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

LiDAR Surveys and Flood Mapping of Abra 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 (GIA) Program and is to be cited as:

E.C. Paringit and C. Pascua. (Eds.). (2017), LiDAR Surveys and Flood Mapping of Abra River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry – 328pp

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National Library of the Philippines
ISBN: 978-621-430-083-9

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AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND ABRA RIVER

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Baguio (UPB). UPB 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 12 river basins in the Ilocos Region and the Cordillera Administrative Region. The university is located in Baguio City in the province of Benguet.

1.2 Overview of the Tineg River Basin

Abra River Basin covers twenty-six (26) municipalities in Abra, five (5) municipalities in Ilocos Sur, two (2) municipalities in Mountain Provice, and two (2) municipalities in Benguet. The DENR River Basin Control Office identified the basin to have a drainage area of 5,125 km2 and an estimated 12,551 million cubic meter (MCM) annual run-off (RBCO, 2015).

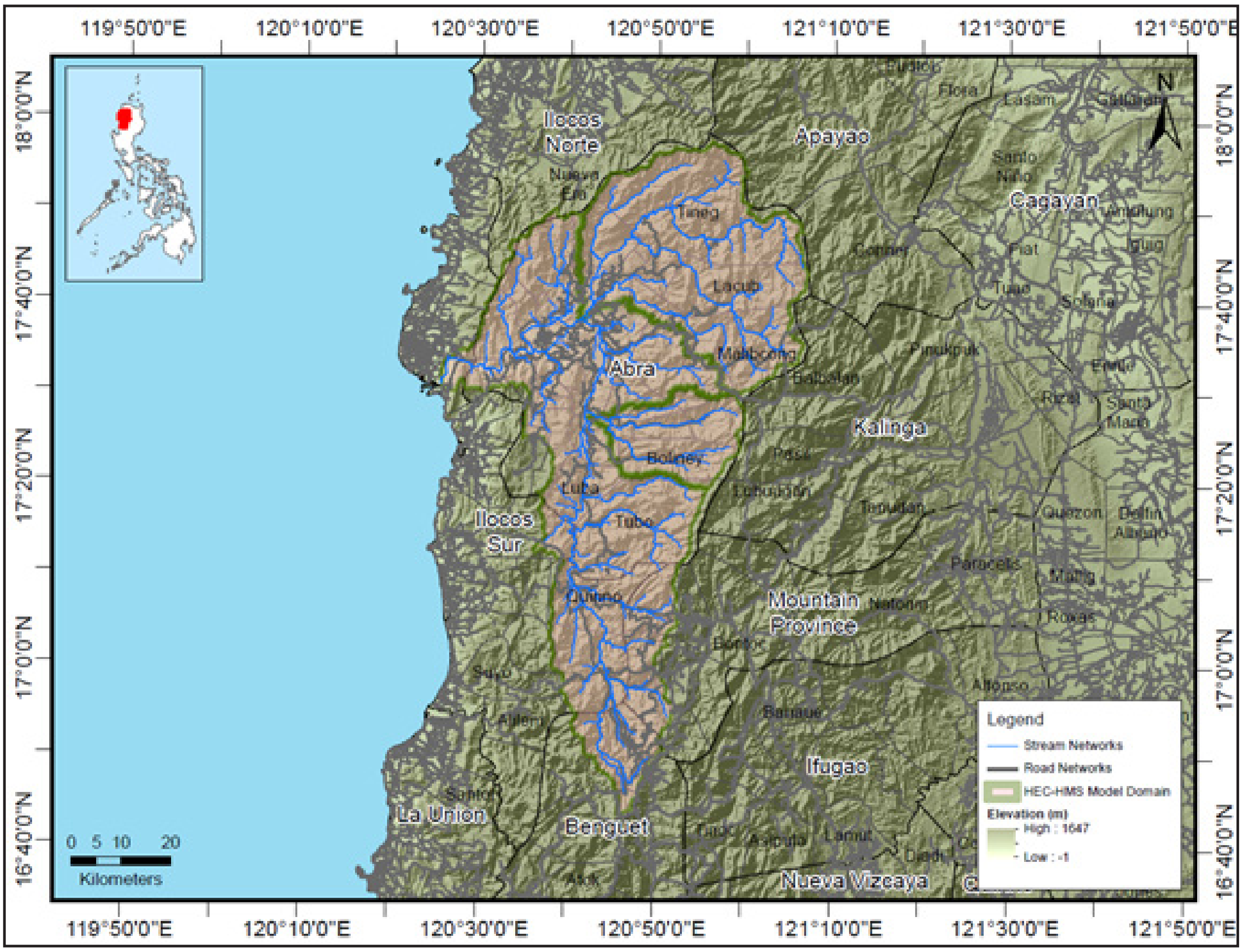

Figure 1. Map of Abra River Basin (in brown).

Its main stem, Abra River, is part of the river systems in Cordillera Administrative Region. According to the 2015 national census of NSO, a total of 3,453 persons are residing within the immediate vicinity of the river which is distributed among three (3) barangays in Municipality of Tayum, namely: Gaddani, Bagalay, and Bumagcat; and in Lagben, Municipality of Langailang in Abra. The province of abra's economy is mainly agricultural based with major crops such as rice, corn, and root crops; moreover their commercial produce are coffee, tobacco, and coconut. Livestock production are also part of their economy as well as cottage industries such as bamboo and rattan craft making, natural dye, loom weaving and embroidery (source: http://www.1stphilippines.com/pp-3ef3b802e10db3ab8b2fc7da5d22eaba.html). On October 19, 2016, a severe flooding advisory by Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAG-ASA) was issued to Abra river and its tributaries due to the heavy rains and winds brought by Typhoon Lawin, internationally known as Haima (source: http://pagasa.dost.gov.ph/).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE ABRA FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Abra floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Abra Floodplain in Abra. These flight missions were planned for 14 lines and ran for at most four and a half hours (4.5) including take-off, landing and turning time using one sensor – the Gemini (see Annex 1 for sensor specifications). The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2, on the other hand, shows the flight plan for Abra floodplain survey.

Table 1. Flight planning parameters for Gemini 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)
BLK6A	1200	30	40	100	50	120	5
BLK6C	1000	40	30	100	50	120	5
BLK6D	1000	50	40	100	50	120	5
BLK6DS	1800	50	30	70	50	120	5
BLK6E	1200	40	30	100	50	120	5
BLK6F	1600	40	30	70	50	120	5
BLK6G	1800	55, 40	30, 36	70	50	120	5
BLK7A	1600	40	30	70	50	120	5
BLK7AS	1000	40	30	100	50	120	5
BLK7B	1300	30	30	70	50	120	5
BLK7BS	1000	40	30	100	40	120	5
BLK7CS	1800	55	36	70	50	120	5
BLK7D	1300	50	30	70	50	120	5
BLK7E	1800	40	30	70	50	120	5
BLK7F	1800	35	30	70	50	120	5
BLK7G	1300	50	30	70	50	120	5
BLK7GS	1400	50	30	70	50	120	5

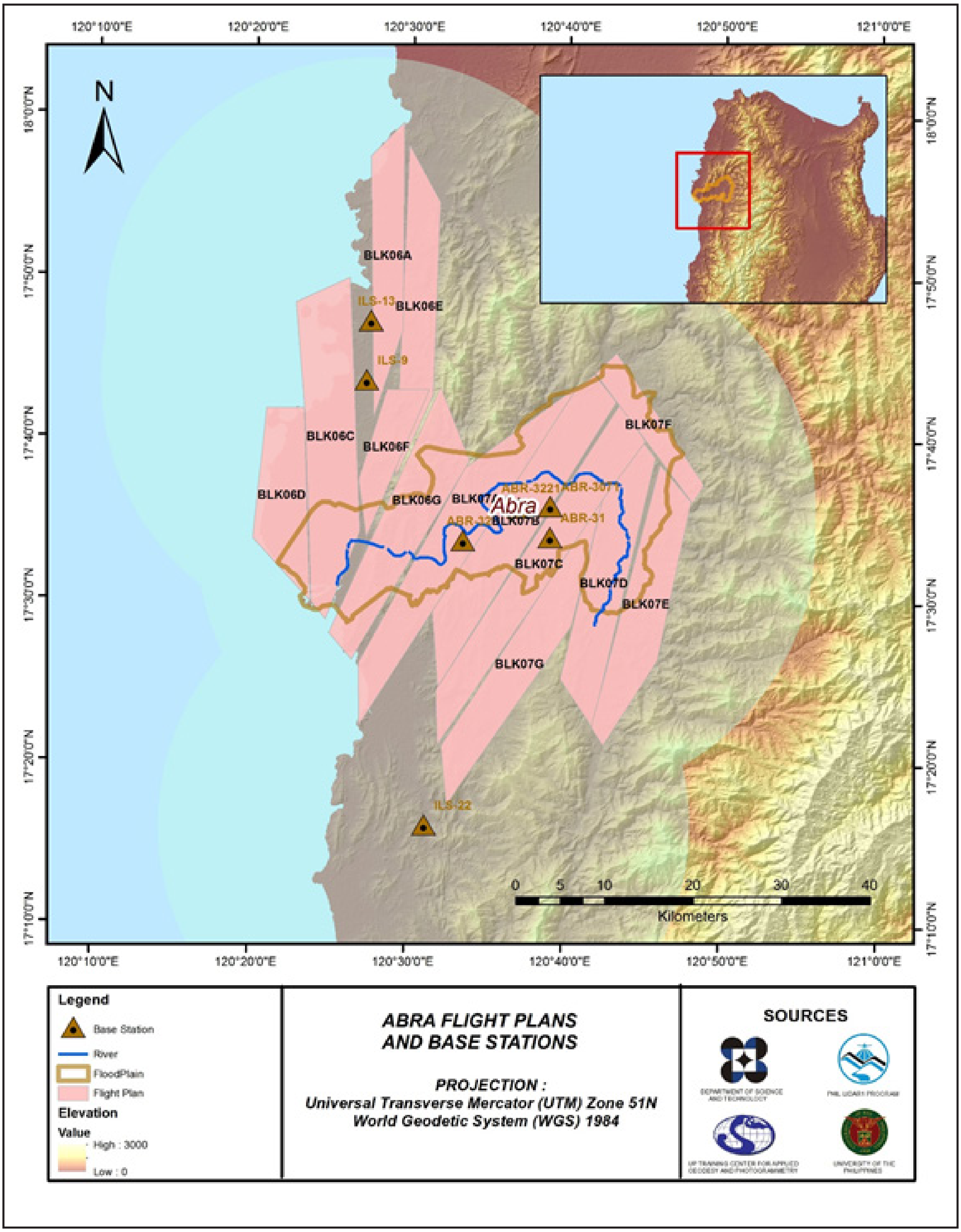

Figure 2. Flight plans and base stations used for Abra floodplain using the Gemini sensor.

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points, ABR-31, ABR-32, ILS-9, ILS-13 and ILS-22 which are of second (2nd) order accuracy and ABR-3221 which is of fourth (4th) order accuracy. The project team also established one (1) ground control point ABR-3071.

The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from February 21 to March 12, 2014 and May 28, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, TRIMBLE SPS 985, and Topcon GR-5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Abra floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Abra Floodplain LiDAR Survey. Figure 3 to Figure 8 show the recovered NAMRIA reference points within the area of the floodplain, while Table 2 to Table 8 show the details about the following NAMRIA control stations and established points. Table 9, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(b)

(a)

Figure 3. GPS set-up over ABR-31 (a) inside Peñarrubia Central School, Peñarrubia Abra; and NAMRIA reference point ABR-31 (b) as recovered by the field team.

Table 2. Details of the reprocessed 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 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°34'4.18831" 120°38'57.99392" 98.78 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	426,785.996 m 1,942,969.967 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°33'58.07703" N 120°39'2.63930" E 132.481 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	250,503.56 m 1,943, 800.89 m

(a)

(b)

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

Table 3. 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 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°33'49.34656" N 120°33'25.07659" E 39.322 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	452,967.729 m 1,942,534.242 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°33'43.229" N 120°33'29.72282" E 72.814m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	240,677.03 m 1,943,468.54 m

(a)

(b)

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

Table 4. Details of the reprocessed 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 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°43’40.62808” N 120°27’9.37799” E 56.577 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	441,941.245 m 1,960,739.965 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°43’34.46721” N 120°27’14.01102” E 89.291 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	229,838.72 m 1,961,798.84 m

(a)

(b)

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

Table 5. 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 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°47’21.51067” N 120°27’23.35275” E 26.741 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	442, 372.629 m 1,967,529.087 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°47’15.33691” N 120°27’27.98067” E 59.267 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	230,342.67 m 1,968,586.44 m

(b)

(a)

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

Table 6. 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**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°16’13.59403” N 120°31’8.89179” E 55.312 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	448,870.206 m 1,910,089 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°16’7.53708” N 120°31’13.56269” E 89.647 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	236, 238.44 m 1,911,053.54 m

(b)

(a)

Figure 8. GPS set-up over ABR-3221 (BLLM 2) (a) inside the Town Plaza of Bangued, Abra; Processed reference point ABR-3221 (BLLM 2) (b) as recovered by the field team.

Table 7. Details of the recovered processed reference point ABR-3221 (BLLM 2) used as base station for the LiDAR acquisition.

Station Name	ABR-3221 (BLLM 2)	
Order of Accuracy	4th	
Relative Error (horizontal positioning)	1 in 10,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°35’52.68407” N 120°36’58.62346” E 56.365 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	459,272.709 m 1,984,6312.003 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°35’46.5637” N 120°37’3.26652” E 89.89 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	247,024.3 m 1,947,181.20 m

Table 8. Details of the established horizontal control point ABR-3071 used as base station for the LiDAR acquisition.

Station Name	ABR-3071	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17°34’00.39935” 120°38’57.75398” 98.489 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17°33’54.28829” 120°39’02.39944” 130.194 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	250495.042 m 1943684.465 m

Table 9. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 3,2014	7104GC	2BLK06E062A	ILS-13 & ILS-9
March 5,2014	7108GC	2BLK06C064A	ILS-13 & ILS-9
March 7,2014	7112GC	2BLK06G066A & 2BLK06DS066A	ILS-13 & ILS-9
March 8,2014	7114GC	2BLK07CS067A & 2BLK06G067A	ABR-31 & ILS-22
March 9,2014	7116GC	2BLK07B068A	ABR-31 & ABR-32
March 10,2014	7118GC	2BLK07DG069A	ABR-32 & ILS-22
March 11,2014	7120GC	2BLK06F070A & 2BLK07A070A	ABR-31 & ABR-32
March 11,2014	7121GC	2BLK07GS070B	ABR-31 & ABR-32
March 12,2014	7122GC	2BL07E071A & 2BLK07F071A	ABR-32 &ABR-3221 (BLLM 2)
May 28,2016	4043GC	2BLK7SA149A	ABR-31 & ABR0-3071
May 28,2016	4045GC	2BLK7SB149B	ABR-31 & ABR0-3071

2.3 Flight Missions

A total of eleven (11) missions were conducted to complete the LiDAR data acquisition in Abra floodplain, for a total of forty-four hours and two minutes (44+2) minutes of flying time for RP-C9322 and RP-C9022 (See Annex 6). All missions were acquired using the Gemini LiDAR system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 10, while the actual parameters used during the LiDAR data acquisition are presented in Table 11.

Table 10. Flight missions for LiDAR data acquisition in Abra floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
March 3,2014	7104GC	209.533	153.144	NA	153.144	NA	3	19
March 5,2014	7108GC	297.03	300.794	74.402	226.392	NA	4	19
March 7,2014	7112GC	201.442	204.835	80.677	124.158	NA	4	7
March 8,2014	7114GC	314.959	205.573	91.195	114.378	NA	4	13
March 9,2014	7116GC	175.220	207.317	133.497	73.820	NA	4	13
March 10,2014	7118GC	268.487	209.529	107.974	101.555	NA	4	12
March 11,2014	7120GC	229.320	274.265	123.711	150.554	NA	4	1
March 11,2014	7121GC	135.552	166.409	31.191	135.218	NA	3	31
March 12,2014	7122GC	185.058	239.859	67.497	172.362	NA	3	55
May 28,2016	4043GC	240.512	247.573	155.546	92.027	NA	4	16
May 28,2016	4045GC	86.380	123.541	71.113	52.428	NA	3	56
TOTAL		2343.493	2332.839	936.803	1396.036	NA	44	2

Table 11. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7104GC	1200, 1000	40, 30	30, 40	100	50	120	5
7108GC	1000	40	30	100	50	120	5
7112GC	1800	55	30	70	50	120	5
7114GC	1800, 1200	55, 40	30	70	50	120	5
7116GC	1300	30	30	70	50	120	5
7118GC	1300	50	30	70	50	120	5
7120GC	1600	40	30	70	50	120	5
7121GC	1400	50	30	70	50	120	5
7122GC	1800	40, 35	30	70	40	130	5
4043G	1000	40	40	100	50	130	5
4045G	1000	40	40	100	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Abra floodplain (See Annex 7). It is situated within the province of Abra with majority of the floodplain situated within the municipalities of Dolores, Tayum, Bangued, Pidigan, Langiden and San Quintin. Municipalities of San Quintin, Tayum, Peñarruba, Pidigan, Bucay, Dolores, La Paz, Caoayan, San Ildefonso, San Vicente, Santa, Santo Domingo, Vigan City and Bantay are mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 12. Figure 9, on the other hand, shows the actual coverage of the LiDAR acquisition for the Abra floodplain.

Table 12. List of municipalities and cities surveyed during Abra floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Abra	San Quintin	62.288	62.288	100%
	Tayum	46.123	46.123	100%
	Peñarrubia	36.842	36.842	100%
	Pidigan	58.130	58.130	100%
	Bucay	104.454	104.446	100%
	Dolores	44.894	44.865	100%
	La Paz	55.189	54.939	100%
	San Isidro	41.689	41.457	99%
	Langiden	98.704	97.866	99%
	Manabo	83.344	70.818	85%
	Bangued	123.747	104.904	85%

	Pilar	92.196	72.964	79%
	Lagangilang	91.537	63.883	70%
	San Juan	64.640	40.793	63%
	Sallapadan	111.230	44.267	40%
	Villaviciosa	81.463	22.473	28%
	Lagayan	144.192	21.137	15%
	Danglas	175.704	24.185	14%
	Luba	126.574	8.548	7%
	Licuan-Baay	305.677	13.673	4%
Ilocos Sur	Caoayan	21.195	21.195	100%
	San Ildefonso	13.210	13.210	100%
	San Vicente	12.196	12.196	100%
	Santa	57.197	57.197	100%
	Santo Domingo	50.360	50.357	100%
	Vigan City	24.006	24.004	100%
	Bantay	71.063	71.016	100%
	Santa Catalina	10.832	10.694	99%
	Magsingal	78.898	73.780	94%
	Nagbukel	36.459	33.395	92%
	Narvacan	97.176	76.347	79%
	San Juan	59.878	39.792	66%
	Cabugao	68.933	42.411	62%
	Sinait	73.767	41.272	56%
	Burgos	49.604	13.567	27%
	Santa Maria	52.319	12.287	23%
	Lidlidda	39.476	0.605	2%
Ilocos Norte	Badoc	77.071	25.422	33%
	Pinili	63.184	11.905	19%
	Currimao	32.965	2.649	8%
	Nueva Era	618.996	19.287	3%
TOTAL		3,557.40	1,687.19	47.43%

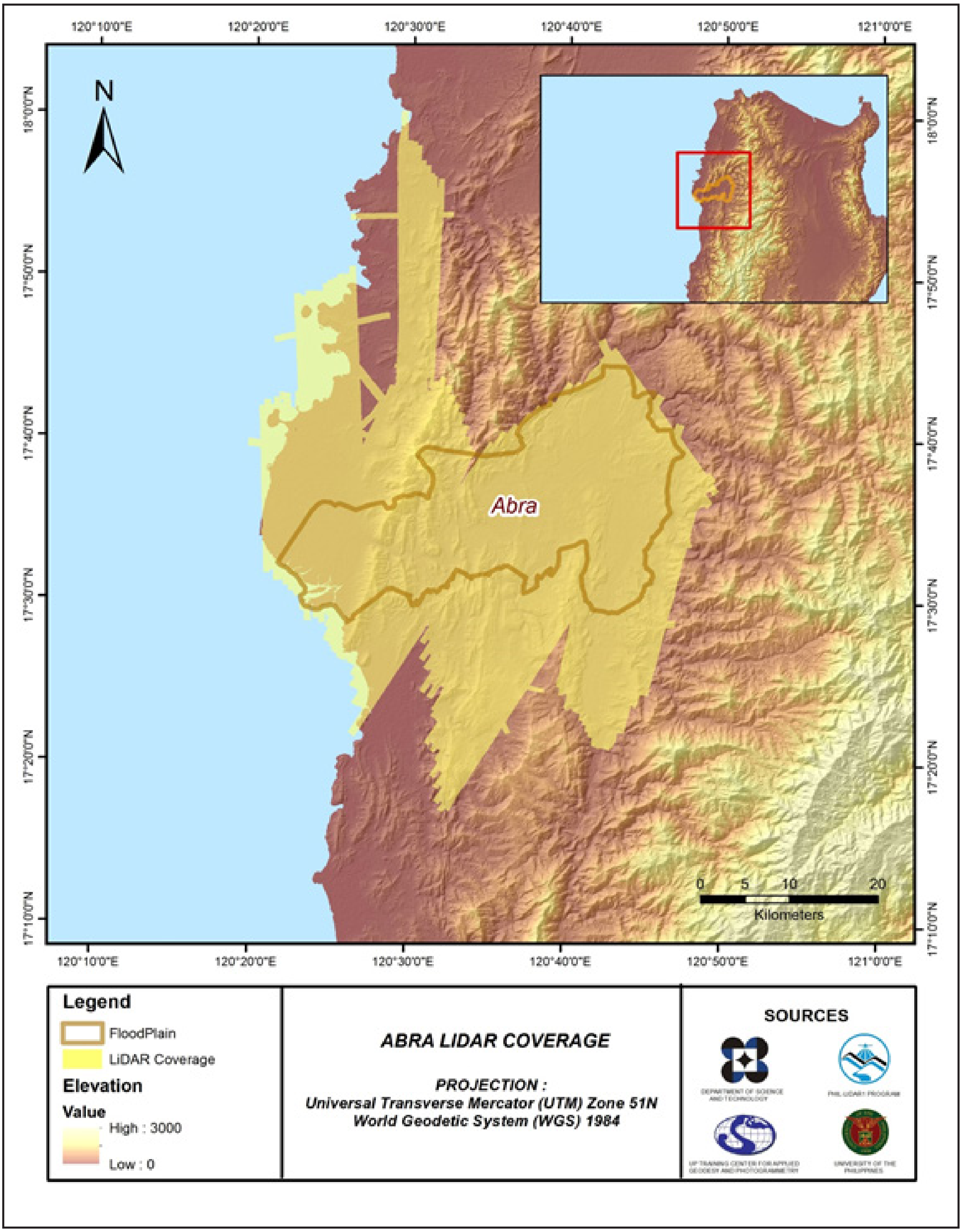

Figure 9. Actual LiDAR survey coverage for Abra floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE ABRA FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

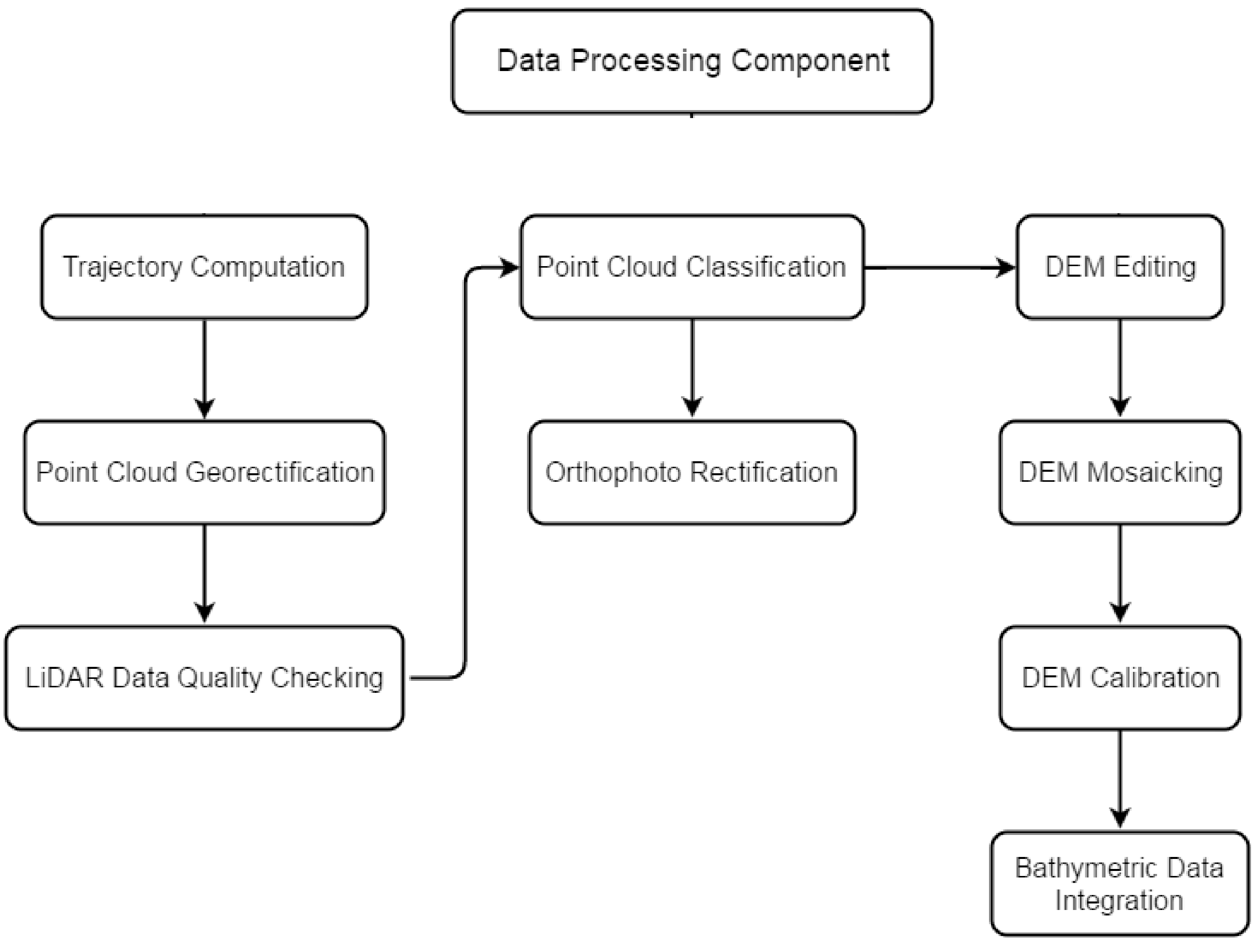

Figure 10. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Abra floodplain can be found in Annex 5. Missions flown during the first survey conducted on March 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the second survey on May 2016 were flown using the same system over Abra and Ilocos.

The Data Acquisition Component (DAC) transferred a total of 208.8 Gigabytes of Range data, 2.67 Gigabytes of POS data, and 105.49 Megabytes of GPS base station 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 Abra was fully transferred on July 1, 2016, as indicated on the Data Transfer Sheets for Abra floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7108GC, one of the Abra flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on March 5, 2014 00:00 AM. The y-axis is the RMSE value for that particular position.

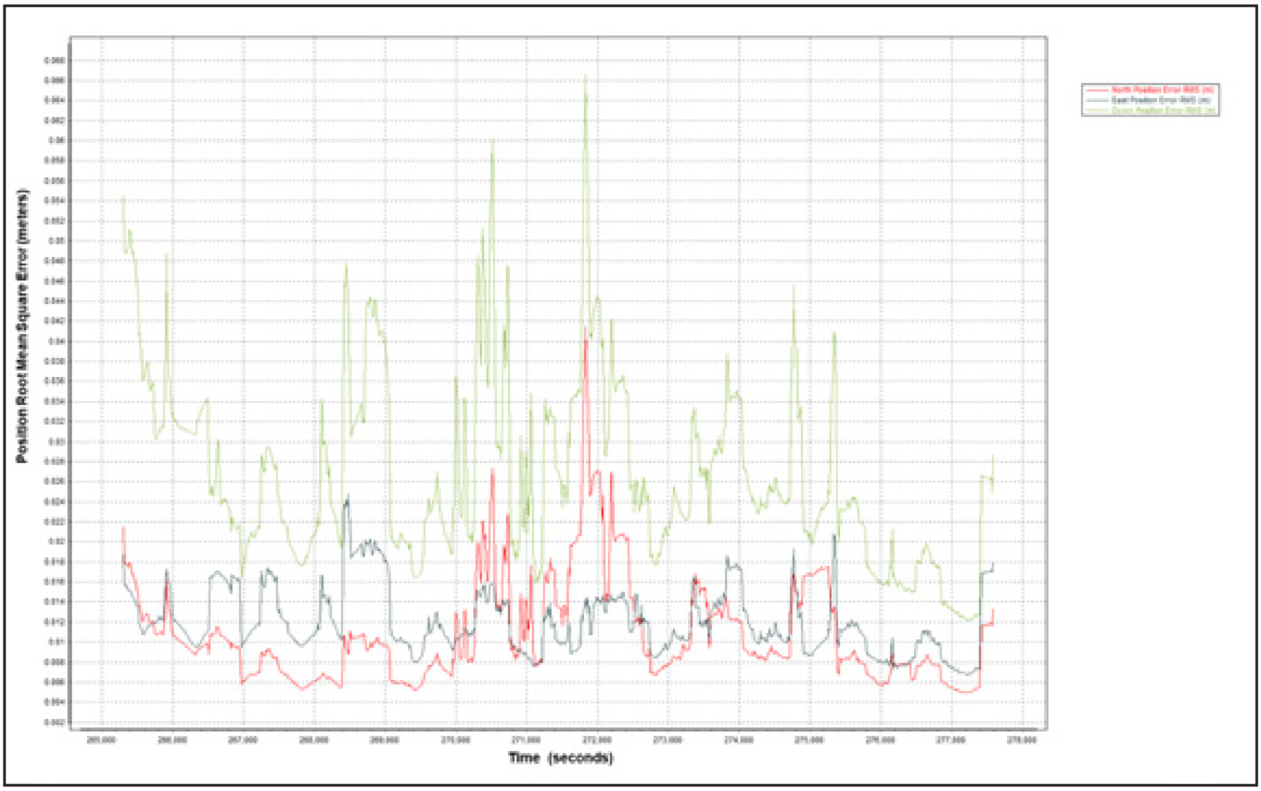

Figure 11. Smoothed Performance Metrics of a Abra Flight 7108GC.

The time of flight was from 265000 seconds to 278000 seconds, which corresponds to afternoon of March 5, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 2.70 centimeters, the East position RMSE peaks at 3.30 centimeters, and the Down position RMSE peaks at 3.30 centimeters, which are within the prescribed accuracies described in the methodology.

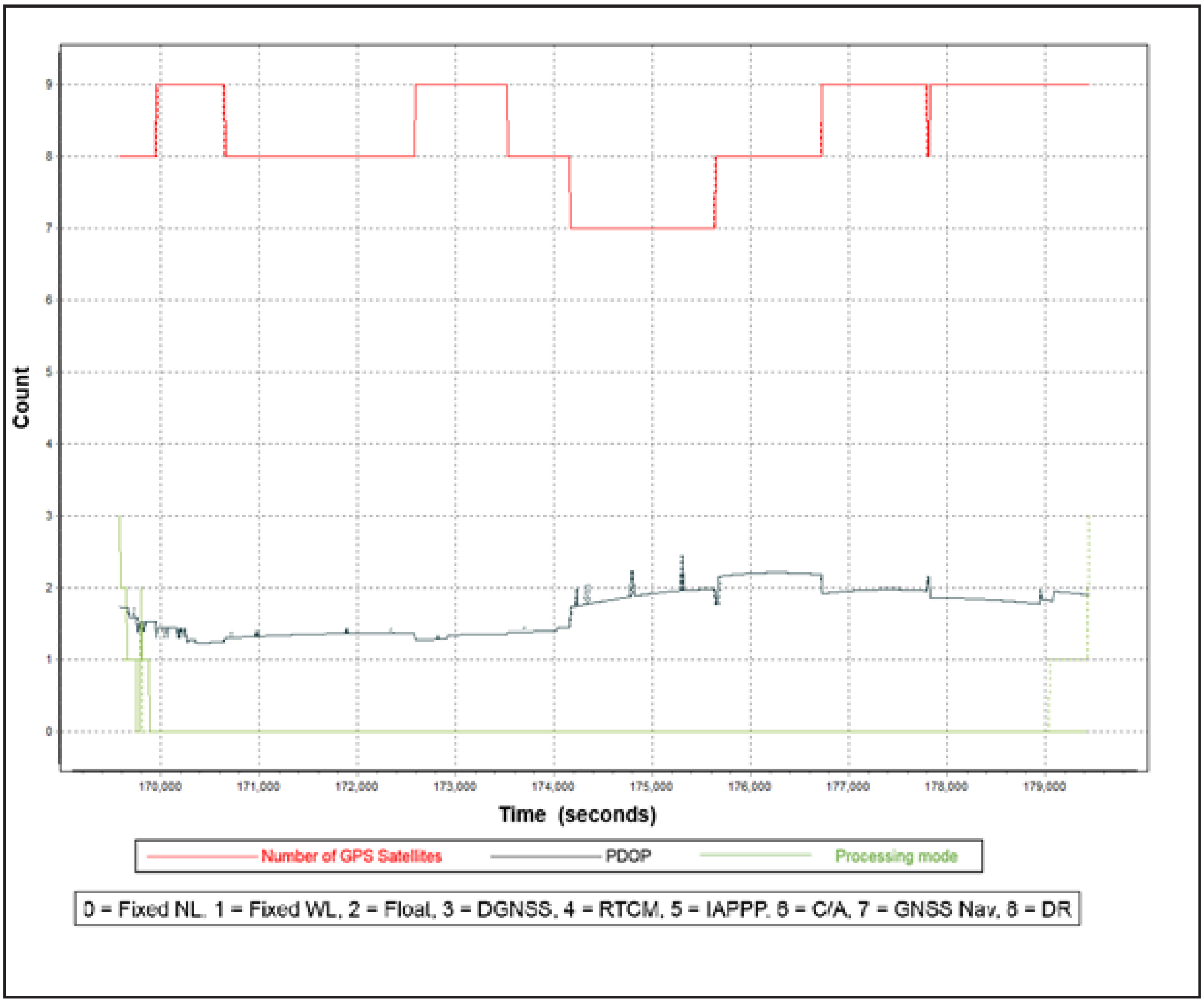

Figure 12. Solution Status Parameters of Abra Flight 7108GC.

The Solution Status parameters of flight 7108GC one of the Abra flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Abra flights is shown in Figure 13.

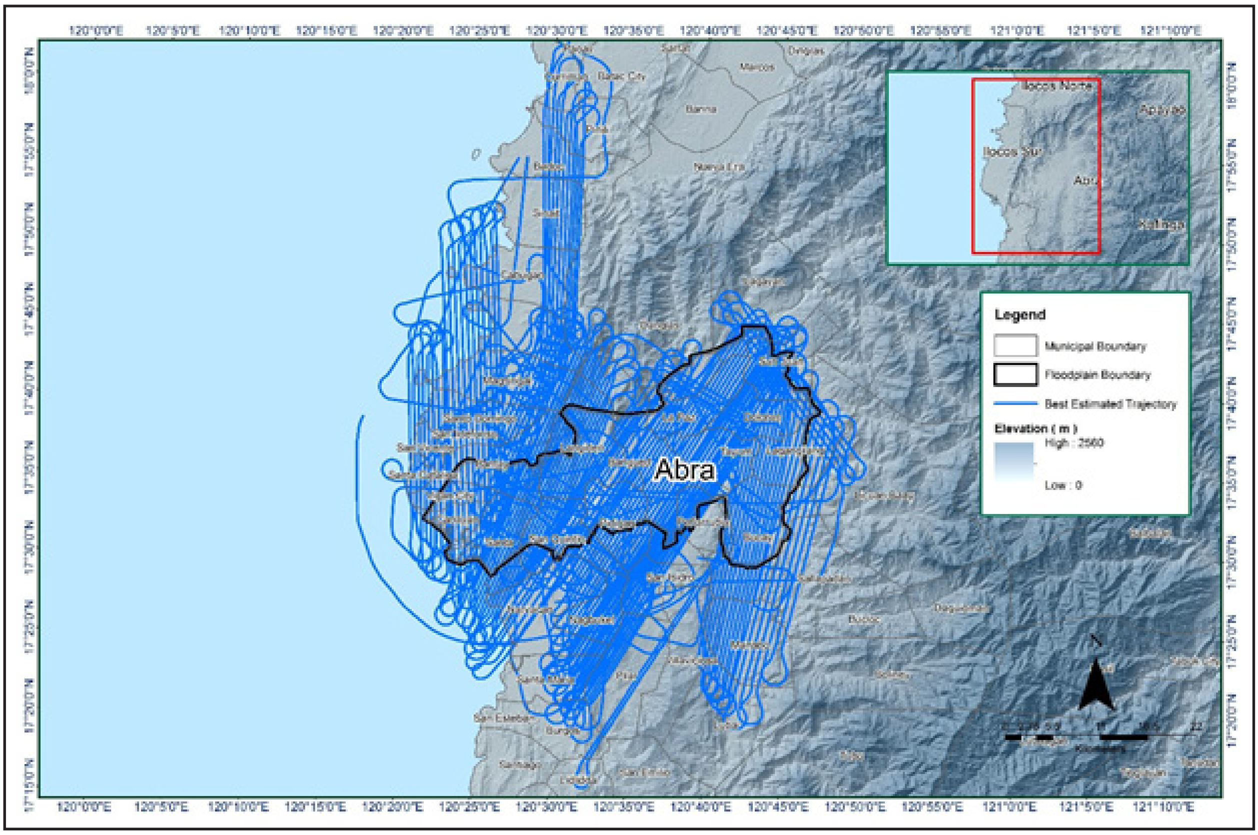

Figure 13. Best Estimated Trajectory of the LiDAR missions conducted over the Abra Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 173 flight lines, with each flight line containing one channel, since the Gemini system contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Abra floodplain are given

Table 13. Self-calibration Results values for Abra flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000303
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000657
GPS Position Z-correction stdev)	<0.01meters	0.0021

The optimum accuracy were obtained for all Abra flights based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are available in the Mission Summary Reports in Annex 8.

3.5 LiDAR Data Quality Checking

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

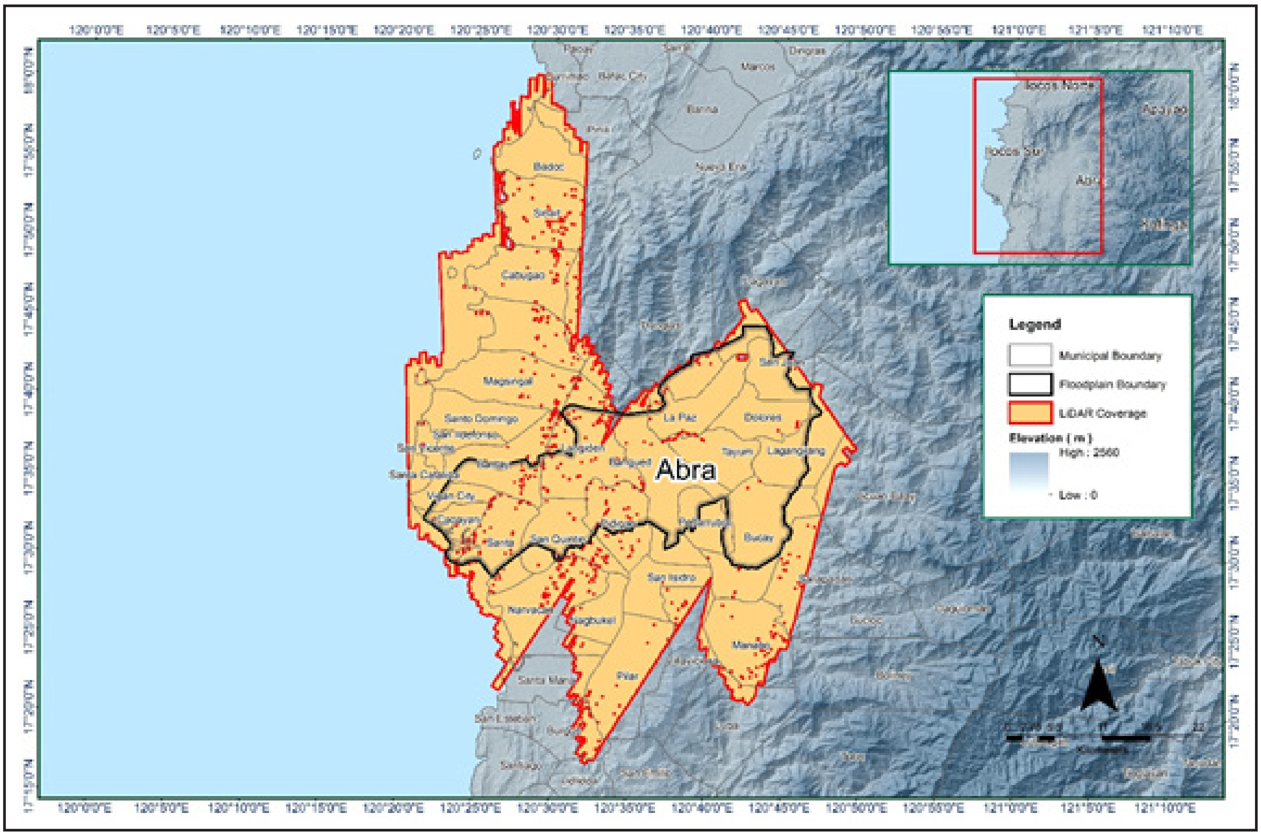

Figure 14. Boundaries of the processed LiDAR data over the Tineg Floodplain.

The total area covered by the Abra missions is 2439.64 square kilometers (sq. kms.) that is comprised of fifteen (15) flight acquisitions grouped and merged into sixteen (16) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for the Abra floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Ilocos_Blk07EF	7122G	230.33
Ilocos_Blk07D	7118G	169.74
Ilocos_Blk07G	7121G	143.44
Ilocos_Blk07C_supplement	7114G	202.76
Ilocos_Blk07B	7116G	199.83
Ilocos_Blk07A_additional	7121G	41.2
Ilocos_Blk07A	7120G	169.39
Ilocos_Blk06G	7112G	84.74
Ilocos_Blk06G_supplement	7114G	94.44
Ilocos_Blk06F	7120G	84.74
Ilocos_Blk06A	7104G	337.98
Ilocos_Blk06D	7108GC	287.83
Ilocos_Blk06D_supplement	7112G	51.49
Ilocos_Blk06D_additional	7108GC	24.722

Laoag_Blk07A	4043G	114.25
	4045G	
Laoag_Blk07C	4043G	202.76
	4045G	
TOTAL		2439.64 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

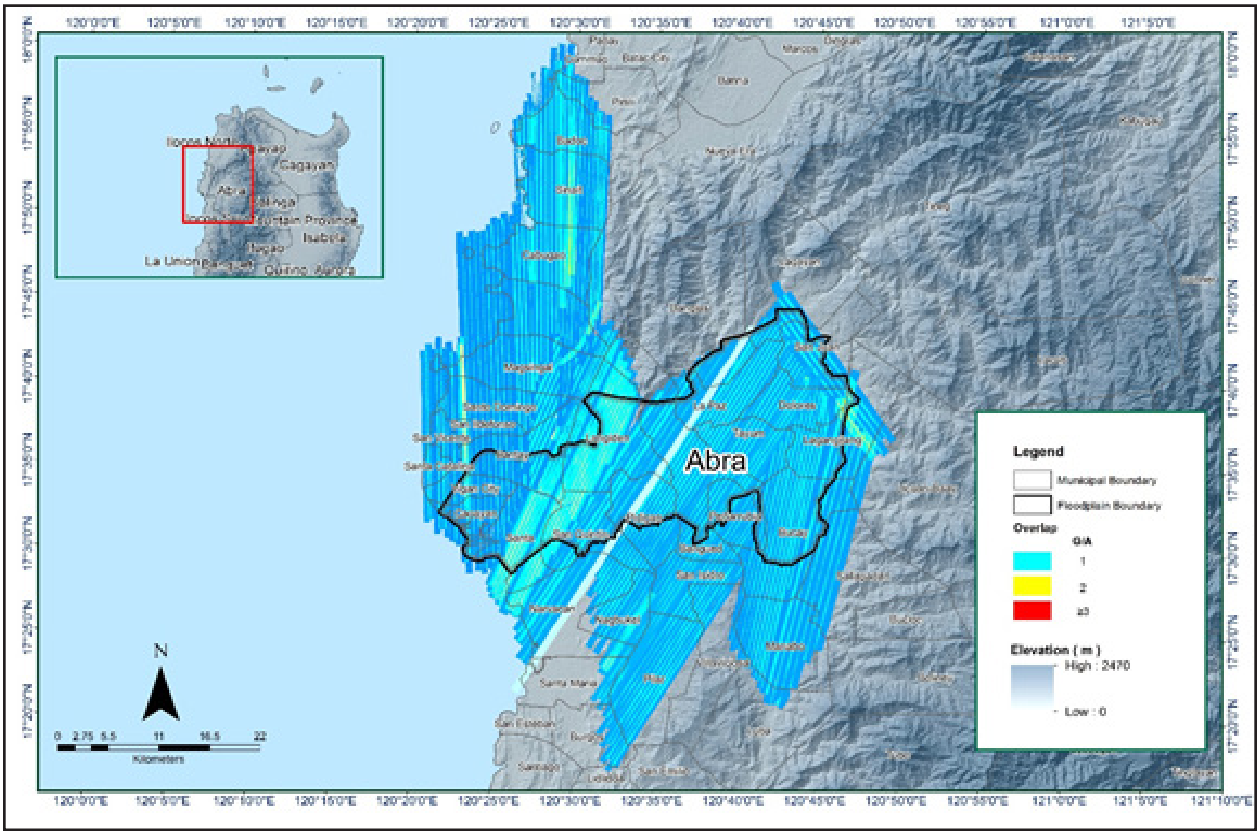

Figure 15. Image of data overlap for Abra floodplain.

The overlap statistics per block for the Abra floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.76% and 63.15% which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for the Abra floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.62 points per square meter.

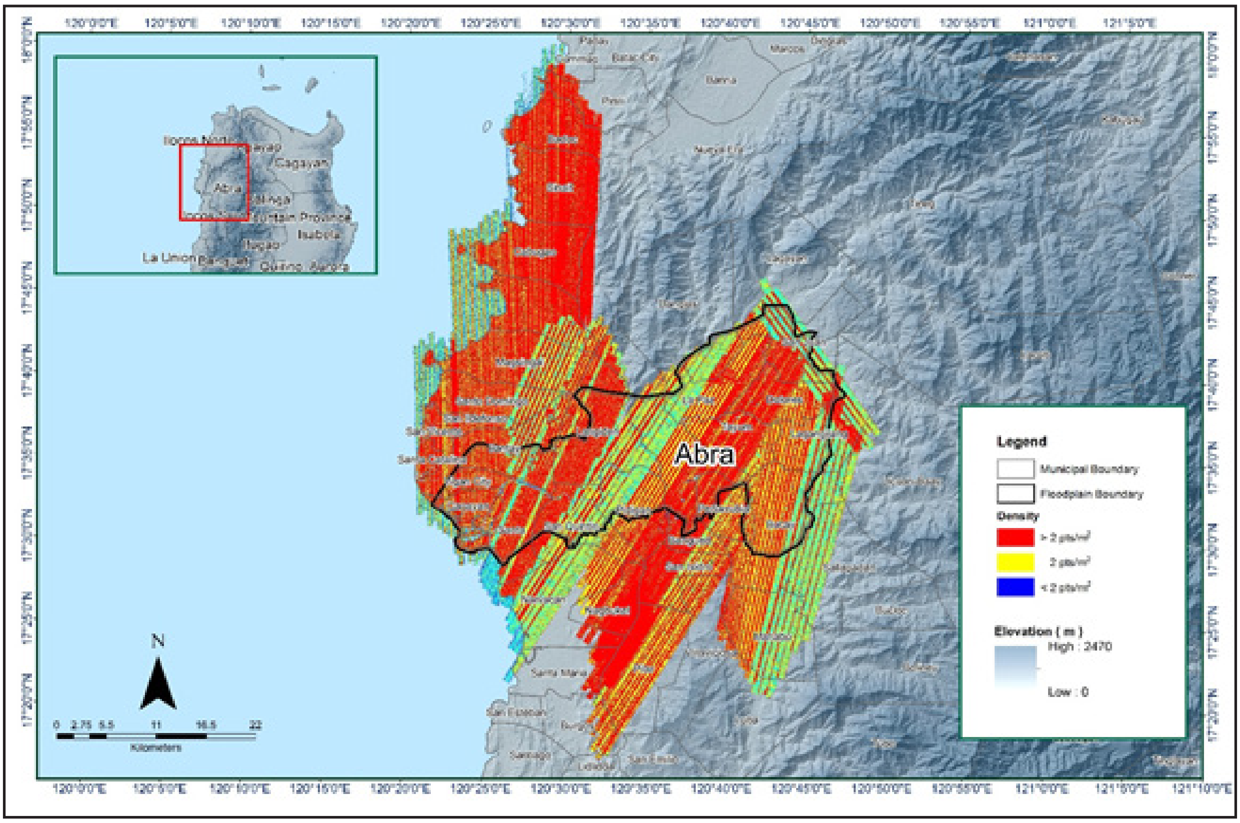

Figure 16. Pulse density map of the merged LiDAR data for Tineg floodplain.

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

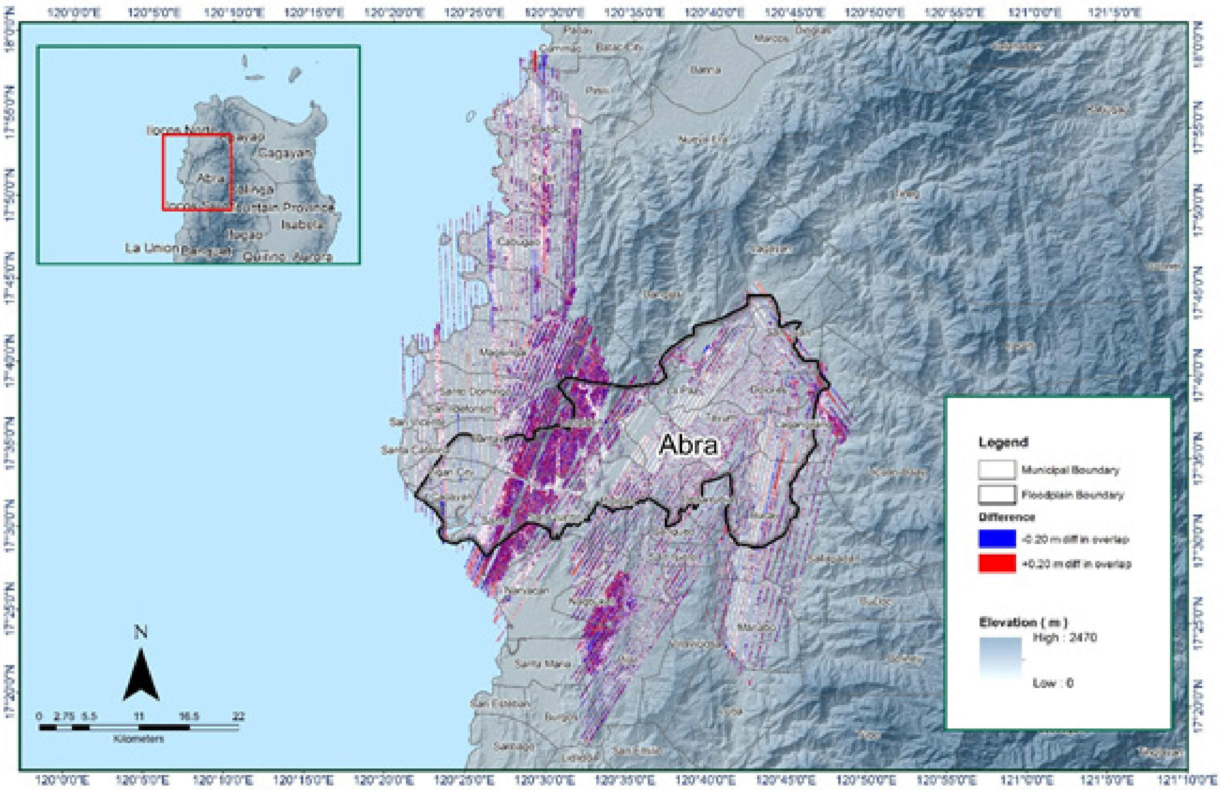

Figure 17. Elevation difference Map between flight lines for the Abra Floodplain Survey

A screen capture of the processed LAS data from a Abra flight 7108GC loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed 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.

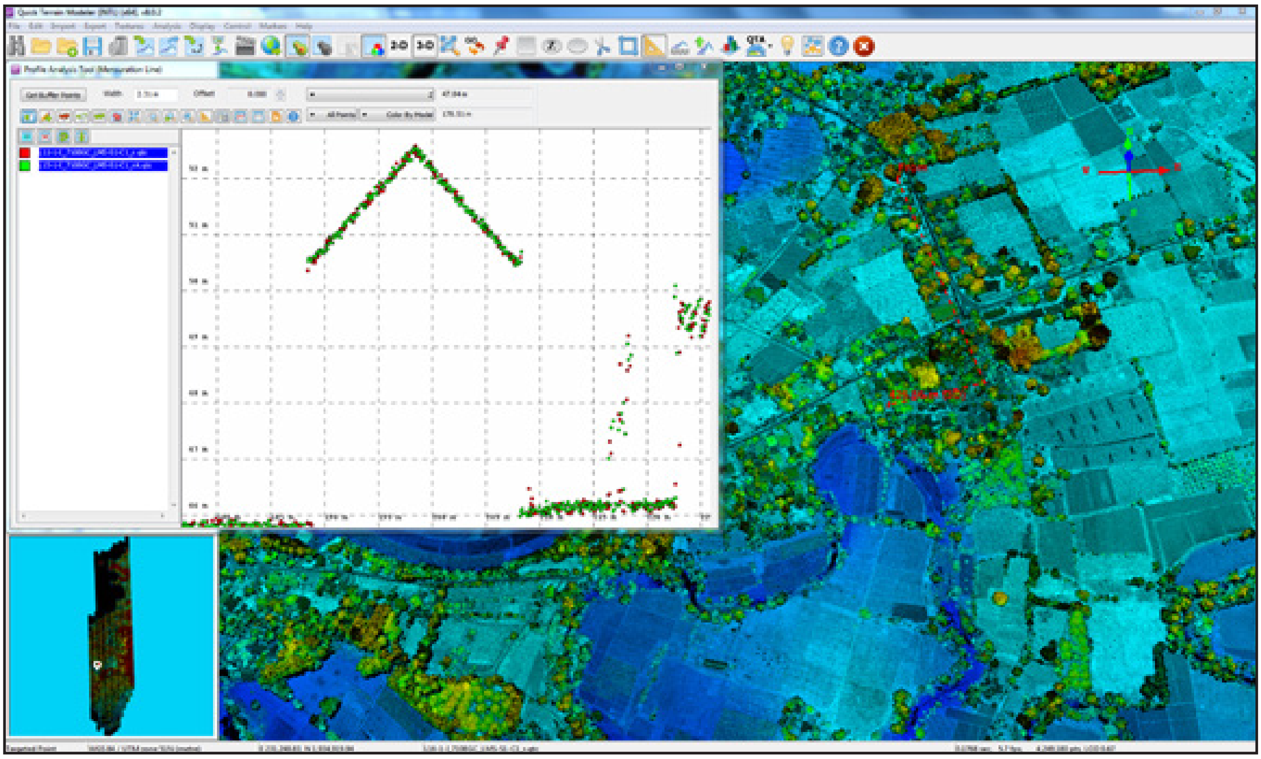

Figure 18. Quality checking for aAbra flight 7108GC using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Abra classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,100,709,129
Low Vegetation	876,806,713
Medium Vegetation	1,373,158,802
High Vegetation	2,258,223,661
Building	254,479,708

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Abra floodplain is shown in Figure 19. A total of 3,341 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 1,140 meters and 23 meters, respectively.

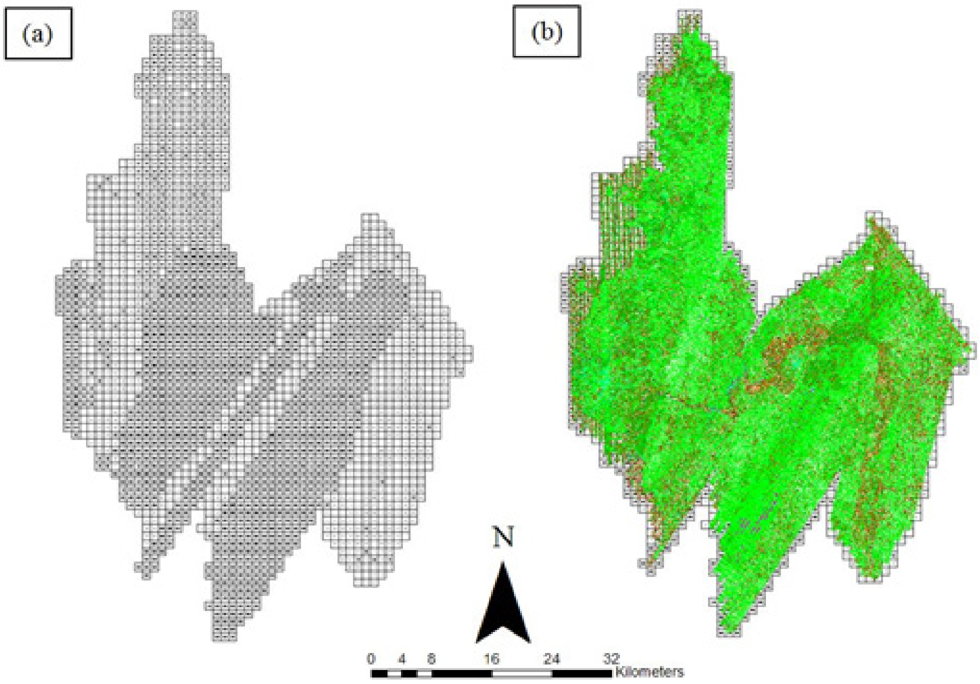

Figure 19. Tiles for Abra floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, while 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 the canopy are classified correctly, due to the density of the LiDAR data.

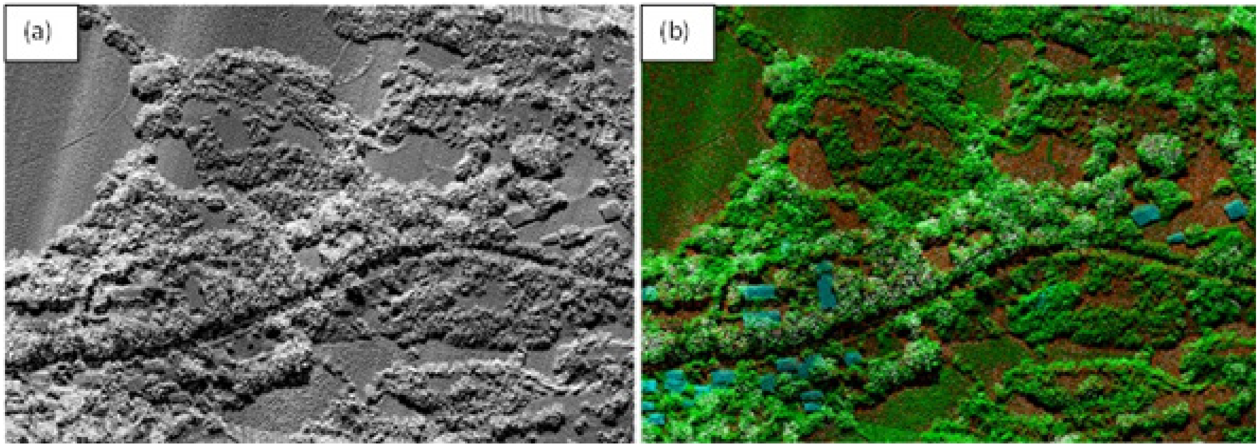

Figure 20. Point cloud before (a) and after (b) classification.

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

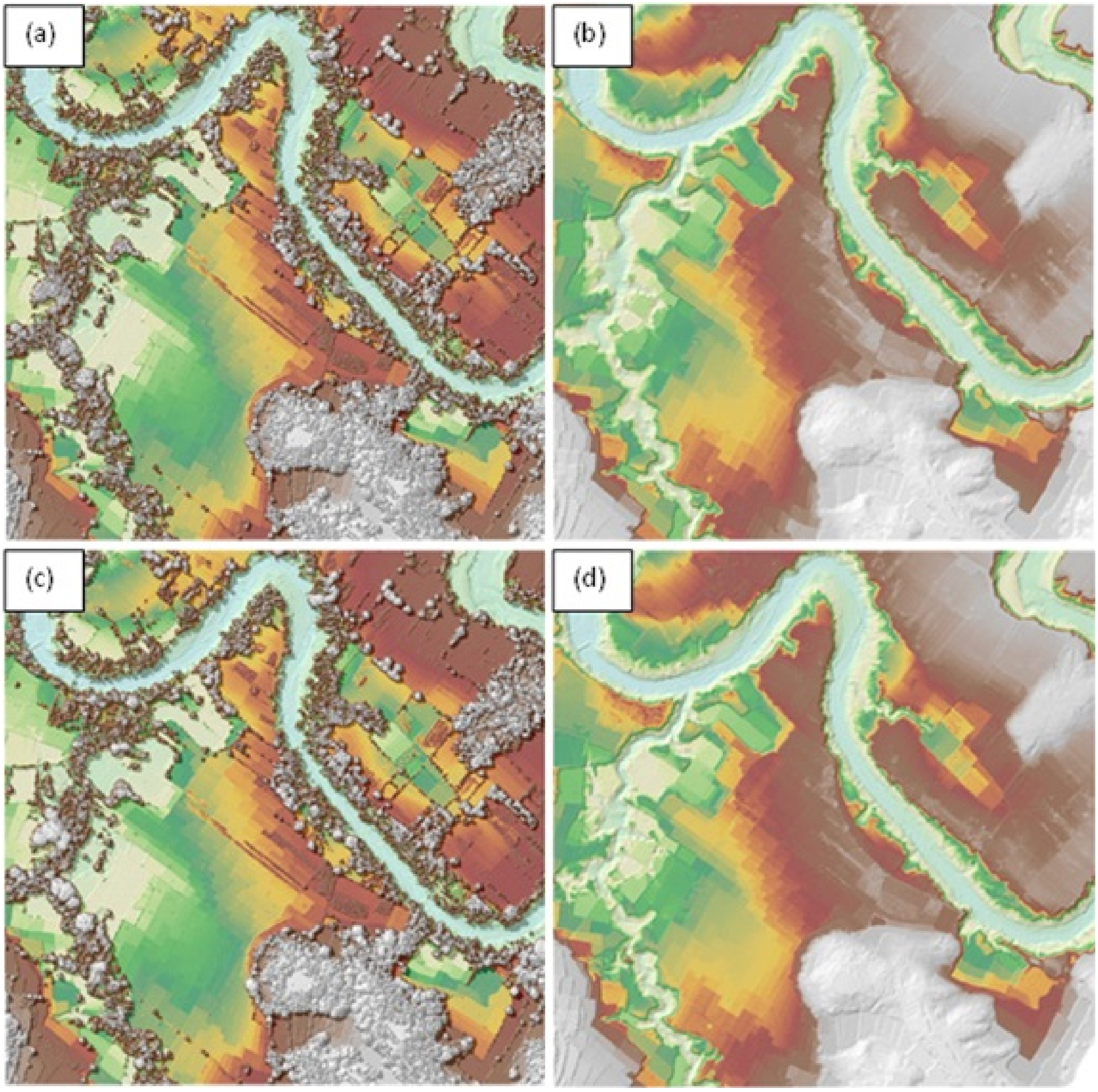

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Tineg floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Tineg floodplain.

3.8 DEM Editing and Hydro-Correction

Sixteen (16) mission blocks were processed for Abra flood plain. These blocks are composed of Laoag and Ilocos blocks with a total area of 2439.64 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Ilocos_Blk07EF	230.33
Ilocos_Blk07D	169.74
Ilocos_Blk07G	143.44
Ilocos_Blk07C_supplement	202.76
Ilocos_Blk07B	199.83
Ilocos_Blk07A_additional	41.20
Ilocos_Blk07A	169.39
Ilocos_Blk06G	84.74
Ilocos_Blk06G_supplement	94.44
Ilocos_Blk06F	84.74
Ilocos_Blk06A	337.98
Ilocos_Blk06D	287.83
Ilocos_Blk06D_supplement	51.49
Laoag_Blk07A	114.25
Laoag_Blk07C	202.76
Ilocos_Blk06D_additional	24.72
TOTAL	2439.64 sq.km

Figure 22 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 22a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 22b).

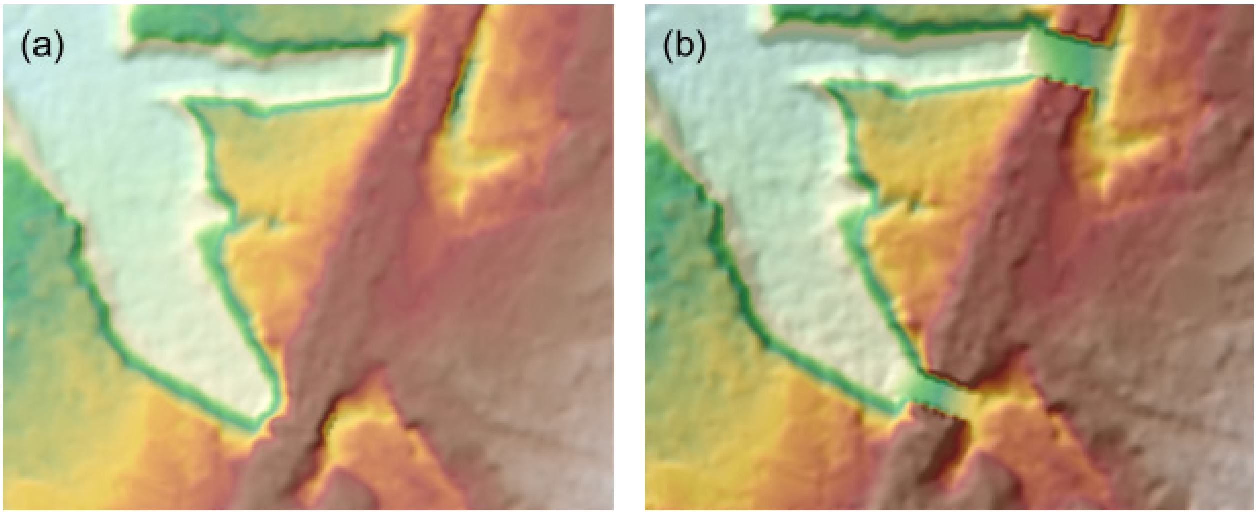

Figure 22. Portions in the DTM of the Abra Floodplain – a bridge before (a) and after (b) manual editing.

3.9 Mosaicking of Blocks

Ilocos_Blk5A was used as the reference block at the start of mosaicking because this block was referred to a base with an acceptable order of accuracy. Table 17 shows the shift values applied to each LiDAR block during mosaicking.

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Mosaicked LiDAR DTM for Abra floodplain is shown in Figure 23. It can be seen that the entire Abra floodplain is 100% covered by LiDAR data.

Table 17. Shift values of each LiDAR block of Abra Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Ilocos_Blk07EF	2.20	0.50	-0.40
Ilocos_Blk07D	2.20	0.50	+2.90
Ilocos_Blk07G	2.20	0.50	+2.90
Ilocos_Blk07C_supplement	2.20	0.50	+2.90
Ilocos_Blk07B	2.20	0.50	+2.90
Ilocos_Blk07A_additional	0.00	0.00	+2.75
Ilocos_Blk07A	0.00	0.00	+2.90
Ilocos_Blk06G	1.20	-1.90	-0.17
Ilocos_Blk06G_supplement	1.20	-1.90	+3.00
Ilocos_Blk06F	1.20	-1.90	+2.84
Ilocos_Blk06A	1.20	-1.90	0.00
Ilocos_Blk06D	1.20	-1.90	0.00
Ilocos_Blk06D_supplement	1.20	-1.90	0.00
Laoag_Blk7A	0.00	0.00	+2.64
Laoag_Blk7C	0.00	0.00	+2.51
Ilocos_Blk06D_additional	0.51	0.00	-0.08

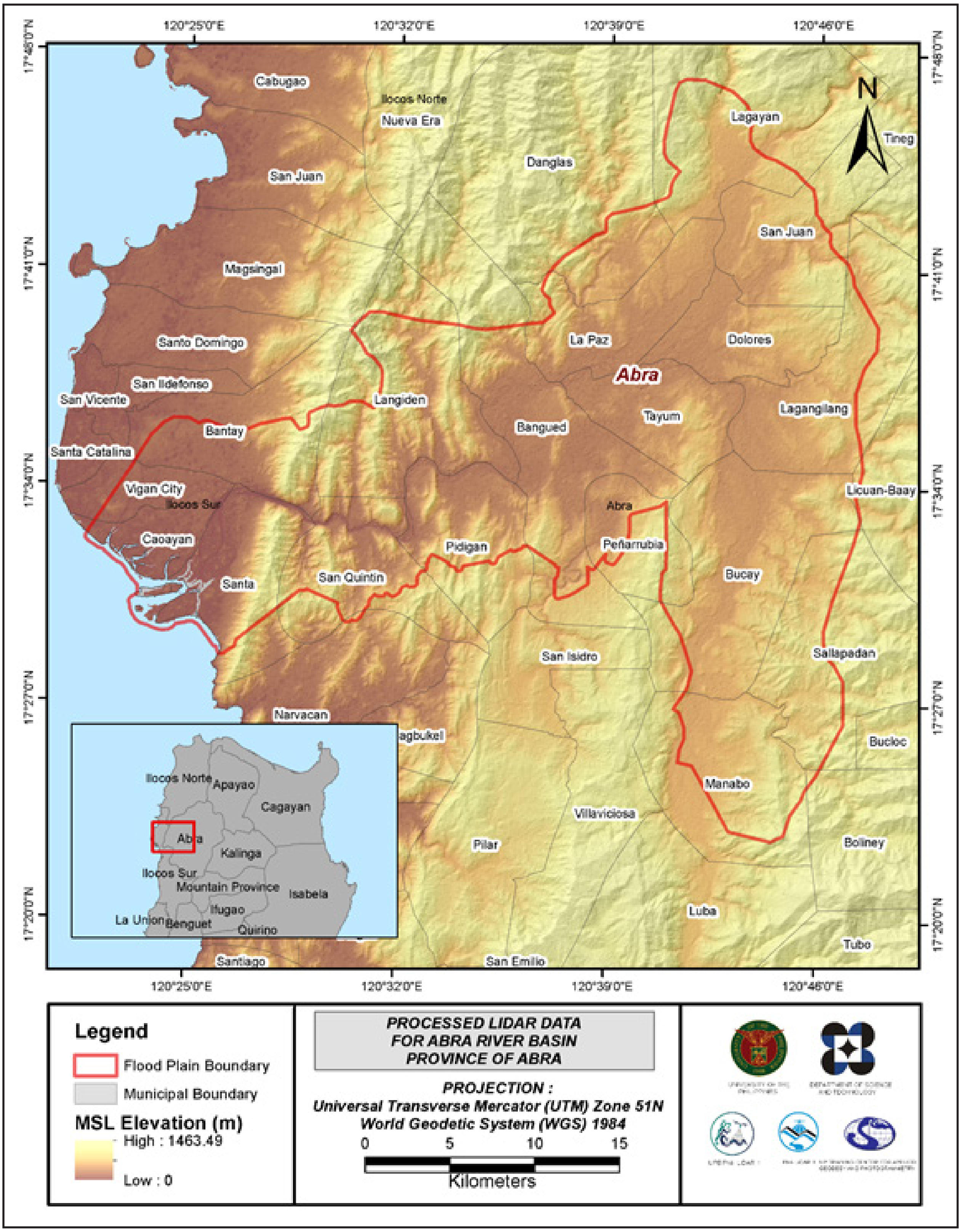

Figure 23. Map of processed LiDAR data for the Abra Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in the provinces of Ilocos, Launion and Abra to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 31,869 points were gathered for all the floodplains within the provinces of Ilocos, La Union and Abra wherein the Abra is located. Random selection of 80% of the survey points, resulting to 25,496 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 25. 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 3.47 meters with a standard deviation of 0.19 meters. Calibration of Abra LiDAR data was done by subtracting the height difference value, 3.47 meters, to the mosaicked LiDAR data for Abra. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

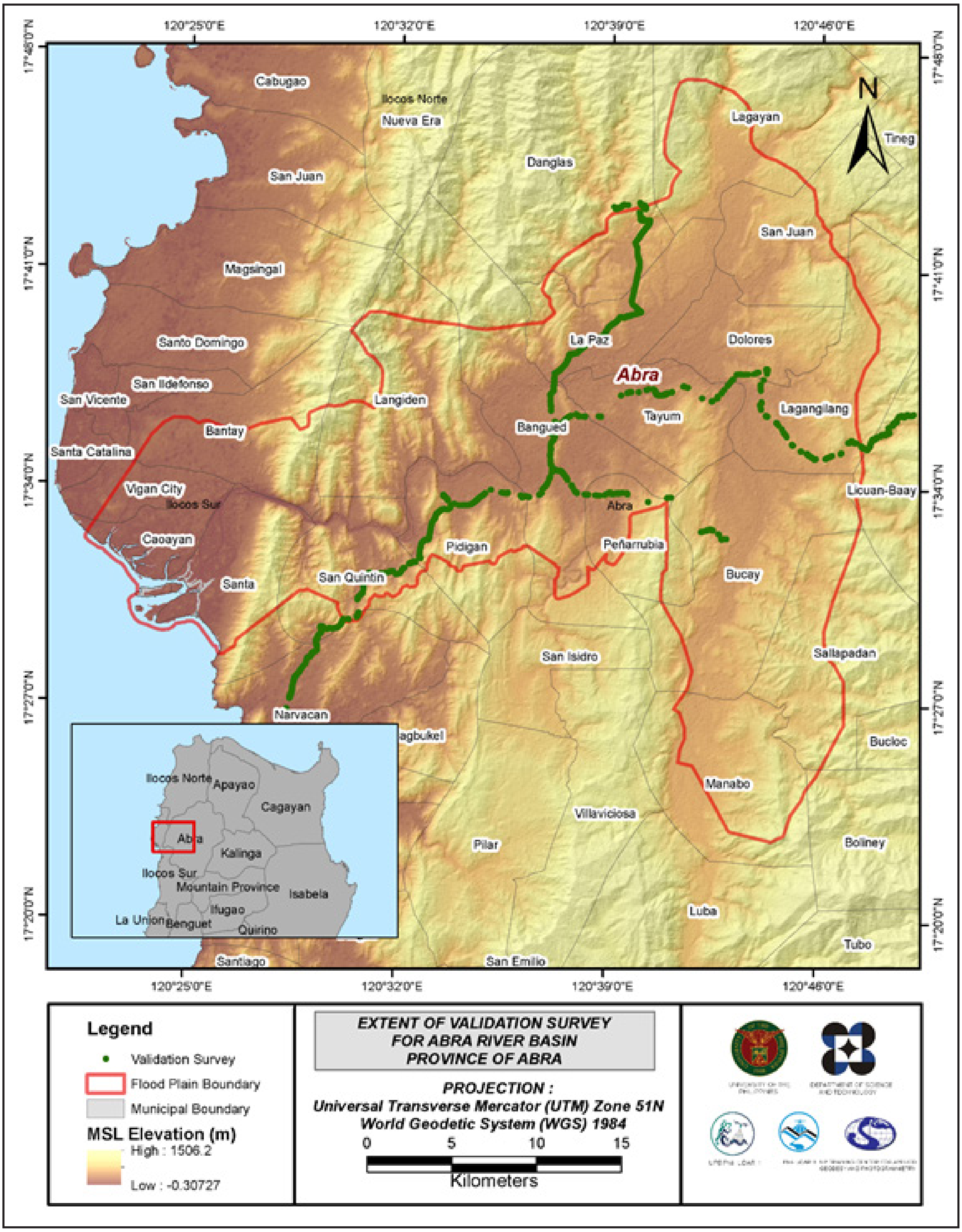

Figure 24. Map of Abra Floodplain with validation survey points in green.

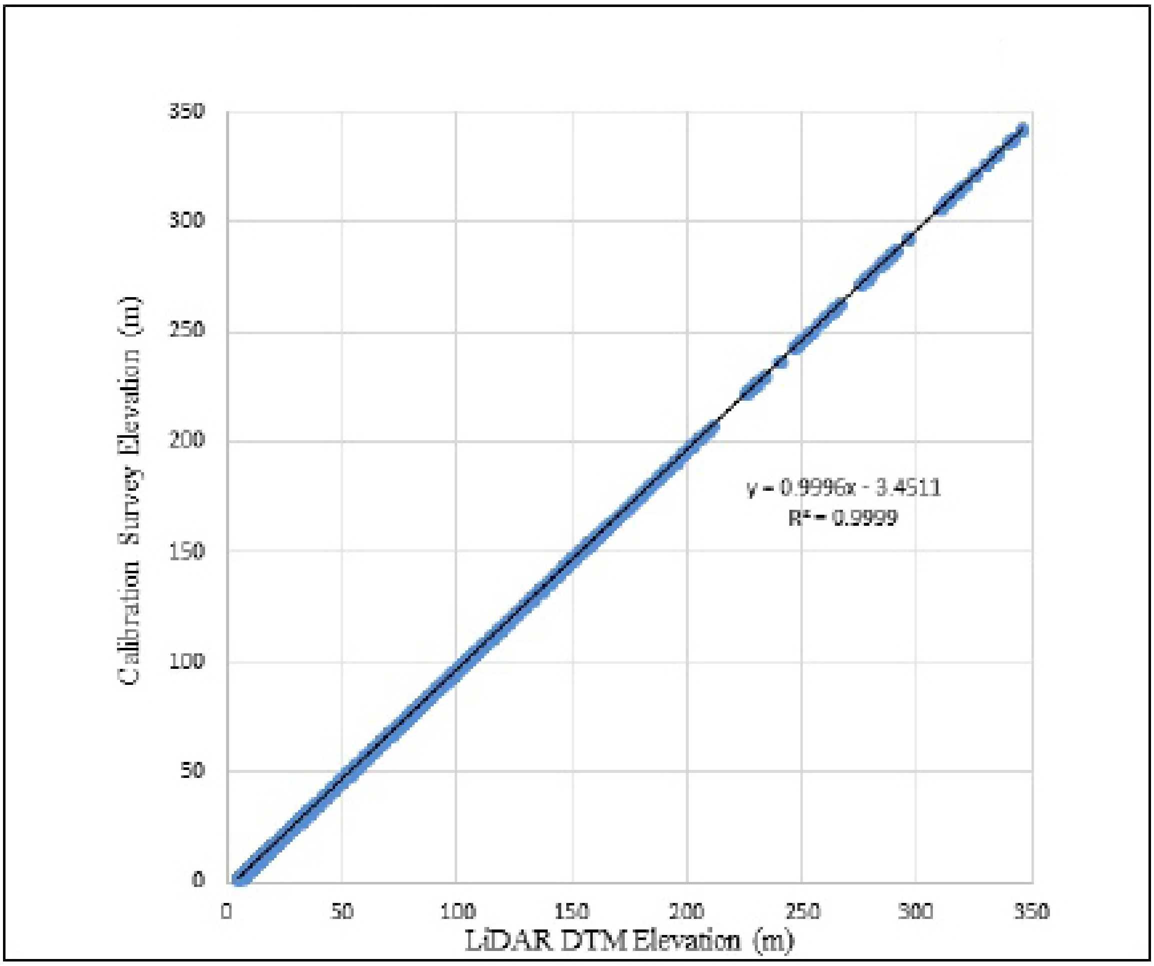

Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 18. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.47
Standard Deviation	0.19
Average	-3.46
Minimum	-4.00
Maximum	-3.00

A total of 970 survey points that are near the Abra flood plain were used for the validation of the calibrated Abra 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.15 meters, as shown in Table 19.

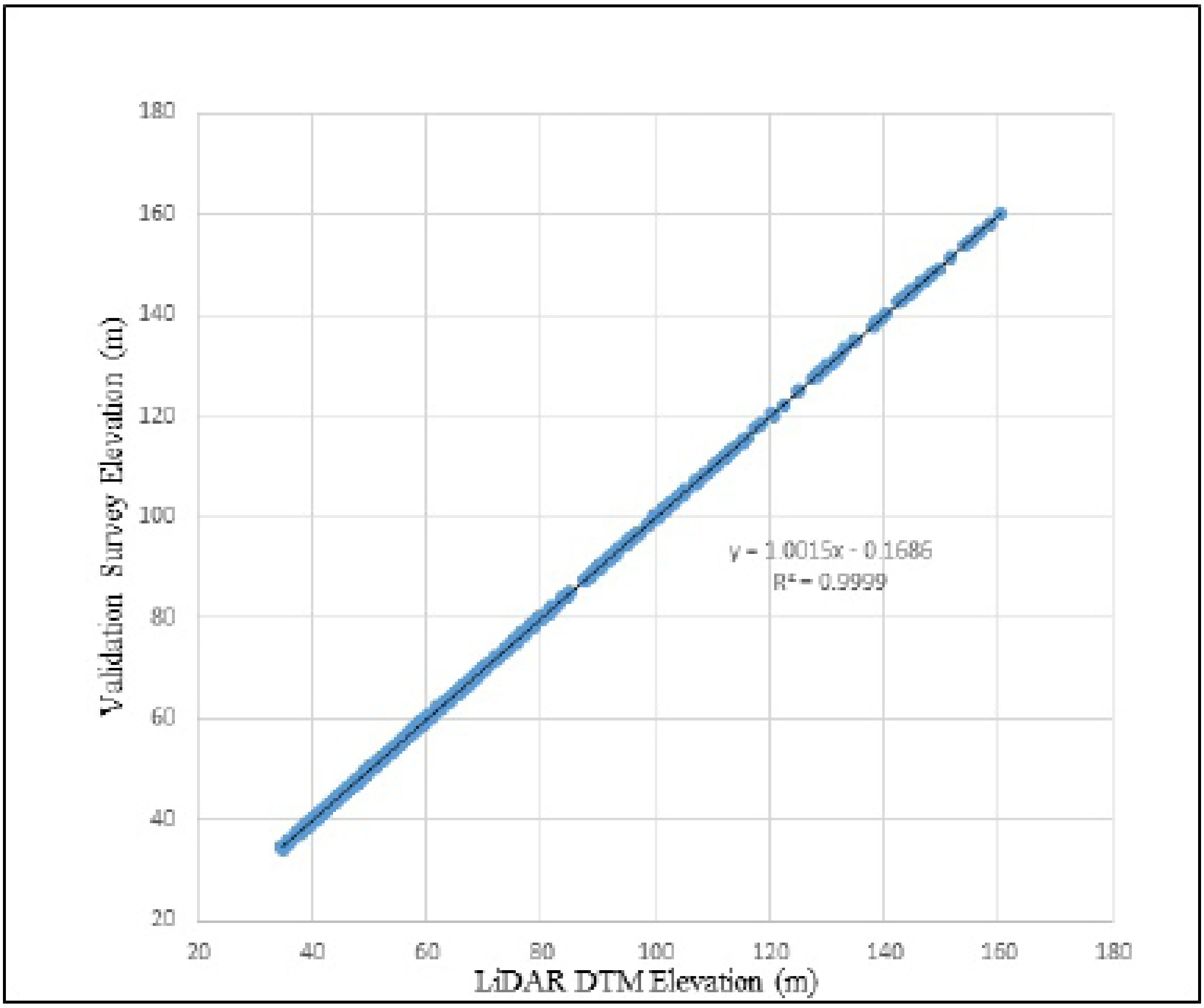

Figure 26. Correlation plot between the validation survey points and the LiDAR data.

Table 19. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.15
Average	-0.07
Minimum	-0.48
Maximum	0.47

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data were available for Abra with 30,311 bathymetric survey points. The floodplain contains three (3) rivers namely Abra, Tineg and Ikmin. Abra River's centerline and cross-section data consists of 2,952 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation method. The river was divided into 6 section and the method was applied on each. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.69 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Abra integrated with the processed LiDAR DEM is shown in Figure 27.

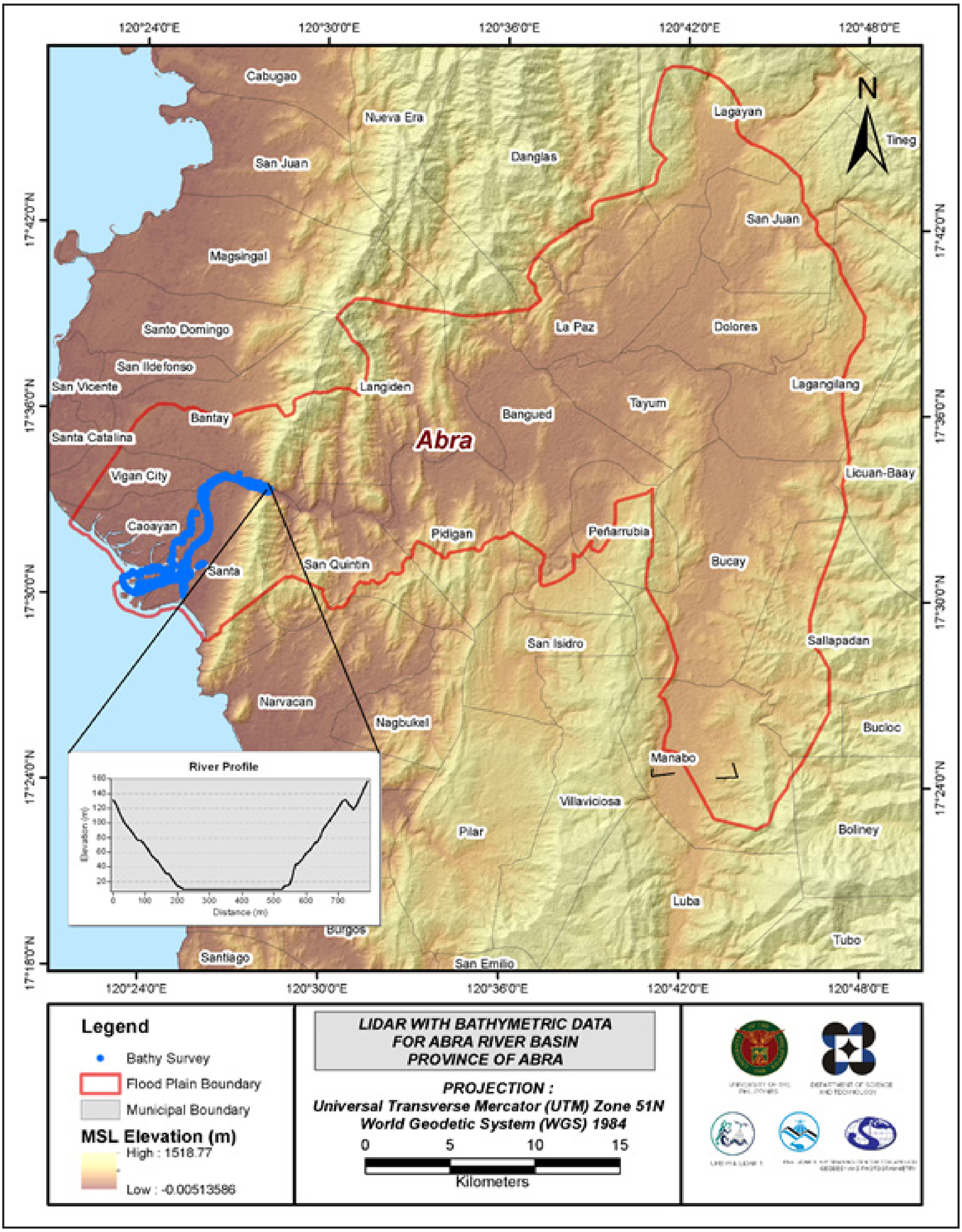

Figure 27. Map of Abra floodplain with bathymetric survey points in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Abra floodplain, including its 200 m buffer, has a total area of 776.76 sq km. For this area, a total of 24.0 sq km, corresponding to a total of 5,893 building features, are considered for QC. Figure 28 shows the QC blocks for Abra floodplain.

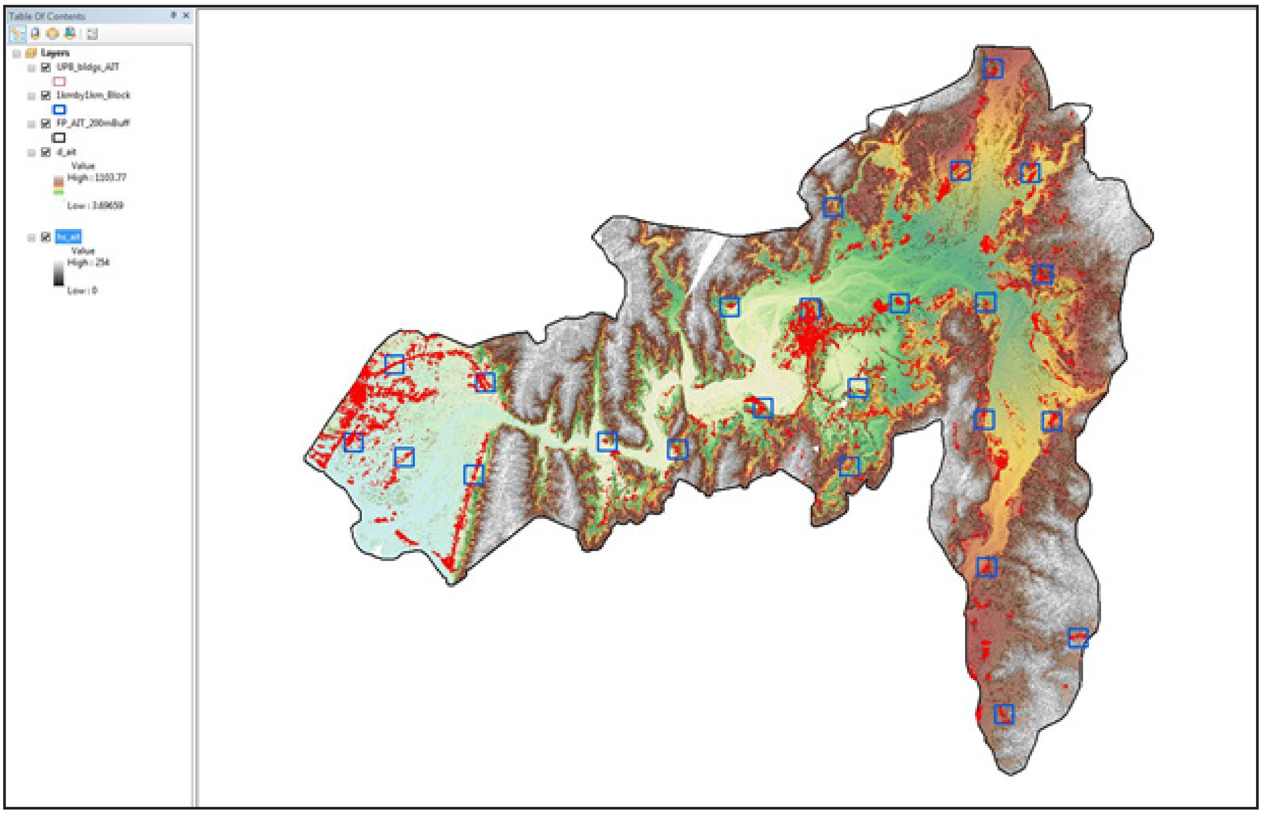

Figure 28. Blocks (in blue) of Abra building features that was subjected to QC.

Quality checking of Abra building features resulted in the ratings shown in Table 20.

Table 20. Details of the quality checking ratings for the building features extracted for the Abra River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Abra	99.44	99.98	97.30	PASSED

3.12.2 Height Extraction

Height extraction was done for 51,234 building features in Abra floodplain. Of these building features, 843 were filtered out after height extraction, resulting to 50,391 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 14.87 meters.

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

Table 21. Building features extracted for Abra Floodplain.

Facility Type	No. of Features
Residential	49,140
School	749
Market	37
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	38
Barangay Hall	6
Military Institution	0
Sports Center/Gymnasium/Covered Court	11
Telecommunication Facilities	2
Transport Terminal	16
Warehouse	3
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	3
Water Supply/Sewerage	0
Religious Institutions	56
Bank	10
Factory	32
Gas Station	23
Fire Station	2
Other Government Offices	51
Other Commercial Establishments	207
Total	50,391

Table 22. Total length of extracted roads for Abra Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Abra	382.5	225.68	12.17	100.03	0.00	720.38

Table 23. Number of extracted water bodies for Abra Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Abra	147	164	0	0	0	311

A total of 25 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 29 shows the completed Digital Surface Model (DSM) of the Abra floodplain overlaid with its ground features.

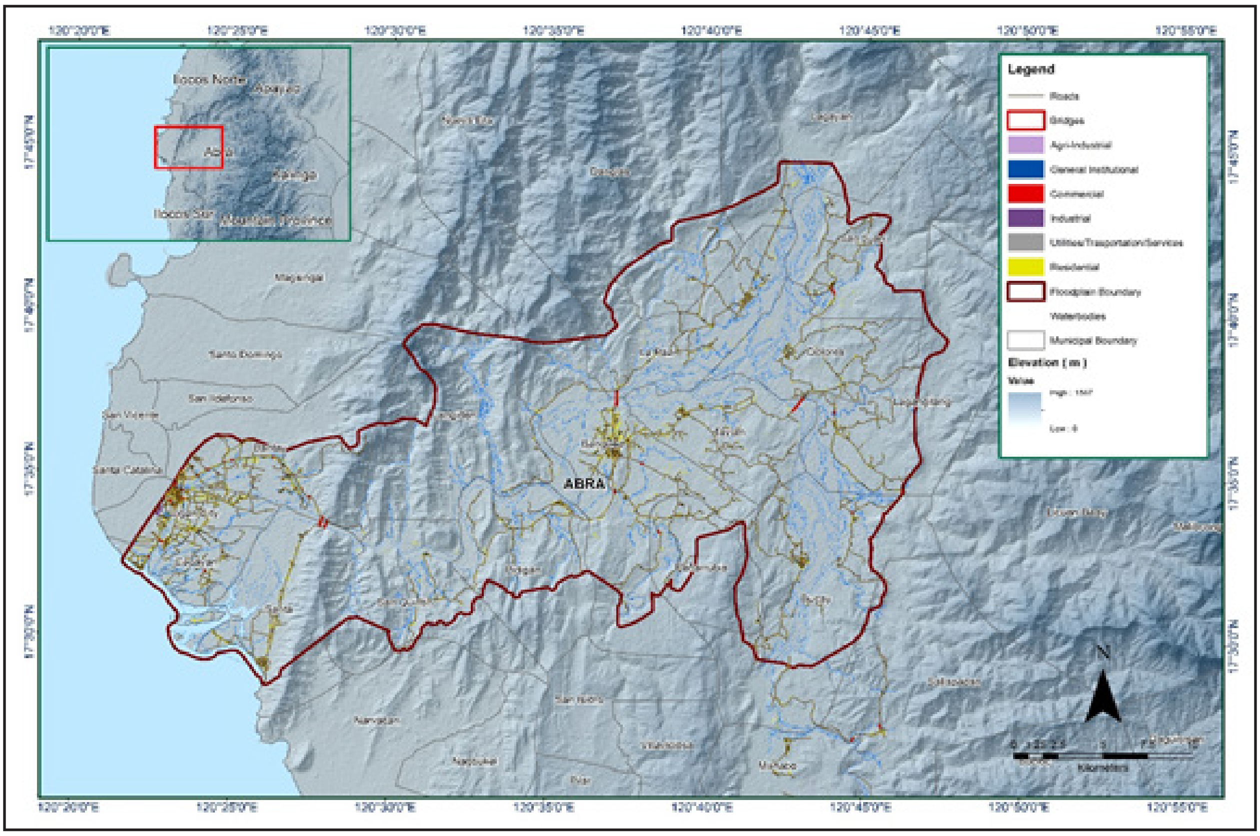

Figure 29. Extracted features of the Abra Floodplain.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Abra River on July 13 to 27, 2016 and September 22 to 30, 2016. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (iii) the cross section re-survey and bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Marcos Bridge in Brgy. Bumagcat, Municipality of Tayum, Abra; (iv) validation points acquisition of about 82 km covering the Abra River Basin area; and (v) bathymetric survey from its upstream in Brgy. Lagben, Municipality of Lagangilang; down to the downstream end of the river located in Brgy. Gaddanai, in Municipality of Tayum, with an approximate total length of 5.935 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique. Figure 30 illustrates the extent of the entire survey in Abra River.

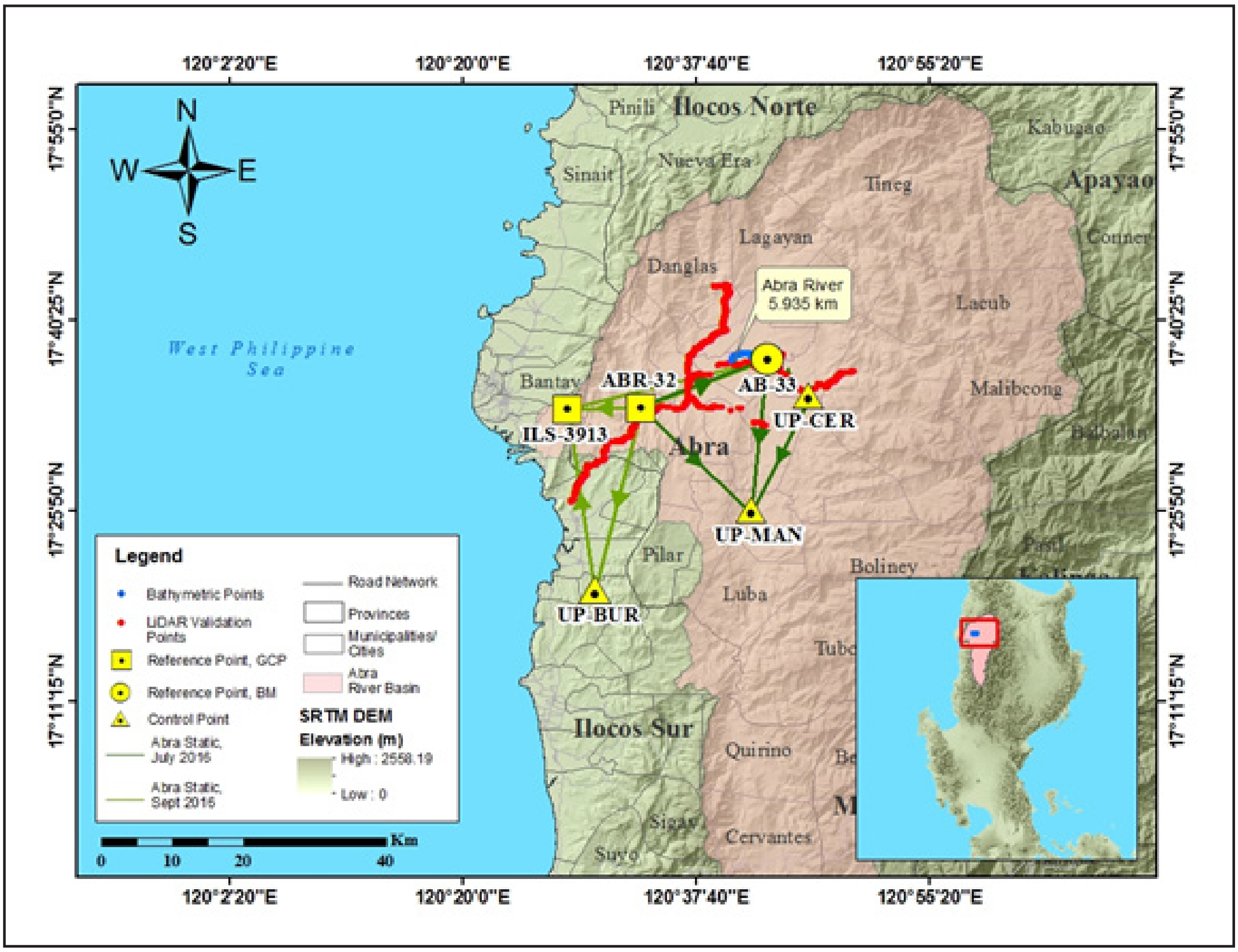


Figure 30. Abra River Survey Extent

4.2 Control Survey

The GNSS network utilized for the Abra River Basin is composed of four (4) loops and a baseline that was established on July 16, 2016, which occupied the following reference points: ABR-32, a second-order GCP in Brgy. Lagben, Municipality of Lagangilang; and AB-33, a first order BM, in Brgy. Pamutic, Municipality of Pidigan, both in Abra; and on September 25, 2016 occupying the reference points: ABR-32, and AB-33.

Three (3) control points were established along the approach of bridges, namely: UP-CER, located at Cervantes Bridge in Brgy. San Isidro, Municipality of Lagangilang; and UP-MAN, located at Manabo Bridge, in Brgy. San Juan Norte, Municipality of Manabo, Abra; and UP-BUR, located at Burgos Bridge, in Brgy. Poblacion Norte, Municipality of Burgos, Ilocos Sur. NAMRIA established control point, ILS-3913 in Brgy. Banaoang, Municipality of Bantay, Ilocos Sur was also occupied and used as marker.

Table 24 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 31 shows the GNSS network established in the Abra River Survey.

Table 24. List of reference and control points used during the survey in Abra River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
Control Survey on July 16, 2016						
ABR-32	2nd order, GCP	17°33'43.22900"N	120°33'29.72282"E	71.266	-	2014
AB-33	1st order, BM	-	-	103.212	64.162	2016
UP-CER	UP Established	-	-	-	-	Jul 16, 2016 11:16 AM
UP-MAN	UP Established	-	-	-	-	Jul 16, 2016 11:17 AM
Control Survey on September 25, 2016						
ABR-32	2nd order, GCP	17°33'43.22900"N	120°33'29.72282"E	-	33.435	03-04-14
AB-33	1st order, BM	17°37'28.81124"N	120°43'02.46322"E	103.212	-	07-16-16
ILS-3913	Used as marker	-	-	-	-	09-25-16
UP-BUR	UP Established	-	-	-	14.873	
	09-25-16					

Figure 31. Abra River Basin Control Survey Extent.

Figure 32 to Figure 37 depict the setup of the GNSS on recovered reference points and established control points in the Abra River.

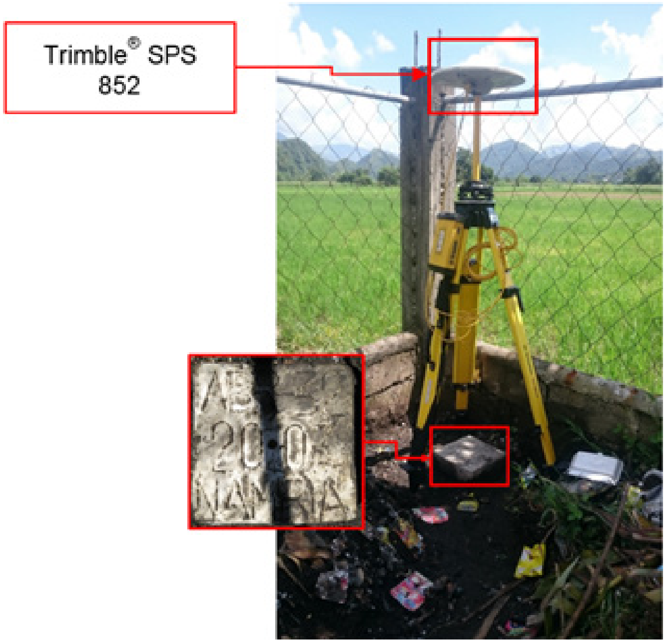


Figure 32. GNSS base set up, Trimble® SPS 852, at ABR-32 located behind the barangay basketball court in Brgy. Lagben, Municipality of Lagangilang, Abra.

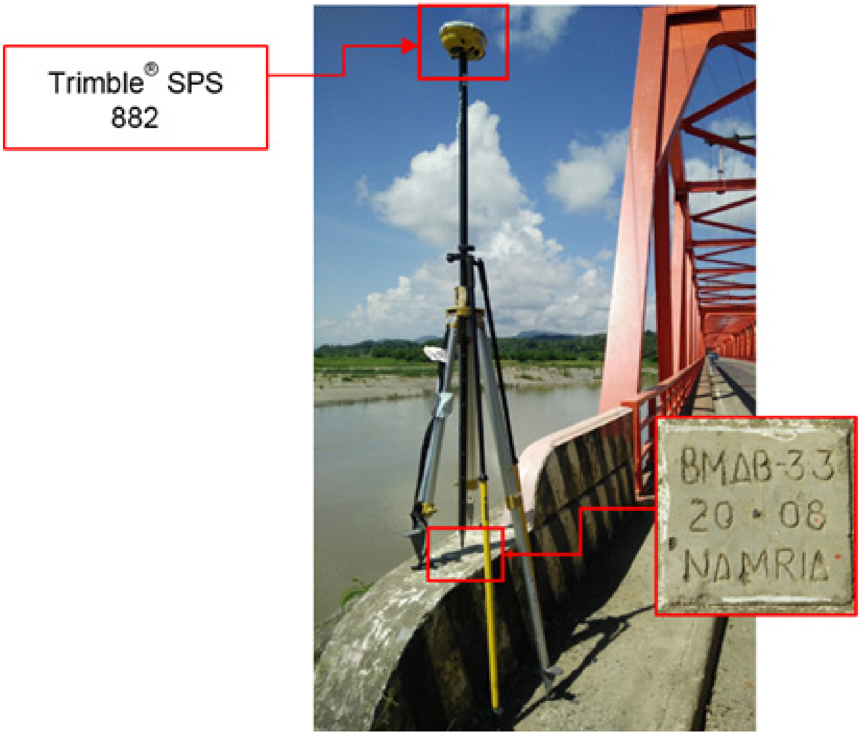


Figure 33. GNSS receiver setup, Trimble® SPS 882, at AB-33 located at the approach of Don Mariano Marcos Bridge, Municipality of Dolores, Abra.

Figure 34. GNSS receiver setup, Trimble® SPS 882, at ILS-3913 located in Brgy. Banaoang, Municipality of Bantay, Ilocos Sur.

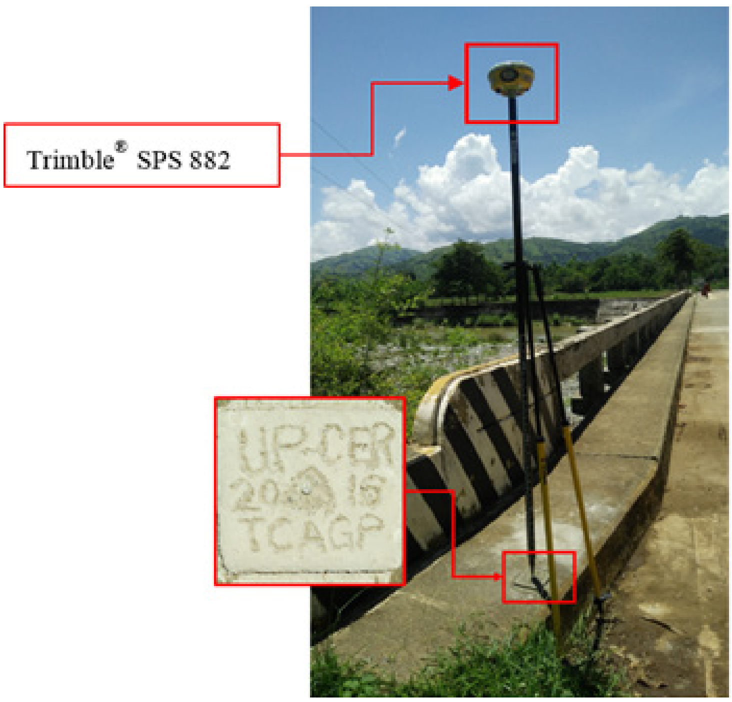


Figure 35. GNSS receiver setup, Trimble® SPS 882, at UP-CER located at the approach of Cervantes Bridge in Brgy. San Isidro, Municipality of Lagangilang, Abra.

Figure 36. GNSS receiver setup, Trimble® SPS 882, at UP-MAN located at the approach of Manabo Bridge in Brgy. San Juan Norte, Municipality of Manabo, Abra.

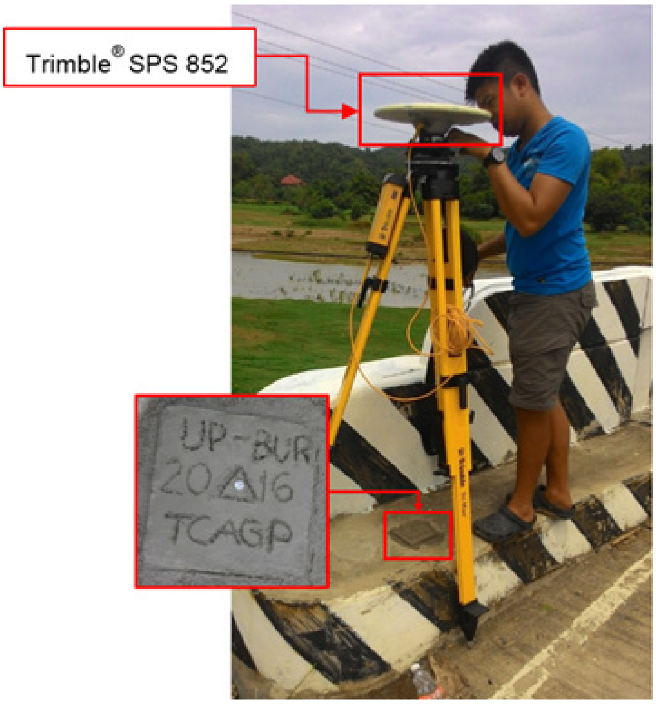


Figure 37. GNSS receiver setup, Trimble® SPS 852, at UP-BUR located at the approach of Burgos Bridge in Brgy. Poblacion Norte, Municipality of Burgos, Abra.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 25 presents the baseline processing results of control points in the Abra River Basin, as generated by the TBC software.

Table 25. The Baseline processing report for the Abra River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
Control Survey on July 16, 2016							
ABR-32 --- AB-33	07-16-16	Fixed	0.005	0.017	67°38'57"	18255.694	31.939
ABR-32 --- UP-MAN	07-16-16	Fixed	0.004	0.023	134°12'01"	20653.613	84.541
AB-33 --- UP-MAN	07-16-16	Fixed	0.00	0.030	185°36'29"	21442.161	52.554
UP-CER --- UP-MAN	07-16-16	Fixed	0.005	0.030	205°21'41"	17879.146	25.826
AB-33 --- UP-CER	07-16-16	Fixed	0.005	0.019	132°59'24"	7598.765	26.762
Control Survey on September 25, 2016							
ILS-3913 --- UP-BUR	09-25-16	Fixed	0.006	0.020	171°46'43"	25691.386	-12.465
ABR-32 --- AB-33	09-24-16	Fixed	0.005	0.0105	67°38'57"	18255.693	31.726
ILS-3913 --- ABR-32	09-24-16	Fixed	0.009	0.024	269°18'16"	9916.007	-6.683
ABR-32 --- UP-BUR	09-25-16	Fixed	0.006	0.022	193°45'16"	26303.822	-19.151
ILS-3913 --- AB-33	09-25-16	Fixed	0.076	0.033	75°12'29"	27714.535	38.387

As shown in Table 25, a total of ten (10) baselines were processed with the coordinates of ABR-32 held fixed for coordinate value; and AB-33 fixed for elevation values; it is apparent that all baselines 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 26 to Table 29.

The four (4) control points, ABR-32, AB-33, UP-CER and UP-MAN were occupied and observed simultaneously to form a GNSS loop on July 16, 2016. On the other hand, the four (4) control points from the control survey on September 25, 2016: ABR-32, AB-33, ILS-3913, and UP-BUR were occupied and observed simultaneously to form a GNSS loop. Coordinates of ABR-32; and elevation value of AB-33 were held fixed during the processing of the control points for the control survey on July 16, 2016; meanwhile, coordinates of ABR-32 and AB-33, and elevation values of ABR-32, AB-33, and UP-BUR were held fixed during the processing of the control points for the control survey on September 25, 2016 as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
July 16, 2016					
ABR-32	Grid				Fixed
AB-33	Local	Fixed	Fixed		
September 25,2016					
AB-33	Grid	Fixed	Fixed		Fixed
ABR-32	Global	Fixed	Fixed	Fixed	
UP-BUR	Grid				Fixed
Fixed = 0.000001 (Meter)					

Likewise, 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 27. The fixed control ABR-32 no value for grid error while AB-33 has no value for elevation error for the control survey on July 16, 2016. On the other hand, the fixed controls ABR-32 and AB-33 have no values for grid and elevation errors, and UP-BUR has no value for elevation error for the control survey on September 25, 2016.

Table 27. Adjusted grid coordinates for the control points used in the Abra River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
July 16,2016							
ABR-32	240815.386	?	1943396.049	?	33.435	0.047	LL
AB-33	257794.046	0.009	1950122.643	0.007	64.162	?	e
UP-CER	263291.187	0.011	1944873.027	0.009	89.924	0.051	
UP-MAN	255441.893	0.009	1928802.720	0.007	115.268	0.055	
September 25, 2016							
ABR-32	240815.3861	?	1943396.048	?	33.43493	?	LLh
AB-33	257794.0460	?	1950122.643	?	64.16200	?	ENe
ILS-3913	230894.7845	0.015	1943403.246	0.009	27.33813	0.071	
UP-BUR	234232.3658	0.016	1917917.030	0.018	14.87300	?	e

The results of the computation for accuracy are as follows:

a. ABR-32
Horizontal Accuracy = Fixed
Vertical Accuracy = 4.7 cm < 10 cm

b. AB-33
Horizontal Accuracy = $\sqrt{((0.9)^2 + (0.7)^2}$
= $\sqrt{(0.81 + 0.49)}$
= 1.14< 20 cm
Vertical Accuracy = Fixed

c. UP-CER
Horizontal Accuracy = $\sqrt{((1.1)^2 + (0.9)^2}$
= $\sqrt{(1.21 + 0.81)}$
= 1.42< 20 cm
Vertical Accuracy = 5.1 cm < 10 cm

d. UP-MAN
Horizontal Accuracy = $\sqrt{((0.9)^2 + (0.7)^2}$
= $\sqrt{(0.81 + 0.49)}$
= 1.14< 20 cm
Vertical Accuracy = 5.5 cm < 10 cm

For the control survey on September 25, 2016 are as follows:

a. ABR-32
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. AB-33
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

c. ILS-3913
Horizontal Accuracy = $\sqrt{((1.5)^2 + (0.9)^2}$
= $\sqrt{(2.25+ 0.81)}$
= 1.75< 20 cm
Vertical Accuracy = 7.1 cm < 10 cm

d. UP-BUR
Horizontal Accuracy = $\sqrt{((1.6)^2 + (1.8)^2}$
= $\sqrt{(2.56 + 3.24)}$
= 2.41< 20 cm
Vertical Accuracy = Fixed

Following the given formula, the horizontal and vertical accuracy result of the two (2) occupied control points are within the required precision.

Table 28. Adjusted geodetic coordinates for control points used in the Abra River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
Control Survey on July 16, 2016					
ABR-32	N17°33'43.22900"	E120°33'29.72282"	71.266	0.047	LL
AB-33	N17°37'28.81122"	E120°43'02.46323"	103.212	?	e
UP-CER	N17°34'40.24943"	E120°46'10.96145"	129.973	0.051	
UP-MAN	N17°25'54.68298"	E120°41'51.46035"	155.794	0.055	
Control Survey on September 25, 2016					
ABR-32	N17°33'43.22900"	E120°33'29.72282"	71.26600	?	LLh
AB-33	N17°37'28.81124"	E120°43'02.46322"	103.21181	?	ENe
ILS-3913	N17°33'39.23389"	E120°27'53.49752"	64.25475	0.071	
UP-BUR	N17°19'52.12416"	E120°29'57.91885"	53.17397	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Abra River GNSS Static Survey are seen in Table 29.

Table 29. The reference and control points utilized in the Abra River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)					
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on July 16, 2016							
ABR-32	2nd order, GCP	17°33'43.22900"	120°33'29.72282"	71.266	1943396.049	240815.386	33.435
AB-33	1st order, BM	17°37'28.81122"	120°43'02.46323"	103.212	1950122.643	257794.046	64.162
UP-CER	UP Established	17°34'40.24943"	120°46'10.96145"	129.973	1944873.027	263291.187	89.924
UP-MAN	UP Established	17°25'54.68298"	120°41'51.46035"	155.794	1928802.720	255441.893	115.268
Control Survey on September 25, 2016							
ABR-32	2nd order, GCP	17°33'43.2290"	120°33'29.7228"	71.266	1943396.049	240815.386	33.435
AB-33	1st order, GCP	17°37'28.8112"	120°43'02.4632"	103.212	1950122.643	257794.046	64.162
ILS-3913	2nd order, GCP	17°33'39.2339"	120°27'53.4975"	64.255	1943403.247	230894.785	27.338
UP-BUR	UP Established	17°19'52.1242"	120°29'57.9188"	53.174	1917917.030	234232.366	14.873

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

The bridge cross-section parallel to Marcos Bridge and as-built survey were conducted on July 24, 2016 and the cross-section perpendicular to the river was conducted on September 28, 2016 both at the downstream side of Marcos Bridge in Brgy. Bumagcat, Municipality of Tayum, Abra using GNSS receiver Trimble® SPS 882 in PPK survey technique (Figure 38).

Figure 38. Marcos Bridge facing upstream.

The length of the cross-sectional line surveyed at Marcos Bridge is about 833 m. with four hundred sixty six (466) cross-sectional points while the cross-section perpendicular to the flow of the river is about 310 m with one hundred three (103) cross-sectional points, both using the control point AB-33 as the GNSS base station. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 39 to Figure 41.

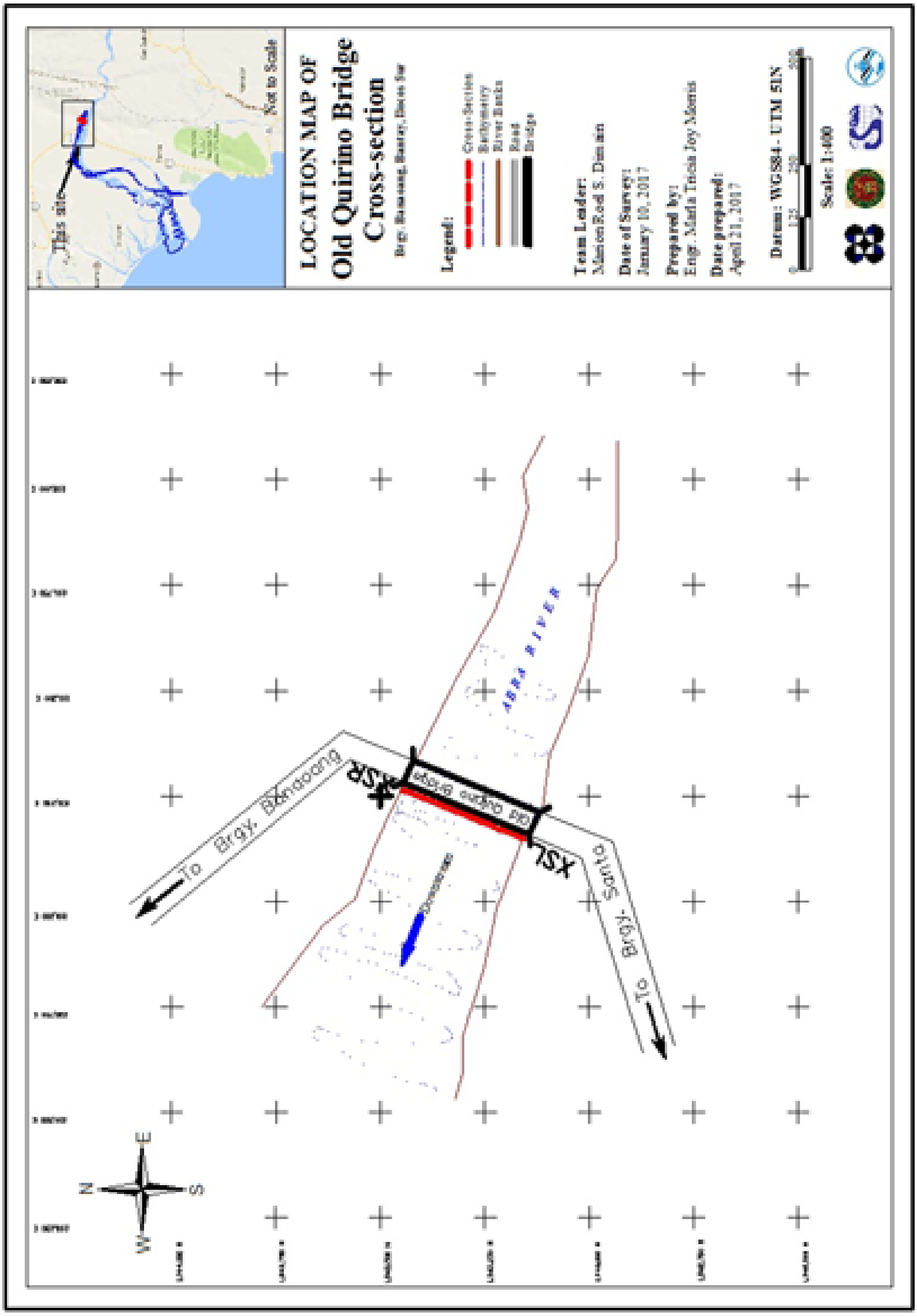


Figure 39. Location map of the Old Quirino Bridge Cross Section.

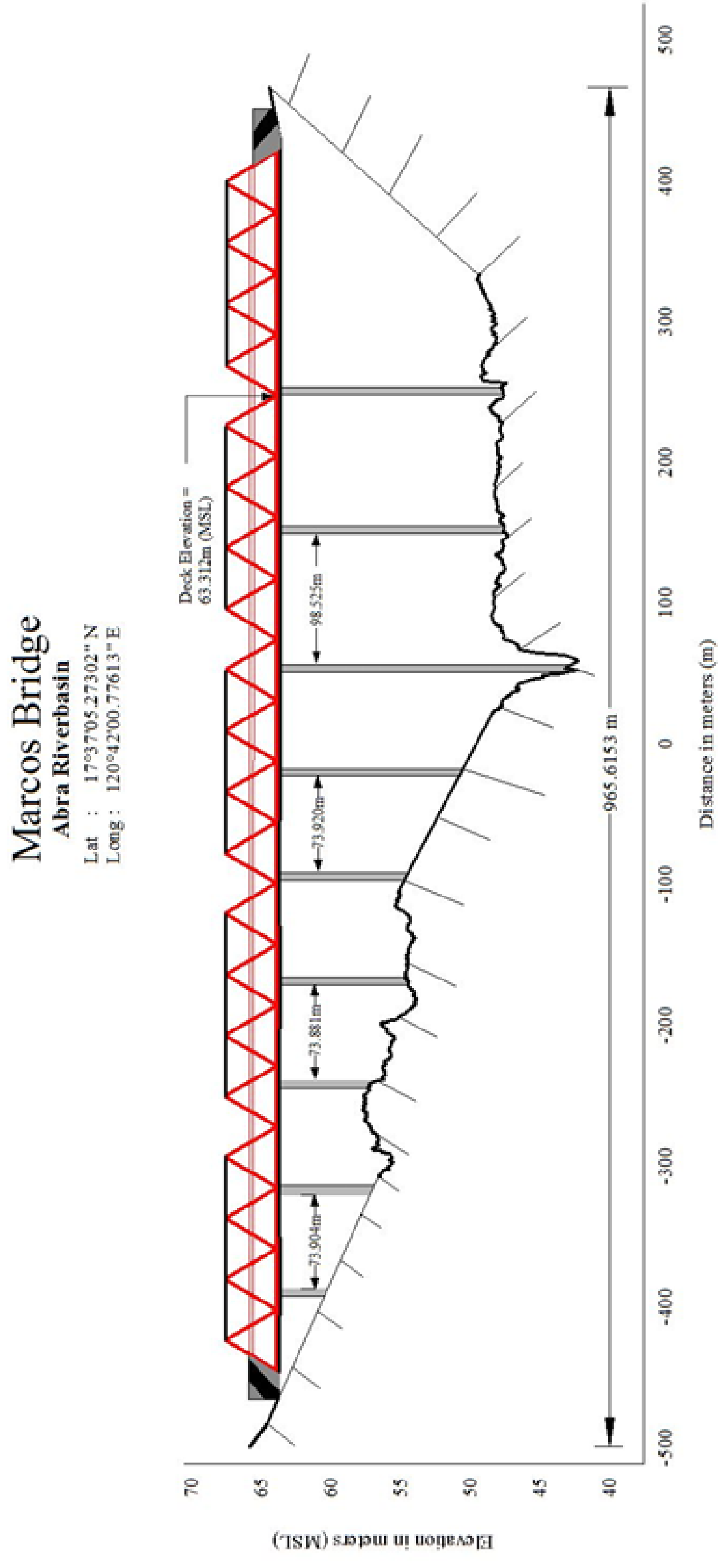


Figure 40. The Marcos Bridge cross-section survey drawn to scale.

Bridge Data Form

Bridge Name: Marcos Bridge — Date: August 22 & 24, 2016

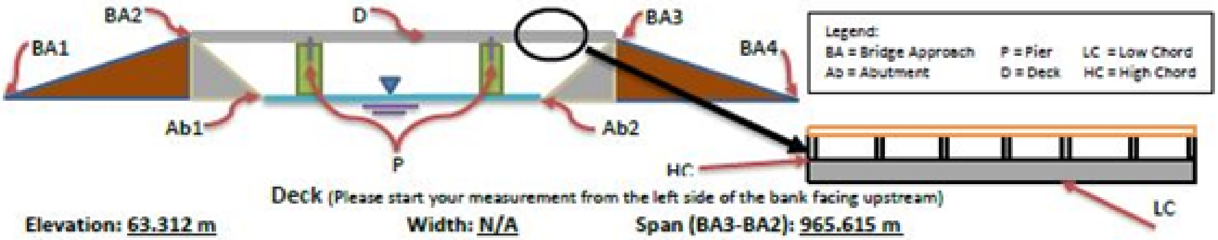
River Name: Abra River — Time: 1:20 PM

Location (Brgy, City,Region): Brgy. Bumagcat, Municipality of Tayum, Abra

Survey Team: Marla Morris, Cibyl Atacador, Randell Pabroquez

Flow condition: normal — Weather Condition: fair

Latitude: 17˚37'05.27302" N — Longitude: 120˚42'42.77613" E



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

Elevation: 63.312 m — Width: N/A — Span (BA3-BA2): 965.615 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	65.736 m	BA3	928.7593 m	63.488 m
BA2	34.3135 m	63.633 m	BA4	965.6153 m	64.304 m

Abutment: Is the abutment sloping? Yes; 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: 9 — Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	111.7132 m	63.535 m	Not available
Pier 2	185.61767 m	63.599 m	Not available
Pier 3	259.5908 m	63.61 m	Not available
Pier 4	333.4725 m	63.5 m	Not available
Pier 5	407.5859 m	63.571 m	Not available
Pier 6	481.5063 m	64.919 m	Not available
Pier 7	555.399 m	63.536 m	Not available

Figure 41. The Marcos Bridge as-built survey data.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on July 15, 19, 20, 22, 23, and 24, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted at the side of a vehicle as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 1.588 m and 1.945 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 ABR-32 and AB-33 occupied as the GNSS base stations in the conduct of the survey.

Figure 42. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The survey started from Brgy. Quinarayan, Municipality of Narvacan went north east traversing five municipalities in Abra namely: San Quintin, Pidigan, Bangued, La Paz, and ending in Brgy. Nagaparan, Municipality of Danglas. Another strip started from Brgy. Zone 5 Pobacion, in Municipality of Bangued, went east and traversed the Municipalities of Tayum, Dolores, Lagangilang and ended in Brgy. Bonglo, Municipality of Licuan-Baay. The survey gathered a total of 7,213 points with approximate length of 82 km using ABR-32 and AB-33 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 43.

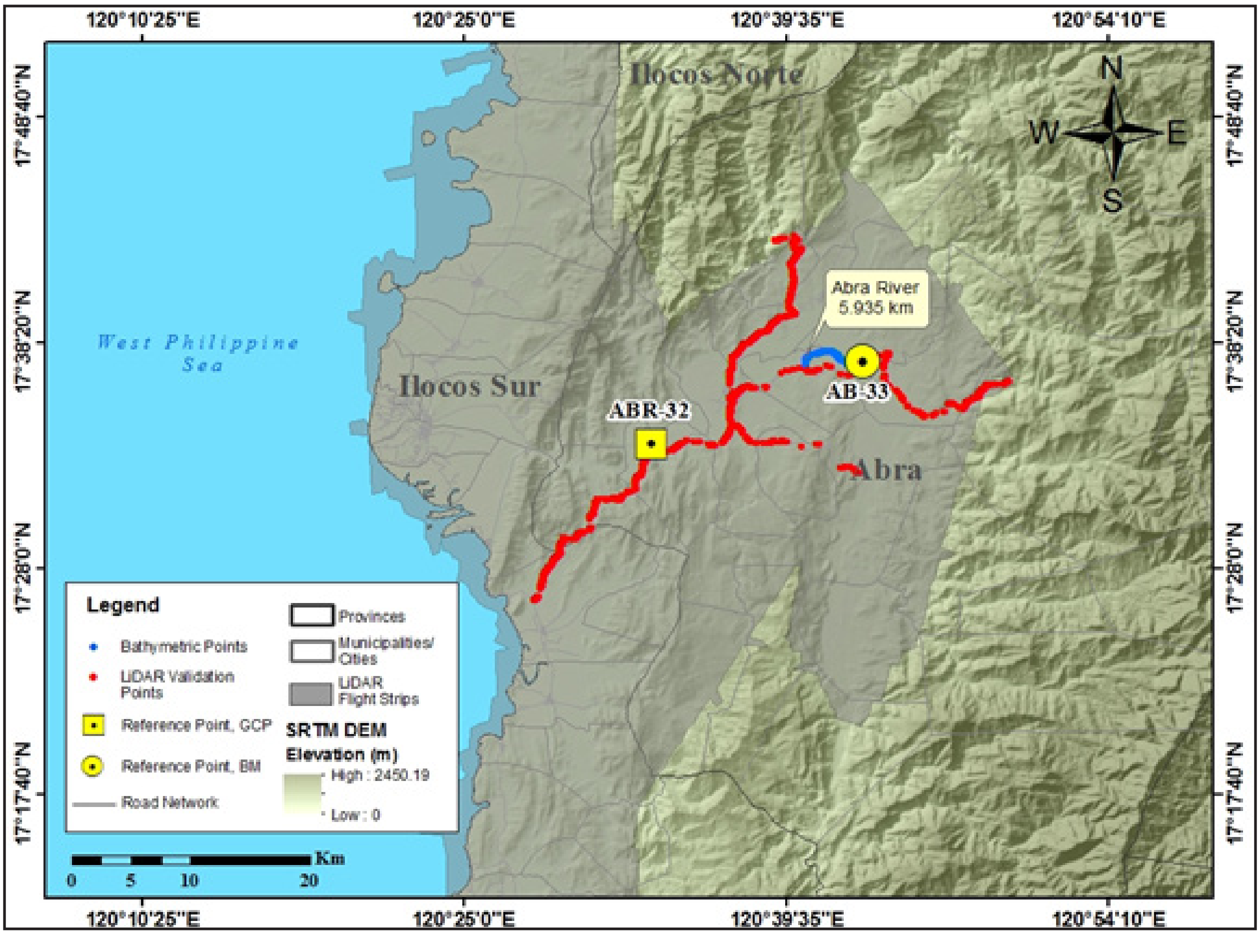


Figure 43. The extent of the LiDAR ground validation survey (in red) for Abra River Basin.

4.7 River Bathymetric Survey

A bathymetric survey was performed on July 24, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode and Ohmex™ single beam echo sounder, as illustrated in Figure 44. The extent of the survey is from Brgy. Lagben, Municipality of Lagangilang with coordinates 17°37’29.28065”N, 120°43’11.19712”E, and ended in Brgy. Gaddani, Municipality of Tayum with coordinates 17°37’22.59140”N, 120°40’25.99512”E, as shown in the map in Figure 45. The control point AB-33 was used as the GNSS base station throughout the entire survey.

Figure 44. Set up of the bathymetric survey at Abra River using Ohmex™ single beam echo sounder.

Overall, the bathymetric survey for Abra River gathered a total of 4,134 points covering 5.935 km of the river traversing four (4) barangays in Municipalities of Lagangilang and Tayum, in Abra. To further illustrate this, a CAD drawing of the riverbed profile of the Abra River was produced. As seen in Figure 46, the highest and lowest elevation has a 13.765-m difference. The highest elevation observed was 49.872 m above MSL located at Brgy. Lagben, Municipality of Lagangilang; while the lowest was 36.107 m in MSL located at the downstream portion of the river in Brgy. Bumagcat, Municipality of Tayum. The delineated length of 49 km was no longer surveyed because it already has LiDAR Data.

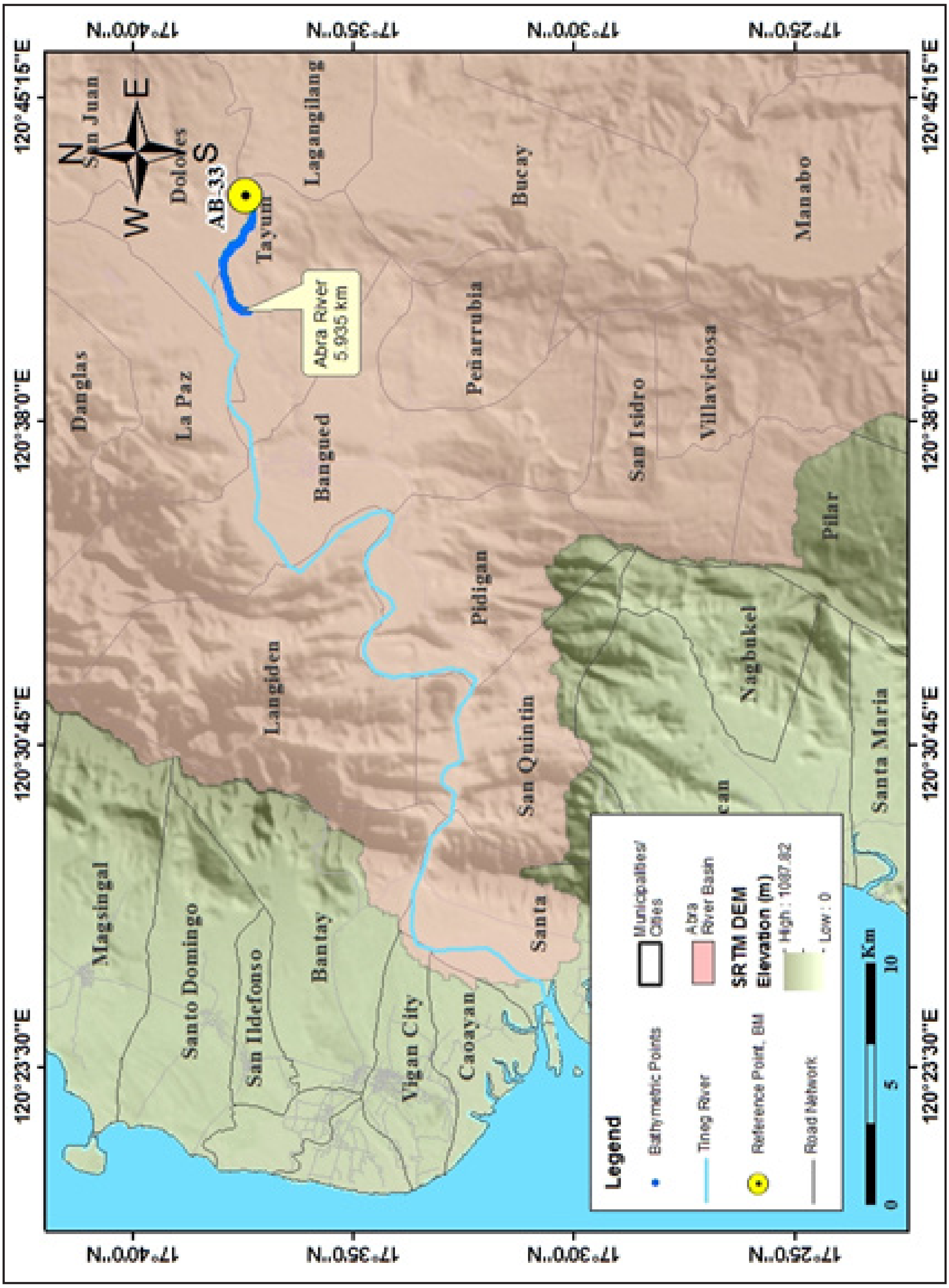


Figure 45. The extent of the Abra River Bathymetry Survey.

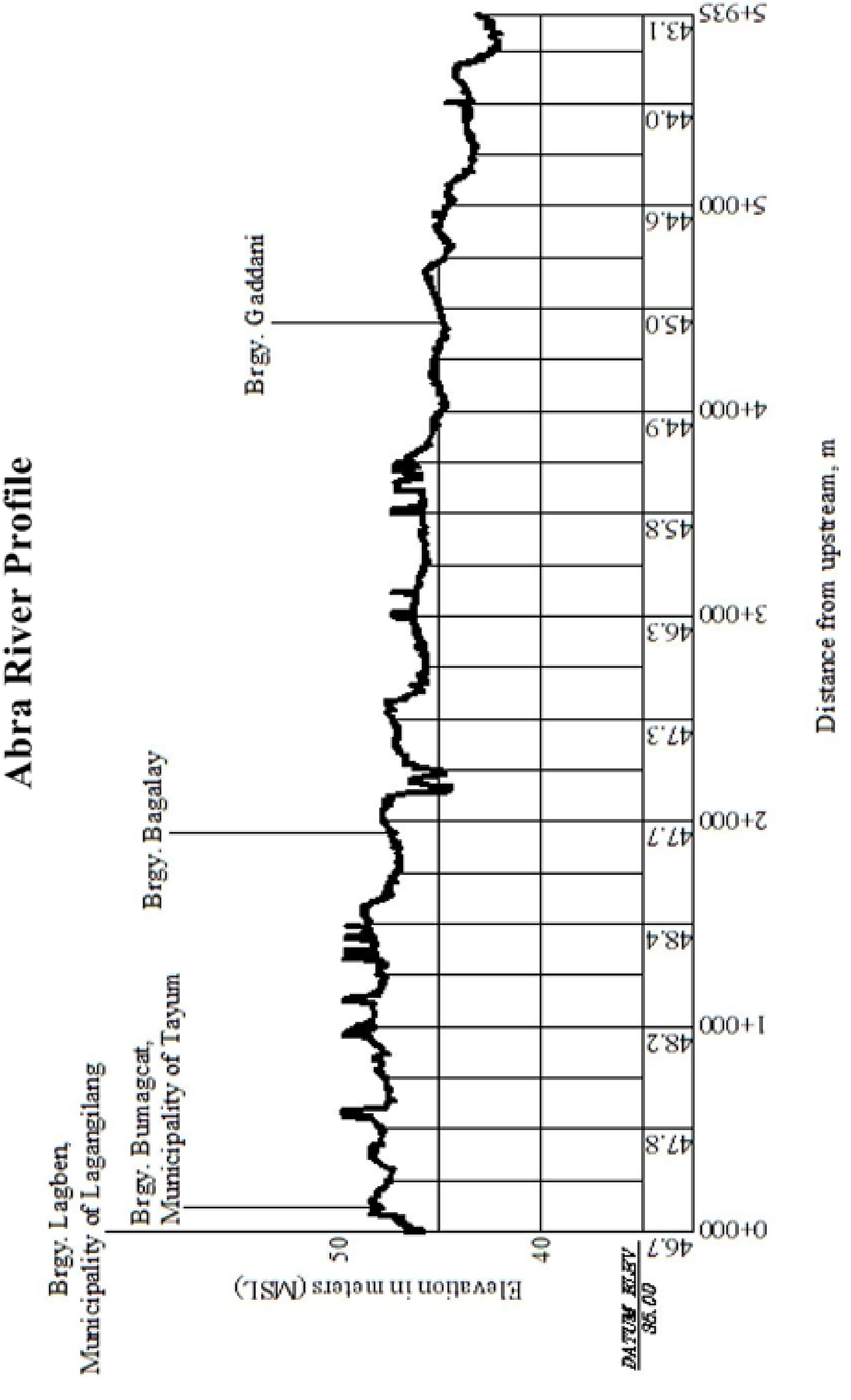


Figure 46. The Abra Riverbed Profile.

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

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Abra 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 Lagayan ARG (17°43'11.6472'' N, 120°42'21.3912'' E), located in Lagayan, Abra, as illustrated in Figure 47. The precipitation data collection started from August 20, 2015 at August 26, 2015 at 11:45 PM with a 15-minute recording interval.

The total precipitation for this event during Typhoon Ineng, in Lagayan ARG was 612.40 mm. It has a peak rainfall of 20.6 mm. on August 21, 2015 at 1:45 AM. The lag time between the peak rainfall and discharge is 22 hours and 55 minutes.

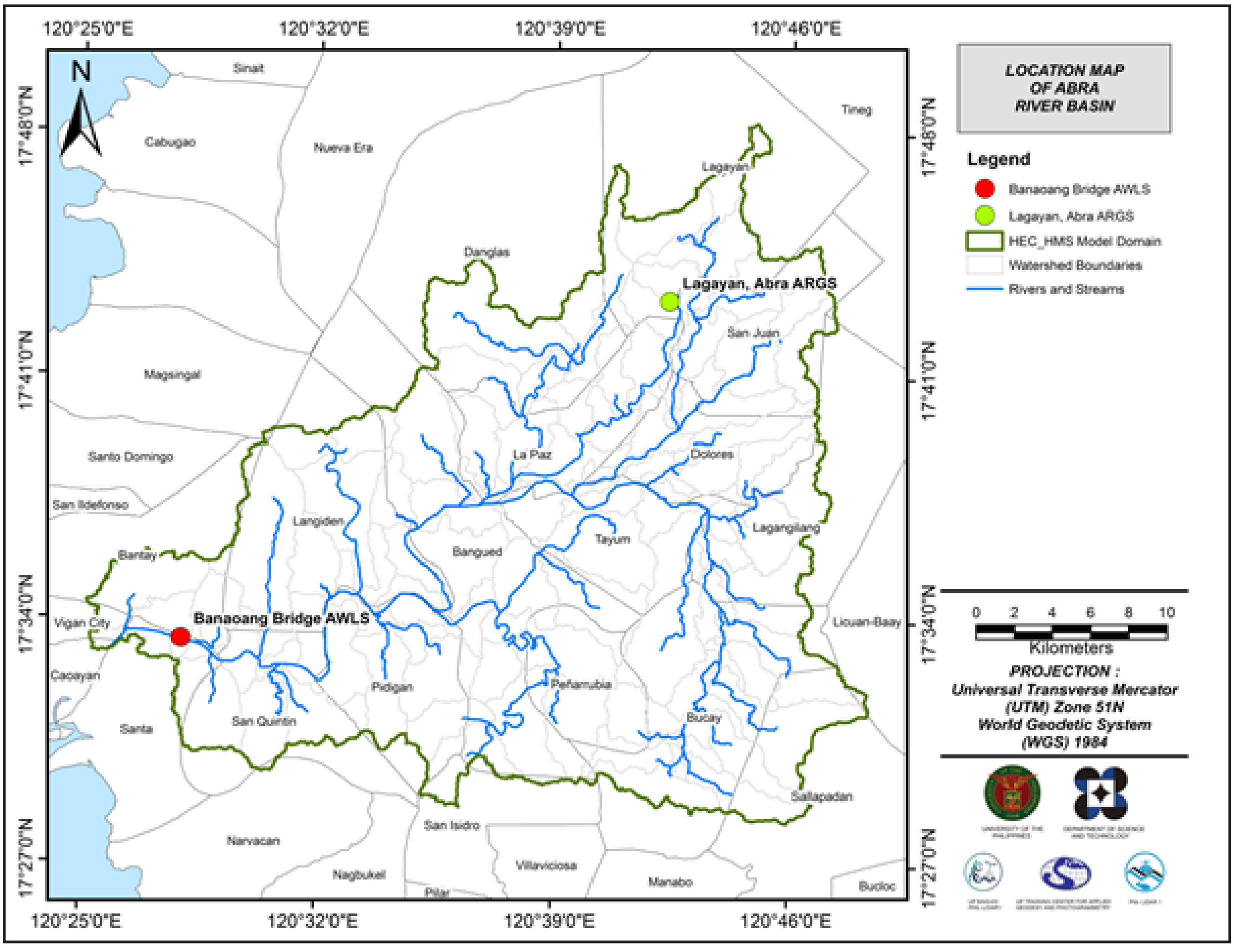


Figure 47. Location Map of the Abra HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48) at Banaoang Bridge or Old Quirino Bridge, Santa, Ilocos Sur (17°33'30.792" N, 120°27'58.254" E) to establish the relationship between the observed water levels (H) from Banaoang Bridge and the outflow (Q) of the watershed at this location.

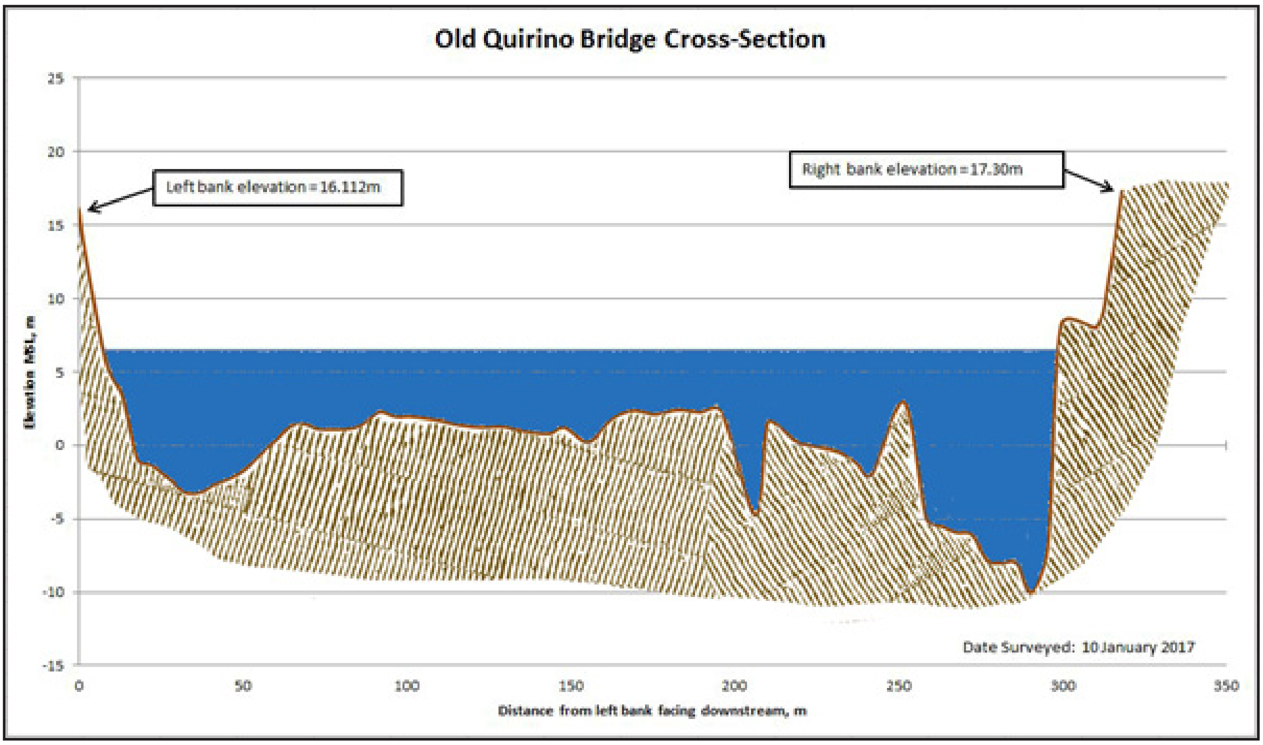


Figure 48. Cross-Section Plot of Banaong Bridge or Old Quirino Bridge.

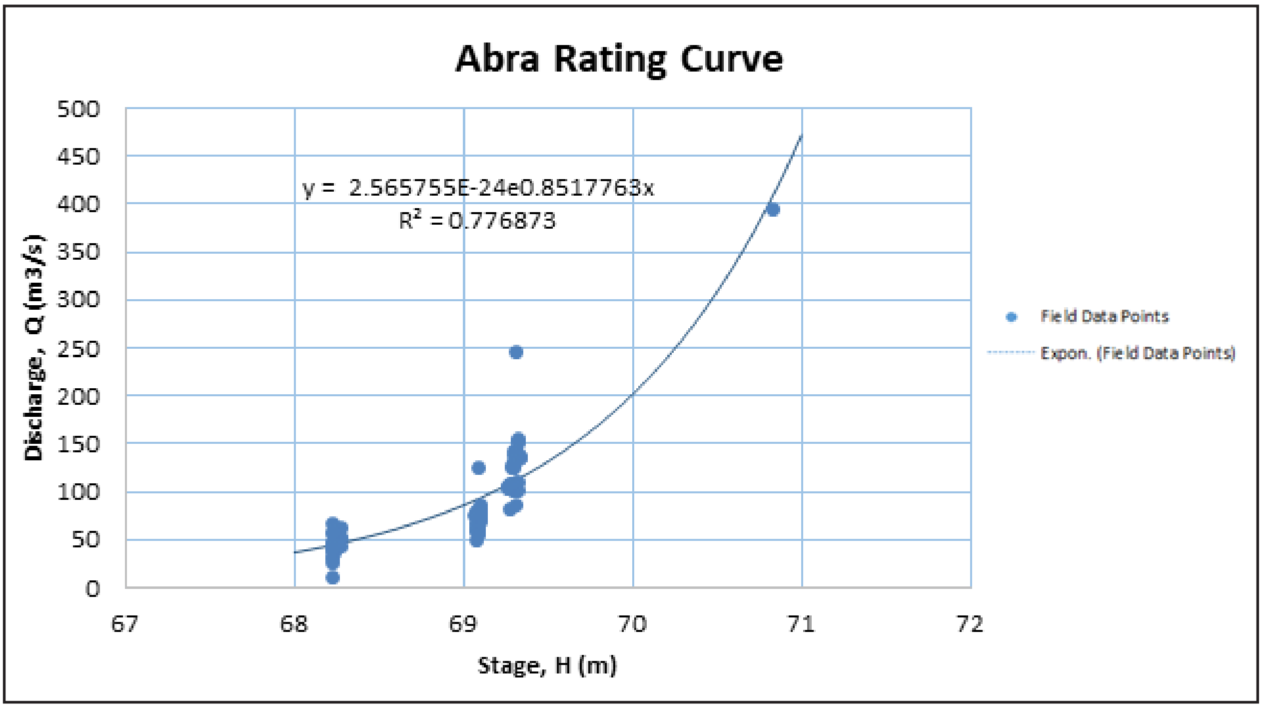


Figure 49. The rating curve at Banaoang Bridge, Santa, Ilocos Sur.

This rating curve equation was used to compute the river outflow at Banaoang Bridge for the calibration of the HEC-HMS model for Abra as shown in Figure 50. The total rainfall for this event is 612.40 mm and the peak discharge is 1526.29 m3/s at 12:40 PM of August 22, 2015.

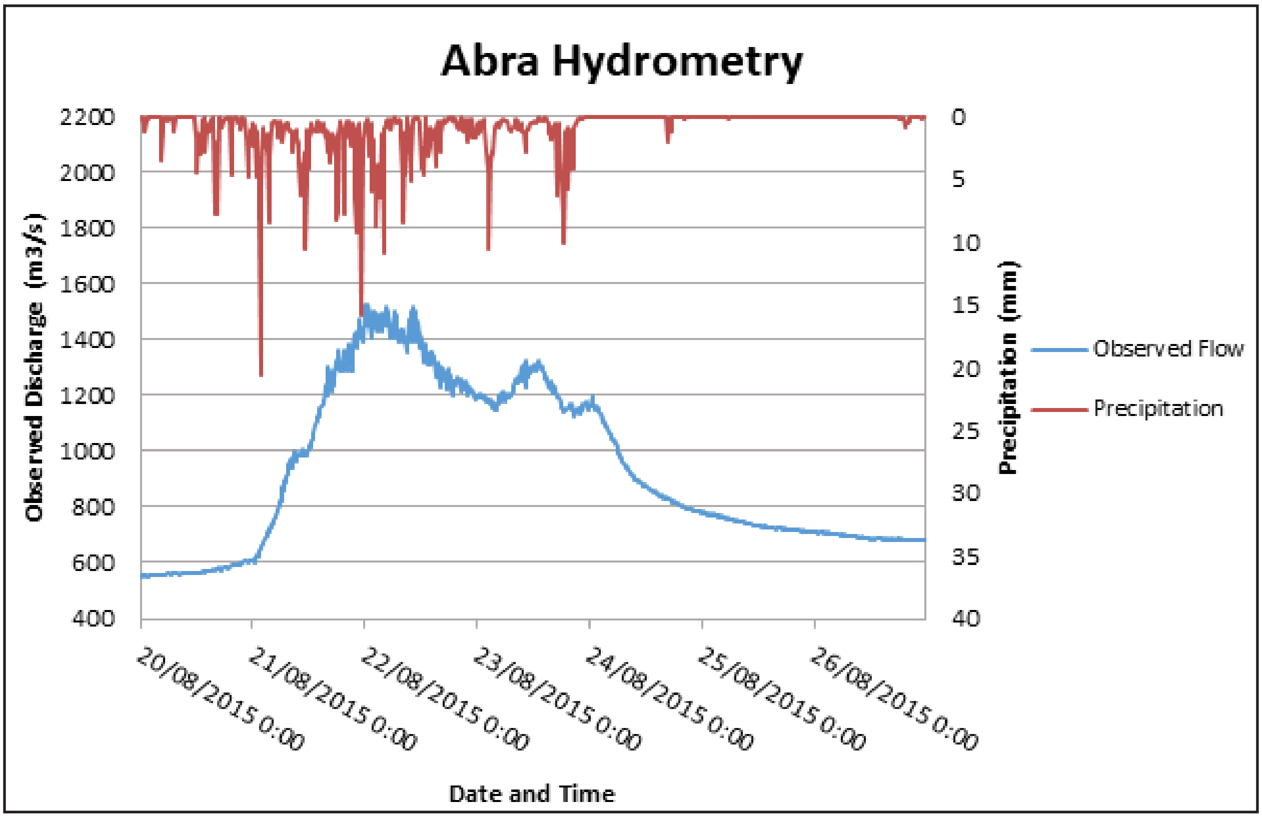


Figure 50. Rainfall and outflow data at Banaoang Bridge, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Laoag Rain Gauge (Table 30). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 51). This station was selected based on its proximity to the Abra watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 30. RIDF values for the Laoag Rain Gauge, as 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

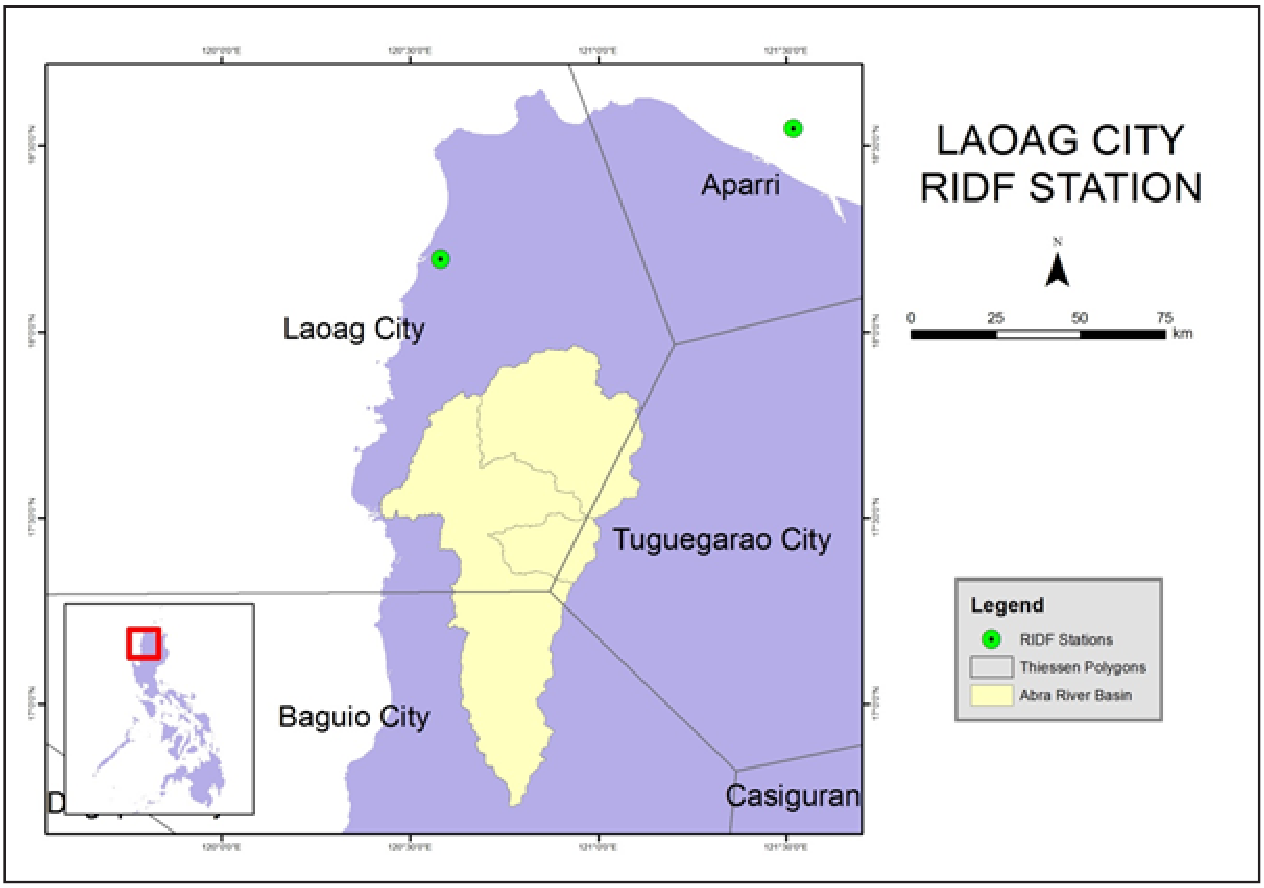


Figure 51. Location of Laoag RIDF Station relative to Abra River Basin.

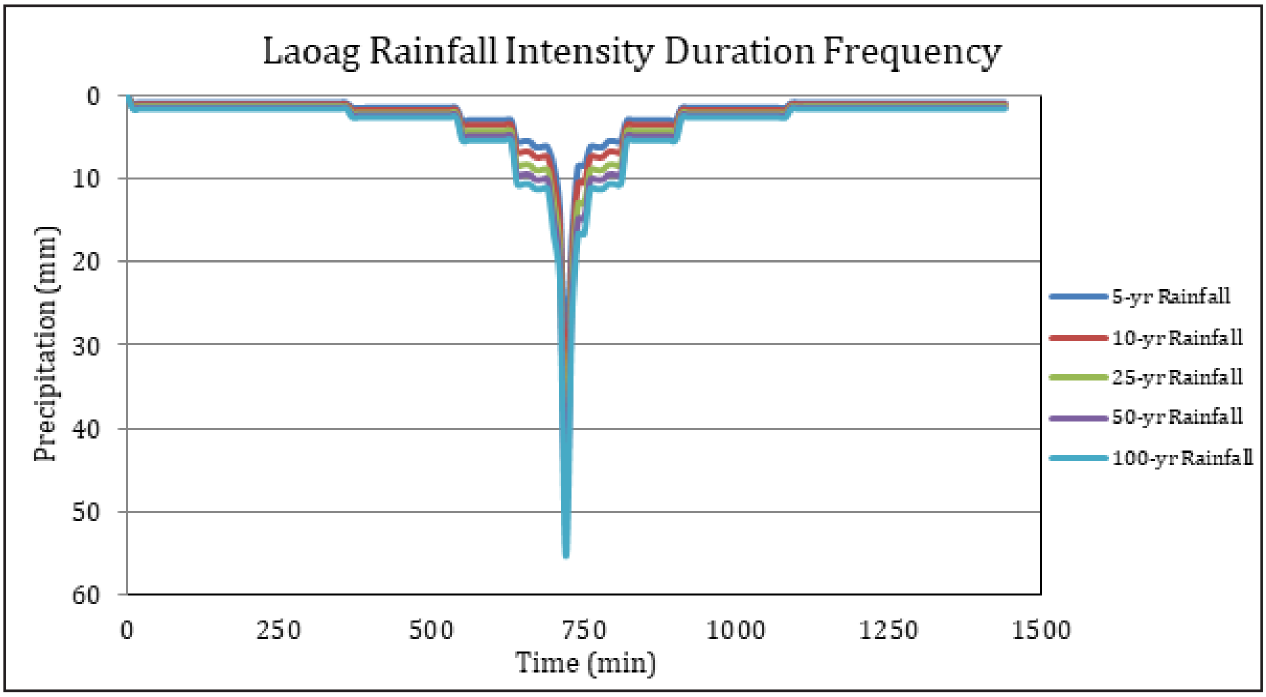


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils under the Department of Environment and Natural Resources Management. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Abra River Basin are shown in Figure 53 and Figure 54, respectively.

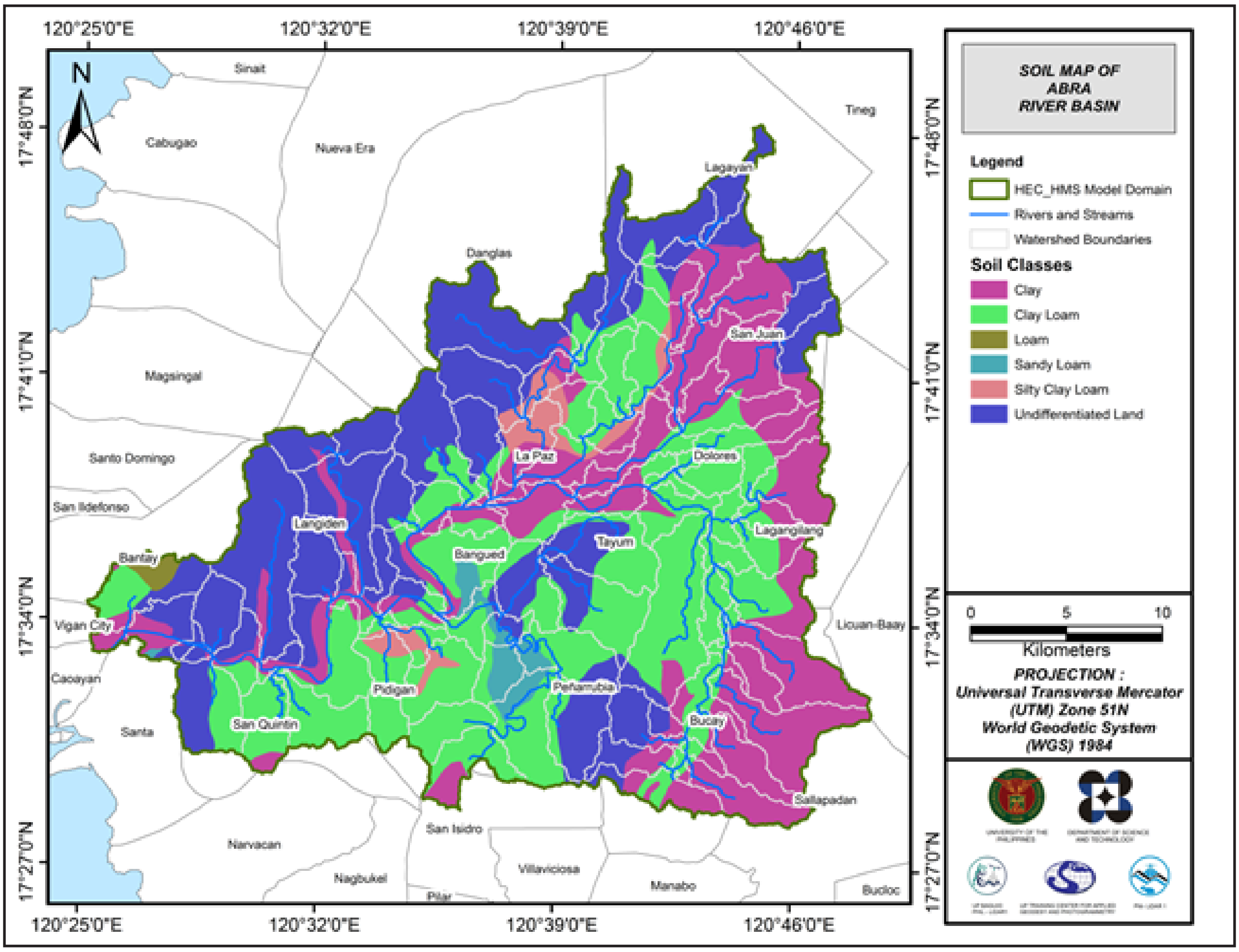


Figure 53. Soil Map of Abra River Basin.

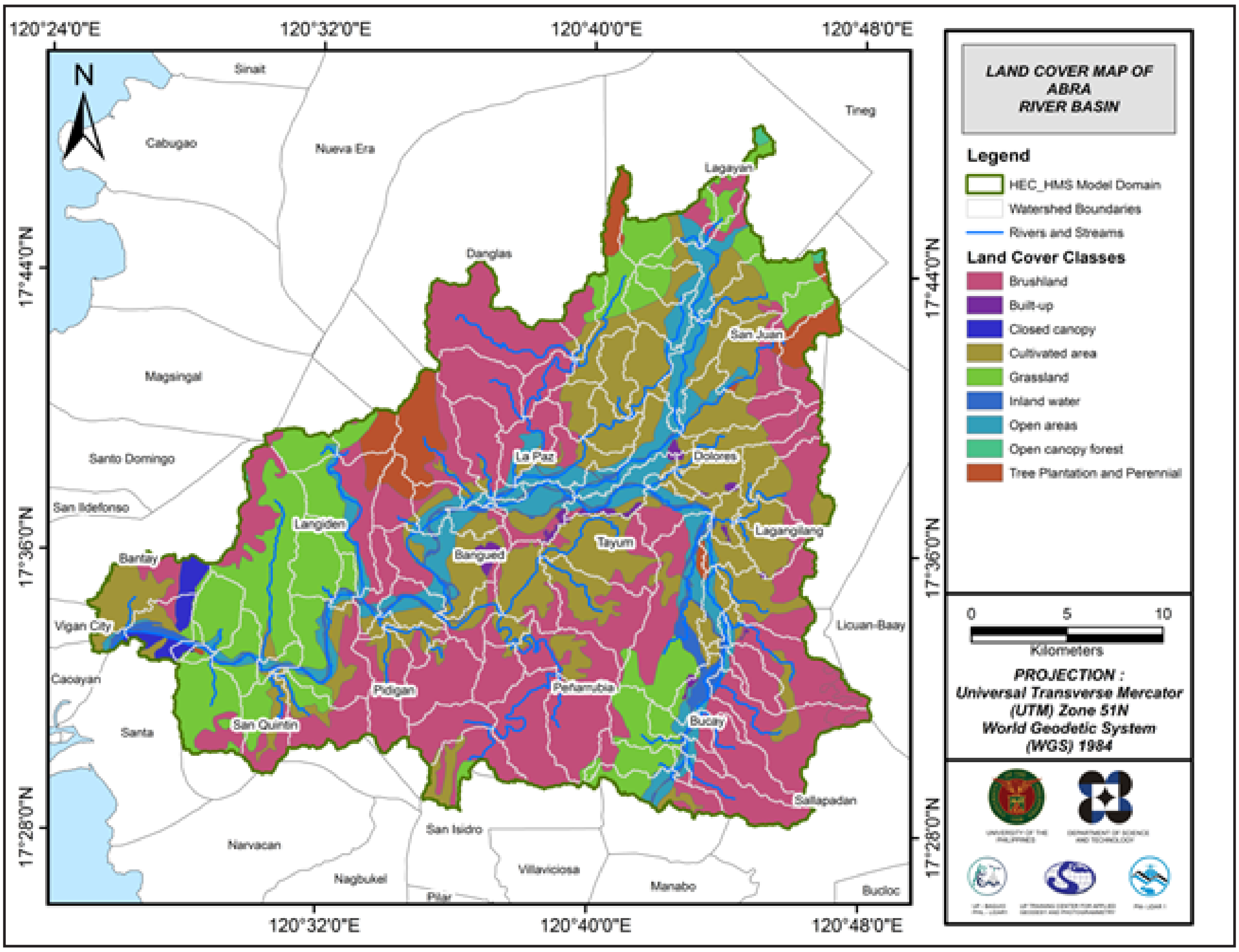


Figure 54. Land Cover Map of Abra River Basin.

For Abra, six (6) soil classes were identified. These are clay, clay loam, loam, sandy loam, silty clay loam and undifferentiated land. Moreover, nine (9) land cover classes were identified. These are brushlands, built-up areas, closed canopy, cultivated areas, grasslands, inland water, open areas, open canopy forests, and tree plantations.

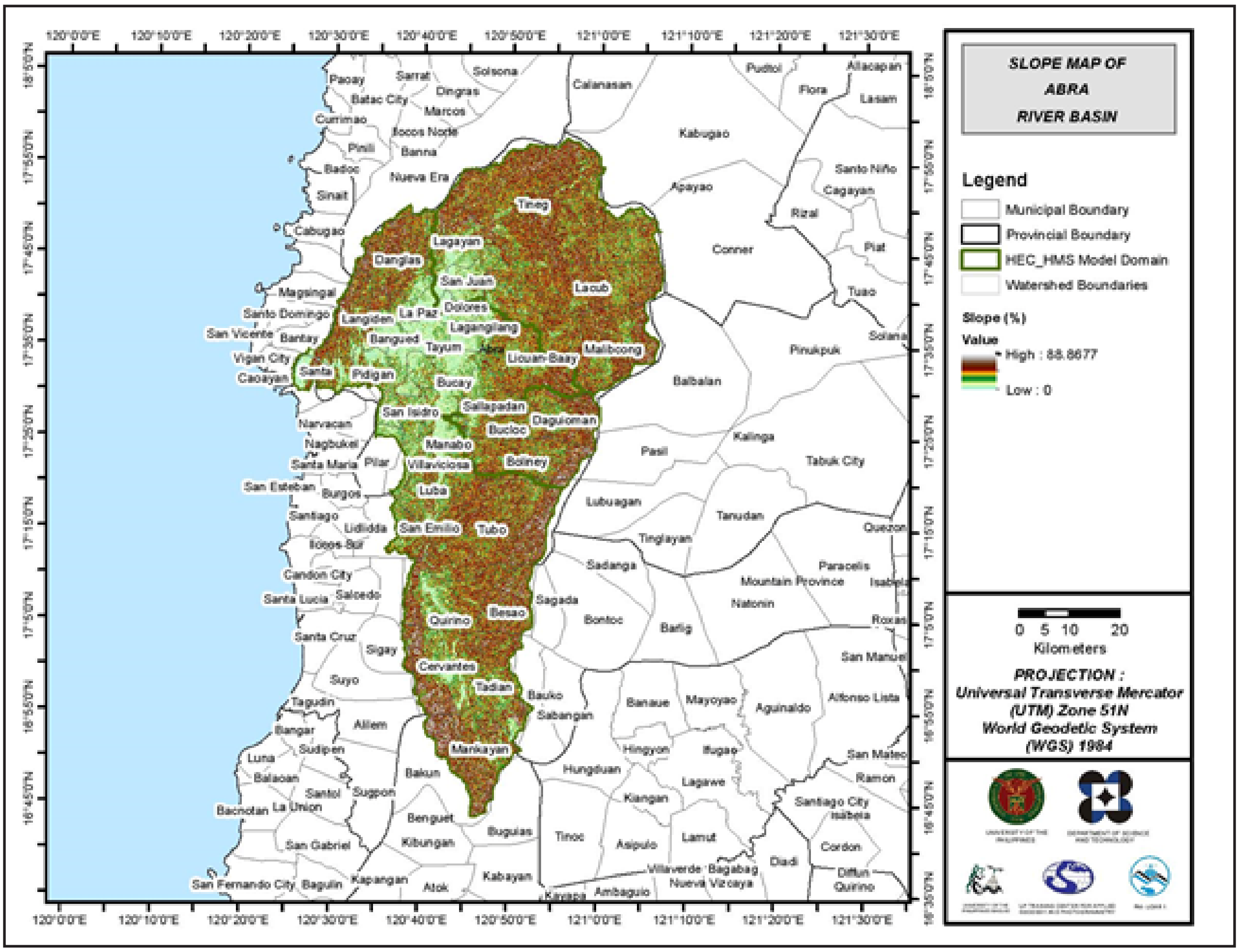


Figure 55. Slope Map of the Abra River Basin.

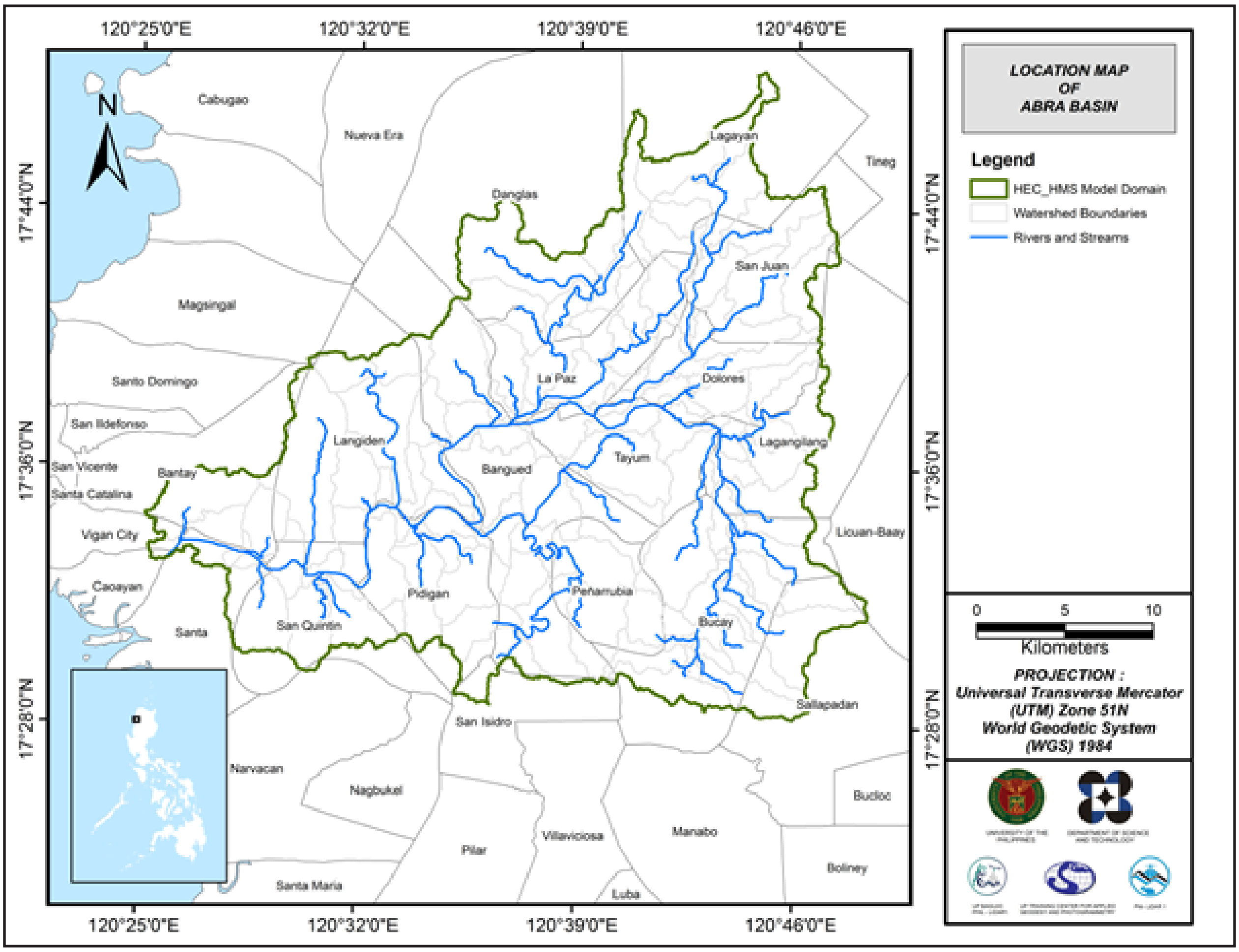


Figure 56. Stream Delineation Map of Abra River Basin

Using the SAR-based DEM, the Abra basin was delineated and further subdivided into subbasins. The model consists of 101 sub basins, 54 reaches, and 54 junctions as shown in Figure 57 (See Annex 10). The main outlet is at 335.

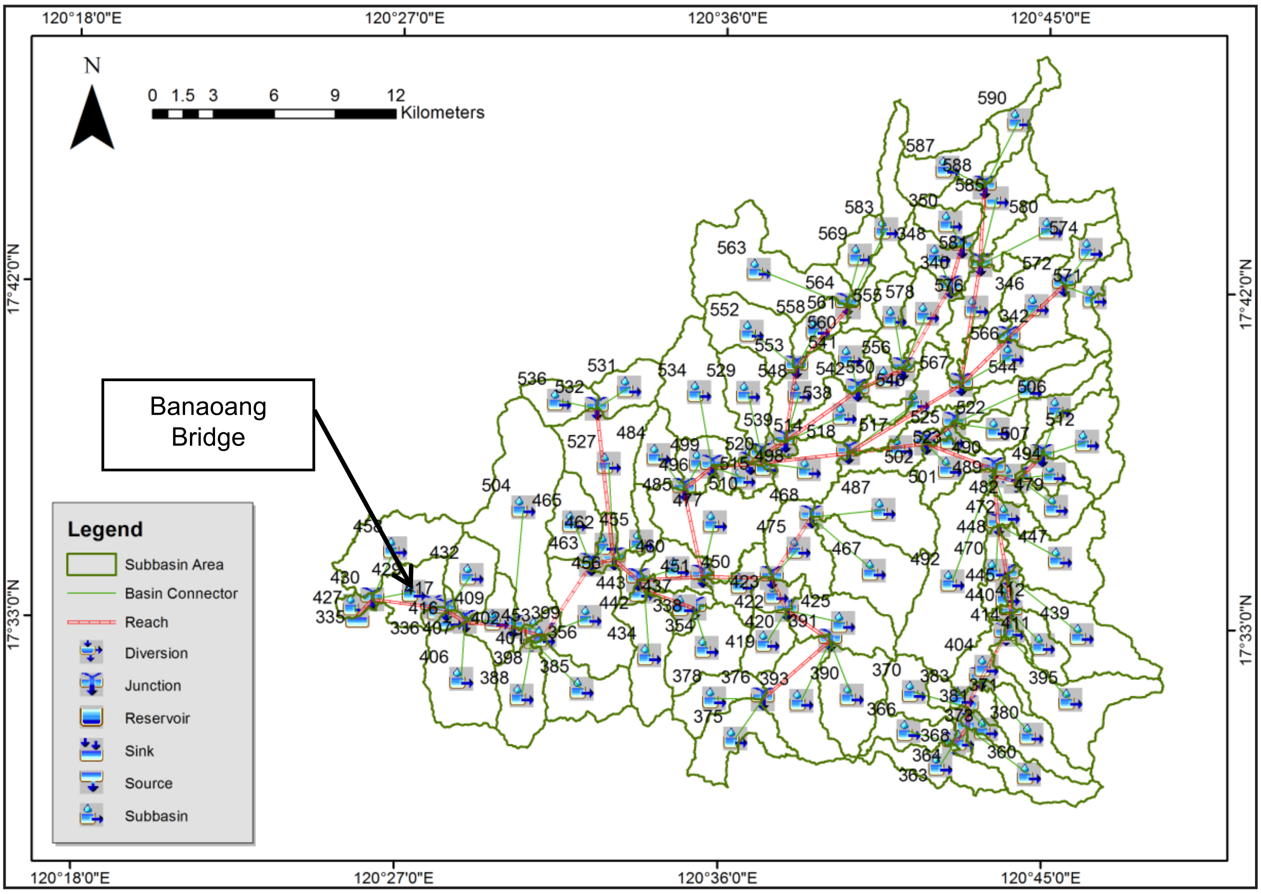


Figure 57. Abra river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 58).

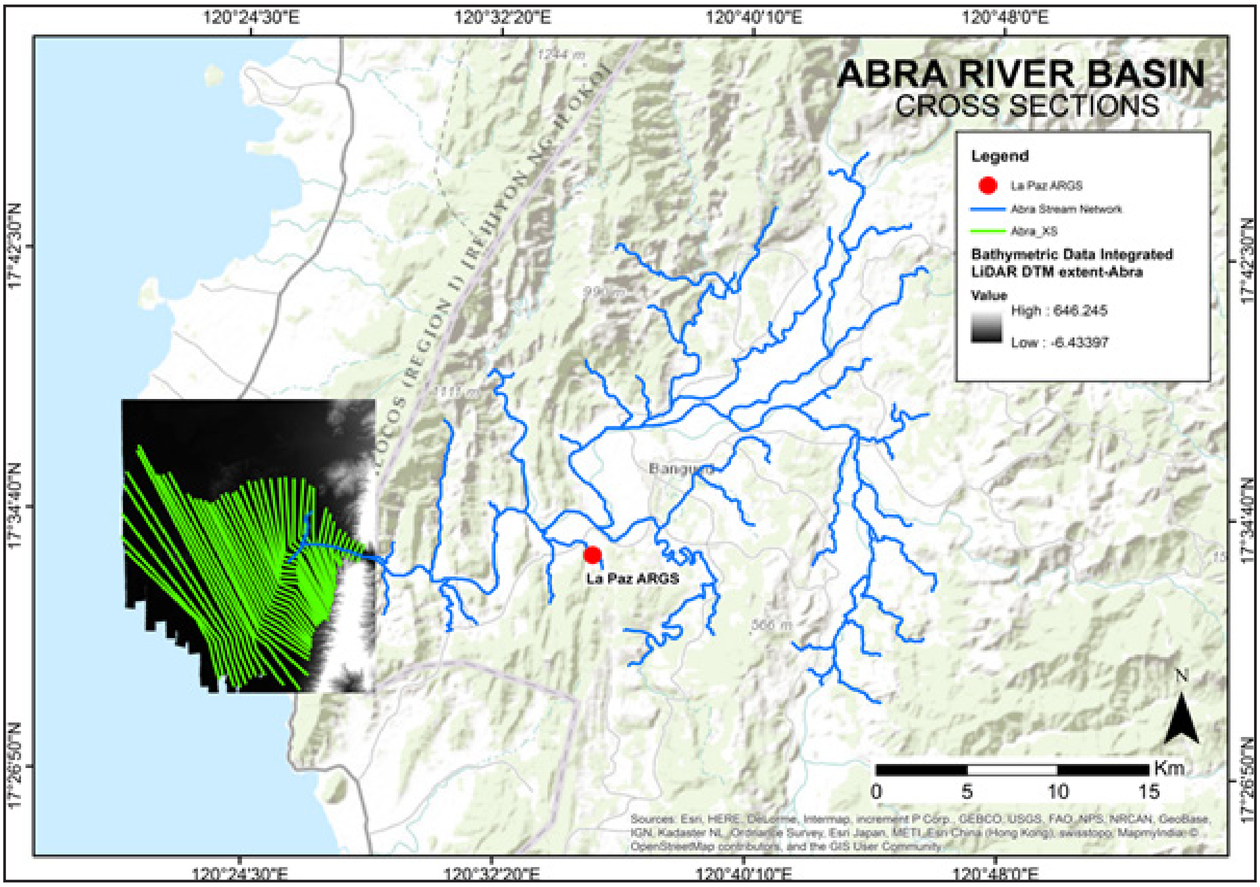


Figure 58. River cross-section of the Abra River through the ArcMap HEC GeoRas tool.

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

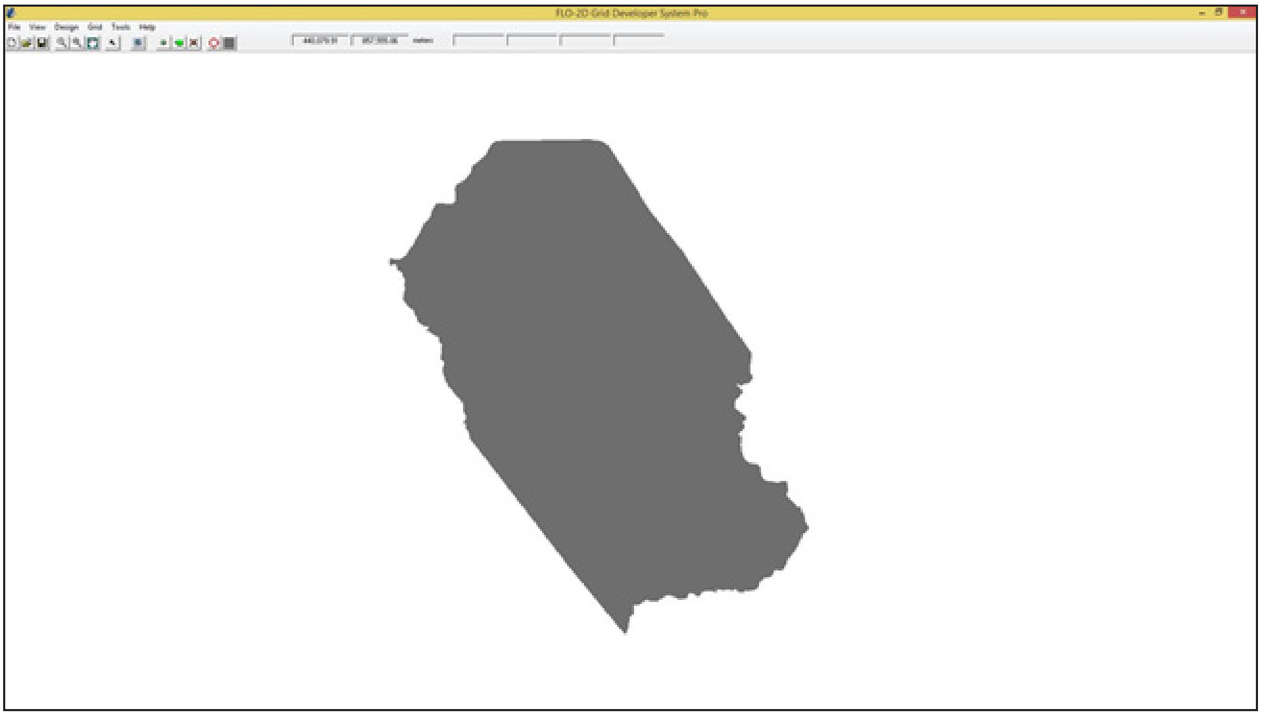


Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 100.06329 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 Abra are in Figure 66, 68, and 70.

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 63 792 800.00 m2. The generated flood depth maps for Abra are in Figure 67, 69, and 71.

There is a total of 465 228 177.98 m3 of water entering the model. Of this amount, 25 253 779.51 m3 is due to rainfall while 439 974 398.47 m3 is inflow from other areas outside the model. 11 329 565.00 m3 of this water is lost to infiltration and interception, while 24 641 579.81 m3 is stored by the flood plain. The rest, amounting up to 429 257 024.59 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Abra HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

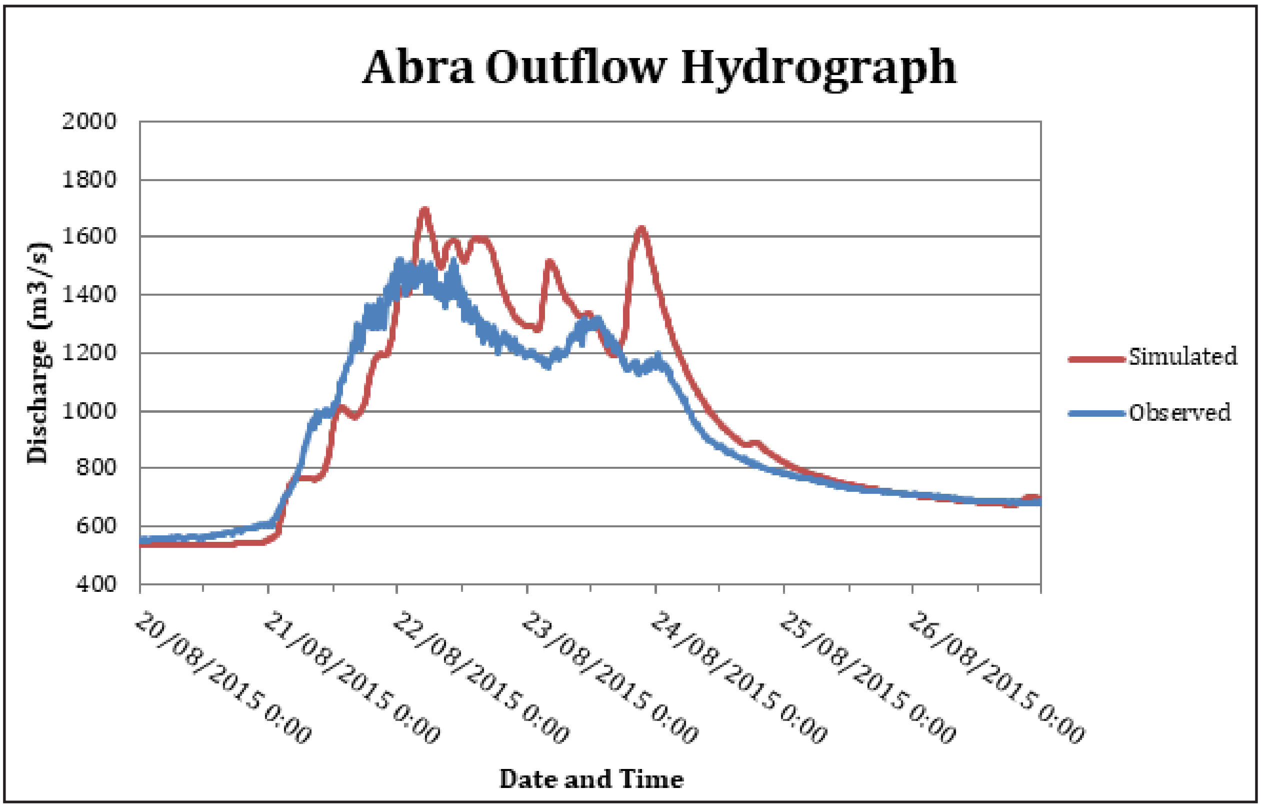


Figure 60. Outflow Hydrograph of Abra produced by the HEC-HMS model compared with observed outflow.

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

Table 31. Range of calibrated values for the Abra River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.734 - 134.09
			Curve Number	35.055 – 51.768
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.01667 – 0.385
			Storage Coefficient (hr)	0.989 – 45.704
	Baseflow	Recession	Recession Constant	0.667 - 1
			Ratio to Peak	0.23 – 0.5145
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.00167 – 0.00375

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.734 mm to 134.09 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 Abra, the basin consists mainly of brushlands, grasslands, and cultivated areas and the soil consists of mostly undifferentiated land, clay loam, 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 0.01667 hours to 45.704 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 0.667 to 1 indicate that the basin is unlikely to quickly go back to its original discharge. Values of ratio to peak within the range of 0.23 to 0.5145 indicate a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Abra river basin reaches' Manning's coefficients range from 0.00167 to 0.00375, showing that there is variety in surface roughness all over the catchment.

Table 32. Summary of the Efficiency Test of the Abra HMS Model

Accuracy measure	Value
RMSE	133.3
r^2	0.8831
NSE	0.79
PBIAS	-3.81
RSR	0.46

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 133.30 (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 0.8831.

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 0.79.

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 -3.81.

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 0.46.

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 61) shows the Abra 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 (PAG-ASA) data. The simulation results show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

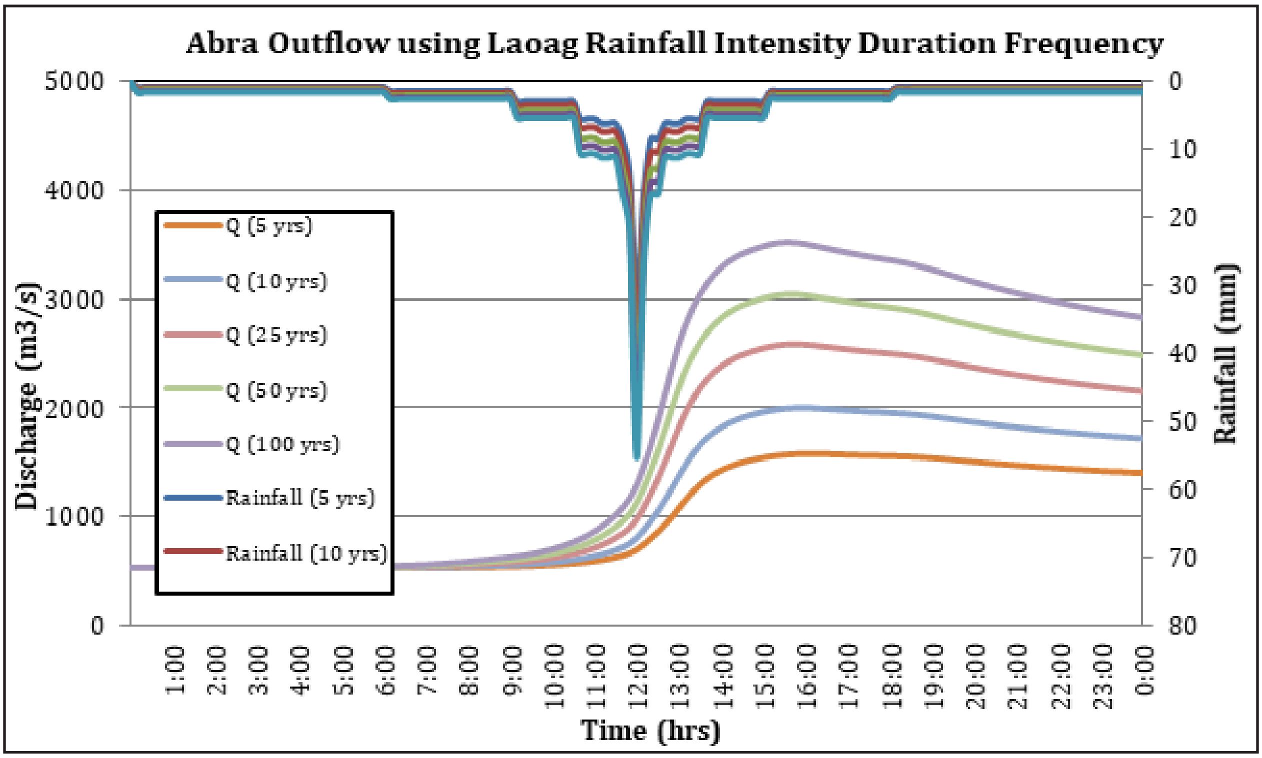


Figure 61. The Outflow hydrograph at the Abra Station, generated using the Laoag RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Abra discharge using the Laoag Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33. The peak values of the Abra HEC-HMS Model outflow using the Maasin RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	331.7	31.4	1582.9	4 hours
10-Year	397.1	37.2	2002.3	3 hours, 50 minutes
25-Year	479.8	44.5	2584.5	3 hours, 40 minutes
50-Year	541.1	50	3042.8	3 hours, 40 minutes
100-Year	602	55.3	3518.4	3 hours, 40 minutes

5.7.2 Discharge Data Using Dr. Horritt's Recommended Hydrologic Method

The river discharge values for the three rivers entering the floodplain are shown in Figure 62 to Figure 64 and the peak values are summarized in Table 34 to Table 36.

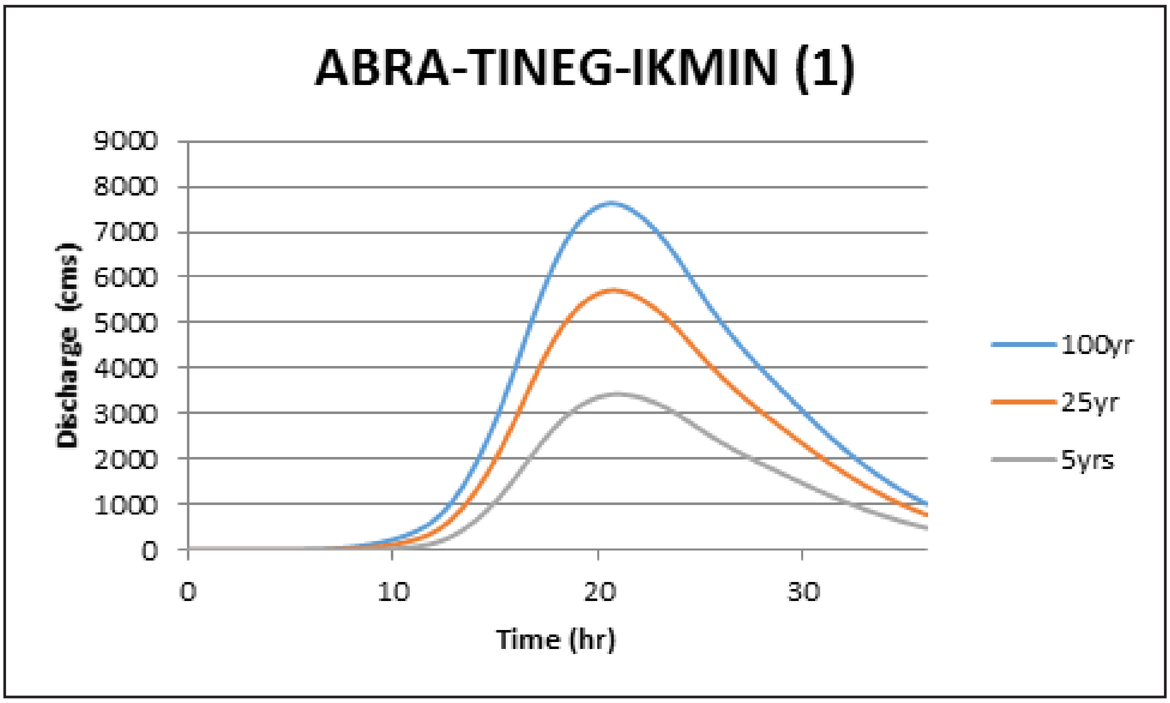


Figure 62. Abra-Tineg-Ikmin river (1) generated discharge using 5-, 25-, and 100-year Laoag rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

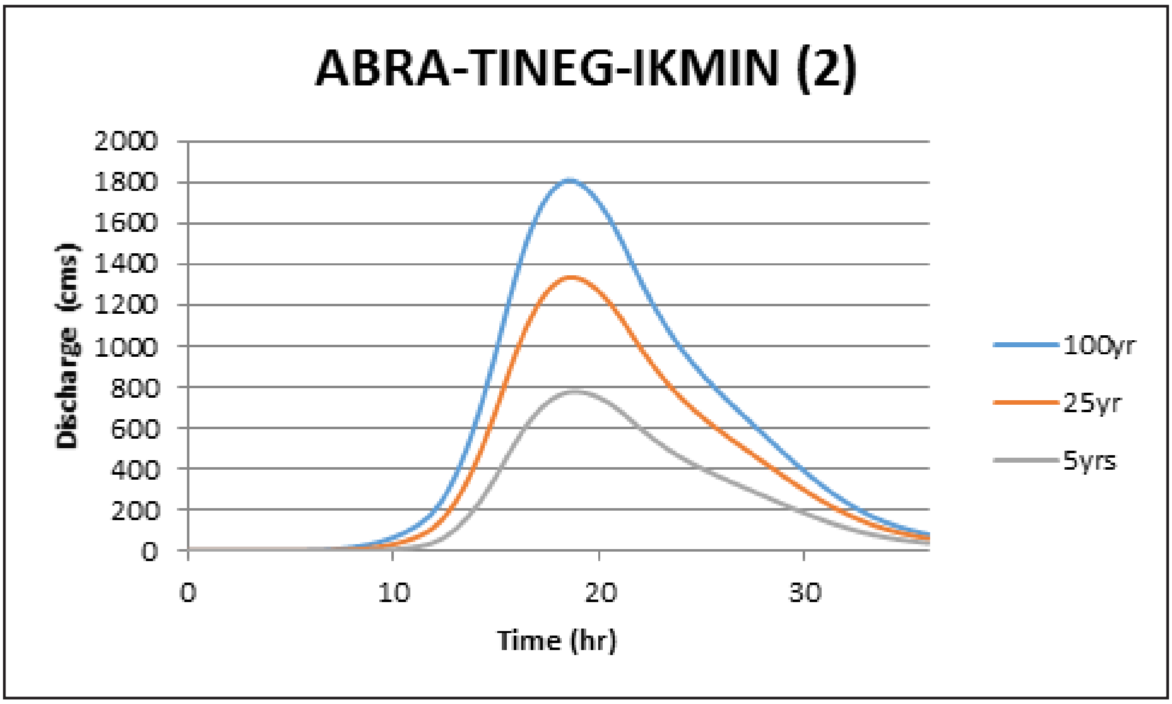


Figure 63. Abra-Tineg-Ikmin river (2) generated discharge using 5-, 25-, and 100-year Laoag rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

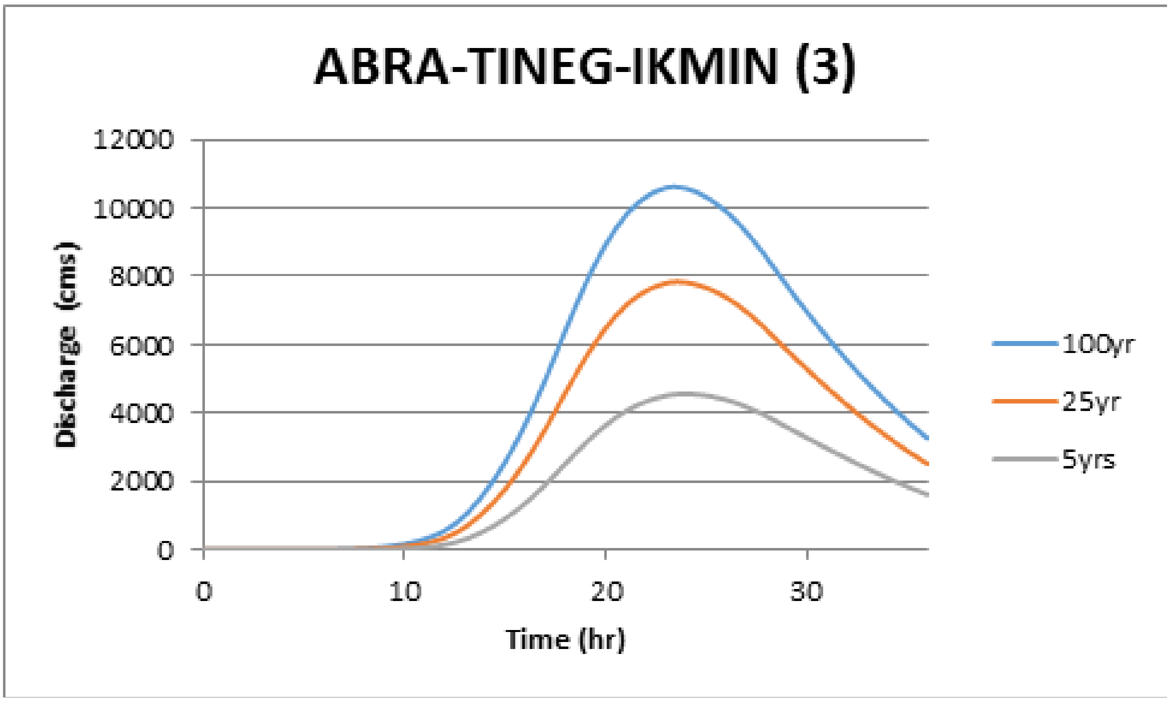


Figure 64. Abra-Tineg-Ikmin river (3) generated discharge using 5-, 25-, and 100-year Laoag rainfall intensity-duration-frequency (RIDF) in HEC-HMS.

Table 34. Summary of Abra-Tineg-Ikmin river (1) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	7629	20 hours, 40 minutes
25-Year	5712.8	20 hours, 40 minutes
5-Year	3429.4	20 hours, 50 minutes

Table 35. Summary of Abra-Tineg-Ikmin river (2) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1808.6	18 hours, 30 minutes
25-Year	1335.7	18 hours, 40 minutes
5-Year	777.7	18 hours, 50 minutes

Table 36. Summary of Abra-Tineg-Ikmin river (3) discharge generated in HEC-HMS.

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	10623.6	23 hours, 20 minutes
25-Year	7840.6	23 hours, 30 minutes
5-Year	4561.3	24 hours

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 37.

Table 37. Validation of river discharge estimates.

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Abra-Tineg-Ikmin (1)	3017.872	1614.315	2473.269	Fail	Pass
Abra-Tineg-Ikmin (2)	684.376	26169.898	1093.832	Fail	Pass
Abra-Tineg-Ikmin (3)	4013.944	10866.502	3157.446	Fail	Pass

The results from the HEC-HMS river discharge estimates were not able to satisfy the conditions for validation using the bankful and specific discharge methods. The values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. Figure 65 shows a generated sample map of the Abra River using the calibrated HMS base flow.

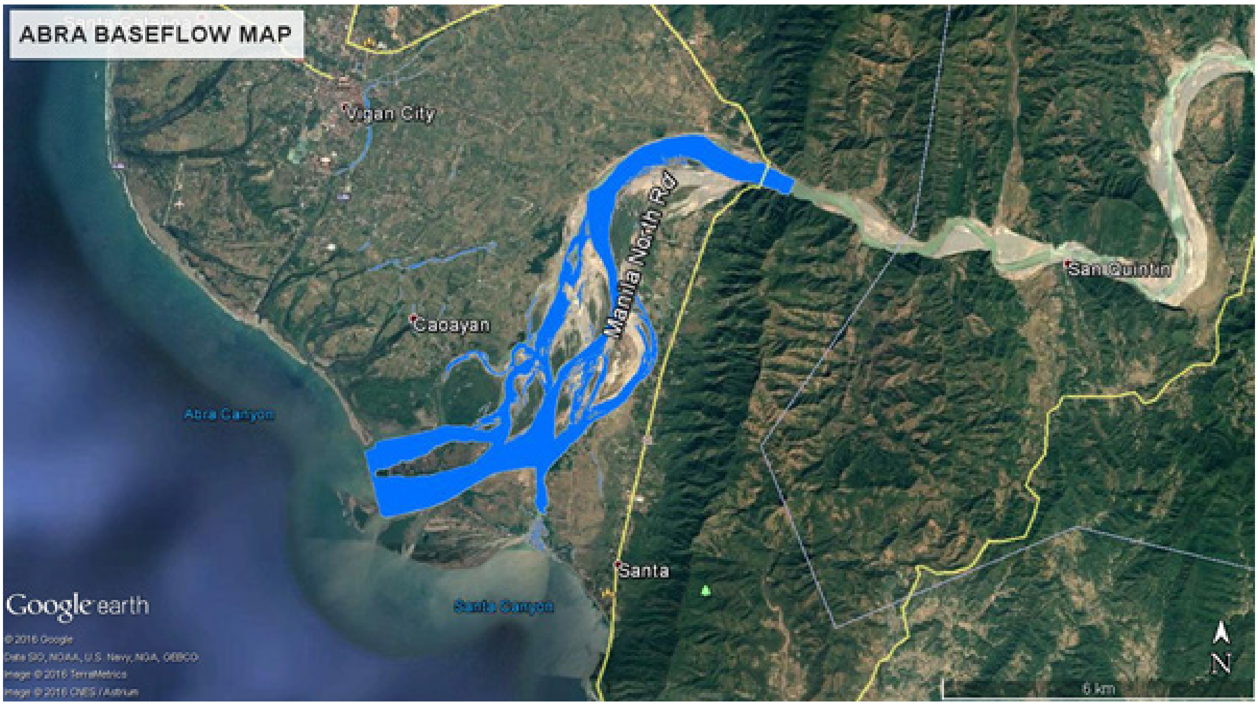


Figure 65. Sample output map of the Abra RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 show the 5-, 25-, and 100-year rain return scenarios of the Abra floodplain. The floodplain, with an area of 566.21 sq. km., covers 16 municipalities from three provinces. Table 38 shows the percentage of area affected by flooding per municipality.

Table 38. Municipalities affected in Ikmin Floodplain

Province	Municipality	Total Area	Area Flooded	% Flooded
Abra	San Quintin	62.29	44.19	70.94%
Abra	Bangued	123.75	30.88	24.96%
Abra	Langiden	98.70	87.67	88.82%
Abra	Pidigan	58.13	45.00	77.41%
Ilocos Norte	Nueva Era	619.00	3.54	0.57%
Ilocos Sur	Bantay	71.06	71.06	100.00%
Ilocos Sur	Caoayan	21.20	20.08	94.73%
Ilocos Sur	Magsingal	78.90	75.66	95.90%
Ilocos Sur	Narvacan	97.18	0.30	0.31%
Ilocos Sur	San Ildefonso	13.21	13.21	100.00%
Ilocos Sur	San Juan	59.88	42.08	70.28%
Ilocos Sur	San Vicente	12.20	12.20	100.00%
Ilocos Sur	Santa Catalina	10.83	8.09	74.65%
Ilocos Sur	Santa	57.20	35.91	62.78%
Ilocos Sur	Santo Domingo	50.36	50.36	99.99%
Ilocos Sur	Vigan City	24.01	23.44	97.66%

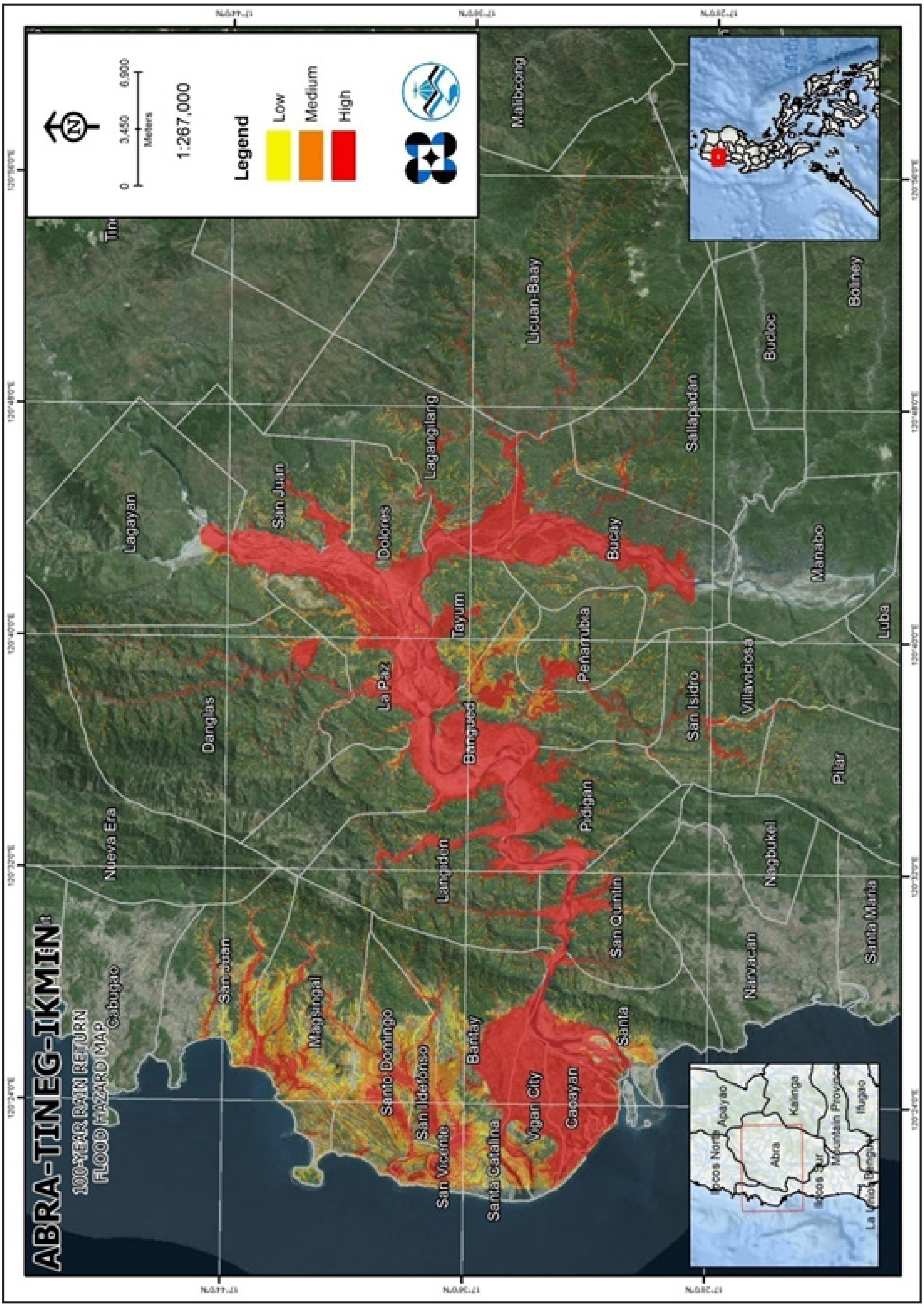


Figure 66. A 100-year Flood Hazard Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery.

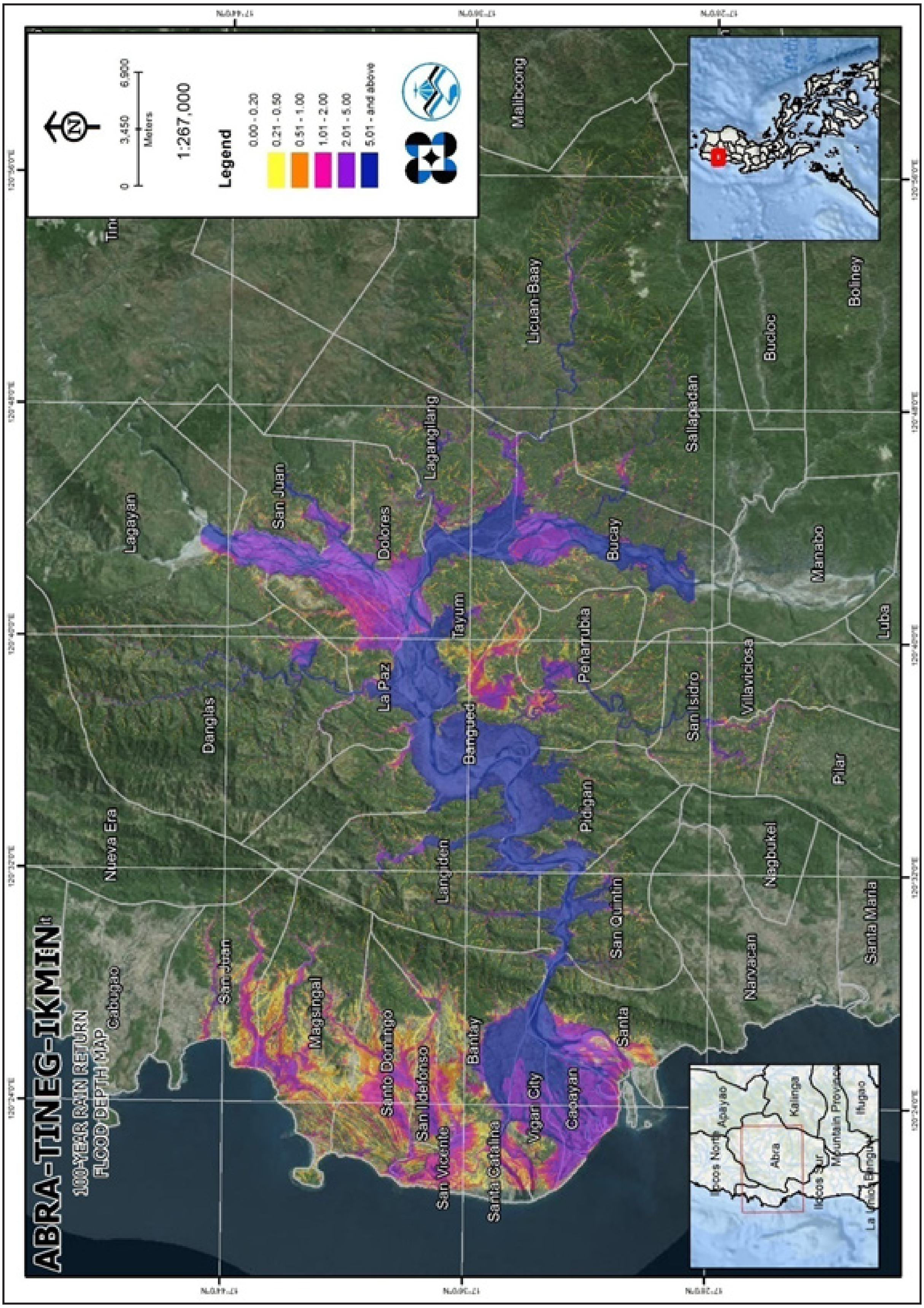


Figure 67. A 100-year Flow Depth Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery.

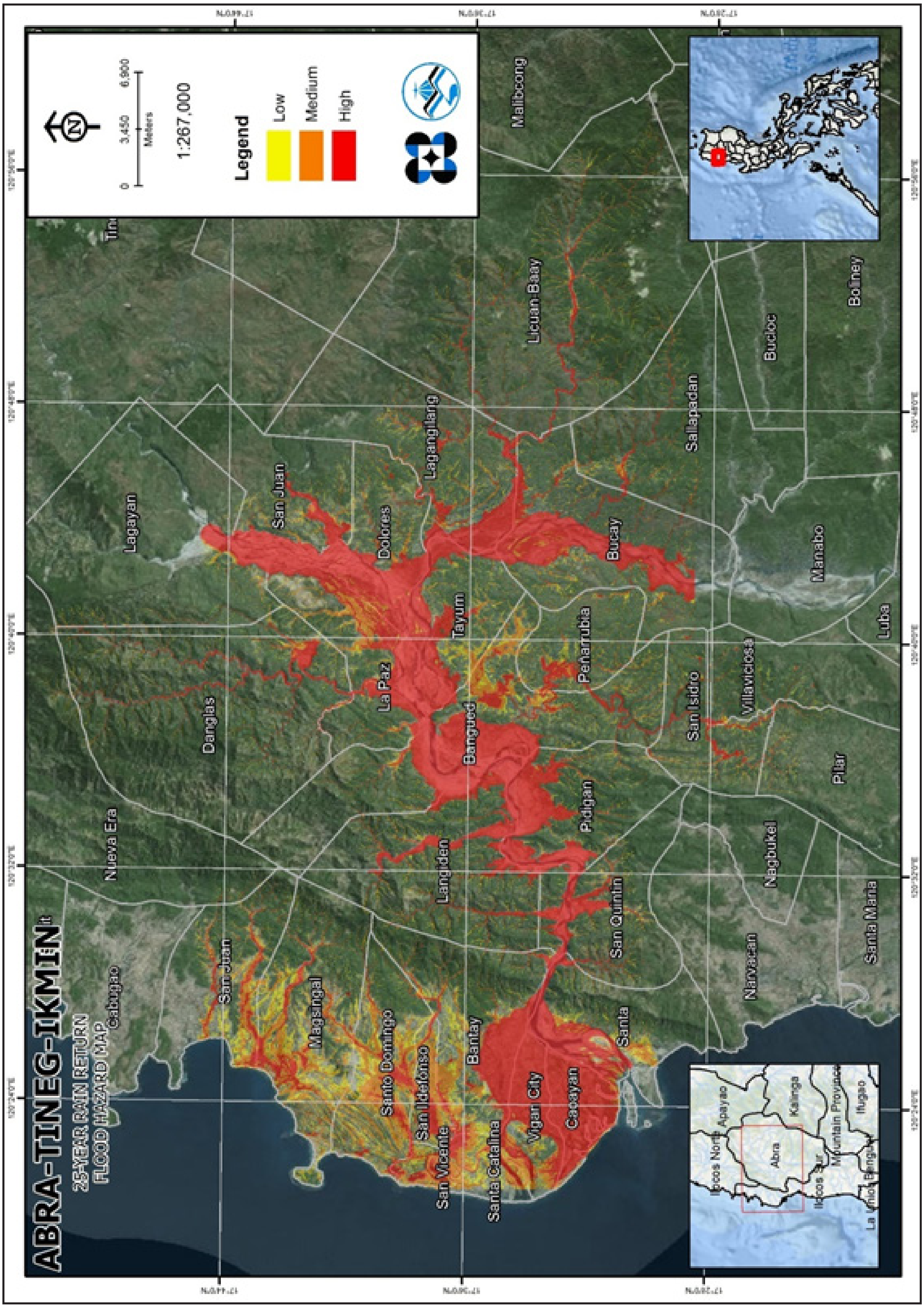


Figure 68. A 25-year Flood Hazard Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery.

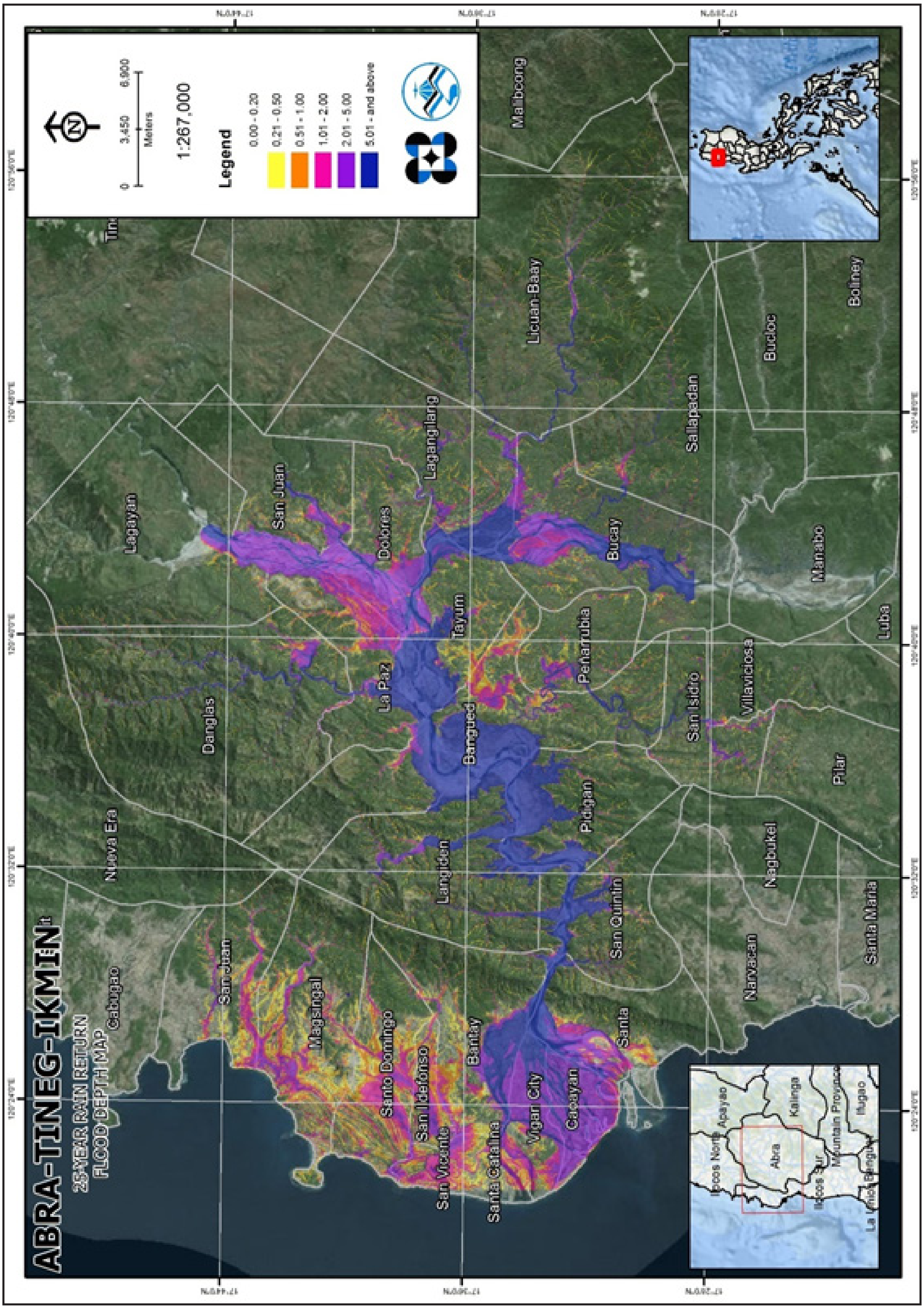


Figure 69. A 25-year Flow Depth Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery.

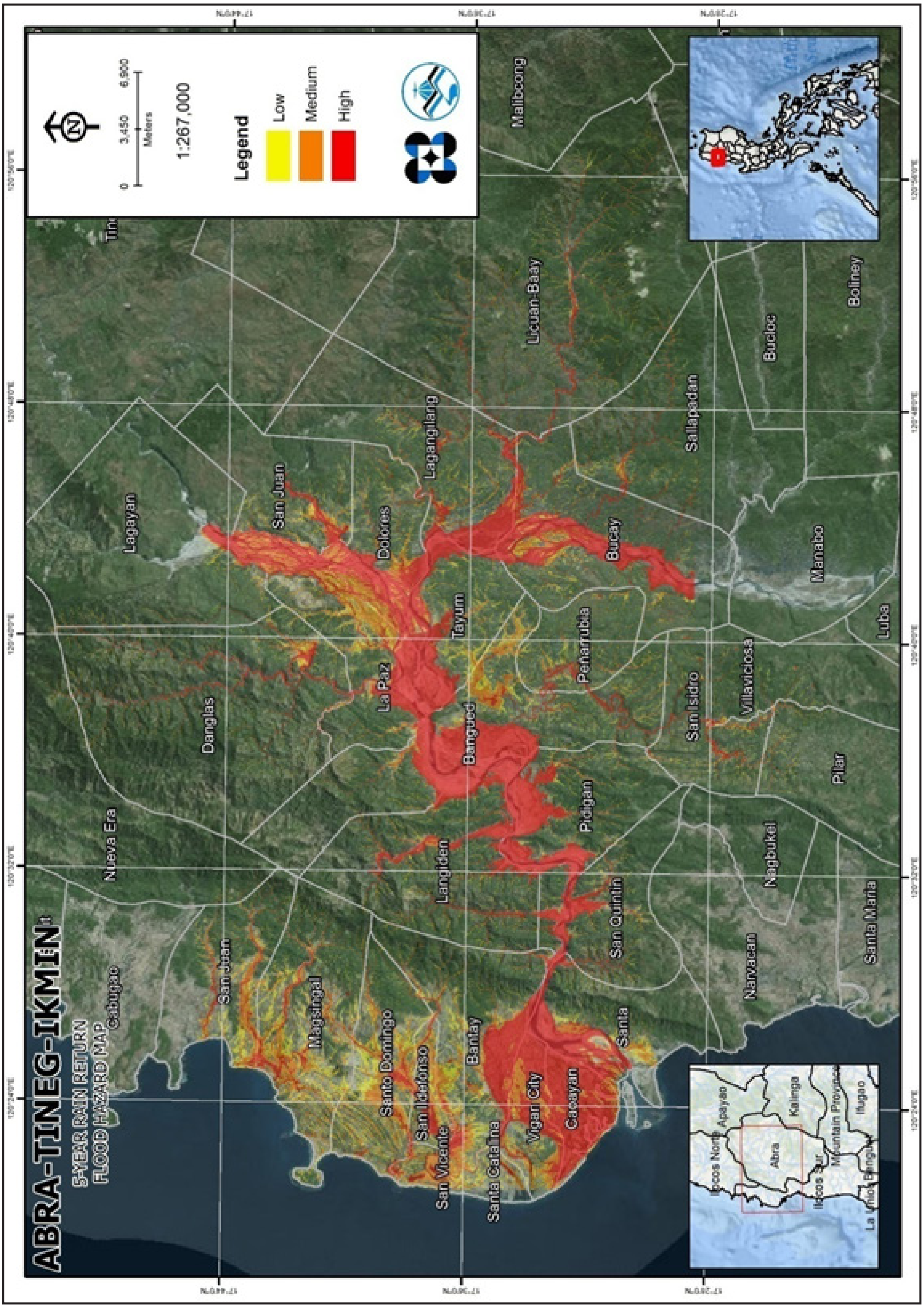


Figure 70. A 5-year Flood Hazard Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery.

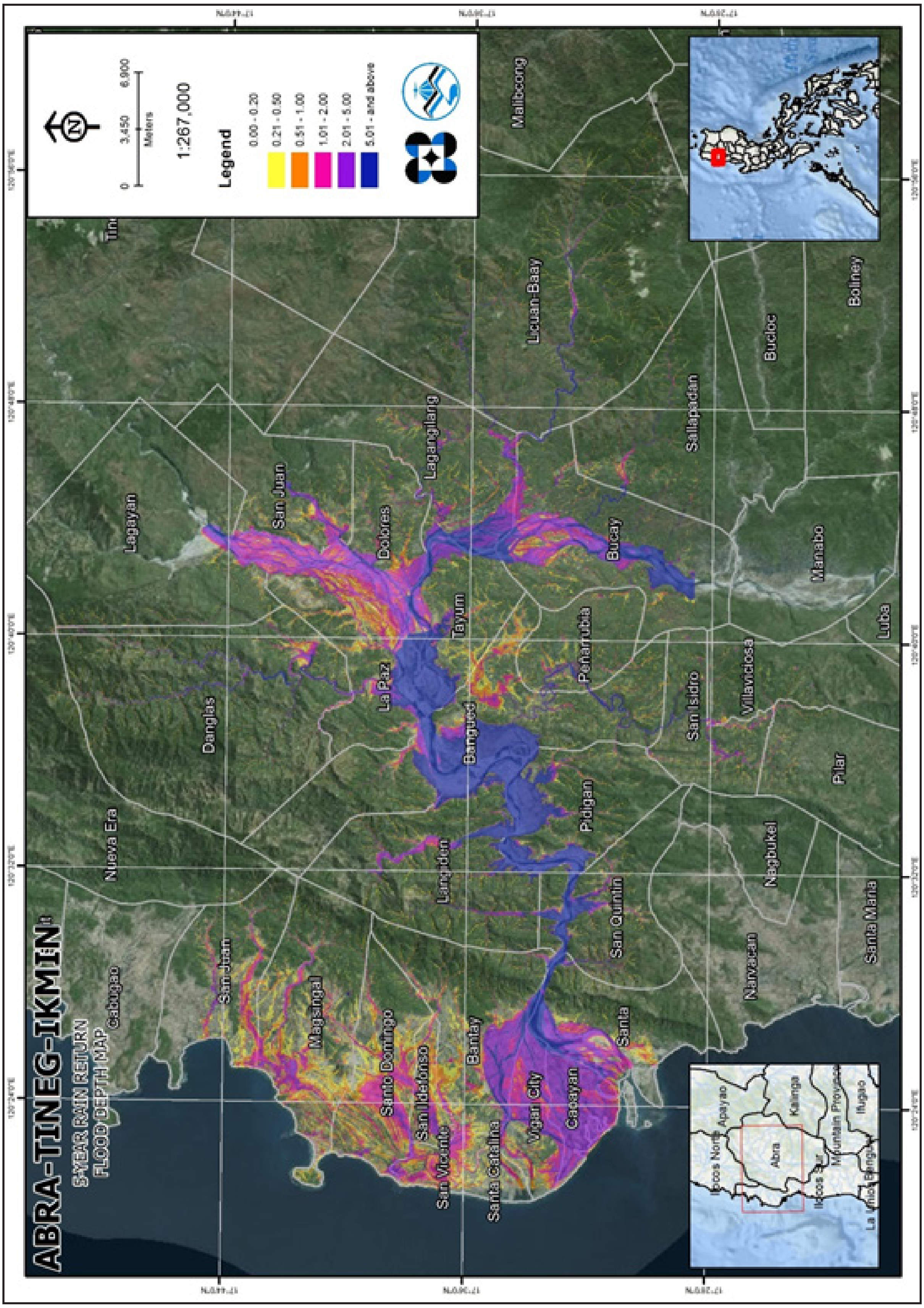


Figure 71. A 5-year Flood Depth Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Abra River Basin, grouped accordingly by municipality. For the said basin, three provinces with 16 municipalities consisting of 282 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 9.13% of the municipality of Bangued with an area of 123.75 sq. km. will experience flood levels of less than 0.20 meters. 0.42% of the area will experience flood levels of 0.21 to 0.50 meters while 0.25%, 0.28%, 1.08%, and 13.71% 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 Bangued in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding.

Table 39. Affected Areas in Bangued, Abra during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangued (in sq. km.)										
	Bañacao	Bangbangar	Cabuloan	Calaba	Dangdangla	Lingtan	Lipcan	Malita	Palao	Patucannay	Sagap
0.03-0.20	0	0	0	0	0.22	0.61	0.4	2.27	0.69	0.23	2.68
0.21-0.50	0	0	0	0	0.0099	0.06	0.009	0.089	0.016	0.0062	0.054
0.51-1.00	0	0	0	0.0031	0	0.045	0.0036	0.045	0.0073	0	0.038
1.01-2.00	0	0.000091	0	0.028	0	0.061	0.0081	0.012	0.013	0	0.022
2.01-5.00	0	0.018	0	0.39	0	0.057	0.026	0.0027	0.023	0	0.0018
> 5.00	2.67	1.69	2.57	0.3	0	0	0.84	0	1.64	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangued (in sq. km.)									
	San Antonio	Santa Rosa	Sao-Atan	Zone 1 Poblacion	Zone 2 Poblacion	Zone 3 Poblacion	Zone 4 Poblacion	Zone 5 Poblacion	Zone 6 Poblacion	Zone 7 Poblacion
0.03-0.20	3.71	0	0.19	0.091	0.036	0.041	0	0	0	0.11
0.21-0.50	0.18	0	0.0031	0.082	0.0022	0.0086	0	0	0	0.00083
0.51-1.00	0.092	0	0.0031	0.055	0.0027	0.011	0	0	0	0.0082
1.01-2.00	0.056	0	0.0023	0.022	0.0087	0.11	0	0	0	0.0074
2.01-5.00	0.15	0	0.0045	0.029	0.2	0.19	0.12	0	0.015	0.1
> 5.00	1.84	4.55	0.00038	0	0.051	0.32	0.018	0.23	0.18	0.065

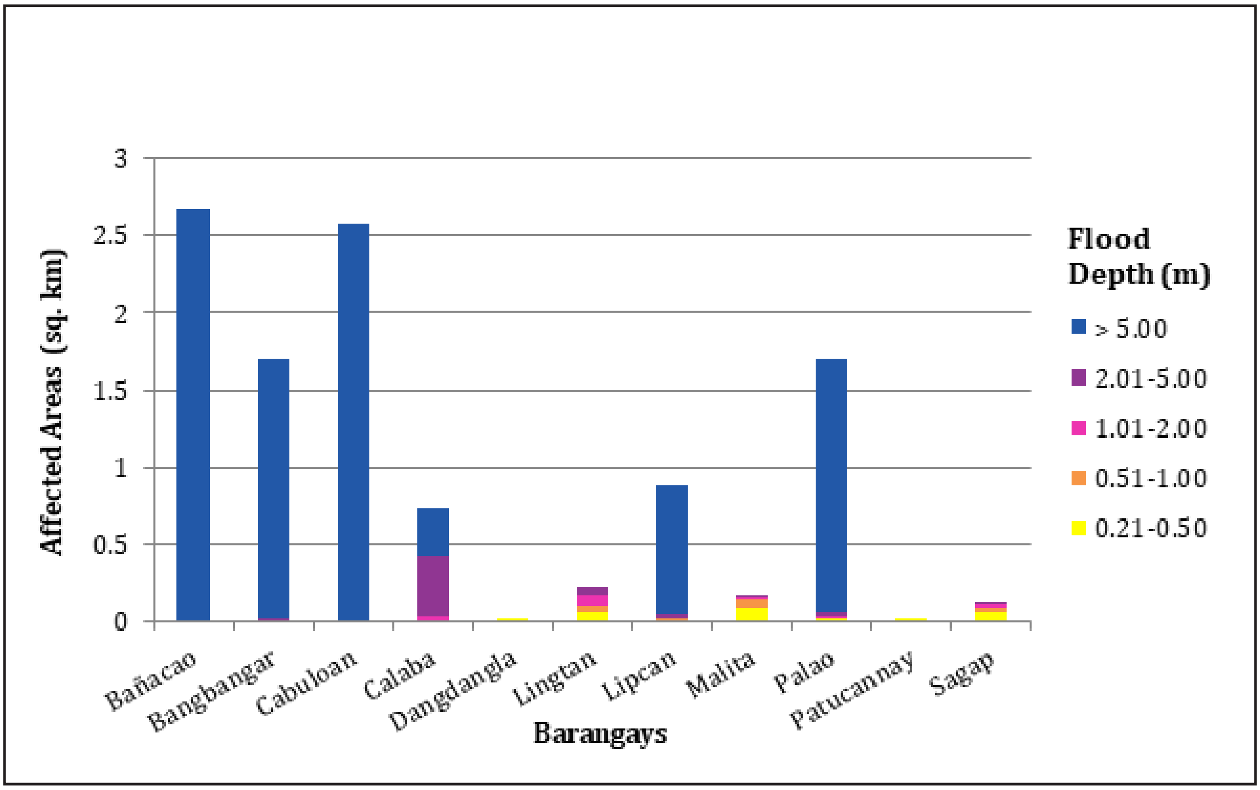


Figure 72. Affected Areas in Bangued, Abra during 5-Year Rainfall Return Period.

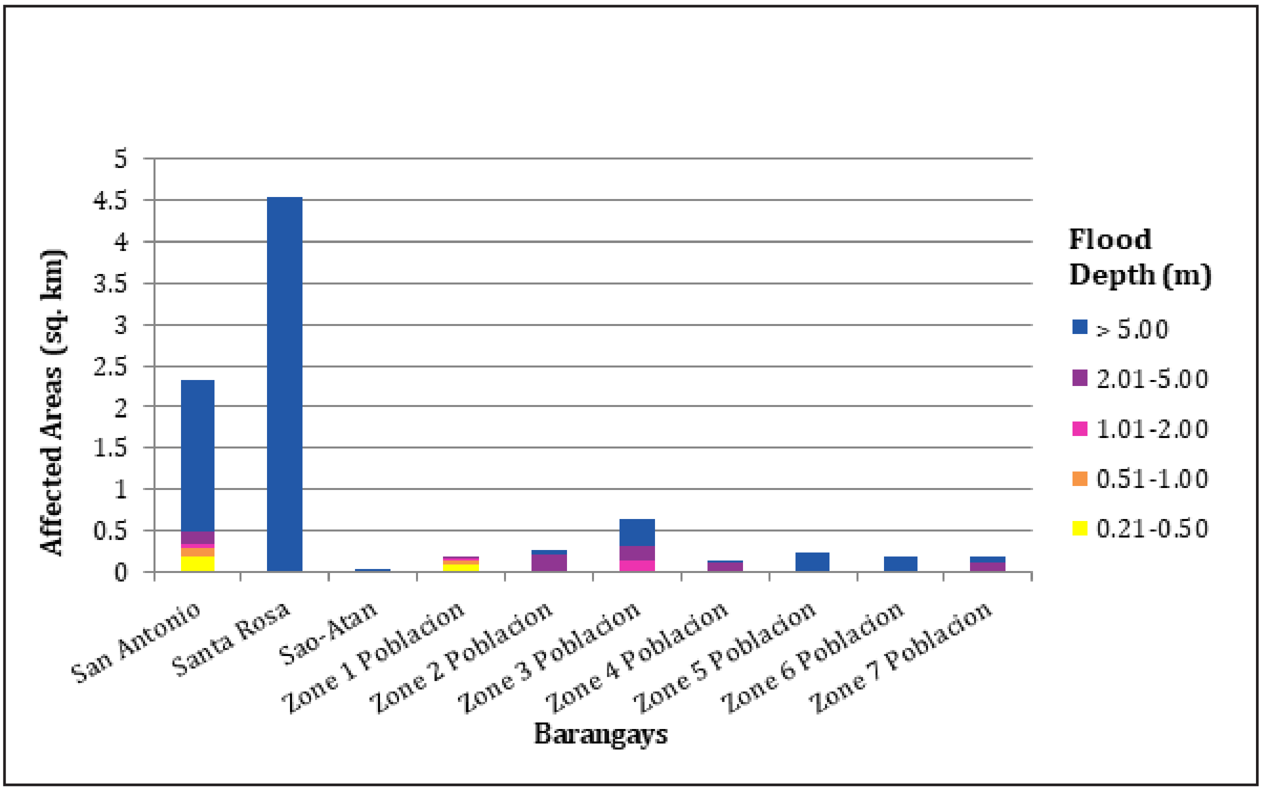


Figure 73. Affected Areas in Bangued, Abra during 5-Year Rainfall Return Period.

For the 5-year return period, 70.48% of the municipality of Langiden with an area of 98.7 sq. km. will experience flood levels of less than 0.20 meters. 2.90% of the area will experience flood levels of 0.21 to 0.50 meters while 1.59%, 1.62%, 3.04%, and 9.20% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 are the affected areas in Langiden in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Langiden, Abra during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays Langiden (in sq. km)					
	Baac	Dalayap	Mabungtot	Malapaao	Poblacion	Quillat
0-0.20	1.92	0.14	27.09	37.44	1.39	1.59
0.21-0.50	0.12	0	1.06	1.6	0.031	0.049
0.51-1.00	0.047	0.0019	0.57	0.87	0.039	0.034
1.01-2.00	0.057	0.0072	0.39	1.06	0.043	0.048
2.01-5.00	0.15	0.027	0.91	1.7	0.083	0.13
> 5.00	1.31	0.52	1.98	1.65	0.3	3.32

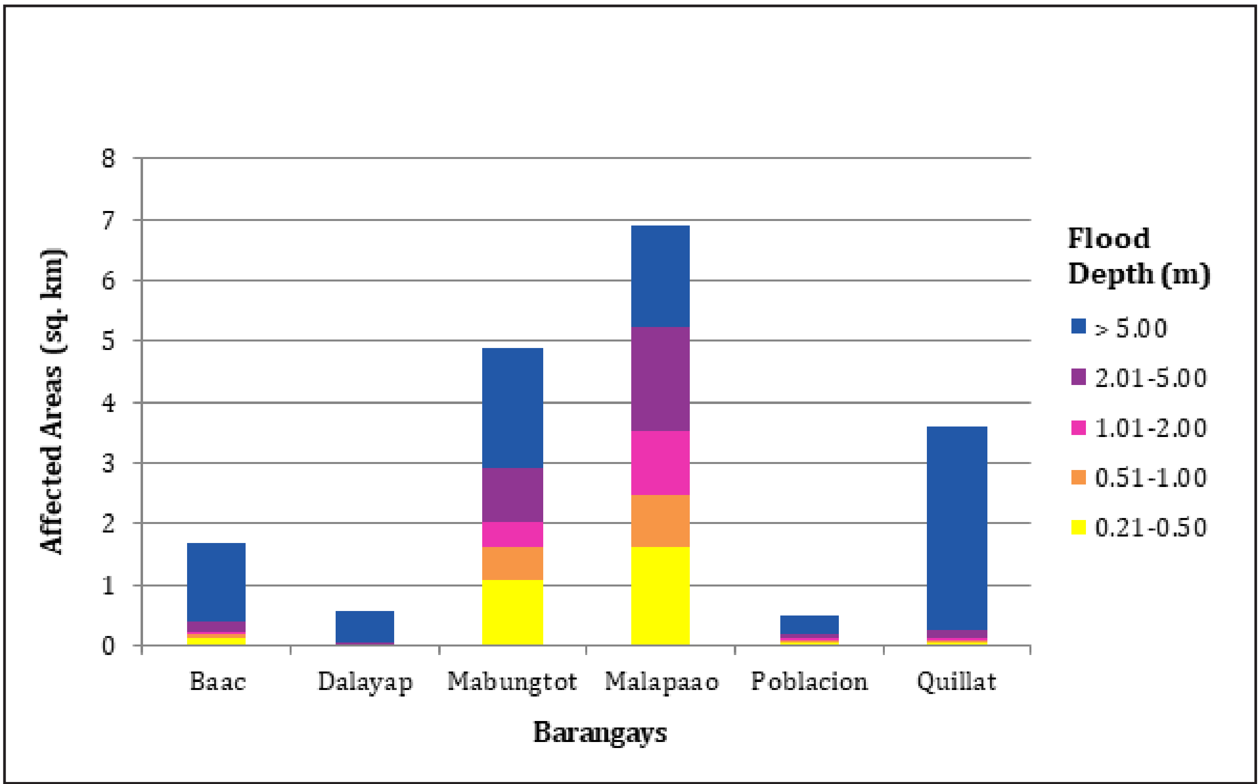


Figure 74. Affected Areas in Langiden, Abra during 5-Year Rainfall Return Period.

For the 5-year return period, 47.77% of the municipality of Pidigan with an area of 58.13 sq. km. will experience flood levels of less than 0.20 meters. 1.95% of the area will experience flood levels of 0.21 to 0.50 meters while 1.18%, 1.15%, 2.01%, and 23.35% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas in Pidigan in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Pidigan, Abra during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pidigan (in sq. km.)						
	Alinaya	Garreta	Immuli	Laskig	Monggoc	Naguirayan	Pamutic
0-0.20	4.79	1.36	1.08	0.73	4.43	0.5	0.64
0.21-0.50	0.17	0.051	0.048	0.025	0.21	0.025	0.0081
0.51-1.00	0.11	0.035	0.014	0.015	0.17	0.013	0.0009
1.01-2.00	0.095	0.019	0.0027	0.019	0.18	0.021	0.0028
2.01-5.00	0.14	0.043	0	0.048	0.26	0.05	0.013
> 5.00	0.23	0.09	0	0.54	0.33	0.82	1.4
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Pidigan (in sq. km.)**						
	Pangtud	**Poblacion East**	**Poblacion West**	**San Diego**	**Sulbec**	**Suyo**	**Yuyeng**
0-0.20	2.85	0	0.31	0.3	3.29	0.76	6.72
0.21-0.50	0.17	0	0.0065	0.042	0.14	0.028	0.21
0.51-1.00	0.12	0	0.0043	0.013	0.077	0.02	0.1
1.01-2.00	0.1	0	0.0057	0.015	0.08	0.025	0.096
2.01-5.00	0.17	0	0.029	0.067	0.16	0.044	0.15
> 5.00	0.77	2.54	1.58	1.89	2.66	0.42	0.29

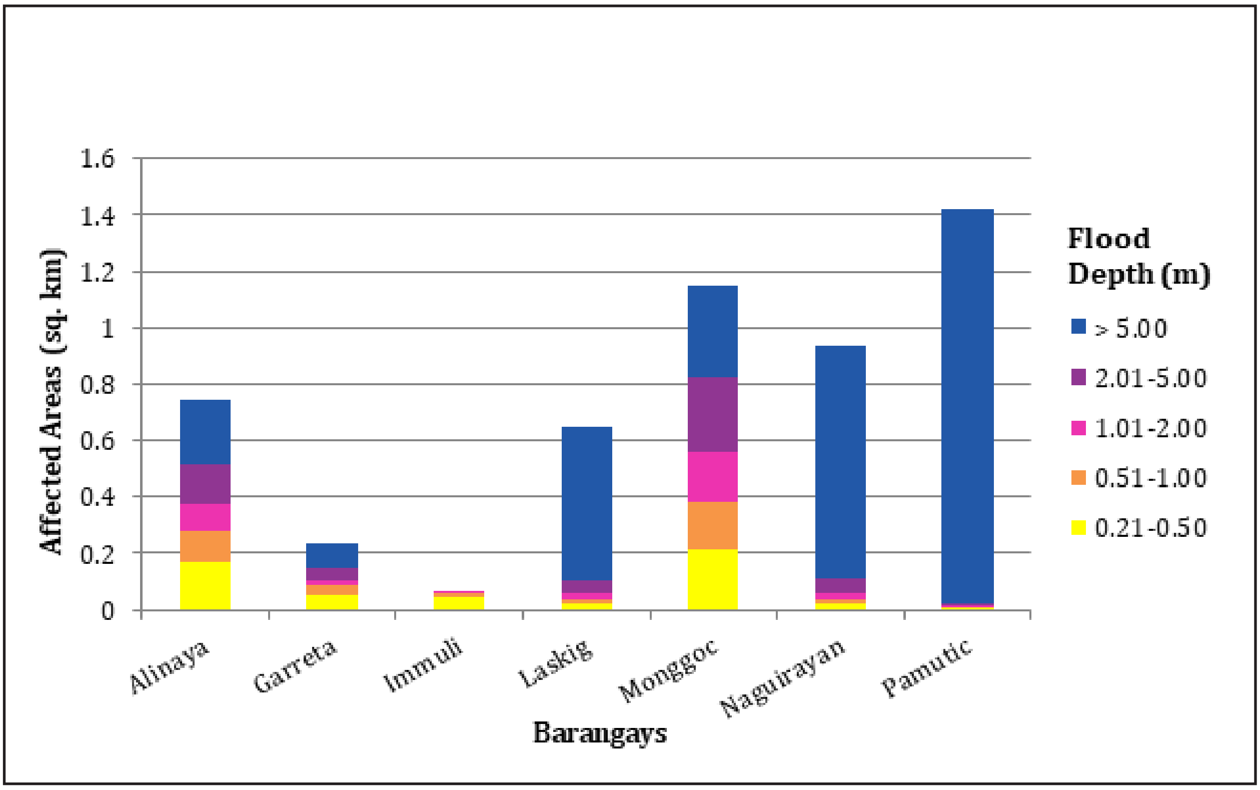


Figure 75. Affected Areas in Pidigan, Abra during 5-Year Rainfall Return Period.

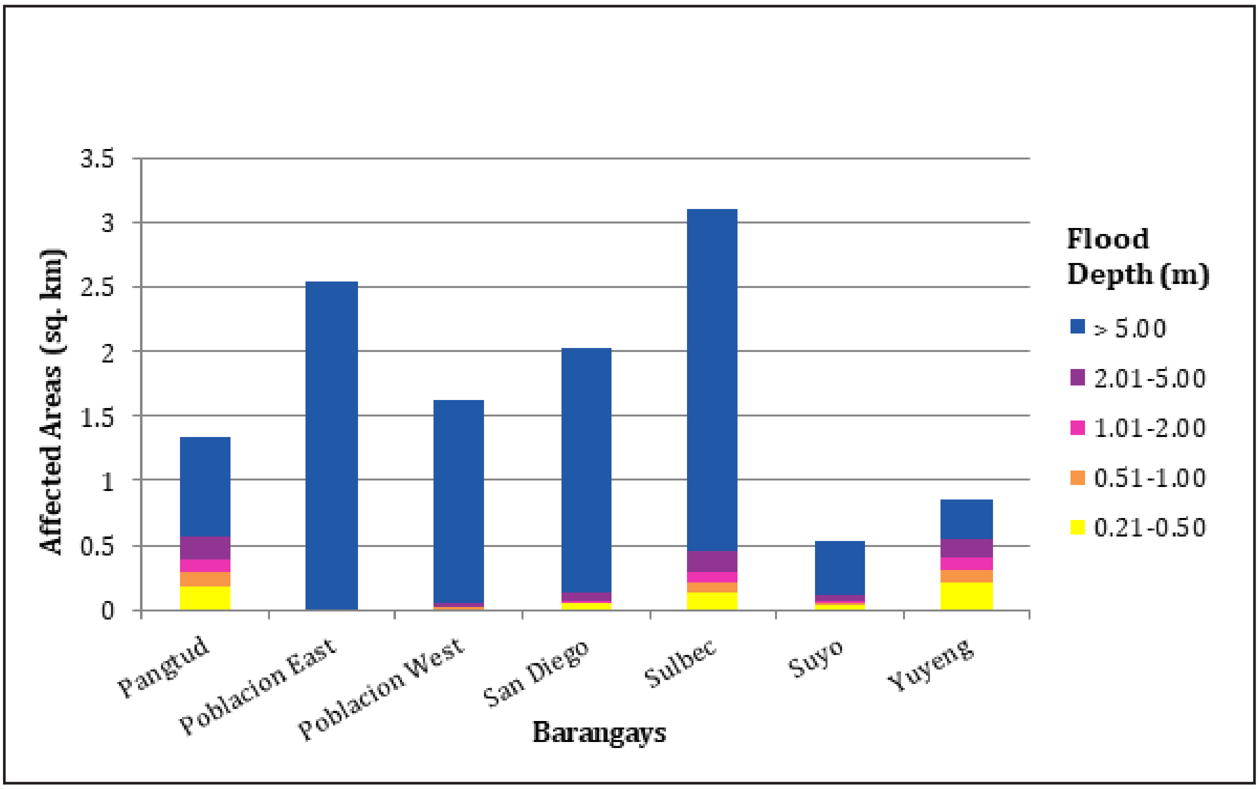


Figure 76. Affected Areas in Pidigan, Abra during 5-Year Rainfall Return Period.

For the 5-year return period, 55.37% of the municipality of San Quintin with an area of 62.29 sq. km. will experience flood levels of less than 0.20 meters. 2.36% of the area will experience flood levels of 0.21 to 0.50 meters while 1.42%, 1.19%, 2.14%, and 8.46% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas in San Quintin in square kilometers by flood depth per barangay.

Table 42. Affected Areas in San Quintin, Abra during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)					
	Labaan	Palang	Pantoc	Poblacion	Tangadan	Villa Mercedes
0-0.20	12.09	5.98	3.87	0.4	9.62	2.53
0.21-0.50	0.46	0.17	0.17	0.012	0.49	0.16
0.51-1.00	0.32	0.13	0.068	0.0071	0.26	0.1
1.01-2.00	0.29	0.092	0.056	0.017	0.19	0.093
2.01-5.00	0.66	0.29	0.036	0.12	0.14	0.091
> 5.00	1.06	3.42	0.0026	0.77	0.0027	0.016

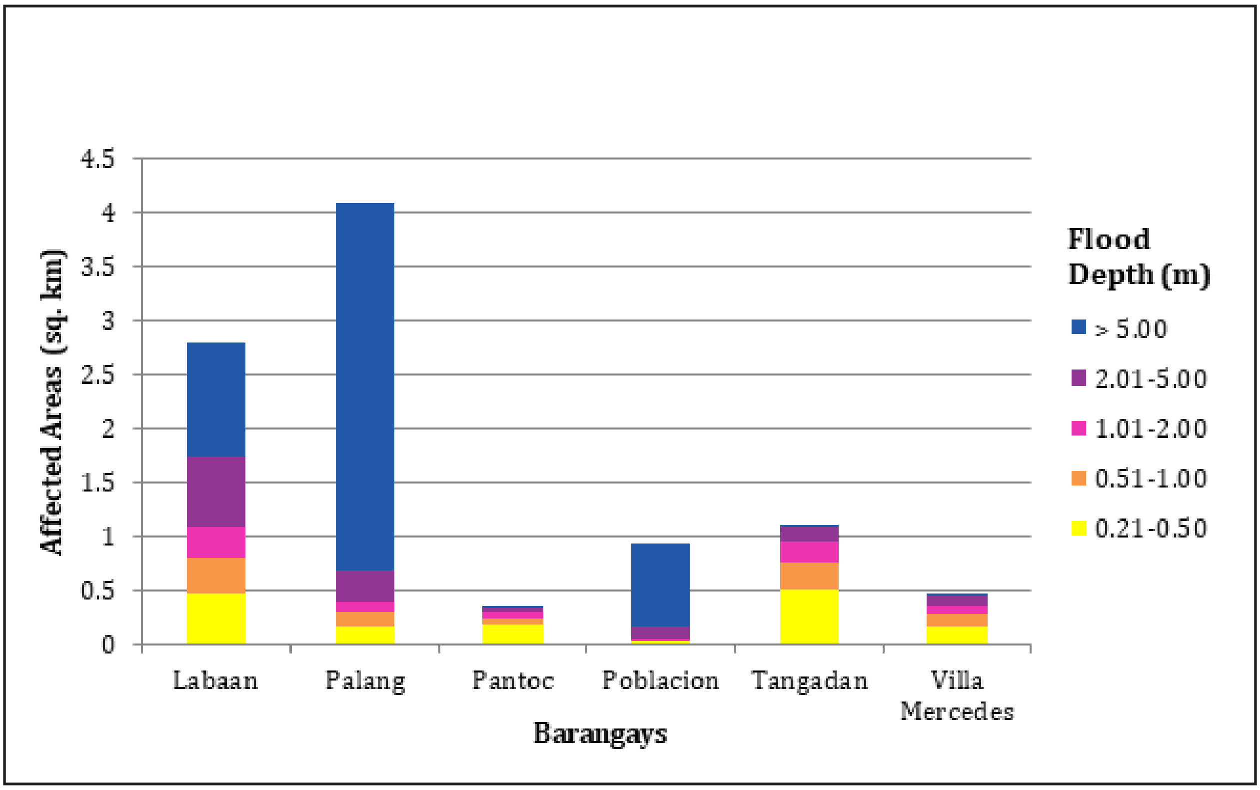


Figure 77. Affected Areas in San Quintin, Abra during 5-Year Rainfall Return Period.

For the 5-year return period, 0.54% of the municipality of Nueva Era with an area of 619 sq. km. will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 43 are the affected areas in Nueva Era in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Nueva Era, Ilocos Norte during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)
	Barangobong
0-0.20	3.31
0.21-0.50	0.11
0.51-1.00	0.069
1.01-2.00	0.033
2.01-5.00	0.013
> 5.00	0.0026

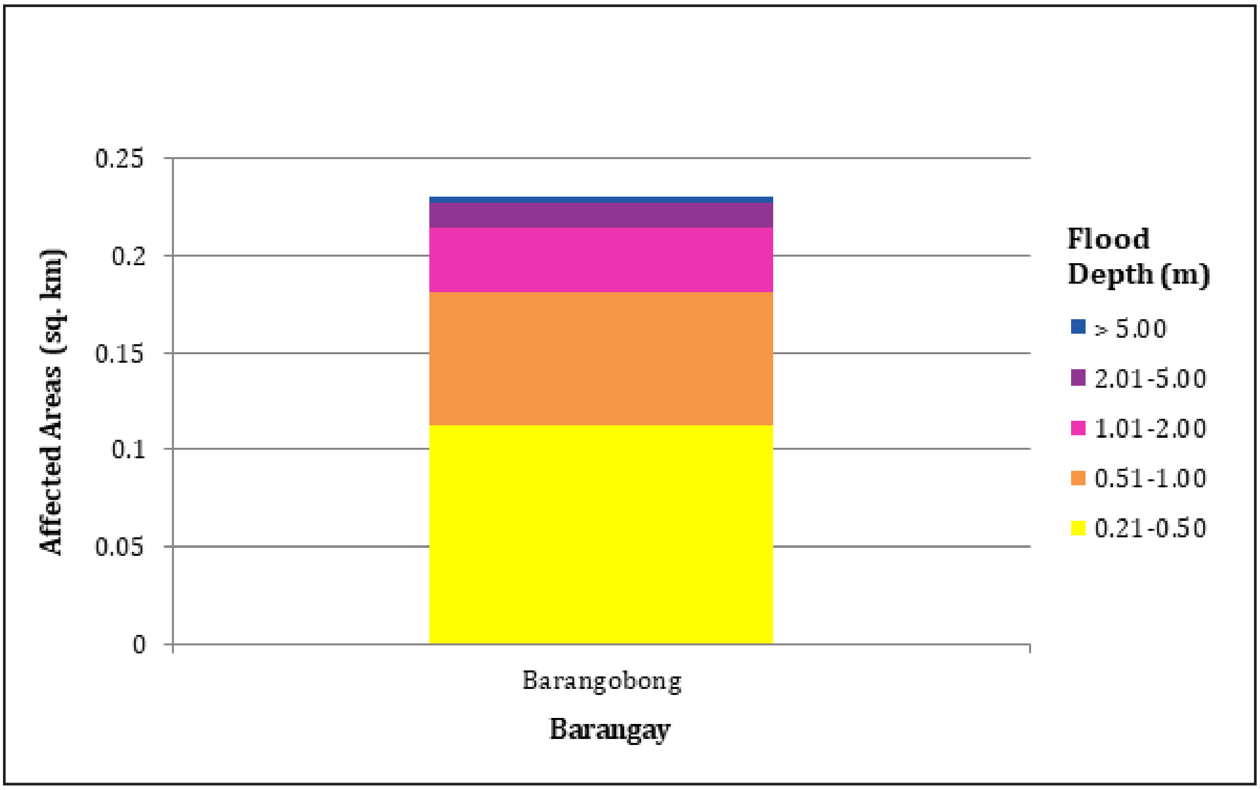


Figure 78. Affected Areas in Nueva Era, Ilocos Norte during 5-Year Rainfall Return Period.

For the 5-year return period, 65.56% of the municipality of Bantay with an area of 71.06 sq. km. will experience flood levels of less than 0.20 meters. 8.61% of the area will experience flood levels of 0.21 to 0.50 meters while 6.00%, 4.82%, 10.99%, and 4.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in Bantay, Ilocos Sur in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)											
	Aggay	An-Annam	Balaleng	Banaoang	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Bulag	Buquig
0.03-0.20	0.35	0.64	0.69	4.04	0.14	0.072	0.11	0.0032	0.11	0.0055	0.75	0.28
0.21-0.50	0.056	0.32	0.43	0.15	0.0067	0.043	0.021	0.0076	0.021	0.0015	0.22	0.023
0.51-1.00	0.027	0.065	0.079	0.075	0.0012	0.0078	0.018	0.036	0.038	0.018	0.19	0.015
1.01-2.00	0.032	0.023	0.017	0.044	0.00076	0.0037	0	0.044	0.023	0.024	0.094	0.023
2.01-5.00	0.04	0.0002	0.0004	0.093	0.00017	0	0	0.019	0.019	0.095	0.64	0.12
> 5.00	0.045	0	0	0.29	0	0	0	0	0	0.025	0.098	0.11

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)										
	Cabalanggan	Cabaroan	Cabusligan	Capangdanan	Guimod	Lingsat	Malingeb	Mira	Naguiddayan	Ora	Paing
0-0.20	0.14	0.097	0.91	1.13	1.01	14.89	0.83	0.68	0.91	0.92	1.53
0.21-0.50	0.17	0.024	0.26	0.85	0.33	0.84	0.29	0.06	0.19	0.13	0.19
0.51-1.00	0.094	0.023	0.18	0.83	0.28	0.47	0.32	0.0086	0.088	0.15	0.13
1.01-2.00	0.098	0.034	0.072	0.17	0.21	0.47	0.04	0.0007	0.062	0.14	0.42
2.01-5.00	0.34	0.054	0	0.013	0.15	0.096	0.0005	0	0.35	0.0036	1.83
> 5.00	0.014	0.05	0	0	0.0002	0.0065	0	0	0.0007	0	0.99

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)										
	Puspus	Quimmarayan	Sagneb	Sagpat	San Isidro	San Julian	San Mariano	Sinabaan	Taguiporo	Taleb	Tay-Ac
0-0.20	0.73	0.74	0.49	0.34	0	0	5.22	0.11	0	2.69	6.04
0.21-0.50	0.22	0.16	0.032	0.11	0	0.00014	0.21	0.06	0	0.23	0.46
0.51-1.00	0.24	0.04	0	0.16	0	0.0046	0.11	0.16	0.000011	0.2	0.21
1.01-2.00	0.082	0.025	0	0.4	0.018	0.32	0.089	0.12	0.11	0.14	0.076
2.01-5.00	0.02	0.0034	0	0.11	0.46	1.67	0.17	0.21	1.14	0.15	0.0023
> 5.00	0.012	0	0	0	0.1	0.51	0.26	0.011	0.34	0	0

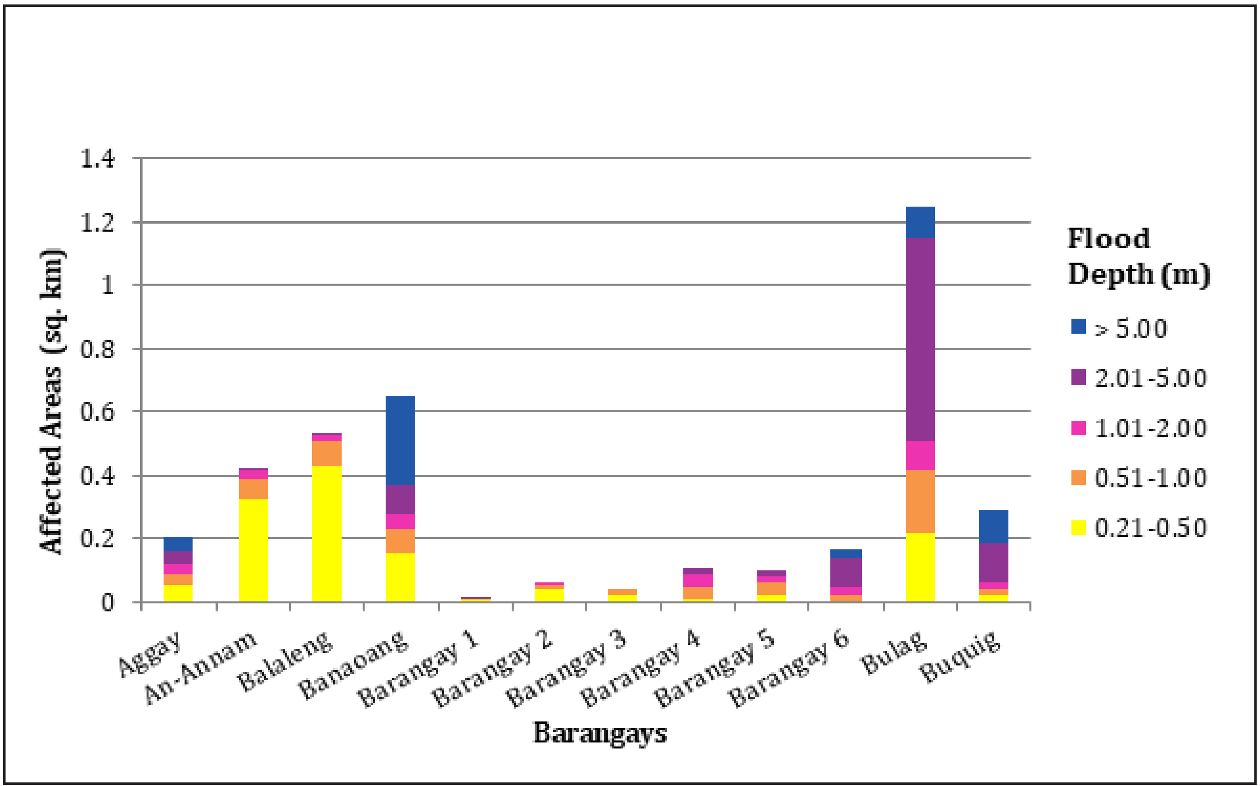


Figure 79. Affected Areas in Bantay, Ilocos Sur during 5-Year Rainfall Return Period.

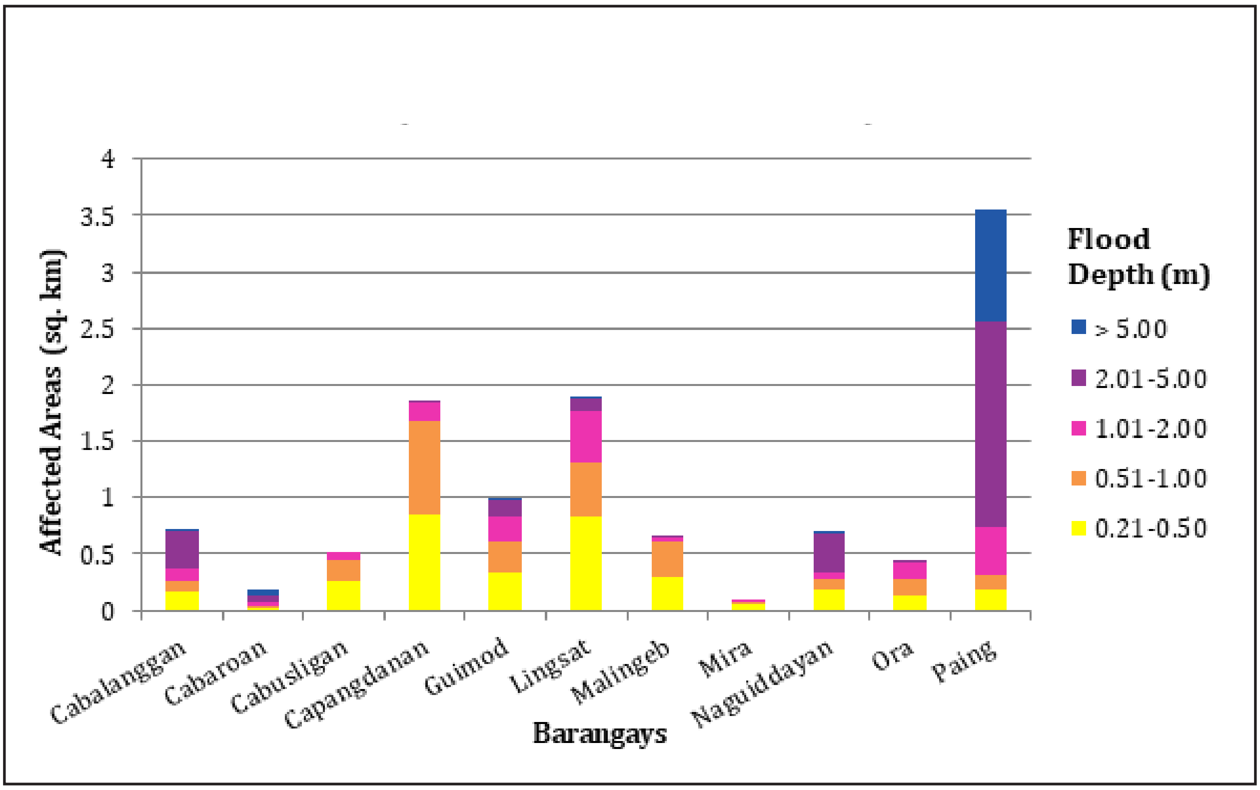


Figure 80. Affected Areas in Bantay, Ilocos Sur during 5-Year Rainfall Return Period.

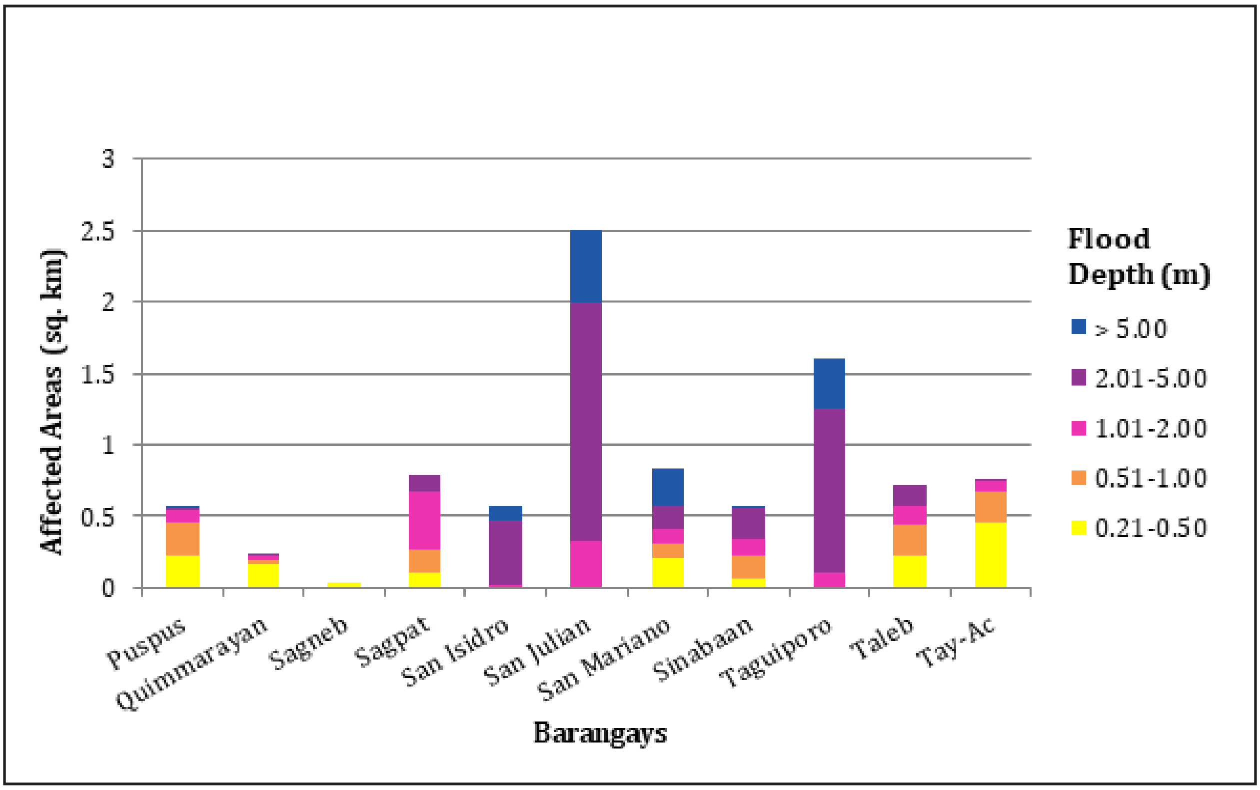


Figure 81. Affected Areas in Bantay, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 1.72% of the municipality of Caoayan with an area of 21.2 sq. km. will experience flood levels of less than 0.20 meters. 0.44% of the area will experience flood levels of 0.21 to 0.50 meters while 1.45%, 14.46%, 72.52%, and 4.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in Caoayan in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Caoayan (in sq. km.)							
	Anonang Mayor	Anonang Menor	Baggoc	Callaguip	Caparacadan	Don Alejandro Quirolgico	Don Dimas Querubin	Don Lorenzo Querubin
0.03-0.20	0	0	0	0	0.24	0	0	0
0.21-0.50	0	0	0.0001	0	0.044	0	0	0
0.51-1.00	0.0058	0	0.0006	0.00011	0.067	0	0	0
1.01-2.00	0.09	0.036	0.0081	0.044	0.16	0	0.0032	0.005
2.01-5.00	0.16	0.31	0.24	0.28	0.61	0.31	0.51	0.34
> 5.00	0.0019	0.027	0.00003	0.0073	0	0.012	0.051	0.026
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Caoayan (in sq. km.)**							
	Fuerte	Manangat	Naguilian	Nansuagao	Pandan	Pantay Tamurong	Pantay-Quitiquit	Villamar
0.03-0.20	0.016	0.064	0	0	0.0001	0.042	0	0.0017
0.21-0.50	0.0082	0.0077	0.0001	0	0.0002	0.031	0	0.0015
0.51-1.00	0.017	0.016	0.0066	0.0008	0.0002	0.19	0	0.0044
1.01-2.00	0.065	0.089	0.27	0.19	0.0013	1.95	0.042	0.11
2.01-5.00	0.21	0.19	3.5	1.85	0.24	3.45	0.37	2.81
> 5.00	0	0	0.42	0.15	0	0.17	0	0.016

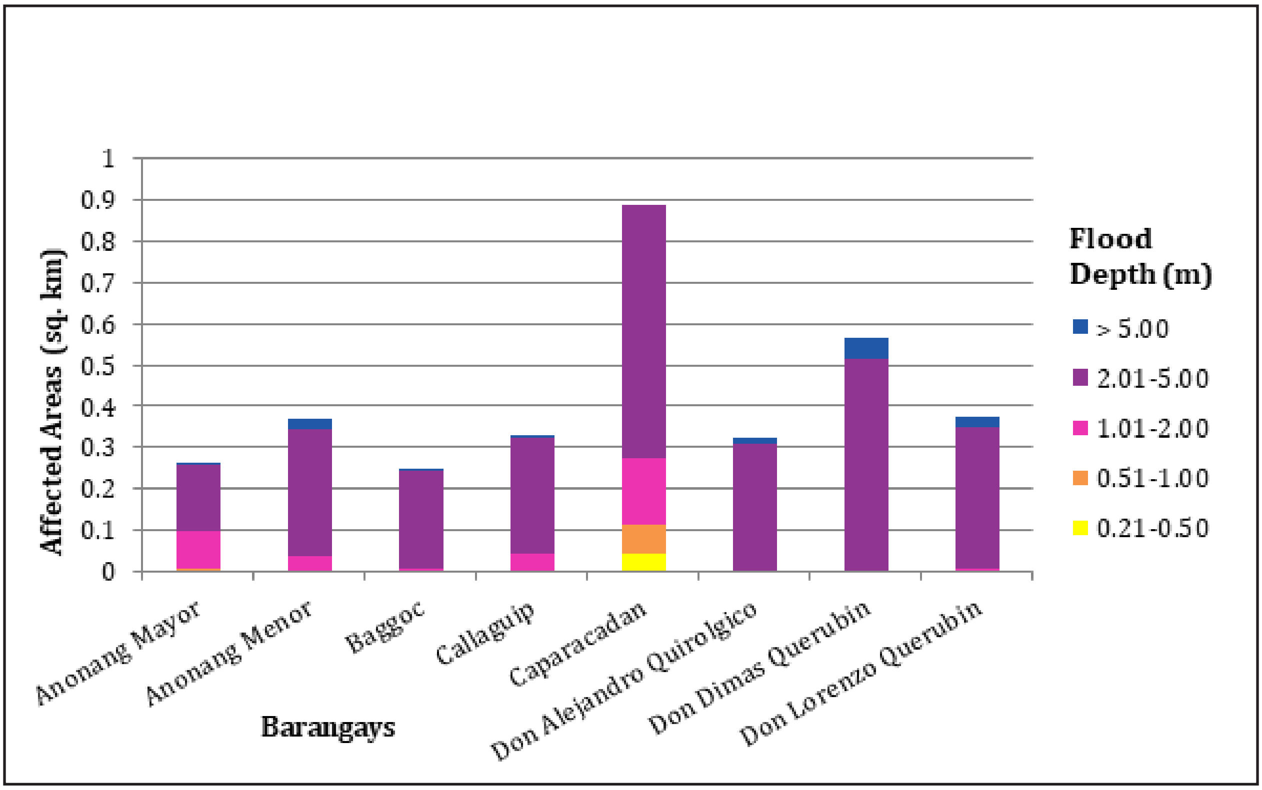


Figure 82. Affected Areas in Caoayan, Ilocos Sur during 5-Year Rainfall Return Period.

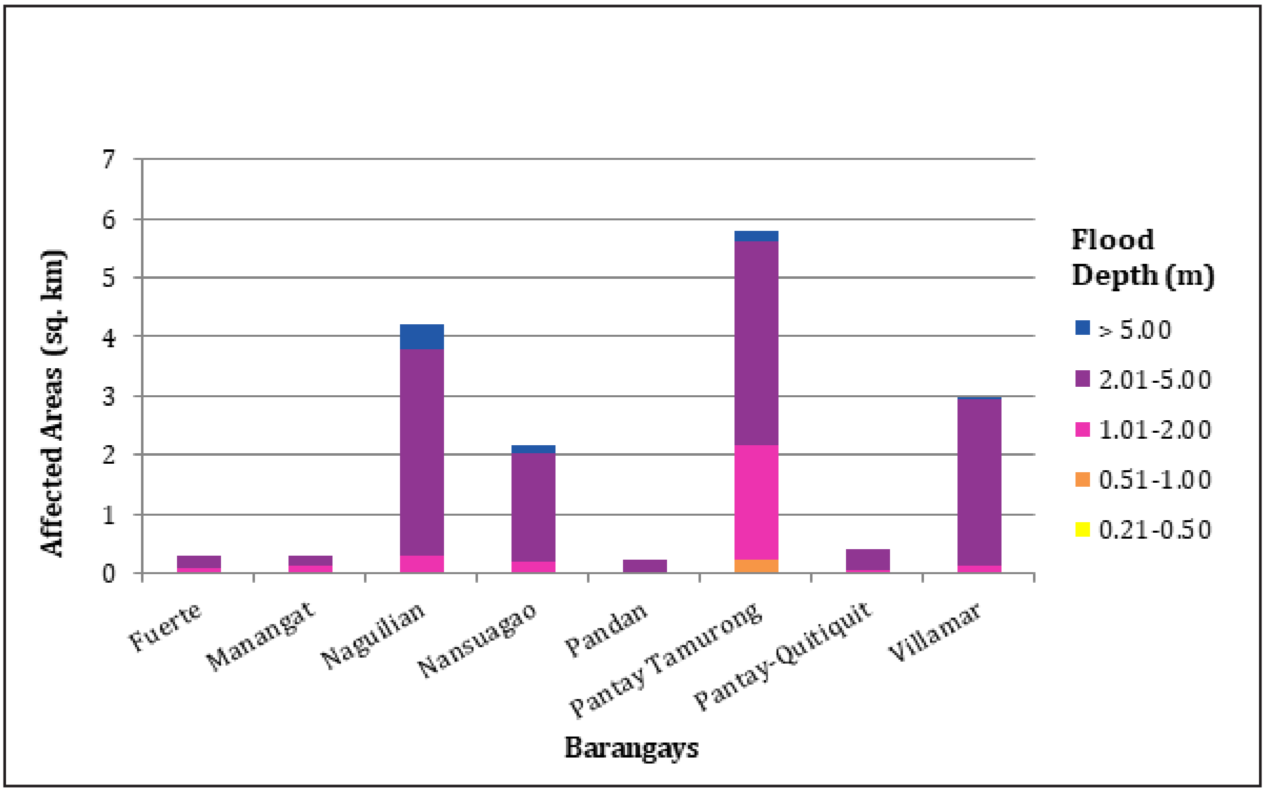


Figure 83. Affected Areas in Caoayan, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 64.77% of the municipality of Magsingal with an area of 78.9 sq. km. will experience flood levels of less than 0.20 meters. 12.46% of the area will experience flood levels of 0.21 to 0.50 meters while 9.02%, 6.87%, 3.60%, 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, and more than 5 meters, respectively. Listed in Table 46 are the affected areas in Magsingal square kilometers by flood depth per barangay.

Table 46. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Alangan	Bacar	Barbarit	Bungro	Cabaroan	Cadanglaan	Caraisan	Dacutan	Labut	Maas-Asin
0.03-0.20	0.93	0.17	1.03	0.86	0.45	1.27	1.9	0.097	1.38	5.06
0.21-0.50	0.23	0.24	0.41	0.45	0.3	0.29	0.58	0.19	0.22	0.77
0.51-1.00	0.22	0.22	0.34	0.31	0.33	0.072	0.053	0.28	0.14	0.46
1.01-2.00	0.2	0.27	0.14	0.12	0.16	0.031	0.029	0.23	0.092	0.4
2.01-5.00	0.022	0.17	0.047	0.15	0.21	0.012	0.019	0.19	0.1	0.18
> 5.00	0	0	0	0	0	0	0	0	0.0001	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Macatcatud	Manzante	Maratudo	Miramar	Namalpalan	Napo	Pagsanaan Norte	Pagsanaan Sur	Panay Norte	Panay Sur
0-0.20	4.18	1	14.16	0.32	1.59	3.59	0.14	0.23	0.71	1.18
0.21-0.50	0.78	0.37	0.55	0.099	0.32	1.04	0.26	0.094	0.45	0.76
0.51-1.00	0.33	0.65	0.36	0.19	0.29	0.4	0.35	0.14	0.33	0.7
1.01-2.00	0.26	0.62	0.32	0.59	0.21	0.1	0.24	0.37	0.11	0.31
2.01-5.00	0.12	0.32	0.16	0.28	0.059	0.036	0.074	0.38	0.036	0.012
> 5.00	0	0.0016	0.0024	0	0.0007	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Patong	Puro	San Basilio	San Clemente	San Julian	San Lucas	San Ramon	San Vicente	Santa Monica	Sarsaracat
0-0.20	6.11	1.1	0.11	0.042	0.063	0.046	0.29	0.38	0.71	1.99
0.21-0.50	0.43	0.35	0.024	0.037	0.062	0.053	0.033	0.072	0.17	0.2
0.51-1.00	0.29	0.14	0.035	0.014	0.08	0.046	0.035	0.024	0.094	0.17
1.01-2.00	0.16	0.013	0.044	0.0021	0.16	0.058	0.0083	0.0024	0.063	0.12
2.01-5.00	0.1	0	0	0	0.071	0.013	0	0	0.016	0.049
> 5.00	0.037	0	0	0	0	0	0	0	0	0.002

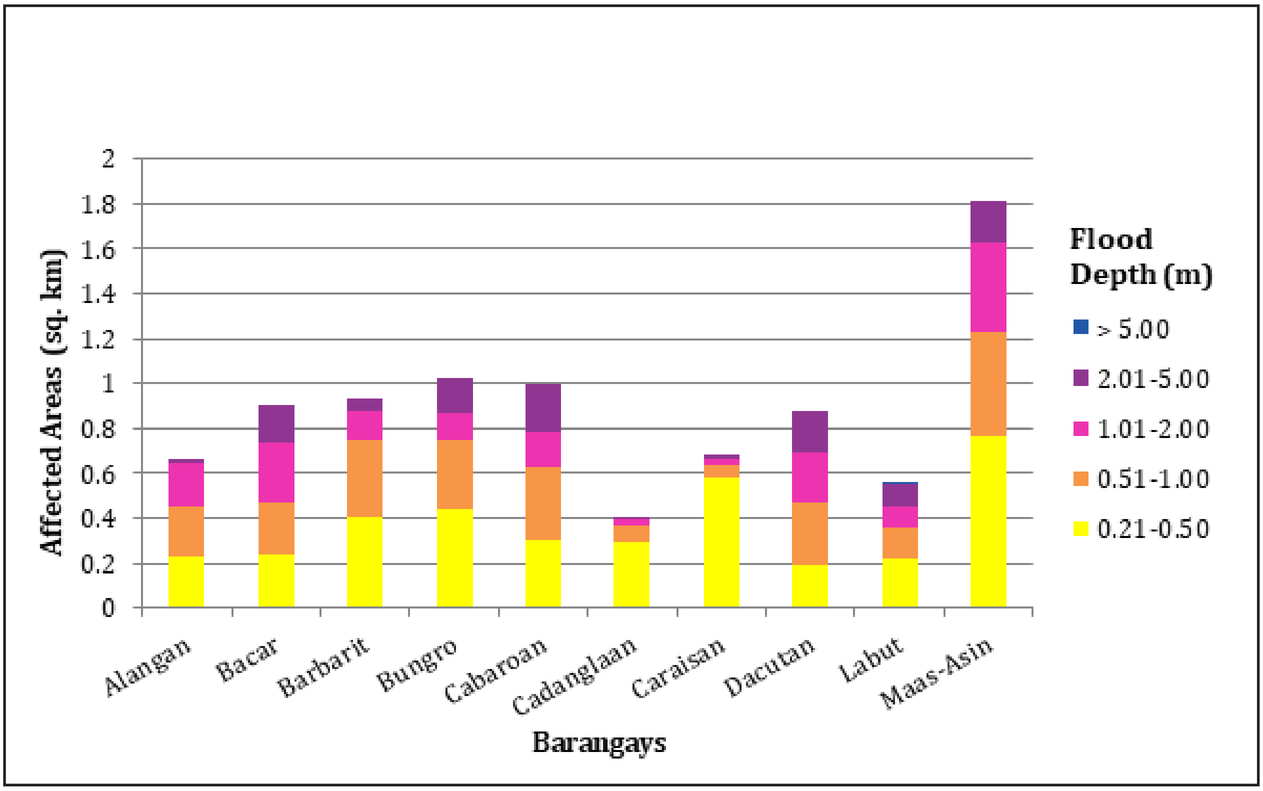


Figure 84. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

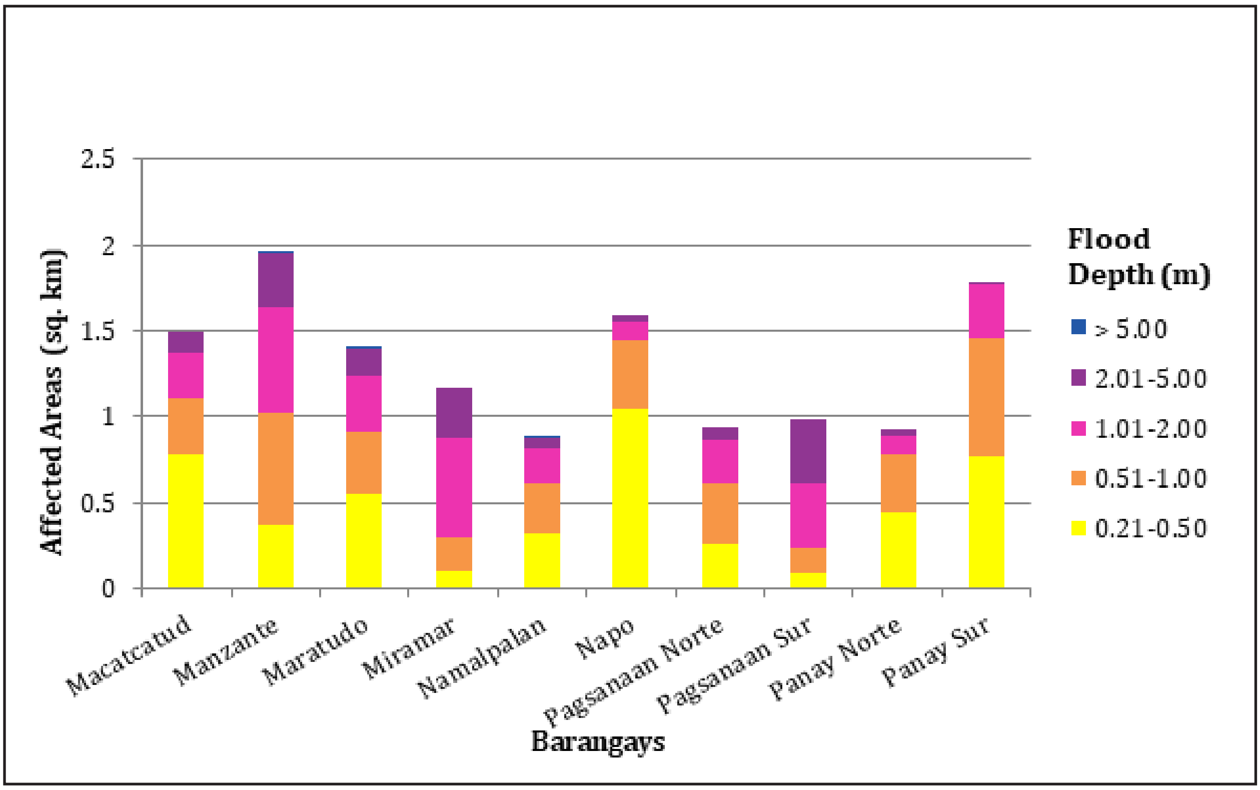


Figure 85. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

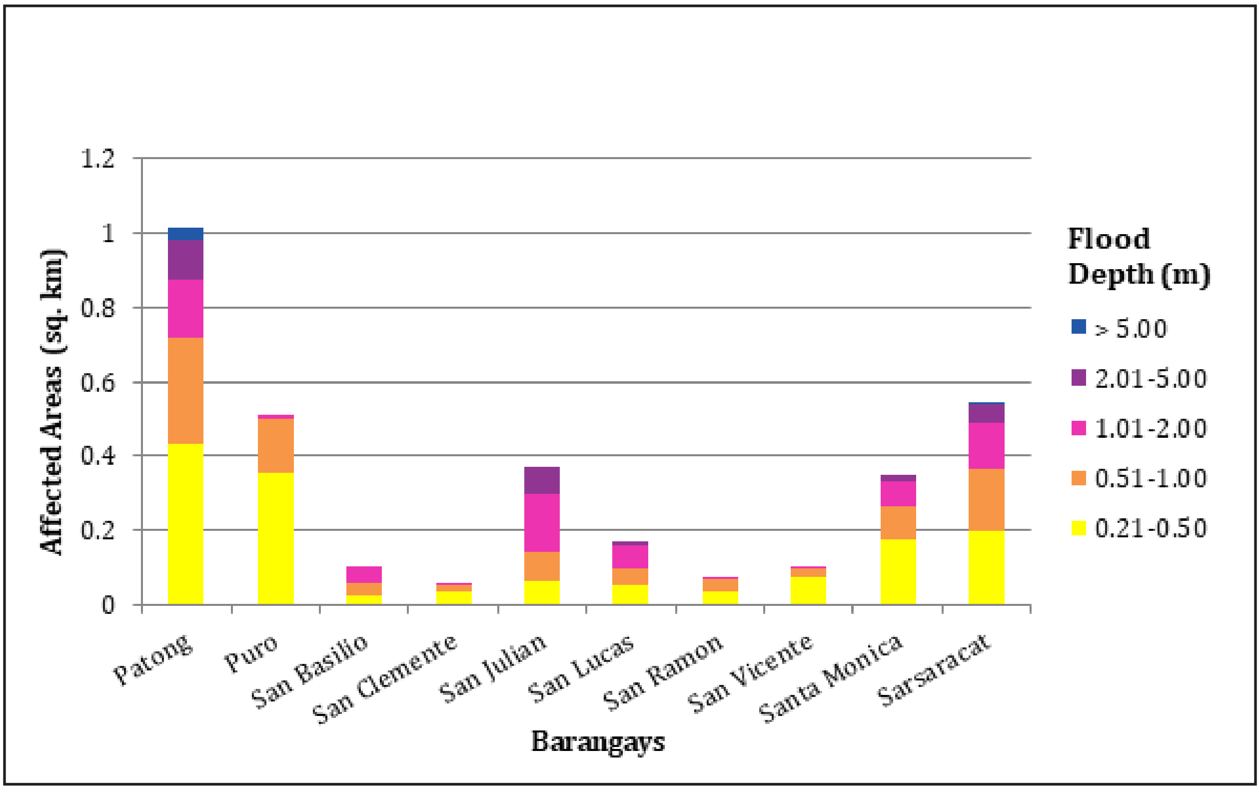


Figure 86. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 0.30% of the municipality of Narvacan with an area of 97.18 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 47 are the affected areas in Narvacan in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)	
	Ambulogan	Lanipao
0-0.20	0.15	0.14
0.21-0.50	0.0081	0
0.51-1.00	0.0015	0.00086
1.01-2.00	0.0009	0
2.01-5.00	0.000025	0
> 5.00	0	0

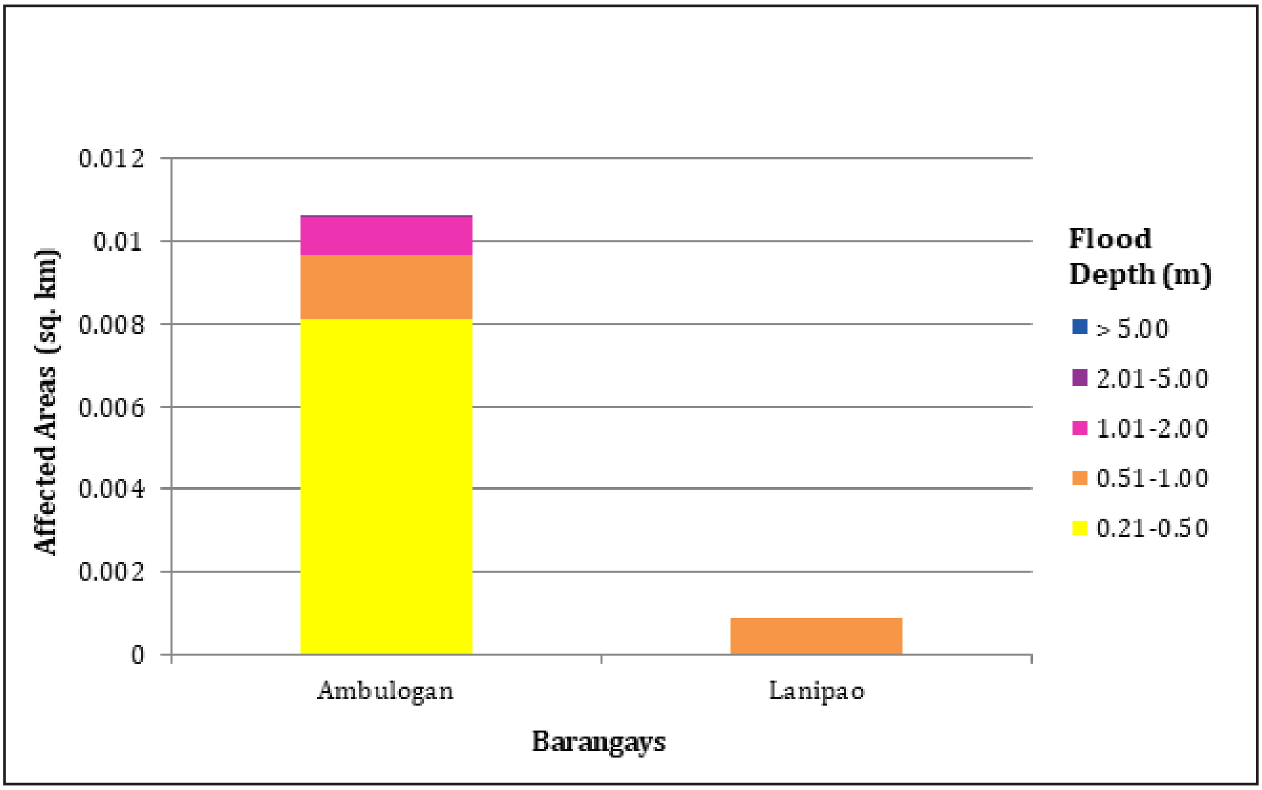


Figure 87. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 32.32% of the municipality of San Ildefonso with an area of 13.21 sq. km. will experience flood levels of less than 0.20 meters. 17.91% of the area will experience flood levels of 0.21 to 0.50 meters while 21.52%, 15.63%, 13.10%, and 0.74% 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 San Ildefonso in square kilometers by flood depth per barangay.

Table 48. Affected Areas in San Ildefonso, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Ildefonso (in sq.km)							
	Arnap	Bahet	Belen	Bungro	Busiing Norte	Busiing Sur	Dongalo	Gongogong
0.03-0.20	0.35	0.14	0.47	0.066	0.45	0.19	0.039	0.0061
0.21-0.50	0.084	0.42	0.53	0.15	0.21	0.021	0.017	0.018
0.51-1.00	0.072	0.48	0.45	0.27	0.11	0.019	0.018	0.13
1.01-2.00	0.088	0.14	0.061	0.14	0.067	0.16	0.13	0.51
2.01-5.00	0.018	0.033	0.036	0.0067	0.087	0.16	0.36	0.18
> 5.00	0	0	0	0	0.004	0	0.03	0.021

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Ildefonso (in sq.km)						
	Iboy	Kinamantirisan	Otol-Patac	Poblacion East	Poblacion West	Sagneb	Sagsagat
0.03-0.20	0.36	0.54	0.51	0.21	0.24	0.23	0.49
0.21-0.50	0.093	0.25	0.11	0.071	0.049	0.2	0.14
0.51-1.00	0.081	0.2	0.062	0.081	0.045	0.61	0.22
1.01-2.00	0.082	0.032	0.23	0.11	0.016	0.079	0.23
2.01-5.00	0.036	0.083	0.28	0.35	0.017	0	0.085
> 5.00	0.0068	0	0	0.027	0.00075	0	0.0085

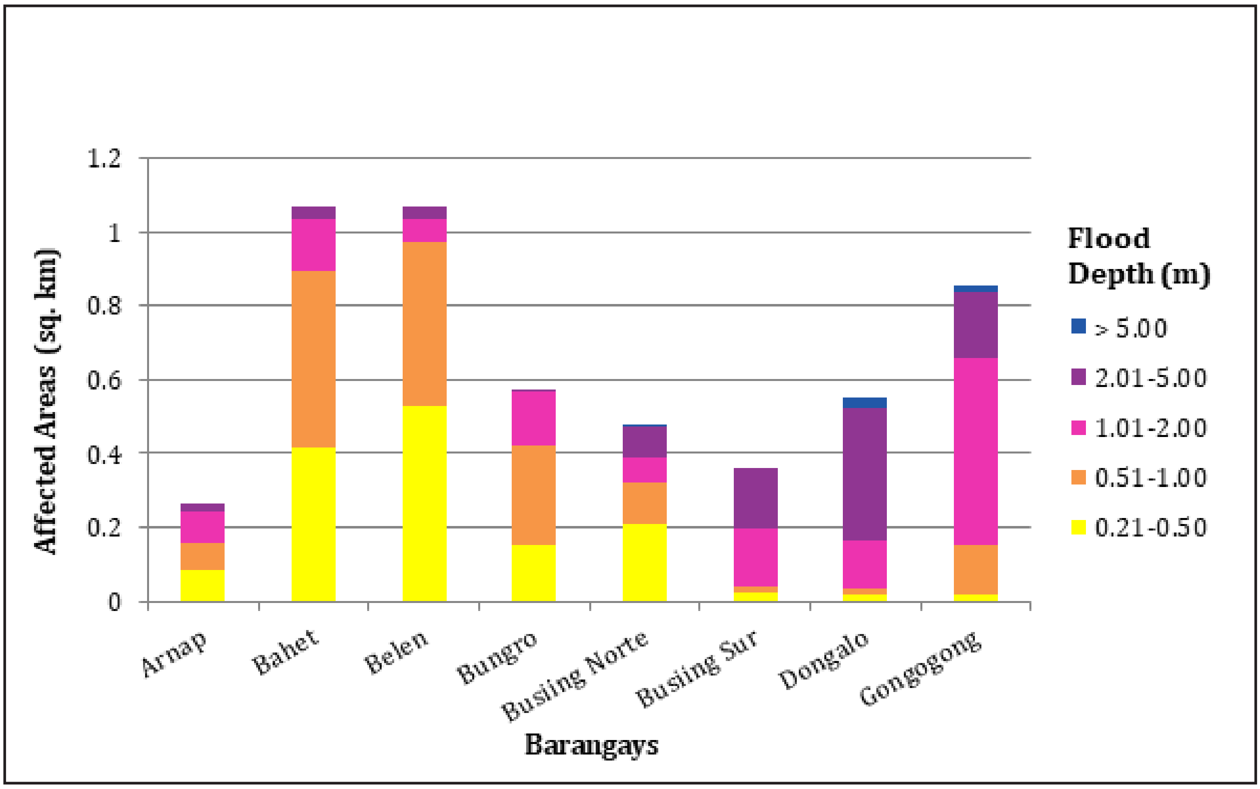


Figure 88. Affected Areas in San Ildefonso, Ilocos Sur during 5-Year Rainfall Return Period.

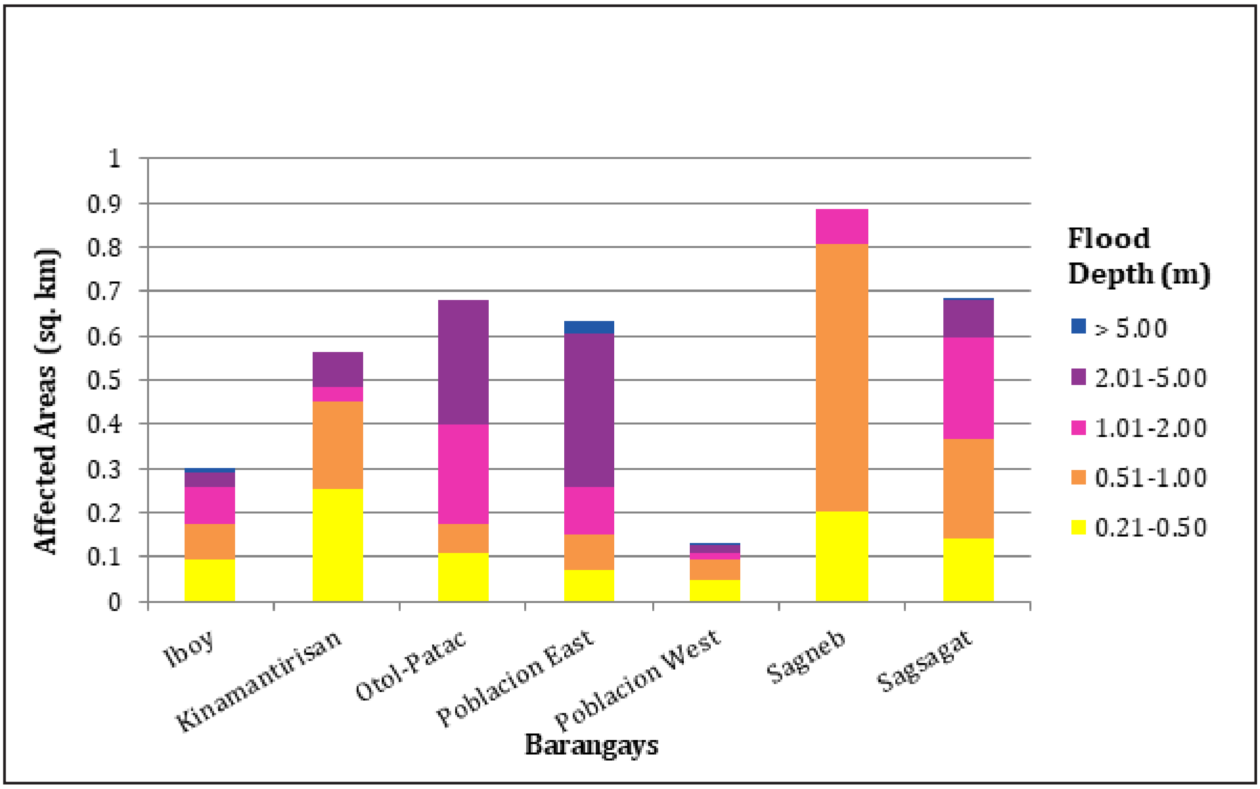


Figure 89. Affected Areas in San Ildefonso, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 51.83% of the municipality of San Juan with an area of 59.88 sq. km. will experience flood levels of less than 0.20 meters. 6.69% of the area will experience flood levels of 0.21 to 0.50 meters while 5.12%, 4.68%, 1.86%, and 0.10% 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 49 are the affected areas in San Juan in square kilometers by flood depth per barangay.

Table 49. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)								
	Asilang	Bacsil	Baliw	Bannuar	Barbar	Cabanglotan	Cacandon-gan	Camang-gaan	Camindoroan
0.03-0.20	1.07	0.46	1.24	0.026	10.93	0.54	1.02	1.41	0.1
0.21-0.50	0.078	0.18	0.34	0	0.5	0.053	0.094	0.11	0.072
0.51-1.00	0.073	0.25	0.078	0	0.32	0.069	0.035	0.11	0.067
1.01-2.00	0.11	0.29	0.084	0	0.28	0.054	0.022	0.068	0.036
2.01-5.00	0.064	0.047	0.13	0	0.21	0.02	0.011	0.015	0.0075
> 5.00	0	0	0.018	0	0.0051	0.0011	0.0004	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)							
	Caronoan	Darao	Guimod Norte	Guimod Sur	Immayos Norte	Immayos Sur	Lira	Malamin
0-0.20	0.034	1.29	0.88	0.4	1.14	0.64	0.22	4.18
0.21-0.50	0.0002	0.11	0.26	0.15	0.15	0.057	0.057	0.19
0.51-1.00	0.0002	0.046	0.07	0.39	0.094	0.16	0.0025	0.13
1.01-2.00	0	0.032	0.007	0.49	0.051	0.17	0.003	0.11
2.01-5.00	0	0.026	0.0023	0.065	0.097	0.034	0.015	0.04
> 5.00	0	0.000008	0	0	0.015	0	0.00089	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)							
	Muraya	Nagsabaran	Nagsupotan	Pandayan	Resurreccion	Sabangan	San Isidro	Saoang
0-0.20	1.8	0.52	0.95	0.089	0.38	0.55	0.45	0.74
0.21-0.50	0.27	0.17	0.31	0.00033	0.044	0.092	0.43	0.3
0.51-1.00	0.14	0.19	0.25	0.00018	0.0094	0.12	0.42	0.036
1.01-2.00	0.19	0.15	0.2	0	0.011	0.043	0.42	0.0012
2.01-5.00	0.16	0.035	0.019	0	0.04	0.015	0.065	0
> 5.00	0.0083	0	0	0	0.013	0	0	0

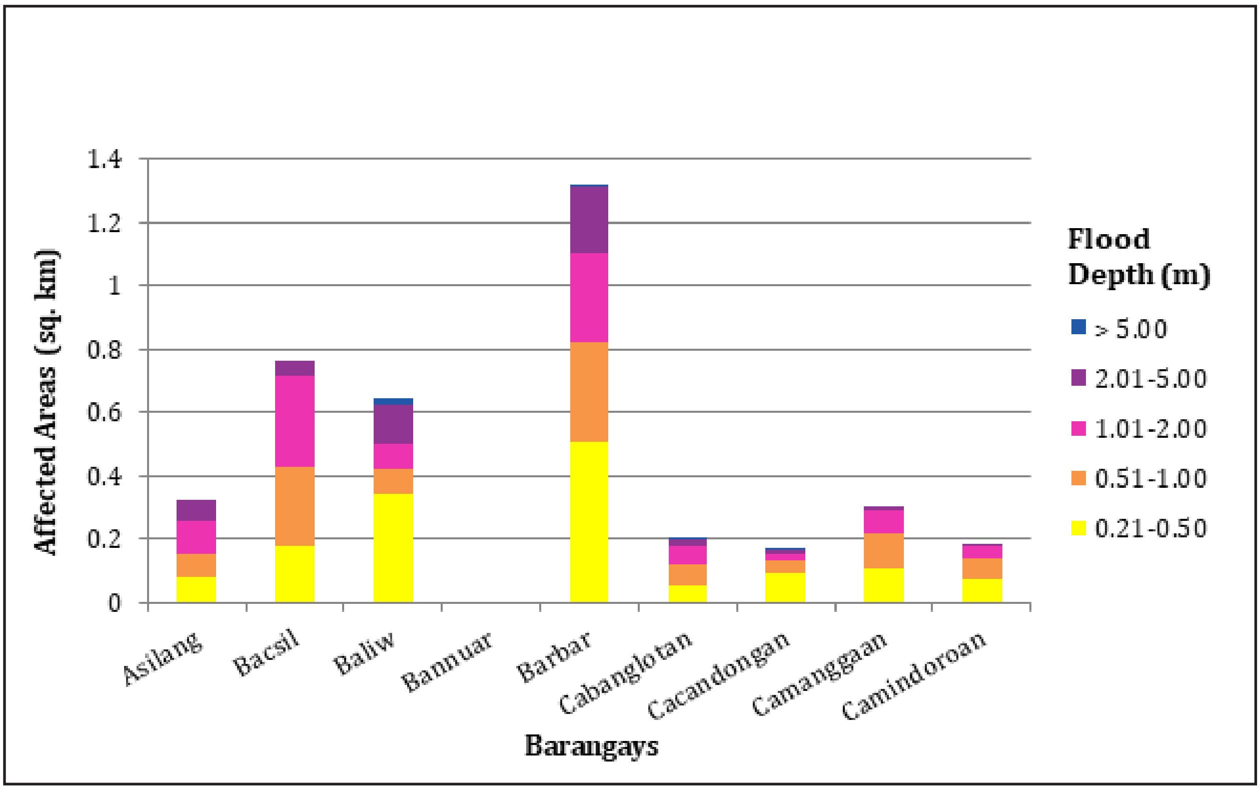


Figure 90. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

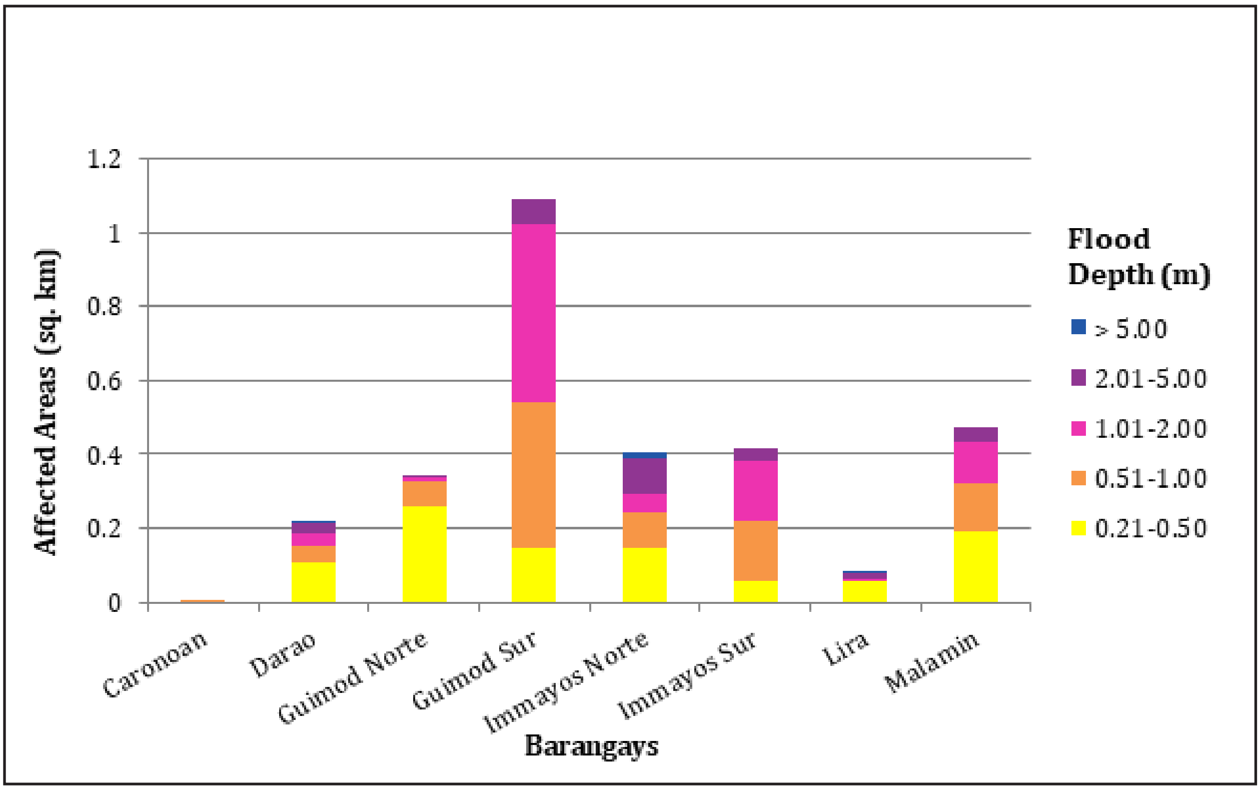


Figure 91. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

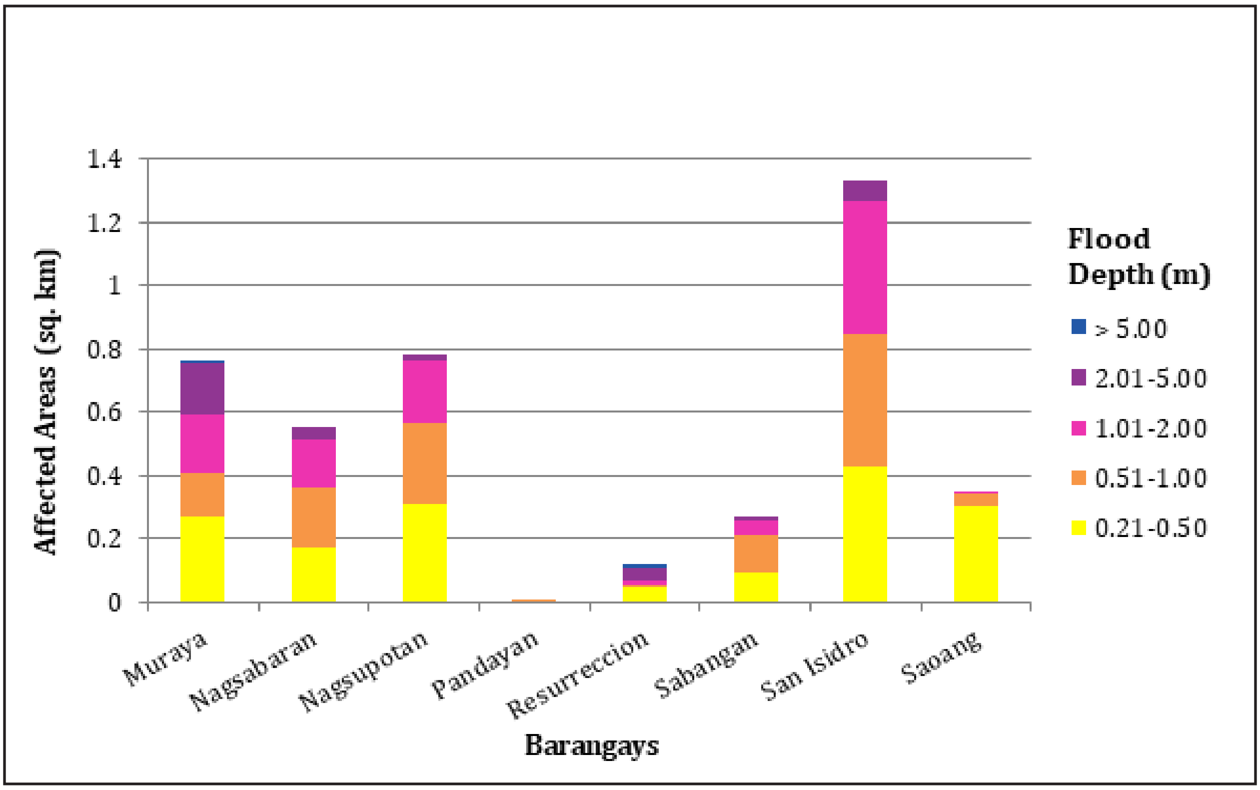


Figure 92. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 26.01% of the municipality of San Vicente with an area of 12.2 sq. km. will experience flood levels of less than 0.20 meters. 12.90% of the area will experience flood levels of 0.21 to 0.50 meters while 21.88%, 33.34%, 8.91%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in San Vicente in square kilometers by flood depth per barangay.

Table 50. Affected Areas in San Vicente, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Vicente (in sq.km)						
	Bantaoay	Bayubay Norte	Bayubay Sur	Lubong	Poblacion	Pudoc	San Sebastian
0-0.20	0.0055	0.24	0.35	0.33	0.33	0.18	1.73
0.21-0.50	0.017	0.16	0.1	0.2	0.15	0.26	0.69
0.51-1.00	0.16	0.084	0.046	0.21	0.11	1.02	1.04
1.01-2.00	0.59	0.011	0.024	0.1	0.0097	1.88	1.45
2.01-5.00	0.22	0	0.013	0.0038	0.00032	0.18	0.67
> 5.00	0	0	0	0	0	0	0.0007

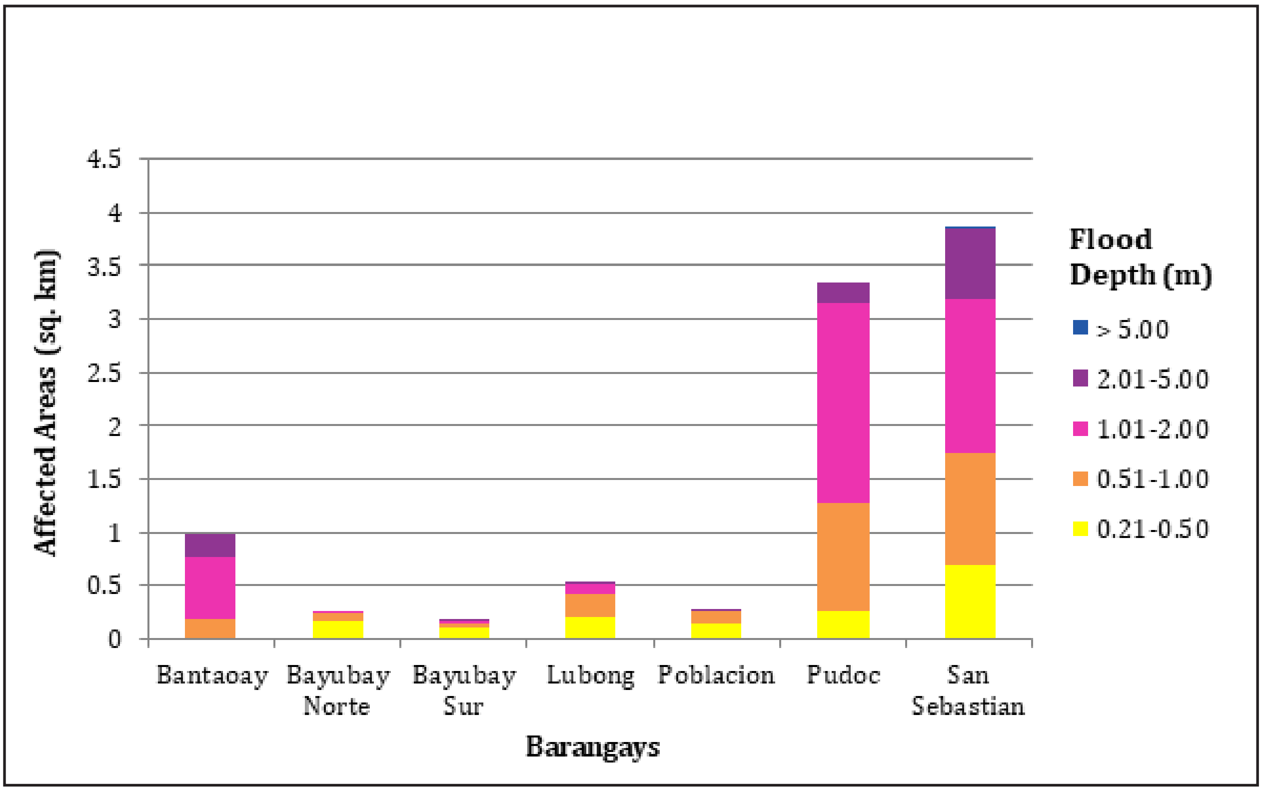


Figure 93. Affected Areas in San Vicente, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 31.91% of the municipality of Santa with an area of 57.2 sq. km. will experience flood levels of less than 0.20 meters. 4.28% of the area will experience flood levels of 0.21 to 0.50 meters while 3.87%, 5.47%, 10.30%, and 6.96% 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 51 are the affected areas in Santa in square kilometers by flood depth per barangay.

Table 51. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa (in sq.km)										
	Ampandula	Banaoang	Basug	Bucalag	Cabangaran	Calungboyan	Dammay	Labut Norte	Labut Sur	Mabilbila Norte	Mabilbila Sur
0.03-0.20	1.02	1.02	0.84	0.039	0.7	0.2	5.03	0.52	0.75	0.34	0.55
0.21-0.50	0.031	0.041	0.039	0.1	0.033	0.13	1.26	0.02	0.03	0.0044	0.015
0.51-1.00	0.011	0.021	0.015	0.095	0.012	0.12	1.23	0.013	0.024	0.0005	0.014
1.01-2.00	0.0022	0.023	0.001	0.014	0.0015	0.032	2.36	0.0075	0.022	0.0001	0.0042
2.01-5.00	0	0.082	0	0.003	0.0001	0	2.75	0.0003	0.0027	0	0.0002
> 5.00	0	0.75	0	0	0	0	1.11	0	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Santa (in sq.km)**										
	Manueva	**Marcos**	**Nagpanaoan**	**Namalangan**	**Oribi**	**Pasungol**	**Quirino**	**Rizal**	**Sacuyya Norte**	**Sacuyya Sur**	**Tabucolan**
0-0.20	0.52	0.055	0.073	1.16	0.04	0.11	1.68	1.25	1.04	1.26	0.061
0.21-0.50	0.012	0.00099	0.056	0.032	0.0086	0.066	0.29	0.047	0.042	0.053	0.14
0.51-1.00	0.0095	0.0012	0.16	0.022	0.0088	0.041	0.15	0.027	0.011	0.017	0.21
1.01-2.00	0.0042	0.0001	0.46	0.0084	0.0078	0.015	0.099	0.015	0	0.003	0.044
2.01-5.00	0	0	2.98	0.035	0	0	0.014	0.012	0.0009	0.00039	0
> 5.00	0	0	2.05	0.056	0	0	0	0.003	0	0	0

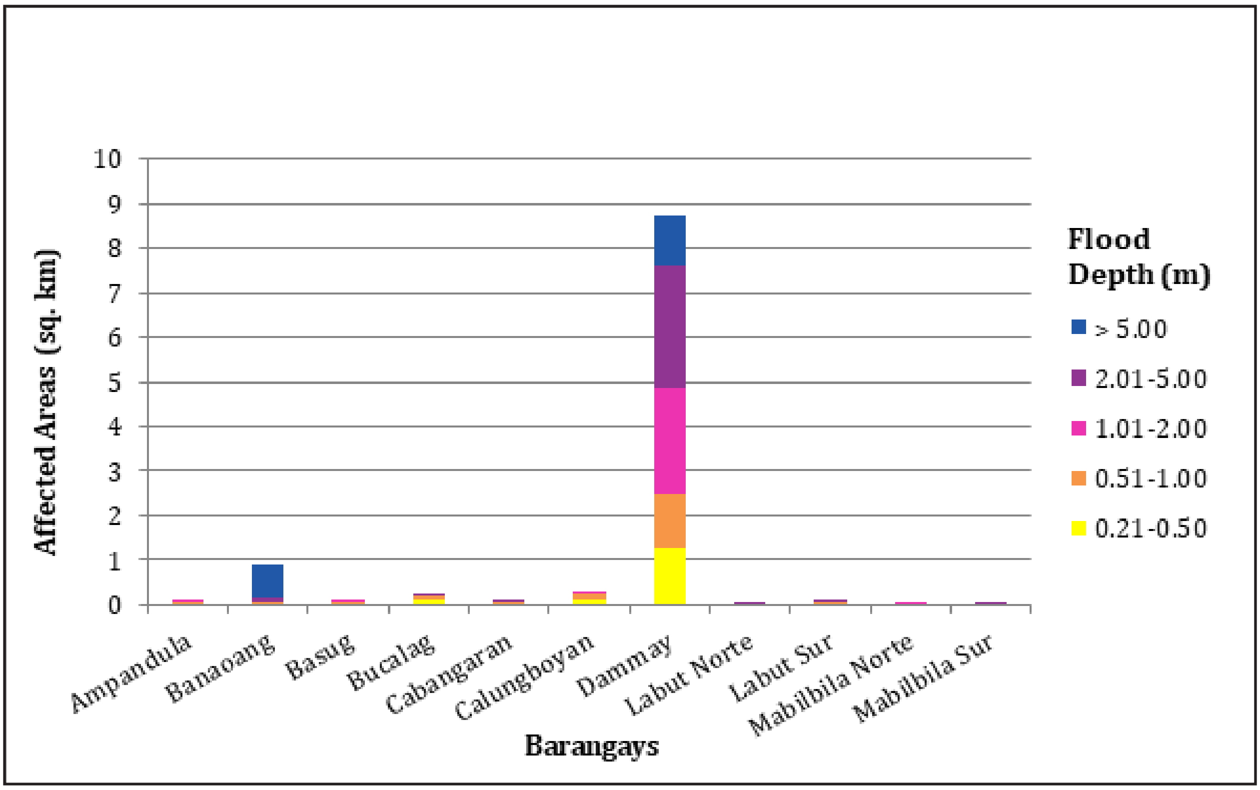


Figure 94. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period.

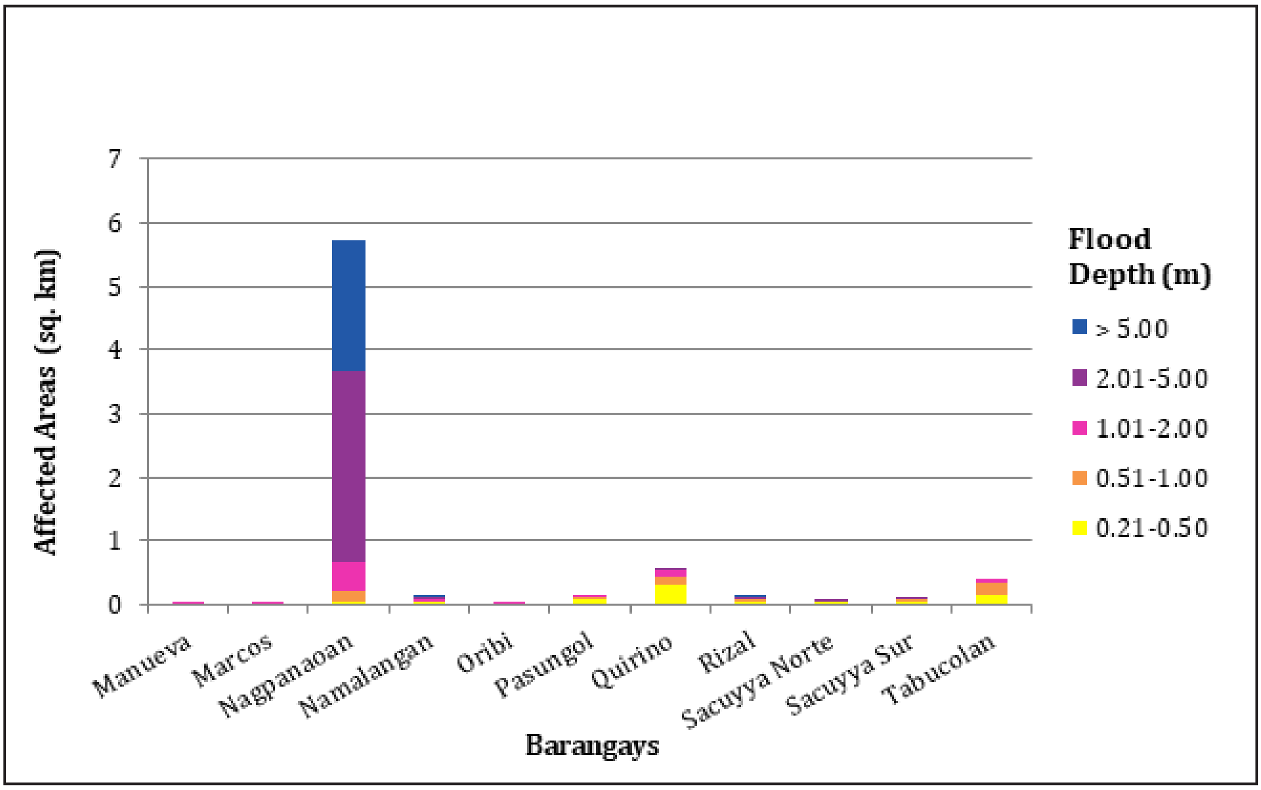


Figure 95. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 42.78% of the municipality of Santa Catalina with an area of 10.83 sq. km. will experience flood levels of less than 0.20 meters. 14.56% of the area will experience flood levels of 0.21 to 0.50 meters while 9.47%, 5.41%, and 2.45% 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 52 are the affected areas in Santa Catalina in square kilometers by flood depth per barangay.

Table 52. Affected Areas in Santa Catalina, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa Catalina (in sq.km)							
	Cabaroan	Cabittaogan	Cabuloan	Pangada	Poblacion	Sinabaan	Subec	Tamorong
0-0.20	0.36	1.45	0.48	0.28	0.24	0.76	0.32	0.74
0.21-0.50	0.079	0.33	0.13	0.063	0.065	0.32	0.065	0.52
0.51-1.00	0.022	0.33	0.11	0.045	0.022	0.067	0.019	0.41
1.01-2.00	0.022	0.3	0.021	0.024	0.025	0.016	0.001	0.18
2.01-5.00	0.0015	0.053	0.078	0.094	0.006	0	0	0.033
> 5.00	0	0	0	0	0	0	0	0

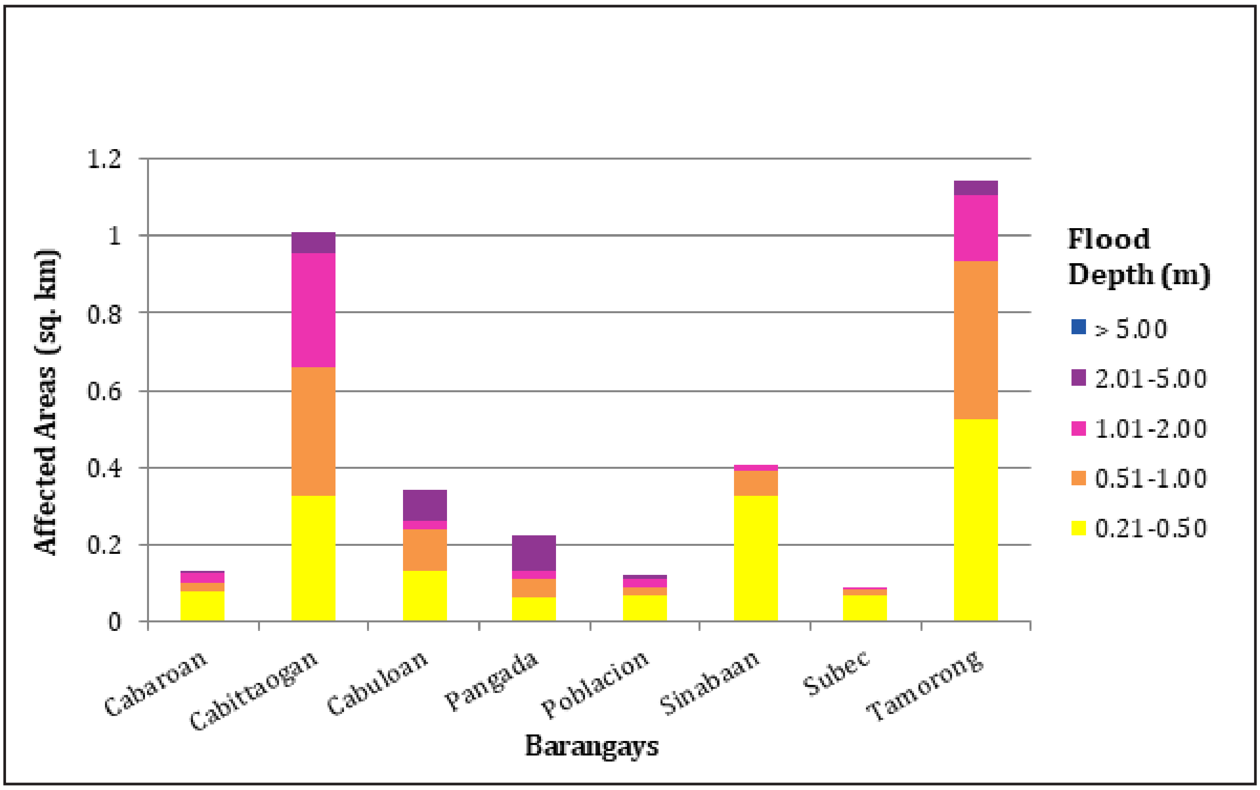


Figure 96. Affected Areas in Santa Catalina, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 50.99% of the municipality of Santo Domingo with an area of 50.36 sq. km. will experience flood levels of less than 0.20 meters. 14.68% of the area will experience flood levels of 0.21 to 0.50 meters while 14.01%, 16.40%, 4.46%, and 0.07% 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 Santo Domingo in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santo Domingo (in sq.km)											
	Binalayangan	Binongan	Borobor	Cabaritan	Cabigbigaan	Calautit	Calay-Ab	Camestizoan	Casili	Flora	Lagatit	Laoingen
0.03-0.20	0.34	0.73	0.79	0.27	0.2	1.1	0.88	0.021	0.71	0.7	3.88	6.28
0.21-0.50	0.22	0.47	0.43	0.14	0.085	0.17	0.16	0.024	0.12	0.21	0.26	0.54
0.51-1.00	0.18	0.23	0.34	0.32	0.13	0.076	0.16	0.0072	0.12	0.37	0.13	0.37
1.01-2.00	0.0055	0.039	0.08	0.63	0.013	0.053	0.12	0.3	0.055	0.18	0.12	0.29
2.01-5.00	0	0.0008	0.041	0.35	0	0.062	0.15	0.4	0.015	0	0.052	0.093
> 5.00	0	0	0.0001	0.000002	0	0.0036	0	0.021	0	0	0	0.0003
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Santo Domingo (in sq.km)**											
	Lussoc	Nagbettedan	Naglaoa-An	Nalasin	Nambaran	Nanerman	Napo	Padu Chico	Padu Grande	Paguraper	Panay	Pangpangdan
0-0.20	0.63	1.65	0.29	0.04	0.27	0.3	0.51	0.57	0.51	0.53	0.23	0.72
0.21-0.50	0.17	0.24	0.29	0.041	0.19	0.04	0.18	0.14	0.098	0.32	0.1	0.14
0.51-1.00	0.17	0.048	0.47	0.058	0.39	0.026	0.0041	0.18	0.11	0.25	0.14	0.18
1.01-2.00	0.091	0.049	0.74	0.16	0.66	0.062	0.0031	0.22	0.083	0.11	0.0031	0.082
2.01-5.00	0.012	0.02	0.16	0.046	0.021	0.056	0.0007	0.0005	0.0003	0.0014	0	0.0094
> 5.00	0.0009	0	0.01	0	0	0	0	0	0	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Santo Domingo (in sq.km)**											
	Parada	Paras	Poblacion	Puerta Real	Pussuac	Quimmarayan	San Pablo	Santa Cruz	Santo Tomas	Sived	Suksukit	Vacunero
0-0.20	0.52	0.34	0.042	0.36	0.31	0.57	0.055	0.53	0.15	0.56	0.1	0.0013
0.21-0.50	0.45	0.53	0.12	0.18	0.16	0.22	0.12	0.32	0.29	0.13	0.079	0.0035
0.51-1.00	0.51	0.11	0.14	0.083	0.22	0.23	0.25	0.64	0.21	0.17	0.038	0.018
1.01-2.00	0.59	0.0088	0.19	0.26	0.41	0.24	0.62	1.01	0.039	0.15	0.066	0.51
2.01-5.00	0.0096	0.00063	0.051	0.071	0.14	0.054	0.056	0.085	0.012	0.17	0.087	0.021
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

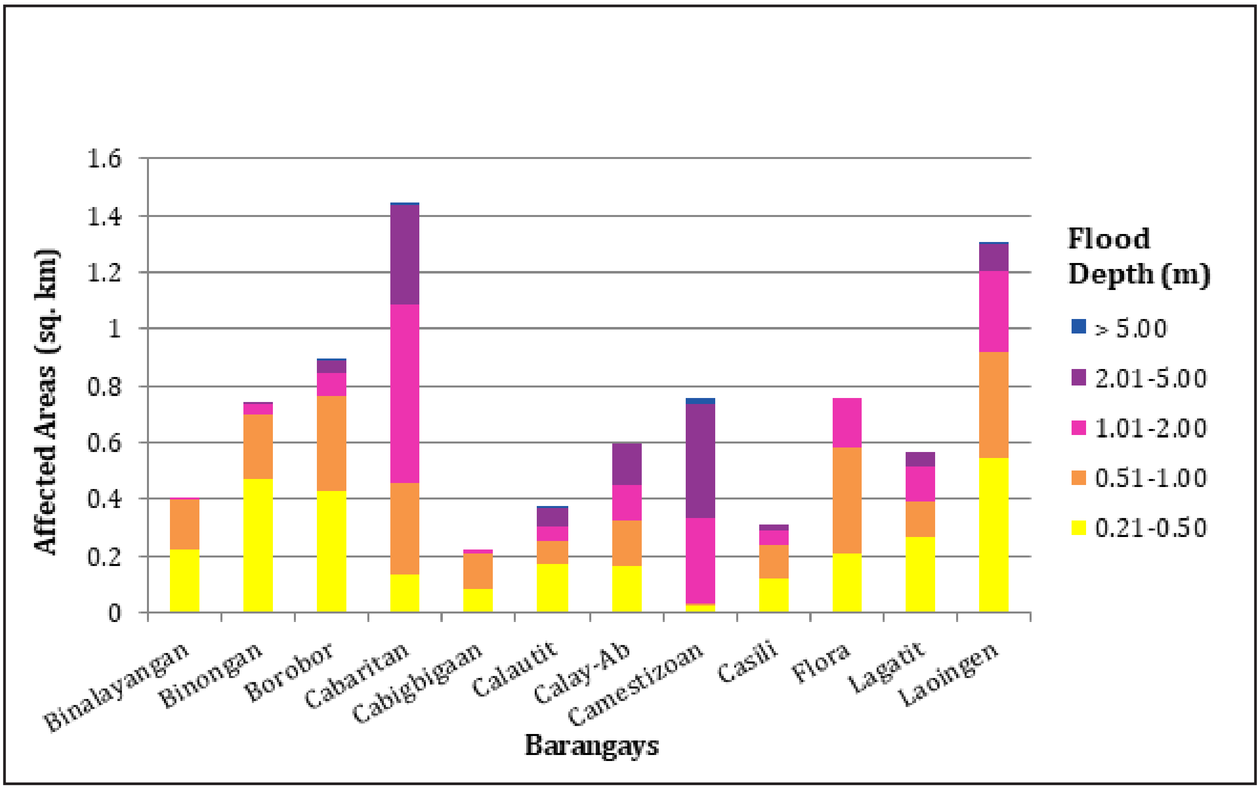


Figure 97. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

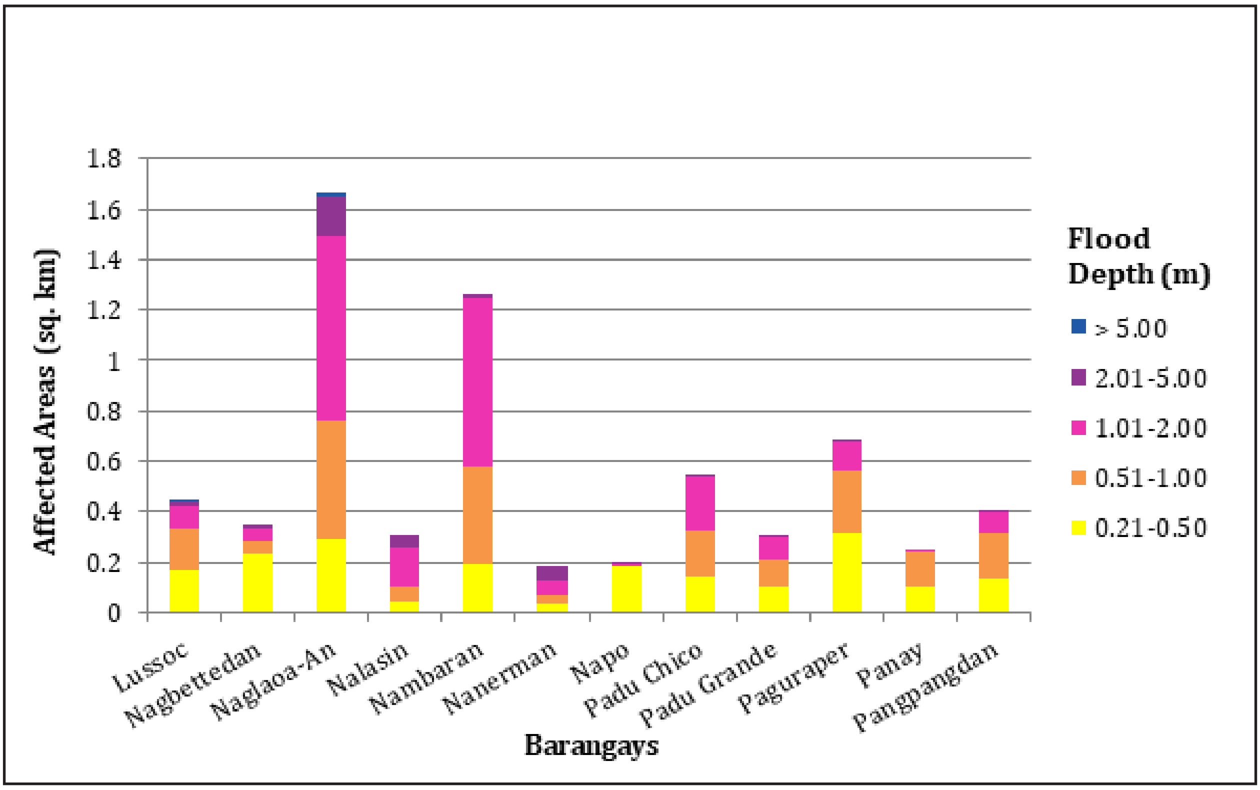


Figure 98. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

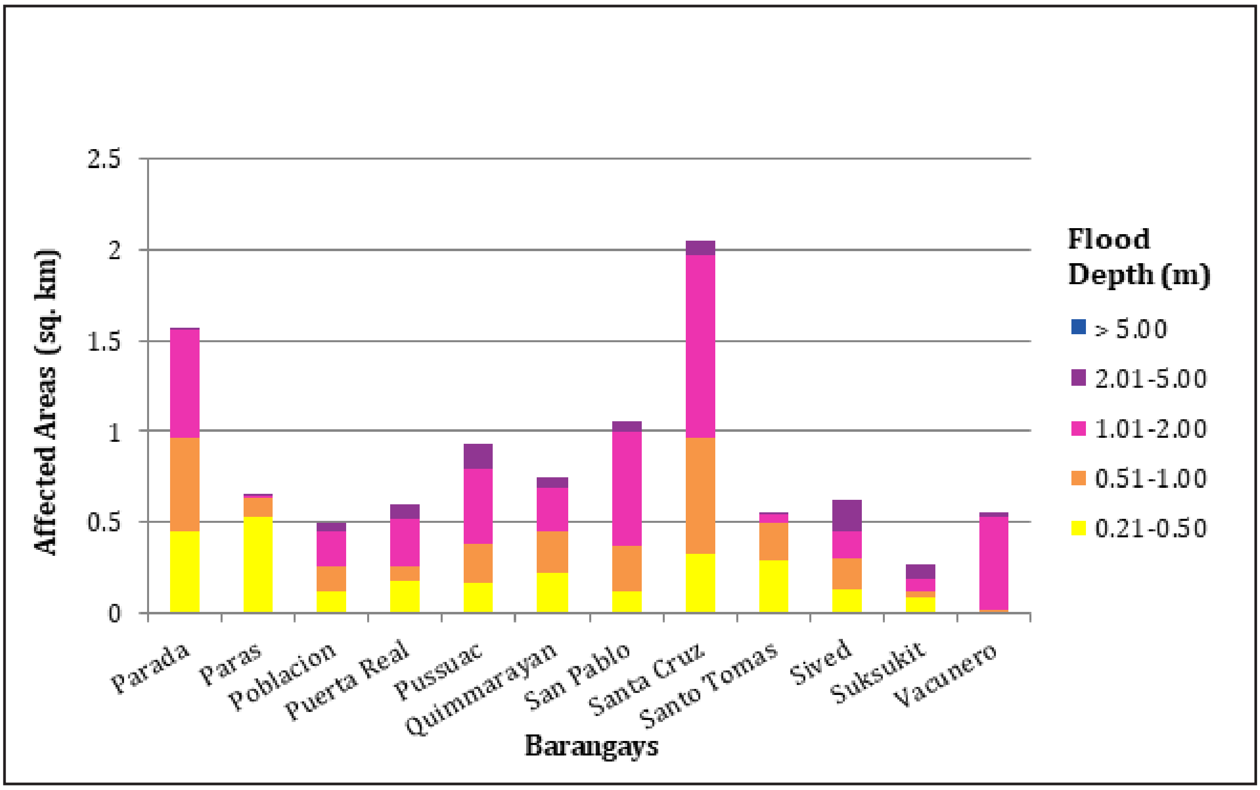


Figure 99. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

For the 5-year return period, 22.39% of the municipality of Vigan City with an area of 24.01 sq. km. will experience flood levels of less than 0.20 meters. 5.82% of the area will experience flood levels of 0.21 to 0.50 meters while 8.25%, 22.36%, 34.50%, and 4.35% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 54 are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Ayusan Norte	Ayusan Sur	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay IX	Barangay V	Barangay VI	Barangay VII
0.03-0.20	1.06	0.38	0.019	0	0.1	0	0	0	0	0.079
0.21-0.50	0.15	0.091	0.0022	0.0012	0.0085	0	0	0	0	0.013
0.51-1.00	0.053	0.031	0.0038	0.023	0.003	0.0037	0.0072	0.0057	0	0.014
1.01-2.00	0.054	0.018	0.0047	0.025	0.0065	0.033	0.057	0.054	0.00024	0.03
2.01-5.00	0.068	0.0039	0.035	0.054	0.0069	0.017	0.28	0.068	0.23	0.19
> 5.00	0.055	0	0.027	0.017	0.023	0.012	0	0	0.0017	0.045
Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Barangay VIII	Barraca	Beddeng Daya	Beddeng Laud	Bongtolan	Bulala	Cabalangegan	Cabaroan Daya	Cabaroan Laud	Camangaan
0-0.20	0	0	0	0	0.0002	0.39	0	0	0	0
0.21-0.50	0	0	0.0005	0	0.0011	0.07	0	0	0.0034	0.0029
0.51-1.00	0	0.04	0.031	0.015	0.029	0.023	0	0.026	0.046	0.03
1.01-2.00	0.022	0.17	0.16	0.24	0.12	0.0068	0.13	0.29	0.17	0.033
2.01-5.00	0.2	0.12	0.029	0.16	0.07	0	0.2	0.34	0.11	0.2
> 5.00	0.09	0	0	0	0.0015	0	0	0.014	0.027	0.033
Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Capangpangan	Mindoro	Nagsan-galan	Pantay Daya	Pantay Fatima	Pantay Laud	Paoa	Paratong	Pong-Ol	Purok-A-Bassit
0-0.20	0	0.35	0	0.41	0.54	0.8	0.26	0.4	0.061	0
0.21-0.50	0	0.19	0.0015	0.21	0.13	0.26	0.064	0.021	0.016	0
0.51-1.00	0.0021	0.24	0.13	0.25	0.12	0.3	0.032	0.05	0.041	0.06
1.01-2.00	0.21	0.11	0.56	0.3	0.15	0.23	0.026	0.11	0.046	0.29
2.01-5.00	0.33	0.012	0.21	0.18	0.098	0.0014	0.034	0.037	0.12	0.043
> 5.00	0.0079	0	0.028	0	0	0	0.0023	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)								
	Purok-A-Dackel	Raois	Rugsuanan	Salindeg	San Jose	San Julian Norte	San Julian Sur	San Pedro	Tamag
0.03-0.20	0	0	0	0.085	0	0	0	0.15	0.3
0.21-0.50	0.0005	0.0006	0	0.012	0	0	0	0.11	0.038
0.51-1.00	0.058	0.035	0.0093	0.0084	0.0044	0.0006	0	0.24	0.018
1.01-2.00	0.21	0.13	0.19	0.17	0.13	0.33	0.0097	0.42	0.11
2.01-5.00	0.055	1.89	1.16	0.32	0.18	0.11	0.29	0.34	0.49
> 5.00	0	0.47	0.054	0.071	0	0	0	0	0.068

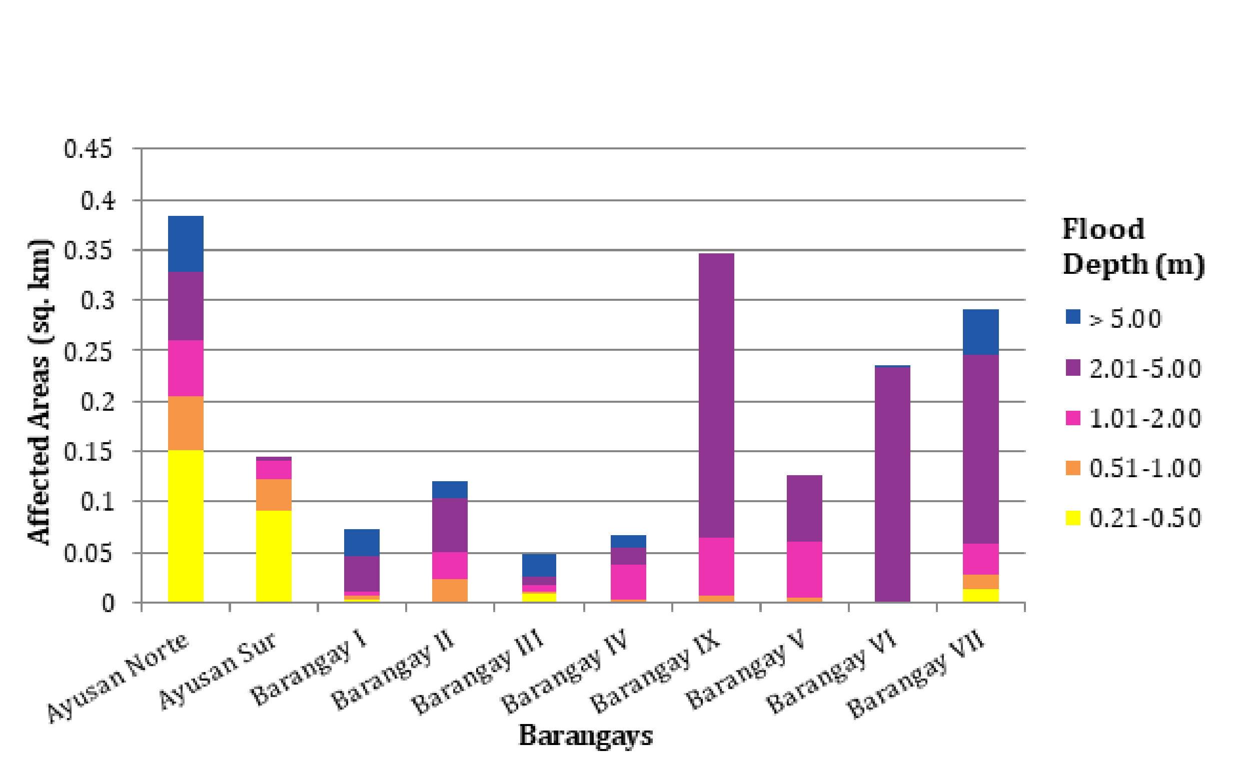


Figure 100. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

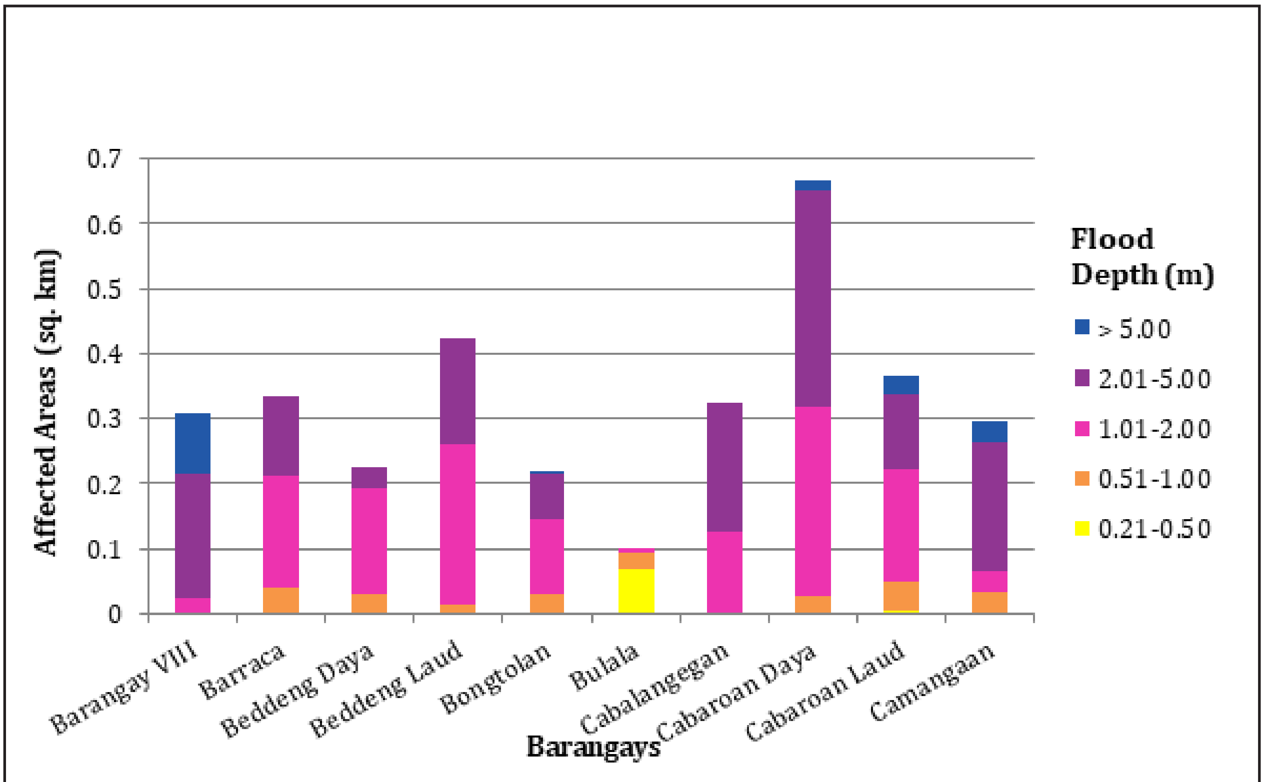


Figure 101. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

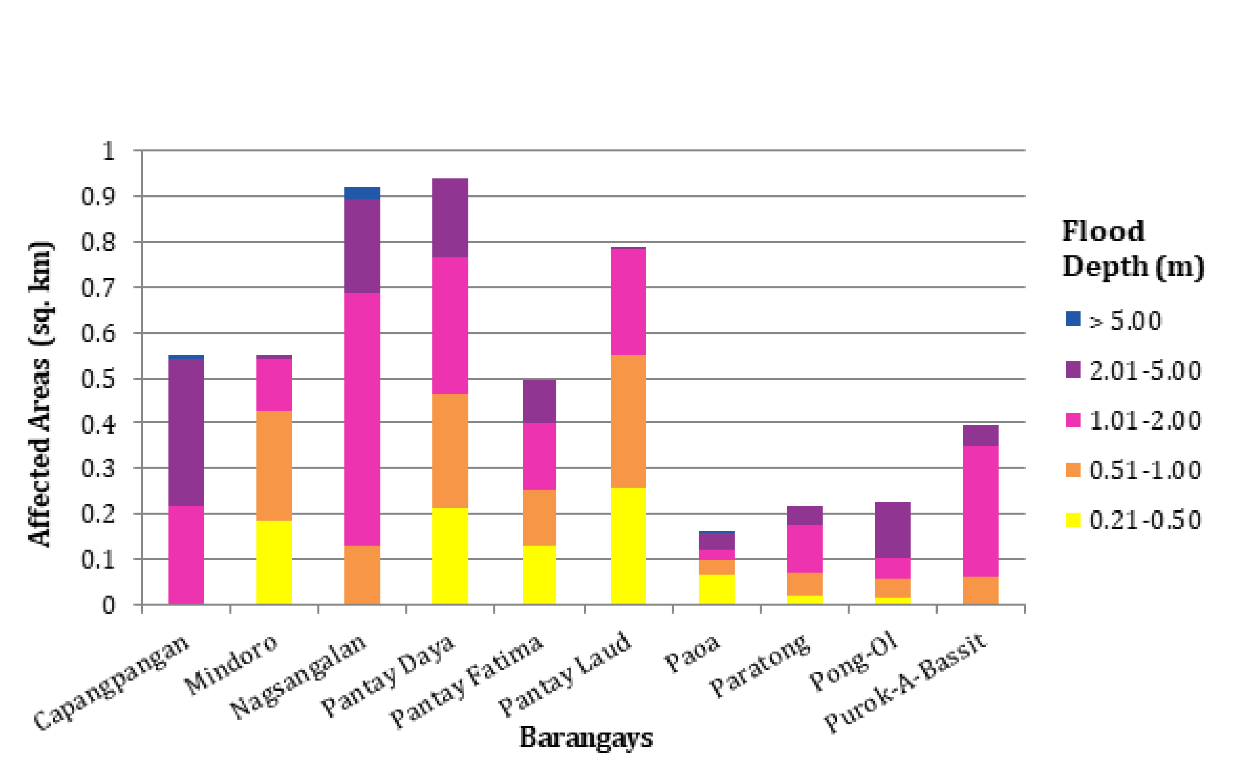


Figure 102. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

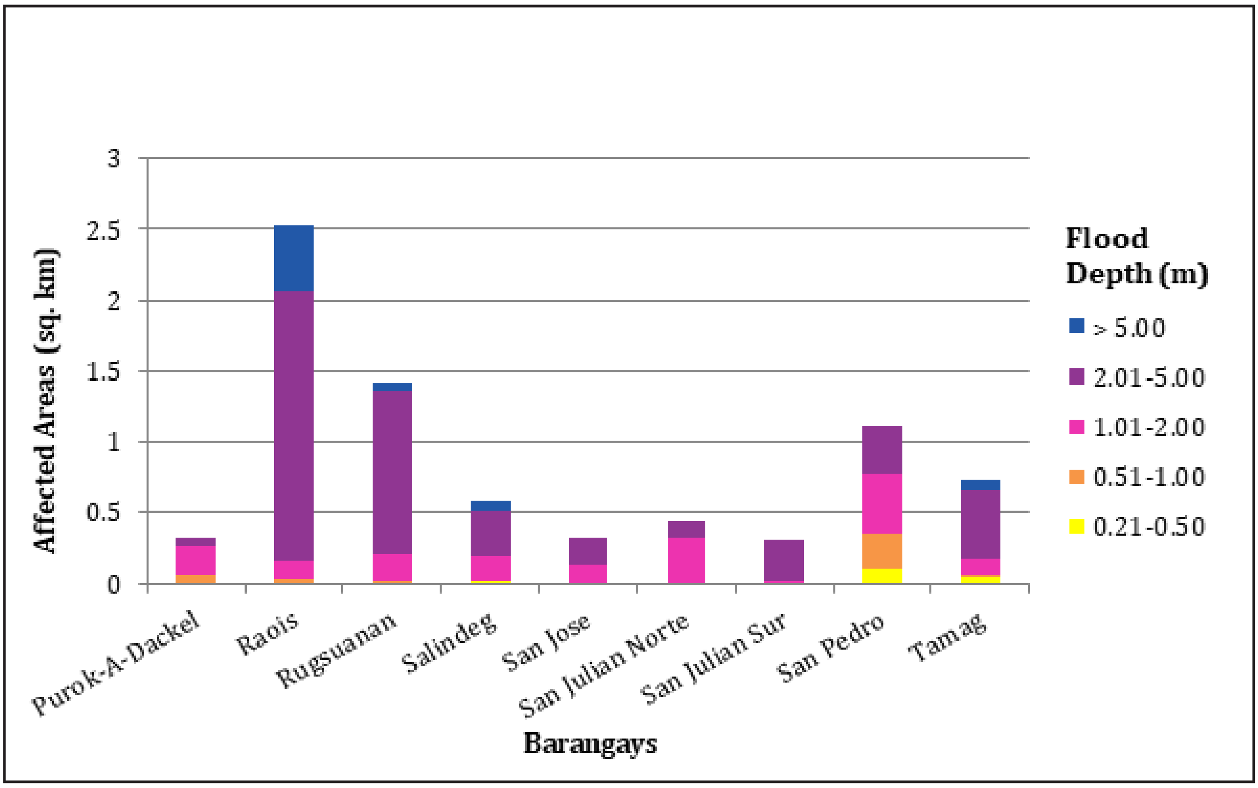


Figure 103. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

For the 25-year return period, 7.72% of the municipality of Bangued with an area of 123.75 sq. km. will experience flood levels of less than 0.20 meters. 0.38% of the area will experience flood levels of 0.21 to 0.50 meters while 0.17%, 0.12%, 0.24%, and 16.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas in Bangued in square kilometers by flood depth per barangay.

Table 55. Affected Areas in Bangued, Abra during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangued (in sq. km.)										
	Bañacao	Bangbangar	Cabuloan	Calaba	Dangdangla	Lingtan	Lipcan	Malita	Palao	Patucannay	Sagap
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0.0018	0.0027	0.0075	0.14	0.0081	0.0054	0.091
0.51-1.00	0	0	0	0	0.0045	0.0027	0.0027	0.051	0.012	0.0018	0.046
1.01-2.00	0	0	0	0	0.0018	0.0059	0.0099	0.03	0.011	0.0031	0.027
2.01-5.00	0	0	0	0	0.023	0.077	0.023	0.0045	0.033	0.013	0.0081
> 5.00	2.67	1.71	2.57	0.73	0.11	0.62	0.93	0	1.77	0.06	0.0009

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangued (in sq. km.)									
	San Antonio	Santa Rosa	Sao-Atan	Zone 1 Poblacion	Zone 2 Poblacion	Zone 3 Poblacion	Zone 4 Poblacion	Zone 5 Poblacion	Zone 6 Poblacion	Zone 7 Poblacion
0.03-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.21	0	0.0027	0	0	0	0	0	0	0
0.51-1.00	0.088	0	0	0	0	0	0	0	0	0
1.01-2.00	0.06	0	0.0005	0	0	0	0	0	0	0.0027
2.01-5.00	0.098	0	0.0042	0	0	0	0	0	0	0.0064
> 5.00	2.31	4.55	0.017	0.28	0.3	0.68	0.14	0.23	0.19	0.24

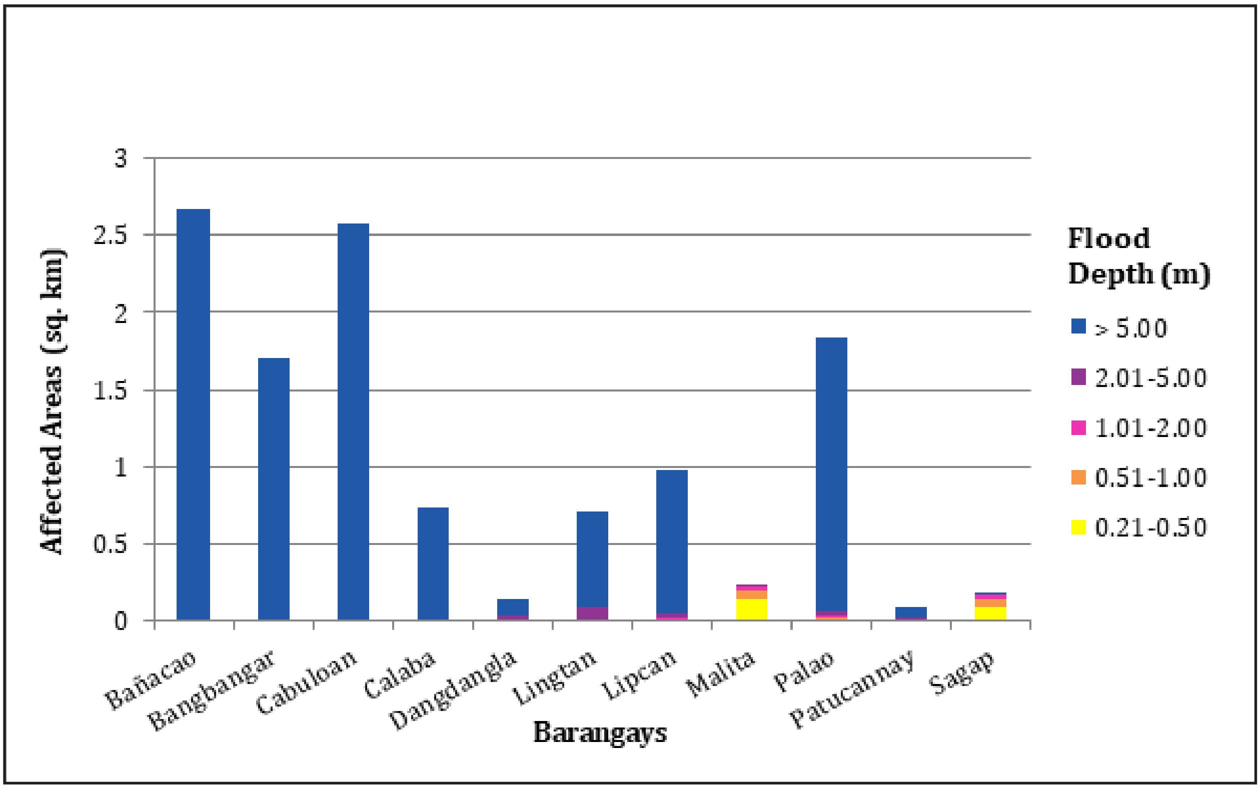


Figure 104. Affected Areas in Bangued, Abra during 25-Year Rainfall Return Period.

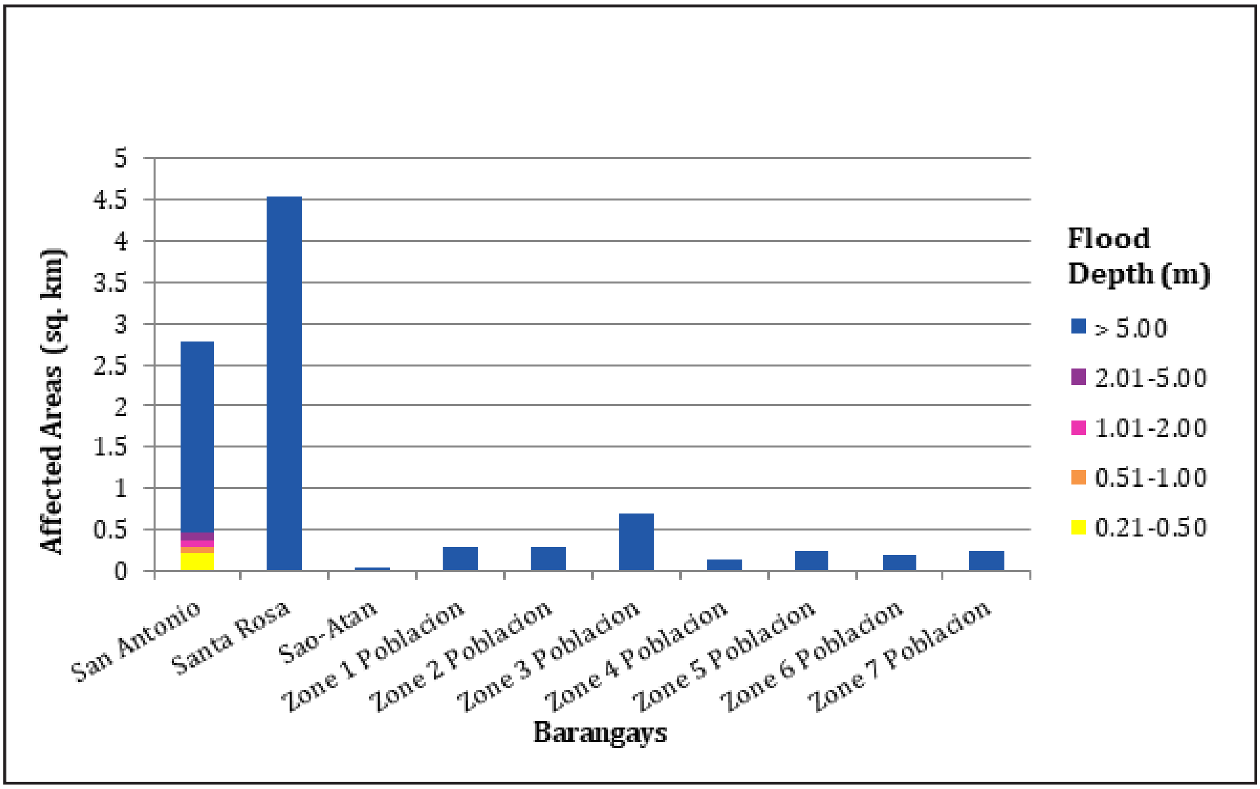


Figure 105. Affected Areas in Bangued, Abra during 25-Year Rainfall Return Period.

For the 25-year return period, 66.16% of the municipality of Langiden with an area of 98.7 sq. km. will experience flood levels of less than 0.20 meters. 3.50% of the area will experience flood levels of 0.21 to 0.50 meters while 1.68%, 1.08%, 2.42%, and 14.00% 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 56 are the affected areas in Langiden in square kilometers by flood depth per barangay.

Table 56. Affected Areas in Langiden, Abra during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays Langiden (in sq. km)					
	Baac	Dalayap	Mabungtot	Malapaao	Poblacion	Quillat
0-0.20	0	0	0	0	0	0
0.21-0.50	0.076	0.0054	1.33	1.98	0.025	0.034
0.51-1.00	0.028	0.0036	0.64	0.95	0.019	0.016
1.01-2.00	0.035	0.0081	0.38	0.59	0.03	0.028
2.01-5.00	0.053	0.019	0.8	1.4	0.066	0.05
> 5.00	1.92	0.62	3.37	3.45	0.6	3.86

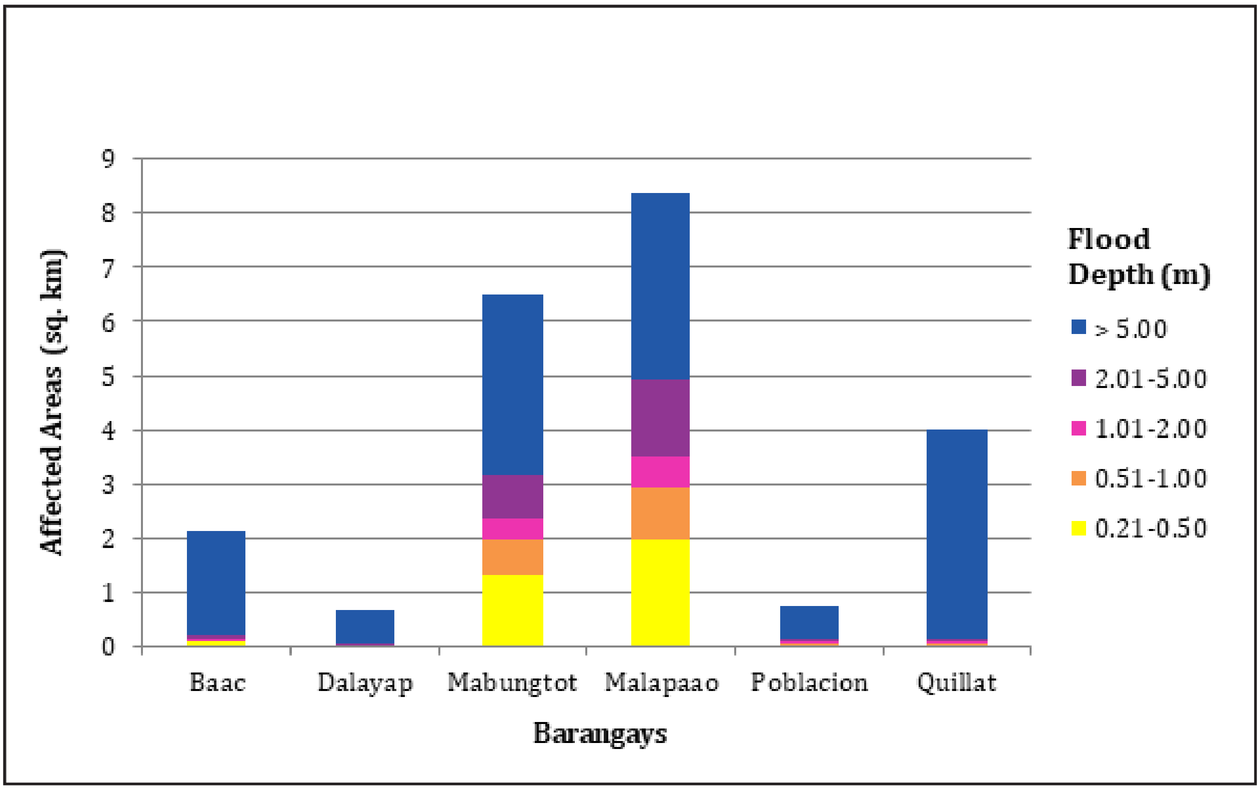


Figure 106. Affected Areas in Langiden, Abra during 25-Year Rainfall Return Period.

For the 25-year return period, 40.94% of the municipality of Pidigan with an area of 58.13 sq. km. will experience flood levels of less than 0.20 meters. 1.93% of the area will experience flood levels of 0.21 to 0.50 meters while 0.91%, 0.89%, 1.37%, and 31.36% 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 Pidigan in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Pidigan, Abra during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pidigan (in sq. km.)						
	Alinaya	Garreta	Immuli	Laskig	Monggoc	Naguirayan	Pamutic
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0.18	0.082	0.059	0.016	0.19	0.0009	0.0079
0.51-1.00	0.093	0.014	0.023	0.02	0.094	0.0018	0.0027
1.01-2.00	0.077	0.027	0.0094	0.008	0.12	0.0058	0.0027
2.01-5.00	0.092	0.051	0	0.037	0.19	0.021	0.009
> 5.00	0.69	0.26	0	0.74	1.18	1.26	1.45
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Pidigan (in sq. km.)**						
	Pangtud	**Poblacion East**	**Poblacion West**	**San Diego**	**Sulbec**	**Suyo**	**Yuyeng**
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0.12	0	0	0.0018	0.13	0.031	0.3
0.51-1.00	0.083	0	0	0.0044	0.057	0.016	0.12
1.01-2.00	0.1	0	0	0.01	0.057	0.014	0.085
2.01-5.00	0.089	0	0	0.035	0.13	0.027	0.12
> 5.00	1.71	2.54	1.93	2.09	3.15	0.57	0.68

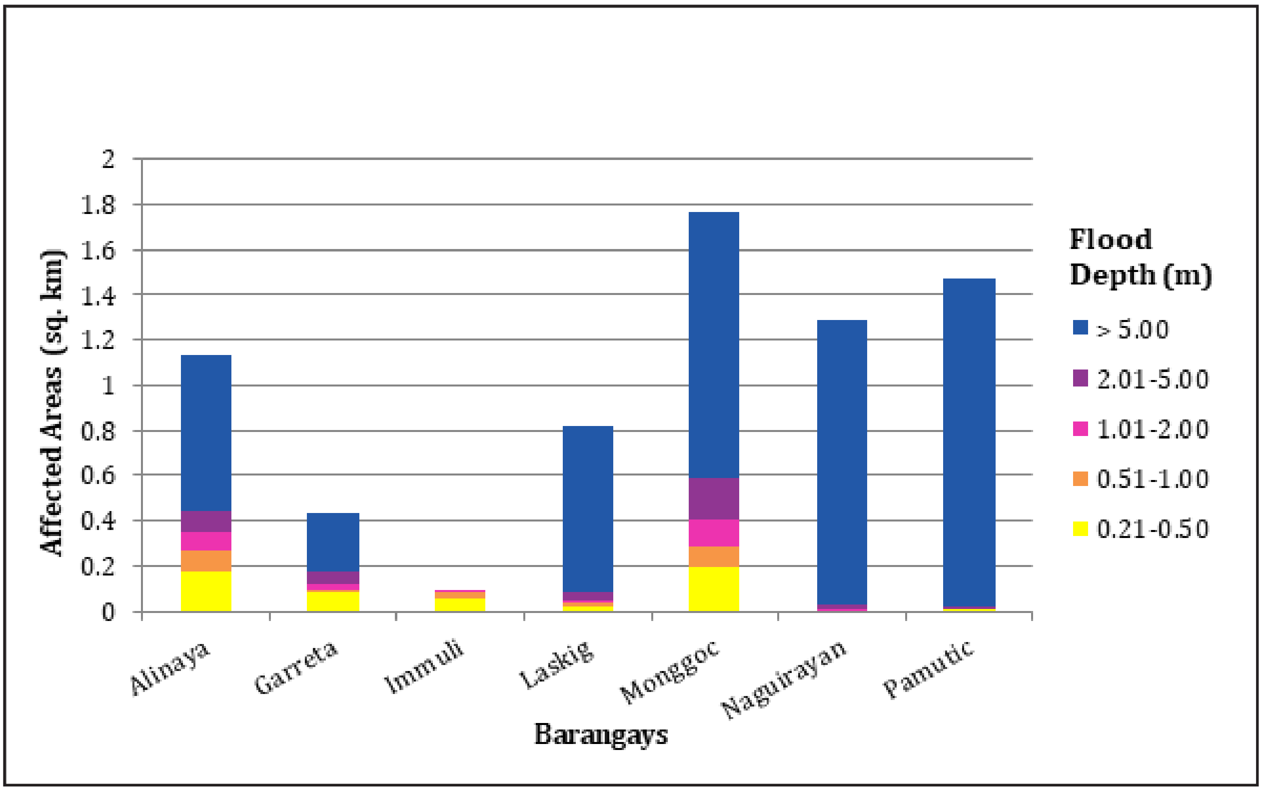


Figure 107. Affected Areas in Pidigan, Abra during 25-Year Rainfall Return Period.

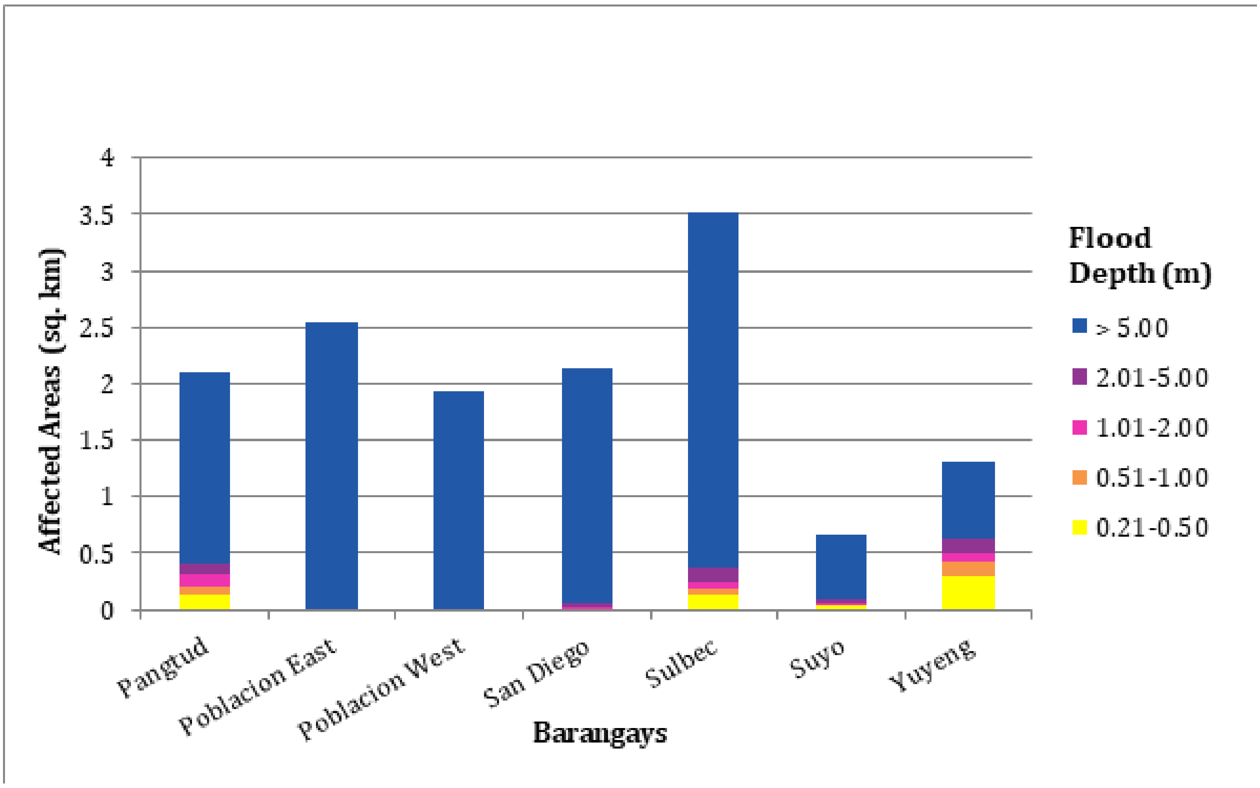


Figure 108. Affected Areas in Pidigan, Abra during 25-Year Rainfall Return Period.

For the 25-year return period, 51.04% of the municipality of San Quintin with an area of 62.29 sq. km. will experience flood levels of less than 0.20 meters. 2.71% of the area will experience flood levels of 0.21 to 0.50 meters while 1.43%, 1.25%, 1.92%, and 12.60% 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 San Quintin in square kilometers by flood depth per barangay.

Table 58. Affected Areas in San Quintin, Abra during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)					
	Labaan	Palang	Pantoc	Poblacion	Tangadan	Villa Mercedes
0-0.20	0	0	0	0	0	0
0.21-0.50	0.48	0.22	0.23	0.013	0.62	0.13
0.51-1.00	0.29	0.081	0.097	0.0036	0.34	0.087
1.01-2.00	0.26	0.095	0.057	0.0076	0.25	0.11
2.01-5.00	0.42	0.2	0.07	0.023	0.25	0.23
> 5.00	2.35	4.2	0.0045	0.98	0.09	0.22

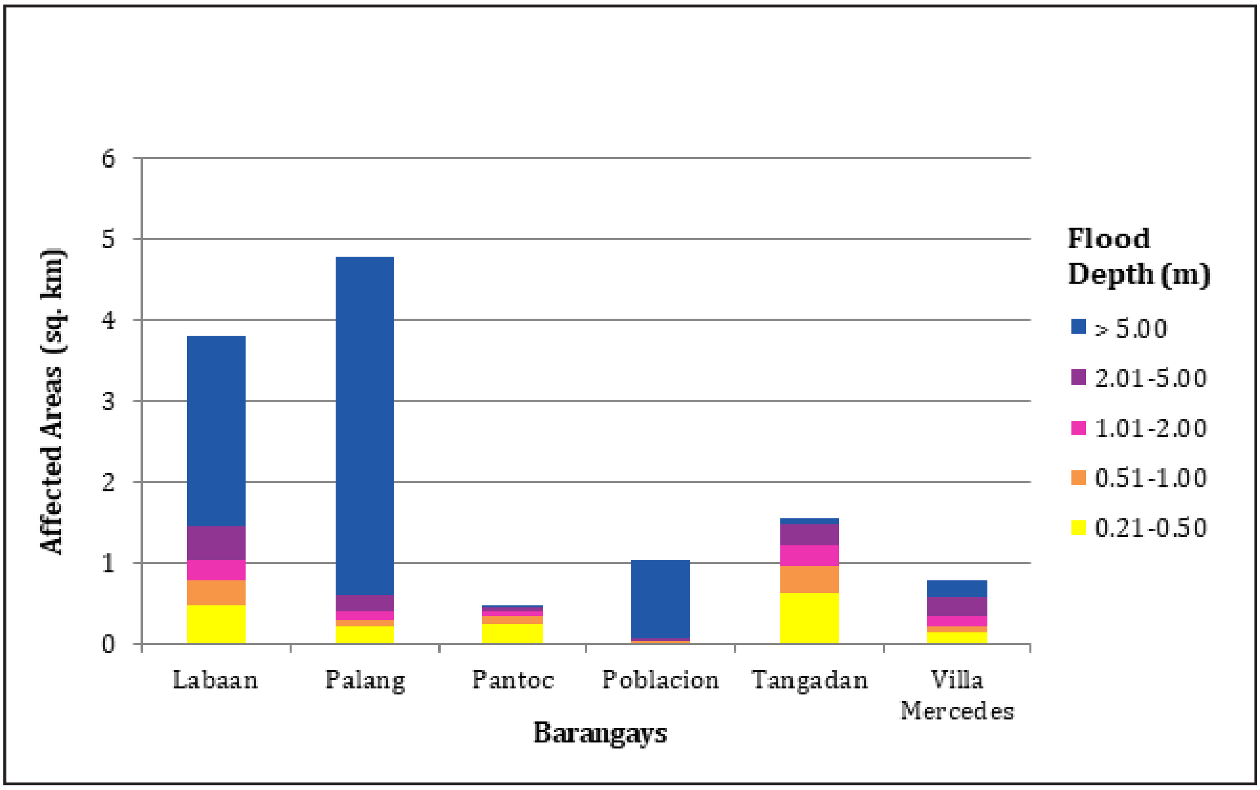


Figure 109. Affected Areas in San Quintin, Abra during 25-Year Rainfall Return Period.

For the 25-year return period, 0.53% of the municipality of Nueva Era with an area of 619 sq. km. will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 59 are the affected areas in Nueva Era in square kilometers by flood depth per barangay.

Table 59. Affected Areas in Nueva Era, Ilocos Norte during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)
	Barangobong
0-0.20	0
0.21-0.50	0.12
0.51-1.00	0.082
1.01-2.00	0.048
2.01-5.00	0.019
> 5.00	0.0027

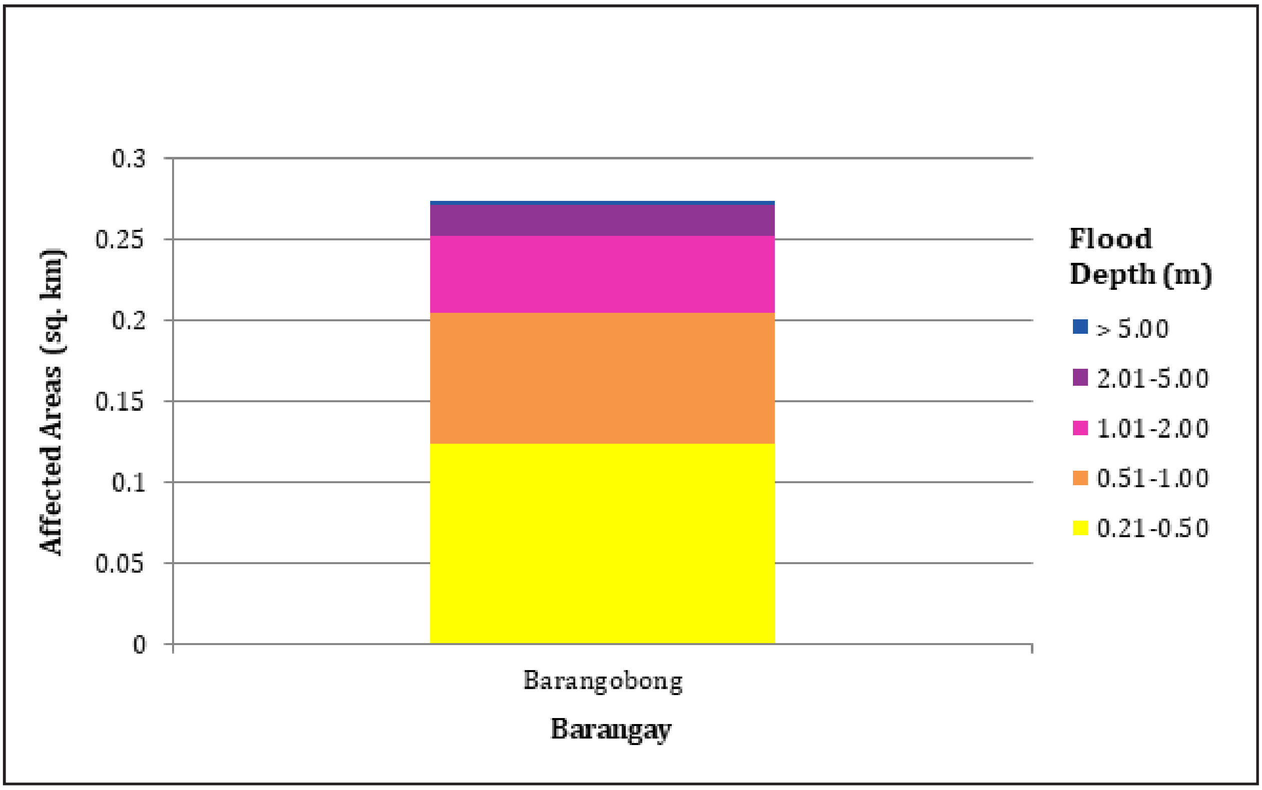


Figure 110. Affected Areas in Nueva Era, Ilocos Norte during 25-Year Rainfall Return Period.

For the 25-year return period, 59.56% of the municipality of Bantay with an area of 71.06 sq. km. will experience flood levels of less than 0.20 meters. 8.37% of the area will experience flood levels of 0.21 to 0.50 meters while 6.53%, 5.34%, 6.85%, and 13.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 60 are the affected areas in Bantay in square kilometers by flood depth per barangay.

Table 60. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)											
	Aggay	An-Annam	Balaleng	Banaoang	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Bulag	Buquig
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.039	0.41	0.47	0.18	0	0	0	0	0	0	0.17	0.028
0.51-1.00	0.03	0.097	0.21	0.085	0	0	0	0	0	0	0.17	0.019
1.01-2.00	0.076	0.038	0.064	0.054	0	0	0	0	0	0	0.17	0.026
2.01-5.00	0.081	0.0008	0.0005	0.063	0	0	0	0	0	0	0.27	0.056
> 5.00	0.06	0	0	0.35	0	0	0	0	0	0	0.7	0.19

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)										
	Cabalanggan	Cabaroan	Cabusligan	Capangdanan	Guimod	Lingsat	Malingeb	Mira	Naguiddayan	Ora	Paing
0-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.0035	0.0092	0.25	0.45	0.32	1.03	0.26	0.077	0.19	0.087	0.15
0.51-1.00	0.0079	0.011	0.26	1.04	0.37	0.53	0.34	0.016	0.14	0.16	0.079
1.01-2.00	0.043	0.049	0.11	0.54	0.34	0.57	0.18	0.001	0.047	0.19	0.098
2.01-5.00	0.57	0.082	0	0.047	0.22	0.28	0.0095	0	0.08	0.088	0.4
> 5.00	0.19	0.072	0	0	0.0005	0.012	0	0	0.35	0	3.15

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)										
	Puspus	Quimmarayan	Sagneb	Sagpat	San Isidro	San Julian	San Mariano	Sinabaan	Taguiporo	Taleb	Tay-Ac
0-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.22	0.28	0.075	0.14	0	0	0.25	0.0081	0	0.18	0.55
0.51-1.00	0.21	0.051	0	0.13	0	0	0.12	0.0072	0	0.15	0.26
1.01-2.00	0.25	0.031	0	0.37	0	0	0.097	0.018	0	0.17	0.13
2.01-5.00	0.035	0.0078	0	0.32	0.087	0.96	0.14	0.4	0.18	0.26	0.0073
> 5.00	0.028	0	0	0	0.49	1.54	0.51	0.2	1.41	0.14	0

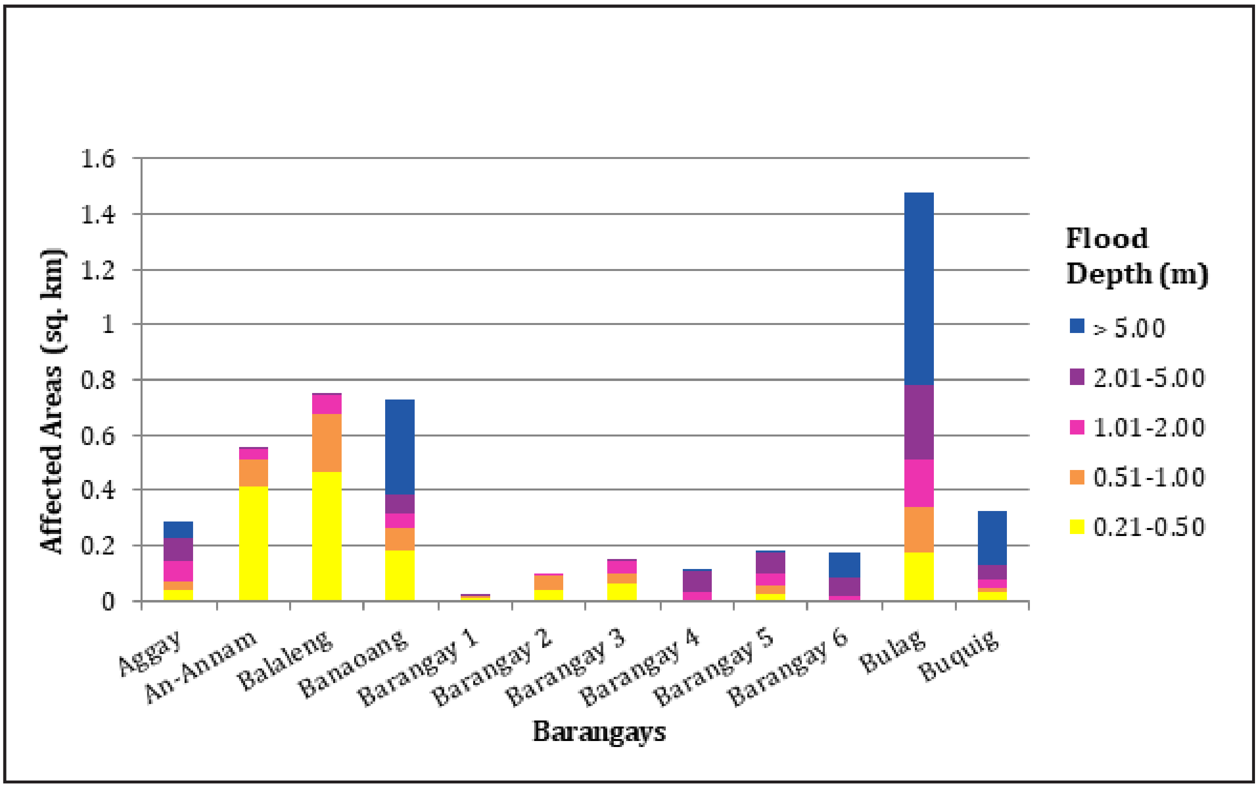


Figure 111. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

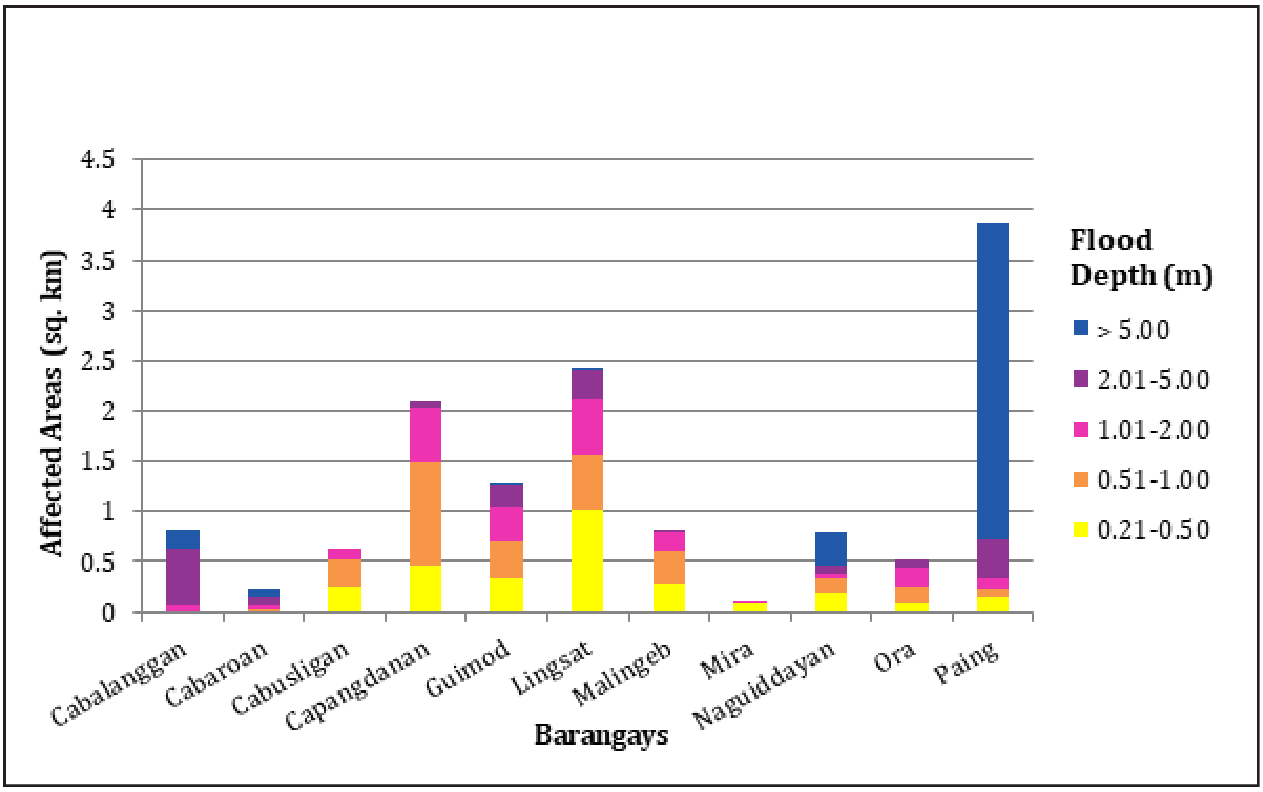


Figure 112. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

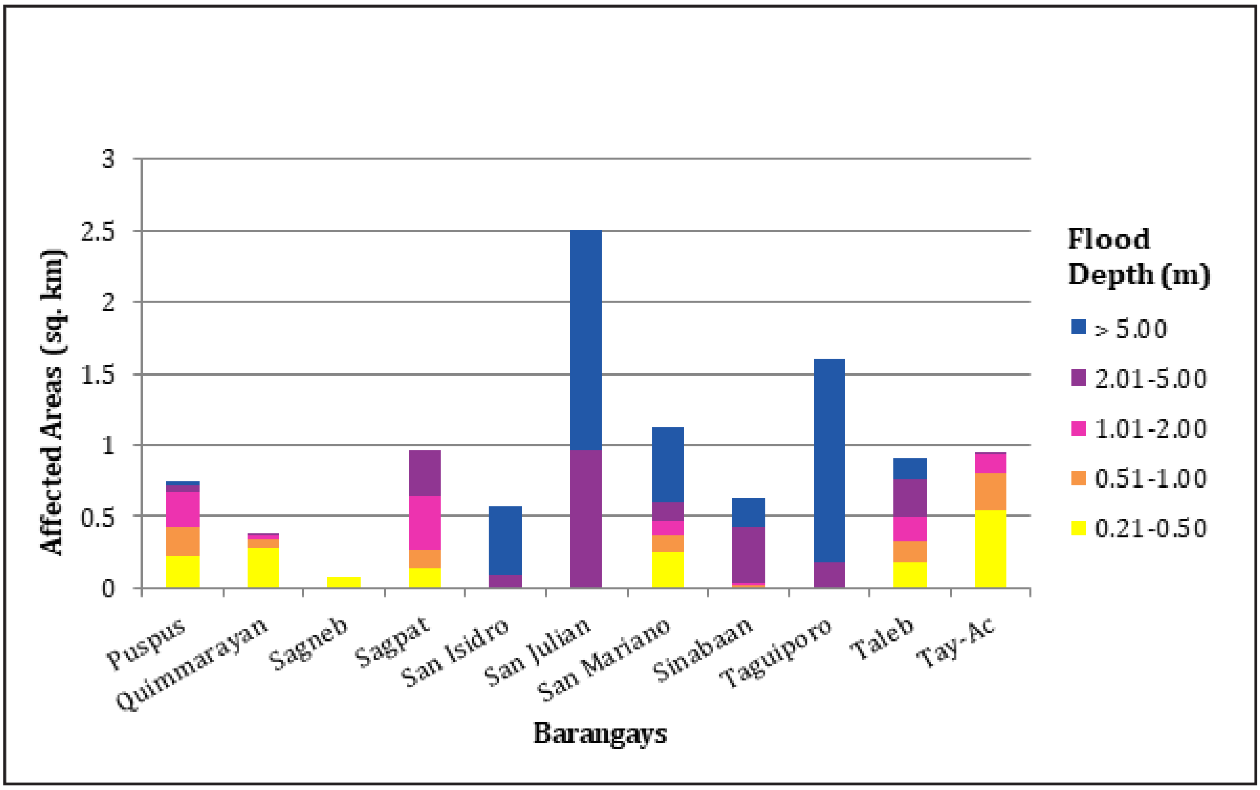


Figure 113. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 1.45% of the municipality of Caoayan with an area of 21.2 sq. km. will experience flood levels of less than 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters while 0.72%, 4.40%, 72.75%, and 15.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 61 are the affected areas in Caoayan in square kilometers by flood depth per barangay.

Table 61. Affected Areas in Caoayan, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Caoayan (in sq. km.)							
	Anonang Mayor	Anonang Menor	Baggoc	Callaguip	Caparacadan	Don Alejandro Quirolgico	Don Dimas Querubin	Don Lorenzo Querubin
0.03-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0.042	0	0	0
0.51-1.00	0	0	0.0001	0	0.063	0	0	0
1.01-2.00	0	0	0.0015	0.0015	0.11	0	0	0
2.01-5.00	0.23	0.28	0.2	0.28	0.69	0.29	0.48	0.28
> 5.00	0.033	0.095	0.04	0.052	0	0.036	0.088	0.095
Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Caoayan (in sq. km.)							
	Fuerte	Manangat	Naguilian	Nansuagao	Pandan	Pantay Tamurong	Pantay-Quitiquit	Villamar
0.03-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.0089	0.0068	0	0	0	0.013	0	0.0004
0.51-1.00	0.015	0.012	0	0	0.0003	0.061	0	0.0008
1.01-2.00	0.049	0.028	0.0002	0.0013	0.0006	0.72	0.0003	0.017
2.01-5.00	0.24	0.26	2.45	1.7	0.24	4.68	0.41	2.73
> 5.00	0	0.0024	1.75	0.48	0.00012	0.32	0	0.2

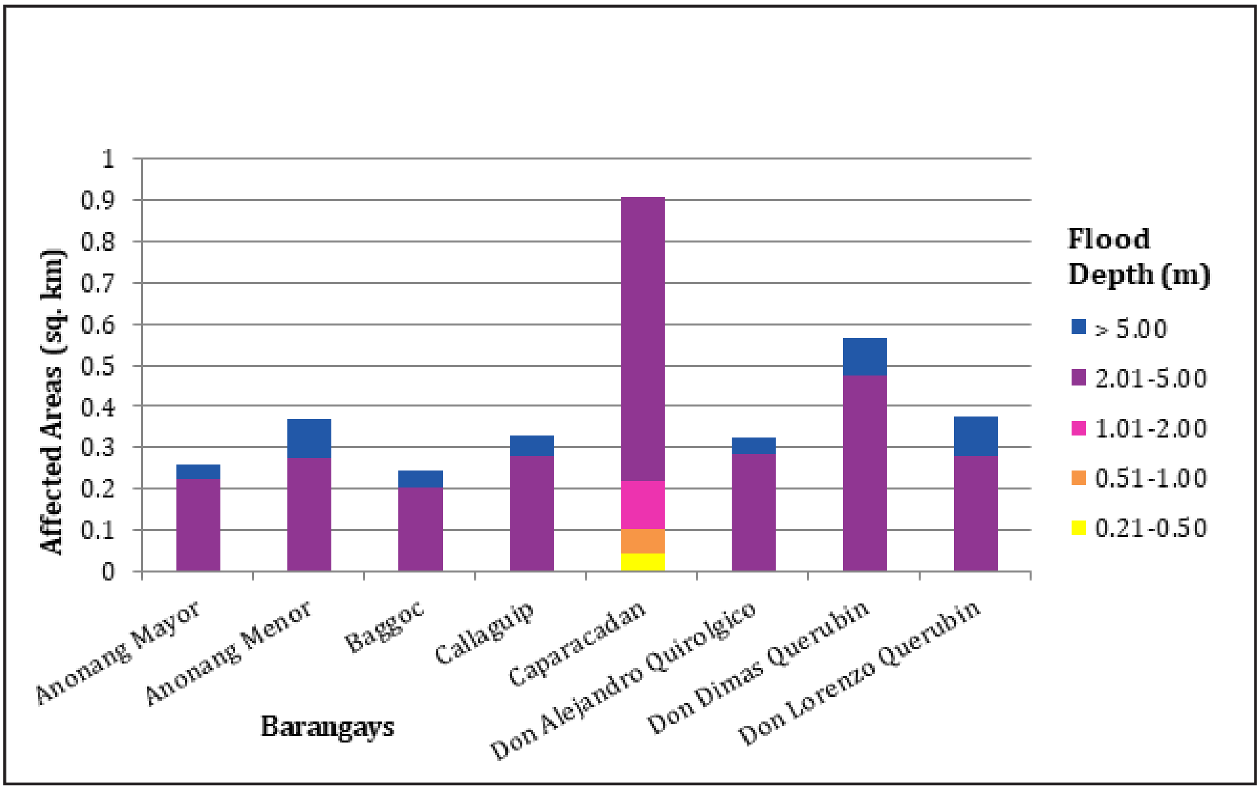


Figure 114. Affected Areas in Caoayan, Ilocos Sur during 25-Year Rainfall Return Period.

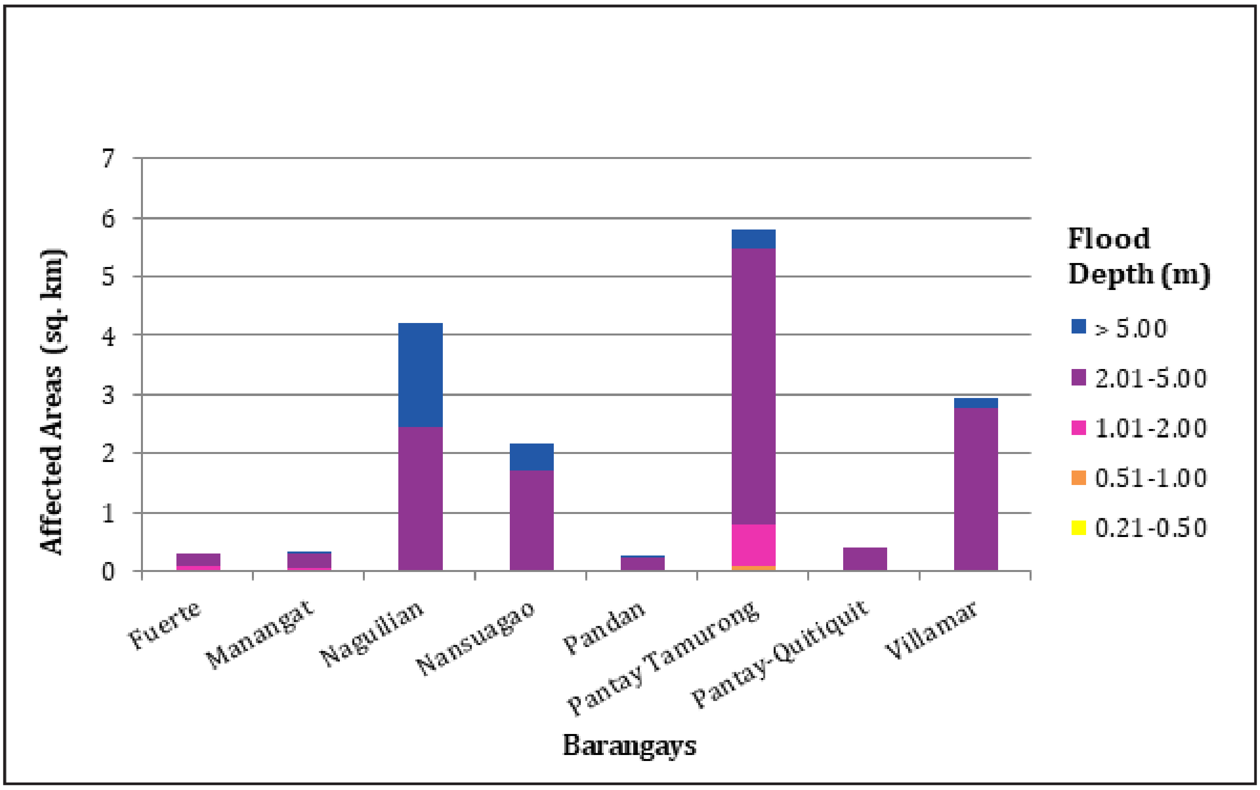


Figure 115. Affected Areas in Caoayan, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 59.72% of the municipality of Magsingal with an area of 78.9 sq. km. will experience flood levels of less than 0.20 meters. 13.68% of the area will experience flood levels of 0.21 to 0.50 meters while 10.50%, 7.70%, 5.01%, and 0.07% 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 62 are the affected areas in Magsingal in square kilometers by flood depth per barangay.

Table 62. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Alangan	Bacar	Barbarit	Bungro	Cabaroan	Cadanglaan	Caraisan	Dacutan	Labut	Maas-Asin
0.03-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.23	0.17	0.37	0.46	0.23	0.35	1.13	0.19	0.26	0.9
0.51-1.00	0.22	0.3	0.48	0.41	0.36	0.12	0.19	0.28	0.22	0.48
1.01-2.00	0.2	0.3	0.33	0.19	0.22	0.041	0.035	0.23	0.15	0.47
2.01-5.00	0.022	0.22	0.11	0.16	0.22	0.022	0.029	0.19	0.13	0.32
> 5.00	0	0	0	0	0	0	0	0	0.0012	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Macatcatud	Manzante	Maratudo	Miramar	Namalpalan	Napo	Pagsanaan Norte	Pagsanaan Sur	Panay Norte	Panay Sur
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.92	0.37	0.64	0.068	0.32	1.13	0.23	0.099	0.45	0.76
0.51-1.00	0.52	0.65	0.39	0.14	0.29	0.61	0.32	0.17	0.33	0.7
1.01-2.00	0.23	0.62	0.37	0.42	0.21	0.17	0.32	0.37	0.11	0.31
2.01-5.00	0.24	0.32	0.28	0.63	0.059	0.048	0.11	0.44	0.036	0.012
> 5.00	0	0.0016	0.0044	0	0.0007	0.0001	0.0002	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Patong	Puro	San Basilio	San Clemente	San Julian	San Lucas	San Ramon	San Vicente	Santa Monica	Sarsaracat
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.47	0.35	0.03	0.031	0.047	0.055	0.037	0.08	0.22	0.19
0.51-1.00	0.36	0.14	0.03	0.034	0.091	0.057	0.04	0.033	0.12	0.19
1.01-2.00	0.22	0.013	0.059	0.004	0.14	0.053	0.013	0.0036	0.11	0.17
2.01-5.00	0.13	0	0.0053	0	0.11	0.036	0	0	0.025	0.064
> 5.00	0.043	0	0	0	0	0	0	0	0	0.0039

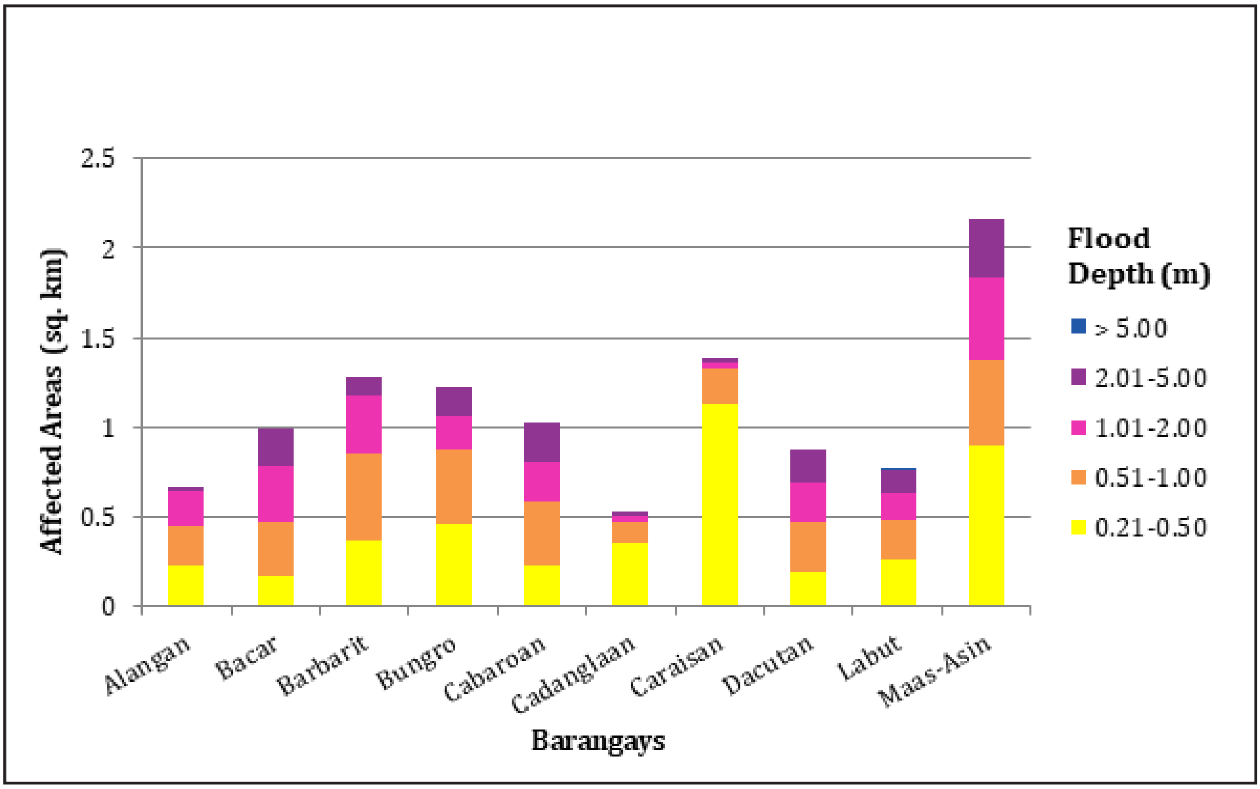


Figure 116. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

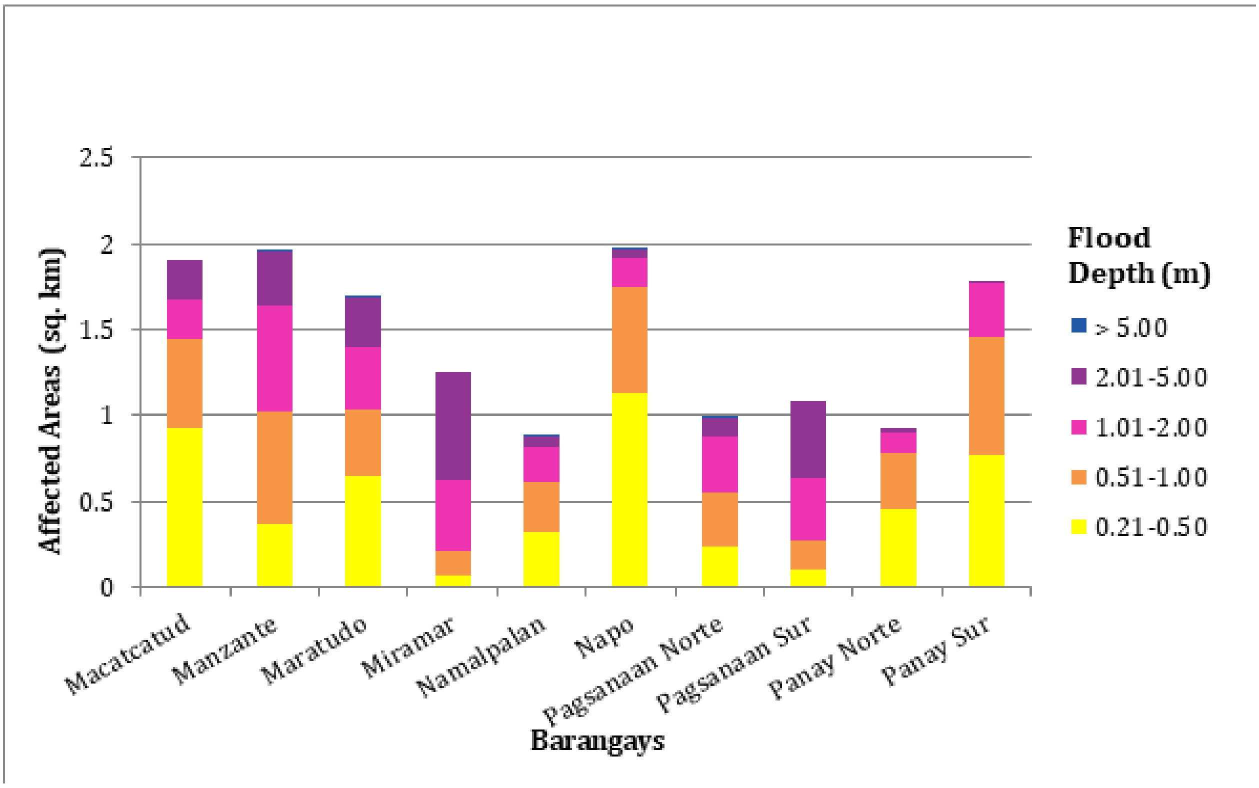


Figure 117. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

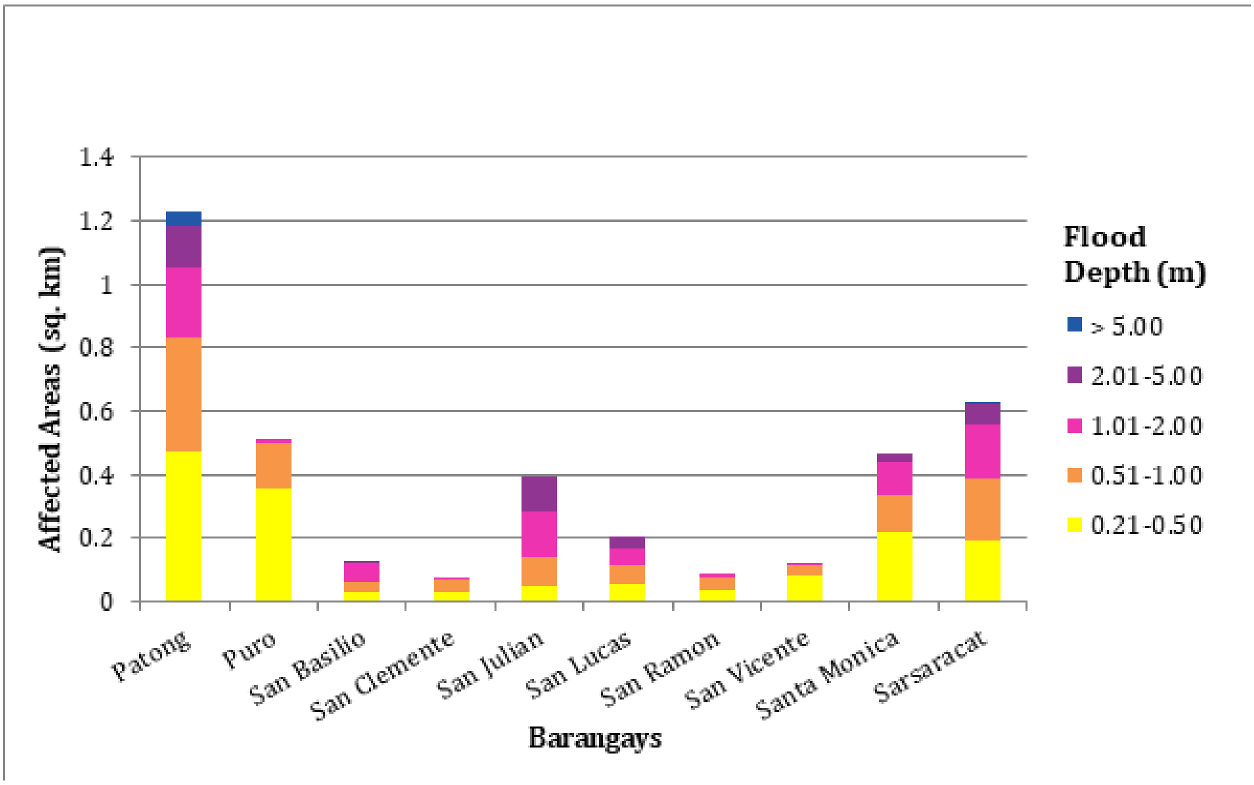


Figure 118. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 0.30% of the municipality of Narvacan with an area of 97.18 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 63 are the affected areas in Narvacan in square kilometers by flood depth per barangay.

Table 63. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)	
	Ambulogan	Lanipao
0-0.20	0	0
0.21-0.50	0.0072	0.0027
0.51-1.00	0.0024	0.00086
1.01-2.00	0.00062	0
2.01-5.00	0.0027	0
> 5.00	0.000025	0

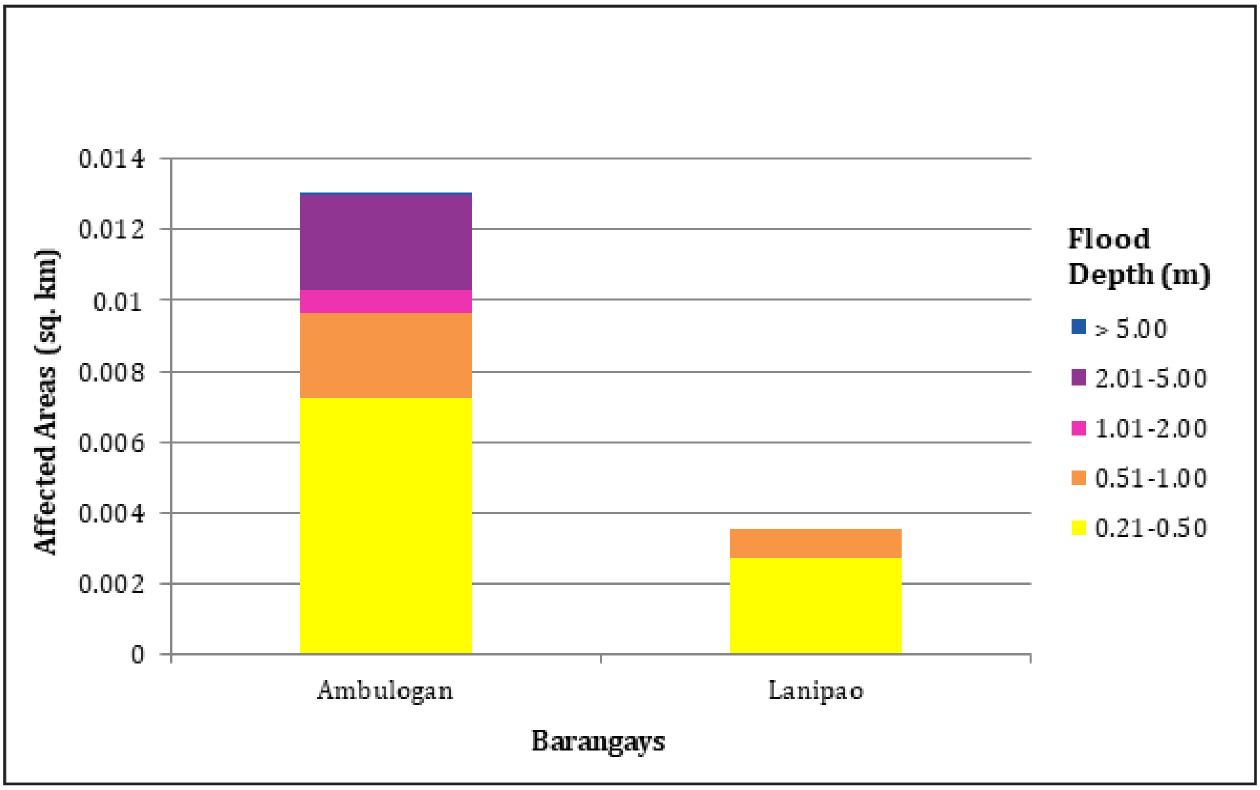


Figure 119. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 24.20% of the municipality of San Ildefonso with an area of 13.21 sq. km. will experience flood levels of less than 0.20 meters. 11.74% of the area will experience flood levels of 0.21 to 0.50 meters while 24.19%, 20.69%, 18.98%, and 1.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 64 are the affected areas in San Ildefonso in square kilometers by flood depth per barangay.

Table 64. Affected Areas in San Ildefonso, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Ildefonso (in sq.km)							
	Arnap	**Bahet**	**Belen**	**Bungro**	**Busiing Norte**	**Busiing Sur**	**Dongalo**	**Gongogong**
0.03-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.1	0.049	0.28	0.072	0.16	0.022	0.013	0.011
0.51-1.00	0.067	0.57	0.73	0.25	0.26	0.018	0.026	0.023
1.01-2.00	0.12	0.51	0.14	0.28	0.15	0.057	0.042	0.4
2.01-5.00	0.028	0.069	0.038	0.0079	0.12	0.28	0.45	0.4
> 5.00	0	0.0002	0	0	0.0064	0	0.048	0.031

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Ildefonso (in sq.km)						
	Iboy	**Kinamantirisan**	**Otol-Patac**	**Poblacion East**	**Poblacion West**	**Sagneb**	**Sagsagat**
0.03-0.20	0	0	0	0	0	0	0
0.21-0.50	0.099	0.28	0.12	0.07	0.049	0.13	0.092
0.51-1.00	0.07	0.26	0.091	0.082	0.053	0.53	0.17
1.01-2.00	0.094	0.052	0.12	0.12	0.025	0.3	0.31
2.01-5.00	0.043	0.086	0.42	0.39	0.023	0.0037	0.14
> 5.00	0.0068	0	0.01	0.041	0.00085	0	0.0085

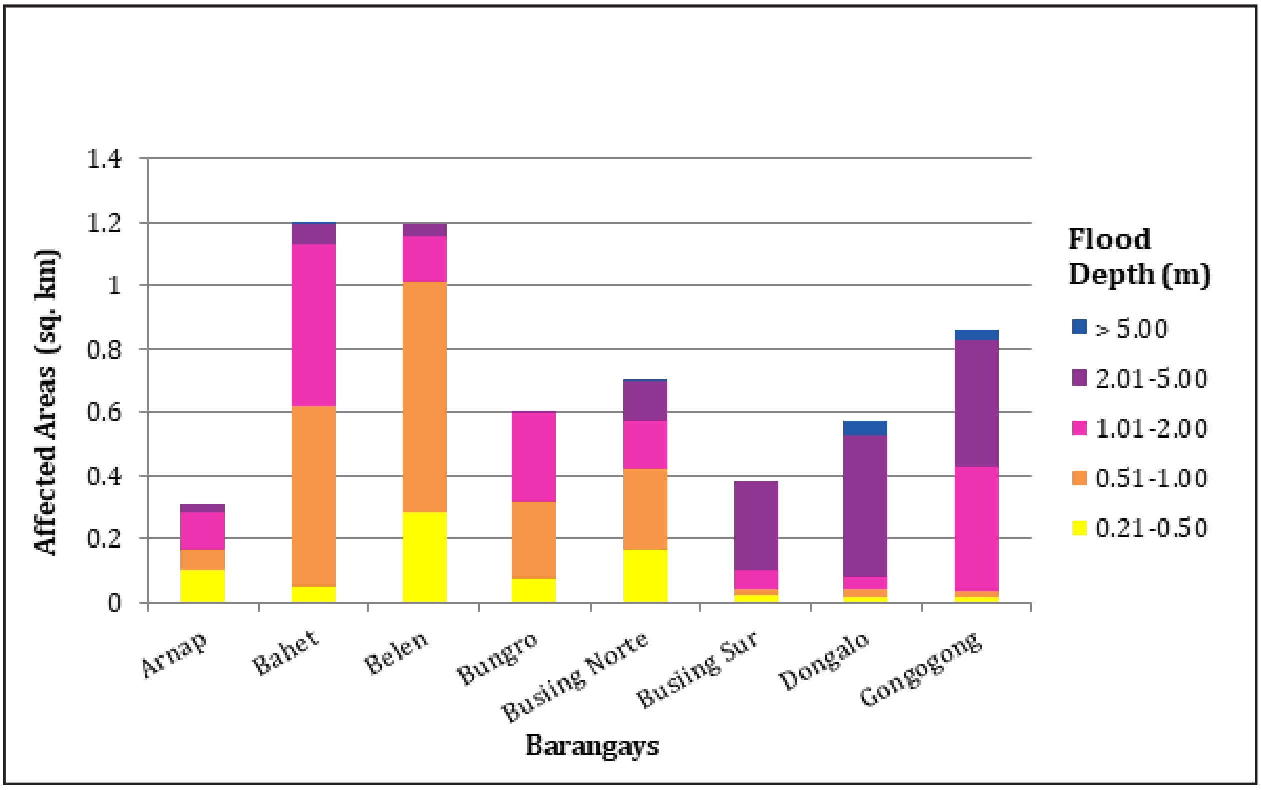


Figure 120. Affected Areas in San Ildefonso, Ilocos Sur during 25-Year Rainfall Return Period.

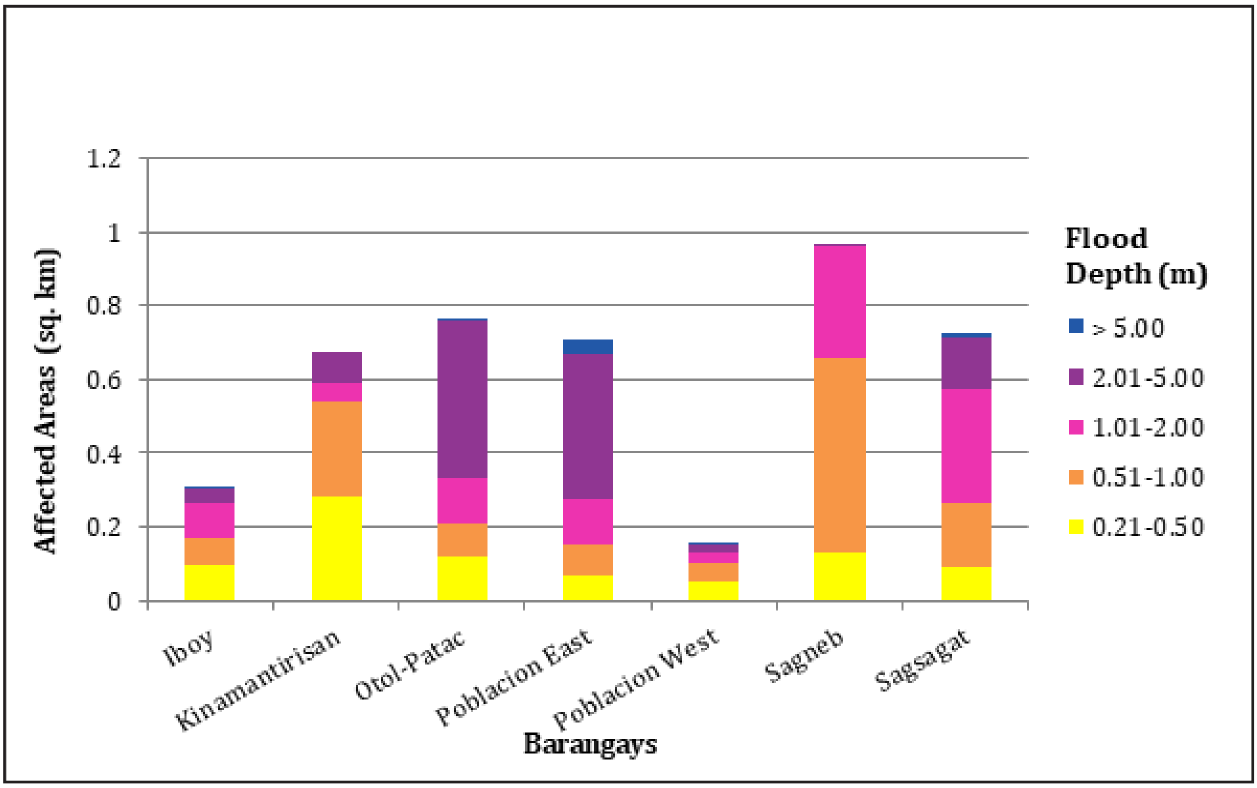


Figure 121. Affected Areas in San Ildefonso, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 48.12% of the municipality of San Juan with an area of 59.88 sq. km. will experience flood levels of less than 0.20 meters. 7.62% of the area will experience flood levels of 0.21 to 0.50 meters while 5.09%, 6.18%, 3.08%, and 0.20% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 65 are the affected areas San Juan in square kilometers by flood depth per barangay.

Table 65. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)								
	Asilang	Bacsil	Baliw	Bannuar	Barbar	Cabanglotan	Cacandon-gan	Camang-gaan	Camindoroan
0.03-0.20	0	0	0	0	0	0	0	0	0
0.21-0.50	0.095	0.19	0.49	0.0001	0.58	0.087	0.1	0.12	0.056
0.51-1.00	0.051	0.19	0.11	0	0.35	0.066	0.056	0.089	0.099
1.01-2.00	0.11	0.42	0.094	0	0.34	0.084	0.023	0.12	0.047
2.01-5.00	0.1	0.087	0.14	0	0.3	0.03	0.017	0.032	0.011
> 5.00	0	0	0.028	0	0.011	0.002	0.0004	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)							
	Caronoan	Darao	Guimod Norte	Guimod Sur	Immayos Norte	Immayos Sur	Lira	Malamin
0-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.0002	0.12	0.24	0.18	0.19	0.042	0.09	0.22
0.51-1.00	0.0002	0.063	0.15	0.25	0.11	0.087	0.016	0.13
1.01-2.00	0	0.036	0.012	0.62	0.066	0.24	0.0031	0.14
2.01-5.00	0	0.043	0.0023	0.18	0.11	0.065	0.016	0.069
> 5.00	0	0.0012	0	0	0.029	0	0.0015	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)							
	Muraya	Nagsabaran	Nagsupotan	Pandayan	Resurreccion	Sabangan	San Isidro	Saoang
0-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.3	0.17	0.31	0.00053	0.059	0.12	0.38	0.42
0.51-1.00	0.15	0.21	0.23	0.00016	0.015	0.1	0.41	0.1
1.01-2.00	0.19	0.2	0.28	0.000017	0.0097	0.087	0.56	0.004
2.01-5.00	0.25	0.068	0.066	0	0.04	0.02	0.19	0
> 5.00	0.024	0	0	0	0.023	0	0	0

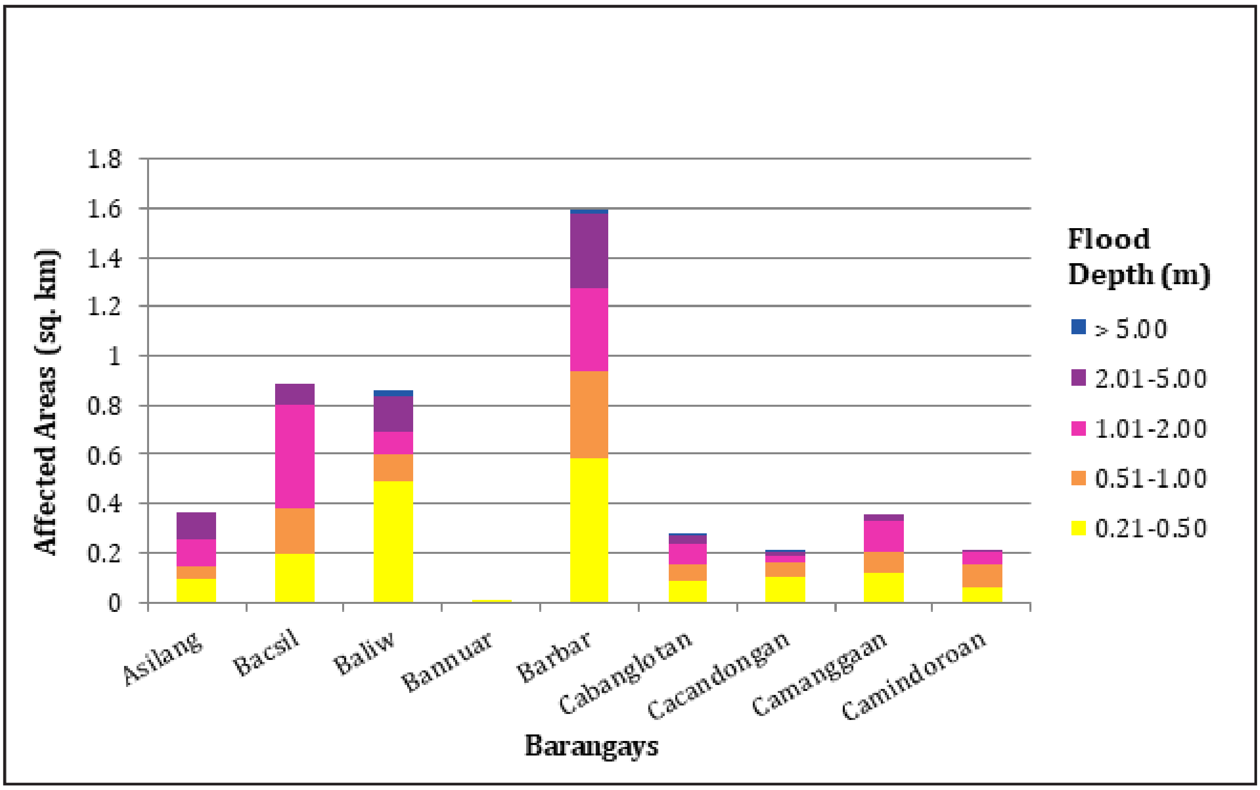


Figure 122. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

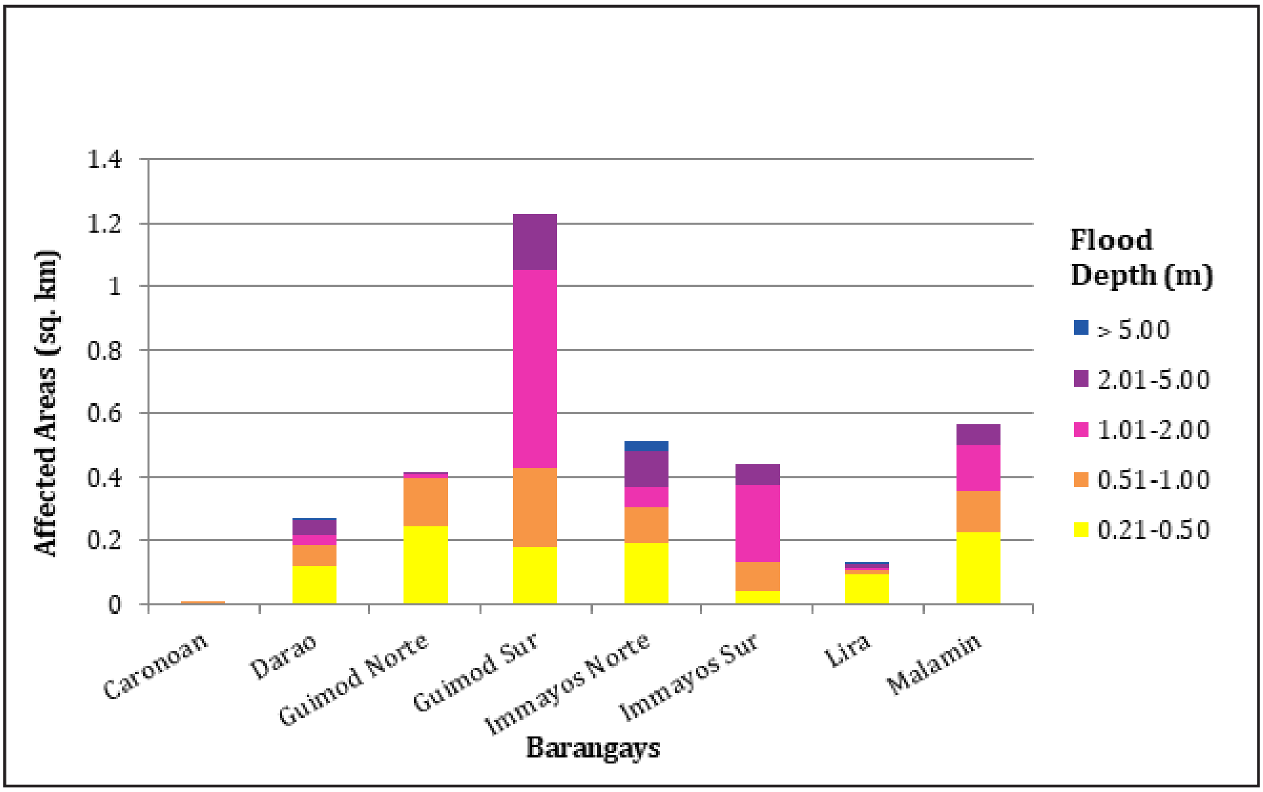


Figure 123. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

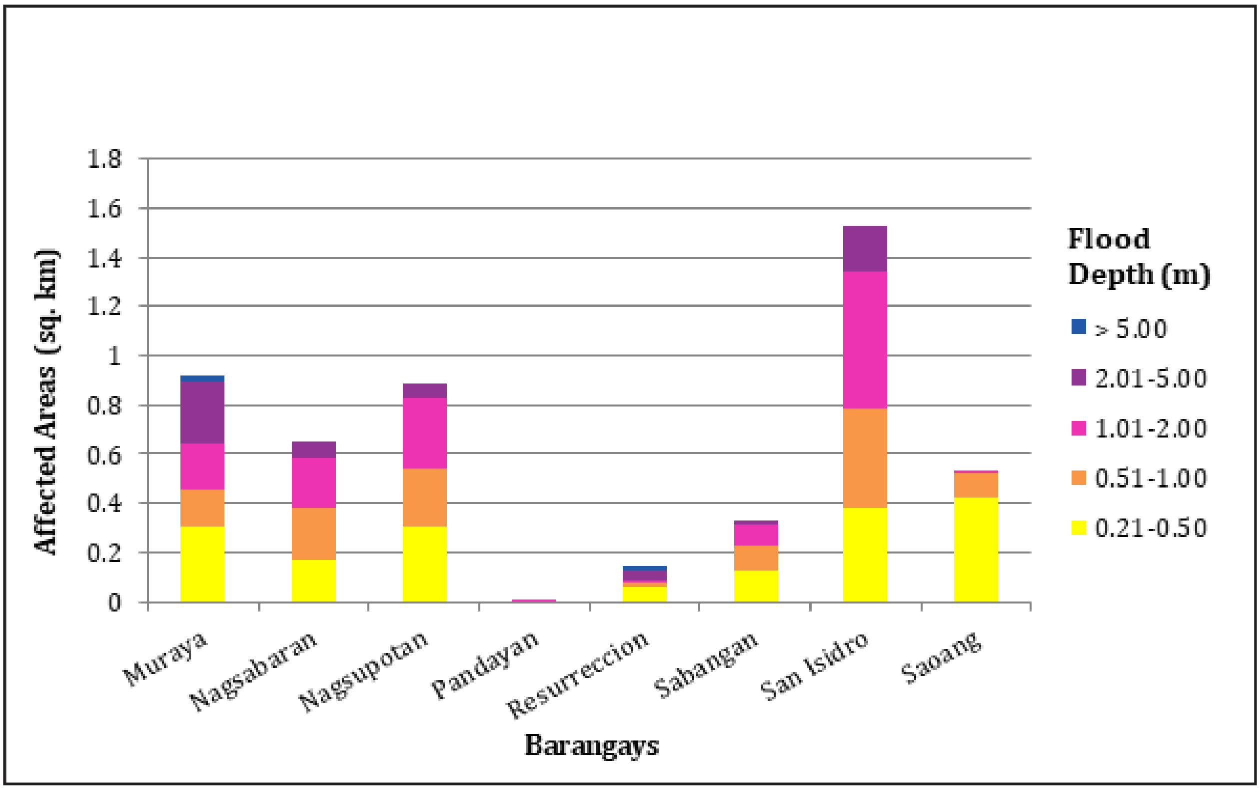


Figure 124. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 16.95% of the municipality of San Vicente with an area of 12.2 sq. km. will experience flood levels of less than 0.20 meters. 12.34% of the area will experience flood levels of 0.21 to 0.50 meters while 17.68%, 39.03%, 16.99%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 66 are the affected areas in San Vicente in quare kilometers by flood depth per barangay.

Table 66. Affected Areas in San Vicente, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Vicente (in sq.km)						
	Bantaoay	Bayubay Norte	Bayubay Sur	Lubong	Poblacion	Pudoc	San Sebastian
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0.0047	0.17	0.17	0.2	0.16	0.095	0.71
0.51-1.00	0.033	0.13	0.17	0.27	0.18	0.44	0.93
1.01-2.00	0.47	0.087	0.086	0.2	0.095	2.18	1.64
2.01-5.00	0.48	0	0.05	0.019	0.0032	0.73	0.79
> 5.00	0	0	0.00084	0	0	0	0.0007

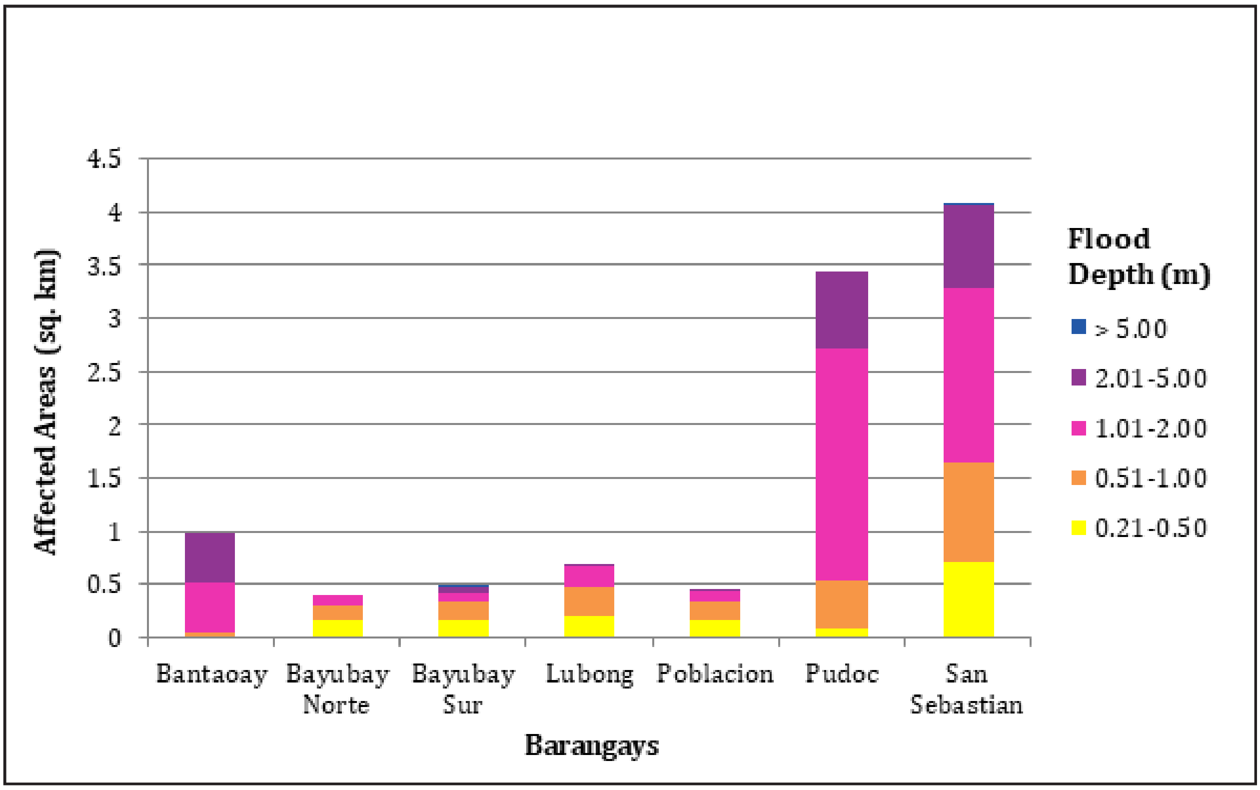


Figure 125. Affected Areas in San Vicente, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 29.84% of the municipality of Santa with an area of 57.2 sq. km. will experience flood levels of less than 0.20 meters. 4.10% of the area will experience flood levels of 0.21 to 0.50 meters while 4.21%, 5.85%, 9.62%, and 9.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 67 are the affected areas in Santa in square kilometers by flood depth per barangay.

Table 67. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa (in sq.km)										
	Ampandula	Banaoang	Basug	Bucalag	Cabangaran	Calungboyan	Dammay	Labut Norte	Labut Sur	Mabilbila Norte	Mabilbila Sur
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.046	0.032	0.047	0.08	0.046	0.11	1.16	0.02	0.043	0.0049	0.016
0.51-1.00	0.016	0.02	0.019	0.13	0.015	0.17	1.24	0.016	0.021	0.0013	0.013
1.01-2.00	0.0034	0.011	0.0044	0.019	0.0035	0.047	2.43	0.011	0.029	0.0002	0.0087
2.01-5.00	0.0001	0.041	0	0.0035	0.0002	0	2.95	0.0012	0.0076	0	0.00093
> 5.00	0	0.9	0	0	0	0	1.5	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa (in sq.km)										
	Manueva	Marcos	Nagpanaoan	Namalangan	Oribi	Pasungol	Quirino	Rizal	Sacuyya Norte	Sacuyya Sur	Tabucolan
0-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.015	0.0013	0.046	0.035	0.01	0.071	0.29	0.065	0.05	0.063	0.1
0.51-1.00	0.0096	0.0013	0.12	0.025	0.0076	0.051	0.23	0.035	0.02	0.026	0.22
1.01-2.00	0.0065	0.0002	0.43	0.018	0.011	0.022	0.13	0.016	0.0014	0.01	0.12
2.01-5.00	0.0004	0	2.45	0.011	0	0	0.018	0.013	0.0009	0.00049	0
> 5.00	0	0	2.7	0.12	0	0	0	0.024	0	0	0

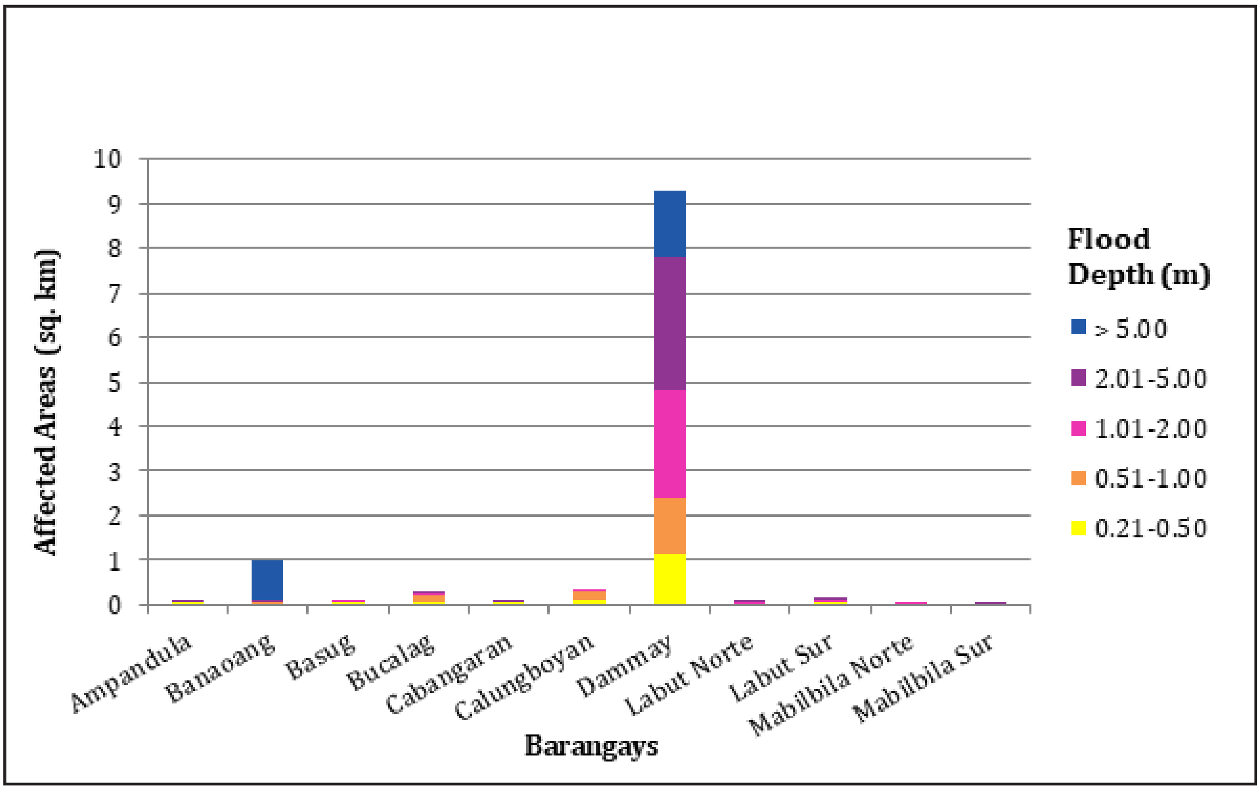


Figure 126. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period.

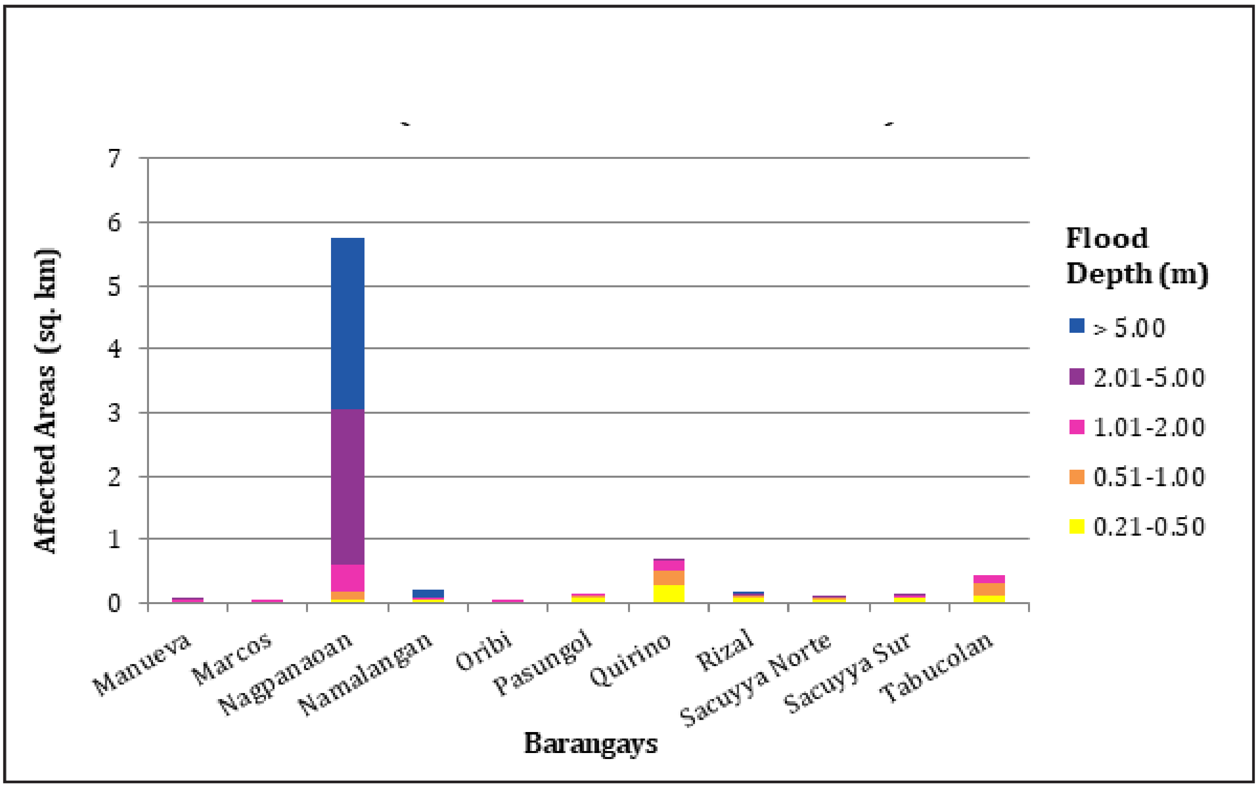


Figure 127. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 24.02% of the municipality of Santa Catalina with an area of 10.83 sq. km. will experience flood levels of less than 0.20 meters. 17.07% of the area will experience flood levels of 0.21 to 0.50 meters while 15.06%, 12.17%, and 6.34% 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 68 are the affected areas in Santa Catalina in square kilometers by flood depth per barangay.

Table 68. Affected Areas in Santa Catalina, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa Catalina (in sq.km)							
	Cabaroan	Cabittaogan	Cabuloan	Pangada	Poblacion	Sinabaan	Subec	Tamorong
0-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.21	0.37	0.19	0.049	0.081	0.44	0.1	0.41
0.51-1.00	0.097	0.57	0.12	0.067	0.026	0.1	0.013	0.63
1.01-2.00	0.025	0.63	0.089	0.17	0.025	0.038	0.011	0.34
2.01-5.00	0.036	0.33	0.092	0.16	0.018	0	0	0.05
> 5.00	0	0	0	0	0	0	0	0

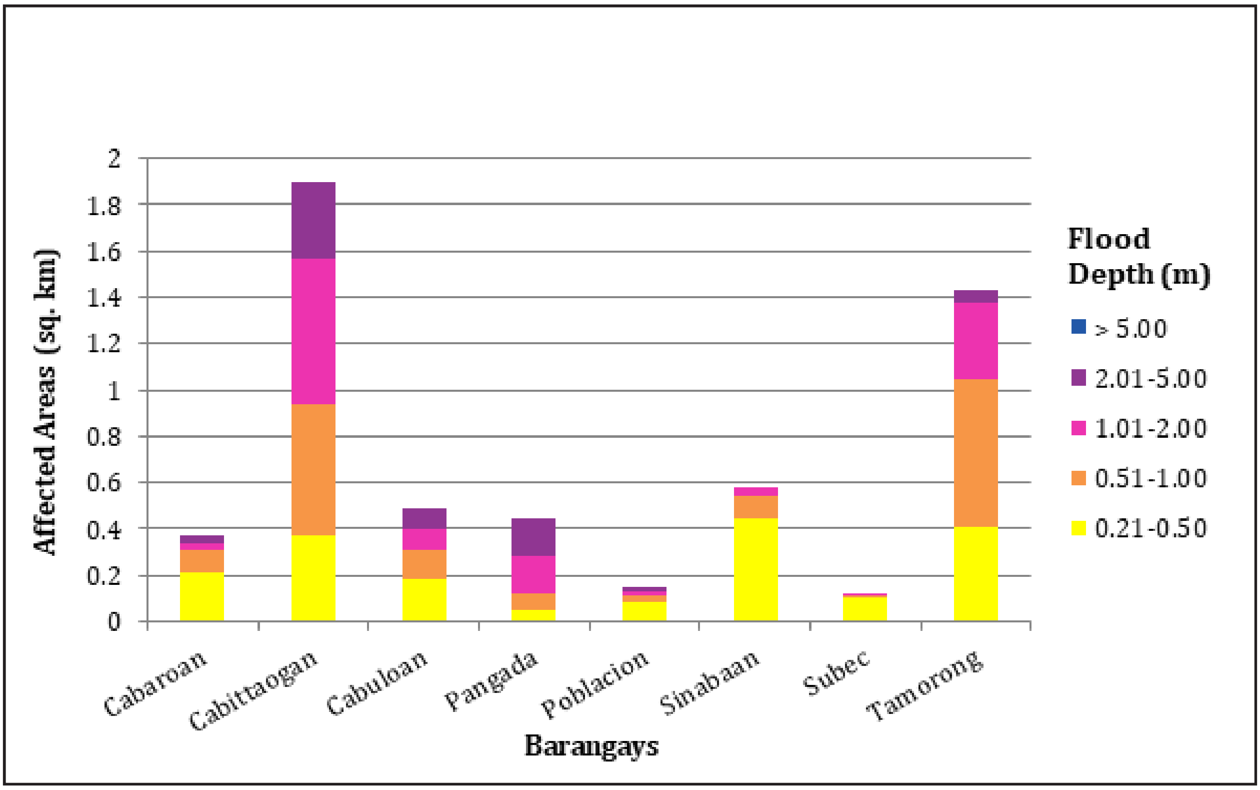


Figure 128. Affected Areas in Santa Catalina, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 46.56% of the municipality of Santo Domingo with an area of 50.36 sq. km. will experience flood levels of less than 0.20 meters. 14.48% of the area will experience flood levels of 0.21 to 0.50 meters while 16.22%, 17.30%, 5.79%, and 0.09% 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 69 are the affected areas in Santo Domingo in square kilometers by flood depth per barangay.

Table 53. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santo Domingo (in sq.km)											
	Binalayangan	Binongan	Borobor	Cabaritan	Cabigbigaan	Calautit	Calay-Ab	Camestizoan	Casili	Flora	Lagatit	Laoingen
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.22	0.48	0.43	0.14	0.085	0.21	0.16	0.024	0.12	0.21	0.35	0.58
0.51-1.00	0.18	0.34	0.52	0.32	0.13	0.16	0.16	0.0072	0.12	0.37	0.15	0.47
1.01-2.00	0.0055	0.072	0.16	0.63	0.013	0.096	0.12	0.3	0.055	0.18	0.14	0.37
2.01-5.00	0	0.0033	0.057	0.35	0	0.076	0.15	0.4	0.015	0	0.08	0.16
> 5.00	0	0	0.0003	0.000002	0	0.0087	0	0.021	0	0	0.001	0.0009
Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santo Domingo (in sq.km)											
	Lussoc	Nagbettedan	Naglaoa-An	Nalasin	Nambaran	Nanerman	Napo	Padu Chico	Padu Grande	Paguraper	Panay	Pangpangdan
0-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.19	0.26	0.29	0.033	0.14	0.04	0.22	0.14	0.098	0.32	0.1	0.14
0.51-1.00	0.18	0.088	0.47	0.038	0.3	0.026	0.16	0.18	0.11	0.25	0.14	0.18
1.01-2.00	0.13	0.05	0.74	0.11	0.81	0.062	0.0046	0.22	0.083	0.11	0.0031	0.082
2.01-5.00	0.033	0.038	0.16	0.13	0.098	0.056	0.0007	0.0005	0.0003	0.0014	0	0.0094
> 5.00	0.0027	0	0.01	0	0	0	0	0	0	0	0	0
Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santo Domingo (in sq.km)											
	Parada	Paras	Poblacion	Puerta Real	Pussuac	Quimmarayan	San Pablo	Santa Cruz	Santo Tomas	Sived	Suksukit	Vacunero
0-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.41	0.4	0.12	0.17	0.16	0.2	0.054	0.32	0.25	0.13	0.079	0.0035
0.51-1.00	0.57	0.49	0.13	0.089	0.2	0.27	0.22	0.64	0.29	0.17	0.038	0.018
1.01-2.00	0.65	0.038	0.19	0.26	0.44	0.22	0.57	1.01	0.058	0.15	0.066	0.51
2.01-5.00	0.0096	0.0014	0.051	0.071	0.21	0.15	0.23	0.085	0.013	0.17	0.087	0.021
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

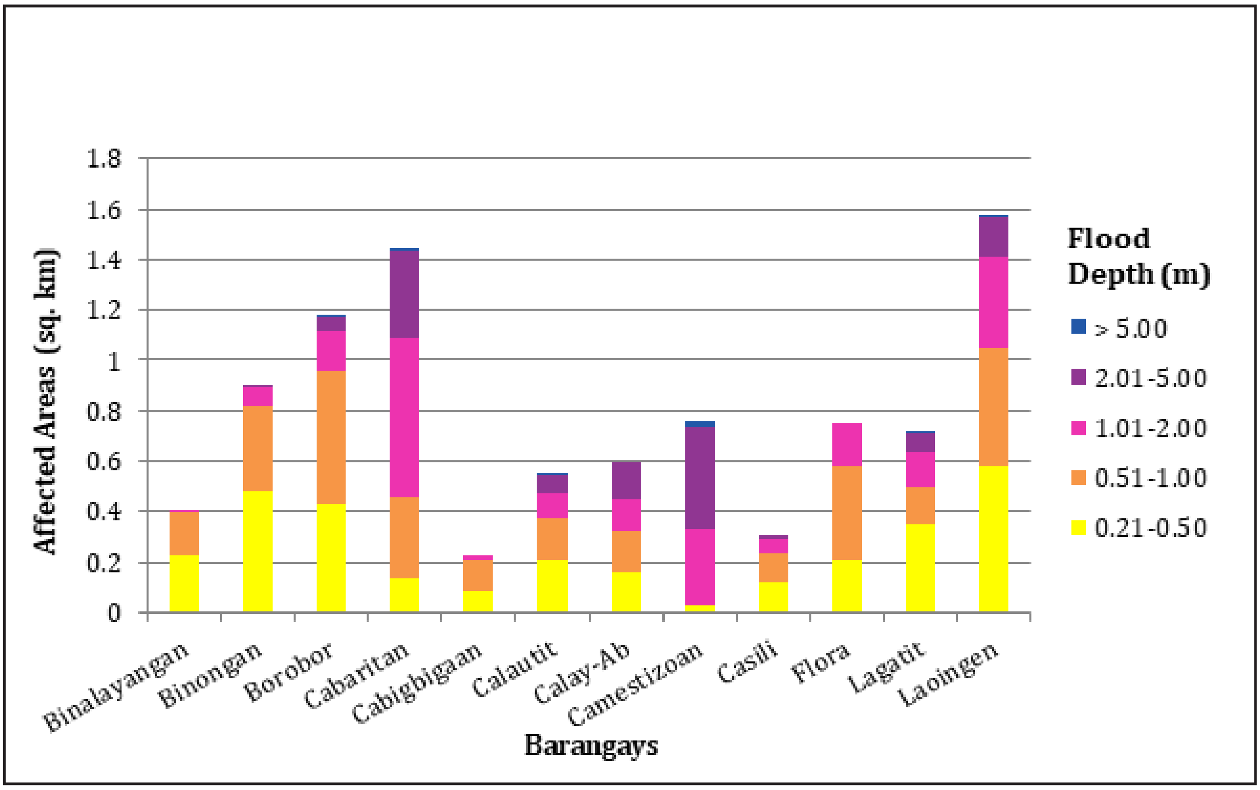


Figure 129. Affected Areas in Santo Domingo, Ilocos Sur during 25-Year Rainfall Return Period.

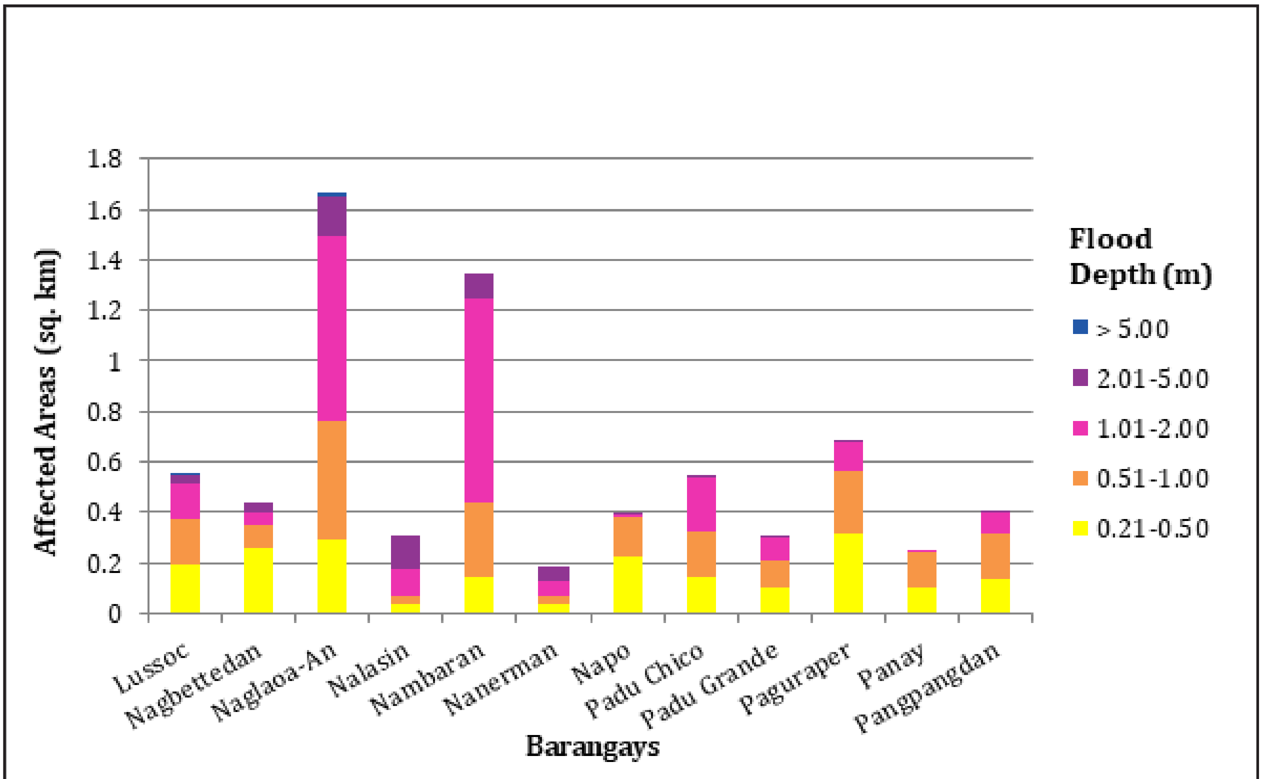


Figure 130. Affected Areas in Santo Domingo, Ilocos Sur during 25-Year Rainfall Return Period.

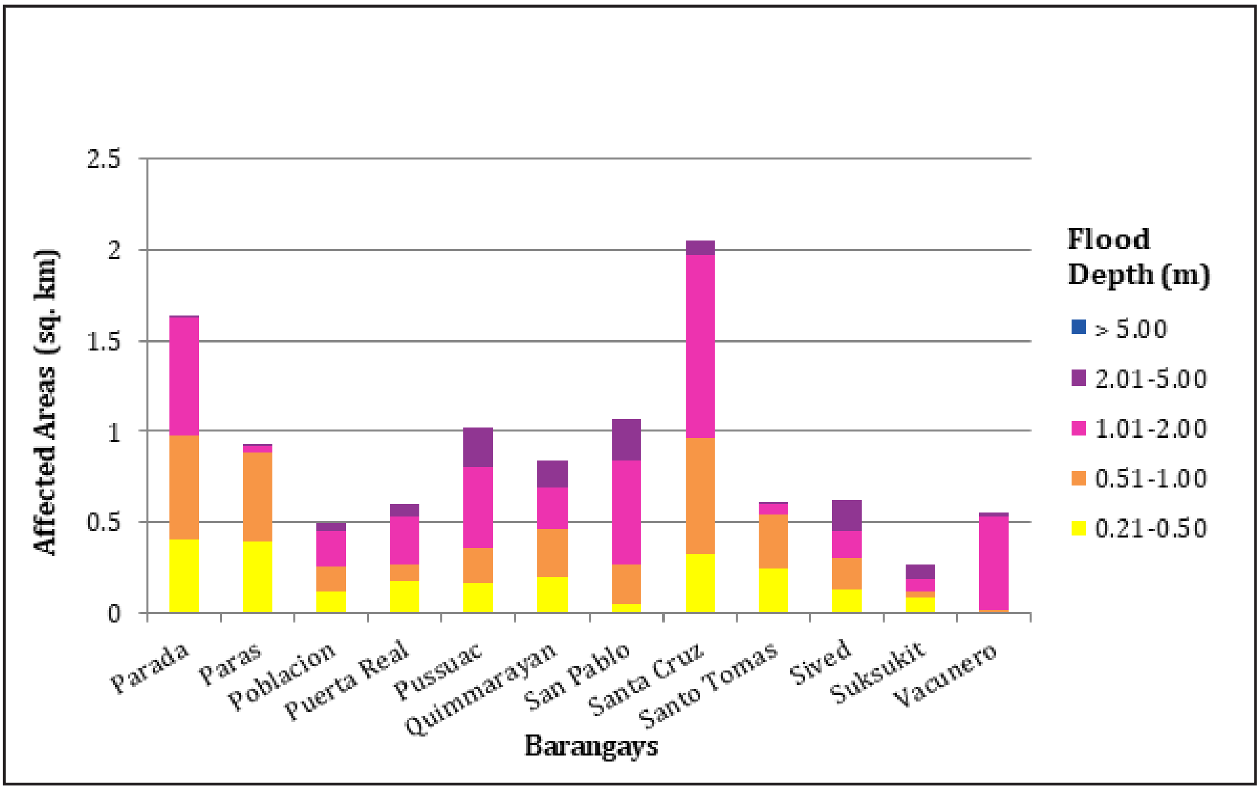


Figure 131. Affected Areas in Santo Domingo, Ilocos Sur during 25-Year Rainfall Return Period.

For the 25-year return period, 14.23% of the municipality of Vigan City with an area of 24.01 sq. km. will experience flood levels of less than 0.20 meters. 4.56% of the area will experience flood levels of 0.21 to 0.50 meters while 6.43%, 11.49%, 43.07%, and 17.91% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 70 are the affected areas in Vigan City in square kilometers by flood depth per barangay.

Table 70. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Ayusan Norte	Ayusan Sur	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay IX	Barangay V	Barangay VI	Barangay VII
0.03-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.14	0.13	0	0	0	0	0	0	0	0
0.51-1.00	0.11	0.052	0	0	0	0	0	0	0	0
1.01-2.00	0.16	0.026	0	0	0	0	0	0	0	0
2.01-5.00	0.089	0.0079	0	0	0	0	0	0	0	0
> 5.00	0.095	0	0	0	0	0	0	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Vigan City (in sq.km)**									
	Barangay VIII	Barraca	Beddeng Daya	Beddeng Laud	Bongtolan	Bulala	Cabalangegan	Cabaroan Daya	Cabaroan Laud	Camangaan
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0	0.091	0	0	0	0
0.51-1.00	0	0.0002	0	0	0	0.027	0	0	0	0
1.01-2.00	0	0.17	0.0048	0	0.0014	0.016	0	0	0.0036	0.004
2.01-5.00	0	0.17	0.21	0.42	0.2	0.00051	0.32	0.6	0.28	0.15
> 5.00	0	0	0.012	0	0.016	0	0	0.071	0.08	0.14
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Vigan City (in sq.km)**									
	Capangpangan	Mindoro	Nagsan-galan	Pantay Daya	Pantay Fatima	Pantay Laud	Paoa	Paratong	Pong-Ol	Purok-A-Bassit
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0.15	0	0.069	0.077	0.15	0.078	0.023	0.0054	0
0.51-1.00	0	0.24	0	0.23	0.18	0.34	0.048	0.015	0.018	0
1.01-2.00	0	0.22	0	0.48	0.3	0.56	0.027	0.14	0.065	0
2.01-5.00	0.52	0.018	0.83	0.5	0.26	0.28	0.065	0.05	0.15	0.38
> 5.00	0.026	0	0.096	0.049	0	0	0.0041	0	0	0.015

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)								
	Purok-A-Dackel	Raois	Rugsuanan	Salindeg	San Jose	San Julian Norte	San Julian Sur	San Pedro	Tamag
0.03-0.20	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0.016	0	0	0	0.078	0.045
0.51-1.00	0	0	0	0.01	0	0	0	0.19	0.024
1.01-2.00	0	0	0	0.022	0	0	0	0.46	0.023
2.01-5.00	0.3	0.4	0.57	0.44	0.31	0.43	0.3	0.44	0.52
> 5.00	0.023	2.13	0.85	0.12	0.0034	0.00019	0.0014	0	0.16

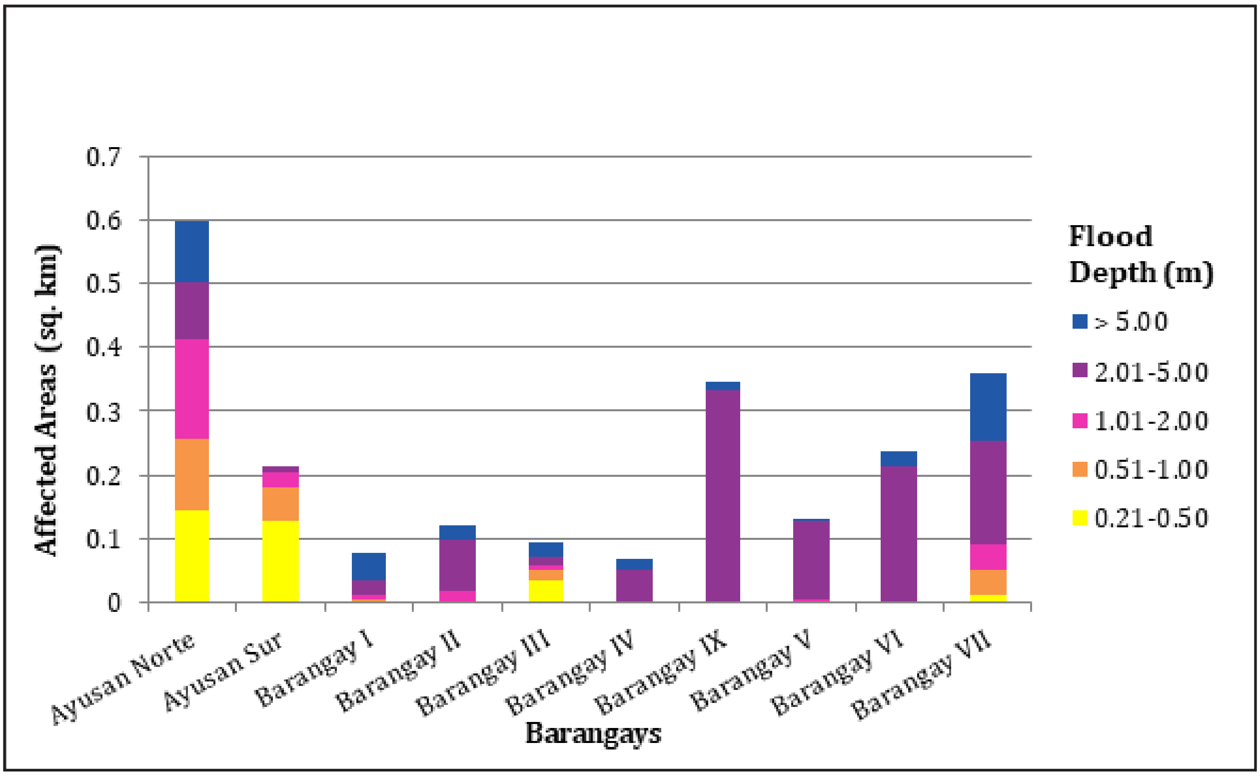


Figure 132. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

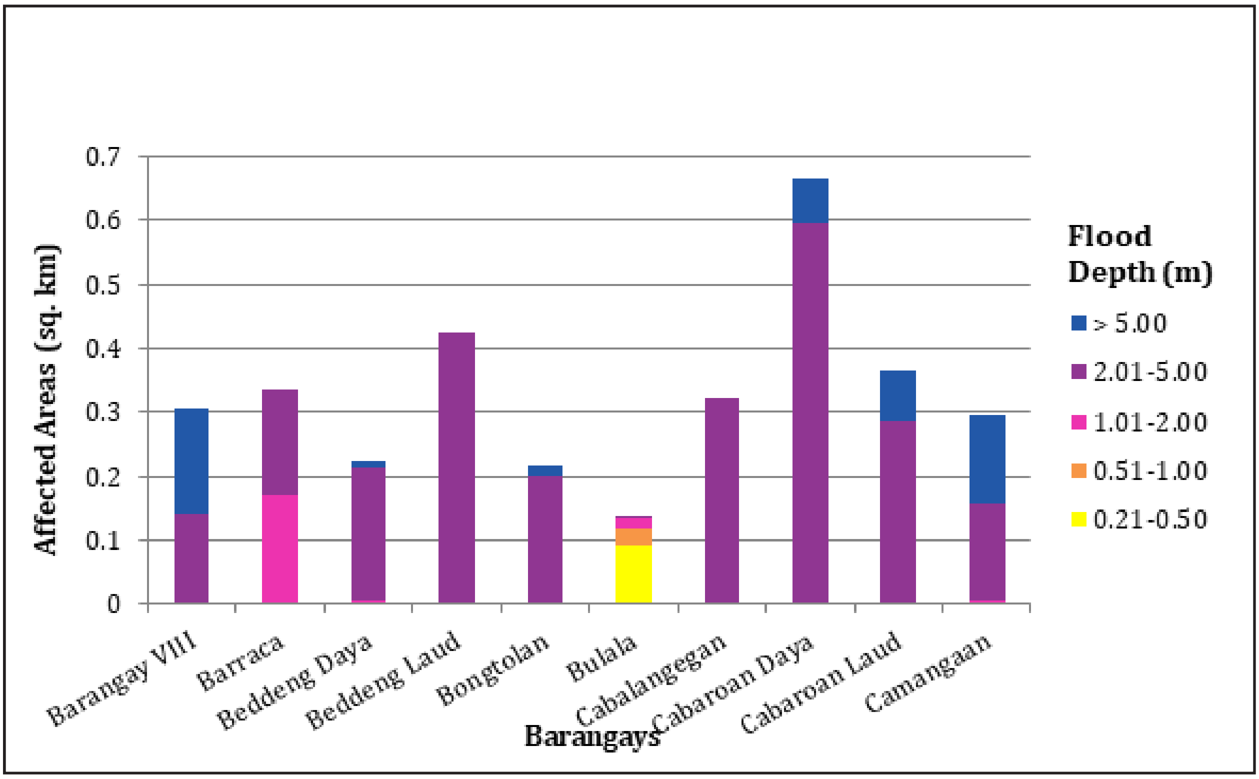


Figure 133. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

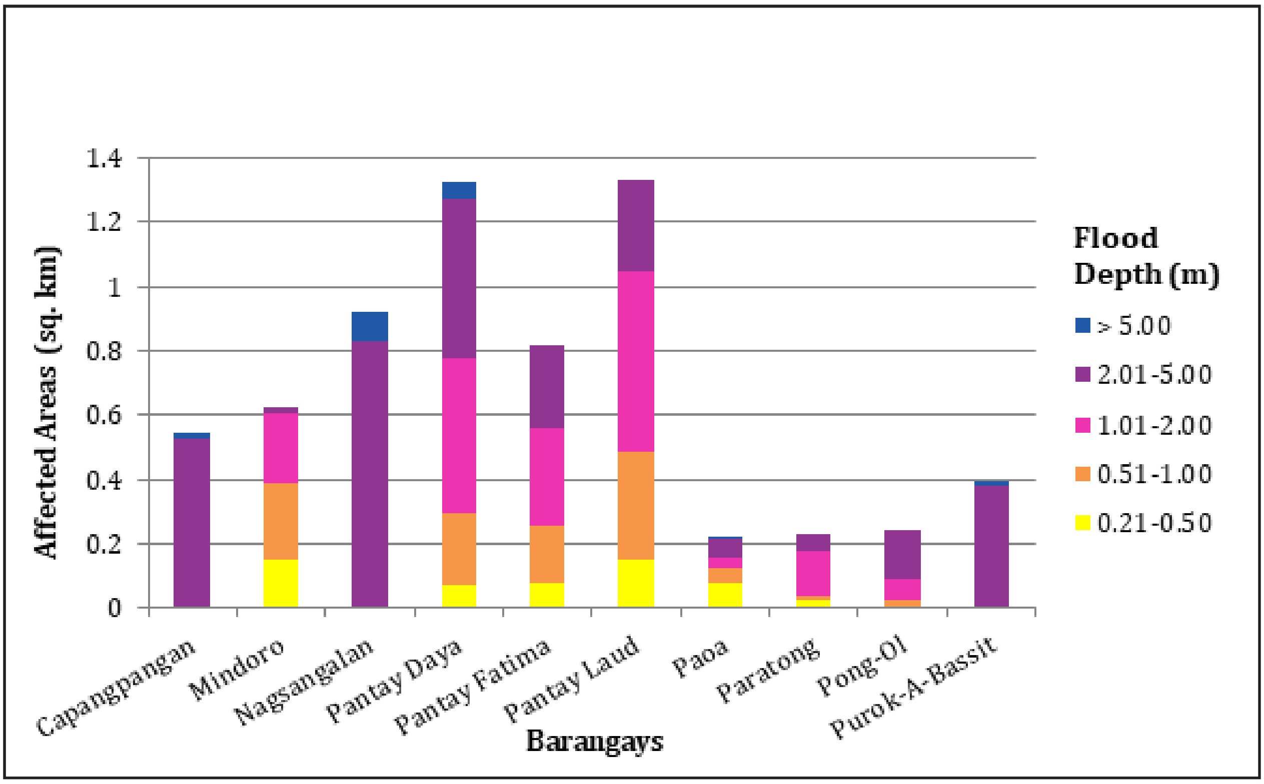


Figure 134. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

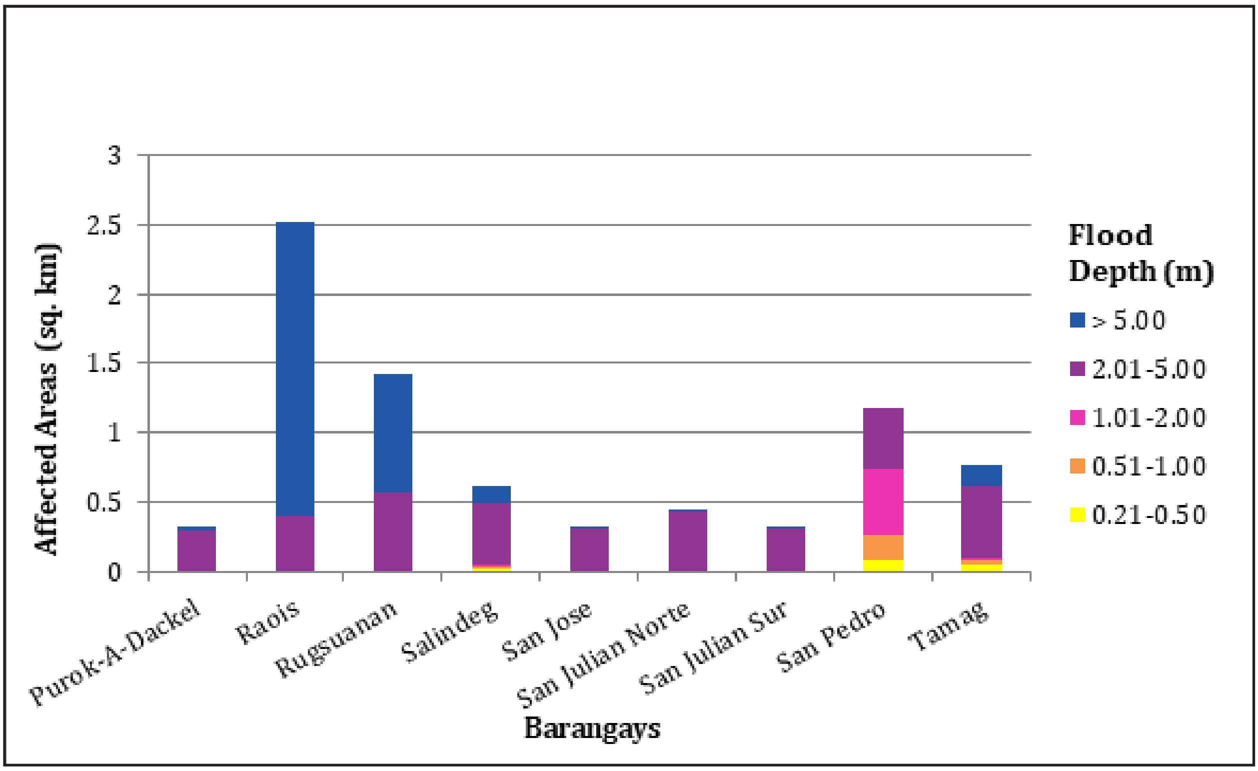


Figure 135. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

For the 100-year return period, 7.72% of the municipality of Bangued with an area of 123.75 sq. km. will experience flood levels of less than 0.20 meters. 0.38% of the area will experience flood levels of 0.21 to 0.50 meters while 0.17%, 0.12%, 0.24%, and 16.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 71 are the affected areas in Bangued in square kilometers by flood depth per barangay.

Table 71. Affected Areas in Bangued, Abra during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangued (in sq. km.)										
	Bañacao	Bangbangar	Cabuloan	Calaba	Dangdangla	Lingtan	Lipcan	Malita	Palao	Patucannay	Sagap
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0.0018	0.0027	0.0075	0.14	0.0081	0.0054	0.091
0.51-1.00	0	0	0	0	0.0045	0.0027	0.0027	0.051	0.012	0.0018	0.046
1.01-2.00	0	0	0	0	0.0018	0.0059	0.0099	0.03	0.011	0.0031	0.027
2.01-5.00	0	0	0	0	0.023	0.077	0.023	0.0045	0.033	0.013	0.0081
> 5.00	2.67	1.71	2.57	0.73	0.11	0.62	0.93	0	1.77	0.06	0.0009

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bangued (in sq. km.)									
	San Antonio	Santa Rosa	Sao-Atan	Zone 1 Poblacion	Zone 2 Poblacion	Zone 3 Poblacion	Zone 4 Poblacion	Zone 5 Poblacion	Zone 6 Poblacion	Zone 7 Poblacion
0.03-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.21	0	0.0027	0	0	0	0	0	0	0
0.51-1.00	0.088	0	0	0	0	0	0	0	0	0
1.01-2.00	0.06	0	0.0005	0	0	0	0	0	0	0.0027
2.01-5.00	0.098	0	0.0042	0	0	0	0	0	0	0.0064
> 5.00	2.31	4.55	0.017	0.28	0.3	0.68	0.14	0.23	0.19	0.24

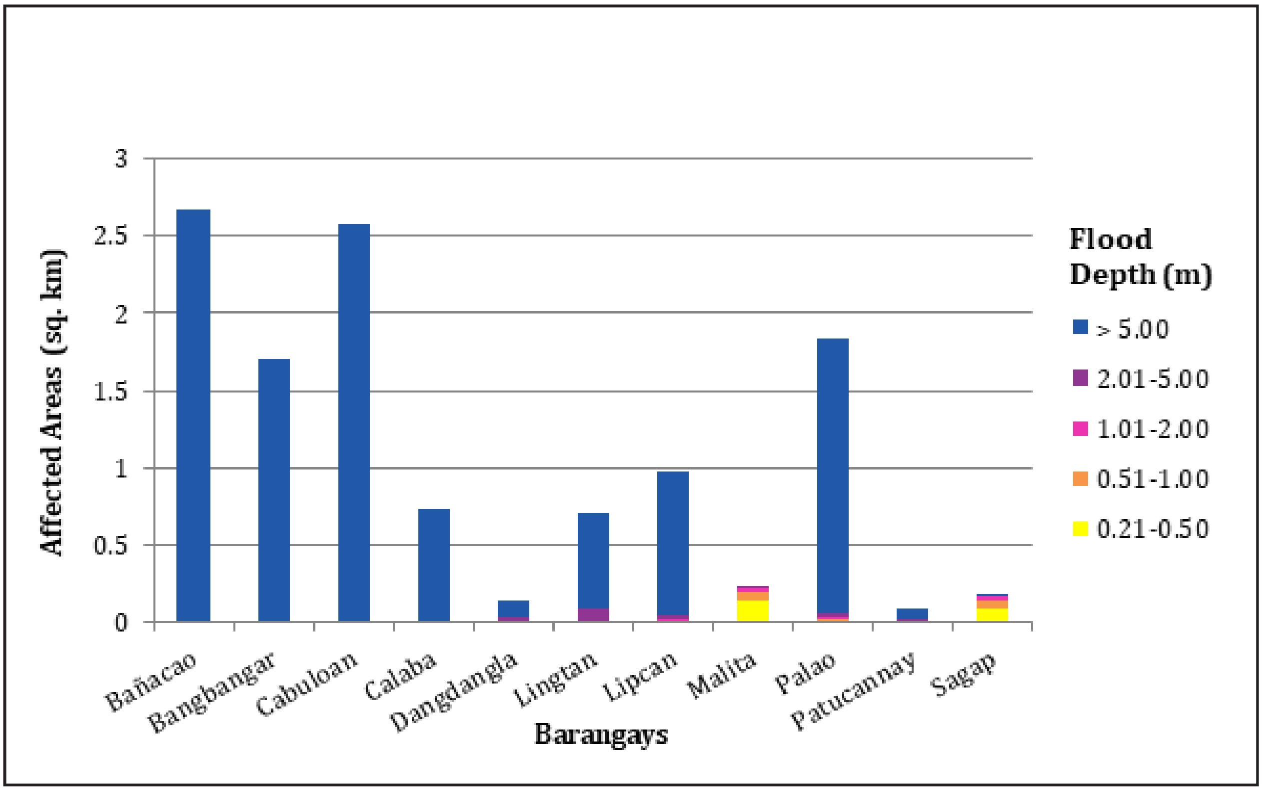


Figure 136. Affected Areas in Bangued, Abra during 100-Year Rainfall Return Period.

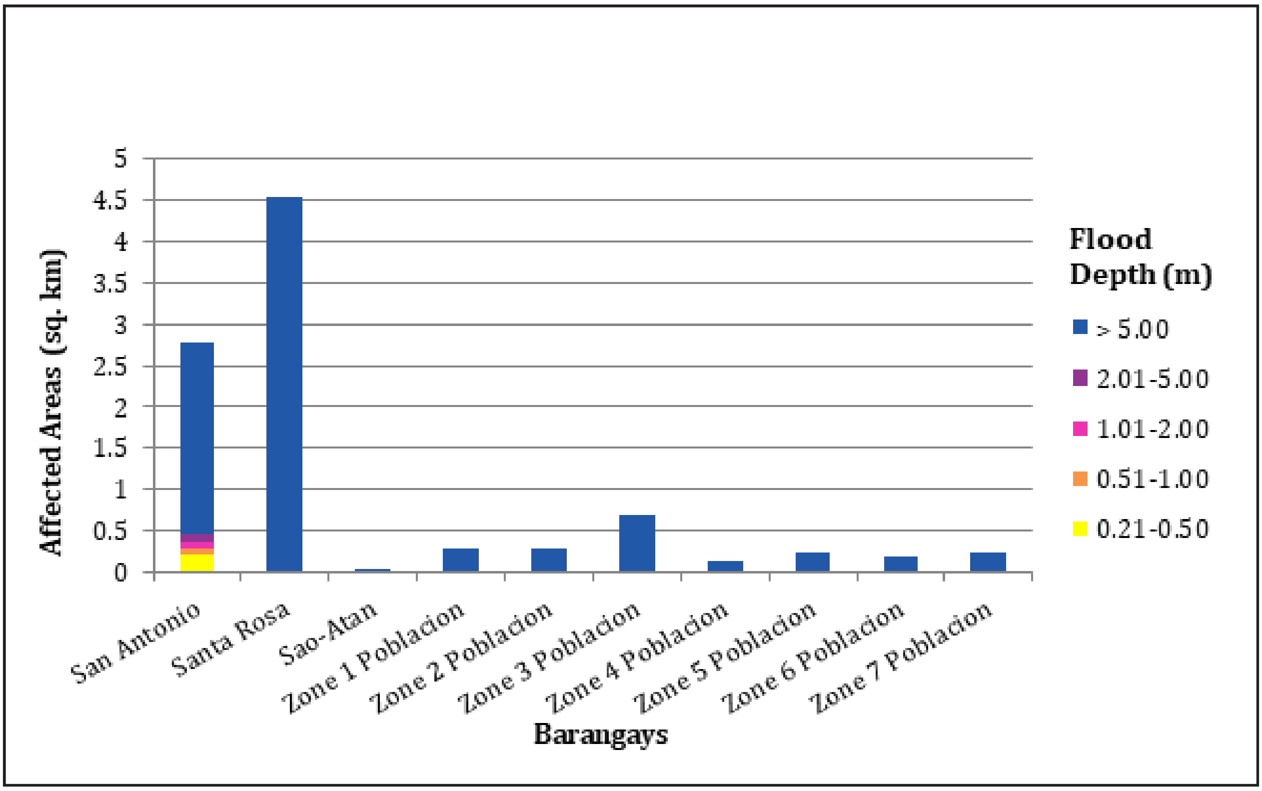


Figure 137. Affected Areas in Bangued, Abra during 100-Year Rainfall Return Period.

For the 100-year return period, 66.16% of the municipality of Langiden with an area of 98.7 sq. km. will experience flood levels of less than 0.20 meters. 3.50% of the area will experience flood levels of 0.21 to 0.50 meters while 1.68%, 1.08%, 2.42%, and 14.00% 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 72 are the affected areas in Langiden in square kilometers by flood depth per barangay.

Table 72. Affected Areas in Langiden, Abra during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays Langiden (in sq. km)					
	Baac	Dalayap	Mabungtot	Malapaao	Poblacion	Quillat
0-0.20	0	0	0	0	0	0
0.21-0.50	0.076	0.0054	1.33	1.98	0.025	0.034
0.51-1.00	0.028	0.0036	0.64	0.95	0.019	0.016
1.01-2.00	0.035	0.0081	0.38	0.59	0.03	0.028
2.01-5.00	0.053	0.019	0.8	1.4	0.066	0.05
> 5.00	1.92	0.62	3.37	3.45	0.6	3.86

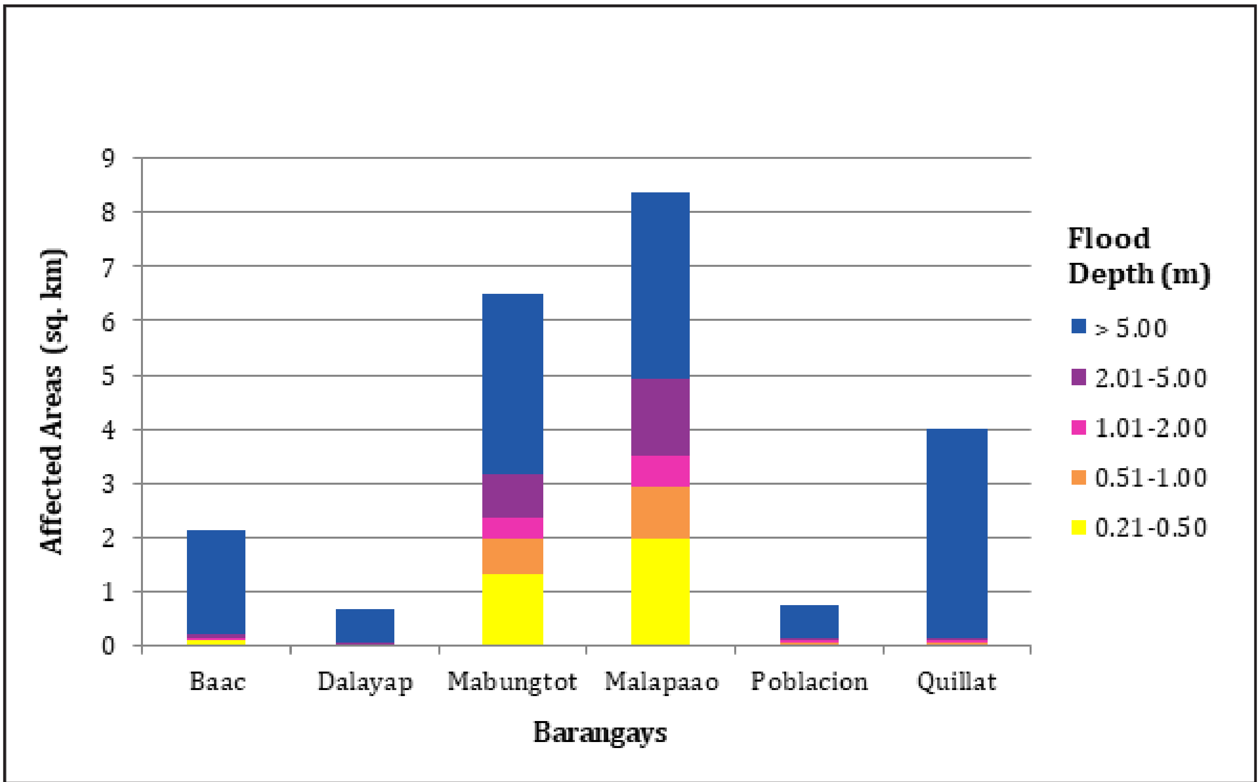


Figure 138. Affected Areas in Langiden, Abra during 100-Year Rainfall Return Period.

For the 100-year return period, 40.94% of the municipality of Pidigan with an area of 58.13 sq. km. will experience flood levels of less than 0.20 meters. 1.93% of the area will experience flood levels of 0.21 to 0.50 meters while 0.91%, 0.89%, 1.37%, and 31.36% 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 73 are the affected areas in Pidigan in square kilometers by flood depth per barangay.

Table 73. Affected Areas in Pidigan, Abra during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pidigan (in sq. km.)						
	Alinaya	Garreta	Immuli	Laskig	Monggoc	Naguirayan	Pamutic
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0.18	0.082	0.059	0.016	0.19	0.0009	0.0079
0.51-1.00	0.093	0.014	0.023	0.02	0.094	0.0018	0.0027
1.01-2.00	0.077	0.027	0.0094	0.008	0.12	0.0058	0.0027
2.01-5.00	0.092	0.051	0	0.037	0.19	0.021	0.009
> 5.00	0.69	0.26	0	0.74	1.18	1.26	1.45
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Pidigan (in sq. km.)**						
	Pangtud	**Poblacion East**	**Poblacion West**	**San Diego**	**Sulbec**	**Suyo**	**Yuyeng**
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0.12	0	0	0.0018	0.13	0.031	0.3
0.51-1.00	0.083	0	0	0.0044	0.057	0.016	0.12
1.01-2.00	0.1	0	0	0.01	0.057	0.014	0.085
2.01-5.00	0.089	0	0	0.035	0.13	0.027	0.12
> 5.00	1.71	2.54	1.93	2.09	3.15	0.57	0.68

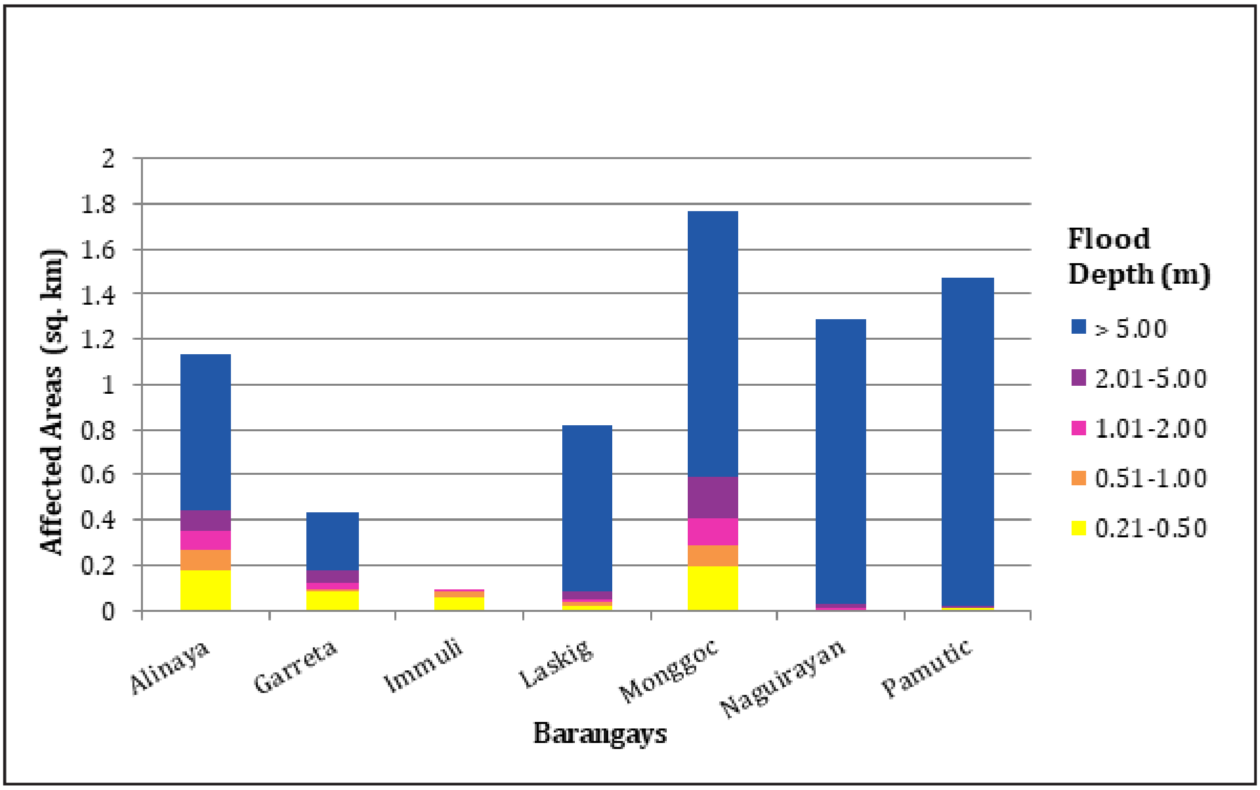


Figure 139. Affected Areas in Pidigan, Abra during 100-Year Rainfall Return Period.

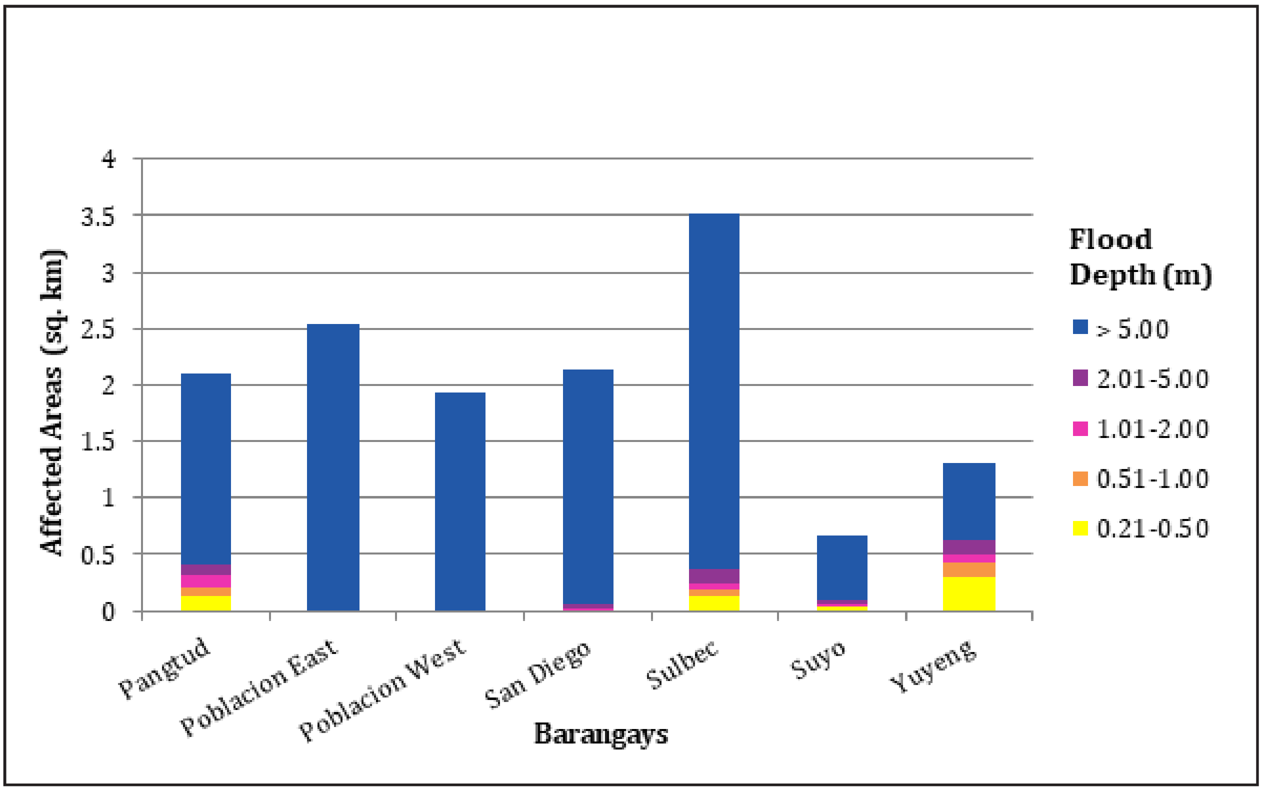


Figure 140. Affected Areas in Pidigan, Abra during 100-Year Rainfall Return Period.

For the 100-year return period, 51.04% of the municipality of San Quintin with an area of 62.29 sq. km. will experience flood levels of less than 0.20 meters. 2.71% of the area will experience flood levels of 0.21 to 0.50 meters while 1.43%, 1.25%, 1.92%, and 12.60% 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 74 are the affected areas in San Quintin in square kilometers by flood depth per barangay.

Table 74. Affected Areas in San Quintin, Abra during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)					
	Labaan	Palang	Pantoc	Poblacion	Tangadan	Villa Mercedes
0-0.20	0	0	0	0	0	0
0.21-0.50	0.48	0.22	0.23	0.013	0.62	0.13
0.51-1.00	0.29	0.081	0.097	0.0036	0.34	0.087
1.01-2.00	0.26	0.095	0.057	0.0076	0.25	0.11
2.01-5.00	0.42	0.2	0.07	0.023	0.25	0.23
> 5.00	2.35	4.2	0.0045	0.98	0.09	0.22

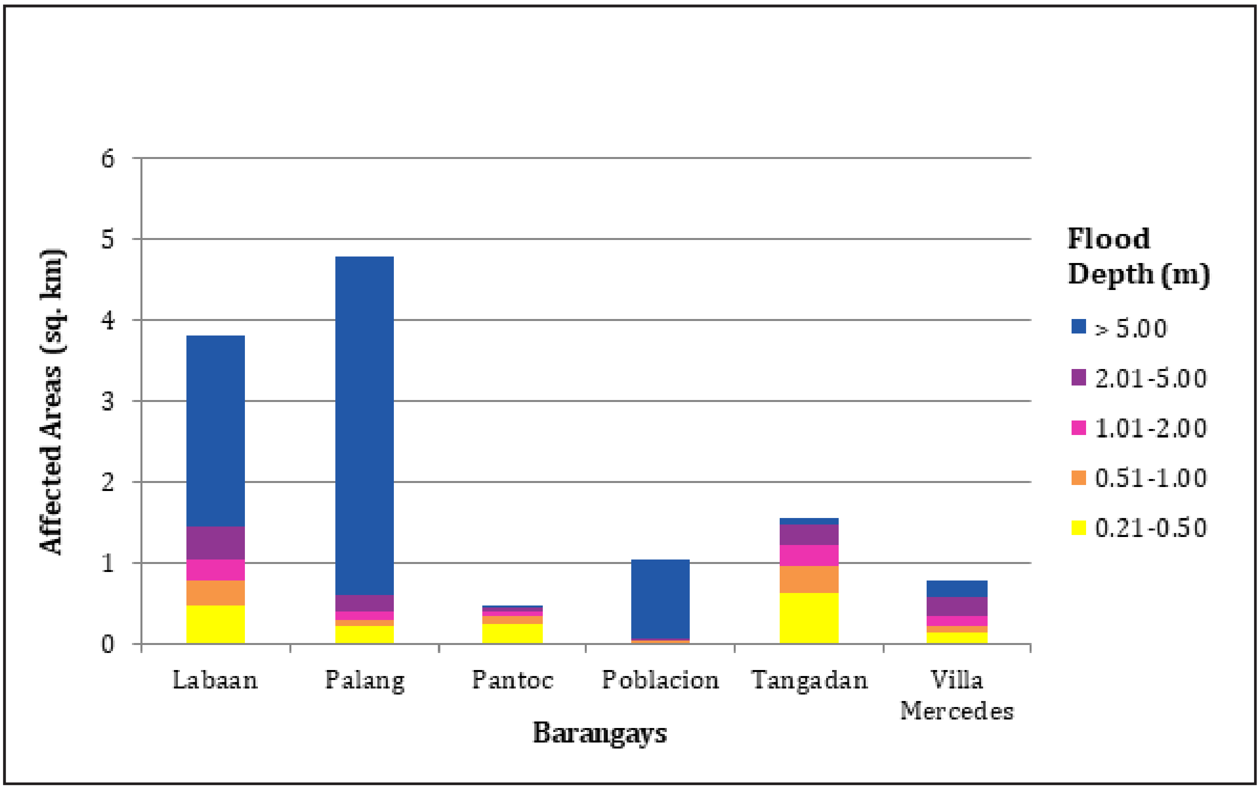


Figure 141. Affected Areas in San Quintin, Abra during 100-Year Rainfall Return Period.

For the 100-year return period, 0.52% of the municipality of Nueva Era with an area of 619 sq. km. will experience flood levels of less than 0.20 meters. 0.02% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01% and 0.01% of the area will experience flood depths of 0.51 to 1 meter and 1.01 to 2 meters, respectively. Listed in Table 75 are the affected areas in Nueva Era in square kilometers by flood depth per barangay.

Table 75. Affected Areas in Nueva Era, Ilocos Norte during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)
	Barangobong
0-0.20	0
0.21-0.50	0.13
0.51-1.00	0.088
1.01-2.00	0.056
2.01-5.00	0.024
> 5.00	0.003

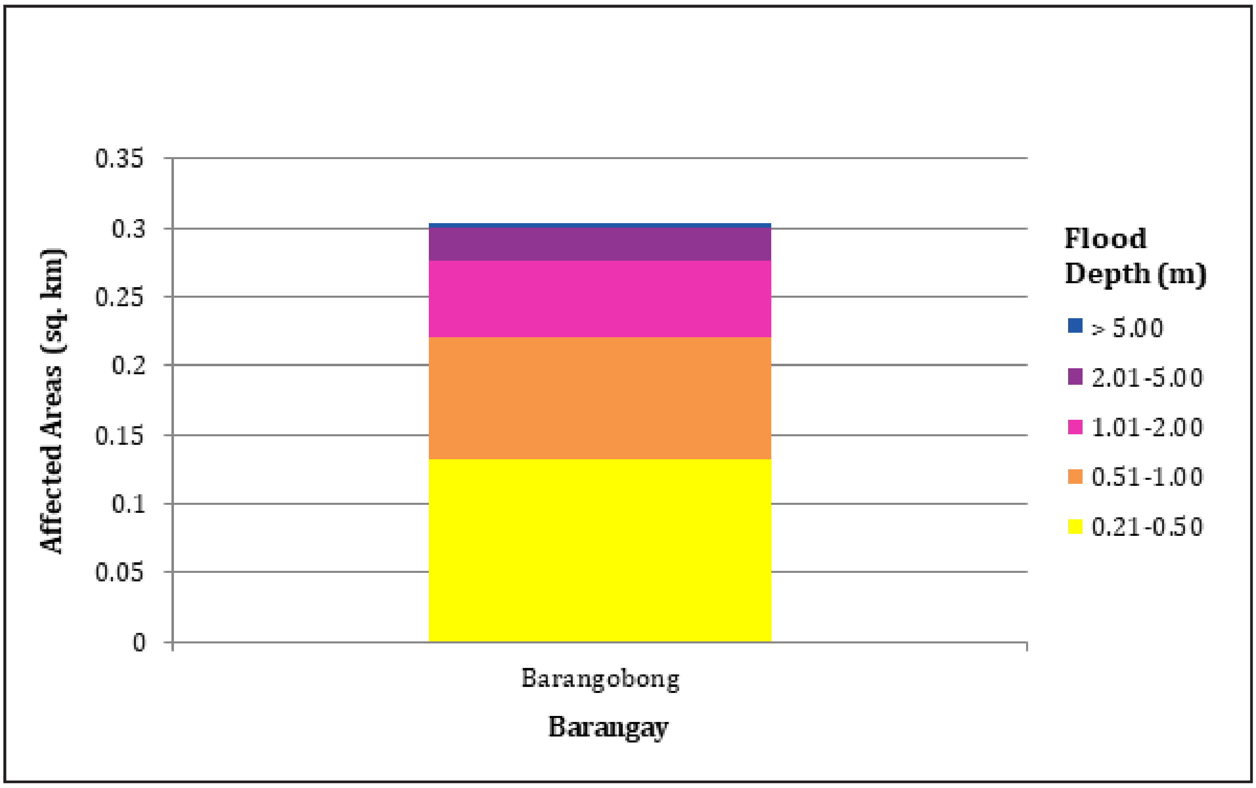


Figure 142. Affected Areas in Nueva Era, Ilocos Norte during 100-Year Rainfall Return Period.

For the 100-year return period, 56.86% of the municipality of Bantay with an area of 71.06 sq. km. will experience flood levels of less than 0.20 meters. 8.39% of the area will experience flood levels of 0.21 to 0.50 meters while 6.81%, 5.95%, 6.08%, and 16.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 76 are the affected areas in Bantay in square kilometers by flood depth per barangay.

Table 76. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)											
	Aggay	An-Annam	Balaleng	Banaoang	Barangay 1	Barangay 2	Barangay 3	Barangay 4	Barangay 5	Barangay 6	Bulag	Buquig
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.03	0.43	0.42	0.19	0	0	0	0	0	0	0.16	0.028
0.51-1.00	0.023	0.14	0.25	0.094	0	0	0	0	0	0	0.13	0.02
1.01-2.00	0.053	0.051	0.12	0.063	0	0	0	0	0	0	0.16	0.029
2.01-5.00	0.14	0.0016	0.0024	0.059	0	0	0	0	0	0	0.4	0.06
> 5.00	0.073	0	0	0.37	0	0	0	0	0	0	0.81	0.2

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)										
	Cabalanggan	Cabaroan	Cabusligan	Capangdanan	Guimod	Lingsat	Malingeb	Mira	Naguiddayan	Ora	Paing
0-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.0012	0.0074	0.26	0.33	0.31	1.11	0.24	0.088	0.18	0.082	0.15
0.51-1.00	0.0032	0.01	0.28	1.03	0.39	0.6	0.32	0.023	0.17	0.15	0.071
1.01-2.00	0.01	0.019	0.13	0.75	0.4	0.59	0.29	0.0013	0.07	0.2	0.091
2.01-5.00	0.34	0.11	0	0.073	0.24	0.45	0.066	0	0.069	0.12	0.32
> 5.00	0.47	0.085	0	0	0.0008	0.028	0	0	0.39	0.028	3.49

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bantay (in sq. km.)										
	Puspus	Quimmarayan	Sagneb	Sagpat	San Isidro	San Julian	San Mariano	Sinabaan	Taguiporo	Taleb	Tay-Ac
0-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.19	0.36	0.11	0.12	0	0	0.25	0.0069	0	0.18	0.6
0.51-1.00	0.21	0.064	0	0.17	0	0	0.12	0.0067	0	0.14	0.29
1.01-2.00	0.31	0.037	0	0.31	0	0	0.097	0.0071	0	0.14	0.17
2.01-5.00	0.073	0.012	0	0.42	0.0086	0.46	0.14	0.31	0	0.2	0.016
> 5.00	0.031	0	0	0	0.57	2.04	0.51	0.31	1.6	0.33	0

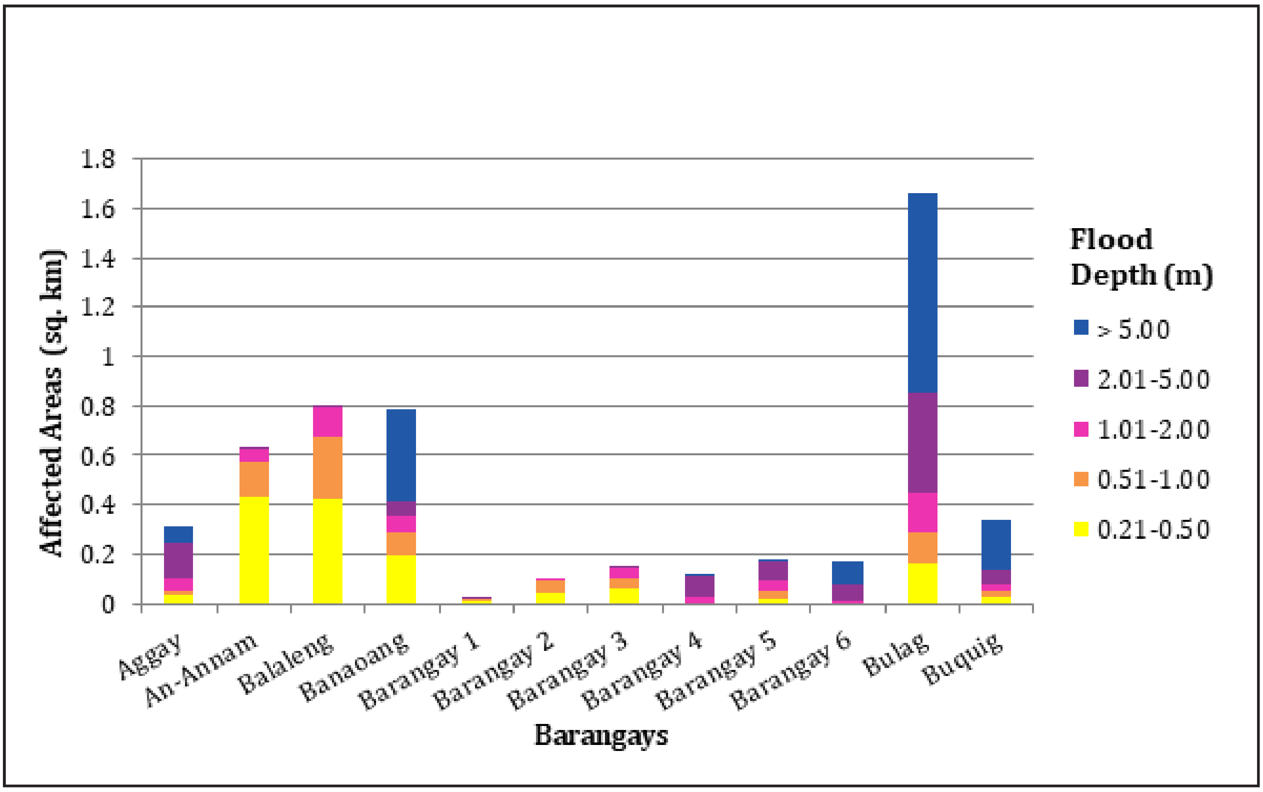


Figure 143. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

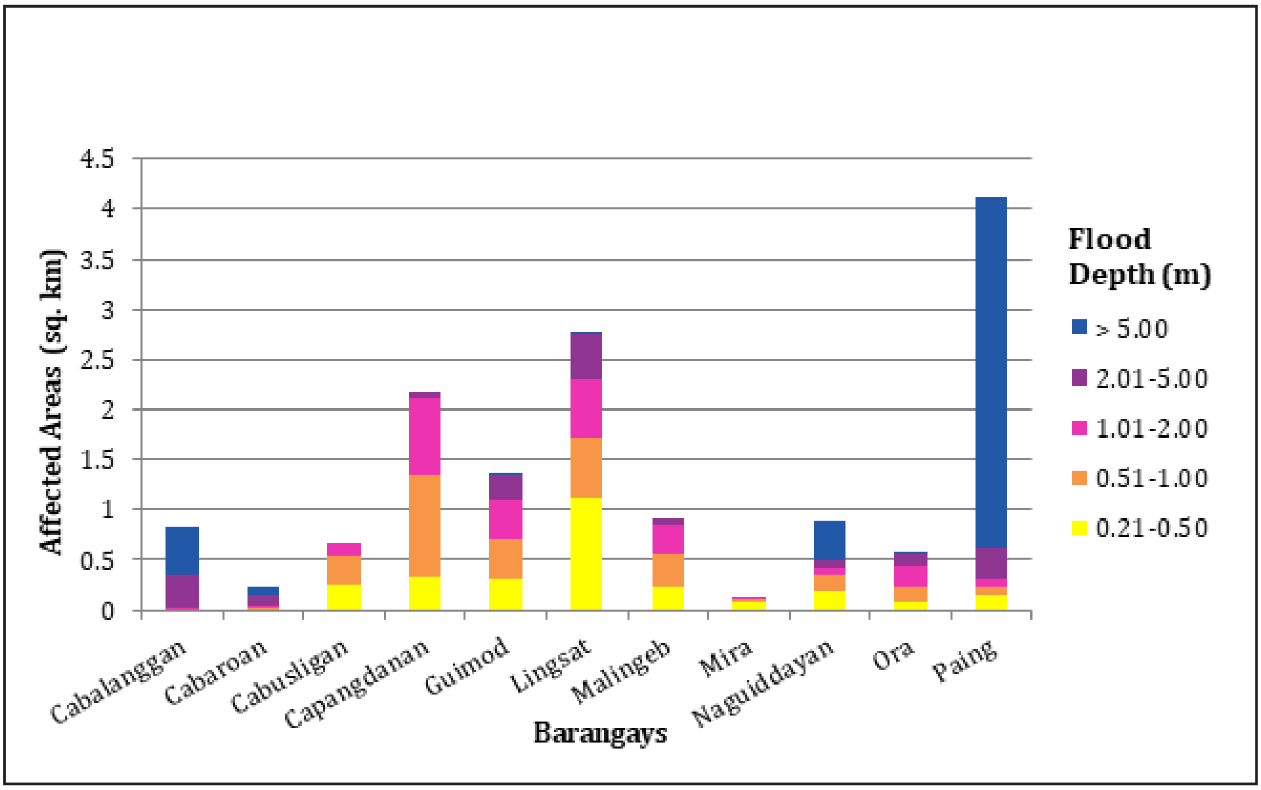


Figure 144. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

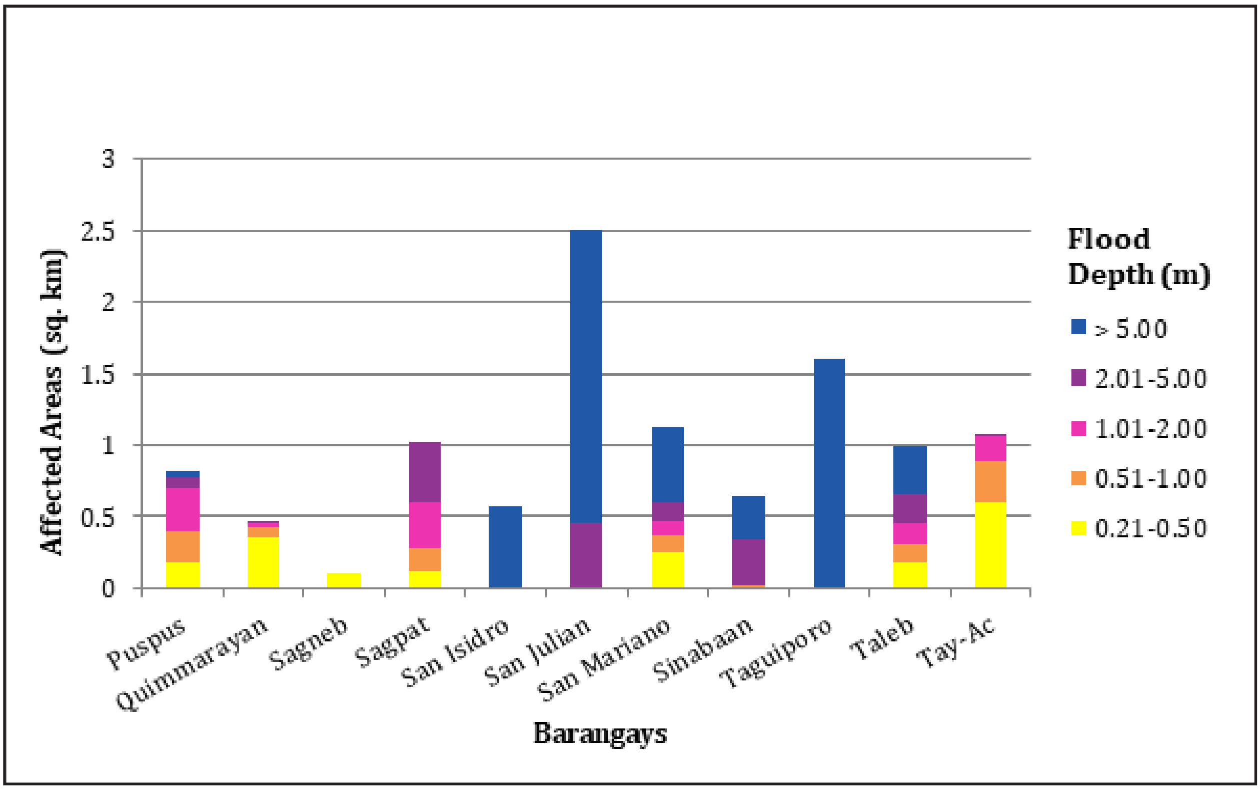


Figure 145. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 1.34% of the municipality of Caoayan with an area of 21.2 sq. km. will experience flood levels of less than 0.20 meters. 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.68%, 2.59%, 62.12%, and 28.49% 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 77 are the affected areas in Caoayan in square kilometers by flood depth per barangay.

Table 77. Affected Areas in Caoayan, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Caoayan (in sq. km.)							
	Anonang Mayor	Anonang Menor	Baggoc	Callaguip	Caparacadan	Don Alejandro Quirolgico	Don Dimas Querubin	Don Lorenzo Querubin
0.03-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0.042	0	0	0
0.51-1.00	0	0	0	0	0.067	0	0	0
1.01-2.00	0	0	0.0007	0	0.11	0	0	0
2.01-5.00	0.21	0.26	0.19	0.26	0.71	0.26	0.42	0.26
> 5.00	0.046	0.11	0.052	0.072	0.0003	0.06	0.14	0.12
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Caoayan (in sq. km.)**							
	Fuerte	**Manangat**	**Naguilian**	**Nansuagao**	**Pandan**	**Pantay Tamurong**	**Pantay-Quitiquit**	**Villamar**
0.03-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.0089	0.0089	0.0077	0	0	0.011	0	0.0001
0.51-1.00	0.011	0.0091	0.023	0	0.0001	0.033	0	0.0008
1.01-2.00	0.041	0.029	0.029	0	0.0005	0.34	0	0.0047
2.01-5.00	0.25	0.26	0.97	1.19	0.24	4.72	0.41	2.56
> 5.00	0	0.006	3.35	0.99	0.0013	0.71	0	0.38

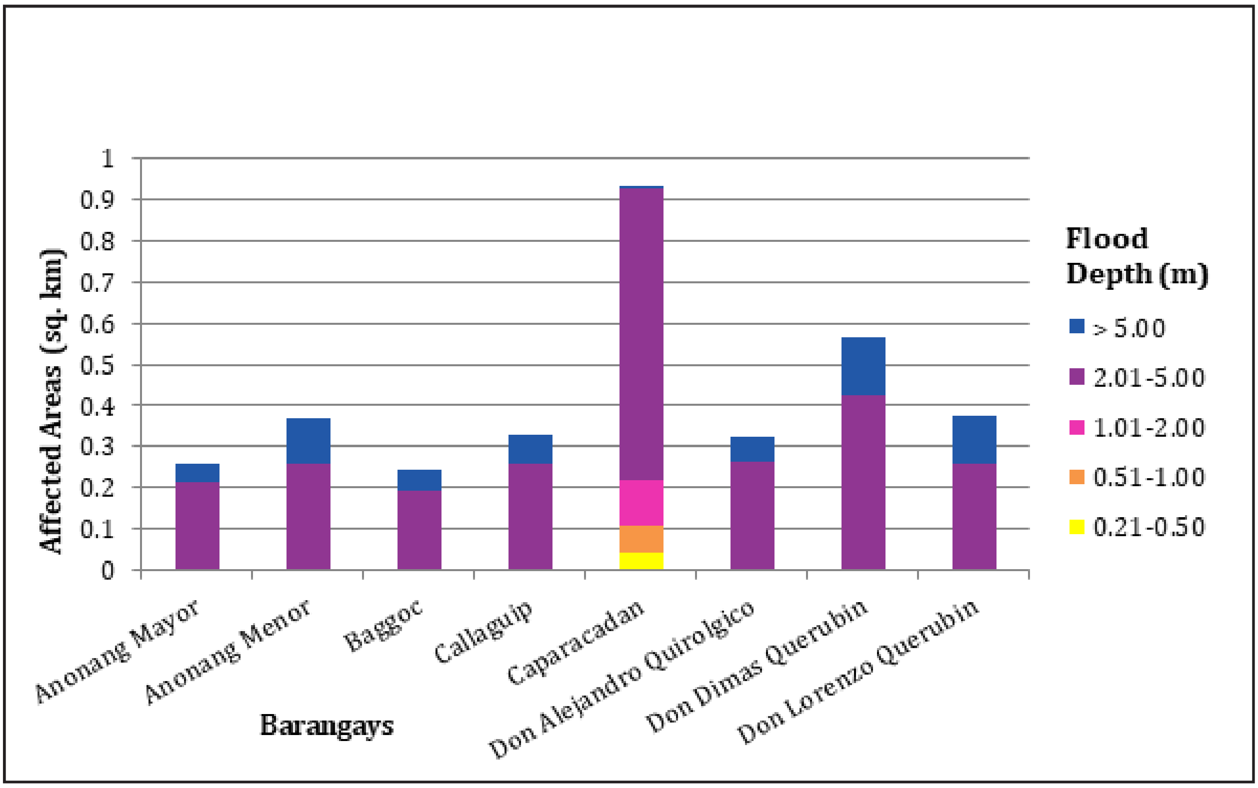


Figure 146. Affected Areas in Caoayan, Ilocos Sur during 100-Year Rainfall Return Period.

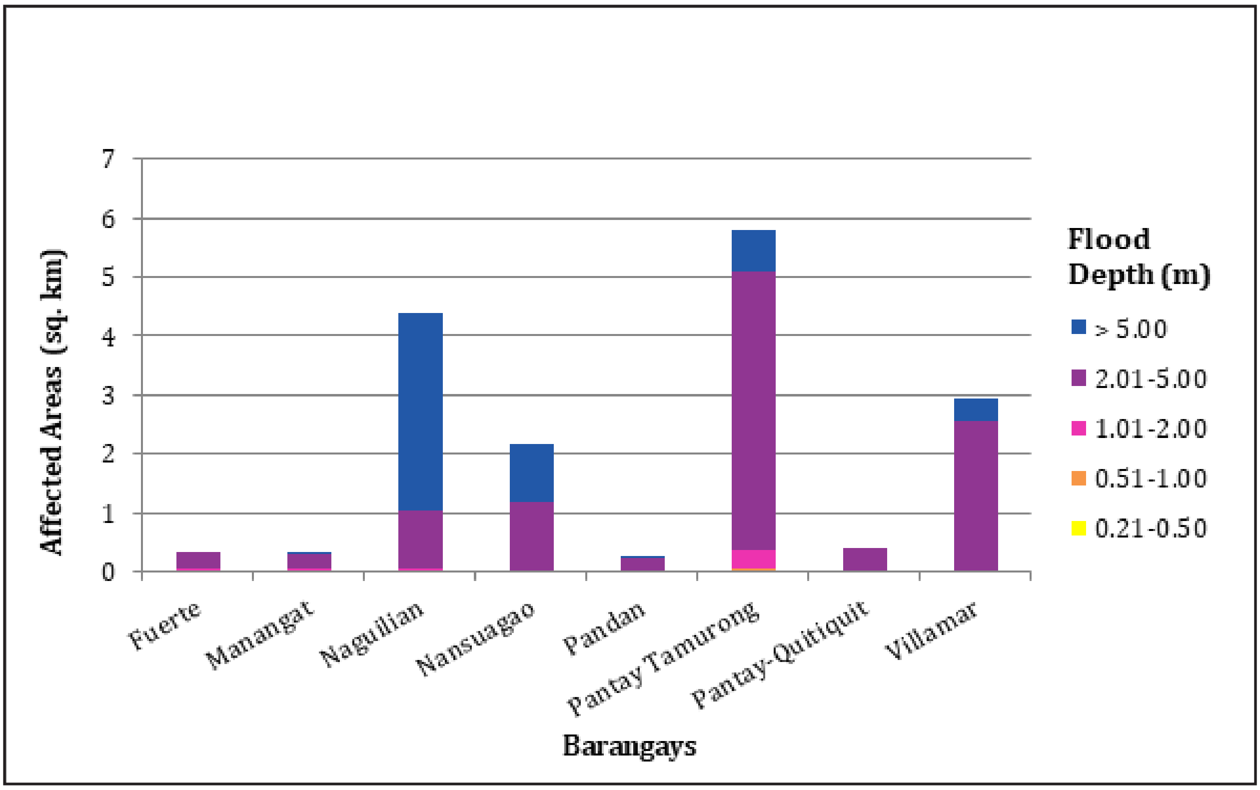


Figure 147. Affected Areas in Caoayan, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 56.80% of the municipality of Magsingal with an area of 78.9 sq. km. will experience flood levels of less than 0.20 meters. 13.67% of the area will experience flood levels of 0.21 to 0.50 meters while 11.67%, 8.45%, 5.92%, and 0.10% 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 78 are the affected areas in Magsingal in square kilometers by flood depth per barangay.

Table 78. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Magsingal (in sq.km)									
	Alangan	Bacar	Barbarit	Bungro	Cabaroan	Cadanglaan	Caraisan	Dacutan	Labut	Maas-Asin
0.03-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.23	0.11	0.38	0.4	0.2	0.36	1.07	0.19	0.27	0.99
0.51-1.00	0.22	0.32	0.51	0.51	0.32	0.16	0.57	0.28	0.24	0.55
1.01-2.00	0.2	0.34	0.46	0.23	0.28	0.057	0.055	0.23	0.22	0.47
2.01-5.00	0.022	0.24	0.15	0.16	0.23	0.03	0.036	0.19	0.15	0.41
> 5.00	0	0	0	0	0	0	0	0	0.0029	0.0021
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Magsingal (in sq.km)**									
	Macatcatud	Manzante	Maratudo	Miramar	Namalpalan	Napo	Pagsanaan Norte	Pagsanaan Sur	Panay Norte	Panay Sur
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.91	0.37	0.7	0.066	0.32	1.13	0.2	0.083	0.45	0.76
0.51-1.00	0.66	0.65	0.4	0.1	0.29	0.75	0.29	0.18	0.33	0.7
1.01-2.00	0.27	0.62	0.4	0.33	0.21	0.25	0.34	0.38	0.11	0.31
2.01-5.00	0.28	0.32	0.36	0.79	0.059	0.058	0.18	0.47	0.036	0.012
> 5.00	0	0.0016	0.013	0	0.0007	0.0005	0.0009	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Magsingal (in sq.km)**									
	Patong	Puro	San Basilio	San Clemente	San Julian	San Lucas	San Ramon	San Vicente	Santa Monica	Sarsaracat
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.51	0.35	0.039	0.026	0.034	0.033	0.037	0.085	0.27	0.2
0.51-1.00	0.39	0.14	0.033	0.045	0.092	0.075	0.041	0.043	0.13	0.19
1.01-2.00	0.28	0.013	0.06	0.0077	0.14	0.05	0.019	0.0046	0.13	0.21
2.01-5.00	0.16	0	0.013	0.0001	0.14	0.052	0	0	0.033	0.074
> 5.00	0.047	0	0	0	0	0	0	0	0	0.0082

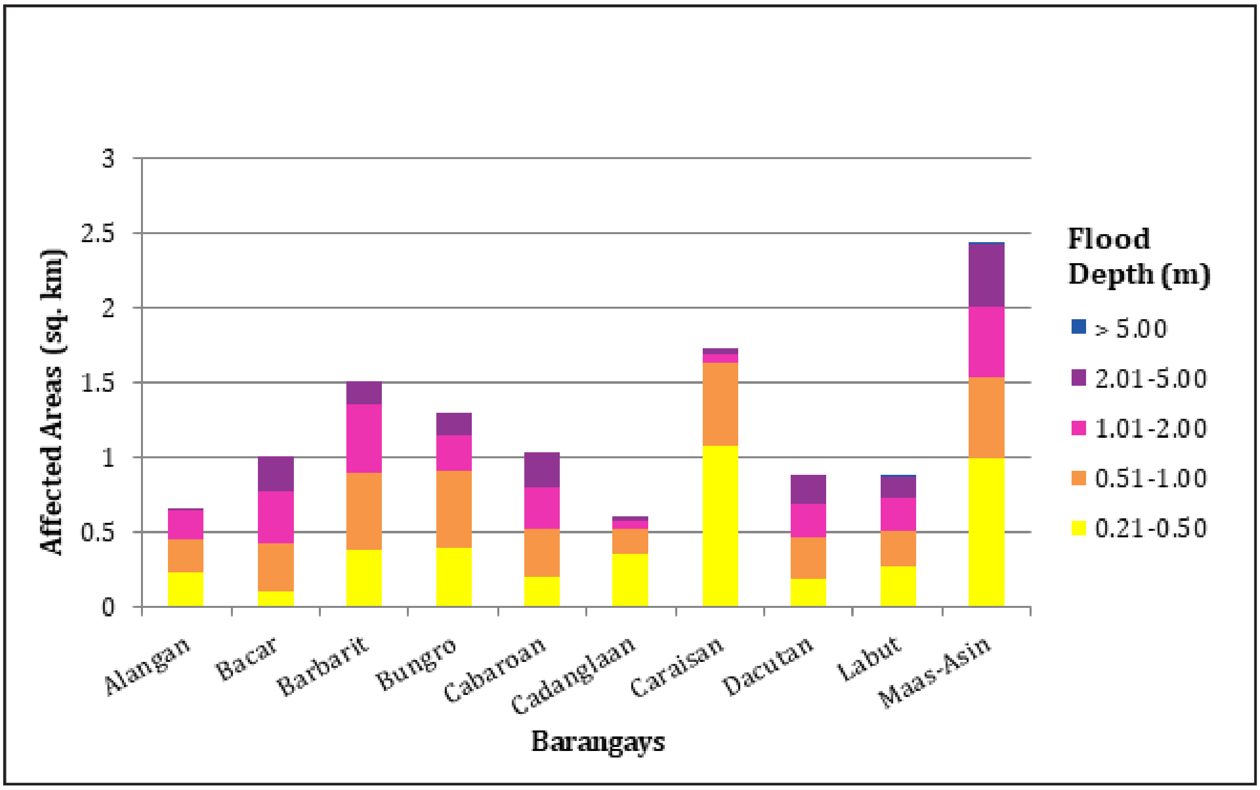


Figure 148. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

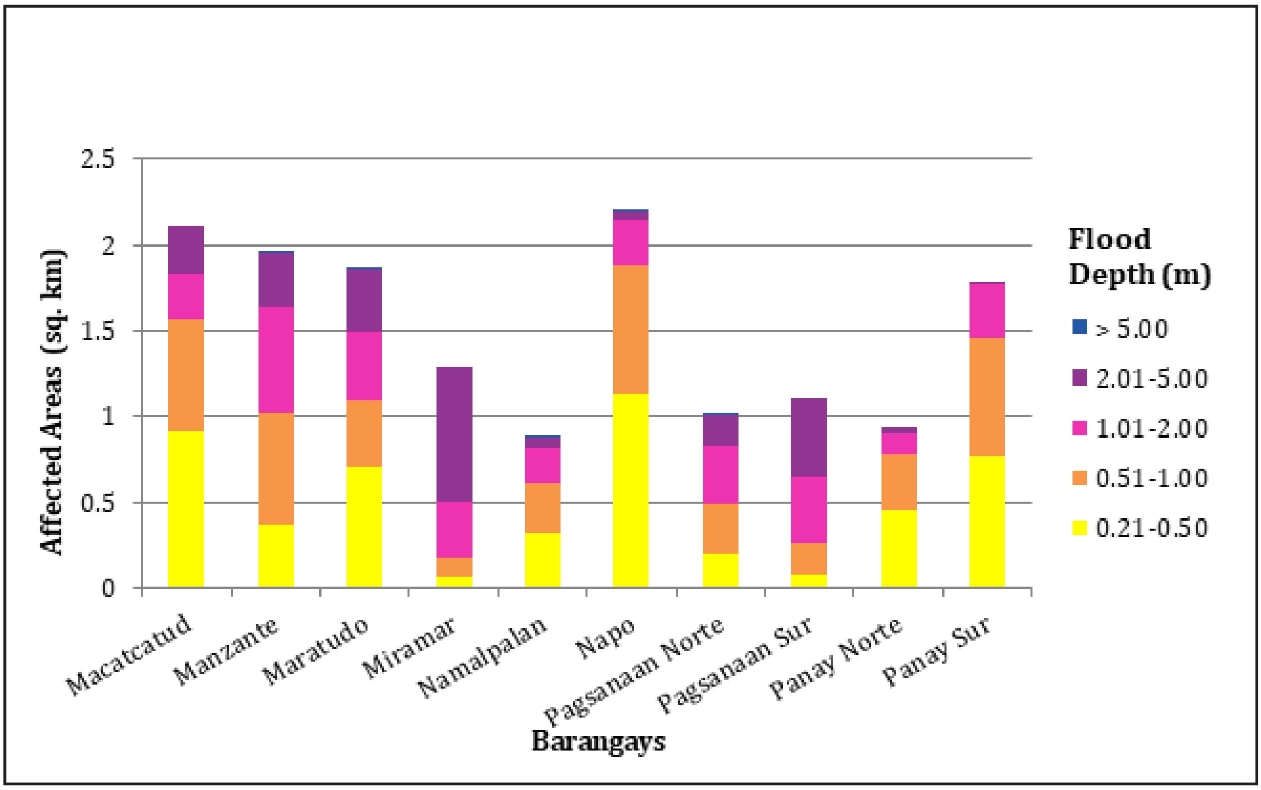


Figure 149. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

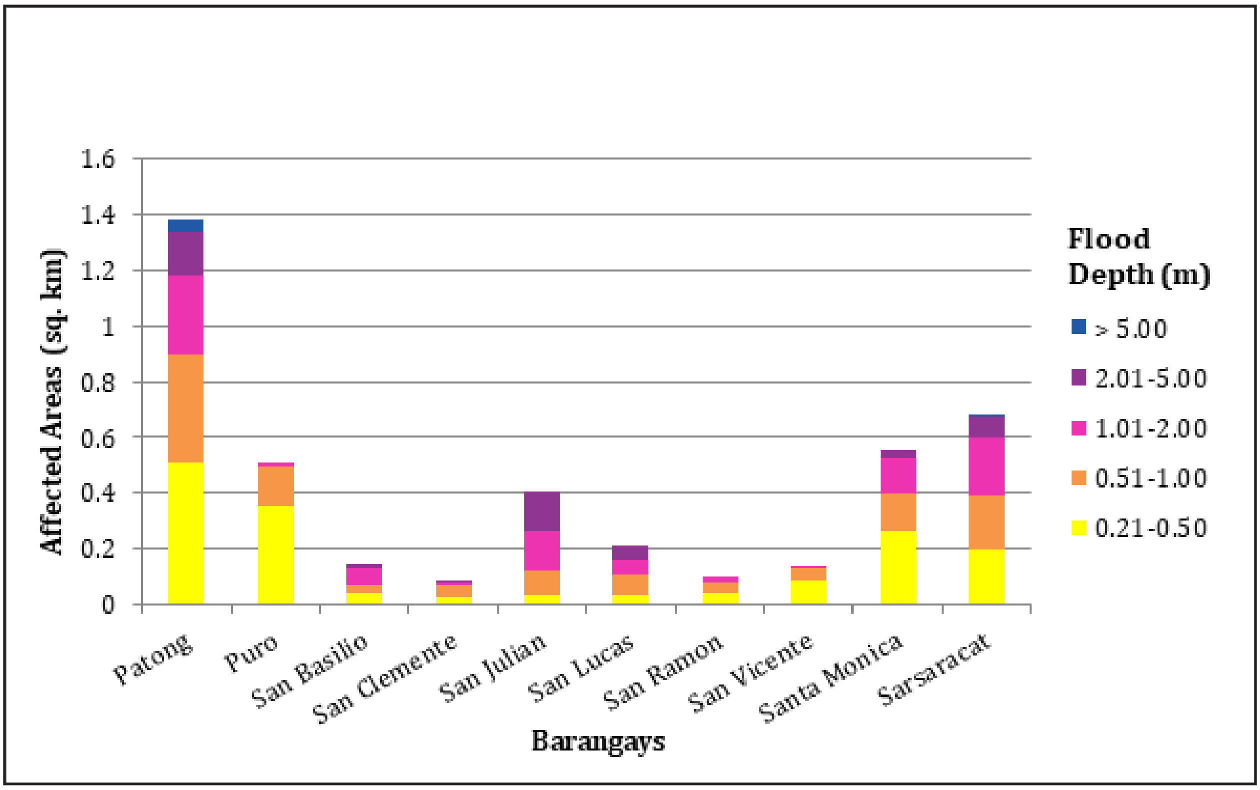


Figure 150. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 0.30% of the municipality of Narvacan with an area of 97.18 sq. km. will experience flood levels of less than 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.00% of the area will experience flood depths of 0.51 to 1 meter. Listed in Table 79 are the affected areas in Narvacan in square kilometers by flood depth per barangay.

Table 79. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Quintin (in sq. km.)	
	Ambulogan	Lanipao
0-0.20	0	0
0.21-0.50	0.0072	0.0027
0.51-1.00	0.0024	0.00086
1.01-2.00	0.00062	0
2.01-5.00	0.0027	0
> 5.00	0.000025	0

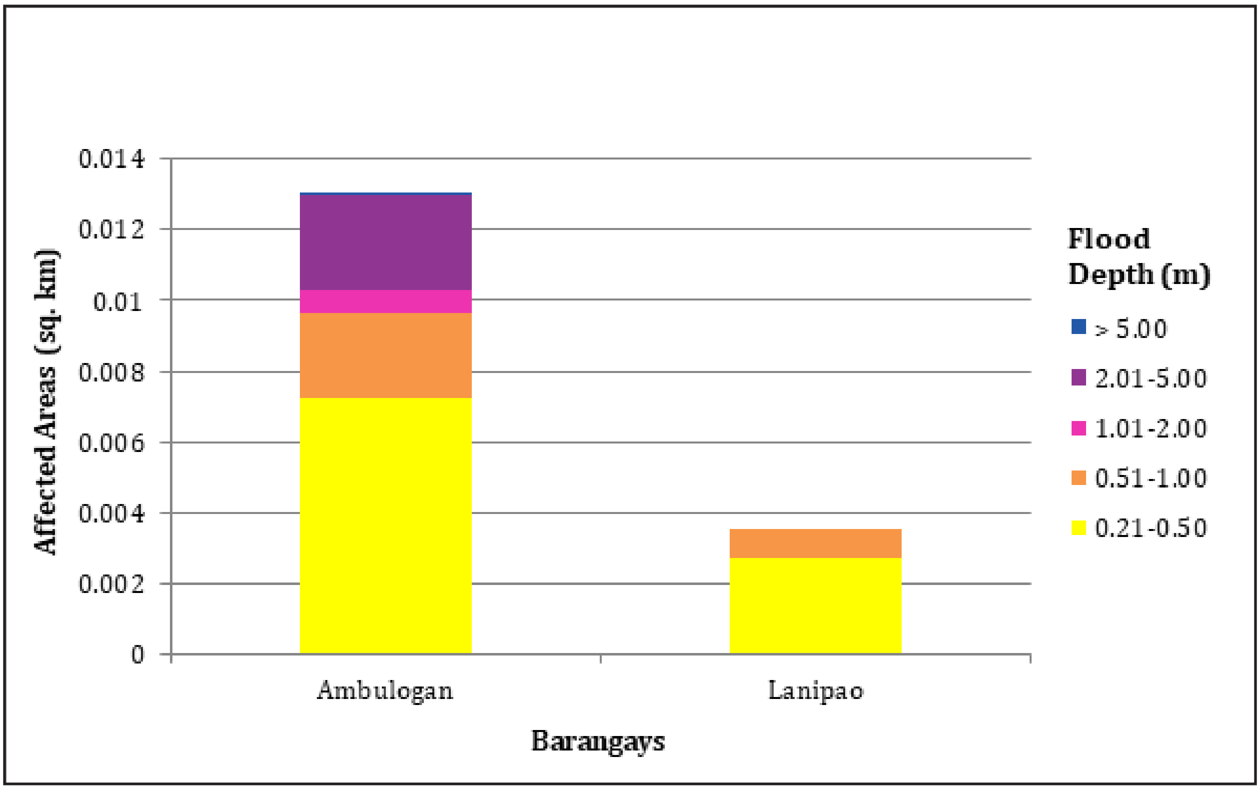


Figure 151. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 20.90% of the municipality of San Ildefonso with an area of 13.21 sq. km. will experience flood levels of less than 0.20 meters. 11.57% of the area will experience flood levels of 0.21 to 0.50 meters while 22.85%, 23.44%, 20.80%, and 1.30% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 80 are the affected areas in San Ildefonso in square kilometers by flood depth per barangay.

Table 64. Affected Areas in San Ildefonso, Ilocos Sur during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Ildefonso (in sq.km)							
	Arnap	Bahet	Belen	Bungro	Busiing Norte	Busiing Sur	Dongalo	Gongogong
0.03-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.12	0.022	0.26	0.054	0.14	0.022	0.013	0.009
0.51-1.00	0.071	0.4	0.73	0.21	0.27	0.019	0.024	0.024
1.01-2.00	0.13	0.69	0.21	0.34	0.19	0.043	0.04	0.31
2.01-5.00	0.05	0.089	0.038	0.01	0.14	0.3	0.45	0.48
> 5.00	0	0.0004	0	0	0.0067	0	0.054	0.035

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Ildefonso (in sq.km)						
	Iboy	Kinamantirisan	Otol-Patac	Poblacion East	Poblacion West	Sagneb	Sagsagat
0.03-0.20	0	0	0	0	0	0	0
0.21-0.50	0.096	0.34	0.11	0.072	0.052	0.14	0.086
0.51-1.00	0.076	0.3	0.11	0.081	0.056	0.5	0.14
1.01-2.00	0.096	0.12	0.1	0.13	0.033	0.34	0.32
2.01-5.00	0.051	0.088	0.46	0.4	0.025	0.0042	0.17
> 5.00	0.0068	0	0.015	0.044	0.00085	0	0.0085

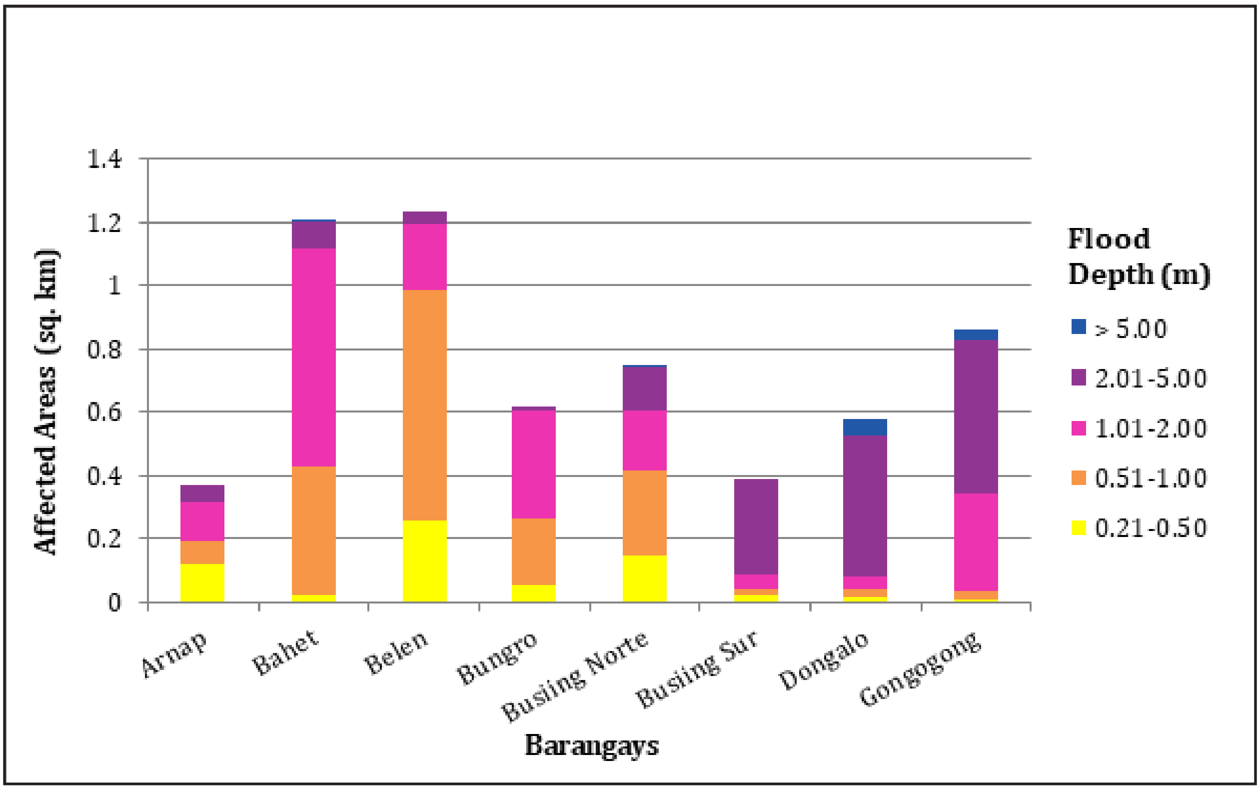


Figure 152. Affected Areas in San Ildefonso, Ilocos Sur during 100-Year Rainfall Return Period.

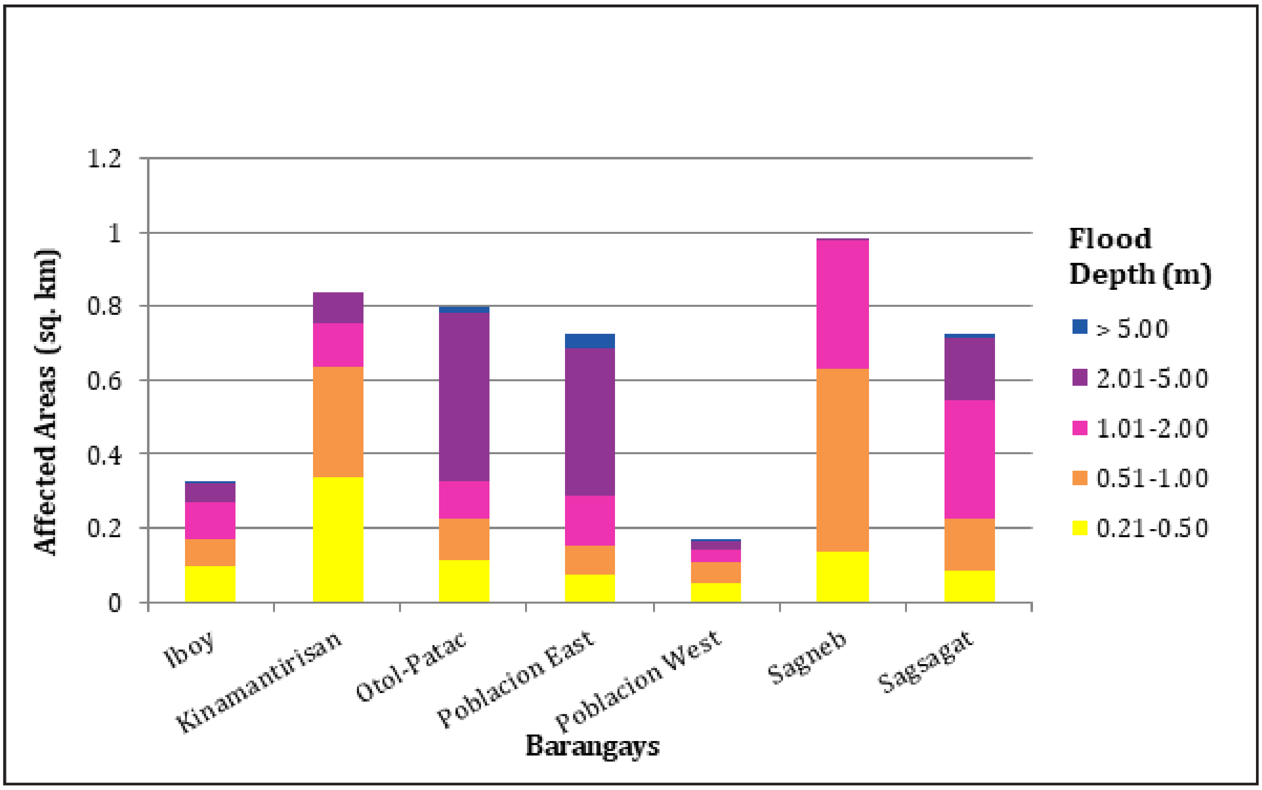


Figure 153. Affected Areas in San Ildefonso, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 45.88% of the municipality of San Juan with an area of 59.88 sq. km. will experience flood levels of less than 0.20 meters. 7.83% of the area will experience flood levels of 0.21 to 0.50 meters while 5.39%, 6.83%, 4.21%, and 0.15% 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 81 are the affected areas in San Juan in square kilometers by flood depth per barangay.

Table 81. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)								
	Asilang	Bacsil	Baliw	Bannuar	Barbar	Cabanglotan	Cacandon-gan	Camang-gaan	Camindoroan
0.03-0.20	0	0	0	0	0	0	0	0	0
0.21-0.50	0.11	0.2	0.59	0.00012	0.62	0.1	0.11	0.13	0.026
0.51-1.00	0.052	0.17	0.12	0	0.38	0.058	0.07	0.067	0.083
1.01-2.00	0.084	0.45	0.1	0	0.37	0.1	0.03	0.15	0.11
2.01-5.00	0.15	0.15	0.15	0	0.38	0.034	0.02	0.049	0.024
> 5.00	0.00026	0	0.021	0	0.022	0.0016	0.0004	0.00055	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)							
	Caronoan	Darao	Guimod Norte	Guimod Sur	Immayos Norte	Immayos Sur	Lira	Malamin
0-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.0002	0.13	0.16	0.19	0.23	0.042	0.1	0.24
0.51-1.00	0.0003	0.076	0.25	0.23	0.11	0.053	0.021	0.13
1.01-2.00	0	0.038	0.026	0.63	0.086	0.26	0.0034	0.17
2.01-5.00	0	0.043	0.0036	0.29	0.13	0.1	0.016	0.093
> 5.00	0	0.0003	0	0	0.019	0	0.0013	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Juan (in sq.km)							
	Muraya	Nagsabaran	Nagsupotan	Pandayan	Resurreccion	Sabangan	San Isidro	Saoang
0-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.31	0.14	0.29	0.00073	0.069	0.15	0.3	0.44
0.51-1.00	0.18	0.23	0.27	0.00016	0.014	0.069	0.41	0.2
1.01-2.00	0.19	0.23	0.29	0.000017	0.012	0.14	0.61	0.014
2.01-5.00	0.28	0.1	0.12	0	0.046	0.03	0.31	0
> 5.00	0.014	0	0	0	0.013	0	0	0

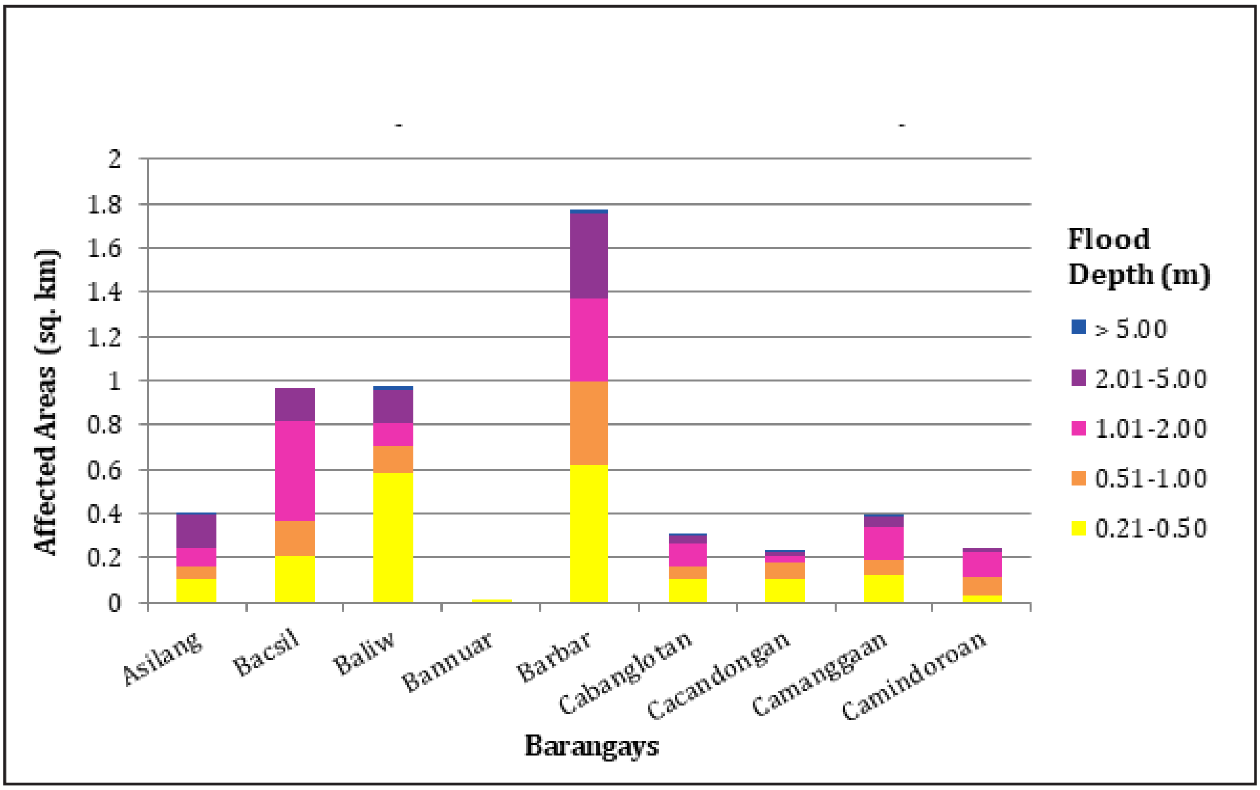


Figure 154. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

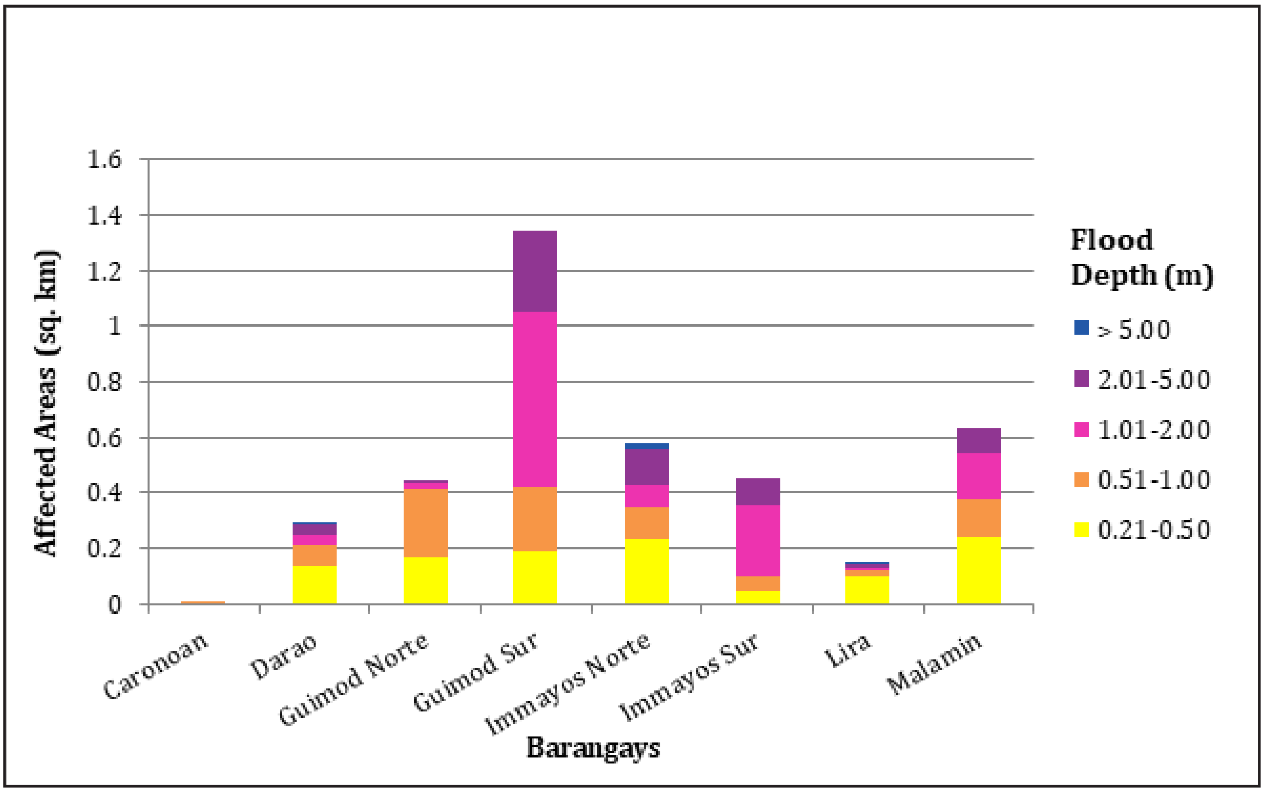


Figure 155. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

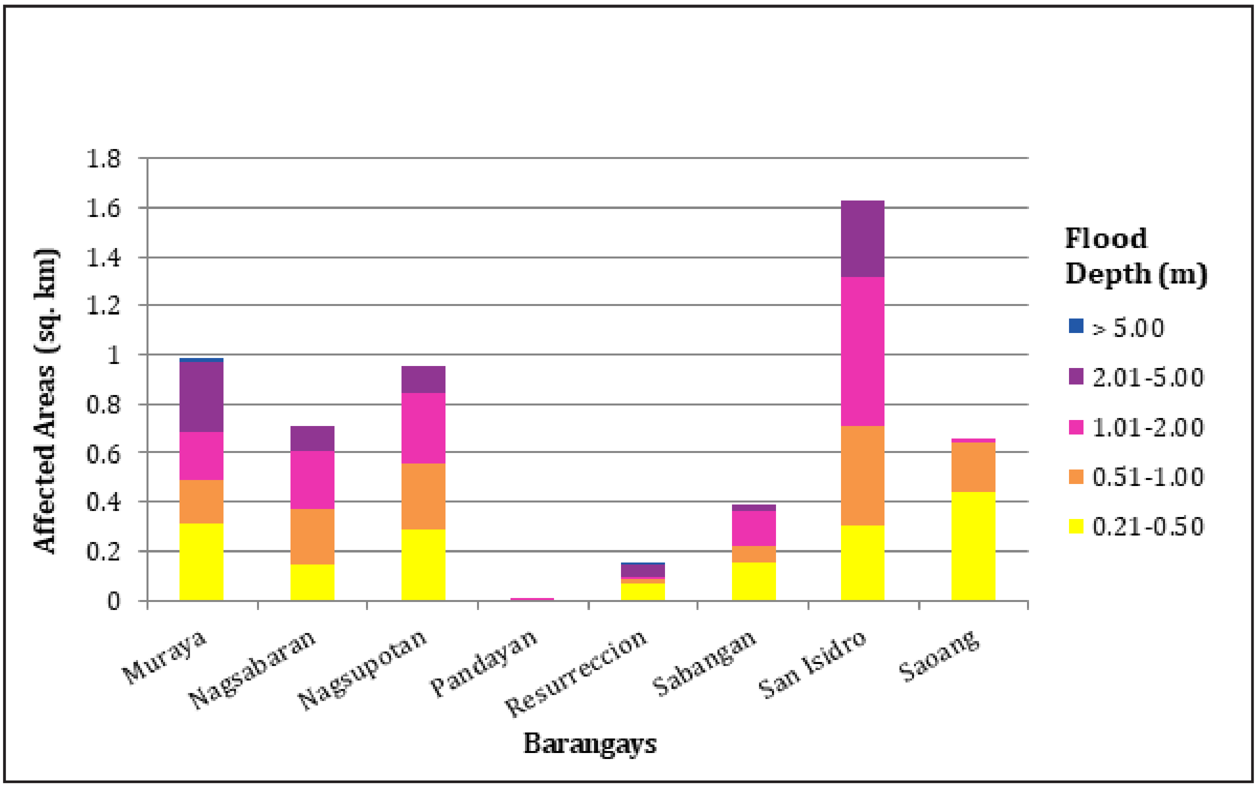


Figure 156. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 15.37% of the municipality of San Vicente with an area of 12.2 sq. km. will experience flood levels of less than 0.20 meters. 11.97% of the area will experience flood levels of 0.21 to 0.50 meters while 16.83%, 38.63%, 20.14%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 82 are the affected areas in San Vicente in square kilometers by flood depth per barangay.

Table 82. Affected Areas in San Vicente, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in San Vicente (in sq.km)						
	Bantaoay	Bayubay Norte	Bayubay Sur	Lubong	Poblacion	Pudoc	San Sebastian
0-0.20	0	0	0	0	0	0	0
0.21-0.50	0.0025	0.16	0.17	0.17	0.15	0.073	0.74
0.51-1.00	0.021	0.13	0.17	0.28	0.19	0.35	0.91
1.01-2.00	0.4	0.13	0.086	0.25	0.14	2.12	1.58
2.01-5.00	0.56	0	0.05	0.019	0.0032	0.92	0.9
> 5.00	0	0	0.00074	0	0	0	0.0007

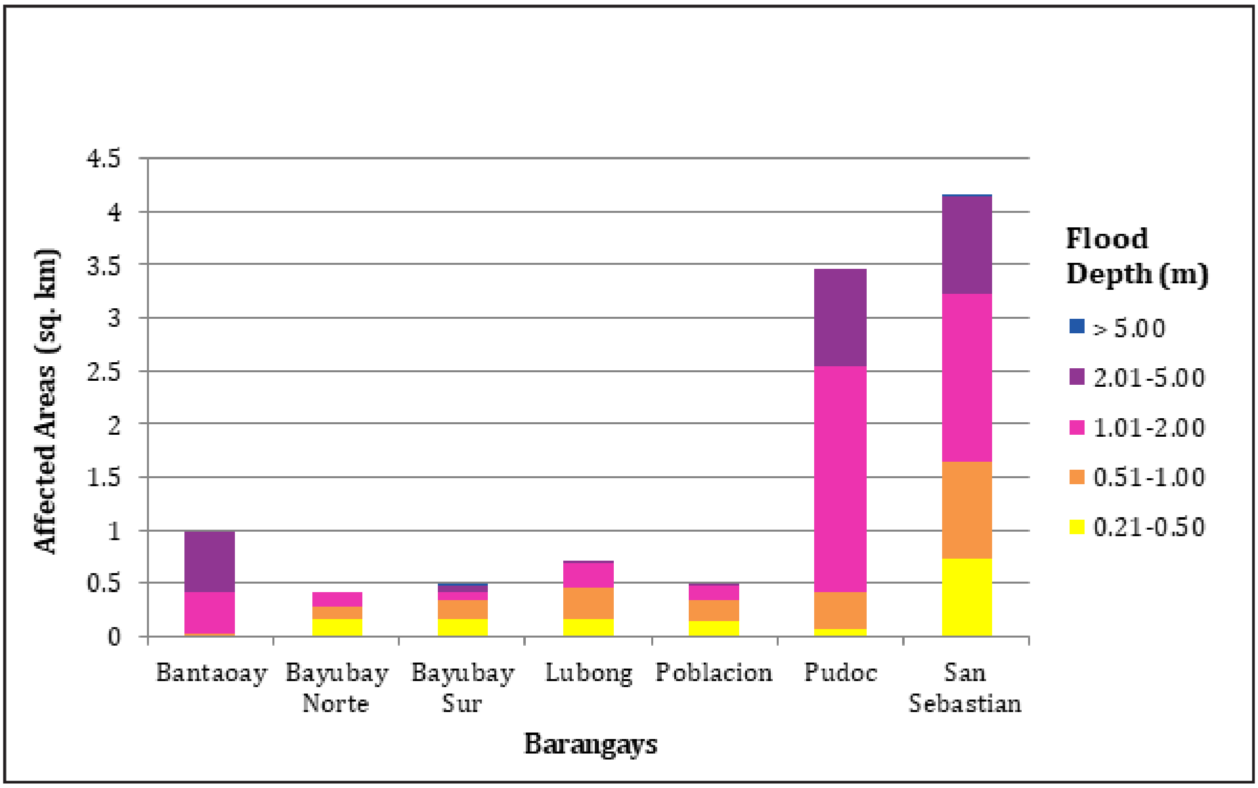


Figure 157. Affected Areas in San Vicente, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 28.98% of the municipality of Santa with an area of 57.2 sq. km. will experience flood levels of less than 0.20 meters. 3.93% of the area will experience flood levels of 0.21 to 0.50 meters while 4.14%, 5.73%, 10.53%, and 10.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 83 are the affected areas in Santa in square kilometers by flood depth per barangay.

Table 83. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa (in sq.km)										
	Ampandula	Banaoang	Basug	Bucalag	Cabangaran	Calungboyan	Dammay	Labut Norte	Labut Sur	Mabilbila Norte	Mabilbila Sur
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.047	0.032	0.049	0.054	0.051	0.083	1.13	0.023	0.049	0.0053	0.018
0.51-1.00	0.017	0.02	0.02	0.15	0.016	0.2	1.1	0.017	0.026	0.0021	0.014
1.01-2.00	0.0047	0.011	0.0064	0.031	0.0059	0.07	2.26	0.011	0.031	0.0002	0.01
2.01-5.00	0.0002	0.041	0	0.0042	0.0004	0	3.59	0.0027	0.012	0	0.0017
> 5.00	0	0.9	0	0	0	0	1.7	0	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Santa (in sq.km)**										
	Manueva	**Marcos**	**Nagpanaoan**	**Namalangan**	**Oribi**	**Pasungol**	**Quirino**	**Rizal**	**Sacuyya Norte**	**Sacuyya Sur**	**Tabucolan**
0-0.20	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.015	0.0016	0.057	0.036	0.013	0.073	0.27	0.066	0.051	0.063	0.062
0.51-1.00	0.01	0.0012	0.12	0.025	0.0044	0.058	0.27	0.035	0.021	0.027	0.21
1.01-2.00	0.0086	0.0003	0.39	0.018	0.016	0.028	0.17	0.016	0.0019	0.011	0.17
2.01-5.00	0.00074	0	2.32	0.011	0.00036	0	0.023	0.013	0.0009	0.00099	0.0002
> 5.00	0	0	3.08	0.12	0	0	0	0.024	0	0	0

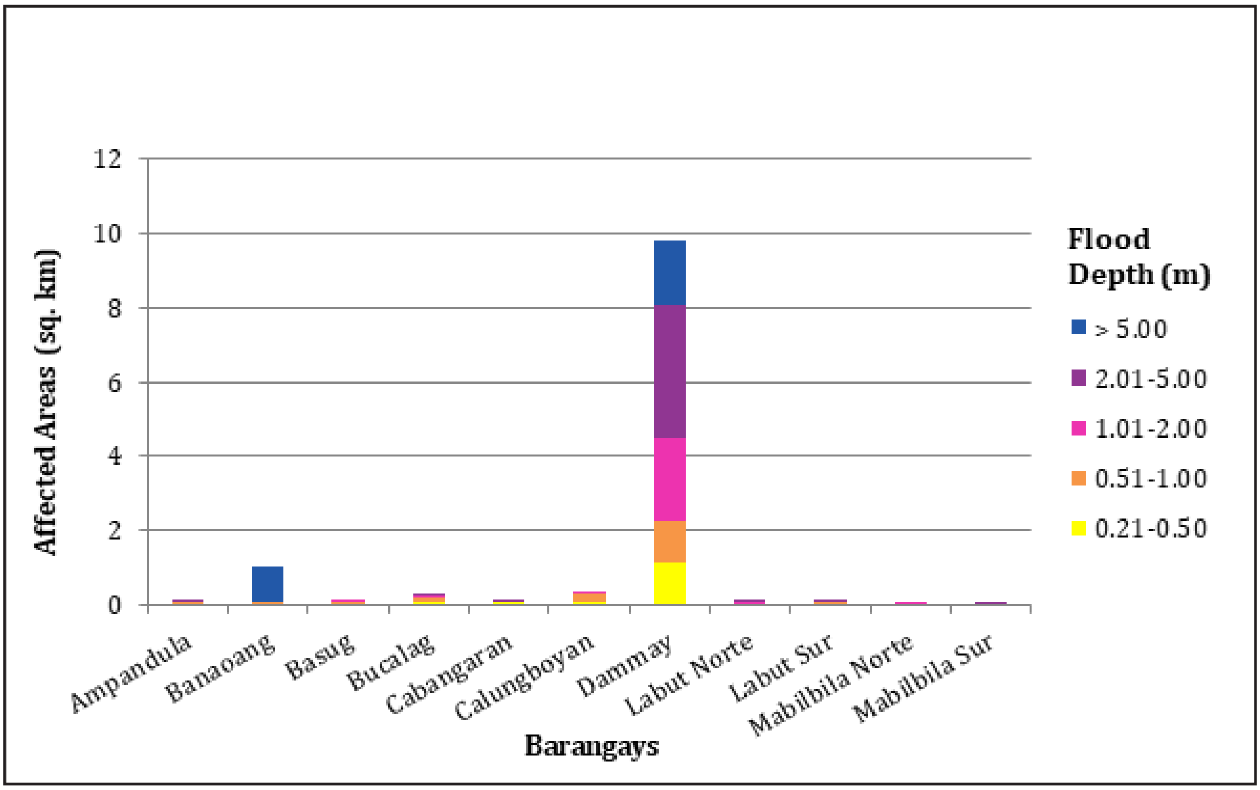


Figure 158. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period.

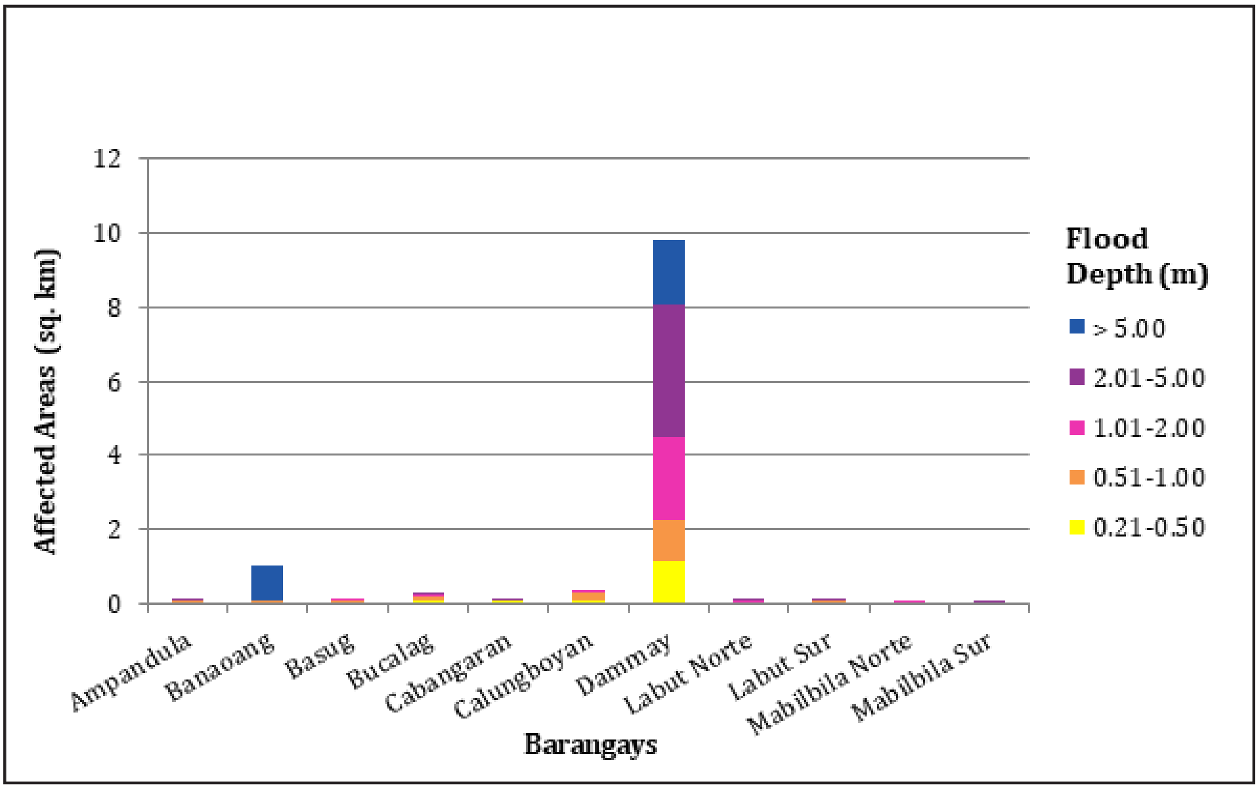


Figure 159. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 20.86% of the municipality of Santa Catalina with an area of 10.83 sq. km. will experience flood levels of less than 0.20 meters. 17.78% of the area will experience flood levels of 0.21 to 0.50 meters while 16.13%, 13.42%, and 6.46% 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 84 are the affected areas in Santa Catalina in square kilometers by flood depth per barangay.

Table 84. Affected Areas in Santa Catalina, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santa Catalina (in sq.km)							
	Cabaroan	Cabittaogan	Cabuloan	Pangada	Poblacion	Sinabaan	Subec	Tamorong
0-0.20	0	0	0	0	0	0	0	0
0.21-0.50	0.21	0.4	0.19	0.05	0.088	0.51	0.11	0.36
0.51-1.00	0.1	0.57	0.14	0.067	0.03	0.14	0.021	0.68
1.01-2.00	0.026	0.63	0.097	0.17	0.028	0.055	0.014	0.44
2.01-5.00	0.036	0.33	0.092	0.16	0.018	0.0003	0	0.061
> 5.00	0	0	0	0	0	0	0	0

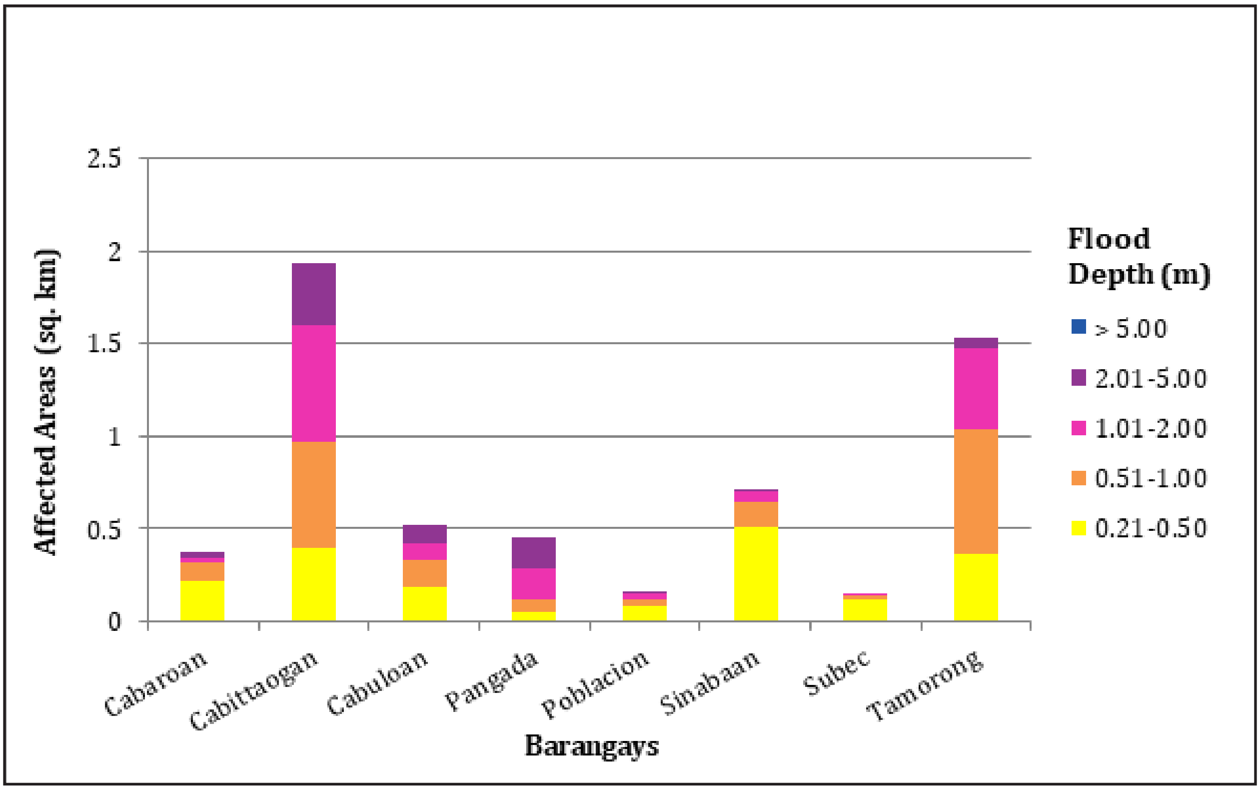


Figure 160. Affected Areas in Santa Catalina, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 44.52% of the municipality of Santo Domingo with an area of 50.36 sq. km. will experience flood levels of less than 0.20 meters. 13.54% of the area will experience flood levels of 0.21 to 0.50 meters while 17.32%, 18.08%, 6.79%, and 0.10% 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 85 are the affected areas in Santo Domingo in square kilometers by flood depth per barangay.

Table 85. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Santo Domingo (in sq.km)											
	Binalayangan	Binongan	Borobor	Cabaritan	Cabigbigaan	Calautit	Calay-Ab	Camestizoan	Casili	Flora	Lagatit	Laoingen
0.03-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.22	0.45	0.37	0.14	0.085	0.23	0.16	0.024	0.12	0.21	0.38	0.61
0.51-1.00	0.18	0.42	0.6	0.32	0.13	0.19	0.16	0.0072	0.12	0.37	0.17	0.5
1.01-2.00	0.0055	0.11	0.27	0.63	0.013	0.13	0.12	0.3	0.055	0.18	0.14	0.43
2.01-5.00	0	0.0056	0.066	0.35	0	0.086	0.15	0.4	0.015	0	0.1	0.22
> 5.00	0	0	0.0017	0.000002	0	0.012	0	0.021	0	0	0.0019	0.0021
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Santo Domingo (in sq.km)**											
	Lussoc	Nagbettedan	Naglaoa-An	Nalasin	Nambaran	Nanerman	Napo	Padu Chico	Padu Grande	Paguraper	Panay	Pangpangdan
0-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.23	0.27	0.29	0.028	0.11	0.04	0.13	0.14	0.098	0.32	0.1	0.14
0.51-1.00	0.2	0.12	0.47	0.029	0.26	0.026	0.3	0.18	0.11	0.25	0.14	0.18
1.01-2.00	0.14	0.053	0.74	0.097	0.78	0.062	0.011	0.22	0.083	0.11	0.0031	0.082
2.01-5.00	0.059	0.052	0.16	0.15	0.23	0.056	0.00086	0.0005	0.0003	0.0014	0	0.0094
> 5.00	0.0035	0	0.01	0	0	0	0	0	0	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of Affected Barangays in Santo Domingo (in sq.km)**											
	Parada	Paras	Poblacion	Puerta Real	Pussuac	Quimmarayan	San Pablo	Santa Cruz	Santo Tomas	Sived	Suksukit	Vacunero
0-0.20	0	0	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.35	0.17	0.12	0.17	0.15	0.18	0.033	0.32	0.2	0.13	0.079	0.0035
0.51-1.00	0.56	0.7	0.13	0.095	0.19	0.27	0.16	0.64	0.34	0.17	0.038	0.018
1.01-2.00	0.75	0.1	0.19	0.26	0.45	0.23	0.53	1.01	0.076	0.15	0.066	0.51
2.01-5.00	0.0096	0.0025	0.051	0.071	0.25	0.21	0.34	0.085	0.014	0.17	0.087	0.021
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

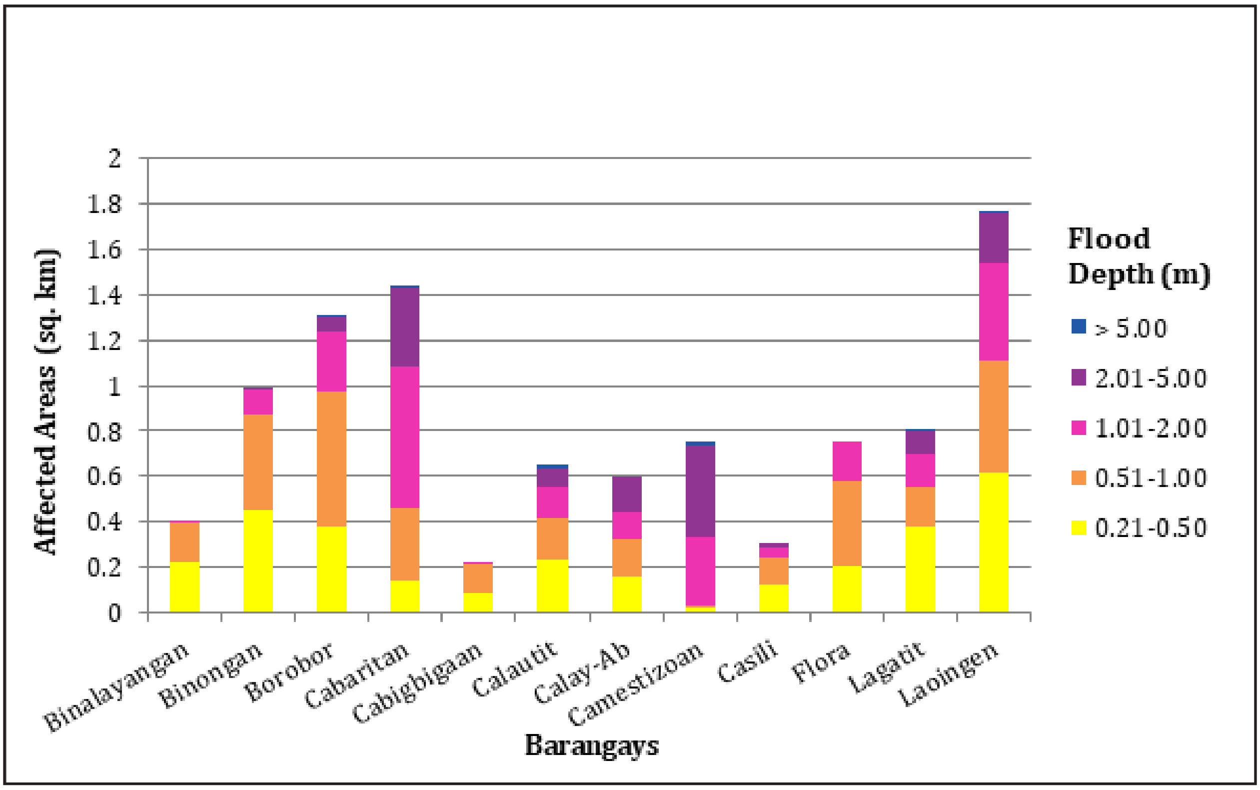


Figure 161. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

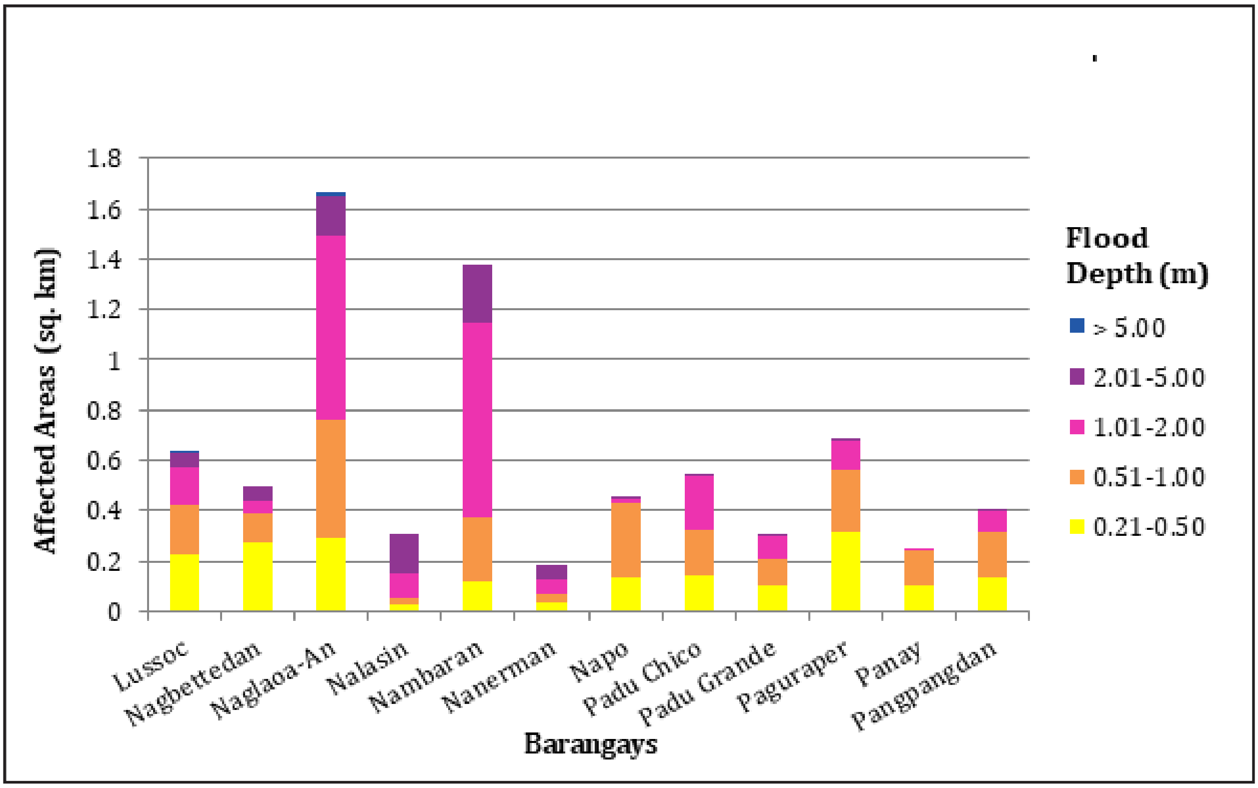


Figure 162. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

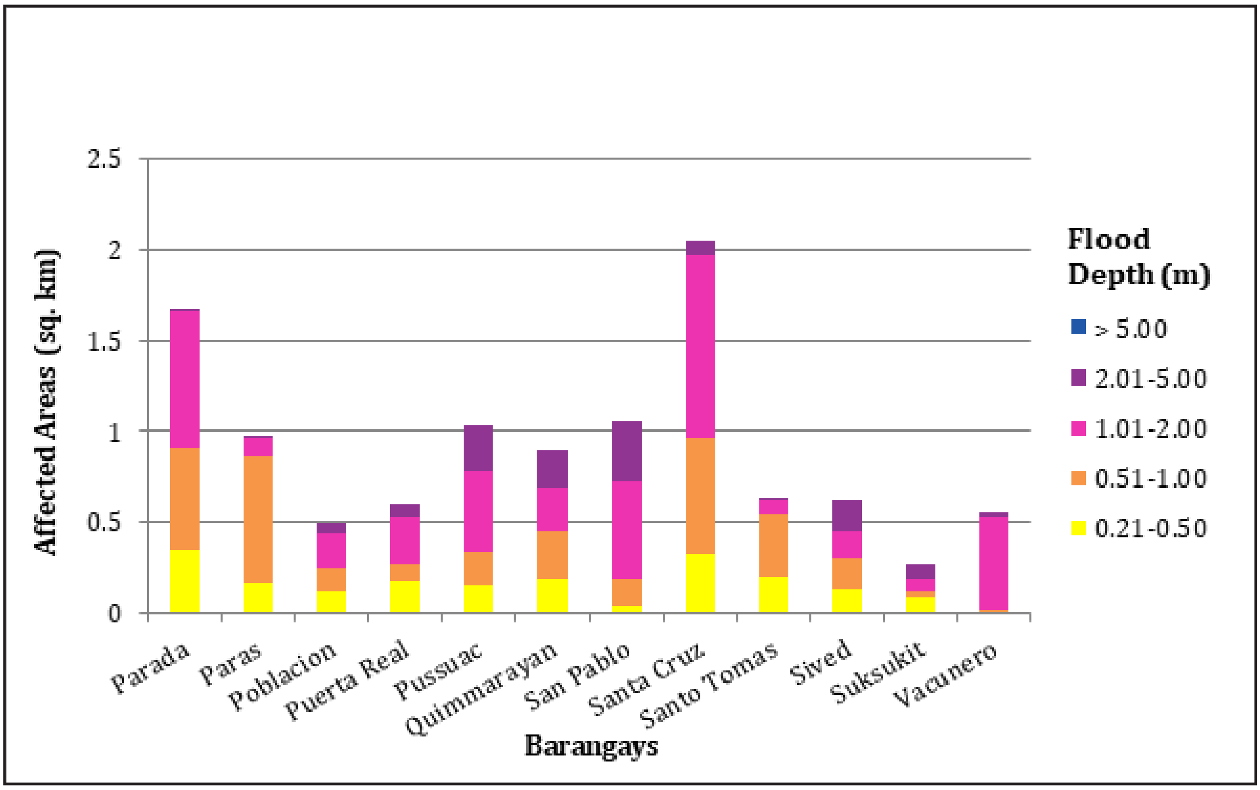


Figure 163. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

For the 100-year return period, 12.79% of the municipality of Vigan City with an area of 24.01 sq. km. will experience flood levels of less than 0.20 meters. 4.50% of the area will experience flood levels of 0.21 to 0.50 meters while 6.31%, 11.93%, 37.06%, and 25.52% 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 86 are the affected areas in Vigan City in square kilometers by flood depth per barangay.

Table 86. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Ayusan Norte	Ayusan Sur	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay IX	Barangay V	Barangay VI	Barangay VII
0.03-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0.14	0.13	0	0	0	0	0	0	0	0
0.51-1.00	0.091	0.073	0	0	0	0	0	0	0	0
1.01-2.00	0.19	0.03	0	0	0	0	0	0	0	0
2.01-5.00	0.14	0.011	0	0	0	0	0	0	0	0
> 5.00	0.097	0.00051	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Barangay VIII	Barraca	Beddeng Daya	Beddeng Laud	Bongtolan	Bulala	Cabalangegan	Cabaroan Daya	Cabaroan Laud	Camangaan
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0	0	0	0	0.099	0	0	0	0
0.51-1.00	0	0	0	0	0	0.036	0	0	0	0
1.01-2.00	0	0.1	0	0	0	0.021	0	0	0	0
2.01-5.00	0	0.23	0.2	0.42	0.18	0.00073	0.32	0.44	0.25	0.1
> 5.00	0	0	0.019	0.0051	0.039	0	0.0078	0.23	0.11	0.2

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)									
	Capangpangan	Mindoro	Nagsan-galan	Pantay Daya	Pantay Fatima	Pantay Laud	Paoa	Paratong	Pong-Ol	Purok-A-Bassit
0-0.20	0	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0.14	0	0.07	0.087	0.15	0.099	0.027	0.0042	0
0.51-1.00	0	0.22	0	0.23	0.19	0.35	0.059	0.01	0.008	0
1.01-2.00	0	0.27	0	0.48	0.3	0.55	0.037	0.14	0.065	0
2.01-5.00	0.47	0.026	0.72	0.5	0.27	0.29	0.069	0.057	0.17	0.34
> 5.00	0.077	0	0.2	0.049	0	0	0.012	0	0	0.052

Affected area (sq. km.) by flood depth (in m.)	Area of Affected Barangays in Vigan City (in sq.km)								
	Purok-A-Dackel	Raois	Rugsuanan	Salindeg	San Jose	San Julian Norte	San Julian Sur	San Pedro	Tamag
0.03-0.20	0	0	0	0	0	0	0	0	0
0.21-0.50	0	0.0009	0	0.016	0	0	0	0.059	0.044
0.51-1.00	0	0.015	0	0.014	0	0	0	0.15	0.025
1.01-2.00	0	0.037	0	0.013	0	0	0	0.48	0.026
2.01-5.00	0.23	0.16	0.21	0.42	0.25	0.41	0.24	0.51	0.42
> 5.00	0.093	2.41	1.21	0.15	0.068	0.026	0.069	0	0.27

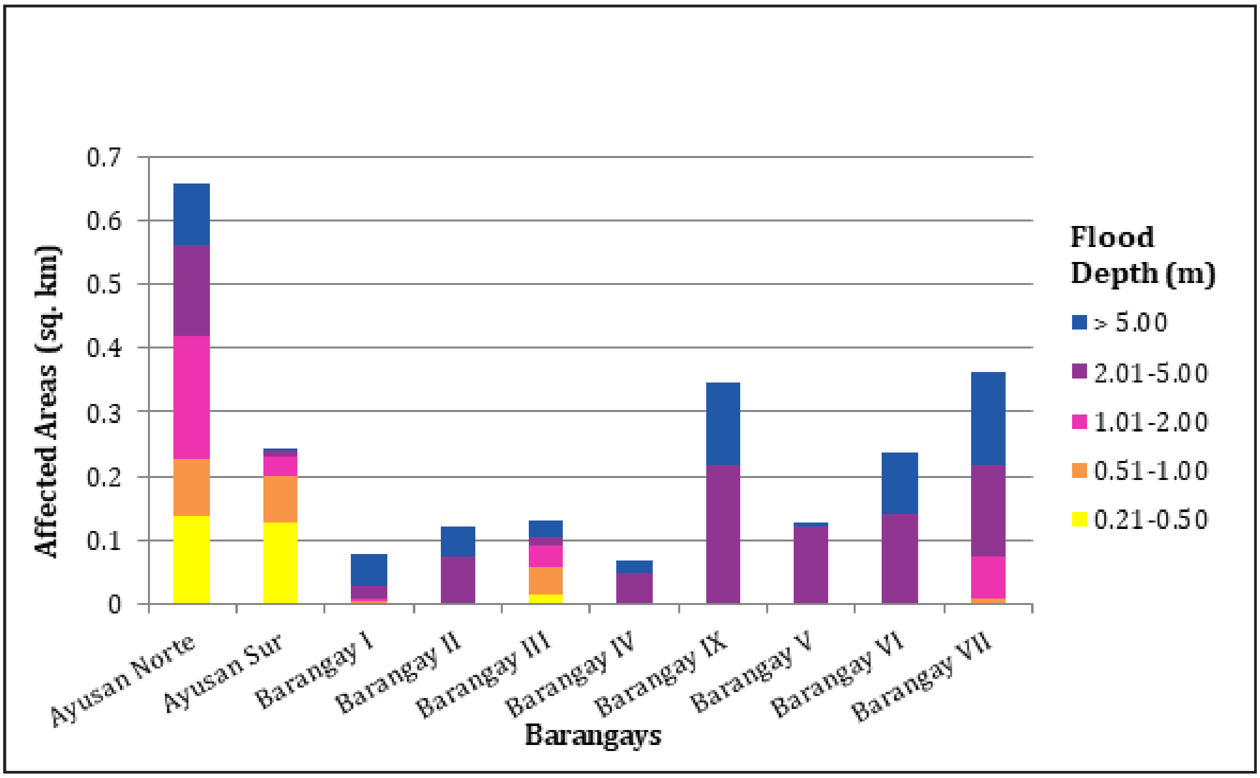


Figure 164. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

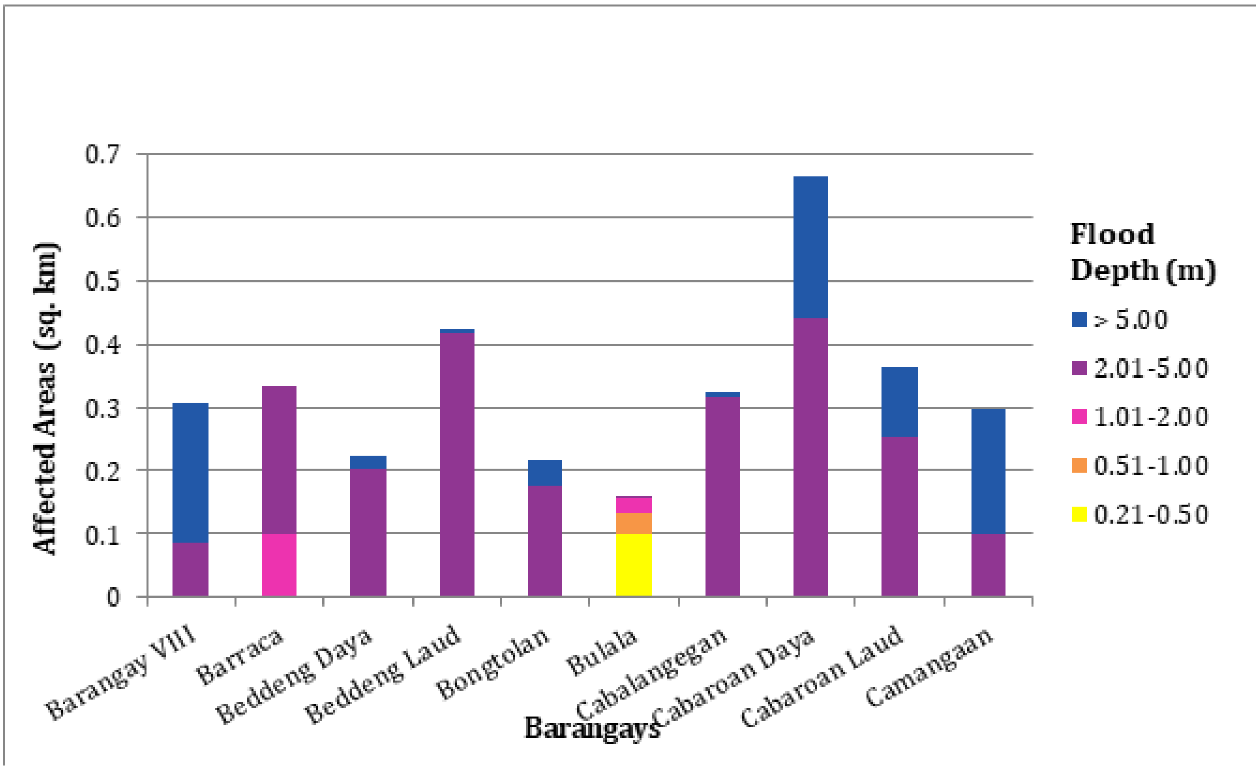


Figure 165. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

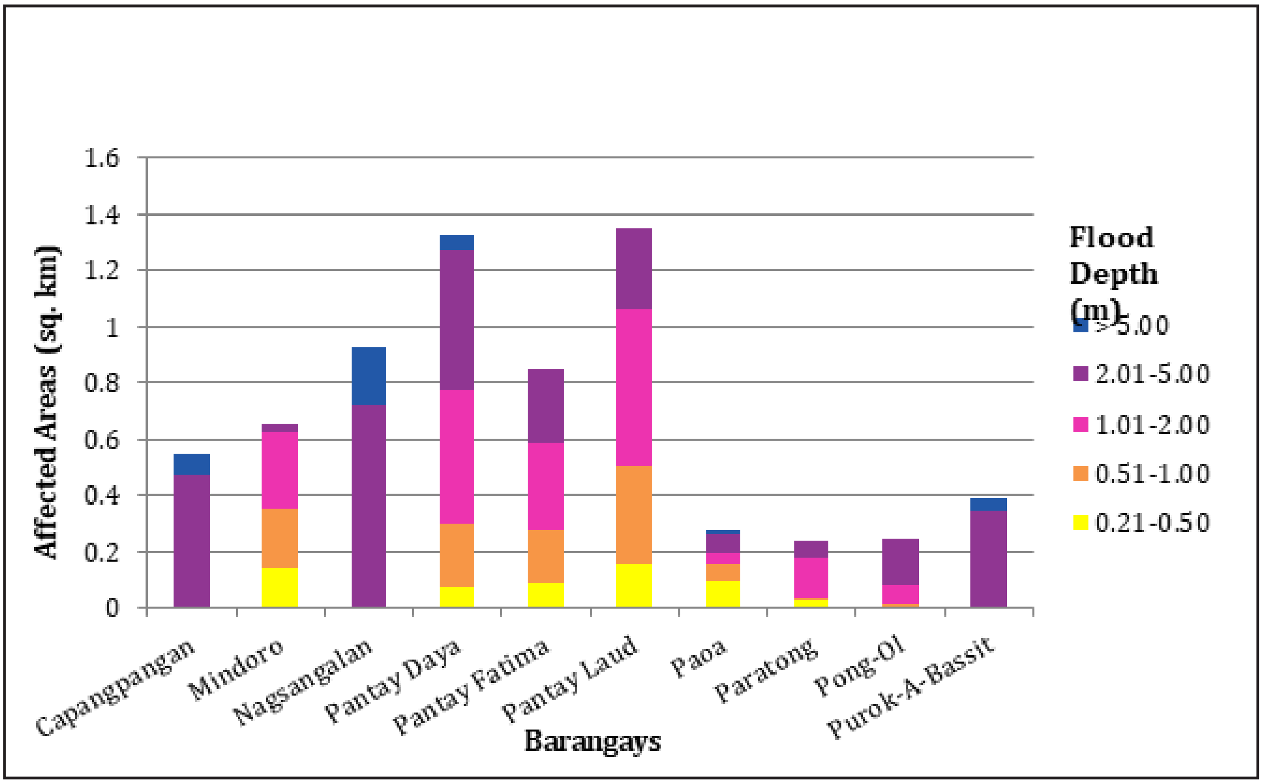


Figure 166. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

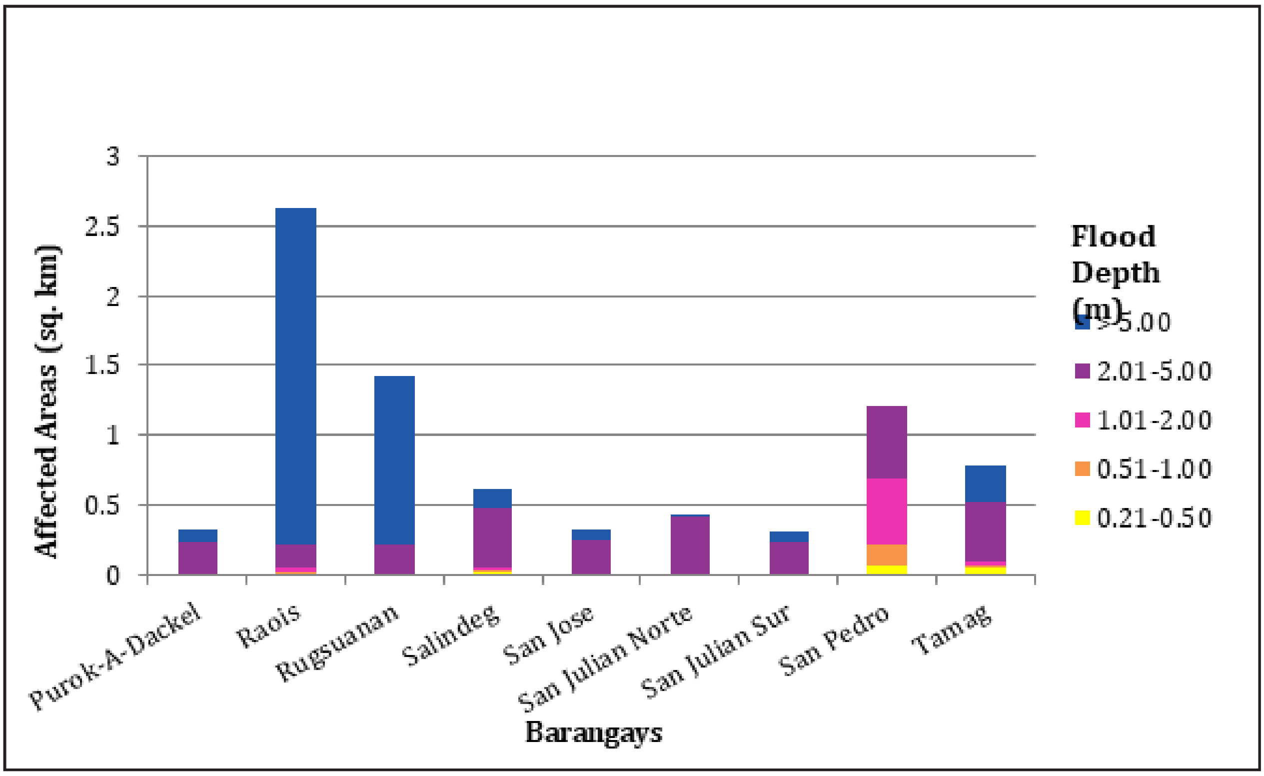


Figure 167. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Bangued in Abra, San Antonio is projected to have the highest percentage of area that will experience flood levels at 4.88%. Meanwhile, Santa Rosa posted the second highest percentage of area that may be affected by flood depths at 3.68%.

Among the barangays in the municipality of Langiden in Abra, Malapaao is projected to have the highest percentage of area that will experience flood levels at 44.91%. Meanwhile, Mabungtot posted the second highest percentage of area that may be affected by flood depths at 32.41%.

Among the barangays in the municipality of Pidigan in Abra, Yuyeng is projected to have the highest percentage of area that will experience flood levels at 13.03%. Meanwhile, Sulbec posted the second highest percentage of area that may be affected by flood depths at 11.00%.

Among the barangays in the municipality of San Quintin in Abra, Labaan is projected to have the highest percentage of area that will experience flood levels at 23.89%. Meanwhile, Tangadan posted the second highest percentage of area that may be affected by flood depths at 17.20%.

Brgy. Barangobong is the only barangay affected in the municipality of Nueva Era in Ilocos Norte. The barangay is projected to experience flood in 0.57% of the municipality.

Among the barangays in the municipality of Bantay in Ilocos Sur, Lingsat is projected to have the highest percentage of area that will experience flood levels at 23.59%. Meanwhile, Tay-Ac posted the second highest percentage of area that may be affected by flood depths at 9.55%.

Among the barangays in the municipality of Caoayan in Ilocos Sur, Pantay Tamurong is projected to have the highest percentage of area that will experience flood levels at 27.52%. Meanwhile, Naguilian posted the second highest percentage of area that may be affected by flood depths at 20.67%.

Among the barangays in the municipality of Magsingal in Ilocos Sur, Maratudo is projected to have the highest percentage of area that will experience flood levels at 19.72%. Meanwhile, Patong posted the second highest percentage of area that may be affected by flood depths at 9.03%.

Among the barangays in the municipality of Narvacan in Ilocos Sur, Ambulogan is projected to have the highest percentage of area that will experience flood levels at 0.17%. Meanwhile, Lanipao posted the second highest percentage of area that may be affected by flood depths at 0.15%.

Among the barangays in the municipality of San Ildefonso in Ilocos Sur, Belen is projected to have the highest percentage of area that will experience flood levels at 11.63%. Meanwhile, Bahet posted the second highest percentage of area that may be affected by flood depths at 9.14%.

Among the barangays in the municipality of San Juan in Ilocos Sur, Barbar is projected to have the highest percentage of area that will experience flood levels at 20.45%. Meanwhile, Malamin posted the second highest percentage of area that may be affected by flood depths at 7.76%.

Among the barangays in the municipality of San Vicente in Ilocos Sur, San Sebastian is projected to have the highest percentage of area that will experience flood levels at 45.67%. Meanwhile, Pudoc posted the second highest percentage of area that may be affected by flood depths at 28.87%.

Among the barangays in the municipality of Santa in Ilocos Sur, Dammay is projected to have the highest percentage of area that will experience flood levels at 24.32%. Meanwhile, Nagpanaoan posted the second highest percentage of area that may be affected by flood depths at 10.55%.

Among the barangays in the municipality of Santa Catalina in Ilocos Sur, Cabittaogan is projected to have the highest percentage of area that will experience flood levels at 22.77%. Meanwhile, Tamorong posted the second highest percentage of area that may be affected by flood depths at 17.39%.

Among the barangays in the municipality of Santo Domingo in Ilocos Sur, Laoingen is projected to have the highest percentage of area that will experience flood levels at 15.05%. Meanwhile, Lagatit posted the second highest percentage of area that may be affected by flood depths at 8.83%.

Among the barangays in the municipality of Vigan City in Ilocos Sur, Raois is projected to have the highest percentage of area that will experience flood levels at 10.94%. Meanwhile, Pantay Laud posted the second highest percentage of area that may be affected by flood depths at 6.59%.

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

Table 87. Area covered by each warning level with respect to the rainfall scenarios.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	81.42	79.64	79.16
Medium	102.41	99.92	100.51
High	226.15	288.35	317.94
TOTAL	409.99	467.92	497.61

Of the 131 identified Educational Institutions in Abra flood plain, 16 schools were assessed to be exposed to the High level flooding for all three rainfall scenarios. 14 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 for a detailed enumeration of schools in the Abra floodplain.

Of the 30 identified Medical Institutions in Abra flood plain, Northeast Care Center in Brgy. Sinabaan was found to be highly prone to flooding, having High level flooding in all three rainfall scenarios. See Annex 13 for a detailed enumeration of hospitals and clinics in the Abra floodplain.

5.11 Flood Validation

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

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

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

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 the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 168.

The flood validation survey was conducted in January 2017. The flood validation consists of 292 points randomly selected all over the Abra flood plain. Comparing it with the flood depth of the nearest storm event, the map has an RMSE value of 1.18m. The validation points are found in Annex 11.

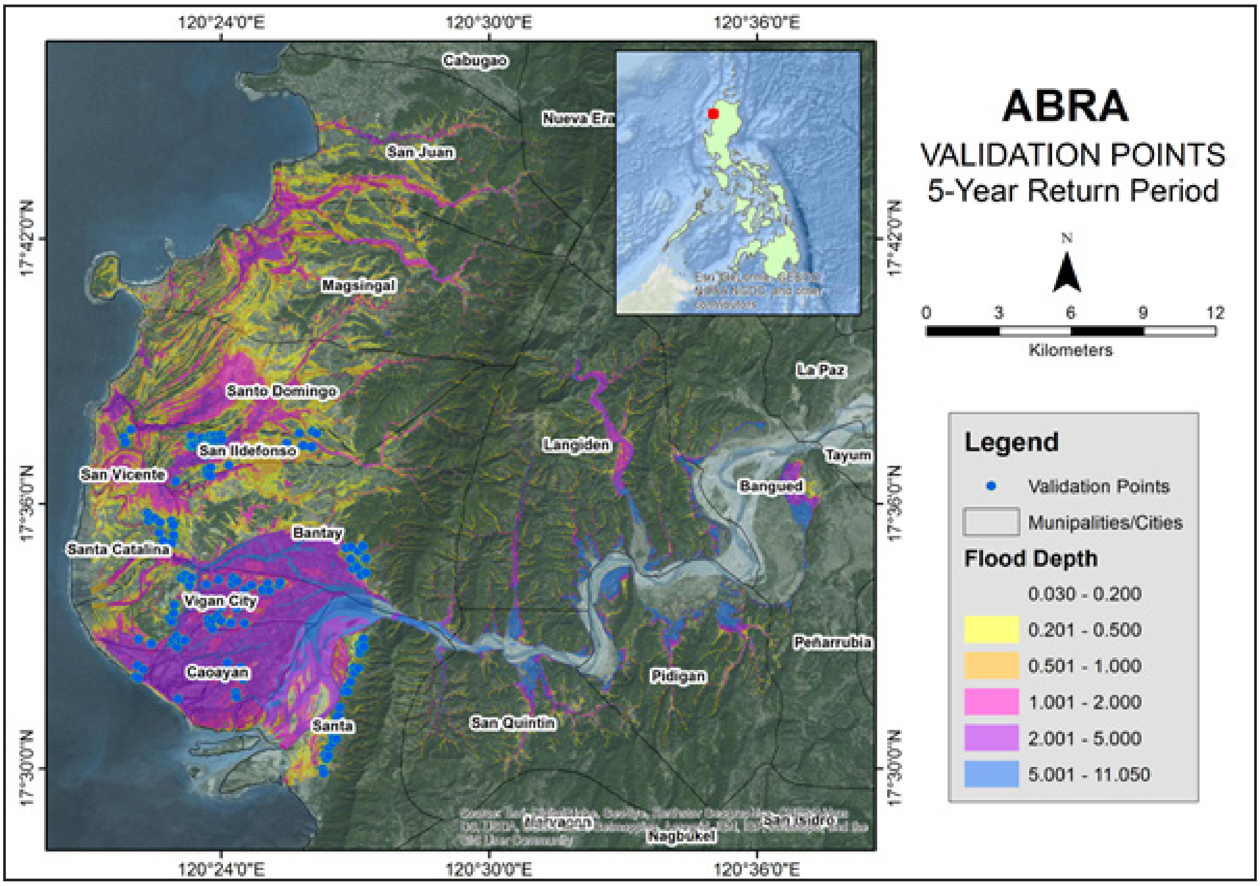


Figure 168. Validation Points for a 5-year Flood Depth Map of the Abra Floodplain.

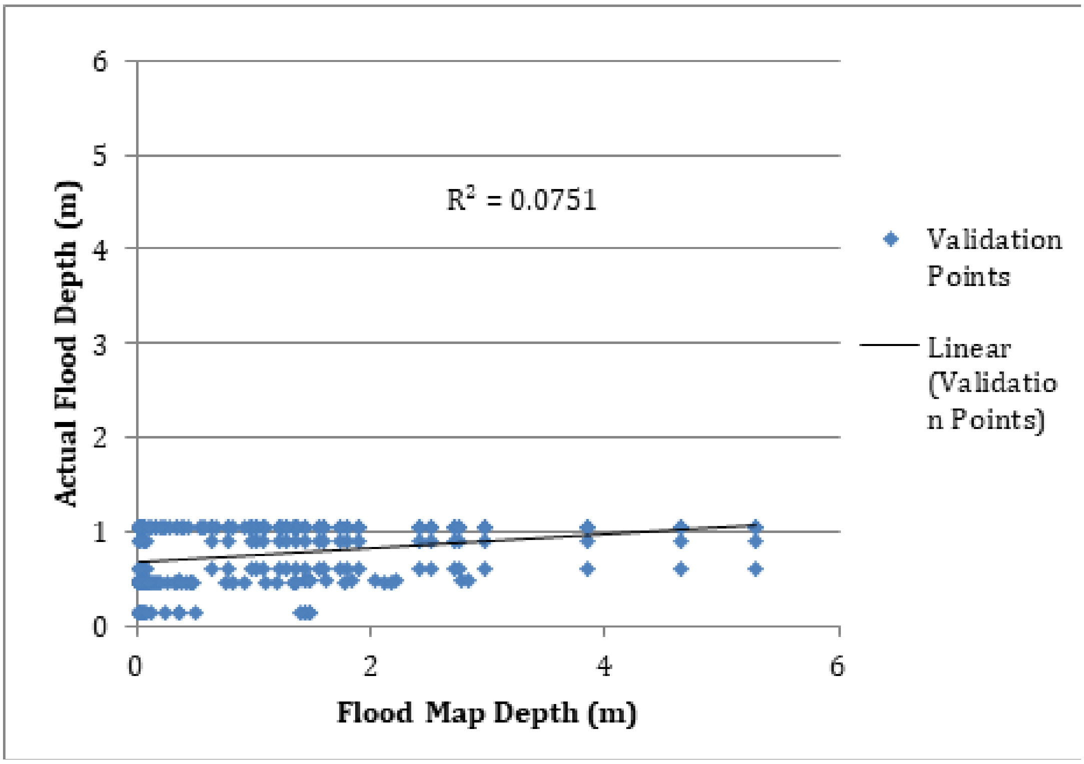


Figure 169. Flood depth map vs actual flood depth.

Table 88. Actual Flood Depth versus Simulated Flood Depth at different levels in the Abra River Basin.

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	17	3	1	6	0	0	27
0.21-0.50	49	10	3	12	6	0	80
0.51-1.00	13	0	6	22	14	2	57
1.01-2.00	38	8	18	40	21	3	128
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	117	21	28	80	41	5	292

On the whole, the overall accuracy generated by the flood model is estimated at 25.00%, with 73 points correctly matching the actual flood depths. In addition, there were 116 points estimated one level above and below the correct flood depths while there were 51 points and 52 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 93 points were overestimated while a total of 126 points were underestimated in the modelled flood depths of Abra. Table 89 depicts the summary of the Accuracy Assessment in the Abra River Basin Flood Depth Map.

Table 89. Summary of the Accuracy Assessment in the Abra River Basin Survey.

	No. of Points	%
Correct	9	6.67
Overestimated	37	27.41
Underestimated	89	65.93
Total	135	100

REFERENCES

Ang M.C., 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

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.C., Lagmay, A.F., 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.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition 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. Technical Specifications of the LIDAR Sensors used in the Abra Floodplain Survey

1. GEMINI SENSOR

Figure A-1.1. Gemini Sensor

Table A-1.1. Parameters and Specifications of Gemini Sensor

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

ANNEX 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

1. 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 ISO 9001:2008
CIP/4701/12/09/814

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

Figure A-2.1. ABR-31

2. 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**		Barangay: **SUYO (MALIDONG)**
Municipality: **PIDIGAN**		
	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

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CIP/4701/12/09/614

Figure A-2.2. ABR-32

3. 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**

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Director, Mapping And Geodesy Branch

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Figure A-2.3. ILS-9

4. 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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4/01/13/09/814

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Figure A-2.4. ILS-13

5. 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**

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CIP/4701/12/09/814

Figure A-2.5. ILS-22

6. ABR-3221

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

March 25, 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-3221 (BLLM-2)**
Order: **4th**

Island: **LUZON**
Municipality: **BANGUED (CAPITAL)**
Barangay: **ZONE 5 POB. (BO. BARIKIR)**

PRS92 Coordinates

Latitude:	**17° 35' 52.68407"**	Longitude:	**120° 36' 58.62346"**	Ellipsoidal Hgt:	**56.36500 m.**

WGS84 Coordinates

Latitude:	**17° 35' 46.56370"**	Longitude:	**120° 37' 3.26652"**	Ellipsoidal Hgt:	**89.89000 m.**

PTM Coordinates

Northing:	**1946312.003 m.**	Easting:	**459272.709 m.**	Zone:	**3**

UTM Coordinates

Northing:	**1,947,181.20**	Easting:	**247,024.30**	Zone:	**51**

Location Description

ABR-3221

BLLM No. 2 is located at the town Plaza of Bangued approximately 30m. East from Abra Valley College and 25m North from Bangued Church. Station is marked by a metal bolt on the center of concrete monument 40 x 40 x 100cm., Set 80cm., below the ground 20cm. above the ground, with inscriptions BANGUED, ABRA, BLLM NO.2, CAD-536-D, DENR, 2010.

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795829 A**
T.N.: **2014-652**

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

9903252014114526

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. ABR-3221

ANNEX 3. Baseline Processing Reports of Control Points used in the LIDAR Survey

1. ABR-3071

Table A-3.1. ABR-3071

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

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

ANNEX 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		ENGR. LOUIE BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	
FIELD TEAM			
Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA	UP-TCAGP
	Senior Science Research Specialist (SSRS) 2016/ RA (2014)	PEARL MARS	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
	RA	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	REGINA AEDRIANNE FELISMINO	UP-TCAGP
Ground Survey / Data Download and Transfer	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	ENGR. KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG RANDY SISON	PHILIPPINE AIR FORCE (PAF)
		SSG.DIOSCORO SOBERANO	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CEASAR ALFONSO III	AAC
		CAPT. MARK TANGONAN	AAC
		CAPT. JEROME MOONEY	AAC

ANNEX 5. Data Transfer Sheet for Abra Floodplain

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	2BLK06EO62A & 2BLK06AO62A	GEMINI	NA	58.1KB	429KB	206MB	NA	NA	19.3GB	NA	12.3MB	1KB	1KB	6/174/10/5/36KB	8KB	Z:\Airborne_Raw\7104GC
Mar 3, 2014	7105GC	2BLK06ASO62B & 2BLK06CO62B	GEMINI	NA	302KB	493KB	254MB	NA	NA	23.3GB	NA	12.6MB	1KB	1KB	6/206/6/206/67KB	11KB	Z:\Airborne_Raw\7105GC
Mar 4, 2014	7107GC	2BLK07CO63B	GEMINI	NA	59.1KB	306KB	187MB	NA	NA	15GB	NA	3.84MB	1KB	1KB	132KB	192KB	Z:\Airborne_Raw\7107GC
Mar 5, 2014	7108GC	2BLK07CO63B	GEMINI	NA	106KB	636KB	268MB	NA	NA	29.2GB	NA	11MB	1KB	1KB	266KB	10/10KB	Z:\Airborne_Raw\7108GC
Mar 7, 2014	7112GC	2BLK06GO66A & 2BLK06DSO66A	GEMINI	NA	286KB	451KB	247MB	NA	NA	18.5GB	NA	11.4MB	1KB	1KB	197/64KB	17KB	Z:\Airborne_Raw\7112GC
Mar 8, 2014	7114GC	2BLK07CSO67A & 2BLK06GO67A	GEMINI	NA	68.4KB	436KB	264MB	NA	NA	19.3GB	NA	8.45MB	1KB	1KB	7/5/304KB	7/5KB	Z:\Airborne_Raw\7114GC
Mar 9, 2014	7116GC	2BLK07BO68A	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	2BLK07DO69A & 2BLK07GO69A	GEMINI	NA	332KB	483KB	259MB	NA	NA	18.7GB	NA	14.5MB	1KB	1KB	6/226/346/10/5/226KB	10KB	Z:\Airborne_Raw\7118GC
MAR 10\	7119GC	2BLK27AO69B	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	2BLK06FO70A & 2BLK07AO70A	GEMINI	NA	67.4KB	506KB	251MB	NA	NA	16GB	NA	11.2MB	1KB	1KB	10/26/219KB	16KB	Z:\Airborne_Raw\7120GC
Mar 11, 2014	7121GC	2BLK07GSO70B & 2BLK07ASO70B	GEMINI	NA	216KB	319KB	217MB	NA	NA	12.7GB	NA	10.6MB	1KB	1KB	146/6KB	10KB	Z:\Airborne_Raw\7121GC
Mar 12, 2014	7122GC	2BLK07EO71A & 2BLK07FO71A	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 JOAQUIN

Position RA

Signature 04/21/14

Received by

Name JOIDA F PRIETO

Position SSRS

Signature 4/22/14

Figure A-5.1. Transfer Sheet for Abra Floodplain - A

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	14.6	NA	334	1KB	NA	6	17	Z:\DAC\RAW DATA

Received from

Name: R. PUNTO
Position: RA
Signature:

Received by

Name: AC Bongat
Position: SSRS
Signature: ACBongat 7/1/16

16-41

Figure A-5.2. Transfer Sheet for Abra Floodplain - B

ANNEX 6. Flight logs for the Flight Missions

1. Flight Log for 7104GC Mission

DREAM Data Acquisition Flight Log — 2BLK06E062A2 — **Flight Log No.:** 7104

1 LIDAR Operator: MVE TONGA	2 ALTM Model: GEMINI	3 Mission Name: 2BLK06A062A	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: 03-03-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 0829H	14 Engine Off: 1158H	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Windy					

20 Remarks:

Mission completed at BLK06B and surveyed 2 lines at BLK06A (without CAL)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	SSg Diosdado Sotelano PAF	R. SAMAR II	MVE T. Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 7104GC

2. Flight Log for 7108GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7108

1 LiDAR Operator: MVE TONGA /	2 ALTM Model: GEM+CAS	3 Mission Name: 2BLK06GC044A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: 03-05-2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0905H	14 Engine Off: 1334H	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Hazy					
20 Remarks: Completed area of BLK06C and surveyed 3 lines of BLK06D (without CA31)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Antony Matias	SSg Dexter Soberano PAF	R. GAMAN II	MVC
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 7108GC

3. Flight Log for 7112GC Mission

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

1 LIDAR Operator: MCE BAUGVAS	2 ALTM Model: LEICA 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 06 G & 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	Sgt Dosbenito Sobrano PAF	R. Samar	CATHERINE BALUYAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 7112GC

4. Flight Log for 7114GC Mission

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

1 LiDAR Operator: MVE TONGA	2 ALTM Model: GEMINI CAS]	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 Dioscoro Soberano PAF		
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 7114GC

5. Flight Log for 7116GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7116

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: GEMINI	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 — SSg [illegible] — Signature over Printed Name (PAF Representative)

Pilot-in-Command — R [illegible] — Signature over Printed Name

Lidar Operator — CATHERINE BALIGUAS — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 7116GC

6. Flight Log for 7118GC Mission

DREAM Data Acquisition Flight Log 2BLK07DG9A **Flight Log No.:** 7118

1 LiDAR Operator: MVE TONGA	2 ALTM Model: GEMINI(CAS)	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9342
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 BLK076 (without CAS)					
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

Figure A-6.6. Flight Log for Mission 7118GC

6. Flight Log for 7120GC Mission

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

1 LIDAR Operator: MCE BALICUAS	2 ALTM Model: GEM+CASI	3 Mission Name: 2BLK06F4 BLK07A 070A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO II	9 Route: Laoag – BLK 06F4 BLK07A – Laoag			
10 Date: 03-11-2014	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 Dioscoro Saturno PAF	R. S.	Catherine Balicuas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 7120GC

7. Flight Log for 7122GC Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 7122

1 LiDAR Operator: M VE Tongco	2 ALTM Model: GEMINI/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: 03-12-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 7:3	14 Engine Off: 11:8	15 Total Engine Time: 4:5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

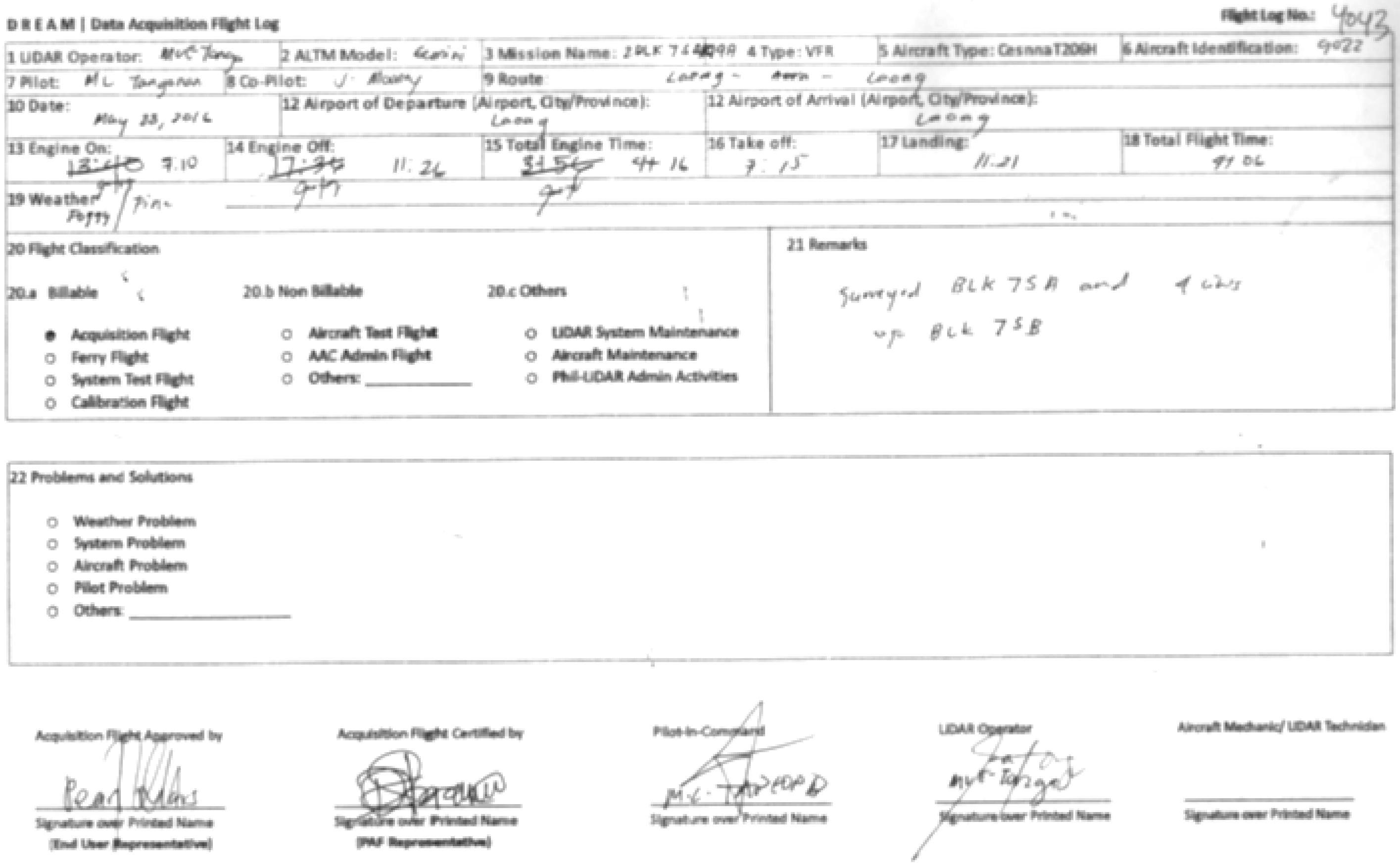
Successful flight; Mission completed (without CASI)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Antonio Matira	SSg Dosato Sobarano PAF	R. Samar II	A. Matira
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.8. Flight Log for Mission 7122GC

8. Flight Log for 4043GC Mission



DREAM | Data Acquisition Flight Log

Flight Log No.: 4043

1 LIDAR Operator: MVC Tongo	2 ALTM Model: Gemini	3 Mission Name: 2BLK 74A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: ML Tangonan	8 Co-Pilot: J. Alamy	9 Route: Laoag - Aero - Laoag			
10 Date: May 23, 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: Foggy / 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: ML Tangonan, Signature over Printed Name

LIDAR Operator: MVC Tongo, Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.9. Flight Log for Mission 4043GC

9. Flight Log for 4045GC Mission

D R E A M | Data Acquisition Flight Log

Flight Log No.: 4046

1 LiDAR Operator: RE Pilapil	2 ALTM Model: Gemini	3 Mission Name: 2BLK7SB/148	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: ML Tangonan	8 Co-Pilot: J. Alviar	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: 17:21	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 BLK7 SB

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

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

Figure A-6.10. Flight Log for Mission 4045GC

ANNEX 7. Flight status reports

Abra and Ilocos Missions
March 3 -13, 2014 and May 2016

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7104GC	BLK06	2BLK06E062A & 2BLK06A062A	MVE TONGA	March 5, 2014	Mission completed at BLK06E and surveyed 2 lines at BLK06A (without CASI)
7108GC	BLK06	2BLK06C064A & 2BLK06D064A	MVE TONGA	March 5, 2014	Completed area of BLK06C and surveyed 3 lines BLK06D (without CASI)
7112GC	BLK06	2BLK06G066A & 2BLK06DS066A	MCE BALIGUAS	March 7, 2014	Surveyed 11 lines at BLK06G and 7 lines at BLK06D (without CASI)
7114GC	BLK07 & BLK06	2BLK07CS067A & 2BLK06G067A	MVE TONGA	March 8, 2014	Completed the rest of blocks 07C & 07B (without CASI)
7116GC	BLK07	2BLK07B068A	MCE BALIGUAS	March 9, 2014	Completed area of BLK07B (without CASI)
7118GC	BLK07	2BLK07D069A & 2BLK07G069A	MVE TONGA	March 10, 2014	Mission completed at BLK07D and surveyed 2 lines of BLK07G (without CASI)
7120GC	BLK06 & BLK07	2BLK06F070A & 2BLK07A070A	MCE BALIGUAS	March 11, 2014	Completed areas of BLK06F and BLK07A (without CASI)
7121GC	BLK07	2BLK07GS070B & 2BLK07AS070B	MVE TONGA	March 11, 2014	Mission completed (without CASI)
7122GC	BLK07	2BLK07E071A & 2BLK07F071A	MVE TONGA	March 12, 2014	Mission completed (without CASI)
4043GC	BLK07	2BLK7SA149A	MVE TONGA	May 28, 2016	Surveyed BLK7SA and 4 lines of BLK 7SB
4045GC	BLK07	2BLK7SB149B	RA FELISMINO	May 28, 2016	Completed BLK7SB

LAS BOUNDARIES PER FLIGHT

Flight No. :	7104 GC		
Area:	BLK06A and BLK06E		
Mission Name:	2BLK06E062A & 2BLK06A062A		
Total Area:			
Altitude:	1200 m / 1000 m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	30 deg / 40 deg	Sidelap:	40% / 30%

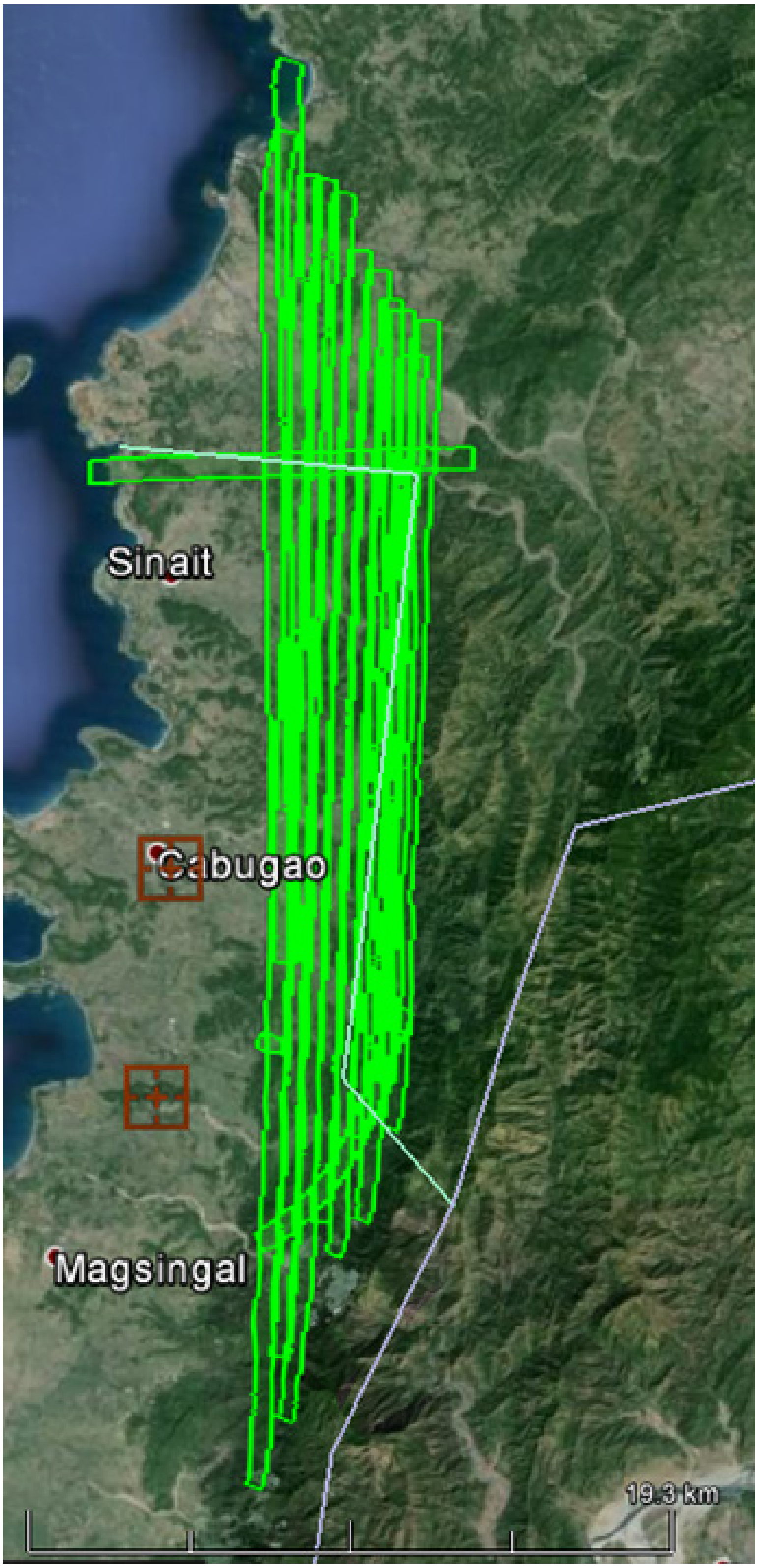


Figure A-7.1. Swath for Flight No. 7104GC

Flight No. :	7108 GC		
Area:	BLK06C and BLK06D		
Mission Name:	2BLK06C064A & 2BLK06D064A		
Total Area:	sq. km.		
Altitude:	1000m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	20 deg	Sidelap:	30%

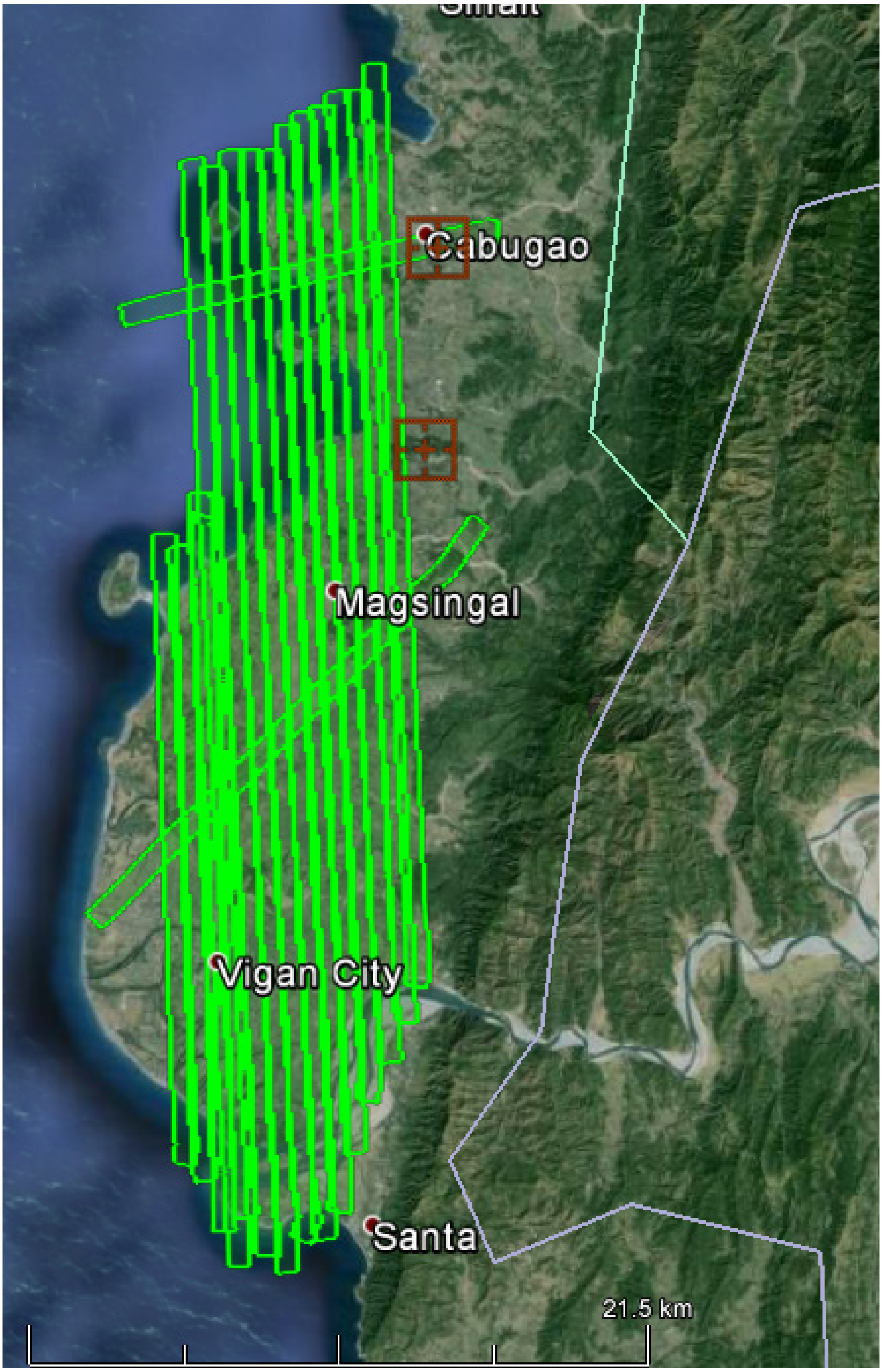


Figure A-7.2. Swath for Flight No. 7108GC

Flight No. :	7112 GC		
Area:	BLK06DS and BLK06G		
Total Area:	160.52 sq km		
Mission Name:	2BLK06G066A & 2BLK6DS066A		
Altitude:	1800m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	55%

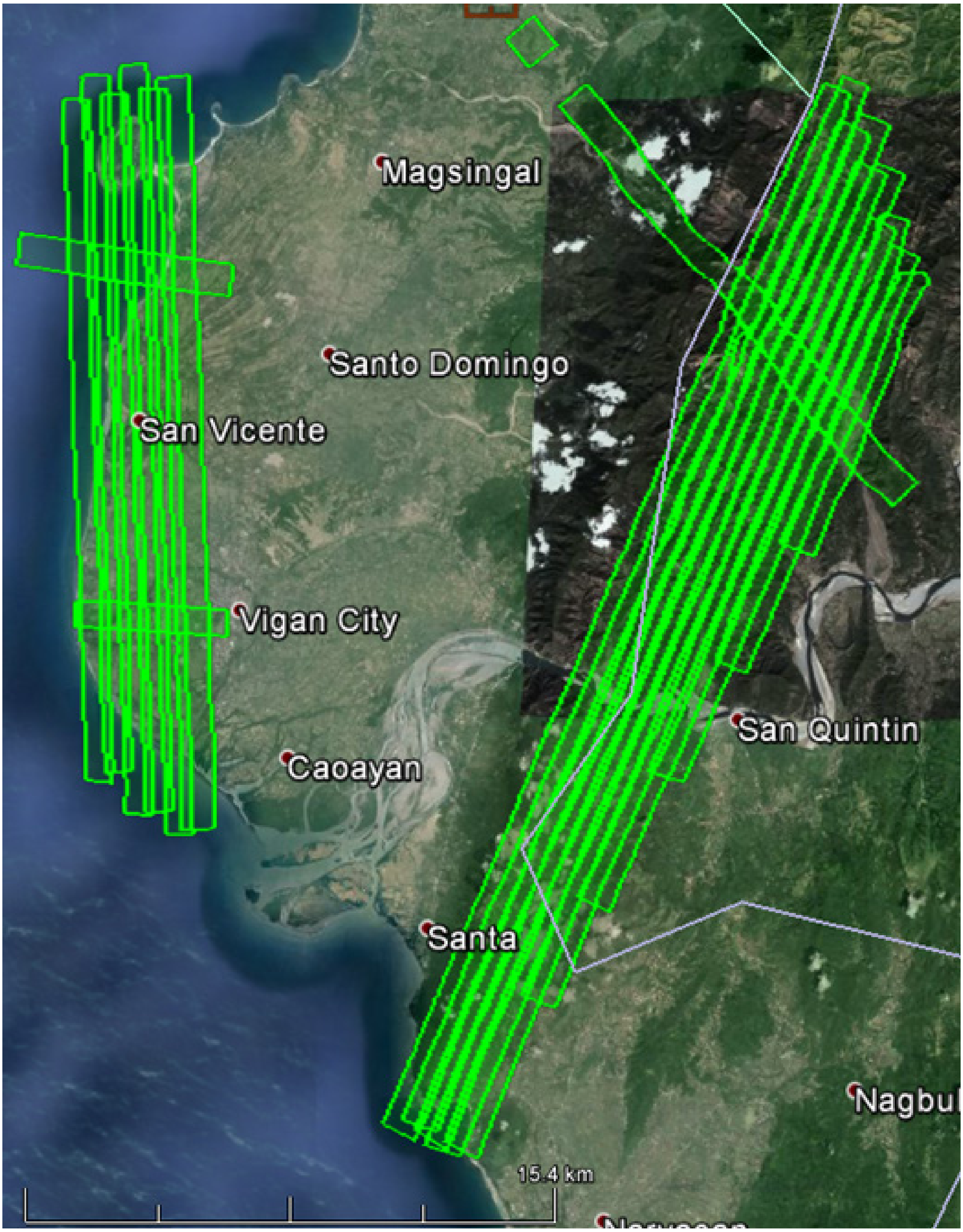


Figure A-7.3. Swath for Flight No. 7112GC

Flight No. :	7114 G		
Area:	BLK07CS& BLK06G		
Total Area:	sq km		
Mission Name:	2BLK07CS067A & 2BLK06G067A		
Altitude:	1800m / 1200m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	55% / 40%

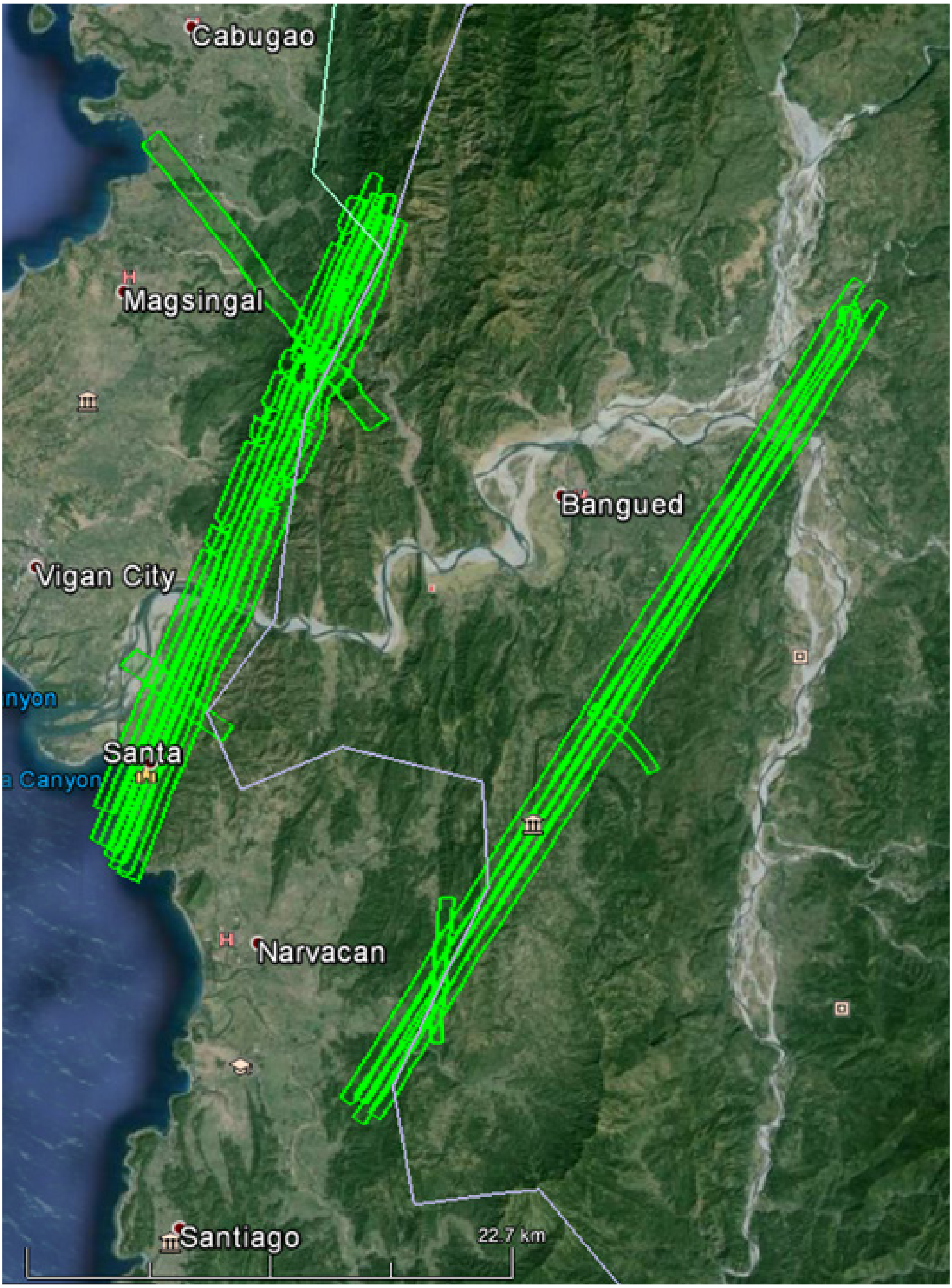


Figure A-7.4. Swath for Flight No. 7114G

Flight No. :	7116 GC		
Area:	BLK07B		
Total Area:	sq km		
Mission Name:	2BLK07B068A		
Altitude:	1300m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	30%

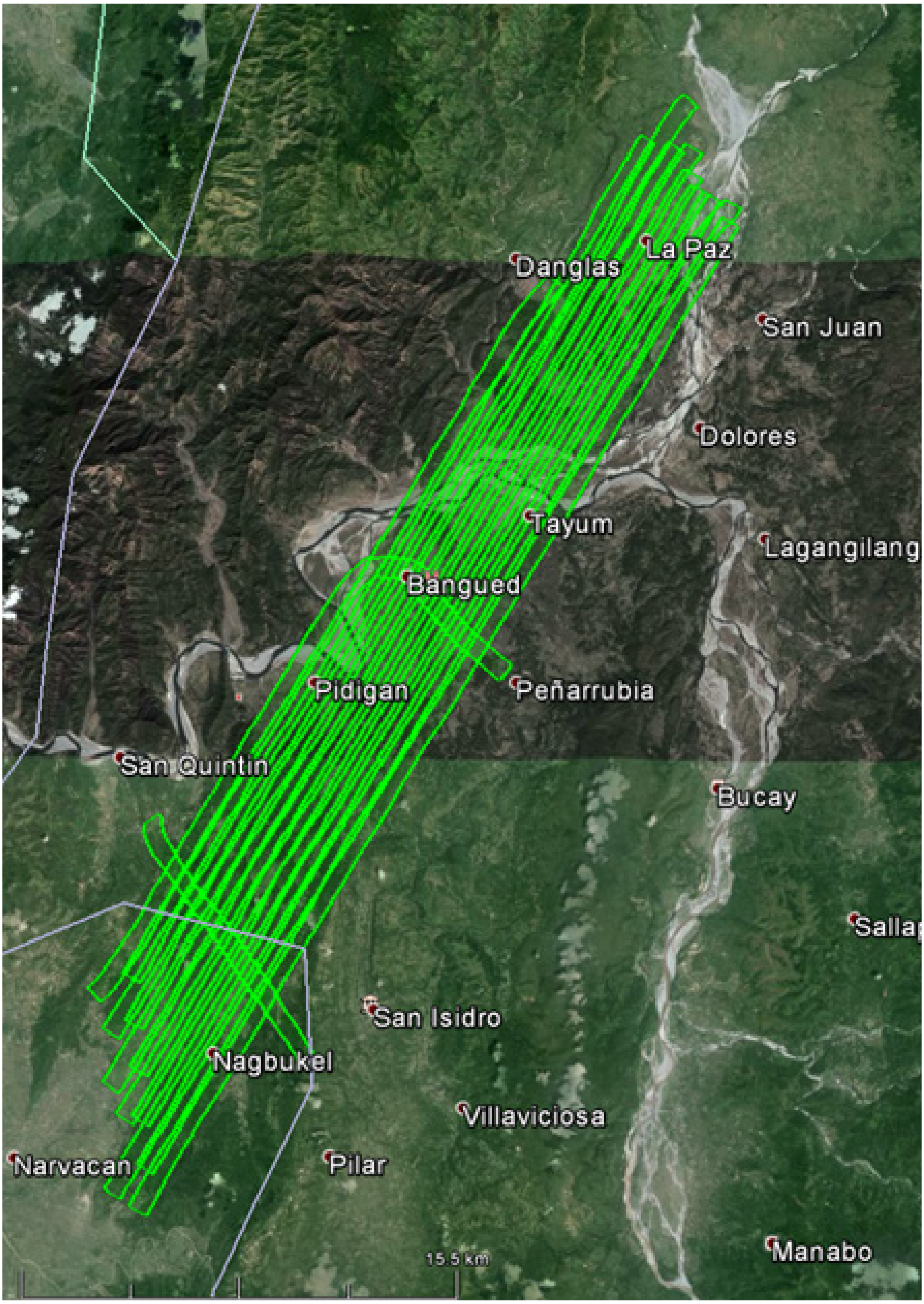


Figure A-7.5. Swath for Flight No. 7116GC

Flight No. :	7118 GC		
Area:	BLK07D		
Total Area:	sq km		
Mission Name:	2BLK07D069A		
Altitude:	1300m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	50%

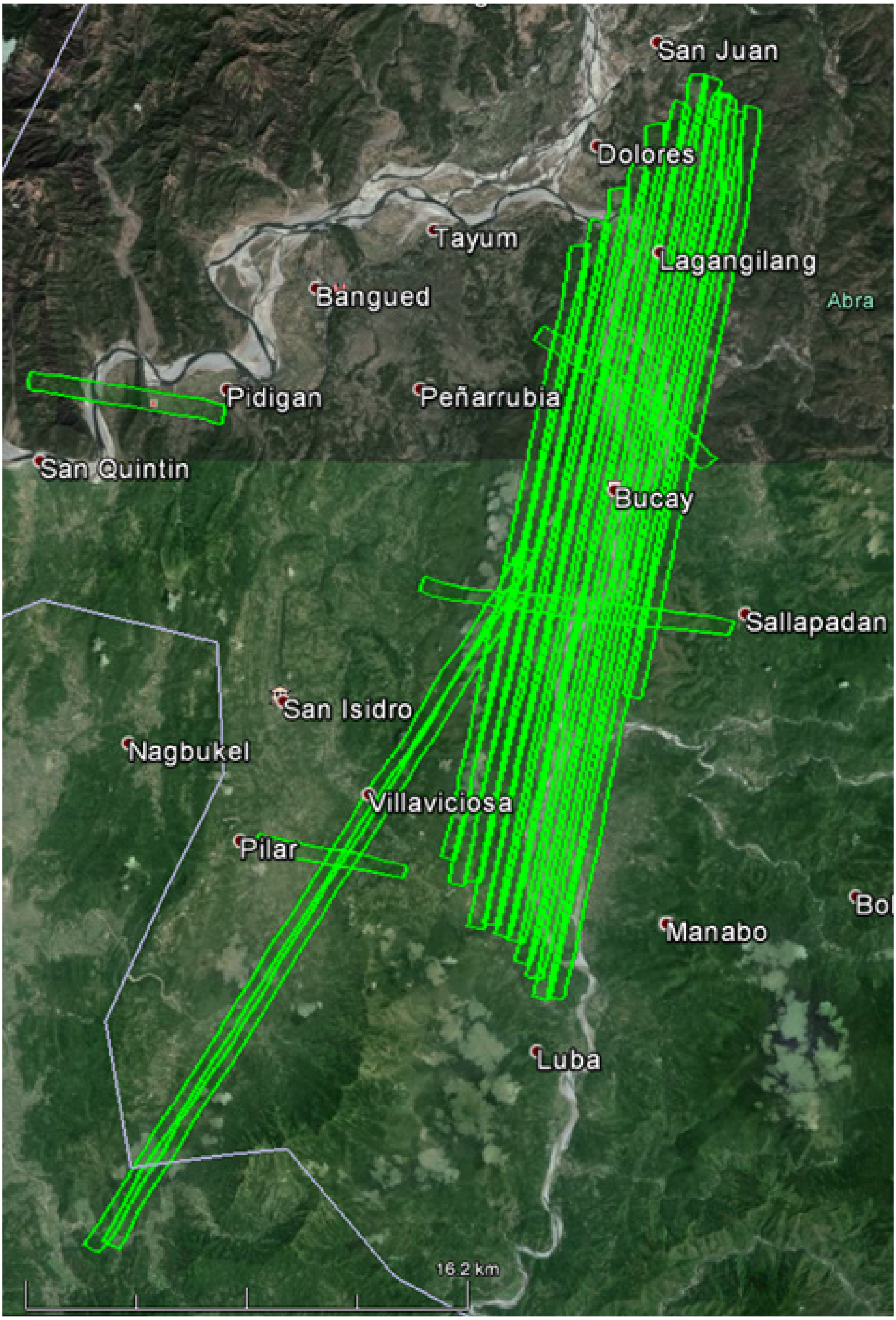


Figure A-7.6. Swath for Flight No. 7118GC

Flight No. :	7120 GC		
Area:	BLK06F& BLK07A		
Total Area:	sq. km.		
Mission Name:	2BLK06F070A & 2BLK07A070A		
Altitude:	1600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	40%

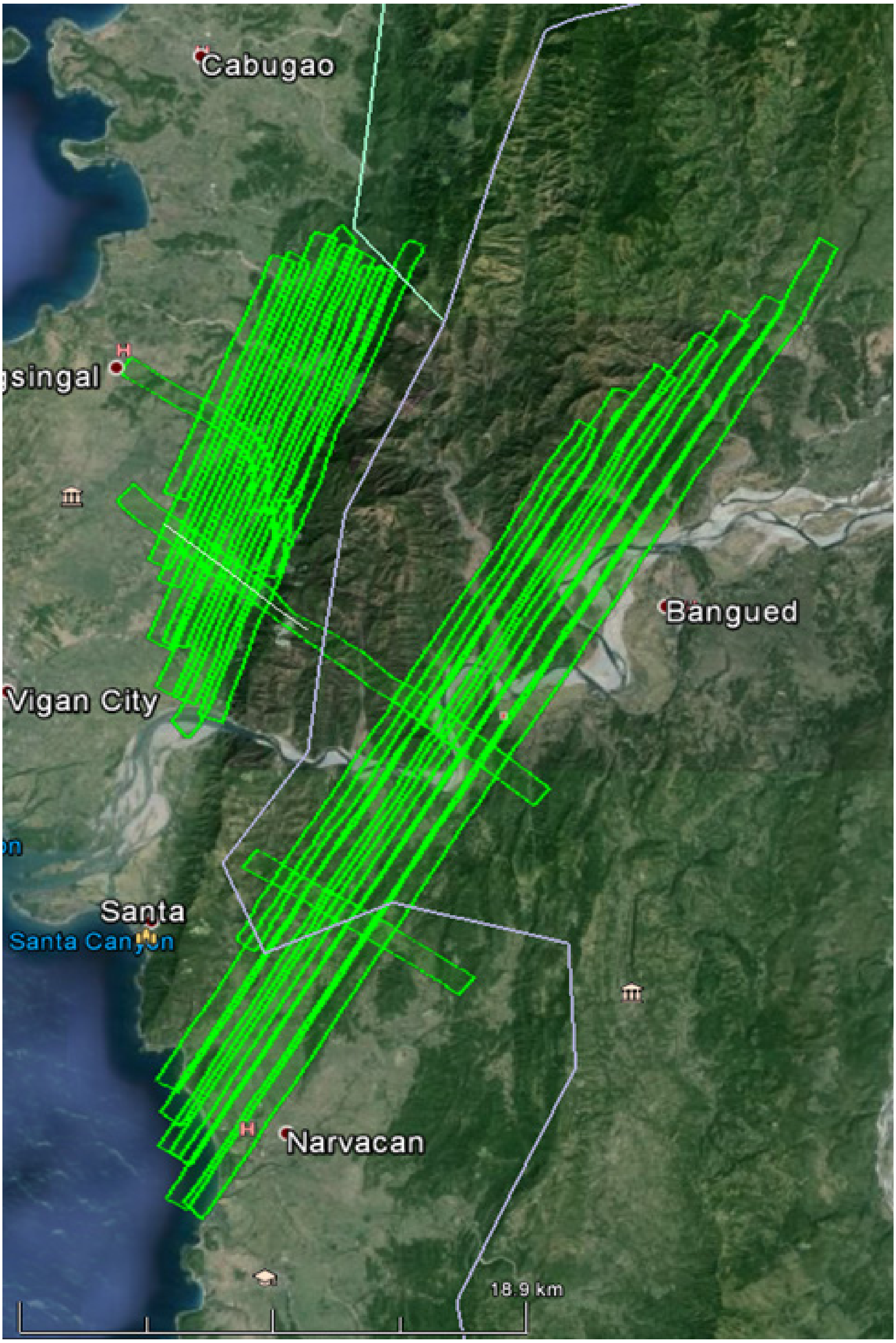


Figure A-7.7. Swath for Flight No. 7120GC

Flight No. :	7121 GC		
Area:	BLK07GS and BLK07AS		
Total Area:	sq. km.		
Mission Name:	2BLK07GS070B & 2BLK07AS070B		
Altitude:	1400m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	50%

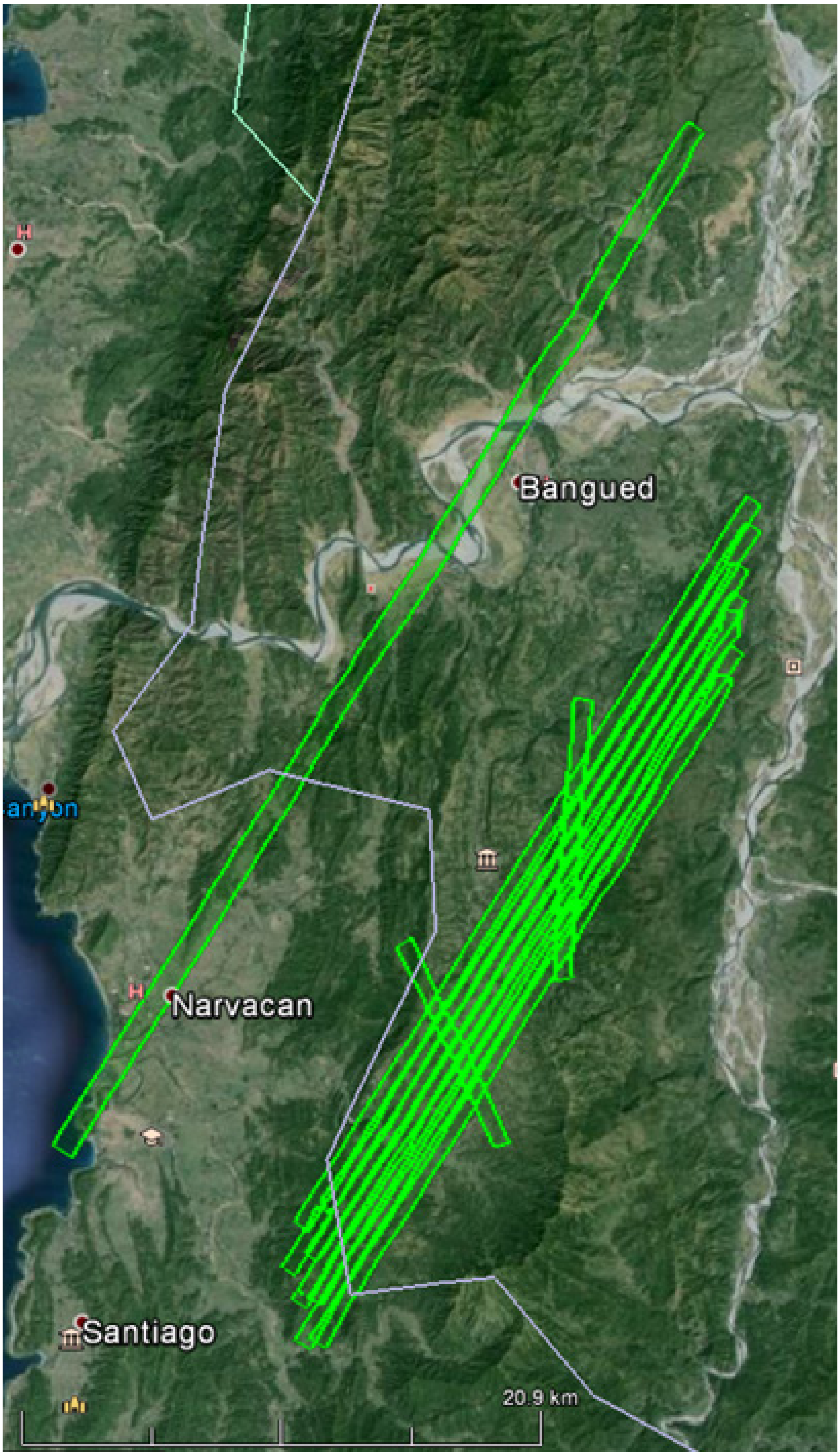


Figure A-7.8. Swath for Flight No. 7121GC

Flight No. :	7122 GC		
Area:	BLK07E and BLK07F		
Total Area:	sq. km.		
Mission Name:	2BLK07E071A & 2BLK07F071A		
Altitude:	1800m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	40% / 35%

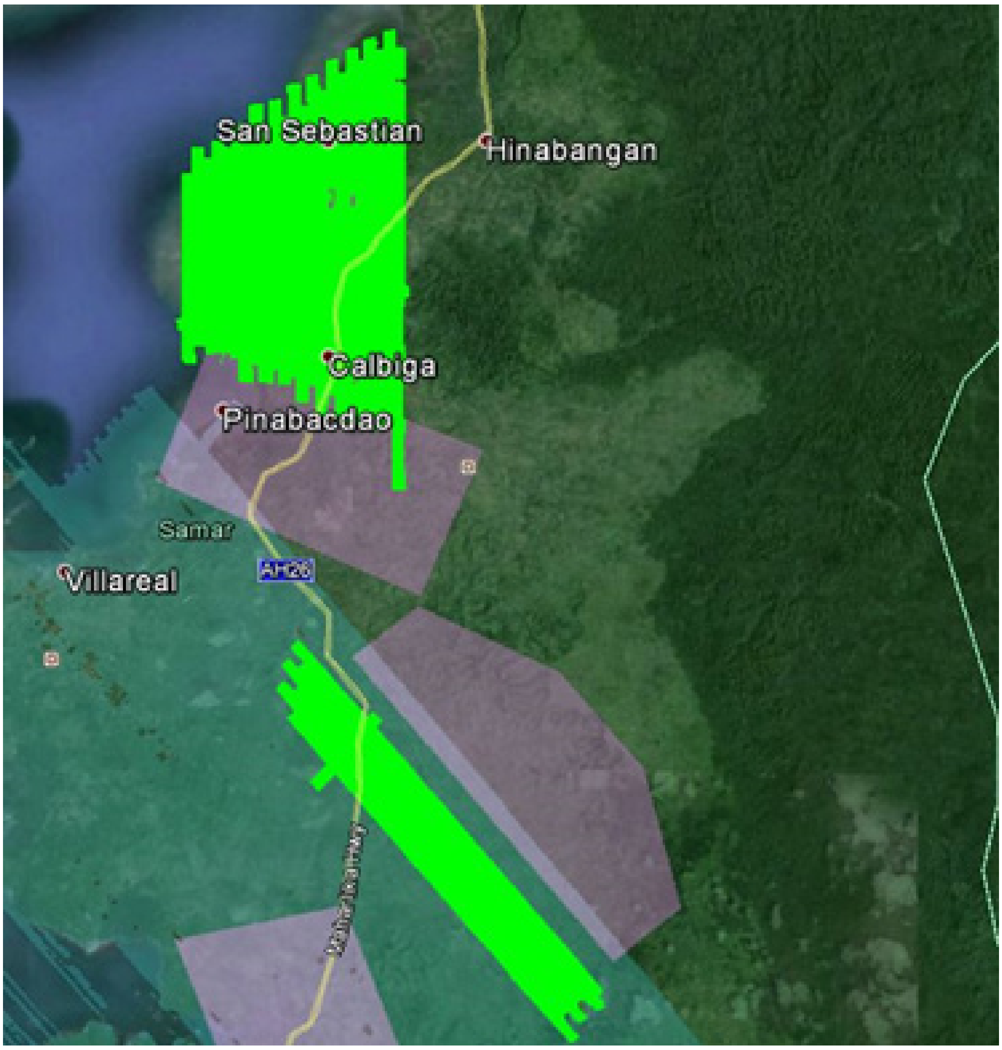


Figure A-7.9. Swath for Flight No. 7122GC

Flight No. :	4043 GC		
Area:	BLK07AS		
Total Area:	sq. km.		
Mission Name:	2BLK7SA149A		
Altitude:	1800m		
PRF:	kHz	SCF:	Hz
Lidar FOV:	deg	Sidelap:	%

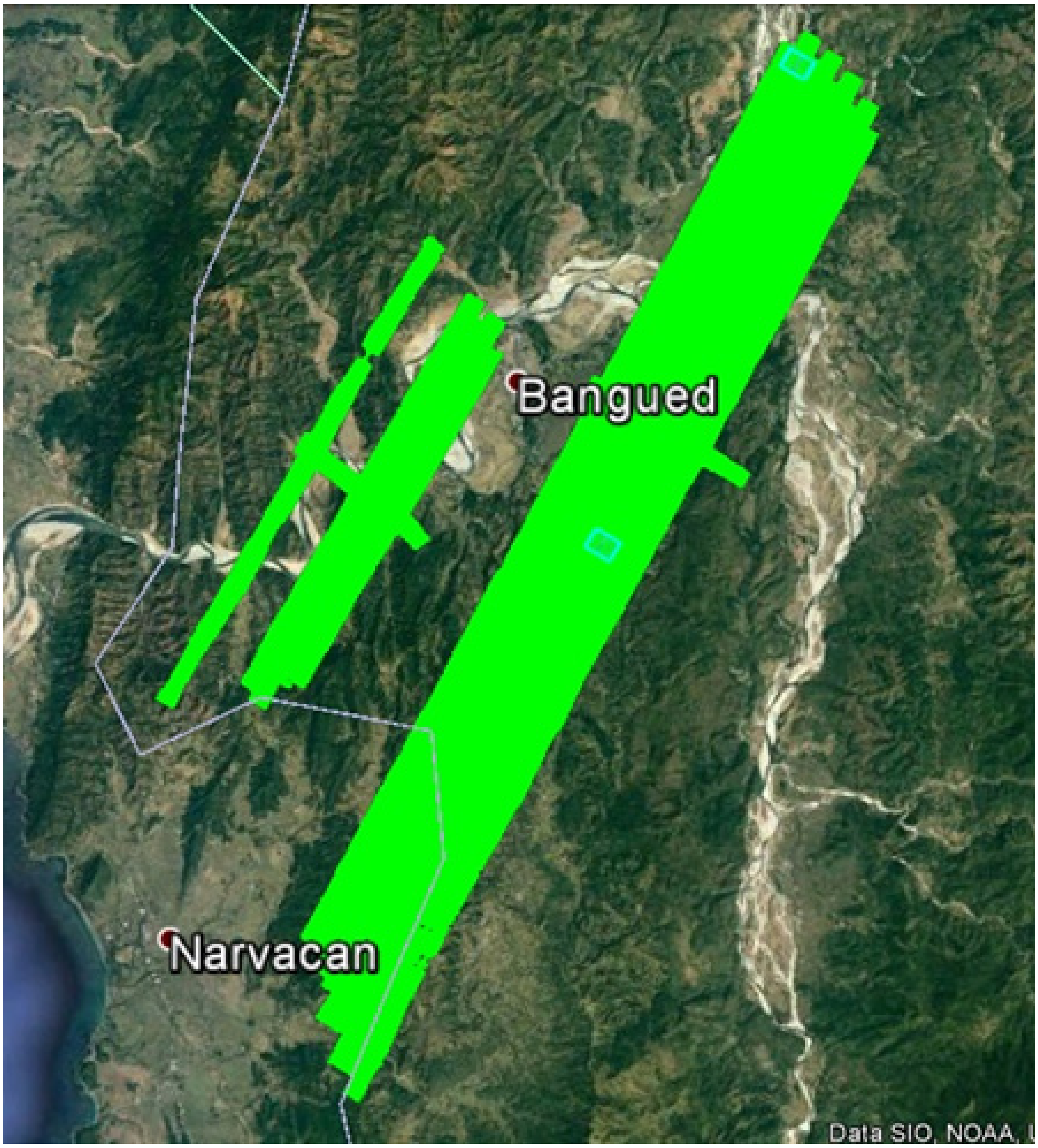


Figure A-7.10. Swath for Flight No. 4043GC

Flight No. :	4045 GC
Area:	BLK07BS
Total Area:	sq. km.
Mission Name:	2BLK7SB149B

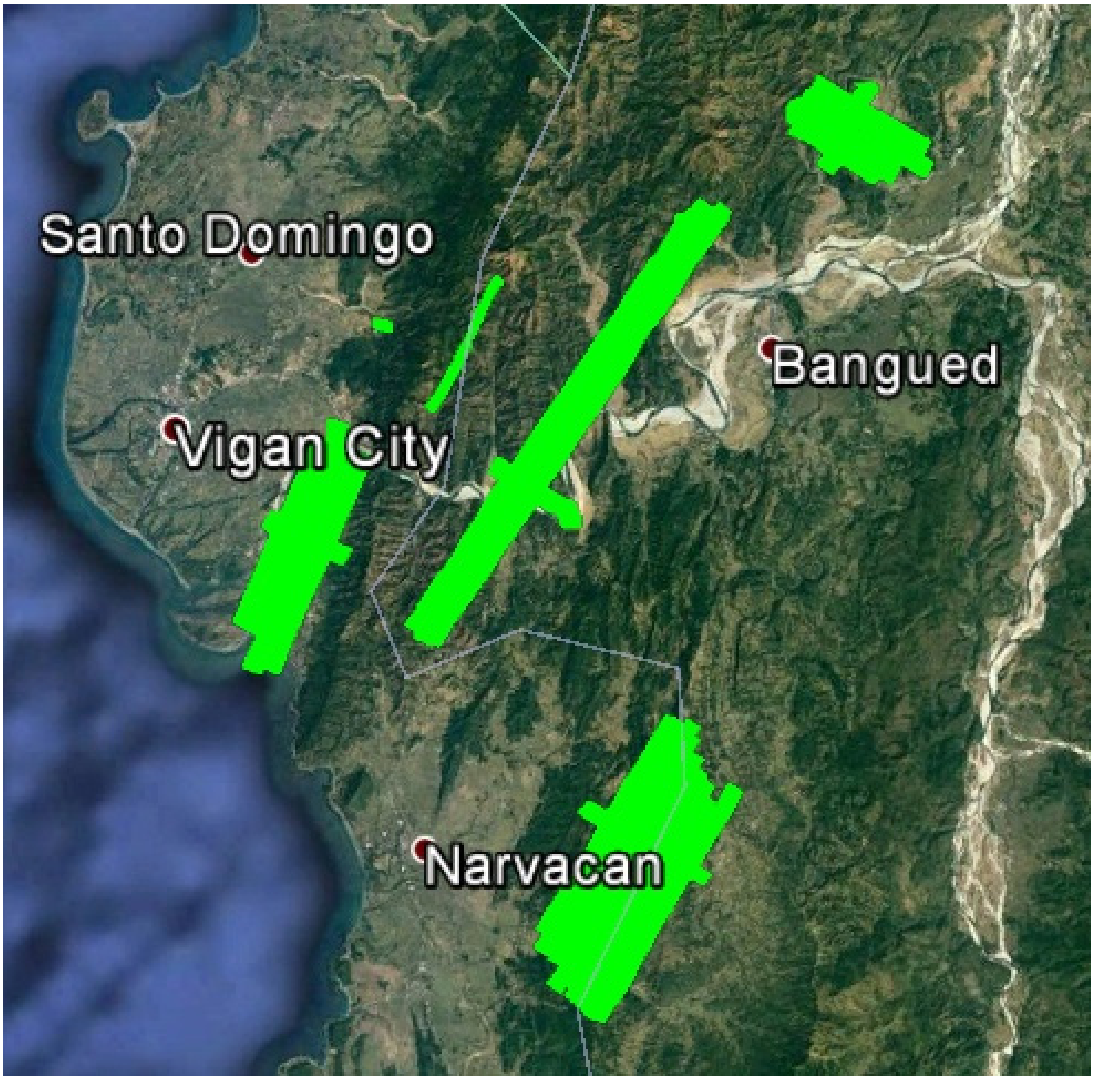


Figure A-7.11. Swath for Flight No. 4045GC

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk06A

Flight Area	Ilocos
Mission Name	Blk06_A
Inclusive Flights	7104GC, 7105GC
Range data size	42.6GB
Base data size	24.9 MB
POS	460MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.7
RMSE for East Position (<4.0 cm)	3.3
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000184
IMU attitude correction stdev (<0.001deg)	0.000642
GPS position stdev (<0.01m)	0.0064
Minimum % overlap (>25)	37.38%
Ave point cloud density per sq.m. (>2.0)	3.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	419
Maximum Height	614.2m
Minimum Height	39.17m
Classification (# of points)	
Ground	167,502,975
Low vegetation	193,929,105
Medium vegetation	261,271,939
High vegetation	401,795,646
Building	13,519,422
Orthophoto	NO
Processed by	Engr. Kenneth Solidum, Engr. Abigail Ching, Engr. Harmond Santos, Engr. Melissa Fernandez

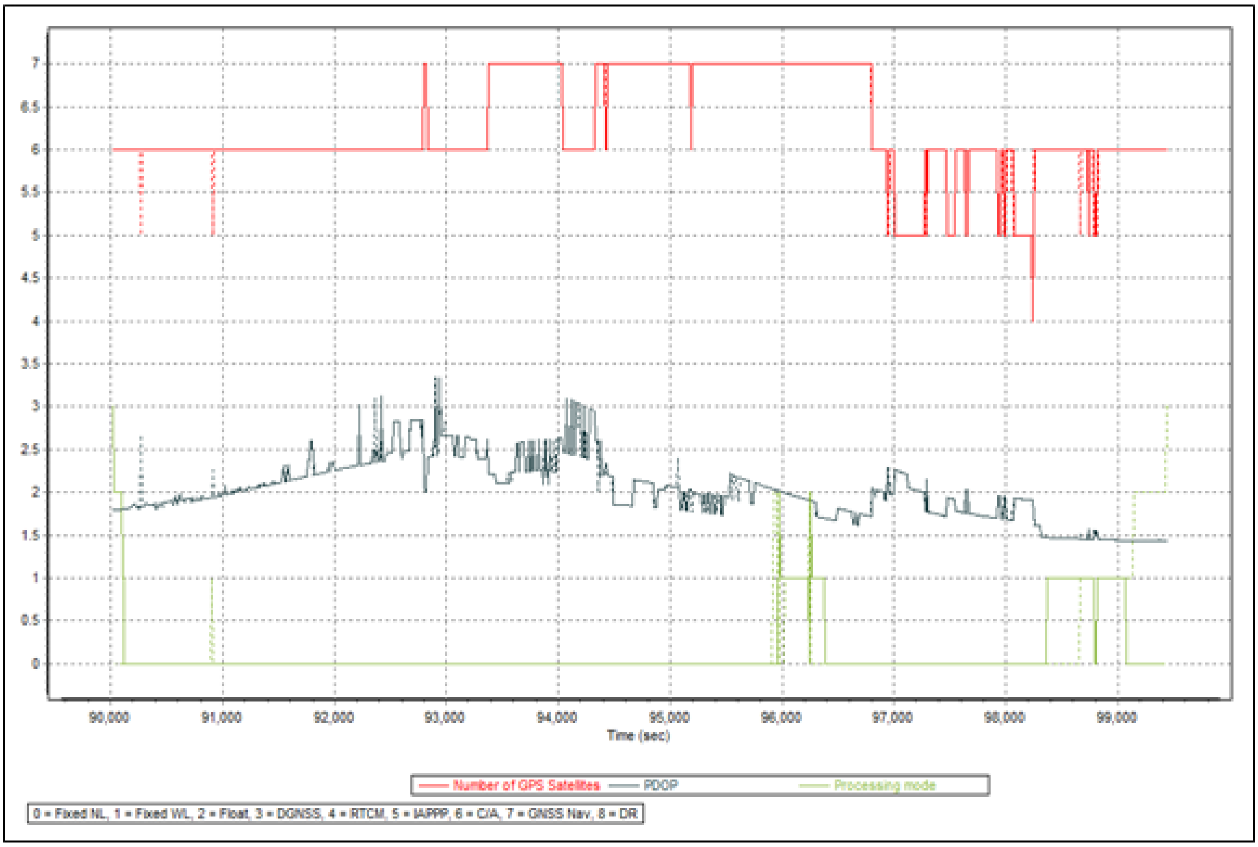


Figure A-8.1. Solution Status

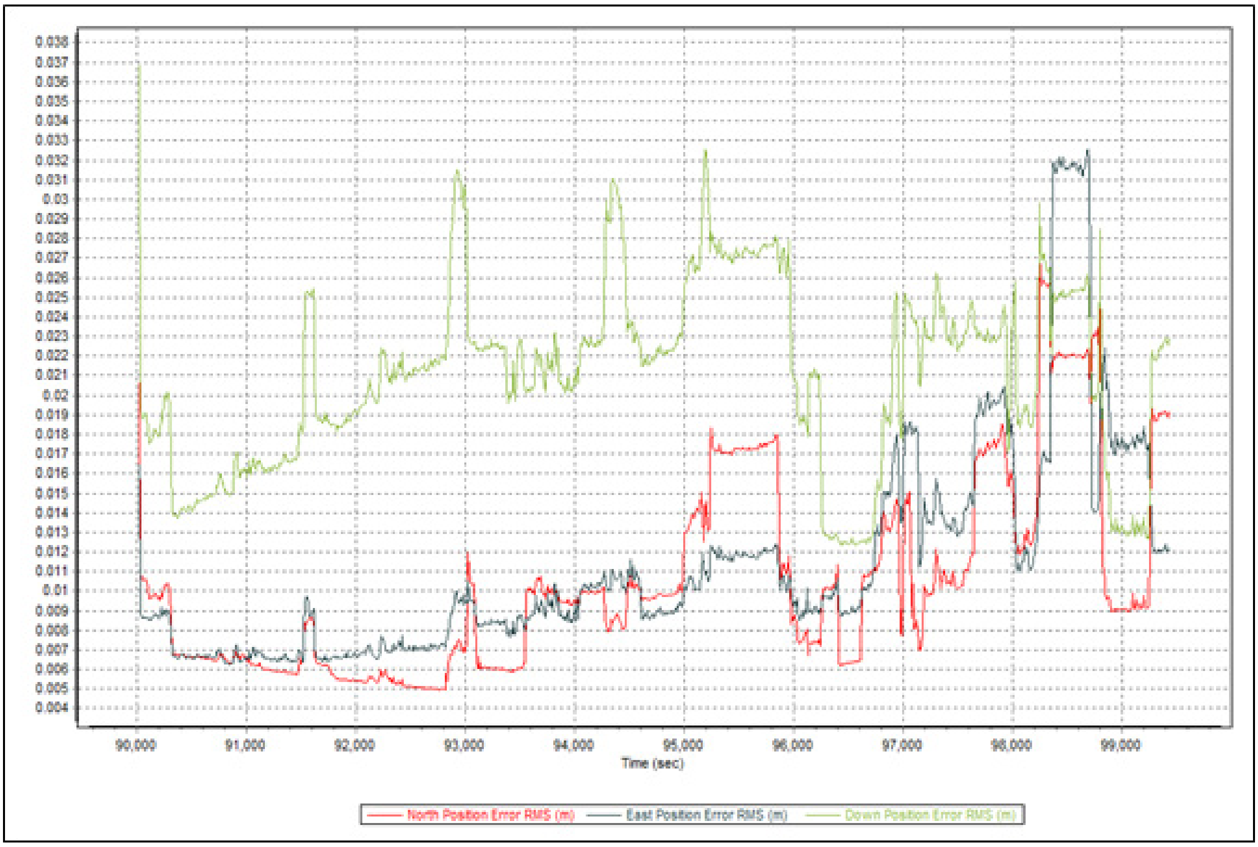


Figure A-8.2. Smoothed Performance Metrics Parameters

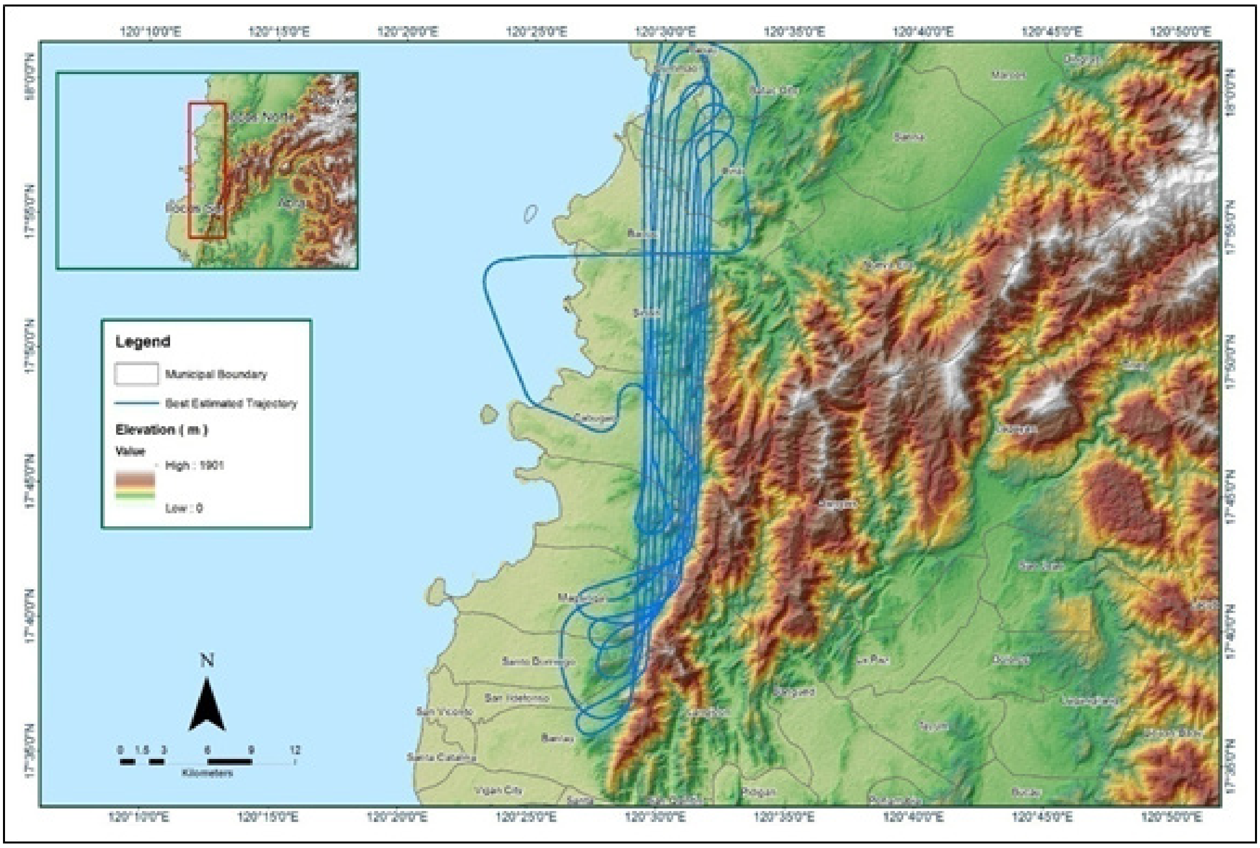


Figure A-8.3. Best Estimated Trajectory

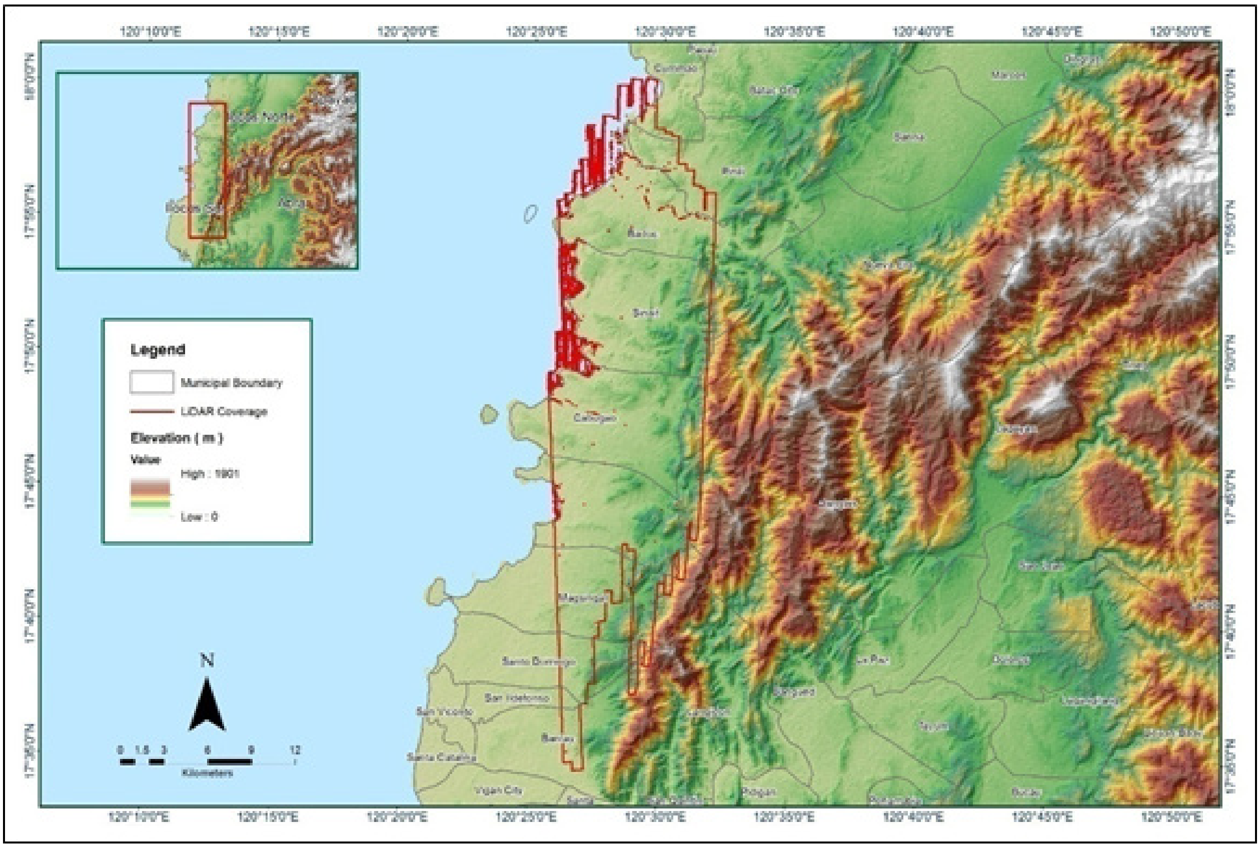


Figure A-8.4. Coverage of LiDAR data

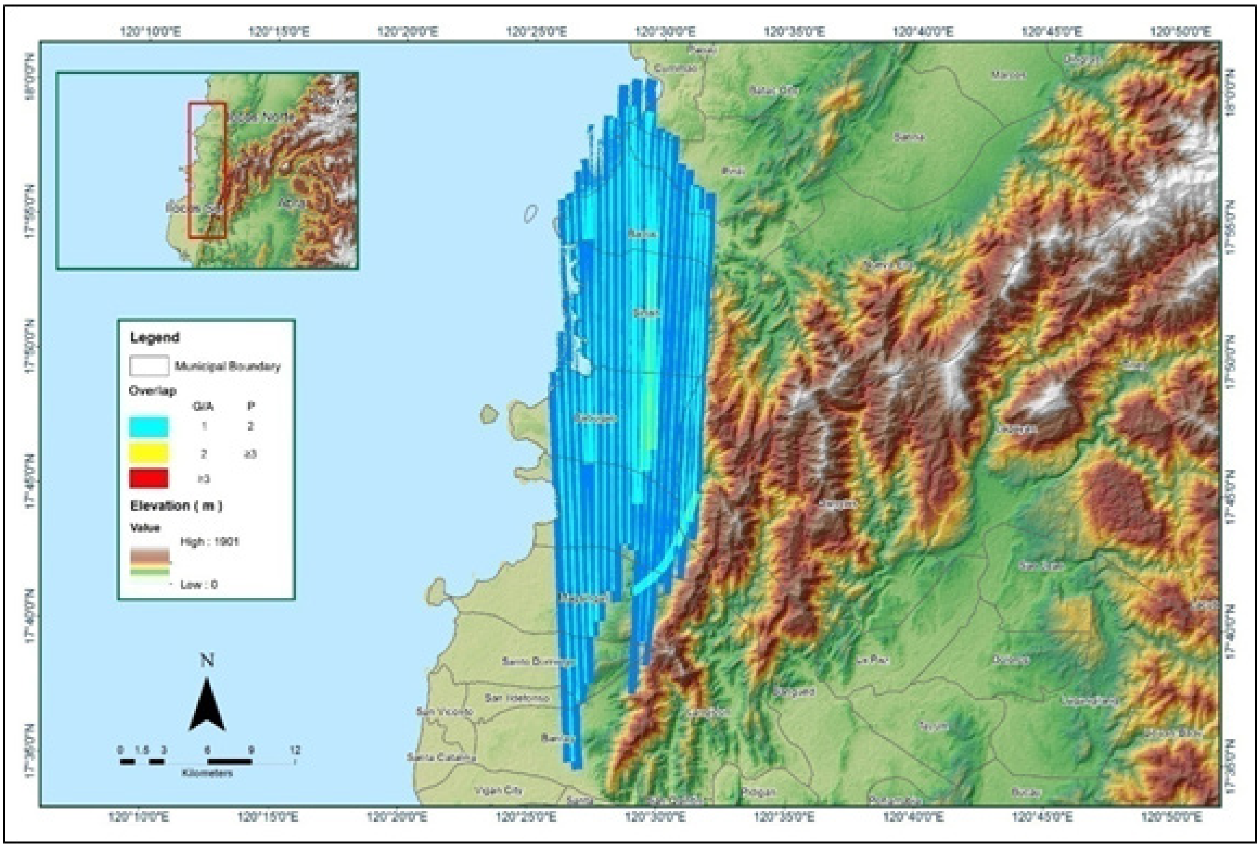


Figure A-8.5. Image of Data Overlap

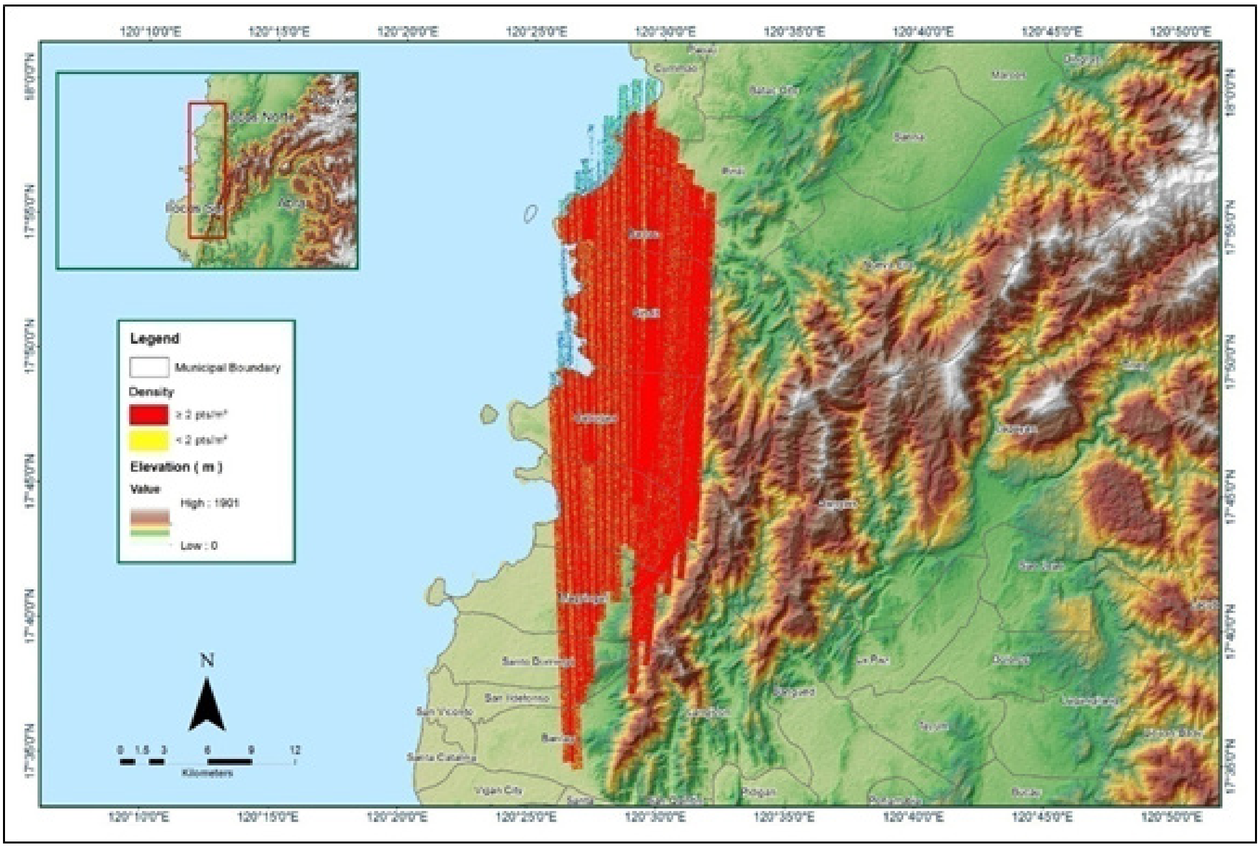


Figure A-8.6.Density map of merged LiDAR data

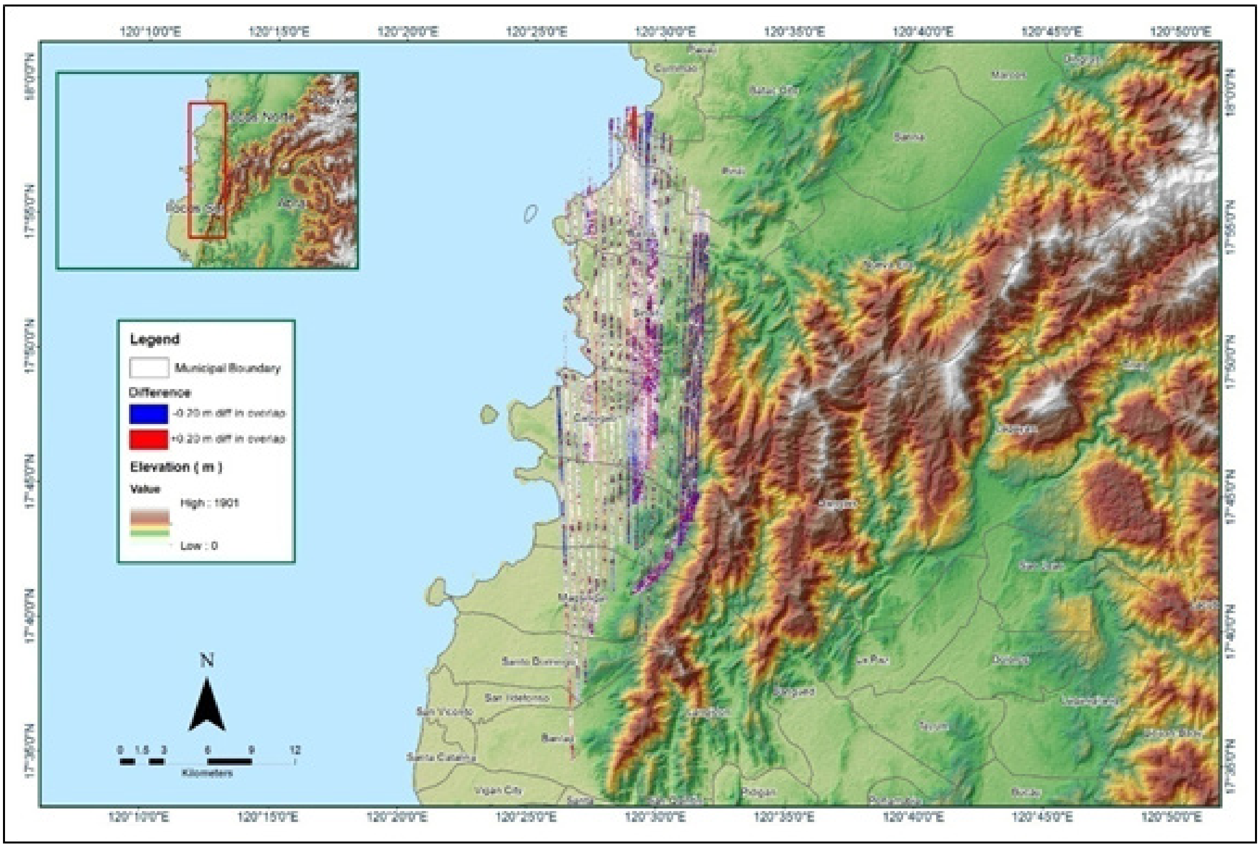


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk06D

Flight Area	Ilocos
Mission Name	Blk06_D
Inclusive Flights	7108GC
Range data size	29.2GB
Base data size	11 MB
POS	268MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.1
RMSE for East Position (<4.0 cm)	2.5
RMSE for Down Position (<8.0 cm)	6.7
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.000657
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	20.38%
Ave point cloud density per sq.m. (>2.0)	2.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	340
Maximum Height	205.57m
Minimum Height	38.73m
Classification (# of points)	
Ground	153,294,422
Low vegetation	170,006,121
Medium vegetation	150,971,074
High vegetation	110,037,274
Building	12,262,298
Orthophoto	NO
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado, Ryan James Nicholai Dizon

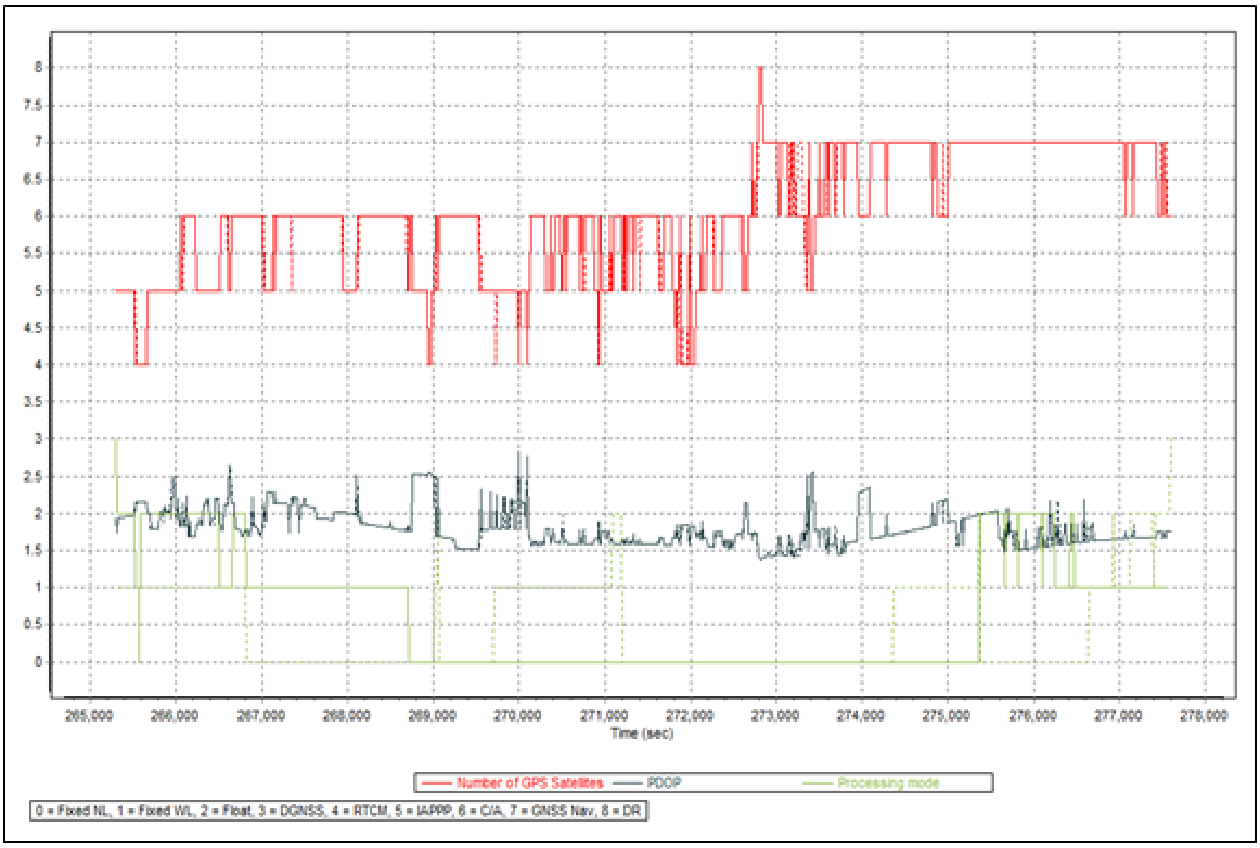


Figure A-8.8. Solution Status Parameters

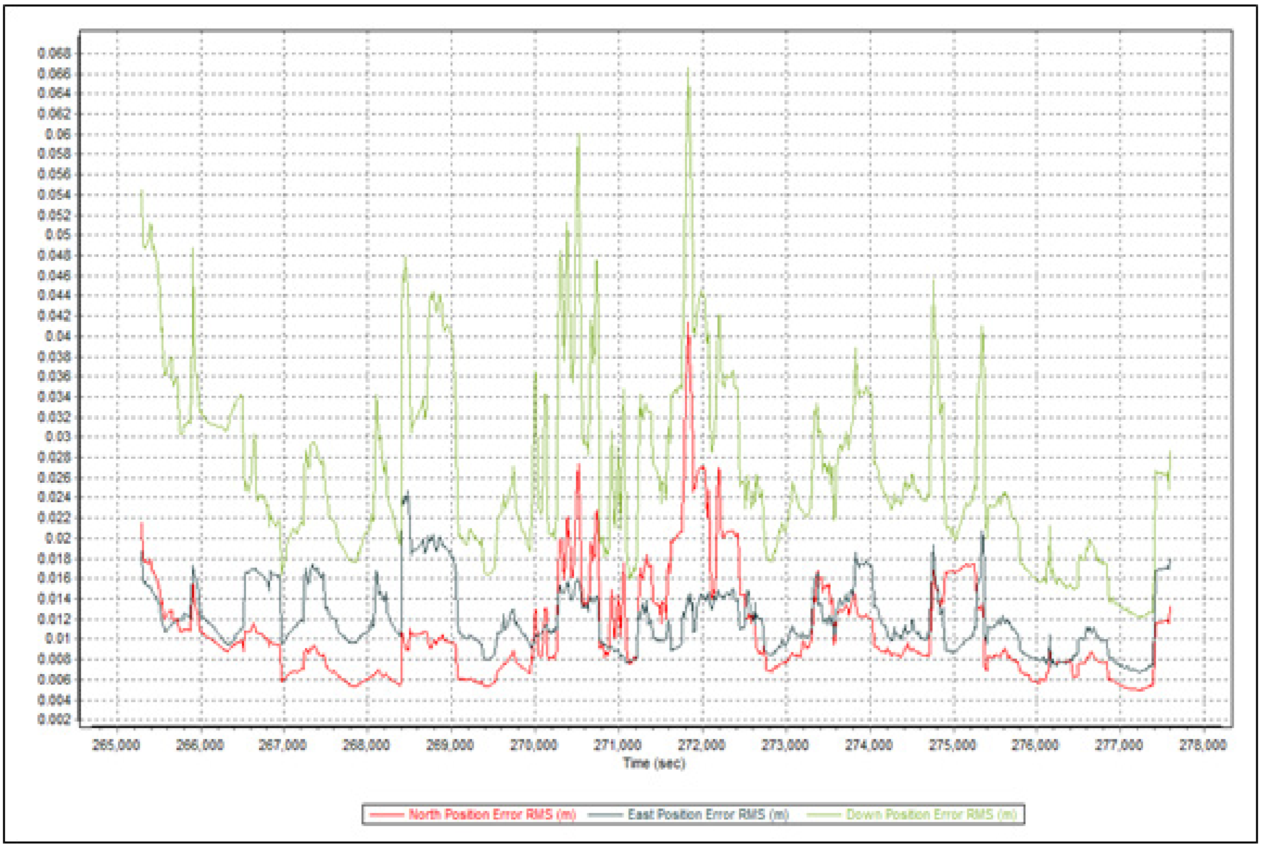


Figure A-8.9. Smoothed Performance Metrics Parameters

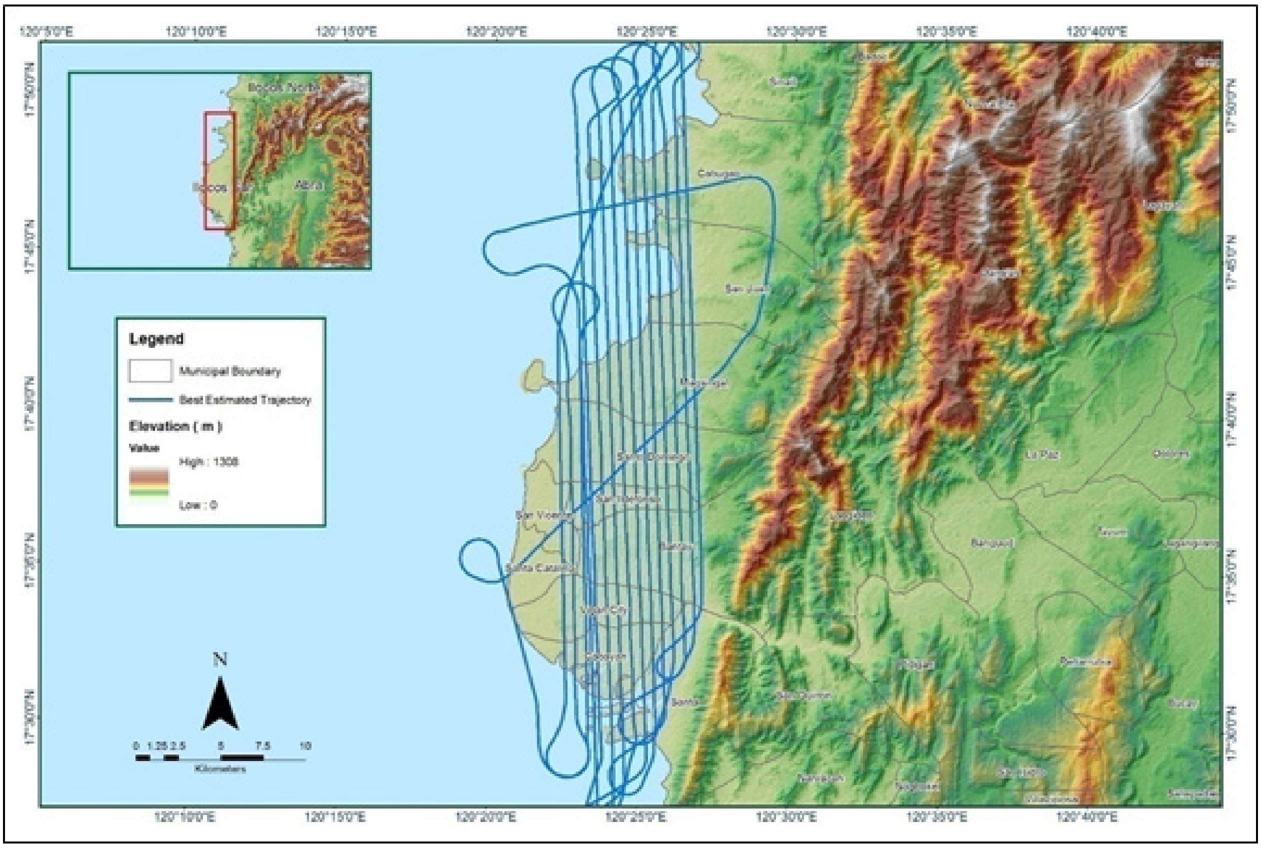


Figure A-8.10. Best Estimated Trajectory

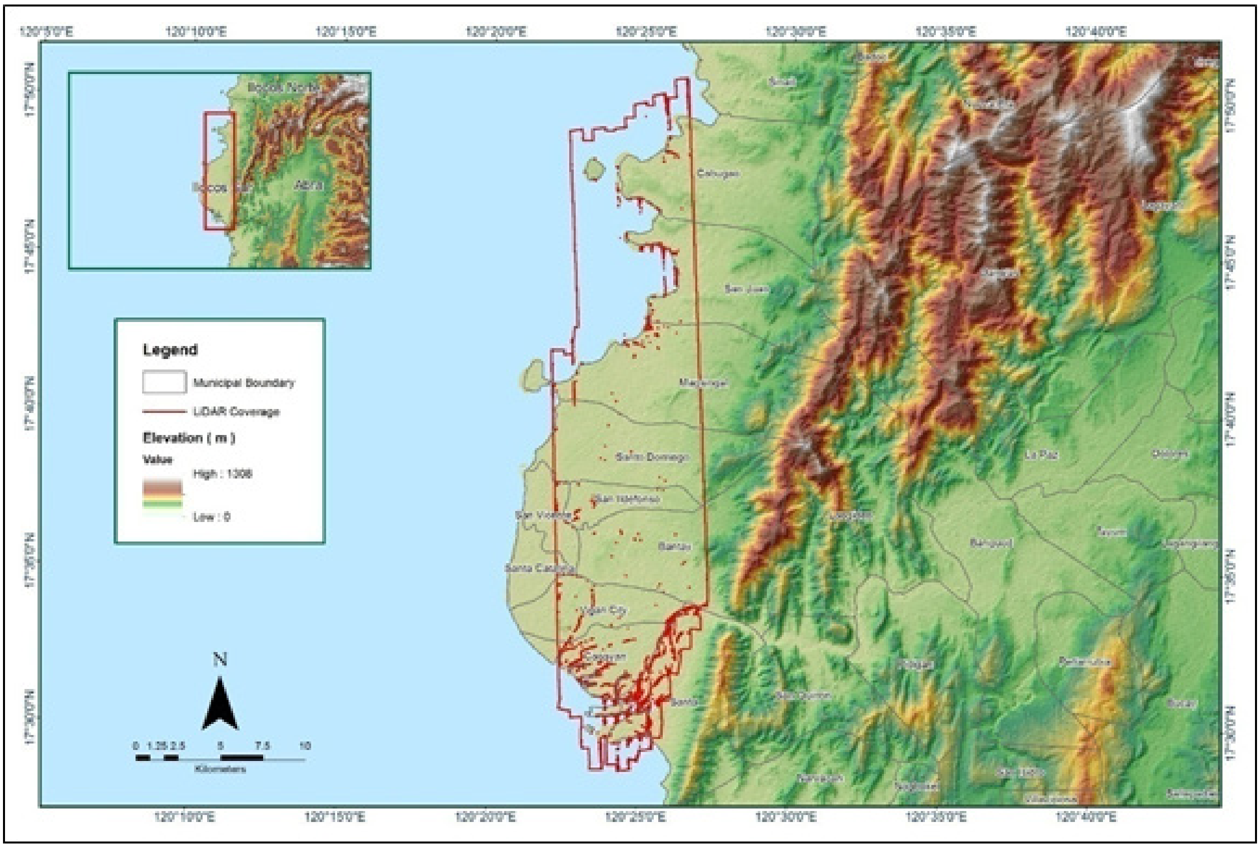


Figure A-8.11. Coverage of LiDAR data

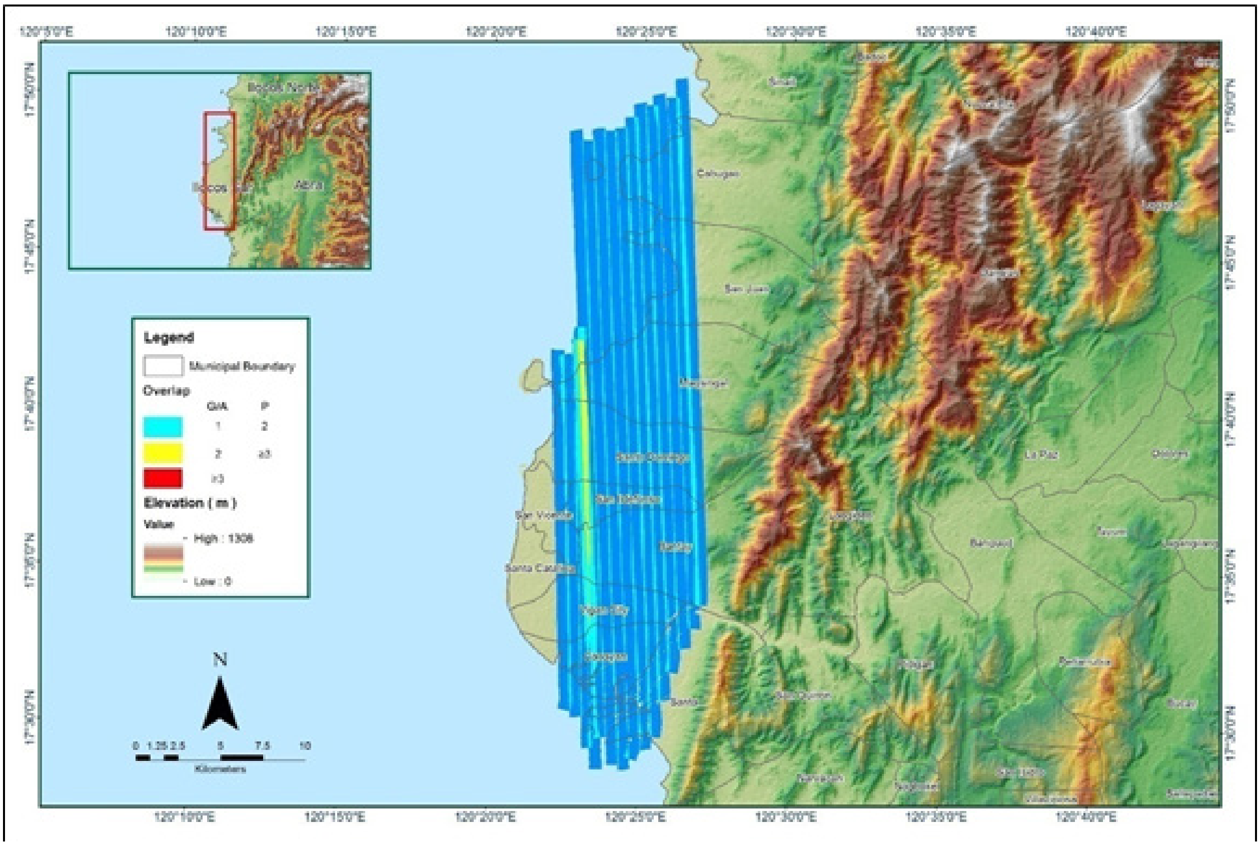


Figure A-8.12. Image of Data Overlap

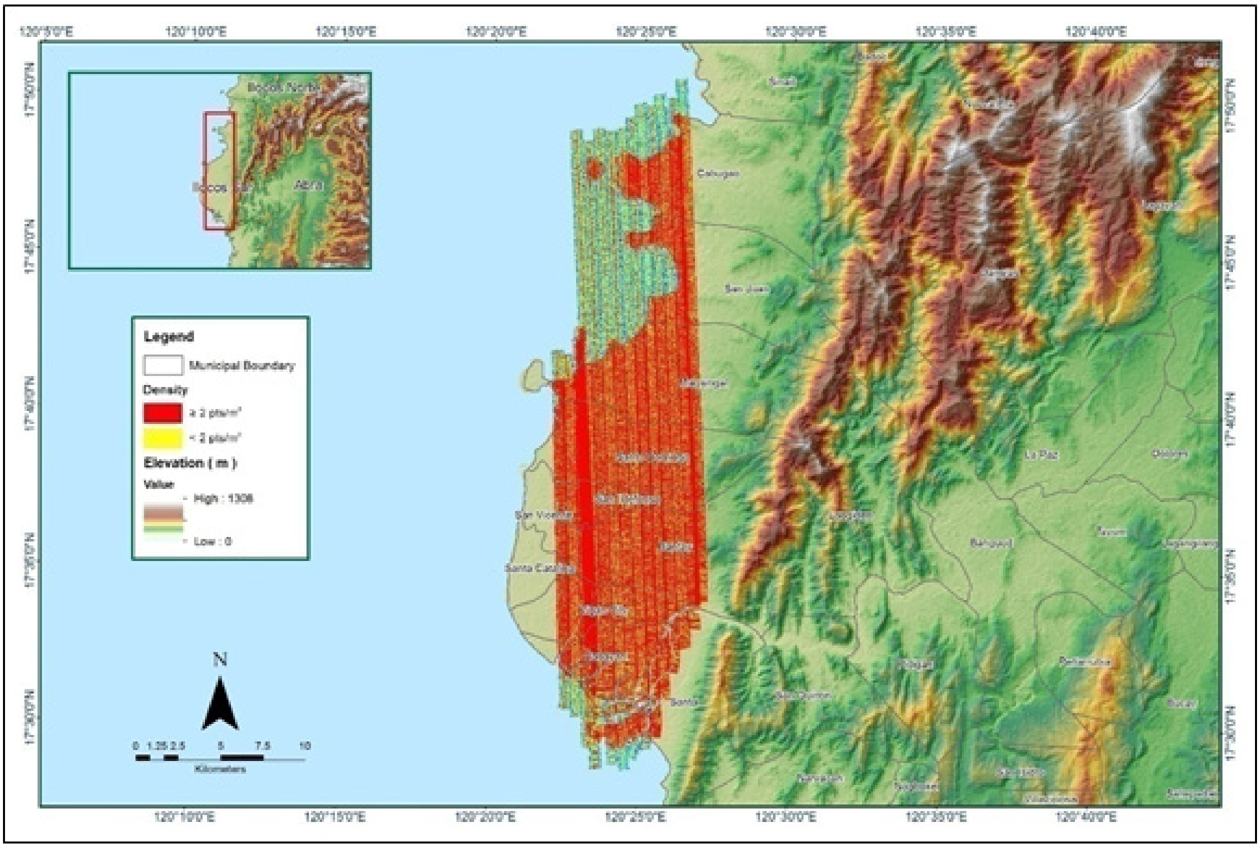


Figure A-8.13. Density map of merged LiDAR data

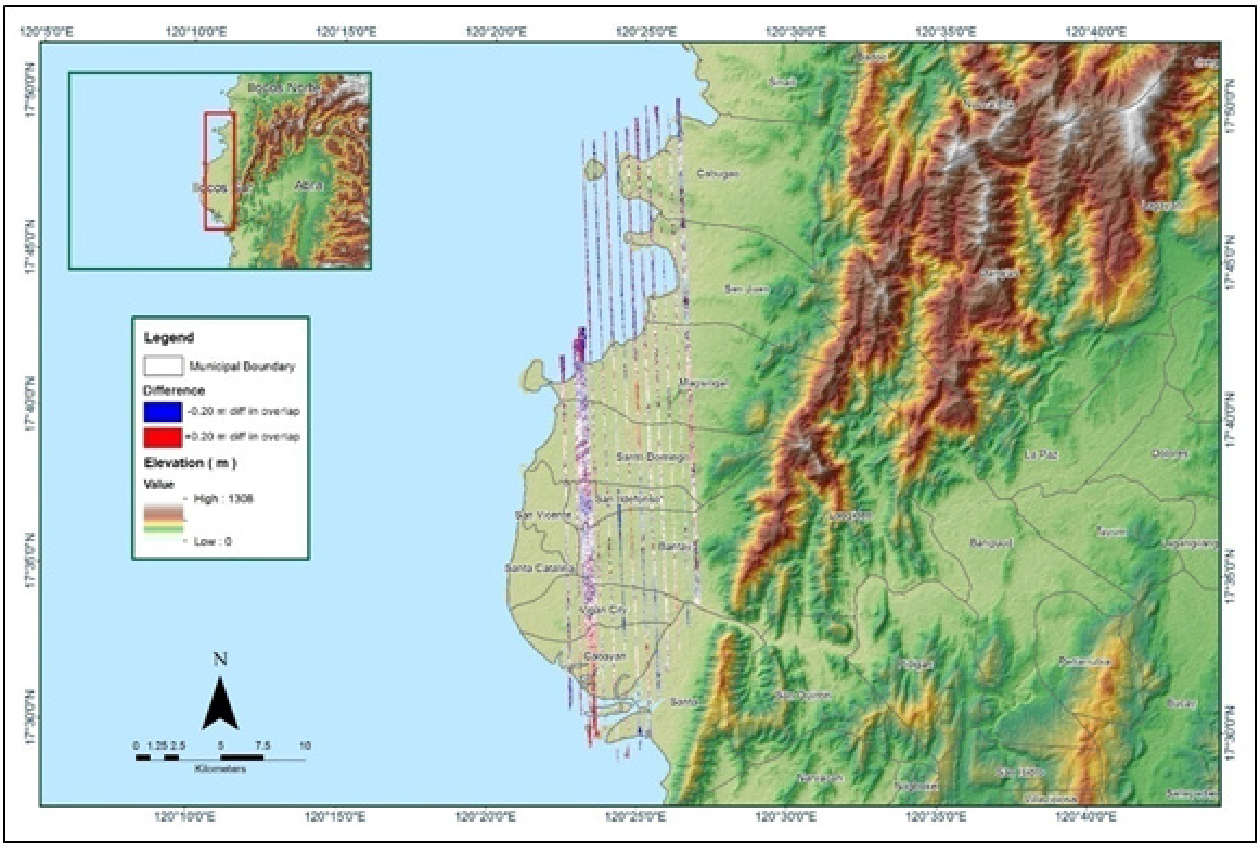


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk06D_additional

Flight Area	Ilocos
Mission Name	Blk06_D_additional
Inclusive Flights	7108GC
Range data size	29.2GB
Base data size	11 MB
POS	268MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.1
RMSE for East Position (<4.0 cm)	2.5
RMSE for Down Position (<8.0 cm)	6.7
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.000657
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	50.45%
Ave point cloud density per sq.m. (>2.0)	3.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	52
Maximum Height	97.71m
Minimum Height	38.92m
Classification (# of points)	
Ground	13,415,941
Low vegetation	18,682,343
Medium vegetation	17,092,601
High vegetation	16,069,039
Building	3,155,099
Orthophoto	NO
Processed by	Engr. Irish Cortez, Engr. Melissa Fernandez, Engr. Chelou Prado

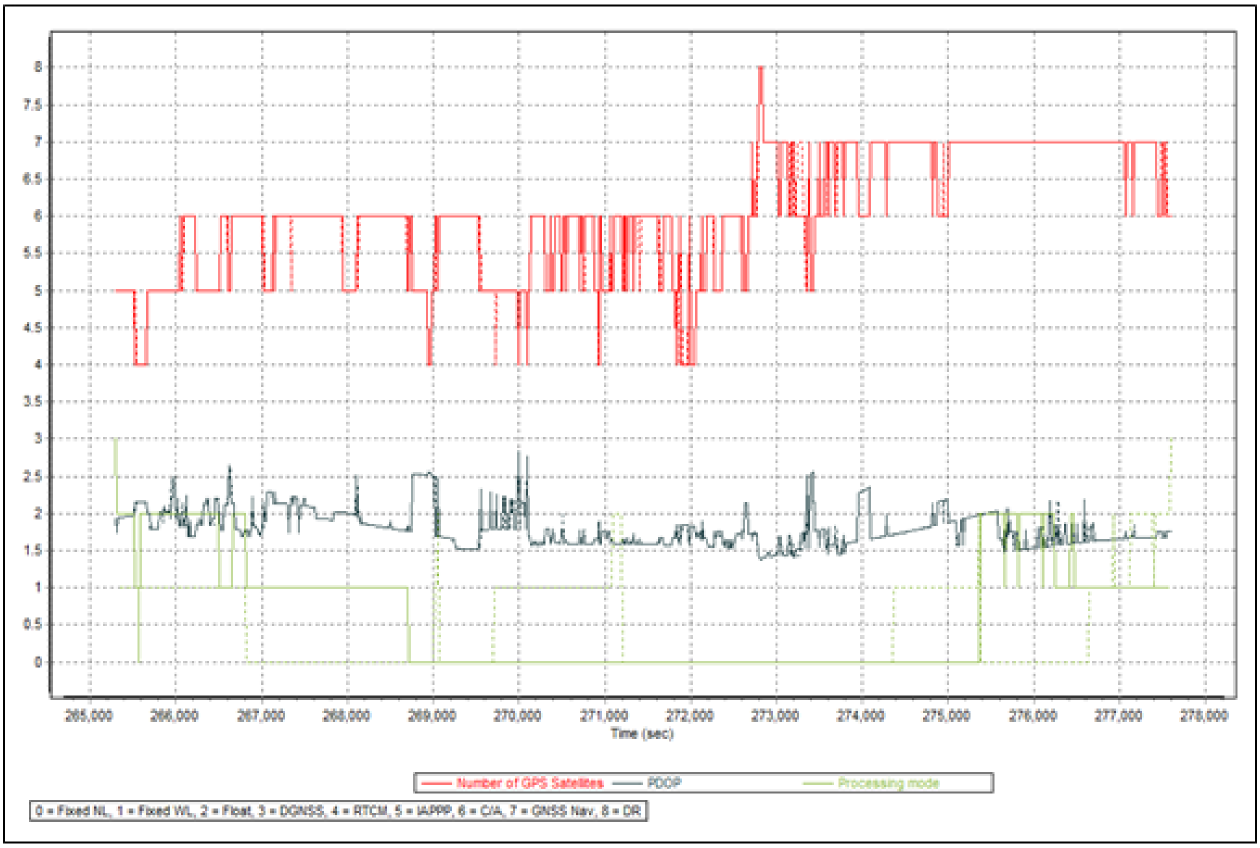


Figure A-8.15. Solution Status Parameters

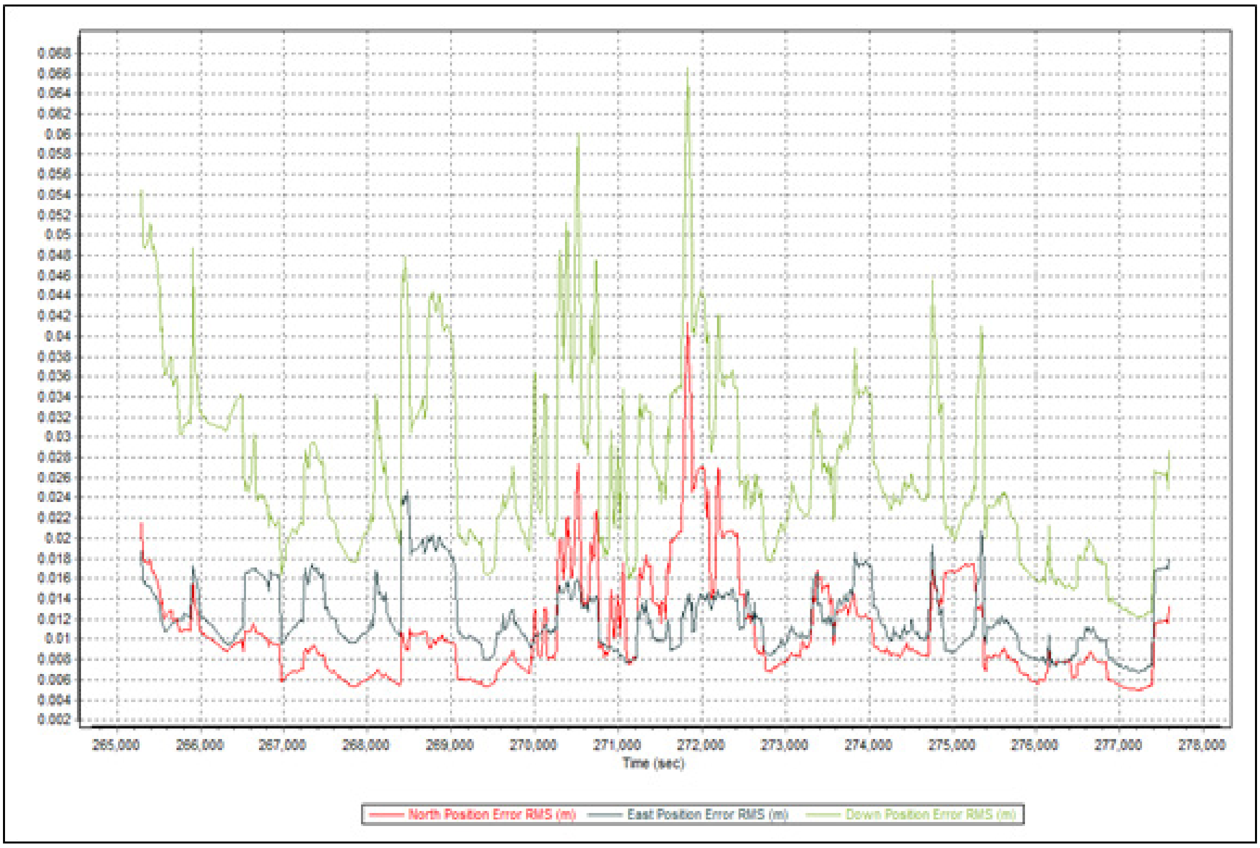


Figure A-8.16. Smoothed Performance Metrics Parameters

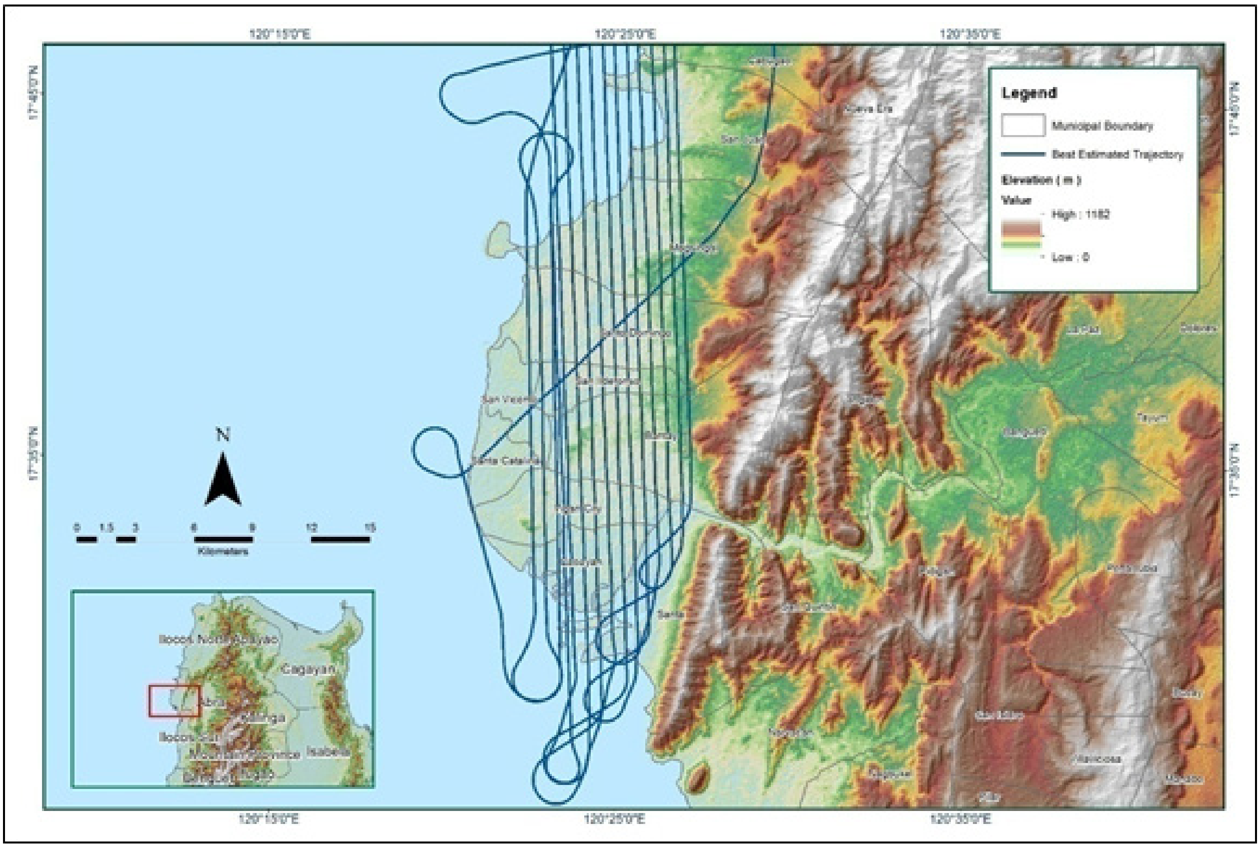


Figure A-8.17. Best Estimated Trajectory

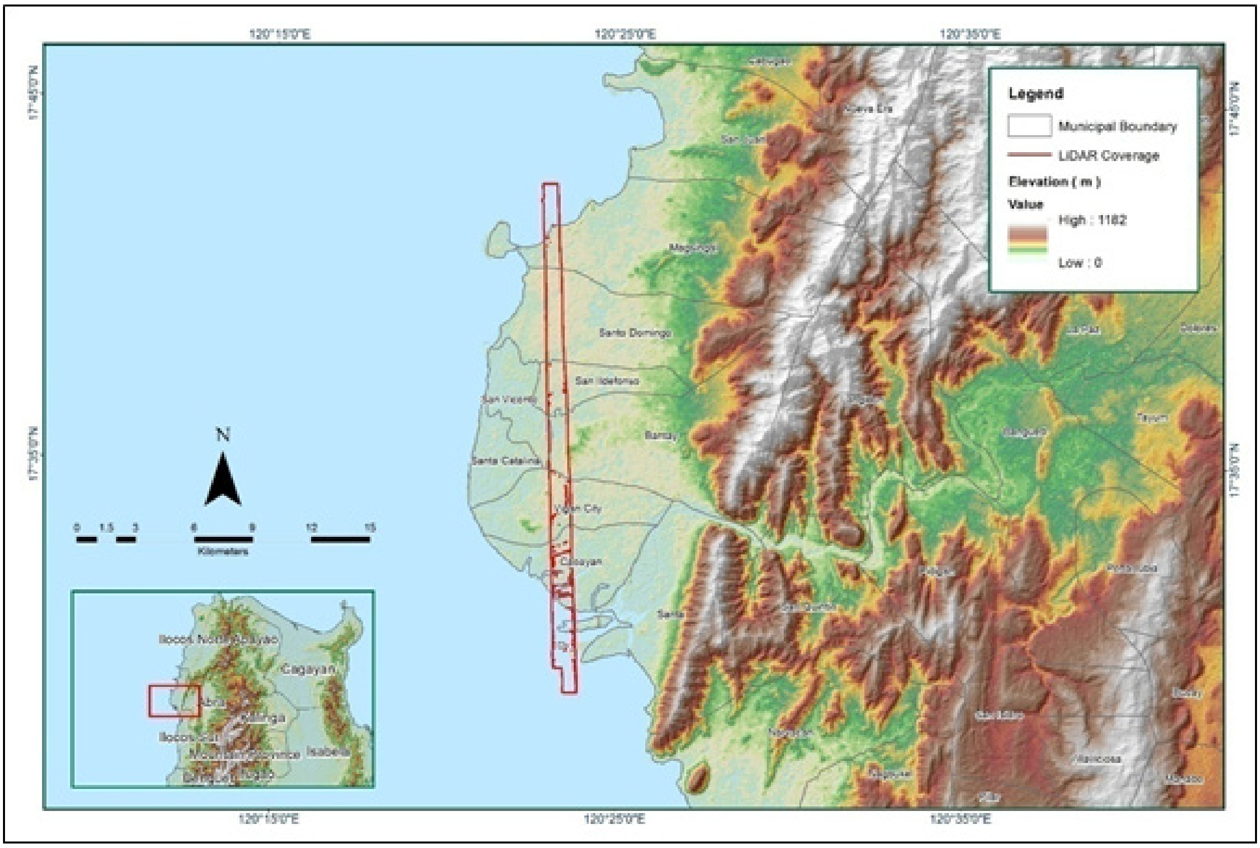


Figure A-8.18. Coverage of LiDAR data

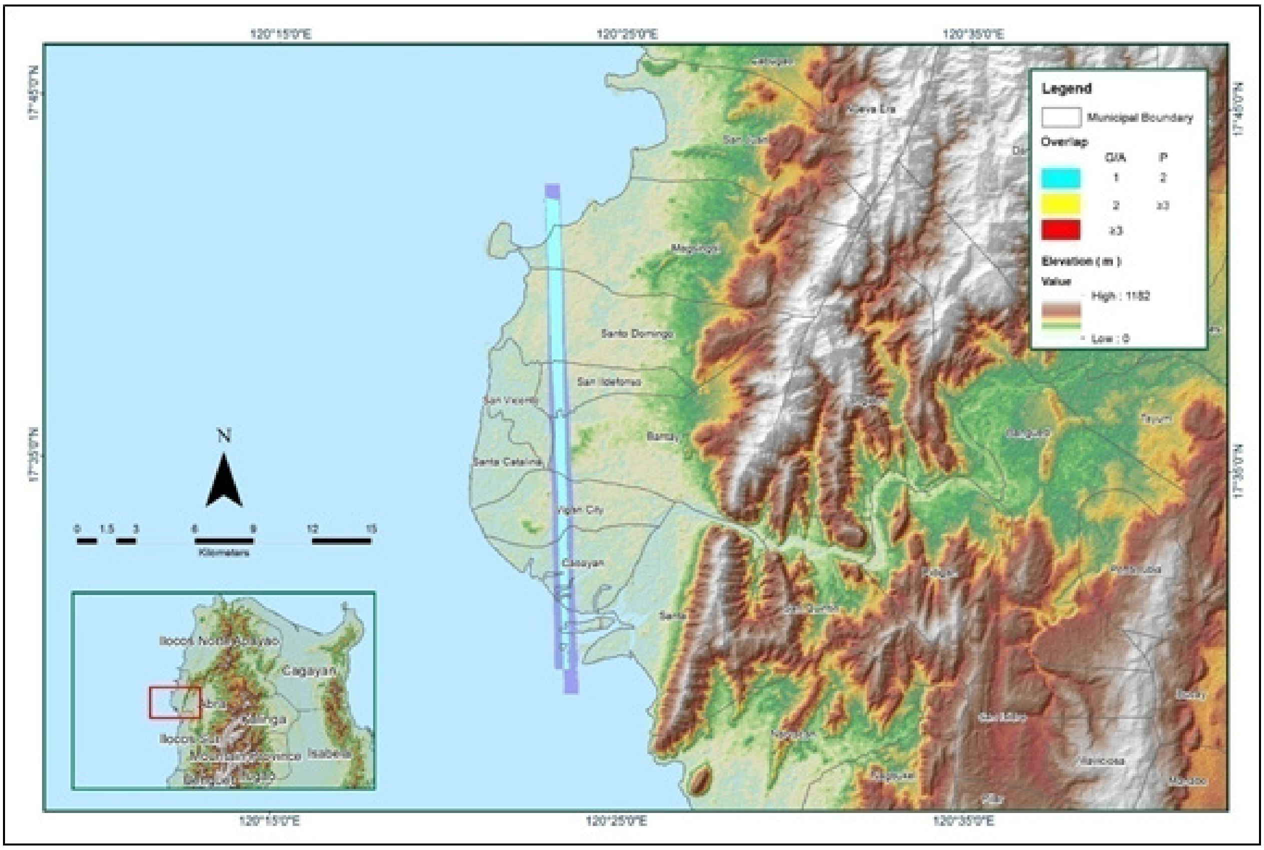


Figure A-8.19. Image of Data Overlap

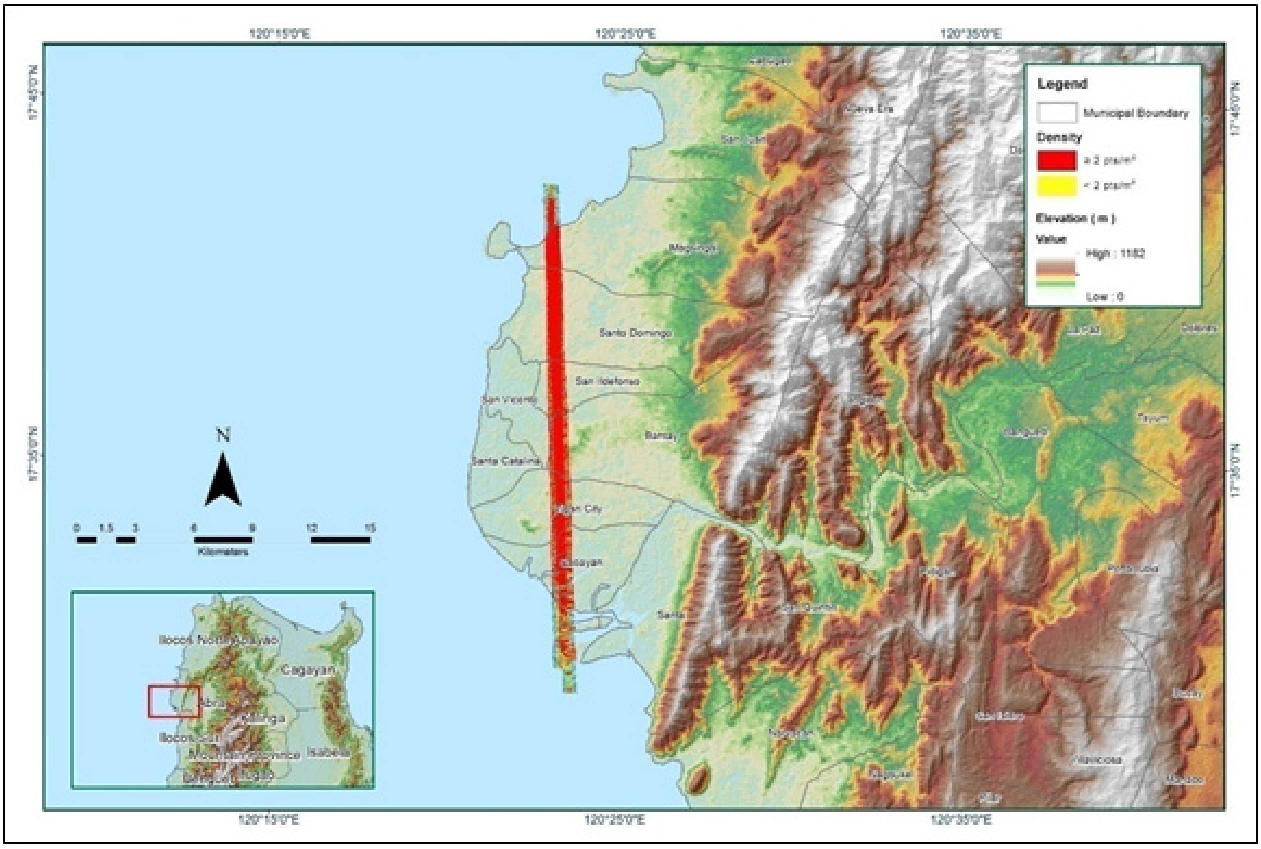


Figure A-8.20. Density map of merged LiDAR data

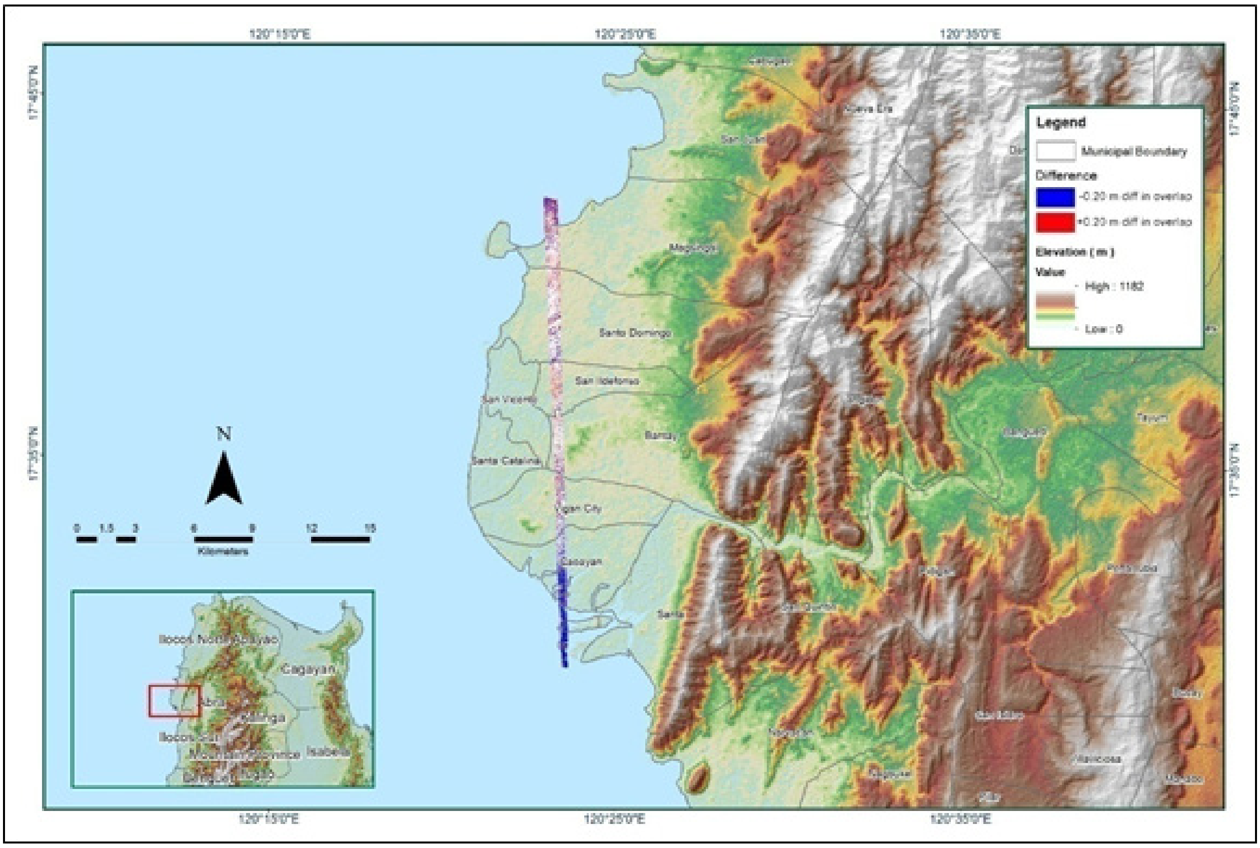


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk06D_supplement

Flight Area	Ilocos
Mission Name	Blk06D_supplement
Inclusive Flights	7112GC
Range data size	18.5GB
Base data size	11.4 MB
POS	247MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.4
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	8.3
Boresight correction stdev (<0.001deg)	0.000189
IMU attitude correction stdev (<0.001deg)	0.000469
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	23.06%
Ave point cloud density per sq.m. (>2.0)	2.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	69
Maximum Height	111.0m
Minimum Height	39.19m
Classification (# of points)	
Ground	24,643,507
Low vegetation	26,932,911
Medium vegetation	21,221,451
High vegetation	18,057,824
Building	3,069,085
Orthophoto	NO
Processed by	Engr. Irish Cortez, Engr. Elainne Lopez, Engr. Jeffrey Delica

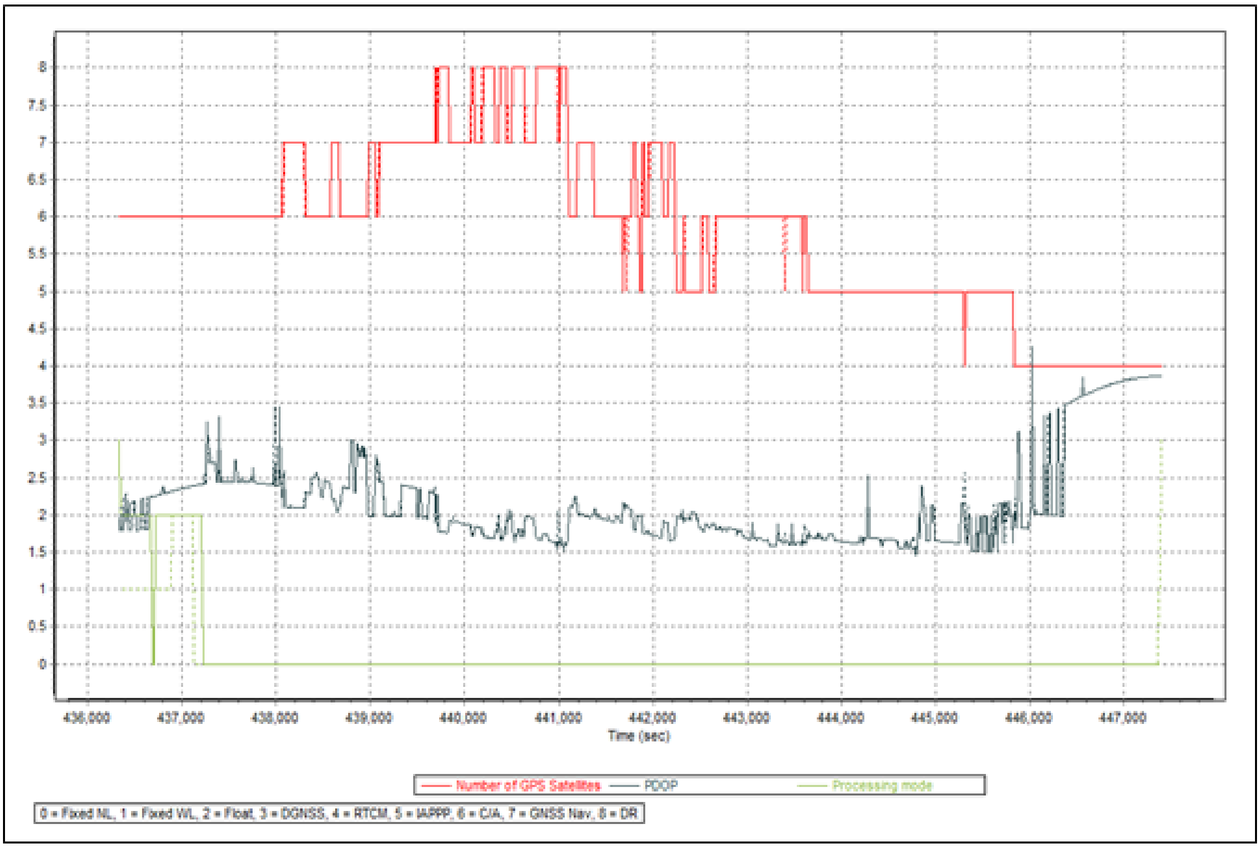


Figure A-8.22. Solution Status Parameters

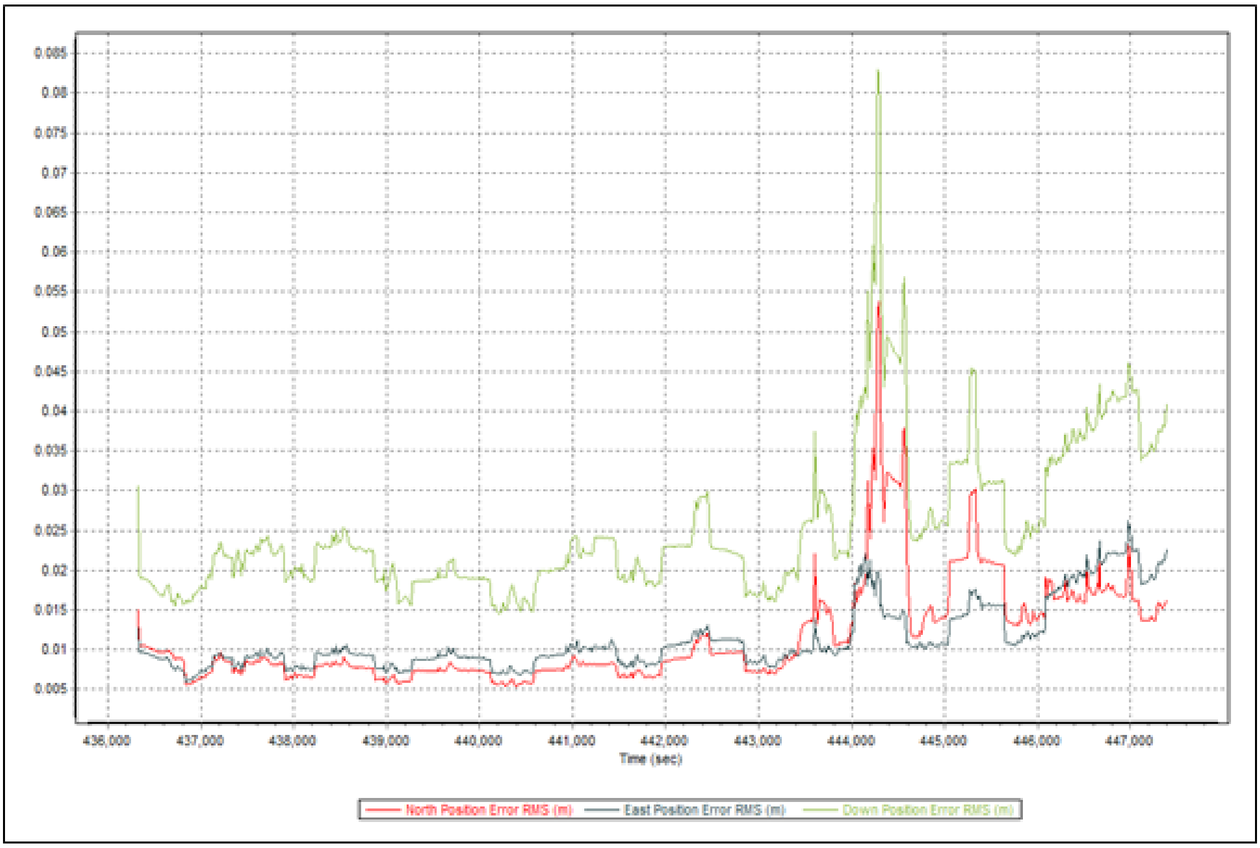


Figure A-8.23. Smoothed Performance Metrics Parameters

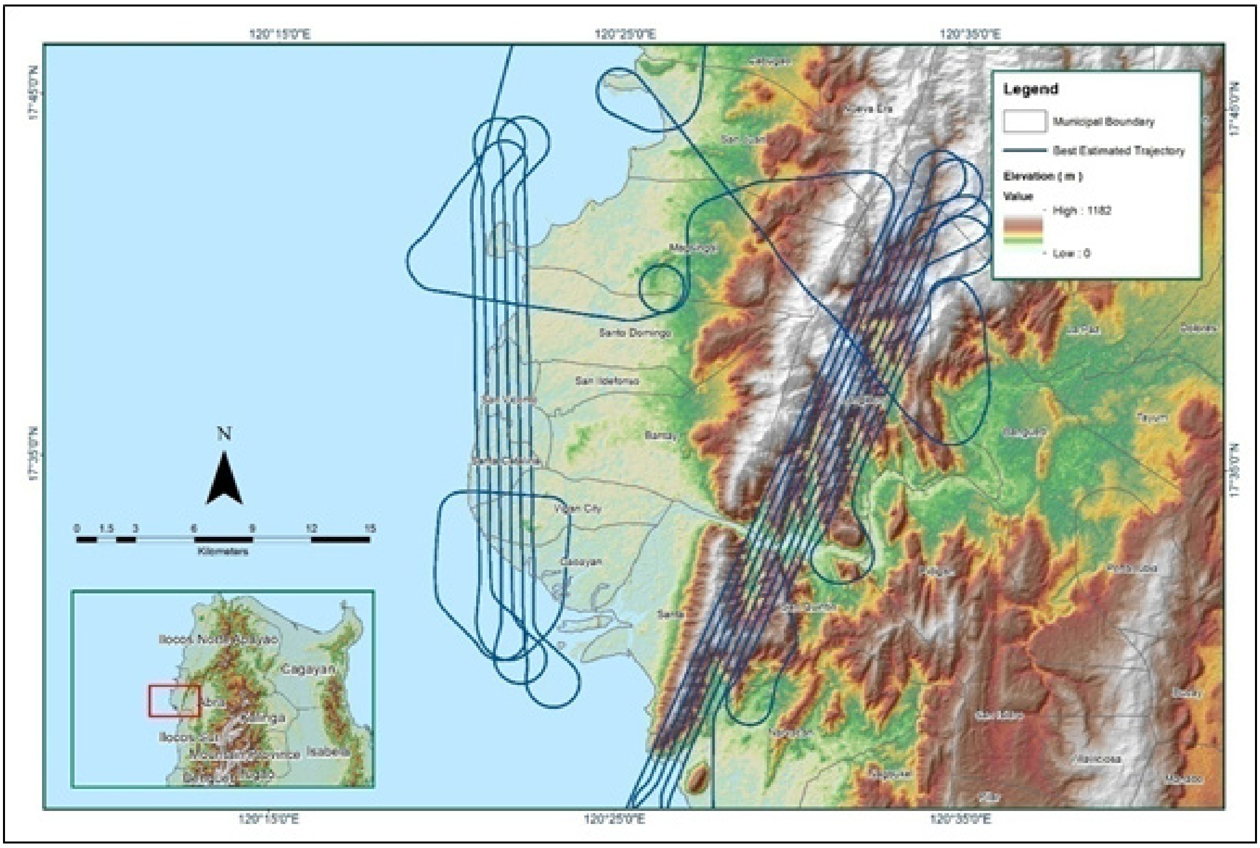


Figure A-8.24. Best Estimated Trajectory

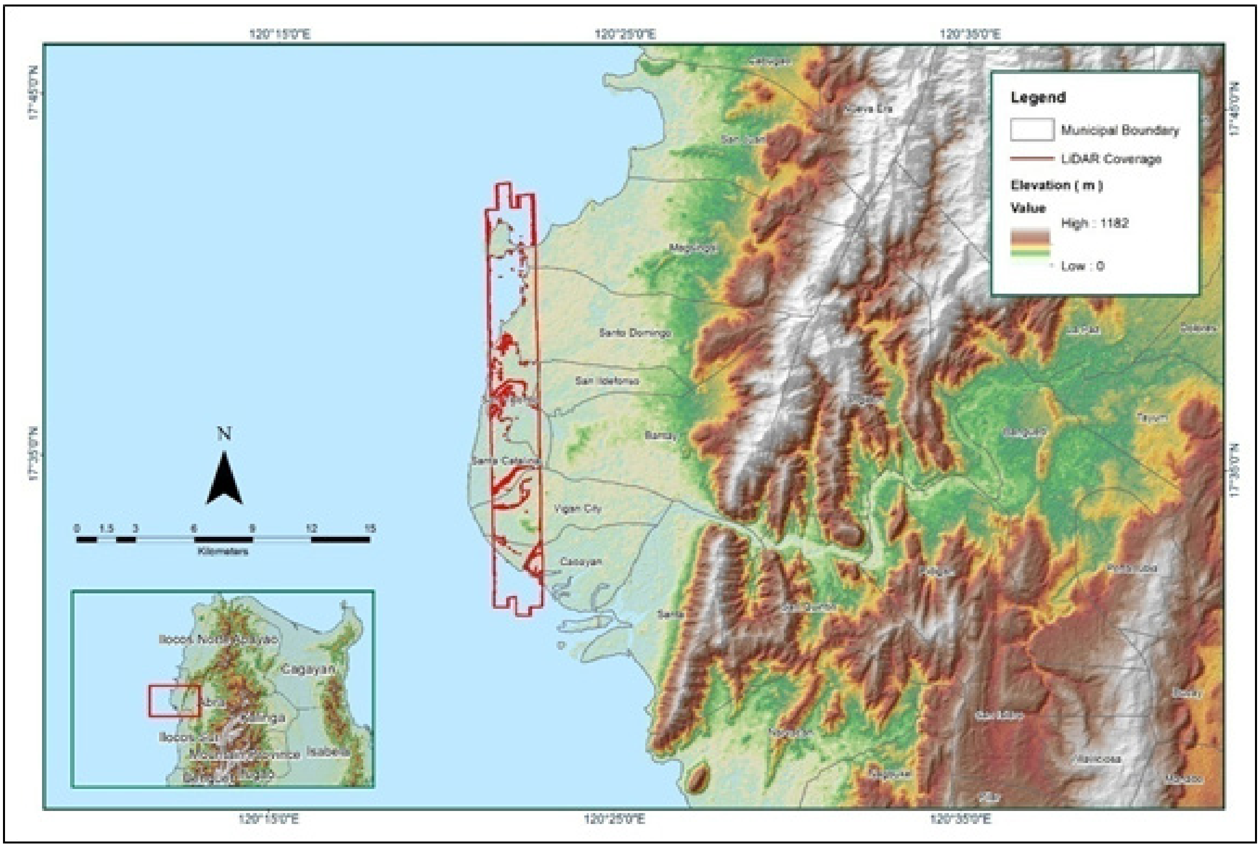


Figure A-8.25. Coverage of LiDAR data

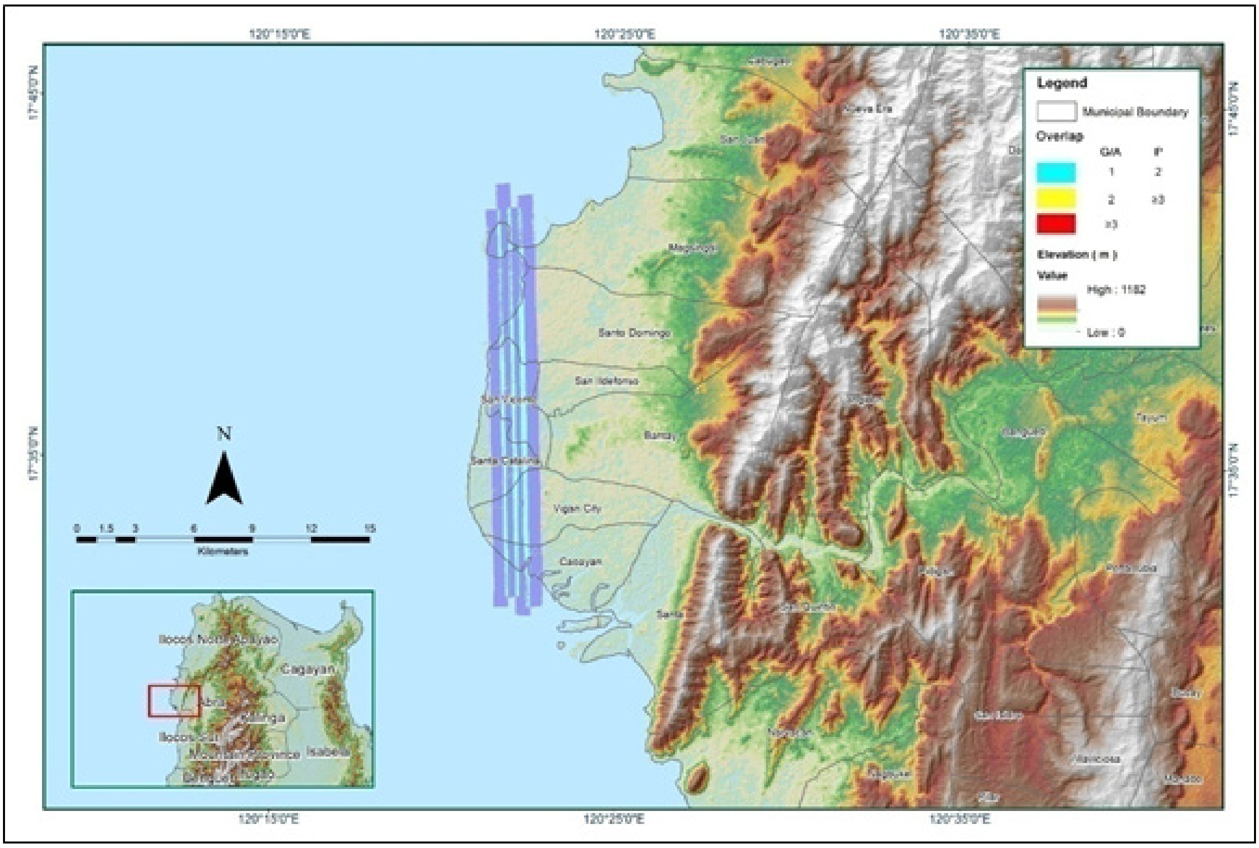


Figure A-8.26. Image of Data Overlap

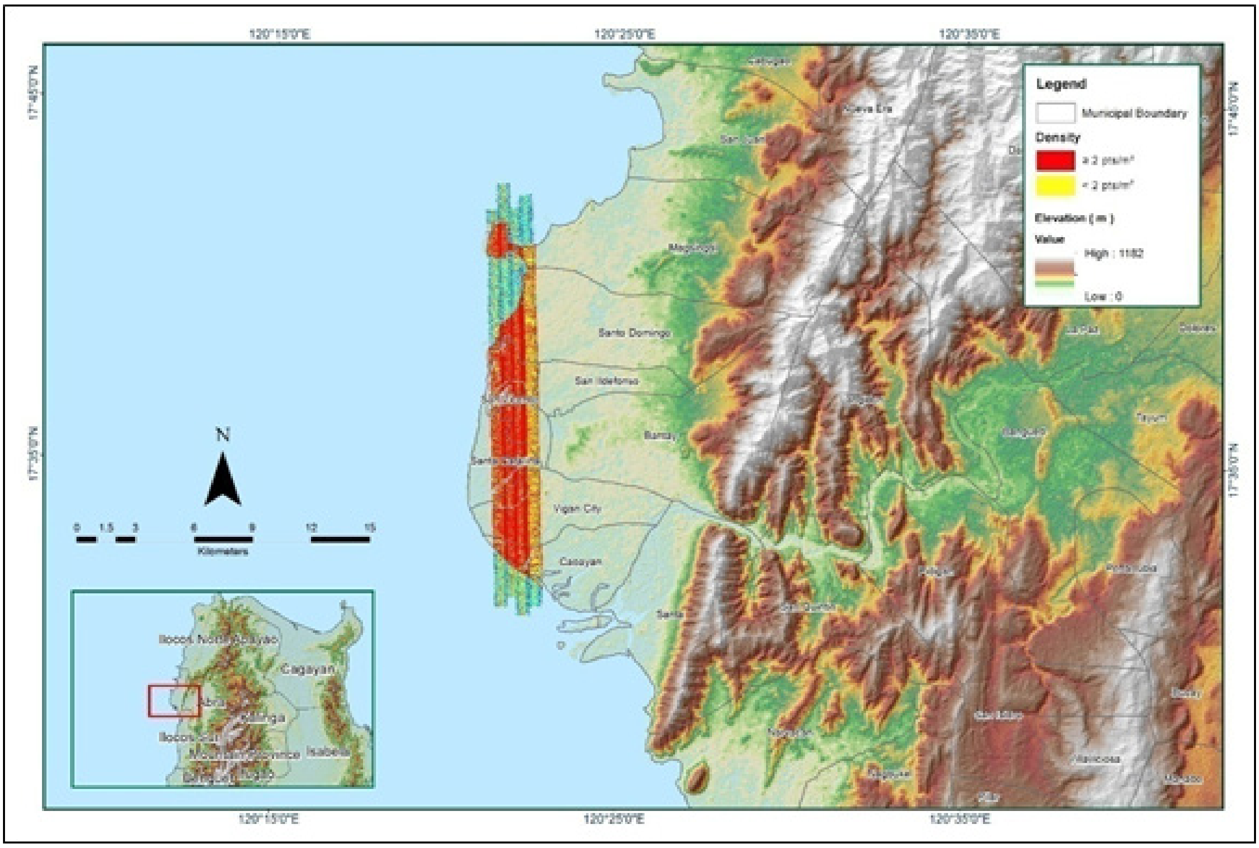


Figure A-8.27. Density map of merged LiDAR data

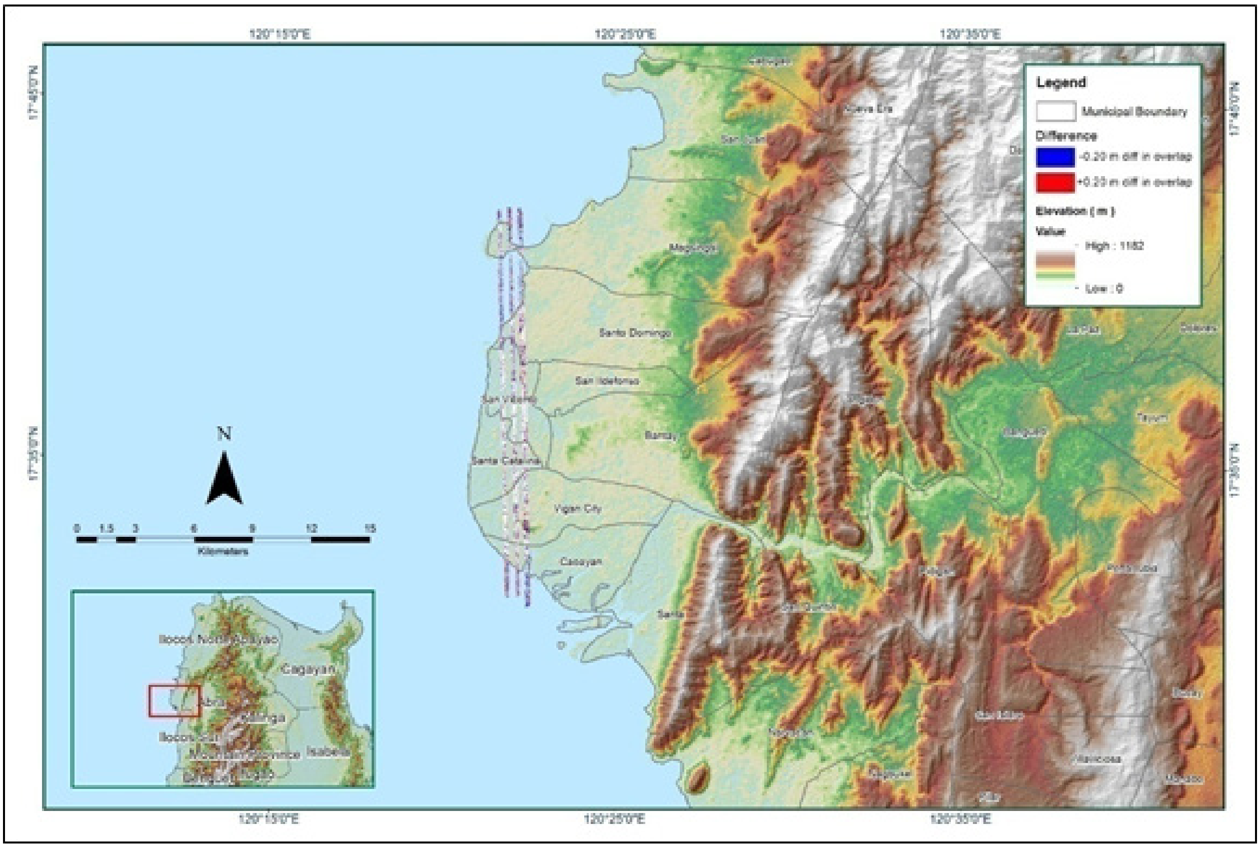


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk06F

Flight Area	Ilocos
Mission Name	Blk6F
Inclusive Flights	7120GC
Range data size	18GB
Base data size	11.2 MB
POS	251MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000244
IMU attitude correction stdev (<0.001deg)	0.003184
GPS position stdev (<0.01m)	0.0129
Minimum % overlap (>25)	40.64%
Ave point cloud density per sq.m. (>2.0)	2.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	824.2m
Minimum Height	40.64m
Classification (# of points)	
Ground	26,991,026
Low vegetation	14,669,095
Medium vegetation	32,965,049
High vegetation	84,682,898
Building	1,196,488
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr, Engr. Elainne Lopez

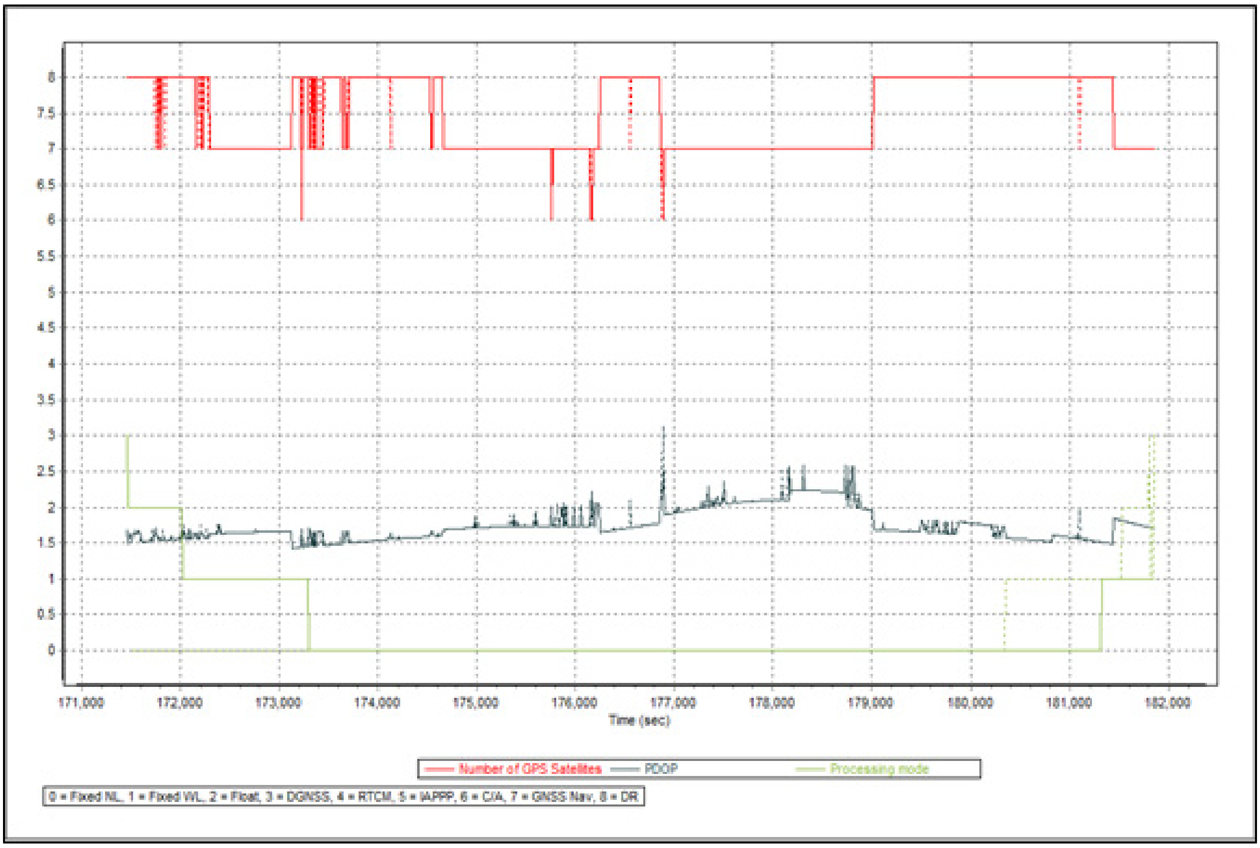


Figure A-8.29. Solution Status Parameters

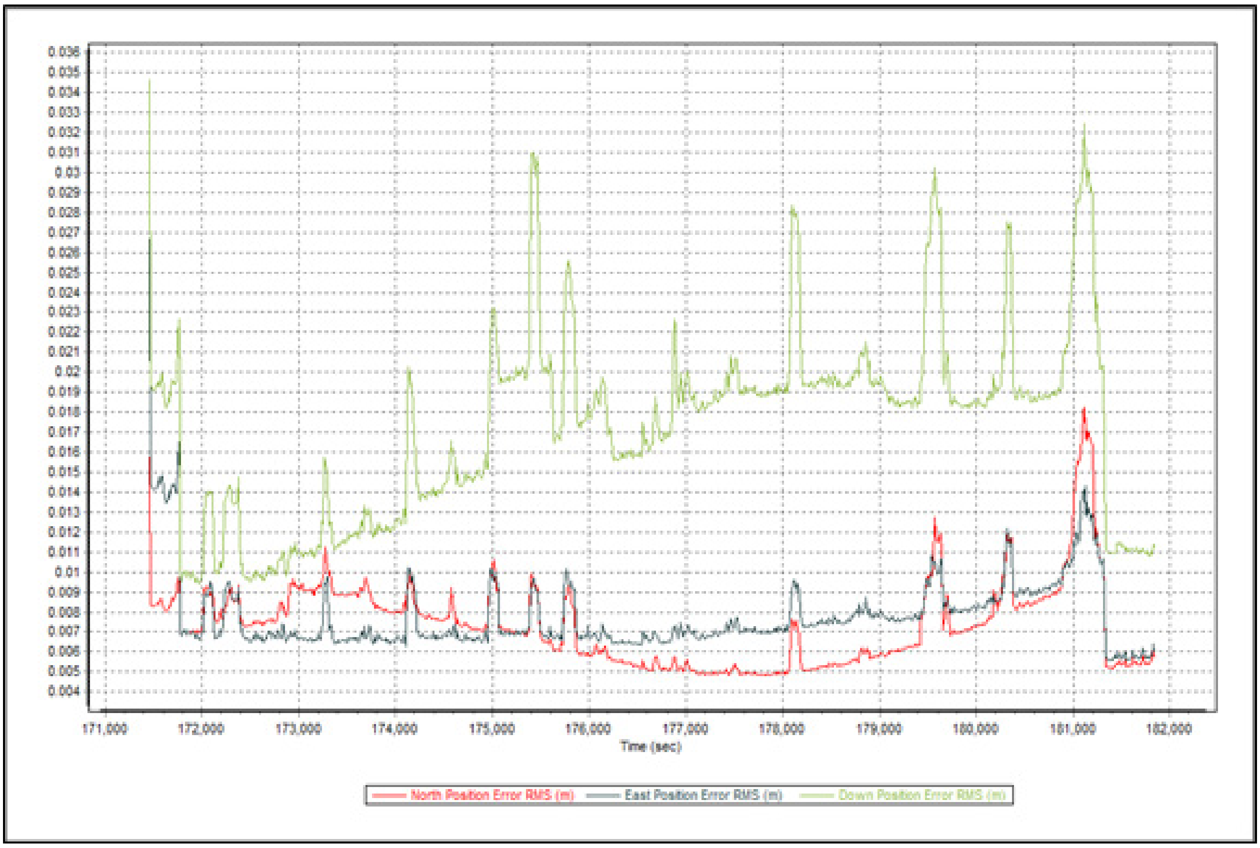


Figure A-8.30. Smoothed Performance Metrics Parameters

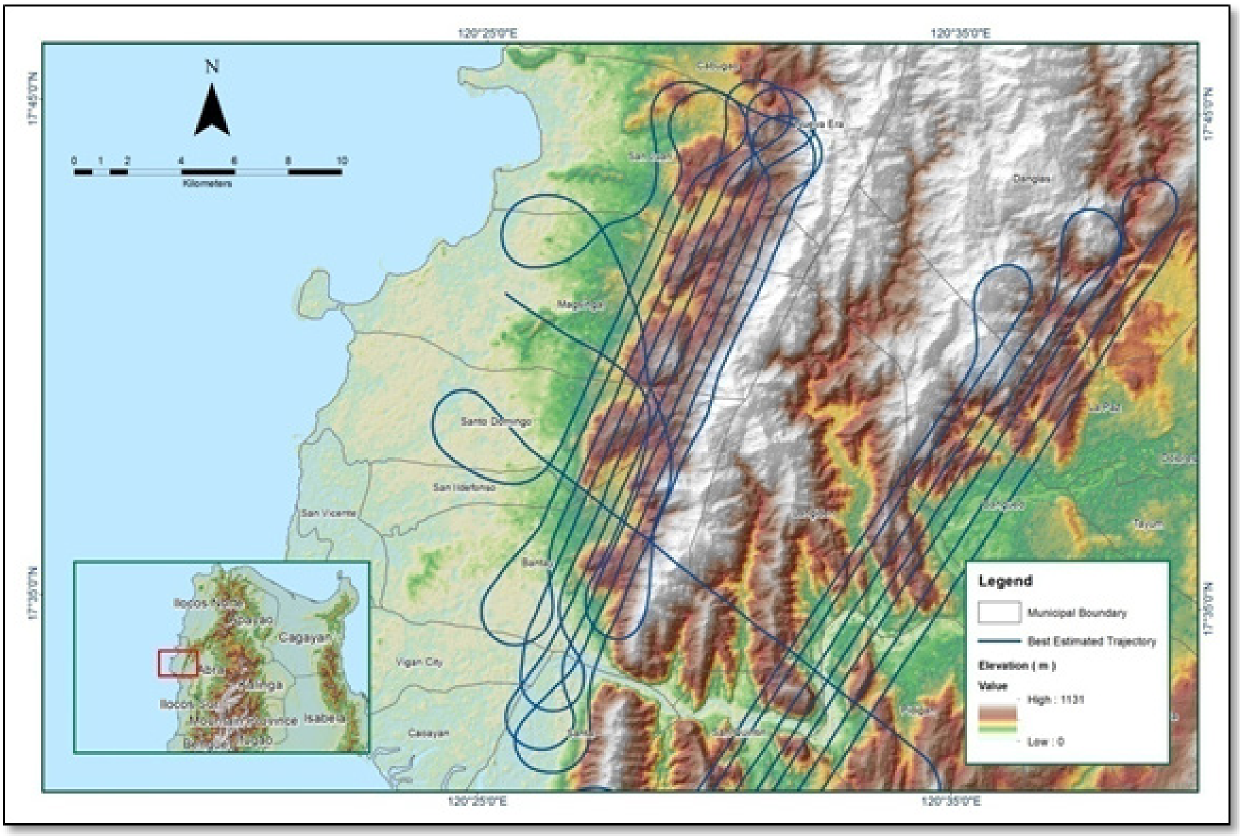


Figure A-8.31. Best Estimated Trajectory

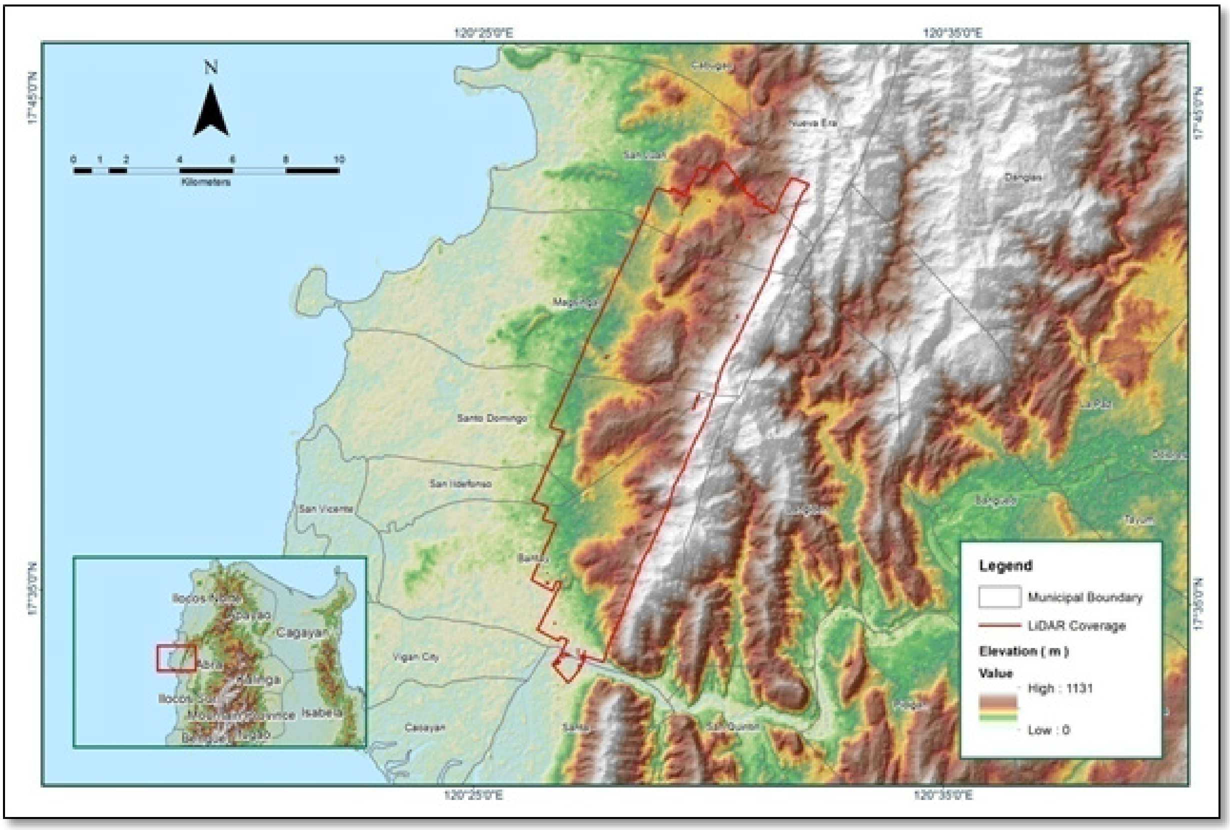


Figure A-8.32. Coverage of LiDAR data

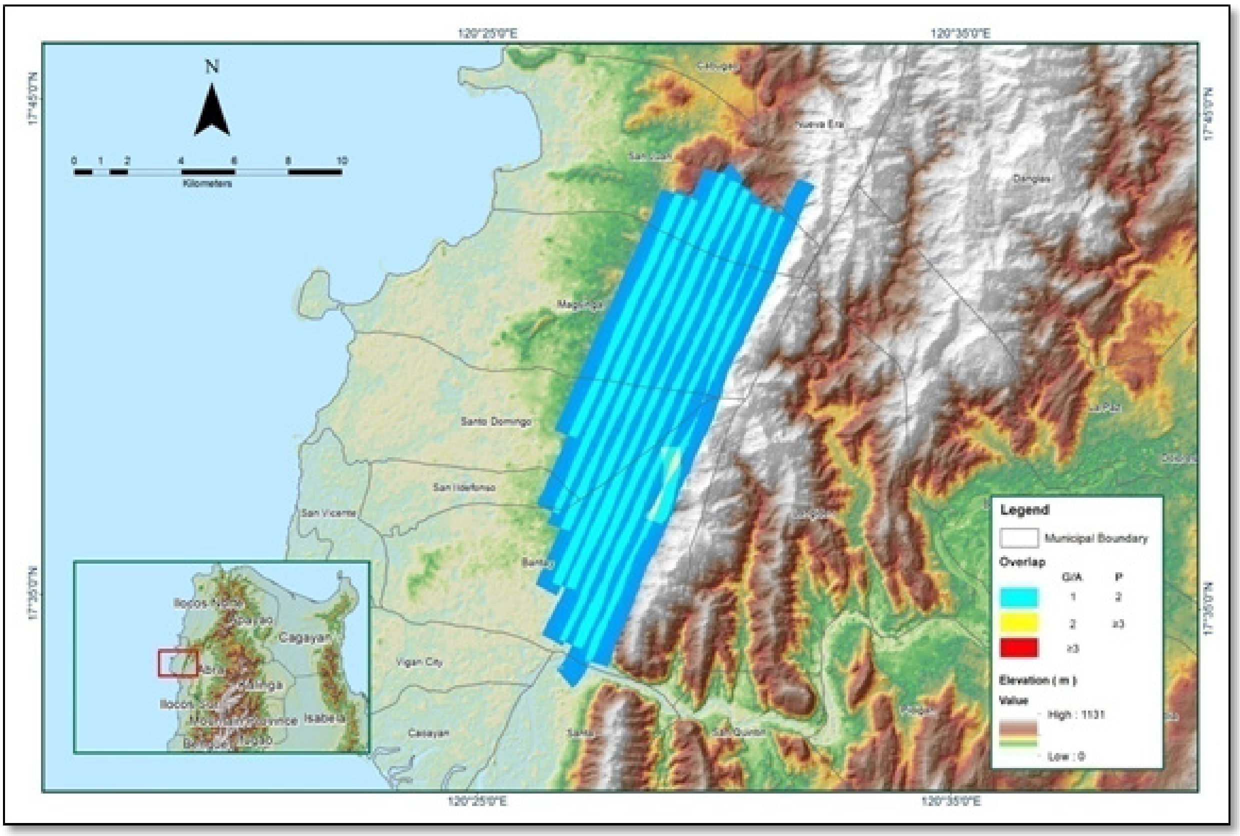


Figure A-8.33. Image of Data Overlap

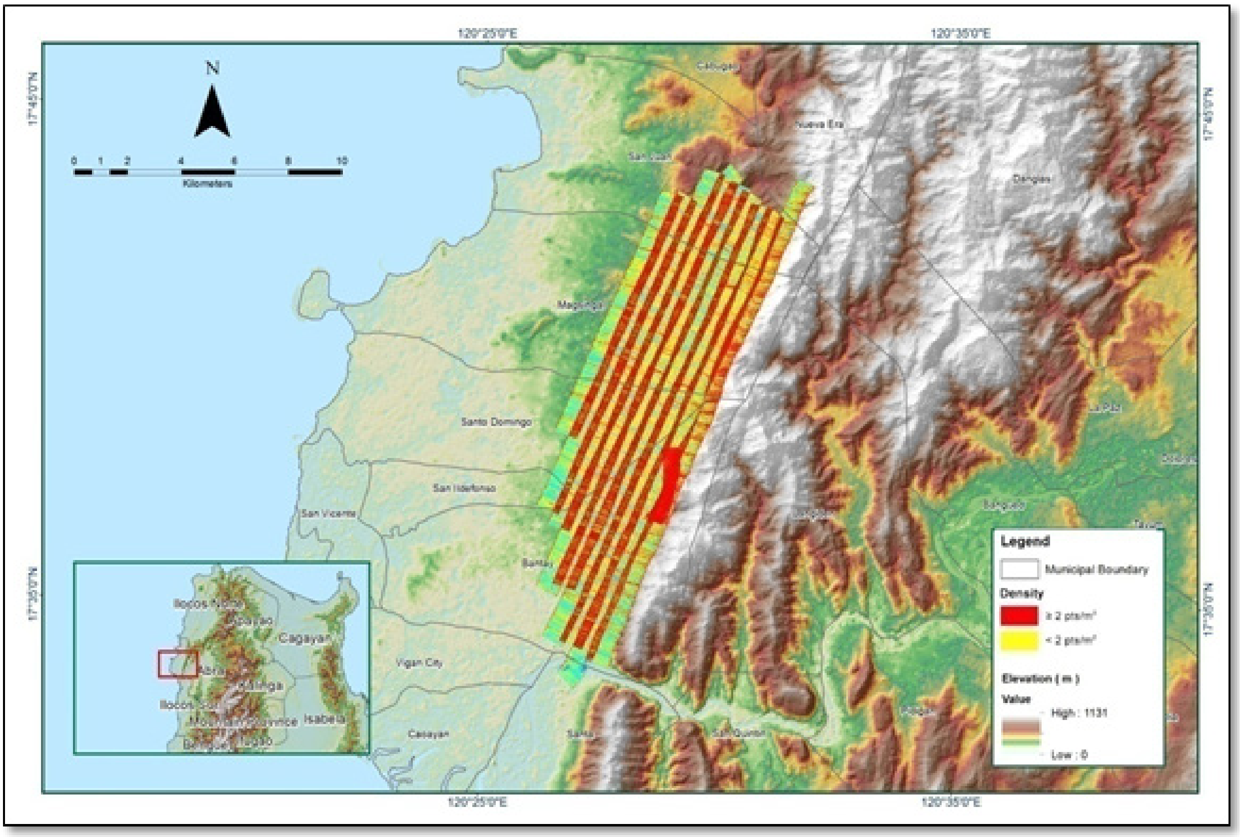


Figure A-8.34. Density map of merged LiDAR data

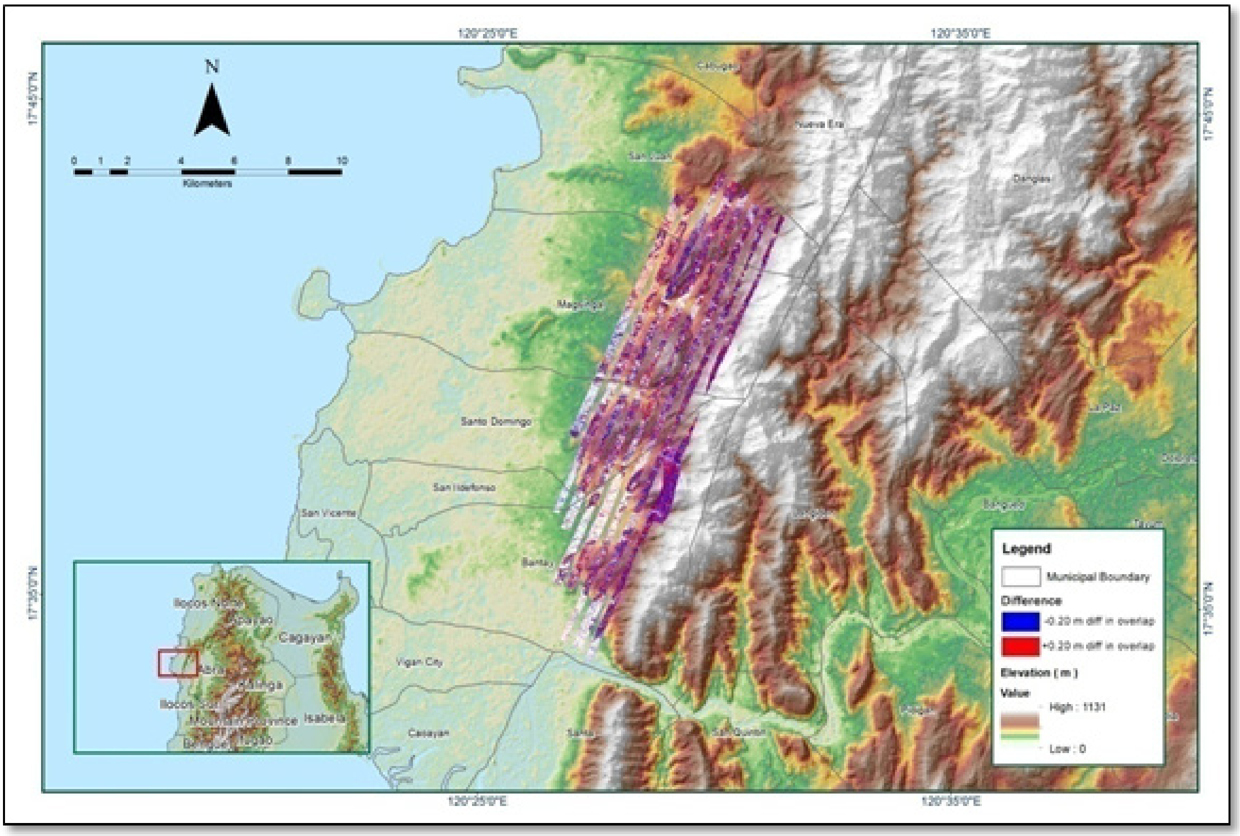


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk06G

Flight Area	Ilocos
Mission Name	Blk6G
Inclusive Flights	7112GC
Range data size	18.5 GB
Base data size	11.4 MB
POS	247 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.3
RMSE for East Position (<4.0 cm)	2.6
RMSE for Down Position (<8.0 cm)	8.3
Boresight correction stdev (<0.001deg)	0.000189
IMU attitude correction stdev (<0.001deg)	0.000469
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	63.15%
Ave point cloud density per sq.m. (>2.0)	2.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	216
Maximum Height	794.29m
Minimum Height	38.75m
Classification (# of points)	
Ground	52,020,781
Low vegetation	29,200,119
Medium vegetation	65,005,667
High vegetation	136,208,210
Building	2,063,864
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Jeffrey Delica

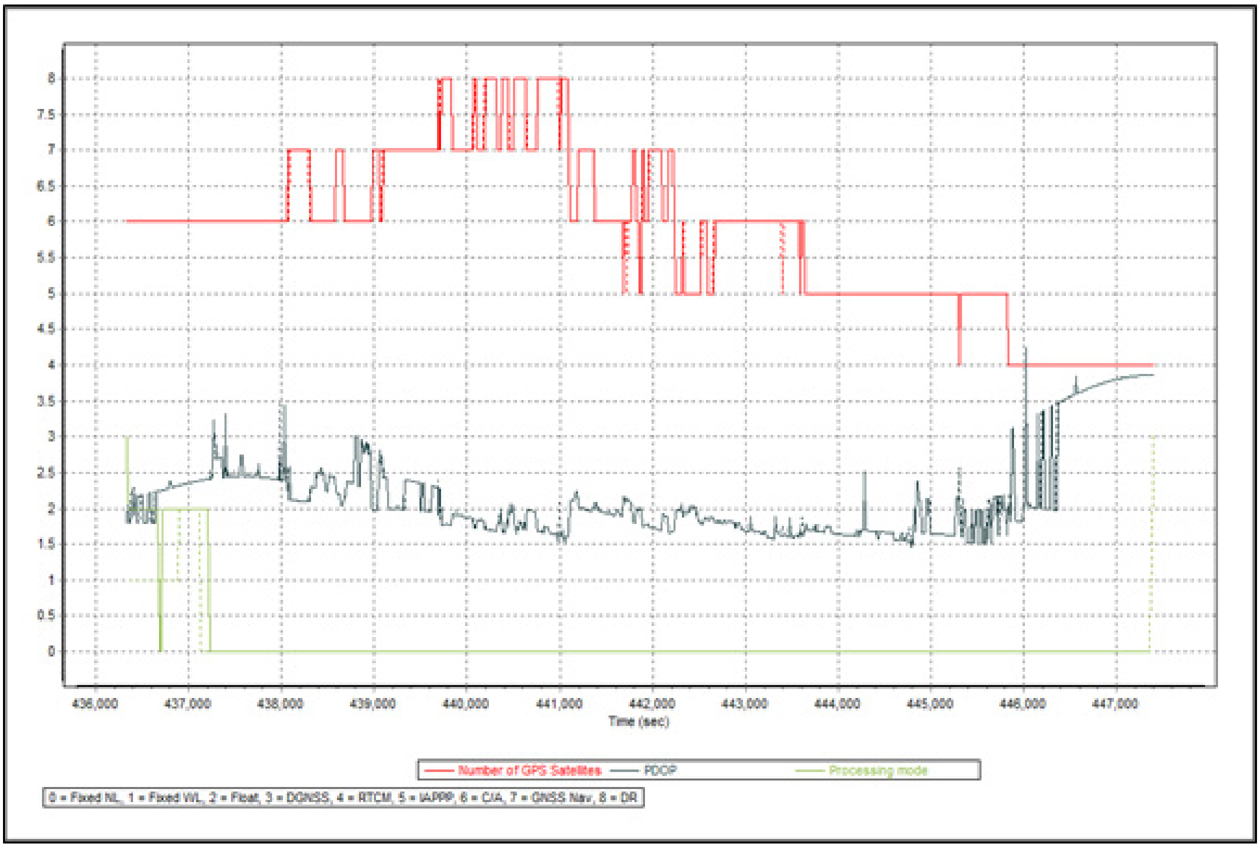


Figure A-8.36 Solution Status Parameters

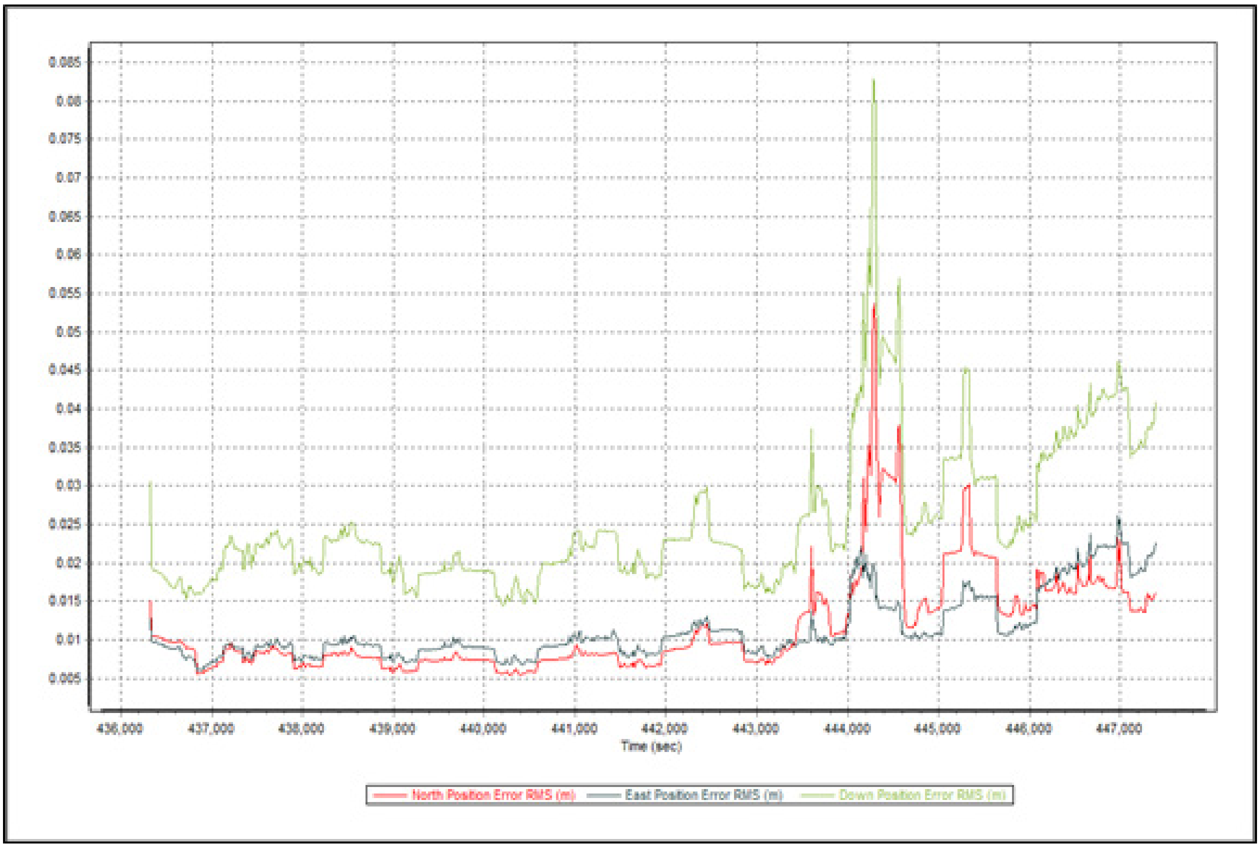


Figure A-8.37. Smoothed Performance Metrics Parameters

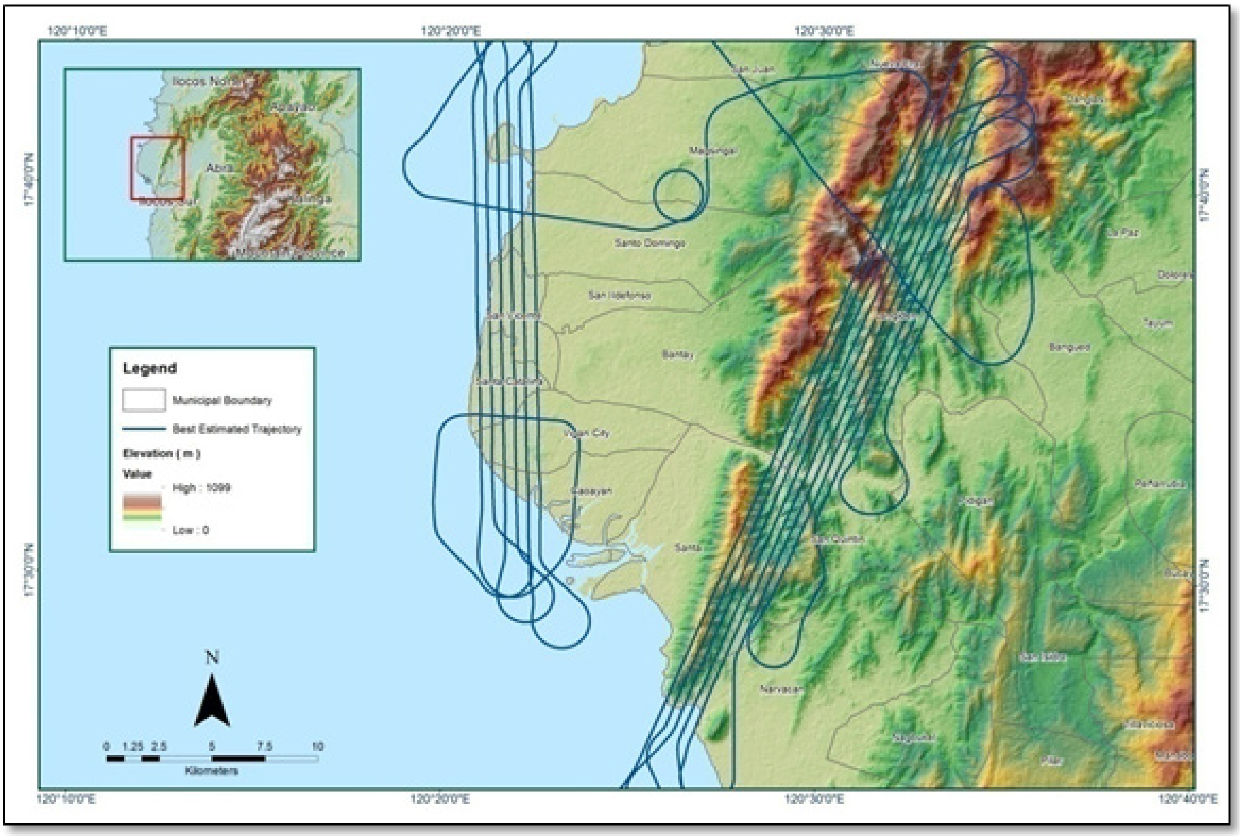


Figure A-8.38. Best Estimated Trajectory

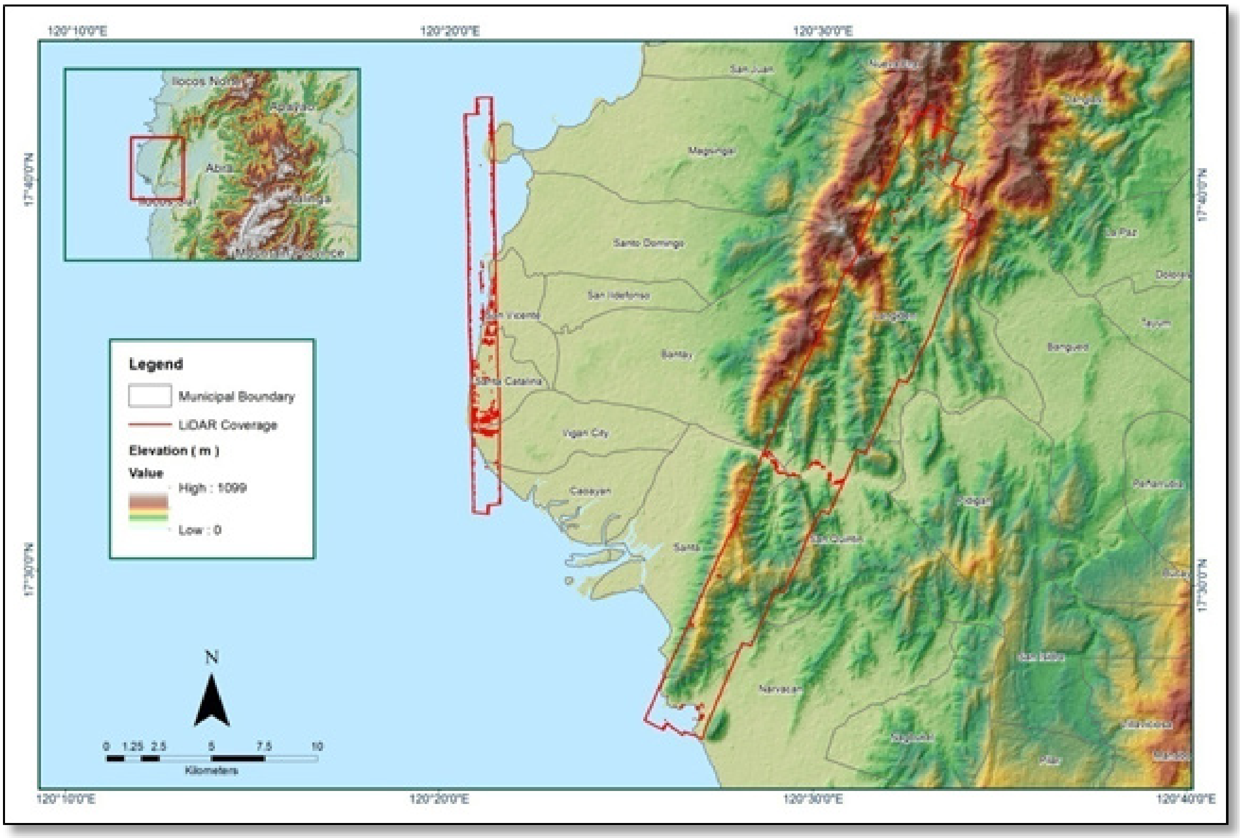


Figure A-8.39 Coverage of LiDAR data

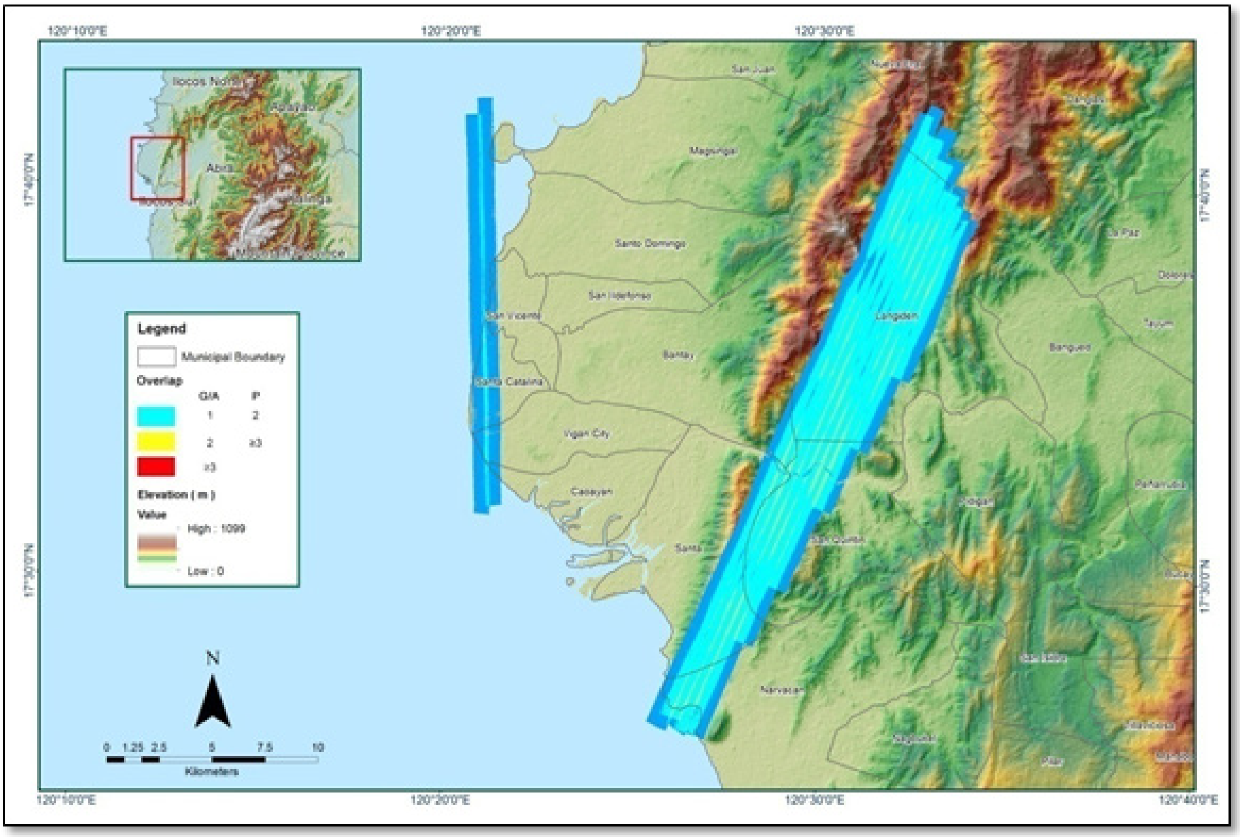


Figure A-8.40. Image of Data Overlap

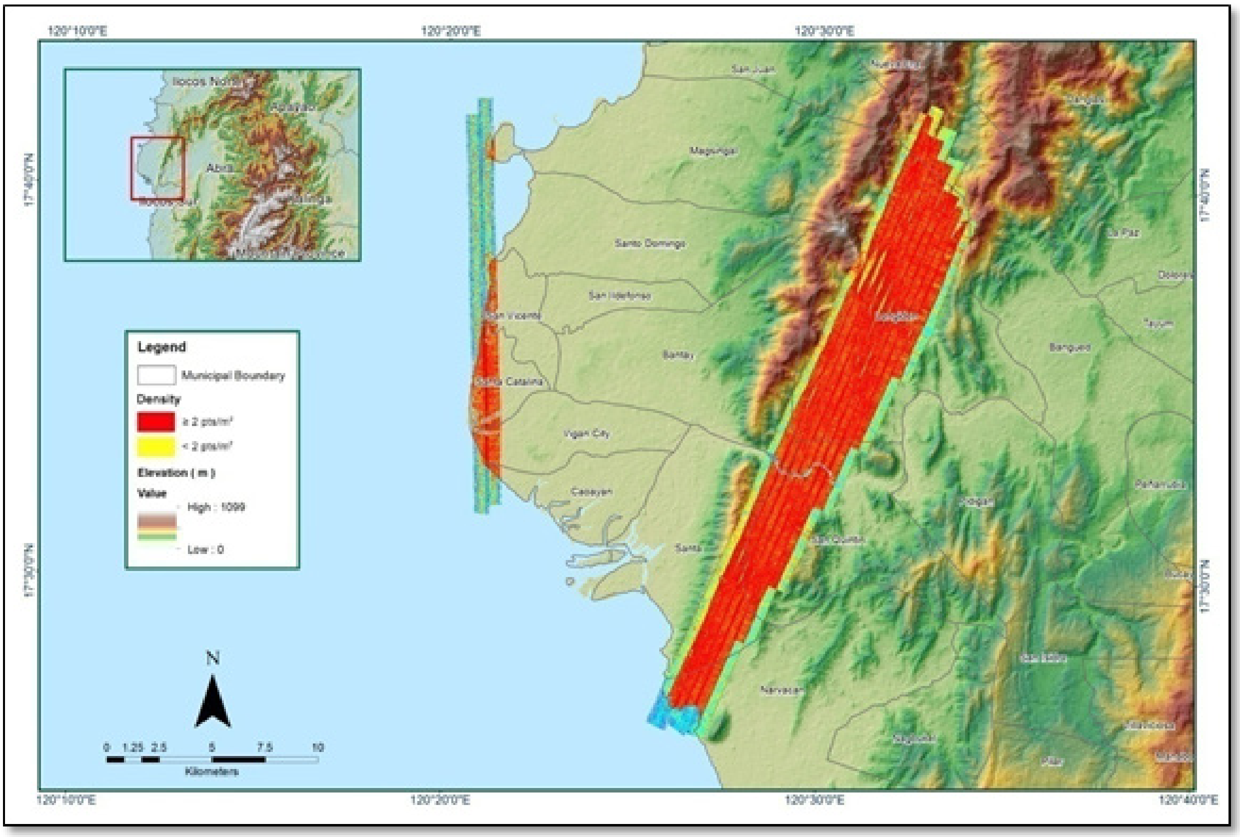


Figure A-8.41. Density map of merged LiDAR data

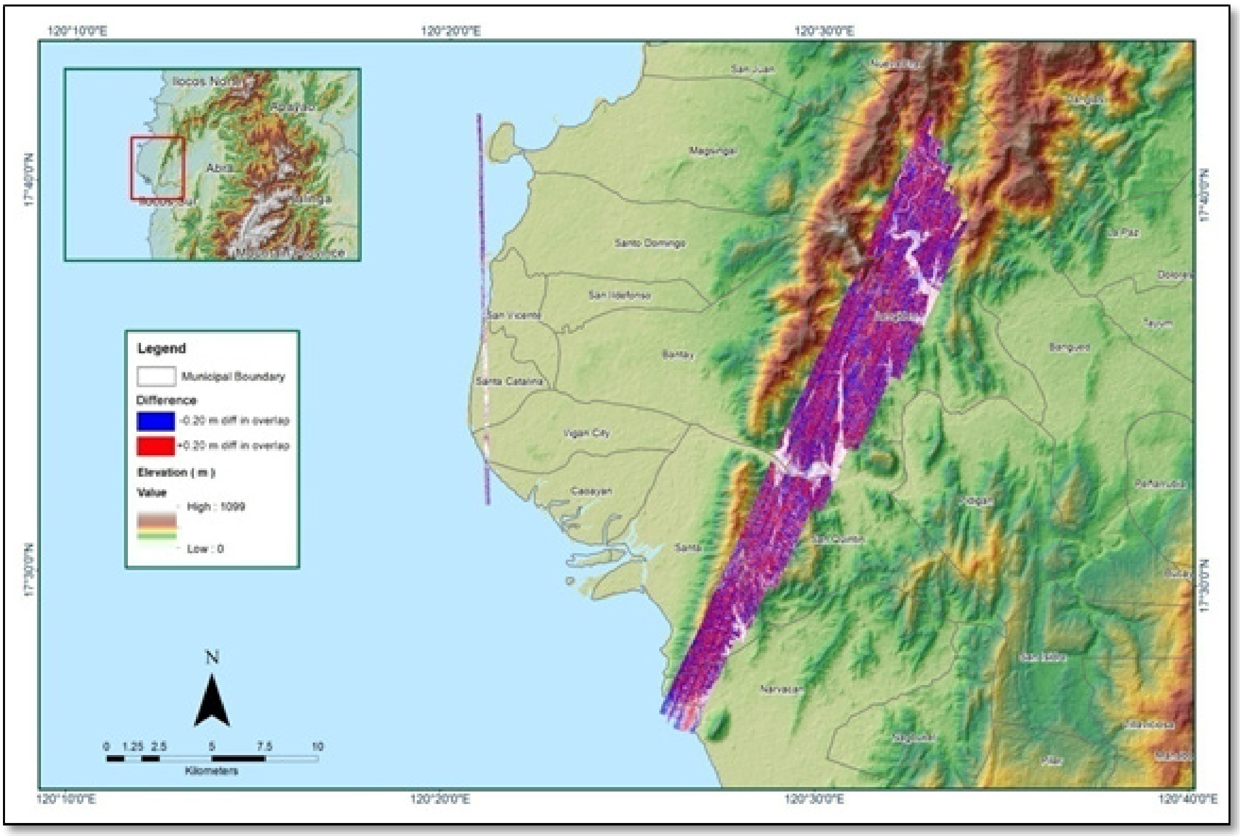


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk06G_supplement

Flight Area	Ilocos
Mission Name	Blk6G_supplement
Inclusive Flights	7114GC
Range data size	19.3 GB
Base data size	8.45 MB
POS	264 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000275
IMU attitude correction stdev (<0.001deg)	0.000712
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	57.53%
Ave point cloud density per sq.m. (>2.0)	2.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	147
Maximum Height	1,139.55m
Minimum Height	22.81m
Classification (# of points)	
Ground	24,231,930
Low vegetation	11,868,541
Medium vegetation	27,741,531
High vegetation	11,6178,031
Building	1,616,209
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, EleynPama, Ryan James Nicholai Dizon

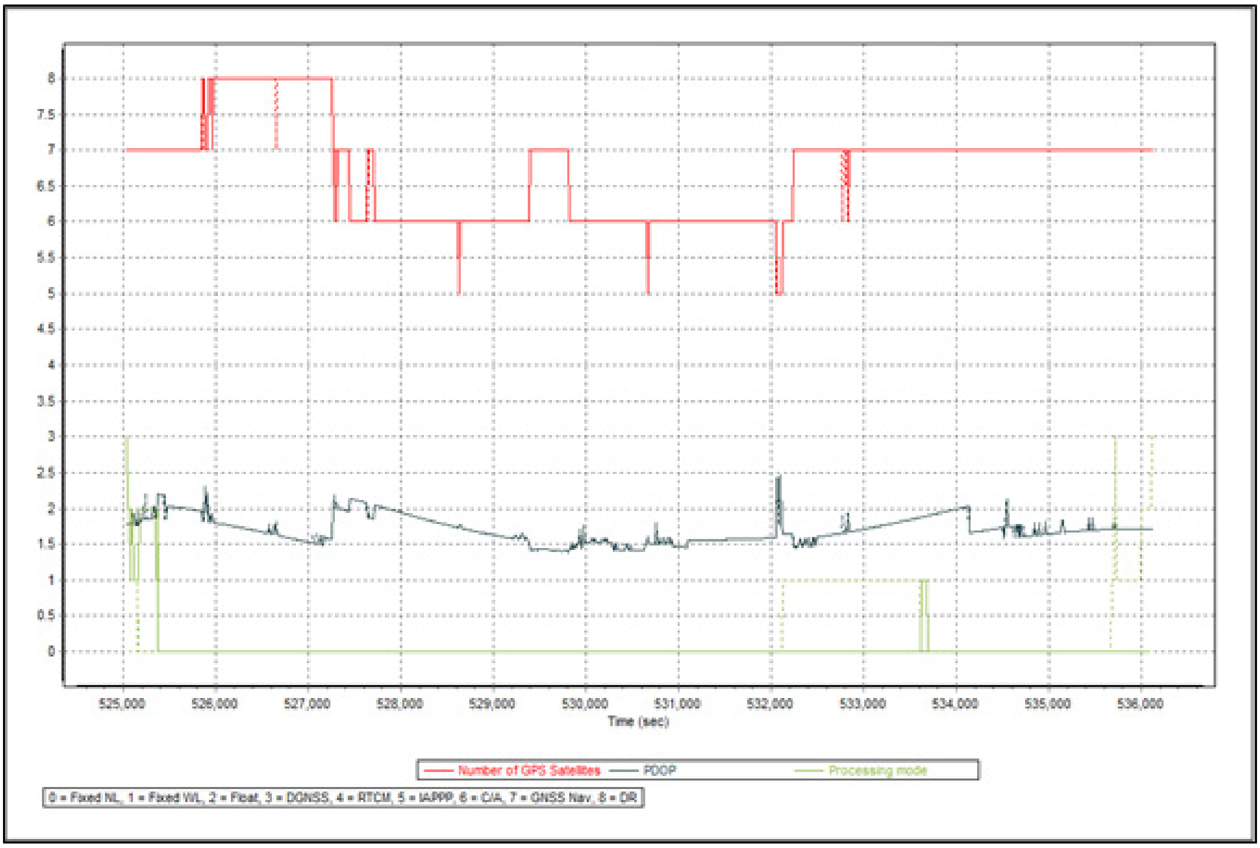


Figure A-8.43Solution Status Parameters

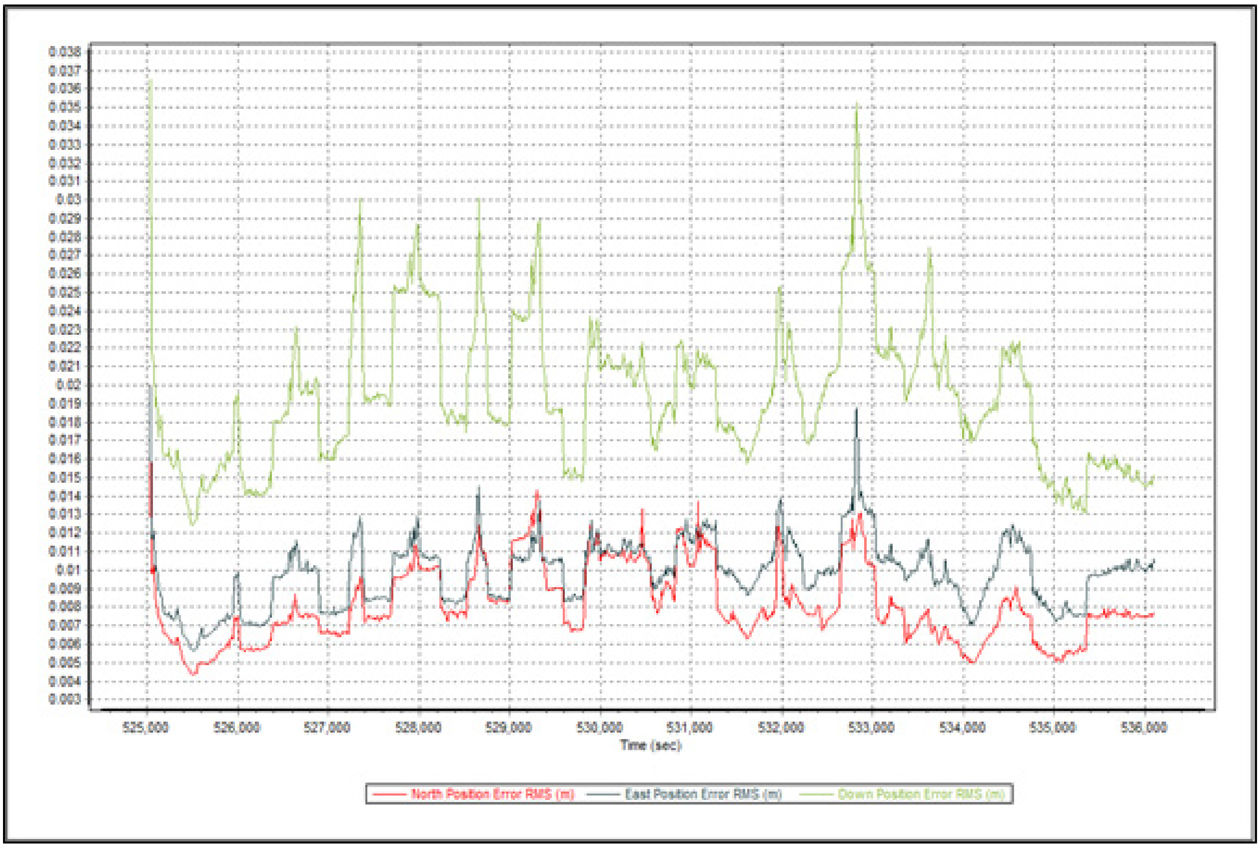


Figure A-8.44. Smoothed Performance Metrics Parameters

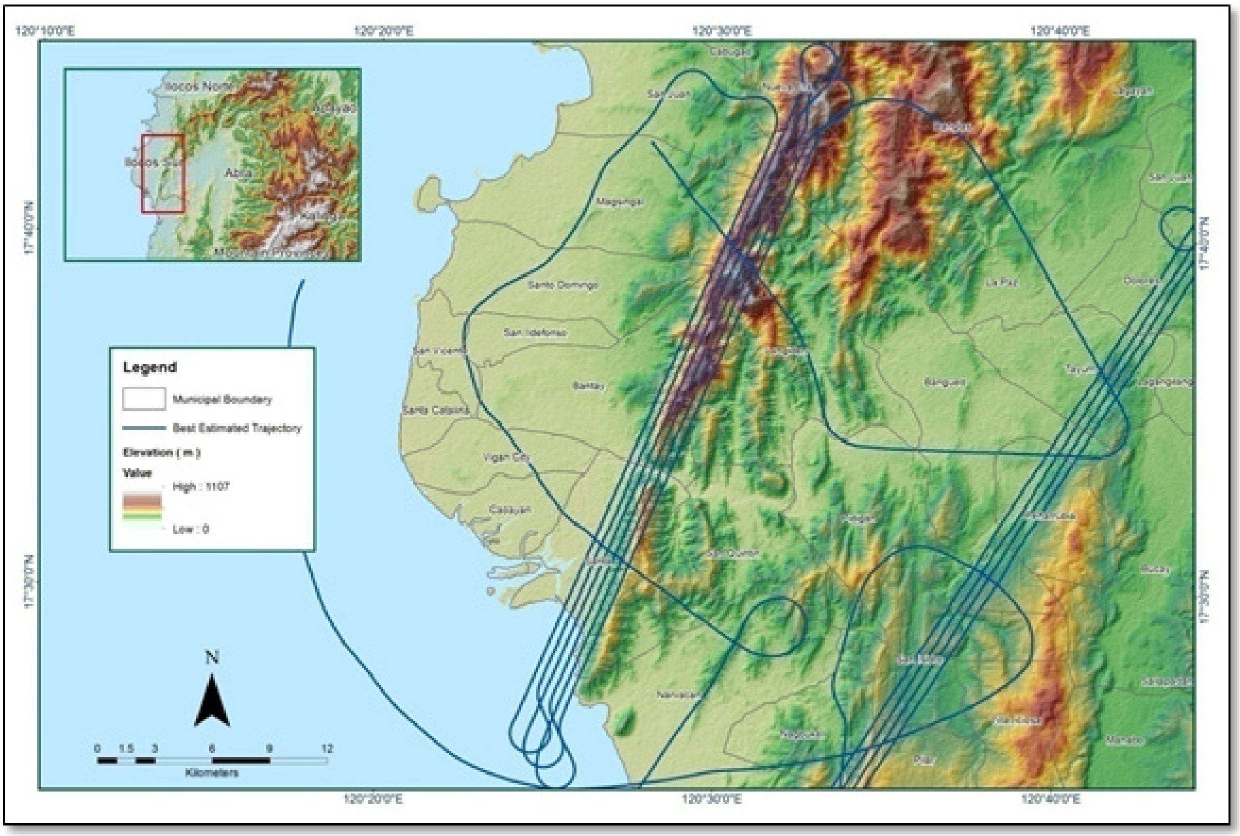


Figure A-8.45. Best Estimated Trajectory

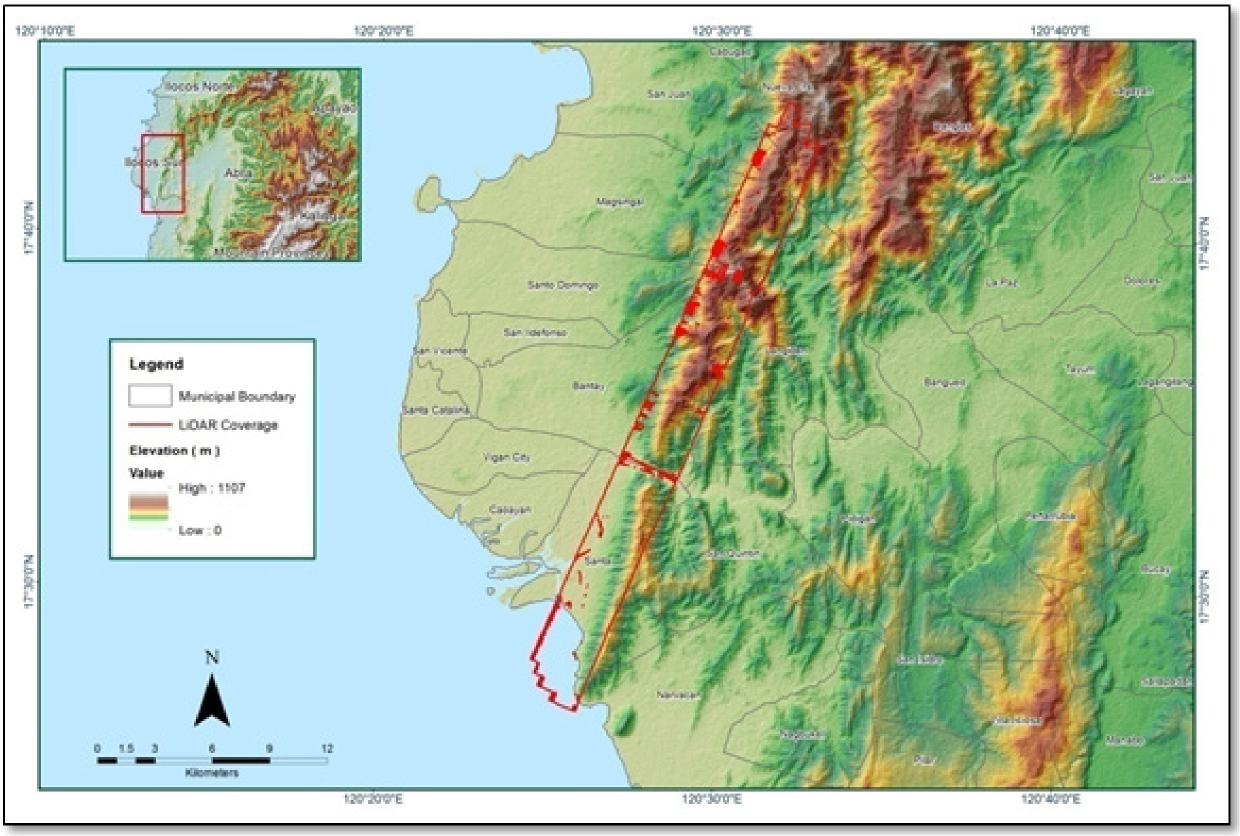


Figure A-8.46 Coverage of LiDAR data

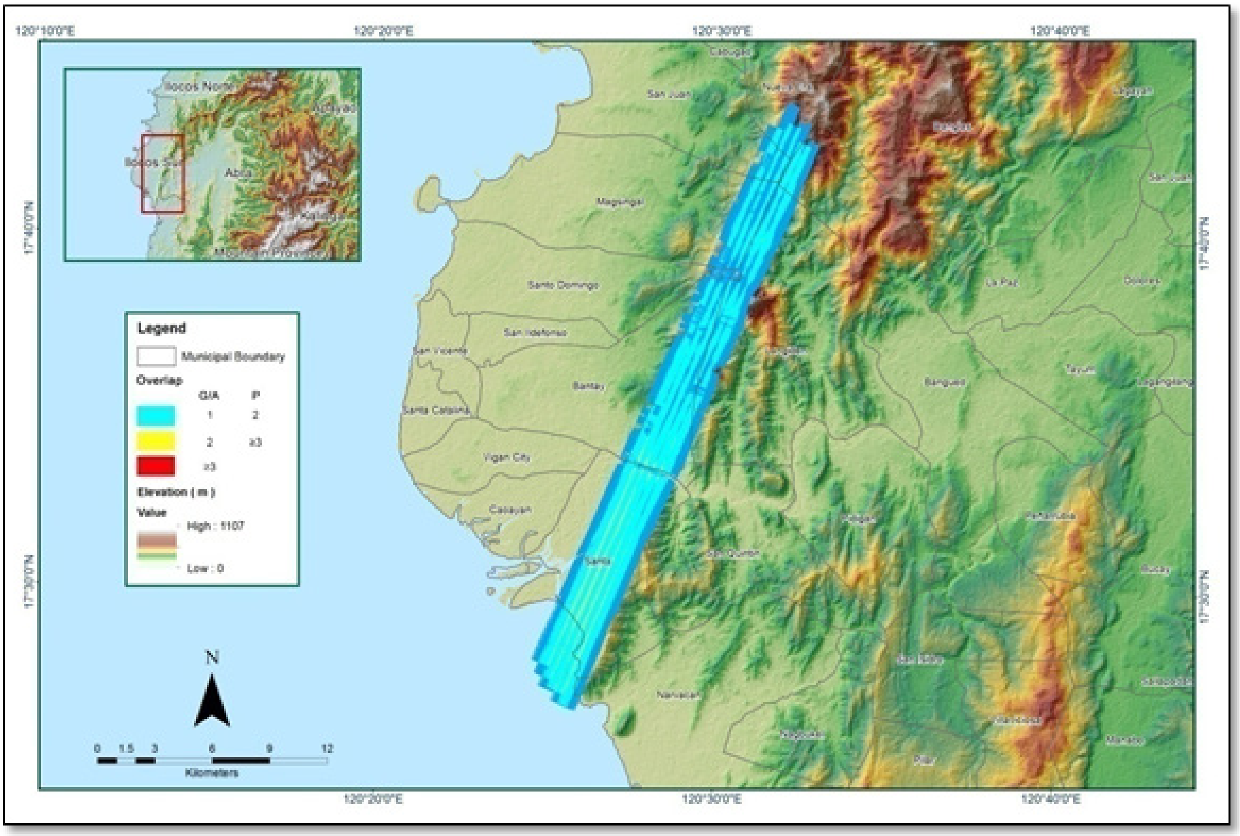


Figure A-8.47. Image of Data Overlap

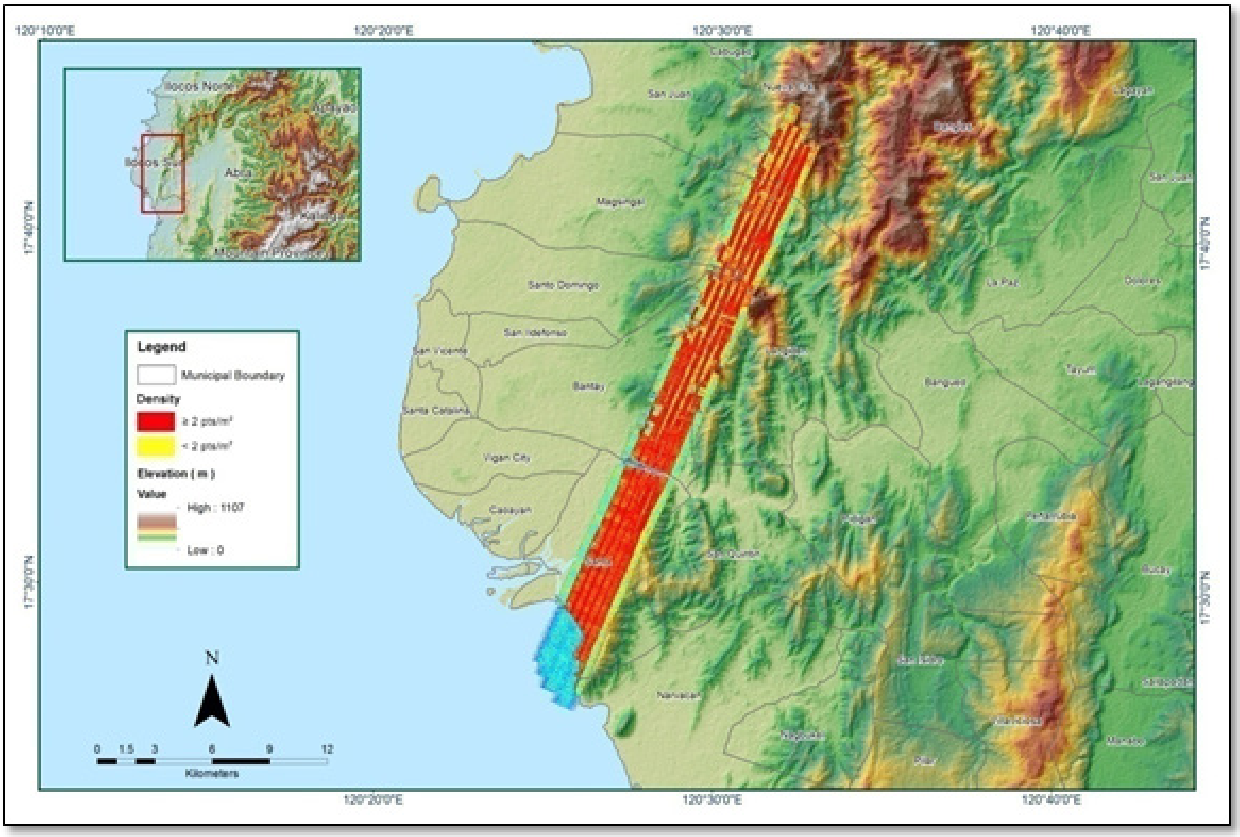


Figure A-8.48. Density map of merged LiDAR data

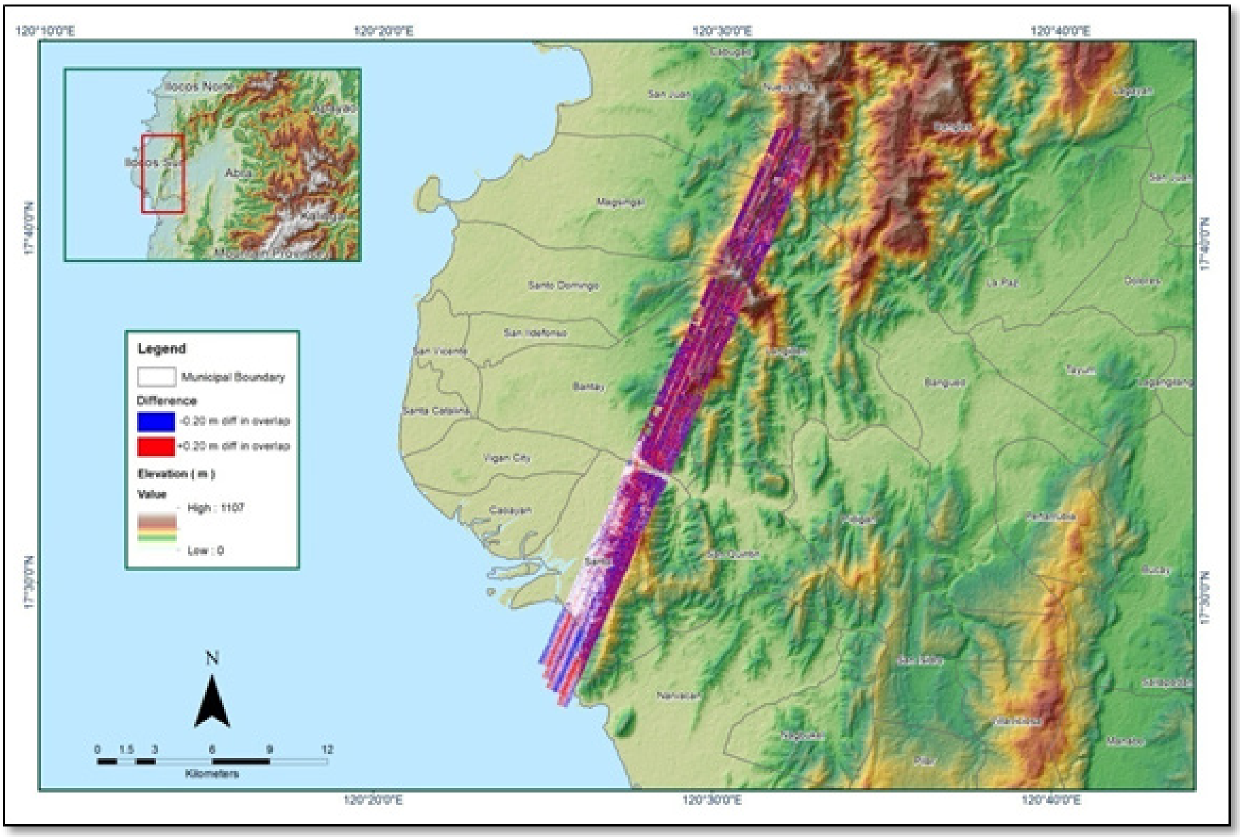


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk07A

Flight Area	Ilocos
Mission Name	Blk7A
Inclusive Flights	7120GC
Range data size	18 GB
Base data size	11.2 MB
POS	251 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000244
IMU attitude correction stdev (<0.001deg)	0.003184
GPS position stdev (<0.01m)	0.0129
Minimum % overlap (>25)	24.10%
Ave point cloud density per sq.m. (>2.0)	1.73
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	234
Maximum Height	863.68m
Minimum Height	37.25m
Classification (# of points)	
Ground	66,515,289
Low vegetation	34,391,072
Medium vegetation	51,772,197
High vegetation	105,129,425
Building	2,192,095
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Mark Joshua Salvacion, Engr. Gladys Mae Apat

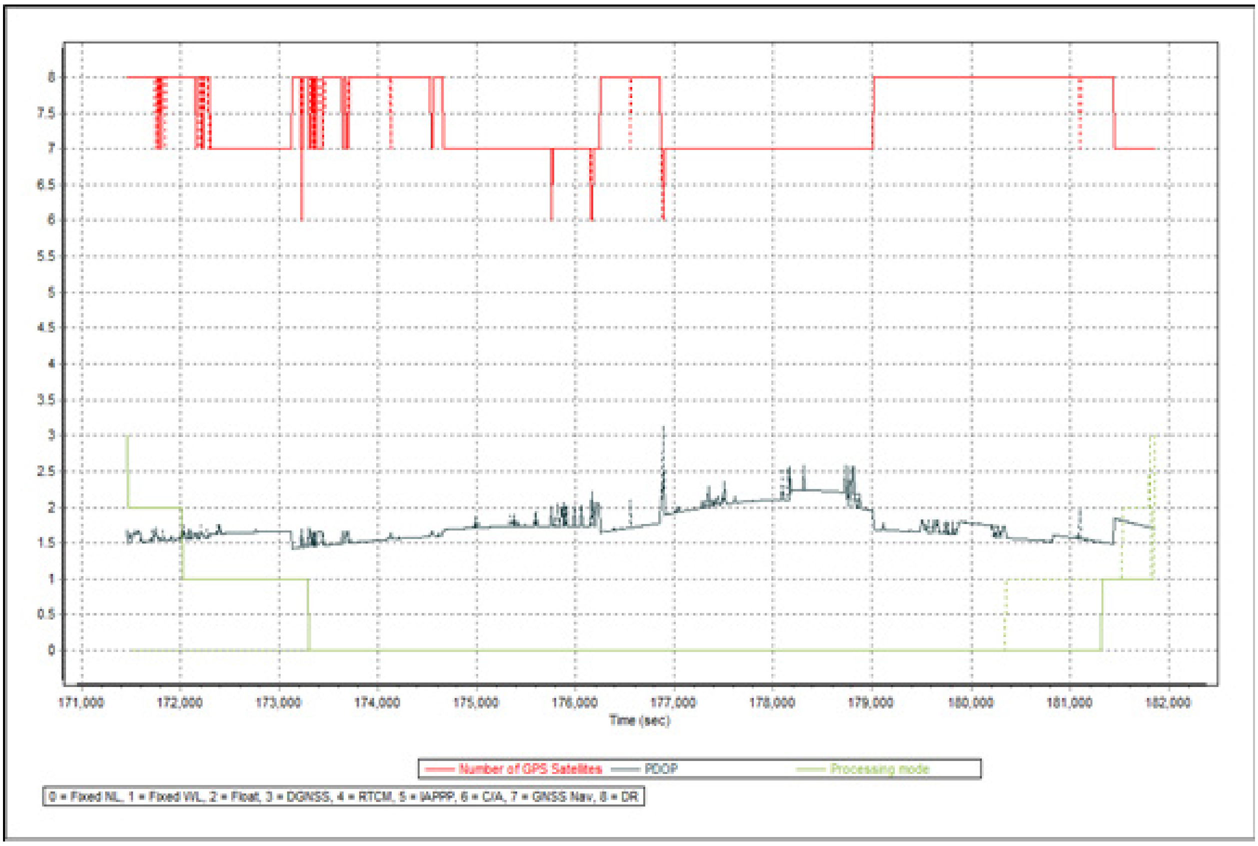


Figure A-8.50. Solution Status Parameters

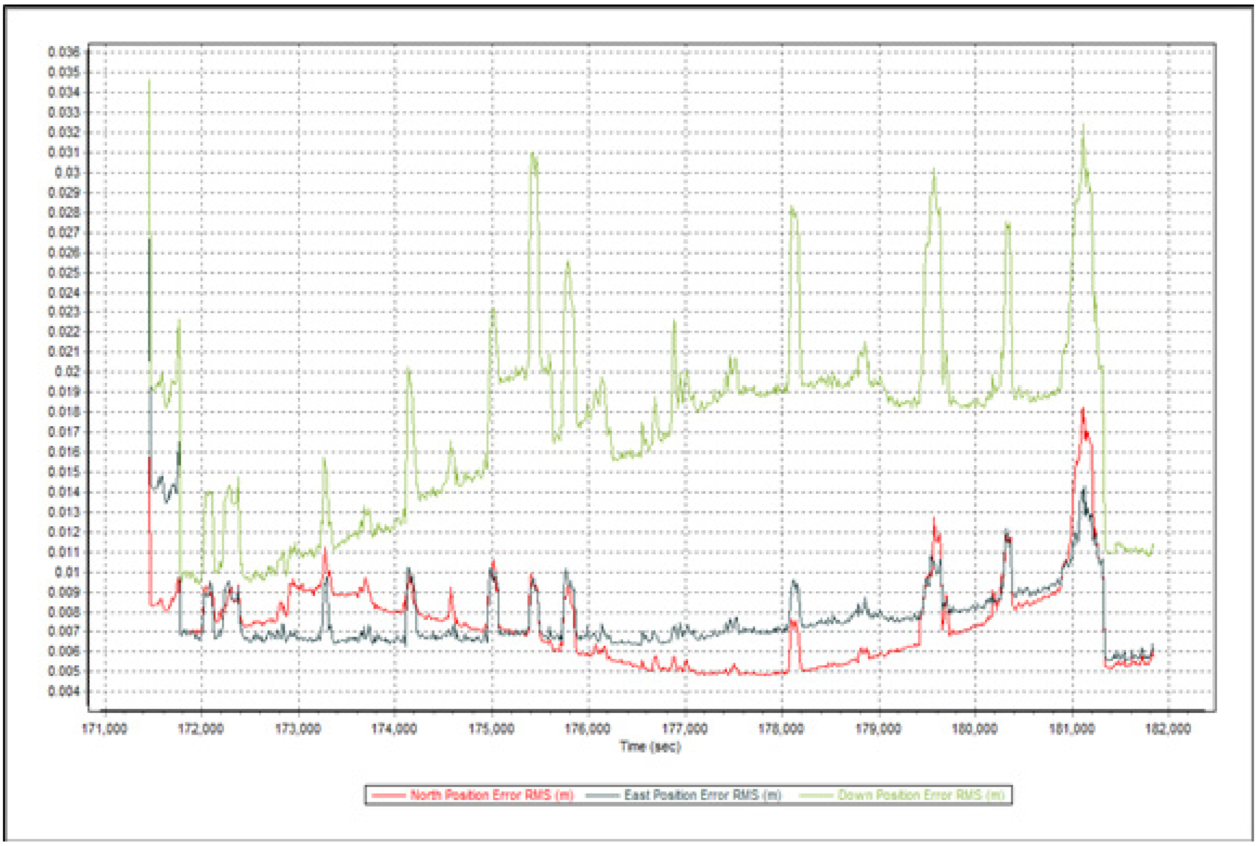


Figure A-8.51. Smoothed Performance Metrics Parameters

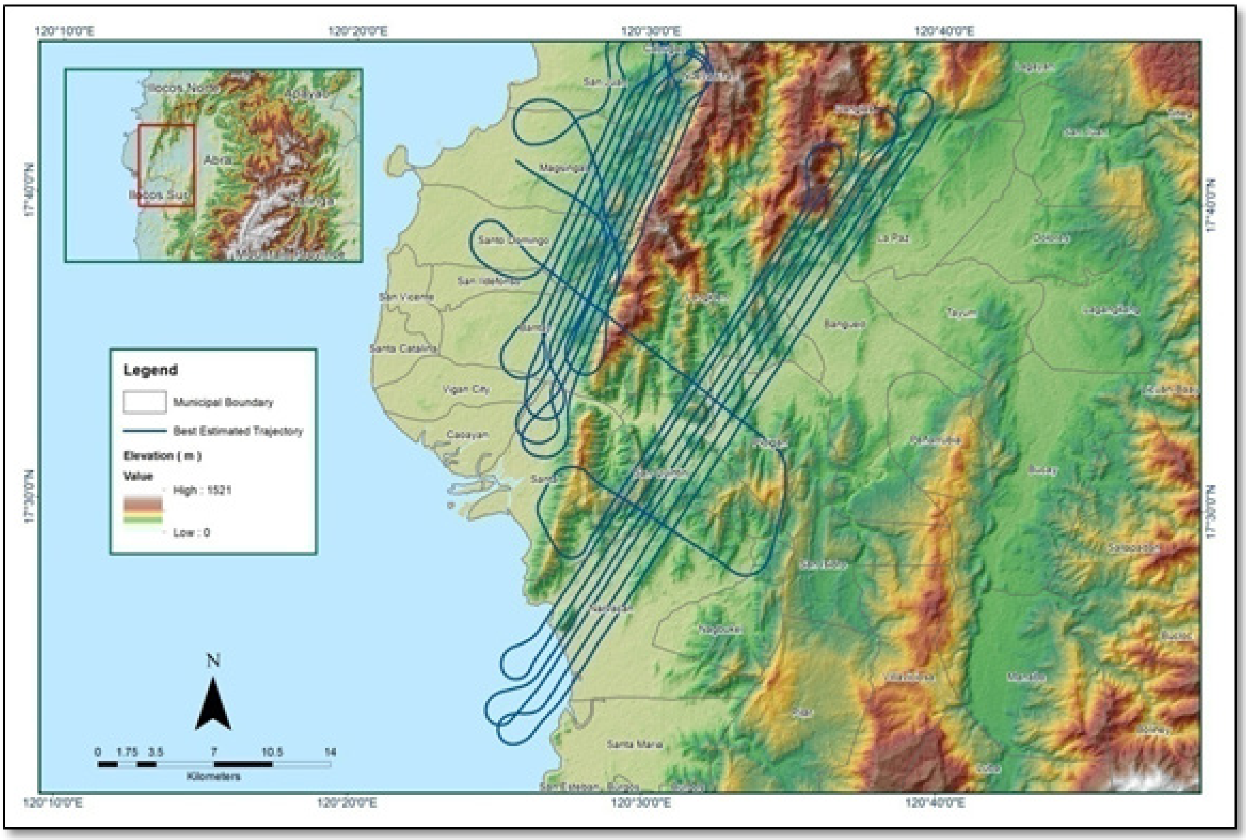


Figure A-8.52. Best Estimated Trajectory

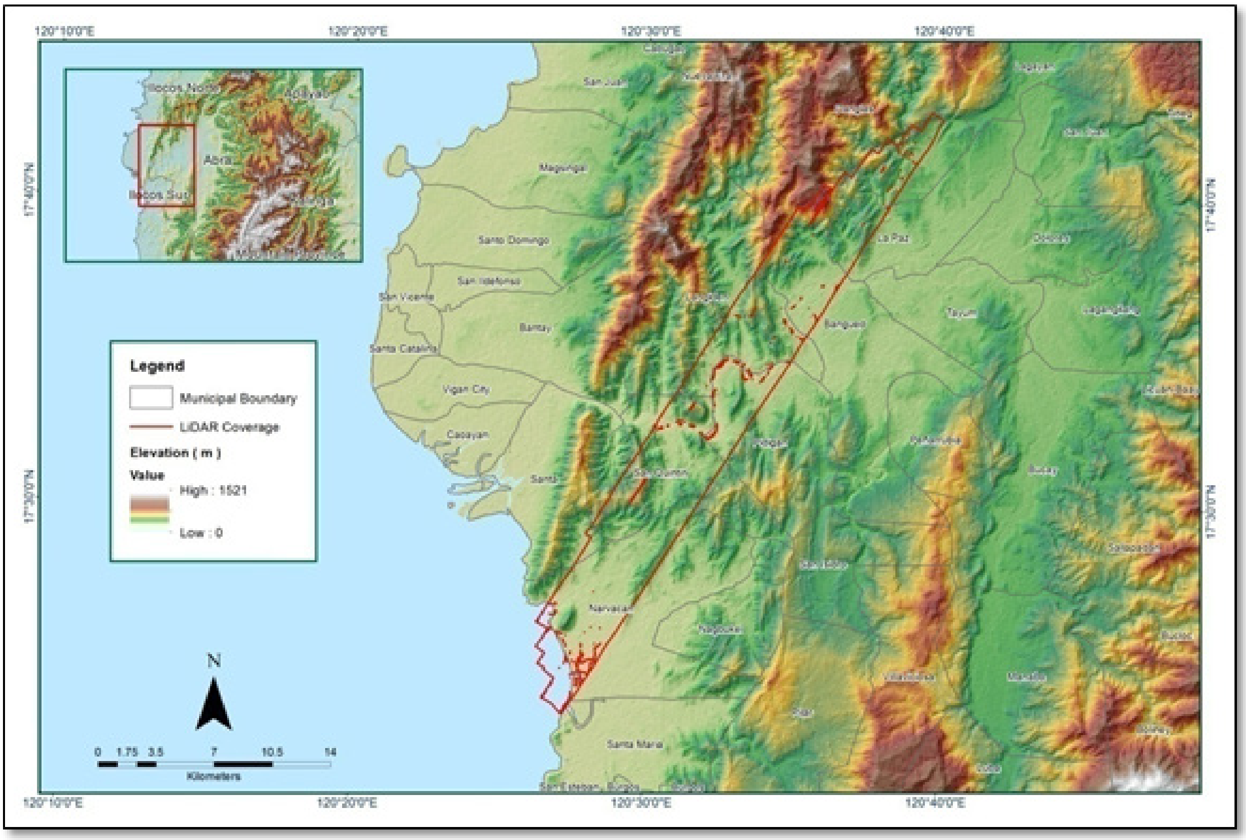


Figure A-8.53 Coverage of LiDAR data

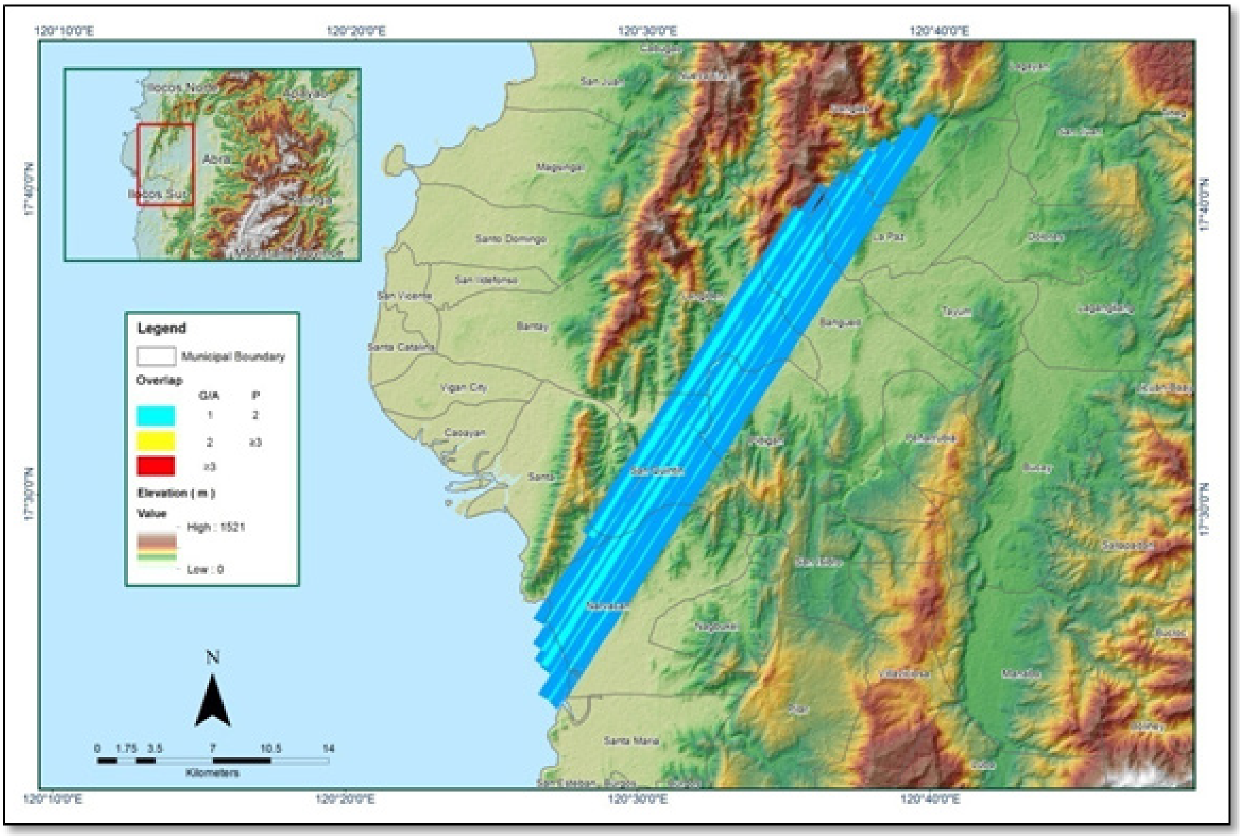


Figure A-8.54. Image of Data Overlap

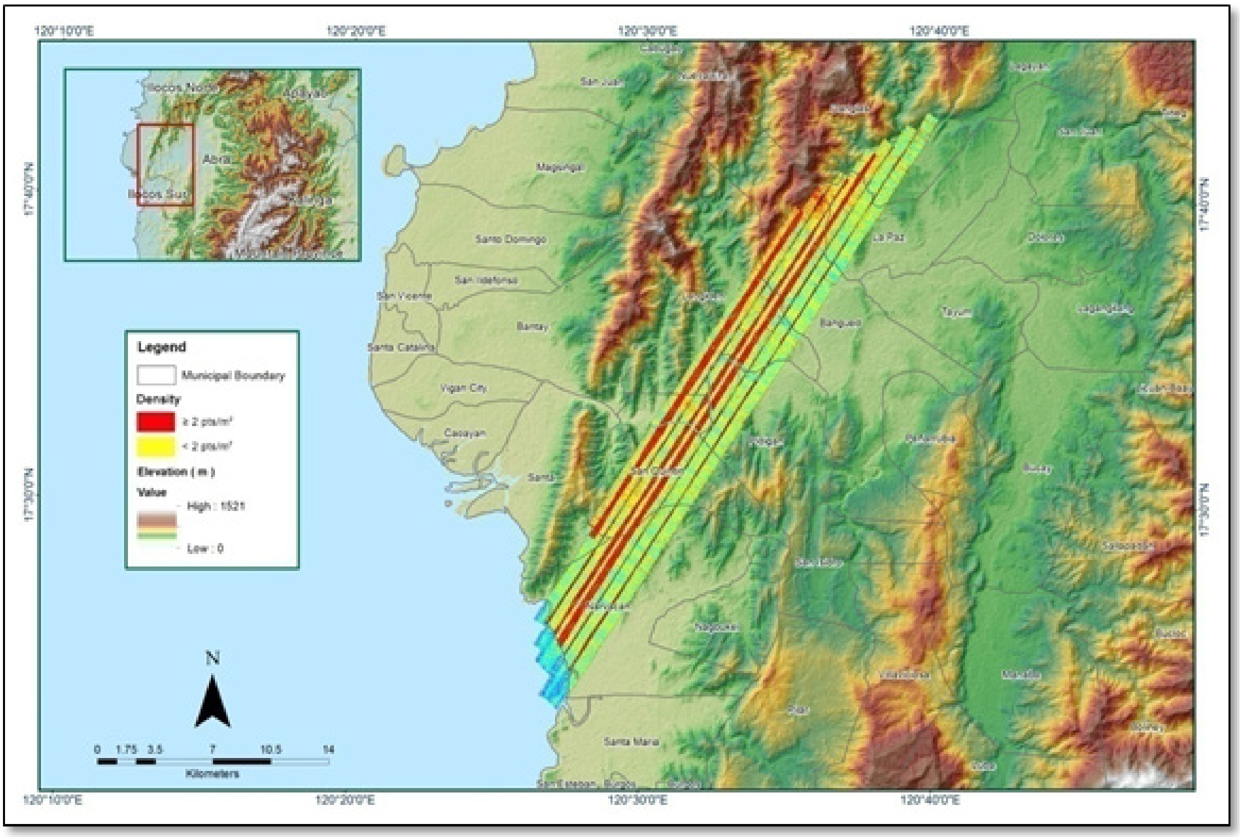


Figure A-8.55. Density map of merged LiDAR data

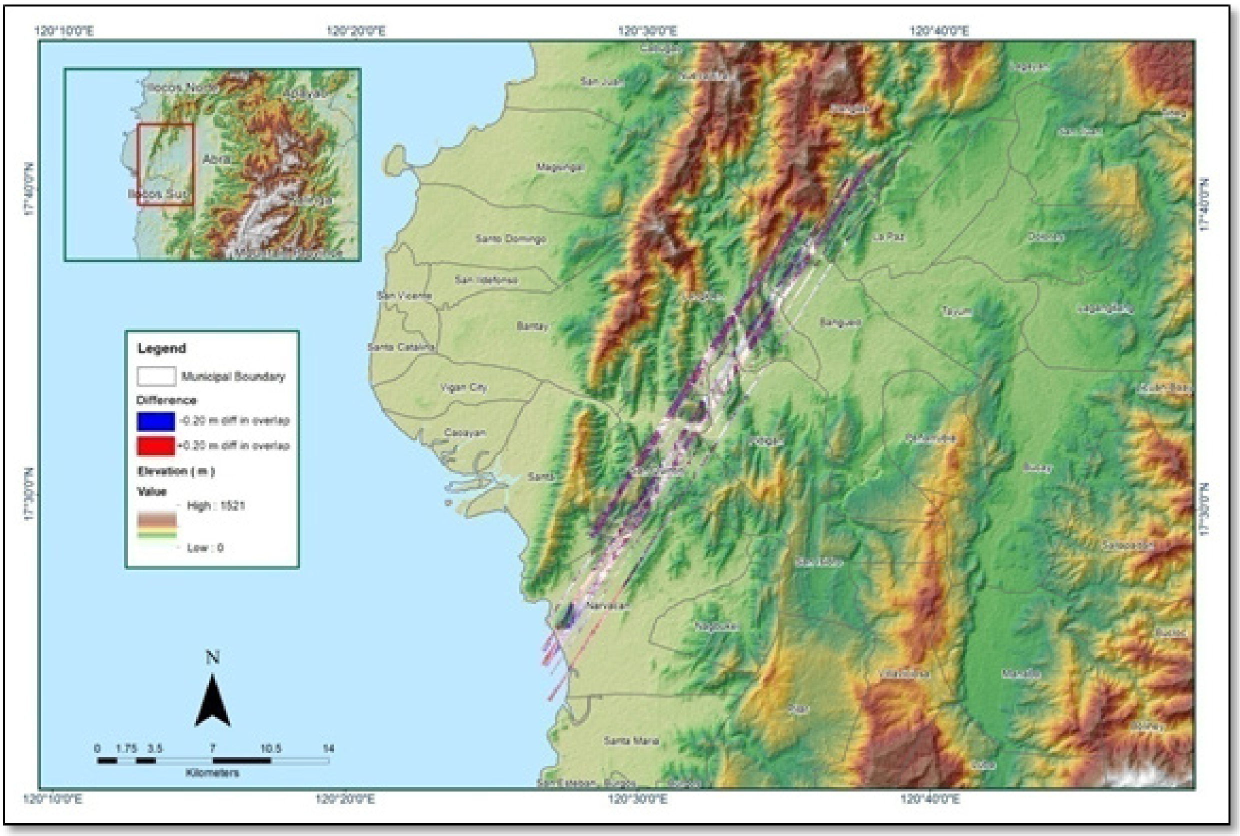


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk07A_additional

Flight Area	Ilocos
Mission Name	Blk07A_additional
Inclusive Flights	7121G
Range data size	12.7GB
POS data size	217MB
Base data size	10.8MB
Image	n/a
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	0.22
Boresight correction stdev (<0.001deg)	0.00284
IMU attitude correction stdev (<0.001deg)	0.000305
GPS position stdev (<0.01m)	0.0109
Minimum % overlap (>25)	NA
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20m)	
Number of 1km x 1km blocks	112
Maximum Height	485.55 m
Minimum Height	37.71 m
Classification (# of points)	
Ground	17,215,681
Low vegetation	7,167,618
Medium vegetation	8,112,707
High vegetation	17,869,377
Building	674,249
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Merven Matthew Natino, Engr. Jeffrey Delica

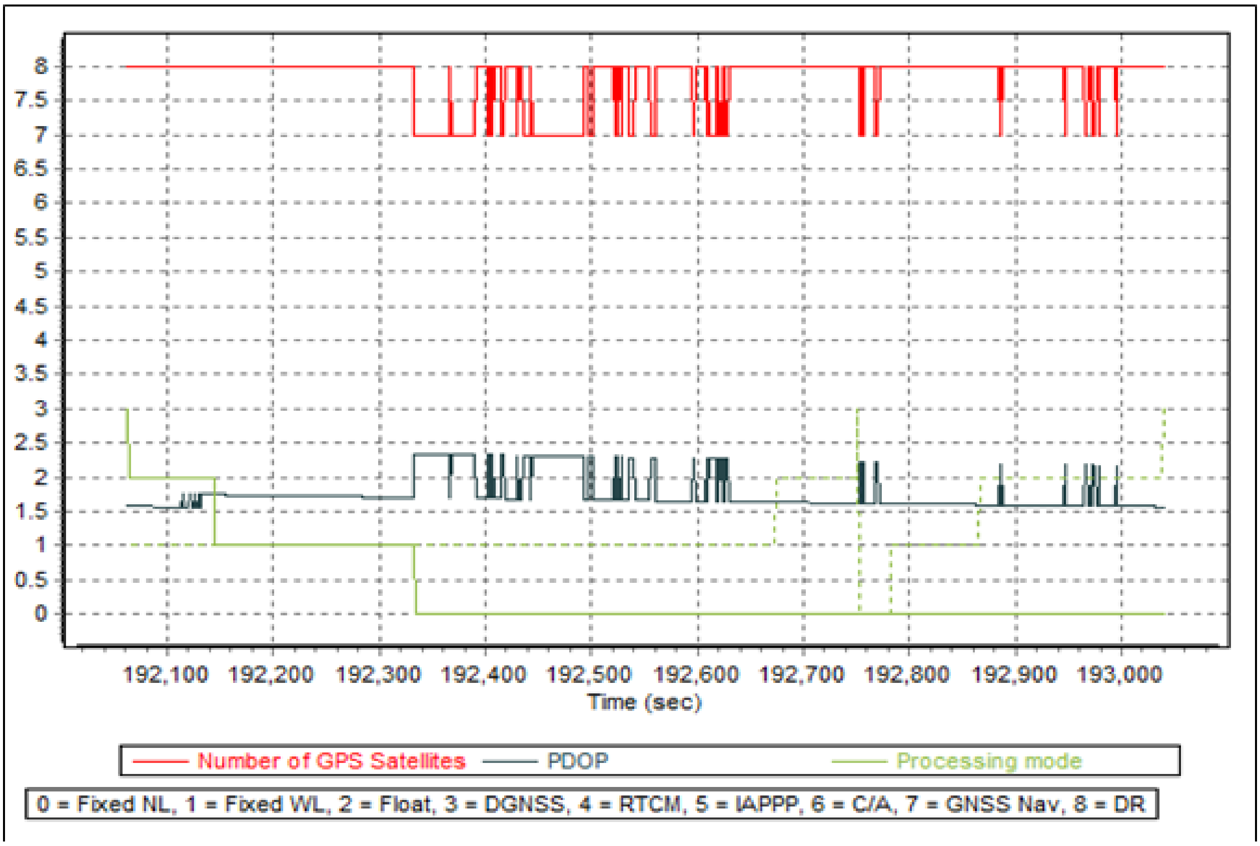


Figure A-8.57. Solution Status Parameters

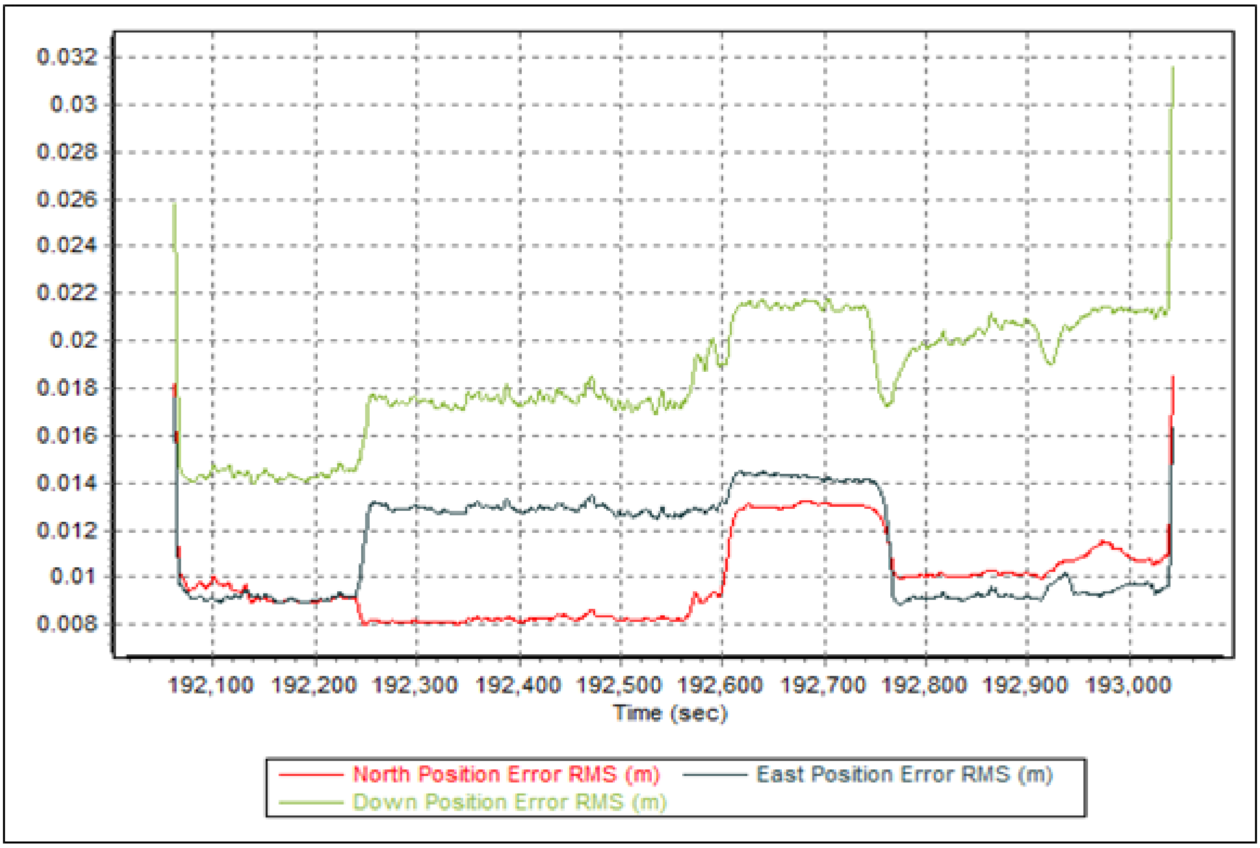


Figure A-8.58. Smoothed Performance Metrics Parameters

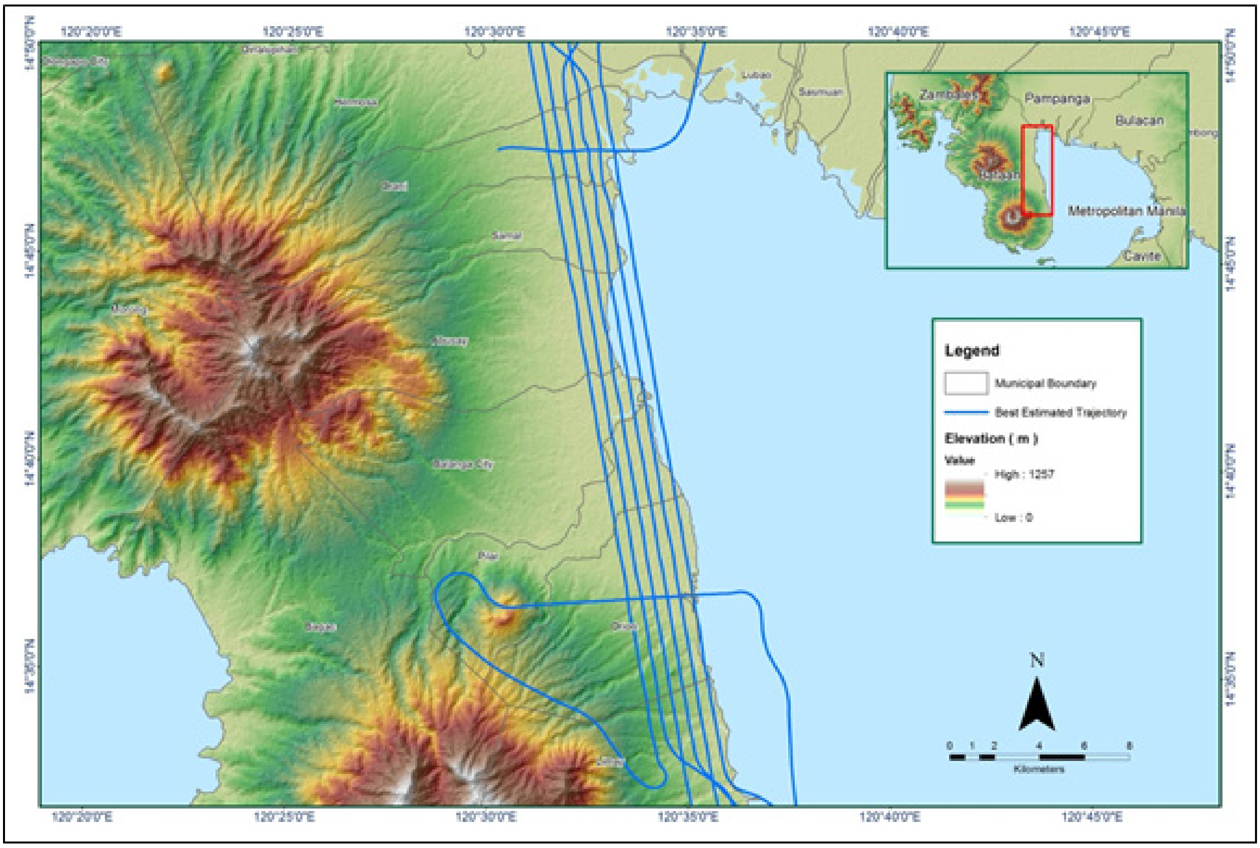


Figure A-8.59. Best Estimated Trajectory

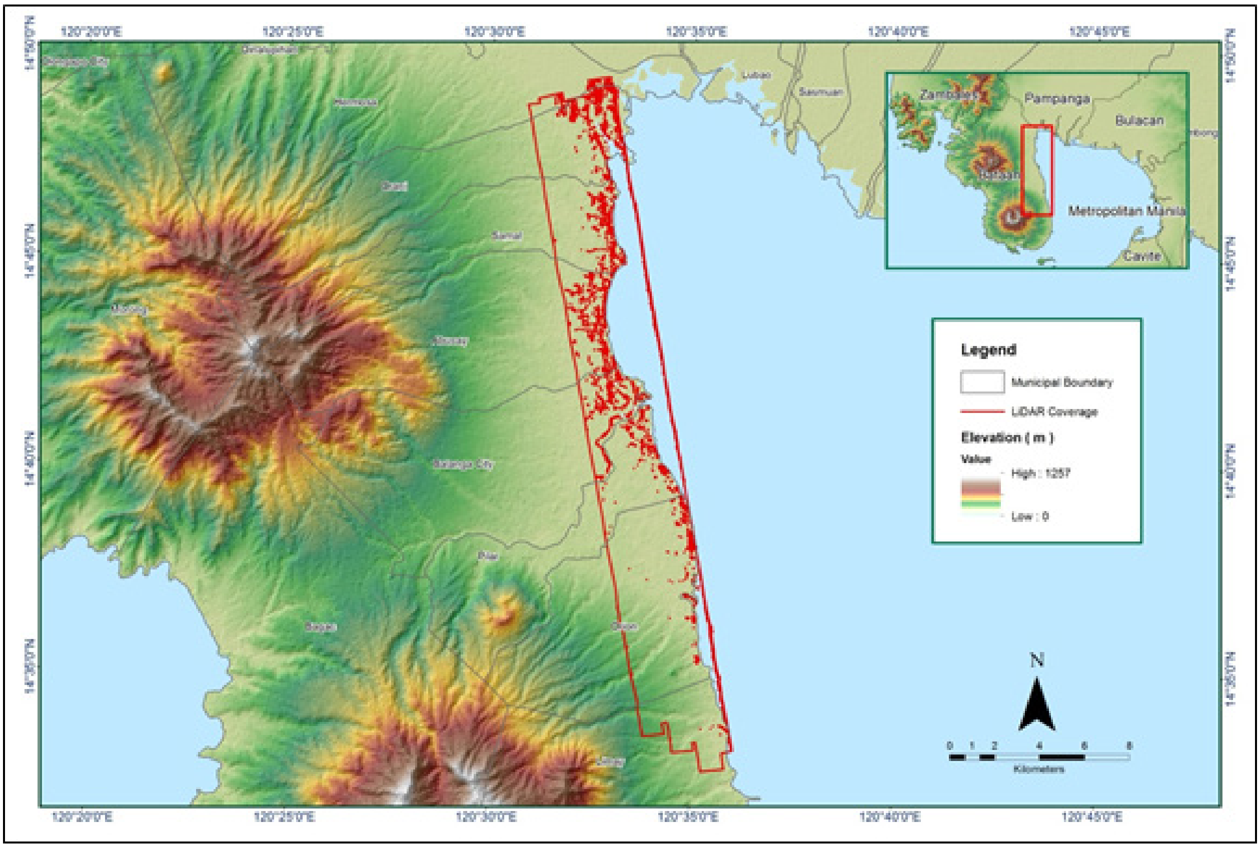


Figure A-8.60. Coverage of LiDAR data

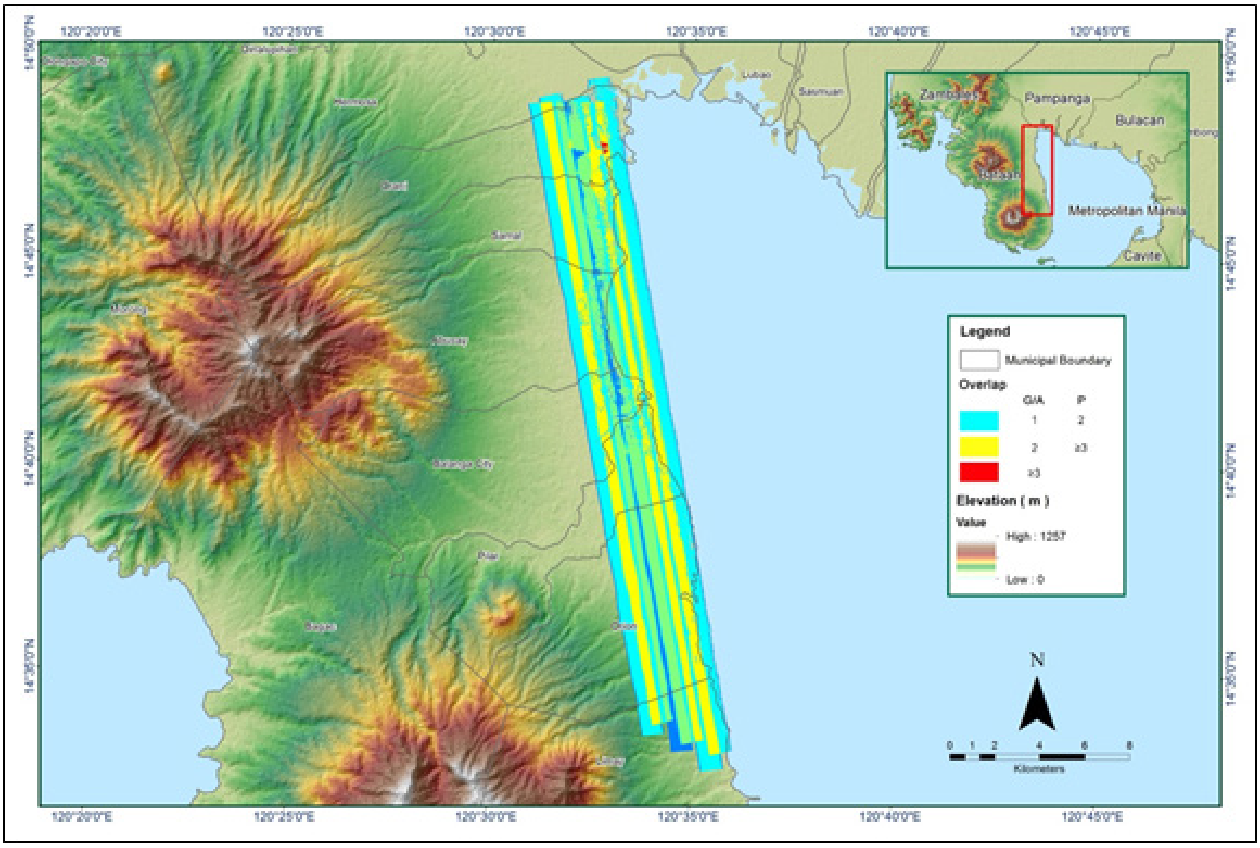


Figure A-8.61. Image of Data Overlap

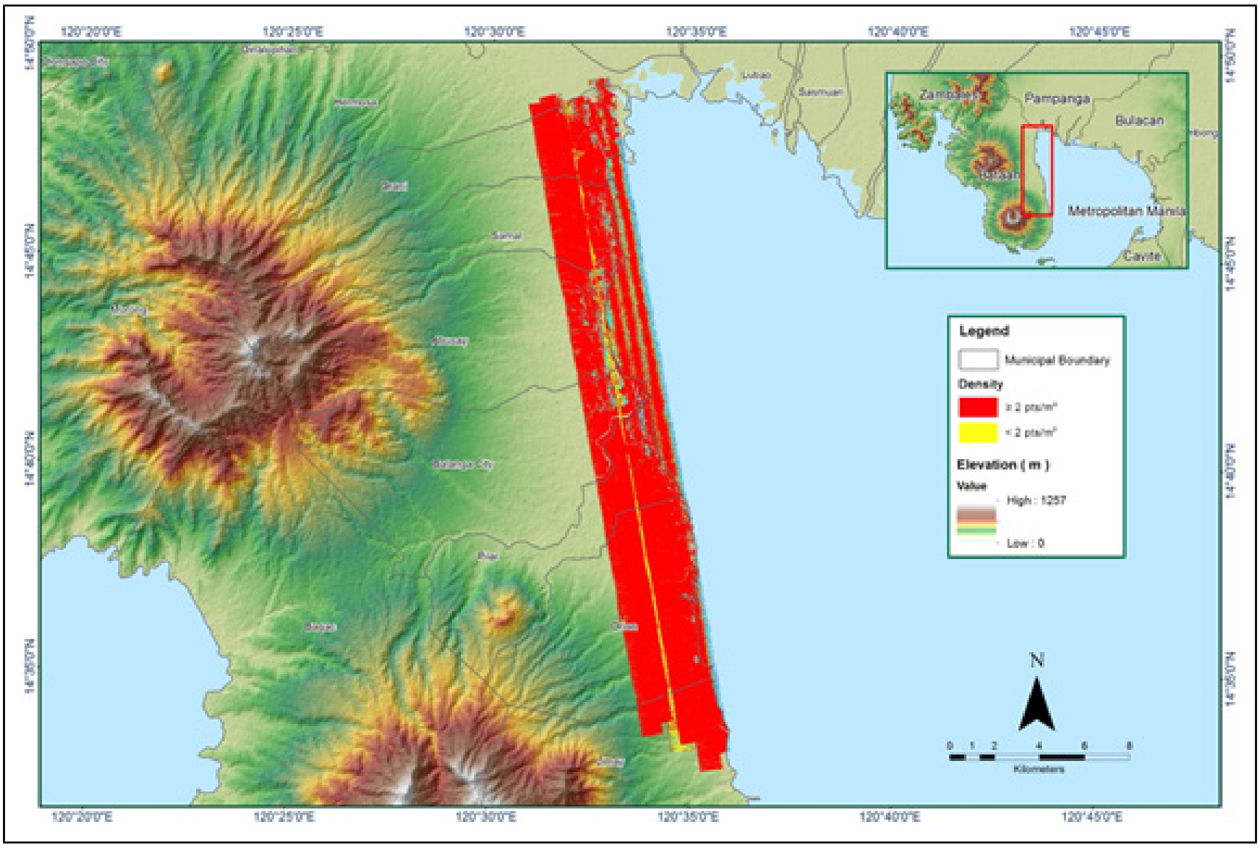


Figure A-8.62. Density map of merged LiDAR data

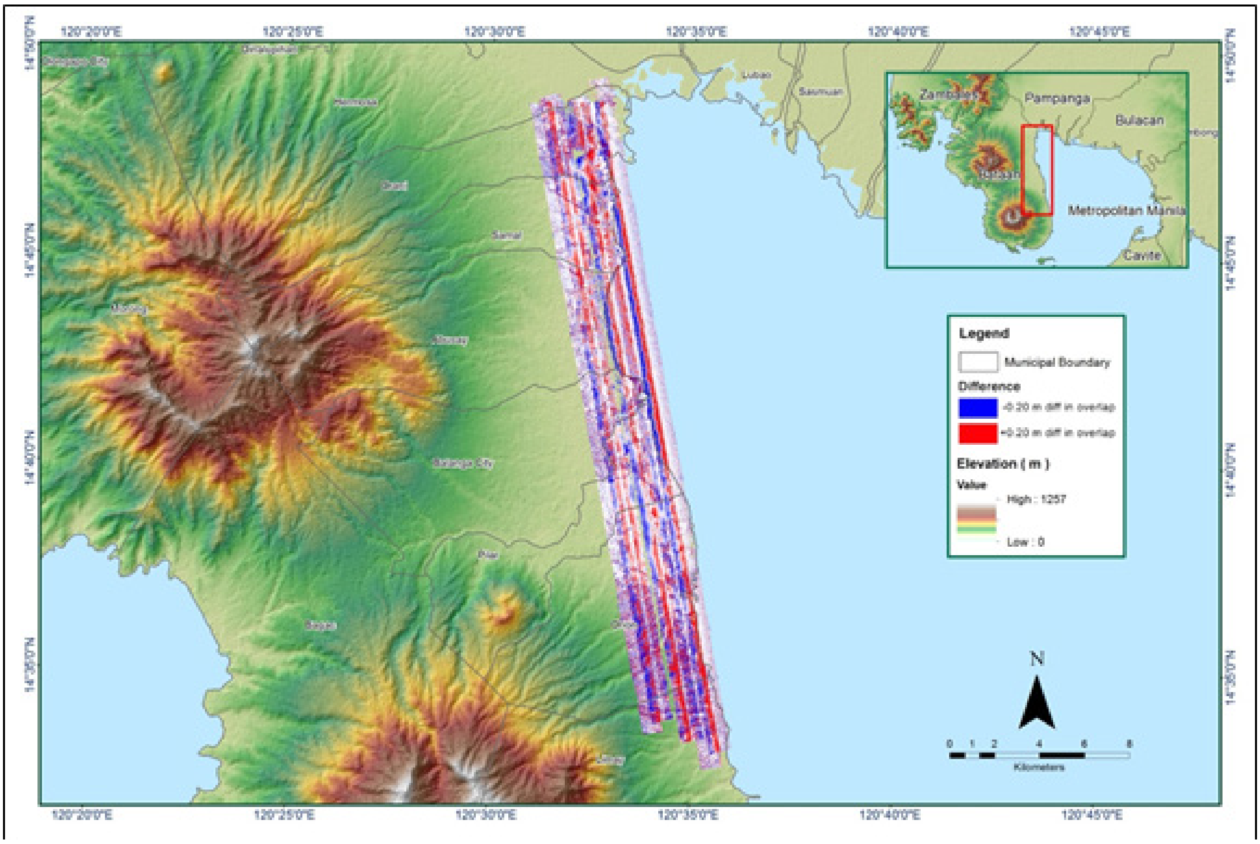


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk07B

Flight Area	Ilocos
Mission Name	Blk7B
Inclusive Flights	7116GC
Range data size	19. 6 GB
Base data size	10.8 MB
POS	257 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000272
IMU attitude correction stdev (<0.001deg)	0.001023
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	31.75%
Ave point cloud density per sq.m. (>2.0)	2.69
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	272
Maximum Height	565.46 m
Minimum Height	44.47 m
Classification (# of points)	
Ground	99,941,447
Low vegetation	84,663,695
Medium vegetation	89,716,585
High vegetation	194,432,190
Building	5,938,744
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Melanie Hingpit, AilynBiñas

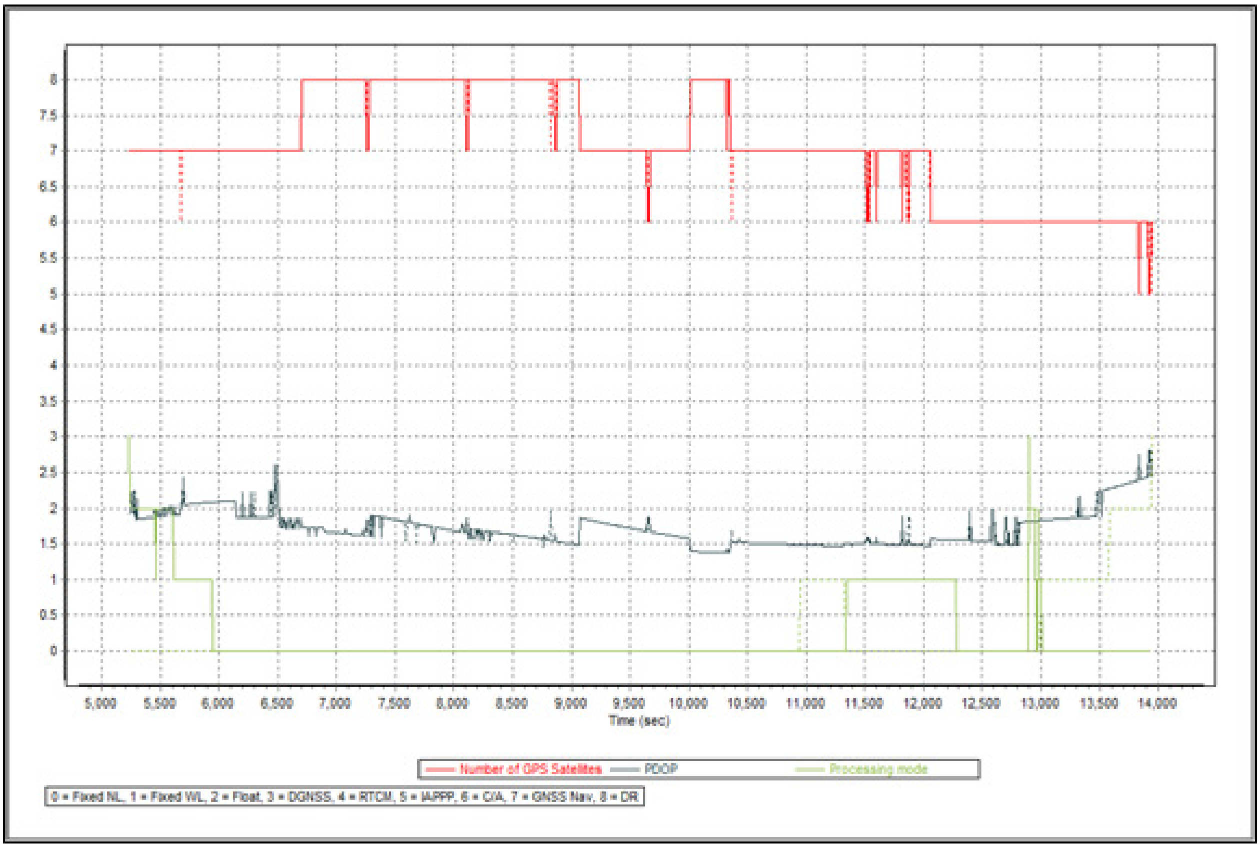


Figure A-8.64. Solution Status Parameters

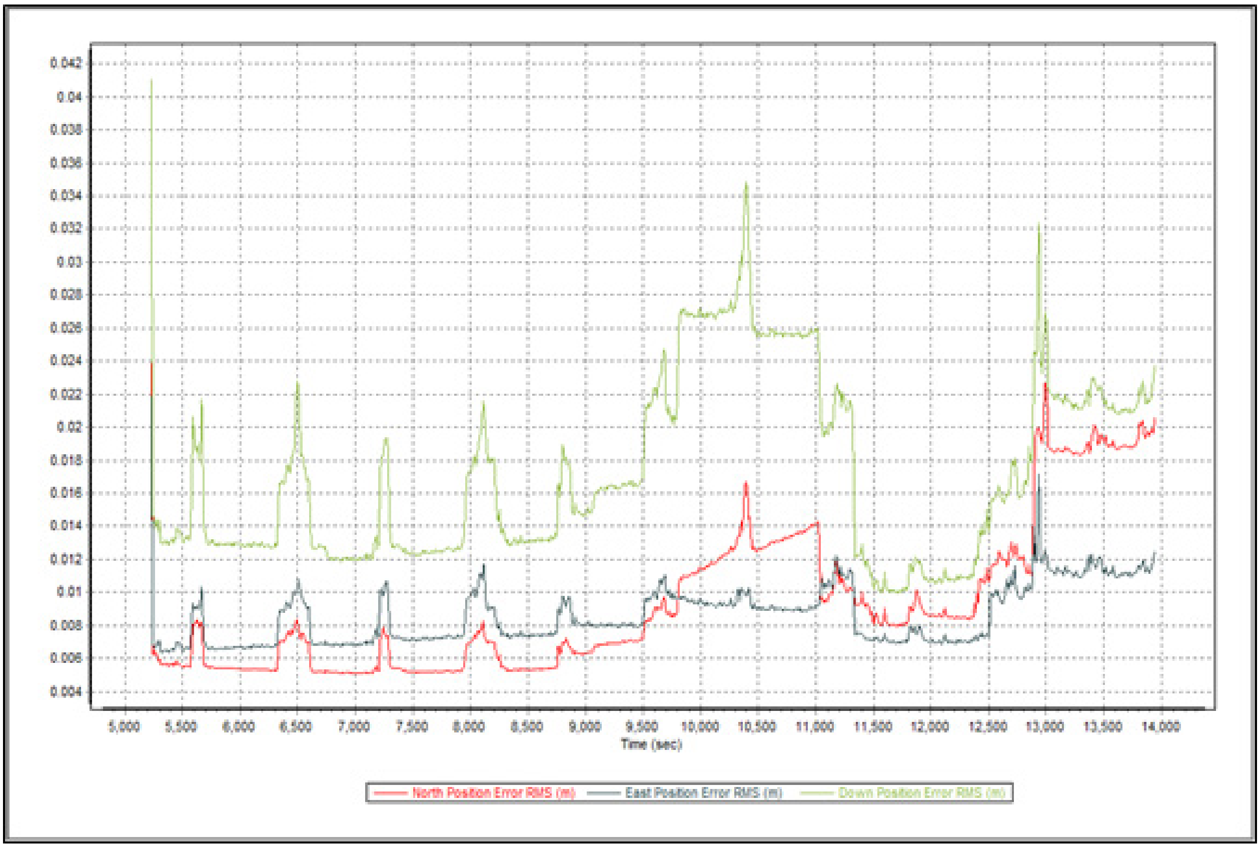


Figure A-8.65. Smoothed Performance Metrics Parameters

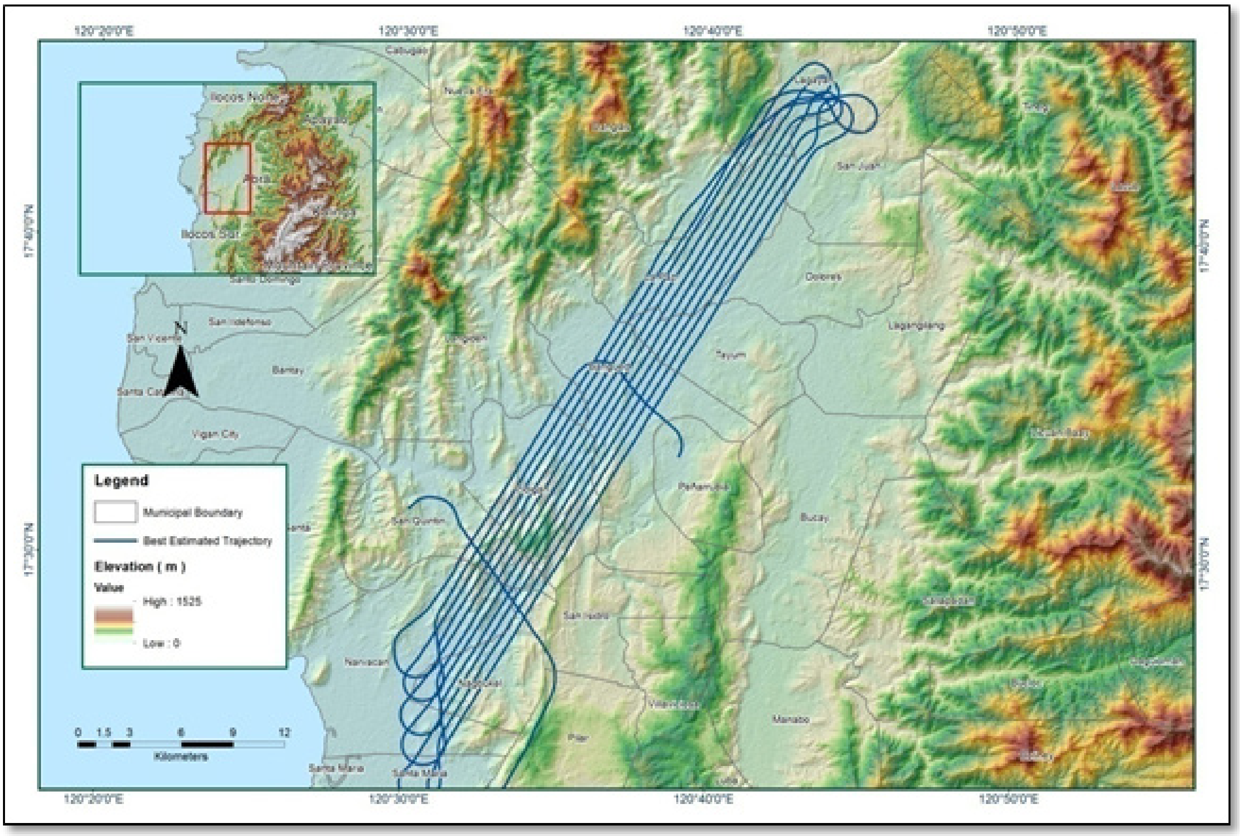


Figure A-8.66. Best Estimated Trajectory

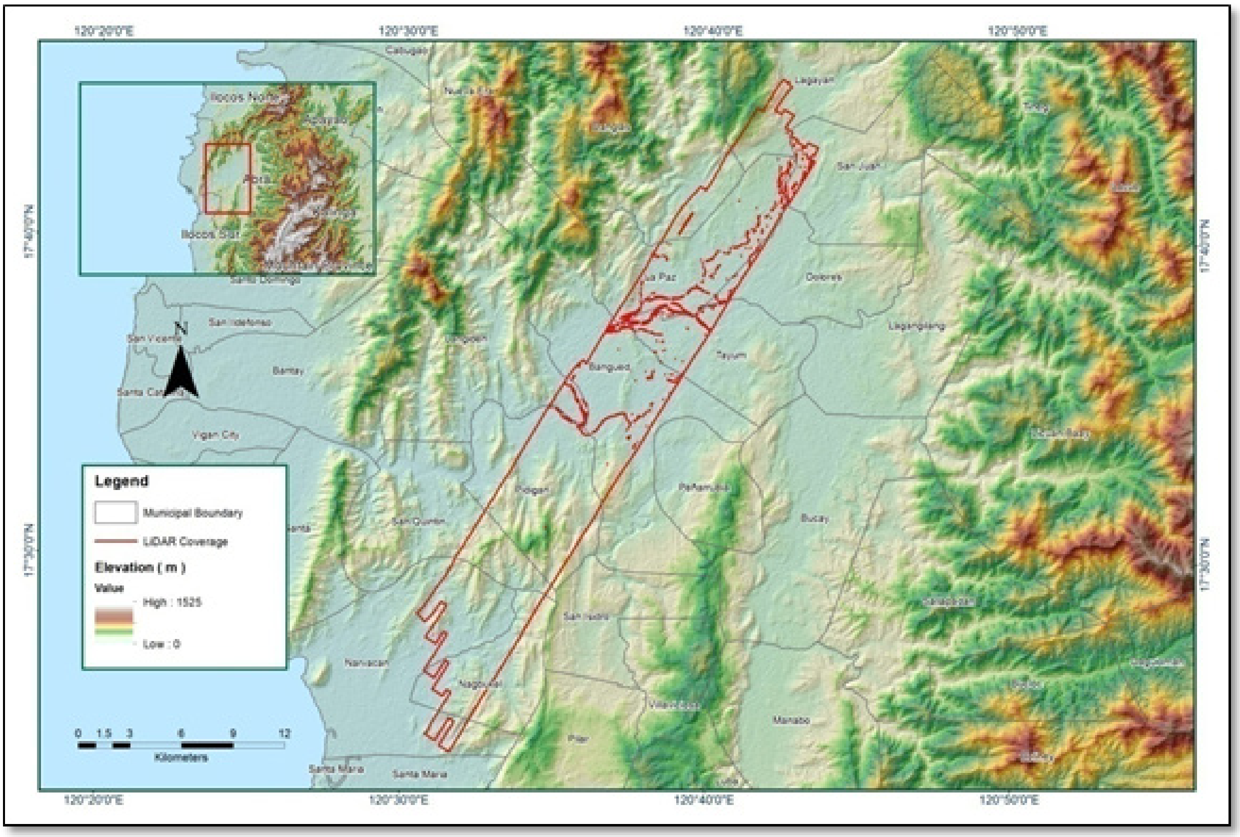


Figure A-8.67. Coverage of LiDAR data

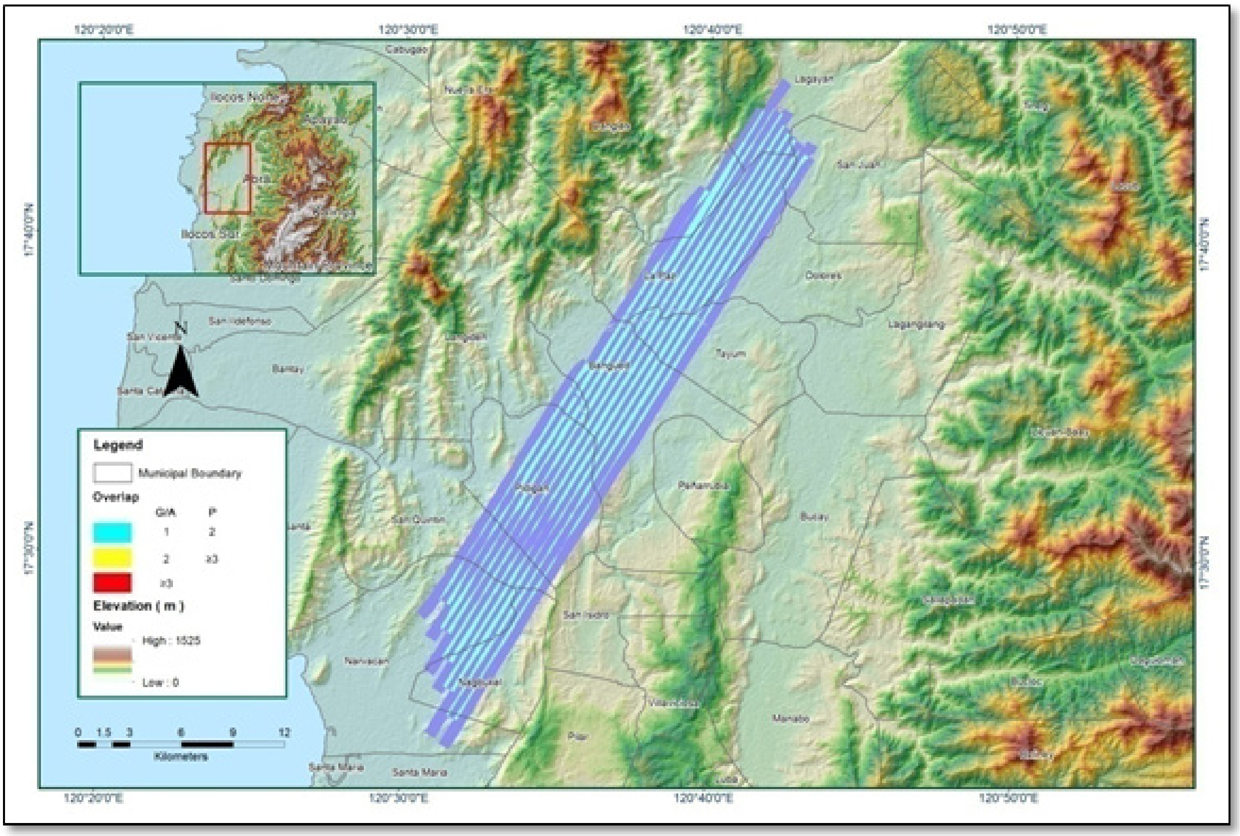


Figure A-8.68. Image of Data Overlap

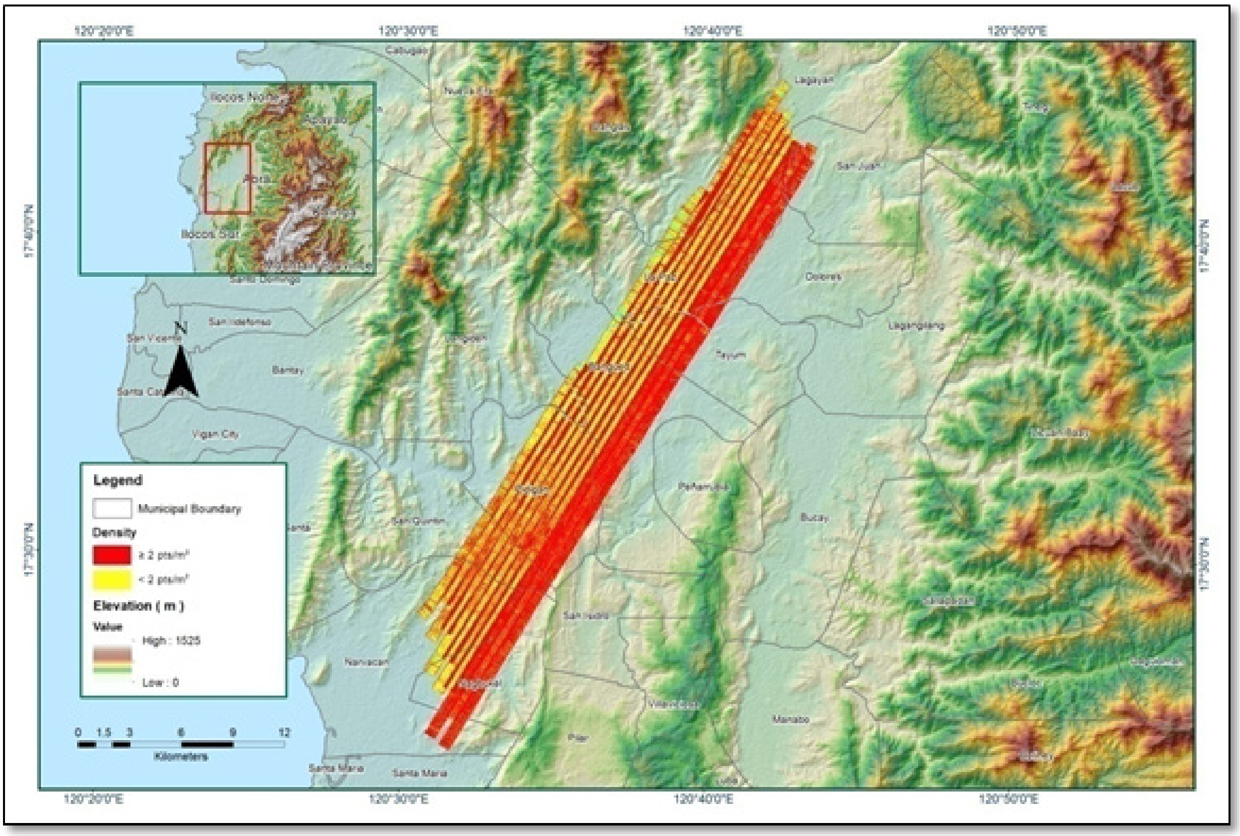


Figure A-8.69. Density map of merged LiDAR data

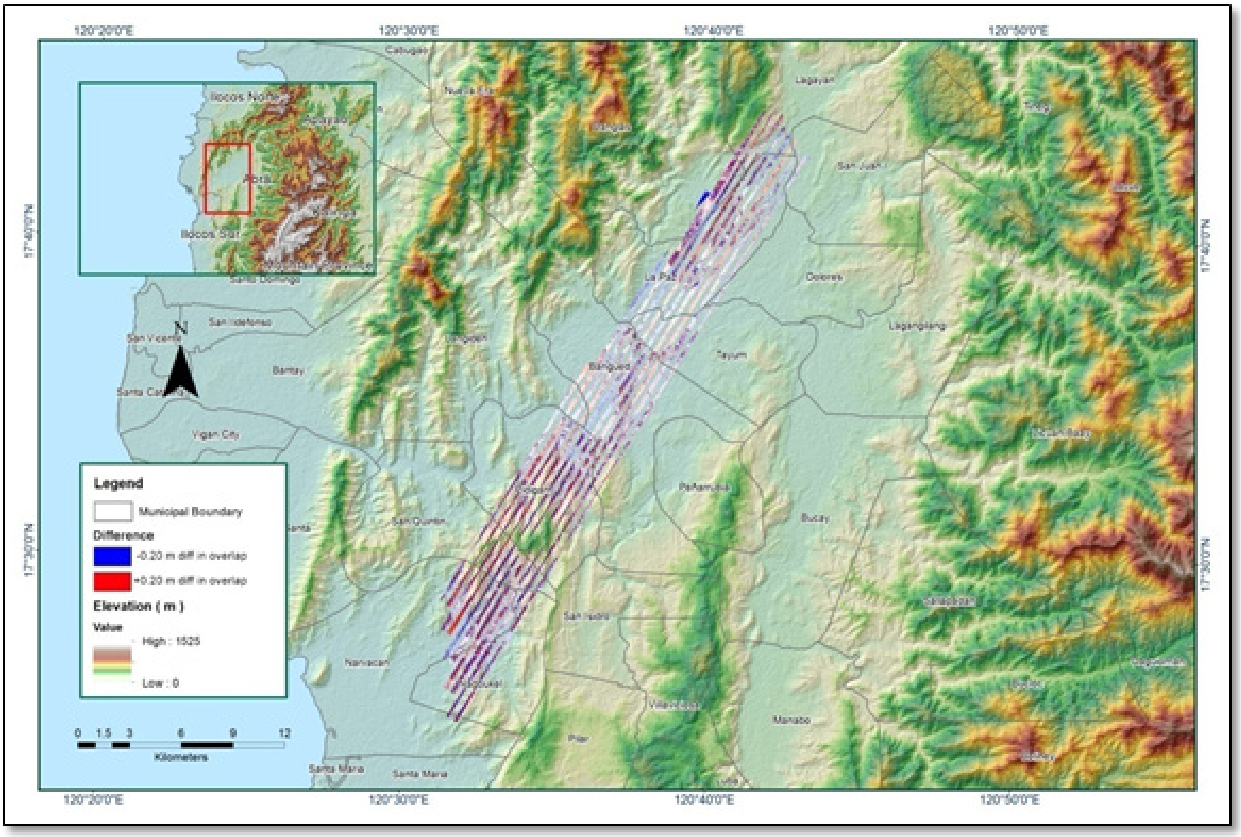


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk07C_supplement

Flight Area	Ilocos
Mission Name	Blk7C_supplement
Inclusive Flights	7114G
Range data size	19.3 GB
Base data size	8.45 MB
POS	264 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000275
IMU attitude correction stdev (<0.001deg)	0.000712
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	18.28%
Ave point cloud density per sq.m. (>2.0)	3.33
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	153
Maximum Height	596.71m
Minimum Height	53.0m
Classification (# of points)	
Ground	41,455,621
Low vegetation	41,107,803
Medium vegetation	55,036,111
High vegetation	123,543,253
Building	2,290,023
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Harmond Santos, Engr. RoaShalemar Redo

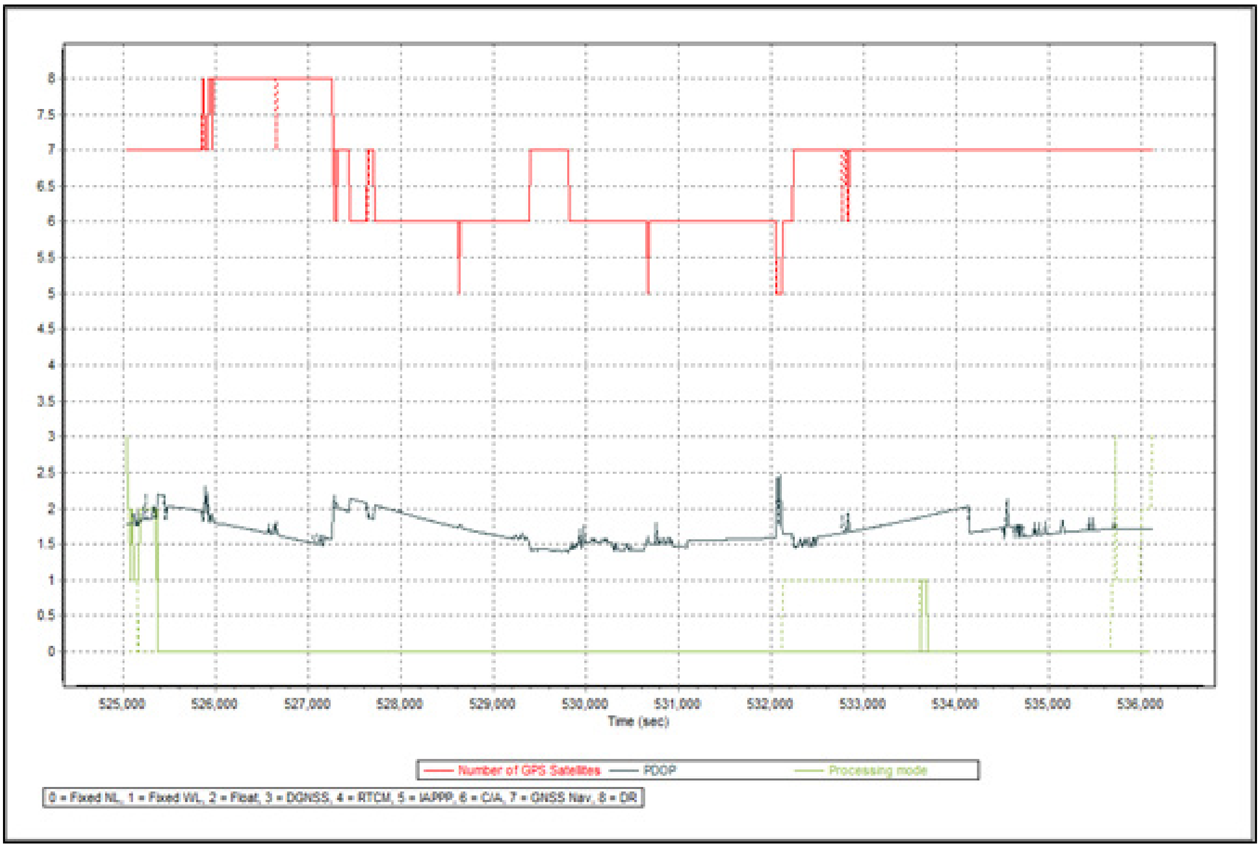


Figure A-8.71. Solution Status Parameters

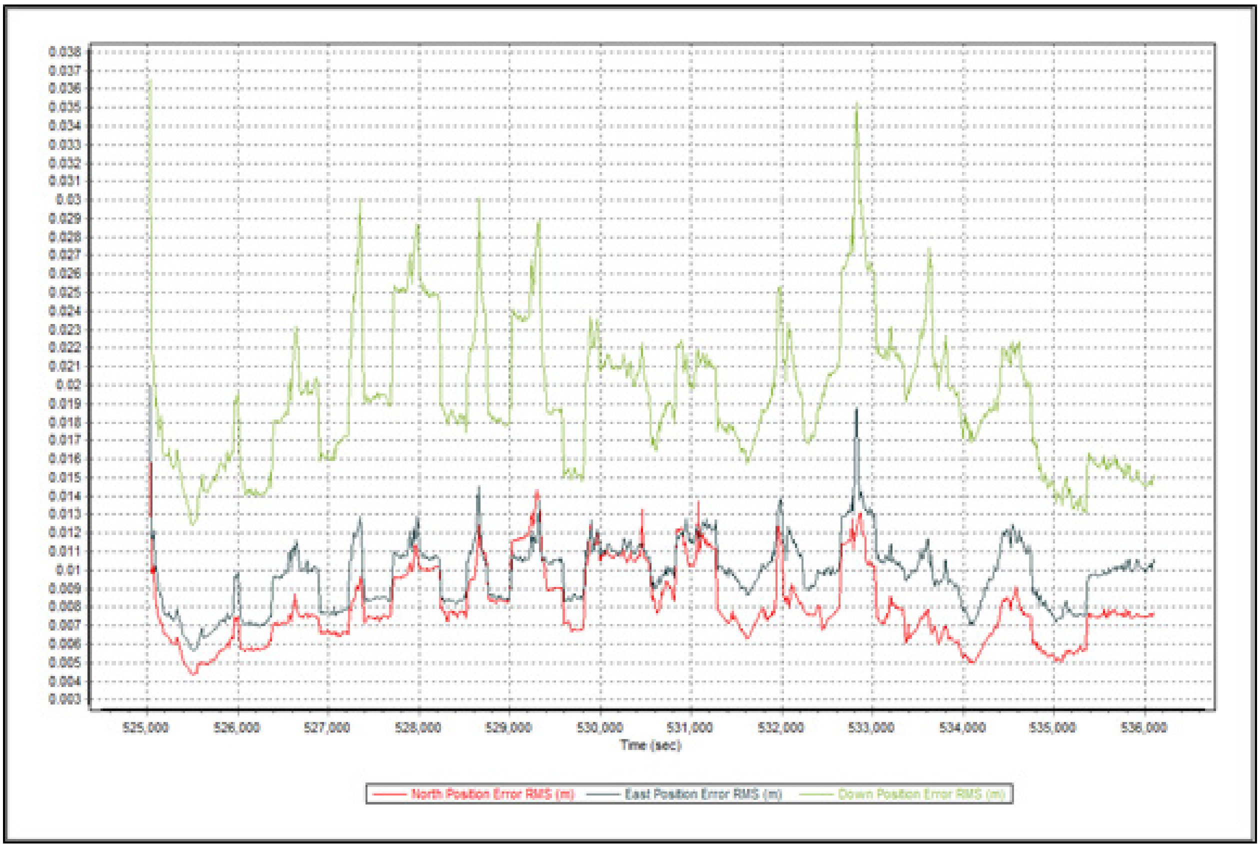


Figure A-8.72. Smoothed Performance Metrics Parameters

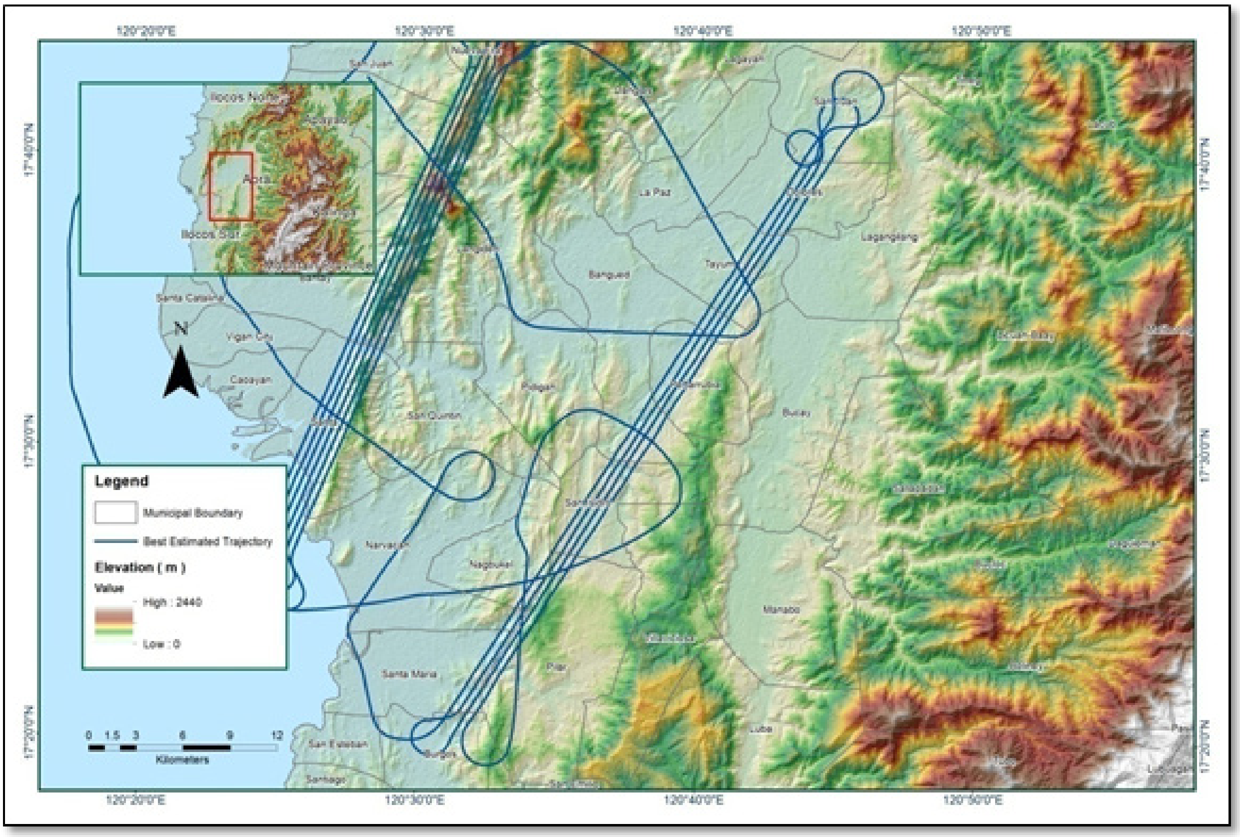


Figure A-8.73. Best Estimated Trajectory

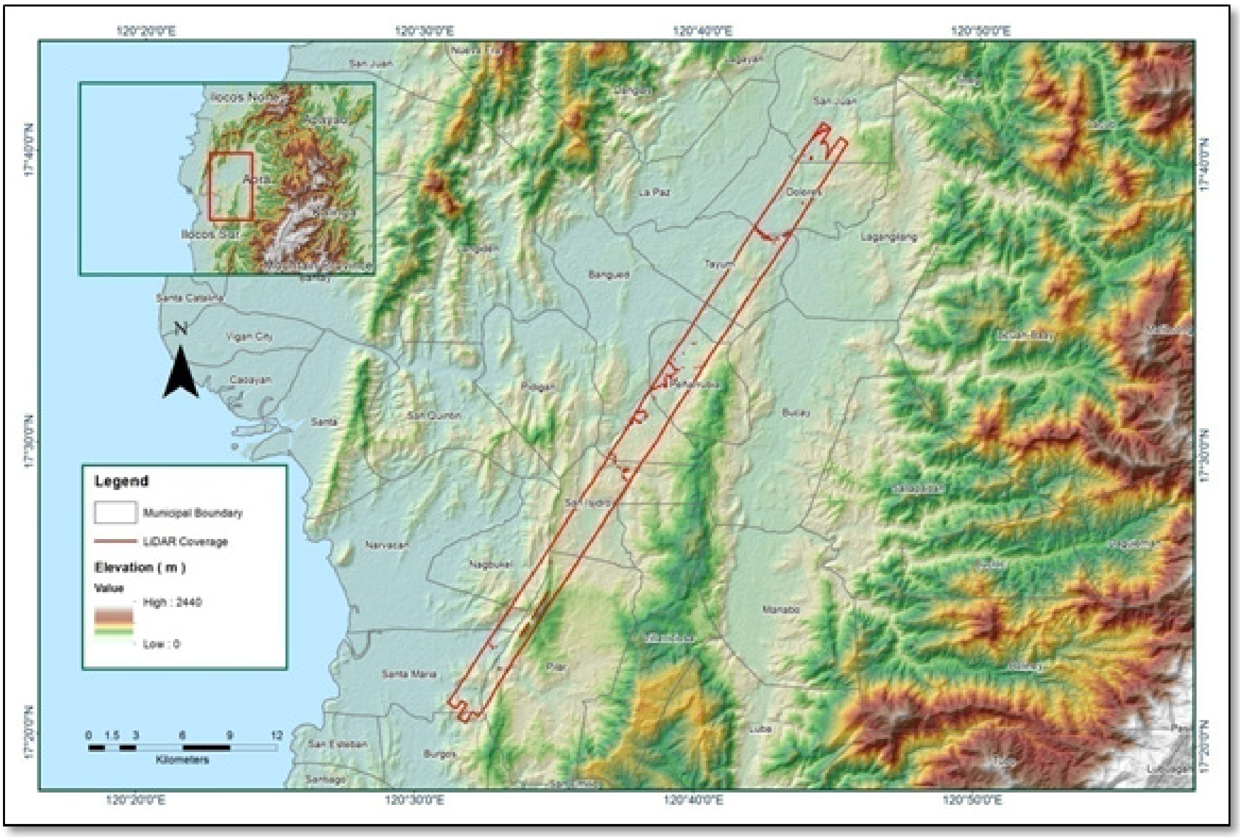


Figure A-8.74. Coverage of LiDAR data

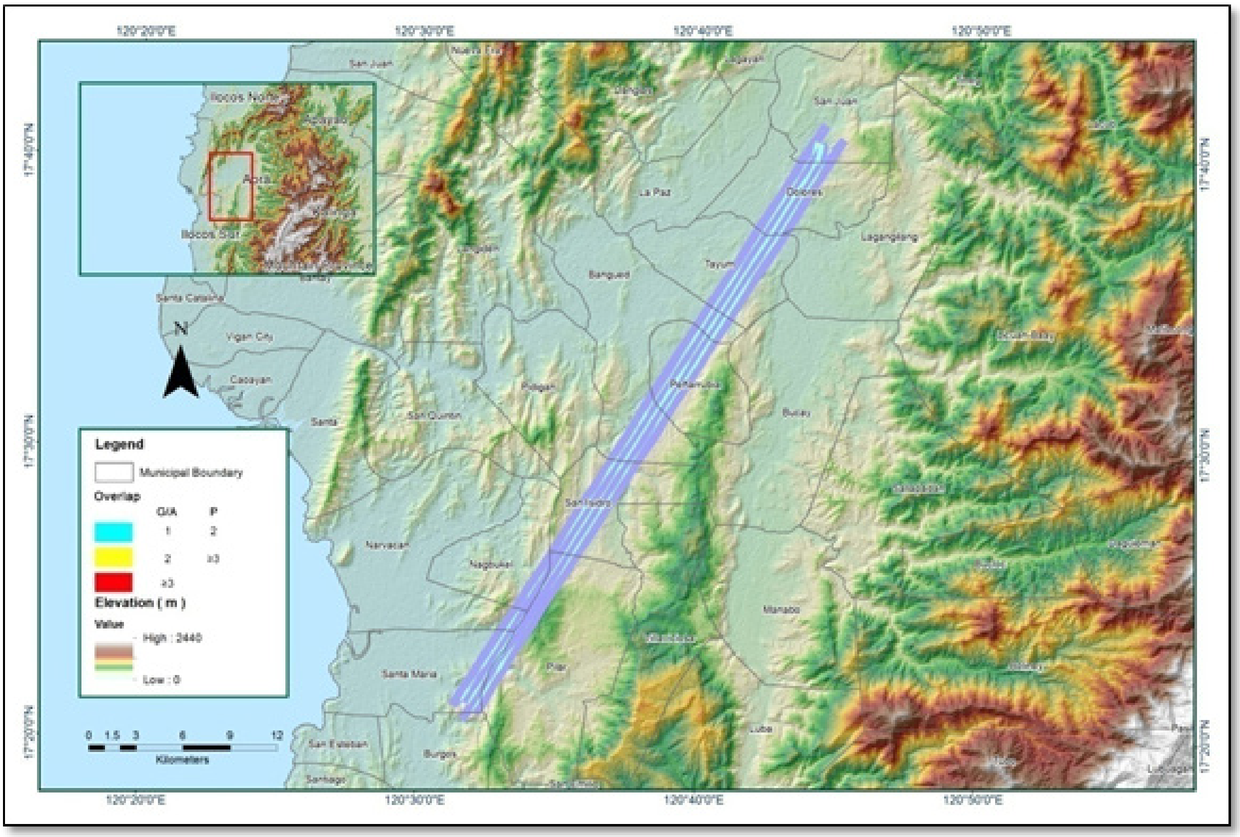


Figure A-8.75. Image of Data Overlap

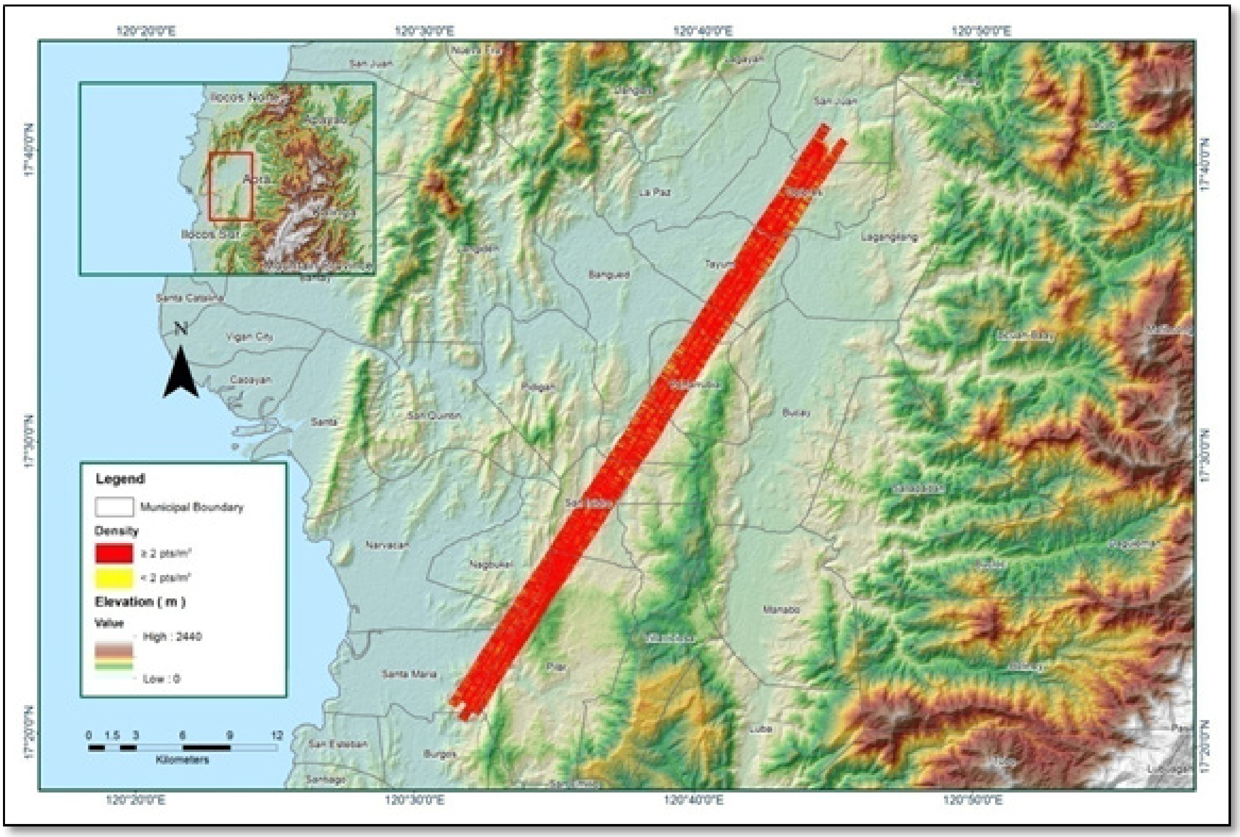


Figure A-8.76. Density map of merged LiDAR data

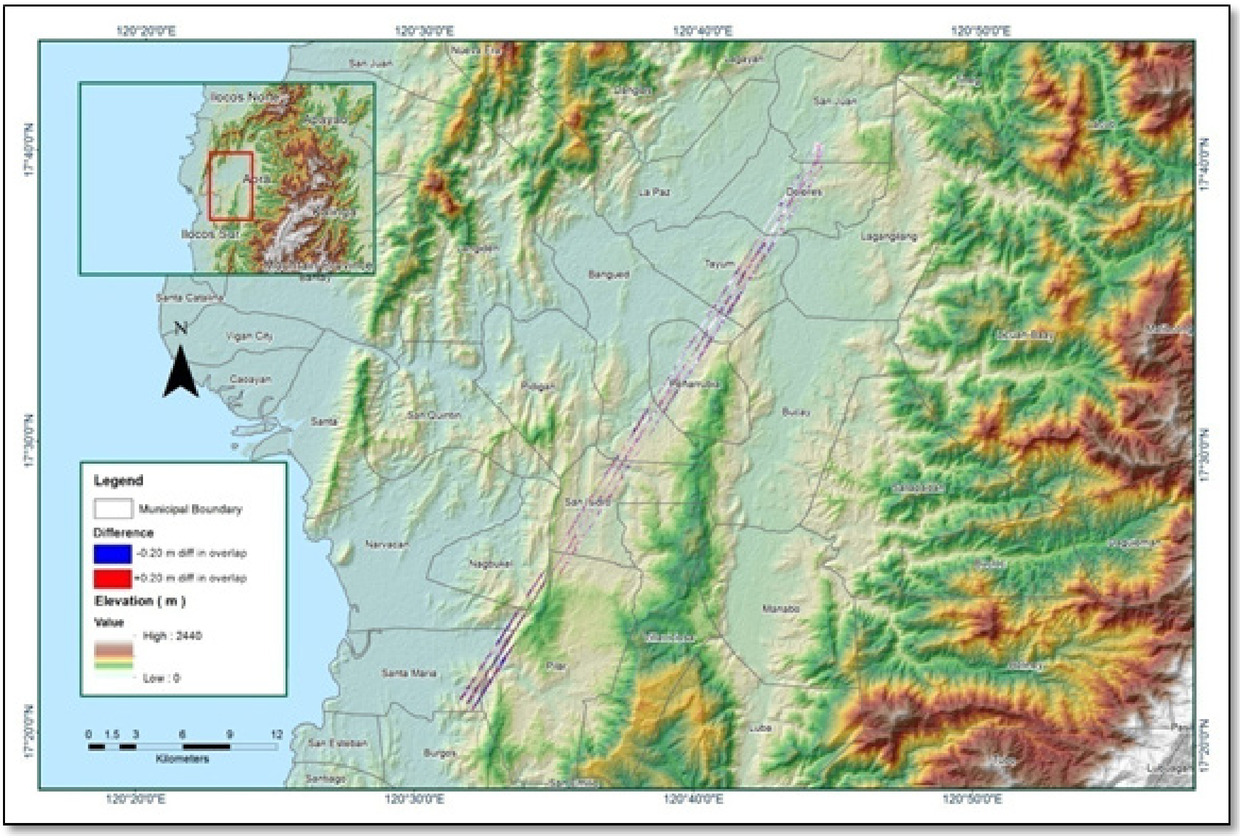


Figure A-8.77. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission Blk07D

Flight Area	Ilocos
Mission Name	Blk7D
Inclusive Flights	7118G
Range data size	18.7 GB
Base data size	14.5 MB
POS	259 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	2.5
RMSE for Down Position (<8.0 cm)	5.7
Boresight correction stdev (<0.001deg)	0.000284
IMU attitude correction stdev (<0.001deg)	0.001635
GPS position stdev (<0.01m)	0.0109
Minimum % overlap (>25)	33.28%
Ave point cloud density per sq.m. (>2.0)	2.56
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	220
Maximum Height	714.89m
Minimum Height	89.59m
Classification (# of points)	
Ground	104,185,627
Low vegetation	72,026,130
Medium vegetation	76,767,455
High vegetation	119,612,686
Building	1,832,149
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, AilynBiñas

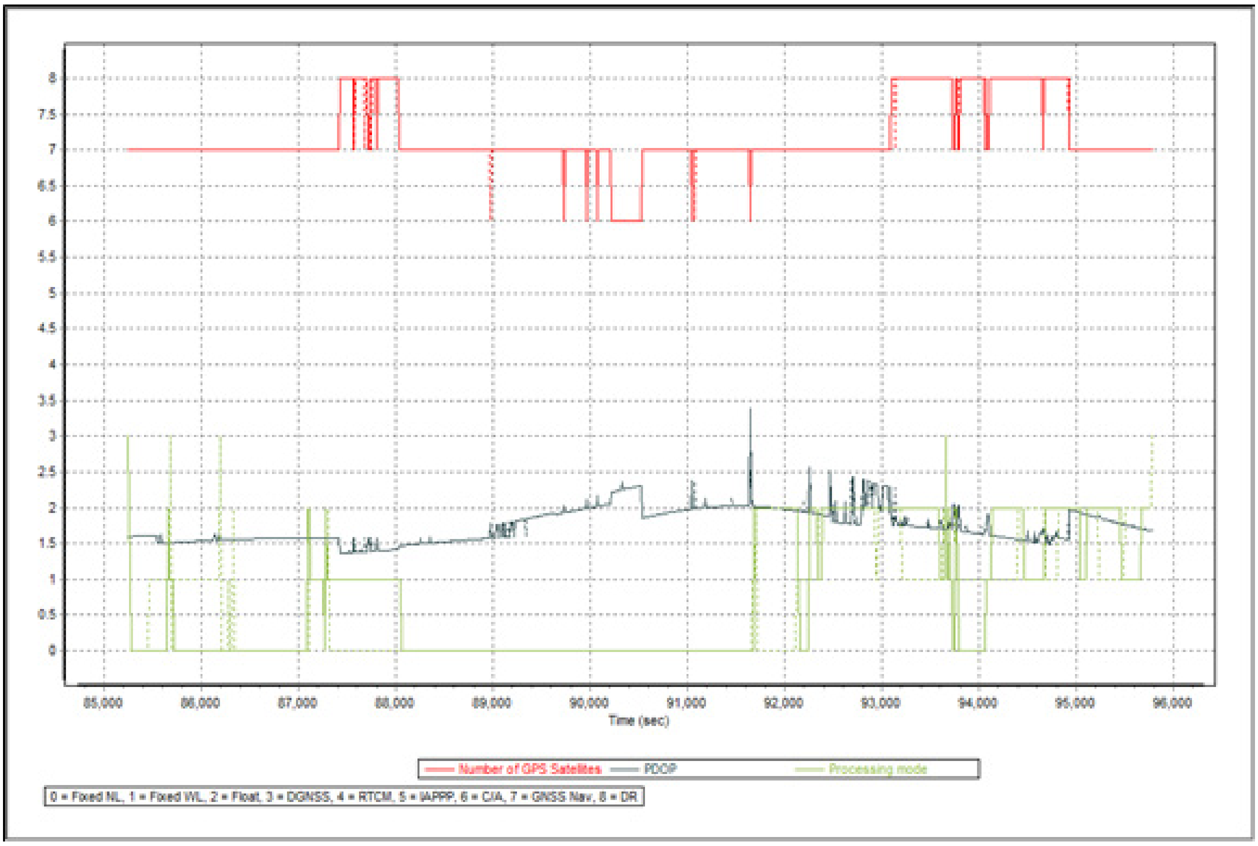


Figure A-8.78. Solution Status Parameters

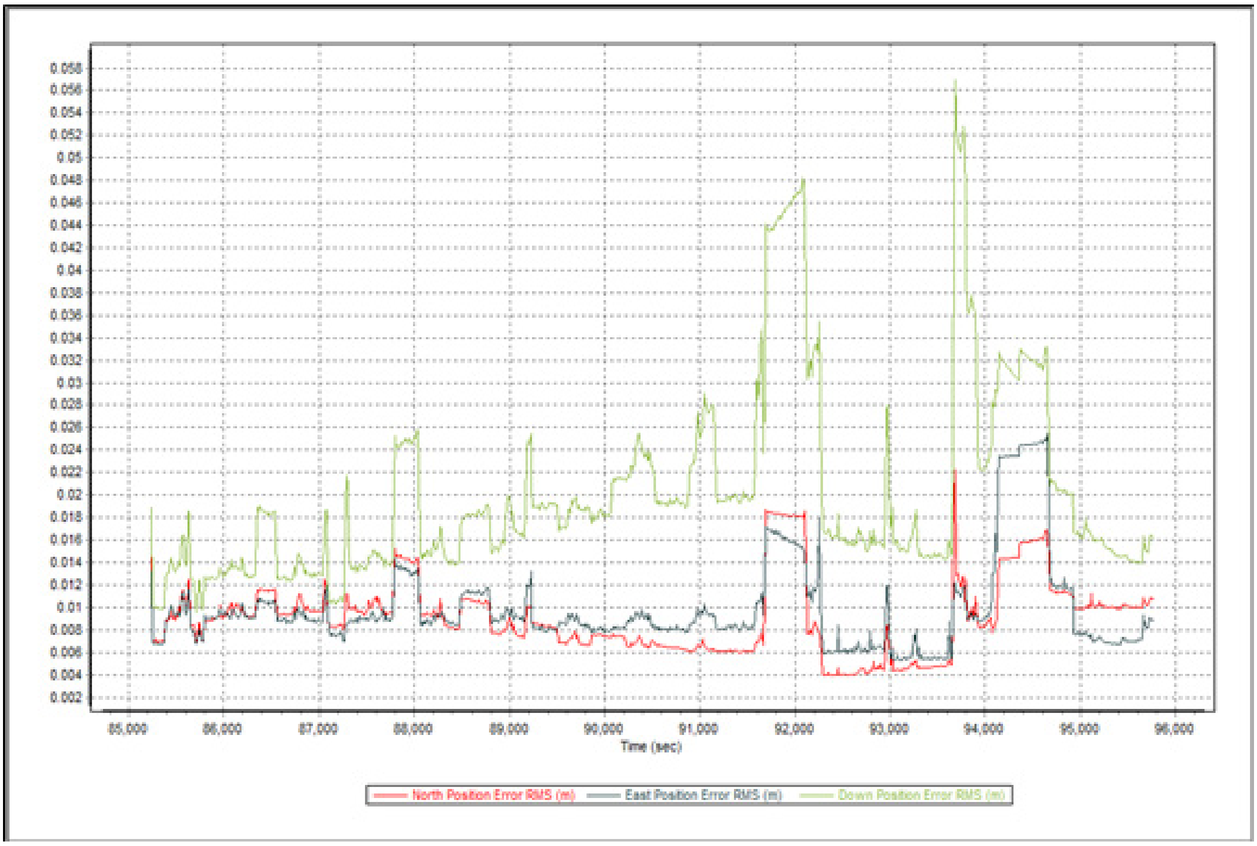


Figure A-8.79. Smoothed Performance Metrics Parameters

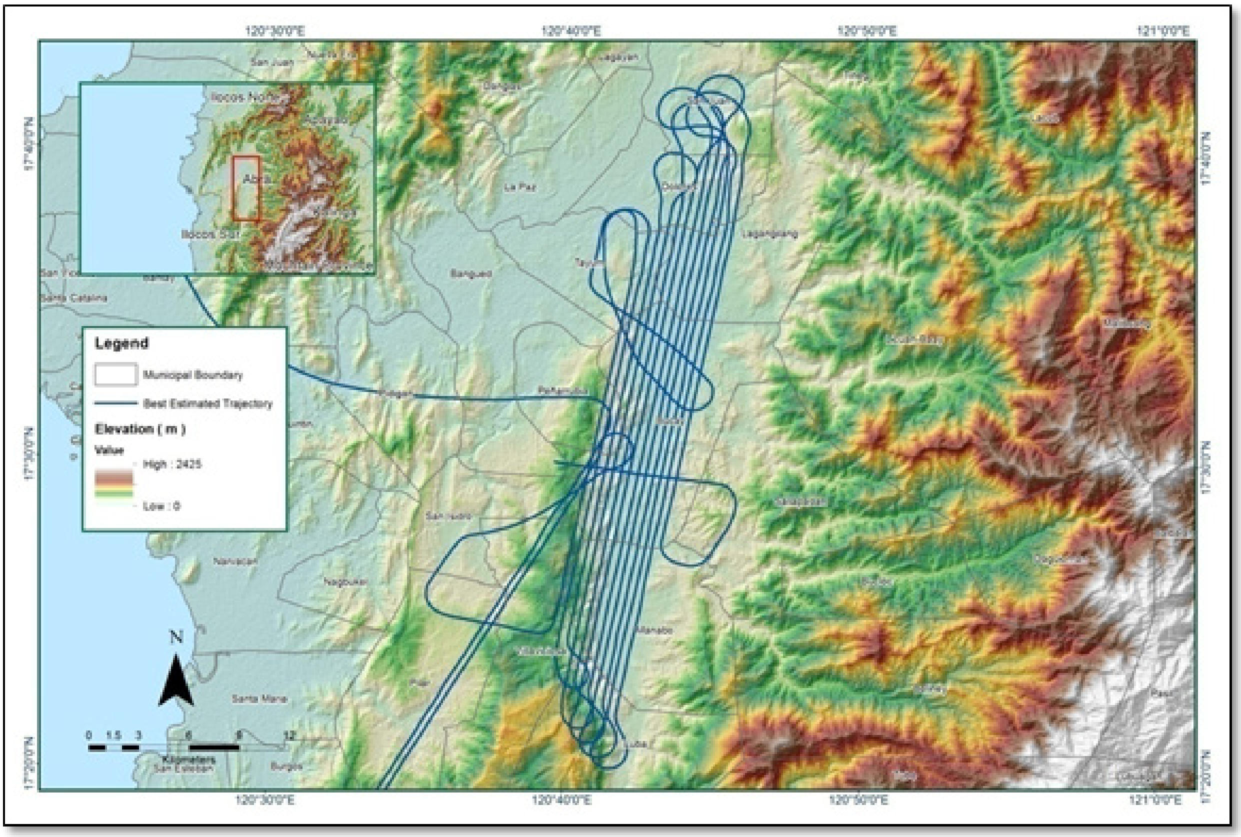


Figure A-8.80. Best Estimated Trajectory

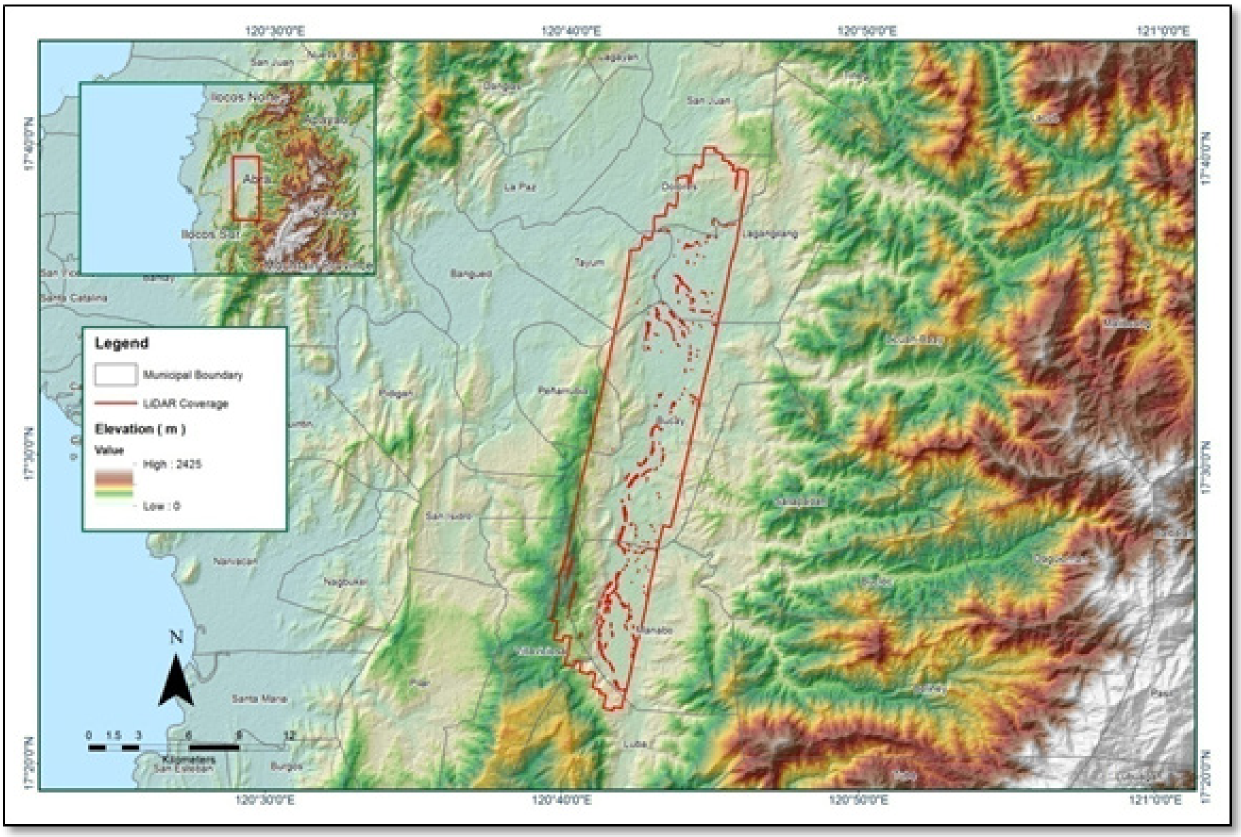


Figure A-8.81. Coverage of LiDAR data

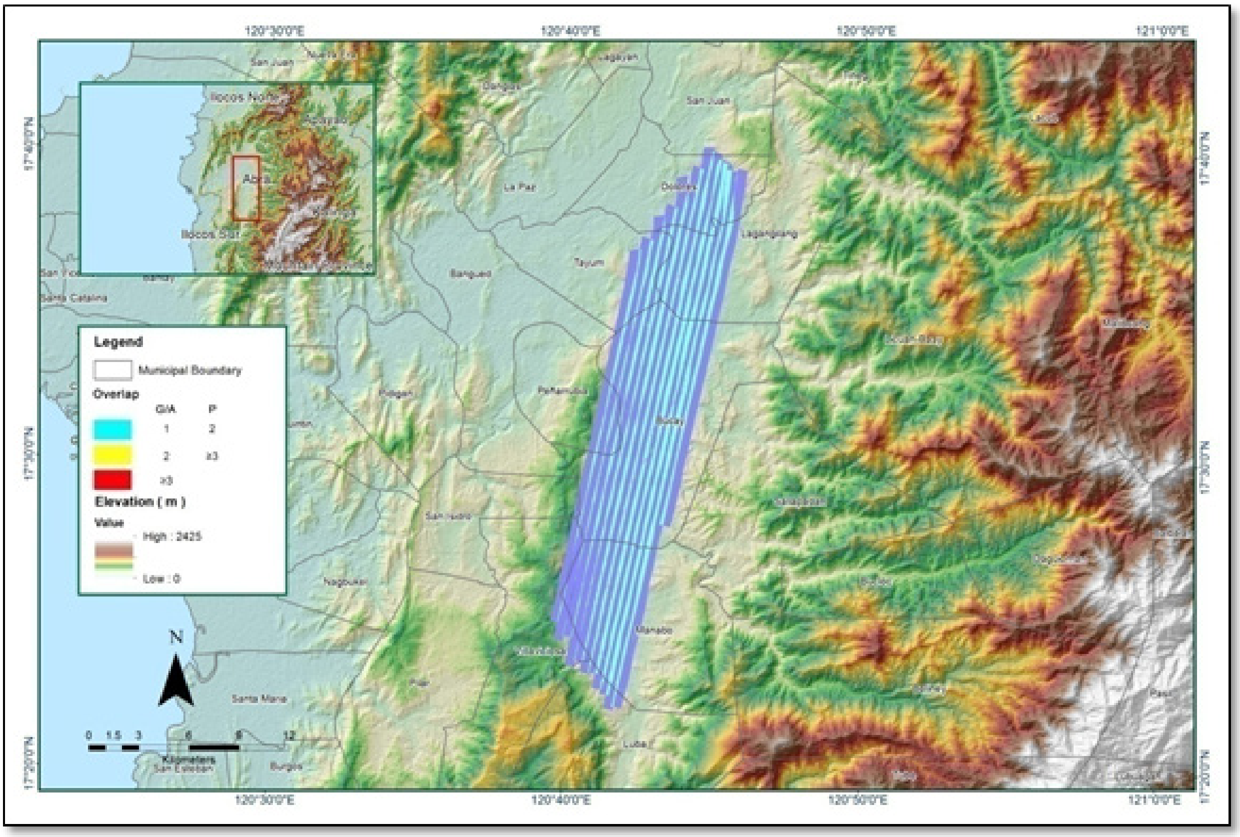


Figure A-8.82. Image of Data Overlap

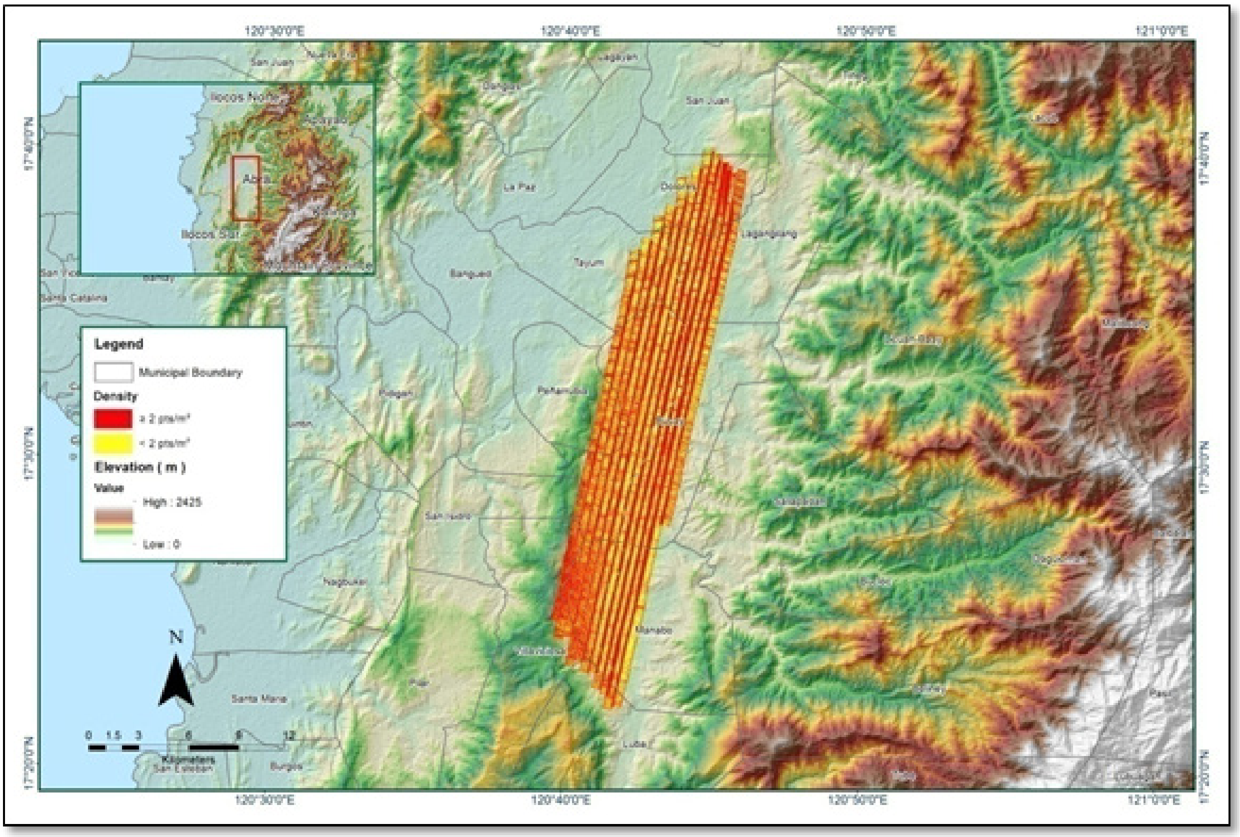


Figure A-8.83.. Density map of merged LiDAR data

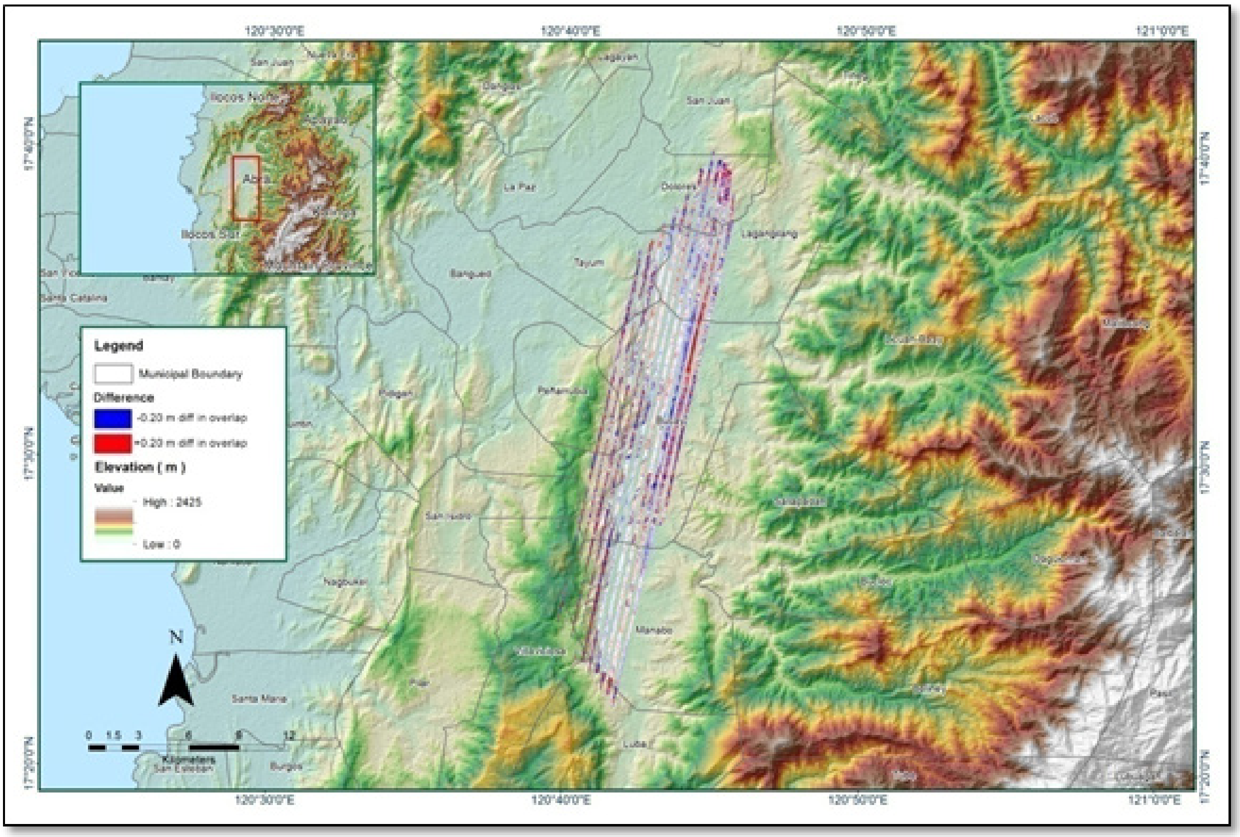


Figure A-8.84. Elevation difference between flight lines

Table A-8.13. Mission Summary Report for Mission Blk07EF

Flight Area	Ilocos
Mission Name	Blk7EF
Inclusive Flights	7122G
Range data size	14.5 GB
Base data size	8.36 MB
POS	228 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.000540
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	25.76%
Ave point cloud density per sq.m. (>2.0)	1.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	302
Maximum Height	626.57m
Minimum Height	111.57m
Classification (# of points)	
Ground	85,875,896
Low vegetation	42,808,375
Medium vegetation	65,051,921
High vegetation	151,302,414
Building	1,108,857
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Ryan James Nicholai Dizon

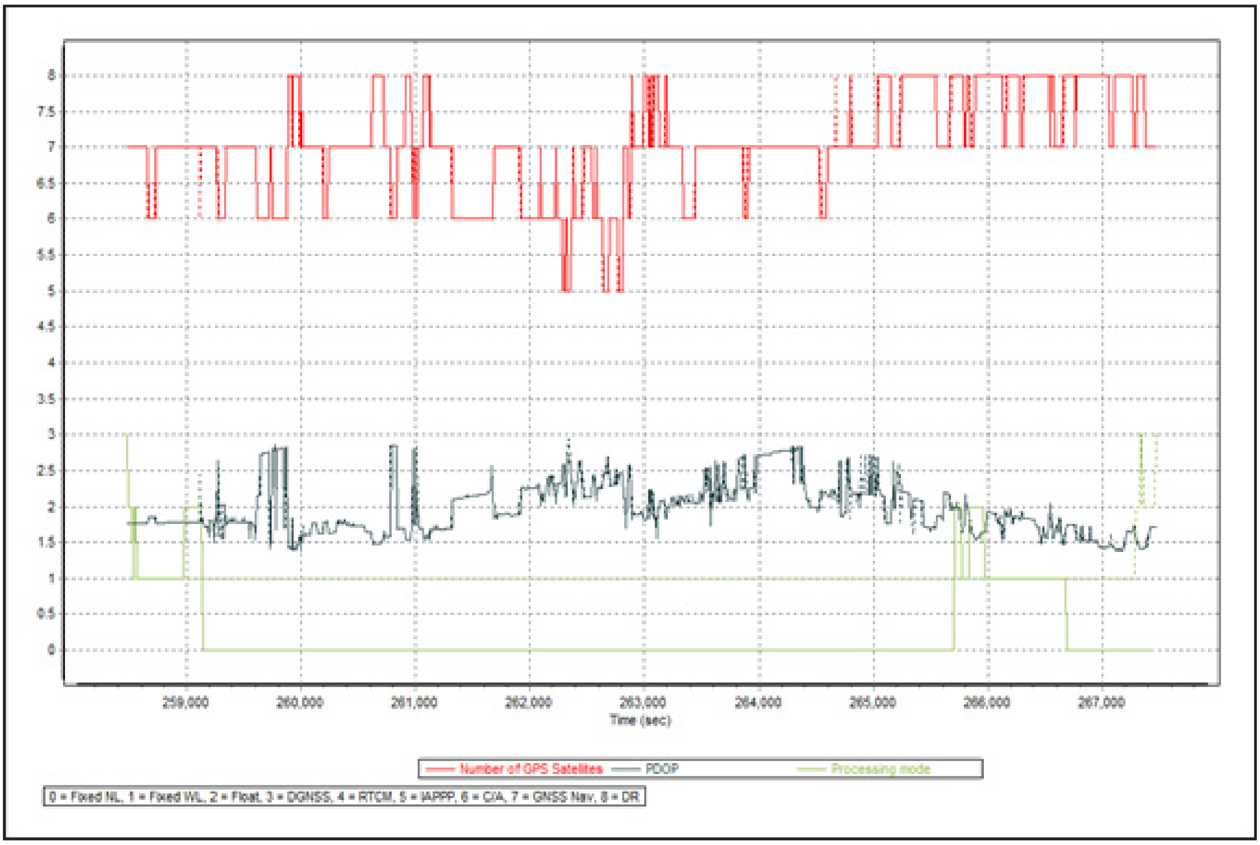


Figure A-8.85 Solution Status

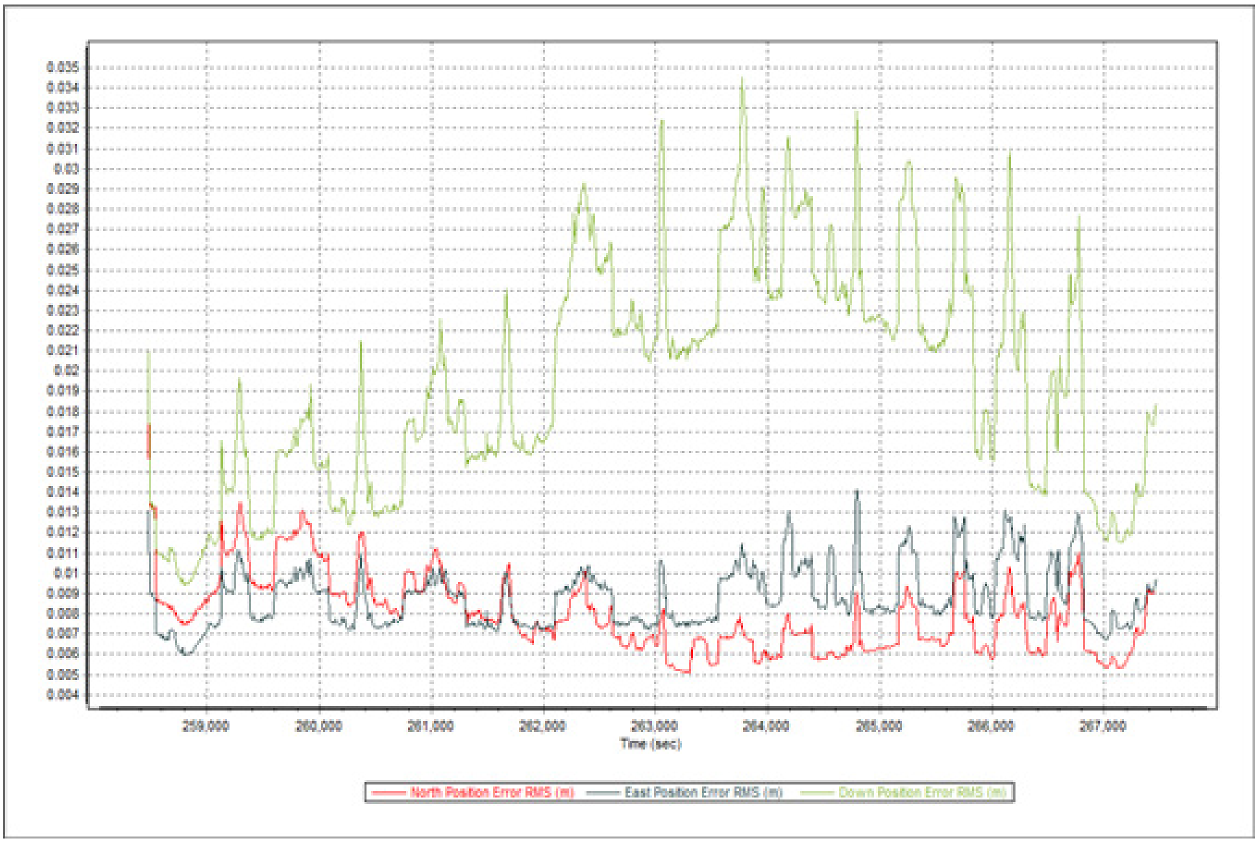


Figure A-8.86 Smoothed Performance Metrics Parameters

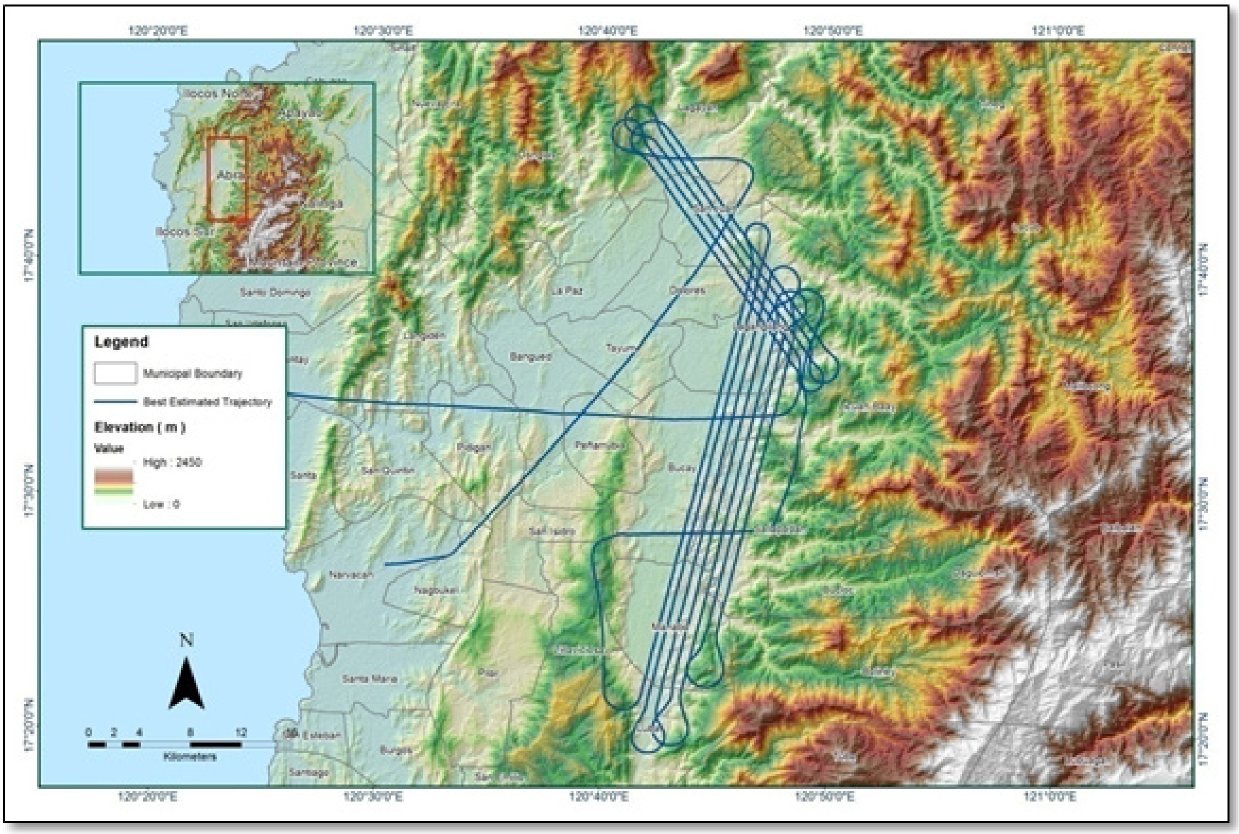


Figure A-8.87 Best Estimated Trajectory

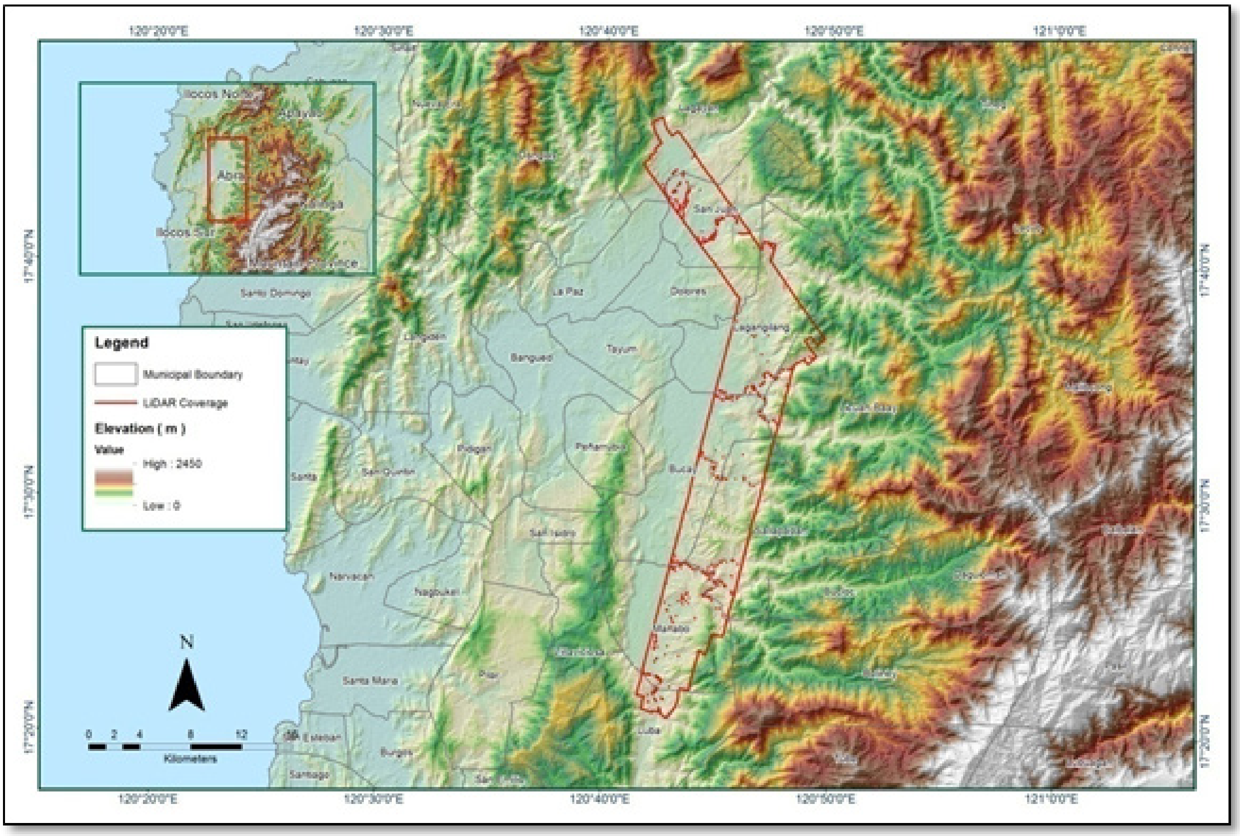


Figure A-8.88 Coverage of LiDAR data

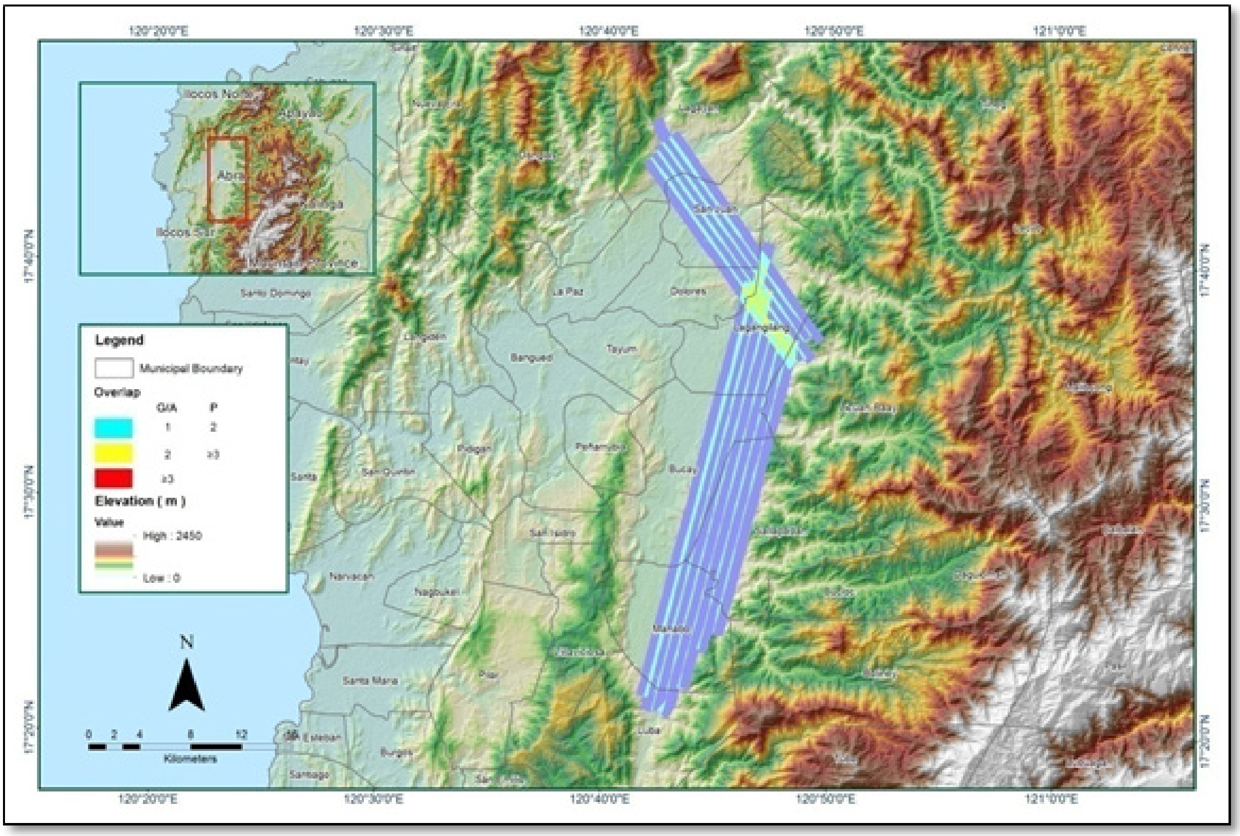


Figure A-8.89 Image of data overlap

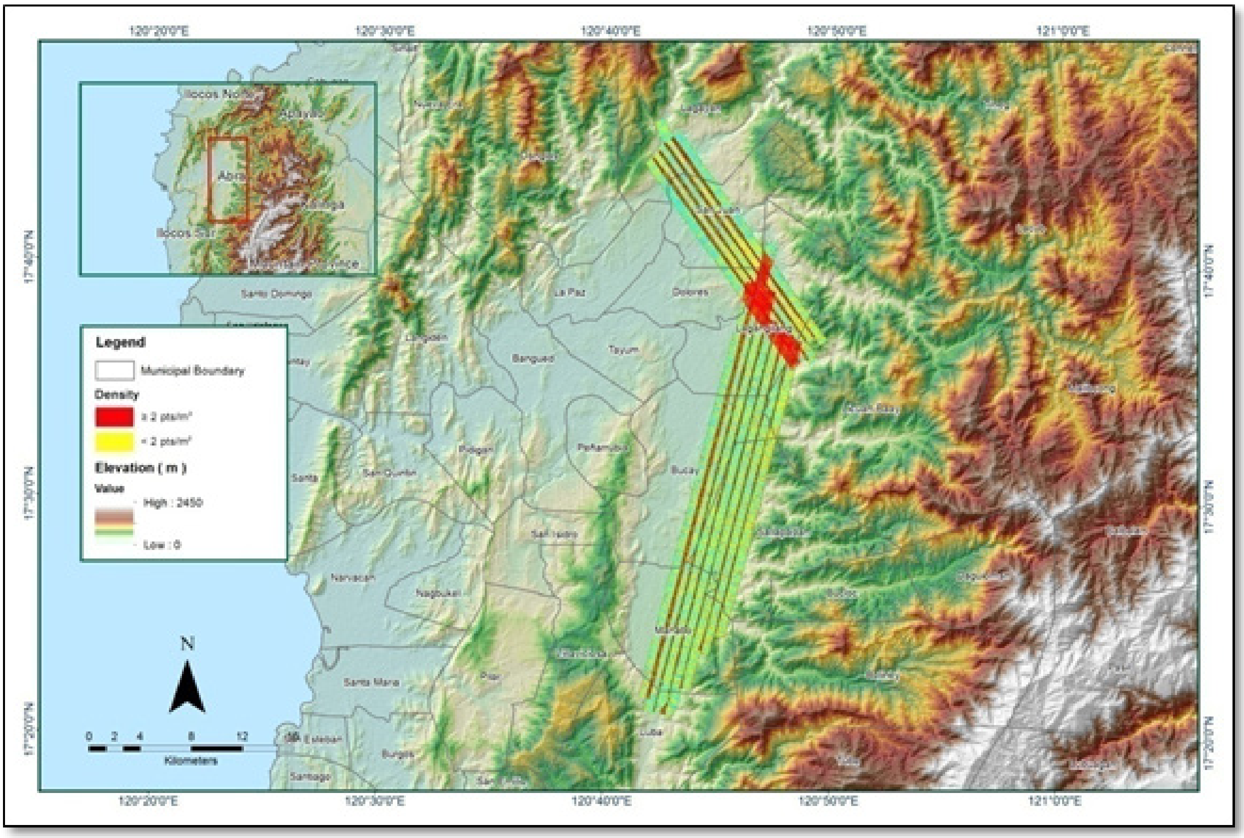


Figure A-8.90 Density map of merged LiDAR data

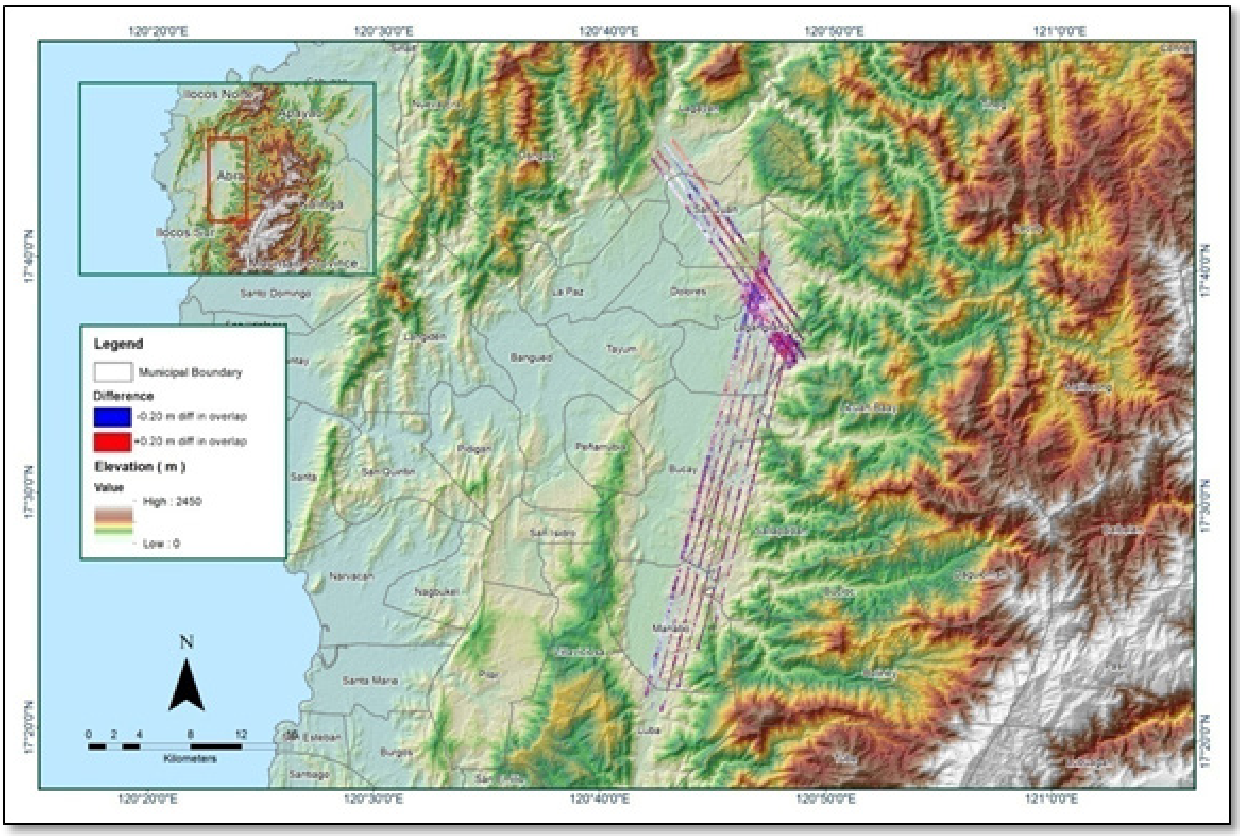


Figure A-8.91 Elevation difference between flight lines

Table A-8.14. Mission Summary Report for Mission Blk07G

Flight Area	Ilocos
Mission Name	Blk7G
Inclusive Flights	7118G, 7121G
Range data size	31.4 GB
POS data size	25.3 MB
Base data size	476 MB
Image	N/A
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000284
IMU attitude correction stdev (<0.001deg)	0.001635
GPS position stdev (<0.01m)	0.0109
Minimum % overlap (>25)	24.05%
Ave point cloud density per sq.m. (>2.0)	2.53
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	203
Maximum Height	615.92m
Minimum Height	65.4m
Classification (# of points)	
Ground	52,148,632
Low vegetation	23,593,702
Medium vegetation	77,121,015
High vegetation	162,057,781
Building	2,198,672
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Jeffrey Delica

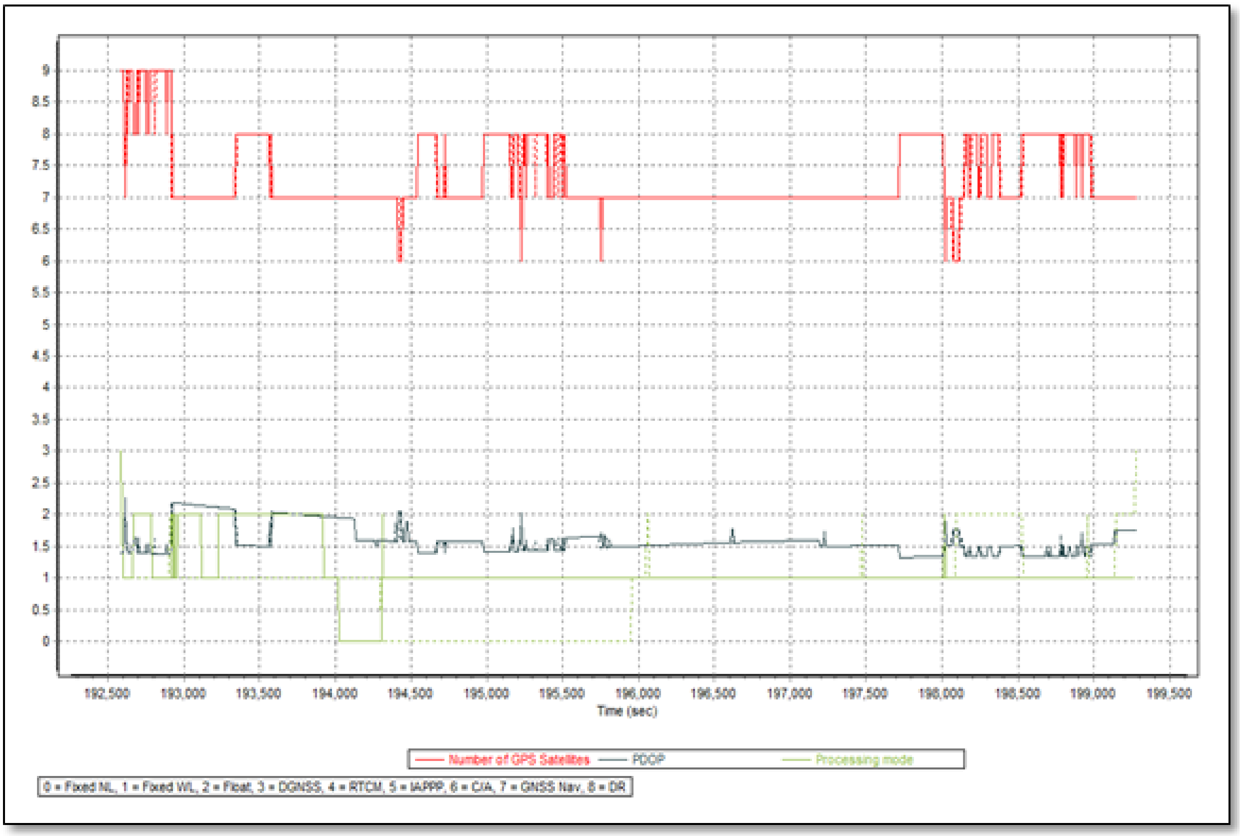


Figure A-8.92 Solution Status

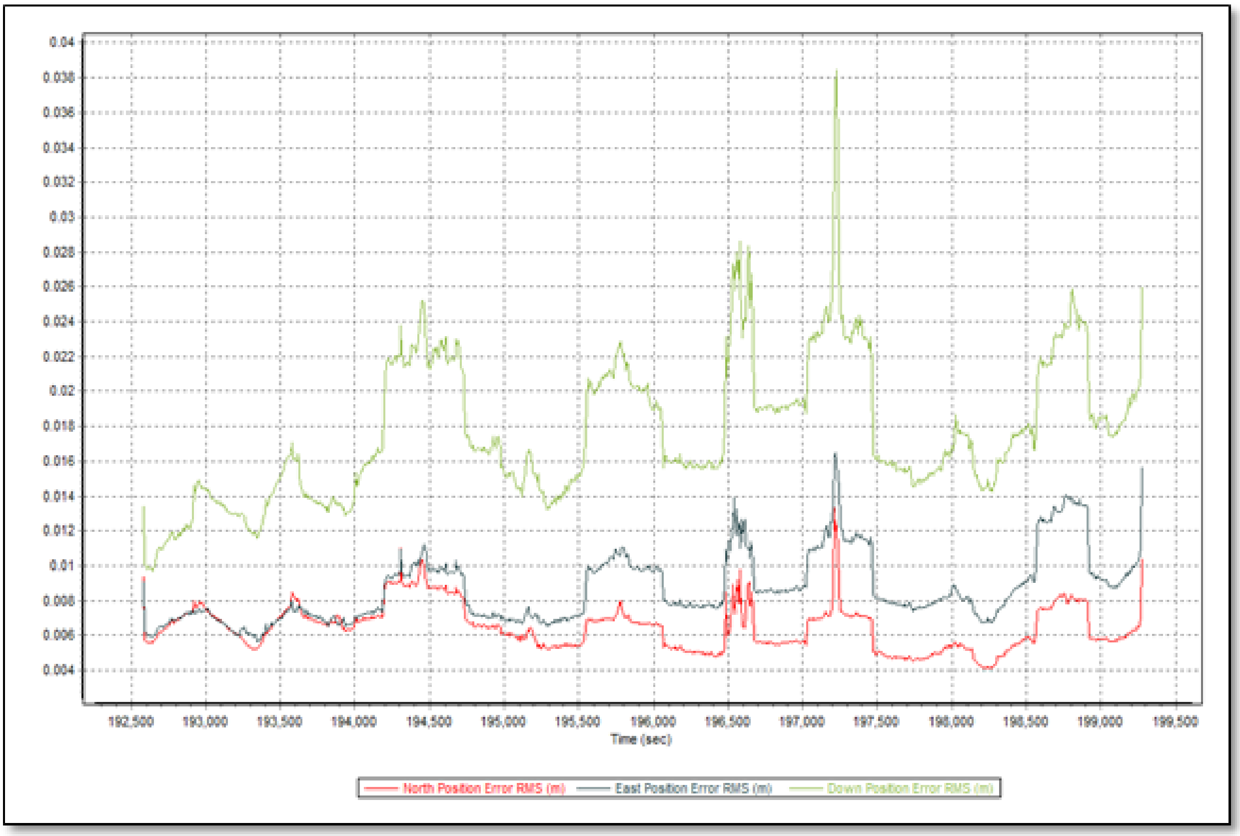


Figure A-8.93 Smoothed Performance Metrics Parameters

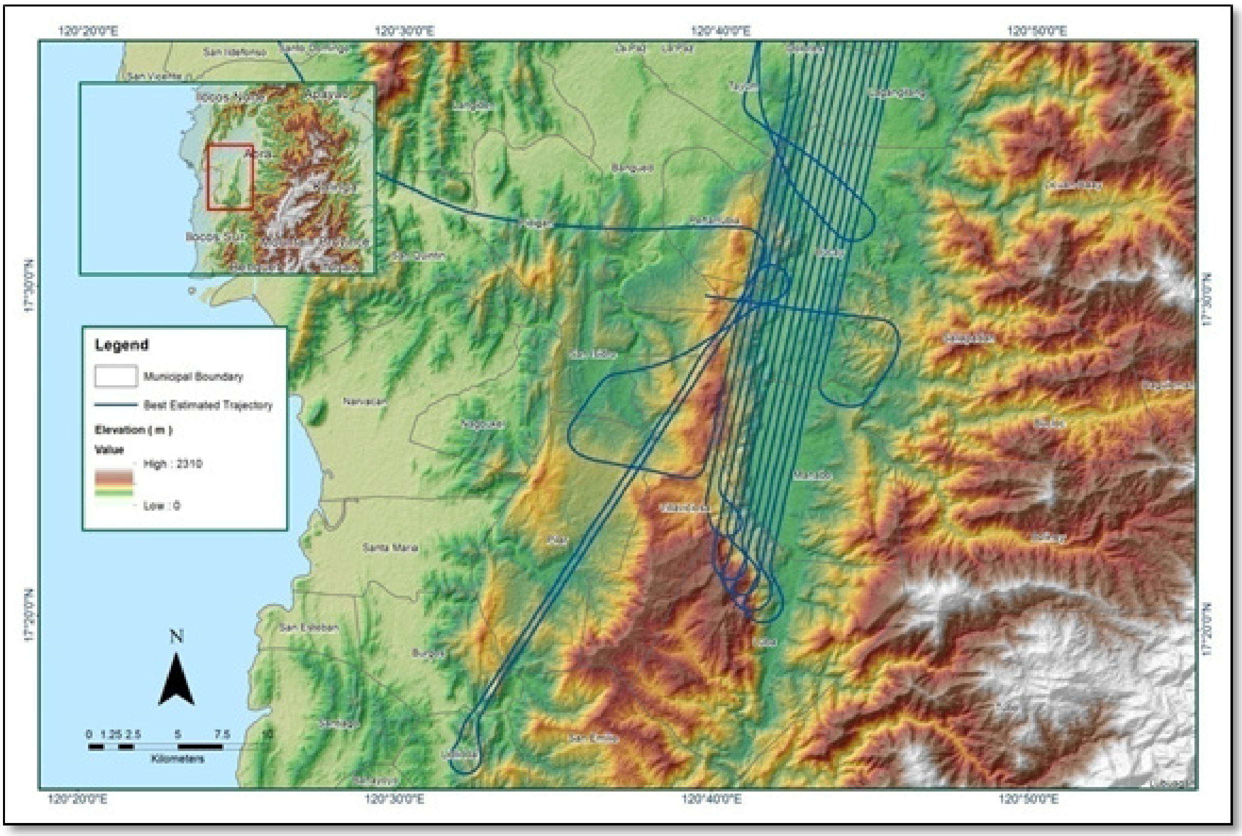


Figure A-8.94 Best Estimated Trajectory

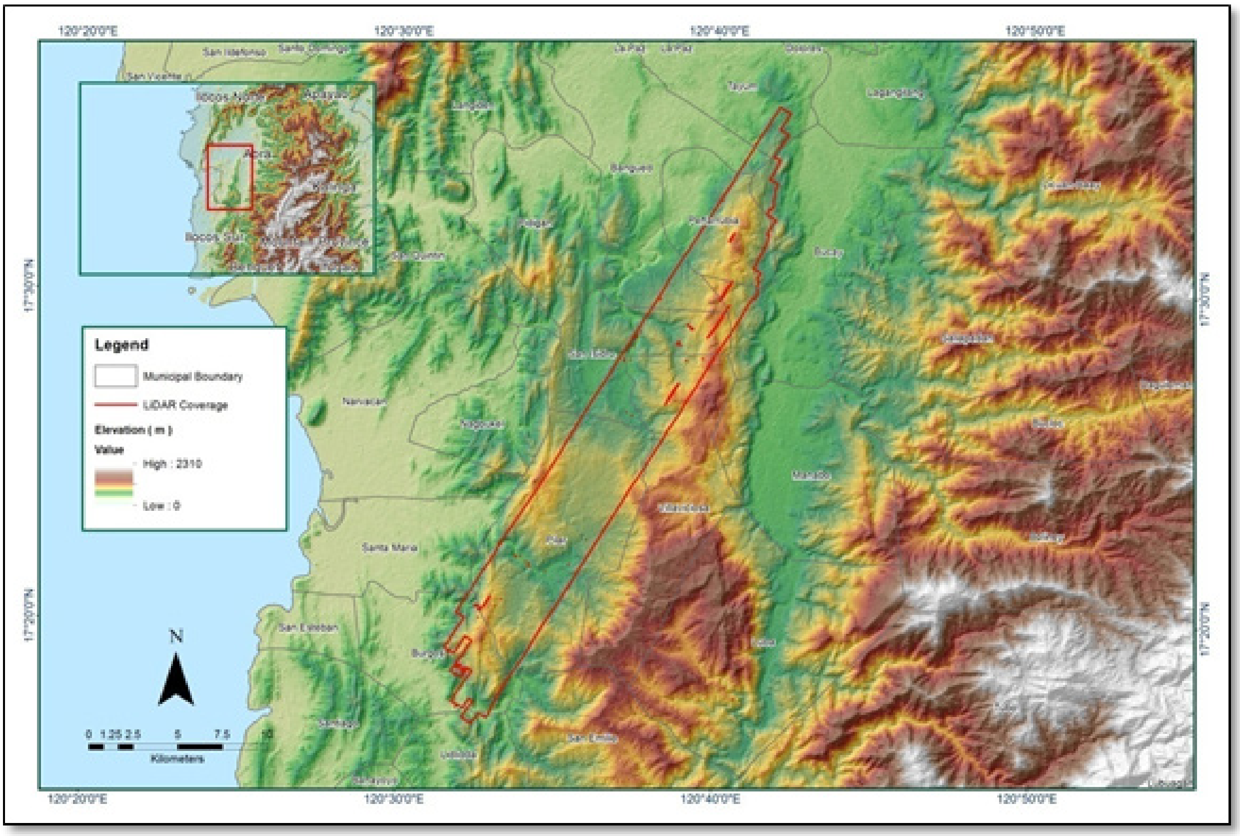


Figure A-8.95 Coverage of LiDAR data

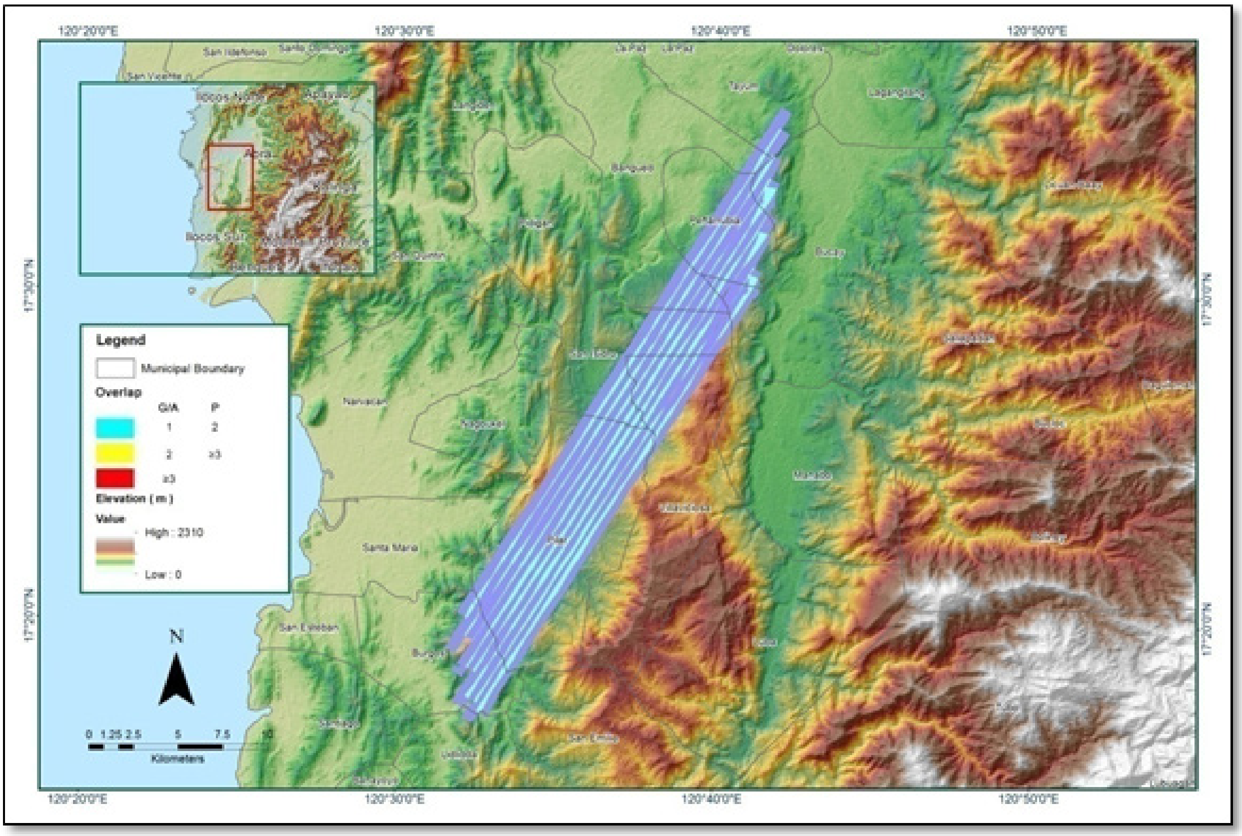


Figure A-8.96 Image of data overlap

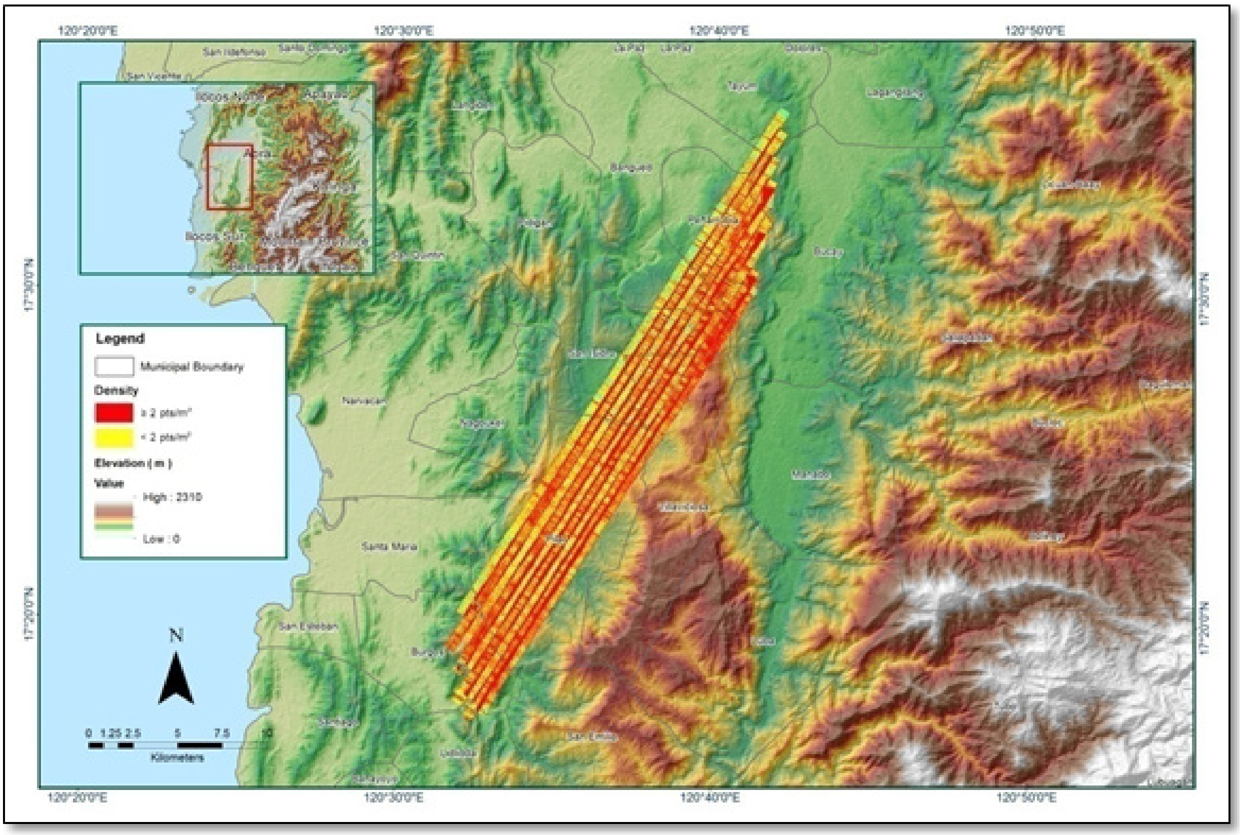


Figure A-8.97 Density map of merged LiDAR data

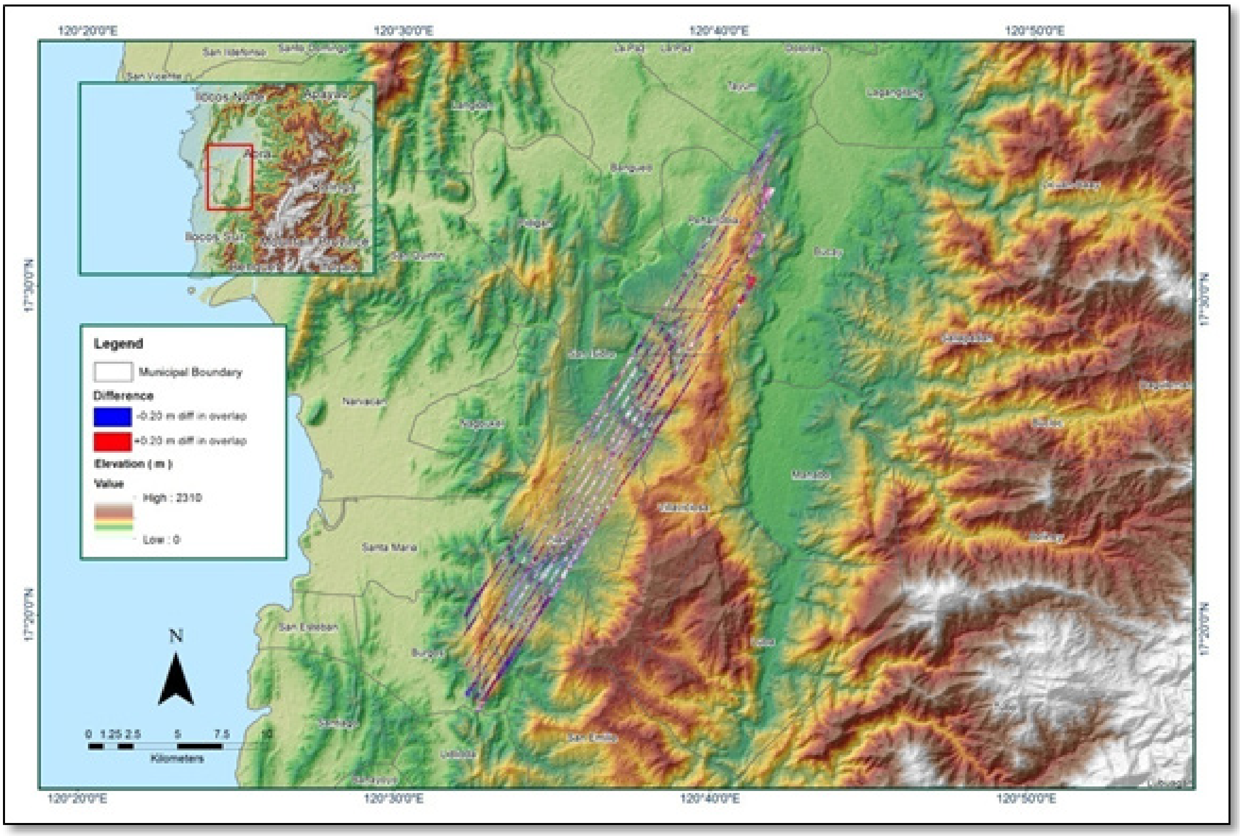


Figure A-8.98 Elevation difference between flight lines

Table A-8.15. Mission Summary Report for Mission Blk07A

Flight Area	Laoag
Mission Name	Blk7A
Inclusive Flights	4045G
Range data size	14.5 GB
POS data size	231MB
Base data size	334 MB
Image	n/a
Transfer date	July 1, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.87
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	2.70
Boresight correction stdev (<0.001deg)	0.000651
IMU attitude correction stdev (<0.001deg)	0.003088
GPS position stdev (<0.01m)	0.0030
Minimum % overlap (>25)	24.95
Ave point cloud density per sq.m. (>2.0)	3.45
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	209
Maximum Height	647.40 m
Minimum Height	36.90 m
Classification (# of points)	
Ground	41,894,399
Low vegetation	29,081,634
Medium vegetation	133,067,728
High vegetation	162,729,291
Building	994,713
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. MervenmatthewNatino, Engr. MonalyneRabino

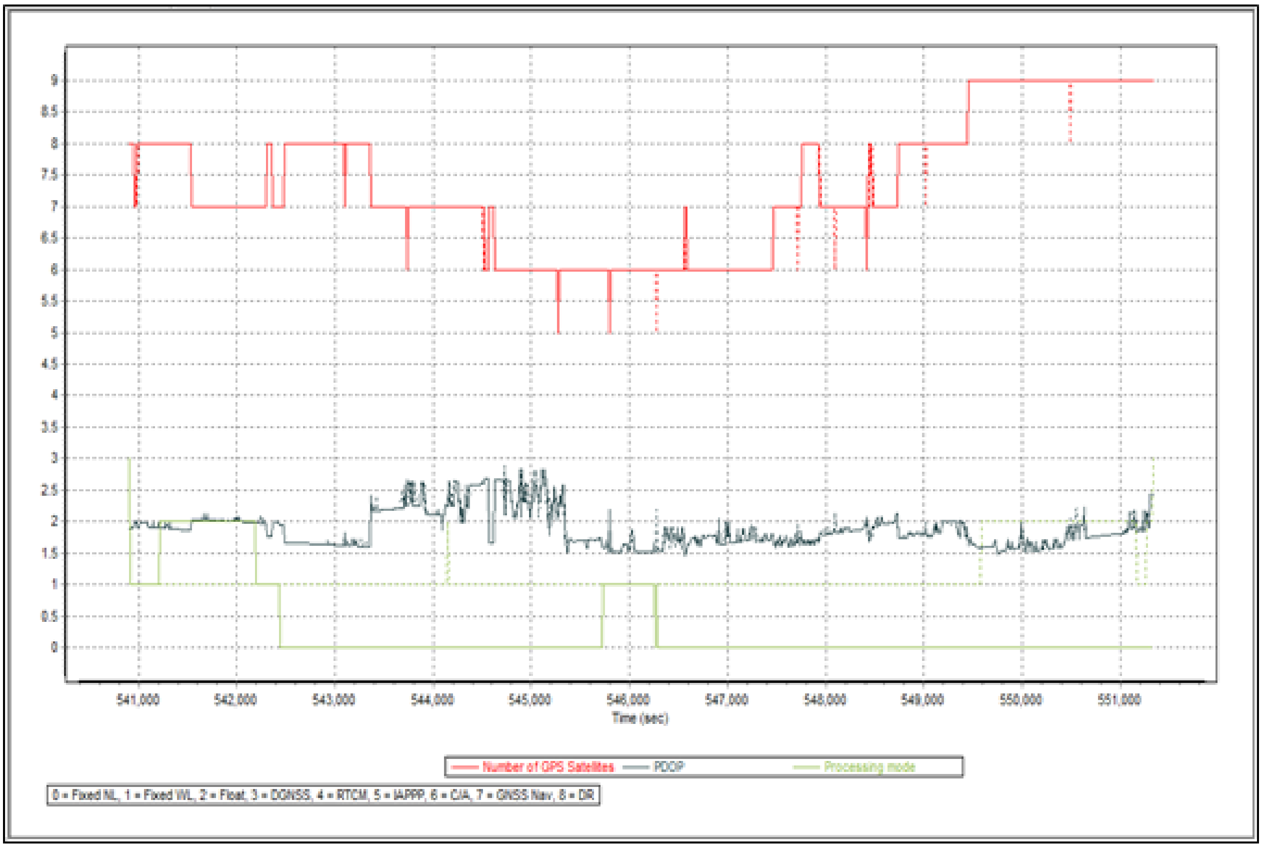


Figure A-8.99 Solution Status

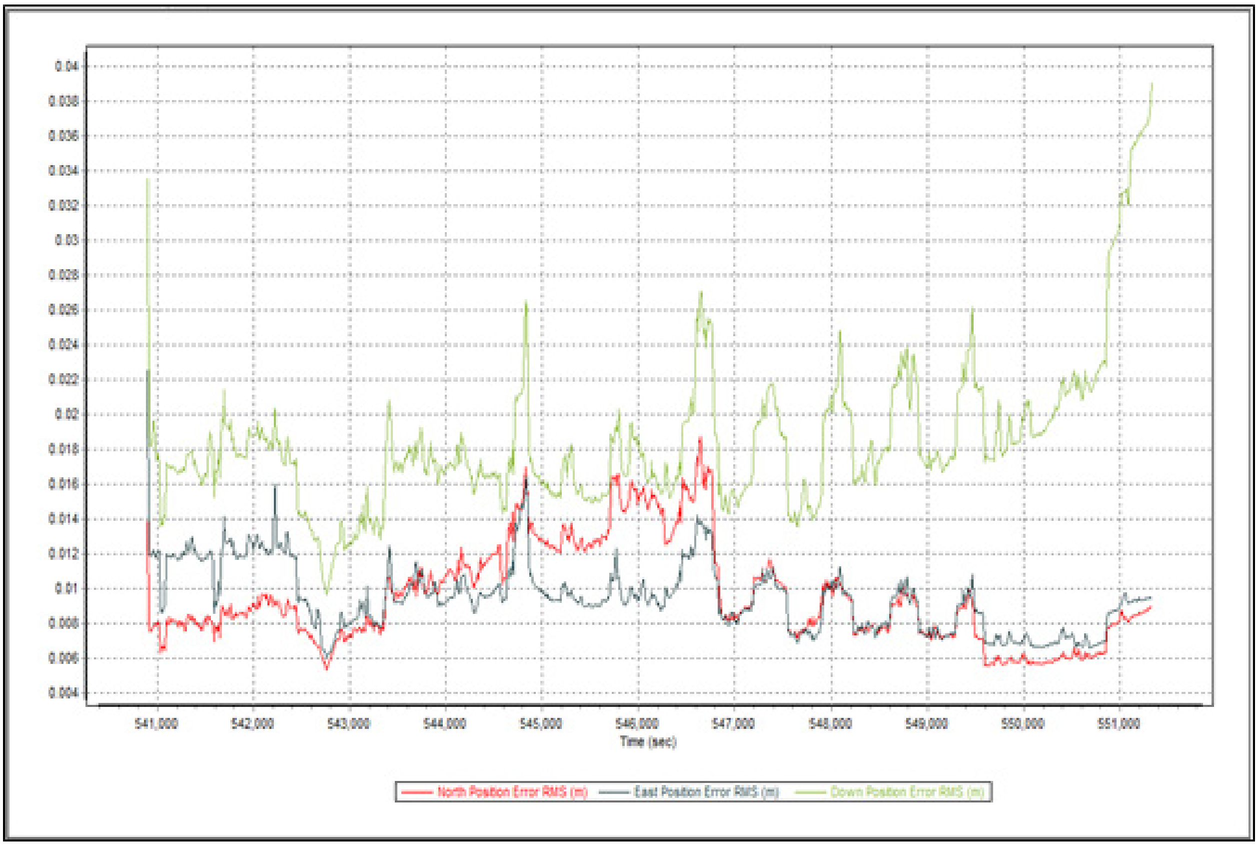


Figure A-8.100 Smoothed Performance Metric Parameters

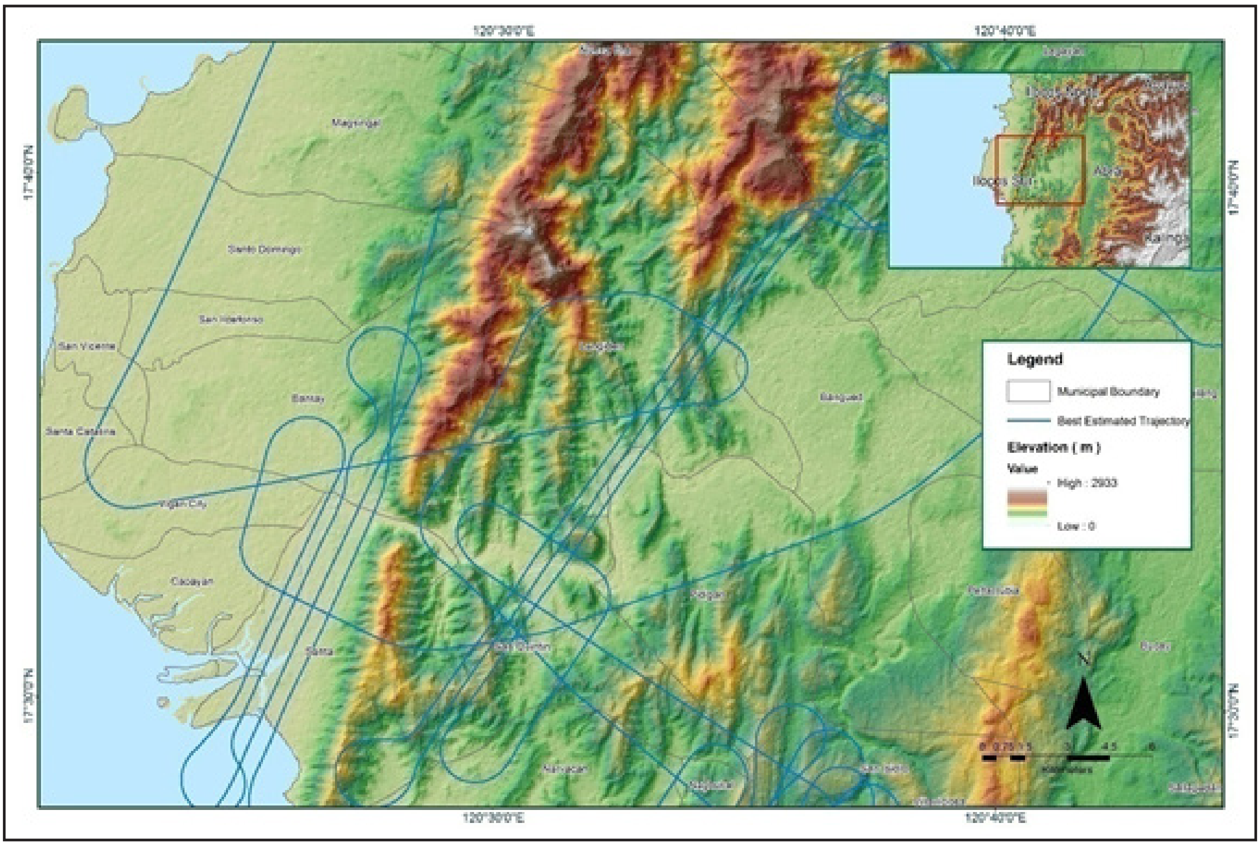


Figure A-8.101 Best Estimated Trajectory

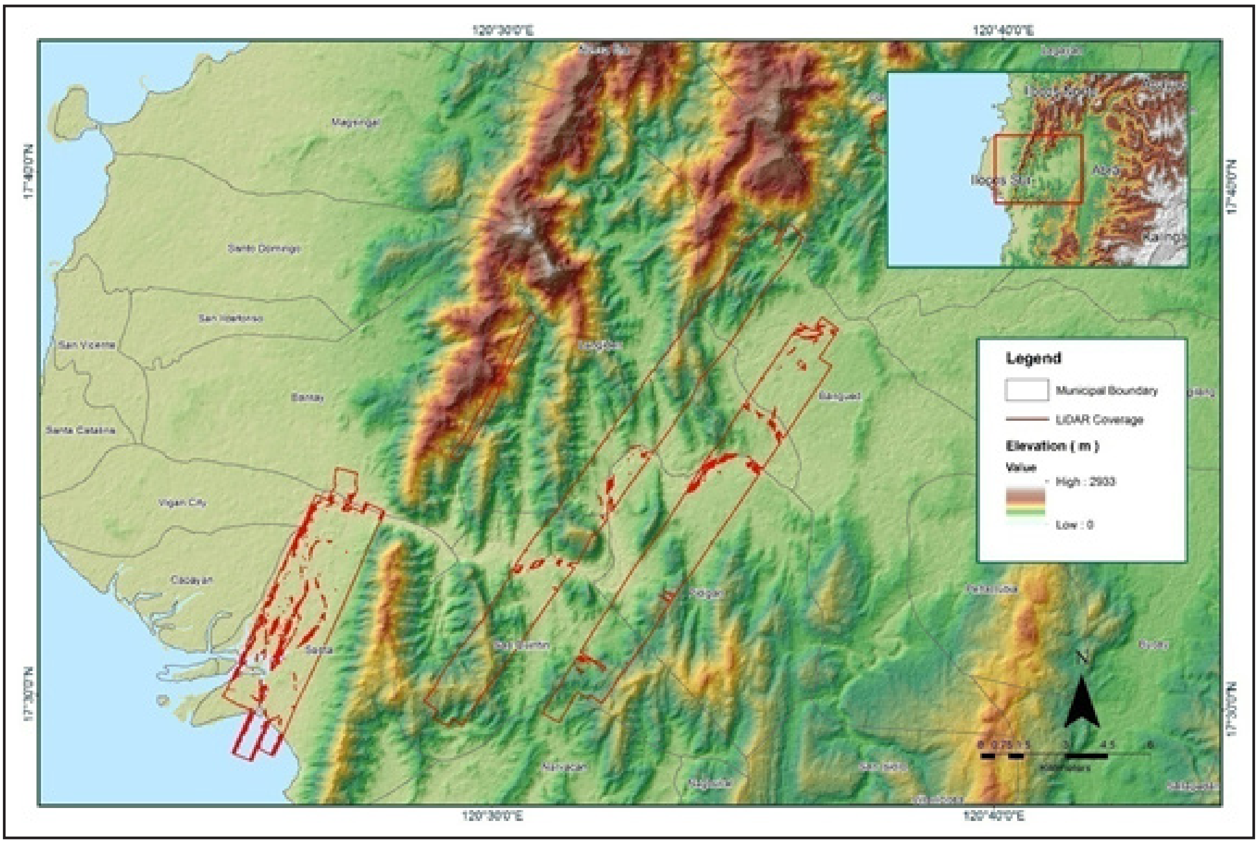


Figure A-8.102 Coverage of LiDAR Data

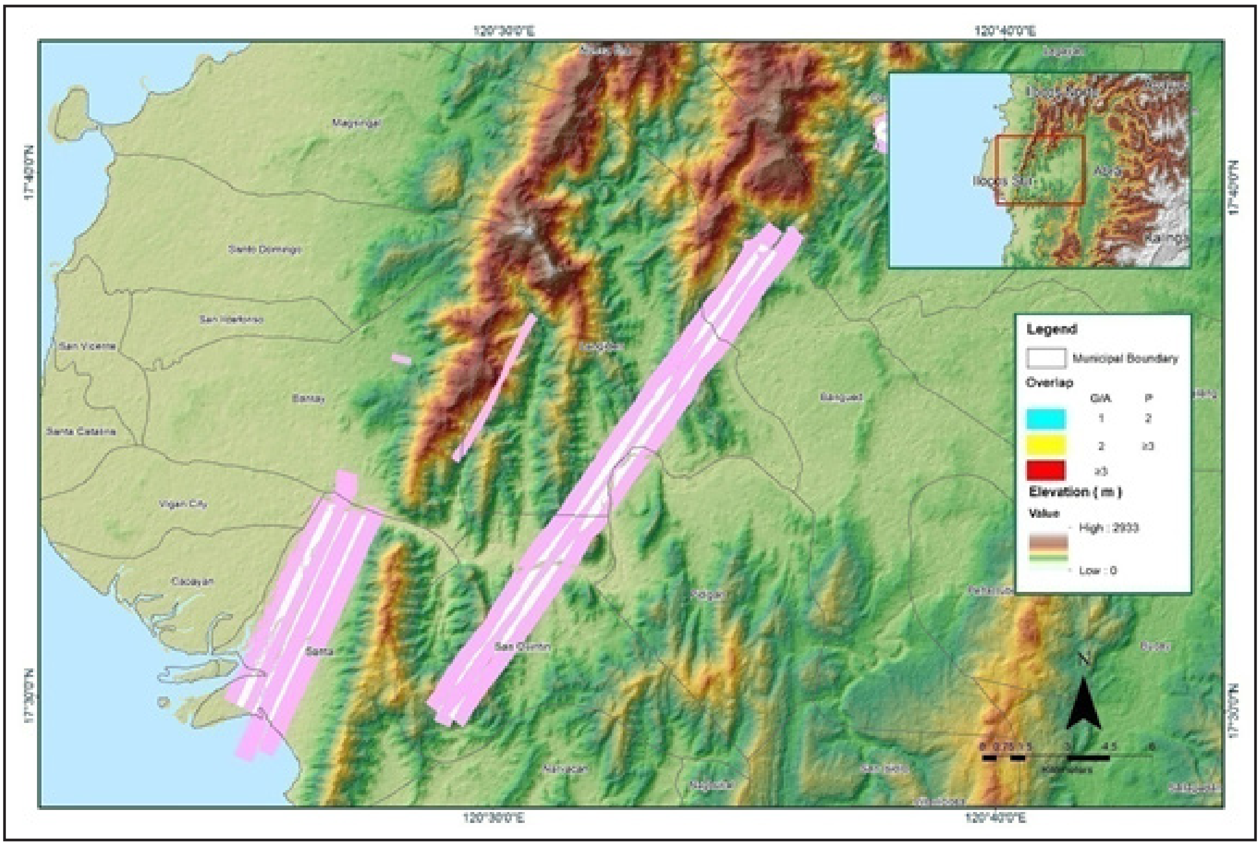


Figure A-8.103 Image of data overlap

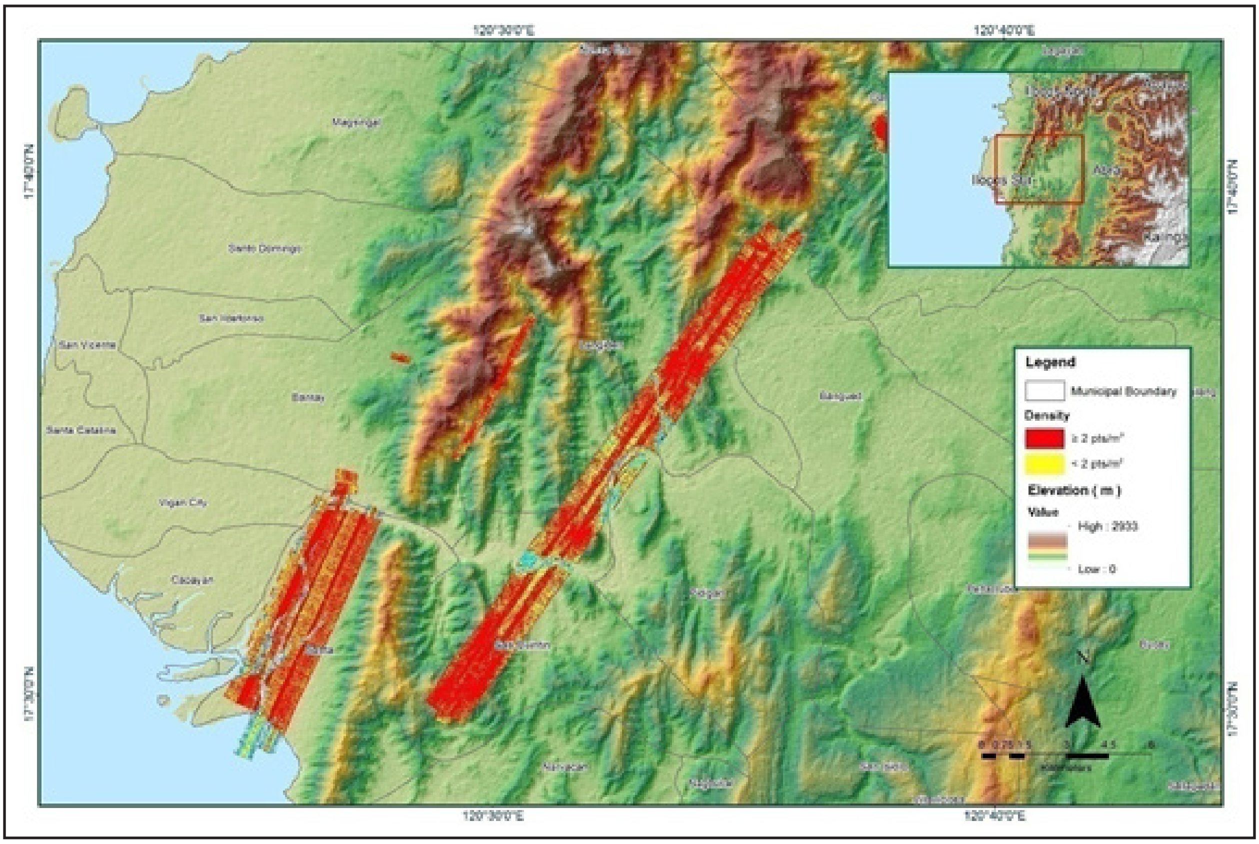


Figure A-8.104 Density map of merged LiDAR data

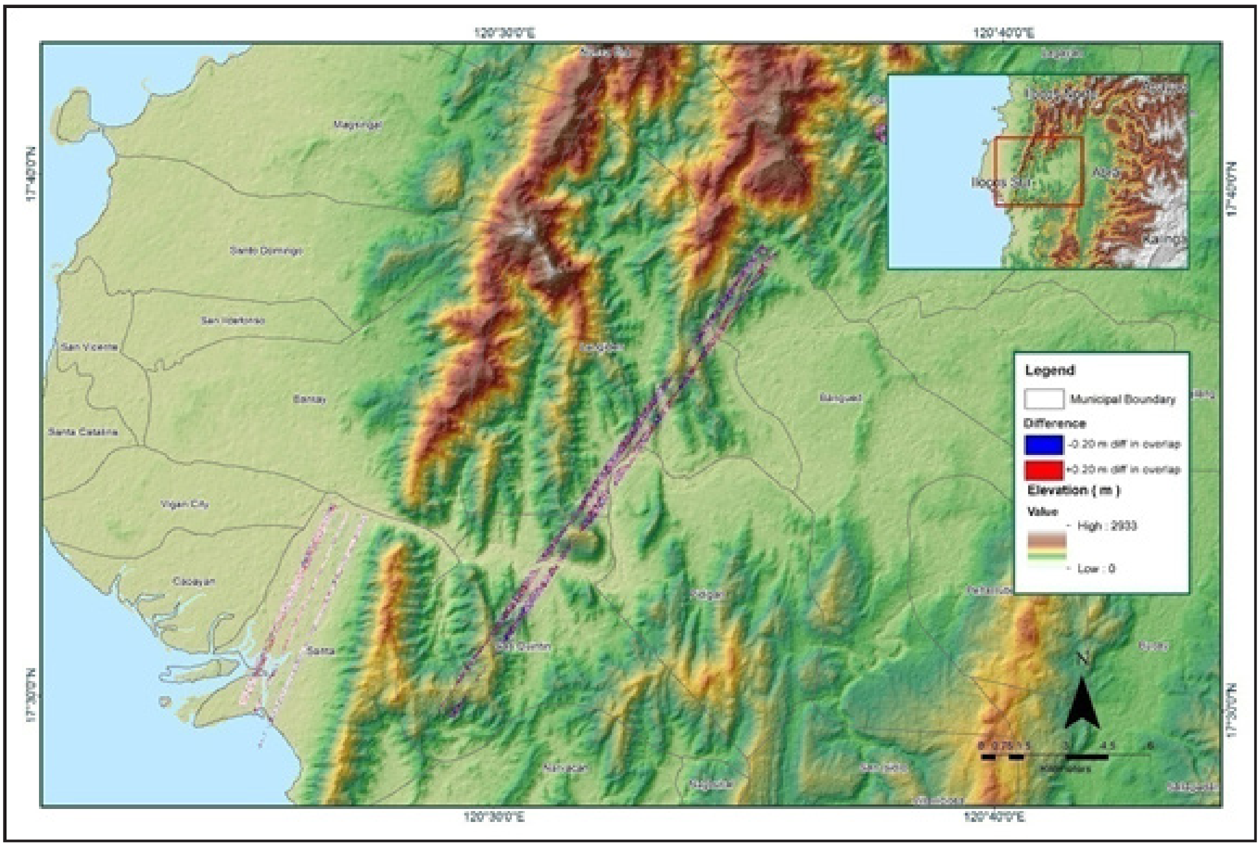


Figure A-8.105 Elevation difference between flight lines

Table A-8.16. Mission Summary Report for Mission Blk07C

Flight Area	Laoag
Mission Name	Blk7C
Inclusive Flights	4043G
Range data size	24.7GB
POS data size	242MB
Base data size	334 MB
Image	n/a
Transfer date	July 1, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.27
RMSE for East Position (<4.0 cm)	1.51
RMSE for Down Position (<8.0 cm)	4.24
Boresight correction stdev (<0.001deg)	0.000764
IMU attitude correction stdev (<0.001deg)	0.006773
GPS position stdev (<0.01m)	0.0160
Minimum % overlap (>25)	38.10
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	273
Maximum Height	596.60 m
Minimum Height	46.06 m
Classification (# of points)	
Ground	129,375,955
Low vegetation	76,678,449
Medium vegetation	241,188,860
High vegetation	338,518,322
Building	2,319,509
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga Jr., Engr. Czarina Jean Añonuevo

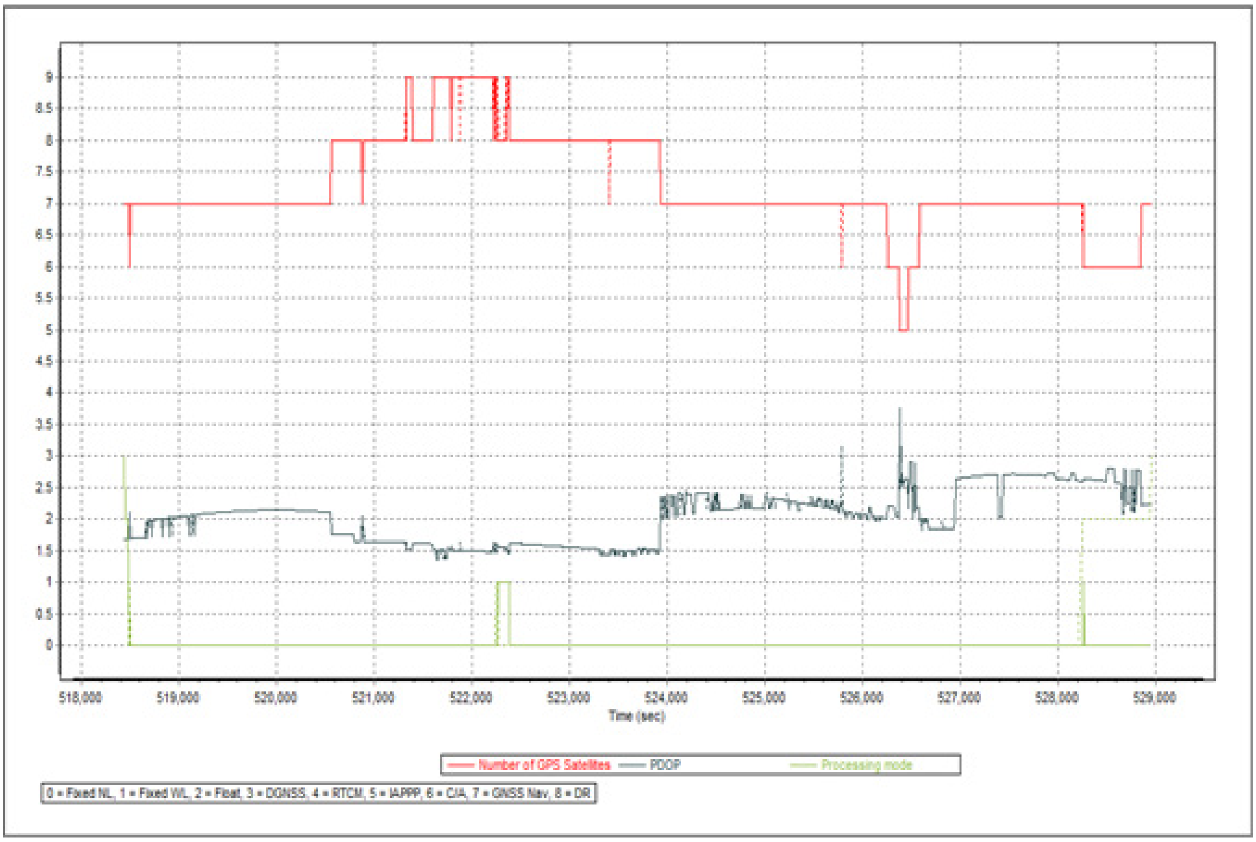


Figure A-8.106 Solution Status

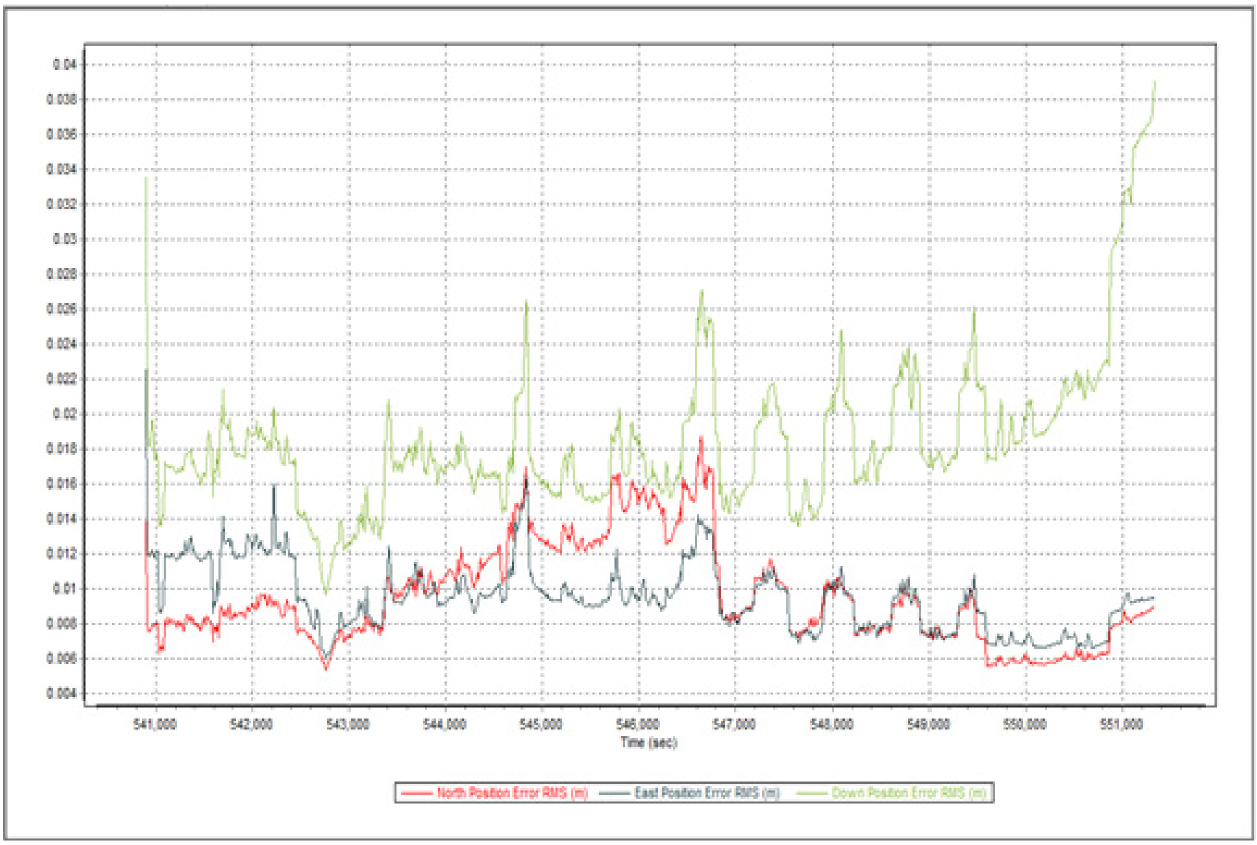


Figure A-8.107 Smoothed Performance Metric Parameters

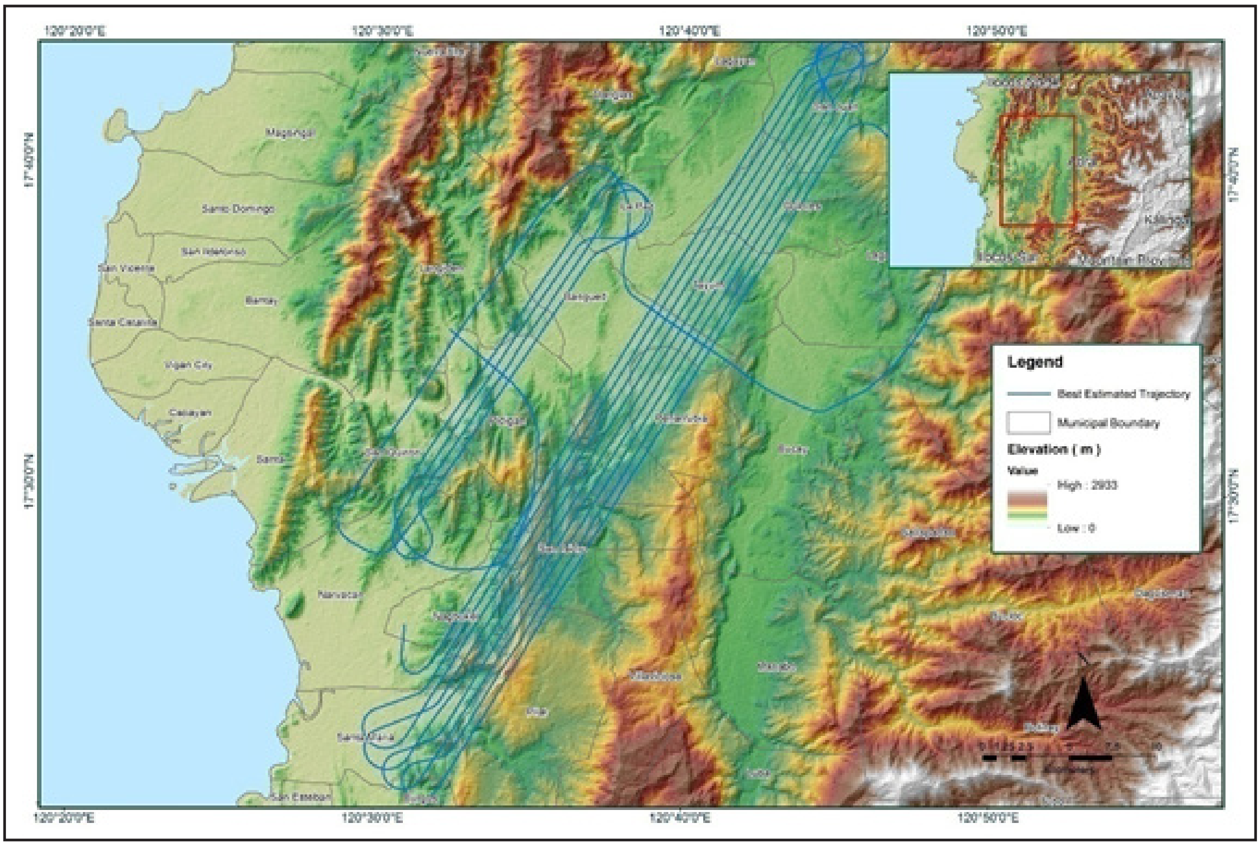


Figure A-8.108 Best Estimated Trajectory

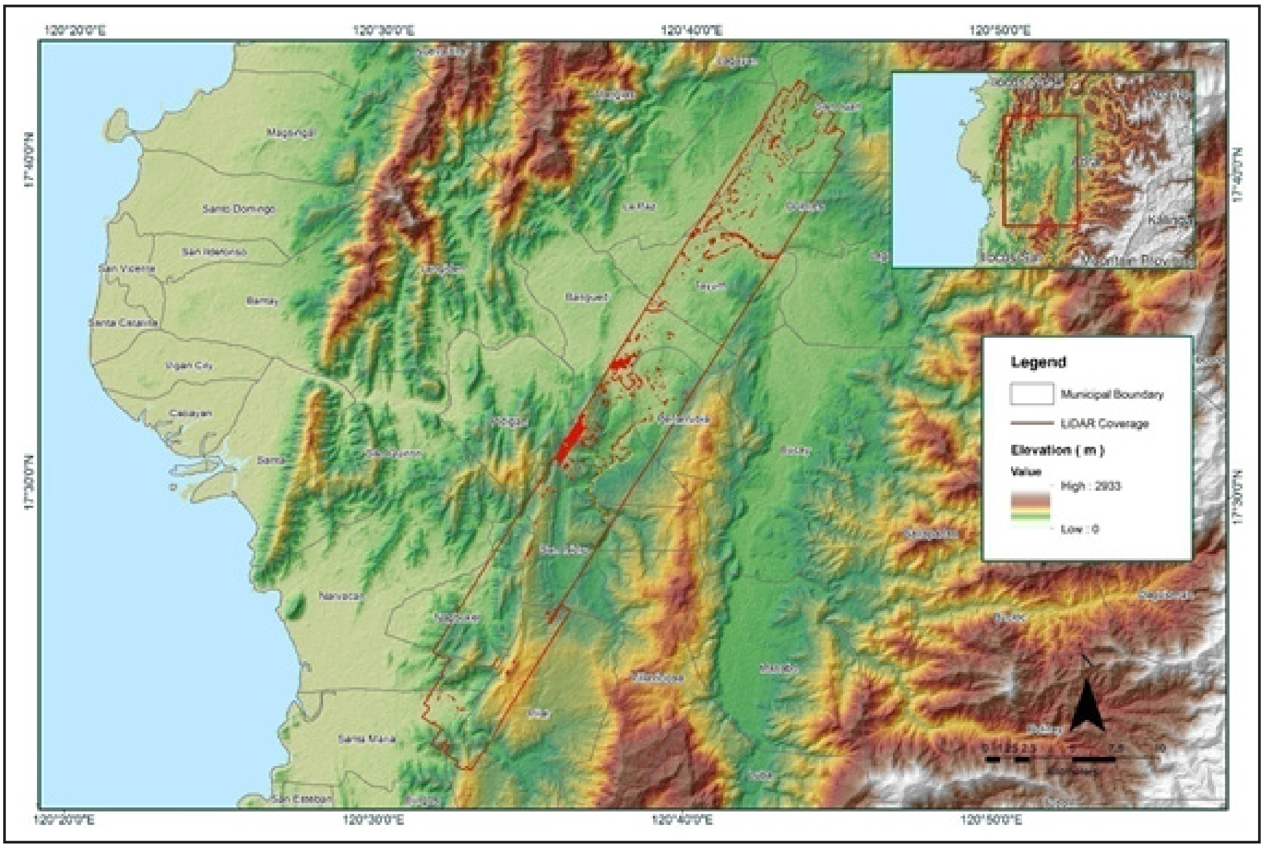


Figure A-8.109 Coverage of LiDAR Data

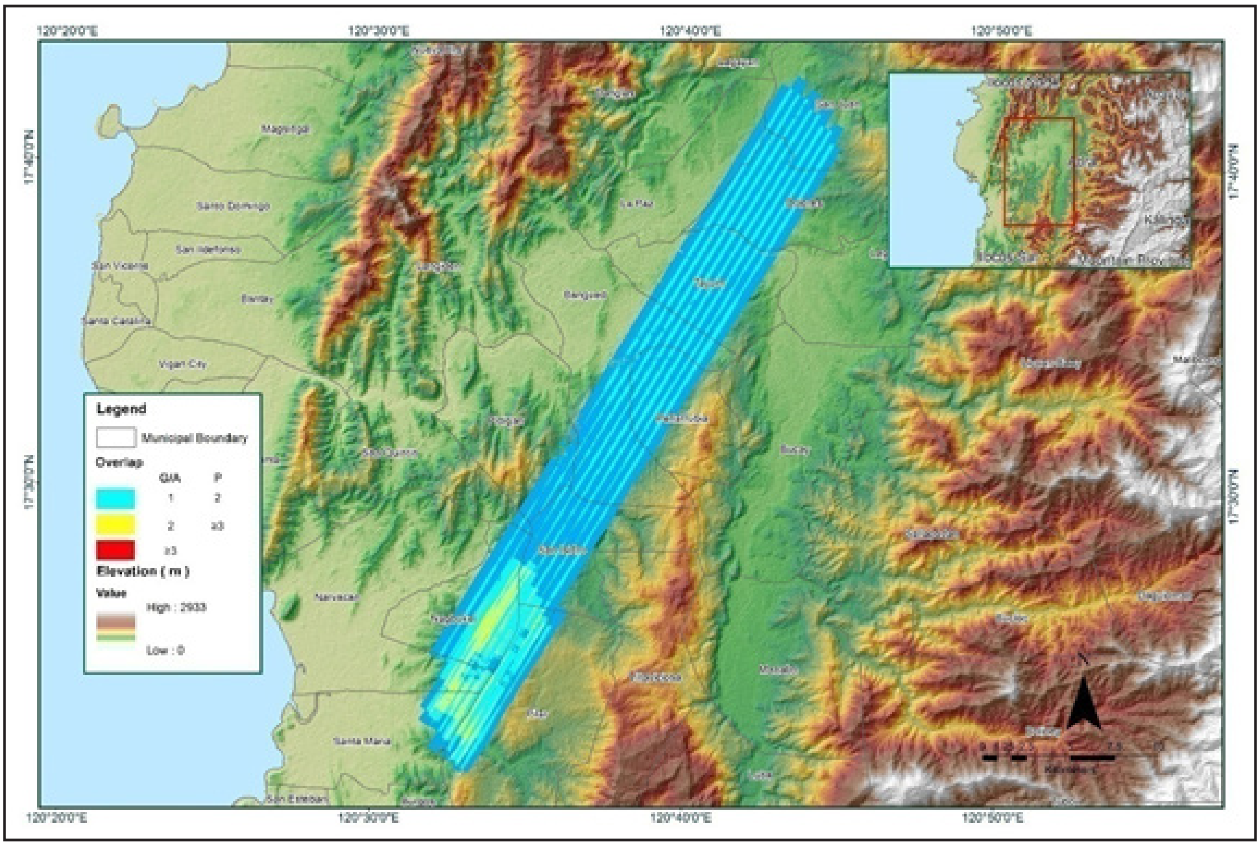


Figure A-8.110 Image of data overlap

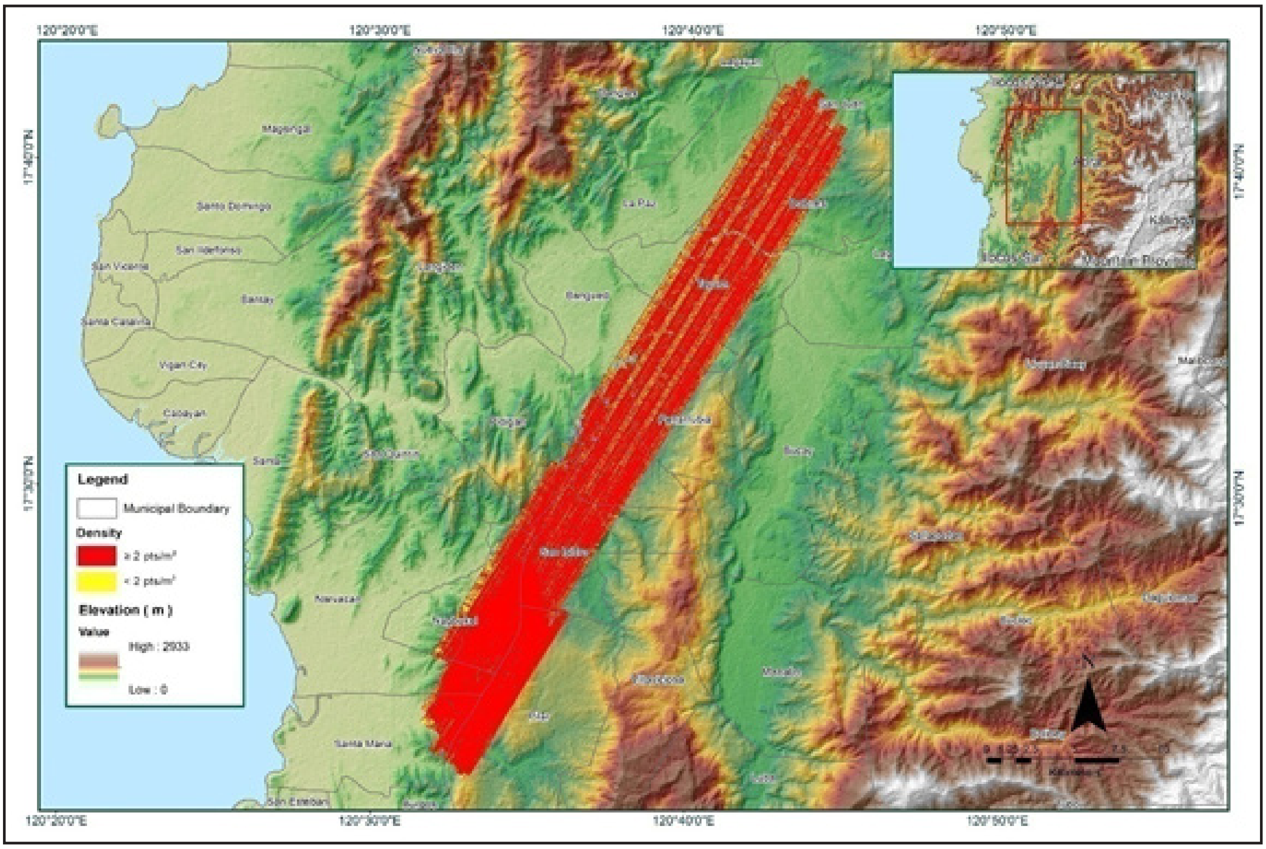


Figure A-8.111 Density map of merged LiDAR data

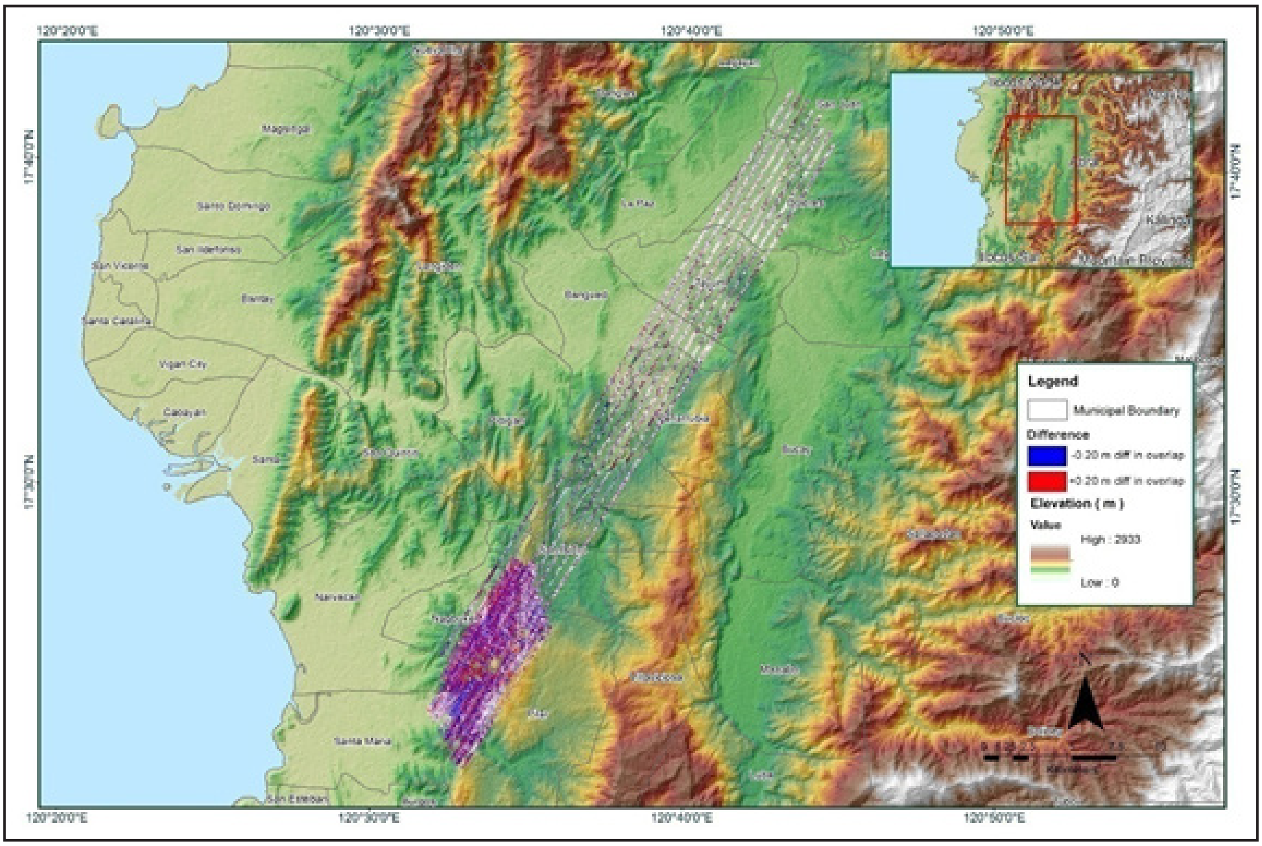


Figure A-8.112 Elevation difference between flight lines

ANNEX 9. Abra Model Basin Parameters

Table A-9.1. Abra Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1580	2.1154	81.84	0	0.41247	5.38512	Discharge	7.3386	1	Ratio to Peak	0.1
W1590	2.244	79.6395	0	0.29621	3.86728	Discharge	5.0451	1	Ratio to Peak	0.1
W1600	1.87238	86.3475	0	0.22282	2.90912	Discharge	3.5202	1	Ratio to Peak	0.1
W1610	1.92486	85.3335	0	0.34571	4.5136	Discharge	8.1227	1	Ratio to Peak	0.1
W1620	2.0498	83.0085	0	0.20964	2.73704	Discharge	3.5026	1	Ratio to Peak	0.1
W1630	2.4548	76.278	0	0.26965	3.52056	Discharge	5.1758	1	Ratio to Peak	0.1
W1640	2.3326	78.192	0	0.2021	2.63864	Discharge	1.9042	1	Ratio to Peak	0.1
W1650	2.4266	76.713	0	0.37763	4.9304	Discharge	5.5776	1	Ratio to Peak	0.1
W1660	2.18	80.721	0	0.35687	4.65928	Discharge	3.1075	1	Ratio to Peak	0.1
W1670	2.6646	73.203	0	0.15989	2.0876	Discharge	0.28158	1	Ratio to Peak	0.1
W1680	2.565	74.634	0	0.54971	7.17704	Discharge	12.715	1	Ratio to Peak	0.1
W1690	2.4212	76.797	0	0.10955	1.43032	Discharge	0.89063	1	Ratio to Peak	0.1
W1700	2.439	76.521	0	0.25955	3.38872	Discharge	5.5793	1	Ratio to Peak	0.1
W1710	2.1226	81.7155	0	0.3949	5.15576	Discharge	4.9211	1	Ratio to Peak	0.1
W1720	1.91344	85.5525	0	0.24486	3.19696	Discharge	3.3012	1	Ratio to Peak	0.1
W1730	1.99502	84.0135	0	0.41235	5.3836	Discharge	6.5491	1	Ratio to Peak	0.1
W1740	2.7516	72	0	0.14452	1.88688	Discharge	0.53411	1	Ratio to Peak	0.1
W1750	2.6612	73.2525	0	0.94913	12.392	Discharge	12.769	1	Ratio to Peak	0.1
W1760	2.7046	72.6465	0	0.31165	4.06888	Discharge	5.1542	1	Ratio to Peak	0.1
W1770	2.4986	75.615	0	0.21116	2.75688	Discharge	1.9851	1	Ratio to Peak	0.1
W1780	2.0194	83.562	0	0.23919	3.1228	Discharge	3.8787	1	Ratio to Peak	0.1
W1790	2.6672	73.1685	0	0.32455	4.23728	Discharge	4.5978	1	Ratio to Peak	0.1

W1800	2.7516	72	0	0.18234	2.38064	Discharge	1.0899	1	Ratio to Peak	0.1
W1810	2.1734	80.835	0	0.29425	3.84176	Discharge	2.7603	1	Ratio to Peak	0.1
W1820	2.6102	73.977	0	0.25391	3.31496	Discharge	2.5904	1	Ratio to Peak	0.1
W1830	2.3934	77.2275	0	0.32125	4.19424	Discharge	4.206	1	Ratio to Peak	0.1
W1840	2.6176	73.872	0	0.22205	2.899	Discharge	2.9375	1	Ratio to Peak	0.1
W1850	2.7516	72	0	0.18762	2.4496	Discharge	0.73359	1	Ratio to Peak	0.1
W1860	2.2706	79.1985	0	0.18977	2.4776	Discharge	2.5243	1	Ratio to Peak	0.1
W1870	2.7516	72	0	0.052071	0.679848	Discharge	0.069391	1	Ratio to Peak	0.1
W1880	2.7516	72	0	0.35613	4.6496	Discharge	4.317	1	Ratio to Peak	0.1
W1890	2.7516	72	0	0.084149	1.09864	Discharge	0.23466	1	Ratio to Peak	0.1
W1900	2.7516	72	0	0.25482	3.32688	Discharge	1.652	1	Ratio to Peak	0.1
W1910	2.7516	72	0	0.26925	3.51536	Discharge	2.3868	1	Ratio to Peak	0.1
W1920	2.1246	81.6795	0	0.27051	3.53176	Discharge	3.0891	1	Ratio to Peak	0.1
W1930	2.4756	75.9645	0	0.32735	4.27384	Discharge	6.2003	1	Ratio to Peak	0.1
W1940	2.6666	73.176	0	0.73422	9.5856	Discharge	12.19128	1	Ratio to Peak	0.1
W1950	2.7516	72	0	0.21835	2.8508	Discharge	2.8777	1	Ratio to Peak	0.1
W1960	2.7516	72	0	0.098916	1.29144	Discharge	0.19629	1	Ratio to Peak	0.1
W1970	1.9324	85.1895	0	0.24988	3.2624	Discharge	4.4004	1	Ratio to Peak	0.1
W1980	2.6916	72.8265	0	0.50077	6.53808	Discharge	8.5052	1	Ratio to Peak	0.1
W1990	2.3338	78.171	0	0.66232	8.6472	Discharge	5.4297	1	Ratio to Peak	0.1
W2000	2.7516	72	0	0.31008	4.04832	Discharge	3.3649	1	Ratio to Peak	0.1
W2010	2.7516	72	0	0.13238	1.7284	Discharge	0.419378	1	Ratio to Peak	0.1
W2020	2.1802	80.718	0	0.20271	2.64656	Discharge	3.6054	1	Ratio to Peak	0.1
W2030	2.0784	82.497	0	0.30807	4.02208	Discharge	3.4043	1	Ratio to Peak	0.1
W2040	1.9769	84.3495	0	0.54478	7.11272	Discharge	5.5143	1	Ratio to Peak	0.1
W2050	2.159	81.0795	0	0.57052	7.44872	Discharge	4.5615	1	Ratio to Peak	0.1
W2060	1.69334	90	0	0.062107	0.81088	Discharge	0.18255	1	Ratio to Peak	0.1
W2070	1.67876	90.3105	0	0.14417	1.88232	Discharge	2.661	1	Ratio to Peak	0.1

W2080	2.3084	78.5805	0	0.225	2.9376	Discharge	2.106	1	Ratio to Peak	0.1
W2090	1.9319	85.1985	0	0.51321	6.7004	Discharge	10.93335	1	Ratio to Peak	0.1
W2100	2.52	75.2955	0	0.21115	2.7568	Discharge	2.058	1	Ratio to Peak	0.1
W2110	1.8254	87.2775	0	0.26918	3.51432	Discharge	6.3738	1	Ratio to Peak	0.1
W2120	2.6722	73.098	0	0.25499	3.3292	Discharge	3.6942	1	Ratio to Peak	0.1
W2130	2.3988	77.145	0	0.20188	2.63568	Discharge	3.0863	1	Ratio to Peak	0.1
W2140	2.0782	82.5	0	0.33206	4.33536	Discharge	5.3258	1	Ratio to Peak	0.1
W2150	2.0782	82.5	0	0.048023	0.626984	Discharge	0.07195	1	Ratio to Peak	0.1
W2160	2.0782	82.5	0	0.28262	3.68984	Discharge	2.858	1	Ratio to Peak	0.1
W2170	2.7516	72	0	0.12206	1.5936	Discharge	1.0835	1	Ratio to Peak	0.1
W2180	2.0476	83.049	0	0.49086	6.40872	Discharge	13.0017	1	Ratio to Peak	0.1
W2190	2.6632	73.224	0	0.30513	3.98368	Discharge	4.2192	1	Ratio to Peak	0.1
W2200	2.243	79.656	0	0.37032	4.83496	Discharge	7.2115	1	Ratio to Peak	0.1
W2210	2.7516	72	0	0.17063	2.22768	Discharge	0.63381	1	Ratio to Peak	0.1
W2220	2.5826	74.3775	0	0.69524	9.0768	Discharge	8.0475	1	Ratio to Peak	0.1
W2230	2.3818	77.4105	0	0.5587	7.29432	Discharge	11.62	1	Ratio to Peak	0.1
W2240	2.0782	82.5	0	0.33472	4.37016	Discharge	3.8975	1	Ratio to Peak	0.1
W2250	2.0782	82.5	0	0.5756	7.51504	Discharge	10.531	1	Ratio to Peak	0.1
W2260	2.7516	72	0	0.25014	3.26584	Discharge	2.4213	1	Ratio to Peak	0.1
W2270	1.96866	84.504	0	0.20464	2.67184	Discharge	1.2387	1	Ratio to Peak	0.1
W2280	1.32014	98.7015	0	0.21708	2.83416	Discharge	3.1343	1	Ratio to Peak	0.1
W2290	2.7516	72	0	0.37236	4.86152	Discharge	2.0326	1	Ratio to Peak	0.1
W2300	2.0052	83.8245	0	0.30934	4.03872	Discharge	2.4141	1	Ratio to Peak	0.1
W2310	2.6076	74.0145	0	0.51144	6.67728	Discharge	7.9861	1	Ratio to Peak	0.1
W2320	2.1362	81.4755	0	0.2556	3.3372	Discharge	3.1477	1	Ratio to Peak	0.1
W2330	2.09	82.2885	0	0.16881	2.204	Discharge	0.89524	1	Ratio to Peak	0.1
W2340	1.42696	96.0435	0	0.24229	3.16336	Discharge	2.8127	1	Ratio to Peak	0.1
W2350	2.7516	72.0015	0	0.26443	3.4524	Discharge	3.5569	1	Ratio to Peak	0.1

W2360	0.7587	99	0	0.031519	0.411512	Discharge	0.015114	1	Ratio to Peak	0.1
W2370	1.01592	99	0	0.18028	2.35376	Discharge	1.241	1	Ratio to Peak	0.1
W2380	2.1838	80.6535	0	0.19048	2.48688	Discharge	2.661	1	Ratio to Peak	0.1
W2390	2.0782	82.5	0	0.27293	3.56336	Discharge	1.8153	1	Ratio to Peak	0.1
W2400	2.0782	82.5	0	0.17075	2.22936	Discharge	2.2007	1	Ratio to Peak	0.1
W2410	0.33594	99	0	0.23957	3.12784	Discharge	1.7206	1	Ratio to Peak	0.1
W2420	2.7516	72	0	0.28644	3.73984	Discharge	2.8196	1	Ratio to Peak	0.1
W2430	2.7516	72	0	0.12374	1.6156	Discharge	0.4376	1	Ratio to Peak	0.1
W2440	2.6716	73.107	0	0.50191	6.55296	Discharge	9.4265	1	Ratio to Peak	0.1
W2450	2.0782	82.5	0	0.55409	7.23424	Discharge	6.1122	1	Ratio to Peak	0.1
W2460	2.0782	82.5	0	0.25172	3.2864	Discharge	2.316	1	Ratio to Peak	0.1
W2470	2.4527	84.66	0	0.30232	13.125	Discharge	4.1274	0.99509	Ratio to Peak	0.1
W2480	3.0975	52.261	0	0.23132	14.989	Discharge	1.9705	1	Ratio to Peak	0.1
W2500	0.63352	99	0	0.32976	2.4568	Discharge	5.9646	1	Ratio to Peak	0.1
W2510	1.4795	59.911	0	0.062161	9.8316	Discharge	0.13227	1	Ratio to Peak	0.1
W2520	2.3901	49.308	0	0.32414	0.76387	Discharge	2.3659	1	Ratio to Peak	0.1
W2530	1.443	88.866	0	0.29105	9.4653	Discharge	1.6494	1	Ratio to Peak	0.1
W2540	2.2492	79.554	0	0.42273	2.48456	Discharge	6.7148	1	Ratio to Peak	0.1
W2560	2.7371	66.411	0	0.29762	18.808	Discharge	0.84762	1	Ratio to Peak	0.1
W2570	2.18	75.138	0	0.48229	12.567	Discharge	4.7729	1	Ratio to Peak	0.1
W2580	0.35808	99	0	0.19638	2.54064	Discharge	1.2681	1	Ratio to Peak	0.1
W2590	0.7772	99	0	0.16646	6.2954	Discharge	6.9403	1	Ratio to Peak	0.1
W2600	2.3756	77.5095	0	0.25999	2.564	Discharge	3.6325	1	Ratio to Peak	0.1
W2610	2.2024	80.34	0	0.20075	4.88992	Discharge	2.7886	1	Ratio to Peak	0.1
W2620	2.7008	43.731	0	0.29847	3.3028	Discharge	3.4559	1	Ratio to Peak	0.1
W2630	2.0782	82.5	0	0.19565	2.62096	Discharge	2.9763	1	Ratio to Peak	0.1
W2640	2.0782	82.5	0	0.25662	3.81408	Discharge	2.0258	1	Ratio to Peak	0.1
W2650	2.7089	67.597	0	0.302	2.5158	Discharge	2.9552	0.99924	Ratio to Peak	0.1

W2660	1.8796	76.943	0	1.4727	3.2299	Discharge	22.565	1	Ratio to Peak	0.1
W2670	1.2552	99	0	0.31008	8.7632	Discharge	1.6449	1	Ratio to Peak	0.1
W2680	2.5248	75.225	0	0.35172	19.476	Discharge	2.7701	1	Ratio to Peak	0.1
W2690	2.4728	76.0035	0	0.18253	2.64712	Discharge	2.1612	1	Ratio to Peak	0.1
W2700	2.7516	72	0	0.15678	4.592	Discharge	1.5596	1	Ratio to Peak	0.1
W2710	2.7516	72	0	0.15521	2.38312	Discharge	0.68025	1	Ratio to Peak	0.1
W2720	2.0898	82.2915	0	0.27873	2.04688	Discharge	3.7746	1	Ratio to Peak	0.1
W2730	0.37418	99	0	0.3976	2.02648	Discharge	1.8278	1	Ratio to Peak	0.1
W2740	2.75	72.0225	0	0.35814	3.63912	Discharge	5.6316	1	Ratio to Peak	0.1
W2750	0.56149	99	0	0.26655	11.85	Discharge	3.1499	1	Ratio to Peak	0.1
W2760	2.2512	79.5195	0	0.26477	4.67592	Discharge	5.4312	1	Ratio to Peak	0.1
W2770	2.3946	77.2095	0	0.1622	2.39216	Discharge	1.9439	1	Ratio to Peak	0.1
W2780	2.5578	74.7375	0	0.24436	3.4568	Discharge	3.1813	1	Ratio to Peak	0.1
W2790	0.34624	99	0	0.37485	2.1176	Discharge	3.2118	1	Ratio to Peak	0.1
W2800	2.7516	72	0	0.16796	3.1904	Discharge	0.95042	1	Ratio to Peak	0.1
W2810	2.7516	72	0	0.23576	4.894	Discharge	2.2604	1	Ratio to Peak	0.1
W2820	2.7516	72	0	0.24387	2.19288	Discharge	1.6133	1	Ratio to Peak	0.1
W2830	2.7106	72.5625	0	0.28805	3.07808	Discharge	2.57	1	Ratio to Peak	0.1
W2840	1.94864	84.8805	0	0.38497	3.184	Discharge	8.973	1	Ratio to Peak	0.1
W2850	0.36838	99	0	0.22117	3.76072	Discharge	1.0076	1	Ratio to Peak	0.1
W2860	0.3484	99	0	0.45051	5.02624	Discharge	2.4779	1	Ratio to Peak	0.1
W2870	2.8068	45.177	0	0.42812	9.8308	Discharge	2.0871	0.98662	Ratio to Peak	0.1
W2880	0.2875	99	0	0.36358	5.88192	Discharge	1.3437	1	Ratio to Peak	0.1
W2890	2.2865	55.808	0	0.2902	1.0881	Discharge	1.5589	0.99	Ratio to Peak	0.1
W2900	2.8069	46.227	0	0.15169	10.781	Discharge	2.5018	1	Ratio to Peak	0.1
W2910	2.6362	73.605	0	0.11362	2.4772	Discharge	0.88992	1	Ratio to Peak	0.1
W2930	2.2324	35.095	0	0.52979	10.026	Discharge	4.7742	1	Ratio to Peak	0.1
W2940	2.3674	77.637	0	0.18214	1.48336	Discharge	2.8169	1	Ratio to Peak	0.1

W2950	2.704	72.654	0	0.56178	6.40968	Discharge	4.9833	1	Ratio to Peak	0.1
W2960	5.3498	73.072	0	0.88666	10.249	Discharge	21.233	1	Ratio to Peak	0.1
W2970	2.6446	73.4865	0	0.25582	2.378	Discharge	2.5745	1	Ratio to Peak	0.1
W2980	1.80838	87.6195	0	0.29036	7.33456	Discharge	5.8437	1	Ratio to Peak	0.1
W2990	2.1827	61.469	0	0.28935	16.434	Discharge	1.8402	1	Ratio to Peak	0.1
W3000	2.1926	80.505	0	0.19896	3.34	Discharge	0.97711	1	Ratio to Peak	0.1
W3010	1.77524	88.2915	0	0.14586	3.79096	Discharge	2.0348	1	Ratio to Peak	0.1
W3020	2.0166	83.616	0	0.16262	2.53272	Discharge	0.9035	1	Ratio to Peak	0.1
W3030	2.5324	97.958	0	0.25765	1.648	Discharge	3.7754	1	Ratio to Peak	0.1
W3040	2.7208	93.112	0	0.16264	0.79867	Discharge	3.3251	0.66667	Ratio to Peak	0.1
W3050	1.89414	85.9245	0	0.29632	2.1232	Discharge	5.5083	1	Ratio to Peak	0.1
W3060	2.1292	81.5985	0	0.20836	2.22088	Discharge	2.7977	1	Ratio to Peak	0.1
W3080	1.69334	90	0	0.34527	2.12344	Discharge	5.5171	1	Ratio to Peak	0.1
W3090	1.77832	88.2285	0	0.34273	3.86872	Discharge	4.9487	1	Ratio to Peak	0.1
W3100	1.90976	85.623	0	0.28081	2.72032	Discharge	7.585	1	Ratio to Peak	0.1
W3110	1.7993	87.8025	0	0.29285	2.33616	Discharge	7.9326	1	Ratio to Peak	0.1
W3120	1.89496	85.908	0	0.27665	4.50792	Discharge	5.7765	1	Ratio to Peak	0.1
W3130	3.1137	64.052	0	0.11525	10.147	Discharge	2.8322	1	Ratio to Peak	0.1
W3140	2.536	99	0	0.13732	0.70912	Discharge	3.1533	1	Ratio to Peak	0.1
W3160	0.77828	99	0	0.18818	3.82344	Discharge	2.371	1	Ratio to Peak	0.1
W3170	0.79804	99	0	0.15876	3.612	Discharge	2.0606	1	Ratio to Peak	0.1
W3210	2.069	35.434	0	0.432	8.7598	Discharge	3.292	1	Ratio to Peak	0.1
W3220	7.0797	68.156	0	0.48639	1.7624	Discharge	2.7359	1	Ratio to Peak	0.1
W3260	2.7516	72	0	0.49094	2.0728	Discharge	2.5856	1	Ratio to Peak	0.1
W3270	2.3938	77.223	0	0.41785	4.1524	Discharge	4.1843	1	Ratio to Peak	0.1
W3310	2.2028	80.3325	0	0.17893	5.45544	Discharge	0.85395	1	Ratio to Peak	0.1
W3320	1.86188	86.5545	0	0.18561	2.42336	Discharge	3.1578	1	Ratio to Peak	0.1

ANNEX 10. Abra Model Reach Parameters

Table A-10.1. Abra Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1010	Automatic Fixed Interval	8127.3	0.009935	0.005	Trapezoid	100.9667	1
R1050	Automatic Fixed Interval	2293.1	0.003597	0.005	Trapezoid	254.6667	1
R110	Automatic Fixed Interval	1866.8	0.021393	0.005	Trapezoid	50.3	1
R1100	Automatic Fixed Interval	4726.6	0.013873	0.005	Trapezoid	31.333	1
R1110	Automatic Fixed Interval	2034.9	0.01696	0.005	Trapezoid	27	1
R1130	Automatic Fixed Interval	2923.4	0.037587	0.005	Trapezoid	34.433	1
R1140	Automatic Fixed Interval	7061	0.003908	0.010766	Trapezoid	234.6667	1
R1170	Automatic Fixed Interval	6802.5	0.005791	0.005	Trapezoid	98.733	1
R1180	Automatic Fixed Interval	1888.5	0.022003	0.005	Trapezoid	49.367	1
R1200	Automatic Fixed Interval	1474.6	0.000934	0.005	Trapezoid	108.8333	1
R1210	Automatic Fixed Interval	3309.2	0.003506	0.005	Trapezoid	387.6667	1
R1220	Automatic Fixed Interval	2385.6	0.004111	0.005	Trapezoid	139.4333	1
R1230	Automatic Fixed Interval	3849.2	0.008172	0.005	Trapezoid	121	1
R1270	Automatic Fixed Interval	2821.6	0.002056	0.005	Trapezoid	382.6667	1
R1280	Automatic Fixed Interval	5294.6	0.009875	0.005	Trapezoid	101.6667	1
R130	Automatic Fixed Interval	5957.2	0.01671	0.005	Trapezoid	55.433	1
R1300	Automatic Fixed Interval	23082	0.006726	0.003381	Trapezoid	67.433	1
R1310	Automatic Fixed Interval	2138.2	0.046091	0.016538	Trapezoid	21.4	1
R1320	Automatic Fixed Interval	2070	0.009056	0.005	Trapezoid	45.733	1
R1340	Automatic Fixed Interval	4864	0.003681	0.005	Trapezoid	427	1
R1370	Automatic Fixed Interval	5785.6	0.015143	0.004952	Trapezoid	52.633	1
R1380	Automatic Fixed Interval	8871	0.010526	0.005	Trapezoid	63.9	1
R1390	Automatic Fixed Interval	3512.3	0.017841	0.005	Trapezoid	47.667	1

R1410	Automatic Fixed Interval	2242.8	0.011599	0.005	Trapezoid	37.967	1
R1420	Automatic Fixed Interval	2244.9	0.022811	0.016914	Trapezoid	63.5	1
R1440	Automatic Fixed Interval	1912.4	0.013234	0.005	Trapezoid	39.5	1
R1480	Automatic Fixed Interval	8039.4	0.013306	0.005	Trapezoid	17.667	1
R1490	Automatic Fixed Interval	2032.1	0.019476	0.005	Trapezoid	25.133	1
R150	Automatic Fixed Interval	1715.5	0.009272	0.005	Trapezoid	43.567	1
R1520	Automatic Fixed Interval	6596.6	0.014199	0.005	Trapezoid	41.767	1
R1530	Automatic Fixed Interval	26164	0.025855	0.002134	Trapezoid	36.367	1
R170	Automatic Fixed Interval	6568.9	0.015864	0.005	Trapezoid	49.3	1
R190	Automatic Fixed Interval	2860.5	5.28E-05	0.005	Trapezoid	57.233	1
R220	Automatic Fixed Interval	5251.2	0.038635	0.005	Trapezoid	19.033	1
R260	Automatic Fixed Interval	4709.5	0.028252	0.005	Trapezoid	45.6	1
R280	Automatic Fixed Interval	1020	0.00579	0.005	Trapezoid	69.933	1
R290	Automatic Fixed Interval	537.99	0.028118	0.005	Trapezoid	66.3	1
R300	Automatic Fixed Interval	2180.7	0.016385	0.005	Trapezoid	48.633	1
R310	Automatic Fixed Interval	16955	0.014687	0.005	Trapezoid	51.167	1
R320	Automatic Fixed Interval	1972.1	0.01417	0.005	Trapezoid	66.9	1
R3230	Automatic Fixed Interval	4325.1	0.016035	0.016967	Trapezoid	37.533	1
R3280	Automatic Fixed Interval	6592.5	0.013201	0.005	Trapezoid	36.033	1
R3330	Automatic Fixed Interval	1808.7	0.022312	0.005	Trapezoid	26.167	1
R340	Automatic Fixed Interval	6377.2	0.007096	0.005	Trapezoid	154.7333	1
R370	Automatic Fixed Interval	816.98	0.001731	0.005	Trapezoid	137	1
R380	Automatic Fixed Interval	1806.3	0.010108	0.005	Trapezoid	191.3333	1
R420	Automatic Fixed Interval	760.83	0.003323	0.005	Trapezoid	87.833	1
R450	Automatic Fixed Interval	5967.3	0.007691	0.005	Trapezoid	84.733	1
R460	Automatic Fixed Interval	4415.7	0.006998	0.005	Trapezoid	75.167	1
R470	Automatic Fixed Interval	9061.8	0.005438	0.005	Trapezoid	58.5	1
R480	Automatic Fixed Interval	454.14	0.051166	0.005	Trapezoid	60.3	1

R490	Automatic Fixed Interval	8523.2	0.003169	0.005	Trapezoid	46.233	1
R520	Automatic Fixed Interval	7338.1	0.007343	0.005	Trapezoid	138.6667	1
R530	Automatic Fixed Interval	3061.8	0.002511	0.005	Trapezoid	64.967	1
R540	Automatic Fixed Interval	13270	0.010103	0.005	Trapezoid	69.4	1
R560	Automatic Fixed Interval	2139.7	0.017635	0.005	Trapezoid	64.833	1
R570	Automatic Fixed Interval	2315.3	0.015574	0.005	Trapezoid	74.567	1
R580	Automatic Fixed Interval	8737.4	0.010432	0.005	Trapezoid	54.867	1
R590	Automatic Fixed Interval	4871.1	0.010513	0.005	Trapezoid	76.067	1
R60	Automatic Fixed Interval	5585.3	0.027109	0.005	Trapezoid	32.133	1
R620	Automatic Fixed Interval	5409	0.008509	0.005	Trapezoid	174.3333	1
R640	Automatic Fixed Interval	6146.7	0.009424	0.005	Trapezoid	25.867	1
R650	Automatic Fixed Interval	2439.9	0.006891	0.005	Trapezoid	97.967	1
R660	Automatic Fixed Interval	11705	0.008587	0.005	Trapezoid	76.533	1
R680	Automatic Fixed Interval	2778.4	0.011715	0.005	Trapezoid	250.3333	1
R70	Automatic Fixed Interval	2467.9	0.026434	0.005	Trapezoid	32.133	1
R700	Automatic Fixed Interval	186.57	0.018427	0.005	Trapezoid	250	1
R730	Automatic Fixed Interval	2850.7	0.003488	0.005	Trapezoid	35.133	1
R740	Automatic Fixed Interval	1313.4	0.006475	0.005	Trapezoid	90.333	1
R750	Automatic Fixed Interval	11016	0.003618	0.005	Trapezoid	317.3333	1
R790	Automatic Fixed Interval	8649.4	0.006668	0.005	Trapezoid	113.3333	1
R80	Automatic Fixed Interval	1789.1	0.016579	0.005	Trapezoid	27.167	1
R800	Automatic Fixed Interval	1190	0.005754	0.005	Trapezoid	78.3	1
R820	Automatic Fixed Interval	3287	0.021564	0.005	Trapezoid	29.467	1
R890	Automatic Fixed Interval	776.98	0.24914	0.011362	Trapezoid	40.5	1
R910	Automatic Fixed Interval	2098.5	0.005214	0.005	Trapezoid	26.1	1
R920	Automatic Fixed Interval	4854.3	0.004261	0.005	Trapezoid	301.6667	1
R930	Automatic Fixed Interval	7404.5	0.01505	0.010937	Trapezoid	30	1
R940	Automatic Fixed Interval	3968.9	0.011796	0.007575	Trapezoid	43	1

R950	Automatic Fixed Interval	11874	0.018651	0.005	Trapezoid	21.533	1
R960	Automatic Fixed Interval	2356.6	0.021065	0.004802	Trapezoid	19.667	1
R990	Automatic Fixed Interval	2935.9	0.00772	0.004865	Trapezoid	108.6667	1

ANNEX 11. Abra Field Validation Points

Table A-11.1. Abra Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	17.67336	120.7331	0.03	1	0.9409	Feria/ 2005	5-Year
2	17.67336	120.7331	0.03	0.381	0.123201	Lawin/ 2016	5-Year
3	17.67336	120.7331	0.03	0.9144	0.782163	Feria/ 2005	5-Year
4	17.67336	120.7331	0.03	0.3048	0.075515	Mina/ 2007	5-Year
5	17.67336	120.7331	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
6	17.67336	120.7331	0.03	0.381	0.123201	Feria/ 2005	5-Year
7	17.67336	120.7331	0.03	0.6096	0.335936	Lawin/ 2016	5-Year
8	17.67336	120.7331	0.03	0.9144	0.782163	Feria/ 2005	5-Year
9	17.67336	120.7331	0.03	0.5	0.2209	Mina/ 2007	5-Year
10	17.67336	120.7331	0.03	0.9144	0.782163	Feria/ 2005	5-Year
11	17.67792	120.7342	1.39	0.9144	0.226195	Feria/ 2005	5-Year
12	17.67792	120.7342	1.39	0.381	1.018081	Lawin/ 2016	5-Year
13	17.67792	120.7342	1.39	0.3048	1.177659	Mina/ 2007	5-Year
14	17.67792	120.7342	1.39	1	0.1521	Feria/ 2005	5-Year
15	17.67792	120.7342	1.39	0.3048	1.177659	Ondoy/ 2009	5-Year
16	17.67792	120.7342	1.39	0.3048	1.177659	Pepeng/ 2009	5-Year
17	17.67792	120.7342	1.39	0.9144	0.226195	Feria/ 2005	5-Year
18	17.67792	120.7342	1.39	0.3048	1.177659	Mina/ 2007	5-Year
19	17.67792	120.7342	1.39	0.6096	0.609024	Feria/ 2005	5-Year
20	17.67792	120.7342	1.39	0.3048	1.177659	Lando/ 2015	5-Year
21	17.66976	120.7262	0.06	0.381	0.103041	Feria/ 2005	5-Year
22	17.66976	120.7262	0.06	0.3048	0.059927	Yolanda/ 2013	5-Year
23	17.66976	120.7262	0.06	0.3048	0.059927	Ondoy/ 2009	5-Year
24	17.66976	120.7262	0.06	0.9144	0.729999	Feria/ 2005	5-Year
25	17.66976	120.7262	0.06	0.3048	0.059927	Lando/ 2015	5-Year
26	17.66976	120.7262	0.06	0.3048	0.059927	Pepeng/ 2009	5-Year
27	17.66976	120.7262	0.06	0.381	0.103041	Mina/ 2007	5-Year
28	17.66976	120.7262	0.06	1	0.8836	Feria/ 2005	5-Year
29	17.66976	120.7262	0.06	0.381	0.103041	Lawin/ 2016	5-Year
30	17.66976	120.7262	0.06	0.9144	0.729999	Feria/ 2005	5-Year
31	17.68263	120.7242	0.03	0.381	0.123201	Feria/ 2005	5-Year
32	17.68263	120.7242	0.03	0.3048	0.075515	Mina/ 2007	5-Year
33	17.68263	120.7242	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
34	17.68263	120.7242	0.03	0.381	0.123201	Lawin/ 2016	5-Year
35	17.68263	120.7242	0.03	0.3048	0.075515	Lando/ 2015	5-Year
36	17.68263	120.7242	0.03	0.3048	0.075515	Lando/ 2015	5-Year
37	17.68263	120.7242	0.03	0.9144	0.782163	Feria/ 2005	5-Year
38	17.68263	120.7242	0.03	0.9144	0.782163	Feria/ 2005	5-Year
39	17.68263	120.7242	0.03	0.381	0.123201	Mina/ 2007	5-Year
40	17.68263	120.7242	0.03	0.3048	0.075515	Yolanda/ 2013	5-Year

RMSE: 0.346129

41	17.68037	120.7296	0.12	1	0.7744	Feria/ 2005	5-Year
42	17.68037	120.7296	0.12	0.3048	0.034151	Lando/ 2015	5-Year
43	17.68037	120.7296	0.12	0.6096	0.239708	Mina/ 2007	5-Year
44	17.68037	120.7296	0.12	0.9144	0.631071	Feria/ 2005	5-Year
45	17.68037	120.7296	0.12	0.3048	0.034151	Pepeng/ 2009	5-Year
46	17.68037	120.7296	0.12	0.3048	0.034151	Lando/ 2015	5-Year
47	17.68037	120.7296	0.12	0.9144	0.631071	Feria/ 2005	5-Year
48	17.68037	120.7296	0.12	0.9144	0.631071	Feria/ 2005	5-Year
49	17.68037	120.7296	0.12	0.6096	0.239708	Mina/ 2007	5-Year
50	17.70968	120.7233	2.78	0.9144	3.480463	Feria/ 2005	5-Year
51	17.70968	120.7233	2.78	1	3.1684	Feria/ 2005	5-Year
52	17.70968	120.7233	2.78	0.3048	6.126615	Ondoy/ 2009	5-Year
53	17.70968	120.7233	2.78	0.3048	6.126615	Mina/ 2007	5-Year
54	17.70968	120.7233	2.78	0.381	5.755201	Pepeng/ 2009	5-Year
55	17.70968	120.7233	2.78	0.9144	3.480463	Feria/ 2005	5-Year
56	17.70968	120.7233	2.78	0.6096	4.710636	Mina/ 2007	5-Year
57	17.70968	120.7233	2.78	0.9144	3.480463	Feria/ 2005	5-Year
58	17.70968	120.7233	2.78	0.381	5.755201	Lawin/ 2016	5-Year
59	17.70968	120.7233	2.78	0.381	5.755201	Lawin/ 2016	5-Year
60	17.68316	120.7491	0.21	0.9144	0.496179	Feria/ 2005	5-Year
61	17.68316	120.7491	0.21	0.381	0.029241	Feria/ 2005	5-Year
62	17.68316	120.7491	0.21	1	0.6241	Feria/ 2005	5-Year
63	17.68316	120.7491	0.21	0.381	0.029241	Lawin/ 2016	5-Year
64	17.68316	120.7491	0.21	0.3048	0.008987	Pepeng/ 2009	5-Year
65	17.68316	120.7491	0.21	0.3048	0.008987	Mina/ 2007	5-Year
66	17.68316	120.7491	0.21	0.381	0.029241	Lawin/ 2016	5-Year
67	17.68316	120.7491	0.21	0.9144	0.496179	Feria/ 2005	5-Year
68	17.68316	120.7491	0.21	0.3048	0.008987	Lando/ 2015	5-Year
69	17.68316	120.7491	0.21	0.3048	0.008987	Mina/ 2007	5-Year
70	17.67733	120.7234	2.12	1	1.2544	Lawin/ 2016	5-Year
71	17.67733	120.7234	2.12	1	1.2544	Feria/ 2005	5-Year
72	17.67733	120.7234	2.12	0.3048	3.294951	Mina/ 2007	5-Year
73	17.67733	120.7234	2.12	0.3048	3.294951	Ondoy/ 2009	5-Year
74	17.67733	120.7234	2.12	0.6096	2.281308	Mina/ 2007	5-Year
75	17.67733	120.7234	2.12	0.381	3.024121	Lawin/ 2016	5-Year
76	17.67733	120.7234	2.12	0.9144	1.453471	Feria/ 2005	5-Year
77	17.67733	120.7234	2.12	1	1.2544	Feria/ 2005	5-Year
78	17.67733	120.7234	2.12	1	1.2544	Lawin/ 2016	5-Year
79	17.7196	120.7419	0.03	0.3048	0.075515	Mina/ 2007	5-Year
80	17.7196	120.7419	0.03	0.381	0.123201	Feria/ 2005	5-Year
81	17.7196	120.7419	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
82	17.72582	120.7246	4.21	0.6096	12.96288	Feria/ 2005	5-Year
83	17.72582	120.7246	4.21	0.3048	15.25059	Lawin/ 2016	5-Year
84	17.66809	120.7362	0.03	0.6096	0.335936	Feria/ 2005	5-Year
85	17.66809	120.7362	0.03	0.3048	0.075515	Mina/ 2007	5-Year

86	17.70109	120.7366	0.3	0.3048	2.3E-05	Feria/ 2005	5-Year
87	17.70109	120.7366	0.3	0.3048	2.3E-05	Ondoy/ 2009	5-Year
88	17.68902	120.7295	0.03	0.381	0.123201	Feria/ 2005	5-Year
89	17.68902	120.7295	0.03	0.3048	0.075515	Mina/ 2007	5-Year
90	17.68902	120.7295	0.03	0.6096	0.335936	Lawin/ 2016	5-Year
91	17.68902	120.7295	0.03	0.381	0.123201	Feria/ 2005	5-Year
92	17.68902	120.7295	0.03	0.381	0.123201	Lawin/ 2016	5-Year
93	17.68902	120.7295	0.03	0.6096	0.335936	Lawin/ 2016	5-Year
94	17.68902	120.7295	0.03	0.6096	0.335936	Feria/ 2005	5-Year
95	17.69118	120.716	3.11	0.3048	7.869147	Lando/ 2015	5-Year
96	17.69118	120.716	3.11	0.3048	7.869147	Lawin/ 2016	5-Year
97	17.69118	120.716	3.11	0.3048	7.869147	Pepeng/ 2009	5-Year
98	17.69118	120.716	3.11	0.3048	7.869147	Ondoy/ 2009	5-Year
99	17.69118	120.716	3.11	0.381	7.447441	Feria/ 2005	5-Year
100	17.69118	120.716	3.11	0.381	7.447441	Feria/ 2005	5-Year
101	17.66949	120.722	0.03	0.6096	0.335936	Feria/ 2005	5-Year
102	17.66949	120.722	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
103	17.66949	120.722	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
104	17.66949	120.722	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
105	17.66949	120.722	0.03	0.3048	0.075515	Mina/ 2007	5-Year
106	17.74043	120.6974	0.05	0.381	0.109561	Feria/ 2005	5-Year
107	17.74043	120.6974	0.05	0.3048	0.064923	Ondoy/ 2009	5-Year
108	17.74043	120.6974	0.05	0.3048	0.064923	Mina/ 2007	5-Year
109	17.74043	120.6974	0.05	0.381	0.109561	Lawin/ 2016	5-Year
110	17.74043	120.6974	0.05	0.381	0.109561	Lawin/ 2016	5-Year
111	17.74043	120.6974	0.05	0.3048	0.064923	Lando/ 2015	5-Year
112	17.74043	120.6974	0.05	0.3048	0.064923	Ondoy/ 2009	5-Year
113	17.74043	120.6974	0.05	0.381	0.109561	Feria/ 2005	5-Year
114	17.74043	120.6974	0.05	0.6096	0.313152	Feria/ 2005	5-Year
115	17.74043	120.6974	0.05	0.6096	0.313152	Lawin/ 2016	5-Year
116	17.74043	120.6974	0.05	0.3048	0.064923	Mina/ 2007	5-Year
117	17.74043	120.6974	0.05	0.9144	0.747187	Feria/ 2005	5-Year
118	17.74043	120.6974	0.05	0.6096	0.313152	Pepeng/ 2009	5-Year
119	17.74043	120.6974	0.05	0.3048	0.064923	Mina/ 2007	5-Year
120	17.74043	120.6974	0.05	0.381	0.109561	Feria/ 2005	5-Year
121	17.71972	120.6903	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
122	17.71972	120.6903	0.03	0.3048	0.075515	Mina/ 2007	5-Year
123	17.71972	120.6903	0.03	0.3048	0.075515	Pepeng/ 2009	5-Year
124	17.71972	120.6903	0.03	0.6096	0.335936	Lawin/ 2016	5-Year
125	17.71972	120.6903	0.03	0.9144	0.782163	Lawin/ 2016	5-Year
126	17.71972	120.6903	0.03	1	0.9409	Feria/ 2005	5-Year
127	17.71972	120.6903	0.03	0.381	0.123201	Lawin/ 2016	5-Year
128	17.71972	120.6903	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
129	17.71972	120.6903	0.03	0.3048	0.075515	Pepeng/ 2009	5-Year
130	17.71972	120.6903	0.03	0.9144	0.782163	Feria/ 2005	5-Year

131	17.71972	120.6903	0.03	0.6096	0.335936	Feria/ 2005	5-Year
132	17.71972	120.6903	0.03	0.3048	0.075515	Mina/ 2007	5-Year
133	17.71972	120.6903	0.03	0.381	0.123201	Lawin/ 2016	5-Year
134	17.71972	120.6903	0.03	0.381	0.123201	Feria/ 2005	5-Year
135	17.71972	120.6903	0.03	0.3048	0.075515	Lando/ 2015	5-Year

ANNEX 12. Educational Institutions affected by flooding Abra Flood Plain

Table A-12.1. Educational Institutions in Abra affected by flooding in Abra Flood Plain

Abra				
Bangued				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BACSIL ES	Angad			
DANGDANGLA ES	Dangdangla			
ABRA VALLEY COLLEGES	Lingtan			
DATA CENTER COLLEGE	Lipcan			
DIVINE WORD COLLEGE OF BANGUED	Lipcan	Medium	Medium	Medium
MACARCARMAY ES	Macarcarmay			
COSILI WEST PS	Macray			
CALOT ES	Maoay			
SINALANG PILOT ELEMENTARY SCHOOL	Palao			
PATUCANNAY DAY CARE CENTER	Patucannay			High
PATUCANNAY ES	Patucannay		Low	High
STA. ROSA PS	Santa Rosa			Low
ABRA HIGH SCHOOL	Zone 2 Poblacion	Low	Low	Low
ABRA HS	Zone 2 Poblacion			
ABRA STATE INSTITUTE OF SCIENCE AND TECHNOLOGY	Zone 2 Poblacion	Medium	Medium	Medium
BANGUED WEST CENTRAL SCHOOL	Zone 2 Poblacion			
BANGBANGAR ES	Zone 3 Poblacion			
ABRA HIGH SCHOOL	Zone 4 Poblacion			
ABRA HIGH SCHOOL	Zone 4 Poblacion			
ABRA HIGH SCHOOL	Zone 4 Poblacion		Low	Low
BANGUED NORTH ES	Zone 4 Poblacion			
BANGUED WEST CENTRAL SCHOOL	Zone 4 Poblacion			
ABRA VALLEY COLLEGES	Zone 5 Poblacion			
HOLY SPIRIT ACADEMY OF BANGUED	Zone 5 Poblacion			
Bucay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BANGBANGCAG PRIMARY SCHOOL	Bangbangcag		Medium	High
PANGTOD NHS	Bangbangcag			

BANGCAGAN PS	Bangcagan			
BANGCAGAN PRIMARY SCHOOL	Bugbog			
PAGALA WEST ELEMENTARY SCHOOL	Bugbog			
BUCAY CS	North Poblacion			
CRISTINA B. GONZALES MHS	North Poblacion	Low	Medium	Medium
OUR LADY OF FATIMA SCHOOL	North Poblacion			
PAGALA EAST PRIMARY SCHOOL	Pagala	Low	High	High
PANGTOD NHS	Palaquio			
BUCAY NORTH ELEMENTARY SCHOOL	San Miguel	Low	High	High
LUBLUBNAC PRIMARY SCHOOL	Tabiog			
TABIOG ES	Tabiog			
Danglas				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
WESTERN ABRA NHS	Padangitan			
Dolores				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
MUDIIT ELEMENTARY SCHOOL	Mudiit			
MUDIIT ES	Mudiit			
DOLORES CS	Poblacion			
DON ROSALIO EDUARTE ES	Talogtog			
La Paz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
CANAN ES	Canan			
Lagangilang				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
METODIO ES	Laguiben			
PRESENTAR ES	Presentar			
TAGODTOD ES	Tagodtod			
TAGODTOD NHS	Tagodtod			
TAPING PS	Taping			

Lagayan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
LAGAYAN CS	Poblacion			
PULOT NHS	Pulot			
Langiden				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
LANGIDEN NHS	Poblacion			
Peñarrubia				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
PEÑARRUBIA CS	Dumayco			
PEÑARRUBIA CS	Poblacion			
SAN QUINTIN NHS	Tattawa			
Pidigan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
CASILAGAN PS	Alinaya	High	High	High
GARRETA ES	Garreta	Low	Medium	High
BANAY PS	Monggoc	High	High	High
PANGTUD PS	Pangtud		High	High
PIDIGAN CS	Poblacion West		High	High
POBLACION WEST PS	Poblacion West		High	High
SUYO NATIONAL HIGH SCHOOL	Suyo			
SUYO PILOT ES	Suyo	High	High	High
San Juan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
NORTHERN ABRA NHS	Lam-Ag		Low	High
NANGOBONGAN PS	Nangobongan			
QUIDAOEN NHS	Quidaoen			

San Quintin				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
PALANG PS	Palang	Low	High	High
PANTOC ES	Pantoc			
SAN QUINTIN CS	Poblacion	High	High	High
SAN QUINTIN NHS	Poblacion		High	High
VILLA MERCEDES ES	Villa Mercedes			
Tayum				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BAGALAY ES	Bagalay			
BASBASA ES	Basbasa			
BUMAGCAT ES	Bumagcat			
DON MARCOS ROSALES ES	Cabaroan		High	High
GADDANI NATIONAL HIGH SCHOOL(G.N.H.S.)	Gaddani	Medium	Medium	Medium
DON MARCOS ROSALES ES	Patucannay		Medium	High
HOLY SPIRIT CONVENT	Poblacion			High
TAYUM CS	Poblacion			

Table A-12.2. Educational Institutions affected by flooding in the Abra Floodplain

Ilocos Sur				
Bantay				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BANAOANG ELEMENTARY SCHOOL	Banaoang			
BANTAY EAST CS	Barangay 5		Medium	Medium
ILOCOS SUR COMMUNITY COLLEGE	Barangay 6	High	High	High
BANTAY NHS	Cabalanggan	Low	High	High
BULAG ES	Cabalanggan	Low	High	High
ORA EAST ES	Ora			
ORA WEST ES	Ora			
PAING ES	Paing		Low	High
SILANG ES	Puspus		Medium	High
SAN JULIAN ES	San Julian	High	High	High
SALLACONG ELEMENTARY SCHOOL	San Mariano			

Caoayan				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
ANONANG NAGUILIAN COMM. SCHOOL	Anonang Mayor	High	High	High
BAGGOC P. QUITIQUIT ES	Baggoc	High	High	High
BAGGOC P. QUITIQUIT ES	Callaguip	High	High	High
FUERTE ES	Manangat			
PANDAN ES	Manangat	High	High	High
NANSUAGAO PS	Nansuagao	Medium	High	High
PURO NHS CAOAYAN	Nansuagao	High	High	High
PANTAY QUITIQUIT PS	Pantay-Quitiquit	High	High	High
NAGPANAOAN ES	PantayTamurong	High	High	High
PANTAY TAMURONG ES	PantayTamurong	High	High	High
PANTAY TAMURONG NHS	PantayTamurong	Medium	High	High
VILLAMAR ES	Villamar	High	High	High
Santa				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BANAOANG COMM. SCH.	Dammay			Low
BASUG COMM. SCH.	Dammay			
BASUG NHS	Dammay			
MABILBILA IS	Dammay			
SACUYYA COMM. SCH.	Dammay			
MABILBILA IS	Labut Norte			
Vigan City				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
BURGOS EAST MES	Ayusan Norte			
CORINTHIAN MONTESSORI	Ayusan Norte			
DIVINE WORLD COLLEGE OF VIGAN	Ayusan Norte		High	High
NATURALES TRAINING INSTITUTE	Ayusan Norte		Medium	High
PATER NOSTER LEARNING CENTER	Ayusan Norte	Low	Low	Low
TESDA	Ayusan Norte		Medium	High
VIGAN CS	Ayusan Norte	Low	Medium	High
CAPANGPANGAN ES	Barangay I	High	High	High

DIVINE WORLD COLLEGE OF VIGAN	Barangay I		High	High
PATER NOSTER LEARNING CENTER	Barangay III		Low	Low
SALINDEG ES	Barraca	Medium	High	High
SALINDEG ES (SPBES)	Barraca	Medium	High	High
CAMANGGAAN ES	Beddeng Laud	Medium	High	High
CABAROAN ES	Cabalangegan	Medium	High	High
SAN JULIAN ES	Capangpangan	Medium	High	High
NAGSANGALAN ES	Nagsangalan	Medium	High	High
VIGAN EAST NHS	Nagsangalan	Medium	High	High
UNIVERSITY OF NORTHERN PHILIPPINES	Paoa	Low	Low	Low
RUGSUNGAN-PUROC ES	Purok-A-Bassit	Medium	High	High
RAOIS ES	Raois	Medium	High	High
CAL-LAQUIP ES	Salindeg	Medium	High	High
CAOAYAN CS	Salindeg	Medium	High	High
CAOAYAN CS	Tamag	Medium	High	High
TAMAG ES	Tamag			

ANNEX 13. Medical Institutions affected by flooding in Abra Flood Plain

Table A-13.1. Medical Institutions in Abra affected by flooding in Abra Flood Plain

Abra				
Bangued				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DICKSON POLYCLINIC	Dangdangla			
PALOS CLINIC	Dangdangla			
ABRA PROVINCIAL HOSPITAL	Zone 1 Poblacion			
BARBADILLO CLINIC	Zone 4 Poblacion			
ABRA MEDICAL CENTER	Zone 5 Poblacion			Low
CASIA CLINIC	Zone 5 Poblacion			
DR. PETRONLO SEARES SR.	Zone 5 Poblacion			
HEALTH CHECK	Zone 5 Poblacion	Medium	Medium	High
MARIBEL MEDICAL CLINIC	Zone 5 Poblacion			
BANEZ CLINIC	Zone 5 Poblacion		Low	Low
DICKSON POLYCLINIC	Zone 7 Poblacion			
MAGALA BAUTISTA CLINIC	Zone 7 Poblacion			
MARIBEL MEDICAL CLINIC	Zone 7 Poblacion			Low
ASSUMPTA CLINIC	Zone 7 Poblacion			
BANGUED CHRISTIAN HOSPITAL	Zone 7 Poblacion			
Bucay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BUCAY HOSPITAL	North Poblacion			

Table A-13.2. Medical Institutions in Abra affected by flooding in Abra Flood Plain

Ilocos Sur				
Bantay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
PATAO CLINIC	Aggay		Medium	High
NORTHEAST CARE CENTER	Sinabaan	High	High	High

Vigan City				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
DENTIST JOEY DE VERZOSA	Ayusan Norte			
LAHOZ CLINIC AND HOSPITAL	Ayusan Norte		Low	Medium
MERCURY DRUG	Ayusan Norte	Low	Medium	Medium
RABARA CLINIC AND HOSPITAL	Ayusan Norte			
RABE DENTAL CLINIC	Ayusan Norte			Low
REODIQUE OPTICAL - DENTAL CLINIC	Ayusan Norte	Low	Low	Low
S. M. AMORES VETERINARY CLINIC	Ayusan Norte			
YADAO OPTICAL CLINIC	Ayusan Norte			
VIGAN POLYCLINIC	Barangay VII			Medium
GABRIELA SILANG GENERAL HOSPITAL	Tamag			
PHARMACY	Tamag			
SABI NI DOC PHARMACY	Tamag			