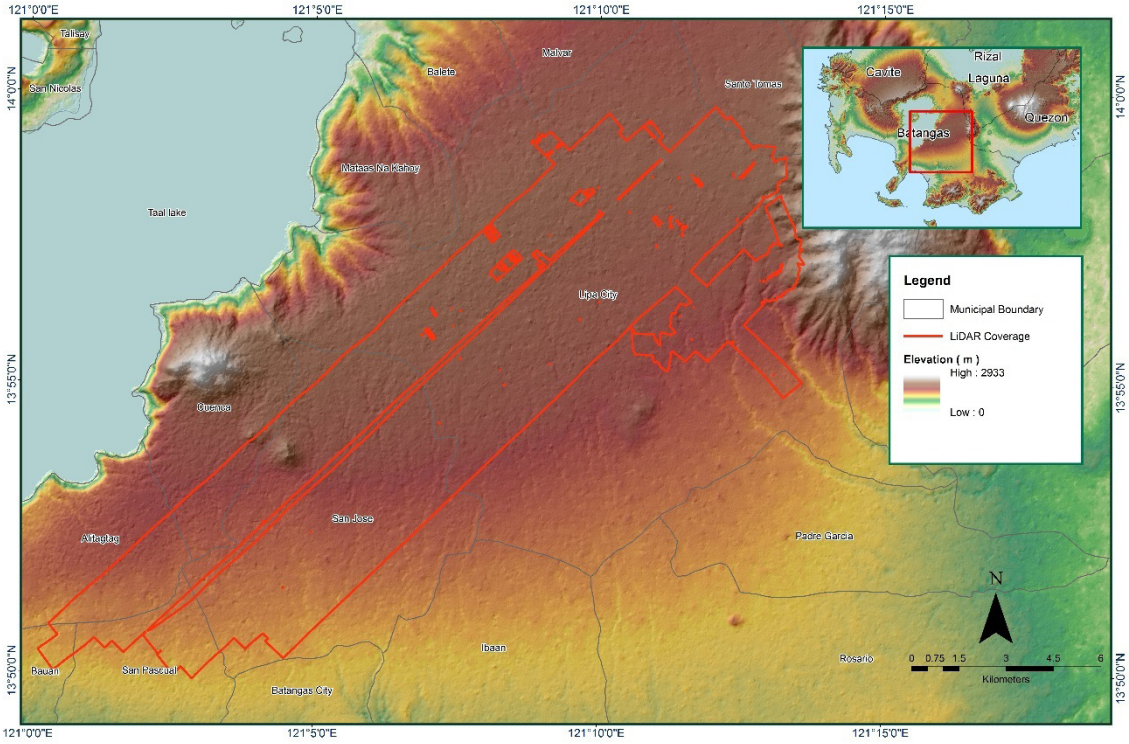


Figure 1.5.4. Coverage of LiDAR Data

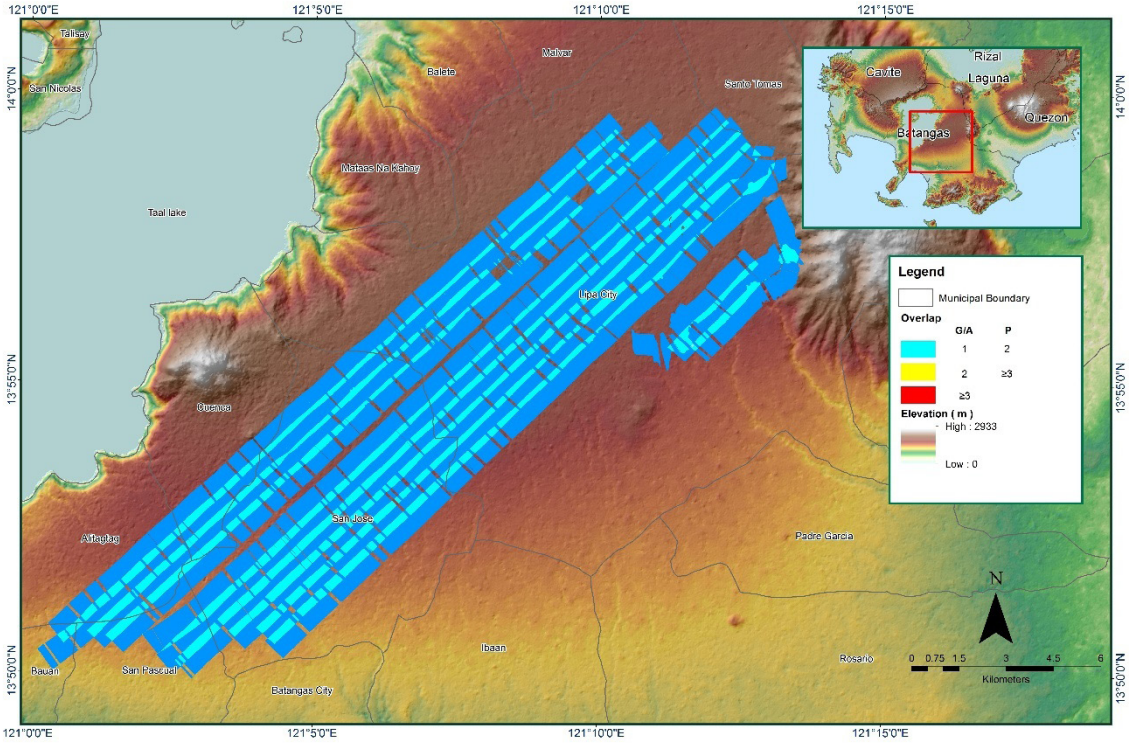


Figure 1.5.5. Image of data overlap

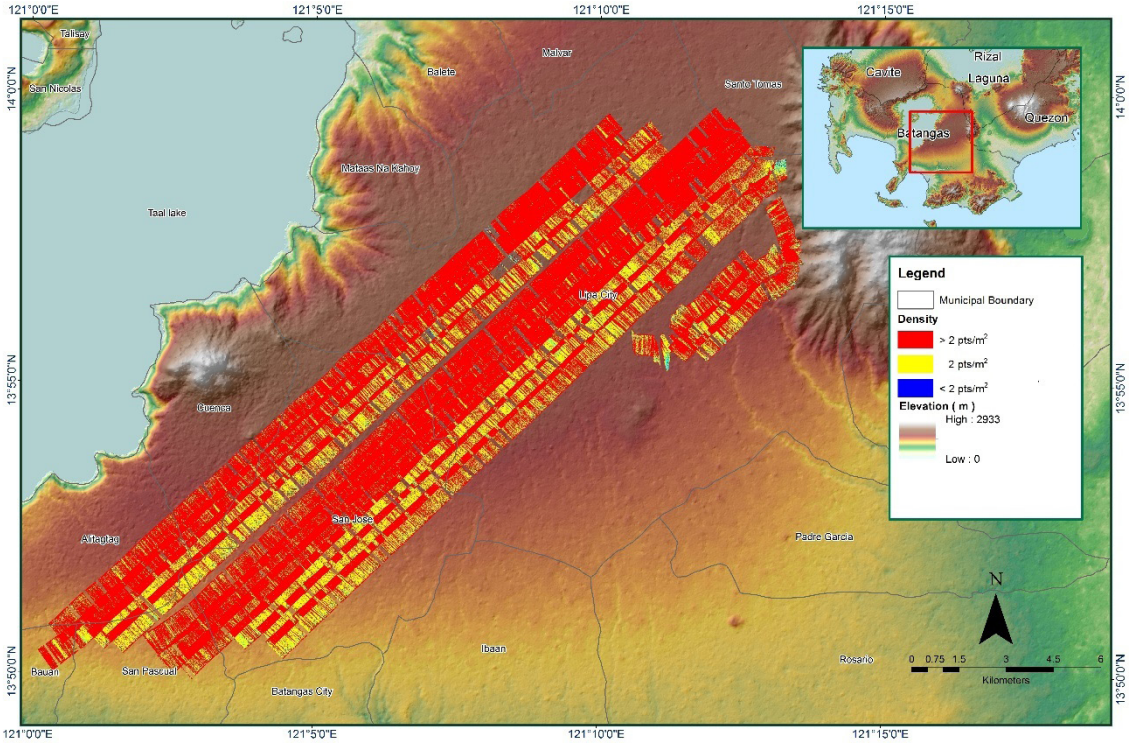


Figure 1.5.6. Density map of merged LiDAR data

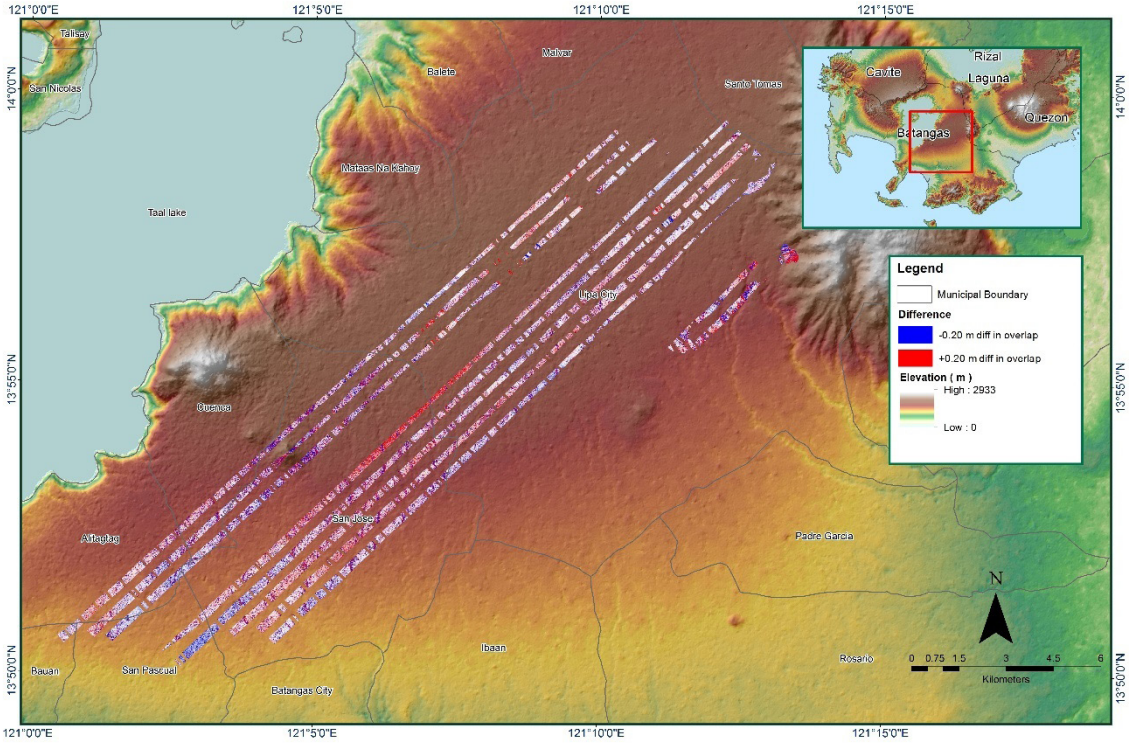


Figure 1.5.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	**Blk18SC**
Inclusive Flights	3671G
Range data size	7.41 GB
POS data size	85 MB
Base data size	7.42 MB
Image	N/A
Transfer date	January 06, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	.80
RMSE for East Position (<4.0 cm)	.88
RMSE for Down Position (<8.0 cm)	1.24
Boresight correction stdev (<0.001deg)	0.001711
IMU attitude correction stdev (<0.001deg)	0.002627
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	1.04 %
Ave point cloud density per sq.m. (>2.0)	3.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	113
Maximum Height	779.19 m
Minimum Height	49.56 m
Classification (# of points)	
Ground	36,956,676
Low vegetation	15,958,180
Medium vegetation	46,648,268
High vegetation	133,227,835
Building	5,156,617
Orthophoto	No
Processed by	Engr. Don Matthew Banatiin, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

Figure 1.6.1. Solution Status

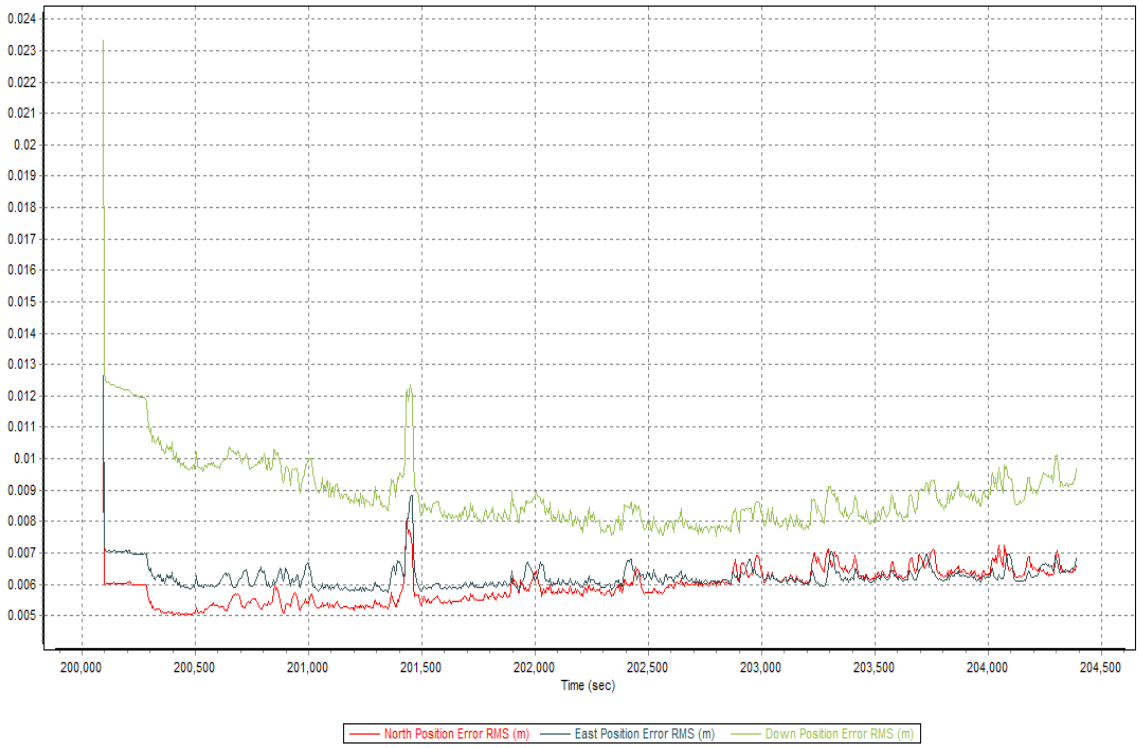


Figure 1.6.2. Smoothed Performance Metric Parameters

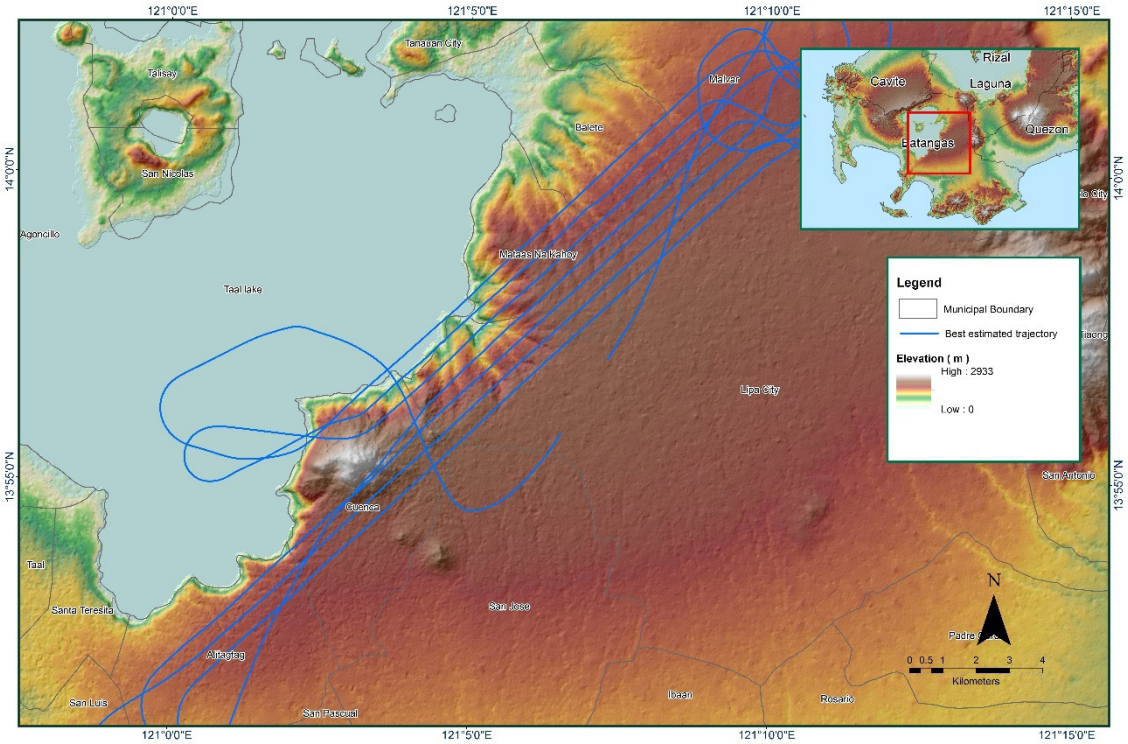


Figure 1.6.3. Best Estimated Trajectory

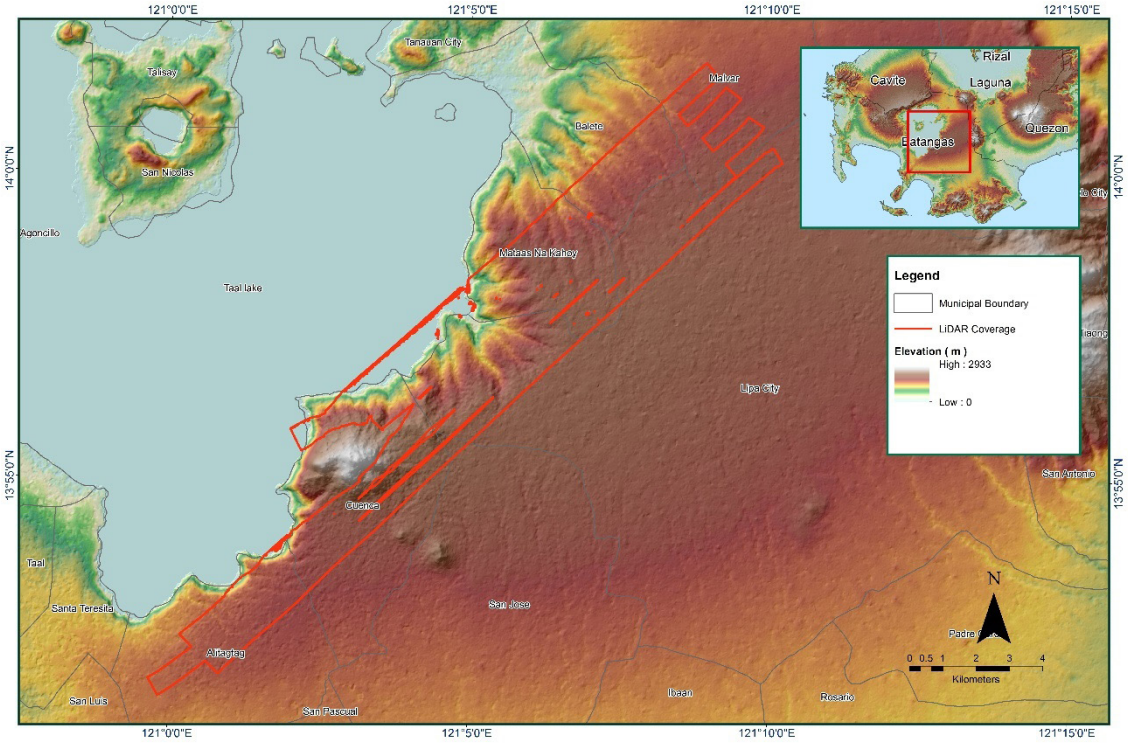


Figure 1.6.4. Coverage of LiDAR Data

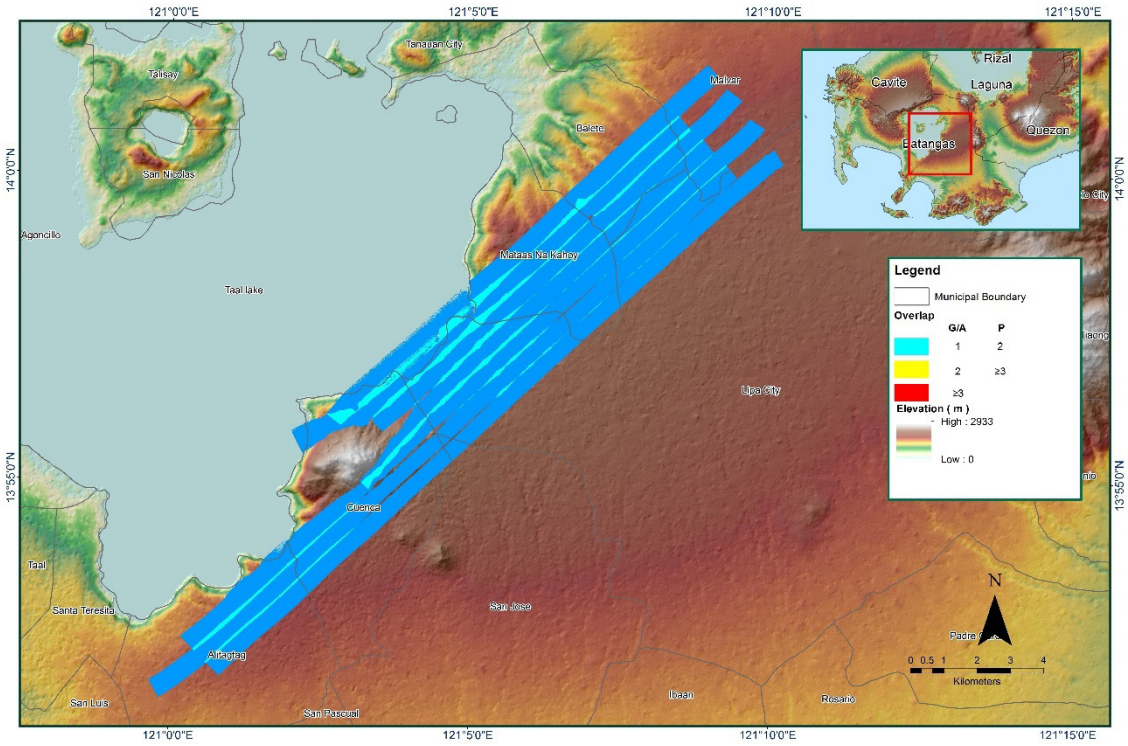


Figure 1.6.5. Image of data overlap

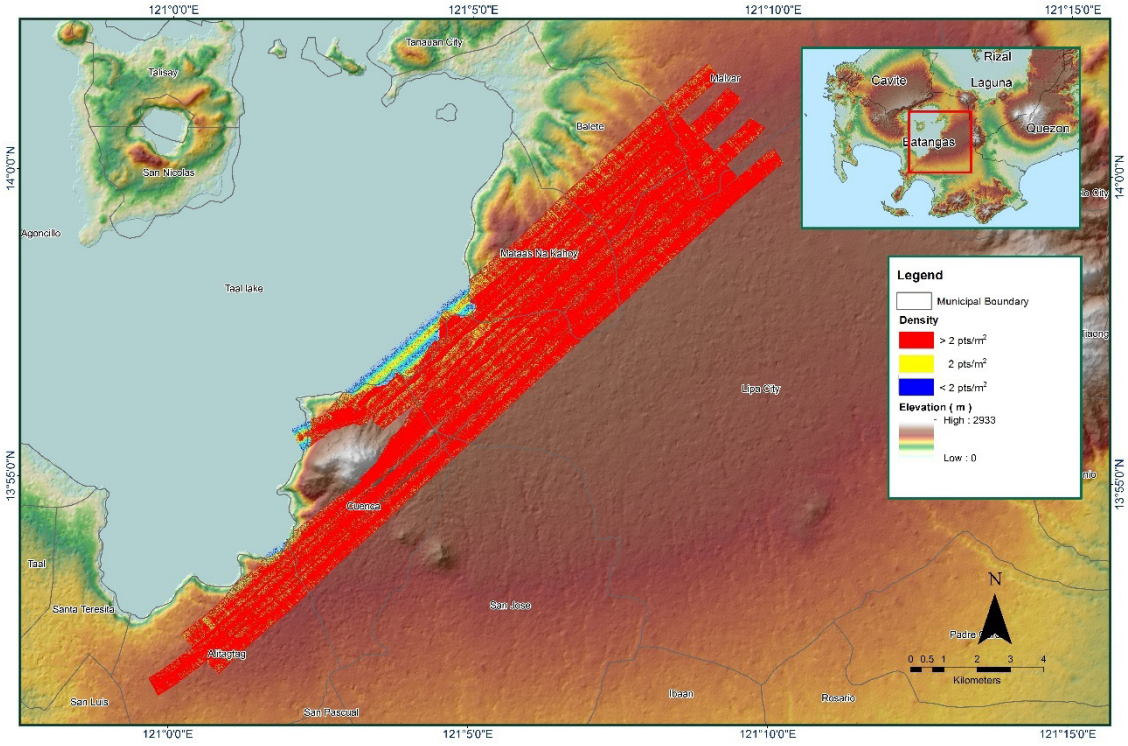


Figure 1.6.6. Density map of merged LiDAR data

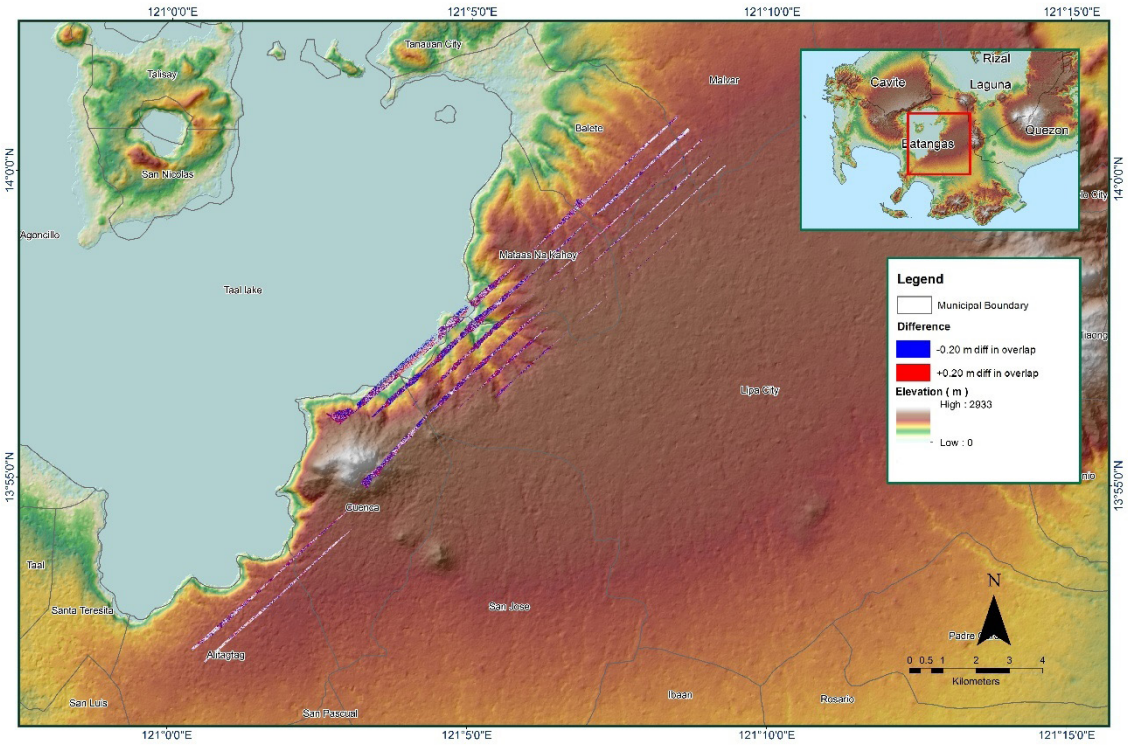


Figure 1.6.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	**Blk18SC_supplement**
Inclusive Flights	3693G
Range data size	7.98 GB
POS data size	82.9 MB
Base data size	8.36 MB
Image	N/A
Transfer date	January 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	.75
RMSE for East Position (<4.0 cm)	1.01
RMSE for Down Position (<8.0 cm)	2.70
Boresight correction stdev (<0.001deg)	0.001711
IMU attitude correction stdev (<0.001deg)	0.002627
GPS position stdev (<0.01m)	0.0018
Minimum % overlap (>25)	38.51 %
Ave point cloud density per sq.m. (>2.0)	4.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	78
Maximum Height	553.45 m
Minimum Height	48.17 m
Classification (# of points)	
Ground	9,620,275
Low vegetation	5,386,146
Medium vegetation	79,015,481
High vegetation	95,038,735
Building	344,062
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Merven Matthew Natino, JovyNarisma

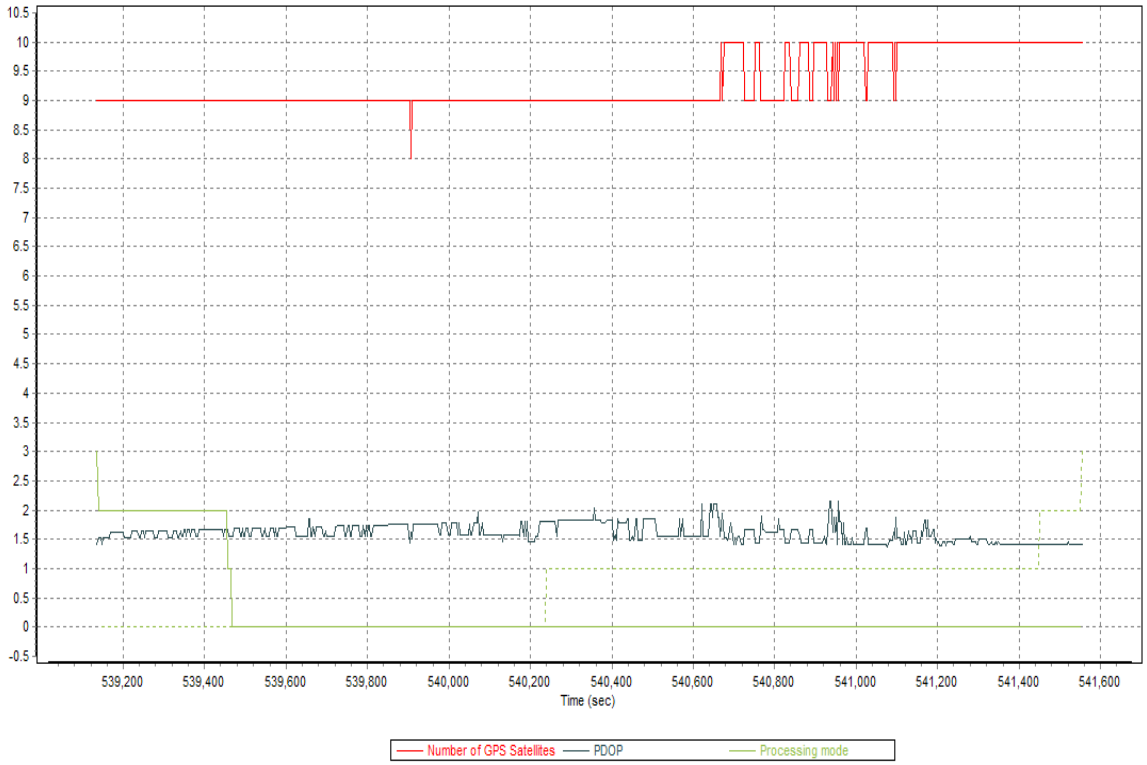


Figure 1.7.1. Solution Status

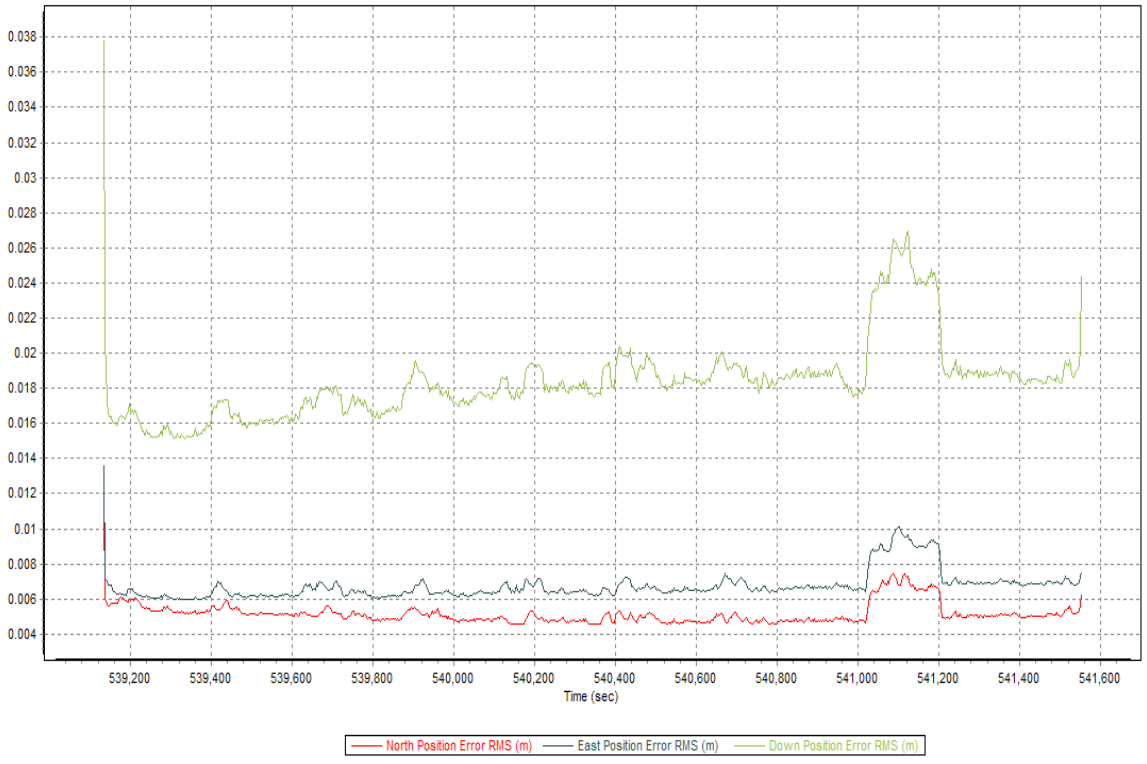


Figure 1.7.2. Smoothed Performance Metric Parameters

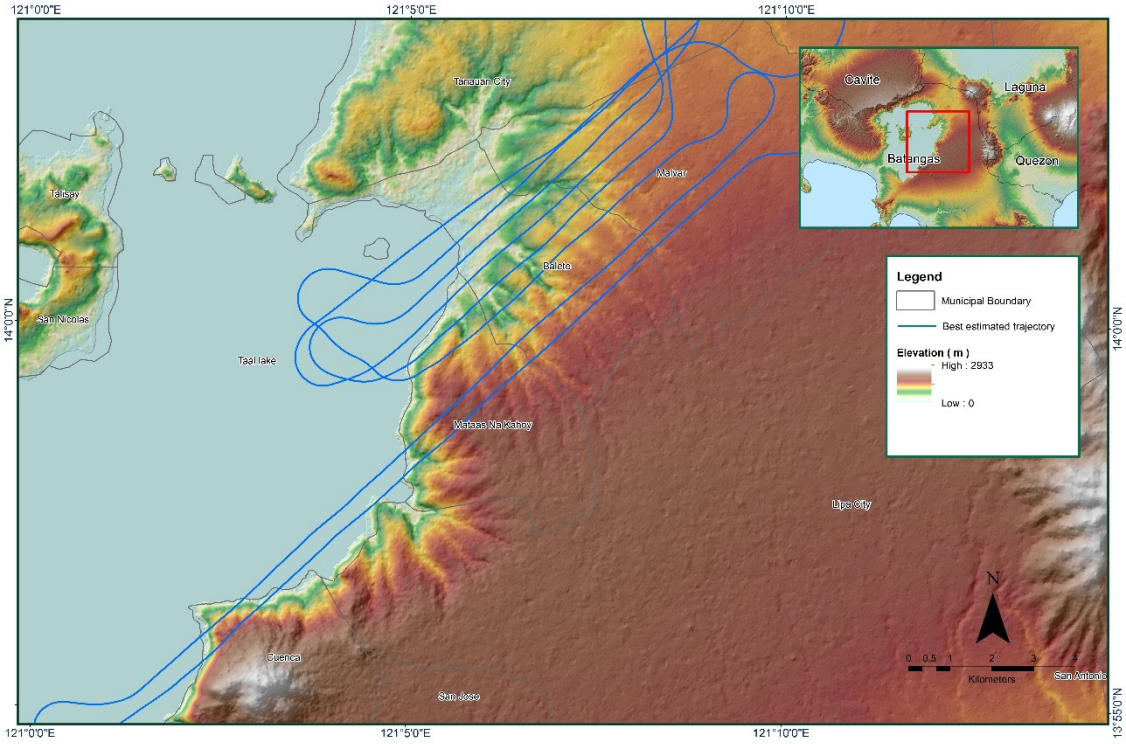


Figure 1.7.3. Best Estimated Trajectory

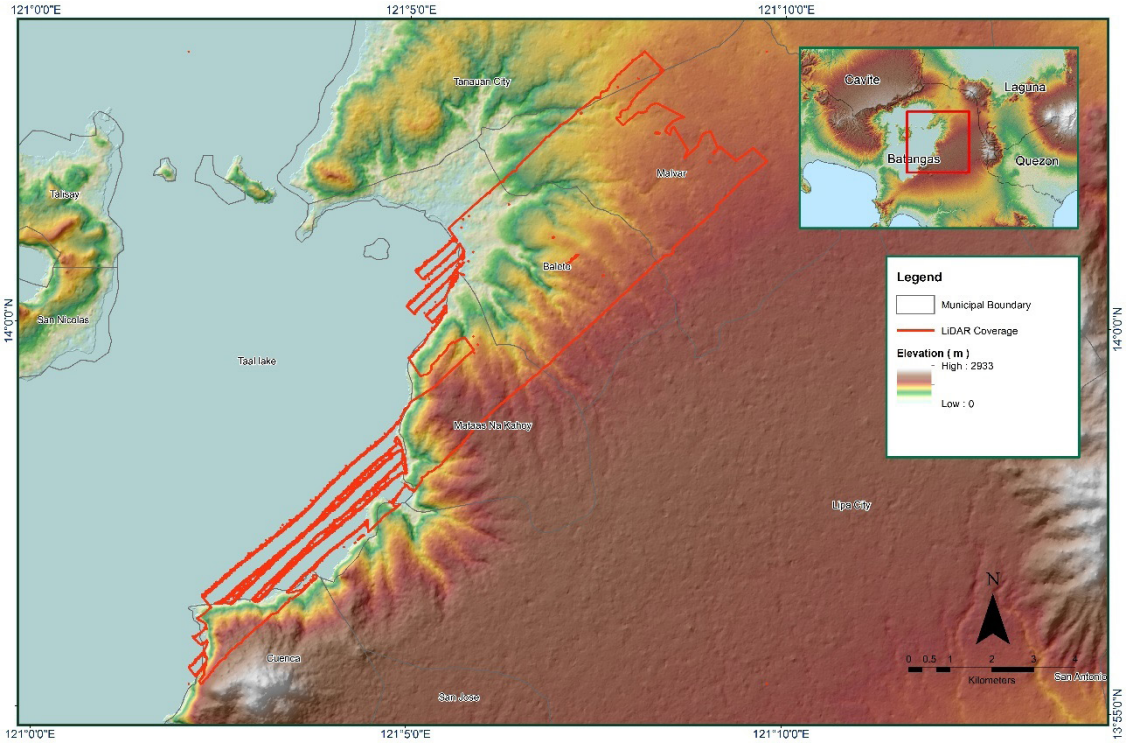


Figure 1.7.4. Coverage of LiDAR Data

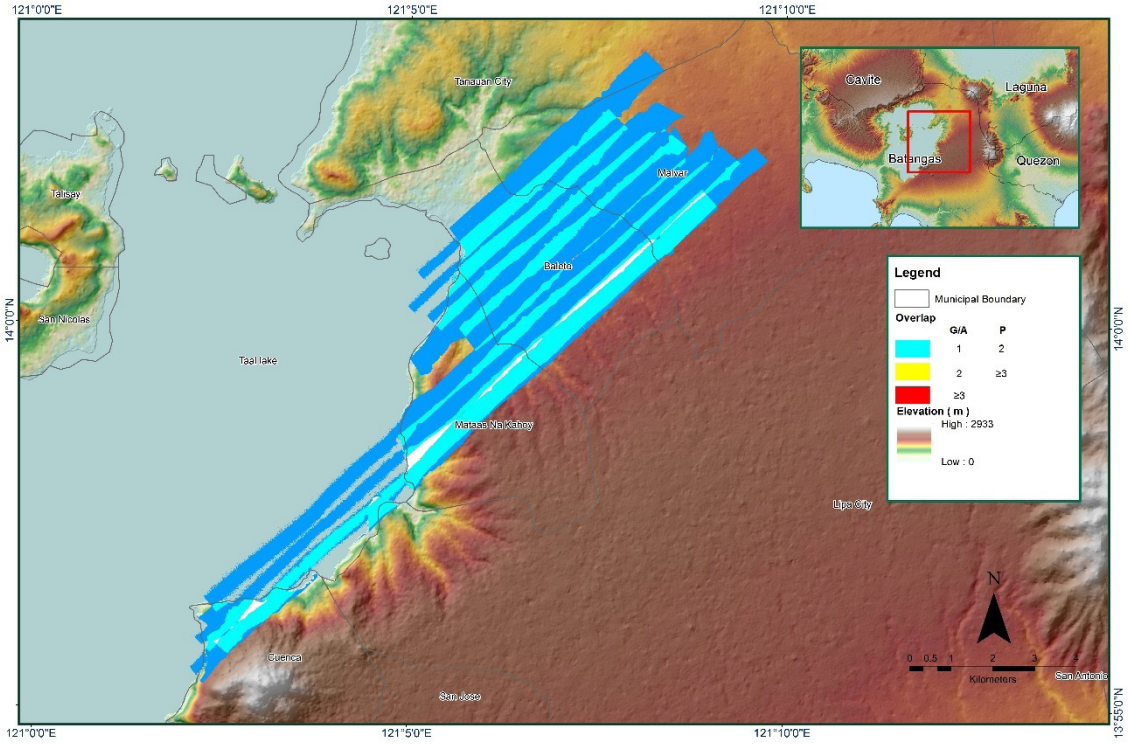


Figure 1.7.5. Image of data overlap

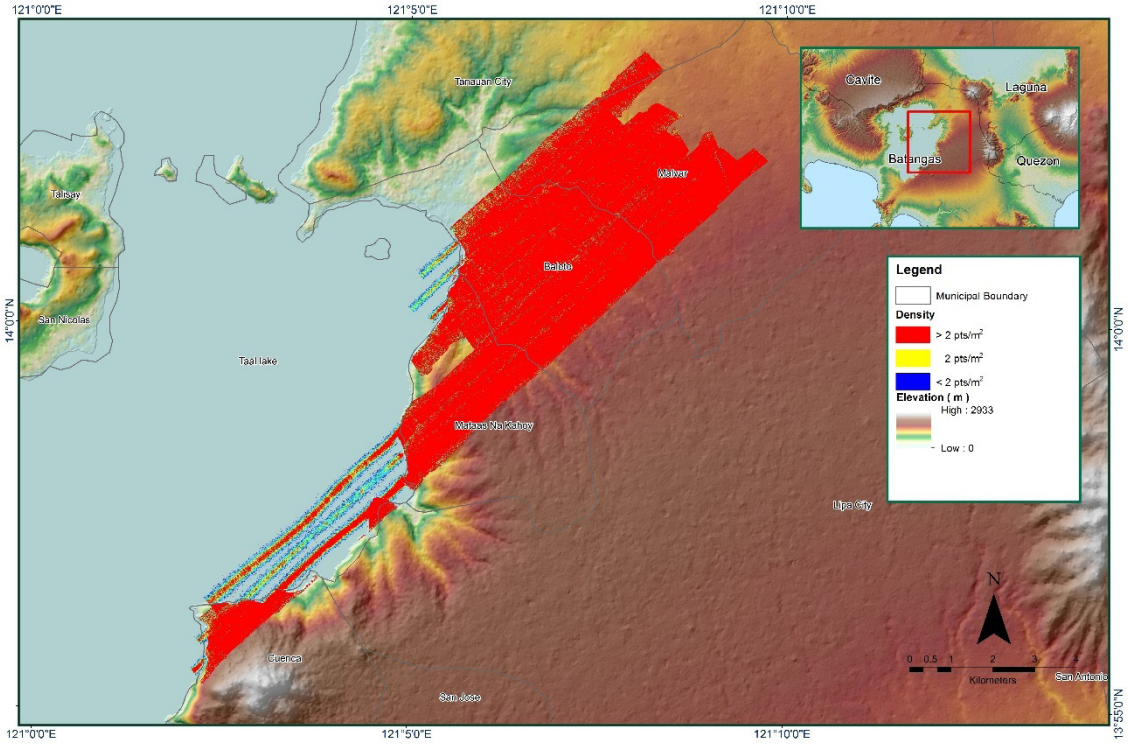


Figure 1.7.6. Density map of merged LiDAR data

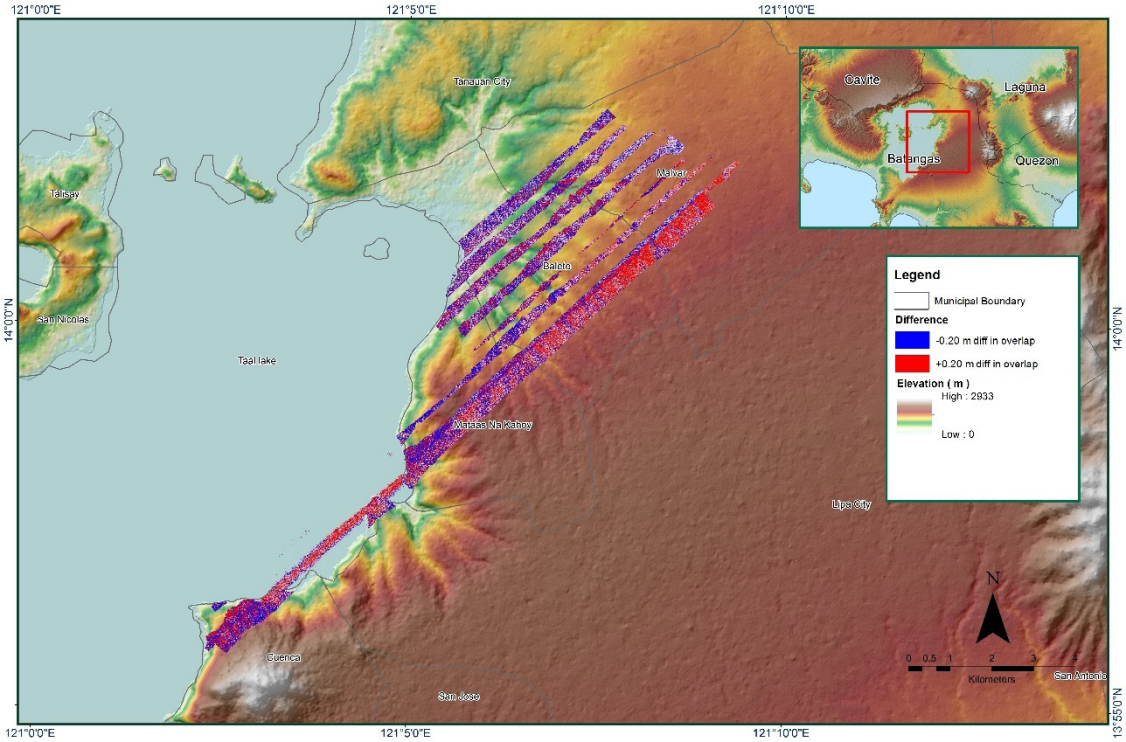


Figure 1.7.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	Blk18O
Inclusive Flights	1119P, 1123P
Range data size	15.8 GB
POS data size	250 MB
Base data size	11.7 MB
Image	21.5 GB
Transfer date	April 14, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.9
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000501
IMU attitude correction stdev (<0.001deg)	0.002500
GPS position stdev (<0.01m)	0.0181
Minimum % overlap (>25)	29.57
Ave point cloud density per sq.m. (>2.0)	1.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	247
Maximum Height	496.05 m
Minimum Height	39.15 m
Classification (# of points)	
Ground	91,045,249
Low vegetation	83,625,596
Medium vegetation	77,719,810
High vegetation	128,136,411
Building	19,065,771
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. RoaShelmar Redo

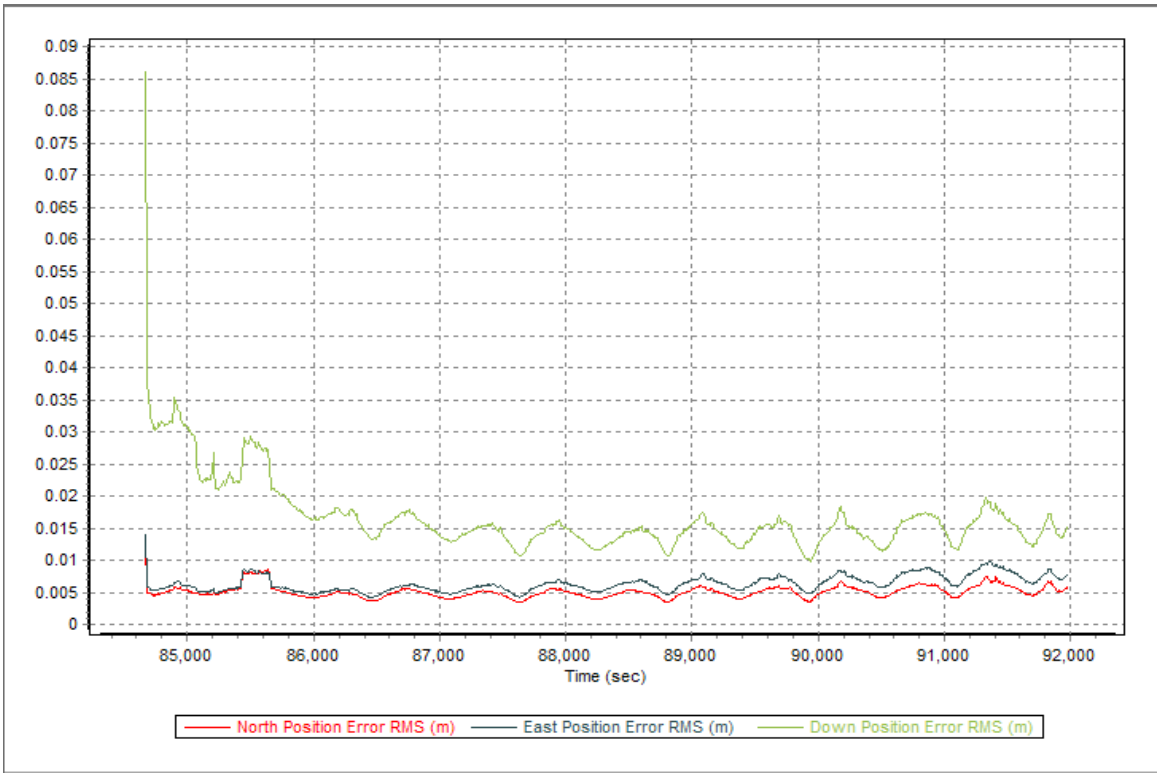


Figure 1.8.1. Solution Status

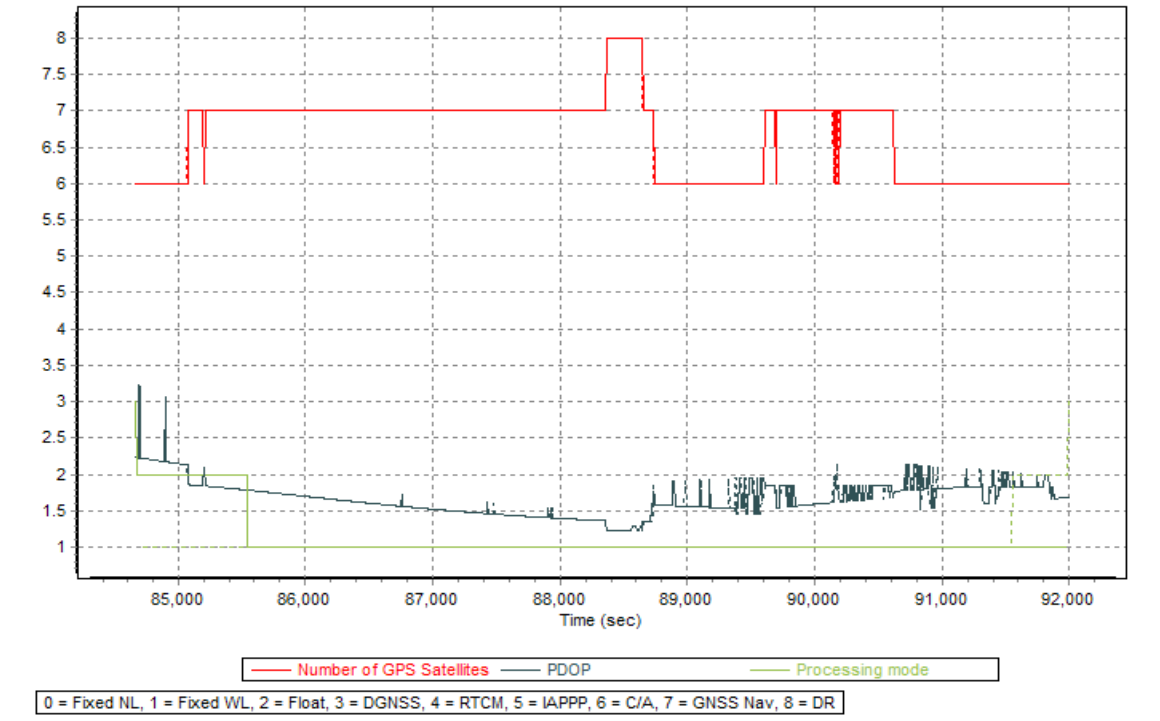


Figure 1.8.2. Smoothed Performance Metric Parameters

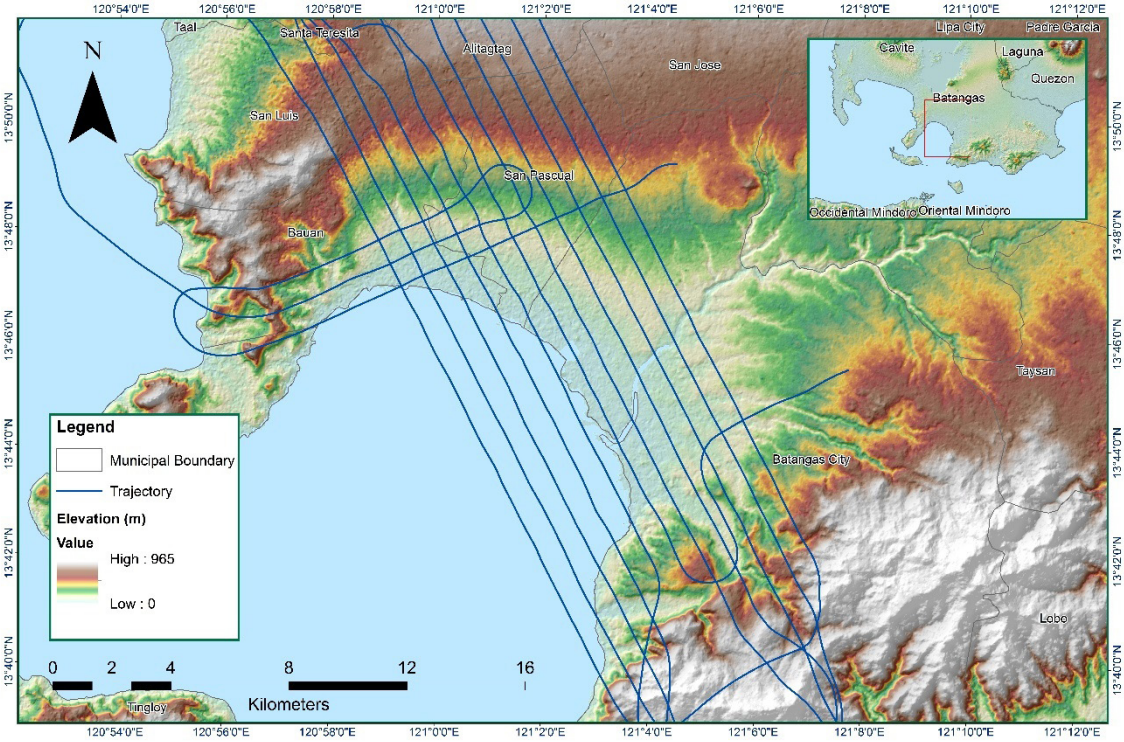


Figure 1.8.3. Best Estimated Trajectory

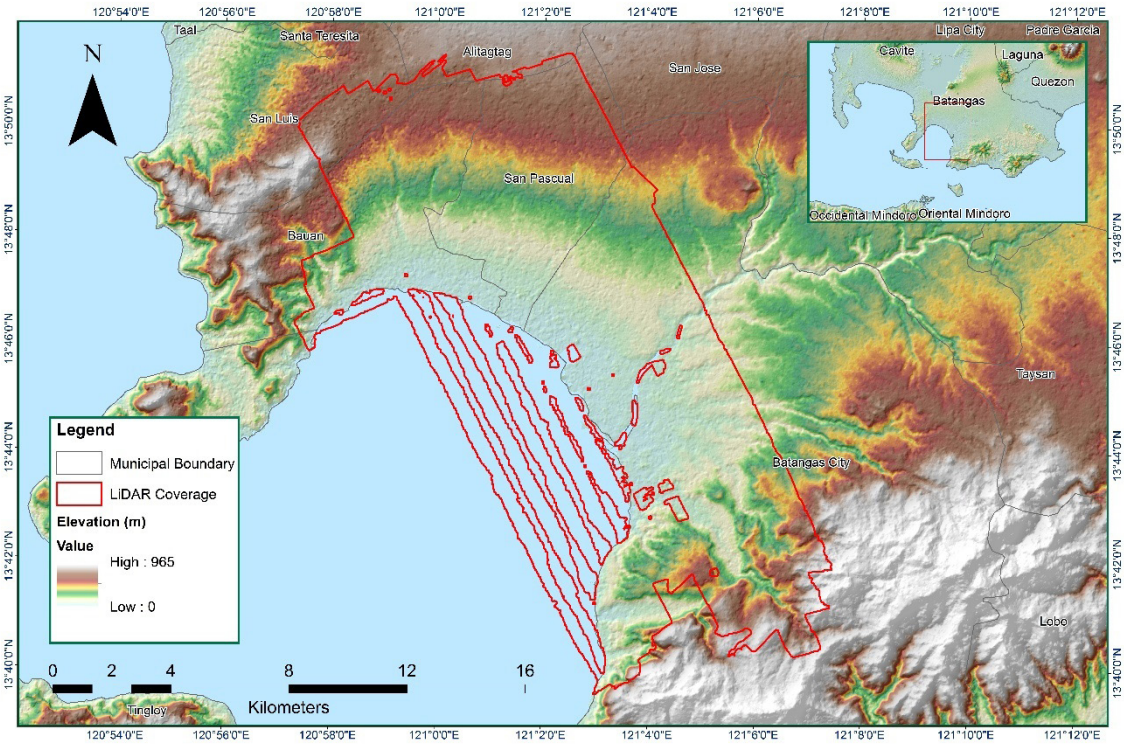


Figure 1.8.4. Coverage of LiDAR Data

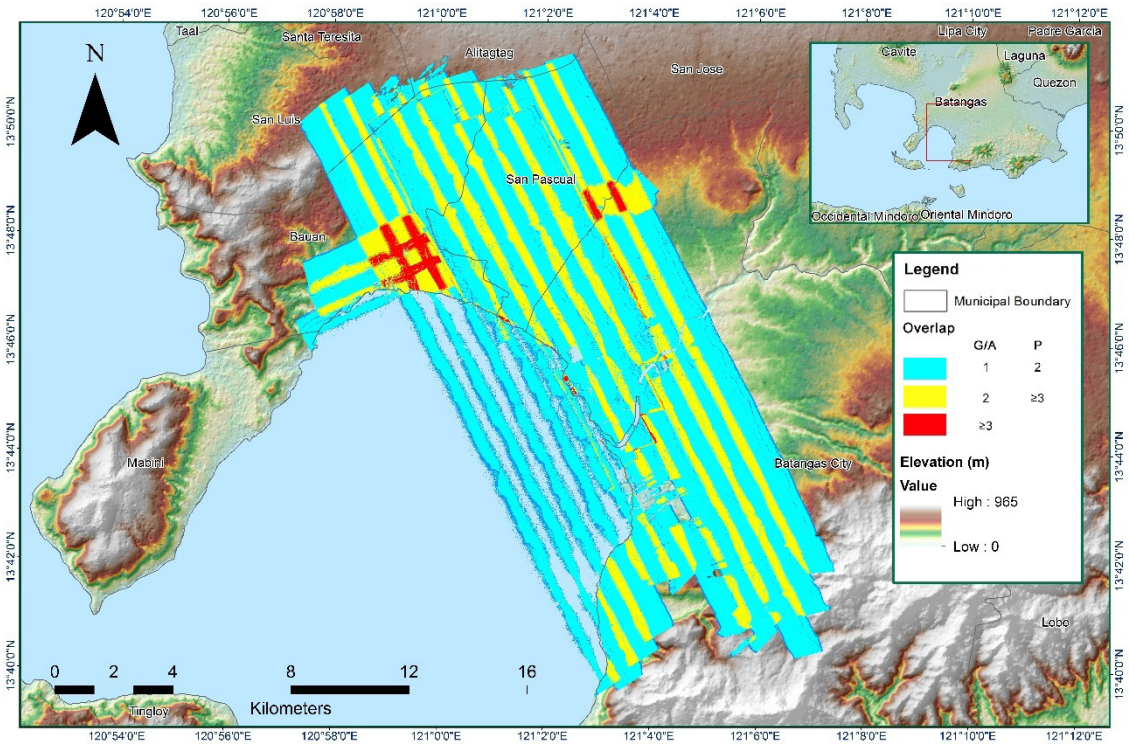


Figure 1.8.5. Image of data overlap

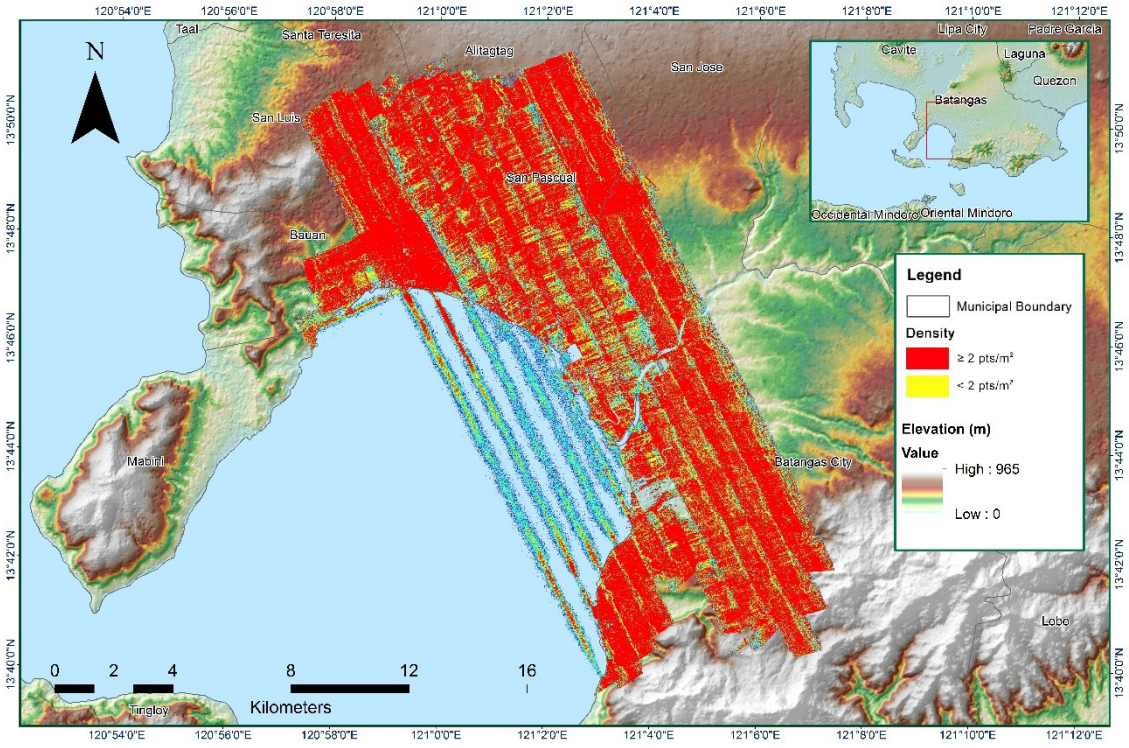


Figure 1.8.6. Density map of merged LiDAR data

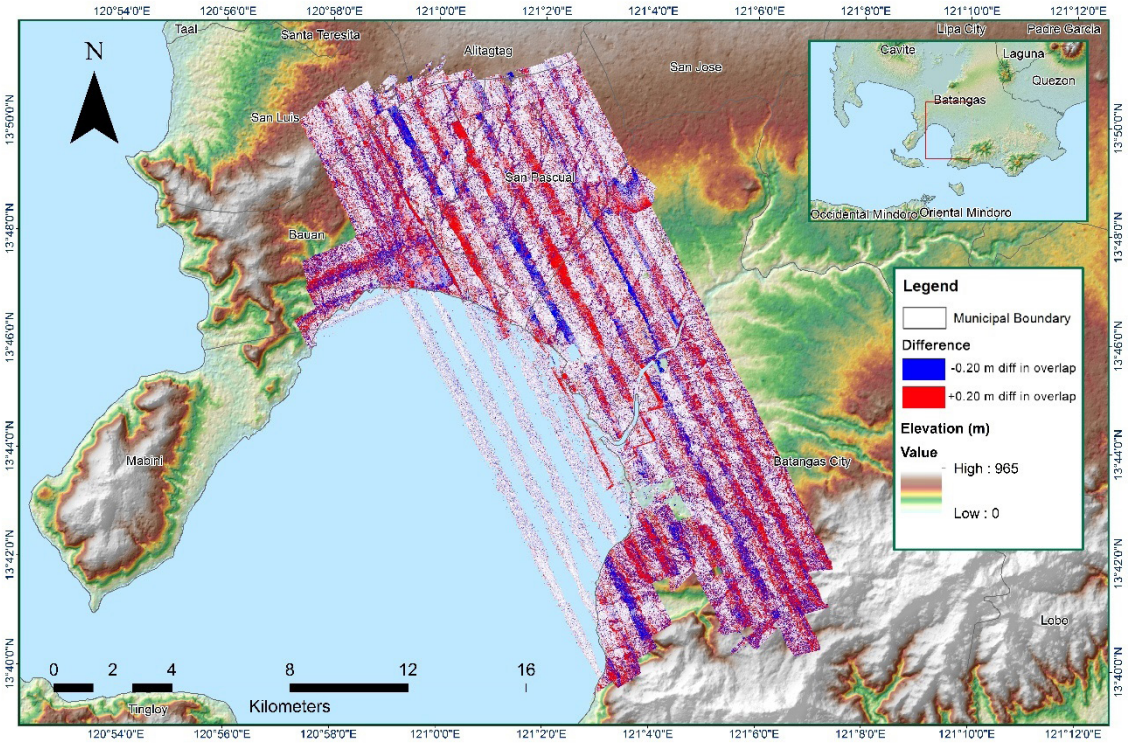


Figure 1.8.7. Elevation difference between flight lines

Flight Area	**Batangas**
Mission Name	**Blk18O_supplement2**
Inclusive Flights	1123P
Range data size	14.7 GB
POS data size	193 MB
Base data size	12.6 MB
Image	NA
Transfer date	April 14, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.82
RMSE for East Position (<4.0 cm)	1.06
RMSE for Down Position (<8.0 cm)	2.27
Boresight correction stdev (<0.001deg)	0.000342
IMU attitude correction stdev (<0.001deg)	0.0086
GPS position stdev (<0.01m)	0.000491
Minimum % overlap (>25)	36.25
Ave point cloud density per sq.m. (>2.0)	1.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	249
Maximum Height	799.89 m
Minimum Height	47.54 m
Classification (# of points)	
Ground	102,344,866
Low vegetation	100,585,314
Medium vegetation	89,099,375
High vegetation	213,535,108
Building	19,838,980
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Charmaine Cruz, JovyNarisma

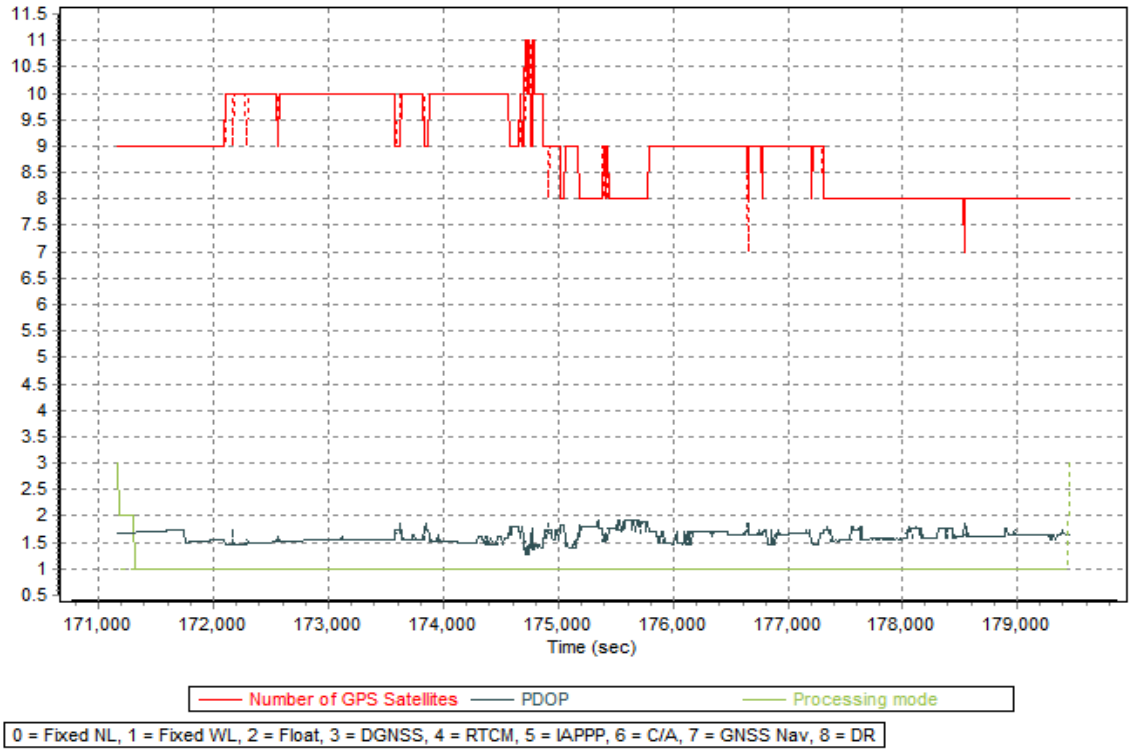


Figure 1.9.1. Solution Status

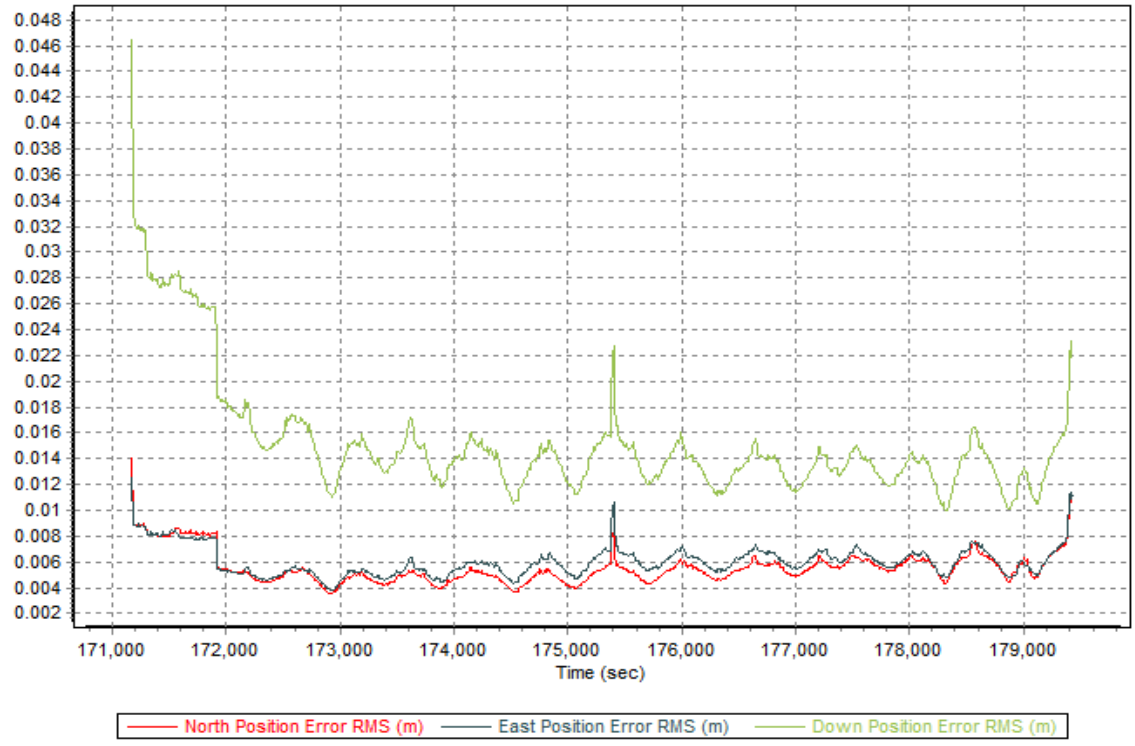


Figure 1.9.2. Smoothed Performance Metric Parameters

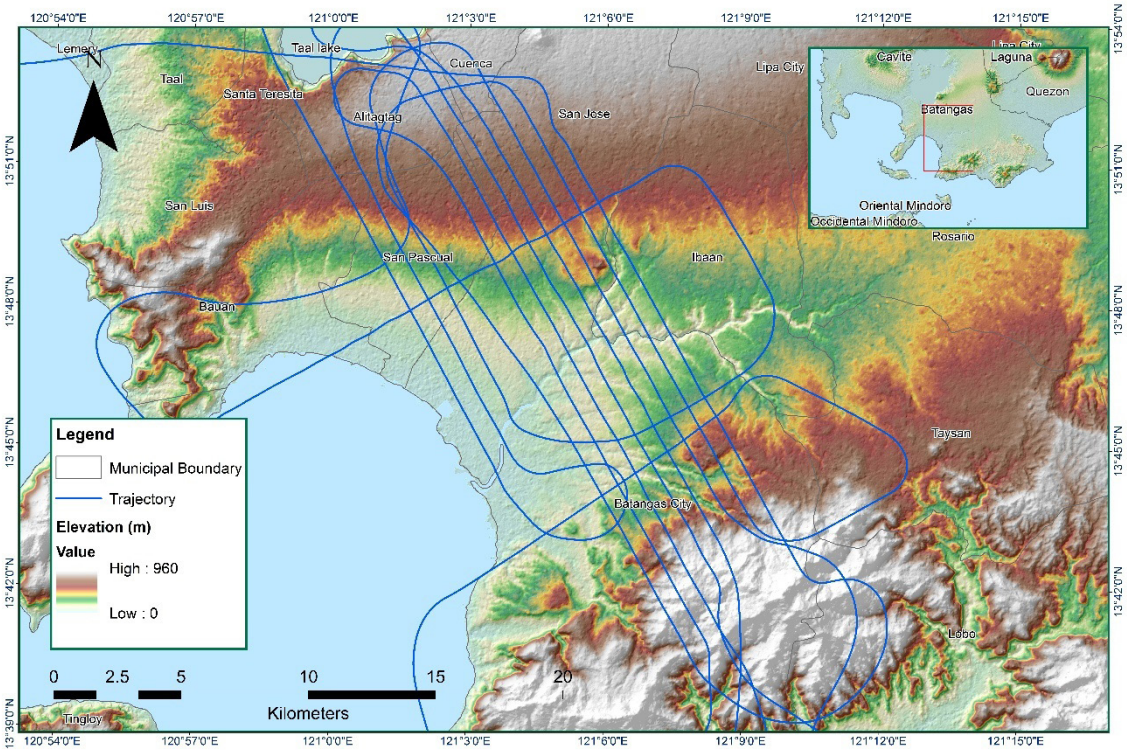


Figure 1.9.3. Best Estimated Trajectory

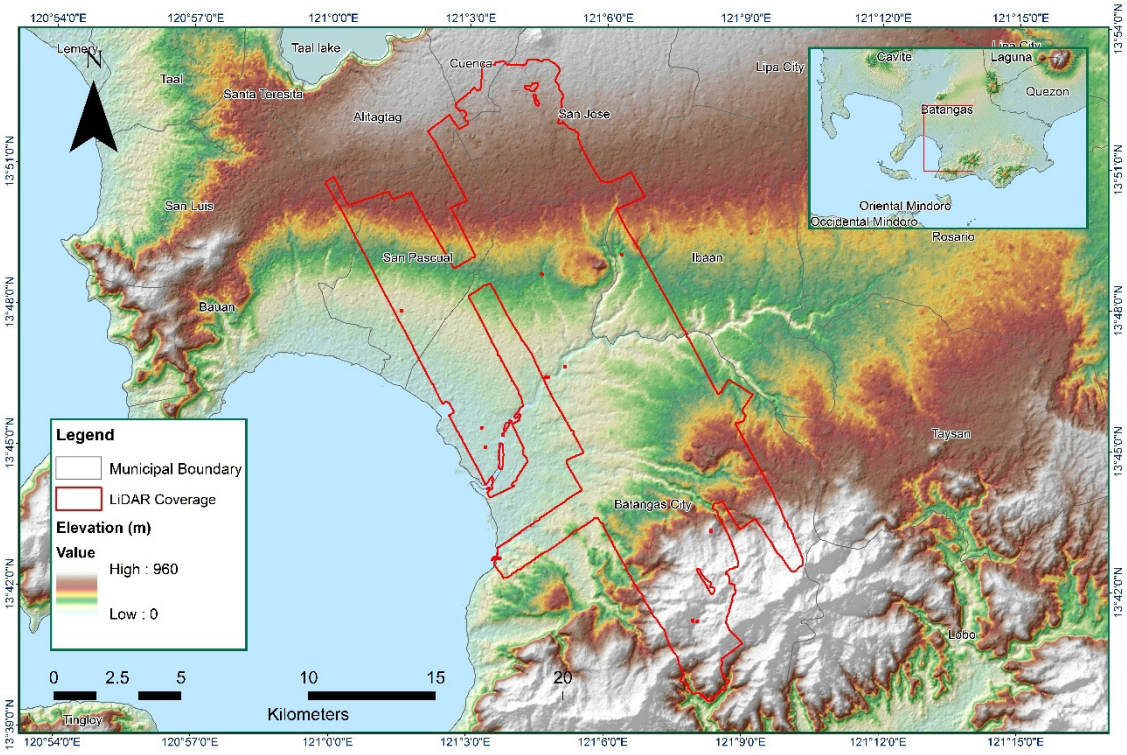


Figure 1.9.4. Coverage of LiDAR Data

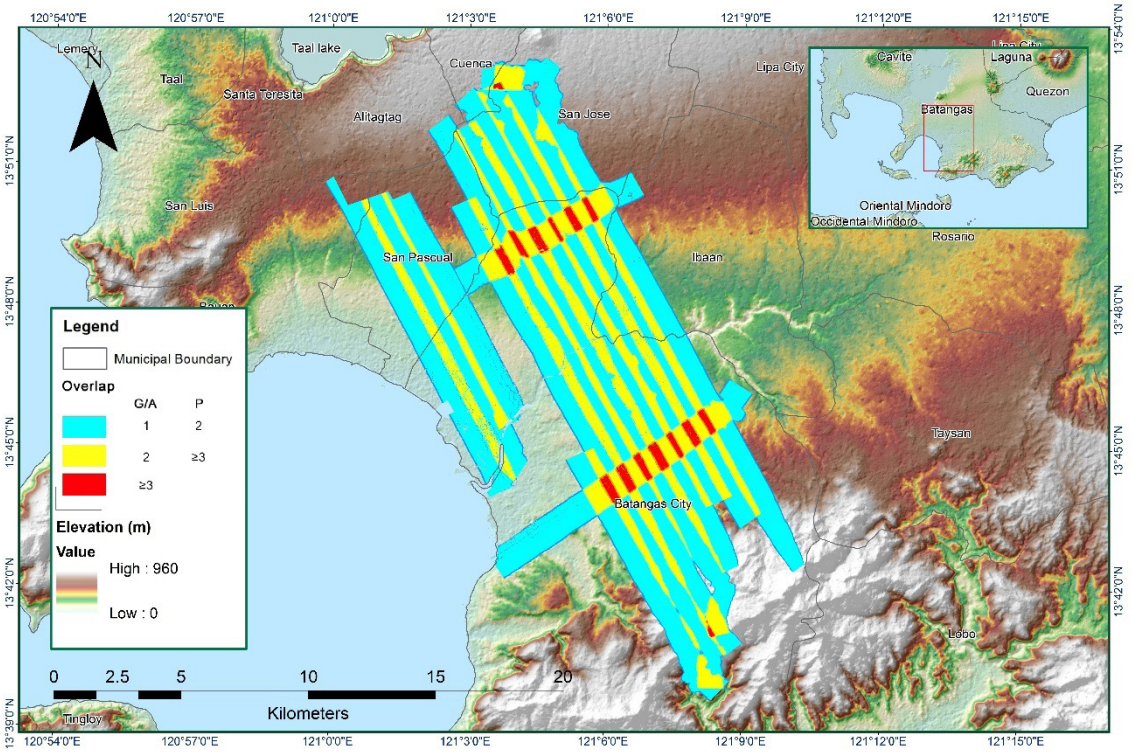


Figure 1.9.5. Image of data overlap

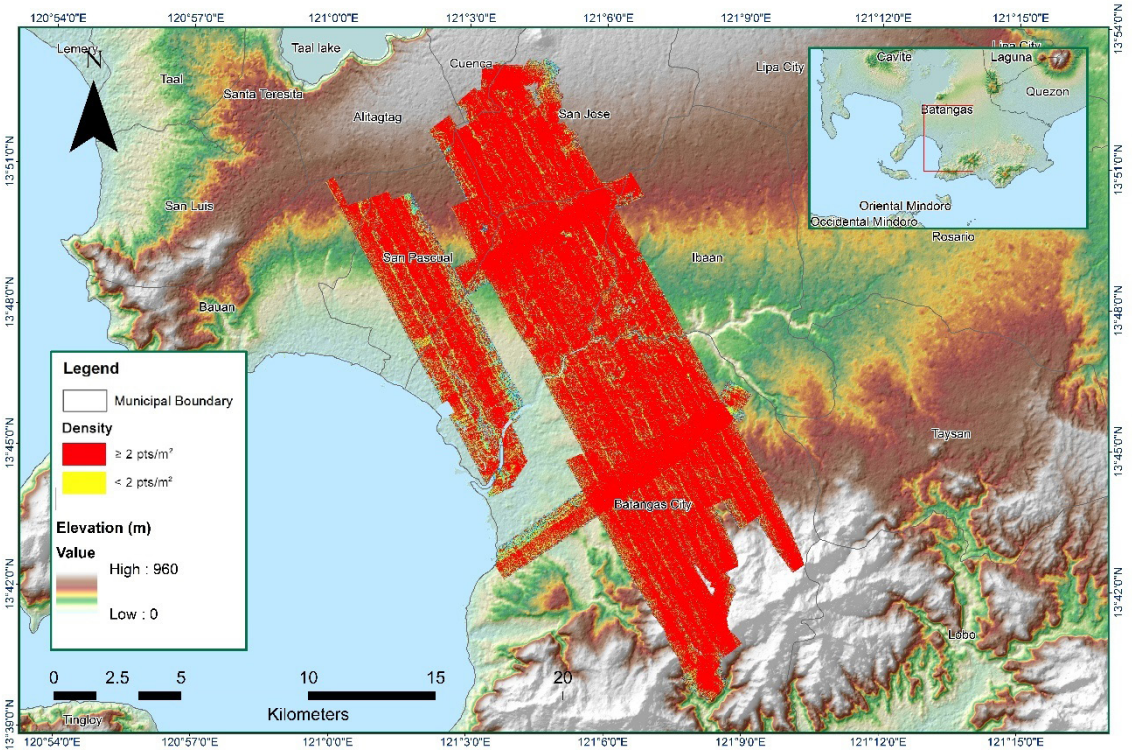


Figure 1.9.6. Density map of merged LiDAR data

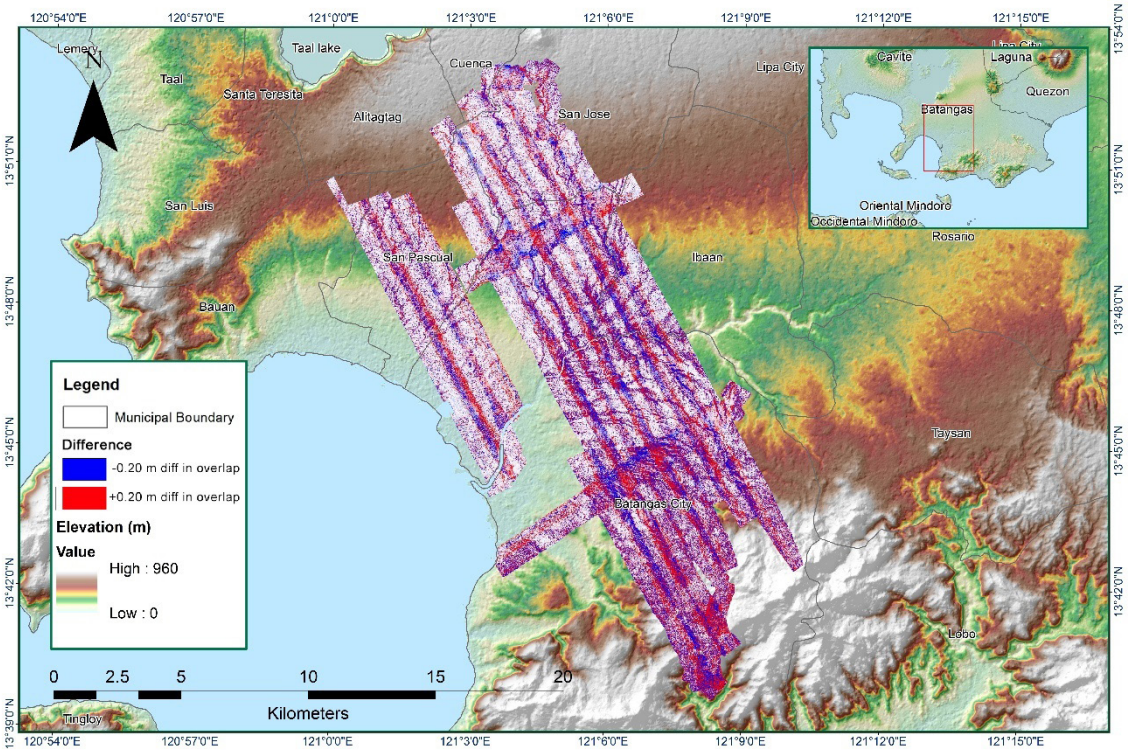


Figure 1.9.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	Blk18QR_supplement1
Inclusive Flights	1107P
Range data size	10.2 GB
POS data size	215 MB
Base data size	12 MB
Image	16.7 GB
Transfer date	April 14, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.96
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	5.13
Boresight correction stdev (<0.001deg)	0.000544
IMU attitude correction stdev (<0.001deg)	0.001183
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	33.45
Ave point cloud density per sq.m. (>2.0)	1.97
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	203
Maximum Height	424.07 m
Minimum Height	37.25 m
Classification (# of points)	
Ground	127,864,102
Low vegetation	116,063,635
Medium vegetation	96,973,073
High vegetation	155,630,114
Building	11,308,922
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, AilynBiñas

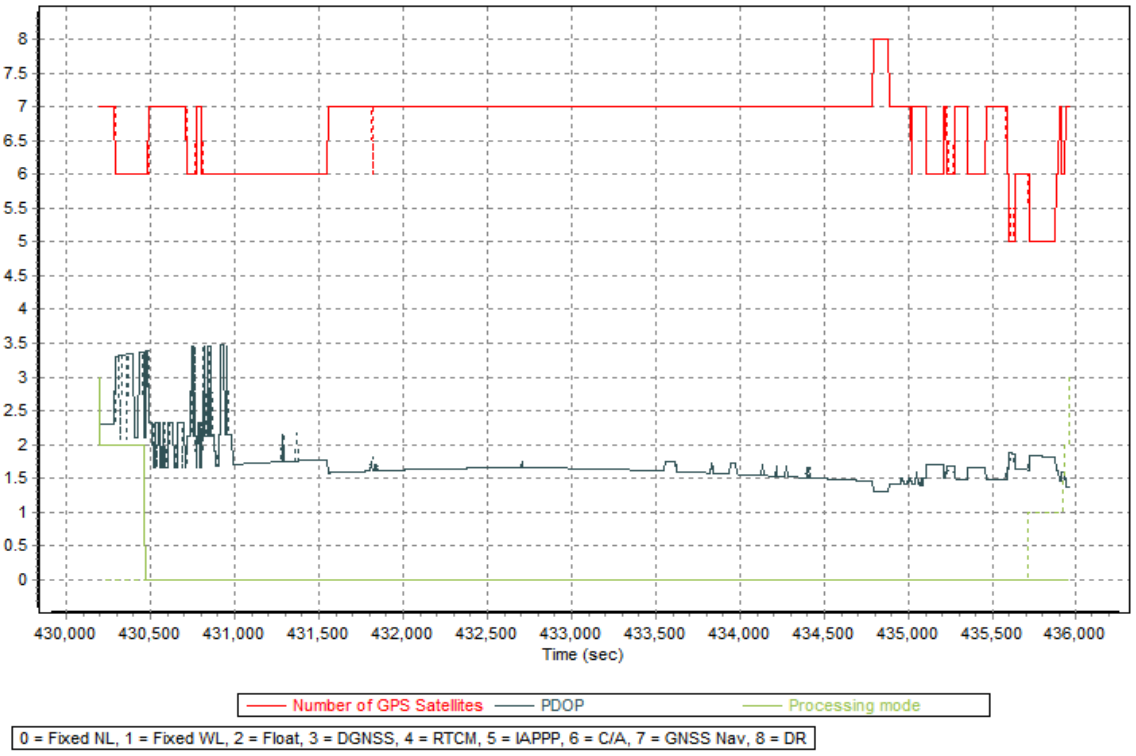


Figure 1.10.1. Solution Status

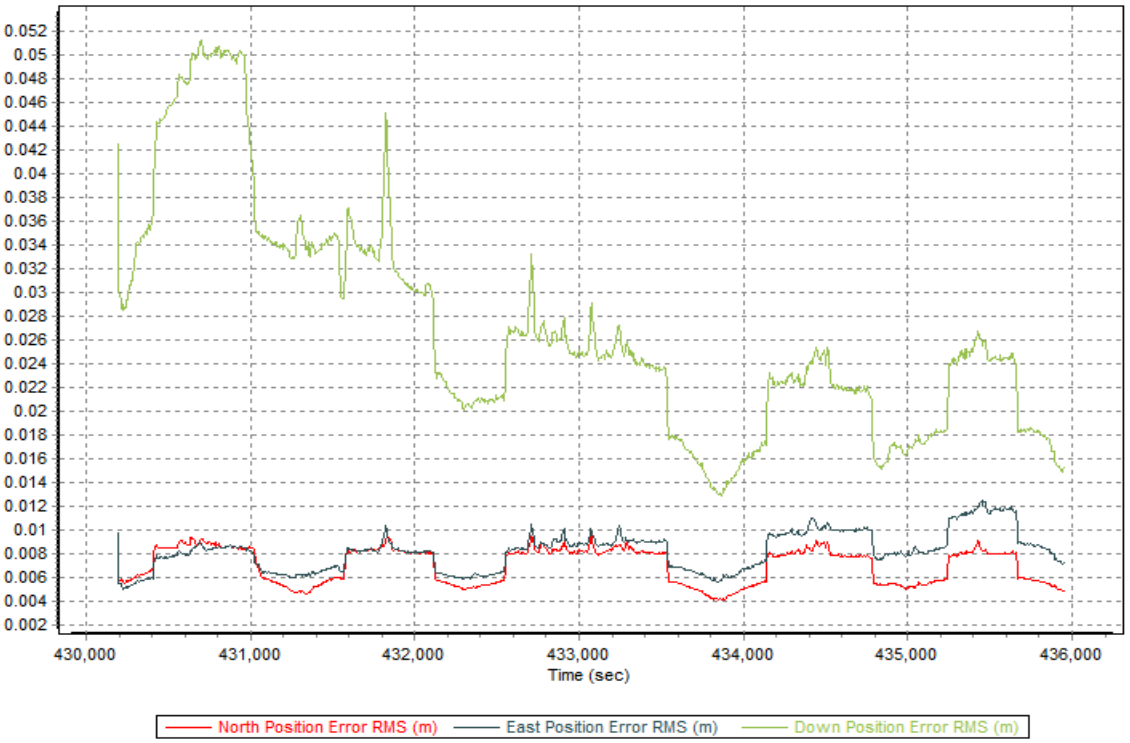


Figure 1.10.2. Smoothed Performance Metric Parameters

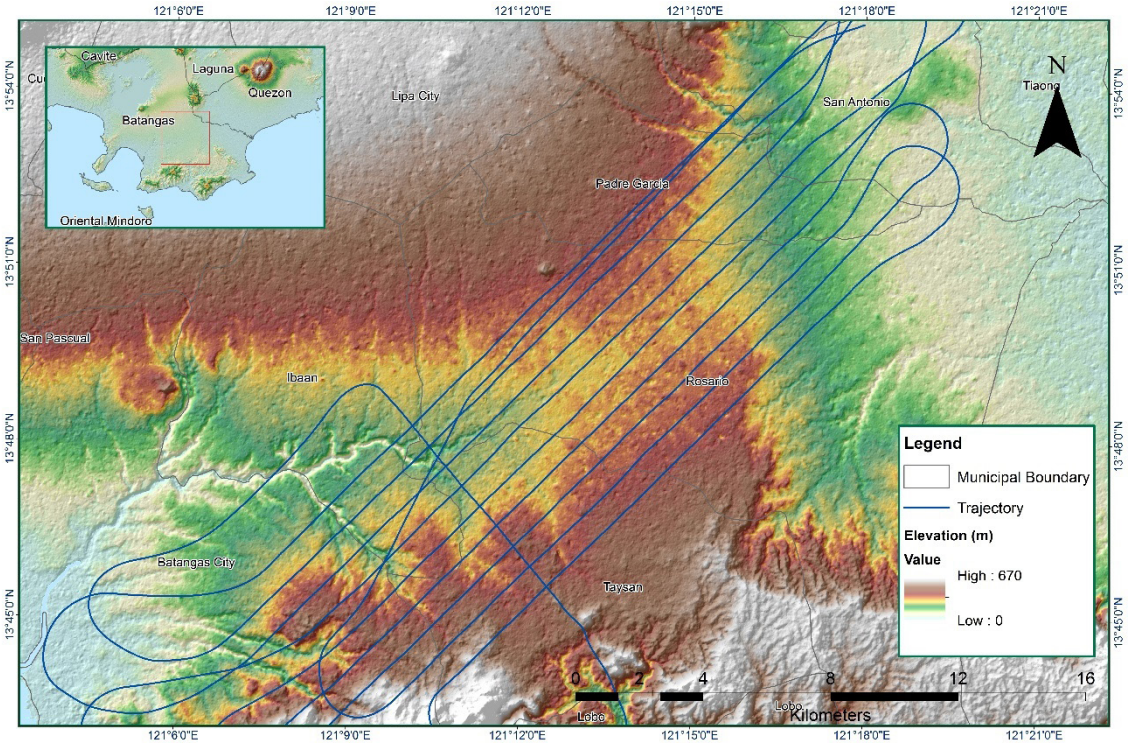


Figure 1.10.3. Best Estimated Trajectory

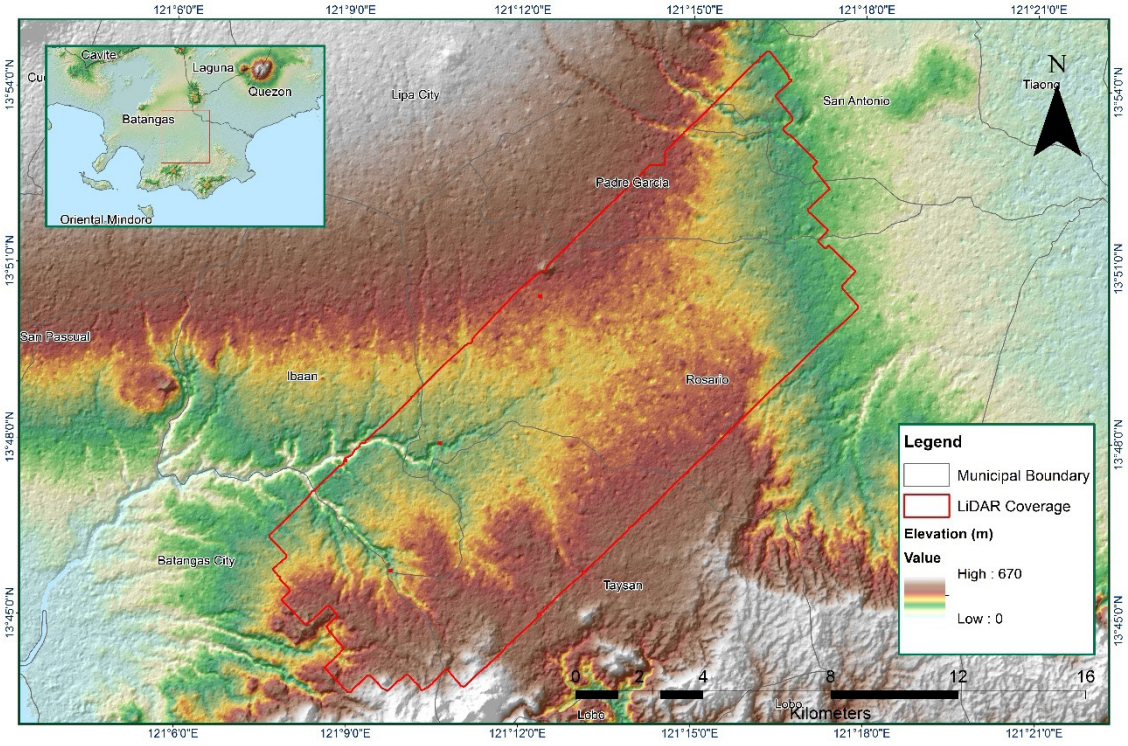


Figure 1.10.4. Coverage of LiDAR Data

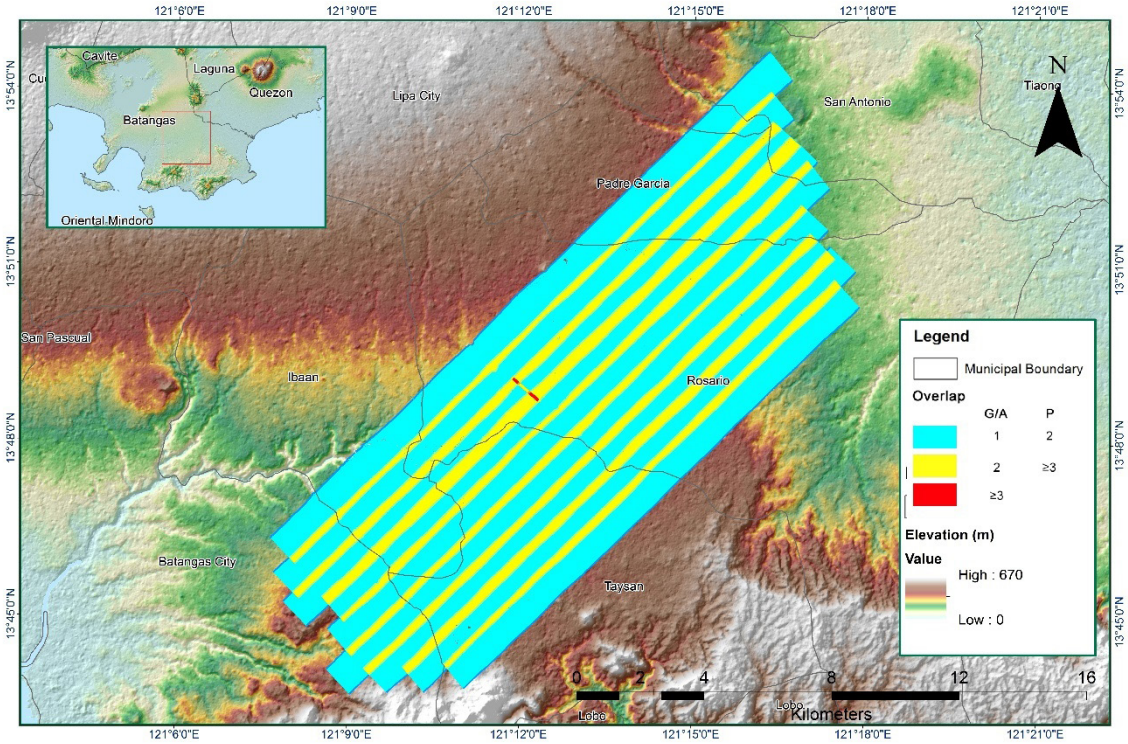


Figure 1.10.5. Image of data overlap

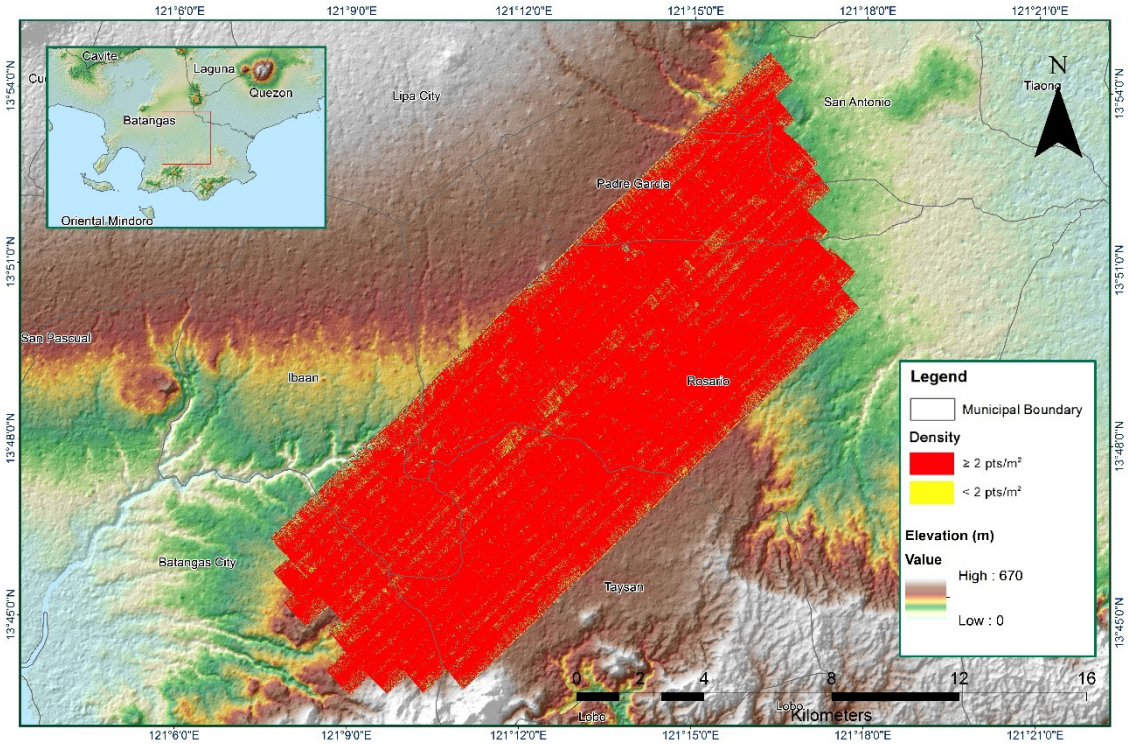


Figure 1.10.6. Density map of merged LiDAR data

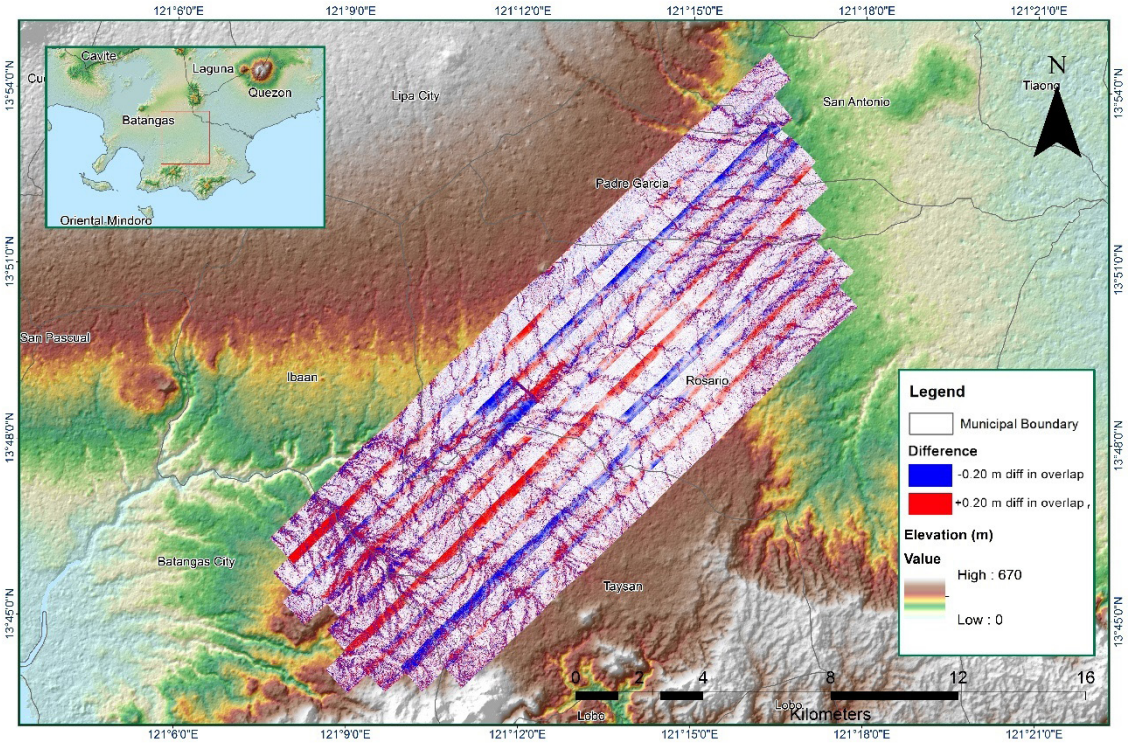


Figure 1.10.7. Elevation difference between flight lines

Flight Area	Batangas
Mission Name	Blk18QR
Inclusive Flights	1111P, 1125P
Range data size	14.7 GB
POS data size	194 MB
Base data size	10.9 MB
Image	19.7 GB
Transfer date	April 14, 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)	1.11
RMSE for East Position (<4.0 cm)	1.38
RMSE for Down Position (<8.0 cm)	3.05
Boresight correction stdev (<0.001deg)	0.000419
IMU attitude correction stdev (<0.001deg)	0.000506
GPS position stdev (<0.01m)	0.0294
Minimum % overlap (>25)	60.87
Ave point cloud density per sq.m. (>2.0)	2.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	240
Maximum Height	858.77 m
Minimum Height	46.29 m
Classification (# of points)	
Ground	125,111,499
Low vegetation	188,073,929
Medium vegetation	174,188,362
High vegetation	204,736,395
Building	22,904,374
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, Ryan James Nicholai Dizon

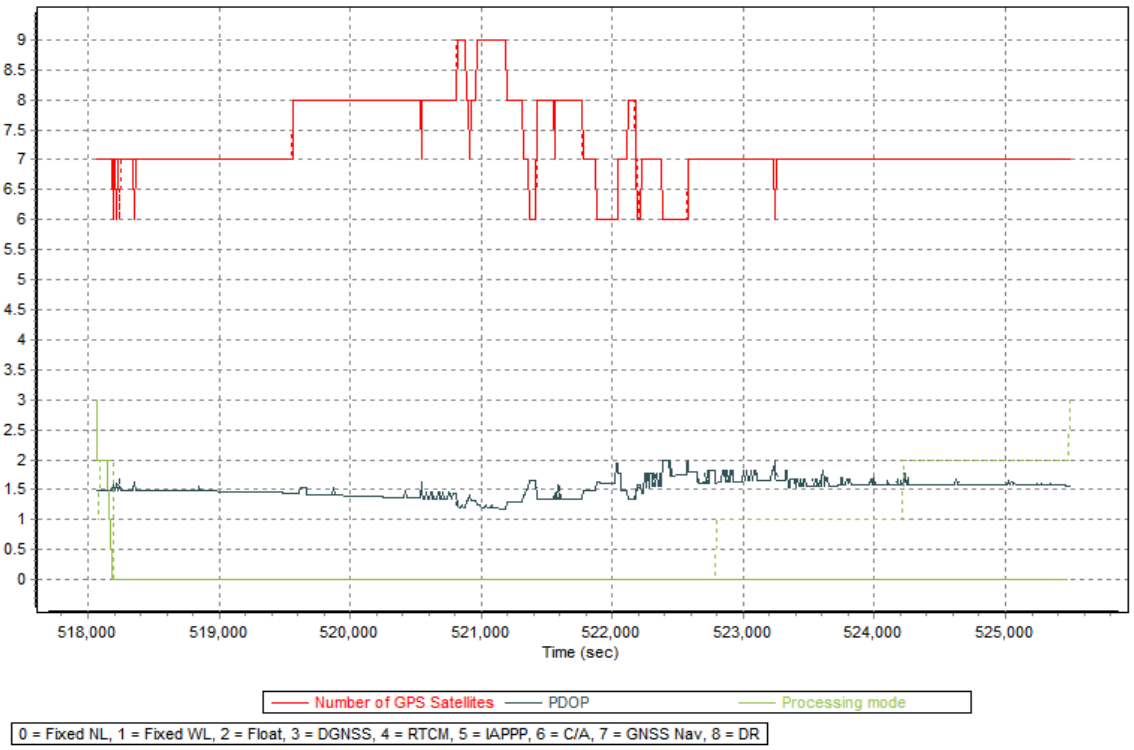


Figure 1.11.1. Solution Status

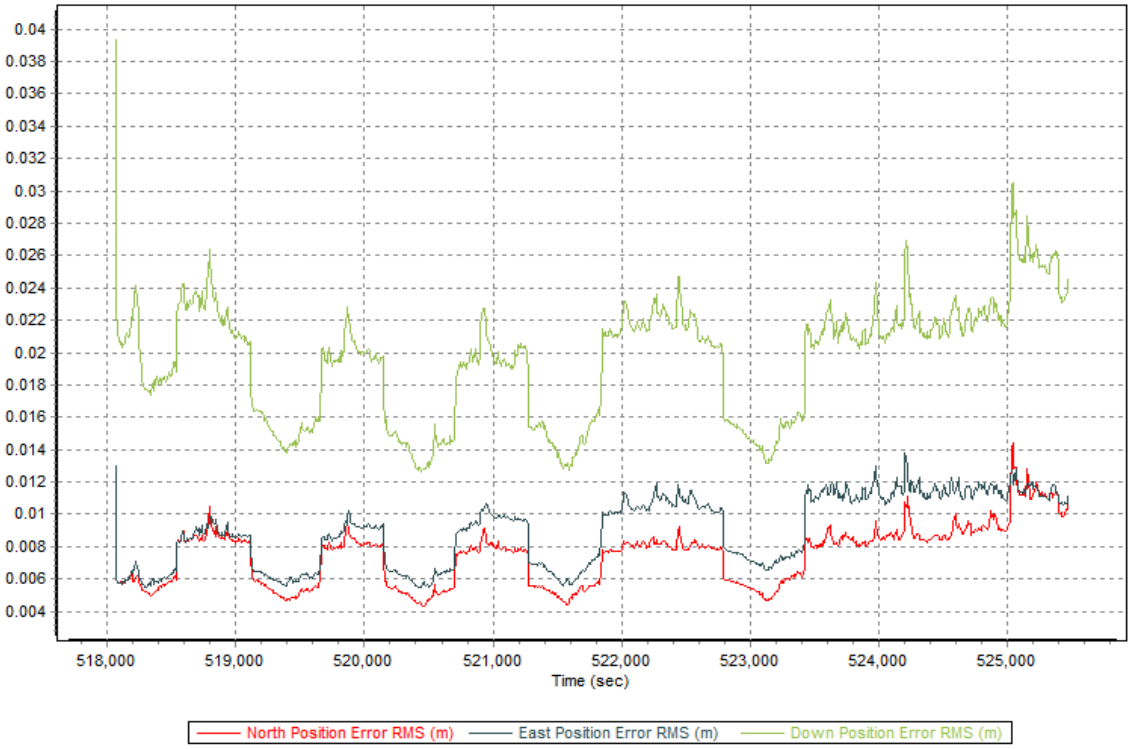


Figure 1.11.2. Smoothed Performance Metric Parameters

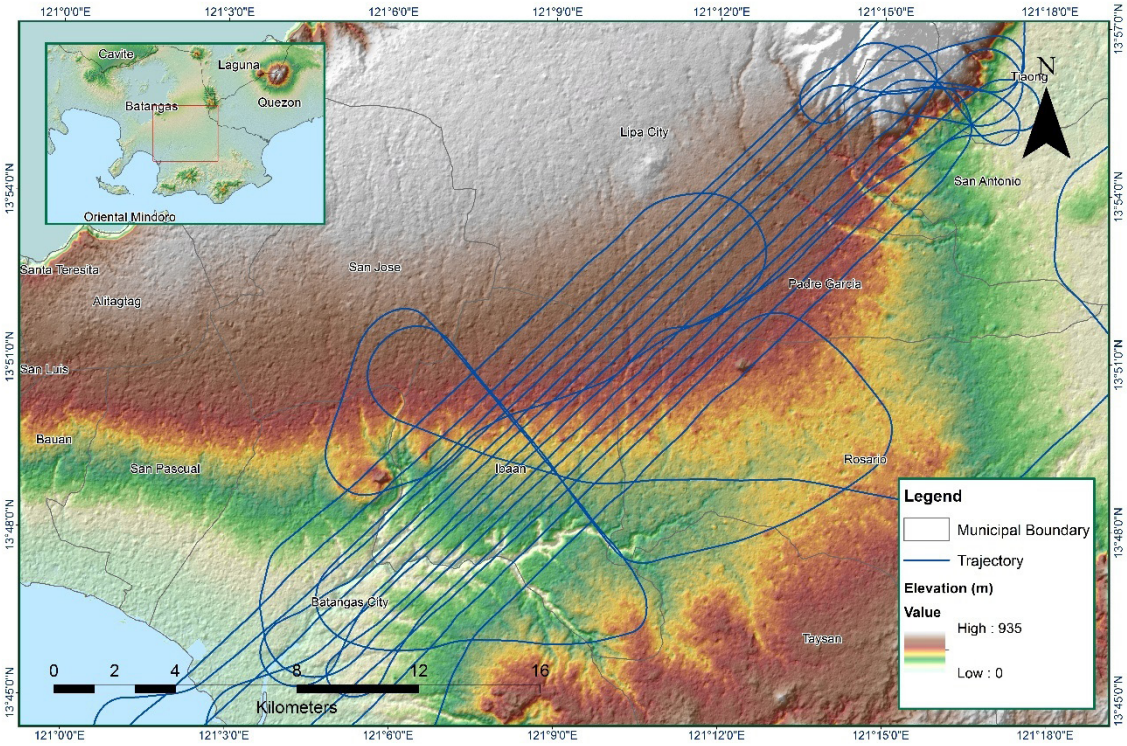


Figure 1.11.3. Best Estimated Trajectory

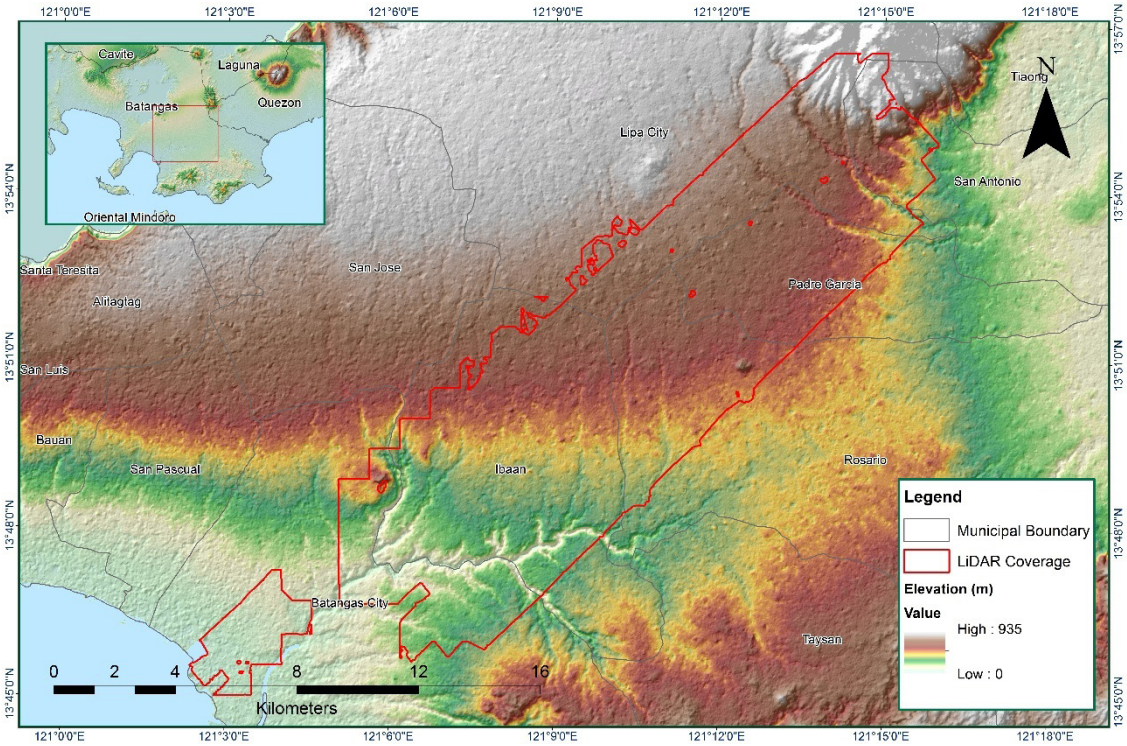


Figure 1.11.4. Coverage of LiDAR Data

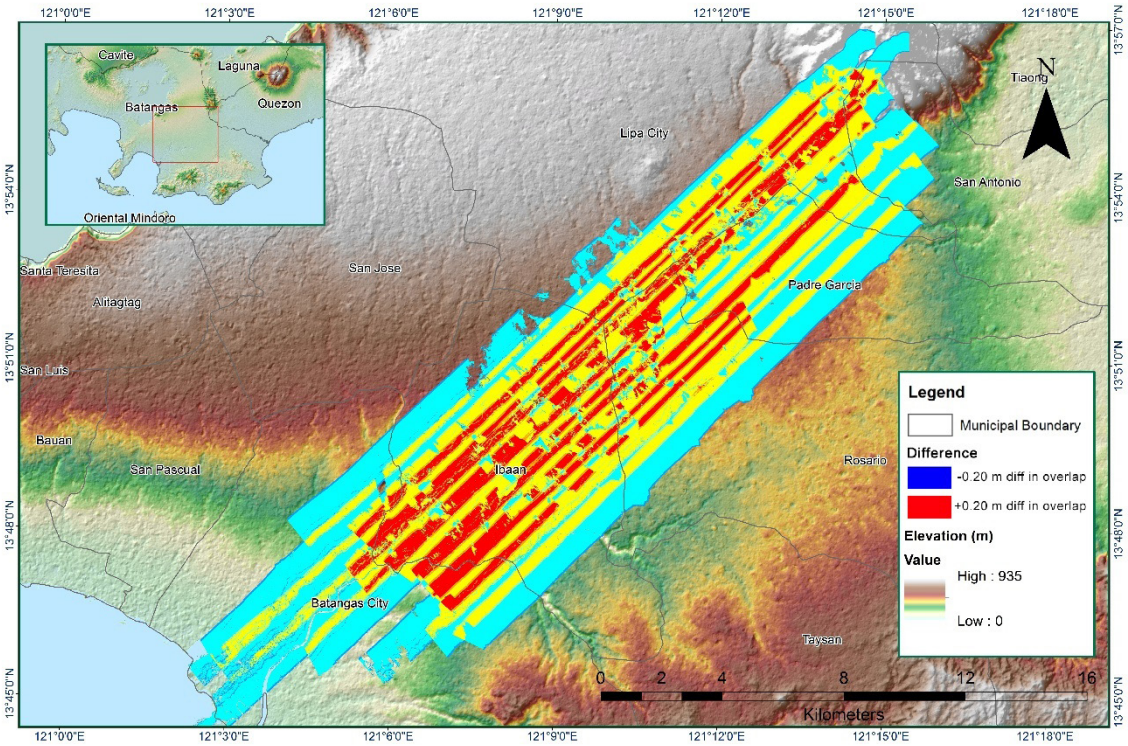


Figure 1.11.5. Image of data overlap

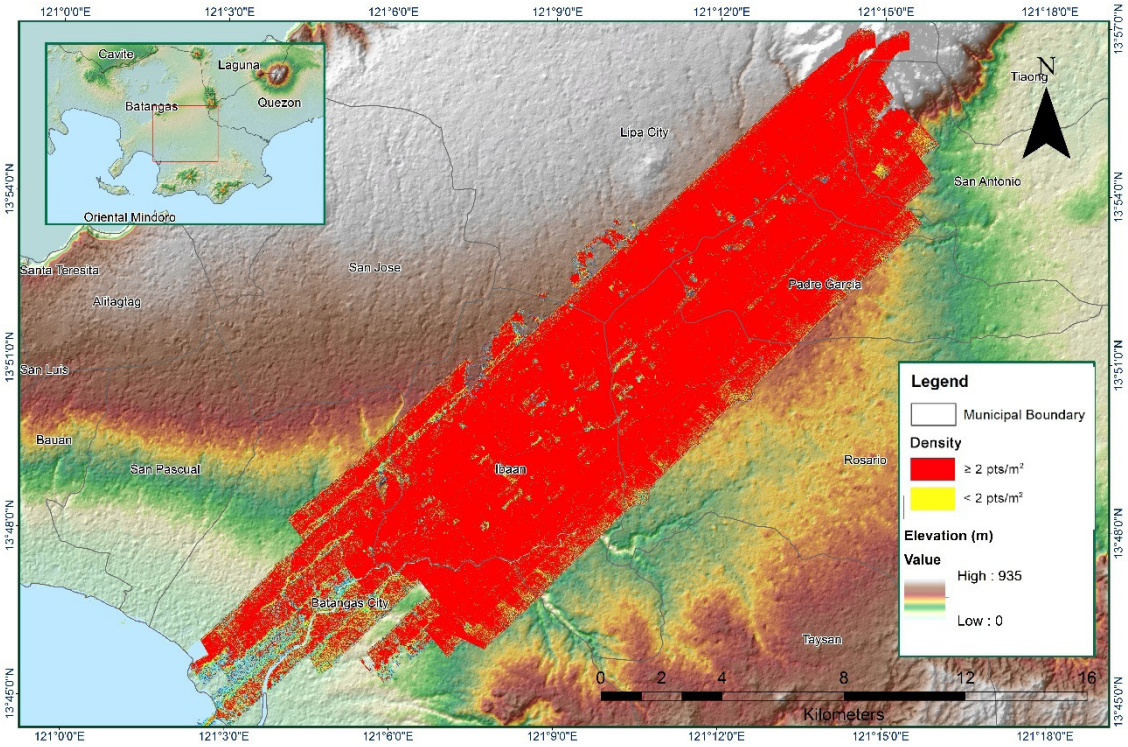


Figure 1.11.6. Density map of merged LiDAR data

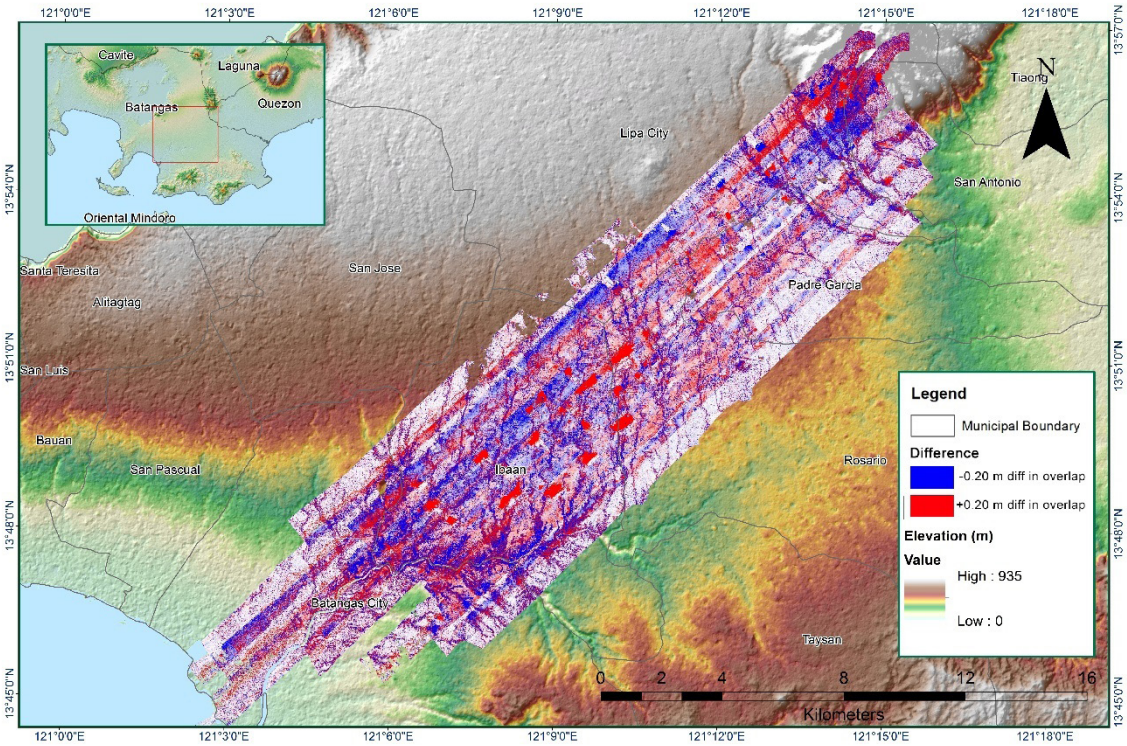


Figure 1.11.7. Elevation difference between flight lines

Flight Area	CALABARZON
Mission Name	Blk18EFGs
Inclusive Flights	1111P
Range data size	14.7 GB
POS	194 MB
Image	19.7 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)	1.4
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000576
IMU attitude correction stdev (<0.001deg)	0.030256
GPS position stdev (<0.01m)	0.0233
Minimum % overlap (>25)	24.19%
Ave point cloud density per sq.m. (>2.0)	1.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	256
Maximum Height	577.15 m
Minimum Height	48.27 m
Classification (# of points)	
Ground	222,961,135
Low vegetation	368,839,290
Medium vegetation	326,022,186
High vegetation	411,722,251
Building	50,368,864
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. John Dill Macapagal

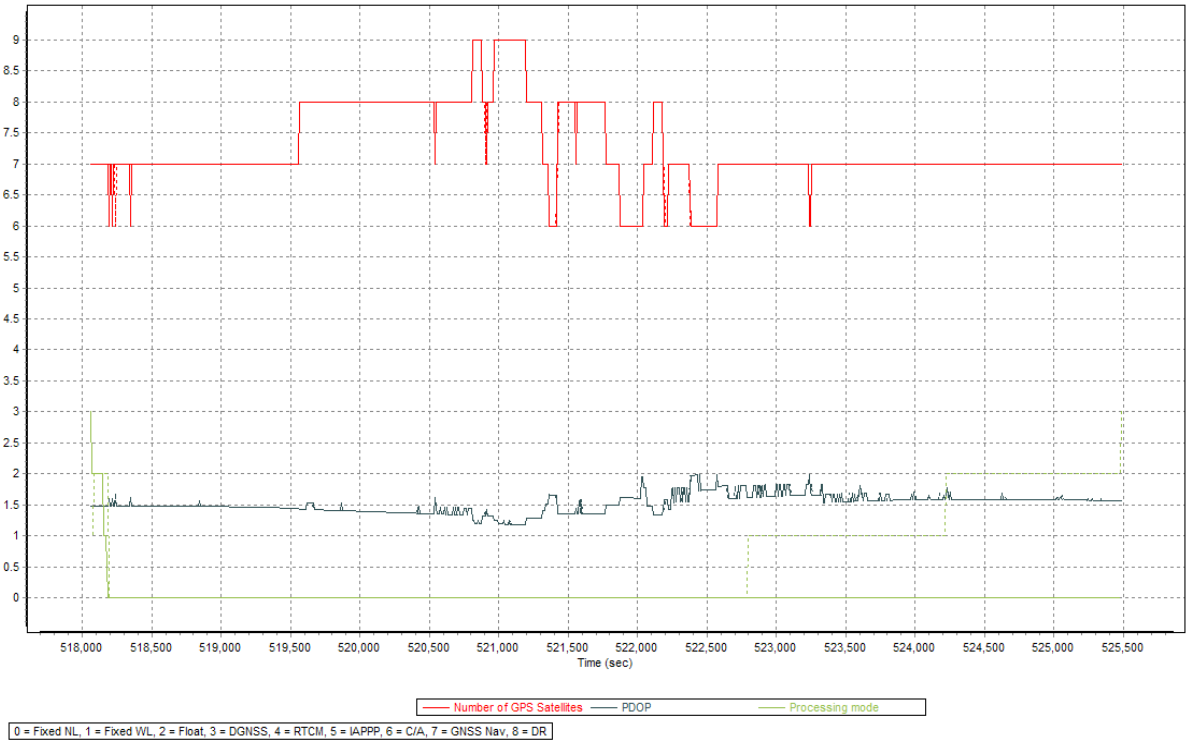


Figure 1.12.1. Solution Status

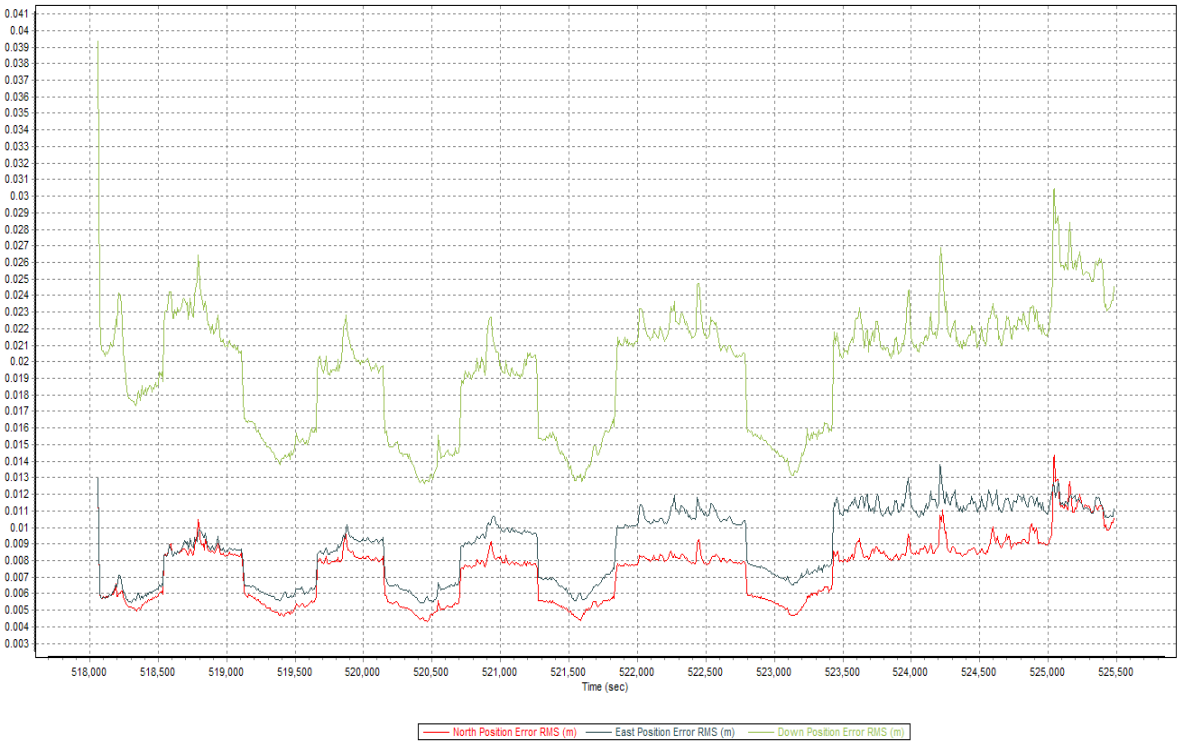


Figure 1.12.2. Smoothed Performance Metrics Parameters

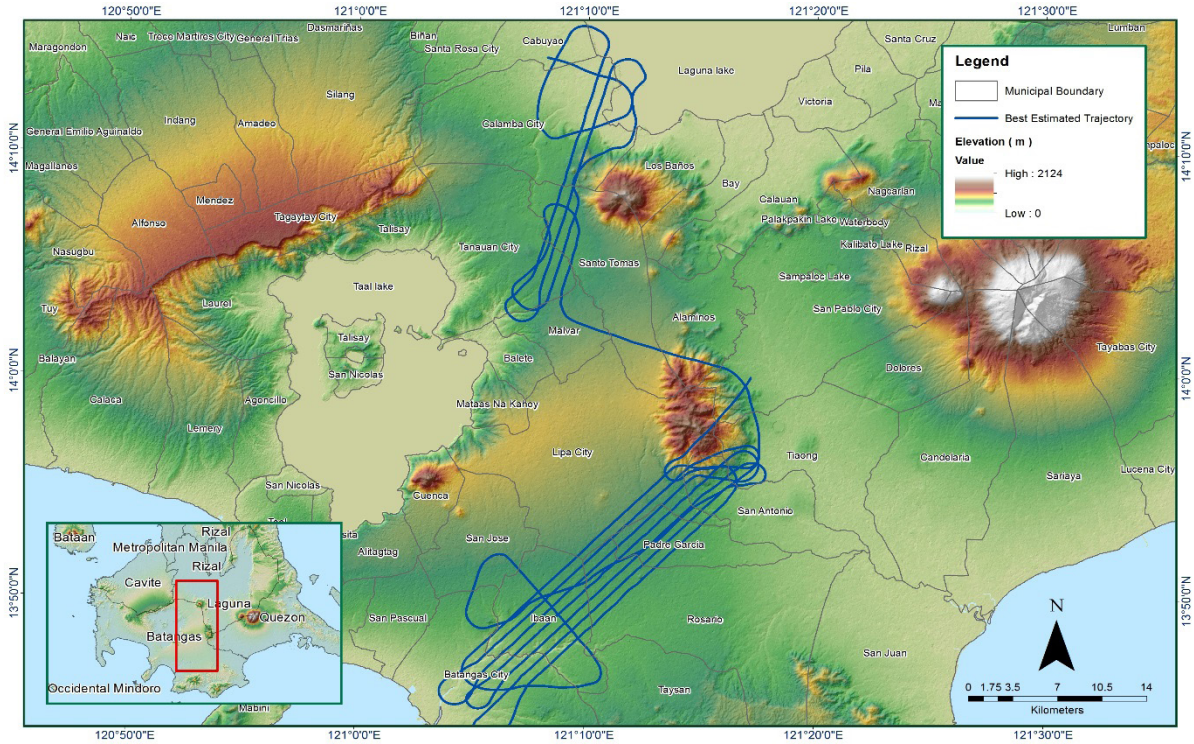


Figure 1.12.3. Best Estimated Trajectory

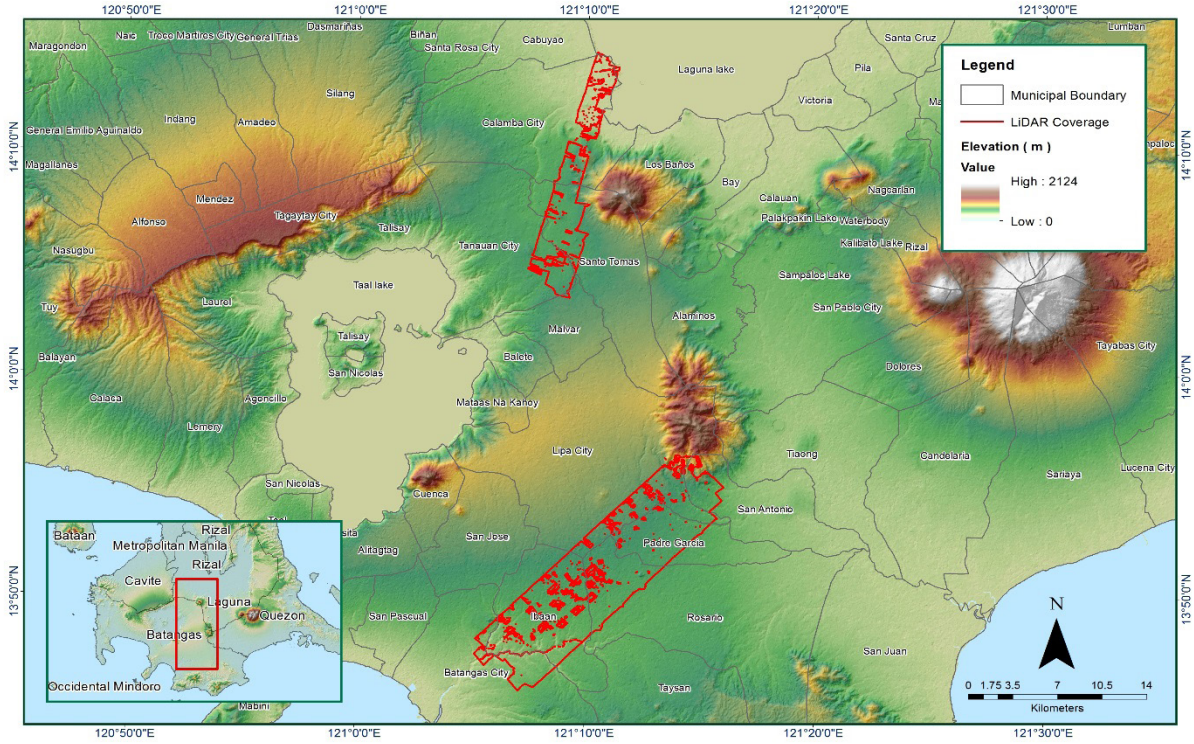


Figure 1.12.4. Coverage of LiDAR data

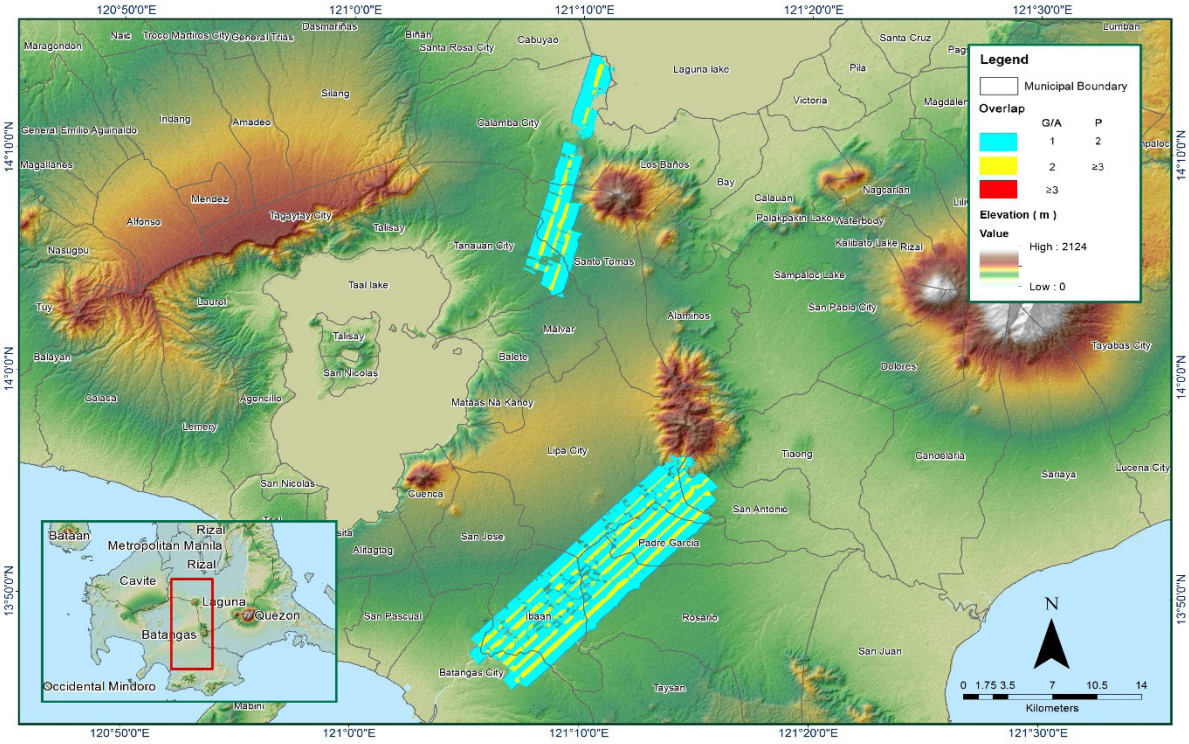


Figure 1.12.5. Image of data overlap

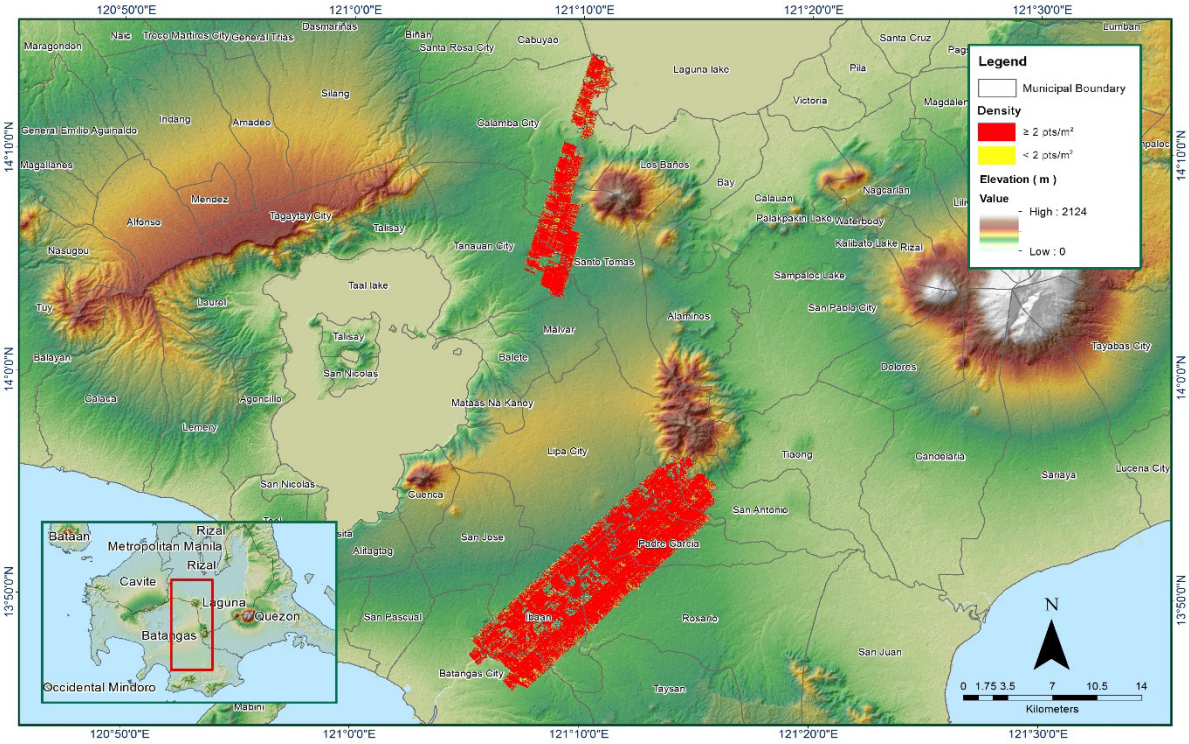


Figure 1.12.6. Density map of merged LiDAR data

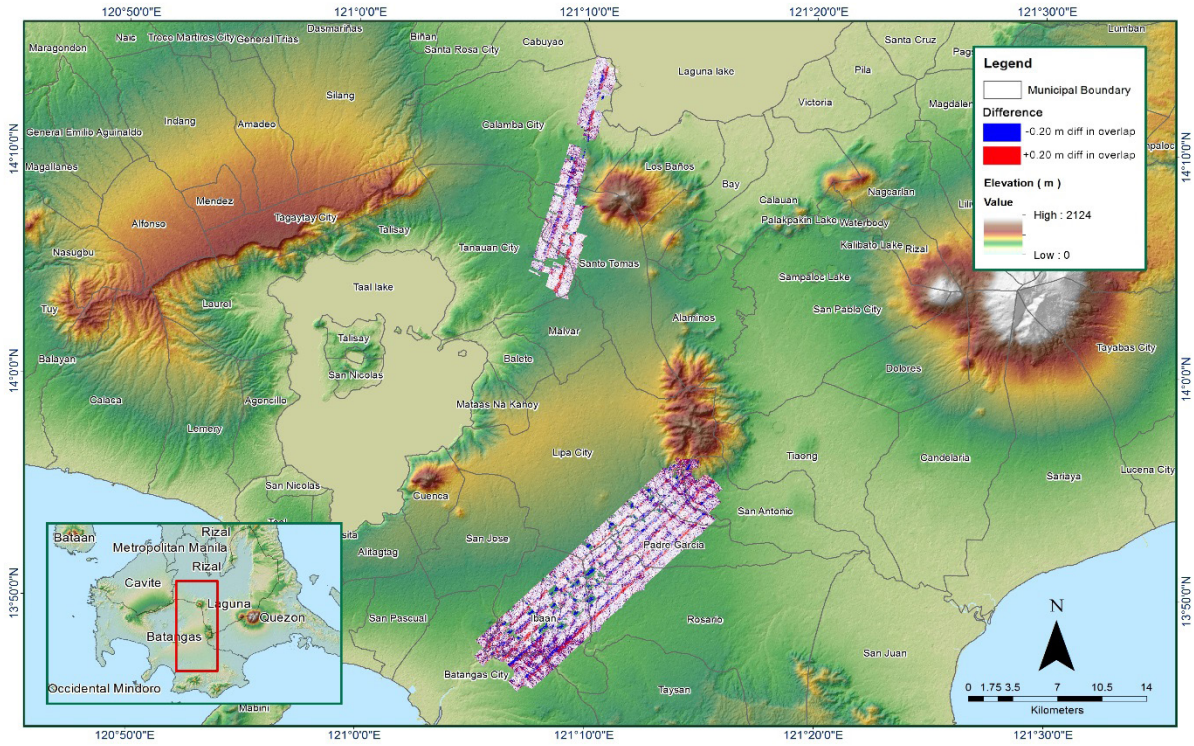


Figure 1.12.7. Elevation difference between flight lines

Annex 9. Calumpang Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Imper-vious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1000	6.4997	50.61	0	16.027	50.446	Discharge	.000219401	0.0213968	Ratio to Peak	0.5
W1010	0.18143	99	0	4.2731	5.8798	Discharge	2.32208E-5	0.0043686	Ratio to Peak	0.0956035
W1020	2.4652	99	0	0.0166667	21.034	Discharge	.000113119	0.0043449	Ratio to Peak	0.5
W1030	7.763	76.981	0	3.7468	3.1395	Discharge	.000477928	0.0014856	Ratio to Peak	0.5
W1040	4.0665	35.236	0	21.648	456.83	Discharge	7.50985E-6	0.0017318	Ratio to Peak	0.5
W1050	0.72586	99	0	3.8434	2.1013	Discharge	0.0011369	0.0711549	Ratio to Peak	0.5
W1060	5.782	39.747	0	26.092	43	Discharge	0.0012837	0.0298211	Ratio to Peak	0.5
W1070	6.2183	57.685	0	1.8029	9.6377	Discharge	2.20959E-5	.000200481	Ratio to Peak	0.5
W1080	12.387	78.895	0	8.2582	0.70597	Discharge	7.32635E-5	.000119695	Ratio to Peak	0.0708667
W1090	0.88965	98.451	0	0.29588	0.42443	Discharge	.000146778	.00019349	Ratio to Peak	0.0054947
W1100	6.7248	74.778	0	5.283	10.499	Discharge	.00040782	0.0146076	Ratio to Peak	0.5
W1110	0.8134	89.099	0	0.0166667	0.07932	Discharge	5.55855E-5	0.0014043	Ratio to Peak	0.0239109
W1120	0.55439	99	0	0.90769	1.9304	Discharge	.000315791	.000614519	Ratio to Peak	0.0104353
W1130	1.8154	93.976	0	0.16631	0.0785829	Discharge	.000244551	.000284409	Ratio to Peak	0.0948509
W1140	1.6418	90.225	0	0.0166667	0.0698002	Discharge	.000156576	0.0014043	Ratio to Peak	0.12352
W580	2.9715	84.722	0	20.877	2.7876	Discharge	.000702646	1.0E-5	Ratio to Peak	0.5
W590	2.3835	72.058	0	14.619	3.7432	Discharge	.000507817	.000257311	Ratio to Peak	0.5
W600	2.2689	99	0	18.576	5.775	Discharge	.000387069	0.07756	Ratio to Peak	0.5
W610	4.0761	49.193	0	66.642	41.385	Discharge	0.0011520	0.1601	Ratio to Peak	0.5
W620	12.321	35.229	0	14.103	5.2019	Discharge	0.0012063	0.0021932	Ratio to Peak	0.5
W630	10.139	86.931	0	352.95	5.7658	Discharge	.000291678	0.0013018	Ratio to Peak	0.5
W640	3.4544	80.073	0	0.0166667	20.19	Discharge	0.0011735	0.18423	Ratio to Peak	0.5
W650	2.9396	93.244	0	9.0666	1.9359	Discharge	.000530271	0.0022608	Ratio to Peak	0.5

W660	8.1786	66.072	0	3.2761	7.1649	Discharge	0.0001496	0.0021822	Ratio to Peak	0.5
W670	1.45	77.353	0	0.0166667	2.9349	Discharge	.000260708	0.15166	Ratio to Peak	0.5
W680	3.2785	68.615	0	1.9017	0.33713	Discharge	.000525382	0.003357	Ratio to Peak	0.5
W690	2.6799	91.688	0	2.5693	5.0133	Discharge	.000103674	0.18409	Ratio to Peak	0.5
W700	3.6147	87.754	0	3.7775	2.0237	Discharge	.000287272	0.47142	Ratio to Peak	0.5
W710	1.759	69.045	0	2.292	0.37893	Discharge	.000235319	0.21082	Ratio to Peak	0.5
W720	3.5761	99	0	4.9346	7.1244	Discharge	.000167027	0.12496	Ratio to Peak	0.5
W730	3.1616	99	0	12.107	0.0166667	Discharge	.000736261	0.60262	Ratio to Peak	0.34825
W740	4.0357	70.567	0	0.0166667	15.832	Discharge	.000528348	0.0022837	Ratio to Peak	0.5
W750	8.3434	77.239	0	4.659	2.9764	Discharge	.000558337	0.003083	Ratio to Peak	0.5
W760	0.39705	98.01	0	5.4008	13.696	Discharge	.00026923	0.27476	Ratio to Peak	0.5
W770	3.4121	77.084	0	7.31	5.6094	Discharge	.00029186	0.26473	Ratio to Peak	0.5
W780	1.6749	91.943	0	18.286	5.82	Discharge	0.0012911	0.0228267	Ratio to Peak	0.28359
W790	0.98216	89.042	0	3.0088	1.1589	Discharge	.000592078	0.93547	Ratio to Peak	0.5
W800	2.9352	65.288	0	6.7205	6.01	Discharge	.000272667	0.63633	Ratio to Peak	0.5
W810	3.0305	99	0	3.46	16.039	Discharge	.000418346	0.18887	Ratio to Peak	0.5
W820	7.1625	46.113	0	4.6826	4.5542	Discharge	.000118492	0.0030676	Ratio to Peak	0.5
W830	3.9729	85.487	0	6.9708	0.0166667	Discharge	.000481492	0.65774	Ratio to Peak	0.5
W840	0.38696	99	0	5.4734	0.0166667	Discharge	.000353214	0.98815	Ratio to Peak	0.5
W850	1.259	99	0	7.7959	0.75067	Discharge	.000770304	0.63875	Ratio to Peak	0.5
W860	6.9892	35.205	0	1.8221	5.9644	Discharge	.000403804	0.0046012	Ratio to Peak	0.5
W870	2.1865	79.989	0	3.1492	0.0166667	Discharge	9.26446E-5	0.3851	Ratio to Peak	0.5
W880	1.8716	99	0	2.4735	4.5212	Discharge	.000183806	0.43386	Ratio to Peak	0.5
W890	2.8074	78	0	0.24241	3.3469	Discharge	.000309111	0.66667	Ratio to Peak	0.5
W900	2.3843	99	0	0.0166667	0.77396	Discharge	.000119221	0.42264	Ratio to Peak	0.4975
W910	0.31933	84.246	0	1.2871	0.0166667	Discharge	.000242666	0.66667	Ratio to Peak	0.75
W920	2.6777	85.3	0	6.5304	9.5474	Discharge	.000254933	0.28456	Ratio to Peak	0.5
W930	1.6734	99	0	16.771	7.3429	Discharge	.00034255	0.42685	Ratio to Peak	0.5

W940	3.6231	46.358	0	10.853	252.57	Discharge	2.49302E-5	0.16801	Ratio to Peak	0.5
W950	5.1534	85.767	0	5.4602	26.014	Discharge	.000193522	0.18971	Ratio to Peak	0.5
W960	3.6534	87.325	0	17.256	6.3404	Discharge	0.0010115	0.19654	Ratio to Peak	0.5
W970	3.6766	52.885	0	5.3516	995	Discharge	6.87262E-5	0.28848	Ratio to Peak	0.5
W980	2.1108	67.064	0	13.093	9.0661	Discharge	.000114363	0.29917	Ratio to Peak	0.5
W990	1.1972	96.827	0	2.2035	5.3218	Discharge	.000481932	0.2963	Ratio to Peak	0.5

Annex 10. Calumpang Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	4279.2	0.0154059	0.0001	Trapezoid	50	45
R140	Automatic Fixed Interval	4206.3	0.0130550	0.0031315	Trapezoid	50	45
R170	Automatic Fixed Interval	2271.4	0.0188560	0.0001	Trapezoid	50	45
R220	Automatic Fixed Interval	1463.7	0.0086518	.000209531	Trapezoid	50	45
R250	Automatic Fixed Interval	2067.4	0.0031983	0.0125833	Trapezoid	50	45
R270	Automatic Fixed Interval	9575.2	0.0080064	0.0660926	Trapezoid	50	45
R280	Automatic Fixed Interval	2285.9	.0007167045832783606	0.0001	Trapezoid	50	45
R290	Automatic Fixed Interval	1226.1	.0007568776528695574	.000312869	Trapezoid	50	45
R300	Automatic Fixed Interval	2618.9	0.0078028	0.0021556	Trapezoid	50	45
R320	Automatic Fixed Interval	1005.3	0.0079183	0.0111447	Trapezoid	50	45
R330	Automatic Fixed Interval	1243.3	0.0284608	.000120614	Trapezoid	50	45
R340	Automatic Fixed Interval	6662.4	0.0175610	0.0031672	Trapezoid	50	45
R350	Automatic Fixed Interval	1644.3	0.0162837	0.0001	Trapezoid	50	45
R360	Automatic Fixed Interval	3903.5	0.0193559	0.0001	Trapezoid	50	45
R370	Automatic Fixed Interval	9173.2	0.0163789	.000664778	Trapezoid	50	45
R380	Automatic Fixed Interval	2548.2	0.0135790	0.0223875	Trapezoid	50	45
R390	Automatic Fixed Interval	1039.5	0.0013045	0.18651	Trapezoid	50	45
R400	Automatic Fixed Interval	7708.4	0.0143203	.000229906	Trapezoid	50	45
R410	Automatic Fixed Interval	365.56	0.0093695	0.0045461	Trapezoid	50	45
R420	Automatic Fixed Interval	1254.7	0.0065916	0.0476641	Trapezoid	50	45
R440	Automatic Fixed Interval	730.12	0.0027957	.000249536	Trapezoid	50	45
R450	Automatic Fixed Interval	685.98	0.0160383	0.0001	Trapezoid	50	45
R460	Automatic Fixed Interval	3881.9	0.0059785	0.0544454	Trapezoid	50	45

R480	Automatic Fixed Interval	1112.7	0.0043431	0.0090216	Trapezoid	50	45
R500	Automatic Fixed Interval	1075.1	.000604183	0.20343	Trapezoid	50	45
R530	Automatic Fixed Interval	1348.1	0.0079600	0.00999	Trapezoid	50	45
R540	Automatic Fixed Interval	415.42	0.0174321	0.0001	Trapezoid	50	45
R70	Automatic Fixed Interval	2822.5	0.0089588	0.0750684	Trapezoid	50	45

Annex 11. Calumpang Field Validation

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
40	13.754154	121.044694	0.05	1	0.95	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
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
83	13.757645	121.059426	0.11	0.2	0.09	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
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
126	13.764127	121.072344	0.28	2	1.72	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
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
168	13.770533	121.050769	0.07	0.5	0.43	Glenda/ July 15, 2014	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
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
				RMSE	2.5576887		

Annex 12. Educational Institutions Affected by Flooding in Calumpang Floodplain

Batangas				
Batangas City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Athena School	Alangilan			
Paaralang Elementarya ng Alingilan	Alangilan			
Star Kids Prime School	Alangilan			Low
Balagtas Elementary School	Balagtas			
Elementary School	Banaba Center	Medium	Medium	Medium
St. Bridget College	Barangay 1		Medium	Medium
UCCP Hope Christian School of Batangas Inc.	Barangay 14			
Elite Kids Tutorial	Barangay 16			
Univeristy of Batangas Elem. Dept.	Barangay 16			
Young Intelligence Tutorial Center	Barangay 16			
Home of Knowledge (Learning Center and Review)	Barangay 17			
St. Bridget College	Barangay 17			Medium
St. Bridget College Auditorium	Barangay 17			
Univeristy of Batangas Elem. Dept.	Barangay 17			
Wonder Kids	Barangay 17			
Elite Kids Tutorial	Barangay 18	Low	Low	Low
Home of Knowledge (Learning Center and Review)	Barangay 18			
Kids Advantage Learning Center	Barangay 18			
St. Bridget College	Barangay 18	Medium	Medium	High
Batangas National High School	Barangay 20			
Julia A. Pastor Elementary School	Barangay 20	Low	Low	Medium
Sterling Tutorial	Barangay 20			
Batangas National High School	Barangay 22	Low	Low	Low
Divine Child Academy (Elementary)	Barangay 3			
East Central School	Barangay 4			
Divine Child Academy (Elementary)	Barangay 5			
Divine Child Academy (Highschool)	Barangay 5			Low
Golden Gate College Building	Barangay 5			Low
Holy Child School	Barangay 5			
East Central School	Barangay 6	Low	Low	Low
STI	Barangay 6			
Golden Gate College (HS)	Barangay 8		Low	Low
Golden Gate College Building	Barangay 8			Low
nstitution for Developmental Education	Barangay 8	Low	Medium	Medium
Branded Overruns Shoppe	Calicanto	Low	Medium	Medium
Immaculate Heart of Mary School of Values	Calicanto			
Day Care Center	Catandala	Low	Low	Low
Katandala Elementary School	Catandala			

Conde Labac Elementary School	Conde Itaas			
Conde Labac National High School	Conde Itaas	Low	Low	Medium
Day Care Center	Conde Itaas			
Day Care Center	Cuta		Medium	Medium
Daycare Center	Cuta		Low	Medium
Holy Cross Montessori School	Cuta		Medium	Medium
Lyceum of the Philippines Batangas	Cuta	Low	Low	Low
Lyceum of the Philippines Martime Training Center	Cuta			
Malitam Elementary School	Cuta		Medium	Medium
Wawa Elementary School	Cuta	Low	Medium	Medium
Dalig Elementary School	Dalig			
Dumuclay Day Care Center	Domoclay			
Dumuclay Elementary School	Domoclay			
Sirang Lupa Elementary School	Domoclay			
Dumantay Elementary School	Dumantay			Low
Gulod Elementary School	Gulod Itaas			
Stonyhurst International School	Gulod Itaas	Low	Medium	Medium
Sunhill Development School	Gulod Itaas			
Dumuclay Elementary School	Gulod Labak			
Christ the Lord Institute Foundation Inc.	Kumintang Ibaba			
East Central School	Kumintang Ibaba	Medium	Medium	Medium
Immaculate Heart of Mary School of Values	Kumintang Ibaba			
Lyceum of the Philippines - Batangas	Kumintang Ibaba			
Lyceum of the Philippines University - Batangas	Kumintang Ibaba			
Sycamore Tree Pre-School	Kumintang Ibaba			Low
WestMead International School	Kumintang Ibaba	Low	Low	Low
Kumintang Elementary School	Kumintang Ilaya			
STI Academic Center	Kumintang Ilaya	Low	Low	Low
Libjo Elementary School	Libjo	Low	Medium	Medium
Libjo National High School	Libjo	Medium	Medium	Medium
Saint Peter D'rock School	Libjo	Medium	Medium	Medium
Store	Libjo	Low	Medium	Medium
Day Care Center	Mahabang Parang			
Mahacot Day Care Center (Old)	Mahacot Silangan			
Mahacot Elementary School	Mahacot Silangan			
Eulalia Talban Ebora Memorial Elementary School	Malalim			
Malitam Elementary School	Malitam		Medium	Medium
Jose Pastor Memorial Elem. School	Pallocan Kanluran	Medium	High	High
St. Therese of the Child Jesus School	Pallocan Kanluran	Low	Medium	Medium
Carmel School of Batangas	Pallocan Silangan	Medium	Medium	Medium
Pallocan East Elementary School	Pallocan Silangan	Low	Low	Low
University of Batangas	Pallocan Silangan			
Day Care Center	Sampaga			
Sampaga Elementary School	Sampaga			

Alternative Learning School	San Isidro		Low	Low
Bahay Unlad Day Care Center	San Isidro	Medium	Medium	Medium
San Isidro Elementary School	San Isidro			
SIMCO Village Learning Center	San Isidro			
San Pedro Elementary School	San Pedro			
Batangas National High School	Santa Clara	Medium	Medium	Medium
Batangas State University	Santa Clara	Low	Low	Low
Day Care Center	Santa Clara			Low
Julia A. Pastor Elementary School	Santa Clara	Medium	Medium	Medium
Sta. Clara Elementary School	Santa Clara	Medium	Medium	Medium
Sta. Rita Aplaya Elementary School	Santa Rita Aplaya	Medium	Medium	Medium
Mababang Paaralan ng Sta. Rita	Santa Rita Karsada	Low	Low	Medium
Princeton Science School	Santa Rita Karsada	Low	Low	Low
Sirang Lupa Elementary School	Sirang Lupa			
Soro Soro National High School	Sorosoro Ibaba			
Galvasteel Corporation	Sorosoro Karsada			
Day Care Center	Tinga Itaas			
Tinga Itaas Elementary School	Tinga Itaas			
Tingga Labac Elementary School	Tinga Labak			
Day Care Center	Tulo			
Guardian Angels School of Batangas	Tulo			
Tulo I Elementary School	Tulo			
Tulo II Elementary School	Tulo			
Wawa Elementary School	Wawa		Low	Medium

Batangas				
Ibaan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Balanga Elementary School	Balanga			
Day Care Center	Balanga			
Bungahan Elementary School	Bungahan			
Day Care Center	Bungahan			
Mabalor-Catandala Elementary School	Catandala			
Coliat Elementary School	Coliat		Low	Low
Day Care Center	Coliat			
Lucsuhin Elementary School	Lucsuhin			
Day Care Center	Mabalor			Low
Ibaan Central School	Palindan			
Paaralang Elementarya ng Pag-Asa	Panghayaan			
Quilo Elementary School	Quilo			
Sabang Day Care Center	Sabang	Low	Low	Low
Sabang Elementary School	Sabang			

Batangas				
Rosario				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Colongan Elementary School	Colongan			
Itlugan National High School	Itlugan			
Day Care Center	Maalas-As			
Maalas-As Elementary School	Maalas-As			
Day Care Center	Timbugan			
Timbugan Elementary School	Timbugan			
Timbugan National High School	Timbugan			

Batangas				
Taysan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Mabayabas Elementary School	Mabayabas			
Taysan Central School	Mabayabas			
Day Care Center	Mahanadiong			
Day Care Center	Pag-Asa		Low	Low
Panghayaan Elementary School	Pag-Asa			
Taysan National High School	Poblacion West	Low	Low	Low

Annex 13. Health Institutions Affected by Flooding in Calumpang Floodplain

Batangas				
Batangas City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Batangas Health Care Hospital	Barangay 12			
Pediatric Clinic	Barangay 12			
Luna-Lacsamana Maternity and Lying-in Clinic	Barangay 14			Low
Gusaling Pangkalusugan	Barangay 16		Low	Low
Clinic for the sick Children	Barangay 17			
Luna-Lacsamana Maternity and Lying-in Clinic	Barangay 23			Low
Children's Clinic	Barangay 3			Low
De Jesus Maternity & Medical Clinic	Barangay 3		Low	Medium
St. Patrick's Hospital Medical Center	Barangay 3			Low
Golden Gate General Hospital	Barangay 5		Low	Low
Trihealth Nutraceuticals	Barangay 6			
Golden Gate General Hospital	Barangay 7	Low	Low	Low
Children's Clinic	Barangay 8			Low
Golden Gate General Hospital	Barangay 8		Low	Low
Montage Skin Science	Barangay 9	Medium	Medium	Medium
St. Camillus Hospital	Bolbok			
Children's Clinic	Calicanto			
Hemotek Renal Center	Calicanto			
Health Center	Domoclay			
Batangas Medical Society	Gulod Itaas			
Jesus of Nazareth Hospital	Gulod Itaas			
Batangas Medical Center	Kumintang Ibaba			
Batangas Regional Hospital	Kumintang Ibaba			
D. Dimaandal Care Center	Kumintang Ibaba			
Guia's Pharmacy	Kumintang Ibaba			
LPU Community Health Care Center	Kumintang Ibaba			Low
LPU Physical Therapy Clinic	Kumintang Ibaba			
Pioneer Clinical Laboratory, Inc.	Kumintang Ibaba	Low	Low	Low
Provincial Health Office	Kumintang Ibaba			
D. Dimaandal Care Center	Kumintang Ilaya			
Health Center	Mahacot Kanluran			
Health Center	Malalim			
Health Center	Malitam		Medium	Medium
San Isidro Health Center and Birthing Facility	San Isidro		Low	Low
JLS Birthing Home Clinic	Santa Clara			
Malabanan Clinic	Santa Clara	Low	Medium	Medium
Children's Clinic	Santa Rita Karsada			
Health Center	Tinga Labak			
Health Center	Tulo			

Batangas				
Ibaan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Dayapan			

Batangas				
Taysan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Mabayabas			
Health Center	Mahanadiong			
Health Center	Pag-Asa		Low	Low
Health Center	Poblacion West			