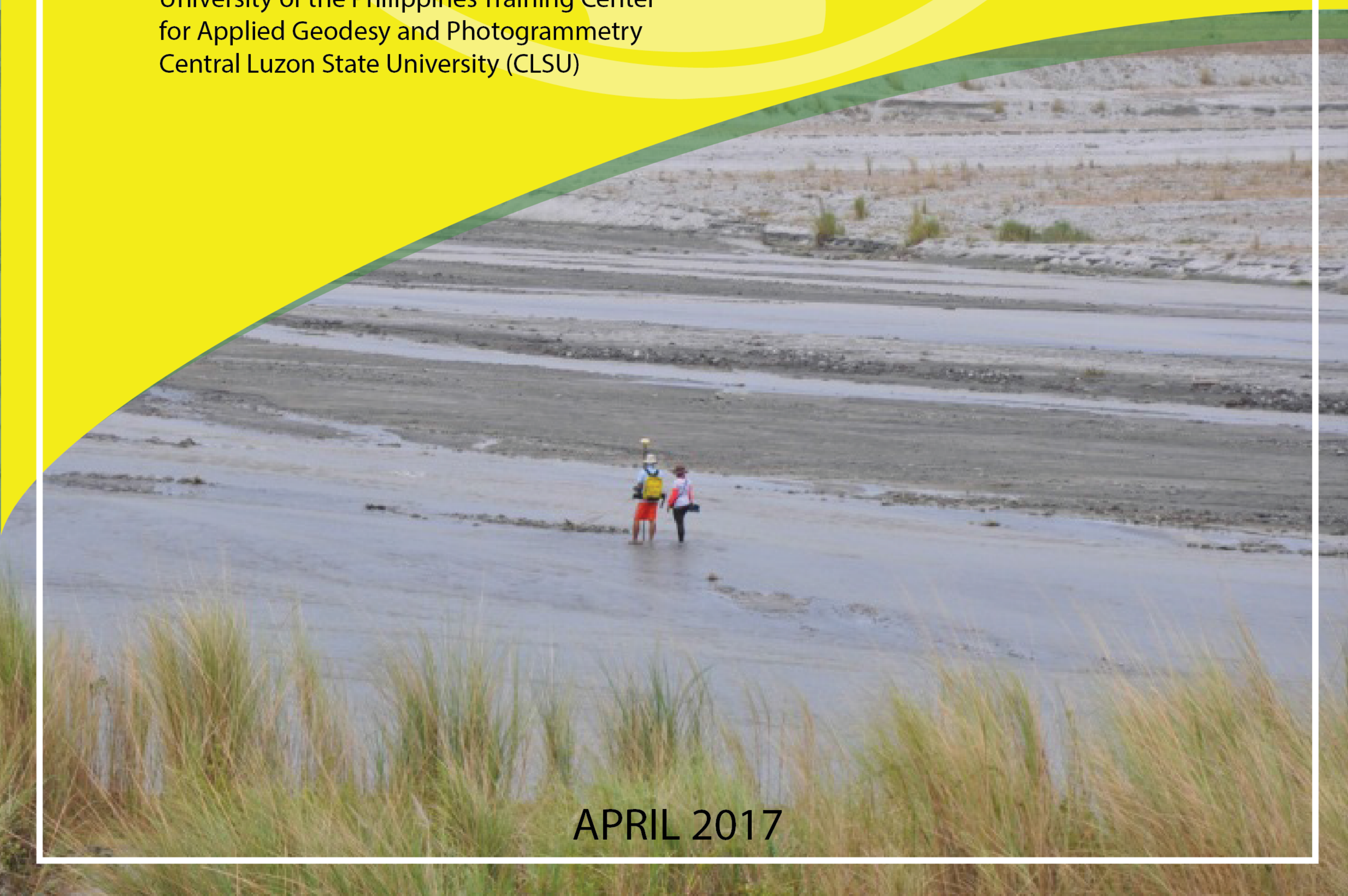
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Sto. Tomas River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Central Luzon State University (CLSU)



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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
CLSU	Central Luzon State University
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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 STO. TOMAS RIVER

Enrico C. Paringit, Dr. Eng., Dr. Annie Melinda Paz-Alberto, and Kathrina M. Mapanao

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 Central Luzon State University (CLSU). CLSU 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 8 river basins in the Central Luzon Region. The university is located in the Science City of Muñoz in the province of Nueva Ecija.

1.2 Overview of the Sto. Tomas River Basin

Sto. Tomas River Basin covers portions of the Municipalities of San Marcelino, San Narciso, Castillejos, Subic, and Olongapo City, in the Province of Zambales. The DENR River Basin Control Office (RBCO) identified it to be one of the 421 river basins in the Philippines, having a drainage area of 263 km2 and an estimated 294 million cubic meter (MCM) annual run-off. It is also one of the two (2) major river basins in Zambales.

Its main stem, Sto. Tomas River, passes along the Municipalities of San Marcelino and San Narciso. The river is part of the (8) river systems in Central Luzon Region. There are about 17,431 people residing in the immediate vicinity of the river distributed among the eleven (11) barangays, namely: Aglao, Consuelo Norte, Laoag, Lucero, Rabanes, and San Rafael in the Municipality of San Marcelino; and Alusiis, Grullo, Namatacan, Omaya, and Paite in the Municipality of San Narciso (NSO, 2010).

During Typhoon Helen on August 2012, Zambales was declared under a state of calamity due to torrential rains. Heavy flooding was experienced by the entire province caused by the swelling of rivers, including Sto. Tomas River, and other waterways.

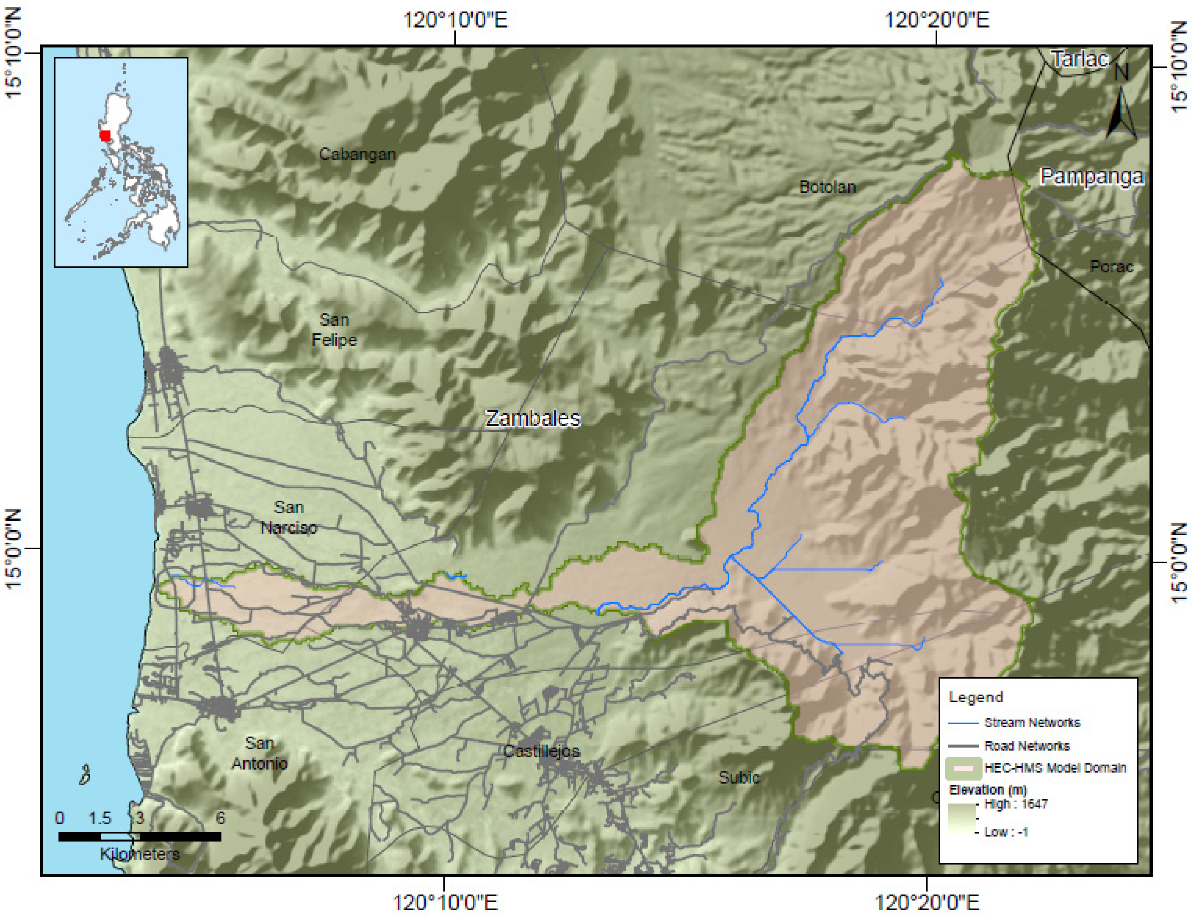

Figure 1. Map of the Sto. Tomas River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN STO. TOMAS FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Sto. Tomas in Zambales. These missions were planned for fourteen (14) lines that run for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 2 and Figure 3 show the flight plans and base stations used for Sto. Tomas Floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%) cfv	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BUC C	1200	30	50	150	30	130	5
BUC D	1200	30	50	150	30	130	5
BUC G	1200	30	50	150	30	130	5
BUC R	1000	30	50	200	30	130	5
BAL D	1200	30	50	150	30	130	5
BAL F	1200	30	50	150	30	130	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BTN C	800	30	40	100	50	130	5
BTN D	800	30	40	100	50	130	5
BUC F	1100	30	40	100	50	130	5
MTAS	1800	30	40	33	50	130	5
BLK 15	1300	30	24	70	65	130	5
PAM S2	850	30	40	100	50	130	5
BUC E	1000	30	40	100	50	130	5

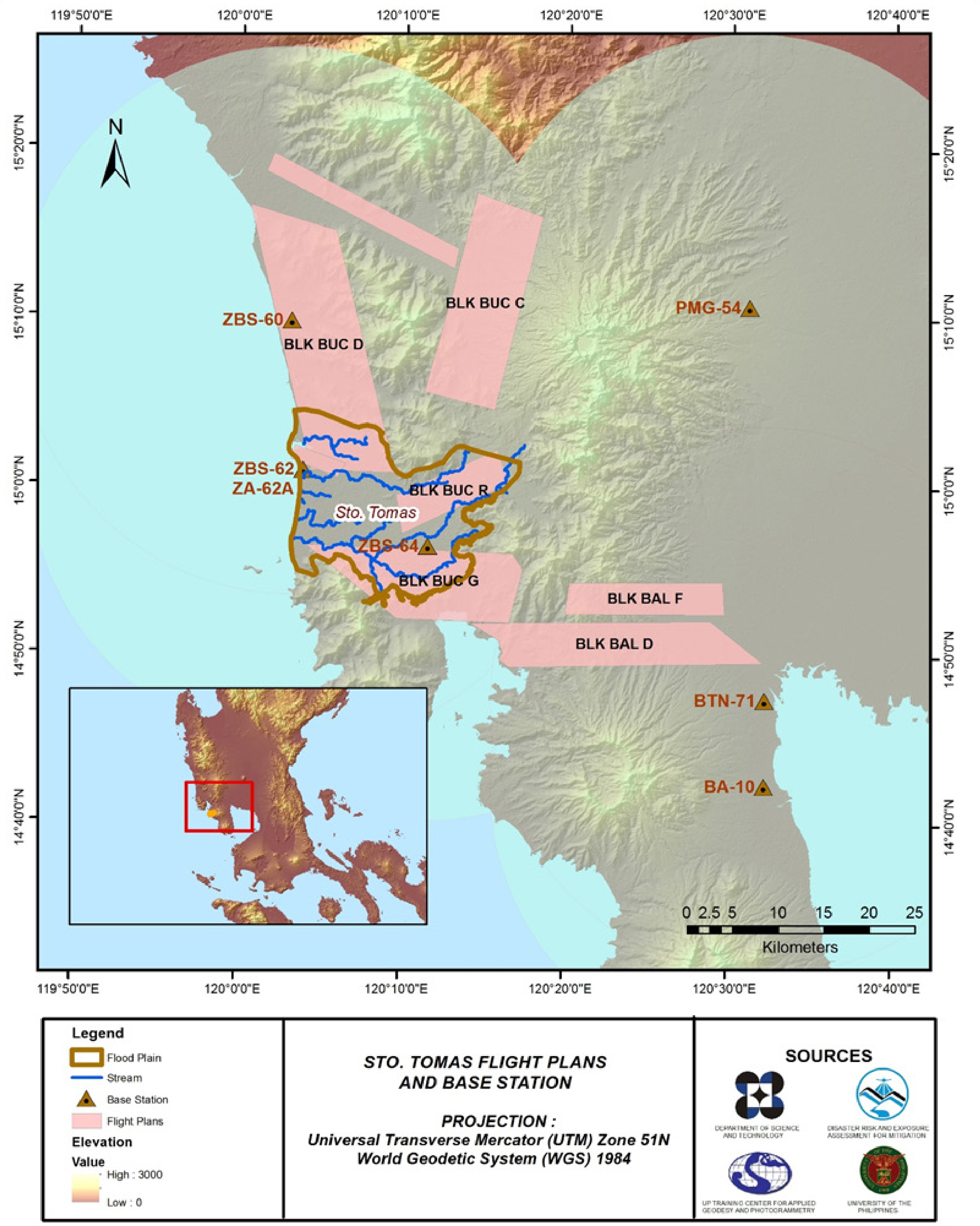


Figure 2. Flight plans and base stations used for Sto. Tomas Floodplain using Pegasus Sensor

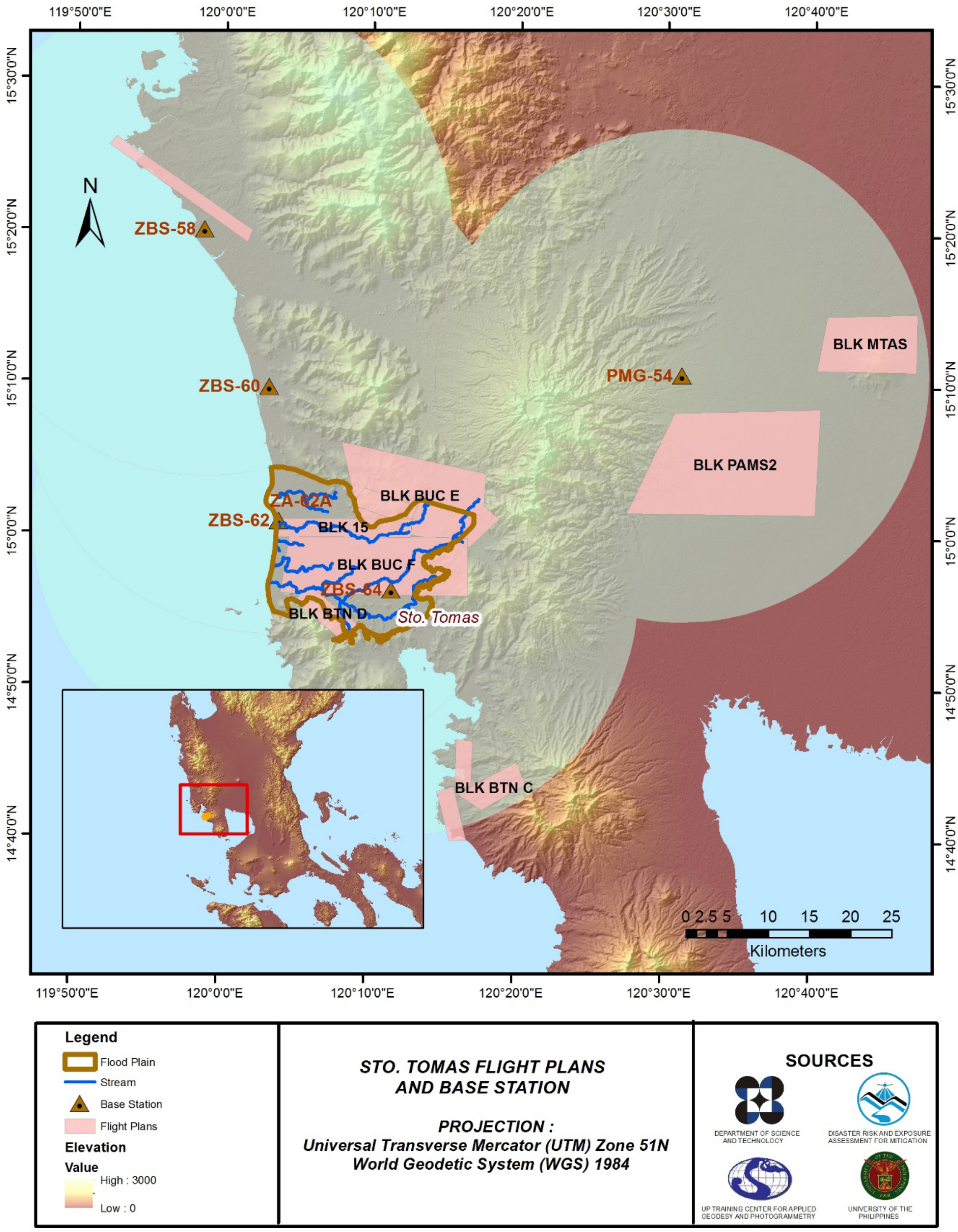
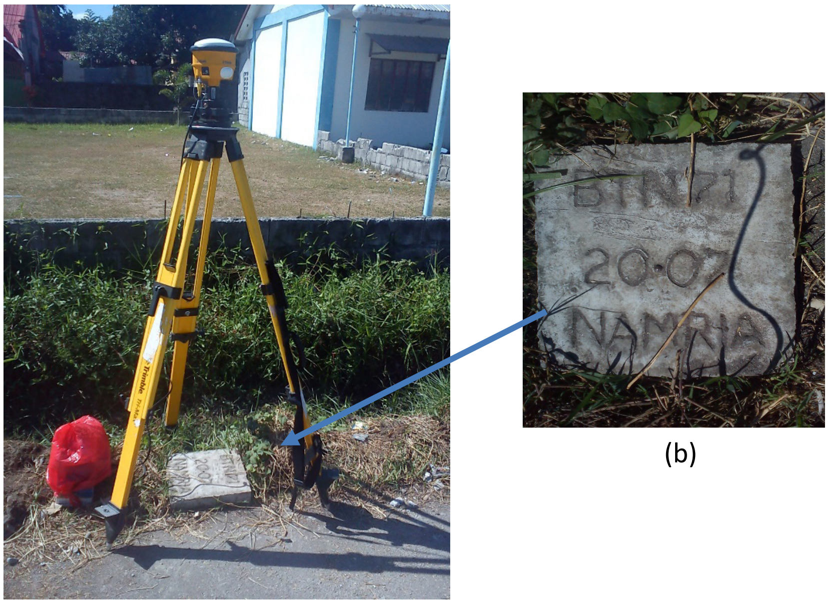


Figure 3. Flight plans and base stations used for Sto. Tomas Floodplain using Gemini Sensor

2.2 Ground Base Stations

The project team was able to recover six (6) NAMRIA horizontal ground control points: BTN-71, ZBS-58, ZBS-60, ZBS-62, ZBS-64 which are all of second (2nd)-order accuracy; and PMG-54 which is of third (3rd)-order accuracy. The project team also established one ground control point (ZA-62A). One (1) NAMRIA benchmark (BA-10) was recovered. It was used as vertical reference point and was established as ground control point. The certification for the NAMRIA reference points and benchmark are found in ANNEX 2 while the baseline processing of the 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 27–January 6, 2014; February 2, 2014; May 17–22, 2014; January 21, 2015, and August 27, 2015). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS852 and TRIMBLE SPS985. Flight plans and location of base stations used during the aerial LiDAR Acquisition in Sto. Tomas Floodplain are shown in Figure 2 and Figure 3.

Figure 4 to Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 10 present the details about the NAMRIA control stations and established points, while Table 11 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.



(b)

(a)

Figure 4. GPS set-up over BTN-71 located in Brgy. Maria Fe, Orani, 30 meters southwest of the Day Care Center, 20 meters southeast of the basketball court and 15 meters of the chapel (a) and NAMRIA reference point BTN-71 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point BTN-71 used as base station for the LiDAR acquisition

Station Name	BTN-71	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	14o 47’ 30.18239” North
	Longitude	120o 32’ 9.95860” East
	Ellipsoidal Height	7.56300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	450060.675 meters
	Northing	1635812.88 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	14o 47’ 24.68277” North
	Longitude	120o 32’ 14.83855” East
	Ellipsoidal Height	49.42500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	234,782.54 meters
	Northing	1,636,645.28 meters

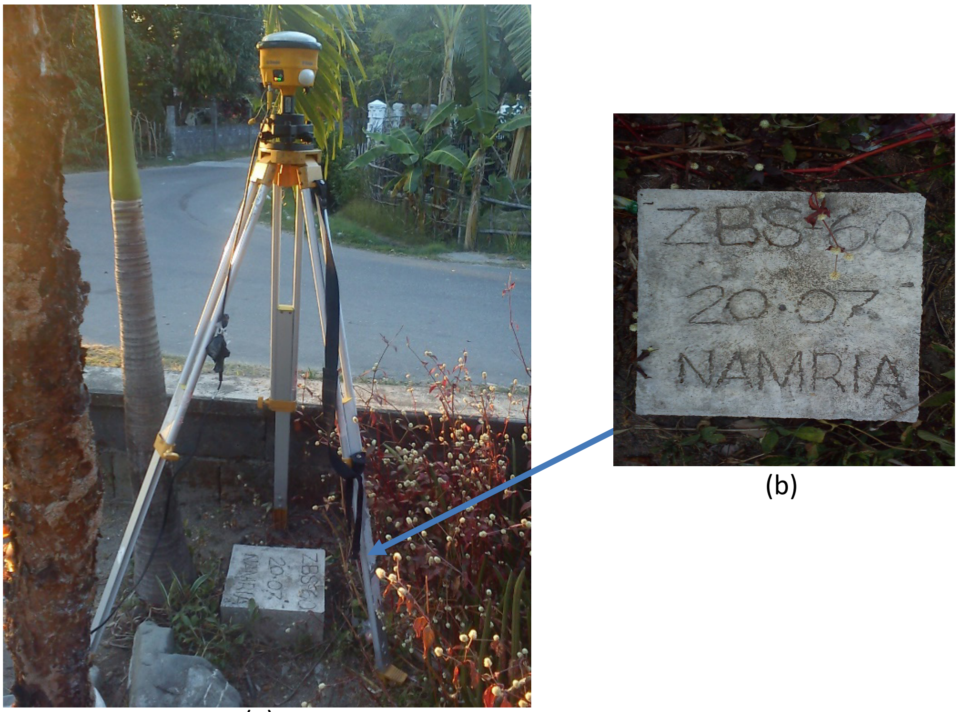
(a)

(b)

Figure 5. GPS set-up over PMG-54 located about 50 meters NE of Bldg. 2127 (Main Bldg.) of Clark Development Corp. and about 3 meters W of the Philippine flagpole (a) and NAMRIA reference point PMG-54 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point PMG-54 used as base station for the LiDAR acquisition

Station Name	PMG-54	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 10' 50.24016" North 120o 31' 8.01131" East 213.00650 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	448156.978 meters 1678845.621 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 10' 44.64998" North 120o 31' 8.01131" East 253.69780 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	233,266.88 meters 1,679,714.68 meters



(b)

(a)

Figure 6. GPS set-up over ZBS-60 located inside the premises of San Antonio Barangay Hall in Cabangan, Zambales, six meters East of Barangay road and ten meters South of basketball court and Children’s Park (a) and NAMRIA reference point ZBS-60 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point ZBS-60 used as base station for the LiDAR acquisition

Station Name	ZBS-60	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 09’ 48.72475” North 120o 03’ 4.60936” East 12.36500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	3998042.381 meters 1677118.723 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 09’ 43.10078” North 120o 03’ 9.45989” East 51.97200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	183,107.00 meters 1,678,445.32 meters

Table 6. Details of the recovered NAMRIA horizontal control point ZBS-58 used as base station for the LiDAR acquisition

Station Name	ZBS-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 20’ 8.92898” North 119o 58’ 34.69353” East 7.77100 meters

Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	390073.626 meters 1696218.486 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 20’ 3.25975” North 119o 58’ 39.52976” East 46.69300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	819,598.83 meters 1,697,561.97 meters

(a) (b)

Figure 7. GPS set-up over ZBS-62 located in the executive park of Barangay La Paz, San Narciso (a) and NAMRIA reference point ZBS-62 (b) as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point ZBS-62 used as base station for the LiDAR acquisition

Station Name	ZBS-62	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15o 0’ 58.08330” North 120o 03’ 50.43021” East 9.87700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	399340.98 meters 1660802.886 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15o 0’ 52.49407” North 120o 03’ 55.29320” East 49.94200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	184,257.98 meters 1,662,105.93 meters

Table 8. Details of the recovered NAMRIA horizontal control point ZBS-64 used as base station for the LiDAR acquisition

Station Name	ZBS-64	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14o 56’ 28.82886” North 120o 11’ 31.25386” East 52.07500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	413077.841 meters 1652473.038 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14o 56’ 23.26711” North 120o 11’ 36.12262” East 92.66800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	197,928.90 meters 1,653,646.25 meters

Table 9. Details of the established NAMRIA horizontal control point BA-10 used as base station for the LiDAR acquisition

Station Name	BA-10	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14o 42’ 24.60522” North 120o 32’ 11.54465” East 14.871 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	234727.081 meters 1627249.500 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14o 42’ 19.12527” North 120o 32’ 16.43182” East 56.977 meters

Table 10. Details of the established NAMRIA horizontal control point ZA-62A used as base station for the LiDAR acquisition

Station Name	ZA-62A	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15^o 00’ 57.82548” North 120^o 03’ 50.43687” East 25.701 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	184258.065 meters 1662097.996 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15^o 00’ 52.23627” North 120^o 03’ 55.29987” East 50.155 meters

Table 11. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
December 27, 2013	923P	1BUCD361A	ZBS-60 and ZBS-62
December 29, 2013	933P	1BALD363B	ZBS-60 and ZBS-62
January 3, 2014	930G	2BUCE003A	ZBS-64 and ZA-62A
January 4, 2014	934G	2BUCF004A	ZBS-60 and ZBS-62 and ZA-62A
January 4, 2014	945P	1BUCCS004B	ZBS-60 and ZBS-62 and ZA-62A
January 5, 2014	949P	1BUCGS005B	ZBS-60 and ZBS-62
January 6, 2014	951P	1BALF006A	BTN-71 and BA-10
February 2, 2014	7047GC	2MTAS033A	PMG-54
May 17, 2014	7254G	2BLK15S1S2137A	PMG-54 and ZBS-60
May 17, 2014	7255GC	2PAMS2137B	PMG-54 and ZBS-60
May 22, 2017	7264G	2BLK15S142A	ZBS-58 and ZBS-62
January 21, 2015	2473P	1BUCR021A	PMG-54
August 27, 2015	2658G	2BTNC239A	ZBS-64

2.3 Flight Missions

Thirteen (13) missions were conducted to complete LiDAR data acquisition in Sto. Tomas Floodplain, for a total of forty-five hours and twelve minutes (45+12) of flying time for RP-C9022 and RP-9322. All missions were acquired using Pegasus and Gemini LiDAR systems. Table 12 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for LiDAR data acquisition in Sto. Tomas Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
December 27, 2013	923P	248.49	60.25	0	60.25	NA	3	17
December 29, 2013	933P	126.02	195.87	0	195.87	NA	3	29
January 3, 2014	930G	153.98	152.36	46.21	106.15	493	4	41
January 4, 2014	934G	159.05	192.75	149.33	43.42	110	5	5
January 4, 2014	945P	171.19	260.67	0	260.67	NA	3	5

January 5, 2014	949P	138.38	120.23	37.86	82.37	NA	3	53
January 6, 2014	951P	59.56	667.48	0	667.48	NA	3	11
February 2, 2014	7047GC	78.59	103.01	0	103.01	NA	1	35
May 17, 2014	7254G	37.17	40.6	15.09	25.51	NA	3	17
May 17, 2014	7255GC	254.97	47.83	0	47.83	NA	2	17
May 22, 2017	7264G	37.17	45.27	27.33	17.94	NA	3	53
January 21, 2015	2473P	108.77	127.5	69.43	58.07	419	3	35
August 27, 2015	2658G	69.96	84.98	12.09	72.89	347	3	54
		1643.3	2098.8	357.34	1741.46	1369		

Table 13. 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)
923P	1200	30	50	150	30	130	5
933P	1200	30	50	150	30	130	5
930G	1000	30	40	100	50	130	5
934G	1100	30	40	100	50	130	5
945P	1200	30	50	150	30	130	5
949P	1200	30	50	150	30	130	5
951P	1200	30	50	150	30	130	5
7047GC	1800	30	40	33	50	130	5
7254G	1300	30	24	70	65	130	5
7255GC	850	30	40	100	50	130	5
7264G	1300	30	24	70	65	130	5
2473P	1000	30	50	200	30	130	5
2658G	1000	30	40	100	50	130	5

2.4 Survey Coverage

Sto. Tomas Floodplain is located in the province of Zambales. Majority of the floodplain is situated in the municipalities of San Marcelino, San Narciso, San Antono, and Castillejos. The municipalities of Dinalupihan, Castillejos, San Narciso, San Marcelino, and the City of Olongapo are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Sto. Tomas Floodplain is presented in Figure 8.

Table 14. List of municipalities and cities surveyed during Balanga floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Bataan	Dinalupihan	95.23	83.89	88.10%
	Hermosa	135.27	46.56	34.42%
	Morong	240.57	55.20	22.94%
	Orani	53.25	4.24	7.97%
Nueva Ecija	Cabiao	110.18	7.53	6.84%
Pampanga	Magalang	99.89	48.38	48.44%
	Arayat	153.46	47.06	30.66%
	Santa Rita	28.49	5.15	18.06%
	Porac	238.99	24.58	10.28%
	Angeles City	64.60	6.47	10.02%
	Bacolor	82.99	5.83	7.02%
	Floridablanca	176.48	7.37	4.18%
	Lubao	166.77	6.08	3.64%
	Mabalacat	257.69	1.90	0.74%
Zambales	Castillejos	72.10	57.96	80.40%
	San Narciso	83.24	59.84	71.90%
	Olongapo City	178.25	96.95	54.39%
	San Marcelino	337.57	178.84	52.98%
	Subic	253.59	84.72	33.41%
	San Antonio	179.71	57.52	32.01%
	Botolan	649.68	195.36	30.07%
	San Felipe	96.23	26.70	27.75%
	Iba	219.08	47.88	21.86%
	Cabangan	231.28	22.23	9.61%
	Palauig	242.92	12.01	4.94%
TOTAL		4447.51	1190.27	26.76%

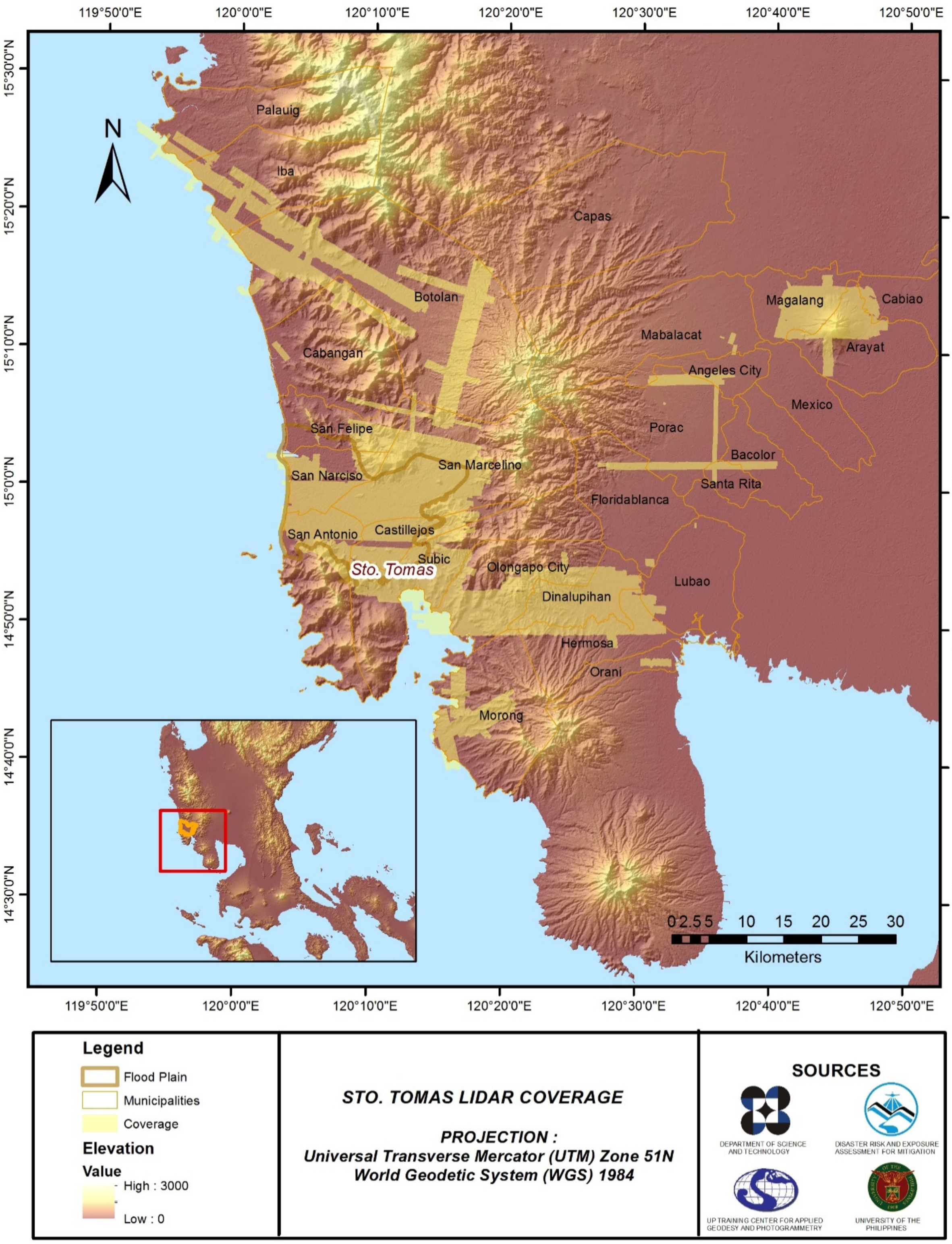


Figure 8. Actual LiDAR survey coverage for Sto. Tomas Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR STO. TOMAS FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Gladys Mae Apat, Engr. Elainne R. Lopez, Engr. Velina Angela S. Bemida, Engr. Monalyne C. Rabino, Engr. Abigail C. Ching, Engr. Jommer M. Medina, John Andrew B. Cruz, Gloria N. Ramos, Hanna Mae T. Carganilla, Cenon Conrado C. Divina, Jeremy Joel J. Barza, Kathrina Mapanao, and Jo Adrianne Espiritu

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 9.

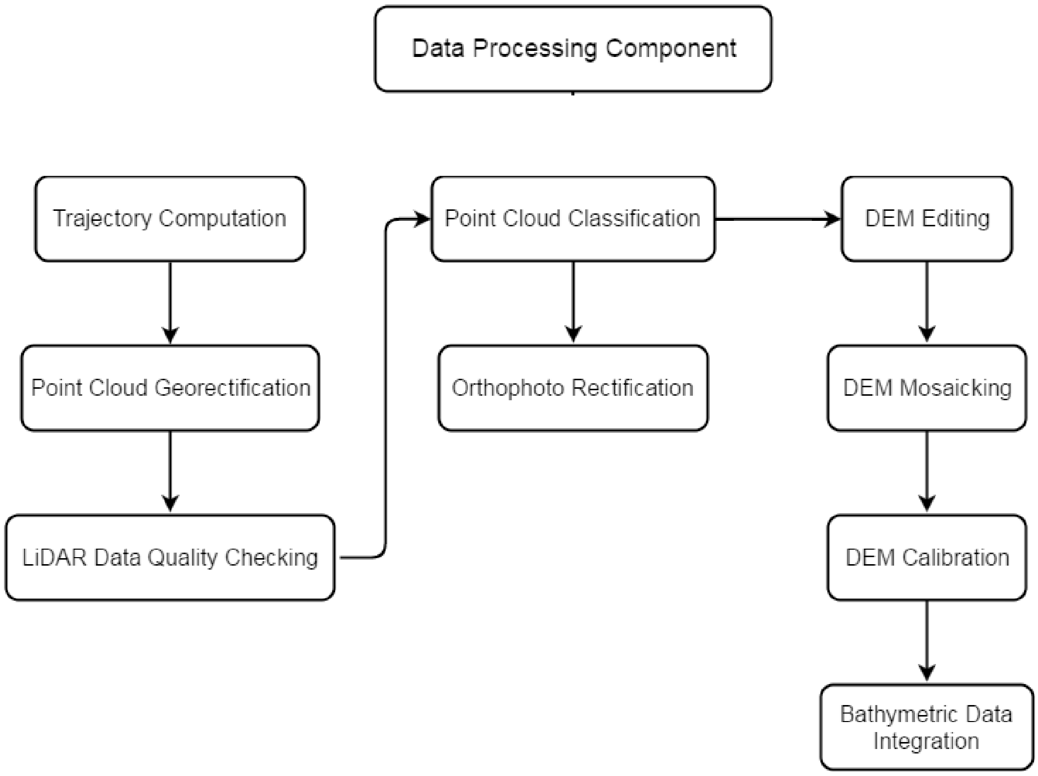


Figure 9. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Sto. Tomas Floodplain can be found in ANNEX 5. Missions flown during the first survey conducted on January 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius and Pegasus systems. The second survey was done on February 2014 and flown using the Gemini system. On May 2014, the third survey used the Gemini system to fly over the Pampanga area. Using the Pegasus system, the fourth survey was conducted over Clark area on January 2015. Lastly, the fifth survey was done on August 2015 using the Gemini system. The Data Acquisition Component (DAC) transferred a total of 205.48 Gigabytes of Range data, 3.20 Gigabytes of POS data, 541.91 Megabytes of GPS base station data, and 134.49 Gigabytes of raw image data to the data server on January 10, 2014 for the first survey, June 17, 2014 for the second survey, May 29, 2014 for the third survey, March 9, 2015 for the fourth survey, and September 11, 2015 for the fifth and last survey. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sto. Tomas was fully transferred on September 11, 2015, as indicated on the data transfer sheets for Sto. Tomas Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 951P, one of the Sto. Tomas flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on January 10, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

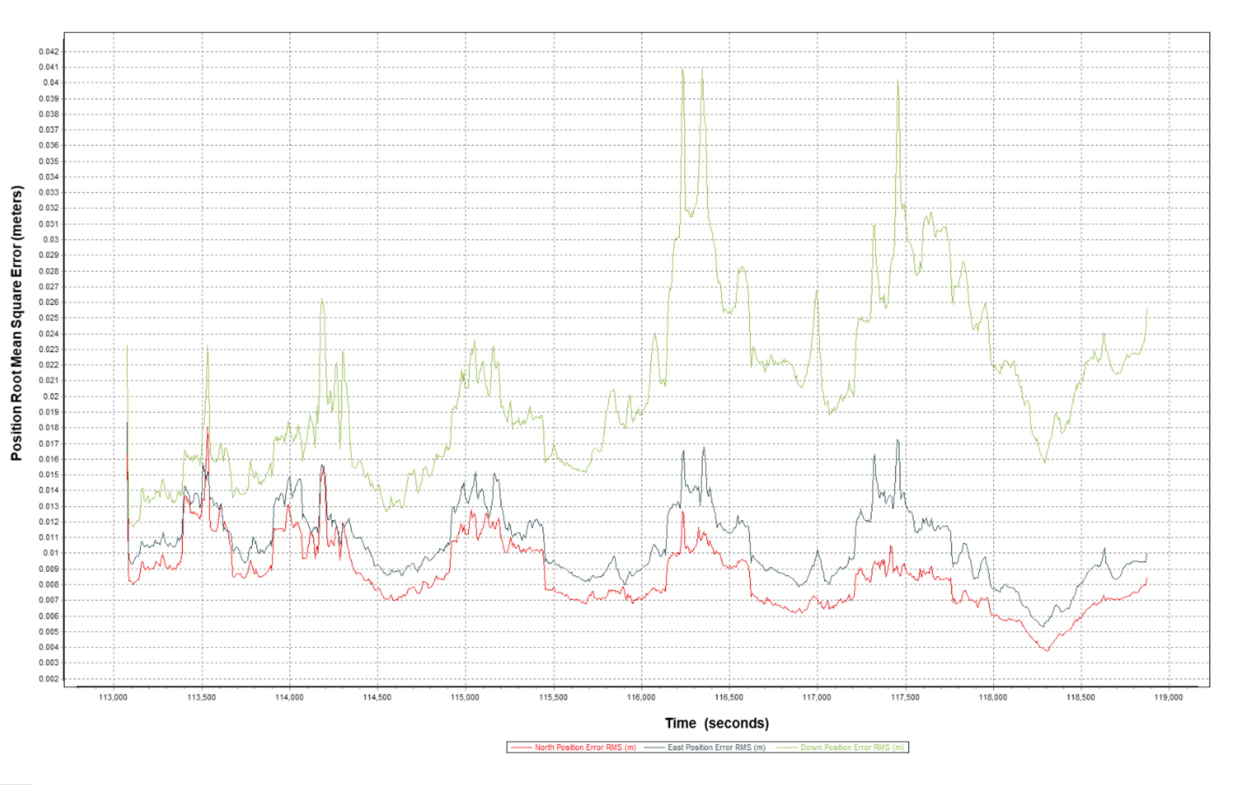


Figure 10. Smoothed Performance Metrics of Sto. Tomas Flight 951P

The time of flight was from 113000 seconds to 119000 seconds, which corresponds to morning of January 10, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.28 centimeters, the East position RMSE peaks at 1.73 centimeters, and the Down position RMSE peaks at 4.09 centimeters, which are within the prescribed accuracies described in the methodology.

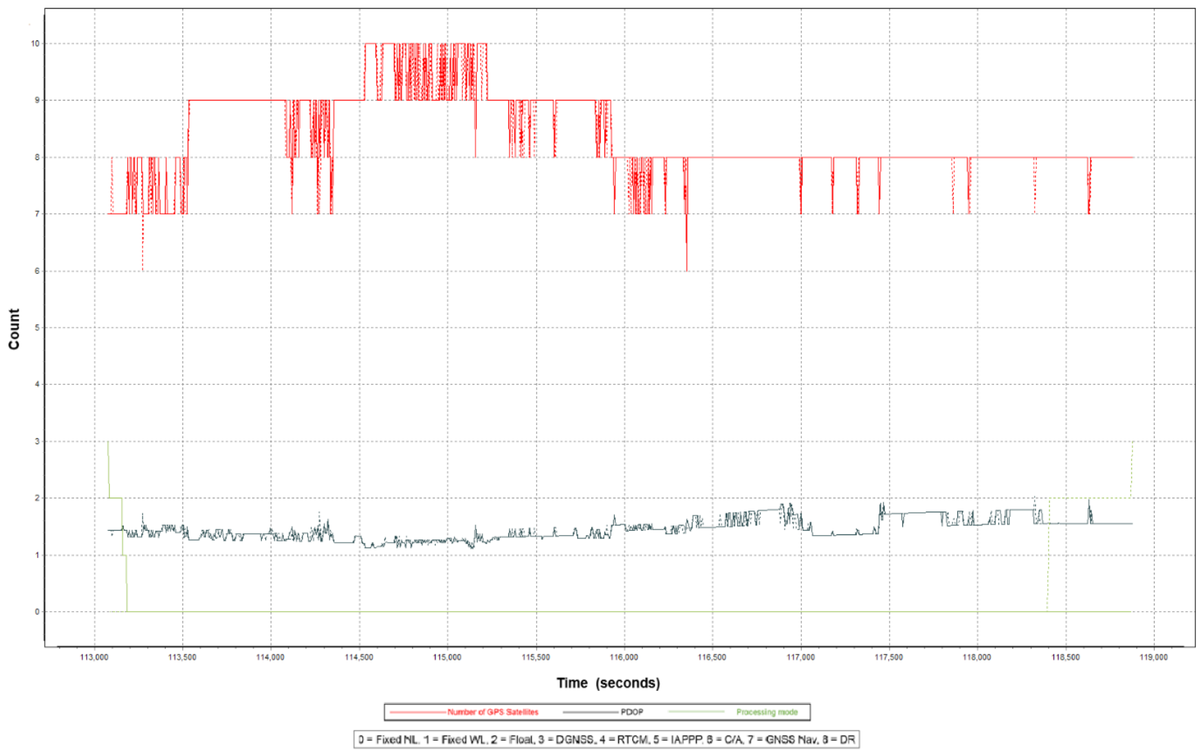


Figure 11. Solution Status parameters of Sto. Tomas Flight 951P

The Solution Status parameters of flight 951P, one of the Sto. Tomas flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most 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 remained at 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 Sto. Tomas flights is shown in Figure 12.

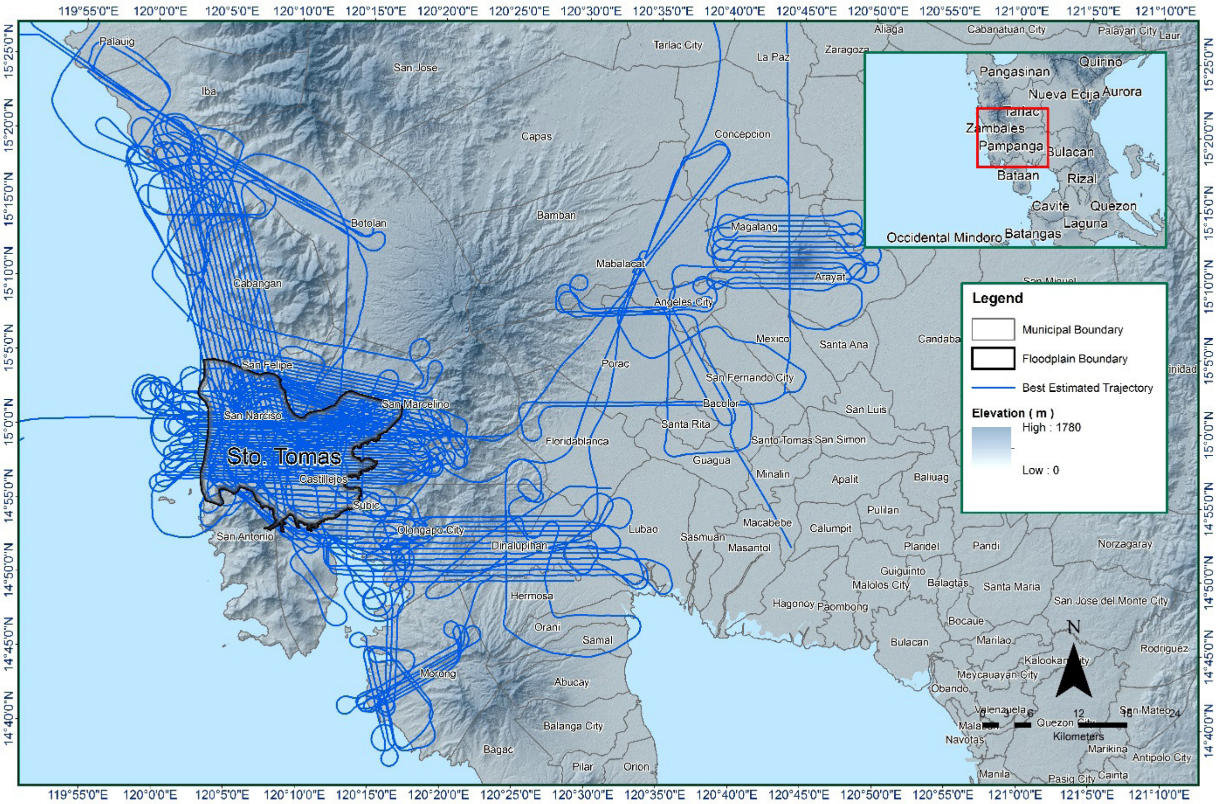


Figure 12. Best estimated trajectory of LiDAR missions conducted over Sto. Tomas Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 165 flight lines, with each flight line 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 Sto. Tomas Floodplain is given in Table 15.

Table 15. Self-calibration results values for Sto. Tomas flights

Parameter	Accepted Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000410
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000664
GPS Position Z-correction stdev	(<0.01meters)	0.0095

The optimum accuracy is obtained for all Sto. Tomas 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 is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

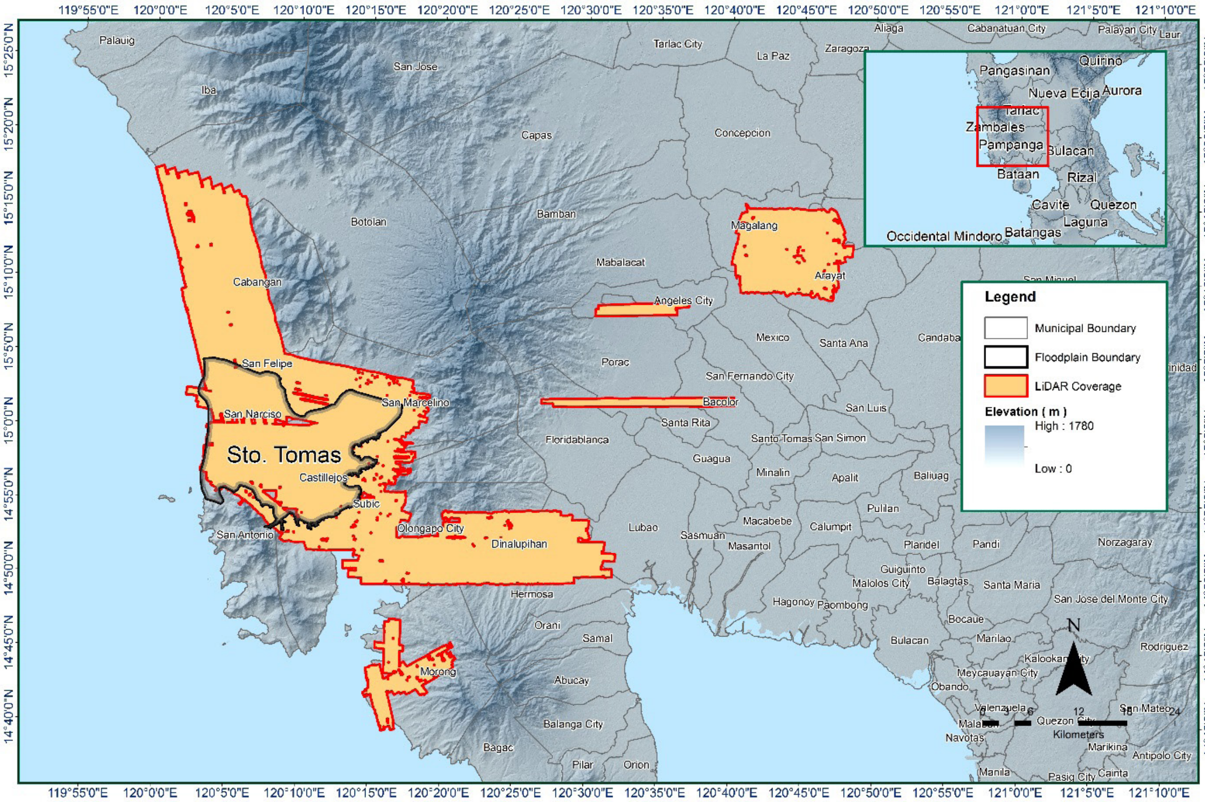


Figure 13. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Sto. Tomas Floodplain.

The total area covered by the Sto. Tomas missions is 1461.05 sq km that is comprised of fifteen (15) flight acquisitions grouped and merged into fifteen (15) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Sto. Tomas Floodplain

LiDAR Blocks	Flight Numbers	Area (sq km)
Bataan_Bal_D	933P	182.29
Bataan_Bal_F	951P	56.63
Bataan_Buc_D	927P 931P	382.91
Bataan_Buc_E	930G	134.15
Bataan_Buc_G	934G	177.57
Bataan_Buc_G_additional	945P	33.22
Bataan_Buc_G_supplement	949P	108.23
Bataan_reflights_Buc_D_additional	2473P	15.73
Bataan_reflights_Buc_E_additional	2473P	54.76
Clark_reflights_BTN_CD	2658G	80.88
MtArayat	7002GC 7047GC	137.49
Pam_Agno_Buc_reflights_upper	7264G	20.29

Pam_Agno_Buc_reflights_lower	7254G 7264G	37.20
Pam_Blk7A_reflights	7255G	15.47
Pam_Blk7C_reflights	7255G	24.23
TOTAL		1461.05 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 14. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

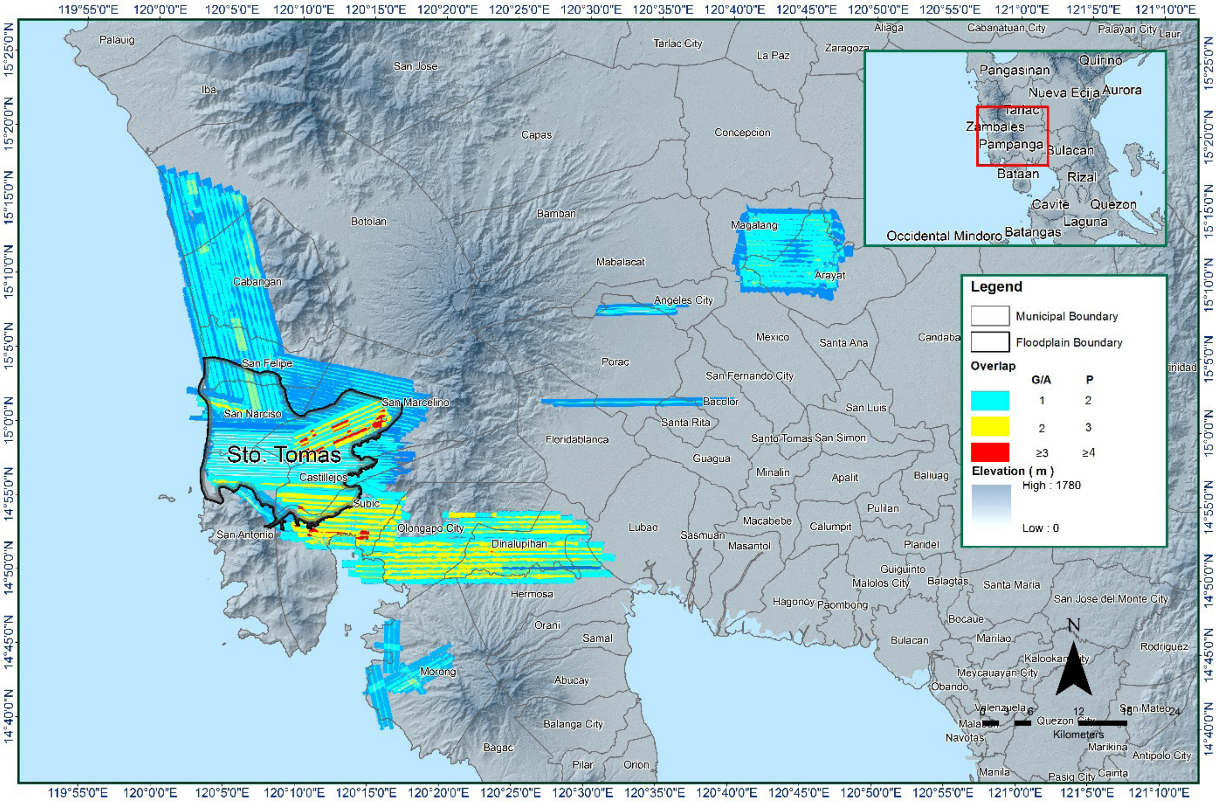


Figure 14. Image of data overlap for Sto. Tomas Floodplain.

The overlap statistics per block for the Sto. Tomas 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 29.04% and 74.50%, 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 15. It was determined that all LiDAR data for Sto. Tomas Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.01 points per square meter.

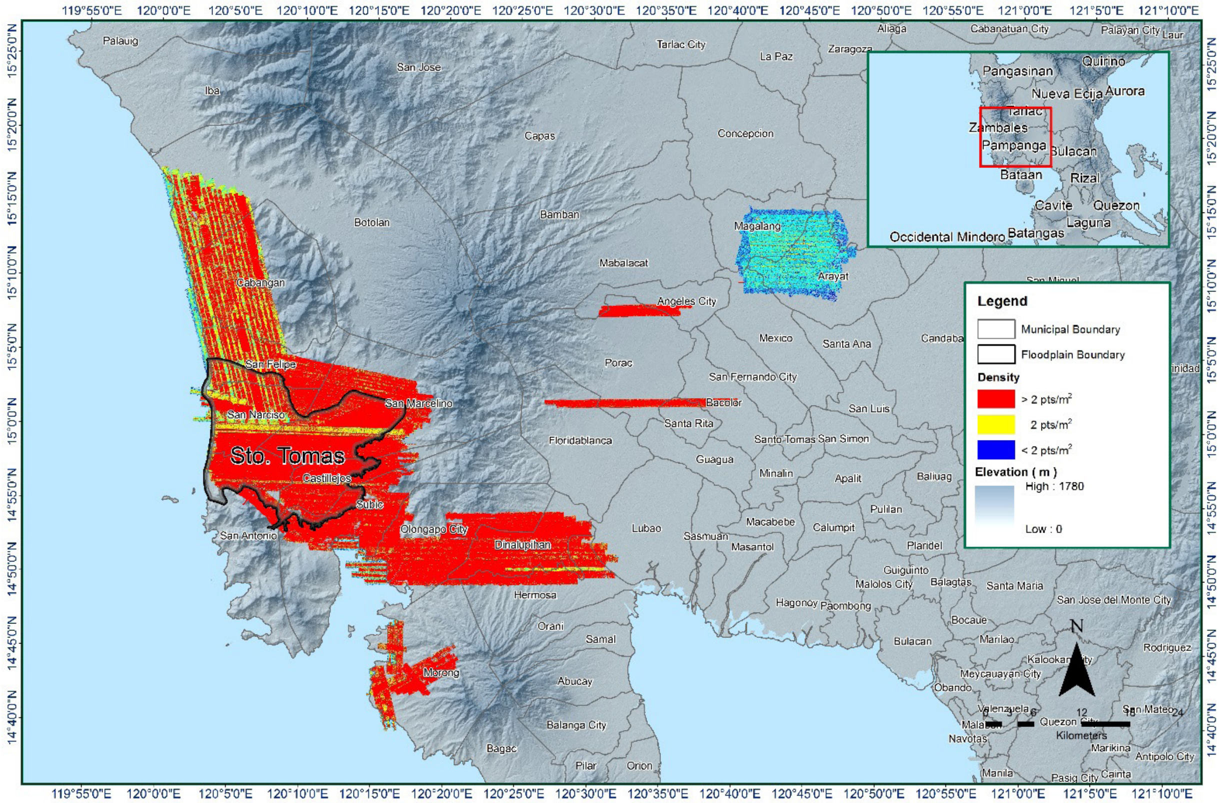


Figure 15. Pulse density map of merged LiDAR data for Sto. Tomas Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 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.

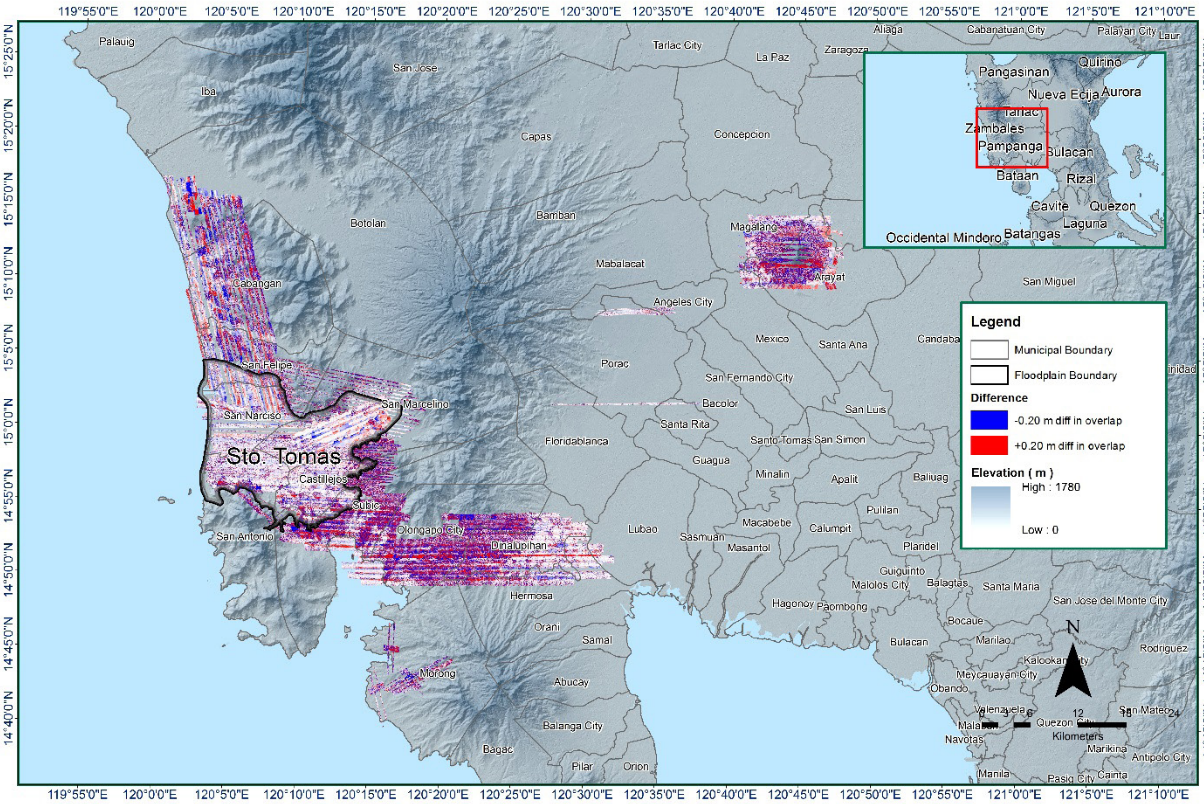


Figure 16. Elevation difference map between flight lines for Sto. Tomas Floodplain.

A screen capture of the processed LAS data from a Sto. Tomas flight 951P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

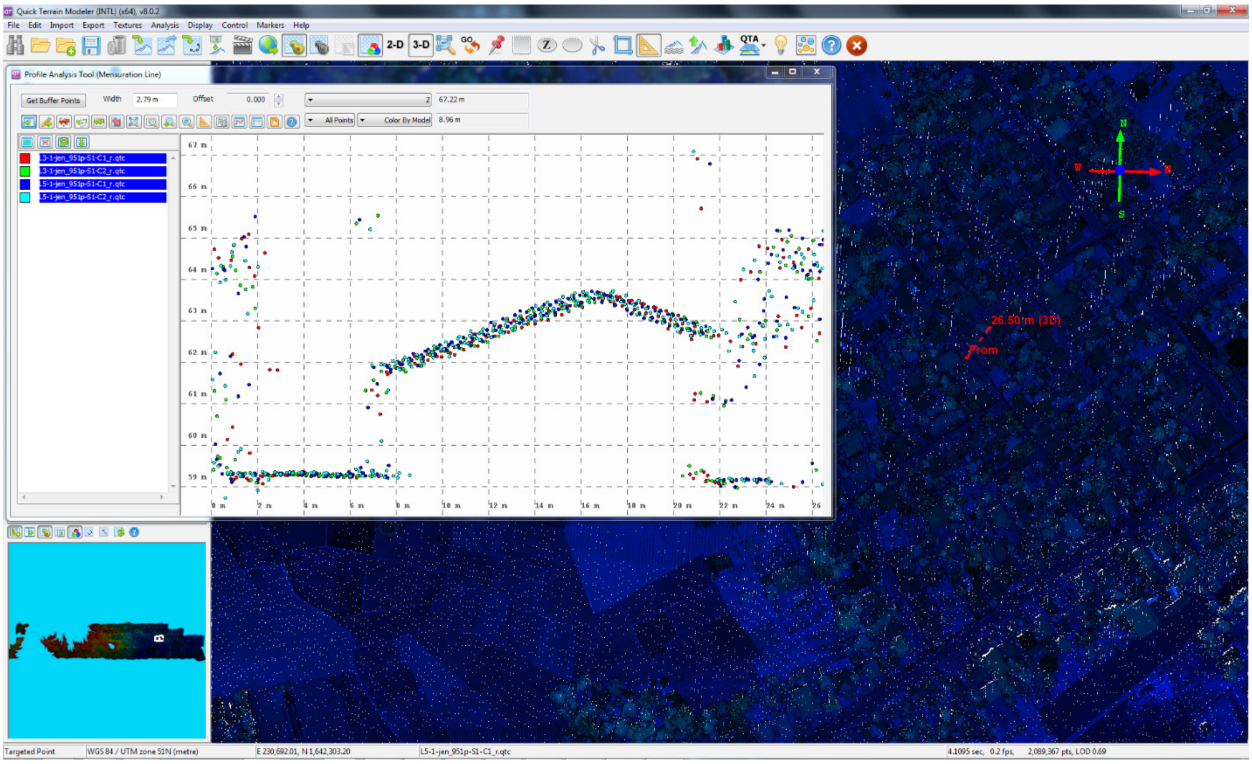


Figure 17. Quality checking for a Sto. Tomas flight 951P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Sto. Tomas classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,147,928,706
Low Vegetation	880,594,122
Medium Vegetation	1,290,861,895
High Vegetation	1,095,951,447
Building	74,747,663

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sto. Tomas Floodplain is shown in Figure 18. A total of 2,031 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 1,089.72 meters and 36.44 meters, respectively.

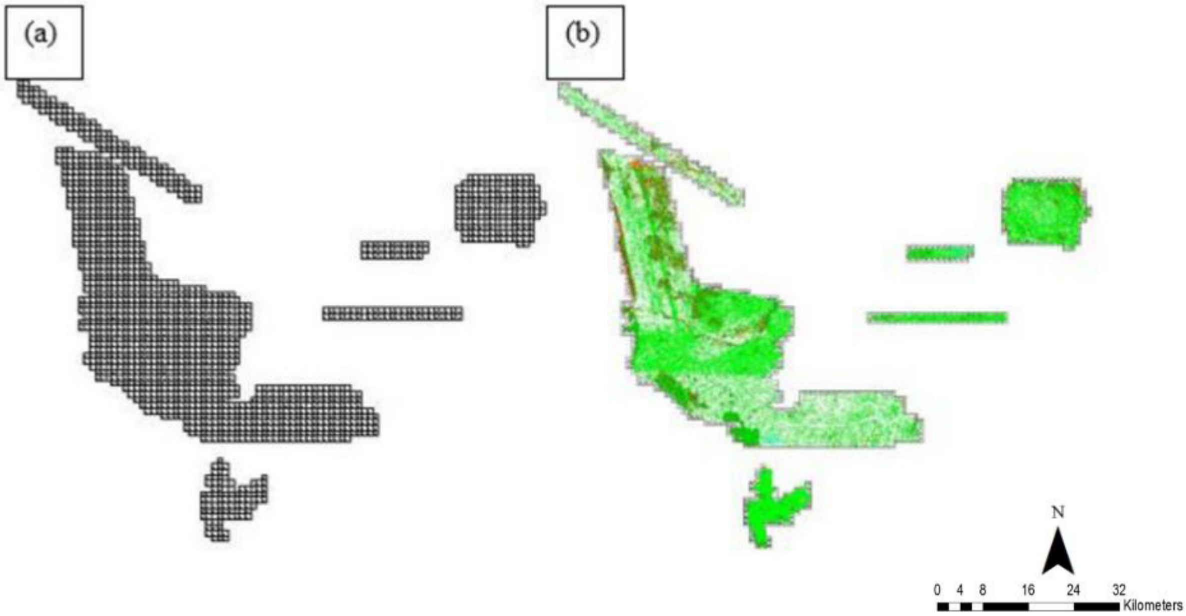


Figure 18. Tiles for Sto. Tomas Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

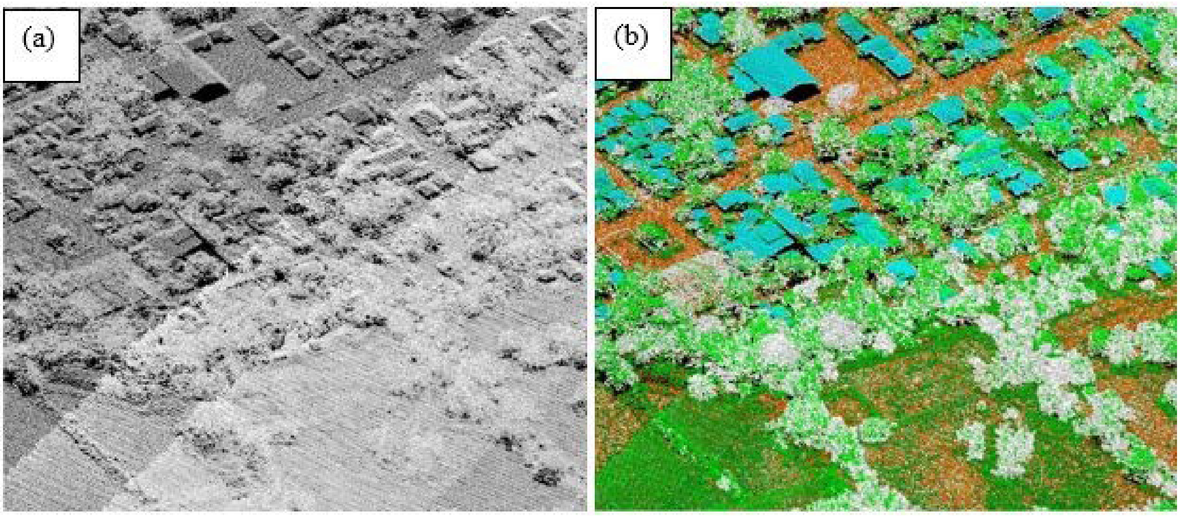


Figure 19. Point cloud before (a) and after (b) classification

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 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

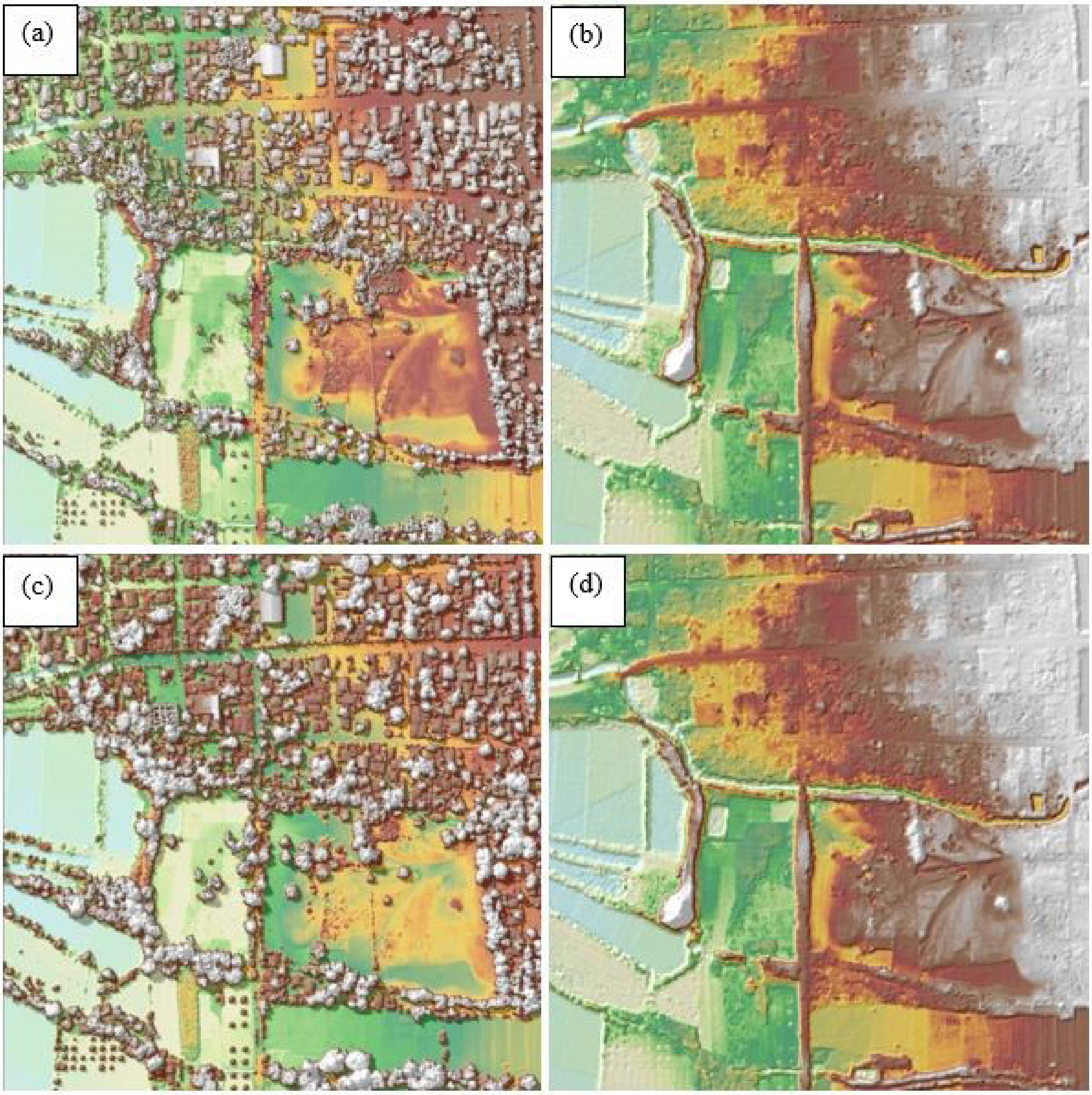


Figure 20. Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sto. Tomas Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 276 1 km by 1 km tiles area covered by Sto. Tomas Floodplain is shown in Figure 21. After tie-point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sto. Tomas Floodplain attained a total of 180.67 sq km in orthophotogaph coverage comprised of 698 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22

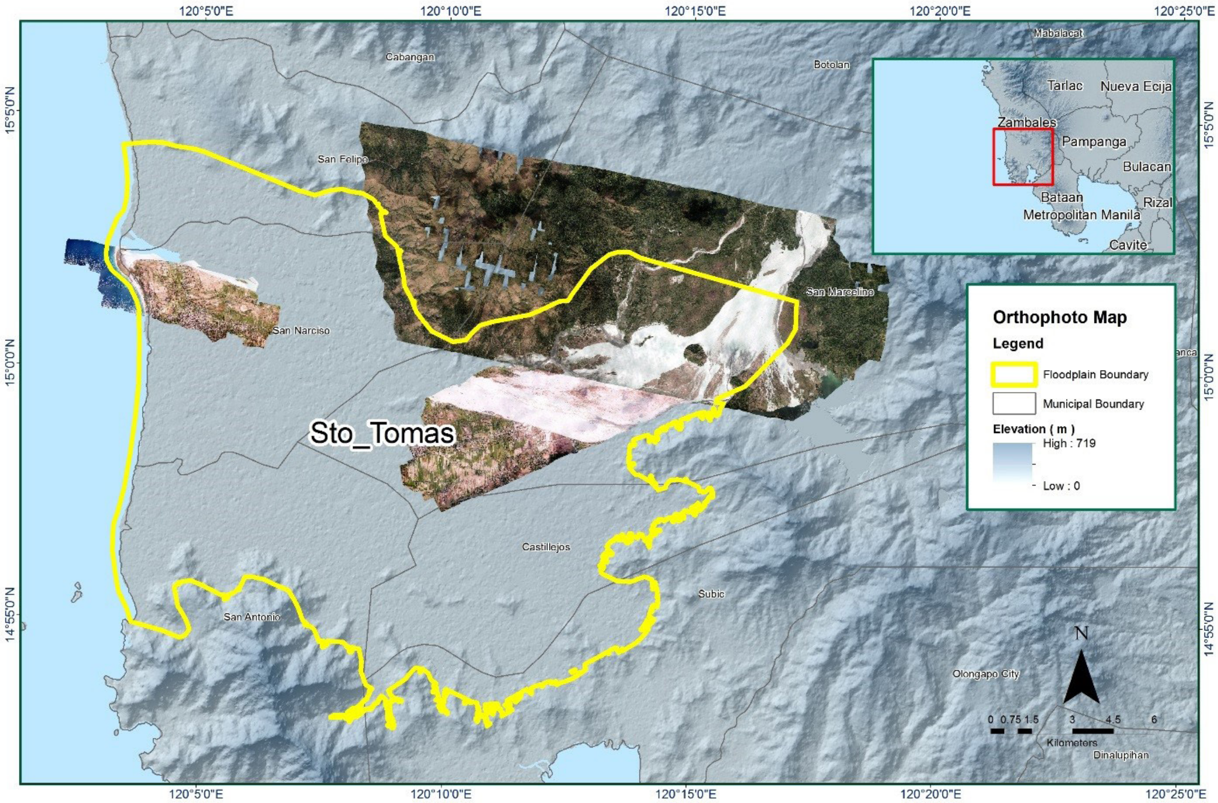


Figure 21. Sto. Tomas Floodplain with available orthophotographs

Figure 22. Sample orthophotograph tiles for Sto. Tomas Floodplain

3.8 DEM Editing and Hydro-Correction

Fourteen (14) mission blocks were processed for Sto. Tomas Floodplain. These blocks are composed of Bataan, Bataan_reflights, Clark_reflights, Mt.Arayat, Pam_Agno_reflights blocks with a total area of 1,461.05 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with their corresponding area

LiDAR Blocks	Area (sq km)
Clark_reflights_BTN_CD	80.88
Bataan_reflights_Buc_E_additional	54.76
Bataan_reflights_Buc_D_additonal	15.73
Bataan_Buc_G_supplement	108.23
Bataan_Buc_G	177.57
Bataan_Buc_G_additional	33.22
Bataan_Buc_D	382.91
Bataan_Buc_E	134.15
Bataan_Bal_F	56.63
Bataan_Bal_D	182.29
Pam_Agno_Buc_reflights_upper	20.29
Pam_Agno_Buc_reflights_lower	37.20
MtArayat	137.49
Pam_Agno_Blk7C_reflight	24.23
Pam_Agno_Blk7A_reflight	15.47
TOTAL	1461.05 sq km

Portions of DTM before and after manual editing are shown in Figure 23. It shows that the river embankment had been misclassified and removed during classification process in Figure 23a and had to be retrieved to complete the surface as in Figure 23b to allow the correct flow of water. The bridge in Figure 23c was an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 23d.

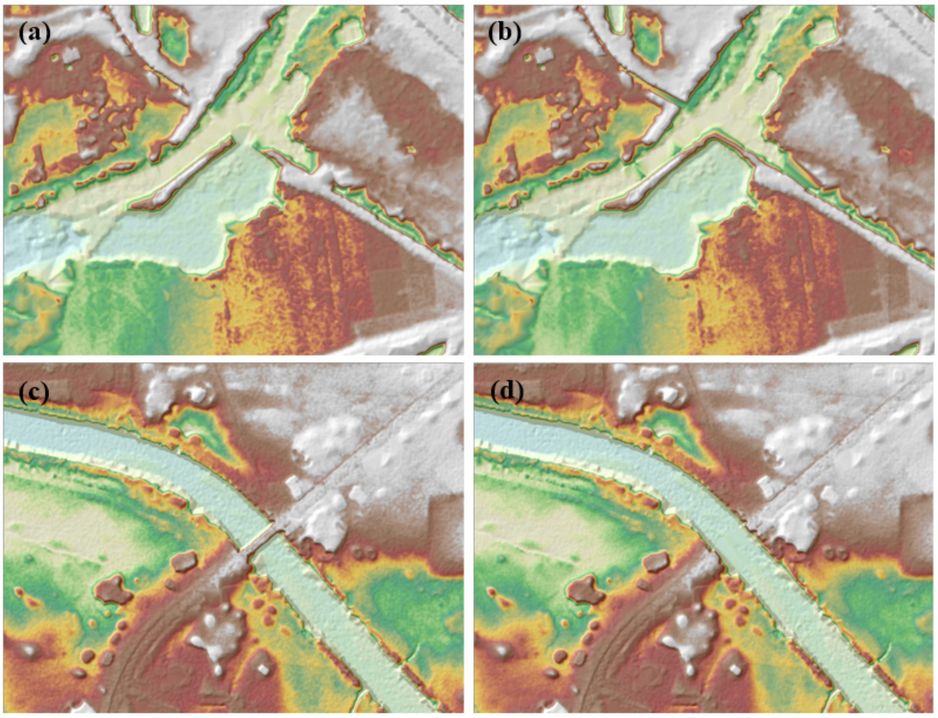


Figure 23. Portions in the DTM of Sto. Tomas Floodplain—a river embankment before (a) and after (b) data retrieval and a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

The mosaicking of blocks for Bucao, Sto Tomas, Morong and Balanga were done, simultaneously because the validation survey datasets used for the said floodplains are connected. Balanga_BlkA was used as the reference block at the start of mosaicking, as one of the first blocks to be first edited. Table 19 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sto. Tomas floodplain is shown in Figure 24. It can be seen that the entire Sto. Tomas floodplain is 97.3% covered by LiDAR data.

Table 19. Shift values of each LiDAR block of Sto. Tomas Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Clark_reflights_BTN_CD	0.00	0.00	0.45
Bataan_reflights_Buc_E_additional	-1.81	-5.86	0.00
Bataan_reflights_Buc_D_additonal	-2.17	-5.79	-0.35
Bataan_Buc_G_supplement	-0.45	1.68	0.50
Bataan_Buc_G	0.12	0.64	0.70
Bataan_Buc_G_additional	-0.36	0.70	0.60
Bataan_Buc_D	-0.94	1.14	0.10
Bataan_Buc_E	-1.12	0.69	0.50
Bataan_Bal_F	-0.50	2.49	0.60
Bataan_Bal_D	-0.26	2.65	0.60
Pam_Agno_Buc_reflights_lower	-0.95	1.53	0.50
Pam_Agno_Buc_reflights_upper	-1.02	0.66	0.50
MtArayat_part1	-9.14	-8.53	1.21
MtArayat_part2	-7.88	-9.79	1.21
MtArayat_part3	-5.02	-2.11	1.21

Pam_Agno_Blk7C_reflight	-12.50	-9.25	-0.69
Pam_Agno_Blk7A_reflight	-10.00	-9.00	-0.89

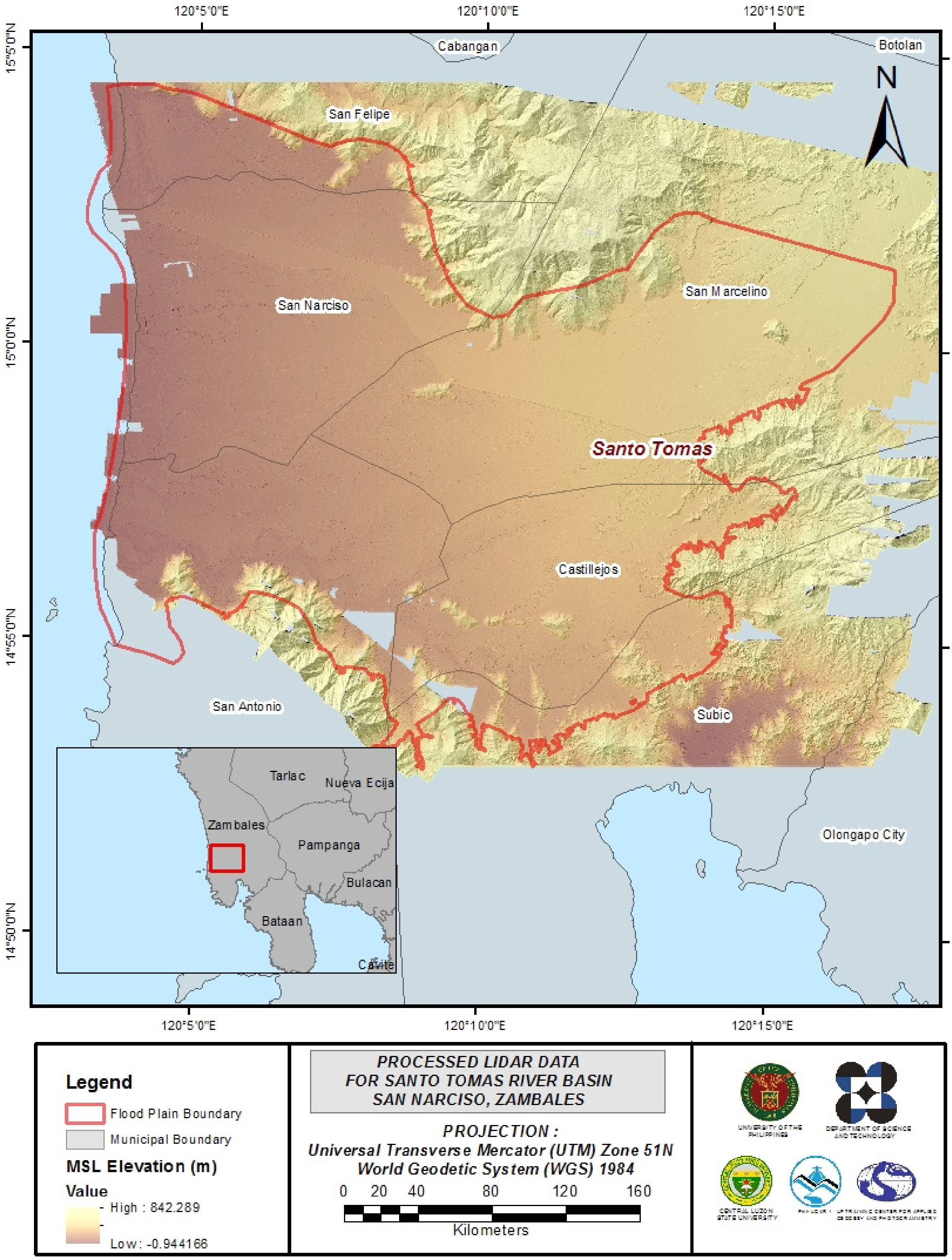


Figure 24. Map of processed LiDAR data for Sto. Tomas Floodplain

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 Sto Tomas to collect points with which the LiDAR dataset is validated is shown in Figure 25, with the validation survey points highlighted in green. Sto Tomas LiDAR data was calibrated using the validation survey points provided for BataanZambales area to be consistent with the other floodplains covered by the mosaicked blocks. A total of 30,472 survey points were gathered within BataanZambales wherein the Sto Tomas floodplain is located. Random selection of 80% of the survey points, resulting to 24,377 points, were used for calibration.

A good correlation between the uncalibrated BataanZambales LiDAR DTM and ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 4.15 meters with a standard deviation of 0.15 meters. Calibration of Sto Tomas LiDAR data was done by subtracting the height difference value, 4.15 meters, to BataanZambales mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between BataanZambales LiDAR data and calibration data.

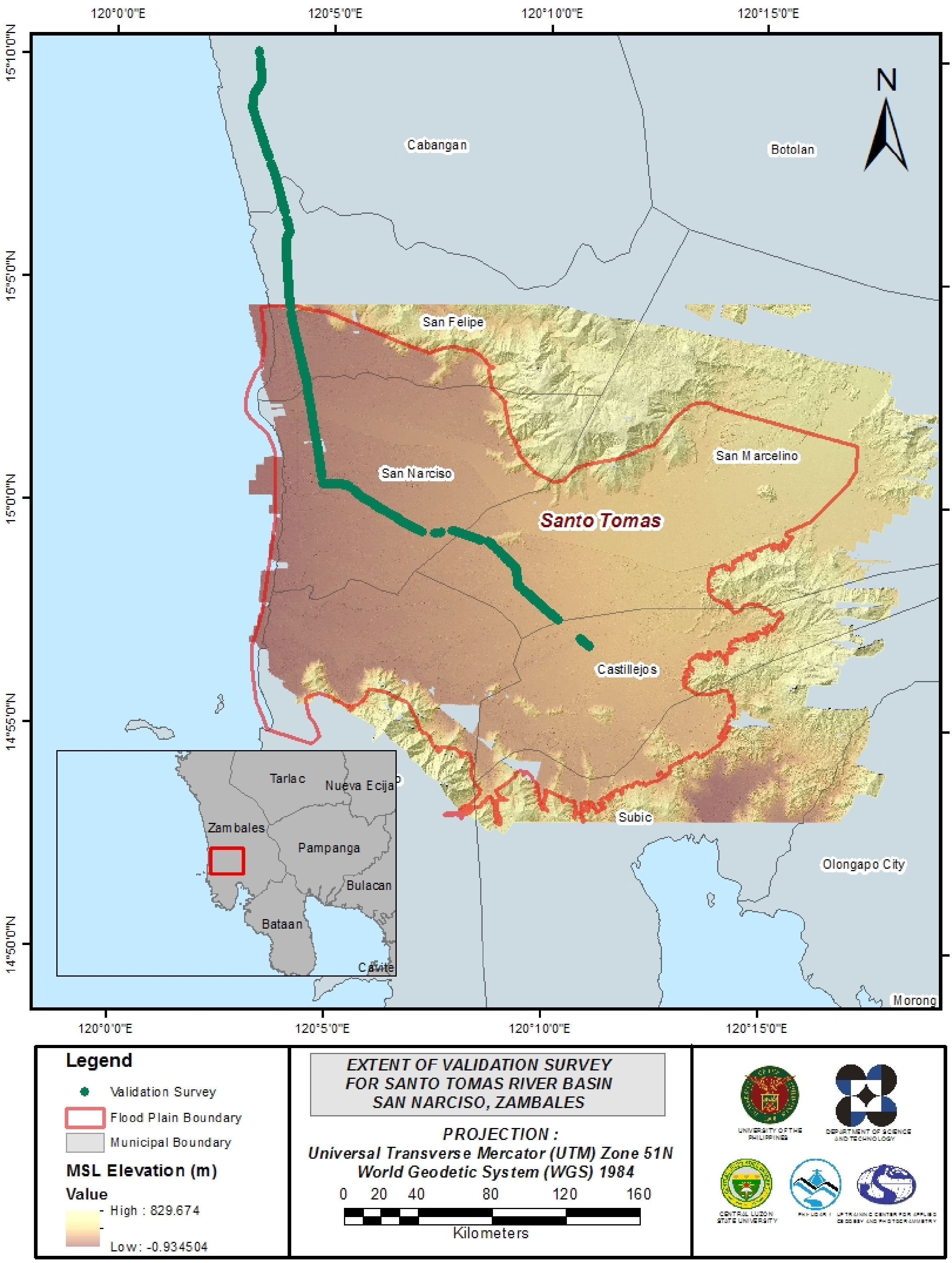


Figure 25. Map of Sto. Tomas Floodplain with validation survey points in green

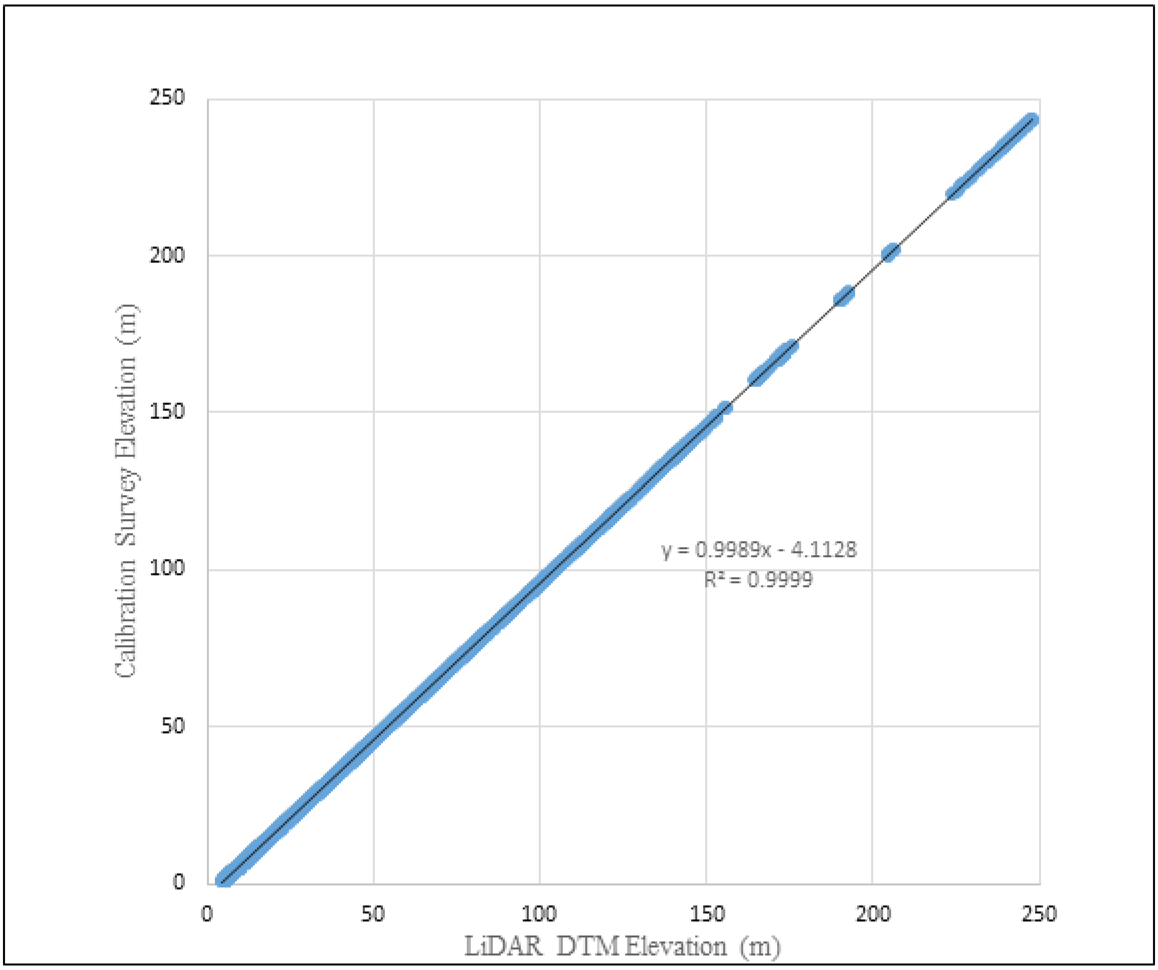


Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 20. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.15
Standard Deviation	0.15
Average	-4.14
Minimum	-4.50
Maximum	-3.85

A total of 609 points were used for the validation of calibrated Sto Tomas DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.14 meters, as shown in Table 21.

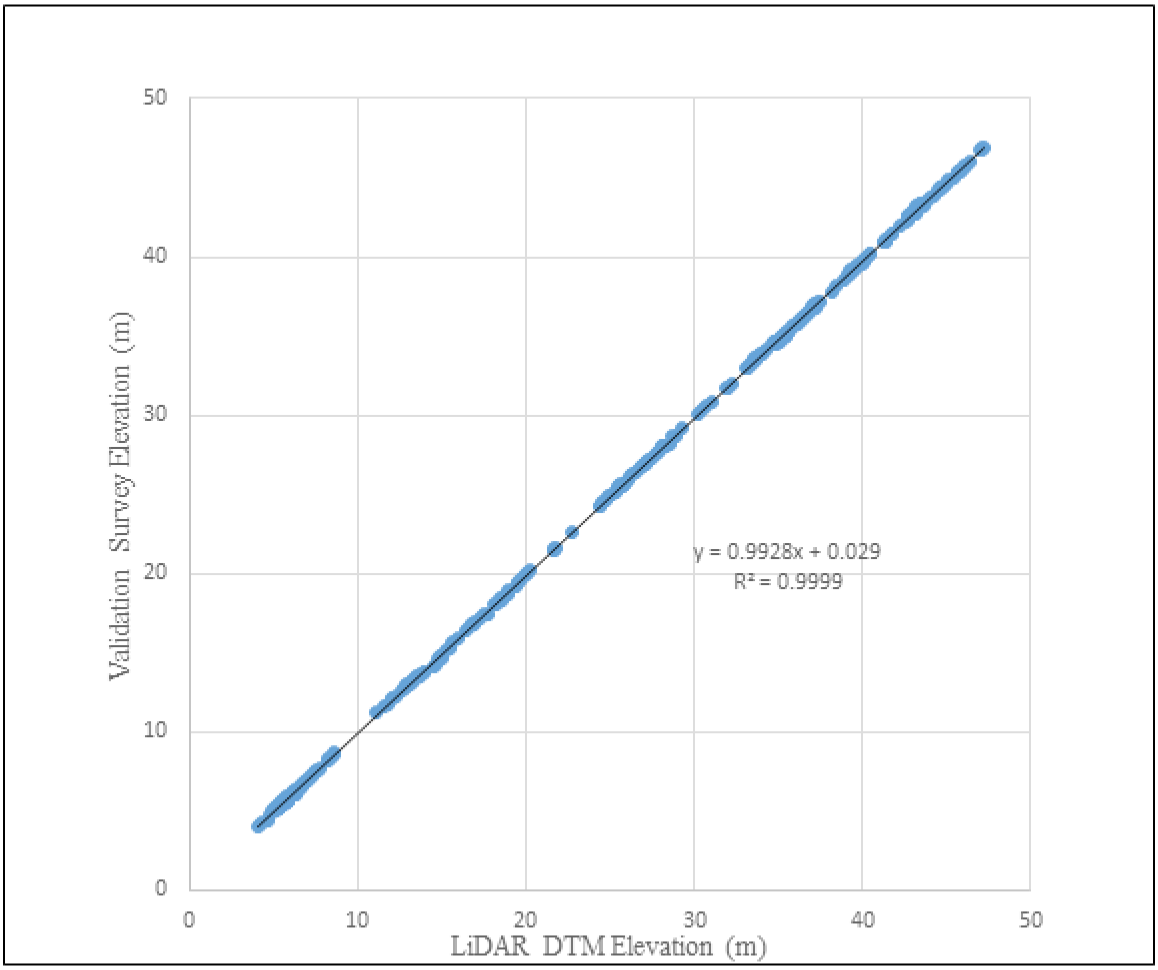


Figure 27. Correlation plot between validation survey points and LiDAR data

Table 21. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.14
Average	-0.14
Minimum	-0.38
Maximum	0.11

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Sto. Tomas with 7,656 bathymetric survey points. A trial was done to produce a raster surface, using Inverse Distance Weighted (IDW) interpolation method. After assessing the interpolated surface, it was found out that the water level along Sto. Tomas is shallow and the LiDAR pulses were able to get to the bottom of the river, thus, creating the river surface. It was decided to treat the originally produced LiDAR data as the river surface, without the integration of bathymetric data to the LiDAR data. This assumption was checked by computing the RMSE value between the bathymetric data and the original LiDAR surface, which resulted in 0.34 m. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sto. Tomas integrated with the processed LiDAR DEM is shown in Figure 28.

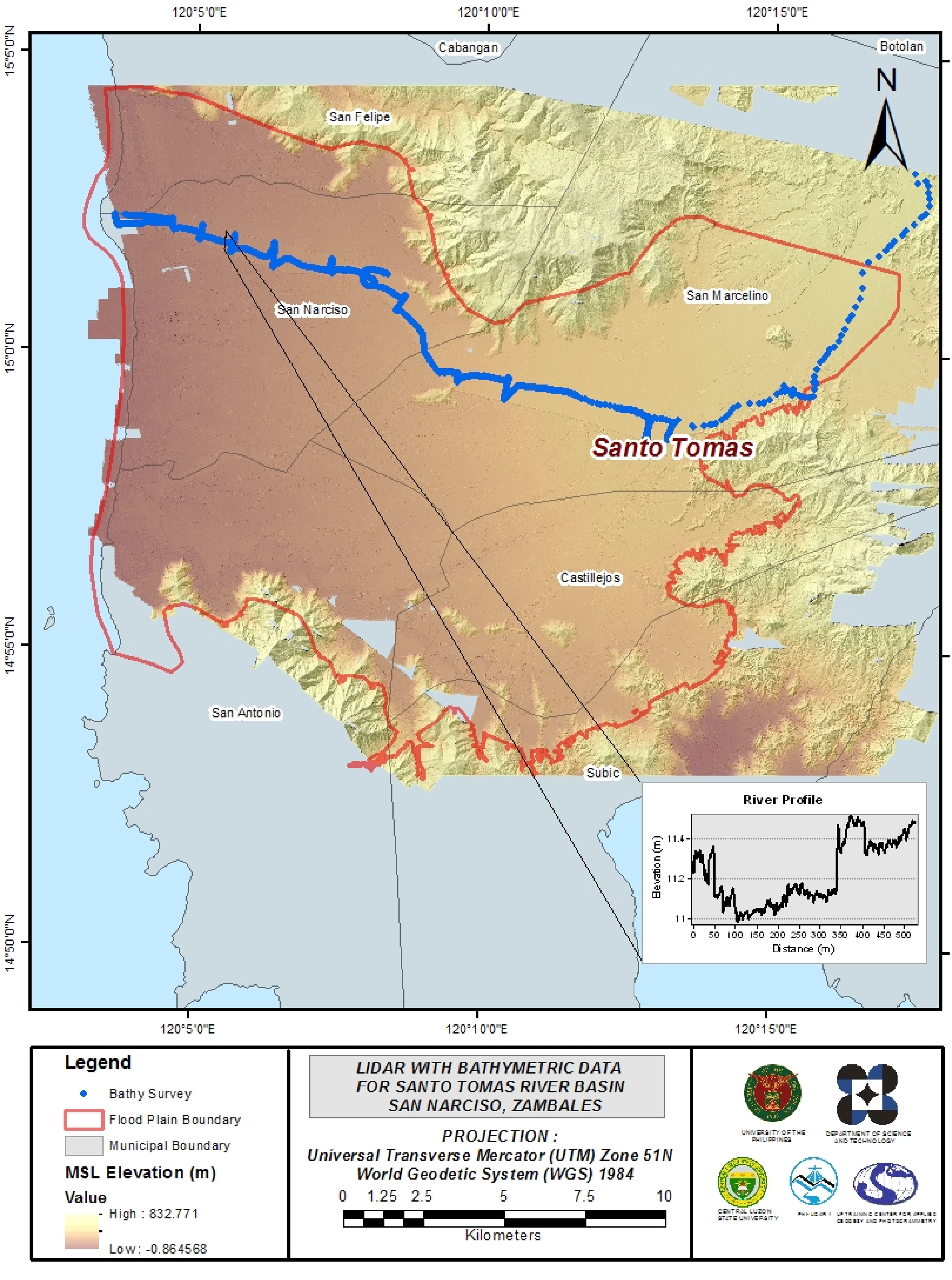


Figure 28. Map of Sto. Tomas Floodplain with bathymetric survey points shown in blue

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

Sto. Tomas Floodplain, including its 200 m buffer, has a total area of 337.70 sq km. For this area, a total of 11.0 sq km, corresponding to a total of 3,491 building features, are considered for QC. Figure 29 shows the QC blocks for Sto. Tomas Floodplain.

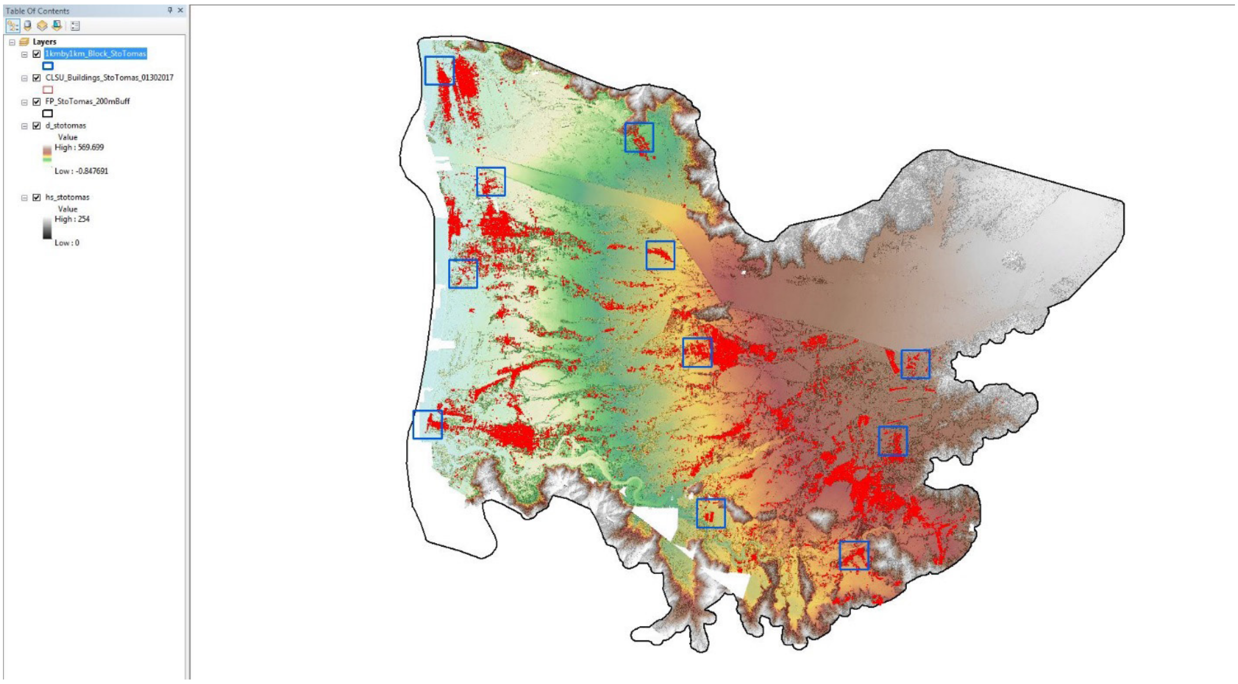


Figure 29. Blocks (in blue) of Sto. Tomas building features subjected to QC

Quality checking of Sto. Tomas building features resulted in the ratings shown in Table 22.

Table 22. Quality checking ratings for Sto. Tomas building features

Floodplain	Completeness	Correctness	Quality	Remarks
Sto. Tomas	100.00	99.99	99.97	PASSED

3.12.2 Height Extraction

Height extraction was done for 41,860 building features in Sto. Tomas Floodplain. Of these building features, 19 were filtered out after height extraction, resulting in 41,841 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 5.73 m.

3.12.3 Feature Attribution

The method used on the attribution of features extracted in Sto. Tomas River Basin consumed a lot of time and effort which headed the team to proceed with another approach for the remaining river basins under study. The team used the video tagging/capture device installed in a vehicle that would roam around the floodplains to capture and tag the buildings, bridges, roads, and water bodies. Courtesy call to the municipal officials and seeking for their approval at the same time were performed before the video tagging had proceeded. Field data for the attribution of features extracted in the floodplain of Sto. Tomas in Zambales were accomplished.

Table 23 summarizes the number of building features per type. On the other hand, Table 24 shows the total length of each road type, while Table 25 presents the number of water features extracted per type.

Table 23. Building features extracted for Sto. Tomas Floodplain

Facility Type	No. of Features
Residential	40,452
School	476
Market	30
Agricultural/Agro-Industrial Facilities	67
Medical Institutions	9
Barangay Hall	55
Military Institution	75
Sports Center/Gymnasium/Covered Court	48
Telecommunication Facilities	4
Transport Terminal	5
Warehouse	51
Power Plant/Substation	6
NGO/CSO Offices	13
Police Station	17
Water Supply/Sewerage	2
Religious Institutions	104
Bank	9
Factory	28
Gas Station	16
Fire Station	2
Other Government Offices	54
Other Commercial Establishments	318
Total	41,841

Table 24. Total length of extracted roads for Sto. Tomas Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Sto. Tomas	449.86	68.78	55.60	14.71	0	588.96

Table 25. Number of extracted water bodies for Sto. Tomas Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Sto. Tomas	42	796	0	0	195	1,033

A total of 152 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of Sto. Tomas Floodplain overlaid with its ground features.

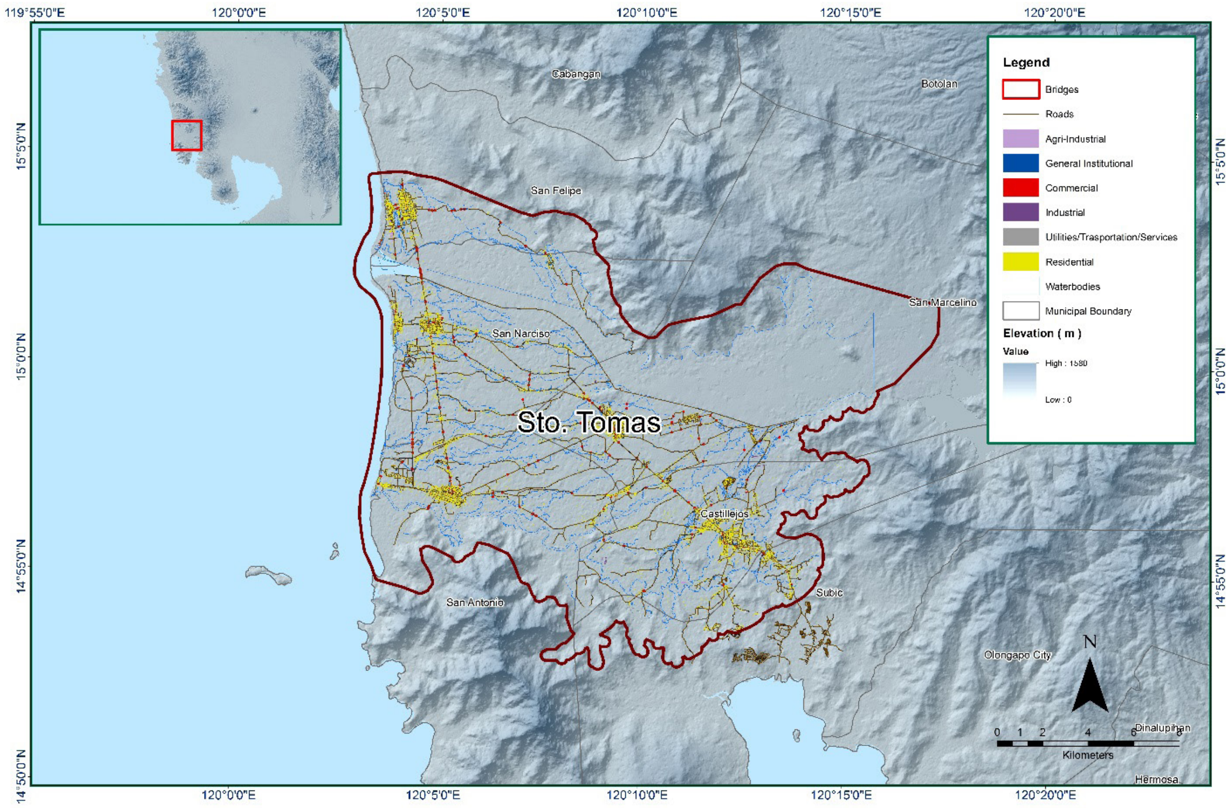


Figure 30. Extracted features for Sto. Tomas Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS IN THE STO. TOMAS RIVER BASIN

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field survey in Sto. Tomas River on December 2–13, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built, and elevation marking of Sto. Tomas Bridge in Brgy. Alusiis, Municipality of San Narciso, Zambales; ground validation data acquisition of about 32 km (covering the national highway from Municipality of Castillejos up to the Municipality of Cabangan); and bathymetric survey from Brgy. Rabanes, Municipality of San Marcelino, Zambales down to the mouth of the river in Brgy. Alusiis, Municipality of San Narciso, Zambales with an estimated length of 35.54 km using GNSS PPK survey technique.

Figure 31. Survey extent of Sto. Tomas River Basin

4.2 Control Survey

The GNSS Network used for Sto. Tomas River Basin is composed of a single loop and established on December 3, 2014 occupying the following reference points: ZBS-62, a second-order GCP, in Brgy. La Paz, Municipality of San Narciso; and ZA-62A, a first-order BM in Brgy. Sindol, Municipality of San Felipe, all in Zambales.

A control point namely UP-MAC was established along approach of Maculcol Bridge in Brgy. Alusiis, Municipality of San Narciso, Zambales

The summary of reference and control points and their location is summarized in Table 26 while the GNSS network established is illustrated in Figure 32.

Figure 32. GNSS network of Sto. Tomas River field survey

Table 26. List of references and control points used in Sto. Tomas River Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	BM Ortho (m)	Date Established
ZBS-62	2nd Order, GCP	15°00’52.08330”	120°03’55.29320”	46.764	-	2007
ZA-62A	1st Order, BM	-	-	47.286	4.164	1992
UP-MAC	UP established	-	-	-	-	12-3-2014

The GNSS set-up in ZBS-62, ZA-62A, and UP-MAC are shown in Figure 33 to Figure 35.

Figure 33. GNSS Base receiver, Trimble® SPS 852 set-up at ZBS-62, located inside Barangay Executive Park in Brgy. La Paz, Municipality of San Narciso, Zambales

Figure 34. Trimble® SPS 882 occupying ZA-62A located at the approach of Sindol Bridge, Brgy. Sindol, Municipality of San Felipe, Zambales

Figure 35. GNSS base receiver, Trimble® SPS 852 set-up at UP-MAC at the approach of Maculcol Bridge, in Brgy. Alusiss, Municipality of San Narciso, Zambales

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 Sto. Tomas River Basin is summarized in Table 27 generated by TBC software.

Table 27. Baseline processing report for Sto. Tomas River control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZBS-62 --- UP-MAC	12-3-2014	Fixed	0.003	0.012	23°20'37"	2728.214	10.290
UP-MAC --- ZA-62A	12-3-2014	Fixed	0.004	0.019	348°33'22"	4744.407	-9.735
ZBS-62--- ZA-62A	12-3-2014	Fixed	0.008	0.032	1°07'01"	7156.314	0.553

As shown in Table 27, three baselines were observed for the control network. And all of them passed the required accuracy set by the project.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid coordinates (Table 29) 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. The following tables show the results of GNSS network adjustment.

The list of control point in which the coordinates were fixed during the network adjustment is shown in Table 28. Through this reference point, the coordinates of the unknown control points would be computed.

Table 28. Control point constraint

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZA-62A	Grid				Fixed
ZBS-62	Local	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 29. The fixed control points, ZBS-62 and ZS-62A, have no values for coordinates and elevation standard errors, respectively.

Table 29. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UP-MAC	185520.290	0.006	1664513.687	0.006	14.031	0.050	
ZA-62A	184640.040	0.009	1669179.71	0.010	4.164	?	e
ZBS-62	184405.132	?	1662021.317	?	4.033	0.055	LL

The network is fixed at reference point, ZBS-62, with known coordinates; and ZS-62A with known elevation. With the mentioned equation, for horizontal and for the vertical, below is the computation for the accuracy that passed the required precision:

ZBS-62

horizontal accuracy = Fixed

vertical accuracy = 5.5 cm < 10 cm

ZA-62A

horizontal accuracy = $\sqrt{((0.9)^2 + (1.0)^2}$

= $\sqrt{(0.81 + 1.0)}$

= 1.34 cm < 20 cm

vertical accuracy = Fixed cm < 10 cm

UP-MAC

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

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

= 0.84 cm < 20 cm

vertical accuracy = 5.0 cm < 10 cm

The list of adjusted geodetic coordinates: Latitude, Longitude, Height, and computed standard errors of the control points in the network are shown in Table 30.

Table 30. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
UP-MAC	N15°02’13.58015”	E120°04’31.48480”	57.042	0.050	
ZA-62A	N15°04’44.87136”	E120°03’59.96470”	47.286	?	e
ZBS-62	N15°00’52.08330”	E120°03’55.29320”	46.764	0.055	LL

After the processing has been made, the geodetic coordinates of the other control points were derived. The errors of the coordinates and elevation passed the required accuracy conditions. Therefore, the result of the control survey for Sto. Tomas River Basin has attained the required data accuracy for GNSS surveys.

The summary of reference and control points used is indicated in Table 31.

Table 31. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
ZBS-62	2nd order, GCP	15°00’52.08330”	120°03’55.29320”	46.764	1662021.317	184405.132	4.033
ZA-62A	1st order, BM	15°04’44.87136”	120°03’59.96470”	47.286	1669179.716	184640.04	4.164
UP-MAC	UP Established	15°02’13.58015”	120°04’31.48480”	57.042	1664513.687	185520.29	14.031

4.5 Cross-section and Bridge As-Built Surveys

The GNSS receiver Trimble® SPS 882 in PPK survey technique was used to get the cross section of the river on December 6, 2014. The conduct of cross-section at the downstream side and as-built surveys of Maculcol Bridge in Brgy. Alusiis, Municipality of San Narciso were presented in Figure 35 (A and B). The cross-sectional line length is about 430 meters with fifty-eight (58) points. The Trimble® SPS 852 was set up at UP-MAC which served as the GNSS base station for this survey.

Figure 36. (A) Bridge as-built survey and (B) cross-section survey in Maculcol Bridge, Municipality of San Narciso

The summary of gathered location map, cross-section, and as-built data are indicated in Figure 37 to Figure 40.

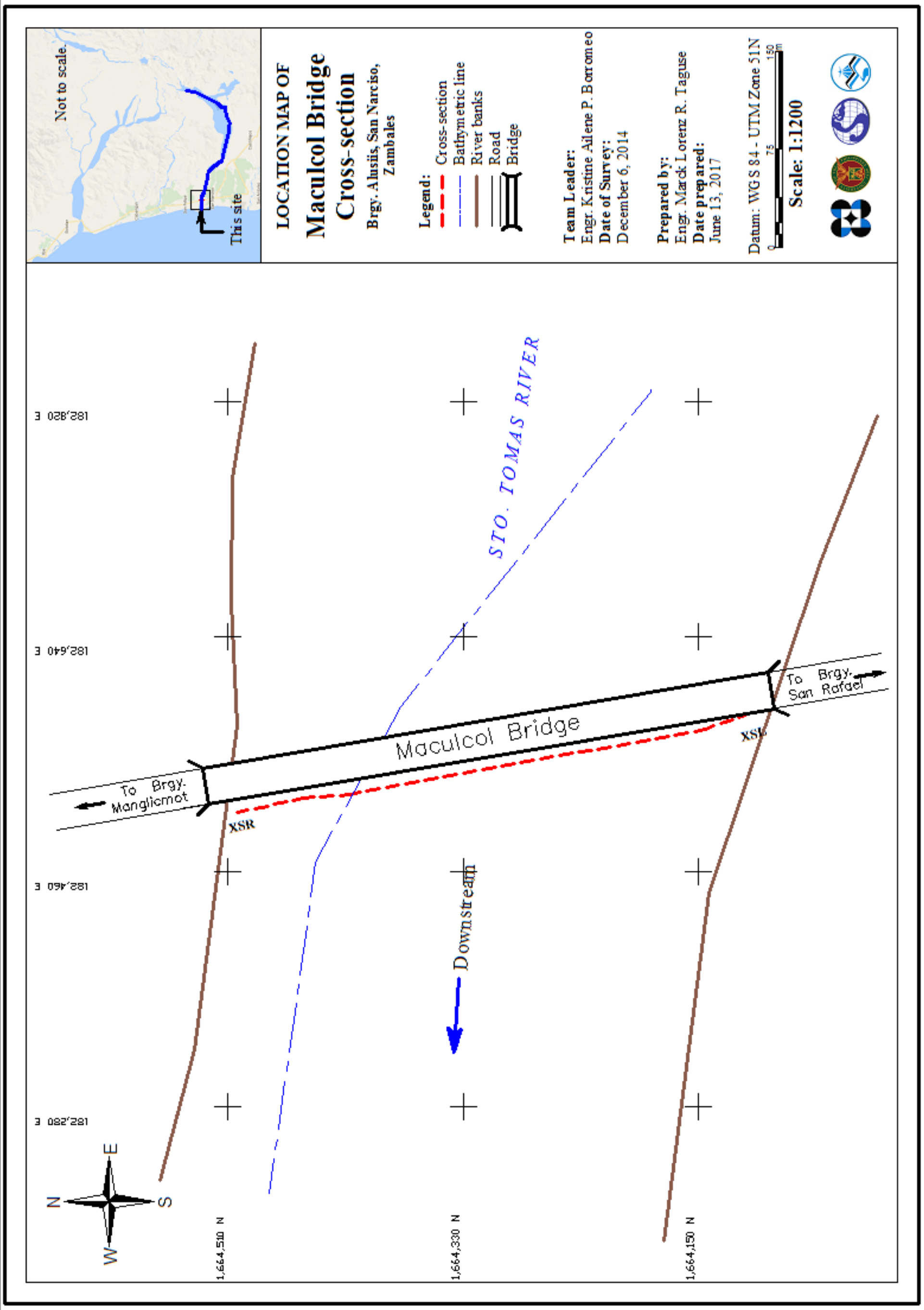


Figure 37. Maculcol Bridge cross-section location map

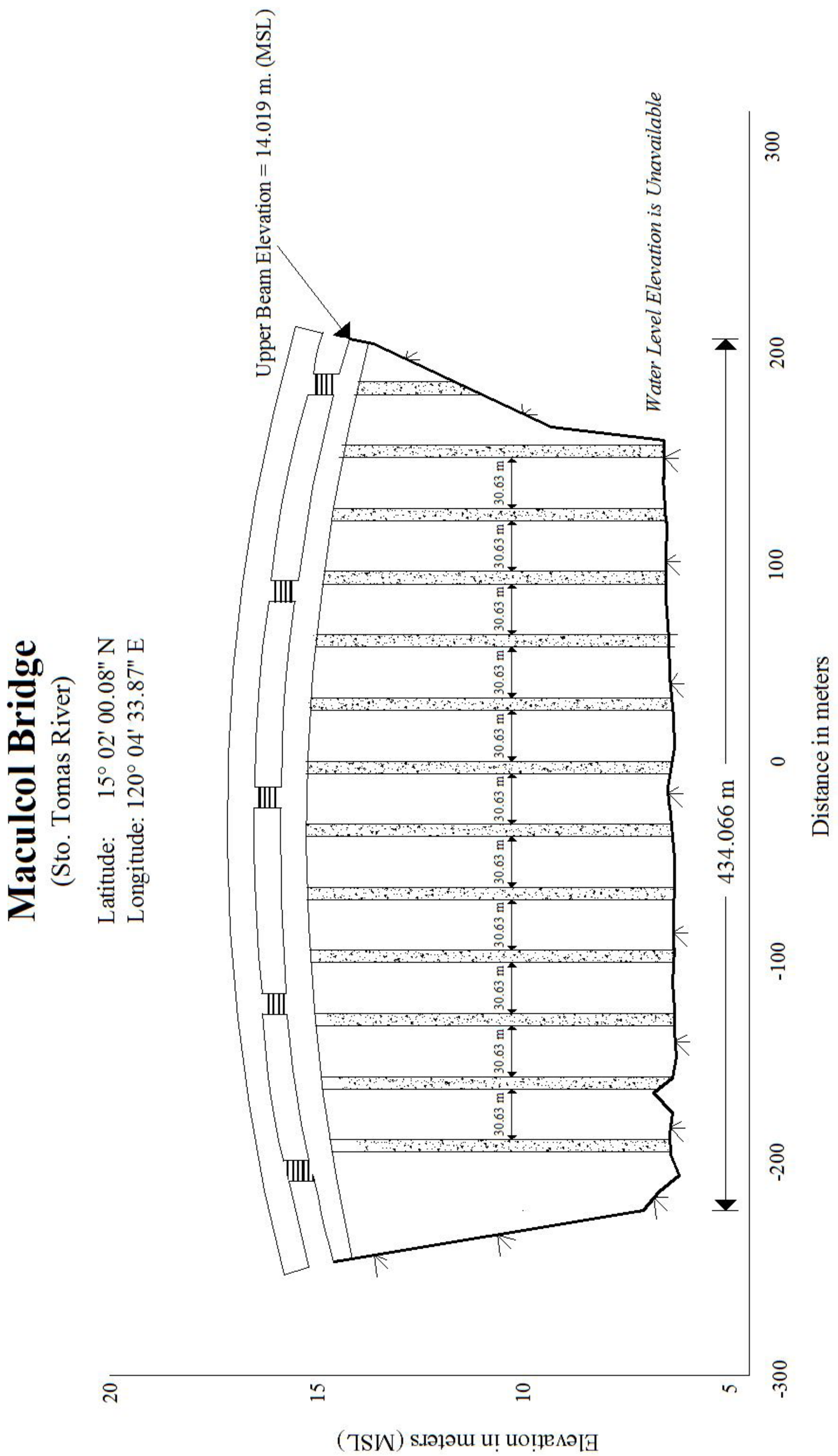


Figure 38. Maculcol Bridge cross-section diagram

Bridge Data Form

Bridge Name: Maculcol Bridge | **Date:** December 6, 2014

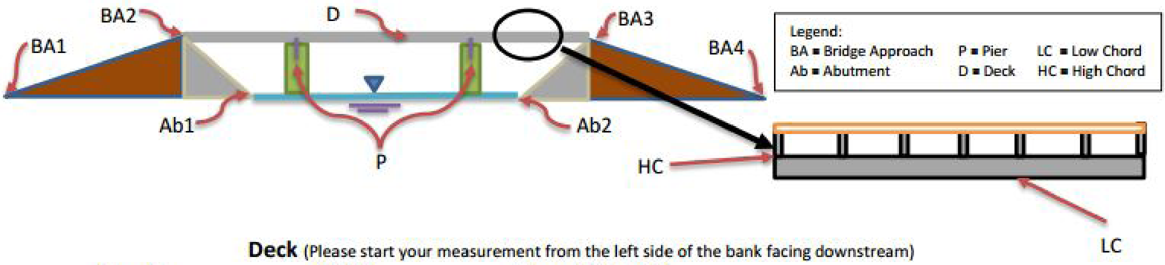
River Name: Sto. Tomas River | **Time:** 2 - 4 PM

Location (Brgy, City,Region): Brgy. Alusiis, Municipality of San Narciso, Province of Zambales

Survey Team: Zambales Survey Team

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

Latitude: 15° 02' 13.99" **Longitude:** 120° 04' 31.49"



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

Elevation: ________ **Width:** ________ **Span (BA3-BA2):** ________

	Station (Distance from BA1) (m)	High Chord Elevation (m) MSL	Low Chord Elevation (m) MSL
1			
2			
3			
4			

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

	Station(Distance from BA1) (m)	Elevation (m) MSL		Station(Distance from BA1) (m)	Elevation (m) MSL
BA1	0	14.019	BA3		
BA2			BA4	434.063	13.954

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

	Station (Distance from BA1) (m)	Elevation (m) MSL
Ab1	N/A	
Ab2	N/A	

Figure 39. Maculcol Bridge data form (1 of 2)

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

Shape: ________ Number of Piers: _________

	Station (Distance from BA1) (m)	Elevation (m) MSL	Pier Width (m)
Pier 1	31.312	14.442	
Pier 2	61.852	14.804	
Pier 3	92.350	15.125	
Pier 4	122.928	15.342	
Pier 5	153.421	15.499	
Pier 6	183.930	15.602	
Pier 7	214.515	15.637	
Pier 8	245.146	15.579	
Pier 9	275.689	15.475	
Pier 10	306.246	15.329	
Pier 11	336.673	15.113	
Pier 12	367.267	14.785	
Pier 13	397.917	14.422	

NOTE: Use the center of the pier as reference to its station

Figure 40. Maculcol Bridge data form (2 of 2)

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 8, 2014 using a survey-grade GNSS rover receiver Trimble® SPS 882 mounted on a pole which was attached in front of the vehicle as show in Figure 41. It was secured with a nylon rope and cable ties to ensure that it was horizontally and vertically balanced. The antenna height, 2.085 m, was measured from the ground up to the bottom of notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topo mode.

The survey started from the Municipality of Castillejos to the Municipality of Cabangan which traversed the main roads. UP-MAC was occupied as the GNSS base station for the validation survey.

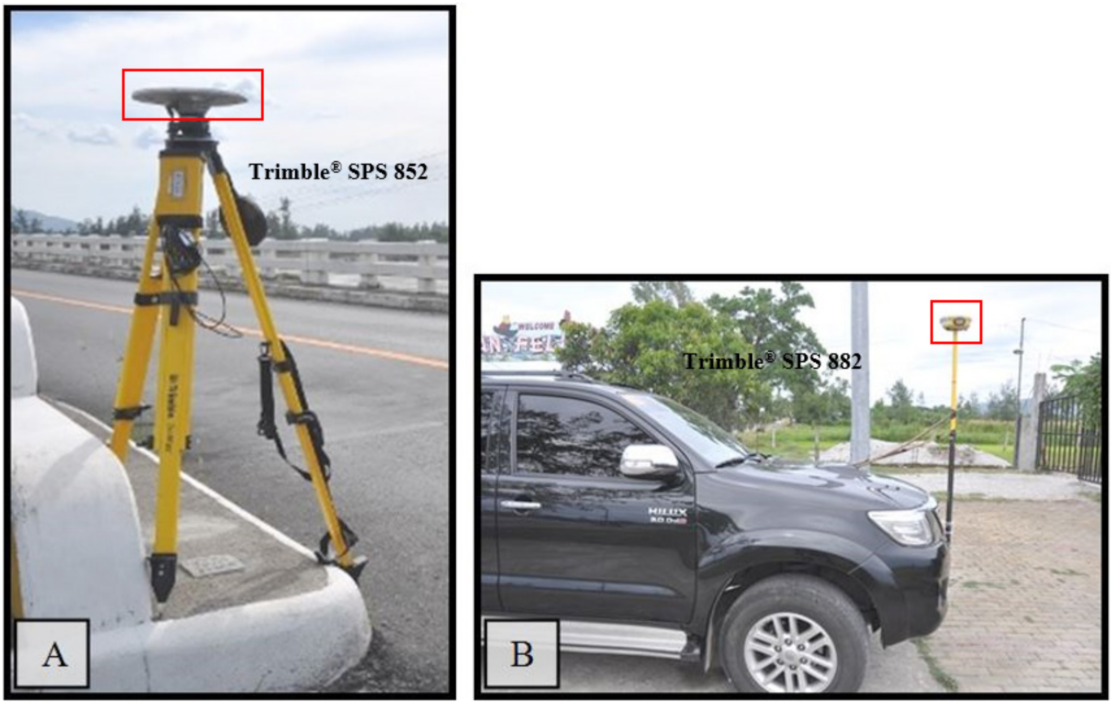


Figure 41. A) The occupied GNSS base station, UP-MAC, in Municipality of San Narciso with Trimble® SPS 852 and (B) the set-up of Trimble® SPS 882 in a vehicle for ground validation acquisition

The survey acquired 3,245 ground validation points with an approximate length of 32 km. The coverage of the validation survey is shown in Figure 42.

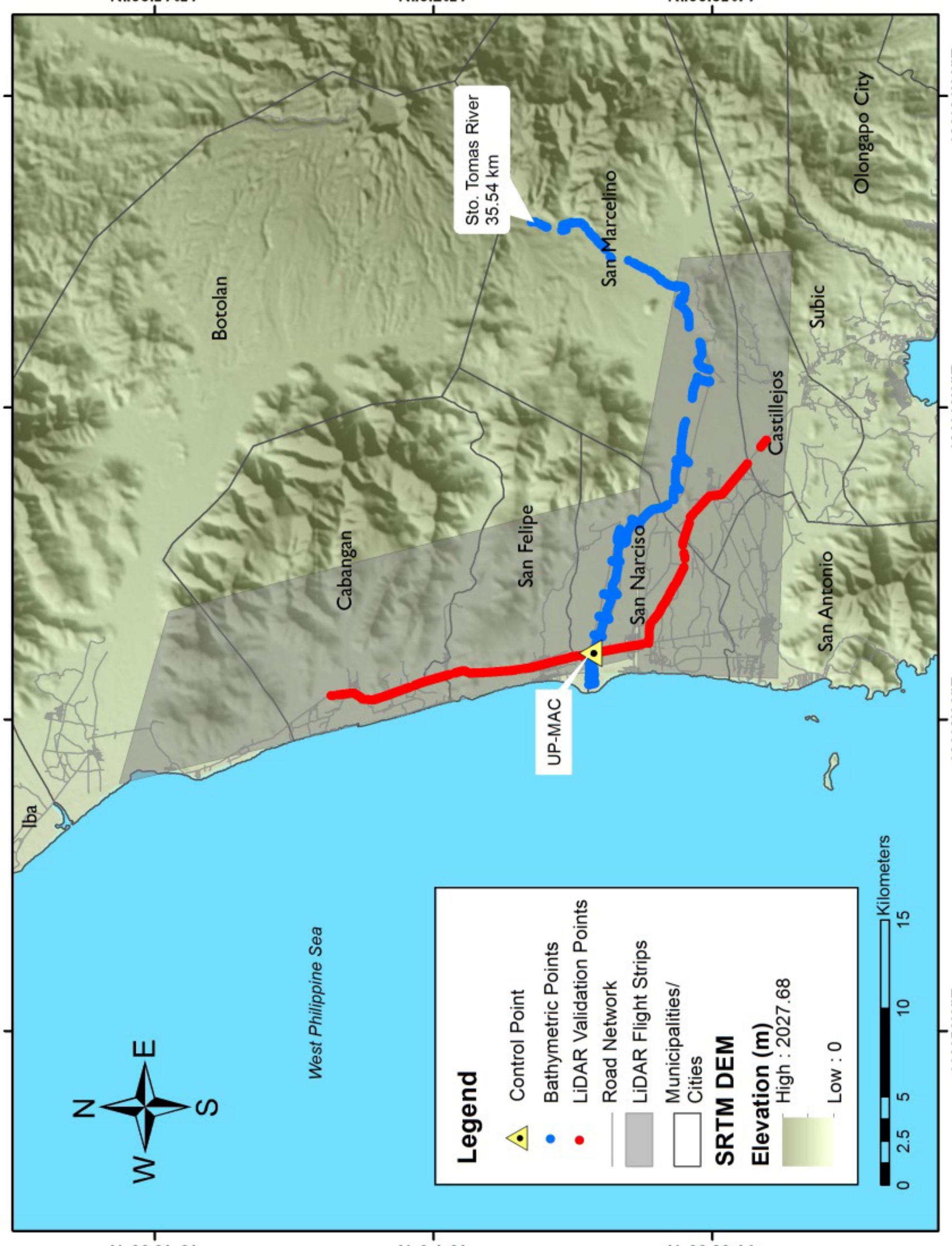


Figure 42. Validation points acquisition survey along Sto. Tomas River Basin

4.7 River Bathymetric Survey

Bathymetric survey was conducted on December 6, 8, and 10, 2014 using Trimble® SPS-882 GNSS receiver in PPK survey technique attached on a four-wheel drive vehicle as shown in Figure 43 or by foot as shown in Figure 44. The control point UP-MAC was used as the GNSS base station for the bathymetric survey. The survey started at the upstream part of the river in Brgy. Rabanes, Mun. of San Marcelino with coordinates 15°04’01.05200” 120120d17’40.22113”17’40.22113” down to Brgy. San Rafael, Mun. of San Felipe, with coordinates 15°02’15.56729” 120°03’34.15361”.

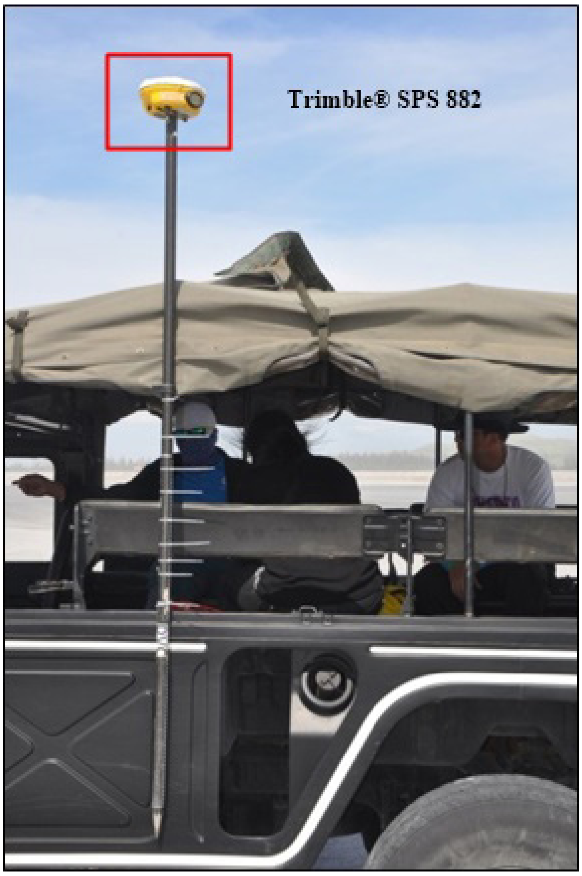


Figure 43. Bathymetric survey along Sto. Tomas River using Trimble® SPS 882 GNSS receiver attached to a four-wheel drive vehicle borrowed from LGU of Botolan

Figure 44. Bathymetric survey along Sto. Tomas River going upstream

Figure 45. Bathymetric points gathered along Sto. Tomas River

The bathymetric survey gathered an estimated total of 35.54 km with 7,454 bathymetric points traversing six barangays in Municipality of San Marcelino, and five barangays in Municipality of San Narciso as shown in Figure 45. A CAD was also produced to illustrate the riverbed profile of the river. As shown in Figure 46 to Figure 48, the highest and lowest elevation of the river has a 43 m difference. The highest elevation value obtained was 300.80 m in MSL located in Brgy. Rabanes, while the lowest elevation value obtained was 1.733 m below MSL in Brgy. San Rafael.

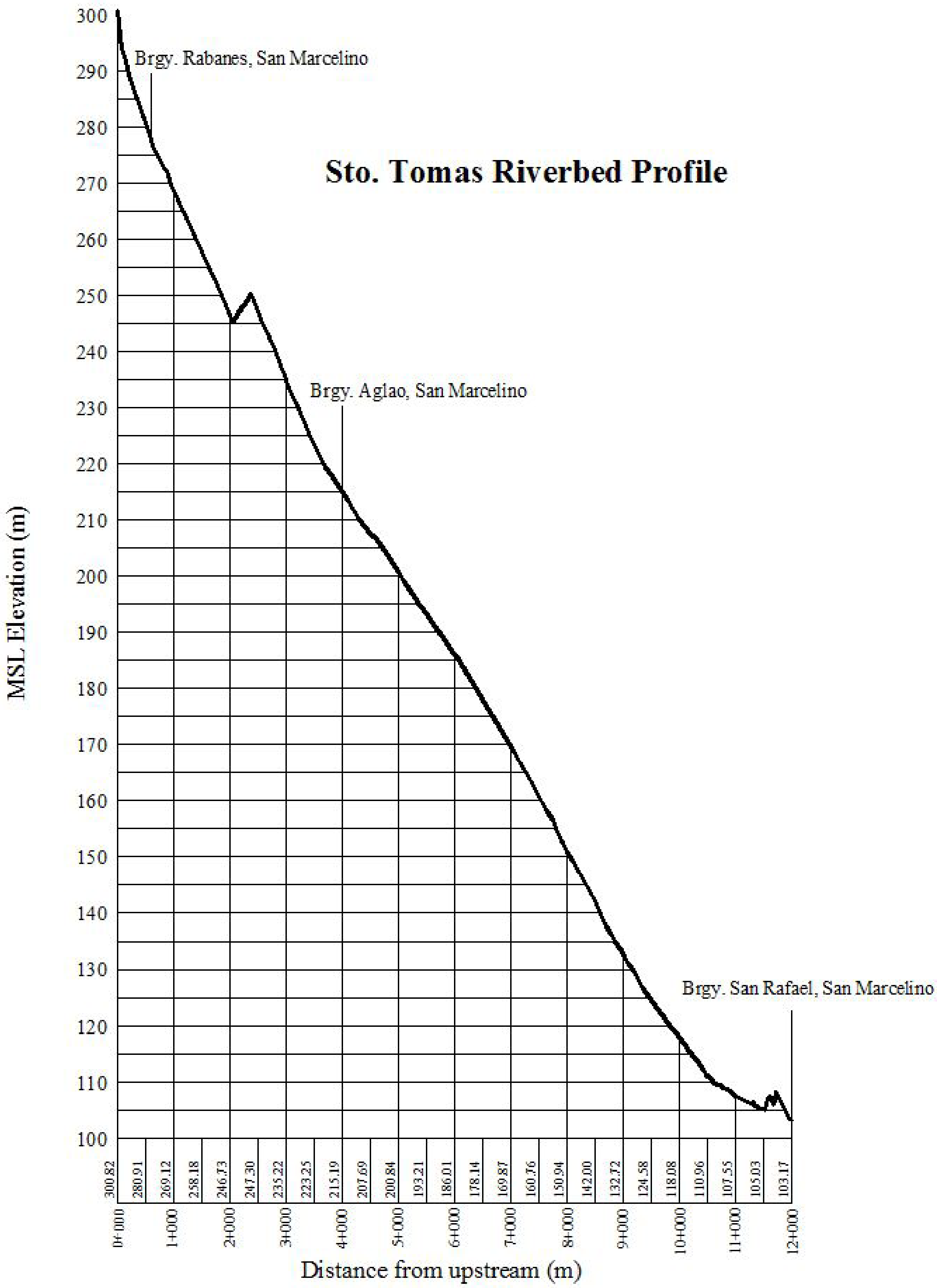


Figure 46. Riverbed profile of Sto.Tomas River (1 of 3)

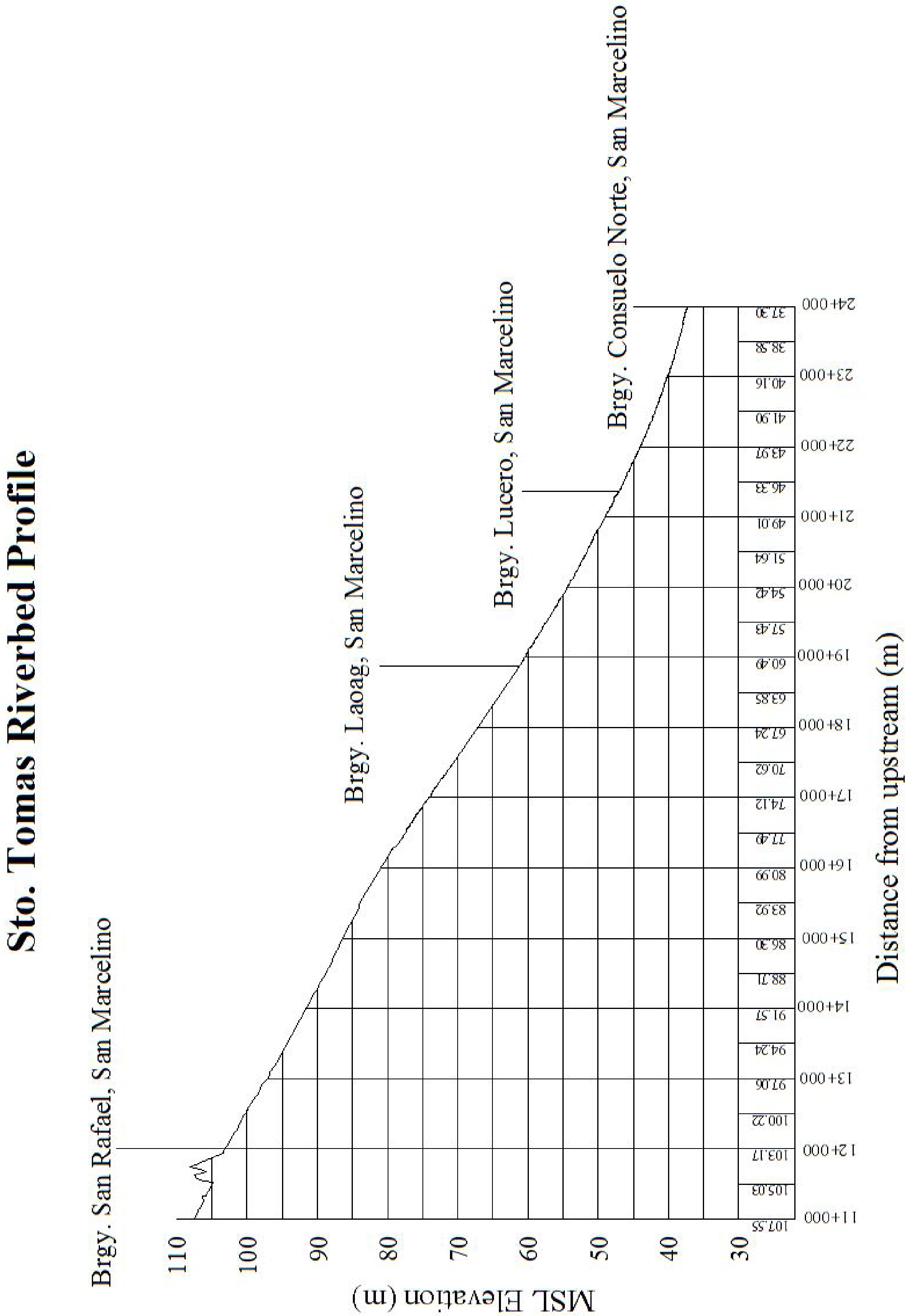


Figure 47. Riverbed profile of Sto.Tomas River (2 of 3)

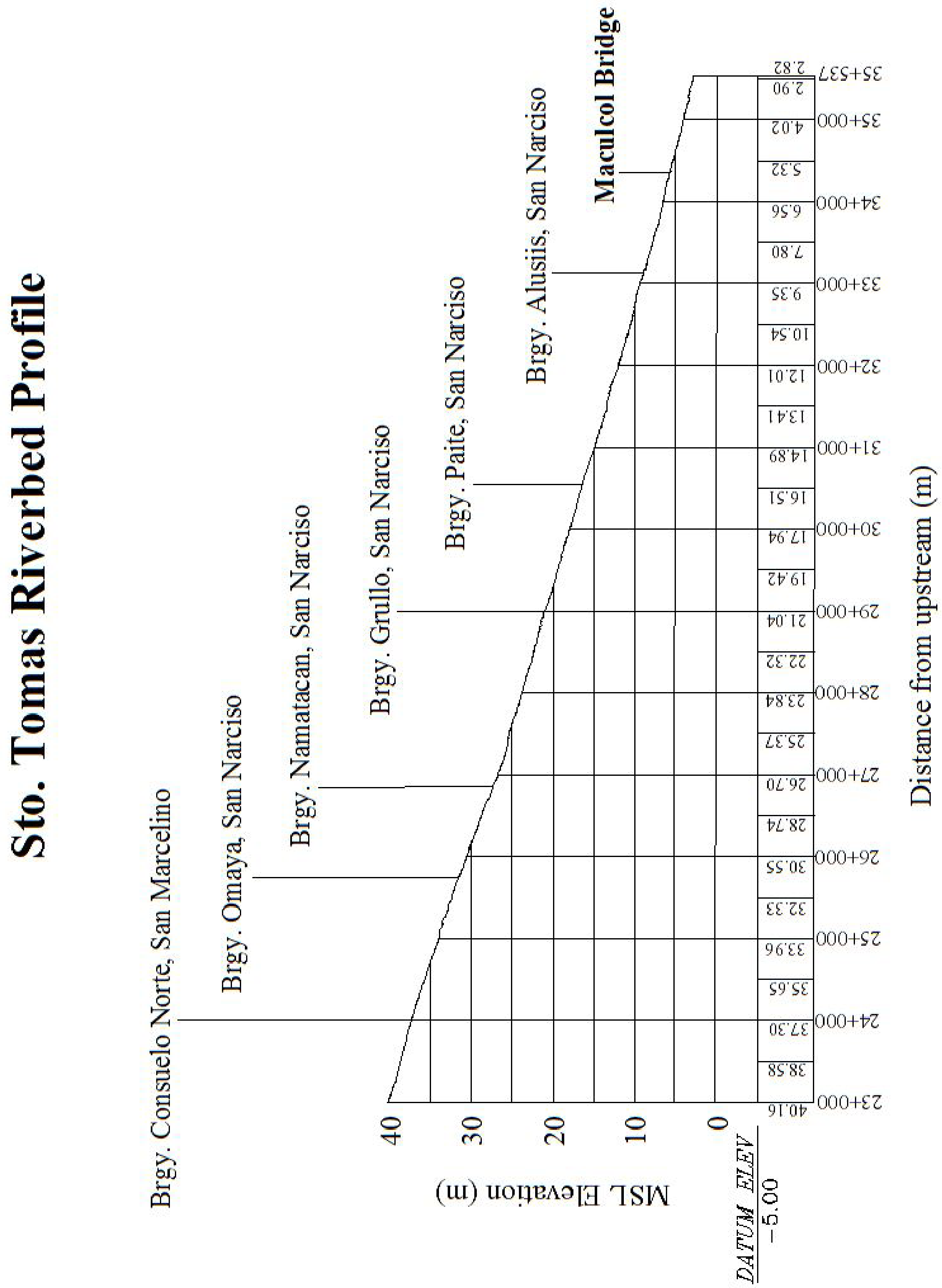


Figure 48. Riverbed profile of Sto.Tomas River (3 of 3)

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, Girlie David, Mariel Monteclaro, Eleazar Raneses, Jr., and Jose T. Gavino

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 river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

In the absence of automatic rain gauge in Sto. Tomas, precipitation data was recorded through manual reading in an 8 inches standard rain gauge installed in the study area. The rain gauge was installed one (1) kilometer upstream from the flow measurement site (Figure 5).

The total rain recorded from the rain gauge is 86.71 mm. It peaked to 8.21 mm on 10 August 2015 at 12:30 PM. The lag time between the peak rainfall and discharge is 12 hours and 30 minutes.

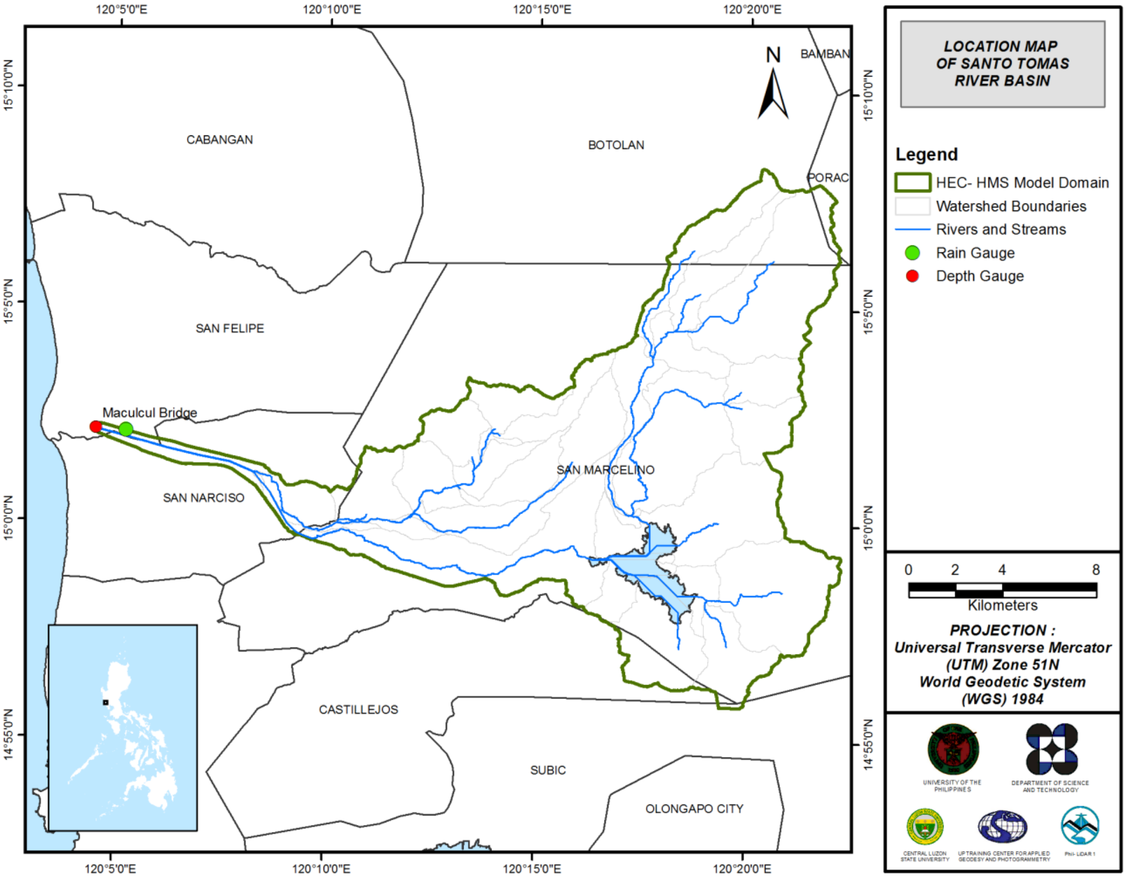


Figure 49. The location map of Sto. Tomas HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Maculcul Bridge, San Felipe, Zambales (15°2'11.1394"N, 120°4' 31.9816"E) It gives the relationship between the observed water levels at Sto. Tomas Bridge and outflow of the watershed at this location.

For Maculcul Bridge, the rating curve is expressed as as $Q = 2E\text{-}21e^{7.8462h}$ as shown in Figure 50.

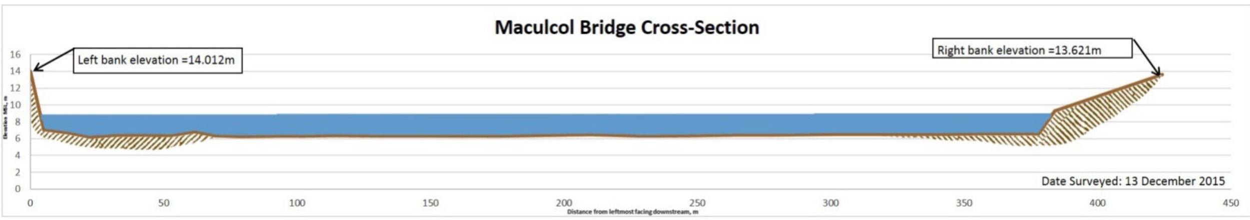


Figure 50. Cross-section plot of Sto. Tomas

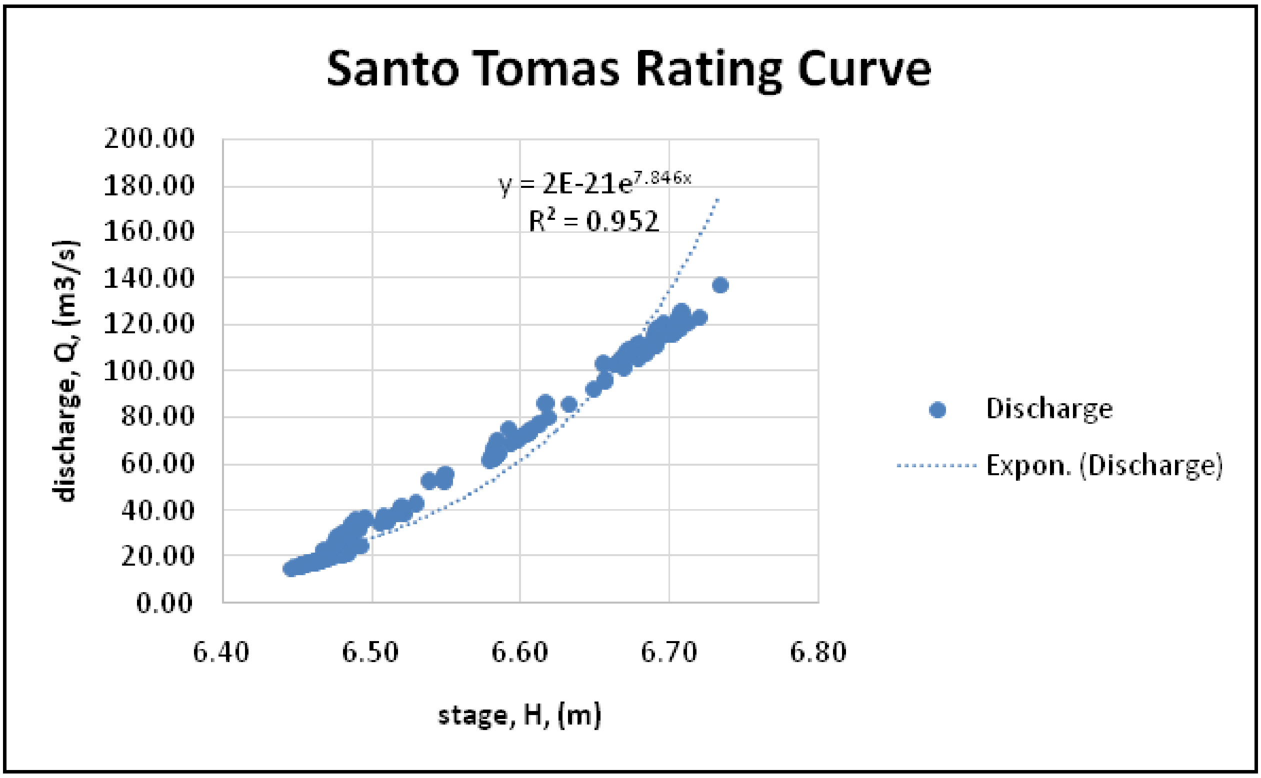


Figure 51. Rating curve at Maculcul Bridge, San Felipe, Zambales

This rating curve equation was used to compute the river outflow at Bucao Bridge for the calibration of the HEC-HMS model shown in Figure 51. Peak discharge is 378.9 cms at 6:20 AM, July 10, 2015.

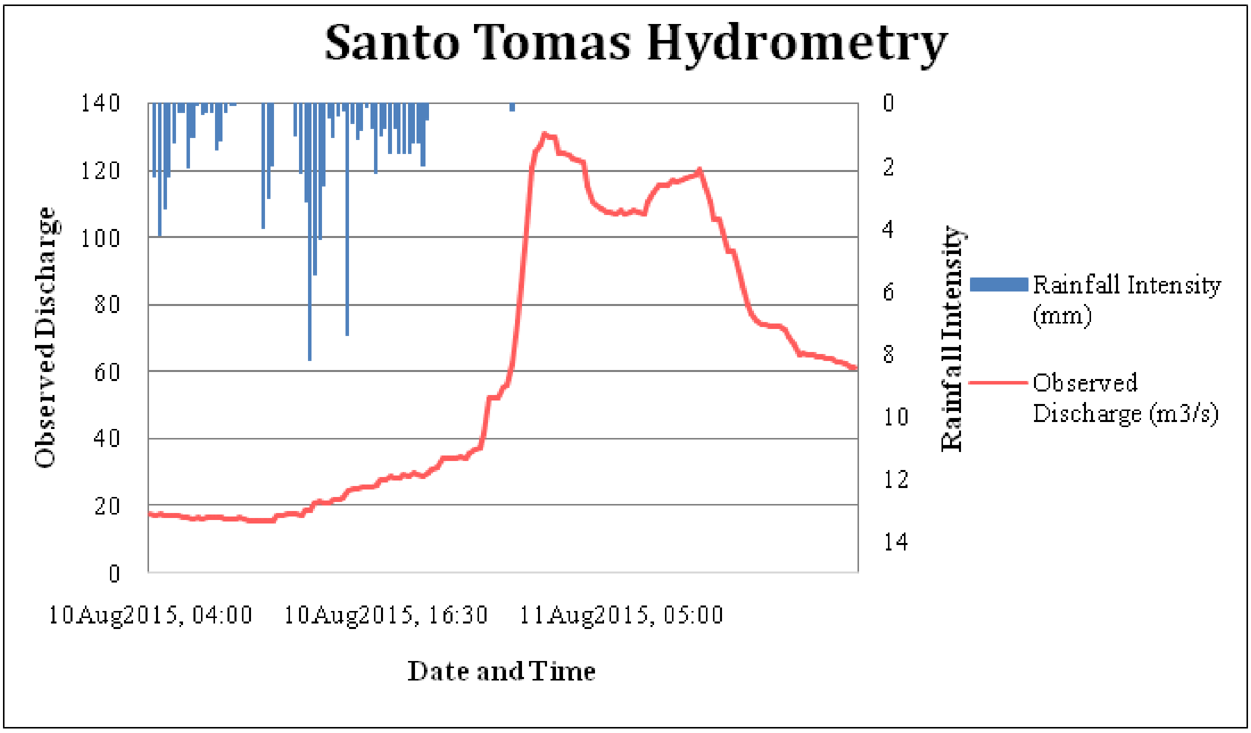


Figure 52. Rainfall and outflow data at Sto. Tomas used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Iba, Zambales Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Sto. Tomas watershed. The extreme values for this watershed were computed based on a 26-year record

Table 32. RIDF values for Iba 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	26.3	41.1	52	67.9	93.7	110.8	148	186.3	224.1
5	36.1	55.9	70.2	92.5	131.7	156.5	208.2	259.5	307
10	42.6	65.8	82.2	108.8	156.9	186.8	248.1	307.9	361.8
15	46.2	71.3	89	118	171.1	203.8	270.6	335.2	392.8
20	48.7	75.2	93.8	124.5	181.1	215.8	286.3	354.4	414.4
25	50.7	78.2	97.4	129.4	188.7	225	298.5	369.1	431.1
50	56.8	87.4	108.7	144.7	212.3	253.4	335.8	414.5	482.5
100	62.8	96.5	119.9	159.9	235.8	281.5	372.9	459.6	533.6

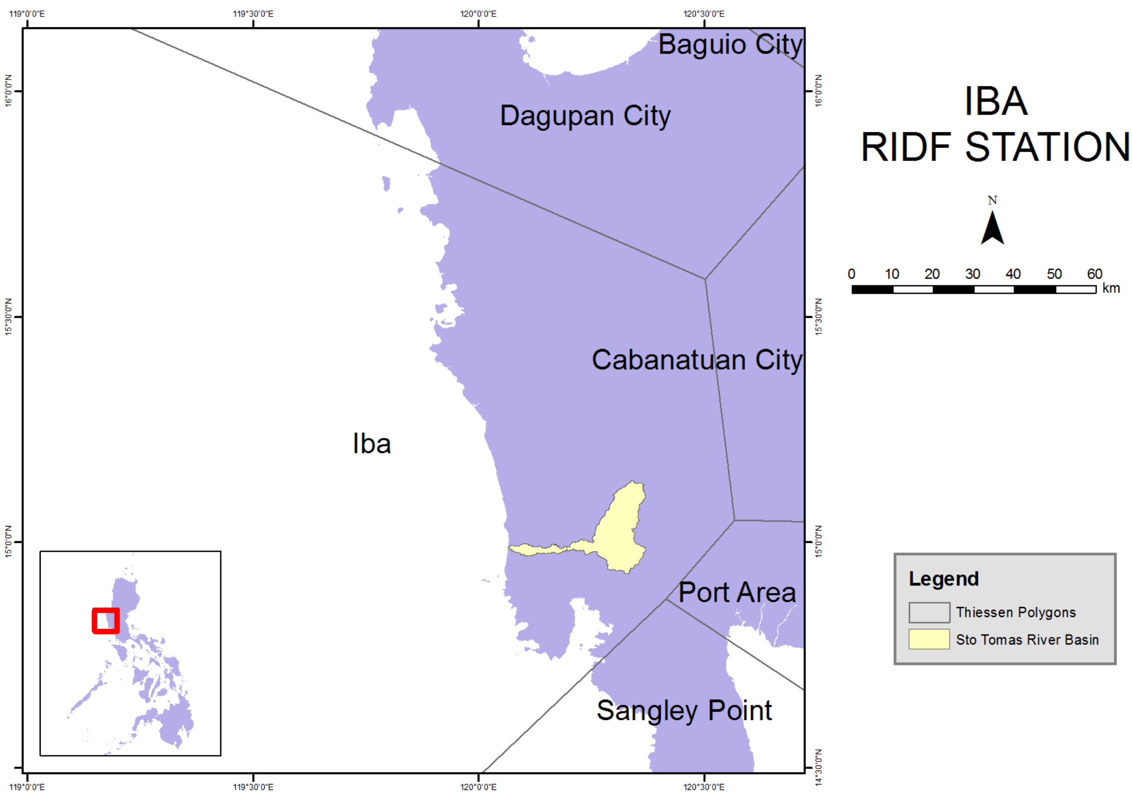


Figure 53. Iba RIDF location relative to Sto. Tomas River Basin

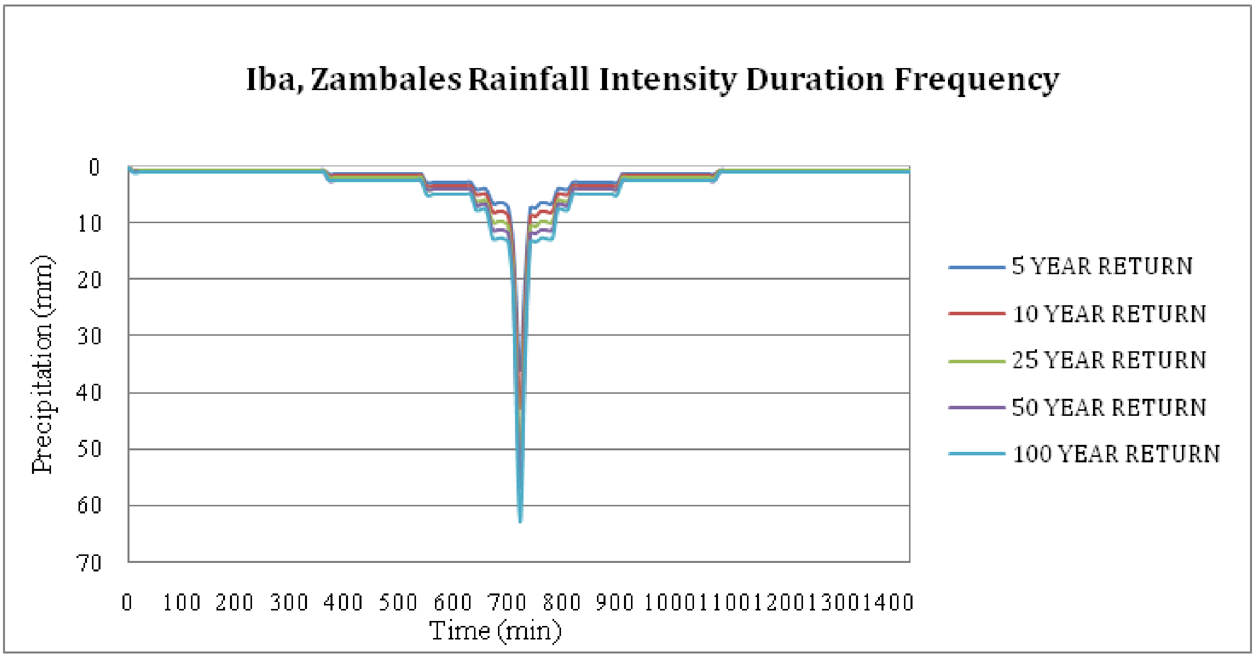


Figure 54. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

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

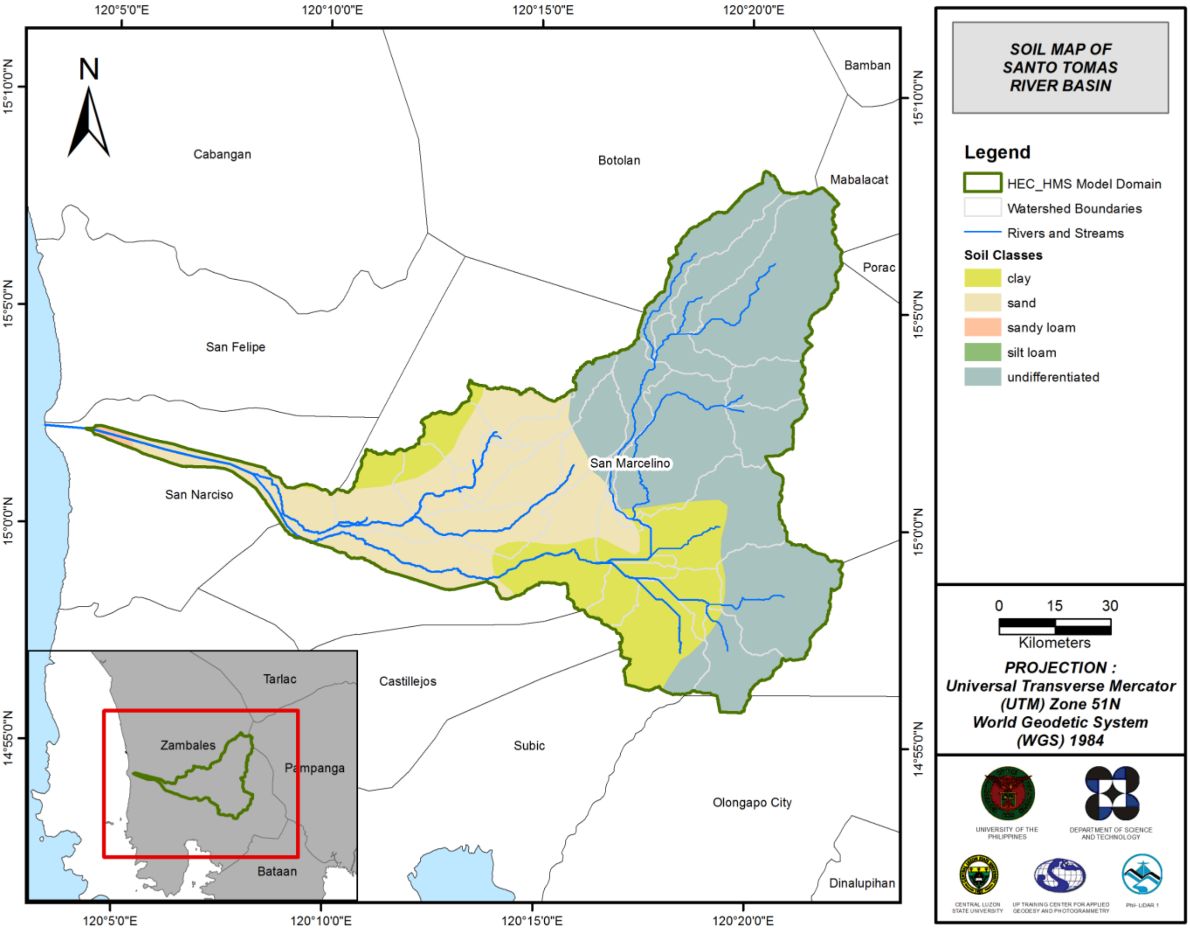


Figure 55. Soil map of Sto. Tomas River Basin

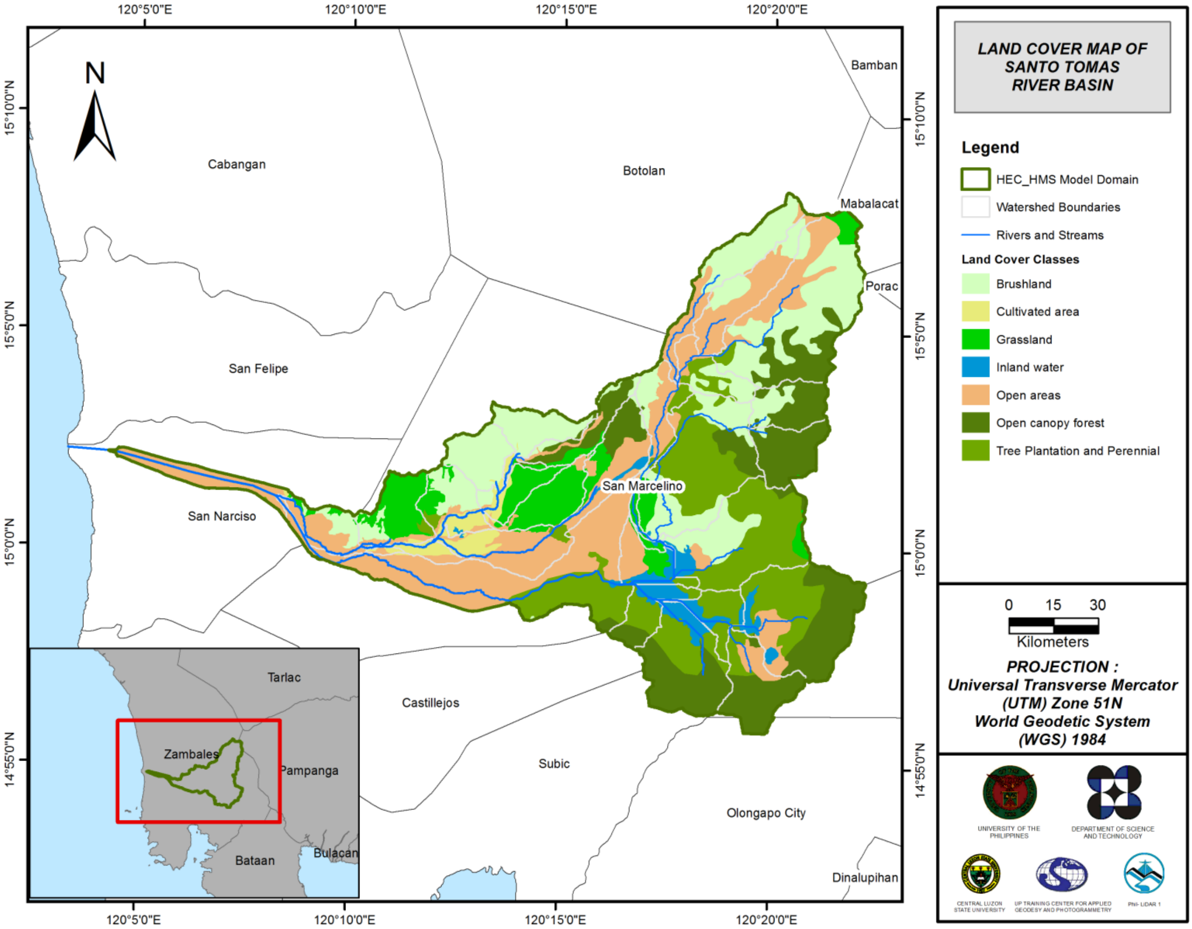


Figure 56. Land cover map of Sto. Tomas River Basin

For Sto. Tomas, five soil classes were identified, namely clay, sand, sandy loam, sandy loam, silt loam, and undifferentiated soil. Moreover, seven land cover classes were identified. These are brushland, cultivated area, grassland, inland water, open areas, open canopy forest and tree plantation, and perennial.

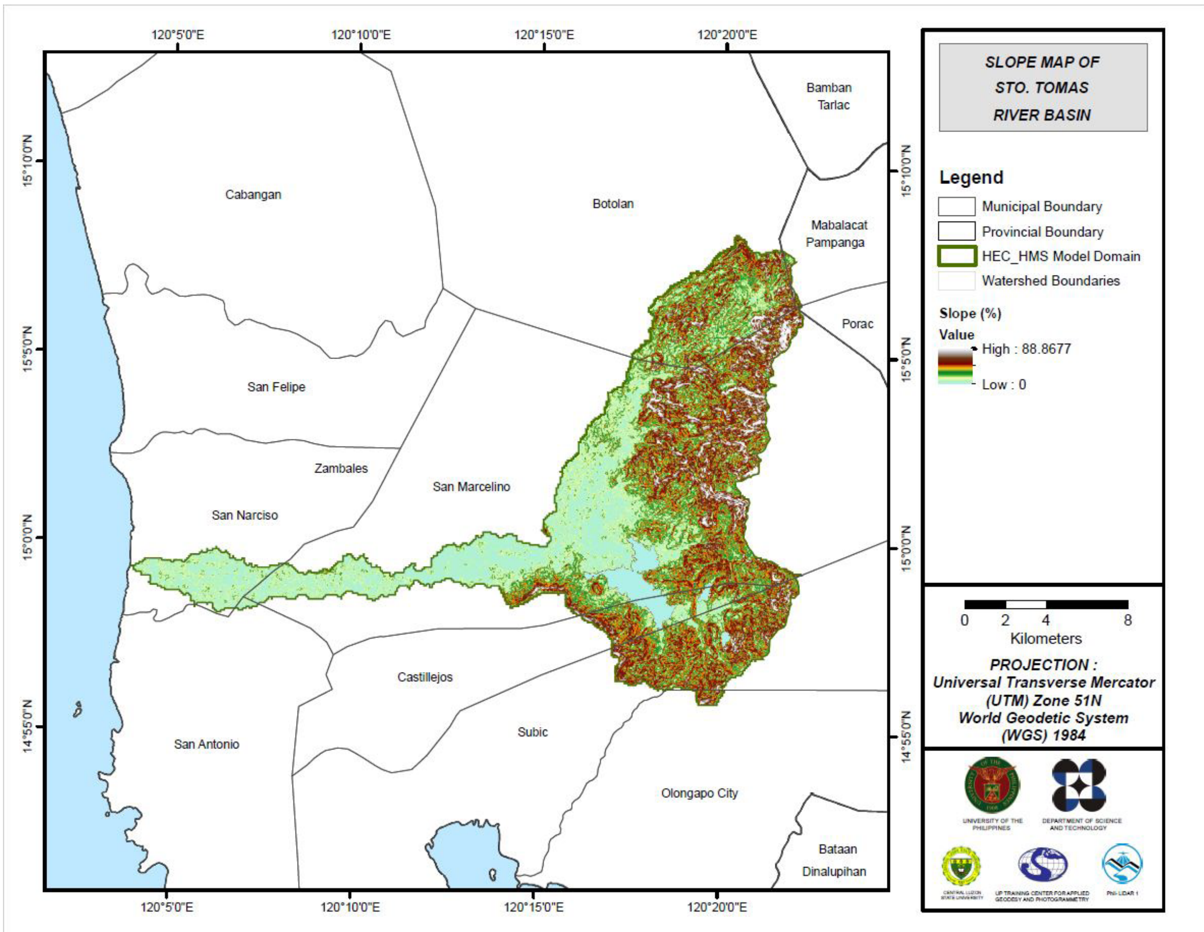


Figure 57. Slope map of Sto. Tomas River Basin

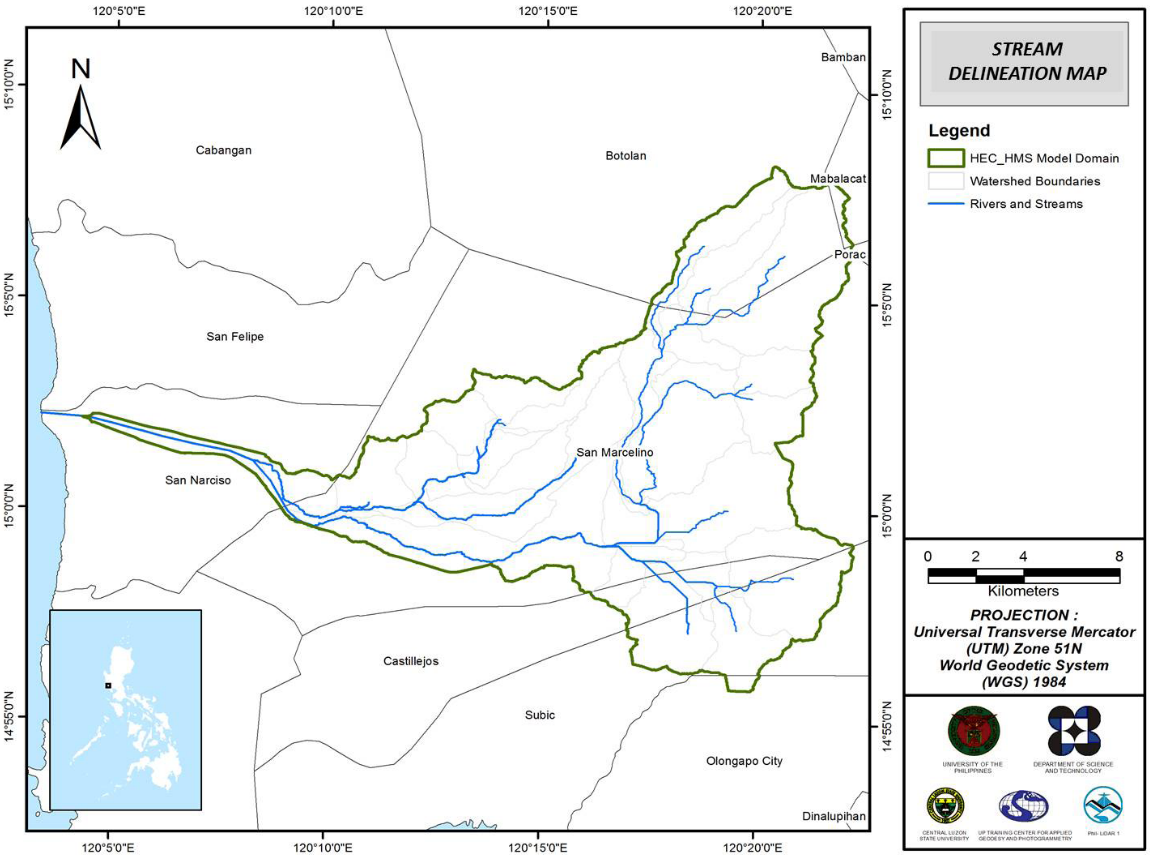


Figure 58. Stream Delineation map of Sto. Tomas River Basin

Using the SAR-based DEM, the Sto. Tomas basin was delineated and further subdivided into subbasin. The Sto. Tomas basin model consists of 29 subbasins, 15 reaches, and 13 junctions as shown in Figure 59. Finally, it was calibrated using depth gauge installed in Maculcul Bridge.

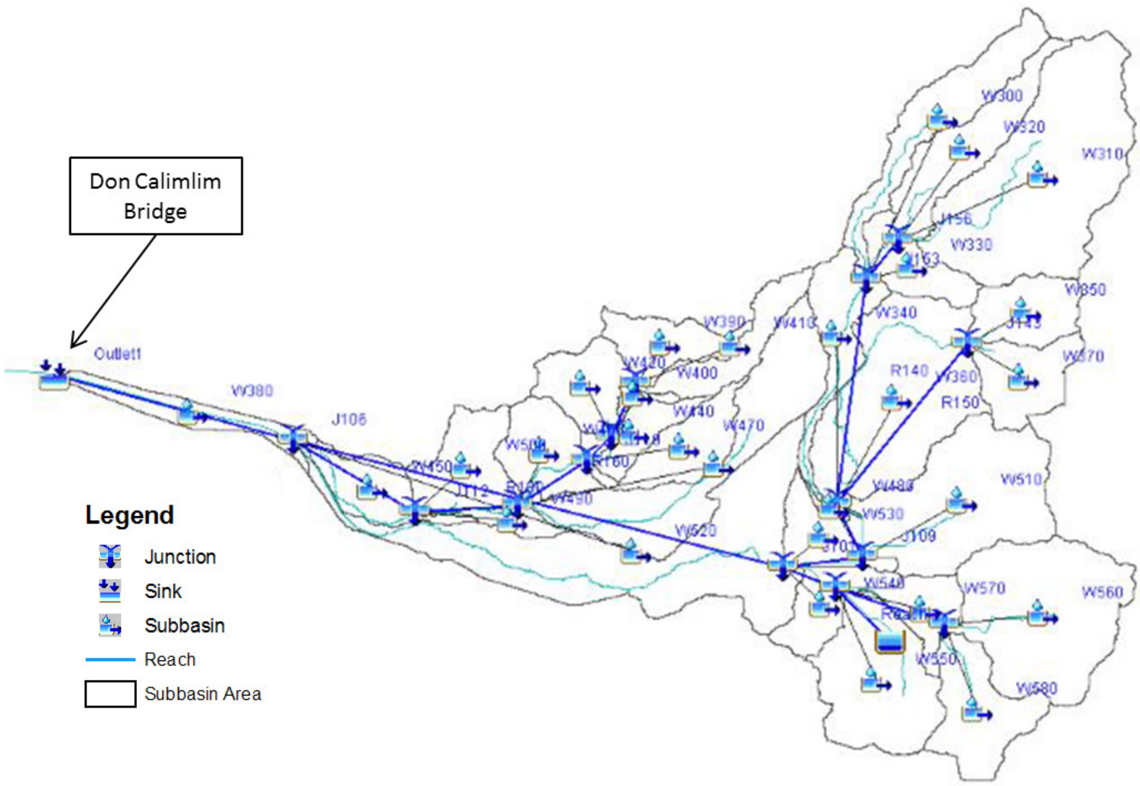


Figure 59. The Sto. Tomas River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

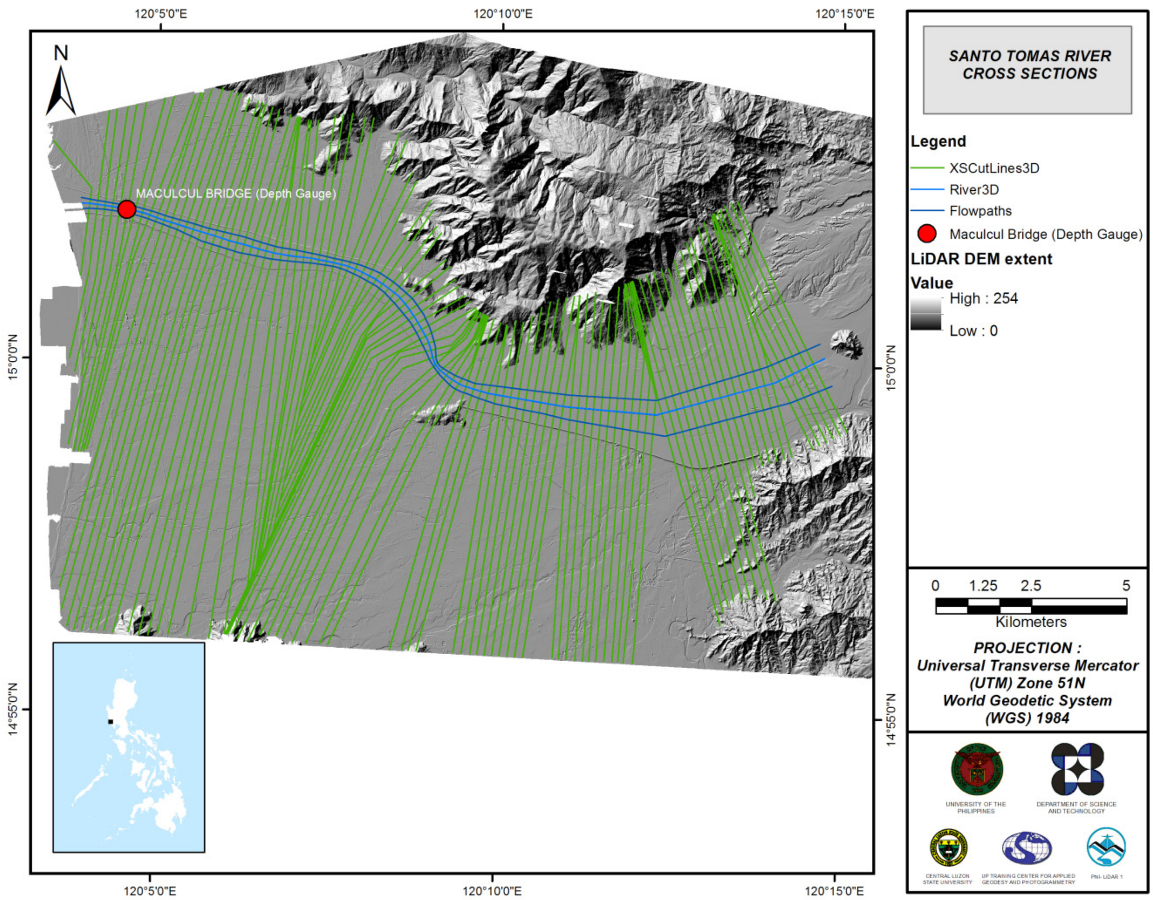


Figure 60. River cross-section of Bucao River generated through Arcmap HEC GeoRAS tool

5.5 FLO-2D Model

The automated modeling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area was divided into square grid elements, 10 meter by 10 meter in size. Each element was assigned a unique grid element number which served as its identifier, then attributed with the parameters required for modeling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the east of the model to the west, following the main channel. As such, boundary elements to the west of the model are assigned as outflow elements.

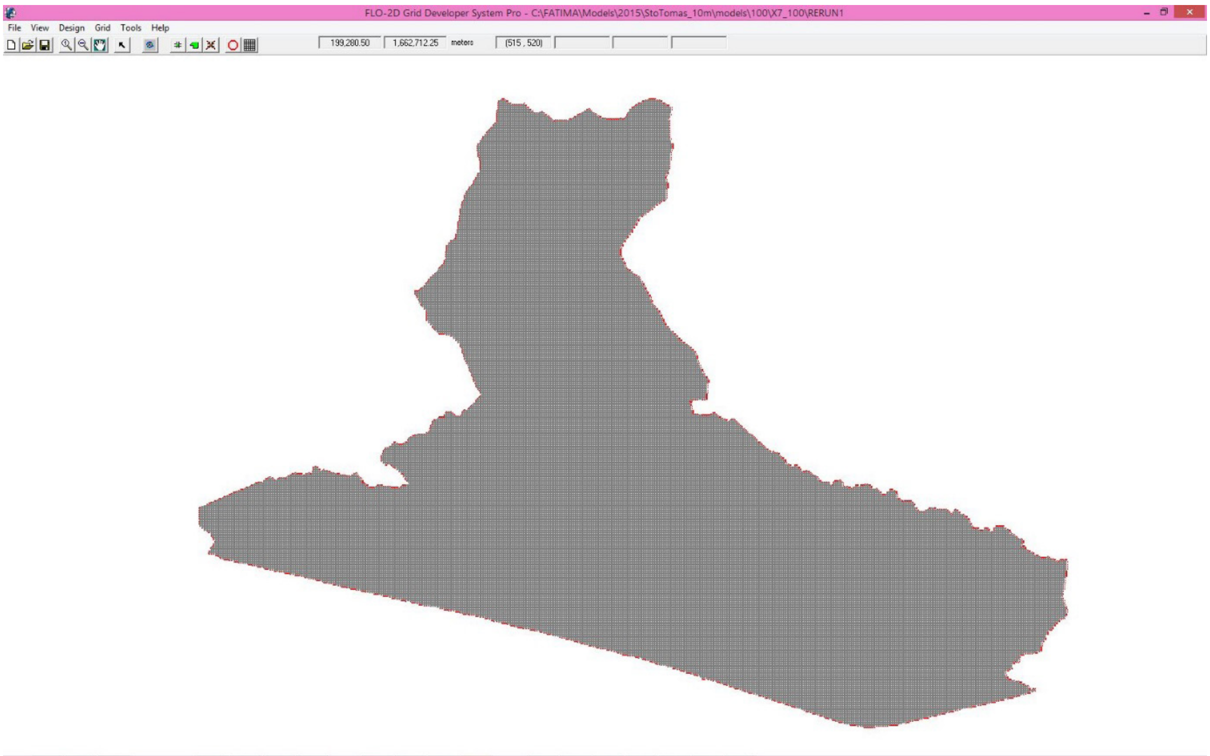


Figure 61. Screenshot of sub-catchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 40.46 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 $m^{2/s.}$

The creation of a flood hazard map from the model also automatically creates a flood depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 54,004,600.00 m2.

There is a total of 70,522,873.22 m3 of water entering the model, of which 28,732,006.11 m3 is due to rainfall and 41,790,867.11 m3 is inflow from basins upstream. About 10,525,877.00 m3 of this water is lost to infiltration and interception, while 4,143,843.78 m3 is stored by the floodplain. The rest, amounting up to 55,853,152.30 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Sto. Tomas HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

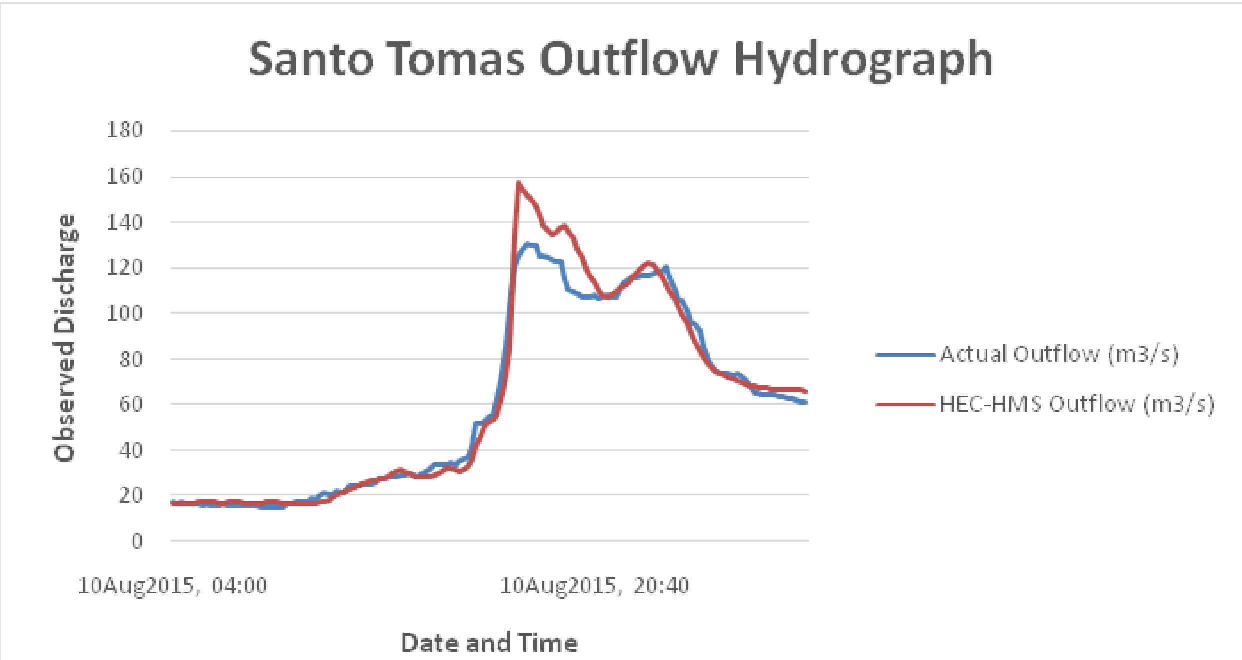


Figure 62. Outflow hydrograph of Sto. Tomas produced by the HEC-HMS model compared with observed outflow

Table 33 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of calibrated values for the Sto. Tomas River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.54 - 16
			Curve Number	20 - 53
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 – 4.2
			Storage Coefficient (hr)	0.1 – 1.2
	Baseflow	Recession	Recession Constant	0.55
			Ratio to Peak	0.3
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.02

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.54 mm to 16 mm signifies that there is minimal amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range for the curve number of Sto. Tomas River Basin is 20 to 53. For Sto. Tomas, the basin mostly consists of open areas, open canopy forest and tree plantation, and perennial and the soil mostly consists of clay, sand, and undifferentiated soil.

The 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 0.1 hour to 4.2 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, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.55 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.3 indicates a steep receding limb of the outflow hydrograph.

Manning’s roughness coefficient of 0.02 corresponds to the common roughness in Sto. Tomas watershed, which is determined to be a cultivated area but with no crop (Brunner, 2010).

Table 34. Summary of the efficiency test of Sto. Tomas HMS Model

Accuracy Measure	Value
RMSE	7.4
r2	0.976
NSE	0.98
PBIAS	-2.39
RSR	0.13

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed at 7.4 $m^{3/s.}$

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. A value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. The computed value of r2 = 0.976 was obtained in this model. This means that the degree of collinearity between simulated and measured data is relatively high.

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 0.98 which means that the model has a very good performance rating in simulating discharge.

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 -2.39 which implies that the model was overestimated at 2.39 percent difference in streamflow volume between simulated and measured data for a particular period.

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 are quantified. The model has an RSR value of 0.13 which indicates that the model has a better simulation performance due to low value of computed RSR.

5.7 Calculated Outflow Hydrographys and Discharge Values for Different Rainfall Return Periods

5.7.1 Hydrograph Using the Rainfall Runoff Model

The summary graph (Figure 63) shows the Sto. Tomas outflow using the Iba RIDF curves 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.

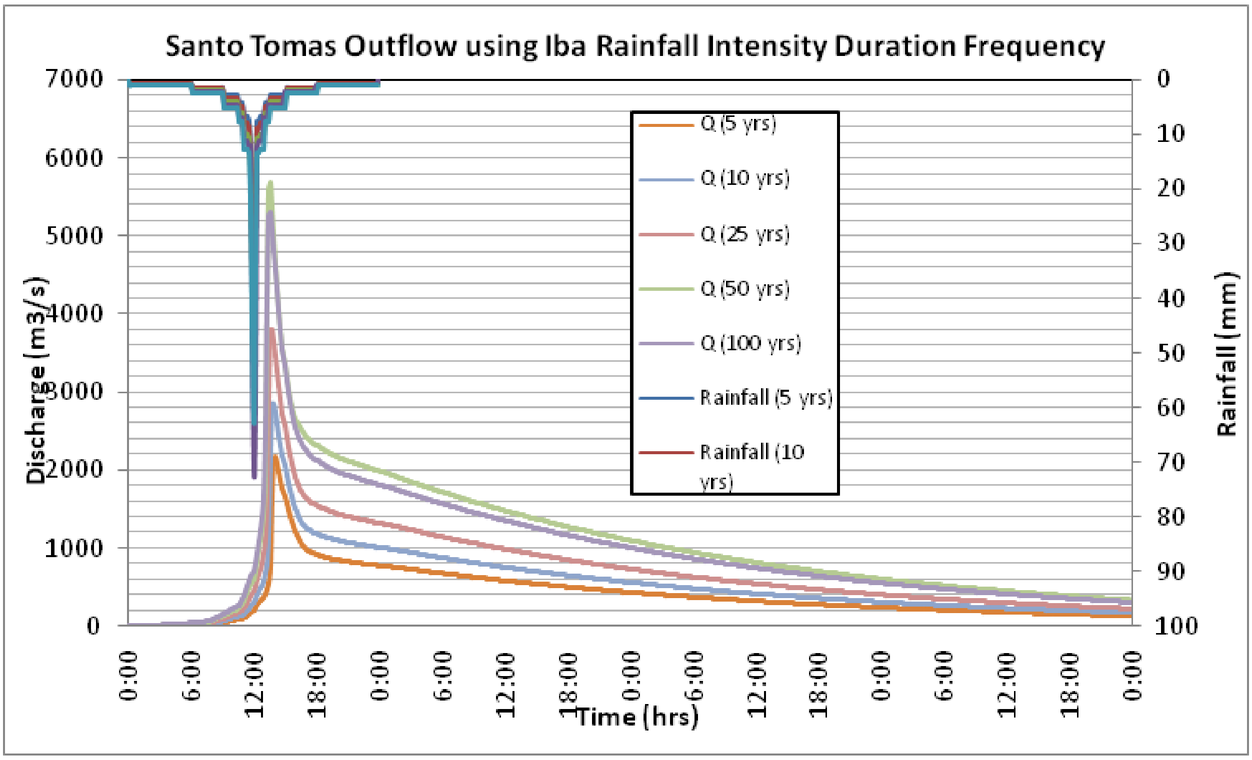


Figure 63. Outflow hydrograph at Sto. Tomas Station generated using Iba RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Sto. Tomas discharge using the Zambales RIDF curves in five different return periods is shown in Table 35.

Table 35. Peak values of the Sto. Tomas HEC-HMS model outflow using Iba RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	286.74	36.1	2163.8	2 hours, 10 min
10-Year	335.49	42.6	2854.9	1 hour, 50 min
25-Year	403.07	50.7	3797.5	1 hour, 50 min
50-Year	451.46	56.8	5678.8	1 hour, 40 min
100-Year	499.31	62.8	5304.8	1 hour, 40 min

5.7.2 Discharge Data using Dr. Horritts's Recommended Hydrologic Method

The river discharges for the three rivers entering the floodplain are shown in Figure 63 to Figure 65 and the peak values are summarized in Table 36 to Table 38.

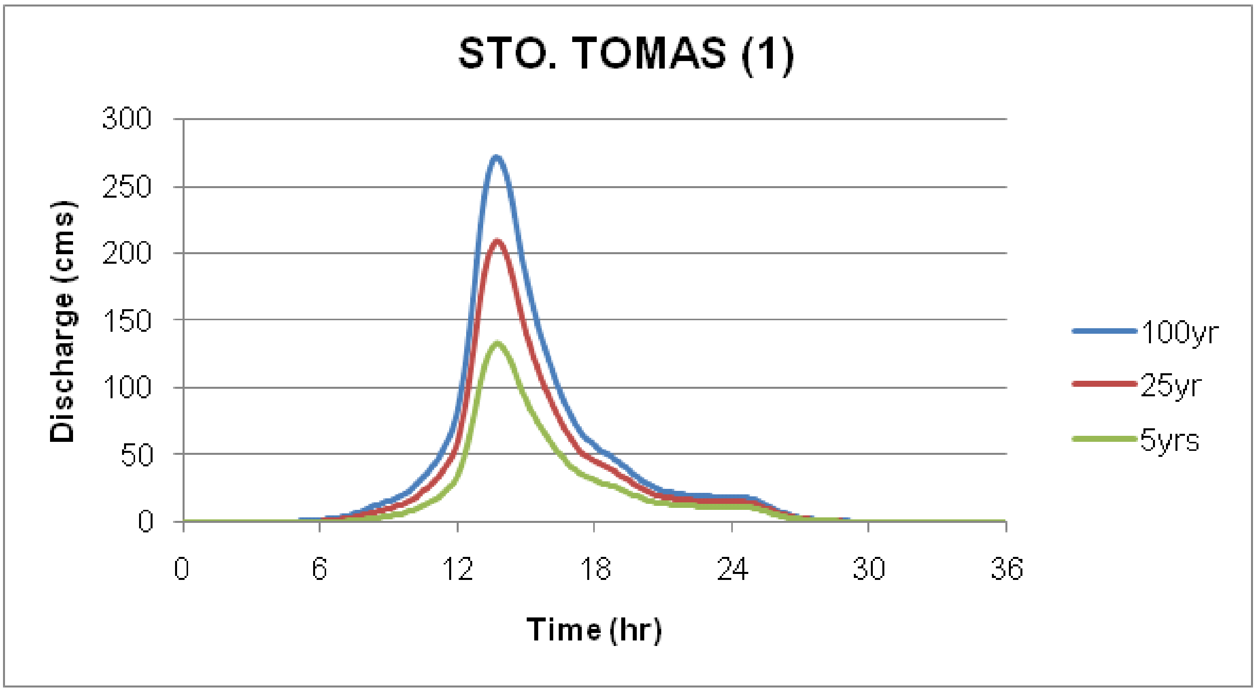


Figure 64. Sto. Tomas River (1) generated discharge using 5-, 25-, and 100-year Iba RIDF in HEC-HMS

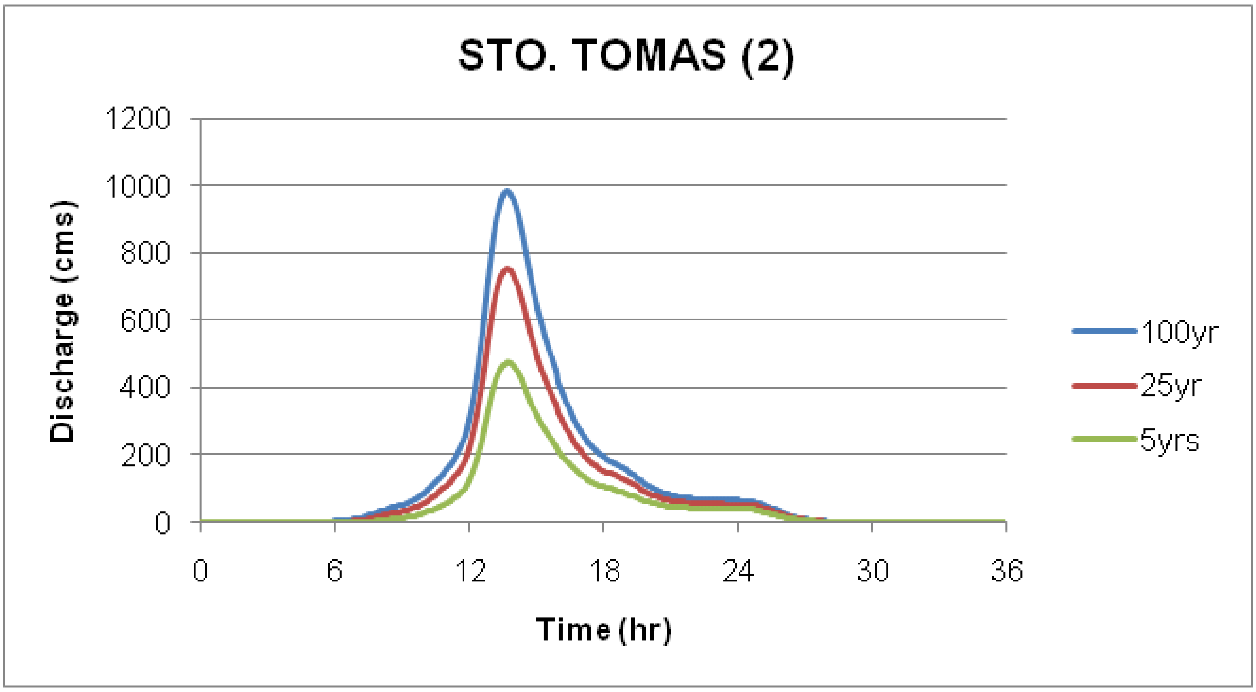


Figure 65. Sto. Tomas river (2) generated discharge using 5-, 25-, and 100-year Iba RIDF in HEC-HMS

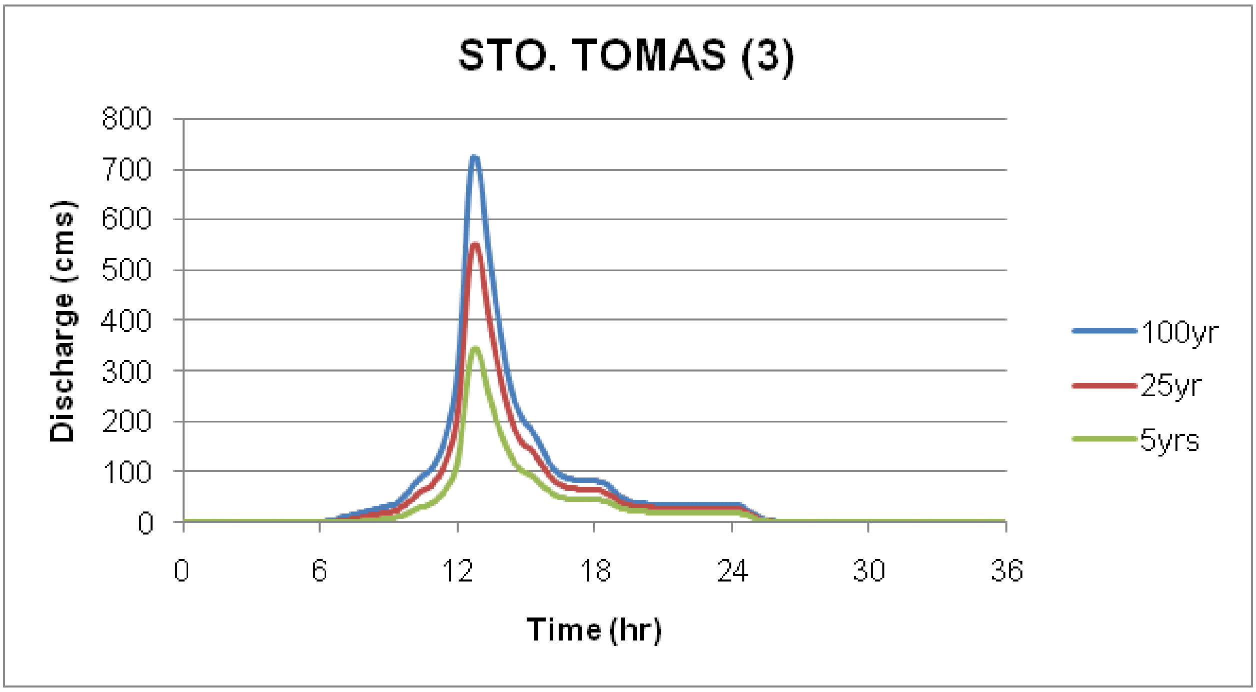


Figure 66. Sto. Tomas river (3) generated discharge using 5-, 25-, and 100-year Iba RIDF in HEC-HMS

Table 36. Summary of Sto. Tomas river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	271.4	13 hours, 40 minutes
25-Year	208.3	13 hours, 40 minutes
5-Year	132.3	13 hours, 40 minutes

Table 37. Summary of Sto. Tomas river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	983.6	13 hours, 40 minutes
25-Year	752.8	13 hours, 40 minutes
5-Year	475.7	13 hours, 40 minutes

Table 38. Summary of Sto. Tomas river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	722.0	12 hours, 40 minutes
25-Year	549.1	12 hours, 50 minutes
5-Year	342.7	12 hours, 50 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 39.

Table 39. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Sto. Tomas (1)	116.424	219.057	132.177	Pass	Pass
Sto. Tomas (2)	418.616	416.266	340.700	Pass	Pass
Sto. Tomas (3)	301.576	604.859	220.069	Pass	Pass

All three values from the HEC-HMS river discharge estimates were able to satisfy at least one of the conditions for validation using the bankful and specific discharge methods. The calculated values were based on theory but were supported using other discharge computation methods so they were good to use flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

The Sto. Tomas model has a minimum and maximum flow discharge of 15.4 and 136.8 m3/s, respectively, and this was needed for unsteady flow analysis as input file. The simulation results showed that the maximum water surface depth elevation of Sto. Tomas River had a value of 17.03 meters and this was located at the upper portion of the river. The simulation results revealed that there is no overflow of water along the banks of the river. However, some areas are being flooded due to low-lying areas like farm land and water swamp. These areas were located in Barangay San Rafael in San Felipe, Barangay Alusiis in San Narciso (located at the right downstream portion of the river), Barangay San Pablo in Castillejos and Barangay San Rafael in San Marcelino (located at left upper portion of the river). The sample 1D flood hazard map using the calibrated discharge of Sto. Tomas River from HMS model is shown in Figure 67.

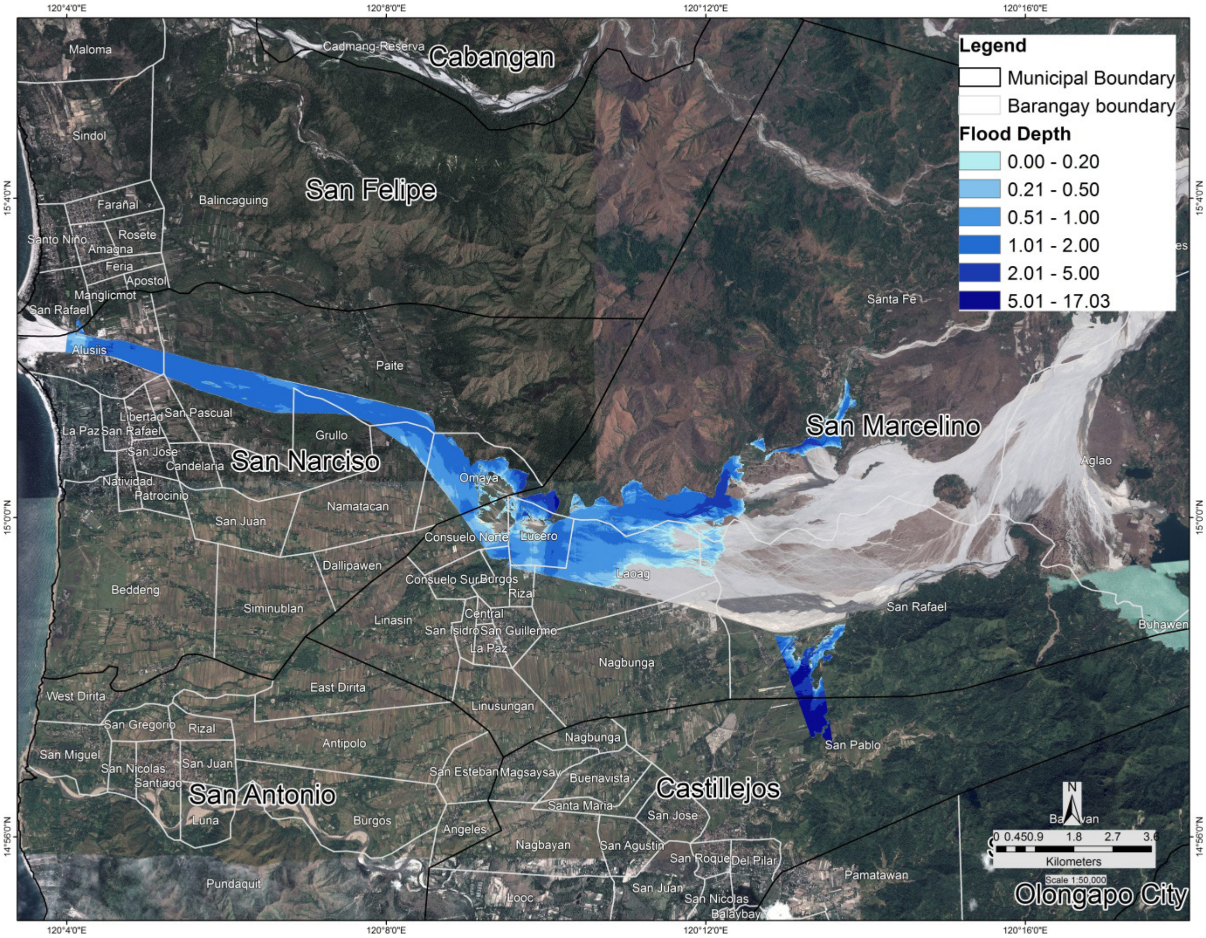


Figure 67. Sample output of Sto. Tomas RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figure 68 to Figure 73 show the 100-, 25-, and 5-year rain return scenarios of the Sto. Tomas Floodplain. The floodplain, with an area of 314.69 sq km, covers six municipalities namely Castillejos, San Antonio, San Felipe, San Marcelino, San Narciso, and Subic. Table 40 shows the percentage of area affected by flooding per municipality.

Table 40. Municipalities affected in Sto. Tomas Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Castillejos	72.10	50.02	69%
San Antonio	179.71	51.48	29%
San Felipe	96.23	20.61	21%
San Marcelino	337.57	93.54	28%
San Narciso	83.24	83.24	100%
Subic	253.60	15.80	6%

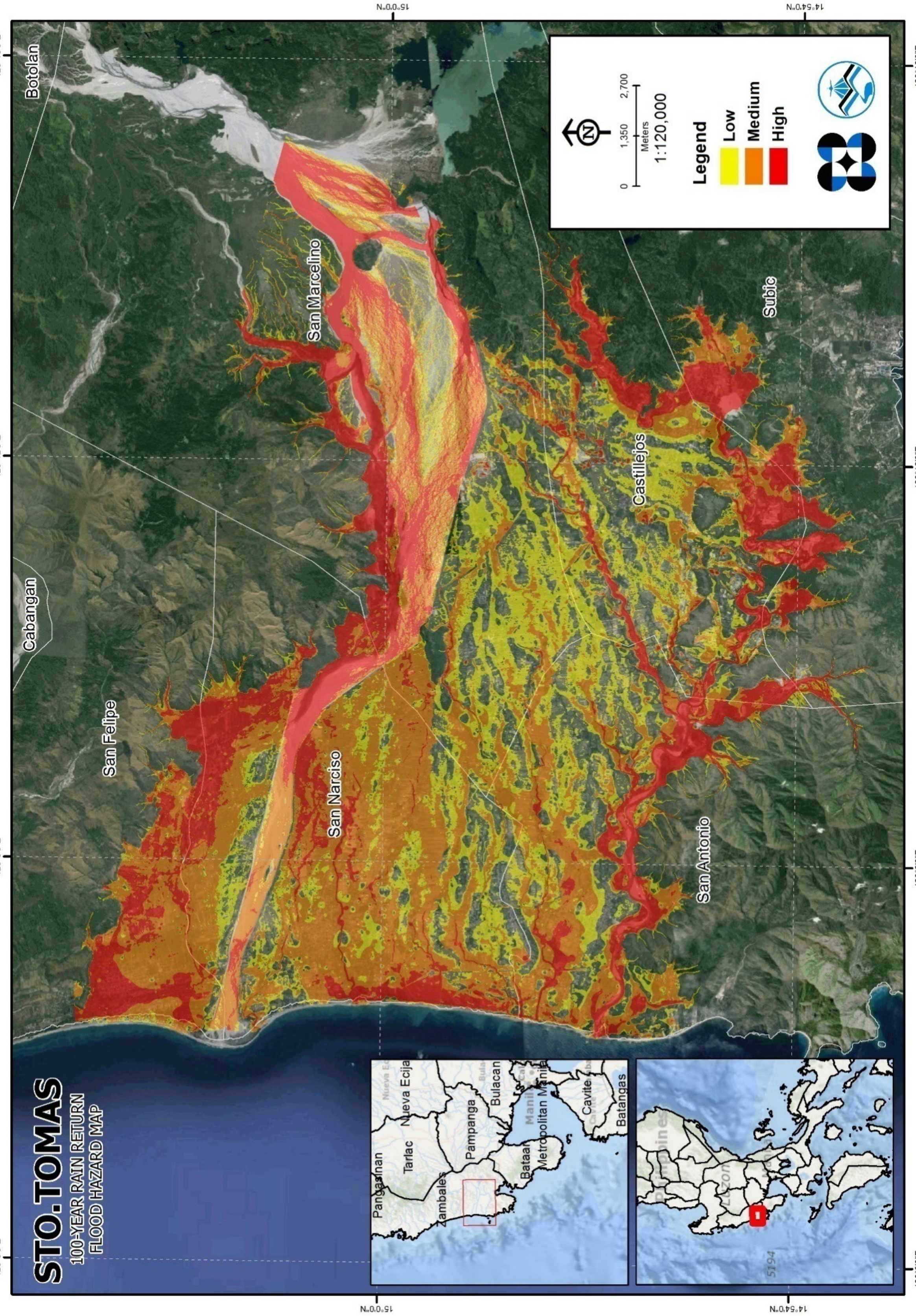


Figure 68. 100-year flood hazard map for Sto. Tomas Floodplain

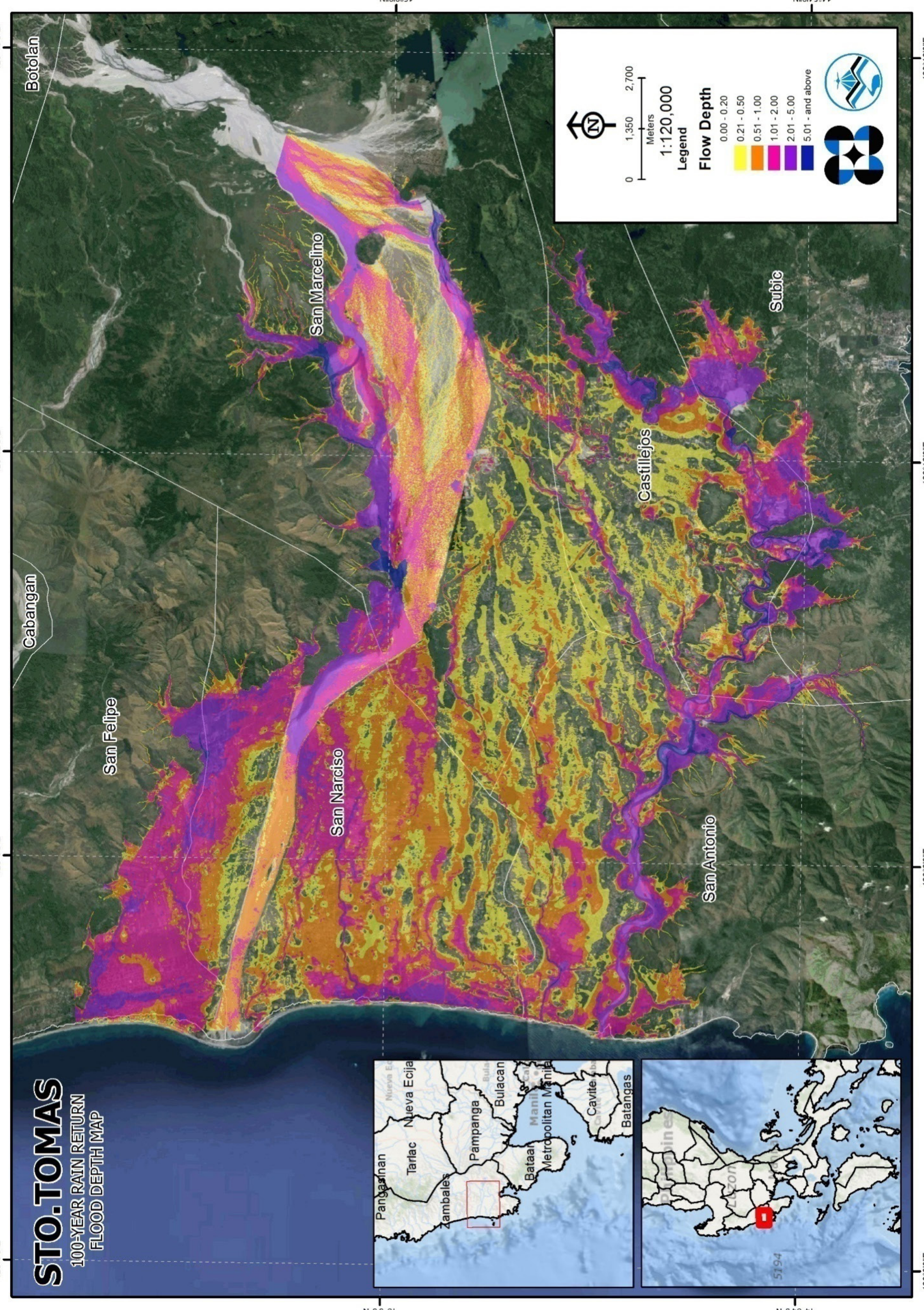


Figure 69. 100-year flow depth map for Sto. Tomas Floodplain

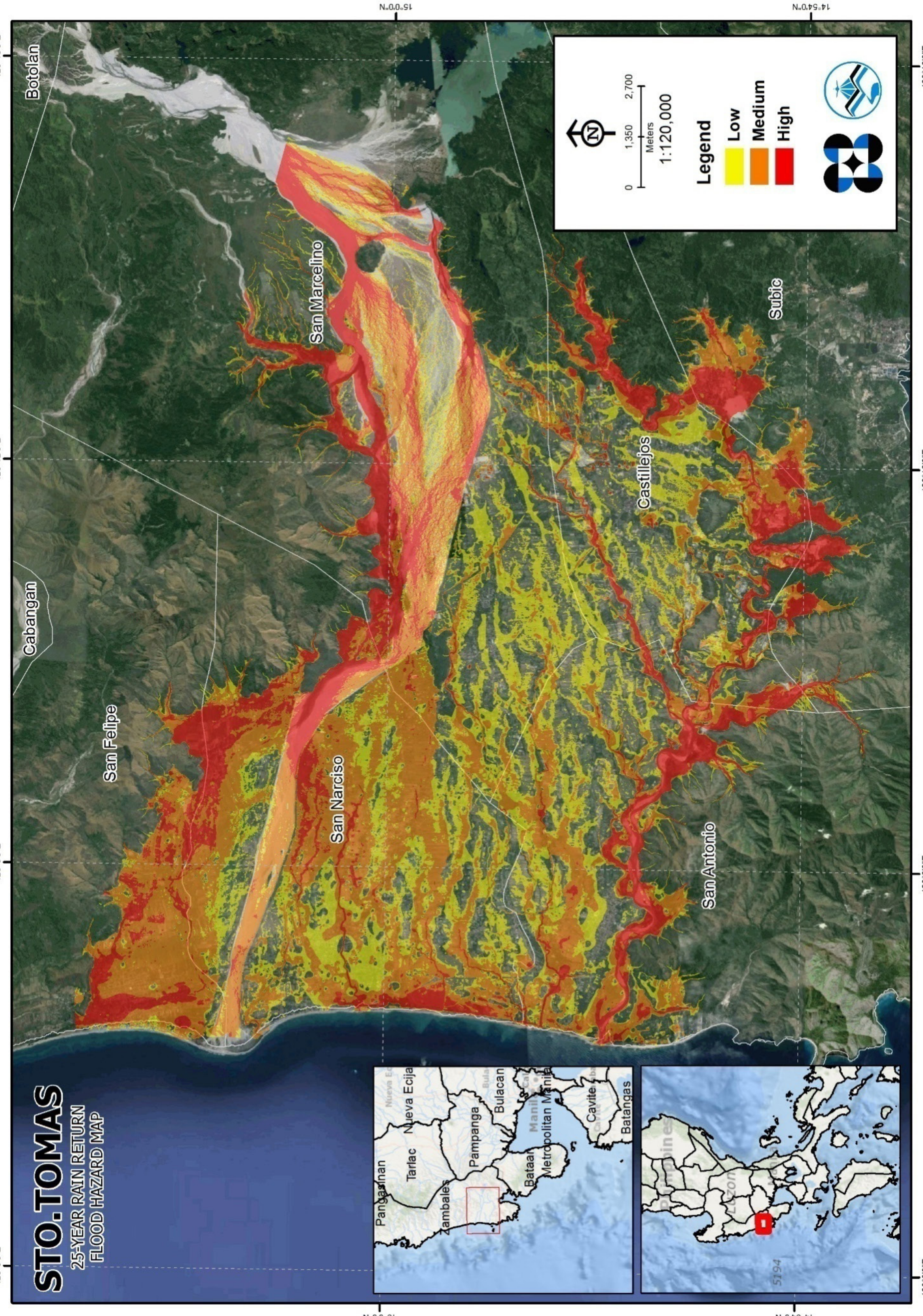


Figure 70. 25-year flood hazard map for Sto. Tomas Floodplain

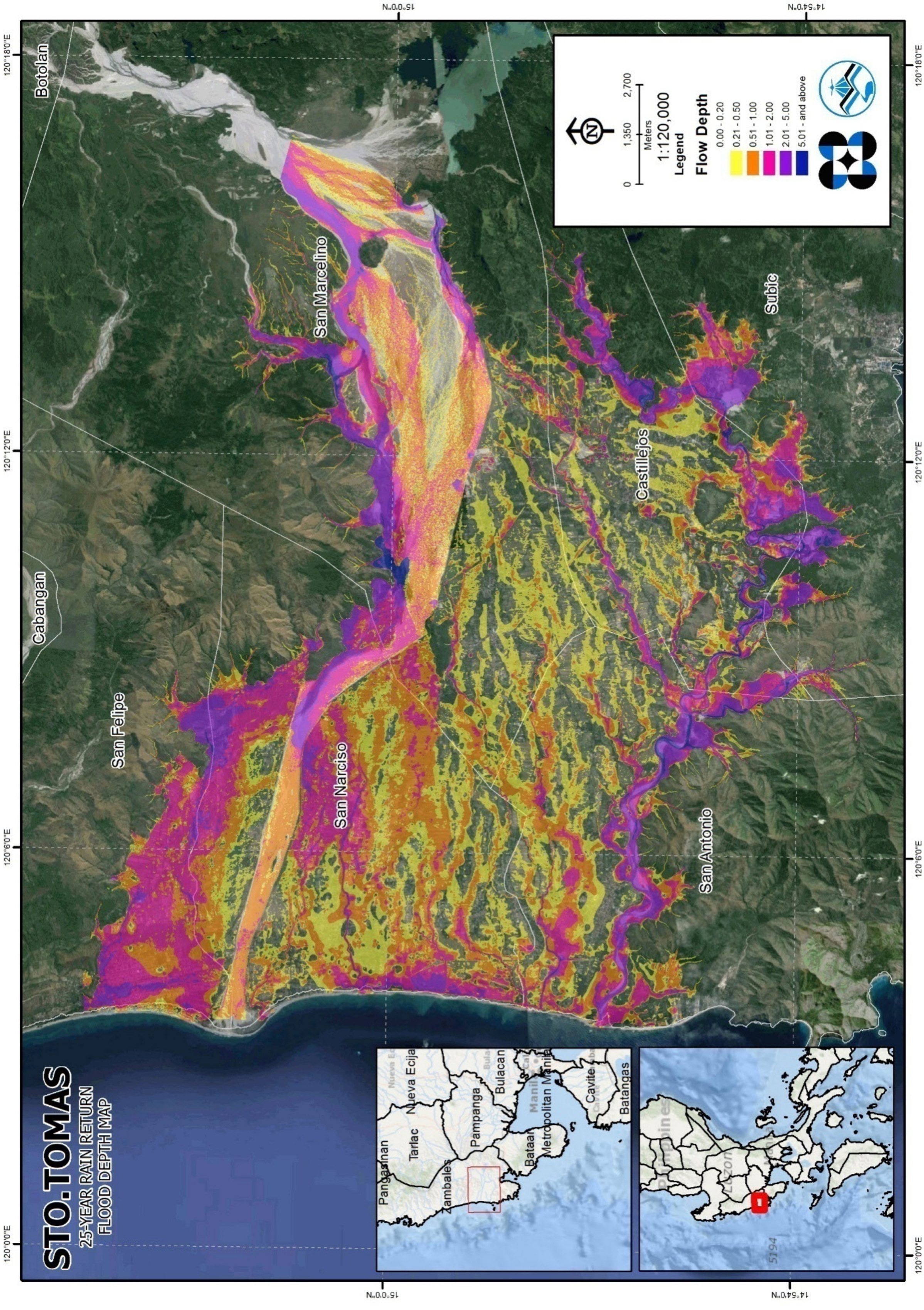


Figure 71. 25-year flow depth map for Sto. Tomas Floodplain

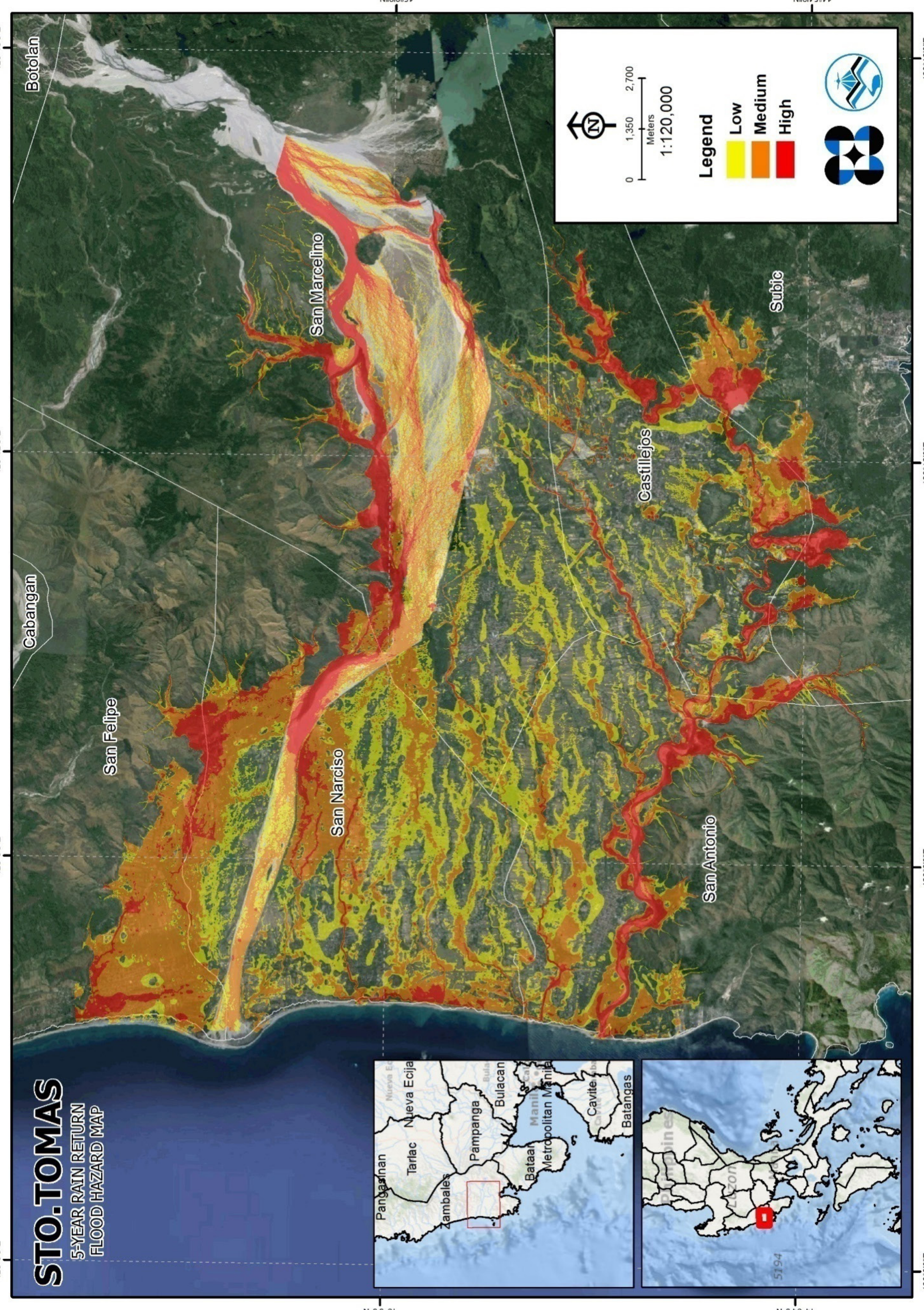


Figure 72. 5-year flood hazard map for Sto. Tomas Floodplain

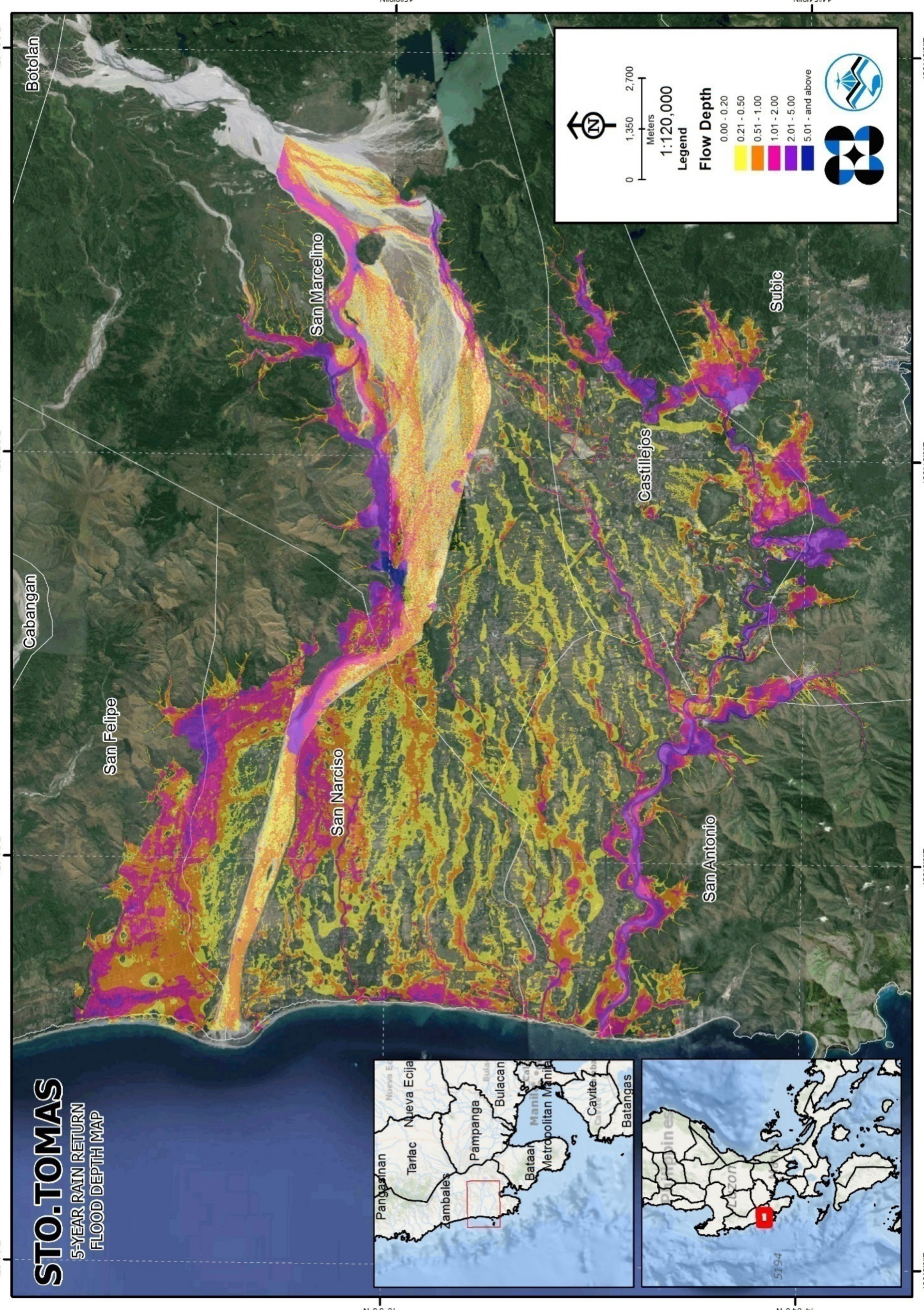


Figure 73. 5-year flood depth map for Sto. Tomas Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Sto. Tomas River Basin, grouped by municipality, are listed below. For the said basin, six municipalities consisting of 76 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-year rainfall return period.

For the 5-year return period, 44.45% of the municipality of Castillejos with an area of 72.098643 sq km will experience flood levels of less than 0.20 meters; 9.77% of the area will experience flood levels of 0.21 to 0.50 meters; while 5.18%, 5.10%, 4.19%, and 0.57% 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 Table 41 and Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 41. Affected areas in Castillejos, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Castillejos (in sq km)						
	Balaybay	Buenavista	Del Pilar	Looc	Magsaysay	Nagbayan	Nagbunga
0.03-0.20	1.07	1.31	0.84	6.19	1.36	3.07	0.73
0.21-0.50	0.38	0.28	0.37	1.15	0.38	0.84	0.32
0.51-1.00	0.72	0.096	0.12	0.73	0.062	0.27	0.03
1.01-2.00	0.91	0.13	0.06	0.73	0.051	0.16	0.0013
2.01-5.00	0.49	0.12	0.071	0.7	0.065	0.055	0
> 5.00	0.078	0	0.0083	0.21	0	0	0

Table 42. Affected areas in Castillejos, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Castillejos (in sq km)						
	San Agustin	San Jose	San Juan	San Nicolas	San Pablo	San Roque	Santa Maria
0.03-0.20	1.05	1.26	2.14	0.6	10.86	0.57	1
0.21-0.50	0.3	0.17	0.82	0.12	1.69	0.064	0.16
0.51-1.00	0.11	0.05	0.41	0.085	1.05	0.00077	0.0044
1.01-2.00	0.02	0.039	0.27	0.034	1.27	0	0
2.01-5.00	0.0041	0.0035	0.12	0.0054	1.39	0	0
> 5.00	0	0	0.0082	0.0039	0.1	0	0

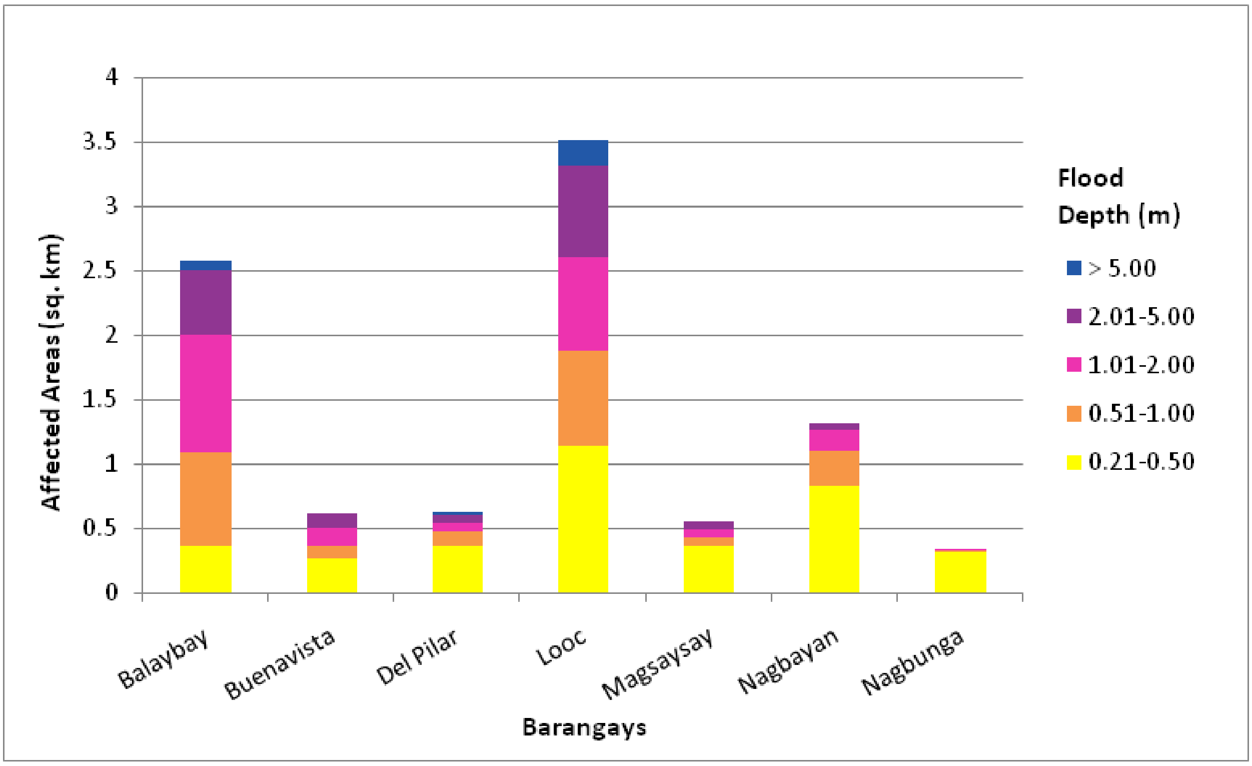


Figure 74. Affected areas in Castillejos, Zambales during a 5-year rainfall return period

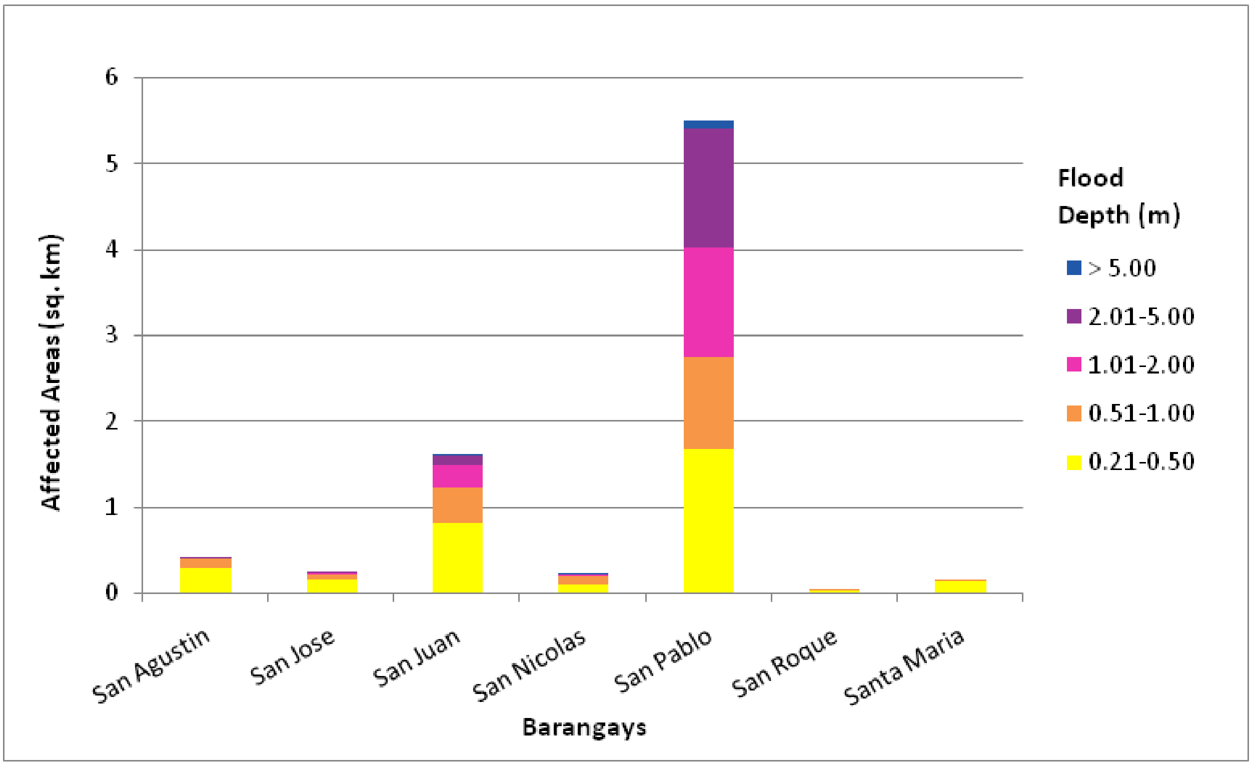


Figure 75. Affected areas in Castillejos, Zambales during a 5-year rainfall return period

For the 5-year return period, 15.84% of the municipality of San Antonio with an area of 179.707518 sq km will experience flood levels of less than 0.20 meters; 5.38% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.31%, 2.28%, 1.73%, 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 43 and Table 44 are the affected areas in square kilometers by flood depth per barangay.

Table 43. Affected areas in San Antonio, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Antonio (in sq km)						
	Angeles	Antipolo	Burgos	East Dirita	Luna	Pundaquit	Rizal
0.03-0.20	0.96	5.39	3.47	1.6	0.65	9.22	0.28
0.21-0.50	0.11	2.01	0.95	1.71	0.13	1.57	0.26
0.51-1.00	0.11	0.51	0.5	0.89	0.17	1.72	0.21
1.01-2.00	0.16	0.12	0.66	0.14	0.32	1.66	0.099
2.01-5.00	0.082	0.0072	0.73	0.014	0.36	1.28	0
> 5.00	0	0	0.063	0	0	0.073	0

Table 44. Affected areas in San Antonio, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Antonio (in sq km)						
	San Esteban	San Gregorio	San Juan	San Miguel	San Nicolas	Santiago	West Dirita
0.03-0.20	1.25	0.12	0.72	1.09	0.43	1.09	2.19
0.21-0.50	0.41	0.34	0.38	0.39	0.1	0.26	1.05
0.51-1.00	0.012	0.52	0.16	0.56	0.063	0.041	0.48
1.01-2.00	0.0045	0.12	0.033	0.26	0.052	0.22	0.25
2.01-5.00	0.0017	0.0055	0.0039	0.15	0.1	0.26	0.12
> 5.00	0	0.000036	0	0	0.0003	0	0.00086

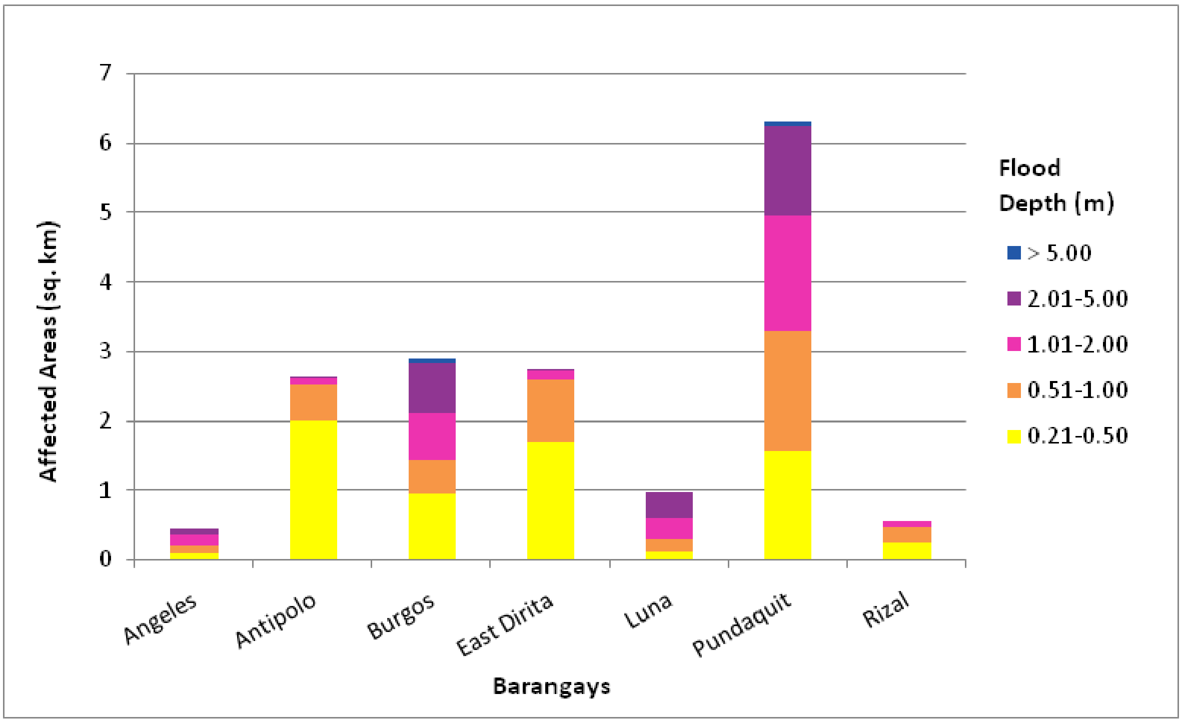


Figure 76. Affected areas in San Antonio, Zambales during a 5-year rainfall return period

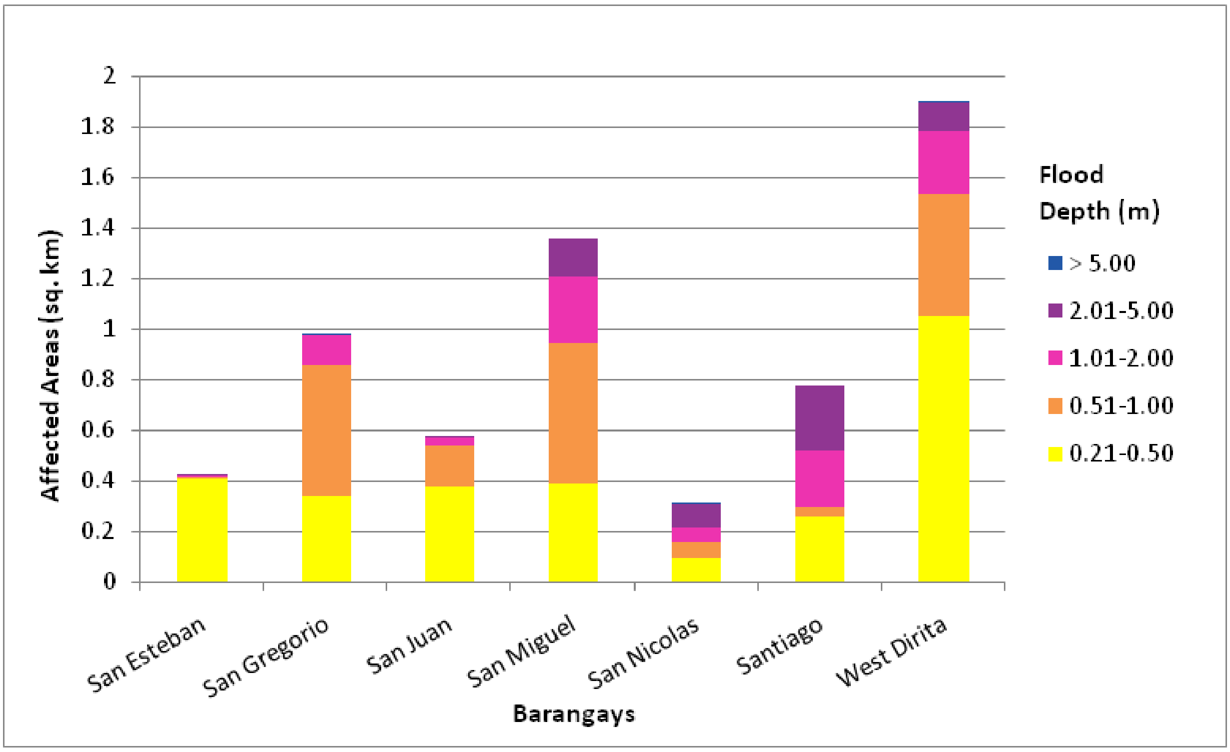


Figure 77. Affected areas in San Antonio, Zambales during a 5-year rainfall return period

For the 5-year return period, 6.13% of the municipality of San Felipe with an area of 96.23041 sq km will experience flood levels of less than 0.20 meters; 1.89% of the area will experience flood levels of 0.21 to 0.50 meters; while 6.73%, 5.40%, 1.25%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected areas in San Felipe, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Felipe (in sq km)									
	Amagna	Apostol	Balincaguing	Farañal	Feria	Manglicmot	Rosete	San Rafael	Santo Niño	Sindol
0.03-0.20	0.034	0.016	4.48	0.34	0.000052	0.0019	0.046	0.34	0.031	0.61
0.21-0.50	0.17	0.076	0.78	0.11	0.015	0.027	0.051	0.35	0.15	0.088
0.51-1.00	0.53	0.36	2.32	0.53	0.62	0.39	0.46	0.71	0.32	0.24
1.01-2.00	0.027	0.035	2.54	0.31	0.068	0.015	0.51	0.57	0.5	0.62
2.01-5.00	0	0.0071	0.79	0.026	0	0	0.013	0.02	0.14	0.21
> 5.00	0	0	0.01	0	0	0	0	0	0	0

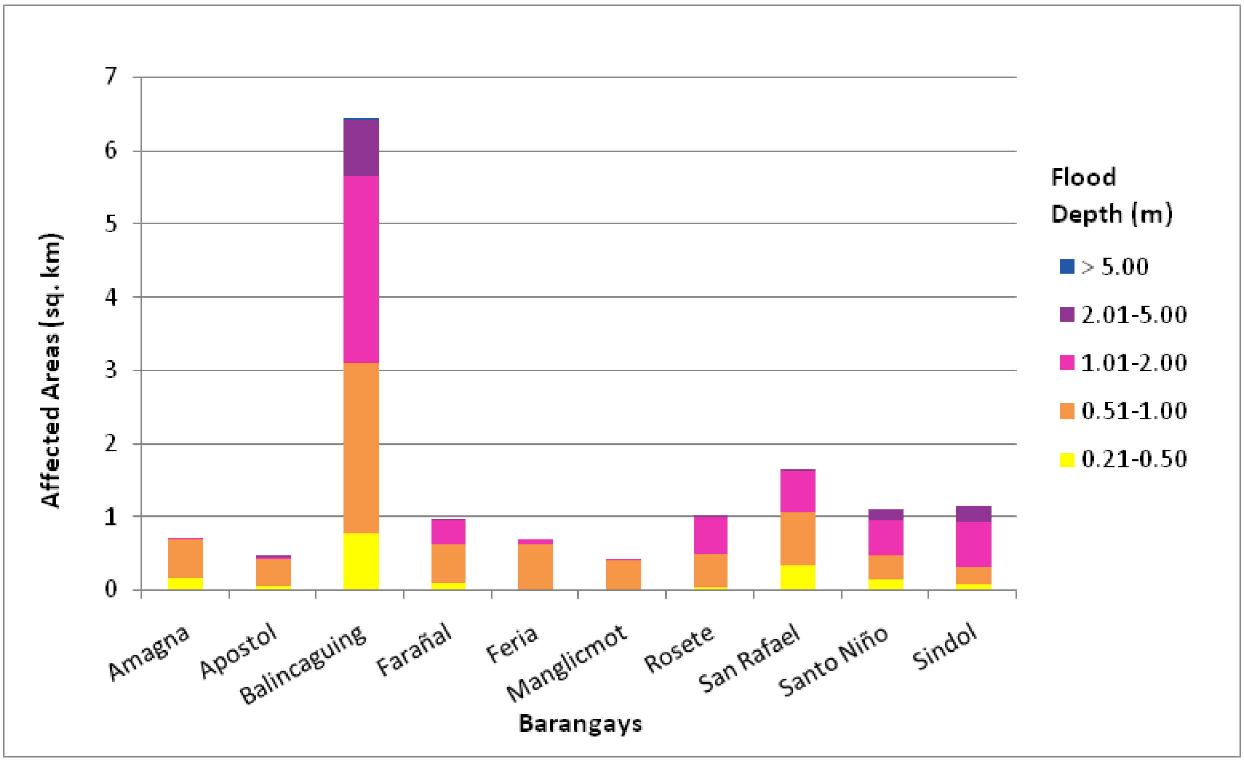


Figure 78. Affected areas in San Felipe, Zambales during a 5-year rainfall return period

For the 5-year return period, 15.02% of the municipality of San Marcelino with an area of 337.569132 sq km will experience flood levels of less than 0.20 meters; 5.34% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.97%, 2.02%, 1.08%, and 0.12% 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 46 and Table 47 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected areas in San Marcelino, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Marcelino (in sq km)							
	Aglao	Burgos	Central	Consuelo Norte	Consuelo Sur	Laoag	LaPaz	Linasin
0.03-0.20	1.82	0.53	0.17	0.29	0.78	2.16	0.48	3.43
0.21-0.50	1.36	0.14	0.0024	0.74	0.18	2.02	0.12	2.04
0.51-1.00	1.17	0.11	0.00028	1.28	0.074	2.2	0.0086	0.75
1.01-2.00	0.4	0.039	0	0.46	0.033	0.43	0	0.071
2.01-5.00	0.035	0.0082	0	0.035	0.015	0.098	0	0.0077
> 5.00	0	0	0	0	0	0.012	0	0

Table 47. Affected areas in San Marcelino, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Marcelino (in sq km)							
	Linusungan	Lucero	Nagbunga	Rizal	San Guillermo	San Isidro	San Rafael	Santa Fe
0.03-0.20	2.06	0.17	7.29	0.28	0.91	0.41	10.28	19.64
0.21-0.50	0.96	0.46	2.62	0.14	0.11	0.12	4.03	2.98
0.51-1.00	0.063	0.66	0.44	0.057	0	0.0044	3.16	3.42
1.01-2.00	0.018	0.54	0.11	0.02	0	0.0044	0.92	3.76
2.01-5.00	0.0003	0.23	0.024	0.0081	0	0	0.31	2.86
> 5.00	0	0.14	0.0016	0	0	0	0.024	0.23

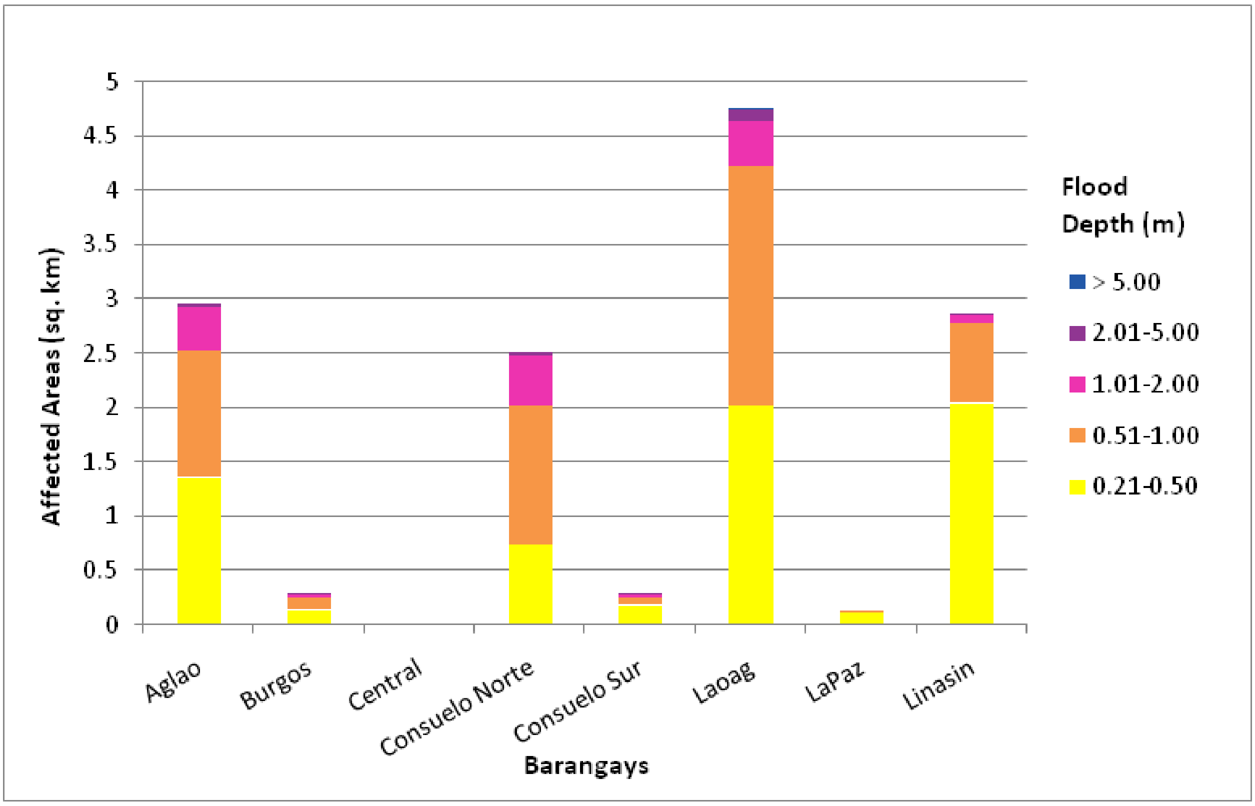


Figure 79. Affected areas in San Marcelino, Zambales during a 5-year rainfall return period

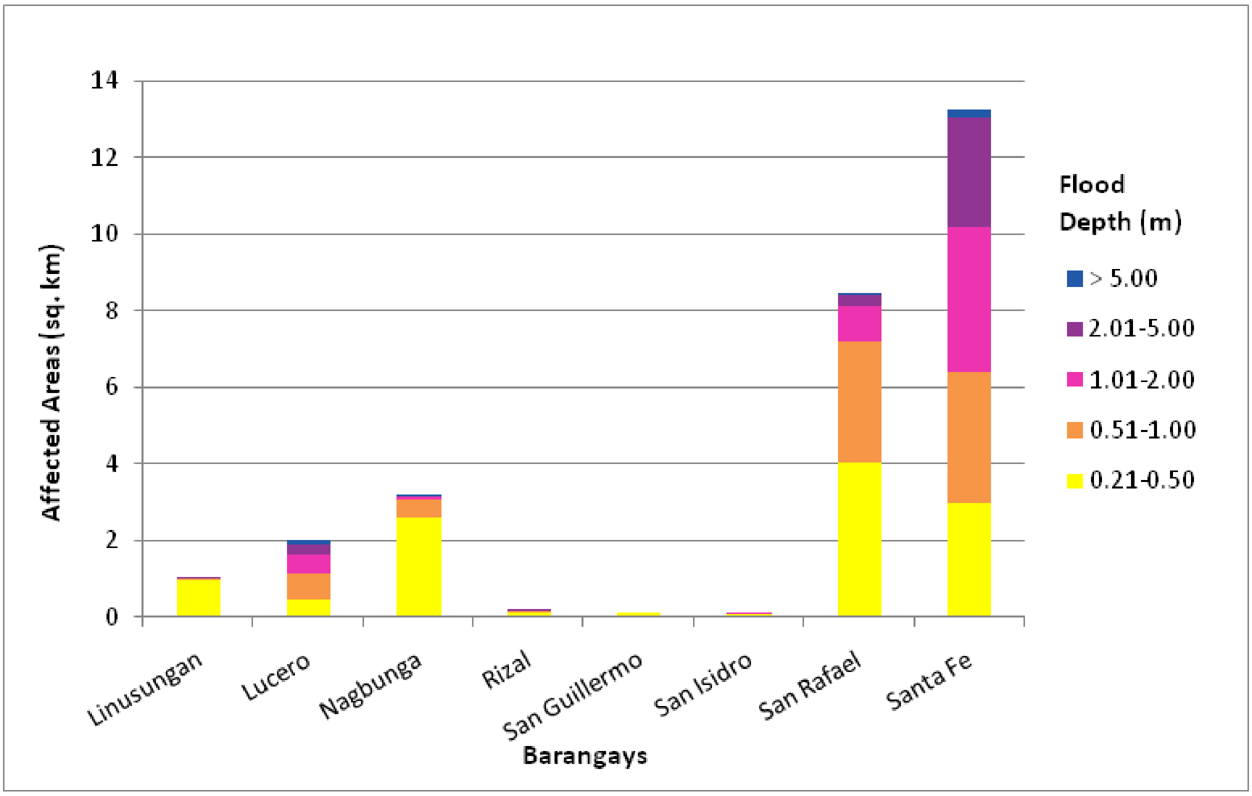


Figure 80. Affected areas in San Marcelino, Zambales during a 5-year rainfall return period

For the 5-year return period, 40.74% of the municipality of San Narciso with an area of 83.236575 sq km will experience flood levels of less than 0.20 meters; 27.37% of the area will experience flood levels of 0.21 to 0.50 meters; while 20.22%, 10.88%, and 2.20% 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 48 and Table 49 are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected areas in San Narciso, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Narciso (in sq km)								
	Alusiis	Beddeng	Candelaria	Dallipawen	Grullo	LaPaz	Libertad	Namatacan	Natividad
0.03-0.20	2.05	7.23	0.59	0.72	2.67	1.46	0.32	2.86	0.51
0.21-0.50	1.26	3.44	0.46	1.12	1.84	0.75	0.26	2.91	0.09
0.51-1.00	1.47	2.14	0.25	0.8	2.73	0.35	0.12	1.19	0.012
1.01-2.00	0.11	1.15	0.13	0.014	1.32	0.067	0.0079	0.54	0.012
2.01-5.00	0.005	0.14	0.024	0	0.22	0.011	0	0.11	0.0047
> 5.00	0	0	0	0	0	0	0	0	0

Table 49. Affected areas in San Narciso, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Narciso (in sq km)							
	Omaya	Paite	Patrocinio	San Jose	San Juan	San Pascual	San Rafael	Siminublan
0.03-0.20	1.3	7.8	0.46	0.34	1.39	0.66	0.31	3.24
0.21-0.50	0.75	4.83	0.41	0.34	1.36	0.25	0.33	2.38
0.51-1.00	1.06	5.51	0.08	0.094	0.39	0.076	0.072	0.49
1.01-2.00	1.06	4.54	0.0088	0.043	0.025	0.0061	0.011	0.013
2.01-5.00	0.2	1.08	0.00017	0.034	0.0022	0	0	0
> 5.00	0	0.00085	0	0	0	0	0	0

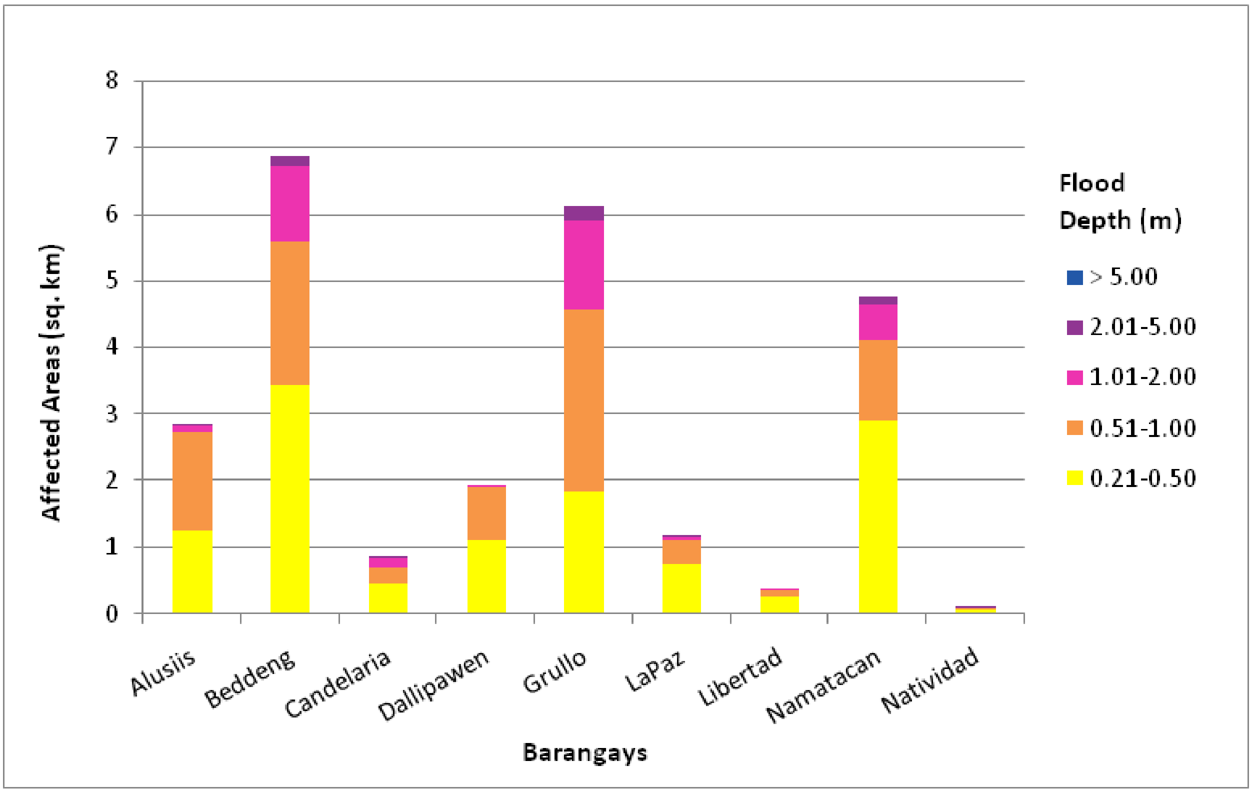


Figure 81. Affected areas in San Narciso, Zambales during a 5-year rainfall return period

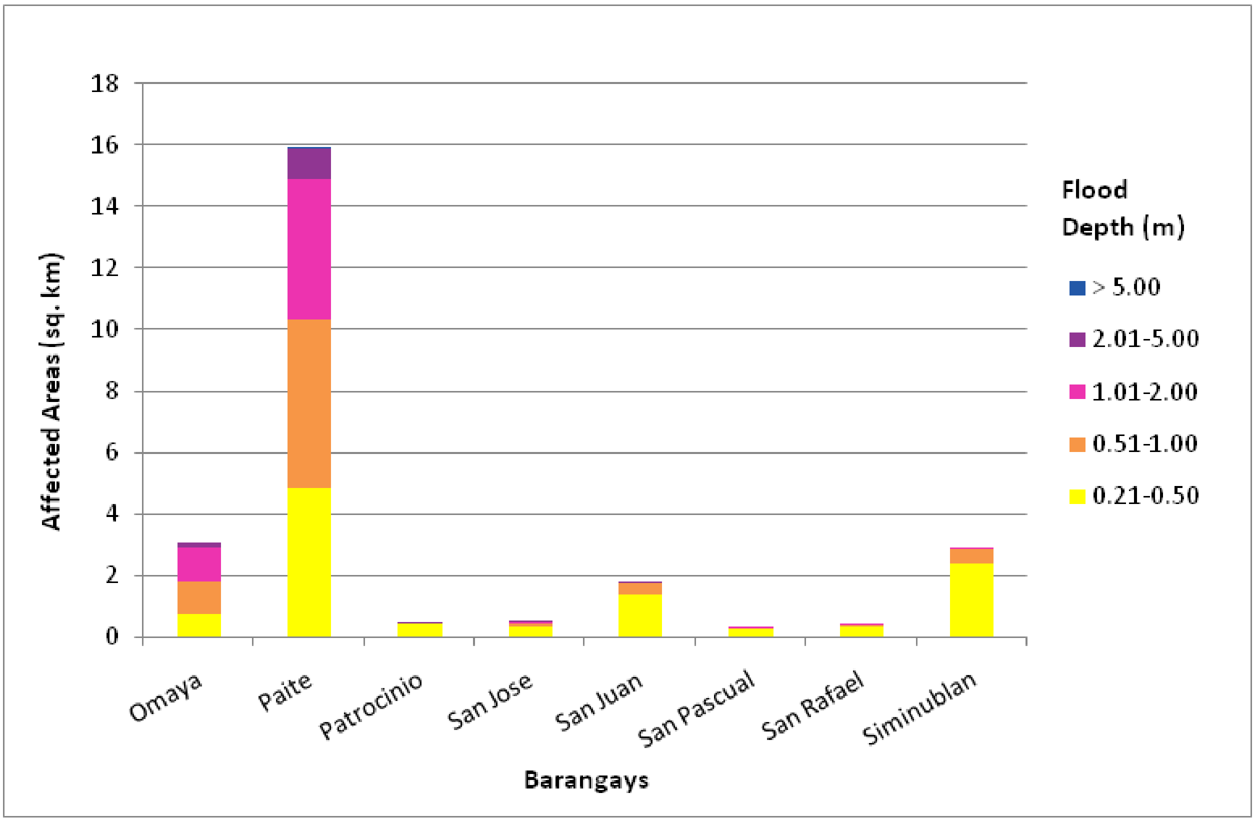


Figure 82. Affected areas in San Narciso, Zambales during a 5-year rainfall return period

For the 5-year return period, 3.14% of the municipality of Subic with an area of 253.594777 sq km will experience flood levels of less than 0.20 meters; 0.51% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.87%, 0.90%, 0.78%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected areas in Subic, Zambales during a 5-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Subic (in sq km)				
	Aningway Sacatihan	Asinan Poblacion	Cawag	Mangan-Vaca	Pamatawan
0.03-0.20	2.28	0.15	3.98	0.0028	1.54
0.21-0.50	0.26	0.036	0.55	0	0.45
0.51-1.00	0.41	0.074	0.61	0	1.11
1.01-2.00	0.47	0.03	0.84	0	0.94
2.01-5.00	0.23	0	1.27	0	0.49
> 5.00	0.0016	0	0.017	0	0.051

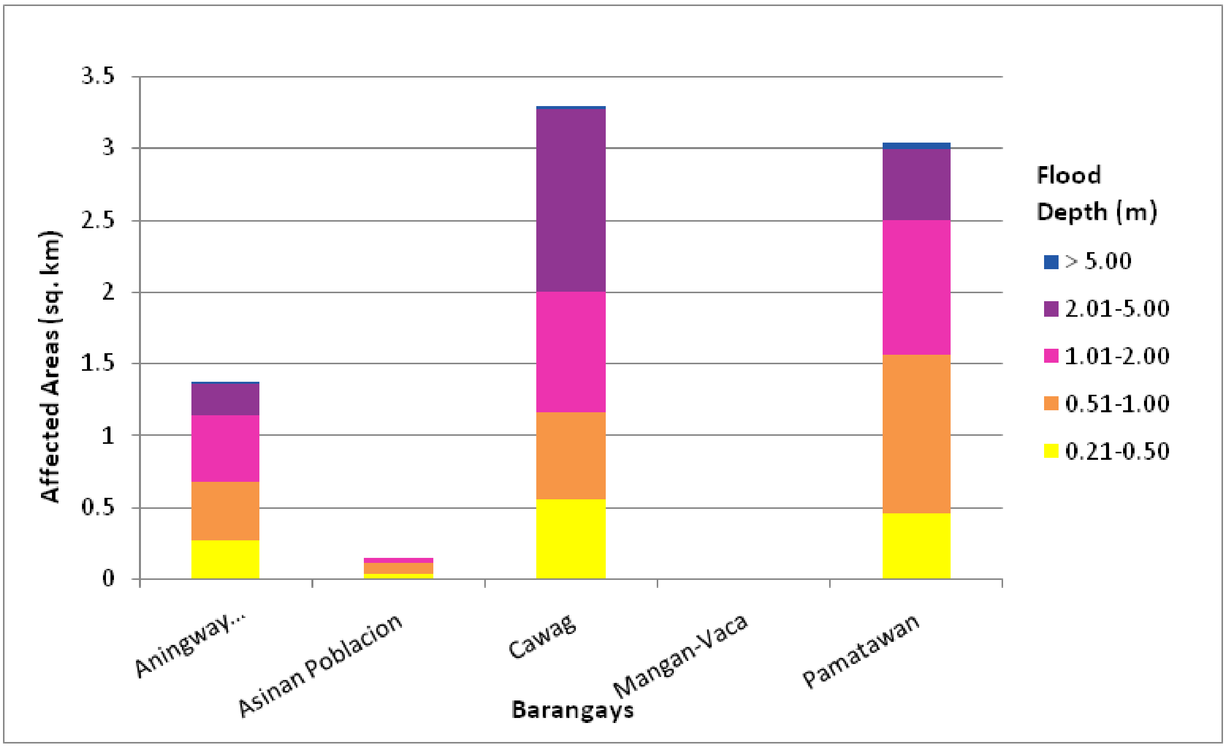


Figure 83. Affected areas in Subic, Zambales during a 5-year rainfall return period

For the 25-year return period, 36.37% of the municipality of Castillejos with an area of 72.098643 sq km will experience flood levels of less than 0.20 meters; 13.23% of the area will experience flood levels of 0.21 to 0.50 meters; while 5.99%, 6.54%, 6.10%, and 1.04% 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 51 and Table 52 are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected areas in Castillejos, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Castillejos (in sq km)						
	Balaybay	Buenavista	Del Pilar	Looc	Magsaysay	Nagbayan	Nagbunga
0.03-0.20	0.85	1.01	0.38	5.29	1.13	2.55	0.53
0.21-0.50	0.16	0.49	0.69	1.21	0.53	1.11	0.49
0.51-1.00	0.45	0.12	0.19	0.98	0.1	0.43	0.06
1.01-2.00	1.05	0.15	0.11	1.02	0.06	0.19	0.005
2.01-5.00	1	0.18	0.087	0.87	0.094	0.11	0
> 5.00	0.14	0	0.019	0.33	0	0	0

Table 52. Affected areas in Castillejos, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Castillejos (in sq km)						
	San Agustin	San Jose	San Juan	San Nicolas	San Pablo	San Roque	Santa Maria
0.03-0.20	0.85	0.94	1.74	0.46	9.26	0.34	0.89
0.21-0.50	0.39	0.48	0.86	0.16	2.42	0.3	0.25
0.51-1.00	0.2	0.062	0.53	0.089	1.09	0.0041	0.017
1.01-2.00	0.029	0.048	0.37	0.11	1.57	0	6.8E-06
2.01-5.00	0.005	0.0045	0.24	0.016	1.79	0	0
> 5.00	0	0	0.018	0.0059	0.24	0	0

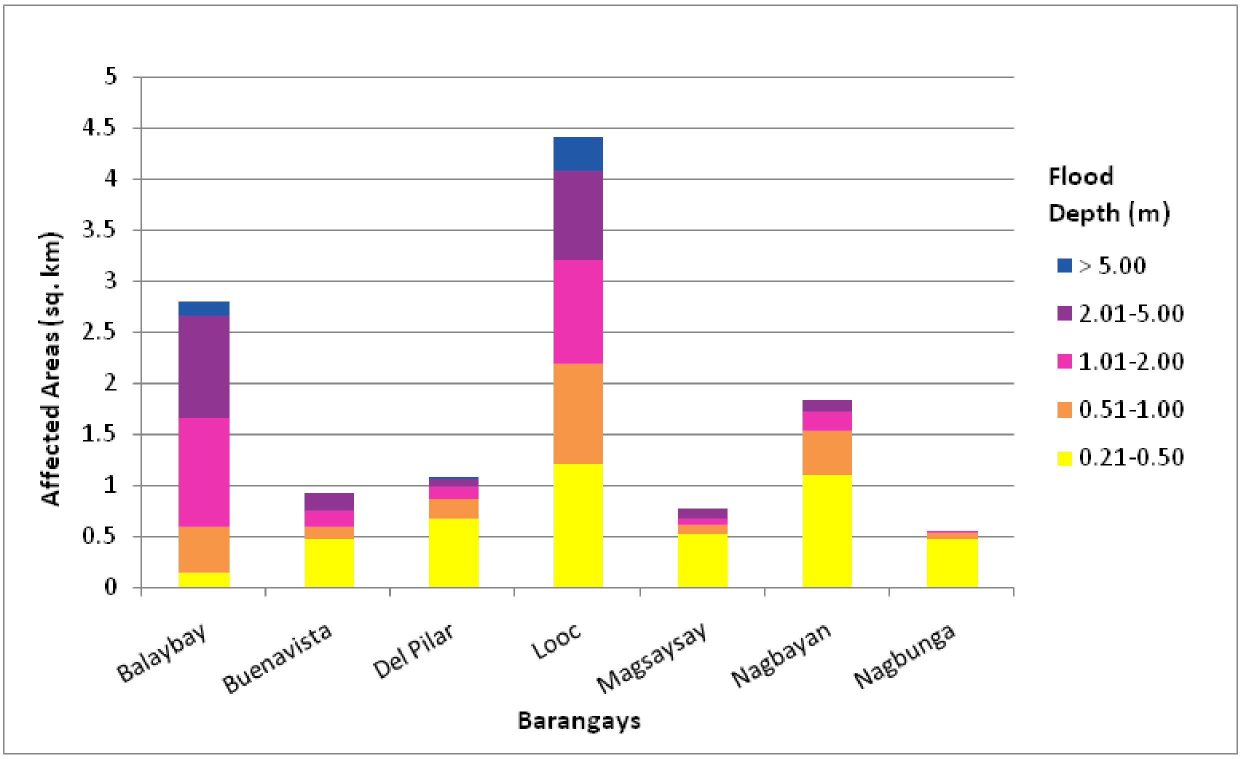


Figure 84. Affected areas in Castillejos, Zambales during a 25-year rainfall return period

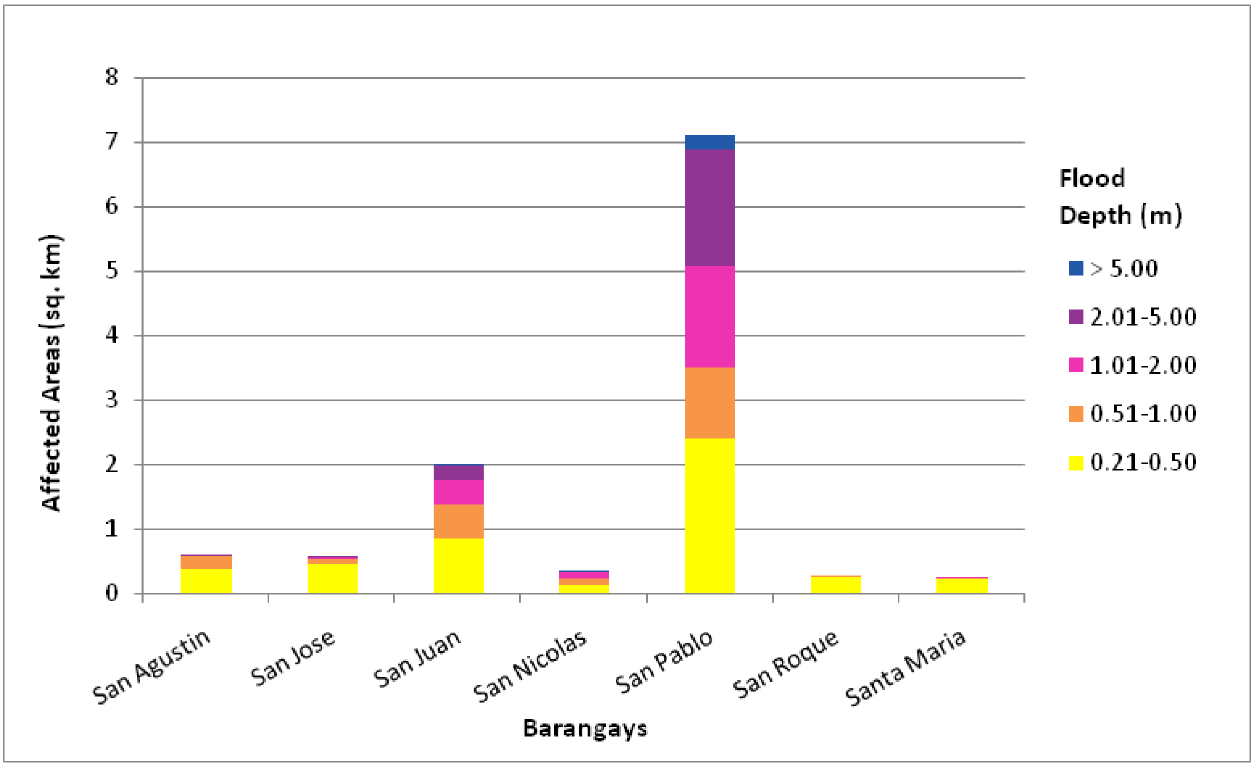


Figure 85. Affected areas in Castillejos, Zambales during a 25-year rainfall return period

For the 25-year return period, 12.84% of the municipality of San Antonio with an area of 179.707518 sq km will experience flood levels of less than 0.20 meters; 5.79% of the area will experience flood levels of 0.21 to 0.50 meters; while 4.33%, 3.08%, 2.37%, and 0.22% 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 53 and Table 54 are the affected areas in square kilometers by flood depth per barangay.

Table 53. Affected areas in San Antonio, Zambales during a 25-Year Rainfall Return Period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Antonio (in sq km)						
	Angeles	Antipolo	Burgos	East Dirita	Luna	Pundaquit	Rizal
0.03-0.20	0.89	4.22	2.81	1.04	0.59	8.55	0.14
0.21-0.50	0.11	2.64	1.14	1.4	0.12	1.4	0.28
0.51-1.00	0.084	0.9	0.65	1.6	0.15	1.61	0.23
1.01-2.00	0.18	0.27	0.65	0.29	0.3	1.93	0.2
2.01-5.00	0.15	0.011	0.95	0.027	0.47	1.81	0.0009
> 5.00	0	0	0.18	0	0	0.21	0

Table 54. Affected areas in San Antonio, Zambales during a 25-Year Rainfall Return Period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Antonio (in sq km)						
	San Esteban	San Gregorio	San Juan	San Miguel	San Nicolas	Santiago	West Dirita
0.03-0.20	0.97	0.0032	0.56	0.77	0.31	0.79	1.44
0.21-0.50	0.68	0.13	0.3	0.42	0.16	0.49	1.14
0.51-1.00	0.032	0.38	0.35	0.69	0.1	0.087	0.92
1.01-2.00	0.0059	0.58	0.079	0.39	0.072	0.16	0.42
2.01-5.00	0.0021	0.012	0.014	0.19	0.11	0.34	0.17
> 5.00	0	0.00017	0	0	0.0008	0.00023	0.0077

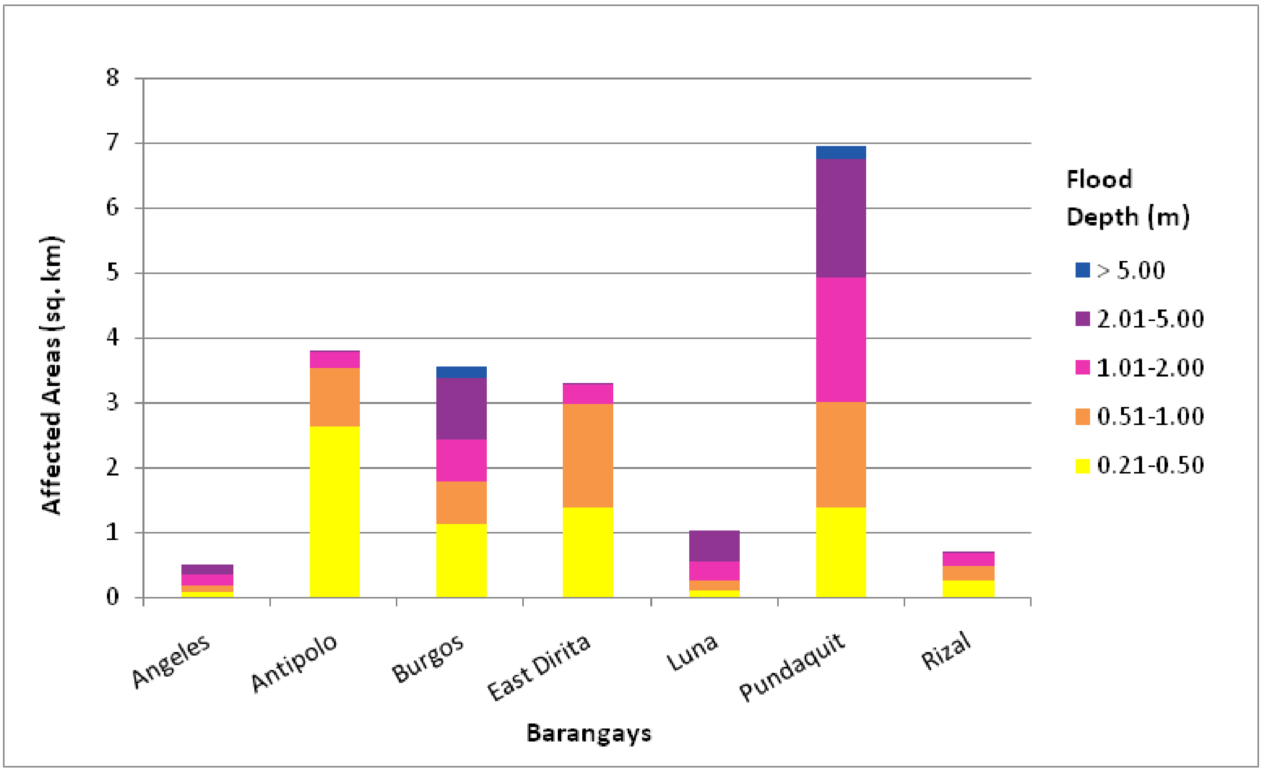


Figure 86. Affected areas in San Antonio, Zambales during a 25-Year Rainfall Return Period

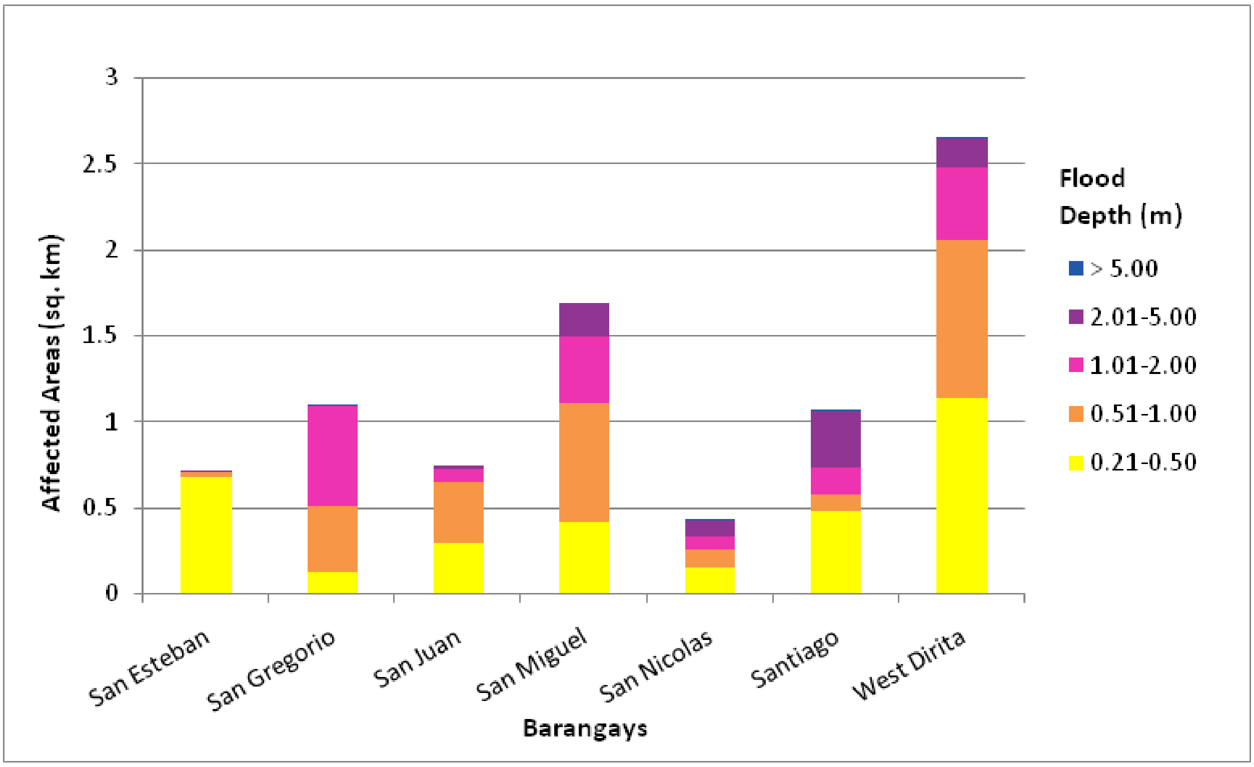


Figure 87. Affected areas in San Antonio, Zambales during a 25-Year Rainfall Return Period

For the 25-year return period, 5.59% of the municipality of San Felipe with an area of 96.23041 sq km will experience flood levels of less than 0.20 meters; 0.91% of the area will experience flood levels of 0.21 to 0.50 meters; while 3.80%, 8.98%, 2.09%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected areas in San Felipe, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Felipe (in sq km)									
	Amagna	Apostol	Balincaguing	Farañal	Feria	Manglicmot	Rosete	San Rafael	Santo Niño	Sindol
0.03-0.20	0.011	0.0062	4.22	0.3	0	0	0.03	0.23	0.0004	0.58
0.21-0.50	0.024	0.017	0.49	0.03	0.000069	0.0019	0.021	0.2	0.035	0.056
0.51-1.00	0.54	0.26	1.36	0.15	0.19	0.16	0.15	0.44	0.28	0.13
1.01-2.00	0.19	0.19	3.72	0.78	0.51	0.27	0.86	1.03	0.56	0.53
2.01-5.00	0	0.0095	1.09	0.061	0	0.0005	0.023	0.083	0.26	0.48
> 5.00	0	0	0.027	0	0	0	0	0	0	0

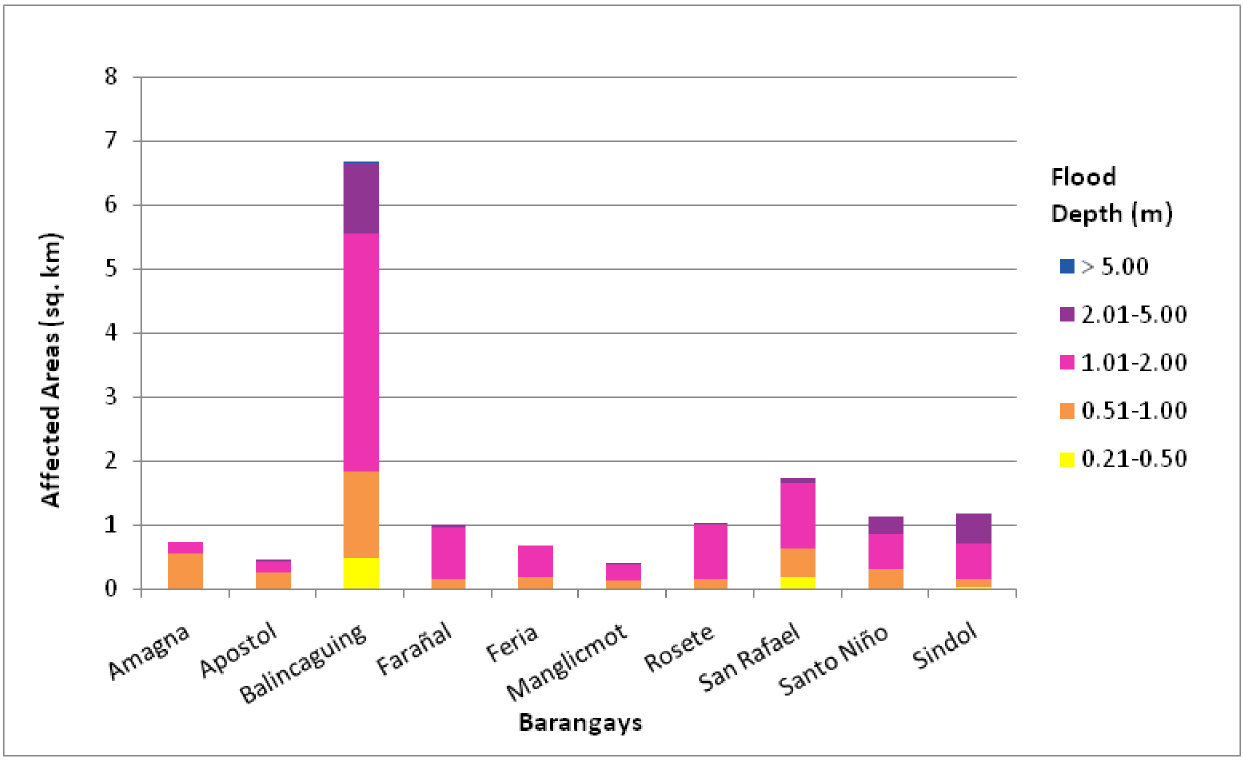


Figure 88. Affected areas in San Felipe, Zambales during a 25-year rainfall return period

For the 25-year return period, 12.41% of the municipality of San Marcelino with an area of 337.569132 sq km will experience flood levels of less than 0.20 meters; 5.25% of the area will experience flood levels of 0.21 to 0.50 meters; while 4.88%, 3.17%, 1.78%, and 0.22% 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 56 and Table 57 are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected areas in San Marcelino, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Marcelino (in sq km)							
	Aglao	Burgos	Central	Consuelo Norte	Consuelo Sur	Laoag	LaPaz	Linasin
0.03-0.20	1	0.43	0.16	0.13	0.62	1.49	0.29	2.57
0.21-0.50	0.95	0.18	0.0062	0.39	0.29	1.51	0.3	2.26
0.51-1.00	1.7	0.17	0.0018	1.32	0.24	2.55	0.014	1.3
1.01-2.00	0.88	0.077	0	1.17	0.087	1.25	0	0.19
2.01-5.00	0.26	0.016	0	0.071	0.025	0.045	0	0.012
> 5.00	0	0	0	0	0	0.065	0	0

Table 57. Affected areas in San Marcelino, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Marcelino (in sq km)							
	Linusungan	Lucero	Nagbunga	Rizal	San Guillermo	San Isidro	San Rafael	Santa Fe
0.03-0.20	1.49	0.085	5.81	0.22	0.71	0.32	8.54	18.04
0.21-0.50	1.38	0.17	3.59	0.16	0.32	0.2	3.59	2.42
0.51-1.00	0.21	0.76	0.83	0.092	0.00077	0.015	4	3.26
1.01-2.00	0.029	0.7	0.22	0.028	0	0.0041	1.91	4.14
2.01-5.00	0.0011	0.35	0.049	0.015	0	0.0022	0.61	4.56
> 5.00	0	0.16	0.0039	0	0	0	0.076	0.43

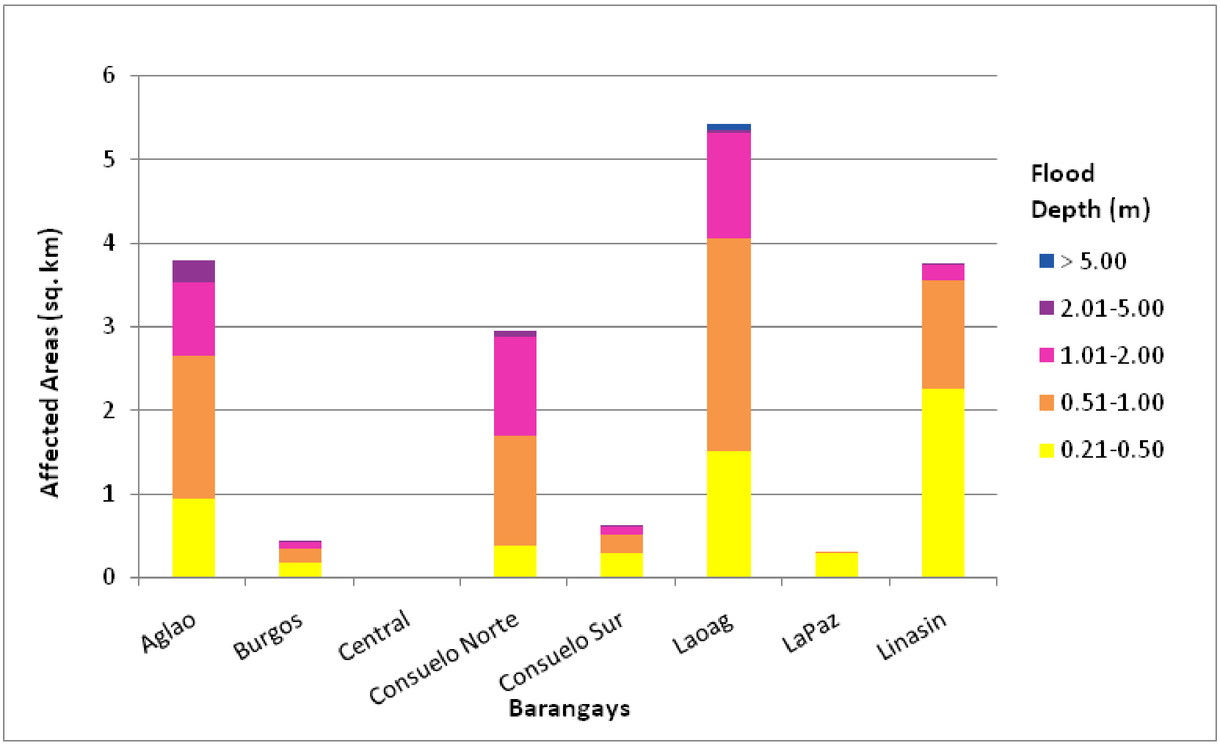


Figure 89. Affected areas in San Marcelino, Zambales during a 25-year rainfall return period

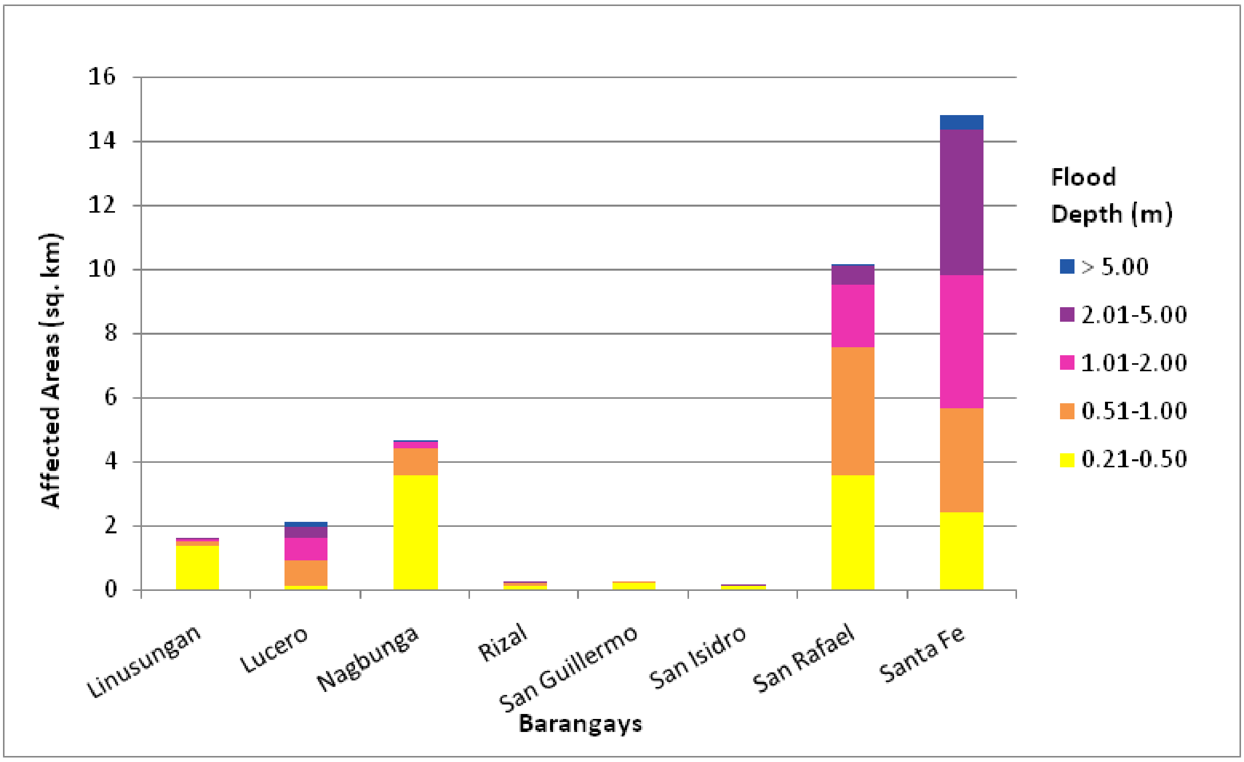


Figure 90. Affected areas in San Marcelino, Zambales during a 25-year rainfall return period

For the 25-year return period, 23.26% of the municipality of San Narciso with an area of 83.236575 sq km will experience flood levels of less than 0.20 meters; 25.65% of the area will experience flood levels of 0.21 to 0.50 meters; while 30.73%, 17.95%, and 5.00% 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 58 and Table 59 are the affected areas in square kilometers by flood depth per barangay.

Table 58. Affected areas in San Narciso, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Narciso (in sq km)								
	Alusiis	Beddeng	Candelaria	Dallipawen	Grullo	LaPaz	Libertad	Namatacan	Natividad
0.03-0.20	1.57	3.9	0.18	0.44	0.93	0.85	0.18	1.2	0.1
0.21-0.50	0.93	3.92	0.56	0.6	1.76	0.73	0.26	3.01	0.43
0.51-1.00	1.96	3.48	0.33	1.43	2.89	0.72	0.24	2.95	0.076
1.01-2.00	0.43	2.09	0.15	0.37	2.6	0.29	0.031	0.93	0.013
2.01-5.00	0.0097	0.73	0.042	0	0.43	0.04	0	0.19	0.0074
> 5.00	0	0	0	0	0.0002	0	0	0	0

Table 59. Affected areas in San Narciso, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Narciso (in sq km)							
	Omaya	Paite	Patrocinio	San Jose	San Juan	San Pascual	San Rafael	Siminublan
0.03-0.20	1.06	5.49	0.2	0.061	0.5	0.44	0.12	2.14
0.21-0.50	0.57	3.67	0.43	0.41	1.2	0.32	0.33	2.22
0.51-1.00	1.11	6.16	0.4	0.26	1.44	0.2	0.24	1.69
1.01-2.00	1.41	6.29	0.028	0.063	0.11	0.03	0.028	0.08
2.01-5.00	0.6	2.07	0.00065	0.041	0.0047	0	0	0.00017
> 5.00	0	0.0036	0	0	0	0	0	0

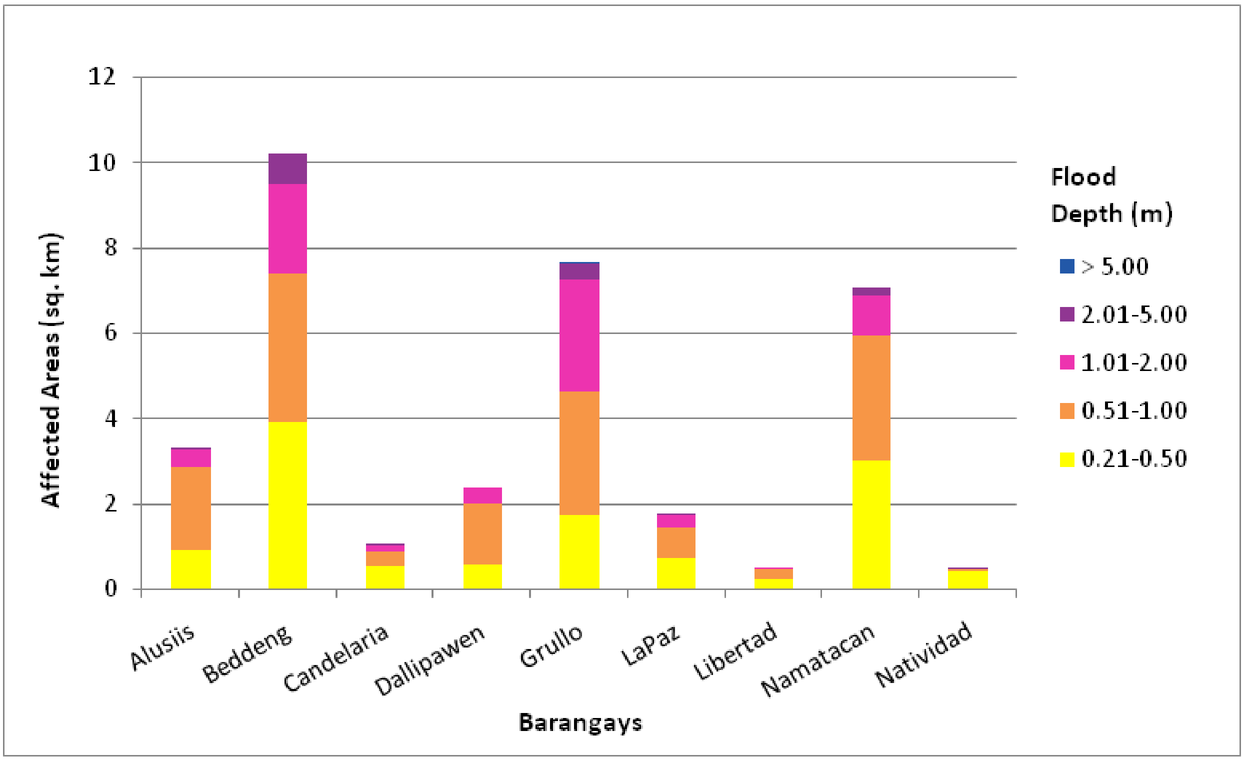


Figure 91. Affected areas in San Narciso, Zambales during a 25-year rainfall return period

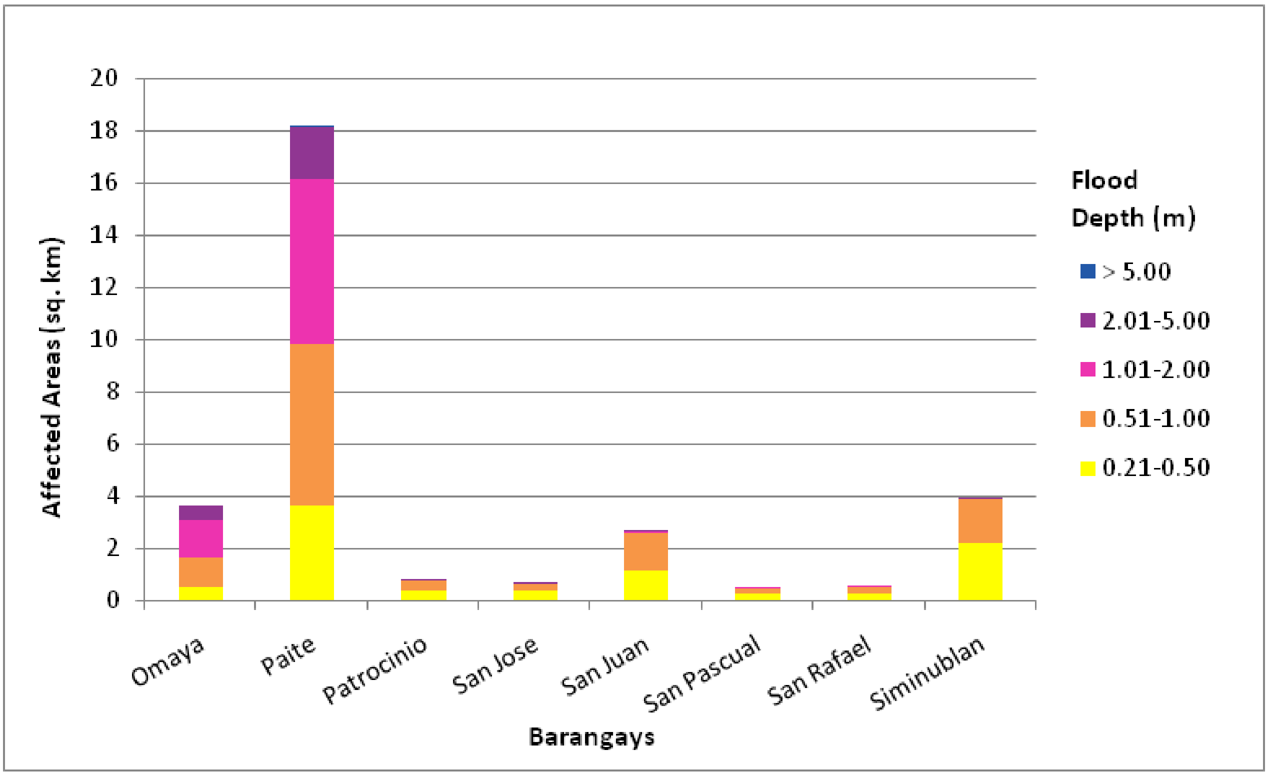


Figure 92. Affected areas in San Narciso, Zambales during a 25-year rainfall return period

For the 25-year return period, 2.87% of the municipality of Subic with an area of 253.594777 sq km will experience flood levels of less than 0.20 meters; 0.39% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.67%, 0.96%, 1.25%, 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 60 are the affected areas in square kilometers by flood depth per barangay.

Table 60. Affected areas in Subic, Zambales during a 25-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Subic (in sq km)				
	Aningway Sacatihan	Asinan Poblacion	Cawag	Mangan-Vaca	Pamatawan
0.03-0.20	2.18	0.14	3.59	0.0028	1.36
0.21-0.50	0.21	0.029	0.48	0	0.28
0.51-1.00	0.33	0.048	0.55	0	0.78
1.01-2.00	0.53	0.073	0.74	0	1.09
2.01-5.00	0.4	0	1.77	0	0.99
> 5.00	0.0068	0	0.13	0	0.076

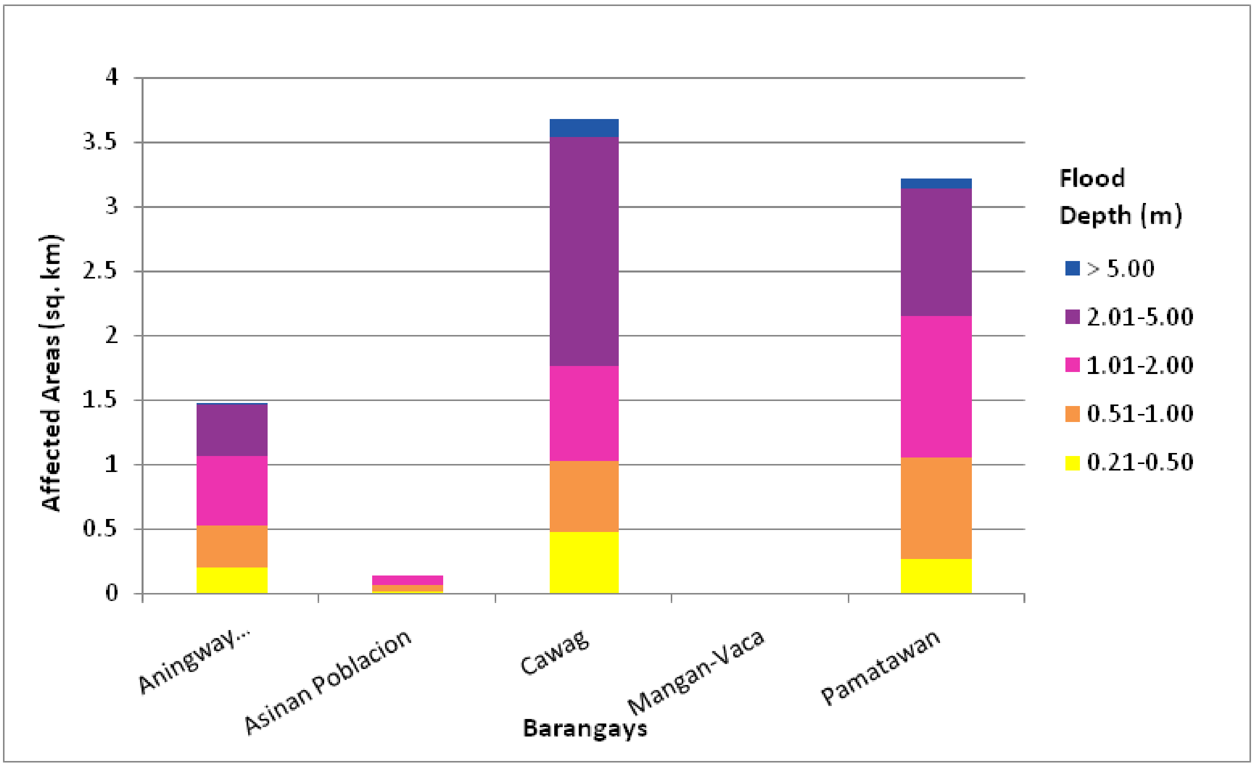


Figure 93. Affected areas in Subic, Zambales during a 25-year rainfall return period

For the 100-year return period, 31.15% of the municipality of Castillejos with an area of 72.098643 sq km will experience flood levels of less than 0.20 meters; 14.99% of the area will experience flood levels of 0.21 to 0.50 meters; while 7.16%, 6.91%, 7.72%, and 1.44% 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 61 and Table 62 are the affected areas in square kilometers by flood depth per barangay.

Table 61. Affected areas in Castillejos, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Castillejos (in sq km)						
	Balaybay	Buenavista	Del Pilar	Looc	Magsaysay	Nagbayan	Nagbunga
0.03-0.20	0.78	0.82	0.2	4.77	0.97	2.17	0.41
0.21-0.50	0.1	0.59	0.4	1.25	0.64	1.29	0.58
0.51-1.00	0.24	0.16	0.58	1.06	0.12	0.57	0.093
1.01-2.00	0.91	0.16	0.18	1.12	0.078	0.2	0.0089
2.01-5.00	1.44	0.21	0.098	1.1	0.11	0.16	0
> 5.00	0.18	0.0004	0.019	0.41	0	0	0

Table 62. Affected areas in Castillejos, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Castillejos (in sq km)						
	San Agustin	San Jose	San Juan	San Nicolas	San Pablo	San Roque	Santa Maria
0.03-0.20	0.73	0.66	1.5	0.34	8.09	0.22	0.8
0.21-0.50	0.44	0.74	0.83	0.21	2.99	0.41	0.34
0.51-1.00	0.27	0.076	0.62	0.11	1.22	0.012	0.03
1.01-2.00	0.04	0.056	0.45	0.15	1.63	0	0.00011
2.01-5.00	0.0057	0.0061	0.34	0.028	2.07	0	0
> 5.00	0	0	0.033	0.0066	0.39	0	0

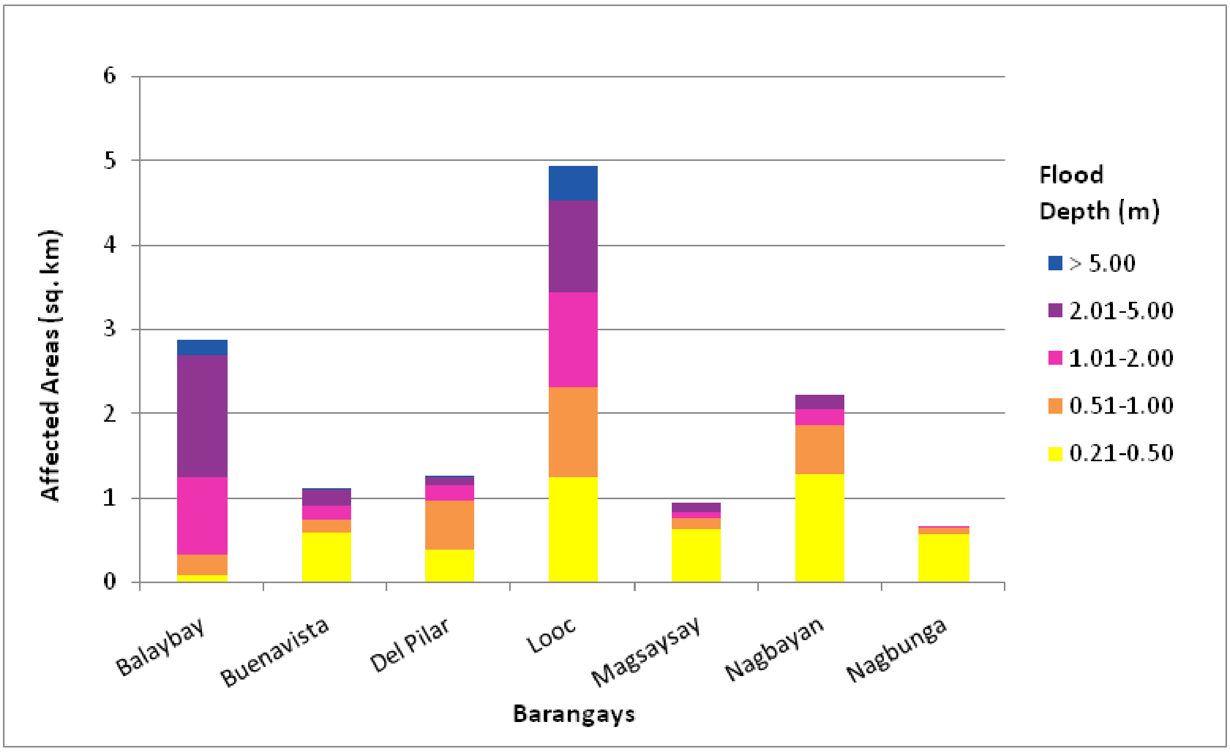


Figure 94. Affected areas in Castillejos, Zambales during a 100-year rainfall return period

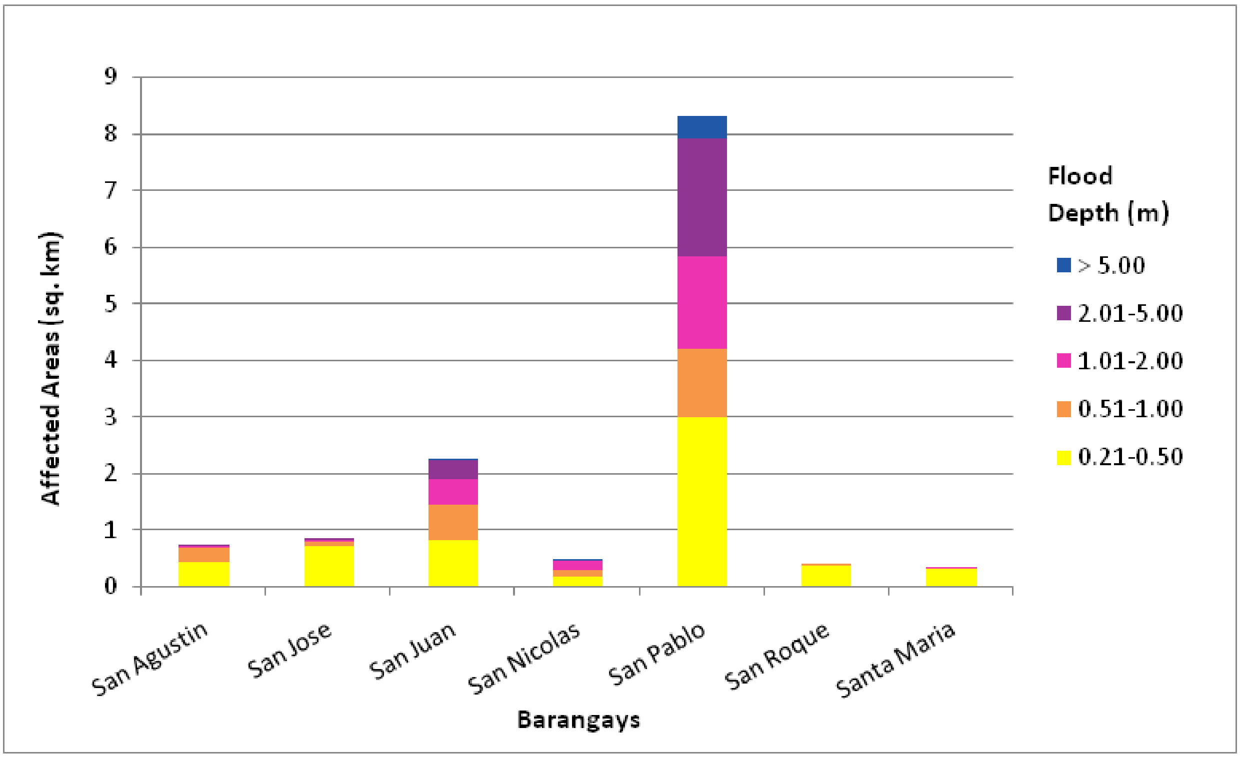


Figure 95. Affected areas in Castillejos, Zambales during a 100-year rainfall return period

For the 100-year return period, 10.94% of the municipality of San Antonio with an area of 179.707518 sq km will experience flood levels of less than 0.20 meters; 5.59% of the area will experience flood levels of 0.21 to 0.50 meters; while 5.21%, 3.77%, 2.79%, and 0.34% 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 63 and Table 64 are the affected areas in square kilometers by flood depth per barangay.

Table 63. Affected areas in San Antonio, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Antonio (in sq km)						
	Angeles	Antipolo	Burgos	East Dirita	Luna	Pundaquit	Rizal
0.03-0.20	0.84	3.42	2.19	0.74	0.56	8.16	0.096
0.21-0.50	0.13	2.85	1.18	1.11	0.11	1.34	0.19
0.51-1.00	0.075	1.32	0.96	1.95	0.14	1.57	0.3
1.01-2.00	0.14	0.44	0.69	0.52	0.27	2.04	0.27
2.01-5.00	0.23	0.013	1.09	0.036	0.53	2.09	0.013
> 5.00	0	0	0.27	0	0	0.32	0

Table 64. Affected areas in San Antonio, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Antonio (in sq km)						
	San Esteban	San Juan	San Miguel	San Nicolas	Santiago	West Dirita	San Gregorio
0.03-0.20	0.77	0.43	0.59	0.22	0.57	1.08	0
0.21-0.50	0.84	0.22	0.4	0.17	0.54	0.97	0.0043
0.51-1.00	0.072	0.49	0.7	0.14	0.22	1.16	0.27
1.01-2.00	0.0067	0.15	0.55	0.1	0.16	0.64	0.79
2.01-5.00	0.0023	0.016	0.22	0.12	0.39	0.23	0.04
> 5.00	0	0	0	0.0011	0.0031	0.015	0.00049

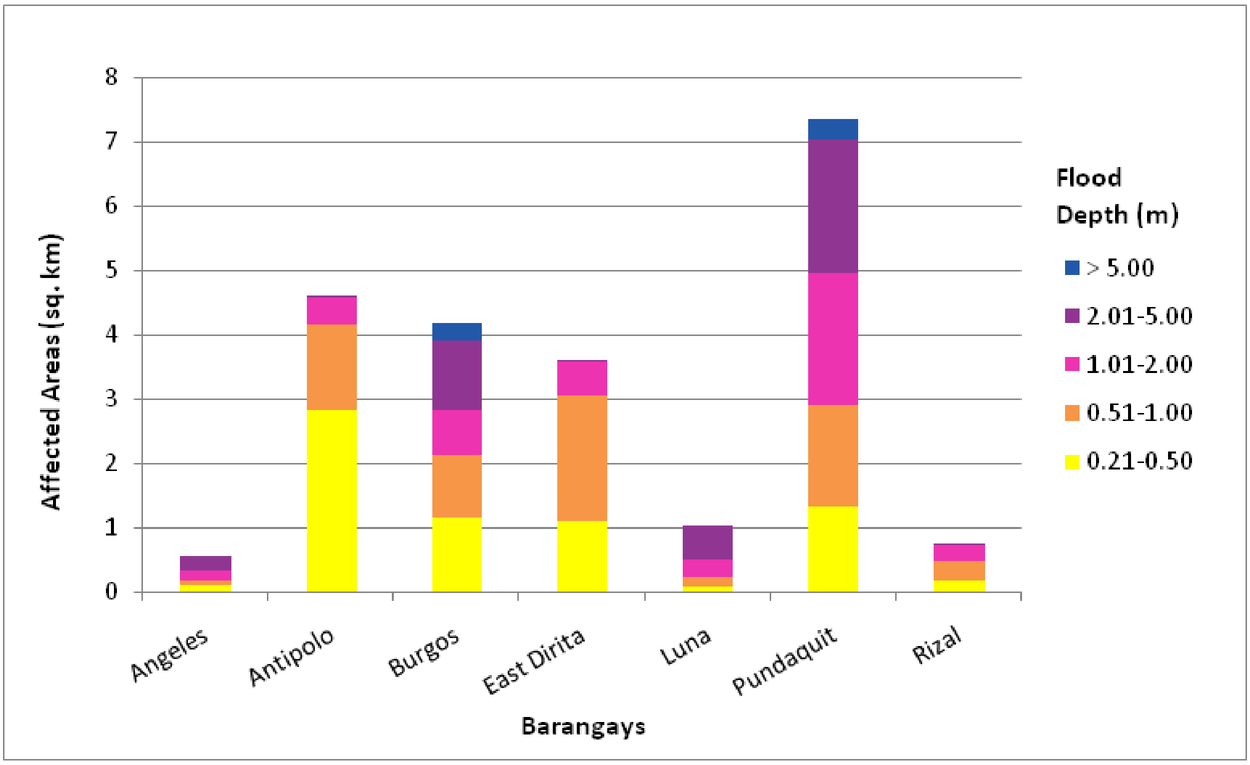


Figure 96. Affected areas in San Antonio, Zambales during a 100-year rainfall return period

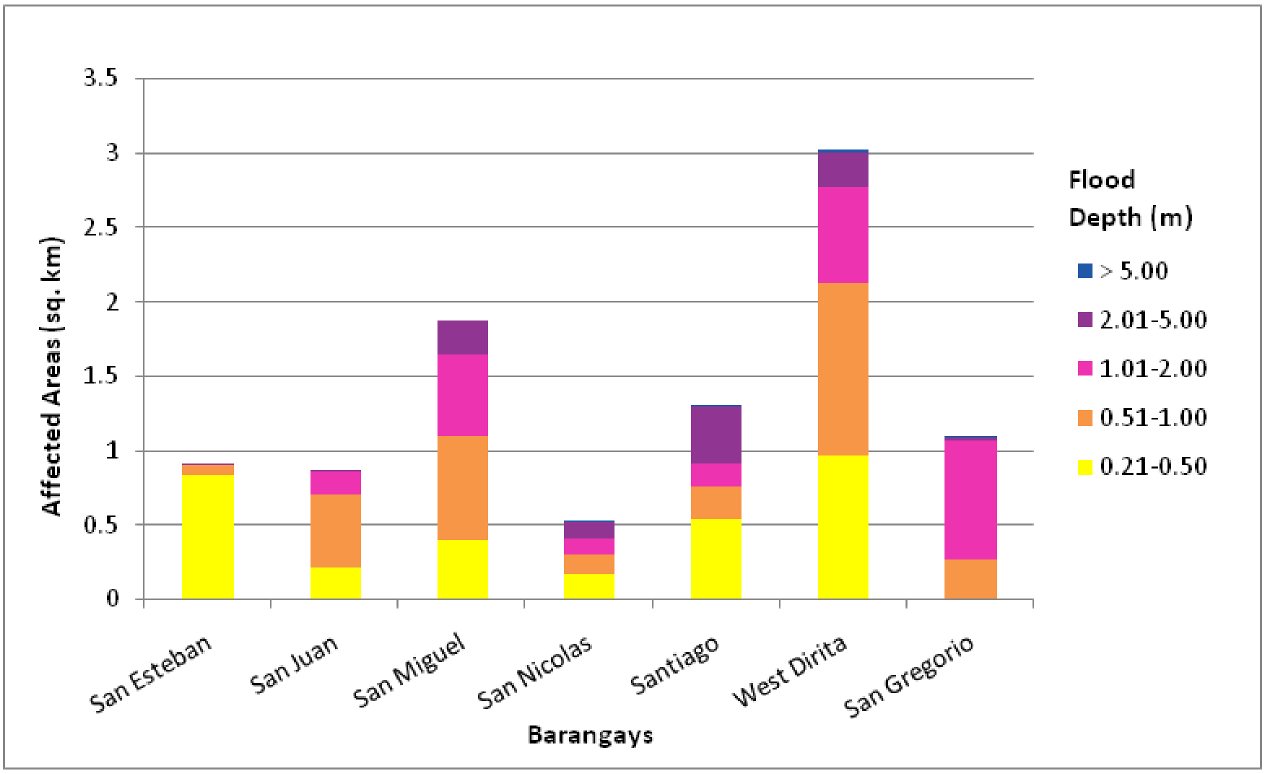


Figure 97. Affected areas in San Antonio, Zambales during a 100-year rainfall return period

For the 100-year return period, 5.40% of the municipality of San Felipe with an area of 96.23041 sq km will experience flood levels of less than 0.20 meters; 0.70% of the area will experience flood levels of 0.21 to 0.50 meters; while 2.33%, 10.10%, 2.85%, 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 65 are the affected areas in square kilometers by flood depth per barangay.

Table 65. Affected areas in San Felipe, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Felipe (in sq km)									
	Amagna	Apostol	Balincaguing	Farañal	Feria	Manglicmot	Rosete	San Rafael	Santo Niño	Sindol
0.03-0.20	0.0049	0.003	4.11	0.29	0	0	0.023	0.21	0	0.56
0.21-0.50	0.009	0.0087	0.4	0.014	0	0.0001	0.013	0.17	0.01	0.048
0.51-1.00	0.29	0.13	1	0.085	0.018	0.013	0.085	0.33	0.17	0.12
1.01-2.00	0.46	0.34	3.98	0.8	0.69	0.41	0.93	1.11	0.58	0.42
2.01-5.00	0.0002	0.011	1.4	0.14	0.0037	0.0016	0.037	0.17	0.36	0.62
> 5.00	0	0	0.04	0	0	0	0	0	0	0

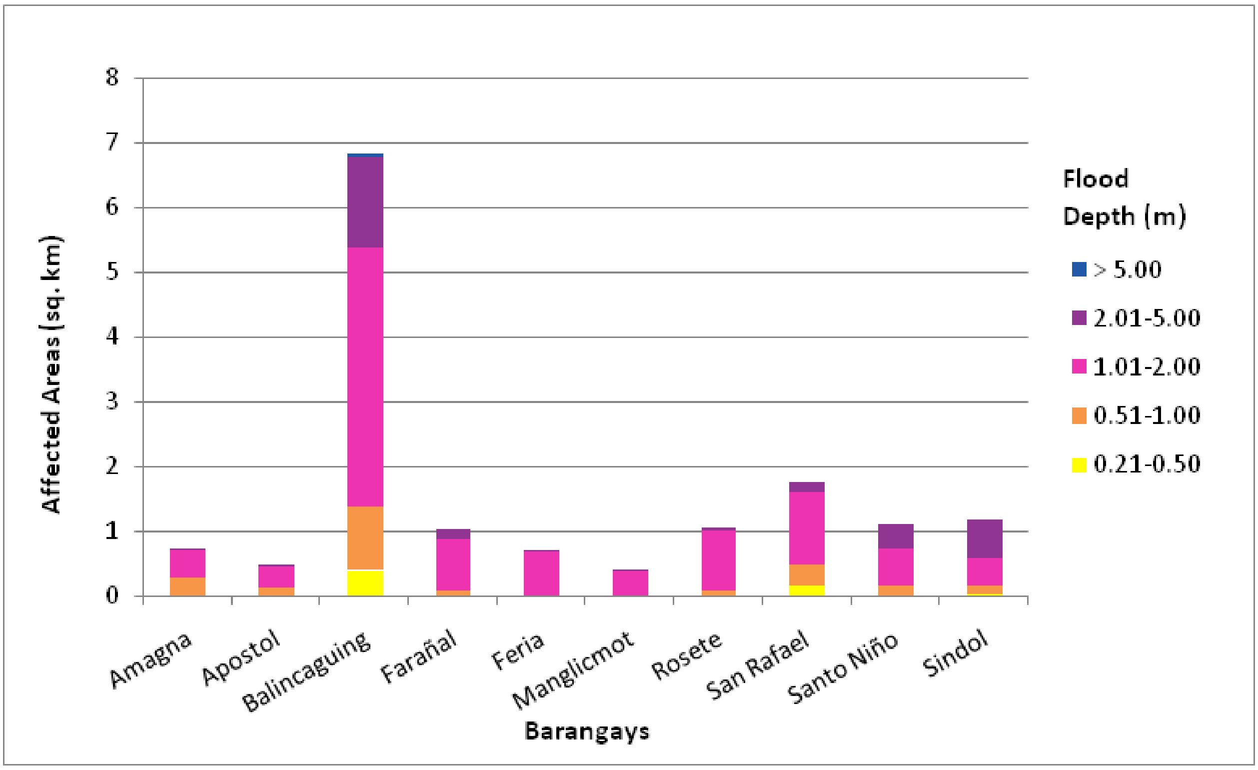


Figure 98. Affected areas in San Felipe, Zambales during a 100-year rainfall return period

For the 100-year return period, 11.11% of the municipality of San Marcelino with an area of 337.569132 sq km will experience flood levels of less than 0.20 meters; 5.43% of the area will experience flood levels of 0.21 to 0.50 meters; while 5.14%, 3.62%, 2.11%, and 0.30% 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 67are the affected areas in square kilometers by flood depth per barangay.

Table 66. Affected areas in San Marcelino, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Marcelino (in sq km)							
	Aglao	Burgos	Central	Consuelo Norte	Consuelo Sur	Laoag	LaPaz	Linasin
0.03-0.20	0.79	0.38	0.15	0.084	0.53	1.25	0.2	2.01
0.21-0.50	0.75	0.18	0.013	0.26	0.28	1.38	0.39	2.31
0.51-1.00	1.75	0.2	0.0034	1.16	0.3	2.54	0.022	1.69
1.01-2.00	1.11	0.12	0.00009	1.39	0.13	1.62	0	0.33
2.01-5.00	0.37	0.022	0	0.12	0.032	0.059	0	0.015
> 5.00	0	0	0	0	0	0.065	0	0

Table 67. Affected areas in San Marcelino, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Marcelino (in sq km)							
	Linusu-ngan	Lucero	Nagbu-nga	Rizal	San Guillermo	San Isidro	San Rafael	Santa Fe
0.03-0.20	1.11	0.073	4.89	0.19	0.55	0.24	7.67	17.38
0.21-0.50	1.58	0.11	4.15	0.14	0.47	0.26	3.78	2.27
0.51-1.00	0.39	0.68	1.12	0.12	0.0071	0.034	4.03	3.32
1.01-2.00	0.039	0.77	0.27	0.041	0	0.0045	2.28	4.13
2.01-5.00	0.0013	0.47	0.064	0.017	0	0.0026	0.83	5.11
> 5.00	0	0.17	0.0047	0	0	0	0.15	0.62

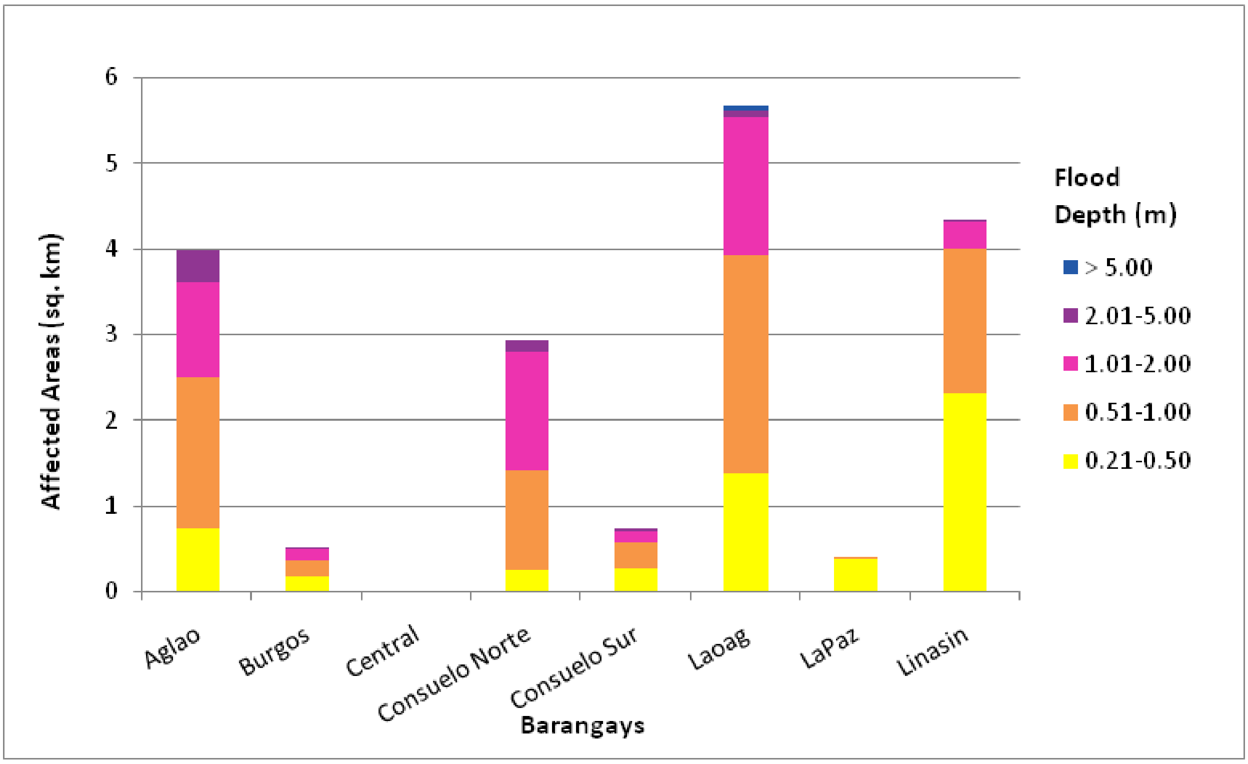


Figure 99. Affected areas in San Marcelino, Zambales during a 100-year rainfall return period

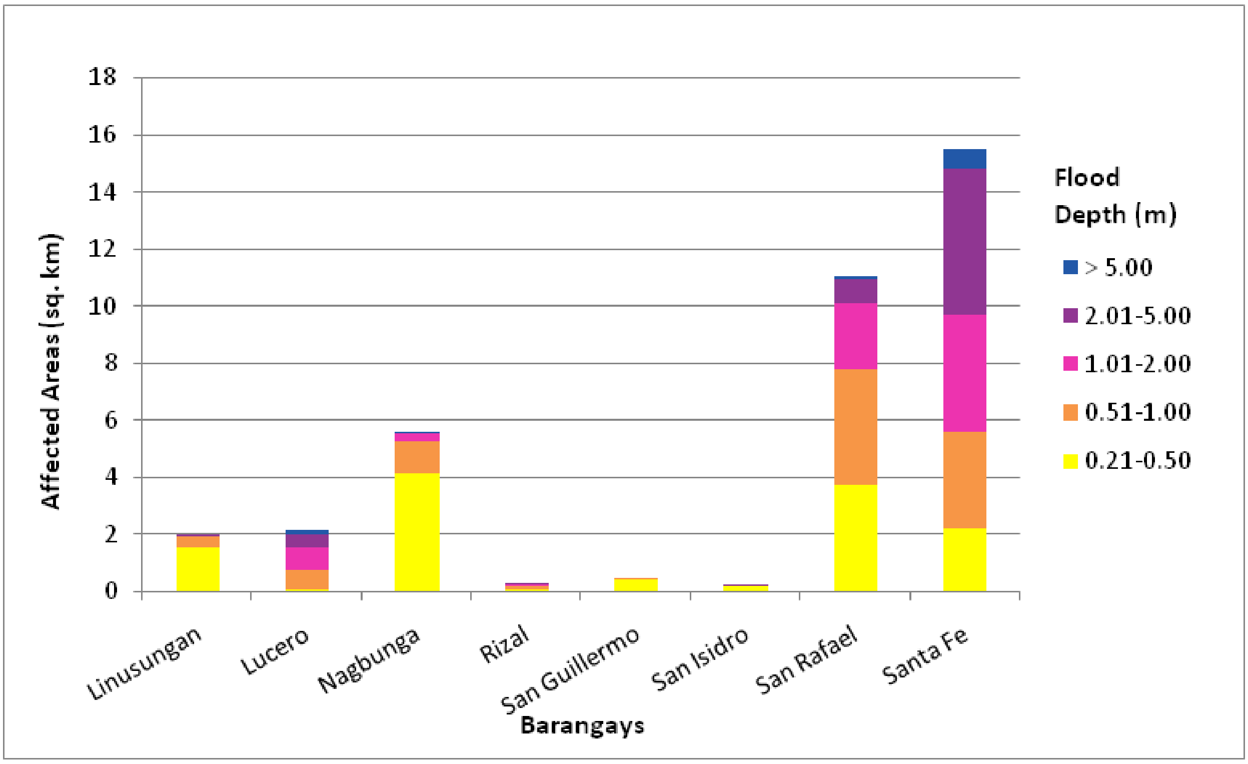


Figure 100. Affected areas in San Marcelino, Zambales during a 100-year rainfall return period

For the 100-year return period, 17.13% of the municipality of San Narciso with an area of 83.236575 sq km will experience flood levels of less than 0.20 meters; 18.32% of the area will experience flood levels of 0.21 to 0.50 meters; while 35.60%, 23.07%, 7.27%, 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 68 and Table 69 are the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected areas in San Narciso, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Narciso (in sq km)								
	Alusiis	Beddeng	Candelaria	Dallipawen	Grullo	LaPaz	Libertad	Namatacan	Natividad
0.03-0.20	1.34	2.72	0.036	0.36	0.45	0.6	0.1	0.62	0.04
0.21-0.50	0.82	2.98	0.22	0.44	0.79	0.44	0.13	2.3	0.22
0.51-1.00	1.95	4.43	0.61	1.41	2.96	0.86	0.4	3.4	0.34
1.01-2.00	0.77	2.83	0.17	0.74	3.29	0.63	0.077	1.21	0.018
2.01-5.00	0.014	1.18	0.052	0	0.56	0.11	0.0006	0.25	0.011
> 5.00	0	0	0	0	0.001	0	0	0	0

Table 69. Affected areas in San Narciso, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in San Narciso (in sq km)							
	Omaya	Paite	Patrocinio	San Jose	San Juan	San Pascual	San Rafael	Siminublan
0.03-0.20	0.98	4.56	0.14	0.019	0.23	0.24	0.08	1.74
0.21-0.50	0.43	2.89	0.37	0.076	0.75	0.3	0.08	2.01
0.51-1.00	1	6.22	0.53	0.61	1.85	0.38	0.49	2.19
1.01-2.00	1.51	7.05	0.15	0.12	0.31	0.063	0.077	0.19
2.01-5.00	0.93	2.88	0.0021	0.05	0.011	0	0	0.00027
> 5.00	0	0.012	0	0	0	0	0	0

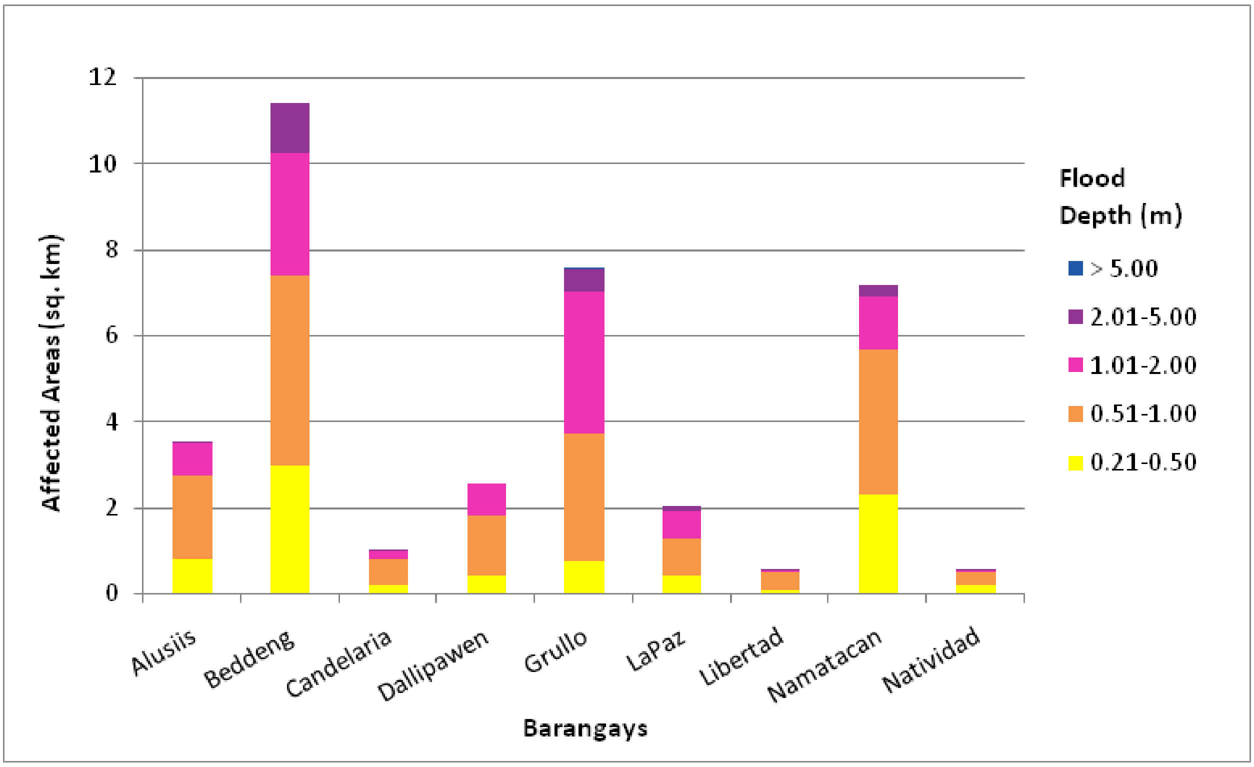


Figure 101. Affected areas in San Narciso, Zambales during a 100-year rainfall return period

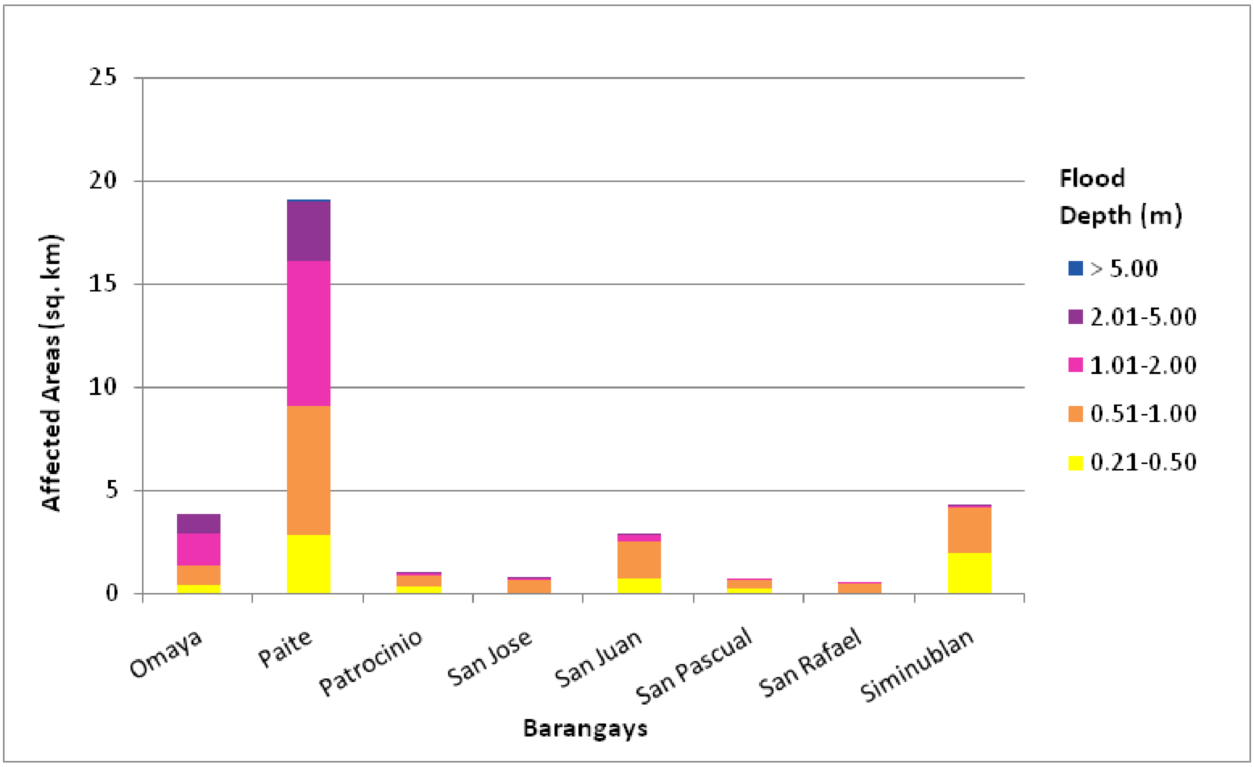


Figure 102. Affected areas in San Narciso, Zambales during a 100-year rainfall return period

For the 100-year return period, 2.72% of the municipality of Subic with an area of 253.594777 sq km will experience flood levels of less than 0.20 meters; 0.36% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.56%, 0.95%, 1.48%, 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 70 are the affected areas in square kilometers by flood depth per barangay.

Table 70. Affected areas in Subic, Zambales during a 100-year rainfall return period

Affected Area (sq km.) by flood depth (in m.)	Area of affected barangays in Subic (in sq km)				
	Aningway Sacatihan	Asinan Poblacion	Cawag	Mangan-Vaca	Pamatawan
0.03-0.20	2.12	0.13	3.38	0.0028	1.26
0.21-0.50	0.19	0.029	0.45	0	0.24
0.51-1.00	0.26	0.034	0.5	0	0.63
1.01-2.00	0.55	0.094	0.76	0	1.01
2.01-5.00	0.53	0.00047	1.88	0	1.35
> 5.00	0.0091	0	0.3	0	0.089

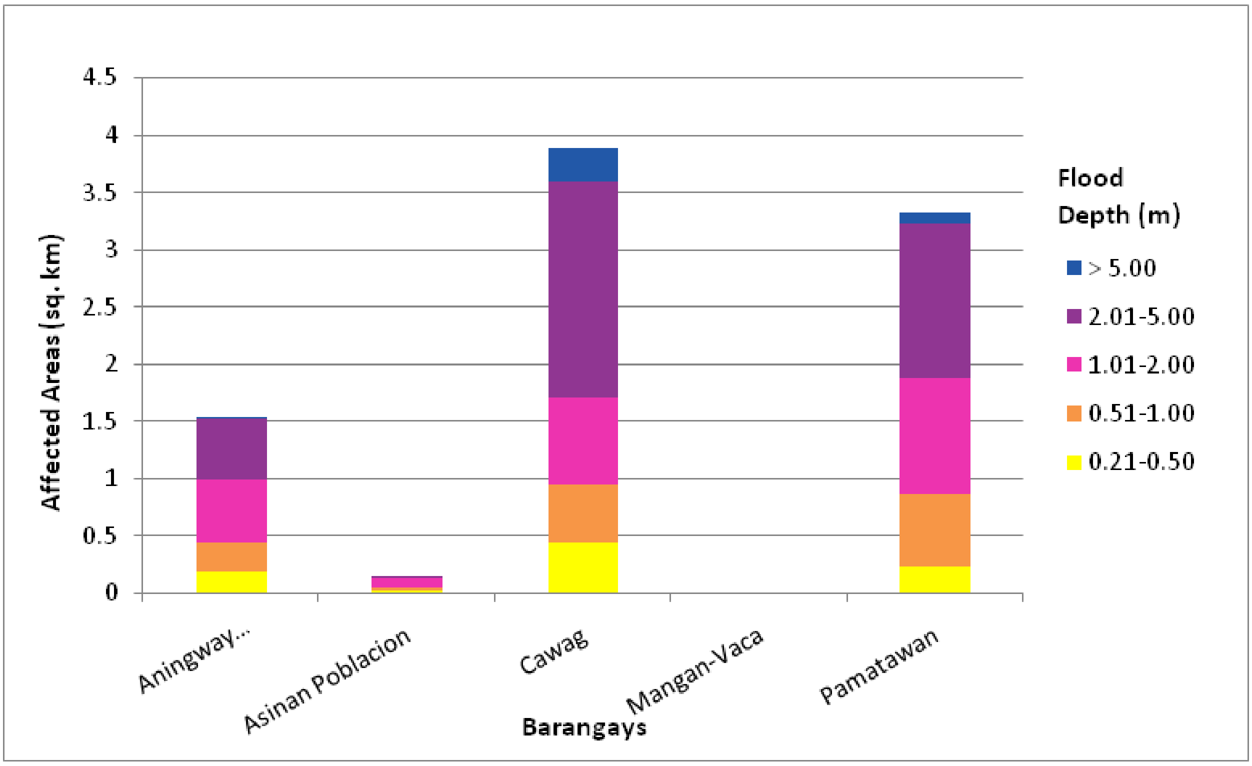


Figure 103. Affected areas in Subic, Zambales during a 100-year rainfall return period

Among the barangays in the municipality of Castillejos in Zambales, San Pablo is projected to have the highest percentage of area that will experience flood levels at 22.73%. Meanwhile, Looc posted the second highest percentage of area that may be affected by flood depths at 13.47%.

Among the barangays in the municipality of San Antonio in Zambales, Pundaquit is projected to have the highest percentage of area that will experience flood levels at 21.53%. Meanwhile, Antipolo posted the second highest percentage of area that may be affected by flood depths at 11.16%.

Among the barangays in the municipality of San Felipe in Zambales, Balincaguing is projected to have the highest percentage of area that will experience flood levels at 15.16%. Meanwhile, San Rafael posted the second highest percentage of area that may be affected by flood depths at 2.76%.

Among the barangays in the municipality of San Marcelino in Zambales, Santa Fe is projected to have the highest percentage of area that will experience flood levels at 45.53%. Meanwhile, San Rafael posted the second highest percentage of area that may be affected by flood depths at 25.99%.

Among the barangays in the municipality of San Narciso in Zambales, Paite is projected to have the highest percentage of area that will experience flood levels at 32.75%. Meanwhile, Beddeng posted the second highest percentage of area that may be affected by flood depths at 19.61%.

Among the barangays in the municipality of Subic in Zambales, Cawag is projected to have the highest percentage of area that will experience flood levels at 10.08%. Meanwhile, Pamatawan posted the second highest percentage of area that may be affected by flood depths at 6.35%.

Moreover, the generated flood hazard maps for the Sto. Tomas 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

	Area Covered in sq km.		
Warning Level	5 year	25 year	100 year
Low	60.14	60.74	56.23
Medium	67.43	83.84	90.70
High	31.17	49.21	63.05
Total	158.74	193.79	209.98

Of the 448 identified buildings of educational institutions in Sto. Tomas Floodplain, one hundred six (106) school buildings were discovered exposed to low-level flooding while forty-eight (48) school buildings were found exposed to medium-level flooding, both during a 5-year scenario.

For the 25-year scenario, one hundred sixty (160) school buildings were discovered exposed to low-level flooding while seventy-seven (77) school buildings were found exposed to medium-level flooding, In the same scenario, thirteen (13) school buildings were discovered exposed to high-level flooding.

For the 100-year scenario, one hundred forty-two (142) school buildings were discovered exposed to low-level flooding while one hundred forty-nine (149) school buildings were found exposed to medium-level flooding, In the same scenario, twenty-three (23) school buildings were discovered exposed to High-level flooding.

Of the 7 identified buildings of medical institutions in Alaminos Floodplain, one (1) building was discovered exposed to high-level flooding during a 5-year scenario.

For the 25-year scenario, two (2) buildings were discovered exposed to low-level flooding while one (1) building was found exposed to high-level flooding.

For the 100-year scenario, five (5) buildings were discovered exposed to low-level flooding while one (1) building was found exposed to high-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 points in the flood map versus its corresponding validation depths are shown in Figure 104.

The flood validation consists of 30 points randomly selected all over the Sto. Tomas Floodplain (Figure 105). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.66 m. Table 72 shows a contingency matrix of the comparison.

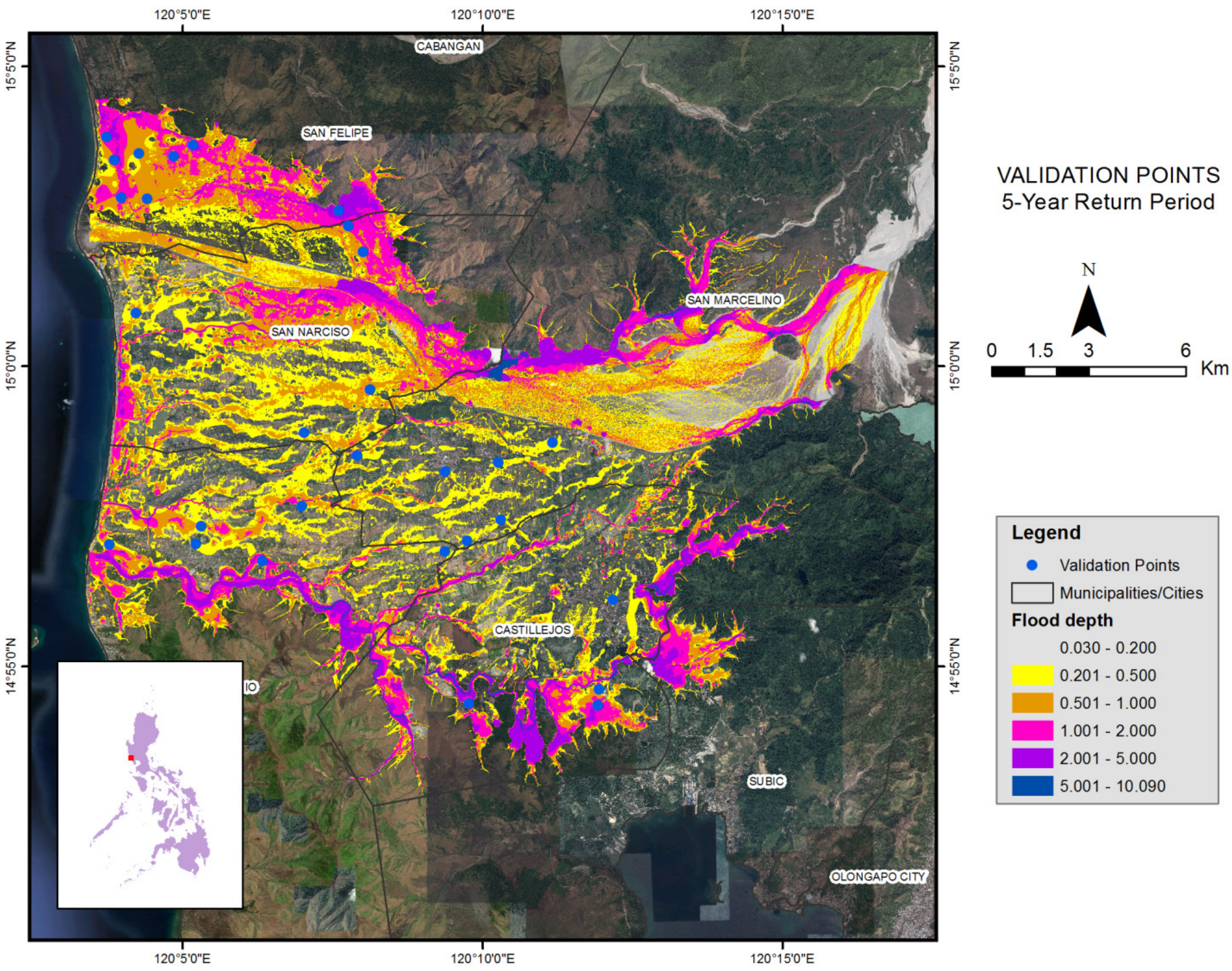


Figure 104. Validation points for 5-year flood depth map of Sto. Tomas Floodplain

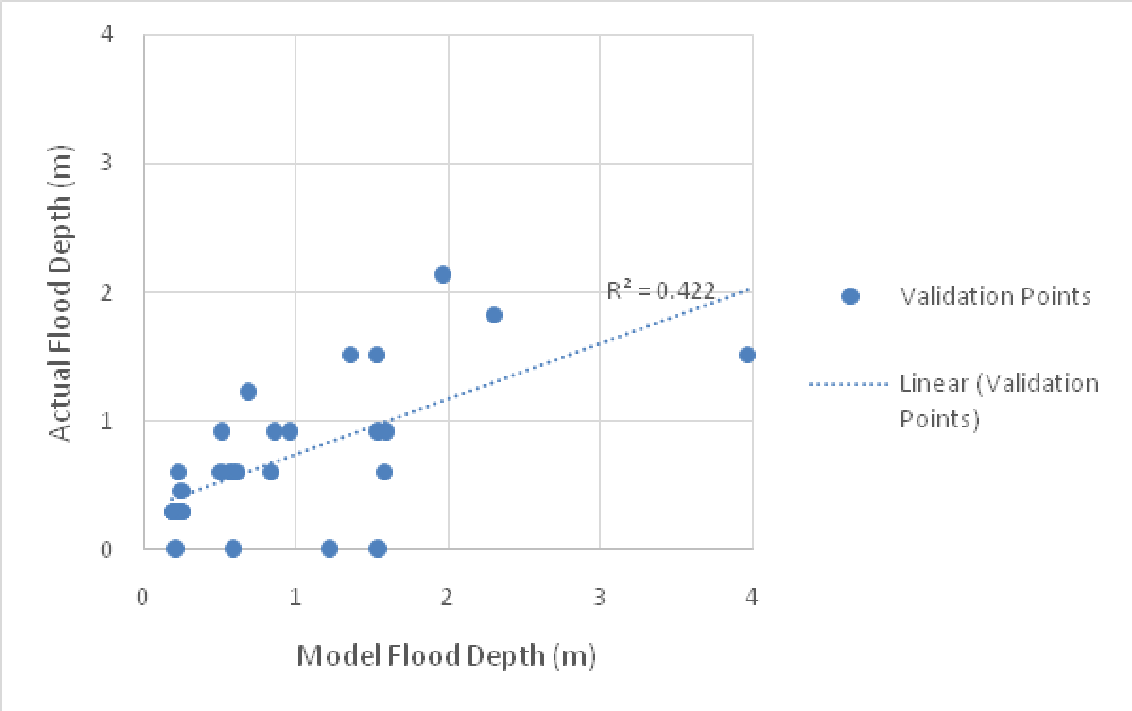


Figure 105. Model flood depth vs. actual flood depth

Table 72. Actual flood depth vs. simulated flood depth in Sto. Tomas

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	0	1	1	2	0	0	4
0.21-0.50	1	7	0	0	0	0	8
0.51-1.00	0	1	8	3	0	0	12
1.01-2.00	0	0	1	2	2	0	5
2.01-5.00	0	0	0	1	0	0	1
> 5.00	0	0	0	0	0	0	0
Total	1	9	10	8	2	0	30

The overall accuracy generated by the flood model is estimated at 56.67% with 17 points correctly matching the actual flood depths. In addition, there were 9 points estimated one level above and below the correct flood depths while there were 1 points and 2 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 4 points were underestimated in the modeled flood depths of Sto. Tomas.

Table 73. Summary of accuracy assessment in Sto. Tomas River Basin Survey

No. of Points		%
Correct	17	**56.67**
Overestimated	9	**30.00**
Underestimated	4	**13.33**
Total	30	**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.

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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 of Sensors

Pegasus

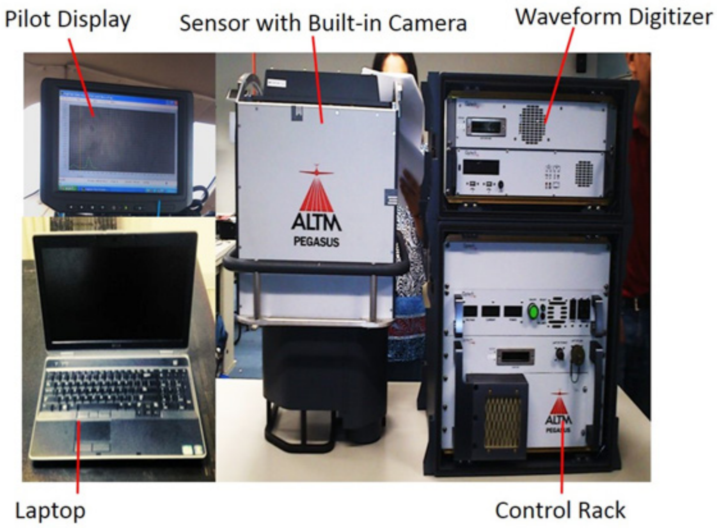

Figure A-1.1. Pegasus Sensor

Table A-1.1. Parameters and Specifications of Pegasus Sensor

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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20˚

4 Target size ≥ laser footprint5 Dependent on system configuration

Gemini

Figure A-1.1. Gemini Sensor

Table A-1.1. Parameters and Specifications of 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

BTN-71

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

January 02, 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: **BATAAN**
Station Name: **BTN-71**
Order: **2nd**

Island: **LUZON**
Municipality: **ORANI**
Barangay: **MARIA FE**

		PRS92 Coordinates			
Latitude:	**14° 47' 30.18239"**	Longitude:	**120° 32' 9.95860"**	Ellipsoidal Hgt:	**7.56300 m.**
		WGS84 Coordinates			
Latitude:	**14° 47' 24.68277"**	Longitude:	**120° 32' 14.83855"**	Ellipsoidal Hgt:	**49.42500 m.**
		PTM Coordinates			
Northing:	**1635812.88 m.**	Easting:	**450060.675 m.**	Zone:	**3**
		UTM Coordinates			
Northing:	**1,636,645.28**	Easting:	**234,782.54**	Zone:	**51**

Location Description

BTN-71
Is located in Brgy. Maria Fe, 30 m Sw of the Day Care Center, 20 m SE of the basketball court and 15 m NE of the chapel of the said barangay. It is also situated on the W edge of the concrete pavement used as volleyball court. Mark is the head of a 4" copper nail centered on a 30 cm x 30 cm concrete monument flushed on the ground with inscriptions BTN-71 2007 NAMRIA.

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-4**

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

9 9 0 1 0 2 2 0 1 4 1 2 3 5 0 2

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

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

Figure A-2.1. BTN-71

PMG-54

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

January 20, 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: **PAMPANGA**	
	Station Name: **PMG-54**	
Island: **LUZON**	Order: **3rd**	Barangay: **C.S.E.Z.**
Municipality: **CLARK DEV'T. CORP.**		
	PRS92 Coordinates	
Latitude: **15º 10' 50.24016"**	Longitude: **120º 31' 3.16452"**	Ellipsoidal Hgt: **213.00650 m.**
	WGS84 Coordinates	
Latitude: **15º 10' 44.64998"**	Longitude: **120º 31' 8.01131"**	Ellipsoidal Hgt: **253.69780 m.**
	PTM Coordinates	
Northing: **1678845.621 m.**	Easting: **448156.978 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,679,714.68**	Easting: **233,266.88**	Zone: **51**

Location Description

PMG-54
Is located about 50 m. NE of Bldg. 2127 (Main Bldg.) of Clark Development Corp. and about 3 m. W of the Phil. flagpole. Mark is the head of a 1 in. concrete nail driven on the marbled tiled footing of a historical mark commemorating the turnover of the U.S. Military Base to the Philippine Gov't.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-96**

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

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

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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Figure A-2.2. PMG-54

ZBS-58

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

January 02, 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: **ZAMBALES**	
	Station Name: **ZBS-58**	
	Order: **2nd**	
Island: **LUZON**		Barangay: **DIRITA-BALOGUEN**
Municipality: **IBA (CAPITAL)**		
	PRS92 Coordinates	
Latitude: **15° 20' 8.92898"**	Longitude: **119° 58' 34.69353"**	Ellipsoidal Hgt: **7.77100 m.**
	WGS84 Coordinates	
Latitude: **15° 20' 3.25975"**	Longitude: **119° 58' 39.52976"**	Ellipsoidal Hgt: **46.69300 m.**
	PTM Coordinates	
Northing: **1696218.486 m.**	Easting: **390073.626 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,697,561.97**	Easting: **819,598.83**	Zone: **50**

Location Description

ZBS-58
The station is inside Barangay Center of Dirita, Iba, Zambales. It is approximately 1m. from the foot of the basketball court at east direction. Mark is the head of 4 inch copper nail, centered on a 30 cm x 30 cmconcrete block flushed on the ground with inscription "IBA-56, 2007,DENR".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-2**

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

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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Figure A-2.3. ZBS-58

ZBS-60

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

January 02, 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: **ZAMBALES**	
	Station Name: **ZBS-60**	
	Order: **2nd**	
Island: **LUZON**		Barangay: **SAN ANTONIO**
Municipality: **CABANGAN**		
	PRS92 Coordinates	
Latitude: **15° 9' 48.72475"**	Longitude: **120° 3' 4.60936"**	Ellipsoidal Hgt: **12.36500 m.**
	WGS84 Coordinates	
Latitude: **15° 9' 43.10078"**	Longitude: **120° 3' 9.45989"**	Ellipsoidal Hgt: **51.97200 m.**
	PTM Coordinates	
Northing: **1677118.723 m.**	Easting: **398042.381 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,678,445.32**	Easting: **183,107.00**	Zone: **51**

Location Description

ZBS-60
From Cabangan, travel southward along the National Road for about 300 m until reaching Barangay San Antonio Proper. Station mark is located inside the Barngay Hall compound about 6 m E of Barangay road. It is situated about 10 m S of basketball court and Children's Park. Mark is the head of 4 inch copper nail, centered on a 30 cm x 30 cm concrete block flushed on the ground with inscription "ZBS-60, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-3**

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

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

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

Figure A-2.4. ZBS-60

ZBS-62

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

January 02, 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: **ZAMBALES**
Station Name: **ZBS-62**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN NARCISO**
Barangay: **LA PAZ**

PRS92 Coordinates

Latitude: **15° 0' 58.08330"**	Longitude: **120° 3' 50.43021"**	Ellipsoidal Hgt: **9.87700 m.**

WGS84 Coordinates

Latitude: **15° 0' 52.49407"**	Longitude: **120° 3' 55.29320"**	Ellipsoidal Hgt: **49.94200 m.**

PTM Coordinates

Northing: **1660802.886 m.**	Easting: **399340.98 m.**	Zone: **3**

UTM Coordinates

Northing: **1,662,105.93**	Easting: **184,257.98**	Zone: **51**

Location Description

ZBS-62
the mark is located in the EXECUTIVE PARK of Barangay La Paz, San Narciso. It is situated on the NW corner of the stage of said plaza about 15 m W of Magsaysay Boulevard. Mark is the head of 4 inch copper nail, centered on a 30 cm x 30 cm concrete block fkushed on the ground with inscription ZBS-62, 2007, NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8794989 A**
T.N.:	**2014-1**

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

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

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

Figure A-2.5. ZBS-62

ZBS-64

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

September 04, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ZAMBALES**		
	Station Name: **ZBS-64**		
	Order: **2nd**		
Island: **LUZON**	Barangay: **MAGSAYSAY**		
Municipality: **CASTILLEJOS**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **14° 56' 28.82886"**	Longitude: **120° 11' 31.25386"**	Ellipsoidal Hgt:	**52.07500 m.**
	WGS84 Coordinates		
Latitude: **14° 56' 23.26711"**	Longitude: **120° 11' 36.12262"**	Ellipsoidal Hgt:	**92.66800 m.**
	PTM / PRS92 Coordinates		
Northing: **1652473.038 m.**	Easting: **413077.841 m.**	Zone:	**3**
	UTM / PRS92 Coordinates		
Northing: **1,653,646.25**	Easting: **197,928.90**	Zone:	**51**

Location Description

ZBS-64
From San Fernando City, travel toward Castillejos Proper via Olongapo City. The station is situated at Barangay Magsaysay which is about 1 km NW of Castillejos Municipal Hall. Mark is located at the left shoulder of the road and is measured 2m from the culvert parapet. Mark is the head of a 4 inch copper nail, centered on a 30 cm x 30 cm concrete block flushed on the ground with inscription "ZBS-64, 2007, NAMRIA".

Requesting Party: **Christopher Cruz**
Purpose: **Reference**
OR Number: **8087195 I**
T.N.: **2015-2551**

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

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

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. ZBS-64

BA-10

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

January 20, 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: **BATAAN**
Station Name: **BA-10**

Island: **LUZON**	Municipality: **DINALUPIHAN**	Barangay: **SAN BENITO**
Elevation: **13.3459 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BA 10
Is in the province of Bataan, town of Dinalupihan, barrio San Benito, along National Highway No.7, on top of the NE end of the NW concrete walk of bridge marked 105.02, 4.10 m. NW of the centerline of the road, stamped. Mark is a 4" x 1/2" diameter brass rod set flush in a drilled hole on top of walk. PC&GS BA 10 1956 are inscribed on a cement putty on top of walk.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-99**

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

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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
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Figure A-2.7. BA-10

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

BA-10

Vector Components (Mark to Mark)

From:	BTN-71				
Grid		Local		Global	
Easting	234780.128 m	Latitude	N14°47'30.39069"	Latitude	N14°47'24.89107"
Northing	1636651.711 m	Longitude	E120°32'09.87566"	Longitude	E120°32'14.75560"
Elevation	14.732 m	Height	15.402 m	Height	57.263 m

To:	BA-10				
Grid		Local		Global	
Easting	234727.081 m	Latitude	N14°42'24.60522"	Latitude	N14°42'19.12527"
Northing	1627249.500 m	Longitude	E120°32'11.54465"	Longitude	E120°32'16.43182"
Elevation	14.370 m	Height	14.871 m	Height	56.977 m

Vector					
ΔEasting	-53.047 m	NS Fwd Azimuth	179°41'44"	ΔX	-1258.605 m
ΔNorthing	-9402.211 m	Ellipsoid Dist.	9397.940 m	ΔY	2034.807 m
ΔElevation	-0.362 m	ΔHeight	-0.531 m	ΔZ	-9088.288 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.008 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.012 m
σ ΔElevation	0.015 m	σ ΔHeight	0.015 m	σ ΔZ	0.005 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000610091		
Y	-0.0000802998	0.0001536132	
Z	-0.0000316368	0.0000504973	0.0000212187

Figure A-3.1. BA-10

ZA-62A

Vector Components (Mark to Mark)

From:	ZBS-62				
Grid		Local		Global	
Easting	184257.971 m	Latitude	N15°00'58.08330"	Latitude	N15°00'52.49407"
Northing	1662105.928 m	Longitude	E120°03'50.43021"	Longitude	E120°03'55.29320"
Elevation	7.211 m	Height	9.877 m	Height	49.942 m

To:	ZBS-62A				
Grid		Local		Global	
Easting	184258.065 m	Latitude	N15°00'57.82648"	Latitude	N15°00'52.23627"
Northing	1662097.996 m	Longitude	E120°03'50.43687"	Longitude	E120°03'55.29987"
Elevation	7.424 m	Height	10.090 m	Height	50.155 m

Vector					
ΔEasting	0.094 m	NS Fwd Azimuth	178°33'38"	ΔX	-1.304 m
ΔNorthing	-7.932 m	Ellipsoid Dist.	7.926 m	ΔY	1.855 m
ΔElevation	0.213 m	ΔHeight	0.213 m	ΔZ	-7.698 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'10"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000003174		
Y	-0.0000002549	0.0000005198	
Z	-0.0000001284	0.0000001364	0.0000001616

Figure A-3.2. ZA-62A

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
Survey Supervisor	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
Survey Supervisor	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
LiDAR Operation	SSRS	AUBREY PAGADOR	UP-TCAGP
LiDAR Operation	SSRS)/ Research Associate (2014)	PAULINE JOANNE ARCEO	UP-TCAGP
LiDAR Operation	Research Associate (RA)	FOR. MA. VERLINA TONGA	UP-TCAGP
LiDAR Operation	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
LiDAR Operation	RA	MA. CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
LiDAR Operation	RA	FOR. REGINA FELISMINO	UP-TCAGP
LiDAR Operation	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation/ Ground Survey, Data Download and Transfer	RA	ENGR. KENNETH QUISADO	UP-TCAGP
LiDAR Operation/ Ground Survey, Data Download and Transfer	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG DIOSCORO SOBERANO	PHILIPPINE AIR FORCE (PAF)
LiDAR Operation	Airborne Security	SSG PRADYUMA DAS RAMIREZ	PAF
LiDAR Operation	Airborne Security	SSG ERWIN DELOS SANTOS	PAF
LiDAR Operation	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Pilot	CAPT. JOHN BRYAN DONGUINES	AAC
LiDAR Operation	Pilot	CAPT. JERICHO JECIEL	AAC
LiDAR Operation	Pilot	CAPT. ALBERT LIM	AAC
LiDAR Operation	Pilot	CAPT. SHERWIN ALFONSO III	AAC

Annex 5. Data Transfer Sheet for Sto. Tomas Floodplain

DATA TRANSFER SHEET

Jan 10, 2013

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS Output LAS	RAW LAS KML (swath)	LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S) BASE STATION(S)	BASE STATION(S) Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN Actual	FLIGHT PLAN KML	SERVER LOCATION
Jan 2 2014	926G	2BALE002A	GEMINI	N/A	N/A	4.05 MB	243 MB	27.2 GB	201 KB	13.3 GB	101 GB	8.23 MB	174 BYTES	471 BYTES	4.68 KB	101 KB	Y:\Airborne_Raw\926G
Jan 3 2014	930G	2BUCE003A	GEMINI	N/A	N/A	848 KB	277 MB	35.2 GB	245 KB	18.9 GB	1.29 GB	27.7 MB	376 BYTES	485 BYTES	5.77 KB	432 KB	Y:\Airborne_Raw\930G
Jan 3 2014	932G	2BUCES003A	GEMINI	N/A	N/A	329 KB	86.8 MB	N/A	N/A	809 MB	N/A	27.7 MB	376 BYTES	438 BYTES	5.77 KB	432 KB	Y:\Airborne_Raw\932G
Jan 4 2014	934G	2BUCF004A	GEMINI	N/A	N/A	0.99 MB	299 MB	7.19 GB	N/A	27.6 GB	189 GB	21.3 MB	278 BYTES	527 BYTES	5.63 KB	664 KB	Y:\Airborne_Raw\934G
Jan 2 2014	935P	1BALAS002A	PEGASUS	970 KB	1124 KB	9.79 MB	265 MB	N/A	N/A	18.5 GB	87.3 GB	8.23 MB	174 BYTES	604 BYTES	19.0 KB	145 KB	Y:\Airborne_Raw\935G
Jan 4 2014	943P	1BUCABC004A	PEGASUS	1415 KB	1152 KB	11.6 MB	274 MB	N/A	N/A	21.6 GB	78.2 GB	21.3 MB	278 BYTES	616 BYTES	47.6 KB	60.7 KB	Y:\Airborne_Raw\943P
Jan 3 2014	941P	1BUCBS003B	PEGASUS	574 KB	699 KB	6.43 MB	205 MB	N/A	N/A	10.8 GB	36.3 GB	27.7 MB	376 BYTES	320 BYTES	22.6 KB	53.4 KB	Y:\Airborne_Raw\941P
Jan 4 2014	945P	1BUCCS004B	PEGASUS	211 KB	258 KB	5.52 MB	172 MB	N/A	N/A	4.69 GB	562 MB	21.3 MB	278 BYTES	374 BYTES	29.2 KB	53.4 KB	Y:\Airborne_Raw\945P
Jan 3 2014	939P	1PLGA003A	PEGASUS	1.38 MB	1.68 MB	10.0 MB	295 MB	N/A	N/A	26.1 GB	121 GB	27.7 MB	376 BYTES	524 BYTES	29.6 KB	18.6 KB	Y:\Airborne_Raw\939P
Jan 5 2014	949P	1BUCGS005B	PEGASUS	671 KB	823 KB	7.24 MB	228 MB	N/A	N/A	12.9 GB	42.9 GB	16.1 MB	222 BYTES	558 BYTES	23.8 KB	243 KB	Y:\Airborne_Raw\949P
Jan 6 2014	951P	1BALF006A	PEGASUS	420 KB	528 KB	6.41 MB	178 MB	N/A	N/A	9.51 GB	41.5 GB	12.8 MB	221 BYTES	442 BYTES	19 KB	158 KB	Y:\Airborne_Raw\951P

Received from

Name Pat Alcantara
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature

Verified by

Name JOIDA PRIETO
Position SSRS
Signature

Figure A-5.1. Data Transfer Sheet for Sto. Tomas Floodplain (A)

14-7

DATA TRANSFER SHEET
Feb 18, 2014

DATE of Operation	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		POS (MB)	RAW IMAGES (GB)	MISSION LOG FILE (KB)	RANGE (GB)	DIGITIZER (GB)	BASE STATION (S)		OPERATOR COMMENTS (DPC LOGS) (Bytes)	Flight Plans		CASI (GB)	SERVER LOCATION
				ACTUAL (MB)	KML (KB)						BASE (MB)	BASE INFO (BYTES)		Actual (KB)	Kml (KB)		
10/29/2013	699G	2CAG61B302A	Gemini	N/A	63KB	281MB	46.4GB	365KB	23.5	157		12.3	459		12	N/A	\\FREENAS\geostorage3\Airborne_Raw\699G
10/29/2013	701G	2CAG61E302B	Gemini	N/A	318KB	145MB	23.7GB	188KB	13.2	N/A		12.3	539		9	N/A	\\FREENAS\geostorage3\Airborne_Raw\701G
2/2/2014	7047GC	2MtAS033A	Gemini	N/A	104	138	N/A	N/A	3.64	N/A	2.42	117	666	72.8	7.9	30.4	\\FREENAS\geostorage3\Airborne_Raw\7047GC
2/4/2014	7051GC	2CAG101DS035A	Gemini	N/A	178	152	N/A	N/A	19	N/A	9.96	143	355	310	8.13	47.9	\\FREENAS\geostorage3\Airborne_Raw\7051GC
2/6/2014	7054GC	2CAG101A037A & 2CAG111C037A	Gemini	N/A	43.3 & 140	210	N/A	N/A	17.9	N/A	1.15 & 9.58	385	721	43.3 & 140	446 & 333	58.4	\\FREENAS\geostorage3\Airborne_Raw\7054GC
2/6/2014	7055GC	2CAG101A037B	Gemini	N/A	210	162	N/A	N/A	15.9	N/A	576KB & 9.58	385	404	166	11.4KB	72.2	\\FREENAS\geostorage3\Airborne_Raw\7055GC
2/7/2014	7057GC	2CAG51D038A & 2CAG101DS038A	Gemini	N/A	251	176	N/A	N/A	19..2	N/A	937KB & 4.70	228	903	265 & 179	217 & 13.4	60.7	\\FREENAS\geostorage3\Airborne_Raw\7057GC
2/8/2014	7059GC	2CAG101AS039A & 2CAG111BS039A	Gemini	N/A	148	185	N/A	N/A	13.5	N/A	809KB & 9.85	252	339	204	NA	41	\\FREENAS\geostorage3\Airborne_Raw\7059GC
2/9/2014	7061GC	2CAG101G040A & 2CAG101H040A	Gemini	N/A	327	260	N/A	N/A	3.34	N/A	1.12 & 7.39	253	467	453 & 330	665	31.3	\\FREENAS\geostorage3\Airborne_Raw\7061GC

Received from

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

Received by

Name/Signature JOIDA F. PRIETO
Position SSRS
Date

Verified by

Name/Signature JOIDA F. PRIETO
Position SSRS
Date

Figure A-5.2. Data Transfer Sheet for Sto. Tomas Floodplain (B)

DATA TRANSFER SHEET
5/22/2014(PAMPANGA REFLIGHTS)

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	
5/16/2014	7253GC	2PAMS1S3136A	GEMINI	na	140	350	228	NA	NA	10.8	NA	11.7	1KB	1KB	93	30	Z:\Airborne_Raw\7 253GC
5/17/2014	7254GC	2BLK15S1S2137A	GEMINI	na	59.7	141	191	NA	NA	5.17	NA	7.17	1KB	1KB	40	NA	Z:\Airborne_Raw\7 254GC
5/17/2014	7255GC	2PAMS2137B	GEMINI	na	78.4	167	121	NA	NA	6.45	NA	7.17	1KB	1KB	53	5	Z:\Airborne_Raw\7 255GC
5/18/2014	7256GC	2PAMS5138A	GEMINI	na	245	486	227	NA	NA	18.9	NA	18.7	1KB	1KB	216	NA	Z:\Airborne_Raw\7 256GC
5/18/2014	7257GC	2PAMS7138B & 2NEJS1138B	GEMINI	na	318	197	146	NA	NA	6.22	NA	18.7	1KB	1KB	216	32	Z:\Airborne_Raw\7 257GC
5/20/2014	7260GC	2BLK17S1140A	GEMINI	na	209	301	183	NA	NA	14.5	NA	10.7	1KB	1KB	241	NA	Z:\Airborne_Raw\7 260GC

Received from

Name C. Joson IV
Position KA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
5/26/2014

14-2n

Figure A-5.3. Data Transfer Sheet for Sto. Tomas Floodplain (C)

DATA TRANSFER SHEET
5/29/2014(Pampanga Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
5/22/2014	7264GC	2BLK15S142A	GEMINI	NA	89.2	276	205	NA	NA	8.92	NA	6.63	1KB	1KB	187	24	Z:\Airborne_Raw\7264GC
5/23/2014	7266GC	2BLK15S143A	GEMINI	NA	168	374	220	NA	NA	14.4	NA	13.2	1KB	1KB	13	18	Z:\Airborne_Raw\7266GC
5/24/2014	7268GC	2PAMS8144A	GEMINI	NA	192	364	223	NA	NA	14.7	NA	11.3	1KB	1KB	23	26	Z:\Airborne_Raw\7268GCA
5/24/2014	7269GC	2PAMS8144B	GEMINI	NA	236	197	140	NA	NA	7.93	NA	11.3	1KB	1KB	18	NA	Z:\Airborne_Raw\7269GC
5/25/2014	7271GC	2PAMS1S3145B	GEMINI	NA	91.8	383	233	NA	NA	15.5	NA	3.68	1KB	1KB	17	na	Z:\Airborne_Raw\7271GC

Received from

Name C.Joaquin
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 5/29/14

14-217

Figure A-5.4. Data Transfer Sheet for Sto. Tomas Floodplain (D)

15-13

DATA TRANSFER SHEET
03/09/2015(Clark)

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	
20-Jan	2471P	1BUC020A	pegasus	847	na	7.8	192	25.1	217	15.5	na	5.41	1KB	1KB	50	na	Z:\DAC\RAW DATA
21-Jan	2473P	1BUC021A	pegasus	1.69	na	10.3	252	31	208	16	na	4.14	1KB	1KB	44	na	Z:\DAC\RAW DATA
22-Jan	2477P	1NEJ022A	pegasus	1.04	na	7.5	197	na	na	10.2	na	4.16	1KB	1KB	na	na	Z:\DAC\RAW DATA
23-Jan	2481P	1BTN023A	pegasus	2.44	na	11.7	273	na	na	24.4	na	2.82	1KB	1KB	113	na	Z:\DAC\RAW DATA
26-Jan	2493P	1BUC026A	pegasus	2.44	na	11.7	273	18.7/11.1	13682.4q	6.71	na	8.56	1KB	1KB	113	na	Z:\DAC\RAW DATA
27-Jan	2497P	1BUC027A	pegasus	631	na	6.73	195	21	170	7.47	na	2.41	1KB	1KB	63	na	Z:\DAC\RAW DATA
28-Jan	2501P	1BUC028A	pegasus	1.9	na	8.65	184	22.5	161	20.7	na	5.3	1KB	1KB	89	na	Z:\DAC\RAW DATA

Received from

Name C JOAQUIN
Position
Signature

Received by

Name AC Bongat 3/9/15
Position CSRS
Signature

Figure A-5.5. Data Transfer Sheet for Sto. Tomas Floodplain (E)

DATA TRANSFER SHEET
~~Datbarzon~~ 9/10/15 CLARK

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	
26-Aug-15	2656G	2BTNAB238B	gemini	na	202	385	185	9.17/1.8/361	81/15/4	9.15	1.22	175	1KB	1KB	8	7	Z:\DAC\RAW DATA
27-Aug-15	2658G	2BTNCD239A	gemini	na	298	623	232	11.6/9.83	1/1/1	13.3	537	94.8	1KB	1KB	10	17	Z:\DAC\RAW DATA
28-Aug-15	2662G	2UMYA240A	gemini	na	273	482	231	134/25.1	2/198	8.59	0	137	1KB	1KB	12	30	Z:\DAC\RAW DATA
29-Aug-15	2666G	2UMYAB241A	gemini	na	301	554	238	17.6	139	12.5	673	104	1KB	1KB	12	na	Z:\DAC\RAW DATA
30-Aug-15	2670G	2CLBUMYABS242A	gemini	na	379	635	247	29.1	233	16.4	321	84.5	1KB	1KB	5	7	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

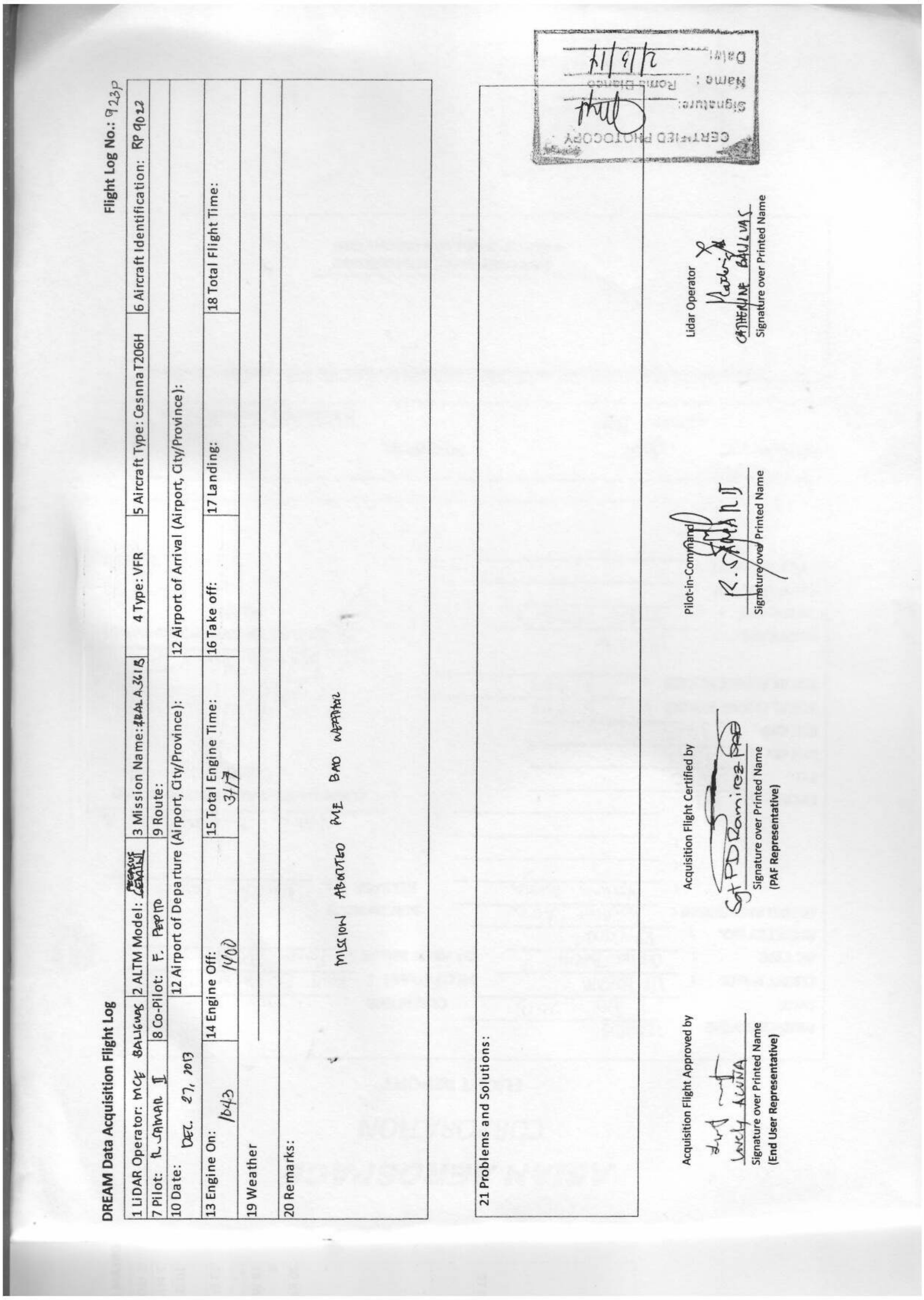
Name AC Bongat 9/11/15 Calib: 10/5/15
Position SSRS
Signature ABongat

15-26

Figure A-5.5. Data Transfer Sheet for Sto. Tomas Floodplain (E)

Annex 6. Flight Logs for the Flight Missions

Figure A-6.1. Flight Log for 923P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 923P

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: PEGASUS GEMINI	3 Mission Name: 1BALA361B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP 9022
7 Pilot: R. SAMAR II	8 Co-Pilot: F. PEPITO	9 Route:			
10 Date: DEC. 27, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1043	14 Engine Off: 1400	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION ABORTED DUE BAD WEATHER					

21 Problems and Solutions:

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

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

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

Lidar Operator
CATHERINE BALUYAS
Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name : Romi Blanco
Date: 2/5/14

Figure A-6.2. Flight Log for 933P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 933P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BALD363B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP 9022
7 Pilot: R. SAMAR II.	8 Co-Pilot: F. PEPITO	9 Route:			
10 Date: DEC. 29, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1448	14 Engine Off: 1817	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	Sgt PD Ramirez PAF	R. SAMAR II	Iro Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for 930G Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 918

1 LiDAR Operator: RENAN PUNTO	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: F. DE OCAMPO	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: JAN. 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0450	14 Engine Off: 1431	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 11/15 LINES IN SURVEY AREA					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	SSgt PD Ramirez PAF Signature over Printed Name (PAF Representative)	FB DE OCAMPO Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for 934G Mission

DREAM Data Acquisition Flight Log

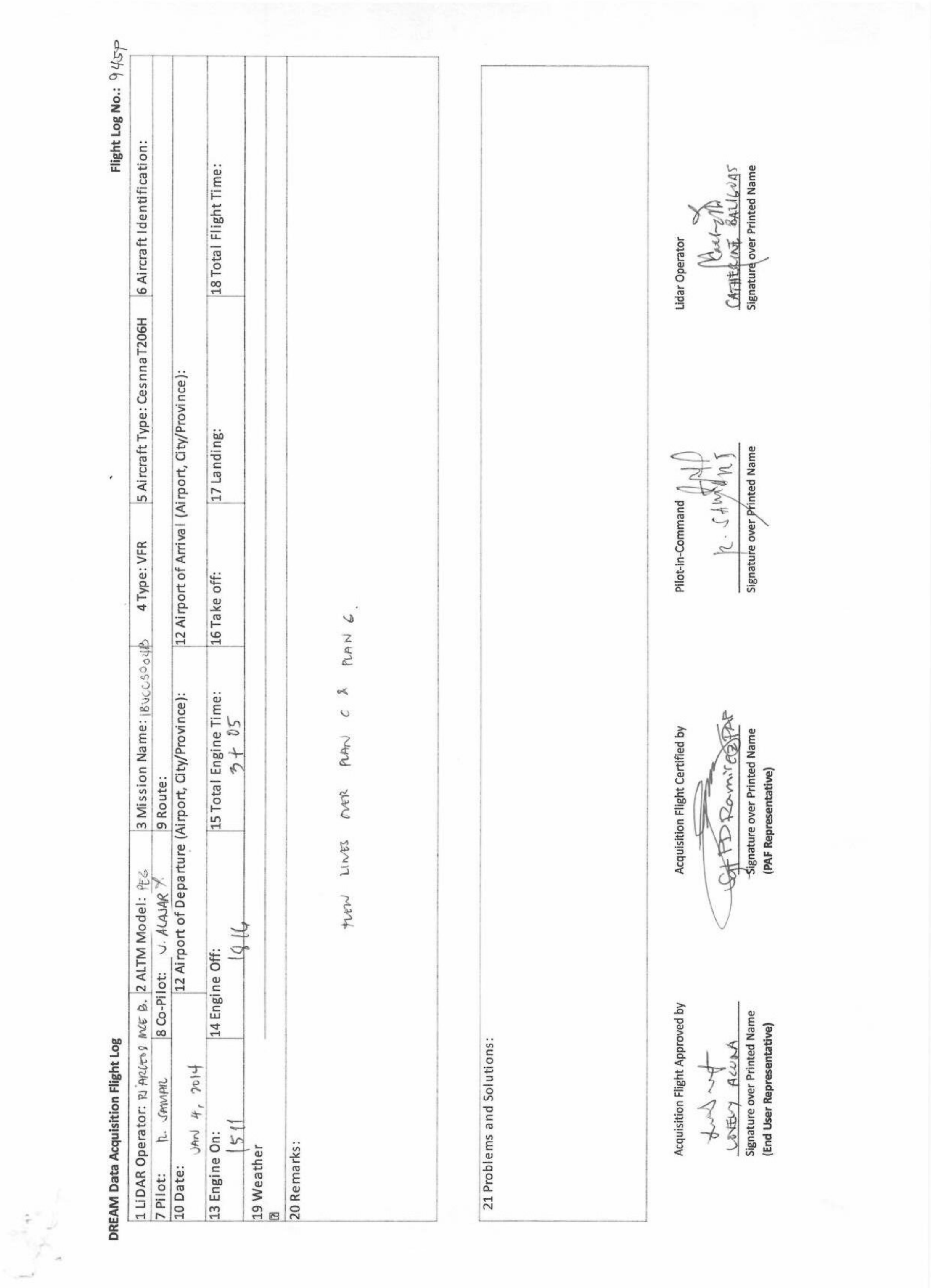
Flight Log No.: 922

1 LiDAR Operator: Dc Aldovino	2 ALTM Model: Gemini	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9122
7 Pilot: F De Ocampo	8 Co-Pilot: J Javier	9 Route:			
10 Date: January 4, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 9+19	14 Engine Off: 14+24	15 Total Engine Time: 5+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Sgt FD Ramirez PAF Signature over Printed Name (PAF Representative)	FB De Ocampo Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for 945P Mission



DREAM Data Acquisition Flight Log — **Flight Log No.:** 945P

1 LiDAR Operator: RJ ARCEO? MCE B.	2 ALTM Model: PEG	3 Mission Name: 1BUCCS004B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: R. SAMPAL	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: JAN 4, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1511	14 Engine Off: 1816	15 Total Engine Time: 3+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FLEW LINES OVER PLAN C & PLAN 6.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	Sgt FD Ramirez PAF	R. SAMPAL	CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6. Flight Log for 949P Mission

DREAM Data Acquisition Flight Log

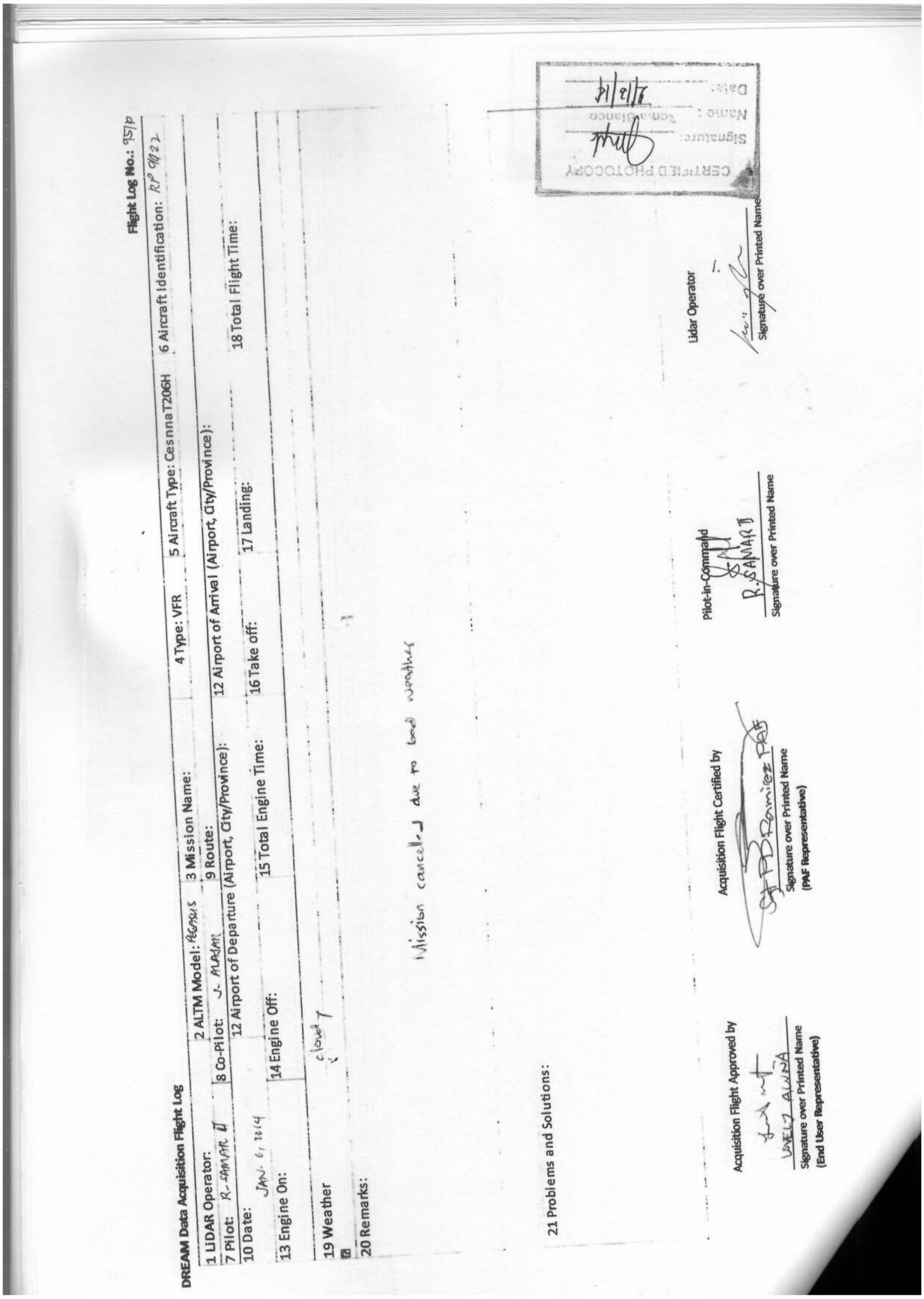
Flight Log No.: 949P

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: GEMINI	3 Mission Name: 1BUCGS005B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9022
7 Pilot: R. SAMAR II	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: Jan. 5, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1436	14 Engine Off: 1829	15 Total Engine Time: 3453	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	S/PDRamirez PAF	R. SAMAR II	CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for 951P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 951P

1 LIDAR Operator:	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP 9122
7 Pilot: R. SAMAR II	8 Co-Pilot: J. ALAJAR	9 Route:	12 Airport of Arrival (Airport, City/Province):		
10 Date: JAN. 6, 2014	12 Airport of Departure (Airport, City/Province):				
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather: cloudy

20 Remarks:

Mission cancelled due to bad weather

21 Problems and Solutions:

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

Acquisition Flight Certified by: S/Sgt P. D. Ramirez PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: R. SAMAR II — Signature over Printed Name

Lidar Operator: — Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Tomas Blanco
Date: 2/18/14

Figure A-6.8. Flight Log for 7047GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7047

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: GEM + CASI	3 Mission Name: 2KHA033A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: SAMAR II	8 Co-Pilot: ALFONSO III	9 Route: Clark - Mt Arayat - Clark			
10 Date: Feb. 2, 2014	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: ~~0725~~ 1635	14 Engine Off: ~~1032~~ 1807	15 Total Engine Time: 1+35	16 Take off:	17 Landing:	18 Total Flight Time: 2+25
19 Weather: cloudy					

20 Remarks:

mission completed; surveyed 11 lines of mt Arayat

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
6H1702170		R. SAMAR II	MCE Baliguas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.9. Flight Log for 7254G Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7254

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini/CASI	3 Mission Name: 2RFL2AM137A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C Alfonso III	9 Route: RPLC - RPLC			
10 Date: 5-17-14	12 Airport of Departure (Airport, City/Province): RPLC	12 Airport of Arrival (Airport, City/Province): RPLC			
13 Engine On: 1207H	14 Engine Off: 1524H	15 Total Engine Time: 3+17	16 Take off: 1210H	17 Landing: 1519H	18 Total Flight Time: 3+08
19 Weather: cloudy					
20 Remarks: Surveyed 4 lines on Blk 15 S1 & S2 (without CASI)					
21 Problems and Solutions:					

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

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

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

Lidar Operator: LK Paragas
Signature over Printed Name

Figure A-6.10. Flight Log for 7255GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7255

1 LIDAR Operator: MV Tonga	2 ALTM Model: Gemini CASI	3 Mission Name: 2RFLPM137B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: F. de Ocampo	9 Route:			
10 Date: 5-17-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 1701H	14 Engine Off: 1918H	15 Total Engine Time: 2+17	16 Take off: 1706H	17 Landing: 1914H	18 Total Flight Time: 2+08
19 Weather	partly cloudy				

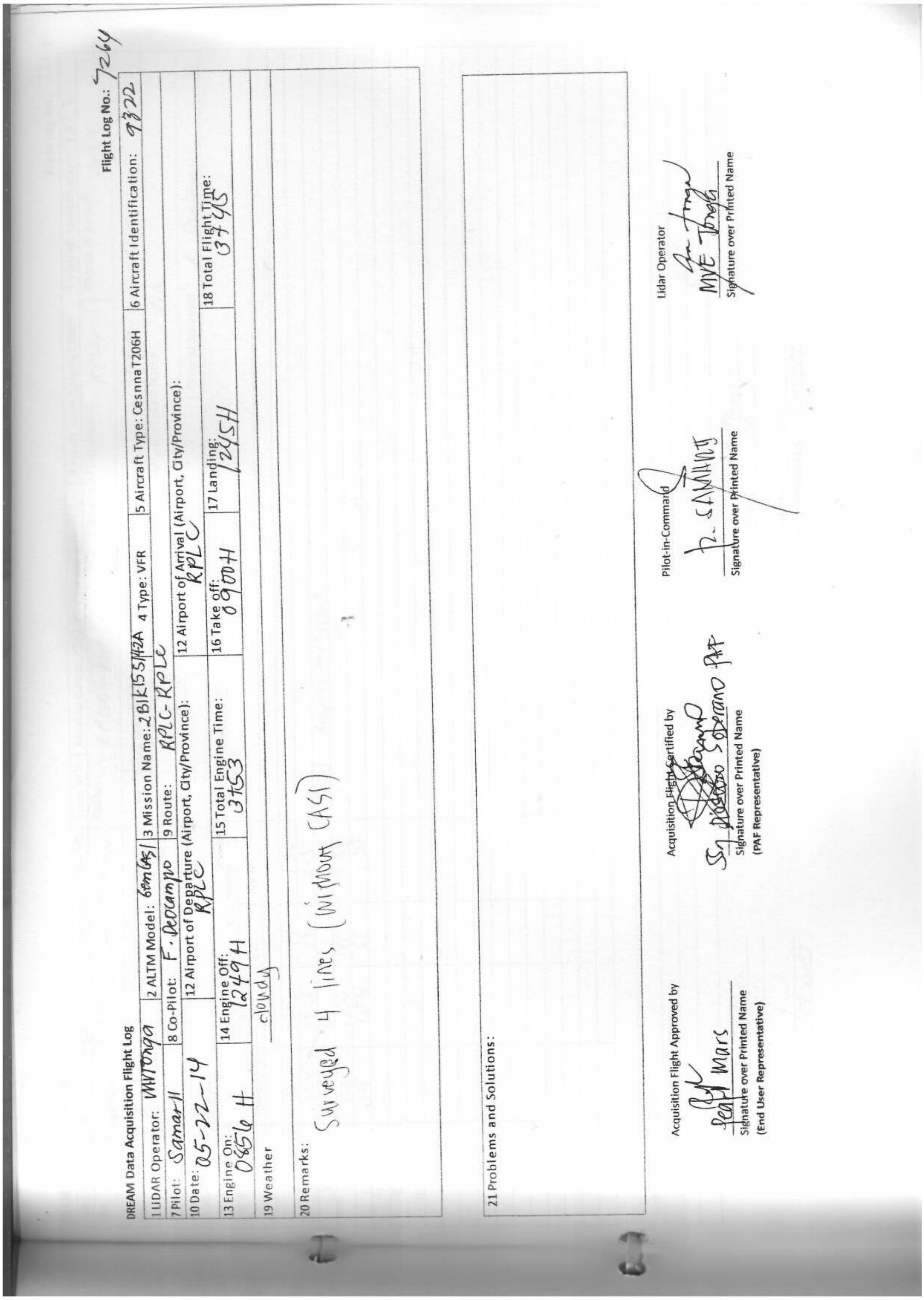
20 Remarks:

surveyed 7 lines on PAMS2 (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Pearl Mars	SSgt Dusoro Solorano PAF	R. Samar II	MVE Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.11. Flight Log for 7264G Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7264

1 LIDAR Operator: M. Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK15S142A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Samaril	8 Co-Pilot: F. Deocampo	9 Route: RPLC-RPLC			
10 Date: 05-22-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 0856 H	14 Engine Off: 1249H	15 Total Engine Time: 3+53	16 Take off: 0900H	17 Landing: 1245H	18 Total Flight Time: 3+45
19 Weather: cloudy					

20 Remarks:

Surveyed 4 lines (without CASI)

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

Figure A-6.12. Flight Log for 2473P Mission

DREAM Data Acquisition Flight Log

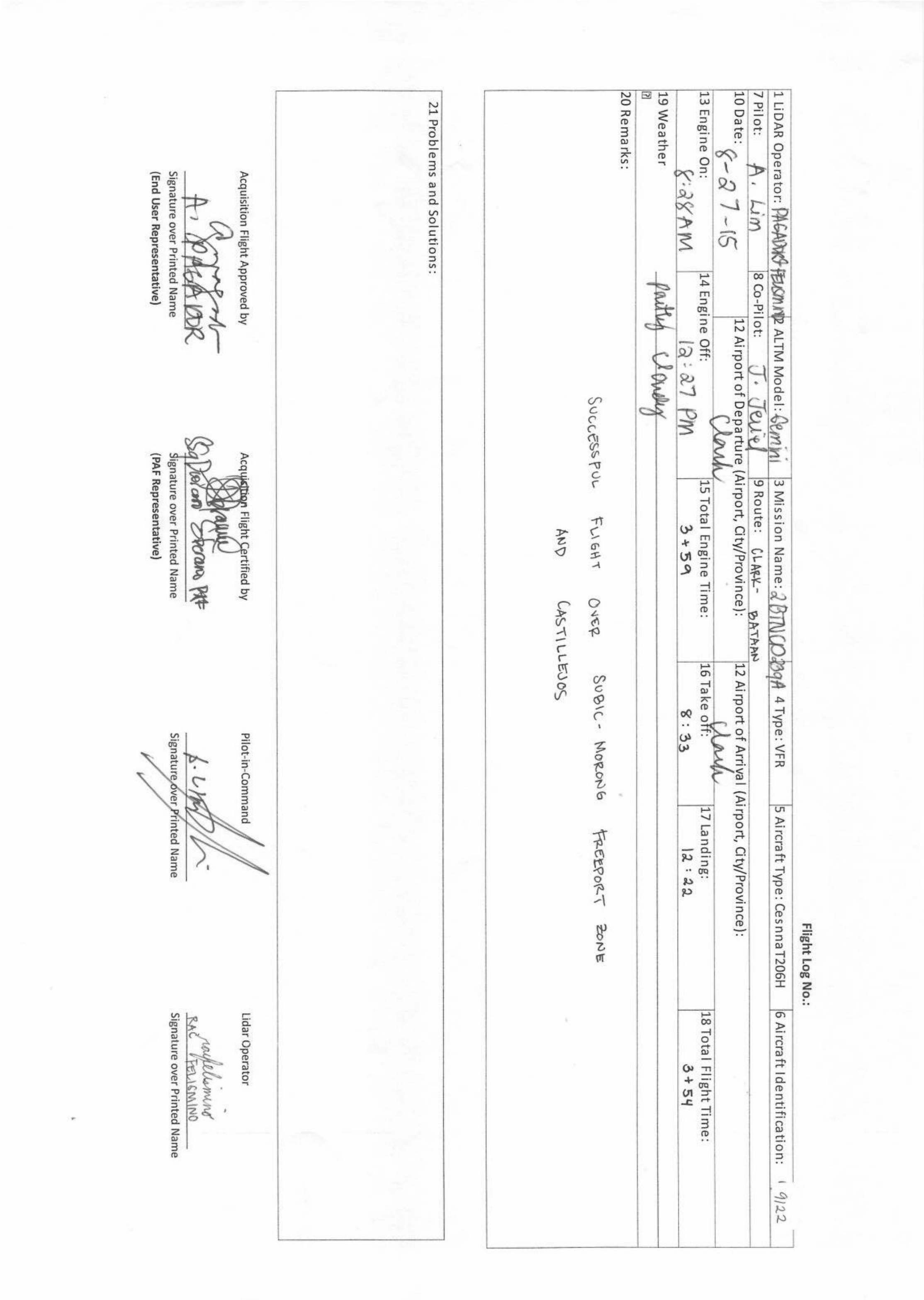
Flight Log No.: 2473

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: A. LIM	9 Route: ZAMBALES			
10 Date: JAN. 21, 2015	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 10+57	14 Engine Off: 15+2	15 Total Engine Time: 4+5	16 Take off: 1102	17 Landing: 1457	18 Total Flight Time: 3+55
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
J. Alviar	ERWIN DELOS SANTOS	JO ALAJAR	RENAN PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.13. Flight Log for 2658G Mission



Flight Log No.:

1 LiDAR Operator: PAGADOR/FELISMINO	2 ALTM Model: Gemini	3 Mission Name: 2BTNCO239A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: J. Jeriel	9 Route: CLARK-BATAAN			
10 Date: 8-27-15	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 8:28AM	14 Engine Off: 12:27 PM	15 Total Engine Time: 3+59	16 Take off: 8:33	17 Landing: 12:22	18 Total Flight Time: 3+54
19 Weather: Partly Cloudy					

20 Remarks:

SUCCESSFUL FLIGHT OVER SUBIC-MORONG FREEPORT ZONE AND CASTILLEJOS

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. PAGADOR	SgDorian Sorano PAF	A. LIM	RAC FELISMINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status Reports

FLIGHT STATUS REPORT

Zambales, Bataan, Clark Reflights

December 27-January 6, 2014; February 2, 2014; May 17-22, 2014; January 21, 2015 and August 27, 2015

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
923P	BUC D	1BUCD361A	PJ ARCEO & MVE TONGA	December 27, 2013	Surveyed BUC D
933P	BAL D	1BALD363B	I ROXAS	December 29, 2013	Finished 8 lines of BAL D. Digtizer hanged.
930G	BUC E	2BUCE003A	R PUNTO	January 3, 2014	Surveyed BUC E
934G	BUC F	2BUCF004A	I ROXAS	January 4, 2014	Surveyed BUC F
945P	BUC C	1BUCCS004B	PJ ARCEO & MCE BALIGUAS	January 4, 2014	Surveyed BUC C. Mission aborted due to heavy cloud build up
949P	BUC G	1BUCGS005B	MCE BALIGUAS	January 5, 2014	Completed the rest of BUC G.
951P	BAL F	1BALF006A	I ROXAS	January 6, 2014	Finished 5 lines of BAL F.
7047GC	MTAS	2MTAS033A	MCE BALIGUAS	February 2, 2014	Surveyed MTAS
7254G	BLK 15	2BLK15S1S2137A	LK PARAGAS	May 17, 2014	Mission aborted due to weather;2 lines at BLK15S2; some lines at BLK15S1
7255GC	PAM S2	2PAMS2137B	MVE TONGA	May 17, 2014	Completed 7 lines of PAMS2 at 850m
7264G	BLK 15	2BLK15S142A	MVE TONGA	May 22, 2017	Completed 7 lines. System restart due to 100% drop outs experienced at the 3rd line
2473P	BUC R	1BUCR021A	R PUNTO	January 21, 2015	Filled up gaps in Sto. Tomas and Bucao
2658G	BTN C, D	2BTNCD239A	AM PAGADOR & MCE BALIGUAS	August 27, 2015	Mission Completed; Supplementary flight for BTNA and finished area BTNB

SWATH/LAS PER MISSION

Flight No. :	923P	
Area:	BUC D	
Mission Name:	1BUCD361A	
Parameters:	Altitude: 1200	Scan Frequency: 30
Scan Angle: 25	Overlap: 30	

SWATH

Figure A-7.1. Swath for Flight No. 923P

Flight No. :	933P	
Area:	BAL D	
Mission Name:	1BALD363B	
Parameters:	Altitude: 1200	Scan Frequency: 30
Scan Angle: 25	Overlap: 30	

SWATH

Figure A-7.2. Swath for Flight No. 933P

Flight No. :	930G	
Area:	BUC E	
Mission Name:	2BUCE003A	
Parameters:	Altitude: 1000	Scan Frequency: 50
Scan Angle: 20	Overlap: 30	

SWATH

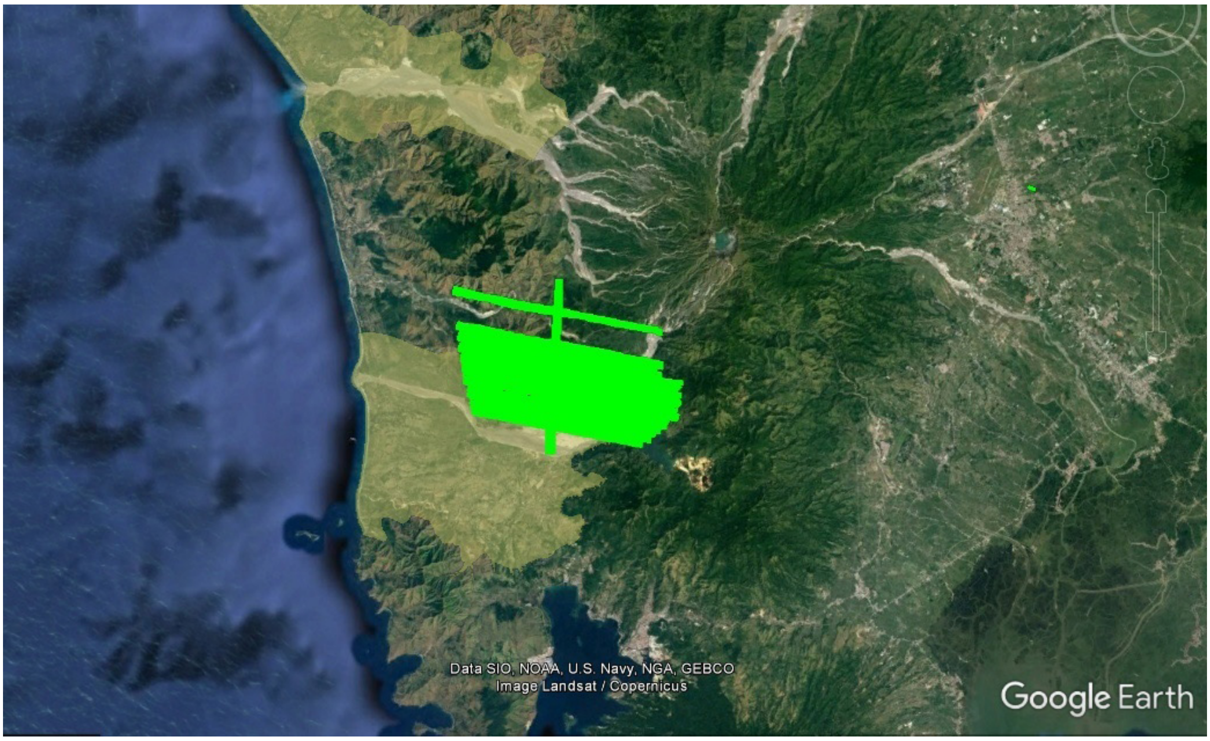


Figure A-7.3. Swath for Flight No. 930G

Flight No. :	934G	
Area:	BUC F	
Mission Name:	2BUCF004A	
Parameters:	Altitude: 1100	Scan Frequency: 50
Scan Angle: 20	Overlap: 30	

SWATH

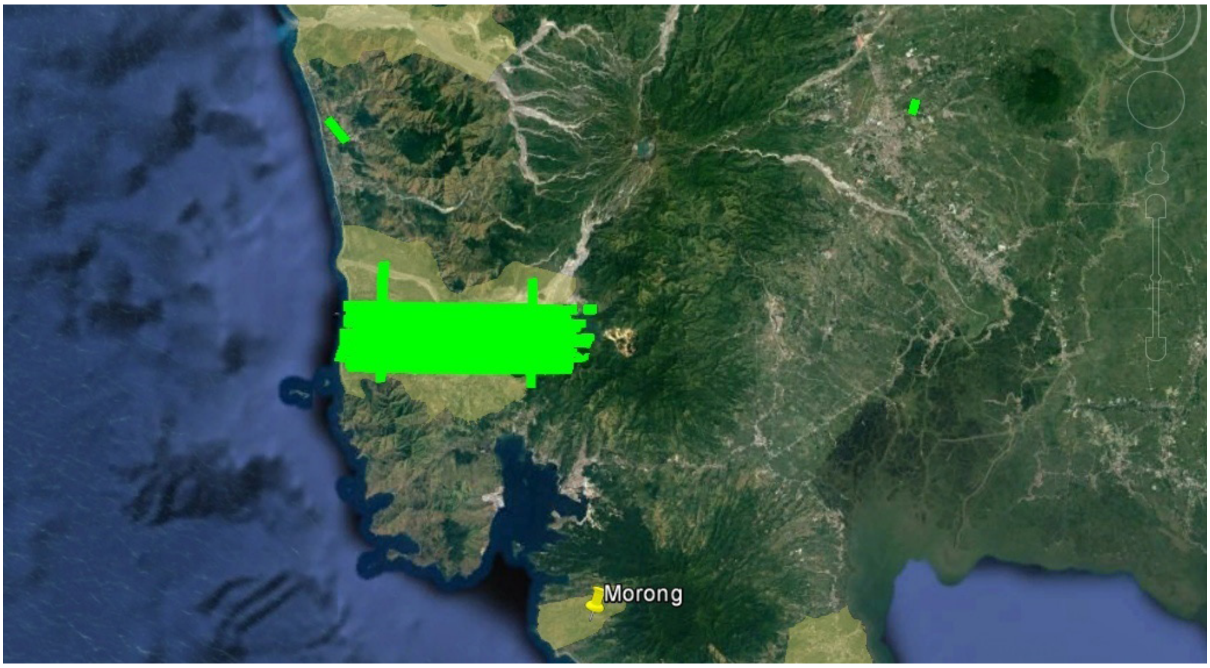


Figure A-7.4. Swath for Flight No. 934G

Flight No. :	945P	
Area:	BUC C	
Mission Name:	1BUCCS004B	
Parameters:	Altitude: 1200	Scan Frequency: 30
Scan Angle: 25	Overlap: 30	

SWATH

Figure A-7.5. Swath for Flight No. 945P

Flight No. :	949P	
Area:	BUC G	
Mission Name:	1BUCGS005B	
Parameters:	Altitude: 1200	Scan Frequency: 30
Scan Angle: 25	Overlap: 30	

LAS

Figure A-7.6. Swath for Flight No. 949P

Flight No. :	951P	
Area:	1BALF006A	
Mission Name:	BAL F	
Parameters:	Altitude: 1200	Scan Frequency: 30
Scan Angle: 25	Overlap: 30	

SWATH

Figure A-7.7. Swath for Flight No. 951P

Flight No. :	7047GC	
Area:	MTAS	
Mission Name:	2MTAS033A	
Parameters:	Altitude: 1800	Scan Frequency: 50
Scan Angle: 20	Overlap: 30	

LAS

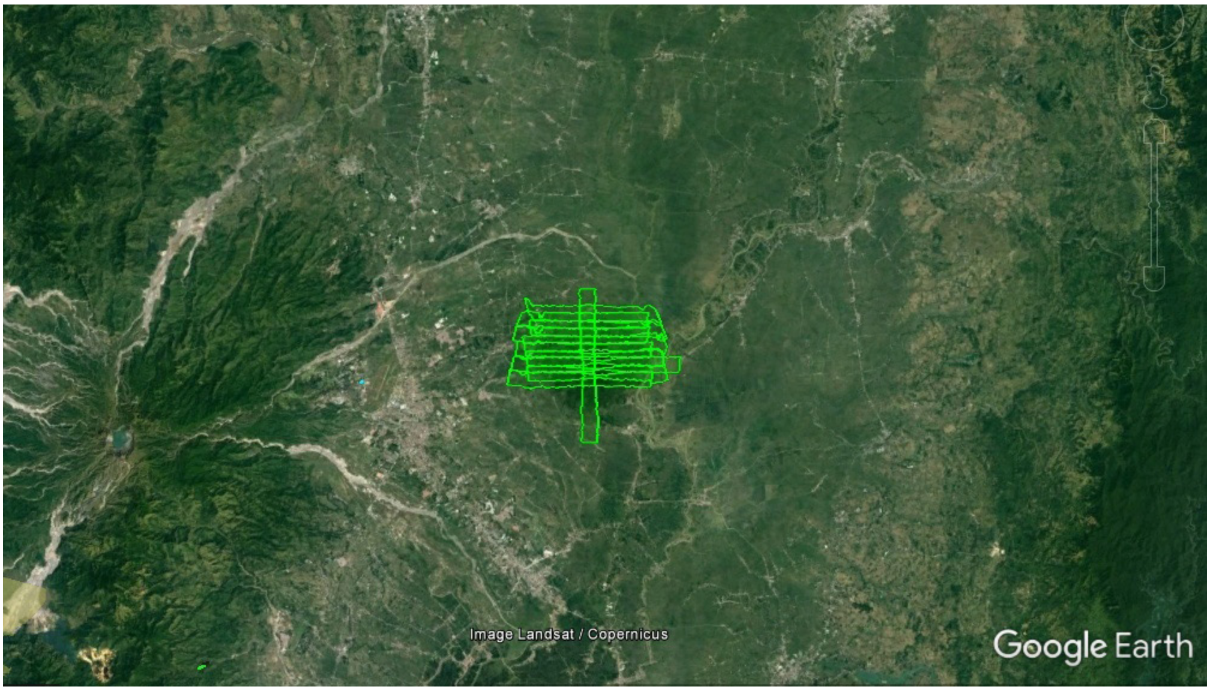


Figure A-7.8. Swath for Flight No. 7047GC

Flight No. :	7254G	
Area:	BLK 15	
Mission Name:	2BLK15S1S2137A	
Parameters:	Altitude: 1300	Scan Frequency: 65
Scan Angle: 12	Overlap: 30	

SWATH

Figure A-7.9. Swath for Flight No. 7254G

Flight No. :	7255GC	
Area:	PAM S2	
Mission Name:	2PAMS2137B	
Parameters:	Altitude: 850	Scan Frequency: 50
Scan Angle: 20	Overlap: 30	

SWATH

Figure A-7.10. Swath for Flight No. 7255GC

Flight No. :	7264G	
Area:	BLK 15	
Mission Name:	2BLK15S142A	
Parameters:	Altitude: 1300	Scan Frequency: 65
Scan Angle: 12	Overlap: 30	

SWATH

Figure A-7.11. Swath for Flight No. 7264G

Flight No. : 2473P
Area: BUC R
Mission Name: 1BUCR021A
Parameters: Altitude: 1000 Scan Frequency: 30
Scan Angle: 25 Overlap: 30

SWATH

Figure A-7.12. Swath for Flight No. 2473P

Flight No. : 2658G
Area: BTN C, D
Mission Name: 2BTNCD239A
Parameters: Altitude: 800 Scan Frequency: 40
Scan Angle: 25 Overlap: 30

SWATH

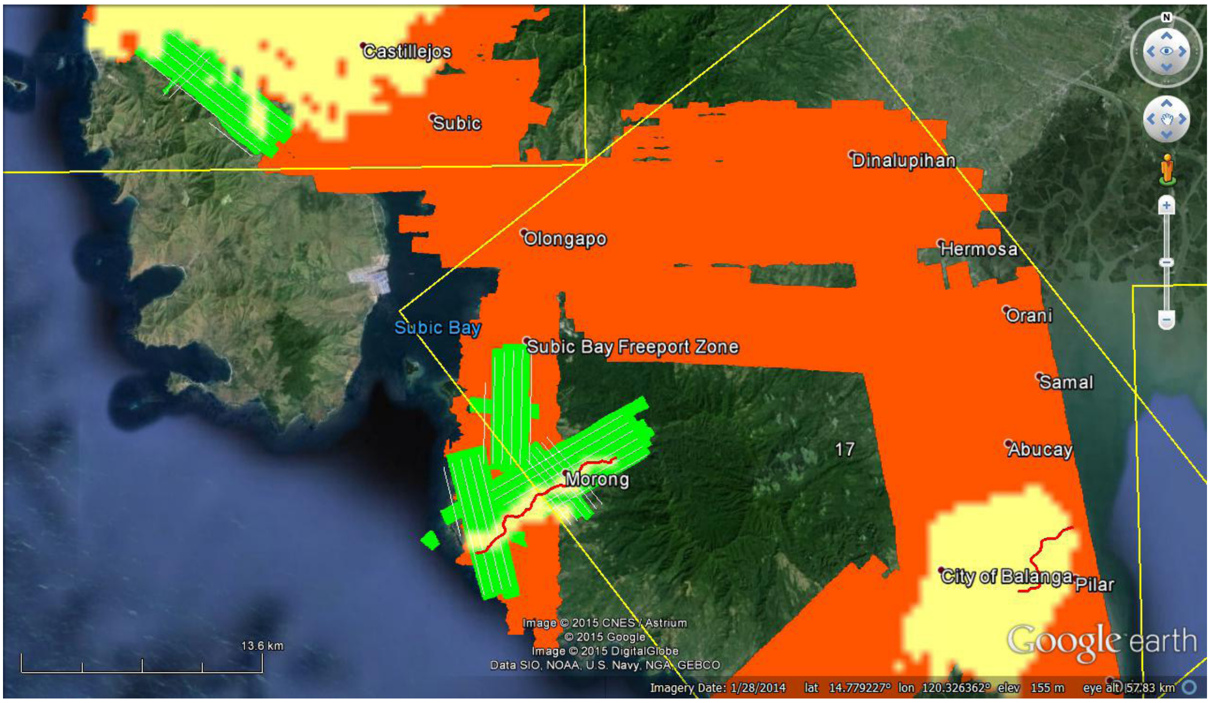


Figure A-7.13. Swath for Flight No. 2658G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission BataanZambales_BucGs

Flight Area	Bataan
Mission Name	BataanZambales_BucGs
Inclusive Flights	949P
Range data size	12.9 GB
POS	228 MB
Base Data	16.1 MB
Image	n/a
Transfer date	January 10, 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)	4.0
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	7.0
Boresight correction stdev (<0.001deg)	0.000410
IMU attitude correction stdev (<0.001deg)	0.000664
GPS position stdev (<0.01m)	0.0095
Minimum % overlap (>25)	52.12
Ave point cloud density per sq.m. (>2.0)	2.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	142
Maximum Height	440.54 m
Minimum Height	36.44 m
Classification (# of points)	
Ground	94,319,894
Low vegetation	71,206,713
Medium vegetation	156,025,126
High vegetation	125,571,391
Building	6,972,979
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, Ryan James Nicholai Dizon

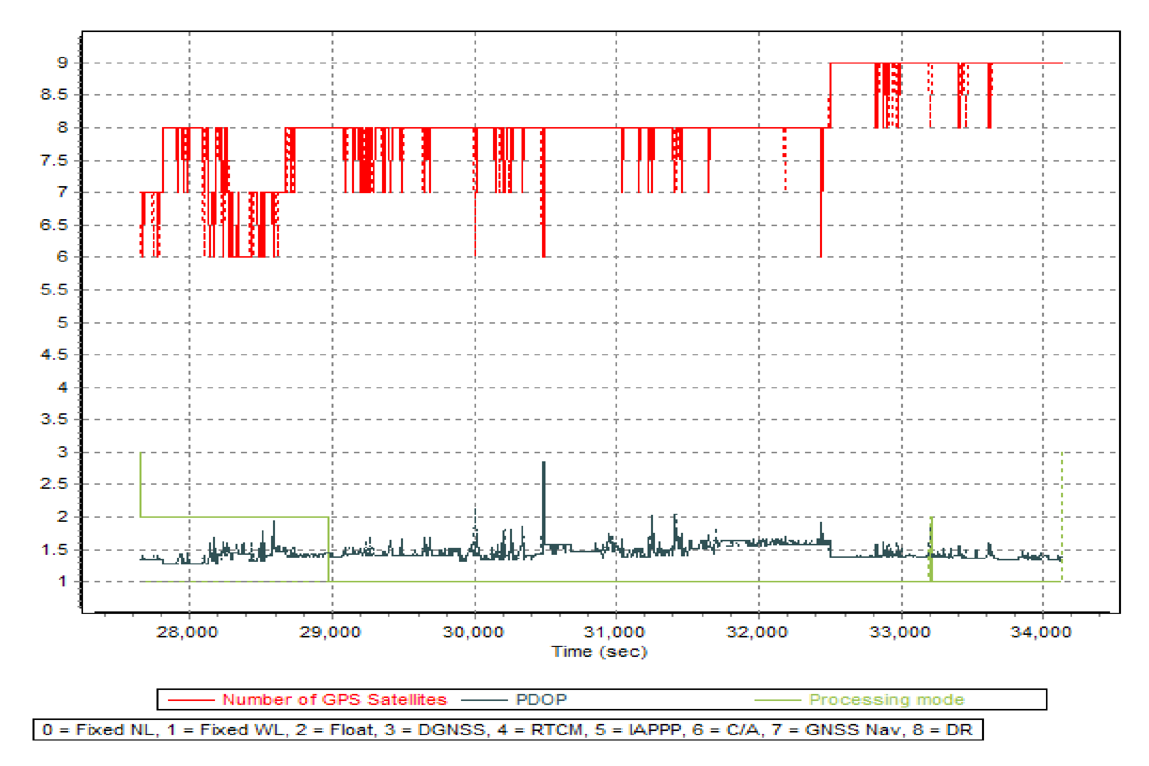


Figure 1.1.1. Solution Status

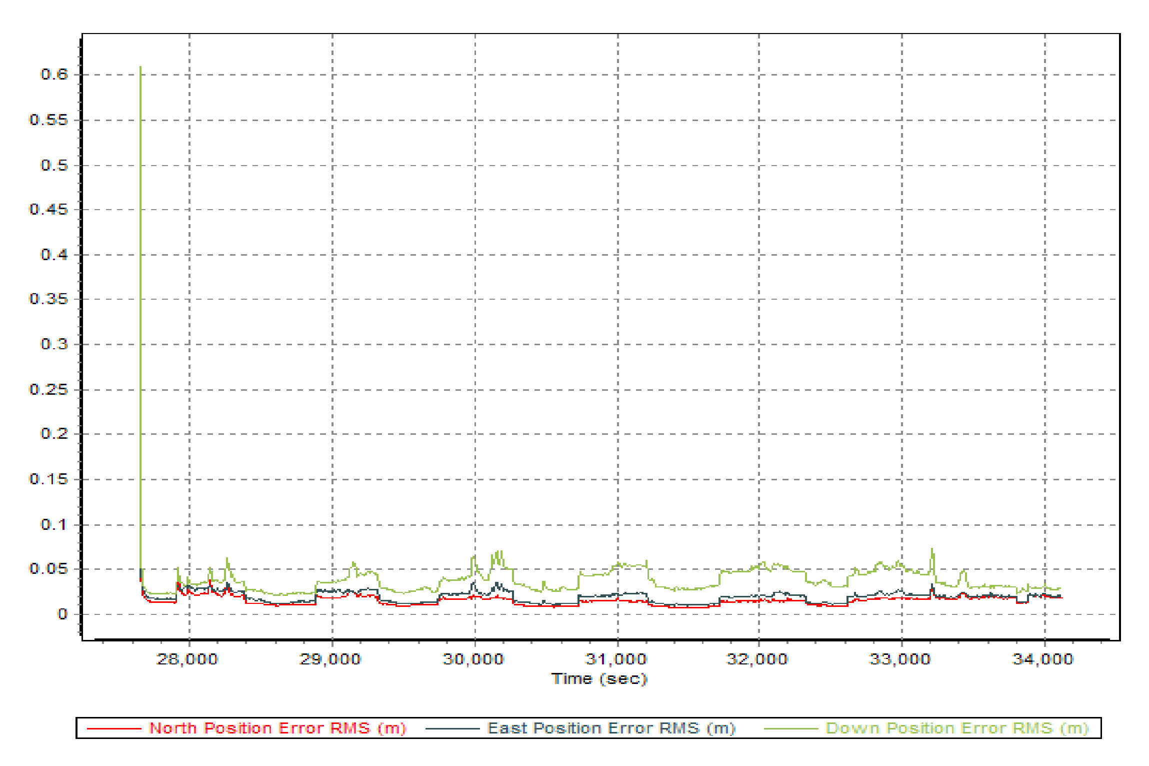


Figure 1.1.2. Smoothed Performance Metric Parameters

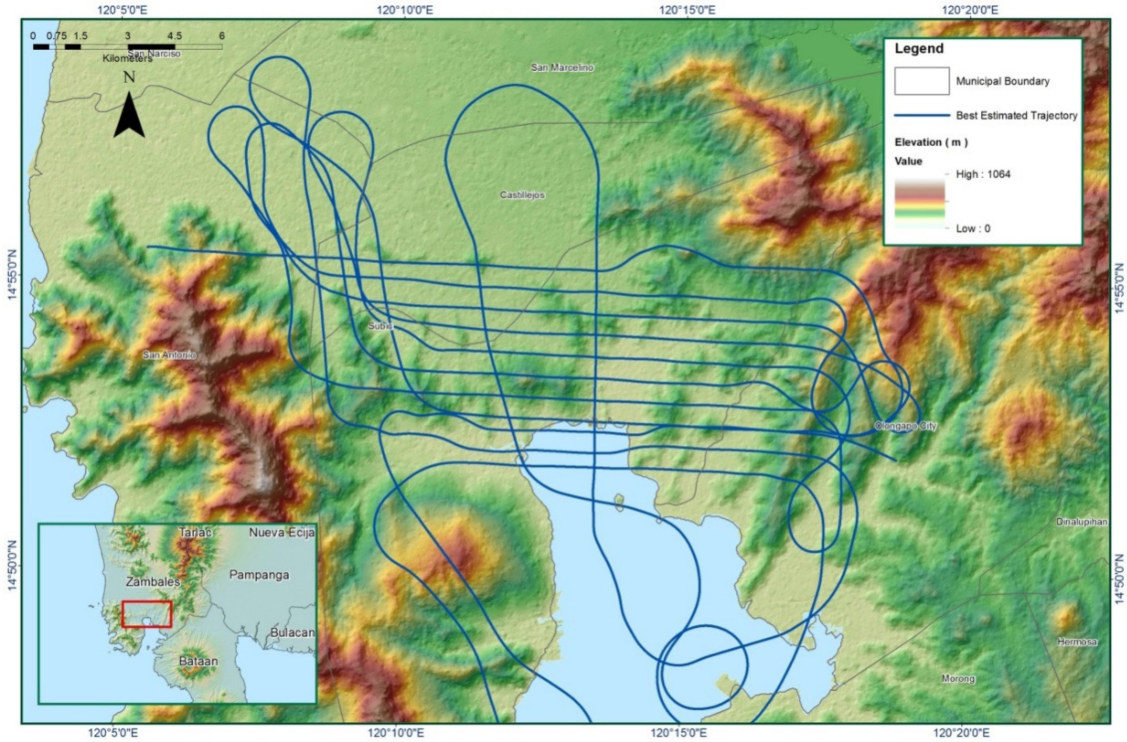


Figure 1.1.3. Best Estimated Trajectory

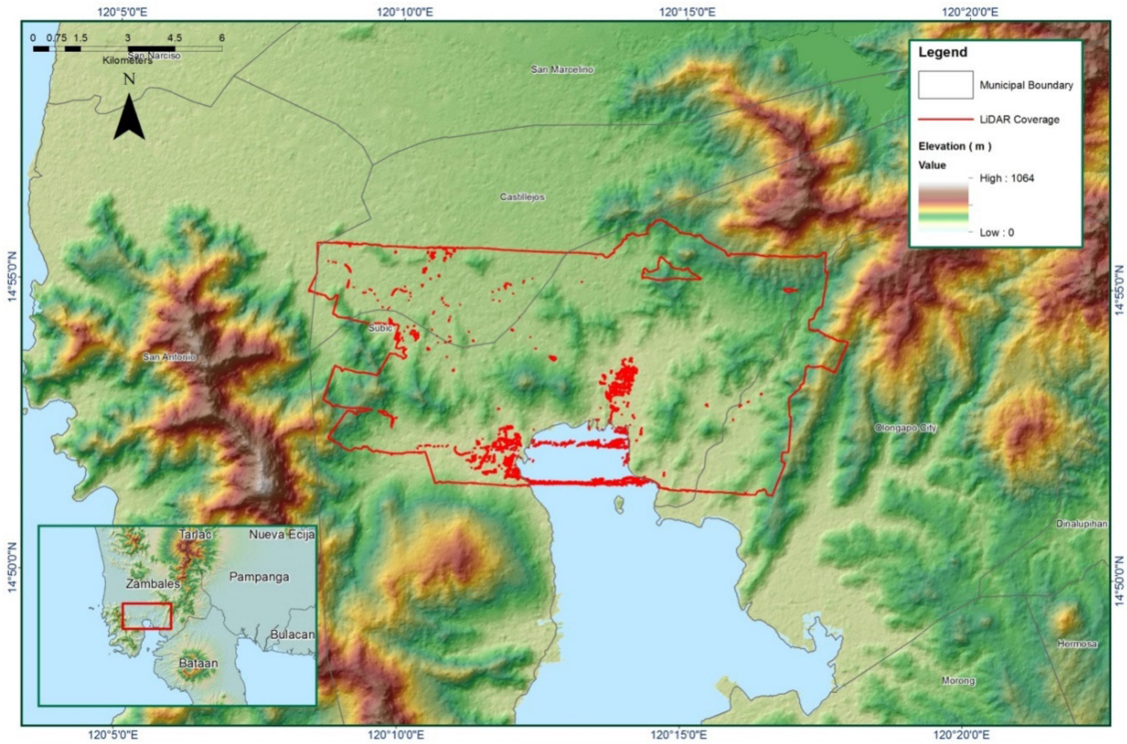


Figure 1.1.4. Coverage of LiDAR Data

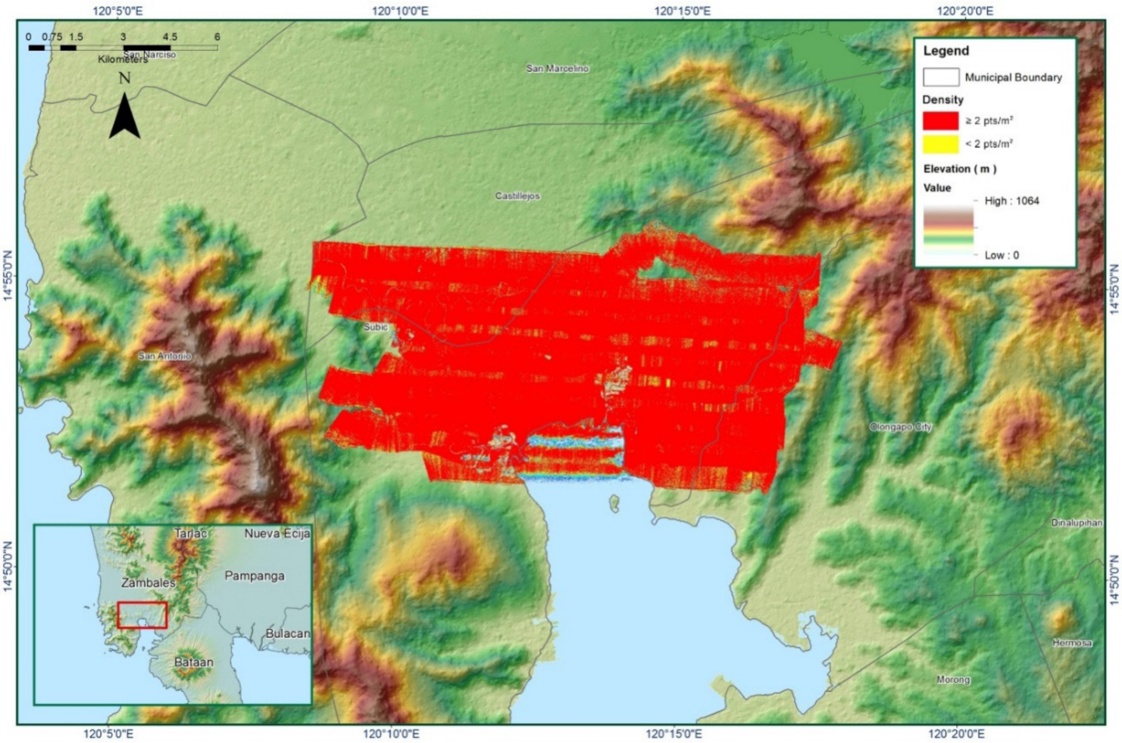


Figure 1.1.5. Image of data overlap

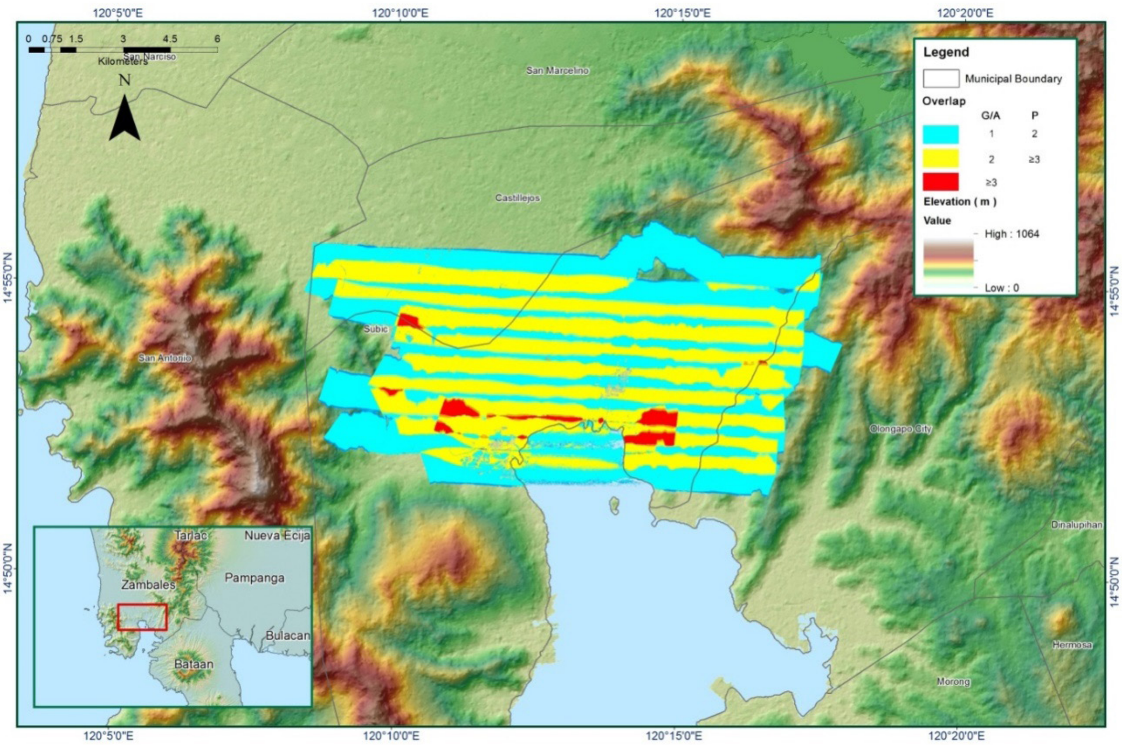


Figure 1.1.6. Density map of merged LiDAR data

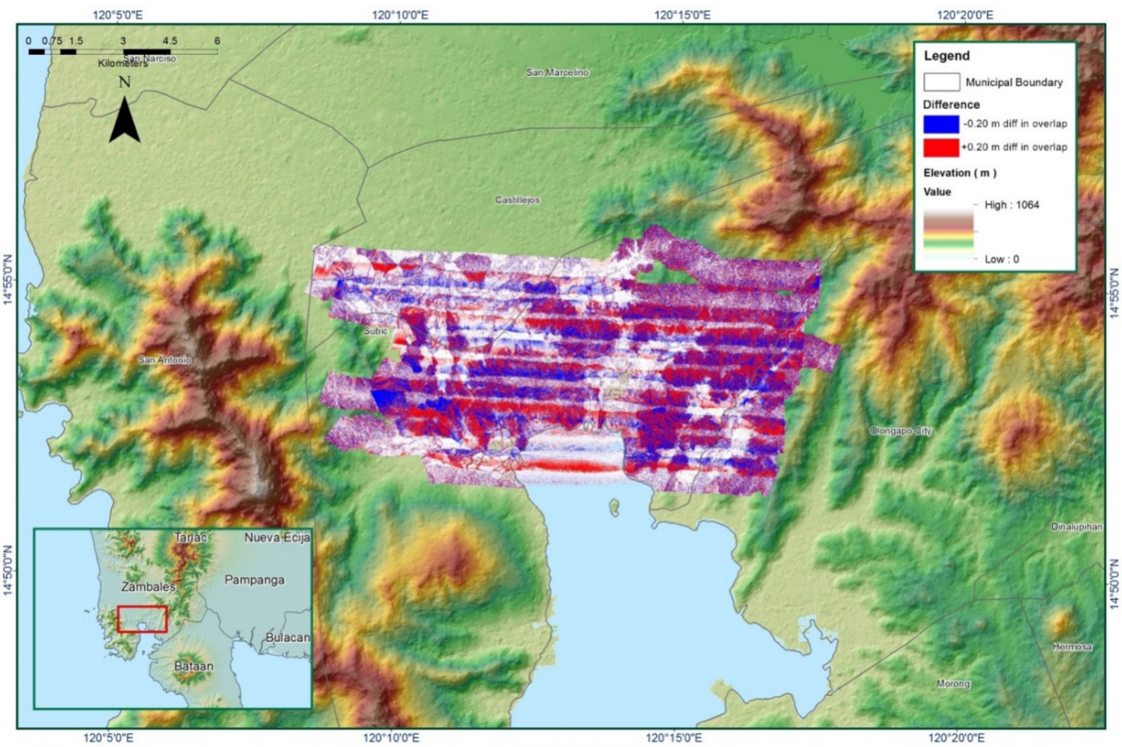


Figure 1.1.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission for BataanZambales_BucG

Flight Area	Bataan
Mission Name	BataanZambales_BucG
Inclusive Flights	934G
Range data size	27.6 GB
POS	299 MB
Base Data	21.3 MB
Image	7.19 GB
Transfer date	January 10, 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)	3.1
RMSE for East Position (<4.0 cm)	4.5
RMSE for Down Position (<8.0 cm)	8.0
Boresight correction stdev (<0.001deg)	0.000400
IMU attitude correction stdev (<0.001deg)	0.001029
GPS position stdev (<0.01m)	0.0060
Minimum % overlap (>25)	74.50
Ave point cloud density per sq.m. (>2.0)	4.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	225
Maximum Height	913.39 m
Minimum Height	44.78 m
Classification (# of points)	
Ground	124,542,366
Low vegetation	195,463,791
Medium vegetation	129,789,393
High vegetation	182,794,352
Building	12,074,309
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Christy Lubiano, For. Simonette Lat

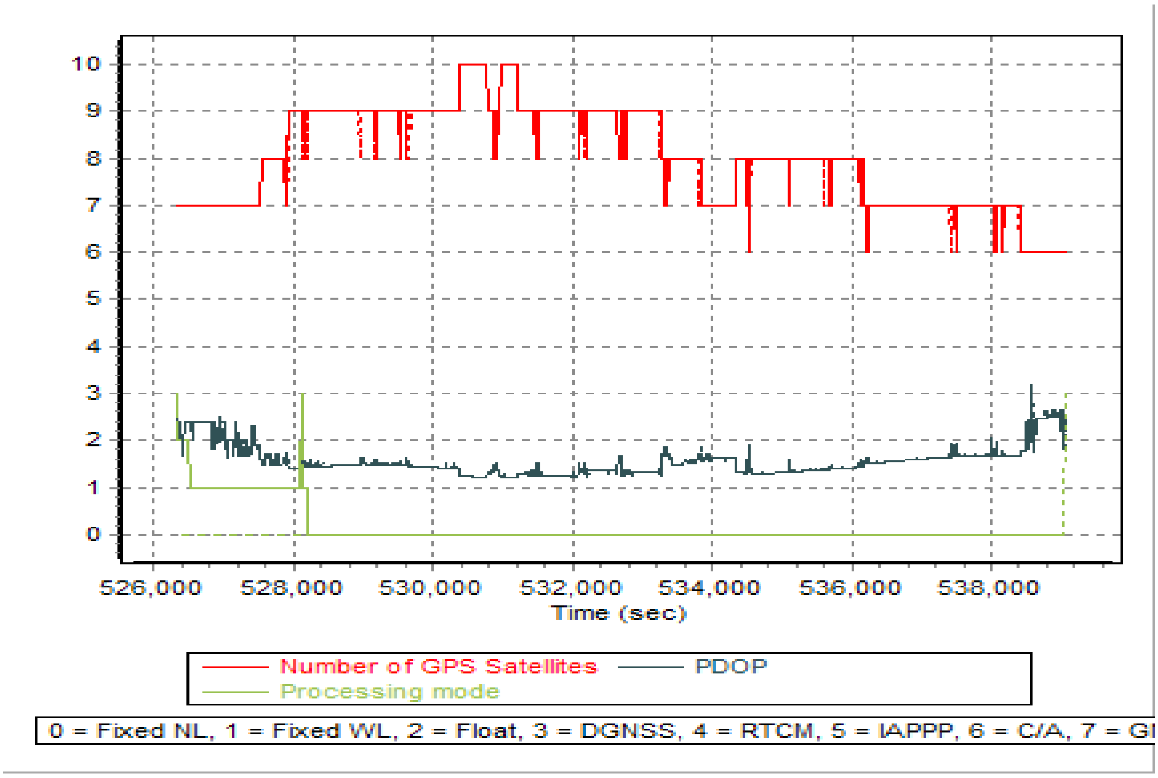


Figure 1.2.1. Solution Status

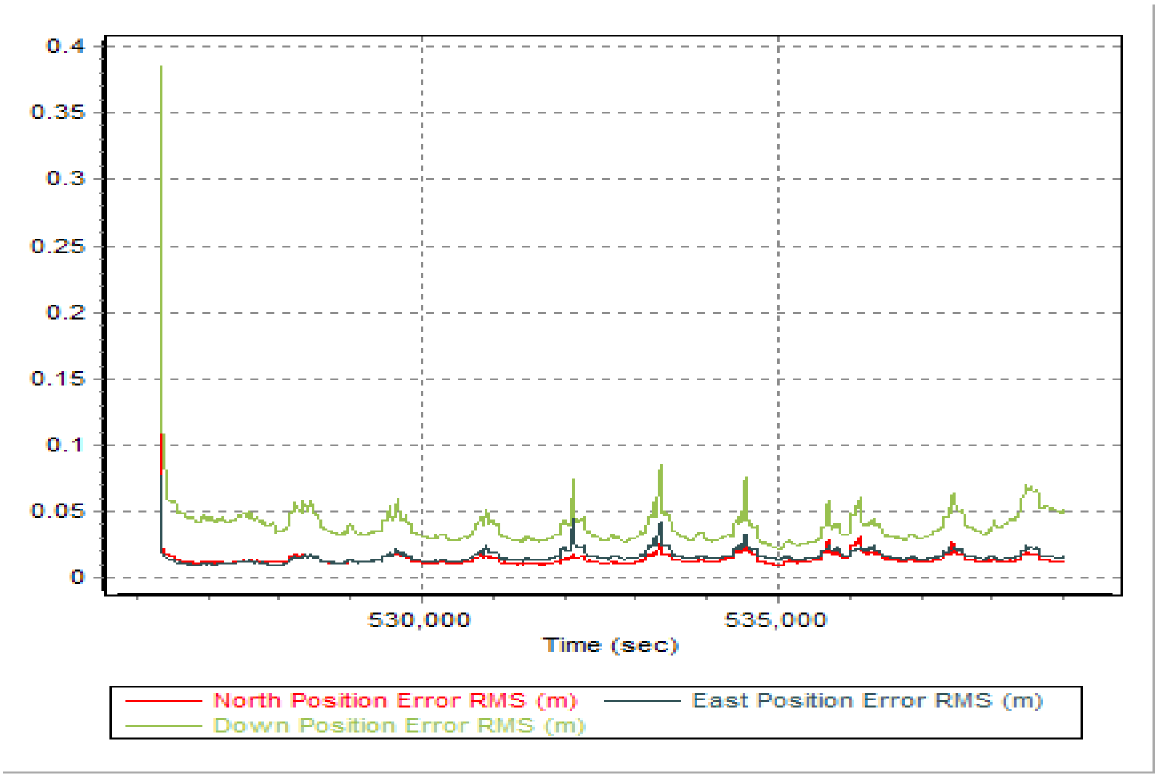


Figure 1.2.2. Smoothed Performance Metric Parameters

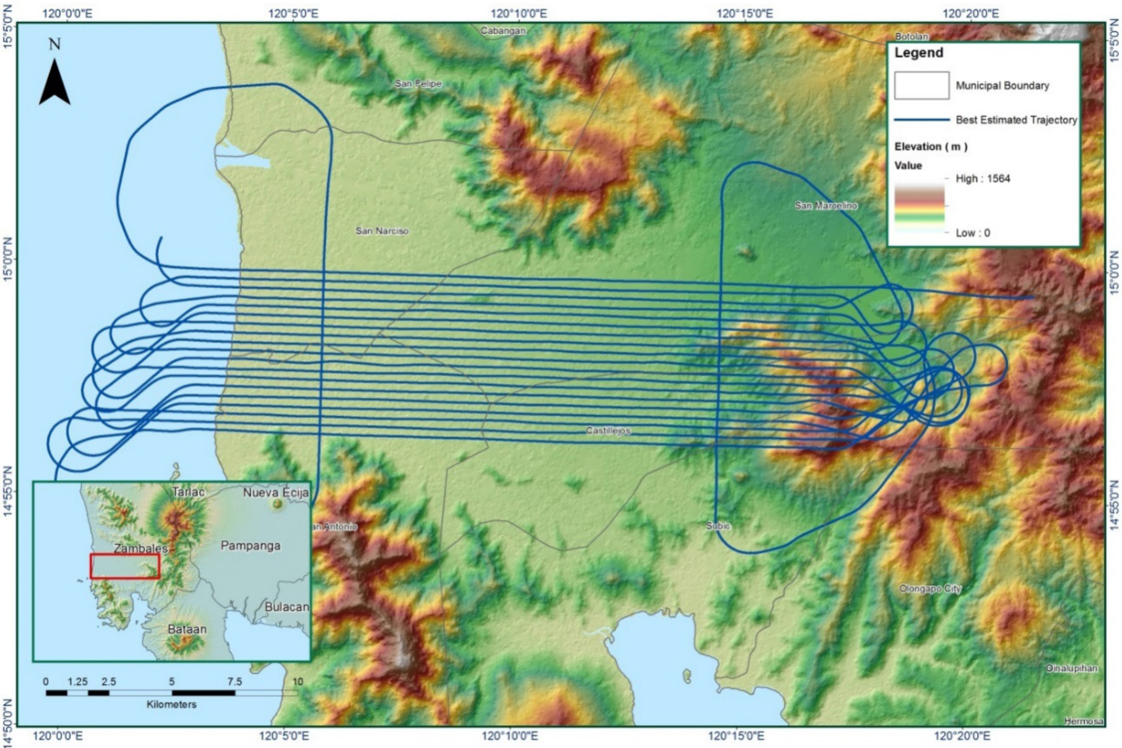


Figure 1.2.3. Best Estimated Trajectory

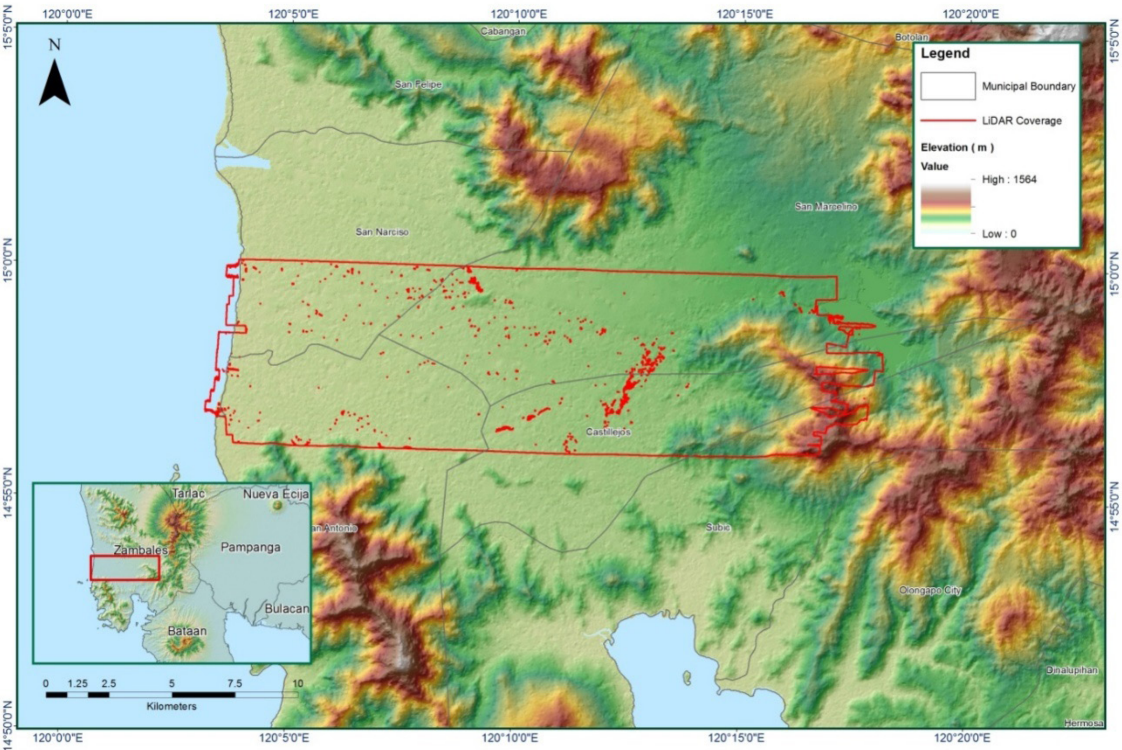


Figure 1.2.4. Coverage of LiDAR Data

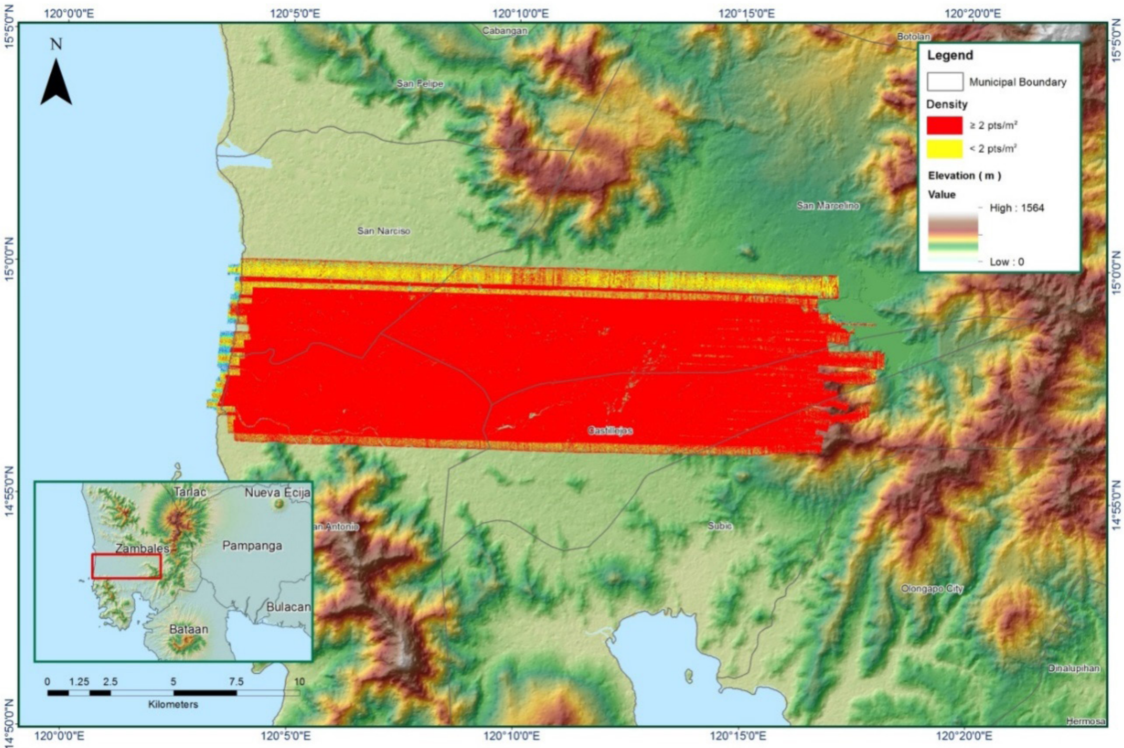


Figure 1.2.5. Image of data overlap

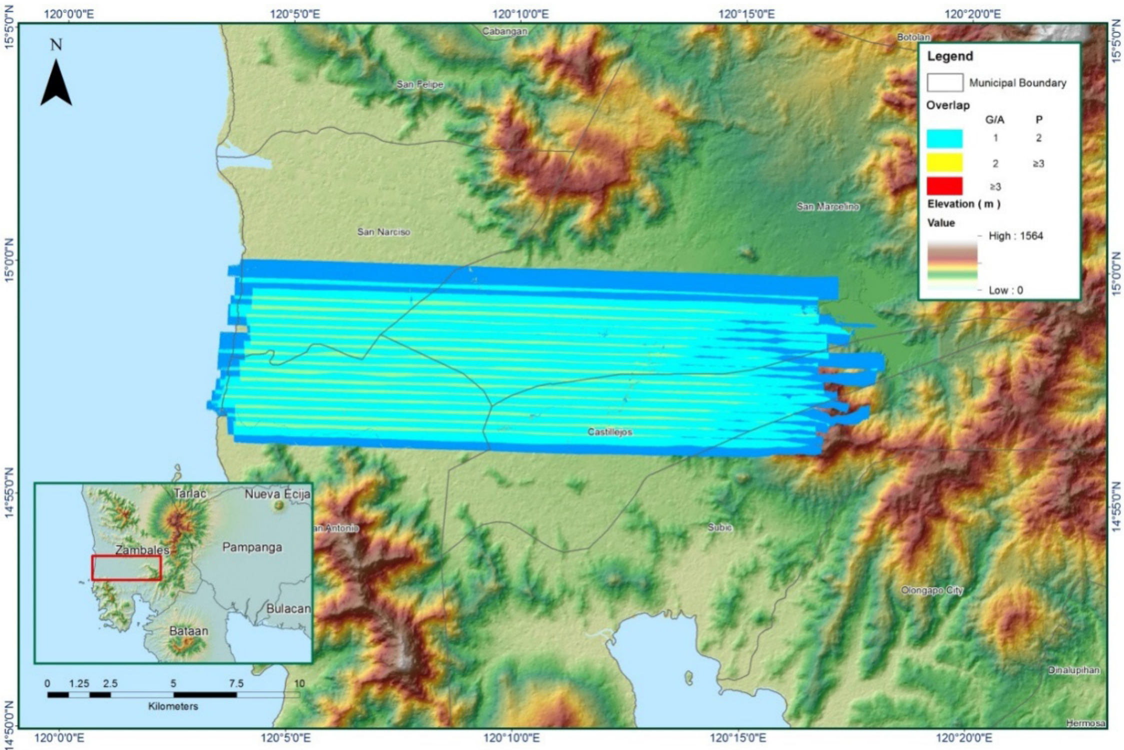


Figure 1.2.6. Density map of merged LiDAR data

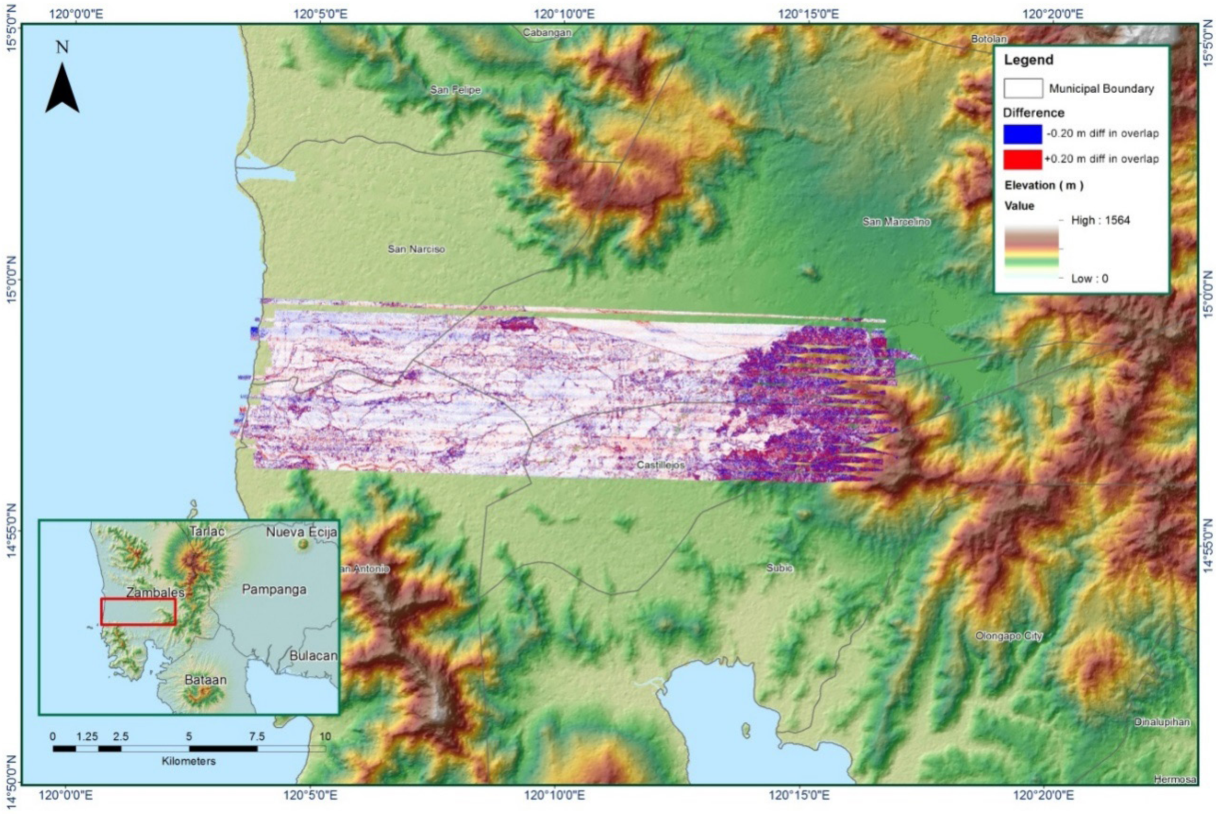


Figure 1.2.7. Elevation difference between flight lines

Table A-8.3. Mission Summary Report of BataanZambales_BucG_additional

Flight Area	Bataan
Mission Name	BataanZambales_BucG_additional
Inclusive Flights	945P
Range data size	4.69 GB
POS	172 MB
Base Data	21.3 MB
Image	n/a
Transfer date	January 10, 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)	2.8
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	9.0
Boresight correction stdev (<0.001deg)	0.001243
IMU attitude correction stdev (<0.001deg)	0.001135
GPS position stdev (<0.01m)	0.0180
Minimum % overlap (>25)	2.08
Ave point cloud density per sq.m. (>2.0)	15.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	67
Maximum Height	578.12 m
Minimum Height	46.00 m
Classification (# of points)	
Ground	32,138,259
Low vegetation	14,931,622
Medium vegetation	20,363,358
High vegetation	18,956,621
Building	2,173,684
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Ma. Celina Rosete, Jovy Narisma

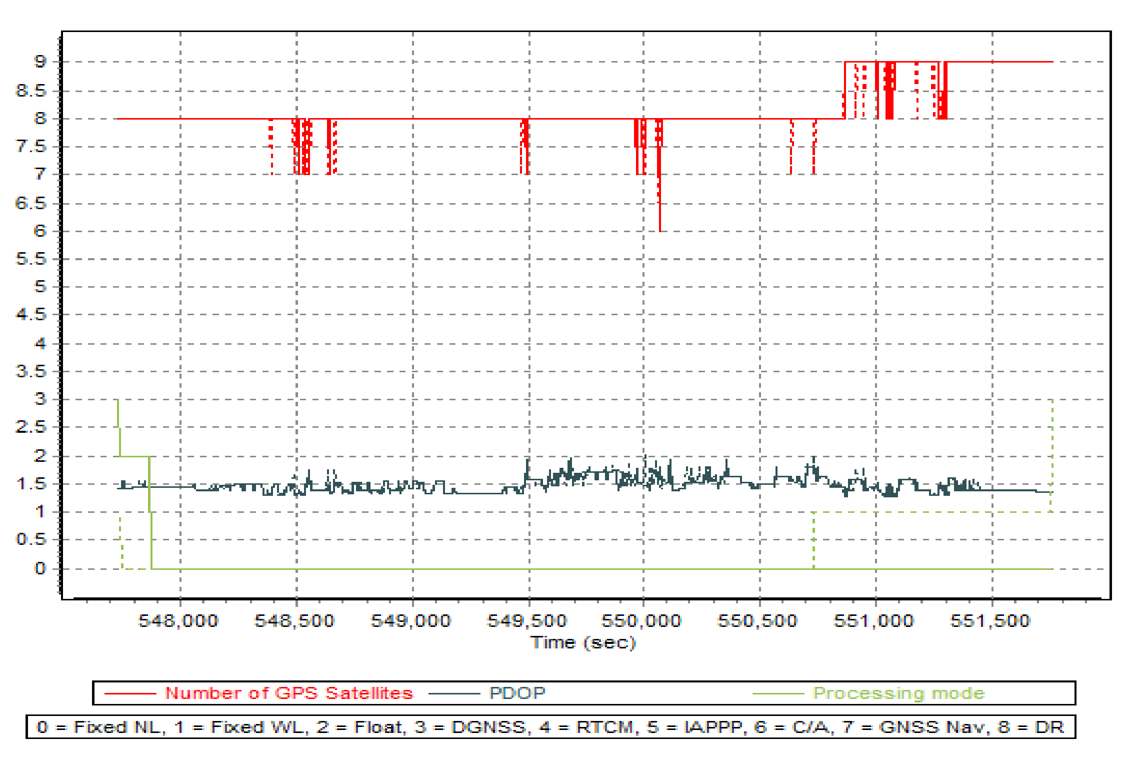


Figure 1.3.1. Solution Status

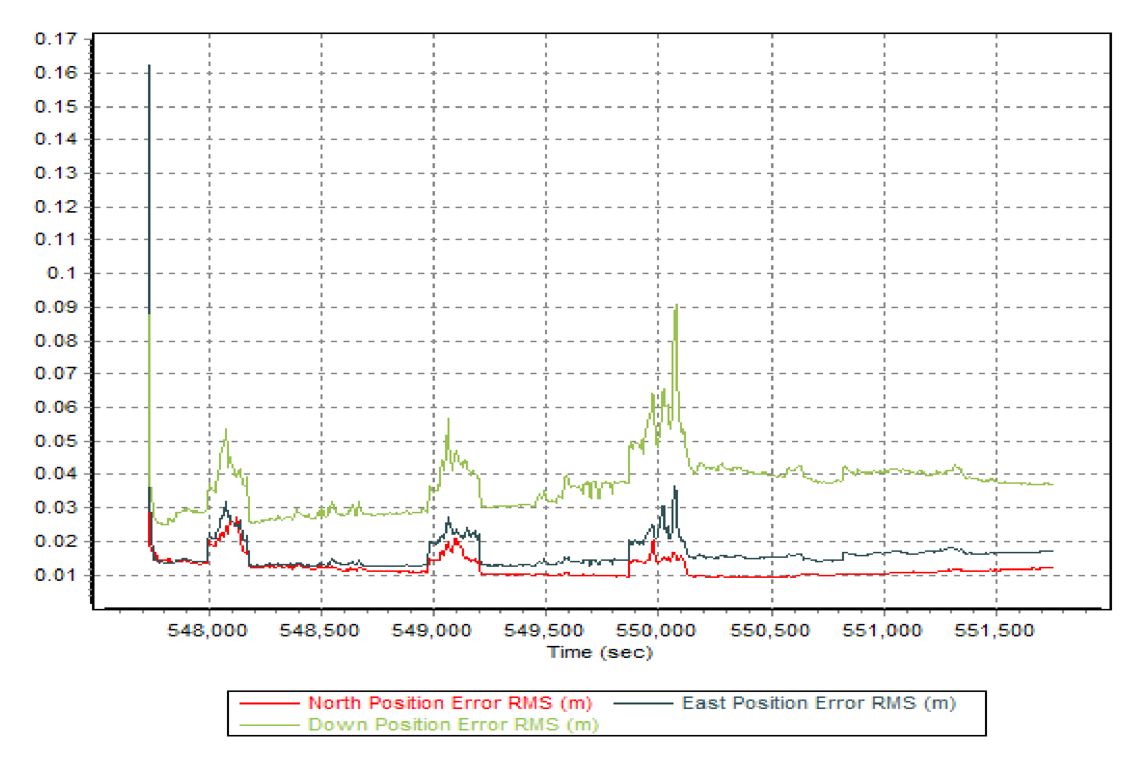


Figure 1.3.2. Smoothed Performance Metric Parameters

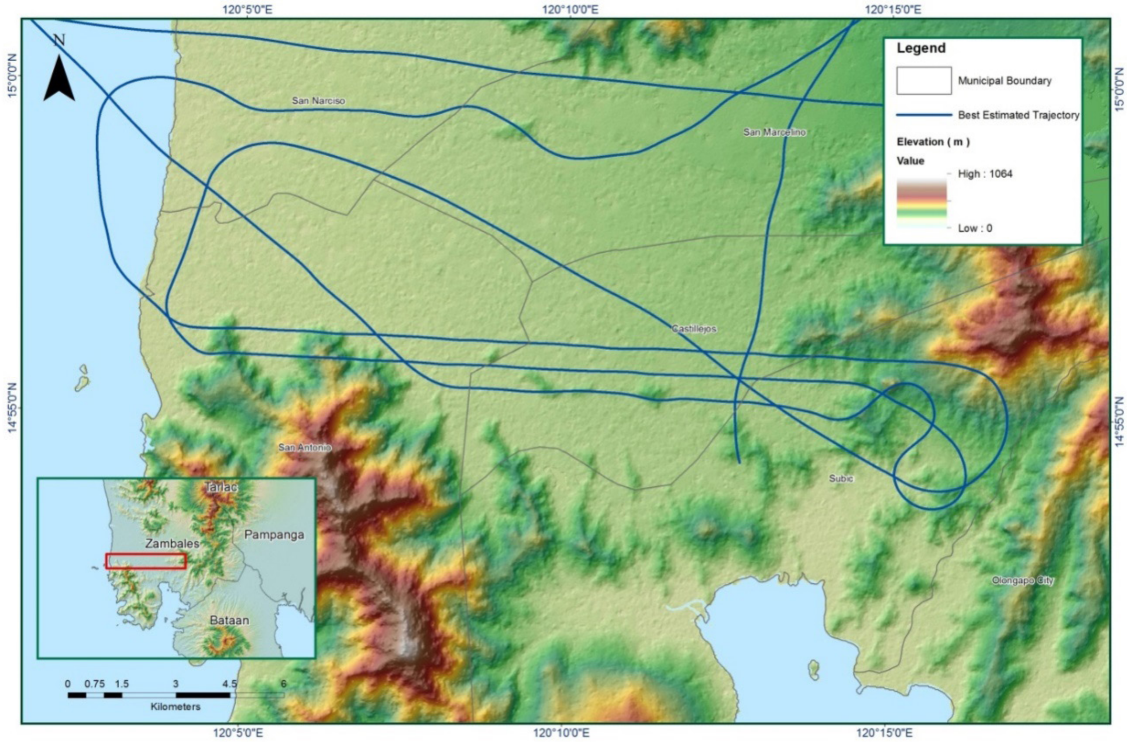


Figure 1.3.3. Best Estimated Trajectory

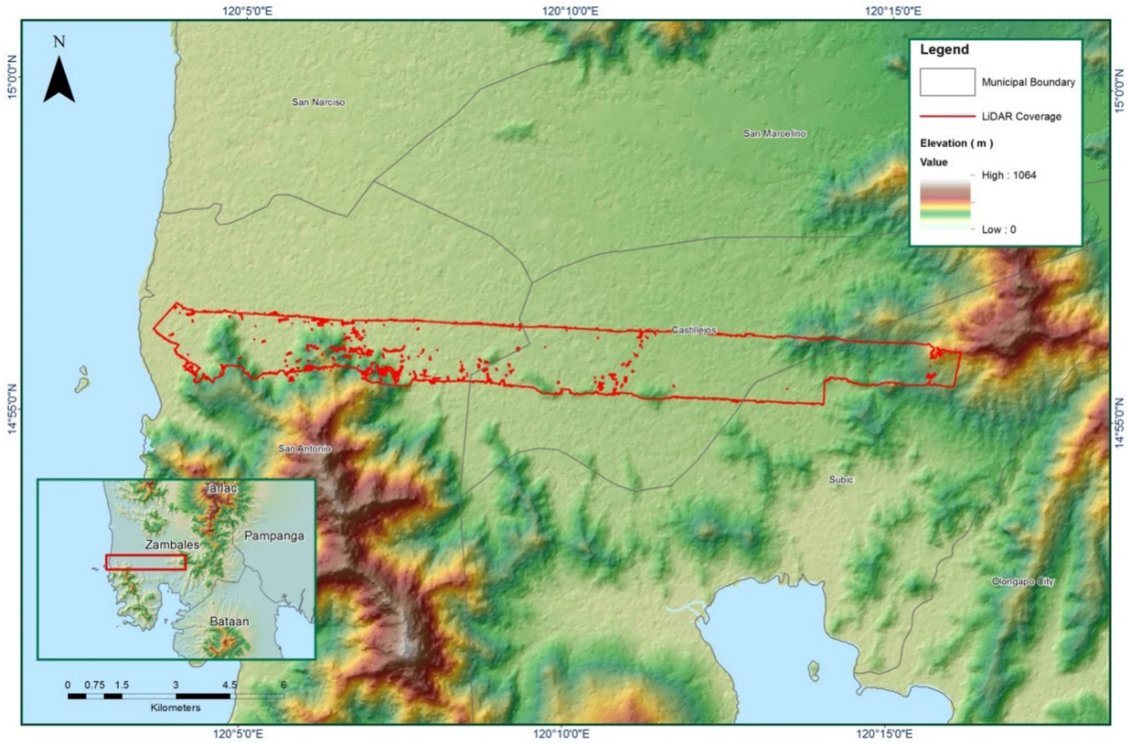


Figure 1.3.4. Coverage of LiDAR Data

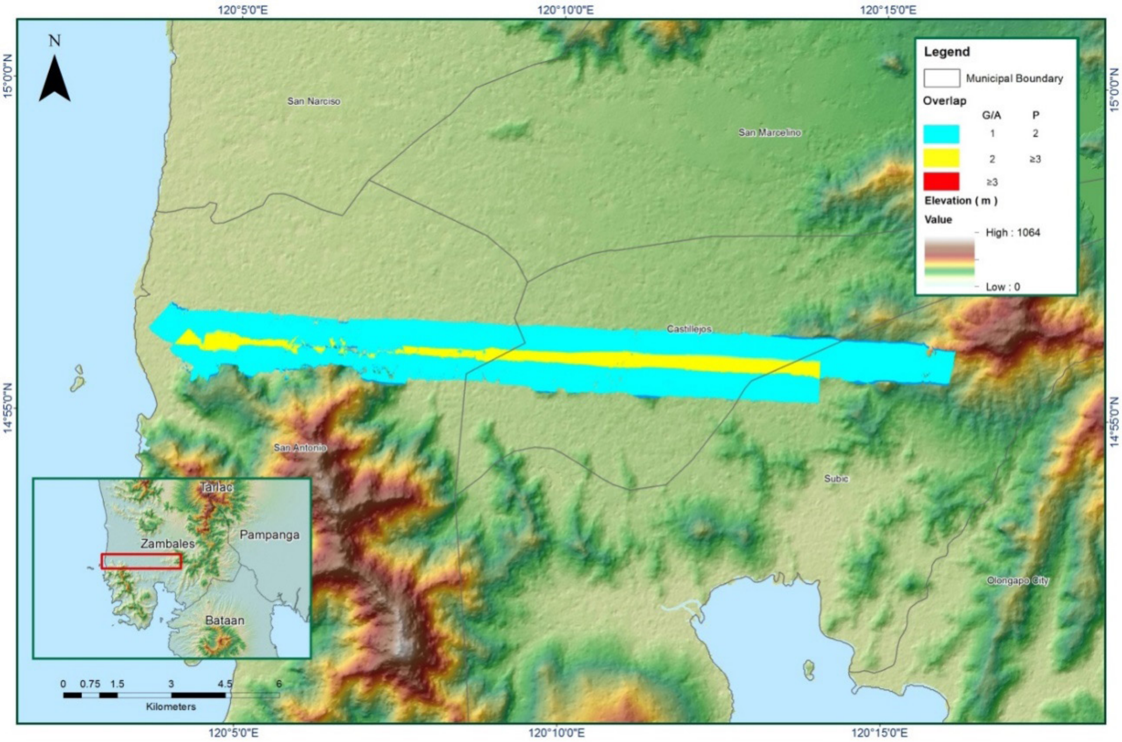


Figure 1.3.5. Image of data overlap

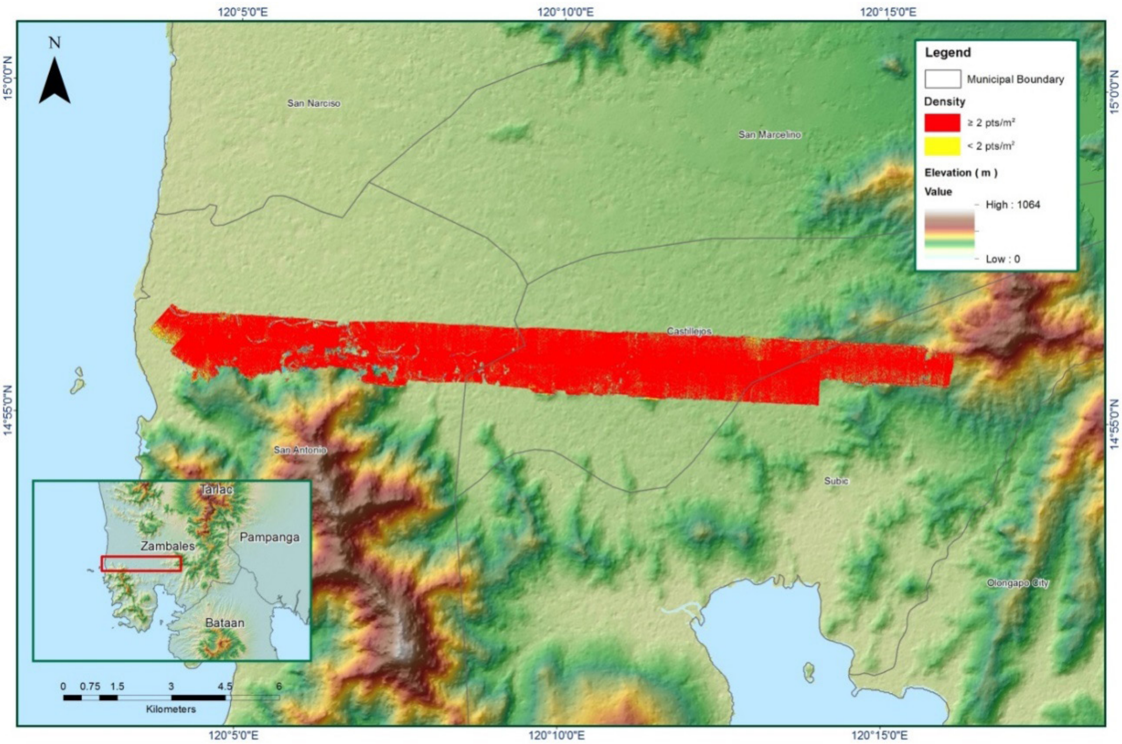


Figure 1.3.6. Density map of merged LiDAR data

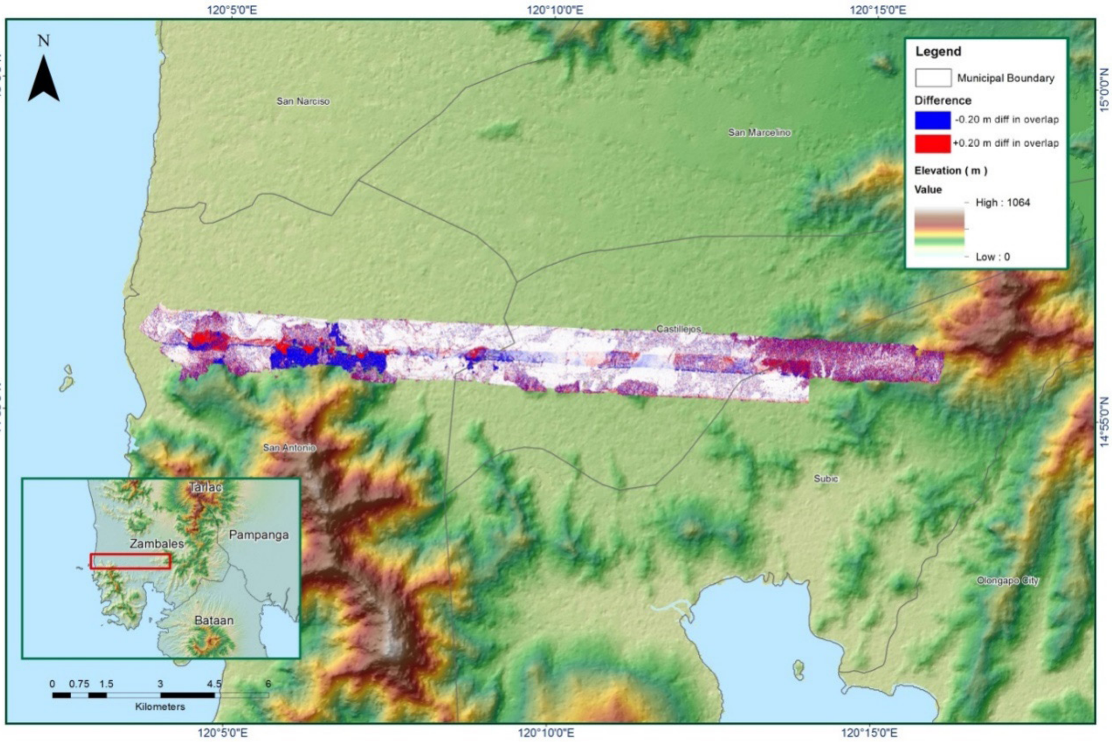


Figure 1.3.7. Elevation difference between flight lines

Table A-8.4. Mission Summary Report of BataanZambales_BucD

Flight Area	Bataan
Mission Name	BataanZambales_BucD
Inclusive Flights	923P
Range data size	5.72 GB
POS	189 MB
Base Data	27.7 MB
Image	n/a
Transfer date	January 10, 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)	4.0
RMSE for East Position (<4.0 cm)	7.0
RMSE for Down Position (<8.0 cm)	12
Boresight correction stdev (<0.001deg)	0.000327
IMU attitude correction stdev (<0.001deg)	0.001505
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	1.34
Ave point cloud density per sq.m. (>2.0)	5.76
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	501
Maximum Height	809.55 m
Minimum Height	40.61 m
Classification (# of points)	
Ground	270,366,880
Low vegetation	137,148,891
Medium vegetation	282,532,413
High vegetation	105,320,651
Building	3,623,320
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Melanie Hingpit, Engr. Jeffrey Delica, Engr. John Dill Macapagal, Engr. Roa Shalemar Redo

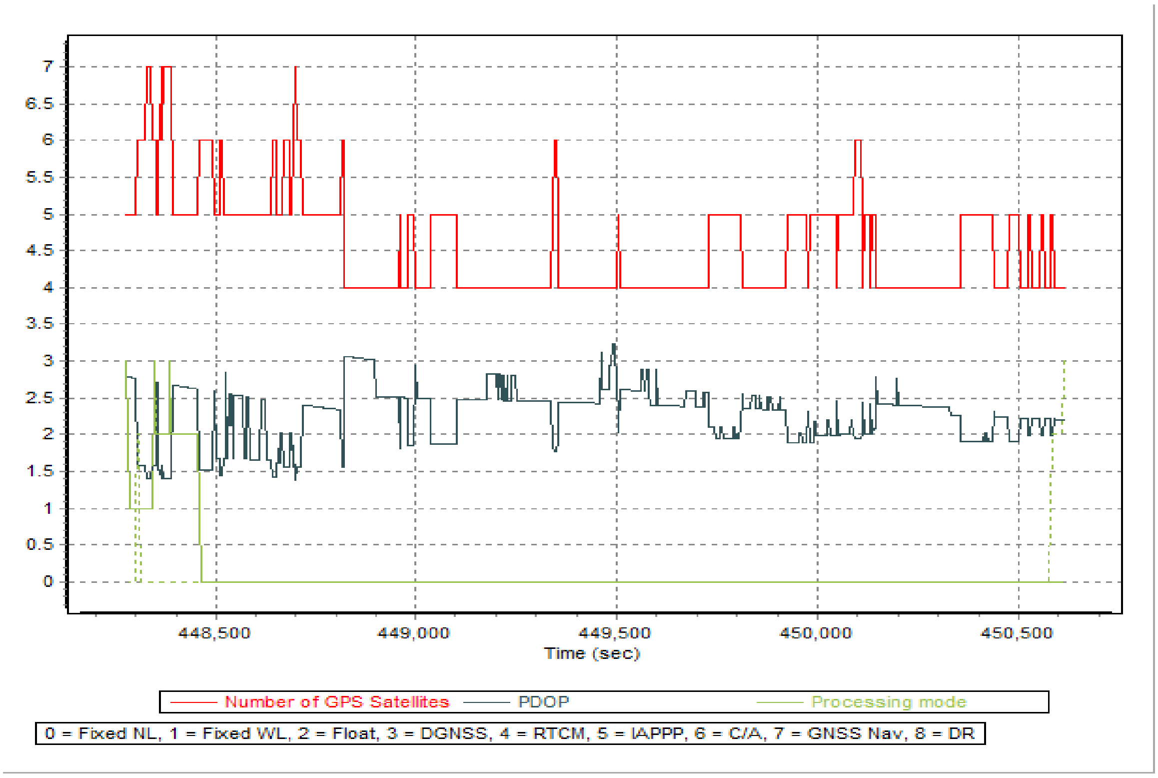


Figure 1.4.1. Solution Status

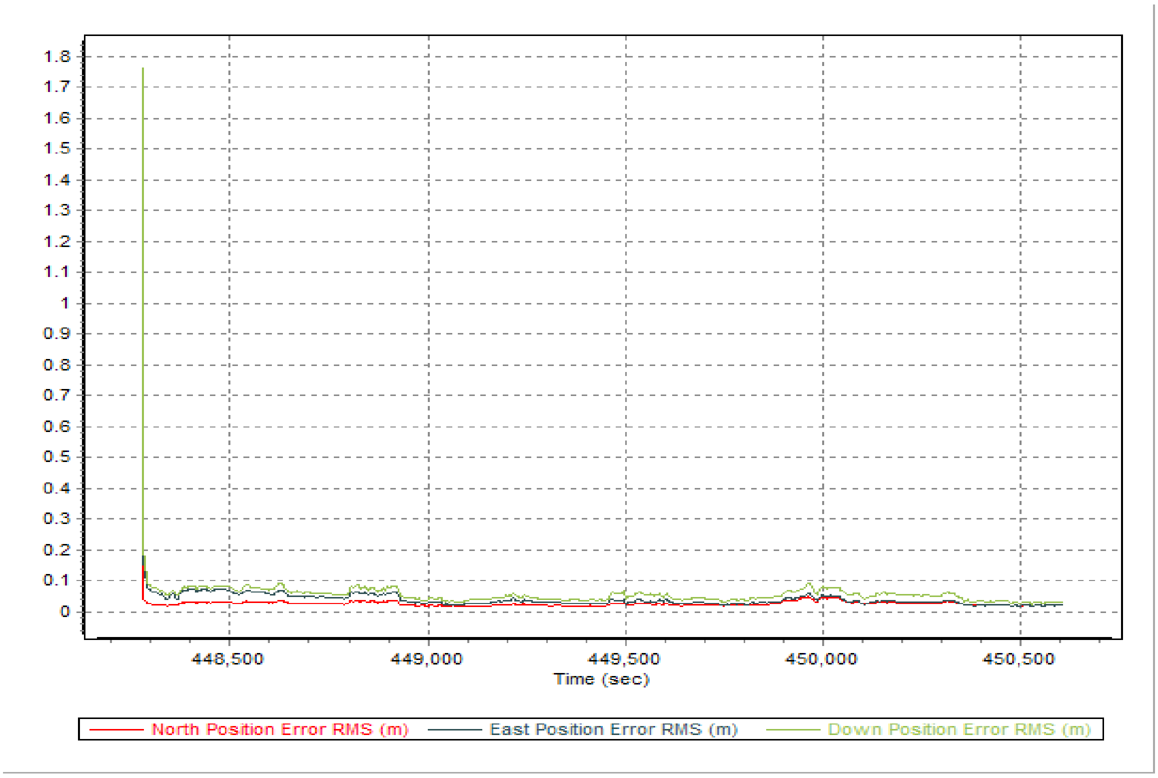


Figure 1.4.2. Smoothed Performance Metric Parameters

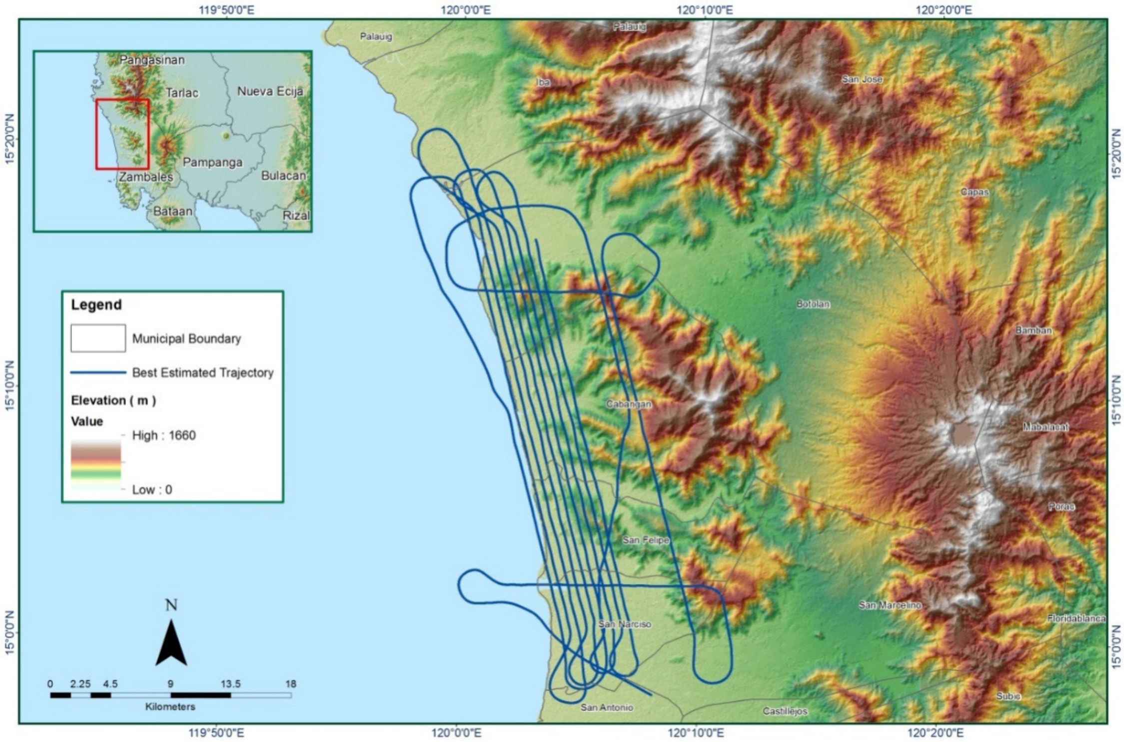


Figure 1.4.3. Best Estimated Trajectory

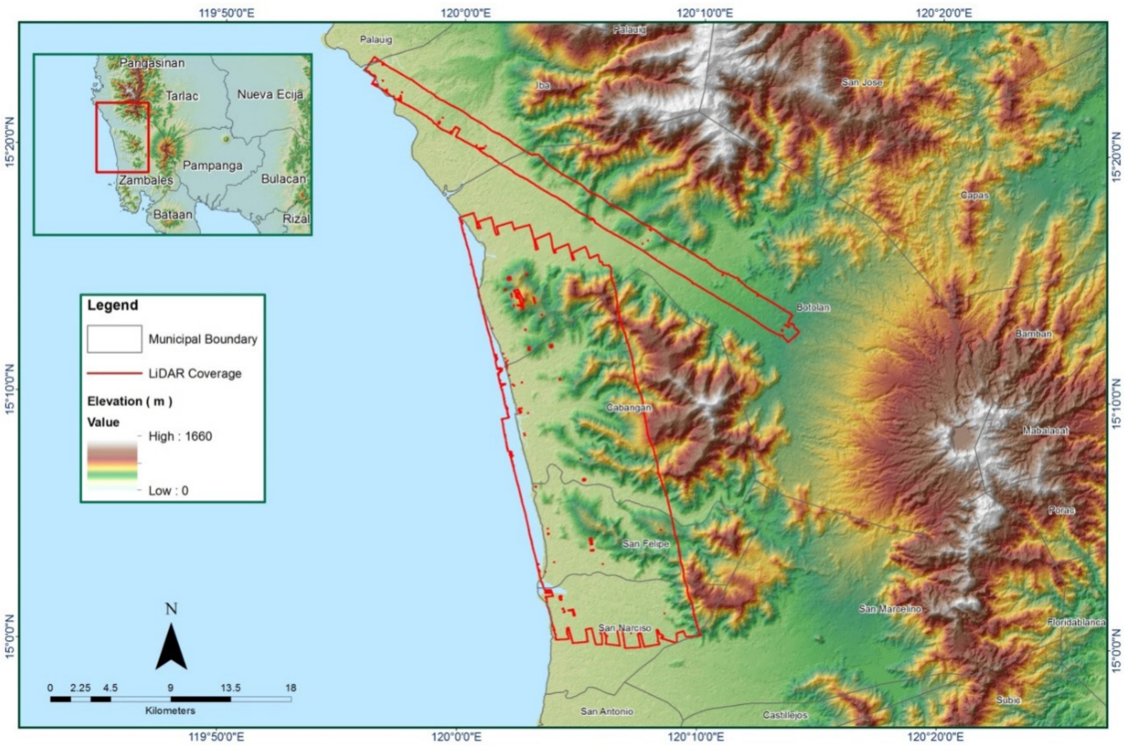


Figure 1.4.4. Coverage of LiDAR Data

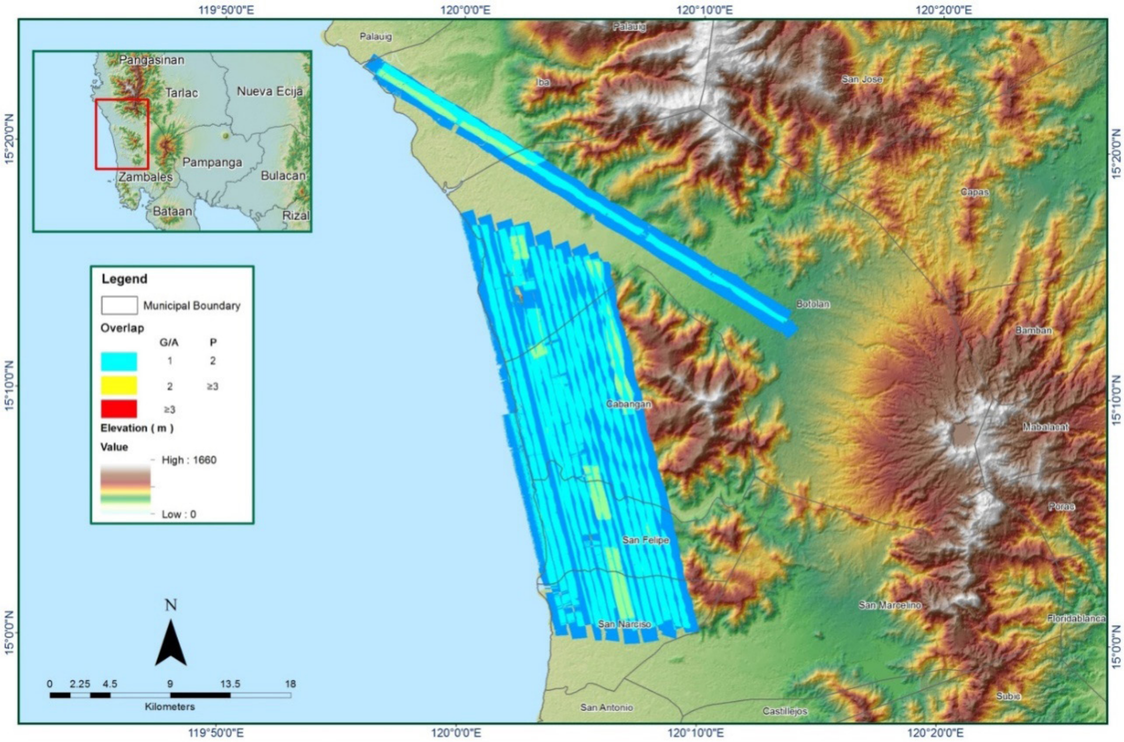


Figure 1.4.5. Image of data overlap

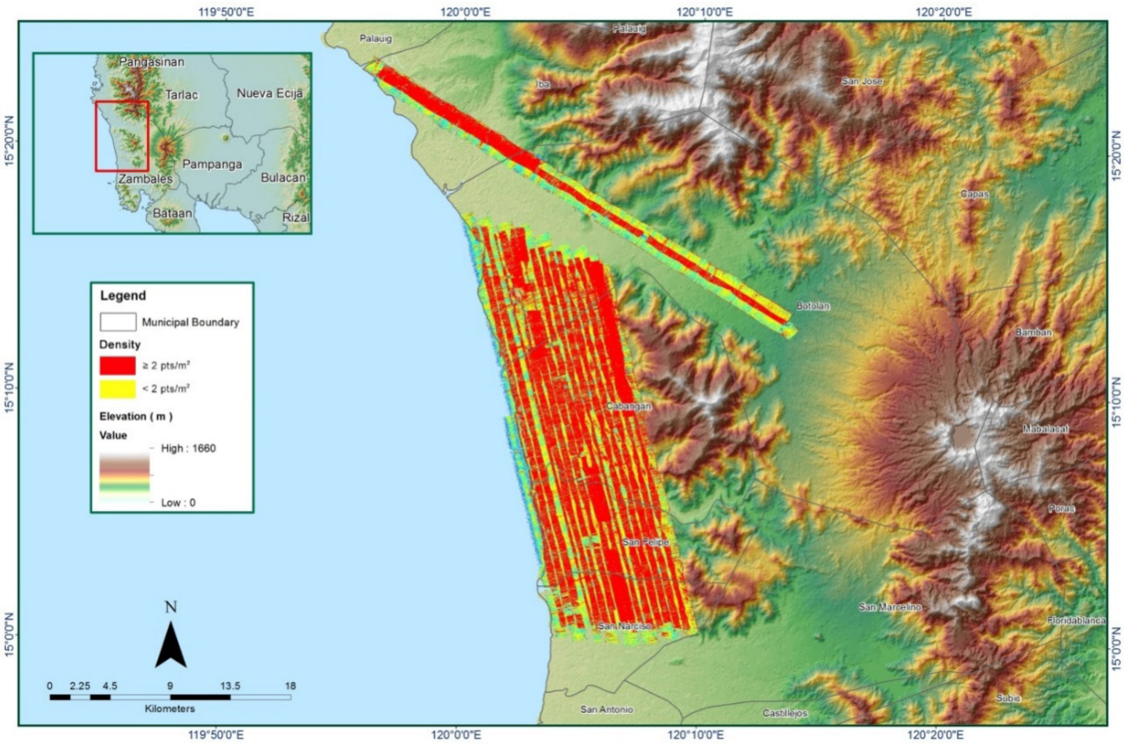


Figure 1.4.6. Density map of merged LiDAR data

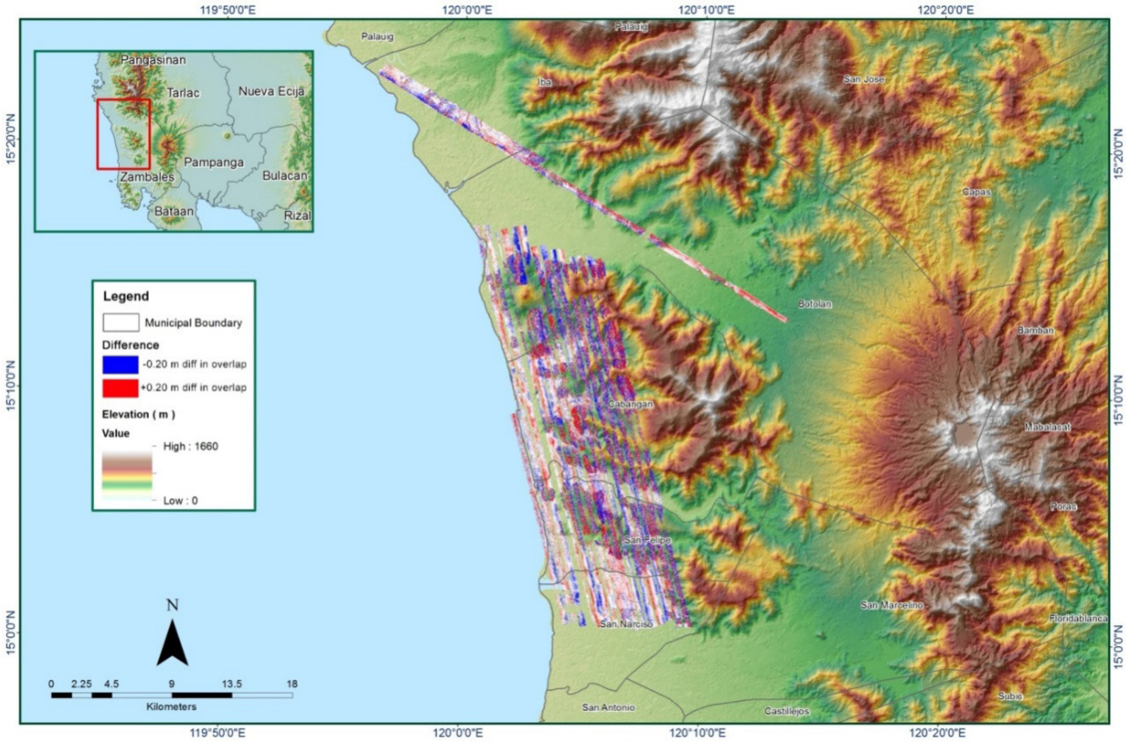


Figure 1.4.7. Elevation difference between flight lines

Table A-8.5. Mission Summary Report of BataanZambales_BucE

Flight Area	Bataan
Mission Name	**BataanZambales_BucE**
Inclusive Flights	930G
Range data size	18.9 GB
POS	277 MB
Base Data	27.7 MB
Image	n/a
Transfer date	January 10, 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)	3.0
RMSE for East Position (<4.0 cm)	4.5
RMSE for Down Position (<8.0 cm)	8.0
Boresight correction stdev (<0.001deg)	0.000315
IMU attitude correction stdev (<0.001deg)	0.003684
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	3.60
Ave point cloud density per sq.m. (>2.0)	29.04
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	170
Maximum Height	884.06 m
Minimum Height	64.67 m
Classification (# of points)	
Ground	79,141,394
Low vegetation	87,244,231
Medium vegetation	136,417,878
High vegetation	138,520,933
Building	3,767,722
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Charmaine Cruz, Engr. John Dill Macapagal

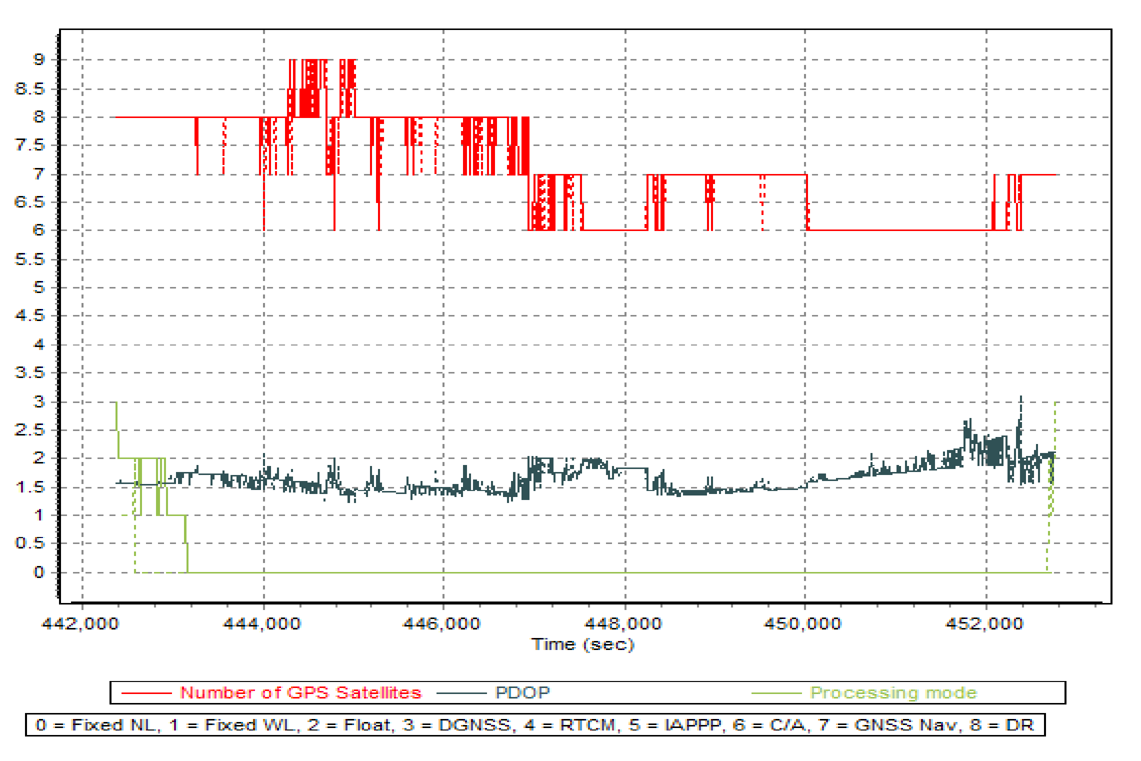


Figure 1.5.1. Solution Status

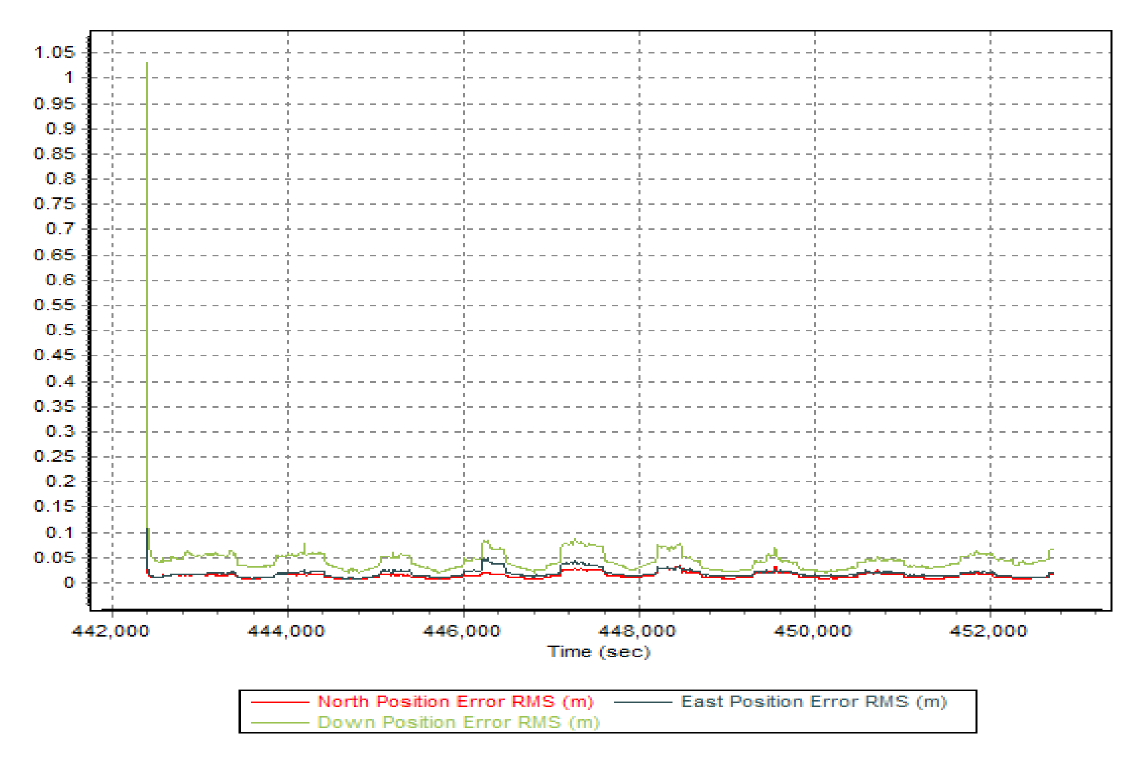


Figure 1.5.2. Smoothed Performance Metric Parameters

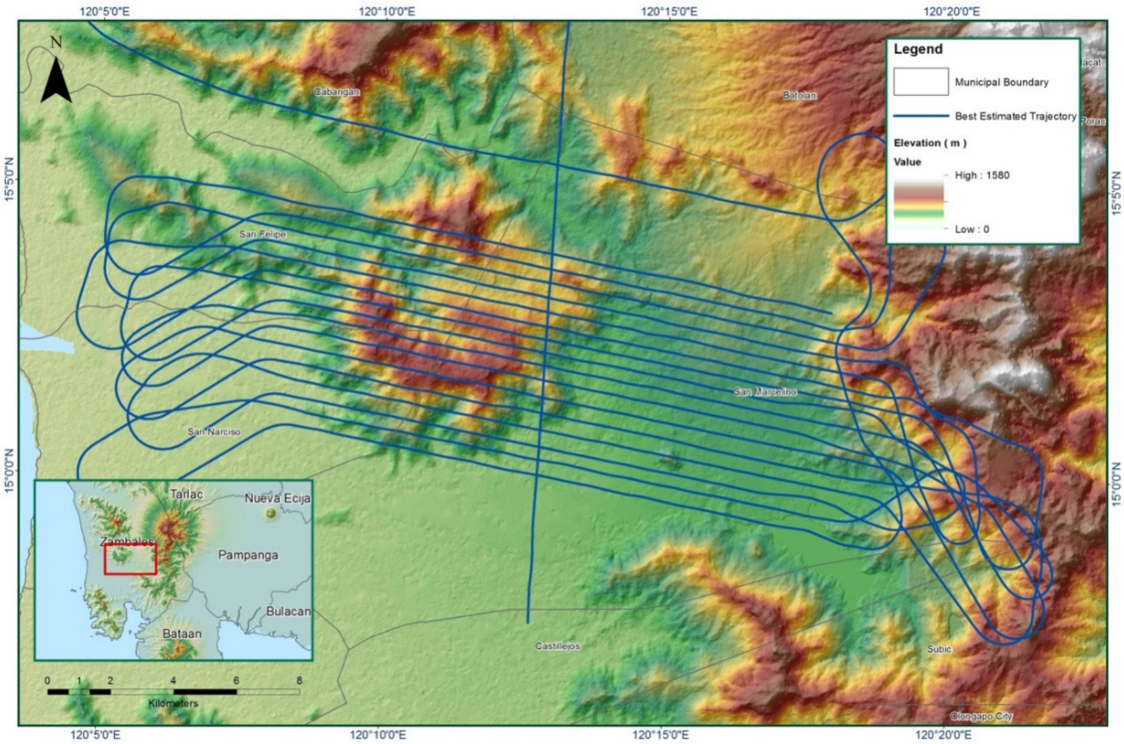


Figure 1.5.3. Best Estimated Trajectory

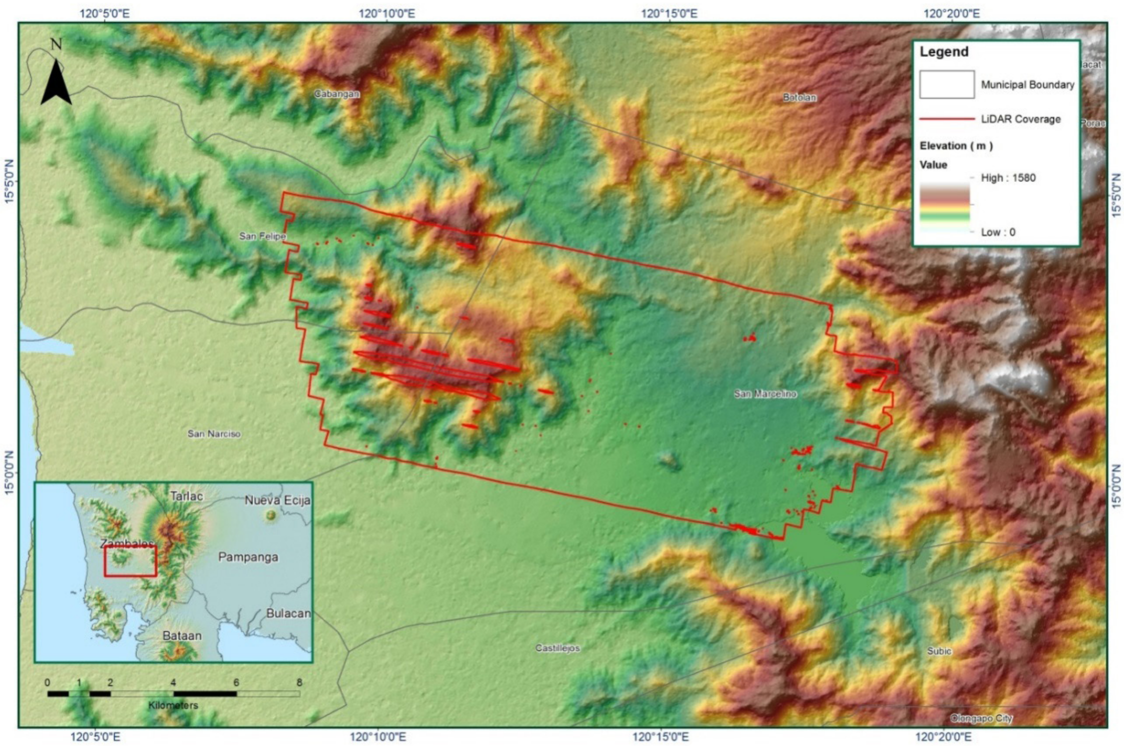


Figure 1.5.4. Coverage of LiDAR Data

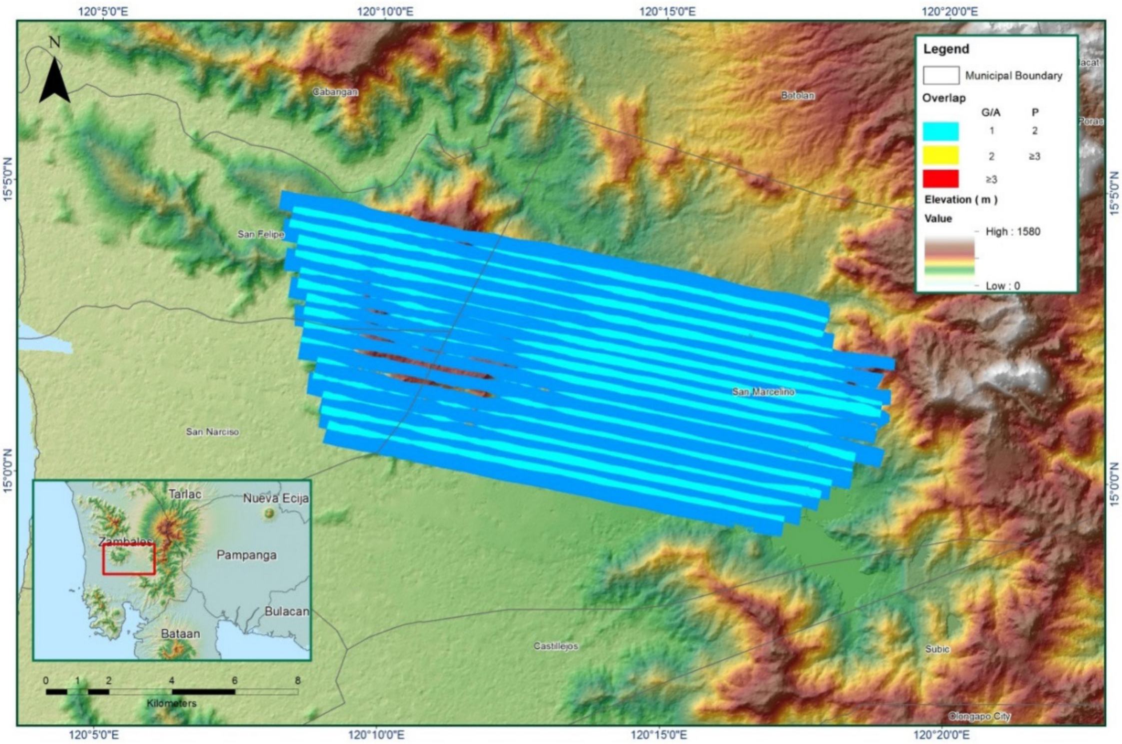


Figure 1.5.5. Image of data overlap

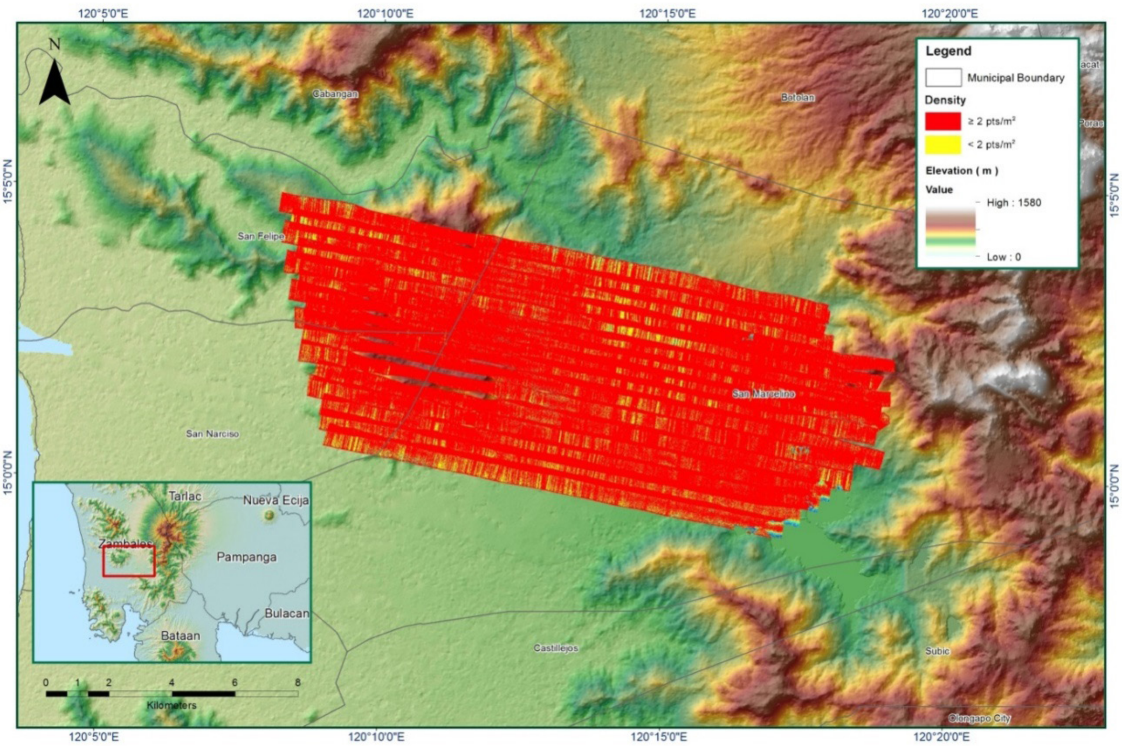


Figure 1.5.6. Density map of merged LiDAR data

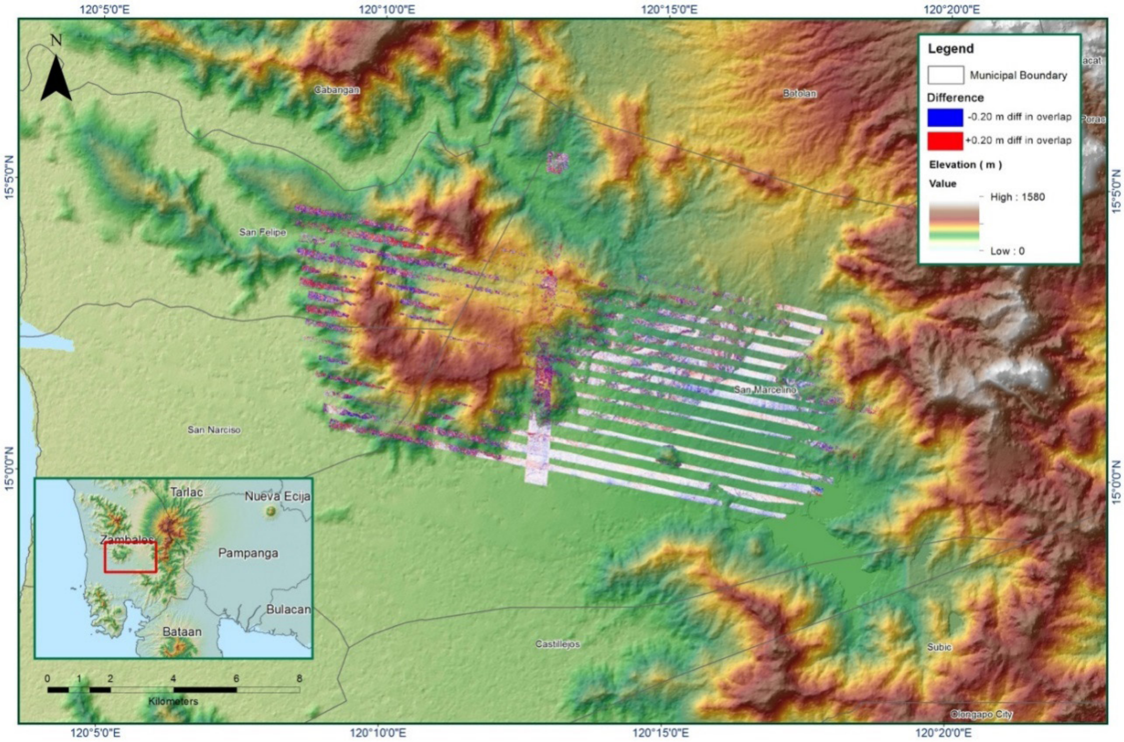


Figure .15.7. Elevation difference between flight lines

Table A-8.6. Mission Summary Report of BataanZambales_BalF

Flight Area	Bataan
Mission Name	BataanZambales_BalF
Inclusive Flights	951P
Range data size	9.51 GB
POS	178 MB
Base Data	12.8 MB
Image	n/a
Transfer date	January 10, 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)	5.0
RMSE for East Position (<4.0 cm)	3.6
RMSE for Down Position (<8.0 cm)	10.5
Boresight correction stdev (<0.001deg)	0.000606
IMU attitude correction stdev (<0.001deg)	0.037826
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	3.98
Ave point cloud density per sq.m. (>2.0)	36.88
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	83
Maximum Height	496.29 m
Minimum Height	43.82 m
Classification (# of points)	
Ground	52,210,728
Low vegetation	35,430,373
Medium vegetation	83,955,977
High vegetation	104,794,542
Building	3,074,943
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Ryan James Nicholai Dizon

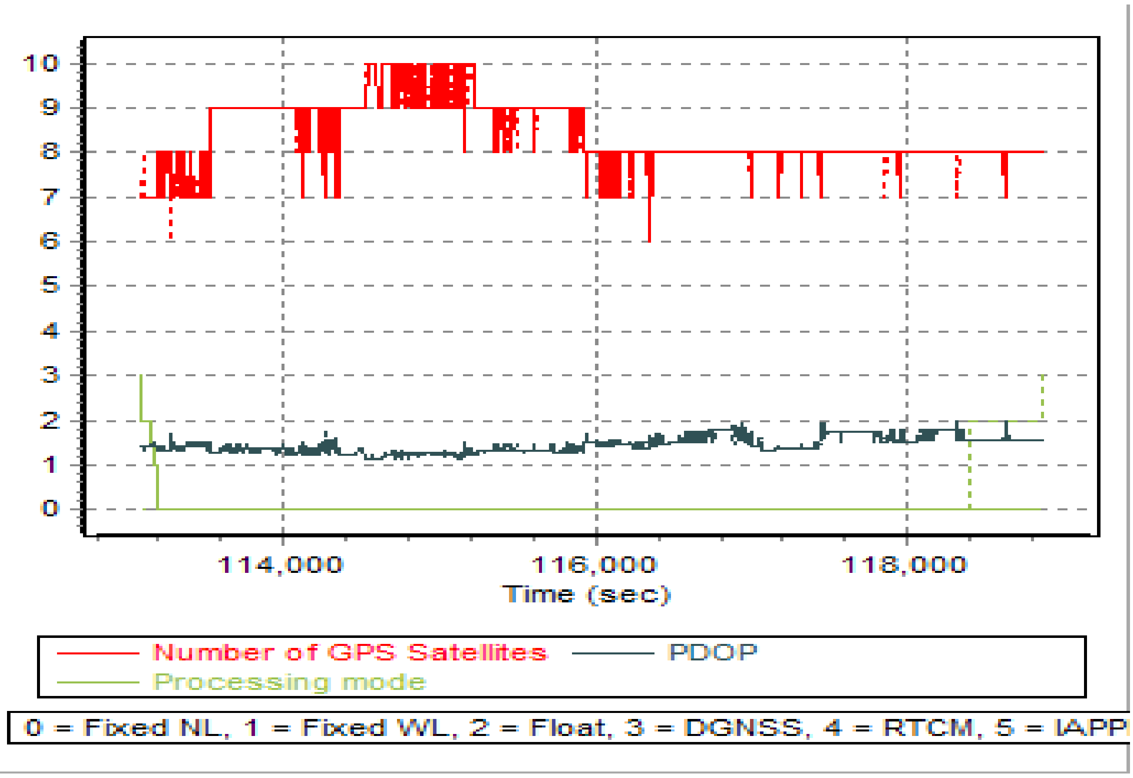


Figure 1.6.1. Solution Status

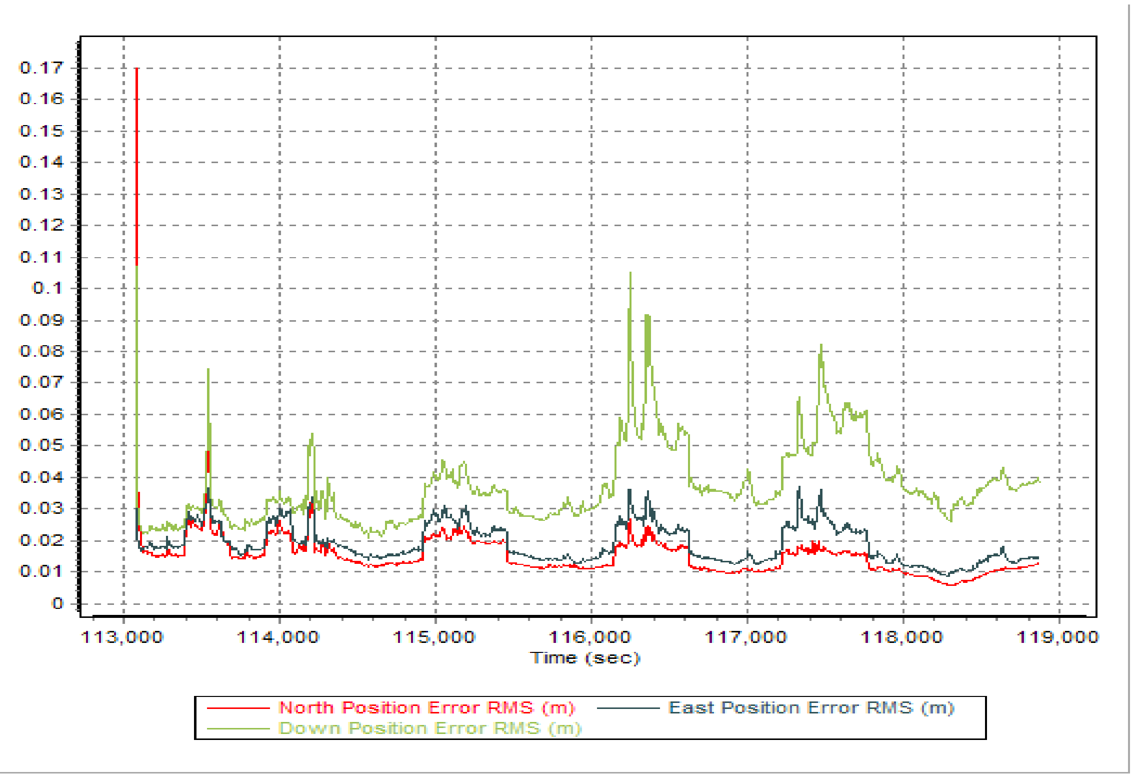


Figure 1.6.2. Smoothed Performance Metric Parameters

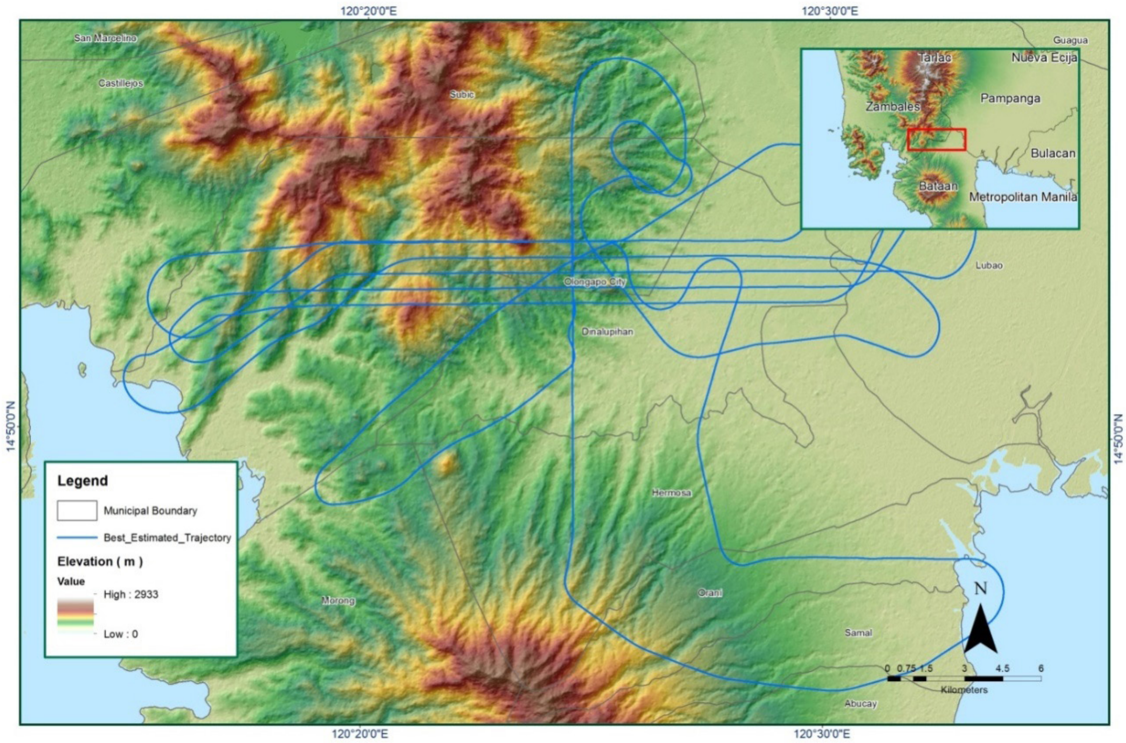


Figure 1.6.3. Best Estimated Trajectory

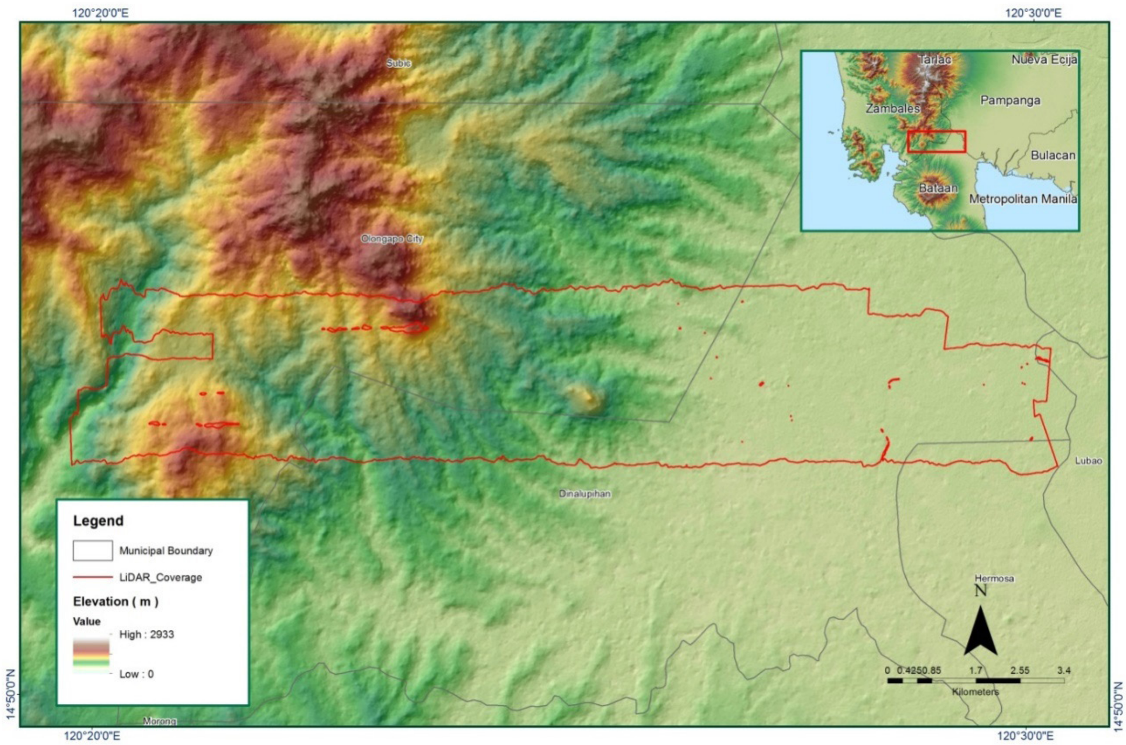


Figure 1.6.4. Coverage of LiDAR Data

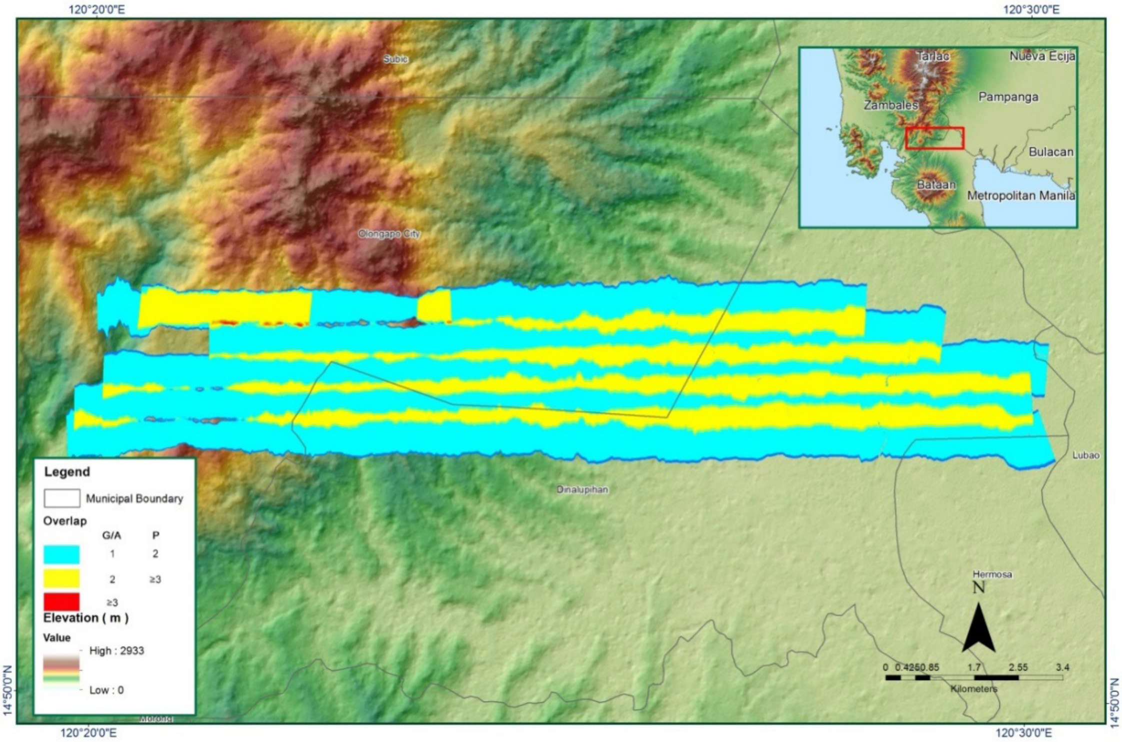


Figure 1.6.5. Image of data overlap

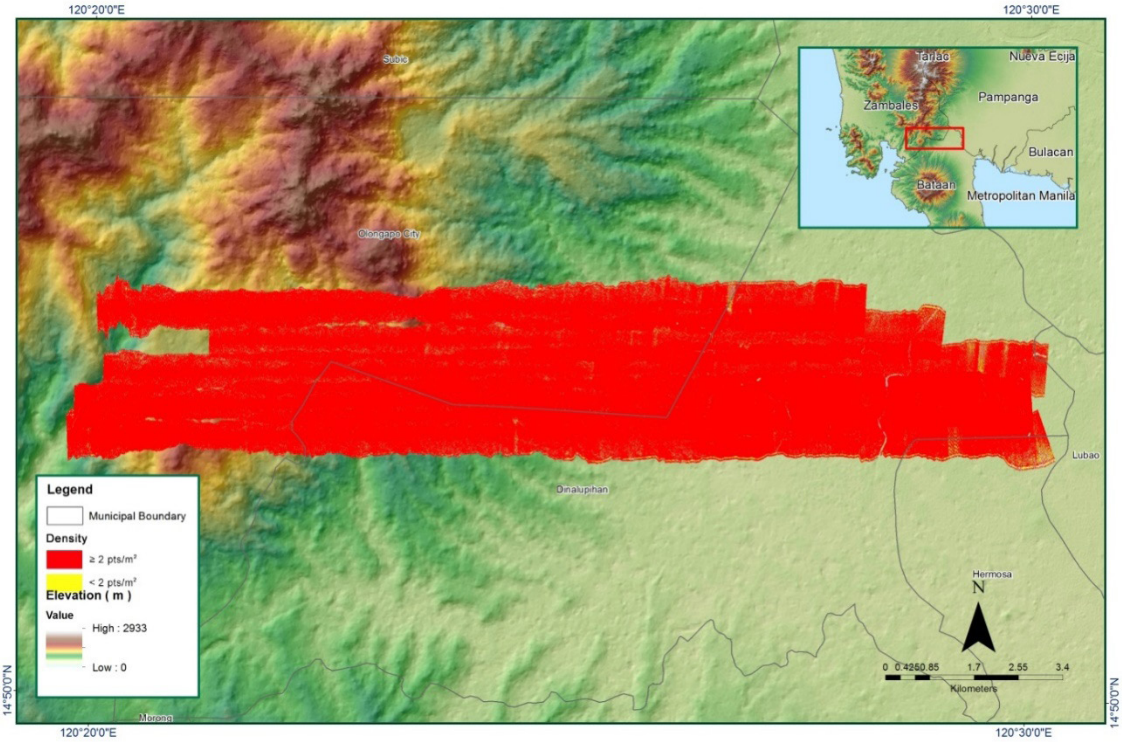


Figure 1.6.6. Density map of merged LiDAR data

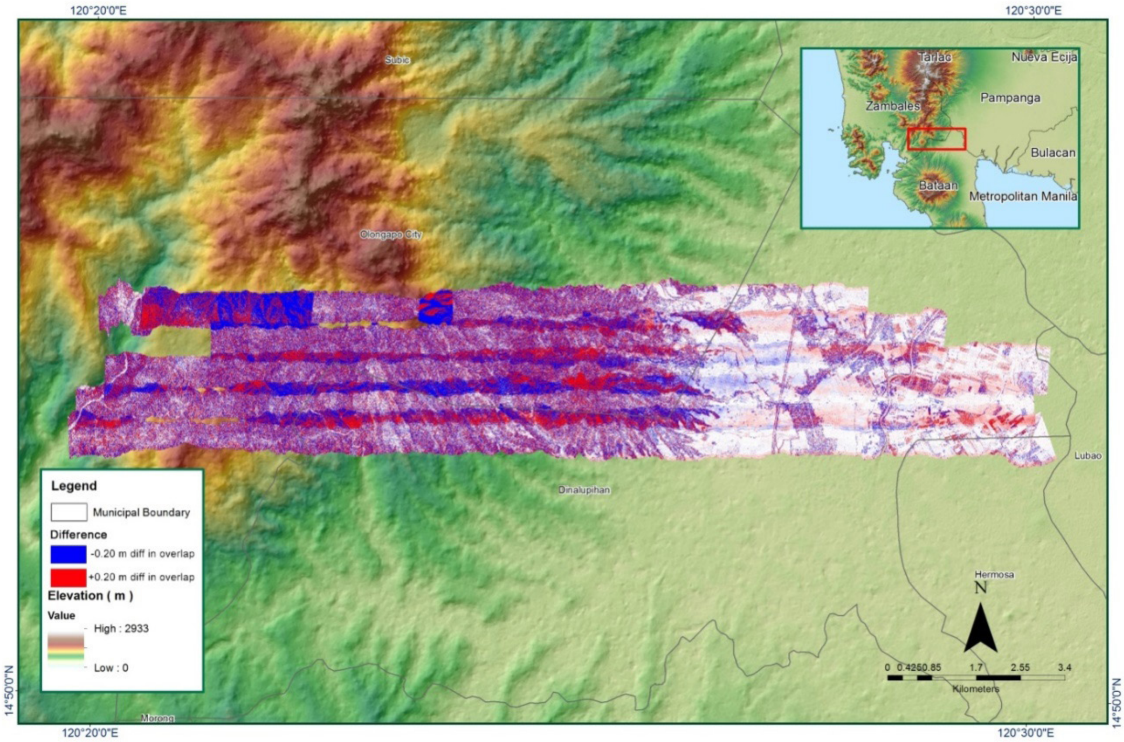


Figure 1.6.7. Elevation difference between flight lines

Table A-8.7. Mission Summary Report of BataanZambales_BalD

Flight Area	Bataan
Mission Name	BataanZambales_BalD
Inclusive Flights	933P
Range data size	19.1 GB
POS	189 MB
Base Data	21.3 MB
Image	n/a
Transfer date	January 10, 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)	3.0
RMSE for East Position (<4.0 cm)	3.2
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000597
IMU attitude correction stdev (<0.001deg)	0.001085
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	2.47
Ave point cloud density per sq.m. (>2.0)	45.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	228
Maximum Height	489.03 m
Minimum Height	37.19 m
Classification (# of points)	
Ground	148,139,259
Low vegetation	102,357,162
Medium vegetation	173,742,476
High vegetation	157,443,026
Building	26,032,165
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Ryan James Nicholai Dizon

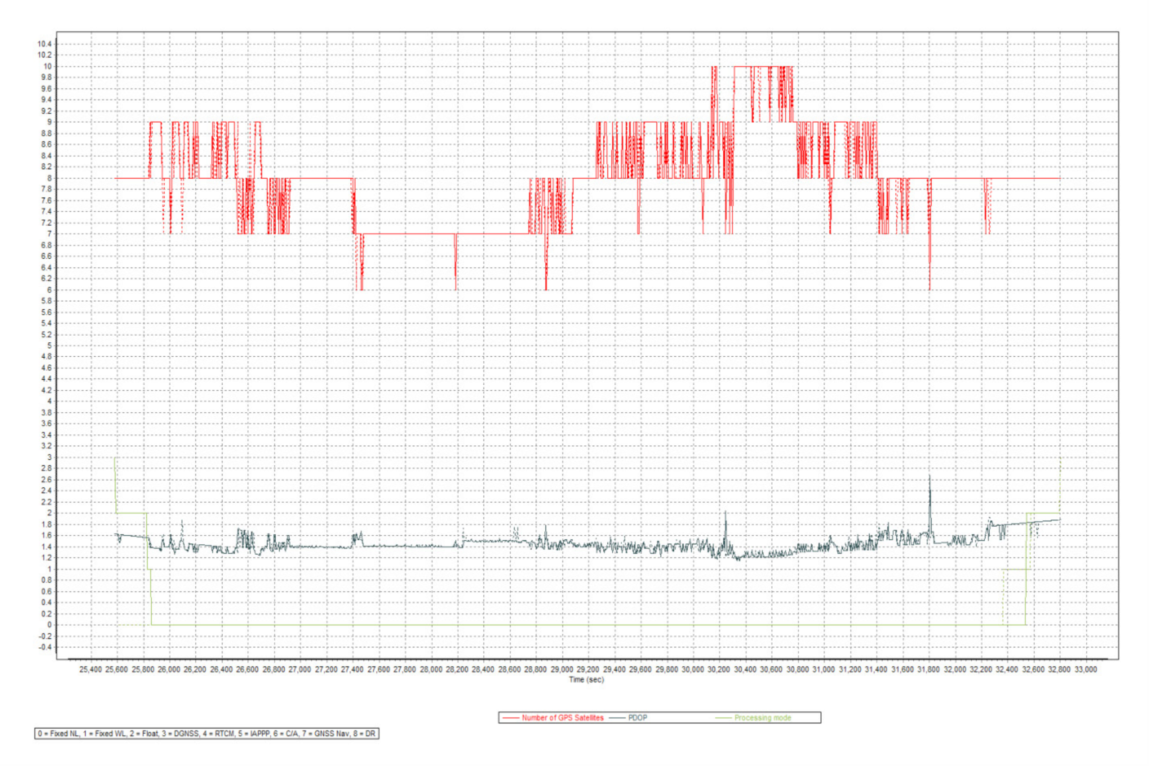


Figure 1.7.1. Solution Status

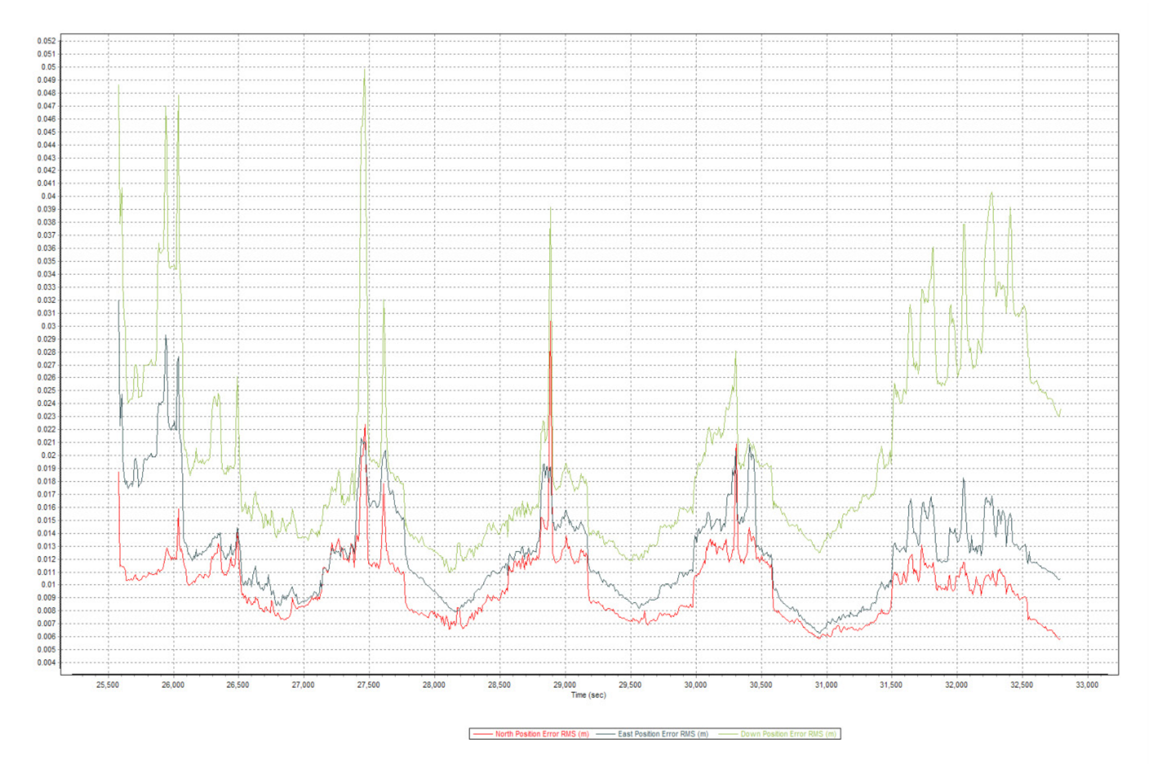


Figure 1.7.2. Smoothed Performance Metric Parameters

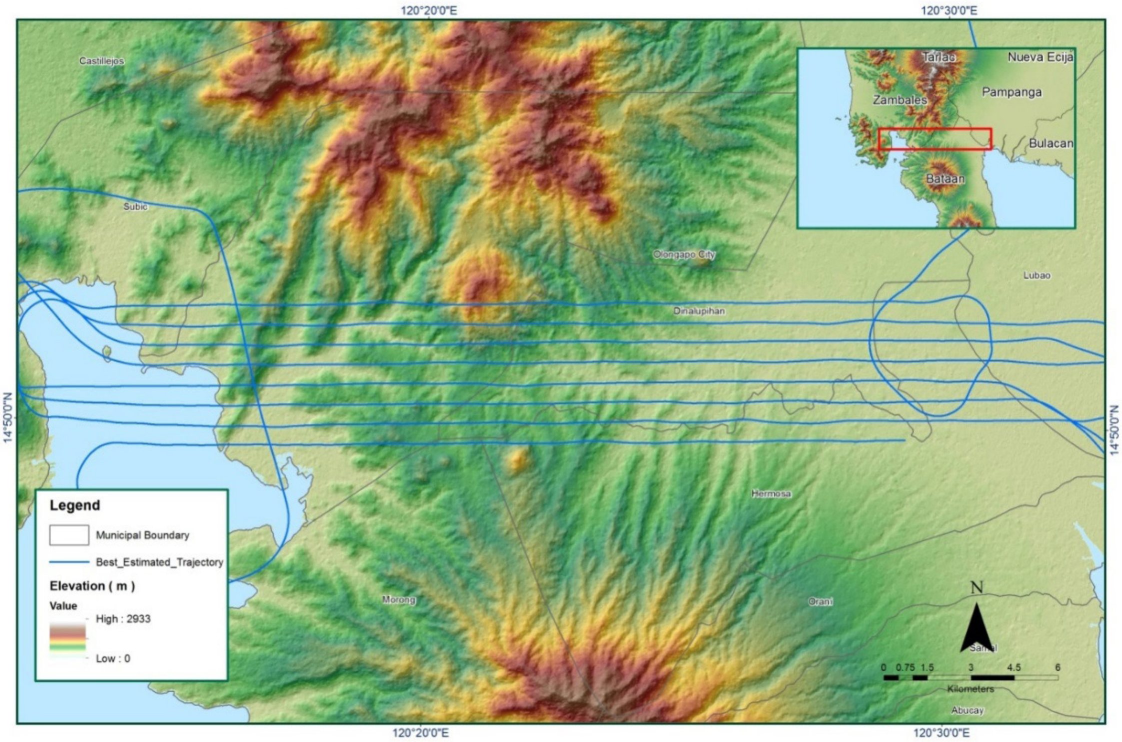


Figure 1.7.3. Best Estimated Trajectory

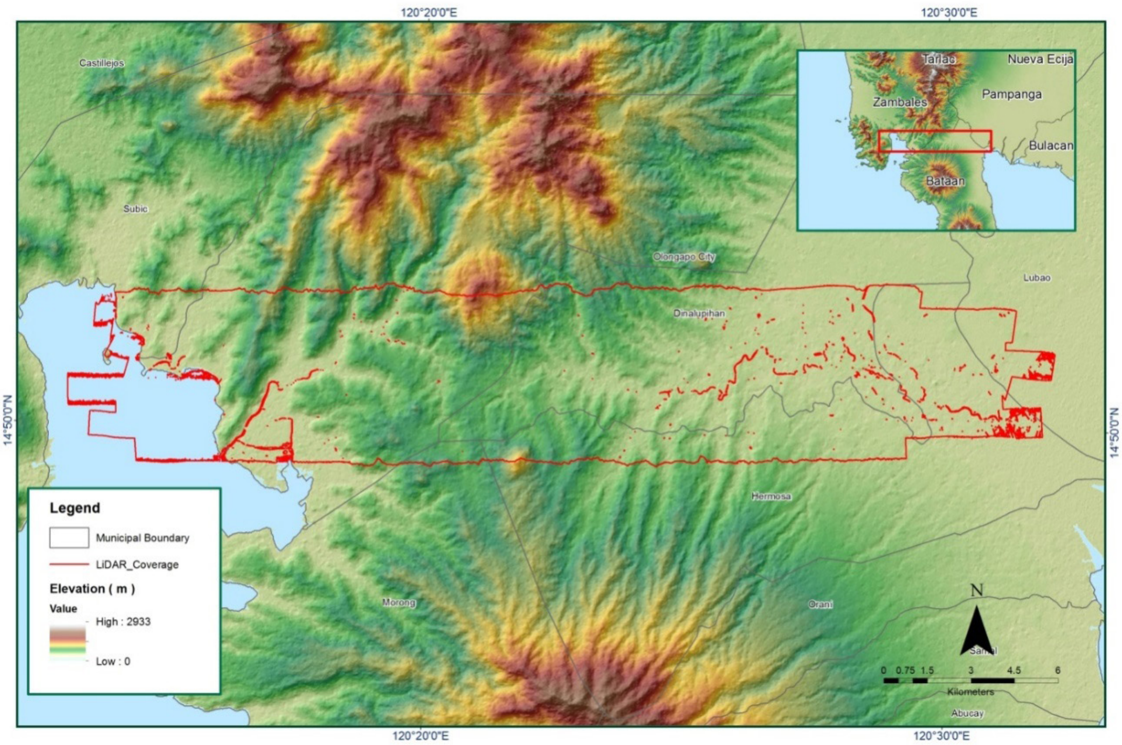


Figure 1.7.4. Coverage of LiDAR Data

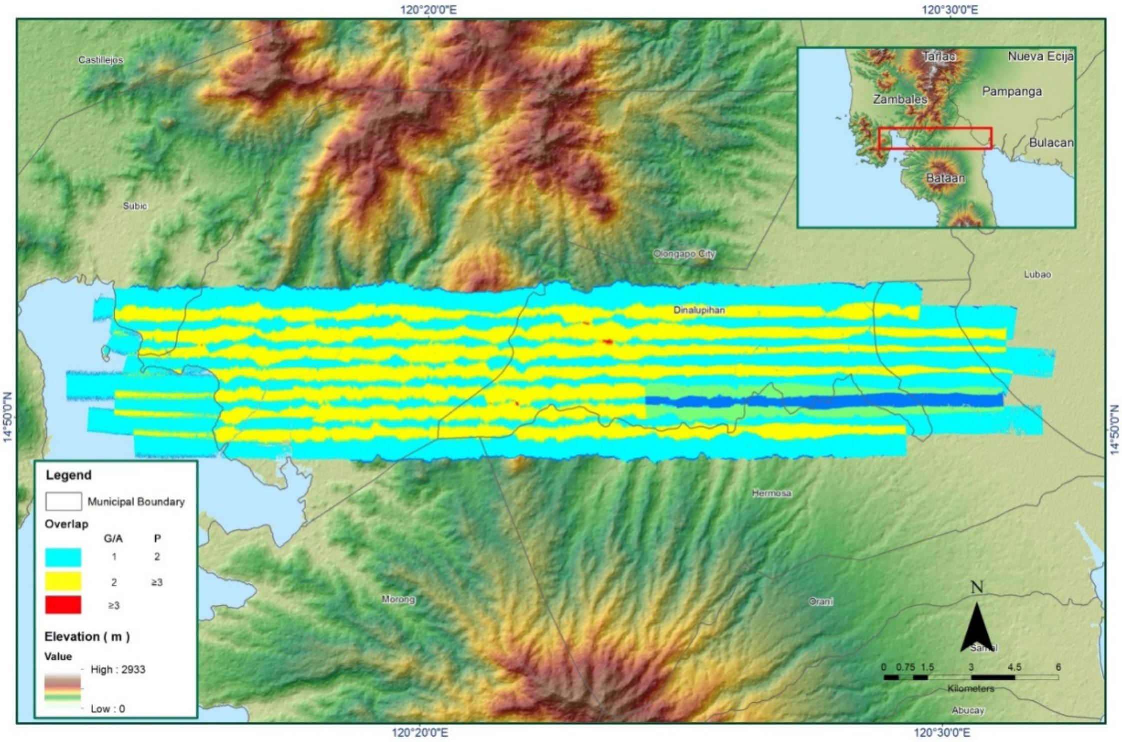


Figure 1.7.5. Image of data overlap

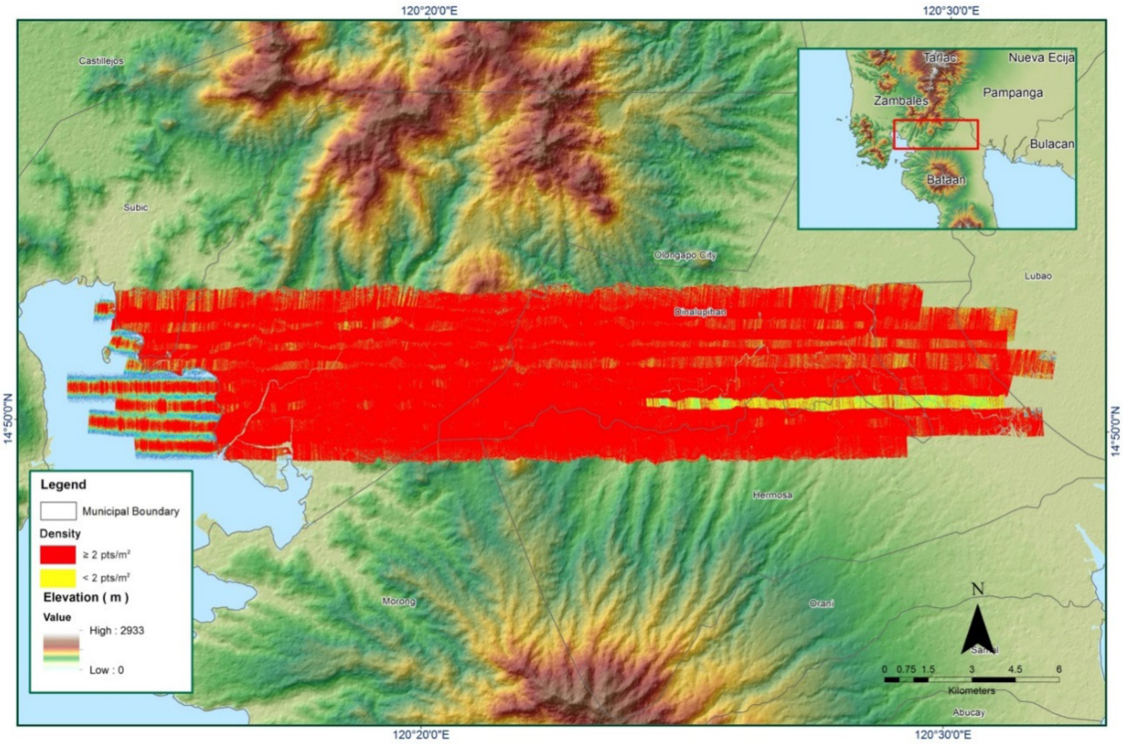


Figure 1.7.6. Density map of merged LiDAR data

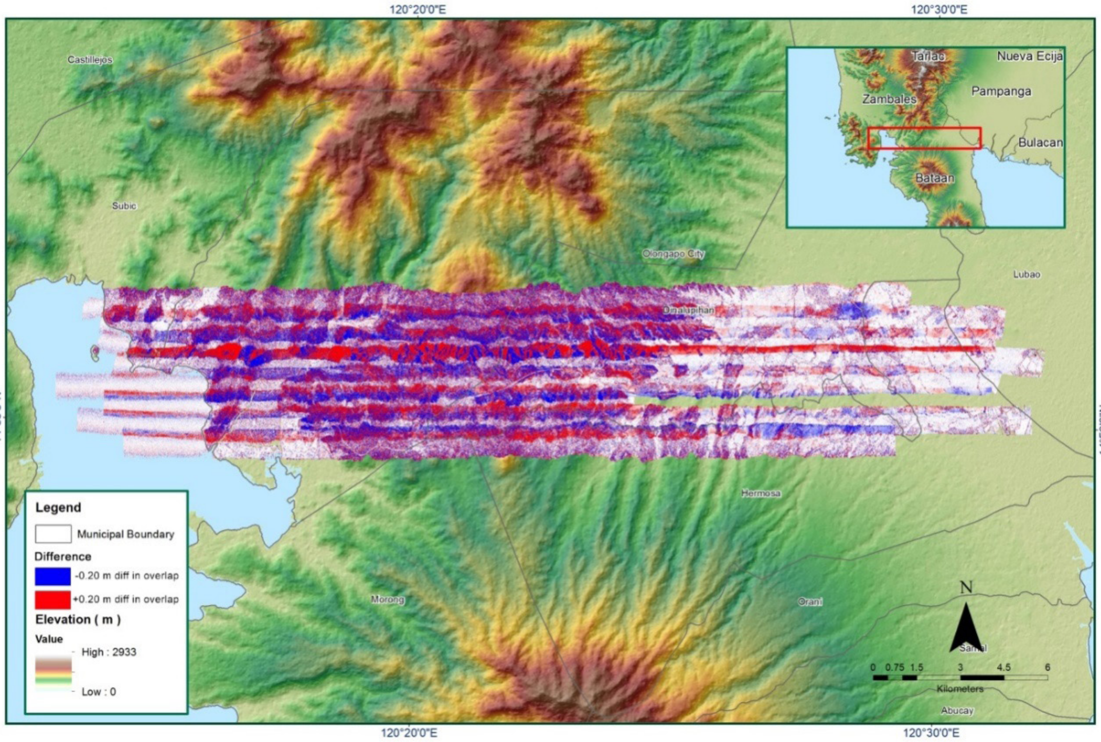


Figure 1.7.7. Elevation difference between flight lines

Table A-8.8. Mission Summary Report of Buc_E_Additional

Flight Area	Bataan_Reflights
Mission Name	Buc_E_Additional
Inclusive Flights	2473P
Range data size	16 GB
POS	252 MB
Base Data	4.14 MB
Image	31 GB
Transfer date	March 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.62
RMSE for East Position (<4.0 cm)	1.96
RMSE for Down Position (<8.0 cm)	4.00
Boresight correction stdev (<0.001deg)	0.000401
IMU attitude correction stdev (<0.001deg)	0.000893
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	54.22
Ave point cloud density per sq.m. (>2.0)	3.18
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	79
Maximum Height	375.75 m
Minimum Height	74.61 m
Classification (# of points)	
Ground	128,640,479
Low vegetation	87,738,856
Medium vegetation	4,293,7294
High vegetation	9,877,920
Building	1,460,436
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

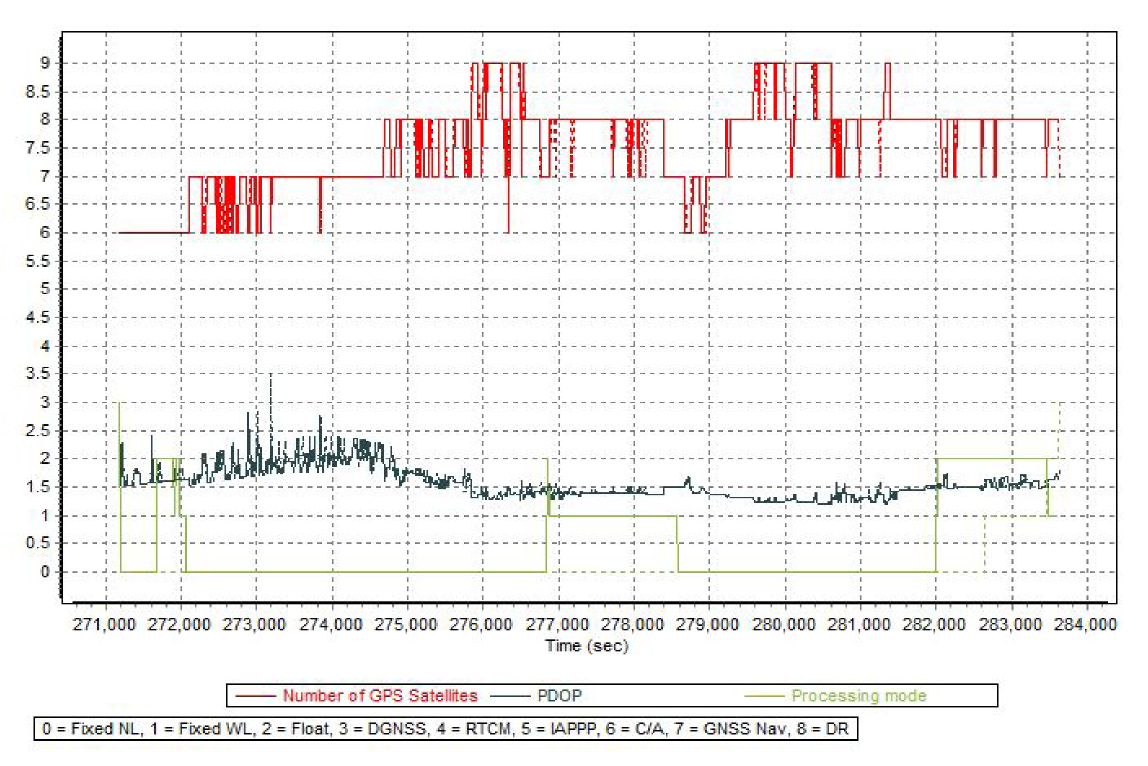


Figure 1.8.1. Solution Status

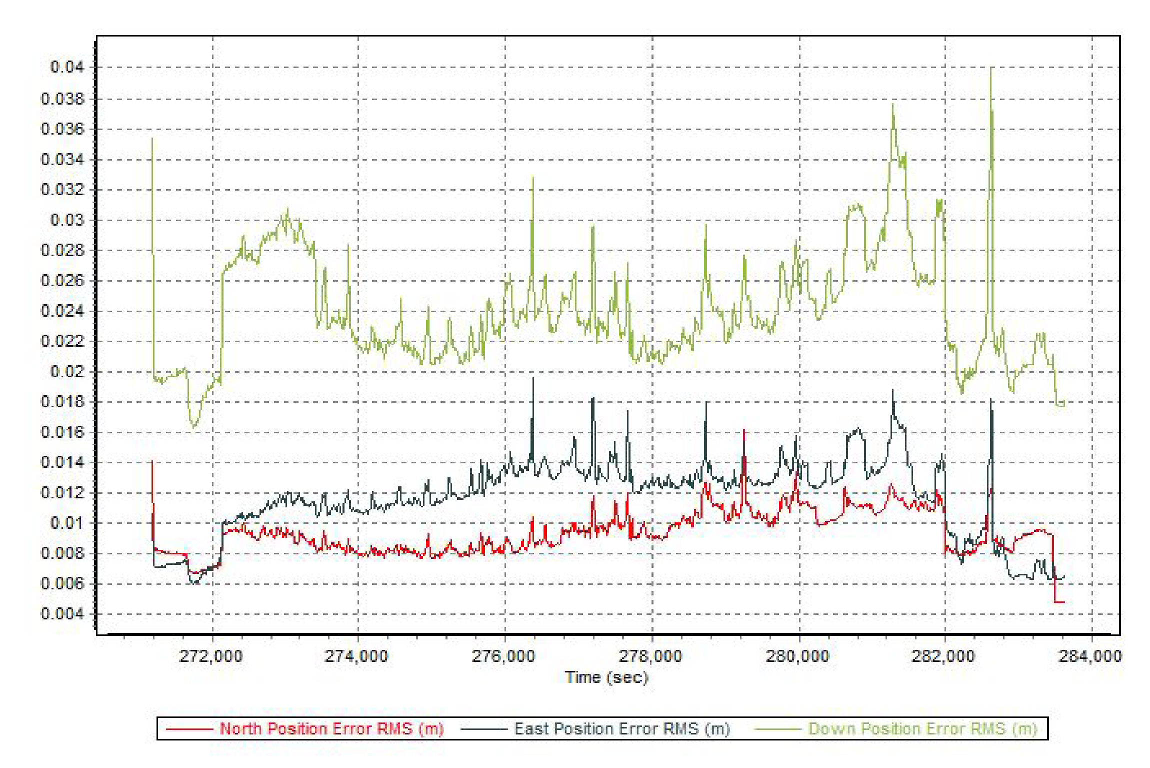


Figure 1.8.2. Smoothed Performance Metric Parameters

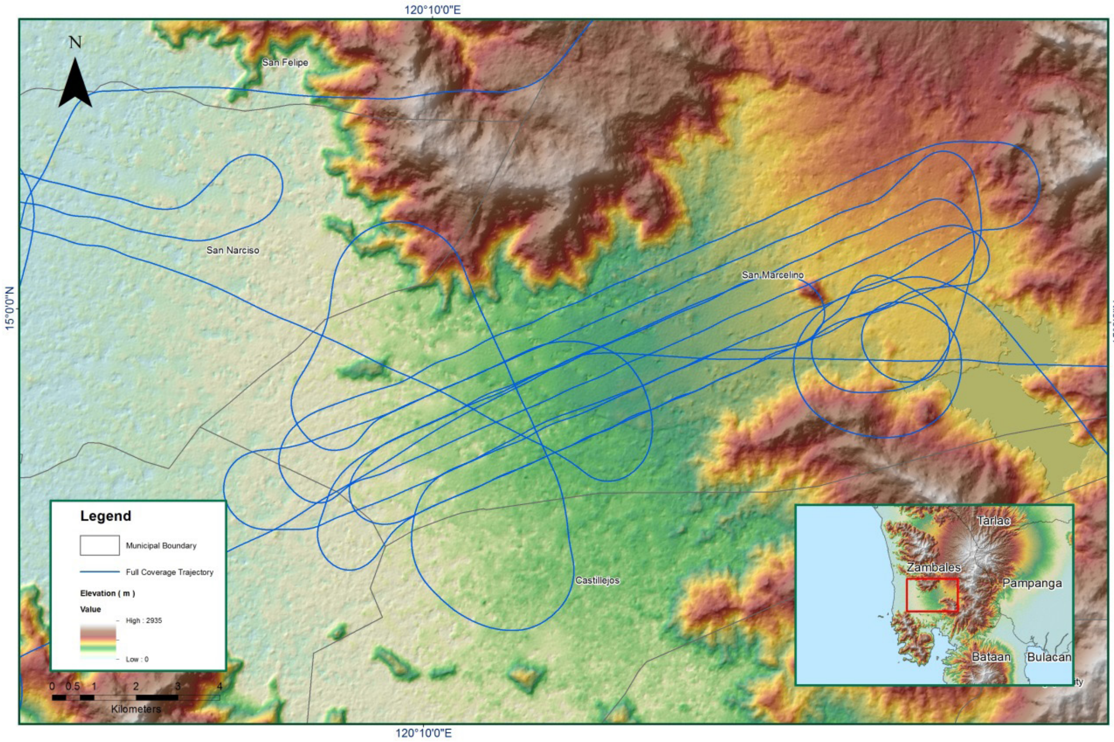


Figure 1.8.3. Best Estimate Trajectory

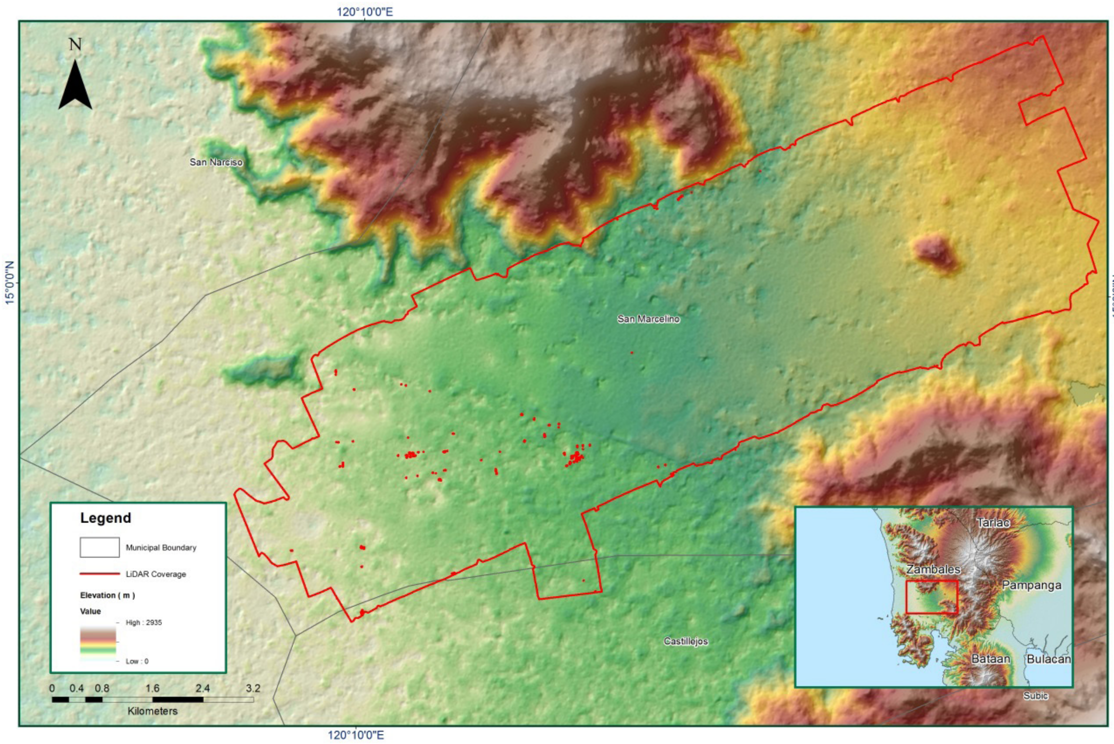


Figure 1.8.4. Coverage of LiDAR data

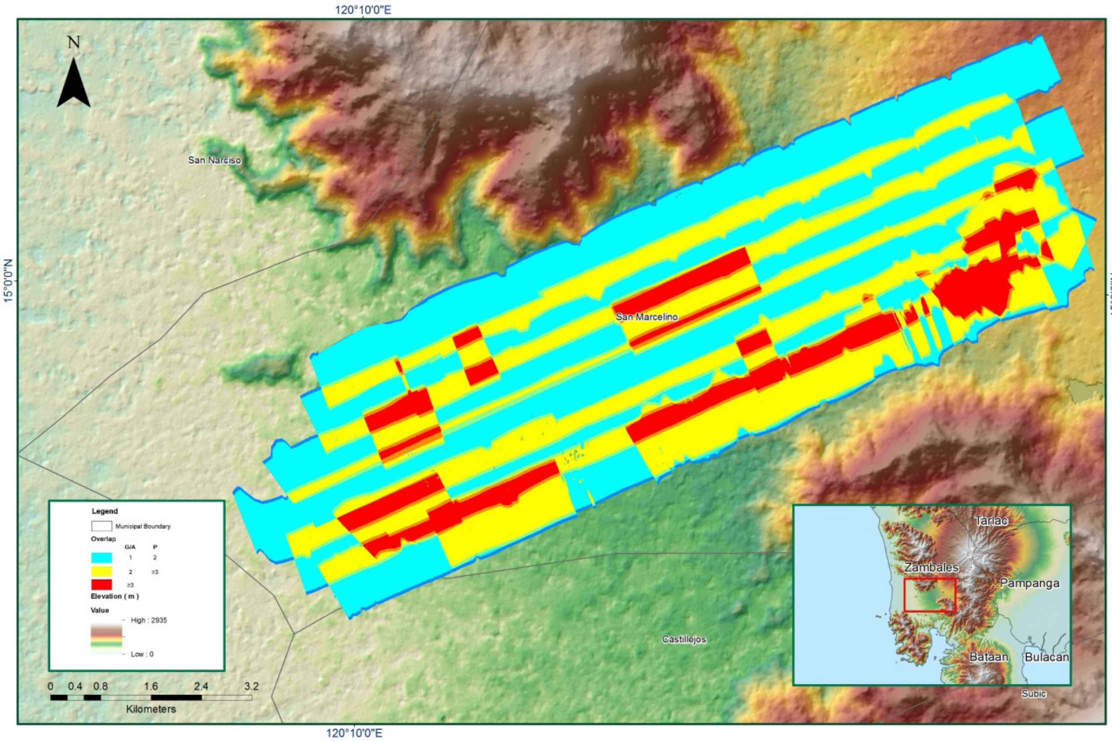


Figure 1.8.5 Image of data overlap

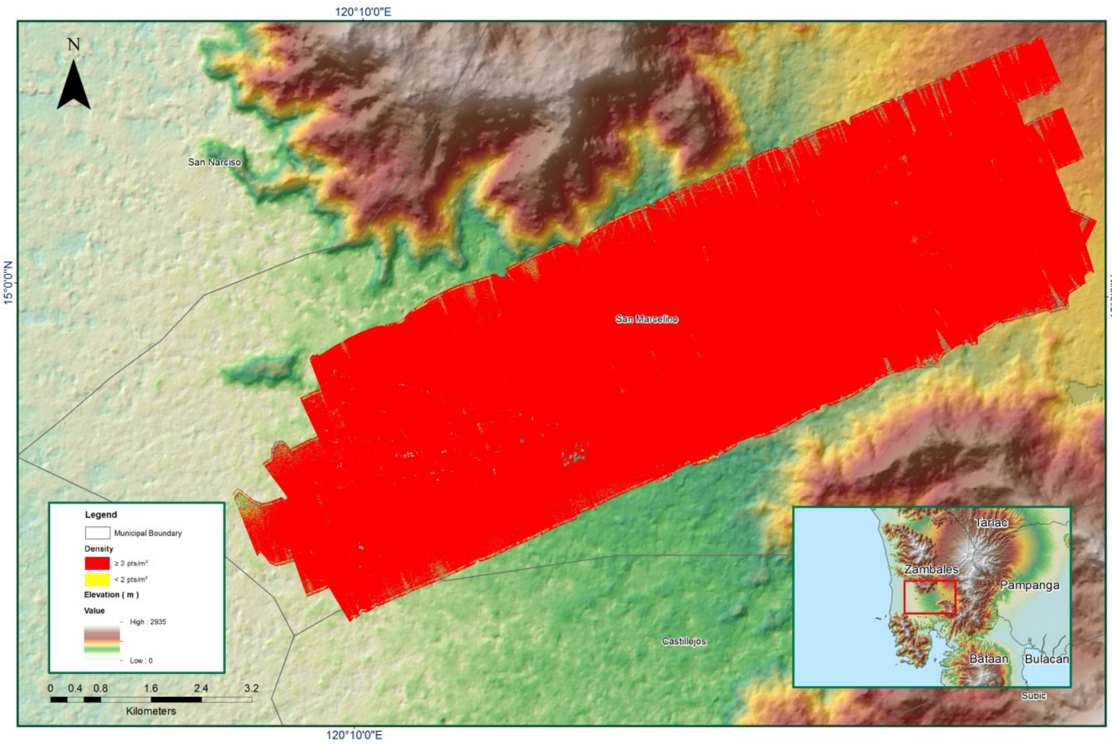


Figure 1.8.6 Density Map of merged LiDAR data

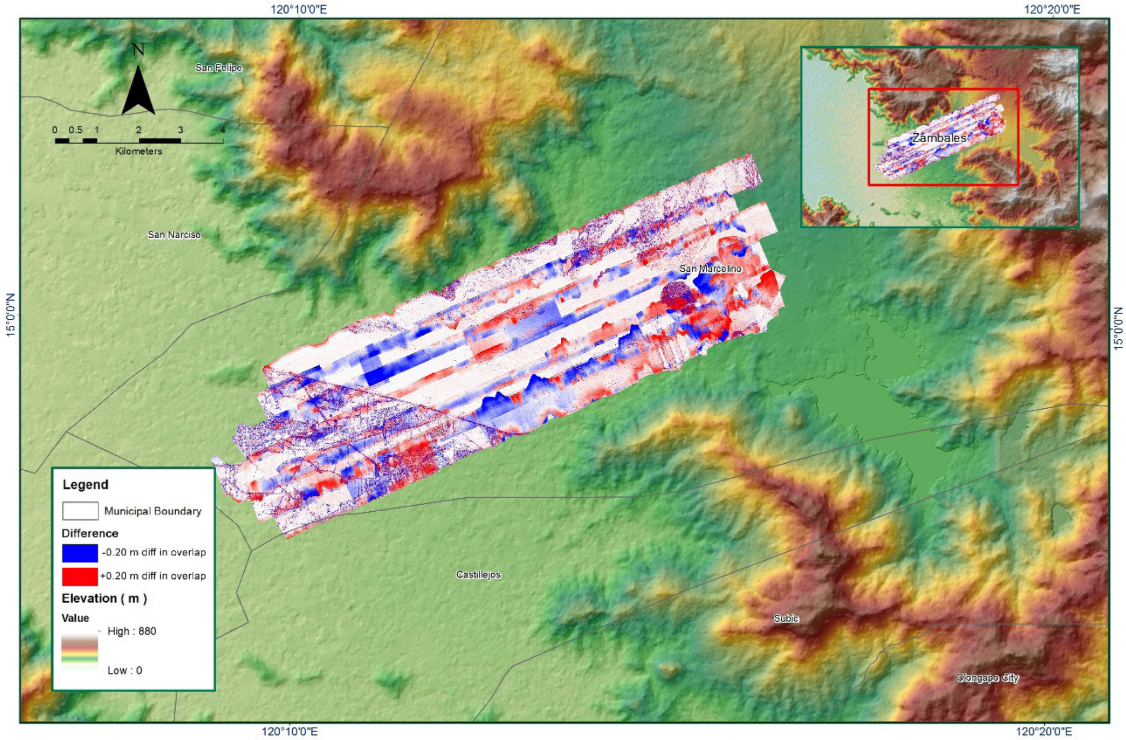


Figure 1.8.7 Elevation Difference Between flight lines

Table A-8.9. Mission Summary Report of Buc_D_Additional

Flight Area	Bataan_Reflights
Mission Name	Buc_D_Additional
Inclusive Flights	2473P
Range data size	16 GB
POS	252 MB
Base Data	4.14 MB
Image	31 GB
Transfer date	March 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.62
RMSE for East Position (<4.0 cm)	1.96
RMSE for Down Position (<8.0 cm)	4.00
Boresight correction stdev (<0.001deg)	0.000380
IMU attitude correction stdev (<0.001deg)	0.000305
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	22.02
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	30
Maximum Height	104.65 m
Minimum Height	45.57 m
Classification (# of points)	
Ground	24,686,859
Low vegetation	16,235,189
Medium vegetation	12,602,700
High vegetation	83,675,37
Building	1,384,866
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga, Jr., Engr. Gladys Mae Apat

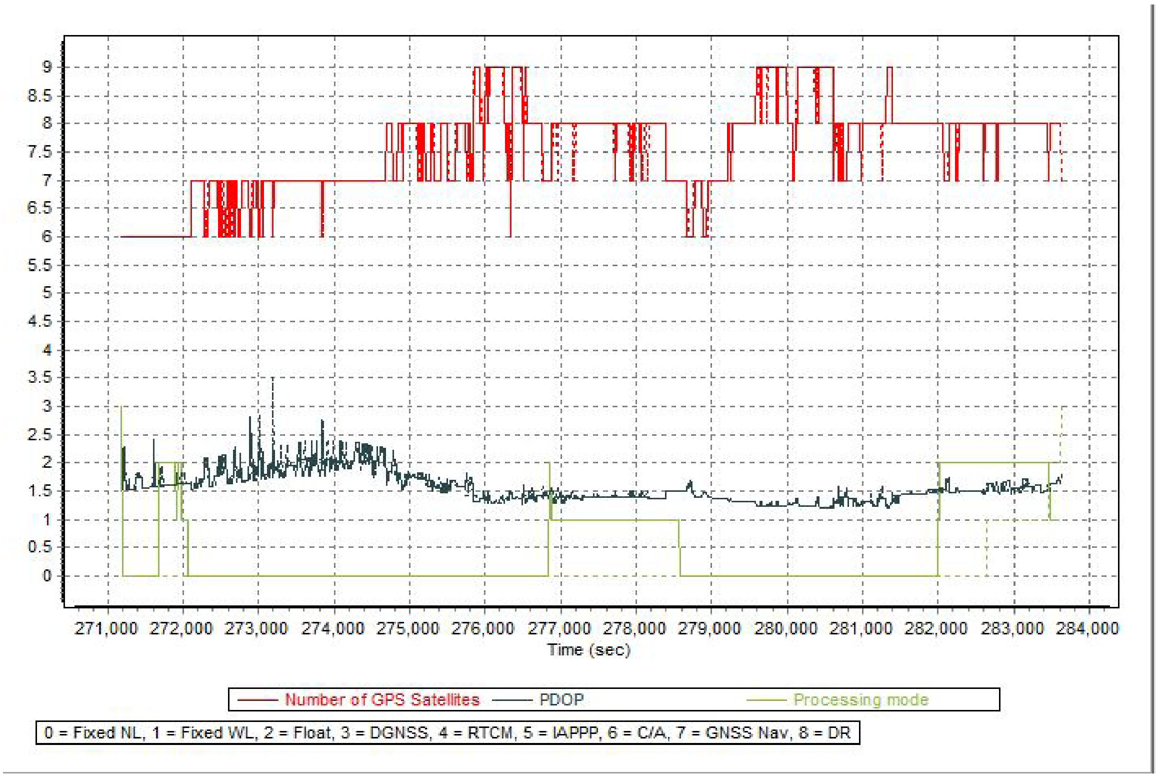


Figure 1.9.1. Solution Status

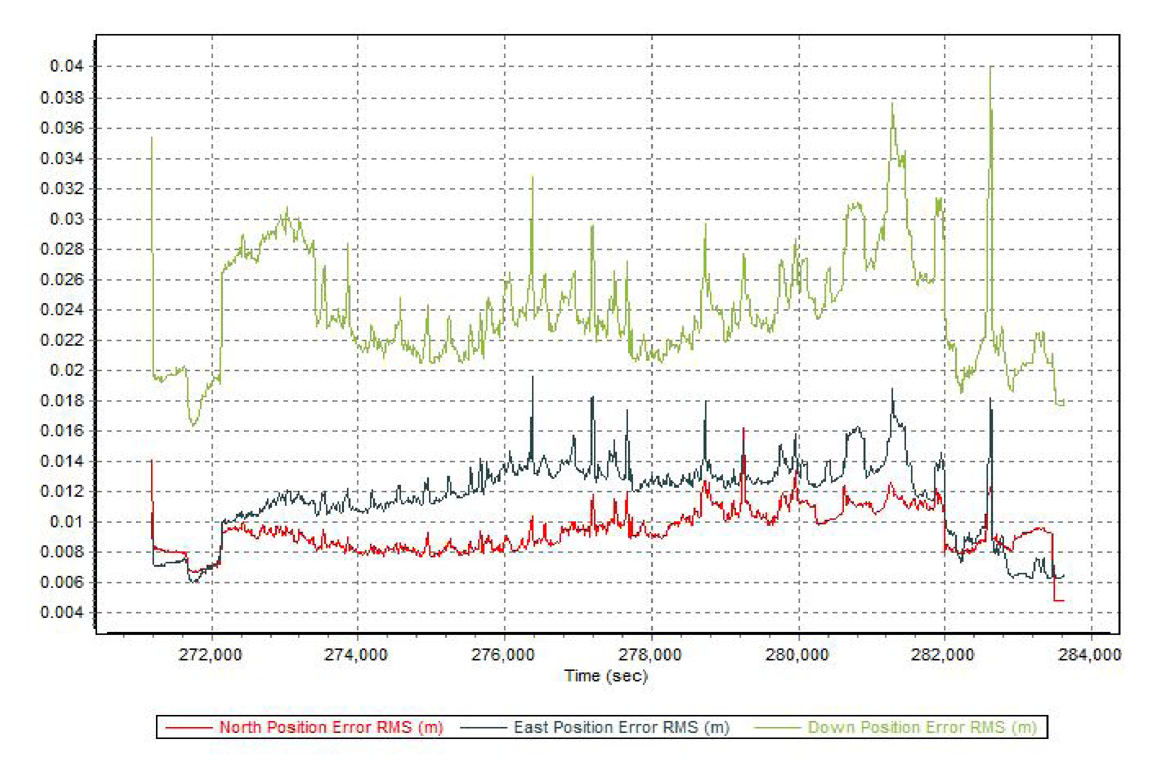


Figure 1.9.2. Smoothed Performance Metric Parameters

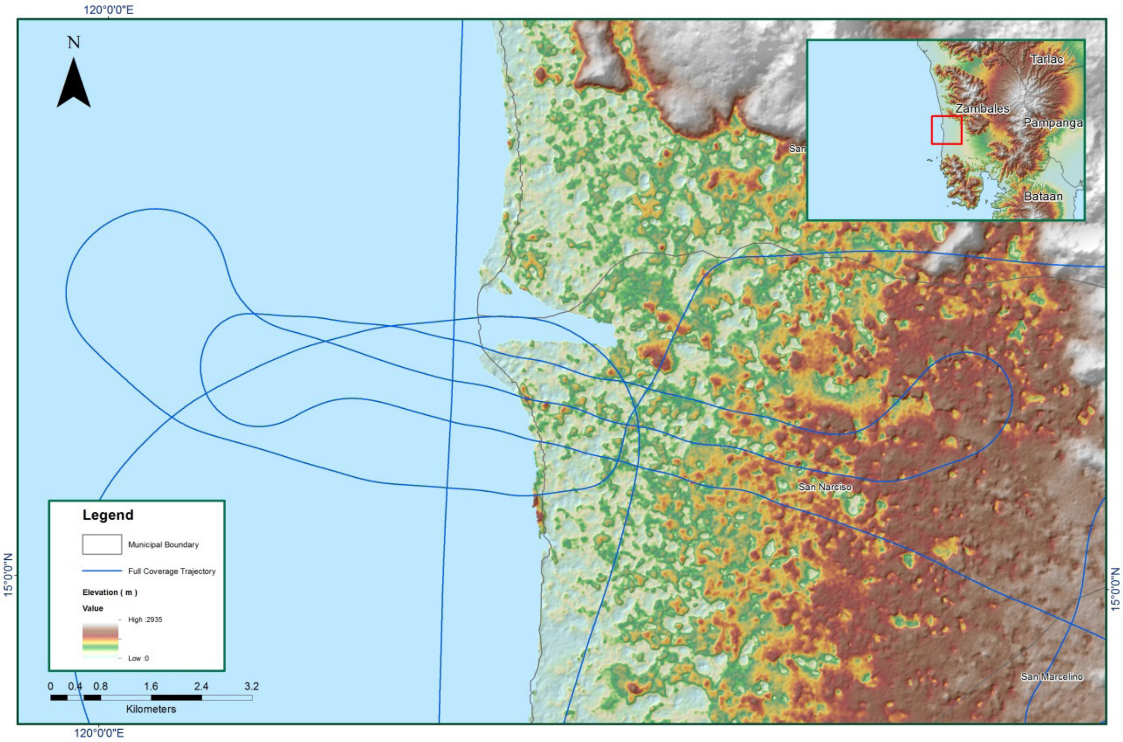


Figure 1.9.3. Best Estimate Trajectory

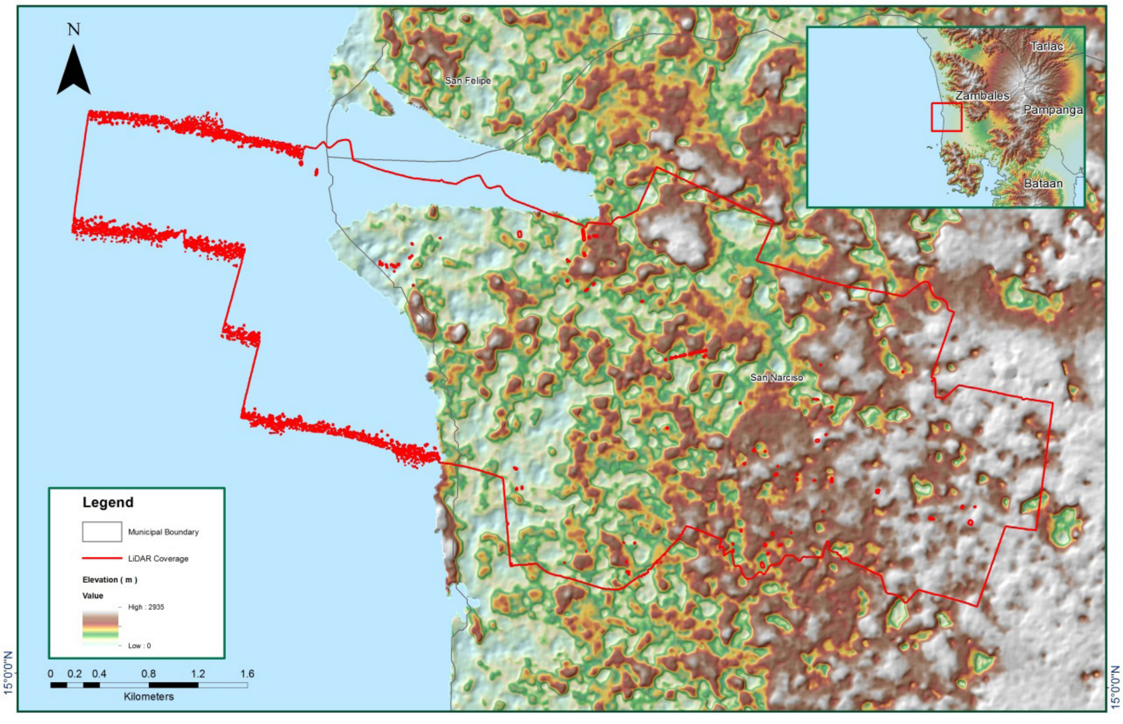


Figure 1.9.4. Coverage of LiDAR data

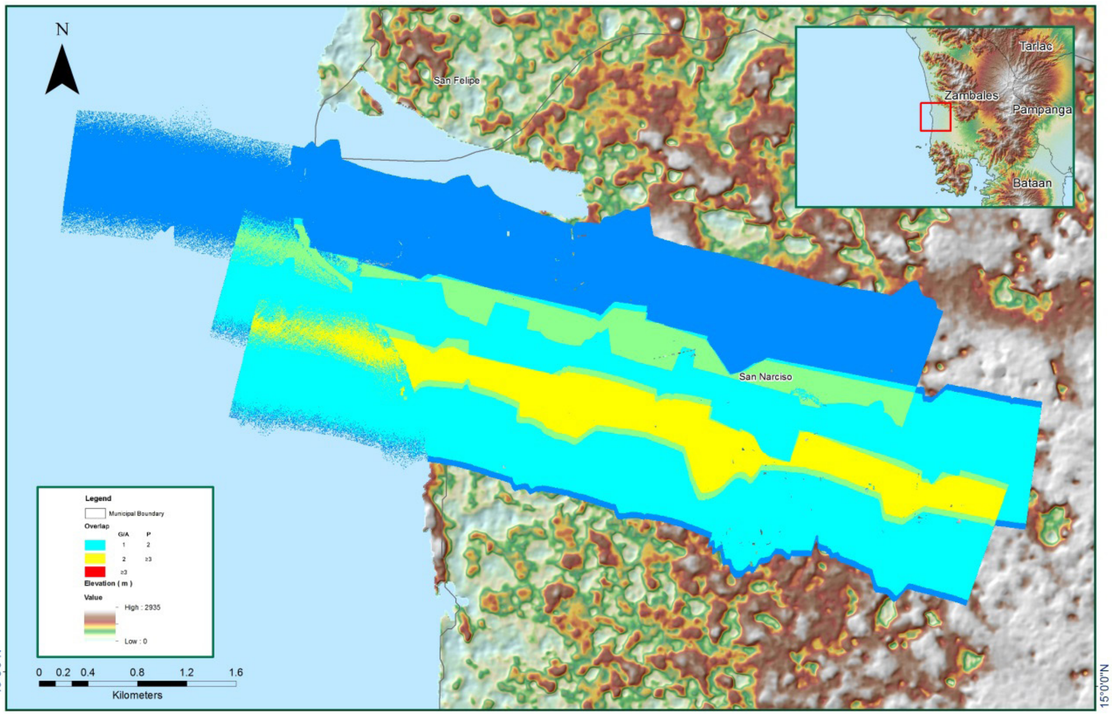


Figure 1.9.5 Image of data overlap

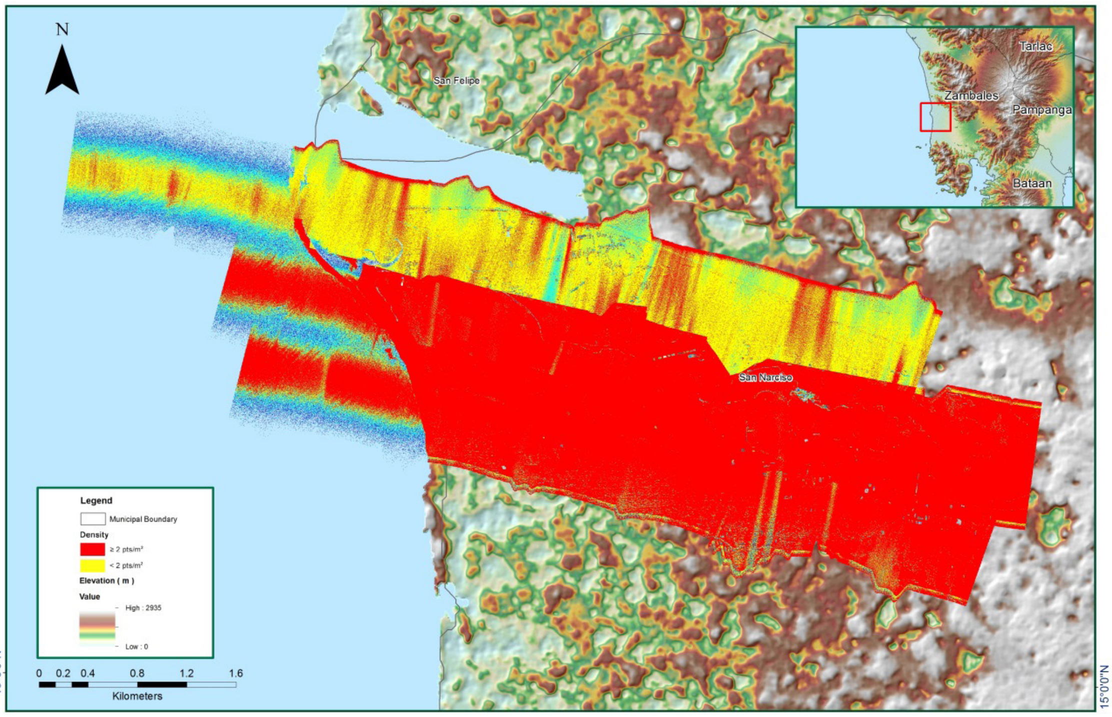


Figure 1.9.6 Density Map of merged LiDAR data

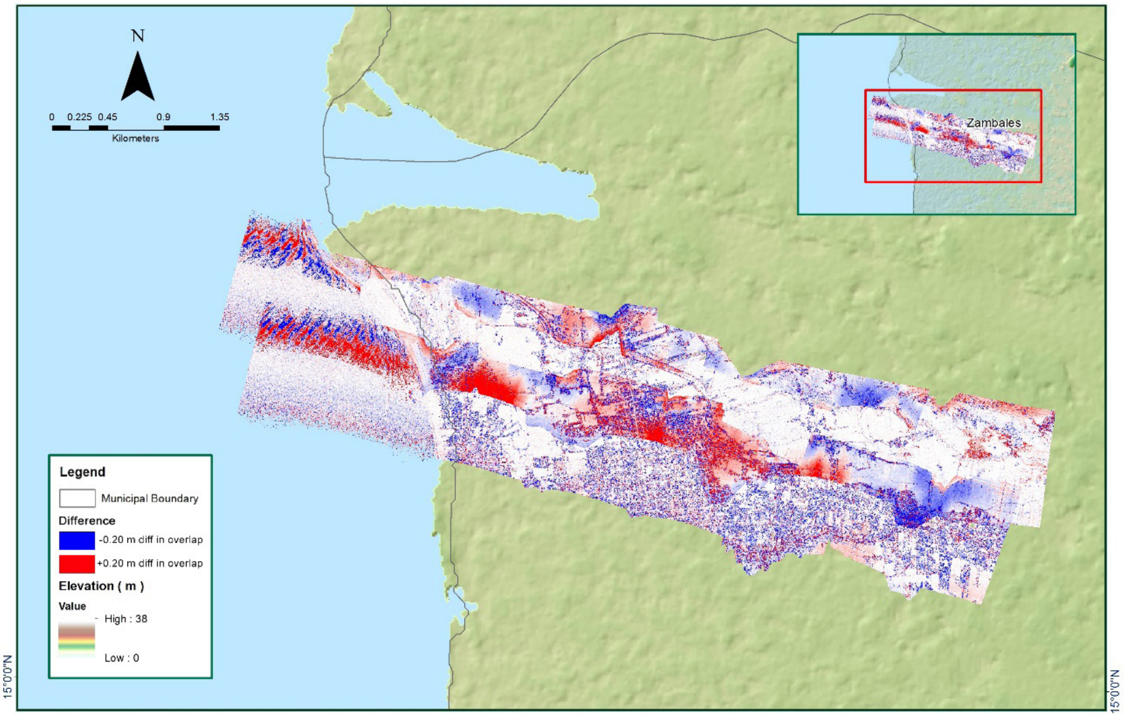


Figure 1.9.7 Elevation Difference Between flight lines

Table A-8.10. Mission Summary Report of Blk Btn_CD

Flight Area	Clark Reflights
Mission Name	Blk Btn_CD
Inclusive Flights	2658G
Range data size	13.3 GB
POS	232 MB
Base Data	94.8 MB
Image	11.6 GB
Transfer date	August 27, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.55
RMSE for East Position (<4.0 cm)	2.20
RMSE for Down Position (<8.0 cm)	4.50
Boresight correction stdev (<0.001deg)	0.000479
IMU attitude correction stdev (<0.001deg)	0.001994
GPS position stdev (<0.01m)	0.0252
Minimum % overlap (>25)	31.52%
Ave point cloud density per sq.m. (>2.0)	4.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	138
Maximum Height	756.92 m
Minimum Height	42.19 m
Classification (# of points)	
Ground	38,589,084
Low vegetation	28,474,542
Medium vegetation	130,248,906
High vegetation	125,243,729
Building	1,746,717
Orthophoto	No
Processed by	Engr. Irish Cortez, Aljon Rie Araneta, Kathryn Claudyn Zarate

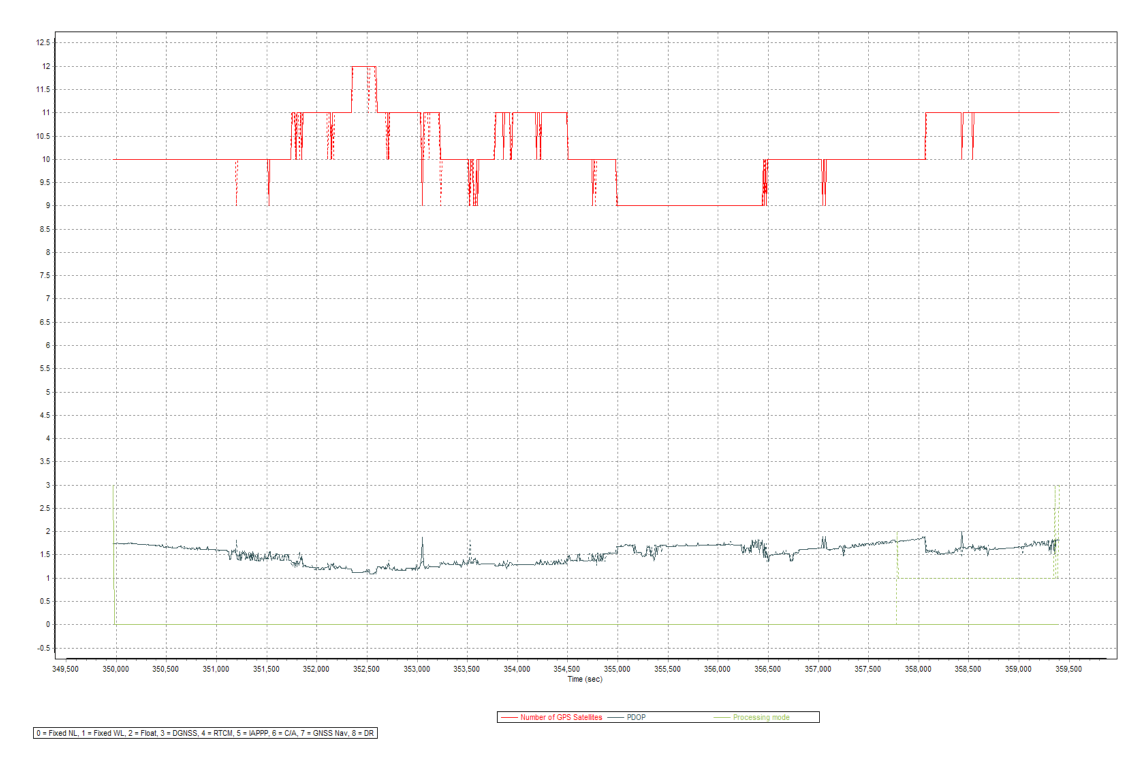


Figure 1.10.1 Solution Status

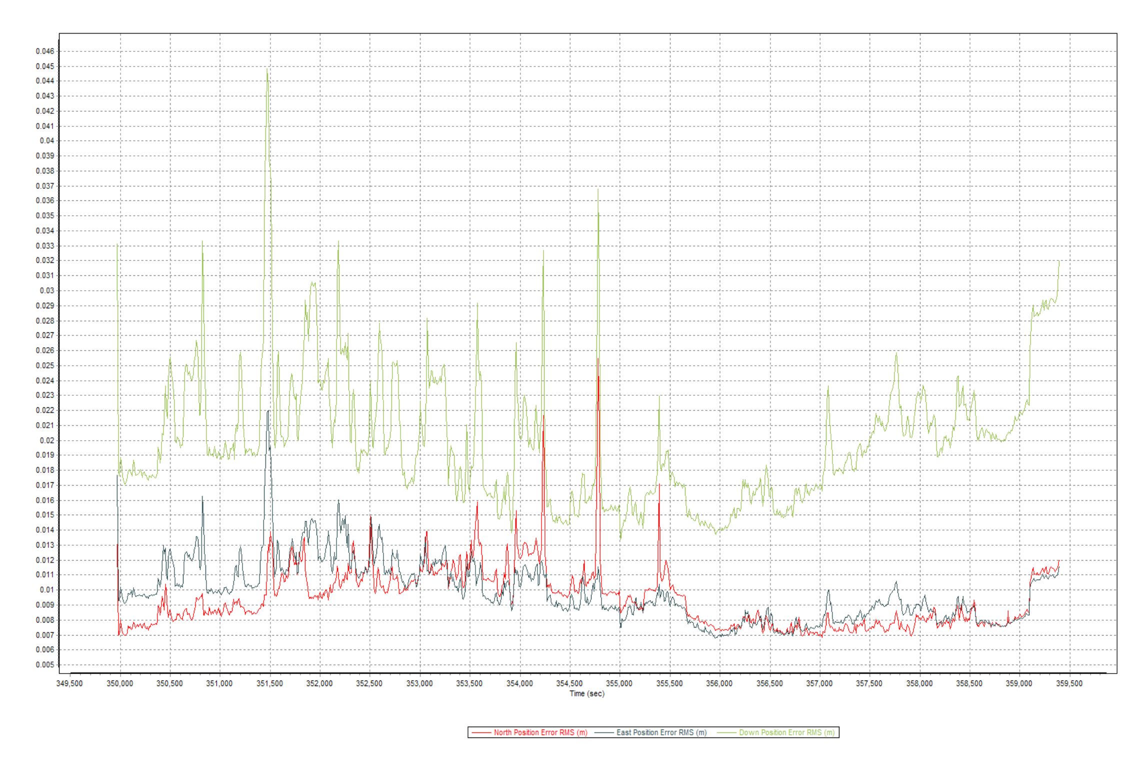


Figure 1.10.2 Smoothed Performance Metric Parameters

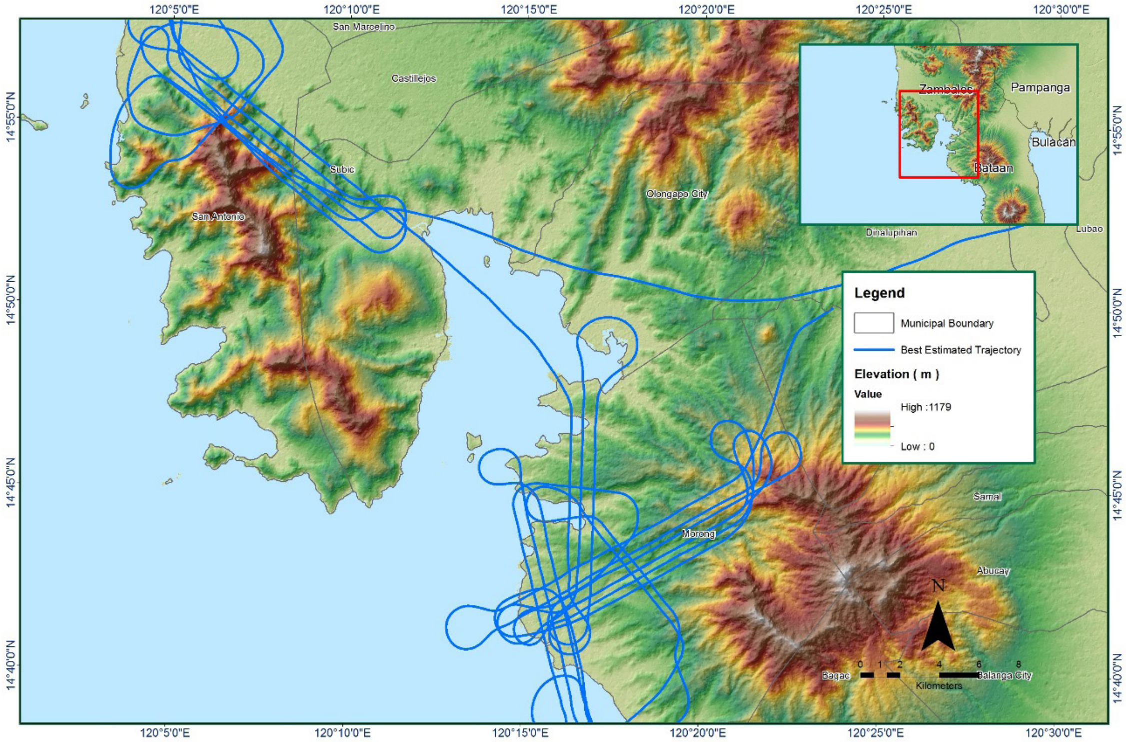


Figure 1.10.3 Best Estimated Trajectory

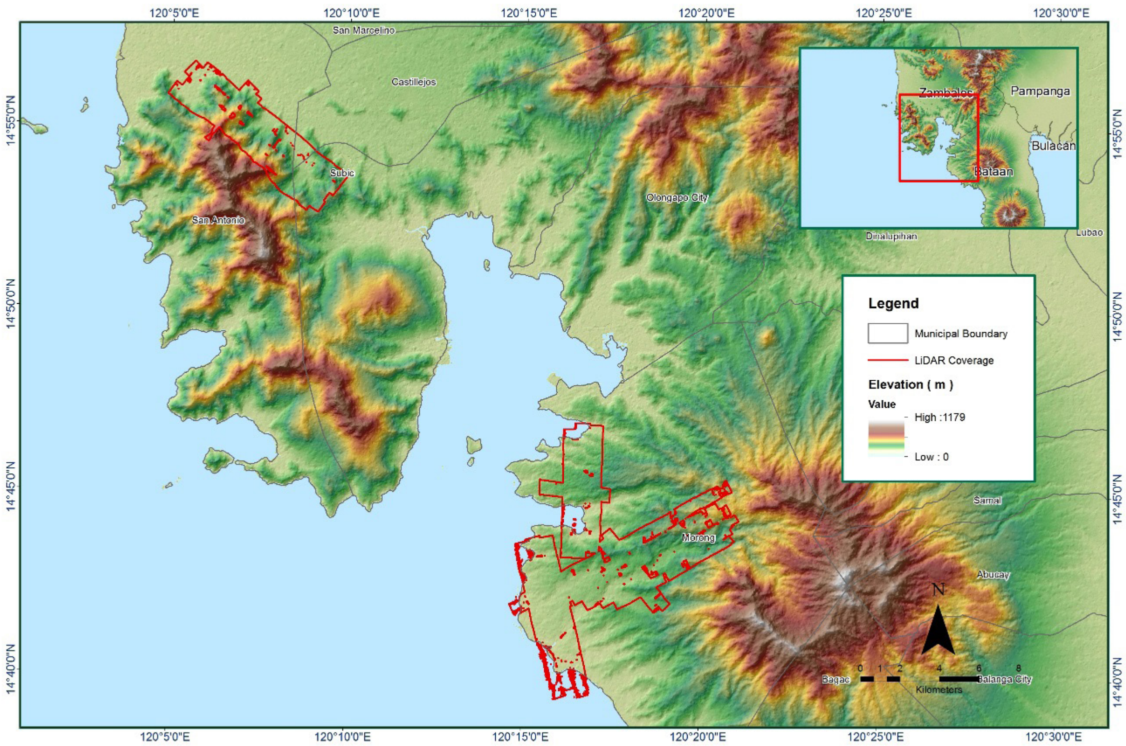


Figure 1.10.4 Coverage of LiDAR data

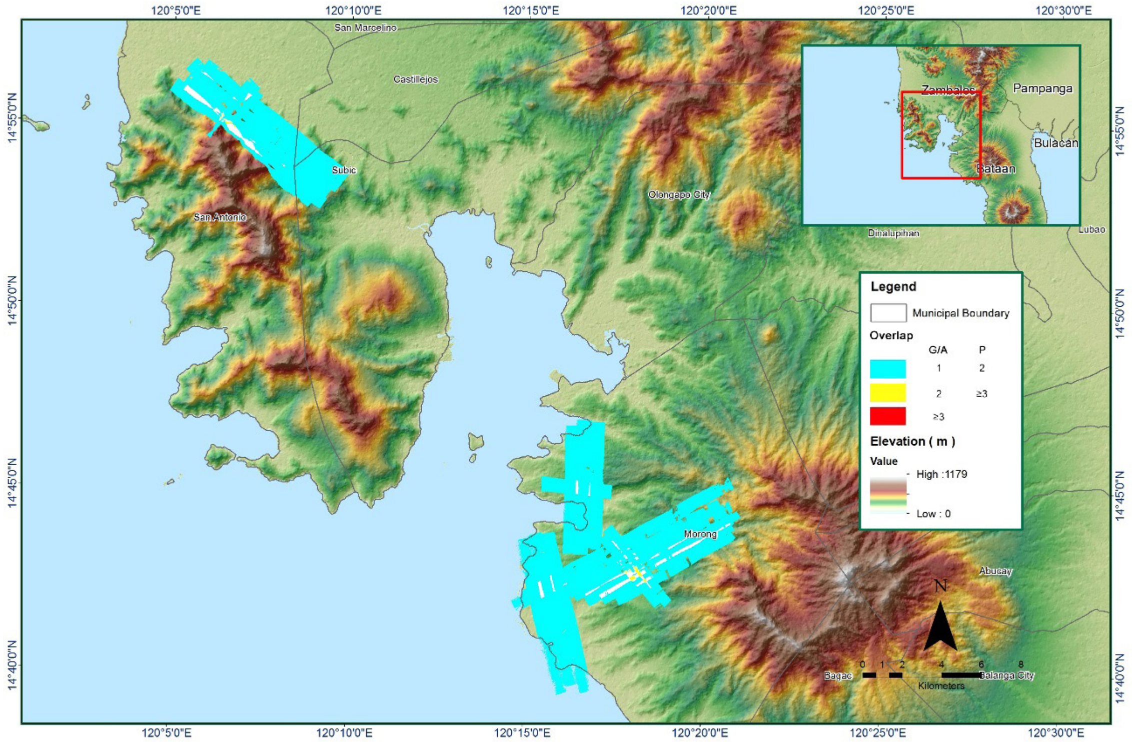


Figure 1.10.5 Image of data overlap

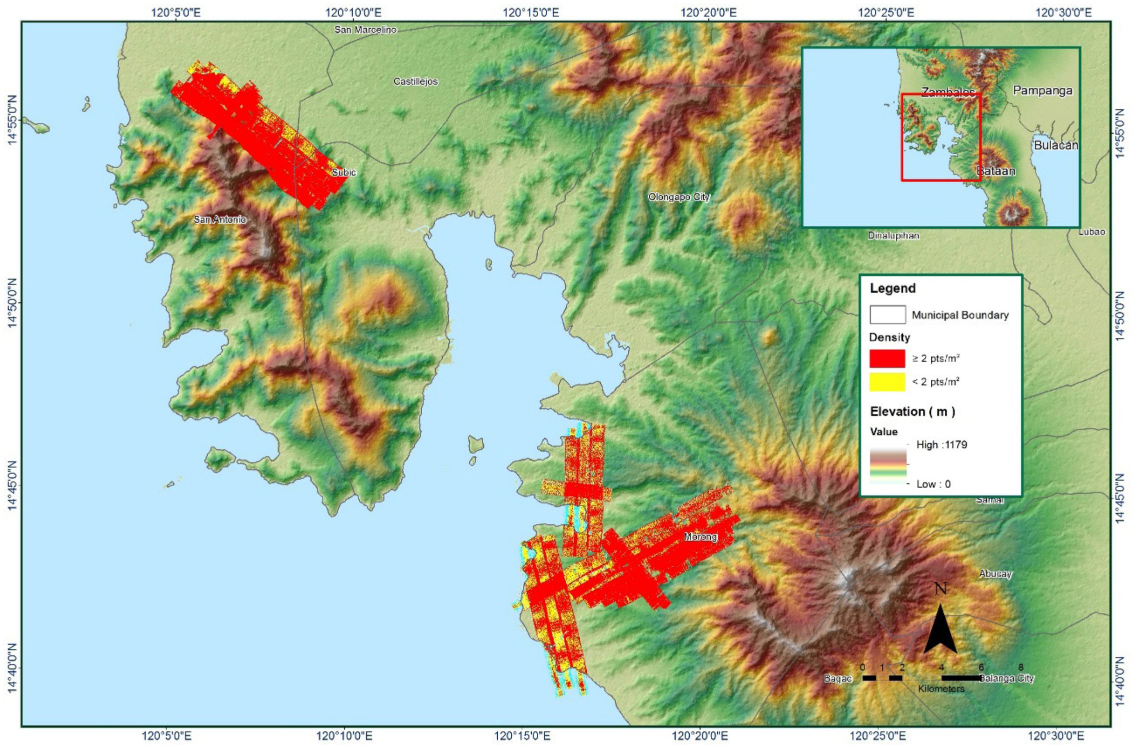


Figure 1.10.6 Density map of merged LiDAR data

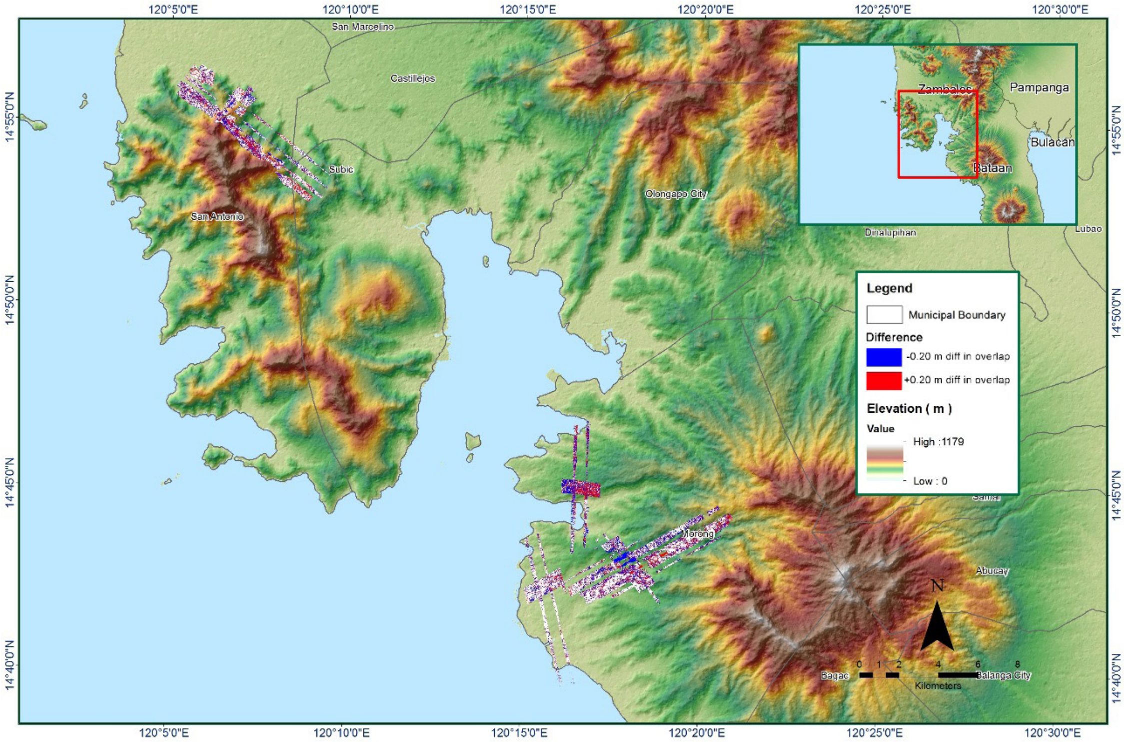


Figure 1.10.7 Elevation difference between flight lines

Table A-8.11. Mission Summary Report of Blk15D

Flight Area	Mt.Arayat
Mission Name	Blk15D
Inclusive Flights	7047GC
Range data size	3.64 GB
POS	138 MB
Base data size	2.42 MB
Image	n/a
Transfer date	February 18, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.001382
IMU attitude correction stdev (<0.001deg)	0.031992
GPS position stdev (<0.01m)	0.0100
Minimum % overlap (>25)	66.52%
Ave point cloud density per sq.m. (>2.0)	0.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	173
Maximum Height	1,089.72 m
Minimum Height	44.10 m
Classification (# of points)	
Ground	88,310,015
Low vegetation	25,359,149
Medium vegetation	57,417,987
High vegetation	65,943,730
Building	1,296,535
Orthophoto	No
Processed by	Victoria Rejuso, Aljon Rie Araneta, Engr. Gladys Mae Apat

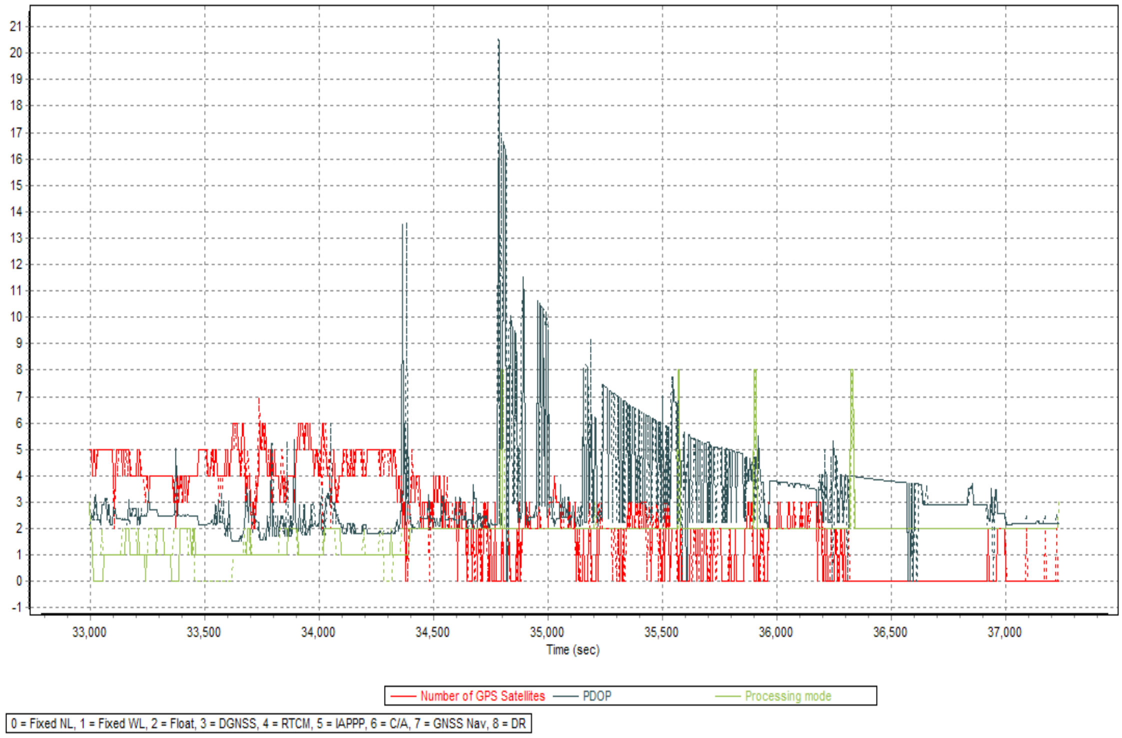


Figure 1.11.1 Solution Status

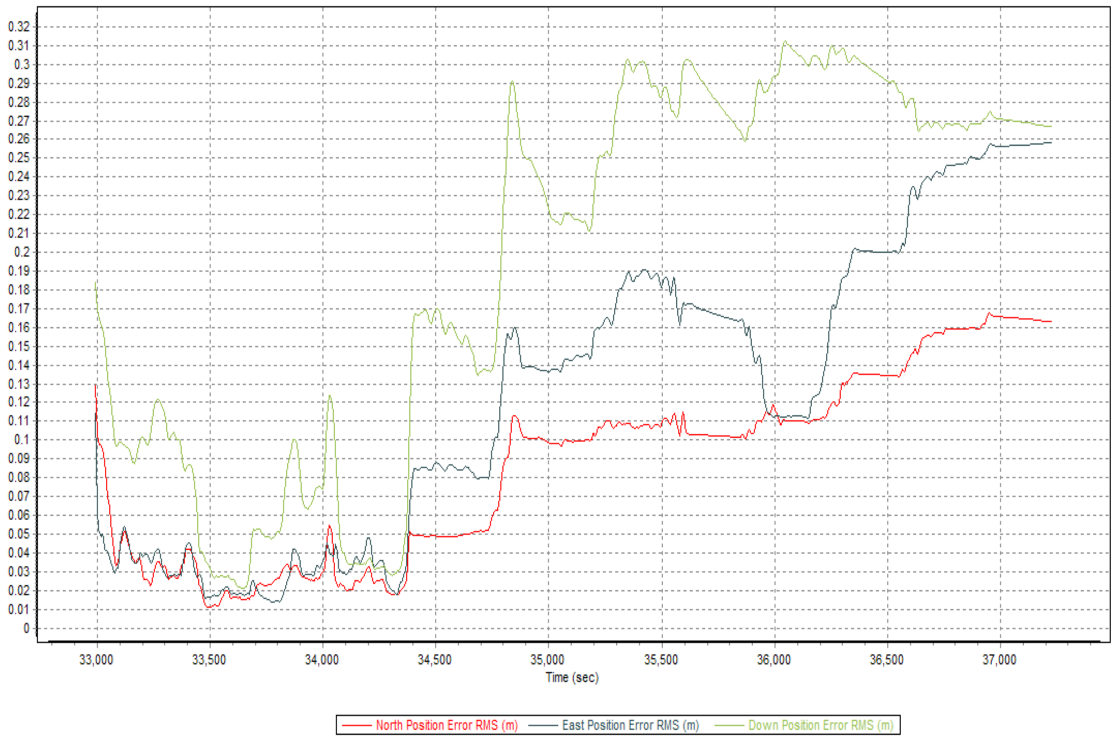


Figure 1.11.2 Smoothed Performance Metric Parameters

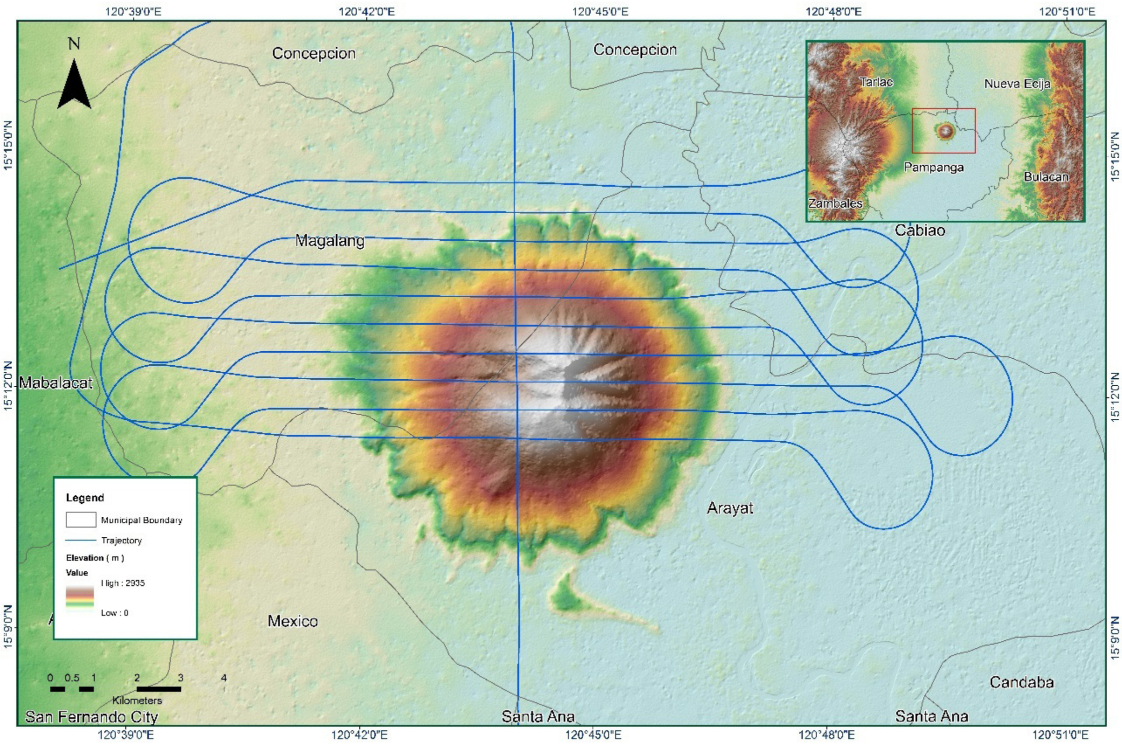


Figure 1.11.3 Best Estimated Trajectory

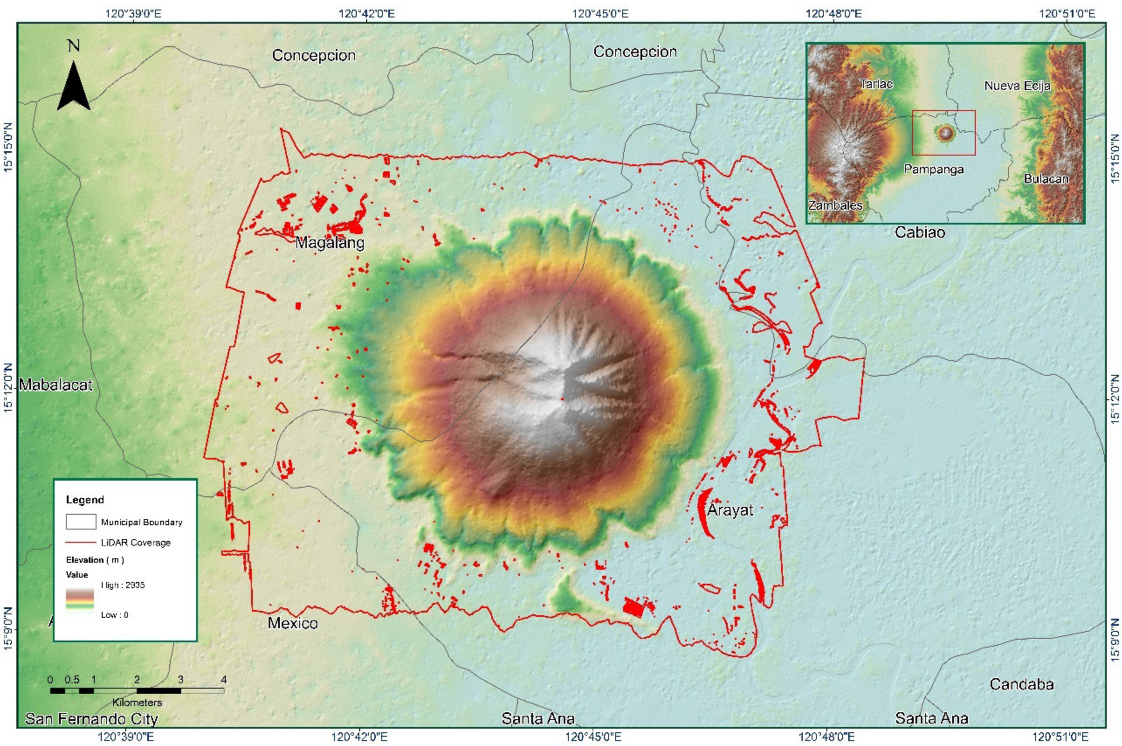


Figure 1.11.4 Coverage of LIDAR data

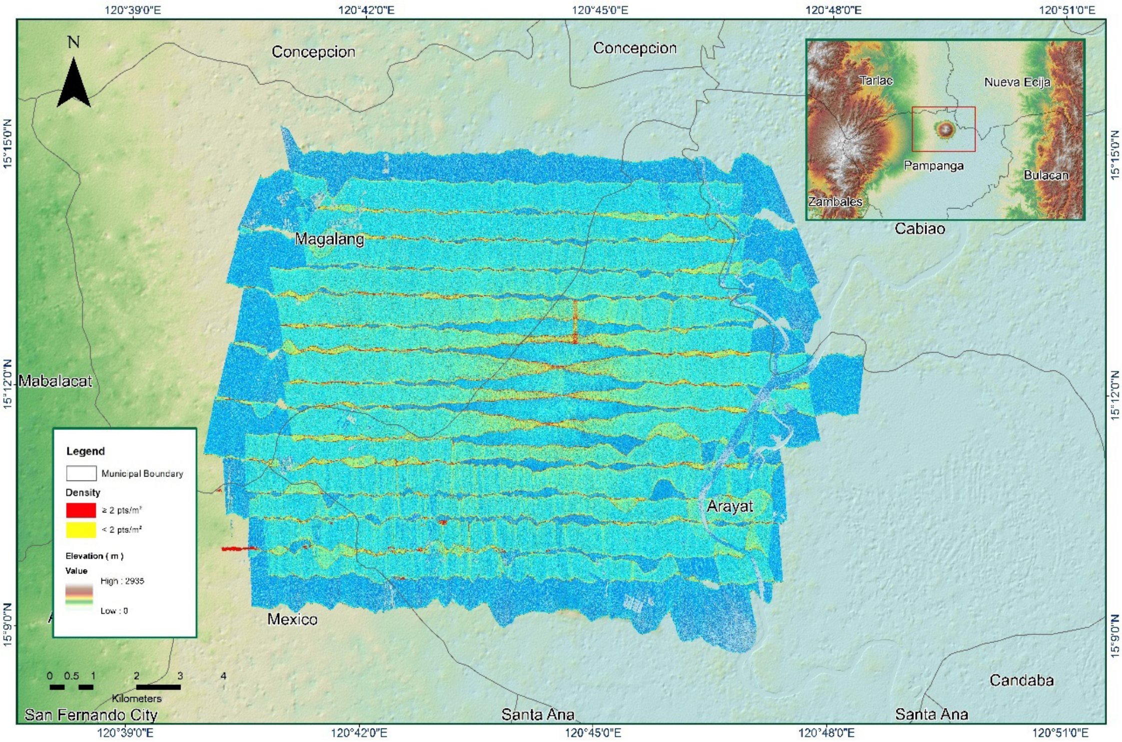


Figure 1.11.5 Image of Data Overlap

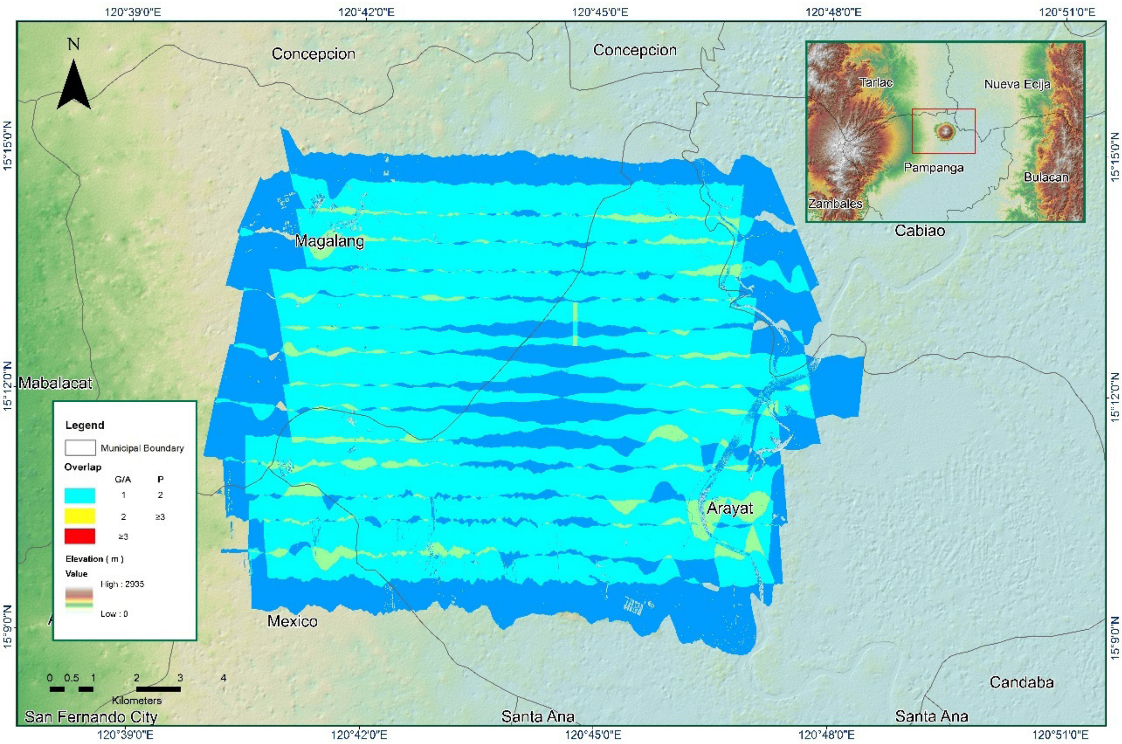


Figure 1.11.6 Density map of merged LIDAR data

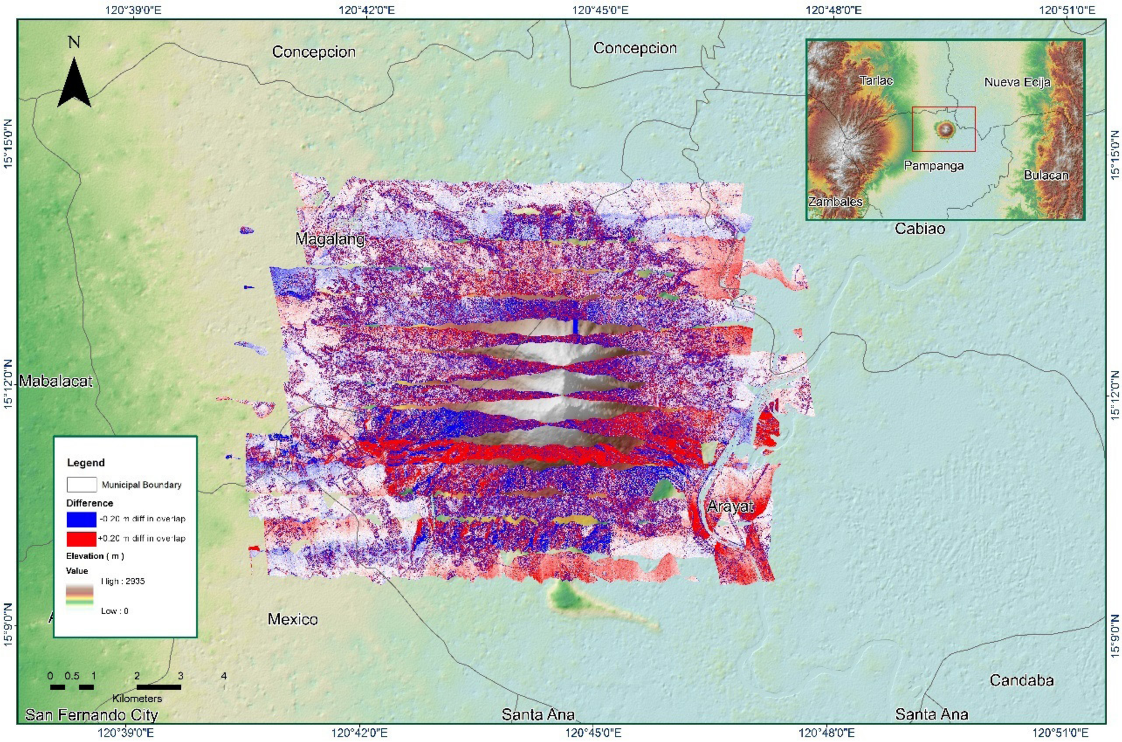


Figure 1.1.7 Elevation difference between flight lines

Table A-8.12. Mission Summary Report of Blk Pam7C_reflight

Flight Area	Pam_Agno_Reflights
Mission Name	Blk Pam7C_reflight
Inclusive Flights	7255GC
Range data size	6.45 GB
POS data size	121 MB
Base data size	7.17 MB
Image	NA
Transfer date	May 26, 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)	0.86
RMSE for East Position (<4.0 cm)	1.00
RMSE for Down Position (<8.0 cm)	1.54
Boresight correction stdev (<0.001deg)	0.000185
IMU attitude correction stdev (<0.001deg)	0.000993
GPS position stdev (<0.01m)	0.0137
Minimum % overlap (>25)	19.50
Ave point cloud density per sq.m. (>2.0)	3.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	50
Maximum Height	296.43 m
Minimum Height	49.81 m
Classification (# of points)	
Ground	173,370,957
Low vegetation	22,475,188
Medium vegetation	21,173,353
High vegetation	8,849,634
Building	1,524,855
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Charmaine Cruz, Engr. John Dill Macapagal

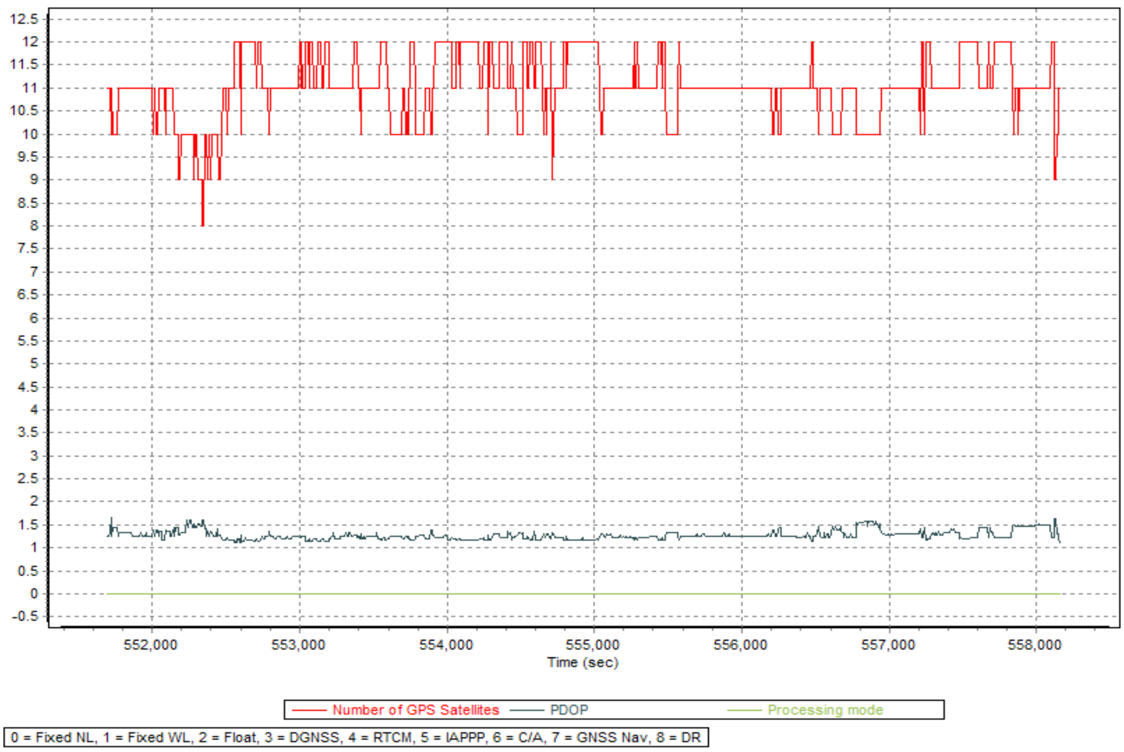


Figure 1.12.1. Solution Status

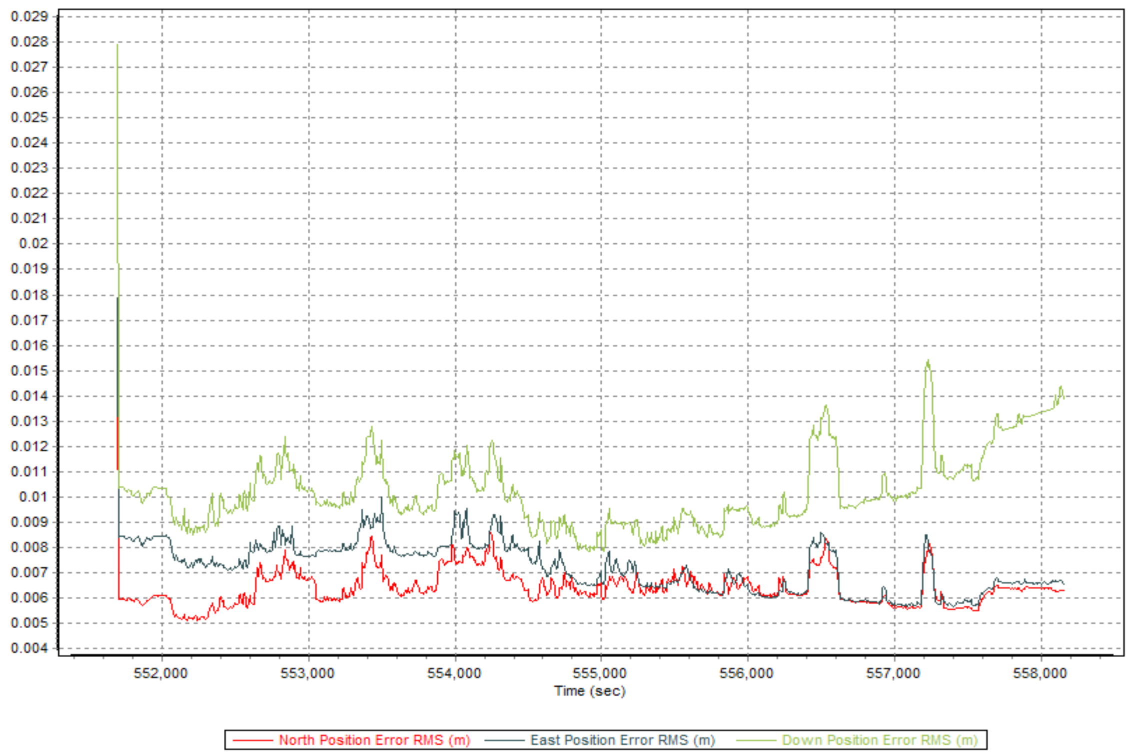


Figure 1.12.2. Smoothed Performance Metric Parameters

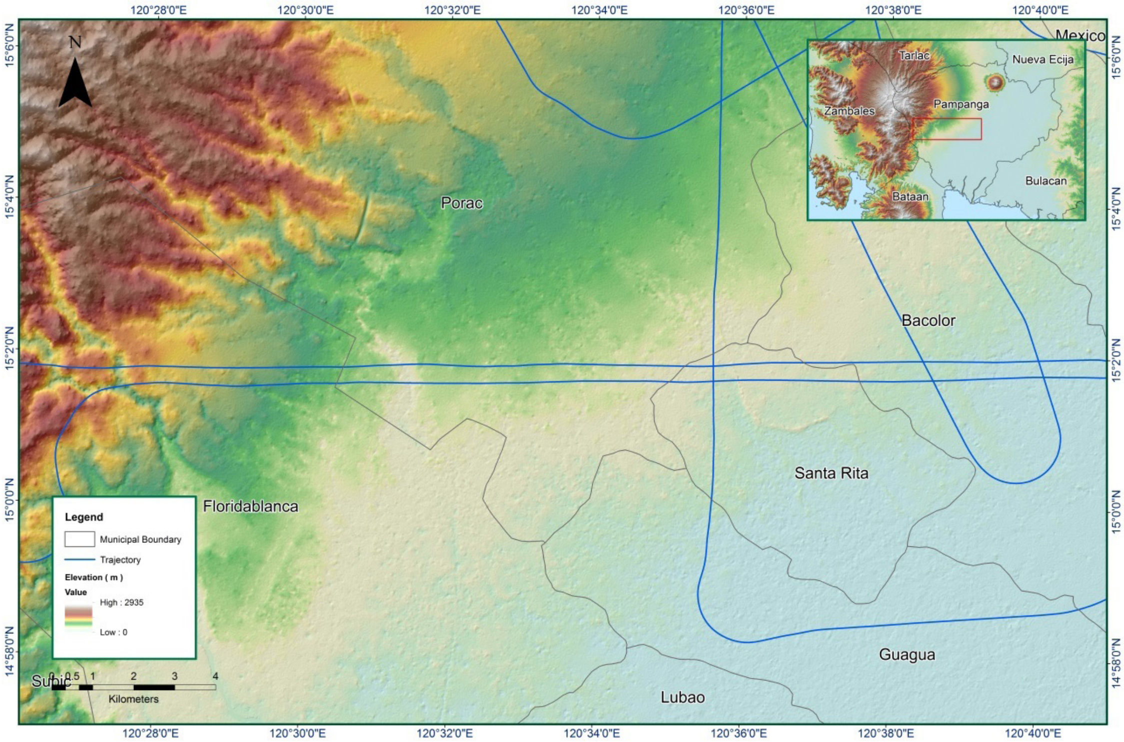


Figure 1.12.3. Best Estimated Trajectory

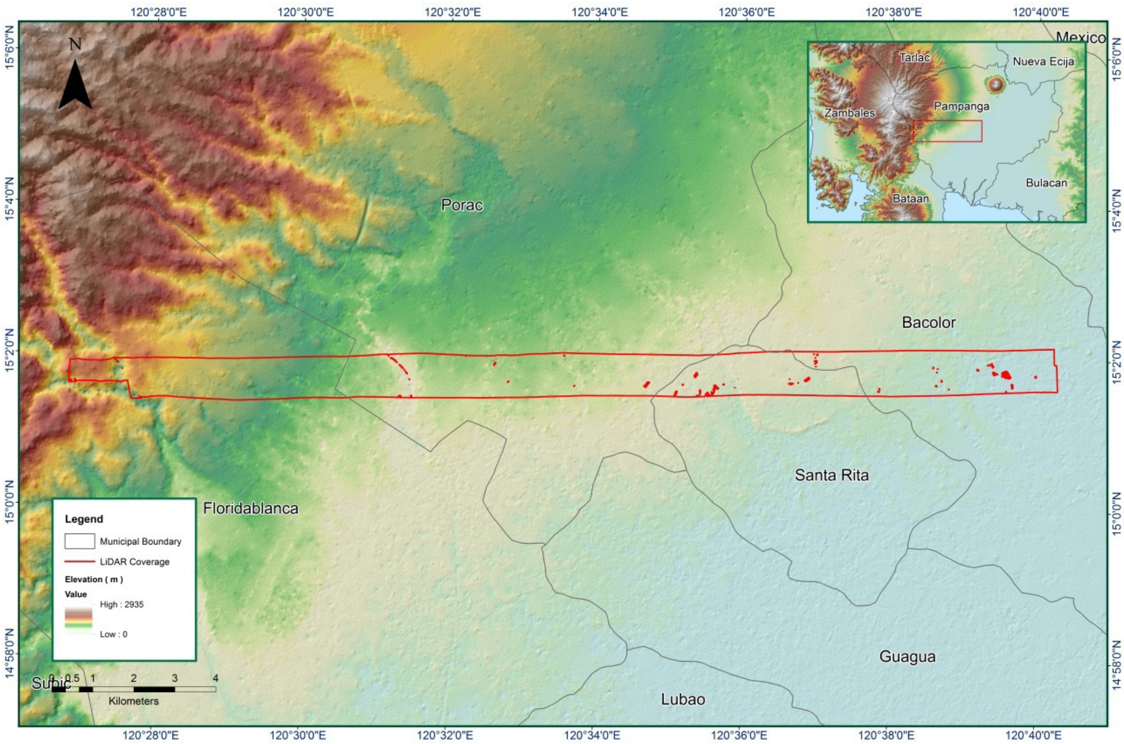


Figure 1.12.4. Coverage of LiDAR Data

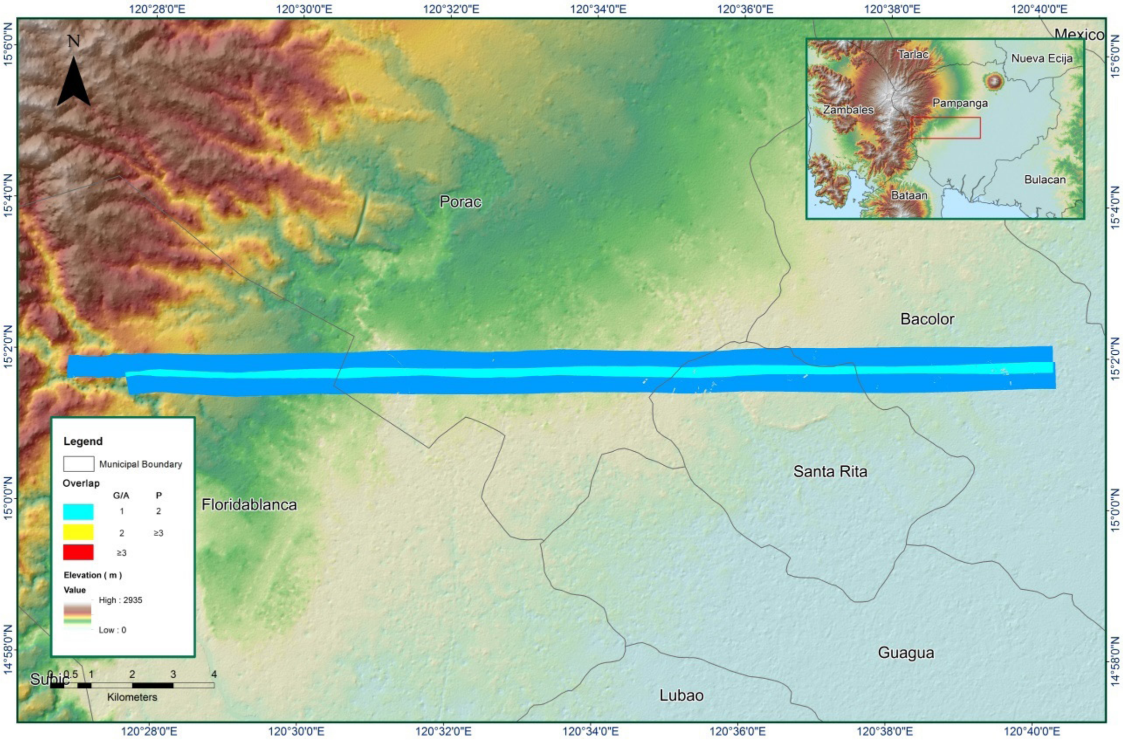


Figure 1.12.5. Image of data overlap

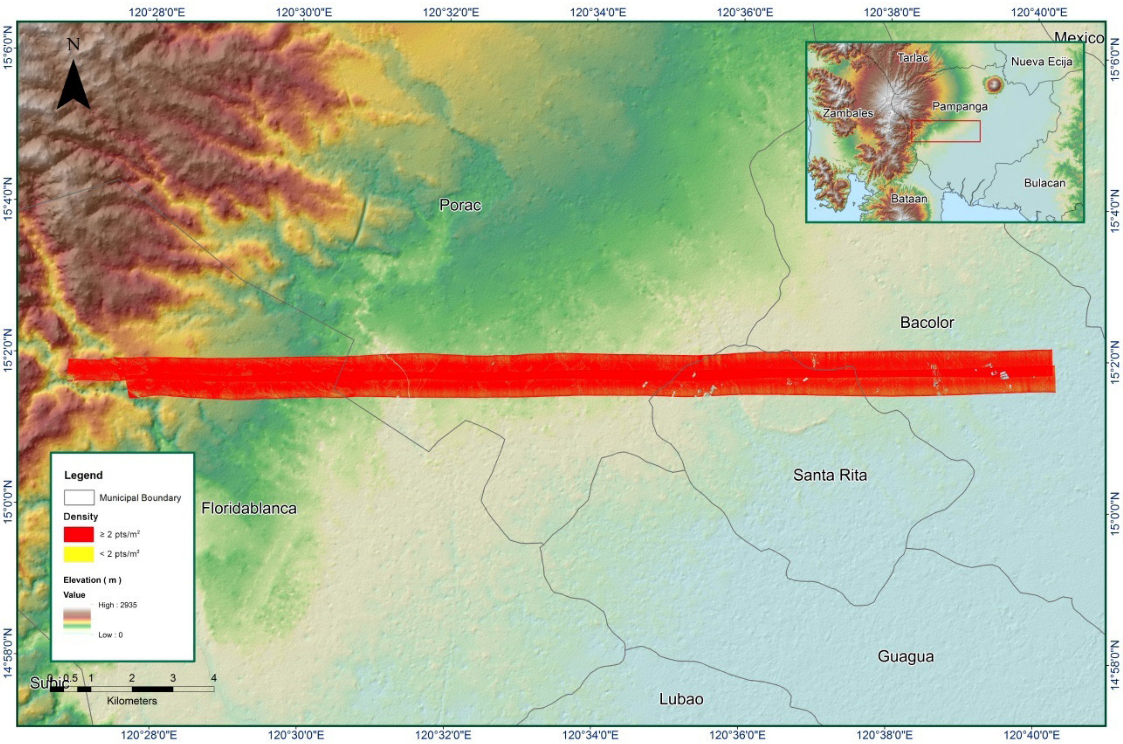


Figure 1.12.6. Density map of merged LiDAR data

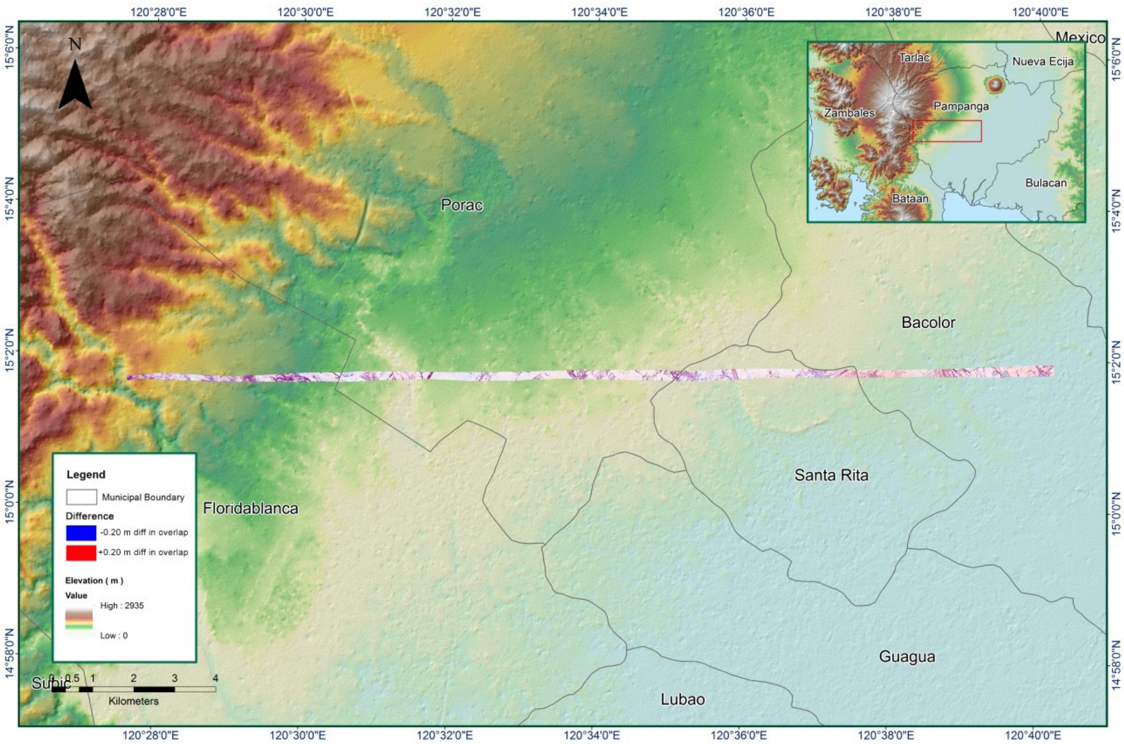


Figure 1.12.7. Elevation difference between flight lines

Table A-8.13. Mission Summary Report of Blk Pam7A_reflight

Flight Area	Pam_Agno_Reflights
Mission Name	Blk Pam7A_reflight
Inclusive Flights	7255GC
Range data size	6.45 GB
POS data size	121 MB
Base data size	7.17 MB
Image	NA
Transfer date	May 26, 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)	0.86
RMSE for East Position (<4.0 cm)	1.00
RMSE for Down Position (<8.0 cm)	1.54
Boresight correction stdev (<0.001deg)	0.000185
IMU attitude correction stdev (<0.001deg)	0.000993
GPS position stdev (<0.01m)	0.0137
Minimum % overlap (>25)	45.07
Ave point cloud density per sq.m. (>2.0)	4.42
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	35
Maximum Height	290.46 m
Minimum Height	113.36 m
Classification (# of points)	
Ground	12,311,736
Low vegetation	19,301,565
Medium vegetation	15,314,078
High vegetation	8,566,649
Building	7,479,984
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Edgardo Gubatanga, Jr., Engr. Jeffrey Delica

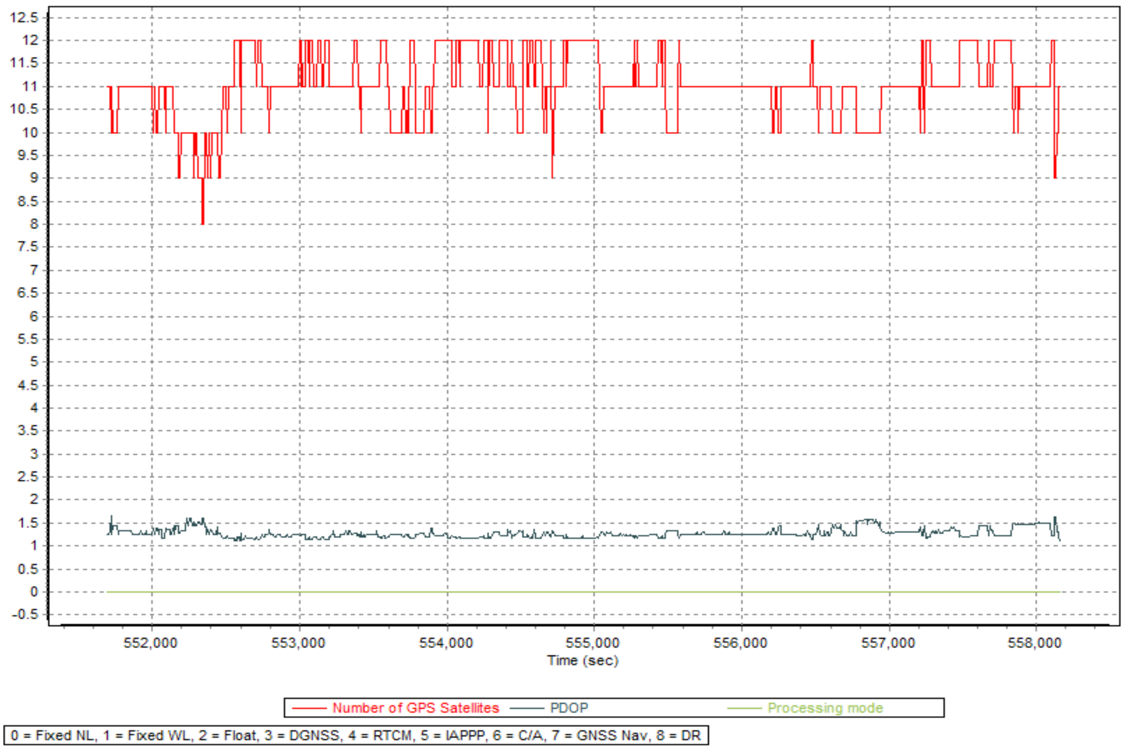


Figure 1.13.1. Solution Status

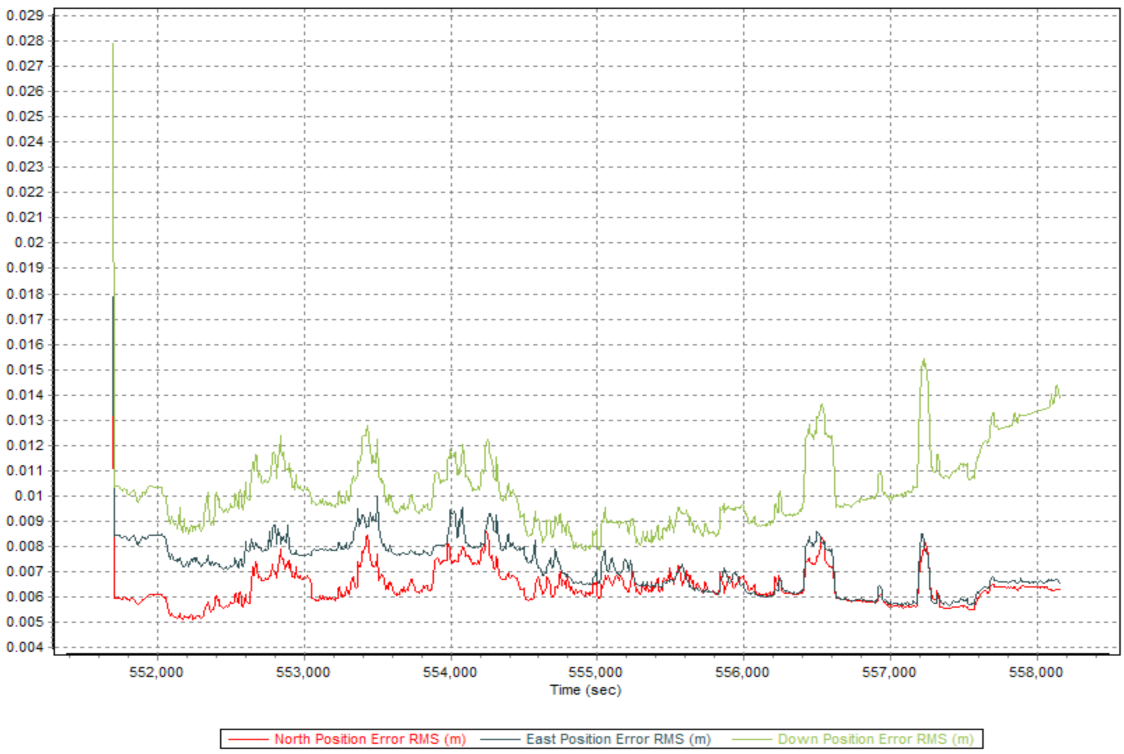


Figure 1.13.2. Smoothed Performance Metric Parameters

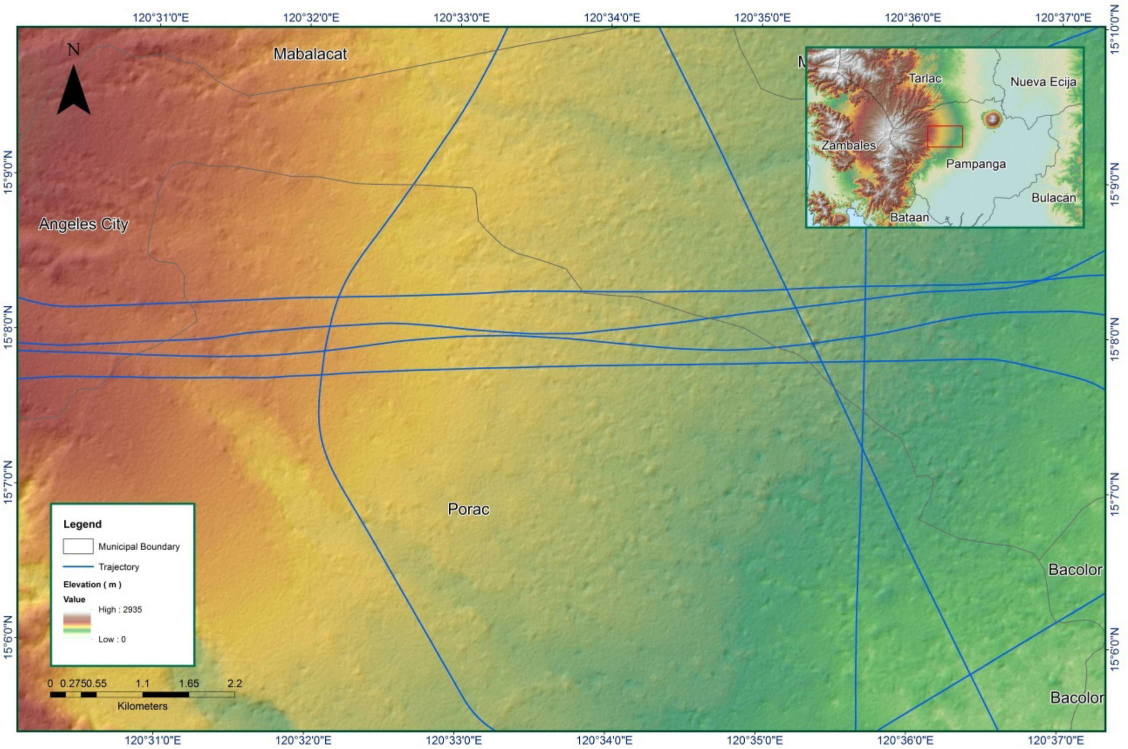


Figure 1.13.3. Best Estimated Trajectory

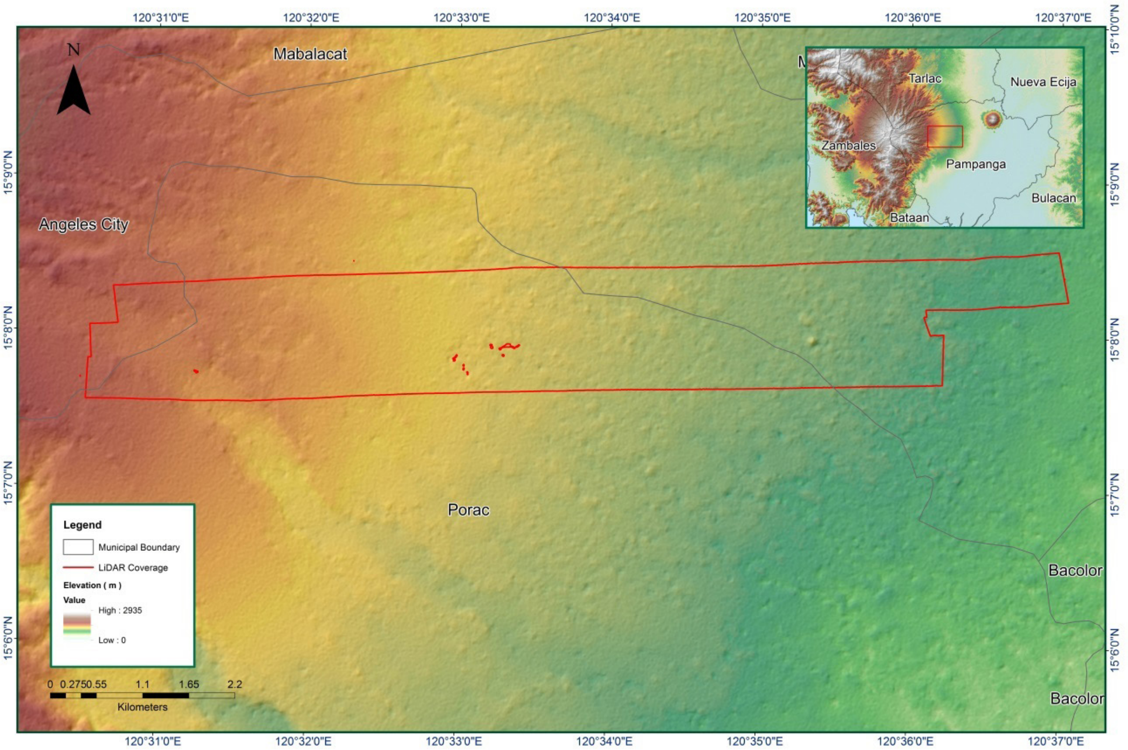


Figure 1.13.4. Coverage of LiDAR Data

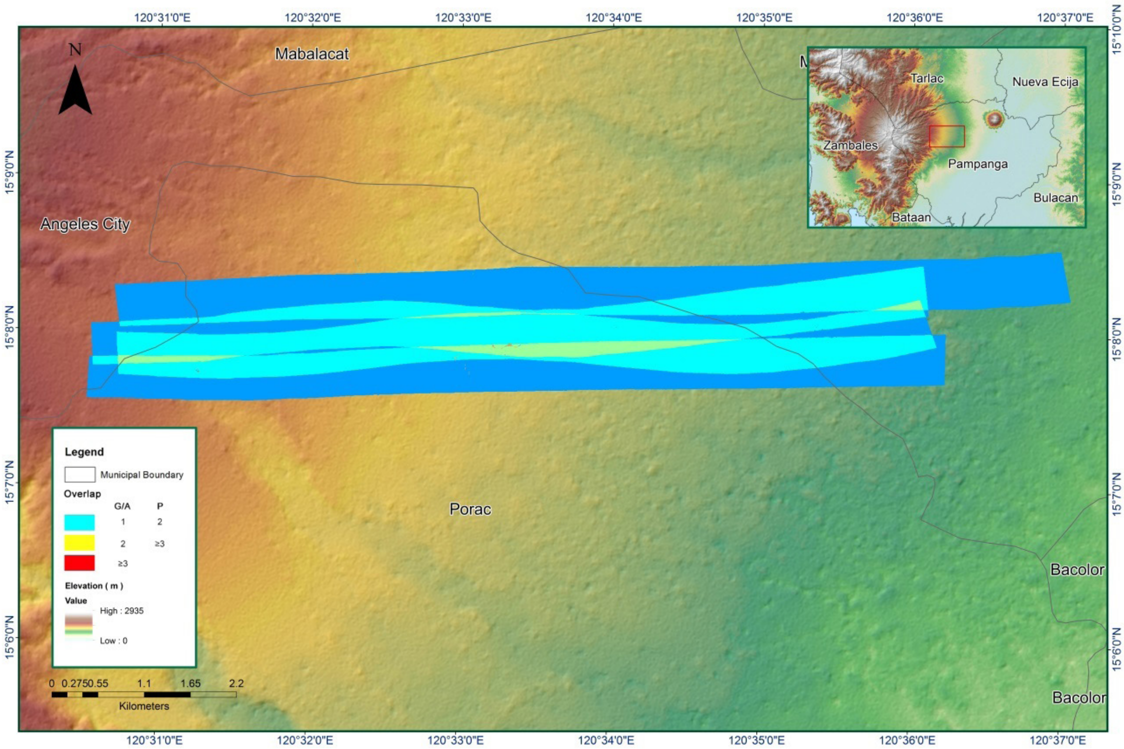


Figure 1.13.5. Image of data overlap

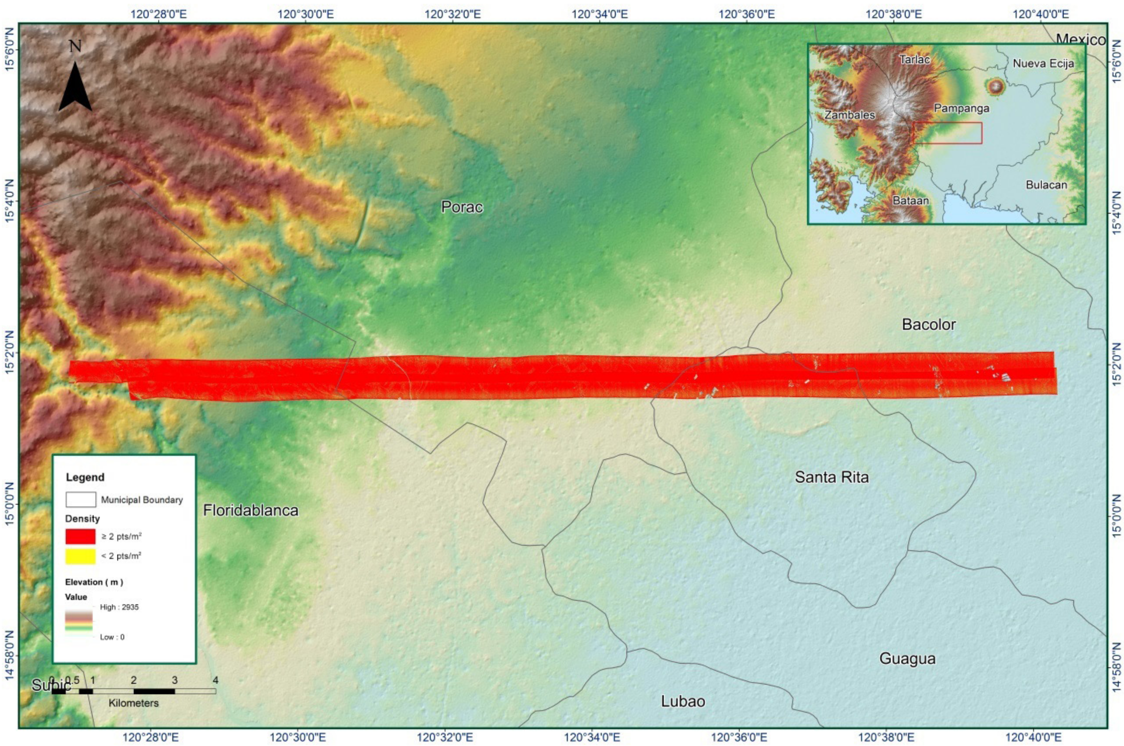


Figure 1.13.6. Density map of merged LiDAR data

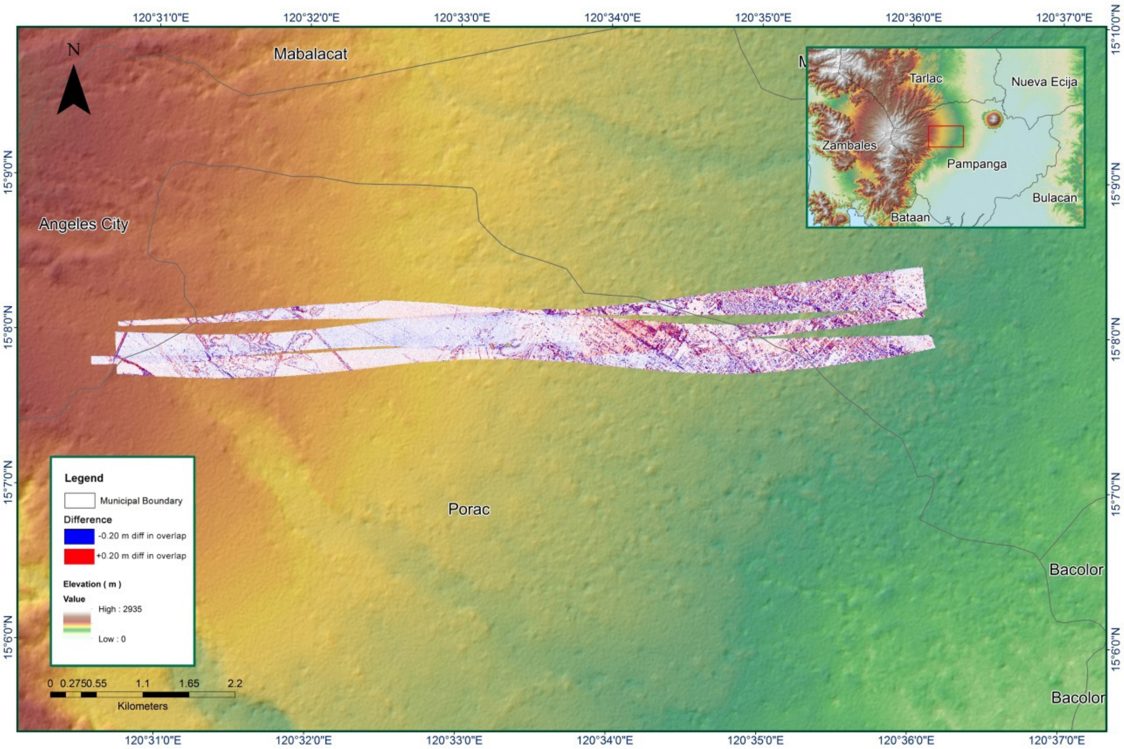


Figure** 1.13.**7. Elevation difference between flight lines

Table A-8.14. Mission Summary Report of Blk lower_Buc_reflights

Flight Area	Pam_Agno_Reflights
Mission Name	Blk lower_Buc_reflights
Inclusive Flights	7264GC
Range data size	8.92 GB
POS data size	205 MB
Base data size	6.63 MB
Image	NA
Transfer date	May 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.975
RMSE for East Position (<4.0 cm)	0.98
RMSE for Down Position (<8.0 cm)	2.20
Boresight correction stdev (<0.001deg)	0.000286
IMU attitude correction stdev (<0.001deg)	0.000704
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	46.58
Ave point cloud density per sq.m. (>2.0)	3.14
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	70
Maximum Height	439.71 m
Minimum Height	45.14 m
Classification (# of points)	
Ground	30,007,256
Low vegetation	31,279,102
Medium vegetation	14,432,172
High vegetation	19,439,962
Building	1,915,136
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Mark Joshua Salvacion, Engr. Jeffrey Delica

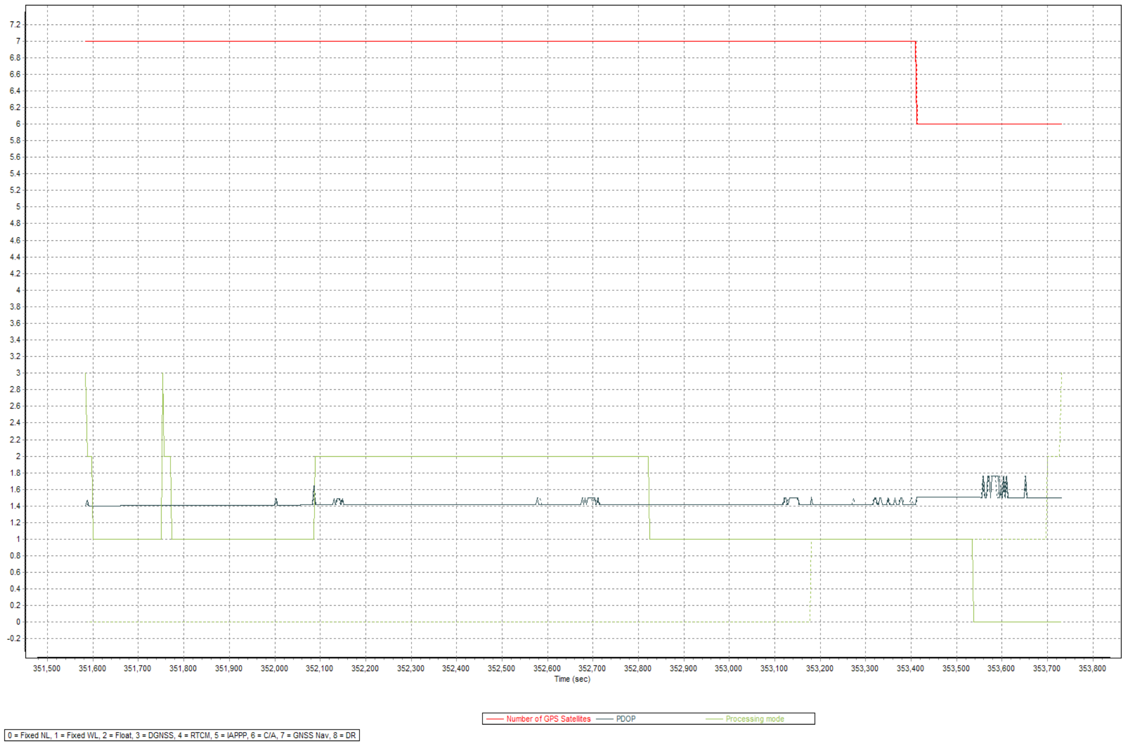


Figure 1.14.1. Solution Status

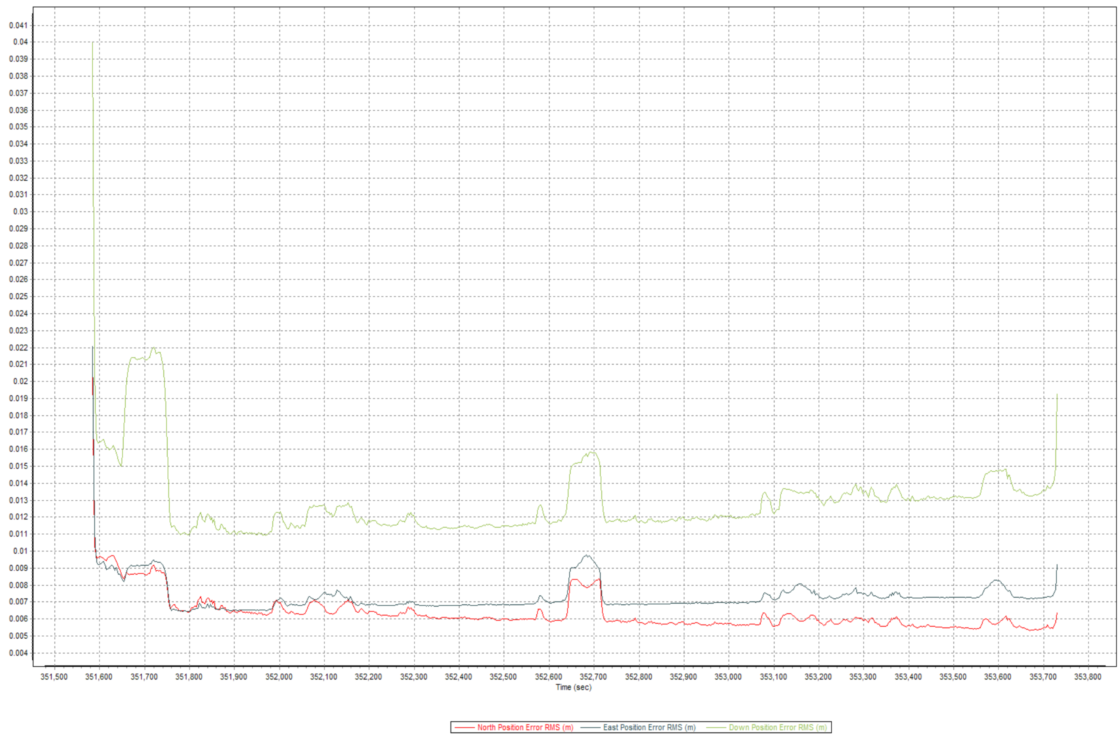


Figure 1.14.2. Smoothed Performance Metric Parameters

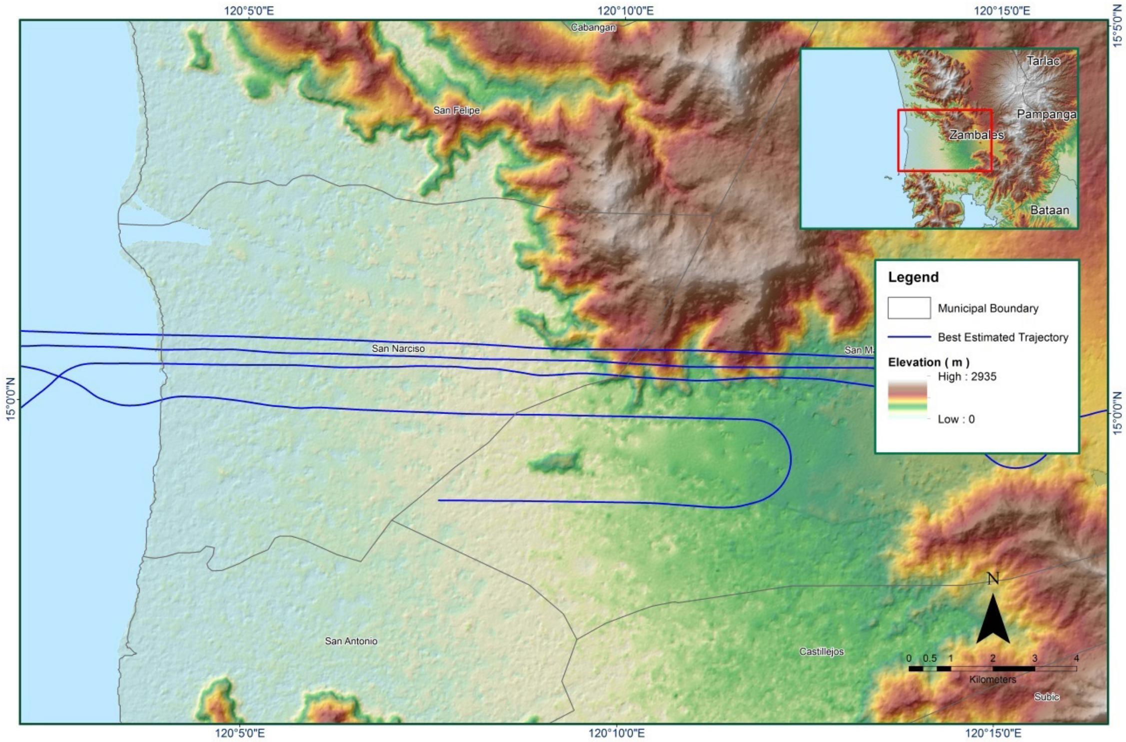


Figure 1.14.3. Best Estimated Trajectory

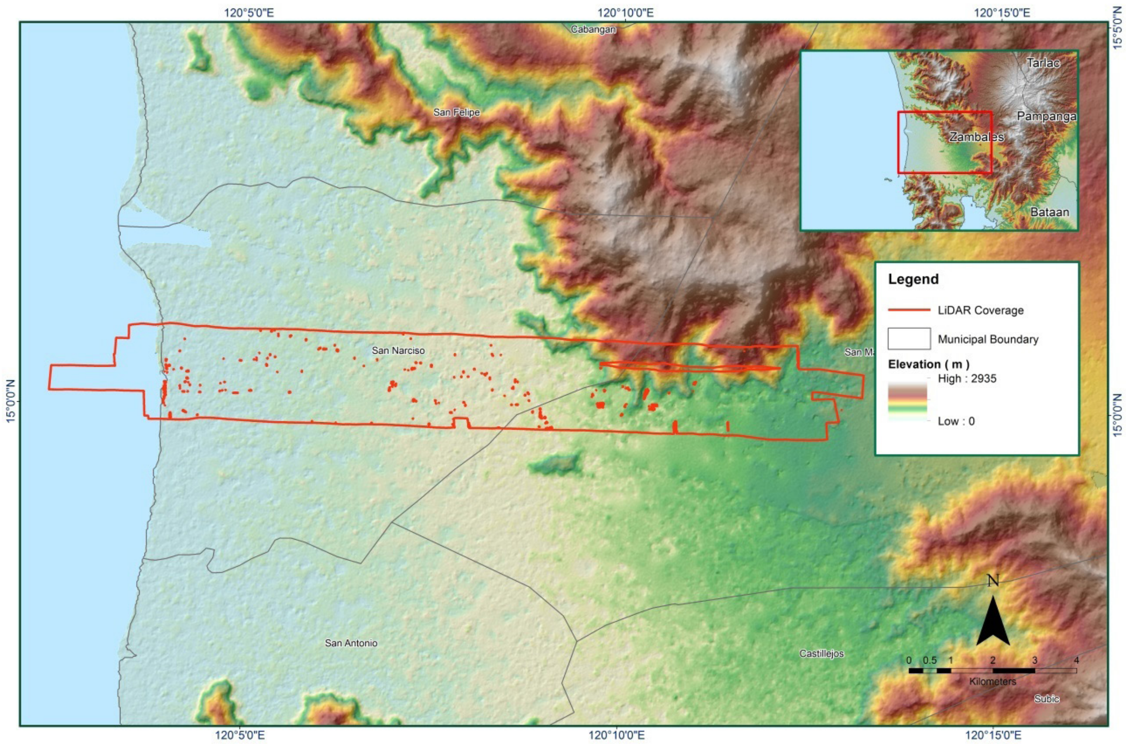


Figure 1.14.4. Coverage of LiDAR Data

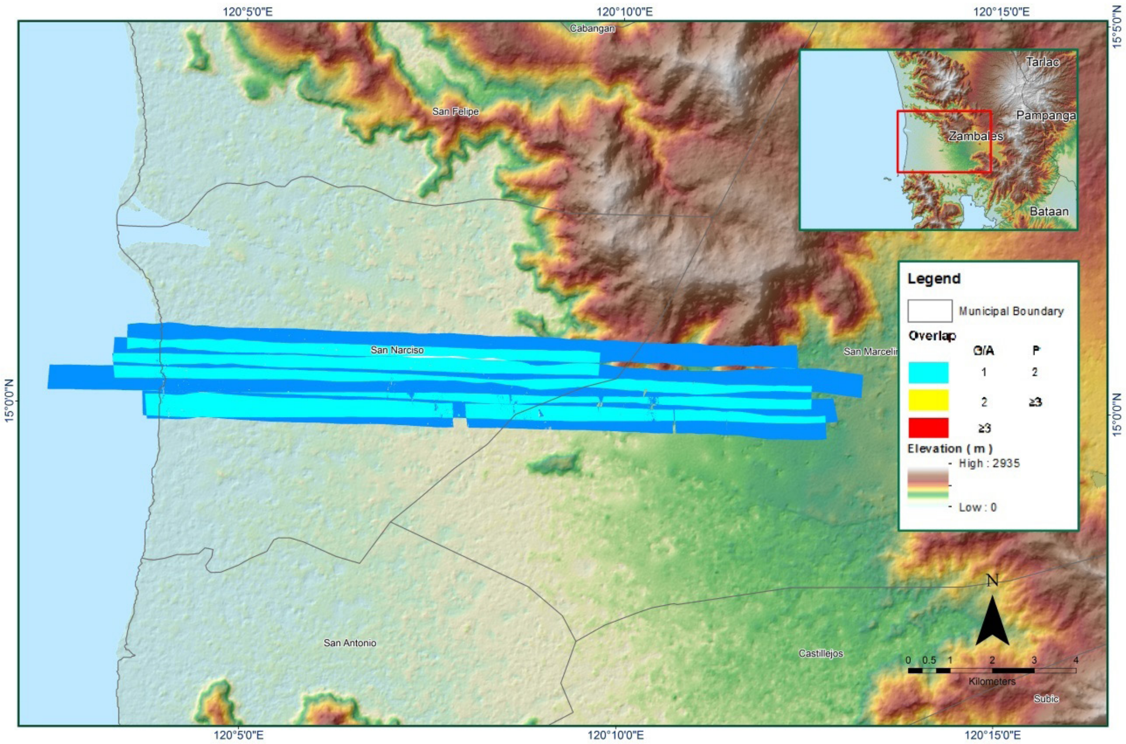


Figure 1.14.5. Image of data overlap

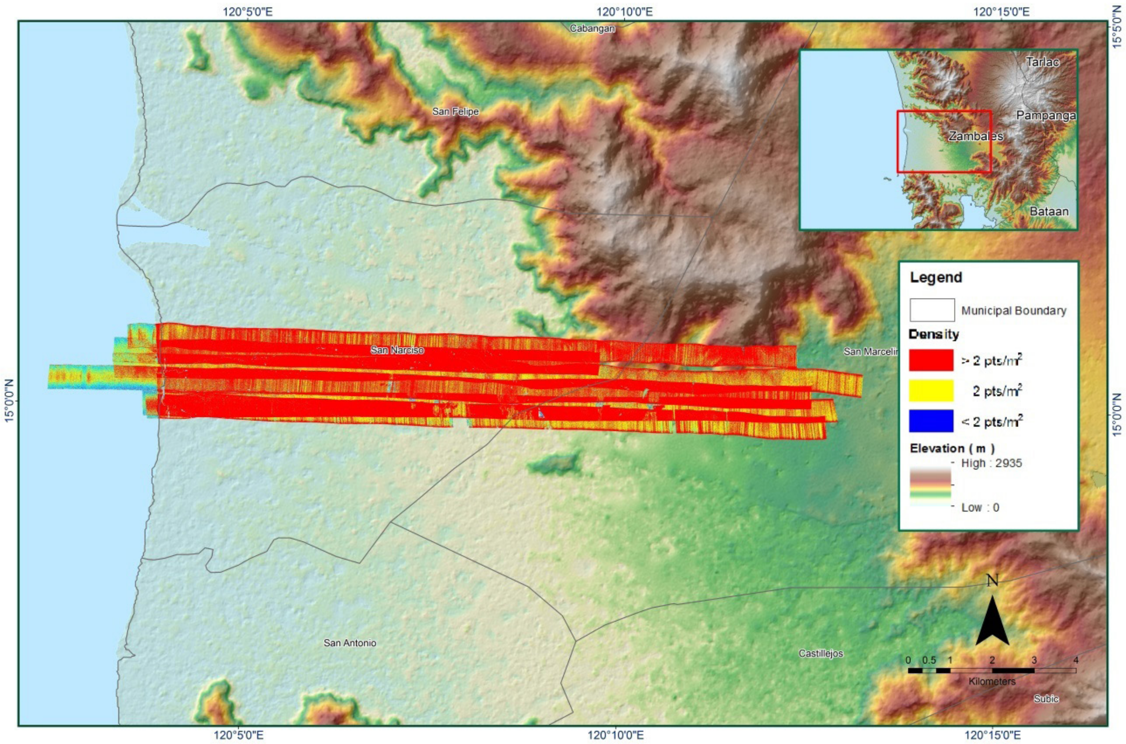


Figure 1.14.6. Density map of merged LiDAR data

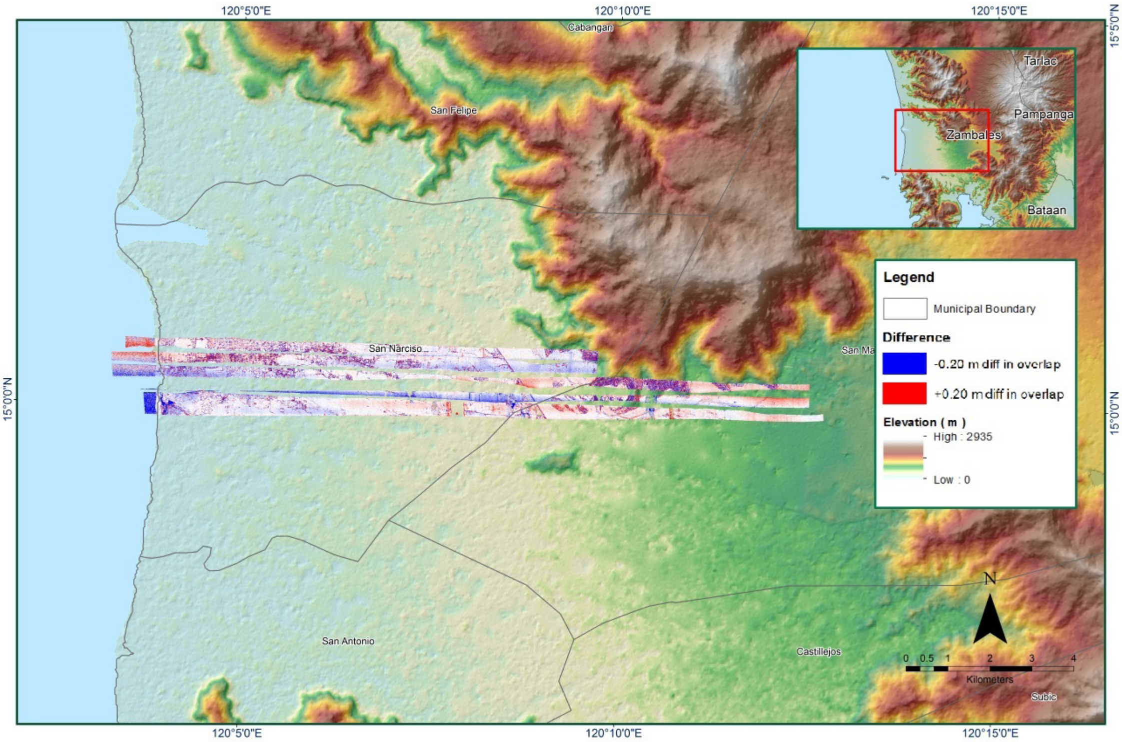


Figure 1.14.7. Elevation difference between flight lines

Table A-8.15. Mission Summary Report of Blk Upper_Buc_reflights

Flight Area	Pam_Agno_Reflights
Mission Name	Blk Upper_Buc_reflights
Inclusive Flights	7255GC
Range data size	6.45 GB
POS data size	121 MB
Base data size	7.17 MB
Image	NA
Transfer date	May 26, 2016
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)	1.225
RMSE for East Position (<4.0 cm)	1.81
RMSE for Down Position (<8.0 cm)	2.80
Boresight correction stdev (<0.001deg)	0.000286
IMU attitude correction stdev (<0.001deg)	0.000704
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	30.08
Ave point cloud density per sq.m. (>2.0)	3.94
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	40
Maximum Height	744.66 m
Minimum Height	64.67 m
Classification (# of points)	
Ground	17,894,585
Low vegetation	13,201,159
Medium vegetation	18,855,738
High vegetation	18,401,621
Building	335,798
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Mark Joshua Salvacion, Engr. Jeffrey Delica

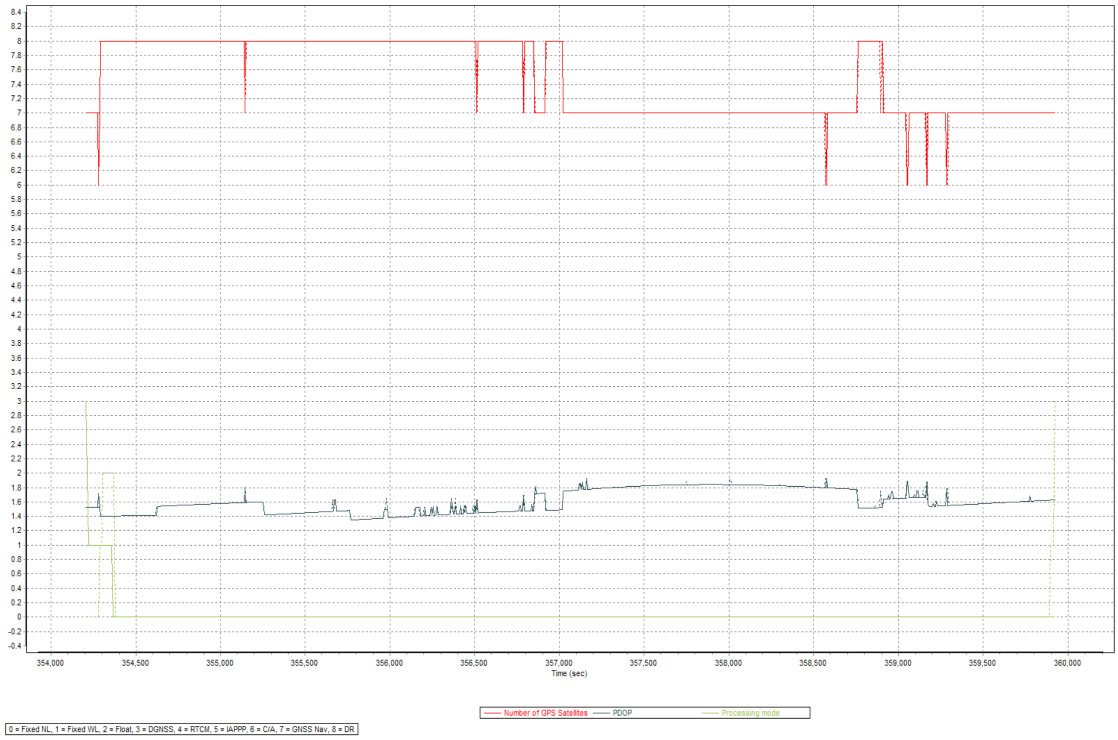


Figure 1.15.1. Solution Status

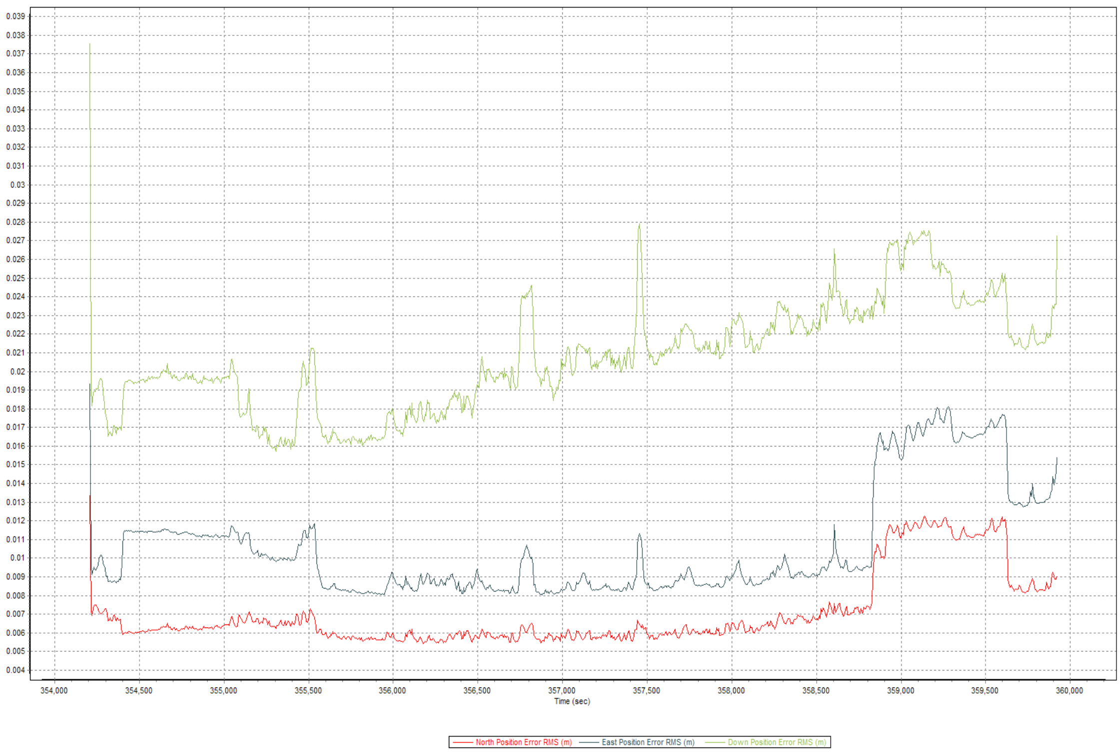


Figure 1.15.2. Smoothed Performance Metric Parameters

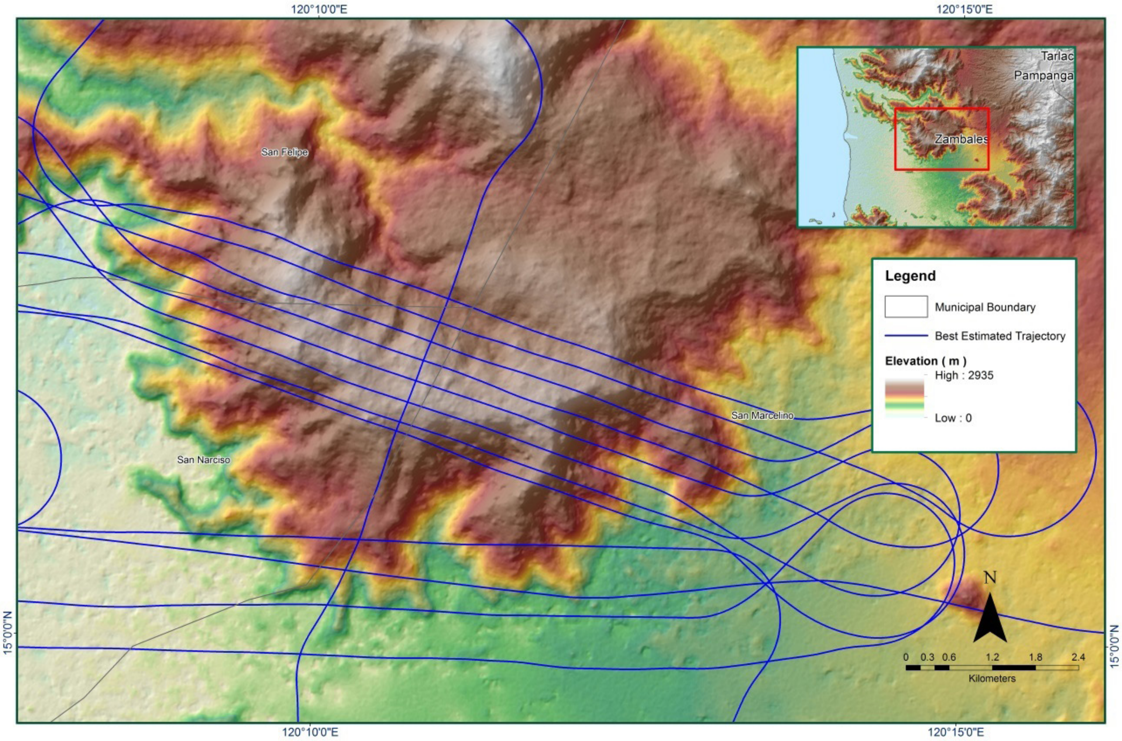


Figure 1.15.3. Best Estimated Trajectory

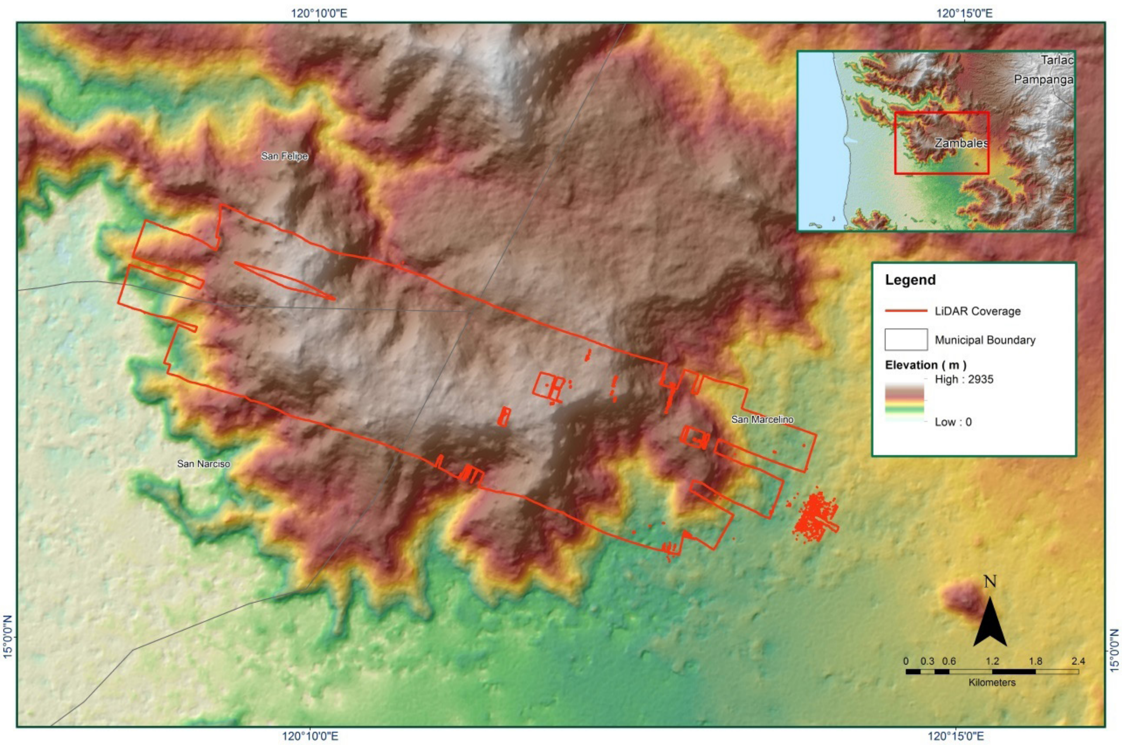


Figure 1.15.4. Coverage of LiDAR Data

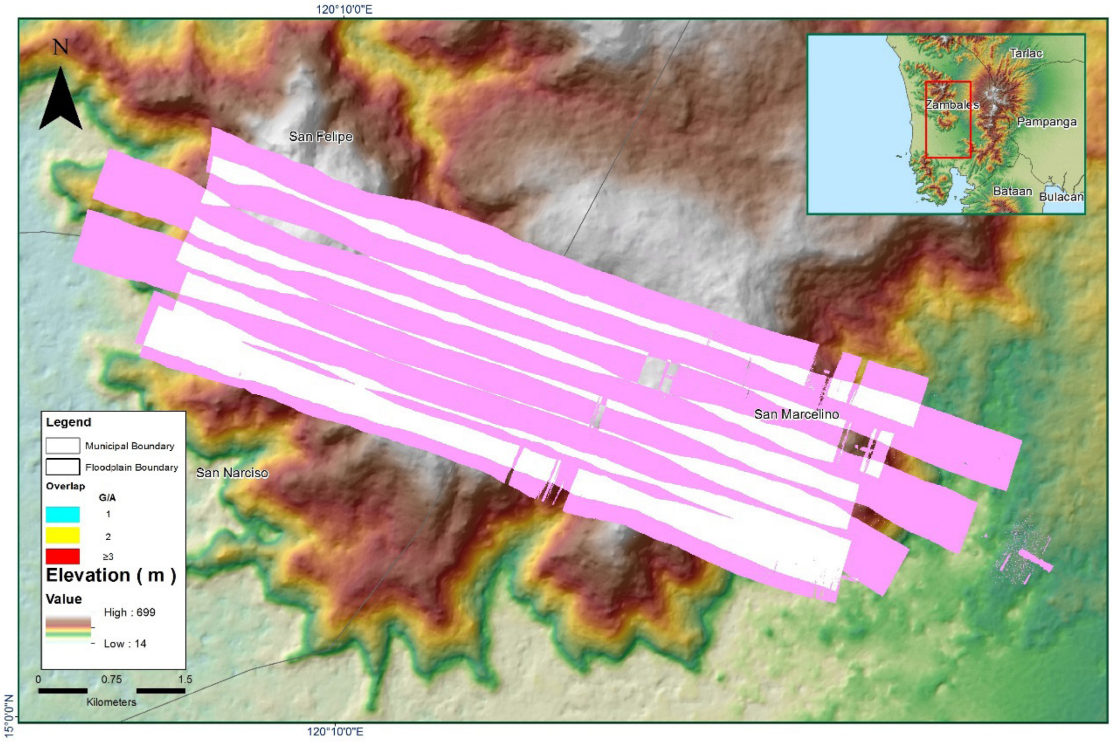


Figure 1.15.5. Image of data overlap

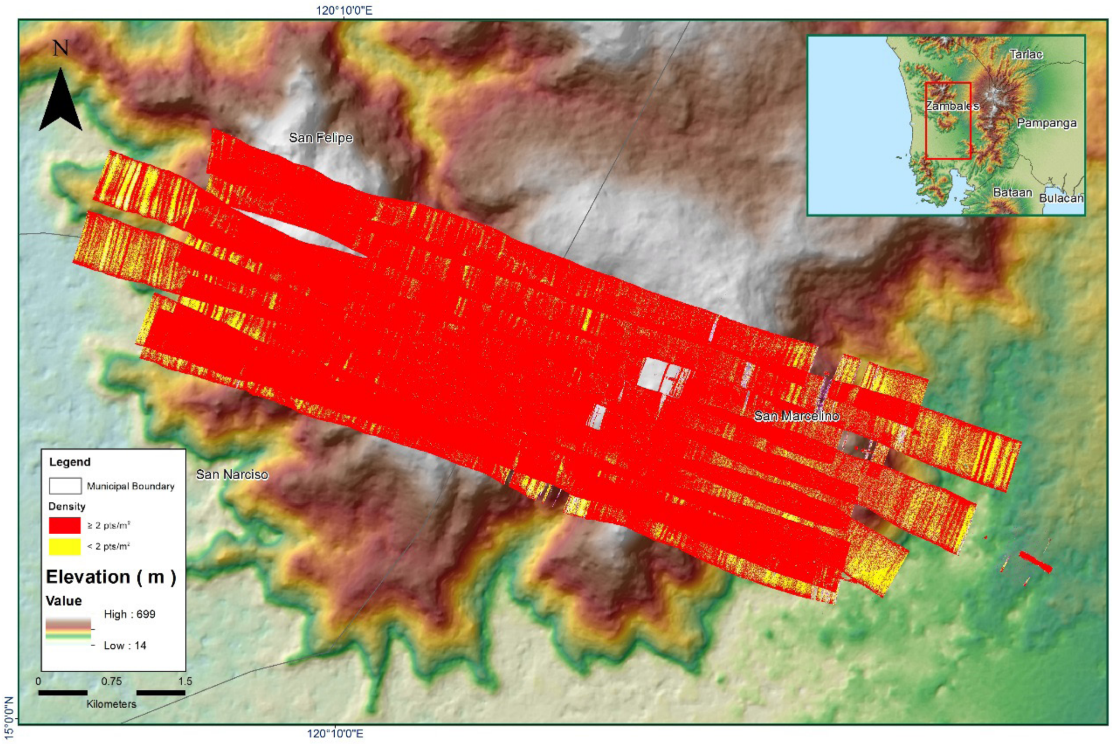


Figure 1.15.6. Density map of merged LiDAR data

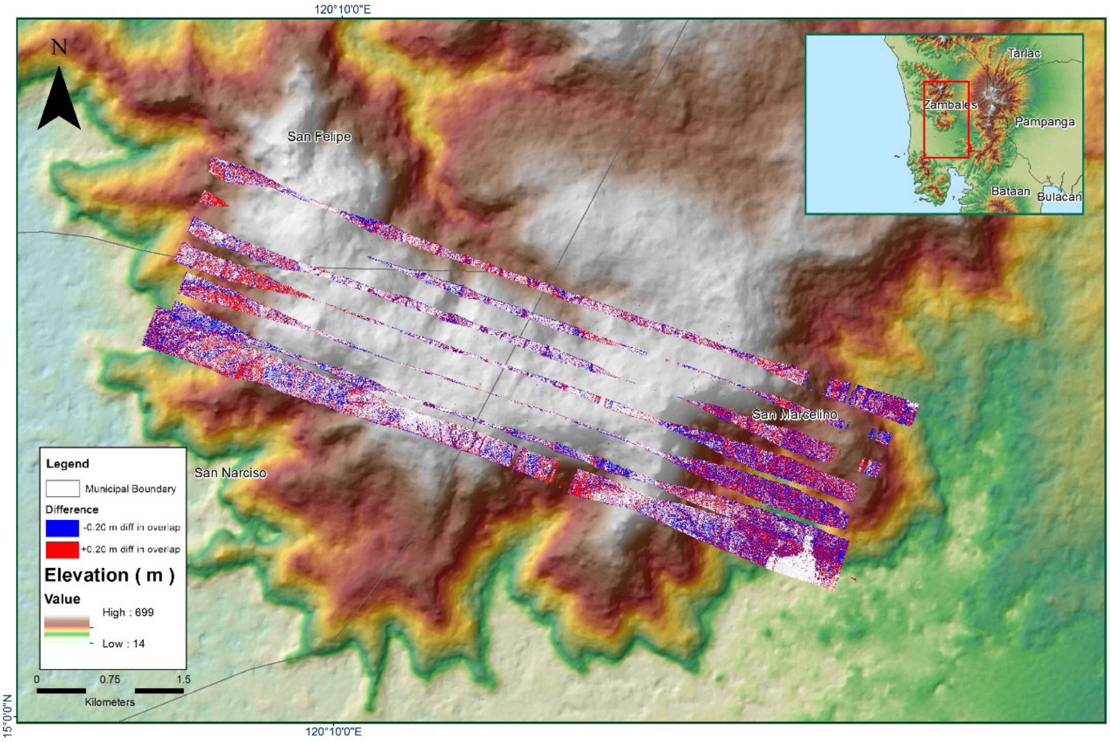


Figure 1.15.7. Elevation difference between flight lines

Annex 9. Sto. Tomas Model Basin Parameters

Table A-9.1. Sto. Tomas Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S	Recession Constant	Threshold Type	Ratio to Peak
W300	2.7439	33.801	0	1.21924	0.33868	Discharge	0.61021	0.55	Ratio to Peak	0.3
W310	2.4735	36.046	0	1.14484	0.31801	Discharge	1.7845	0.55	Ratio to Peak	0.3
W320	2.043	37.775	0	0.80492	0.22359	Discharge	0.56268	0.55	Ratio to Peak	0.3
W330	2.0272	39.711	0	0.4166	0.11572	Discharge	0.31205	0.55	Ratio to Peak	0.3
W340	1.9555	39.207	0	1.43468	0.39852	Discharge	0.42643	0.55	Ratio to Peak	0.3
W350	2.9317	20.706	0	0.44092	0.12248	Discharge	0.38104	0.55	Ratio to Peak	0.3
W360	2.2416	39.098	0	1.2938	0.35939	Discharge	1.3875	0.55	Ratio to Peak	0.3
W370	2.5231	36.498	0	0.4174	0.11594	Discharge	0.40667	0.55	Ratio to Peak	0.3
W380	2.447	40.06	0	0.7	0.19444	Discharge	0.31235	0.55	Ratio to Peak	0.3
W390	7.0806	53.243	0	1.5672	0.43533	Discharge	0.33739	0.55	Ratio to Peak	0.3
W400	5.8974	48.585	0	1.117	0.31028	Discharge	0.0487576	0.55	Ratio to Peak	0.3
W410	4.4011	41.381	0	1.609	0.44694	Discharge	0.34559	0.55	Ratio to Peak	0.3
W420	3.2534	53.098	0	0.561	0.15583	Discharge	0.35502	0.55	Ratio to Peak	0.3
W430	2.4584	43.214	0	0.98828	0.27452	Discharge	1.0788	0.55	Ratio to Peak	0.3
W440	4.9429	44.097	0	1.41836	0.39399	Discharge	0.26129	0.55	Ratio to Peak	0.3
W450	3.4637	19.862	0	0.9984	0.27733	Discharge	0.34912	0.55	Ratio to Peak	0.3
W460	3.2614	29.546	0	0.61564	0.17101	Discharge	0.4103	0.55	Ratio to Peak	0.3
W470	7.536	42.85	0	2.29476	0.63743	Discharge	0.39272	0.55	Ratio to Peak	0.3
W480	1.9471	36.34	0	1.03052	0.28626	Discharge	0.0396314	0.55	Ratio to Peak	0.3
W490	2.0424	39.102	0	1.8502	0.51394	Discharge	0.11693	0.55	Ratio to Peak	0.3
W500	3.8766	39.7705	0	0.82764	0.2299	Discharge	0.4666	0.55	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S	Recession Constant	Threshold Type	Ratio to Peak
W510	15.788	34.797	0	0.56332	0.15648	Discharge	1.2015	0.55	Ratio to Peak	0.3
W520	15.832	32.184	0	4.2292	1.1748	Discharge	1.828	0.55	Ratio to Peak	0.3
W530	15.6858	31.266	0	1.0086	0.28017	Discharge	0.30966	0.55	Ratio to Peak	0.3
W540	14.833	25.871	0	0.303388	0.0842744	Discharge	0.31306	0.55	Ratio to Peak	0.3
W550	0.93549	27.6155	0	0.44244	0.1229	Discharge	0.86435	0.55	Ratio to Peak	0.3
W560	1.7301	36.43	0	0.61388	0.17052	Discharge	1.2746	0.55	Ratio to Peak	0.3
W570	0.53623	23.278	0	0.356668	0.0990744	Discharge	0.26387	0.55	Ratio to Peak	0.3
W580	1.9068	32.221	0	0.52124	0.14479	Discharge	0.55938	0.55	Ratio to Peak	0.3

Annex 10. Sto. Tomas Model Reach Parameters

Table A-10.1. Sto. Tomas Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
100 R	Automatic Fixed Interval	2133.4	0.009319	0.018	Trapezoid	123.11	0.5
110 R	Automatic Fixed Interval	7928.1	0.002366	0.018	Trapezoid	184.19	0.5
120 R	Automatic Fixed Interval	1560.7	0.003757	0.018	Trapezoid	823.36	0.5
140 R	Automatic Fixed Interval	9203.2	0.017481	0.018	Trapezoid	12.25	0.5
150 R	Automatic Fixed Interval	10997	0.024333	0.018	Trapezoid	5	0.5
160 R	Automatic Fixed Interval	3833.1	0.003461	0.018	Trapezoid	125.27	0.5
180 R	Automatic Fixed Interval	3972.2	0.003825	0.018	Trapezoid	74.5	0.5
190 R	Automatic Fixed Interval	6580.2	0.002998	0.018	Trapezoid	1441.89	0.5
210 R	Automatic Fixed Interval	2220.9	0.004848	0.018	Trapezoid	15.86	0.5
230 R	Automatic Fixed Interval	2477.5	0.002366	0.018	Trapezoid	8.44	0.5
240 R	Automatic Fixed Interval	1833.4	0.002366	0.018	Trapezoid	4	0.5
250 R	Automatic Fixed Interval	21962	0.004343	0.018	Trapezoid	473.11	0.5
260 R	Automatic Fixed Interval	3719.8	0.002366	0.018	Trapezoid	19.27	0.5
40 R	Automatic Fixed Interval	2037.5	0.026935	0.018	Trapezoid	12.25	0.5
Reach-1	Automatic Fixed Interval	3719.8	0.002366	0.018	Trapezoid	5	0.5

Annex 11. Sto. Tomas Field Validation Points

Table A-11.1. Sto. Tomas Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	14° 56’ 6.044” N	120° 12’ 11.364” E	0.25	0.30	-0.05	Habagat 2013	5-Year
2	14° 58’ 43.537” N	120° 11’ 10.297” E	0.23	0.30	-0.07	Habagat 2012	5-Year
3	14° 58’ 23.761” N	120° 10’ 16.222” E	0.26	0.30	-0.04	Lando 2015	5-Year
4	14° 57’ 26.519” N	120° 10’ 18.888” E	0.21	0.30	-0.09	Lando 2015	5-Year
5	14° 57’ 4.950” N	120° 9’ 44.990” E	0.21	0.30	-0.09	Habagat 2012	5-Year
6	14° 56’ 54.822” N	120° 9’ 22.796” E	0.24	0.30	-0.06	Habagat 2012	5-Year
7	14° 58’ 14.894” N	120° 9’ 23.158” E	0.19	0.30	-0.11	Habagat 2012	5-Year
8	14° 58’ 30.722” N	120° 7’ 55.130” E	0.22	0	0.22	None	5-Year
9	14° 58’ 53.744” N	120° 7’ 1.865” E	0.26	0.46	-0.20	Habagat 2012	5-Year
10	14° 57’ 1.946” N	120° 5’ 13.383” E	0.23	0.61	-0.38	Lando 2015	5-Year
11	15° 2’ 47.504” N	120° 4’ 24.778” E	0.51	0.91	-0.40	Habagat 2012	5-Year
12	15° 3’ 32.690” N	120° 4’ 16.459” E	0.56	0.61	-0.05	Kiko 2009	5-Year
13	15° 3’ 29.643” N	120° 4’ 51.029” E	0.96	0.91	0.05	Habagat 2012	5-Year
14	15° 1’ 54.263” N	120° 8’ 1.065” E	0.86	0.91	-0.05	Habagat 2013	5-Year
15	14° 59’ 36.768” N	120° 8’ 8.179” E	0.59	0.61	-0.02	Kiko 2009	5-Year
16	15° 0’ 53.124” N	120° 4’ 13.715” E	0.69	1.22	-0.53	Habagat 2012	5-Year
17	14° 54’ 36.677” N	120° 11’ 56.876” E	0.84	0.61	0.23	Habagat 2012	5-Year
18	14° 57’ 39.843” N	120° 6’ 59.881” E	0.59	0	0.59	None	5-Year
19	14° 57’ 20.091” N	120° 5’ 18.829” E	0.52	0.61	-0.09	Lando 2015	5-Year
20	14° 57’ 1.397” N	120° 3’ 46.987” E	0.61	0.61	0.00	Habagat 2012	5-Year
21	15° 2’ 20.405” N	120° 7’ 46.432” E	1.59	0.91	0.68	Habagat 2013	5-Year
22	15° 2’ 35.507” N	120° 7’ 36.866” E	3.97	1.52	2.45	Habagat 2012	5-Year
23	15° 3’ 40.842” N	120° 5’ 10.648” E	1.36	1.52	-0.16	Habagat 2012	5-Year
24	15° 3’ 49.346” N	120° 3’ 44.390” E	1.58	0.61	0.97	Habagat 2012	5-Year
25	15° 3’ 25.962” N	120° 3’ 51.666” E	1.55	0.91	0.64	Habagat 2012	5-Year
26	15° 2’ 48.673” N	120° 3’ 58.712” E	1.22	0	1.22	None	5-Year
27	14° 54’ 20.747” N	120° 11’ 55.587” E	1.97	2.13	-0.16	Habagat 2012	5-Year
28	14° 54’ 22.388” N	120° 9’ 47.095” E	2.30	1.83	0.47	Habagat 2012	5-Year
29	14° 56’ 45.370” N	120° 6’ 20.038” E	1.53	1.52	0.01	Habagat 2012	5-Year
30	15° 0’ 28.734” N	120° 6’ 38.322” E	1.55	0	1.55	None	5-Year

Annex 12. Educational Institutions Affected by Flooding in Sto. Tomas Floodplain

Table A-12.1. Educational Institutions Affected in Castillejos

Zambales				
Castillejos				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BALAYBAY ELEMENTARY 1	Balaybay	Medium	Medium	Medium
BALAYBAY ELEMENTARY 2	Balaybay	Medium	Medium	Medium
BALAYBAY ELEMENTARY 3	Balaybay	Medium	Medium	Medium
BALAYBAY ELEMENTARY 4	Balaybay	Medium	Medium	Medium
BALAYBAY ELEMENTARY 5	Balaybay	Medium	Medium	Medium
CASTILLEJOS NATIONAL HIGH SCHOOL	Del Pilar		Low	Low
COLEGIO DE CASTILLEJOS 1	Del Pilar			
COLEGIO DE CASTILLEJOS 2	Del Pilar			Low
COLEGIO DE CASTILLEJOS 3	Del Pilar			
COLEGIO DE CASTILLEJOS 4	Del Pilar		Low	Low
COLEGIO DE CASTILLEJOS 5	Del Pilar		Low	Low
COLEGIO DE CASTILLEJOS 6	Del Pilar			Low
COLEGIO DE CASTILLEJOS 7	Del Pilar			
DEL PILAR ELEMENTARY	Del Pilar		Low	Medium
VILLAFLOR ELEMENTARY 6	Del Pilar			
DAYCARE AND HEALTH CENTER	Looc			
DAY CARE CENTER LINUSUNGAN	Magsaysay	Low	Low	Low
DAYCARE AND PRE-SCHOOL	Magsaysay			Low
LINUSUNGAN ELEMENTARY 1	Magsaysay	Low	Low	Low
LINUSUNGAN ELEMENTARY 2	Magsaysay	Low	Low	Low
LINUSUNGAN ELEMENTARY 3	Magsaysay	Low	Low	Low
LINUSUNGAN ELEMENTARY 4	Magsaysay	Low	Low	Low
LINUSUNGAN ELEMENTARY 5	Magsaysay	Low	Low	Low
LINUSUNGAN ELEMENTARY 7	Magsaysay	Low	Low	Low
PRE-SCHOOL	Magsaysay			
SALCAEDO ELEMENTARY	Magsaysay	Low	Medium	Medium
SALCAEDO ELEMENTARY 2	Magsaysay	Low	Low	Medium
NAGBAYAN ELEMENTARY	Nagbayan			
NAGBAYAN ELEMENTARY 2	Nagbayan			
NAGBAYAN ELEMENTARY 3	Nagbayan			
NAGBAYAN ELEMENTARY 4	Nagbayan			
NAGBUNGA ELEMENTARY	Nagbunga	Low	Low	Medium
NAGBUNGA ELEMENTARY 2	Nagbunga	Low	Low	Low
BELEN DELOS REMEDIOS COLLEGE	San Jose	Medium	Medium	Medium
BELEN DELOS REMEDIOS COLLEGE 2	San Jose	Low	Low	Low
BELEN DELOS REMEDIOS COLLEGE 3	San Jose	Low	Medium	Medium
JESUS MAGSAYSAY HIGH SCHOOL 2	San Jose			
JESUS MAGSAYSAY HIGH SCHOOL 3	San Jose			
JESUS MAGSAYSAY HIGH SCHOOL 4	San Jose			

JESUS MAGSAYSAY HIGH SCHOOL 5	San Jose			
MAGSAYSAY ELEMENTARY SCHOOL 1	San Jose			
MAGSAYSAY ELEMENTARY SCHOOL 2	San Jose			
MAGSAYSAY ELEMENTARY SCHOOL 3	San Jose			
MAGSAYSAY ELEMENTARY SCHOOL 4	San Jose			
MAGSAYSAY ELEMENTARY SCHOOL 6	San Jose			
MAGSAYSAY ELEMENTARY SCHOOL 7	San Jose			
PRECIOUS CHILD MONTESSORI	San Jose			
SAN AGUSTIN HIGH SCHOOL 1	San Jose		Low	Low
SAN AGUSTIN HIGH SCHOOL 10	San Jose		Low	Low
SAN AGUSTIN HIGH SCHOOL 11	San Jose			Low
SAN AGUSTIN HIGH SCHOOL 12	San Jose			Low
SAN AGUSTIN HIGH SCHOOL 13	San Jose			Low
SAN AGUSTIN HIGH SCHOOL 2	San Jose	Low	Low	Low
SAN AGUSTIN HIGH SCHOOL 3	San Jose		Low	Low
SAN AGUSTIN HIGH SCHOOL 4	San Jose		Low	Low
SAN AGUSTIN HIGH SCHOOL 5	San Jose	Low	Low	Low
SAN AGUSTIN HIGH SCHOOL 6	San Jose	Low	Low	Low
SAN AGUSTIN HIGH SCHOOL 7	San Jose		Low	Low
SAN AGUSTIN HIGH SCHOOL 8	San Jose		Low	Low
SAN AGUSTIN HIGH SCHOOL 9	San Jose		Low	Low
SANTA MARIA ELEMENTARY	San Jose			
BAYANIHAN ELEMENTARY	San Pablo		Low	Low
DEL PILAR ELEMENTARY	San Pablo		Low	Medium
DEL PILAR ELEMENTARY 2	San Pablo		Low	Medium
HANJIN INTEGRATED SCHOOL	San Pablo		Low	Medium
HANJIN SECONDARY	San Pablo		Low	Low
HANNIEL CHRISTIAN ACADEMY	San Pablo		Low	Low
HANNIEL CHRISTIAN ACADEMY 2	San Pablo			
SAINT NICHOLAS ACADEMY	San Pablo		Low	Low
SAN ISIDRO ELEMENTARY 1	San Pablo			Low
SAN ISIDRO ELEMENTARY 2	San Pablo		Low	Low
SAN PABLO DAYCARE	San Pablo			
CASTILLEJOS ELEMENTARY 1	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 10	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 11	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 12	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 13	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 14	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 15	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 4	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 6	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 8	San Roque		Low	Low
CASTILLEJOS ELEMENTARY 9	San Roque		Low	Low
DAYCARE SAN NICOLAS	San Roque		Low	Low
GUIDANCE OFFICE	San Roque			

SAINT NICHOLAS ACADEMY	San Roque			Low
VILLAFLOR ELEMENTARY 1	San Roque			
VILLAFLOR ELEMENTARY 3	San Roque			
VILLAFLOR ELEMENTARY 4	San Roque			
VILLAFLOR ELEMENTARY 5	San Roque			
VILLAFLOR ELEMENTARY 6	San Roque			
VILLAFLOR ELEMENTARY 7	San Roque			
MAGSAYSAY ELEMENTARY SCHOOL 3	Santa Maria			
MAGSAYSAY ELEMENTARY SCHOOL 5	Santa Maria			
MAGSAYSAY ELEMENTARY SCHOOL 8	Santa Maria			
MAGSAYSAY ELEMENTARY SCHOOL 9	Santa Maria			

Table A-12.2. Educational Institutions Affected in San Antonio

Zambales				
San Antonio				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BURGOS DAY CARE CENTER	San Juan			
BURGOS ELEMENTARY SCHOOL 1	San Juan			Low
BURGOS ELEMENTARY SCHOOL 2	San Juan			Low
BURGOS ELEMENTARY SCHOOL 3	San Juan			Low
BURGOS ELEMENTARY SCHOOL 4	San Juan			Low
BURGOS ELEMENTARY SCHOOL 5	San Juan		Low	Low
LUNA DAY CARE CENTER	San Juan	Low	Low	Medium
PHILIPPINE NAVY SCHOOL CENTER 1	San Miguel		Low	Medium
PHILIPPINE NAVY SCHOOL CENTER 2	San Miguel		Low	Medium
SAN NICOLAS ELEMENTARY SCHOOL 1	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 10	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 2	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 3	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 4	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 5	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 6	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 7	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 8	San Nicolas			
SAN NICOLAS ELEMENTARY SCHOOL 9	San Nicolas			
SAN NICOLAS HIGH SCHOOL 1	San Nicolas			Low
SAN NICOLAS HIGH SCHOOL 2	San Nicolas			Low
SAN NICOLAS HIGH SCHOOL 3	San Nicolas			Low
SAN NICOLAS HIGH SCHOOL 4	San Nicolas			Low
SAN NICOLAS HIGH SCHOOL 5	San Nicolas			Low
SAN NICOLAS HIGH SCHOOL 6	San Nicolas			Low

HILDEGARD ACADEMY	Santiago	Low	Medium	Medium
SAN ANTONIO CENTRAL SCHOOL 1	Santiago	Low	Low	Medium
SAN ANTONIO CENTRAL SCHOOL 2	Santiago	Low	Low	Medium
SAN ANTONIO CENTRAL SCHOOL 3	Santiago	Low	Low	Medium
SAN ANTONIO CENTRAL SCHOOL 4	Santiago	Low	Low	Medium
SAN ANTONIO NATIONAL HIGH SCHOOL 1	Santiago			Low
SAN ANTONIO NATIONAL HIGH SCHOOL 10	Santiago		Low	Low
SAN ANTONIO NATIONAL HIGH SCHOOL 11	Santiago		Low	Low
SAN ANTONIO NATIONAL HIGH SCHOOL 2	Santiago			Low
SAN ANTONIO NATIONAL HIGH SCHOOL 3	Santiago			
SAN ANTONIO NATIONAL HIGH SCHOOL 4	Santiago		Low	Low
SAN ANTONIO NATIONAL HIGH SCHOOL 5	Santiago			Low
SAN ANTONIO NATIONAL HIGH SCHOOL 6	Santiago			
SAN ANTONIO NATIONAL HIGH SCHOOL 7	Santiago			
SAN ANTONIO NATIONAL HIGH SCHOOL 8	Santiago		Low	Low
SAN ANTONIO NATIONAL HIGH SCHOOL 9	Santiago		Low	Low
SAN ESTEBAN ELEMENTARY 1	Santiago		Low	Low
SAN ESTEBAN ELEMENTARY 2	Santiago			Low
SAN GREGORIO DAY CARE CENTER	Santiago	Low	Low	Low
PHILIPPINE NAVY SCHOOL CENTER 1	West Dirita		Low	Medium
PHILIPPINE NAVY SCHOOL CENTER 2	West Dirita		Low	Medium

Table A-12.3. Educational Institutions Affected in San Felipe

Zambales				
San Felipe				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BOBULON ELEMENTARY SCHOOL 1	Amagna	Low	Medium	Medium
BOBULON ELEMENTARY SCHOOL 2	Amagna	Low	Medium	Medium
BOBULON ELEMENTARY SCHOOL 3	Amagna	Low	Medium	Medium
BOBULON ELEMENTARY SCHOOL 4	Amagna	Low	Medium	Medium
BOBULON ELEMENTARY SCHOOL 5	Amagna	Low	Medium	Medium
SAN FELIPE EAST ELEMENTARY SCHOOL 1	Amagna	Medium	Medium	Medium
SAN FELIPE EAST ELEMENTARY SCHOOL 2	Amagna	Medium	Medium	Medium
SAN FELIPE EAST ELEMENTARY SCHOOL 3	Amagna	Medium	Medium	Medium
SAN FELIPE EAST ELEMENTARY SCHOOL 4	Amagna	Medium	Medium	Medium
SAN FELIPE EAST ELEMENTARY SCHOOL 5	Amagna	Medium	Medium	Medium
SAN FELIPE EAST ELEMENTARY SCHOOL 6	Amagna	Medium	Medium	Medium
SAN FELIPE ELEMENTARY SCHOOL WEST 1	Amagna	Medium	Medium	Medium
SAN FELIPE ELEMENTARY SCHOOL WEST 3	Amagna	Medium	Medium	Medium
SAN FELIPE ELEMENTARY SCHOOL WEST 4	Amagna	Medium	Medium	Medium
SCHOOL	Amagna	Medium	Medium	Medium
ZAMBALES CENTRAL INSITUTE 1	Amagna	Low	Medium	Medium
ZAMBALES CENTRAL INSITUTE 2	Amagna	Low	Medium	Medium
ZAMBALES CENTRAL INSITUTE 4	Amagna	Low	Medium	Medium

ZAMBALES CENTRAL INSITUTE 5	Amagna	Low	Medium	Medium
BALINGCAGUING DAY CARE CENTER	Balincaguing		Medium	Medium
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 1	Santo Niño	Medium	High	High
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 2	Santo Niño	Medium	High	High
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 4	Santo Niño	Medium	High	High
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 5	Santo Niño	Medium	High	High
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 6	Santo Niño	Medium	High	High
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 7	Santo Niño	Medium	High	High
SAN RAFAEL TECHNICAL VOCATIONAL HIGH SCHOOL 8	Santo Niño	Medium	High	High
STO. NIÑO DAY CARE CENTER	Santo Niño	Medium	Medium	Medium
STO. NIÑO ELEMENTARY SCHOOL 1	Santo Niño	Medium	High	High
STO. NIÑO ELEMENTARY SCHOOL 2	Santo Niño	Medium	Medium	High
STO. NIÑO ELEMENTARY SCHOOL 4	Santo Niño	Medium	High	High
STO. NIÑO ELEMENTARY SCHOOL 3	Santo Niño	Medium	Medium	High
STO. NIÑO ELEMENTARY SCHOOL 5	Santo Niño	Medium	High	High
STO. NIÑO ELEMENTARY SCHOOL 6	Santo Niño	Medium	High	High
STO. NIÑO ELEMENTARY SCHOOL 7	Santo Niño	Medium	High	High
STO. TOMAS ELEMENTARY SCHOOL 1	Sindol	Medium	Medium	High
STO. TOMAS ELEMENTARY SCHOOL 2	Sindol	Medium	Medium	High
STO. TOMAS ELEMENTARY SCHOOL 3	Sindol	Medium	Medium	High
STO. TOMAS ELEMENTARY SCHOOL 4	Sindol	Medium	Medium	High
STO. TOMAS ELEMENTARY SCHOOL 5	Sindol	Medium	Medium	High

Table A-12.4. Educational Institutions Affected in San Marcelino

Zambales				
San Marcelino				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DAYCARE CENTER BURGOS	Central			
SAN GUILLERMO ELEMENTARY 1	Central			
SAN GUILLERMO ELEMENTARY 2	Central			
SAN MARCELINO ELEMENTARY 10	Central			
SAN MARCELINO ELEMENTARY 11	Central			
SAN MARCELINO ELEMENTARY 12	Central			
SAN MARCELINO ELEMENTARY 13	Central			
SAN MARCELINO ELEMENTARY 16	Central			
SAN MARCELINO ELEMENTARY 17	Central			
SAN MARCELINO ELEMENTARY 18	Central			
SAN MARCELINO ELEMENTARY 20	Central			
SAN MARCELINO ELEMENTARY 21	Central			

SAN MARCELINO ELEMENTARY 22	Central			
SAN MARCELINO ELEMENTARY 23	Central			
SAN MARCELINO ELEMENTARY 24	Central			
SAN MARCELINO ELEMENTARY 26	Central			
SAN MARCELINO ELEMENTARY 27	Central			
SAN MARCELINO ELEMENTARY 28	Central			
SAN MARCELINO ELEMENTARY 29	Central			
SAN MARCELINO ELEMENTARY 3	Central			
SAN MARCELINO ELEMENTARY 30	Central			
SAN MARCELINO ELEMENTARY 31	Central			
SAN MARCELINO ELEMENTARY 32	Central			
SAN MARCELINO ELEMENTARY 33	Central			
SAN MARCELINO ELEMENTARY 34	Central			
SAN MARCELINO ELEMENTARY 4	Central			
SAN MARCELINO ELEMENTARY 5	Central			
SAN MARCELINO ELEMENTARY 6	Central			
SAN MARCELINO ELEMENTARY 8	Central			
SAN MARCELINO ELEMENTARY 9	Central			
LAOAG ELEMENTARY 1	Laoag			
LAOAG ELEMENTARY 2	Laoag			
LAOAG ELEMENTARY 3	Laoag			
LAOAG ELEMENTARY 4	Laoag			
LAOAG ELEMENTARY 5	Laoag			
LAOAG ELEMENTARY 6	Laoag			
LAOAG ELEMENTARY 7	Laoag			
LAOAG ELEMENTARY 8	Laoag			
BEST CHILD LEARNING CENTER 1	LaPaz			Low
BEST CHILD LEARNING CENTER 2	LaPaz			Low
BEST CHILD LEARNING CENTER 3	LaPaz			Low
BEST CHILD LEARNING CENTER 4	LaPaz			Low
GIS INSTITUTE OF TECHNOLOGY	LaPaz	Low	Low	Low
ST WILLIAM SCHOOL 1	LaPaz		Low	Low
ST WILLIAM SCHOOL 2	LaPaz		Low	Low
ST WILLIAM SCHOOL 4	LaPaz		Low	Low
BAPTIST DAYCARE	Nagbunga		Low	Low
DAY CARE CENTER RABANES	Nagbunga	Low	Low	Low
LAOAG DAYCARE	Nagbunga			
LAOAG ELEMENTARY 1	Nagbunga			
LAOAG ELEMENTARY 2	Nagbunga			
LINUSUNGAN DAYCARE	Nagbunga			Low
OLD RMTU ADMIN	Nagbunga			
RABANES ELEMENTARY 2	Nagbunga	Low	Low	Low
RABANES ELEMENTARY 3	Nagbunga	Low	Low	Low
RABANES ELEMENTARY 4	Nagbunga	Low	Low	Low
RABANES ELEMENTARY 5	Nagbunga	Low	Low	Low
RMTU ADMIN ANNEX	Nagbunga	Low	Low	Low

RMTU COLLEGE OF AGRICULTURE 1	Nagbunga		Low	Low
RMTU COLLEGE OF AGRICULTURE 2	Nagbunga			Low
RMTU COLLEGE OF AGRICULTURE 3	Nagbunga			Low
RMTU COLLEGE OF HRM	Nagbunga		Low	Low
RMTU ECS BUILDING	Nagbunga	Low	Low	Low
RMTU OLD LIBRARY	Nagbunga		Low	Low
DAYCARE CENTER	San Guillermo			Low
DREAM KIDS LEARNING CENTER	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 1	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 2	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 3	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 4	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 5	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 6	San Guillermo			Low
SAN GUILLERMO ELEMENTARY 7	San Guillermo			Low
SAN MARCELINO ELEMENTARY 12	San Guillermo			
SAN MARCELINO ELEMENTARY 20	San Guillermo			
SAN MARCELINO ELEMENTARY 23	San Guillermo			
SAN MARCELINO ELEMENTARY 31	San Guillermo			
DAYCARE LINASIN	San Isidro			
LINASIN ELEMENTARY 2	San Isidro			Low
LINASIN ELEMENTARY 3	San Isidro			Low
LINASIN ELEMENTARY 4	San Isidro			Low
LINASIN ELEMENTARY 5	San Isidro			Low
LINASIN ELEMENTARY 6	San Isidro			Low
LINASIN ELEMENTARY 7	San Isidro			Low
LINASIN ELEMENTARY 8	San Isidro			
LAWIN ELEMENTARY SCHOOL 1	San Rafael			
LAWIN ELEMENTARY SCHOOL 2	San Rafael			
LAWIN ELEMENTARY SCHOOL 3	San Rafael			
LAWIN ELEMENTARY SCHOOL 4	San Rafael			
LAWIN ELEMENTARY SCHOOL 5	San Rafael			
SAN RAFAEL ELEMENTARY 1	San Rafael			Low
SAN RAFAEL ELEMENTARY 2	San Rafael	Low	Low	Low
SAN RAFAEL ELEMENTARY 3	San Rafael			
SAN RAFAEL ELEMENTARY 4	San Rafael	Low	Low	Low
SAN RAFAEL ELEMENTARY 5	San Rafael			
SAN RAFAEL HIGHSCHOOL 1	San Rafael	Low	Low	Low
SAN RAFAEL HIGHSCHOOL 2	San Rafael	Low	Low	Low
SAN RAFAEL HIGHSCHOOL 3	San Rafael		Low	Low
SAN RAFAEL HIGHSCHOOL 4	San Rafael			
SAN RAFAEL HIGHSCHOOL 5	San Rafael			

Table A-12.5. Educational Institutions Affected in San Narciso

Zambales				
San Narciso				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ALUSIIS ELEMENTARY 1	Alusiis			Low
ALUSIIS ELEMENTARY 10	Alusiis		Low	Low
ALUSIIS ELEMENTARY 2	Alusiis			Low
ALUSIIS ELEMENTARY 3	Alusiis			Low
ALUSIIS ELEMENTARY 4	Alusiis			Low
ALUSIIS ELEMENTARY 5	Alusiis			Low
ALUSIIS ELEMENTARY 6	Alusiis			Low
ALUSIIS ELEMENTARY 7	Alusiis			Low
ALUSIIS ELEMENTARY 8	Alusiis		Low	Low
ALUSIIS ELEMENTARY 9	Alusiis			Low
BEDDENG-MABANGCAL ELEMENTARY 1	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 10	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 11	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 12	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 13	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 14	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 2	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 3	Beddeng			
BEDDENG-MABANGCAL ELEMENTARY 4	Beddeng			
BEDDENG-MABANGCAL ELEMENTARY 5	Beddeng			Low
BEDDENG-MABANGCAL ELEMENTARY 6	Beddeng			
BEDDENG-MABANGCAL ELEMENTARY 7	Beddeng			
BEDDENG-MABANGCAL ELEMENTARY 9	Beddeng			Low
KLAVENESS HALL	Beddeng		Low	Low
PMMA ARMS AND AMMUNITION	Beddeng		Medium	Medium
PMMA COMPLEX	Beddeng	Low	Medium	Medium
PMMA COVERED BLEACHER	Beddeng	Medium	Medium	Medium
PMMA COVERED SWIMMING POOL	Beddeng	Low	Medium	Medium
PMMA GUARD HOUSE CHECKPOINT	Beddeng		Low	Medium
PMMA HALL 1	Beddeng		Low	Medium
PMMA HALL 2	Beddeng		Low	Medium
PMMA HALL 3	Beddeng		Low	Medium
PMMA HALL 4	Beddeng	Low	Medium	Medium
PMMA INDOOR SPORT CENTER	Beddeng	Low	Medium	High
PMMA MAIN OFFICE	Beddeng	Low	Medium	Medium
PMMA MPG	Beddeng		Low	Medium
PMMA OFFICE 1	Beddeng		Medium	Medium
PMMA OFFICE 2	Beddeng		Low	Medium
PMMA OFFICE 3	Beddeng		Medium	Medium
PMMA OFFICE 4	Beddeng	Low	Medium	Medium

PMMA OFFICE 5	Beddeng	Low	Medium	Medium
PMMA STUDENT HALL	Beddeng	Low	Medium	Medium
PMMA STUDENT HALL 2	Beddeng		Medium	Medium
PMMA STUDENT HALL 3	Beddeng		Low	Medium
PMMA STUDENT HALL 4	Beddeng			Low
PMMA WATER TANK	Beddeng	Low	Medium	High
DOCE MARTIRES ELEMENTARY SCHOOL 1	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 2	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 3	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 4	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 5	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 7	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 8	Candelaria		Low	Medium
DOCE MARTIRES ELEMENTARY SCHOOL 9	Candelaria		Low	Medium
DAY CARE CENTER	Grullo	Medium	Low	Medium
LA PAZ ELEMENTARY 1	LaPaz	Medium	Medium	Medium
LA PAZ ELEMENTARY 10	LaPaz	Medium	Medium	Medium
LA PAZ ELEMENTARY 11	LaPaz	Medium	Medium	Medium
LA PAZ ELEMENTARY 12	LaPaz	Medium	Medium	Medium
LA PAZ ELEMENTARY 2	LaPaz	Medium	Medium	Medium
LA PAZ ELEMENTARY 3	LaPaz	Medium	Medium	High
LA PAZ ELEMENTARY 4	LaPaz	Medium	Medium	Medium
LA PAZ ELEMENTARY 6	LaPaz	Low	Medium	Medium
LA PAZ ELEMENTARY 7	LaPaz	Low	Medium	Medium
LA PAZ ELEMENTARY 8	LaPaz	Low	Medium	Medium
LA PAZ ELEMENTARY 9	LaPaz	Medium	Medium	Medium
SAN RAFAEL-NATIVIDAD ELEMENTARY 1	LaPaz		Low	Low
SAN RAFAEL-NATIVIDAD ELEMENTARY 2	LaPaz		Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 10	Libertad	Low	Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 5	Libertad	Low	Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 7	Libertad		Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 9	Libertad	Low	Low	Medium
SAN PASCUAL ELEMENTARY 1	Libertad	Low	Low	Medium
SAN PASCUAL ELEMENTARY 2	Libertad	Low	Low	Medium
SAN PASCUAL ELEMENTARY 3	Libertad	Low	Low	Medium
SAN PASCUAL ELEMENTARY 4	Libertad	Low	Low	Medium
SAN PASCUAL ELEMENTARY 5	Libertad	Low	Low	Medium
DALLIPAWEN DAY CARE CENTER	Namatacan	Low	Low	Low
DALLIPAWEN ELEMANTARY SCHOOL	Namatacan	Low	Low	Medium
DALLIPAWEN ELEMENTARY SCHOOL 2	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 1	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 10	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 11	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 12	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 13	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 14	Namatacan	Low	Low	Medium

NAMATACAN ELEMENTARY SCHOOL 2	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 3	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 4	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 5	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 6	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 7	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 8	Namatacan	Low	Low	Medium
NAMATACAN ELEMENTARY SCHOOL 9	Namatacan	Low	Low	Medium
PAITE-BALINGCAGUING ELEMENTARY/NATIONAL HIGH SCHOOL	Paite	Medium	High	High
CANDELARIA DAY CARE CENTER	San Jose	Low	Medium	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 10	San Jose	Low	Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 5	San Jose	Low	Low	Medium
SAN JOSE PATROCINIO ELEMENTARY 1	San Jose			Low
SAN JOSE PATROCINIO ELEMENTARY 2	San Jose		Low	Low
SAN JOSE PATROCINIO ELEMENTARY 3	San Jose		Low	Medium
SAN JOSE PATROCINIO ELEMENTARY 4	San Jose		Low	Medium
SAN JOSE PATROCINIO ELEMENTARY 5	San Jose		Low	Low
SAN JOSE PATROCINIO ELEMENTARY 6	San Jose		Low	Low
SAN JOSE PATROCINIO ELEMENTARY 7	San Jose		Low	Medium
SAN JOSE PATROCINIO ELEMENTARY 8	San Jose		Low	Medium
SAN JOSE PATROCINIO ELEMENTARY 9	San Jose		Low	Low
SAN JUAN ELEMENTARY SCHOOL	San Jose		Low	Medium
SAN JUAN ELEMENTARY SCHOOL 1	San Jose		Low	Medium
ALUSIIS DAY CARE CENTER	San Rafael	Low	Medium	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 1	San Rafael		Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 11	San Rafael	Low	Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 2	San Rafael	Low	Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 3	San Rafael		Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 4	San Rafael		Low	Medium
MAGSAYSAY MEMORIAL COLLEGE OF ZAMBALES 7	San Rafael	Low	Low	Medium
SAN NARCISO CENTRAL ELEMENTARY 1	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 2	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 3	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 4	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 6	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 7	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 8	San Rafael	Low	Medium	Medium
SAN NARCISO CENTRAL ELEMENTARY 9	San Rafael	Low	Medium	Medium
SAN RAFAEL-NATIVIDAD ELEMENTARY 2	San Rafael			
SAN RAFAEL-NATIVIDAD ELEMENTARY 3	San Rafael		Low	Medium
SAN RAFAEL-NATIVIDAD ELEMENTARY 4	San Rafael	Low	Low	Medium
SAN RAFAEL-NATIVIDAD ELEMENTARY 5	San Rafael	Low	Low	Medium
SAN RAFAEL-NATIVIDAD ELEMENTARY 6	San Rafael		Low	Medium
ZAMBALES ACADEMY 1	San Rafael	Low	Low	Medium
ZAMBALES ACADEMY 2	San Rafael	Medium	Medium	Medium

ZAMBALES ACADEMY 3	San Rafael	Low	Medium	Medium
ZAMBALES ACADEMY 4	San Rafael		Low	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 1	Siminublan		Low	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 2	Siminublan		Low	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 3	Siminublan		Low	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 4	Siminublan	Low	Medium	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 5	Siminublan		Low	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 6	Siminublan	Low	Medium	Medium
SIMMINUBLAN ELEMANTARY SCHOOL 7	Siminublan	Low	Medium	Medium
SITIO MABALUIGEN DAY CARE	Siminublan	Low	Low	Medium

Table A-12.6. Educational Institutions Affected in Subic

Zambales				
Subic				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
AETA’S CHILDREN HOME AND SCHOOL 1	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 10	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 11	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 13	Asinan Poblacion	Low	Low	Low
AETA’S CHILDREN HOME AND SCHOOL 14	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 15	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 16	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 17	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 18	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 19	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 2	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 21	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 22	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 23	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 3	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 4	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 5	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 6	Asinan Poblacion			
AETA’S CHILDREN HOME AND SCHOOL 7	Asinan Poblacion	Low	Low	Low
AETA’S CHILDREN HOME AND SCHOOL 9	Asinan Poblacion			
LOOC ELEMENTARY	Cawag			
LOOC ELEMENTARY 2	Cawag			
LOOC ELEMENTARY 3	Cawag			
LOOC ELEMENTARY 4	Cawag			
LOOC ELEMENTARY 5	Cawag			

Annex 13. Medical Institutions Affected by Flooding in Sto. Tomas Floodplain

Table A-13.1. Medical Institutions Affected in Castillejos

Zambales				
Castillejos				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
MEDEX CLINIC DIABETES CENTER	San Jose			Low
HEALTH AND DAY CARE CENTER	San Roque		Low	Low
JOSE MEDICAL CLINIC	San Roque		Low	Low

Table A-13.2. Medical Institutions Affected in San Felipe

Zambales				
San Felipe				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
HEALTH CLINIC	Balincaguing	High	High	High

Table A-13.3. Medical Institutions Affected in San Marcelino

Zambales				
San Marcelino				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
IMMACULATE CONCEPCION LABORATORY	LaPaz			Low
SAN MARCELINO DISTRICT HOSPITAL 1	Nagbunga			

Table A-13.4. Medical Institutions Affected in San Narciso

Zambales				
San Narciso				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ZMMG PHARMACY CLINIC	San Rafael			Low