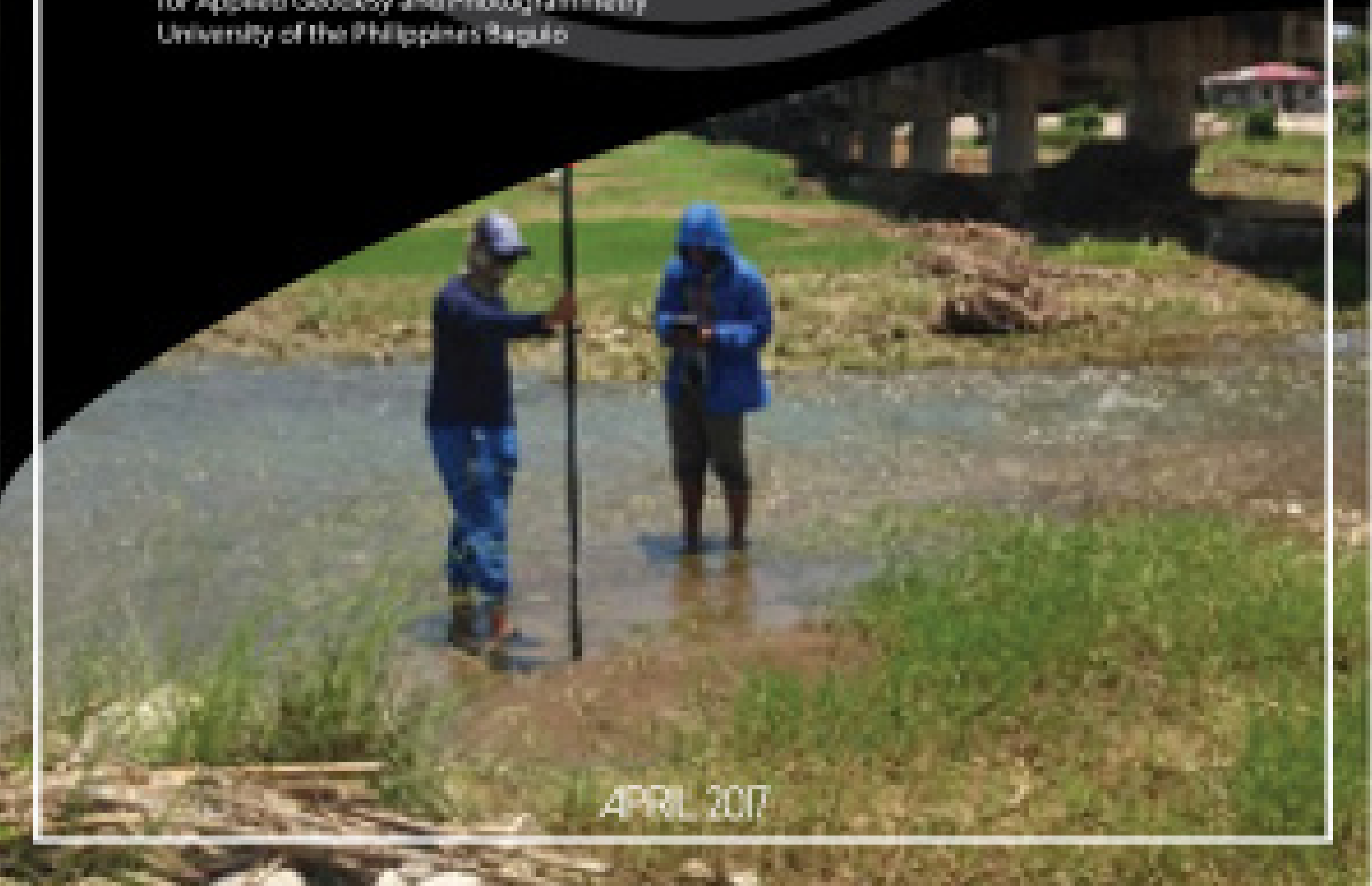
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Silay River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Baguio



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 and C. Pascua, (Eds.). (2017), LiDAR Surveys and Flood Mapping Report of Aklan River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LiDAR-193pp

For questions/queries regarding this report, contact:

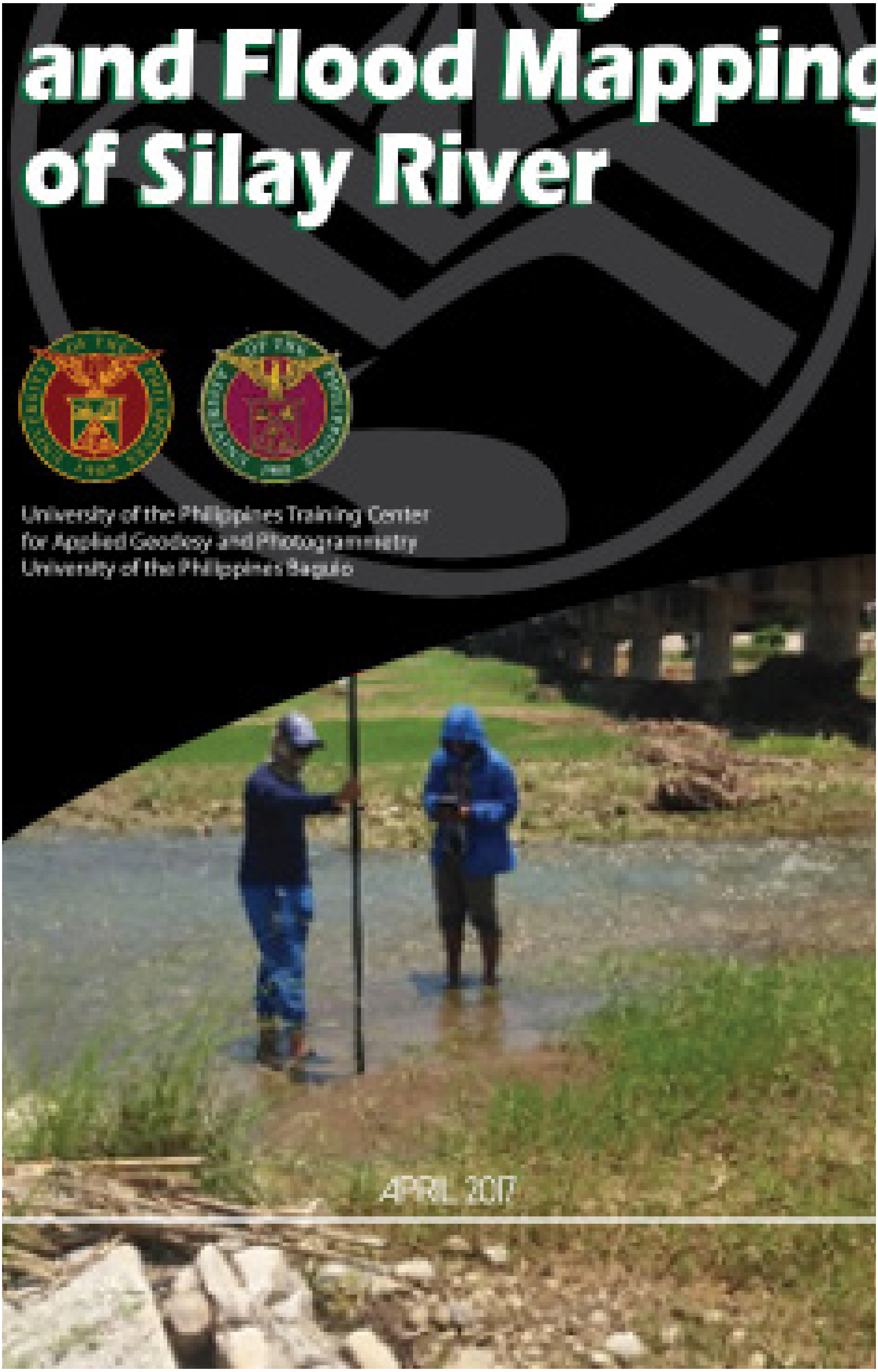
Dr. Chelo Pascua
Project Leader, PHIL-LIDAR 1 Program
University of the Philippines, Baguio
Baguio City, Philippines 2600
pascua.chelo@yahoo.com

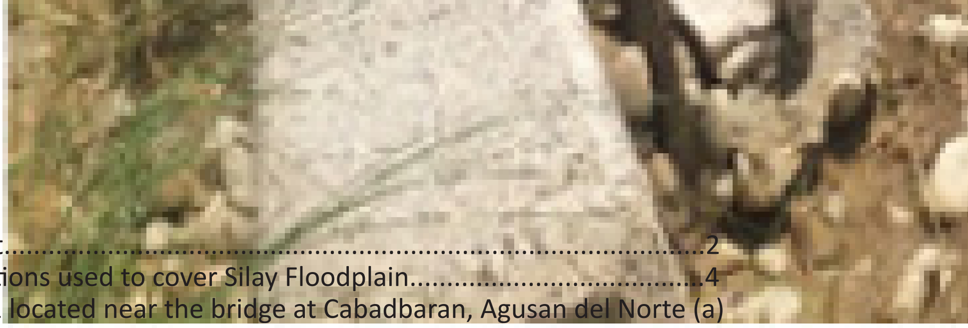
Enrico C. Paringit, Dr. Eng.
Program Leader, DREAM Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-093-8

TABLE OF CONTENTS

LIST OF TABLES


and Flood Mapping
of Silay River
University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Baguio
APRIL 2017



CHAPTER 1: OVERVIEW OF THE PROGRAM AND SILAY RIVER

Dr. Enrico C. Paringit and Dr. Chelo Pascua

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 implementing partner university for the Phil-LiDAR 1 Program is the Visayas State University (VSU). VSU 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 27 river basins in the Easter Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Silay River Basin

Silay River Basin covers six (6) municipalities of Ilocos Sur namely: Burgos, Lidlidda, San Emilio and Santa Maria, Banayoyo and Santiago; and one (1) Municipality of Pilar in Abra. The DENR River Basin Control Office identified the basin to have a drainage area of 244 km2 and an estimated 517 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Silay River, is part of the 13 river systems under the Phil-LiDAR 1 partner HEI, UP Baguo. There is a total of 14,629 persons residing within the immediate vicinity of the river according to the 2010 National Census, which are distributed among the thirteen (13) barangays in Municipality of Santa Maria; and two (2) barangays in Narvacan., both in Ilocos Sur. Most of the land around the area is dedicated to farming. Major products include rice, vegetables and tobacco. Other activities include fishing (http://www.seemyphilippines.com/2009/santa-maria-ilocos-sur-north-luzon-philippines/, 2016). Ilocos Region suffered major damages from Typhoon "Ineng", internationally known as Goni, on August 2015, reaching P246 million damages in agriculture, multi-million worth of road constructions, and isolated 730 families in the midst of the typhoon (http://www.newsinfo.inquirer.net, 2015).

In line with this, DVBC conducted a field survey in Silay River on June 9 – 23, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Sta. Maria Bridge in Brgy. Quinsoriano, Municipality of Santa Maria and Burgos Bridge in Brgy. Poblacion Norte, Municipality of Burgos; validation points acquisition of about 78.68 km covering the Silay River Basin area; and bathymetric survey from its upstream in Brgy. Cabaroan in the Municipality of Santa Maria to the mouth of the river located in Brgy. Nagsayaoan in the same Municipality, with an approximate length of 8.867 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 1).

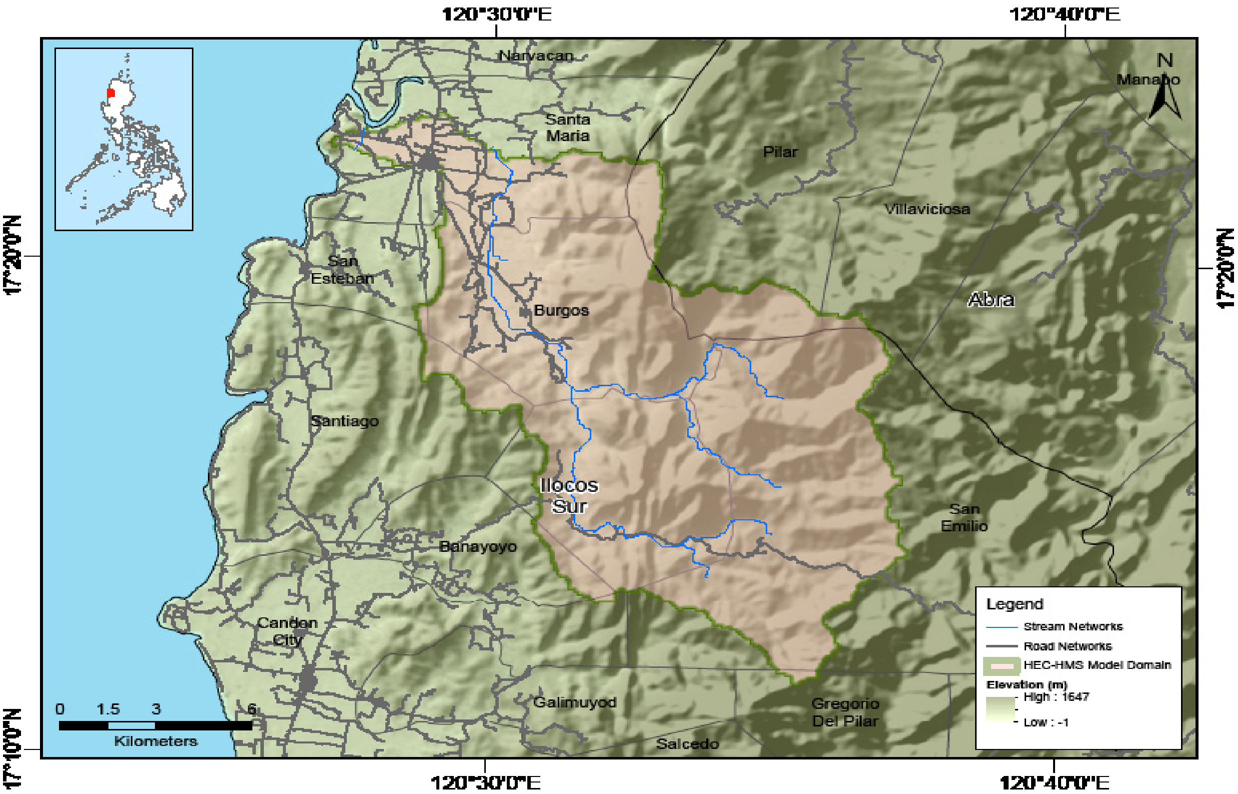


Figure 1. Map of Silay River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SILAY FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, Ms. Mary Catherine Elizabeth M. Baliguas

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Silay Floodplain in Ilocos Sur. These missions were planned for 19 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plans and base stations used for Silay Floodplain.

Table 1. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK06D	1800	55	30	70	50	130	5
BLK06F	1700	40	30	70	50	130	5
BLK06G	1800	55	30	70	50	130	5
BLK07A	1700	40	30	70	50	130	5
BLK07B	1200	40	30	100	50	130	5
BLK07C	1200	40	30	100	50	130	5
BLK07D	1300	50	30	70	50	130	5
BLK07G	1300,1400	50	30	70	50	130	5
BLK27A	1000,1200	25,30	40,50	100,200	30	130	5
BLK27B	1200	30	50	200	30	130	5

Table 2. Flight planning parameters for Pegasus LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK27A	1000,1200	25,30	40,50	100,200	30	130	5
BLK27B	1200	30	50	200	30	130	5

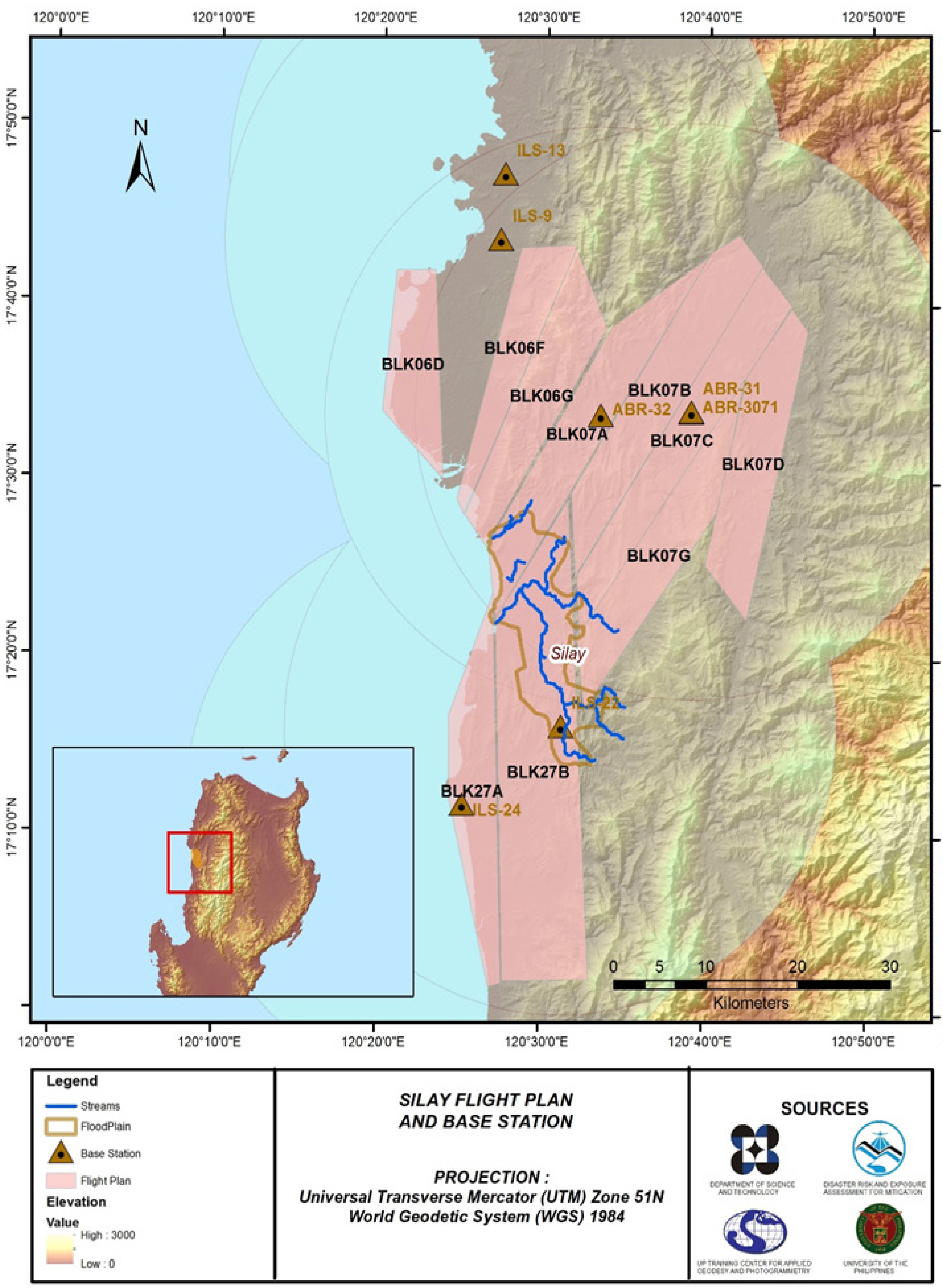


Figure 2. Flight plan and base stations used to cover Silay Floodplain.

2.2 Ground Base Stations

The project team was able to recover seven (7) NAMRIA ground control points: ABR-31, ABR-32, ILS-9, ILS-13, ILS-22, ILS-24 which are of second (2nd) order and ABR-3071 which is of fourth 4th order accuracy. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing report for the NAMRIA reference point (ABR-3071) is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 19-March 12, 2014, February 25-March 9, 2014 and May 23-31, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 985 and TOPCON GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Silay floodplain are shown in Figure 2.

Figures 3 to 9 show the recovered NAMRIA reference points within the area. Tables 3 to 9 show the details about the following NAMRIA control stations and establish points, while Table 10 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

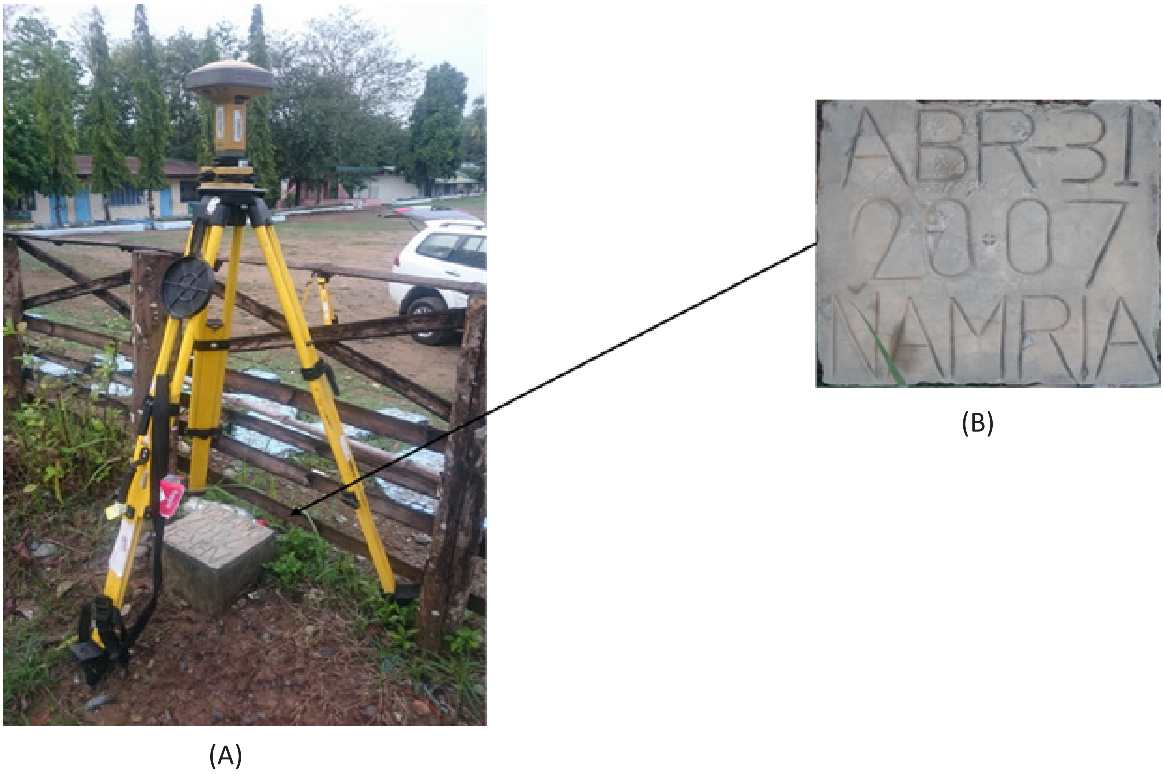


Figure 3. GPS set-up over ABR- 31 located near the bridge at Cabadbaran, Agusan del Norte (a) and NAMRIA reference point ABR-31 (b) as recovered by the field team.

Table 3.Details of the recovered NAMRIA horizontal control point ABR-31 used as base station for the LiDAR acquisition.

Station Name	ABR- 31	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17° 34’ 04.18832” North 120° 38’ 57.99393” East 98.78000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	462,785.996 meters 1,942,969.967 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17° 33’ 58.07703” North 120° 39’ 02.63930” East 132.48100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	250,503.563 meters 1,943,800.890 meters

(A)

(B)

Figure 4. GPS set-up over ABR-32 located inside the Barangay Hall Compound of Barangay Suyo, Pidigan Abra (a) and NAMRIA reference point ABR-32 (b) as recovered by the field team.

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

Station Name	**ABR-32**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°33'49.34656" North 120°33'25.07659" East 39.32200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	452,967.729 meters 1,942,534.242 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°33'43.22900" North 120°33'29.72282" East 72.81400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	240,677.03 meters 1,943,468.54 meters

(A)

(B)

Figure 5. GPS set-up over 5. ILS-9 located on the hilly portion of Bacsil National High School in Barangay Bacsil, San Juan Ilocos Sur (a) and NAMRIA reference point ILS-9 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ILS-9 used as base station for the LiDAR acquisition.

Station Name	**ILS-9**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°43’40.62808” North 120°27’9.37799” East 56.57700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Latitude Longitude Ellipsoidal Height	441,941.245 meters 1,960,739.965 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°43’34.46721” North 120°27’14.01102” East 89.291 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	229,838.72 meters 1,961,798.84 meters

(A) (B)

Figure 6. GPS set-up over ILS-13 located beside the school oval of Cabugao South Central School in Barangay Bonifacio, Cabugao Ilocos Sur (a) and NAMRIA reference point ILS-13 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point ILS-13 used as base station for the LiDAR acquisition.

Station Name	**ILS-13**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°47’21.51067” North 120°27’23.35275” East 26.74100 meters
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Easting Northing	442,372.629 meters 1,967,529.087 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°47’15.33691” North 120°27’27.98067” East 59.26700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	230,342.67 meters 1,968,586.44 meters

(A) (B)

Figure 7. GPS set-up over ILS-22 as recovered inside Lidlidda North Central School in Lidlidda, Ilocos Sur (a) and NAMRIA reference point ILS-22 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point ILS-22 used as base station for the LiDAR acquisition.

Station Name	ILS-22	
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	17°16’13.59403” North 120°31’8.89179” East 55.31200 meters
Grid Coordinates, Philippine Transverse Mercator Zone (PTM Zone 3 PRS 92)	Easting Northing	448,870.206 meters 1,910,089 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°16’7.53708” North 120°31’13.56269” East 89.64700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	236, 238.44 meters 1,911,053.54 meters

(A) (B)

Figure 8. ILS-24 (CANDON-1) as recovered beside the University of Northern Philippines Annex in Barangay Darapidap, Ilocos Sur (a) and NAMRIA reference point ILS-24 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point ILS-24 used as base station for the LiDAR acquisition.

Station Name	**ILS-24**	
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	17°11’46.25613” North 120°25’8.83897” East 12.287 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	438,210.77 m 1,901,900.937 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°11’40.20757” North 120°25’13.51659” East 46.616m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	225,489.39 m 1,902,971.42 m

(A)

(B)

Figure 9. GPS set-up over ABR – 3071 was recovered in front of Buhang National High School, Municipality of Magallanes, Agusan del Norte (a) and NAMRIA reference point ABR-3071 (b) as recovered by the field team.

Table 9. Details of the recovered NAMRIA horizontal control point ABR- 3071 used as base station for the LiDAR acquisition.

Station Name	ABR-3071	
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	17° 34’ 00.39935” 120° 38’ 57.99393” 96.489 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 3 PRS 92)	Easting Northing	252,863.056 meters 2,173,296.623 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17° 33’ 54.28829” North 120° 39’ 02.39944” East 130.194 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	250,495.042 meters 1,943,684.465 meters

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
4-Mar-14	1179P	1BLK27B063A	ILS-22 and ILS-24
4-Mar-14	7107G	2BLK07C063B	ABR-31 and ABR-32
7-Mar-14	7112G	2BLK06G066A & 2BLK06DS066A	ILS-13 and ILS-9
8-Mar-14	1195P	1BLK27ABS067A	ILS-22
8-Mar-14	7114G	2BLK07CS067A & 2BLK06G067A	ABR-31 and ILS-22
9-Mar-14	7116G	2BLK07B068A	ABR-31 and ABR-32
10-Mar-14	7118G	2BLK07D069A & 2BLK07G069A	ABR-32 and ILS-22
10-Mar-14	7119G	2BLK27A069B	ABR-32 and ILS-22
11-Mar-14	7120G	2BLK06F070A & 2BLK07A070A	ABR-31 and ABR-32
11-Mar-14	7121G	2BLK07GS070B	ABR-31 and ABR-32
28-May-16	4043G	2BLK7SA7149A	ABR-31 and ABR-3071

2.3 Flight Missions

Twelve (12) missions were conducted to complete the LiDAR Data Acquisition in Silay Floodplain, for a total of forty-seven hours and thirty-five minutes (47+35) hours for RP-C9322 and RP-C9022. All missions are acquired using the Pegasus and Gemini LiDAR system. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight Missions for LiDAR Data Acquisition in Silay 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
4-Mar-14	1179P	386.94	348.32	113.92	43.38	647	4	15
4-Mar-14	7107G	174.12	128.15	2.24	155.06	NA	3	17
7-Mar-14	7112G	243.42	205.04	2.21	155.09	NA	4	17
8-Mar-14	1195P	527.05	139.93	20.62	136.68	257	2	17
8-Mar-14	7114G	317.80	205.75	2.91	154.39	NA	4	23
9-Mar-14	7116G	183.39	205.74	1.25	156.05	NA	4	23
10-Mar-14	7118G	247.81	209.67	2.56	154.74	NA	4	22
10-Mar-14	7119G	140.10	235.53	4.42	152.88	NA	4	17
11-Mar-14	7120G	271.52	274.52	23.45	133.85	NA	4	11
11-Mar-14	7121G	148.07	166.54	11.60	145.70	NA	3	41
28-May-16	4043G	240.00	247.77	0.39	156.91	NA	4	16
28-May-16	4045G	115.00	121.49	2.10	155.20	NA	3	56
TOTAL	2995.22	2488.44	187.66	1699.93	904.00	47	35	

Table 12. 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
1410A	600	30	36	70	50	120	5
1414A	600	30	36	70	50	120	5
1438A	600	30	36	70	50	120	5
1440A	600	30	36	70	50	120	5
1442A	600	30	36	70	50	120	5
1444A	600	30	36	70	50	120	5
1450A	600	30	36	70	50	120	5
1452A	600	30	36	70	50	120	5
3727G	800	30	50	125	40	130	5
3729G	650	30	40	125	50	130	5
3753G	850	30	40	125	50	130	5
3757G	850	30	40	125	50	130	5

2.4 Survey Coverage

Silay floodplain is located in the province of Ilocos Sur and Abra. Municipalities of San Quintin, Tayum, La Paz, Peñarrubia, Pidigan,Banayoyo, Candon, Nagbukel, Narvacan, San Esteban, Santa Maria and Santiago are mostly covered by the survey (Annex 7). The list of municipalities and cities surveyed with at least (1) square kilometer coverage is shown in Table 13. The actual coverage of the LiDAR acquisition for Silay floodplain is presented in Figure 10.

Table 13. List of municipalites and cities surveyed during Silay floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
	San Quintin	62.29	62.29	100%
	Tayum	46.12	46.12	100%
	La Paz	55.19	54.94	100%
	Peñarrubia	36.84	36.84	100%
	Pidigan	58.13	58.13	100%
	San Isidro	41.69	41.46	99%
	Langiden	98.7	97.87	99%
	Dolores	44.89	40.61	90%
	Bangued	123.75	104.9	85%
	Pilar	92.2	72.96	79%
	Bucay	104.45	77.99	75%
	Manabo	83.34	33.24	40%
	San Juan	64.64	18.06	28%
	Villaviciosa	81.46	22.47	28%
	Lagangilang	91.54	21.22	23%
	Danglas	175.7	24.18	14%
	Lagayan	144.19	10.19	7%
	Luba	126.57	2.97	%

Ilocos Norte	Nueva Era	619.00	4.00	1%
Ilocos Sur	Banayoyo	23.23	23.23	100%
	Candon City	80.18	80.13	100%
	Nagbukel	36.46	36.46	100%
	Narvacan	97.18	97.18	100%
	San Esteban	17.27	17.27	100%
	Santa Maria	52.32	52.32	100%
	Santiago	65.57	65.48	100%
	Santa Lucia	43.88	43.44	99%
	Santa Catalina	10.83	10.67	98%
	Burgos	49.6	47.29	95%
	Santa	57.2	54.12	95%
	San Vicente	12.2	10.72	88%
	Galimuyod	32.81	27.97	85%
	Santa Cruz	105.95	88.8	84%
	Bantay	71.06	44.2	62%
	Lidlidda	39.48	24.37	62%
	Magsingal	78.9	39.51	50%
	Salcedo	69.23	31.8	46%
	Santo Domingo	50.36	22.5	45%
	Vigan City	24.01	9.49	40%
	San Juan	59.88	19.22	32%
	Caoayan	21.2	3.19	15%
	San Ildefonso	13.21	1.62	12%
	Suyo	148.52	12.18	8%
	San Emilio	138.02	1.85	1%
	Sigay	98.45	1.2	1%

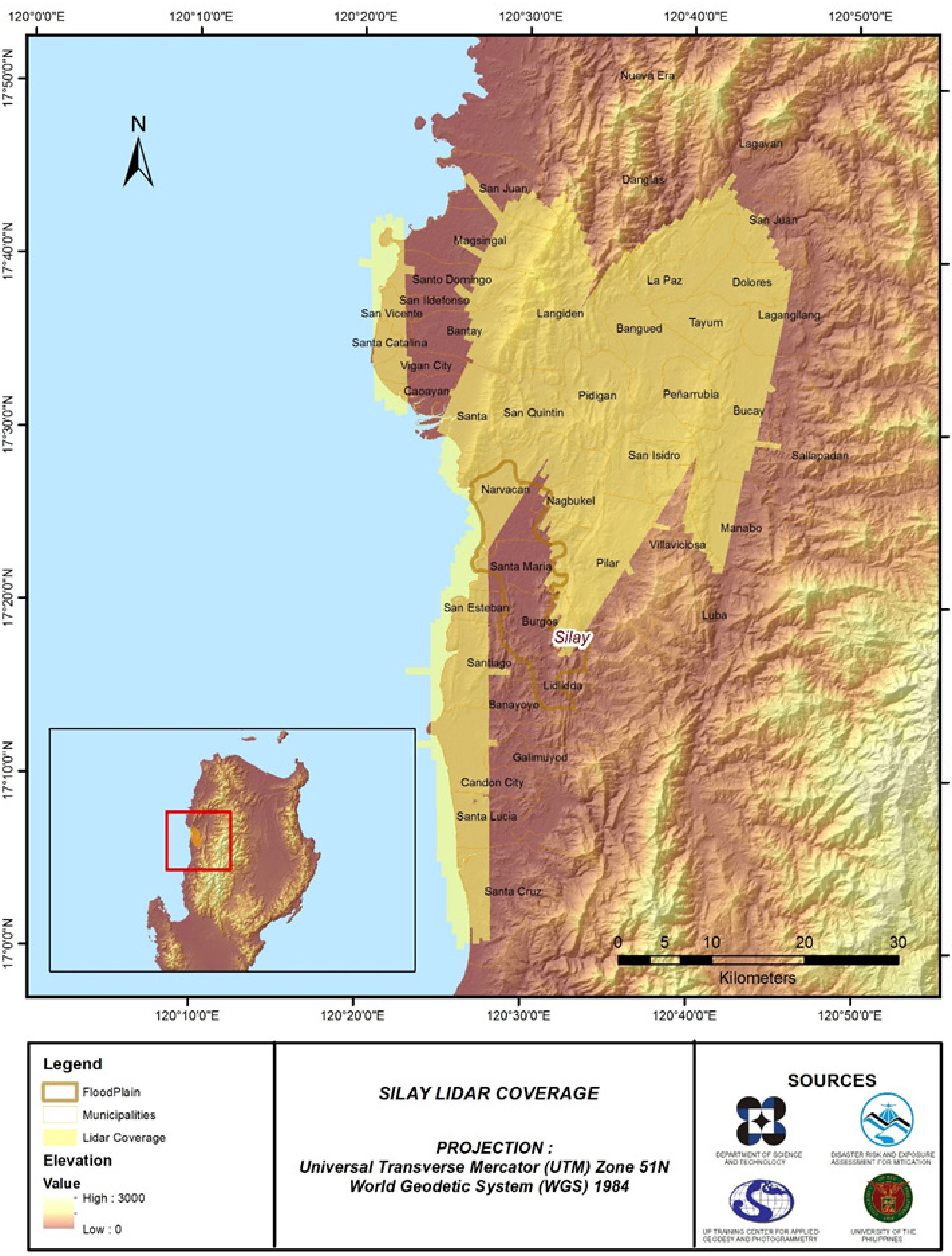


Figure 10. Actual LiDAR data acquisition for Silay floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SILAY FLOODPLAIN

EEngr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Harmond F. Santos, Jovy Anne S. Narisma , Engr. Ma. Ailyn L. Olanda, Engr. Antonio B. Chua Jr., Engr Kenneth A. Solidum, Engr. Jommer M. Medina, Carl Joshua S. Lacsina

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

3.1 Overview of the LiDAR Data Pre-Processing

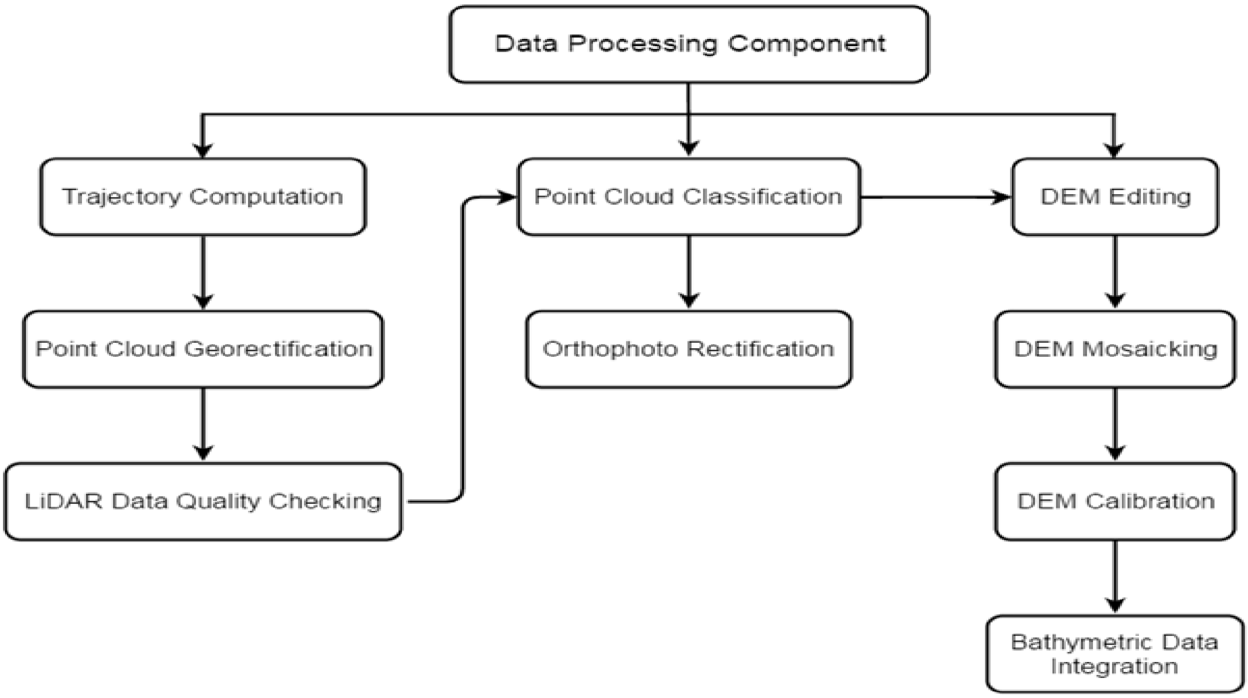


Figure 11. Schematic Diagram for Data Pre-Processing Component

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 11.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Silay floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey in Ilocos conducted on March 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini-CASI system while missions acquired during the second survey on May 2016 in Laoag were flown using the Gemini system. The Data Acquisition Component (DAC) transferred a total of 211.40 Gigabytes of Range data, 2.52 Gigabytes of POS data, 744.85 Megabytes of GPS base station data, and 55.40 Gigabytes of raw image data to the data server on April 22, 2014 for the first survey and July 1, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Silay was fully transferred on July 1, 2016, as indicated on the Data Transfer Sheets for Silay floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 4043G, one of the Silay flights, which is the North, East, and Down position RMSE values are shown in Figure 12. 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 May 28, 2016 00:00AM. The y-axis is the RMSE value for that particular position

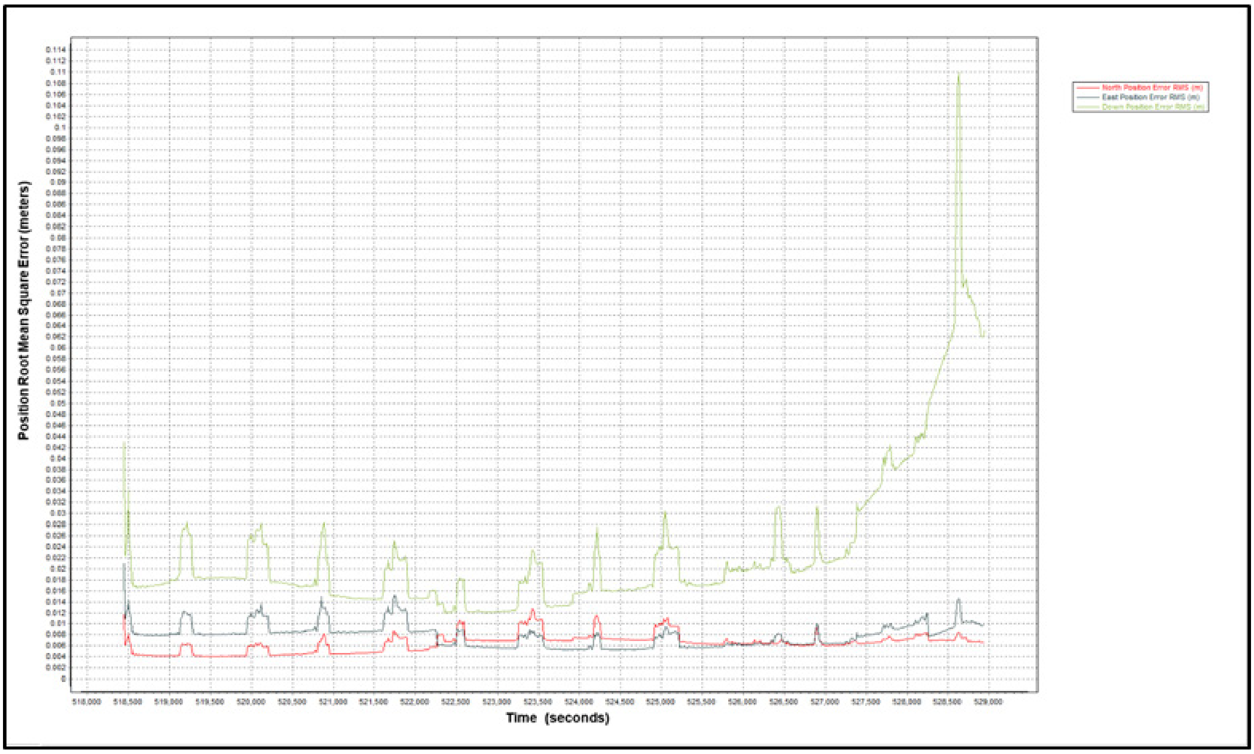


Figure 12. Smoothed Performance Metrics of a Silay Flight 4043G.

The time of flight was from 518400 seconds to 529000 seconds, which corresponds to morning of May 28, 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 minimize 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 12 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1. 60 centimeters, and the Down position RMSE peaks at 4.40 centimeters, which are within the prescribed accuracies described in the methodology.

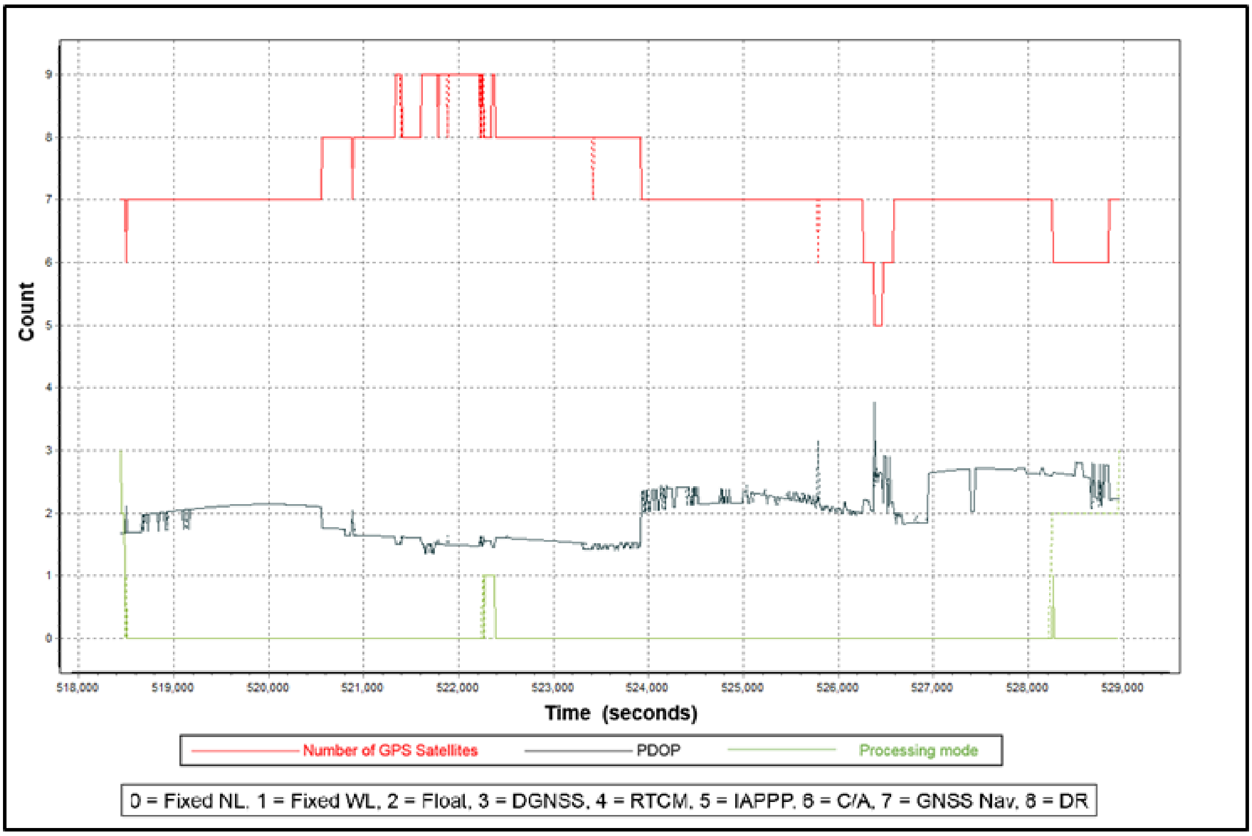


Figure 13. Solution Status Parameters of Silay Flight 4043G.

The Solution Status parameters of flight 4043G, one of the Silay flights, which are the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition. Majority of the time, the number of satellites tracked was between 6 and 9. The PDOP value 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 Silay flights is shown in Figure 14.

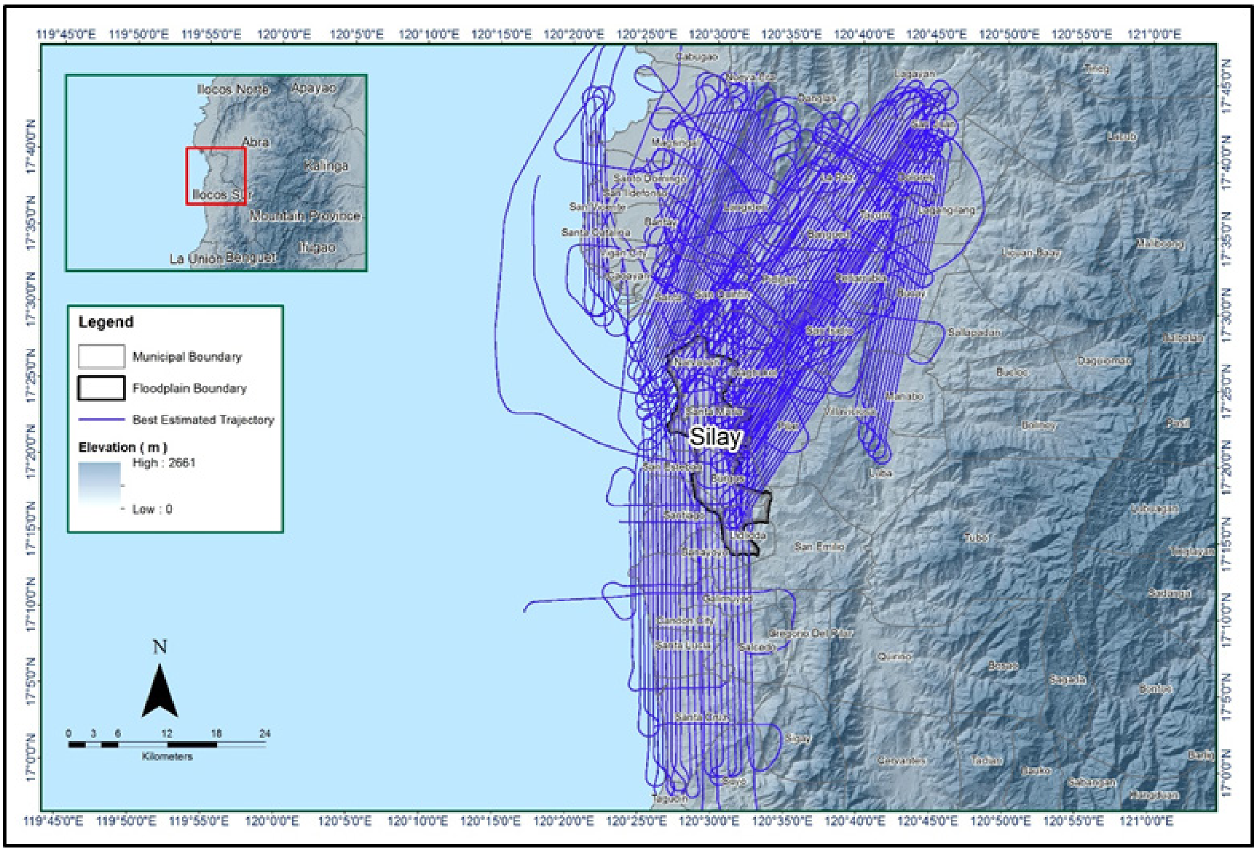


Figure 14. The best estimated trajectory of LiDAR missions conducted over the Silay floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 110 flight lines, with some flight line containing two channels, since the Gemini Casi systems contain one channel only and two channels for Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Silay floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Silay flights.

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000272
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000787
GPS Position Z-correction stdev (<0.01meters)	0.0092

The optimum accuracy is obtained for all Silay 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 Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Silay Floodplain is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

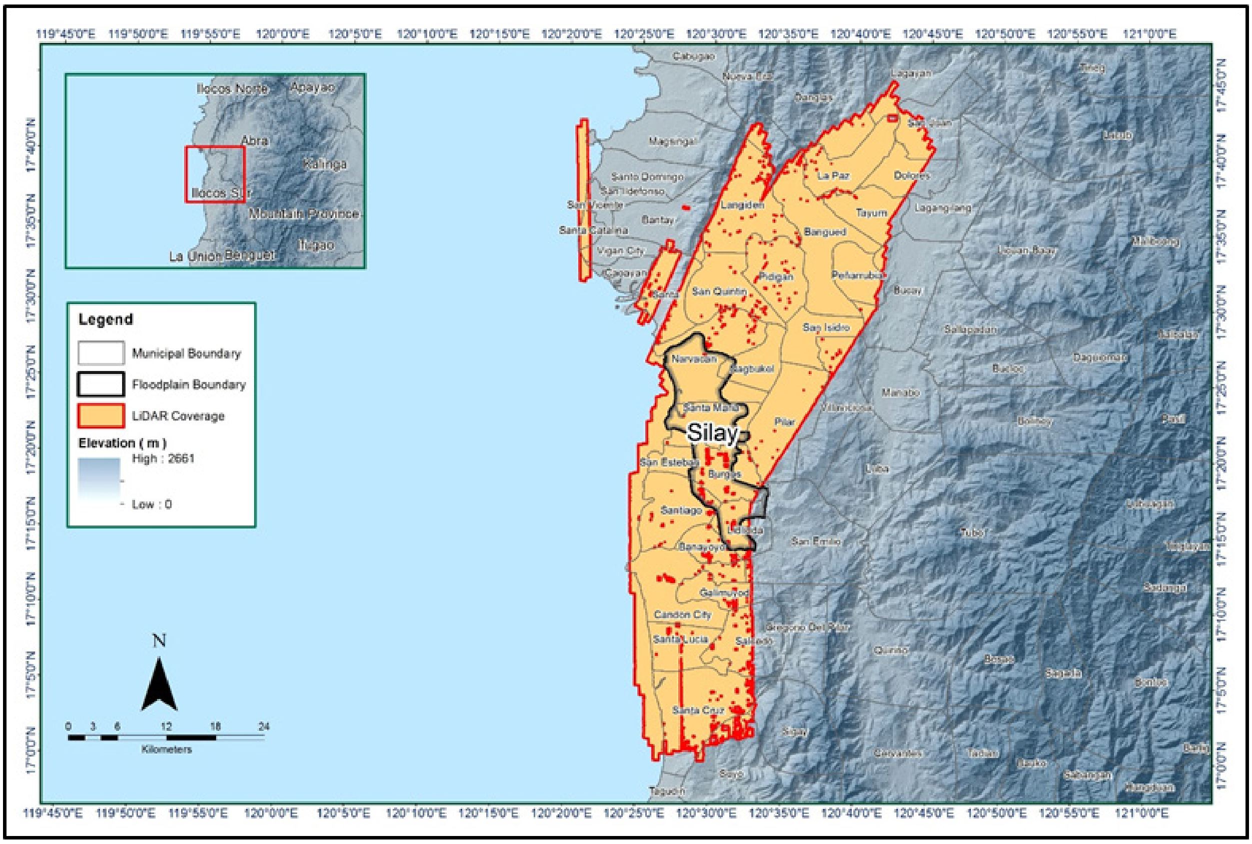


Figure 15. Boundary of the processed LiDAR data over Silay Floodplain

The total area covered by the Silay missions is 1922.38 sq.km that is comprised of eleven (11) flight acquisitions grouped and merged into ten (10) blocks as shown in Table 15

Table 15. List of LiDAR blocks for Silay floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Ilocos_Blk27A	7119GC	227.64
Ilocos_Blk27BCD	1179G	412.32
	1195G	
Ilocos_Blk6G	7112G	141.83
Ilocos_Blk7A	7120G	227.64
Ilocos_Blk7A_additional	7121G	41.20
Ilocos_Blk7B	7116G	199.83
Ilocos_Blk7C_supplement	7114G	87.67
Ilocos_Blk7G	7121GC	143.45
Laoag_Blk7A	4043G	114.25
	4045G	
Laoag_Blk7C	4043G	202.76
	4045G	
TOTAL		**1922.38 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 16. Since the Gemini system employ one channel and two channels for Pegasus system, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

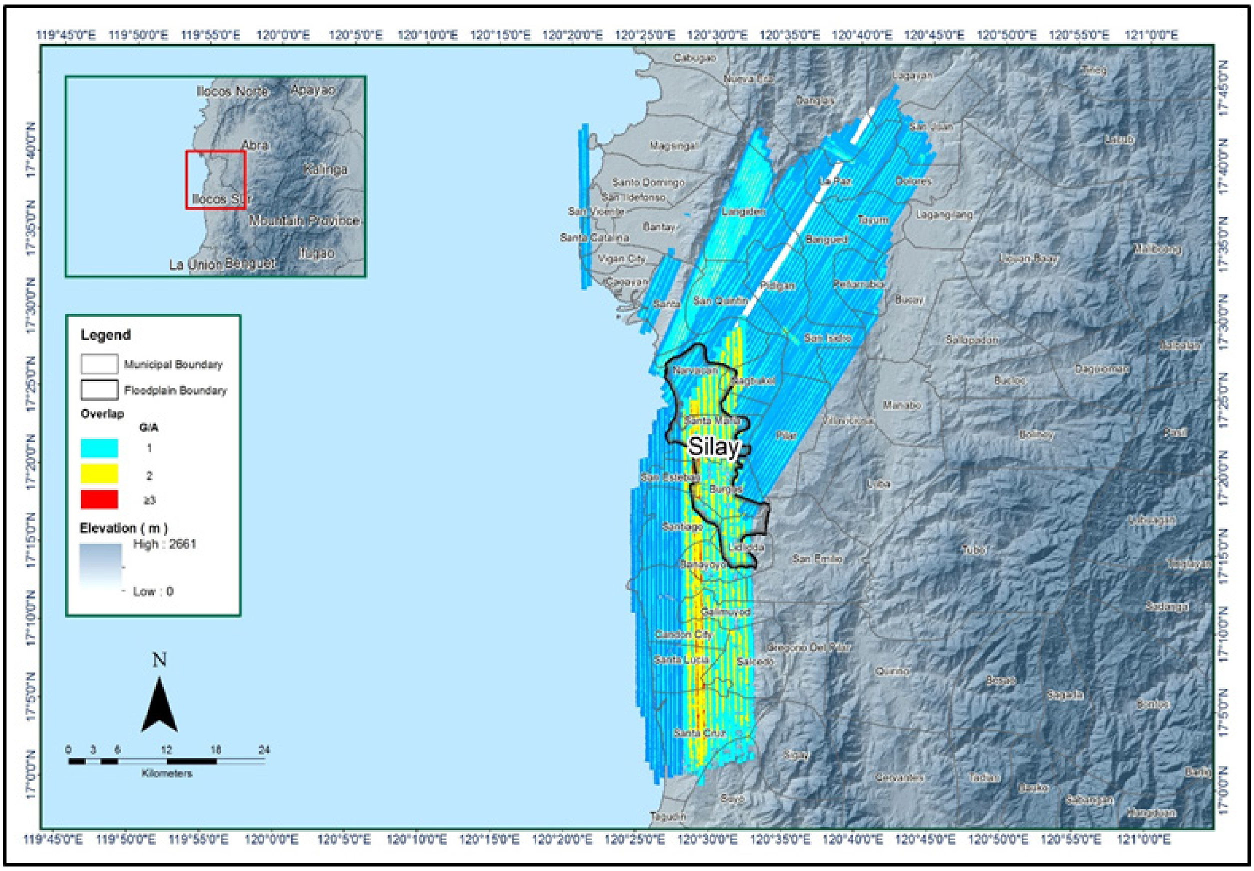


Figure 16. Image of data overlap for Silay floodplain.

The overlap statistics per block for the Silay 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 25.68% and 59.21% 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 17. It was determined that all LiDAR data for Silay floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.73 points per square meter.

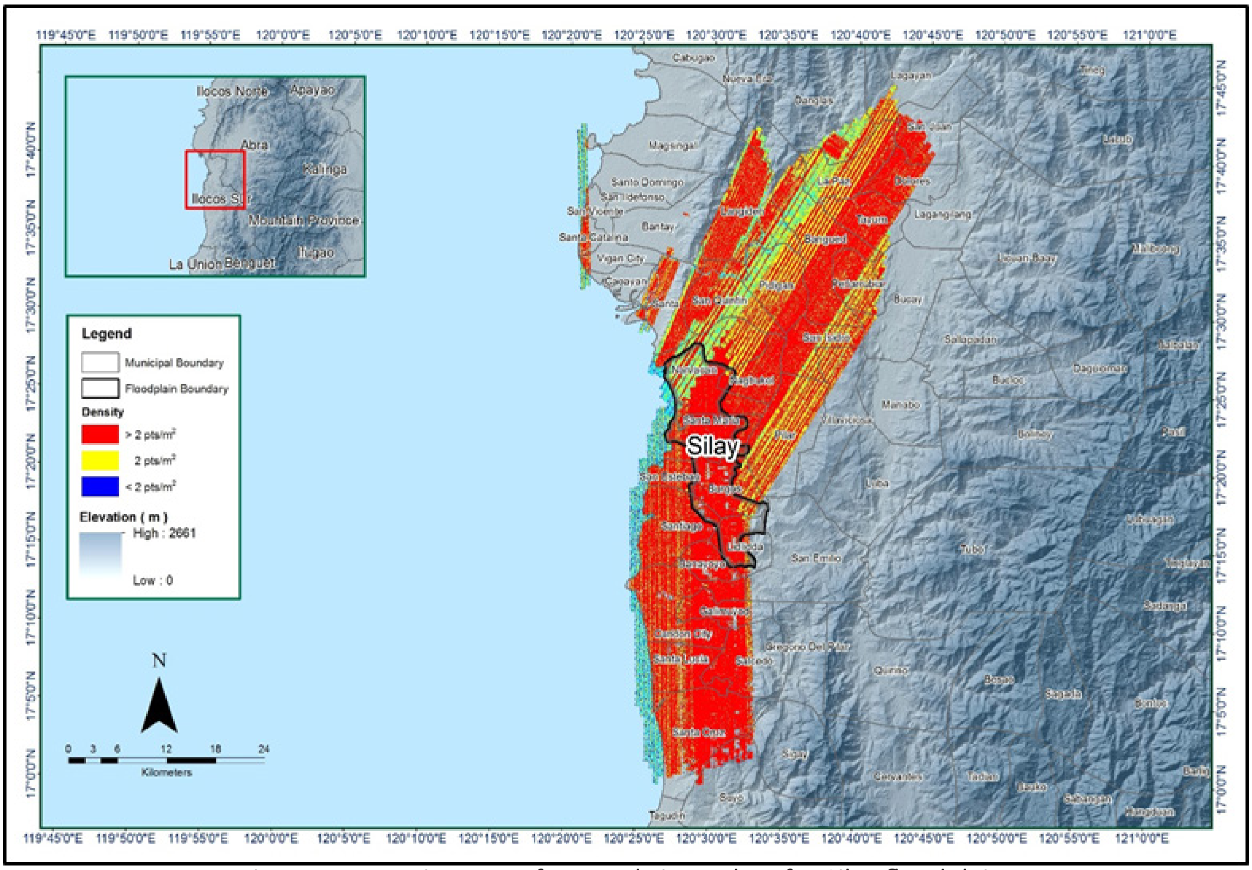


Figure 17. Density map of merged LiDAR data for Silay floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. 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.

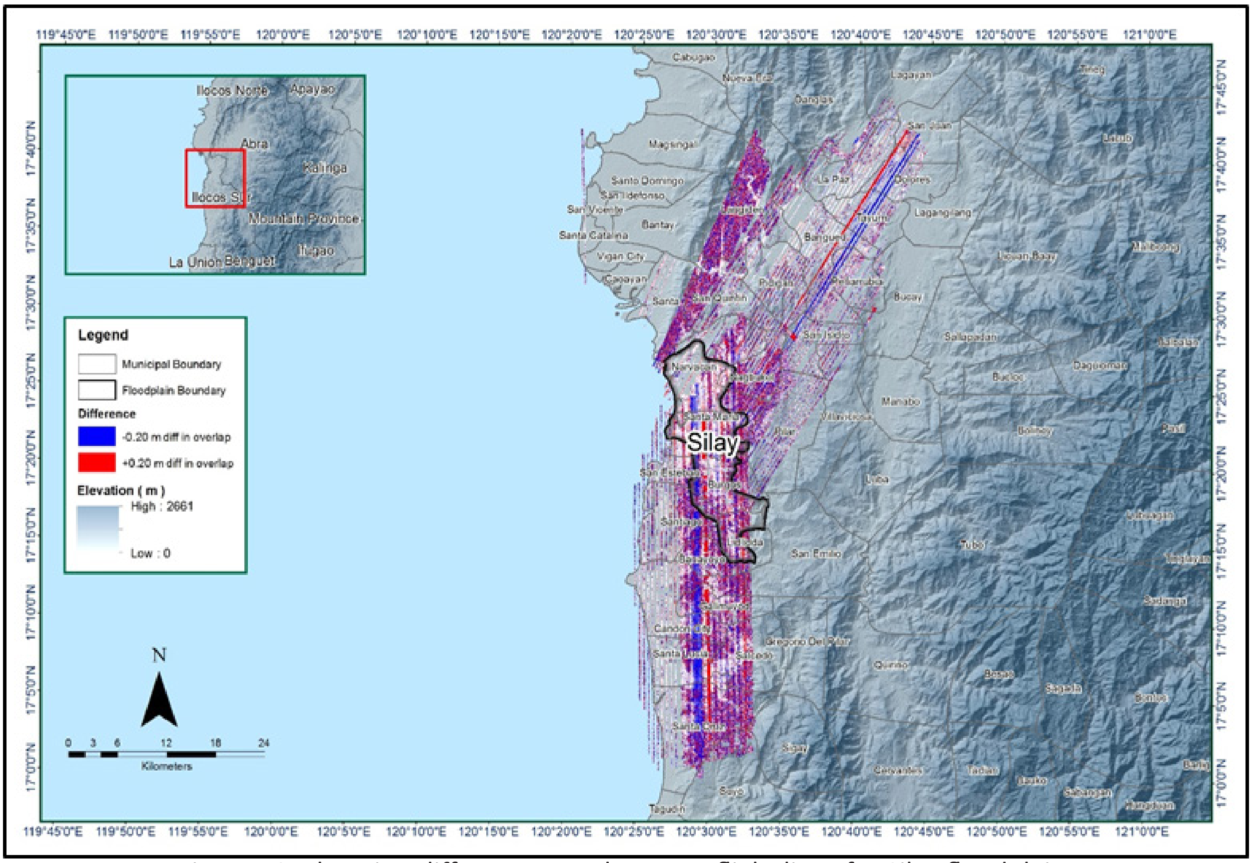


Figure 18. Elevation difference map between flight lines for Silay floodplain.

A screen capture of the processed LAS data from a Silaga flight 1444A loaded in QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

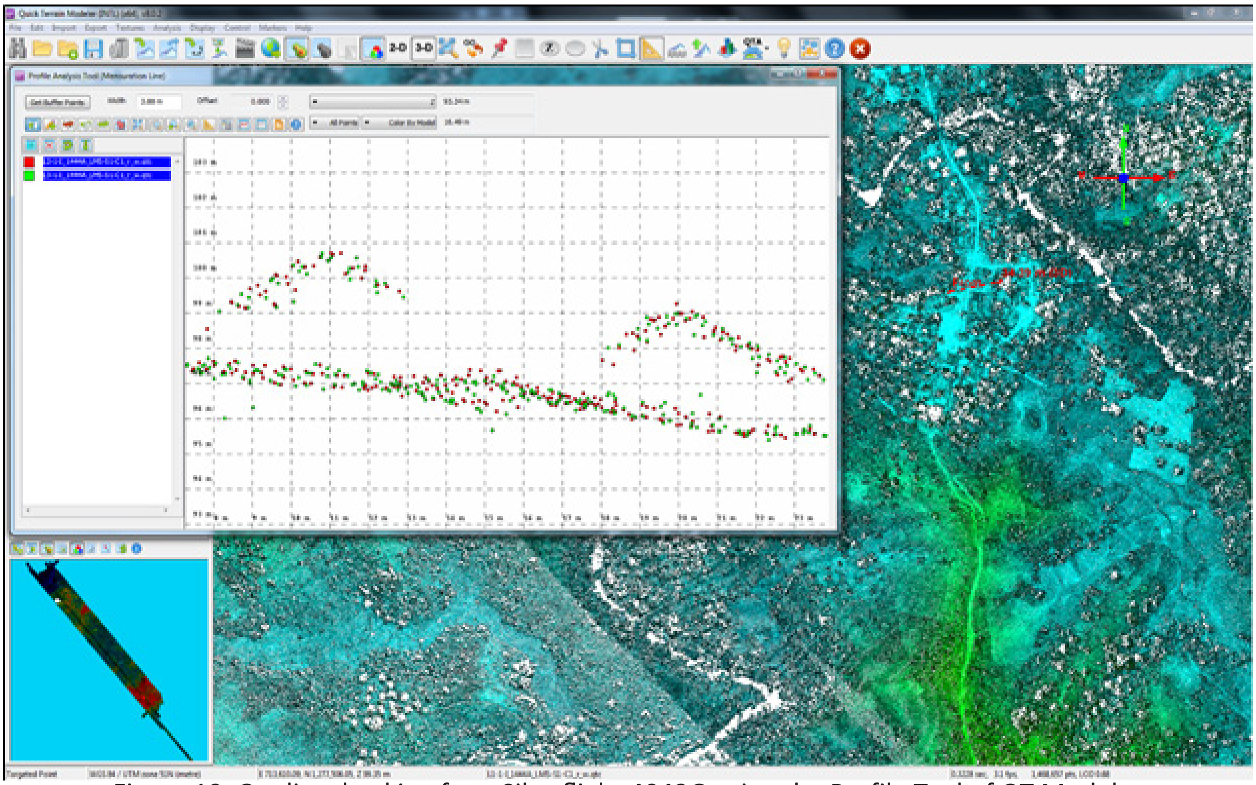


Figure 19. Quality checking for a Silay flight 4043G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Silay classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	862,184,993
Low Vegetation	635,995,198
Medium Vegetation	850,718,637
High Vegetation	1,909,826,683
Building	45,778,776

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Silay floodplain is shown in Figure 20. A total of 2,446 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 863.68 meters and 36.90 meters respectively.

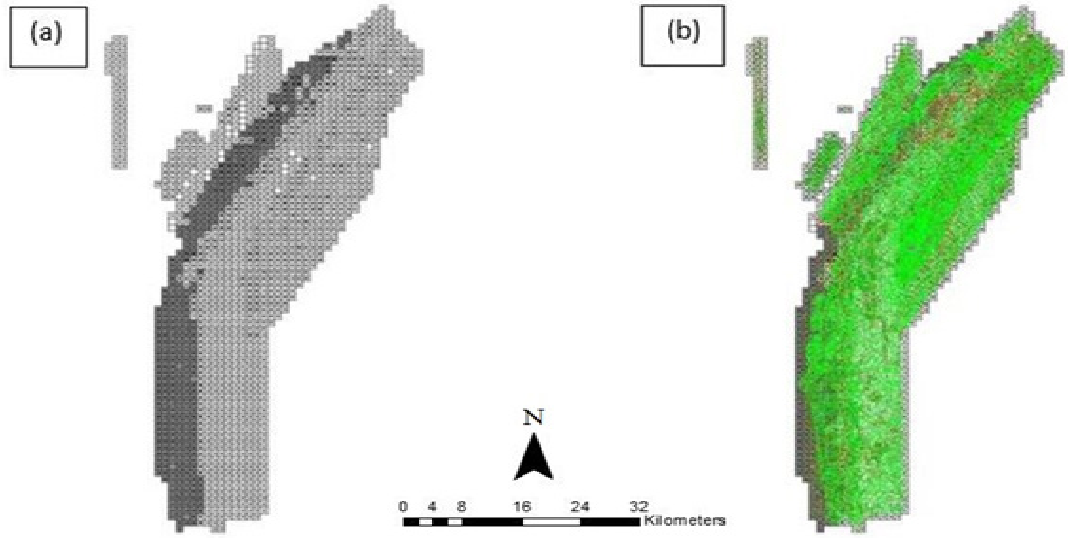


Figure 20. Tiles for Silay floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. 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.

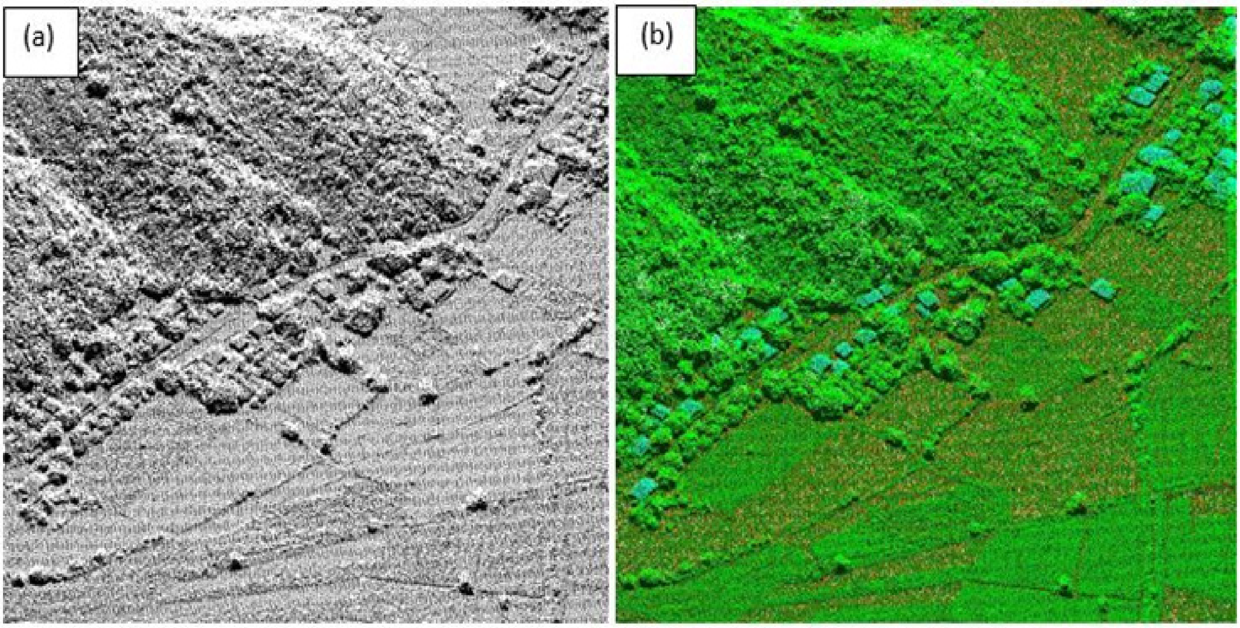


Figure 21. Point cloud before (a) and after (b) classification.

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

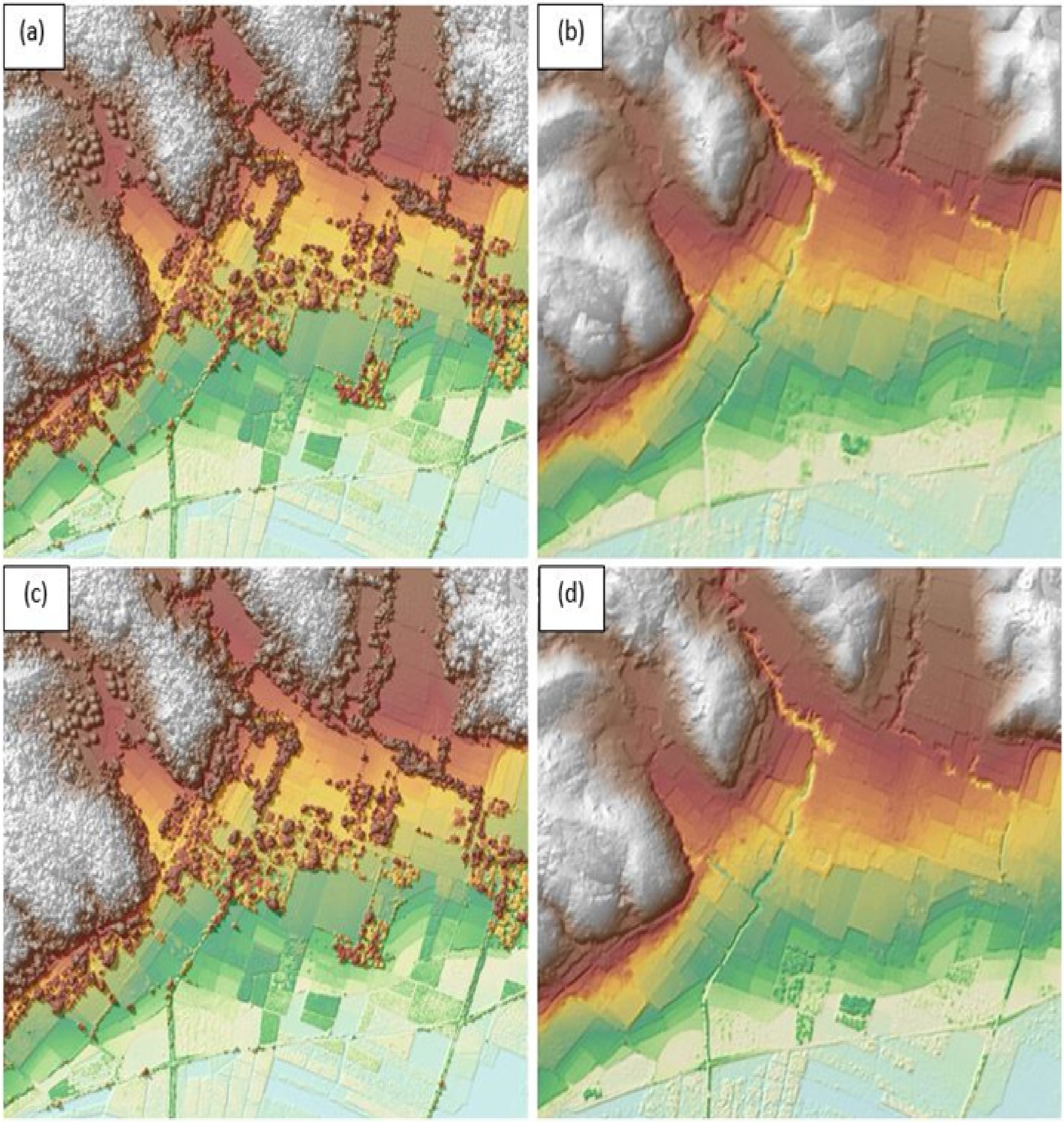


Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Silay floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Silay floodplain.

3.8 DEMs Editing and Hydro-Correction

Ten (10) mission blocks were processed for Silay flood plain. These blocks are composed of Ilocos and Laoag blocks with a total area of 1,922.38 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km)
Ilocos_Blk27A	227.64
Ilocos_Blk27BCD	412.32
Ilocos_Blk6G	141.83
Ilocos_Blk7A	227.64
Ilocos_Blk7A_additional	41.20
Ilocos_Blk7B	199.83
Ilocos_Blk7C_supplement	87.67
Ilocos_Blk7G	143.45
Laoag_Blk7A	114.25
Laoag_Blk7C	202.76
TOTAL	**1922.38 sq.km**

Portions of DTM before and after manual editing are shown in Figure 23. The river embankment (Figure 23a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23b) to allow the correct flow of water. The bridge (Figure 23c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23d) in order to hydrologically correct the river.

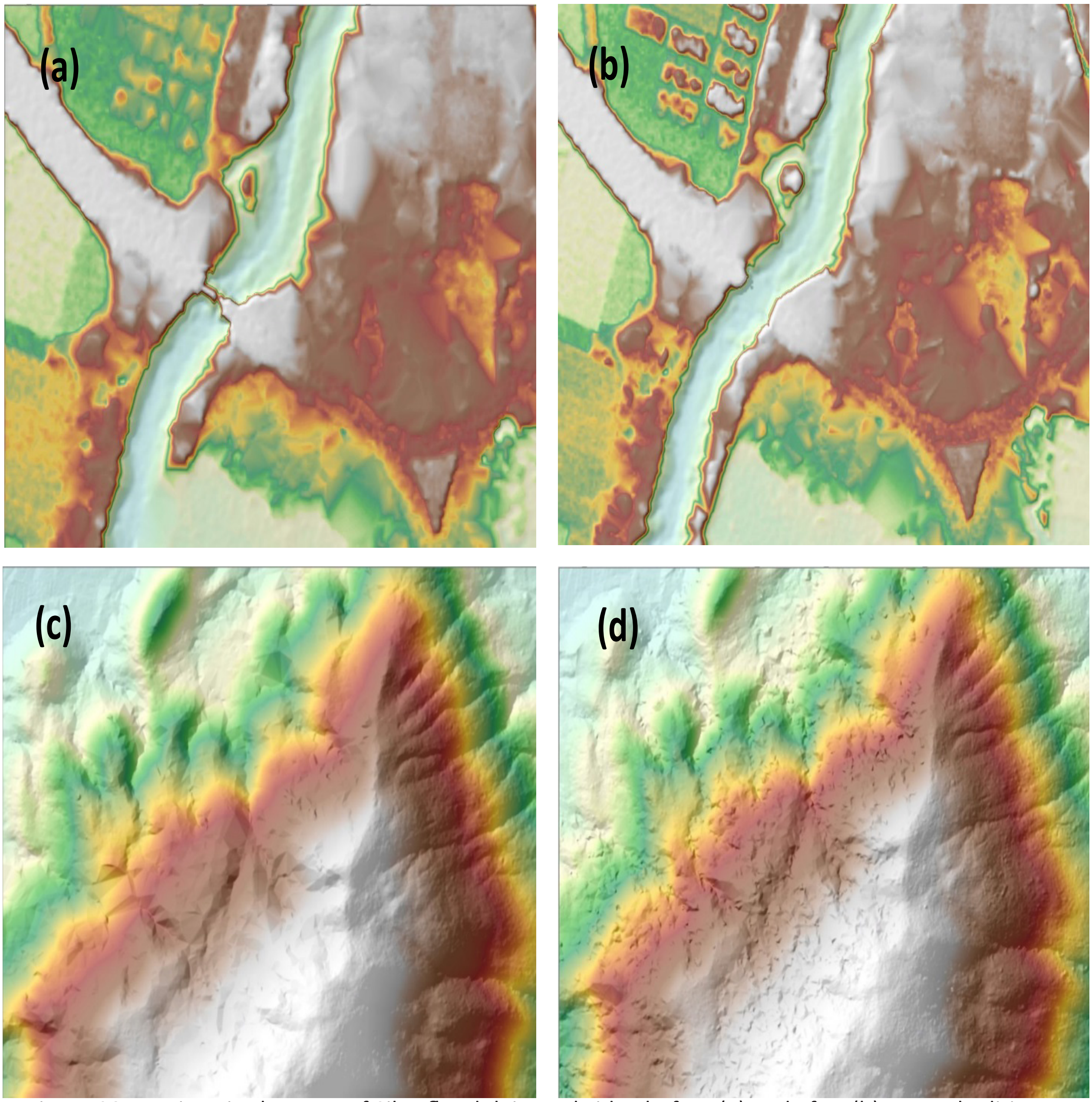


Figure 23. Portions in the DTM of Silay floodplain – a bridge before (a) and after (b) manual editing; a misclassified hill before (c) and after (d) data retrieval.

3.9 Mosaicking of Blocks

Ilocos_Blk5A 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.

Mosaicked LiDAR DTM for Silay floodplain is shown in Figure 24. It can be seen that the entire Silay floodplain is 100% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Silay floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Ilocos_Blk27A	+0.75	+3.17	+2.40
Ilocos_Blk27BCD	+2.00	+2.08	+0.30
Ilocos_Blk06G	+1.20	-1.90	-0.17
Ilocos_Blk07A	0.00	0.00	+2.90
Ilocos_Blk07A_additional	0.00	0.00	+2.75
Ilocos_Blk07B	+1.65	1.00	+2.90
Ilocos_Blk07C_supplement	+2.20	+0.50	+2.90
Ilocos_Blk07G	+2.20	+0.50	+2.90
Laoag_Blk07A	0.00	0.00	+2.64
Laoag_Blk07C	0.00	0.00	+2.51

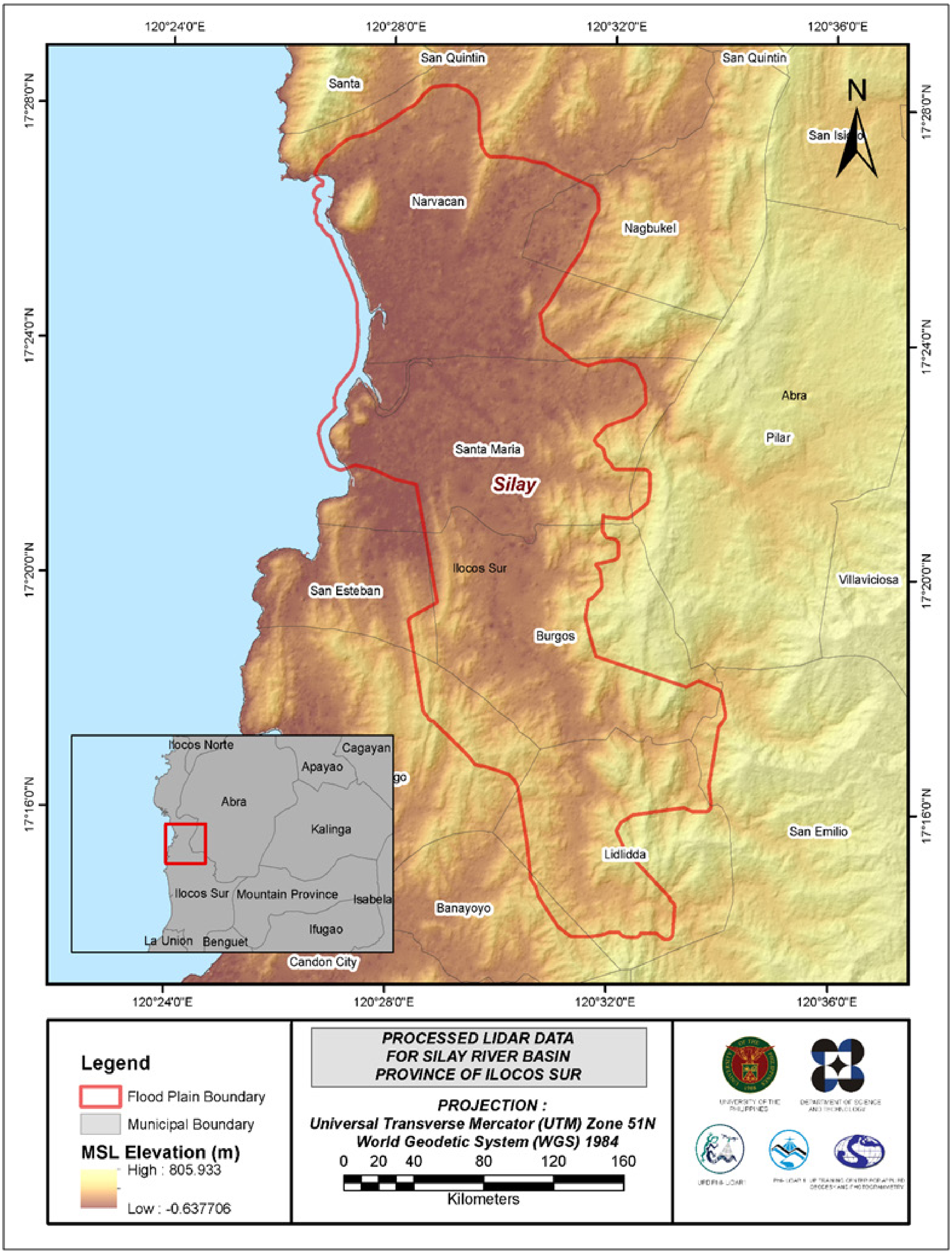


Figure 24. Map of Processed LiDAR Data for Silay Flood Plain

3.10 Calibration and Validation of Mosaicked LiDAR DEMs

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Silay to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 6555 survey points were used for calibration and validation of Silay LiDAR data. Random selection of 80% of the survey points, resulting to 6555 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 26 Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 3.48 meters with a standard deviation of 0.13 meters. Calibration of Silay LiDAR data was done by subtracting the height difference value, 3.48 meters, to Silay mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

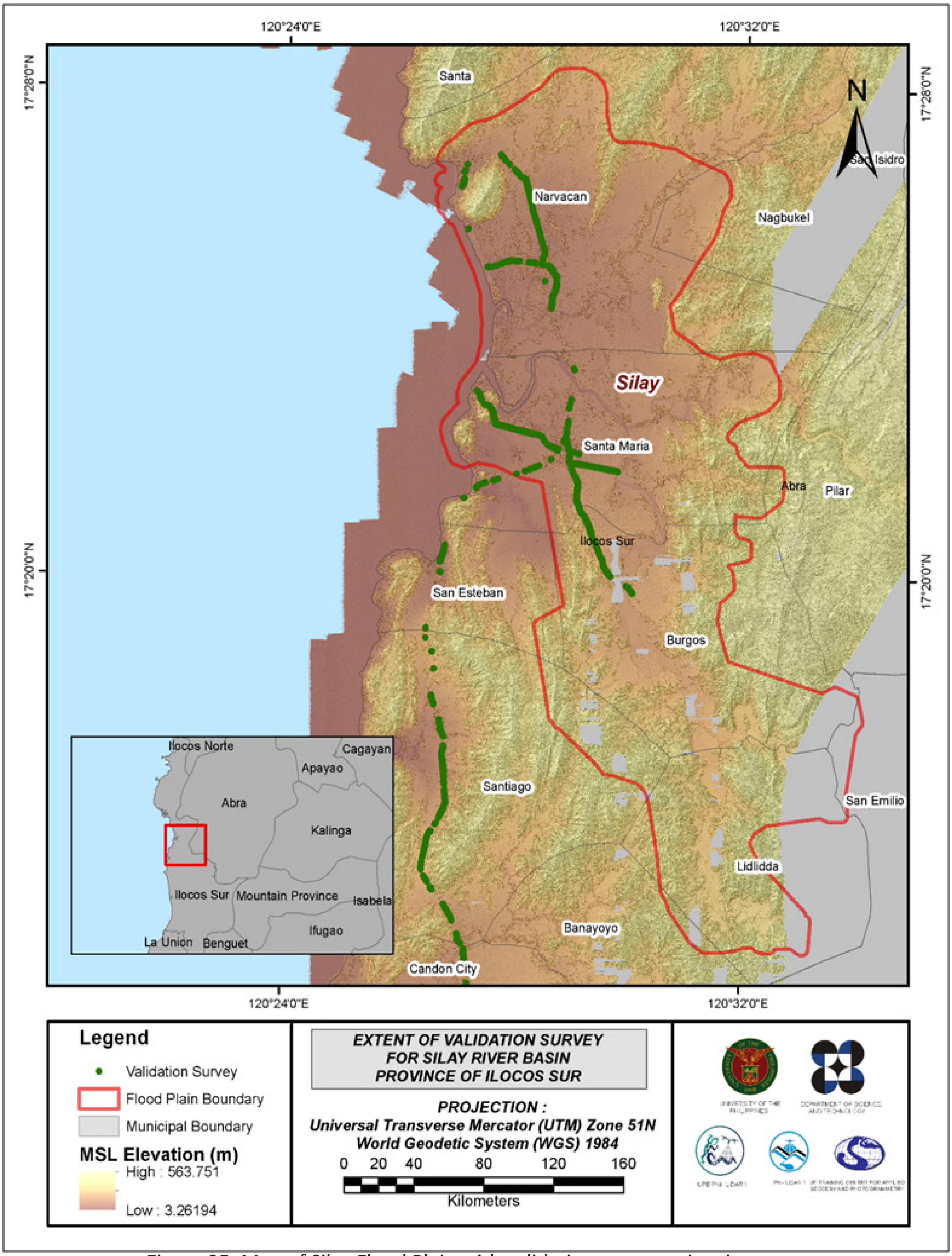


Figure 25. Map of Silay Flood Plain with validation survey points in green.

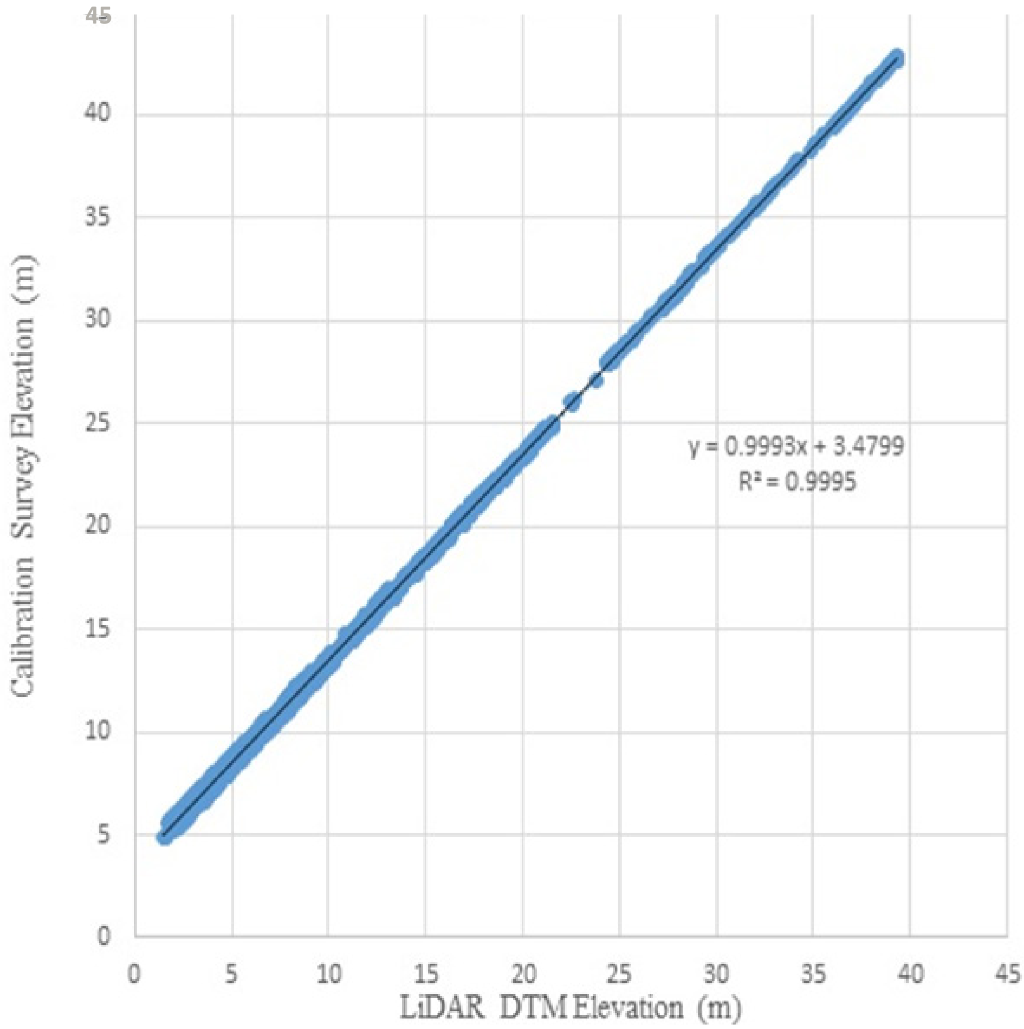


Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.48
Standard Deviation	0.13
Average	-3.47
Minimum	-3.74
Maximum	-3.21

The remaining 20% of the total survey points, resulting to 1994 points, were used for the validation of calibrated Silay DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.12 meters with a standard deviation of 0.12 meters, as shown in Table 20.

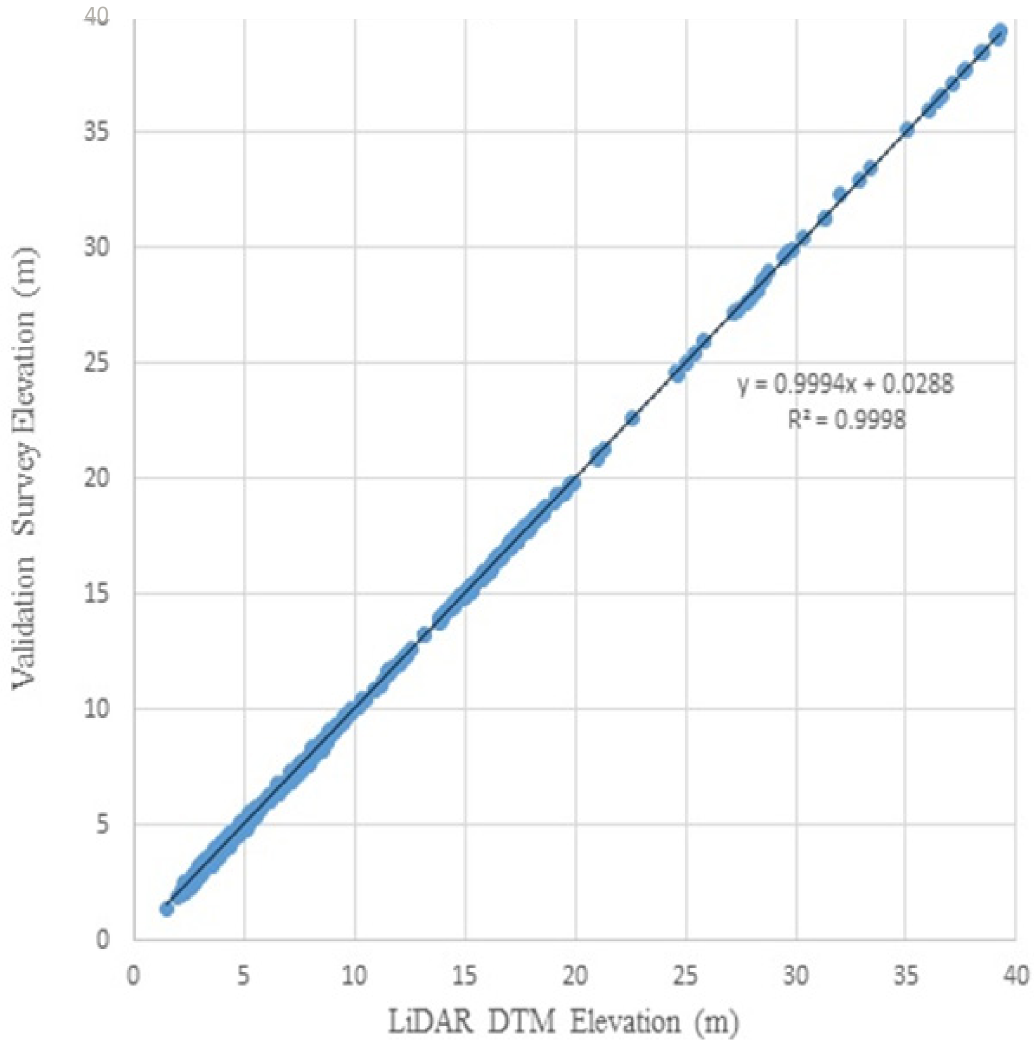


Figure 27. Correlation plot between validation survey points and LiDAR data

Table 20. Validation Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.12
Standard Deviation	0.12
Average	-0.02
Minimum	-0.28
Maximum	0.29

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Silay with 13,255 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 0.37 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Silay integrated with the processed LiDAR DEMs is shown in Figure 28.

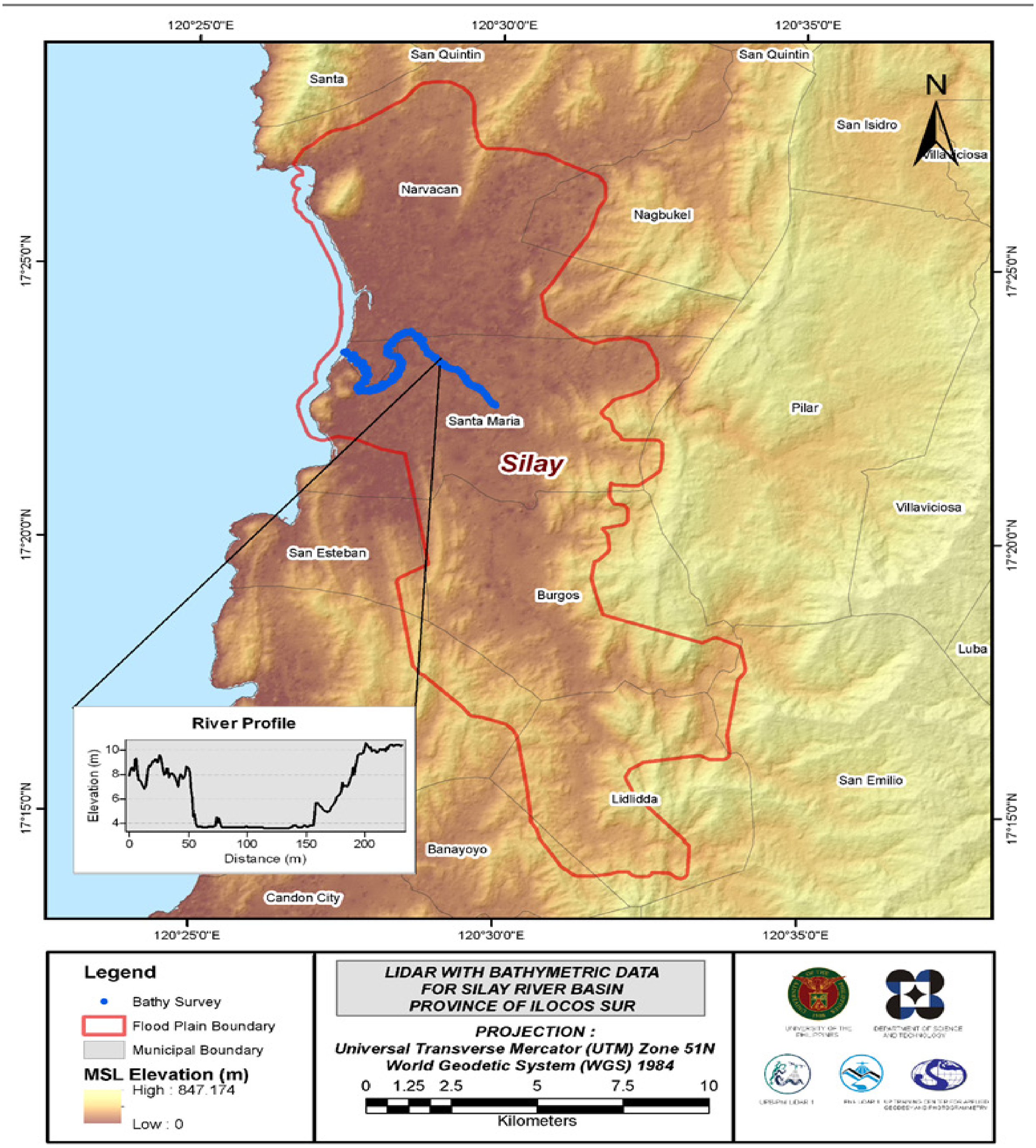


Figure 28. Extent of the bathymetric survey (in blue line) in Silay River and the LiDAR data validation survey (red).

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Silay floodplain, including its 200 m buffer, has a total area of 173.94 sq km. For this area, a total of 6.0 sq km, corresponding to a total of 820 building features, are considered for QC. Figure 29 shows the QC blocks for Silay floodplain.

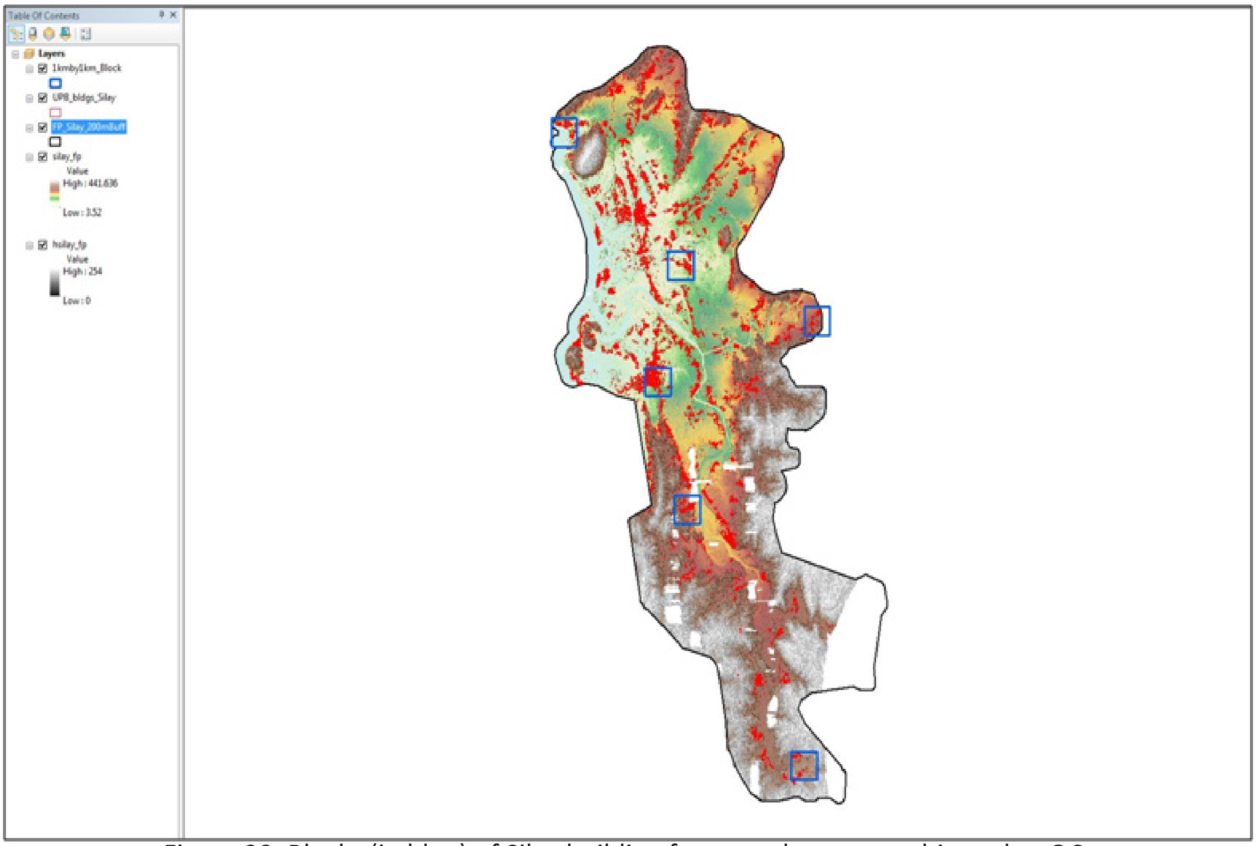


Figure 29. Blocks (in blue) of Silay building features that were subjected to QC.

Quality checking of Silay building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Silay Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Silaga	89.53	99.92	86.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 22,856 building features in Silay floodplain. Of these building features, 392 buildings were filtered out after height extraction, resulting to 22,464 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 10.47 m.

3.12.3 Feature Attribution

Data collected from various sources which includes OpenStreetMap and Google Maps/Earth were used in the attribution of building features. Areas where there is no available data were subjected for field attribution using ESRI's Collector App. The app can be accessed offline and data collected can be synced to ArcGIS Online when WiFi or mobile data is available.

Table 22 summarizes the number of building features per type. On the other hand, Table 23 shows the total length of each road type, while Table 24 shows the number of water features extracted per type.

Table 22. Building Features Extracted for Silay Floodplain.

Facility Type	No. of Features
Residential	21,614
School	475
Market	44
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	23
Barangay Hall	15
Military Institution	12
Sports Center/Gymnasium/Covered Court	11
Telecommunication Facilities	0
Transport Terminal	4
Warehouse	6
Power Plant/Substation	9
NGO/CSO Offices	5
Police Station	1
Water Supply/Sewerage	2
Religious Institutions	61
Bank	5
Factory	0
Gas Station	4
Fire Station	0
Other Government Offices	13
Other Commercial Establishments	156
Total	**22,464**

Table 23. Total Length of Extracted Roads for Silay Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Silay	167.45	32.31	13.67	17.27	0	230.70

Table 24. Number of Extracted Water Bodies for Silay Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Silay	27	23	0	0	0	50

A total of 57 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of Silay floodplain overlaid with its ground features.

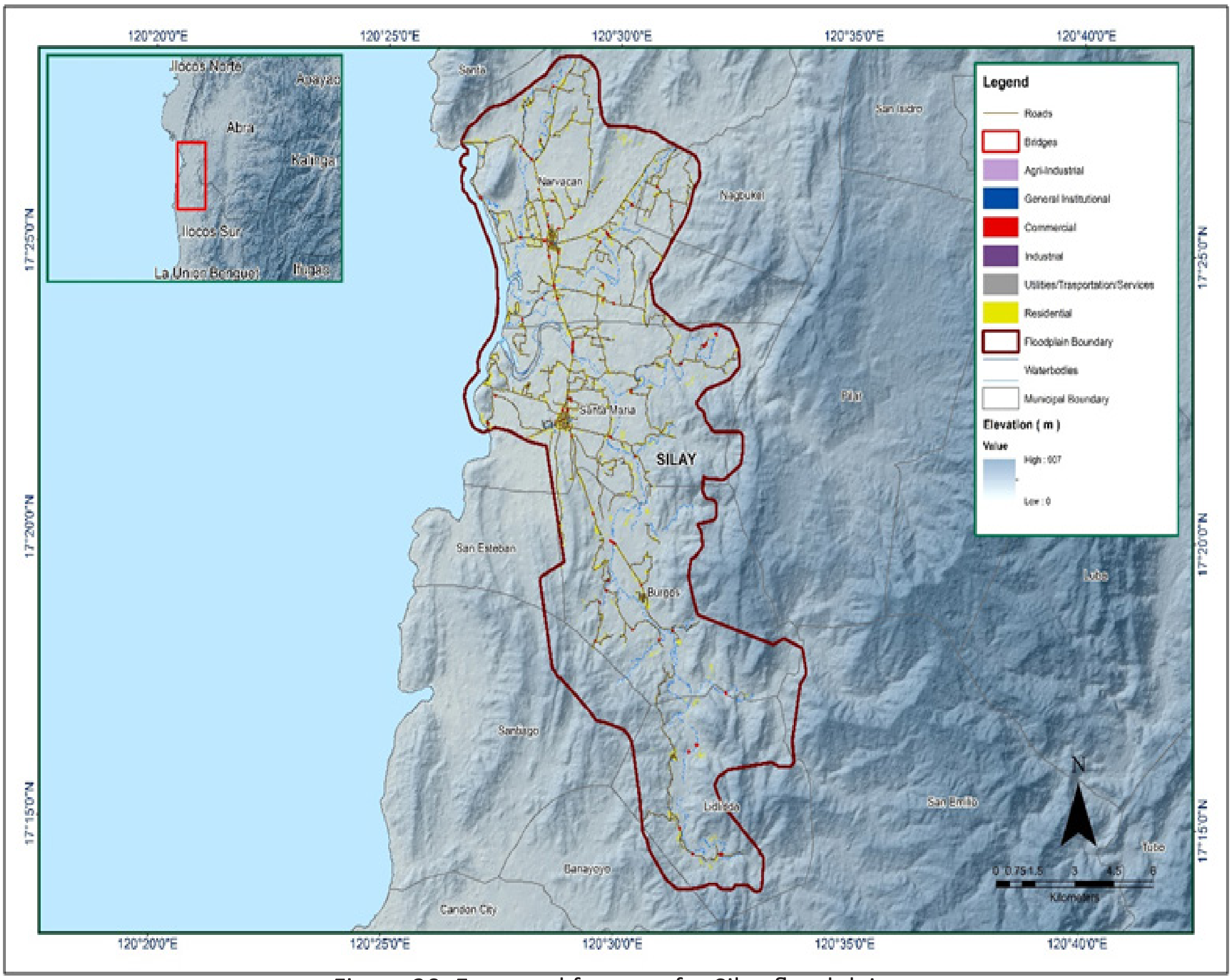


Figure 30. Extracted features for Silay floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto

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

4.1 Summary of Activities

DVBC conducted a field survey in Silay River on June 9 – 23, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Sta. Maria Bridge in Brgy. Quinsoriano, Municipality of Santa Maria and Burgos Bridge in Brgy. Poblacion Norte, Municipality of Burgos; validation points acquisition of about 78.68 km covering the Silay River Basin area; and bathymetric survey from its upstream in Brgy. Cabaroan in the Municipality of Santa Maria to the mouth of the river located in Brgy. Nagsayaoan in the same Municipality, with an approximate length of 8.867 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 31).

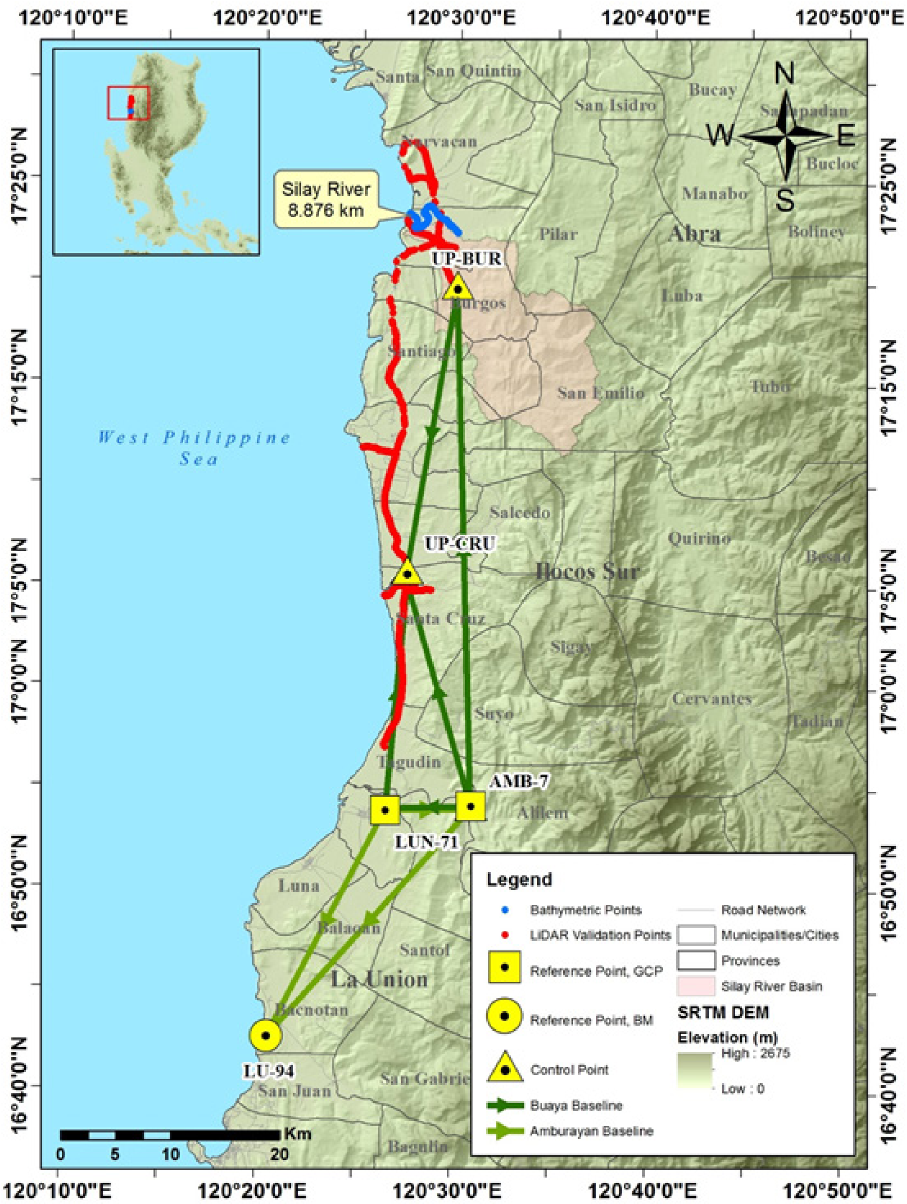


Figure 31. Silay River survey extent

4.2 Control Survey

A GNSS network from Amburayan River Survey was established on May 7, 2016 occupying the control points LUN-71, a second-order GCP, in Brgy. Gen. Prim West, Municipality of Bangar; and LU-94, a first-order BM, in Brgy. Nagsimbaanan, Muncipality of Bacnotan; both in La Union Province.

The GNSS network used for Silay River Basin is composed of two (2) loops established on June 10, 2016 occupying the following reference points: LUN-71, a second-order GCP from Amburayan Survey; and AMB-7, a NAMRIA established reference point with fixed value of elevation, located at the approach of Alilem Bridge, in Brgy. Kiat, Municipality of Alilem, Ilocos Sur, from Amburayan Survey.

Two (2) control points were established along the approach of bridges namely: UP-BUR, located at Burgos Bridge in Brgy. Poblacion Norte, Municipality of Burgos; and UP-CRU, at Sta. Cruz Bridge, in Brgy Quinsoriano, Municipality of Santa Cruz.

The summary of reference and control points and its location is summarized in Table 25 while the GNSS network established is illustrated in Figure 32.

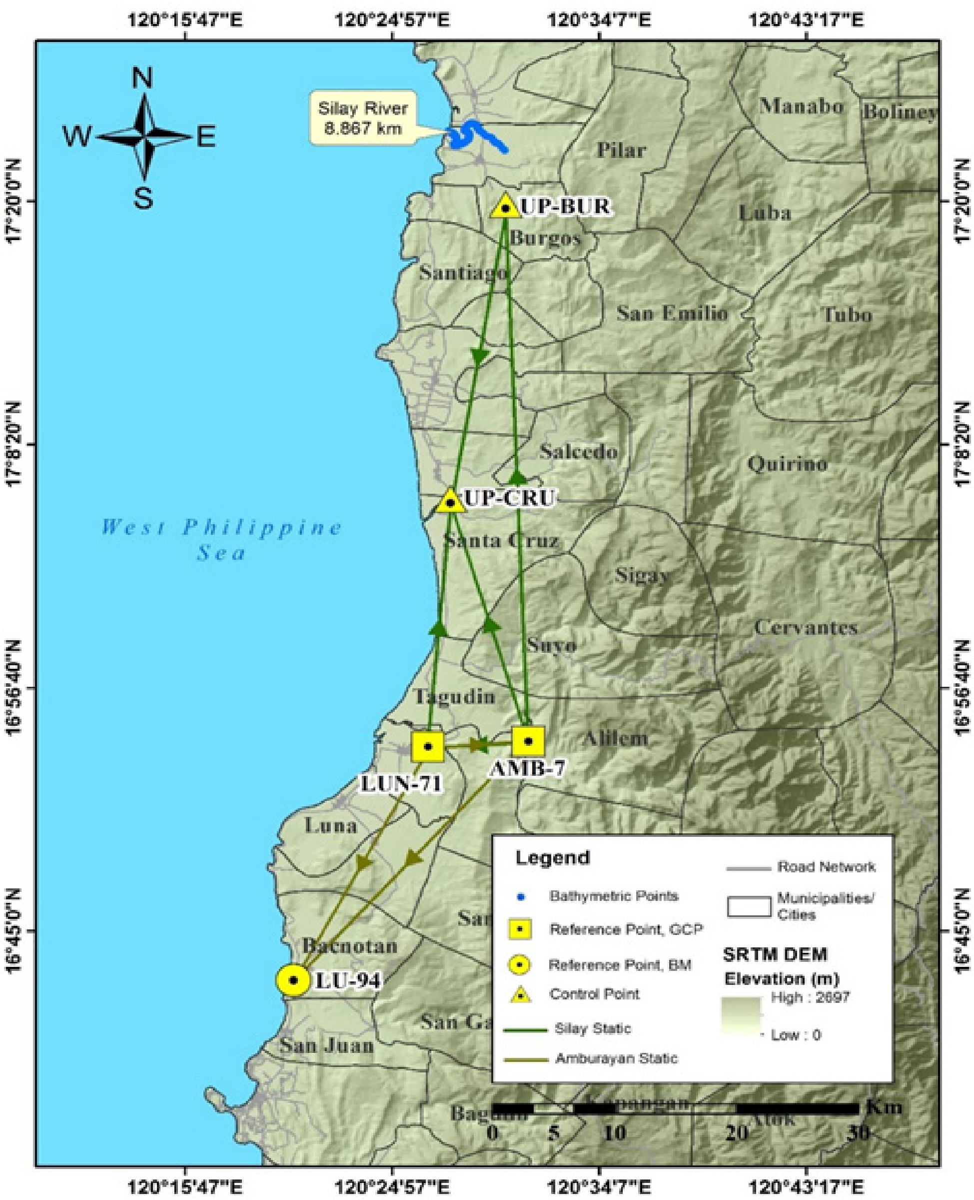


Figure 32. GNSS Network covering Slay River

Table 25. List of Reference and Control Points occupied for Silay River Survey
(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey on May 7, 2016						
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	12.794	2007
LU-94	1st order, BM	16°42'38.41914"N	120°20'35.13397"E	46.965	7.349	04-04-2014
AMB-7	Used as Marker	16°54'6.54124"N	120°30'58.32790"E	86.879	46.253	2010
Control Survey on June 10, 2016						
LUN-71	2nd order, GCP	16°53'51.58283"N	120°26'32.77383"E	52.356	12.794	2007
AMB-7	Fixed Control	16°54'6.54124"N	120°30'58.32790"E	86.879	46.253	2010
UP-BUR	UP Established	-	-	-	-	06-10-2016
UP-CRU	UP Established	-	-	-	-	06-10-2016

The GNSS set-ups on recovered reference points and established control points in Silay River are shown in Figure 33 to Figure 36.

Figure 33. GNSS base set up, Trimble® SPS 852, at LUN-71, situated beside the irrigation canal at the right intersection of barangay roads, in Brgy. General Prim West, Municipality of Sudipen, La Union

Figure 34. GNSS receiver setup, Trimble® SPS 882, at AMB-7, located at the approach of Alilem Bridge, in Brgy. Kiat, Municipality of Alilem, Ilocos Sur

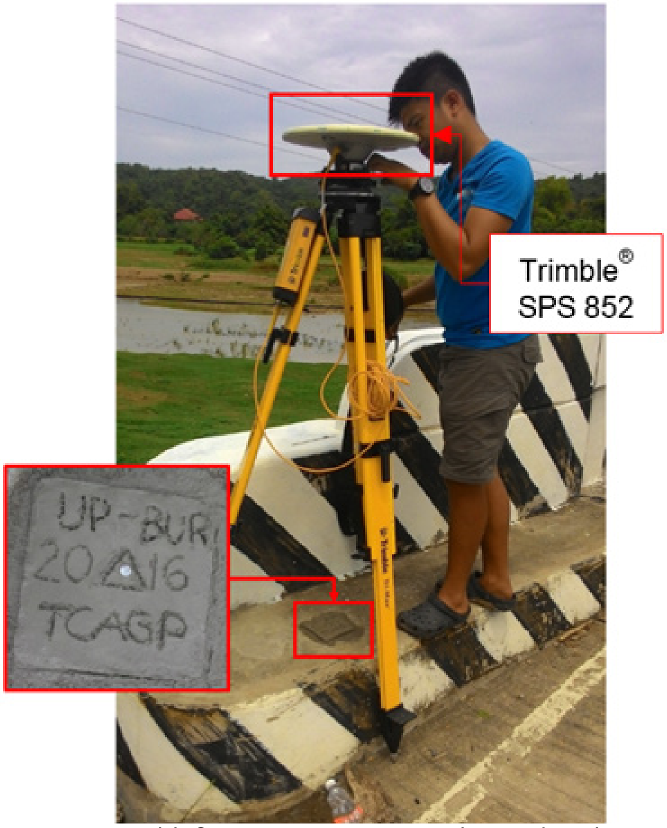


Figure 35. GNSS receiver setup, Trimble® SPS 852, at UP-BUR, located at the approach of Burgos Bridge, in Brgy. Poblacion Norte, Municipality of Burgos, Ilocos Sur

Figure 36. GNSS receiver setup, Trimble® SPS 882, at UP-CRU, located at the approach of Santa Cruz Bridge, in Brgy. Quinsoriano, Municipality of Santa Cruz, Ilocos Sur

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking 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 Silay River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline Processing Summary Report for Silay River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-BUR --- AMB-7	06-10-16	Fixed	0.004	0.013	357°51'02"	47547.951	-33.725
UP-BUR --- UP-CRU	06-10-16	Fixed	0.004	0.014	189°25'31"	26406.856	-4.843
AMB-7 --- LUN-71	06-10-16	Fixed	0.004	0.012	266°39'44"	7872.513	-34.551
AMB-7 --- UP-CRU	06-10-16	Fixed	0.005	0.017	344°06'39"	22317.155	-38.497
LUN-71 --- UP-CRU	06-10-16	Fixed	0.005	0.018	4°32'26"	21992.529	-3.979

As shown Table 26 a total of five (5) baselines were processed with reference points LUN-71 and AMB-7 held fixed for grid and elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. Looking at the Adjusted Grid Coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm for each control point; or in equation form:

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

where:

xe is the Easting Error,
ye is the Northing Error, and
ze is the Elevation Error

For complete details, see the Network Adjustment Report shown in Table 28 to Table 31.

The eight (8) control points: SME-18, SE-85, SME-12, SMR-3322, SE-49, SM-33S, UP-CNG, and UP-CLG were occupied and observed simultaneously to form a GNSS loop. Coordinates of SME-18 and elevation values SE-85 were held fixed during the processing of the control points, as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 27. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LUN-71	Local	Fixed	Fixed	Fixed	
AMB-7	Local	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 28. The fixed control point LUN-71 and AMB-7 have no values for grid and elevation errors.

Table 28. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LU-71	227541.709	?	1870002.301	?	12.794	?	LLh
AMB-7	235409.911	?	1870361.711	?	46.253	?	LLh
UP-BUR	234232.833	0.043	1917917.546	0.055	14.873	0.042	
UP-CRU	229569.844	0.021	1891912.463	0.026	9.383	0.041	

With the mentioned equation, $\sqrt{((Xe)^2+(Ye)^2)}<20\text{cm}$ for horizontal and $Ze<10$ cm for the vertical; the computation for the accuracy are as follows:

LUN-71
horizontal accuracy = Fixed
vertical accuracy = Fixed

AMB-7
horizontal accuracy = Fixed
vertical accuracy = Fixed

UP-BUR
horizontal accuracy = $\sqrt{((4.3)^2 + (5.5)^2}$
= $\sqrt{(18.49 + 30.25)}$
= 6.98 < 20 cm
vertical accuracy = 4.2 cm < 10 cm

UP-CRU
horizontal accuracy = $\sqrt{((2.1)^2 + (2.6)^2}$
= $\sqrt{(4.41 + 6.76)}$
= 3.34 < 20 cm
vertical accuracy = 4.1 cm < 10 cm

Following the given formula and based on the result of the computations the horizontal and vertical accuracy conditions of the two occupied control points are satisfied.

Table 29. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
LUN-71	N16°53'51.58283"	E120°26'32.77383"	52.356	?	LLh
AMB-7	N16°54'06.54124"	E120°30'58.32790"	86.879	?	LLh
UP-BUR	N17°19'52.14111"	E120°29'57.93445"	53.174	0.042	
UP-CRU	N17°05'44.74025"	E120°27'31.66275"	48.353	0.041	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 30.

Table 30. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on May 7, 2016							
LUN-71	2nd order, GCP	16°53’51.58283”N	120°26’32.77383”E	52.356	1870002.301	227541.709	12.794
LU-94	1st order, BM	16°42’38.41914”N	120°20’35.13397”E	46.965	1849438.439	216674.512	7.349
AMB-7	Used as Marker	16°54’06.54124”N	120°30’58.32790”E	86.879	1870361.711	235409.911	46.253
Control Survey on June 10, 2016							
LUN-71	2nd order, GCP	16°53’51.58283”N	120°26’32.77383”E	52.356	1870002.301	227541.709	12.794
AMB-7	Fixed Control	16°54’06.54124”N	120°30’58.32790”E	86.879	1870361.711	235409.911	46.253
UP-BUR	UP Established	17°19’52.14111”N	120°29’57.93445”E	53.174	1917917.546	234232.833	14.873
UP-CRU	UP Established	17°05’44.74025”N	120°27’31.66275”E	48.353	1891912.463	229569.844	9.383

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

Cross-section and as-built survey were conducted on June 12 and 16, 2016 at the upstream side of Burgos Bridge in Brgy. Poblacion Norte, Municipality of Burgos, as shown in Figure 37. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey as shown in Figure 38.


Figure 37. Burgos Bridge facing upstream

Figure 38. As-Built Survey of Burgos Bridge

Another cross-section and as-built survey were conducted on June 16, 2016 at the upstream side of Santa Maria Bridge in Brgy. Maynganay Norte, Municipality of Santa Maria, as shown in Figure 39. A Total Station was used through Open Traverse method for this survey as shown in Figure 40.

Figure 39. Sta. Maria Bridge facing upstream

Figure 40. Cross section Survey of Santa Maria Bridge using Total Station

The cross-sectional line of Burgos Bridge is about 351.490 m with three hundred forty (340) cross-sectional points; while the length of the cross-sectional line for Sta. Maria Bridge is about 414.886 m with ninety-seven (97) cross-sectional points acquired. The control point UP-CRU was used as the GNSS base station for both surveys. The location maps, cross-section diagrams, and the bridge data forms are shown in Figure 41 to Figure 45.

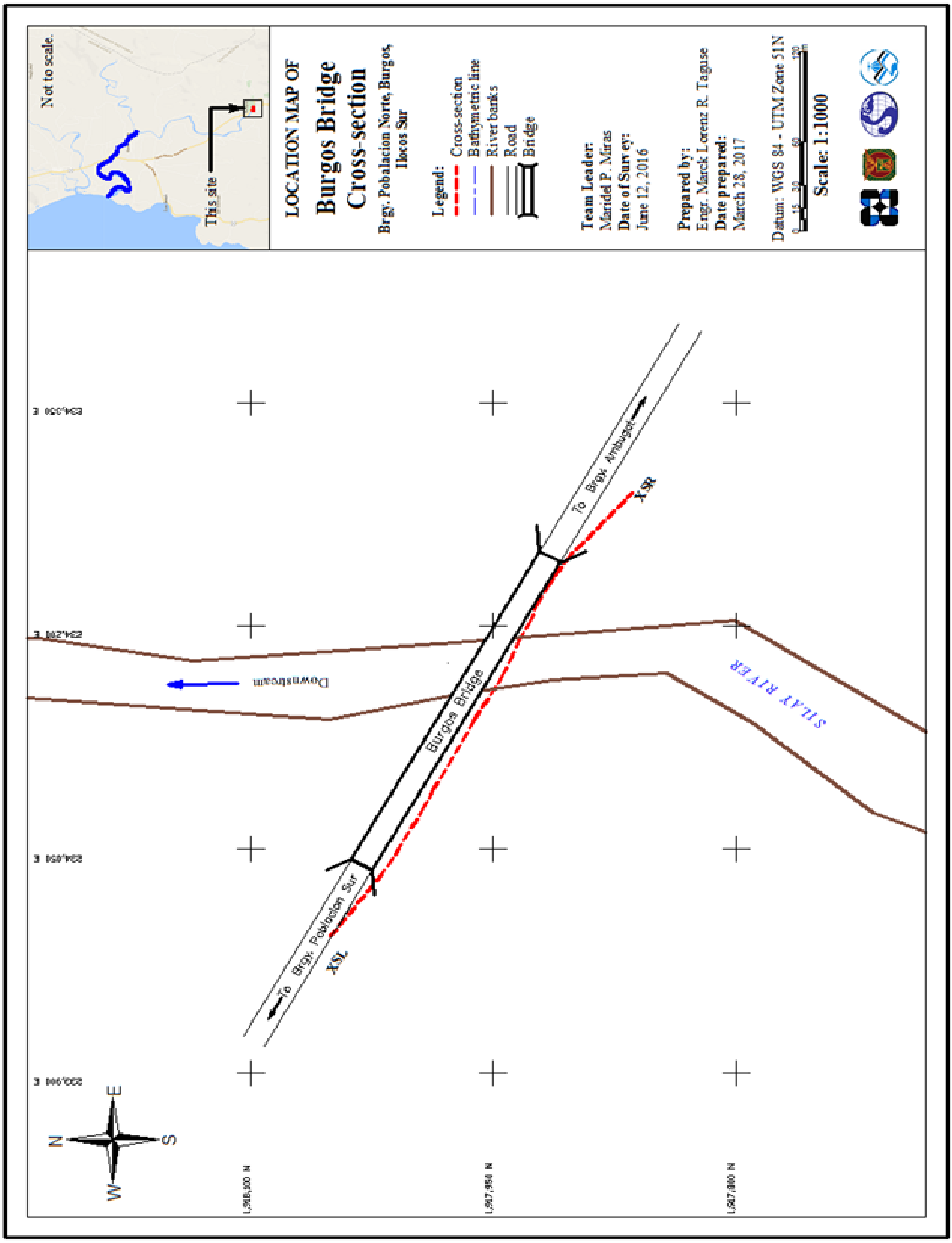


Figure 41. Burgos bridge cross-section location map

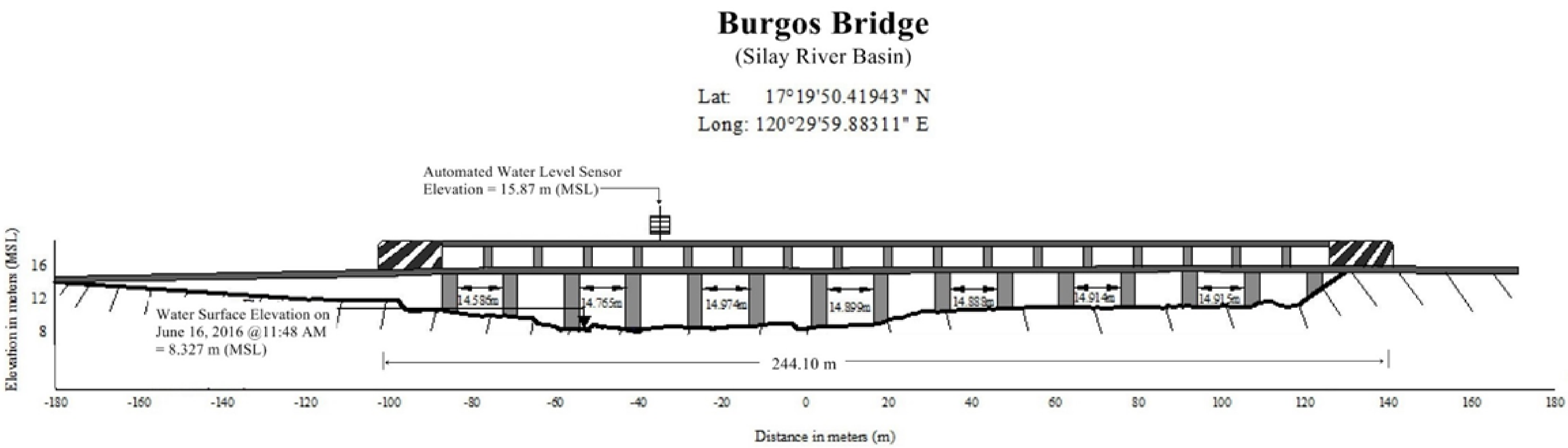


Figure 42. Burgos Bridge cross-section diagram

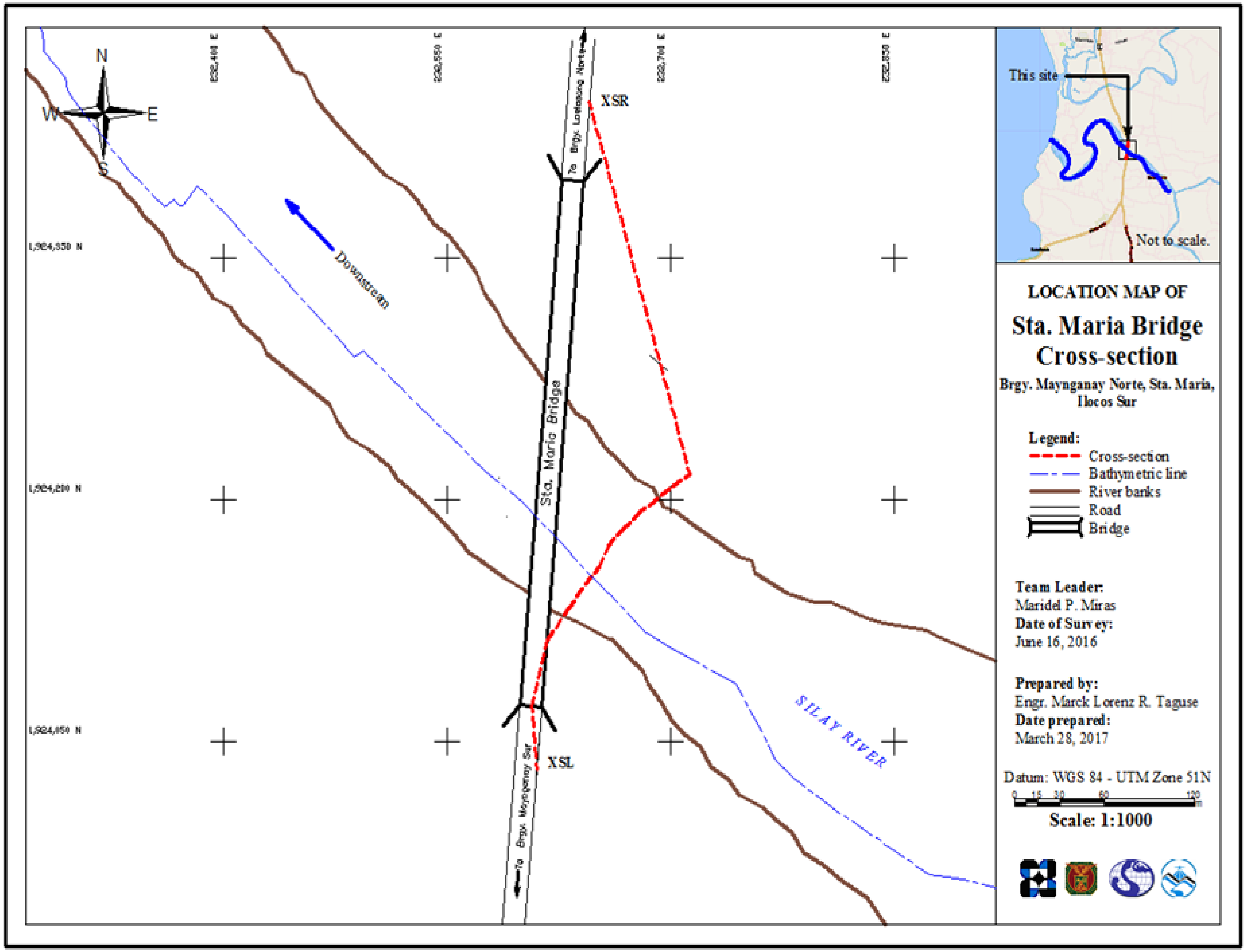


Figure 43. Sta. Maria bridge cross-section location map

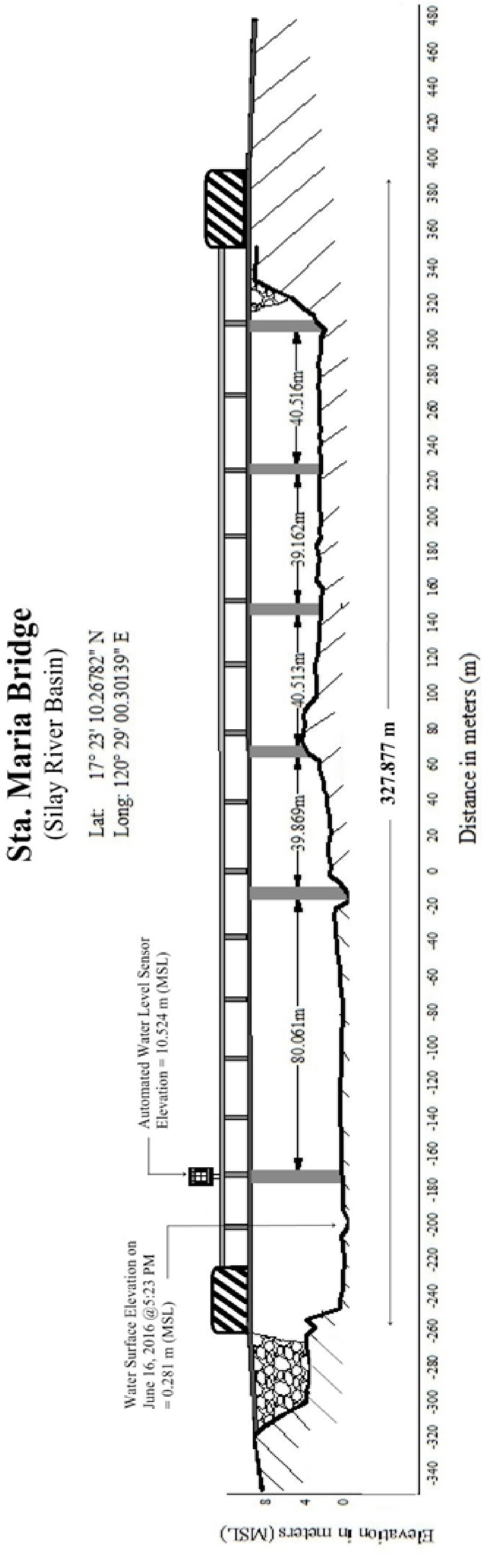


Figure 44. Sta. Maria Bridge cross section diagram

Bridge Data Form

Bridge Name: Burgos Bridge **Date:** June 12, 2016

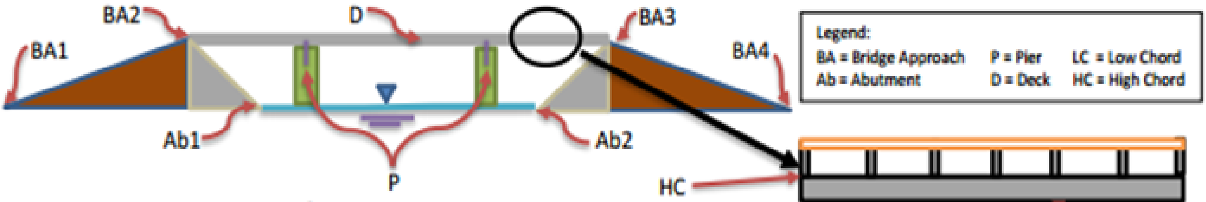
River Name: Silay River **Time:** 2:30 PM

Location (Brgy, City,Region): Brgy. Poblacion Norte, Municipality of Burgos, Ilocos Sur

Survey Team: Maridel Miras, Caren Ordoña

Flow condition: normal **Weather Condition:** fair

Latitude: 17°19'50.41943" N **Longitude:** 120°29'59.88311" E



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

Elevation: 13.802 m **Width:** 8.05 m **Span (BA3-BA2):** 244.10 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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	13.802 m	BA3	321.652 m	14.973 m
BA2	77.552 m	14.507 m	BA4	351.490 m	14.888 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: Cylindrical Number of Piers: 15 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	94.672 m	14.805 m	Not Available
Pier 2	109.258 m	14.854 m	Not Available
Pier 3	124.024 m	14.883 m	Not Available
Pier 4	138.789 m	14.89 m	Not Available
Pier 5	153.599 m	14.862 m	Not Available
Pier 6	168.573 m	14.866 m	Not Available
Pier 7	183.421 m	14.834 m	Not Available
Pier 8	198.320 m	14.876 m	Not Available
Pier 9	213.217 m	14.976 m	Not Available
Pier 10	228.105 m	14.955 m	Not Available
Pier 11	242.799 m	14.964 m	Not Available
Pier 12	257.713 m	15.029 m	Not Available
Pier 13	272.600 m	15.096 m	Not Available
Pier 14	287.515 m	15.013 m	Not Available
Pier 15	302.504 m	15.057 m	Not Available

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

Figure 45. Bridge as-built form of Burgos Bridge

Bridge Data Form

Bridge Name: Santa Maria Bridge **Date:** June 16, 2016

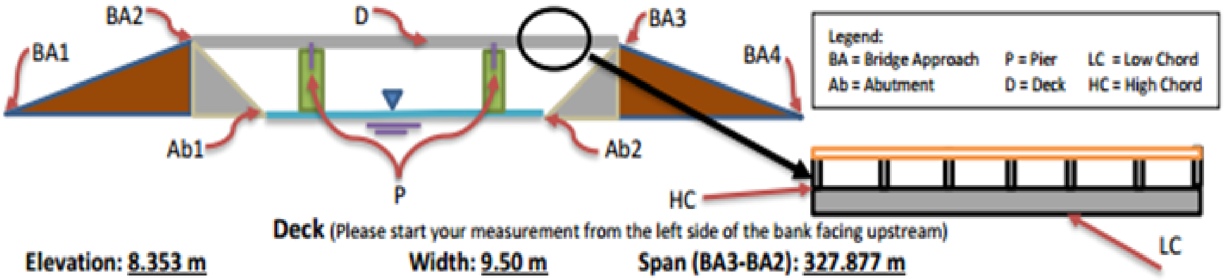
River Name: Silay River **Time:** 2:15 PM

Location (Brgy, City,Region): Brgy. Mayngnay Norte, Municipality of Santa Maria, Ilocos Sur

Survey Team: Maridel Miras, Caren Ordoña

Flow condition: normal **Weather Condition:** fair

Latitude: 17°23'10.26782" N **Longitude:** 120°29'00.30139" E



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

Elevation: 8.353 m **Width:** 9.50 m **Span (BA3-BA2):** 327.877 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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	8.353 m	BA3	372.674 m	9.506 m
BA2	44.797 m	9.411 m	BA4	414.886 m	8.872 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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

Shape: Circular Number of Piers: 6 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	88.409 m	9.417 m	2.750 m
Pier 2	168.442 m	9.513 m	2.750 m
Pier 3	168.471 m	9.519 m	2.750 m
Pier 4	208.340 m	9.485 m	2.750 m
Pier 5	248.853 m	9.485 m	2.750 m
Pier 6	288.014 m	9.494 m	2.750 m
Pier 7	328.531 m	9.471 m	2.750 m
Pier 8	372.750 m	9.489 m	2.750 m

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

Figure 46. Bridge As-built form of Santa Maria Bridge

Water surface elevation of Silay River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on June 16, 2016 at 11:48 AM with a value of 8.327 m in MSL for Burgos Bridge; and on June 16, 2016 at 5:23 PM with a value of 0.281 m in MSL for Santa Maria Bridge as shown in Figure 47 A and B, respectively. This was translated into marking on the bridge's deck using the same technique with a value of 14.890 and 9.473 m in MSL, respectively. This will serve as reference for flow data gathering and depth gauge deployment of UPB for Silay River.

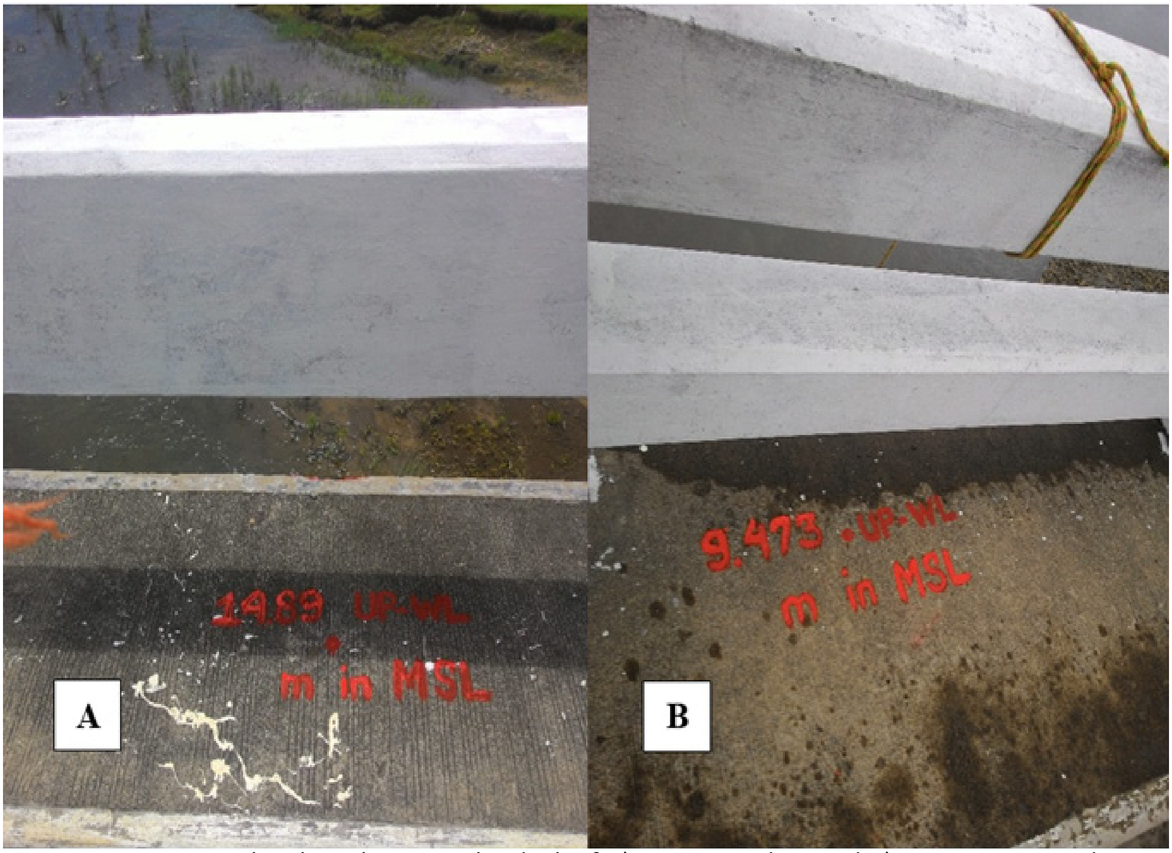


Figure 47. Water-level markings on the deck of A) Burgos Bridge, and B) Santa Maria Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on June 12 and 16, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown in Figure 48. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 2.090 m and 2.025 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-CRU occupied as the GNSS base stations in the conduct of the survey.

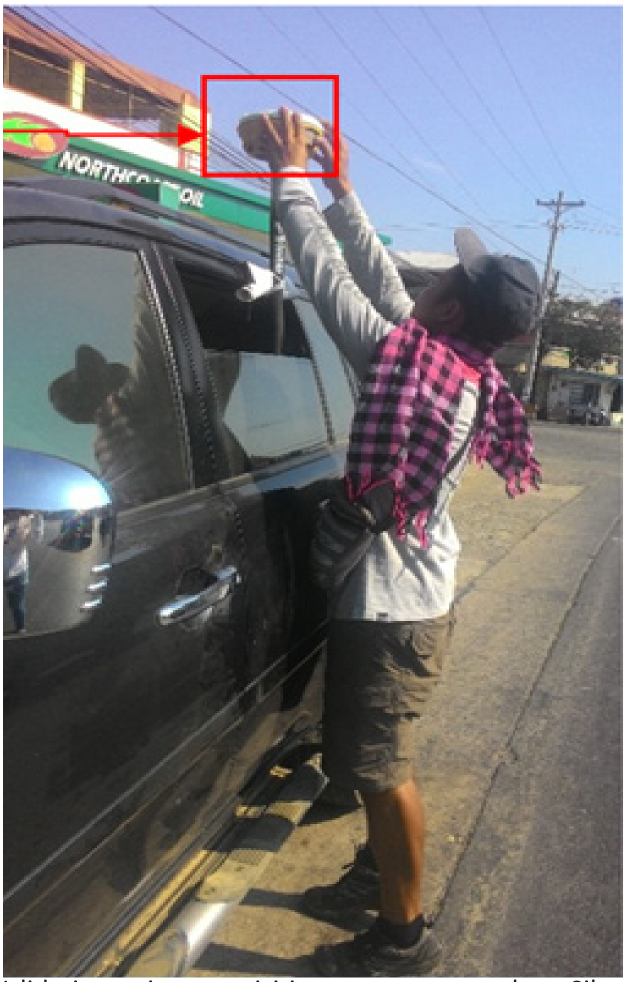


Figure 48. Validation points acquisition survey set up along Silay River Basin

The survey started from Brgy. Borono in the Municipality of Tagudin, going north covering seven (7) Municipalities of Ilocos Sur namely: Santa Lucia, Santiago, San Esteban, Burgos, Santa Maria and Narvacan; and Candon City. The survey gathered a total of 9,969 points with approximate length of 78.68 km using UP-CRU as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 49.

Figure 49. Validation point acquisition survey of Silay River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on June 17, 2016 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 50. The survey started in Brgy. Naguneg, Municipality of Narvacan, with coordinates 17°23'46.50419"N, 120°28'32.69234"E, and ended in Brgy. Nagsayaoan, Municipality of Santa Maria with coordinates 17°23'24.18436"N, 120°27'26.65629"E.

Figure 50. Bathymetric survey using Ohmex™ single beam echo sounder in Silay River

Manual bathymetric survey, on the other hand, was conducted simultaneously on the same day using a Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 51. The survey started from the upstream of the river in Brgy. Cabaroan, Municipality of Santa Maria, with coordinates 17°22'27.18389"N, 120°29'56.64312"E, traversed down by foot, and ended at the starting point of bathymetric survey by boat. The control point UP-BUR was used as the GNSS base station all throughout the entire survey.

Figure 51. Manual bathymetric survey in Silay River

The bathymetric survey for Silay River gathered a total of 14,030 points covering 8.867 km of the river traversing thirteen (13) barangays in Municipality of Santa Maria and two (2) barangays in Municipality of Narvacan. A CAD drawing was also produced to illustrate the riverbed profile of Silay River. As shown in Figure 53, the highest and lowest elevation has a 9-m difference. The highest elevation observed was 1.239 m above MSL located in Brgy. Nagsayaoan, while the lowest was -8.469 m below MSL located in Brgy. Lingsat, both in Municipality of Santa Maria. The survey for the remaining 12 km upstream of the river was cut because LiDAR data for its riverbed is already available.

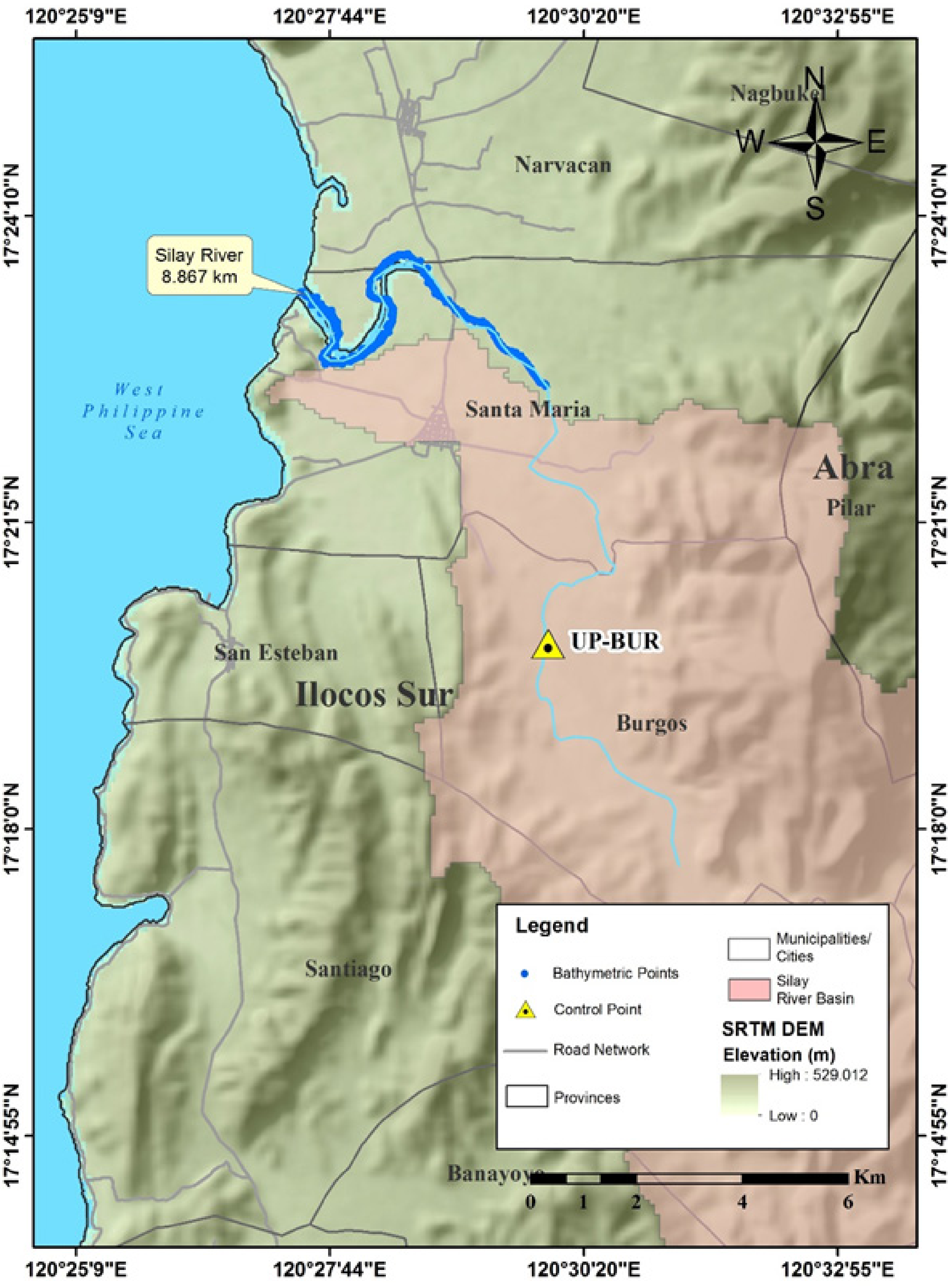


Figure 52. Bathymetric survey of Silay River

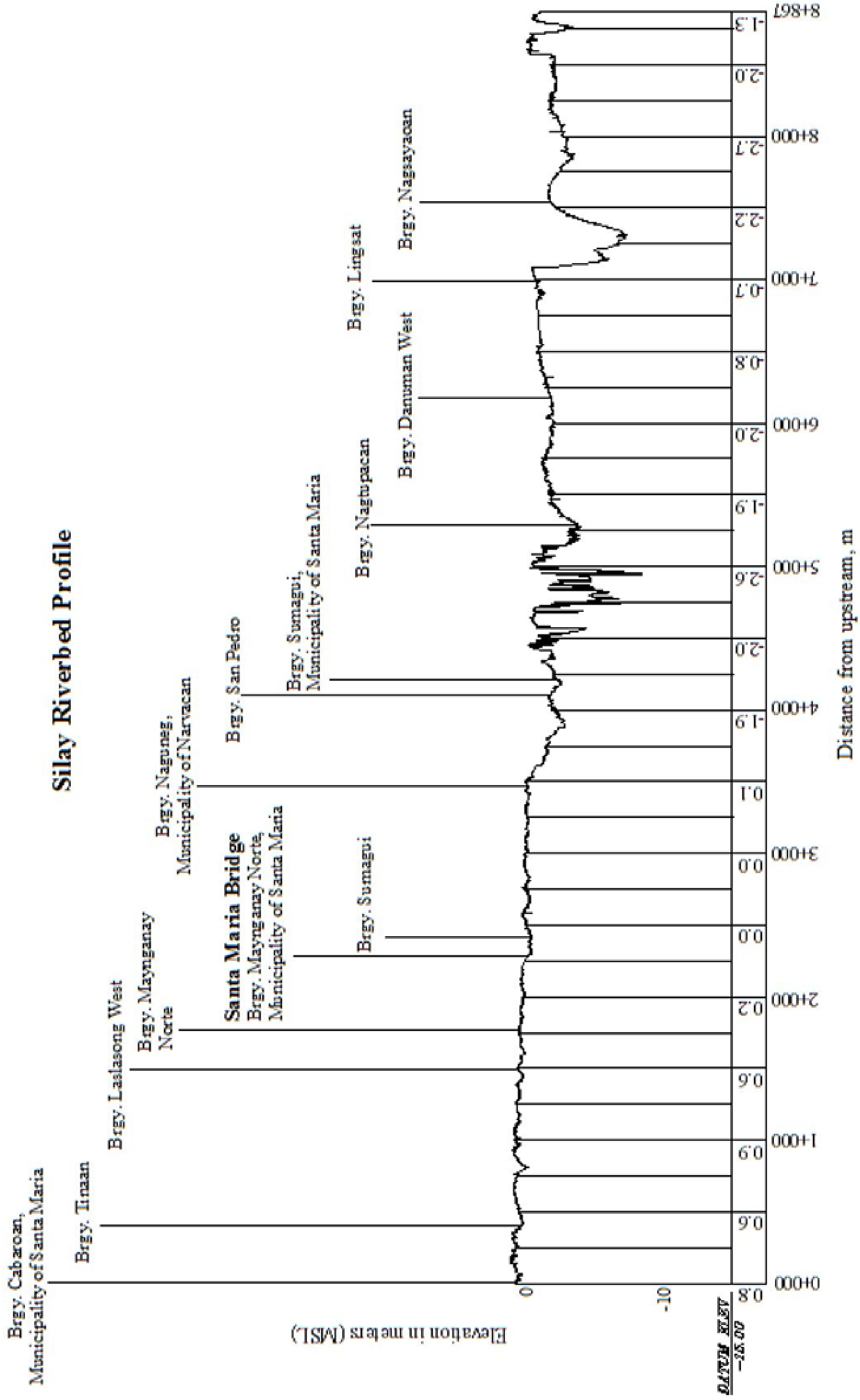


Figure 53. Silay Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Hannah Aventurado

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the Silay River Basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Silay River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This rain gauge is the Pilar ARG (17°24’53.61” N, 120°35’44.1” E), located in Pilar, Abra, as shown in Figure 52. The precipitation data collection started from August 24, 2016 at 11:00 AM to August 30, 2016 at 7:30 AM with a 15-minute recording interval.

The total precipitation for this event in Pilar ARG was 112 mm. It has a peak rainfall of 12.6 mm. on August 27, 2016 at 2:00 PM. The lag time between the peak rainfall and discharge is 13 hours.

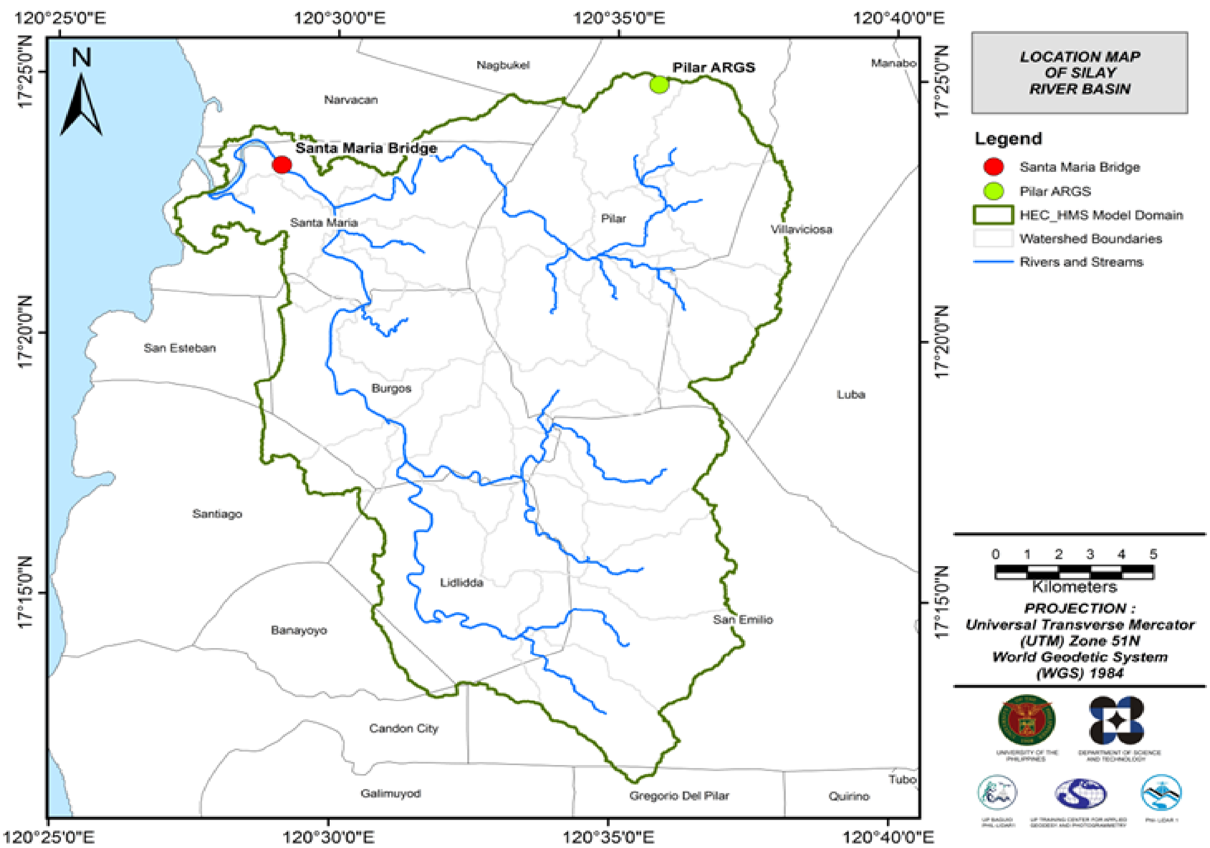


Figure 54. The location map of Silay HEC-HMS model used for calibration

5.1.3 Rating Curves and Outflow

A rating curve was developed at Santa Maria Bridge or Mayngayngay Norte Bridge, Santa Maria, Ilocos Sur (17°23'16.08" N, 120°29'0.39" E). It gives the relationship between the observed water level from the Santa Maria Bridge and outflow of the watershed at this location.

For Santa Maria or Mayngayngay Norte Bridge, the rating curve is expressed as Q = 2.3211e1.1665x as shown in Figure 56.

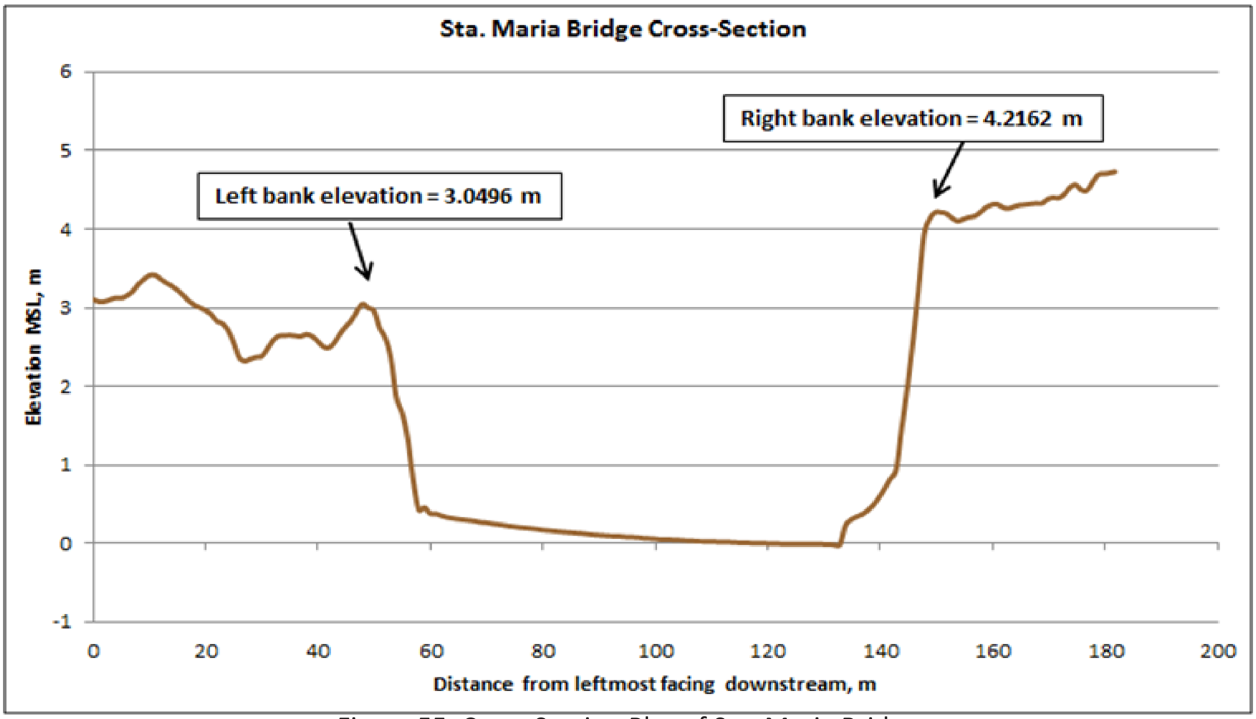


Figure 55. Cross-Section Plot of Sta. Maria Bridge

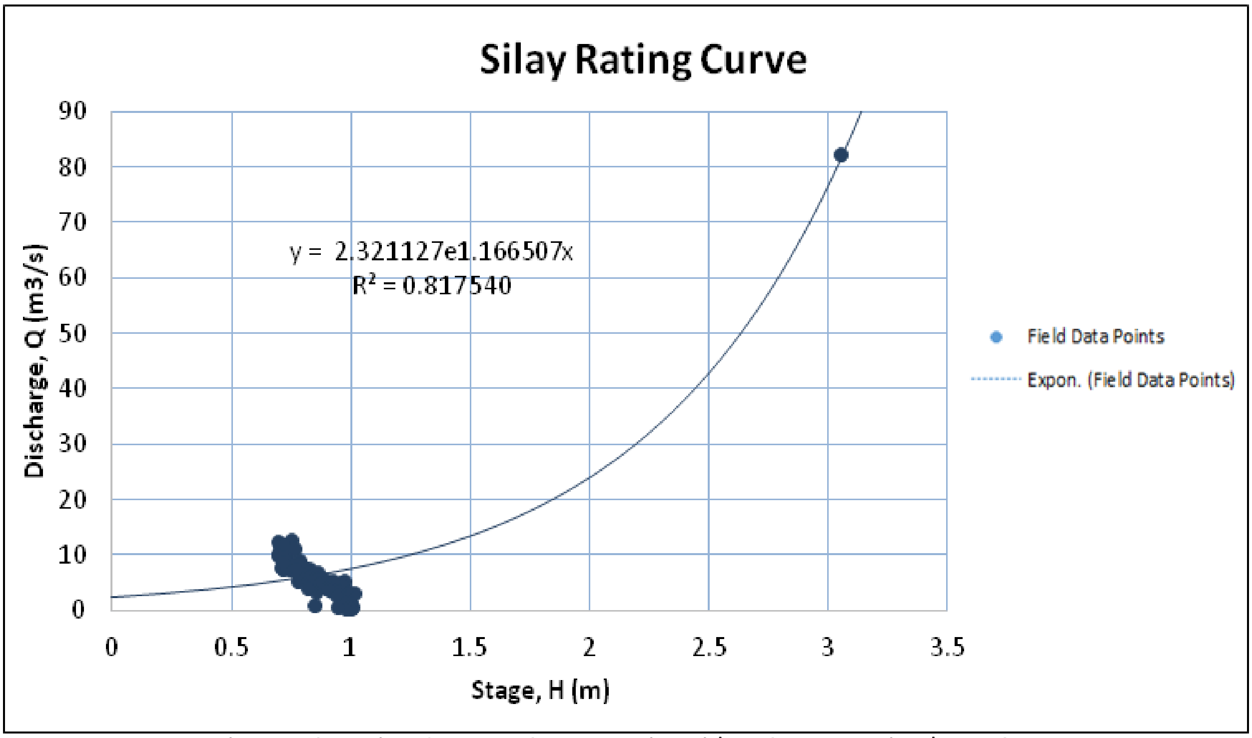


Figure 56. Rating Curve at Santa Maria Bridge, Santa Maria, Ilocos Sur

The rating curve equation was used to compute for the river outflow at Santa Maria Bridge for the calibration of the HEC-HMS model for Silay, as shown in Figure 57. The total rainfall for this event is 112 mm and the peak discharge is 17.28 m3/s at 3:00 AM of August 28, 2016.

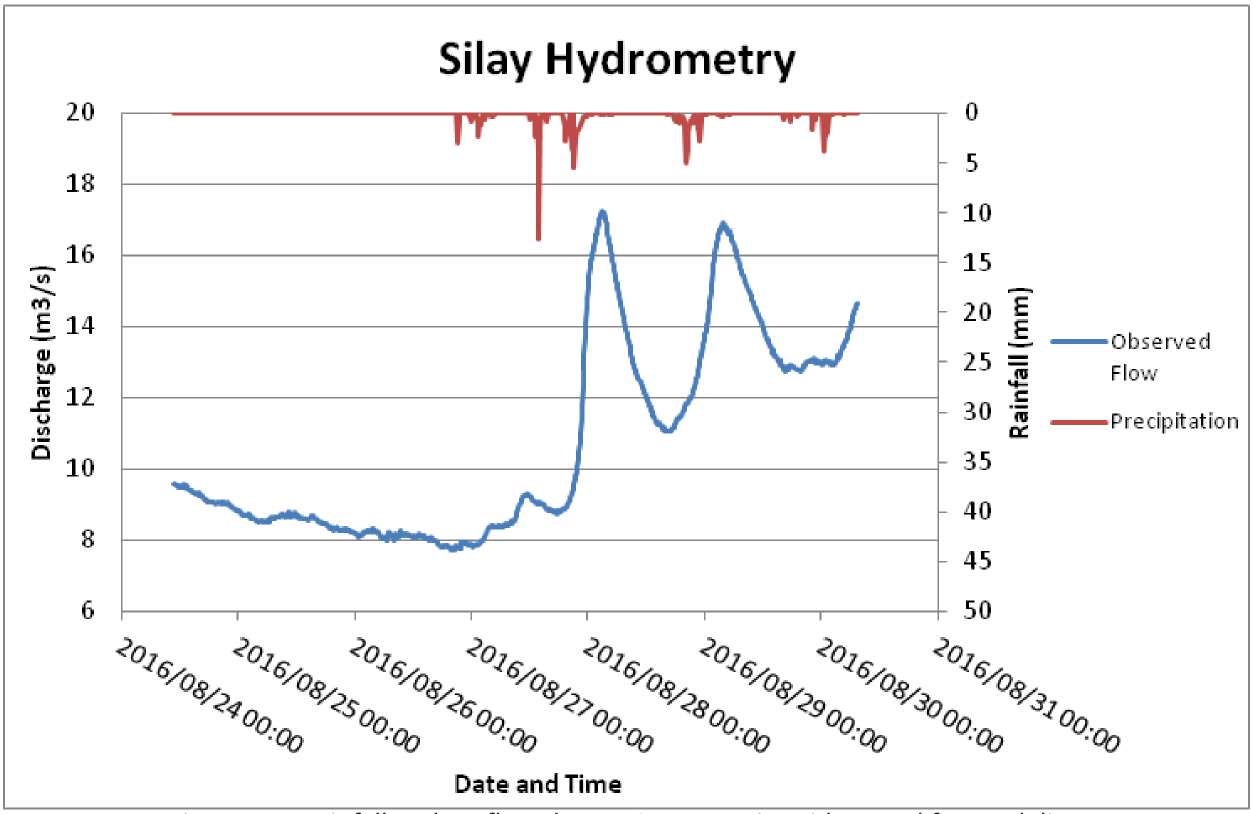


Figure 57. Rainfall and outflow data at Santa Maria Bridge used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Laoag 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 is chosen based on its proximity to the Silay watershed. The extreme values for this watershed were computed based on a 59-year record

Table 31. RIDF values for Laoag 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	35.4	45.7	62.5	89	110.9	148.5	187.8	232.8
5	31.4	48	61.5	87.1	124.6	157.8	211.7	266.3	331.7
10	37.2	56.3	71.9	103.5	148.2	189	253.6	318.3	397.1
15	40.5	61	77.8	112.7	161.6	206.5	277.2	347.7	434
20	42.8	64.3	81.9	119.1	170.9	218.8	293.7	368.2	459.9
25	44.5	66.8	85.1	124.1	178.1	228.3	306.4	384.1	479.8
50	50	74.6	94.8	139.4	200.2	257.4	345.7	432.8	541.1
100	55.3	82.4	104.5	154.6	222.2	286.4	384.6	481.2	602

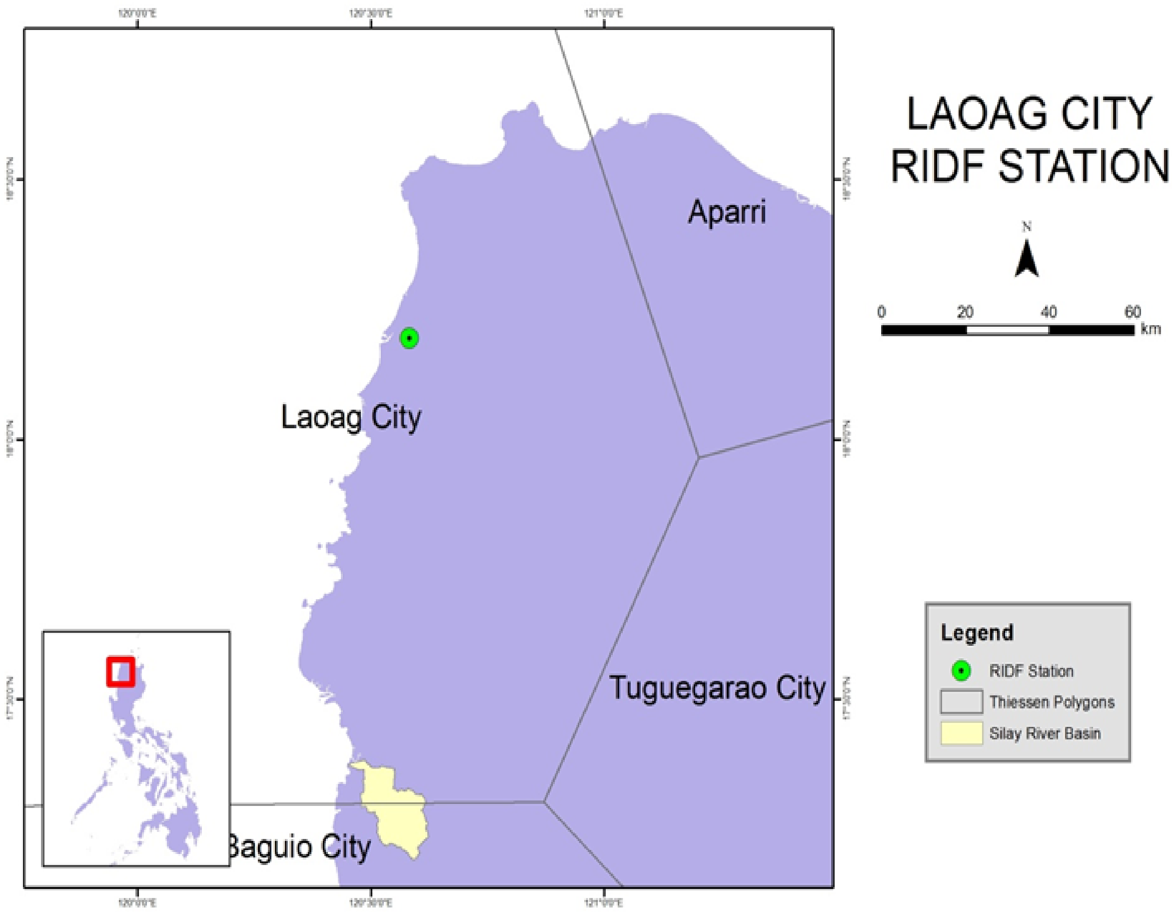


Figure 58. Location of Laoag RIDF Station relative to Silay River Basin

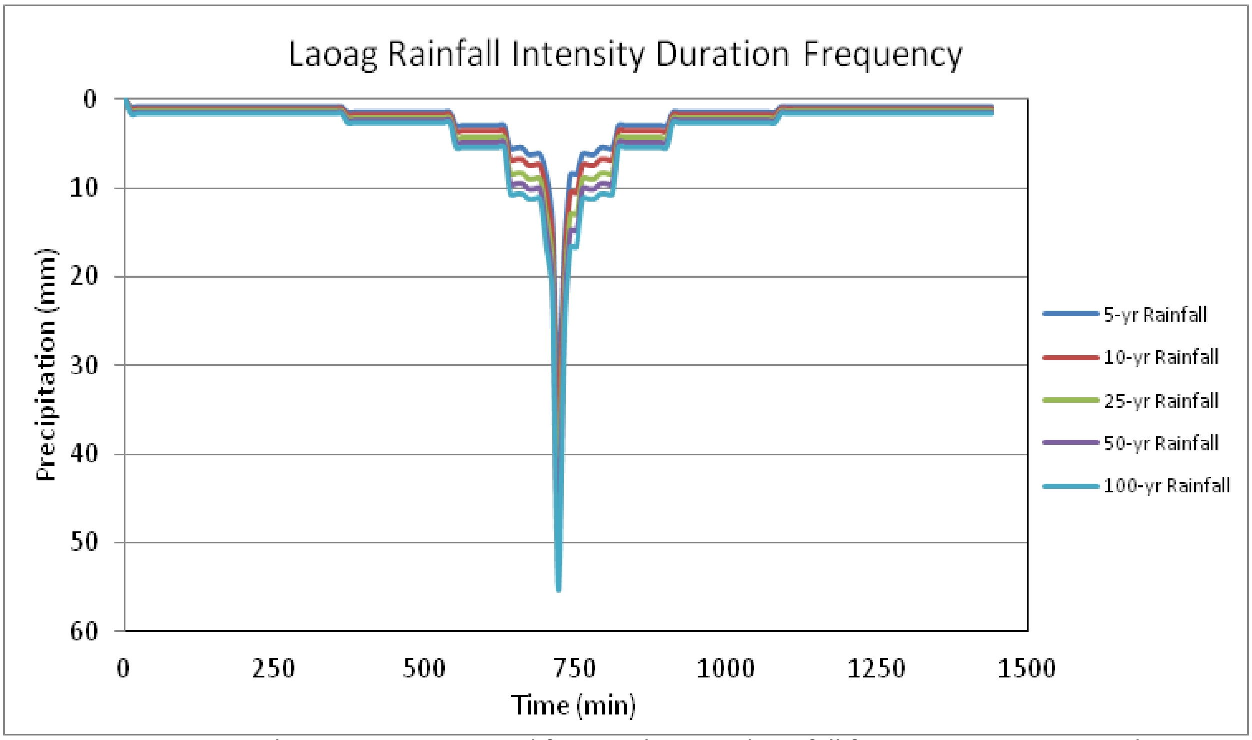


Figure 59. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management (DENR). The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Silay River Basin are shown in Figures 60 and 61, respectively.

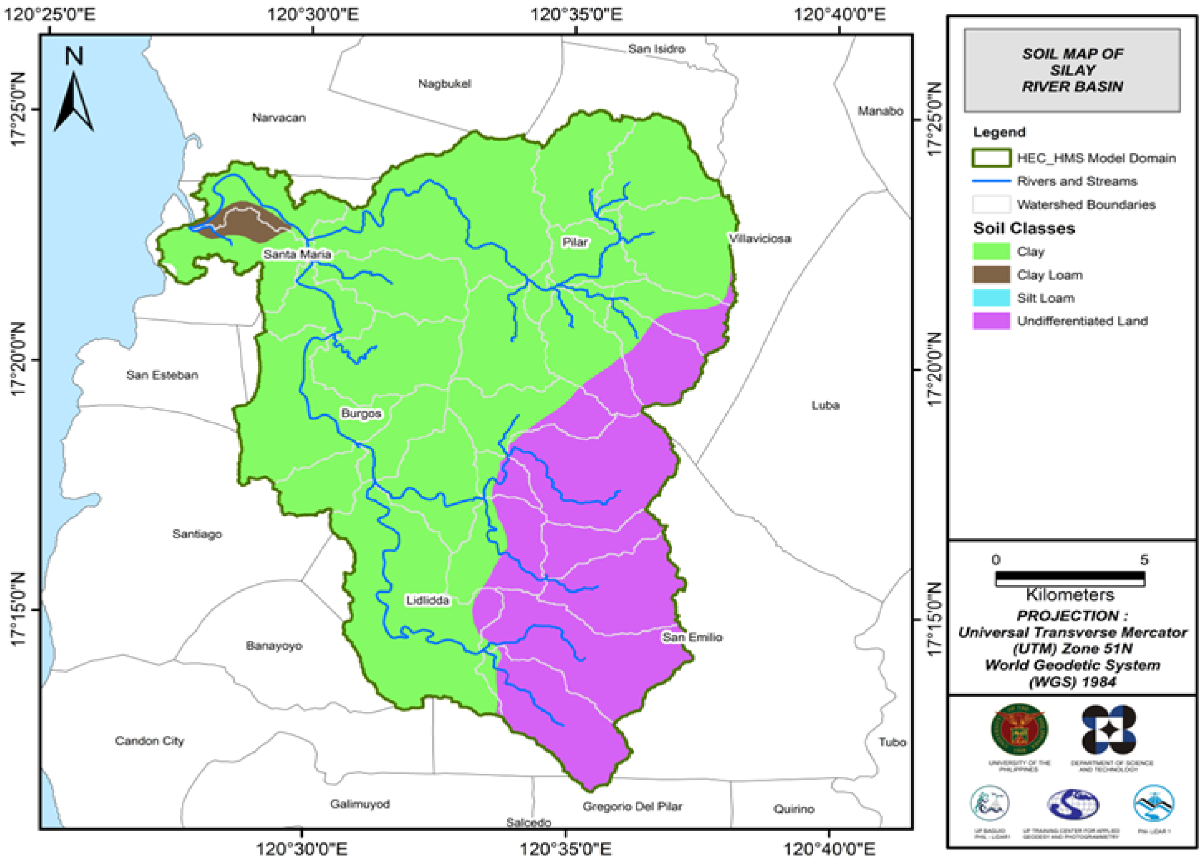


Figure 60. Soil Map of Silay River Basin

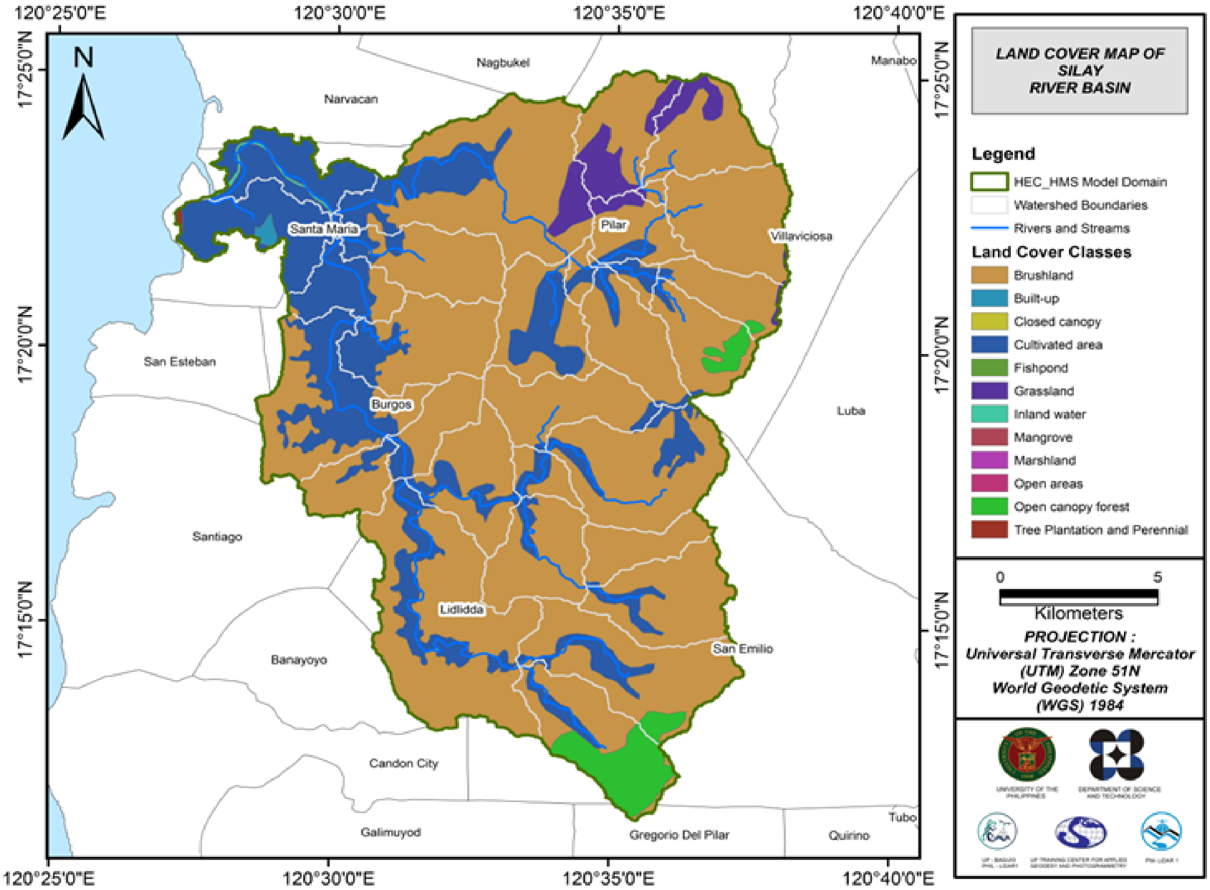


Figure 61. Land Cover Map of Silay River Basin

For Silay, four soil classes were identified. These are clay, clay loam, silt loam and undifferentiated land. Moreover, 12 land cover classes were identified. These are brushlands, built-up areas, closed canopy, cultivated areas, fishponds, grasslands, inland water, mangroves, marshlands, open areas, open canopy forests, and tree plantations.

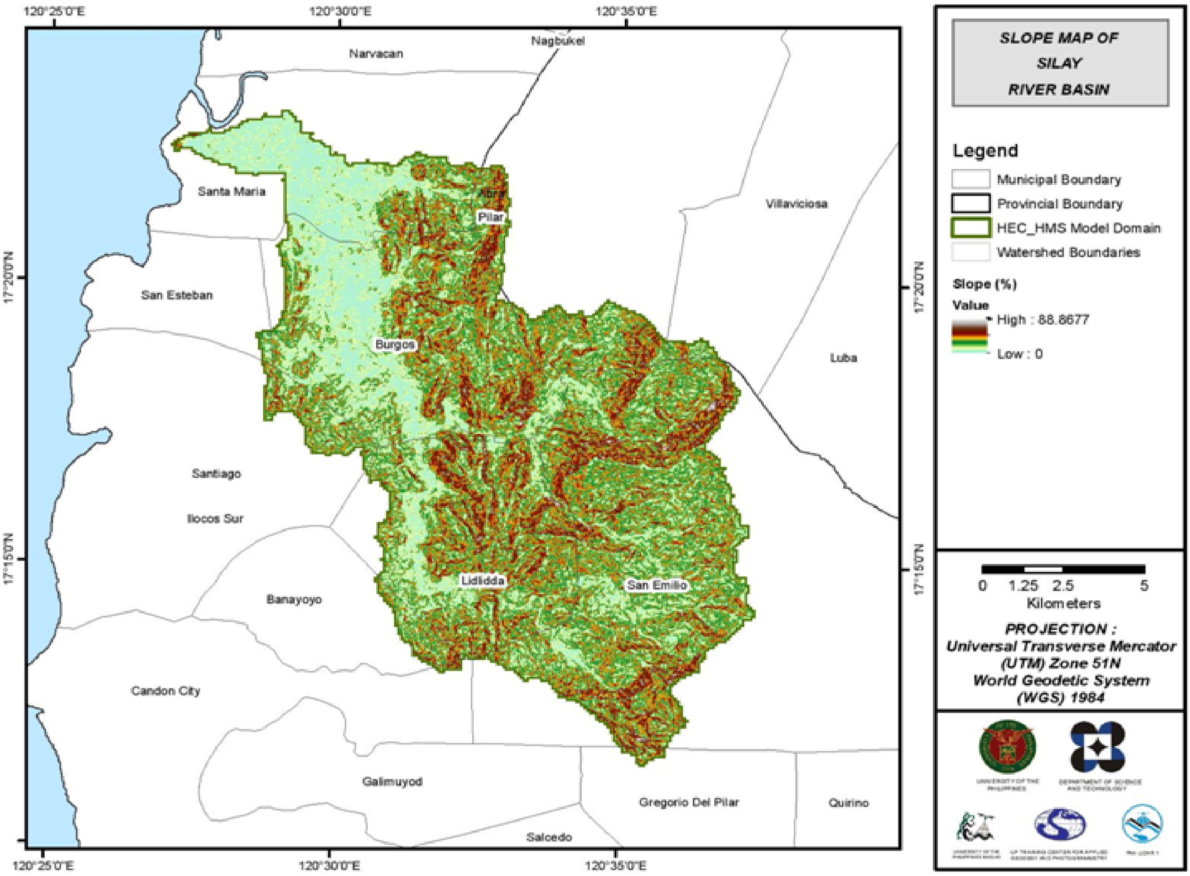


Figure 62. Slope Map of Silay River Basin

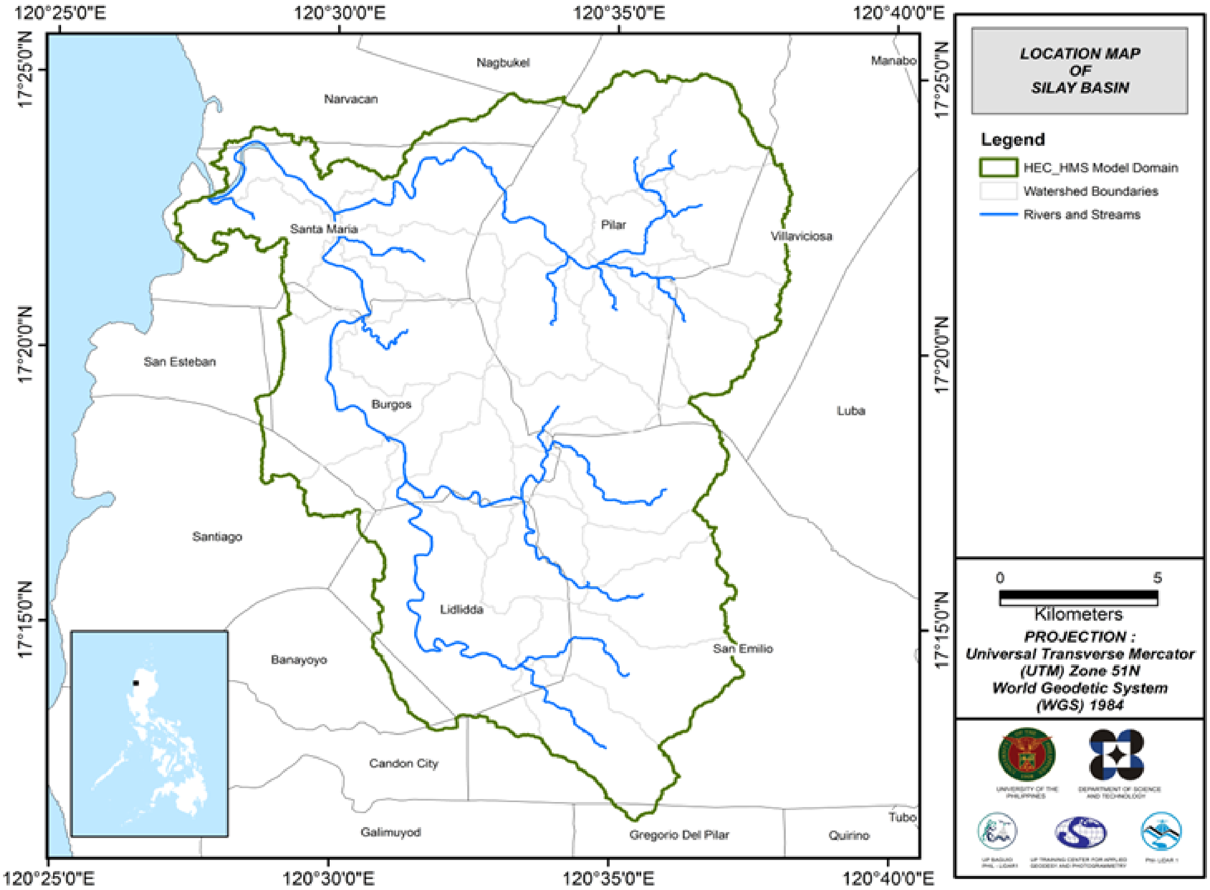


Figure 63. Stream Delineation Map of Silay River Basin

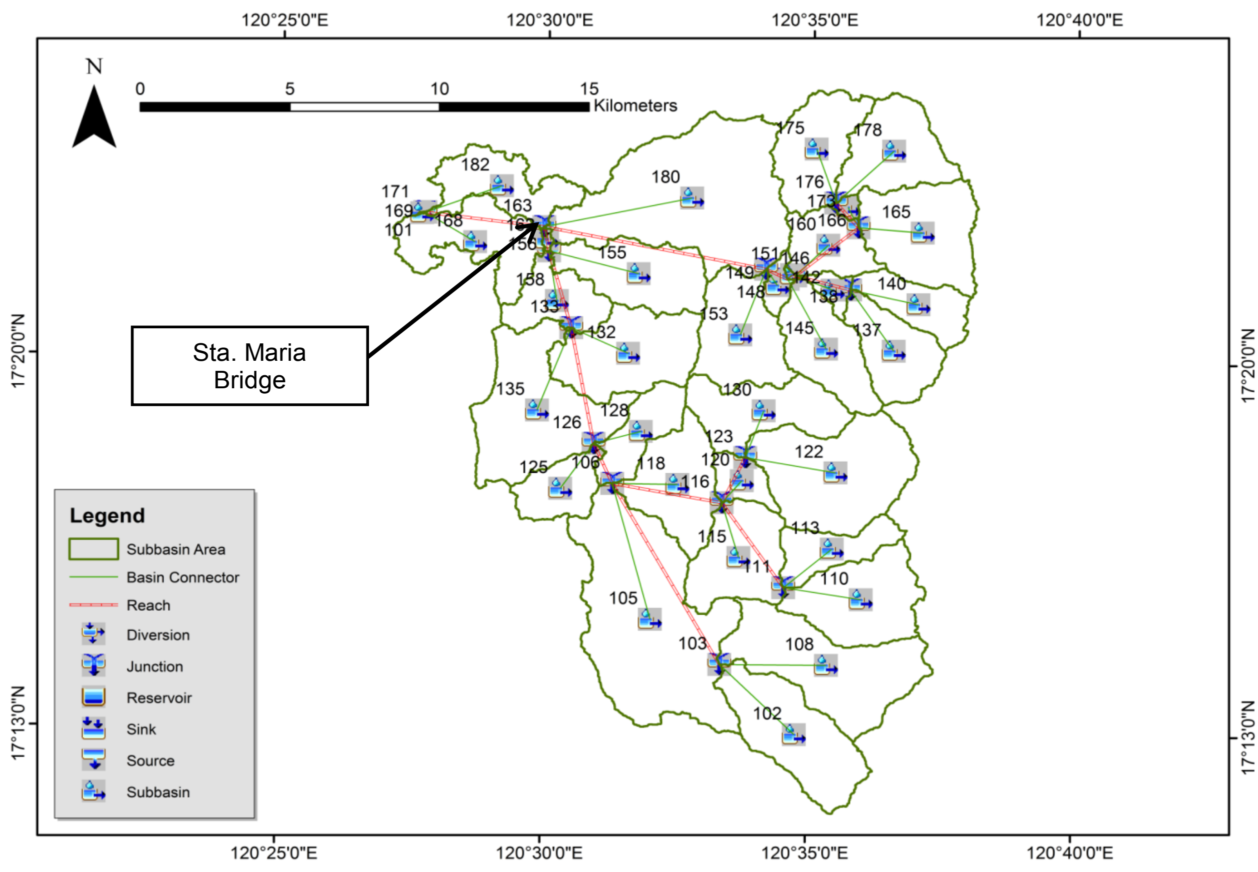


Figure 64. The Silay river basin model generated using HEC-HMS.

Using the SAR-based DEMs, the Silay basin was delineated and further subdivided into subbasins (Annex 10). The model consists of 33 sub basins, 16 reaches, and 16 junctions, as shown in Figure 63. The main outlet is 169.

5.4 Cross-section Data

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

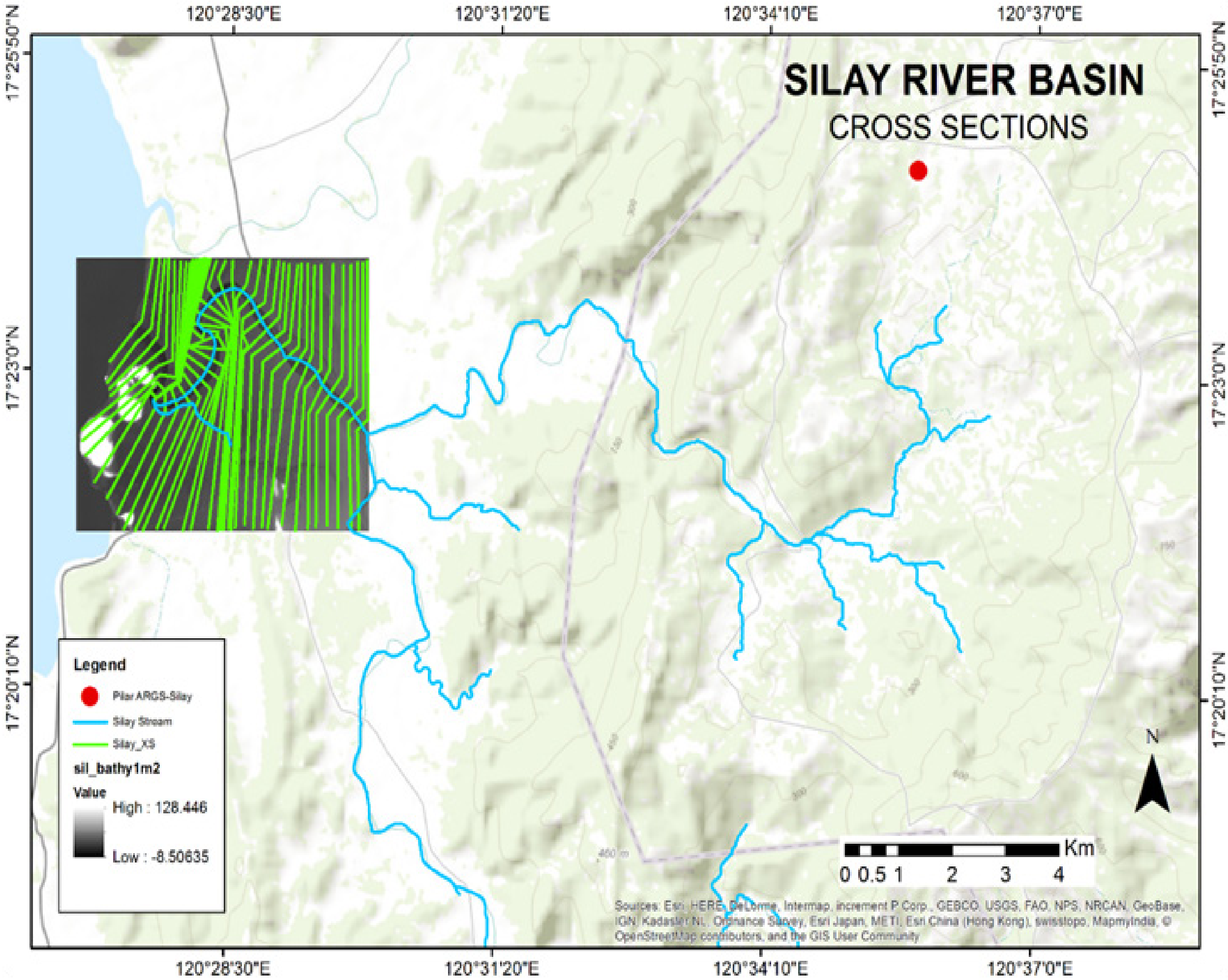


Figure 65. River cross-section of River generated through Arcmap HEC GeoRAS tool

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

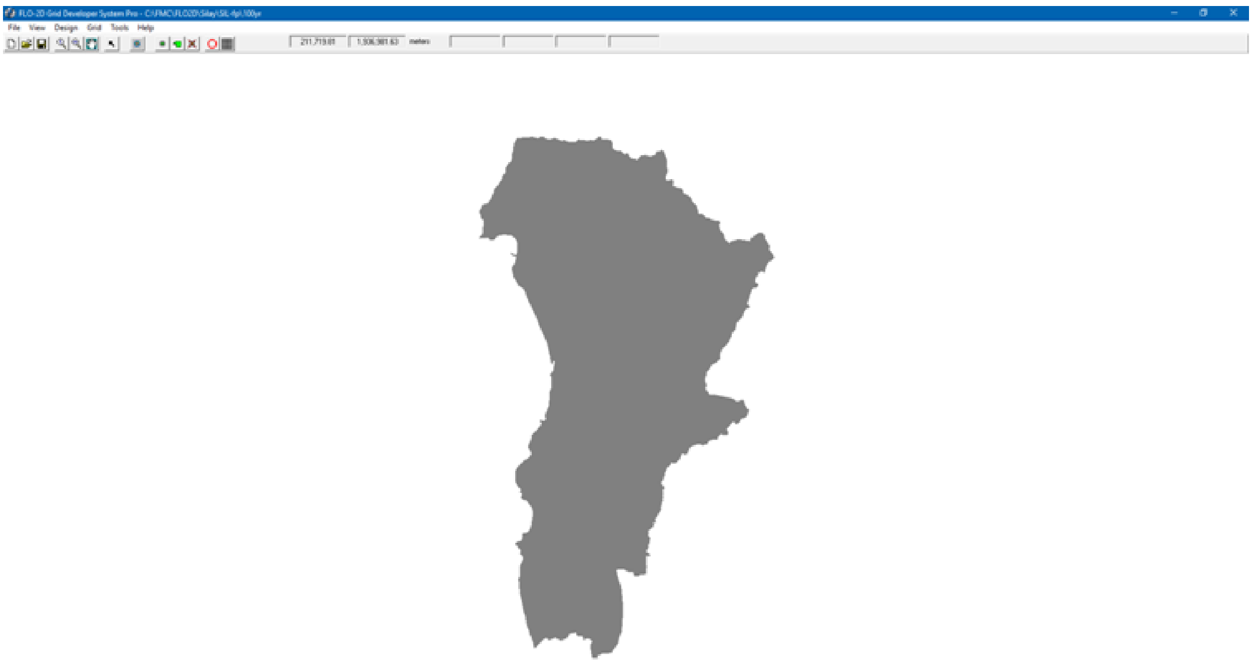


Figure 66. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 185.18750 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 generated hazard maps for Silay are in Figures 70, 72, and 74.

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 99 142 272.00 m2. The generated flood depth maps for Silay are in Figures 71, 73, and 75.

There is a total of 266 162 532.84 m3 of water entering the model. Of this amount, 65 907 782.34 m3 is due to rainfall while 200 254 750.50 m3 is inflow from other areas outside the model. 24 037 788.00 m3 of this water is lost to infiltration and interception, while 64 057 088.90 m3 is stored by the flood plain. The rest, amounting up to 178 067 726.38 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Silay HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 67 shows the comparison between the two discharge data.

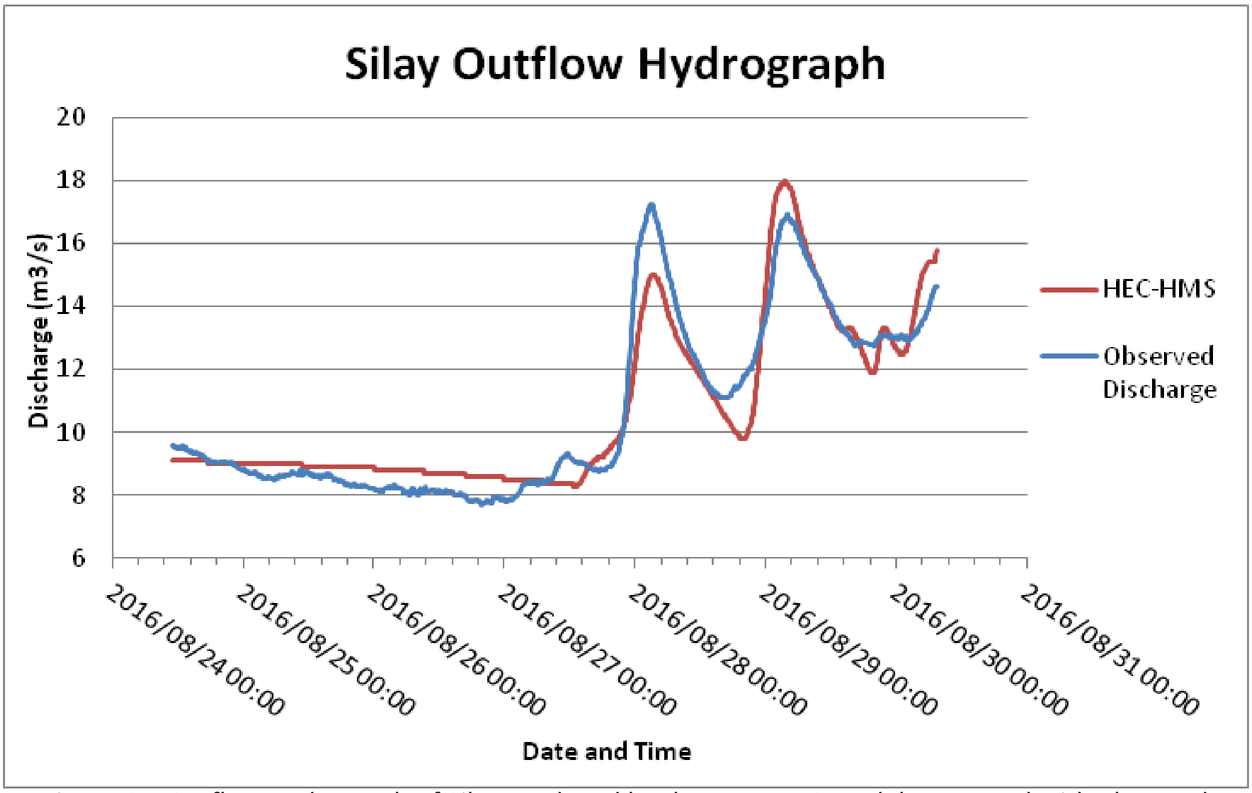


Figure 67. Outflow Hydrograph of Silay produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 32. Range of Calibrated Values for Silay River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	7.38 - 137.58
			Curve Number	35 – 52.5
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.207 – 15.77
			Storage Coefficient (hr)	0.0167 – 3.19
	Baseflow	Recession	Recession Constant	0.805 - 1
			Ratio to Peak	0.0001 – 0.00015
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.627 - 1

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 7.38 mm to 137.58 mm means that the amount of infiltration or rainfall interception by vegetation all over the basin varies greatly.

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 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Silay, the basin consists mainly of brushlands and the soil consists of mostly undifferentiated land and clay.

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 0.0167 hours to 15.77 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant values within the range of 0.805 to 1 indicate that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Values of ratio to peak within the range of 0.0001 to 0.00015 indicate a much steeper receding limb of the outflow hydrograph. Silay model basin parameters are presented in Annex 9.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Quiaoit river basin reaches' Manning's coefficients range from 0.627 to 1, showing that there is variety in surface roughness all over the catchment (Brunner, 2010).

Table 33. Summary of the Efficiency Test of Silay HMS Model

Accuracy Measure	Value
RMSE	0.8
r2	0.918
NSE	0.92
PBIAS	-0.38
RSR	0.29

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.8 m3/s.

The Pearson correlation coefficient (r2) 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 0.918.

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 0.92.

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 -0.38.

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 0.29.

.

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 68) shows the Silay outflow using the Laoag Rainfall 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.

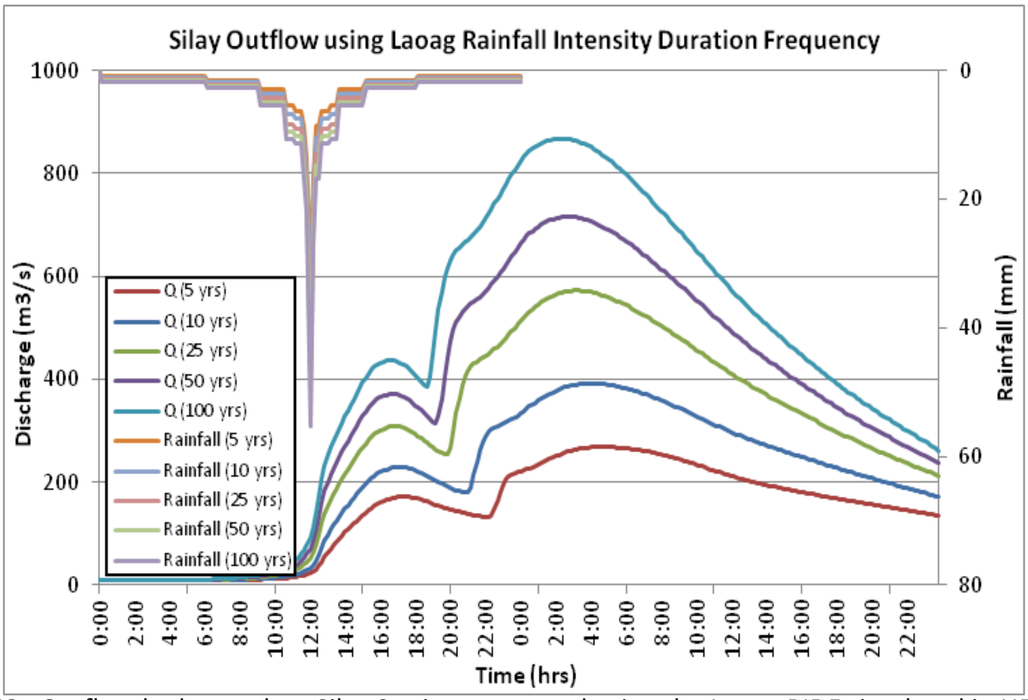


Figure 68. Outflow hydrograph at Silay Station generated using the Laoag RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Silay discharge using the Laoag Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Silay HEC-HMS Model outflow using the Laoag RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m3/s)	Time to Peak
5-Year	331.7	31.4	268.4	16 hours,30 minutes
10-Year	397.1	37.2	392.2	16 hours
25-Year	479.8	44.5	572.5	15 hours, 10 minutes
50-Year	541.1	50	715.8	14 hours, 40 minutes
100-Year	602	55.3	867.9	14 hours, 20 minutes

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Silay River using the calibrated HMS base flow is shown in Figure 69.

Figure 69. Sample output of Silay RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 5-, 25-, and 100-year rain return scenarios of the Silay floodplain are shown in Figures 69 to 74. The floodplain, with an area of 158.193 sq. km., covers eight municipalities from two provinces. Table 35 shows the percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in Silay floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Abra	Pilar	92.1961	2.47482	2.68%
Ilocos Sur	Burgos	49.604	3.13972	6.33%
Ilocos Sur	Nagbukel	36.4591	12.6393	34.67%
Ilocos Sur	Narvacan	97.1762	72.9262	75.05%
Ilocos Sur	San Esteban	17.2667	9.97464	57.77%
Ilocos Sur	Santa Maria	52.3193	48.9689	93.60%
Ilocos Sur	Santa	57.1968	3.15538	5.52%
Ilocos Sur	Santiago	65.566	4.13186	6.30%

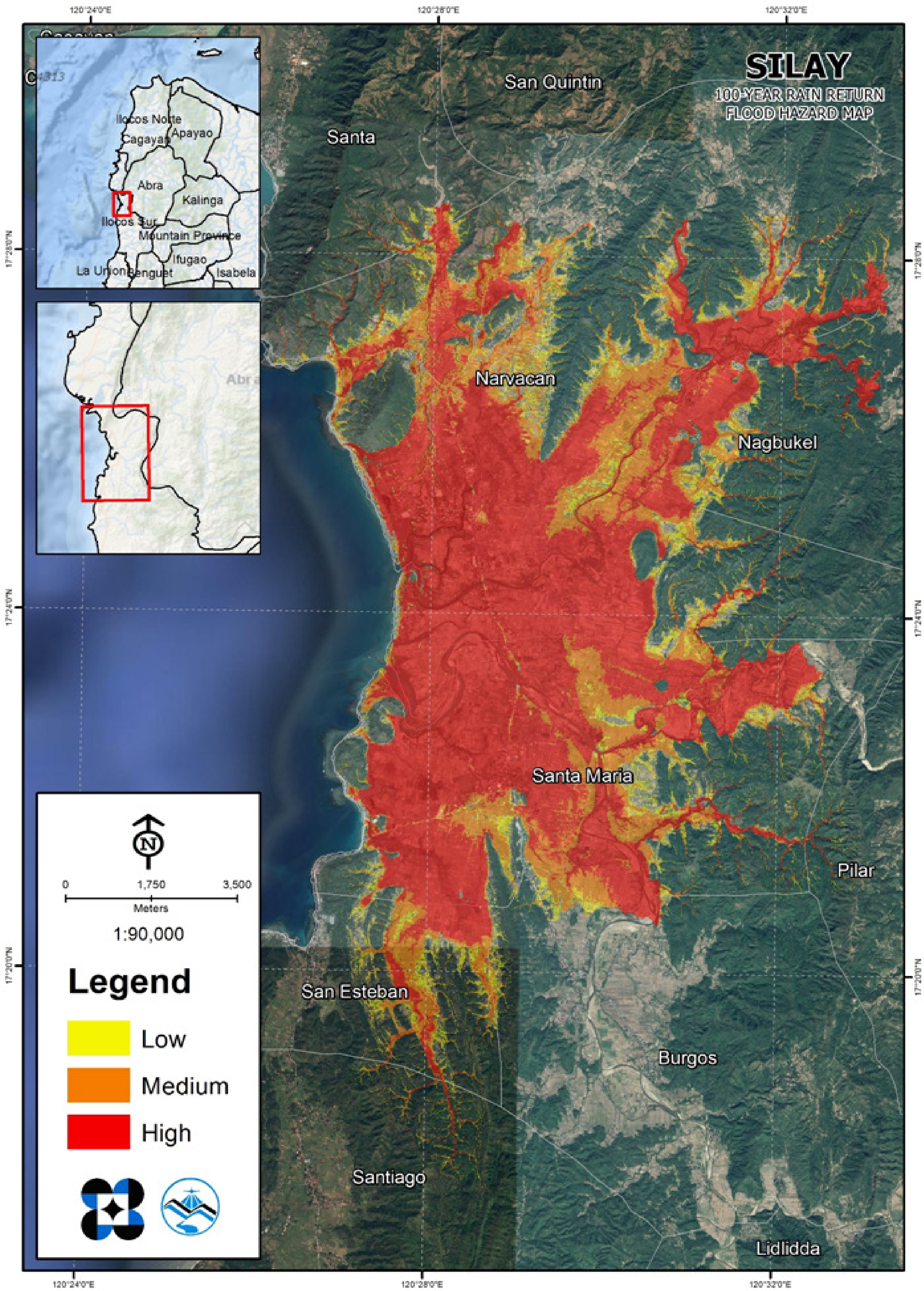


Figure 70. 100-year Flood Hazard Map for Silay Floodplain overlaid on Google Earth imagery

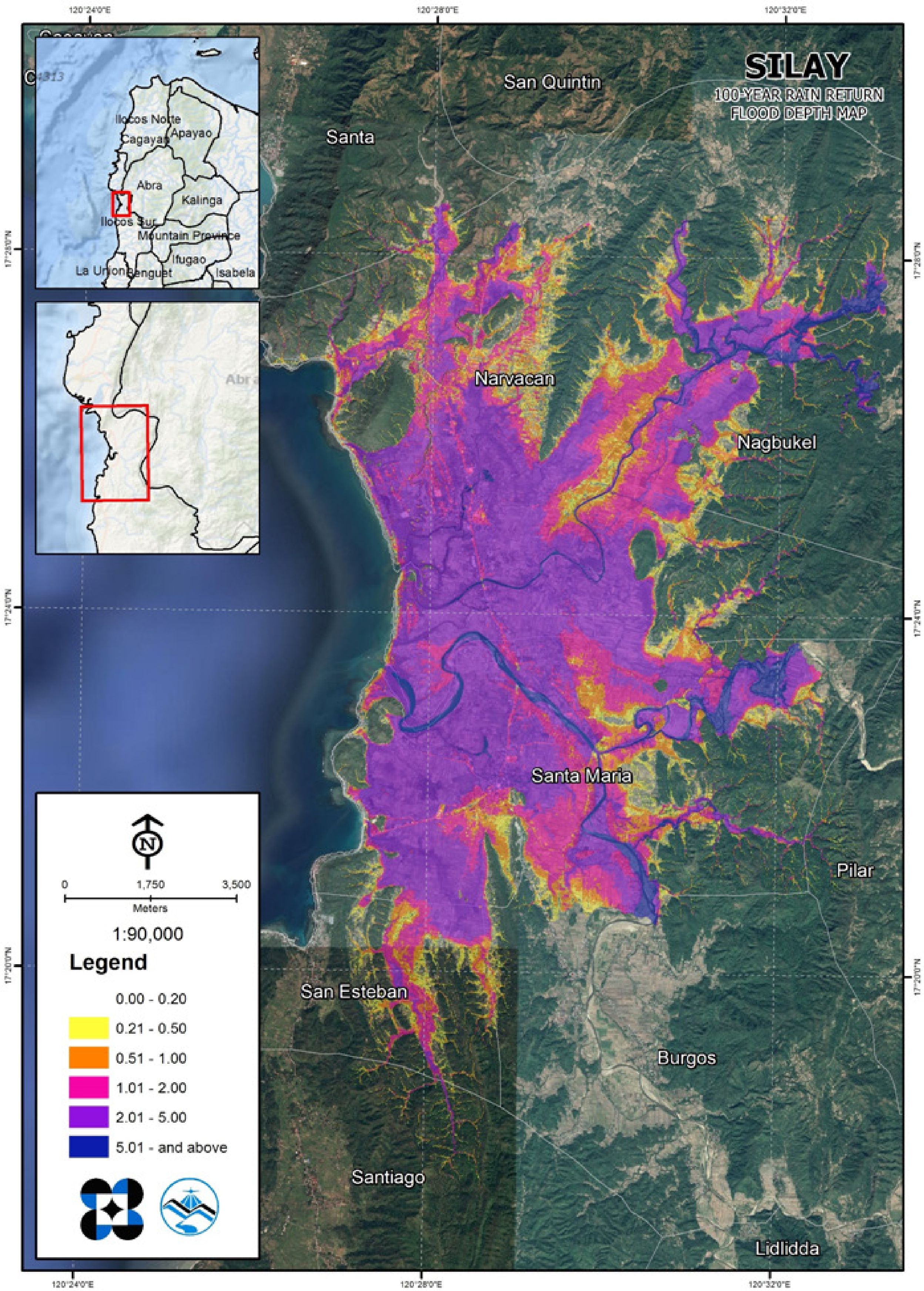


Figure 71. 100-year Flow Depth Map for Silay Floodplain overlaid on Google Earth imagery

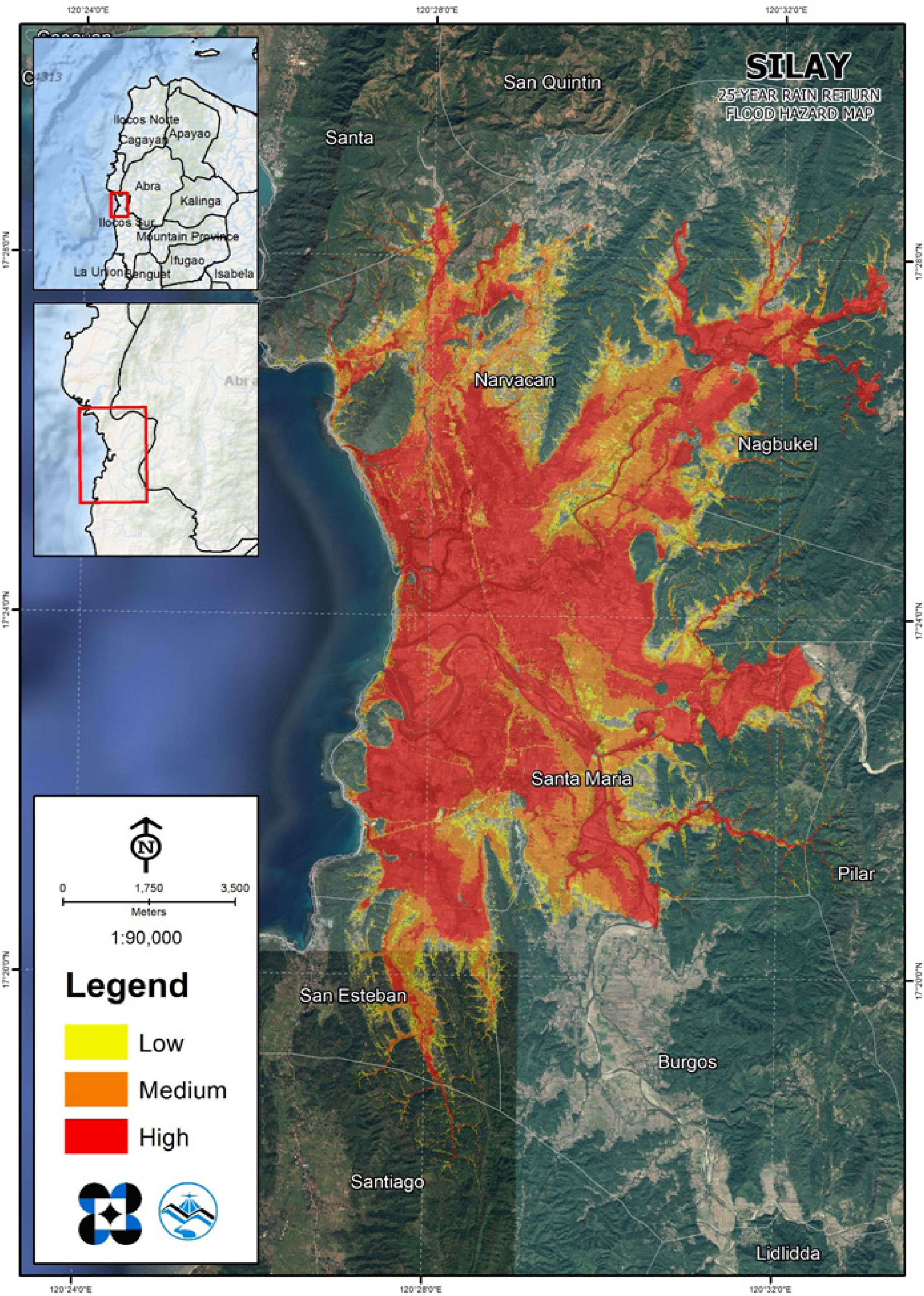


Figure 72. 25-year Flood Hazard Map for Silay Floodplain overlaid on Google Earth imagery

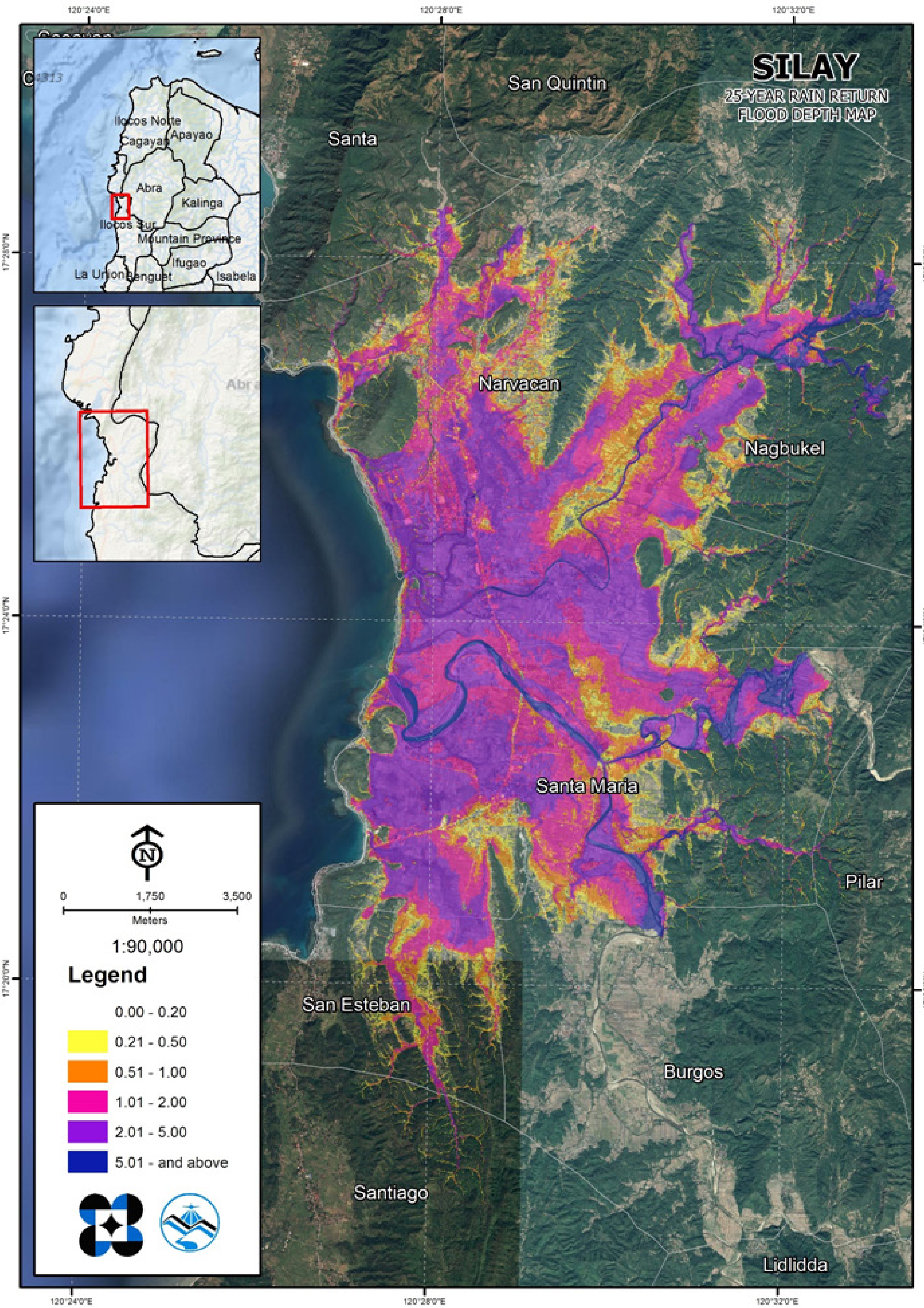


Figure 73. 25-year Flow Depth Map for Silay Floodplain overlaid on Google Earth imagery

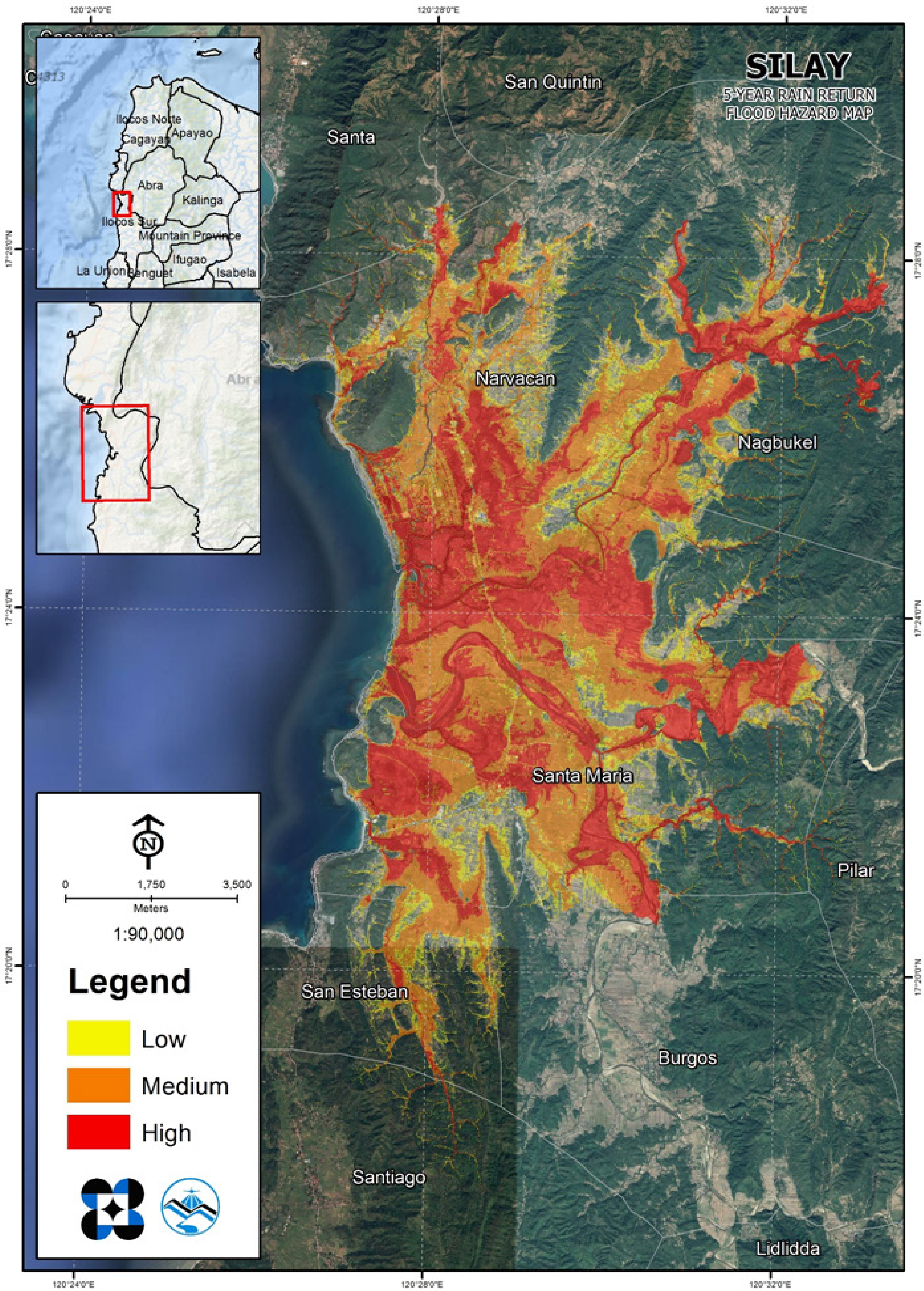


Figure 74. 5-year Flow Hazard Map for Silay Floodplain overlaid on Google Earth imagery

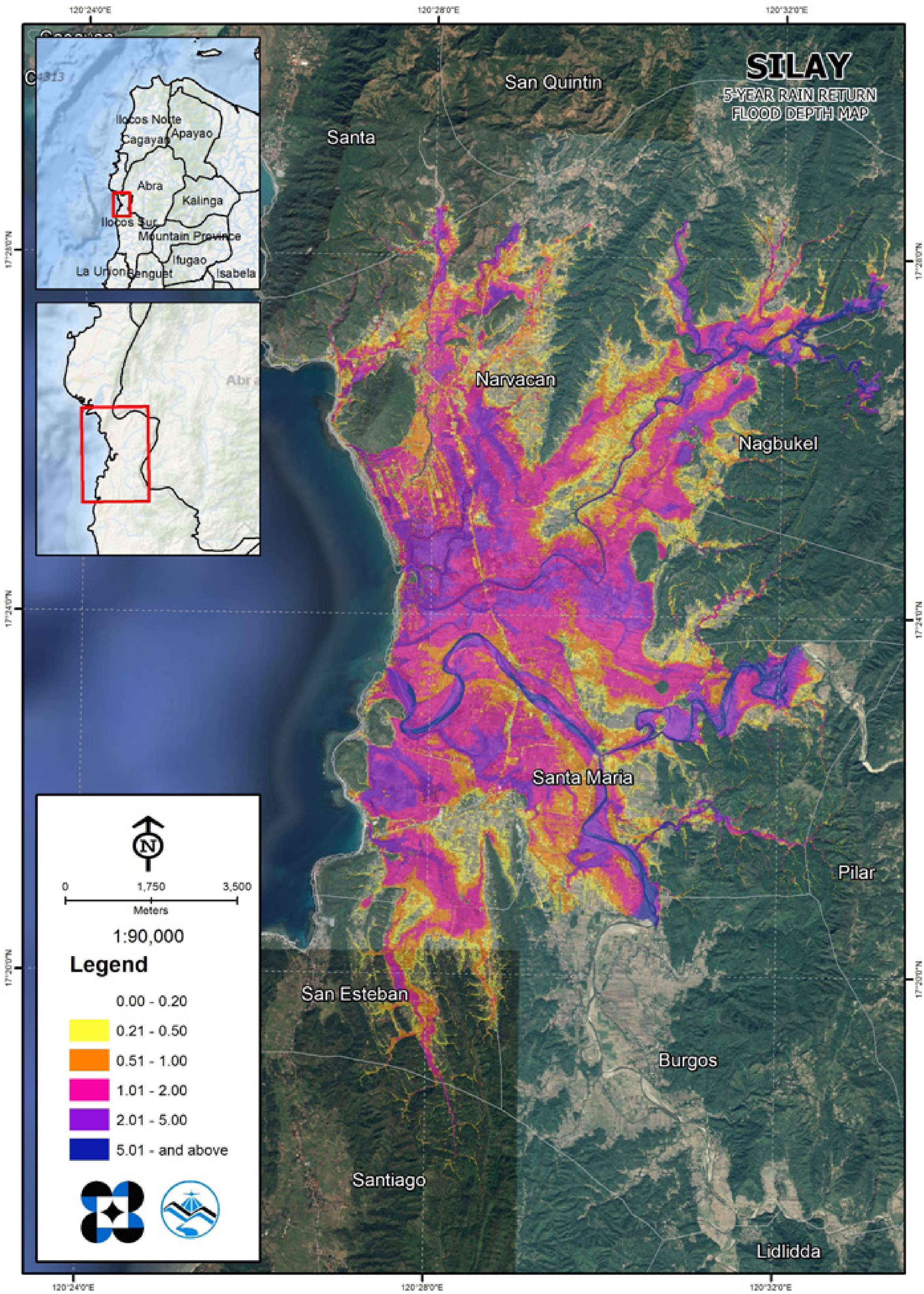


Figure 75. 5-year Flow Depth Map for Silay Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Silay River Basin, grouped by municipality, are listed below. For the said basin, two (2) provinces with eight (8) municipalities consisting of 99 barangays are expected to experience flooding when subjected to 5-yr rainfall return period. Annexes 12 and 13 list the educational and health institutions, respectively, that will be affected by flooding in Silay River Basin.

For the 5-year return period, 2.53% of the municipality of Pilar with an area of 92.196 sq. km. will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.03%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Pilar, Abra during 5-Year Rainfall Return Period

Affected are (sq. km.) by flood depth (in m.)	Affected Barangay in Pilar	
	Bookside	Nagcanasan
0-0.20	1.59	0.74
0.21-0.50	0.05	0.022
0.51-1.00	0.026	0.0078
1.01-2.00	0.022	0.0036
2.01-5.00	0.0093	0.00085
> 5.00	0.0003	0

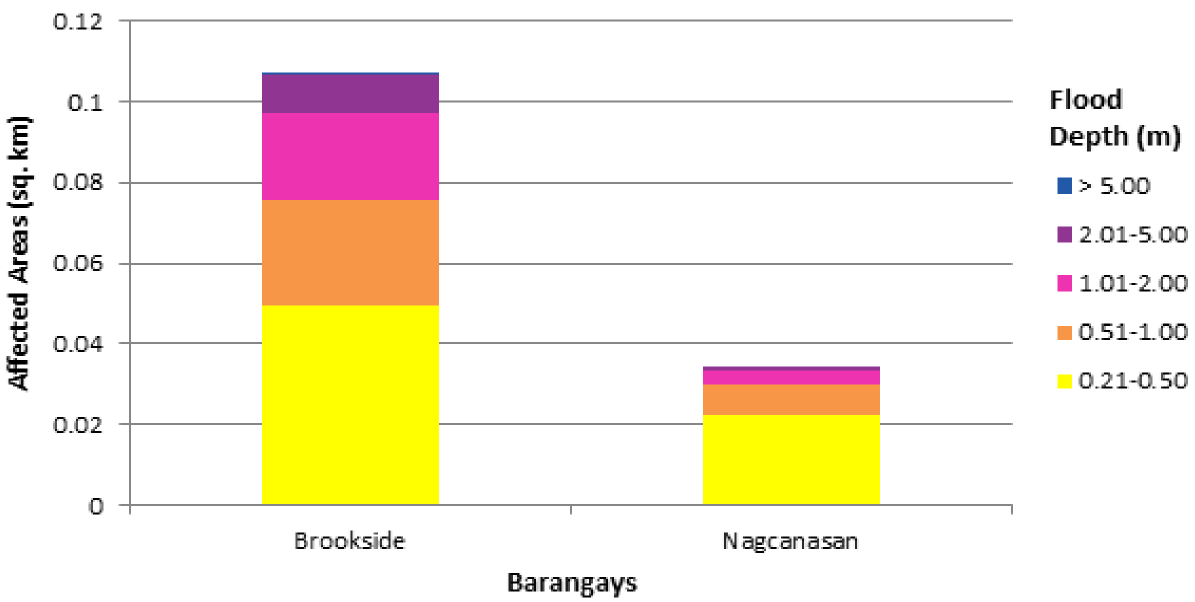


Figure 76. Affected Areas in Pilar, Abra during 5-Year Rainfall Return Period

For the 5-year return period, 5.02% of the municipality of Burgos with an area of 49.604 sq. km. will experience flood levels of less than 0.20 meters. 0.72% of the area will experience flood levels of 0.21 to 0.50 meters while 0.45%, 0.09%, 0.04%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Burgos, Ilocos Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) By flood depth (in m.)	Affected Barangays in Burgos								
	Cabcab-urao	Cadacad	Lesseb	Lucaban	Macaoayan	Mambug	Nagpa-naoan	Poblacion Sur	Taliao
0-0.20	0.52	0.23	0.014	0.42	0.18	0.47	0.016	0.35	0.29
0.21-0.50	0.02	0.042	0.00078	0.055	0.0014	0.16	0.00026	0.054	0.03
0.51-1.00	0.009	0.024	0.0054	0.046	0.0001	0.1	0.0023	0.01	0.022
1.01-2.00	0.014	0.0019	0.0036	0.013	0.000005	0.0077	0.000001	0.00093	0.0046
2.01-5.00	0.016	0	0.0041	0	0	0	0	0	0.0001
> 5.00	0.0037	0	0.013	0	0	0	0	0	0

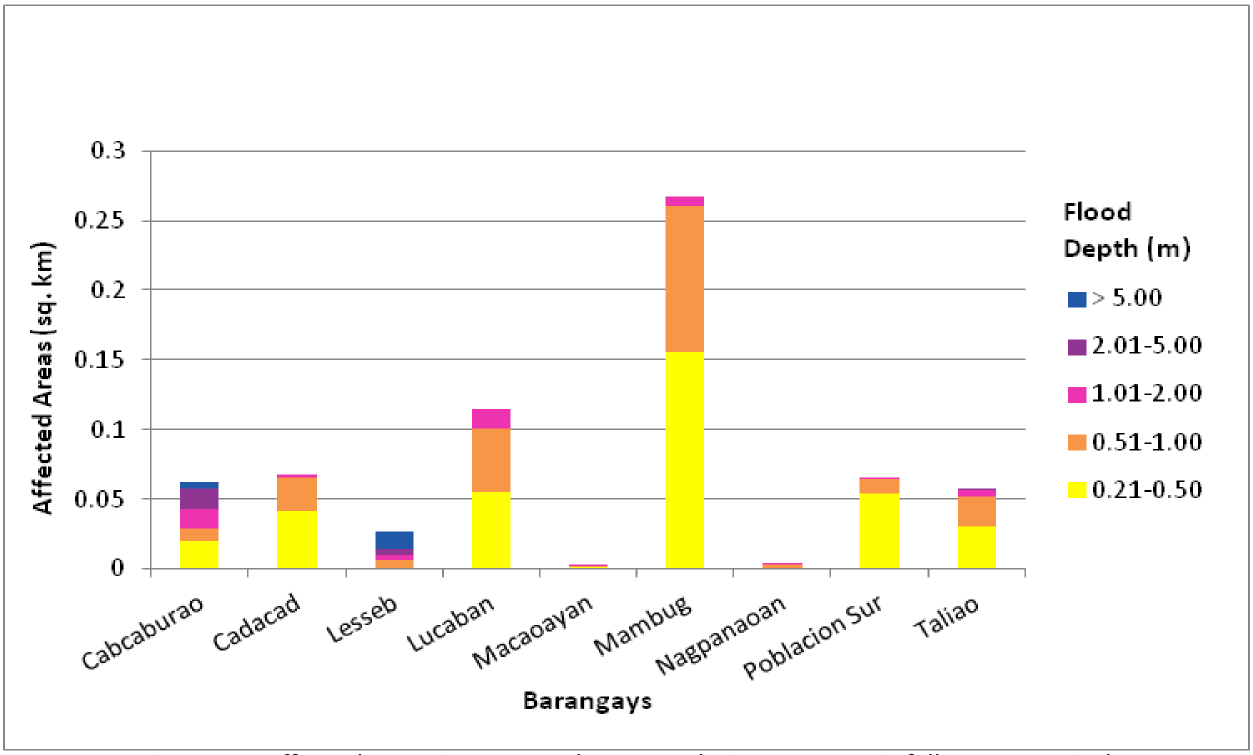


Figure 77. Affected Areas in Burgos, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 22.44% of the municipality of Nagbukel with an area of 36.46 sq. km. will experience flood levels of less than 0.20 meters. 2.37% of the area will experience flood levels of 0.21 to 0.50 meters while 2.83%, 4.21%, 2.20%, and 0.64% 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 38 are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Nagbukel, Ilocos Sur during 5-Year Rainfall Return Period

"Affected area (sq. km.) By flood depth (in m.)"	Area of affected barangays in Nagbukel (in sq. km)								
	Balaweg	Bandril	Bantugo	Casilagan	Mapisi	Mission	Poblacion East	Poblacion West	Taleb
0-0.20	0.14	1.91	0.097	1.01	1.54	1.07	0.65	1.44	0.33
0.21-0.50	0.085	0.24	0.077	0.058	0.069	0.15	0.058	0.12	0.016
0.51-1.00	0.27	0.085	0.29	0.025	0.06	0.13	0.09	0.056	0.017
1.01-2.00	0.39	0.028	0.79	0.023	0.052	0.06	0.16	0.017	0.017
2.01-5.00	0.3	0.024	0.1	0.094	0.12	0.047	0.079	0.0033	0.038
> 5.00	0.0007	0.00093	0	0.13	0.087	0.0001	0	0	0.017

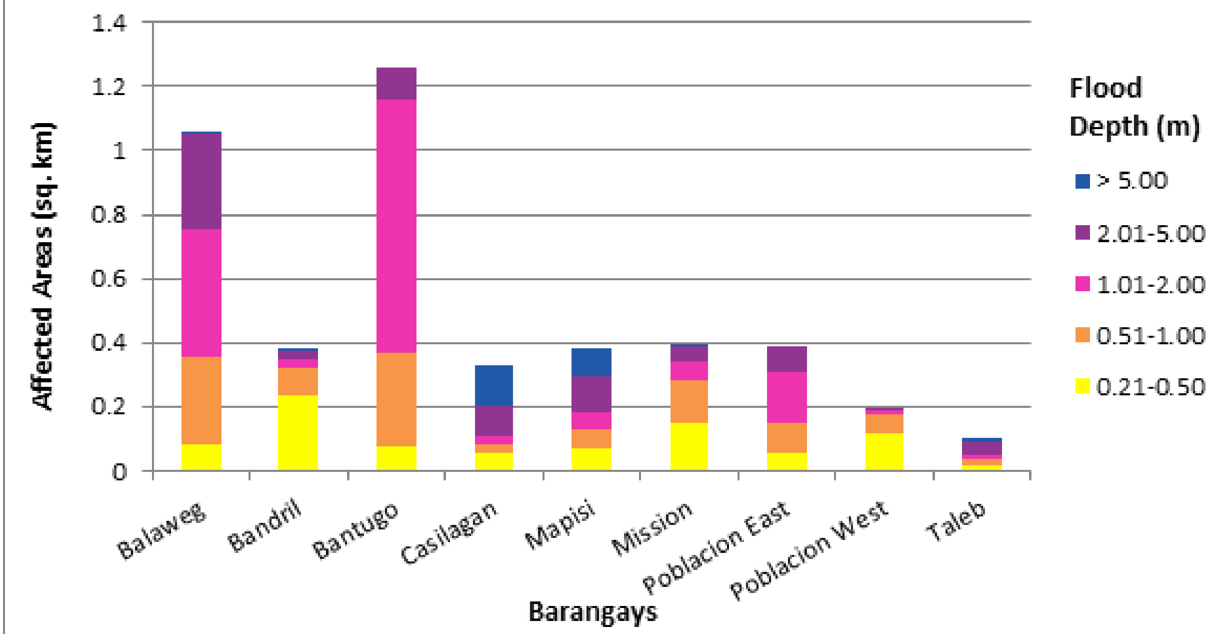


Figure 78. Affected Areas in Nagbukel, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 35.12% of the municipality of Narvacan with an area of 97.176 sq. km. will experience flood levels of less than 0.20 meters. 6.74% of the area will experience flood levels of 0.21 to 0.50 meters while 8.50%, 15.10%, 8.82%, and 0.79% 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 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period

SILAY BASIN		Affected Barangays in Narvacan											
		Abuor	Ambulogan	Aquib	Banglayan	Bantay Abot	Bulanos	Cadacad	Cagayungan	Camarao	Casilagan	Codoog	Dasay
Affected Area	**0-0.20**	0.0012	3.41	1.87	3.07	0.79	1.34	0.51	0.0063	2.08	1.5	1.07	2.21
(sq. km.)	**0.21-0.50**	0.004	0.51	0.57	0.29	0.14	0.17	0.021	0.021	0.42	0.098	0.48	0.48
	0.51-1.00	0.022	0.38	0.39	0.17	0.17	0.46	0.014	0.21	0.53	0.042	0.64	0.63
	1.01-2.00	0.25	0.16	0.21	0.18	0.23	0.5	0.0075	1.38	0.39	0.041	0.41	1.47
	2.01-5.00	0.29	0.0058	0.11	0.39	0.067	0.092	0.0024	0.94	0.17	0.12	0.37	0.53
	> 5.00	0	0	0	0.016	0	0	0.0002	0.017	0	0.12	0.12	0.026

SILAY BASIN		Affected Barangays in Narvacan										
		Dinalaoan	Estancia	Lanipao	Lungog	Margaay	Marozo	Naguneg	Orence	Pantoc	Paratong	Parparia
Affected Area	**0-0.20**	0.039	0.049	0.64	1.47	0.11	2.27	0.008	0.3	0.12	0.023	0.7
(sq. km.)	**0.21-0.50**	0.034	0.0067	0.039	0.27	0.11	0.27	0.018	0.25	0.03	0.053	0.22
	0.51-1.00	0.093	0.047	0.018	0.35	0.29	0.24	0.11	0.18	0.053	0.25	0.27
	1.01-2.00	0.56	0.12	0.0057	0.3	0.63	0.38	0.93	0.29	0.2	0.51	0.56
	2.01-5.00	0.29	0.1	0.01	0.26	0.37	0.19	0.59	0.022	0.58	0.27	0.031
	> 5.00	0	0.08	0.0011	0.022	0	0.0027	0.046	0.018	0	0	0

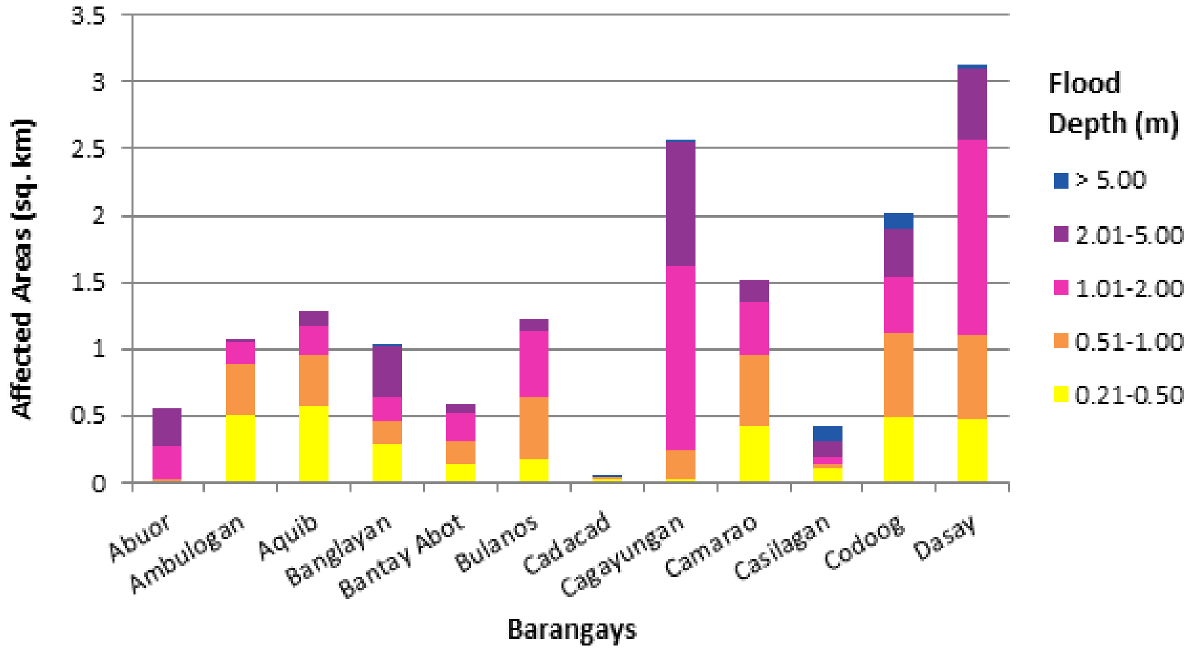


Figure 79. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period

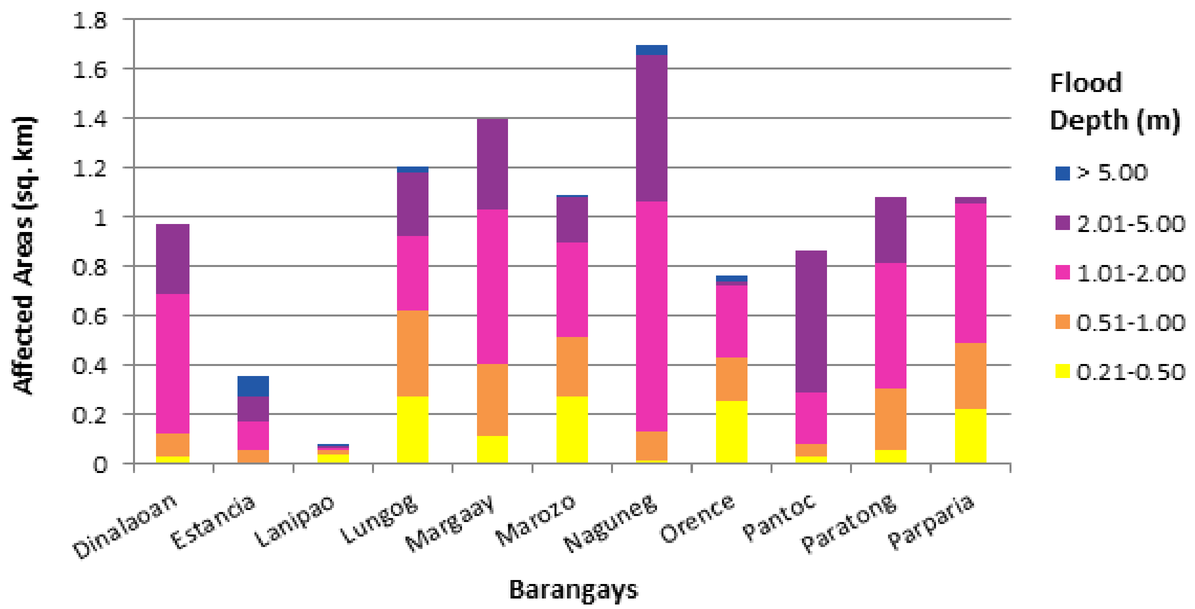


Figure 80. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period

Table 40 Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Narvacan										
	Quinarayan	**Rivadavia**	**San Antonio**	**San Jose**	**San Pablo**	**San Pedro**	**Santa Lucia**	**Sarmingan**	**Sucoc**	**Sulvec**	**Turod**
0-0.20	1.92	0.21	0.0052	0.027	0.26	0.076	0.019	0.99	4.63	2.29	0.1
0.21-0.50	0.47	0.13	0.014	0.016	0.66	0.024	0.026	0.15	0.42	0.098	0.031
0.51-1.00	0.7	0.36	0.093	0.049	0.76	0.11	0.041	0.22	0.17	0.088	0.098
1.01-2.00	1.06	0.71	1.06	0.19	0.27	0.59	0.19	0.23	0.33	0.07	0.29
2.01-5.00	0.23	0.12	0.81	0.19	0.057	0.44	0.16	0.16	0.41	0.021	0.21
> 5.00	0	0.029	0.000012	0	0.044	0.0027	0	0.22	0.0018	0.0001	0

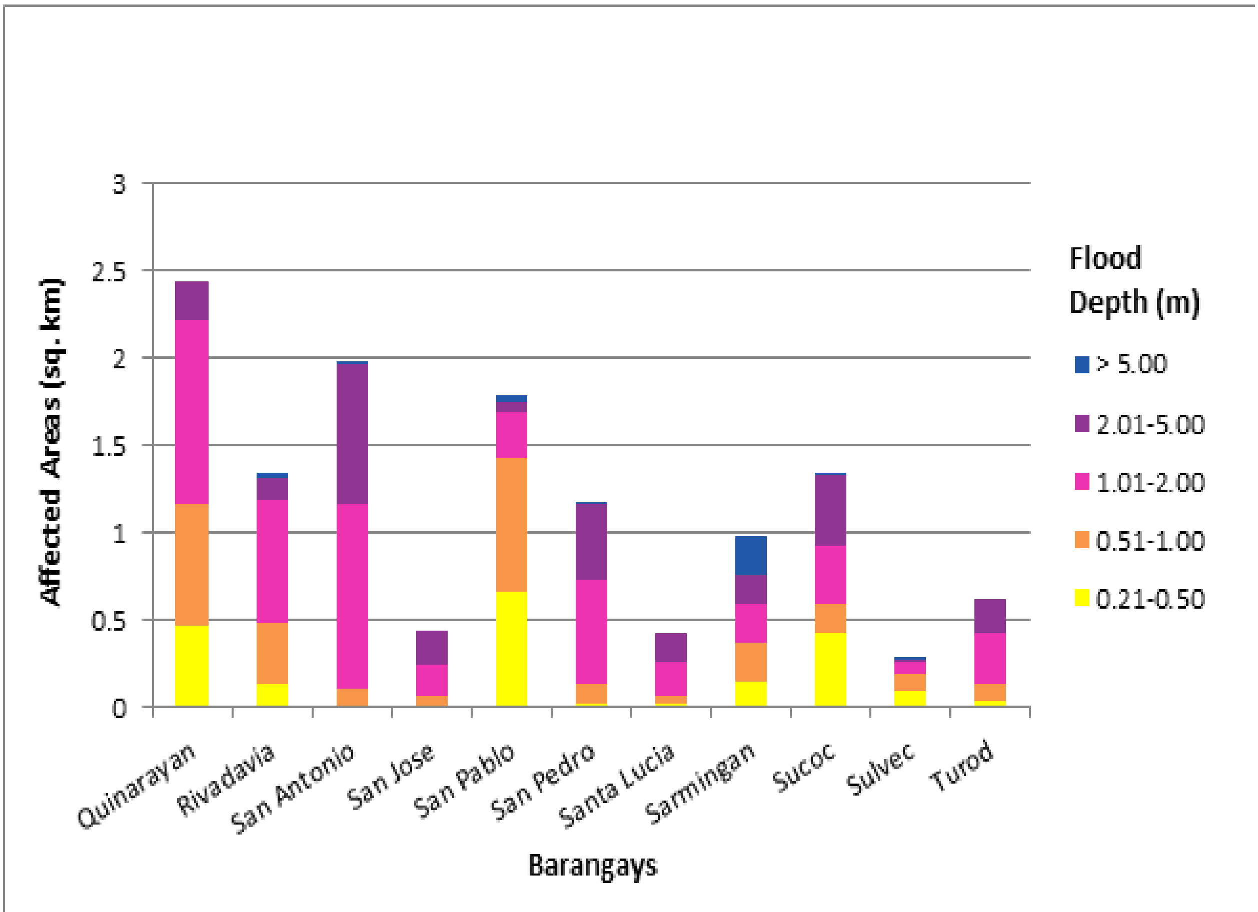


Figure 81. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period

Table 41. Affected Areas in San Esteban, Ilocos Sur during 5-Year Rainfall Return Period

Silay Basin		Affected Barangays in San Esteban						
		Ansad	Cabaroan	Cappa-Cappa	Poblacion	San Nicolas	San Pablo	San Rafael
Affected Are (sq. km.)	0-0.20	1.41	2	1.25	0.26	0.38	0.79	0.3
	0.21-0.50	0.24	0.17	0.58	0.02	0.02	0.064	0.036
	0.51-1.00	0.4	0.093	0.78	0.0017	0.0051	0.029	0.008
	1.01-2.00	0.32	0.016	0.7	0.00098	0.0015	0.026	0.00039
	2.01-5.00	0.038	0.0019	0.034	0.000008	0.00072	0.00011	0
	> 5.00	0	0	0	0	0.000019	0	0

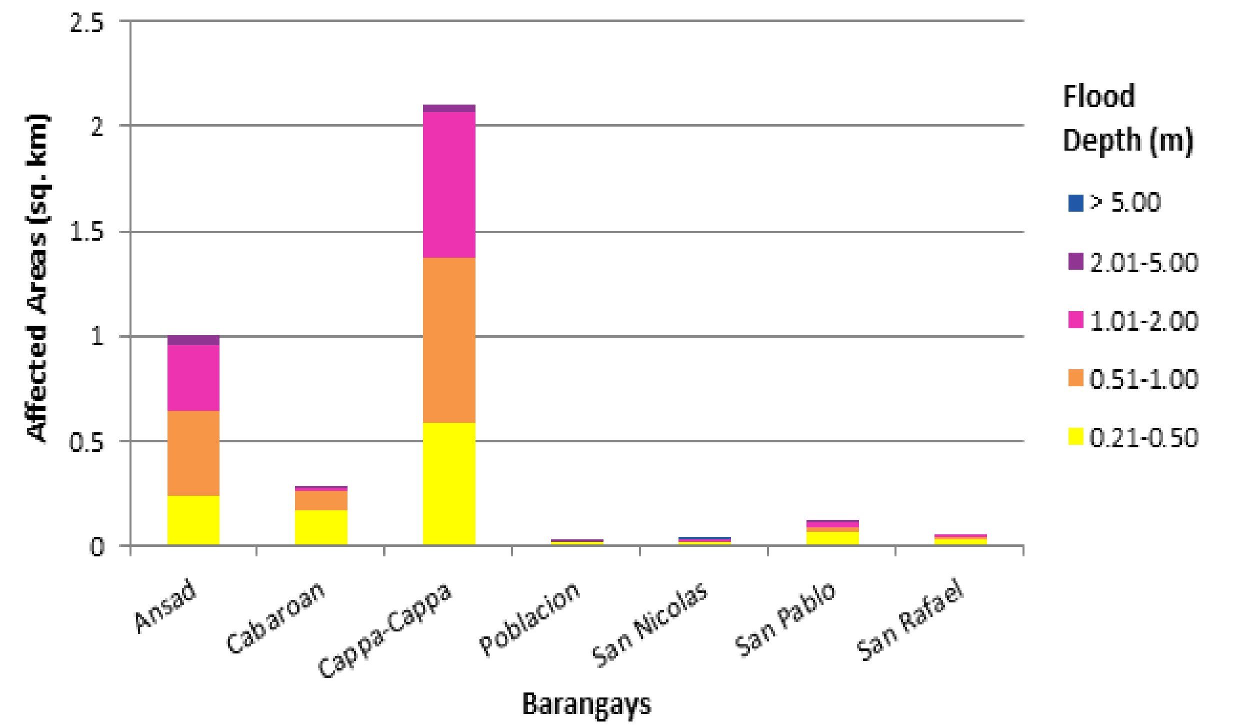


Figure 82. Affected Areas in San Esteban, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 4.93% of the municipality of Santa with an area of 57.2 sq. km. will experience flood levels of less than 0.20 meters. 0.23% of the area will experience flood levels of 0.21 to 0.50 meters while 0.11%, 0.13%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period

Affected Area (sq. km.)	Affected Barangays in Santa	
	Magsaysay District	Quezon
0-0.20	1.55	1.27
0.21-0.50	0.1	0.031
0.51-1.00	0.052	0.014
1.01-2.00	0.071	0.0042
2.01-5.00	0.064	0.0006
> 5.00	0.00025	0

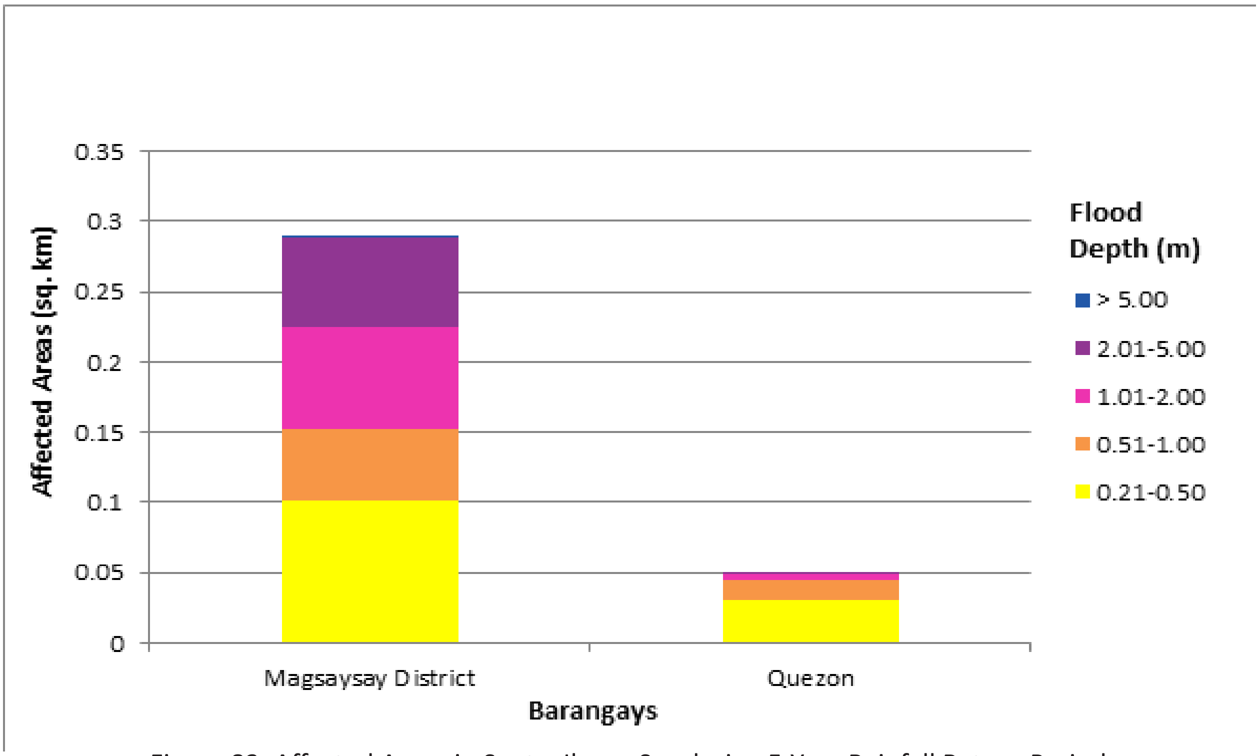


Figure 83. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period

For the 5-year return period, 34.83% of the municipality of Santa Maria with an area of 52.32 sq. km. will experience flood levels of less than 0.20 meters. 8.25% of the area will experience flood levels of 0.21 to 0.50 meters while 13.73%, 22.26%, 11.33%, and 3.37% 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 kilometers by flood depth per barangay.

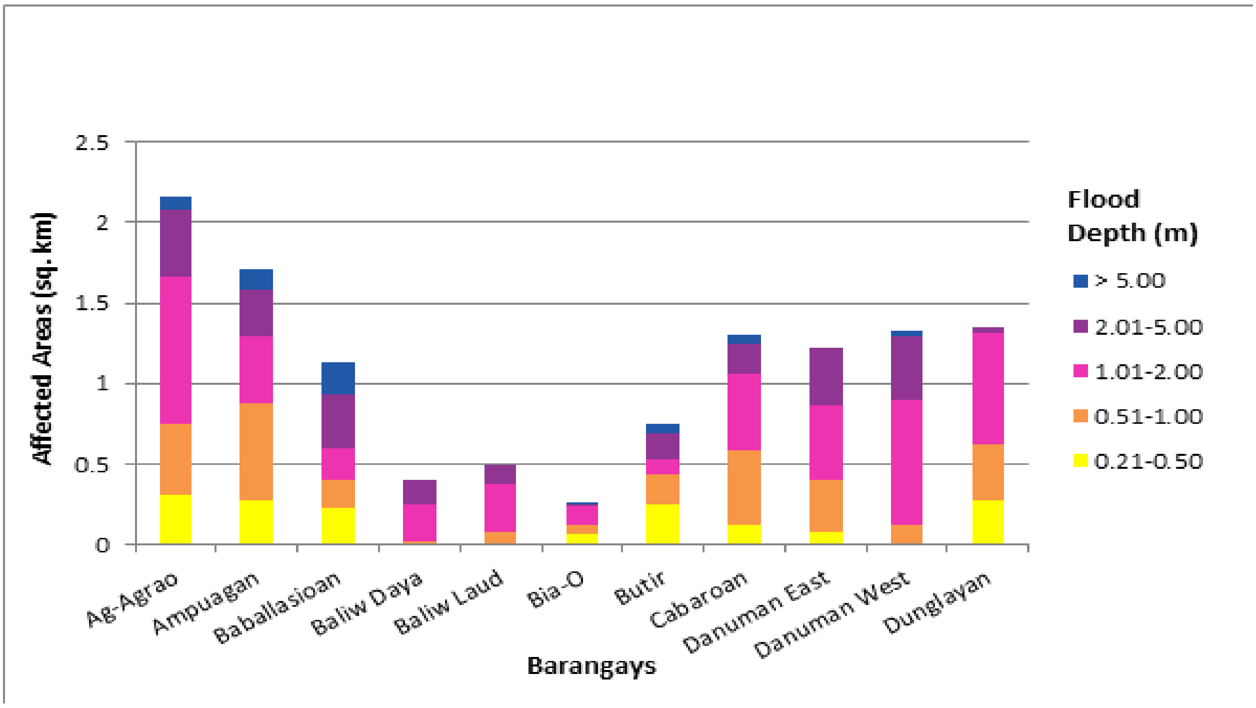


Figure 84. Affected Areas in Santa Maria, Ilocos Sur during 5-Year Rainfall Return Period

Table 43. Affected Areas in Santa Maria, Ilocos Sur during 5-Year Rainfall Return Period

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Santa Maria										
	Ag-Agrao	Ampuagan	Baballasioan	Baliw Daya	Baliw Laud	Bia-O	Butir	Cabaroan	Danuman East	Danuman West	Dunglayan
0-0.20	0.55	0.22	2.04	0.0002	0.0028	0.42	0.67	0.058	0.049	0.0014	0.75
0.21-0.50	0.31	0.28	0.23	0.0026	0.014	0.065	0.25	0.13	0.075	0.011	0.27
0.51-1.00	0.43	0.6	0.17	0.018	0.064	0.063	0.18	0.46	0.33	0.11	0.35
1.01-2.00	0.92	0.41	0.2	0.23	0.31	0.11	0.092	0.48	0.46	0.77	0.69
2.01-5.00	0.42	0.29	0.33	0.15	0.11	0.006	0.16	0.19	0.35	0.4	0.035
> 5.00	0.079	0.14	0.2	0	0	0.00046	0.06	0.051	0	0.032	0

Affected Areas (in sq.m.) by flood depth (in m.)	Affected Barangays in Santa Maria										
	Gusing	Langaoan	Laslasong Norte	Laslasong Sur	Laslasong West	Lesseb	Lingsat	Lubong	Maynganay Norte	Maynganay Sur	Nagsayaoan
0-0.20	1.56	0.071	0.016	0.28	0.1	0.14	0.5	1.13	0.014	0.0085	0.019
0.21-0.50	0.17	0.14	0.022	0.25	0.23	0.062	0.021	0.43	0.08	0.03	0.028
0.51-1.00	0.096	0.46	0.13	0.29	0.51	0.098	0.026	0.28	0.31	0.056	0.35
1.01-2.00	0.33	0.32	0.54	0.52	0.5	0.16	0.16	0.34	0.16	0.44	0.74
2.01-5.00	0.44	0.33	0.077	0.035	0.052	0.037	0.18	0.052	0.024	0.058	0.14
> 5.00	0.27	0.091	0.00033	0.000001	0.03	0.19	0.019	0	0.074	0	0.059

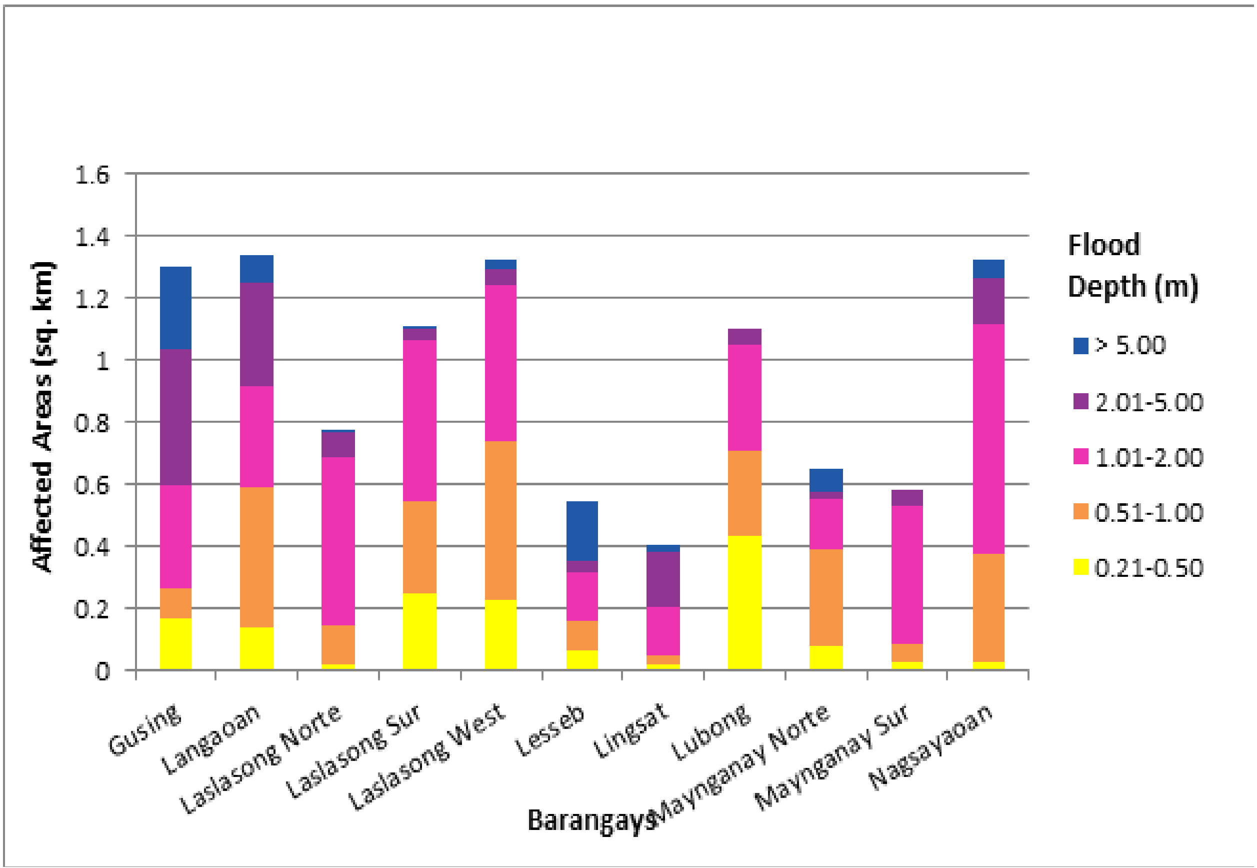


Figure 85. Affected Areas in Santa Maria, Ilocos Sur during 5-Year Rainfall Return Period

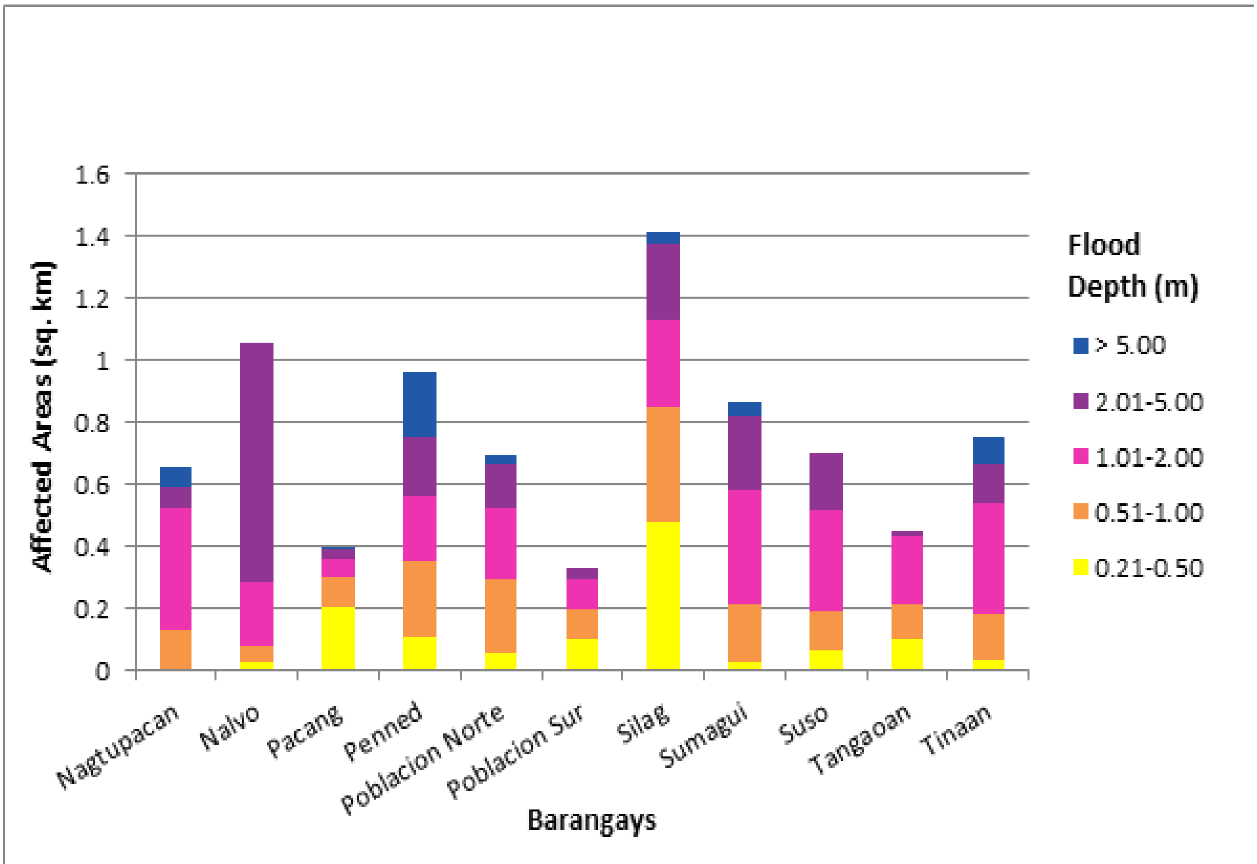


Figure 86. Affected Areas in Santa Maria, Ilocos Sur during 5-Year Rainfall Return Period

Table 44. Affected Areas in Santa Maria, Ilocos Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Maria (in sq. km.)										
	Nagtupacan	Nalvo	Pacang	Penned	Poblacion Norte	Poblacion Sur	Silag	Sumagui	Suso	Tangaoan	Tinaan
0-0.20	0.0008	0.45	3.34	0.51	0.069	0.23	3.93	0.0071	0.31	0.76	0.02
0.21-0.50	0.0047	0.031	0.2	0.11	0.054	0.1	0.48	0.03	0.065	0.099	0.034
0.51-1.00	0.13	0.047	0.1	0.24	0.24	0.097	0.37	0.18	0.12	0.11	0.15
1.01-2.00	0.39	0.21	0.055	0.2	0.23	0.093	0.28	0.37	0.33	0.23	0.35
2.01-5.00	0.068	0.77	0.033	0.2	0.14	0.039	0.24	0.24	0.18	0.012	0.13
> 5.00	0.063	0	0.005	0.2	0.025	0	0.038	0.042	0	0	0.09

For the 5-year return period, 5.83% of the municipality of Santiago with an area of 65.57 sq. km. will experience flood levels of less than 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.07%, 0.03%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Santiago, Ilocos Sur during 5-Year Rainfall Return Period

Affected Area(sq. km.) by Flood Depth (in m.)		Affected Barangays in Santiago		
		Bigbiga	Mambug	Salincub
	0-0.20v	0.083	3.71	0.028
	0.21-0.50	0.00084	0.16	0.00075
	0.51-1.00	0.00025	0.08	0.00043
	1.01-2.00	0.000054	0.045	0.00011
	2.01-5.00	0	0.019	0.000008
	> 5.00	0	0	0

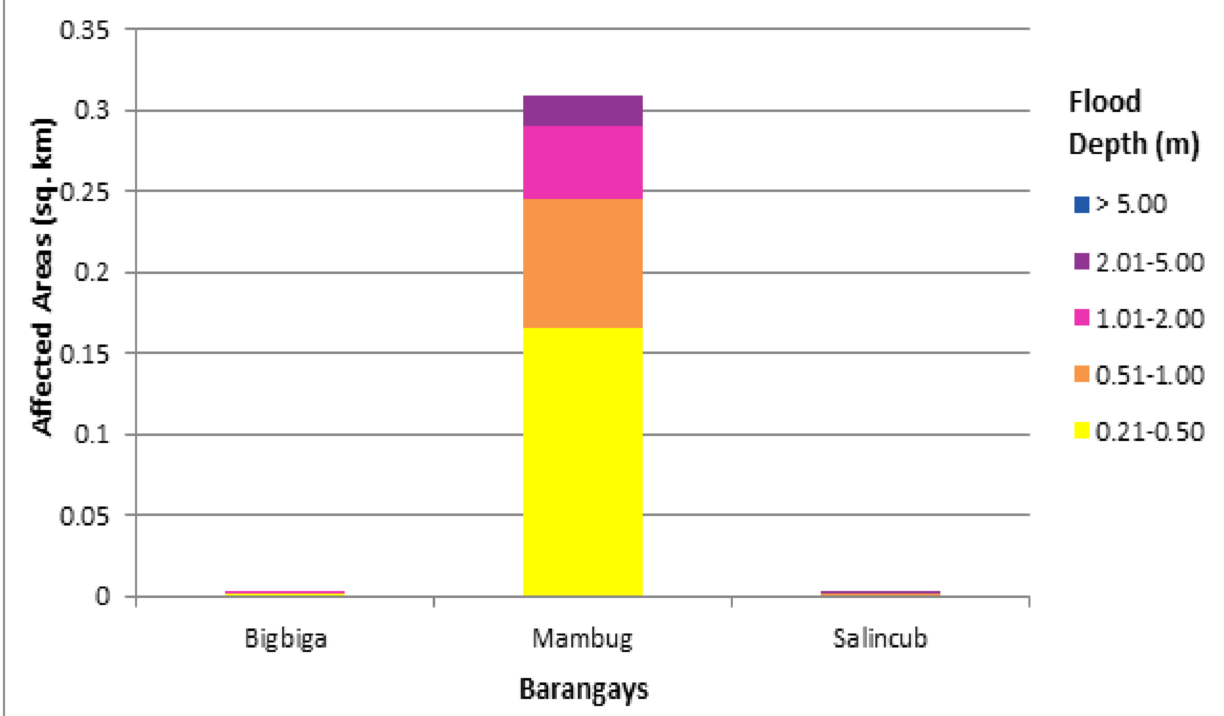


Figure 87. Affected Areas in Santiago, Ilocos Sur during 5-Year Rainfall Return Period

For the 25-year return period, 2.49% of the municipality of Pilar with an area of 92.196 sq. km. will experience flood levels of less than 0.20 meters. 0.10% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.03%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 46 are the affected areas in square kilometers by flood depth per barangay.

Table 46. Affected Areas in Pilar, Abra during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pilar (in sq. km.)	
	Brookside	Nagcanasan
0-0.20	1.59	0.74
0.21-0.50	0.05	0.022
0.51-1.00	0.026	0.0078
1.01-2.00	0.022	0.0036
2.01-5.00	0.0093	0.00085
> 5.00	0.0003	0

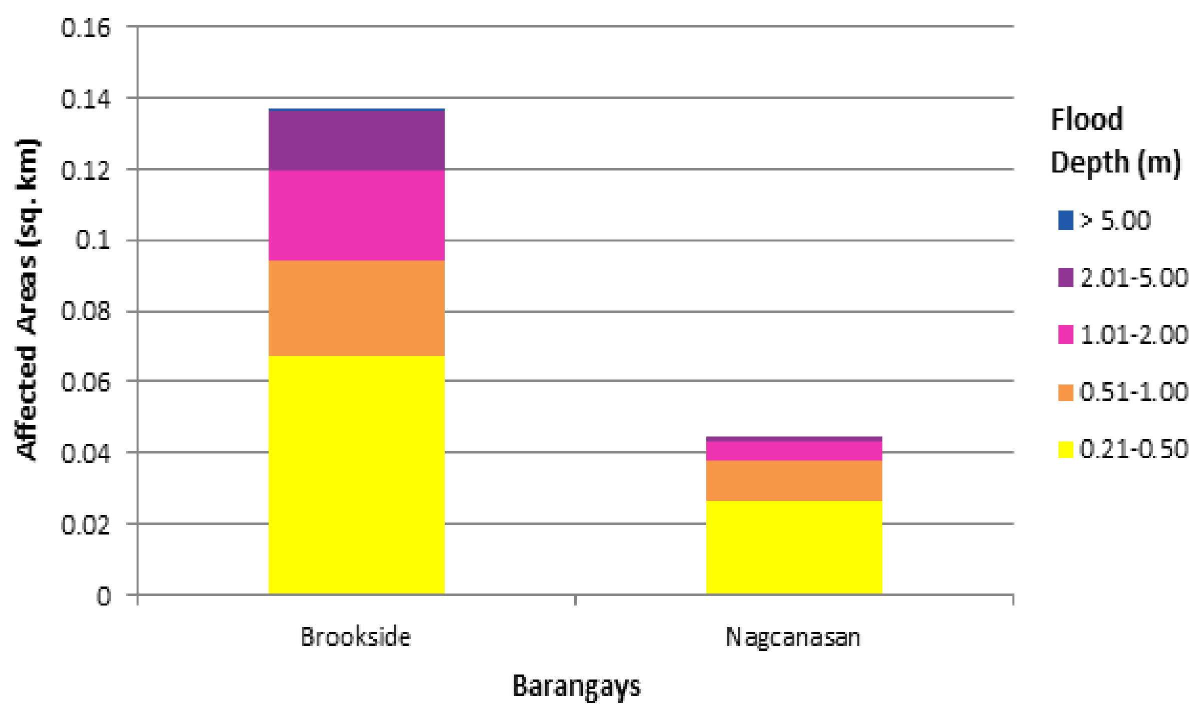


Figure 88. Affected Areas in Pilar, Abra during 25-Year Rainfall Return Period

For the 25-year return period, 4.66% of the municipality of Burgos with an area of 49.604 sq. km. will experience flood levels of less than 0.20 meters. 0.81% of the area will experience flood levels of 0.21 to 0.50 meters while 0.50%, 0.26%, 0.09%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the Table 47 are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Burgos, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Burgos (in sq. km.)								
	Cabca-burao	Cadacad	Lesseb	Lucaban	Macaoayan	Mambug	Nagpanaoan	Poblacion Sur	Taliao
0-0.20	0.52	0.23	0.014	0.42	0.18	0.47	0.016	0.35	0.29
0.21-0.50	0.02	0.042	0.00078	0.055	0.0014	0.16	0.00026	0.054	0.03
0.51-1.00	0.009	0.024	0.0054	0.046	0.0001	0.1	0.0023	0.01	0.022
1.01-2.00	0.014	0.0019	0.0036	0.013	0.000005	0.0077	0.000001	0.00093	0.0046
2.01-5.00	0.016	0	0.0041	0	0	0	0	0	0.0001
> 5.00	0.0037	0	0.013	0	0	0	0	0	0

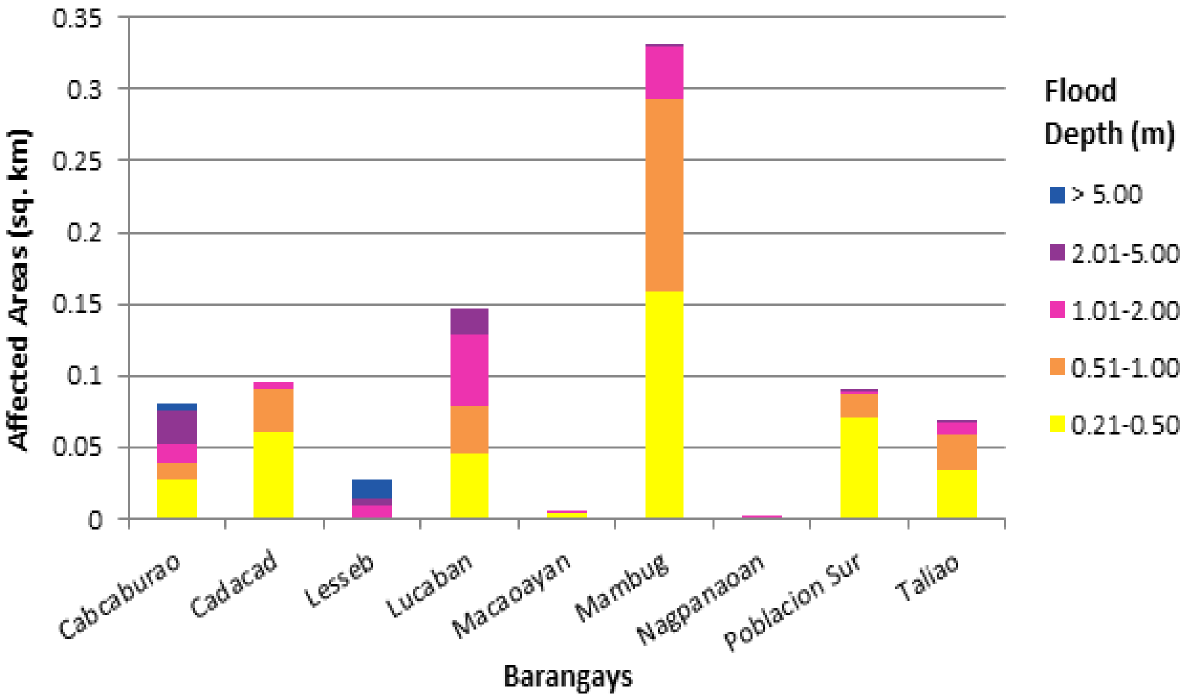


Figure 89. Affected Areas in Burgos, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 21.14% of the municipality of Nagbukel with an area of 36.46 sq. km. will experience flood levels of less than 0.20 meters. 2.17% of the area will experience flood levels of 0.21 to 0.50 meters while 2.04%, 4.65%, 3.69%, and 1.00% 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 48 are the affected areas in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Nagbukel, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.)	Area of affected barangays in Nagbukel (in sq. km.)								
	Balaweg	Bandril	Bantugo	Casilagan	Mapisi	Mission	Poblacion East	Poblacion West	Taleb
0-0.20	0.14	1.91	0.097	1.01	1.54	1.07	0.65	1.44	0.33
0.21-0.50	0.085	0.24	0.077	0.058	0.069	0.15	0.058	0.12	0.016
0.51-1.00	0.27	0.085	0.29	0.025	0.06	0.13	0.09	0.056	0.017
1.01-2.00	0.39	0.028	0.79	0.023	0.052	0.06	0.16	0.017	0.017
2.01-5.00	0.3	0.024	0.1	0.094	0.12	0.047	0.079	0.0033	0.038
> 5.00	0.0007	0.00093	0	0.13	0.087	0.0001	0	0	0.017

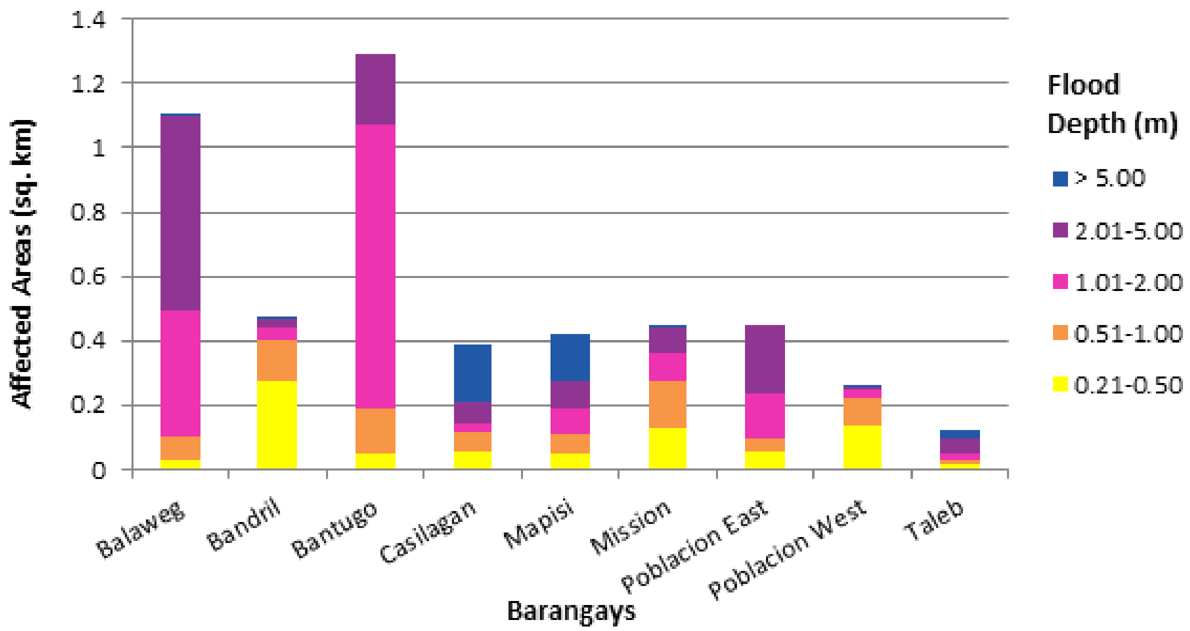


Figure 90. Affected Areas in Nagbukel, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 31.39% of the municipality of Narvacan with an area of 97.176 sq. km. will experience flood levels of less than 0.20 meters. 5.52% of the area will experience flood levels of 0.21 to 0.50 meters while 6.58%, 12.69%, 17.68%, and 1.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the Table 49 are the affected areas in square kilometers by flood depth per barangay.

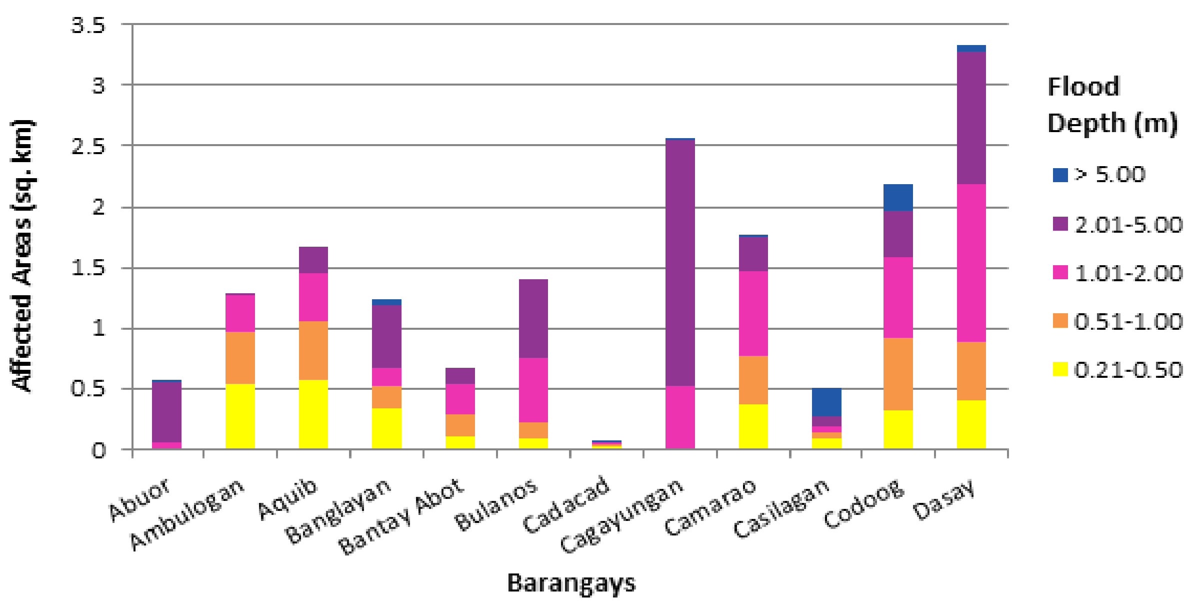


Figure 91. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period

Table 49. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Narvacan (in sq. km.)											
	Abuor	Ambulogan	Aquib	Banglayan	Bantay Abot	Bulanos	Cadacad	Cagayungan	Camarao	Casilagan	Codoog	Dasay
0-0.20	0.0012	3.41	1.87	3.07	0.79	1.34	0.51	0.0063	2.08	1.5	1.07	2.21
0.21-0.50	0.004	0.51	0.57	0.29	0.14	0.17	0.021	0.021	0.42	0.098	0.48	0.48
0.51-1.00	0.022	0.38	0.39	0.17	0.17	0.46	0.014	0.21	0.53	0.042	0.64	0.63
1.01-2.00	0.25	0.16	0.21	0.18	0.23	0.5	0.0075	1.38	0.39	0.041	0.41	1.47
2.01-5.00	0.29	0.0058	0.11	0.39	0.067	0.092	0.0024	0.94	0.17	0.12	0.37	0.53
> 5.00	0	0	0	0.016	0	0	0.0002	0.017	0	0.12	0.12	0.026

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Narvacan (in sq.km.)										
	Dinalaoan	Estancia	Lanipao	Lungog	Margaay	Marozo	Naguneg	Orence	Pantoc	Paratong	Parparia
0-0.20	0.039	0.049	0.64	1.47	0.11	2.27	0.008	0.3	0.12	0.023	0.7
0.21-0.50	0.034	0.0067	0.039	0.27	0.11	0.27	0.018	0.25	0.03	0.053	0.22
0.51-1.00	0.093	0.047	0.018	0.35	0.29	0.24	0.11	0.18	0.053	0.25	0.27
1.01-2.00	0.56	0.12	0.0057	0.3	0.63	0.38	0.93	0.29	0.2	0.51	0.56
2.01-5.00	0.29	0.1	0.01	0.26	0.37	0.19	0.59	0.022	0.58	0.27	0.031
> 5.00	0	0.08	0.0011	0.022	0	0.0027	0.046	0.018	0	0	0

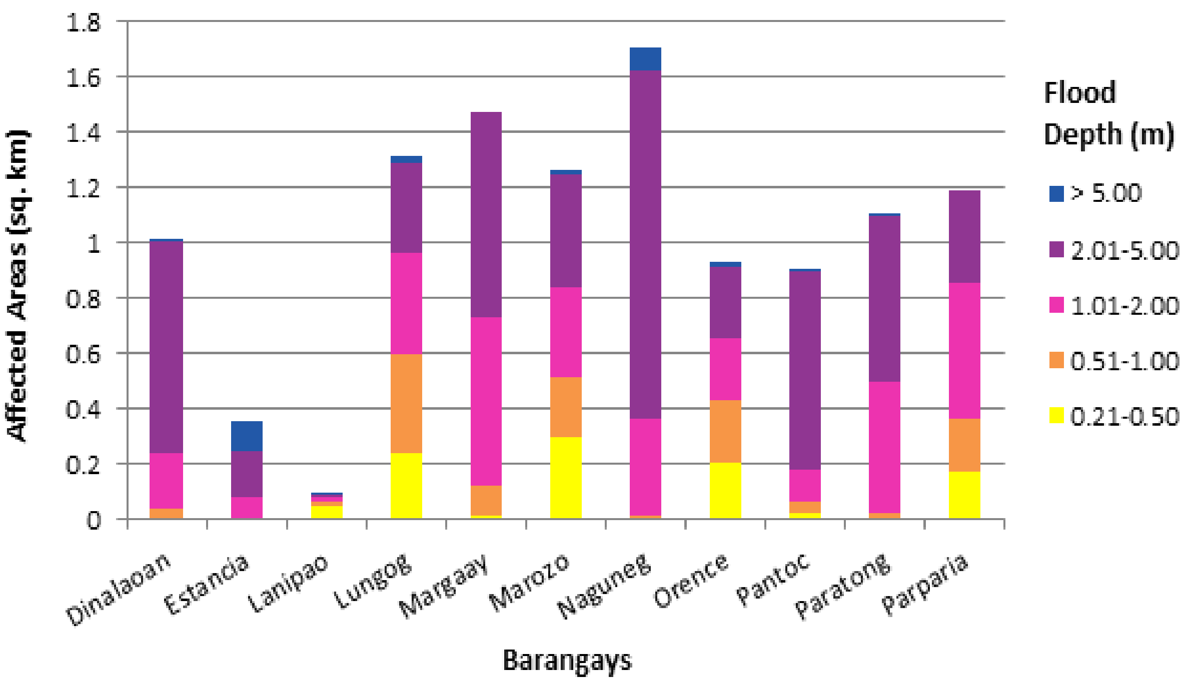


Figure 92. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period

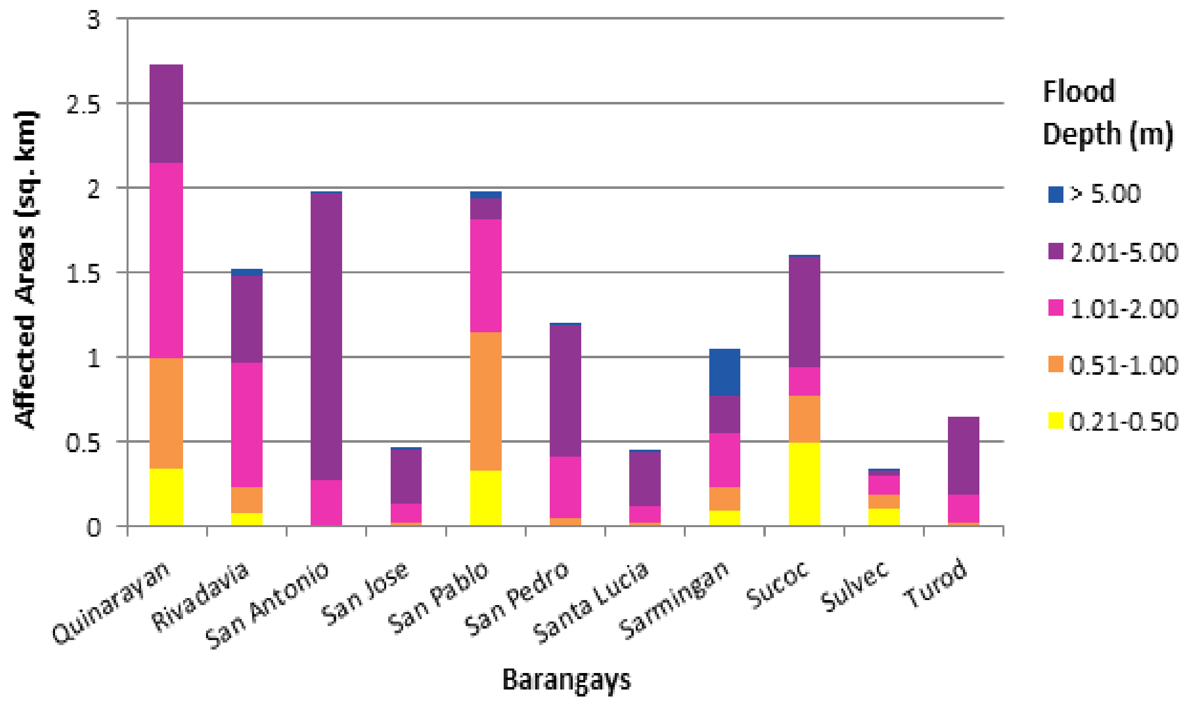


Figure 93. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period

Table 50. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Narvacan (in sq.km.)										
	Quinarayan	Rivadavia	San Antonio	San Jose	San Pablo	San Pedro	Santa Lucia	Sarmingan	Sucoc	Sulvec	Turod
0-0.20	1.92	0.21	0.0052	0.027	0.26	0.076	0.019	0.99	4.63	2.29	0.1
0.21-0.50	0.47	0.13	0.014	0.016	0.66	0.024	0.026	0.15	0.42	0.098	0.031
0.51-1.00	0.7	0.36	0.093	0.049	0.76	0.11	0.041	0.22	0.17	0.088	0.098
1.01-2.00	1.06	0.71	1.06	0.19	0.27	0.59	0.19	0.23	0.33	0.07	0.29
2.01-5.00	0.23	0.12	0.81	0.19	0.057	0.44	0.16	0.16	0.41	0.021	0.21
> 5.00	0	0.029	0.000012	0	0.044	0.0027	0	0.22	0.0018	0.0001	0

For the 25-year return period, 34.21% of the municipality of San Esteban with an area of 17.27 sq. km. will experience flood levels of less than 0.20 meters. 6.12% of the area will experience flood levels of 0.21 to 0.50 meters while 6.70%, 7.53%, and 3.29% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 51 are the affected areas in square kilometers by flood depth per barangay.

Table 51. Affected Areas in San Esteban, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in San Esteban (in sq. km.)						
	Ansad	Cabaroan	Cappa-Cappa	Poblacion	San Nicolas	San Pablo	San Rafael
0-0.20	1.41	2	1.25	0.26	0.38	0.79	0.3
0.21-0.50	0.24	0.17	0.58	0.02	0.02	0.064	0.036
0.51-1.00	0.4	0.093	0.78	0.0017	0.0051	0.029	0.008
1.01-2.00	0.32	0.016	0.7	0.00098	0.0015	0.026	0.00039
2.01-5.00	0.038	0.0019	0.034	0.000008	0.00072	0.00011	0
> 5.00	0	0	0	0	0.000019	0	0

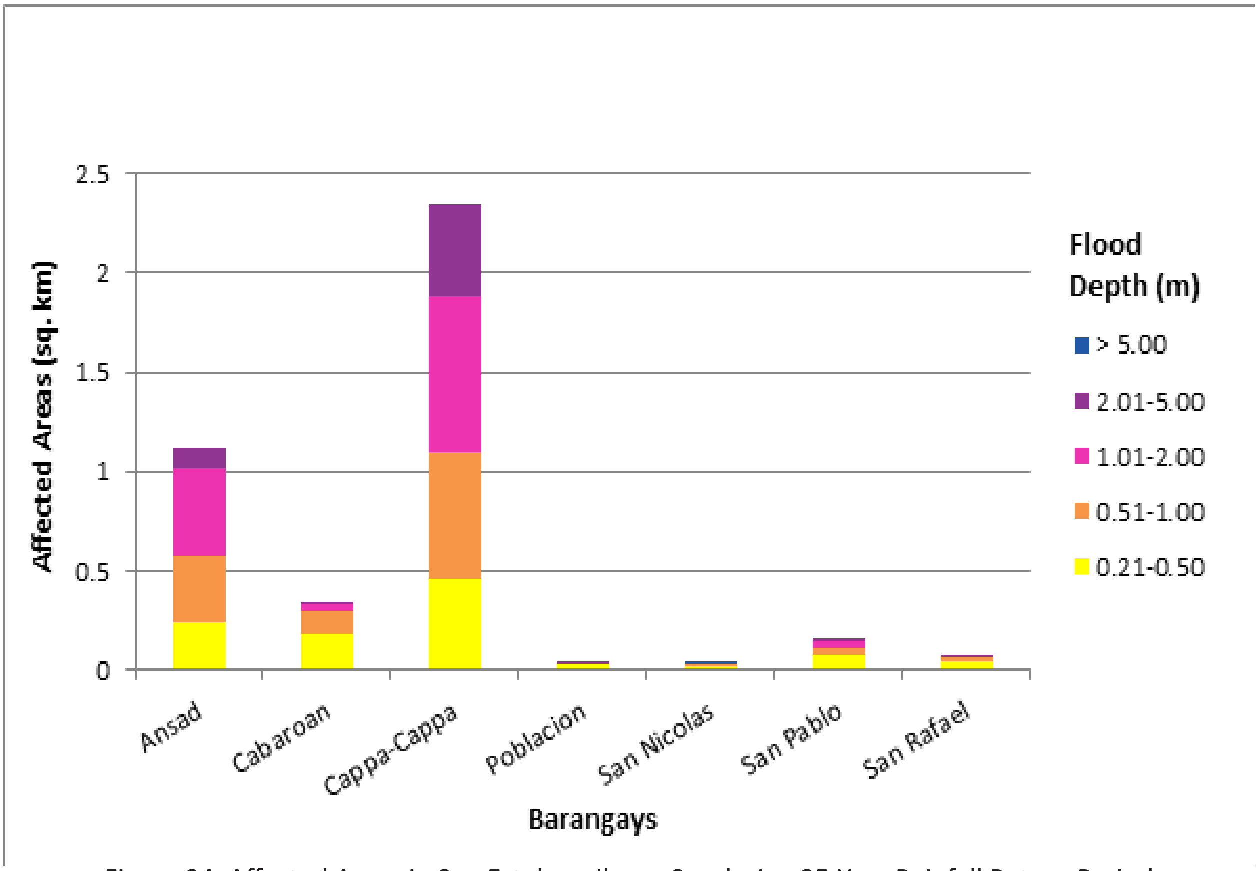


Figure 94. Affected Areas in San Esteban, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 4.78% of the municipality of Santa with an area of 57.2 sq. km. will experience flood levels of less than 0.20 meters. 0.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.13%, 0.13%, and 0.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 52 are the affected areas in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa (in sq. km.)	
	Magsaysay District	**Quezon**
0-0.20	1.55	1.27
0.21-0.50	0.1	0.031
0.51-1.00	0.052	0.014
1.01-2.00	0.071	0.0042
2.01-5.00	0.064	0.0006
> 5.00	0.00025	0

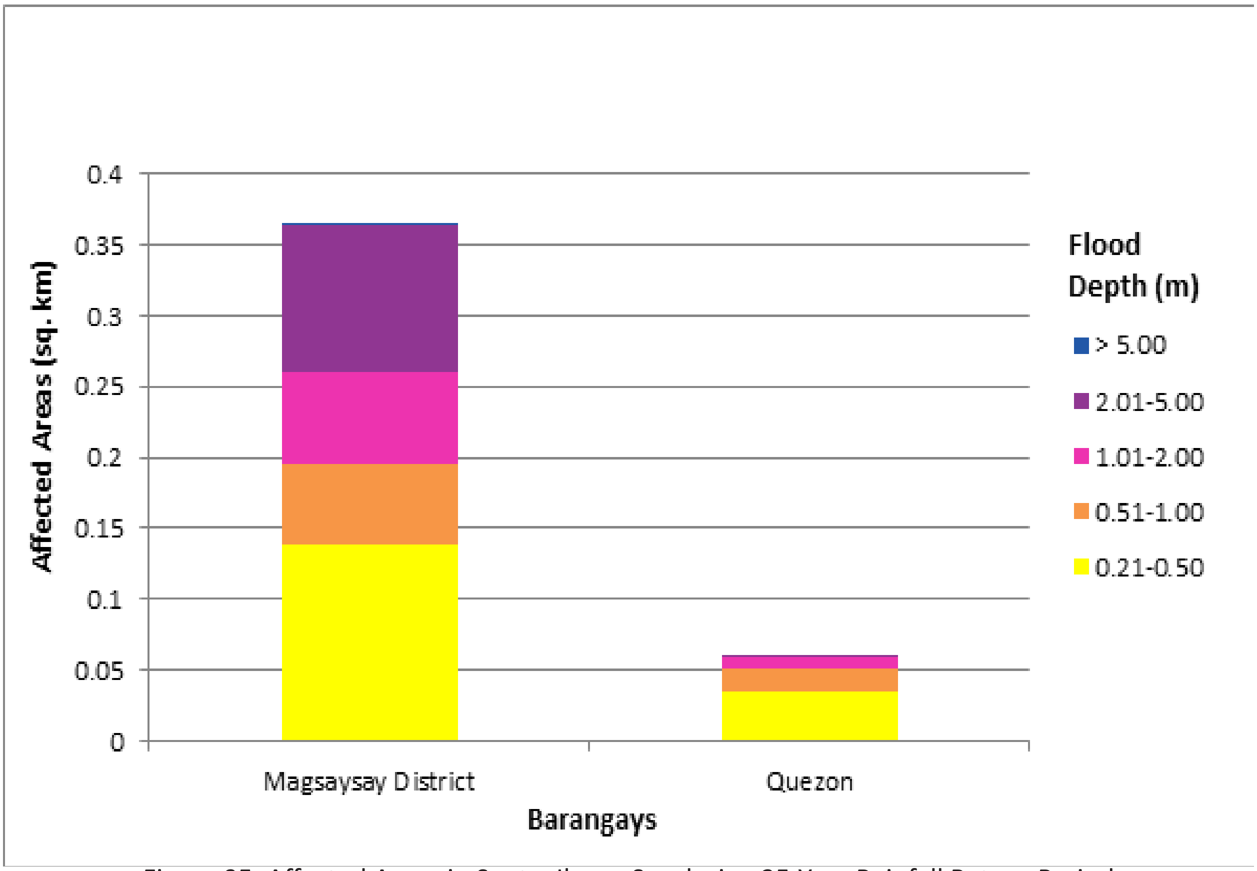


Figure 95. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period

For the 25-year return period, 29.07% of the municipality of Santa Maria with an area of 52.32 sq. km. will experience flood levels of less than 0.20 meters. 5.67% of the area will experience flood levels of 0.21 to 0.50 meters while 8.70%, 20.86%, 25.02%, and 4.45% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 53 are the affected areas in square kilometers by flood depth per barangay.

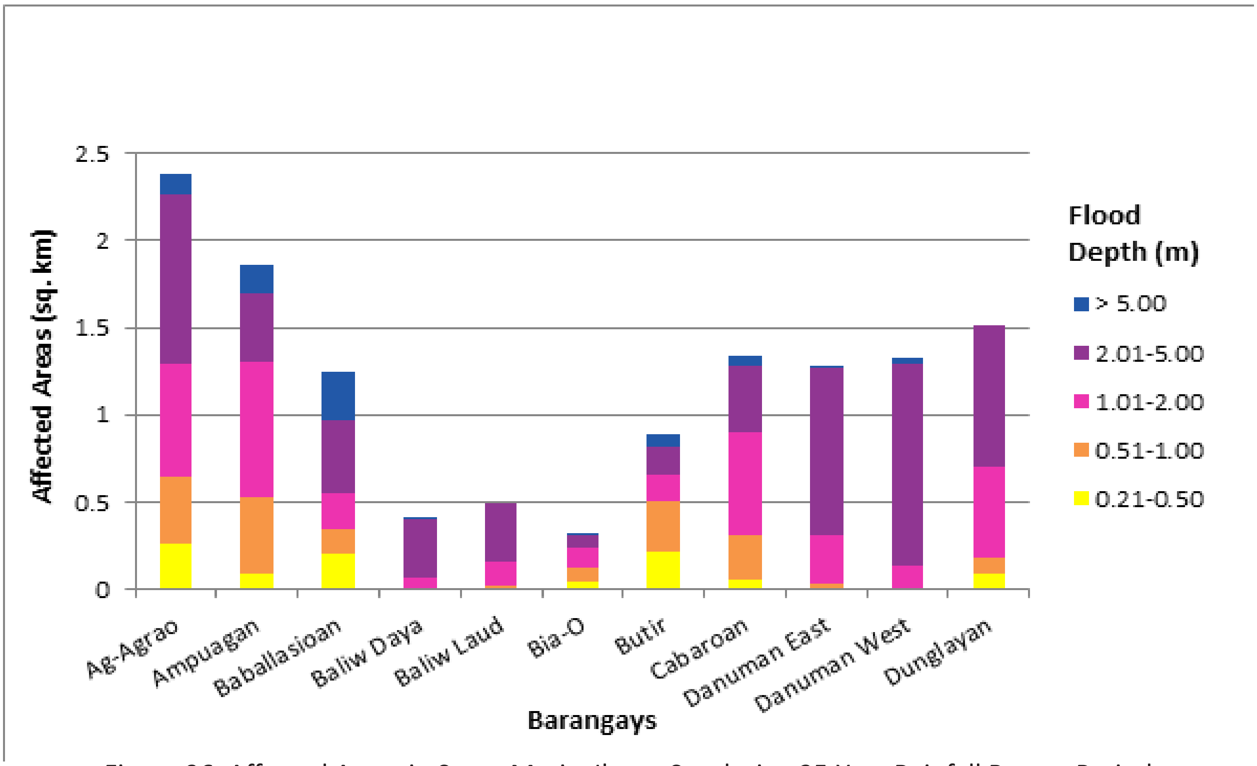


Figure 96. Affected Areas in Santa Maria, Ilocos Sur during 25-Year Rainfall Return Period

Table 53. Affected Areas in Santa Maria, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Maria (in sq. km.)										
	Ag-Agrao	Ampuagan	Baballasioan	Baliw Daya	Baliw Laud	Bia-O	Butir	Cabaroan	Danuman East	Danuman West	Dunglayan
0-0.20	0.55	0.22	2.04	0.0002	0.0028	0.42	0.67	0.058	0.049	0.0014	0.75
0.21-0.50	0.31	0.28	0.23	0.0026	0.014	0.065	0.25	0.13	0.075	0.011	0.27
0.51-1.00	0.43	0.6	0.17	0.018	0.064	0.063	0.18	0.46	0.33	0.11	0.35
1.01-2.00	0.92	0.41	0.2	0.23	0.31	0.11	0.092	0.48	0.46	0.77	0.69
2.01-5.00	0.42	0.29	0.33	0.15	0.11	0.006	0.16	0.19	0.35	0.4	0.035
> 5.00	0.079	0.14	0.2	0	0	0.00046	0.06	0.051	0	0.032	0

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Maria (in sq. km.)										
	Gusing	Langaoan	Laslasong Norte	Laslasong Sur	Laslasong West	Lesseb	Lingsat	Lubong	Maynganay Norte	Maynganay Sur	Nagsayaoan
0-0.20	1.56	0.071	0.016	0.28	0.1	0.14	0.5	1.13	0.014	0.0085	0.019
0.21-0.50	0.17	0.14	0.022	0.25	0.23	0.062	0.021	0.43	0.08	0.03	0.028
0.51-1.00	0.096	0.46	0.13	0.29	0.51	0.098	0.026	0.28	0.31	0.056	0.35
1.01-2.00	0.33	0.32	0.54	0.52	0.5	0.16	0.16	0.34	0.16	0.44	0.74
2.01-5.00	0.44	0.33	0.077	0.035	0.052	0.037	0.18	0.052	0.024	0.058	0.14
> 5.00	0.27	0.091	0.00033	0.000001	0.03	0.19	0.019	0	0.074	0	0.059

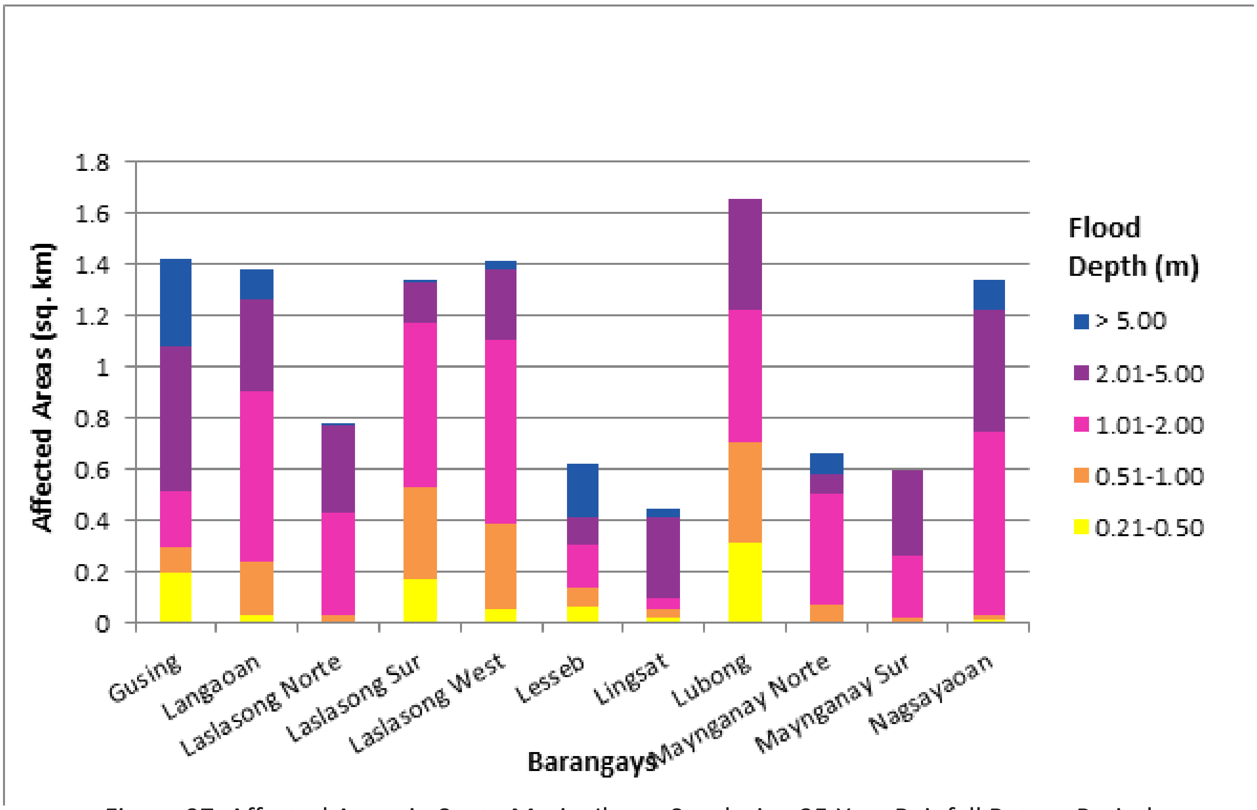


Figure 97. Affected Areas in Santa Maria, Ilocos Sur during 25-Year Rainfall Return Period

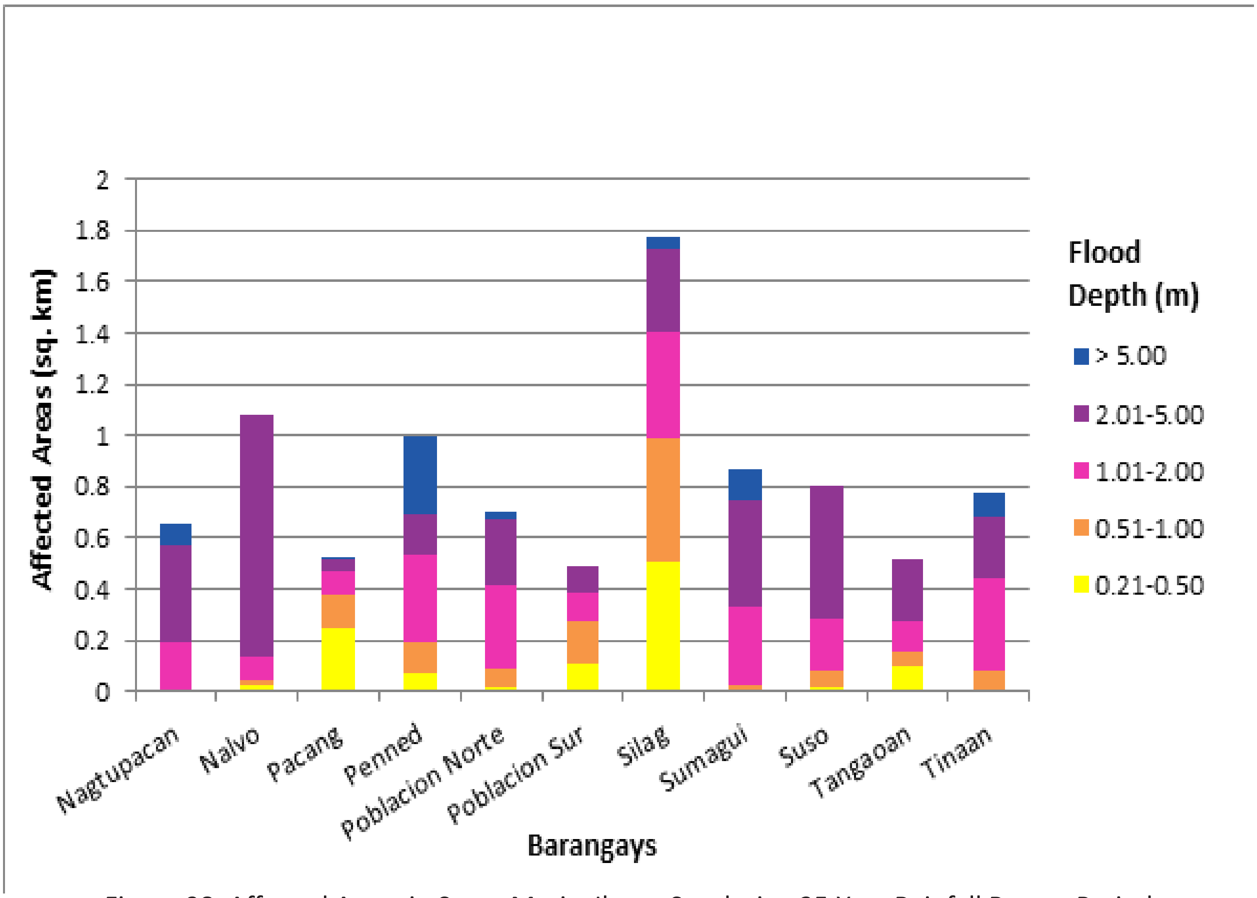


Figure 98. Affected Areas in Santa Maria, Ilocos Sur during 25-Year Rainfall Return Period

Table 54. Affected Areas in Santa Maria, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Maria (in sq. km.)										
	Nagtupacan	Nalvo	Pacang	Penned	Poblacion Norte	Poblacion Sur	Silag	Sumagui	Suso	Tangaoan	Tinaan
0-0.20	0.0008	0.45	3.34	0.51	0.069	0.23	3.93	0.0071	0.31	0.76	0.02
0.21-0.50	0.0047	0.031	0.2	0.11	0.054	0.1	0.48	0.03	0.065	0.099	0.034
0.51-1.00	0.13	0.047	0.1	0.24	0.24	0.097	0.37	0.18	0.12	0.11	0.15
1.01-2.00	0.39	0.21	0.055	0.2	0.23	0.093	0.28	0.37	0.33	0.23	0.35
2.01-5.00	0.068	0.77	0.033	0.2	0.14	0.039	0.24	0.24	0.18	0.012	0.13
> 5.00	0.063	0	0.005	0.2	0.025	0	0.038	0.042	0	0	0.09

For the 25-year return period, 5.72% of the municipality of Santiago with an area of 65.57 sq. km. will experience flood levels of less than 0.20 meters. 0.29% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.08%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected Areas in Santiago, Ilocos Sur during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santiago (in sq. km.)		
	Bigbiga	Mambug	Salincub
0-0.20	0.083	3.71	0.028
0.21-0.50	0.00084	0.16	0.00075
0.51-1.00	0.00025	0.08	0.00043
1.01-2.00	0.000054	0.045	0.00011
2.01-5.00	0	0.019	0.000008

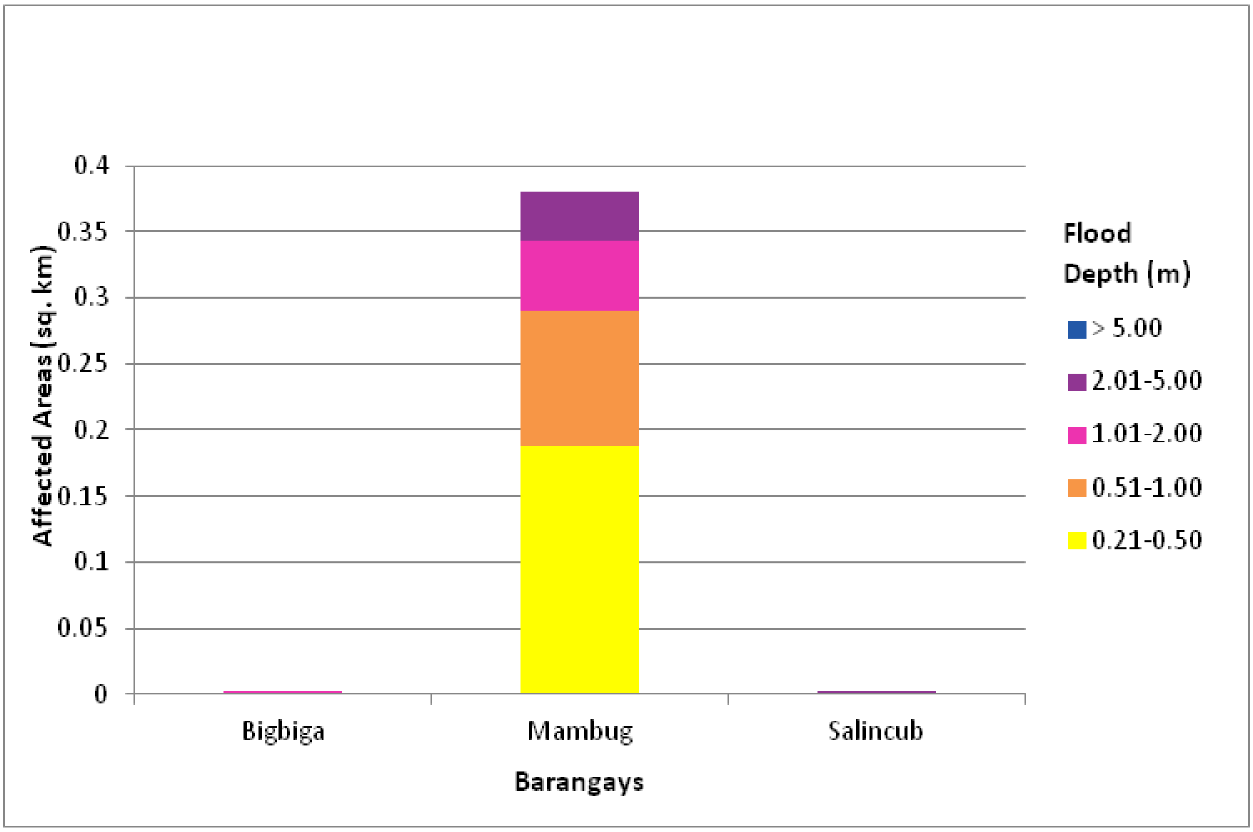


Figure 99. Affected Areas in Santiago, Ilocos Sur during 25-Year Rainfall Return Period

For the 100-year return period, 2.45% of the municipality of Pilar with an area of 92.196 sq. km. will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.05%, 0.04%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 56 are the affected areas in square kilometers by flood depth per barangay.

Table 56. Affected Areas in Pilar, Abra during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Pilar (in sq. m.)	
	Brookside	Nagcanasan
0-0.20	1.59	0.74
0.21-0.50	0.05	0.022
0.51-1.00	0.026	0.0078
1.01-2.00	0.022	0.0036
2.01-5.00	0.0093	0.00085
> 5.00	0.0003	0

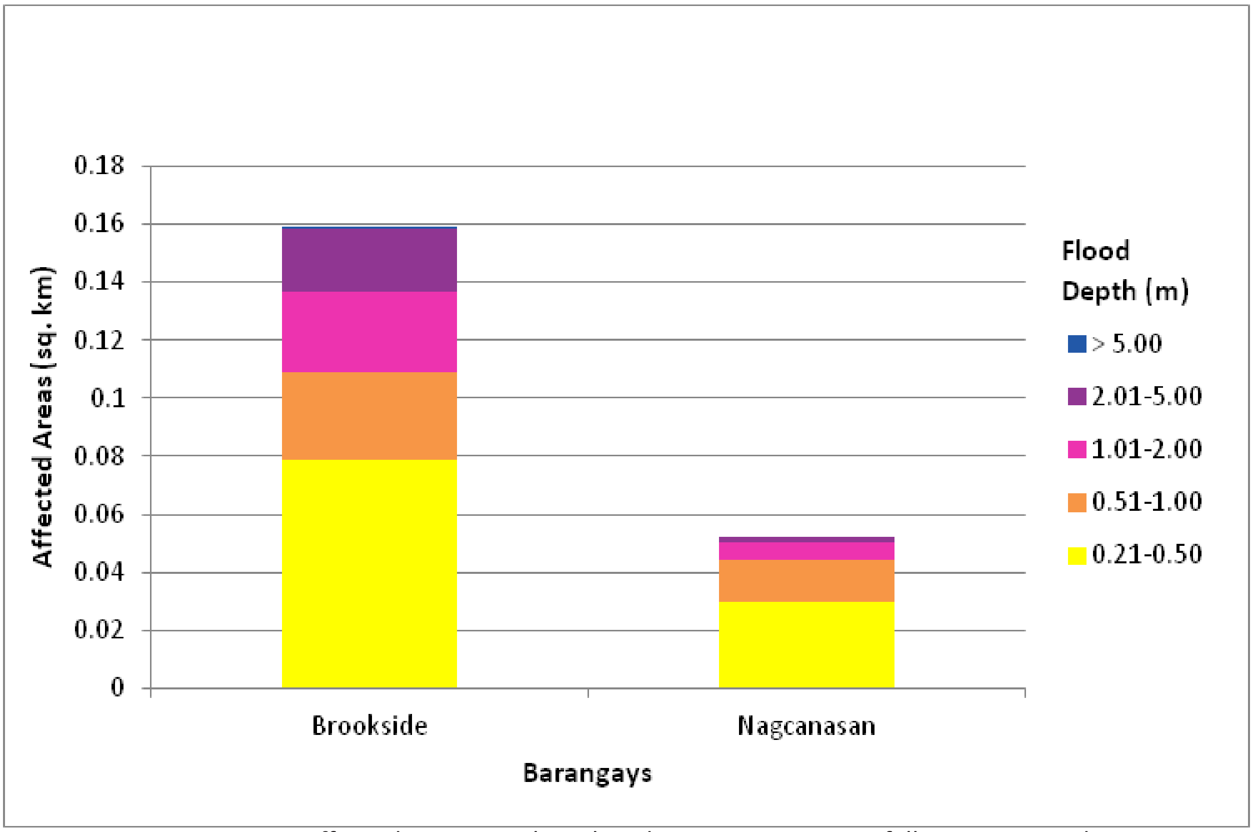


Figure 100. Affected Areas in Pilar, Abra during 100-Year Rainfall Return Period

For the 100-year return period, 4.36% of the municipality of Burgos with an area of 49.604 sq. km. will experience flood levels of less than 0.20 meters. 0.87% of the area will experience flood levels of 0.21 to 0.50 meters while 0.59%, 0.30%, 0.20%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 57 are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Burgos, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Burgos (in sq. m.)								
	Cabca-burao	Cadacad	Lesseb	Lucaban	Macaoayan	Mambug	Nagpanaoan	Poblacion Sur	Taliao
0-0.20	0.52	0.23	0.014	0.42	0.18	0.47	0.016	0.35	0.29
0.21-0.50	0.02	0.042	0.00078	0.055	0.0014	0.16	0.00026	0.054	0.03
0.51-1.00	0.009	0.024	0.0054	0.046	0.0001	0.1	0.0023	0.01	0.022
1.01-2.00	0.014	0.0019	0.0036	0.013	0.000005	0.0077	0.000001	0.00093	0.0046
2.01-5.00	0.016	0	0.0041	0	0	0	0	0	0.0001
> 5.00	0.0037	0	0.013	0	0	0	0	0	0

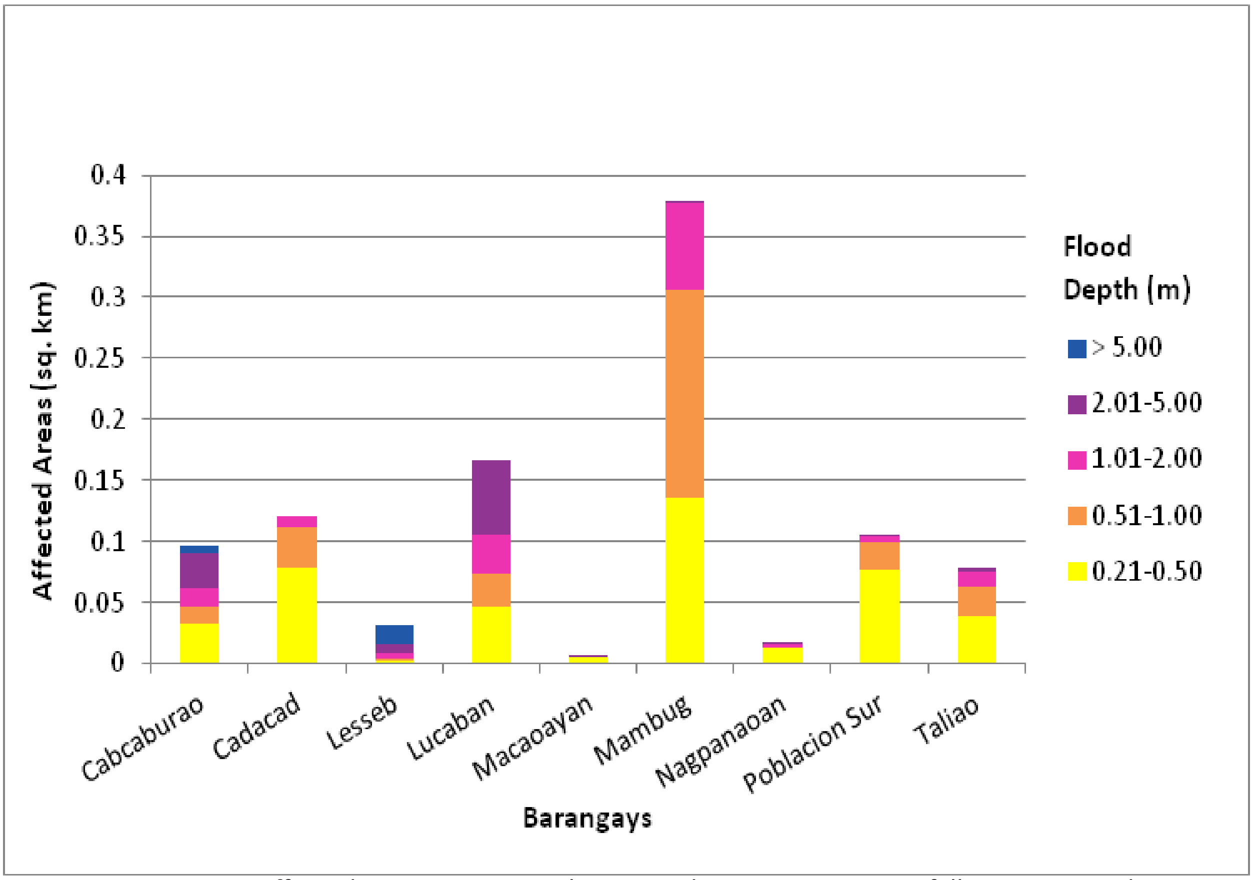


Figure 101. Affected Areas in Burgos, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 20.44% of the municipality of Nagbukel with an area of 36.46 sq. km. will experience flood levels of less than 0.20 meters. 2.10% of the area will experience flood levels of 0.21 to 0.50 meters while 1.94%, 4.31%, 4.71%, and 1.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 58 are the affected areas in square kilometers by flood depth per barangay.

Table 58. Affected Areas in Nagbukel, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Nagbukel (in sq. km.)								
	Balaweg	Bandril	Bantugo	Casilagan	Mapisi	Mission	Poblacion East	Poblacion West	Taleb
0-0.20	0.14	1.91	0.097	1.01	1.54	1.07	0.65	1.44	0.33
0.21-0.50	0.085	0.24	0.077	0.058	0.069	0.15	0.058	0.12	0.016
0.51-1.00	0.27	0.085	0.29	0.025	0.06	0.13	0.09	0.056	0.017
1.01-2.00	0.39	0.028	0.79	0.023	0.052	0.06	0.16	0.017	0.017
2.01-5.00	0.3	0.024	0.1	0.094	0.12	0.047	0.079	0.0033	0.038
> 5.00	0.0007	0.00093	0	0.13	0.087	0.0001	0	0	0.017

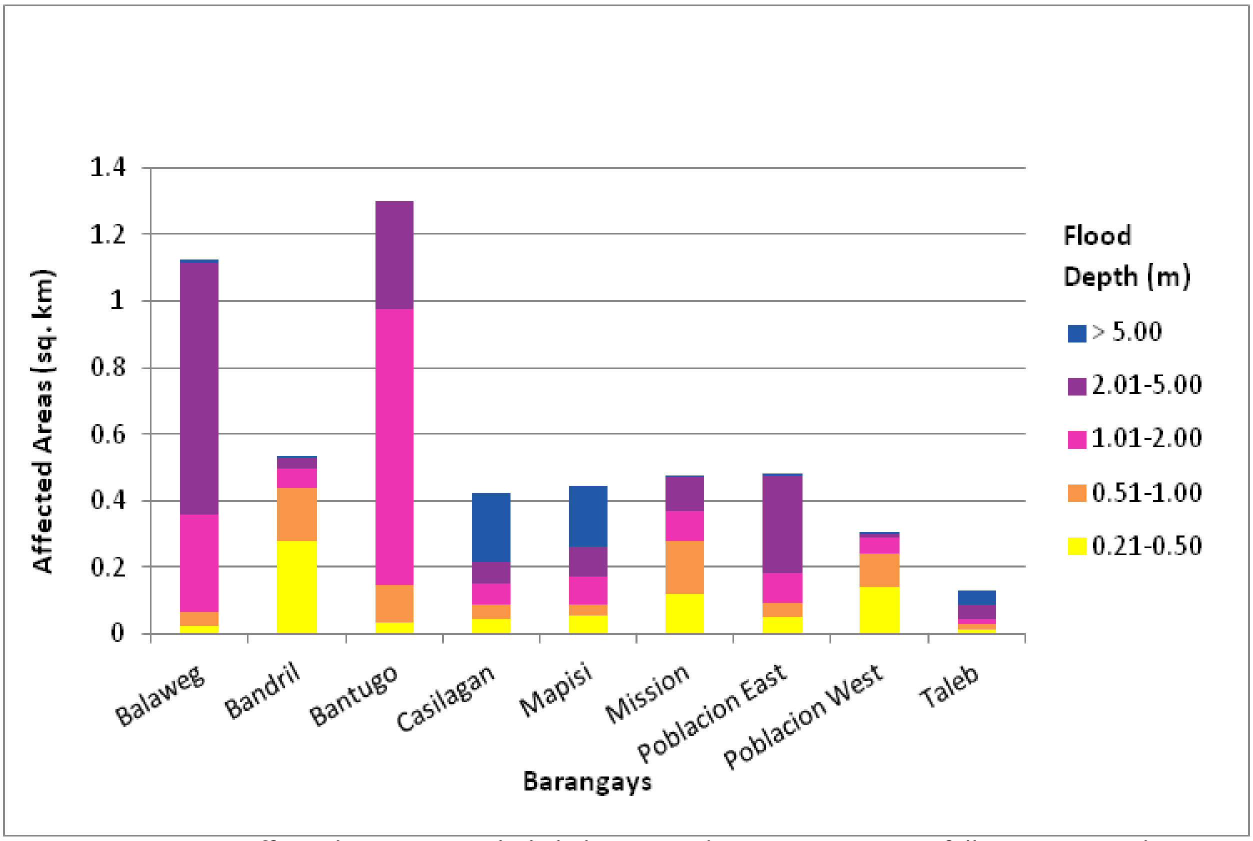


Figure 102. Affected Areas in Nagbukel, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 29.58% of the municipality of Narvacan with an area of 97.176 sq. km. will experience flood levels of less than 0.20 meters. 4.94% of the area will experience flood levels of 0.21 to 0.50 meters while 5.78%, 10.24%, 22.96%, and 1.58% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 59 are the affected areas in square kilometers by flood depth per barangay.

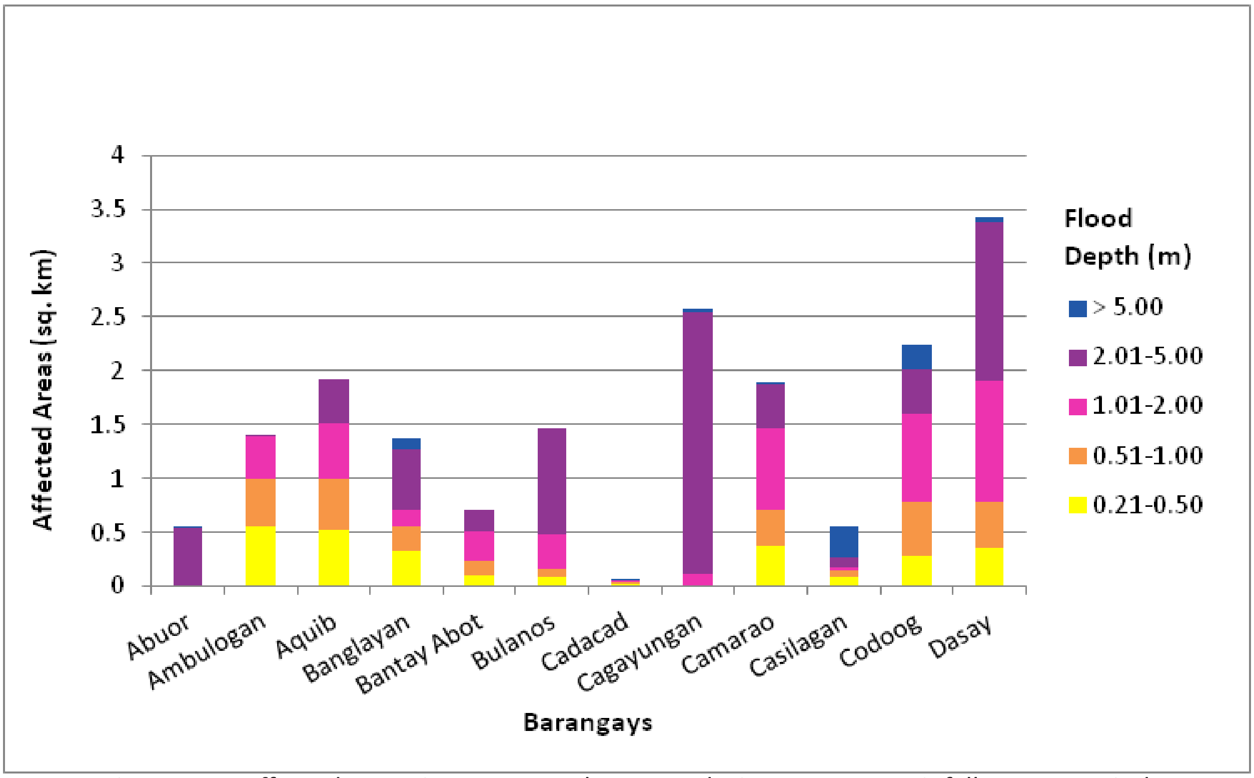


Figure 103. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period

Table 59. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Narvacan (in sq. km.)											
	Abuor	Ambulogan	Aquib	Banglayan	Bantay Abot	Bulanos	Cadacad	Cagayungan	Camarao	Casilagan	Codoog	Dasay
0-0.20	0.0012	3.41	1.87	3.07	0.79	1.34	0.51	0.0063	2.08	1.5	1.07	2.21
0.21-0.50	0.004	0.51	0.57	0.29	0.14	0.17	0.021	0.021	0.42	0.098	0.48	0.48
0.51-1.00	0.022	0.38	0.39	0.17	0.17	0.46	0.014	0.21	0.53	0.042	0.64	0.63
1.01-2.00	0.25	0.16	0.21	0.18	0.23	0.5	0.0075	1.38	0.39	0.041	0.41	1.47
2.01-5.00	0.29	0.0058	0.11	0.39	0.067	0.092	0.0024	0.94	0.17	0.12	0.37	0.53
> 5.00	0	0	0	0.016	0	0	0.0002	0.017	0	0.12	0.12	0.026

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Narvacan (in sq. km.)										
	Dinalaoan	Estancia	Lanipao	Lungog	Margaay	Marozo	Naguneg	Orence	Pantoc	Paratong	Parparia
0-0.20	0.039	0.049	0.64	1.47	0.11	2.27	0.008	0.3	0.12	0.023	0.7
0.21-0.50	0.034	0.0067	0.039	0.27	0.11	0.27	0.018	0.25	0.03	0.053	0.22
0.51-1.00	0.093	0.047	0.018	0.35	0.29	0.24	0.11	0.18	0.053	0.25	0.27
1.01-2.00	0.56	0.12	0.0057	0.3	0.63	0.38	0.93	0.29	0.2	0.51	0.56
2.01-5.00	0.29	0.1	0.01	0.26	0.37	0.19	0.59	0.022	0.58	0.27	0.031
> 5.00	0	0.08	0.0011	0.022	0	0.0027	0.046	0.018	0	0	0

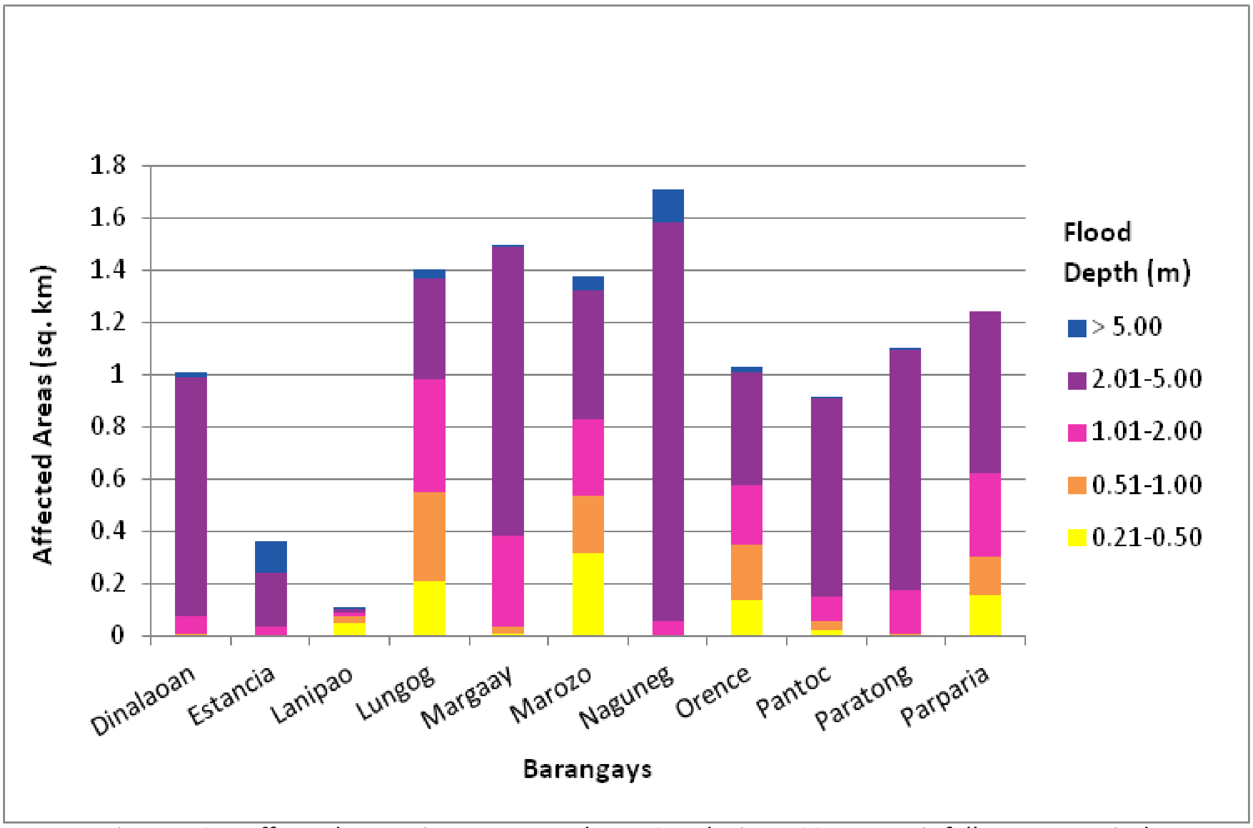


Figure 104. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period

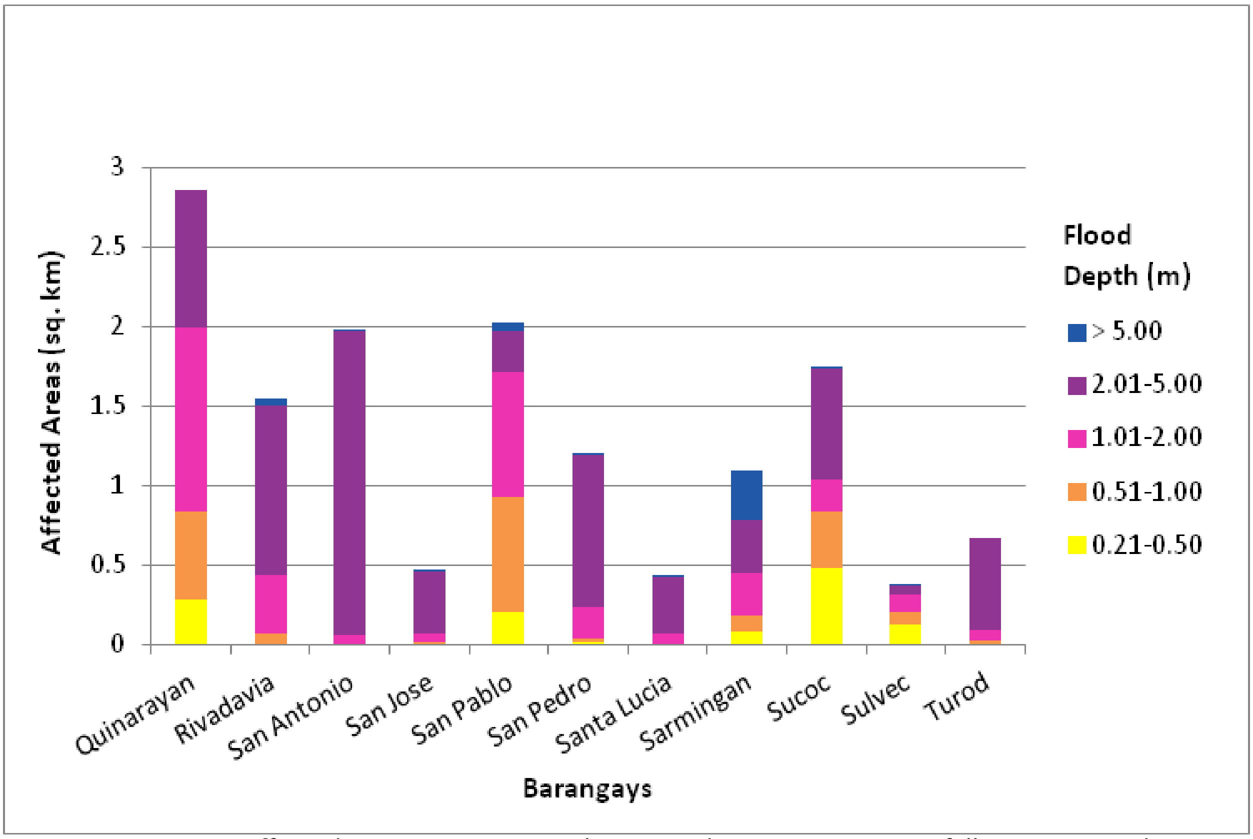


Figure 105. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period

Table 60. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Narvacan (in sq. km.)										
	Quinarayan	Rivadavia	San Antonio	San Jose	San Pablo	San Pedro	Santa Lucia	Sarmingan	Sucoc	Sulvec	Turod
0-0.20	1.92	0.21	0.0052	0.027	0.26	0.076	0.019	0.99	4.63	2.29	0.1
0.21-0.50	0.47	0.13	0.014	0.016	0.66	0.024	0.026	0.15	0.42	0.098	0.031
0.51-1.00	0.7	0.36	0.093	0.049	0.76	0.11	0.041	0.22	0.17	0.088	0.098
1.01-2.00	1.06	0.71	1.06	0.19	0.27	0.59	0.19	0.23	0.33	0.07	0.29
2.01-5.00	0.23	0.12	0.81	0.19	0.057	0.44	0.16	0.16	0.41	0.021	0.21
> 5.00	0	0.029	0.000012	0	0.044	0.0027	0	0.22	0.0018	0.0001	0

For the 100-year return period, 32.64% of the municipality of San Esteban with an area of 17.27 sq. km. will experience flood levels of less than 0.20 meters. 5.83% of the area will experience flood levels of 0.21 to 0.50 meters while 5.95%, 7.86%, and 5.57% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 61 are the affected areas in square kilometers by flood depth per barangay.

Table 61. Affected Areas in San Esteban, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in San Esteban (in sq. km.)						
	Ansad	Cabaroan	Cappa-Cappa	Poblacion	San Nicolas	San Pablo	San Rafael
0-0.20	1.41	2	1.25	0.26	0.38	0.79	0.3
0.21-0.50	0.24	0.17	0.58	0.02	0.02	0.064	0.036
0.51-1.00	0.4	0.093	0.78	0.0017	0.0051	0.029	0.008
1.01-2.00	0.32	0.016	0.7	0.00098	0.0015	0.026	0.00039
2.01-5.00	0.038	0.0019	0.034	0.000008	0.00072	0.00011	0
> 5.00	0	0	0	0	0.000019	0	0

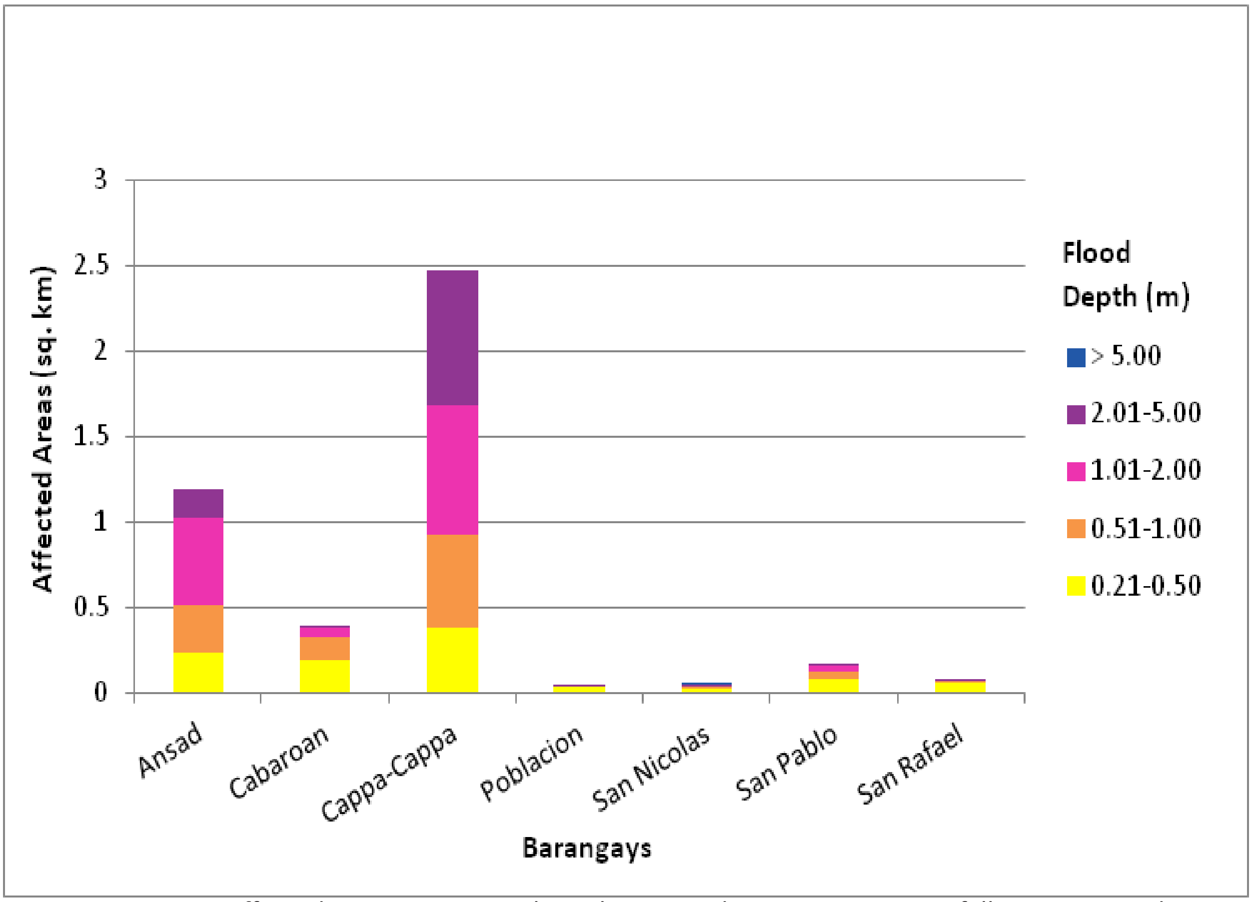


Figure 106. Affected Areas in San Esteban, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 4.68% of the municipality of Santa with an area of 57.2 sq. km. will experience flood levels of less than 0.20 meters. 0.33% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.13%, and 0.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 62 are the affected areas in square kilometers by flood depth per barangay.

Table 62. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa (in sq. km.)	
	Magsaysay District	Quezon
0-0.20	1.55	1.27
0.21-0.50	0.1	0.031
0.51-1.00	0.052	0.014
1.01-2.00	0.071	0.0042
2.01-5.00	0.064	0.0006
> 5.00	0.00025	0

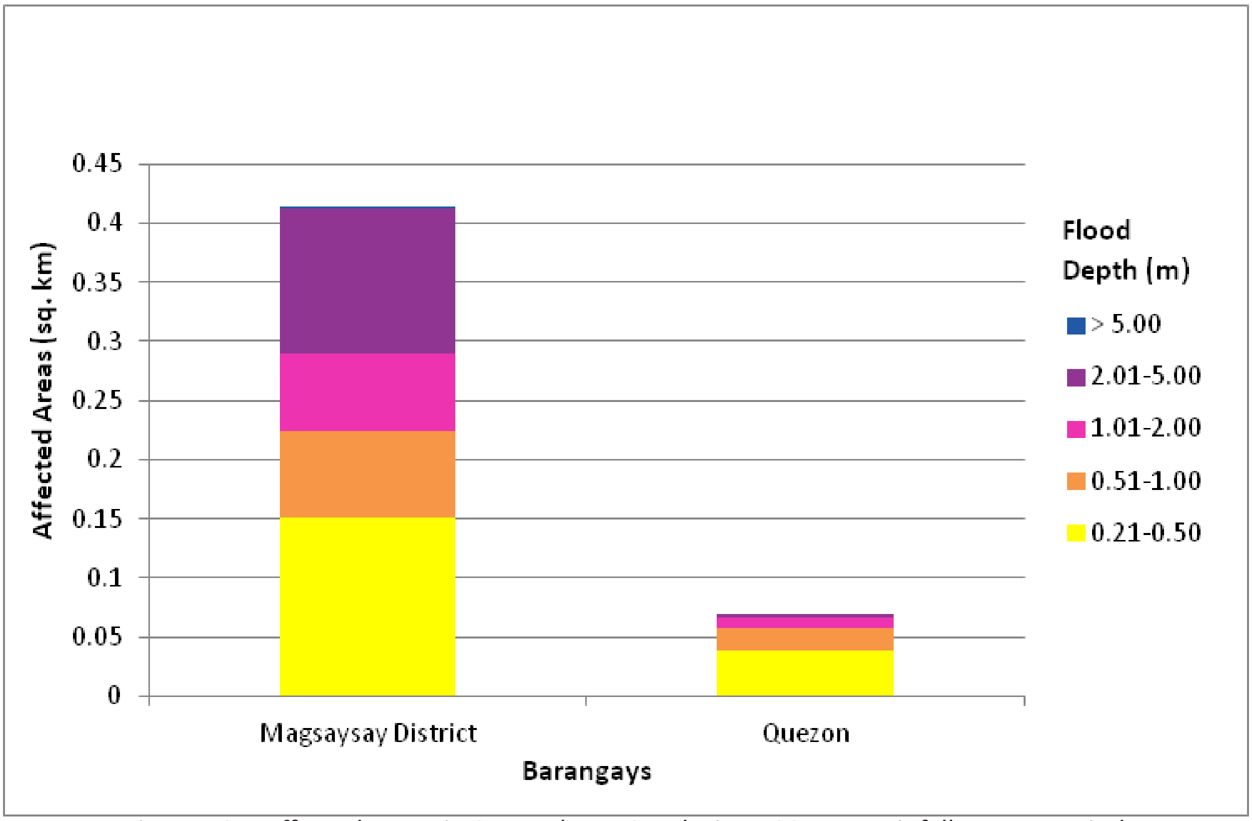


Figure 107. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period

For the 100-year return period, 26.92% of the municipality of Santa Maria with an area of 52.32 sq. km. will experience flood levels of less than 0.20 meters. 4.42% of the area will experience flood levels of 0.21 to 0.50 meters while 6.41%, 16.22%, 34.84%, and 4.96% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 63 are the affected areas in square kilometers by flood depth per barangay

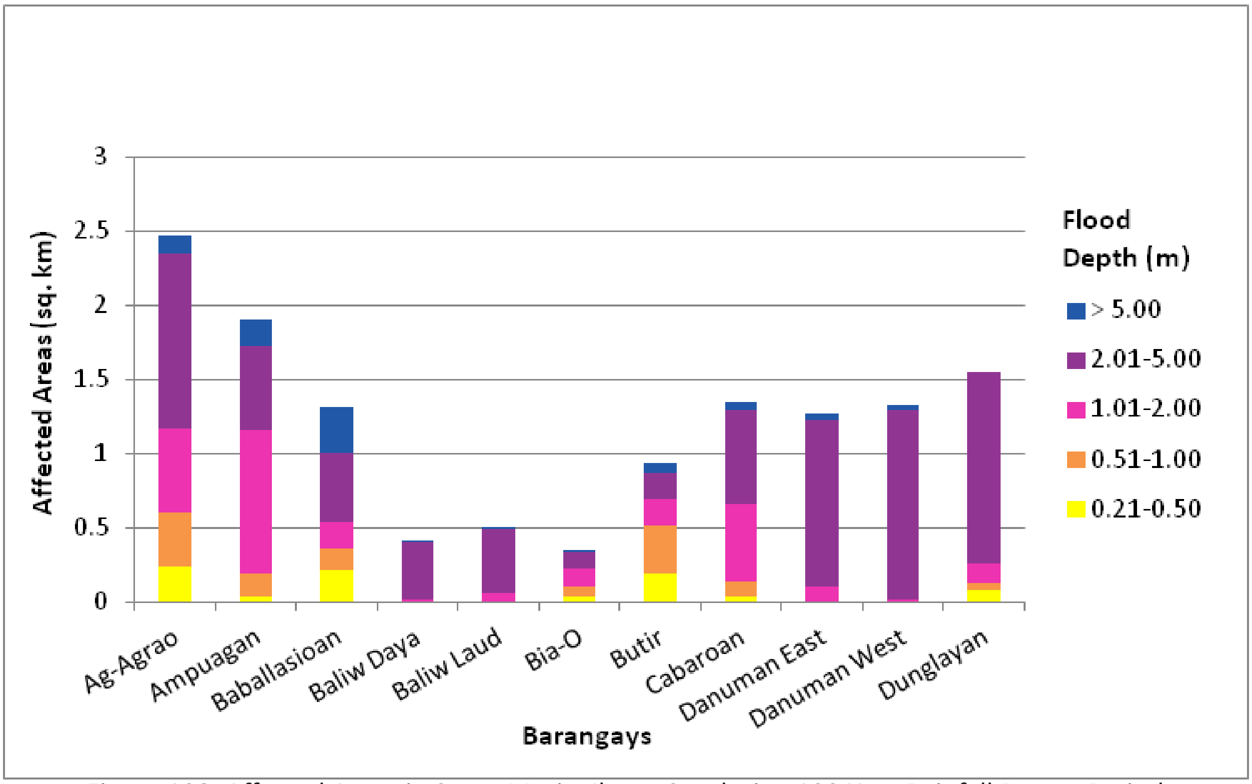


Figure 108. Affected Areas in Santa Maria, Ilocos Sur during 100-Year Rainfall Return Period

Table 63. Affected Areas in Santa Maria, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Santa Maria (in sq. km.)										
	Ag-Agrao	Ampuagan	Baballasioan	Baliw Daya	Baliw Laud	Bia-O	Butir	Cabaroan	Danuman East	Danuman West	Dunglayan
0-0.20	0.55	0.22	2.04	0.0002	0.0028	0.42	0.67	0.058	0.049	0.0014	0.75
0.21-0.50	0.31	0.28	0.23	0.0026	0.014	0.065	0.25	0.13	0.075	0.011	0.27
0.51-1.00	0.43	0.6	0.17	0.018	0.064	0.063	0.18	0.46	0.33	0.11	0.35
1.01-2.00	0.92	0.41	0.2	0.23	0.31	0.11	0.092	0.48	0.46	0.77	0.69
2.01-5.00	0.42	0.29	0.33	0.15	0.11	0.006	0.16	0.19	0.35	0.4	0.035
> 5.00	0.079	0.14	0.2	0	0	0.00046	0.06	0.051	0	0.032	0

Affected Area (sq. km.) (by flood depth (in m.)	Affected Barangays in Santa Maria (in sq. km.)										
	Gusing	Langaoan	Laslasong Norte	Laslasong Sur	Laslasong West	Lesseb	Lingsat	Lubong	Maynganay Norte	Maynganay Sur	Nagsayaoan
0-0.20	1.56	0.071	0.016	0.28	0.1	0.14	0.5	1.13	0.014	0.0085	0.019
0.21-0.50	0.17	0.14	0.022	0.25	0.23	0.062	0.021	0.43	0.08	0.03	0.028
0.51-1.00	0.096	0.46	0.13	0.29	0.51	0.098	0.026	0.28	0.31	0.056	0.35
1.01-2.00	0.33	0.32	0.54	0.52	0.5	0.16	0.16	0.34	0.16	0.44	0.74
2.01-5.00	0.44	0.33	0.077	0.035	0.052	0.037	0.18	0.052	0.024	0.058	0.14
> 5.00	0.27	0.091	0.00033	0.000001	0.03	0.19	0.019	0	0.074	0	0.059

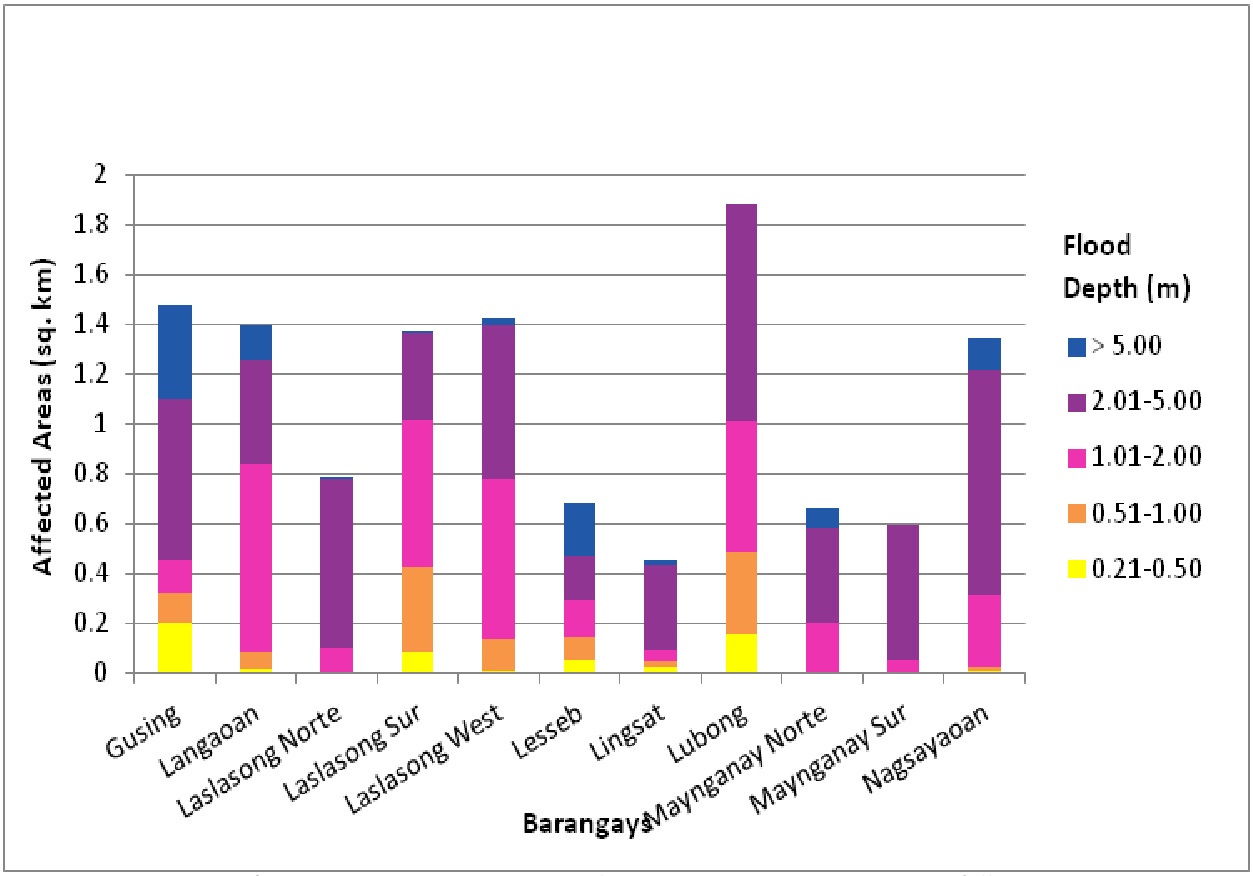


Figure 109. Affected Areas in Santa Maria, Ilocos Sur during 100-Year Rainfall Return Period

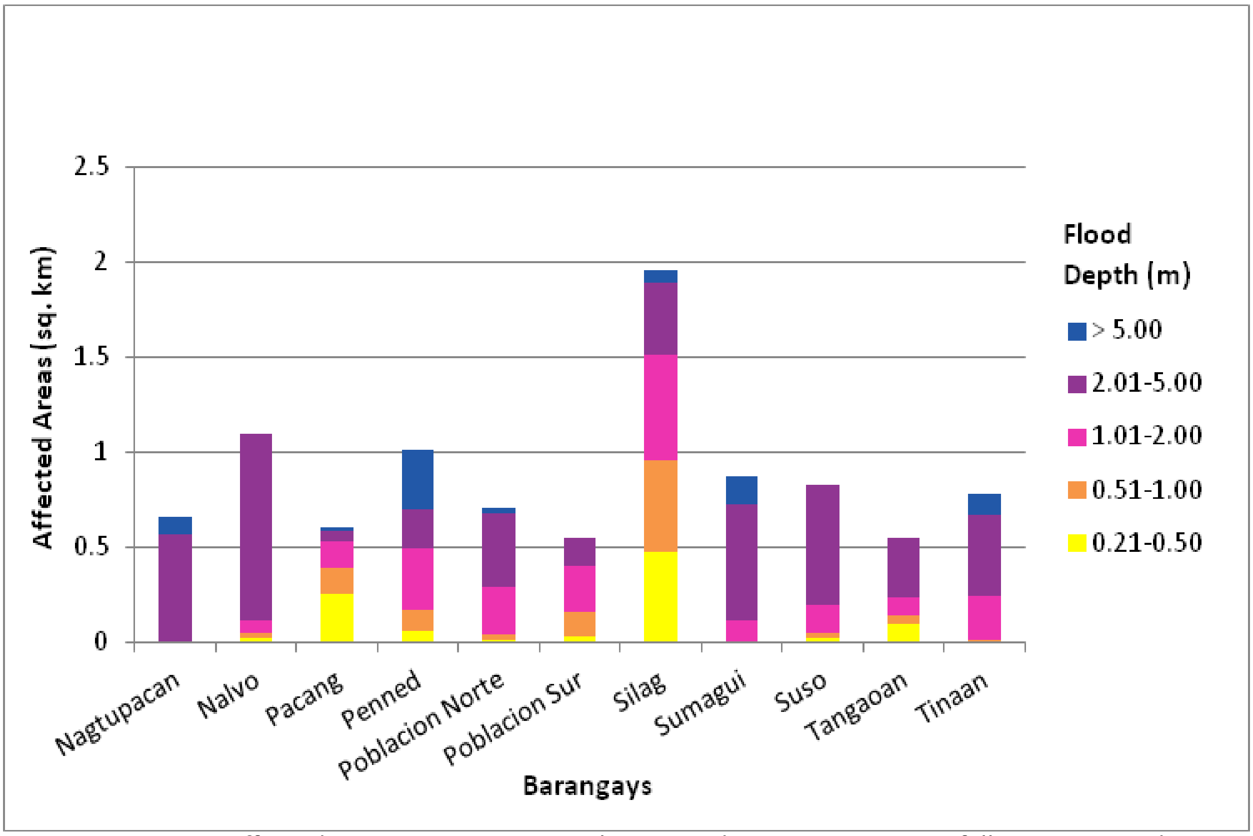


Figure 110. Affected Areas in Santa Maria, Ilocos Sur during 100-Year Rainfall Return Period

Table 64. Affected Areas in Santa Maria, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.)	Affected Barangays in Santa Maria (in sq. km.)										
	Nagtupacan	Nalvo	Pacang	Penned	Poblacion Norte	Poblacion Sur	Silag	Sumagui	Suso	Tangaoan	Tinaan
0-0.20	0.0008	0.45	3.34	0.51	0.069	0.23	3.93	0.0071	0.31	0.76	0.02
0.21-0.50	0.0047	0.031	0.2	0.11	0.054	0.1	0.48	0.03	0.065	0.099	0.034
0.51-1.00	0.13	0.047	0.1	0.24	0.24	0.097	0.37	0.18	0.12	0.11	0.15
1.01-2.00	0.39	0.21	0.055	0.2	0.23	0.093	0.28	0.37	0.33	0.23	0.35
2.01-5.00	0.068	0.77	0.033	0.2	0.14	0.039	0.24	0.24	0.18	0.012	0.13
> 5.00	0.063	**0**	0.005	0.2	0.025	0	0.038	0.042	0	0	0.09

For the 100-year return period, 5.64% of the municipality of Santiago with an area of 65.57 sq. km. will experience flood levels of less than 0.20 meters. 0.32% of the area will experience flood levels of 0.21 to 0.50 meters while 0.17%, 0.10%, and 0.07% the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, respectively. Listed in Table 65 are the affected areas in square kilometers by flood depth per barangay.

Table 65. Affected Areas in Santiago, Ilocos Sur during 100-Year Rainfall Return Period

Affected Area (sq. km.) (by flood depth (in m.)	Affected Barangays in Santiago (in sq. km.)		
	Bigbiga	Mambug	Salincub
0-0.20	0.083	3.71	0.028
0.21-0.50	0.00084	0.16	0.00075
0.51-1.00	0.00025	0.08	0.00043
1.01-2.00	0.000054	0.045	0.00011
2.01-5.00	0	0.019	0.000008
> 5.00	0	0	0

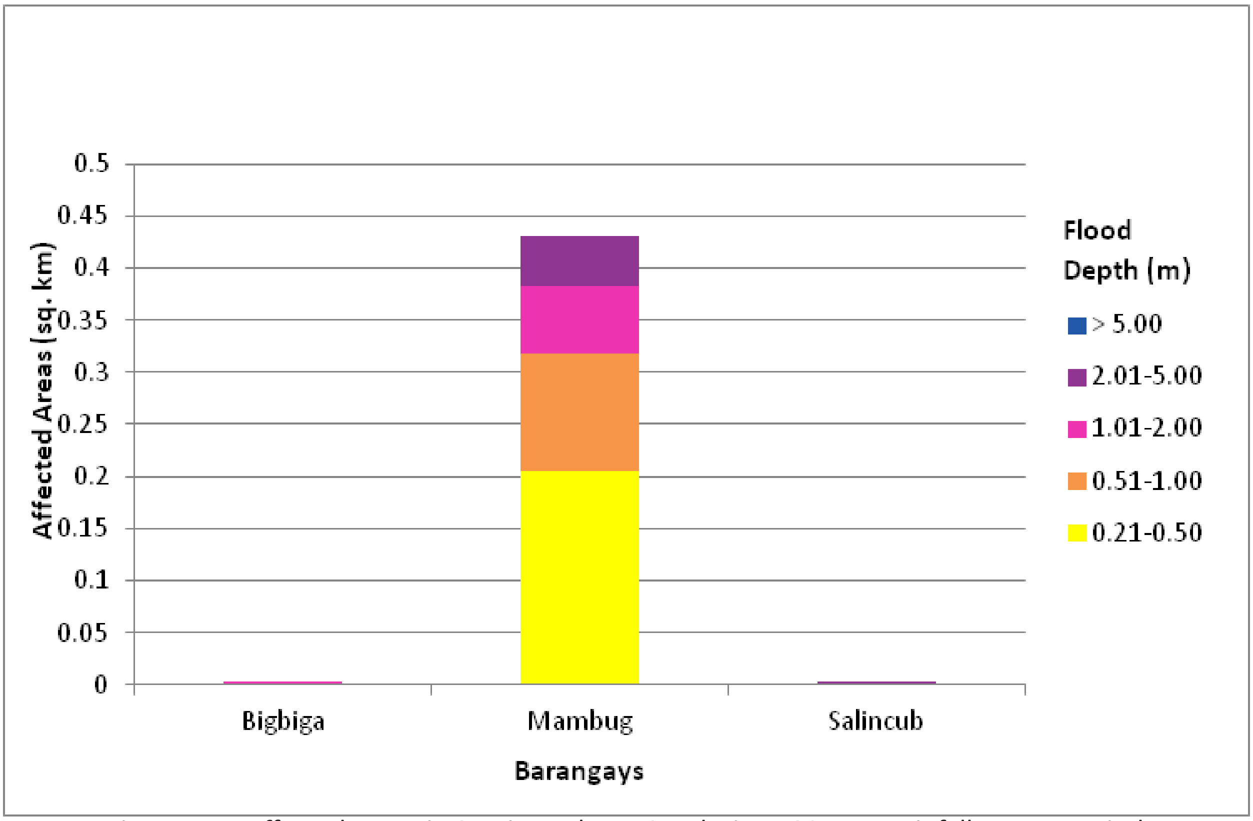


Figure 111. Affected Areas in Santiago, Ilocos Sur during 100-Year Rainfall Return Period

Among the barangays in the municipality of Pilar in Abra, Brookside is projected to have the highest percentage of area that will experience flood levels at 1.84%. Meanwhile, Nagcanasan posted the second highest percentage of area that may be affected by flood depths at 0.84%.

Among the barangays in the municipality of Burgos in Ilocos Sur, Mambug is projected to have the highest percentage of area that will experience flood levels at 1.50%. Meanwhile, Cabcaburao posted the second highest percentage of area that may be affected by flood depths at 1.17%.

Among the barangays in the municipality of Nagbukel in Ilocos Sur, Bandril is projected to have the highest percentage of area that will experience flood levels at 6.26%. Meanwhile, Mapisi posted the second highest percentage of area that may be affected by flood depths at 5.29%.

Among the barangays in the municipality of Narvacan in Ilocos Sur, Sucoc is projected to have the highest percentage of area that will experience flood levels at 6.14%. Meanwhile, Dasay posted the second highest percentage of area that may be affected by flood depths at 5.49%.

Among the barangays in the municipality of San Esteban in Ilocos Sur, Cappa-Cappa is projected to have the highest percentage of area that will experience flood levels at 19.41%. Meanwhile, Ansad posted the second highest percentage of area that may be affected by flood depths at 13.95%.

Among the barangays in the municipality of Santa in Ilocos Sur, Magsaysay District is projected to have the highest percentage of area that will experience flood levels at 3.22%. Meanwhile, Quezon posted the second highest percentage of area that may be affected by flood depths at 2.30%.

Among the barangays in the municipality of Santa Maria in Ilocos Sur, Silag is projected to have the highest percentage of area that will experience flood levels at 10.20%. Meanwhile, Pacang posted the second highest percentage of area that may be affected by flood depths at 7.15%.

Among the barangays in the municipality of Santiago in Ilocos Sur, Mambug is projected to have the highest percentage of area that will experience flood levels at 6.13%. Meanwhile, Bigbiga posted the second highest percentage of area that may be affected by flood depths at 0.13%.

Of the 69 identified educational institutions in the Silay floodplain, Brgy. Poblacion Norte Day Care Center in Brgy. Poblacion Sur was assessed to be exposed to the High level flooding for all three rainfall scenarios. Meanwhile, 20 other institutions were found to be susceptible to flooding, experiencing Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios.

13 medical institutions were identified in the Silay floodplain. Cadacio's Clinic in Brgy. Santa Lucia and Dolores-Idica Dental Clinic in Brgy. Baliw Daya were found to be highly prone to flooding, having High level flooding in all three rainfall scenarios.

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

Table 66. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	13.56	10.96	9.72
Medium	34.46	26.32	21.60
High	32.39	51.04	60.68
Total	80.41	88.32	92.00

Of the 69 identified educational institutions in the Silay floodplain, one school was assessed to be exposed to the High level flooding for all three rainfall scenarios. This is the Brgy. Poblacion Norte Day Care Center in Brgy. Poblacion Sur. 21 other institutions were found to be susceptible to flooding, experiencing Medium level flooding in the 5-year return period, and High level flooding in the 25- and 100-year rainfall scenarios. See Annex 12.

13 medical institutions were identified in the Silay floodplain. Cadacio’s Clinic in Brgy. Santa Lucia and Dolores-Idica Dental Clinic in Brgy. Baliw Daya were found to be highly prone to flooding, having High level flooding in all three rainfall scenarios. See Annex 13.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gathered secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

The validation personnel went to the specified points identified in a river basin and 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 were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The flood validation data were obtained on January 2017.

The flood validation consisted of 339 points randomly selected all over the Silay floodplain. It has an RMSE value of 0.85.

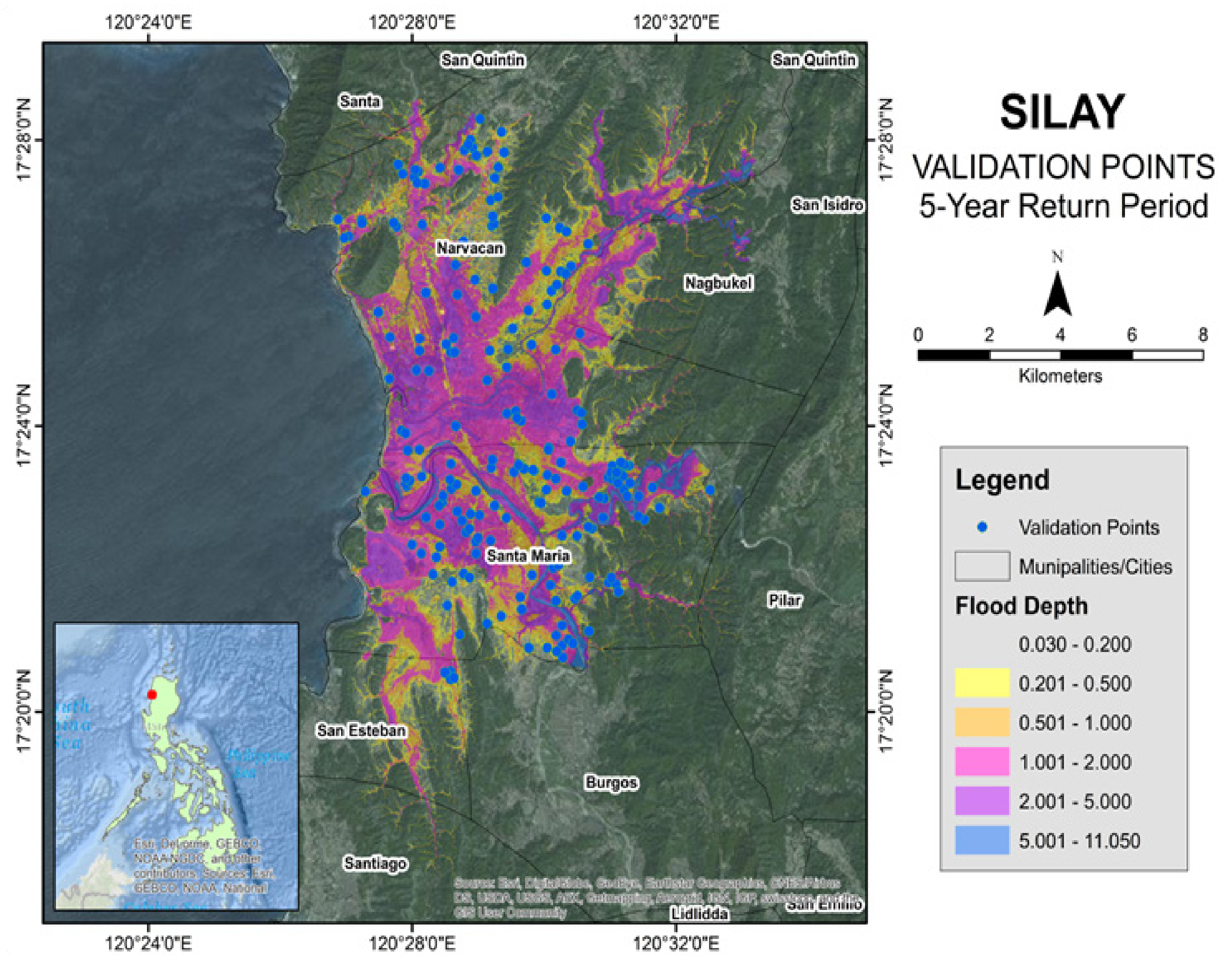


Figure 112. Flood Validation Points for Silay River Basin

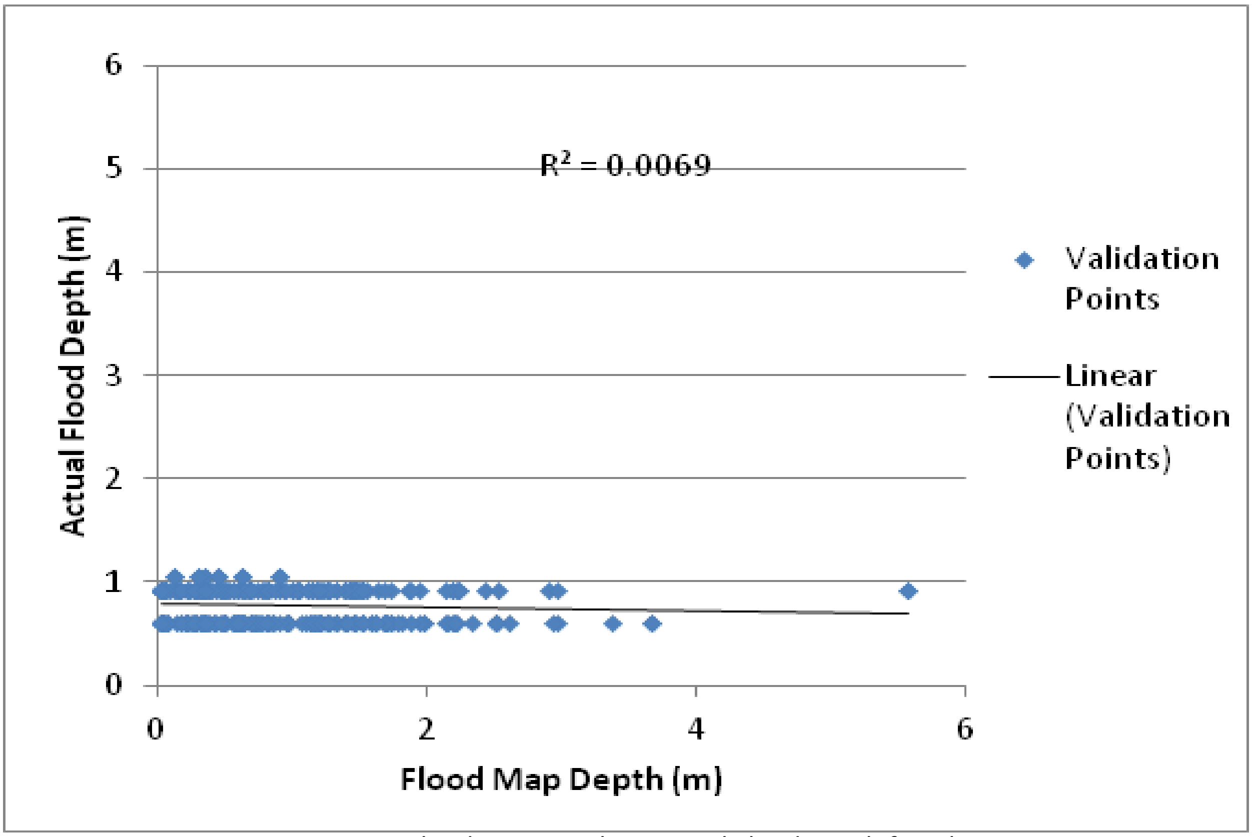


Figure 113. Flood Map Depth vs Actual Flood Depth for Silay

Table 67. Actual Flood Depth vs Simulated Flood Depth in Silay

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0	0	0
0.51-1.00	47	66	78	107	27	2	327
1.01-2.00	2	6	4	0	0	0	12
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	49	72	82	107	27	2	339

The overall accuracy generated by the flood model is estimated at 23.01%, with 78 points correctly matching the actual flood depths. In addition, there were 177 points estimated one level above and below the correct flood depths while there were 80 points and 4 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 136 points were overestimated while a total of 125 points were underestimated in the modelled flood depths of Silay.

Table 68. Summary of Accuracy Assessment in Silay River Basin Survey

	No. of Points	%
Correct	78	23.01
Overestimated	136	40.12
Underestimated	125	36.87
Total	339	100

REFERENCES

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

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

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

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

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

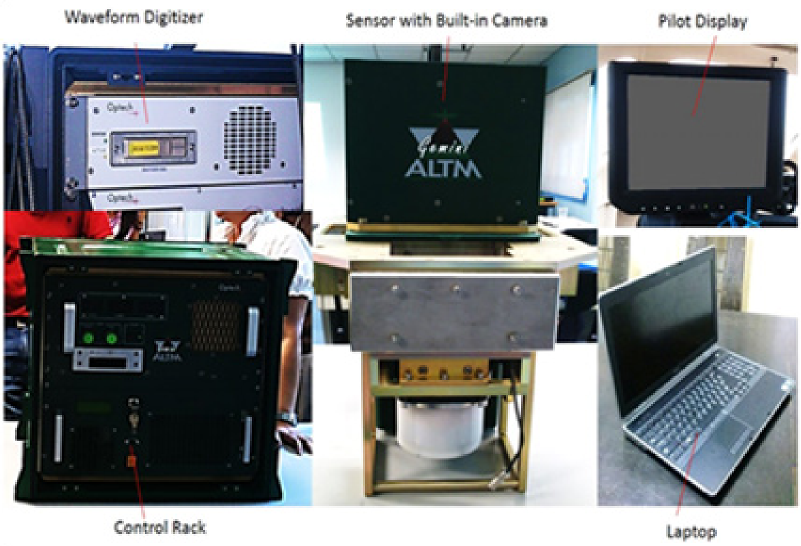
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

Annex 1. OPTECH TECHNICAL SPECIFICATION OF THE GEMINI SENSOR

GEMINI



Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy A(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

PEGASUS

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

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20˚
4 Target size ≥ laser footprint5 Dependent on system configuration

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded
computers with AMD TurionTM 64 X2 CPU	
4 GB RAM, 4 GB flash disk local storage	
IEEE 1394 Firewire interface	
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels

Annex 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

ABR - 31

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ABRA**
Station Name: **ABR-31**
Order: **2nd**

Island: **LUZON**
Municipality: **PEÑARRUBIA**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **17° 34' 4.18831"**	Longitude: **120° 38' 57.99392"**	Ellipsoidal Hgt: **98.78000 m.**

WGS84 Coordinates

Latitude: **17° 33' 58.07703"**	Longitude: **120° 39' 2.63930"**	Ellipsoidal Hgt: **132.48100 m.**

PTM Coordinates

Northing: **1942969.967 m.**	Easting: **462785.996 m.**	Zone: **3**

UTM Coordinates

Northing: **1,943,800.89**	Easting: **250,503.56**	Zone: **51**

Location Description

ABR-31

From the town proper of Bangued, travel towards Narvacan, Ilocos Sur. A road intersection will be reached in about 2.5 Km. just before Sinalang Bridge. At the intersection, turn left and continue travelling for about 6.9 Km. towards the access road leading to the compound of Peñarrubia Central School, about 100 m NW of the Mun. Hall. Station is located 150 m N of the main gate of the said school. Mark is the head of a brass rod with cross cut on top flushed at the center of a 30 cm x 30 cm x 120 cm concrete monument with inscriptions, "ABR-31, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-442**

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

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

ABR-32

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ABRA**
Station Name: **ABR-32**
Order: **2nd**

Island: **LUZON**
Municipality: **PIDIGAN**
Barangay: **SUYO (MALIDONG)**

PRS92 Coordinates

Latitude:	**17° 33' 49.34656"**	Longitude:	**120° 33' 25.07659"**	Ellipsoidal Hgt:	**39.32200 m.**

WGS84 Coordinates

Latitude:	**17° 33' 43.22900"**	Longitude:	**120° 33' 29.72282"**	Ellipsoidal Hgt:	**72.81400 m.**

PTM Coordinates

Northing:	**1942534.242 m.**	Easting:	**452967.729 m.**	Zone:	**3**

UTM Coordinates

Northing:	**1,943,468.54**	Easting:	**240,677.03**	Zone:	**51**

Location Description

ABR-32

From Bangued, travel towards Ilocos Sur for about 8 km. Turn right at the intersection road and continue travel for about 3.6 km. until reaching the Barangay Hall of Suyo. The station is located about 15 m NE of the stage. Mark is the head of a brass rod with cross cut on top flushed at the center of a 30 cm x 30 cm x 120 cm concrete monument with inscriptions, "ABR-32, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-443**

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

9903042014160036

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

ILS-9

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ILOCOS SUR**
Station Name: **ILS-9**
Order: **2nd**

Island: **LUZON**		Barangay: **BACSIL**
Municipality: **SAN JUAN**		
	PRS92 Coordinates	
Latitude: **17° 43' 40.62808"**	Longitude: **120° 27' 9.37799"**	Ellipsoidal Hgt: **56.57700 m.**
	WGS84 Coordinates	
Latitude: **17° 43' 34.46721"**	Longitude: **120° 27' 14.01102"**	Ellipsoidal Hgt: **89.29100 m.**
	PTM Coordinates	
Northing: **1960739.965 m.**	Easting: **441941.245 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,961,798.84**	Easting: **229,838.72**	Zone: **51**

Location Description

ILS-9

Is located in Bo. Bacsil, San Juan, Ilocos Sur at the hilly portion of Bacsil National High School compound, 10 m. W from the school building.

Station mark is the head of a 4 in. copper nail embedded and centered on a 8 in. x 8 in. cement putty set at the edge of a concrete road with inscribe station name "ILS-9, NAMRIA, 2000".

*Note: Station upgraded to 2nd Order (by: LTSG. Custodio G. Armengol, May 2005).

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-438**

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

CP/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

ILS-13

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ILOCOS SUR**
Station Name: **ILS-13**
Order: **2nd**

Island: **LUZON**
Municipality: **CABUGAO**
Barangay: **BONIFACIO**

PRS92 Coordinates

Latitude:	**17° 47' 21.51067"**	Longitude:	**120° 27' 23.35275"**	Ellipsoidal Hgt:	**26.74100 m.**

WGS84 Coordinates

Latitude:	**17° 47' 15.33691"**	Longitude:	**120° 27' 27.98067"**	Ellipsoidal Hgt:	**59.26700 m.**

PTM Coordinates

Northing:	**1967529.087 m.**	Easting:	**442372.629 m.**	Zone:	**3**

UTM Coordinates

Northing:	**1,968,586.44**	Easting:	**230,342.67**	Zone:	**51**

Location Description

ILS-13

Is located inside the compound of Cabugao South Central School, Brgy. Bonifacio, Cabugao, Ilocos Sur. It is situated on a dike of an uncultivated farm owned by the municipality. It is located about 30 m. SE of the school oval and about 20 m. SE of a concrete shed. It is reached by traveling N coming from Vigan City. The school is on the left side of the highway, opposite Cabugao National High School.

Mark is the head of a 3 in. copper nail embedded and centered on a 30 cm. x 30 cm. concrete monument, about 60 cm. deep, protruding by 5 cm., with inscriptions "ILS-13, 2005, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-439**

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

9903042014155518

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 CP/4/01/12/09/814

ILS-22

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ILOCOS SUR**
Station Name: **ILS-22**
Order: **2nd**

Island: **LUZON**
Municipality: **LIDLIDDA**
Barangay: **POBLACION NORTE**

PRS92 Coordinates

Latitude: **17° 16' 13.59403"**	Longitude: **120° 31' 8.89179"**	Ellipsoidal Hgt: **55.31200 m.**

WGS84 Coordinates

Latitude: **17° 16' 7.53708"**	Longitude: **120° 31' 13.56269"**	Ellipsoidal Hgt: **89.64700 m.**

PTM Coordinates

Northing: **1910089.724 m.**	Easting: **448870.206 m.**	Zone: **3**

UTM Coordinates

Northing: **1,911,053.54**	Easting: **236,238.44**	Zone: **51**

Location Description

ILS-22

From Candon City, travel N along the national highway for about 6 km. then turn E at the junction and travel for about 8 km. until reaching the Lidlidda Public Market. Turn NW and travel for about 4 km. to reach the North Central School. It is located inside the school compound on the science park near the NE corner of the concrete stage. It is 1.5 m. NNW of the E corner of the concrete stage and 0.8 m. NNE of the NE side of the stage.

Mark is the head of a 4 in. copper nail, centered on a concrete block 30 cm. x 30 cm. and 10 cm. above the ground surface, with inscriptions "ILS-22, 2005, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-440**

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

9 9 0 3 0 4 2 0 1 4 1 5 5 6 1 1

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

ILS-24

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ILOCOS SUR**
Station Name: **ILS-24**
Order: **2nd**

Island: **LUZON**
Municipality: **CANDON CITY**
Barangay: **DARAPIDAP**

PRS92 Coordinates

Latitude: **17° 11' 46.25613"**	Longitude: **120° 25' 8.83897"**	Ellipsoidal Hgt: **12.28700 m.**

WGS84 Coordinates

Latitude: **17° 11' 40.20757"**	Longitude: **120° 25' 13.51659"**	Ellipsoidal Hgt: **46.61600 m.**

PTM Coordinates

Northing: **1901900.937 m.**	Easting: **438210.77 m.**	Zone: **3**

UTM Coordinates

Northing: **1,902,971.42**	Easting: **225,489.39**	Zone: **51**

Location Description

ILS-24

From the national highway of Candon City proper going to Vigan City, turn left on the road fronted by Jollibee. Continue traveling this road passing through the City Wet Market and University of Northern Philippines (UNP) Annex on the left side until reaching its end, which is a "T" intersection. Take the road to the left passing through Darapidap Beach Resort until reaching the E gate of Ilocos Sur Polytechnic State College (ISPSC). It is located on the right side of the concrete road, approx. 10 m. SSE of the campus' E gate, about 75 m. S of the main entrance. It is also about 15 m. ESE of the campus' concrete water tank.

Mark is the head of an umbrella type G.I. roofing nail embedded and centered on a 30 cm. x 30 cm. concrete monument protruding by about 5 cm., with inscriptions "CANDON-1, 2004, PRS-92, FNSP-LMS-DENR".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-441**

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

9 9 0 3 0 4 2 0 1 4 1 3 3 6 5 8

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

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

Annex 3. BASELINE PROCESSING REPORTS

ABR-3070

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ABR-31 --- ABR-3071 (B1)	ABR-31	ABR-3071	Fixed	0.002	0.003	183°28'35"	116.693	-2.290

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

ABR-31 - ABR-3071 (6:36:50 AM-5:29:43 PM) (S1)

Baseline observation:	ABR-31 --- ABR-3071 (B1)
Processed:	5/30/2016 3:44:18 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.003 m
RMS:	0.001 m
Maximum PDOP:	6.905
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	5/28/2016 6:36:58 AM (Local: UTC+8hr)
Processing stop time:	5/28/2016 5:29:43 PM (Local: UTC+8hr)
Processing duration:	10:52:45
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	ABR-31				
Grid		Local		Global	
Easting	250503.563 m	Latitude	N17°34'04.18832"	Latitude	N17°33'58.07703"
Northing	1943800.890 m	Longitude	E120°38'57.99392"	Longitude	E120°39'02.63930"
Elevation	93.704 m	Height	98.780 m	Height	132.481 m

To:	ABR-3071				
Grid		Local		Global	
Easting	250495.042 m	Latitude	N17°34'00.39935"	Latitude	N17°33'54.28829"
Northing	1943684.465 m	Longitude	E120°38'57.75398"	Longitude	E120°39'02.39944"
Elevation	91.410 m	Height	96.489 m	Height	130.194 m

Vector					
ΔEasting	-8.521 m	NS Fwd Azimuth	183°28'35"	ΔX	-10.725 m
ΔNorthing	-116.425 m	Ellipsoid Dist.	116.693 m	ΔY	31.972 m
ΔElevation	-2.295 m	ΔHeight	-2.290 m	ΔZ	-111.739 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000013627		
Y	-0.0000010122	0.0000021053	
Z	-0.0000004683	0.0000008588	0.0000007466

Occupations

	From	To
Point ID:	ABR-31	ABR-3071
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(3)\ABR-31 05-28-2016 (1.373, Bottom of Antenna Mount).16O	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(3)\ABR-3071 05-28-2016 (1.509, Bottom of Antenna Mount).16O
Receiver type:	Unknown	Unknown
Receiver serial number:	U06AIR0WLC8	U01KKH3S8AW
Antenna type:	CR.G5	CR.G5
Antenna serial number:	-Unknown-	-Unknown-
Antenna height (measured):	1.373 m	1.509 m
Antenna method:	Bottom of antenna mount	Bottom of antenna mount

Tracking Summary

Annex 4. THE SURVEY TEAM

Data Acquisition Component Sub-team	Designation	Name	Agency/Affiliation
Sub-Team			
Phil-LiDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Data Component Project Leader –I	ENGR. LOUIE BALICANTA	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
Field-Team			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	SSRS	AUBREY MATIRA	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
	RA	REGINA AEDRIANNE FELISMINO	UP-TCAGP
	RA	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	ENGR. RENAN PUNTO	UP-TCAGP
	RA	FAITH JOY SABLE	UP-TCAGP
Ground Survey	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Airborne Security	DIOSCORO SOBERANO	PHILIPPINE AIR FORCE (PAF)
		OLIVER SACLOT	PAF
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RAUL CZ SAMAR II	AAC
		CAPT. NEIL AGAWIN	AAC
		CAPT JEROME MOONEY	AAC
		CAPT. CEASAR ALFONSO III	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. DATA TRANSFER SHEET FOR SILAY FLOODPLAIN

14-16

DATA TRANSFER SHEET
3/19/2014(ILOCOS BATCH 2)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/ CASI	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Mar 3, 2014	7104GC	2BLK06E062A & 2BLK06A062A	GEMINI	NA	68.1KB	429KB	206MB	NA	NA	19.3GB	NA	12.3MB	1KB	1KB	6/174/10/5/38KB	8KB	Z:\Airborne_Raw\7104GC
Mar 3, 2014	7105GC	2BLK06AS062B & 2BLK06C062B	GEMINI	NA	302KB	493KB	254MB	NA	NA	23.3GB	NA	12.6MB	1KB	1KB	6/208/6/208/67KB	11KB	Z:\Airborne_Raw\7105GC
Mar 4, 2014	7107GC	2BLK07C063B	GEMINI	NA	59.1KB	308KB	187MB	NA	NA	15GB	NA	3.84MB	1KB	1KB	132KB	192KB	Z:\Airborne_Raw\7107GC
Mar 5, 2014	7108GC	2BLK07C063B	GEMINI	NA	106KB	536KB	268MB	NA	NA	29.2GB	NA	11MB	1KB	1KB	266KB	10/10KB	Z:\Airborne_Raw\7108GC
Mar 7, 2014	7112GC	2BLK06G066A & 2BLK06DS066A	GEMINI	NA	288KB	451KB	247MB	NA	NA	18.5GB	NA	11.4MB	1KB	1KB	197/64KB	17KB	Z:\Airborne_Raw\7112GC
Mar 8, 2014	7114GC	2BLK07CS067A & 2BLK06G067A	GEMINI	NA	68.4KB	438KB	264MB	NA	NA	19.3GB	NA	8.45MB	1KB	1KB	7/5/304KB	7/5KB	Z:\Airborne_Raw\7114GC
Mar 9, 2014	7116GC	2BLK07B068A	GEMINI	NA	306KB	476KB	257MB	NA	NA	19.4GB	NA	10.8MB	1KB	1KB	5/209/51/5/209KB	9KB	Z:\Airborne_Raw\7116GC
Mar 10, 2014	7118GC	2BLK07D069A & 2BLK07G069A	GEMINI	NA	332KB	483KB	259MB	NA	NA	18.7GB	NA	14.5MB	1KB	1KB	6/228/346/10/5/228KB	10KB	Z:\Airborne_Raw\7118GC
MAR 10\	7119GC	2BLK27A069B	GEMINI	NA	321KB	520KB	253MB	NA	NA	24.6GB	NA	14.7MB	1KB	1KB	5/48/5/221/51KB	NA	Z:\Airborne_Raw\7119GC
Mar 11, 2014	7120GC	2BLK06F070A & 2BLK07A070A	GEMINI	NA	87.4KB	506KB	251MB	NA	NA	18GB	NA	11.2MB	1KB	1KB	10/26/218KB	16KB	Z:\Airborne_Raw\7120GC
Mar 11, 2014	7121GC	2BLK07GS070B & 2BLK07AS070B	GEMINI	NA	216KB	319KB	217MB	NA	NA	12.7GB	NA	10.8MB	1KB	1KB	149/6KB	10KB	Z:\Airborne_Raw\7121GC
Mar 12, 2014	7122GC	2BLK07E071A & 2BLK07F071A	GEMINI	NA	74.4KB	399KB	228MB	NA	NA	14.5GB	NA	8.36MB	1KB	1KB	399/7/399/6KB	9KB	Z:\Airborne_Raw\7122GC

Received from

Name CHRIS [illegible]

Position RA

Signature [signature] 04/21/14

Received by

Name JOIDA F PRIETO

Position SSKS

Signature [signature] 4/22/14

CLA Unicorn

DATA TRANSFER SHEET
Mar 17, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
2/25/2014	1151P	1BLK10A056A	PEGASUS	3.03GB	NA	12.3MB	229MB	N/A	N/A	19.8	N/A	6.5	1KB	459B	35	NA	X:\Airborne_Raw\1151P
2/25/2014	1153P	1BLK10AS056B	PEGASUS	836MB	NA	3.57MB	84.5MB	N/A	N/A	8.02	N/A	6.51	1KB	244B	38	N/A	X:\Airborne_Raw\1153P
2/26/2014	1155P	1BLK10C057A	PEGASUS	2.64GB	NA	11MB	220MB	33.1GB	289KB	26.4	N/A	6.95	1KB	610B	44	N/A	X:\Airborne_Raw\1155P
2/26/2014	1157P	1BLK10B057B	PEGASUS	1.85GB	NA	6.62MB	129MB	25.6GB	229KB	17.4	N/A	6.95	1KB	485B	45	N/A	X:\Airborne_Raw\1157P
2/27/2014	1159P	1BLK10GD058A	PEGASUS	2.76GB	NA	11.4MB	221MB	4.7GB	148KB	27.9	N/A	6.55	1KB	669B	29	N/A	X:\Airborne_Raw\1159P
2/27/2014	1161P	1BLK10DS058B	PEGASUS	1.28GB	NA	7.08MB	152MB	22.3GB	186KB	15.6	N/A	6.55	1KB	474B	50	N/A	X:\Airborne_Raw\1161P
2/28/2014	1163P	1BLK10F059A	PEGASUS	3.42GB	NA	12MB	216MB	53.2GB	416KB	31.7	N/A	6.05	1KB	328B	31	N/A	X:\Airborne_Raw\1163P
2/28/2014	1165P	1BLK10E059B	PEGASUS	1.41GB	NA	7.12MB	143MB	25.6GB	208KB	16.7	N/A	6.05	1KB	502B	n/a	N/A	X:\Airborne_Raw\1165P
3/1/2014	1167P	1BLK10H060A	PEGASUS	831MB	NA	7.42MB	170MB	17.5GB	145KB	8.66	N/A	6.64	1KB	318B	20	N/A	X:\Airborne_Raw\1167P
3/1/2014	1169P	1BLK10ES060B	PEGASUS	2.05GB	NA	7.17MB	133MB	28.6GB	224KB	19.1	N/A	6.64	1KB	304B	45	N/A	X:\Airborne_Raw\1169P
3/2/2014	1171P	1BLK10CDS061A	PEGASUS	1.72GB	NA	9.73MB	206MB	21GB	170KB	17	N/A	7.08	1KB	310B	32	N/A	X:\Airborne_Raw\1171P
3/2/2014	1173P	1BLK10DS061B	PEGASUS	1.52GB	NA	5.95MB	116MB	20.3GB	169KB	14.5	N/A	7.08	1KB	481B	50	N/A	X:\Airborne_Raw\1173P
3/3/2014	1175P	1BLK10BS062A	PEGASUS	3.14GB	NA	11.8MB	214MB	43.1GB	341KB	29.5	N/A	6.74	1KB	305B	38	N/A	X:\Airborne_Raw\1175P
3/3/2014	1177P	1BLK10CS062B	PEGASUS	1.18GB	NA	8.31MB	157MB	30GB	254KB	11.3	N/A	6.74	1KB	741B	42	N/A	X:\Airborne_Raw\1177P
Mar 4, 2014	1179P	1BLK27B063A	PEGASUS	3.54GB	NA	14MB	260MB	39.3GB	361KB	34.5	N/A	5.86	1KB	1KB	38	N/A	X:\Airborne_Raw\1179P
Mar 5, 2014	1183P	1BLK12AC064A	PEGASUS	1.5GB	NA	10.3MB	206MB	35.6GB	304KB	22.5GB	N/A	5.94	1KB	1KB	42/38/33/4234	N/A	X:\Airborne_Raw\1183P
Mar 5, 2014	1185P	1BLK10D064B	PEGASUS	1.18GB	NA	5.86MB	151MB	16.4GB	142KB	11.7GB	N/A	5.94	1KB	1KB	n/a	N/A	X:\Airborne_Raw\1185P
Mar 6, 2014	1187P	1BLK12DS065A	PEGASUS	2.34GB	NA	11MB	212MB	35.3GB	302KB	24.4GB	N/A	6.62	1KB	1KB	36	N/A	X:\Airborne_Raw\1187P
Mar 6, 2014	1189P	1BLK12CS065B	PEGASUS	2.06GB	NA	8.08MB	151MB	37.7GB	332KB	19.7GB	N/A	6.62	1KB	1KB	42	N/A	X:\Airborne_Raw\1189P
Mar 8, 2014	1195P	1BLK27ABS067A	PEGASUS	915MB	NA	4.91MB	110MB	16.1GB	130KB	10.2GB	N/A	From Ilocos	1KB	1KB	36	N/A	X:\Airborne_Raw\1195P
Mar 8, 2014	1197P	1BLK10CGS067B	PEGASUS	714MB	NA	4.95MB	112MB	14.5GB	131KB	8.16GB	N/A	1.44MB	1KB	1KB	27	N/A	X:\Airborne_Raw\1197P

Received from

Name: CHRIS JOAQUIN
Position: RA
Signature: [signature]

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature]

14-13

DATA TRANSFER SHEET
LAOAG 6/29/2016

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	
May 28, 2016	4043G	2BLKSA7149A	GEMINI	NA	325	604	242	NA	NA	24.7	NA	334	1KB	NA	6KB	14	Z:\DAC\RAW DATA
May 28, 2016	4045G	2BLKSB7149B	GEMINI	NA	190	402	231	NA	NA	14.5	NA	334	1KB	NA	8	17	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 7/1/16

16-41

Annex 6. FLIGHT LOGS

Flight Log for 1BLK27B063A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 1179P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEG	3 Mission Name: 1BLK27B063A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route: LA UNION			
10 Date: MAR. 4, 2014	12 Airport of Departure (Airport, City/Province): SAN FERNANDO, LA UNION		12 Airport of Arrival (Airport, City/Province): SAN FERNANDO, LA UNION		
13 Engine On: 0851	14 Engine Off: 1306	15 Total Engine Time: 4+15	16 Take off:	17 Landing:	18 Total Flight Time: 4+05
19 Weather					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUNA	OLIVER BACLOT	M. J. TANGONAN	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Flight Log for 2BLK07C063B Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 7107

1 LIDAR Operator: MVE TONGA	2 ALTM Model: GEMI+CASI	3 Mission Name: 2BLK07C063B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR III	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-04-2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1546H	14 Engine Off: 1903H	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Windy					
20 Remarks: Surveyed 8 lines at BLK07C (without CASI)					

21 Problems and Solutions:

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

Flight Log for 2BLK06G066A & 2BLK06DS066A Mission.

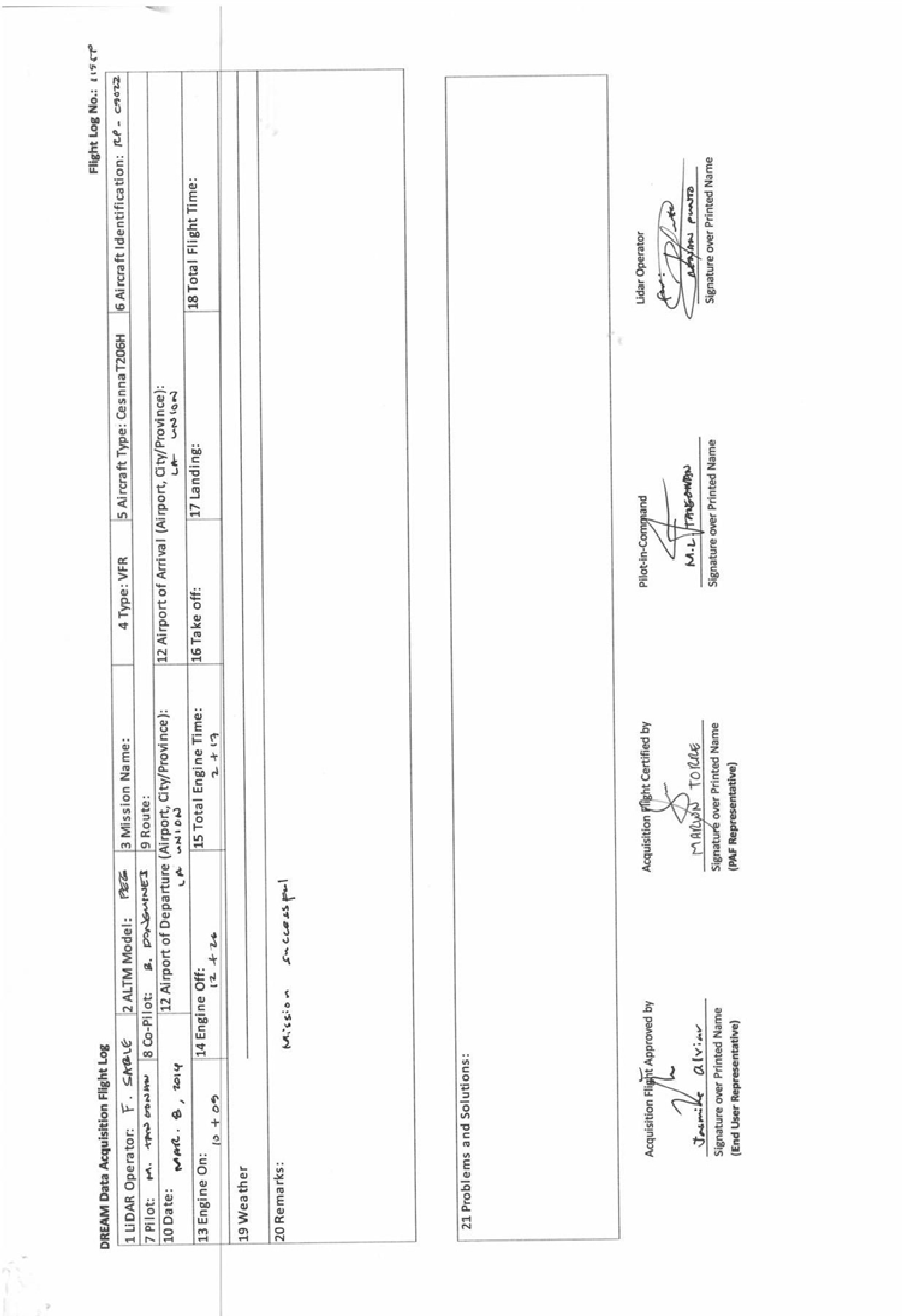
DREAM Data Acquisition Flight Log 2BLK06G066A 8 **Flight Log No.:** 7112

1 LiDAR Operator: M.CE BALUYAS	2 ALTM Model: LEMT(CASI)	3 Mission Name: 2BLK06DS066A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: Mar. 7, 2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: surveyed 11 lines of BLK 06G & 7 lines of BLK 06 Q (without CASI)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	SSgt Dioscoro Soberano PAF	R. Samar II	Catherine Baluyas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 1BLK27ABS067A Mission.



DREAM Data Acquisition Flight Log

Flight Log No.: 1155P

1 LiDAR Operator: F. SABLE	2 ALTM Model: PEG	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP - C9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route:			
10 Date: MAR. 8, 2014	12 Airport of Departure (Airport, City/Province): LA UNION		12 Airport of Arrival (Airport, City/Province): LA UNION		
13 Engine On: 10 + 05	14 Engine Off: 12 + 26	15 Total Engine Time: 2 + 17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission successful					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	MARVIN TORRE	M.L TANGONAN	PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 2BLK07CS067A & 2BLK06G067A Mission.

DREAM Data Acquisition Flight Log — 2BLK07CS067A Q — **Flight Log No.:** 7114

1 LiDAR Operator: MVE TONGA	2 ALTM Model: GEMT CAS1	3 Mission Name: 2BLK06G067A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-08-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 0910H	14 Engine Off: 1333H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Windy				

20 Remarks:

Completed the rest of blocks BLK07C & BLK07B

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	SSg Dosono Sofera PAF		MVE
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 2BLK07B068A Mission.

DREAM Data Acquisition Flight Log

Flight Log No.: 7116

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: GEM+CASI	3 Mission Name: 2BLK07B068A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-09-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 0829H	14 Engine Off: 1252H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed area of BLK07B					

21 Problems and Solutions:

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
CATHERINE BALIGUAS
Signature over Printed Name

Flight Log for 2BLK07D069A & 2BLK07G069A Mission.

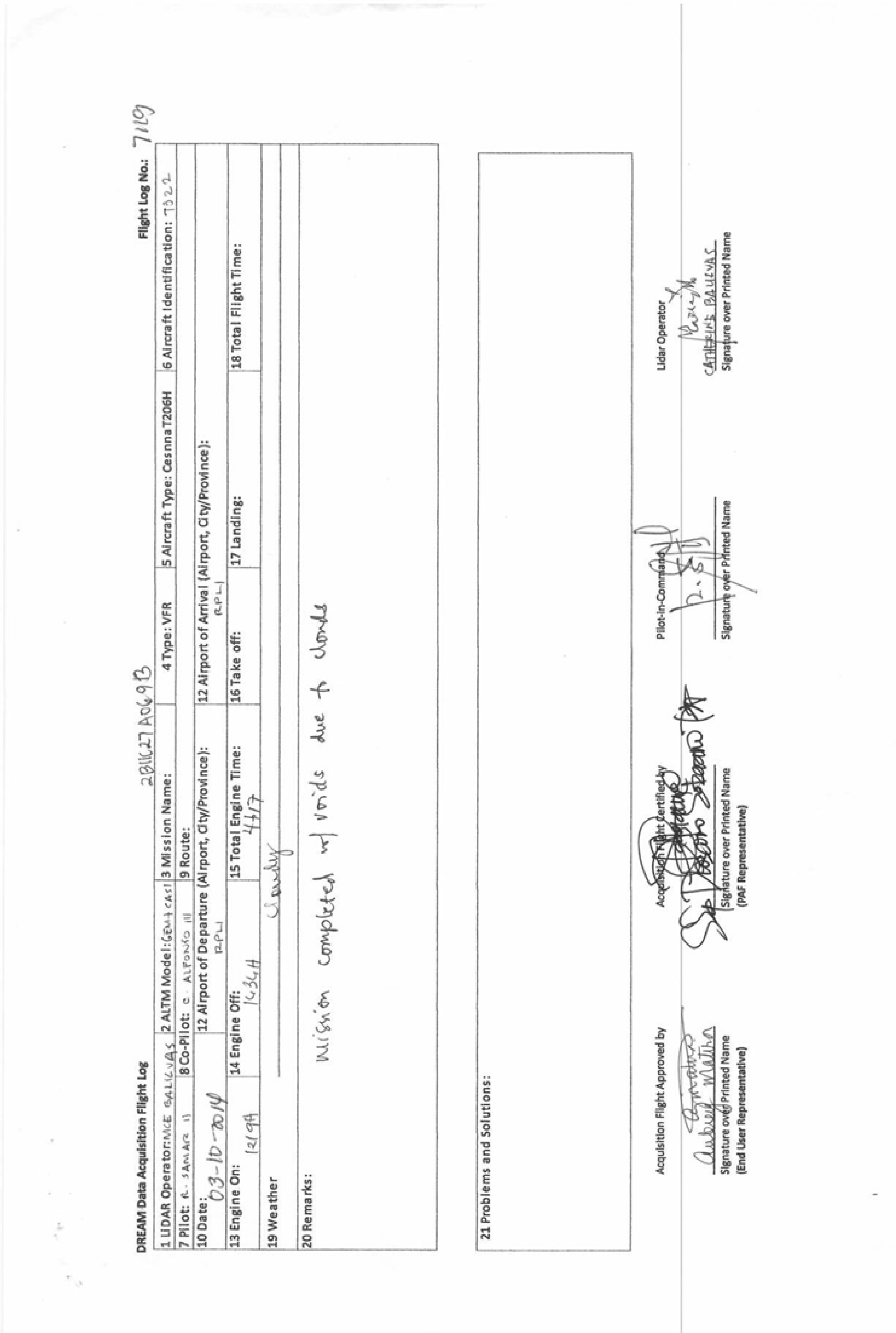
DREAM Data Acquisition Flight Log 2BLK07069A **Flight Log No.:** 7118

1 LIDAR Operator: MVE TONGA	2 ALTM Model: GEMT CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R-SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-10-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 0648H	14 Engine Off: 1110H	15 Total Engine Time: 4+22	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: windy					
20 Remarks: Mission completed at BLK07D & surveyed 2 lines of BLK07G (without CASI)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	Sgt Dioscoro Salcedo PAF		
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 2BLK27A069B Mission.



DREAM Data Acquisition Flight Log 2BLK27A069B **Flight Log No.:** 7119

1 LIDAR Operator: MCE BALICVAS	2 ALTM Model: GEMINI CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 7322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-10-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 1219H	14 Engine Off: 1634H	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Mission completed w/ voids due to clouds					

21 Problems and Solutions:

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

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

Pilot-in-Command: Signature over Printed Name

Lidar Operator: CATHERINE BALICVAS — Signature over Printed Name

Flight Log for 2BLK06F070A & 2BLK07A070A Mission.

DREAM Data Acquisition Flight Log — **Flight Log No.:** 5120

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: GEMINI+CASI	3 Mission Name: 2BLK06F & BLK07A 070A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route: Laoag – BLK 06F & BLK07A – Laoag			
10 Date: 0311-2014	12 Airport of Departure (Airport, City/Province): Laoag Airport		12 Airport of Arrival (Airport, City/Province): Laoag Airport		
13 Engine On: 0700 H	14 Engine Off: 1111 H	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Successful Flight; Completed areas of BLK06F and BLK07A (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	SSg Diosdado Sotelo PAF	R. S. II	Catherine Baliguas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 2BLK07GS070B Mission.

DREAM Data Acquisition Flight Log — Flight Log No.: 7121

1 LIDAR Operator: MVE TONGA	2 ALTM Model: LEMITCASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-11-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 1234H	14 Engine Off: 1615H	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Windy				

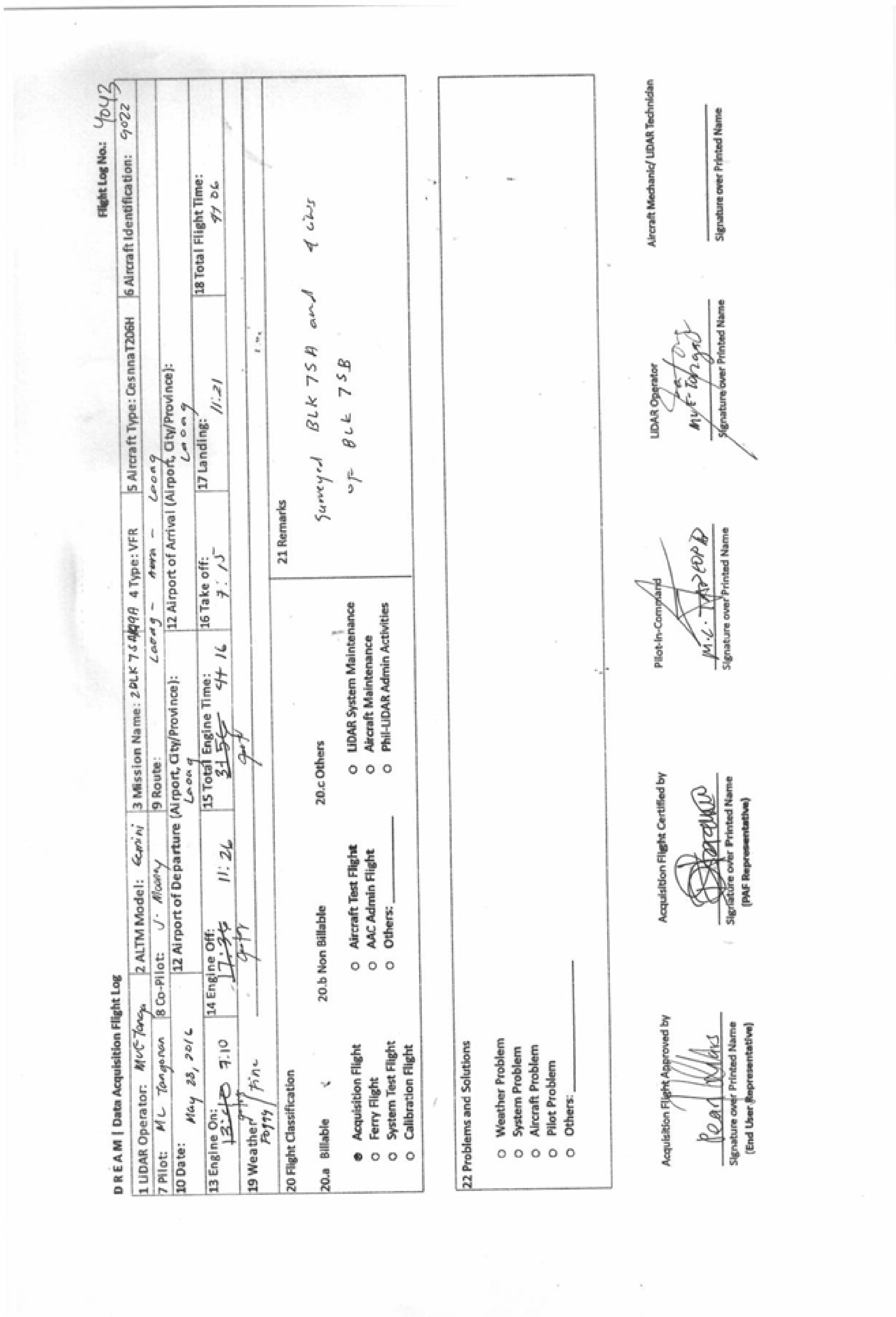
20 Remarks:

Successful flight; Mission completed (without CASI)

21 Problems and Solutions:

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

Flight Log for 2BLKSA7149A Mission.



DREAM | Data Acquisition Flight Log

Flight Log No.: 4043

1 LiDAR Operator: MVE Tanga	2 ALTM Model: Gemini	3 Mission Name: 2BLK75A149A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M L Tangonan	8 Co-Pilot: J. Alcoey	9 Route: Laoag - Aora - Laoag			
10 Date: May 28, 2016	12 Airport of Departure (Airport, City/Province): Laoag		12 Airport of Arrival (Airport, City/Province): Laoag		
13 Engine On: 7:10	14 Engine Off: 11:26	15 Total Engine Time: 4+16	16 Take off: 7:15	17 Landing: 11:21	18 Total Flight Time: 4+06
19 Weather: Fine					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 75A and 4 lines of BLK 75B

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

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

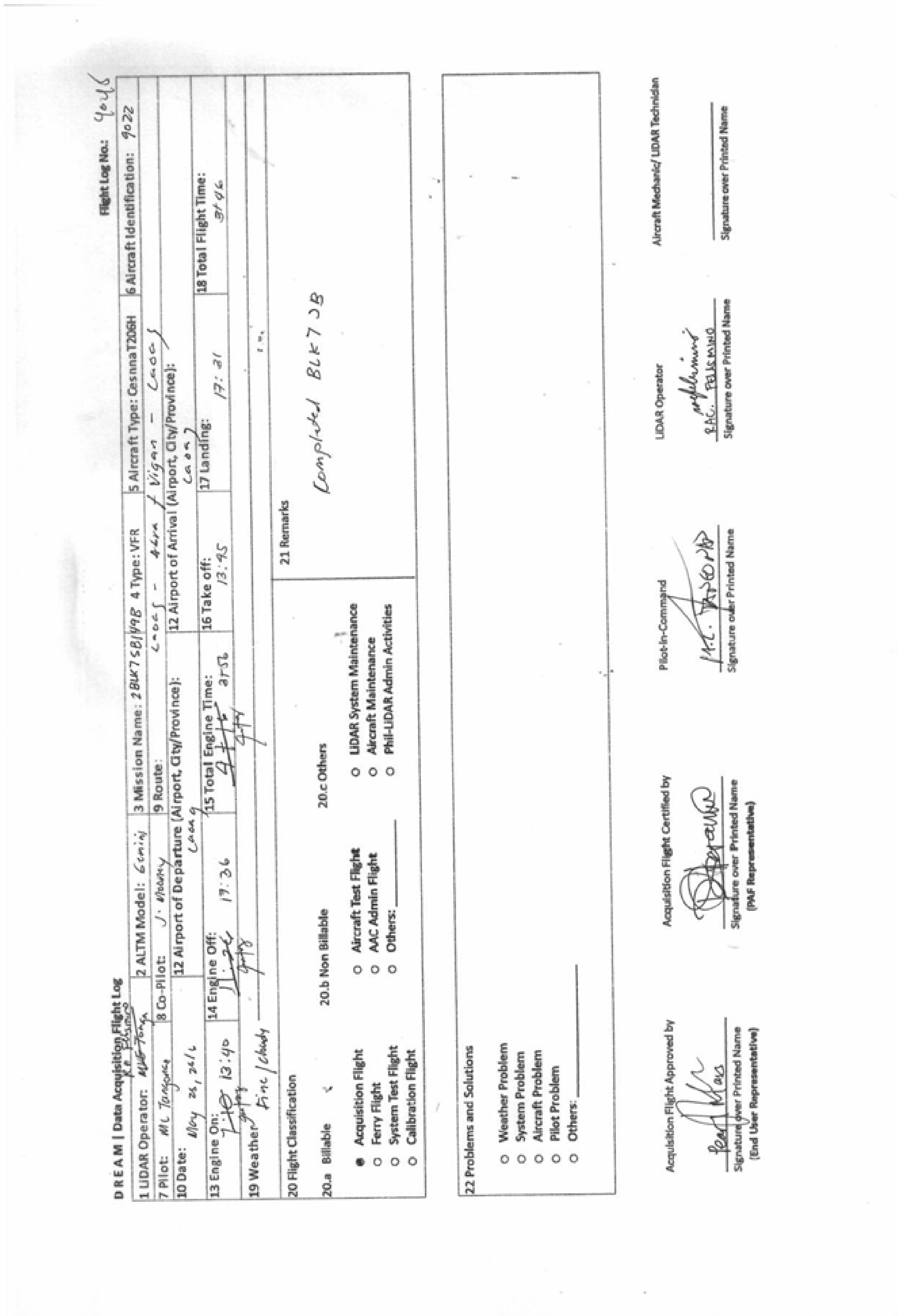
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

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

LiDAR Operator — MVE Tanga — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Flight Log for 2BLK7SB149B Mission.



DREAM | Data Acquisition Flight Log

Flight Log No.: 4046

1 LiDAR Operator: RC Felismino	2 ALTM Model: Gemini	3 Mission Name: 2BLK7SB149B 4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: MC Tangonan	8 Co-Pilot: J. Mooney	9 Route: Laoag - Abra / Vigan - Laoag		
10 Date: May 26, 2016	12 Airport of Departure (Airport, City/Province): Laoag	12 Airport of Arrival (Airport, City/Province): Laoag		
13 Engine On: 13:40	14 Engine Off: 17:36	15 Total Engine Time: 3+56	16 Take off: 13:45	17 Landing: 17:31	18 Total Flight Time: 3+46
19 Weather: Fine / cloudy				

20 Flight Classification

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

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

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

21 Remarks

Completed BLK7SB

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

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

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

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

LiDAR Operator — RAC. Felismino — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

ILOCOS NORTE, ILOCOS SUR and ABRA					
FLIGHT NO.	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
7107	BLK07	2BLK07C063B	MVE TONGA	04 MAR 14	Surveyed 8 lines at BLK07C (without CASI)
7112	BLK06	2BLK06G066A & 2BLK06DS066A	MCE BALIGUAS	07 MAR 14	Surveyed 11 lines at BLK06G and 7 lines at BLK06D (without CASI)
7114	BLK07 & BLK06	2BLK07CS067A & 2BLK06G067A	MVE TONGA	May 10, 2014	Completed the rest of blocks 07C & 07B (without CASI)
7116	BLK07	2BLK07B068A	08 MAR 14	May 10, 2014	Completed 15 lines over BLK33G.
7118	BLK07	2BLK07D069A & 2BLK07G069A	MCE BALIGUAS	May 11, 2014	. Mission completed at BLK07D and surveyed 2 lines of BLK07G (without CASI)
7119	BLK21	2BLK27A069B	MVE TONGA	Completed area of BLK07B (without CASI)	Mission completed with voids due to clouds (without CASI)
7120	BLK06 & BLK07	2BLK06F070A & 2BLK07A070A	MCE BALIGUAS	11 MAR 14	Completed areas of BLK06F and BLK07A (without CASI)
7121	BLK07	2BLK07GS070B & 2BLK07AS070B	MVE TONGA	11 MAR 14	Mission completed (without CASI)

Annex 7. FLIGHT STATUS

FLIGHT STATUS REPORT					
4043 G	BLKSA7	2BLKSA7149A	V. TONGA	MAY 28	SURVEYED BLKSA7 227.908 SQ.KM
4045 G	BLKSB7	2BLKSB7149B	R. FELISMINO	MAY 28	SURVEYED BLKSB7 87.9 SQ.KM

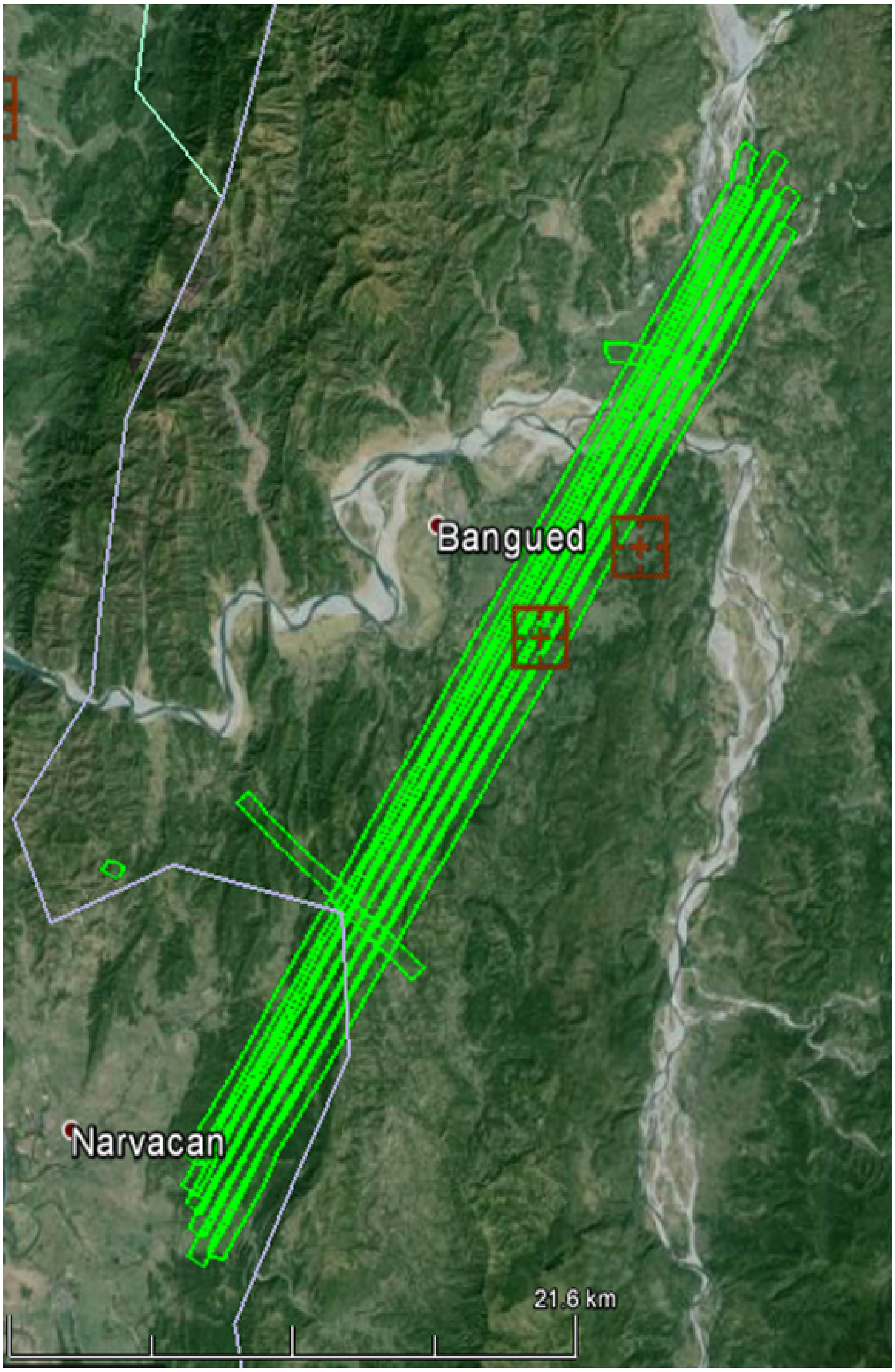
La Union Flight Status Report (2015)

Laoag Flight Status Report (2016)

Flight No.	Area	Mission	Operator	Date Flown	Remarks
1179P	BLOCK 27B	1BLK27B063A	R. PUNTO	March 4, 2014	Survey of Ilocos Sur Block (Narvacan-Candon City; not finish ; renamed from 1177P
1195P	BLOCK 27A,27B	1BLK27ABS067A	F. SABLE	March 8, 2015	Mission Complete

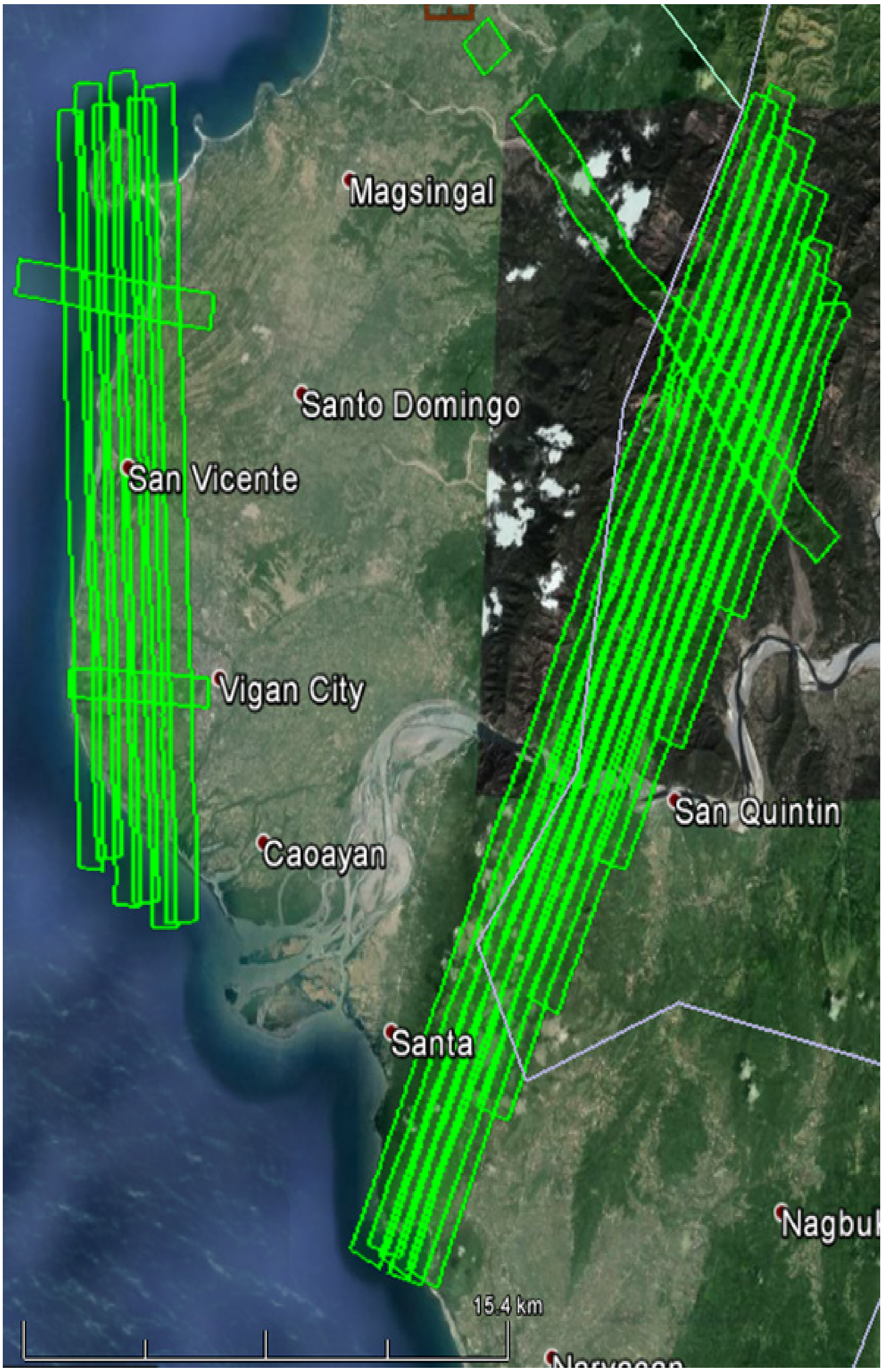
1. Swath Coverage for Mission 2BLK07C063B

Flight No. :	71077 G
Area:	BLK07
Mission Name:	2BLK07C063B
Parameters:	Altitude: 1200m; Scan Frequency: 50; Scan angle: 15; Overlap: 40%



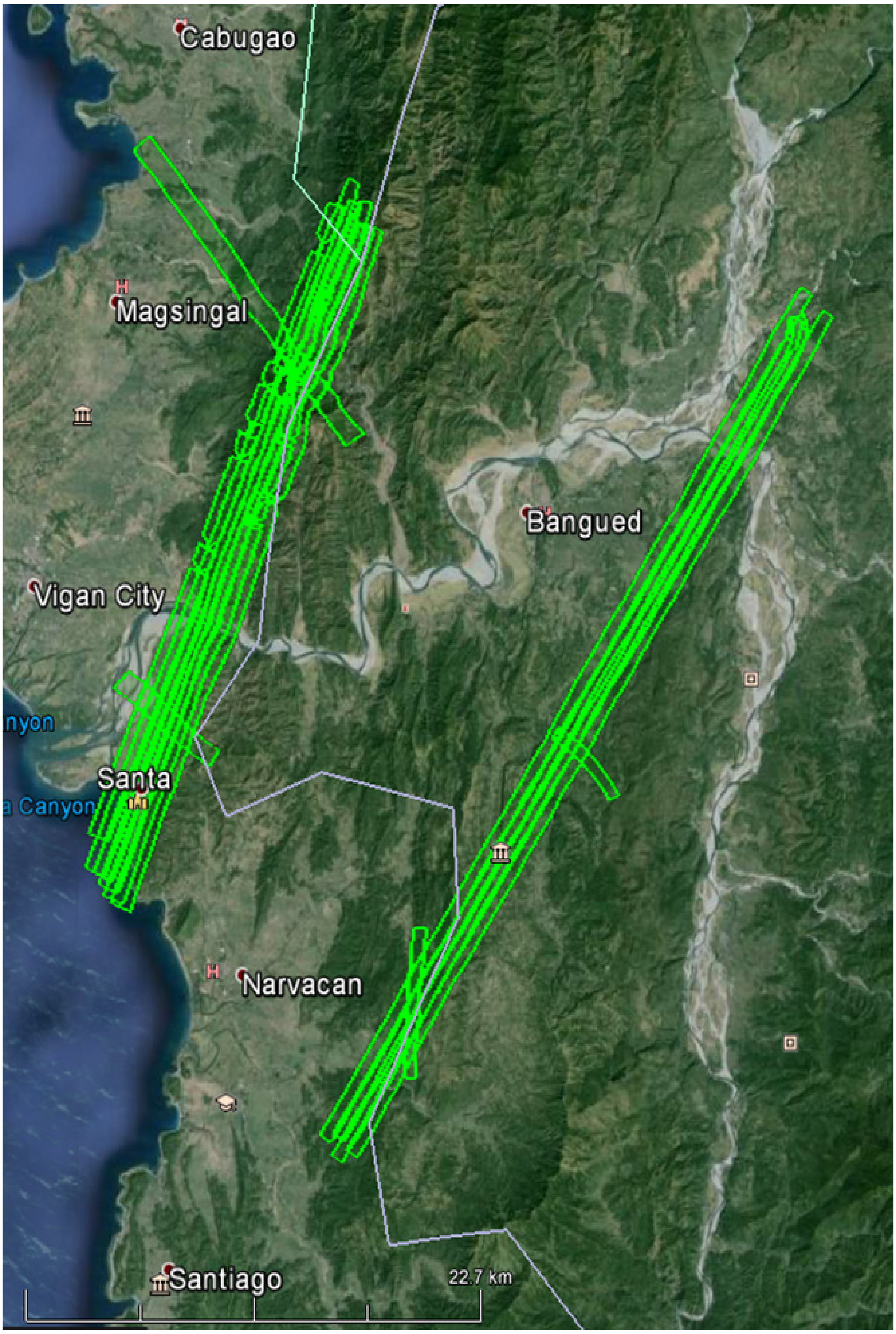
2. Swath Coverage for Mission 2BLK06G066A & 2BLK6DS066A

Flight No. : 71122 G
Area: BLK06
Mission Name: 2BLK06G066A & 2BLK6DS066A
Parameters: Altitude: 1800; Scan Frequency: 50 ; Scan angle: 15; Overlap: 55%



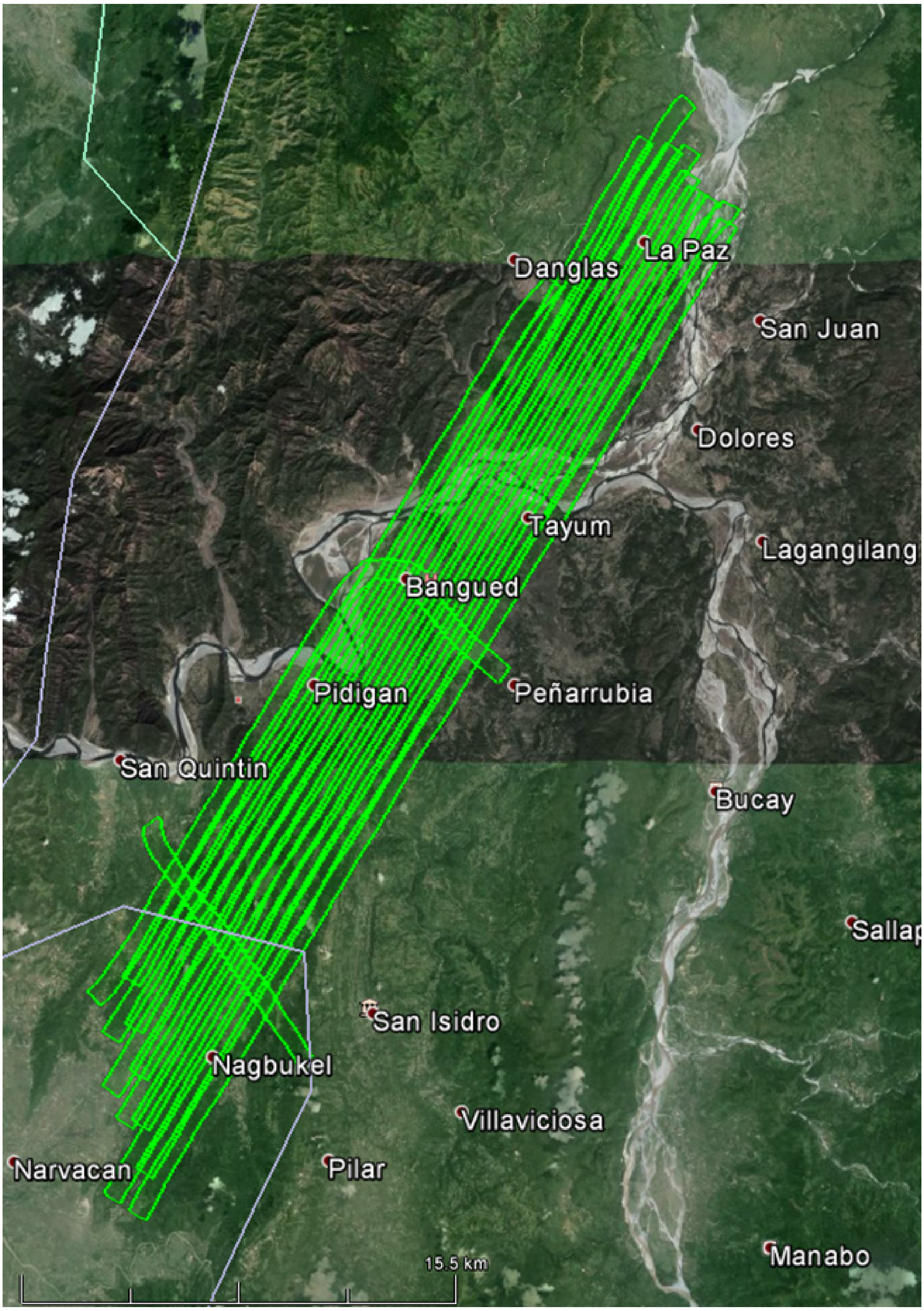
3. Swath Coverage for Mission 2BLK07CS067A & 2BLK06G067A

Flight No. : 71142 G
Area: BLK07 & BLK06
Mission Name: 2BLK07CS067A & 2BLK06G067A
Parameters: BLK07G - Altitude: 1800m; Scan Frequency: 50; Scan angle: 15; Overlap: 55 %
BLK07C - Altitude: 1200 m; Scan Frequency: 50; Scan angle: 15;Overlap: 40%



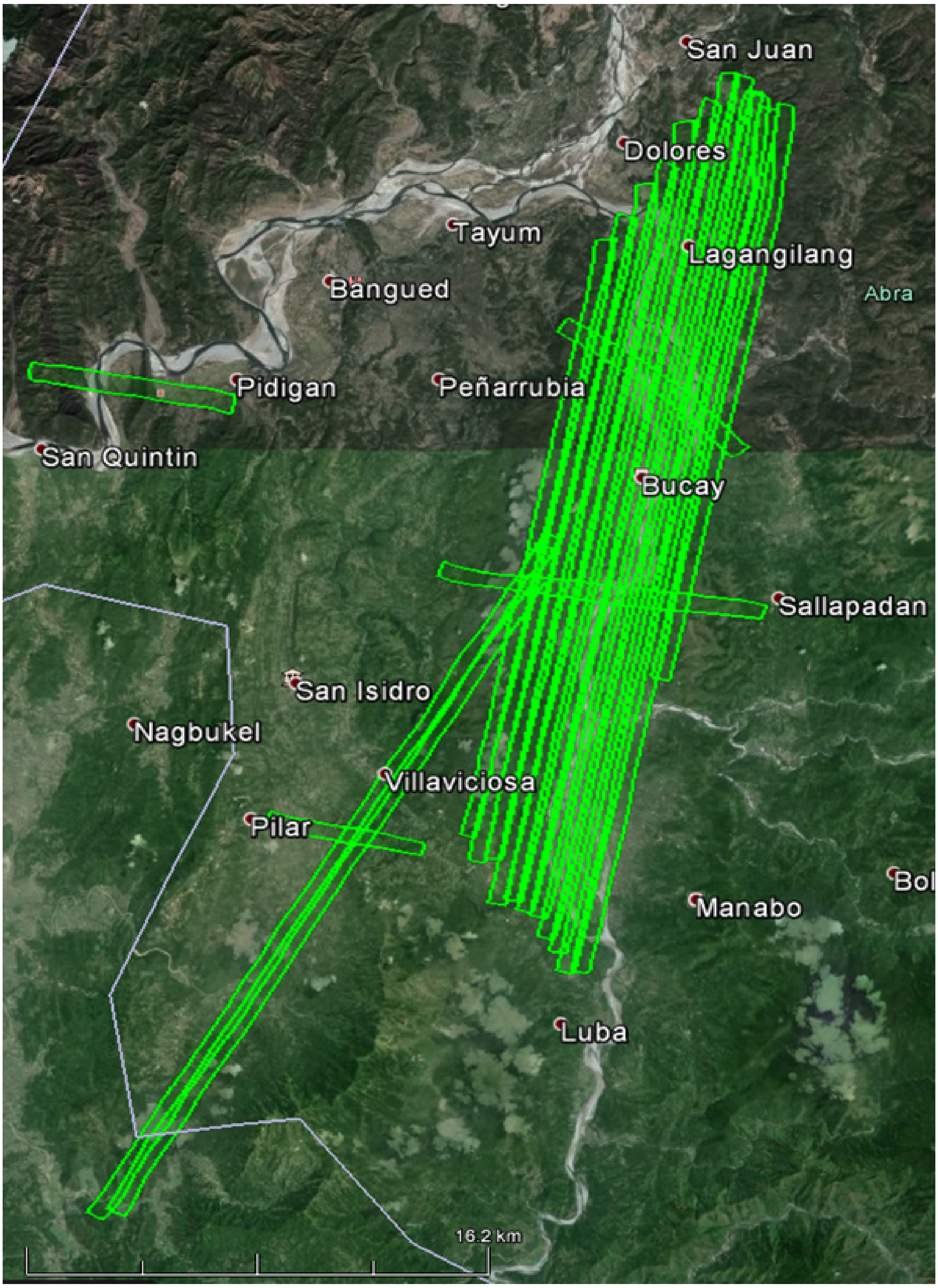
4. Swath Coverage for Mission 2BLK07B068A

Flight No. : 71162 G
Area: BLK07
Mission Name: 2BLK07B068A
Parameters: Altitude: 1300m; Scan Frequency: 50 ; Scan angle: 15; Overlap: 30 %



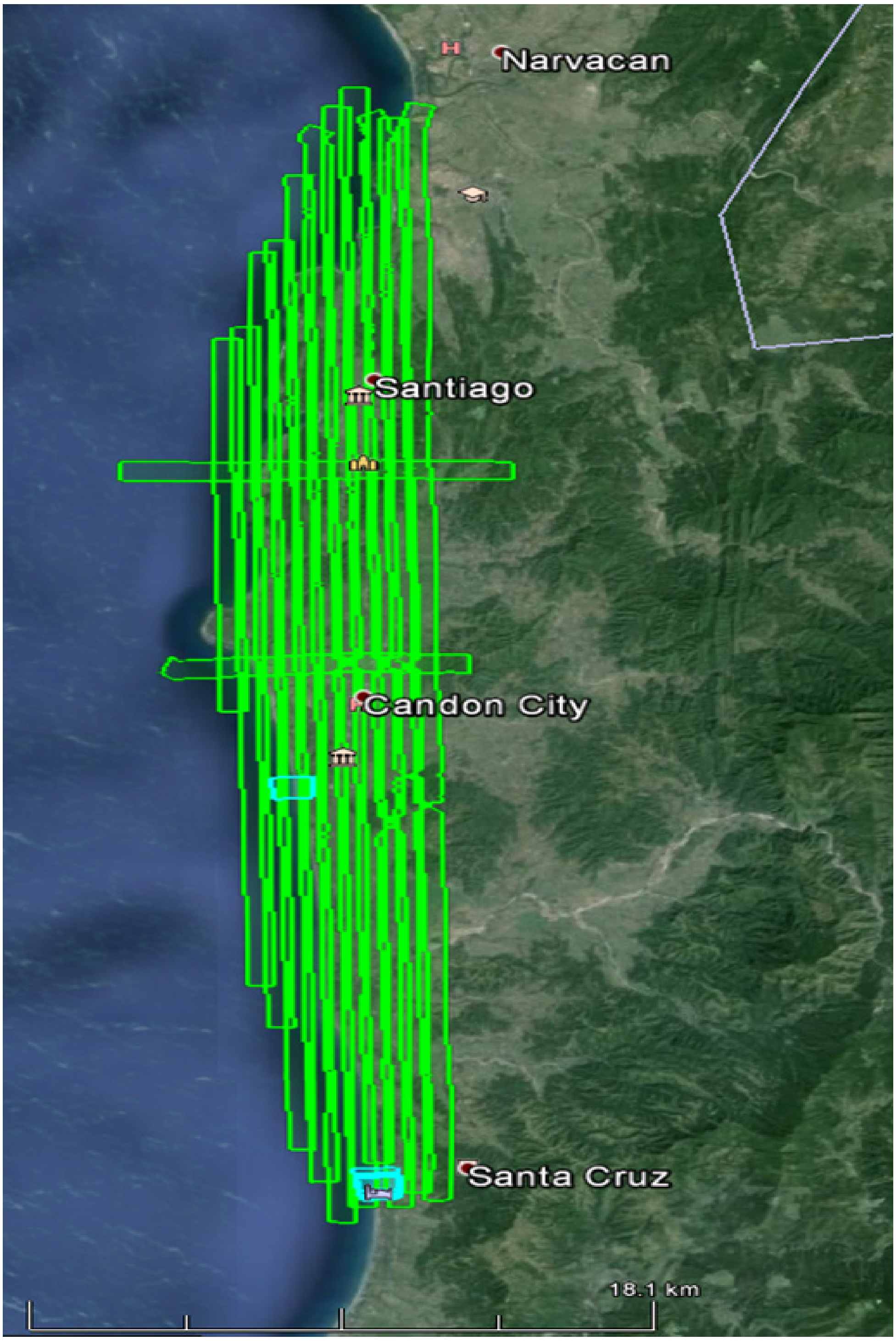
5. Swath Coverage for Mission 2BLK07D069A

Flight No. :	71182 G
Area:	BLK07
Mission Name:	2BLK07D069A
Parameters:	Altitude: 1300; Scan Frequency:50 ; Scan angle:15 ; Overlap:50 %



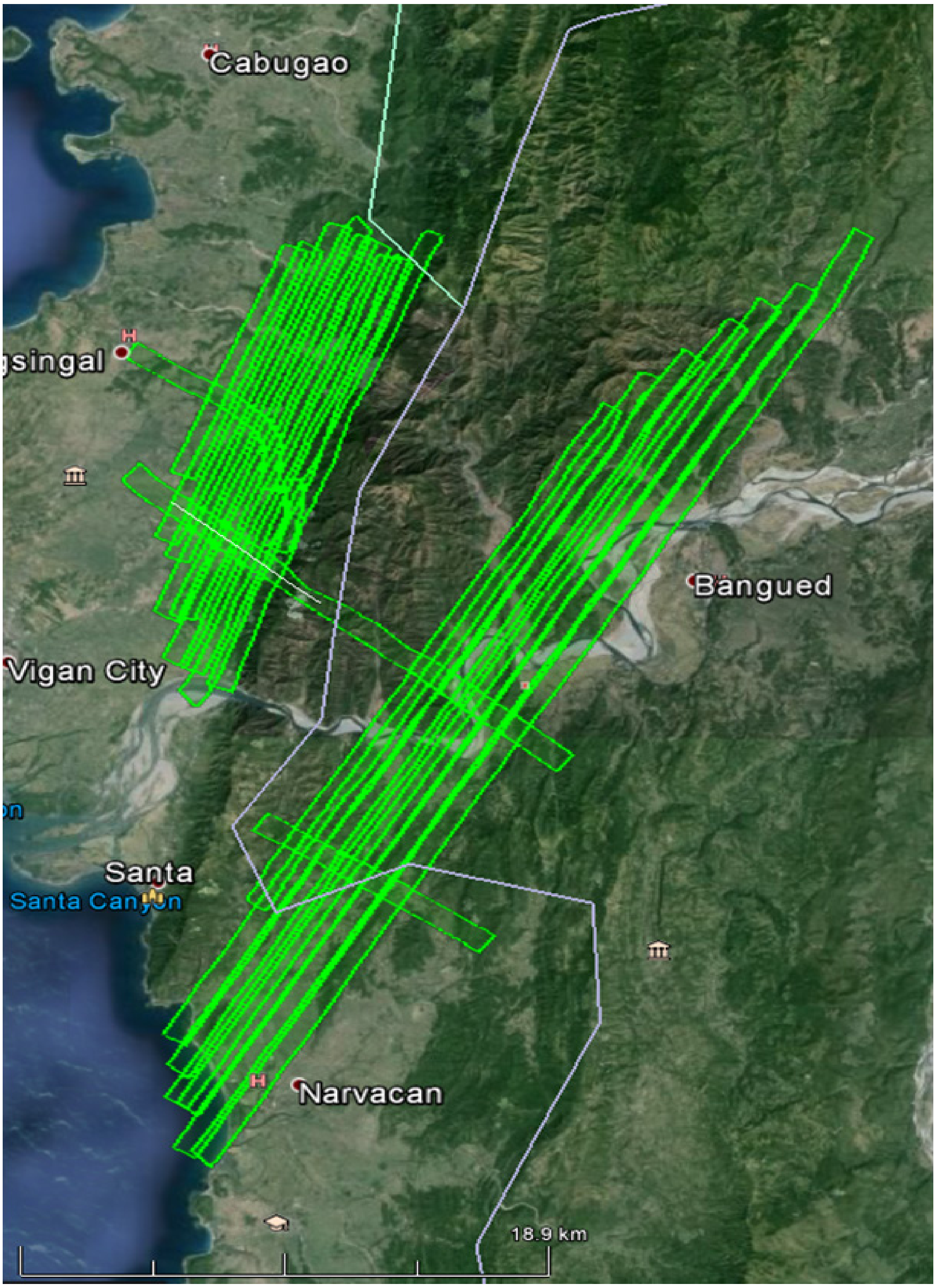
6.Swath Coverage for Mission 2BLK27A069B

Flight No. : 71192 G
Area: BLK27
Mission Name: 2BLK27A069B
Parameters: Altitude: 1000m; Scan Frequency:50 ; Scan angle:20 ; Overlap:25 %



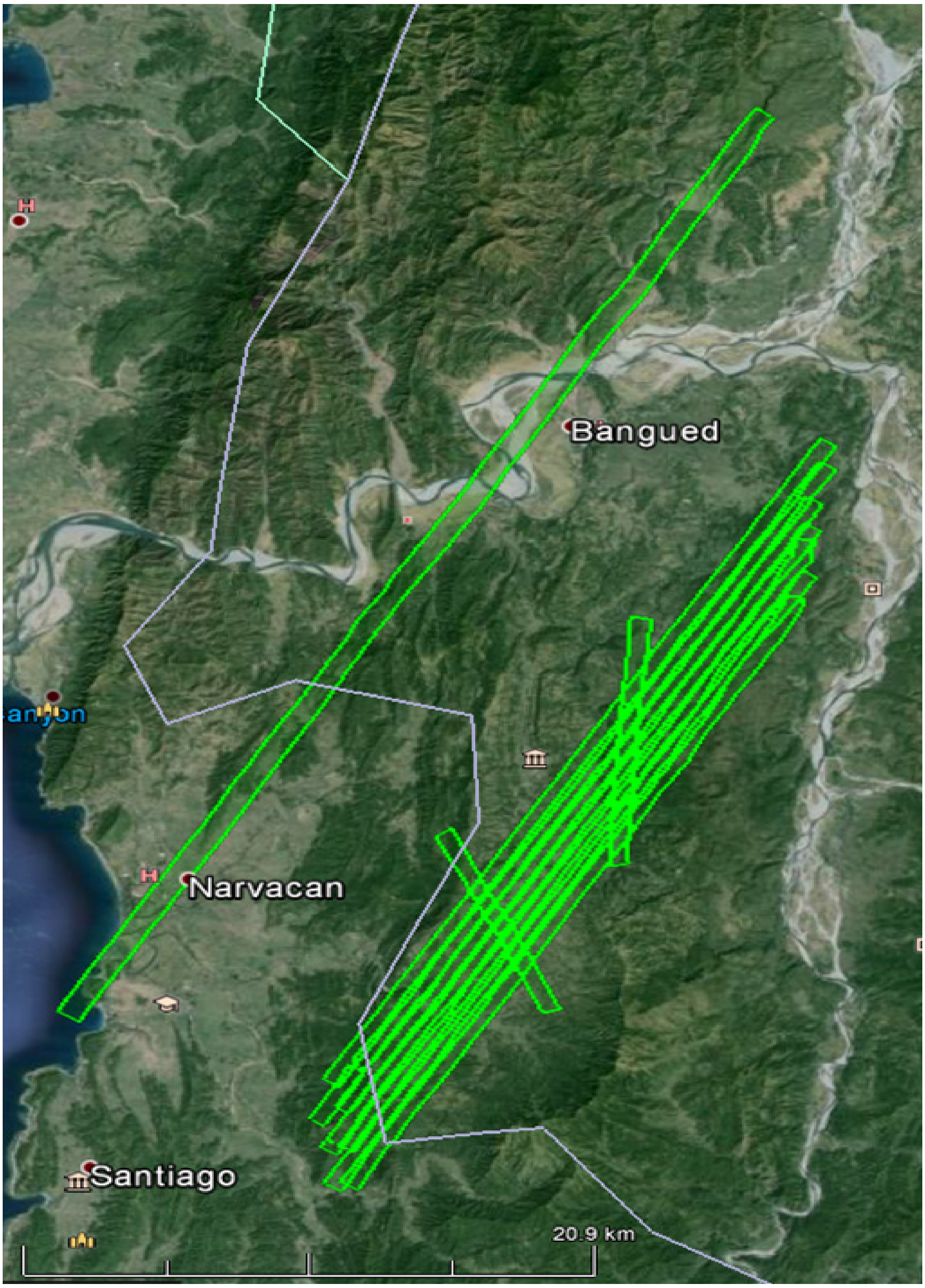
7. Swath Coverage for Mission 2BLK06F070A & 2BLK07A070A

Flight No. :	71202 G
Area:	BLK06 & BLK07
Mission Name:	2BLK06F070A & 2BLK07A070A
Parameters:	Altitude: 1600m; Scan Frequency: 50; Scan angle: 15; Overlap: 40 %



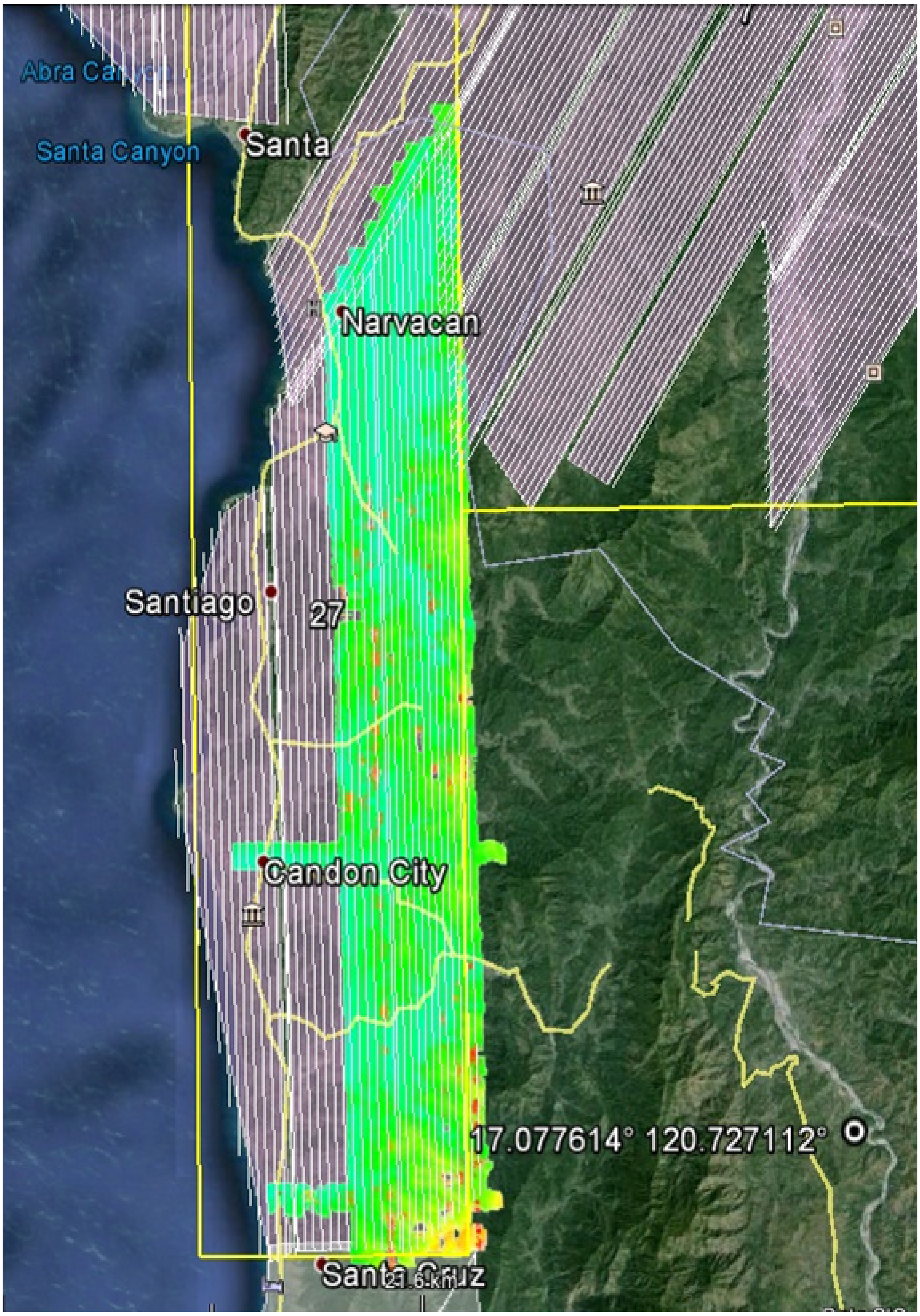
8. Swath Coverage for Mission 2BLK07GS070B & 2BLK07AS070B

Flight No. :	71212 G
Area:	BLK07
Mission Name:	2BLK07GS070B & 2BLK07AS070B
Parameters:	Altitude: 1400m; Scan Frequency: 50; Scan angle: 15; Overlap: 50%



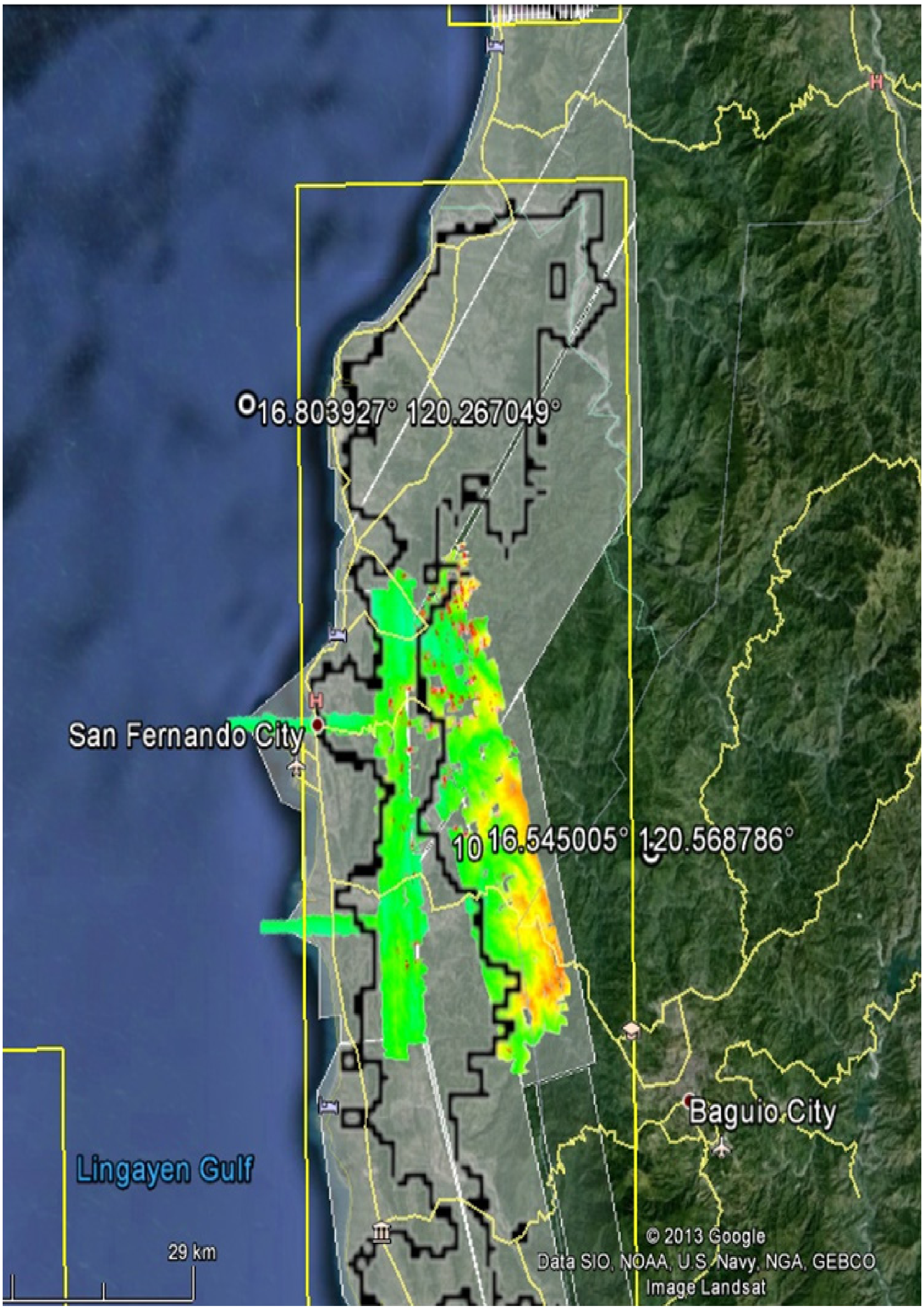
9. Swath Coverage of Mission 1BLK27B063A

Flight No.:	1179P
Area:	27B
Mission Name:	1BLK27B063A
Parameters:	Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50



10. .Swath Coverage of Mission 1BLK27ABS067A

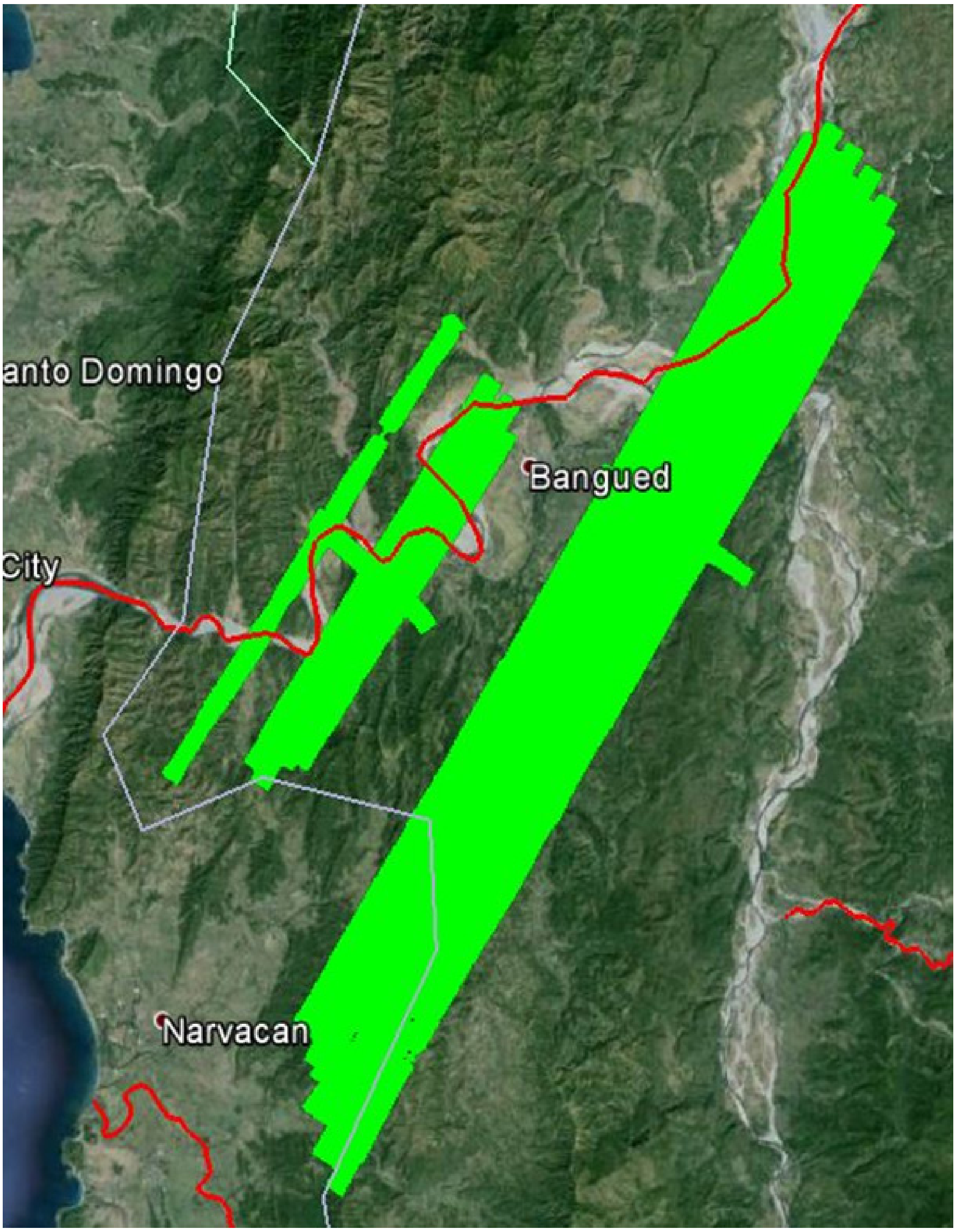
Flight No.: 1195P
Area: 27A & 27B
Mission Name: 1BLK27ABS067A
Parameters: Altitude: 1200m; Scan Frequency: 30; Scan Angle: 50



Swath Coverage of Mission 2BLKSA7149A

Flight No. :	4043 G		
Area:	BLKSA7		
Mission Name:	2BLKSA7149A		
Parameters:	PRF 100	SF 50	SCAN ANGLE 20
Flying Height:	1000 M		

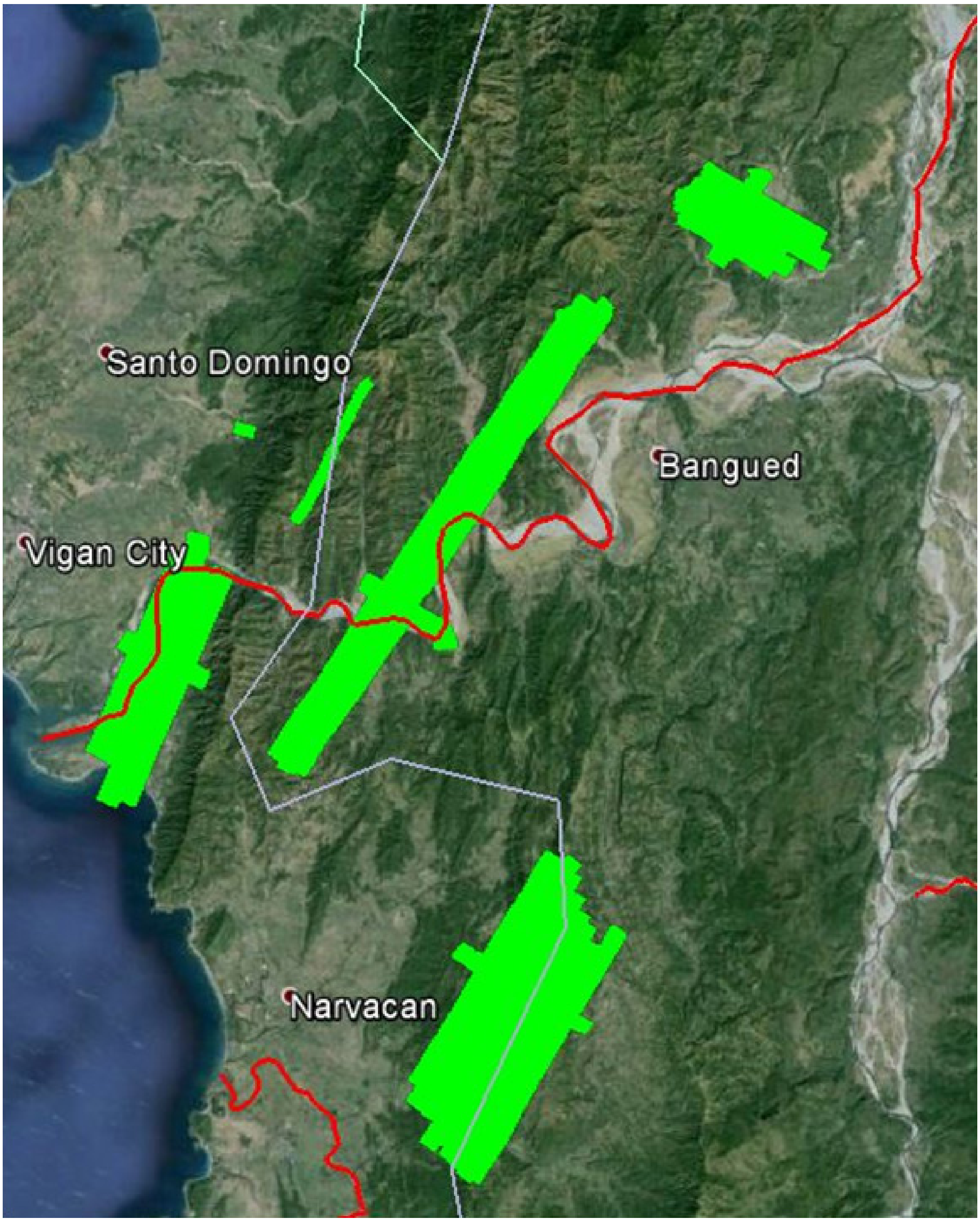
LAS/SWATH



Swath Coverage of Mission 2BLKSB7149B

Flight No. :	4045 G		
Area:	BLKSB		
Mission Name:	2BLKSB7149B		
Parameters:	PRF 100	SF 50	SCAN ANGLE 20
Flying Height:	1000 M		

LAS/SWATH



Annex 8. Mission Summary Reports

Flight Area	Samar-Leyte
Mission Name	Blk33H
Inclusive Flights	1444A, 1450A, 1452A
Range data size	30.84 GB
POS data size	619 MB
Base data size	36 MB
Image	160.5 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000310
IMU attitude correction stdev (<0.001deg)	0.000915
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	46.76%
Ave point cloud density per sq.m. (>2.0)	3.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	261
Maximum Height	328.04 m
Minimum Height	56.94 m
Classification (# of points)	
Ground	120,058,822
Low vegetation	54,325,156
Medium vegetation	230,234,006
High vegetation	163,298,807
Building	1,762,420
Orthophoto	Yes
Processed by	Aljon Araneta

Annex 9. Silay Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W340	7.3785	44.795	0	14.399	2.35	Discharge	0.24797	0.95	Ratio to Peak	0.0001
W350	23.39	39.309	0	22.224	2.6441	Discharge	0.86249	0.91549	Ratio to Peak	0.00015
W360	28.442	35.046	0	9.1786	1.4945	Discharge	0.2815	0.97957	Ratio to Peak	0.00015
W370	42.548	35.867	0	10.692	0.78097	Discharge	0.28295	0.93914	Ratio to Peak	0.00015
W380	44.869	35.309	0	3.2808	0.2408	Discharge	0.027045	0.9	Ratio to Peak	0.00015
W390	7.8485	44.5	0	0.20734	0.033836	Discharge	0.000491	0.95	Ratio to Peak	0.0001
W400	8.131	44.3245	0	9.6188	1.5698	Discharge	0.30857	0.95	Ratio to Peak	0.0001
W410	49.161	35.283	0	7.2581	0.79103	Discharge	0.56683	0.95705	Ratio to Peak	0.00015
W420	12.423	99	0	3.7861	0.17317	Discharge	0.007303	1	Ratio to Peak	0.00015
W430	41.434	35.468	0	0.89004	0.065875	Discharge	0.30485	0.96244	Ratio to Peak	0.00015
W440	19.152	65.366	0	7.2786	1.7851	Discharge	0.18877	0.92131	Ratio to Peak	0.00015
W450	16.584	36.817	0	6.039	0.40722	Discharge	0.30608	0.93381	Ratio to Peak	0.00015
W460	51.993	37.093	0	2.6198	0.13191	Discharge	0.31304	0.96286	Ratio to Peak	0.00015
W470	103.74	35.948	0	0.44245	0.072209	Discharge	0.002877	1	Ratio to Peak	0.00015
W480	54.146	37.851	0	0.76945	0.016667	Discharge	0.040961	1	Ratio to Peak	0.00015
W490	90.928	35	0	4.6705	0.74341	Discharge	0.27215	0.96075	Ratio to Peak	0.00015

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W500	37.979	35.398	0	1.4493	0.071512	Discharge	0.043563	0.96048	Ratio to Peak	0.00015
W510	81.394	35	0	13.13	0.64501	Discharge	0.17223	0.96047	Ratio to Peak	0.00015
W520	93.772	37.12	0	10.203	2.5127	Discharge	0.24031	0.96005	Ratio to Peak	0.00015
W530	19.531	39.879	0	5.6157	0.40732	Discharge	0.53464	0.93132	Ratio to Peak	0.00015
W540	10.765	38.47	0	1.2467	0.20038	Discharge	0.38075	0.9507	Ratio to Peak	0.00015
W550	64.738	40.432	0	9.0036	1.5017	Discharge	0.29902	0.80472	Ratio to Peak	0.00015
W560	40.508	35.109	0	2.6258	0.12785	Discharge	0.11532	0.9352	Ratio to Peak	0.00015
W570	63.083	35.302	0	12.605	0.40493	Discharge	0.23757	0.93467	Ratio to Peak	0.00015
W580	62.706	50.927	0	9.0571	0.016667	Discharge	0.5207	0.87625	Ratio to Peak	0.00015
W590	62.815	35	0	8.6633	0.65636	Discharge	0.085951	0.8974	Ratio to Peak	0.00015
W600	40.375	35.157	0	6.1869	1.509	Discharge	0.34303	0.93681	Ratio to Peak	0.00015
W610	78.088	50.421	0	11.619	1.8974	Discharge	0.29971	0.89666	Ratio to Peak	0.00015
W620	137.58	52.5	0	9.2508	1.0065	Discharge	0.16367	0.87625	Ratio to Peak	0.00015
W630	119.7	52.5	0	11.23	1.2218	Discharge	0.24406	0.87625	Ratio to Peak	0.00015
W640	113.68	52.5	0	15.771	1.7159	Discharge	0.61864	0.59609	Ratio to Peak	0.00015
W650	43.626	35.197	0	43.626	3.1888	Discharge	0.90482	0.961	Ratio to Peak	0.00015
W660	94.359	52.5	0	10.589	1.1521	Discharge	0.41756	0.59609	Ratio to Peak	0.00015

Annex 10. Silay Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R110	Automatic Fixed Interval	3502.2	0.022108	1	Trapezoid	49	1
R120	Automatic Fixed Interval	299.71	0.006394	0.75184	Trapezoid	52	1
R130	Automatic Fixed Interval	923.97	0.025665	1	Trapezoid	48	1
R140	Automatic Fixed Interval	2376.1	0.020154	1	Trapezoid	39	1
R170	Automatic Fixed Interval	4010.3	0.00062	0.62746	Trapezoid	55	1
R210	Automatic Fixed Interval	6336	0.002125	1	Trapezoid	85	1
R240	Automatic Fixed Interval	1861.5	0.002322	1	Trapezoid	115	1
R250	Automatic Fixed Interval	2585.9	0.010753	1	Trapezoid	44.2	1
R270	Automatic Fixed Interval	5174.6	0.008589	1	Trapezoid	57	1
R290	Automatic Fixed Interval	4980	0.022495	1t	Trapezoid	45.5	1
R30	Automatic Fixed Interval	29.142	0.0001	1	Trapezoid	116	1
R310	Automatic Fixed Interval	13412	0.006359	1	Trapezoid	46	1
R40	Automatic Fixed Interval	7039.3	0.000513	1	Trapezoid	109	1
R50	Automatic Fixed Interval	1455.7	0.027961	1	Trapezoid	24	1
R80	Automatic Fixed Interval	906.27	0.003584	0.89966	Trapezoid	47	1
R90	Automatic Fixed Interval	13294	0.009006	0.86436	Trapezoid	60	1

Annex 11. Silay Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	17.430687	120.47807	1.940	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
2	17.383178	120.515133	0.500	0.610	0.372	Mario/ September 18-22, 2014	5-Year
3	17.371899	120.473629	0.590	0.610	0.372	Mario/ September 18-22, 2014	5-Year
4	17.369451	120.472776	0.860	0.610	0.372	Mario/ September 18-22, 2014	5-Year
5	17.365444	120.471885	0.810	0.610	0.372	Mario/ September 18-22, 2014	5-Year
6	17.370317	120.468934	1.590	0.610	0.372	Mario/ September 18-22, 2014	5-Year
7	17.372391	120.466593	1.680	0.610	0.372	Mario/ September 18-22, 2014	5-Year
8	17.378748	120.470219	1.460	0.610	0.372	Mario/ September 18-22, 2014	5-Year
9	17.370317	120.468934	1.590	0.610	0.372	Mario/ September 18-22, 2014	5-Year
10	17.372391	120.466593	1.680	0.610	0.372	Mario/ September 18-22, 2014	5-Year
11	17.378748	120.470219	1.460	0.610	0.372	Mario/ September 18-22, 2014	5-Year
12	17.417878	120.502906	0.780	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
13	17.383178	120.515133	0.500	0.610	0.372	Mario/ September 18-22, 2014	5-Year
14	17.41899	120.496799	0.350	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
15	17.42161	120.509013	1.560	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
16	17.407423	120.501956	1.860	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
17	17.41899	120.496799	0.350	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
18	17.41899	120.496799	0.350	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
19	17.41899	120.496799	0.350	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
20	17.425485	120.482788	2.220	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
21	17.425485	120.482788	2.220	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
22	17.358169	120.475534	0.170	0.610	0.372	Mario/ September 18-22, 2014	5-Year
23	17.35137	120.478708	0.070	0.610	0.372	Mario/ September 18-22, 2014	5-Year
24	17.383415	120.513875	2.510	0.610	0.372	Mario/ September 18-22, 2014	5-Year
25	17.358169	120.475534	0.170	0.914	0.836	Mario/ September 18-22, 2014	5-Year
26	17.442499	120.511114	0.270	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
27	17.442499	120.511114	0.270	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
28	17.388029	120.516141	1.980	0.610	0.372	Mario/ September 18-22, 2014	5-Year
29	17.37616	120.512033	0.340	0.610	0.372	Mario/ September 18-22, 2014	5-Year
30	17.3907	120.517187	1.700	0.610	0.372	Mario/ September 18-22, 2014	5-Year
31	17.378693	120.514885	3.670	0.610	0.372	Mario/ September 18-22, 2014	5-Year
32	17.39118	120.476435	1.320	0.610	0.372	Mario/ September 18-22, 2014	5-Year
33	17.385731	120.527384	1.270	0.610	0.372	Mario/ September 18-22, 2014	5-Year
34	17.380973	120.52914	0.320	0.610	0.372	Mario/ September 18-22, 2014	5-Year
35	17.452735	120.486426	0.380	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
36	17.374472	120.504528	0.560	0.610	0.372	Mario/ September 18-22, 2014	5-Year
37	17.378218	120.525332	0.200	0.610	0.372	Mario/ September 18-22, 2014	5-Year
38	17.362939	120.501533	0.560	0.610	0.372	Mario/ September 18-22, 2014	5-Year
39	17.388029	120.516141	1.980	0.610	0.372	Mario/ September 18-22, 2014	5-Year
40	17.37616	120.512033	0.340	0.610	0.372	Mario/ September 18-22, 2014	5-Year
41	17.3907	120.517187	1.700	0.610	0.372	Mario/ September 18-22, 2014	5-Year
42	17.378693	120.514885	3.670	0.610	0.372	Mario/ September 18-22, 2014	5-Year
43	17.39118	120.476435	1.320	0.610	0.372	Mario/ September 18-22, 2014	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
44	17.385731	120.527384	1.270	0.610	0.372	Mario/ September 18-22, 2014	5-Year
45	17.380973	120.52914	0.320	0.610	0.372	Mario/ September 18-22, 2014	5-Year
46	17.457892	120.48757	0.320	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
47	17.374472	120.504528	0.560	0.610	0.372	Mario/ September 18-22, 2014	5-Year
48	17.378218	120.525332	0.200	0.610	0.372	Mario/ September 18-22, 2014	5-Year
49	17.362939	120.501533	0.560	0.610	0.372	Mario/ September 18-22, 2014	5-Year
50	17.340964	120.476389	0.650	0.610	0.372	Mario/ September 18-22, 2014	5-Year
51	17.390336	120.486597	0.830	0.914	0.836	Mario/ September 18-22, 2014	5-Year
52	17.392185	120.486892	1.000	0.914	0.836	Mario/ September 18-22, 2014	5-Year
53	17.381466	120.487495	0.680	0.914	0.836	Mario/ September 18-22, 2014	5-Year
54	17.390884	120.493755	0.060	0.914	0.836	Mario/ September 18-22, 2014	5-Year
55	17.390336	120.486597	0.830	0.914	0.836	Mario/ September 18-22, 2014	5-Year
56	17.392185	120.486892	1.000	0.914	0.836	Mario/ September 18-22, 2014	5-Year
57	17.4686	120.489196	0.470	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
58	17.381466	120.487495	0.680	0.914	0.836	Mario/ September 18-22, 2014	5-Year
59	17.390884	120.493755	0.060	0.914	0.836	Mario/ September 18-22, 2014	5-Year
60	17.388623	120.500759	1.170	0.610	0.372	Mario/ September 18-22, 2014	5-Year
61	17.391534	120.504224	1.400	0.610	0.372	Mario/ September 18-22, 2014	5-Year
62	17.385201	120.500559	0.630	0.610	0.372	Mario/ September 18-22, 2014	5-Year
63	17.384861	120.505648	0.760	0.610	0.372	Mario/ September 18-22, 2014	5-Year
64	17.382269	120.498635	0.040	0.610	0.372	Mario/ September 18-22, 2014	5-Year
65	17.385201	120.500559	0.630	0.914	0.836	Mario/ September 18-22, 2014	5-Year
66	17.387725	120.502933	1.510	0.914	0.836	Mario/ September 18-22, 2014	5-Year
67	17.382087	120.499201	0.050	0.914	0.836	Mario/ September 18-22, 2014	5-Year
68	17.46381	120.489899	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
69	17.389322	120.492407	1.450	0.610	0.372	Mario/ September 18-22, 2014	5-Year
70	17.395033	120.50115	1.330	0.610	0.372	Mario/ September 18-22, 2014	5-Year
71	17.390053	120.494916	0.480	0.610	0.372	Mario/ September 18-22, 2014	5-Year
72	17.38961	120.49742	0.810	0.610	0.372	Mario/ September 18-22, 2014	5-Year
73	17.390053	120.494916	0.480	0.914	0.836	Mario/ September 18-22, 2014	5-Year
74	17.394512	120.501024	1.450	0.914	0.836	Mario/ September 18-22, 2014	5-Year
75	17.38978	120.497205	0.800	0.914	0.836	Mario/ September 18-22, 2014	5-Year
76	17.390953	120.493555	0.330	0.914	0.836	Mario/ September 18-22, 2014	5-Year
77	17.346026	120.504732	1.180	0.914	0.836	Mario/ September 18-22, 2014	5-Year
78	17.460307	120.488413	0.220	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
79	17.348865	120.504546	1.630	0.914	0.836	Mario/ September 18-22, 2014	5-Year
80	17.347491	120.503171	0.520	0.914	0.836	Mario/ September 18-22, 2014	5-Year
81	17.348359	120.50077	0.290	0.914	0.836	Mario/ September 18-22, 2014	5-Year
82	17.34832	120.496132	0.240	0.914	0.836	Mario/ September 18-22, 2014	5-Year
83	17.385122	120.541973	0.220	0.914	0.836	Mario/ September 18-22, 2014	5-Year
84	17.374404	120.508279	0.030	0.914	0.836	Mario/ September 18-22, 2014	5-Year
85	17.465639	120.480797	0.600	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
86	17.459746	120.478422	2.900	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
87	17.460259	120.473694	0.330	0.914	0.836	Lawin/ October 18-22, 2016	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
88	17.464933	120.481916	0.310	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
89	17.453433	120.488337	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
90	17.471667	120.483795	0.480	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
91	17.463128	120.482857	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
92	17.46437	120.479816	0.570	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
93	17.466767	120.481359	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
94	17.465639	120.480797	0.600	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
95	17.431082	120.470121	2.190	0.914	0.836	Mario/ September 18-22, 2014	5-Year
96	17.431082	120.470121	2.190	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
97	17.431082	120.470121	2.190	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
98	17.44627	120.503861	0.140	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
99	17.44627	120.503861	0.140	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
100	17.46403	120.485686	0.060	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
101	17.379545	120.481362	0.740	0.610	0.372	Mario/ September 18-22, 2014	5-Year
102	17.380138	120.47809	1.480	0.914	0.836	Mario/ September 18-22, 2014	5-Year
103	17.379262	120.483656	1.490	0.914	0.836	Mario/ September 18-22, 2014	5-Year
104	17.379545	120.481362	0.740	0.914	0.836	Mario/ September 18-22, 2014	5-Year
105	17.360155	120.493954	0.650	0.914	0.836	Mario/ September 18-22, 2014	5-Year
106	17.385983	120.465237	1.230	0.914	0.836	Mario/ September 18-22, 2014	5-Year
107	17.386549	120.464973	1.210	0.914	0.836	Mario/ September 18-22, 2014	5-Year
108	17.349315	120.507251	1.480	0.914	0.836	Mario/ September 18-22, 2014	5-Year
109	17.388243	120.469052	0.810	0.914	0.836	Mario/ September 18-22, 2014	5-Year
110	17.382227	120.474234	1.440	0.914	0.836	Mario/ September 18-22, 2014	5-Year
111	17.430687	120.47807	1.940	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
112	17.452735	120.486426	0.380	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
113	17.381472	120.473468	1.390	0.914	0.836	Mario/ September 18-22, 2014	5-Year
114	17.387324	120.466049	0.680	0.914	0.836	Mario/ September 18-22, 2014	5-Year
115	17.38538	120.476539	1.450	0.914	0.836	Mario/ September 18-22, 2014	5-Year
116	17.386415	120.477869	1.050	0.914	0.836	Mario/ September 18-22, 2014	5-Year
117	17.387512	120.476196	0.680	0.914	0.836	Mario/ September 18-22, 2014	5-Year
118	17.384908	120.482754	0.500	0.914	0.836	Mario/ September 18-22, 2014	5-Year
119	17.382227	120.474234	1.440	0.914	0.836	Mario/ September 18-22, 2014	5-Year
120	17.381472	120.473468	1.390	0.914	0.836	Mario/ September 18-22, 2014	5-Year
121	17.387324	120.466049	0.680	0.914	0.836	Mario/ September 18-22, 2014	5-Year
122	17.38538	120.476539	1.450	0.914	0.836	Mario/ September 18-22, 2014	5-Year
123	17.457892	120.48757	0.320	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
124	17.386415	120.477869	1.050	0.914	0.836	Mario/ September 18-22, 2014	5-Year
125	17.387512	120.476196	0.680	0.914	0.836	Mario/ September 18-22, 2014	5-Year
126	17.384908	120.482754	0.500	0.914	0.836	Mario/ September 18-22, 2014	5-Year
127	17.387863	120.465063	1.270	0.914	0.836	Mario/ September 18-22, 2014	5-Year
128	17.383738	120.474402	1.400	0.914	0.836	Mario/ September 18-22, 2014	5-Year
129	17.400025	120.477699	1.520	0.914	0.836	Mario/ September 18-22, 2014	5-Year
130	17.422781	120.492114	0.050	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
131	17.422781	120.492114	0.050	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
132	17.363538	120.51626	1.150	0.610	0.372	Mario/ September 18-22, 2014	5-Year
133	17.363538	120.51626	1.150	0.914	0.836	Mario/ September 18-22, 2014	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
134	17.4686	120.489196	0.470	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
135	17.365597	120.479646	0.530	0.914	0.836	Mario/ September 18-22, 2014	5-Year
136	17.359793	120.507722	0.470	0.914	0.836	Mario/ September 18-22, 2014	5-Year
137	17.352204	120.511351	0.030	0.914	0.836	Mario/ September 18-22, 2014	5-Year
138	17.359267	120.502988	0.340	0.914	0.836	Mario/ September 18-22, 2014	5-Year
139	17.363538	120.51626	1.150	0.914	0.836	Mario/ September 18-22, 2014	5-Year
140	17.417593	120.468532	1.180	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
141	17.417593	120.468532	1.180	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
142	17.413079	120.467714	2.610	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
143	17.411051	120.460928	1.100	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
144	17.420424	120.468545	0.830	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
145	17.46381	120.489899	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
146	17.420424	120.468545	0.830	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
147	17.438235	120.495497	1.260	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
148	17.438235	120.495497	1.260	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
149	17.389835	120.519499	0.160	0.914	0.836	Mario/ September 18-22, 2014	5-Year
150	17.387667	120.517174	2.230	0.914	0.836	Mario/ September 18-22, 2014	5-Year
151	17.385203	120.520101	1.040	0.914	0.836	Mario/ September 18-22, 2014	5-Year
152	17.38918	120.516855	1.520	0.914	0.836	Mario/ September 18-22, 2014	5-Year
153	17.389661	120.519421	1.420	0.914	0.836	Mario/ September 18-22, 2014	5-Year
154	17.383628	120.523911	5.570	0.914	0.836	Mario/ September 18-22, 2014	5-Year
155	17.388173	120.518258	1.430	0.914	0.836	Mario/ September 18-22, 2014	5-Year
156	17.460307	120.488413	0.220	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
157	17.376495	120.511091	0.600	0.914	0.836	Mario/ September 18-22, 2014	5-Year
158	17.383651	120.520949	1.260	0.914	0.836	Mario/ September 18-22, 2014	5-Year
159	17.390814	120.521388	1.480	0.914	0.836	Mario/ September 18-22, 2014	5-Year
160	17.390865	120.520653	1.260	0.914	0.836	Mario/ September 18-22, 2014	5-Year
161	17.386719	120.521704	0.700	0.914	0.836	Mario/ September 18-22, 2014	5-Year
162	17.39108	120.520189	0.690	0.914	0.836	Mario/ September 18-22, 2014	5-Year
163	17.388407	120.519989	1.390	0.914	0.836	Mario/ September 18-22, 2014	5-Year
164	17.389198	120.518324	1.110	0.914	0.836	Mario/ September 18-22, 2014	5-Year
165	17.389835	120.519499	0.160	0.914	0.836	Mario/ September 18-22, 2014	5-Year
166	17.387667	120.517174	2.230	0.914	0.836	Mario/ September 18-22, 2014	5-Year
167	17.453433	120.488337	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
168	17.385203	120.520101	1.040	0.914	0.836	Mario/ September 18-22, 2014	5-Year
169	17.38918	120.516855	1.520	0.914	0.836	Mario/ September 18-22, 2014	5-Year
170	17.389661	120.519421	1.420	0.914	0.836	Mario/ September 18-22, 2014	5-Year
171	17.383628	120.523911	5.570	0.914	0.836	Mario/ September 18-22, 2014	5-Year
172	17.388173	120.518258	1.430	0.914	0.836	Mario/ September 18-22, 2014	5-Year
173	17.376495	120.511091	0.600	0.914	0.836	Mario/ September 18-22, 2014	5-Year
174	17.383651	120.520949	1.260	0.914	0.836	Mario/ September 18-22, 2014	5-Year
175	17.390814	120.521388	1.480	0.914	0.836	Mario/ September 18-22, 2014	5-Year
176	17.390865	120.520653	1.260	0.914	0.836	Mario/ September 18-22, 2014	5-Year
177	17.386719	120.521704	0.700	0.914	0.836	Mario/ September 18-22, 2014	5-Year
178	17.46403	120.485686	0.060	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
179	17.39108	120.520189	0.690	0.914	0.836	Mario/ September 18-22, 2014	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
180	17.388407	120.519989	1.390	0.914	0.836	Mario/ September 18-22, 2014	5-Year
181	17.389198	120.518324	1.110	0.914	0.836	Mario/ September 18-22, 2014	5-Year
182	17.342835	120.476354	1.330	0.610	0.372	Mario/ September 18-22, 2014	5-Year
183	17.342835	120.476354	1.330	0.914	0.836	Mario/ September 18-22, 2014	5-Year
184	17.365289	120.496931	0.290	0.914	0.836	Mario/ September 18-22, 2014	5-Year
185	17.39118	120.476435	1.320	0.914	0.836	Mario/ September 18-22, 2014	5-Year
186	17.364722	120.481125	0.370	0.610	0.372	Mario/ September 18-22, 2014	5-Year
187	17.364722	120.481125	0.370	0.914	0.836	Mario/ September 18-22, 2014	5-Year
188	17.447016	120.46919	1.730	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
189	17.385122	120.541973	0.220	0.610	0.372	Mario/ September 18-22, 2014	5-Year
190	17.447016	120.46919	1.730	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
191	17.413782	120.49055	1.280	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
192	17.417645	120.486259	0.910	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
193	17.417942	120.49086	0.130	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
194	17.413782	120.49055	1.280	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
195	17.412911	120.47089	2.430	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
196	17.417274	120.476372	0.440	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
197	17.410682	120.485626	0.680	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
198	17.417274	120.476372	0.440	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
199	17.420561	120.477086	2.970	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
200	17.350297	120.506116	0.970	0.610	0.372	Mario/ September 18-22, 2014	5-Year
201	17.420561	120.477086	2.970	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
202	17.34197	120.475759	1.060	0.610	0.372	Mario/ September 18-22, 2014	5-Year
203	17.437309	120.506758	0.360	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
204	17.428371	120.500712	0.120	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
205	17.436245	120.500582	0.900	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
206	17.426992	120.496008	0.630	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
207	17.436061	120.50419	0.300	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
208	17.431547	120.501876	0.450	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
209	17.437309	120.506758	0.360	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
210	17.353536	120.504567	0.850	0.610	0.372	Mario/ September 18-22, 2014	5-Year
211	17.428371	120.500712	0.120	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
212	17.436245	120.500582	0.900	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
213	17.426992	120.496008	0.630	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
214	17.436061	120.50419	0.300	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
215	17.431547	120.501876	0.450	1.067	1.138	Lawin/ October 18-22, 2016	5-Year
216	17.398974	120.463894	1.130	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
217	17.398335	120.464941	1.730	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
218	17.394539	120.468467	1.210	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
219	17.394323	120.465546	0.720	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
220	17.398974	120.463894	1.130	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
221	17.3859	120.509855	1.620	0.610	0.372	Mario/ September 18-22, 2014	5-Year
222	17.351159	120.503021	1.400	0.610	0.372	Mario/ September 18-22, 2014	5-Year
223	17.398335	120.464941	1.730	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
224	17.394539	120.468467	1.210	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
225	17.394323	120.465546	0.720	0.610	0.372	Lawin/ October 18-22, 2016	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
226	17.342562	120.474954	1.190	0.610	0.372	Mario/ September 18-22, 2014	5-Year
227	17.342562	120.474954	1.190	0.914	0.836	Mario/ September 18-22, 2014	5-Year
228	17.417216	120.477437	0.230	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
229	17.417216	120.477437	0.230	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
230	17.432948	120.503222	0.580	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
231	17.432948	120.503222	0.580	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
232	17.360414	120.508355	0.030	0.610	0.372	Mario/ September 18-22, 2014	5-Year
233	17.357291	120.494331	0.420	0.610	0.372	Mario/ September 18-22, 2014	5-Year
234	17.366989	120.502274	1.200	0.610	0.372	Mario/ September 18-22, 2014	5-Year
235	17.363078	120.518205	0.260	0.610	0.372	Mario/ September 18-22, 2014	5-Year
236	17.36758	120.503635	0.390	0.610	0.372	Mario/ September 18-22, 2014	5-Year
237	17.361412	120.518762	0.030	0.610	0.372	Mario/ September 18-22, 2014	5-Year
238	17.364836	120.51149	0.030	0.610	0.372	Mario/ September 18-22, 2014	5-Year
239	17.364687	120.51697	2.140	0.610	0.372	Mario/ September 18-22, 2014	5-Year
240	17.364687	120.51697	2.140	0.914	0.836	Mario/ September 18-22, 2014	5-Year
241	17.403704	120.508324	2.160	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
242	17.396466	120.50663	1.810	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
243	17.402952	120.490602	1.160	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
244	17.355708	120.489124	0.630	0.610	0.372	Mario/ September 18-22, 2014	5-Year
245	17.401253	120.494204	0.830	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
246	17.403101	120.509468	0.080	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
247	17.403504	120.492838	1.210	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
248	17.419112	120.475285	0.230	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
249	17.400434	120.509649	1.690	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
250	17.400434	120.509649	1.690	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
251	17.44801	120.453918	0.290	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
252	17.447344	120.453992	0.030	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
253	17.444238	120.4506	0.360	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
254	17.448257	120.447874	0.230	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
255	17.353962	120.485604	0.040	0.610	0.372	Mario/ September 18-22, 2014	5-Year
256	17.44801	120.453918	0.290	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
257	17.447344	120.453992	0.030	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
258	17.444238	120.4506	0.360	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
259	17.448257	120.447874	0.230	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
260	17.378585	120.490456	0.940	0.914	0.836	Mario/ September 18-22, 2014	5-Year
261	17.340964	120.476389	0.650	0.914	0.836	Mario/ September 18-22, 2014	5-Year
262	17.363694	120.476716	0.030	0.610	0.372	Mario/ September 18-22, 2014	5-Year
263	17.363694	120.476716	0.030	0.914	0.836	Mario/ September 18-22, 2014	5-Year
264	17.400025	120.477699	1.520	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
265	17.400025	120.477699	1.520	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
266	17.385122	120.541973	0.220	0.610	0.372	Mario/ September 18-22, 2014	5-Year
267	17.420744	120.461067	0.690	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
268	17.420744	120.461067	0.690	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
269	17.350297	120.506116	0.970	0.610	0.372	Mario/ September 18-22, 2014	5-Year
270	17.353536	120.504567	0.850	0.610	0.372	Mario/ September 18-22, 2014	5-Year
271	17.351159	120.503021	1.400	0.610	0.372	Mario/ September 18-22, 2014	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
272	17.357291	120.494331	0.420	0.610	0.372	Mario/ September 18-22, 2014	5-Year
273	17.355708	120.489124	0.630	0.610	0.372	Mario/ September 18-22, 2014	5-Year
274	17.383415	120.513875	2.510	0.610	0.372	Mario/ September 18-22, 2014	5-Year
275	17.353962	120.485604	0.040	0.610	0.372	Mario/ September 18-22, 2014	5-Year
276	17.341334	120.477238	0.570	0.610	0.372	Mario/ September 18-22, 2014	5-Year
277	17.341334	120.477238	0.570	0.914	0.836	Mario/ September 18-22, 2014	5-Year
278	17.437609	120.477626	2.530	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
279	17.434173	120.482552	0.870	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
280	17.446749	120.486782	0.290	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
281	17.443025	120.479543	0.320	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
282	17.432127	120.487022	0.400	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
283	17.447196	120.487353	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
284	17.448919	120.487	0.090	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
285	17.383178	120.515133	0.500	0.610	0.372	Mario/ September 18-22, 2014	5-Year
286	17.440785	120.484802	0.170	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
287	17.440785	120.484802	0.170	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
288	17.386699	120.518636	0.620	0.610	0.372	Mario/ September 18-22, 2014	5-Year
289	17.391565	120.519384	0.710	0.610	0.372	Mario/ September 18-22, 2014	5-Year
290	17.378985	120.523771	3.370	0.610	0.372	Mario/ September 18-22, 2014	5-Year
291	17.370305	120.482812	1.880	0.610	0.372	Mario/ September 18-22, 2014	5-Year
292	17.370305	120.482812	1.880	0.914	0.836	Mario/ September 18-22, 2014	5-Year
293	17.375262	120.480292	2.930	0.610	0.372	Mario/ September 18-22, 2014	5-Year
294	17.373342	120.48644	1.790	0.610	0.372	Mario/ September 18-22, 2014	5-Year
295	17.374	120.483277	1.690	0.610	0.372	Mario/ September 18-22, 2014	5-Year
296	17.383178	120.515133	0.500	0.610	0.372	Mario/ September 18-22, 2014	5-Year
297	17.373094	120.48269	0.620	0.610	0.372	Mario/ September 18-22, 2014	5-Year
298	17.374	120.483277	1.690	0.914	0.836	Mario/ September 18-22, 2014	5-Year
299	17.448547	120.500541	0.060	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
300	17.448547	120.500541	0.060	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
301	17.443861	120.449472	0.700	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
302	17.443861	120.449472	0.700	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
303	17.384771	120.454816	0.030	0.610	0.372	Mario/ September 18-22, 2014	5-Year
304	17.384771	120.454816	0.030	0.914	0.836	Mario/ September 18-22, 2014	5-Year
305	17.420744	120.461067	0.690	0.610	0.372	Mario/ September 18-22, 2014	5-Year
306	17.426577	120.45811	0.350	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
307	17.383415	120.513875	2.510	0.610	0.372	Mario/ September 18-22, 2014	5-Year
308	17.426577	120.45811	0.350	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
309	17.360155	120.493954	0.650	0.610	0.372	Mario/ September 18-22, 2014	5-Year
310	17.349315	120.507251	1.480	0.610	0.372	Mario/ September 18-22, 2014	5-Year
311	17.376081	120.48109	2.340	0.610	0.372	Mario/ September 18-22, 2014	5-Year
312	17.384908	120.482754	0.500	0.610	0.372	Mario/ September 18-22, 2014	5-Year
313	17.387863	120.465063	1.270	0.610	0.372	Mario/ September 18-22, 2014	5-Year
314	17.383738	120.474402	1.400	0.610	0.372	Mario/ September 18-22, 2014	5-Year
315	17.401914	120.493133	0.950	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
316	17.401914	120.493133	0.950	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
317	17.461012	120.46315	0.030	0.914	0.836	Lawin/ October 18-22, 2016	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
318	17.3859	120.509855	1.620	0.610	0.372	Mario/ September 18-22, 2014	5-Year
319	17.459366	120.468249	0.970	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
320	17.458067	120.467148	0.460	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
321	17.456534	120.469827	1.410	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
322	17.459794	120.467389	0.590	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
323	17.456719	120.467926	0.900	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
324	17.446557	120.462777	0.850	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
325	17.458818	120.464237	0.780	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
326	17.447387	120.461953	0.030	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
327	17.461012	120.46315	0.030	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
328	17.445395	120.505636	0.280	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
329	17.383415	120.513875	2.510	0.610	0.372	Mario/ September 18-22, 2014	5-Year
330	17.445395	120.505636	0.280	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
331	17.435538	120.505445	0.360	0.914	0.836	Lawin/ October 18-22, 2016	5-Year
332	17.435538	120.505445	0.360	0.610	0.372	Lawin/ October 18-22, 2016	5-Year
333	17.377966	120.479249	2.210	0.610	0.372	Mario/ September 18-22, 2014	5-Year
334	17.377042	120.473637	1.530	0.610	0.372	Mario/ September 18-22, 2014	5-Year
335	17.371899	120.473629	0.590	0.610	0.372	Mario/ September 18-22, 2014	5-Year
336	17.369451	120.472776	0.860	0.610	0.372	Mario/ September 18-22, 2014	5-Year
337	17.365444	120.471885	0.810	0.610	0.372	Mario/ September 18-22, 2014	5-Year
338	17.377966	120.479249	2.210	0.610	0.372	Mario/ September 18-22, 2014	5-Year
339	17.377042	120.473637	1.530	0.610	0.372	Mario/ September 18-22, 2014	5-Year

Annex 12. Educational Institutions Affected in Silay Floodplain

Ilocos Sur				
Burgos				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
TANGAOAN ES	Lucaban	Low	Low	Low
MAMBUG PS	Mambug			
Nagbukel				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BANTUGO-MISSION ES	Bantugo	Low	Medium	Medium
NAGBUKEL CS	Poblacion East			
Narvacant				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
NARVACAN NORTH	Aquib			
ILOCOS SUR POLYTECHNIC STATE COLLEGE - COLLEGE OF FISHERIES AND MARINE SCIENCES-NARVACAN	Bantay Abot	Medium	Medium	Medium
SULVEC IS	Bantay Abot	Medium	High	High
BULANOS PS	Bulanos	Medium	High	High
CABAROAN ES	Bulanos	Medium	High	High
CAGAYUNGAN ES	Cagayungan	Medium	High	High
CAMARAO ES	Camarao			
CODOOG ES	Codoog			
NAGBUKEL CS	Codoog			
SAN PABLO ES	Codoog	Low	Medium	Medium
DASAY ES	Dasay	Medium	Medium	Medium
DINALAOAN PS	Dinalaoan		Medium	Medium
LUNGOG IS	Lungog	Medium	Medium	Medium
ORENCE ES	Orence		Medium	High
PANTOC ELEMENTARY SCHOOL	Pantoc	Medium	High	High
NARVACAN NAT'L. CENTRAL HS	Paratong	Medium	High	High
NARVACAN NORTH CS	Paratong	Medium	High	High
PARATONG ES	Paratong	Medium	High	High
PARPARIA ES	Parparia			Low
QUINARAYAN ES	Quinarayan	Medium	Medium	Medium

ST. GREGORY E/S	Quinarayan			
RIVADAVIA ES	Rivadavia		Low	Medium
DAY CARE CENTER	San Antonio	Medium	High	High
SAN ANTONIO ES	San Antonio	Medium	High	High
NARVACAN CATHOLIC SCHOOL	San Jose		Low	Medium
NARVACAN CS	San Jose			Medium
NARVACAN SOUTH CENTRAL SCHOOL	San Jose	Medium	High	High
NANGUNEG WEST PS	San Pedro	Medium	High	High
SAN PEDRO ES	San Pedro	Medium	High	High
SAN PEDRO NHS	San Pedro	Medium	Medium	High
NARVACAN CATHOLIC SCHOOL	Santa Lucia		Medium	Medium
NARVACAN CS	Santa Lucia		Medium	Medium
NARVACAN SOUTH CENTRAL SCHOOL	Santa Lucia	Medium	Medium	High
SAN JOSE DAY CARE	Santa Lucia		Medium	Medium
SUCOC ES	Sucoc		Low	Medium
TUROD ELEMENTARY SCHOOL	Turod	Medium	High	High
TUROD ES	Turod	Medium	High	High

Santa Maria				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
AG-AGRAO NHS	Ag-Agrao	Medium	High	High
AMPUAGAN ES	Ampuagan	Medium	High	High
BABAL-LASIOAN ES	Baballasioan	Low	Medium	Medium
GUSING ES	Baballasioan			Medium
BIA-O DAY CARE CENTER	Bia-O		Medium	Medium
BIA-O ES	Bia-O		Medium	Medium
BUTIR ES	Butir			
CABAROAN ES	Cabaroan	Low	Medium	Medium
ILOCOS SUR POLYTECHNIC STATE COLLEGE	Danuman East	Low	High	High
DANUMAN ES	Danuman West	Medium	High	High
GUSING ES	Gusing		Medium	Medium
IMELDA NHS	Laslasong Norte	Medium	High	High
NANGUNEG EAST ELEMENTARY SCHOOL	Laslasong Norte	Medium	Medium	High
LASLASONG ES	Laslasong West	Low	Medium	Medium
ILOCOS SUR POLYTECHNIC STATE COLLEGE	Lubong		Medium	High
SANTA MARIA NHS	Lubong		Low	Medium
MAYNGANAY ES	Maynganay Sur	Medium	High	High
DAYCARE CENTER	Nagsayaoan	Medium	High	High
NAGSAYAOAN ES	Nagsayaoan	Medium	Medium	High
NALVO ES	Nalvo	Medium	Medium	High
BRGY. POBLACION NORTE DAY CARE CENTER	Poblacion Sur	High	High	High
ILOCOS SUR POLYTECHNIC STATE COLLEGE	Poblacion Sur		Low	Medium
SAINT MARY'S COLLEGE	Poblacion Sur		Low	Medium
SANTA MARIA NHS	Poblacion Sur	Low	Medium	Medium
STA. MARIA EAST CS	Poblacion Sur	Low	Medium	Medium
STA. MARIA WEST CS	Poblacion Sur	Medium	Medium	Medium
SILAG-PACANG ES	Silag	Low	Medium	Medium
TINAAN ES	Tinaan	Medium	Medium	High

Annex 13. Medical Institutions Affected in Silay Floodplain

Ilocos Sur				
Narvacan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
NARVACAN PROVINCIAL HOSPITAL	Paratong	Medium	High	High
SAN ANTONIO HEALTH CENTER	San Antonio	Medium	High	High
CATOLICO FAMILY CLINIC	San Jose	Medium	High	High
RURAL HEALTH UNIT	San Jose	Medium	High	High
CADACIO'S CLINIC	Santa Lucia	High	High	High
Santa Rita				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DOLORES-IDICA DENTAL CLINIC	Baliw Daya	High	High	High
M.R GRANADA OPTICAL	Baliw Laud	Medium	High	High
STO NINO HOSPITAL	Baliw Laud	Medium	High	High
BIA-O HEALTH CENTER	Bia-O	Low	Medium	Medium
LINGSAT HEALTH CENTER	Lingsat			
MUNICIPAL HEALTH CENTER	Poblacion Norte	Low	Medium	Medium
JUDGE CELESTINO GUERRERO MORIAL HOSPITAL	Poblacion Sur	Low	Medium	Medium
REYES-ULEP CLINIC & HOSPITAL	Poblacion Sur			Medium