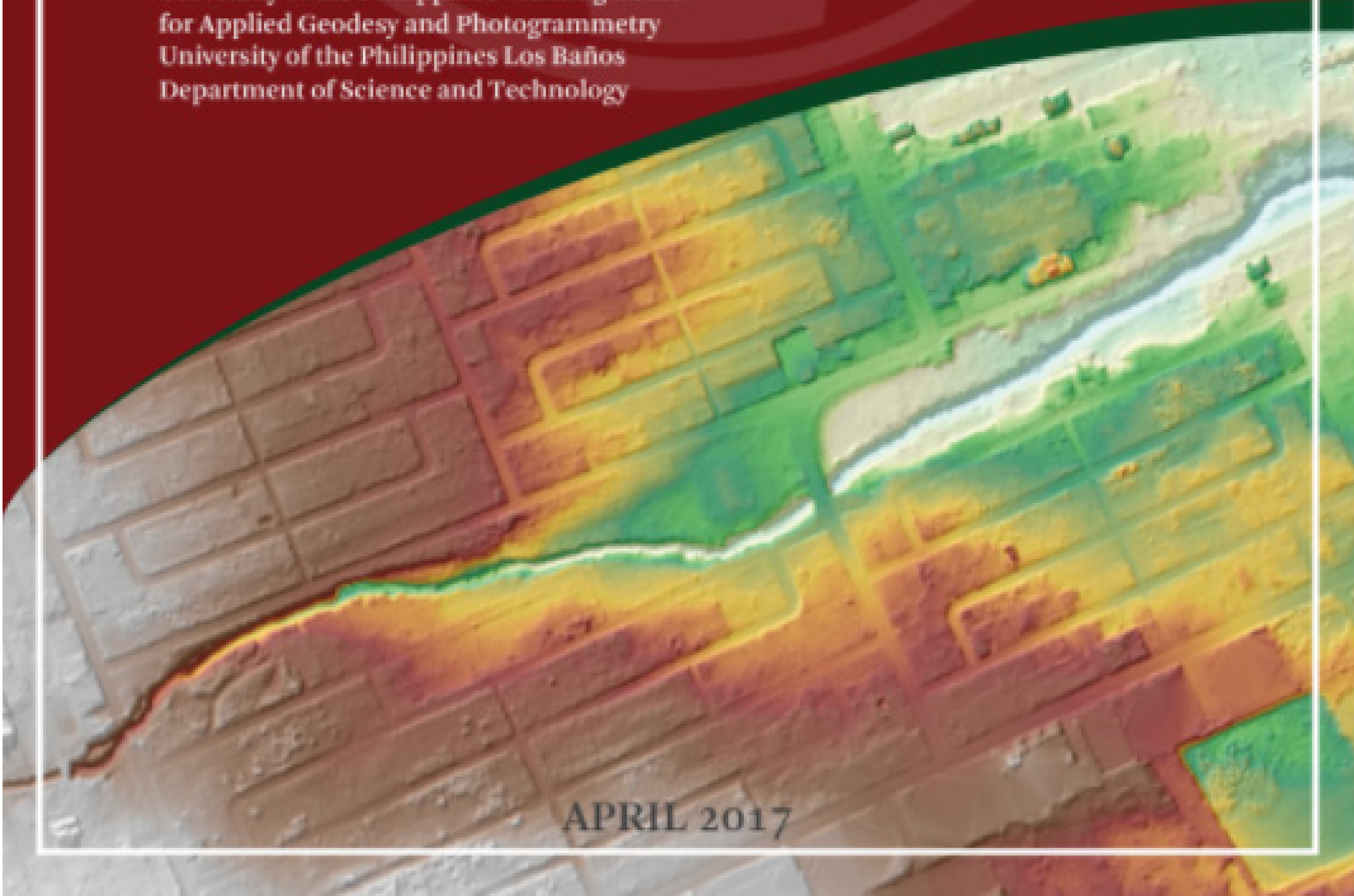
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of San Cristobal River

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



APRIL 2017

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

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

E.C. Paringit, E.R. Abucay, (Eds). (2017), LiDAR Surveys and Flood Mapping Report of San Cristobal River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry – 162pp

For questions/queries regarding this report, contact:

Asst. Prof. Edwin R. Abucay
Project Leader, PHIL-LiDAR 1 Program
University of the Philippines Los Baños
Los Baños, Philippines 4031
erabucay@up.edu.ph

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

National Library of the Philippines
ISBN: 987-621-430-157-7

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
UPLB	University of the Philippines Los Baños
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SAN CRISTOBAL RIVER

Dr. Chelo Pascua and Enrico C. Paringit, Dr. Eng., Miyah D. Queliste

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.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

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

1.2 Overview of the San Cristobal River Basin

San Cristobal River Basin covers most of the City of Calamba, and a small portion of the Municipality of Los Baños and City of Tanauan, all of which are in Laguna. The DENR-RCBO identified it to be one of the 421 river basins in the Philippines, having a drainage area of 131 km² and an estimated 210 million cubic meter annual run-off.

Its main stem, San Cristobal River, passes along Calamba City. San Cristobal River is part of the (47) river systems in MIMAROPA Region IVB. There is a total of 74,574 people residing within the immediate vicinity of the river which is distributed among five (5) barangays, namely: Paciano Rizal, Parian, San Cristobal, Banadero, Looc, and Sampiruhan which are barangays located in Calamba City (NSO, 2010).

Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

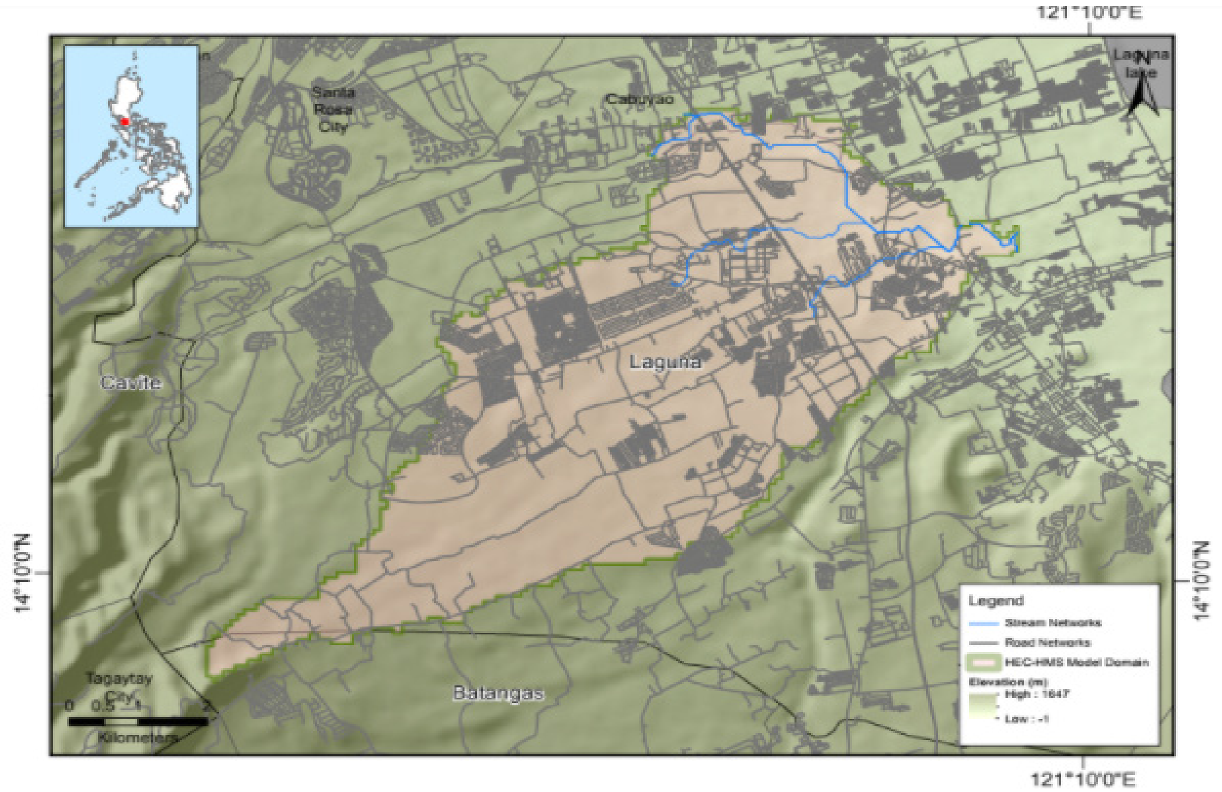
San Cristobal River Basin is a 4,500-hectare watershed located in Laguna. It covers the barangays of Bubuyan, Barandal, Banlic, Batino, Bunggo, Burol, Canlubang, Hornalan, Laguerta, Lawa, Mabato, Majaba Labas, Mapagong, Mayapa, Paciano Rizal, Palo –Alto, Parian, Prinza, Punta, San Cristobal and Sirang Lupa in the City of Calamba; and Turbina, Banlic, Diezmo and San Isidro in Cabuyao City. The basin area has two geological classifications: Pliocene-Quaternary as the most dominant type while the others is Recent. Majority (80%) of the areas in within river basin is level to gently sloping and elevation of 10-150 meters above mean sea level. San Cristobal River Basin is dominated by Lipa loam soil type. Other soils that can be found in the area include Quiangua silt loam, Tagaytay sandy loam, Taal fine sandy loam, Taal loam and

Tagaytay loam. The most predominant land cover type in the area is arable land with crops mainly cereals and sugar followed by cropland mixed with coconut plantation.

San Cristobal River passes through Babuyan, Banadero, Banlic, Barandal, Batino, Bunggo, Canlubang, Hornalan, Laguerta, Lawa, Looc, Mabato, Majada Labas, Mapagong, Mayapa, Paciano Rizal, Palo –Alto, Parian, Punta, San Cristobal and Sirang Lupa in Calamba; Banlic, Casile, Diezmo, Pittland in Cabuyao; Don Jose and Santo Domingo in Santa Rosa; Cabangaan, Hoyo, Lumil, Pasong Langka, pooc I, Putting Kahoy in Silang; and, Calabuso North and South, DapDap East and West and Iruhin East. Based on the records of the 2010 NSO Census of Population and Housing, Lawa in Calamba, Banlic in Cabuyao, Don Jose in Santa Rosa, Tartaria in Silang and Iruhin East in Tagaytay are the most populated barangays in their respective municipalities.

As stated in the Ecological Profile of Laguna (2011), most municipalities in the 2nd, 3rd and 4th districts of the province are mostly affected by flood hazards and rain-induced to landslide hazard as assessed by the Office of Civil Defence (OCD), DENR- Mines Geosciences Bureau (MGB) and NAMRIA. On the other hand, municipalities including Calauan, Cavinti, Lumban, Mabitac, Nagcarlan, Paete, Rizal, Siniloan and Sta. Maria are susceptible to soil and river bank erosion. Whereas the municipalities of Bay, Biñan, Cabuyao, Calamba, Famy , Kalayaan, Los Baños, Lumban, Paete, Pagsanjan, Pakil, Pangil, Mabitac, San Pedro, Sta. Cruz, Sta. Rosa, Sta. Maria, Siniloan and Victoria are prone to liquefaction. Moreover, municipalities of San Pedro and Calamba are also prone to highly ground rupture hazard.

The field surveys conducted by the PHIL-LiDAR 1 validation team found that several weather disturbances caused flooding in 1995 (Rosing), 2006 (Milenyo), 2009 (Ondoy), 2013 (Yolanda), and 2014 (Glenda). Heavy rains brought by southwest monsoon in 2012 and 2013 also caused flooding affecting barangay Looc and Uwisan.



CHAPTER 2: LIDAR DATA ACQUISITION OF THE SAN CRISTOBAL FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuna, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, Engr. Millie Shane R. Reyes

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).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for San Cristobal floodplain in Samar. These missions were planned for 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 Error! Reference source not found. and Error! Reference source not found.. Error! Reference source not found. shows the flight plan for San Cristobal floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK33E	600	30	36	70	50	120	5
BLK33F	600	30	36	70	50	120	5
BLK33G	600	30	36	70	50	120	5
BLK33H	600	30	36	70	50	120	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)
BLK33A	850	30	40	125	50	130	5
BLK33B	850	30	40	125	50	130	5
BLK34H	650	30	40	125	50	130	5
BLK34I	800	30	50	125	40	130	5
BLK34J	800	30	50	125	40	130	5
BLK34K	850	30	40	125	50	130	5
BLK34M	850	30	40	125	40	130	5

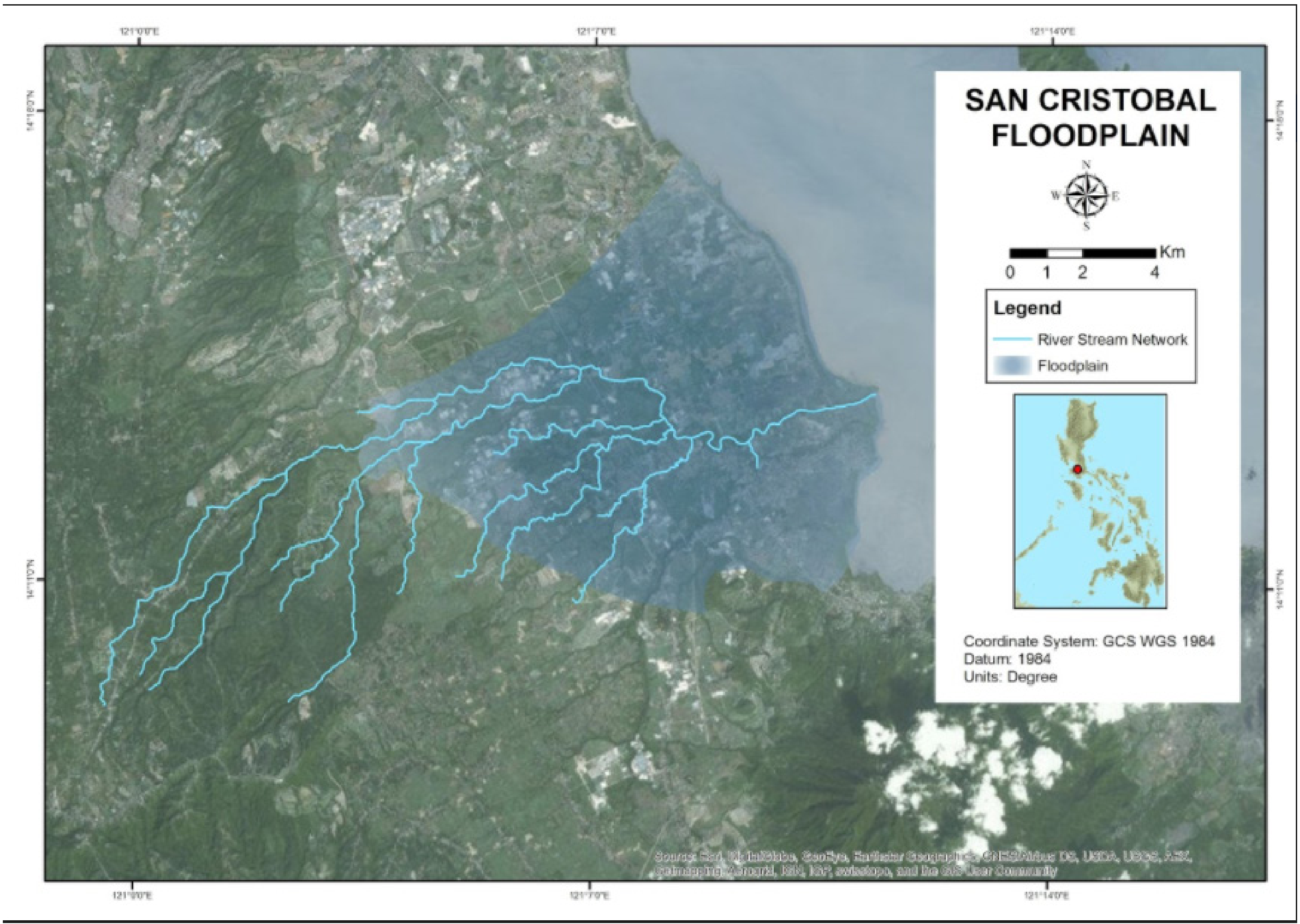


Figure 1. Flight plan and base stations used for San Cristobal floodplain.

2.2 Ground Base Stations

The project team was able to recover four (4) NAMRIA horizontal ground control points: BTG 45, BTG-51, LAG-20 and QZN-21 which are all of second (2nd) order accuracy. The project team also established ground control points LAG-20A, LAG-20B, LAG20D, BTG-A, BTG-45A and QZN-21A. The certification for the NAMRIA reference points are found in ANNEX 2 while the baseline processing reports for the established control points are found in ANNEX 3. These were used as base stations during flight operations for the entire duration of the survey (May 3-13, 2014 and January 29-February 6, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in San Cristobal floodplain are shown in Figure 1.

Figure 2 to Figure 8 show the recovered NAMRIA reference points within the area. Table 3 to Table 10 show the details about the following NAMRIA control stations and established points, whileError! Reference source not found. shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

(a) (b)

Figure 2. GPS set-up over SMR-53 located near the school building flag pole of San Isidro Elementary, Brgy. San Isidro, Santa Rita (a) and NAMRIA reference point SMR-53 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point SMR-53 used as base station for the LiDAR acquisition.

Station Name	**SMR-53**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 30’ 17.85657” North 125° 1’ 29.837339” East 26.13400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	502722.403 meters 1272180.079 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 30’ 13.52495” North 125° 1’ 34.96980” East 87.78700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	720874.14 meters 1272513.40 meters

(a)

(b)

Figure 3. GPS set-up over SMR-56 located inside Cabacungan Elementary School in Brgy. Cabacungan, Sta. Rita, Samar (a) and NAMRIA reference point SMR-56 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point SMR-56 used as base station for the LiDAR acquisition.

Station Name	SMR-56	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 23’ 6.52702” North 125° 0’ 23.99607” East 11.82200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	500727.475 meters 1258927.861 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 23’ 2.22413” North 125° 0’ 29.13917” East 73.72700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718970.61 meters 1259244.38 meters

(a) (b)

Figure 4. GPS set-up over SMR-58 located inside Serum Elementary School, Brgy. Serum, Basey (a) and NAMRIA reference point SMR-58 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point SMR-58 used as base station for the LiDAR acquisition.

Station Name	SMR-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	11° 17' 55.05617" North 125° 7' 51.16145" East 6.30062 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	514288.239 meters 1249361.531 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 17' 50.78580" North 125° 7' 56.31100" East 68.72300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	732600.57 meters 1249768.75 meters

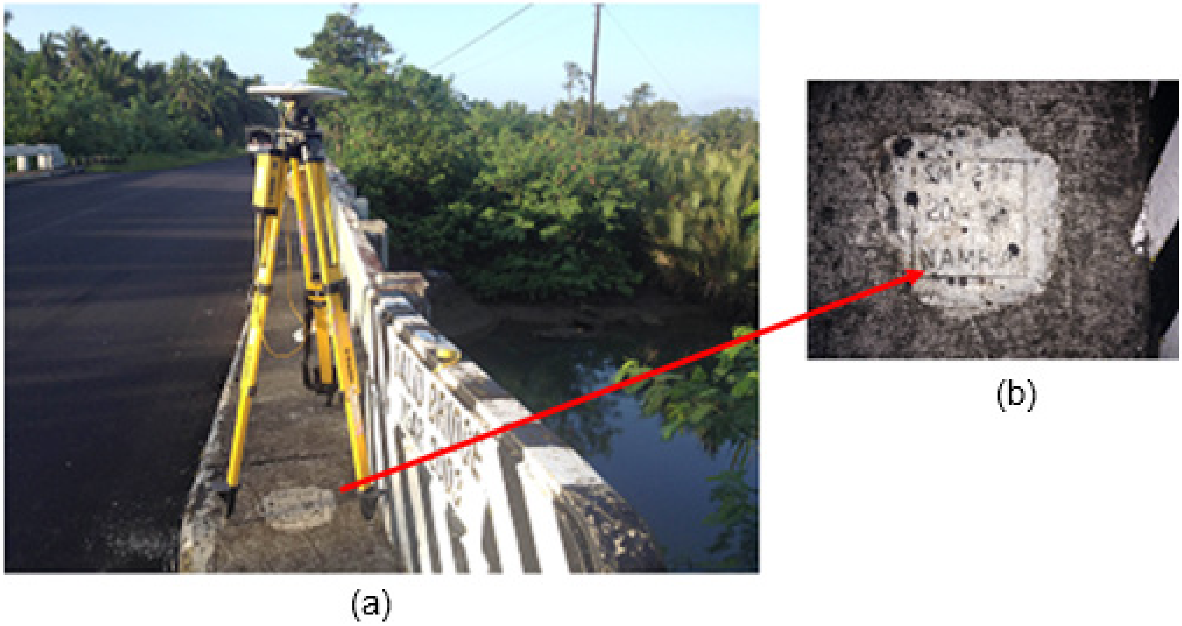


Figure 5. GPS set-up over SM-286 located at Dalid bridge along national highway in Brgy. San Pascual, Sta. Rita, Samar (a) and NAMRIA reference point SM-286 (a) as recovered by the field team.

Table 6. Details of the recovered NAMRIA vertical control point SM-286 used as base station for the LiDAR acquisition with established coordinates.

Station Name	**SM-286**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 24’ 35.73” North 124° 59’ 44.05” East 5.47 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	499516.558 meters 1261668.44 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 24’ 30.81671” North 124° 59’ 48.35250” East 67.268 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	717869.251 meters 1261905.903 meters

(a) (b)

Figure 6. GPS set-up over SM-271 located beside kilometer post 864 along right side of the national highway, Bgry. Laygayon, Pinabacdao (a) and NAMRIA reference point SM-271 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA vertical control point SM-271 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SM-271	
Order of Accuracy	**2^{nd} order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 31' 31.48945" North 125° 01' 36.88429" East 82.083 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 31' 27.15288" North 125° 01' 34.96980" East 143.69 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	721071.742 meters 1274777.721 meters

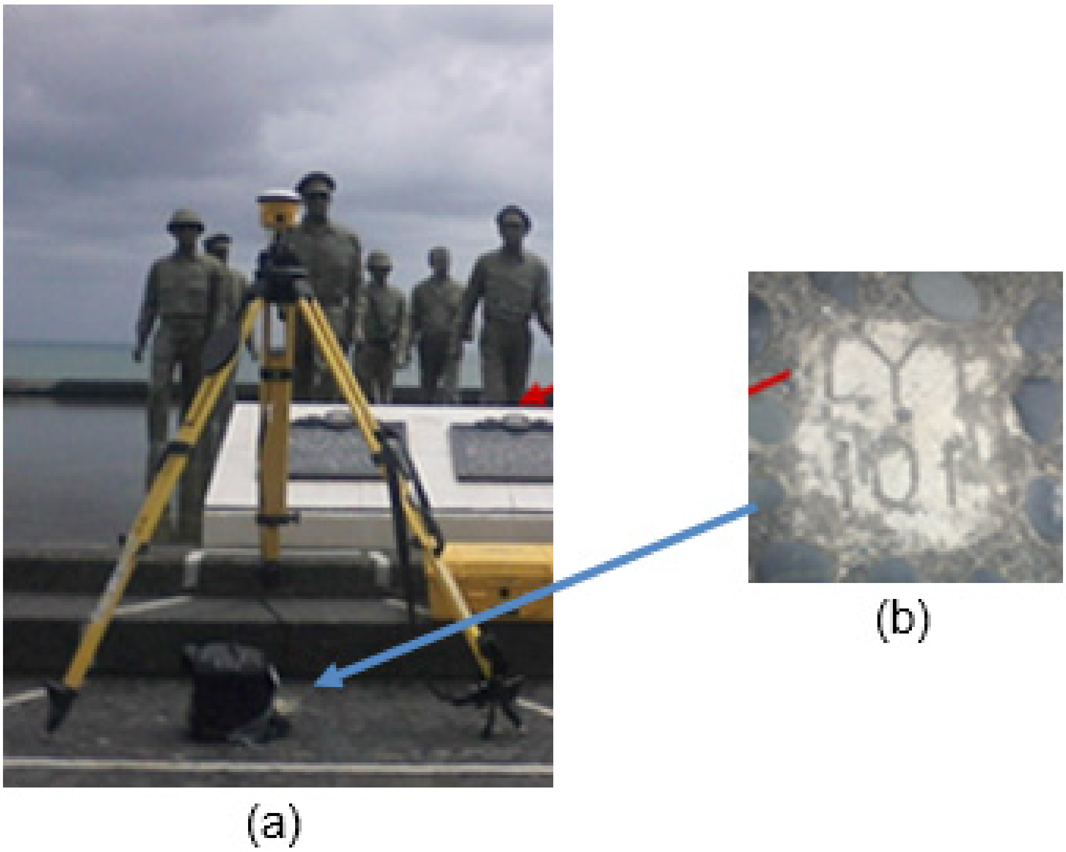


Figure 7. GPS set-up over LYT-101 located within the premises of MacArthur's Landing Memorial Park, Palo, Leyte (a) and NAMRIA reference point LYT-101 (a) as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point LYT-101 used as base station for the LiDAR acquisition.

Station Name	LYT-101	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11°10'23.89707" North 125° 0' 38.62071"East 6.58600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	501171.719 meters 1235497.253 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10' 19.64869" North 125° 0' 43.78230"East 69.02100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	719575.03 meters 1235811.61 meters

(a) (b)

Figure 8. GPS set-up over LYT-104 located and re-established along rice paddy trail, approximately 90 meters from the centerline, east side of Pastrana-Santa Fe Road, District IV, Pastrana, Leyte (a) and NAMRIA reference point LYT-104 (b) as recovered by the field team.

Table 9. Details of the recovered and re-established NAMRIA horizontal control point LYT-104 used as base station for the LiDAR acquisition.

Station Name	**LYT-104**	
Order of Accuracy	**2nd order**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 08’38.92234” North 124° 53’ 13.52786” East 33.659 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 08’34.67033” North 124° 53’ 18.69323” East 95.861 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	706089.510 meters 1232496.838 meters

Table 10. Details of the recovered NAMRIA vertical control point SM-309 used as base station for the LiDAR acquisition with established coordinates.

Station Name	SM-309	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 17' 59.30748" North 125° 06' 56.29744" East 9.743 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 17' 55.03553" North 125° 07' 01.44700" East 72.125 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	730935.362 meters 1249887.315 meters

Table 11. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 31, 2014	1051P	1BLK18E031A	LAG-20 and LAG-20A
February 2, 2014	1059P	1BLK18F033A	LAG-20 and LAG-20A
February 7, 2014	1079P	1BLK18DES038A	LAG20 and LAG-20B
February 15, 2014	1111P	1BLK18QRS46A	QZN-21 and QZN-21A
February 22, 2014	1139P	1BLK18X53A	BTG-45 and BTG-45A
December 21, 2015	3002P	1BLK18S356A	BTG-51 and BTG-A
August 27, 2015	3347P	1BLK18TS239B	LAG-20 and LAG-20D
January 6, 2016	3677G	2BLK18SK006A	BTG-51 and BTG-A
January 8, 2016	3685G	2BLK18SF008A	BTG-51 and BTG-A
January 9, 2016	3689G	2BLK18SV009A	BTG-51 and BTG-A

2.3 Flight Missions

Twelve (12) missions were conducted to complete LiDAR data acquisition in San Cristobal Floodplain, for a total of forty-seven hours and six minutes (47+6) of flying time for RP-C9122 and RP-C9022. All missions were acquired using Aquarius and Gemini LiDAR systems. Error! Reference source not found.12 shows the total area of actual coverage and the corresponding flying hours per mission, while Error! Reference source not found.3 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for LiDAR data acquisition in San Cristobal 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
January 31, 2014	1051P		151.658	36.132	115.526			
February 2, 2014	1059P		92.543	42.686	49.857			
February 7, 2014	1079P		55.091	28.730	26.361			
February 15, 2014	1111P		177.512	9.876	167.636			
February 22, 2014	1139P		269.499	0	269.499			
December 21, 2015	3002P		280.862	0	280.862			
August 27, 2015	3347P		106.509	19.418	87.091			
January 6, 2016	3677G		160.739	0	160.739			
January 8, 2016	3685G		72.798	0.990	71.808			
January 9, 2016	3689G		102.103	0	102.103			
TOTAL								

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)
1051P	600	30	36	70	50	120	5
1059P	600	30	36	70	50	120	5
1079P	600	30	36	70	50	120	5
1111P	600	30	36	70	50	120	5
1139P	600	30	36	70	50	120	5
3002P	600	30	36	70	50	120	5
3347P	600	30	36	70	50	120	5
3677G	600	30	36	70	50	120	5
3685G	800	30	50	125	40	130	5
3689G	650	30	40	125	50	130	5

2.4 Survey Coverage

San Cristobal floodplain is located in the province of Samar with majority of the floodplain situated within the municipality of Santa Rita. Municipalities of Villareal, Talalora, Santa Rita and San Sebastian are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Error! Reference source not found.4. The actual coverage of the LiDAR acquisition for San Cristobal Floodplain is presented in Error! Reference source not found..

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

Province	Municipality/City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Eastern Samar	Balangiga	206.52	46.45	22%
	Lawaan	141.75	5.68	4%
Leyte	Babatngon	136.57	42.92	31%
Samar	Villareal	130.22	127.61	98%
	Santa Rita	250.37	243.71	97%
	Talalora	26.56	25.73	97%
	San Sebastian	15.84	15.17	96%
	Pinabacdao	118.38	62.12	52%
	Basey	627.97	206.67	33%
	Calbiga	216.76	71.98	33%
	Daram	109.26	3.18	3%
Total		**1,980.20**	**851.22**	**42.99%**

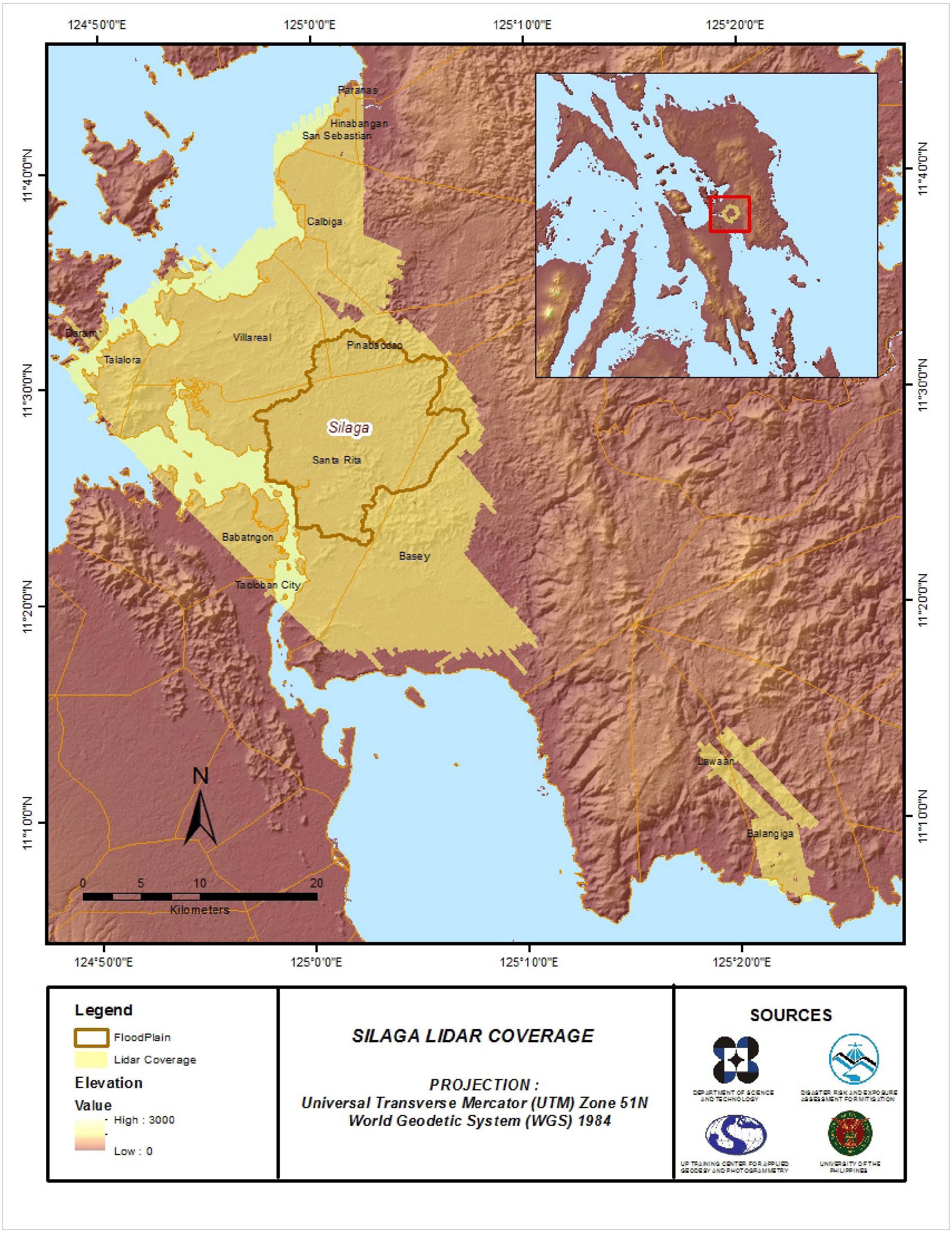


Figure 9. Actual LiDAR survey coverage for San Cristobal floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE OGOD FLOODPLAIN

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

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

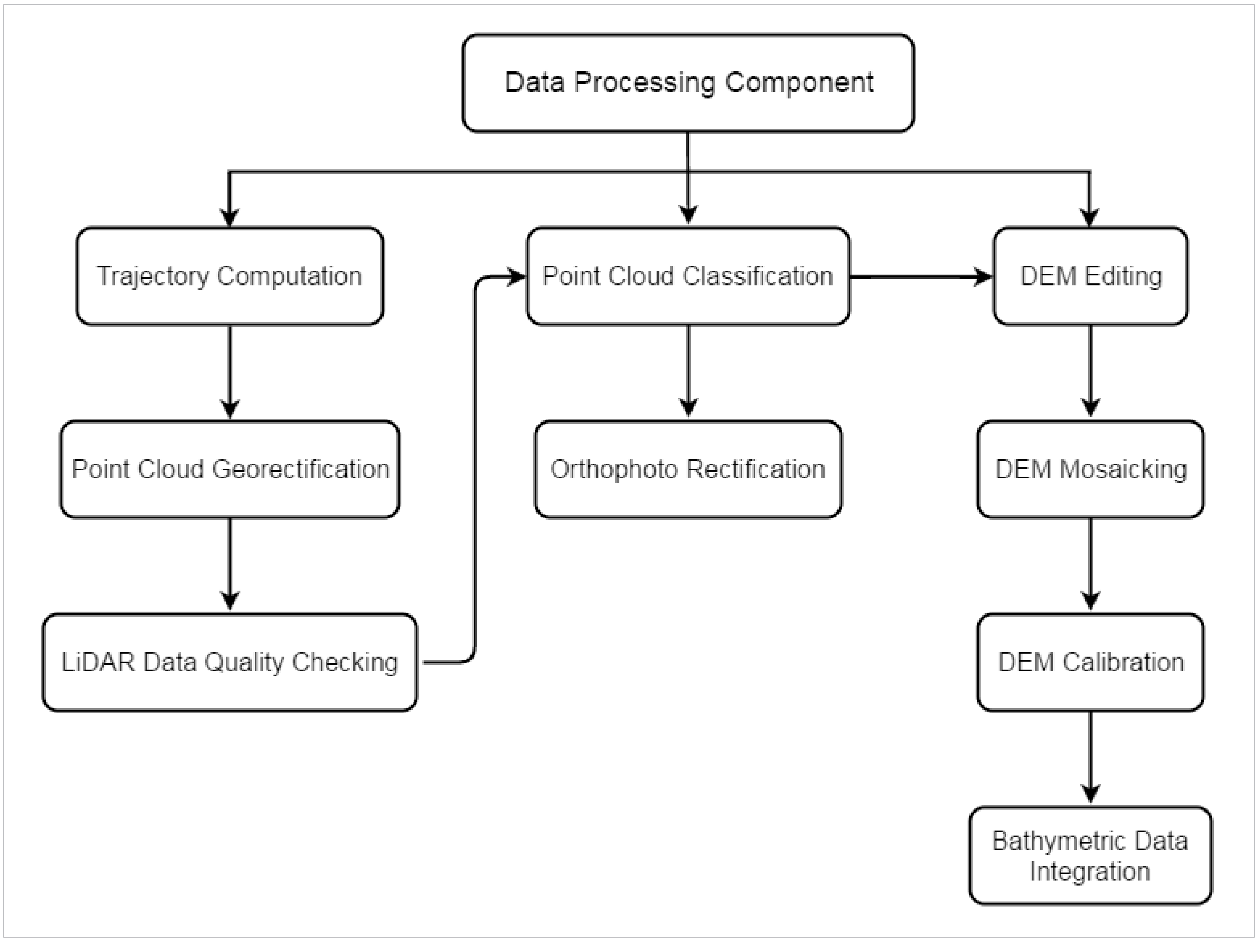


Figure 10. Schematic Diagram for Data Pre-Processing Component.

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 10.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for San Cristobal floodplain can be found in ANNEX 5. Missions flown during the first and second survey conducted on January 2014 and August 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the third survey on January 2016 were flown using the Gemini system over Calamba City, Laguna. The Data Acquisition Component (DAC) transferred a total of 179.38 Gigabytes of Range data, 2.01 Gigabytes of POS data, 123.86 Megabytes of GPS base station data, and 121.95 Gigabytes of raw image data to the data server on October 6, 2014 for the first survey, December 22, 2015 for the second survey and January 9, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for San Cristobal was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for San Cristobal floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3685G, one of the San Cristobal flights, which is the North, East, and Down position RMSE values are shown in Figure 11. 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 8, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

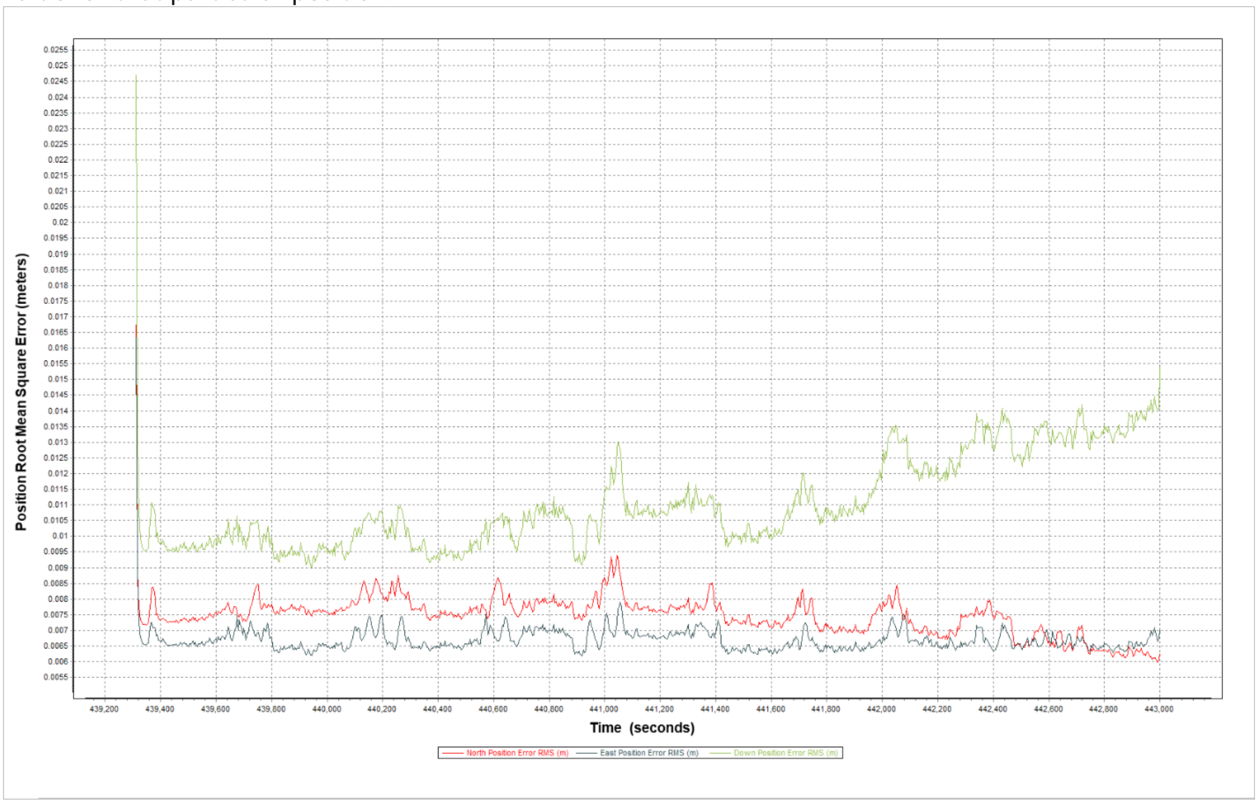


Figure 11. Smoothed Performance Metric Parameters of a San Cristobal Flight 3685G.

The time of flight was from 439320 seconds to 443000 seconds, which corresponds to morning of January 8, 2016. 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 11 shows that the North position RMSE peaks at 0.95 centimeters, the East position RMSE peaks at 0.80 centimeters, and the Down position RMSE peaks at 1.45 centimeters, which are within the prescribed accuracies described in the methodology.

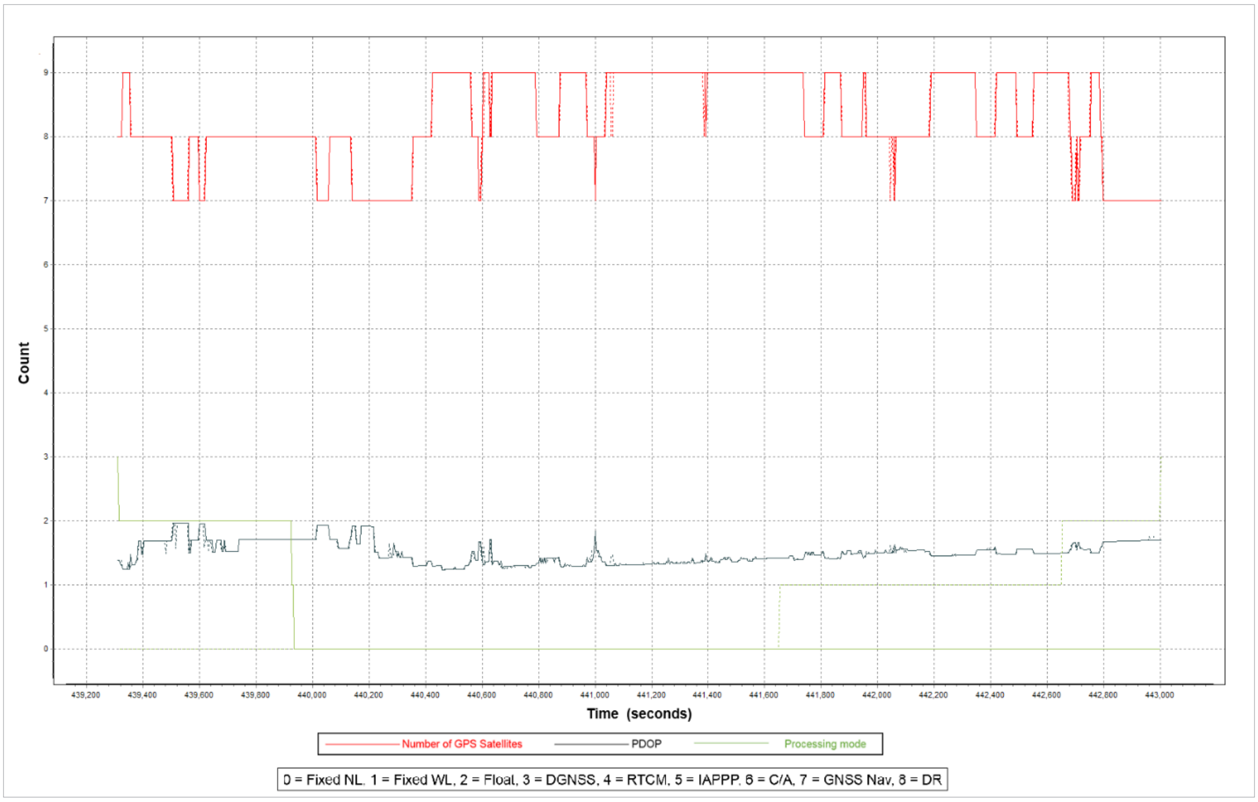


Figure 12. Solution Status Parameters of San Cristobal Flight 3685G.

The Solution Status parameters of flight 3685G, one of the San Cristobal flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all San Cristobal flights is shown in Figure 13.

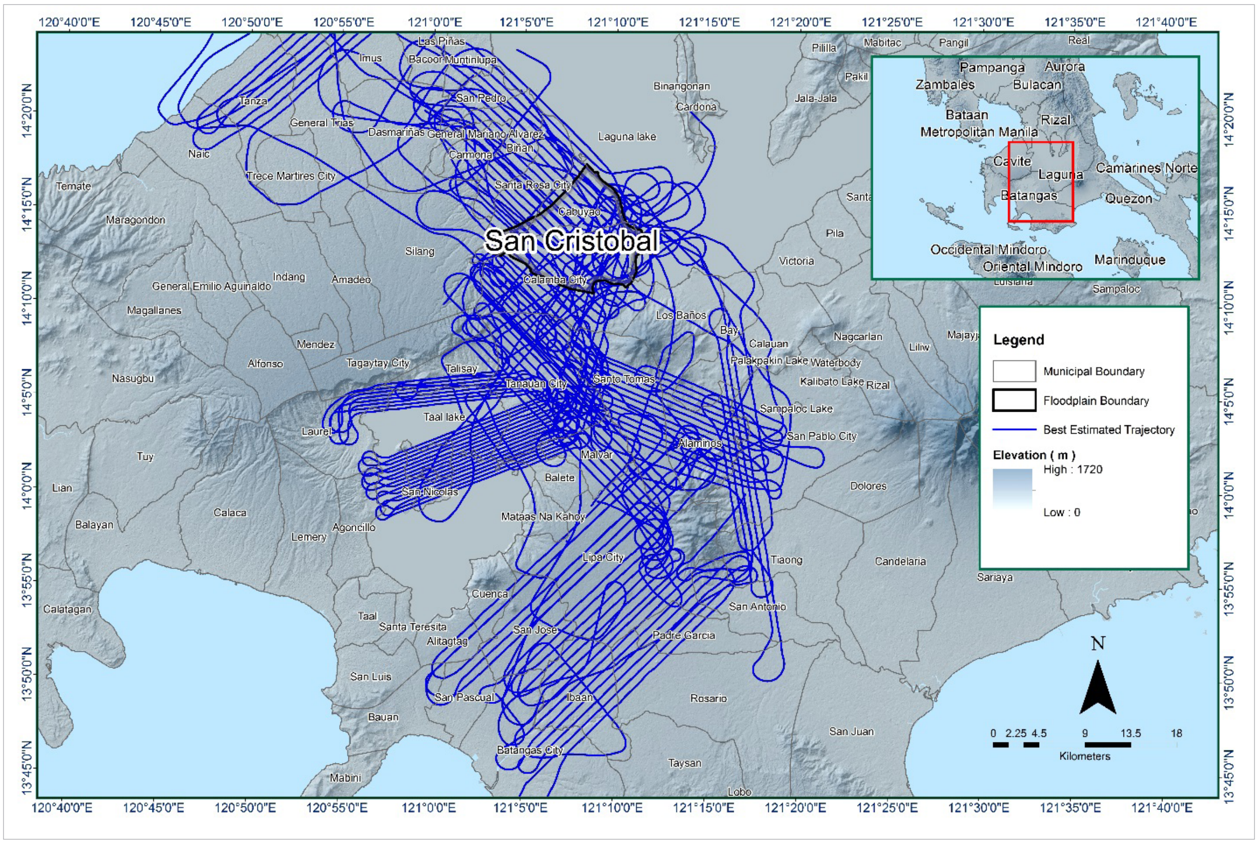


Figure 13. Best Estimated Trajectory for San Cristobal floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 102 flight lines, with each flight line containing one channel for the Gemini system and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over San Cristobal floodplain are given in Table 15.

Table 15. Self-Calibration Results values for San Cristobal flights.

Parameter		Acceptable Value
Boresight Correction stdev	(<0.001degrees)	0.000283
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000945
GPS Position Z-correction stdev	(<0.01meters)	0.0025

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

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over San Cristobal Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

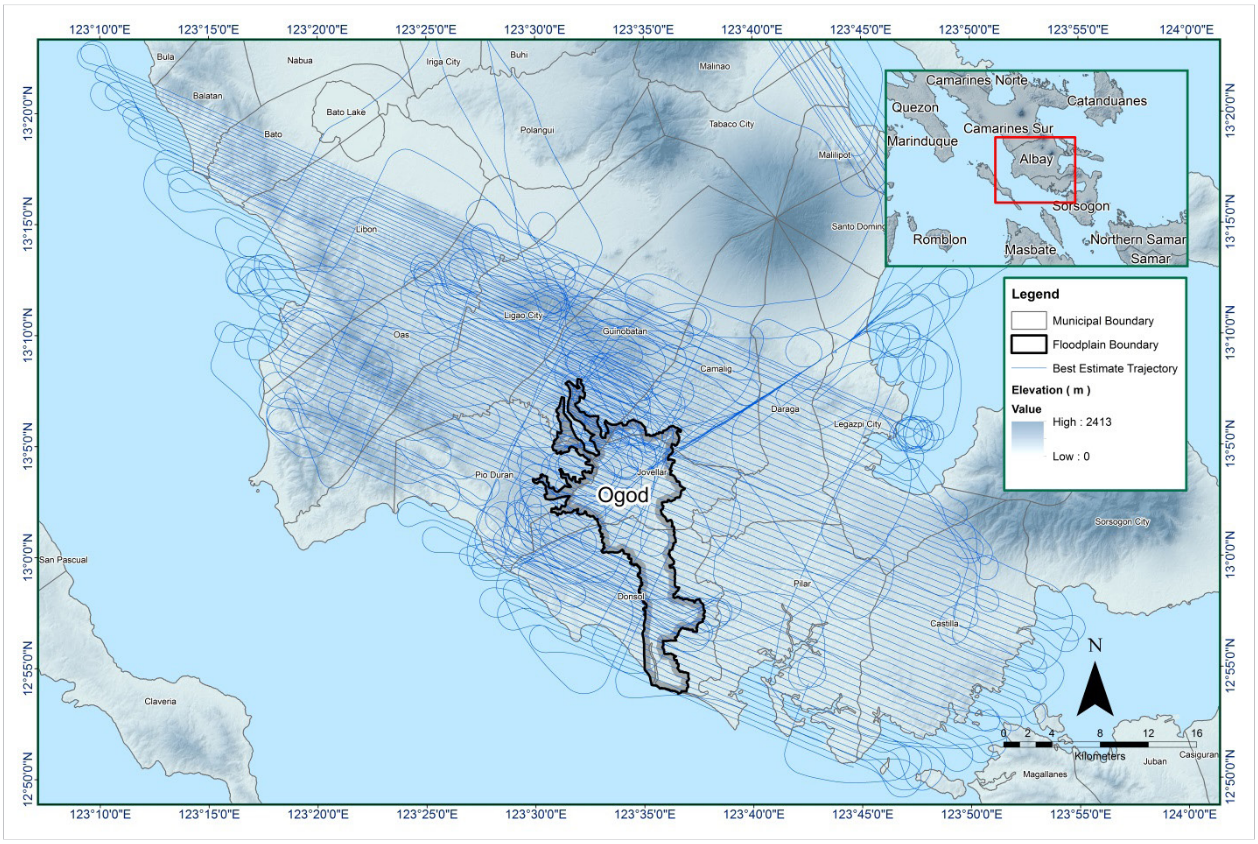


Figure 14. Boundary of the processed LiDAR data over San Cristobal Floodplain.

The total area covered by the San Cristobal missions is 1,025.68 sq.km that is comprised of ten (10) flight acquisitions grouped and merged into ten (10) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for San Cristobal floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Calabarzon_Blk18A	3347P	229.66
Batangas_Blk18SF	3685G	70.53
Batangas_Blk18SE_additional2	3689G	14.99
Batangas_Blk18SK	3677G	42.08
Batangas_Blk18SK_additional	3002P	22.37
Laguna_Blk18EF	1079P	188.11
Laguna_Blk18EF_supplement	1139P	67.31
Laguna_Blk18EFG_supplement	1111P	166.71
Cavite_Blk18E	1051P	149.06
Cavite_Blk18F	1059P	74.86
TOTAL		**1,025.68 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. 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 the Pegasus system employs two channels, where 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.

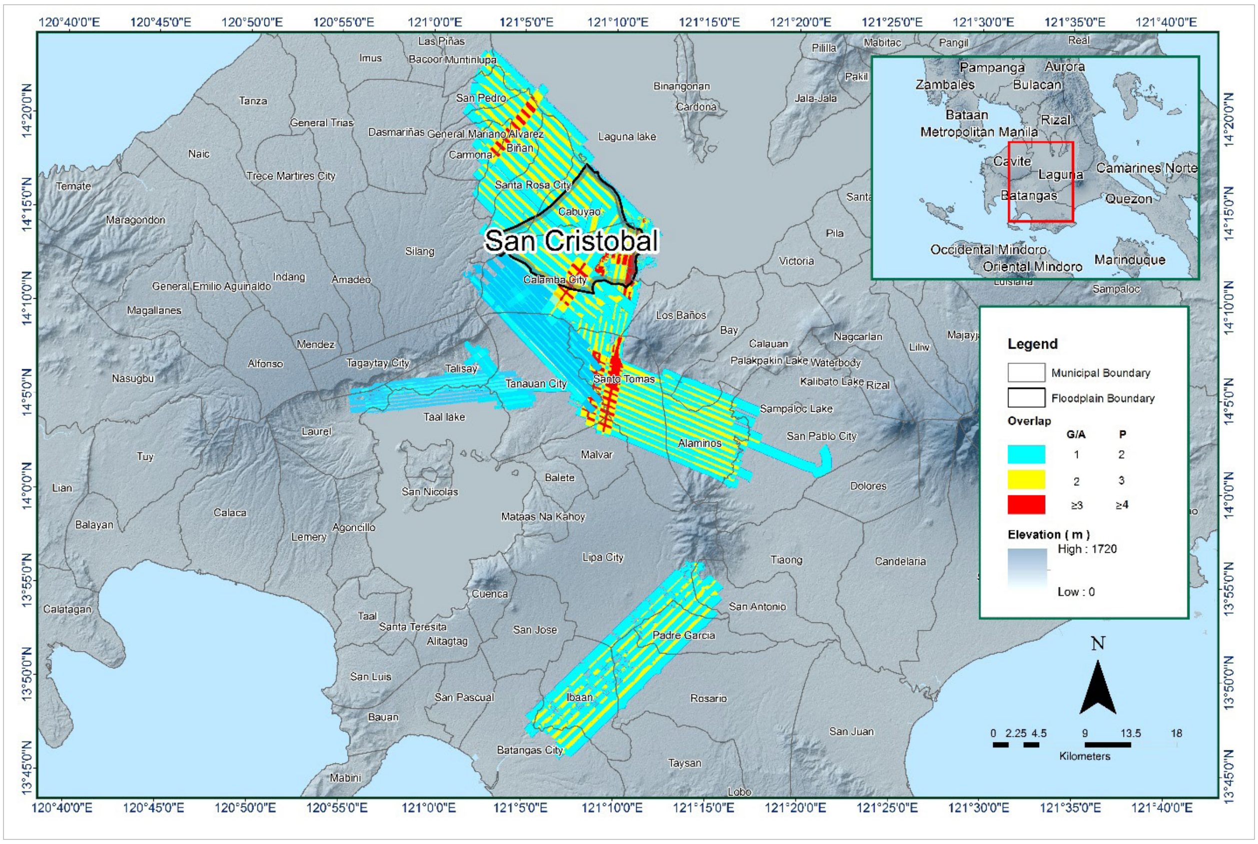


Figure 15. Image of data overlap for San Cristobal floodplain.

The overlap statistics per block for the San Cristobal 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 25.47% and 46.85% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for San Cristobal floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.07 points per square meter.

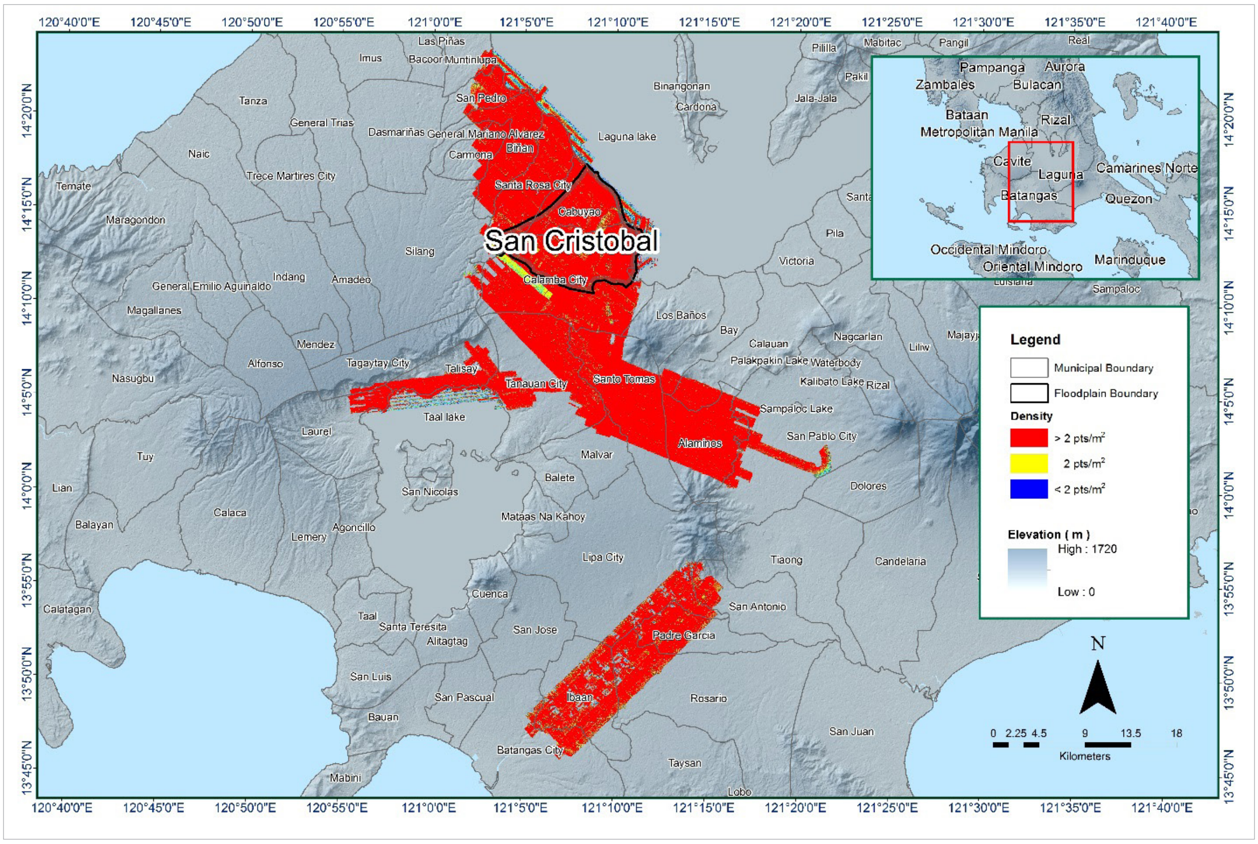


Figure 16. Density map of merged LiDAR data for San Cristobal floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

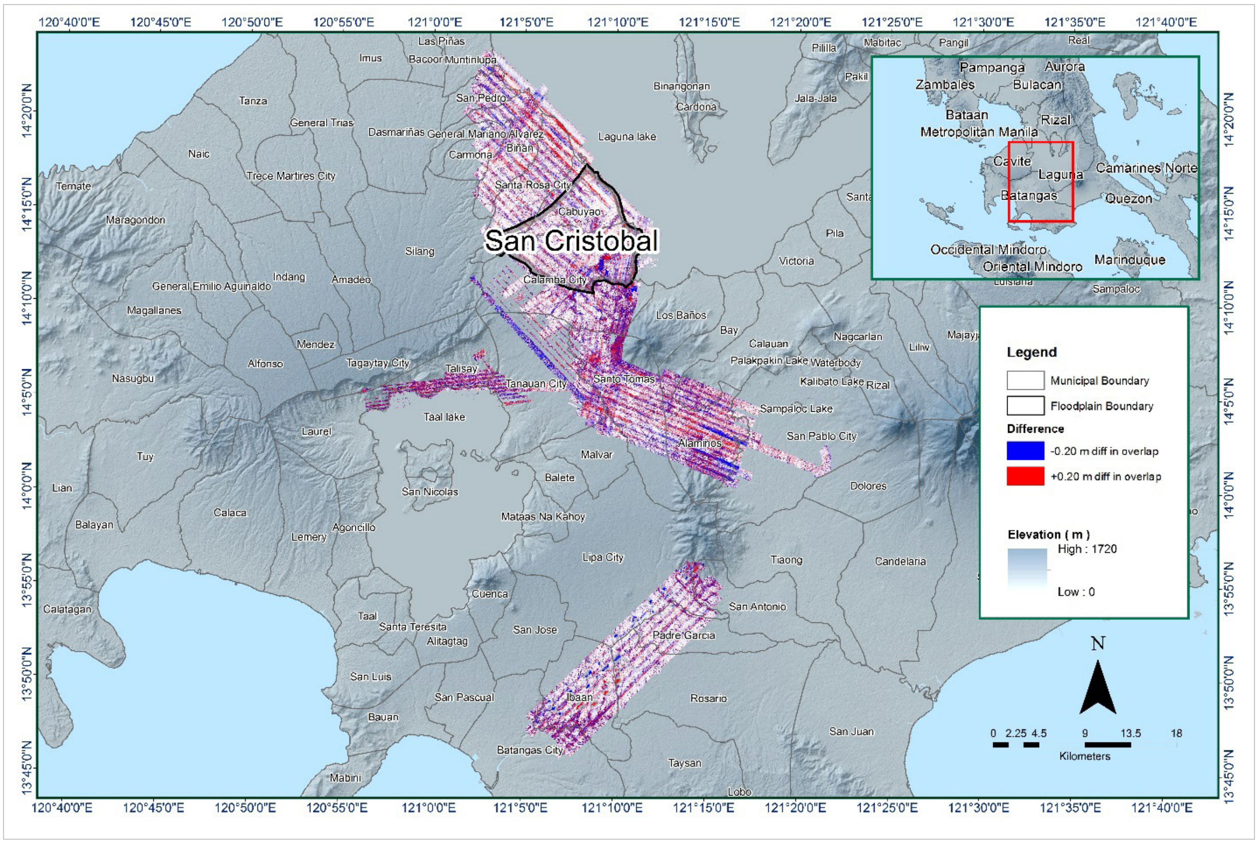


Figure 17. Elevation difference map between flight lines for San Cristobal floodplain.

A screen capture of the processed LAS data from a San Cristobal flight 3685G loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

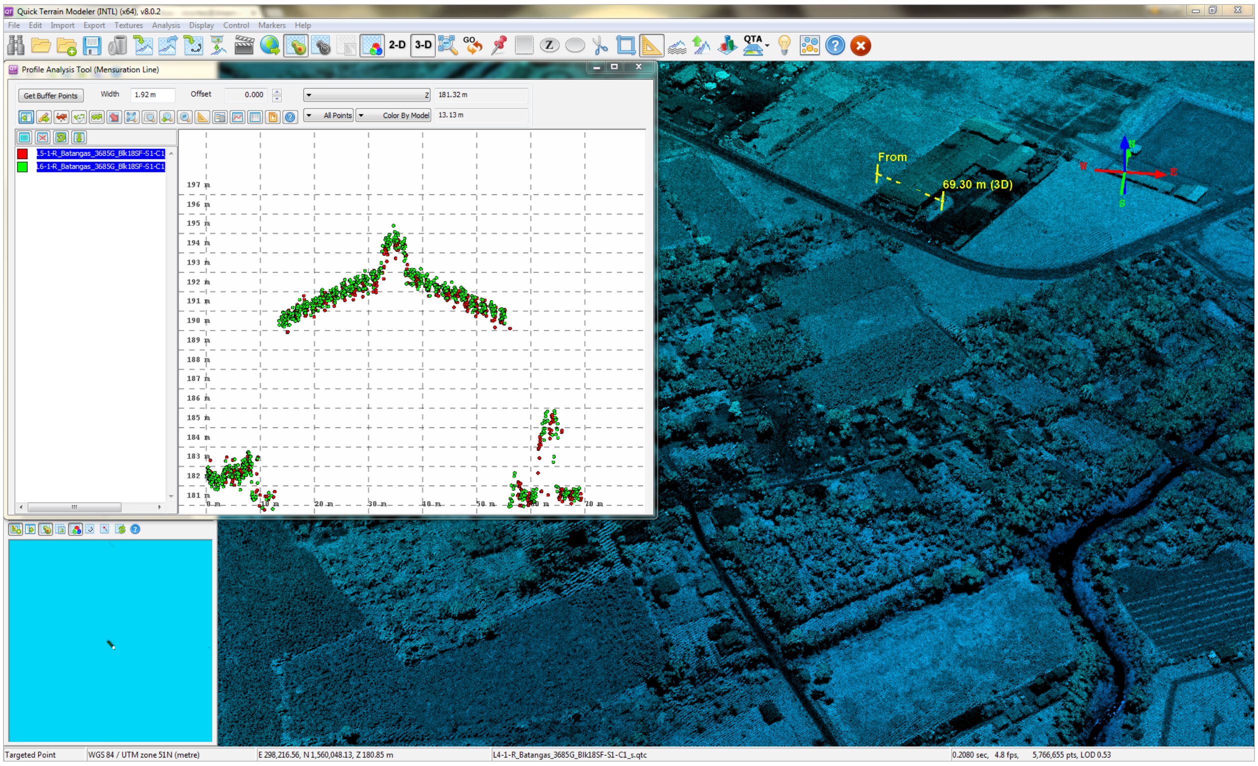


Figure 18. Quality checking for a San Cristobal flight 3685G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. San Cristobal classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	831,506,091
Low Vegetation	845,637,835
Medium Vegetation	1,299,722,999
High Vegetation	1,345,558,444
Building	305,668,576

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in San Cristobal floodplain is shown in Figure 19. A total of 1,434 1km by 1km 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 622.28 meters and 39.80 meters respectively.

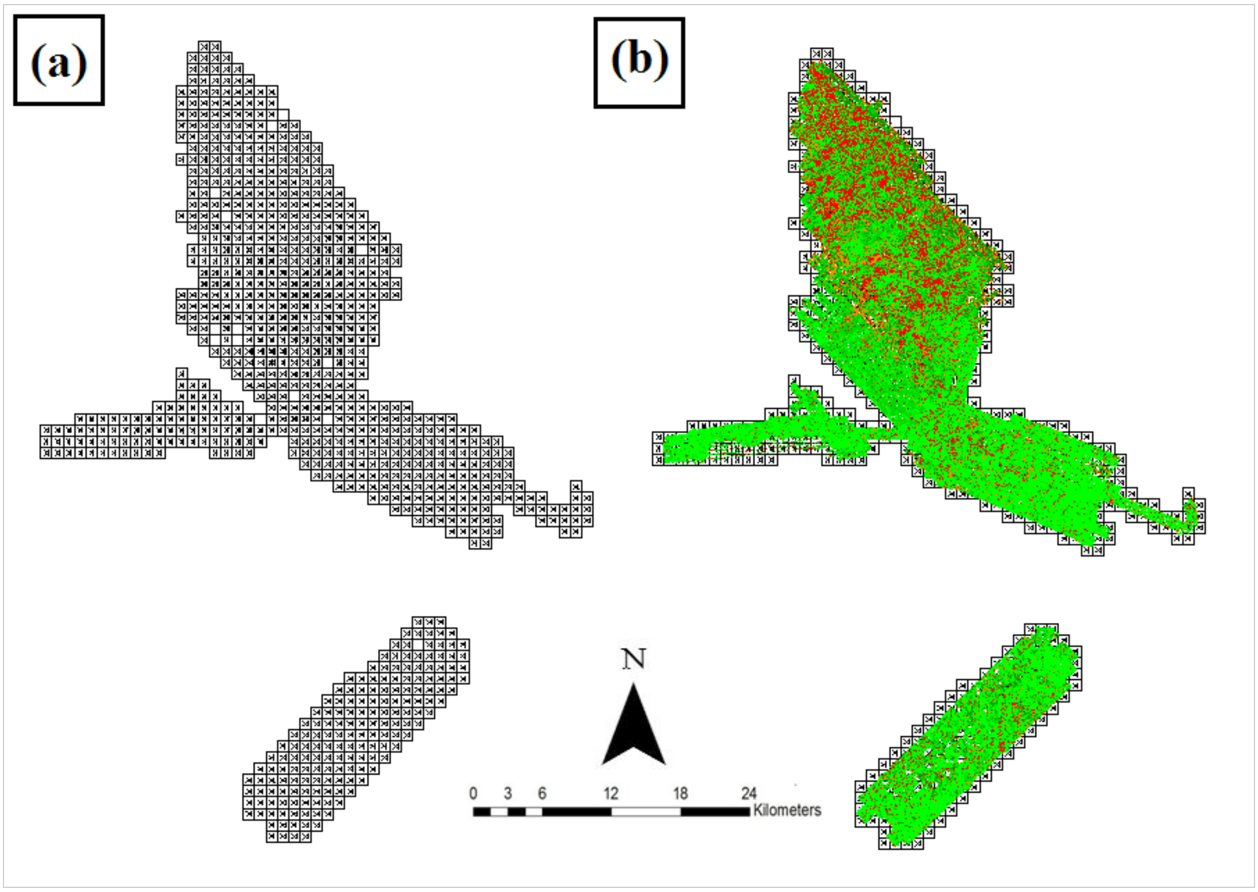


Figure 19. Tiles for San Cristobal floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

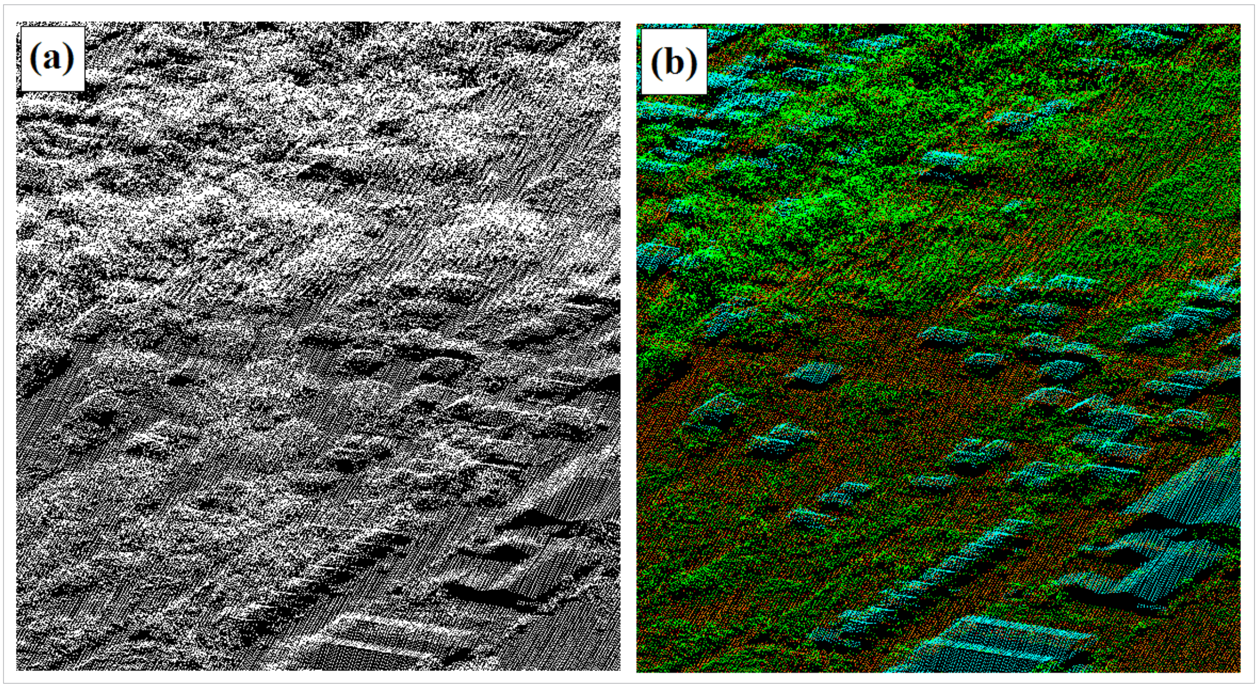


Figure 20. Point cloud before (a) and after (b) classification.

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

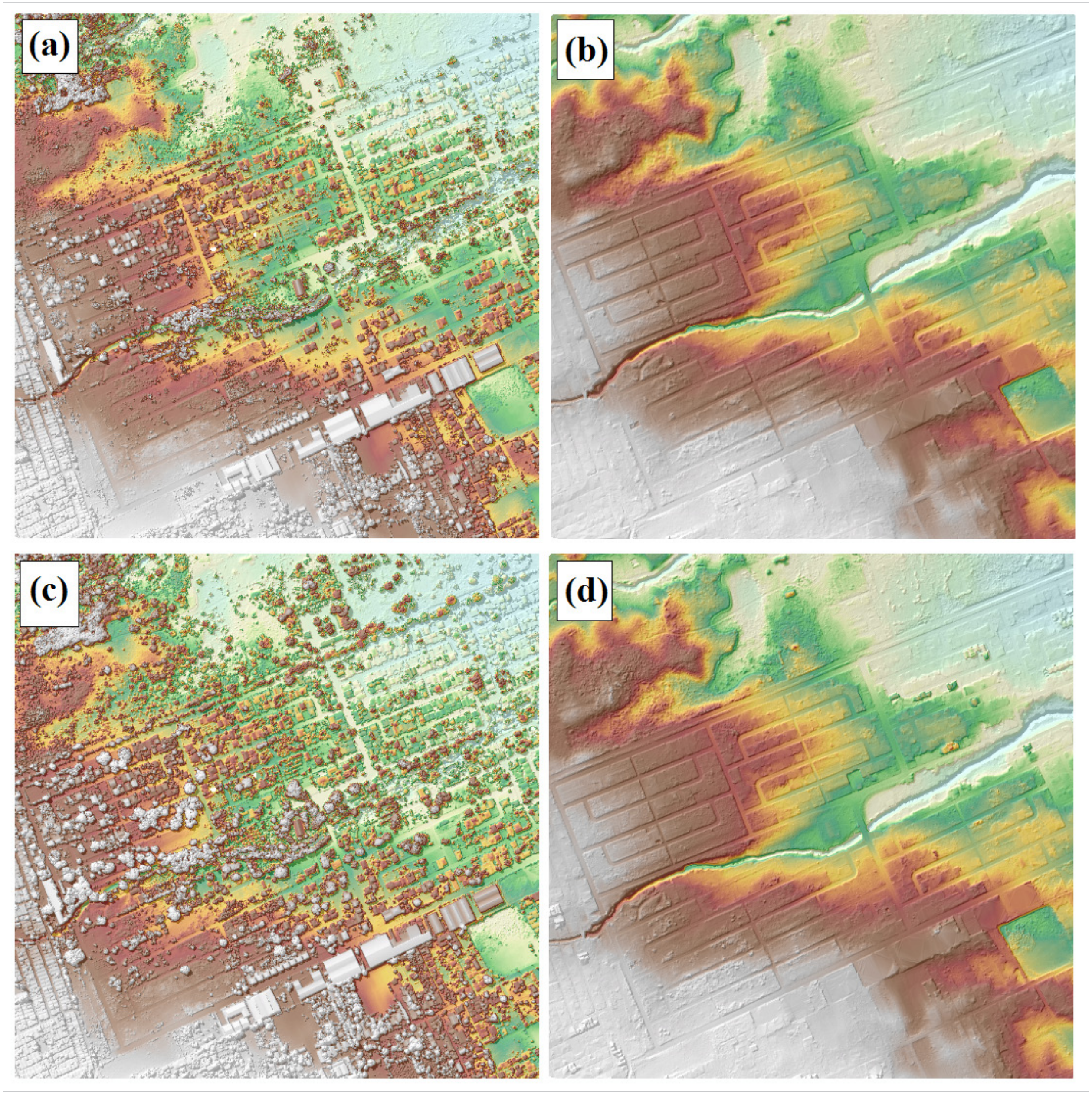


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of San Cristobal floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 621 1km by 1km tiles area covered by San Cristobal floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The San Cristobal floodplain has a total of 374.73 sq.km orthophotogaph coverage comprised of 909 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

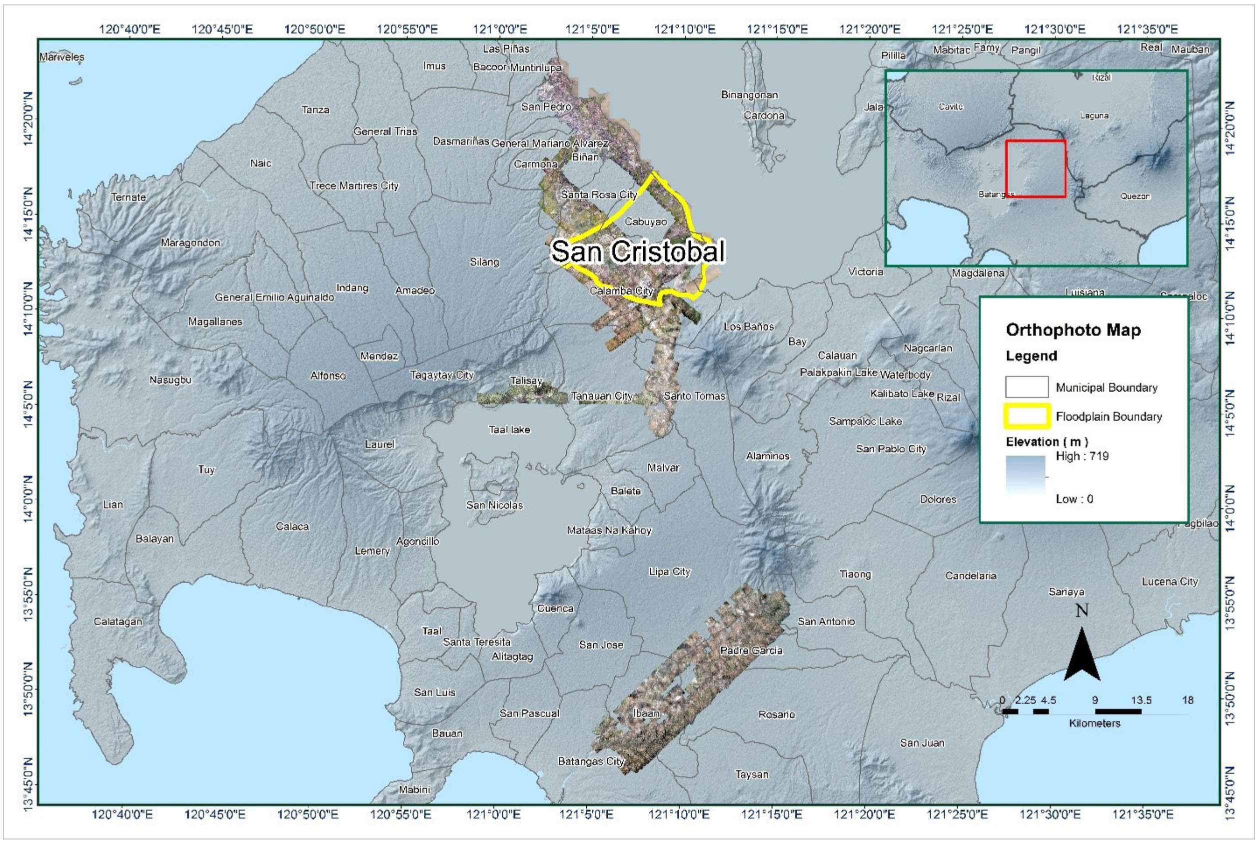


Figure 22. San Cristobal floodplain with available orthophotographs

Figure 23. Sample orthophotograph tiles for San Cristobal floodplain.

3.8 DEM Editing and Hydro-Correction

Ten (10) mission blocks were processed for San Cristobal flood plain. These blocks are composed of CALABARZON, Batangas, Laguna and Cavite blocks with a total area of 1,025.68 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
CALABARZON_Blk18A	229.66
Batangas_Blk18SF	70.53
Batangas_Blk18SE_additional2	14.99
Batangas_Blk18SK	42.08
Batangas_Blk18SK_additional	22.37
Laguna_Blk18EF	188.11
Laguna_Blk18EF_supplement	67.31
Laguna_Blk18EFG_supplement	166.71
Cavite_Blk18E	149.06
Cavite_Blk18F	74.86
TOTAL	**1,025.68 sq.km**

Portions of DTM before and after manual editing are shown in Figure 24. The bridge (Figure 24a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 24b) in order to hydrologically correct the river. The mountain (Figure 24c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 24d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 24e) and has to be removed through manual editing (Figure 24f).

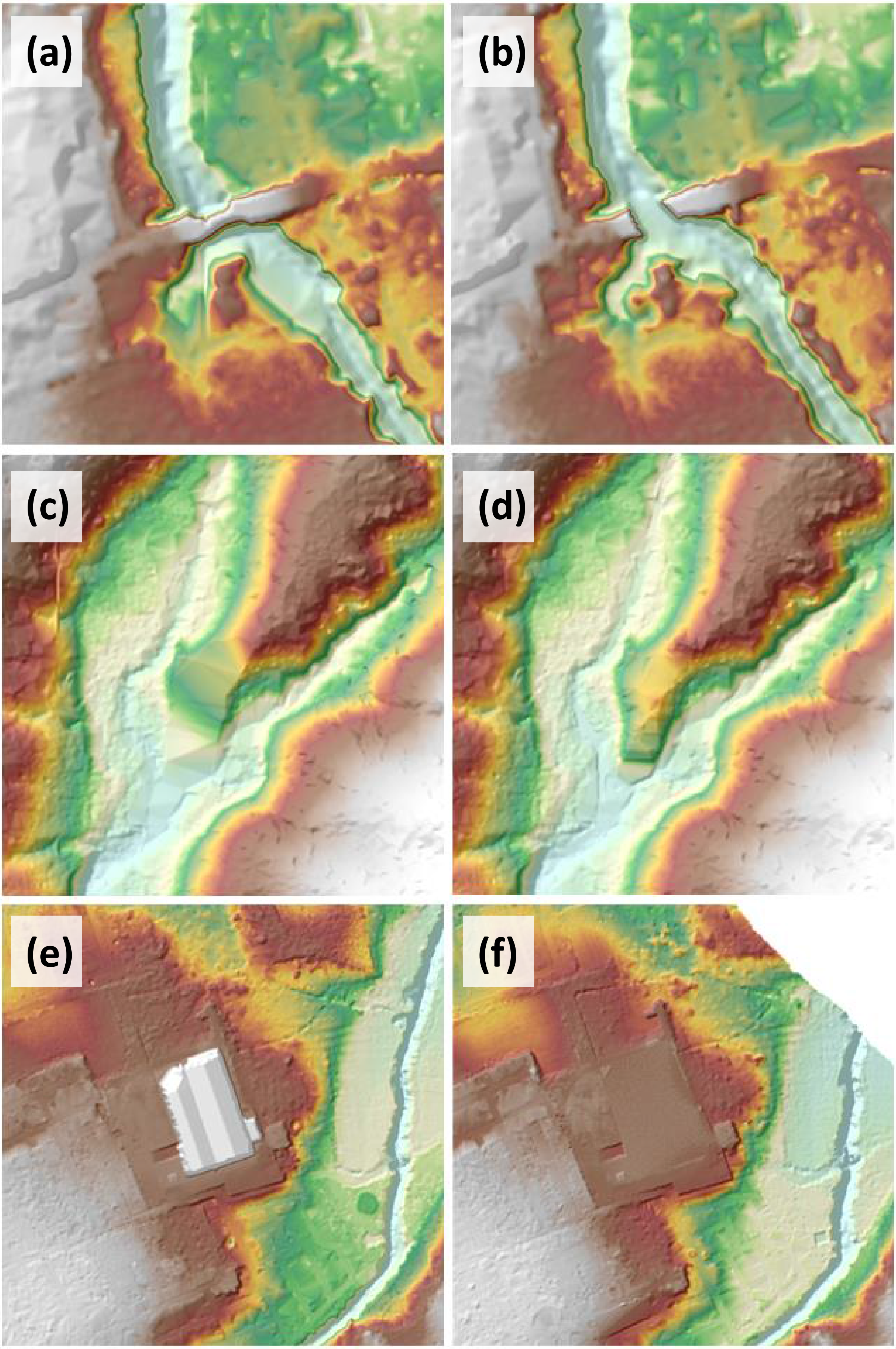


Figure 24. Portions in the DTM of San Cristobal floodplain – a bridge before (a) and after (b) manual editing; a mountain before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Batangas_Blk18Z was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 19 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for San Cristobal floodplain is shown in Figure 25. It can be seen that the entire San Cristobal floodplain is 97.48% covered by LiDAR data.

Table 19. Shift Values of each LiDAR Block of San Cristobal floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_Blk18A	0.00	0.00	0.00
Batangas_Blk18SF	0.00	0.00	0.00
Batangas_Blk18SE_additional2	0.00	0.00	0.00
Batangas_Blk18SK	0.00	0.00	0.00
Batangas_Blk18SK_additional	0.00	0.00	0.00
Laguna_Blk18EF (Upper)	1.32	-24.08	0.24
Laguna_Blk18EF (Lower)	0.00	0.00	0.00
Laguna_Blk18EF_supplement	0.00	0.00	-0.05
Laguna_Blk18EFG_supplement	0.00	0.00	-0.27
Cavite_Blk18E	-2.38	1.77	-0.60
Cavite_Blk18F	-2.38	1.77	0.63

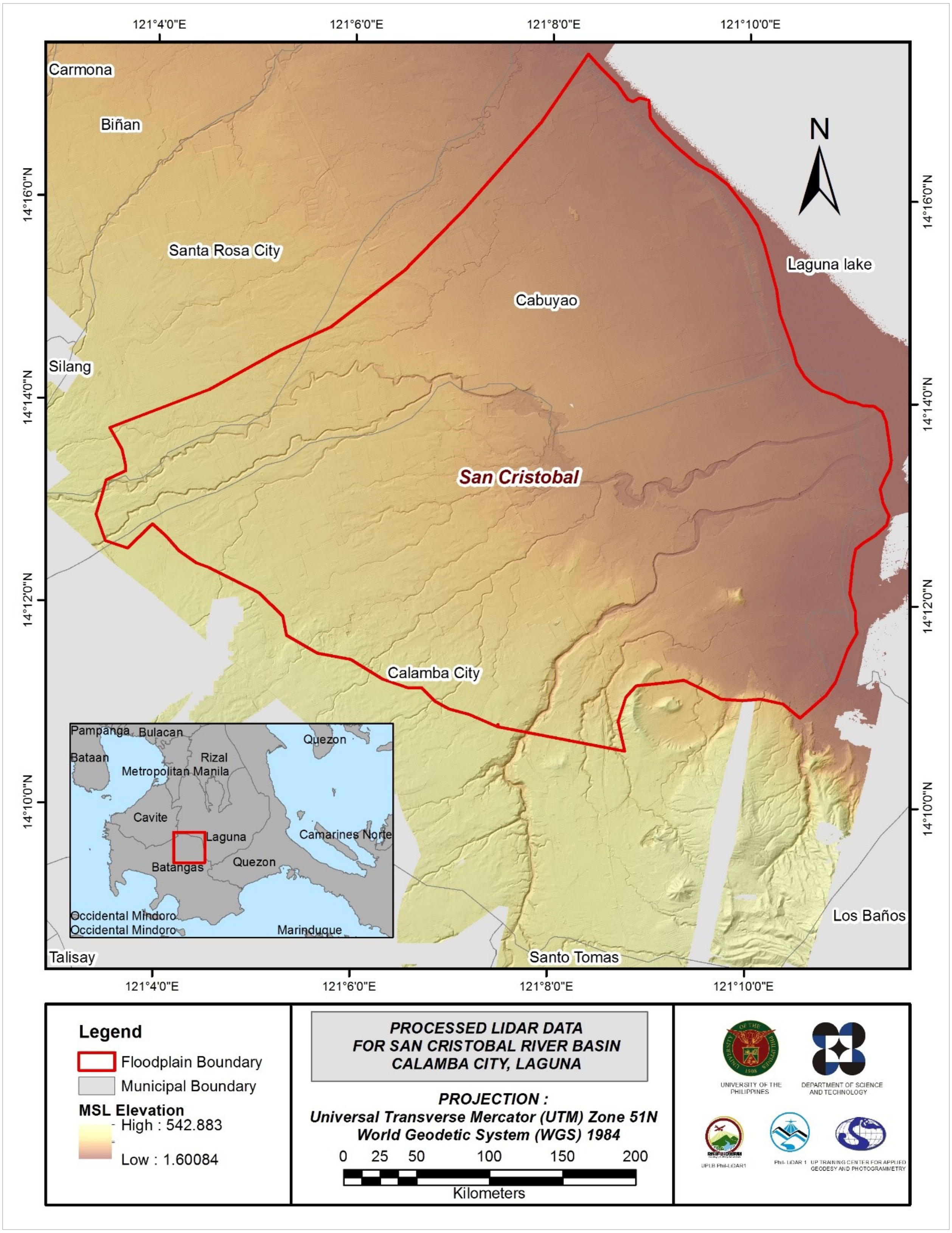


Figure 25. Map of Processed LiDAR Data for San Cristobal Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in San Cristobal to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 1,746 survey points were used for calibration and validation of San Cristobal LiDAR data. Random selection of 80% of the survey points, resulting to 1,397 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.59 meters with a standard deviation of 0.09 meters. Calibration of San Cristobal LiDAR data was done by subtracting the height difference value, 2.59 meters, to San Cristobal mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

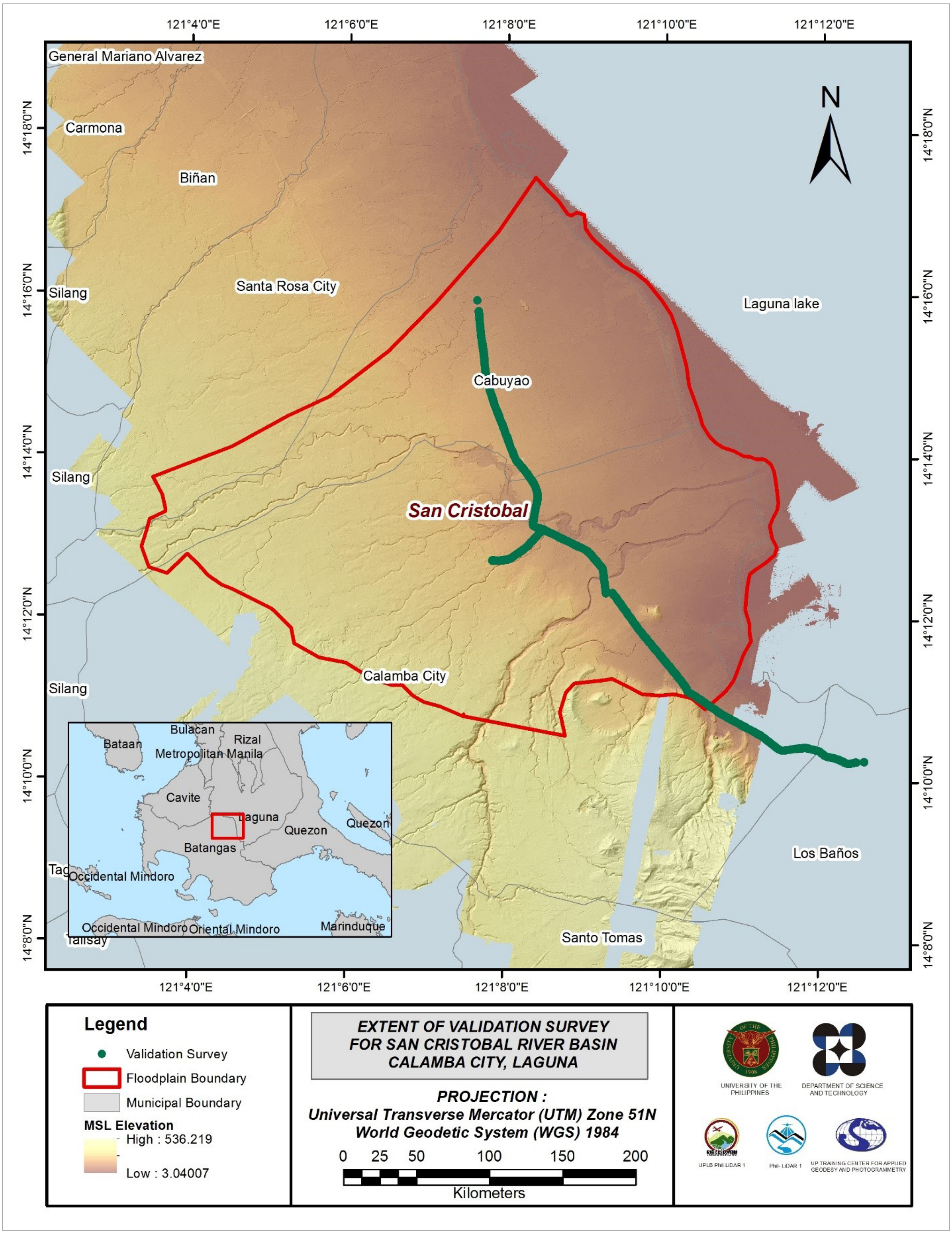


Figure 26. Map of San Cristobal Flood Plain with validation survey points in green.

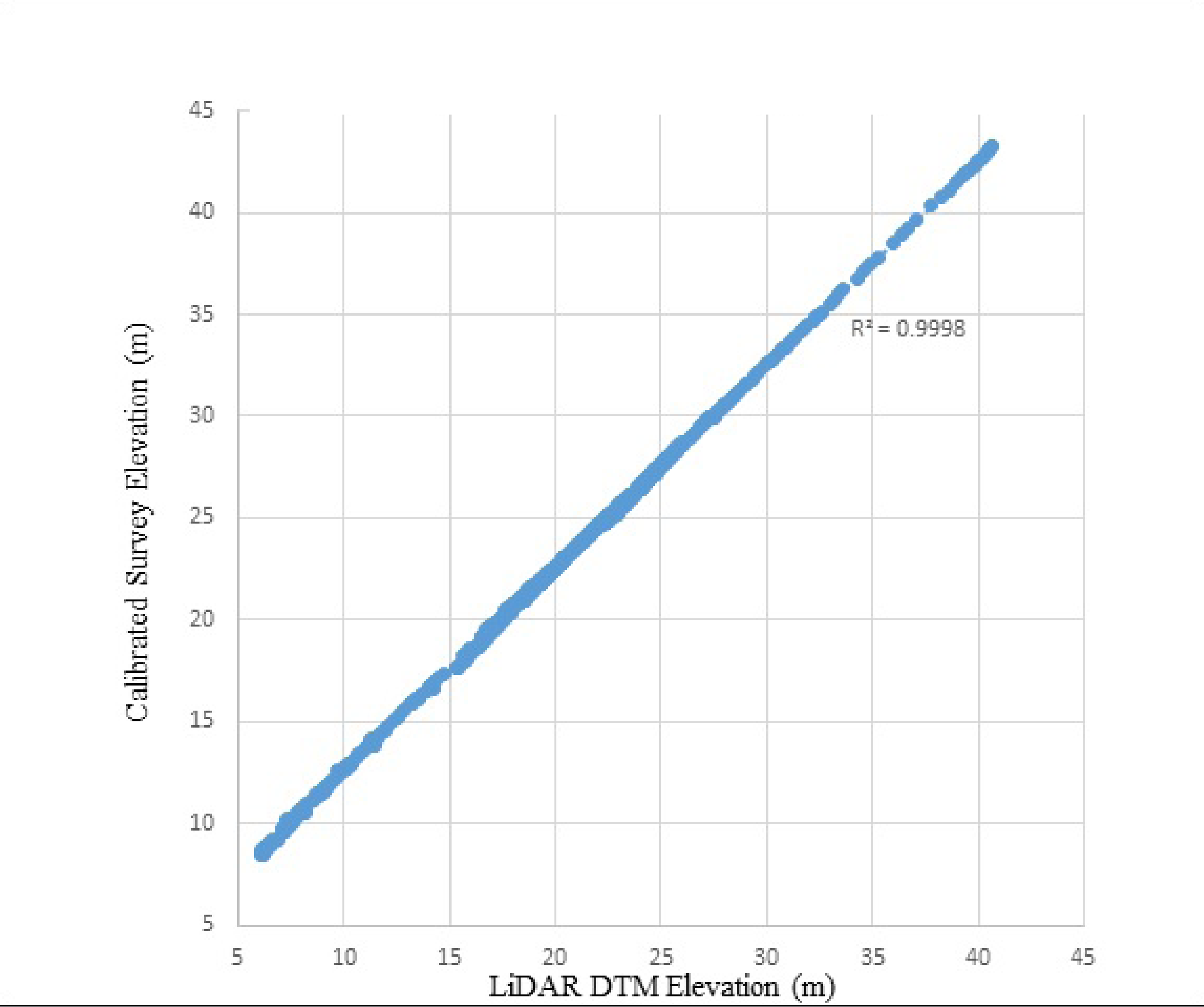


Figure 27. Correlation plot between calibration survey points and LiDAR data

Table 20. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.59
Standard Deviation	0.09
Average	-2.59
Minimum	-2.77
Maximum	-2.42

The remaining 20% of the total survey points, resulting to 349 points, were used for the validation of calibrated San Cristobal 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.08 meters with a standard deviation of 0.08 meters, as shown in Table 21.

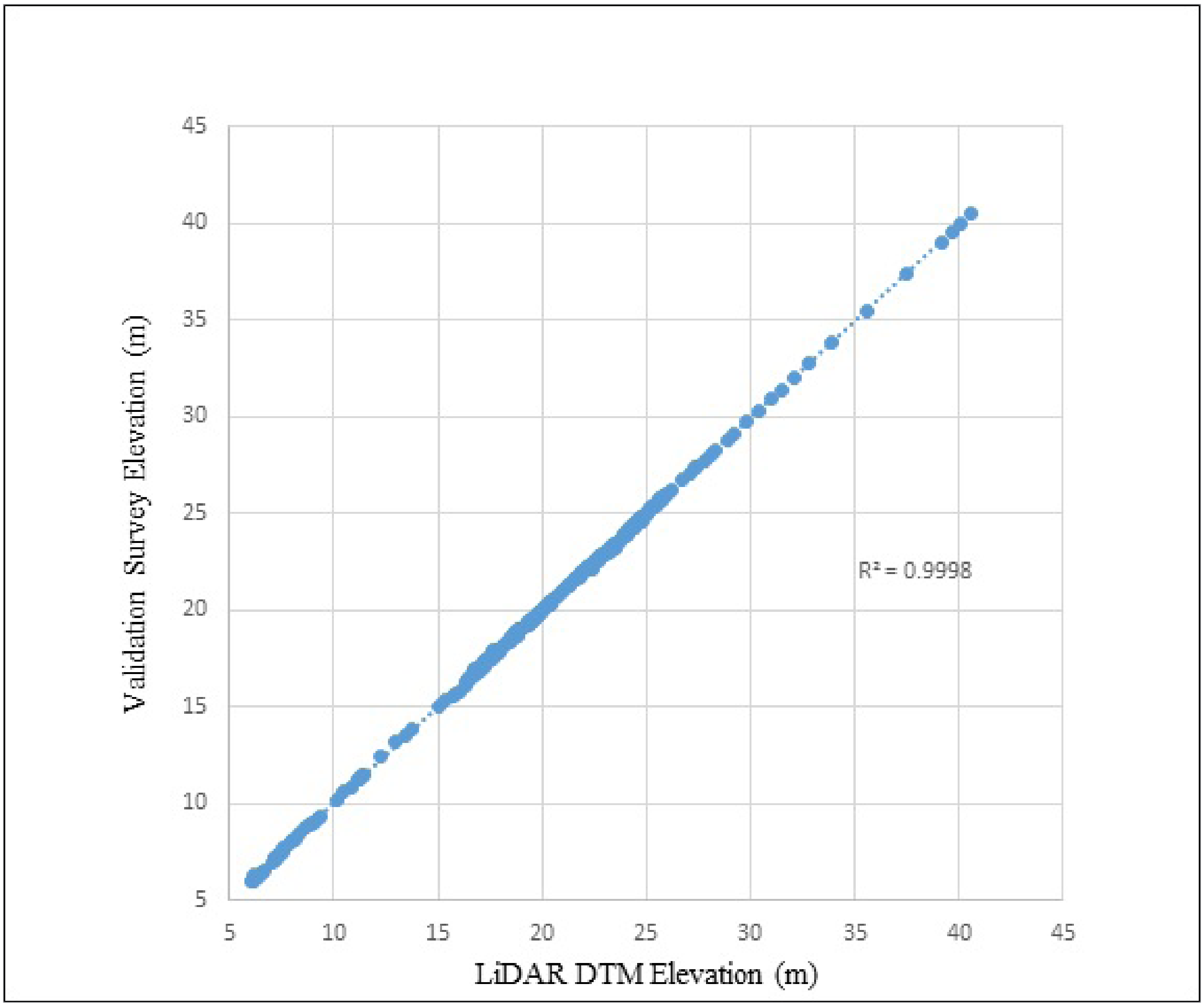


Figure 28. Correlation plot between validation survey points and LiDAR data

Table 21. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.08
Average	-0.003
Minimum	-0.17
Maximum	0.16

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for San Cristobal with 5,628 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.06 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in San Cristobal integrated with the processed LiDAR DEM is shown in Figure 29.

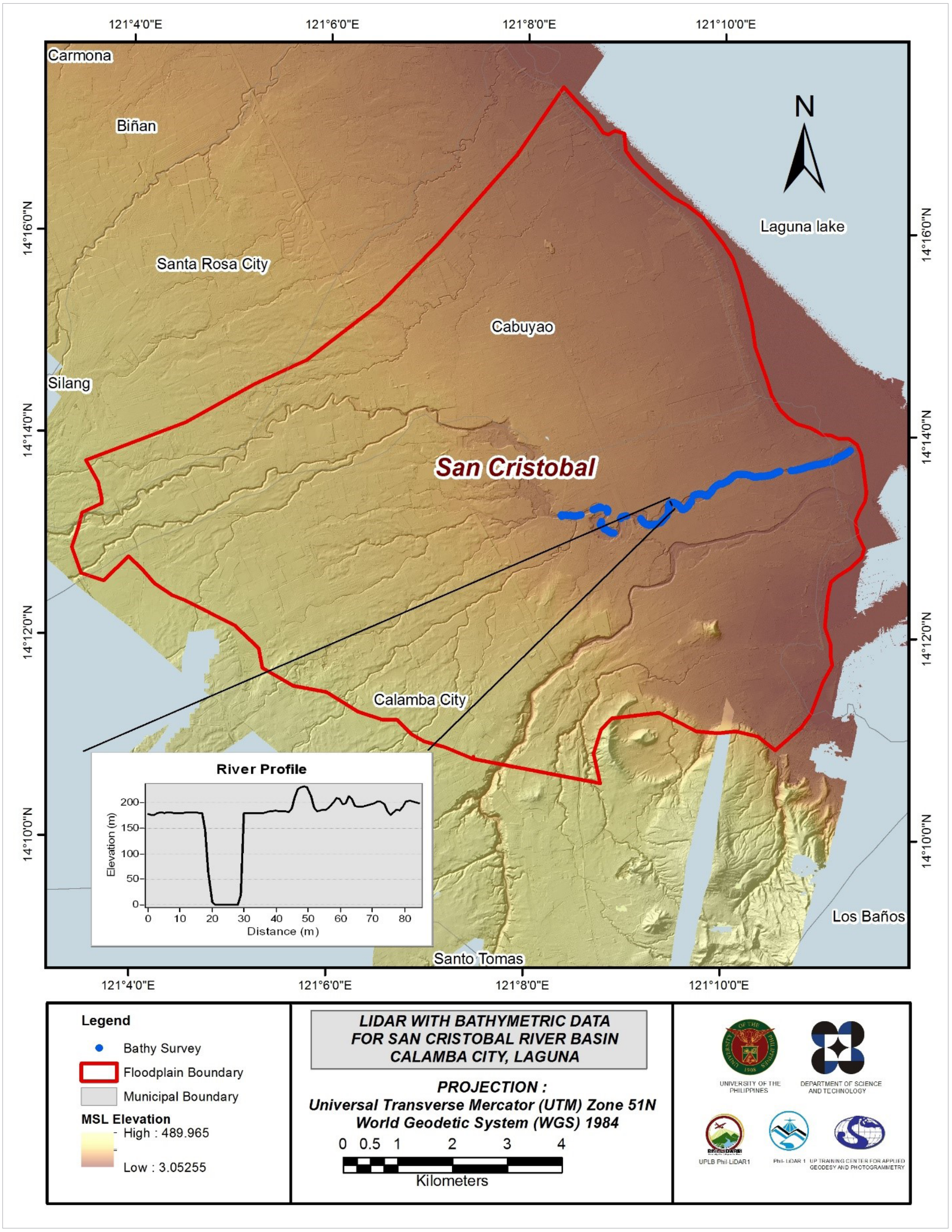


Figure 29. Map of San Cristobal Flood Plain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE OGOD RIVER BASIN

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

The methods applied in this chapter were based on the DREAM methods manual (Ang, 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 a field survey in San Cristobal River on May 14–22 and September 2–6, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built of San Cristobal Bridge piers; ground validation data acquisition of about 17.08 km from Niugan, Municipality of Cabuyao to Bambang, Municipality of Los Baños; and bathymetric survey from Brgy. Paciano Rizal, Calamba City, Laguna down to Brgy. Looc, Calamba City, Laguna with an estimated length of 6.84 km using GNSS PPK survey technique.

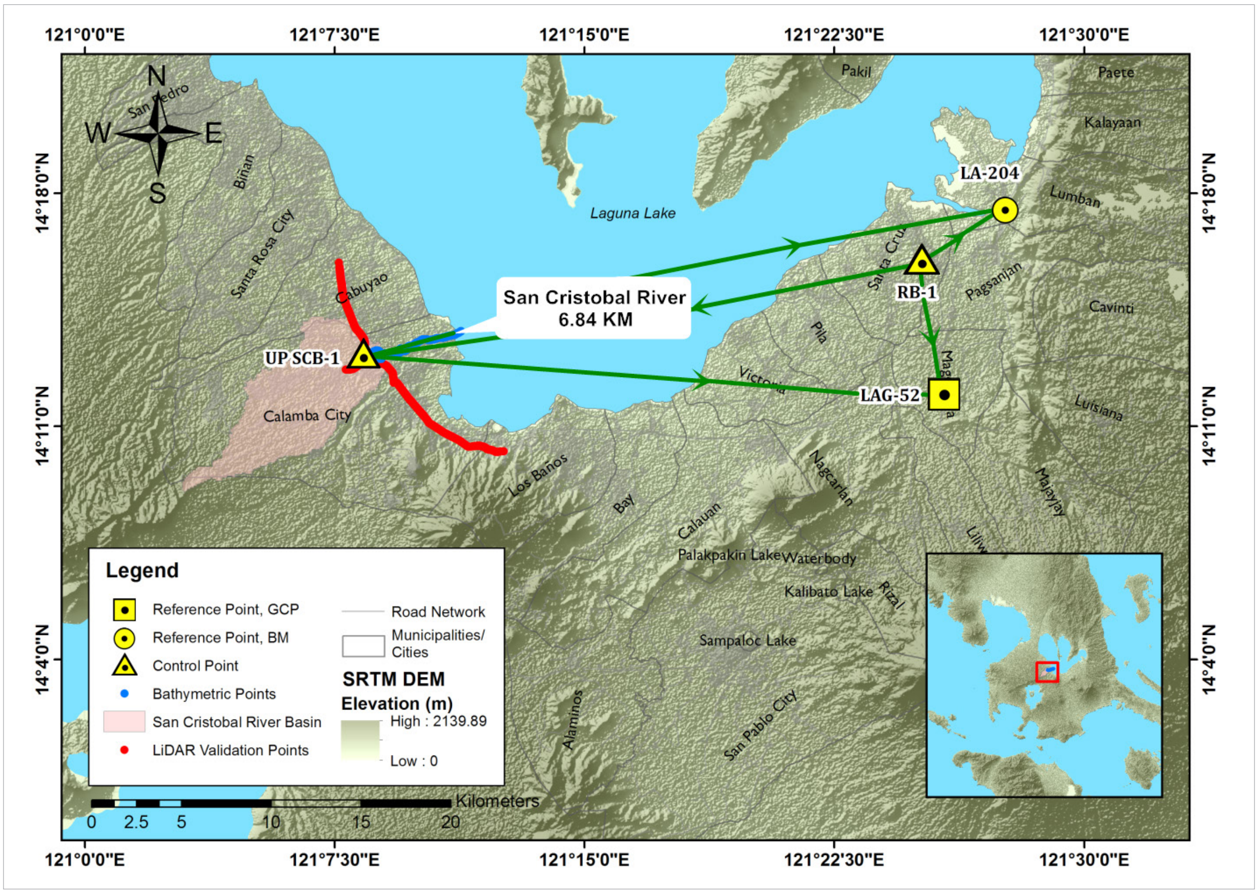


Figure 30. San Cristobal Survey Extent.

4.2 Control Survey

The GNSS network used for San Cristobal Survey is composed of two loops established on Sept 2, 2014 occupying the following reference points: LAG-52, second-order GCP, located in Brgy. Poblacion, Municipality of Magdalena, Laguna; and LA-204, first-order BM, located in Brgy. Balubad, Municipality of Lumban, Laguna.

A control point was established on the approach of San Cristobal Bridge, UP-SCB-1, in Brgy. Paciano Rizal, Calamba City, Laguna; and RB-1, on top of a hotel in Brgy. Patimbao, Municipality of Sta. Cruz Laguna, to use as marker.

The summary of control points used is in Table 22, while the GNNS network established is illustrated in Figure 31.

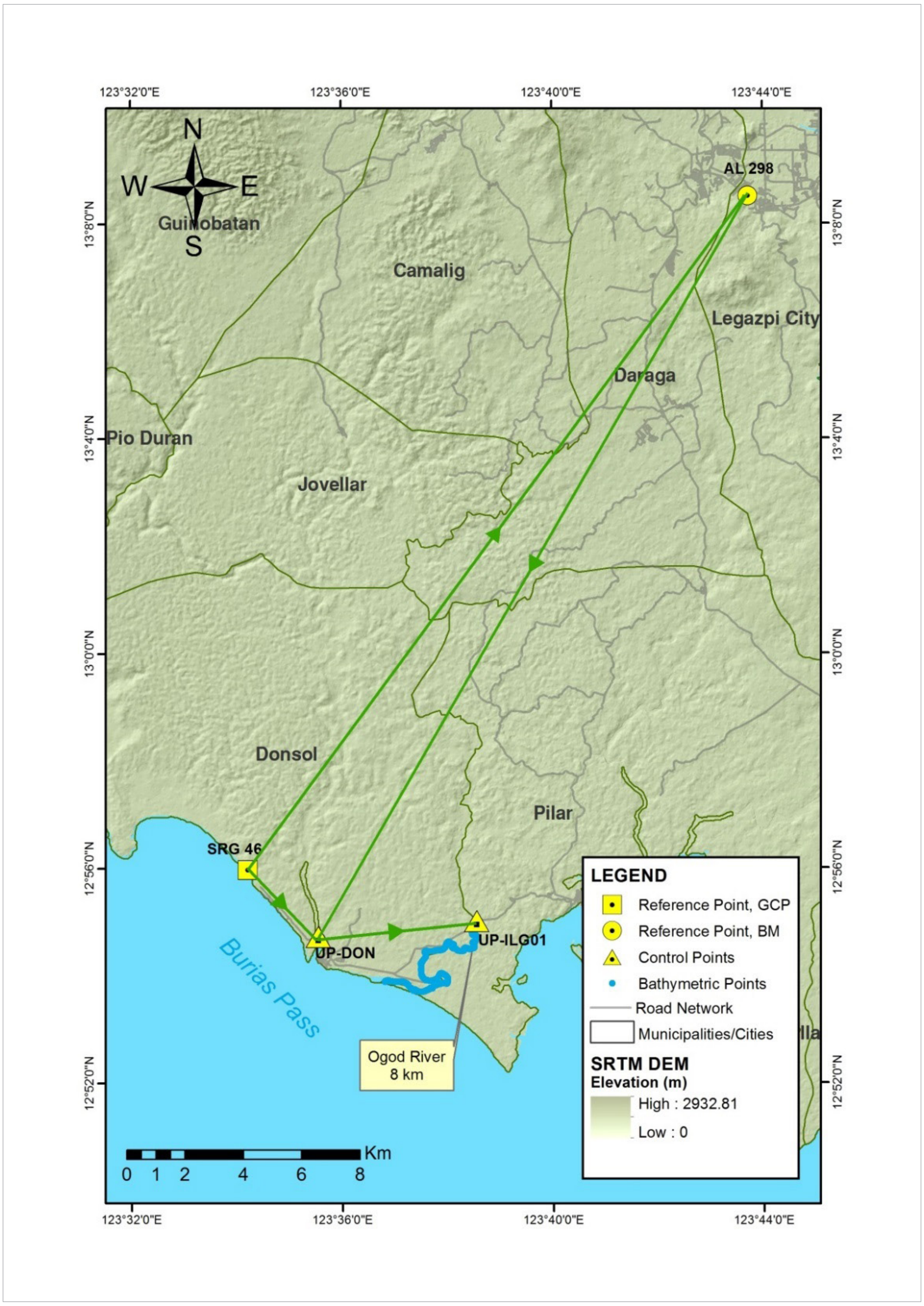


Figure 31. GNSS Network of San Cristobal River Field Survey.

Table 22. List of references and control points used in San Cristobal river survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
FIRST LOOP: September 2, 2014						
LAG-52	2nd Order GCP	14°11'59.35842"	121°25'46.26158"	112.41	-	2007
RB-1	UP Established	-	-	-	-	Sept 2, 2014
UP SCB-1	UP Established	-	-	-	-	Sept 2, 2014
SECOND LOOP: September 2, 2014						
RB-1	UP Established	-	-	-	-	Sept 2, 2014
UP SCB-1	UP Established	-	-	-	-	Sept 2, 2014
LA-204	1st Order BM	-	-	57.117	8.5636	2007

The GNSS set up in reference points used in the survey are exhibited in Error! Reference source not found.2 to Figure 35.

Figure 32. GNSS receiver setup, Trimble® SPS 985 at LAG-52 in the Municipality of Magdalena, Laguna

Figure 33. GNSS receiver setup, Trimble® SPS 882 at LA-204 in the Municipality of Lumban, Laguna

Figure 34. GNSS base receiver setup, Trimble® SPS 852 at RB-1, located at the roof top of Asia Blooms Hotel, Brgy. Patimbao, Sta. Cruz, Laguna

Figure 35. GNSS base receiver setup, Trimble® SPS 852 at UP-SCB-1, San Cristobal Bridge in Calamba City, Laguna

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 cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in San Cristobal River Basin is summarized in Error! Reference source not found.3 generated by TBC software.

Table 23. Baseline Processing Report for San Cristobal River static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (m)
FIRST LOOP BASELINE							
RB-1 --- LAG-52 (B2)	9-2-2014	Fixed	0.018	0.047	170°47'20"	7571.511	49.882
RB-1 --- UP-SCB-1 (B3)	9-2-2014	Fixed	0.007	0.045	260°12'22"	30546.039	5.455
UP-SCB-1 --- LAG-52 (B1)	9-2-2014	Fixed	0.006	0.040	94°05'32"	31395.592	44.399
SECOND LOOP BASELINE							
UP-SCB-1 --- RB-1 (B2)	9-2-2014	Fixed	0.003	0.008	260°12'22"	30546.003	5.424
RB-1 --- LA-204 (B3)	9-2-2014	Fixed	0.005	0.017	59°01'24"	5280.224	-5.389
UP-SCB-1 --- LA-204 (B1)	9-2-2014	Fixed	0.005	0.020	77°03'30"	35520.748	-10.871

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table C-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:

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

Where:

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

for each control point. The following tables show the results of GNSS network adjustment.

The three control points LAG-52, UP-SCB, and RB-1 were first occupied and observed simultaneously to form the first GNSS loop. The coordinates of LAG-52 was held fixed during the processing of the control points. The second loop comprises LA-204, RB-1 and UP-SCB where the values of RB-1 were held fixed from the first loop. The fixed controls are presented in Error! Reference source not found..Through the reference point, the coordinates of the unknown control points will be computed. A difference in elevation of 2.6134 m between geoid (EGM2008) and MSL values of the reference point, LA-204, was applied for referring the elevation of the control points to MSL.

Table 24. Control Point Constraints

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
FIRST LOOP					
LAG-52					
Global	Fixed	Fixed	Fixed		
Fixed = 0.000001 (Meter)					
SECOND LOOP					
RB-1	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network are indicated in Error! Reference source not found.25 and Error! Reference source not found..

The fixed control point in the 1st loop, LAG-52, has no values for standard errors.

Table 25. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
RB-1	319188.891	0.010	1365393.240	0.010	6.868	0.052	
329369.947	0.008	1577877.316	0.008	-30.799	0.017		
LAG-52							
330531.105	?	1570395.630	?	20.590	?	LLh	
UP-SCB-1							
299233.366	0.026	1572885.811	0.017	-22.235	0.089		

For the 1st loop of the network, the network is fixed at the reference point LAG-52, with known coordinates. The standard errors (xe, ye and ze) of RB-1 are 0.8, 0.8 and 1.7 cm, respectively. While the errors (xe, ye and ze) of UP-SCB-1 are 2.6, 1.7 and 8.9 cm, respectively. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20$ cm for horizontal and $z_e < 10$ cm for the vertical; the computation for the accuracy for

a. RB-1

horizontal accuracy = $\sqrt{((0.8)^2 + (0.8)^2}$
= $\sqrt{(0.64 + 0.64)}$
= 1.13 cm < 20 cm

vertical accuracy = 1.7 cm < 10 cm

b. UP-SCB-1

horizontal accuracy = $\sqrt{((2.6)^2 + (1.7)^2}$
= $\sqrt{(6.76 + 2.89)}$
= 3.11 cm < 20 cm

vertical accuracy = 8.9 cm < 10 cm

Meanwhile, the fixed control point in the 2nd loop, LA-204, has no values for standard errors.

Table 26. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
RB-1	329369.956	?	1577877.26	?	16.758	?	LLh
LA-204	333915.286	0.014	1580563.907	0.011	11.177	0.069	
UP-SCB-1	299233.674	0.01	1572885.795	0.006	23.196	0.038	

For the 2nd loop of the network, the network is fixed at the reference point RB-1, with known coordinates. The standard errors (xe, ye and ze) of LA-204 are 1.4, 1.1 and 6.9 cm, respectively. While the errors (xe, ye and ze) of UP-SCB-1 are 1.0, 0.6 and 3.8 cm, respectively. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20$ cm for horizontal and $z_e < 10$ cm for the vertical; the computation for the accuracy for

a. LA-204

horizontal accuracy = $\sqrt{((1.4)^2 + (1.1)^2}$
= $\sqrt{(1.96 + 1.21)}$
= 1.78 cm < 20 cm

vertical accuracy = 6.9 cm < 10 cm

b. UP-SCB-1

horizontal accuracy = $\sqrt{((1.0)^2 + (0.6)^2}$
= $\sqrt{(1.0 + 0.36)}$
= 1.17 cm < 20 cm

vertical accuracy = 3.8 cm < 10 cm

Based on the results of the computation, the horizontal and vertical accuracies of the occupied control points are within the required accuracy of the program.

The summary of reference and control points used is indicated in Table 27.

Table 27. Table 367. 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	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
First Loop: September 2, 2014							
LAG-52	2nd Order GCP	14°11'59.35842"	121°25'46.26158"	112.41	1570395.63	330531.105	63.8866
UP-SCB	UP Established	14°13'12.89165"	121°08'21.82978"	67.988	1572885.806	299233.65	20.6156
RB-1	UP Established	14°16'02.54138"	121°25'05.84018"	62.528	1577877.26	329369.956	14.1446
Second Loop: September 2, 2014							
RB-1	UP Established	14°16'02.54138"	121°25'05.84018"	62.528	1577877.26	329369.956	14.1446
UP-SCB	UP Established	14°13'12.89165"	121°08'21.82978"	67.988	1572885.806	299233.65	20.6156
LA-204	1st Order BM	14°17'30.95422"	121°27'36.89034"	57.117	1580563.907	333915.286	8.5636

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

The GNSS receiver Trimble® SPS 882 in PPK survey technique was used to get the cross section of the river. The cross-section survey was done along the upstream side of San Cristobal Bridge in Brgy. Paciano Rizal, Calamba City on May 16, 2014.

In addition to cross-section survey, the location of the piers of the bridge was determined. The cross-sectional line for San Cristobal Bridge is about 127 m with fifty four (54) points acquired using UP-SCB as GNSS base station. The cross-section diagram, its location map, and bridge as-built form are illustrated in Error! Reference source not found.36 to Error! Reference source not found..

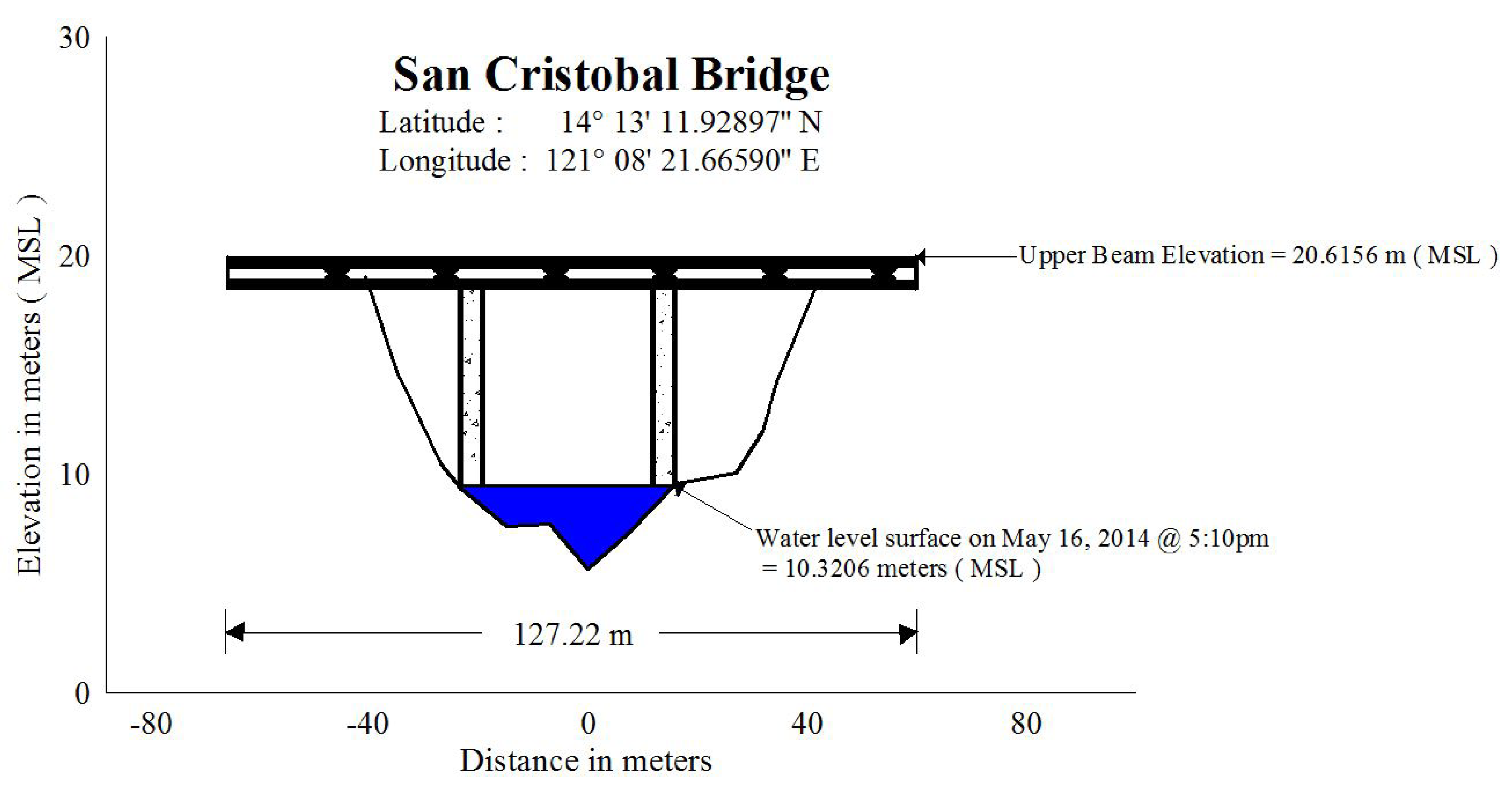


Figure 36. San Cristobal Bridge cross section diagram.

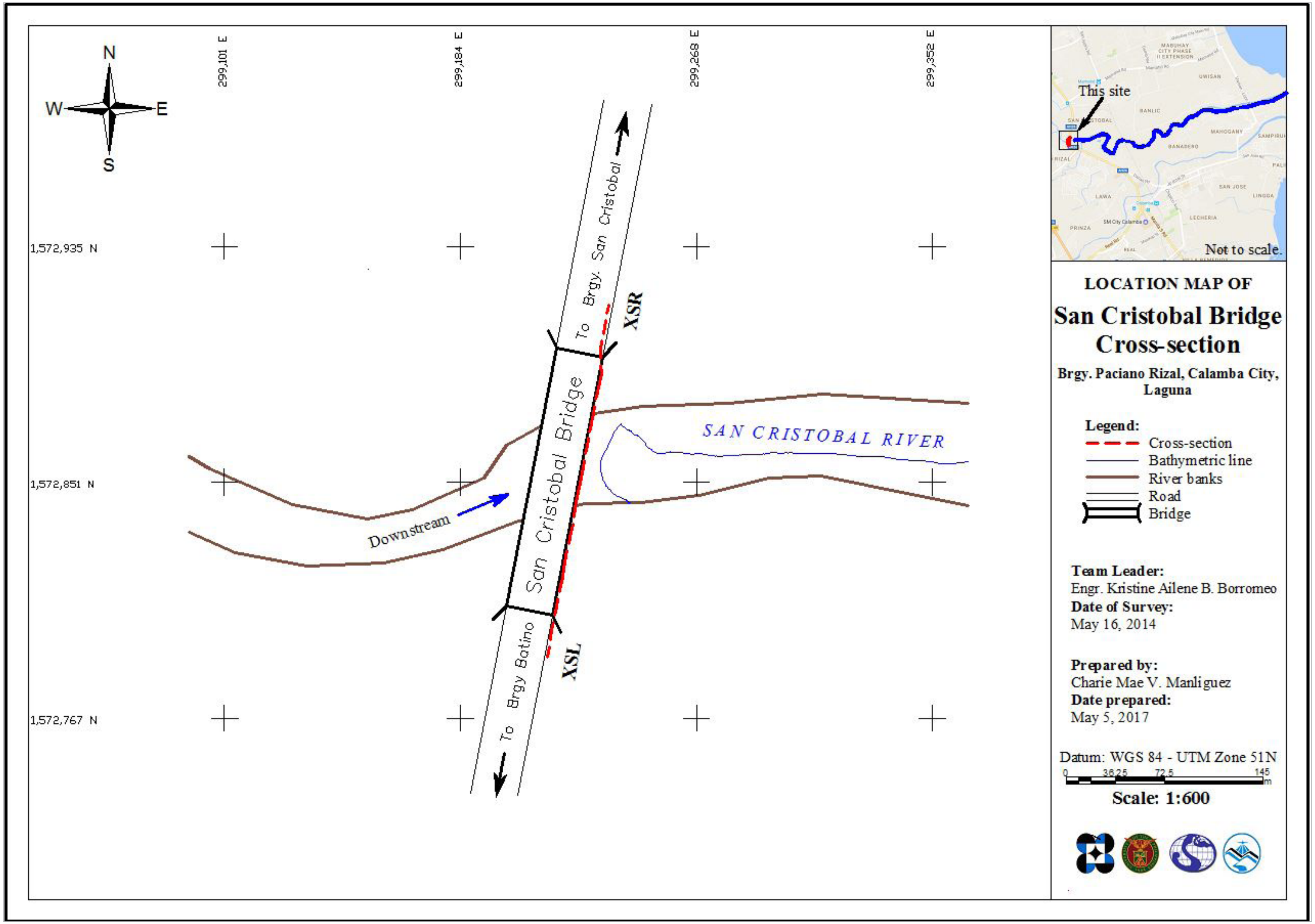


Figure 37. San Cristobal bridge cross-section location map.

Bridge Data Form

Bridge Name: San Cristobal Bridge **Date:** ____________________

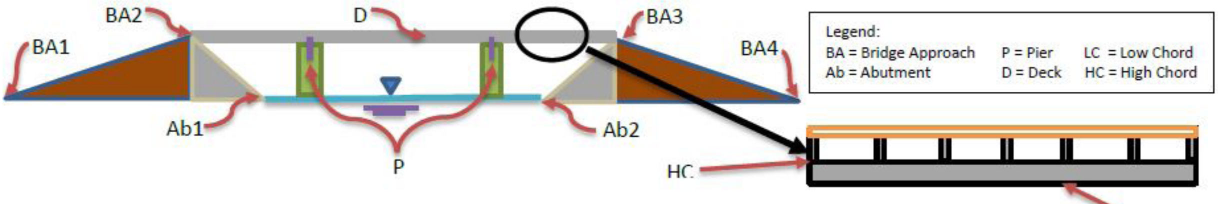
River Name: San Cristobal River **Time:** ____________________

Location (Brgy, City,Region): Brgy. Paciano Rizal, Calamba City, Laguna

Survey Team: Borromeo, Labrador, Salvador

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

Latitude: 14d13'12.89" **Longitude:** 121d08'21.83"



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

Elevation: ____________ **Width:** ____________________ **Span (BA3-BA2):** ____________________

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0		BA3		
BA2			BA4		

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: ____________________ Number of Piers: __________ Height of column footing: ______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	42.65m	20.43m	
Pier 2	82.10m	20.46m	
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 38. San Cristobal Bridge Data Form

4.6 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted on September 3 and 4, 2014 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Error! Reference source not found.. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 1.53 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 first day of ground validation started from the Municipality of Cabuyao and traversed major roads going to Calamba City. Meanwhile, the second day of survey started from Calamba City to the Municipality of Los Baños. UP-SCB-1 was used as the GNSS base station all throughout the conduct of the survey

Figure 39. (A) Setup of Trimble® SPS 882 attached to a vehicle and (B) Setting up of GNSS base station at UP-SCB-1

The survey acquired 2,693 ground validation points with an approximate length of 17.08 km using the base station UP-SCB, as shown in the map in Error! Reference source not found.40.

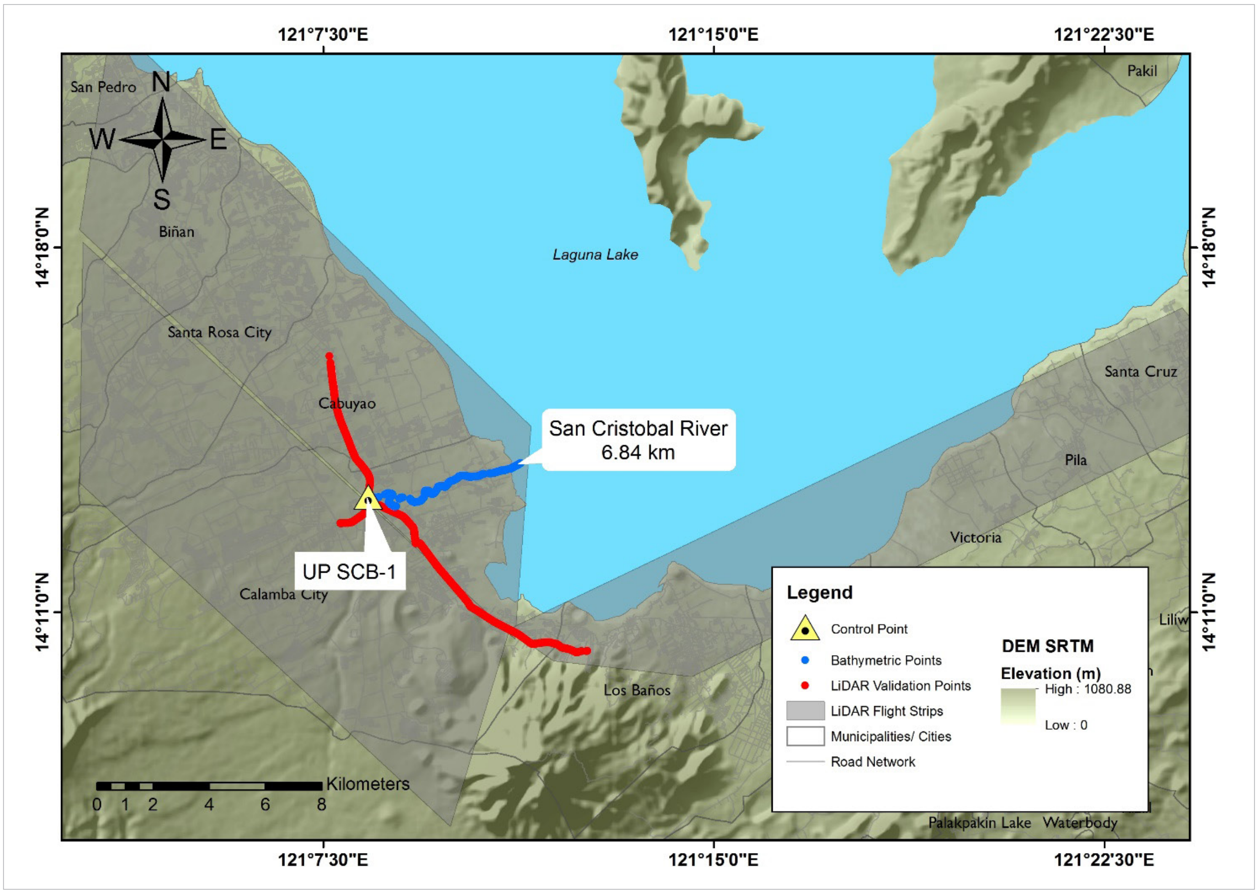


Figure 40. Validation Points Acquisition Survey along the Municipality of Cabuyao to Municipality of Los Baños

4.7 River Bathymetric Survey

Bathymetric survey was executed with the aid of MDRRMO on September 3 and 4, 2014 using Trimble® SPS 882 in GNSS PPK survey technique and an Ohmex™ single beam echosoudner as shown in Error! Reference source not found.. The survey began in the upstream part of the river in Brgy. Paciano Rizal, Calamba City with coordinates 14°13'11.53626" 121°08'22.23092", down to the mouth of the river in Brgy. Sampiruhan, Calamba City with coordinates 14°13'51.31943" 121°11'16.98425".

Figure 41. Bathymetric Survey along San Cristobal River.

The bathymetric line has an estimated length of 6.84 km with a total of 5,646 points gathered using UP-SCB as GNSS base station. The processed data was generated into a map using GIS and processed further using CAD for plotting the centerline of the river. The generated map, shown in Error! Reference source not found., exhibits the bathymetry survey coverage, while Error! Reference source not found. illustrates the San Cristobal riverbed profile. There is an abrupt change in elevation of about 7.9 m within the acquired bathymetry data. The highest elevation was 9.46 m in MSL in Brgy. Paciano Rizal, while the lowest elevation was -1.75 m below MSL in Brgy. Looc. The gaps in the gathered bathymetric points are uncollected data due to obstructions, e.g. dam, encountered in the river during the fieldwork.

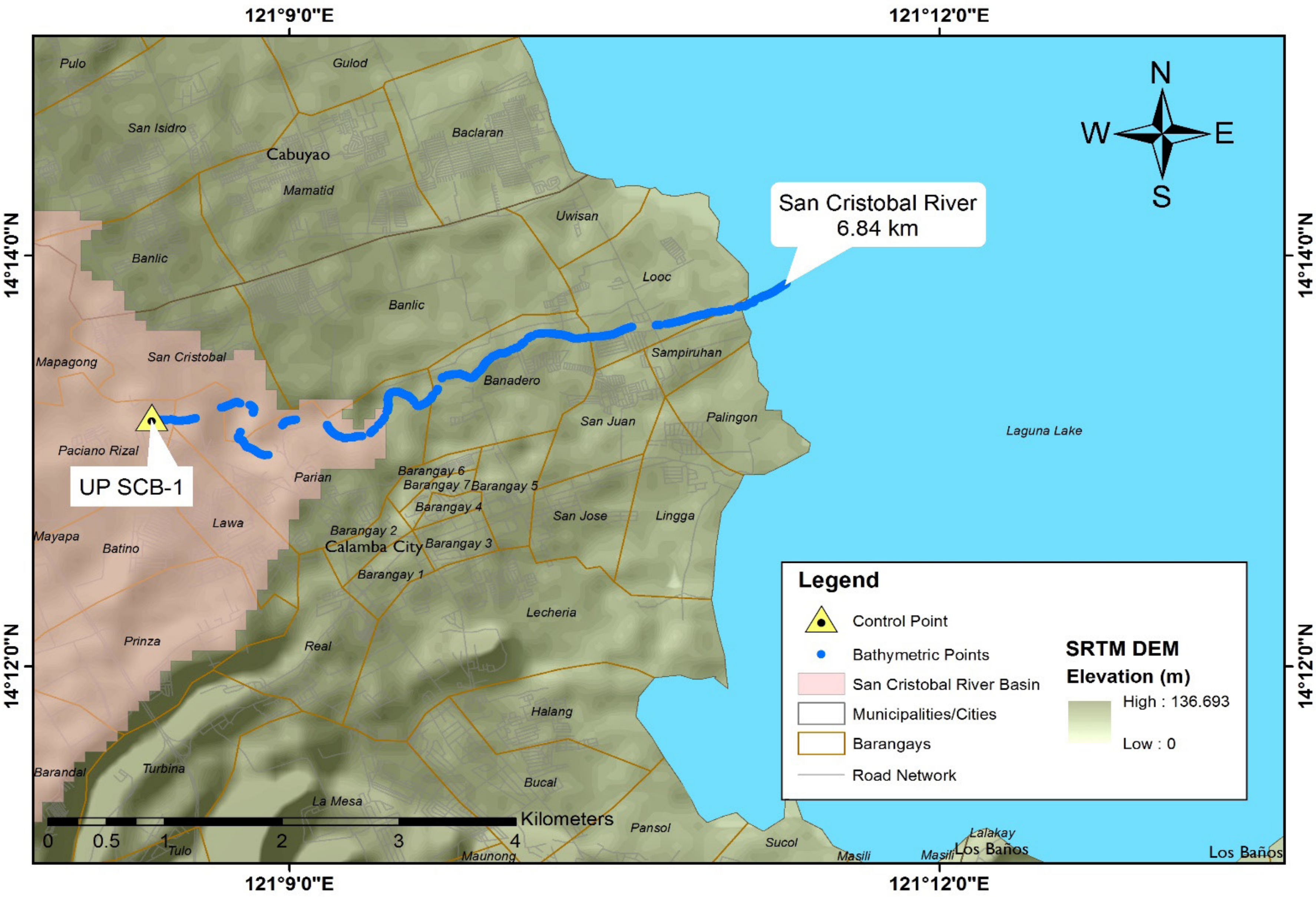


Figure 42. Bathymetric points gathered from San Cristobal River

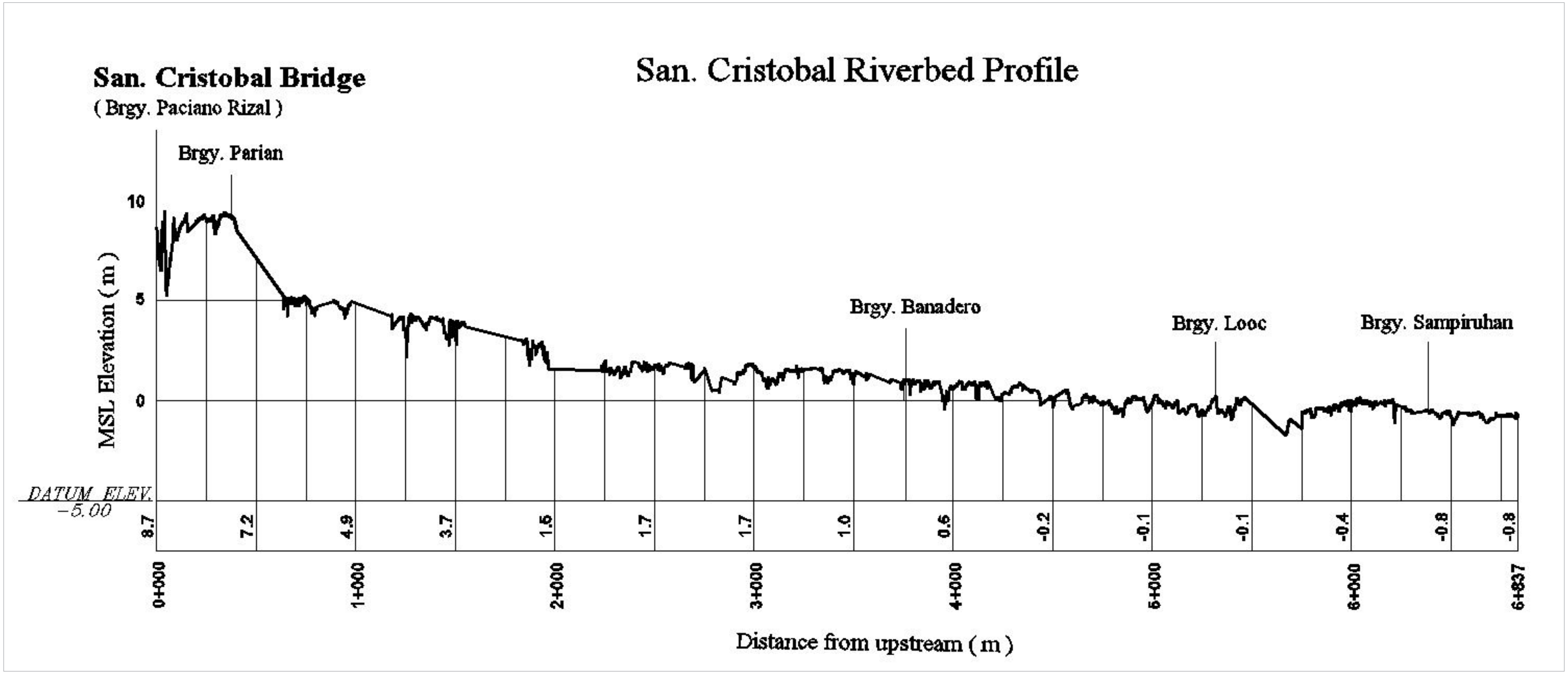


Figure 43. San Cristobal Riverbed Profile from Brgy. Parian, Calamba City down to Brgy. Sampiruhan, Calamba City

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, Gianni Sumajit, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Kevin M. Manalo

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. These include the rainfall, water level, and flow in a certain period of time.

5.1.2 Precipitation

Precipitation data was taken from four surrounding Automatic Rain Gauge (ARG) Stations surrounding the watershed. The location of the rain gauges is seen in Figure 49.

The total precipitation data for each rain gauge station are as follows: Cabuyao, 34.01 mm, Silang 21.2 mm, Amadeo 18.4 mm and Sto.Tomas 53.0 mm. The corresponding peak rainfall are as follows: 2.54 mm on

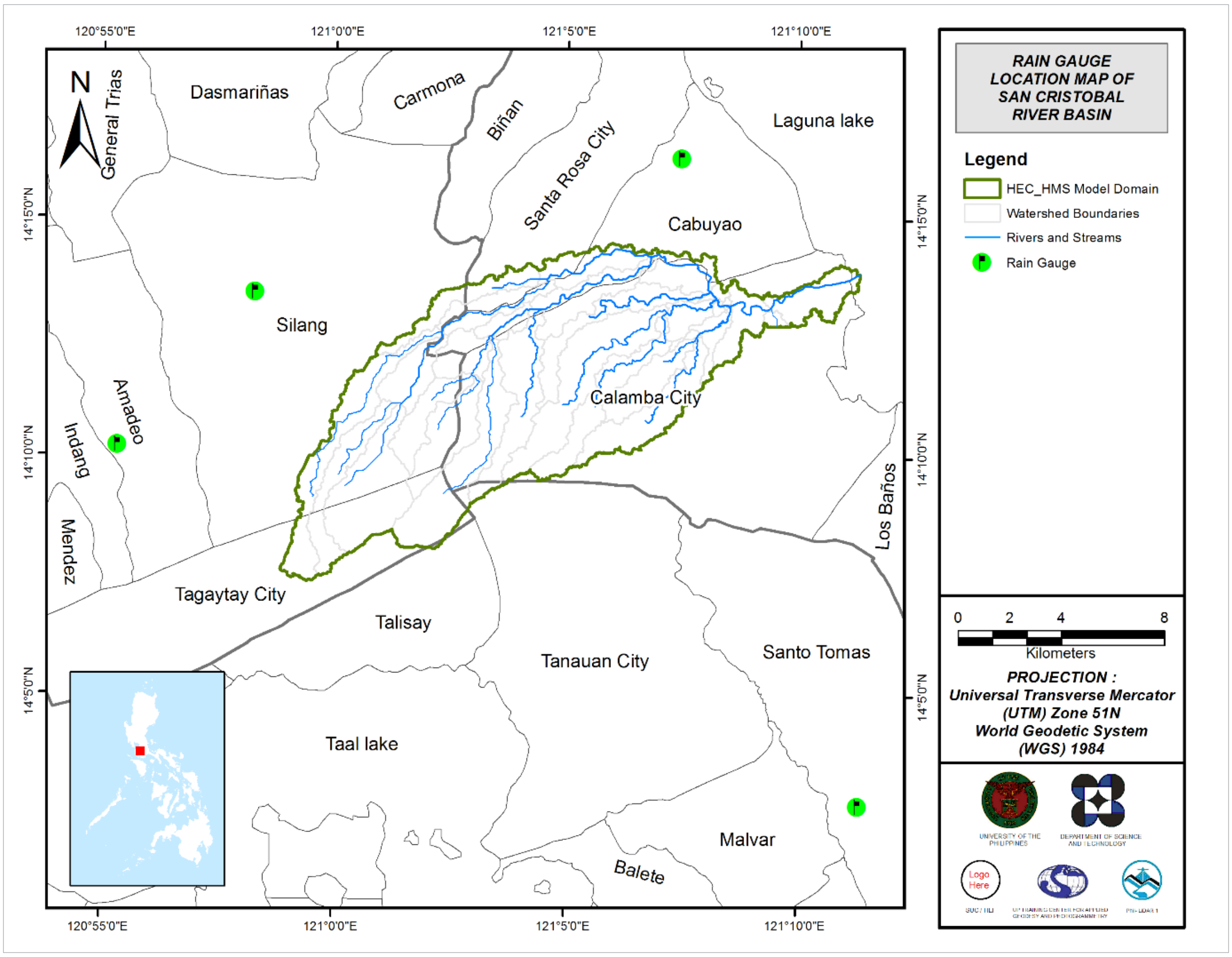


Figure 44. The location map of San Cristobal HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at San Cristobal Bridge, Calamba Laguna (14.219887° N, 121.139255° E) using Manning's Bankfull Method. It gives the relationship between the observed change in water and the outflow of the watershed at this location.

For San Cristobal Bridge, the rating curve is expressed as Q = -1.3678x2 +40.851x -256.52 as shown in Figure 51.

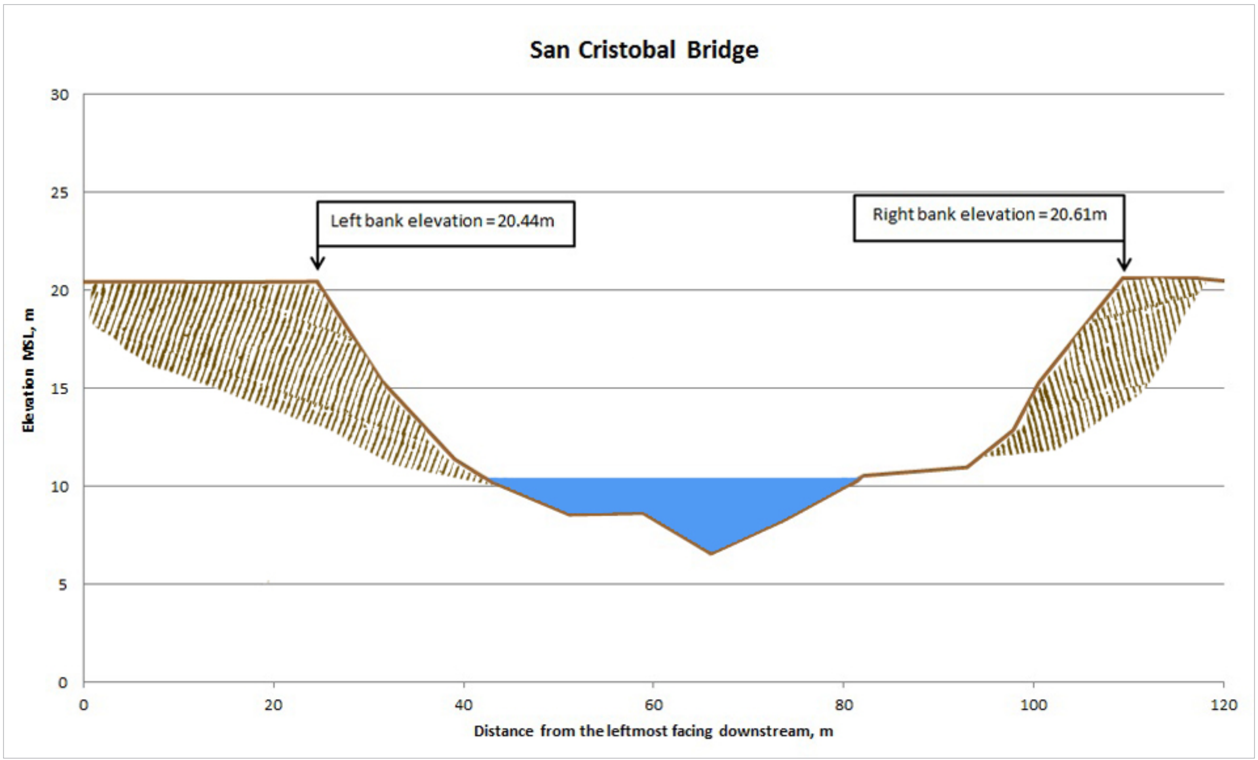


Figure 45. Cross-Section Plot of San Cristobal Bridge.

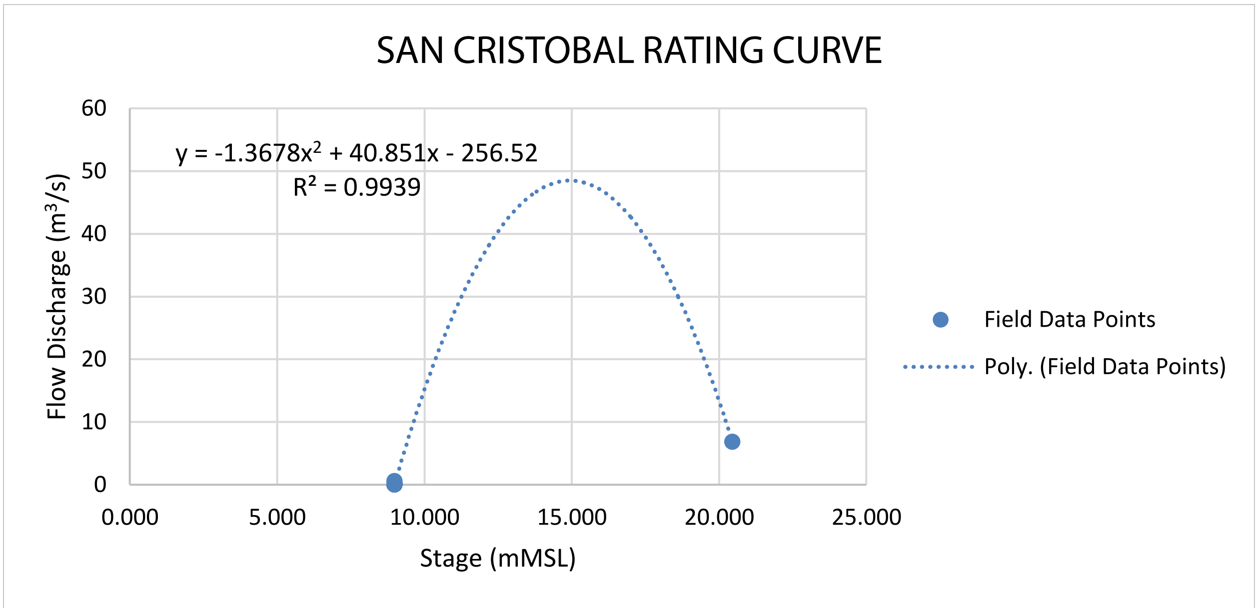


Figure 46. Rating Curve at San Cristobal Bridge, Calamba, Laguna.

For the calibration of the HEC-HMS model, shown in Figure 52, actual flow discharge during a rainfall event was collected in the San Cristobal bridge. Peak discharge is 20.3147 cu.m/s on January 10, 2017 at 6:05 pm.

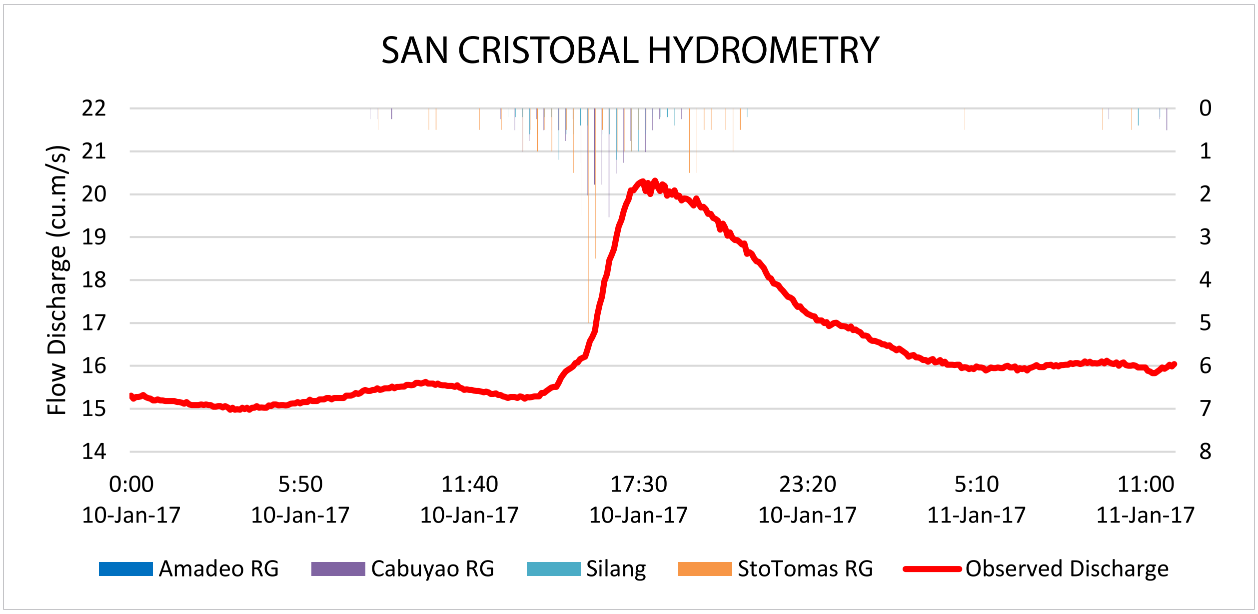


Figure 47. Rainfall and outflow data at San Cristobal used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Ambulong Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the San Cristobal watershed. The extreme values for this watershed were computed based on a 54-year record.

Table 28. RIDF values for Ambulong Rain Gauge computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	22.7	35.5	36.3	50.2	68.2	80.1	104.1	125.7	150.8
5	27.9	45.5	53.8	74.2	103.4	122.5	159.7	192.9	226.7
10	34.2	52.1	65.4	90.1	126.7	150.6	196.5	237.3	276.9
15	37.8	57.4	71.9	99	139.8	166.4	217.3	262.4	305.3
20	40.3	61	76.5	105.3	149	177.5	231.9	280	325.1
25	42.2	63.9	80	110.1	156.1	186	243.1	293.5	340.4
50	48.1	72.6	90.9	125	178	212.3	277.6	335.2	387.5
100	54	81.2	101.6	139.8	199.7	238.4	311.8	376.6	434.3

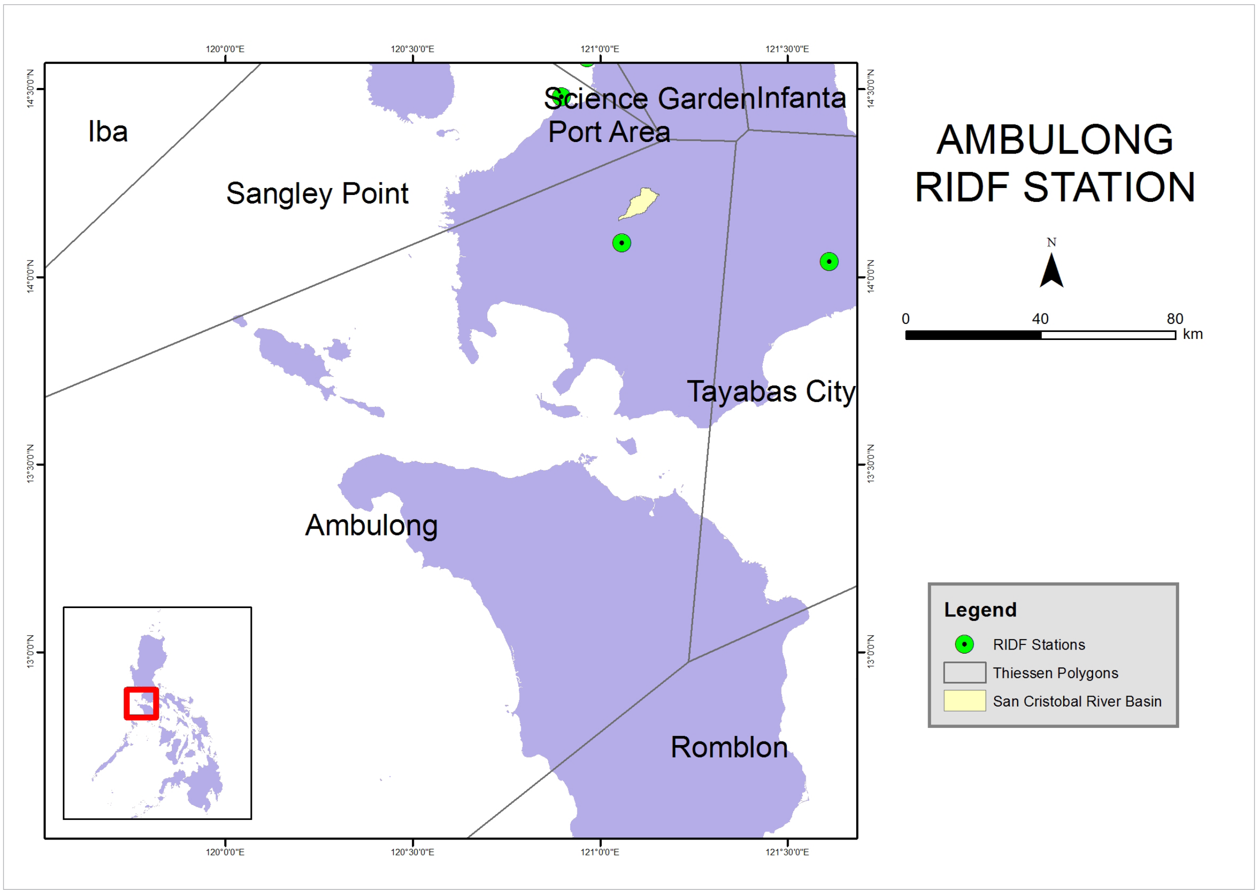


Figure 48. Location of Ambulong RIDF station relative to San Cristobal River Basin

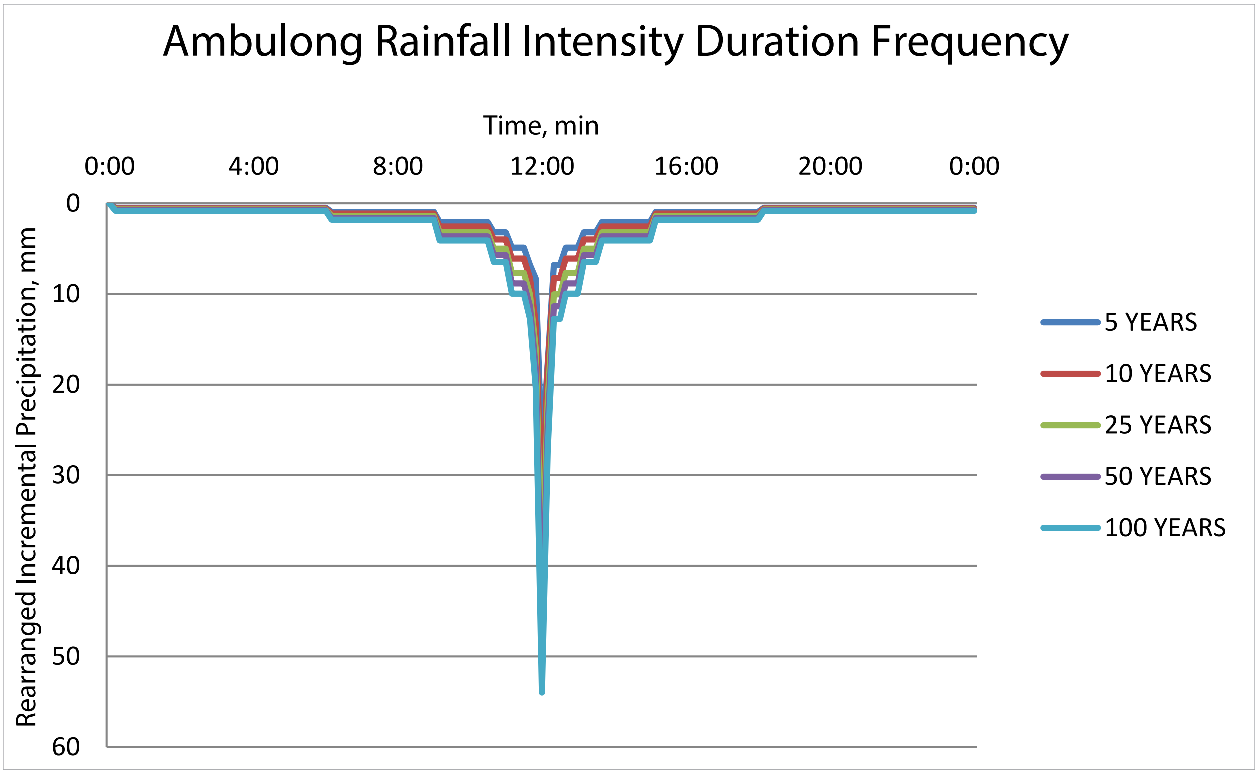


Figure 49. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods

5.3 HMS Model

The soil shape file was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA).

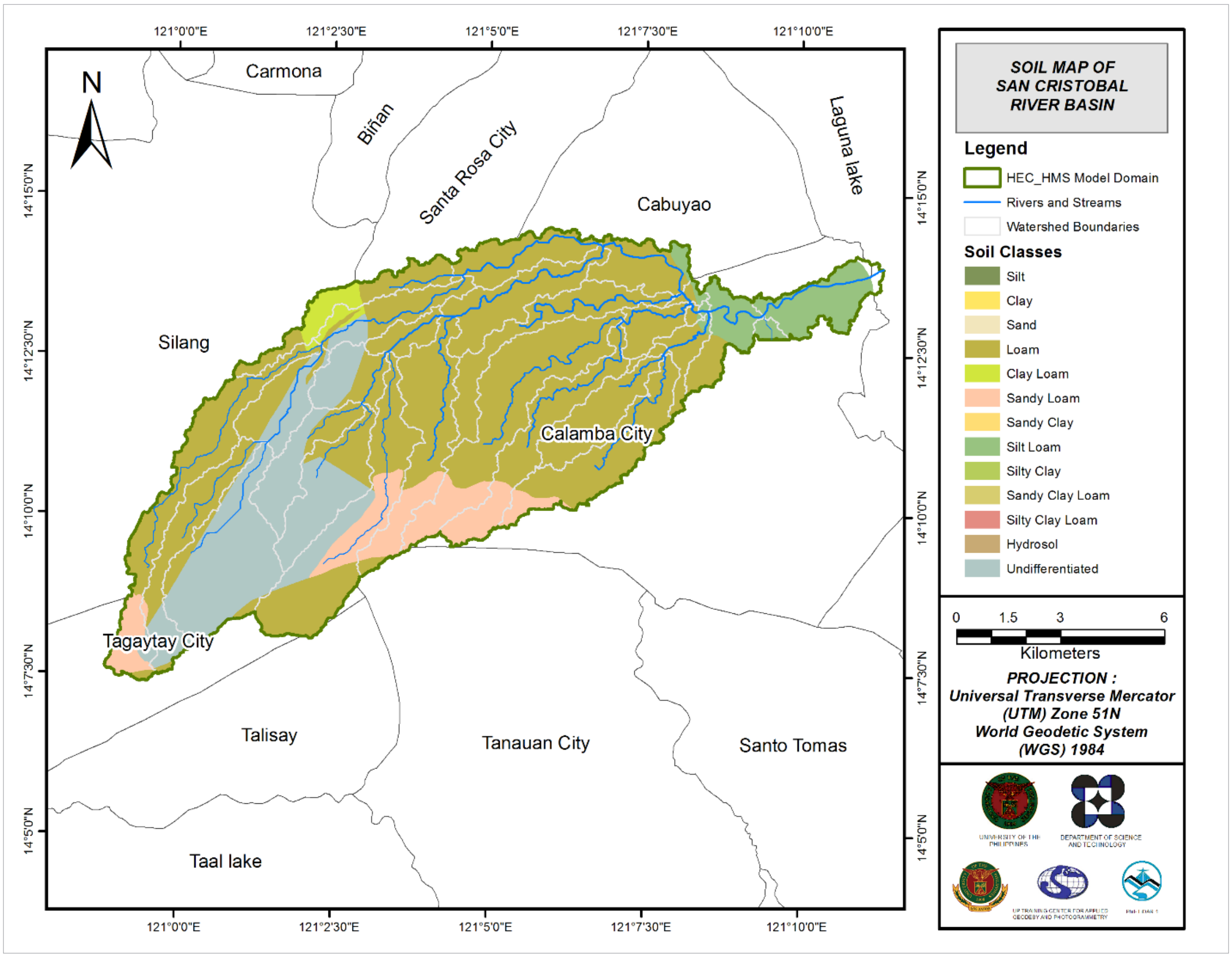


Figure 50. The soil map of the San Cristobal River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

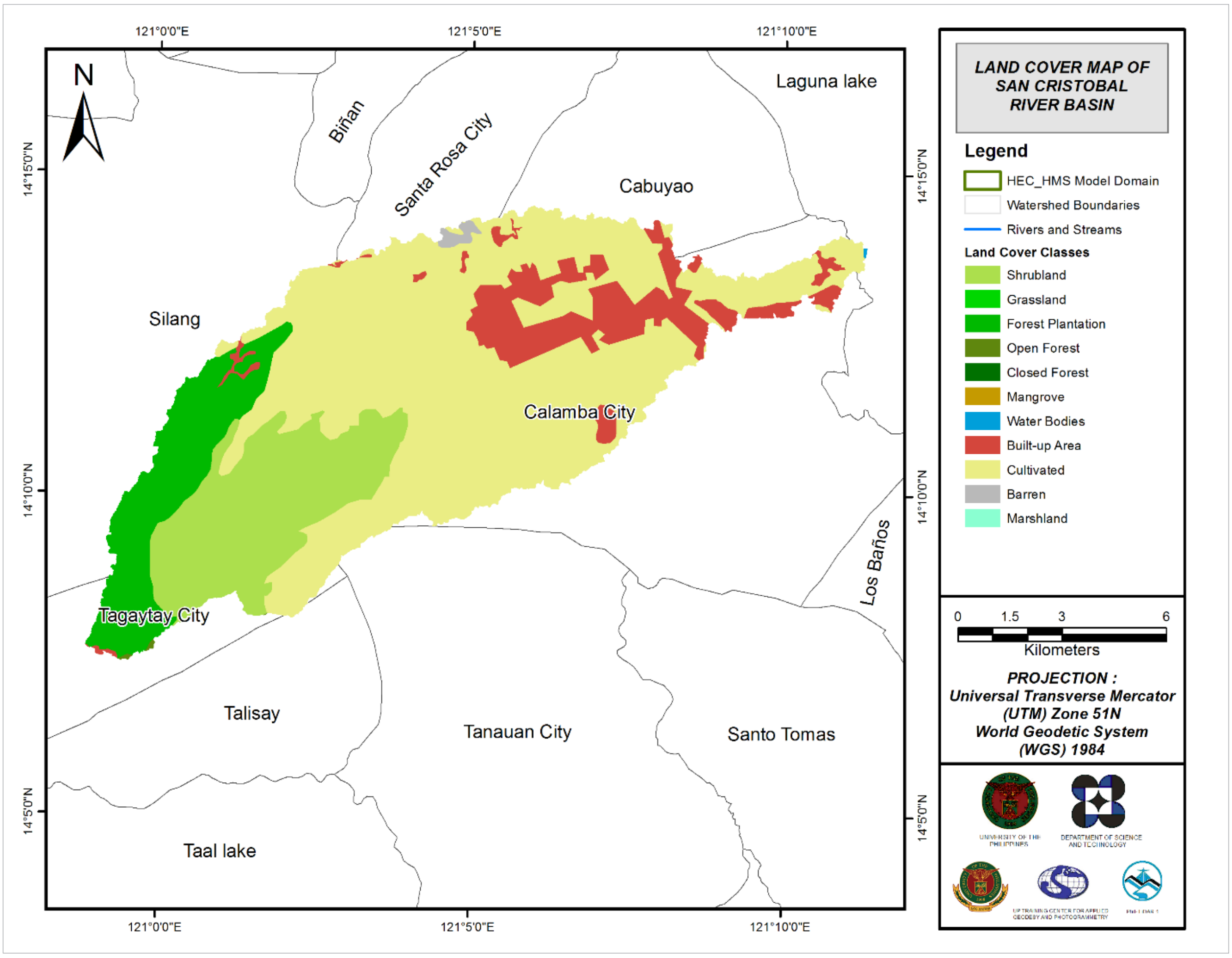


Figure 51. The land cover map of the San Cristobal River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

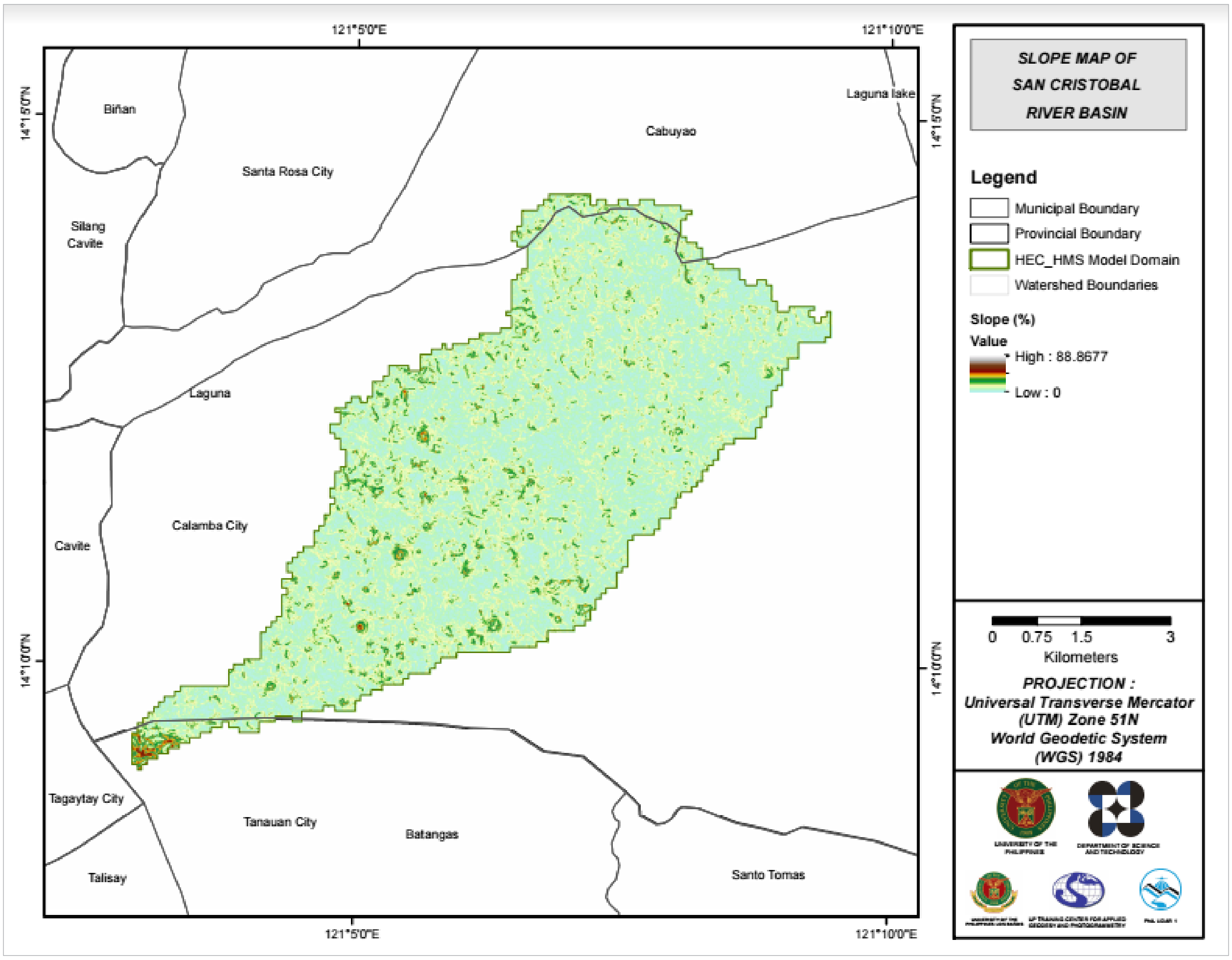


Figure 52. Slope Map of the San Cristobal River Basin.

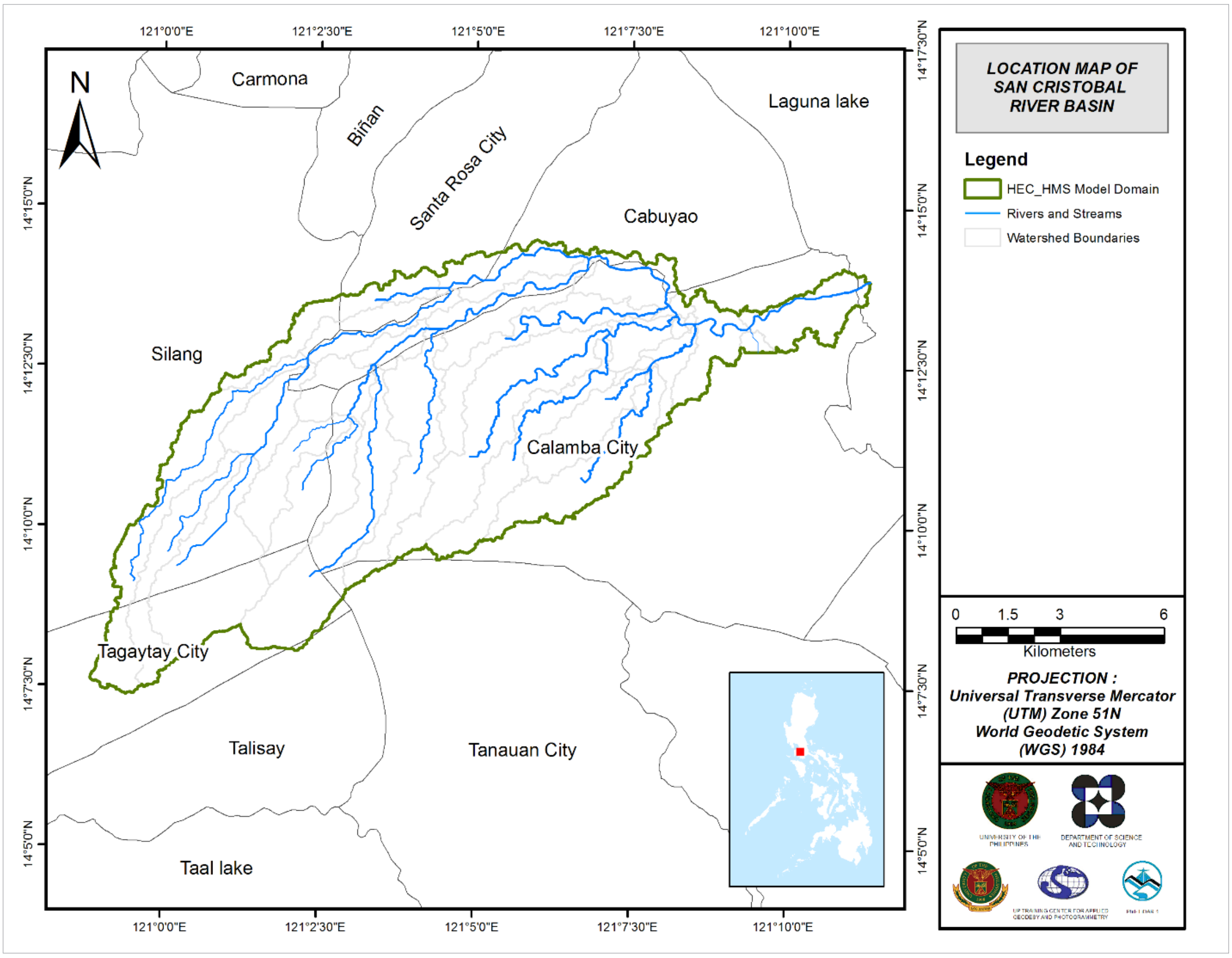


Figure 53. Stream Delineation Map of the San Cristobal River Basin.

Using SAR-based DEM, the San Cristobal basin was delineated and further subdivided into subbasins. The model consists of 38 sub basins, 21 reaches, and 21 junctions as shown in Figure 6. The main outlet is at San Cristobal Bridge.

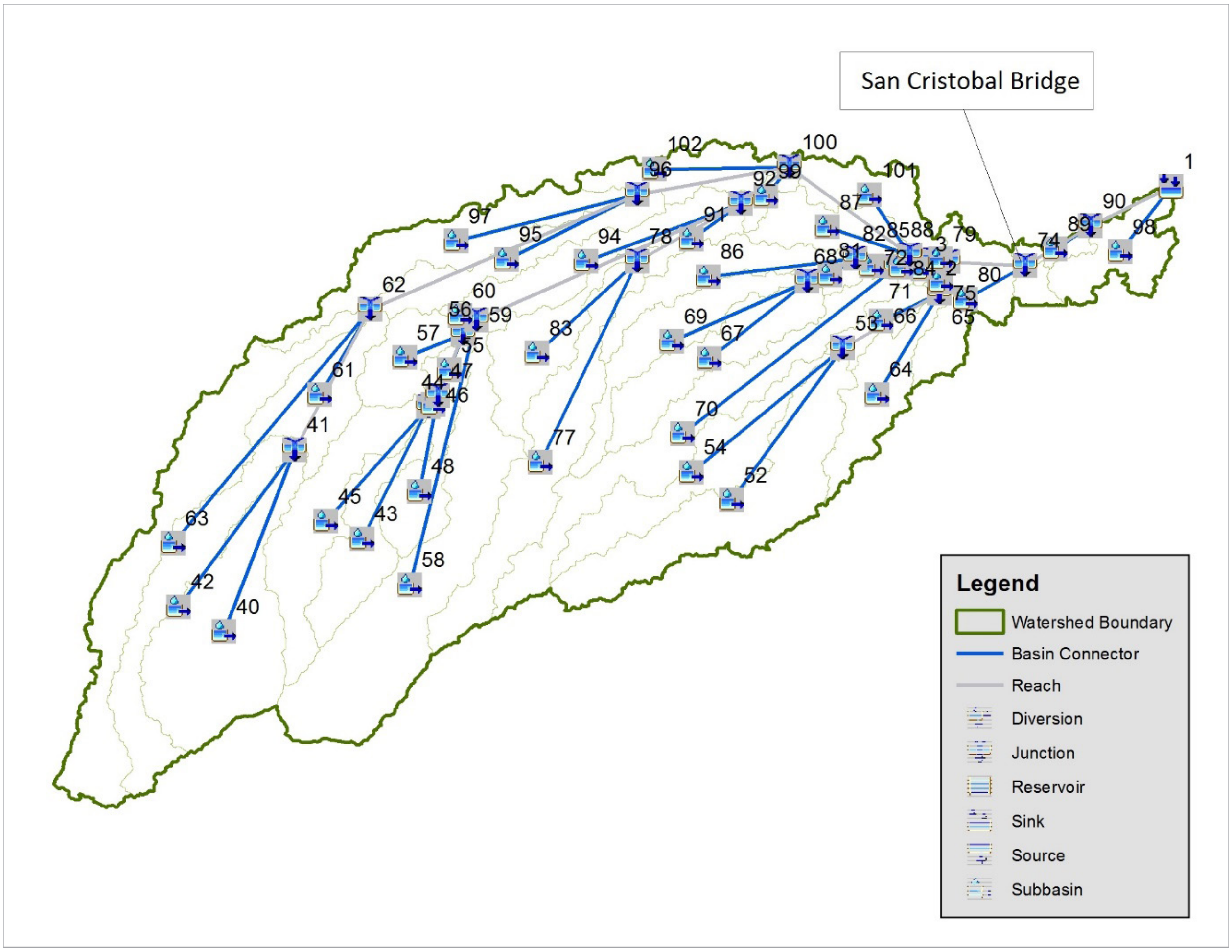


Figure 54. The San Cristobal river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

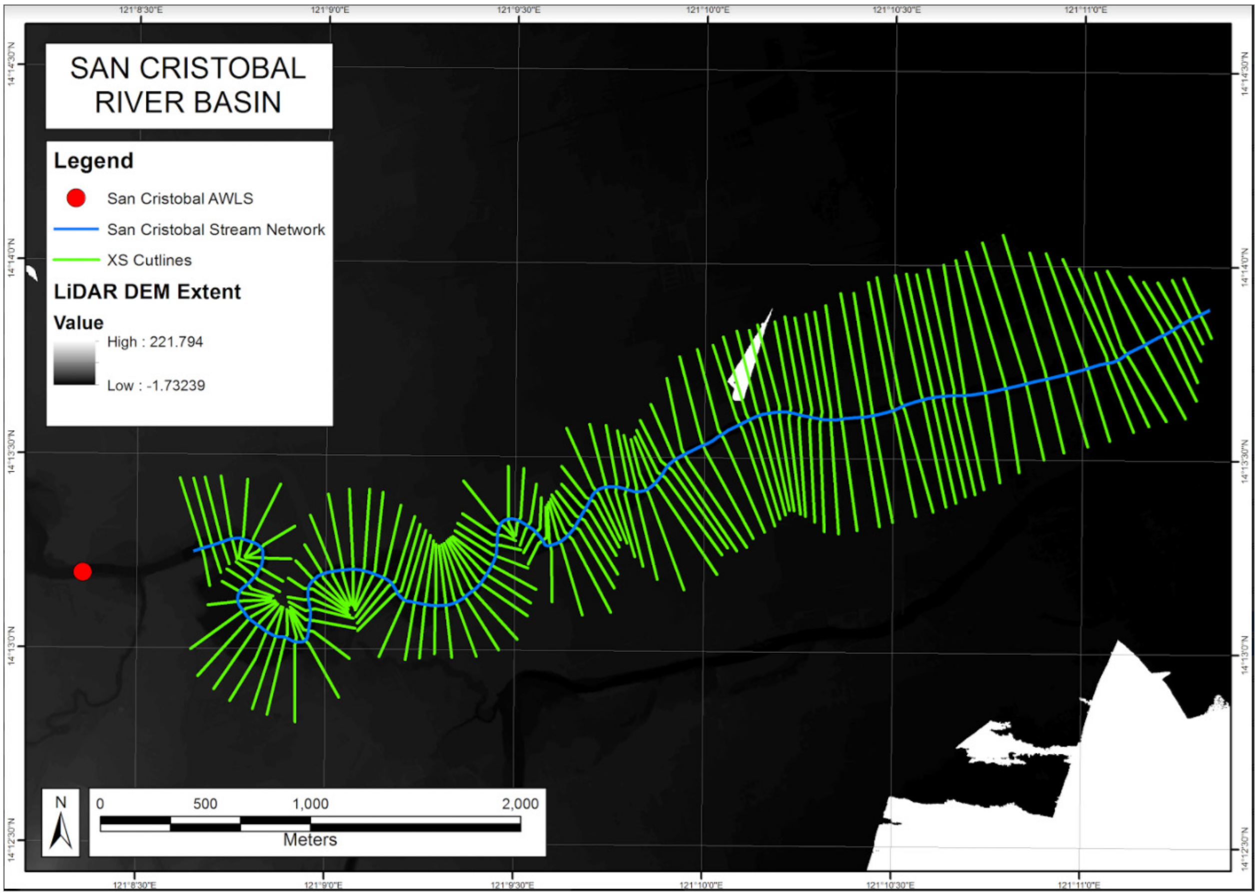


Figure 55. River cross-section of San Cristobal River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

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

Based on the elevation and flow direction, it is seen that the water will generally flow from the southwest of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

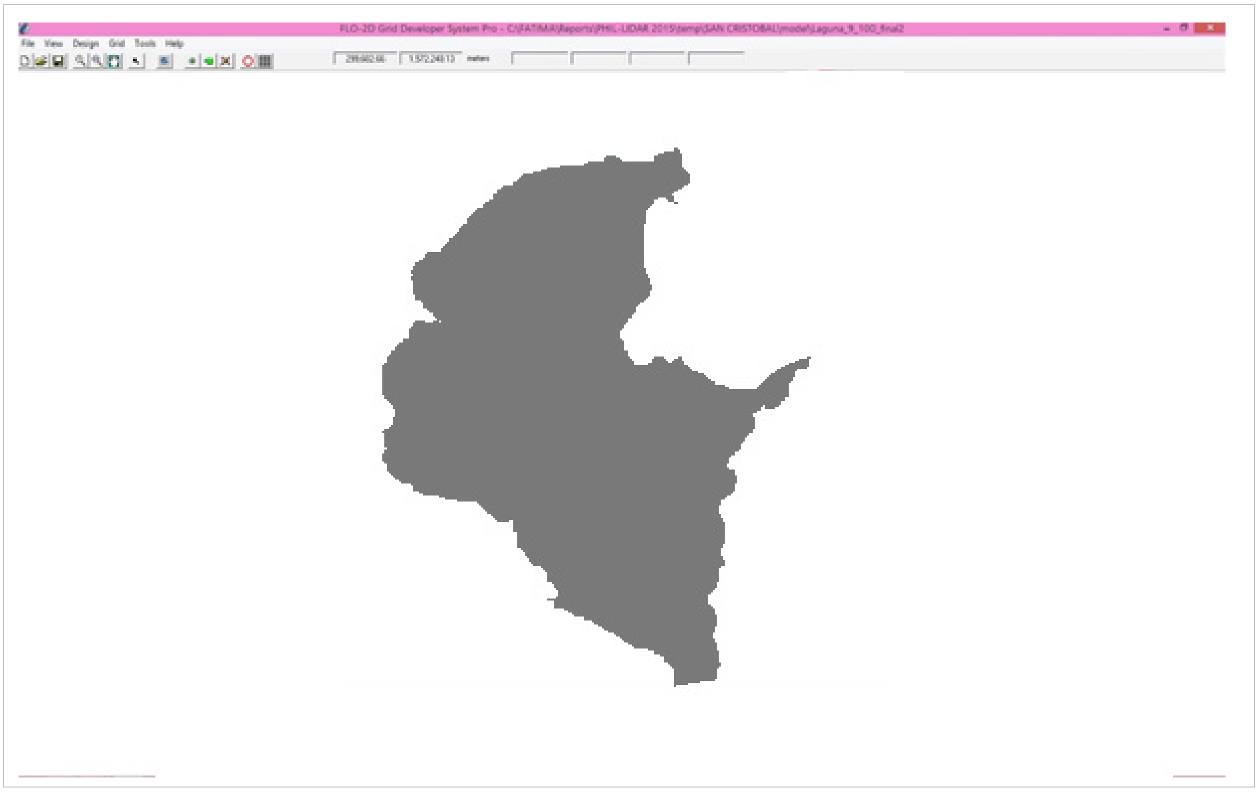


Figure 56. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 10.81665 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 30321300.00 m2.

There is a total of 74398767.13 m3 of water entering the model. Of this amount 74398767.13 m3 is due to rainfall while 61287085.43 m3 is inflow from other areas outside the model. 2515490.50 m3 of this water is lost to infiltration and interception, while 1300206.70 m3 is stored by the flood plain. The rest, amounting up to 5572280.96 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the San Cristobal HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 11 shows the comparison between the two discharge data.

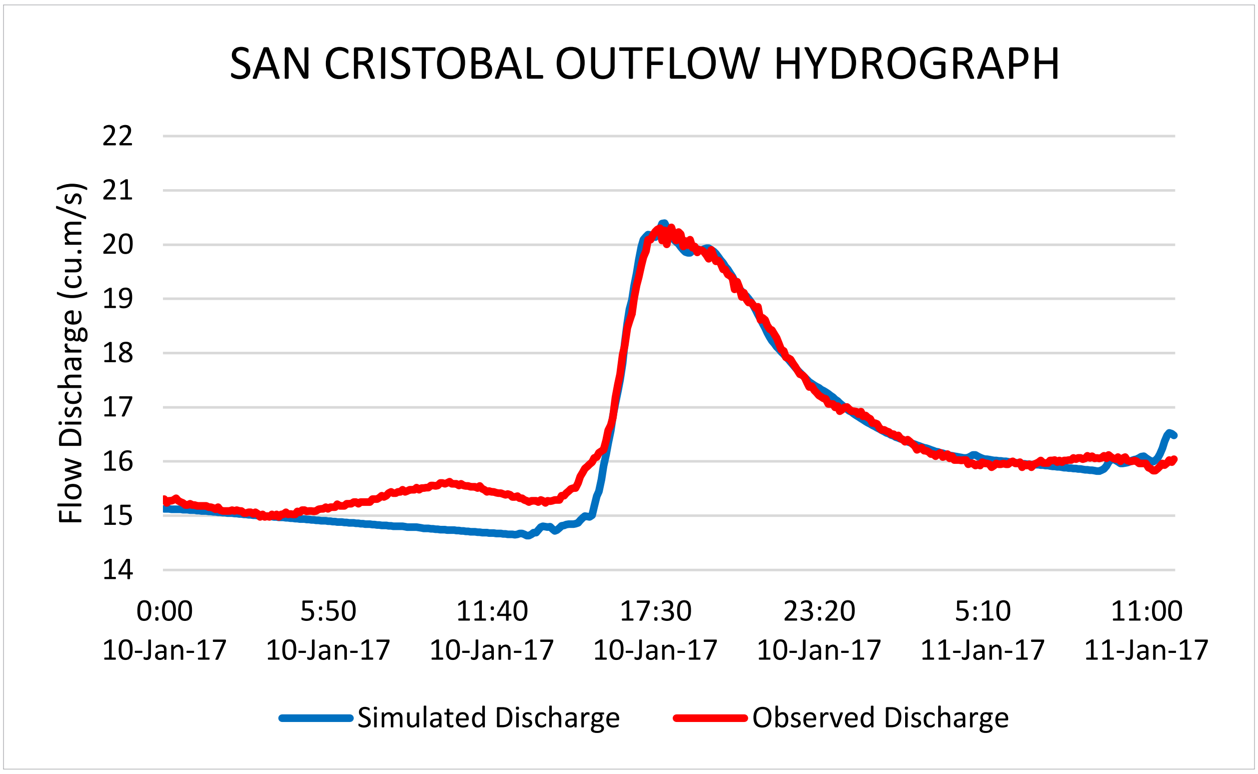


Figure 58. Outflow Hydrograph of San Cristobal produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for San Cristobal.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.05 - 14
			Curve Number	44 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.03 - 37
			Storage Coefficient (hr)	0.03 - 7
	Baseflow	Recession	Recession Constant	0.1 - 1
			Ratio to Peak	0.2 – 0.7
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.01-0.05

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 0.05 to 14mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 44 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

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 0.03 hours to 37 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. For this watershed, the characteristics differ per reach.

Manning's roughness coefficient of 0.01 to 0.05 is relatively low compared to the common roughness of watersheds (Brunner, 2010).

Table 30. Summary of the Efficiency Test of San Cristobal HMS Model.

Root Mean Square Error (RMSE)	0.3666
Pearson Correlation Coefficient (r^2)	0.9839
Nash-Sutcliffe (E)	0.9384
Percent Bias (PBIAS)	1.1161
Observation Standard Deviation Ratio (RSR)	0.2483

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.3666.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9839.

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 0.9384.

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 1.1161.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.2483.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 63) shows the San Cristobal outflow using the Ambulong Rainfail Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

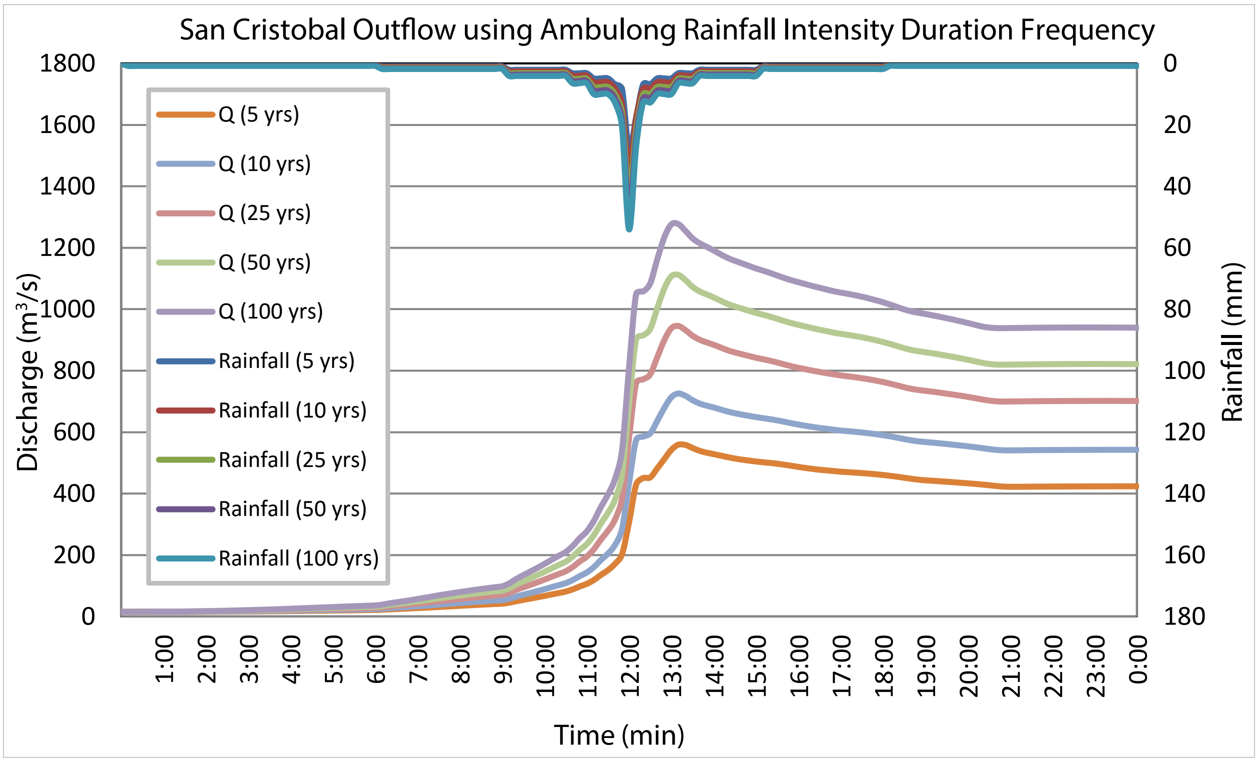


Figure 59. Outflow hydrograph at San Cristobal Station generated using Ambulong RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the San Cristobal discharge using the Ambulong Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 3.

Table 31. Peak values of the San Cristobal HECHMS Model outflow using the Ambulong RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak	Lag Time
5-yr	226.7	27.9	559.206	13 hours 10 minutes	1 hour 10 minutes
10-yr	276.9	34.2	725.705	13 hours 10 minutes	1 hour 10 minutes
25-yr	340.4	42.2	945.455	13 hours 10 minutes	1 hour 10 minutes
50-yr	387.5	48.1	111.630	13 hours 10 minutes	1 hour 10 minutes
100-yr	434.3	54.0	1277.137	13 hours 10 minutes	1 hour 10 minutes

5.7.2 Discharge data using Dr. Horritts' recommended hydrologic method

The river discharges for the three rivers entering the floodplain (Error! Reference source not found._) are shown in Error! Reference source not found. to Error! Reference source not found. and the peak values are summarized in Error! Reference source not found.32 to Error! Reference source not found.37.

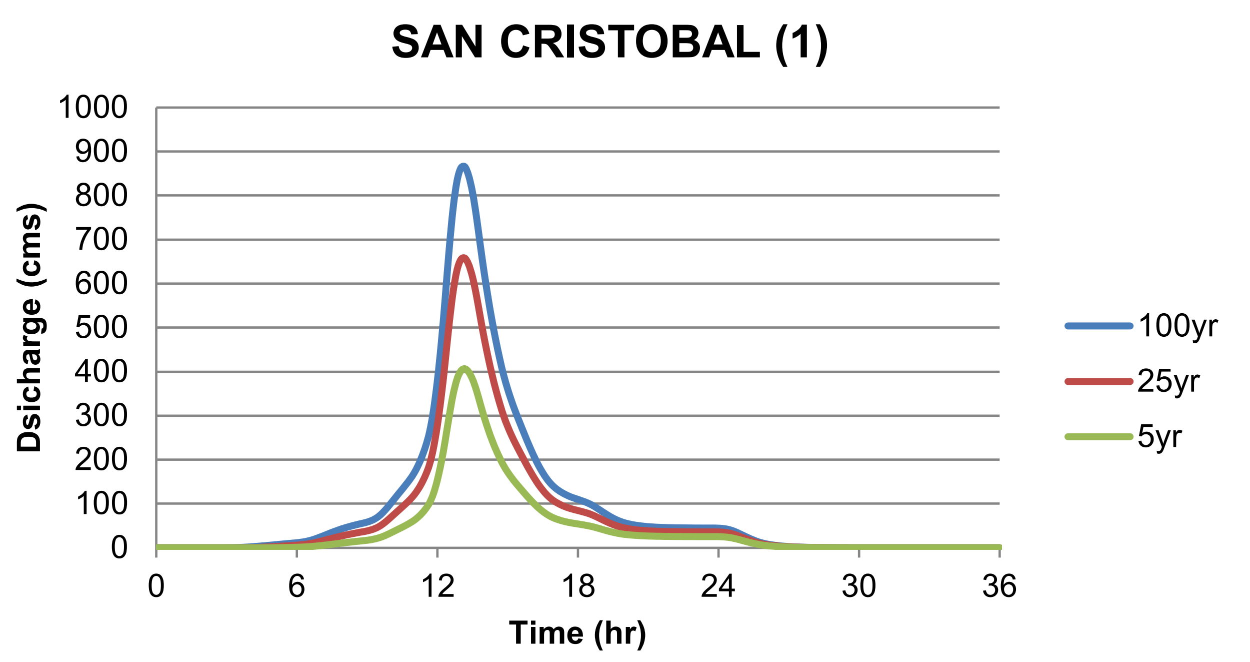


Figure 60. San Cristobal river (1) generated discharge using 5-, 25-, and 100-year Ambulong rainfall intensity-duration-frequency (RIDF) in HEC-HMS

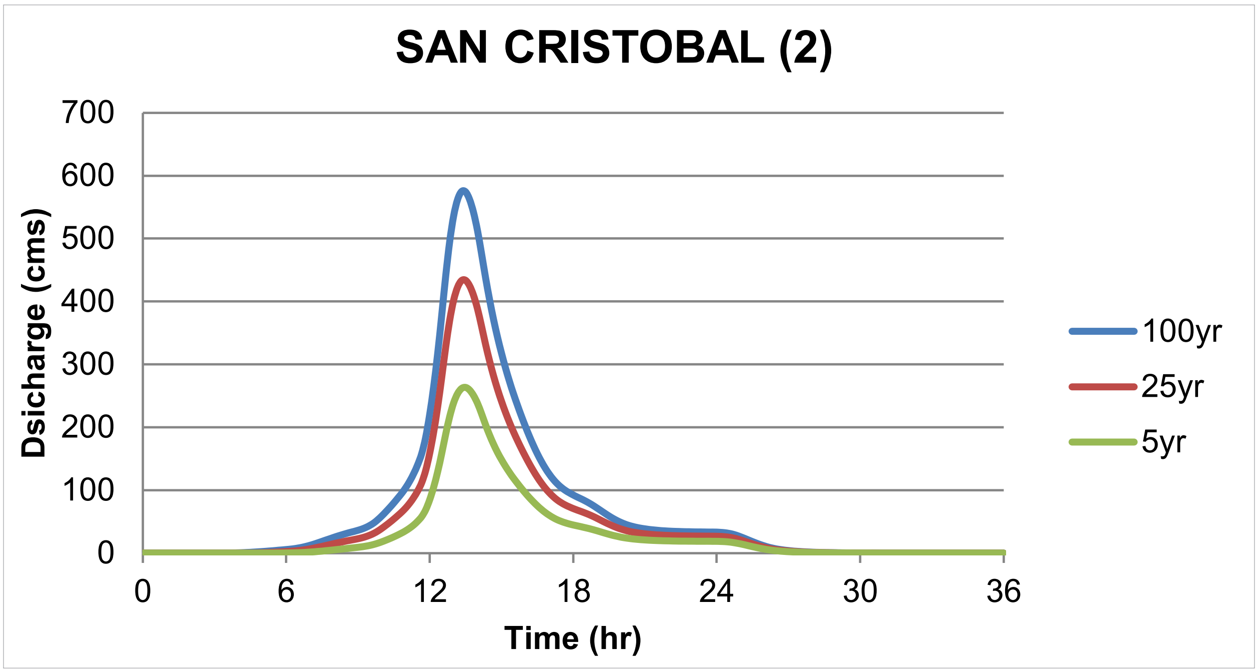


Figure 61. San Cristobal river (2) generated discharge using 5-, 25-, and 100-year Ambulong rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

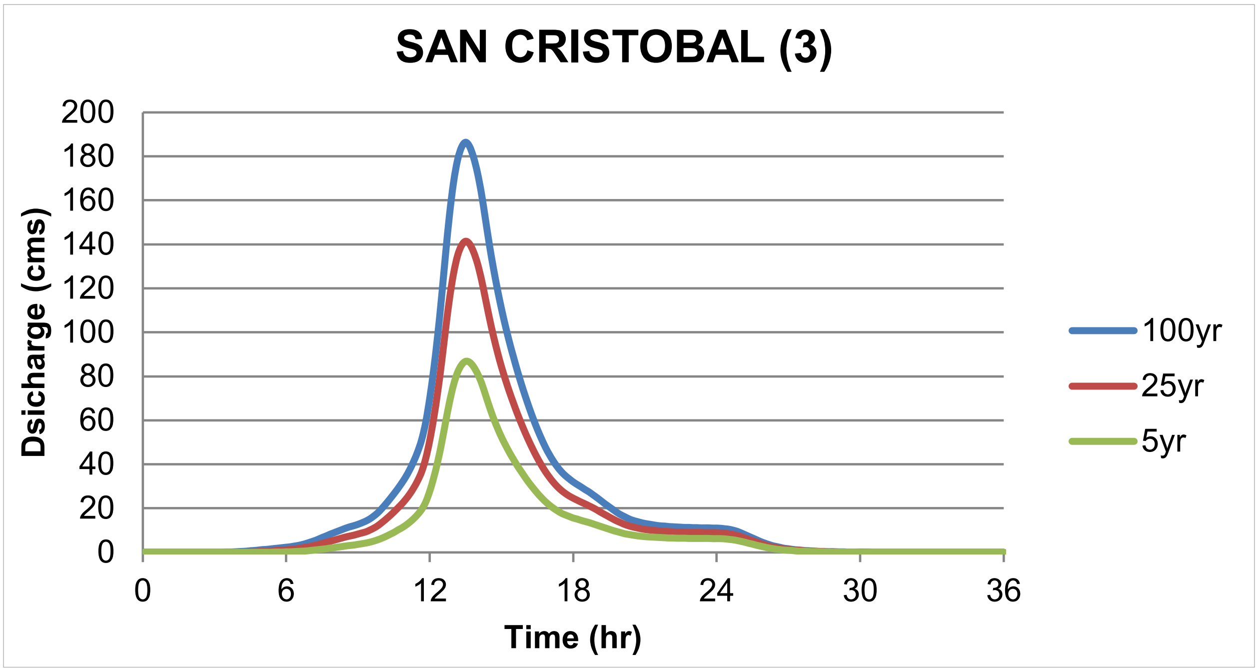


Figure 62. San Cristobal river (3) generated discharge using 5-, 25-, and 100-year Ambulong rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

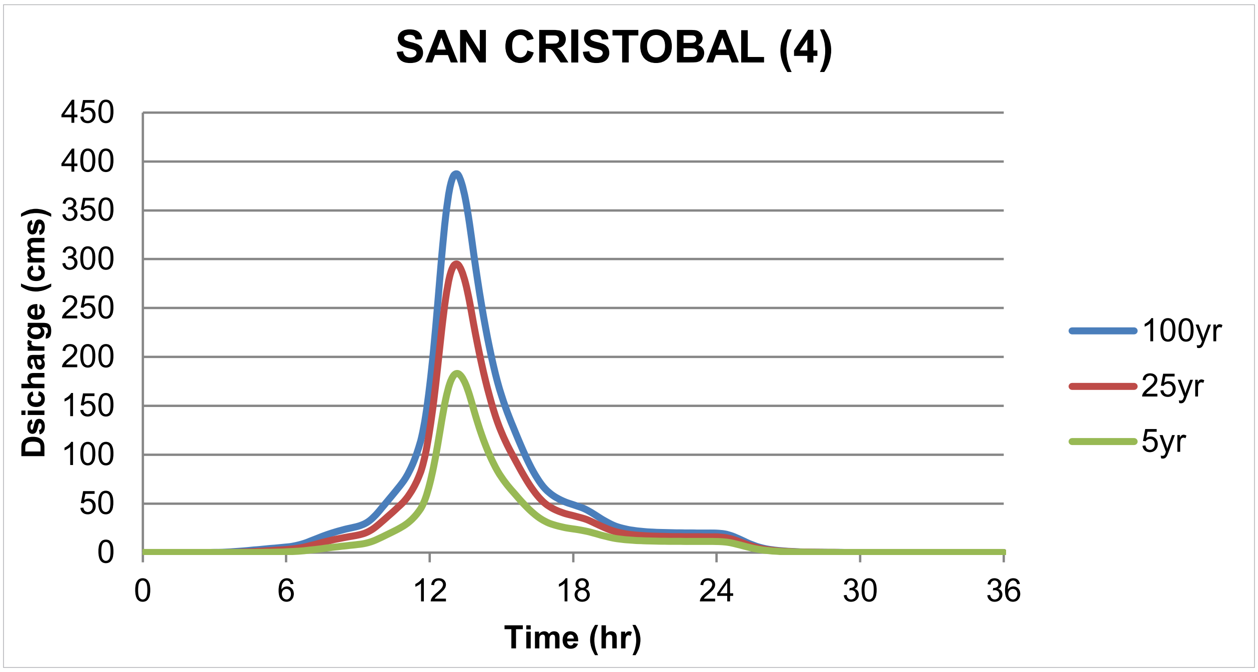


Figure 63. San Cristobal river (4) generated discharge using 5-, 25-, and 100-year Ambulong rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

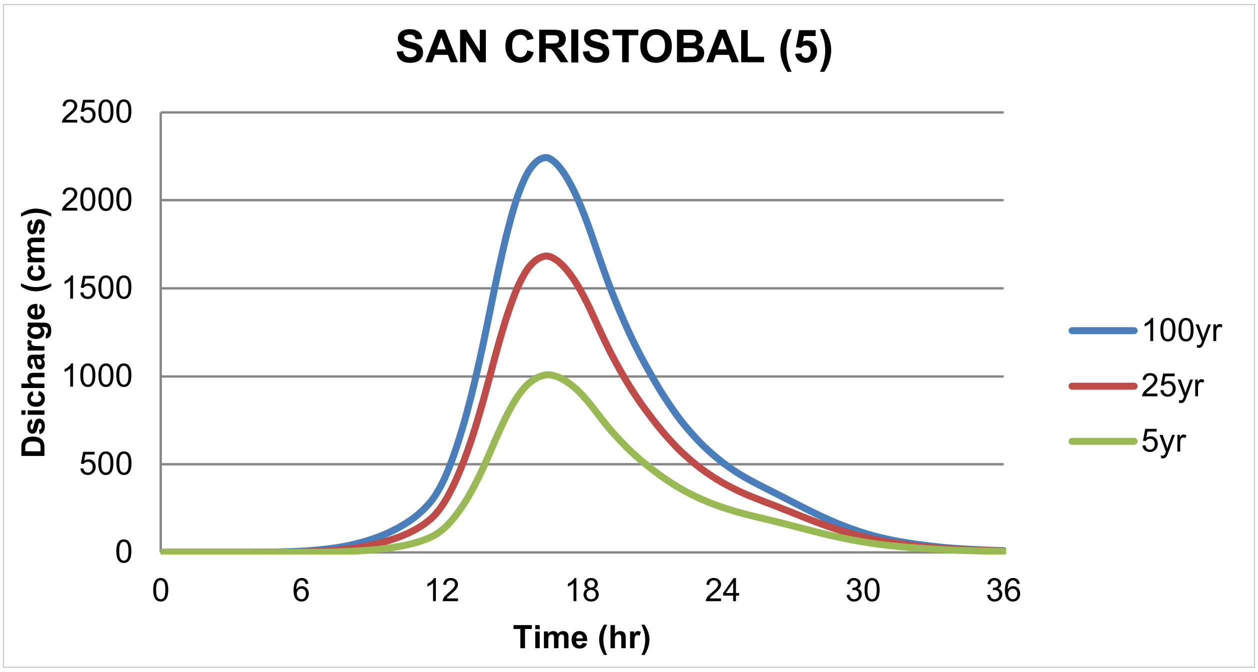


Figure 64. San Cristobal river (5) generated discharge using 5-, 25-, and 100-year Ambulong rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

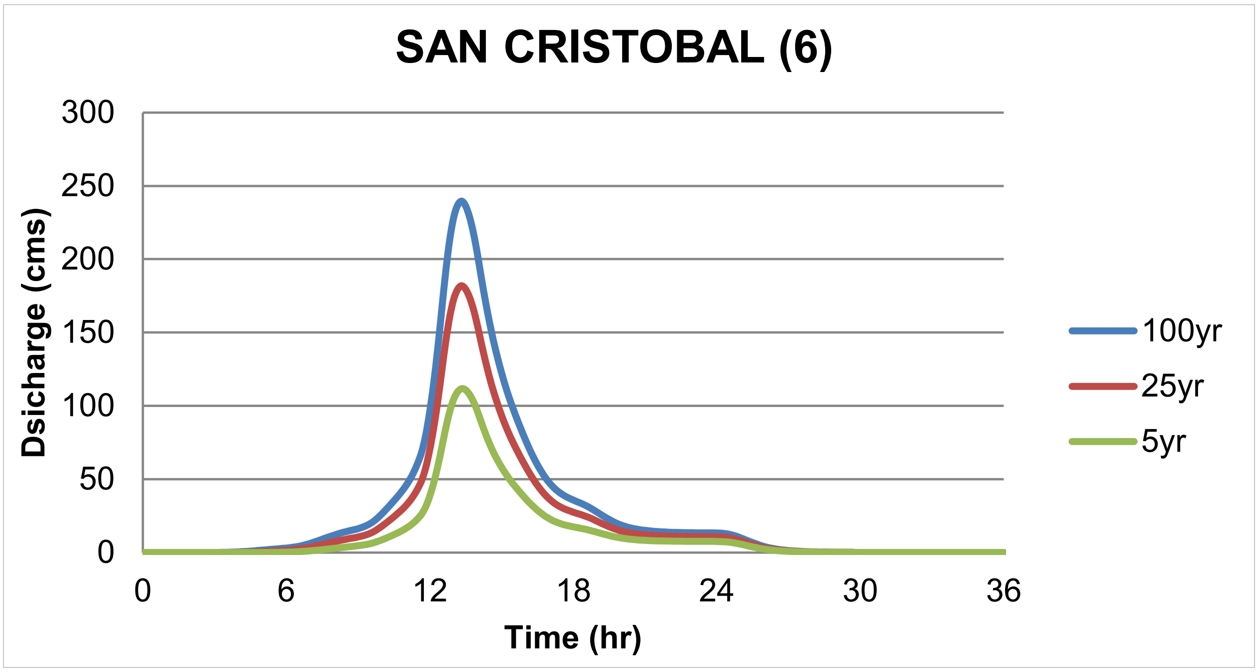


Figure 65. San Cristobal river (6) generated discharge using 5-, 25-, and 100-year Ambulong rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 32. Summary of San Cristobal river (1) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	865.7	13 hours, 10 minutes
25-Year	658.1	13 hours, 10 minutes
5-Year	406.5	13 hours, 10 minutes

Table 33. Summary of San Cristobal river (2) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	574.9	13 hours, 20 minutes
25-Year	433.7	13 hours, 20 minutes
5-Year	263.4	13 hours, 30 minutes

Table 34. Summary of San Cristobal river (3) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	186.4	13 hours, 30 minutes
25-Year	141.4	13 hours, 30 minutes
5-Year	86.8	13 hours, 30 minutes

Table 35. Summary of San Cristobal river (4) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	386.9	13 hours, 10 minutes
25-Year	294.8	13 hours, 10 minutes
5-Year	183.1	13 hours, 10 minutes

Table 36. Summary of San Cristobal river (5) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2242.7	16 hours, 30 minutes
25-Year	1683.5	16 hours, 30 minutes
5-Year	1008.7	16 hours, 30 minutes

Table 37. Summary of San Cristobal river (6) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	239.6	13 hours, 20 minutes
25-Year	181.9	13 hours, 20 minutes
5-Year	111.7	13 hours, 20 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 38.

Table 38. Validation of river discharge estimates.

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
San Cristobal (1)	357.720	476.722	303.342	Pass	Pass
San Cristobal (2)	231.792	378.281	252.609	Pass	Pass
San Cristobal (3)	76.384	74.797	107.352	Pass	Pass
San Cristobal (4)	161.128	123.661	60.168	Pass	Fail
San Cristobal (5)	887.656	1286.858	603.059	Pass	Pass
San Cristobal (6)	98.296	114.011	123.757	Pass	Pass

All six 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 are based on theory but are 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 sample map of San Cristobal River using the HMS base flow is shown on Figure 70 below.

Figure 66. San Cristobal HEC-RAS Output.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the San Cristobal floodplain are shown in Figure 71 to 75. The floodplain, with an area of 101.16 sq. km., covers four municipalities namely Cabuyao, Calamba City, Laguna Lake, and Santa Rosa City. Table shown the percentage of area affected by flooding per municipality.

Table 39. Municipalities affected in San Cristobal floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Cabuyao	45.70	34.74	76.03
Calamba City	130.68	56.97	43.59
Laguna lake	892.20	2.18	0.24
Santa Rosa City	47.65	7.27	15.26

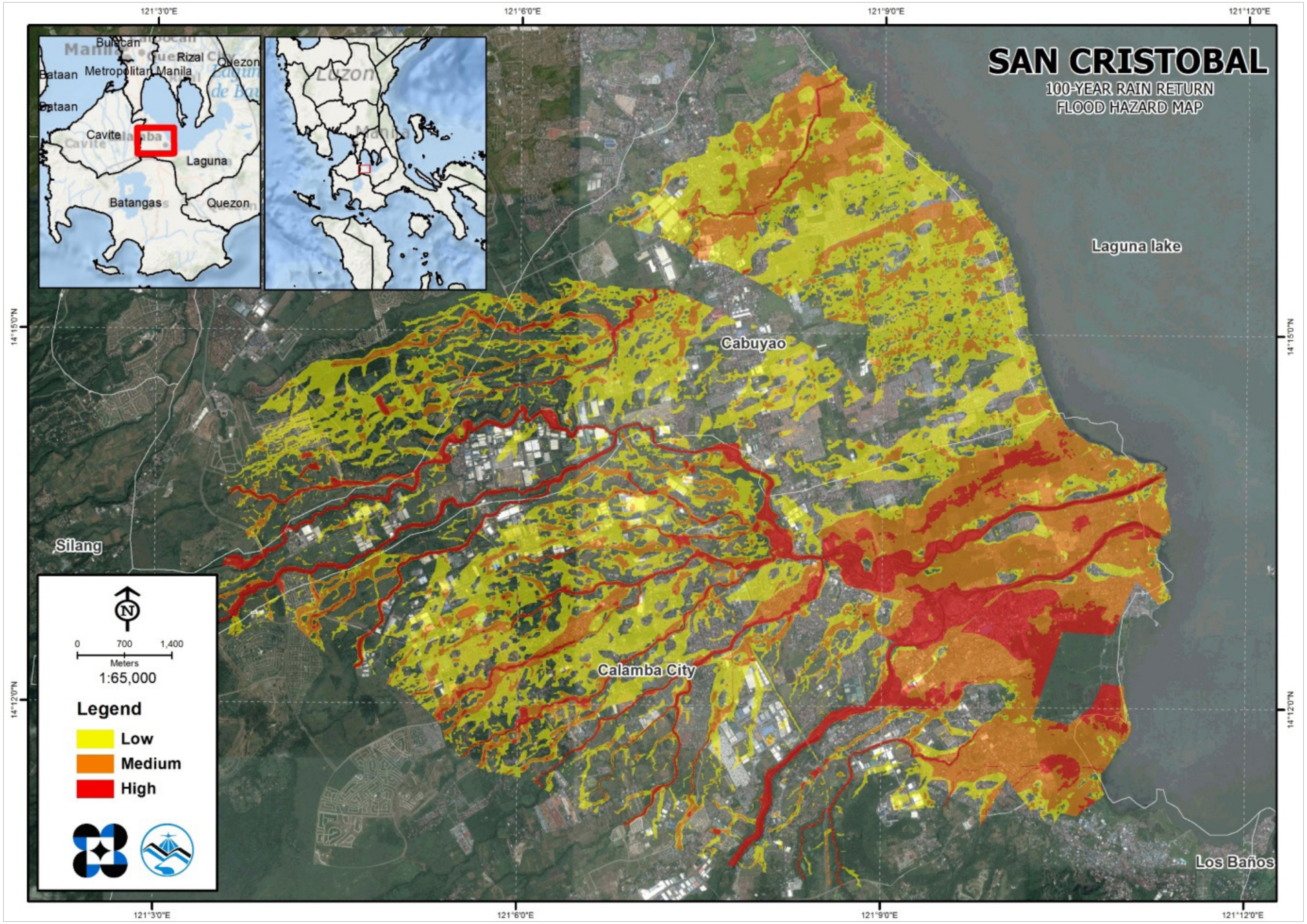


Figure 67. 100-year Flood Hazard Map for San Cristobal Floodplain.

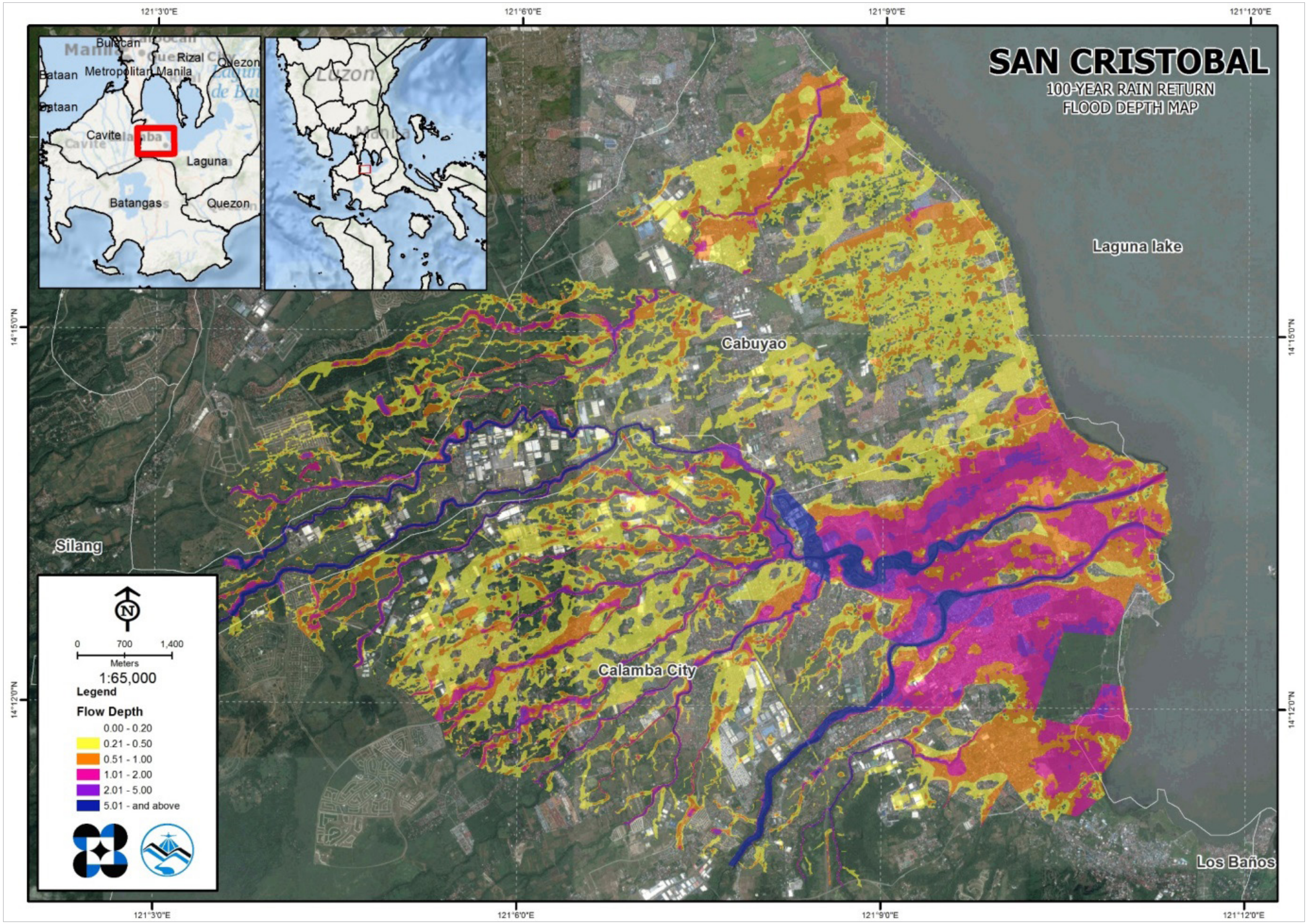


Figure 68. 100-year Flow Depth Map for San Cristobal Floodplain.

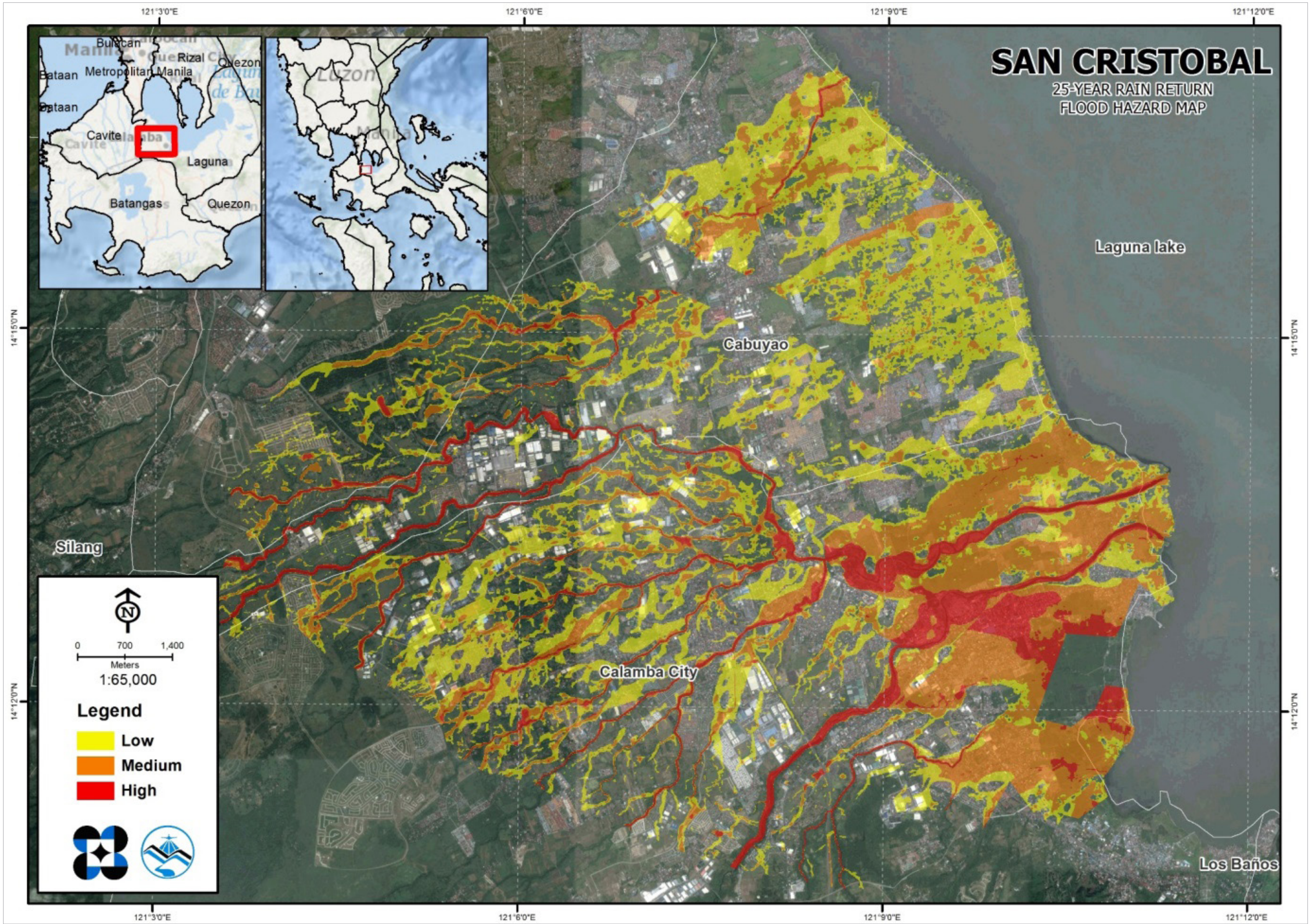


Figure 69. 25-year Flood Hazard Map for San Cristobal Floodplain.

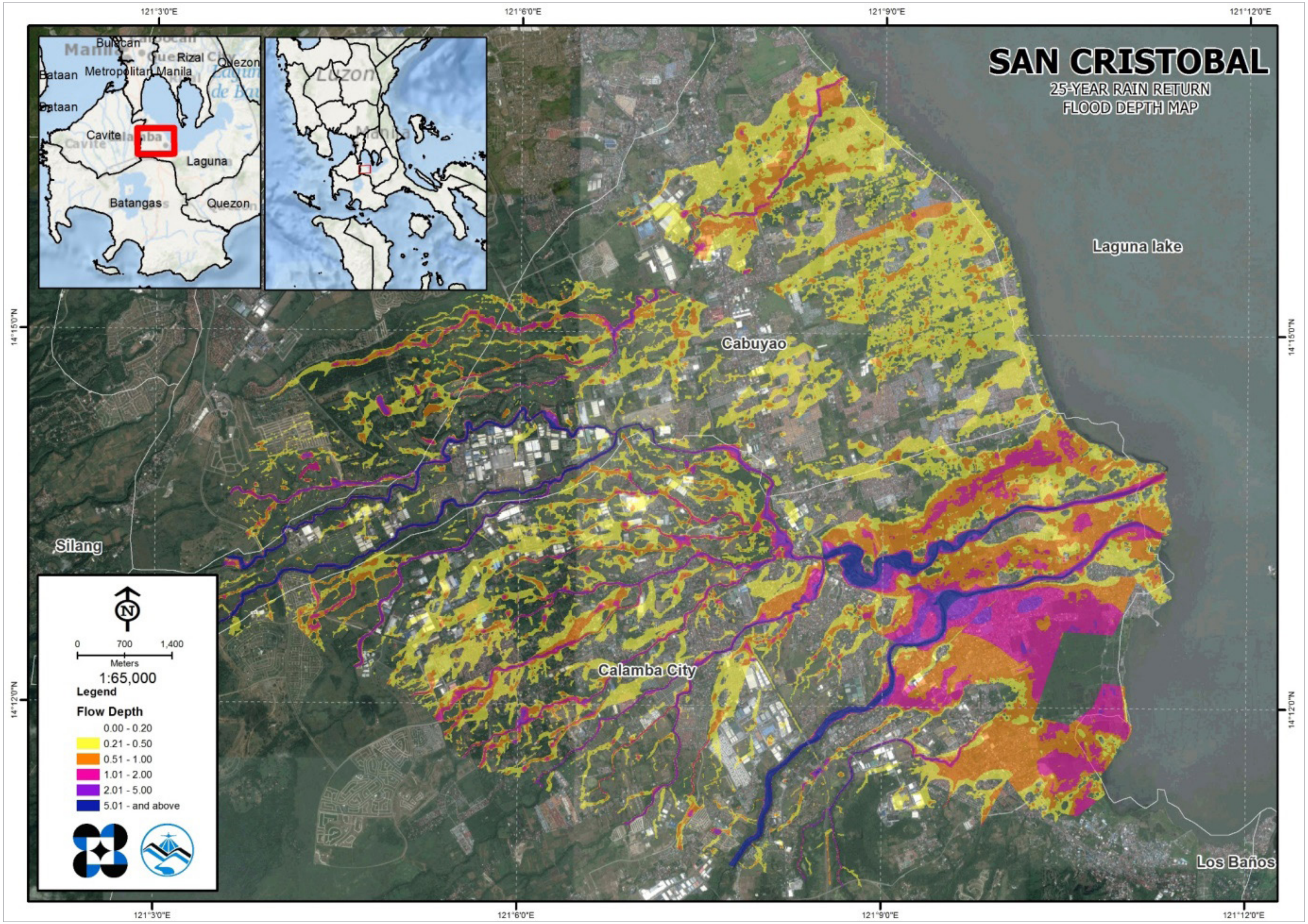


Figure 70. 25-year Flow Depth Map for San Cristobal Floodplain

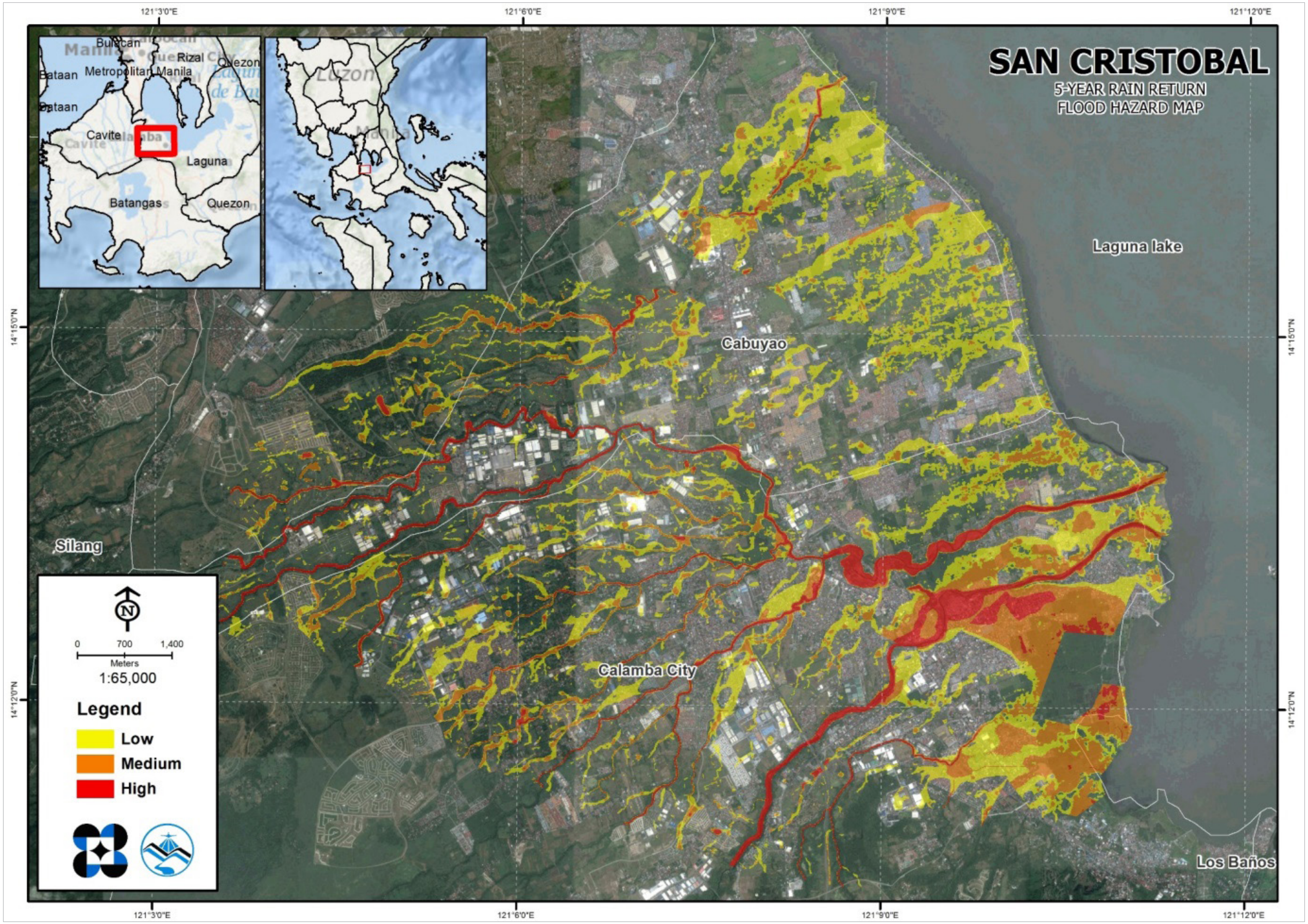


Figure 71. 5-year Flood Hazard Map for San Cristobal Floodplain.

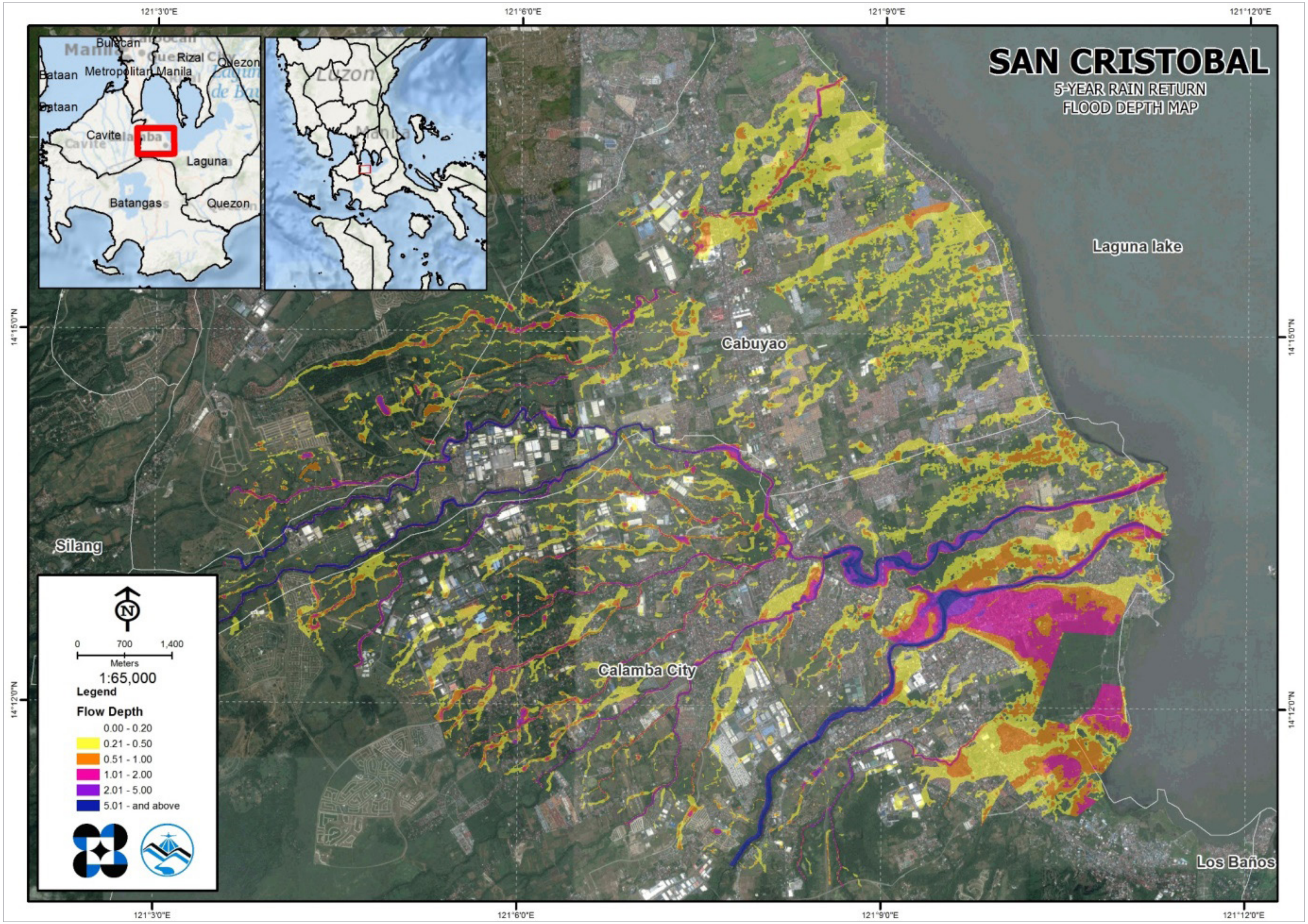


Figure 72. 5-year Flow Depth Map for San Cristobal Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the San Cristobal river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 58 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 53.34% of the city of Cabuyao with an area of 47.4 sq. km. will experience flood levels of less 0.20 meters. 15.74% of the area will experience flood levels of 0.21 to 0.50 meters while 2.01%, 0.72%, 0.68%, and 0.85% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in square kilometres by flood depth per barangay.

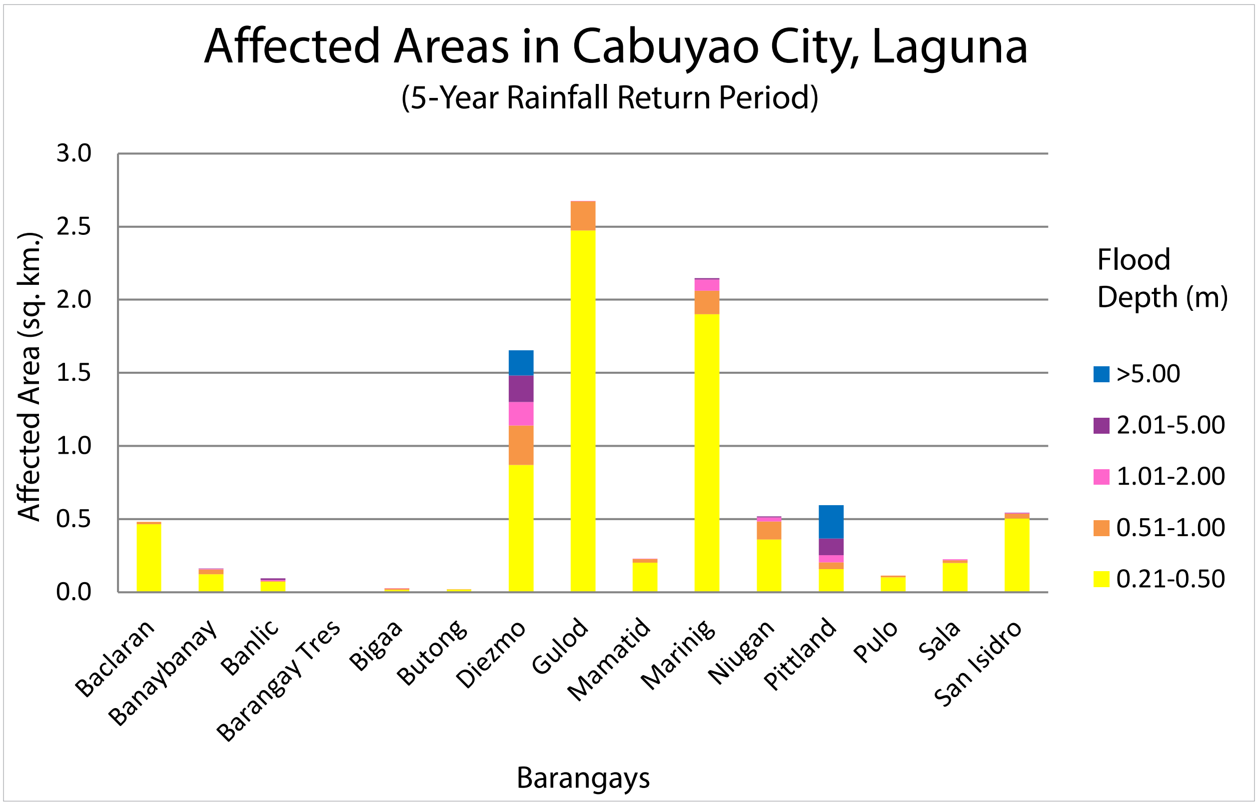


Figure 73. Affected Areas in Cabuyao City, Laguna during 5-Year Rainfall Return Period.

Table 40. Affected Areas in Cabuyao City, Laguna during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabuyao City (in sq. km.)							
	Baclaran	Banaybanay	Banlic	Barangay Tres	Bigaa	Butong	Diezmo	Gulod
0.03-0.20	1.25792	0.320579	1.04425	0.054926	0.021472	0.004631	7.27264	4.39759
0.21-0.50	0.46535	0.122794	0.072038		0.014118	0.017047	0.870593	2.47242
0.51-1.00	0.016176	0.032072	0.00475		0.00944	0.0008	0.269766	0.200832
1.01-2.00		0.003792	0.005927		0.00001		0.160407	0.0019
2.01-5.00		0.0012	0.01149				0.180445	
> 5.00							0.172445	

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabuyao City (in sq. km.)							
	Mamatid	Marinig	Niugan	Pittland	Pulo	Sala	San Isidro	
0.03-0.20	1.8159	1.5275	0.43698	2.93541	0.958055	1.14642	2.07928	
0.21-0.50	0.200849	1.90129	0.359921	0.157879	0.101844	0.198938	0.503814	
0.51-1.00	0.025686	0.15896	0.122227	0.046083	0.01171	0.01952	0.032465	
1.01-2.00	0.0001	0.078153	0.029768	0.048791		0.007309	0.004087	
2.01-5.00		0.009059	0.006175	0.114886			0.000708	
> 5.00				0.228051				

For the city of Calamba, with an area of 139.4 sq. km., 28.1% will experience flood levels of less 0.20 meters. 6.4% of the area will experience flood levels of 0.21 to 0.50 meters while 2.9%, 2.05%, 0.89%, 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 in Table 41 are the affected areas in square kilometres by flood depth per barangay.

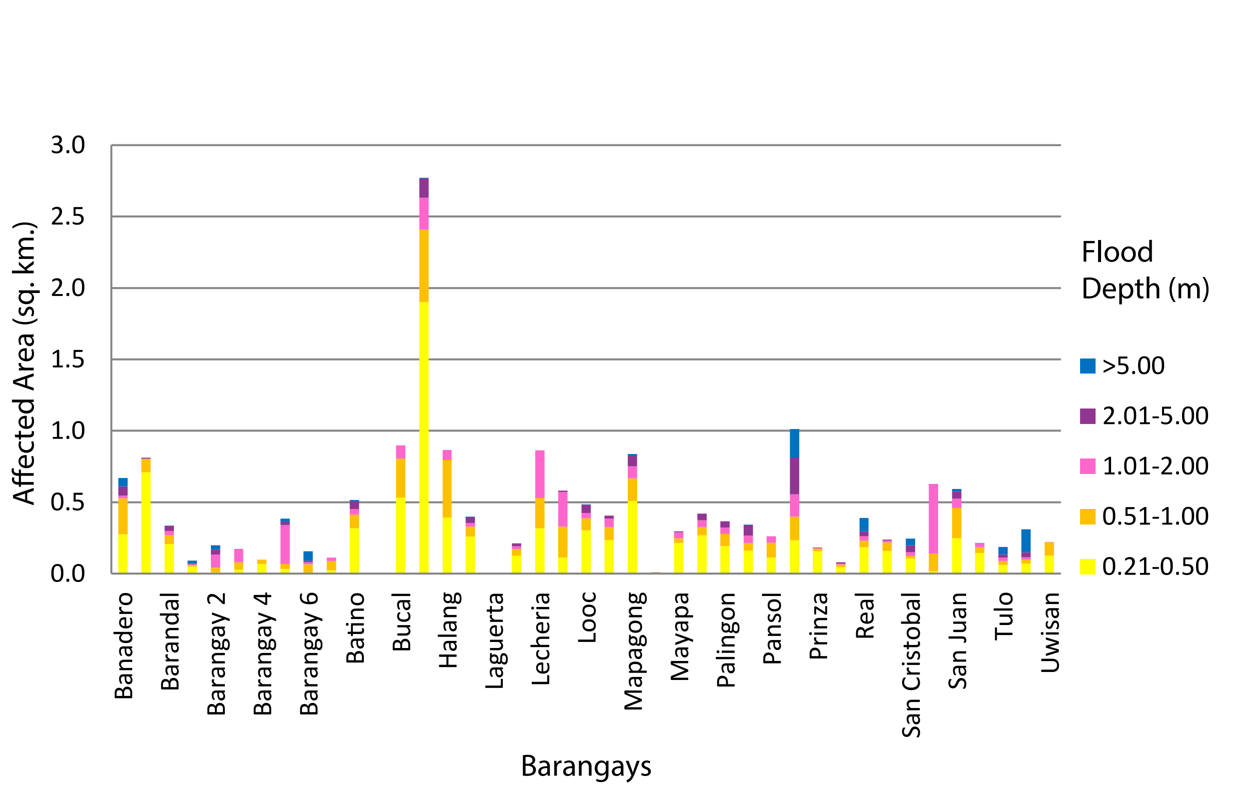


Figure 74. Affected Areas in Calamba City, Laguna during 5-Year Rainfall Return Period

Table 41. Affected Areas in Calamba City, Laguna during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Banadero	Banlic	Barandal	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Batino
0.03-0.20	0.637397	2.08162	2.41042	0.188669	0.016482	0.061361	0.002187	0.06874	0.000491	0.000741	0.80156
0.21-0.50	0.275434	0.709975	0.20803	0.049836	0.010361	0.027036	0.06728	0.033196	0.00678	0.022378	0.318344
0.51-1.00	0.252593	0.094147	0.062444	0.011094	0.031758	0.051289	0.031847	0.035614	0.059642	0.067153	0.094164
1.01-2.00	0.018401	0.001206	0.027891	0.004695	0.09139	0.091861		0.271503	0.012579	0.022807	0.040495
2.01-5.00	0.064298	0.006404	0.034937	0.006545	0.034119	0.002125		0.021788	0.012089		0.055798
> 5.00	0.058132		0.001841	0.01786	0.031531			0.021911	0.066388		0.0057

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Bubuyan	Bucal	Canlubang	Halang	La Mesa	Laguerta	Lawa	Lecheria	Lingga	Looc	Majada Labas
0.03-0.20	0.000328	0.248218	10.0817	0.043488	1.77656	0.000012	0.529024	1.49538	0.127866	0.776463	1.44878
0.21-0.50	0.000055	0.53222	1.90067	0.39273	0.259747	0.000029	0.125674	0.317455	0.11173	0.302719	0.236571
0.51-1.00	0.000208	0.272176	0.505646	0.403208	0.068261	0.000188	0.046743	0.21141	0.217339	0.084903	0.089471
1.01-2.00	0.000266	0.092555	0.224333	0.068992	0.027252	0.000252	0.018795	0.334597	0.241682	0.035933	0.059039
2.01-5.00			0.135193		0.042225		0.018738		0.009915	0.058518	0.021201
> 5.00			0.0052		0.0002		0.0029			0.000208	

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Mapagong	Maunong	Mayapa	Paciano Rizal	Palingon	Palo-Alto	Pansol	Parian	Prinza	Punta	Real
0.03-0.20	2.35539	0.074874	1.7523	1.07781	0.331041	2.25673	0.148064	0.930769	1.79414	0.673955	0.596405
0.21-0.50	0.507655	0.006402	0.214931	0.268106	0.193489	0.161065	0.111603	0.232857	0.155935	0.044654	0.183967
0.51-1.00	0.160281	0.001314	0.031624	0.057796	0.084989	0.052931	0.106364	0.165914	0.018953	0.019358	0.047891
1.01-2.00	0.082324	0.000289	0.042892	0.046972	0.04344	0.051398	0.043601	0.156475	0.0046	0.006507	0.030622
2.01-5.00	0.0795		0.007662	0.046444	0.043525	0.074997		0.255297	0.000297	0.009521	0.032955
> 5.00	0.006618					0.0023		0.202655	0.00004		0.094771

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Sampiruhan	San Cristobal	San Jose	San Juan	Sirang Lupa	Tulo	Turbina	Uwisan			
0.03-0.20	0.121994	1.08235	0.004381	0.10695	0.482396	1.07874	1.24756	0.241731			
0.21-0.50	0.15781	0.105893	0.015566	0.246663	0.144166	0.061704	0.070791	0.126231			
0.51-1.00	0.061235	0.018157	0.123602	0.213774	0.039254	0.027004	0.026924	0.092601			
1.01-2.00	0.010974	0.024302	0.484869	0.064779	0.028959	0.02292	0.017371	0.0008			
2.01-5.00	0.007048	0.049115	0.0042	0.049565	0.0001	0.023517	0.03453				
> 5.00		0.047378		0.0173		0.050598	0.16127				

For the city of Santa Rosa , with an area of 59.19 sq. km., 10.79% will experience flood levels of less 0.20 meters. 1.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.6%, 0.2%, 0.13%, and 0.006% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas in square kilometres by flood depth per barangay.

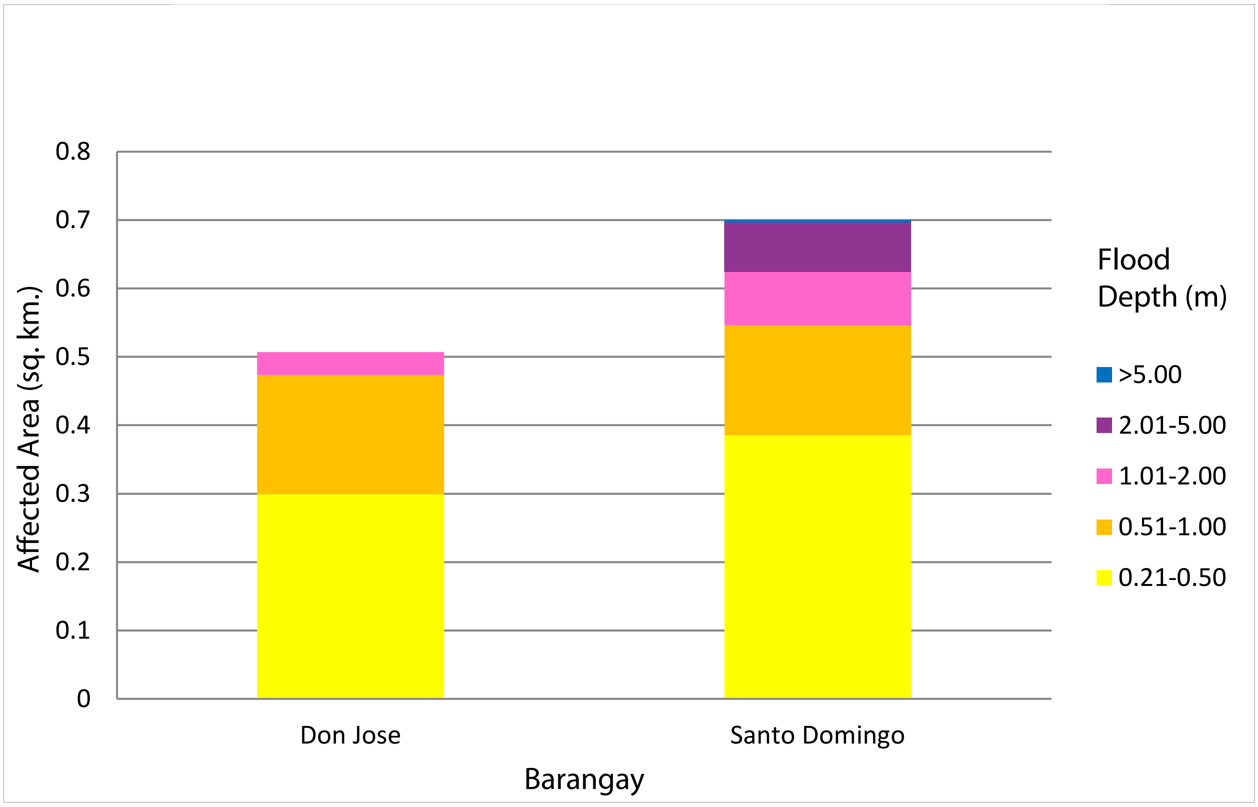


Figure 75. Affected Areas in Santa Rosa City, Laguna during 5-Year Rainfall Return Period

Table 42. Affected Areas in Santa Rosa City, Laguna during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rosa City (in sq. km.)	
	Don Jose	Santo Domingo
0.03-0.20	1.655	4.40881
0.21-0.50	0.299524	0.385237
0.51-1.00	0.173861	0.160851
1.01-2.00	0.033783	0.078456
2.01-5.00		0.071909
> 5.00		0.003395

For the 25-year return period, 42.27% of the city of Cabuyao with an area of 47.4 sq. km. will experience flood levels of less 0.20 meters. 22.74% of the area will experience flood levels of 0.21 to 0.50 meters while 5.35%, 0.98%, 0.82%, and 1.18% 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 are the affected areas in square kilometres by flood depth per barangay.

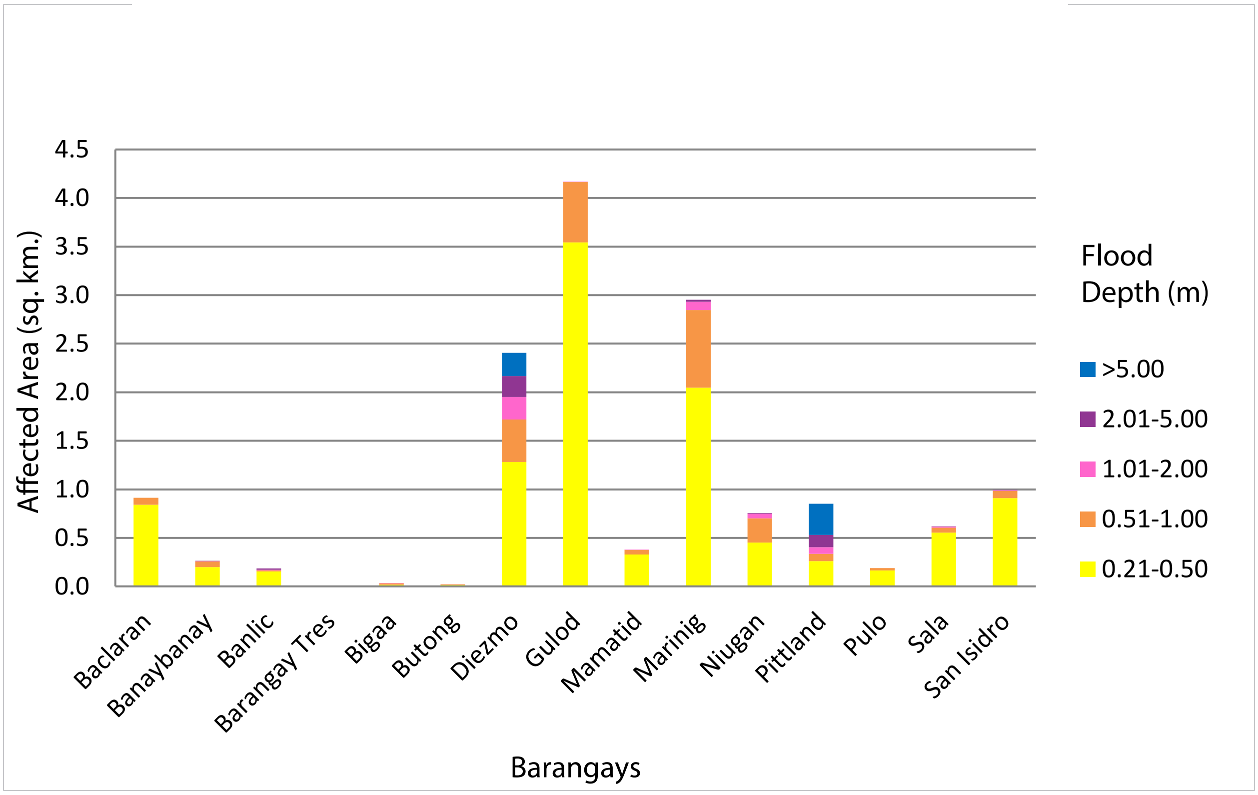


Figure 76. Affected Areas in Cabuyao City, Laguna during 25-Year Rainfall Return Period

Table 43. Affected Areas in Cabuyao City, Laguna during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabuyao City (in sq. km.)							
	Baclaran	Banaybanay	Banlic	Barangay Tres	Bigaa	Butong	Diezmo	Gulod
0.03-0.20	0.826311	0.217399	0.952312	0.054926	0.01293	0.001763	6.52173	2.90367
0.21-0.50	0.840345	0.19935	0.155603		0.019251	0.014236	1.28017	3.54425
0.51-1.00	0.072789	0.05728	0.009073		0.011869	0.00648	0.440121	0.618991
1.01-2.00		0.004908	0.005797		0.00099		0.230205	0.006222
2.01-5.00		0.0015	0.015665				0.216738	
> 5.00							0.238927	

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabuyao City (in sq. km.)							
	Mamatid	Marinig	Niugan	Pittland	Pulo	Sala	San Isidro	
0.03-0.20	1.6659	0.724571	0.197723	2.68086	0.881839	0.754421	1.62987	
0.21-0.50	0.328205	2.04821	0.451964	0.26228	0.166187	0.554384	0.910447	
0.51-1.00	0.046929	0.796826	0.249789	0.074268	0.023483	0.05215	0.075417	
1.01-2.00	0.0015	0.084954	0.046953	0.067854		0.010537	0.004271	
2.01-5.00		0.02039	0.008643	0.124673		0.0007	0.000345	
> 5.00				0.321268				

For the city of Calamba, with an area of 139.4 sq. km., 20.96% will experience flood levels of less 0.20 meters. 7.94% of the area will experience flood levels of 0.21 to 0.50 meters while 6.32%, 3.6%, 1.35%, and 0.77% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometres by flood depth per barangay.

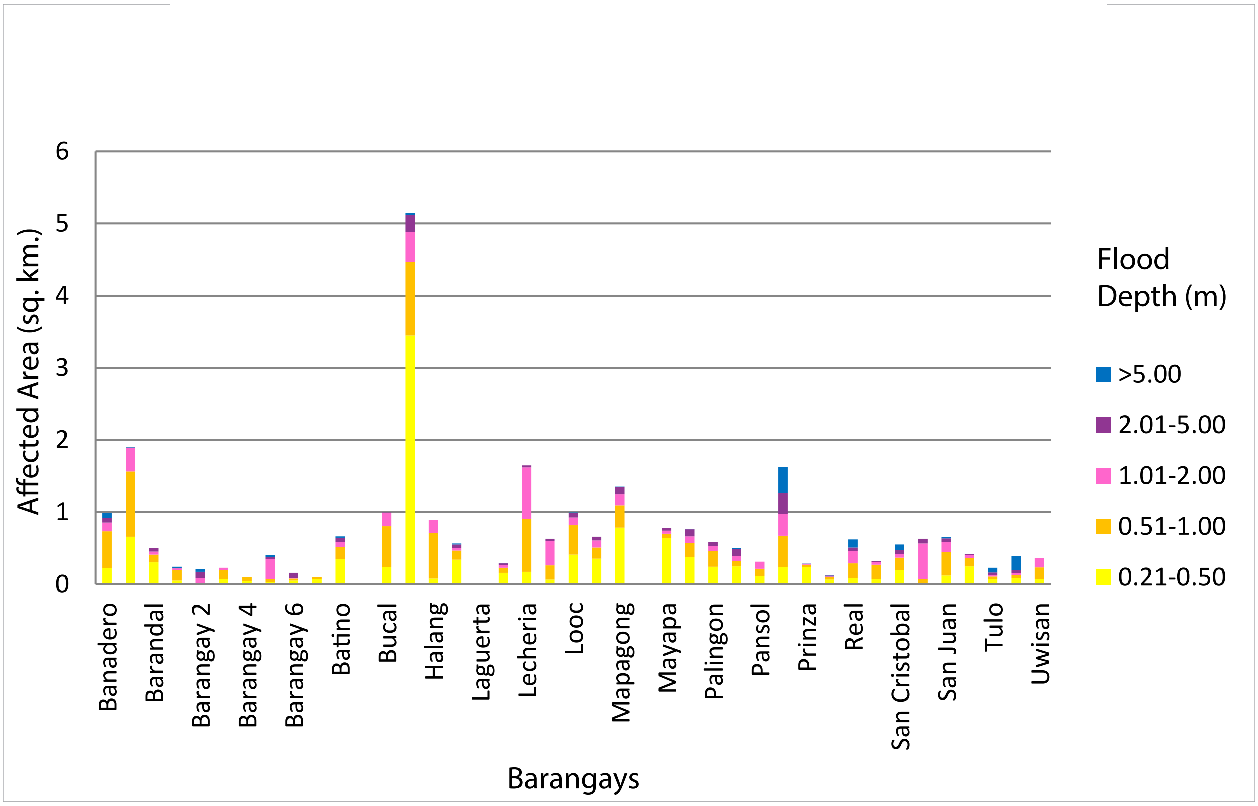


Figure 77. Affected Areas in Calamba City, Laguna during 25-Year Rainfall Return Period

Table 44. Affected Areas in Calamba City, Laguna during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Banadero	Banlic	Barandal	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Batino
0.03-0.20	0.316348	0.995599	2.2399	0.034007	0.00598	0.002472	0.0007	0.052949	0.00077	0.01247	0.653313
0.21-0.50	0.226327	0.655761	0.302214	0.050845	0.010446	0.075877	0.044335	0.028794	0.052178	0.076459	0.343805
0.51-1.00	0.504587	0.905725	0.107867	0.14634	0.010261	0.120414	0.056279	0.045709	0.025553	0.024149	0.172057
1.01-2.00	0.124208	0.327403	0.04401	0.020767	0.063365	0.034909		0.272491	0.010301		0.071504
2.01-5.00	0.058761	0.003511	0.043044	0.007206	0.09003			0.030297	0.069168		0.056978
> 5.00	0.076024	0.005356	0.00853	0.019433	0.035761			0.022311			0.018405

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Bubuyan	Bucal	Canlubang	Halang	La Mesa	Laguerta	Lawa	Lecheria	Lingga	Looc	Majada Labas
0.03-0.20	0.000263	0.156452	7.71047	0.022483	1.6115	0.000012	0.449257	0.712986	0.078492	0.265432	1.19821
0.21-0.50	0.000004	0.23887	3.44615	0.079867	0.340479	0.000096	0.159186	0.170885	0.06376	0.412145	0.355034
0.51-1.00	0.000116	0.565658	1.02131	0.629729	0.126628	0.000372	0.069104	0.734424	0.195565	0.402449	0.155171
1.01-2.00	0.000022	0.183889	0.417142	0.176069	0.034093		0.036796	0.713262	0.343304	0.10804	0.096154
2.01-5.00	0.000452	0.0003	0.234804	0.00027	0.047795		0.023975	0.027279	0.027937	0.068171	0.050994
> 5.00			0.023737		0.014348		0.004979			0.002508	

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Mapagong	Maunong	Mayapa	Paciano Rizal	Palingon	Palo-Alto	Pansol	Parian	Prinza	Punta	Real
0.03-0.20	1.83996	0.06846	1.27225	0.732728	0.114573	2.10109	0.097692	0.323367	1.69294	0.632715	0.369332
0.21-0.50	0.7847	0.012078	0.640065	0.377633	0.241416	0.248256	0.112543	0.238271	0.239074	0.06525	0.085083
0.51-1.00	0.30634	0.001378	0.058613	0.196132	0.218721	0.076026	0.104616	0.435517	0.033593	0.03447	0.204223
1.01-2.00	0.153621	0.00096	0.043963	0.088282	0.072911	0.067773	0.09478	0.295618	0.007309	0.008477	0.166627
2.01-5.00	0.105645	0.000002	0.035815	0.100033	0.050537	0.099215		0.297084	0.000911	0.012854	0.05467
> 5.00	0.001801			0.0036		0.007064		0.355361	0.000438	0.000228	0.108277

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Sampiruhan	San Cristobal	San Jose	San Juan	Sirang Lupa	Tulo	Turbina	Uwisan			
0.03-0.20	0.037861	0.776488	0.000823	0.045577	0.276419	1.03623	1.16587	0.100584			
0.21-0.50	0.075377	0.197872	0.008635	0.119625	0.246791	0.073996	0.08309	0.076529			
0.51-1.00	0.194976	0.171173	0.068612	0.325918	0.11041	0.033641	0.04973	0.158927			
1.01-2.00	0.03977	0.047325	0.486214	0.136932	0.047897	0.021615	0.023495	0.125323			
2.01-5.00	0.011078	0.055829	0.068334	0.05208	0.013359	0.03625	0.03994				
> 5.00		0.079452		0.0192		0.062747	0.196327				

For the city of Santa Rosa , with an area of 59.19 sq. km., 9.8% will experience flood levels of less 0.20 meters. 1.81% of the area will experience flood levels of 0.21 to 0.50 meters while 0.75%, 0.38%, 0.2%, and 0.007% 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 are the affected areas in square kilometres by flood depth per barangay.

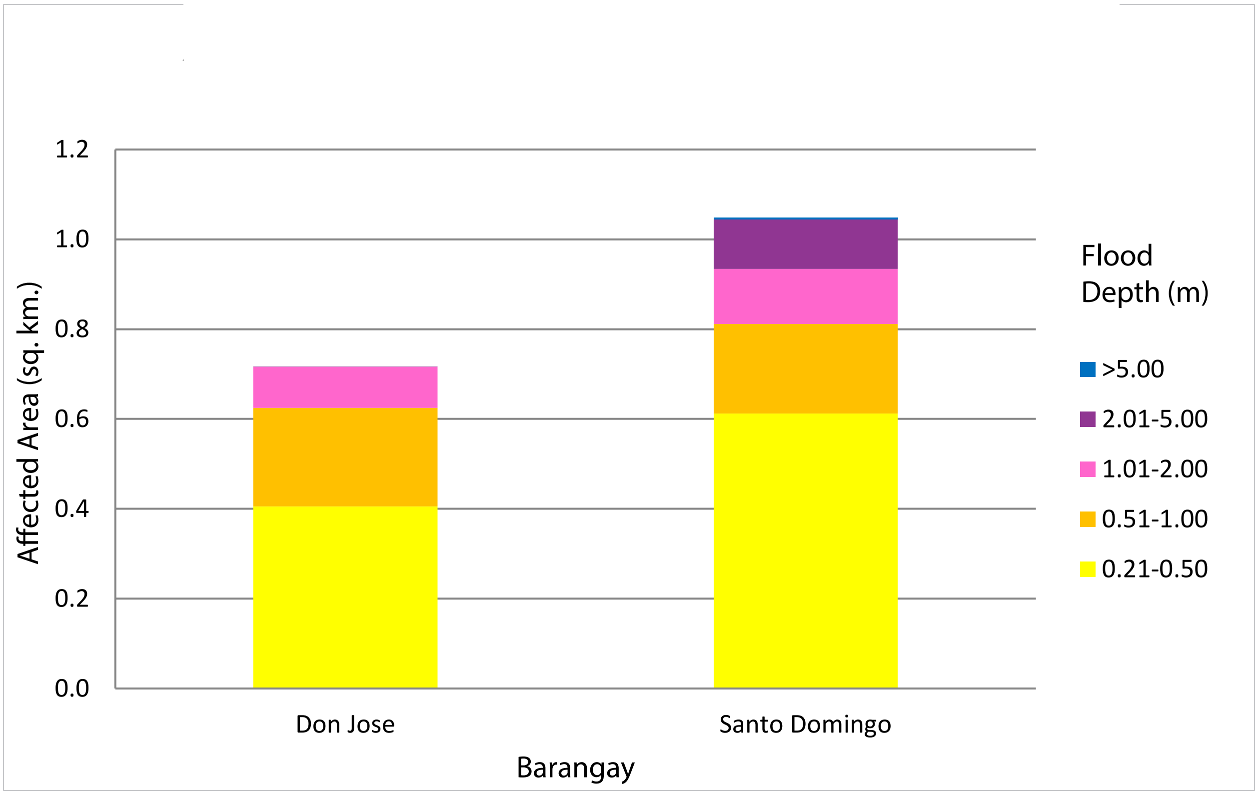


Figure 78. Affected Areas in Santa Rosa City, Laguna during 25-Year Rainfall Return Period

Table 45. Affected Areas in Santa Rosa City, Laguna during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rosa City (in sq. km.)	
	Don Jose	Santo Domingo
0.03-0.20	1.44533	4.0617
0.21-0.50	0.405518	0.612072
0.51-1.00	0.219377	0.199507
1.01-2.00	0.091528	0.122067
2.01-5.00	0.000411	0.110545
> 5.00		0.003764

For the 100-year return period, 35.27% of the city of Cabuyao with an area of 47.4 sq. km. will experience flood levels of less 0.20 meters. 23.67% of the area will experience flood levels of 0.21 to 0.50 meters while 10.38%, 1.52%, 1.03%, and 1.5% 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 kilometres by flood depth per barangay.

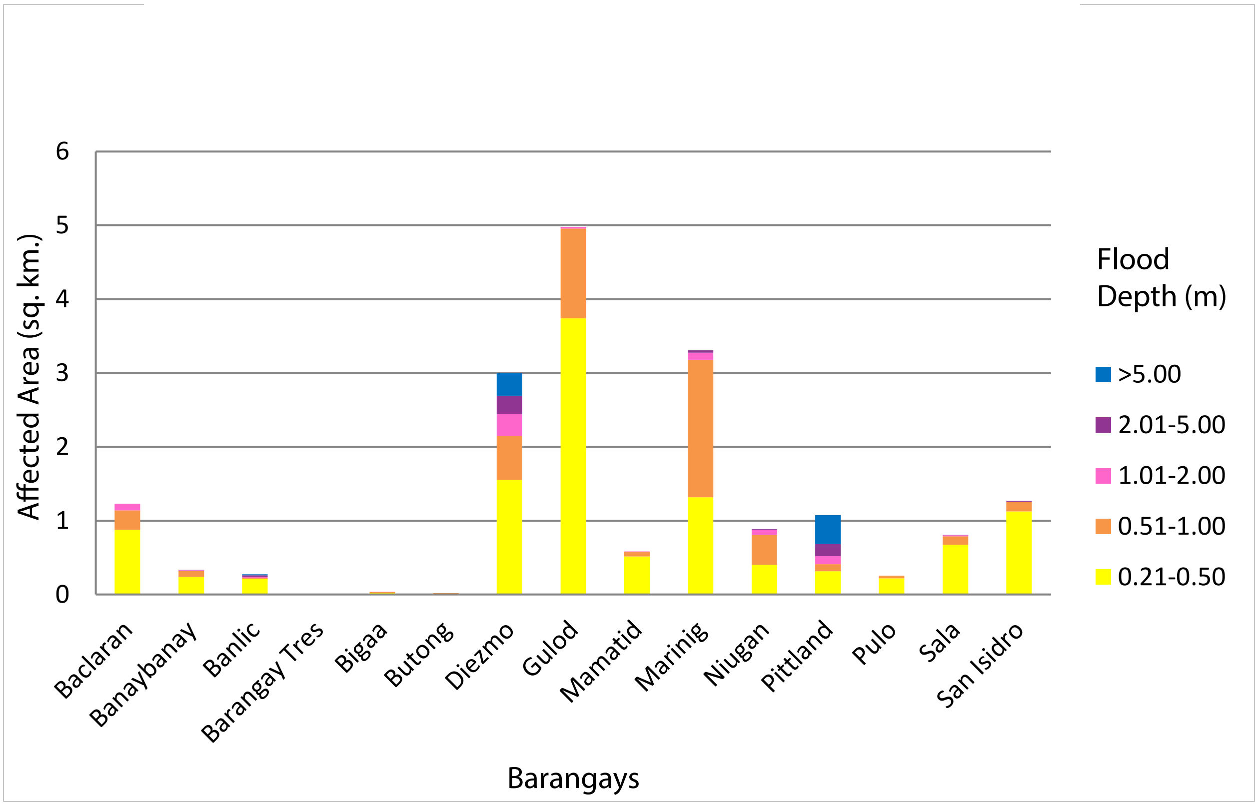


Figure 79. Affected Areas in Cabuyao City, Laguna during 100-Year Rainfall Return Period

Table 46. Affected Areas in Cabuyao City, Laguna during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabuyao City (in sq. km.)							
	Baclaran	Banaybanay	Banlic	Barangay Tres	Bigaa	Butong	Diezmo	Gulod
0.03-0.20	0.506955	0.147613	0.874189	0.054526	0.007024	0.000787	5.93285	2.09219
0.21-0.50	0.875033	0.239203	0.209321	0.0004	0.018278	0.004009	1.55536	3.73829
0.51-1.00	0.265064	0.082876	0.021002		0.015096	0.017682	0.595139	1.21699
1.01-2.00	0.092393	0.009245	0.010005		0.004642		0.292588	0.025554
2.01-5.00		0.0015	0.021194				0.248162	
> 5.00			0.014748				0.304699	

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabuyao City (in sq. km.)							
	Mamatid	Marinig	Niugan	Pittland	Pulo	Sala	San Isidro	
0.03-0.20	1.4601	0.369633	0.070777	2.45441	0.814583	0.569383	1.35473	
0.21-0.50	0.516621	1.31932	0.401547	0.316317	0.2197	0.674579	1.12586	
0.51-1.00	0.063011	1.86103	0.404734	0.095397	0.037226	0.11469	0.12895	
1.01-2.00	0.0028	0.093296	0.067469	0.106967		0.011939	0.004514	
2.01-5.00		0.031676	0.010544	0.166229		0.0016	0.006295	
> 5.00				0.391984				

For the city of Calamba, with an area of 139.4 sq. km., 16.66% will experience flood levels of less 0.20 meters. 8.58% of the area will experience flood levels of 0.21 to 0.50 meters while 6.02%, 6.53%, 2.18%, and 1.25% 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 are the affected areas in square kilometres by flood depth per barangay.

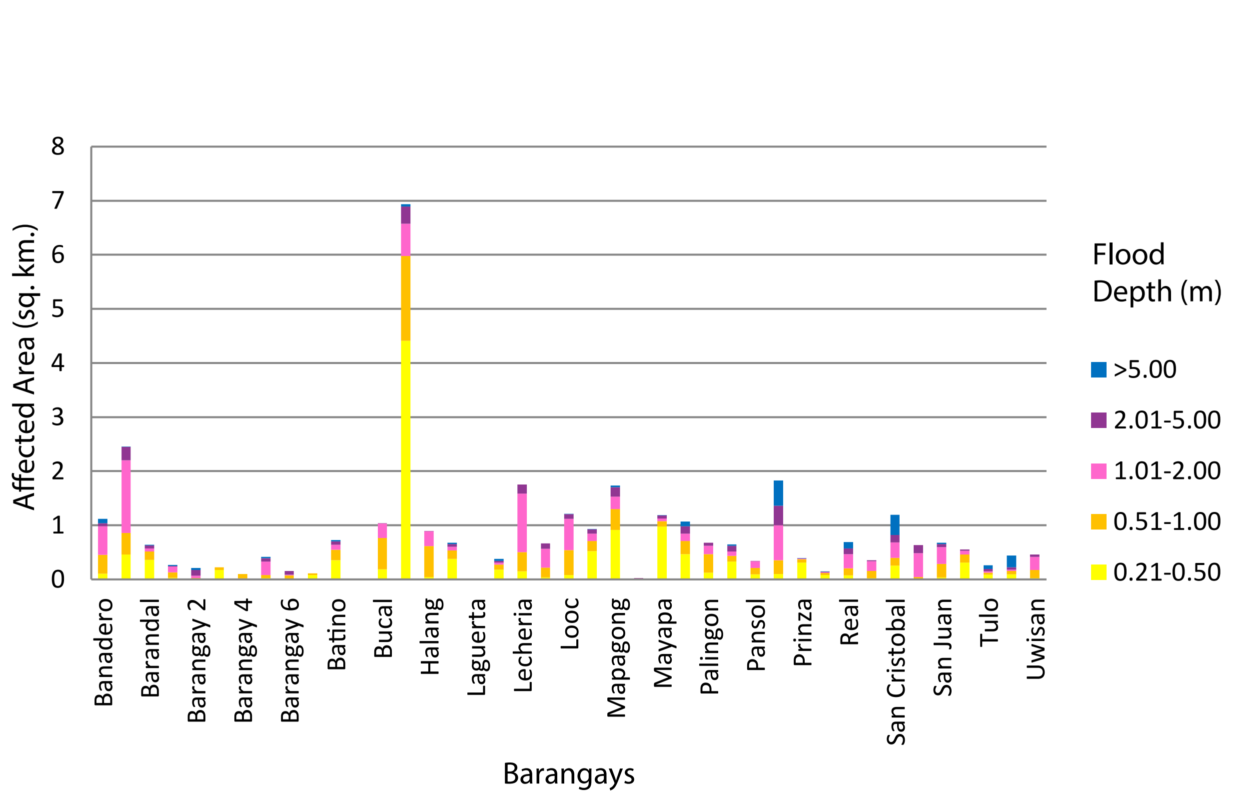


Figure 80. Affected Areas in Calamba City, Laguna during 100-Year Rainfall Return Period

Table 47. Affected Areas in Calamba City, Laguna during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Banadero	Banlic	Barandal	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Barangay 7	Batino
0.03-0.20	0.183526	0.436211	2.10276	0.0133	0.00215	0.008183	0.000389	0.035475	0.000257	0.003477	0.586657
0.21-0.50	0.103538	0.4633	0.363742	0.028995	0.010125	0.171898	0.021097	0.024049	0.00833	0.082715	0.355674
0.51-1.00	0.351303	0.393447	0.152882	0.101688	0.013184	0.053591	0.079828	0.054689	0.067008	0.026886	0.192516
1.01-2.00	0.526639	1.34463	0.055856	0.107977	0.043981			0.253718	0.011963		0.09402
2.01-5.00	0.057233	0.249369	0.053585	0.008691	0.108957			0.060191	0.070412		0.062898
> 5.00	0.084016	0.006404	0.016731	0.019948	0.037445			0.02393			0.024298

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Bubuyan	Bucal	Canlubang	Halang	La Mesa	Laguerta	Lawa	Lecheria	Lingga	Looc	Majada Labas
0.03-0.20	0.000166	0.110711	5.92072	0.016052	1.4995	0.000012	0.397525	0.603707	0.041502	0.04636	0.930367
0.21-0.50	0.000086	0.186455	4.41125	0.044272	0.381004	0.000029	0.178995	0.151777	0.03958	0.083625	0.523283
0.51-1.00	0.000014	0.579492	1.56471	0.570024	0.155752	0.00044	0.094745	0.354597	0.17634	0.460929	0.189171
1.01-2.00	0.000116	0.265684	0.597753	0.276298	0.066125		0.040569	1.07879	0.348827	0.572585	0.1315
2.01-5.00	0.000474	0.002826	0.315828	0.001771	0.04847		0.02639	0.169965	0.102909	0.089328	0.080941
> 5.00			0.044852		0.024691		0.039441			0.005916	0.0002

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Mapagong	Maunong	Mayapa	Paciano Rizal	Palingon	Palo-Alto	Pansol	Parian	Prinza	Punta	Real
0.03-0.20	1.45939	0.064504	0.868252	0.490045	0.019575	1.95383	0.071682	0.161994	1.58722	0.606657	0.300632
0.21-0.50	0.912788	0.015808	0.974943	0.469004	0.122838	0.328452	0.092332	0.097023	0.31214	0.07952	0.077446
0.51-1.00	0.390355	0.001182	0.099869	0.241541	0.346962	0.106579	0.119713	0.260632	0.059839	0.041443	0.129804
1.01-2.00	0.228414	0.001336	0.054335	0.135767	0.150308	0.082121	0.125451	0.6448	0.011685	0.010802	0.259801
2.01-5.00	0.174495	0.00005	0.053904	0.134955	0.058275	0.108235	0.000454	0.358823	0.002547	0.014697	0.103484
> 5.00	0.026822		0.000008	0.090562		0.020208		0.464846	0.001232	0.000876	0.117544

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calamba City (in sq. km.)										
	Sampiruhan	San Cristobal	San Jose	San Juan	Sirang Lupa	Tulo	Turbina	Uwisan			
0.03-0.20	0.005614	0.41162	0.000002	0.019198	0.14124	1.00102	1.11367	0.003366			
0.21-0.50	0.027283	0.253757	0.003067	0.039003	0.310953	0.087924	0.09162	0.02261			
0.51-1.00	0.130703	0.143537	0.043431	0.247627	0.147688	0.037129	0.061636	0.150111			
1.01-2.00	0.180451	0.288495	0.43657	0.310374	0.071136	0.022927	0.025209	0.242013			
2.01-5.00	0.01501	0.136649	0.149549	0.058629	0.023859	0.04316	0.043364	0.043263			
> 5.00		0.369044		0.0251		0.072318	0.222949				

For the city of Santa Rosa , with an area of 59.19 sq. km., 9.00% will experience flood levels of less 0.20 meters. 2.32% of the area will experience flood levels of 0.21 to 0.50 meters while 0.88%, 0.50%, 0.24%, and 0.009% 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 are the affected areas in square kilometres by flood depth per barangay.

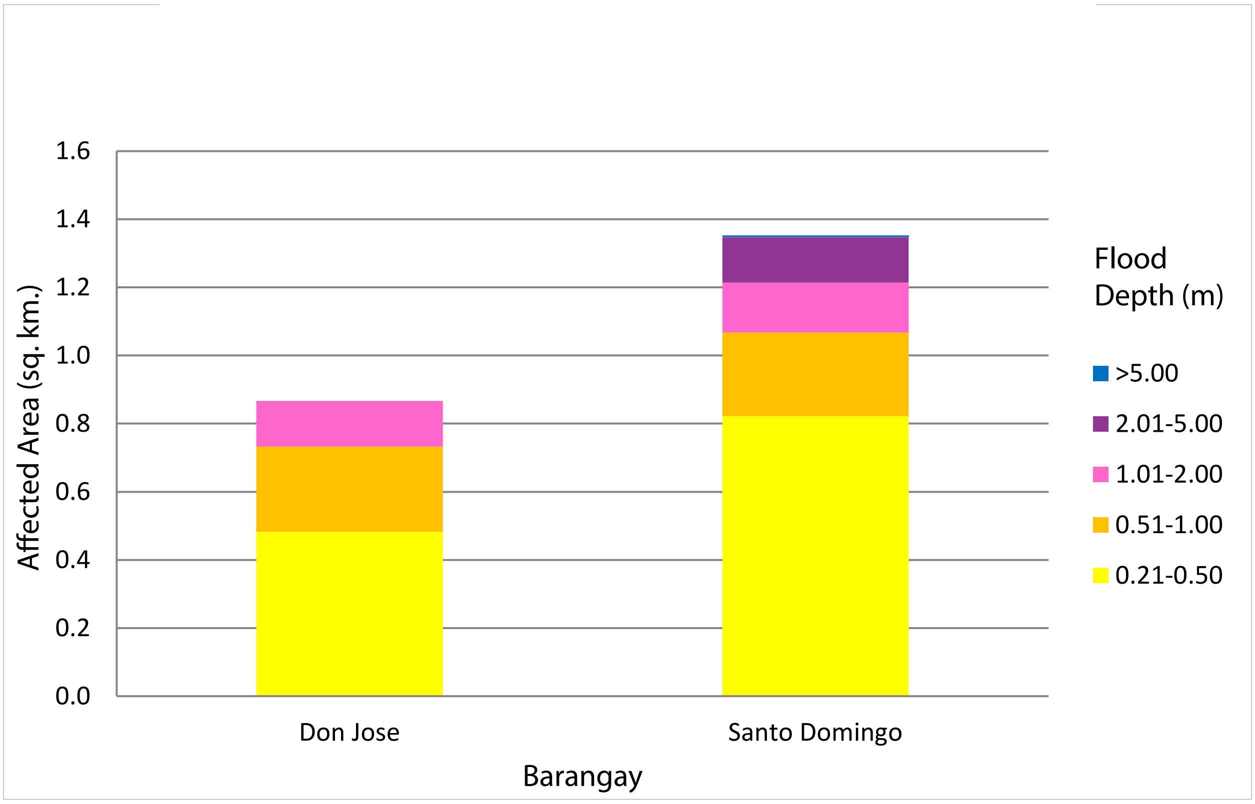


Figure 81. Affected Areas in Santa Rosa City, Laguna during 100-Year Rainfall Return Period

Table 48. Affected Areas in Santa Rosa City, Laguna during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Rosa City (in sq. km.)	
	Don Jose	Santo Domingo
0.03-0.20	1.29554	3.75901
0.21-0.50	0.482587	0.822327
0.51-1.00	0.250306	0.24468
1.01-2.00	0.132018	0.14644
2.01-5.00	0.001711	0.133793
> 5.00		0.004909

Among the barangays in the city of Cabuyao, Diezmo is projected to have the highest percentage of area that will experience flood levels at 18.84%. Meanwhile, Gulod posted the second highest percentage of area that may be affected by flood depths at 14.93%.

Among the barangays in the city of Calamba, Canlubang is projected to have the highest percentage of area that will experience flood levels at 9.22%. Meanwhile, Mapagong posted the second highest percentage of area that may be affected by flood depths at 2.29%.

Among the barangays in the city of Santa Rosa, Santo Domingo is projected to have the highest percentage of area that will experience flood levels at 9.09%. Meanwhile, Don Jose posted the second highest percentage of area that may be affected by flood depths at 3.85%.

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 gather 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 are identified for validation.

The validation personnel will then go to the specified points identified in a river basin and will gather data regarding the actual flood level in each location. Data gathering can be done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field will be 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 88.

The flood validation consists of 103 points randomly selected all over the San Cristobal flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.706m. Error! Reference source not found.7 shows a contingency matrix of the comparison.

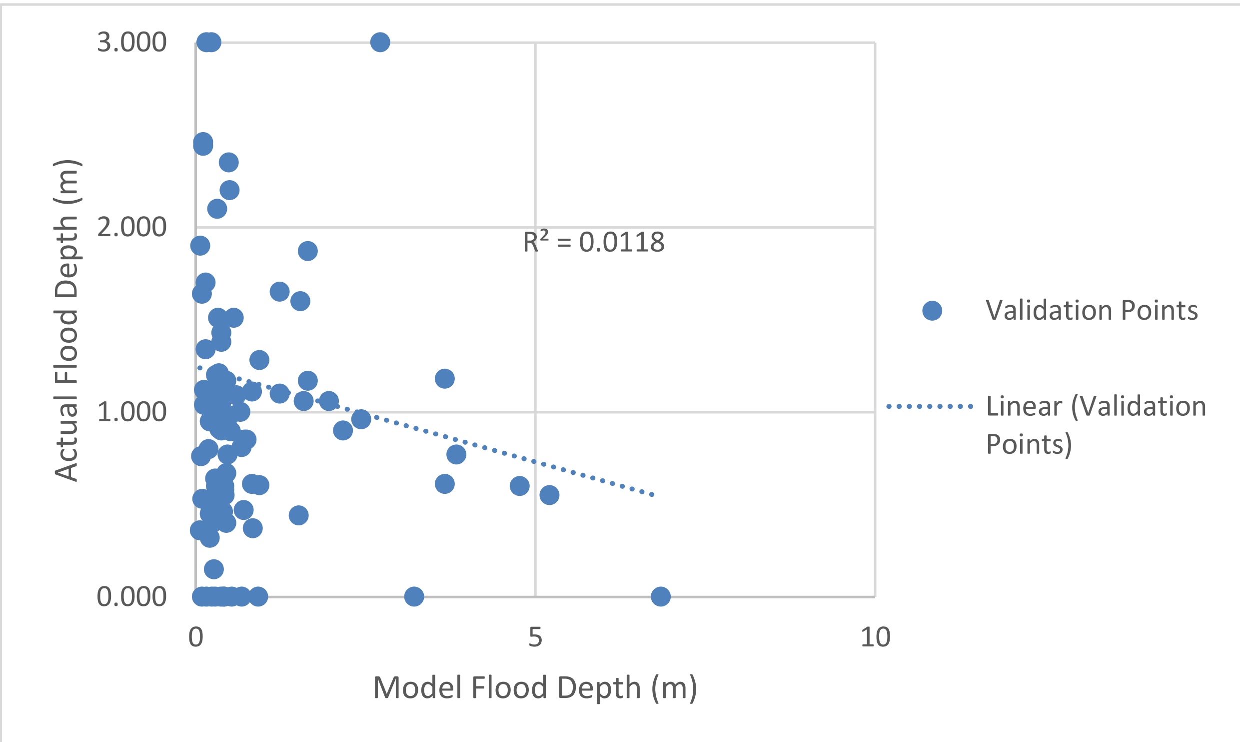


Figure 82. Flood map depth vs actual flood depth.

Table 49. Actual Flood Depth vs Simulated Flood Depth at different levels in the San Cristobal River Basin.

SAN CRISTOBAL BASIN		MODELED FLOOD DEPTH (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	2	6	3	0	1	1	**13**
	0.21-0.50	1	6	2	1	0	0	**10**
	0.51-1.00	3	19	7	0	5	1	**35**
	1.01-2.00	6	13	4	7	1	0	**31**
	2.01-5.00	5	4	0	2	1	0	**12**
	> 5.00	0	2	0	0	0	0	**2**
	Total	**17**	**50**	**16**	**10**	**8**	**2**	**103**

The overall accuracy generated by the flood model is estimated at 22.33% with 23 points correctly matching the actual flood depths. In addition, there were 16 points estimated one level above and below the correct flood depths while there were 25 points and 20 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 59 points were underestimated in the modelled flood depths of San Cristobal. Error! Reference source not found.8 depicts the summary of the Accuracy Assessment in the San Cristobal River Basin Survey.

Table 50. Summary of Accuracy Assessment in the San Cristobal River Basin Survey.

	No. of Points	%
Correct	23	22.33
Overestimated	21	20.39
Underestimated	59	57.28
Total	**103**	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEX

ANNEX 1. Optech Technical Specifications

1. PEGASUS SENSOR

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
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

2. GEMINI SENSOR

Table A-1.2 Parameters and Specifications of the Pegasus Sensor

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

ANNEX 2. NAMRIA Certificates Of Reference Points Used

1. SMR-53

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

April 23, 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: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-53**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SANTA RITA**
Barangay: **SAN ISIDRO**

PRS92 Coordinates

Latitude: **11° 30' 17.85657"**	Longitude: **125° 1' 29.83739"**	Ellipsoidal Hgt: **26.13400 m.**

WGS84 Coordinates

Latitude: **11° 30' 13.52495"**	Longitude: **125° 1' 34.96980"**	Ellipsoidal Hgt: **87.78700 m.**

PTM Coordinates

Northing: **1272180.079 m.**	Easting: **502722.403 m.**	Zone: **5**

UTM Coordinates

Northing: **1,272,513.40**	Easting: **720,874.14**	Zone: **51**

Location Description

SMR-53
From Tacloban City Proper, travel about 45 km. north going to Brgy. San.Isidro. The NAMRIA monument was located about 15 m. west inside the San Isidro Elementary School, and almost near at the school building and flag pole about 5 m. north. Mark is the head of a 4" copper nail flushed in a cement block embedded in the ground with inscriptions "SMR-53; 2007; NAMRIA."

Requesting Party:	**Engr. Christopher Cruz/ UP-DREAM**
Pupose:	**Reference**
OR Number:	**8796021 A**
T.N.:	**2014-920**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 SMR-53

2. SMR-56

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

April 23, 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: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-56**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SANTA RITA**
Barangay: **CABACUNGAN**

PRS92 Coordinates

Latitude: **11° 23' 6.52702"**	Longitude: **125° 0' 23.99607"**	Ellipsoidal Hgt: **11.82200 m.**

WGS84 Coordinates

Latitude: **11° 23' 2.22413"**	Longitude: **125° 0' 29.13917"**	Ellipsoidal Hgt: **73.72700 m.**

PTM Coordinates

Northing: **1258927.861 m.**	Easting: **500727.475 m.**	Zone: **5**

UTM Coordinates

Northing: **1,259,244.38**	Easting: **718,970.61**	Zone: **51**

Location Description

SMR-56
From Tacloban City, travel about 15 km. north going to Brgy. Cabacungan. Before reaching the of Sta. Rita town proper Western Samar. The monument was established at the Brgy. Cabacungan Elementary School, at the side of the road, 20 m. east fronting school's entrance gate, 50 m. northeast from Waiting Shed about , and 3 m. east along the side the of pathway. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-56; 2007; NAMRIA."

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-919**

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

9904232014154910

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

CIP/4701/12/09/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 SMR-56

3. SMR-58

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-58**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**SERUM**		
Municipality:	**BASEY**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**11° 17' 55.05617"**	Longitude:	**125° 7' 51.16145"**	Ellipsoidal Hgt:	**6.30062 m.**
		WGS84 Coordinates			
Latitude:	**11° 17' 50.78580"**	Longitude:	**125° 7' 56.31100"**	Ellipsoidal Hgt:	**68.72300 m.**
		PTM / PRS92 Coordinates			
Northing:	**1249361.531 m.**	Easting:	**514288.239 m.**	Zone:	**5**
		UTM / PRS92 Coordinates			
Northing:	**1,249,768.75**	Easting:	**732,600.57**	Zone:	**51**

Location Description

SMR-58
From Basey proper, travel about 20 km. north going to Brgy. Serum. From National Road, travel another 1 km. north going to Brgy. Serum. The NAMRIA was established inside the Serum Elementary School, 10 m. east from the school gate, and 15 m. north from the school building. The School site was near the River about 30 m. north. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-58; 2007; NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0327**

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

9 9 0 2 1 0 2 0 1 6 1 2 1 8 3 7

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Figure A-2.3 SMR-58

4. SM-271

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

January 27, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-271**

Island: **VISAYAS**	Municipality: **PINABACDAO**	Barangay: **LAYGAYON**
Elevation: **80.1571 +/- 0.05 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

SM-271 is in the Province of Western Samar, town of Pinabakdaw, Brgy. Laygayon along right side of the National highway. It is located beside km post 864 and about 5.00m E from the centerline of the national highway. Station mark is the head of 4" copper nail centered on a 0.30m x 0.30m concrete block and mark with "SM-271,2007,NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0241**

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

9 9 0 1 2 7 2 0 1 6 1 5 1 2 2 0

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4 SM-271

5. SM-286

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

June 06, 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: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-286**

Island: **VISAYAS**	Municipality: **SANTA RITA**	Barangay: **SAN PASCUAL**
Elevation: **3.3970 m.**	Order: **1st Order**	Datum:

Location Description

SM-286 is in the Province of Western Samar, town of Sta. Rita, Brgy. San Pascual. It is located at Dalib bridge, positioned at the SE part of the bridge, 4m from the centerline of the national highway. Station mark is the head of 4" copper nail on a drilled hole set flush on a 0.10m x 0.10cement putty inscribed "SM-286, 2007, NAMRIA."

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1291**

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

9906062014164047

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

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

Figure A-2.5 SM-286

6. SM-309

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-309**

Island: **VISAYAS**	Municipality: **BASEY**	Barangay: **ANGLIT**
Elevation: **4.1232 +/- 0.06 m.**	Accuracy Class at 95% C.L: **6 CM**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

SM-309 is in the Province of Western Samar, town of Basey, Brgy. Anglit. It is located at Anglit bridge at the SE part, 4.50m from the centerline of the national highway. Station mark is the head of 4" copper nail on a drilled hole set flush on a 0.10m x 0.10cement putty inscribed "SM-309, 2007, NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089774 I**
T.N.: **2016-0326**

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

9 9 0 2 1 0 2 0 1 6 1 2 1 8 1 4

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6 SM-309

7. LYT-101

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: **LEYTE**
Station Name: **LYT-101**
Order: **2nd**

Island: **VISAYAS**
Municipality: **PALO**
Barangay:

PRS92 Coordinates

Latitude: **11° 10' 23.89707"** Longitude: **125° 0' 38.62071"** Ellipsoidal Hgt: **6.58600 m.**

WGS84 Coordinates

Latitude: **11° 10' 19.64869"** Longitude: **125° 0' 43.78230"** Ellipsoidal Hgt: **69.02100 m.**

PTM Coordinates

Northing: **1235497.253 m.** Easting: **501171.719 m.** Zone: **5**

UTM Coordinates

Northing: **1,235,811.61** Easting: **719,575.03** Zone: **51**

Location Description

LYT-101
Station is located in the province of Leyte, municipality of Palo. From Tacloban City travel SE to McArthur Park. The point is located infront of Gen. Douglas McArthur Shrine and is approximately 10 m away and adjacent to center of lower step. Station mark is a concrete nail on center of a 20 x 20 cm. cement putty on the concrete ground.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-94**

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

9 9 0 1 2 0 2 0 1 4 1 4 3 7 3 3

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

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

Figure A-2.7 LYT-101

ANNEX 3. Baseline Processing Report

1. LYT-104

Table A-3.1 LYT-104

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-53 --- LYT-104 (B1)	SMR-53	LYT-104	Fixed	0.008	0.017	200°40'31"	42653.401	7.525
SMR-53 --- LYT-104 (B2)	SMR-53	LYT-104	Fixed	0.004	0.016	200°40'31"	42653.384	7.601

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SMR-53				
Grid		Local		Global	
Easting	720874.133 m	Latitude	N11°30'17.85656"	Latitude	N11°30'13.52495"
Northing	1272513.396 m	Longitude	E125°01'29.83738"	Longitude	E125°01'34.96980"
Elevation	24.750 m	Height	26.134 m	Height	87.787 m

To:	LYT-104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

Vector					
ΔEasting	-14784.623 m	NS Fwd Azimuth	200°40'31"	ΔX	7839.600 m
ΔNorthing	-40016.558 m	Ellipsoid Dist.	42653.401 m	ΔY	15051.644 m
ΔElevation	7.561 m	ΔHeight	7.525 m	ΔZ	-39131.928 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

2. SM-271

Table A-3.2 SM-271

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SM-271 --- SMR-53 (B2)	SMR-53	SM-271	Fixed	0.004	0.018	5°23'32"	2272.463	55.956
SM-271 --- SMR-53 (B1)	SMR-53	SM-271	Fixed	0.004	0.014	5°23'31"	2272.470	55.944

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SMR-53				
Grid		Local		Global	
Easting	720874.133 m	Latitude	N11°30'17.85656"	Latitude	N11°30'13.52495"
Northing	1272513.396 m	Longitude	E125°01'29.83738"	Longitude	E125°01'34.96980"
Elevation	24.750 m	Height	26.134 m	Height	87.787 m

To:	SM-271				
Grid		Local		Global	
Easting	721071.745 m	Latitude	N11°31'31.48932"	Latitude	N11°31'27.15275"
Northing	1274777.717 m	Longitude	E125°01'36.88440"	Longitude	E125°01'42.01496"
Elevation	80.707 m	Height	82.090 m	Height	143.697 m

Vector					
ΔEasting	197.612 m	NS Fwd Azimuth	5°23'32"	ΔX	52.927 m
ΔNorthing	2264.321 m	Ellipsoid Dist.	2272.463 m	ΔY	-447.483 m
ΔElevation	55.957 m	ΔHeight	55.956 m	ΔZ	2228.061 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000261223		
Y	-0.0000356331	0.0000567847	
Z	-0.0000091774	0.0000140863	0.0000048698

Vector Components (Mark to Mark)

From:	SMR-53				
Grid		Local		Global	
Easting	720874.133 m	Latitude	N11°30'17.85656"	Latitude	N11°30'13.52495"
Northing	1272513.396 m	Longitude	E125°01'29.83738"	Longitude	E125°01'34.96980"
Elevation	24.750 m	Height	26.134 m	Height	87.787 m

To:	SM-271				
Grid		Local		Global	
Easting	721071.738 m	Latitude	N11°31'31.48956"	Latitude	N11°31'27.15300"
Northing	1274777.724 m	Longitude	E125°01'36.88417"	Longitude	E125°01'42.01474"
Elevation	80.695 m	Height	82.078 m	Height	143.685 m

Vector					
ΔEasting	197.605 m	NS Fwd Azimuth	5°23'31"	ΔX	52.941 m
ΔNorthing	2264.328 m	Ellipsoid Dist.	2272.470 m	ΔY	-447.490 m
ΔElevation	55.945 m	ΔHeight	55.944 m	ΔZ	2228.066 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000168455		
Y	-0.0000221649	0.0000355369	
Z	-0.0000052344	0.0000087190	0.0000031341

3. SM-286

Table A-3.3 SM-286

Baseline Processing Report

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Satellite Available
SM-286 --- SMR-56 (B1)	SMR-56	SM-286	5/11/2014 6:44:03 AM	5/11/2014 1:54:43 PM	Fixed	0.003	0.009	1325.025	263.512	2667.292	335°34'26"	2989.904	-6.335	GPS: 14 GLONASS: 13 Galileo: 0 QZSS: 0

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	SMR-56				
Grid		Local		Global	
Easting	718970.608 m	Latitude	N11°23'06.52702"	Latitude	N11°23'02.22413"
Northing	1259244.377 m	Longitude	E125°00'23.99607"	Longitude	E125°00'29.13917"
Elevation	10.345 m	Height	11.822 m	Height	73.727 m

To:	SM-286				
Grid		Local		Global	
Easting	717715.152 m	Latitude	N11°24'35.12705"	Latitude	N11°24'30.81697"
Northing	1261958.553 m	Longitude	E124°59'43.21146"	Longitude	E124°59'48.35252"
Elevation	4.047 m	Height	5.488 m	Height	67.304 m

Vector					
ΔEasting	-1255.456 m	NS Fwd Azimuth	335°34'25"	ΔX	1325.020 m
ΔNorthing	2714.176 m	Ellipsoid Dist.	2989.904 m	ΔY	263.518 m
ΔElevation	-6.298 m	ΔHeight	-6.335 m	ΔZ	2667.293 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

4. SM-309

Table A-3.4 SM-309

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-58 --- SM-309 (B1)	SMR-58	SM-309	Fixed	0.002	0.003	274°29'25"	1668.981	3.442

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

Vector Components (Mark to Mark)

From:	SMR-58				
Grid		Local		Global	
Easting	732600.570 m	Latitude	N11°17'55.05616"	Latitude	N11°17'50.78580"
Northing	1249768.751 m	Longitude	E125°07'51.16148"	Longitude	E125°07'56.31100"
Elevation	4.664 m	Height	6.301 m	Height	68.723 m

To:	SM-309				
Grid		Local		Global	
Easting	730935.362 m	Latitude	N11°17'59.30748"	Latitude	N11°17'55.03553"
Northing	1249887.315 m	Longitude	E125°06'56.29744"	Longitude	E125°07'01.44700"
Elevation	8.117 m	Height	9.743 m	Height	72.125 m

Vector					
ΔEasting	-1665.207 m	NS Fwd Azimuth	274°29'25"	ΔX	1373.678 m
ΔNorthing	118.564 m	Ellipsoid Dist.	1668.981 m	ΔY	939.122 m
ΔElevation	3.453 m	ΔHeight	3.442 m	ΔZ	128.718 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

ANNEX 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016/ RA (2014)	PAULINE JOANNE ARCEO	
	Research Associate (RA)	ENGR. IRO NIEL ROXAS	
		GRACE SINADJAN	
		JONATHAN ALMALVEZ	
Ground Survey	RA	JERIEL PAUL ALAMBAN, GEOL.	
LiDAR Operation	Airborne Security	SSG RANDY SISON	Philippine Air Force (PAF)
		SSG RAYMUND DOMINE	
	Pilot	CAPT. ALBERT PAUL LIM	Asian Aerospace Corporation (AAC)
		CAPT. RANDY LAGCO	
		CAPT. JACKSON JAVIER	
		CAPT. NIEL AGAWIN	

ANNEX 5. Data Transfer Sheets for the San Cristobal Floodplain Flights

DATA TRANSFER SHEET
5/22/2014 (Leyte Ongoing)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
4/20/2014	1358A	3BLK34F110A	AQUARIUS	NA	NA	1.17MB	243MB	63.3/10.7GB	3/510/67KB	14.1GB	NA	12.1MB	1KB	1KB	6KB	773/12KB	Z:\Airborne_Raw\1358A
4/20/2014	1360A	3BLK34FS110B	AQUARIUS	NA	NA	7.75MB	174MB	41.1GB	206KB	8.26GB	NA	11.3MB	1KB	1KB	6KB	649/12KB	Z:\Airborne_Raw\1360A
4/22/2014	1366A	3BLK34E112A	AQUARIUS	NA	NA	1.37MB	257MB	95.5GB	418/1/263KB	14.9GB	NA	8.53MB	1KB	1KB	5KB	889/10KB	Z:\Airborne_Raw\1366P
5/11/2014	1442A	3BLK33GS131A	AQUARIUS	NA	NA	5.86MB	275MB	108GB	59/697/KB	16.6GB	NA	14.3MB	1KB	1KB	NA	2652KB	Z:\Airborne_Raw\1442A
5/11/2014	1444A	3BLK33GSH131B	AQUARIUS	NA	NA	2.82MB	254MB	79.3GB	1/1/515/1/139KB	15.2GB	229GB	14.3MB	1KB	1KB	5/5KB	2813/700 KB	Z:\Airborne_Raw\1444A
5/13/2014	1450A	3BLK33HS133A	AQUARIUS	NA	NA	906KB	132MB	34.1GB	257KB	6.07GB	87.0GB	10.5MB	1KB	1KB	5KB	1019KB	Z:\Airborne_Raw\1450A
5/13/2014	1452A	3BLK33HSES133B	AQUARIUS	NA	NA	2.33MB	233MB	47.1GB	1/415KB	9.57GB	86.8GB	11.2MB	1KB	1KB	6/10KB	512KB	Z:\Airborne_Raw\1452A
5/14/2014	1454A	3BLK34D134A	AQUARIUS	NA	NA	1.88MB	268MB	15.7/71.5GB	23/102/517KB	14.6GB	206GB	8.41MB	1KB	1KB	5/2KB	1522KB	Z:\Airborne_Raw\1454A
5/14/2014	1456A	3BLK34C134B	AQUARIUS	NA	NA	0.98MB	212MB	66.6GB	278/226KB	11.6GB	58.6GB	7.92MB	1KB	1KB	5KB	641KB	Z:\Airborne_Raw\1456P
5/15/2014	1460A	3BLK35CD135B	AQUARIUS	NA	NA	1.24MB	273MB	74.8GB	622KB	14.7GB	235GB	11.4MB	1KB	1KB	5/5KB	476/807KB	Z:\Airborne_Raw\1460A
5/16/2014	1462A	3BLK35DSE136A	AQUARIUS	NA	NA	1.29MB	275MB	91.2GB	685KB	15.2GB	NA	11.6MB	1KB	1KB	5/4KB	842KB	Z:\Airborne_Raw\1462A
5/16/2014	1464A	3BLK35ES136B	AQUARIUS	NA	NA	1.20MB	251MB	76.9GB	637KB	14.0GB	NA	11.4MB	1KB	1KB	4KB	786KB	Z:\Airborne_Raw\1464A

Received from

Name: Dan Aldovino
Position: Research Associate
Signature: [signature]

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature] 5/28/2014

Figure A-5.1 Data Transfer Sheet for BSan Cristobal Floodplain - A

DATA TRANSFER SHEET
Tacloban,Leyte 2/23/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
29-Jan	3727G	2BLK34IJ029B	GEMINI	NA	322	691	243	NA	NA	22.8	NA	4.2	1KB	1KB	206	NA	Z:\DAC\RAW DATA
30-Jan	3729G	2BLK34HJ030A	GEMINI	NA	592	0.97	243	NA	NA	20.3	NA	608	1KB	1KB	209	NA	Z:\DAC\RAW DATA
30-Jan	3731G	2BLK34LM030B	GEMINI	NA	29	NA	208	NA	NA	24.2	NA	3.19	1KB	1KB	206/209/194	NA	Z:\DAC\RAW DATA
31-Jan	3733G	2BLK33ABLK34L031A	GEMINI	NA	646	1.03	172	NA	NA	11.4	NA	3.84	1KB	1KB	239/293/293	NA	Z:\DAC\RAW DATA
5-Feb	3753G	2BLK34K33AB036A	GEMINI	NA	853	712	227	NA	NA	16.2	NA	4.1	1KB	1KB	293/431/293	NA	Z:\DAC\RAW DATA
6-Feb	3757G	2BLK34K037A	GEMINI	NA	772	483	177	NA	NA	10.2	NA	4.51	1KB	1KB	378	NA	Z:\DAC\RAW DATA

Received from

Name REDAN PUNTO
Position R.A.
Signature

Received by

Name AC Bongat
Position SSRS
Signature 2/26/16

Figure A-5.2 Data Transfer Sheet for BSan Cristobal Floodplain - B

ANNEX 6. Flight Logs

1. Flight Log for 1410A Mission

DREAM Data Acquisition Flight Log

AQUATACTF123A

Flight Log No.: 1410

1 LiDAR Operator: IRO ROXAS	2 ALTM Model: AQUA	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N-AGAWIN	9 Route:			
10 Date: MAY 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 911	14 Engine Off: 1358	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: computed test flight for Aquarius over survey area of BLK34N (15 lines completed)					

21 Problems and Solutions:

CERTIFIED PHOTOCOPY

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO	[illegible]	JRS Javier	IRO ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1 Flight Log for 1410A Mission

2. Flight Log for 1414A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1414

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUA	3 Mission Name: AQUATACT F1414A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 4, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1058	14 Engine Off: 1409	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed test flight for aquarius over survey area BLK 34N (9 lines)

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 — J R S Javier — Signature over Printed Name

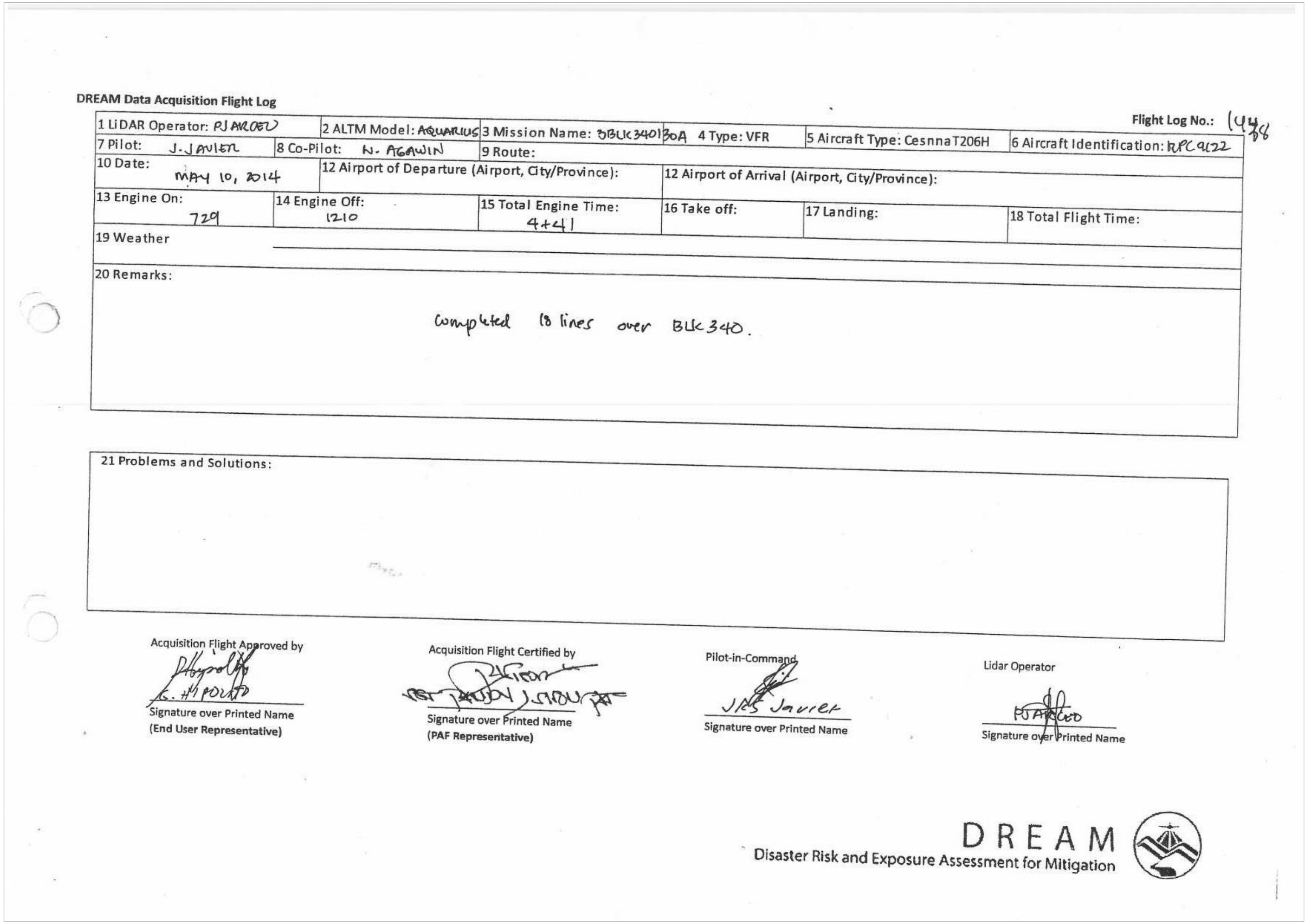
Lidar Operator — RJ ARCEO — Signature over Printed Name

CERTIFIED PHOTOCOPY

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2 Flight Log for 1414A Mission

3. Flight Log for 1438A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1438

1 LiDAR Operator: RJ ARCOLO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK340130A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 10, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 729	14 Engine Off: 1210	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

completed 18 lines over BLK340.

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)

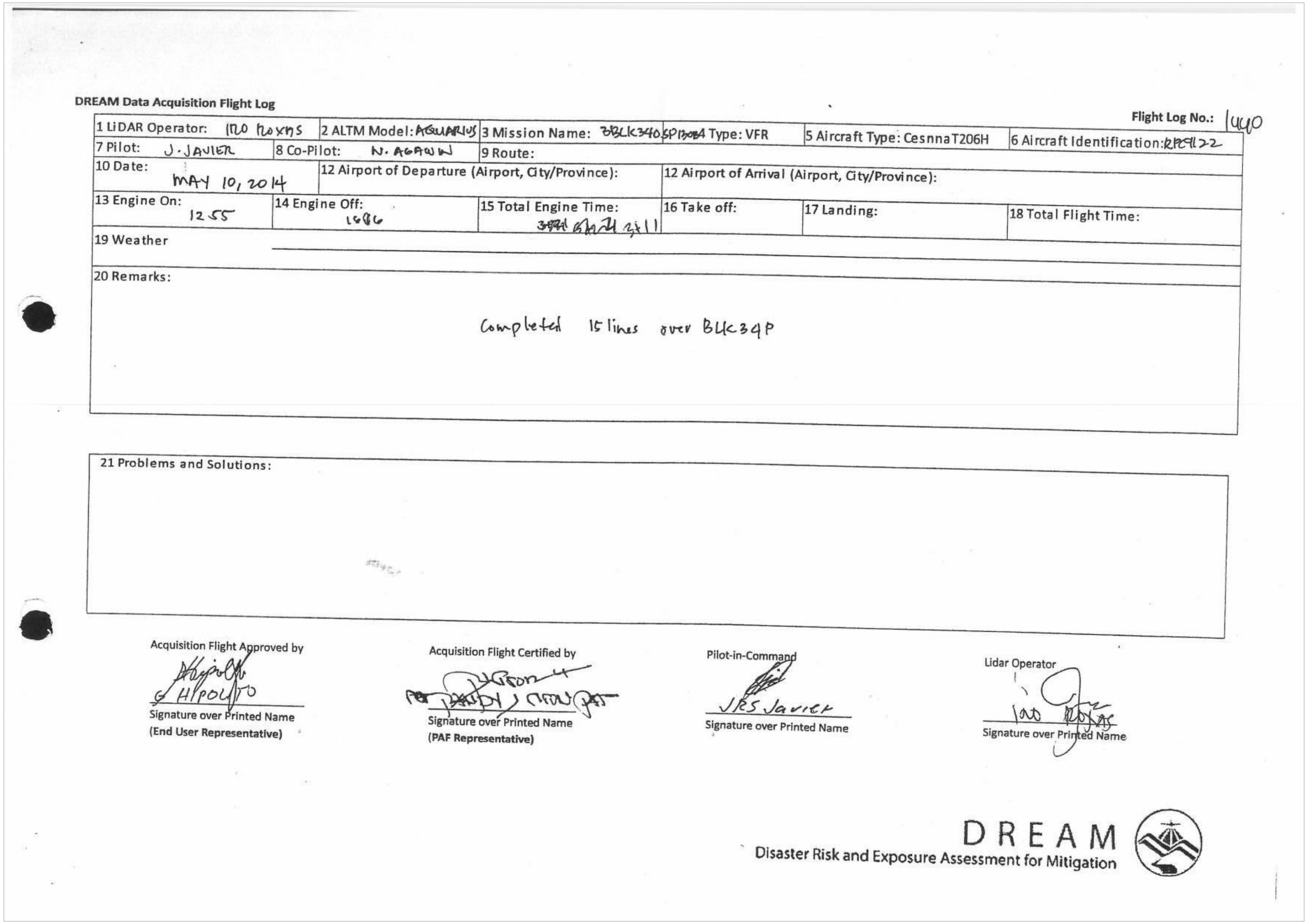
Pilot-in-Command: J. Javier, Signature over Printed Name

Lidar Operator: RJ Arcelo, Signature over Printed Name

DREAM Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3 Flight Log for 1438A Mission

4. Flight Log for 1440A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1440

1 LiDAR Operator: IRO ROXAS	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34OSP130B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 10, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1255	14 Engine Off: 1606	15 Total Engine Time: 3+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 15 lines over BLK34P

21 Problems and Solutions:

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

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

Pilot-in-Command: JRS Javier — Signature over Printed Name

Lidar Operator: IRO ROXAS — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4 Flight Log for 1440A Mission

5. Flight Log for 1442A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1442

1 LiDAR Operator: I. ROXAS	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34PS131A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 722	14 Engine Off: 1209	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 15/21 lines over BLK34Q & 2 lines from BLK 34P

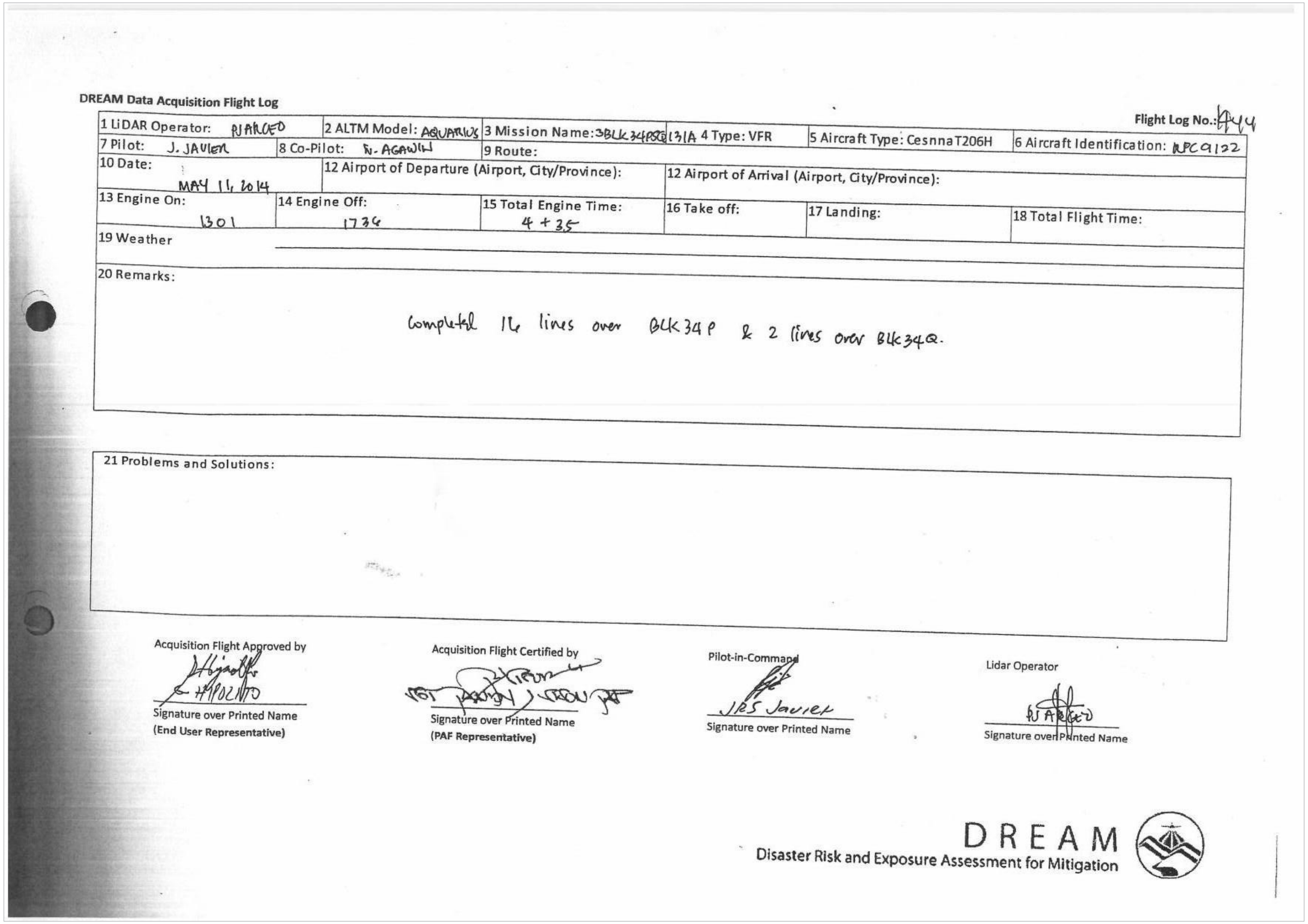
21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO	[illegible]	JRS Javier	I. ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.5 Flight Log for 1442A Mission

6. Flight Log for 1444A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1444

1 LiDAR Operator: N ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34PSQ131A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 11, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1301	14 Engine Off: 1736	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 16 lines over BLK34P & 2 lines over BLK34Q.					
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 — JRS Javier — Signature over Printed Name

Lidar Operator — N ARCEO — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.6 Flight Log for 1444A Mission

7. Flight Log for 1450A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1450

1 LiDAR Operator: I. Roxas	2 ALTM Model: Aquarius	3 Mission Name: 3BLK34GS133D	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. Javier	8 Co-Pilot: N. Aganon	9 Route:			
10 Date: May 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 9:04	14 Engine Off: 11:27	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK34G & voids over BLK 34W.					
21 Problems and Solutions:					

Acquisition Flight Approved by: G. A. Hipolito — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

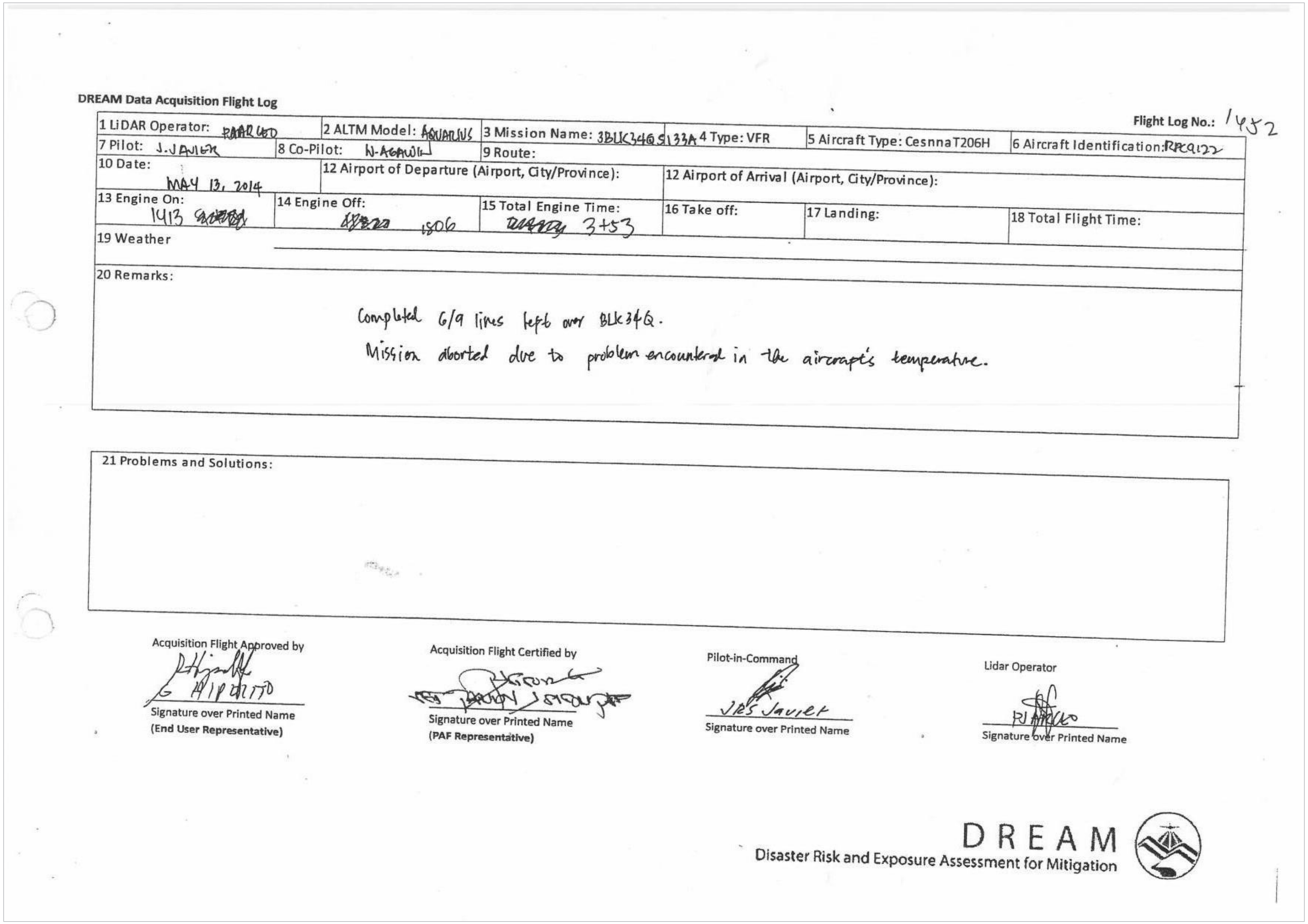
Pilot-in-Command: JRS Javier — Signature over Printed Name

Lidar Operator: I. Roxas — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.7 Flight Log for 1450A Mission

8. Flight Log for 1452A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1452

1 LiDAR Operator: RJ ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34Q S133A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: MAY 13, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1413	14 Engine Off: 1806	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 6/9 lines left over BLK34Q.
Mission aborted due to problem encountered in the aircraft's temperature.

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)

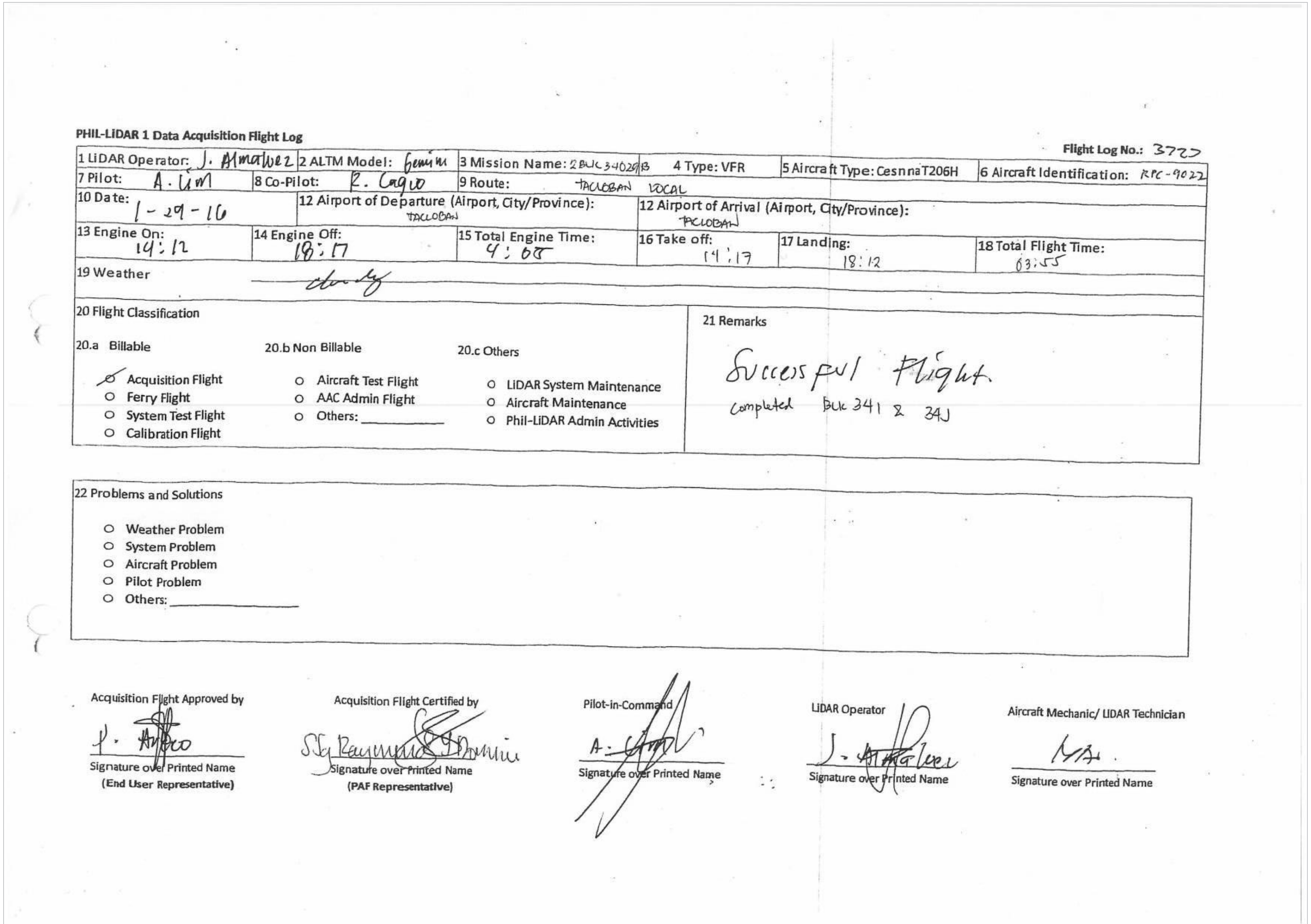
Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
RJ Arceo
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.8 Flight Log for 1452A Mission

9. Flight Log for 3727G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3727

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK34029B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Cagro	9 Route: TACLOBAN LOCAL			
10 Date: 1-29-16		12 Airport of Departure (Airport, City/Province): TACLOBAN		12 Airport of Arrival (Airport, City/Province): TACLOBAN	
13 Engine On: 14:12	14 Engine Off: 18:17	15 Total Engine Time: 4:05	16 Take off: 14:17	17 Landing: 18:12	18 Total Flight Time: 03:55
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful Flight.
Completed Blk 341 & 34J

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

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

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

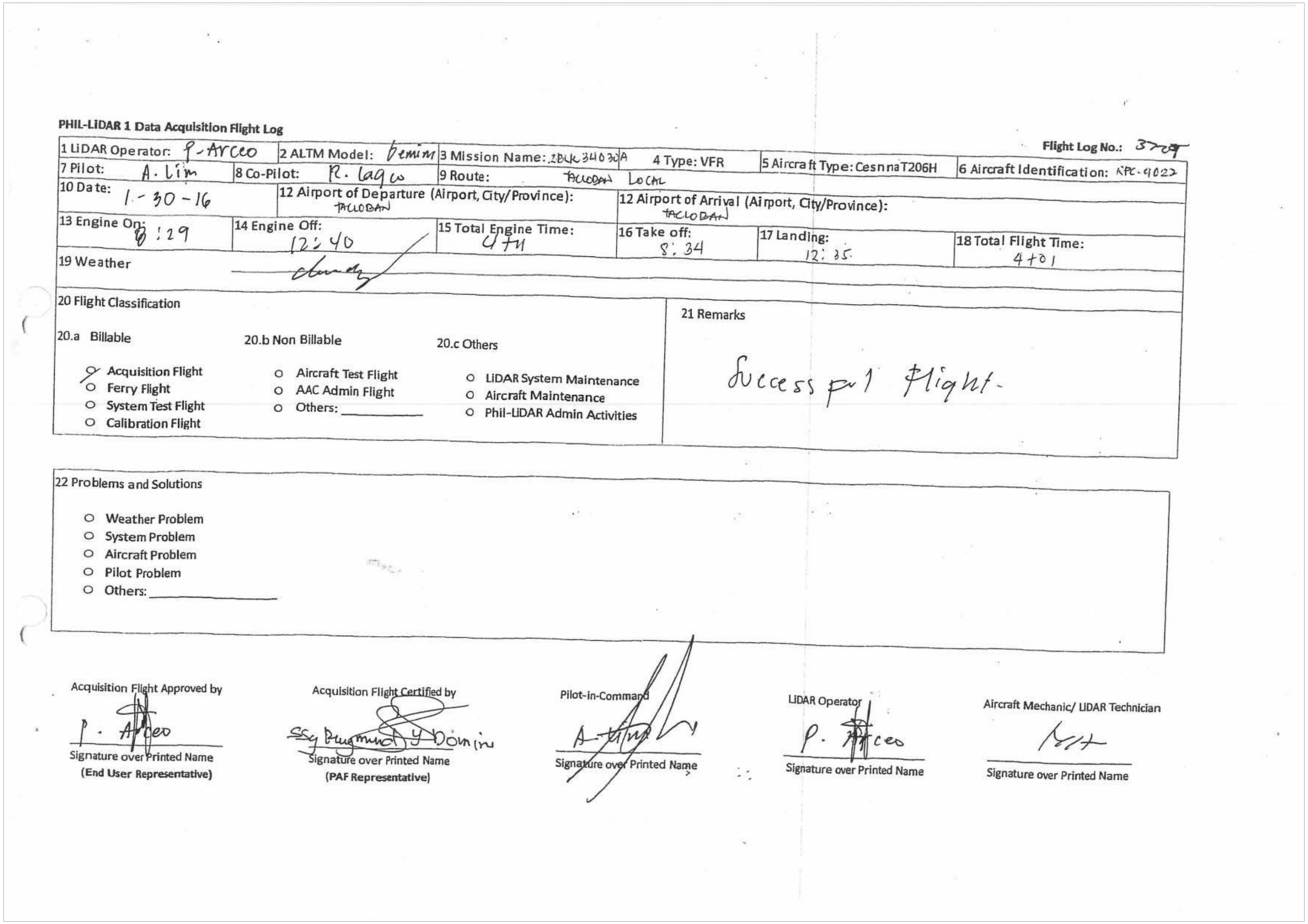
Pilot-in-Command — A. Lim — Signature over Printed Name

LiDAR Operator — J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.9 Flight Log for 3727G Mission

10. Flight Log for 3729G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3729

1 LiDAR Operator: P. Arceo	2 ALTM Model: Gemini	3 Mission Name: 2BLK34030A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route: Tacloban Local			
10 Date: 1-30-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 8:29	14 Engine Off: 12:40	15 Total Engine Time: 4+11	16 Take off: 8:34	17 Landing: 12:35	18 Total Flight Time: 4+01
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful Flight.

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

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

Acquisition Flight Certified by: SSg Bugmund Y Domini — Signature over Printed Name (PAF Representative)

Pilot-in-Command: A. Lim — Signature over Printed Name

LiDAR Operator: P. Arceo — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.10 Flight Log for 3729G Mission

11. Flight Log for 3753G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3753

1 LiDAR Operator: G-Sinadjan	2 ALTM Model: Gemini	3 Mission Name: 2BLK34K33AB036A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC-9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route: Tacloban Local			
10 Date: 2-5-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 9:58	14 Engine Off: 14:17	15 Total Engine Time: 4+17	16 Take off: 10:03	17 Landing: 14:20	18 Total Flight Time: 4+07
19 Weather: low clouds to partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

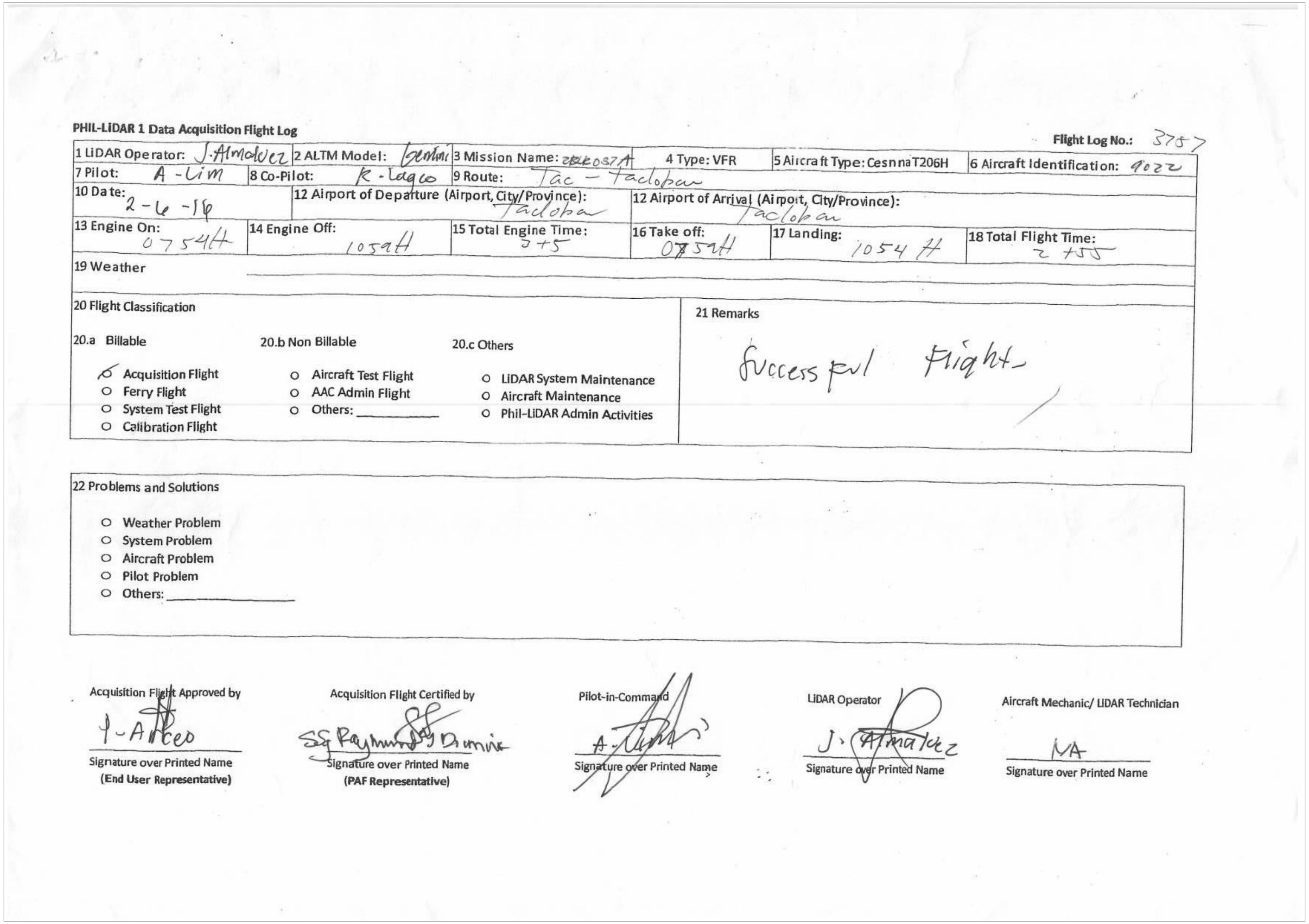
Successful flight

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
P. Arceo	SG Raymund D. Domini	A. Lim	G. Sinadjan	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.11 Flight Log for 3753G Mission

12. Flight Log for 3757G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3757

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK037A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: A. Lim	8 Co-Pilot: R. Lagco	9 Route: Tac - Tacloban			
10 Date: 2-6-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 0754H	14 Engine Off: 1059H	15 Total Engine Time: 3+5	16 Take off: 0759H	17 Landing: 1054 H	18 Total Flight Time: 2+55
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Successful Flight

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

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

Acquisition Flight Certified by: SSg Raymund Dumnic — Signature over Printed Name (PAF Representative)

Pilot-in-Command: A. Lim — Signature over Printed Name

LiDAR Operator: J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: NA — Signature over Printed Name

Figure A-6.12 Flight Log for 3757G Mission

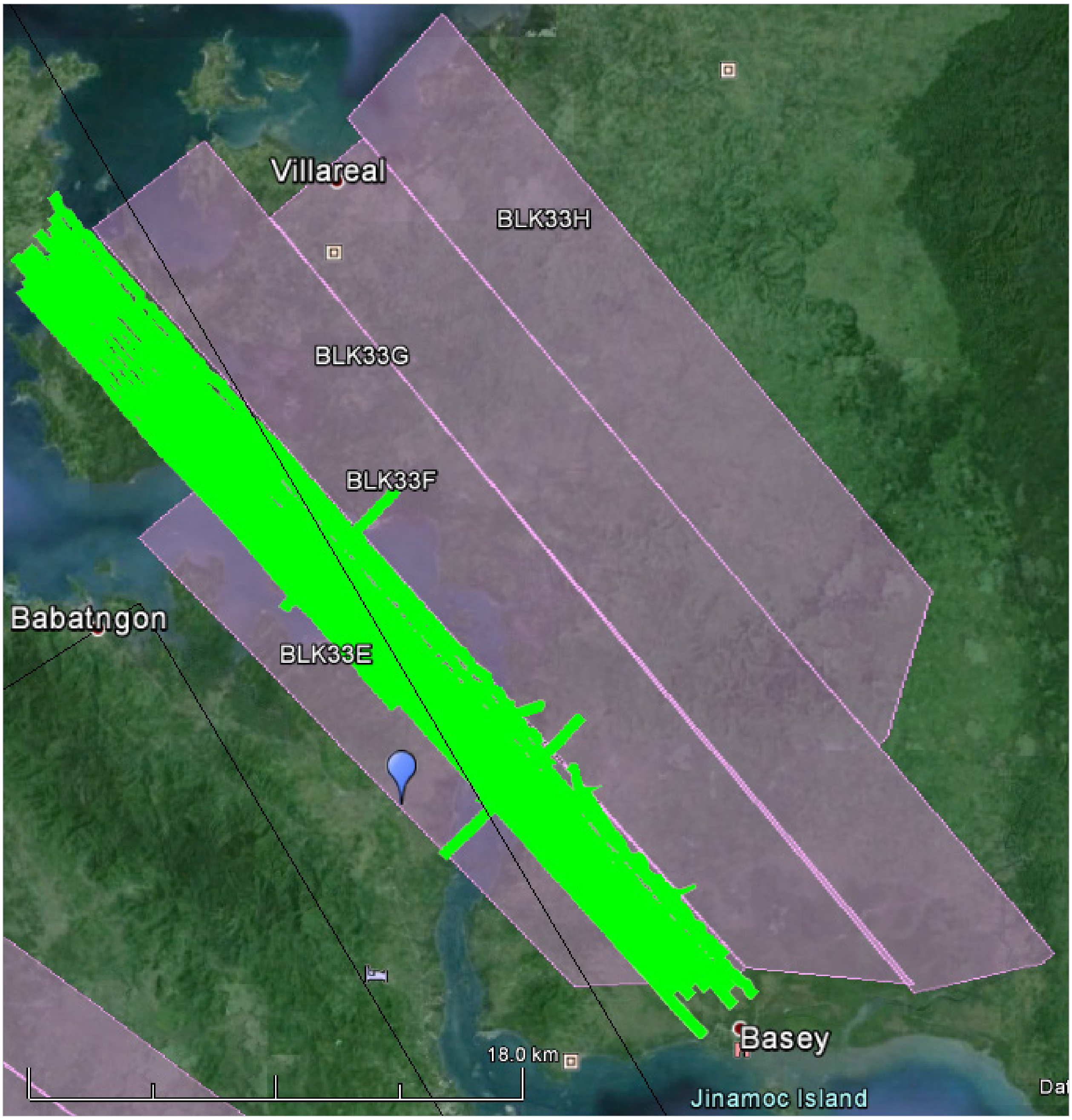
ANNEX 7. Flight Status Reports

TACLOBAN
May 3 -13, 2014 and January 29 - February 6, 2016

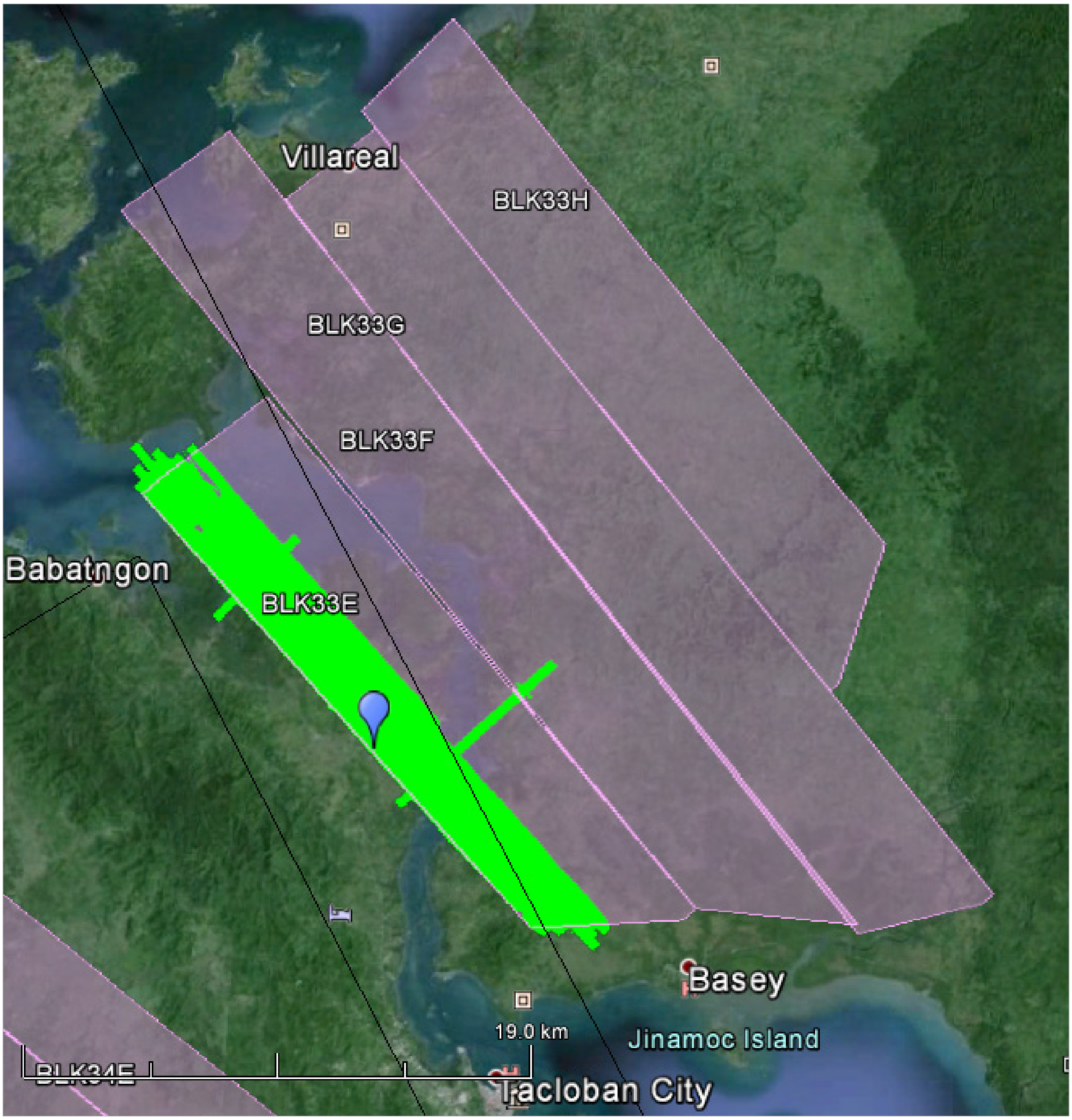
Flight No	Area	Mission	Operator	Date Flown	Remarks
1410A	BLK33E	AQUATACTF123A	I. ROXAS	May 3, 2014	Completed test flight for Aquarius over survey area BLK33E.
1414A	BLK33E	AQUATACTF124A	P. ARCEO	May 4, 2014	Completed test flight for Aquarius over survey area BLK33E.
1438A	BLK33f	3BLK34O130A	P. ARCEO	May 10, 2014	Completed 18 lines over BLK34F.
1440A	BLK33F BLK33G	3BLK34OSP130B	I. ROXAS	May 10, 2014	Completed 15 lines over BLK33G.
1442A	BLK33G	3BLK34PS131A	I. ROXAS	May 11, 2014	Completed 15/21 lines over BLK33G.
1444A	BLK33G BLK33H	3BLK34PSQ131B	P. ARCEO	May 11, 2014	Completed 16 lines over BLK33H and 2 lines over BLK33G.
1450A	BLK33H	3BLK34QS133A	P. ARCEO	May 13, 2014	Completed 6 out of 9 lines left over BLK34H, need to abort due to problem encountered in the aircraft temperature.
1452A	BLK33H BLK33E	3BLK34QS133Bf	I. ROXAS	May 13, 2014	Completed mission over BLK34H and some voids over BLK33E.
3727G	BLK34I BLK34J	2BLK34IJ029B	J. ALMALVEZ	January 29, 2016	Completed BLK34I and surveyed 15 lines at BLK34J.
3729G	BLK34H BLK34J	2BLK34HJ030A	P. ARCEO	January 30, 2016	Completed BLK34H and BLK34J.
3753G	BLK34K BLK33A BLK33B	2BLK34K33AB036A	G. SINADJAN	February 5, 2016	Surveyed BLK34K and completed BLK33A & 33B
3757G	BLK34K	2BLK34K037A	J. ALMALVEZ	February 6, 2016	Completed BLK34K

SWATH PER FLIGHT MISSION

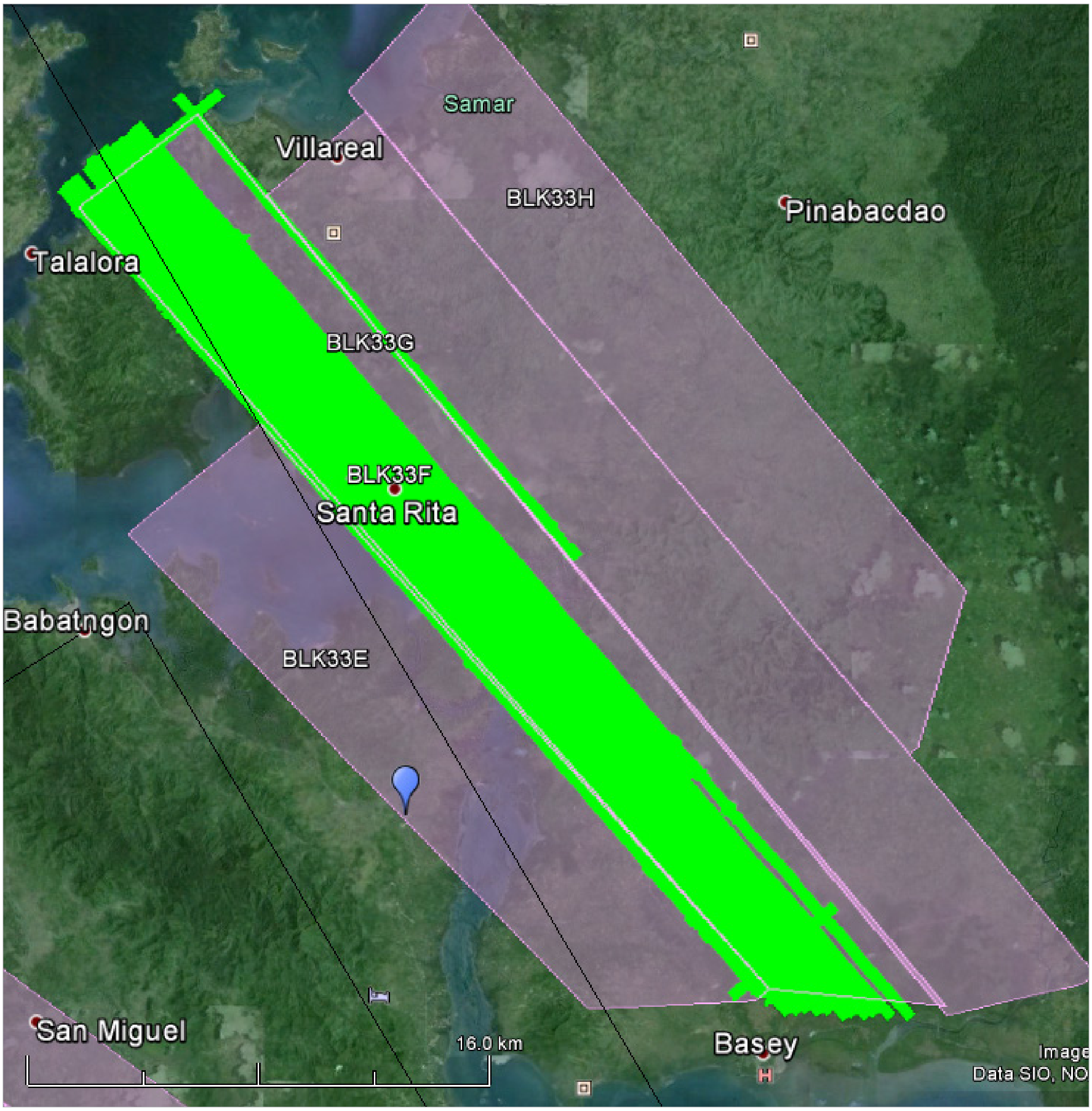
Flight No. :	**1410A**		
Area:	BLK33E		
Mission Name:	3BLK33E123A		
Total Area:	124.21 sq. km.		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



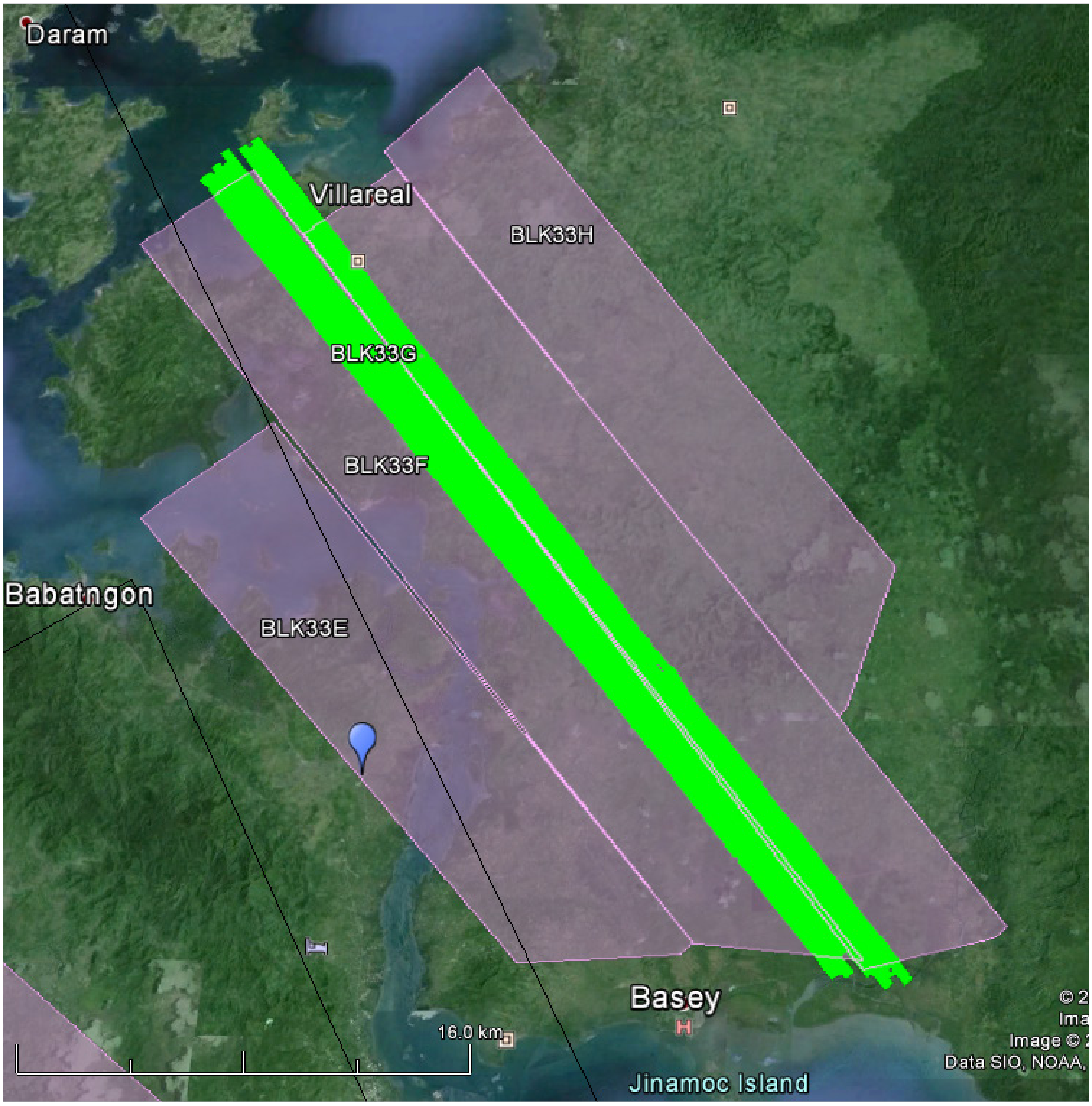
Flight No. :	**1414A**		
Area:	BLK33E		
Mission Name:	3BLK33E124A		
Total Area:	67.279 sq. km.		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



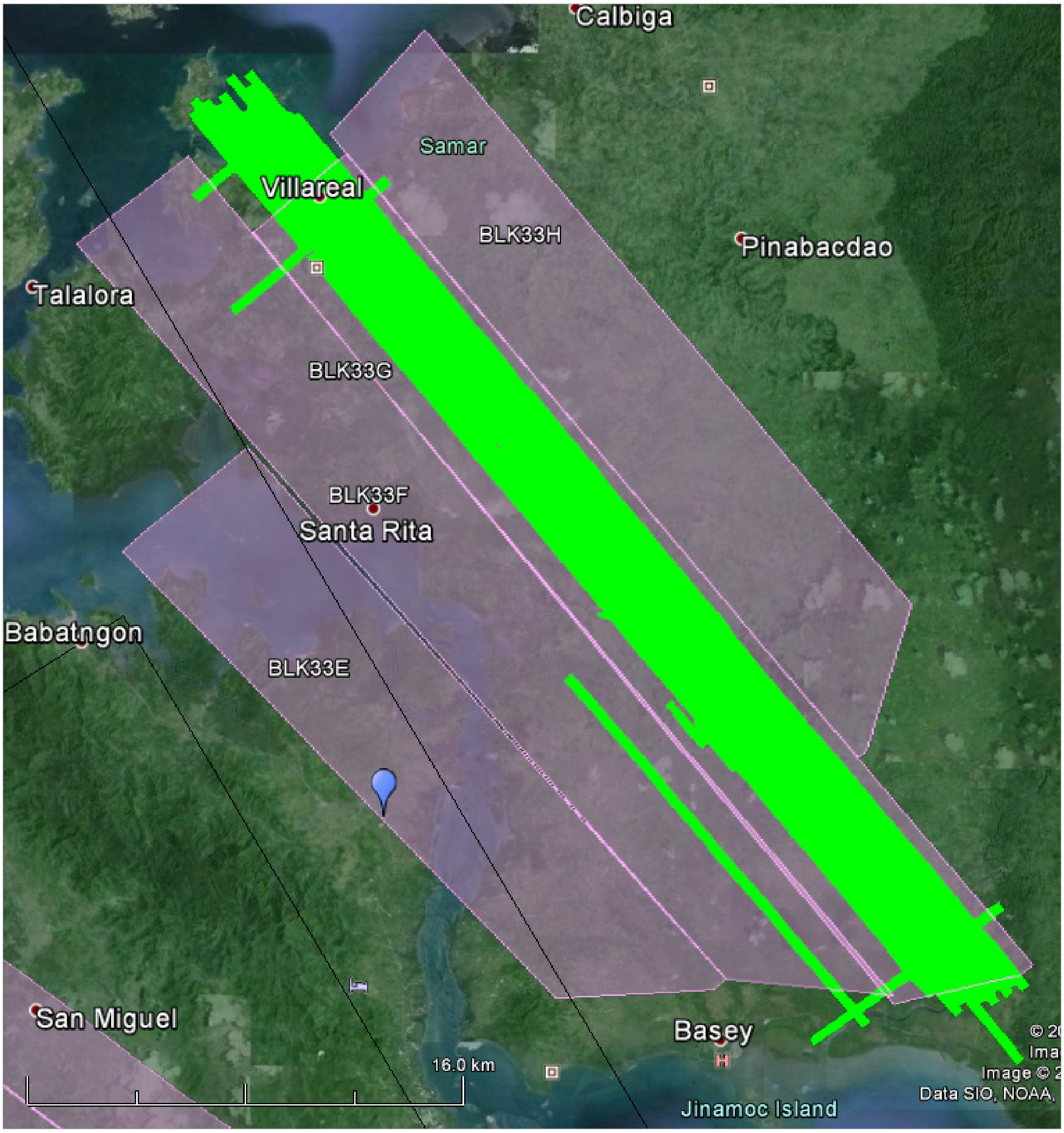
Flight No. :	**1438A**		
Area:	BLK33F		
Total Area:	160.52 sq km		
Mission Name:	3BLK33F130A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



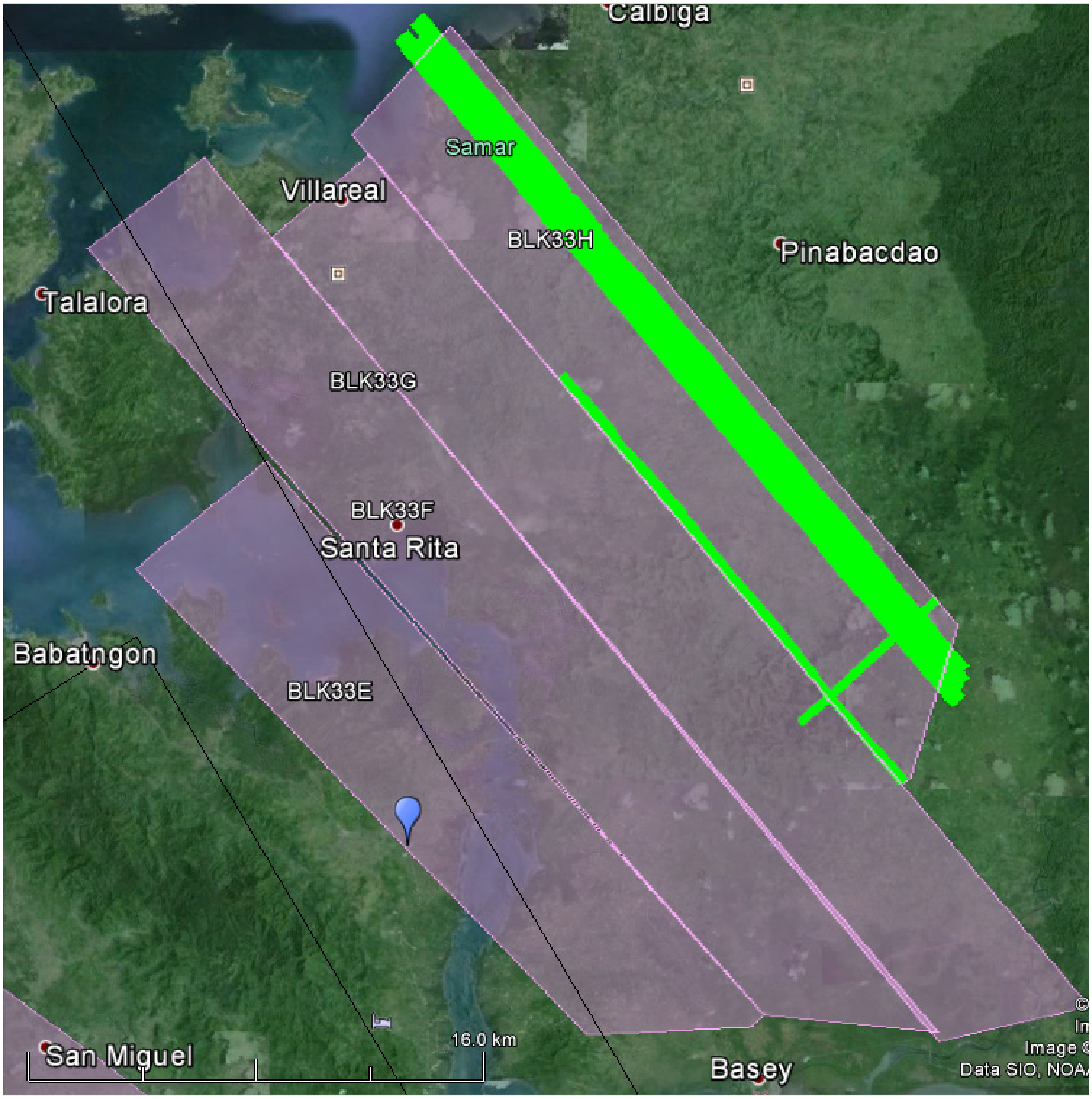
Flight No. : **1440A**
Area: BLK33F & BLK33G
Total Area: 107.08 sq km
Mission Name: 3BLK33FSG130B
Altitude: 600m
PRF: 50 kHz SCF: 50 Hz
Lidar FOV: 18 deg Sidelap: 30%



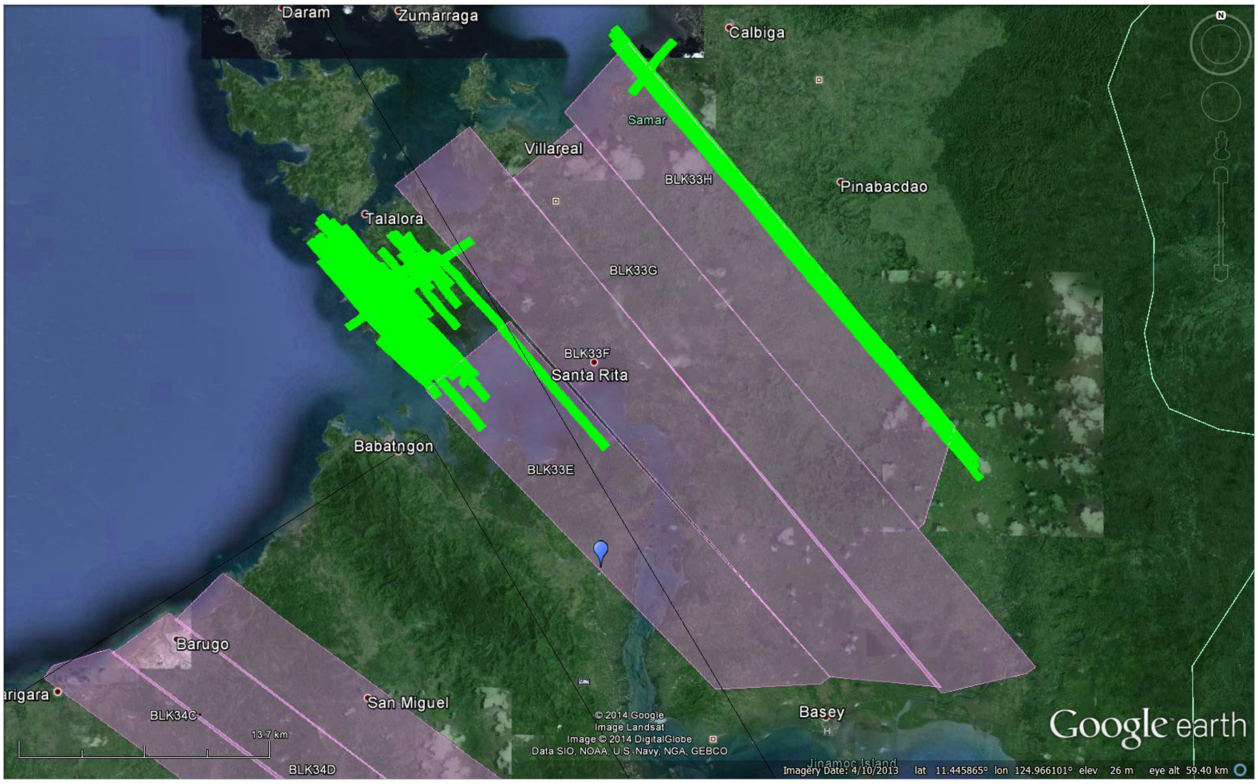
Flight No. :	**1442A**		
Area:	BLK33G		
Total Area:	154.2 sq km		
Mission Name:	3BLK33GS131A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



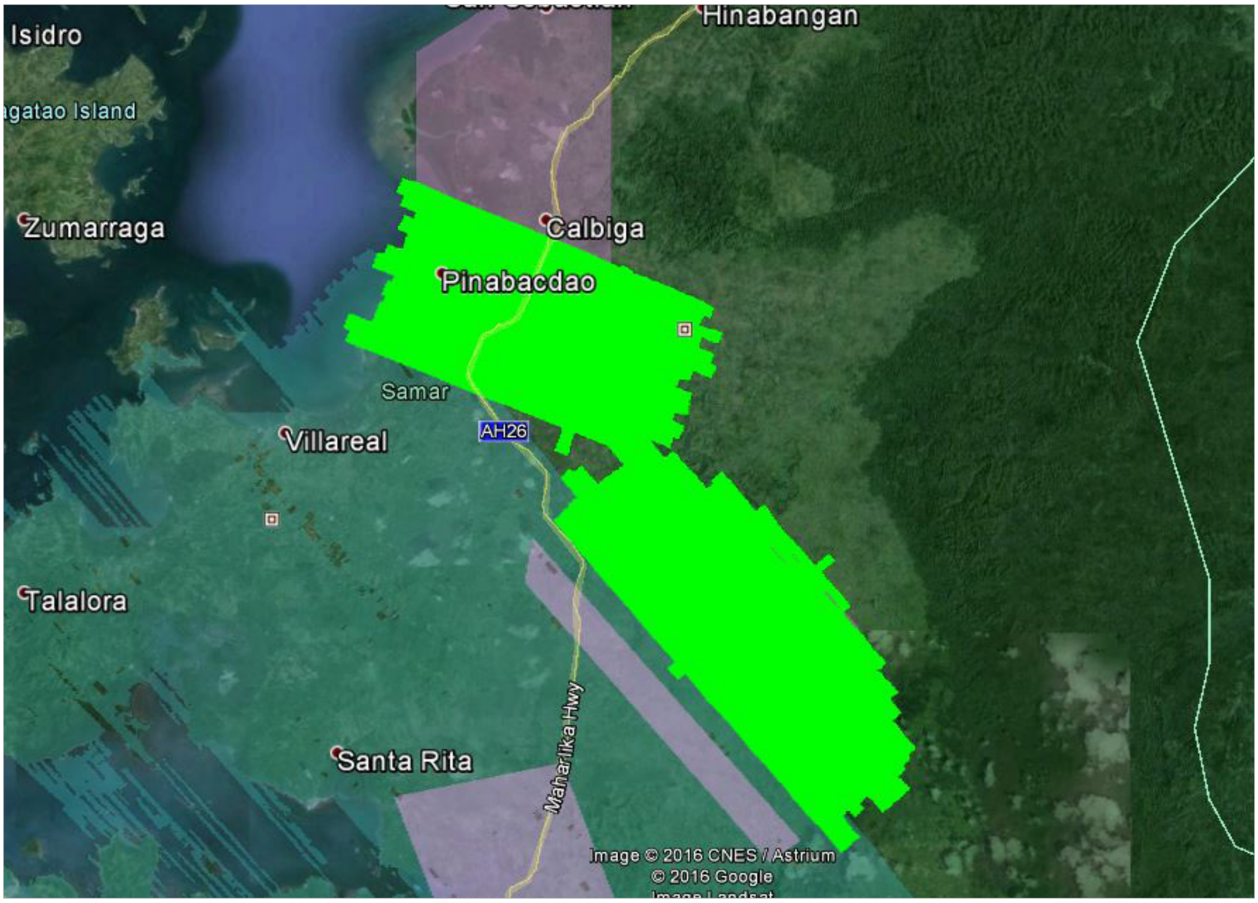
Flight No. :	**1450A**		
Area:	BLK33H		
Total Area:	52.534 sq km		
Mission Name:	3BLK33HS133A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



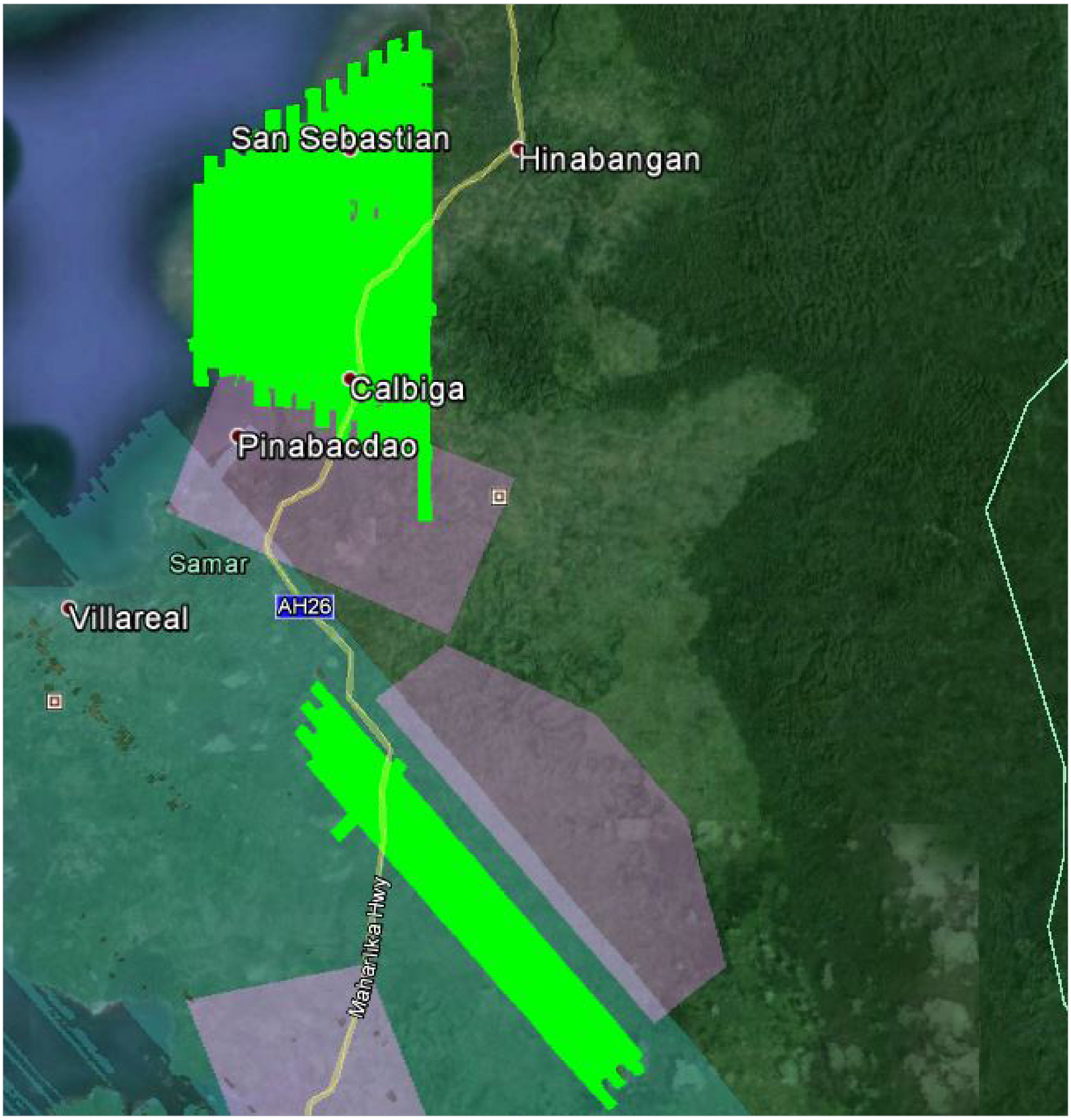
Flight No. :	**1452A**		
Area:	BLK33H, BLK33E		
Total Area:	75.806 sq. km.		
Mission Name:	3BLK33HSES133B		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%



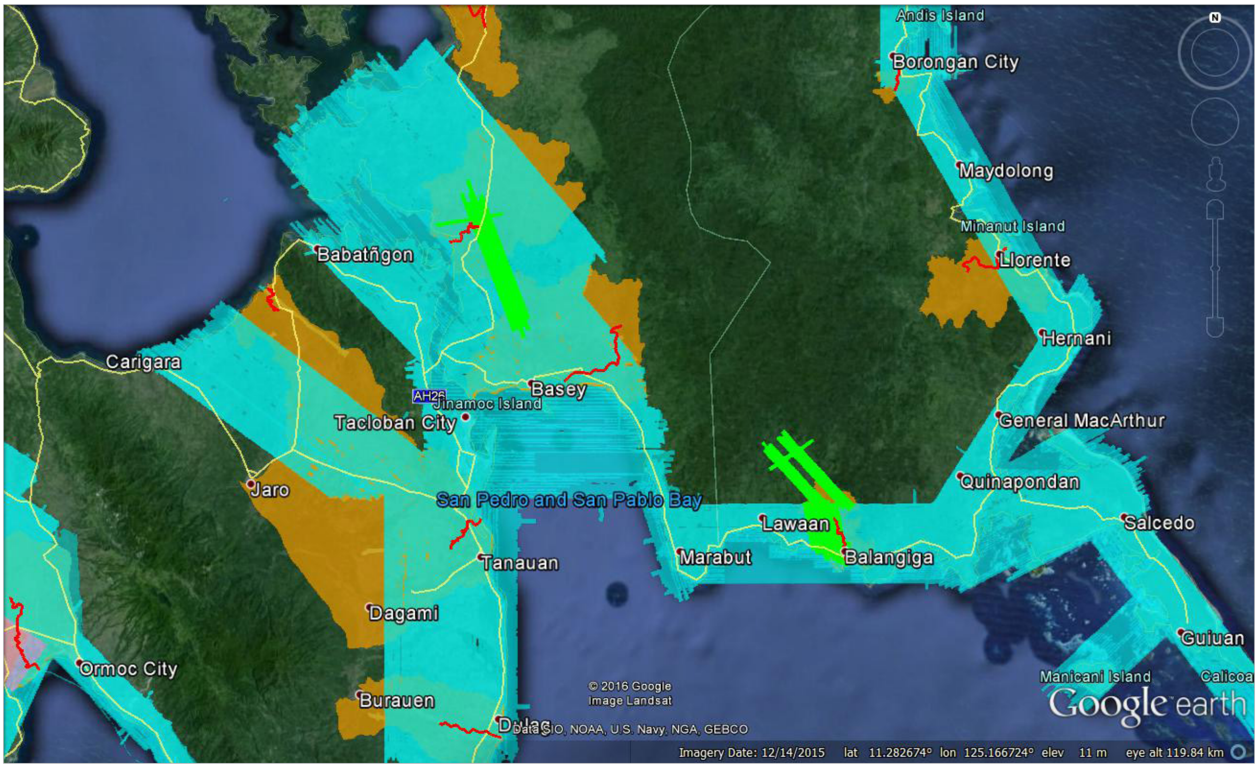
FLIGHT NO.:	**3727G**		
AREA:	Samar		
MISSION NAME:	2BLK34IJ029B		
ALT: 800m	SCAN FREQ:	40Hz	
SCAN ANGLE: 25 deg	SURVEYED AREA:	144.55 sq.km.	



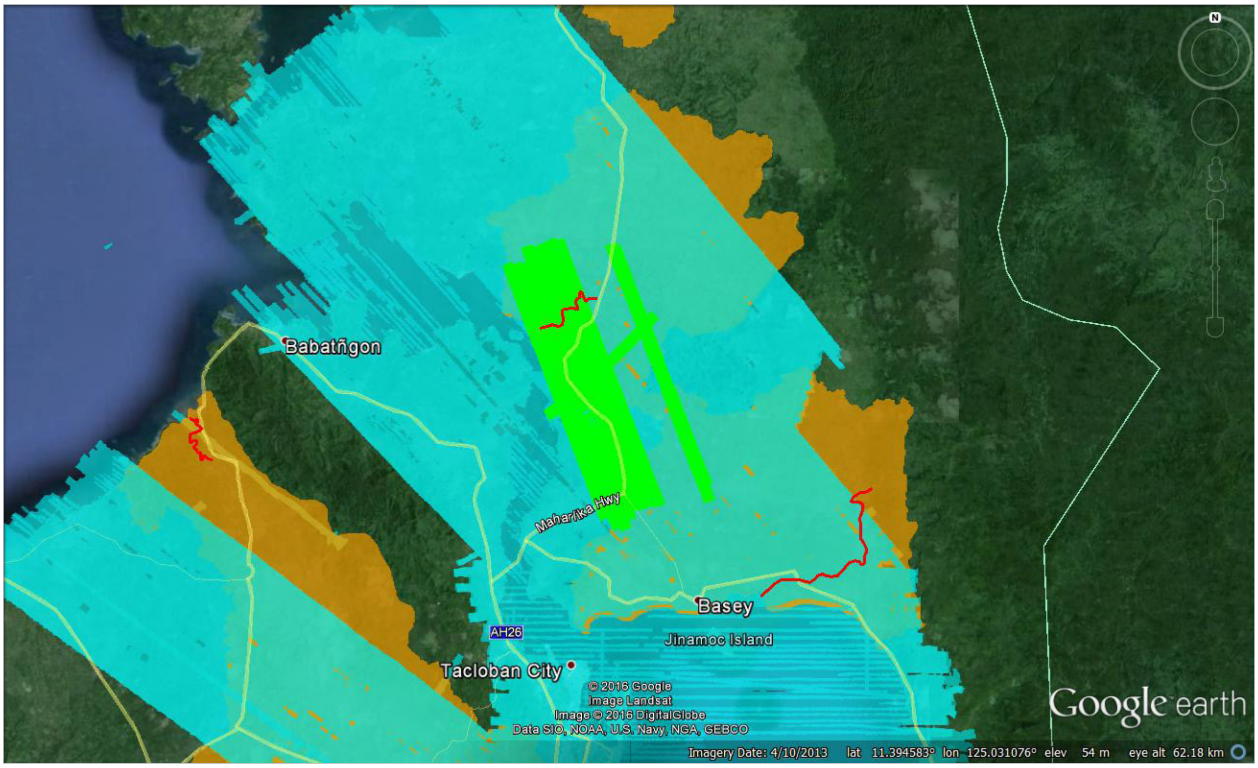
FLIGHT NO.:	**3729G**	
AREA:	Samar	
MISSION NAME:	2BLK34HJ030A	
ALT: 650m	SCAN FREQ:	50Hz
SCAN ANGLE: 20deg	SURVEYED AREA:	105.73 km²



FLIGHT NO.: **3753G**
AREA: Samar
MISSION NAME: 2BLK34K33AB036A
ALT: 850 m SCAN FREQ: 50 Hz
SCAN ANGLE: 20 deg SURVEYED AREA: 79.46 km²



FLIGHT NO.:	**3757**	
AREA:	Samar	
MISSION NAME:	2BLK34K037A	
ALT: 850 m	SCAN FREQ:	50 Hz
SCAN ANGLE: 20	SURVEYED AREA:	75.3 km²



ANNEX 8. San Cristobal Model Basin Parameters

Table A-8.1 San Cristobal Model Basin Parameters

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow		
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W1000	2.8402	77.487	0	4.5807	0.0405	0.0539	0.6625	0.2178
W1010	4.0528	75.8084	0	3.595	5.867	0.3205	1	0.5
W1020	4.2915	74.7435	0	4.2413	6.9218	0.5253	1	0.5
W1050	5.3873	71.509	0	8.2584	0.1112	0.1591	1	0.5
W1060	6.9646	70.39	0	0.0968	0.0333	0.0057	0.6328	0.6918
W1070	1.9737	75.088	0	6.0223	0.3718	0.3467	1	0.5
W1080	6.8862	63.948	0	8.2318	0.1648	0.2399	1	0.5
W1090	2.6329	54.423	0	2.7549	0.295	0.3576	1	0.5
W1100	6.9221	44.48	0	7.691	0.2171	0.6017	1	0.5
W1360	2.1536	85.5011	0	0.4848	0.7912	0.0063	1	0.5
W1370	0.2485	99	0	0.0333	0.0333	0.0161	0.1354	0.2713
W680	4.5937	59.358	0	4.1964	0.5205	0.2465	1	0.5
W690	1.5977	61.803	0	1.7948	0.1758	0.1734	0.6623	0.4019
W700	7.9675	58.784	0	0.1521	0.5034	0.0407	0.6626	0.2805
W720	2.5464	62.567	0	26.094	0.4668	0.3917	1	0.5
W730	3.0901	67.076	0	6.1963	0.2058	0.2114	0.6619	0.4672
W740	4.7725	67.487	0	2.1227	0.4902	0.2477	1	0.5
W760	5.2851	62.664	0	2.6996	0.1615	0.0670	1	0
W770	3.55	78	0	1.5575	2.5418	0.0442	1	0.5
W780	2.5727	65.956	0	1.4099	0.3028	0.1672	0.913	0.4171

Sub Basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow		
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W790	0.7738	69.542	0	0.3942	0.2811	0.1997	0.9815	0.4179
W810	0.1004	72.975	0	0.0932	0.0333	0.0148	0.2041	0.4198
W820	3.6398	71.941	0	2.8733	0.8232	0.2207	1	0.4802
W830	0.0455	83.963	0	0.6142	0.0333	0.0389	0.939	0.4348
W840	2.5999	83.0073	0	2.2694	3.7037	0.2154	1	0.5
W860	5.7444	70.972	0	16.481	0.1502	0.4468	1	0.5
W870	1.7815	87.6981	0	0.7302	1.1917	0.0123	1	0.5
W890	0.8464	64.951	0	0.0333	0.0333	0.0143	0.1943	0.434
W900	4.4133	68.86	0	0.0745	0.1333	0.4849	1	0.472
W910	1.3524	73.649	0	1.2523	0.127	0.2327	0.6906	0.4244
W920	14.044	82.343	0	1.0875	0.1717	0.2778	0.6705	0.4353
W930	1.3682	90.2747	0	1.6241	2.6505	0.0799	1	0.5
W940	2.9617	81.0895	0	2.3371	3.8142	0.2114	1	0.5
W950	6.9199	93.75	0	36.571	0.9553	0.6134	1	0.5
W960	4.8252	85.27	0	0.7293	0.402	0.2412	0.9817	0
W970	6.7116	94.911	0	0.1446	0.0988	0.0173	1	0.4546
W980	9.3633	83.027	0	31.237	0.0359	0.7273	0.989	0.5
W990	3.4302	83.152	0	1.8435	0.1519	0.1564	1	0.4511

ANNEX 9. San Cristobal Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	4670.3	0.007732	0.0260888	Trapezoid	30	1
R100	Automatic Fixed Interval	2675.2	0.011403	0.0100961	Trapezoid	30	1
R110	Automatic Fixed Interval	316.57	0.008457	0.01	Trapezoid	30	1
R120	Automatic Fixed Interval	1663.4	0.011403	0.01	Trapezoid	30	1
R130	Automatic Fixed Interval	492.13	0.006455	0.0337546	Trapezoid	30	1
R1390	Automatic Fixed Interval	503.85	0.008457	0.010196	Trapezoid	30	1
R140	Automatic Fixed Interval	950.83	0.023121	0.0338953	Trapezoid	30	1
R150	Automatic Fixed Interval	1132.3	0.006292	0.0151484	Trapezoid	30	1
R160	Automatic Fixed Interval	2798.8	0.003429	0.01	Trapezoid	30	1
R170	Automatic Fixed Interval	688.7	0.006259	0.01	Trapezoid	30	1
R190	Automatic Fixed Interval	8775.5	0.015777	0.0147888	Trapezoid	30	1
R20	Automatic Fixed Interval	1326.1	0.016884	0.0225974	Trapezoid	30	1
R200	Automatic Fixed Interval	7267.4	0.007254	0.0150714	Trapezoid	30	1
R220	Automatic Fixed Interval	542.43	0.01479	0.014406	Trapezoid	30	1
R260	Automatic Fixed Interval	2620.8	0.015268	0.01	Trapezoid	30	1
R280	Automatic Fixed Interval	2411.4	0.008046	0.0199289	Trapezoid	30	1
R300	Automatic Fixed Interval	424.14	0.031296	0.050625	Trapezoid	30	1
R310	Automatic Fixed Interval	4817.7	0.010772	0.0101919	Trapezoid	30	1
R50	Automatic Fixed Interval	2540.1	0.016884	0.01	Trapezoid	30	1
R70	Automatic Fixed Interval	4315	0.003624	0.0152741	Trapezoid	30	1
R80	Automatic Fixed Interval	14.142	0.036007	0.0152227	Trapezoid	30	1

ANNEX 10. San Cristobal Field Validation

Table A-10.1 Table A-11.1. San Cristobal Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
1	14.22121	121.1378	0.09	4	3.91	Milenyo	Sept. 28, 2006	25-Year
2	14.22052	121.1379	0.38	1.38	1		July, 2009	25-Year
3	14.22049	121.1378	1.65	1.87	0.22	Milenyo	Sept. 28, 2006	25-Year
4	14.22059	121.1379	0.38	1.43	1.05	Ondoy	Sept. 26, 2009	25-Year
5	14.22022	121.1379	3.22	0	-3.22		July, 2012	25-Year
6	14.22034	121.1381	0.12	1.12	1	Ondoy	Sept. 26, 2009	25-Year
7	14.22267	121.1383	0.09	1.64	1.55	Ondoy	Sept. 26, 2009	25-Year
8	14.22212	121.1381	0.11	2.46	2.35	Milenyo	Sept. 28, 2006	25-Year
9	14.22211	121.1382	0.11	2.44	2.33	Milenyo	Sept. 28, 2006	25-Year
10	14.2224	121.1378	0.34	1.19	0.85	Milenyo; Ondoy	Sept 28, 2006; Sept. 26,2009	25-Year
11	14.22184	121.1378	0.08	0.76	0.68	Milenyo	Sept. 28, 2006	25-Year
12	14.22119	121.1381	0.09	0	-0.09	Ondoy	Sept. 26, 2009	25-Year
13	14.2218	121.1399	0.16	3	2.84	Milenyo	Sept. 28, 2006	25-Year
14	14.2204	121.1397	0.07	1.9	1.83	Yolanda	Nov. 8, 2013	25-Year
15	14.22044	121.1405	0.08	4.075	3.995	Milenyo	Sept. 28, 2006	25-Year
16	14.21362	121.1372	0.66	1	0.34	Milenyo	Sept. 28, 2006	25-Year
17	14.21362	121.1395	0.34	1.21	0.87	Ondoy	Sept. 26, 2009	25-Year
18	14.2134	121.1398	0.15	1.7	1.55	Milenyo	Sept. 28, 2006	25-Year
19	14.21376	121.1401	0.5	2.2	1.7	Milenyo	Sept. 28, 2006	25-Year
20	14.21401	121.1398	2.72	3	0.28	Milenyo	Sept. 28, 2006	25-Year
21	14.21425	121.1393	1.63	4	2.37	Milenyo	Sept. 28, 2006	25-Year
22	14.21185	121.1369	0.23	3	2.77	Milenyo	Sept. 28, 2006	25-Year
23	14.21926	121.1418	1.46	3.2	1.74	Ondoy	Sept. 26, 2009	25-Year
24	14.21925	121.1416	0.32	2.1	1.78	Milenyo	Sept. 28, 2006	25-Year
25	14.21906	121.1412	0.68	0	-0.68	Milenyo	Sept. 28, 2006	25-Year
26	14.23484	121.1793	0.37	1.04	0.67	Ondoy	Sept. 26, 2009	25-Year
27	14.23453	121.1786	0.23	1	0.77	Ondoy	Sept. 26, 2009	25-Year
28	14.23436	121.1786	0.3	1.2	0.9	Habagat	42593	25-Year
29	14.24965	121.1673	0.4	1.1	0.7	Ondoy	Sept. 26, 2009	25-Year
30	14.23298	121.1801	0.6	1.09	0.49	Glenda	July, 2014	25-Year
31	14.23224	121.1759	0.29	1.12	0.83	Habagat	2015	25-Year
32	14.23266	121.1769	0.83	1.11	0.28	Ondoy	Sept. 26, 2009	25-Year
33	14.23295	121.1772	0.42	0.6	0.18	Habagat		25-Year
34	14.23295	121.1772	0.42	0.58	0.16	Habagat		25-Year
35	14.23157	121.176	0.28	1	0.72	Milenyo	Sept. 28, 2006	25-Year
36	14.2309	121.1752	0.3	0.6	0.3	Ondoy	Sept. 26, 2009	25-Year
37	14.2311	121.1762	0.15	1.34	1.19	Milenyo	Sept. 28, 2006	25-Year
38	14.23062	121.1765	0.06	0.36	0.3	Milenyo	Sept. 28, 2006	25-Year
39	14.23006	121.1767	0.1	0.53	0.43	Ondoy	Sept. 26, 2009	25-Year
40	14.22984	121.1772	0.27	0.15	-0.12	Glenda	July, 2014	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
41	14.22965	121.1774	0.34	0.95	0.61	Habagat	2014	25-Year
42	14.22982	121.1783	0.26	0.5	0.24	Milenyo	Sept. 28, 2006	25-Year
43	14.22774	121.1798	1.52	0.44	-1.08	Milenyo	Sept. 28, 2006	25-Year
44	14.22714	121.1799	0.42	0	-0.42	Milenyo	Sept. 28, 2006	25-Year
45	14.22713	121.1801	0.38	0.9	0.52	Milenyo	Sept. 28, 2006	25-Year
46	14.24965	121.1673	0.4	0.46	0.06	Milenyo	Sept. 28, 2006	25-Year
47	14.22733	121.1811	0.45	0.4	-0.05	Milenyo	Sept. 28, 2006	25-Year
48	14.23237	121.1731	0.33	0.55	0.22	Milenyo	Sept. 28, 2006	25-Year
49	14.21562	121.1714	1.54	1.6	0.06	Ondoy	Sept. 26, 2009	25-Year
50	14.23412	121.1723	1.24	1.65	0.41	Ondoy	Sept. 26, 2009	25-Year
51	14.23412	121.1723	1.24	1.1	-0.14	Ondoy	Sept. 26, 2009	25-Year
52	14.2313	121.176	0.25	0.4	0.15	Rosing	Nov. 1995	25-Year
53	14.2315	121.1762	0.25	1	0.75	Ondoy	Sept. 26, 2009	25-Year
54	14.23941	121.1722	0.21	0.45	0.24	Ondoy	Sept. 26, 2009	25-Year
55	14.23792	121.1725	0.35	0.91	0.56	Ondoy	Sept. 26, 2009	25-Year
56	14.23941	121.1722	0.21	0.32	0.11	Ondoy	Sept. 26, 2009	25-Year
57	14.23728	121.1725	0.47	0.98	0.51	Ondoy	Sept. 26, 2009	25-Year
58	14.23883	121.1709	0.12	1.04	0.92	Ondoy	Sept. 26, 2009	25-Year
59	14.2312	121.1763	0.19	0.8	0.61	Habagat	2011	25-Year
60	14.23793	121.1728	0.45	0.67	0.22	Ondoy	Sept. 26, 2009	25-Year
61	14.22735	121.1818	0.53	0	-0.53			25-Year
62	14.22727	121.1824	0.29	0	-0.29			25-Year
63	14.22783	121.183	0.16	0	-0.16			25-Year
64	14.228	121.1834	0.24	0	-0.24			25-Year
65	14.23317	121.1804	0.56	1.51	0.95	Milenyo	2006	25-Year
66	14.23365	121.1803	0.33	1.51	1.18	Milenyo	2006	25-Year
67	14.23348	121.1799	0.43	0.55	0.12	Milenyo	2006	25-Year
68	14.23338	121.1794	0.5	0.98	0.48	Milenyo	2006	25-Year
69	14.23347	121.1796	0.49	2.35	1.86	Milenyo	2006	25-Year
70	14.23381	121.18	0.29	0.64	0.35	Milenyo	2006	25-Year
71	14.23405	121.18	0.21	6	5.79	Milenyo	2006	25-Year
72	14.2342	121.1793	0.37	0	-0.37	Milenyo	2006	25-Year
73	14.23401	121.1791	0.41	0	-0.41	Milenyo	2006	25-Year
74	14.23388	121.1789	0.42	5.95	5.53	Milenyo	2006	25-Year
75	14.23432	121.1791	0.36	0.97	0.61	Habagat	2012/2013	25-Year
76	14.23458	121.1796	0.4	1.08	0.68	Ondoy	2009	25-Year
77	14.21968	121.141	0.21	0.95	0.74	Ondoy, Milenyo	2009, 2006	25-Year
78	14.21968	121.141	0.21	1.03	0.82	Habagat	2012/2013	25-Year
79	14.21952	121.1413	0.27	0.95	0.68	Habagat	2012/2013	25-Year
80	14.21948	121.1414	0.25	1.02	0.77	Ondoy	2009	25-Year
81	14.21372	121.1388	1.96	1.06	-0.9	Habagat	2012	25-Year
82	14.21433	121.1394	2.44	0.96	-1.48	Ondoy, Habagat	2009, 2012	25-Year
83	14.2142	121.1392	2.17	0.9	-1.27	Ondoy, Habagat	2009, 2012	25-Year
84	14.21457	121.1403	1.65	1.17	-0.48	Ondoy, Habagat	2009, 2012	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Lat	Long						
85	14.21812	121.1487	1.59	1.06	-0.53	Ondoy, Habagat	2009, 2012	25-Year
86	14.2181	121.1489	3.67	1.18	-2.49	Ondoy	2009	25-Year
87	14.22156	121.1447	3.84	0.77	-3.07	Habagat	2012	25-Year
88	14.22165	121.1449	3.67	0.61	-3.06	Ondoy	2009	25-Year
89	14.22172	121.1452	4.77	0.6	-4.17	Ondoy	2009	25-Year
90	14.22172	121.1454	5.21	0.55	-4.66	Ondoy, Habagat	2009, 2012	25-Year
91	14.22163	121.1456	6.85	0	-6.85			25-Year
92	14.23551	121.1741	0.92	0	-0.92			25-Year
93	14.23586	121.1737	0.72	0.85	0.13	Habagat	2012/ 2013	25-Year
94	14.2364	121.1734	0.71	0.47	-0.24	Ondoy	2009	25-Year
95	14.23673	121.1737	0.68	0.81	0.13	Ondoy, Habagat	2009, 2012/2013	25-Year
96	14.2273	121.1812	0.45	1.17	0.72	Ondoy, Habagat	2009, 2012/2013	25-Year
97	14.23512	121.1741	0.94	0.603	-0.337	Ondoy, Habagat	2009, 2012/2013	25-Year
98	14.23445	121.1748	0.94	1.28	0.34	Ondoy	2009	25-Year
99	14.2339	121.1749	0.84	0.37	-0.47	Glenda	2014	25-Year
100	14.23321	121.1753	0.83	0.61	-0.22	Ondoy	2009	25-Year
101	14.2324	121.1756	0.47	0.77	0.3	Habagat	2012/ 2013	25-Year
102	14.23244	121.1759	0.52	0.895	0.375	Habagat	2012/ 2013	25-Year
103	14.23269	121.1764	0.75	0.85	0.1	Ondoy, Habagat	2009, 2012/ 2013	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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

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

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

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

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

Information Systems Analyst
Jan Martin C. Magcale

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