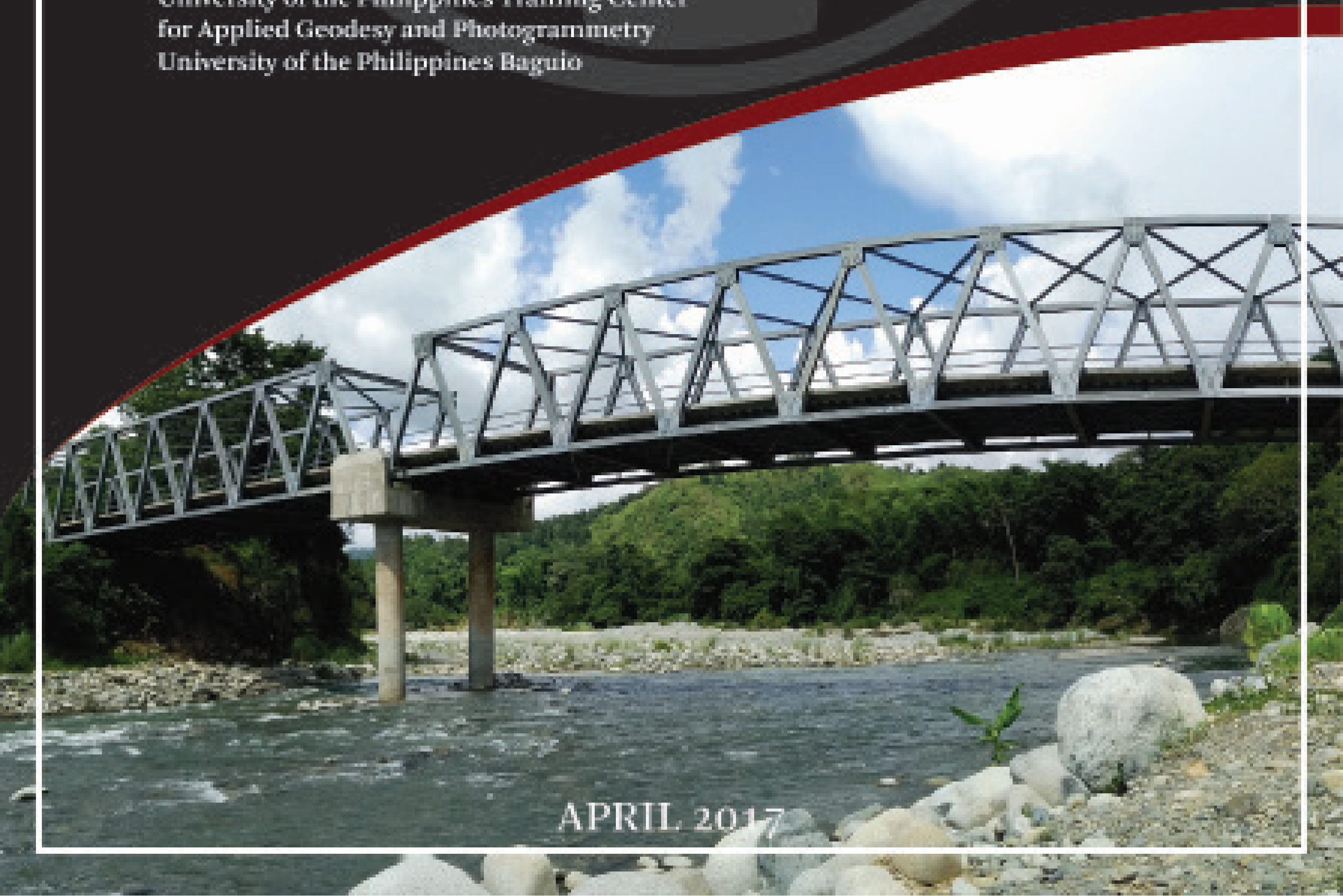
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Ikmin River

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



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

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

1.2 Overview of the Ikmin River Basin

Ikmin River Basin covers Municipalities of Sallapadan, Boliney, Daguioman, Licuan-Baay, and Manabo in Abra. The DENR River Basin Control Office identified the basin to have a drainage area of 444 km2 and an estimated 1,086 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Ikmin River, is part of the twelve (12) river systems in Abra Region under the PHIL-LIDAR 1 partner HEI, University of the Philippines Baguio.

According to the 2015 national census of NSO, a total of 11,516 people distributed among seventeen (17) barangays in the Municipalities of Manabo, Bucay, Bucloc, Daguioman, Manabo,and Sallapadan in Abra are residing within the immediate vicinity of the river. Most of the families in the area are engaged in farming as their primary source of living. There are also quarry sites in the river for sand and rocks (http://www.dilgcar.com/index.php/2015-07-10-04-38-51/municipality-of-boliney, 2016).

The most recent flood event in the area was in October 2016 brought by Typhoon Lawin; communities living along the river were instructed to evacuate to avoid casualties due to flooding (http://news.pia.gov.ph/article/view/3191476785199/abra-prepares-for-typhoon-lawin, 2016).

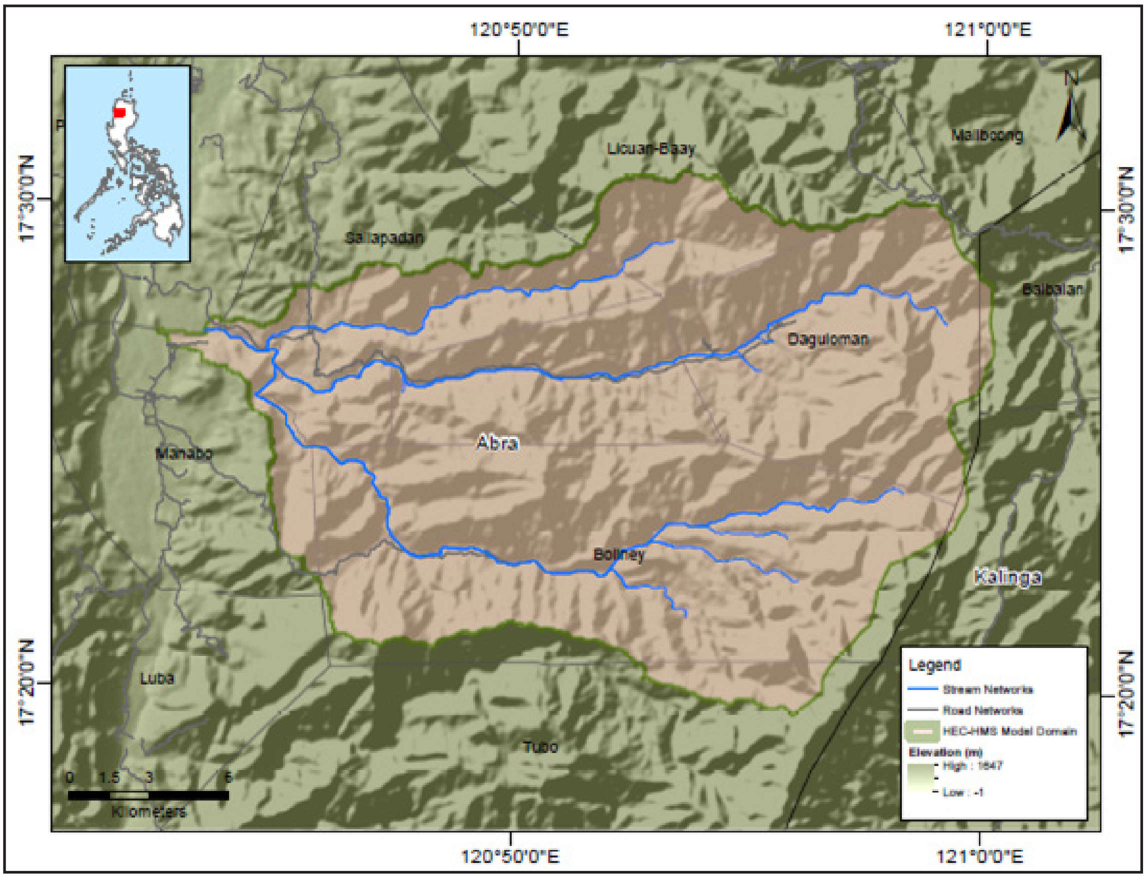

Figure 1. Map of Ikmin River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE IKMIN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Ikmin Floodplain in Abra. These missions were planned for 14 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plan for Ikmin 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

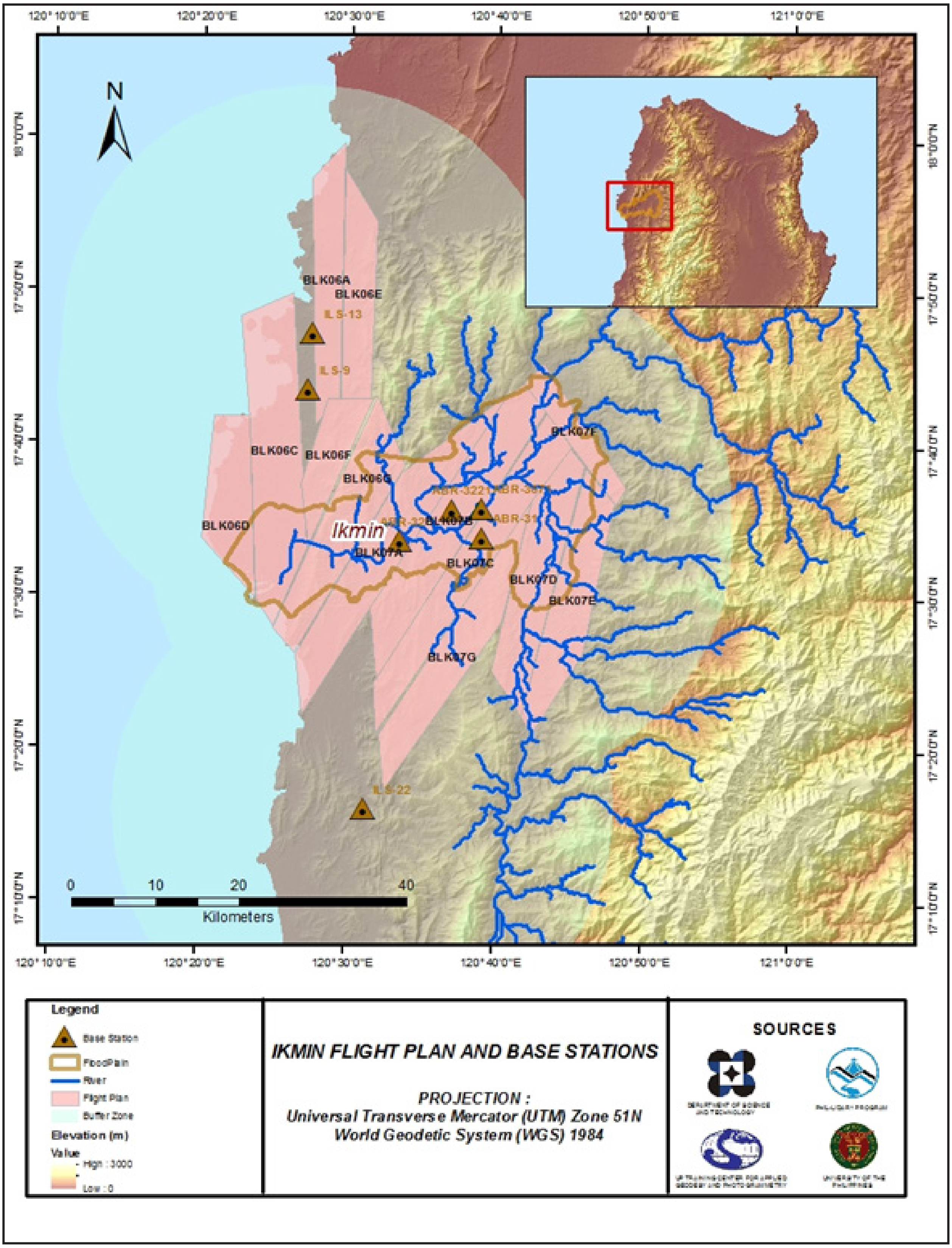

Figure 2. Flight plan and base stations used for Ikmin Floodplain.

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 4th order. The team also established one (1) control point (ABR-3071). The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports are found in Annex 3. These points were used as base stations during flight operations for the entire duration of the survey (February 21 – 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 Ikmin Floodplain are shown in Figure 2.

Figure 3 to Figure 8 show the recovered NAMRIA reference points within the area. In addition Table 2 to Table 8 present the details about the following NAMRIA control stations and established points. Table 9 shows the list of all ground control points occupied during the acquisition together with the dates of utilization.

(b)

(a)

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

Table 2. Details of the recovered NAMRIA horizontal control point ABR-31 used as base station for the LiDAR acquisition.

Station Name	ABR-31	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 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

(b)

(a)

Figure 4. a) GPS set-up over ABR-32 inside the Barangay Hall Compound of Barangay Suyo, Pidigan Ikmin. b) NAMRIA reference point ABR-32 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

(b)

(a)

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

Table 4. Details of the recovered NAMRIA horizontal control point ILS-9 used as base station for the LiDAR acquisition.

Station Name	ILS-9	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 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

(b)

(a)

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

(a) (b)

Figure 7. a) GPS set-up over ILS-22 at the science park in North Central Elementary School in the Municipality of Lidlidda, Ilocos Sur. b) NAMRIA reference point ILS-22 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. a) GPS set-up over ABR-3221 (BLLM 2)inside the Town Plaza of Bangued, Ikmin. b) processed reference point ABR-3221 (BLLM 2) 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 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

Three (3) missions were conducted to complete the LiDAR data acquisition in Buaya floodplain, for a total of ten hours and forty nine minutes (10+49) of flying time for RP-C9322 and RP-C9022. All missions were acquired using the Gemini and Pegasus LiDAR systems. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Ikmin 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

Ikmin floodplain is located in the province of Abra and Ilocos Sur. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Ikmin Floodplain is presented in Figure 9.

Table 12. List of municipalities and cities surveyed during Ikmin 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%

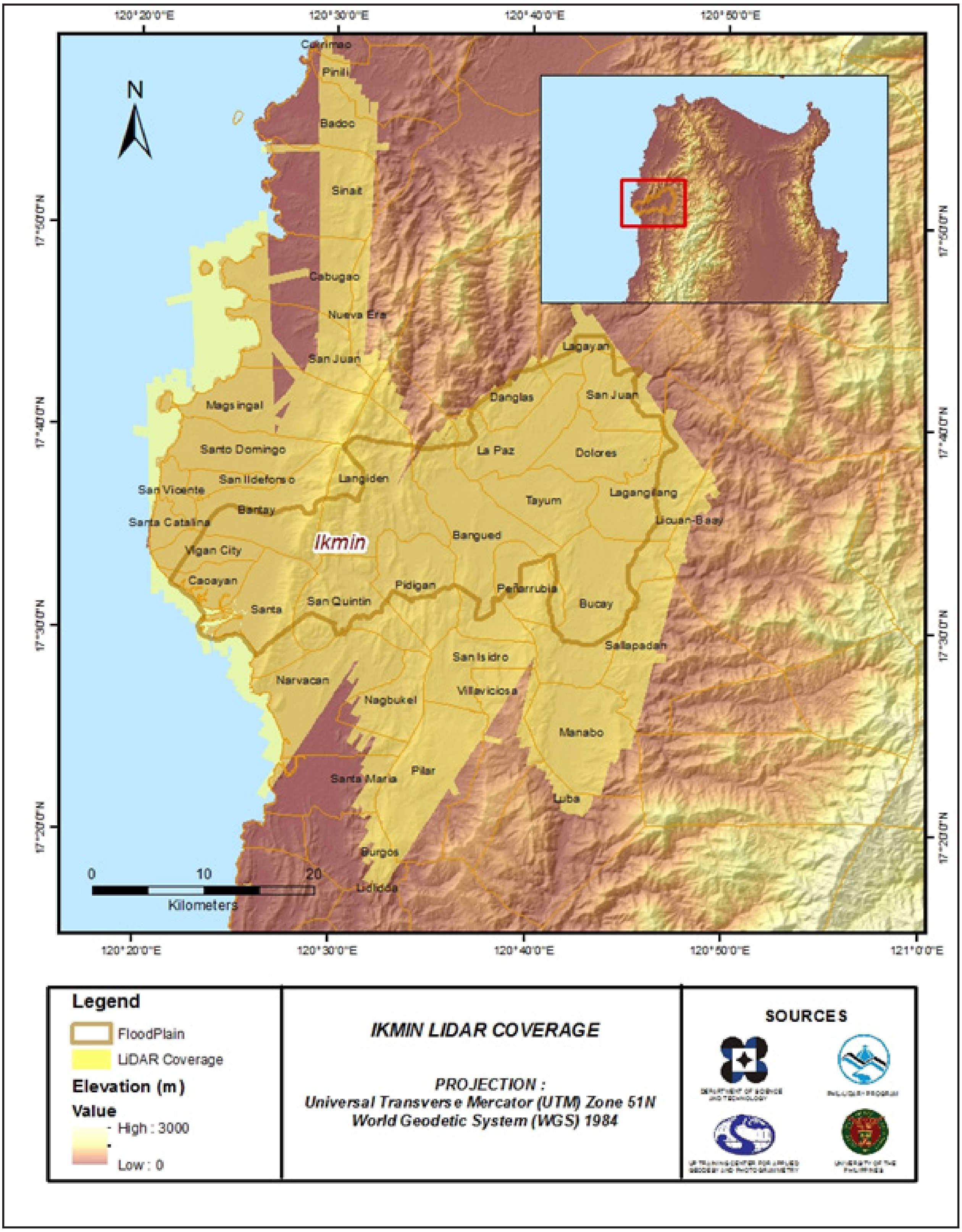

Figure 9. Actual LiDAR survey coverage for Ikmin Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE IKMIN 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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectoryis done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which were the minimum point density, vertical and horizontal accuracies, were met. The point clouds 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 were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was done through the help of the georectified point clouds and the metadata containing the time the image was captured.

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

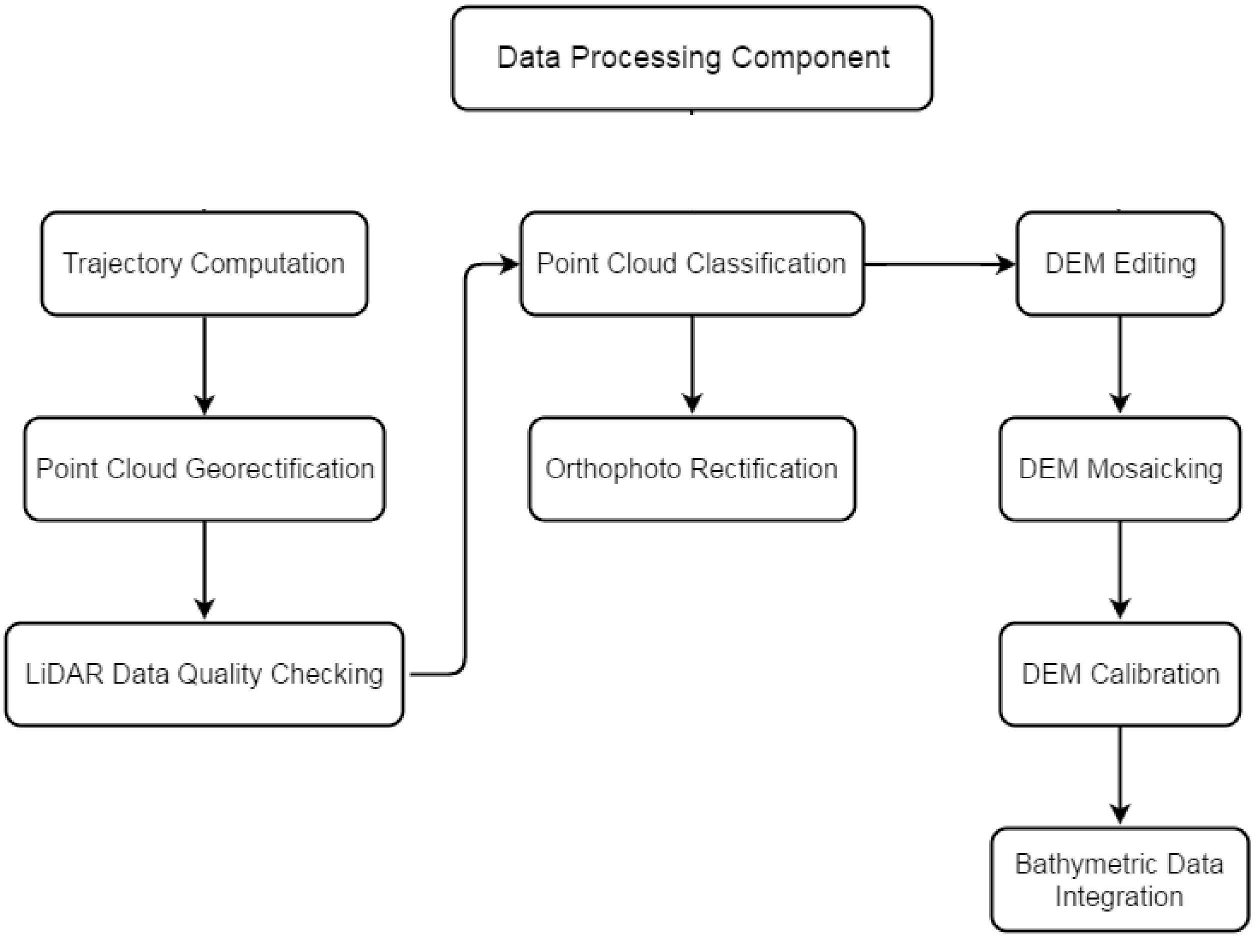


Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ikmin 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 in May 2016 were flown using the Gemini system over Sta. Rita, Samar.

The Data Acquisition Component (DAC) transferred a total of208.8 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 July1, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ikmin was fully transferred on July1, 2016, as indicated in the Data Transfer Sheets for Ikmin Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7108GC, one of the Ikminflights, 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 00:00AM. The y-axis is the RMSE value for that particular position.

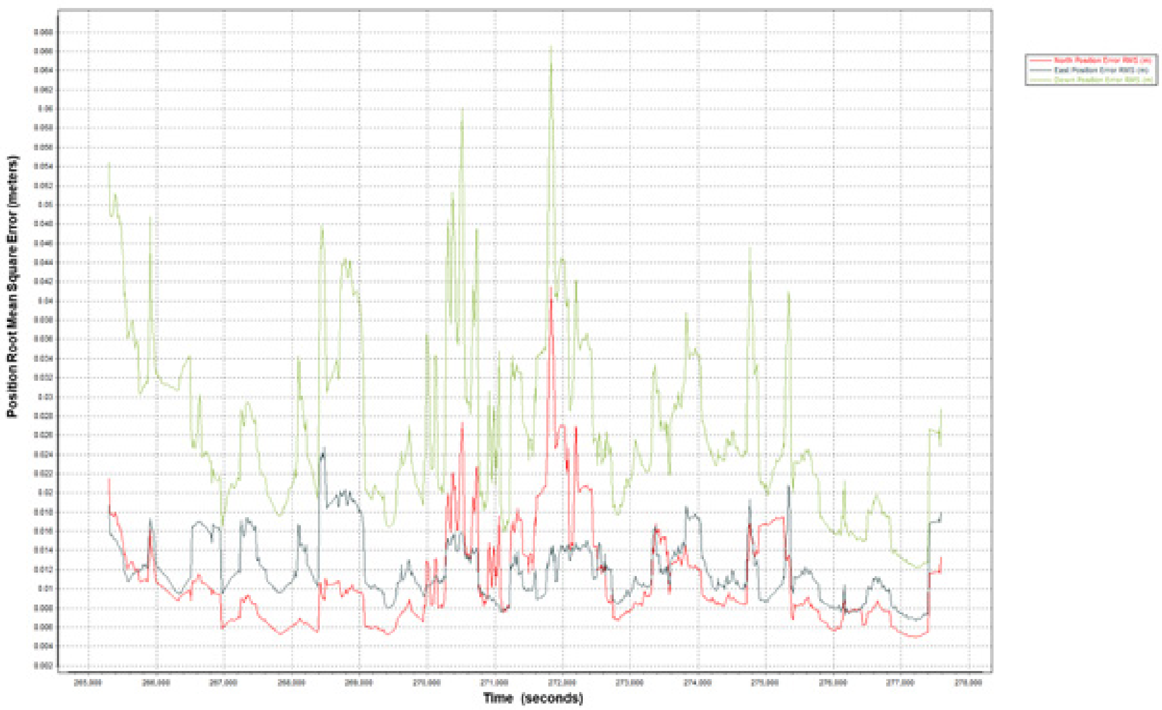


Figure 11. Smoothed Performance Metrics of Ikmin Flight 7108GC.

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 3.30centimeters, and the Down position RMSE peaks at 3.30centimeters, which are within the prescribed accuracies described in the methodology.

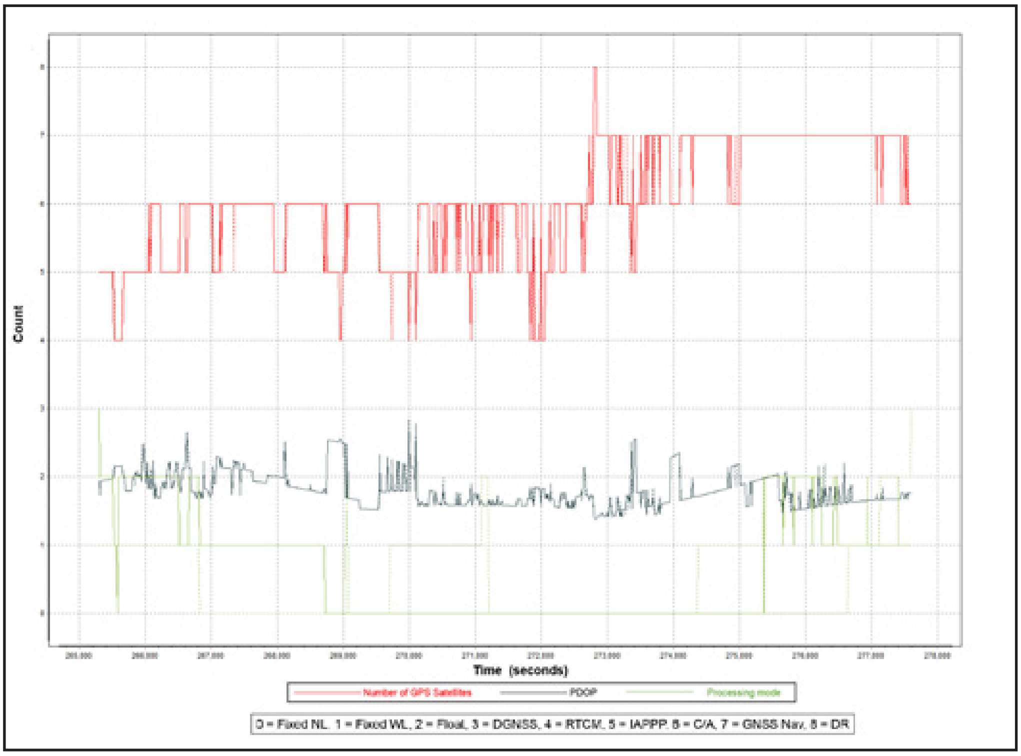


Figure 12. Solution Status Parameters of Ikmin Flight 7108GC.

The Solution Statusparameters offlight 7108GC,one of the Ikminflights, 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 4. Majority of the time, the number of satellites tracked was between 4 and 8. 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 Ikminflights is shown in Figure 13.

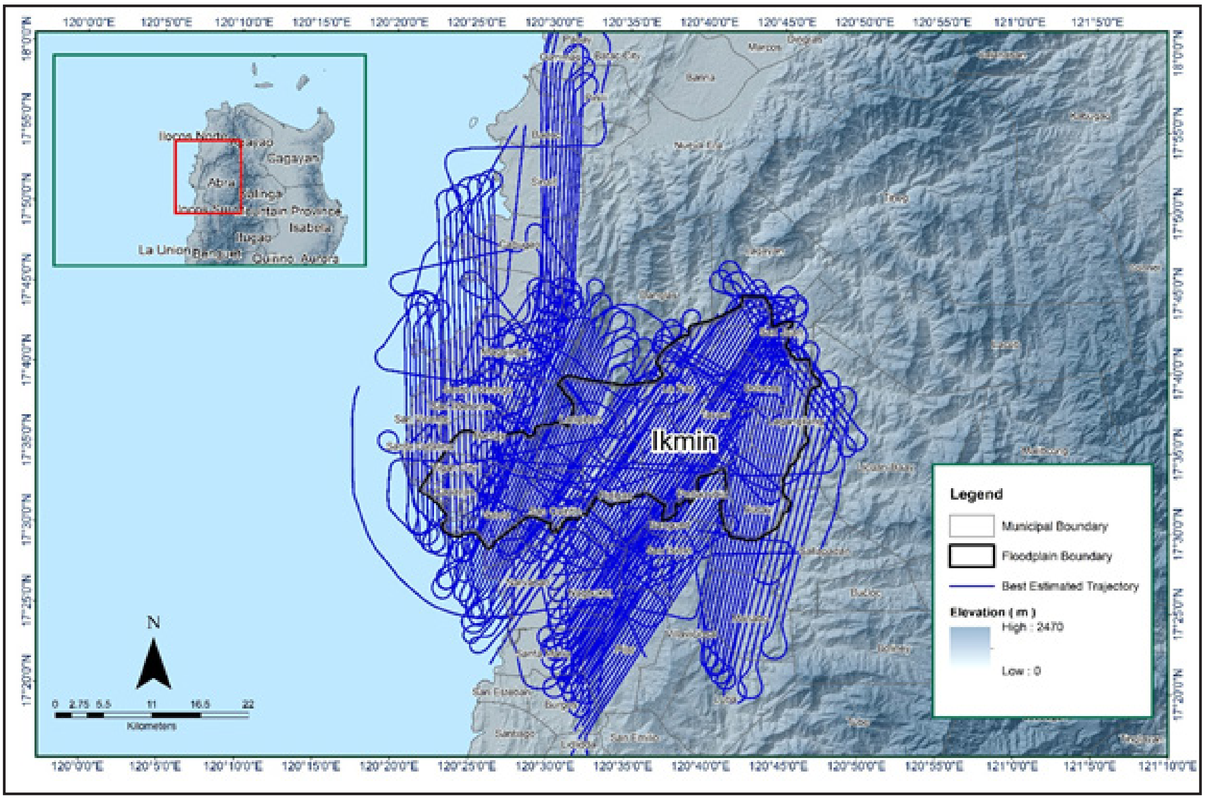


Figure 10. Figure 13. Best Estimated Trajectory for Ikmin Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 173flight lines, with each flight line containing one channel, since the Geminisystemcontains only one channel. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Ikmin Floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Ikmin 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 is obtained for all Ikmin flights based on the computed standard deviationsof the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8.

3.5 LiDAR Data Quality Checking

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

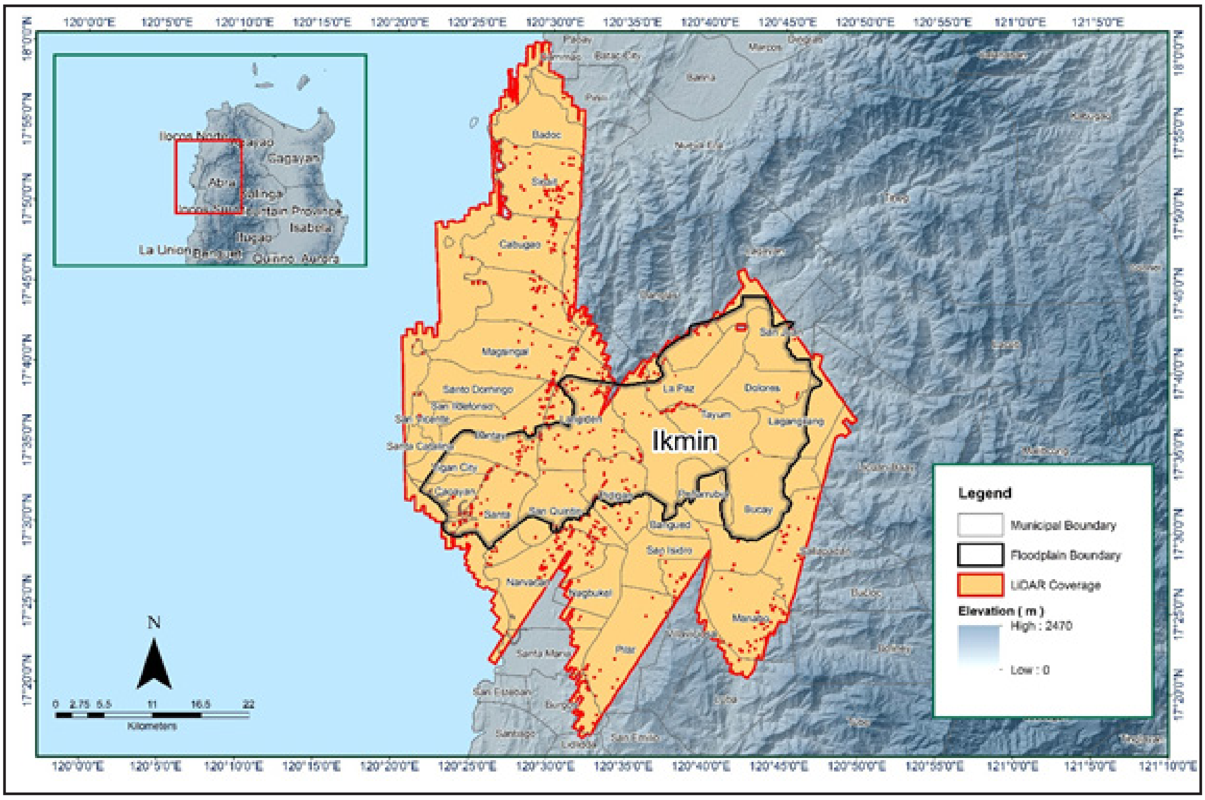


Figure 14. Boundary of the processed LiDAR data over Ikmin Floodplain

The total area covered by the Ikmin missions is 2439.64sq.km 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 Ikmin 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		2439.64sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular locationis shown in Figure 15. Since the Gemini system employs one channel, 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 are expected.

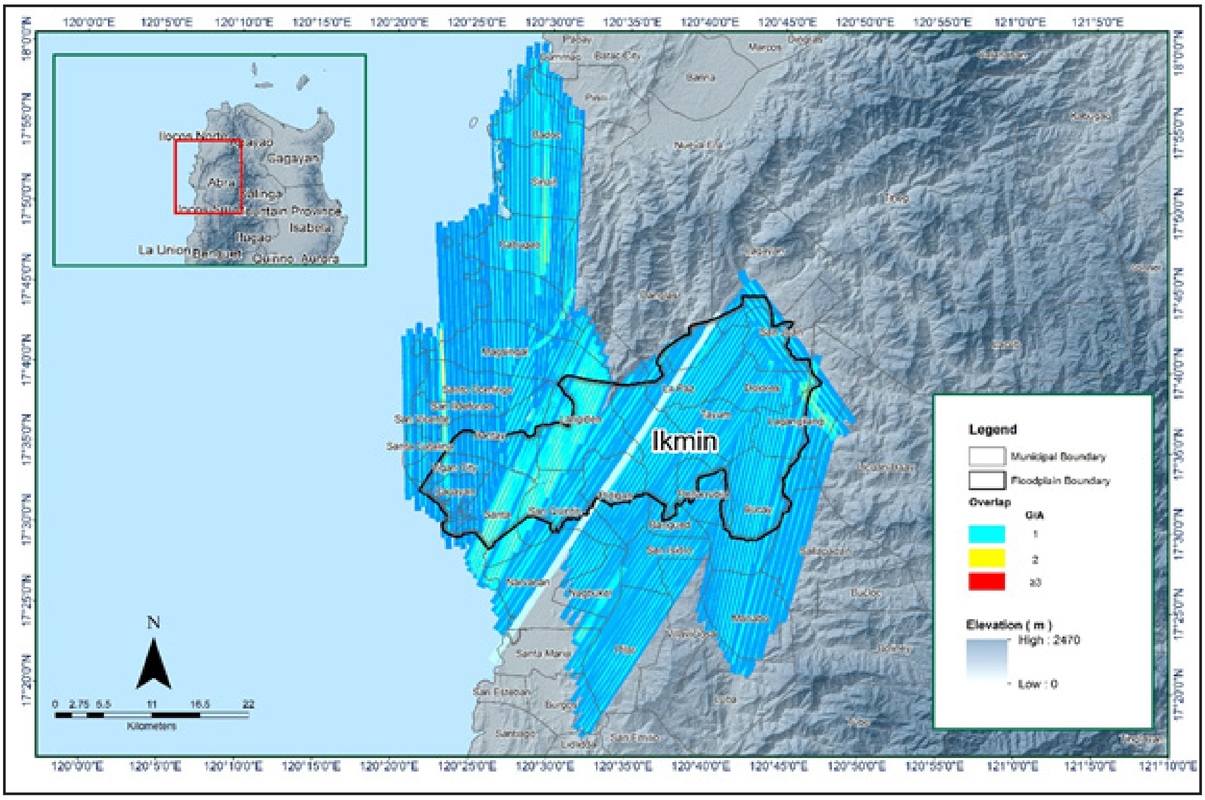


Figure 15. Image of data overlap for Ikmin Floodplain.

The overlap statistics per block for the Ikmin Floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlapsare25.76% and 63.15% respectively, which passed the 25% requirement.

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

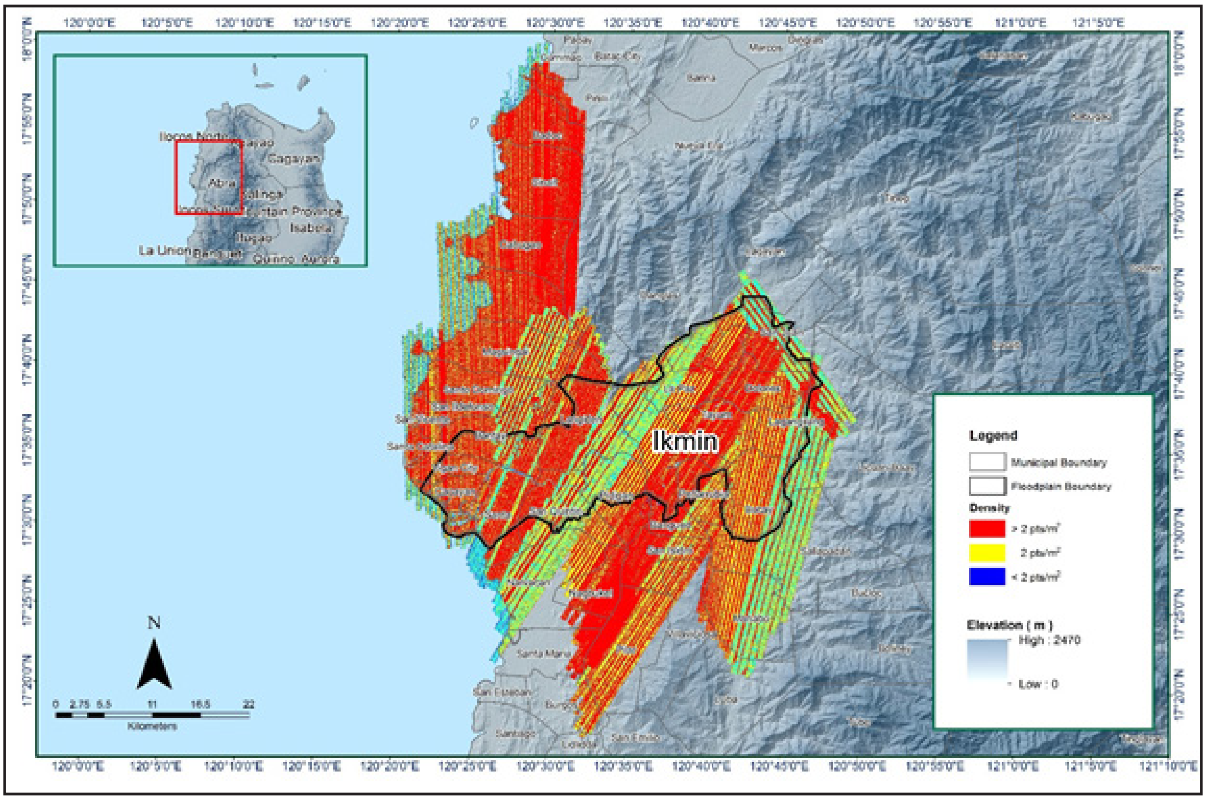


Figure 16. Pulse density map of merged LiDAR data for Ikmin Floodplain.

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.

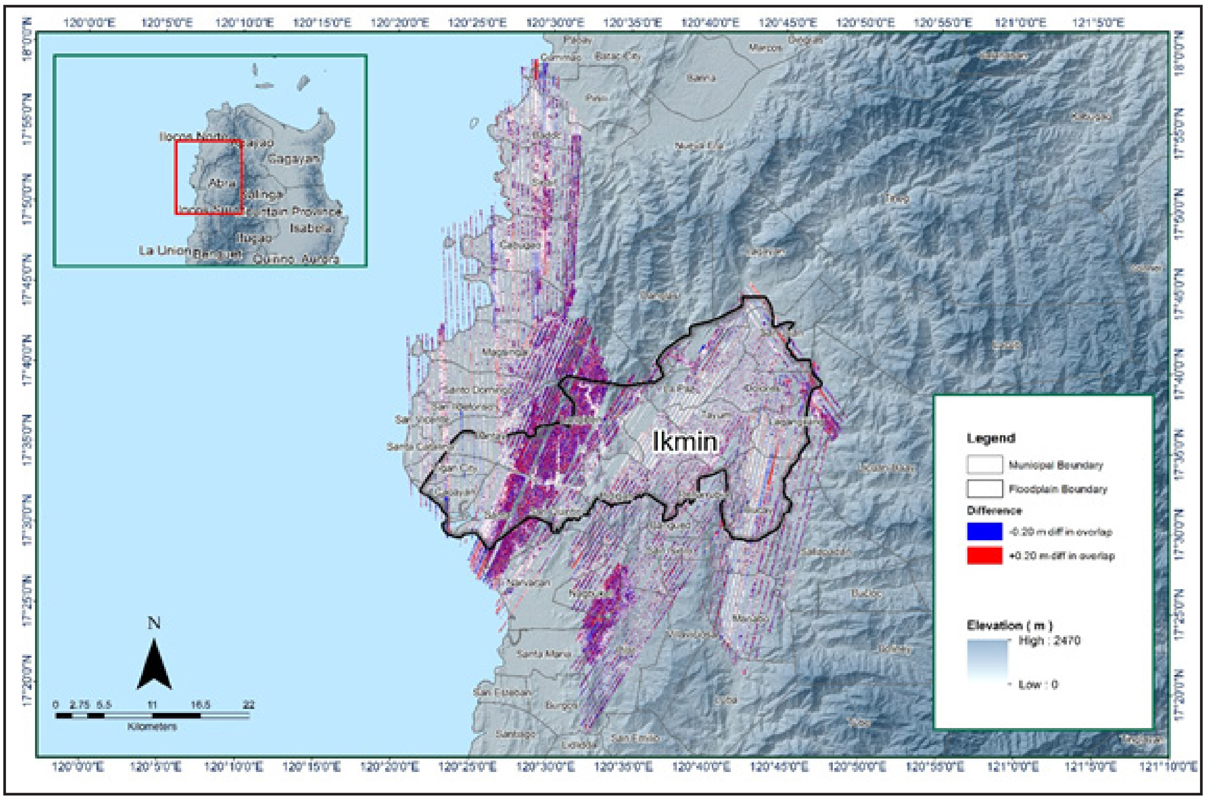


Figure 17. Elevation difference map between flight lines for Ikmin Floodplain.

A screen capture of the processed LAS datafromIkminflight 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.

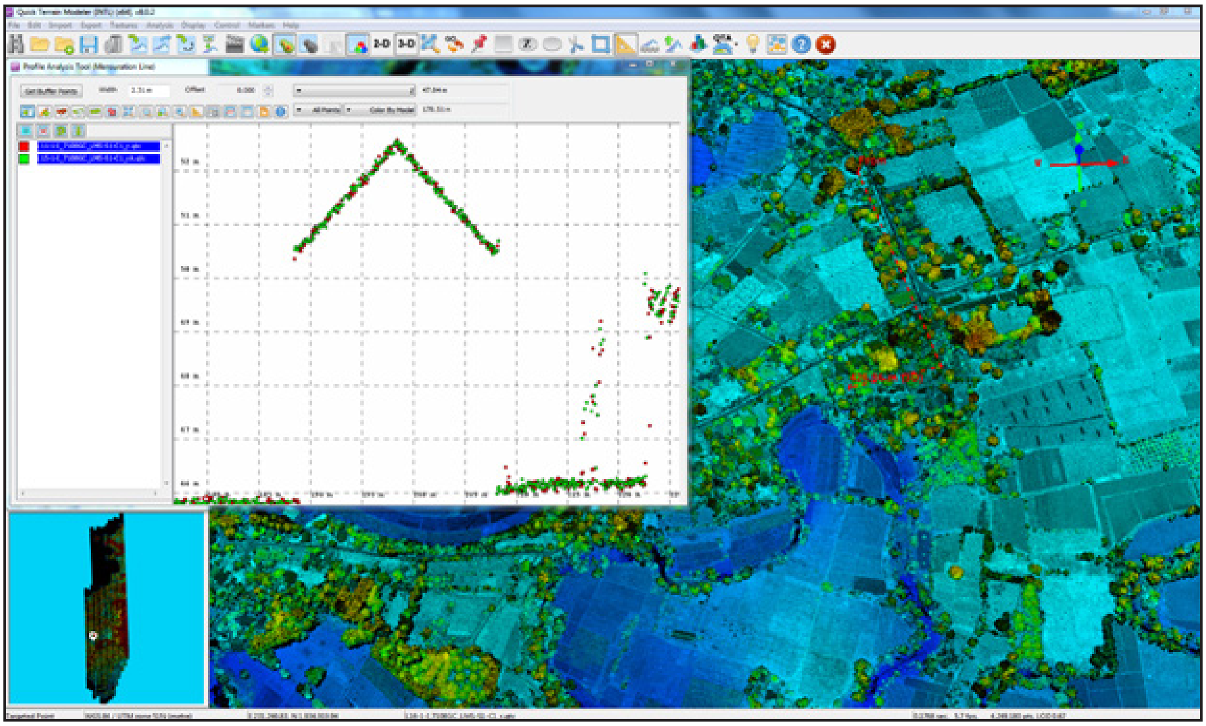


Figure 18. Quality checking for a Ikmin flight 7108GC using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Ikmin 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 Ikmin Floodplain is shown in Figure 19. A total of 3,3411km 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.

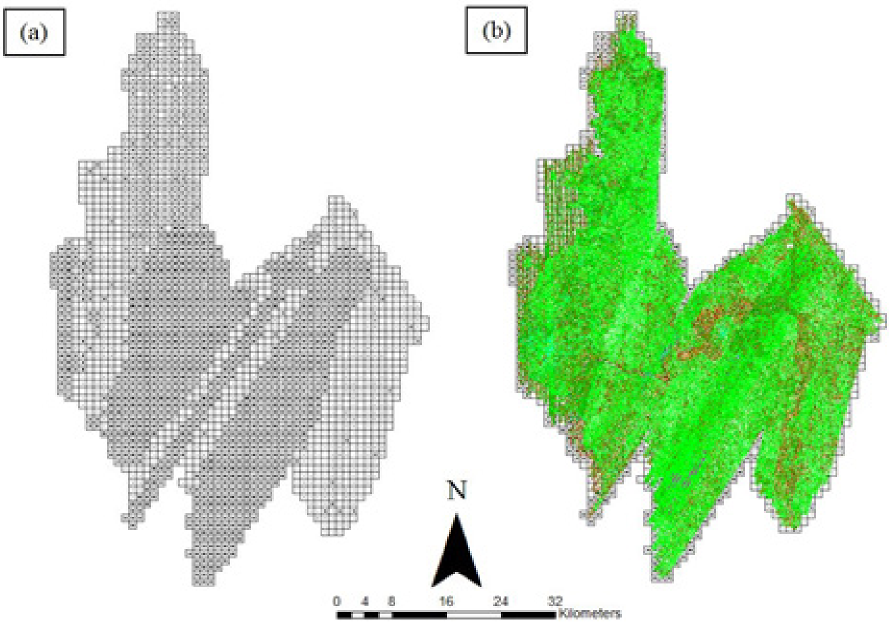


Figure 19. Tiles for Ikmin Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

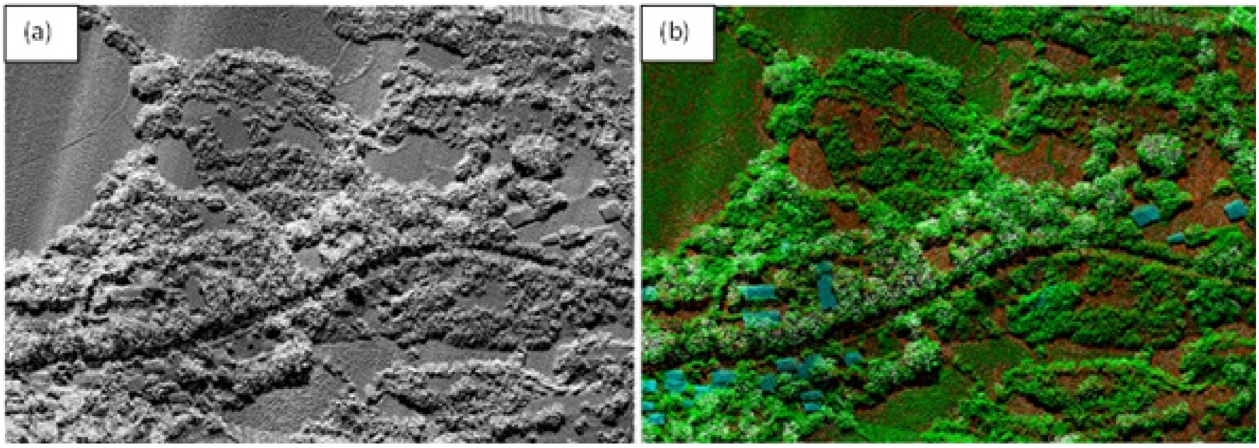


Figure 20. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 21. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

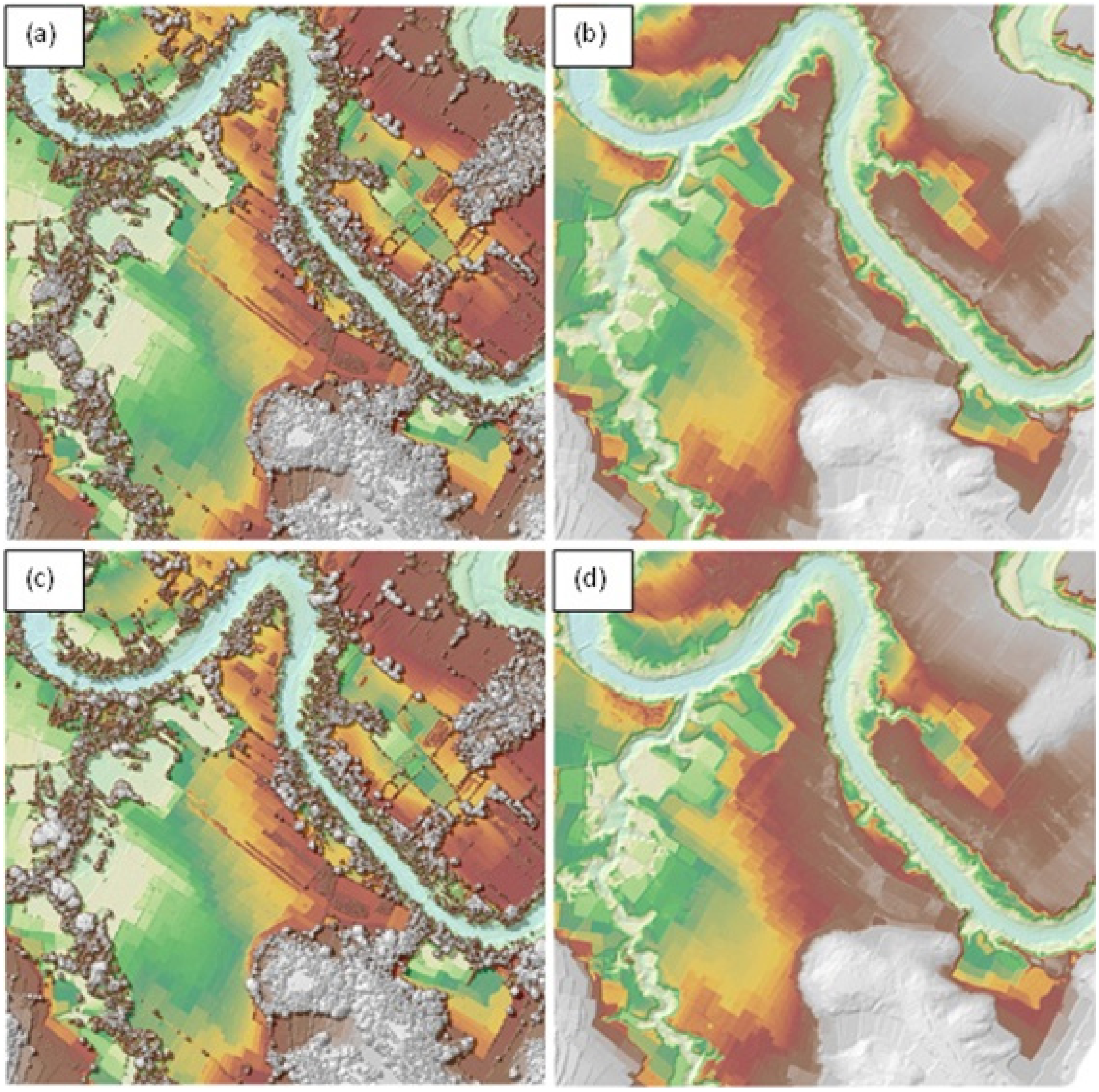


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ikmin Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Ikmin Floodplain.

3.8 DEM Editing and Hydro-Correction

Sixteen (16) mission blocks were processed for Ikmin Floodplain. These blocks are composed of Laoag and Ilocos blocks with a total area of 2439.64square 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

Portions of DTM before and after manual editing are shown in Figure 22. The bridge (Figure 22a) would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 22b.

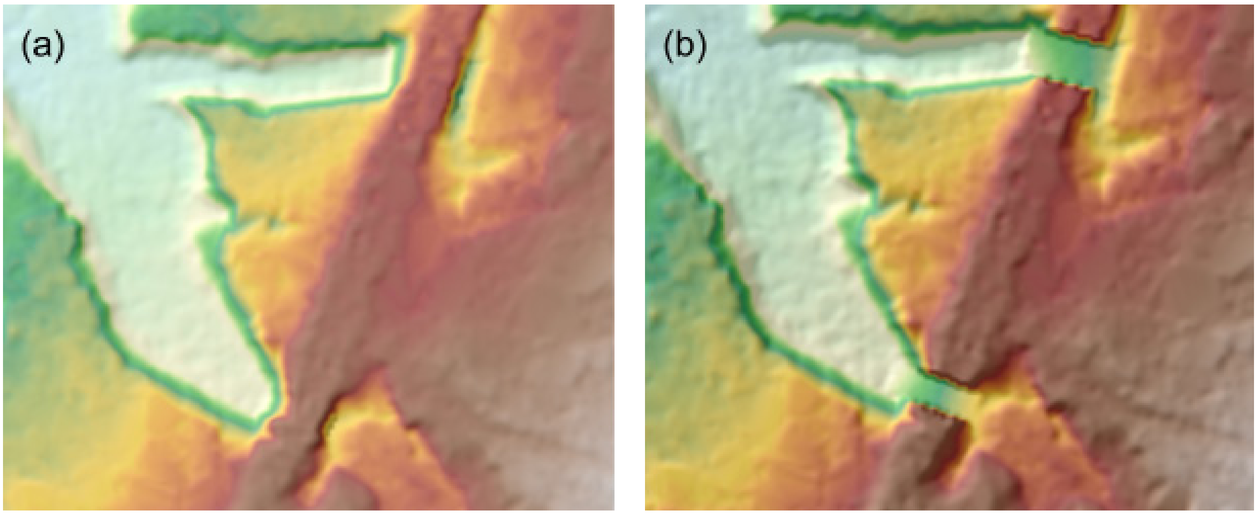


Figure 22. Portions in the DTM of Ikmin Floodplain – a bridge before (a) and after (b) manual editing

3.9 Mosaicking of Blocks

Ilocos_Blk5A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy.

Mosaicked LiDAR DTM for Buaya floodplain is shown in Figure 14. It can be seen that the entire Buaya floodplain is 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Buaya 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

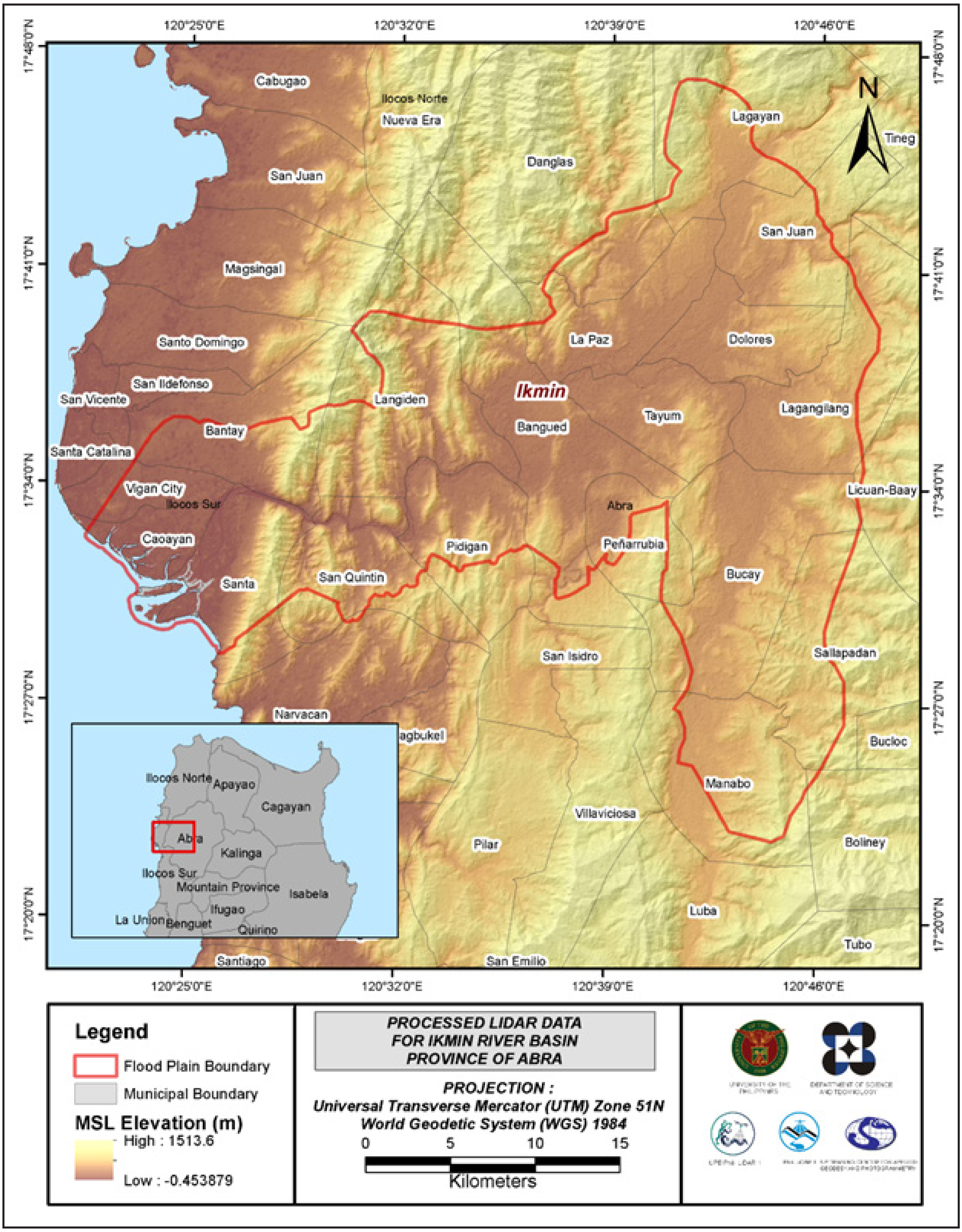


Figure 23. Map of Processed LiDAR Data for Ikmin Floodplain.

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 Ikmin 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 Ikmin LiDAR data was done by subtracting the height difference value, 3.47 meters, to the mosaicked LiDAR data for Ikmin. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

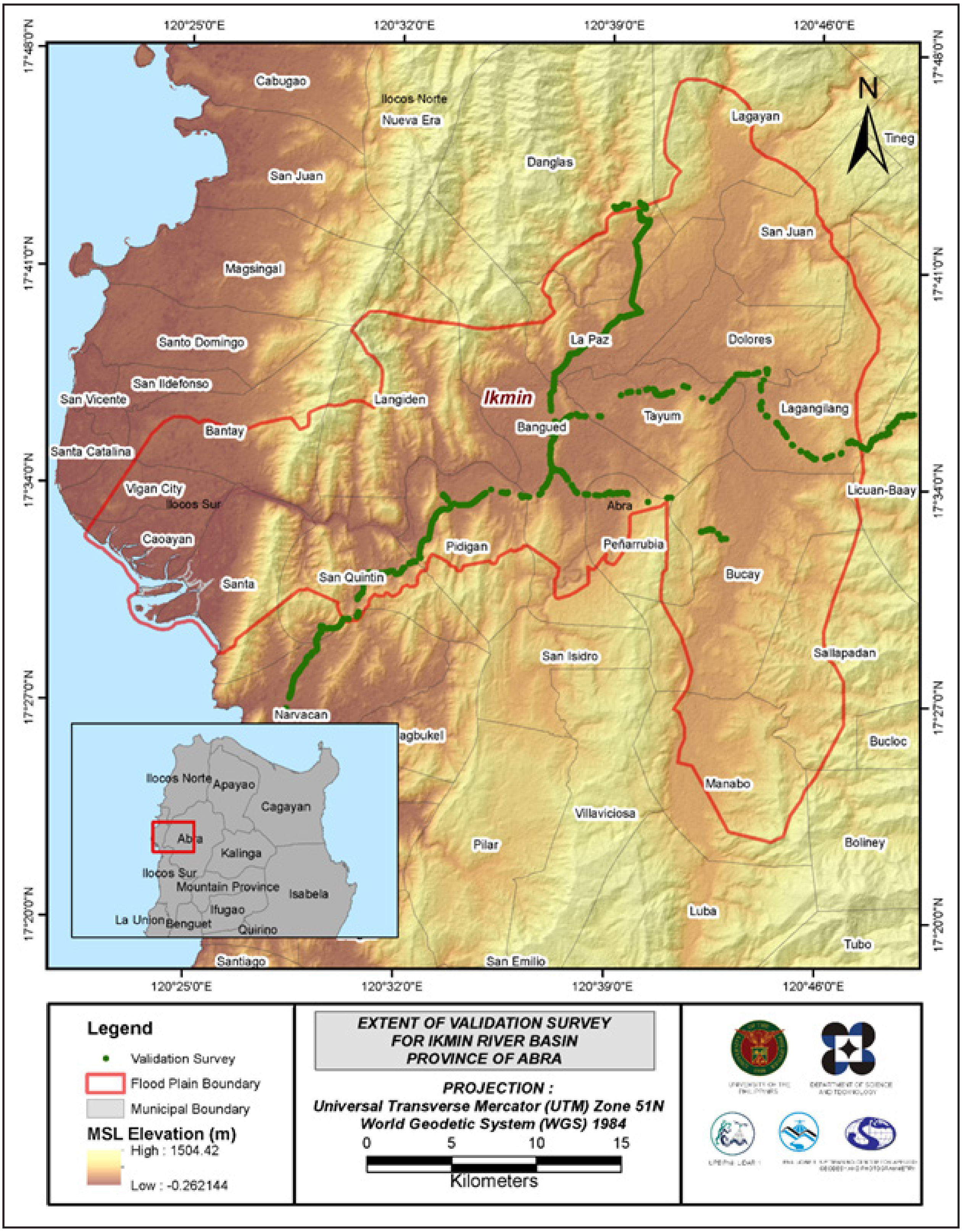


Figure 24. Map of Ikmin Floodplain with validation survey points in green.

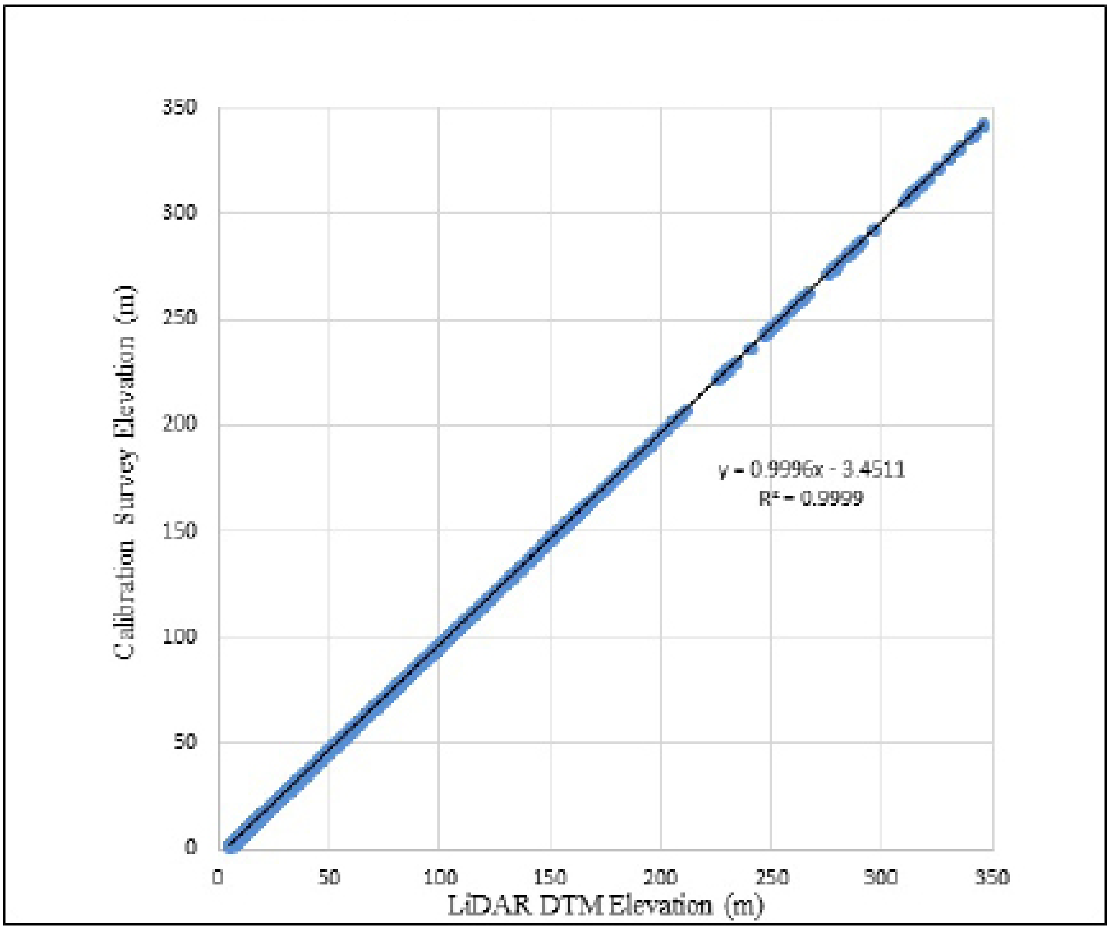


Figure 25. Correlation plot between calibration survey points and LiDAR data.

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 Ikmin flood plain were used for the validation of the calibrated Ikmin 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.

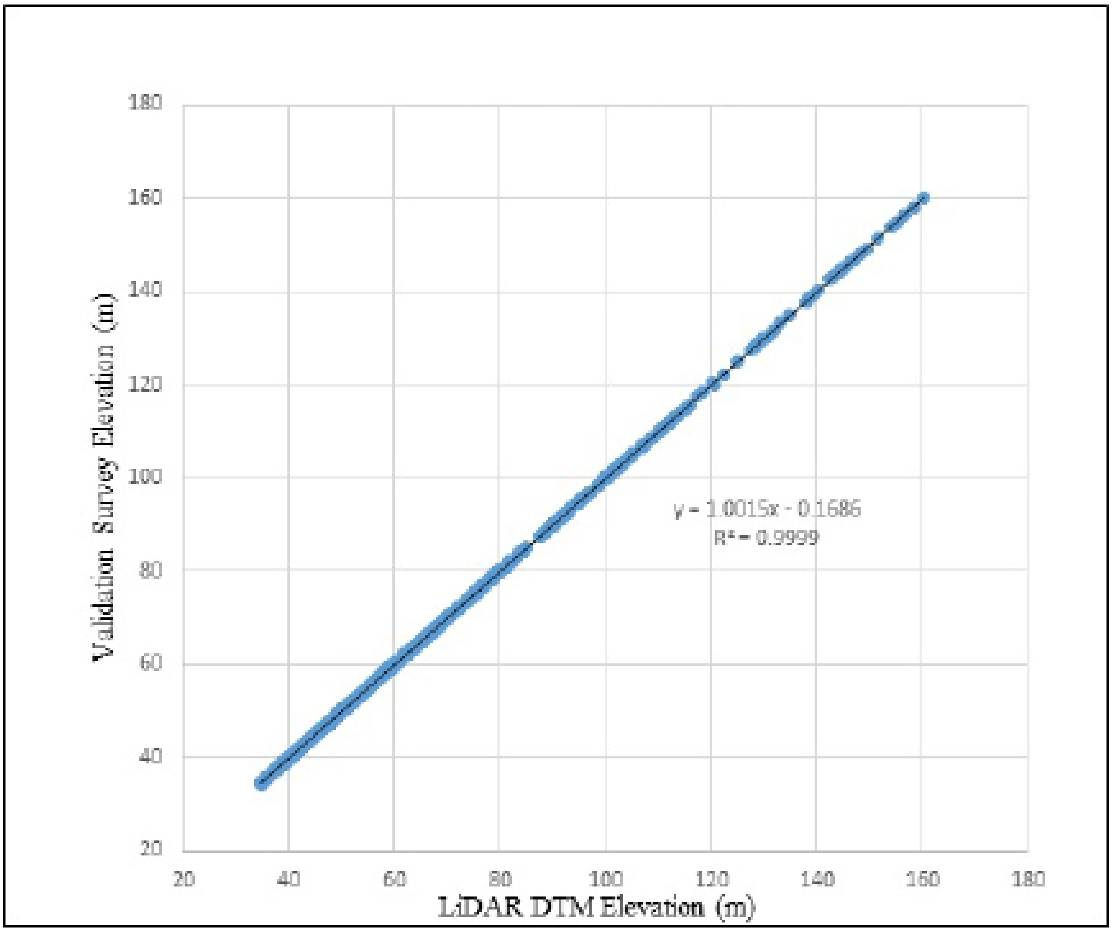


Figure 26. Correlation plot between validation survey points and LiDAR data.

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, centreline and cross-section data were available for Ikmin with a total of 30,311 bathymetric survey points. The floodplain contains three (3) rivers namely Abra, Tineg and Ikmin. The production of the raster surface for Ikmin is discussed below.

Ikmin River
Ikmin River was dry during the February 2014 LiDAR data acquisition and therefore did not require Bathymetric Burning.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Ikmin 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 5893 building features, are considered for QC. Figure 27 shows the QC blocks for Ikmin Floodplain.

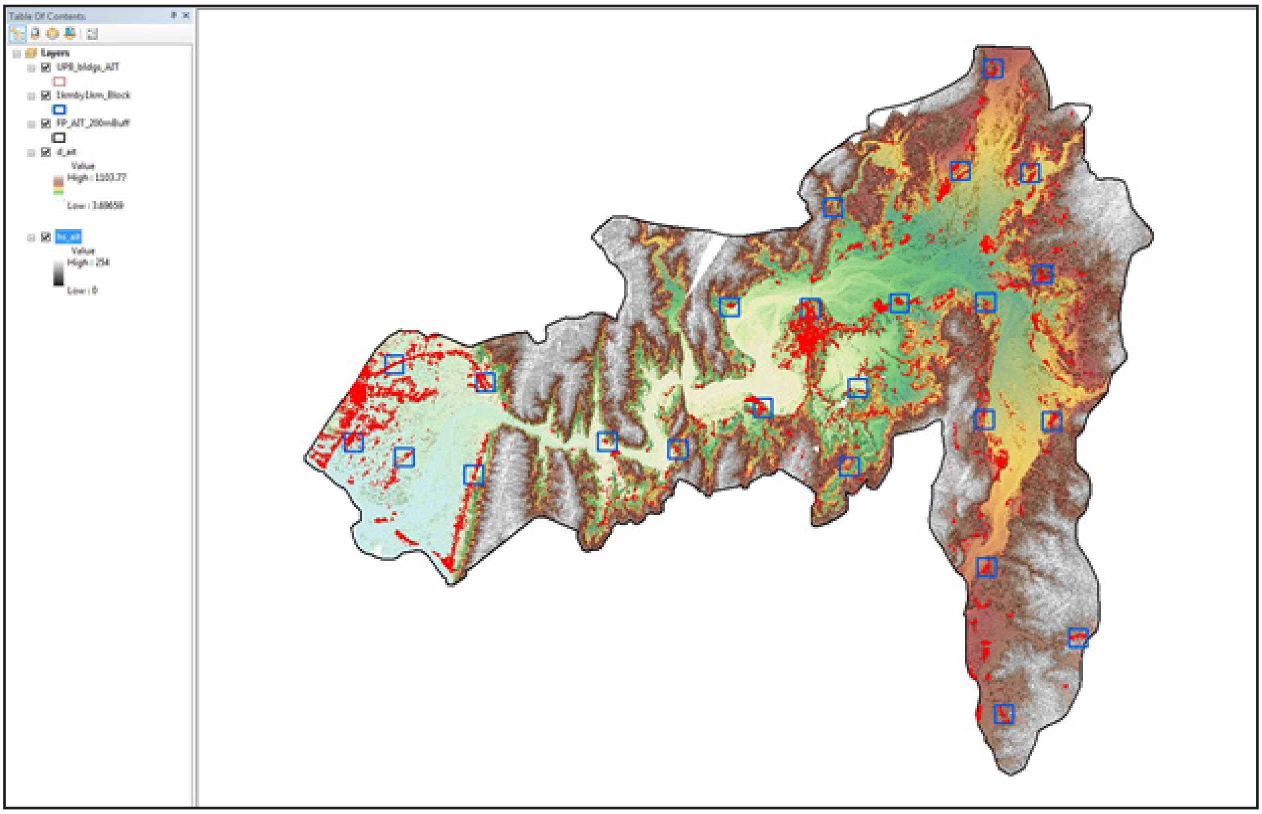


Figure 27. Blocks (in blue) for Ikmin building features subjected to QC.

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

Table 20. Quality Checking Ratings for Ikmin Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Ikmin	99.44	99.98	97.30	PASSED

3.12.2 Height Extraction

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

3.12.3 Feature Attribution

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

Table 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 Ikmin 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 IkminFloodplain.

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 Ikmin 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.

Figure 28 shows the Digital Surface Model (DSM) of Ikmin Floodplain overlaid with its ground features.

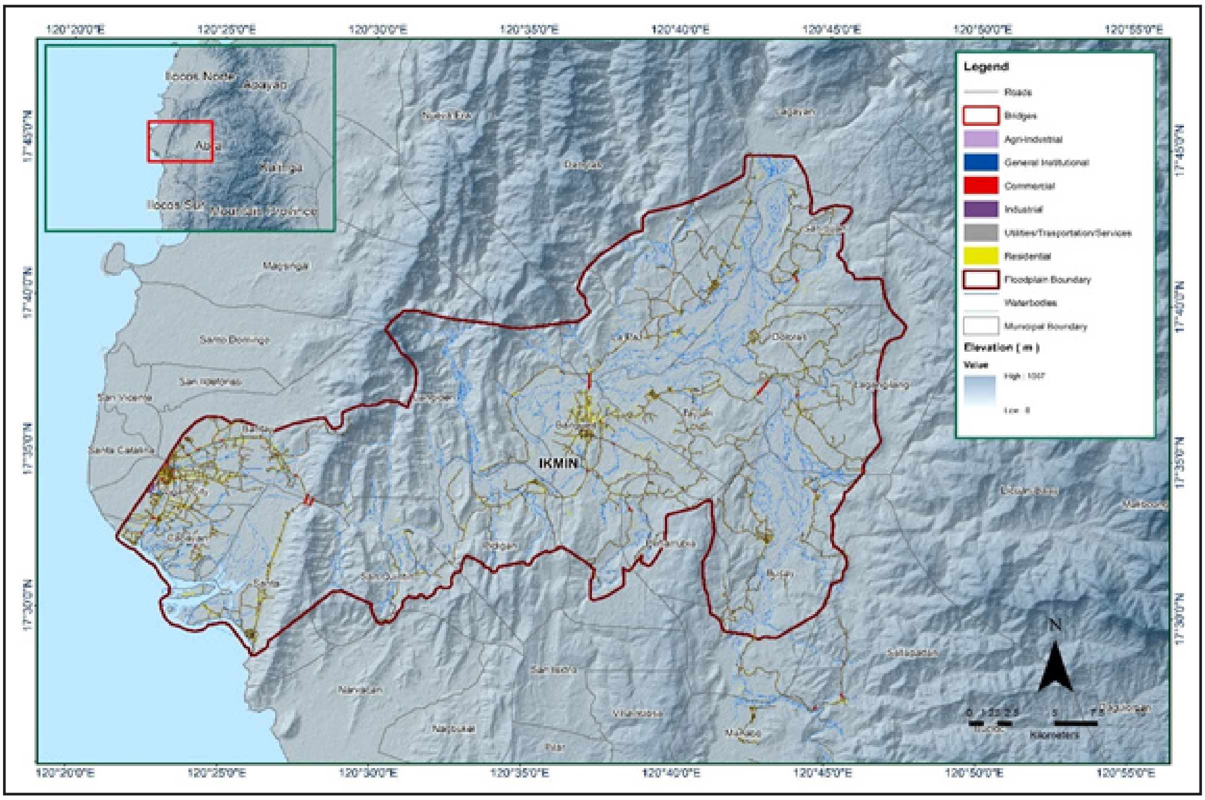


Figure 28. Extracted features for Buaya floodplain.

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

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

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

4.1 Summary of Activities

The DVBC conducted a field survey in IkminRiver on July13 – 27, and September 22-30, 2016 with the following scopeof work: reconnaissance; control survey; cross-section and as-built survey at Cervantez, Manabo, Manicbel and New Ikmin Bridges; and validation points acquisition of about 82 km covering the IkminRiver Basin area using a Trimble® SPS 882 GNSS PPKsurvey techniqueas shown in Figure 29.

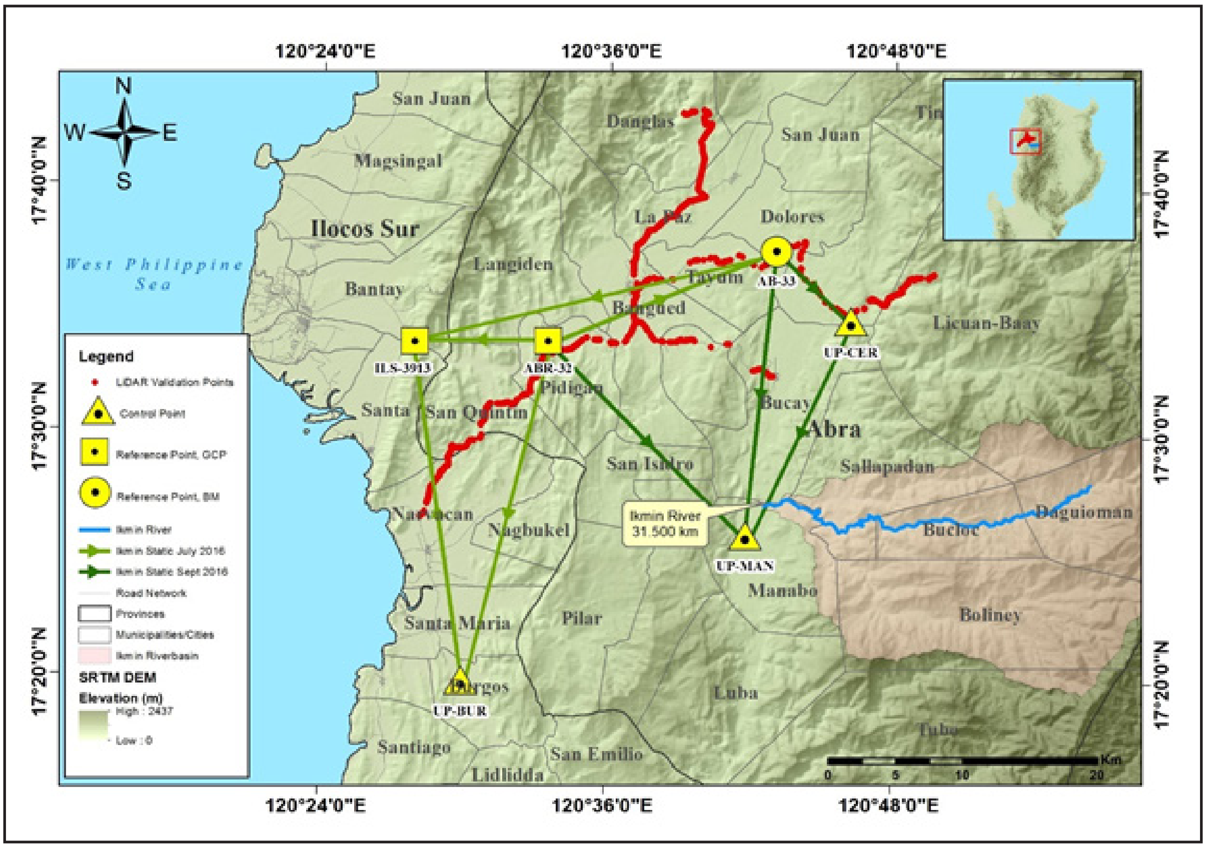


Figure 29. Extent of the bathymetric survey (in blue) in Ikmin River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Ikmin River Basin is composed of four (4) loops established on July 16, 2016 occupying 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; 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.

The summary of reference and control points and its location is summarized in Table 24 while the GNSS network established is illustrated in Figure 30.

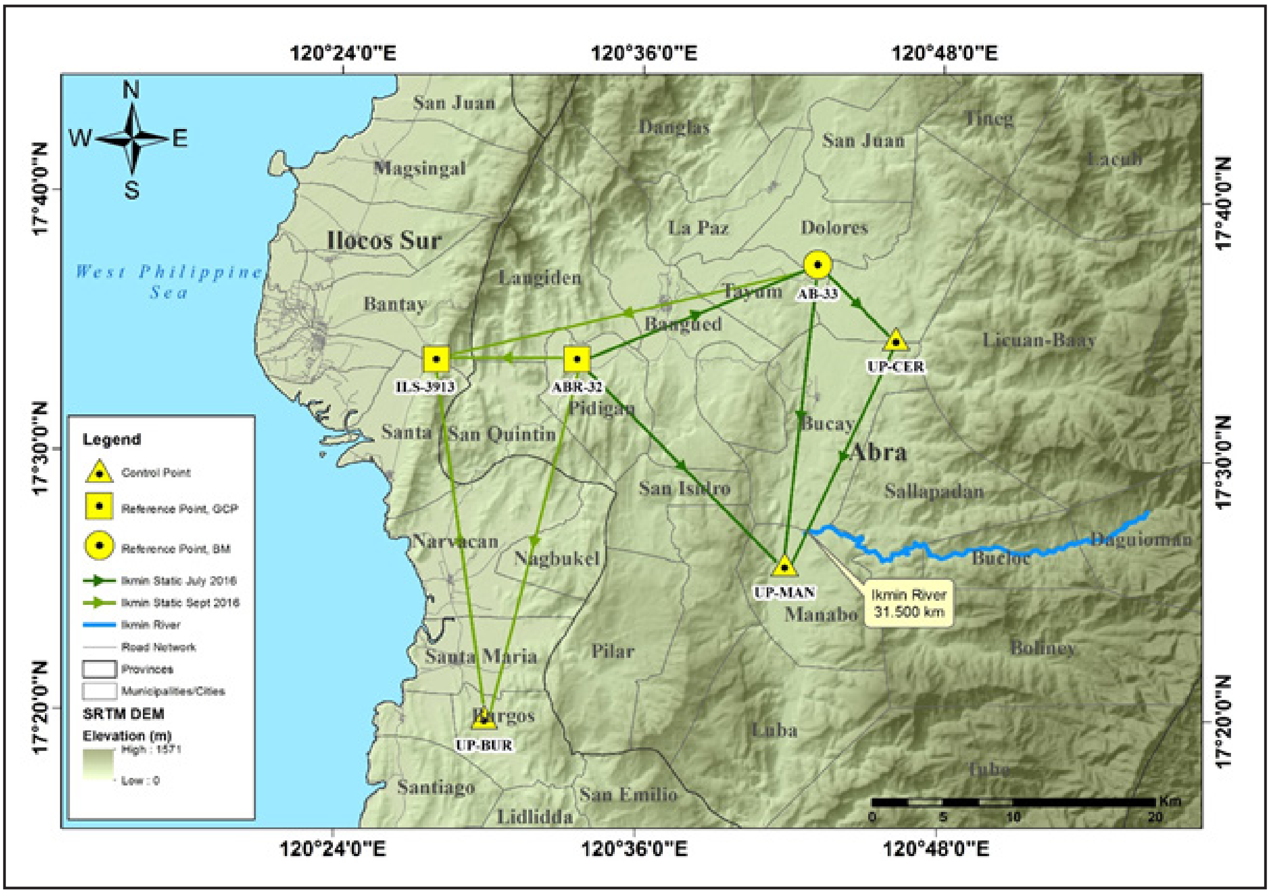


Figure 30. GNSS Network covering Ikmin River

Table 24. List of Reference and Control Points occupied for Ikmin River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
Control Survey on September 24 and 25, 2016						
ABR-32	2nd order GCP	17°33'43.22900"	120°33'29.72282"	71.266	33.435	03-04-14
AB-33	1st order BM	17°37'28.81124"	120°43'02.46322"	103.212	64.162	07-16-16
ILS-3913	Used as marker	-	-	-	-	09-25-16
UP-BUR	UP Established	-	-	53.174	14.873	09-25-16
Control Survey on July 16, 2016						
ABR-32	2nd order, GCP	17d33'43.22900"	120d33'29.72282"	71.266	33.435	03-04-14
AB-33	1st order, BM	17d37'28.81122"	120d43'02.46323"	103.212	64.162	07-16-16
UP-CER	UP Established	-	-	-	-	07-16-16
UP-MAN	UP Established	-	-	-	-	07-16-16

The GNSS set-ups on recovered reference points and established control points in Ikmin River are shown in Figure 31 to Figure 36.

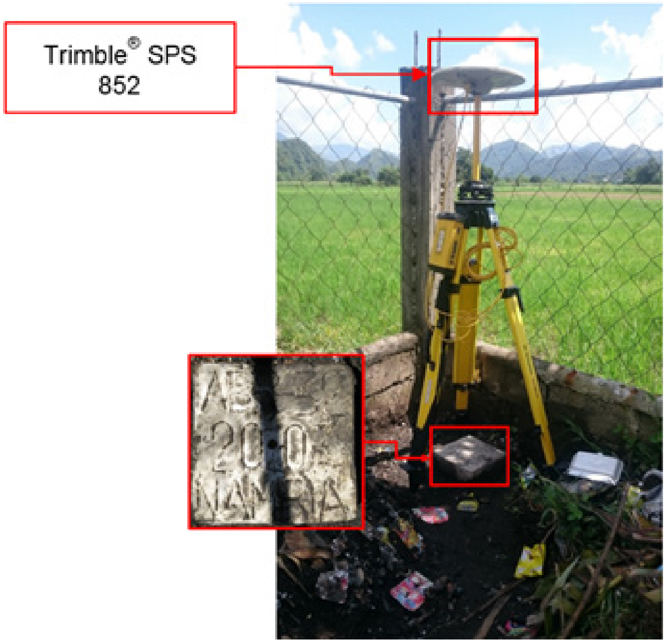


Figure 31. GNSS base set up, Trimble® SPS 852, at ABR-32, located behind basketball court in Brgy. Lagben, Municipality of Lagangilang, Abra

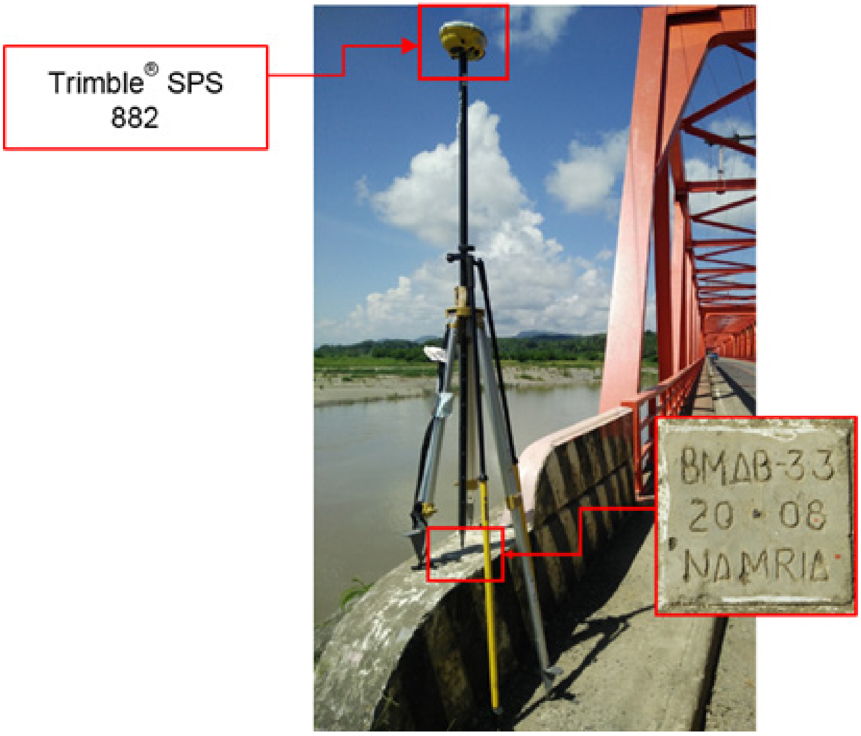


Figure 32. GNSS receiver setup, Trimble® SPS 882, atAB-33, located at the approach ofDon Mariano Marco Bridge, Brgy. Pamutic, Municipality of Pidigan, Abra

Figure 33. GNSS receiver setup, Trimble® SPS 882, at ILS-3913, located at the approach of BanganBridge in Brgy. Bangan, Municipality of Sanchez Mira, Cagayan

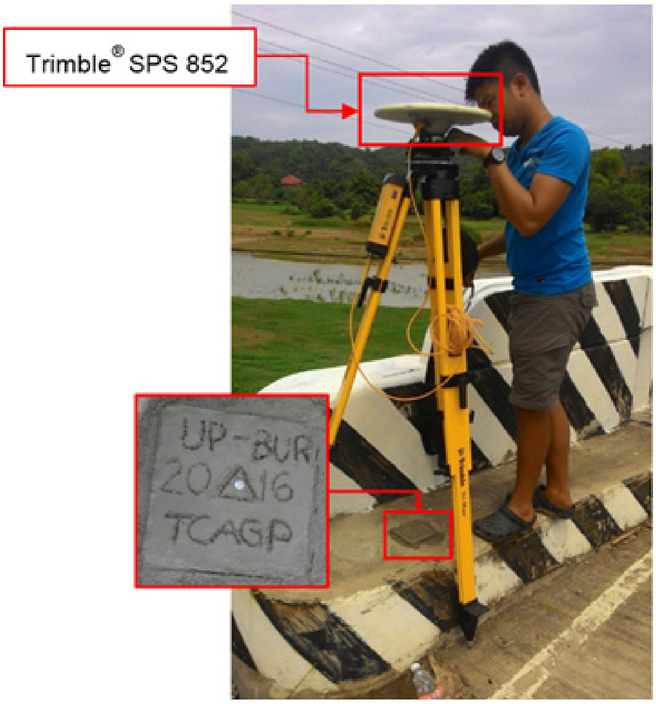


Figure 34. GNSS receiver setup, Trimble® SPS 852, at UP-BUR, located at the approach of Cabicungan Bridge in Brgy. Dibalio, Municipality of Claveria, Cagayan

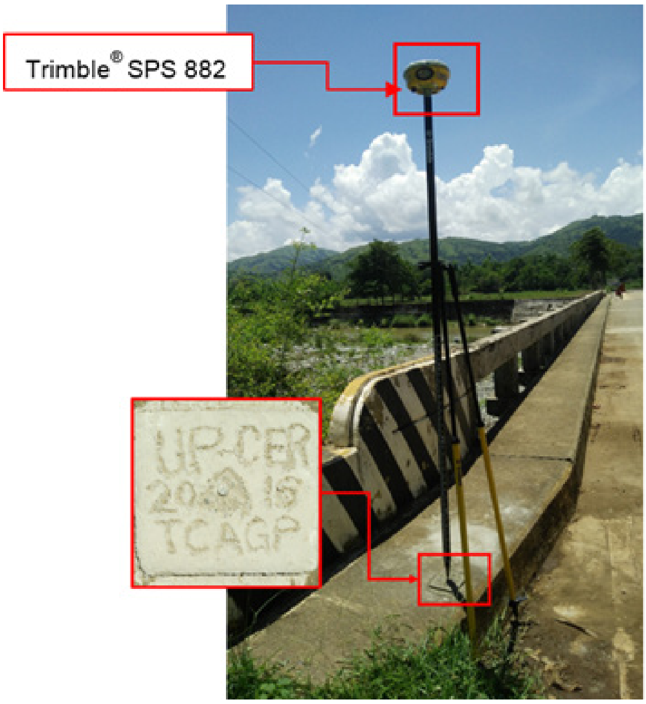


Figure 35. GNSS receiver setup, Trimble® SPS 882, at UP-CER, located at the approach of Cervantes Bridge, in Brgy. San Isidro, Municipality of Lagangilang,Abra

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

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in IkminRiver Basin is summarized in Table 25 generated by TBC software.

Table 25. Baseline Processing Summary Report for IkminRiver Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
Control Survey on September 24 and 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
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

As shown Table 25 a total of five (5) baselines were processed on July survey with reference points ABR-32 and AB-33 held fixed for coordinate and elevation values respectively; and another five (5) baselines on September with reference points ABR-32 and AB-33 held fixed for coordinate and elevation values along with UP-BUR elevation value. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates (Table 27) of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 26 to Table 29 for complete details.

The four (4) control points, ABR-32, AB-33,UP-CER and UP-MANwere occupied and observed simultaneously to form a GNSS loop on July survey; and ABR-32, AB-33, ILS03913, and UP-BUR were occupied on September survey. Coordinates of ABR-32 and and elevation values of AB-33 were held fixed on the first survey; and their coordinates and elevation along with elevation value of UP-BUR were held fixed during the processing of the control points as presented in Table 26.Through these reference points, the coordinates and elevation of the unknown control points were 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)
September 24 and 25,2016					
AB-33	Grid	Fixed	Fixed		Fixed
ABR-32	Global	Fixed	Fixed	Fixed	
UP-BUR	Grid				Fixed
July 16, 2016					
ABR-32	Grid				Fixed
AB-33	Local	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 27. The fixed control points have no values for grid and elevation errors.

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

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
September 24 and 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
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	

With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10\ cm$ for the vertical; the computation for the 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 24 and 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 occupied control points are within the required precision.

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

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
September 24 and 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"	103.211	?	ENe
ILS-3913	N17°33'39.23389"	E120°27'53.49752"	64.254	0.071	
UP-BUR	N17°19'52.12416"	E120°29'57.91885	53.173	?	e
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	

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

The summary of reference and control points used is indicated in Table 29.

Table 29. List of reference and control points used and its location (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 September 24 and 25, 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°37'28.81124"	120°43'02.46322"	103.212	1950122.643	257794.046	64.162
ILS-3913	Used as marker	17°33'39.23389"	120°27'53.49752"	64.255	1943403.247	230894.785	27.338
UP-BUR	UP Established	17°19'52.12416"	120°29'57.91885"	53.174	1917917.030	234232.366	14.873
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

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

Cross-section andas-built surveyswere conducted on July 17 and 20, 2016 at the downstream sidesof Cervantes, Manabo,Manicbel and New Ikminbridges as shown in Figure 37, Figure 38, Figure 39, and Figure 40. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey as shown in Figure 37 to Figure 40, respectively.

Figure 37. Cervantes Bridge facing downstream

Figure 38. Manabo Bridge facing downstream

Figure 39. Manicbel Bridge facing downstream

Figure 40. New Ikmin Bridge facing downstream

Figure 41. As-Built Survey of Cervantes Bridge

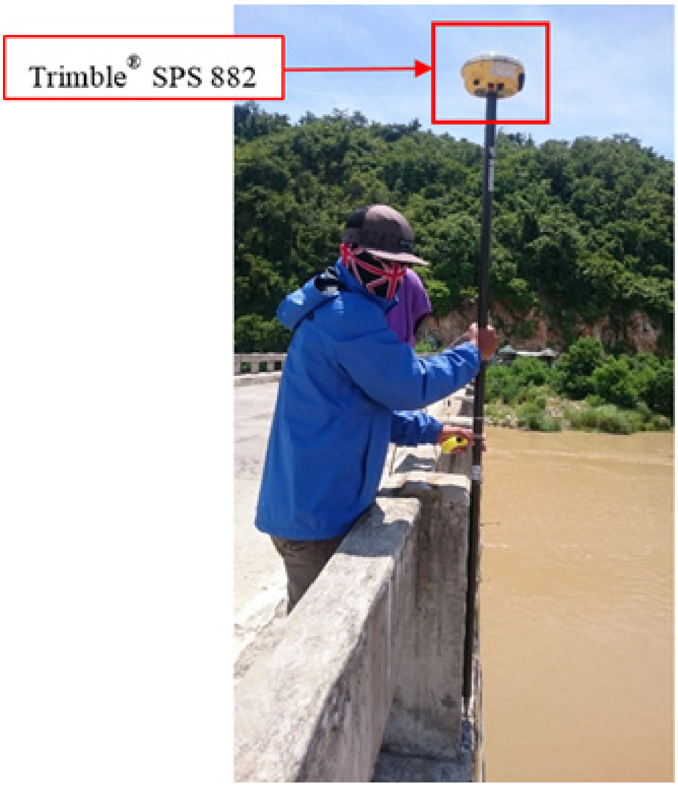


Figure 42. As-Built Survey of Manabo Bridge

Figure 43. Cross-section Survey of Manicbel Bridge

Figure 44. Cross-section Survey of New Ikmin Bridge

The cross-sectional line of Cervantes Bridge is about 160m with 66 cross-sectional points using UP-CER as base station; Manabo Bridge about 760m with 751 cross-sectional points using UP-MAN as base station; Manicbel Bridge about 167 m with 16 cross-sectional points using UP-MAN as base station; and New Ikmin Bride about 171 m with 27 cross-sectional points also using UP-MAN as GNSS base station. The cross-section diagrams and their location maps are shown in Figure 45 to Figure 52 and the bridge data forms are shown in Figure 53 to Figure 56.

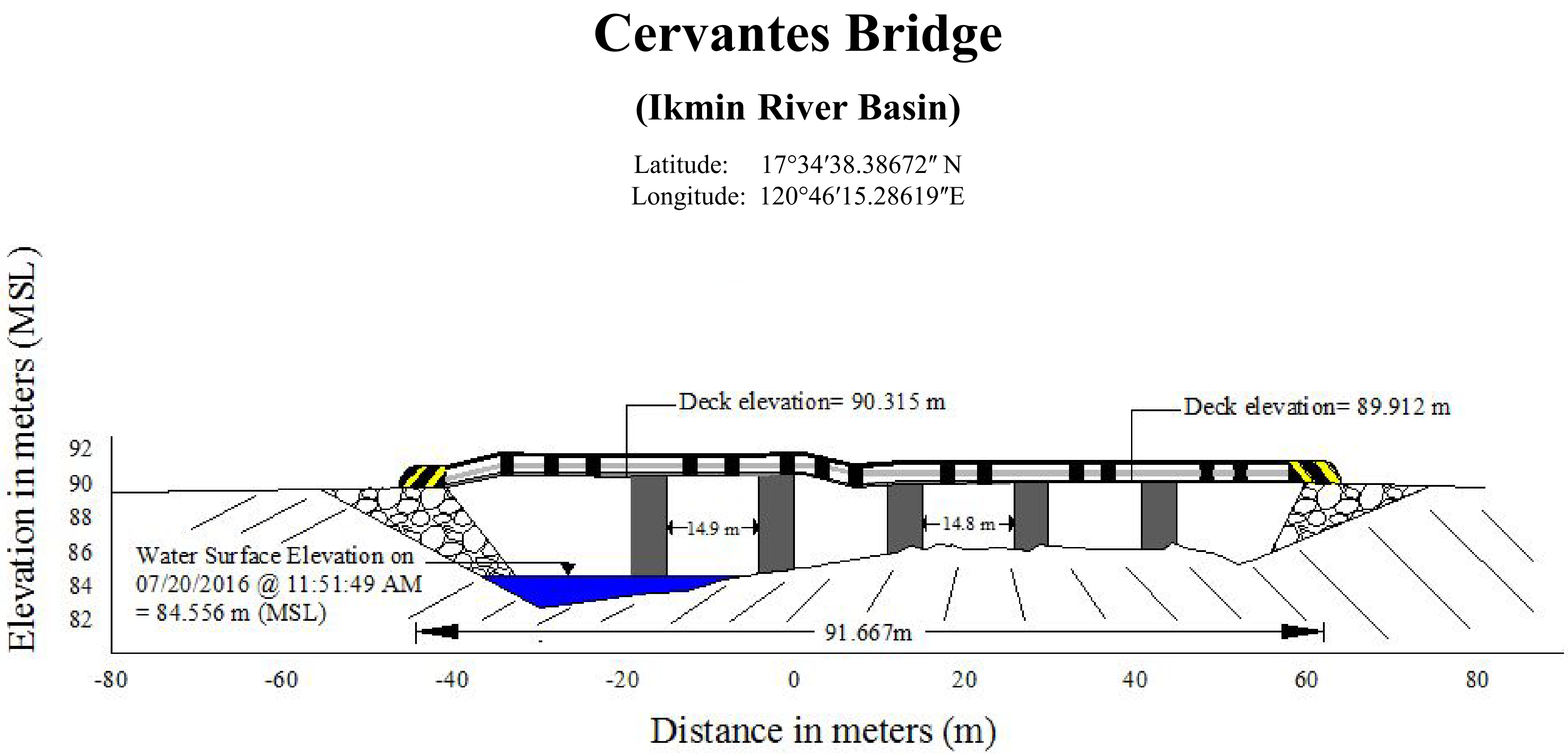


Figure 45. Cervantes Bridge cross-section diagram

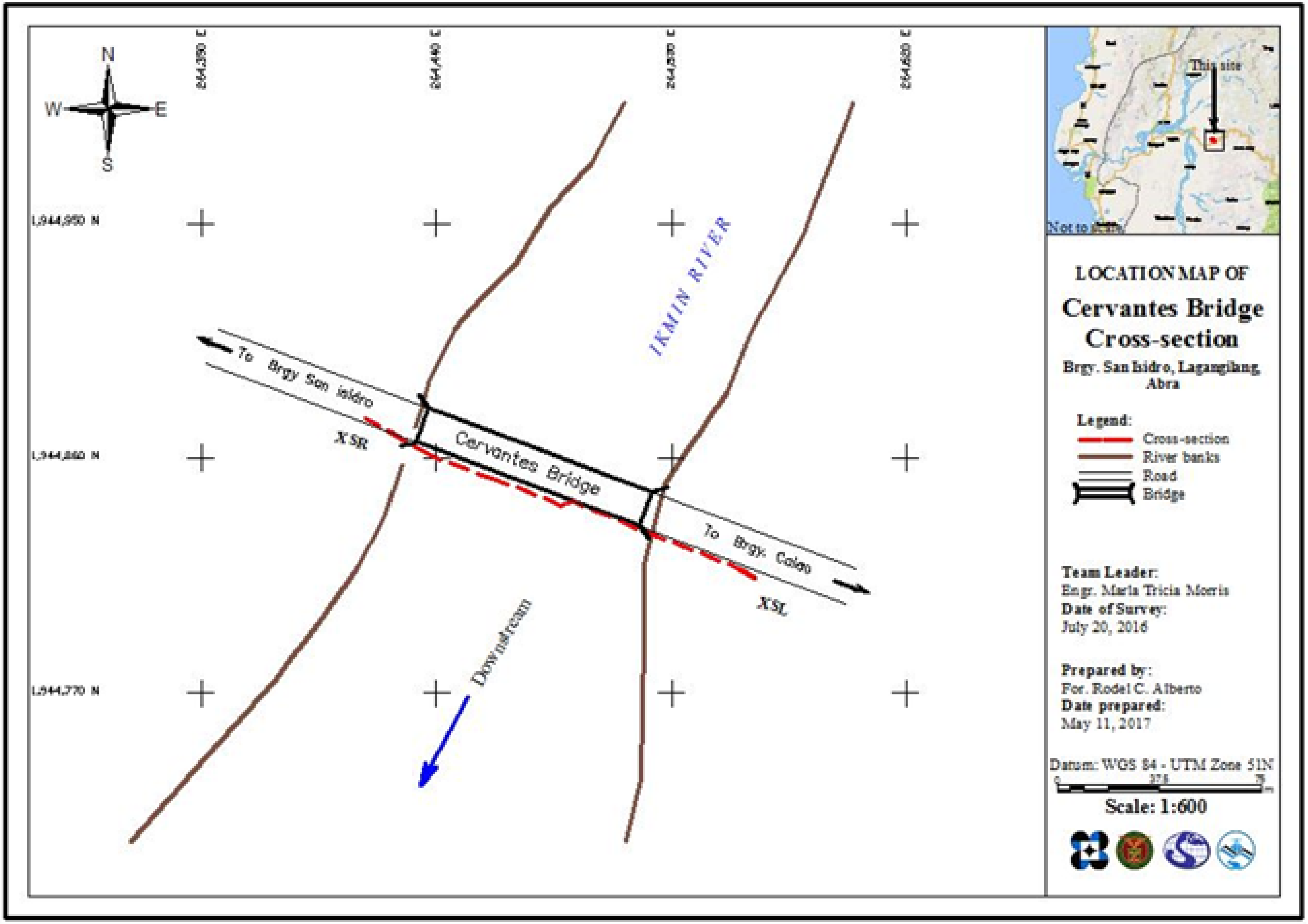


Figure 46. Cervantes bridge cross-section location map

Manabo Bridge

(Ikmin River Basin)

Latitude: 17°26′02.33679″ N
Longitude: 120°41′29.05434″E

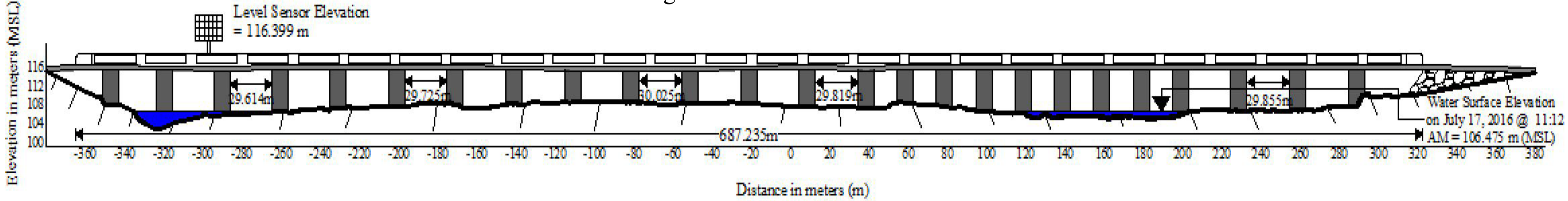


Figure 47. Manabo Bridge cross-section diagram

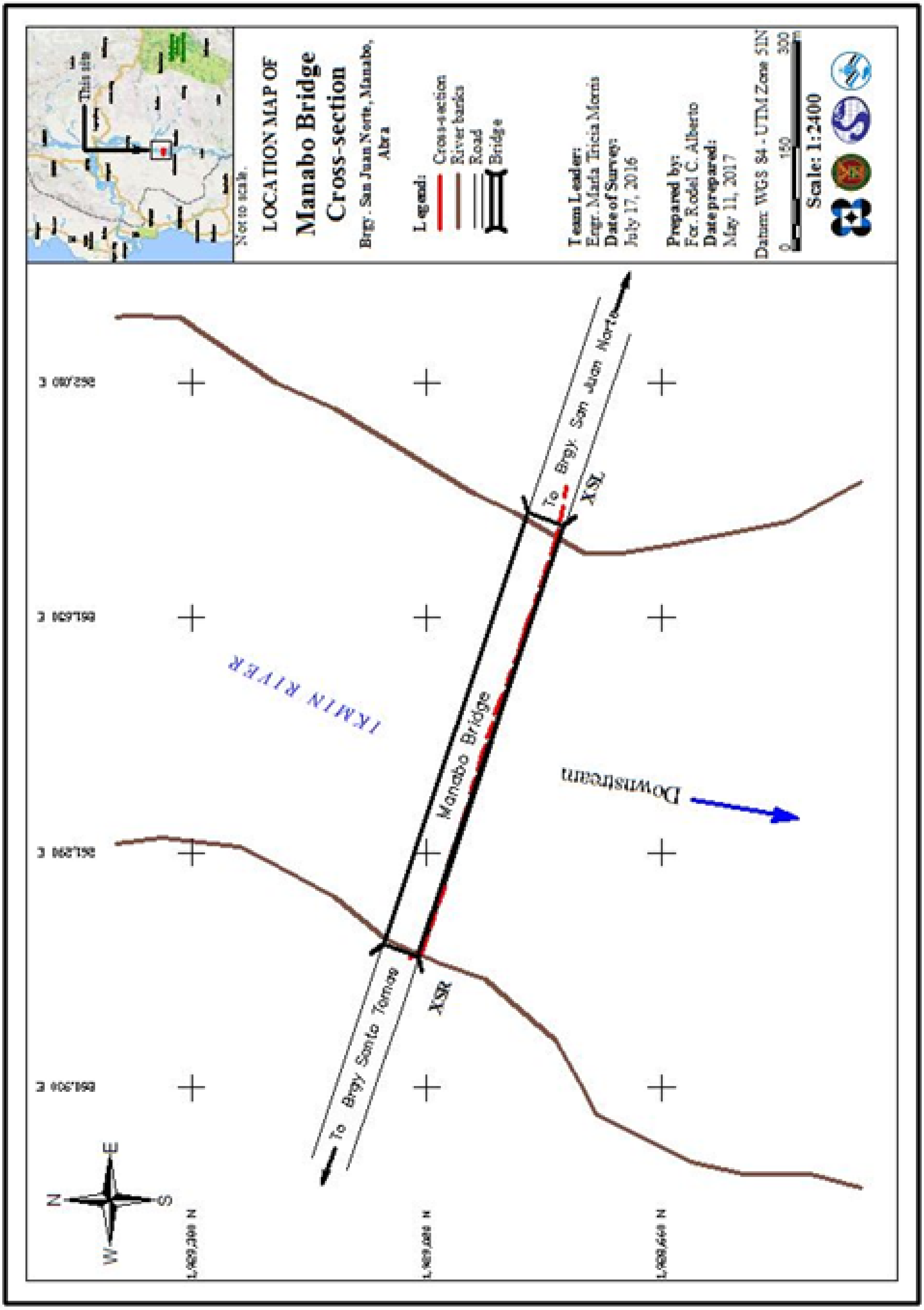


Figure 48. Manabo bridge cross-section location map

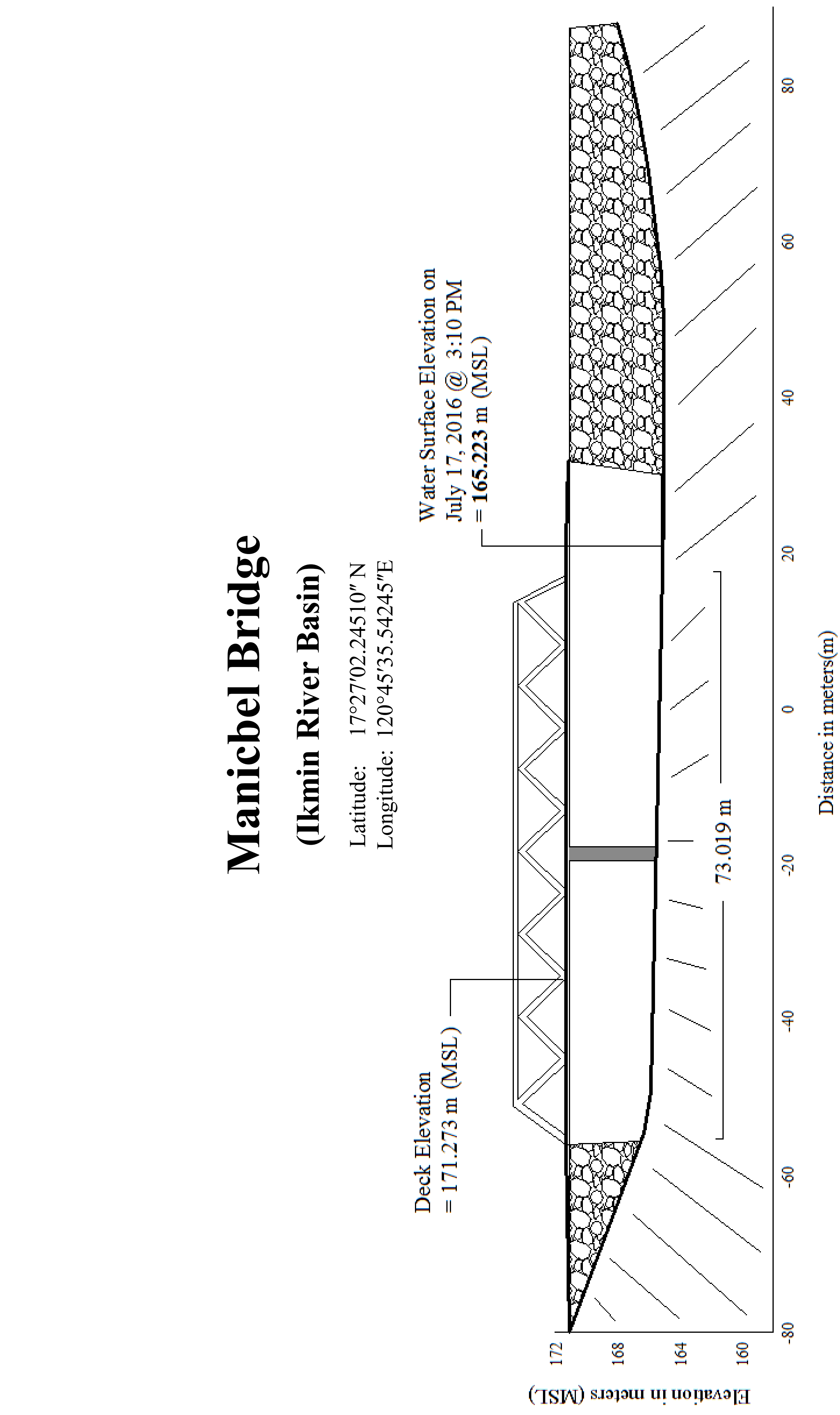


Figure 49. Manicbel Bridge cross-section diagram

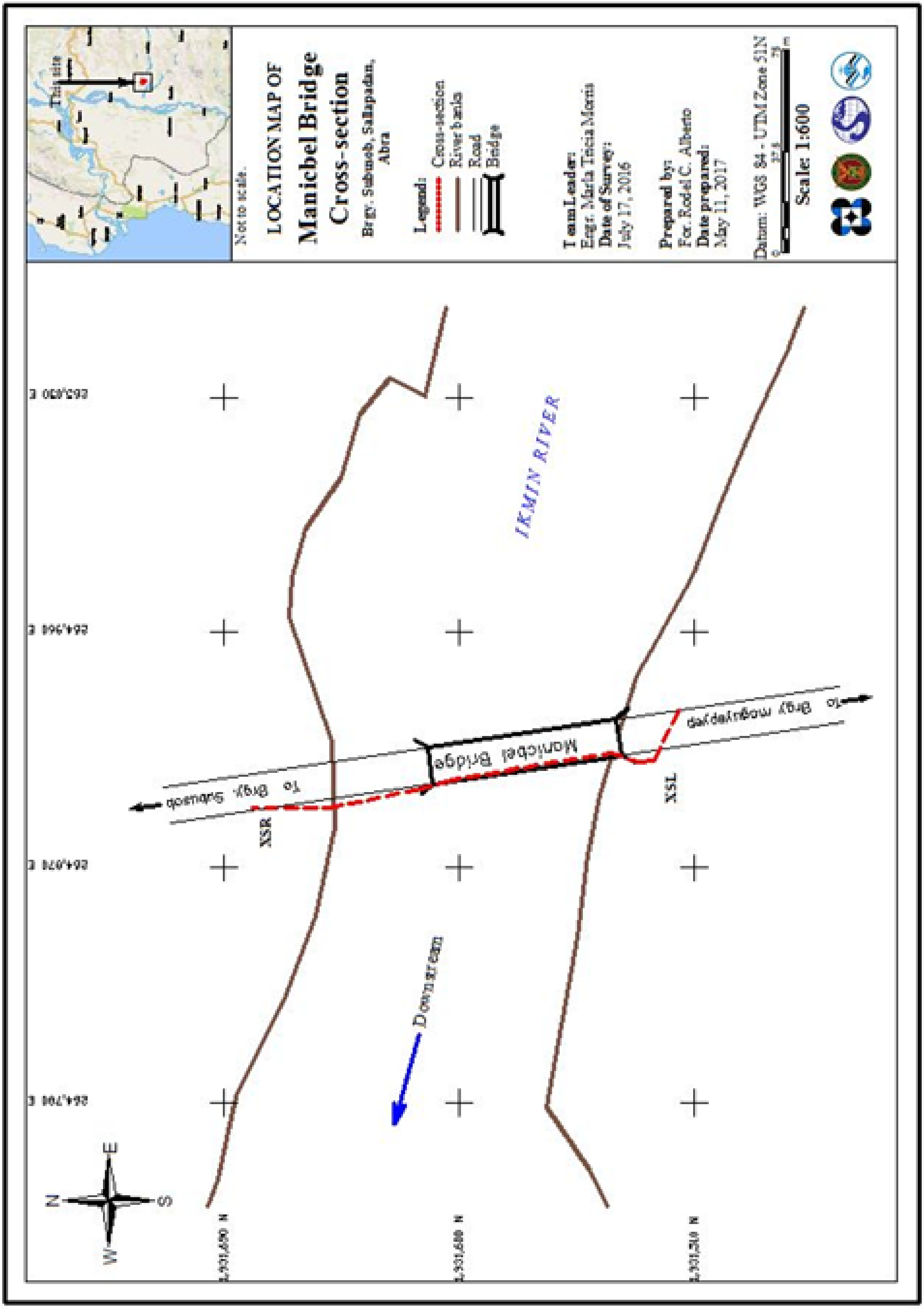


Figure 50. Manicbel bridge cross-section location map

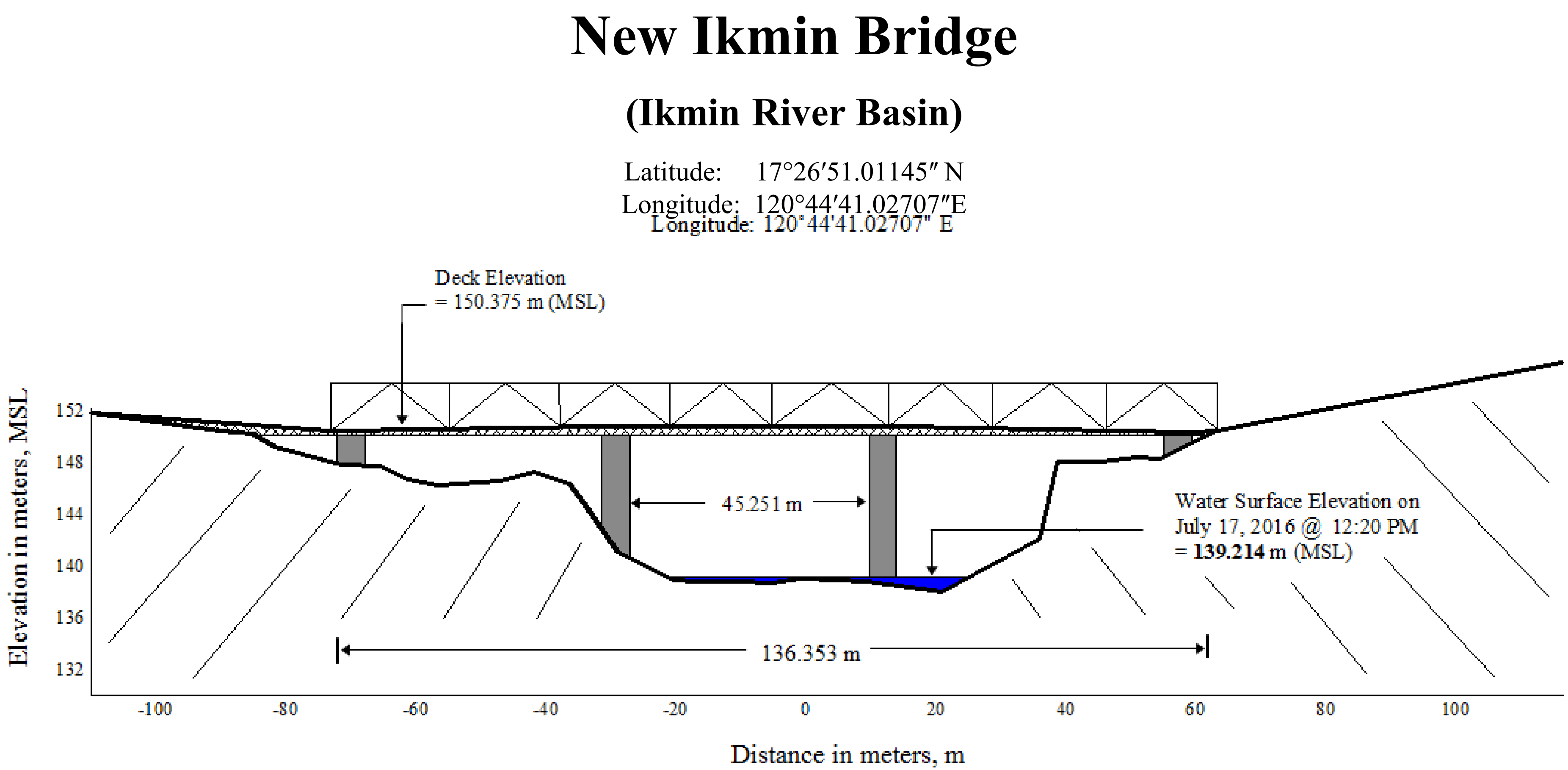


Figure 51. New Ikmin Bridge cross-section diagram

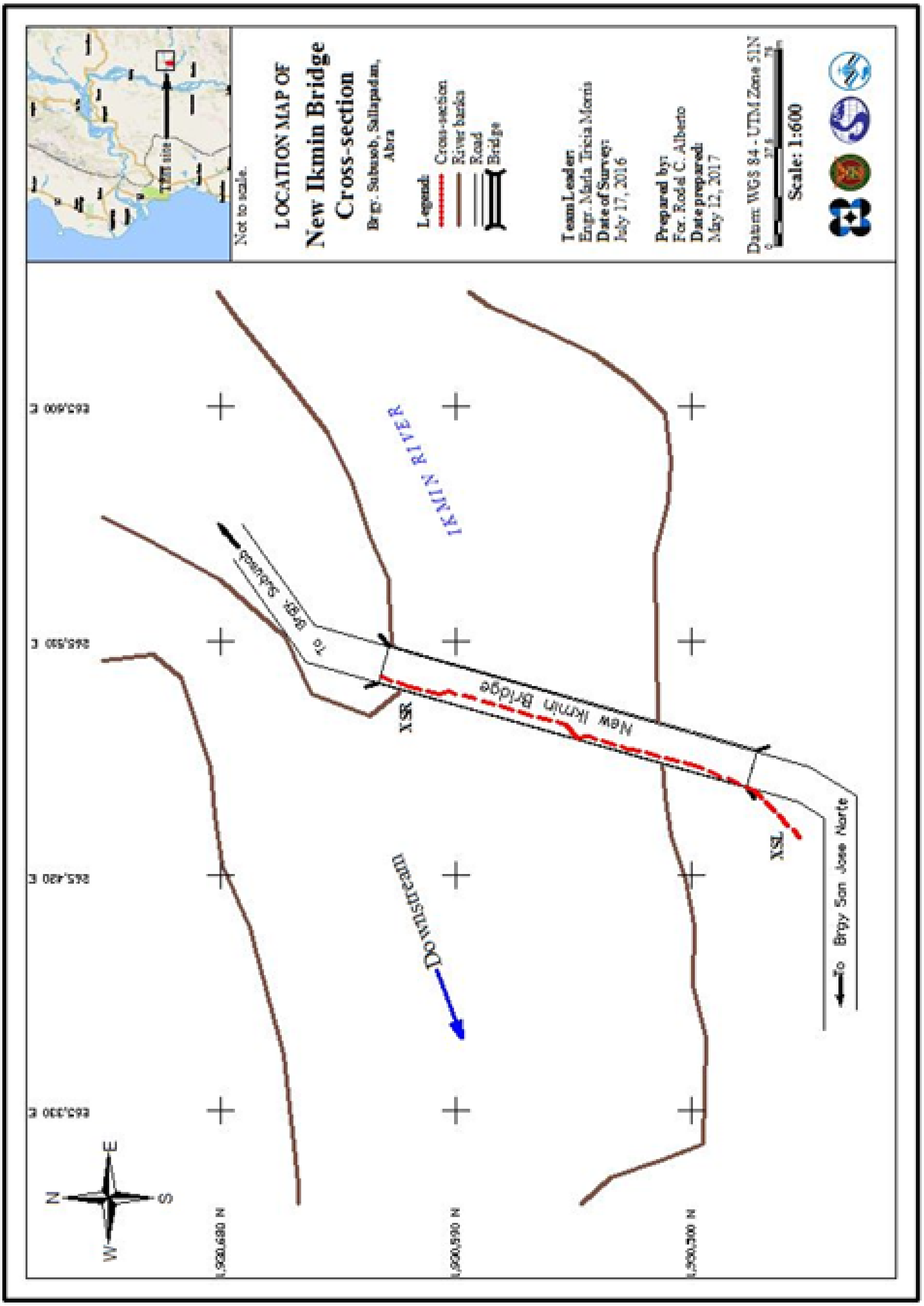


Figure 52. New Ikmin bridge cross-section location map

Bridge Data Form

Bridge Name: Cervantes Bridge | Date: July 20, 2016

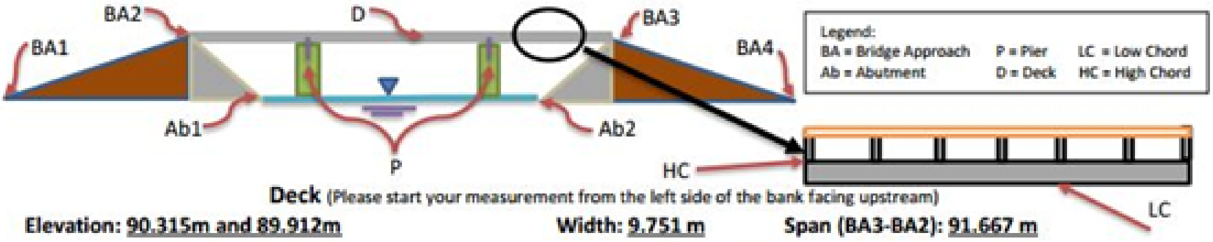
River Name: Ikmin River | Time: 11:51 AM

Location (Brgy, City,Region): Brgy. San Isidro, Municipality of Lagangilang, Abra

Survey Team: Marla Morris, Cibyl Atacador, Randell Pabroquez

Flow condition: normal | Weather Condition: fair

Latitude: 17°34'38.38672" N | Longitude: 120°46'15.28619" E



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

Elevation: 90.315m and 89.912m | Width: 9.751 m | Span (BA3-BA2): 91.667 m

	Station	High Chord Elevation	Low Chord Elevation
1	N/A	N/A	N/A

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	89.363 m	BA3	139.751 m	89.937m m
BA2	48.084m	89.868 m	BA4	160.722 m	89.672 m

Abutment: Is the abutment sloping? **Yes**; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	47.078m	89.751m
Ab2	135.695m	85.833m

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

Shape: cylinder Number of Piers: 5 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	62.908m	88.893m	N/A
Pier 2	77.820m	89.930m	N/A
Pier 3	92.928m	89.911m	N/A
Pier 4	107.743m	89.925m	N/A
Pier 5	122.708m	89.932m	N/A

Figure 53. Bridge as-built form of Cervantes Bridge

Bridge Data Form

Bridge Name: **Manabo Bridge** | **Date:** **July 17, 2016**

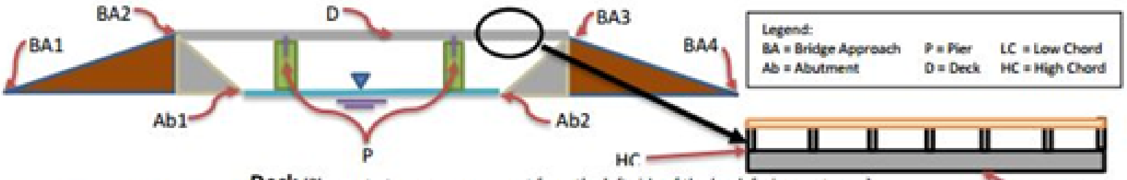
River Name: **Ikmin River** | **Time:** **11:11 AM**

Location (Brgy, City,Region): **Brgy. San Juan Norte, Municipality of Manabo, Abra**

Survey Team: **Marla Morris, Cibyl Atacador, Randell Pabroquez**

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

Latitude: **17°26'02.33679" N** | **Longitude:** **120°41'29.05434" E**



LC

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

Elevation: **114.843 m** **Width:** **9.751 m** **Span (BA3-BA2):** **687.235 m**

	Station	High Chord Elevation	Low Chord Elevation
1	314.795m	115.108	114.857

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	114.843 m	BA3	702.480 m	115.273 m
BA2	15.245m	115.191 m	BA4	760.234 m	114.691 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)

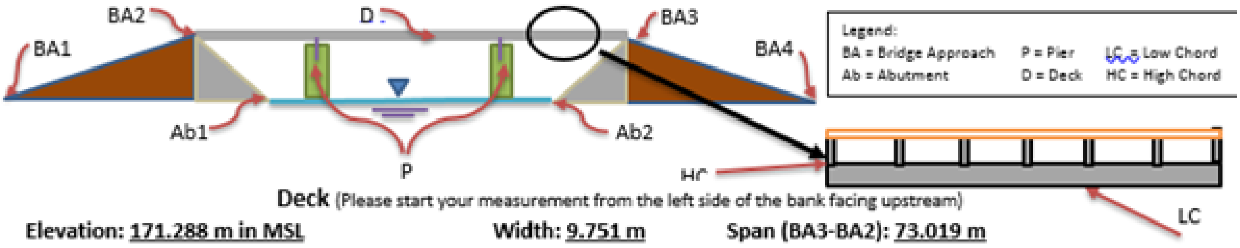
Shape: rectangular Number of Piers: 25 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	32.545m	115.189m	N/A
Pier 2	60.260m	115.160m	N/A
Pier 3	89.610m	115.122m	N/A
Pier 4	119.224m	115.180m	N/A
Pier 5	148.697m	115.195m	N/A
Pier 6	178.956m	115.186m	N/A
Pier 7	208.682m	115.187m	N/A
Pier 8	238.575m	115.166m	N/A

Figure 54. Bridge as-built form of Manabo Bridge

Bridge Data Form

Bridge Name: Manicbel Bridge	Date: July 17, 2016
River Name: Ikmin River	Time: 3:10 PM
Location (Brgy, City,Region): Brgy. Subusob, Municipality of Sallapadan, Abra	
Survey Team: Marla Morris, Cibyl Atacador, Randell Pabroquez	
Flow condition: normal	Weather Condition: fair
Latitude: 17°27'25.47289" N	Longitude: 120°45'35.7888" E



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

Elevation: 171.288 m in MSL Width: 9.751 m Span (BA3-BA2): 73.019 m

	Station	High Chord Elevation	Low Chord Elevation
1	N/A	N/A	N/A

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	171.090 m	BA3	97.121 m	171.332 m
BA2	24.102 m	171.273 m	BA4	111.684 m	171.167 m

Abutment: Is the abutment sloping? **Yes**; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	NA	NA
Ab2	NA	NA

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

Shape: cylinder Number of Piers: 5 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	60.506 m	171.288 m	0.6 m

Figure 55. Bridge as-built form of Manicbel Bridge

Bridge Data Form

Bridge Name: New Ikmin Bridge **Date:** July 17, 2016

River Name: Ikmin River **Time:** 12:20 PM

Location (Brgy, City,Region): Brgy. Subusob, Municipality of Sallapadan, Abra

Survey Team: Marla Morris, Cibyl Atacador, Randell Pabroquez

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

Latitude: 17°26'50.44708" N **Longitude:** 120°44'39.92773" E

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

Elevation: 150.375 m in MSL **Width:** 8.754 m **Span (BA3-BA2):** 136.353 m

	Station	High Chord Elevation	Low Chord Elevation
1	N/A	N/A	N/A

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	151.739 m	BA3	173.152 m	150.333 m
BA2	3.799 m	150.375 m	BA4	22.328 m	155.542 m

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

	Station (Distance from BA1)	Elevation
Ab1	NA	NA
Ab2	NA	NA

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

Shape: cylinder Number of Piers: 5 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	37.784 m	150.331 m	0.74 m
Pier 2	78.635 m	150.659 m	0.74 m
Pier 3	123.886 m	150.707 m	0.74 m
Pier 4	169.274 m	150.257 m	0.74 m

Figure 56. Bridge as-built form of New Ikmin Bridge

Water surface elevation of Ikmin River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on July 17 for Manabo, Manicbel and New Ikmin Bridges with values 106.475 m, 165.223 m, and 139.214 m, respectively; and on July 20, 2016 for Cervantes Bridge with a value of 84.55 m in MSL as shown in Figure 57 to Figure 60. This was translated into marking on the bridge's deck using the same technique as shown in Figure 57 to Figure 60 and these served as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Ikmin River, the University of the Philippines Baguio.

Figure 57. Water-level markings on Cervantes Bridge

Figure 58. Water-level markings on Manabo Bridge

Figure 59. Water-level markings on Manicbel Bridge

Figure 60. Water-level markings on New Ikmin Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on August 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 61. 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.

Figure 61. Validation points acquisition survey set up along Ikmin River Basin

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. A total of 7,213 points were gathered 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 62.

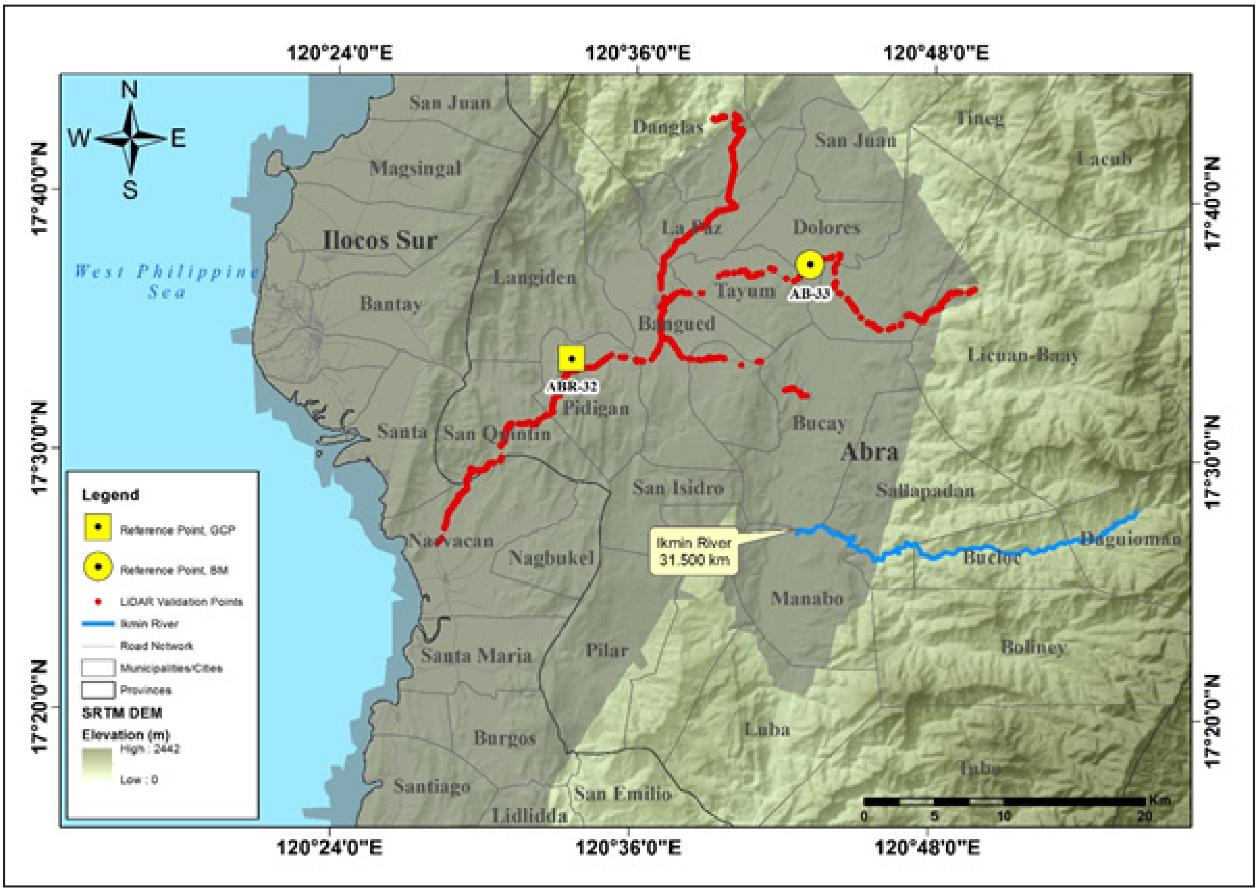


Figure 62. Validation point acquisition survey of Ikmin River Basin

4.7 River Bathymetric Survey

Bathymetric survey was not performed because of two reasons: a) DTM for the first 7km downstream of the river is already available because itwas dry during the time of acquisition of DAC. Hence, there is no need to conduct bathymetric survey since the riverbed is exposed; b) there are no communities along the riverside at the upstream areaas shown in the screenshot from DPPC in Figure 63.

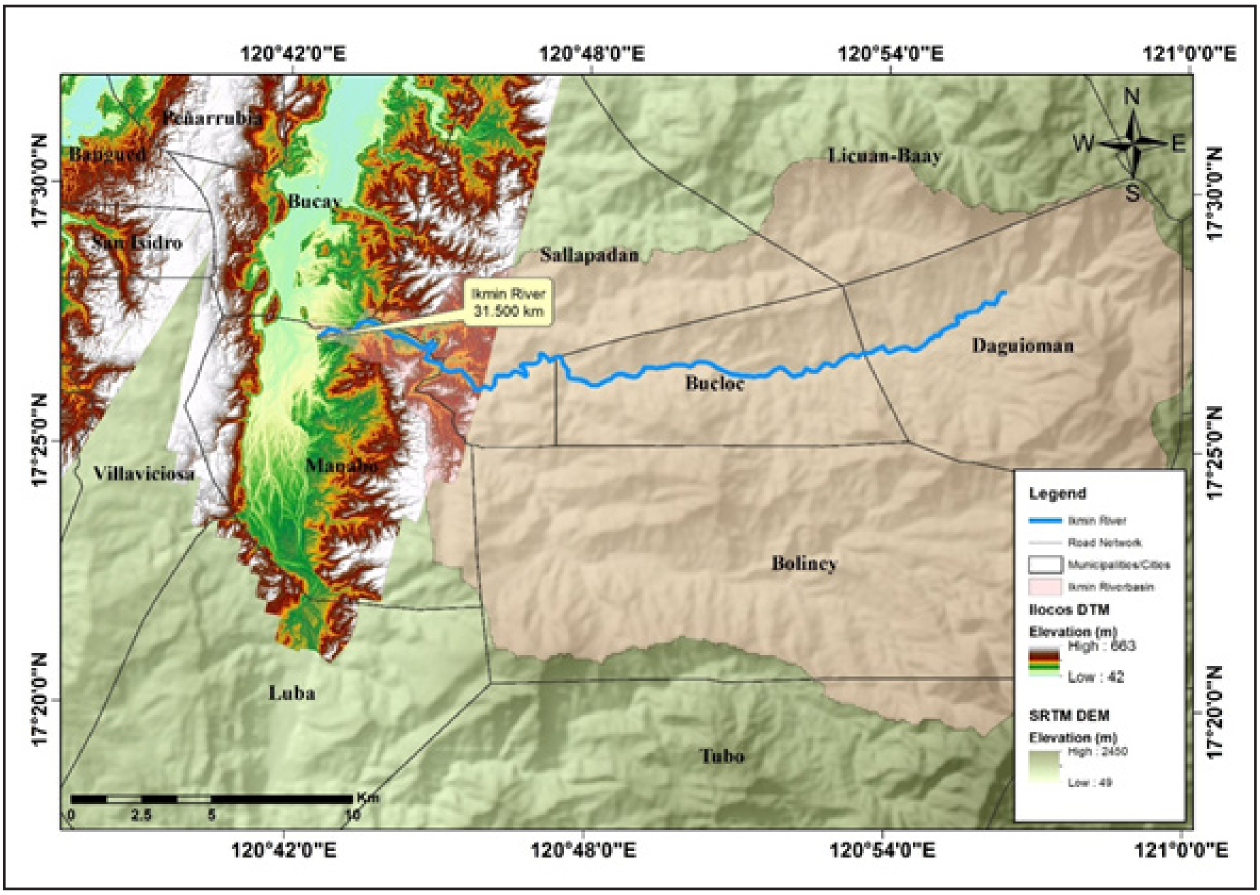


Figure 63. Digital Terrain Model of Ikmin River Basin

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from 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 Licuan-Baay ARG (17°34’16.53” N, 120°54’5.82” E), located in Licuan-Baay, Abra, as shown in Figure 1. The precipitation data collection started from July 23, 2016 at 12:00 PM to July 24, 2016 at 12:00 PM with a 15-minute recording interval.

The total precipitation for this event in Licuan-BaayARG was 0.762 mm. It has a peak rainfall of 0.508 mm. on July 23, 2016 at 4:30 PM. The lag time between the peak rainfall and discharge is 2 hours.

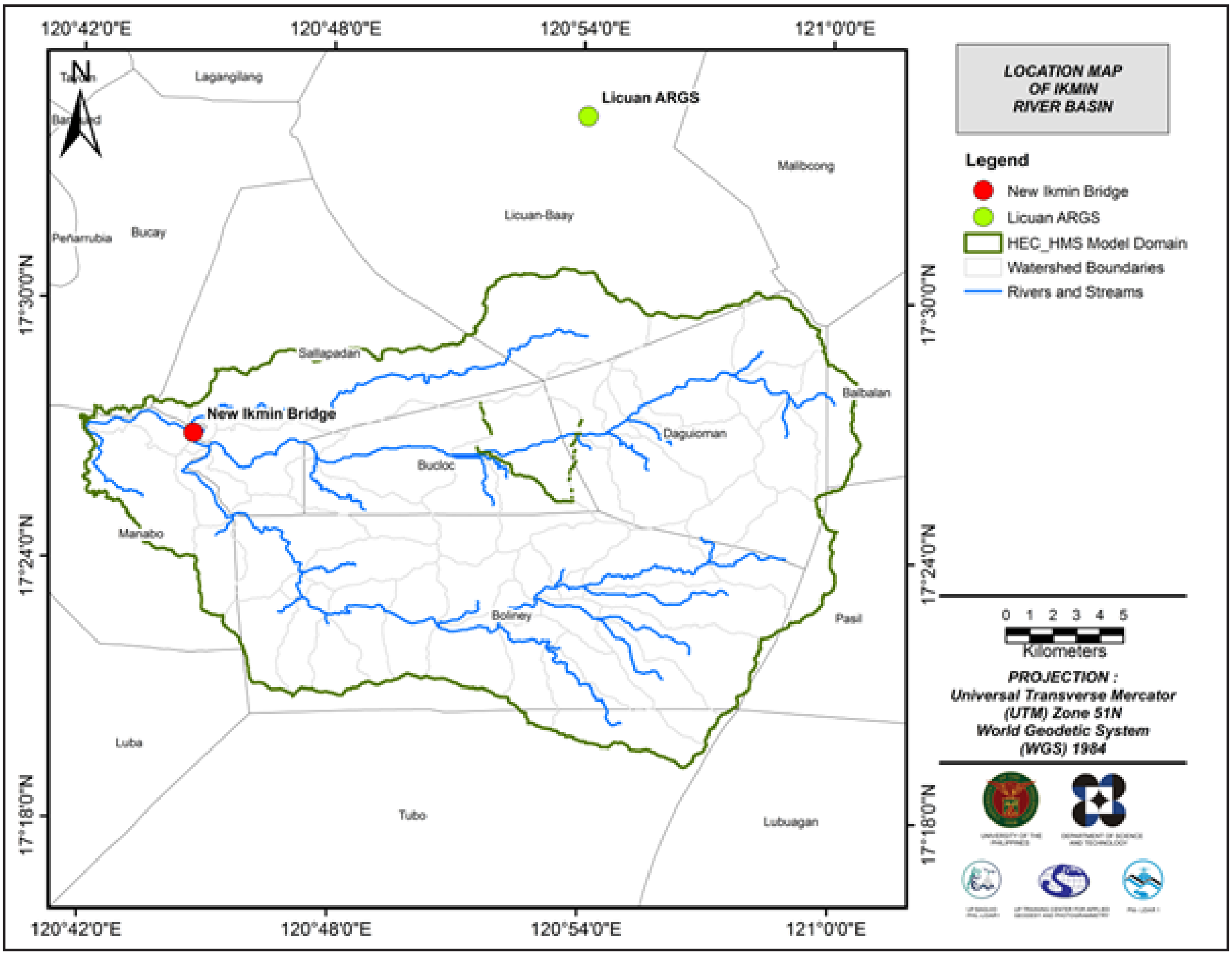


Figure 64. The location map of Ikmin HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Ikmin Bridge, Manabo, Abra (17°26’53.19” N, 120°44’41.51” E). It gives the relationship between the observed water level from the Ikmin Bridgeonsite water level measurements and outflow of the watershed at this location.

For Ikmin Bridge, the rating curve is expressed as Q = 4.0489E-23e0.3871xas shown in Figure 66.

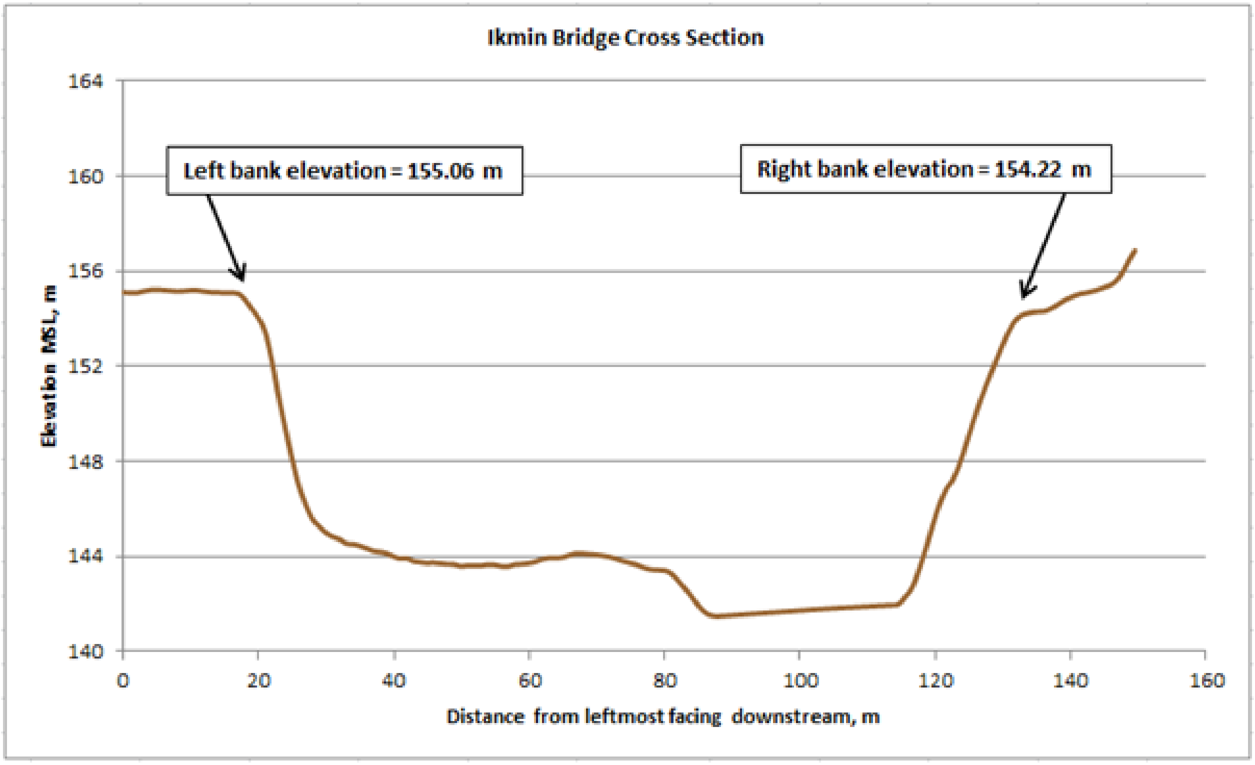


Figure 65. Cross-Section Plot of Ikmin Bridge

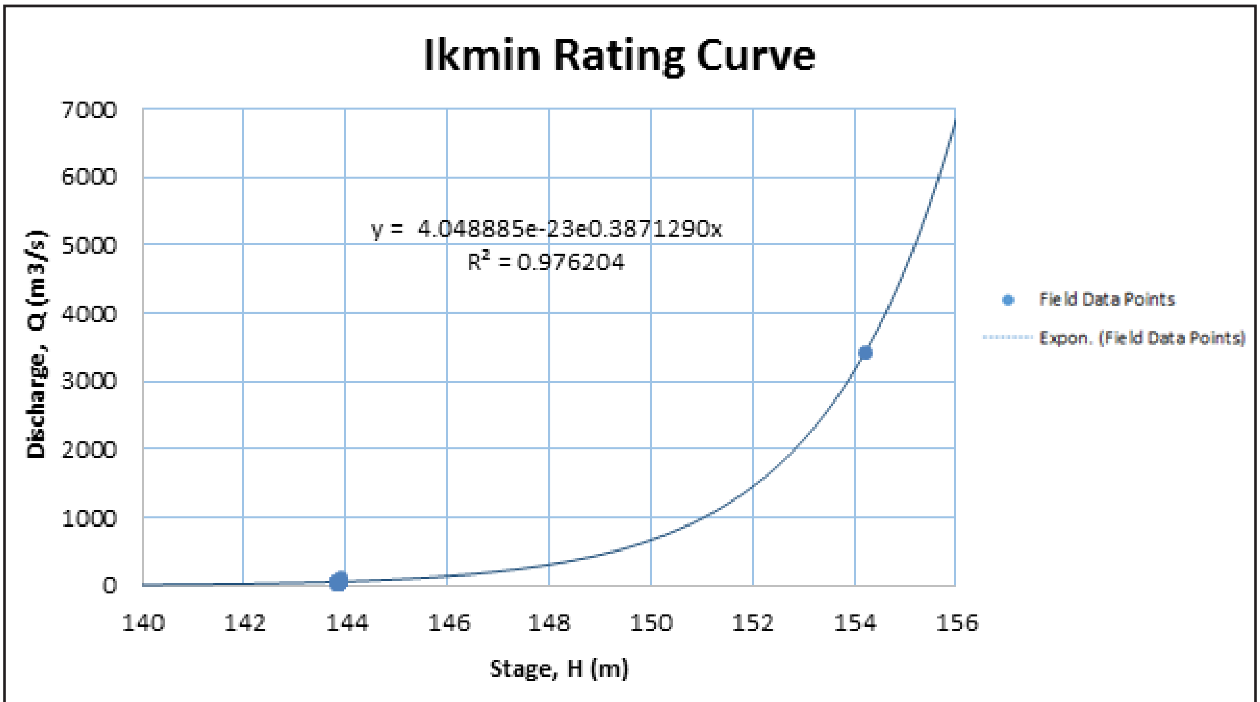


Figure 66. Rating Curve at Ikmin Bridge, Batac, Ilocos Norte

The rating curve equation was used to compute for the river outflow at IkminBridge for the calibration of the HEC-HMS model forIkmin, as shown in Figure 67. The total rainfall for this event is 0.762 mm and the peak discharge is 68.94 m3/s at 6:30 PM of July 23, 2016.

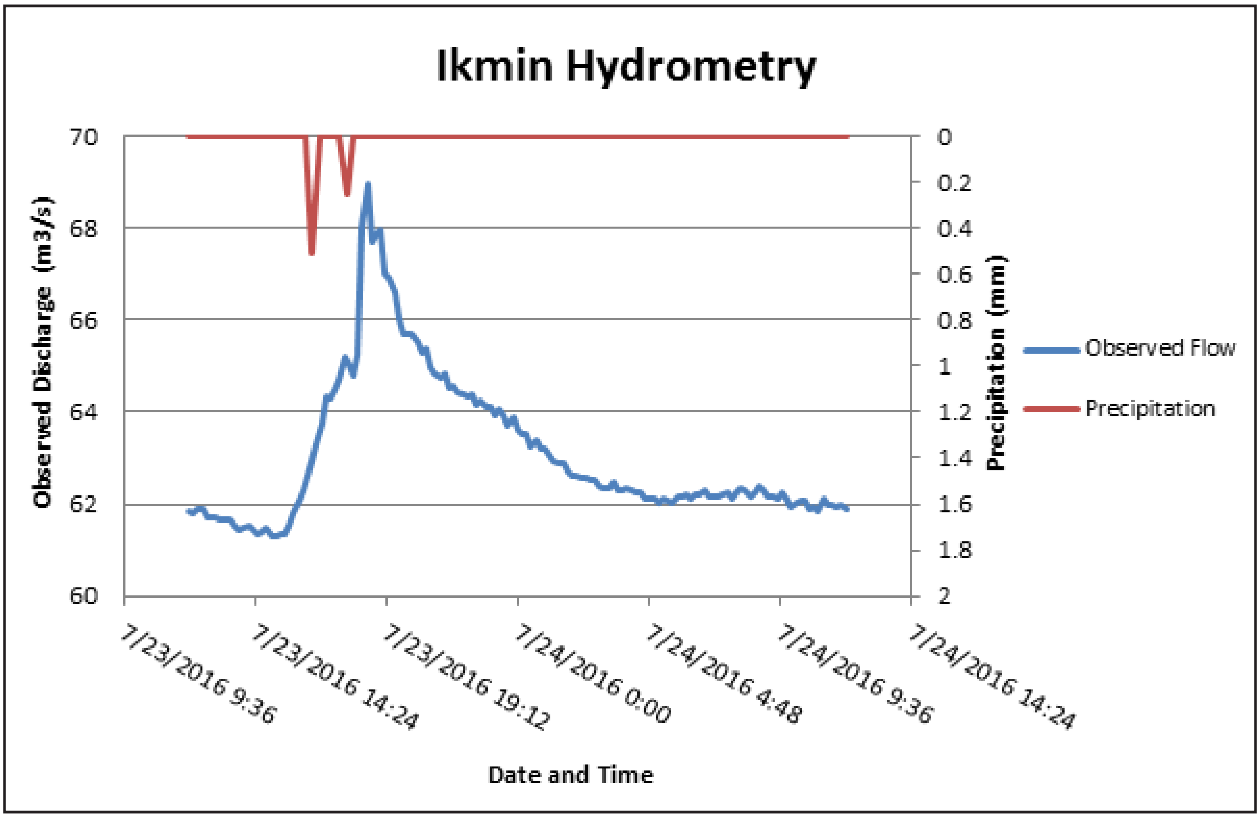


Figure 67. Rainfall and outflow data at Ikmin Bridge used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Laoag Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value would be attained at a certain time. This station was chosen based on its proximity to the Ikmin watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 30. RIDF values for Laoag Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	22.7	35.4	45.7	62.5	89	110.9	148.5	187.8	232.8
5	31.4	48	61.5	87.1	124.6	157.8	211.7	266.3	331.7
10	37.2	56.3	71.9	103.5	148.2	189	253.6	318.3	397.1
15	40.5	61	77.8	112.7	161.6	206.5	277.2	347.7	434
20	42.8	64.3	81.9	119.1	170.9	218.8	293.7	368.2	459.9
25	44.5	66.8	85.1	124.1	178.1	228.3	306.4	384.1	479.8
50	50	74.6	94.8	139.4	200.2	257.4	345.7	432.8	541.1
100	55.3	82.4	104.5	154.6	222.2	286.4	384.6	481.2	602

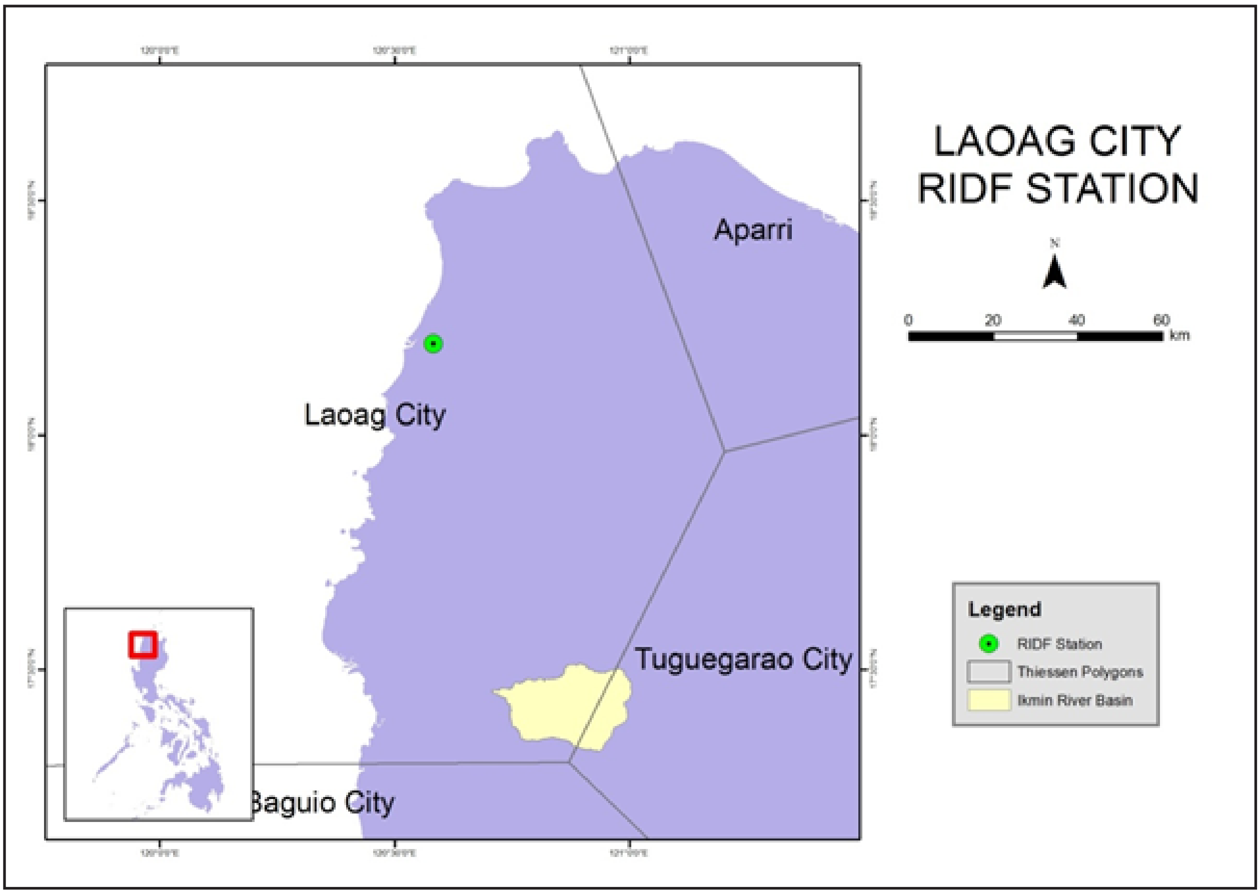


Figure 68. Location of Laoag RIDF Station relative to Ikmin River Basin

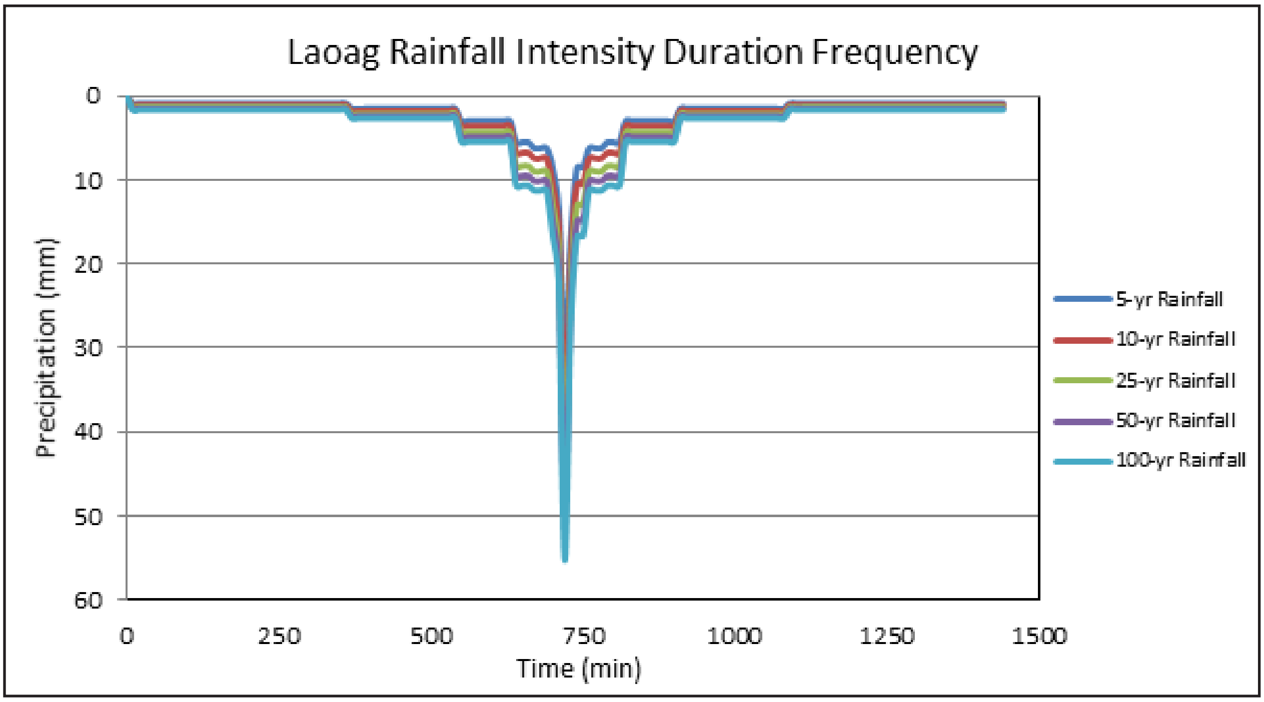


Figure 69. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Ikmin River Basin are shown in Figure 70 and Figure 71, respectively.

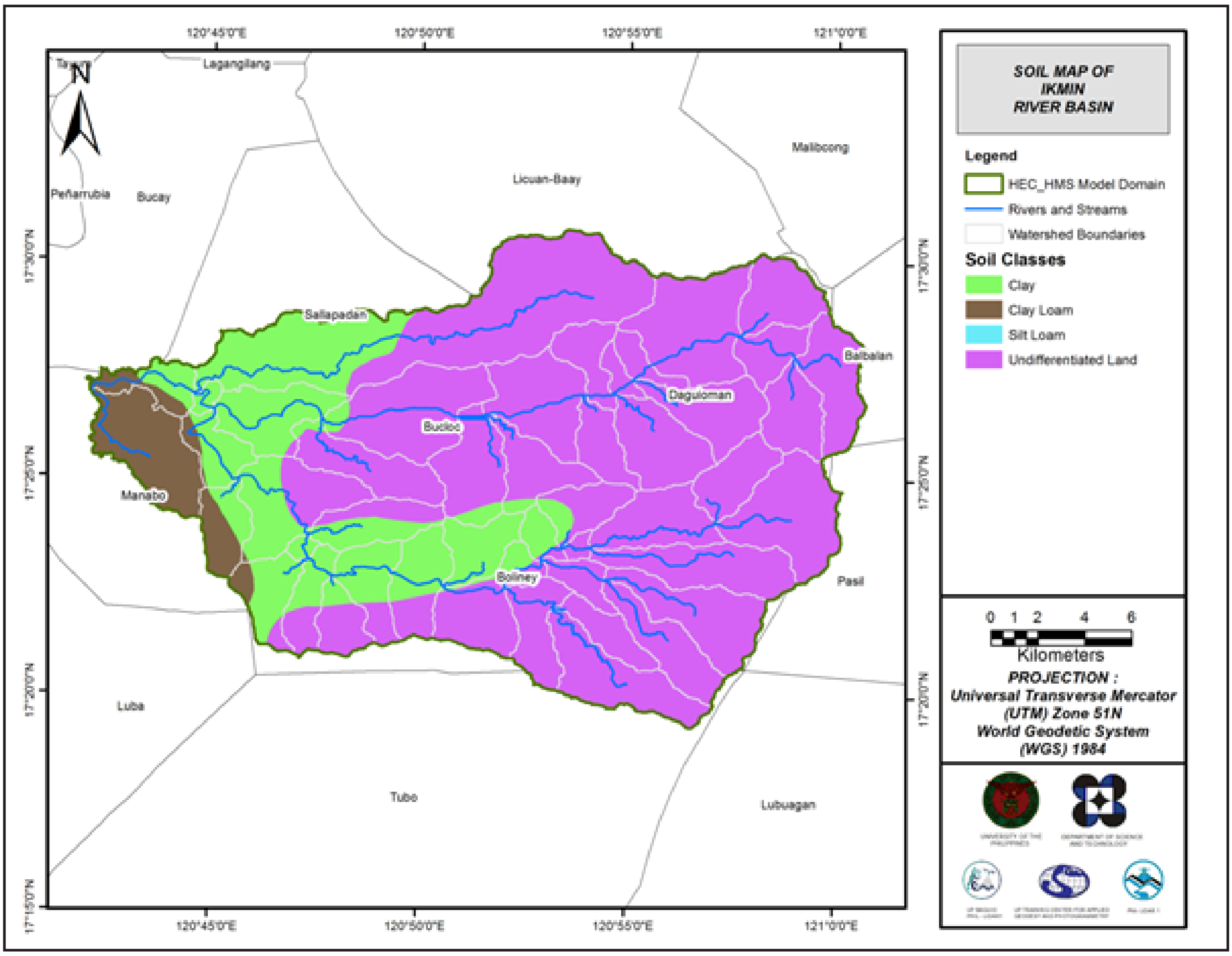


Figure 70. Soil Map of Ikmin River Basin

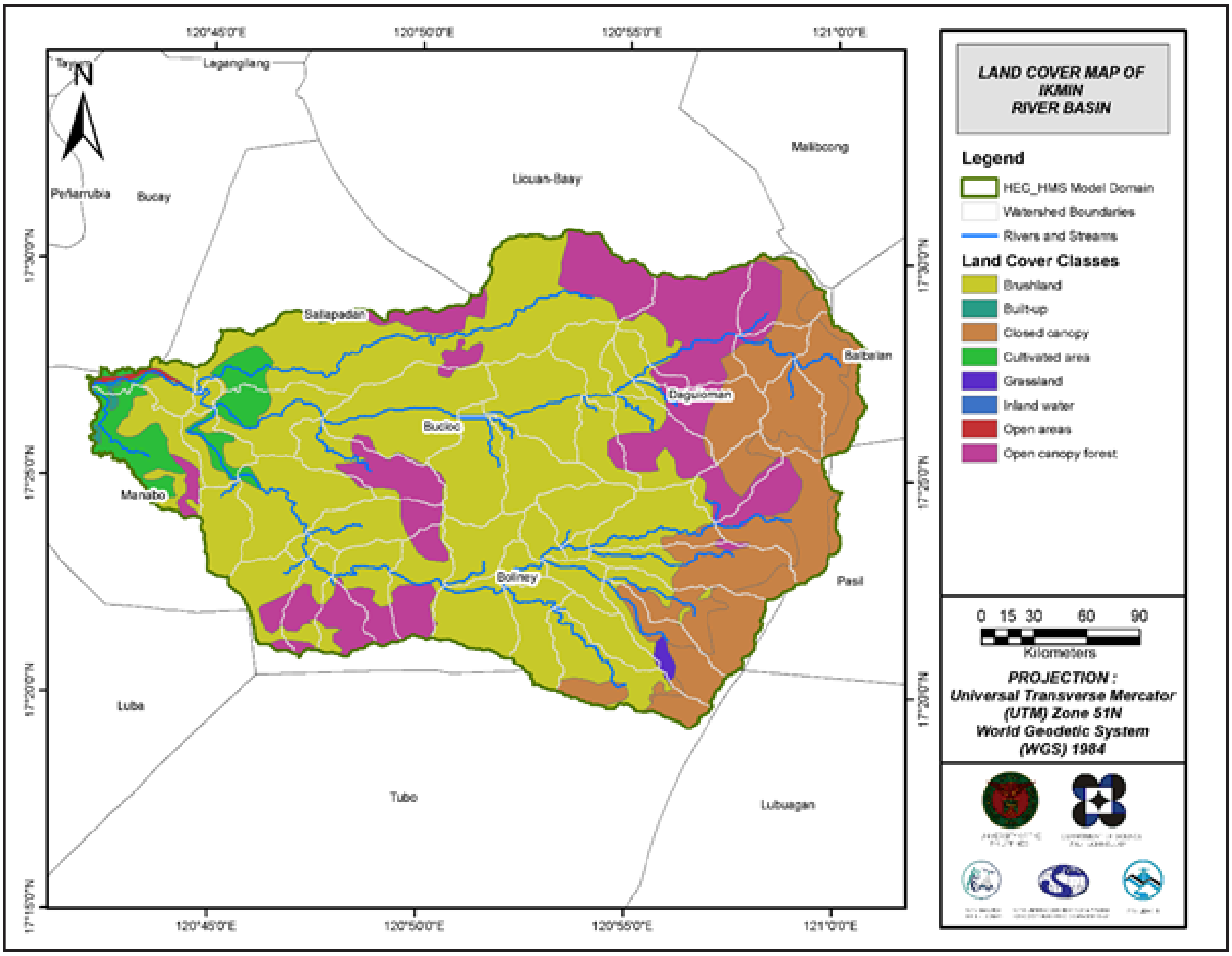


Figure 71. Land Cover Map of Ikmin River Basin

For Ikmin, four soil classes were identified. These are clay, clay loam, silt loam and undifferentiated land. Moreover, eight land cover classes were identified. These are brushlands, built-up areas, closed canopy, cultivated areas, grasslands, inland water, open areas, and open canopy forests.

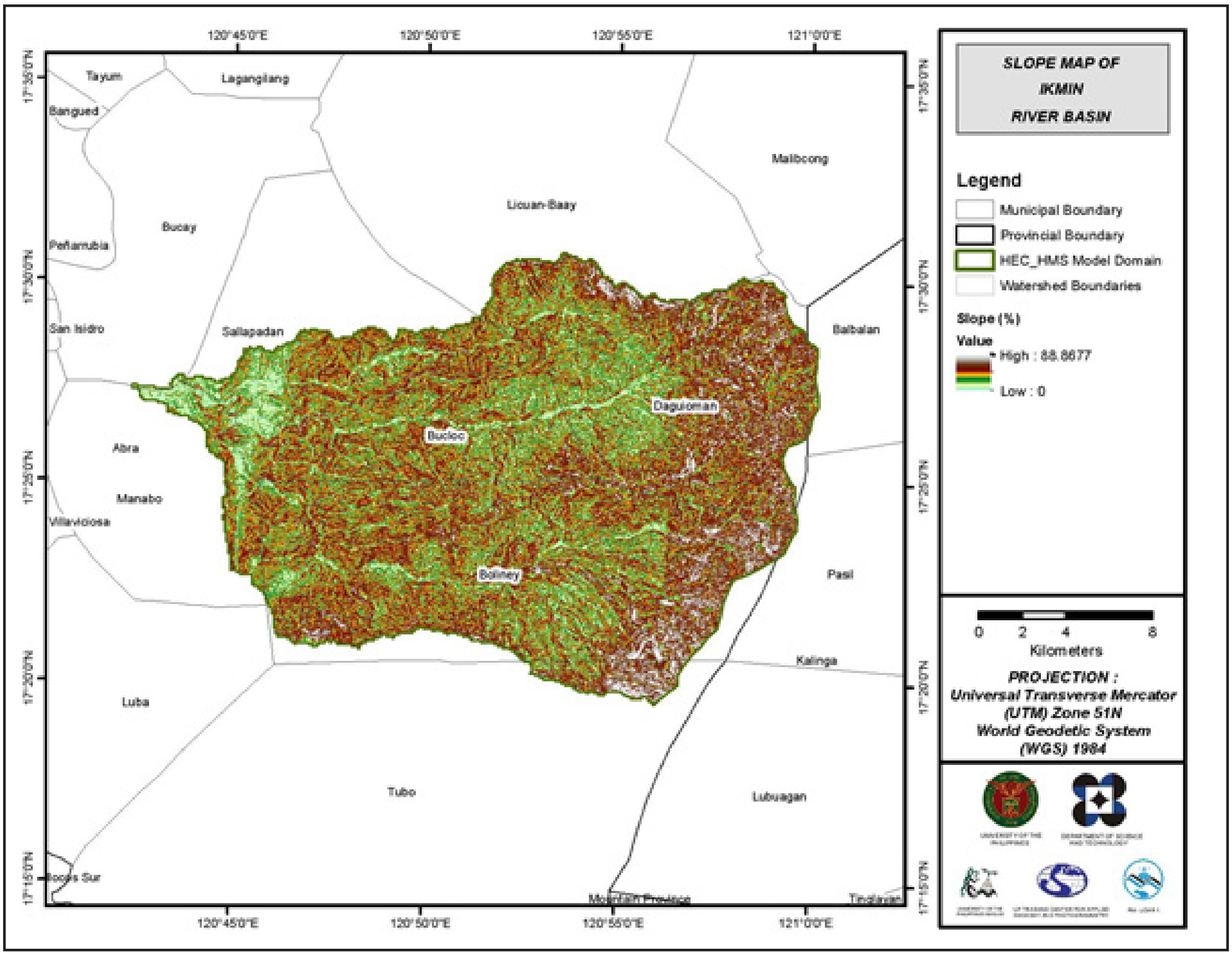


Figure 72. Slope Map of Ikmin River Basin

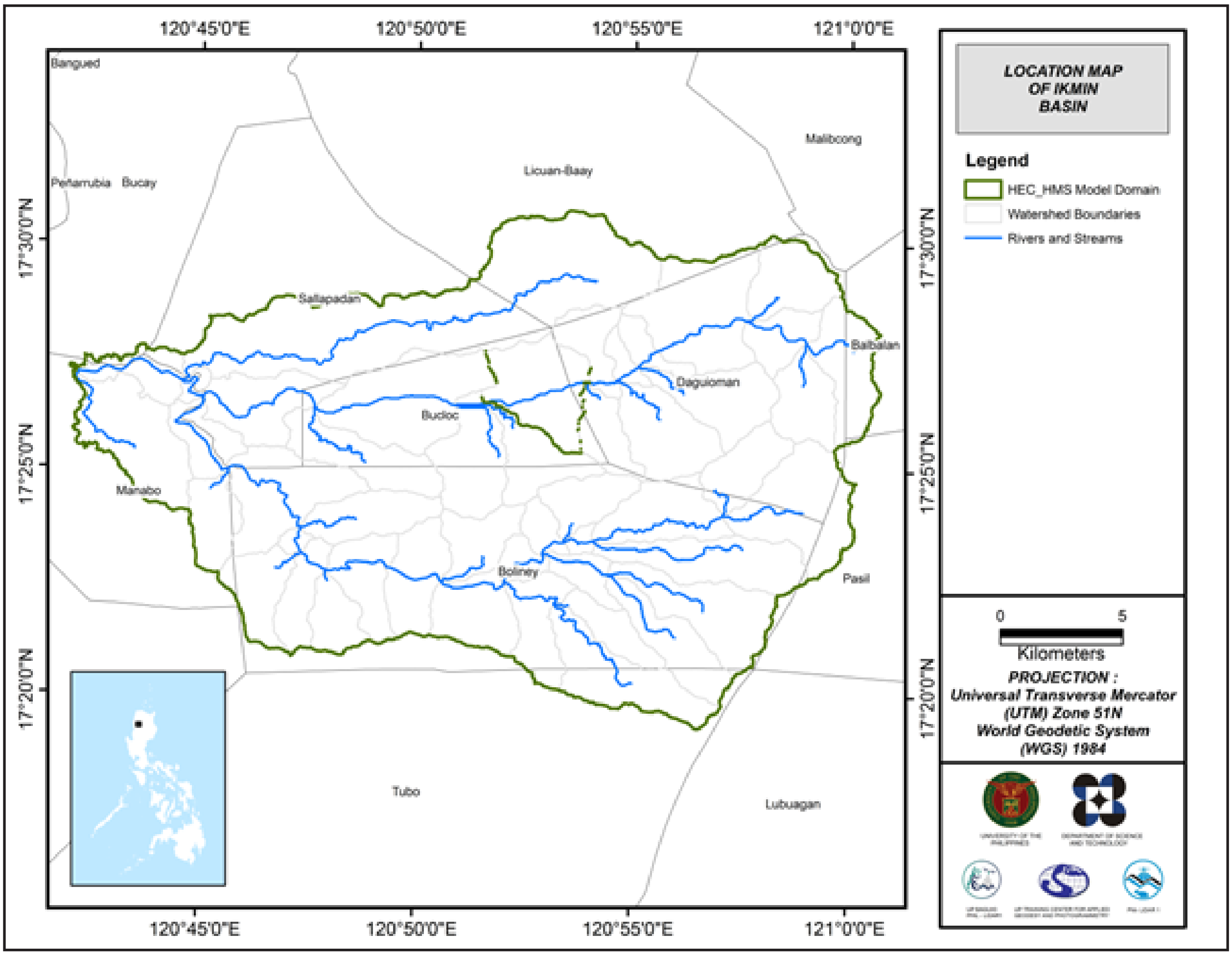


Figure 73. Stream Delineation Map of Ikmin River Basin

Using the SAR-based DEM, the Ikmin basin was delineated and further subdivided into subbasins. The model consists of 49 sub basins, 25 reaches, and 25 junctions, as shown in Figure 74. The main outlet is 260.

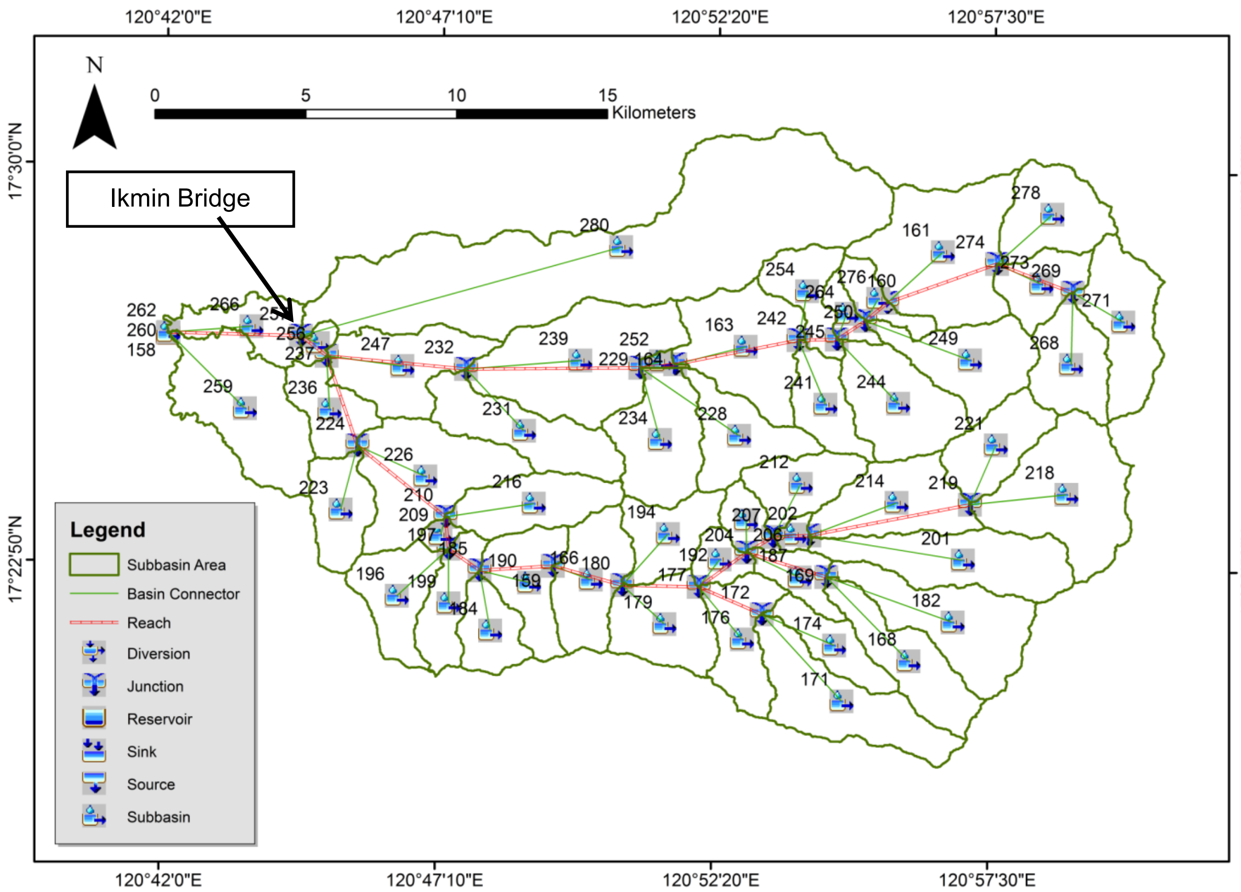


Figure 74. The Ikmin river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

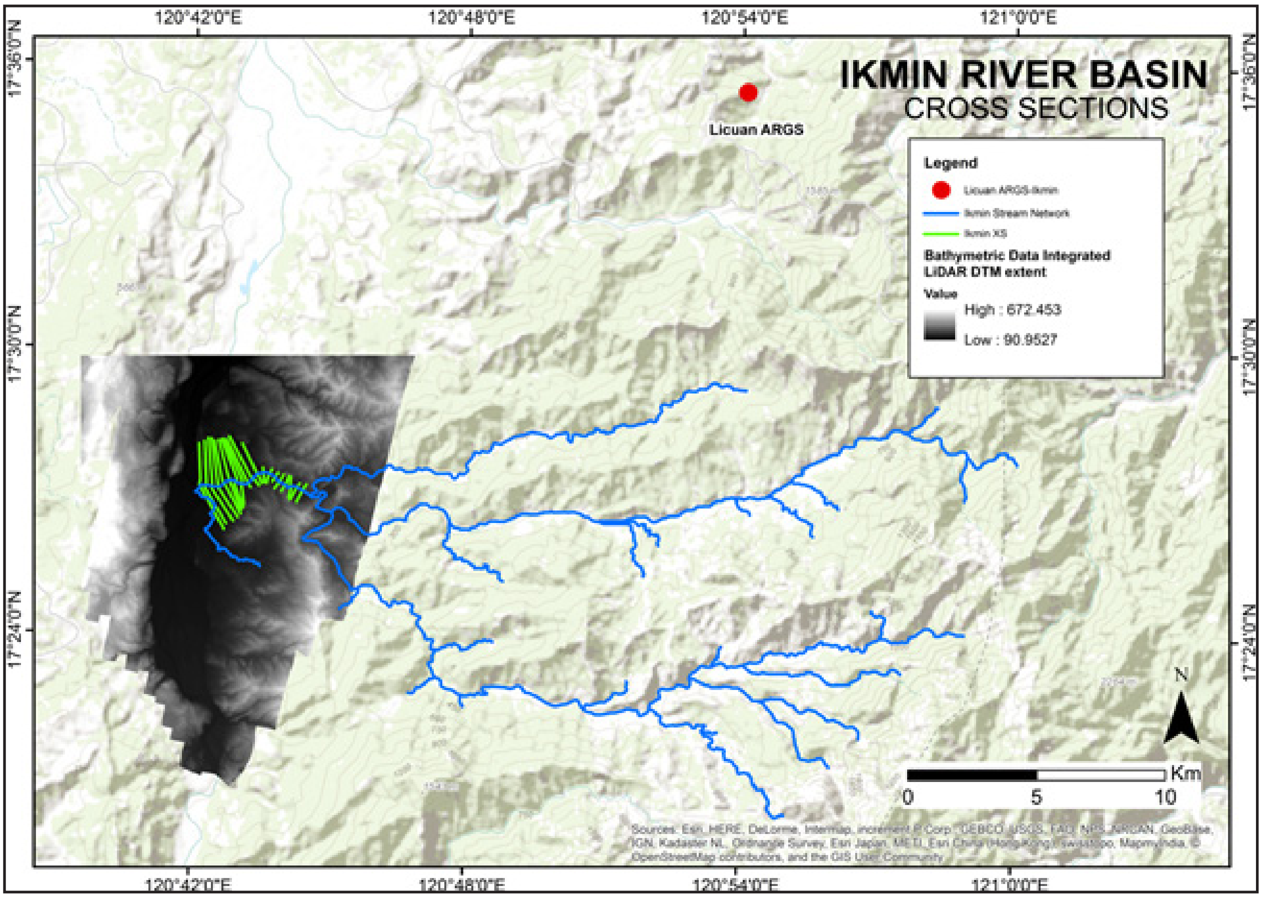


Figure 75. River cross-section ofIkmin River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

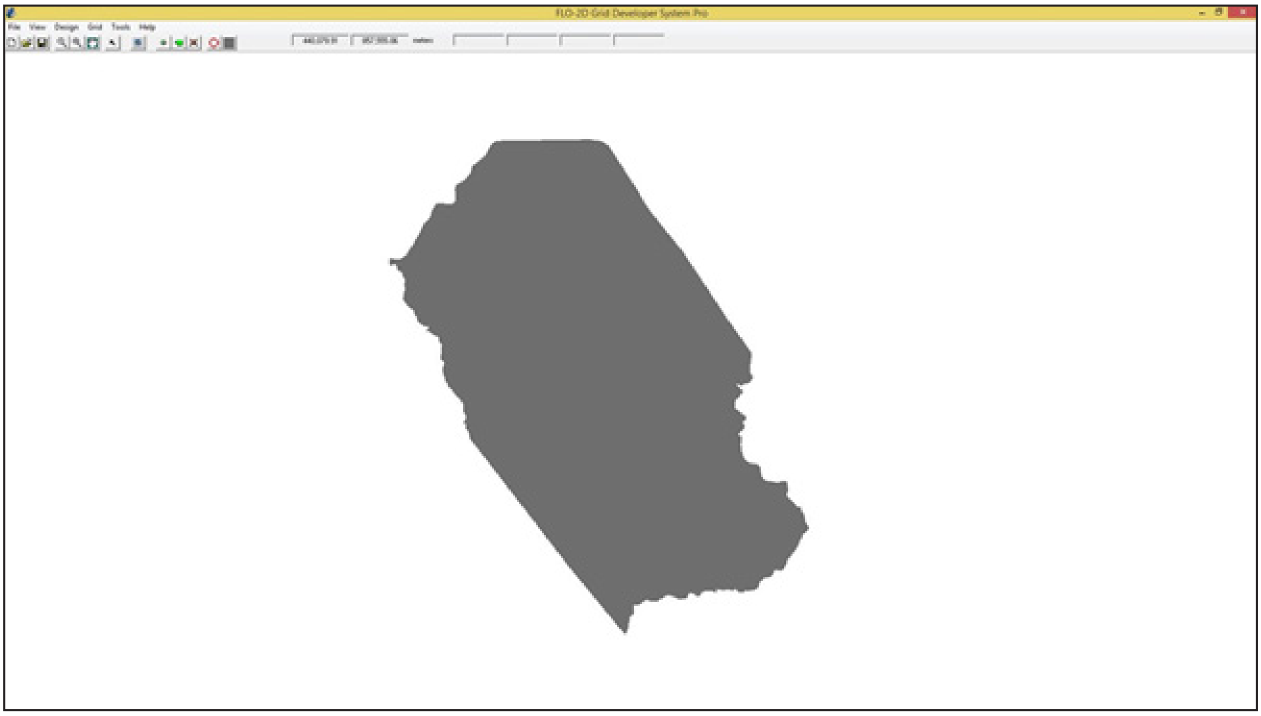


Figure 76. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 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 Ikmin are in Figures __, __, and __.

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 Ikmin are in Figures __, __, and __.

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 floodplain. The rest, amounting up to 429 257 024.59 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Ikmin HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 77 shows the comparison between the two discharge data.

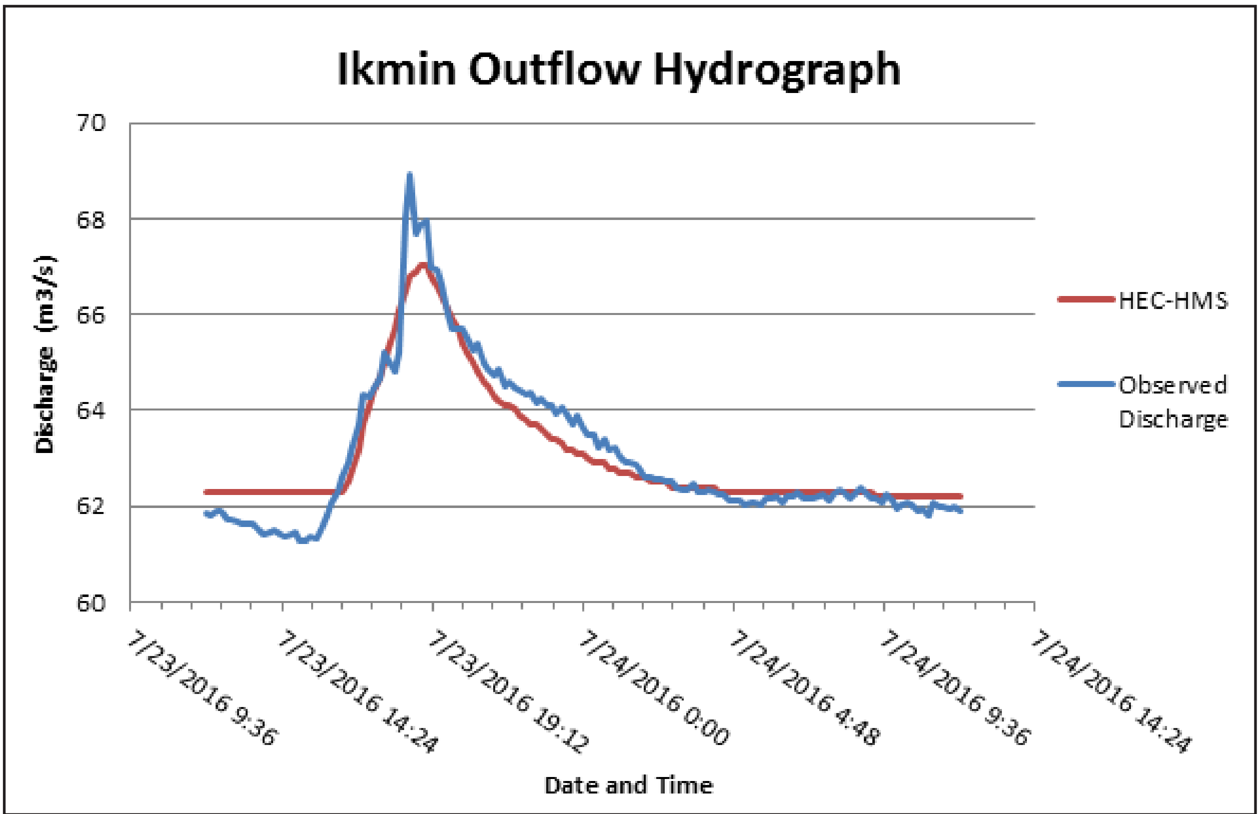


Figure 77. Outflow Hydrograph of Ikmin produced by the HEC-HMS model compared with observed outflow

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

Table 31. Range of Calibrated Values for Ikmin River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001 – 0.002
			Curve Number	81.85 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.0167 – 8.55
			Storage Coefficient (hr)	0.018 – 1.09
	Baseflow	Recession	Recession Constant	0.983 - 1
			Ratio to Peak	0.48 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001

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 0.001 mm to 0.002 mm means that there is a very small initial fraction of the storm depth after which runoff begins, significantly increasing the river outflow.
The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range 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 Ikmin, the basin consists mainly of brushlands and closed canopies and the soil consists of mostly undifferentiated land and clay.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.0167 hours to 8.55 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 0.983 to 1 indicate that the discharge will slowly go back to its usual flow. Values of ratio to peak within the range of 0.48 to 0.5 indicate an average receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Ikmin river basin reaches' Manning's coefficient is 0.0001, showing that the catchment is filled with areas that allow the runoff to flow smoothly to the river streams.

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

Accuracy measure	Value
RMSE	0.5
r^2	0.9982
NSE	0.90
PBIAS	-0.0011
RSR	0.31

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as0.5 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 0.9982.

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 0.90.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -0.0011.

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 0.31.

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

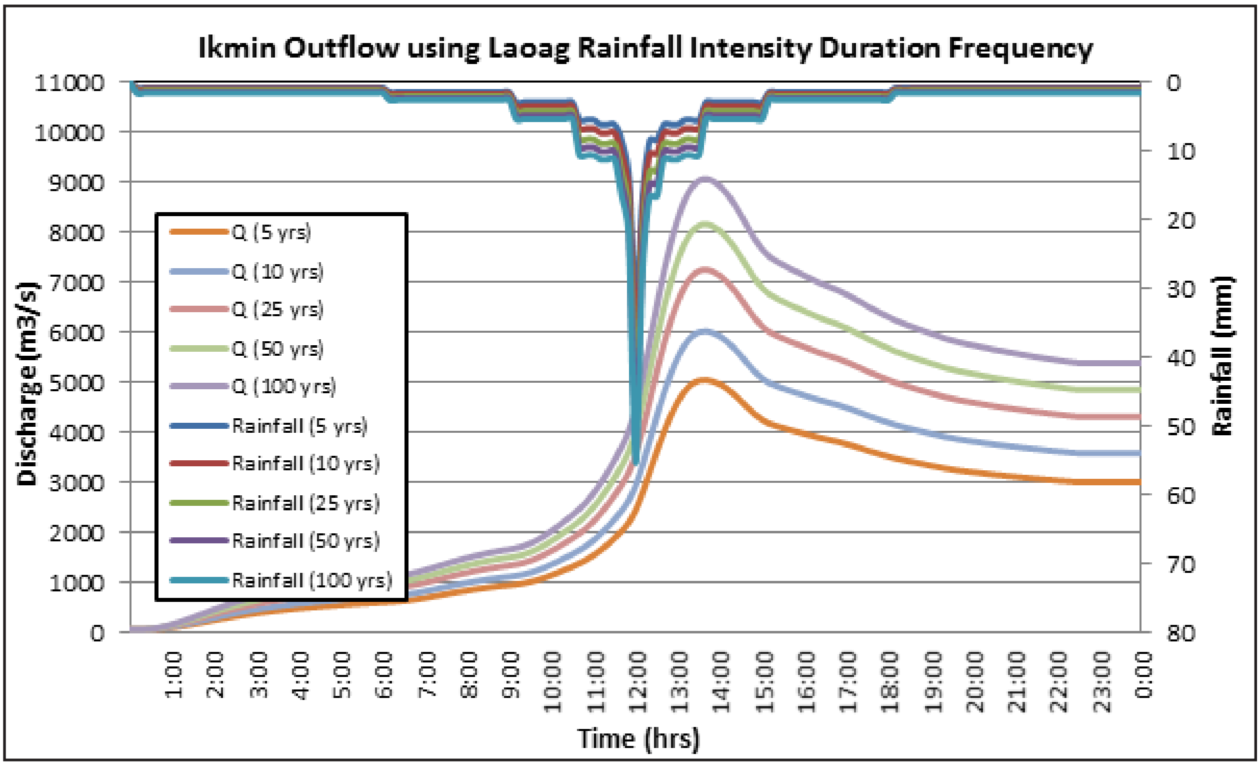


Figure 78. Outflow hydrograph at Ikmin Station generated using the Laoag RIDF simulated in HEC-HMS.

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

Table 33. Peak values of the Ikmin HEC-HMS Model outflow using the Laoag RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	331.7	31.4	5047	1 hour, 40 minutes
10-Year	397.1	37.2	6019.8	1 hour, 40 minutes
25-Year	479.8	44.5	7247.2	1 hour, 40 minutes
50-Year	541.1	50	8155	1 hour, 40 minutes
100-Year	602	55.3	9059.6	1 hour, 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 79 to Figure 81 and the peak values are summarized in Table 34 to Table 37.

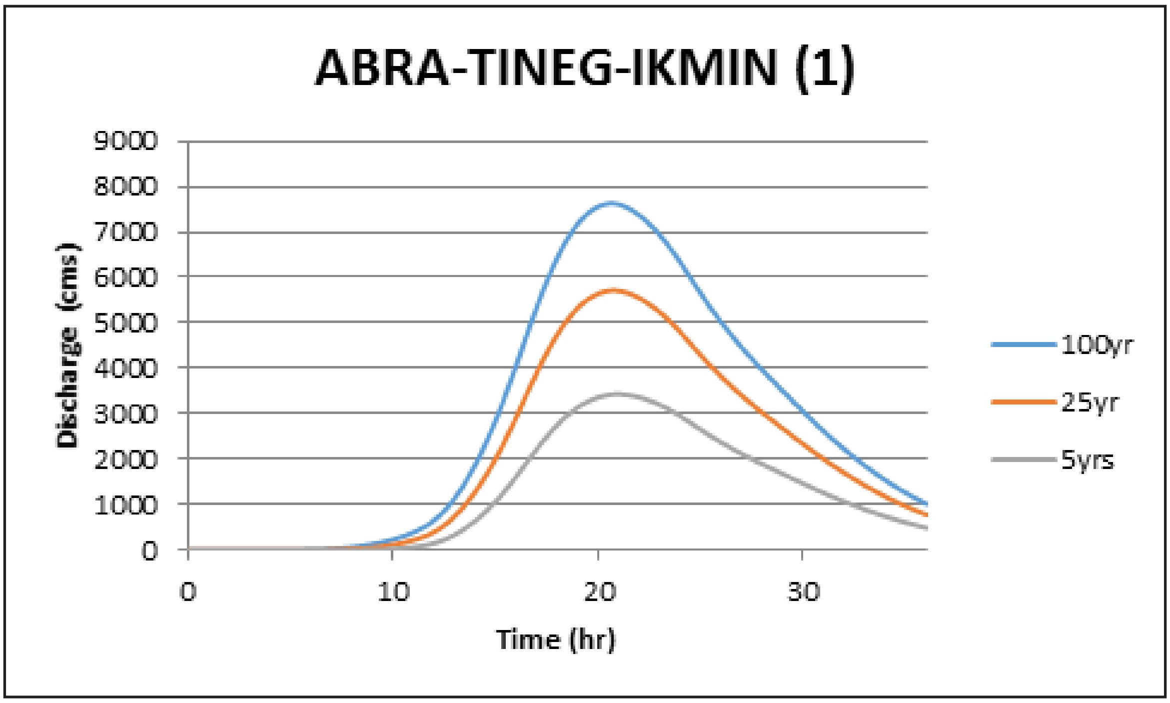


Figure 79. Abra-Tineg-Ikminriver (1) generated discharge using 5-, 25-, and 100-year Laoag rainfall intensity-duration-frequency (RIDF) in HEC-HMS

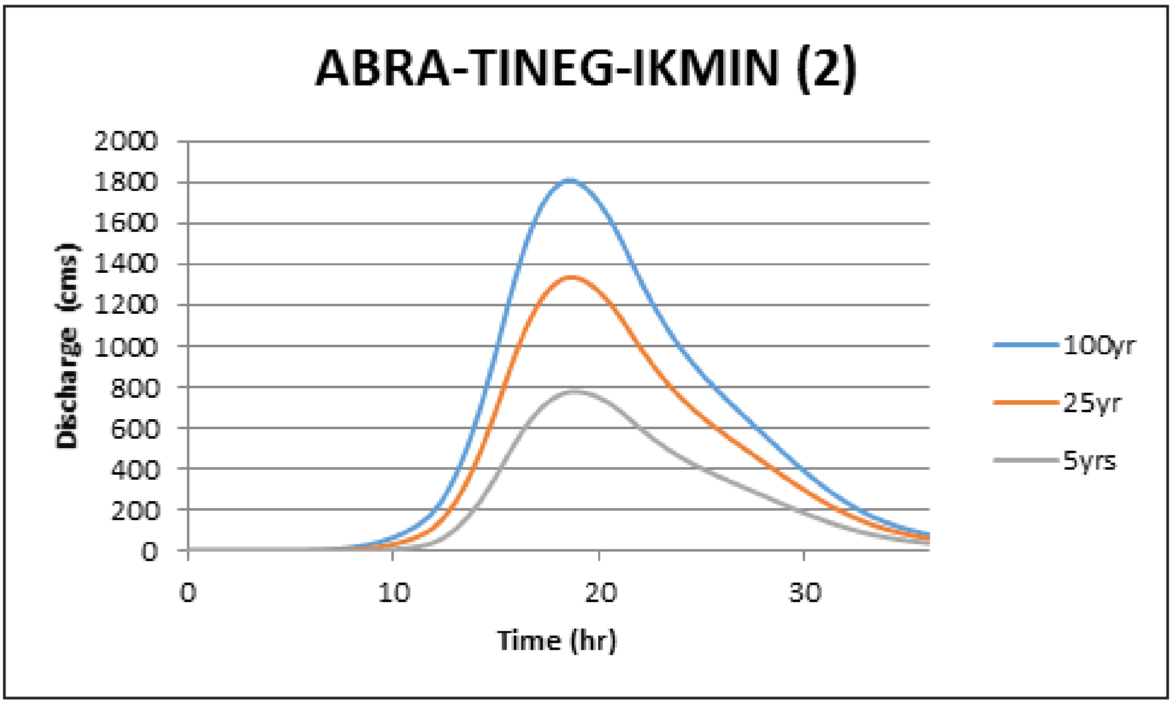


Figure 80. Abra-Tineg-Ikminriver (2) generated discharge using 5-, 25-, and 100-year Laoag rainfall intensity-duration-frequency (RIDF) in HEC-HMS

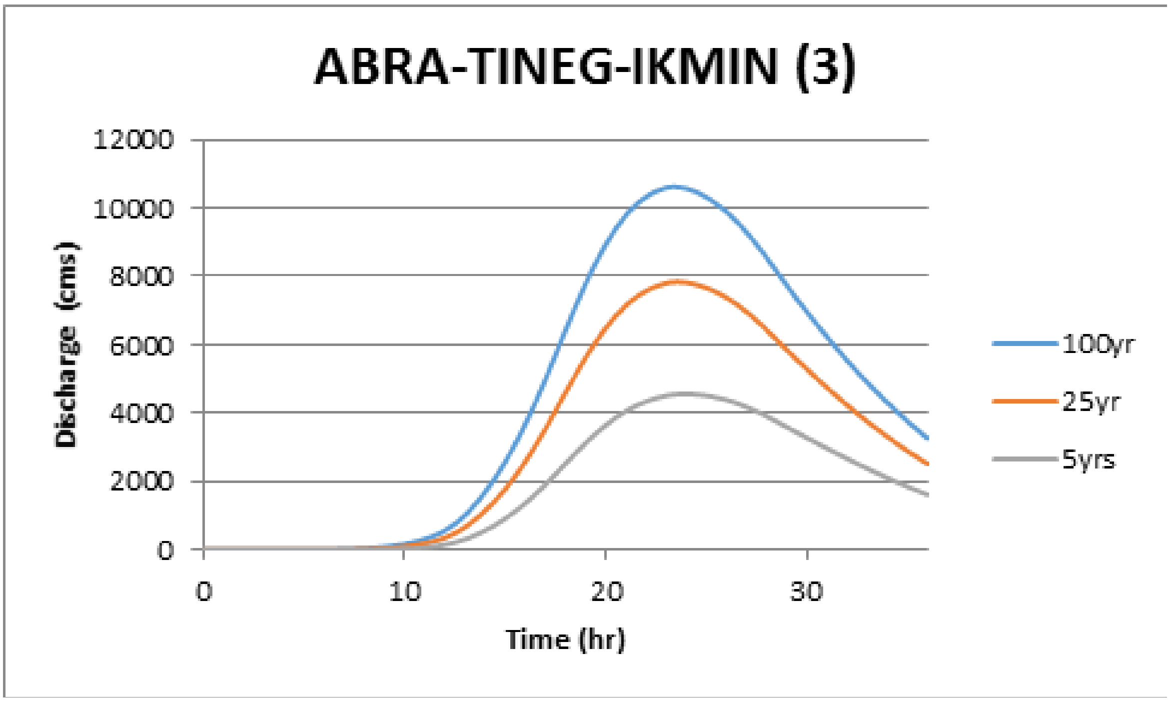


Figure 81. Abra-Tineg-Ikminriver (3) generated discharge using 5-, 25-, and 100-year Laoag rainfall intensity-duration-frequency (RIDF) in HEC-HMS

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 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 was used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Ikmin River using the calibrated HMS base flow is shown in Figure 82.

Figure 82. Sample output of Ikmin RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. The 100-, 25-, and 5-year rain return scenarios of the Ikmin Floodplain are shown in Figure 83 to Figure 88. 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%

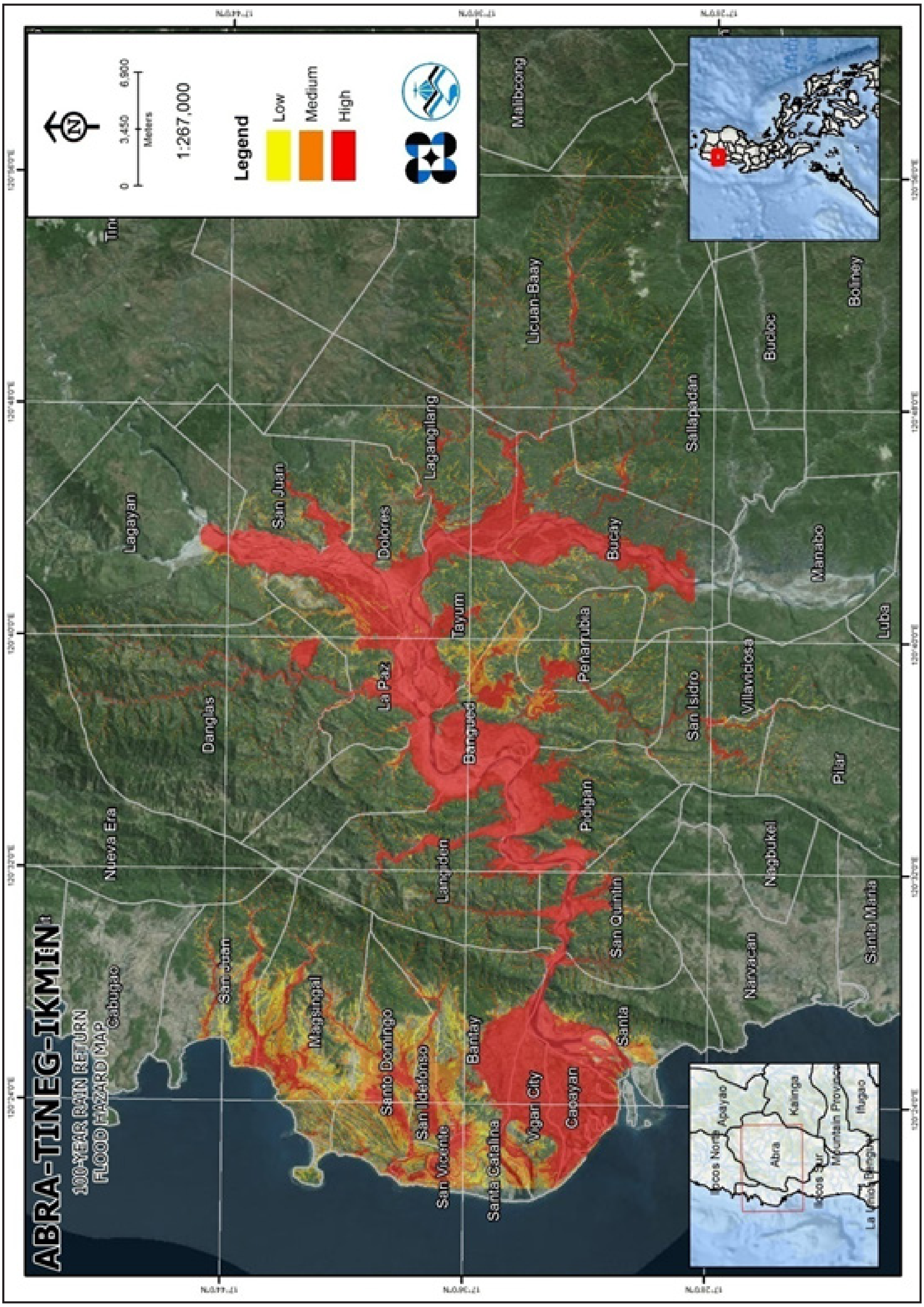


Figure 83. 100-year Flood Hazard Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery

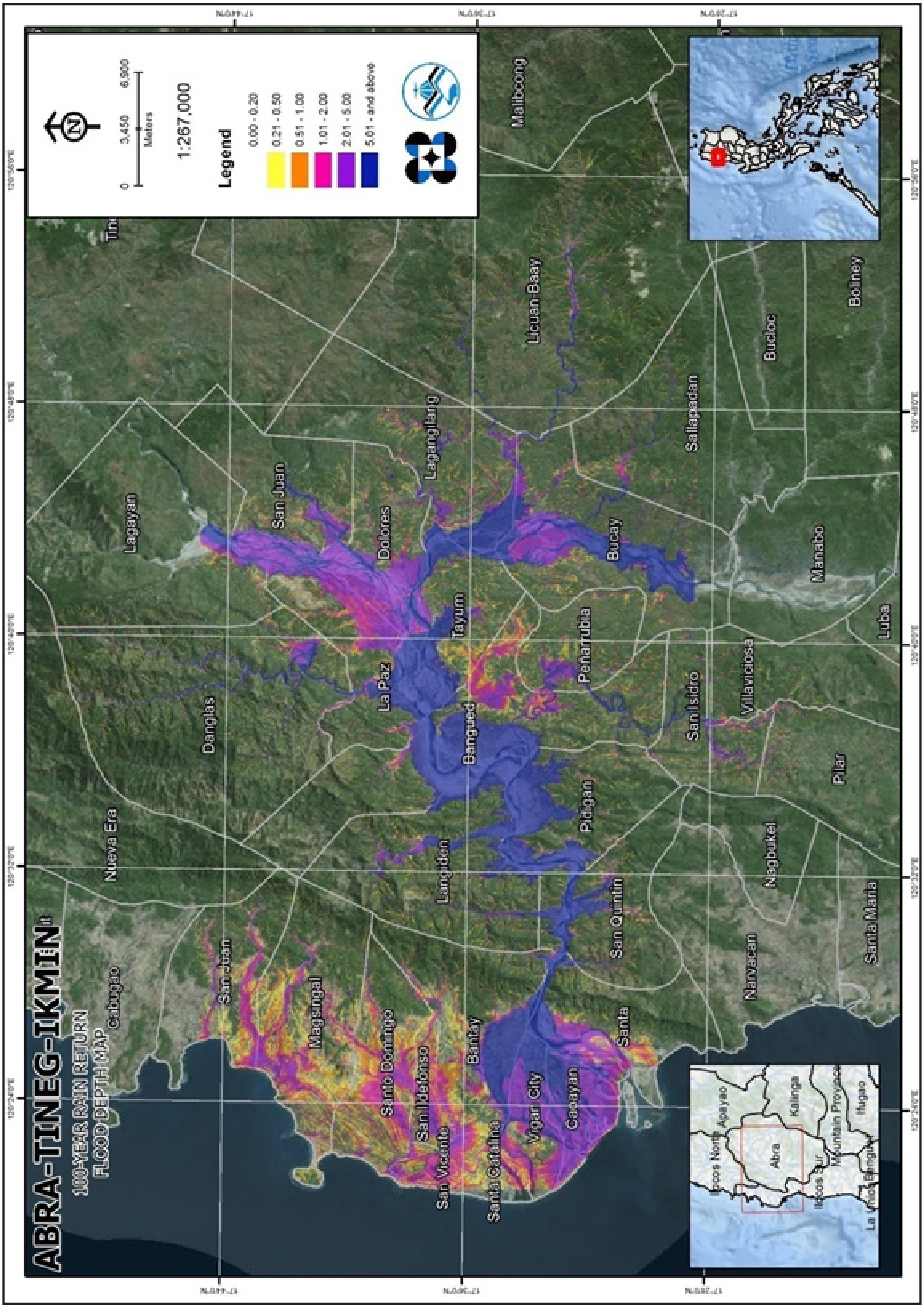


Figure 84. 100-year Flow Depth Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery

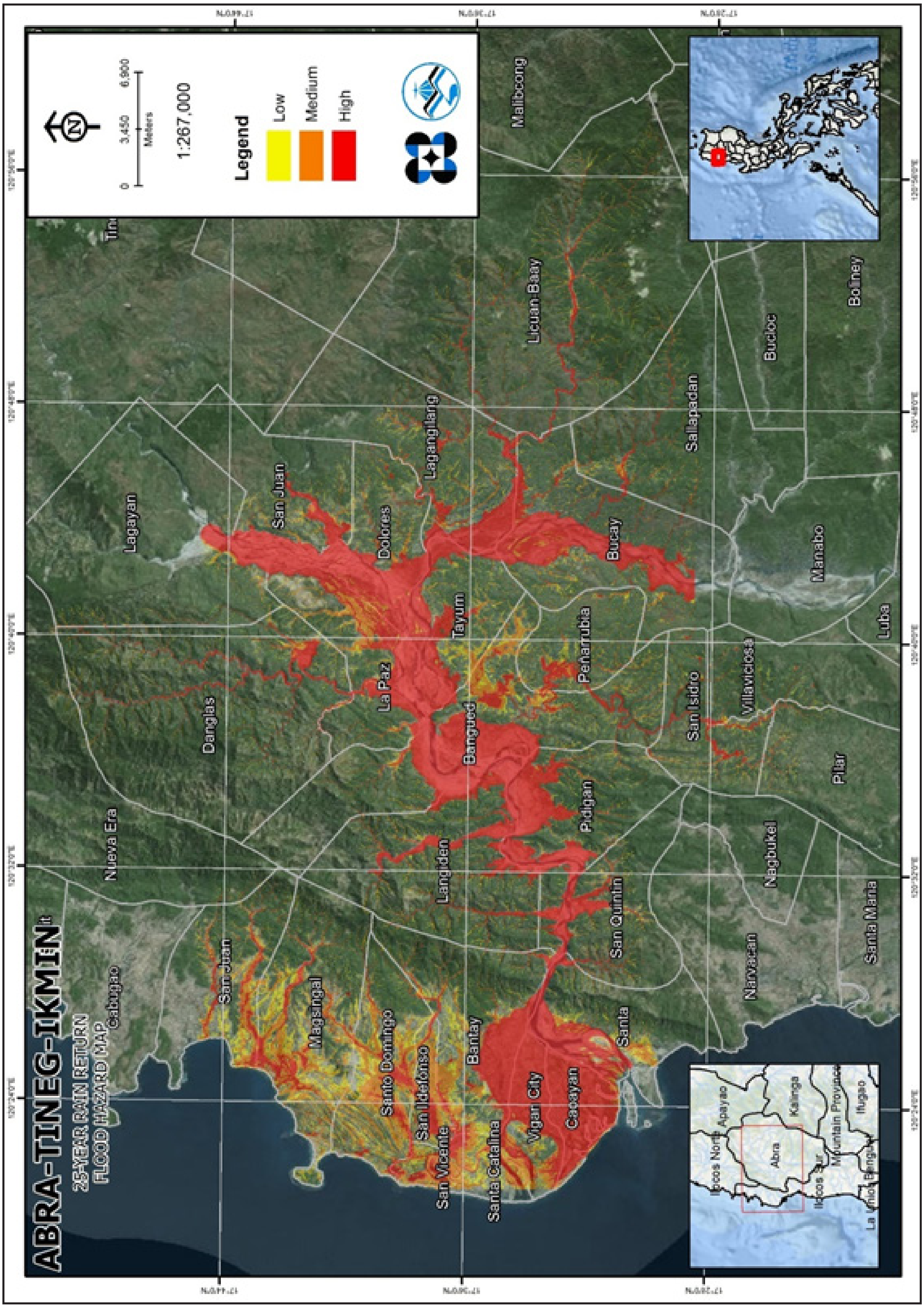


Figure 85. 25-year Flood Hazard Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery

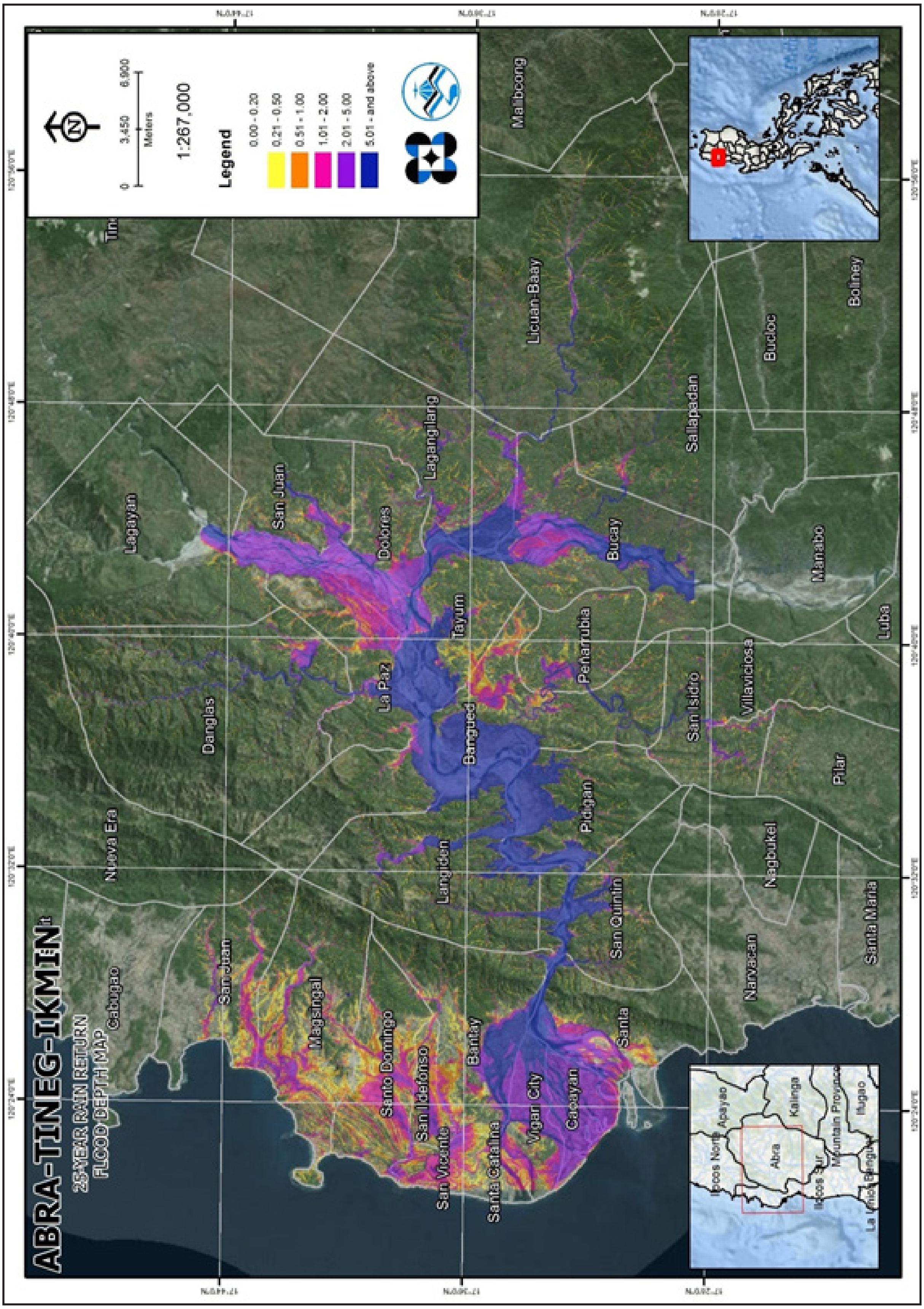


Figure 88. 5-year Flood Depth Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery

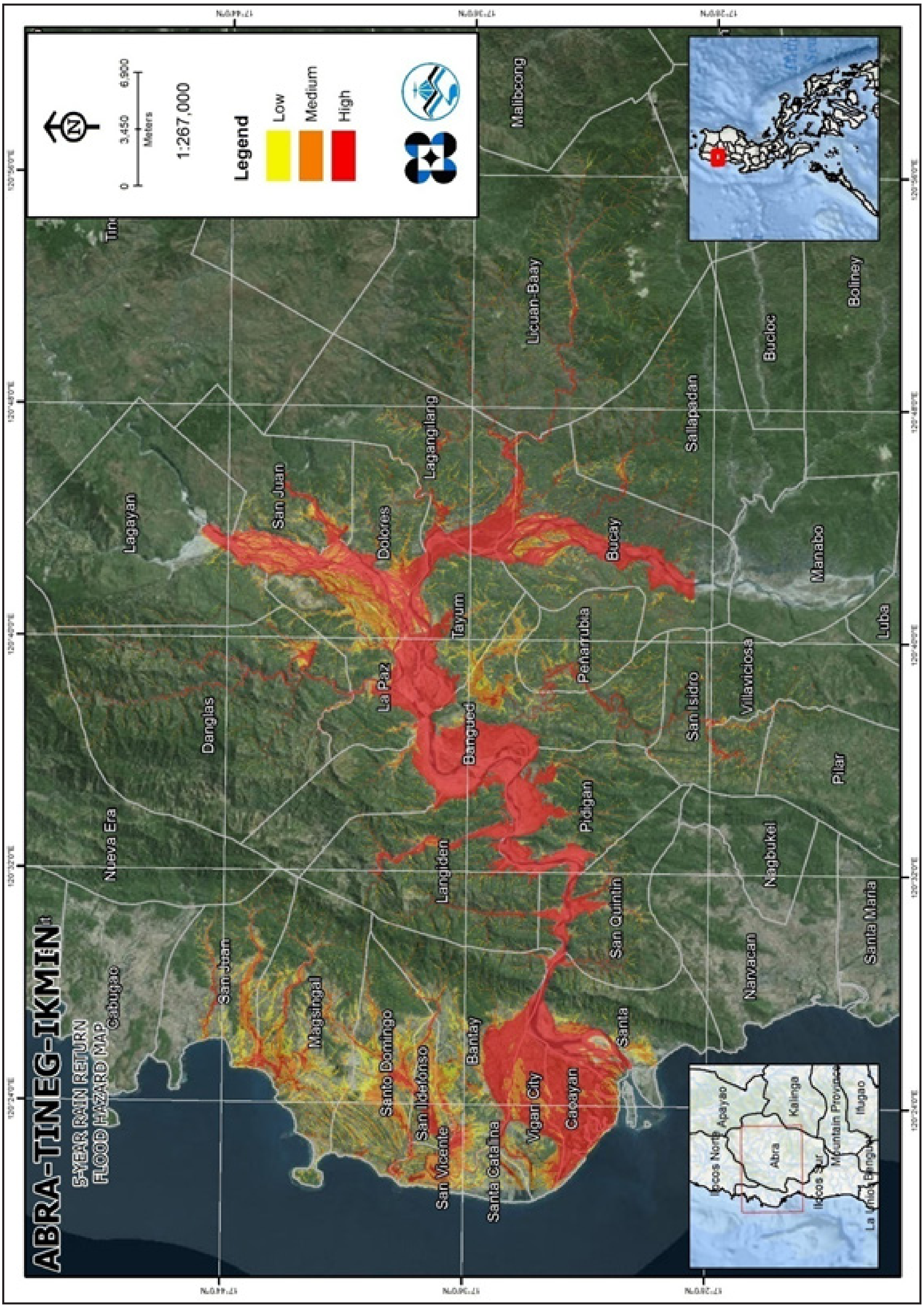


Figure 87. 5-year Flood Hazard Map for Abra-Tineg-Ikmin Floodplain overlaid on Google Earth imagery

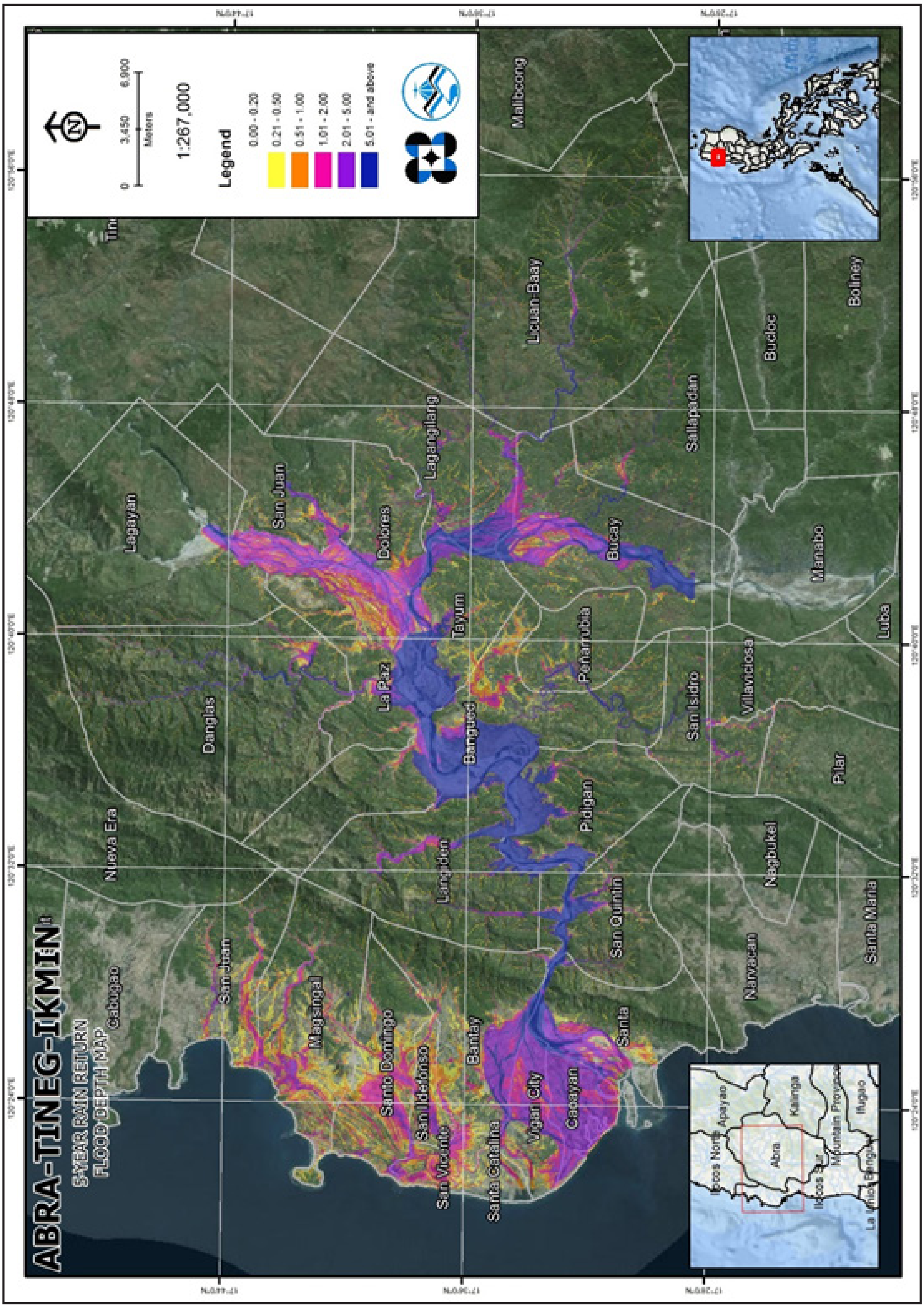


Figure 88. 5-year Flood Depth Map for Buaya Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Ikmin 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

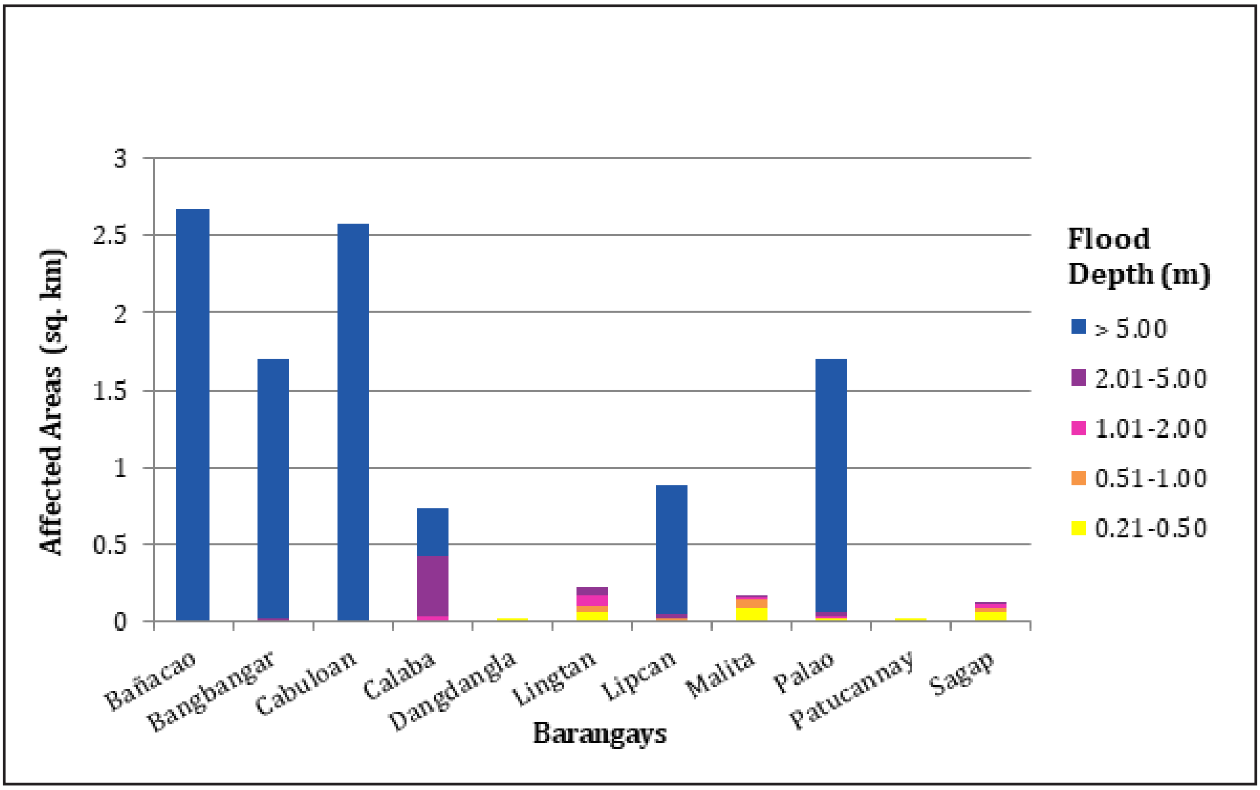


Figure 89. Affected Areas in Bangued, Abra during 5-Year Rainfall Return Period.

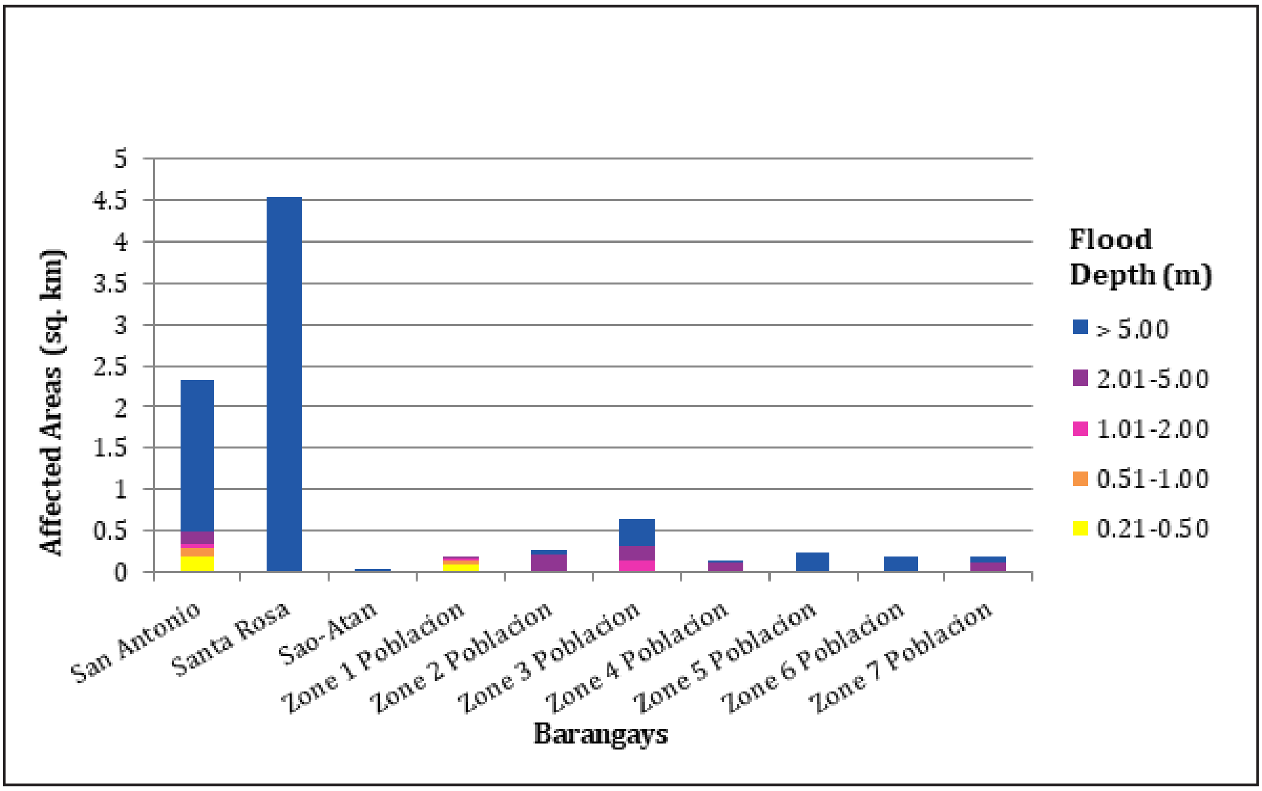


Figure 90. Affected Areas in Bangued, Abra during 5-Year Rainfall Return Period.

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

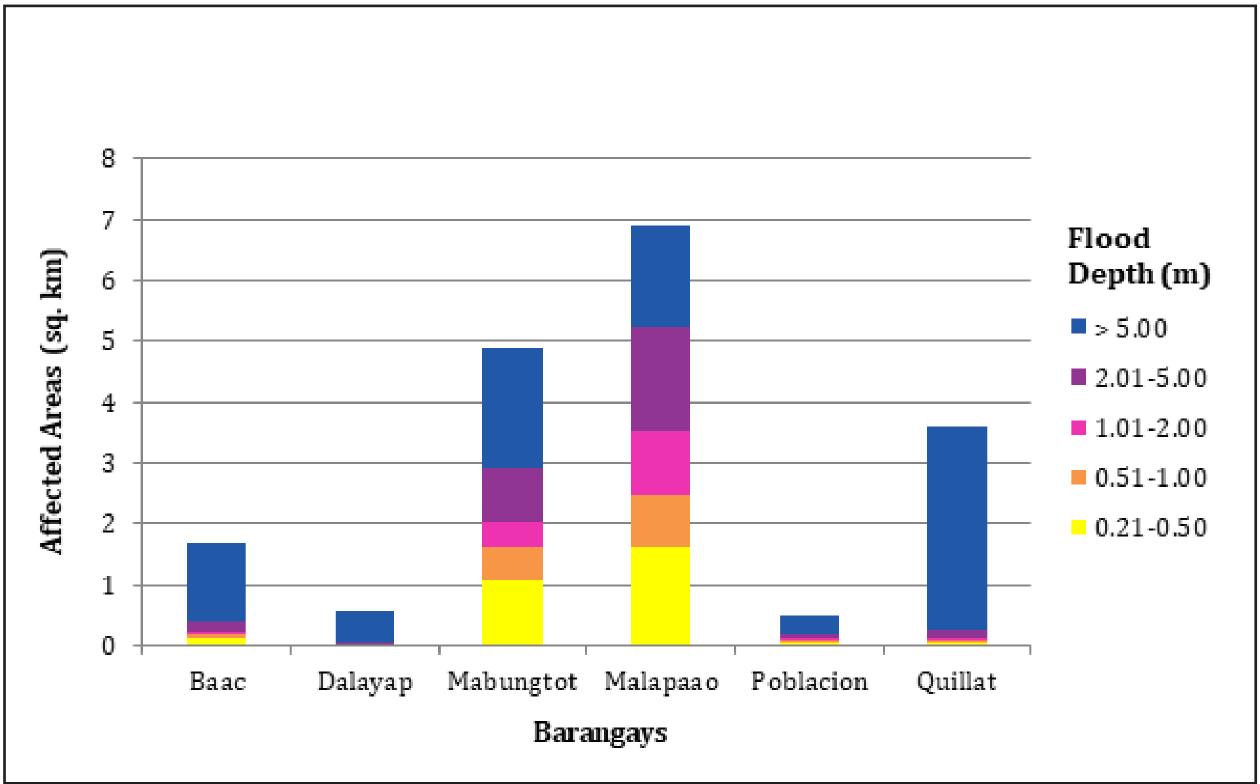


Figure 91. Affected Areas in Langiden, Abra during 5-Year Rainfall Return Period.

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

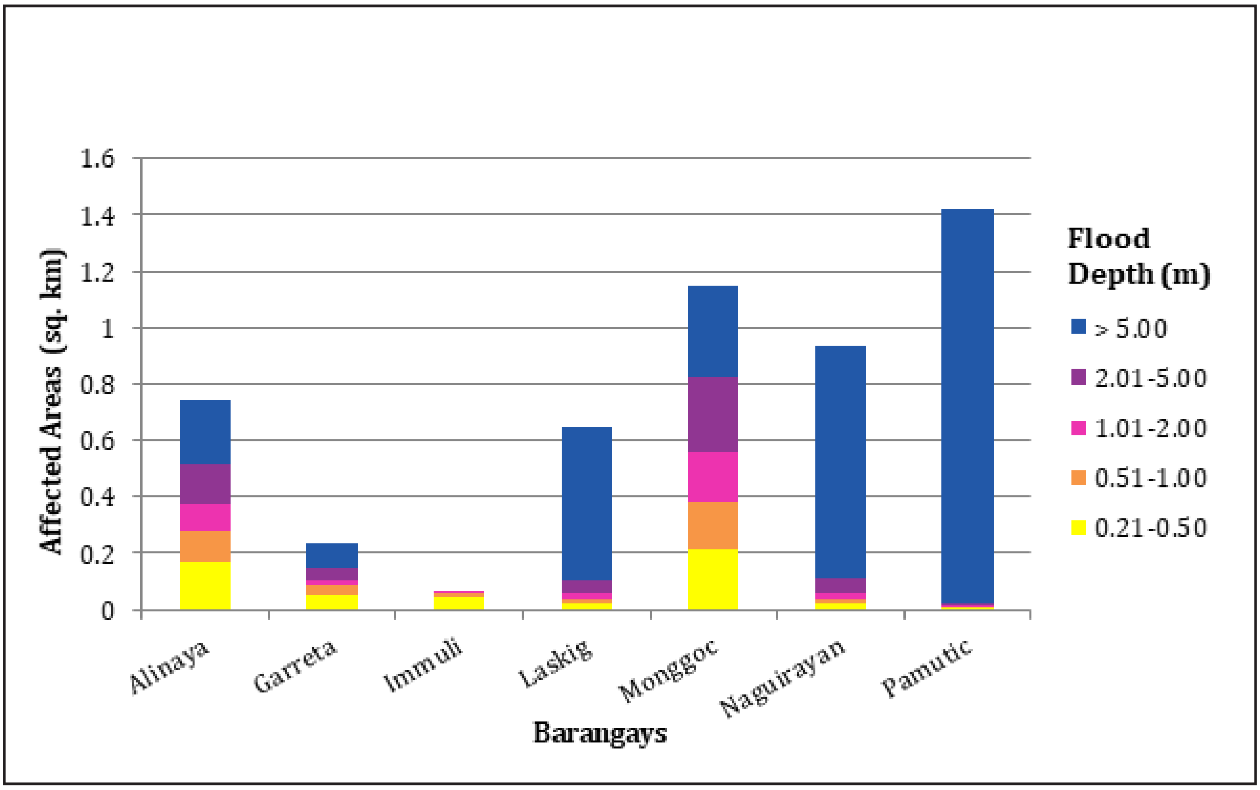


Figure 92. Affected Areas in Pidigan, Abra during 5-Year Rainfall Return Period.

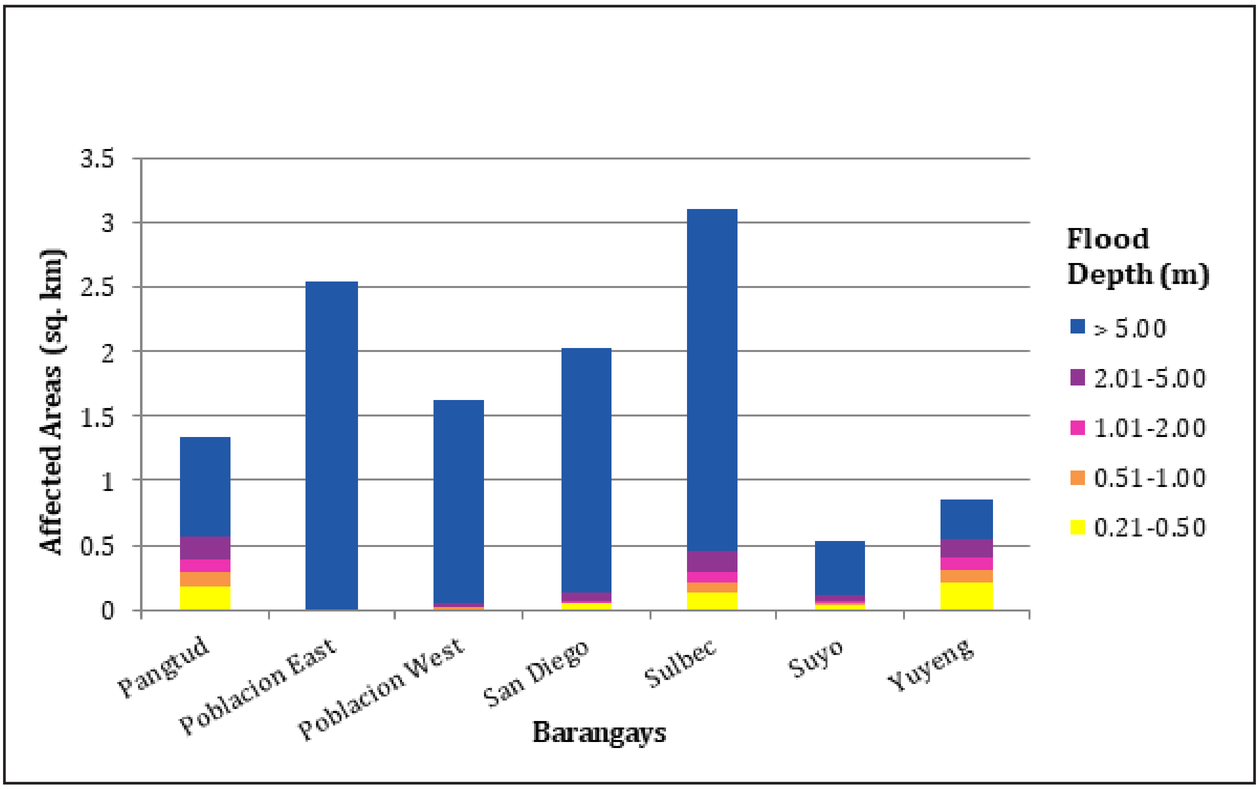


Figure 93. Affected Areas in Pidigan, Abra during 5-Year Rainfall Return Period.

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

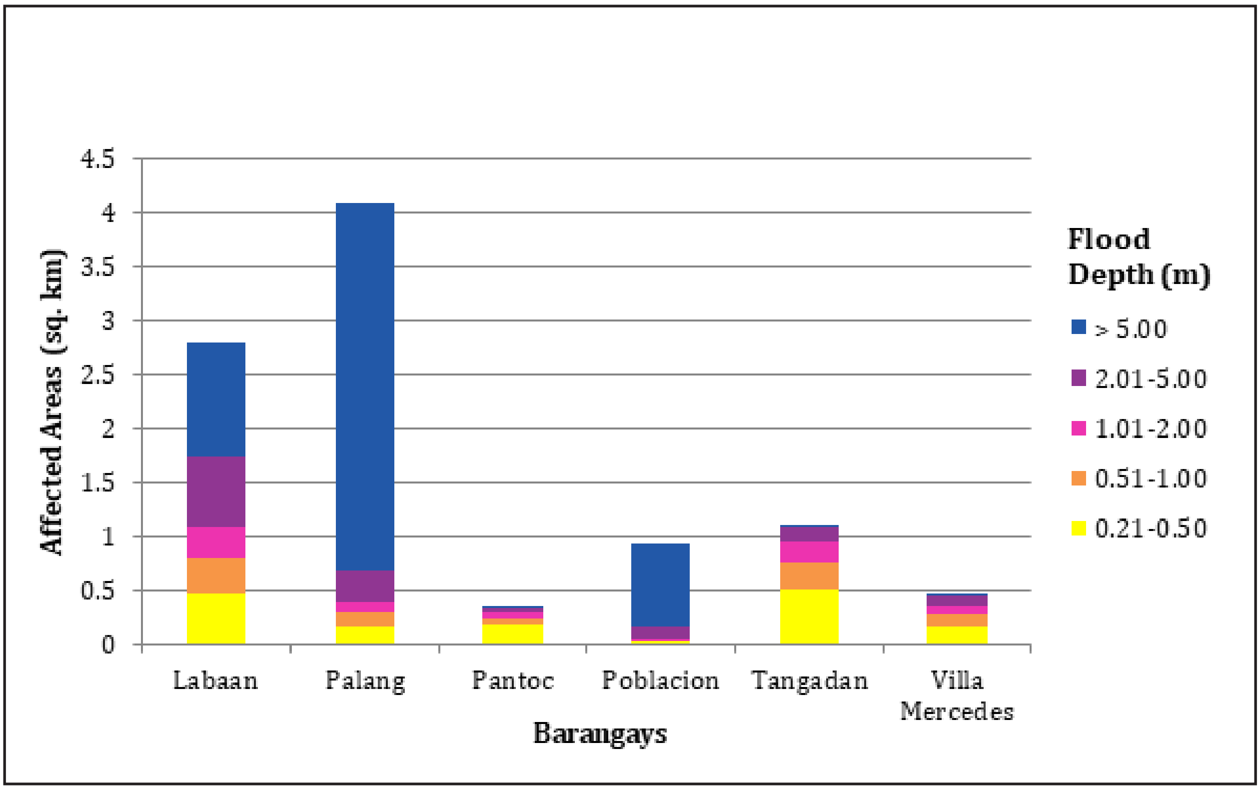


Figure 94. Affected Areas in San Quintin, Abra during 5-Year Rainfall Return Period.

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

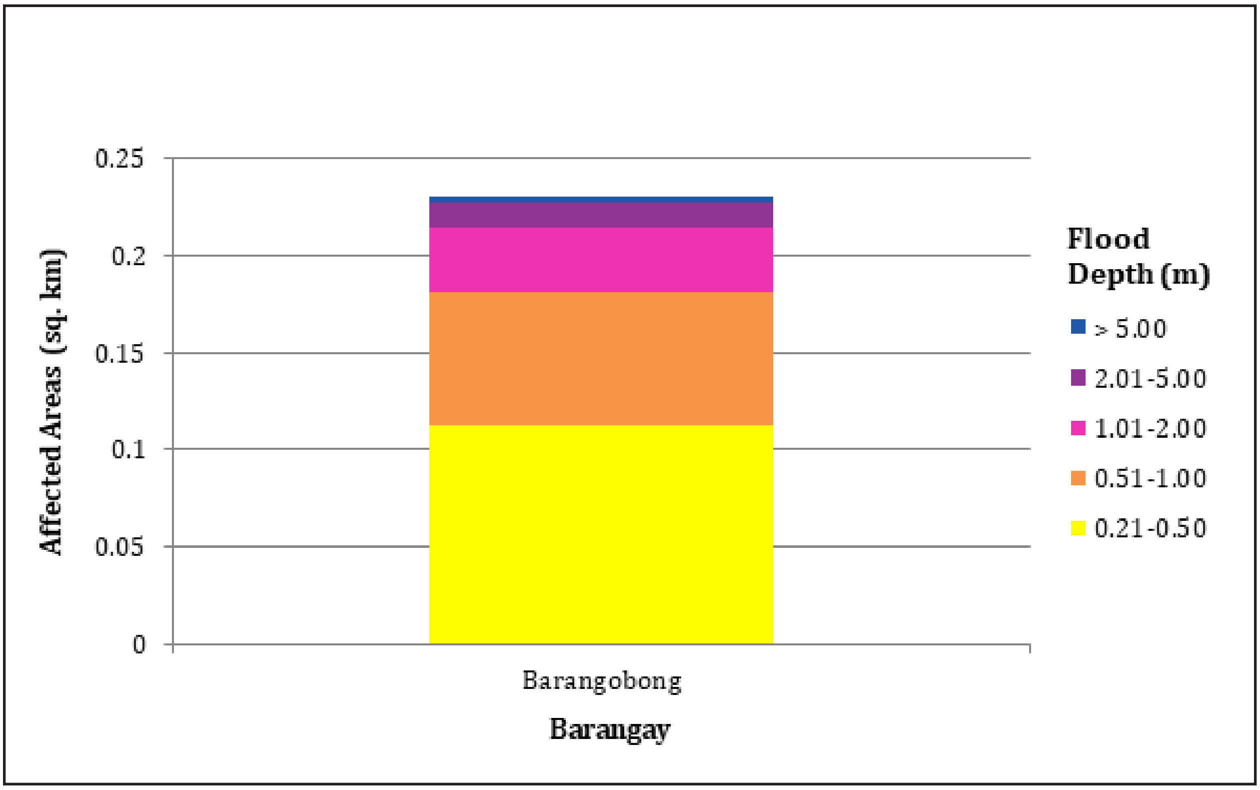


Figure 95. Affected Areas in Nueva Era, Ilocos Norte during 5-Year Rainfall Return Period.

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

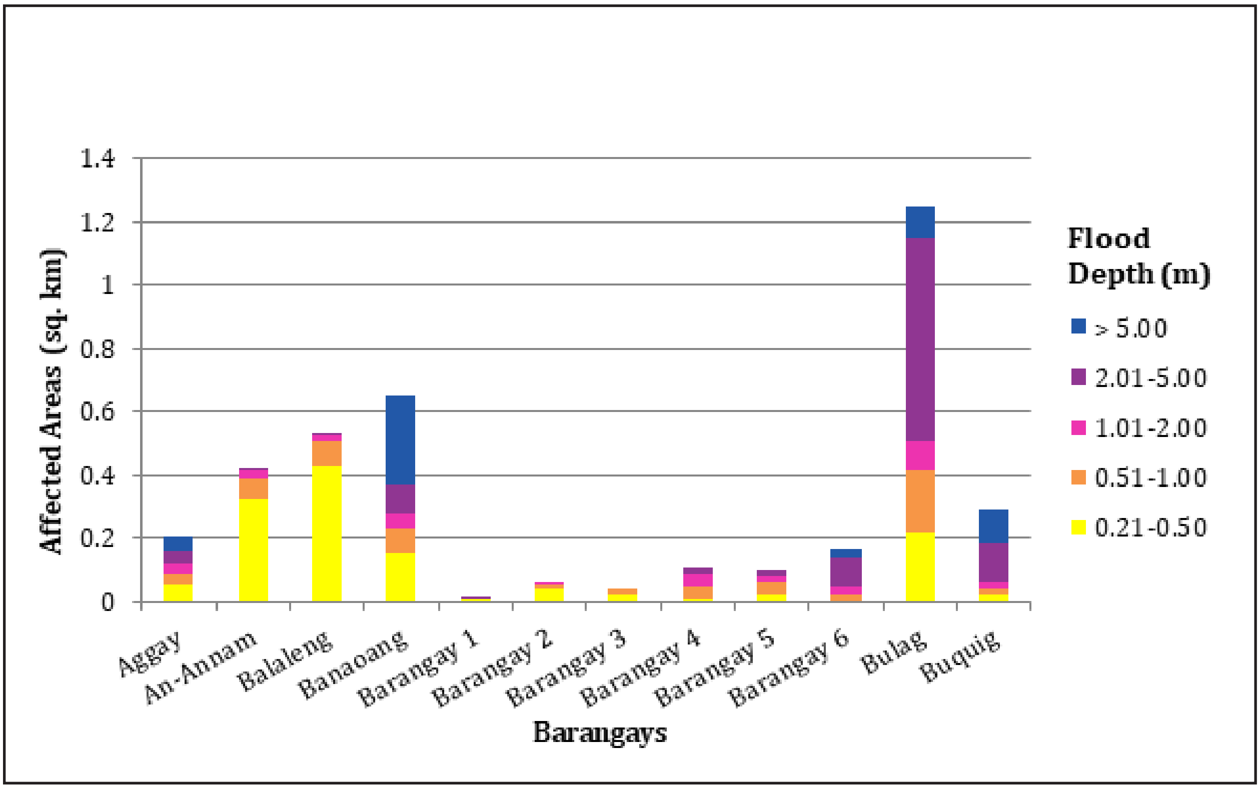


Figure 96. Affected Areas in Bantay, Ilocos Sur during 5-Year Rainfall Return Period.

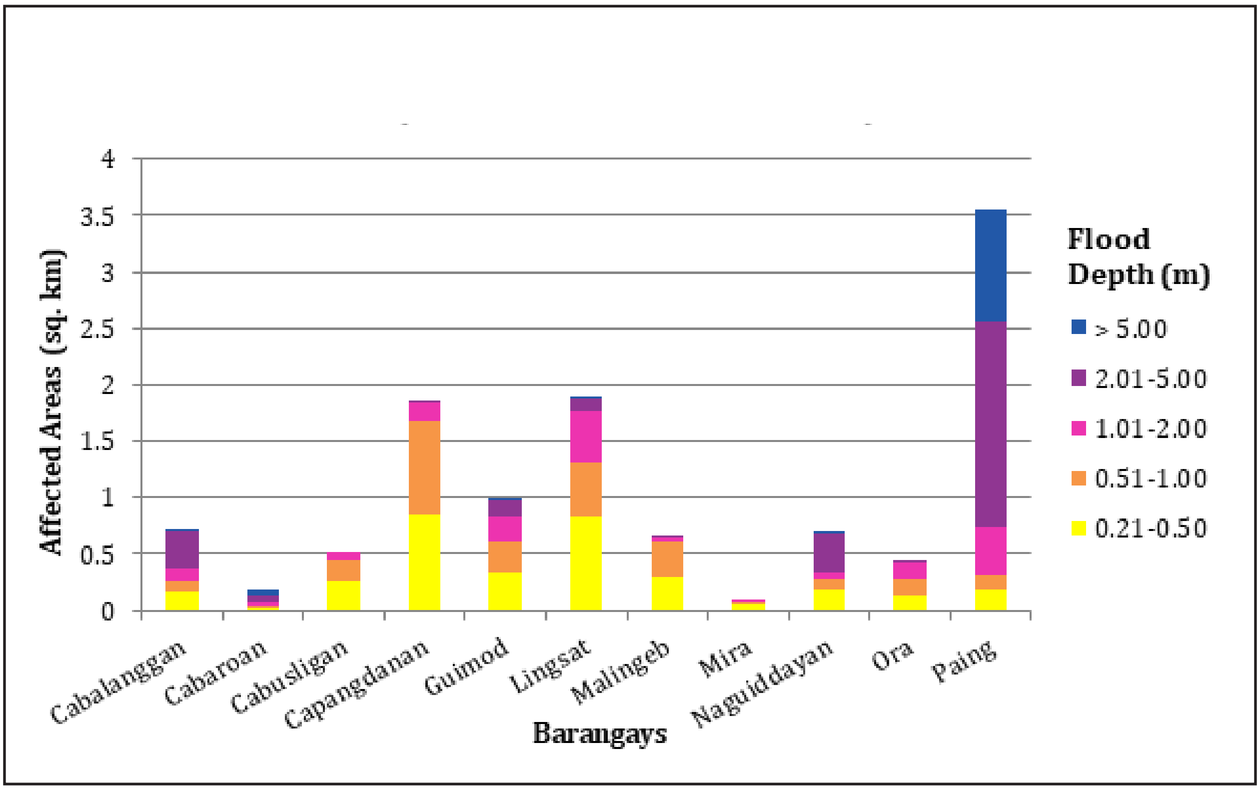


Figure 97. Affected Areas in Bantay, Ilocos Sur during 5-Year Rainfall Return Period.

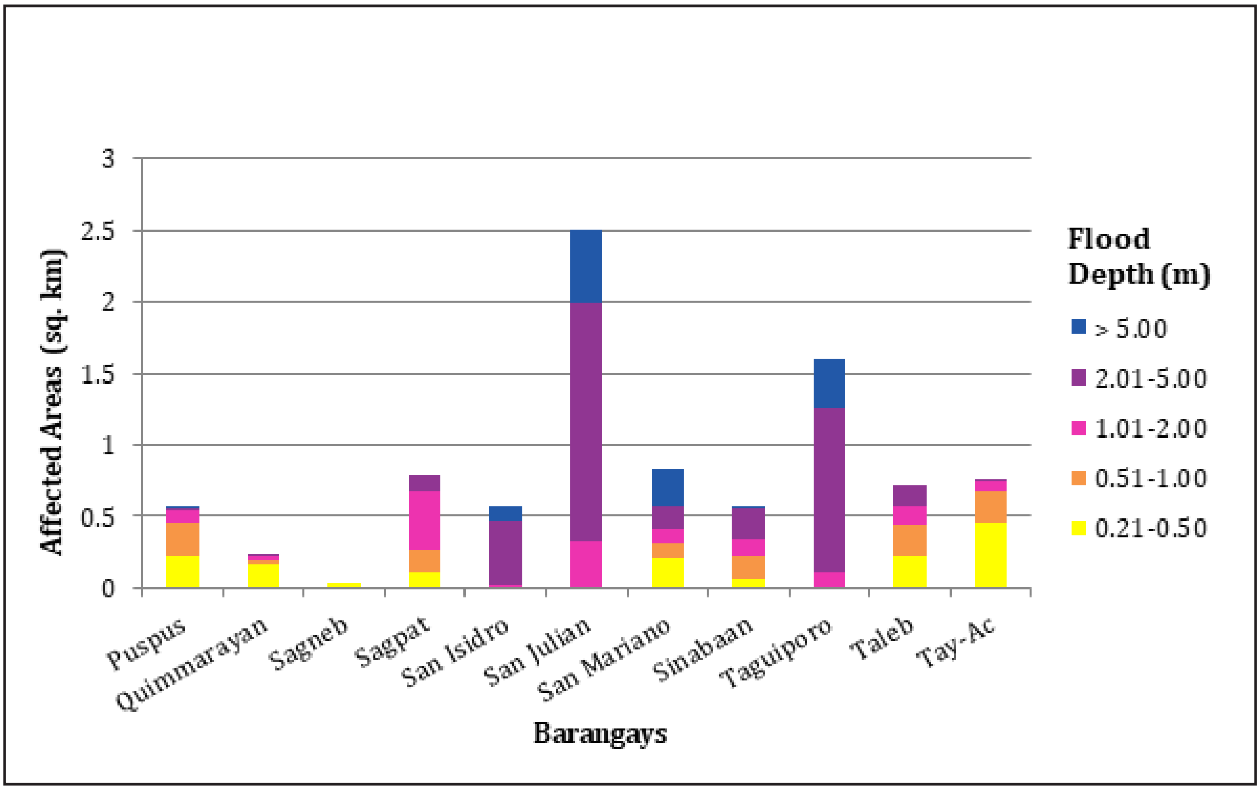


Figure 98. Affected Areas in Bantay, Ilocos Sur during 5-Year Rainfall Return Period.

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

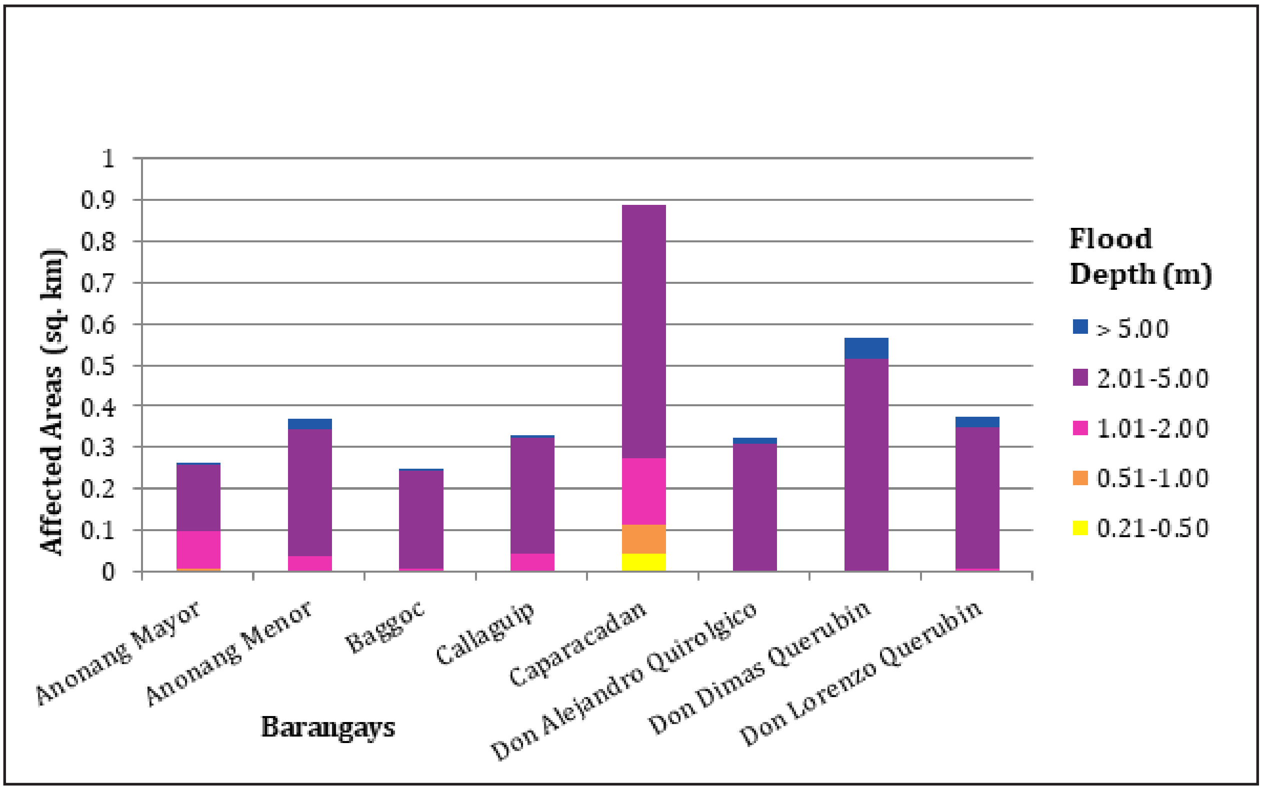


Figure 99. Affected Areas in Caoayan, Ilocos Sur during 5-Year Rainfall Return Period.

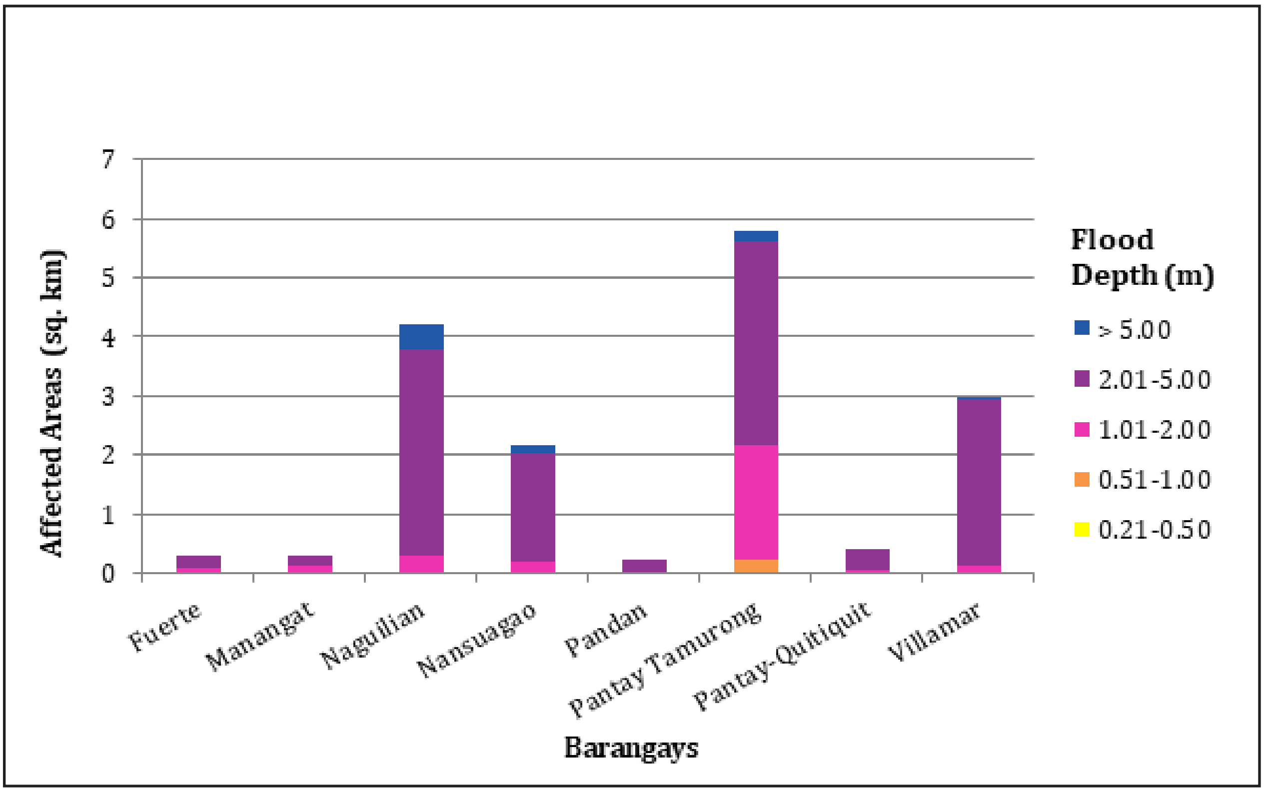


Figure 100. Affected Areas in Caoayan, Ilocos Sur during 5-Year Rainfall Return Period.

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

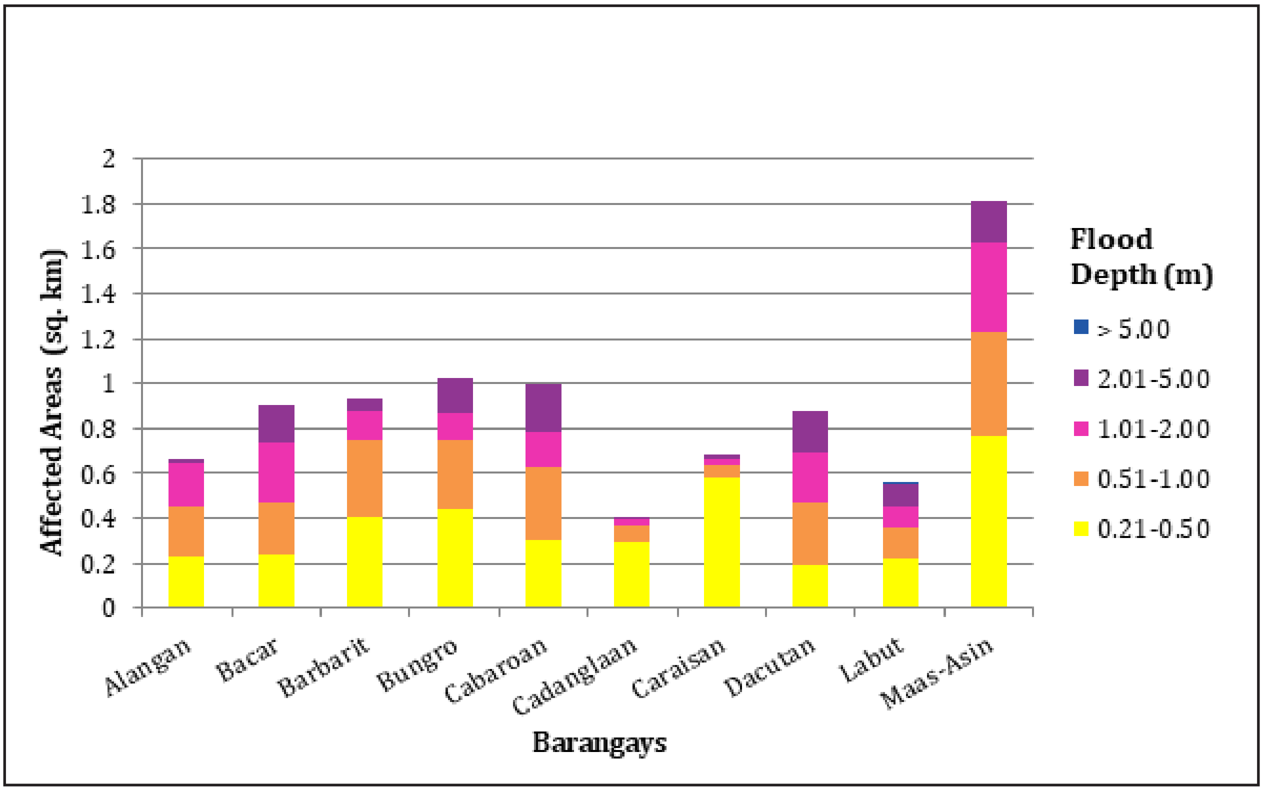


Figure 101. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

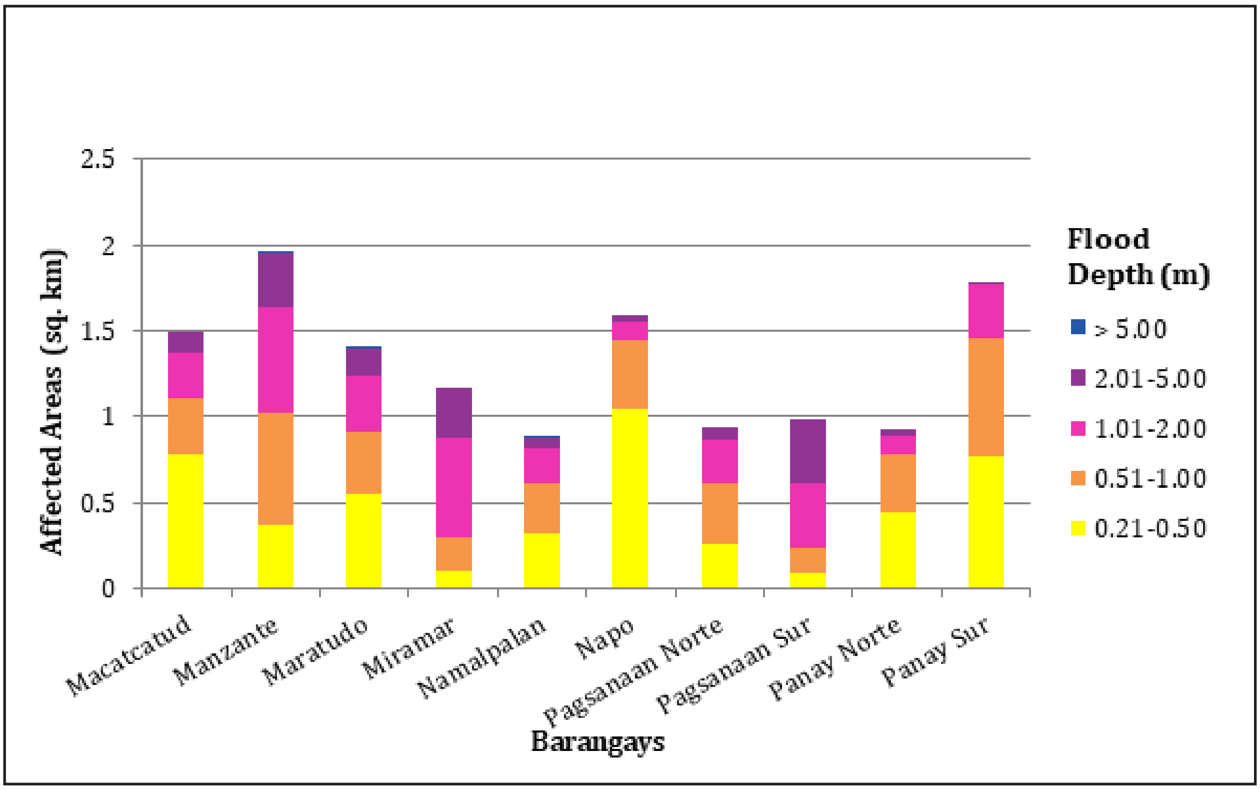


Figure 102. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

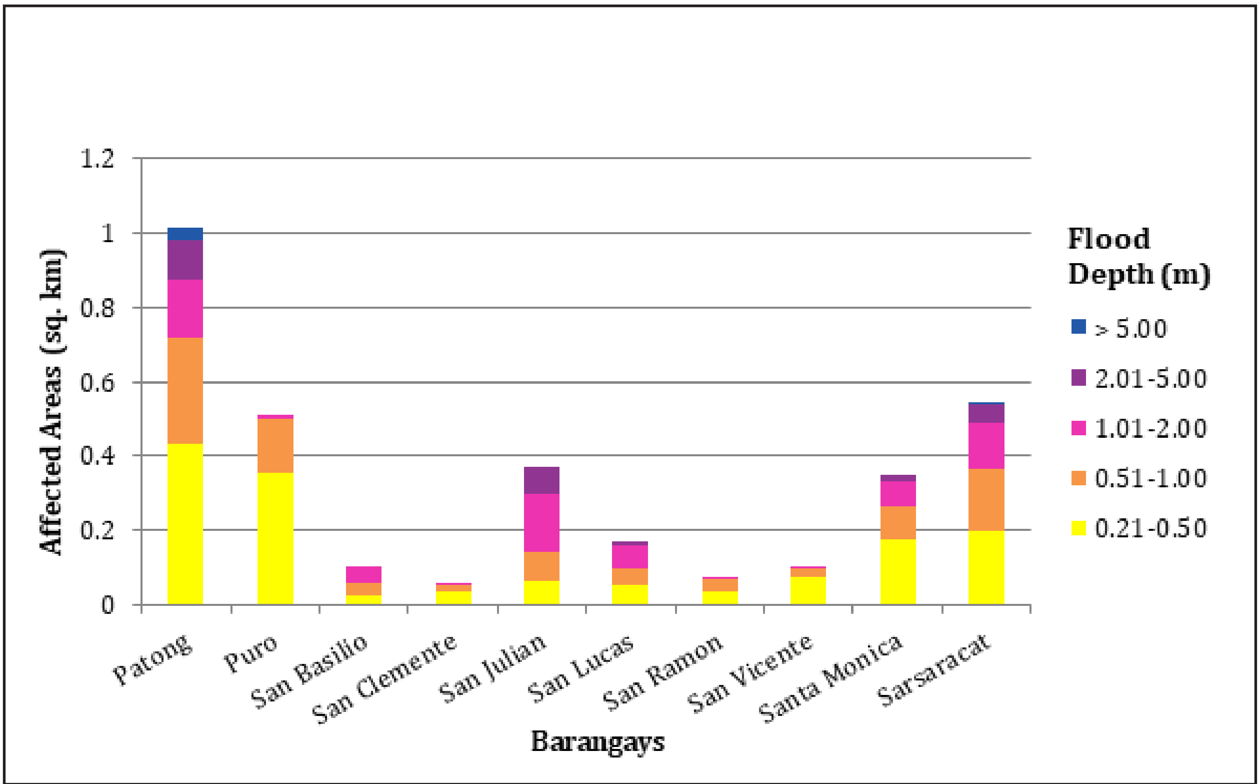


Figure 103. Affected Areas in Magsingal, Ilocos Sur during 5-Year Rainfall Return Period.

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

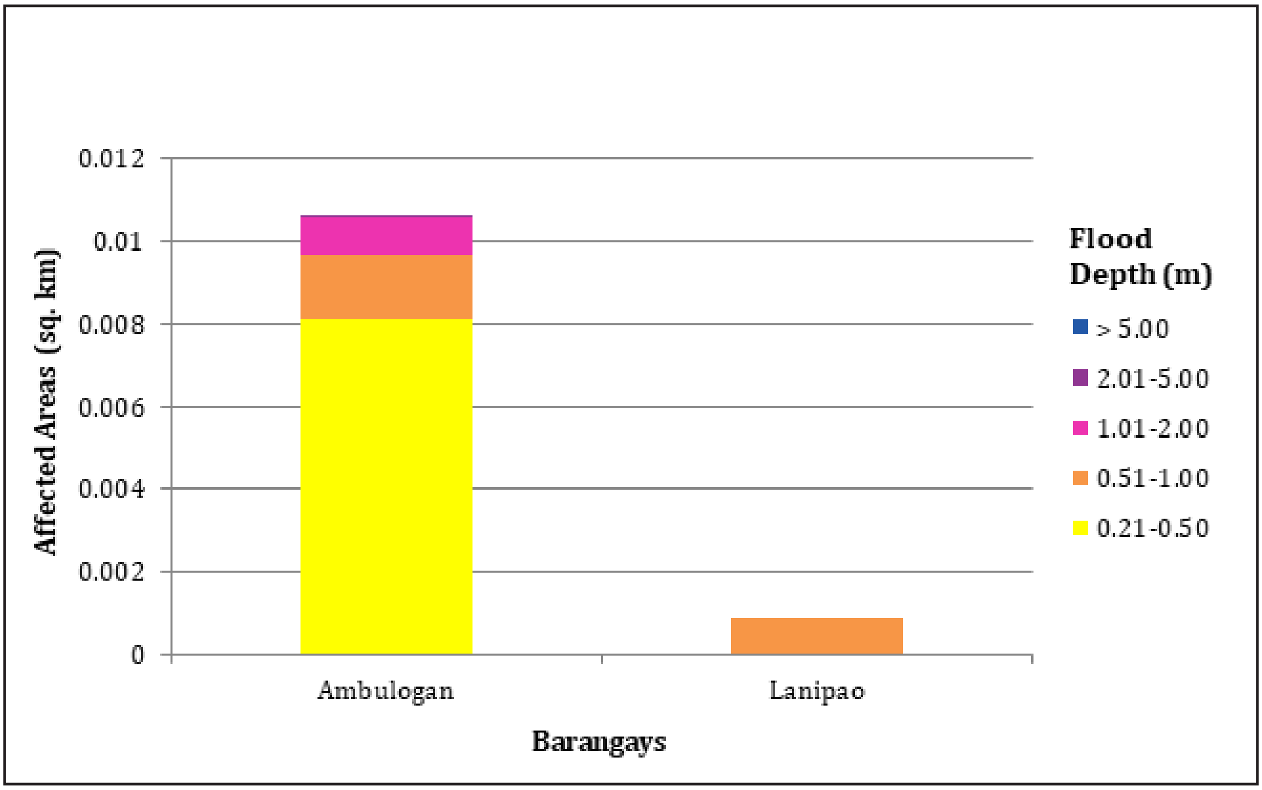


Figure 104. Affected Areas in Narvacan, Ilocos Sur during 5-Year Rainfall Return Period.

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

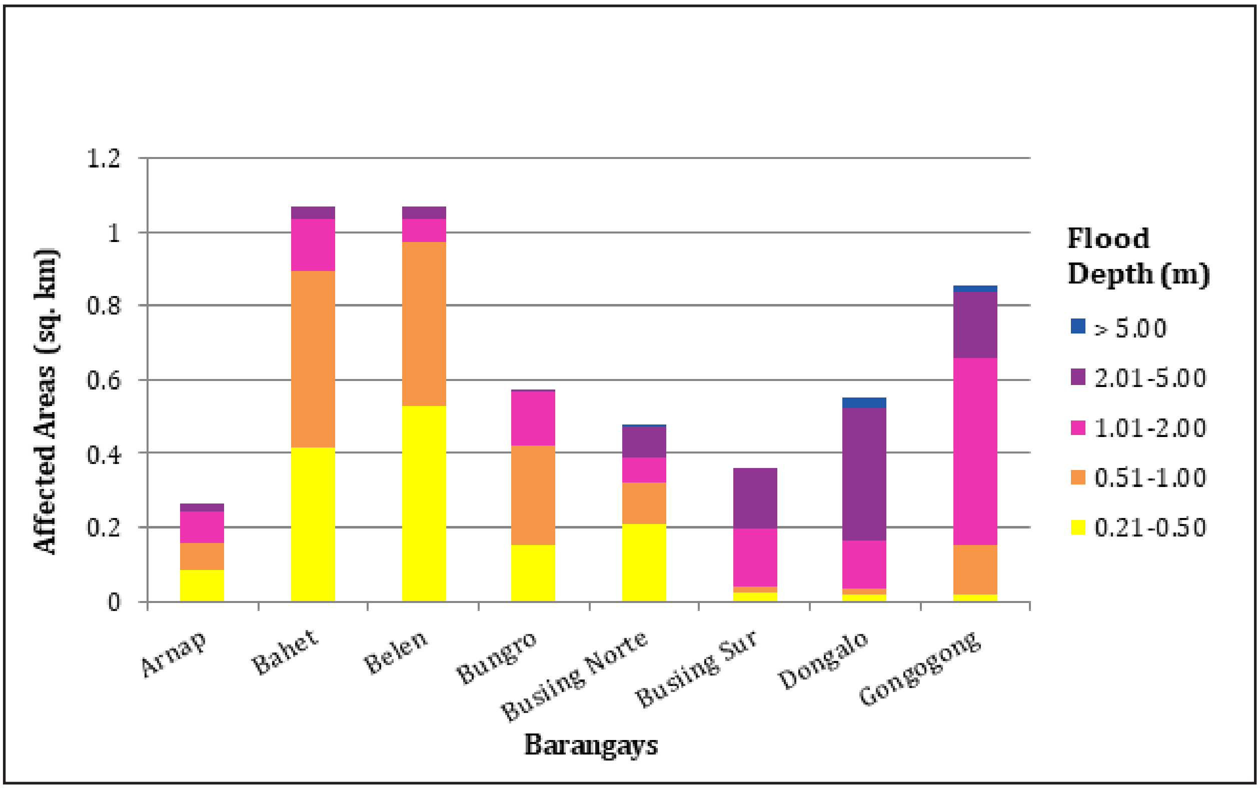


Figure 105. Affected Areas in San Ildefonso, Ilocos Sur during 5-Year Rainfall Return Period.

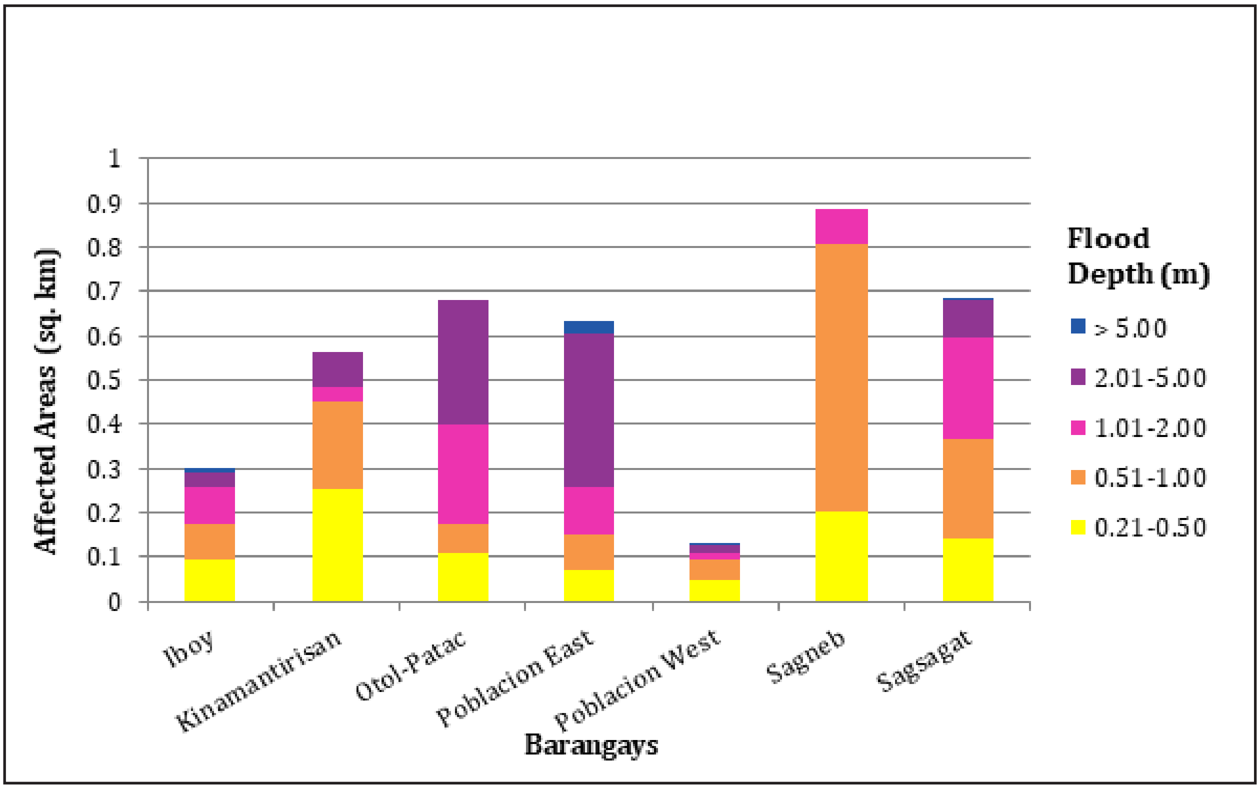


Figure 106. Affected Areas in San Ildefonso, Ilocos Sur during 5-Year Rainfall Return Period.

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

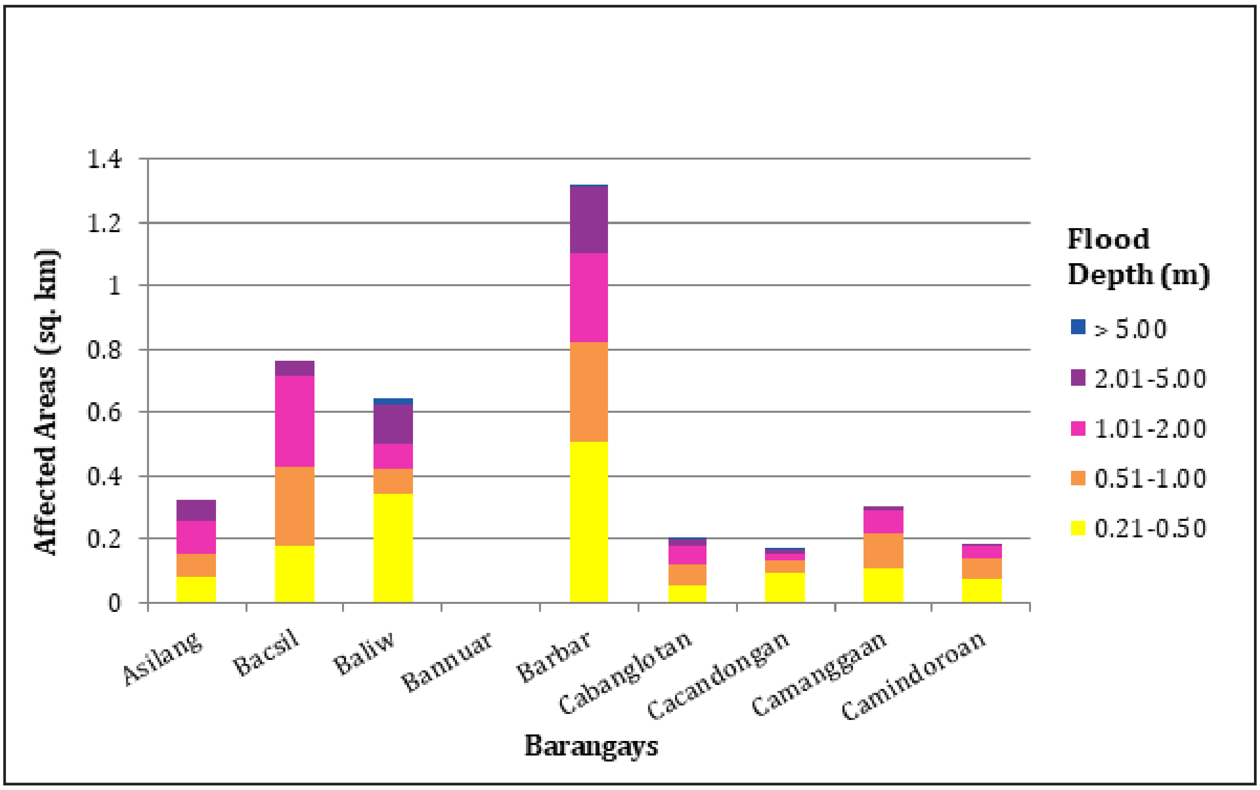


Figure 107. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

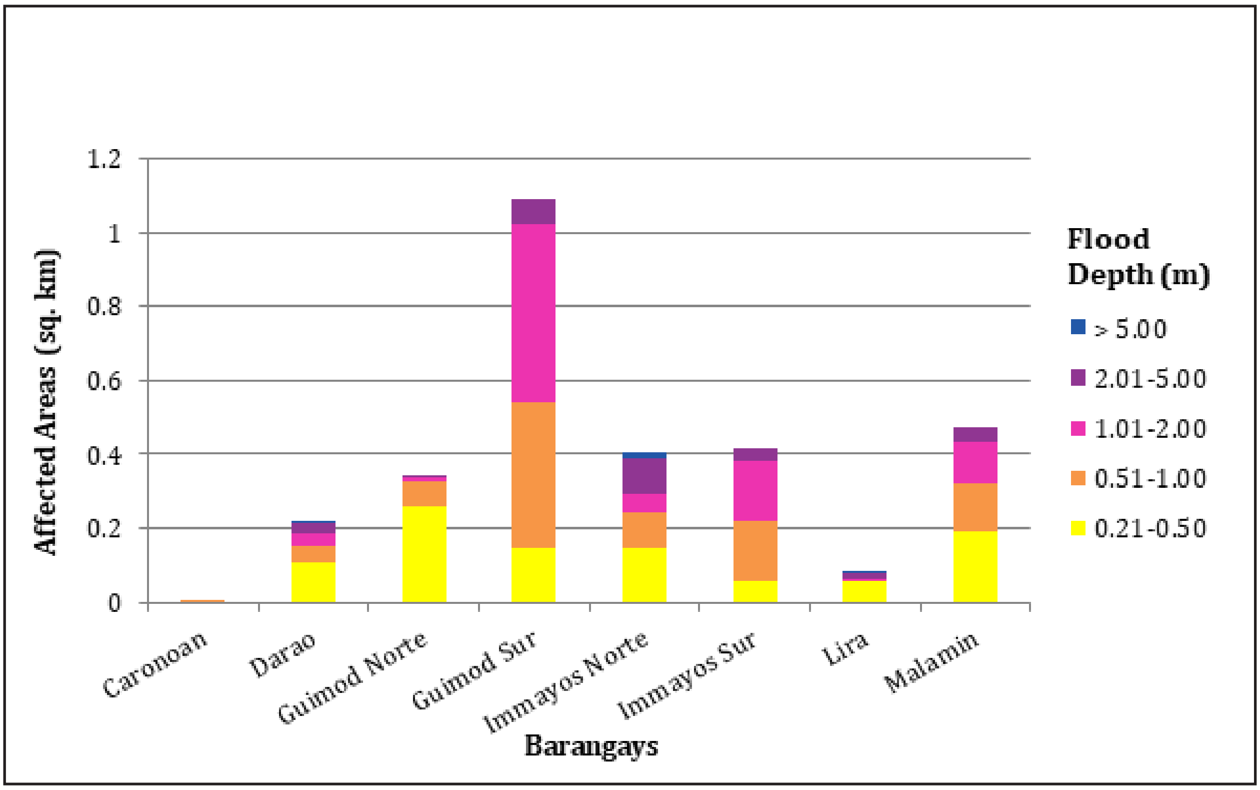


Figure 108. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

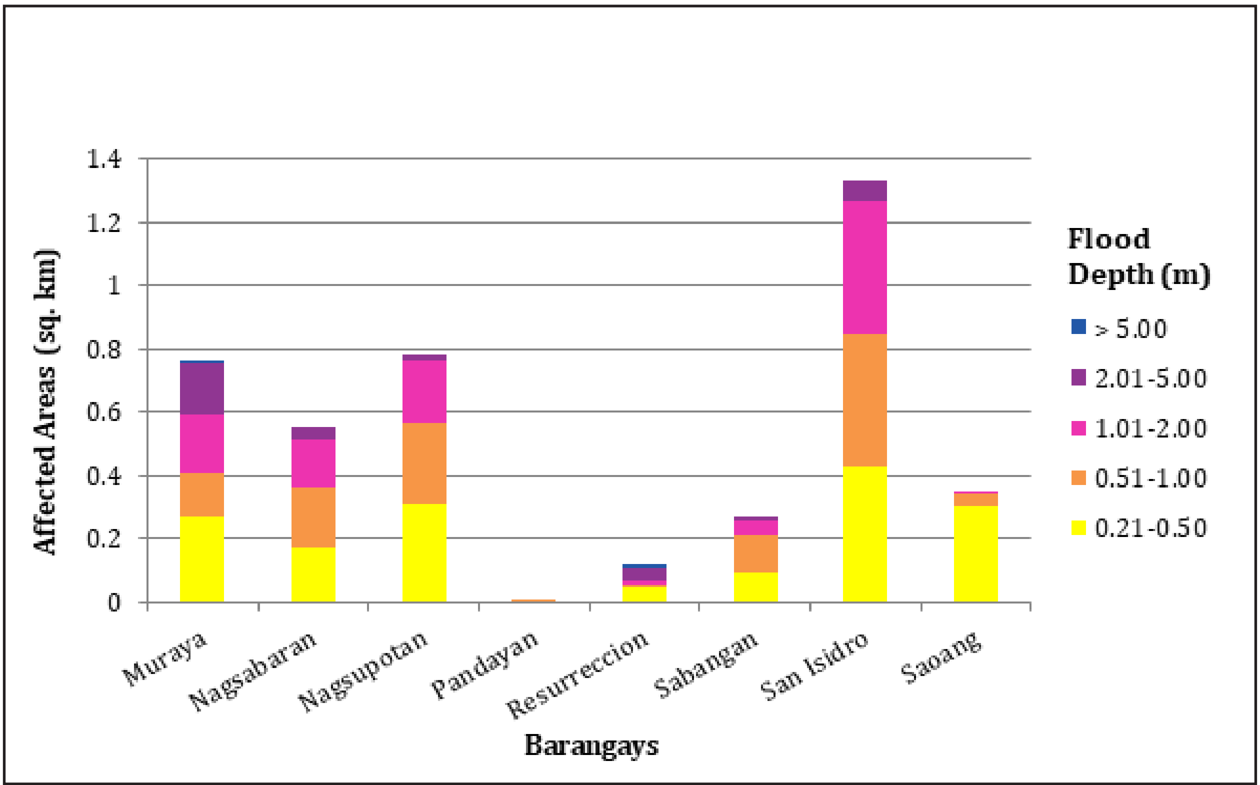


Figure 109. Affected Areas in San Juan, Ilocos Sur during 5-Year Rainfall Return Period.

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

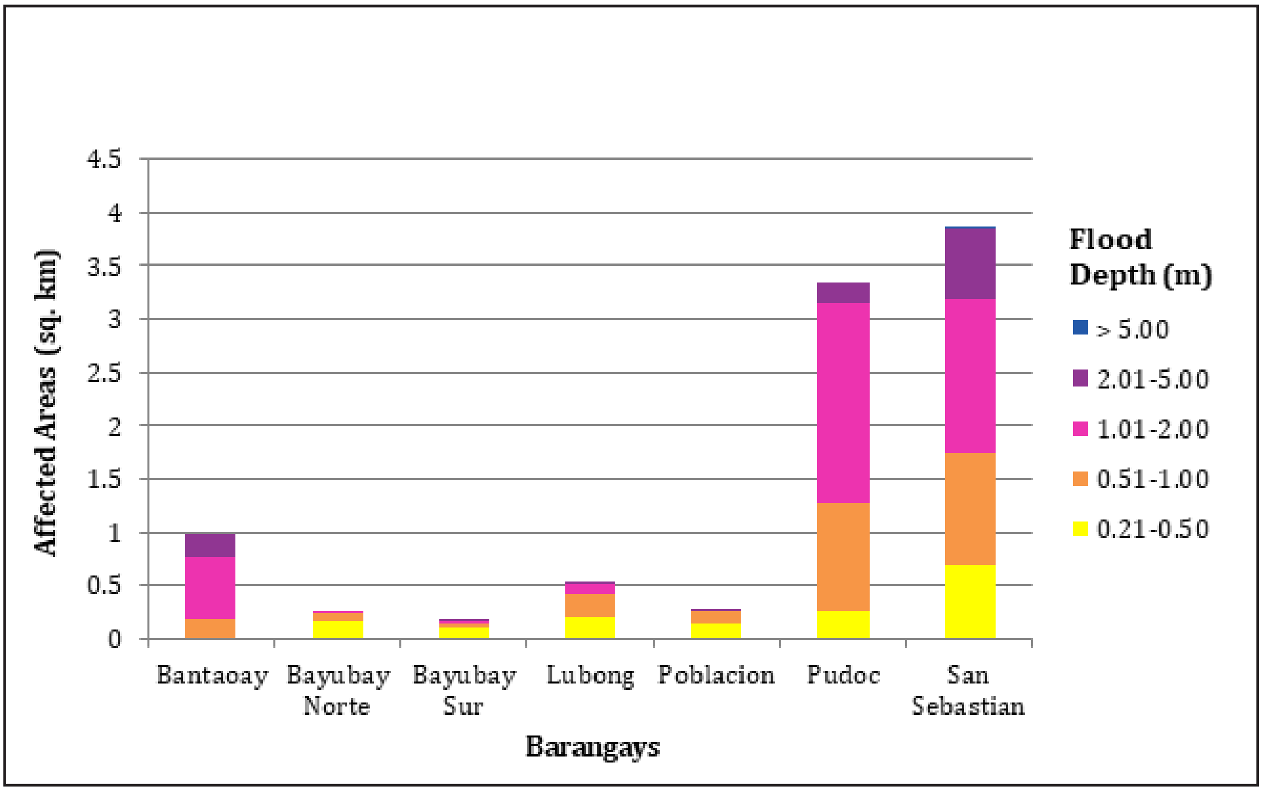


Figure 110. Affected Areas in San Vicente, Ilocos Sur during 5-Year Rainfall Return Period.

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

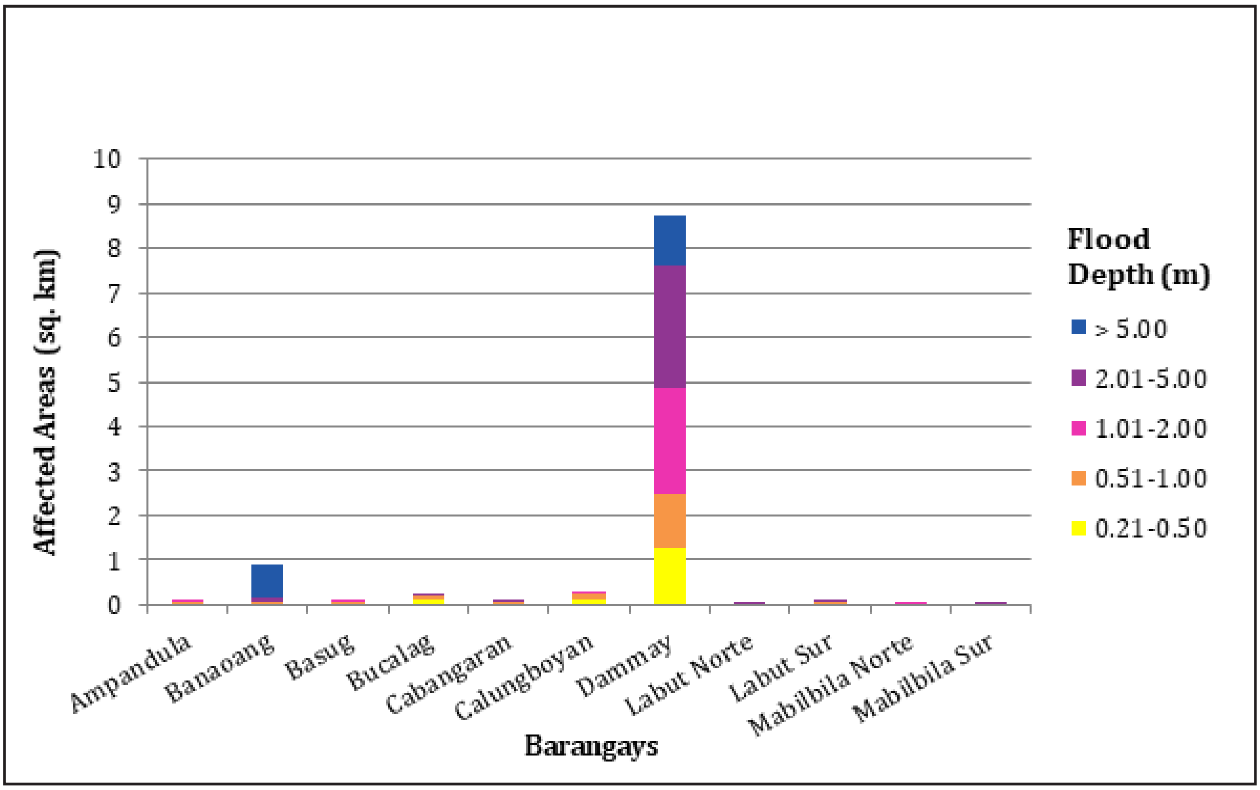


Figure 111. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period.

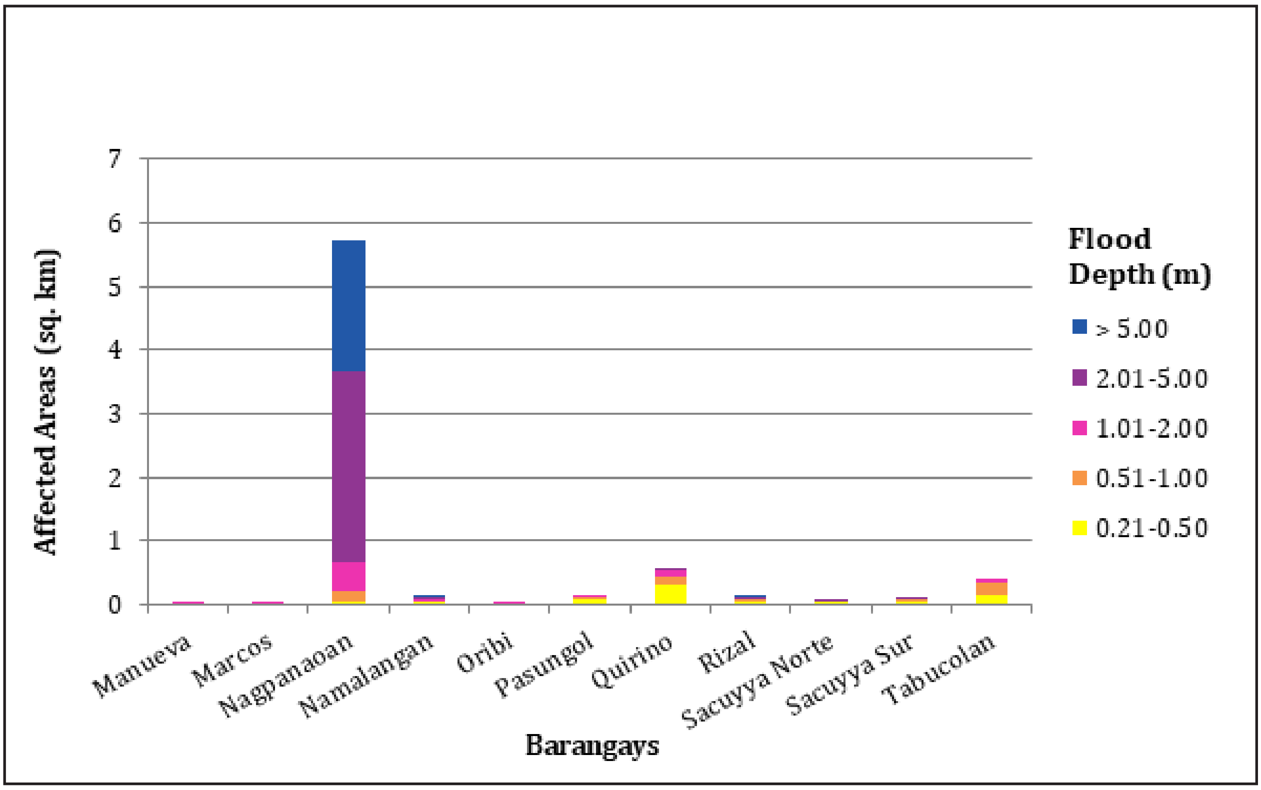


Figure 112. Affected Areas in Santa, Ilocos Sur during 5-Year Rainfall Return Period.

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

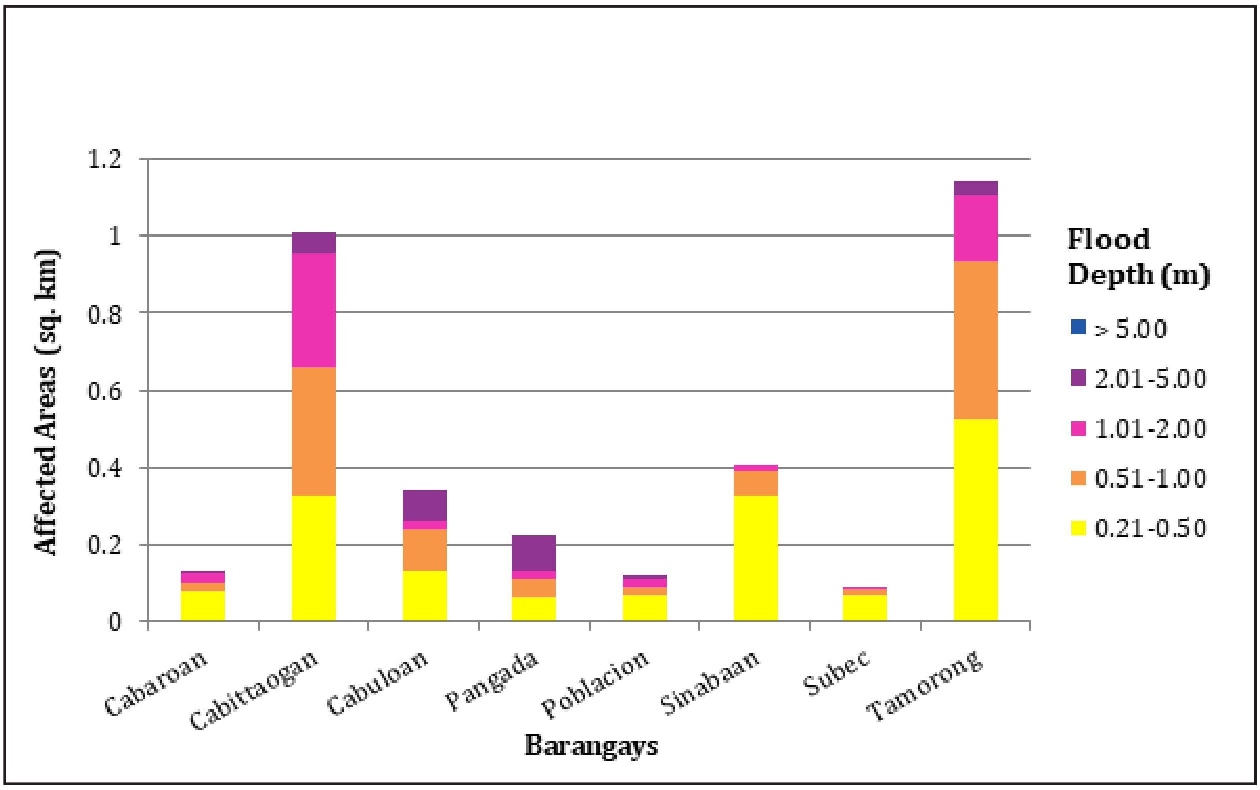


Figure 113. Affected Areas in Santa Catalina, Ilocos Sur during 5-Year Rainfall Return Period.

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

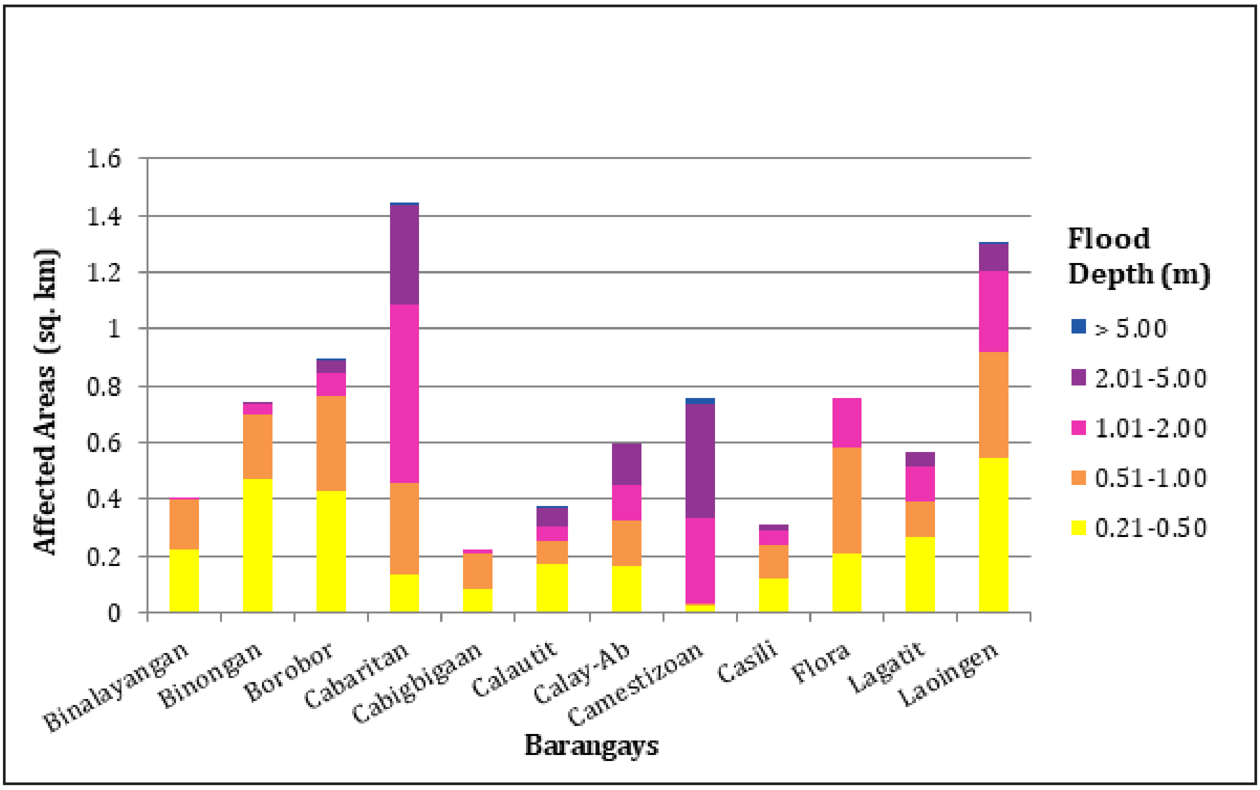


Figure 114. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

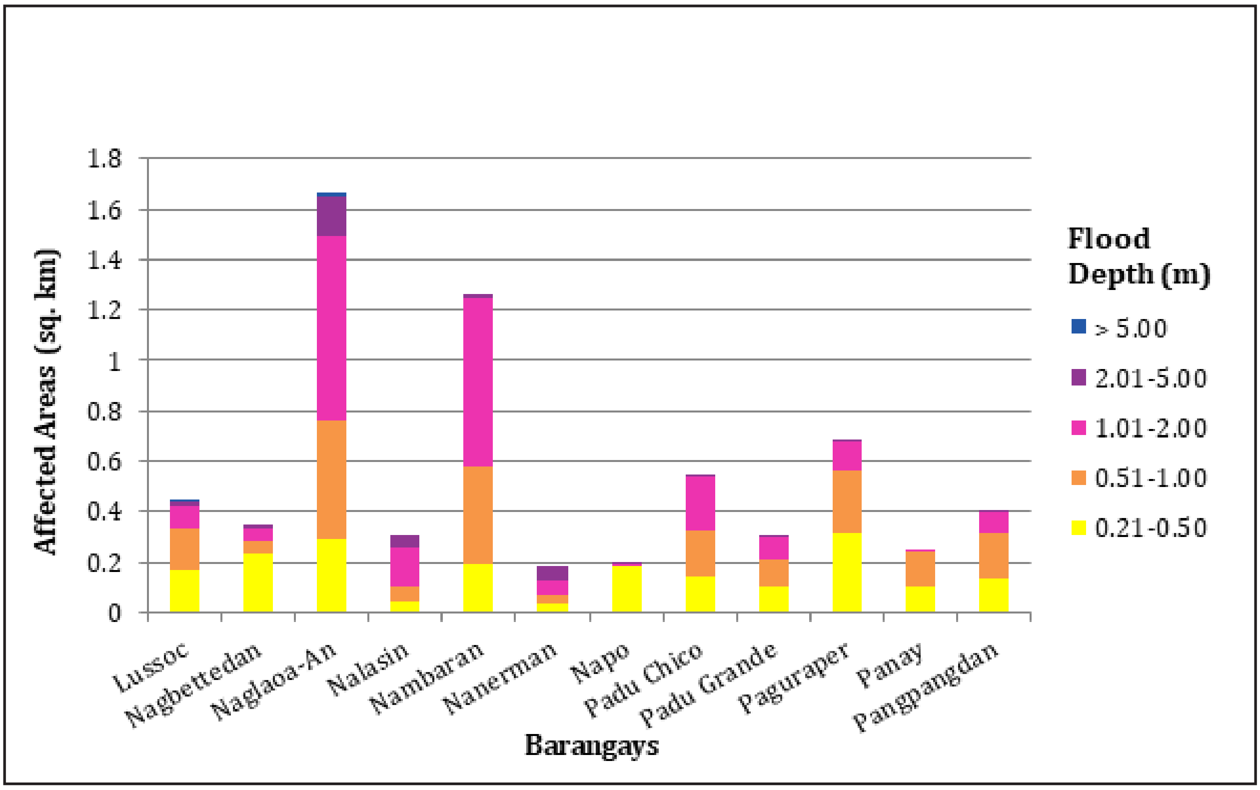


Figure 115. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

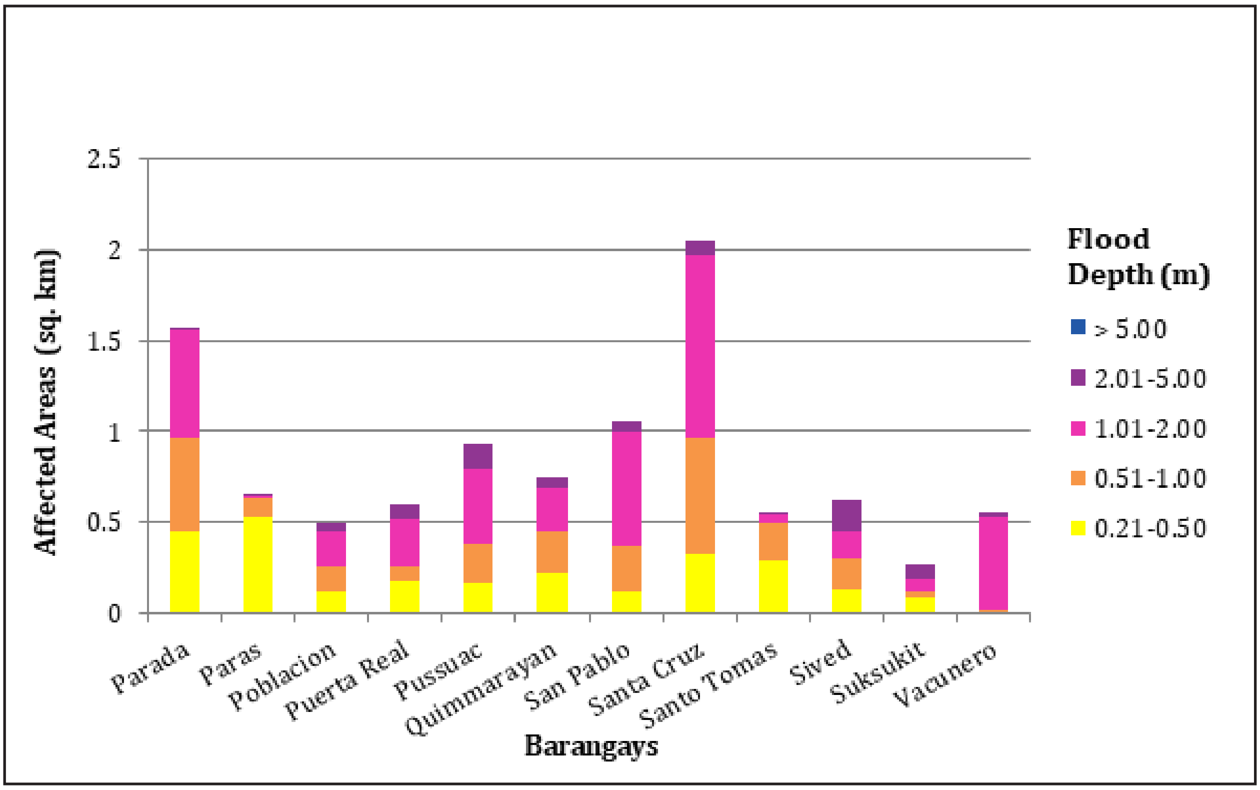


Figure 116. Affected Areas in Santo Domingo, Ilocos Sur during 5-Year Rainfall Return Period.

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

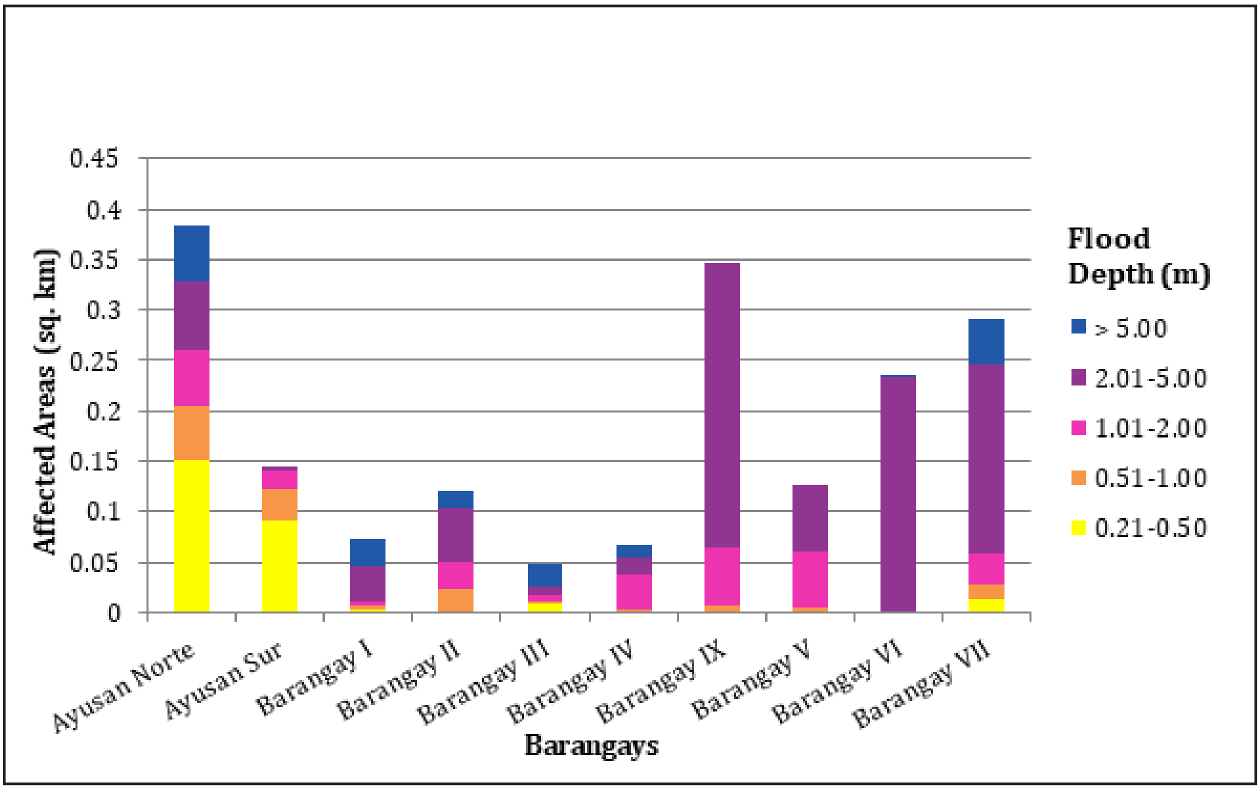


Figure 117. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

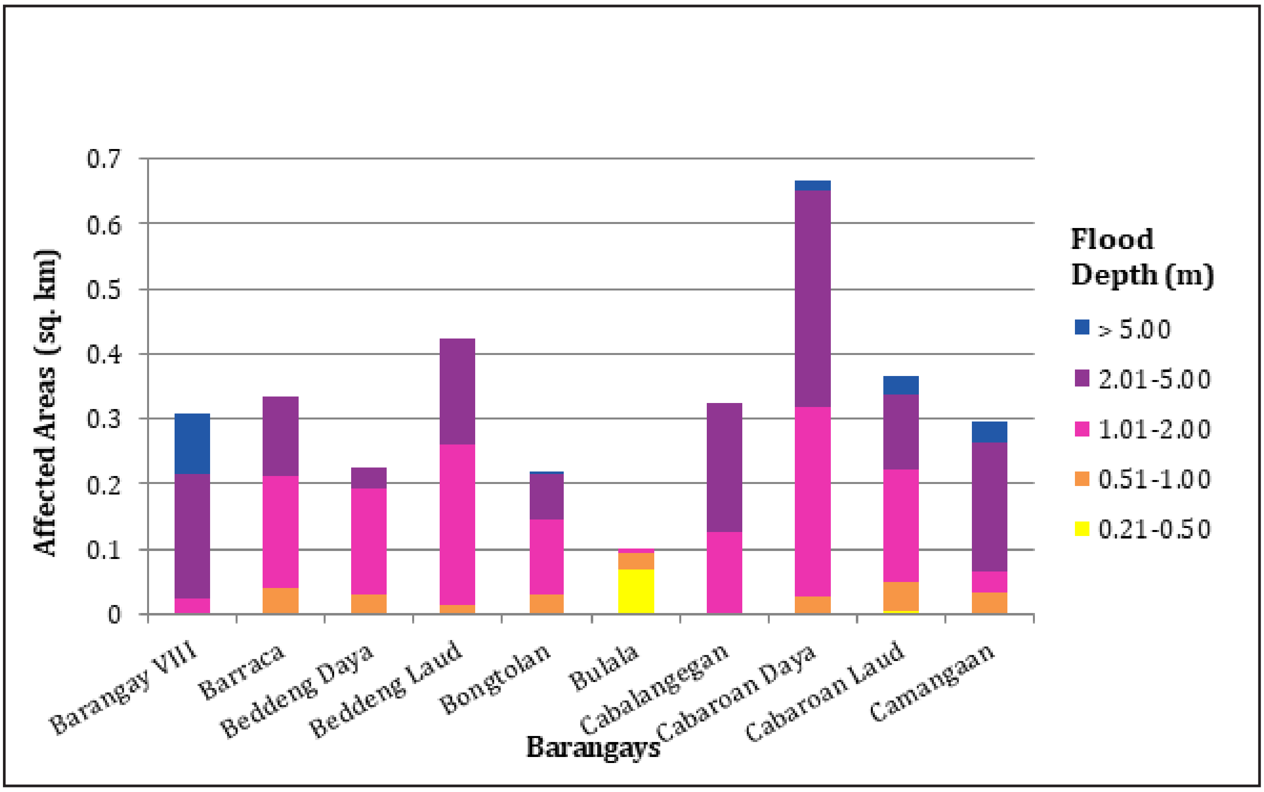


Figure 118. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

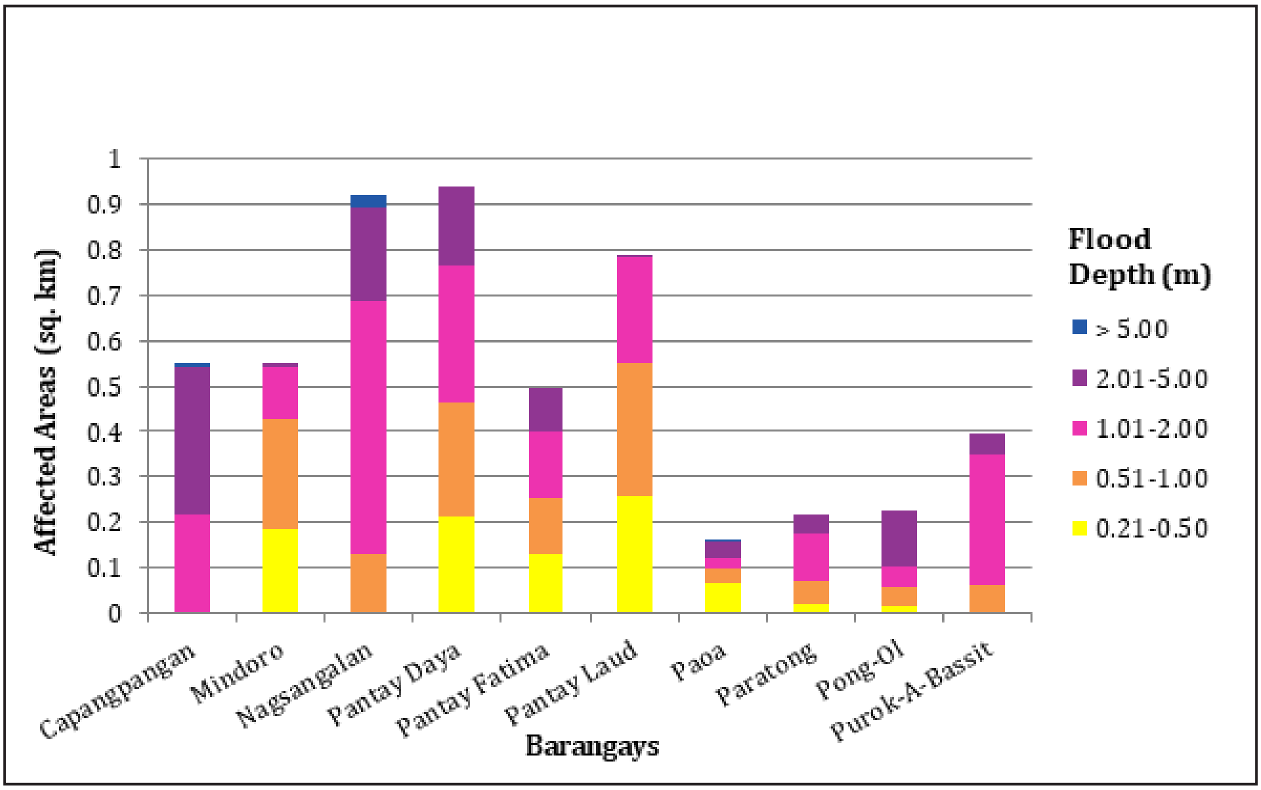


Figure 119. Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

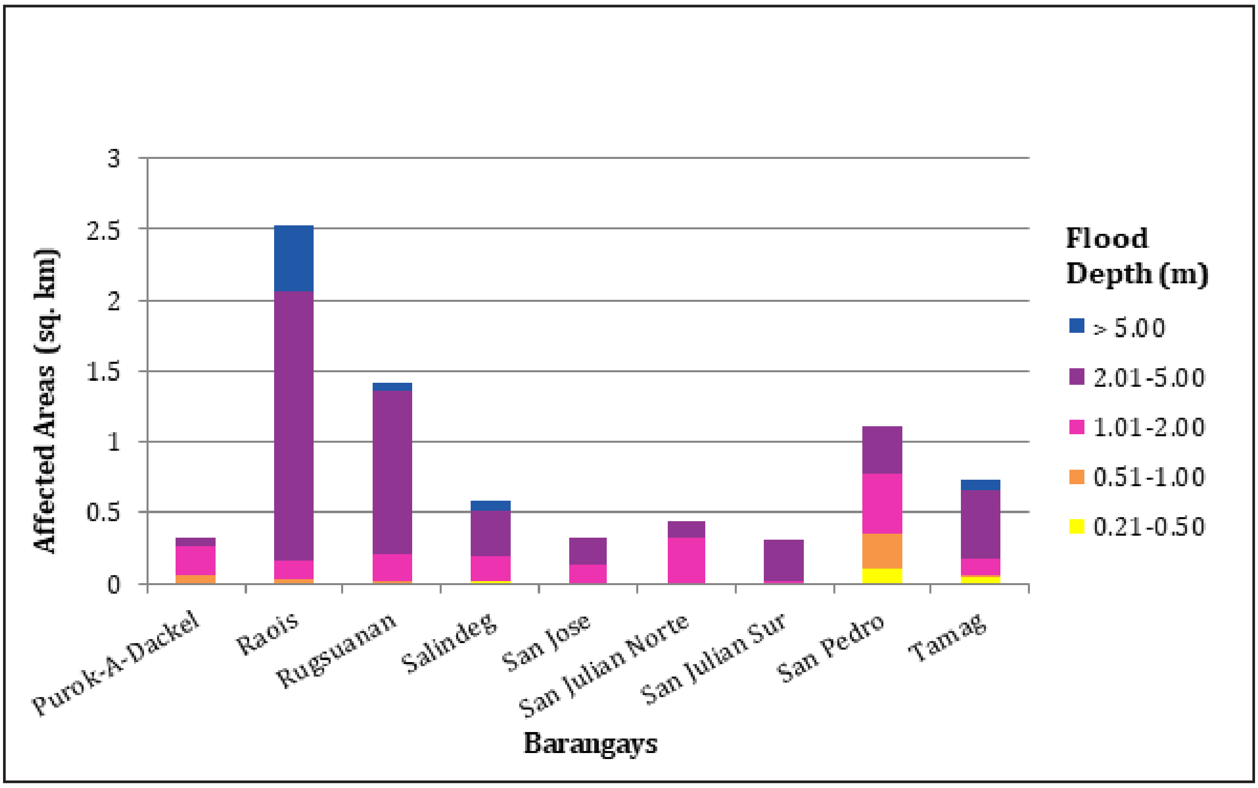


Figure 120 Affected Areas in Vigan City, Ilocos Sur during 5-Year Rainfall Return Period.

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

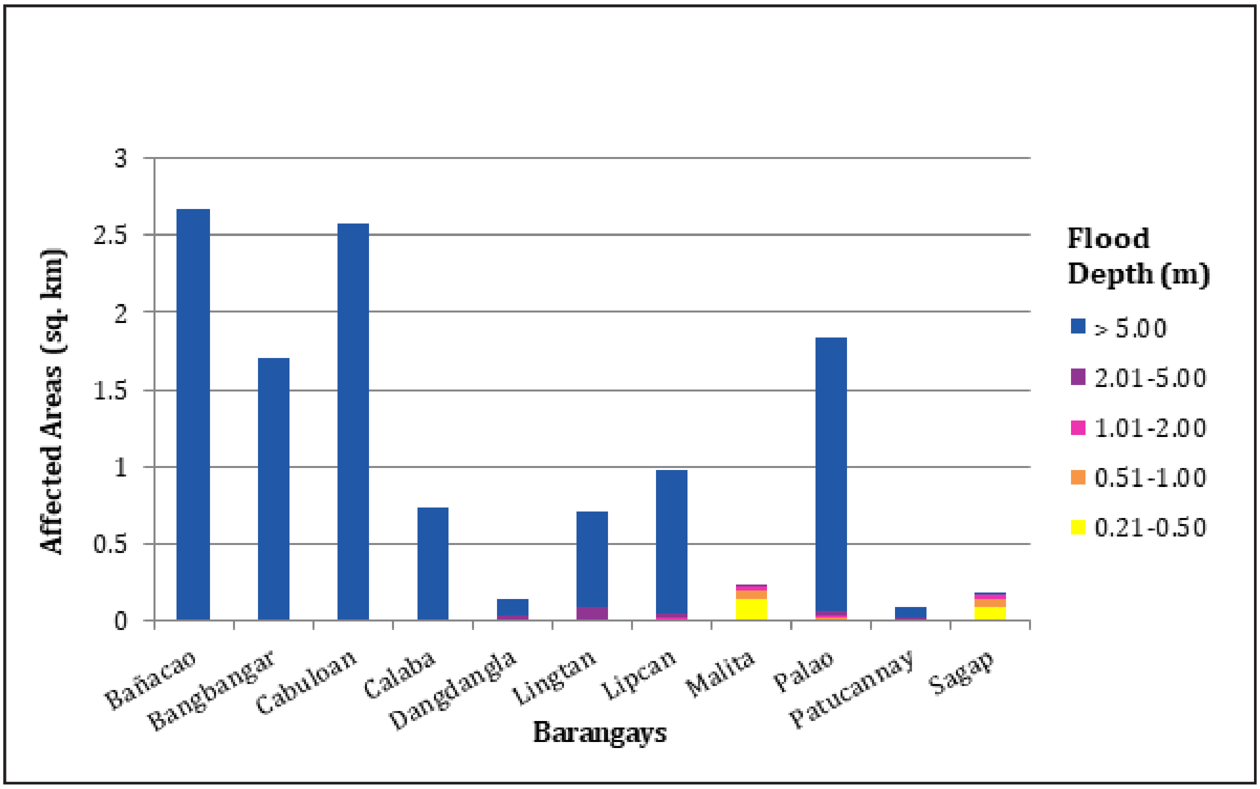


Figure 121. Affected Areas in Bangued, Abra during 25-Year Rainfall Return Period.

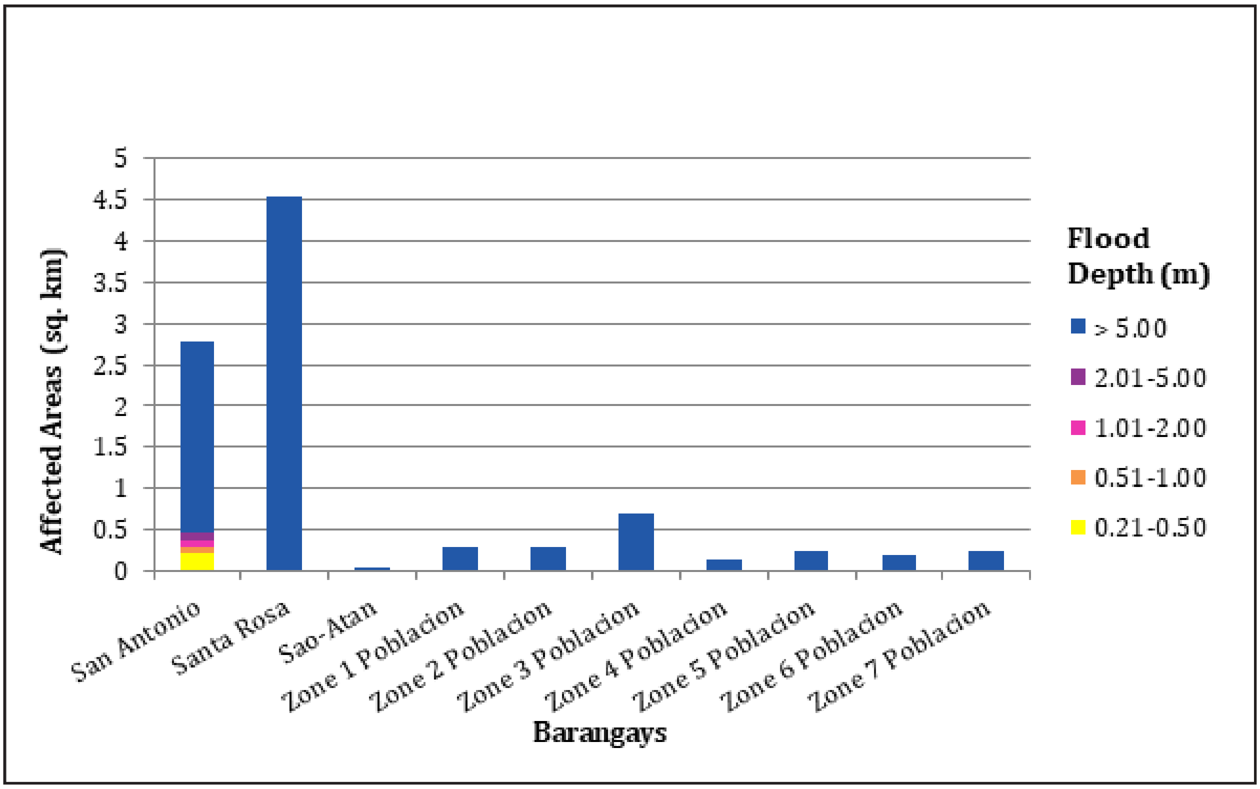


Figure 122. Affected Areas in Bangued, Abra during 25-Year Rainfall Return Period.

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

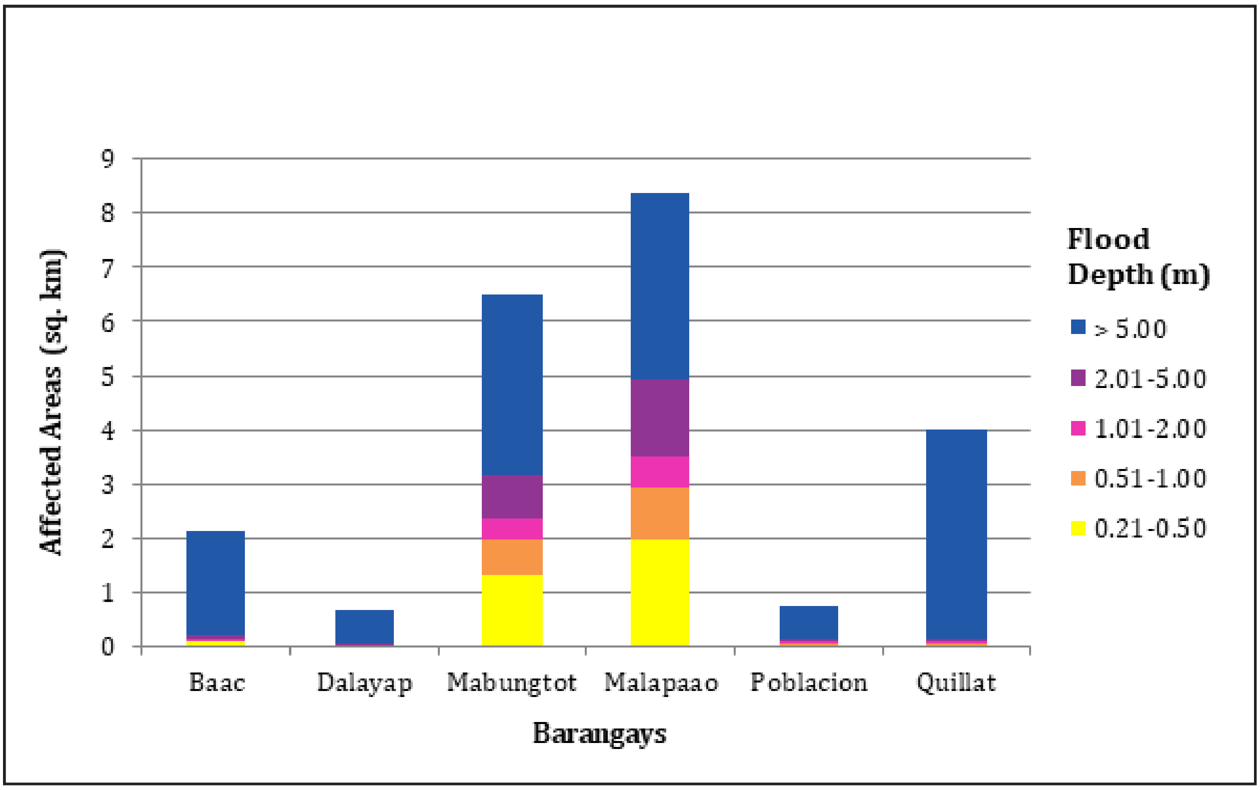


Figure 123. Affected Areas in Langiden, Abra during 25-Year Rainfall Return Period.

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

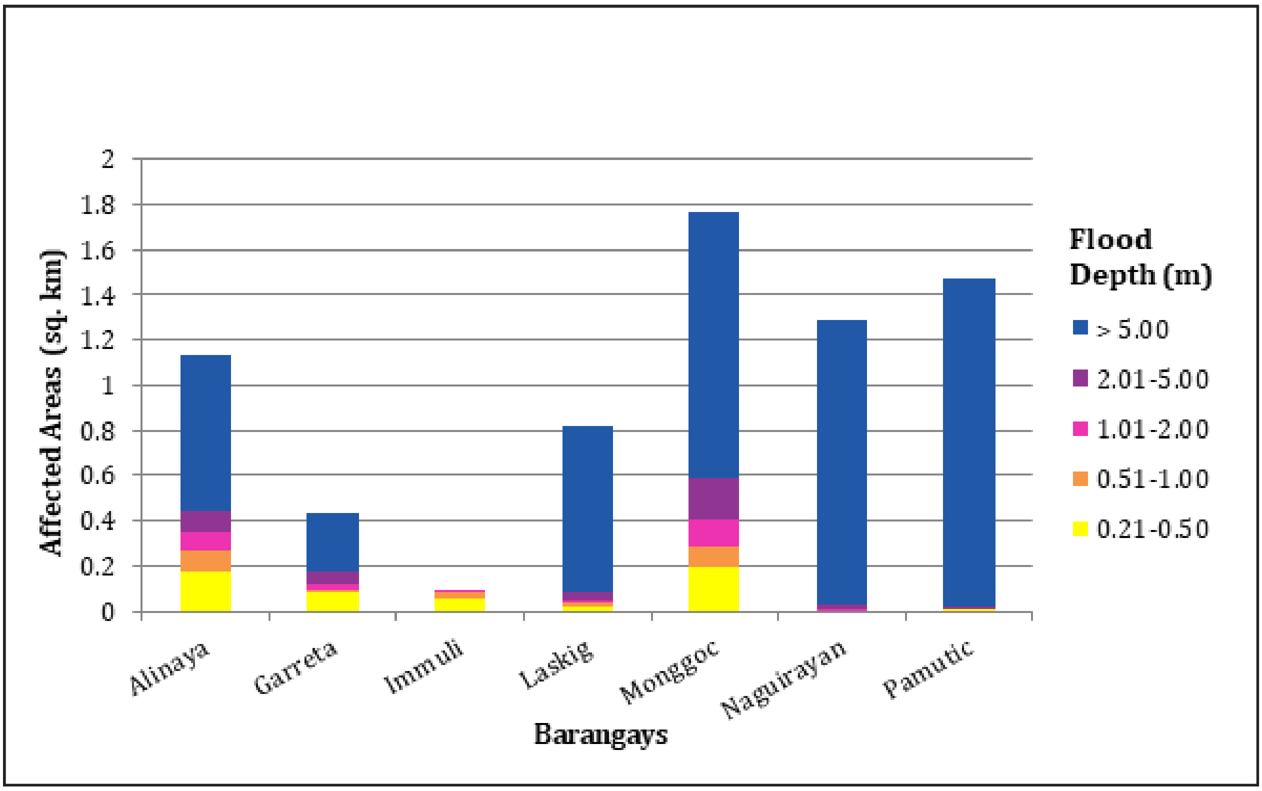


Figure 124. Affected Areas in Pidigan, Abra during 25-Year Rainfall Return Period.

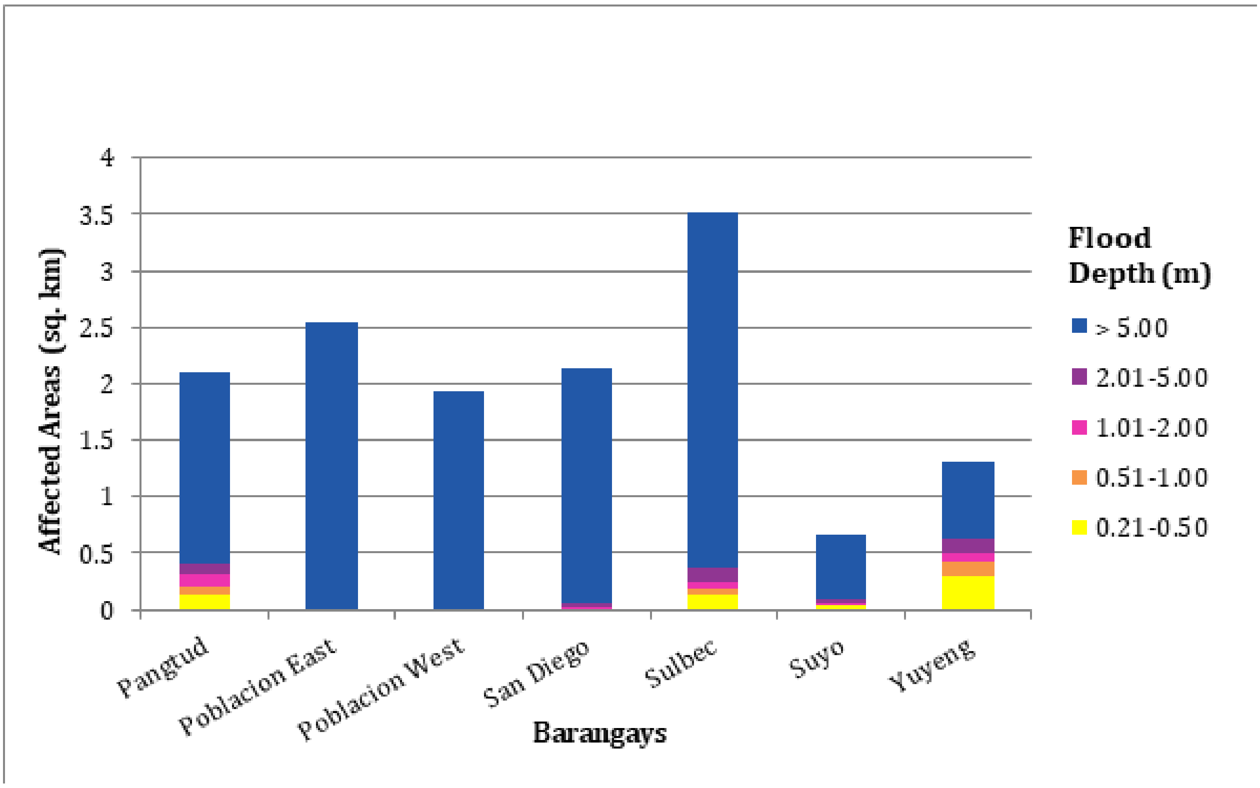


Figure 125. Affected Areas in Pidigan, Abra during 25-Year Rainfall Return Period.

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

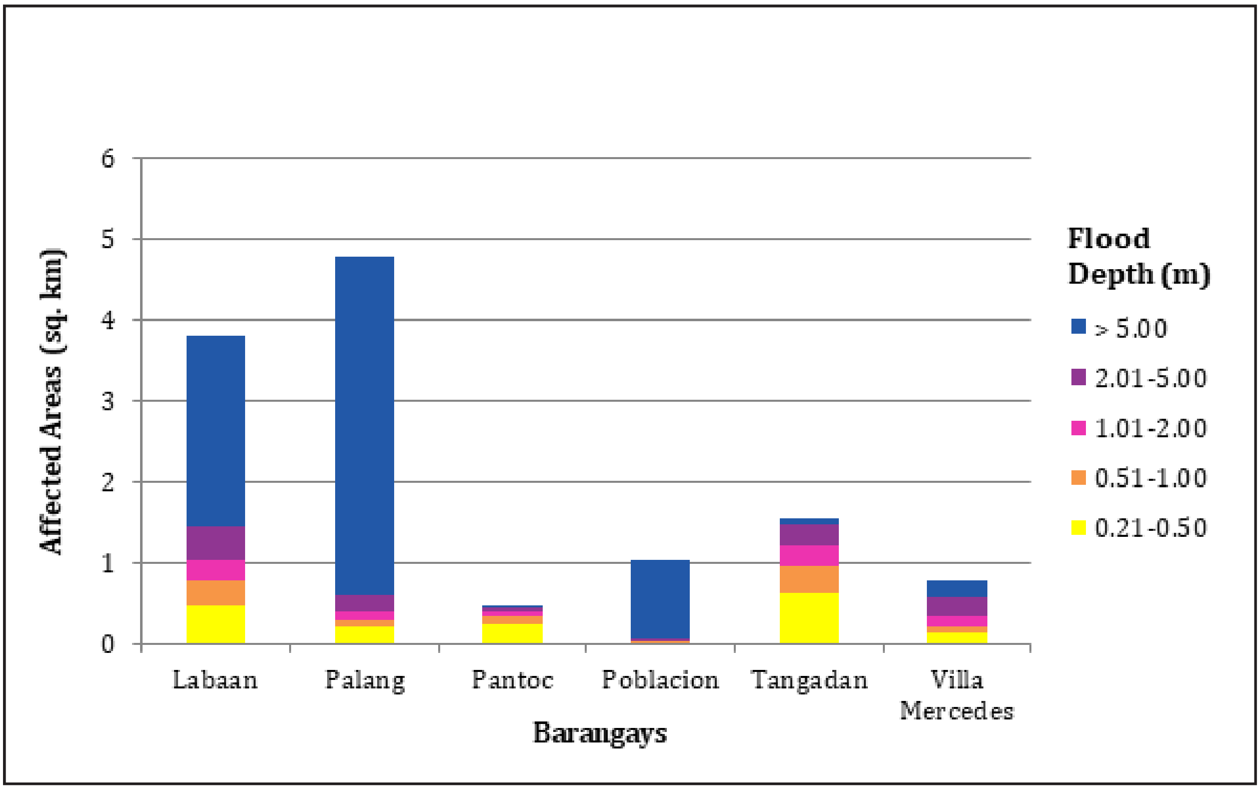


Figure 126. Affected Areas in San Quintin, Abra during 25-Year Rainfall Return Period.

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

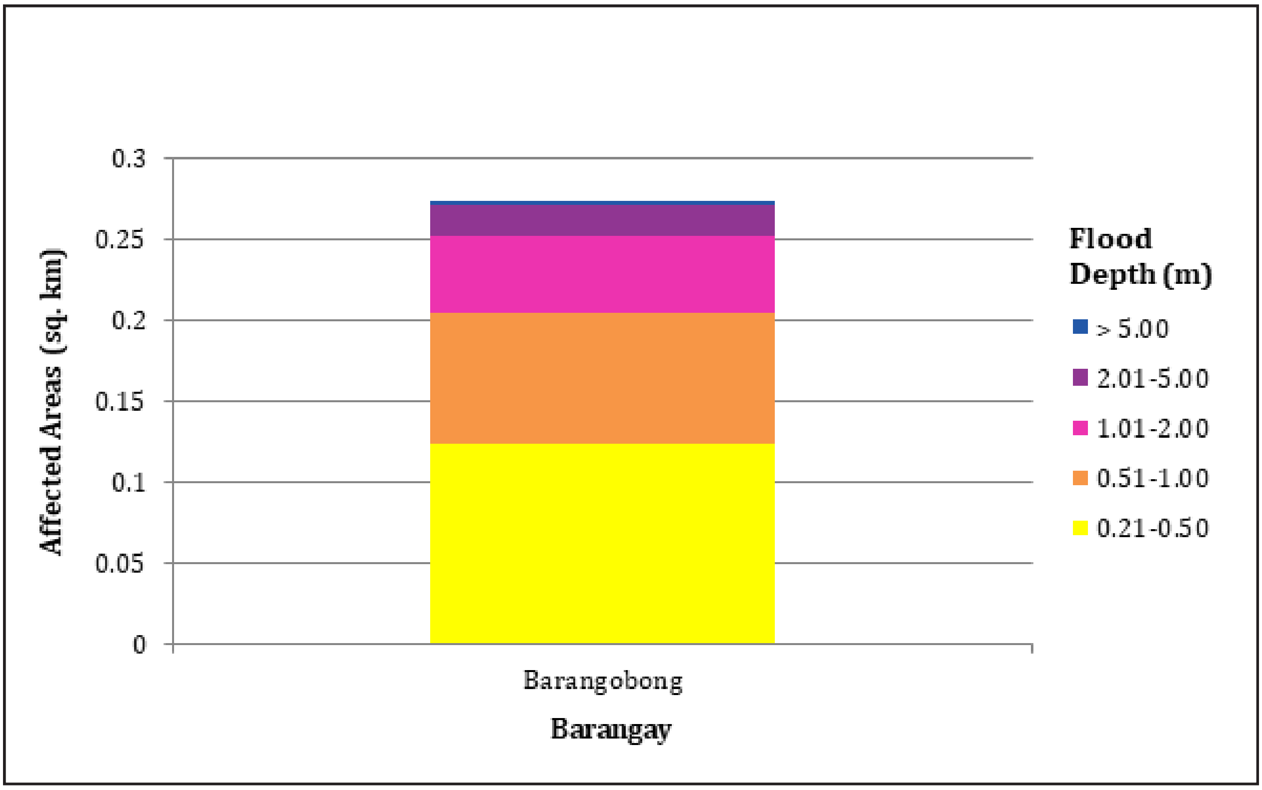


Figure 127. Affected Areas in Nueva Era, Ilocos Norte during 25-Year Rainfall Return Period.

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

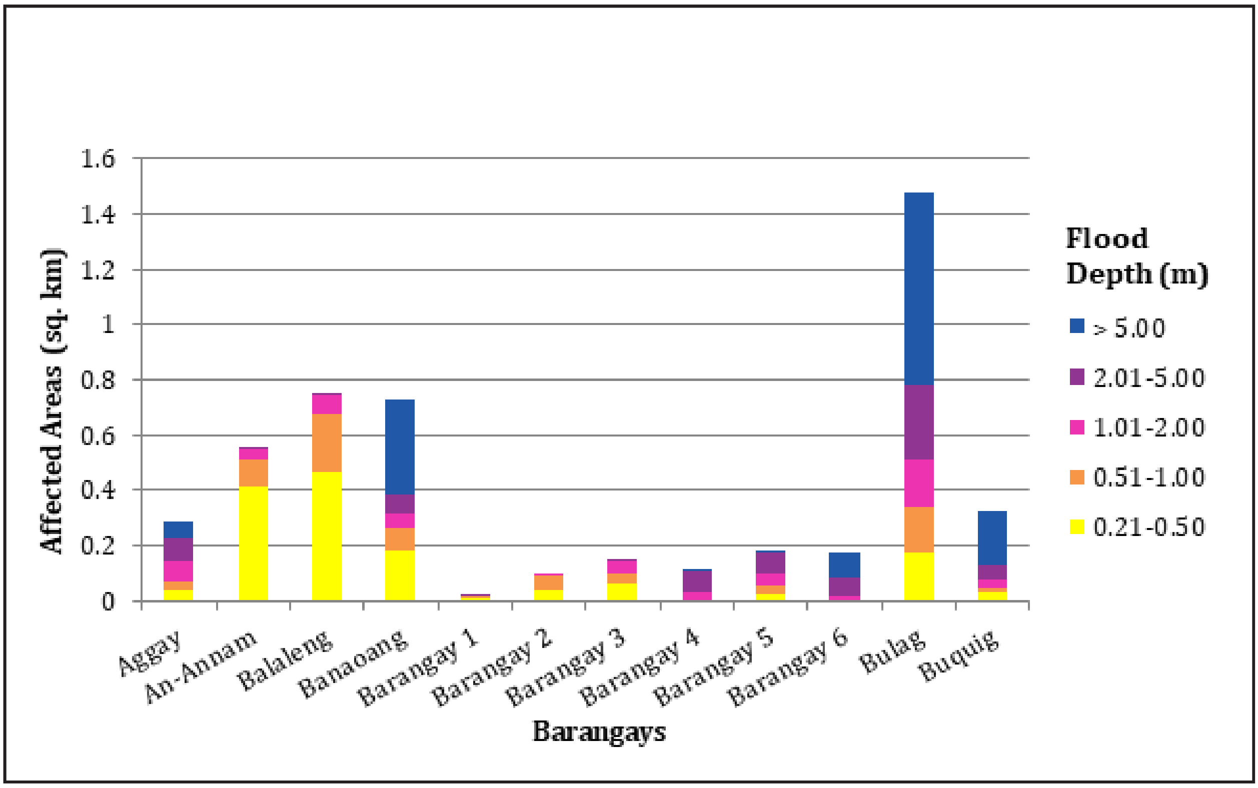


Figure 128. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

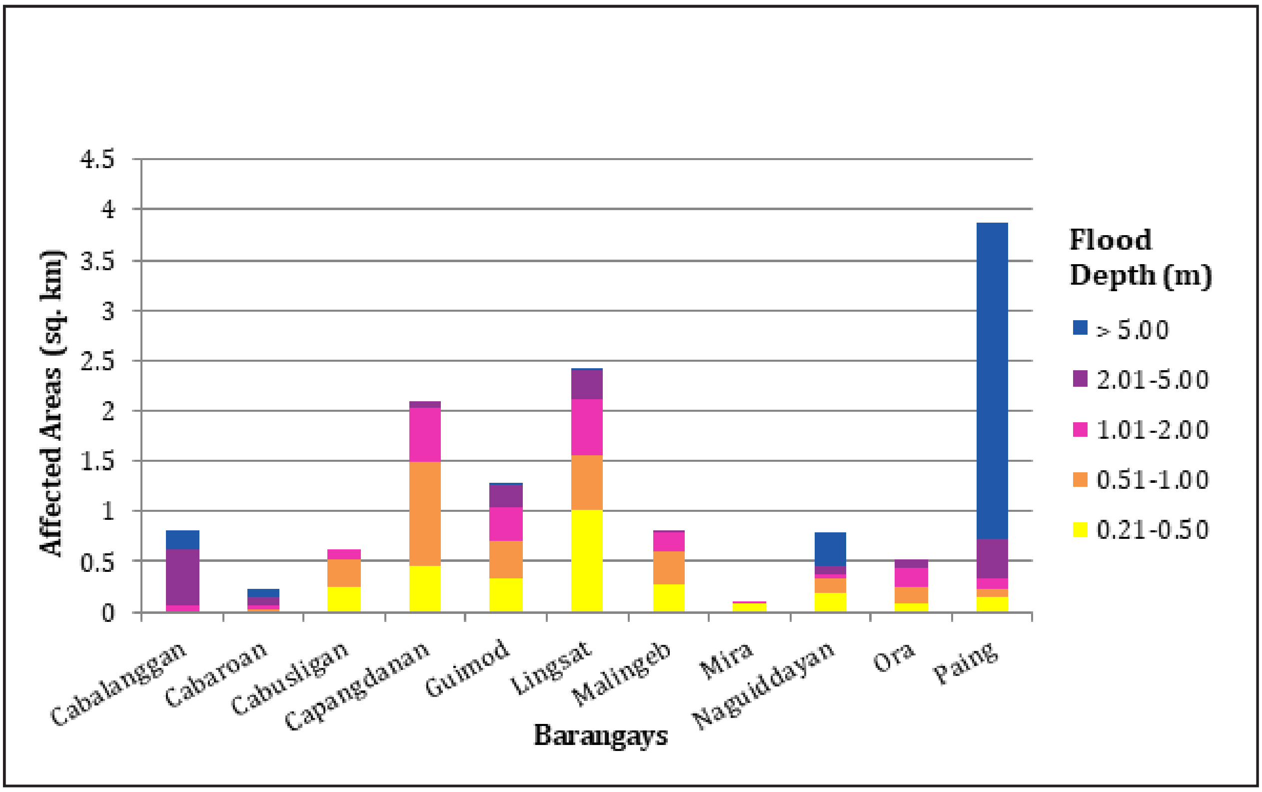


Figure 129. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

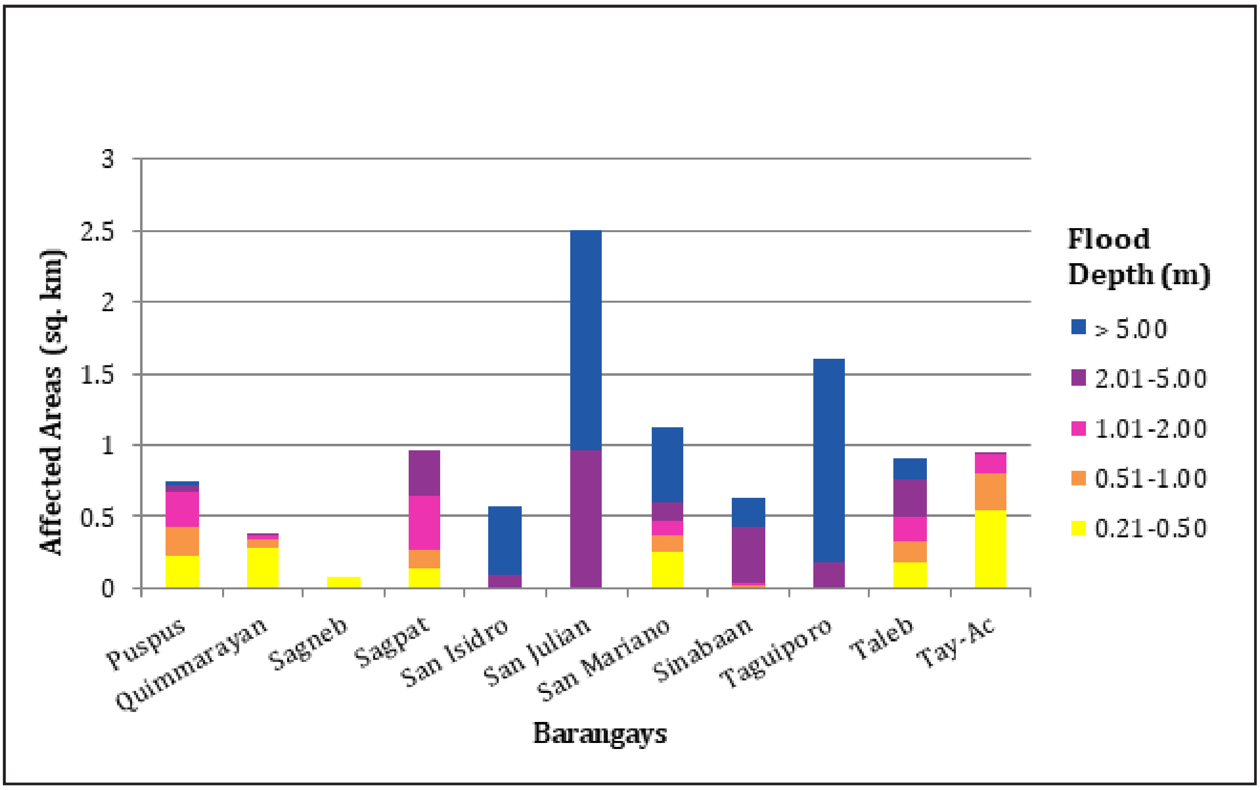


Figure 130. Affected Areas in Bantay, Ilocos Sur during 25-Year Rainfall Return Period.

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

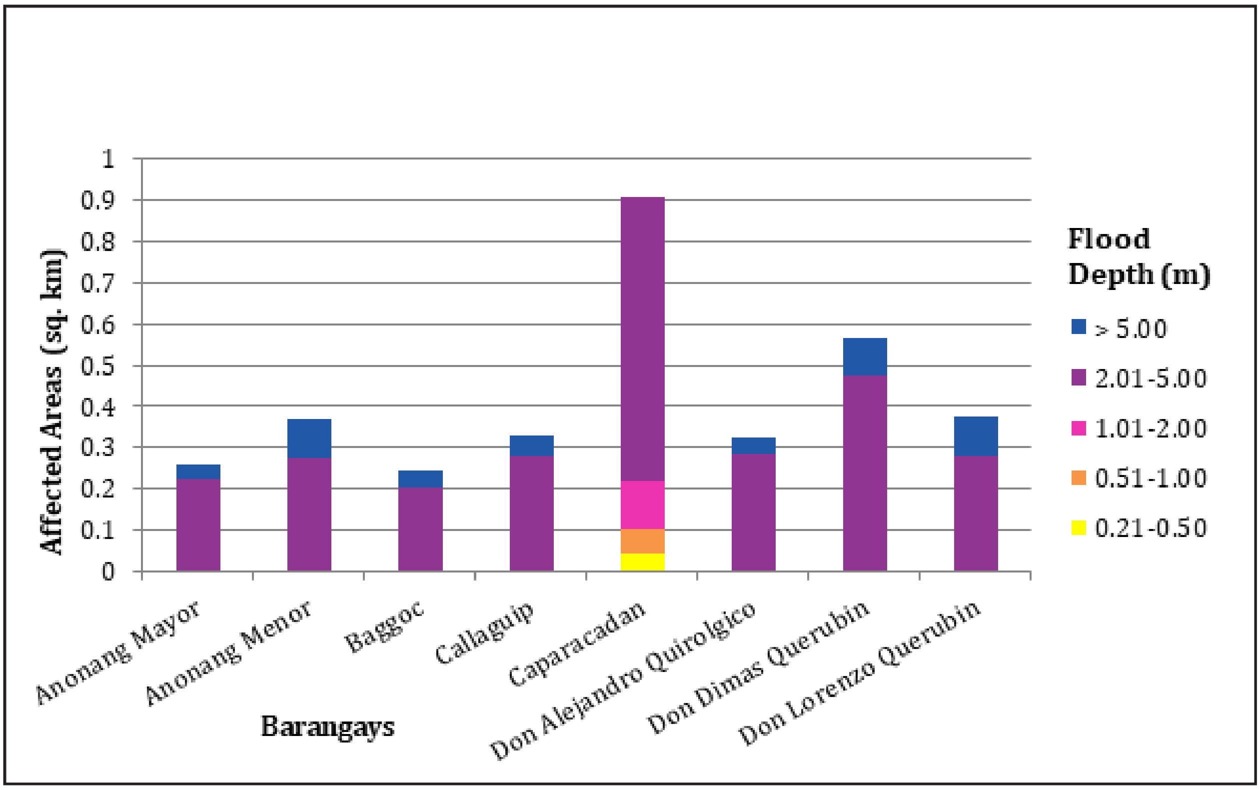


Figure 131. Affected Areas in Caoayan, Ilocos Sur during 25-Year Rainfall Return Period.

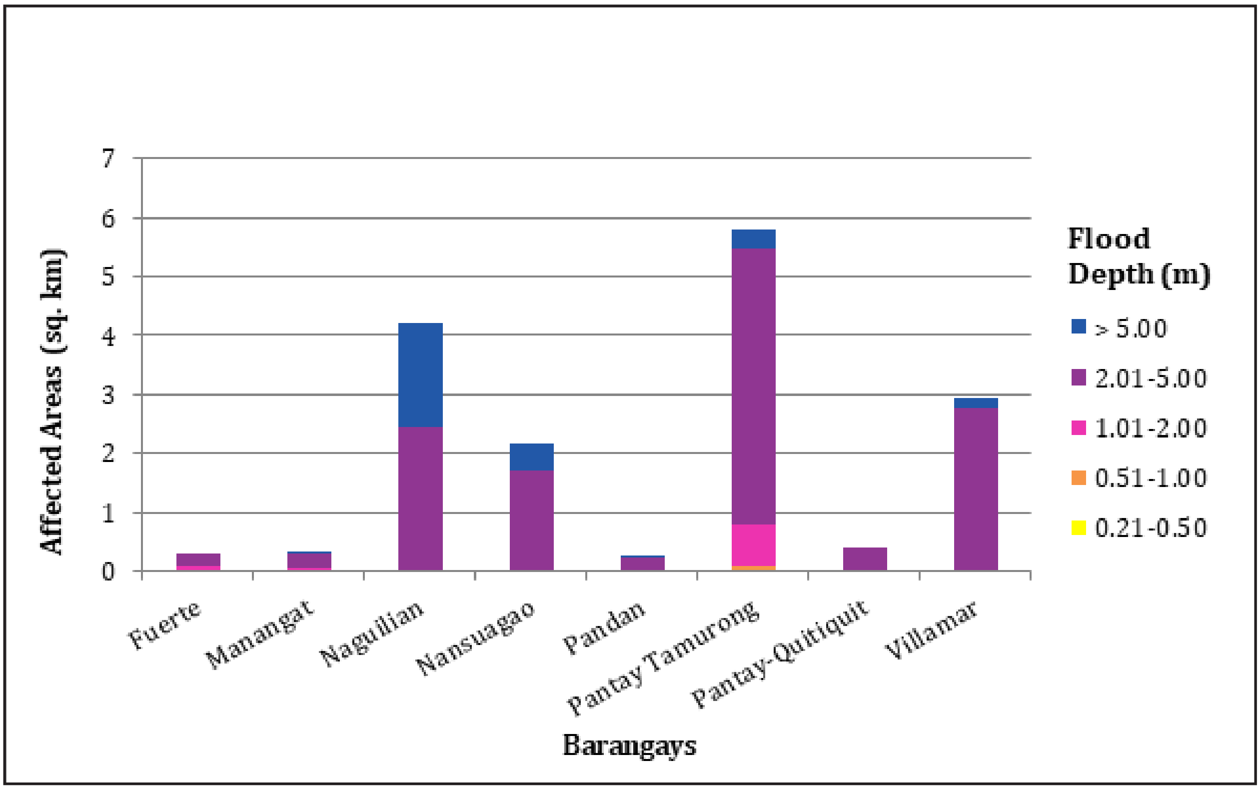


Figure 132. Affected Areas in Caoayan, Ilocos Sur during 25-Year Rainfall Return Period.

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

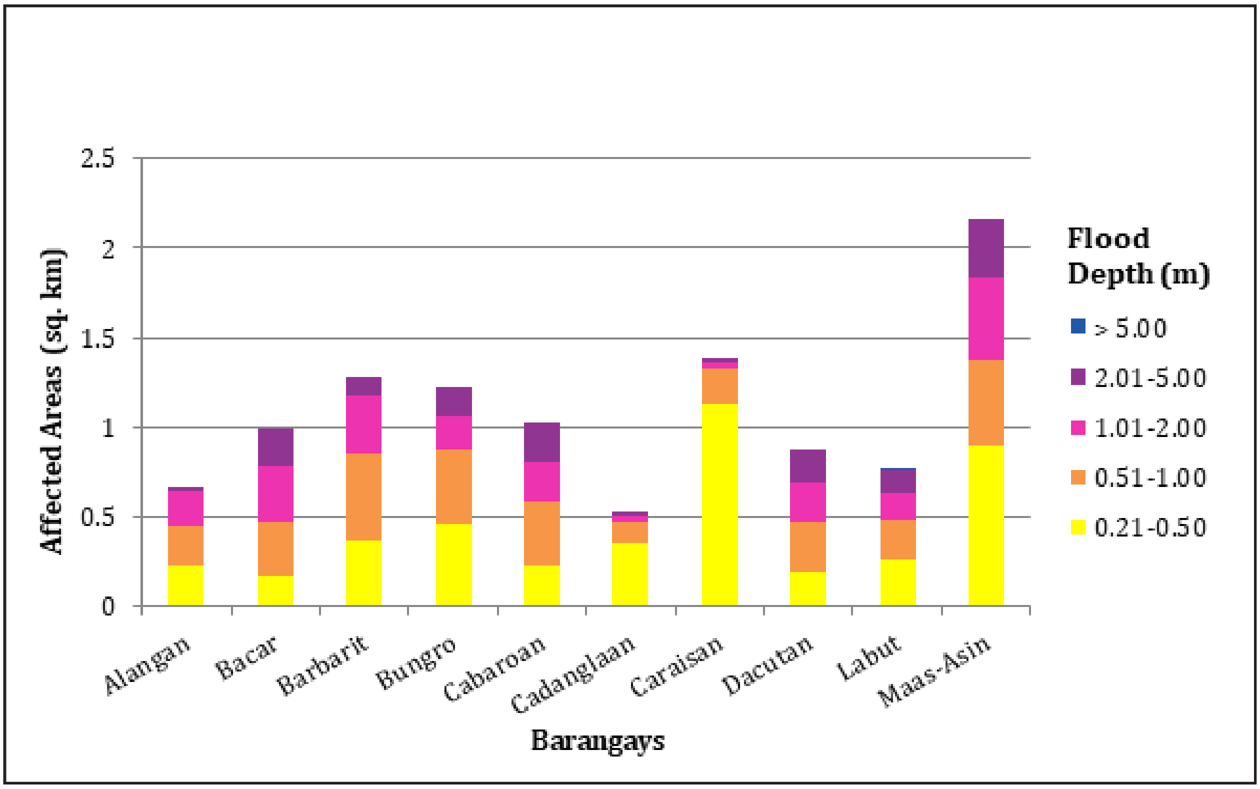


Figure 133. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

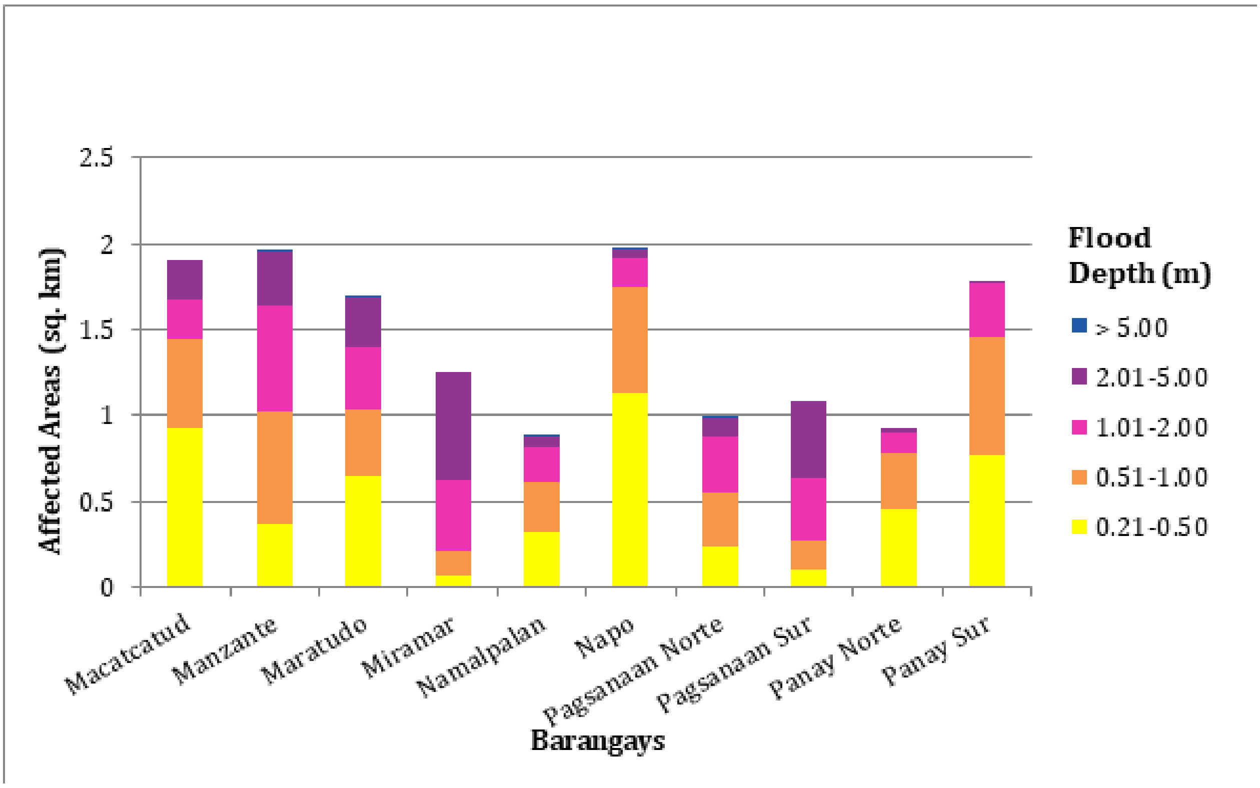


Figure 134. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

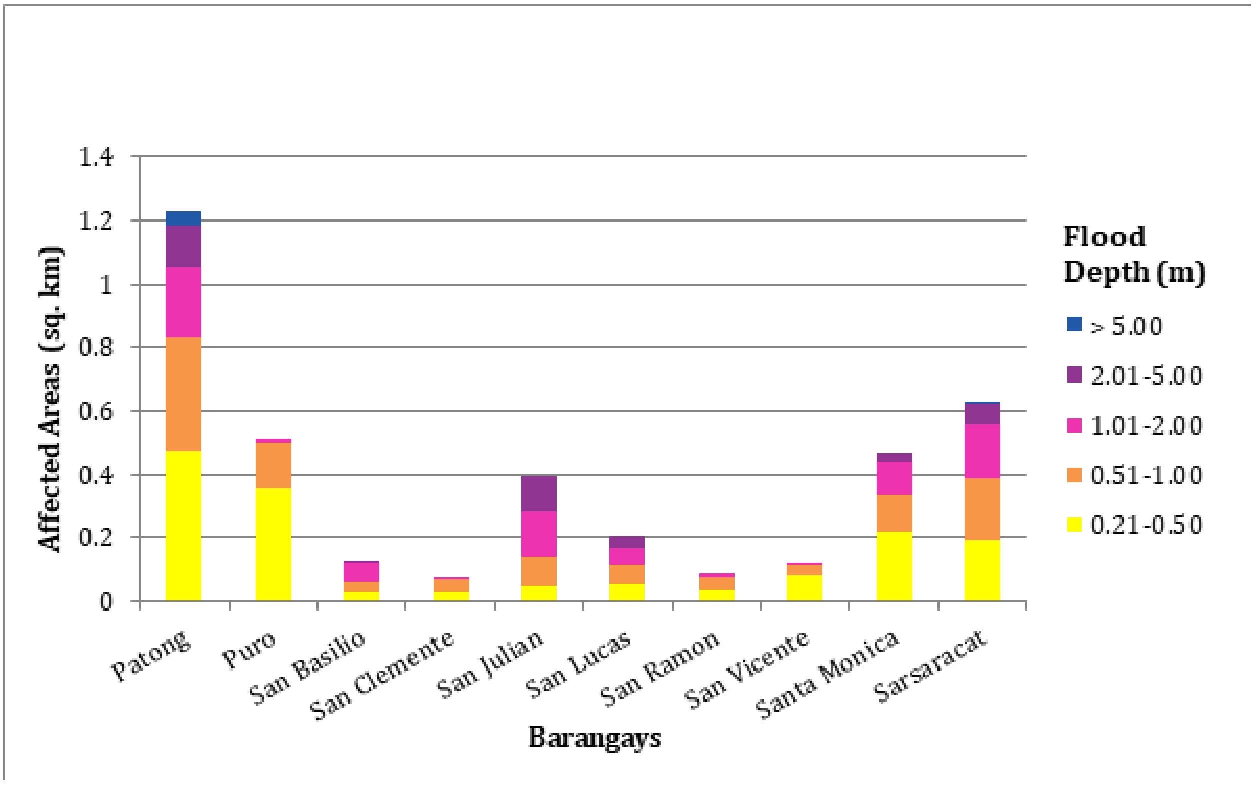


Figure 135. Affected Areas in Magsingal, Ilocos Sur during 25-Year Rainfall Return Period.

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

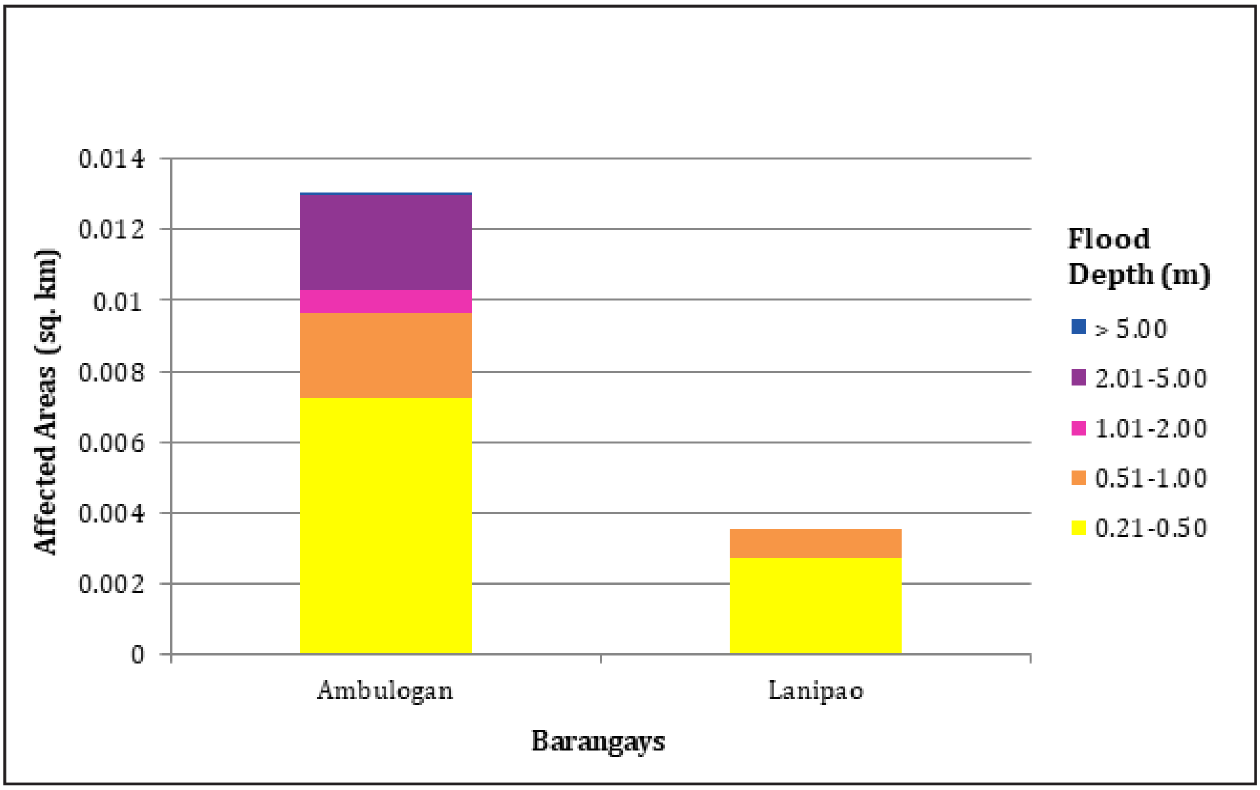


Figure 136. Affected Areas in Narvacan, Ilocos Sur during 25-Year Rainfall Return Period.

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

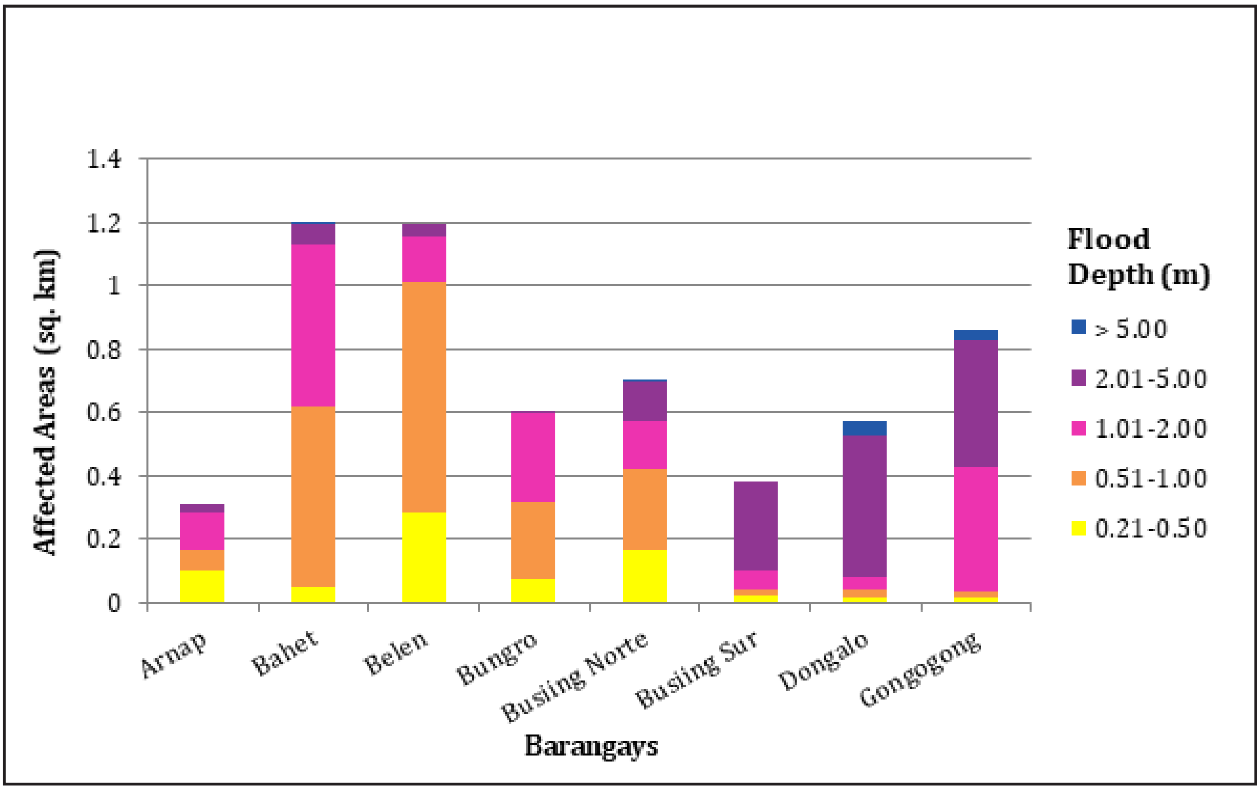


Figure 137. Affected Areas in San Ildefonso, Ilocos Sur during 25-Year Rainfall Return Period.

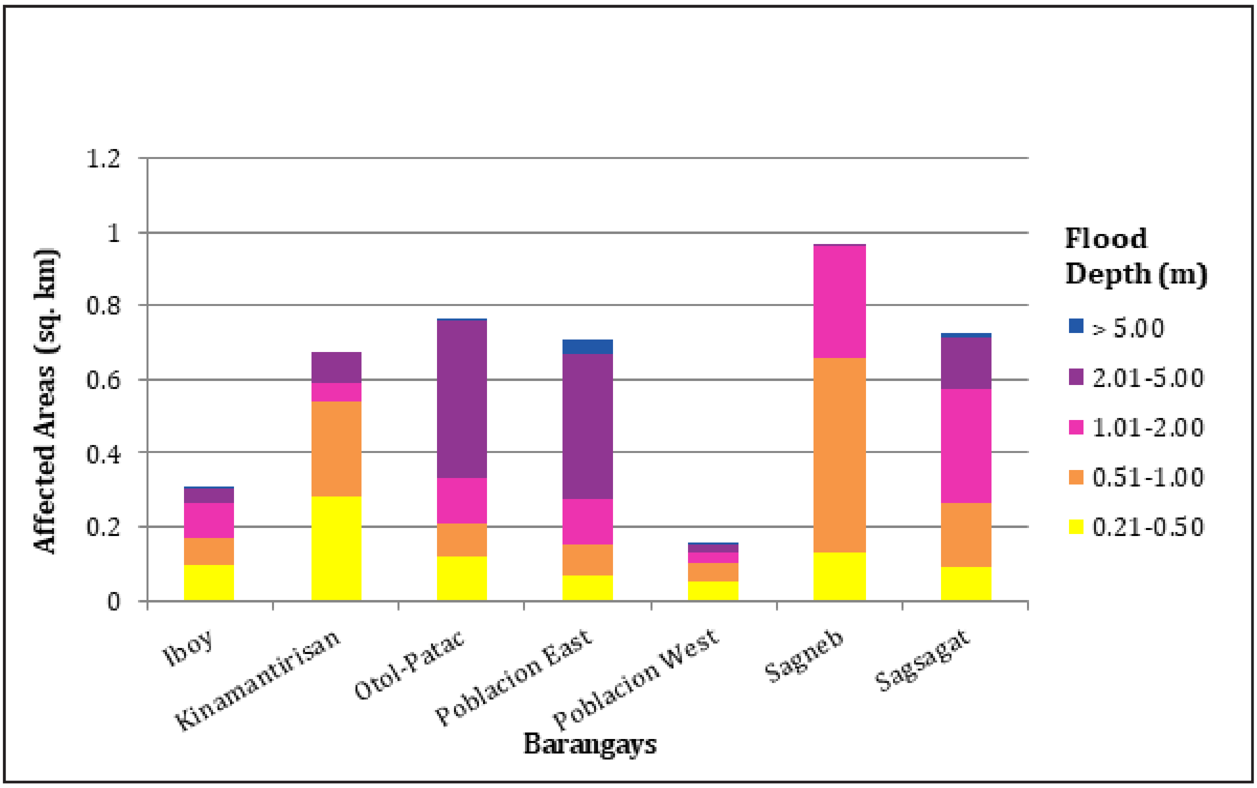


Figure 138. Affected Areas in San Ildefonso, Ilocos Sur during 25-Year Rainfall Return Period.

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

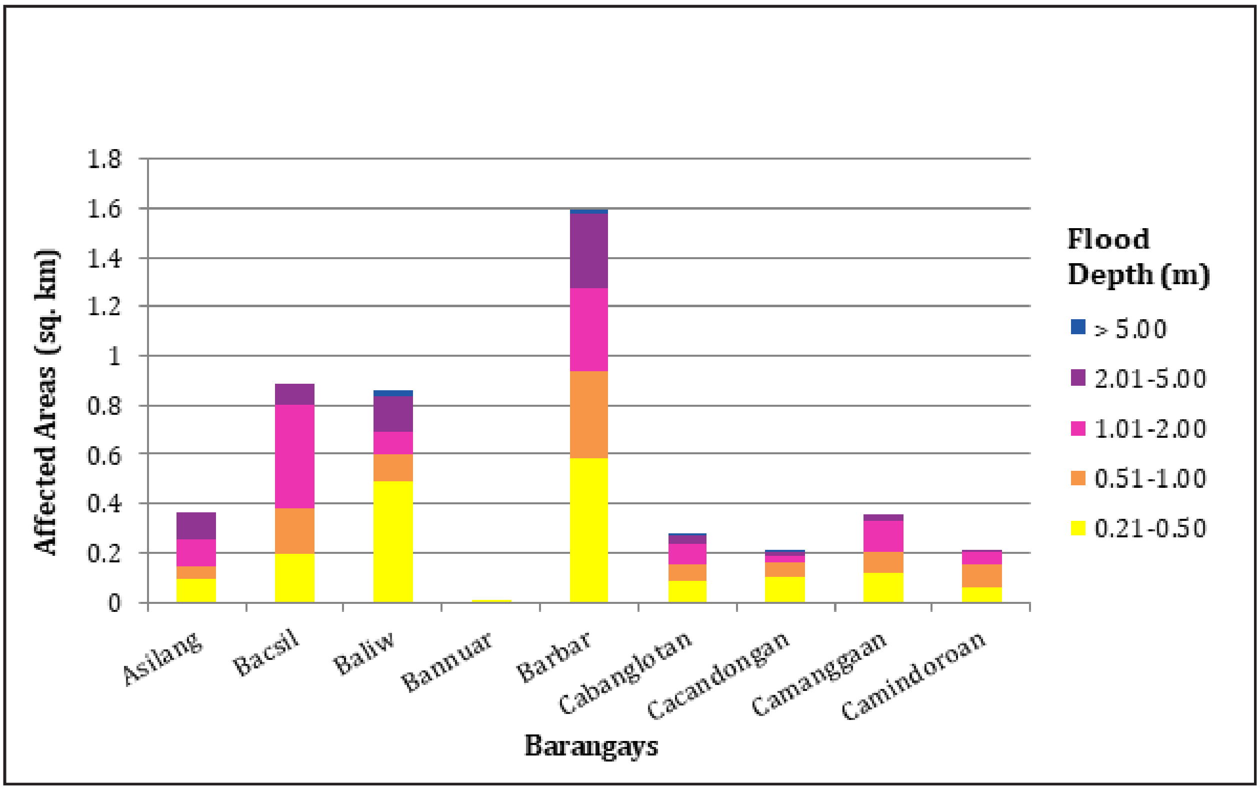


Figure 139. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

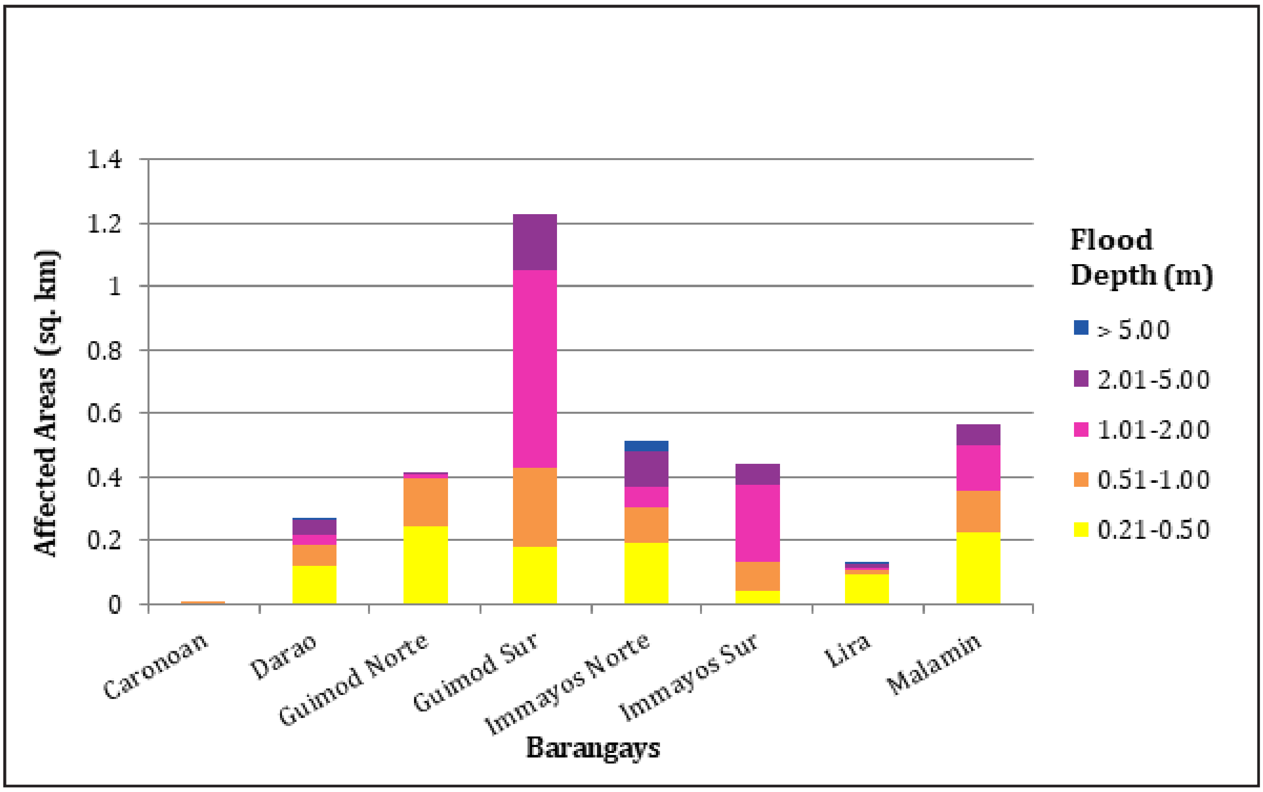


Figure 140. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

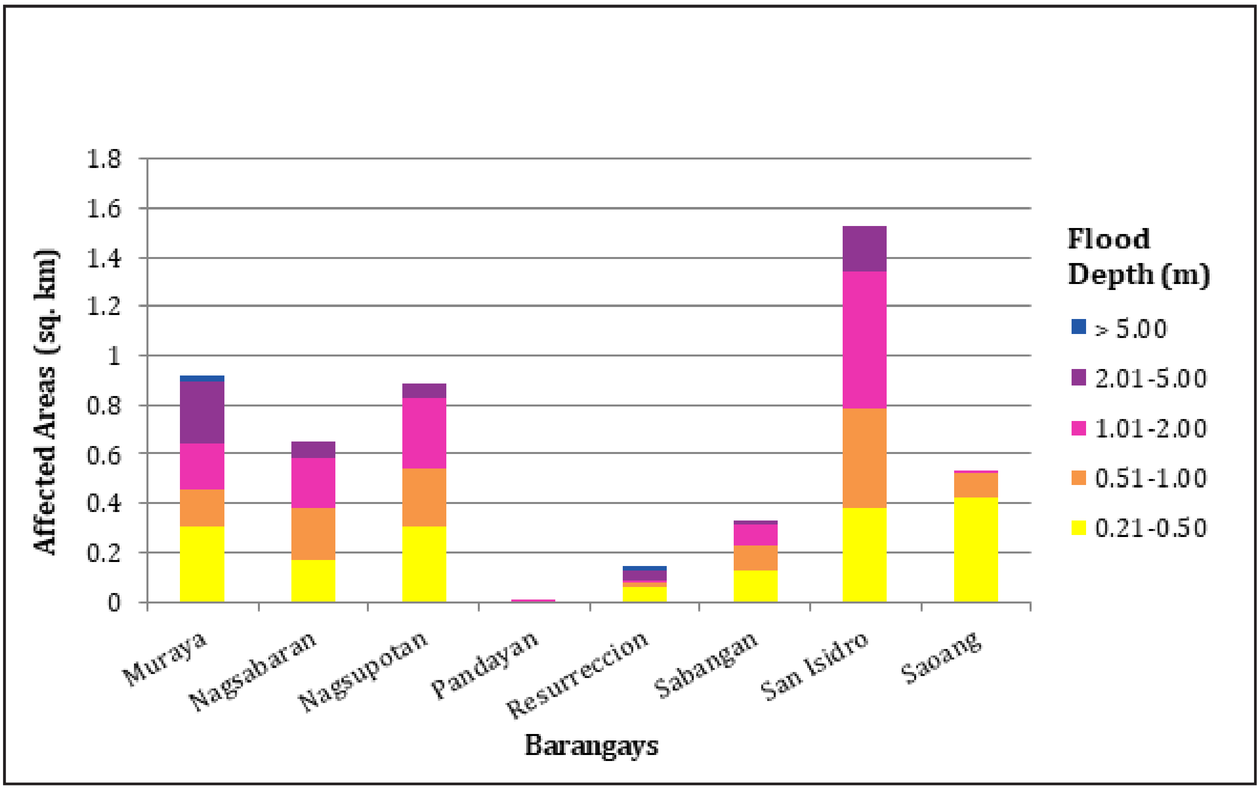


Figure 141. Affected Areas in San Juan, Ilocos Sur during 25-Year Rainfall Return Period.

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

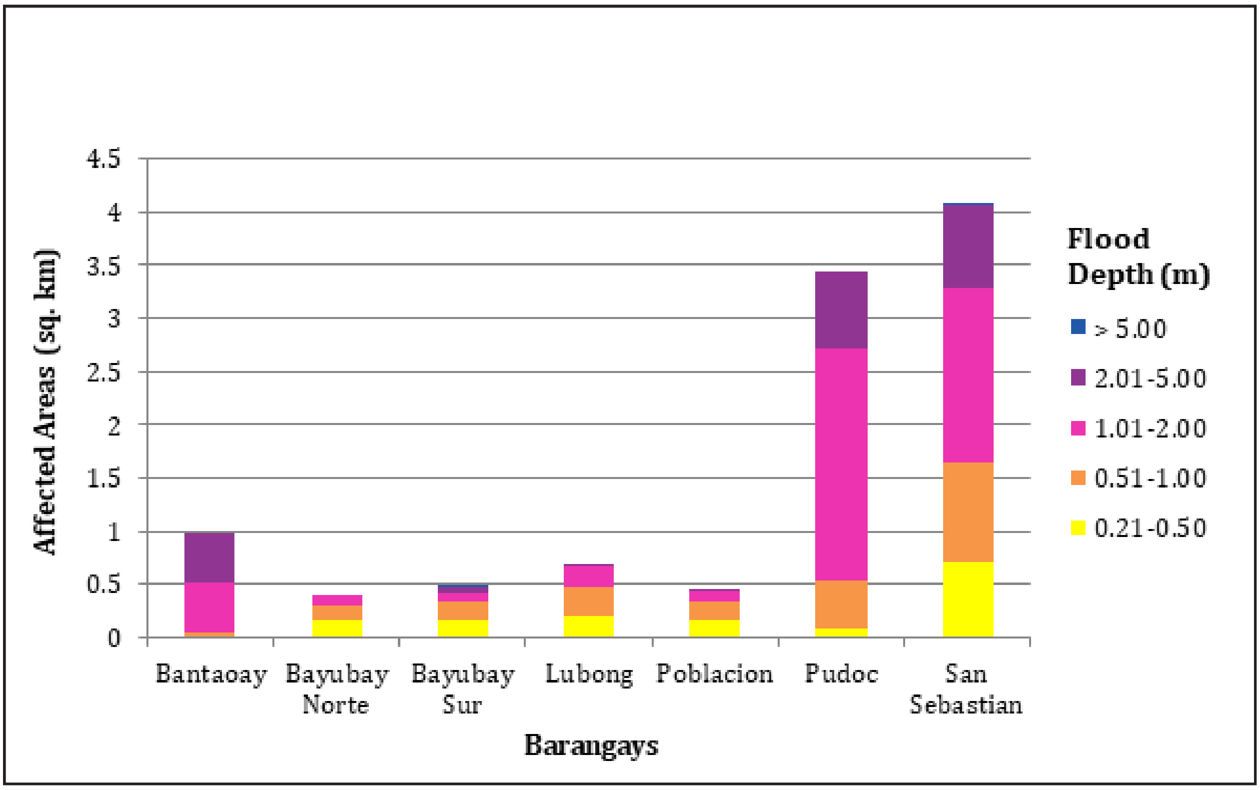


Figure 142. Affected Areas in San Vicente, Ilocos Sur during 25-Year Rainfall Return Period.

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

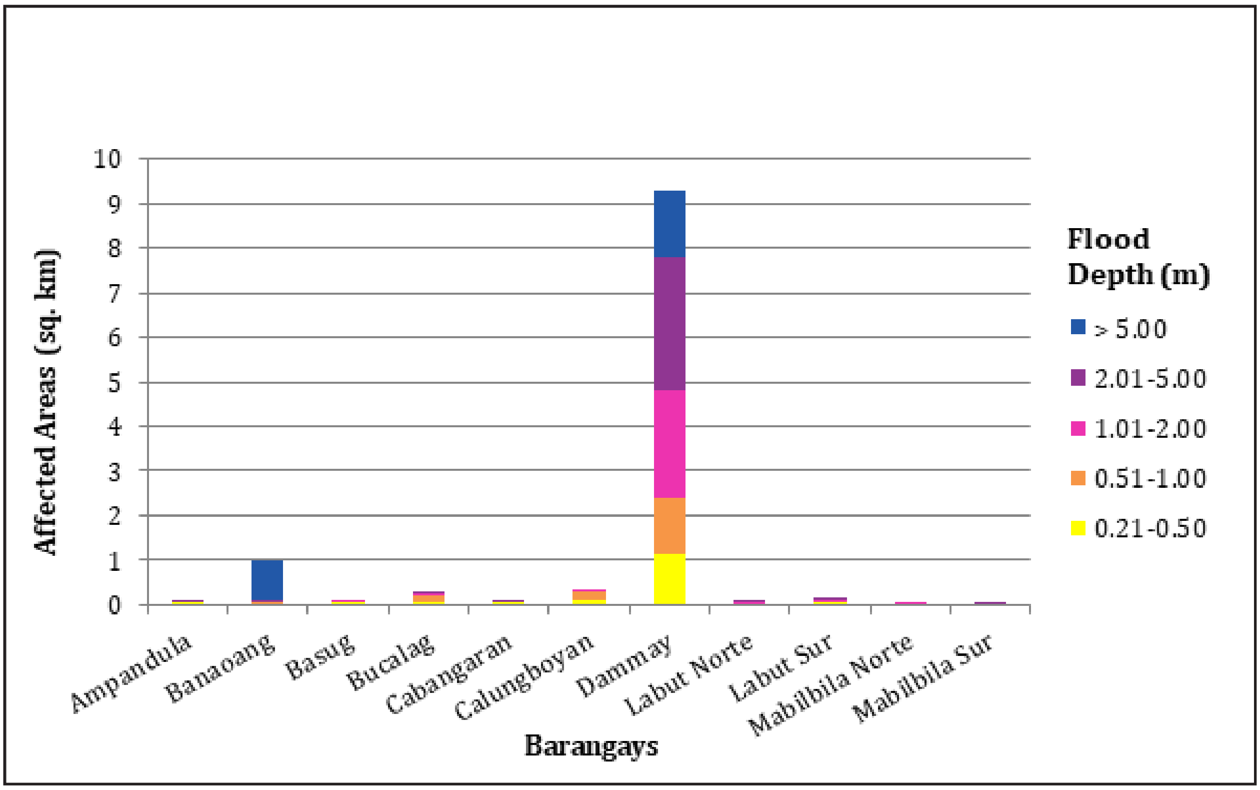


Figure 143. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period.

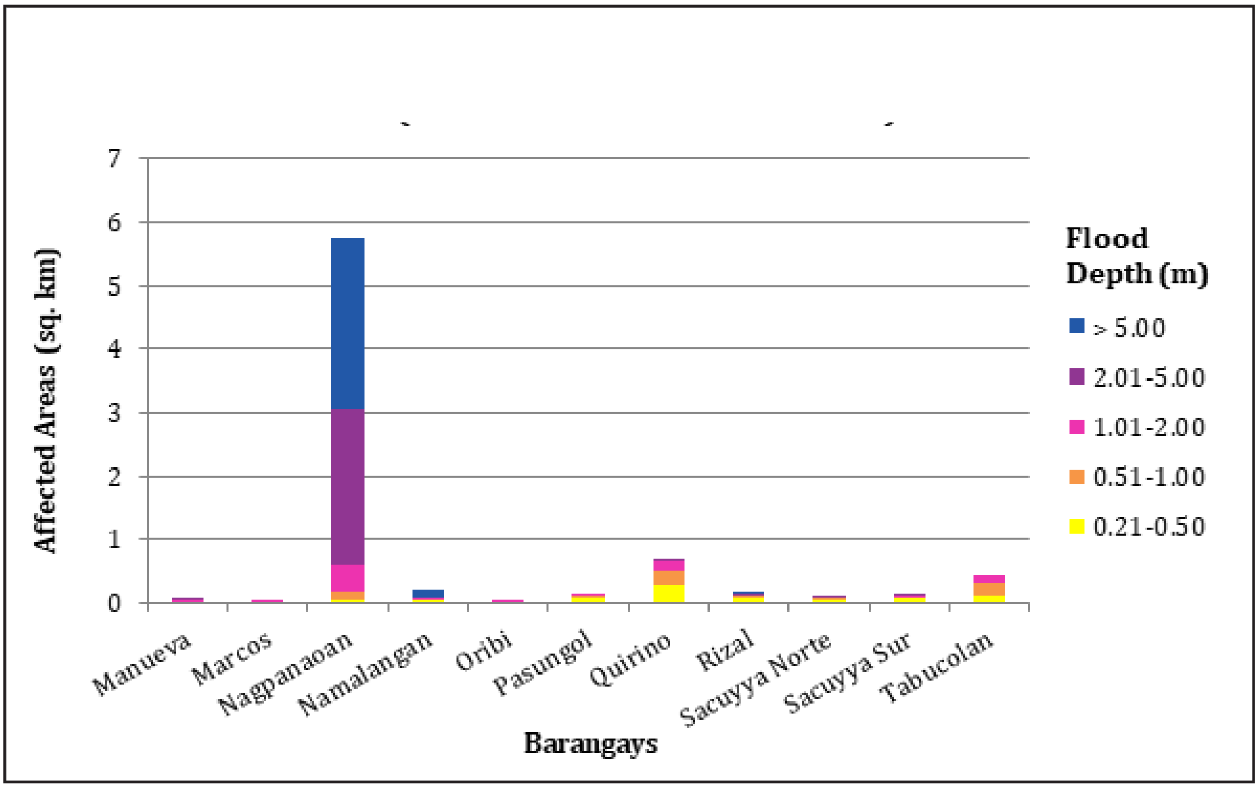


Figure 144. Affected Areas in Santa, Ilocos Sur during 25-Year Rainfall Return Period.

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

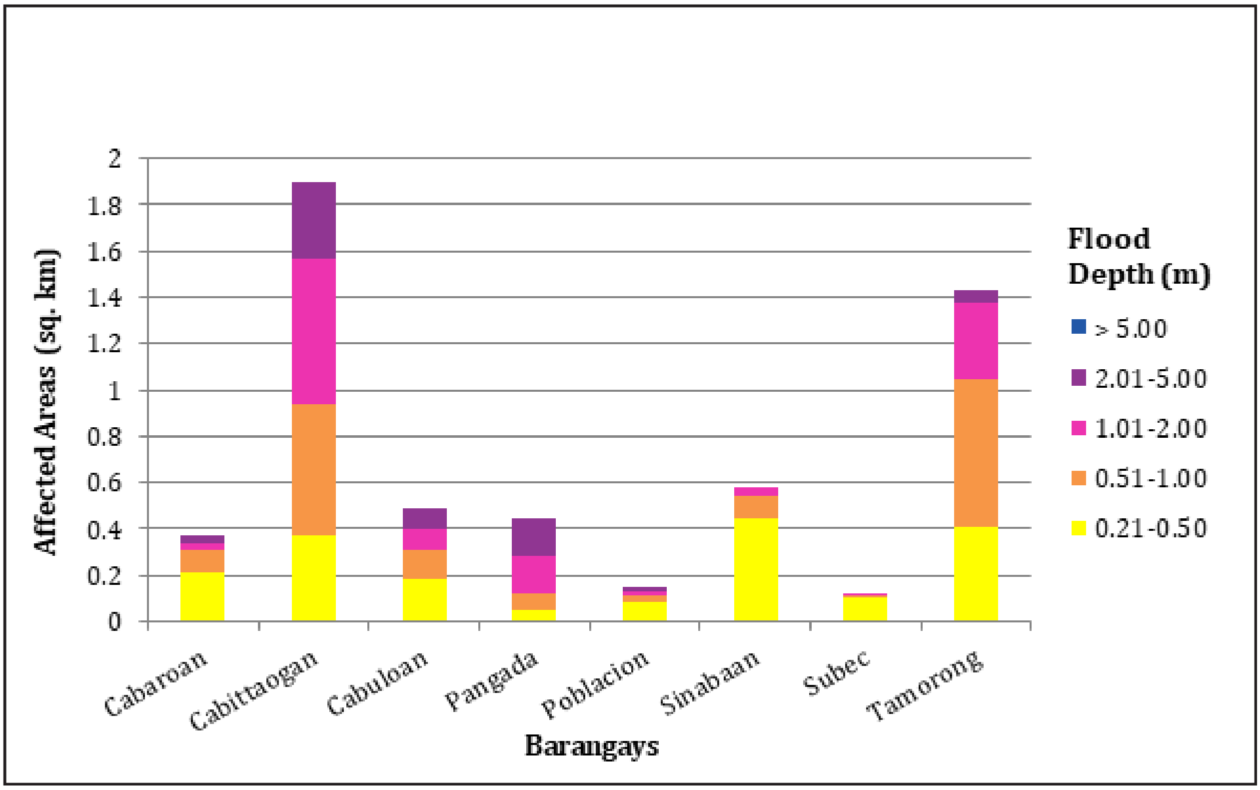


Figure 145. Affected Areas in Santa Catalina, Ilocos Sur during 25-Year Rainfall Return Period.

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

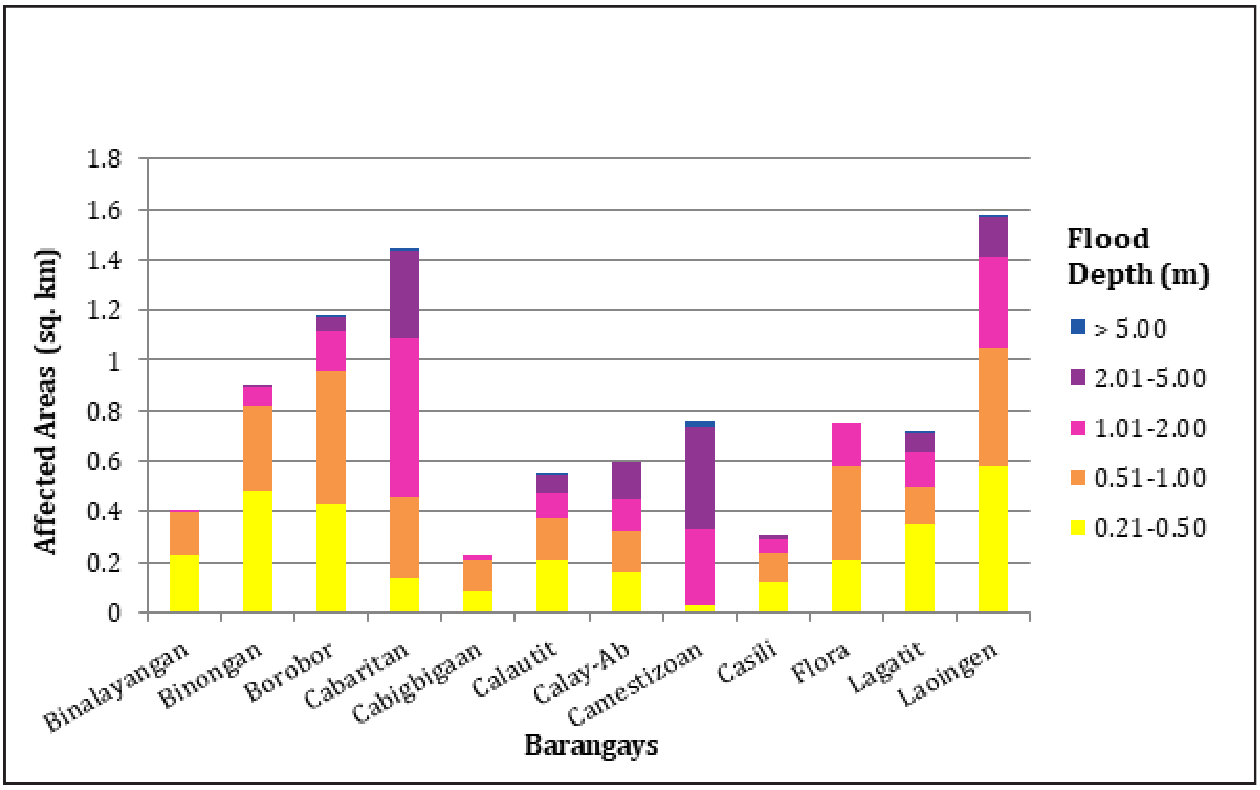


Figure 146. Affected Areas in Santo Domingo, Ilocos Sur during 25-Year Rainfall Return Period.

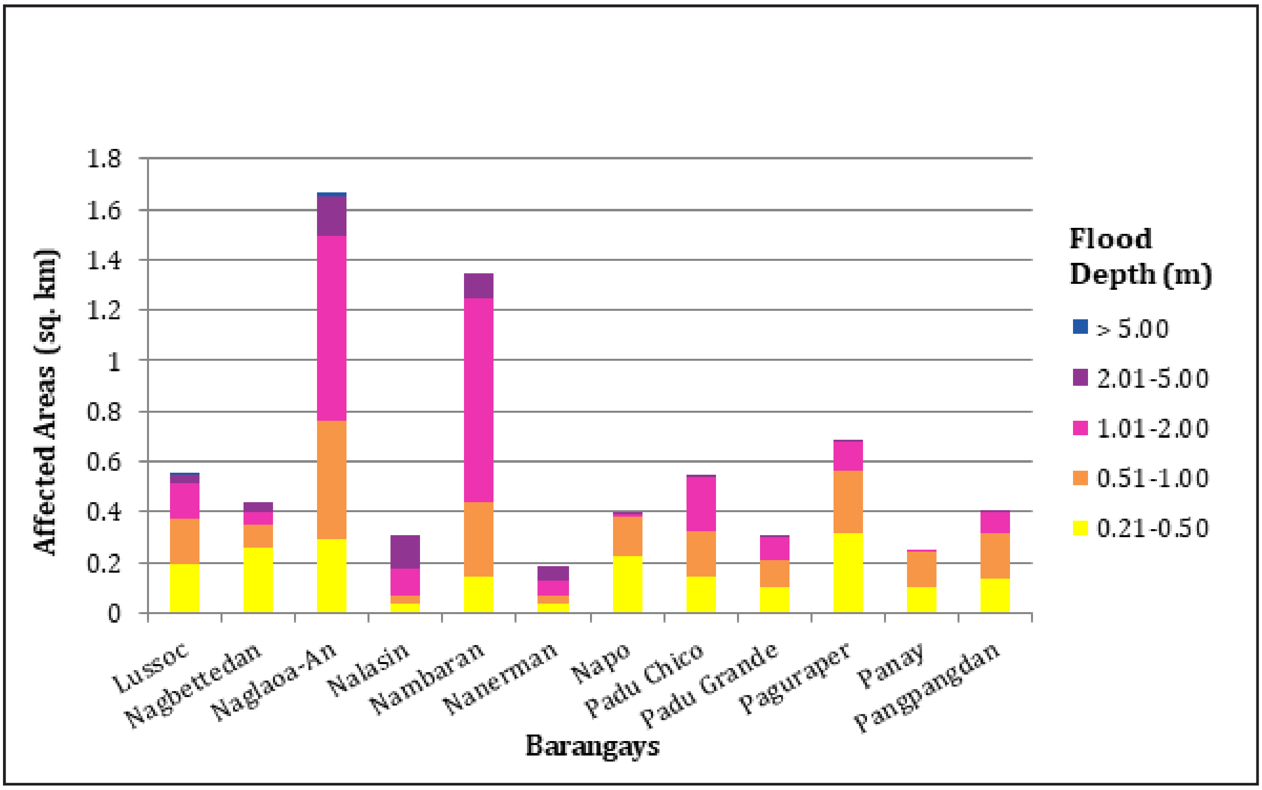


Figure 147. Affected Areas in Santo Domingo, Ilocos Sur during 25-Year Rainfall Return Period.

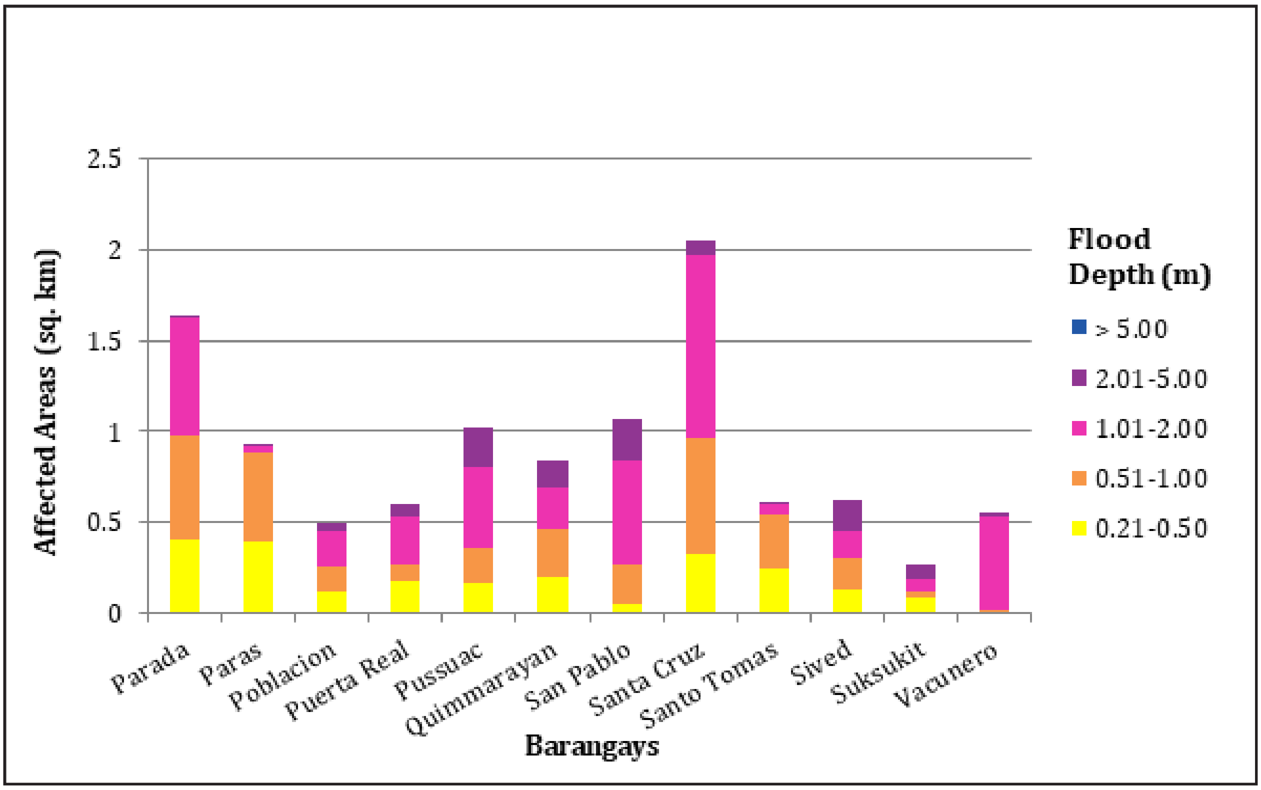


Figure 148. Affected Areas in Santo Domingo, Ilocos Sur during 25-Year Rainfall Return Period.

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

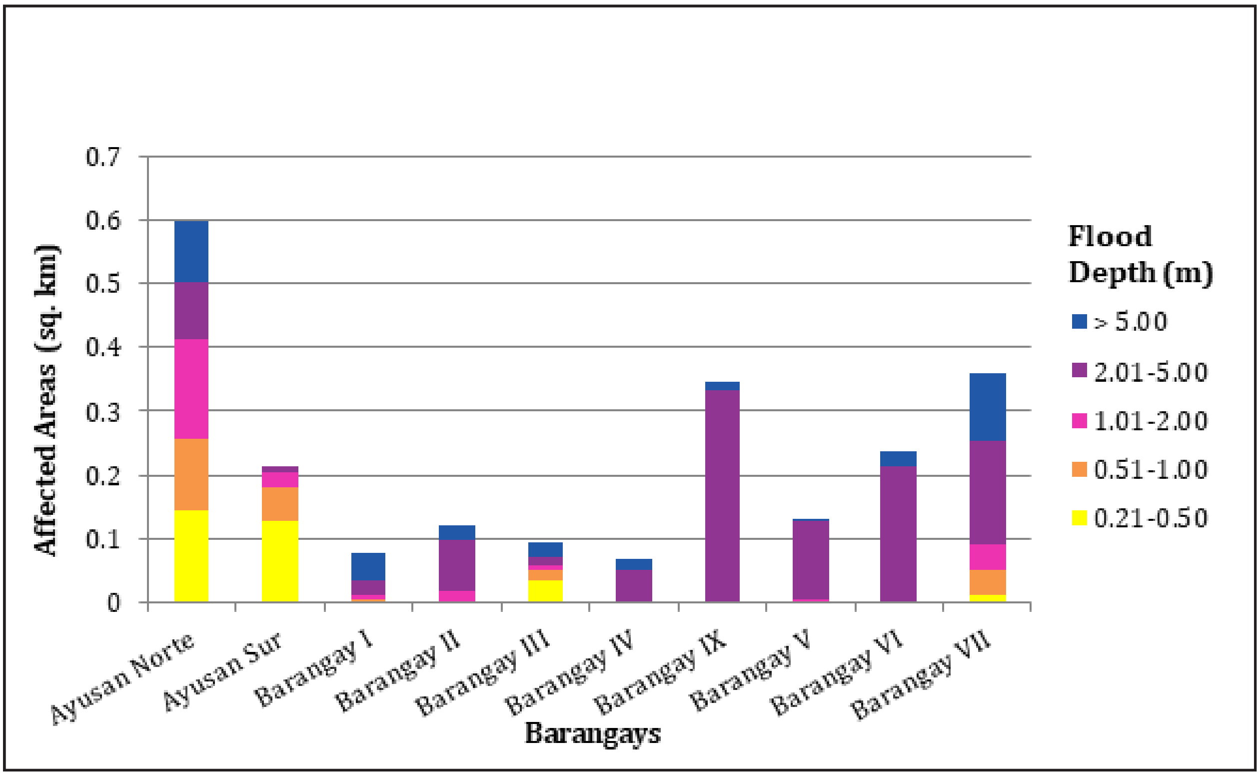


Figure 149. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

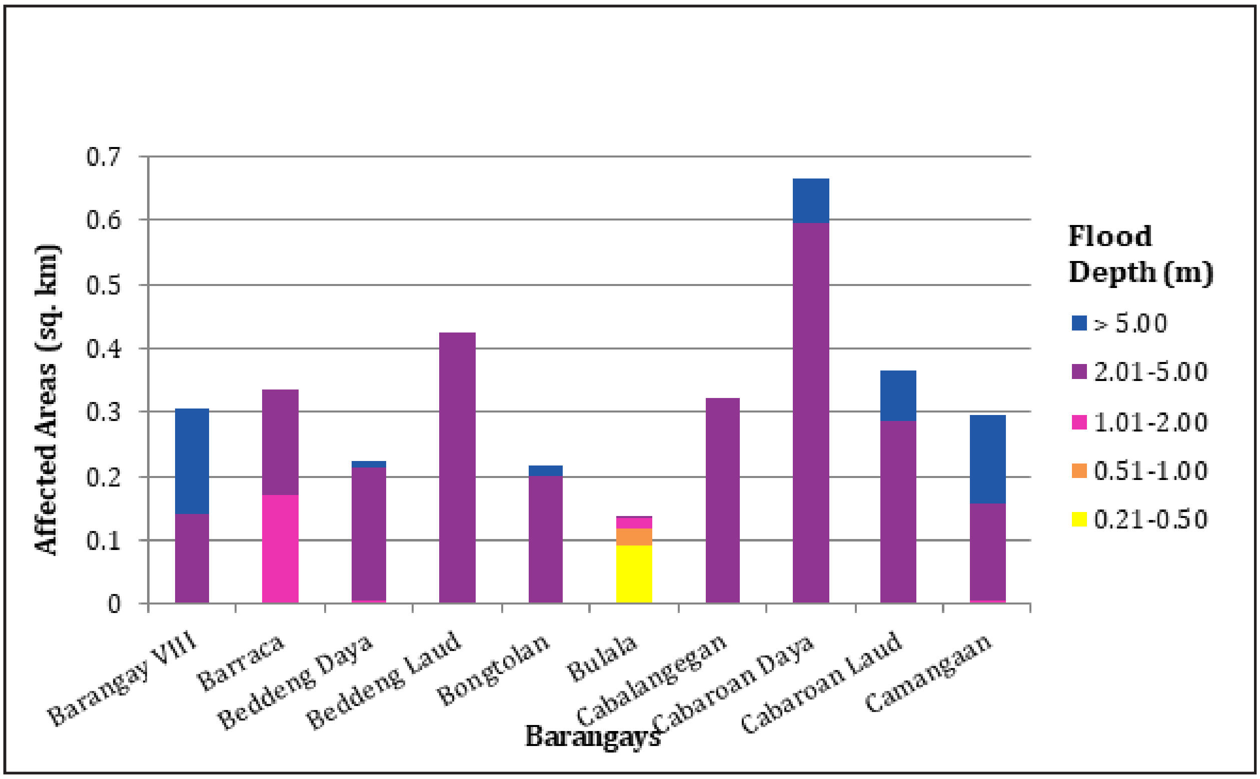


Figure 150. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

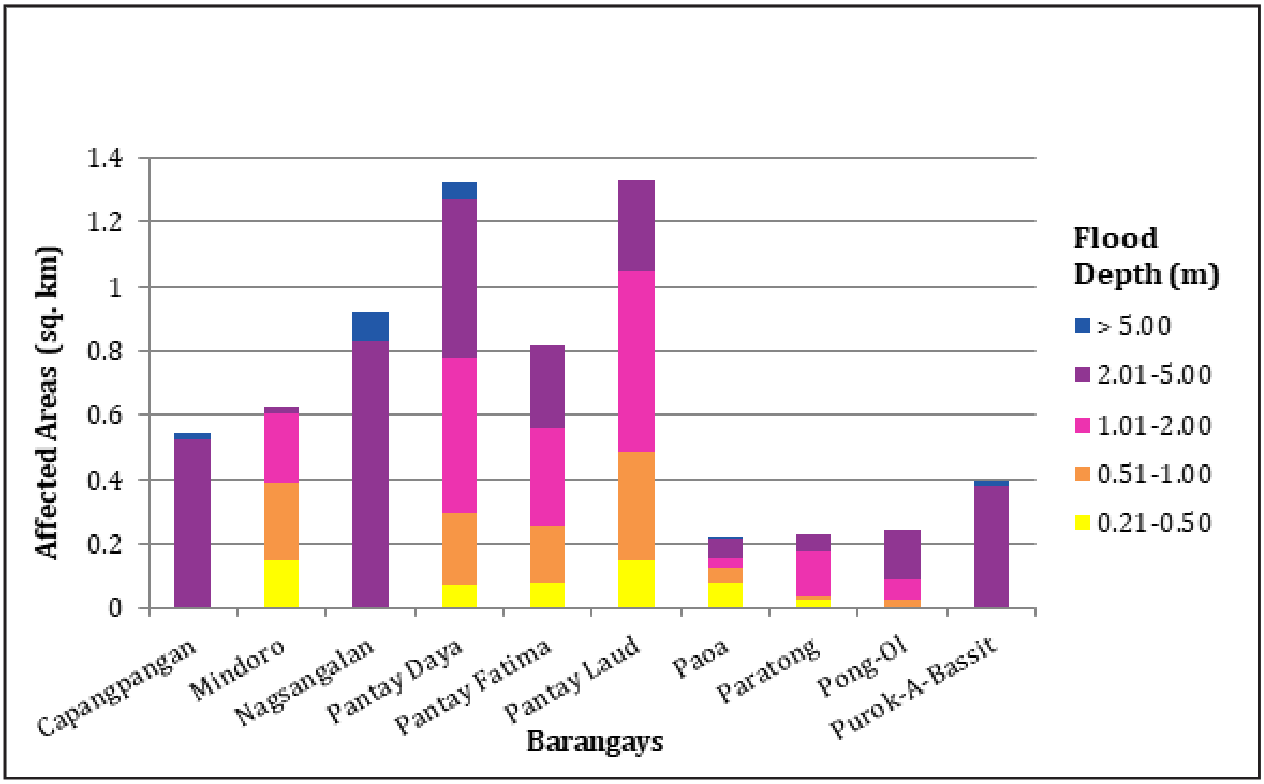


Figure 151. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

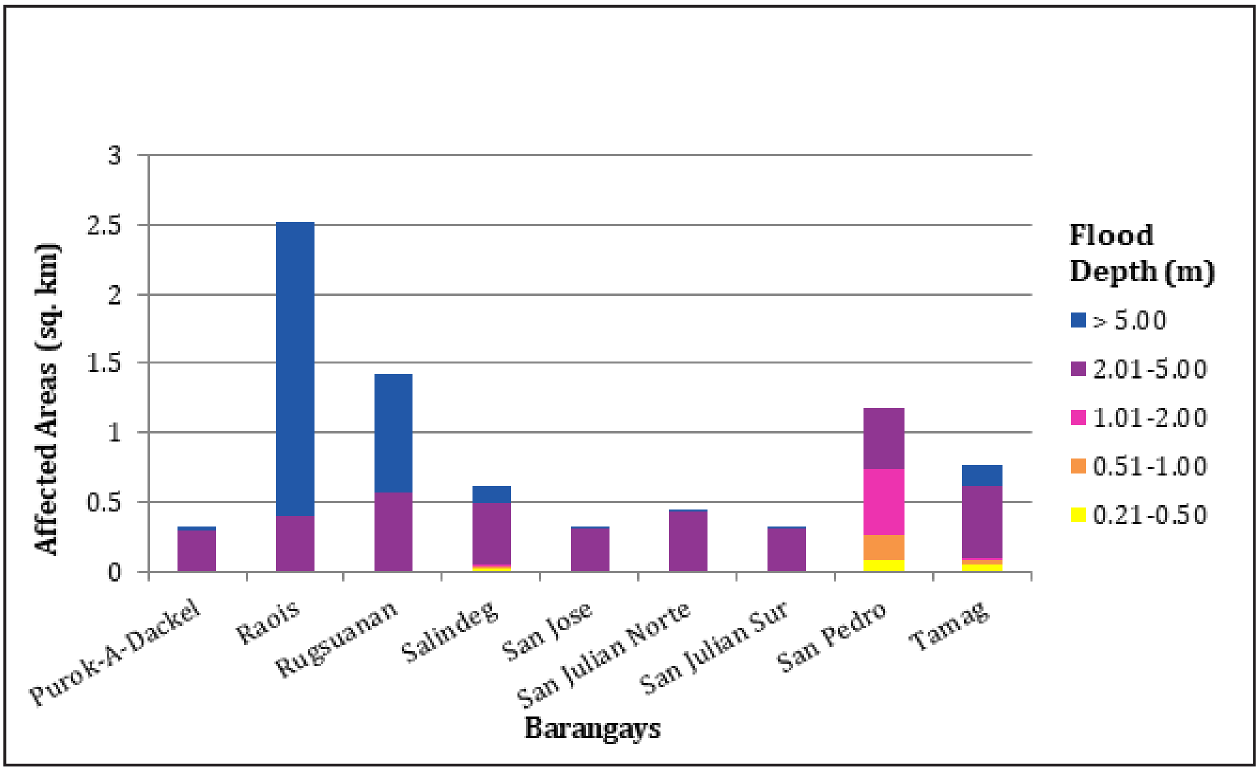


Figure 152. Affected Areas in Vigan City, Ilocos Sur during 25-Year Rainfall Return Period.

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

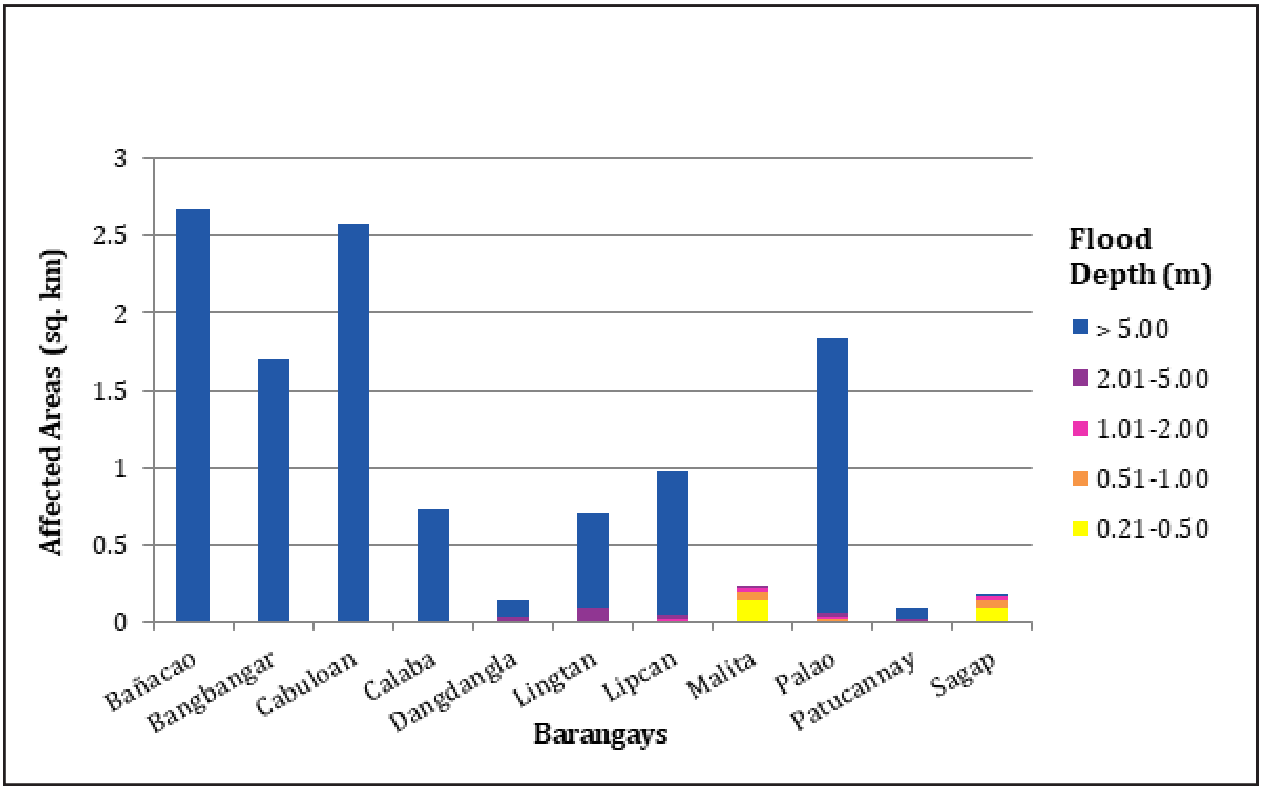


Figure 153. Affected Areas in Bangued, Abra during 100-Year Rainfall Return Period.

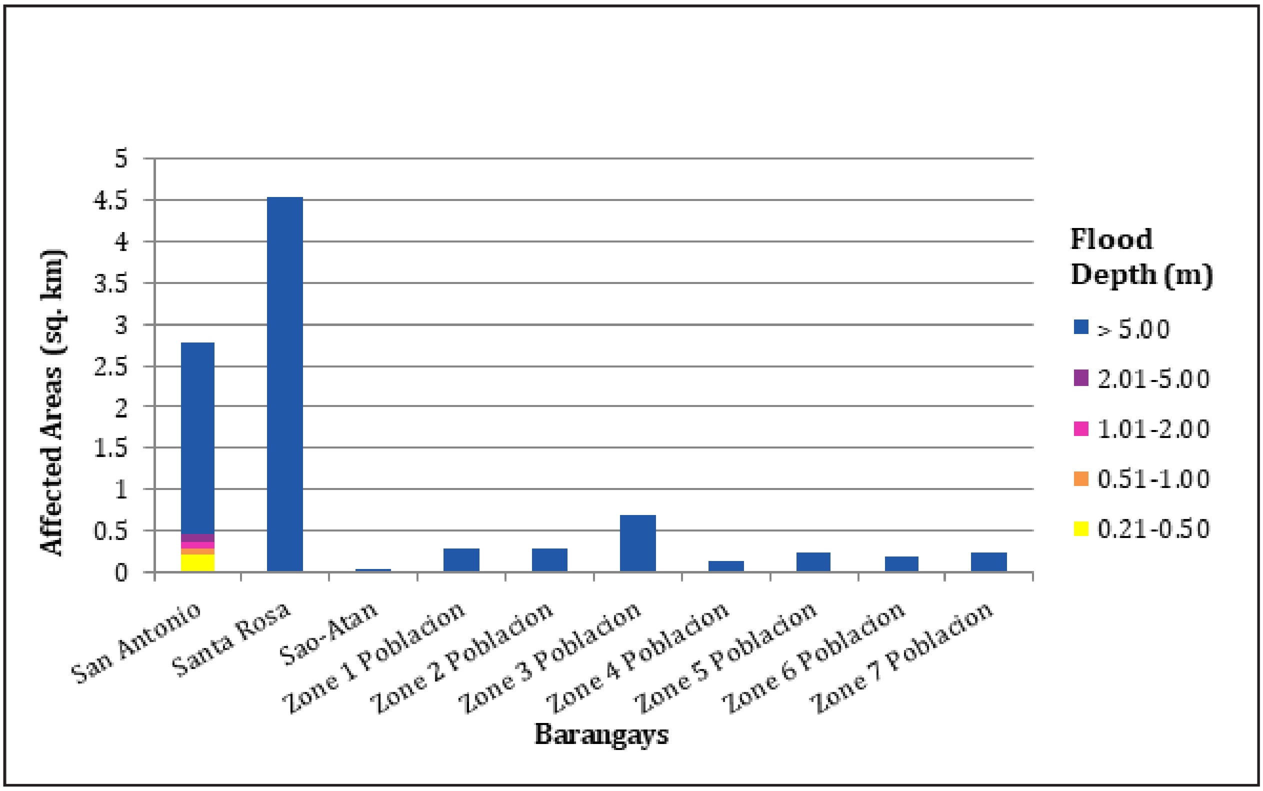


Figure 154. Affected Areas in Bangued, Abra during 100-Year Rainfall Return Period.

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

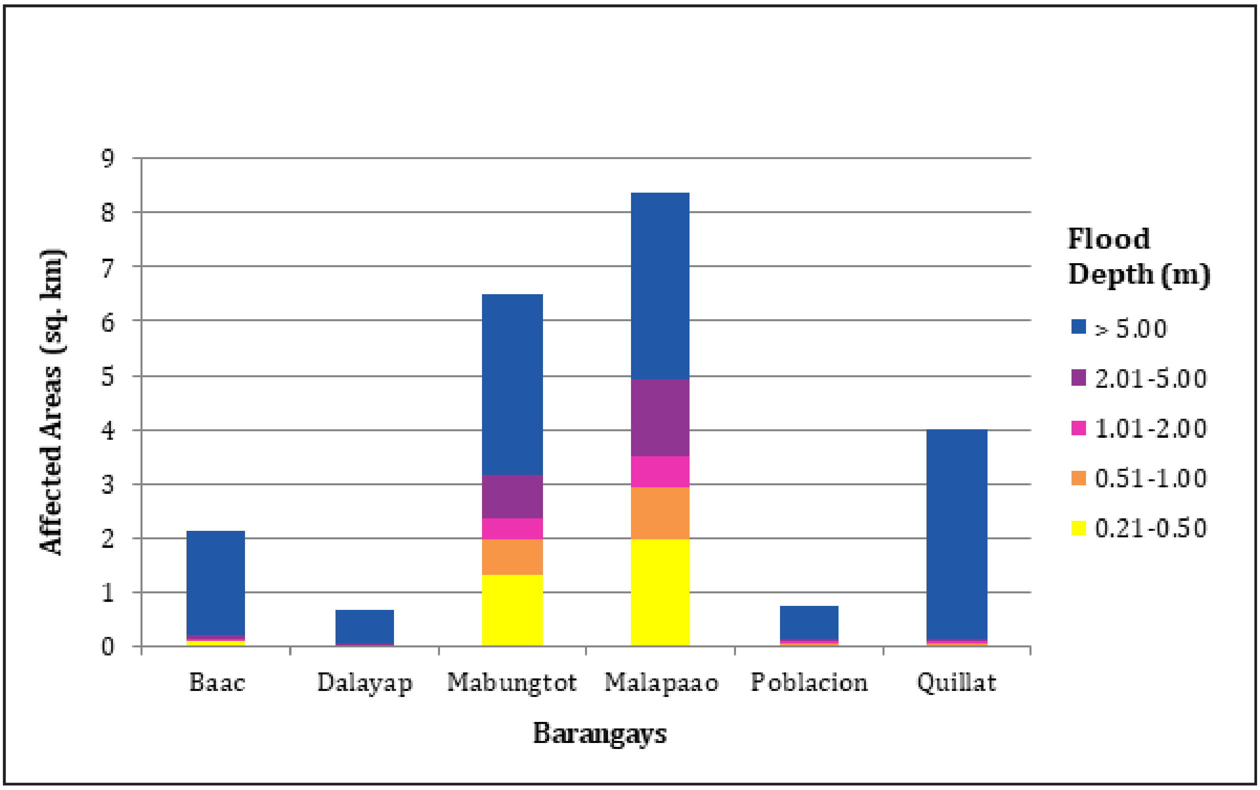


Figure 155. Affected Areas in Langiden, Abra during 100-Year Rainfall Return Period.

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

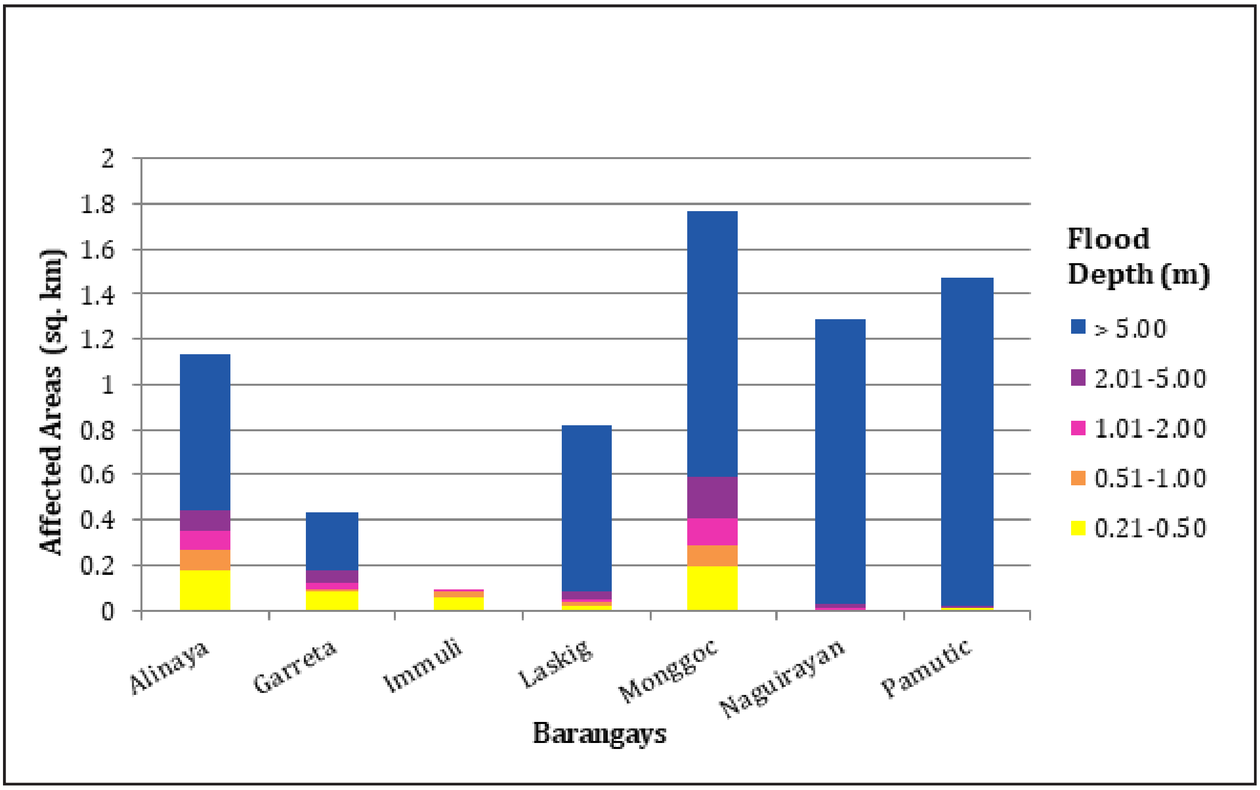


Figure 156. Affected Areas in Pidigan, Abra during 100-Year Rainfall Return Period.

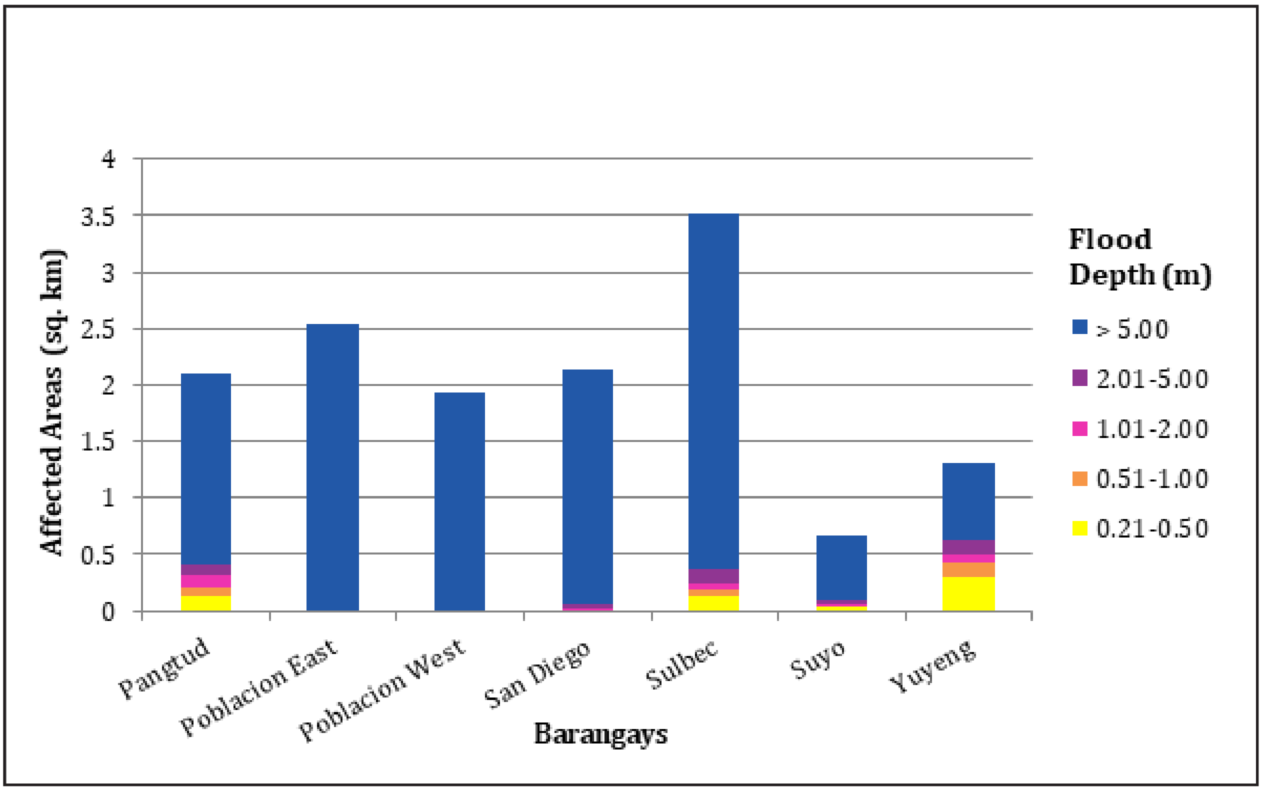


Figure 157. Affected Areas in Pidigan, Abra during 100-Year Rainfall Return Period.

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

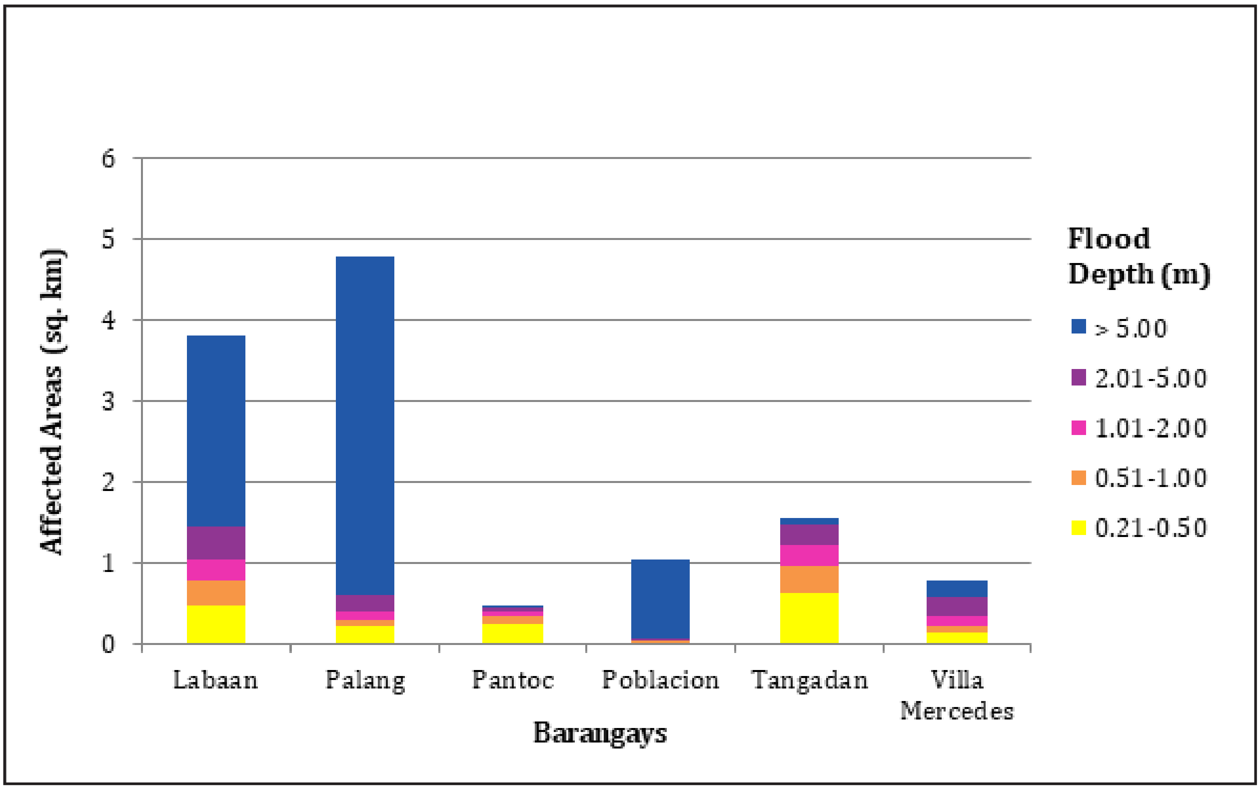


Figure 158. Affected Areas in San Quintin, Abra during 100-Year Rainfall Return Period.

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

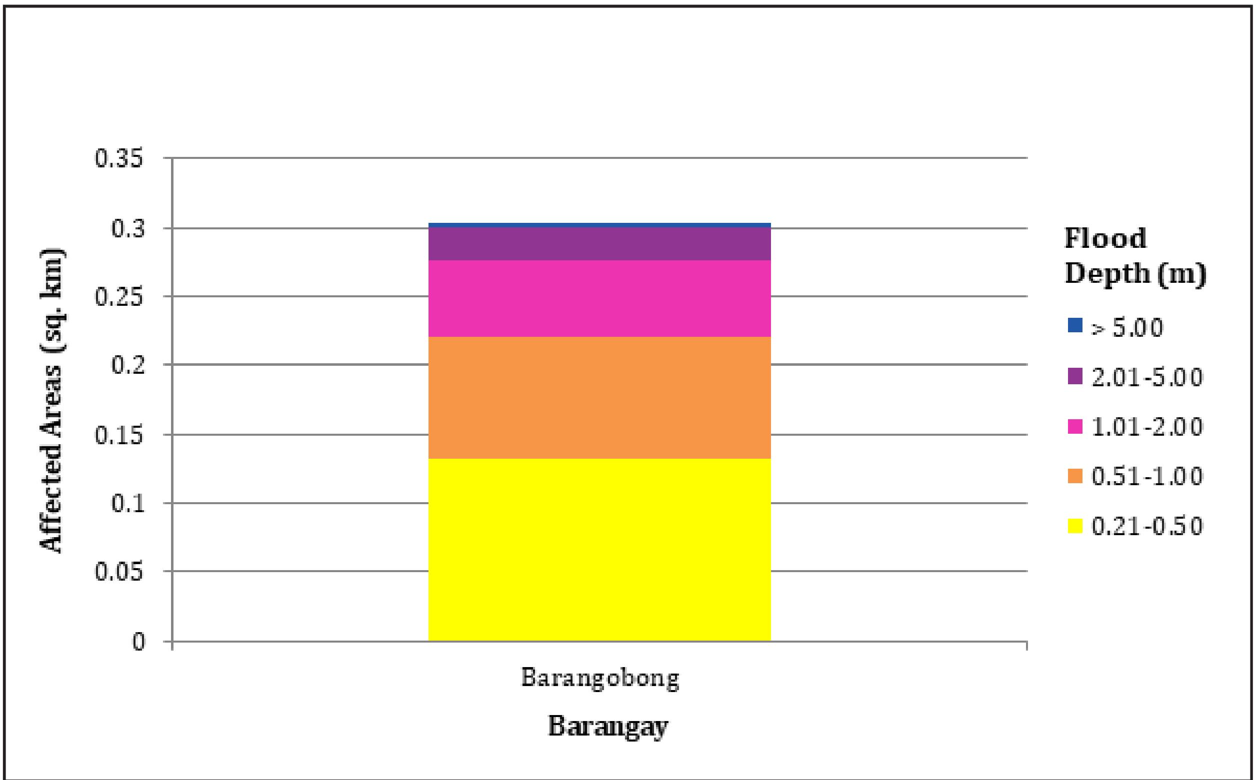


Figure 159. Affected Areas in Nueva Era, Ilocos Norte during 100-Year Rainfall Return Period.

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

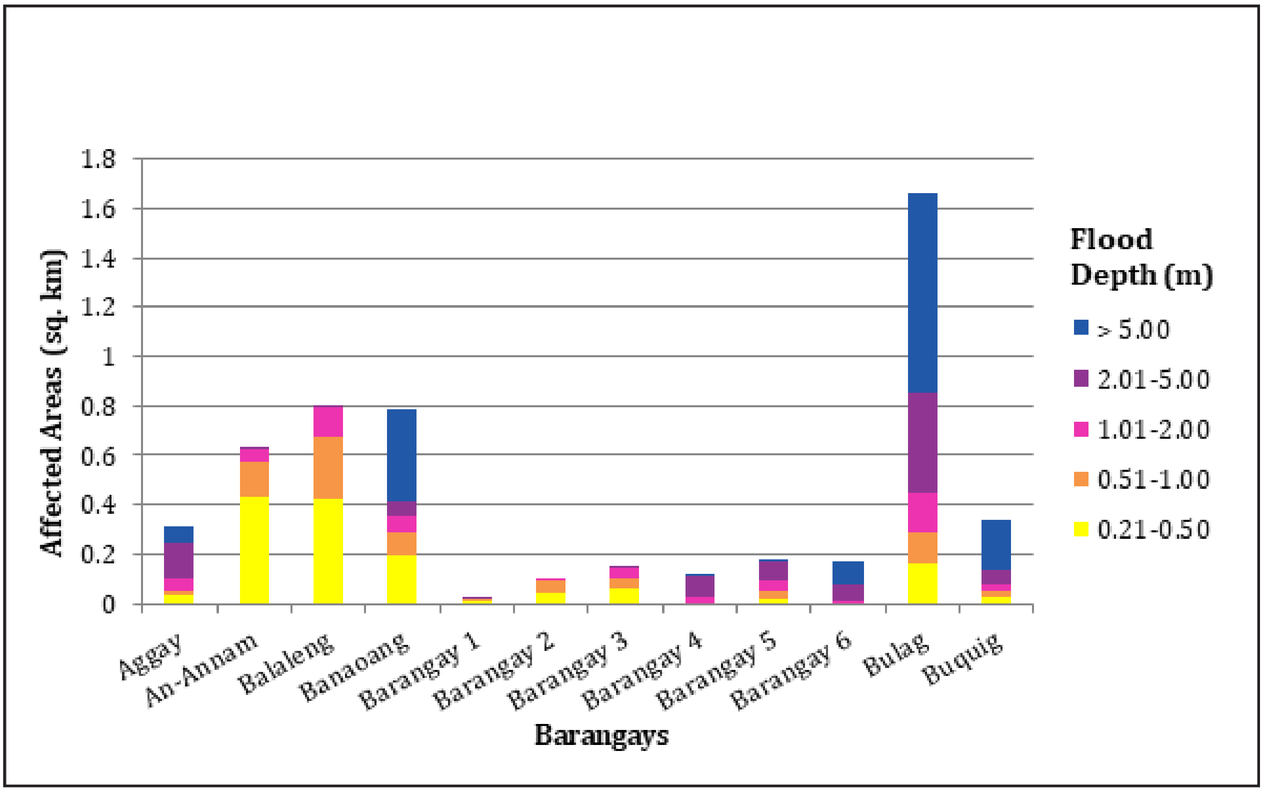


Figure 160. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

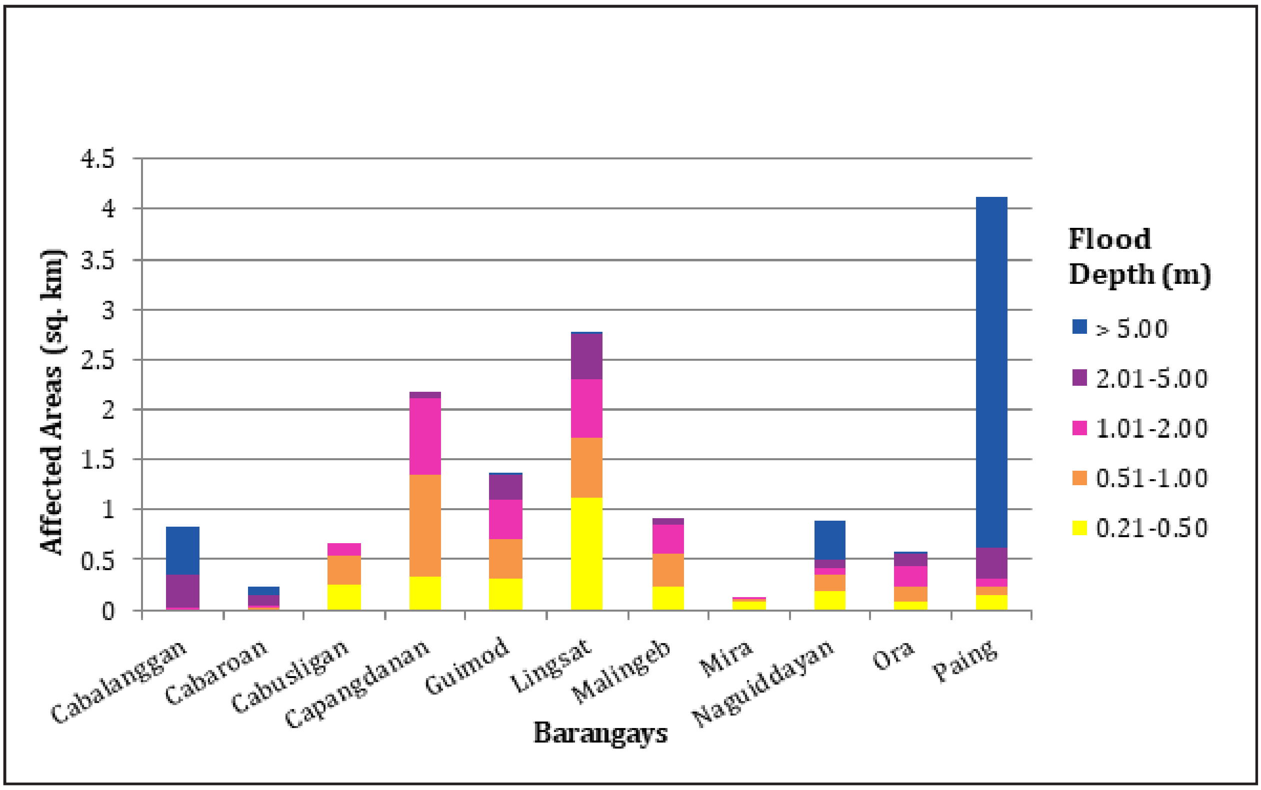


Figure 161. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

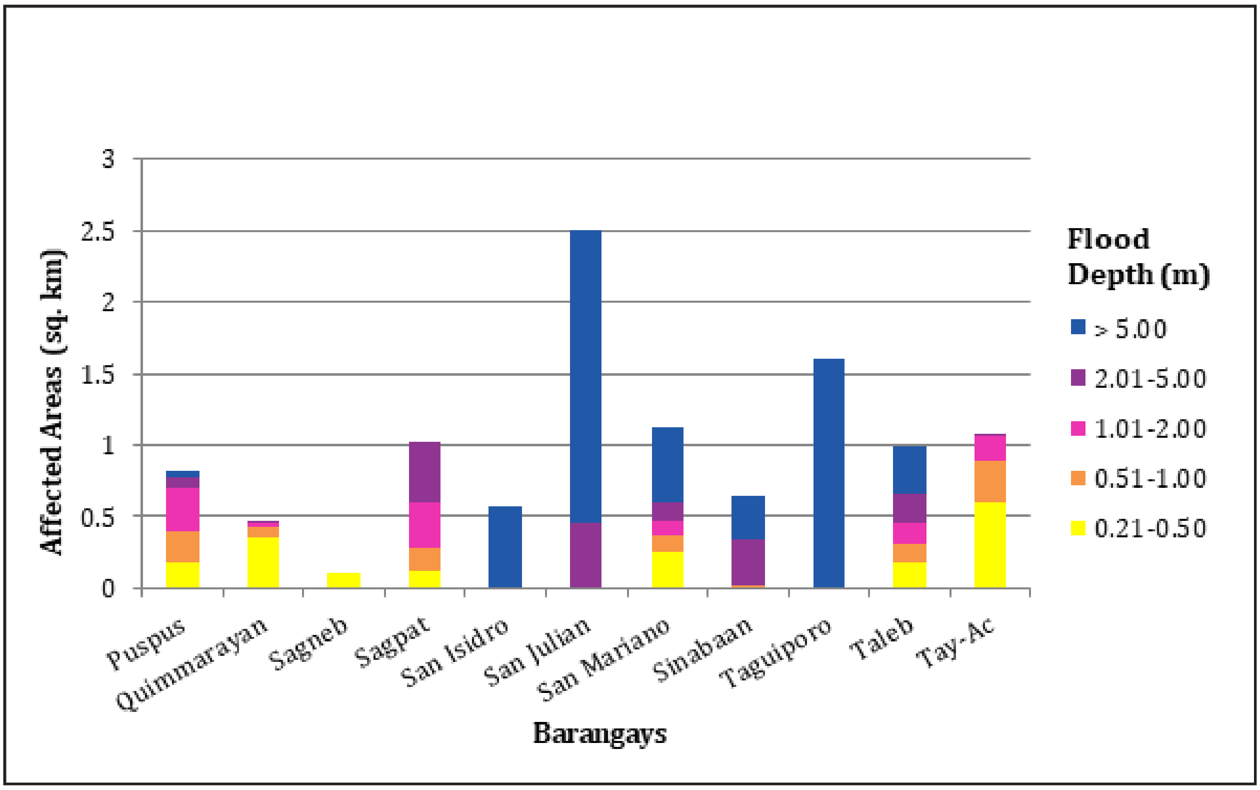


Figure 162. Affected Areas in Bantay, Ilocos Sur during 100-Year Rainfall Return Period.

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

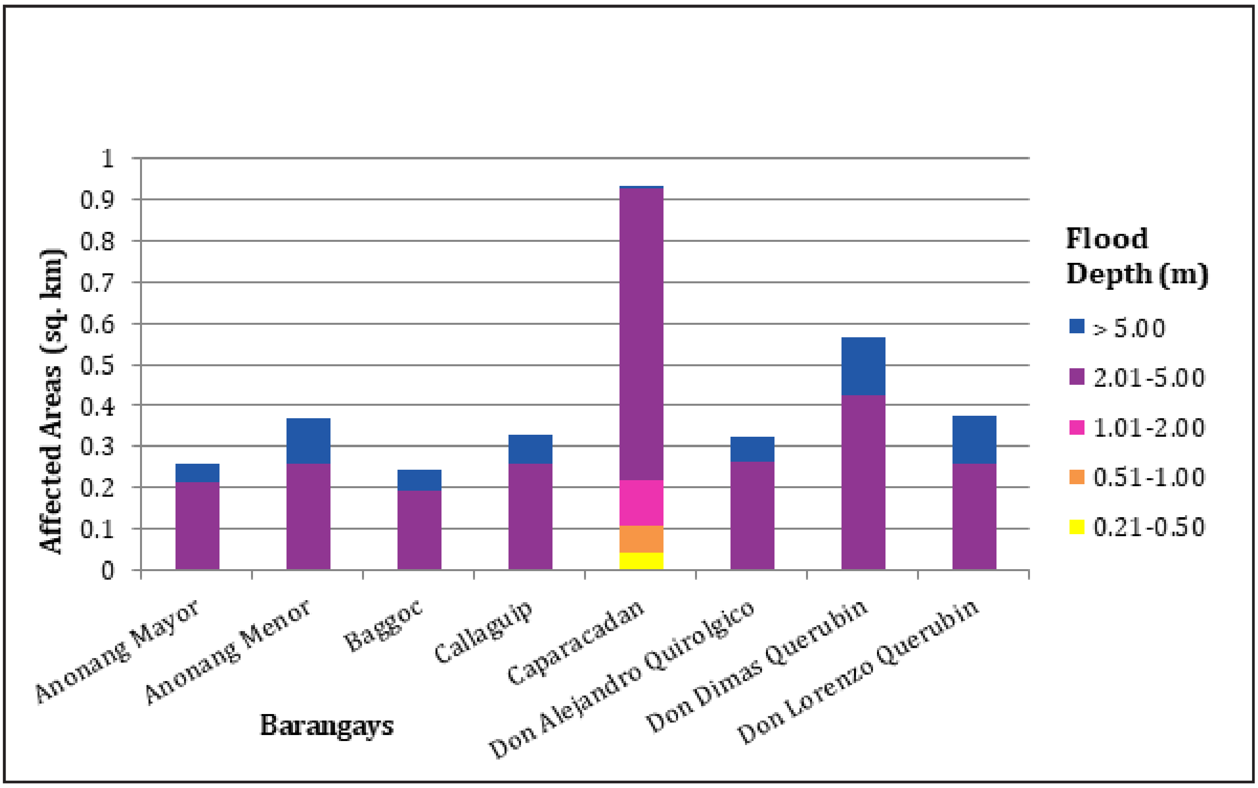


Figure 163. Affected Areas in Caoayan, Ilocos Sur during 100-Year Rainfall Return Period.

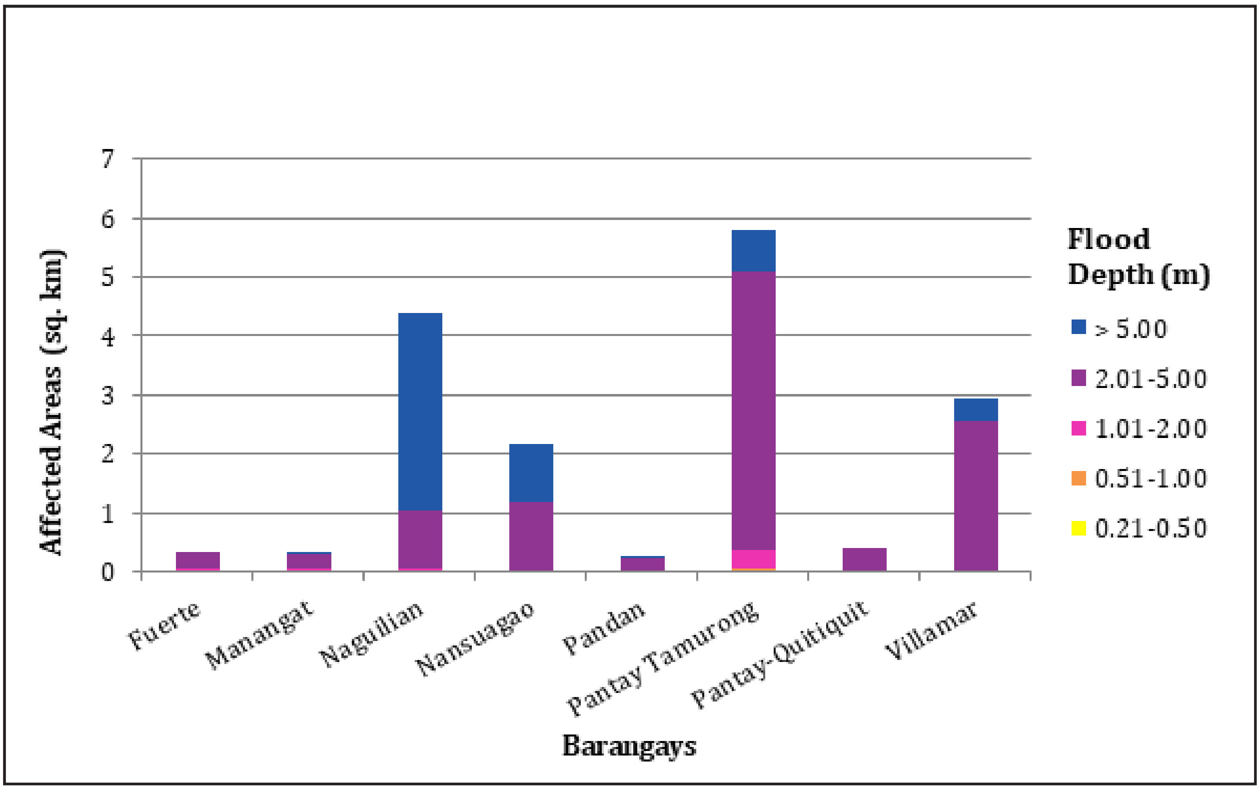


Figure 164. Affected Areas in Caoayan, Ilocos Sur during 100-Year Rainfall Return Period.

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

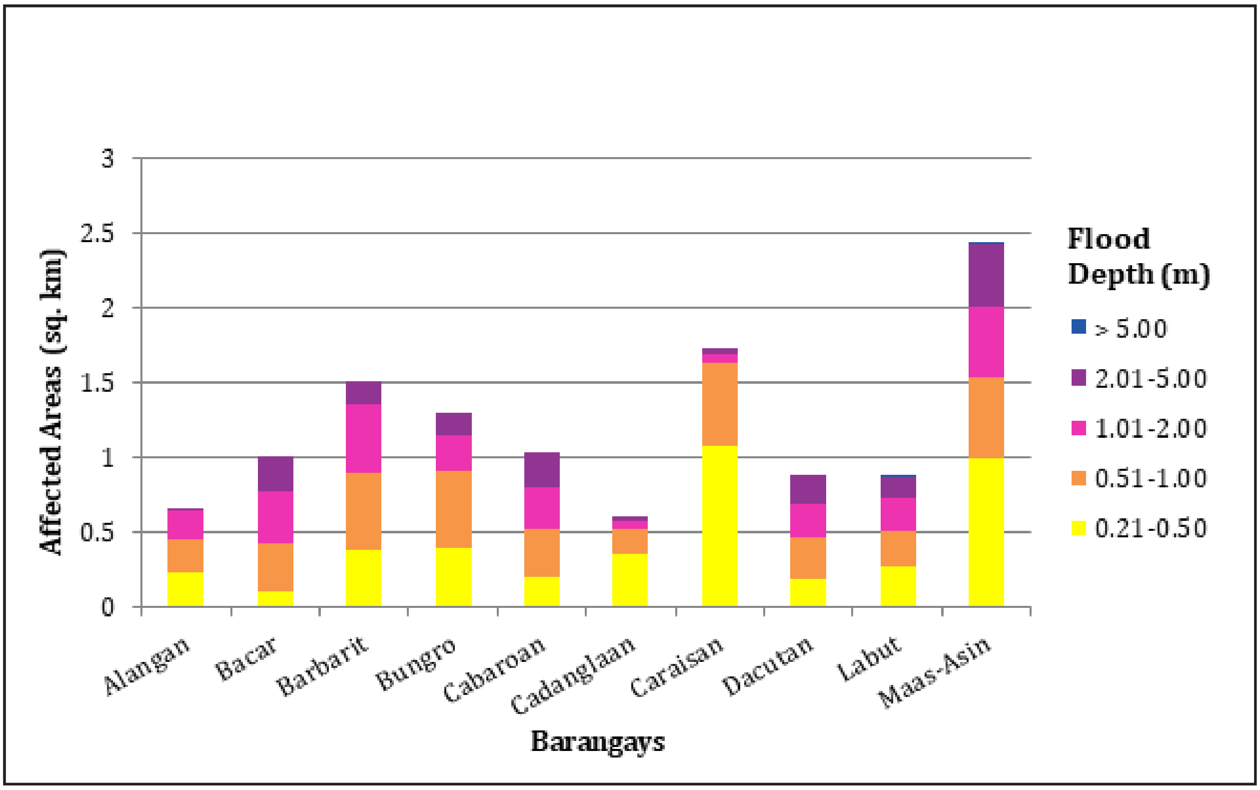


Figure 165. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

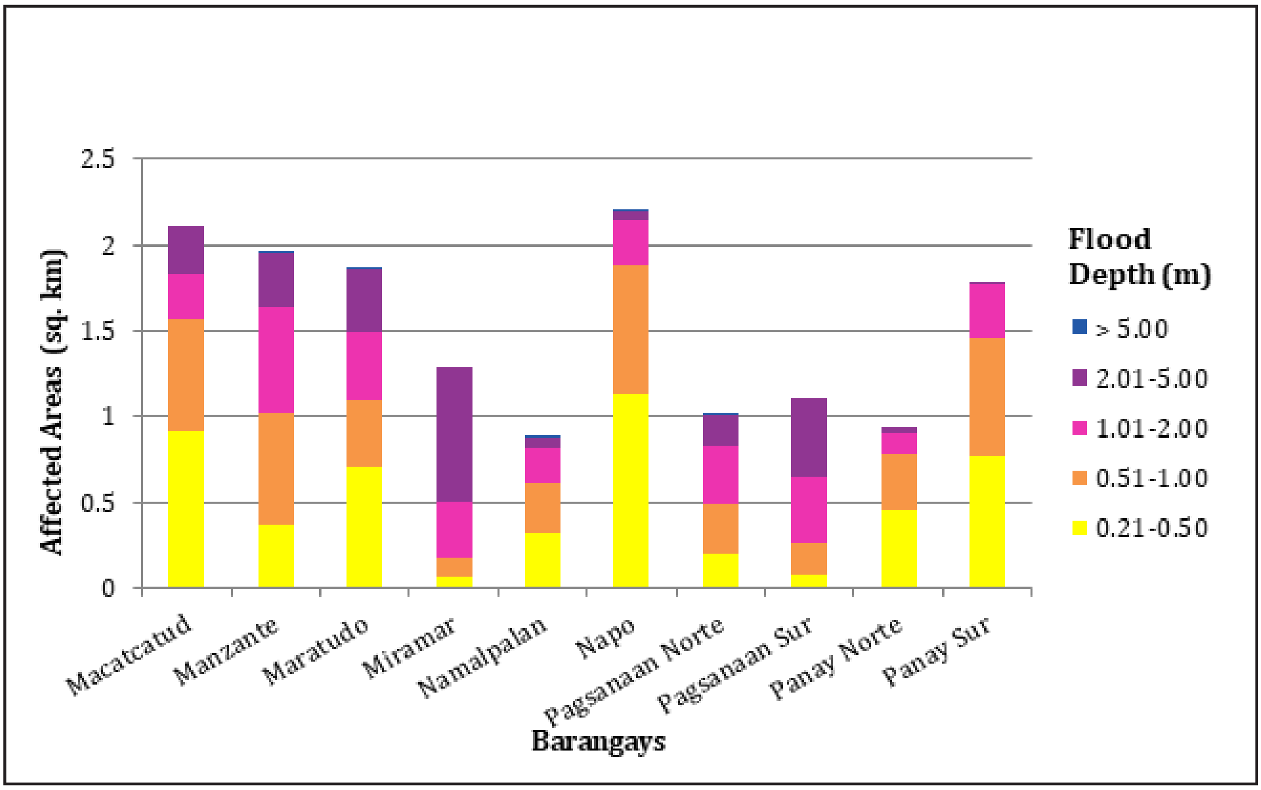


Figure 166. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

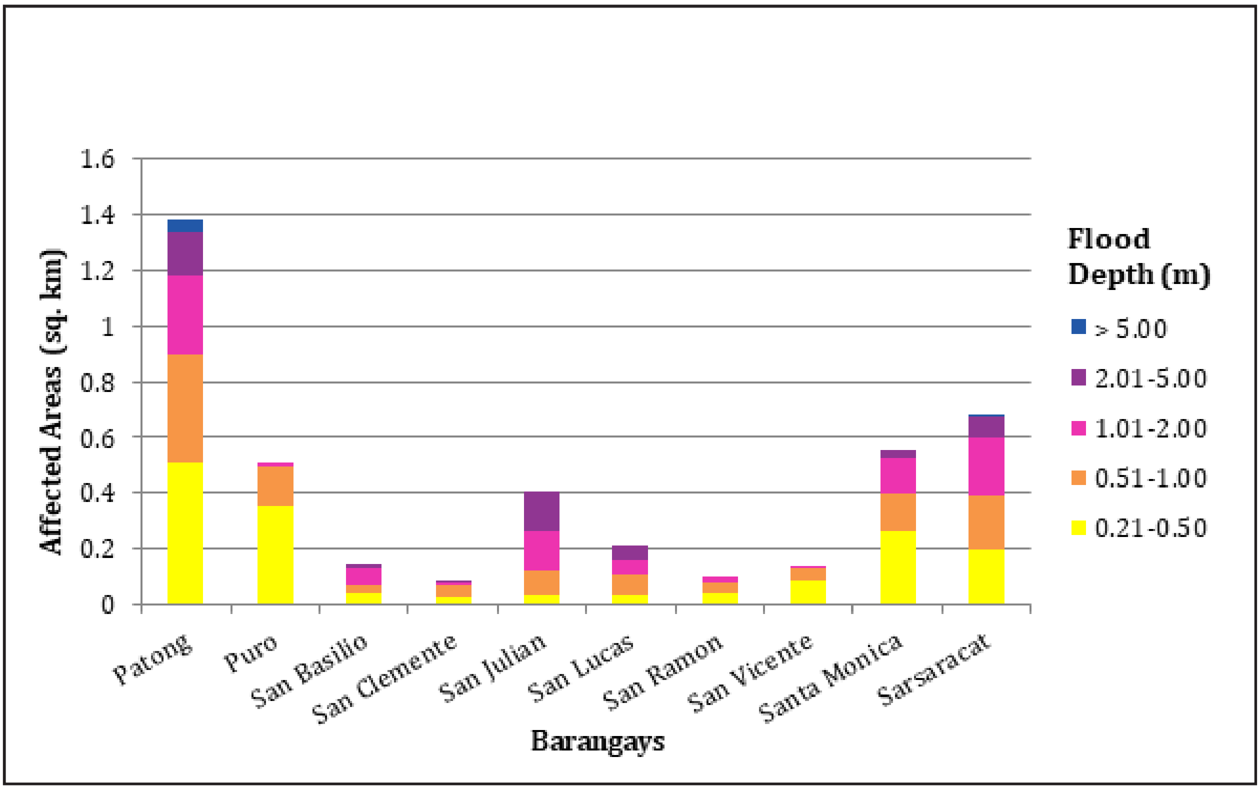


Figure 167. Affected Areas in Magsingal, Ilocos Sur during 100-Year Rainfall Return Period.

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

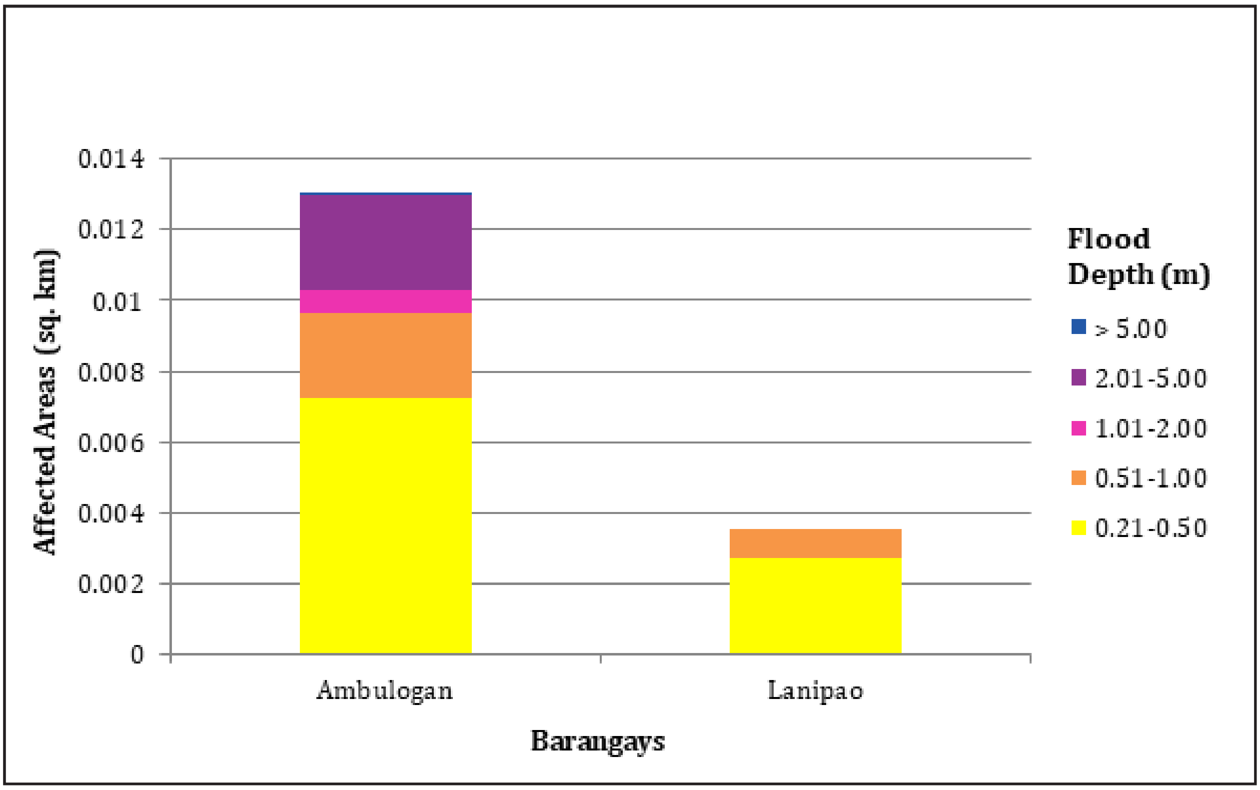


Figure 168. Affected Areas in Narvacan, Ilocos Sur during 100-Year Rainfall Return Period.

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

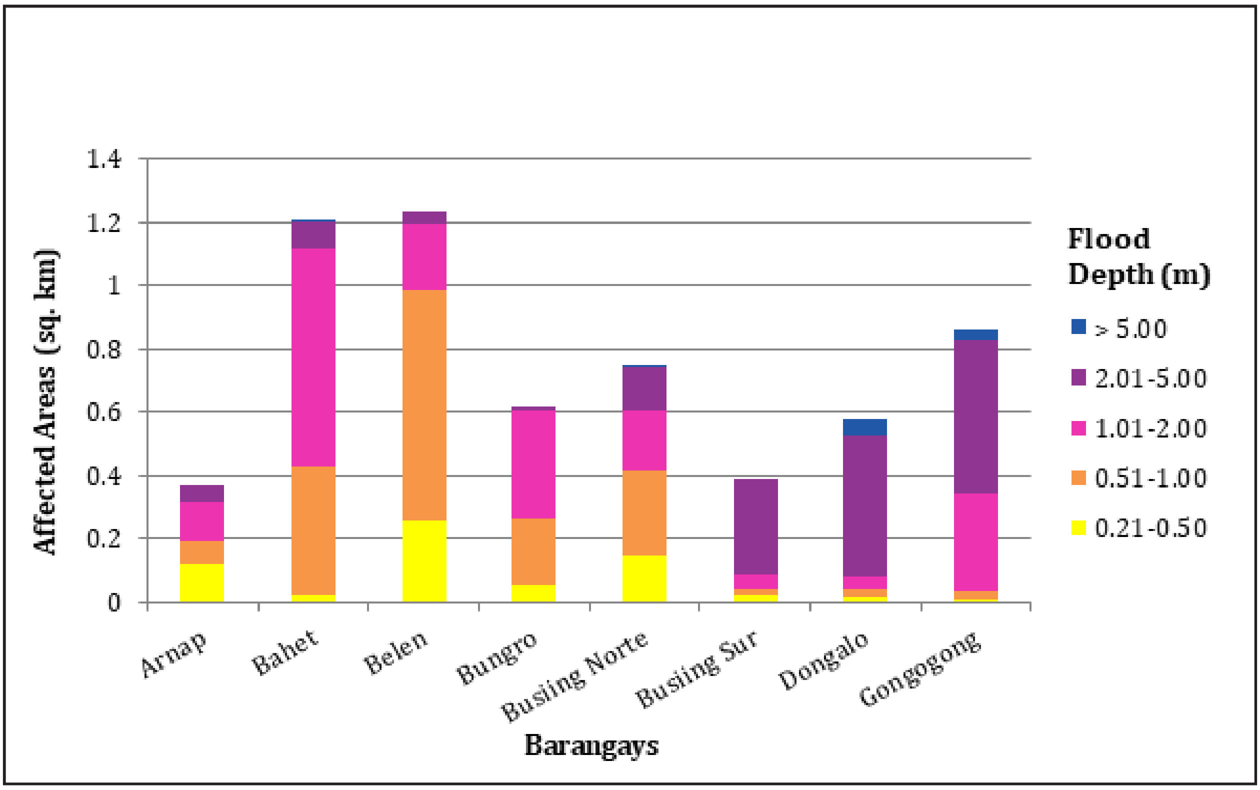


Figure 169. Affected Areas in San Ildefonso, Ilocos Sur during 100-Year Rainfall Return Period.

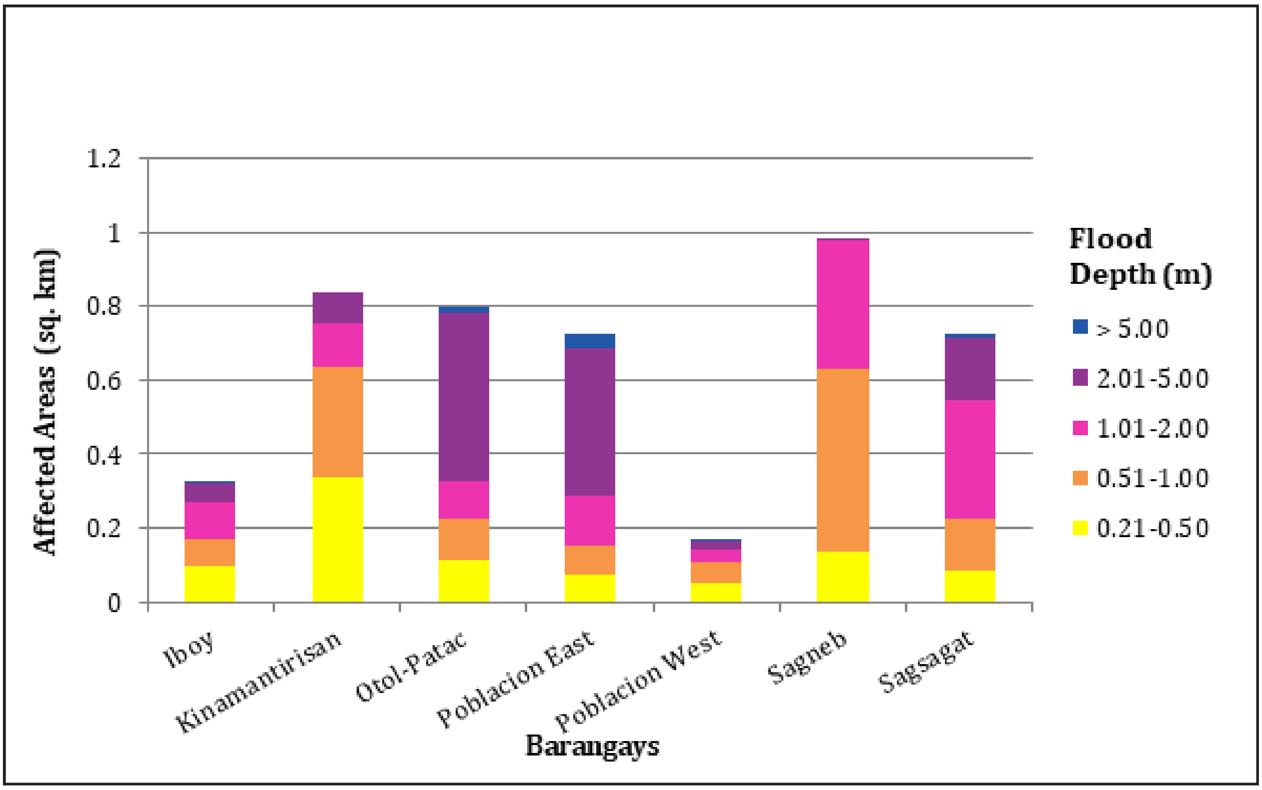


Figure 170. Affected Areas in San Ildefonso, Ilocos Sur during 100-Year Rainfall Return Period.

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

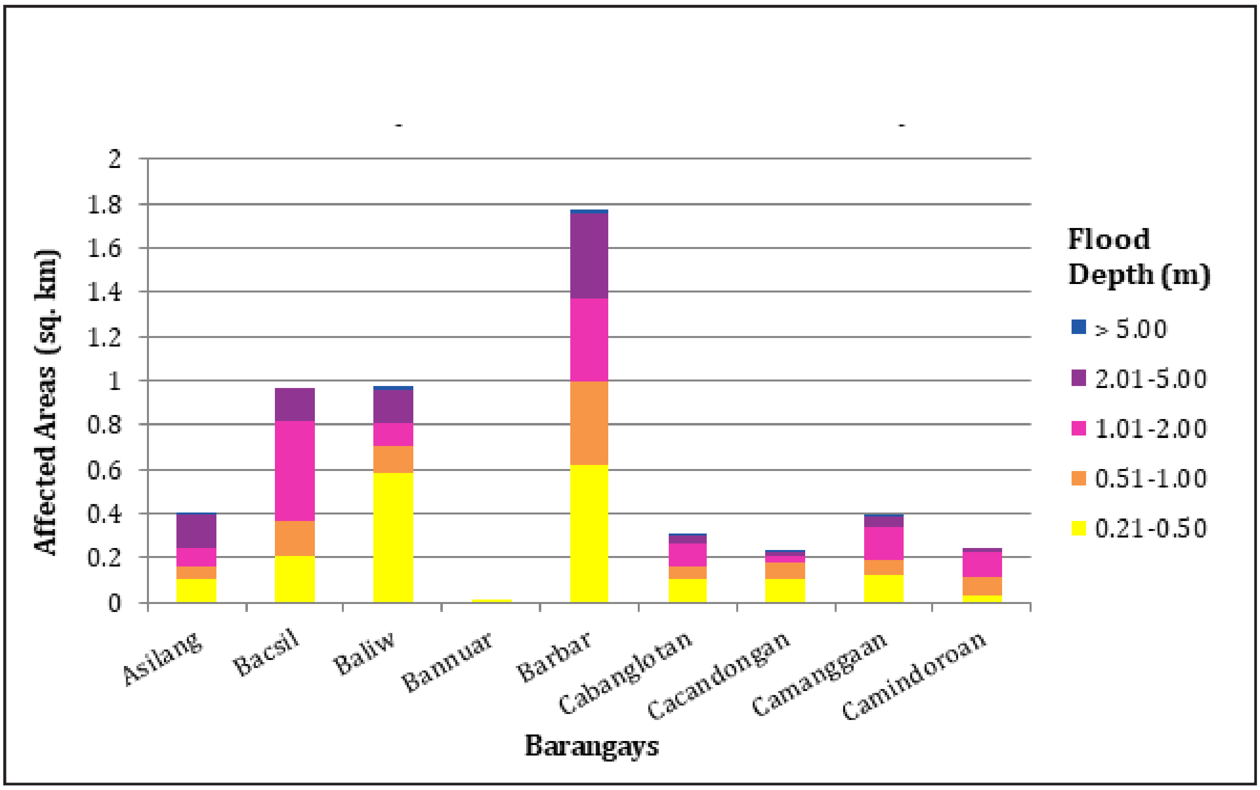


Figure 171. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

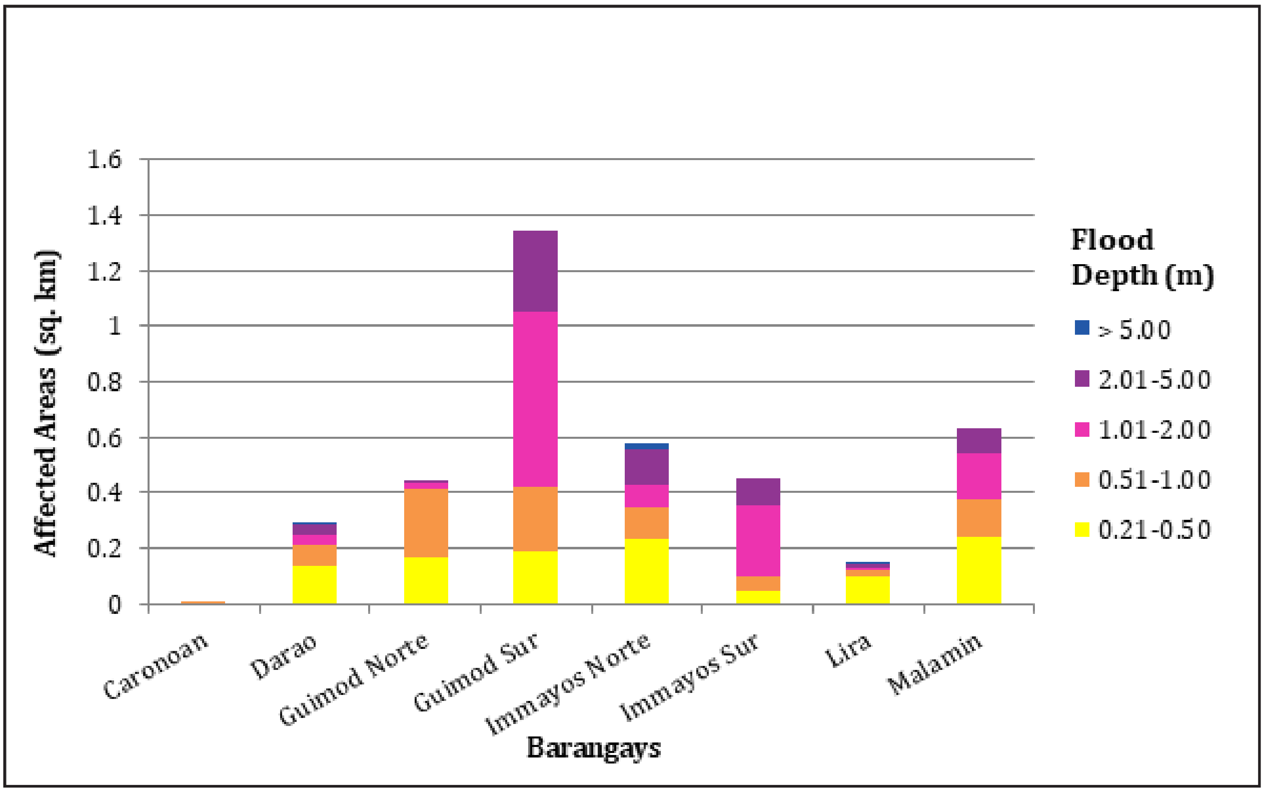


Figure 172. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

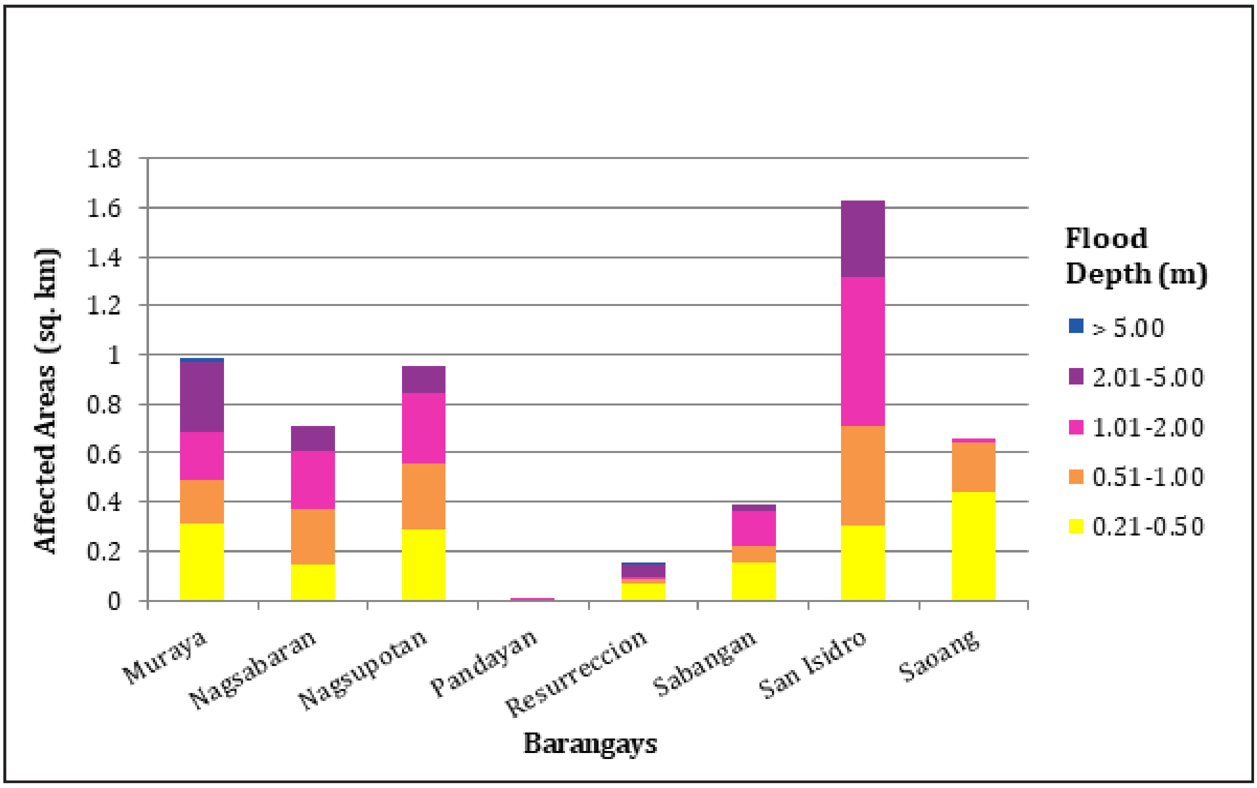


Figure 173. Affected Areas in San Juan, Ilocos Sur during 100-Year Rainfall Return Period.

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

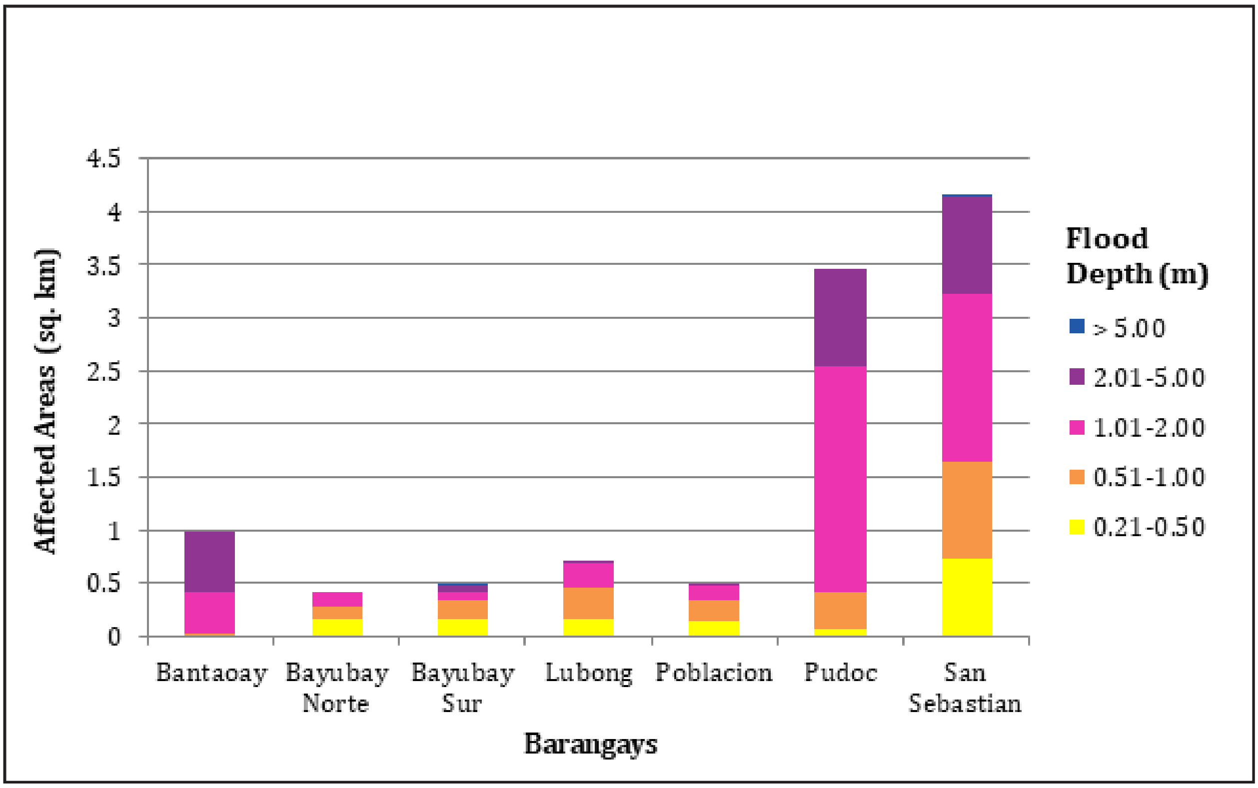


Figure 174. Affected Areas in San Vicente, Ilocos Sur during 100-Year Rainfall Return Period.

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

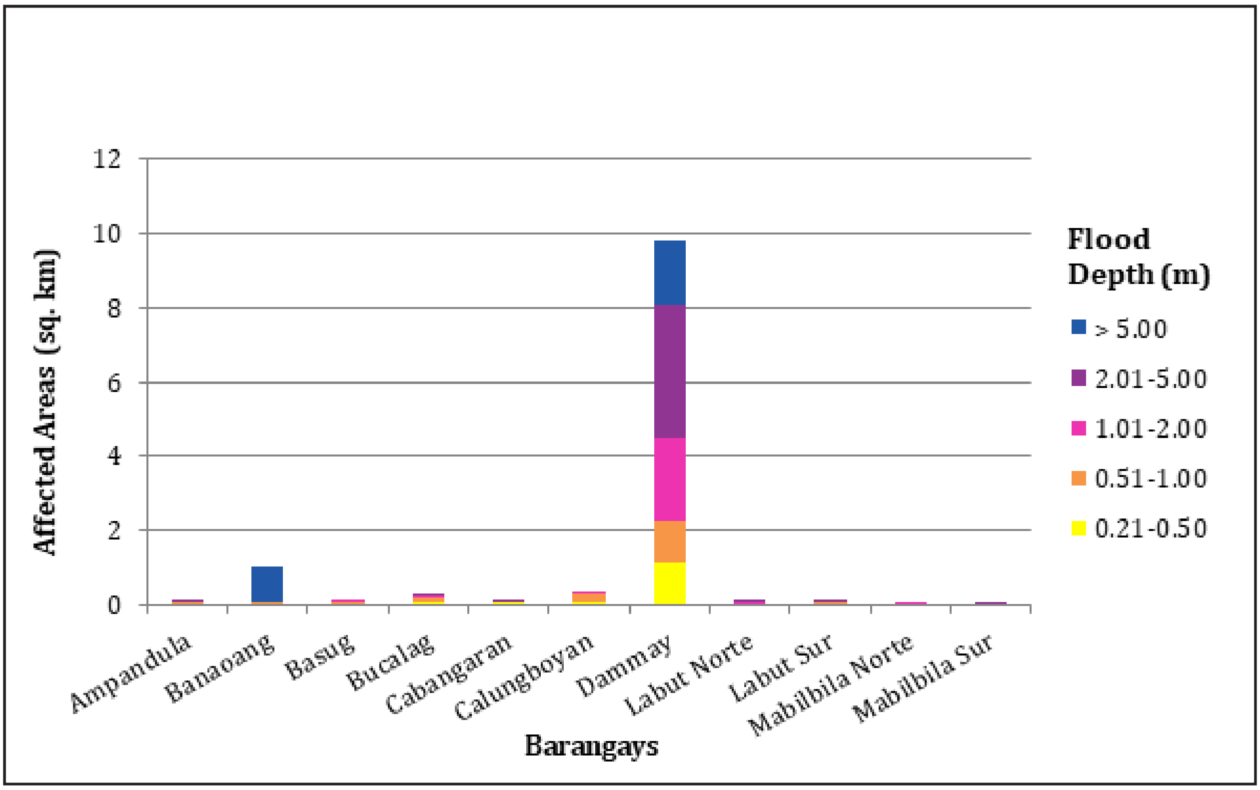


Figure 175. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period.

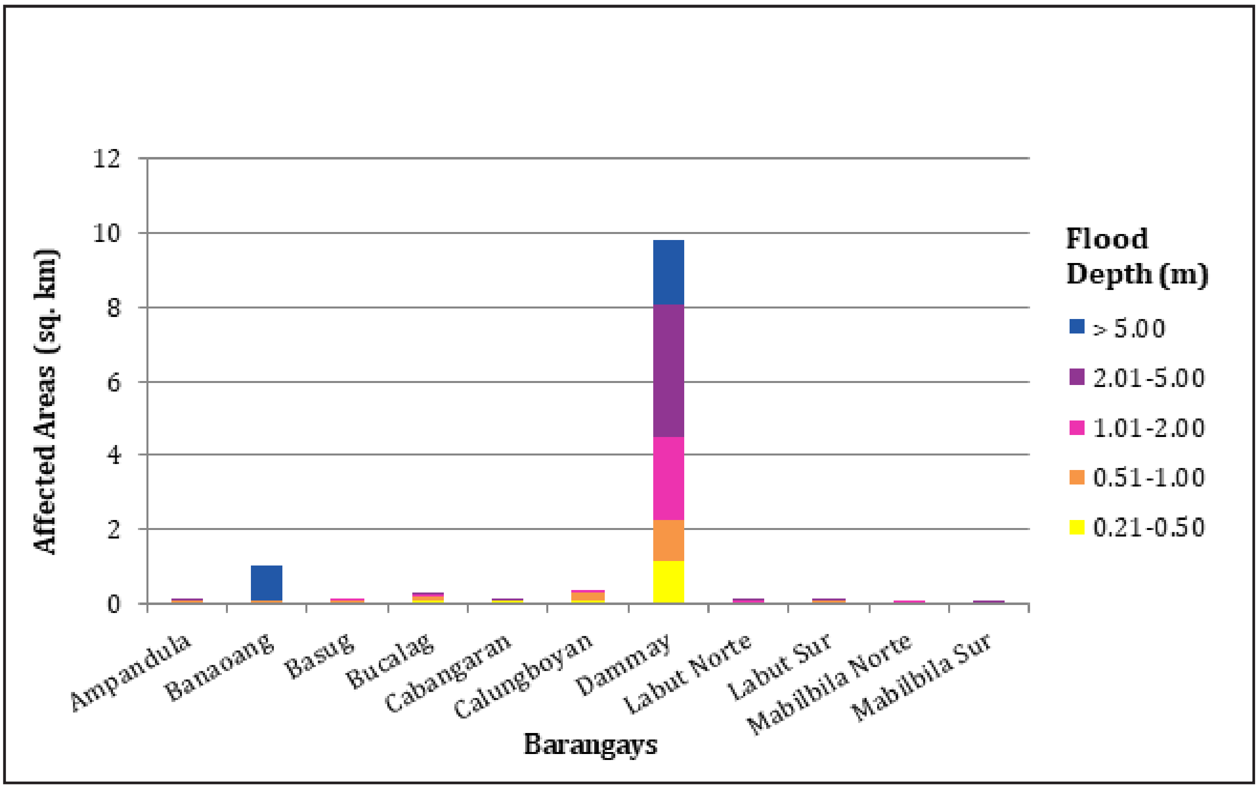


Figure 176. Affected Areas in Santa, Ilocos Sur during 100-Year Rainfall Return Period.

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

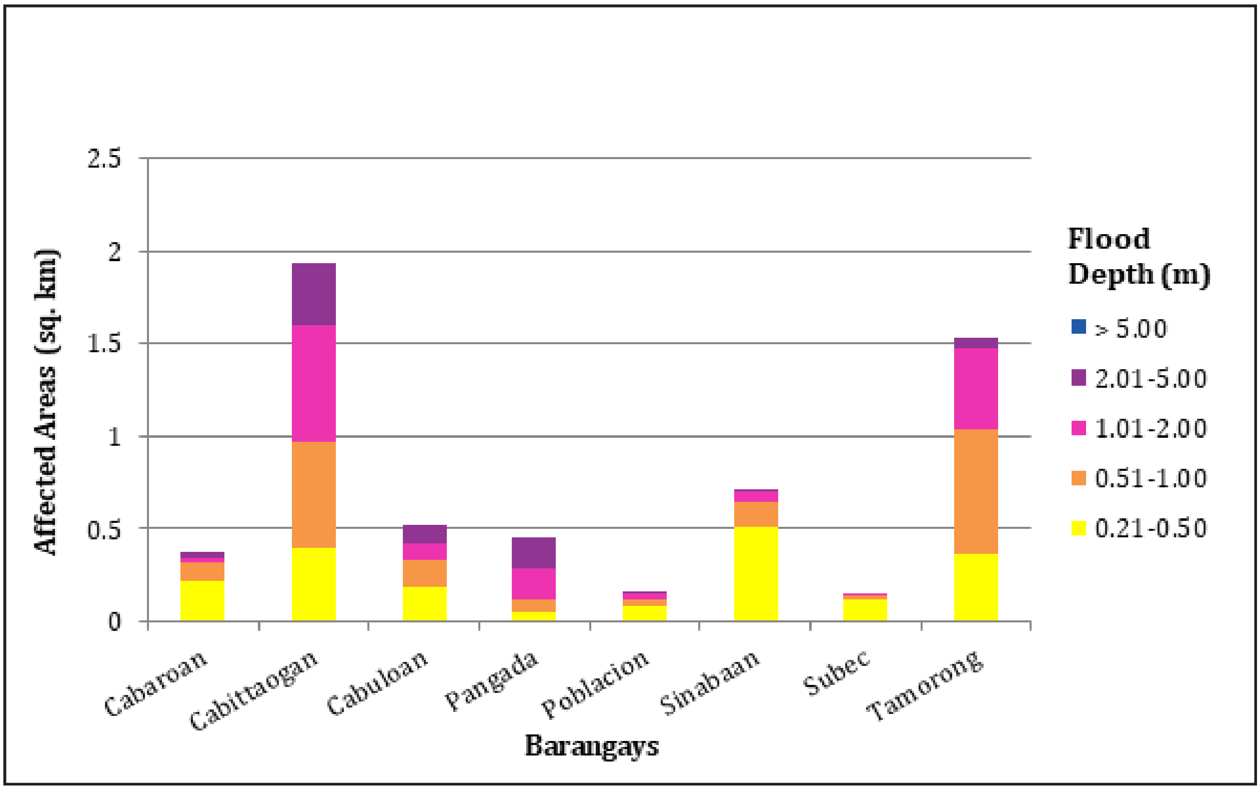


Figure 177. Affected Areas in Santa Catalina, Ilocos Sur during 100-Year Rainfall Return Period.

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

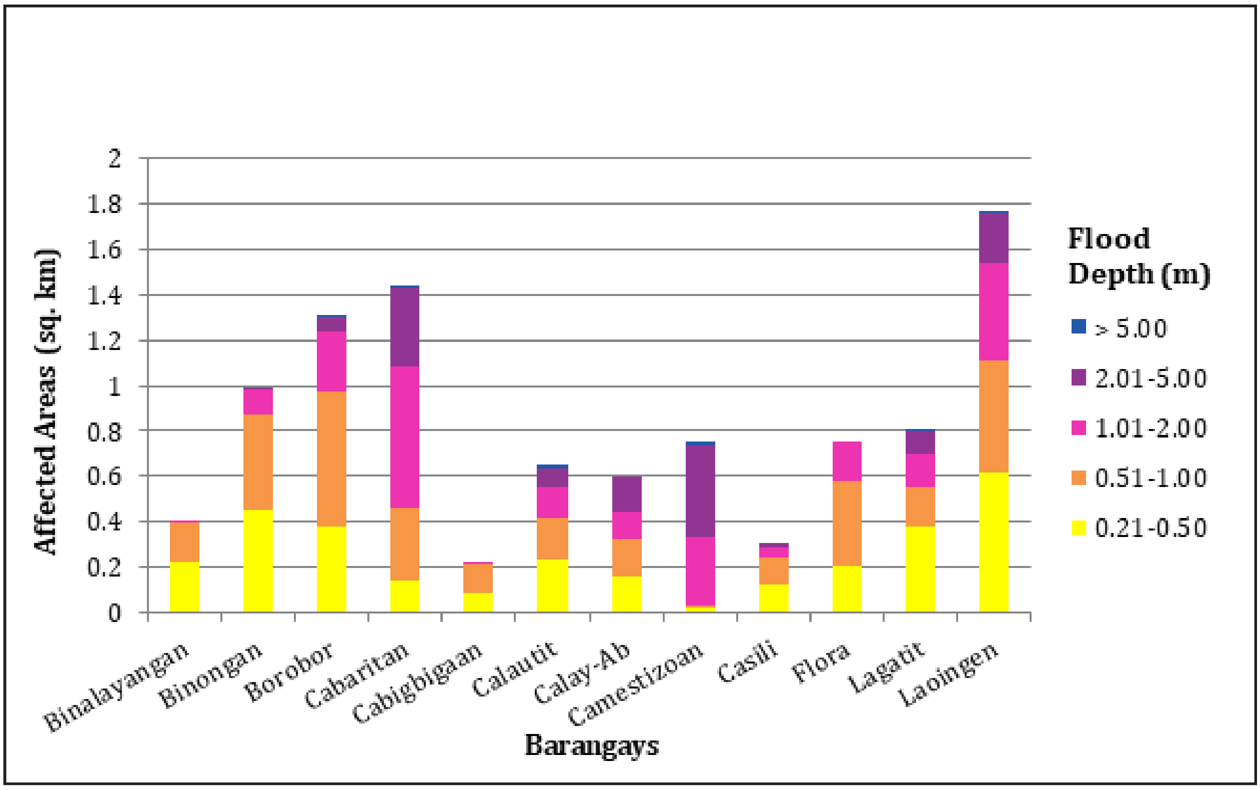


Figure 178. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

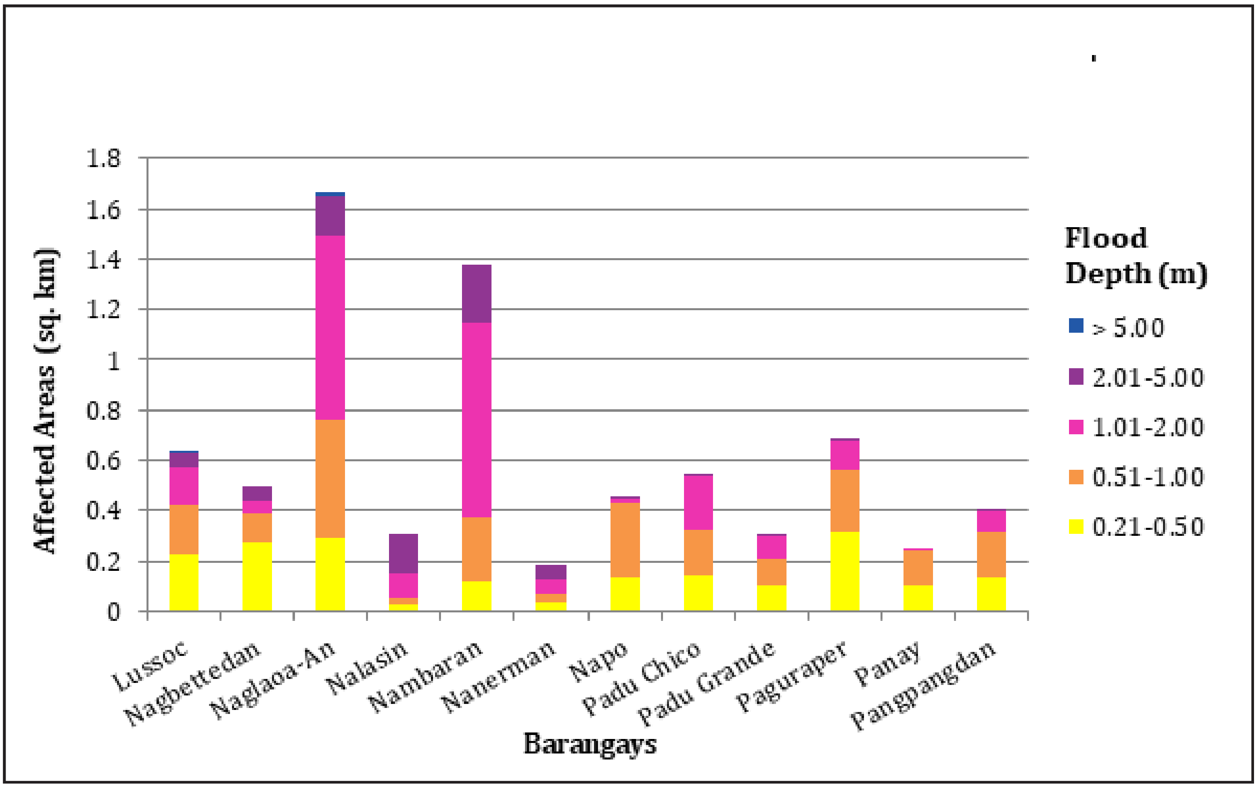


Figure 179. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

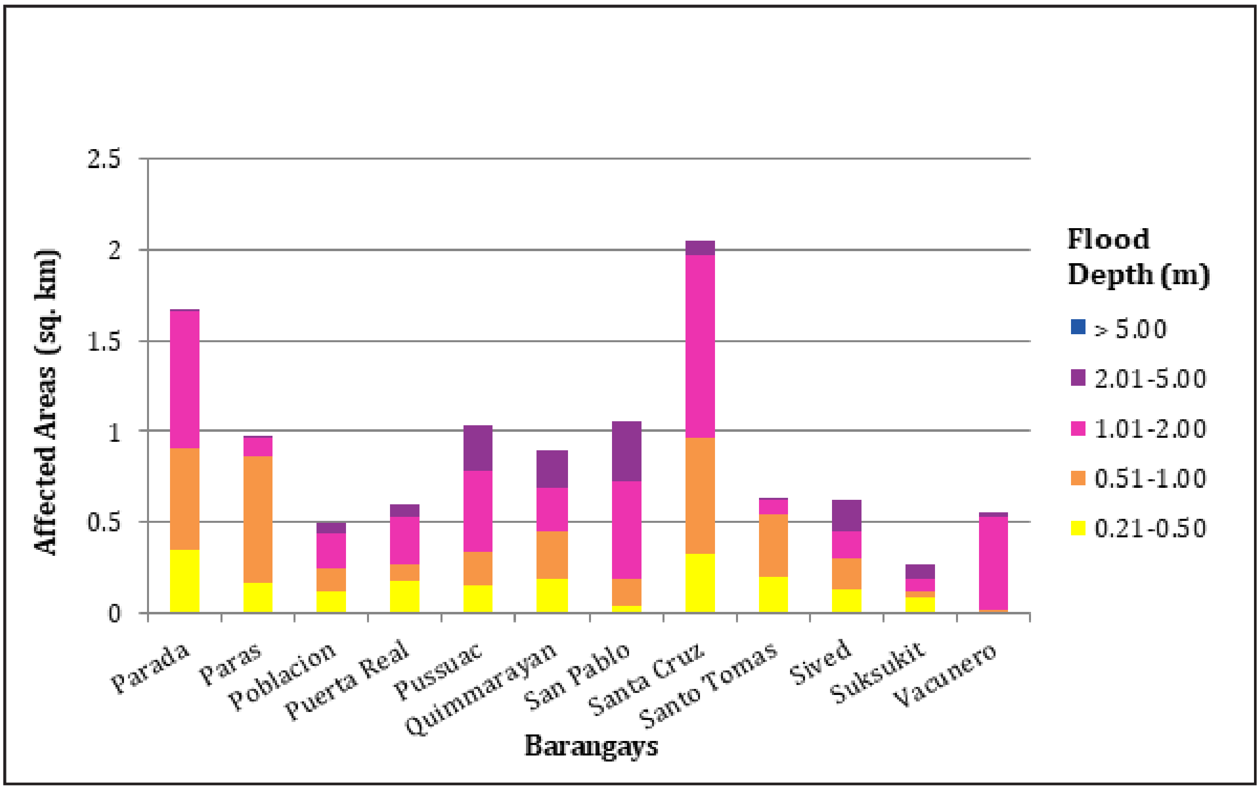


Figure 180. Affected Areas in Santo Domingo, Ilocos Sur during 100-Year Rainfall Return Period.

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

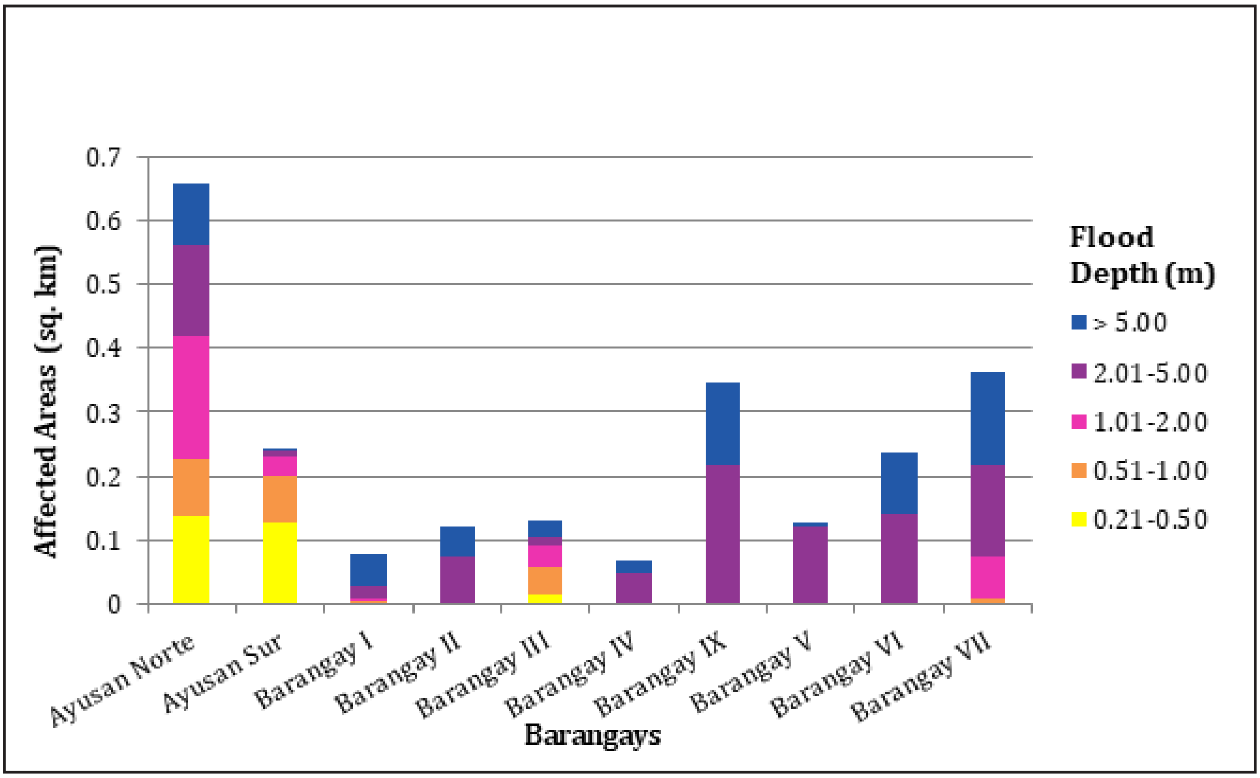


Figure 181. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

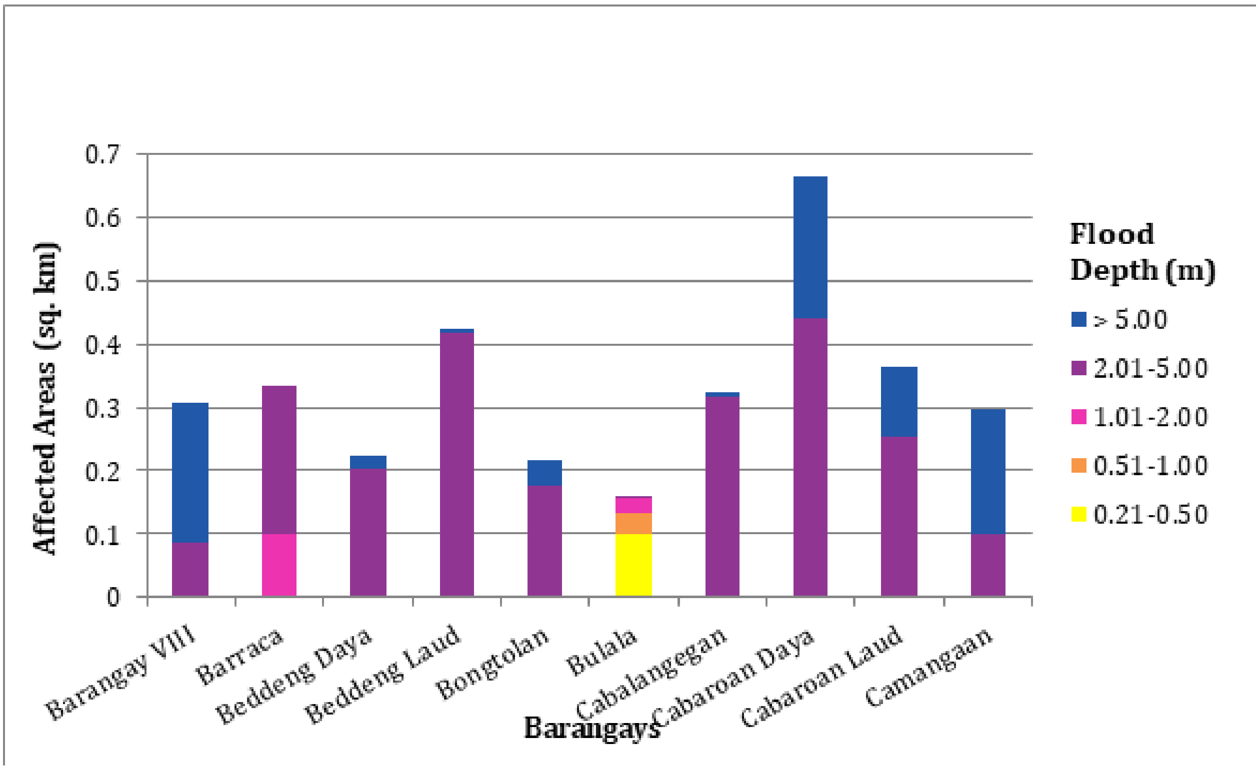


Figure 182. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

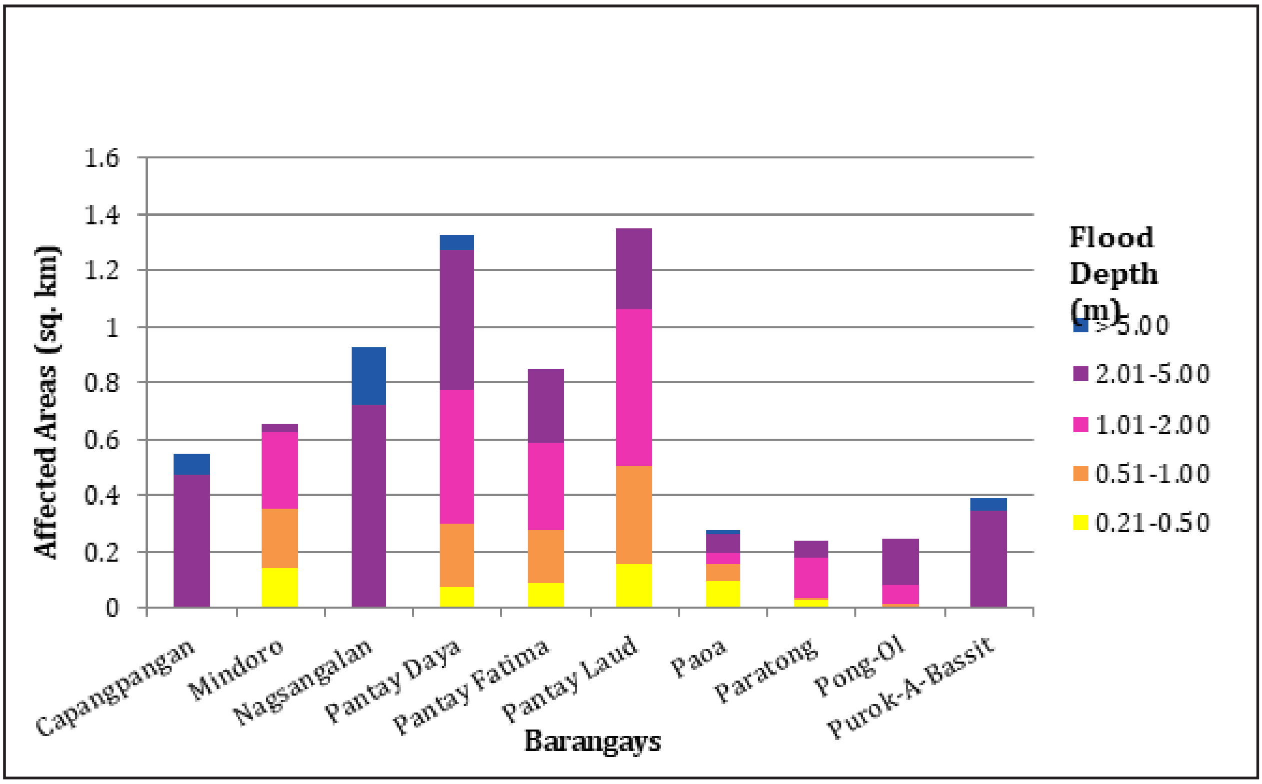


Figure 183. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

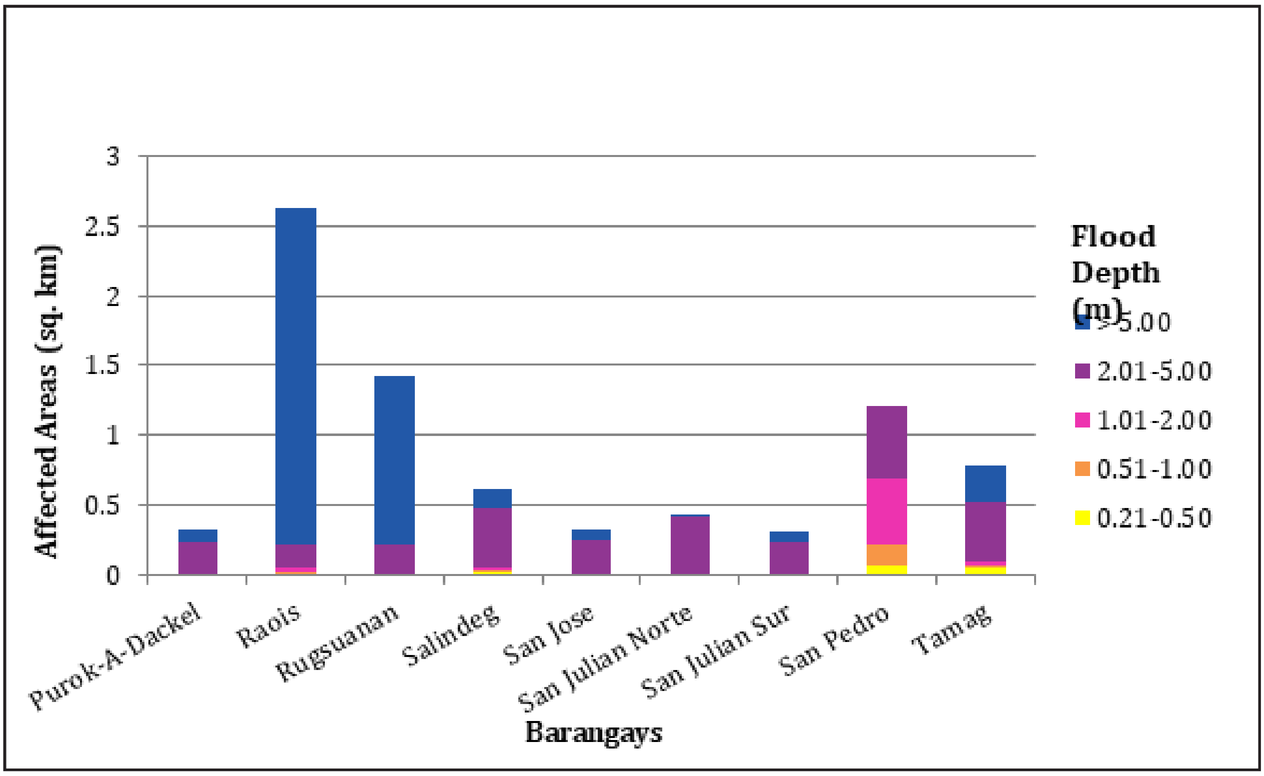


Figure 184. Affected Areas in Vigan City, Ilocos Sur during 100-Year Rainfall Return Period.

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 Ikmin 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 Ikmin 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 Ikmin floodplain.

Of the 30 identified Medical Institutions in Ikmin 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 Ikmin 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 gathered secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.
The flood validation survey was conducted in December 2016.The flood validation consists of 35 points randomly selected all over the Ikmin Floodplain. It has an RMSE value of 0.35. The validation points are found in Annex 11.

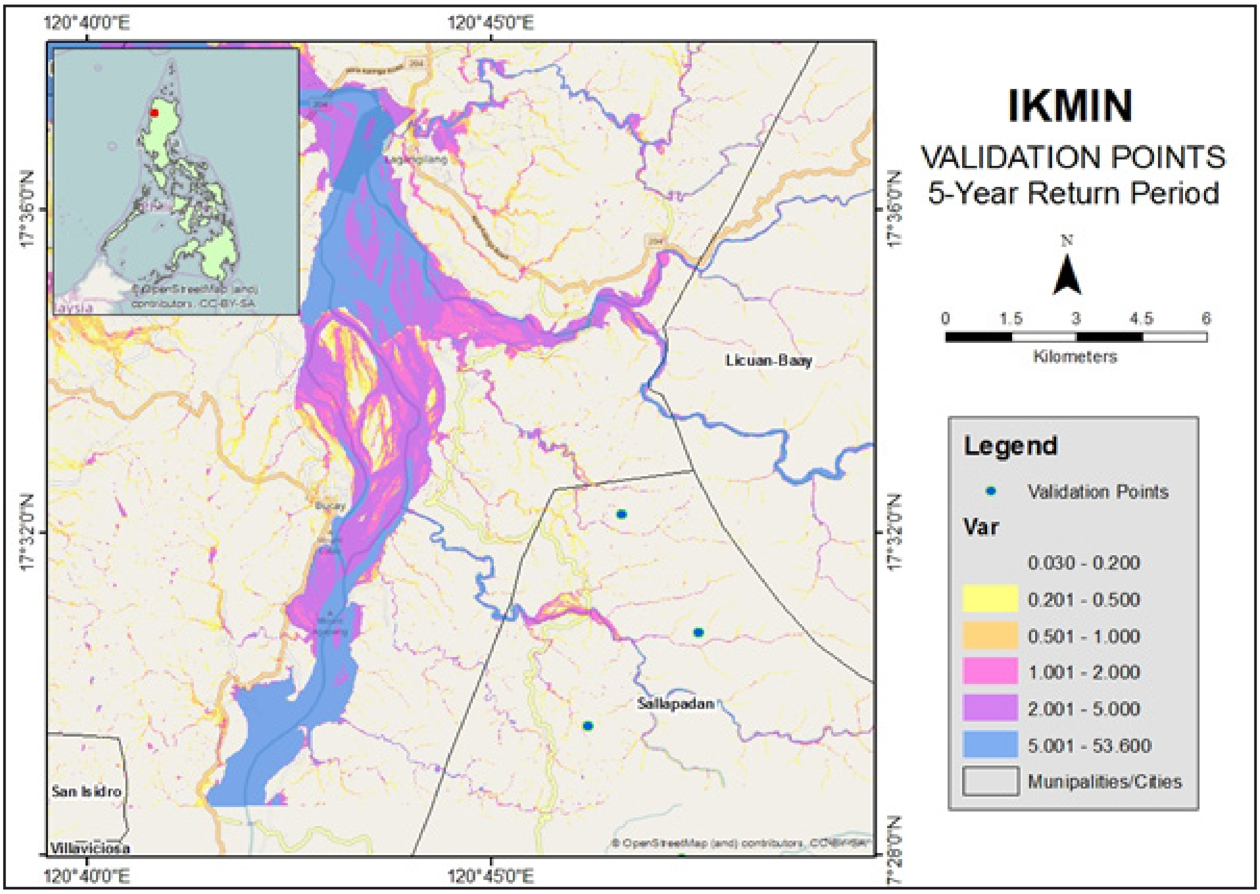


Figure 185. Flood Validation Points of Ikmin River Basin

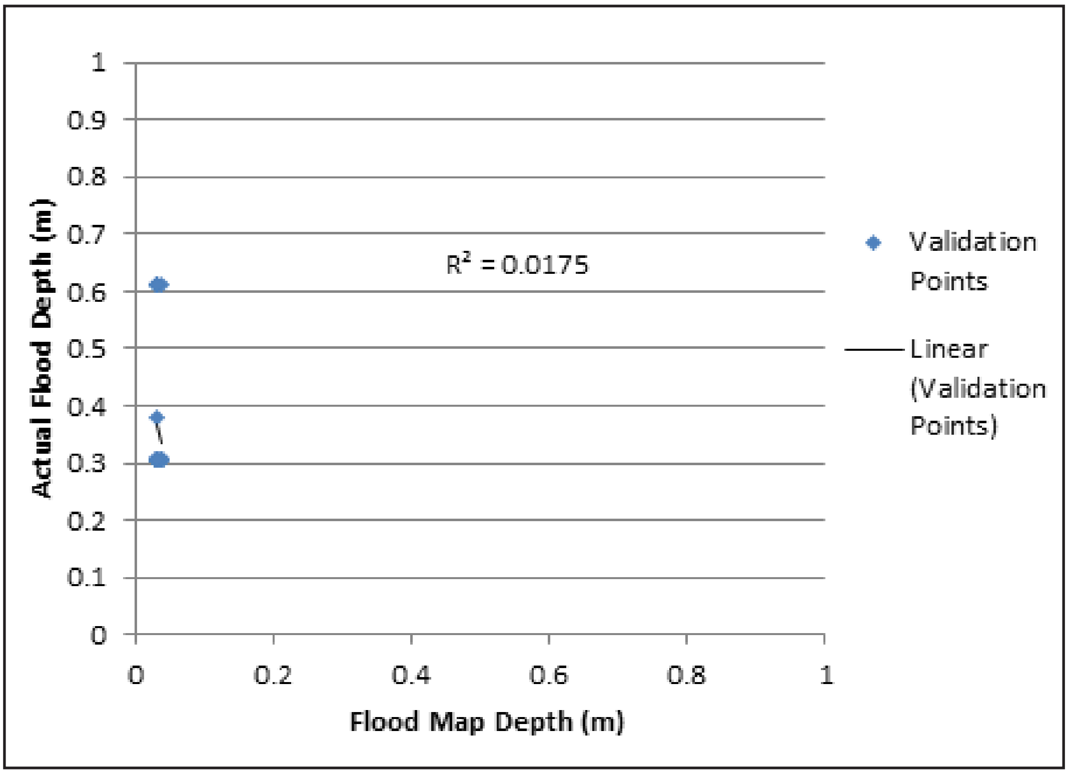


Figure 186. Flood Map Depth vs Actual Flood Depth for Ikmin

Table 40. Actual Flood Depth vs Simulated Flood Depth in Ikmin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	0	0	0	0	0	0	0
0.21-0.50	29	0	0	0	0	0	29
0.51-1.00	6	0	0	0	0	0	6
1.01-2.00	0	0	0	0	0	0	0
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	35	0	0	0	0	0	35

The overall accuracy generated by the flood model is estimated at 0.00%, with 0 points correctly matching the actual flood depths. In addition, there were 29 points estimated one level above and below the correct flood depths while there were 6 points and 0 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 0 points were overestimated while a total of 35 points were underestimated in the modelled flood depths of Ikmin.

Table 41. Summary of Accuracy Assessment in Ikmin

	No. of Points	%
Correct	0	0.00
Overestimated	0	0.00
Underestimated	35	100.00
Total	35	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 Ikmin Floodplain Survey

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**		Barangay: **POBLACION**
Municipality: **PEÑARRUBIA**		
	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

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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

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

PRS92 Coordinates		
Latitude: **17° 33' 49.34656"**	Longitude: **120° 33' 25.07659"**	Ellipsoidal Hgt: **39.32200 m.**
WGS84 Coordinates		
Latitude: **17° 33' 43.22900"**	Longitude: **120° 33' 29.72282"**	Ellipsoidal Hgt: **72.81400 m.**
PTM Coordinates		
Northing: **1942534.242 m.**	Easting: **452967.729 m.**	Zone: **3**
UTM Coordinates		
Northing: **1,943,468.54**	Easting: **240,677.03**	Zone: **51**

Location Description

ABR-32

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

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

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

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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

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**
Municipality: **SAN JUAN**
Barangay: **BACSIL**

PRS92 Coordinates

Latitude: **17° 43' 40.62808"**	Longitude: **120° 27' 9.37799"**	Ellipsoidal Hgt: **56.57700 m.**

WGS84 Coordinates

Latitude: **17° 43' 34.46721"**	Longitude: **120° 27' 14.01102"**	Ellipsoidal Hgt: **89.29100 m.**

PTM Coordinates

Northing: **1960739.965 m.**	Easting: **441941.245 m.**	Zone: **3**

UTM Coordinates

Northing: **1,961,798.84**	Easting: **229,838.72**	Zone: **51**

Location Description

ILS-9

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

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

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

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

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

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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

CP/4701/12/09/814

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

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CP/4/01/13/09/814

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

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**

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

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

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

CP/4701/12/09/814

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

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

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

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
ΔElevation	-2.295 m	ΔHeight	-2.290 m	ΔZ	-111.739 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.001 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

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

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	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

ANNEX 5. Data Transfer Sheet for Ikmin 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	2BLK06E062A & 2BLK06A062A	GEMINI	NA	68.1KB	429KB	206MB	NA	NA	19.3GB	NA	12.3MB	1KB	1KB	6/174/10/5/38KB	8KB	Z:\Airborne_Raw\7104GC
Mar 3, 2014	7105GC	2BLK06AS062B & 2BLK06C062B	GEMINI	NA	302KB	493KB	254MB	NA	NA	23.3GB	NA	12.6MB	1KB	1KB	6/206/6/206/67KB	11KB	Z:\Airborne_Raw\7105GC
Mar 4, 2014	7107GC	2BLK07C063B	GEMINI	NA	59.1KB	306KB	187MB	NA	NA	15GB	NA	3.84MB	1KB	1KB	132KB	192KB	Z:\Airborne_Raw\7107GC
Mar 5, 2014	7108GC	2BLK07C063B	GEMINI	NA	106KB	638KB	268MB	NA	NA	29.2GB	NA	11MB	1KB	1KB	266KB	10/10KB	Z:\Airborne_Raw\7108GC
Mar 7, 2014	7112GC	2BLK06G066A & 2BLK06DS066A	GEMINI	NA	298KB	451KB	247MB	NA	NA	18.5GB	NA	11.4MB	1KB	1KB	197/64KB	17KB	Z:\Airborne_Raw\7112GC
Mar 8, 2014	7114GC	2BLK07CS067A & 2BLK06G067A	GEMINI	NA	68.4KB	436KB	264MB	NA	NA	19.3GB	NA	8.45MB	1KB	1KB	7/5/304KB	7/5KB	Z:\Airborne_Raw\7114GC
Mar 9, 2014	7116GC	2BLK07B068A	GEMINI	NA	306KB	476KB	257MB	NA	NA	19.4GB	NA	10.8MB	1KB	1KB	5/209/51/5/209KB	9KB	Z:\Airborne_Raw\7116GC
Mar 10, 2014	7118GC	2BLK07D069A & 2BLK07G069A	GEMINI	NA	332KB	483KB	259MB	NA	NA	18.7GB	NA	14.5MB	1KB	1KB	6/228/346/10/5/228KB	10KB	Z:\Airborne_Raw\7118GC
MAR 10\	7119GC	2BLK27A069B	GEMINI	NA	321KB	520KB	253MB	NA	NA	24.6GB	NA	14.7MB	1KB	1KB	5/48/5/221/51KB	NA	Z:\Airborne_Raw\7119GC
Mar 11, 2014	7120GC	2BLK06F070A & 2BLK07A070A	GEMINI	NA	87.4KB	506KB	251MB	NA	NA	18GB	NA	11.2MB	1KB	1KB	10/26/219KB	16KB	Z:\Airborne_Raw\7120GC
Mar 11, 2014	7121GC	2BLK07GS070B & 2BLK07AS070B	GEMINI	NA	216KB	319KB	217MB	NA	NA	12.7GB	NA	10.8MB	1KB	1KB	149/6KB	10KB	Z:\Airborne_Raw\7121GC
Mar 12, 2014	7122GC	2BLK07E071A & 2BLK07F071A	GEMINI	NA	74.4KB	399KB	228MB	NA	NA	14.5GB	NA	8.36MB	1KB	1KB	399/7/399/6KB	9KB	Z:\Airborne_Raw\7122GC

Received from

Name CHRIS JOAQUIN
Position RA
Signature 04/21/14

Received by

Name JOIDA F PRIETO
Position SSRS
Signature 4/22/14

DATA TRANSFER SHEET
LAOAG 6/29/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
May 28, 2016	4043G	2BLKSA7149A	GEMINI	NA	325	604	242	NA	NA	24.7	NA	334	1KB	NA	6KB	14	Z:\DAC\RAW DATA
May 28, 2016	4045G	2BLKSB7149B	GEMINI	NA	190	402	231	NA	NA	14.5	NA	334	1KB	NA	8	17	Z:\DAC\RAW DATA

Received from

Name R PUNTO
Position RA
Signature

Received by

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

16-41

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 CASI)

21 Problems and Solutions:

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

Acquisition Flight Certified by
SSg [illegible] PAF
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
MVE T[illegible]
Signature over Printed Name

2. Flight Log for 7108GC Mission

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

1 LiDAR Operator: MVE TONGA /	2 ALTM Model: GEMINI (CAS)	3 Mission Name: 2BLK06C044A	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 BLK 06D (without CA31)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Antonio Matira	SSg Dorado Soberano PAF	R. GAMALIEL II	MVG
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 7112GC Mission

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

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: LEMS (CASI)	3 Mission Name: 2BLK06DS066A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: Mar. 7, 2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: surveyed 11 lines of BlK 06G & 7 lines of BlK 06 Q (without CASI)					

21 Problems and Solutions:

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

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

Pilot-in-Command
R. S
Signature over Printed Name

Lidar Operator
CATHERINE BALIGUAS
Signature over Printed Name

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 CAS1	3 Mission Name: 2BLK06GO67A	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 Soteraño PAF	R. Ey	M. Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight Log for 7116GC Mission

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

1 LIDAR Operator: NICE BALIGUAS	2 ALTM Model: GEMINI	3 Mission Name: 2BLK07BO69A	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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Aubrey Matira	SSg Dinsao Sorgalo PAF	R. [illegible]	CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 7118GC Mission

DREAM Data Acquisition Flight Log 2BLK07OG9A **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: 9322
7 Pilot: R-SAMAR II	8 Co-Pilot: C. ALFONSO III	9 Route:			
10 Date: 03-10-2014	12 Airport of Departure (Airport, City/Province): RPLI		12 Airport of Arrival (Airport, City/Province): RPLI		
13 Engine On: 0648H	14 Engine Off: 1110H	15 Total Engine Time: 4+22	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	windy				

20 Remarks: Mission completed at BLK 07D & surveyed 2 lines of BLK 076 (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

6. Flight Log for 7120GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 520

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: GEM+CASI	3 Mission Name: 2BLK06F & BLK07A 070A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR II	8 Co-Pilot: C. ALFONSO II	9 Route: Laoag – BLK 06F & 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: 0700H	14 Engine Off: 1111H	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	SSgt Dioscoro Sotero PAF	R Samar II	Catherine Baliguas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

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
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

8. Flight Log for 4043GC Mission

D R E A M | Data Acquisition Flight Log

Flight Log No.: 4043

1 LIDAR Operator: MVC Tongga	2 ALTM Model: Gemini	3 Mission Name: 2BLK74A099A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: ML Tangonan	8 Co-Pilot: J. Alcazar	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: ~~13:40~~ 7:10	14 Engine Off: ~~17:36~~ 11:26	15 Total Engine Time: ~~3+56~~ 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	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Rean Alidas		M.L. Tangonan	MVC Tongga	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

9. Flight Log for 4045GC Mission

DREAM | Data Acquisition Flight Log

Flight Log No.: 4046

1 LiDAR Operator: RE Pelicano	2 ALTM Model: Gemini	3 Mission Name: 2BLK7SB198 4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: ML Tangonan	8 Co-Pilot: J. Alburo	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: 12:40	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 BLK7SB

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.A.C. Pelicano Signature over Printed Name	Signature over Printed Name

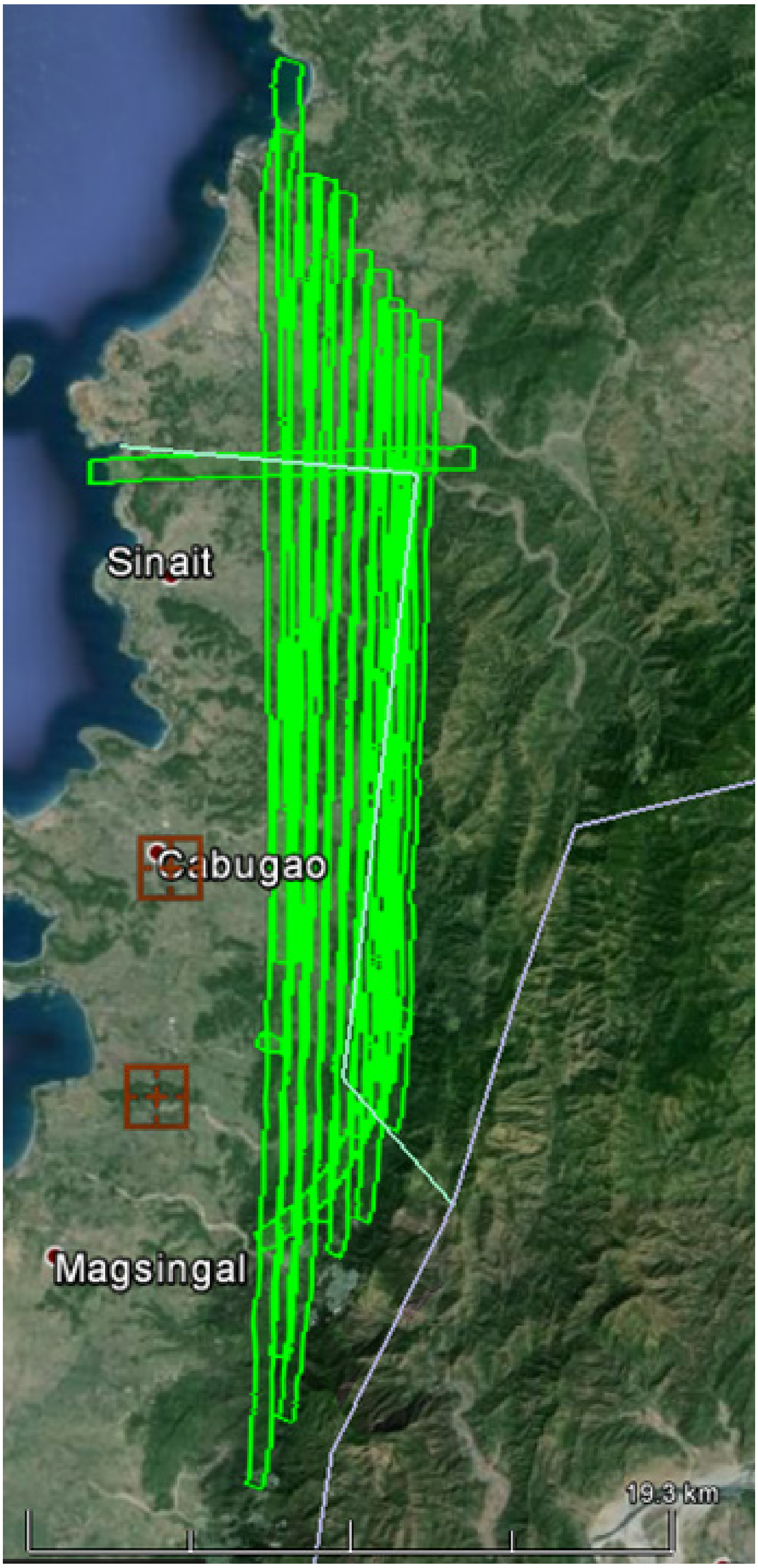
ANNEX 7. Flight status reports

FLIGHT STATUS REPORT
ABRA and ILOCOS

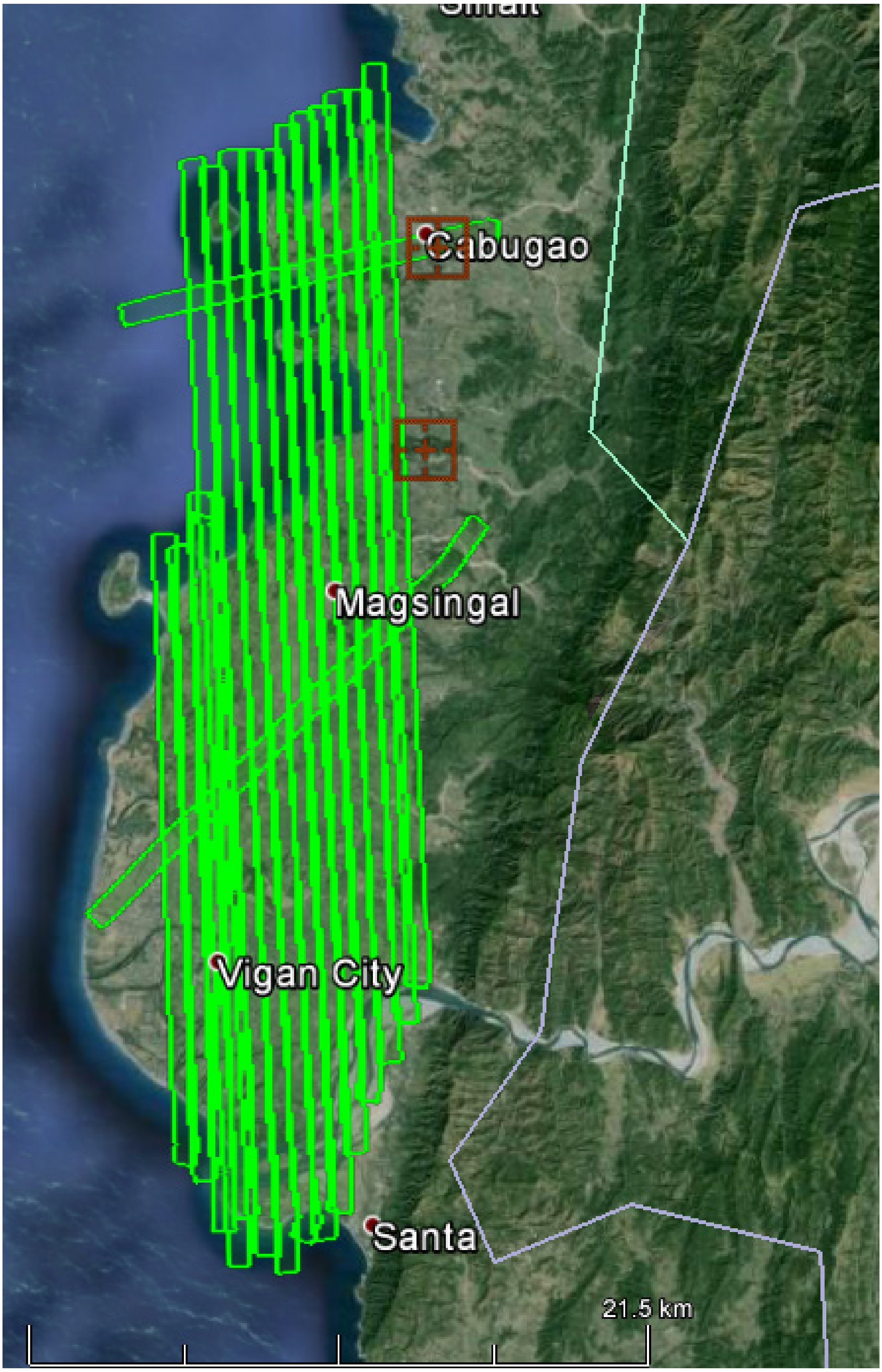
FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7104GC	BLK06	2BLK06E062A & 2BLK06A062A	MVE TONGA	March 5, 2014	Mission completed at BLK06E and surveyed 2 lines at BLK06A (without CASI)
7108GC	BLK06	2BLK06C064A & 2BLK06D064A	MVE TONGA	March 5, 2014	Completed area of BLK06C and surveyed 3 lines BLK06D (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

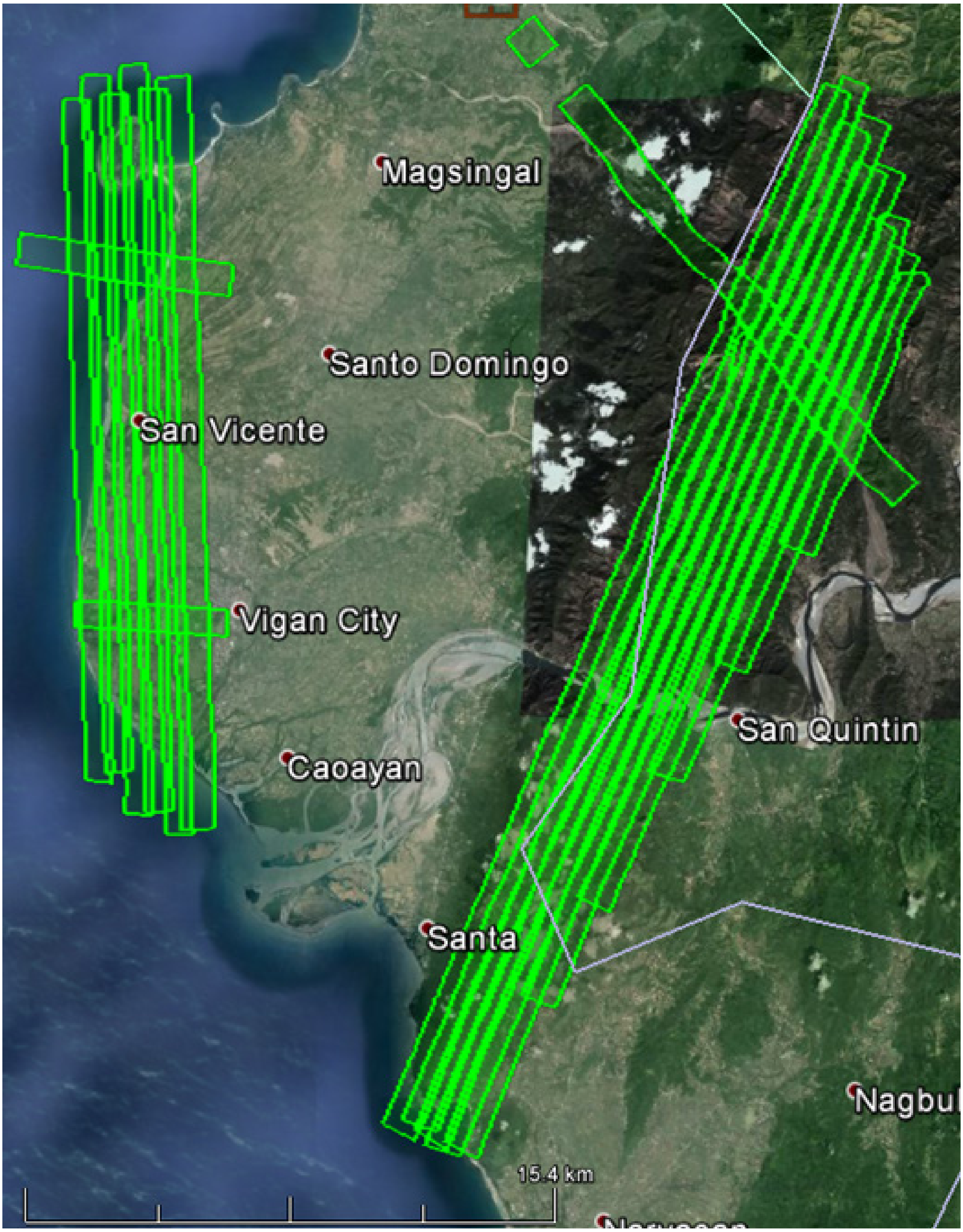
Flight No. :	7104 GC		
Area:	BLK06A and BLK06E		
Mission Name:	2BLK06E062A & 2BLK06A062A		
Total Area:			
Altitude:	1200 m / 1000 m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	30 deg / 40 deg	Sidelap:	40% / 30%



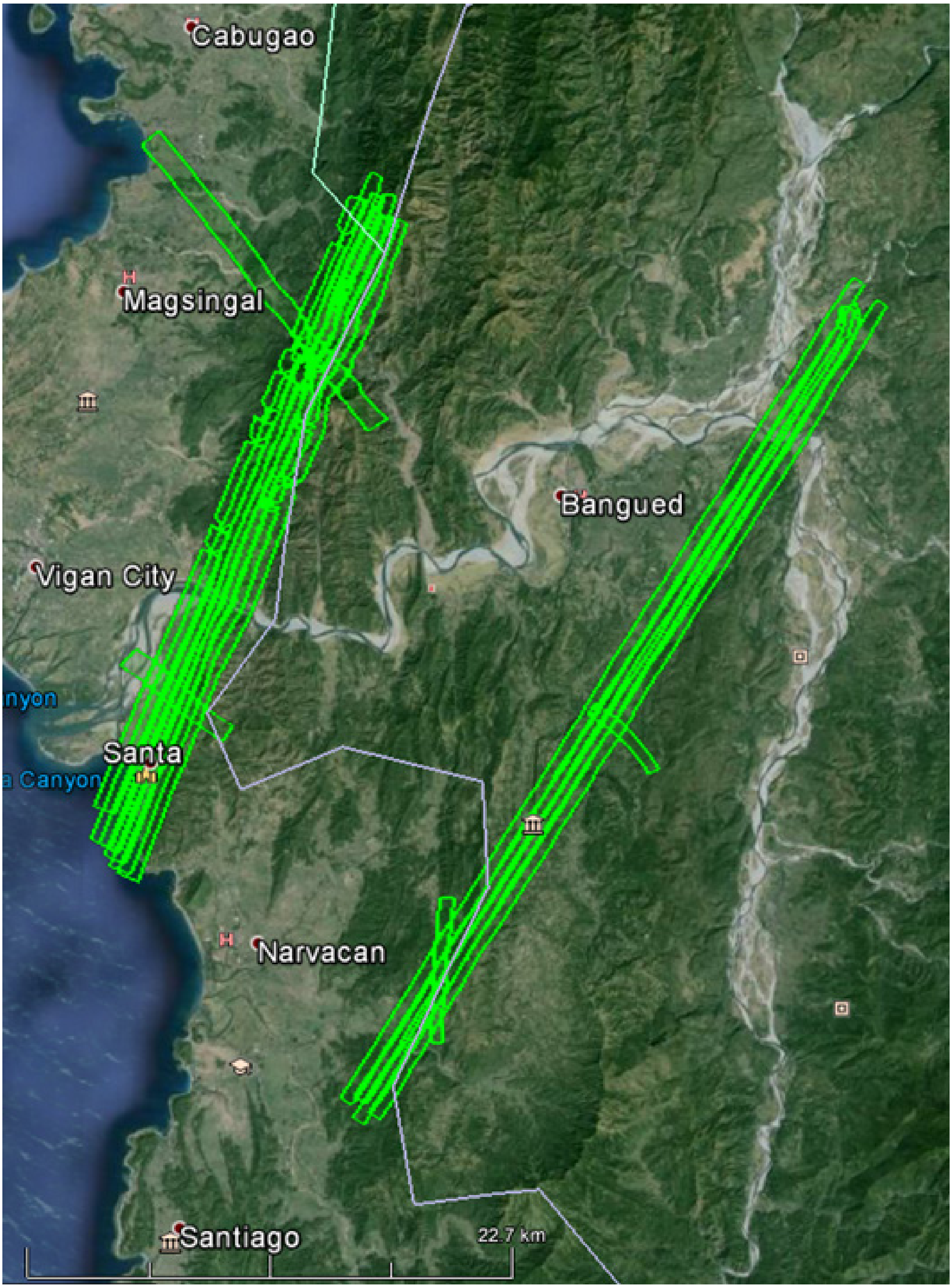
Flight No. :	7108 GC		
Area:	BLK06C and BLK06D		
Mission Name:	2BLK06C064A & 2BLK06D064A		
Total Area:	sq. km.		
Altitude:	1000m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	20 deg	Sidelap:	30%



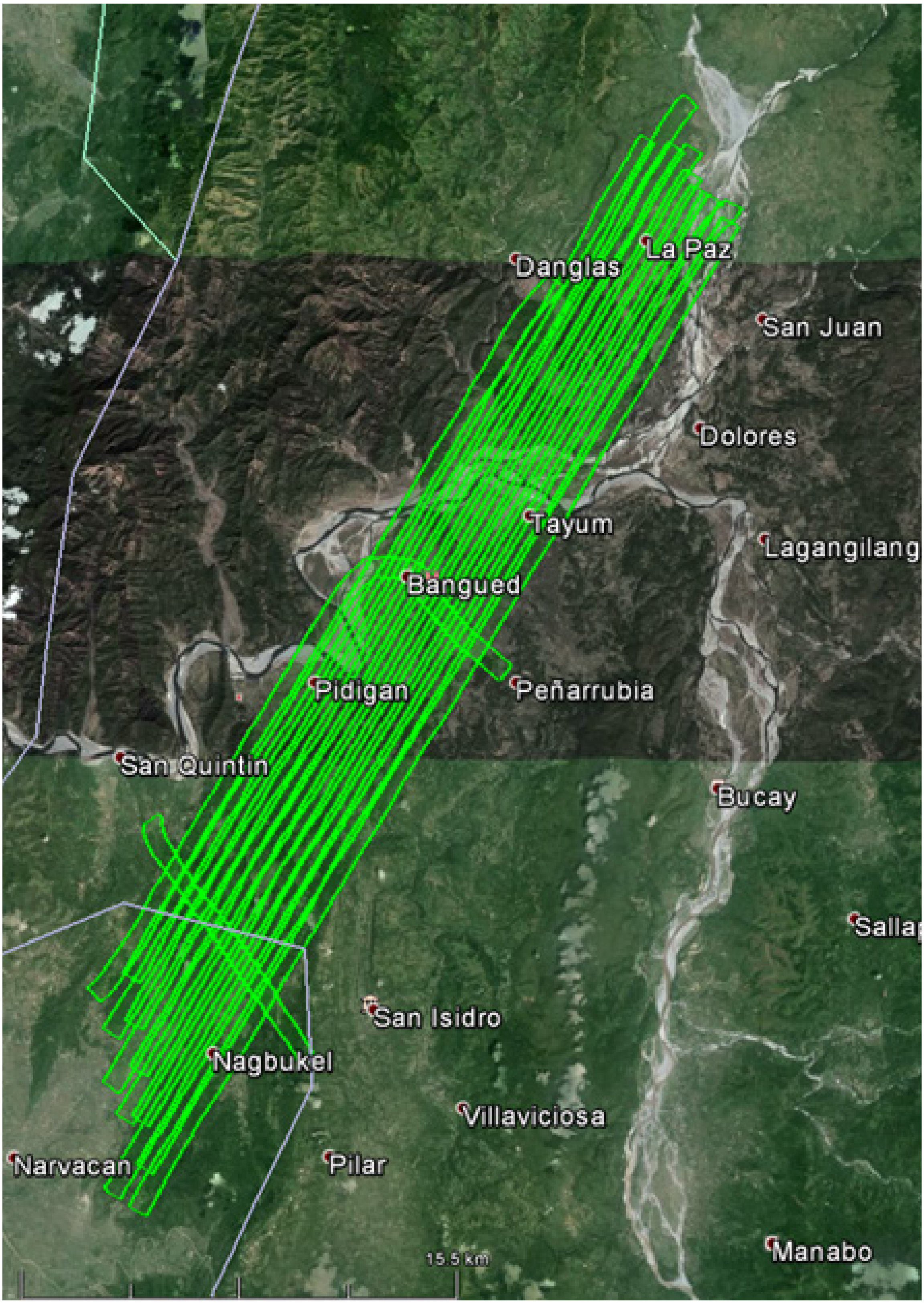
Flight No. :	7112 GC		
Area:	BLK06DS and BLK06G		
Total Area:	160.52 sq km		
Mission Name:	2BLK06G066A & 2BLK6DS066A		
Altitude:	1800m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	55%



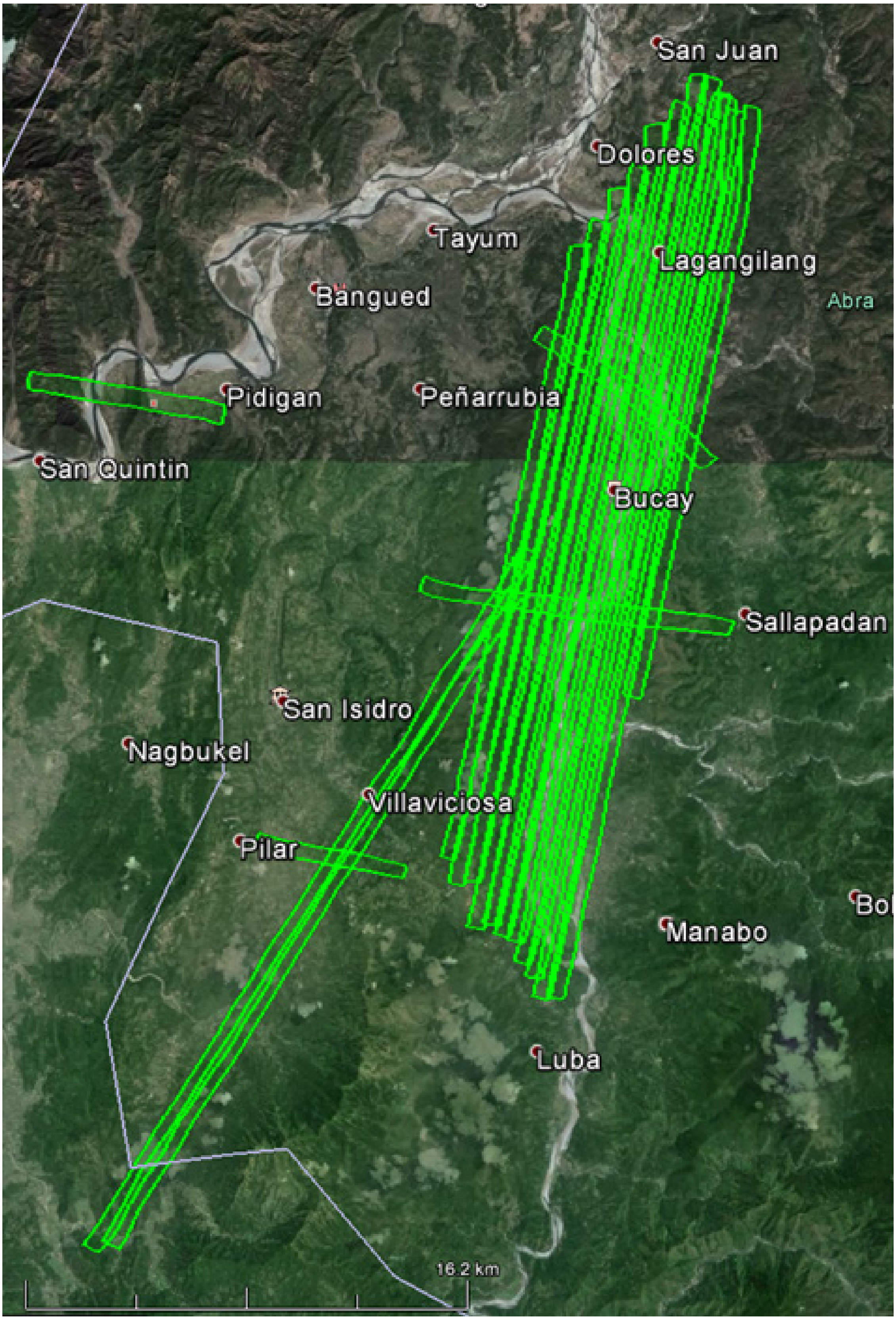
Flight No. :	7114 G		
Area:	BLK07CS& BLK06G		
Total Area:	sq km		
Mission Name:	2BLK07CS067A & 2BLK06G067A		
Altitude:	1800m / 1200m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	55% / 40%



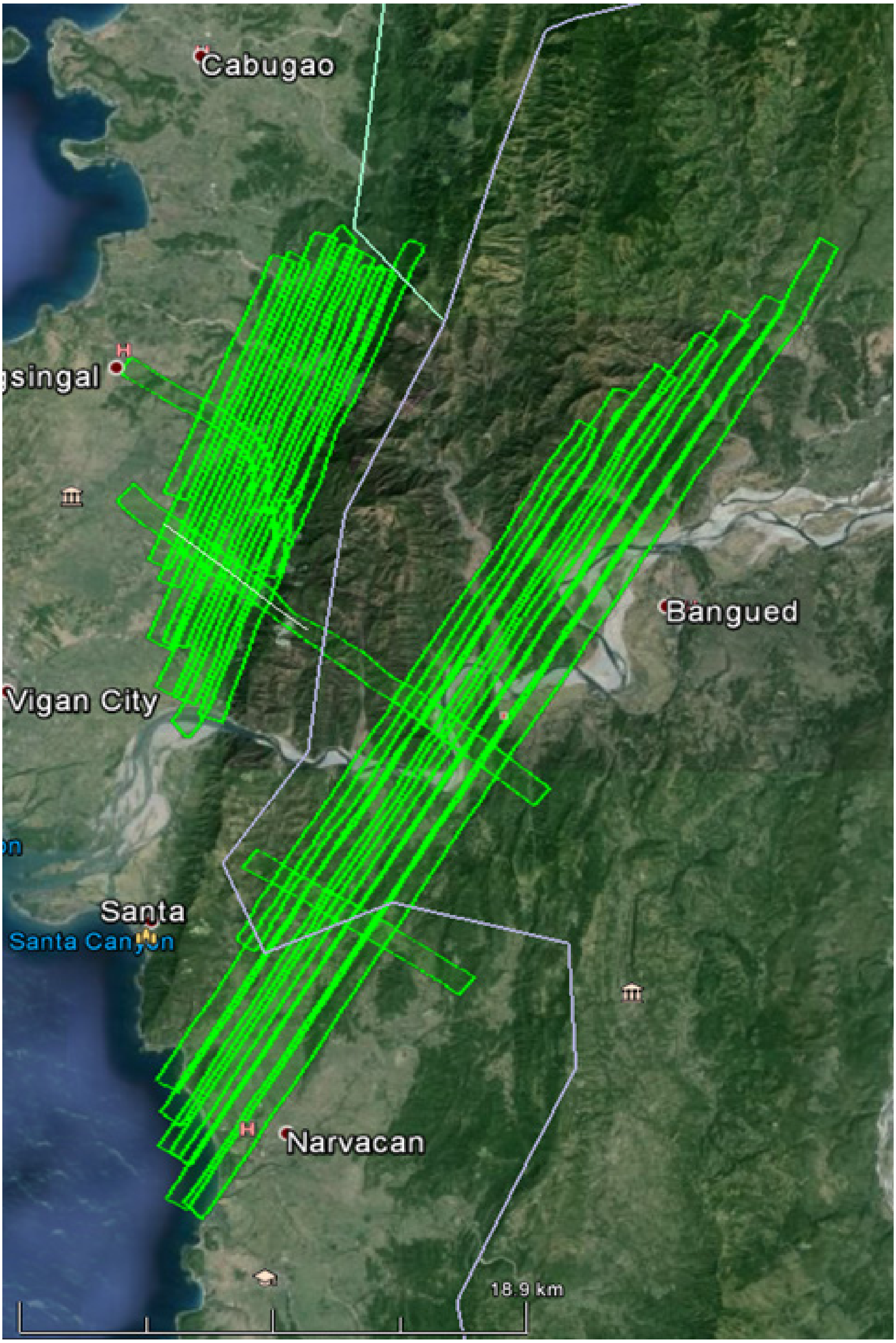
Flight No. :	7116 GC		
Area:	BLK07B		
Total Area:	sq km		
Mission Name:	2BLK07B068A		
Altitude:	1300m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	30%



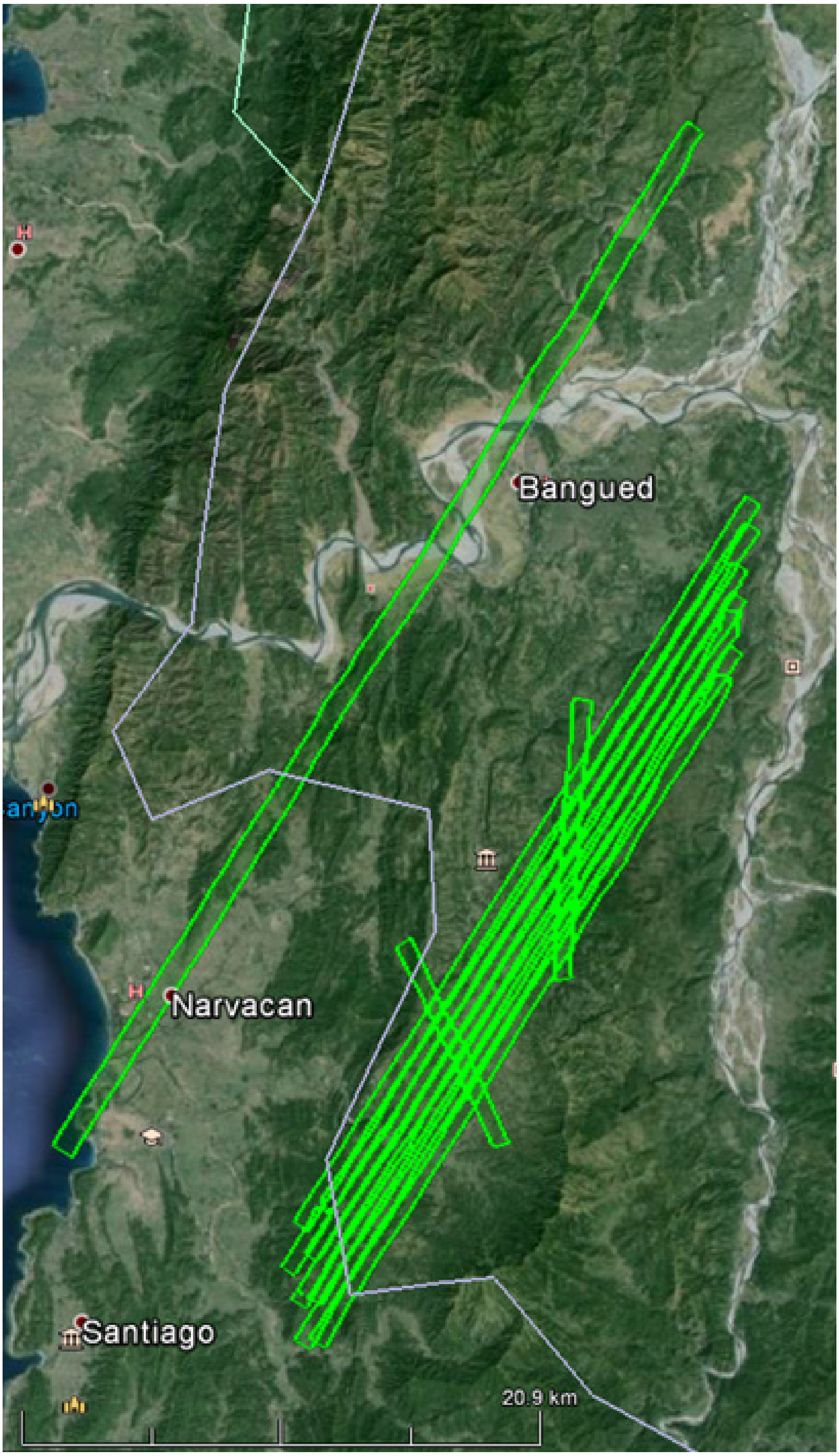
Flight No. :	7118 GC		
Area:	BLK07D		
Total Area:	sq km		
Mission Name:	2BLK07D069A		
Altitude:	1300m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	50%



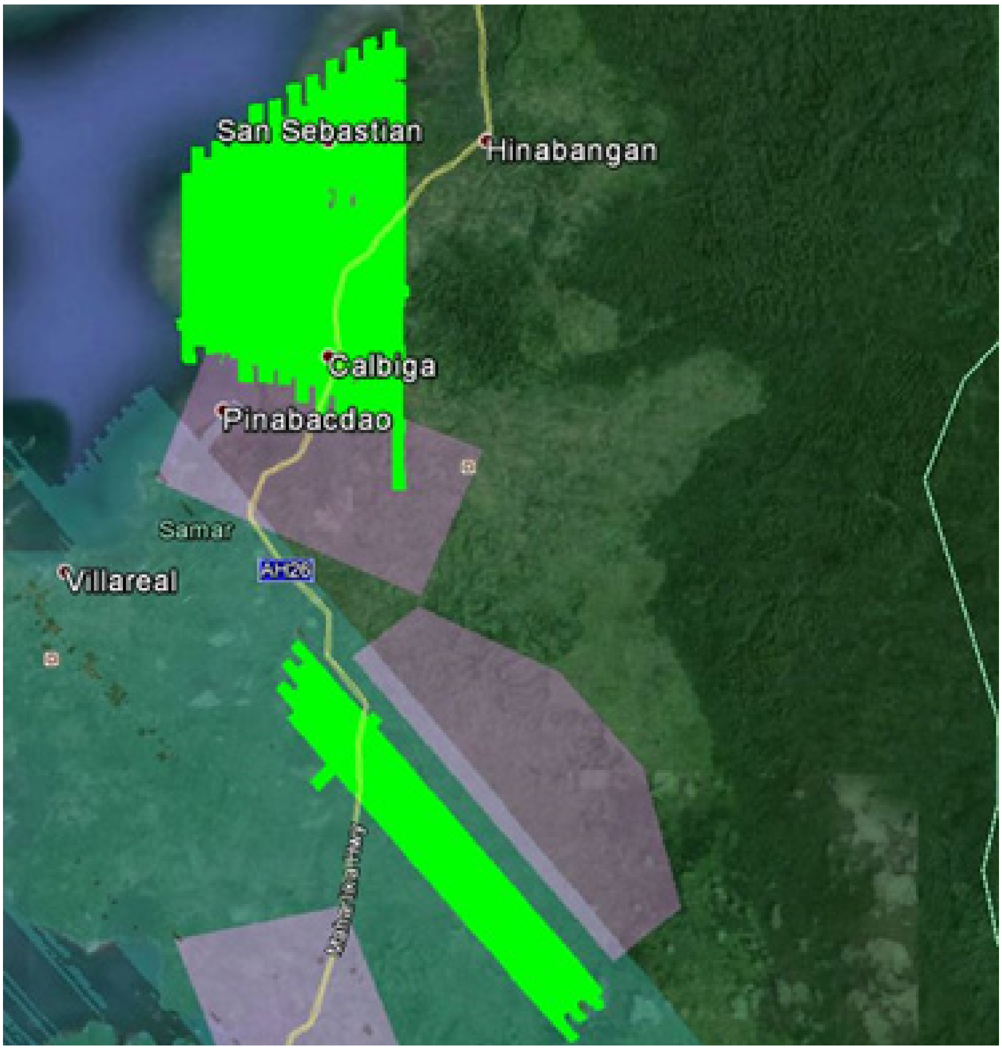
Flight No. :	7120 GC		
Area:	BLK06F& BLK07A		
Total Area:	sq. km.		
Mission Name:	2BLK06F070A & 2BLK07A070A		
Altitude:	1600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	40%



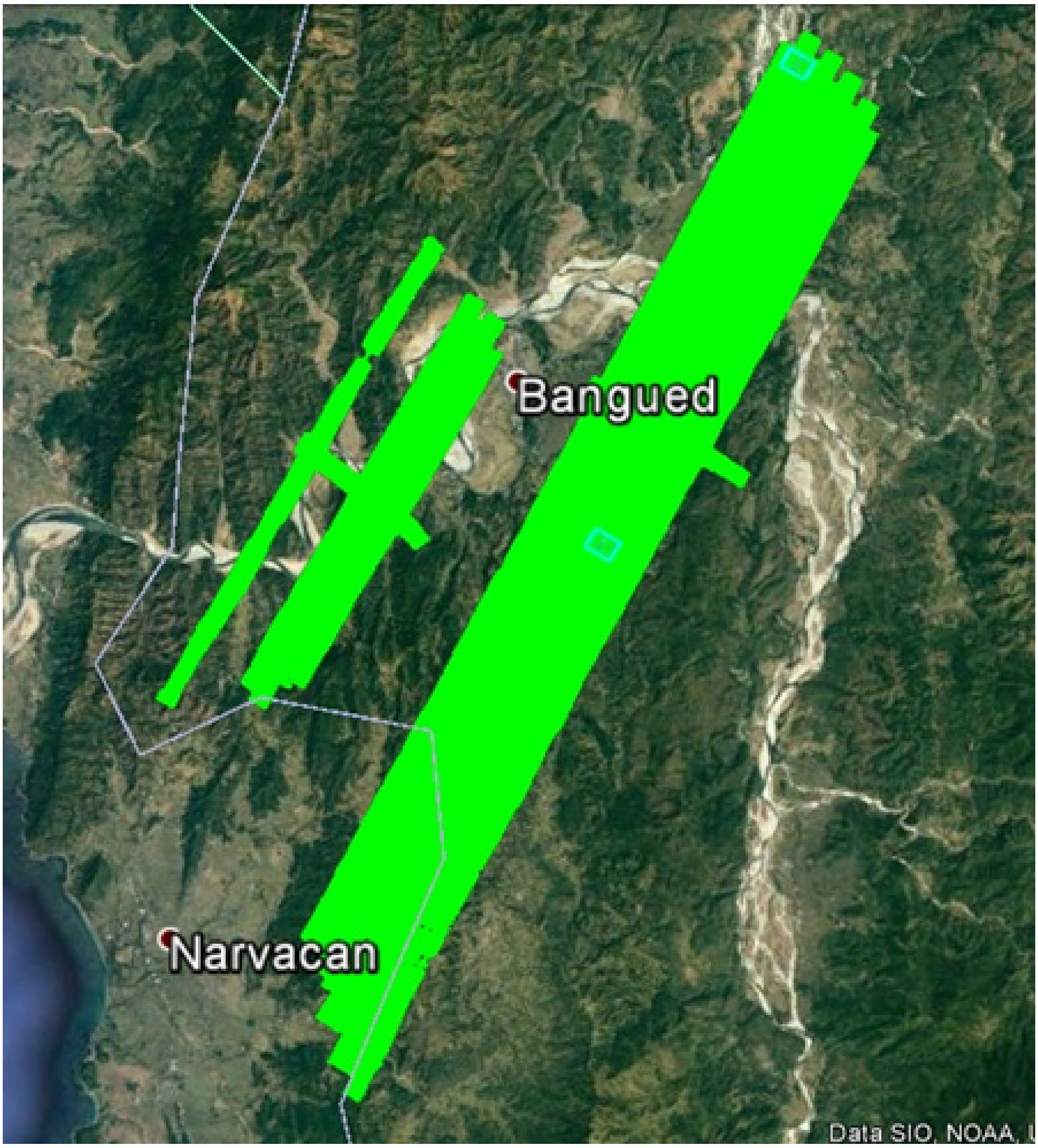
Flight No. :	7121 GC		
Area:	BLK07GS and BLK07AS		
Total Area:	sq. km.		
Mission Name:	2BLK07GS070B & 2BLK07AS070B		
Altitude:	1400m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	50%



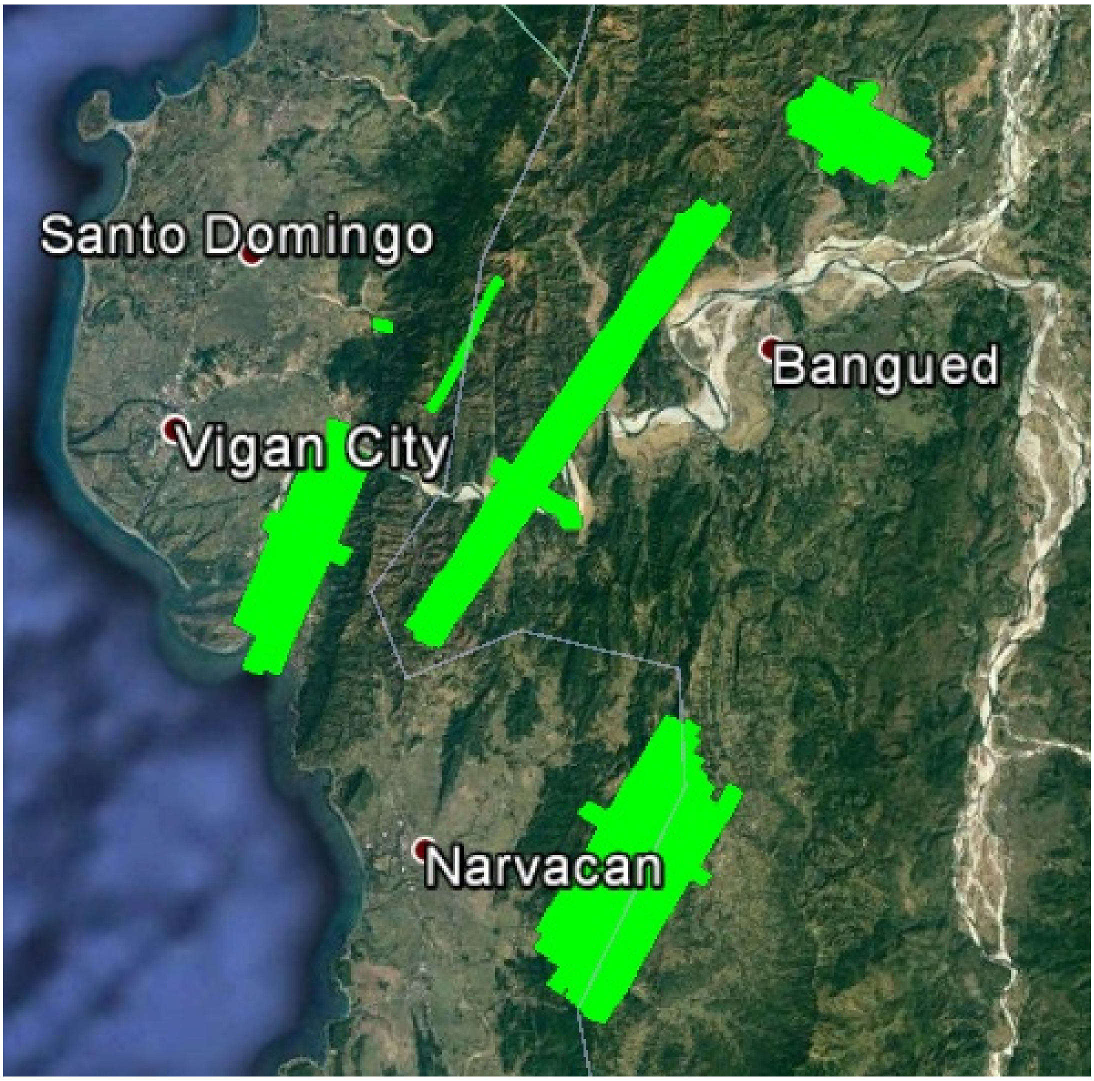
Flight No. :	7122 GC		
Area:	BLK07E and BLK07F		
Total Area:	sq. km.		
Mission Name:	2BLK07E071A & 2BLK07F071A		
Altitude:	1800m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	15 deg	Sidelap:	40% / 35%



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



Flight No. :	4045 GC		
Area:	BLK07BS		
Total Area:	sq. km.		
Mission Name:	2BLK7SB149B		
Altitude:	m		
PRF:	kHz	SCF:	Hz
Lidar FOV:	deg	Sidelap:	%



ANNEX 8. Mission Summary Reports

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

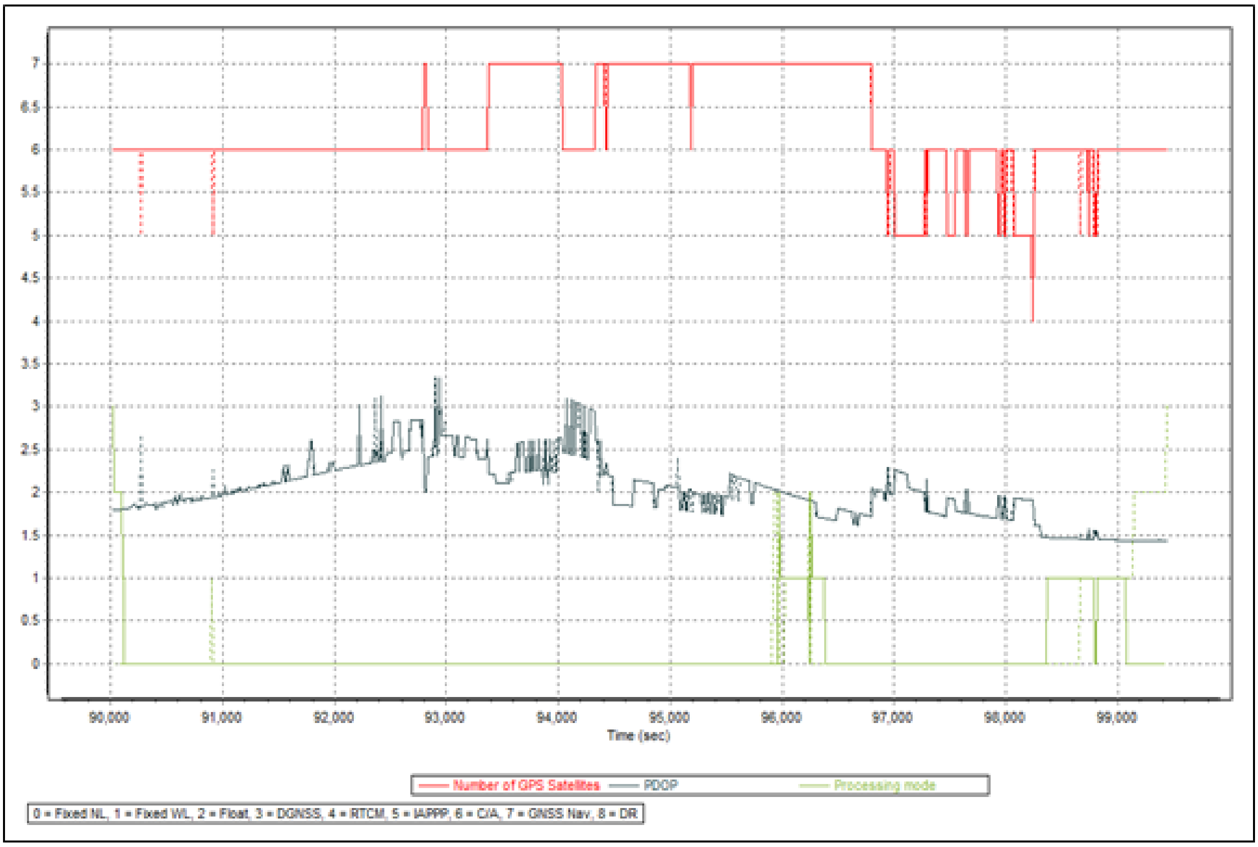


Figure A-8.1. Solution Status

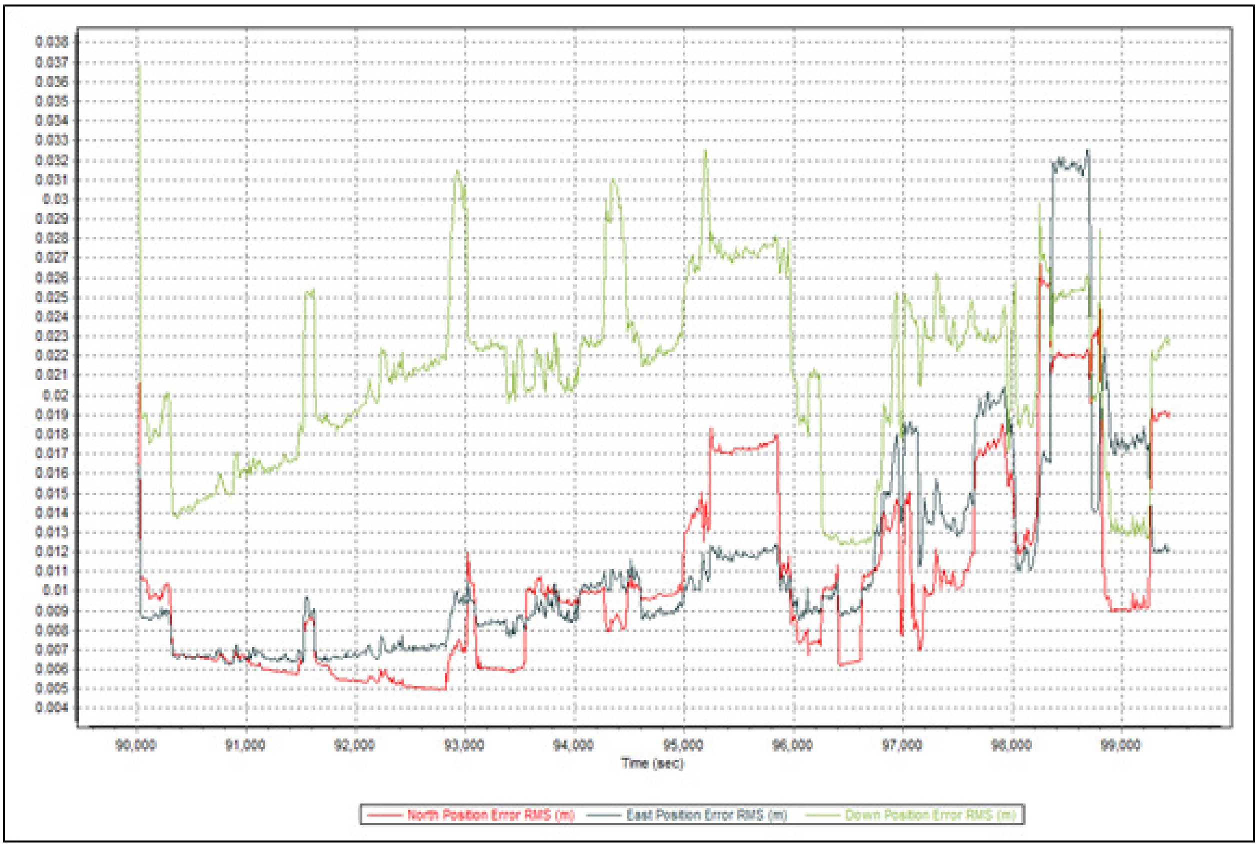


Figure A-8.2. Smoothed Performance Metrics Parameters

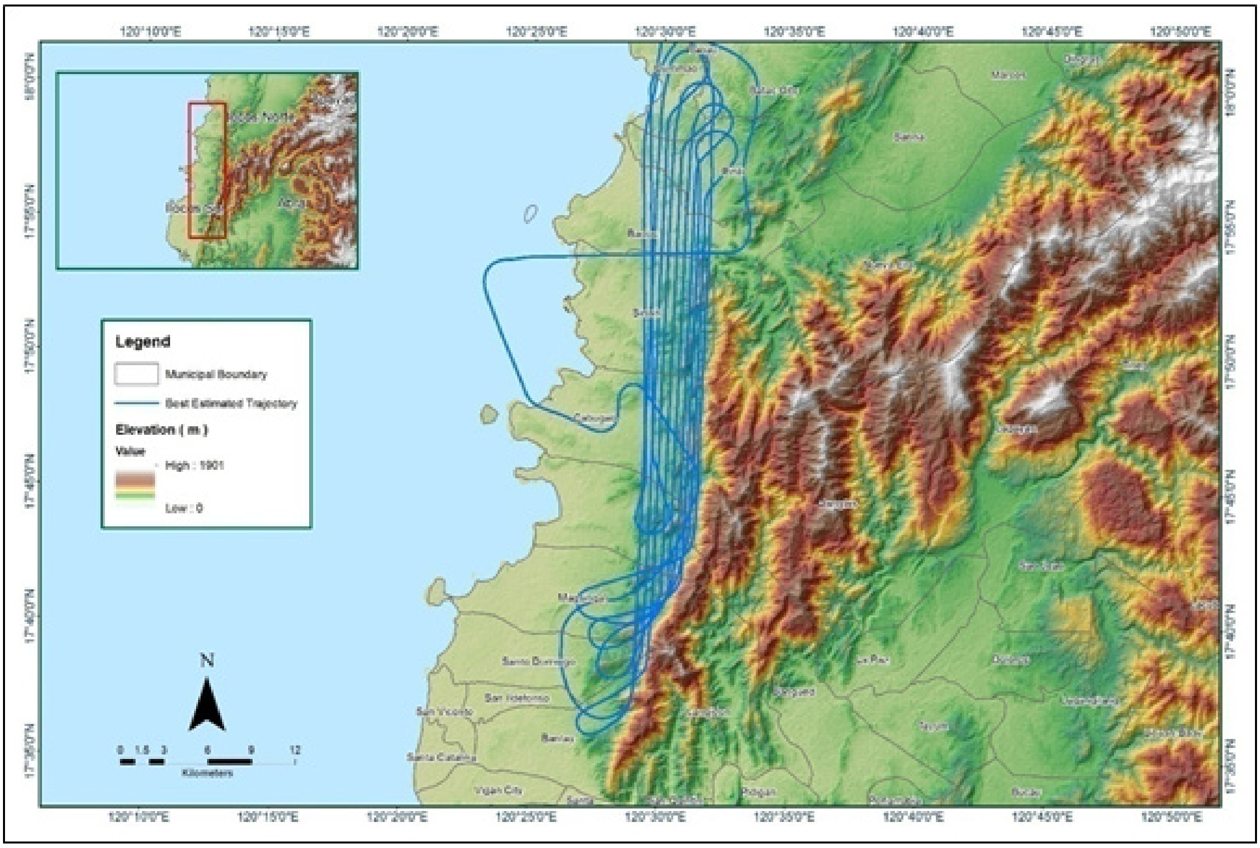


Figure A-8.3. Best Estimated Trajectory

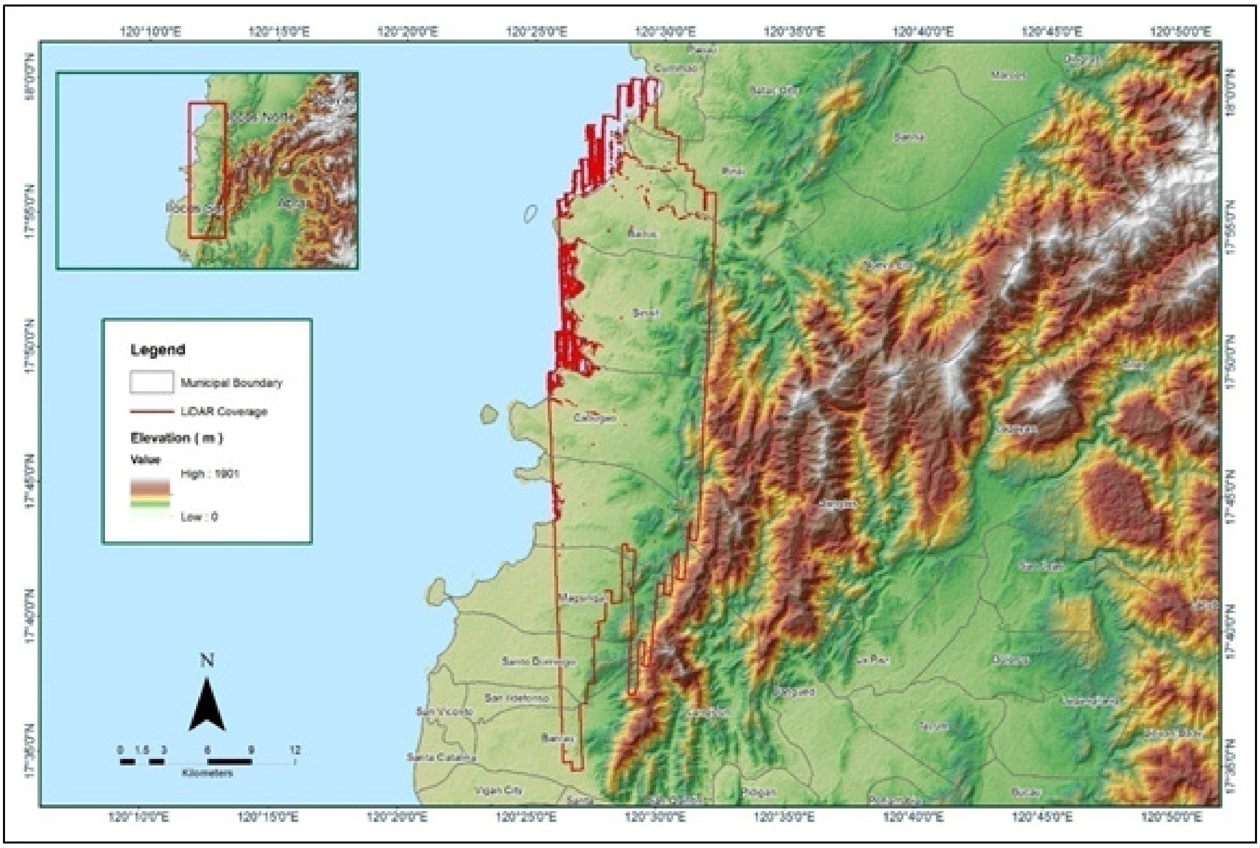


Figure A-8.4. Coverage of LiDAR data

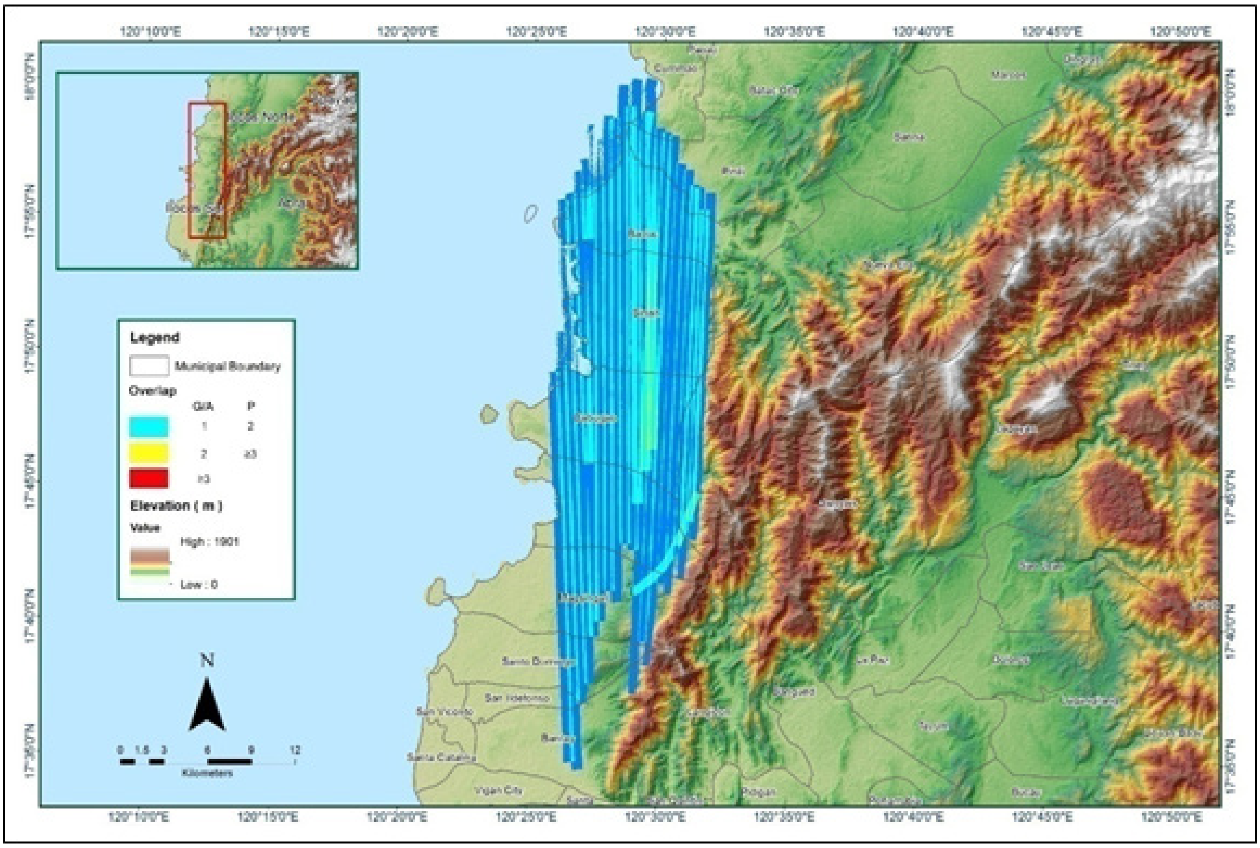


Figure A-8.5. Image of Data Overlap

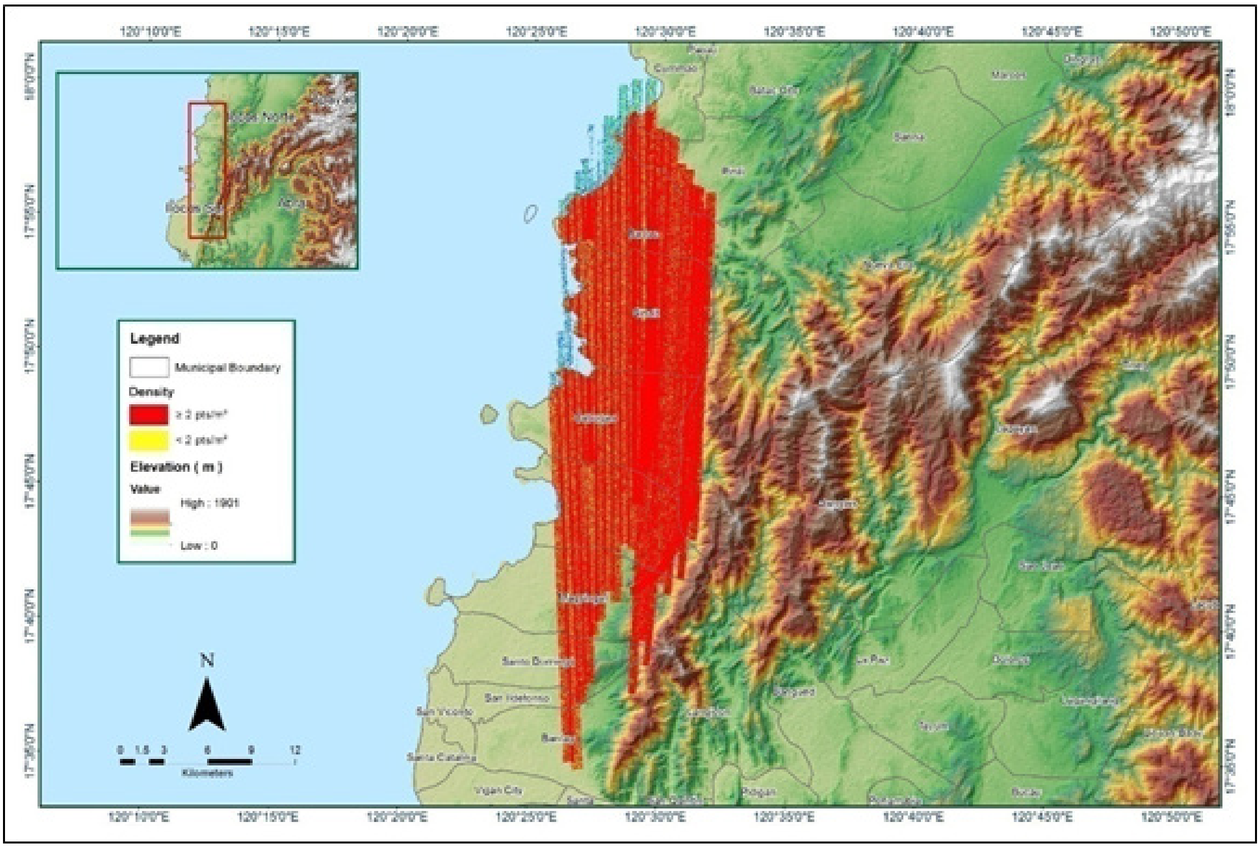


Figure A-8.6.Density map of merged LiDAR data

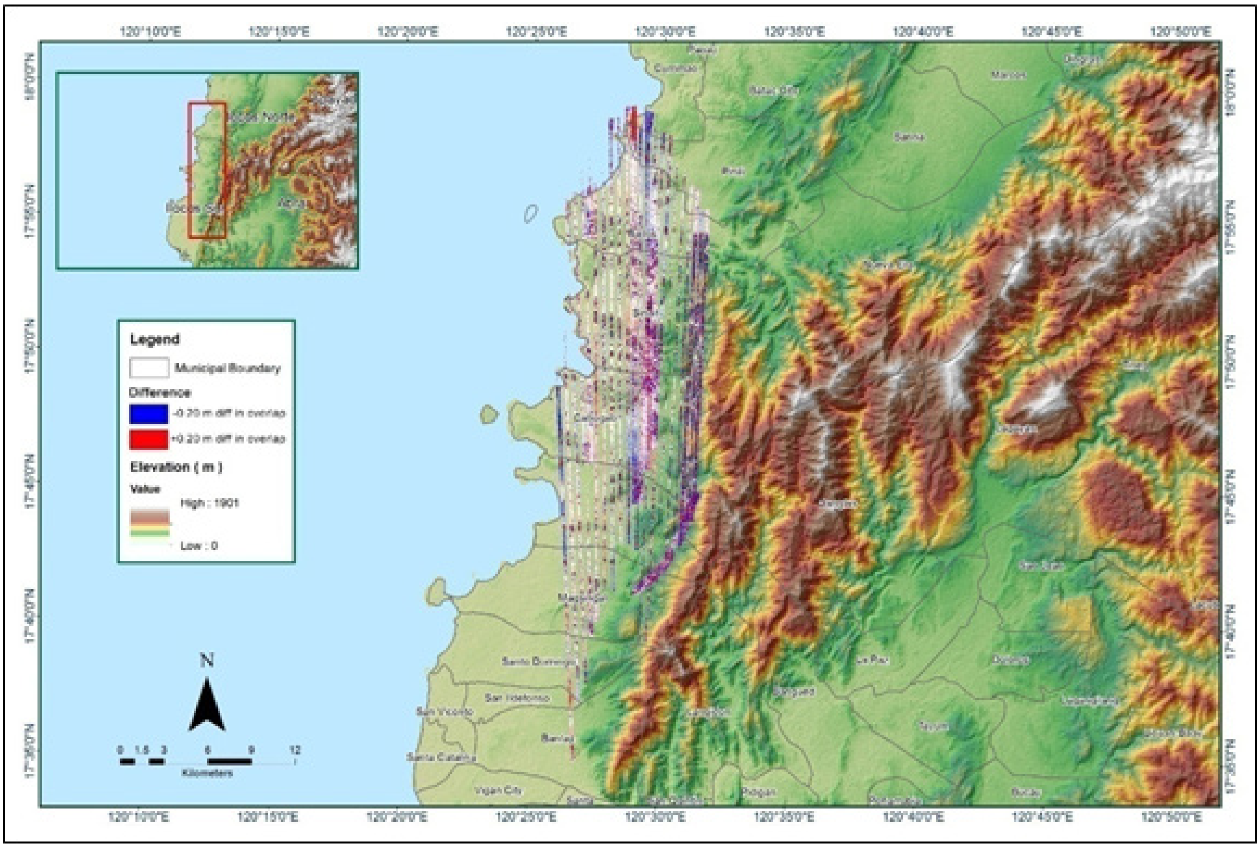


Figure A-8.7. Elevation difference between flight lines

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

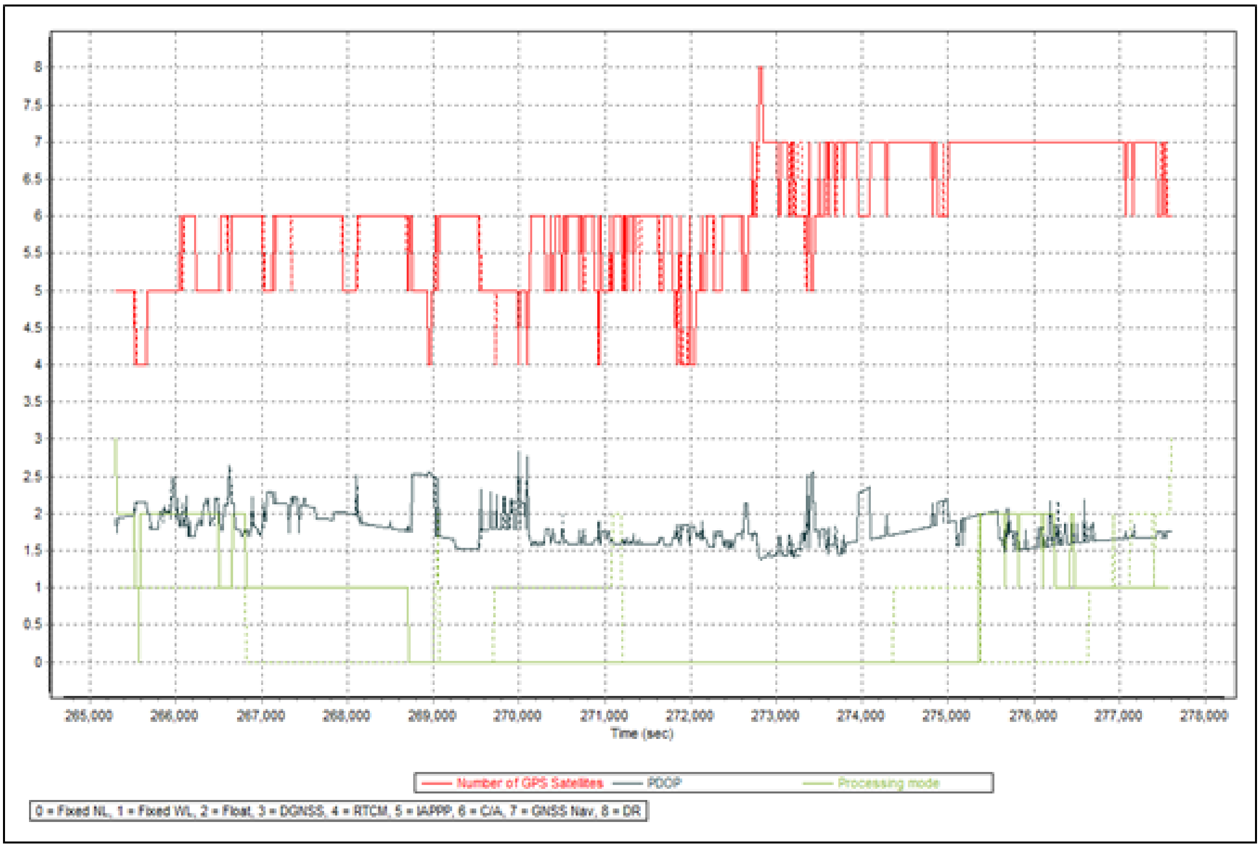


Figure A-8.8. Solution Status Parameters

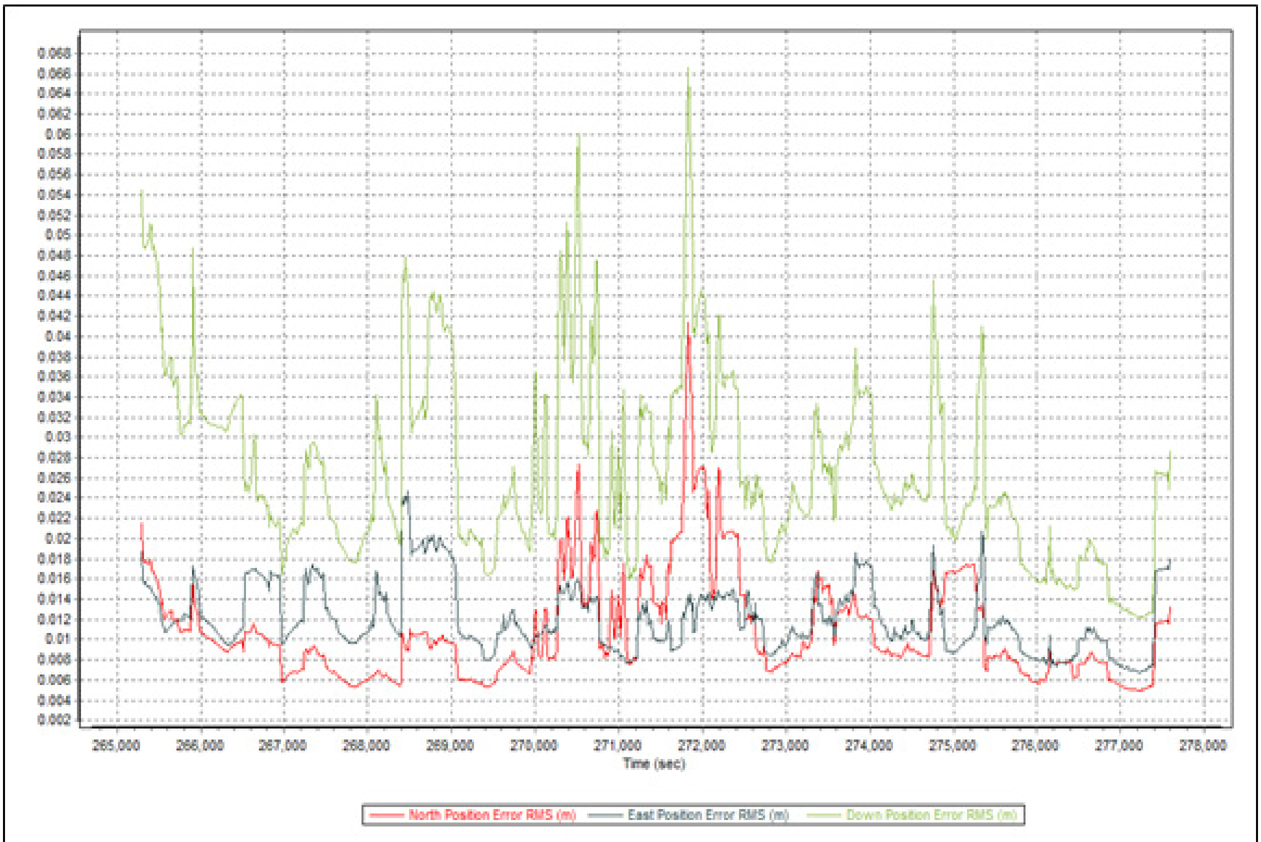


Figure A-8.9. Smoothed Performance Metrics Parameters

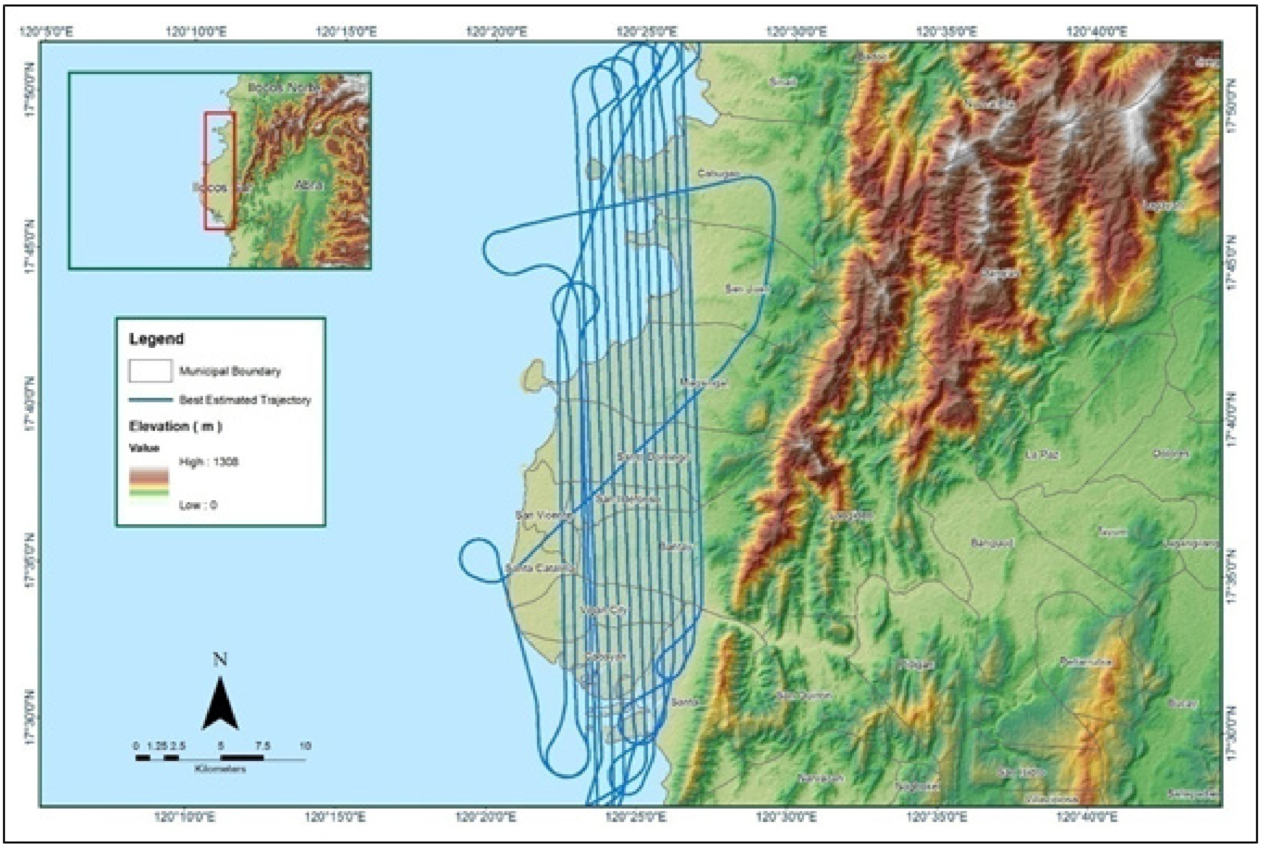


Figure A-8.10. Best Estimated Trajectory

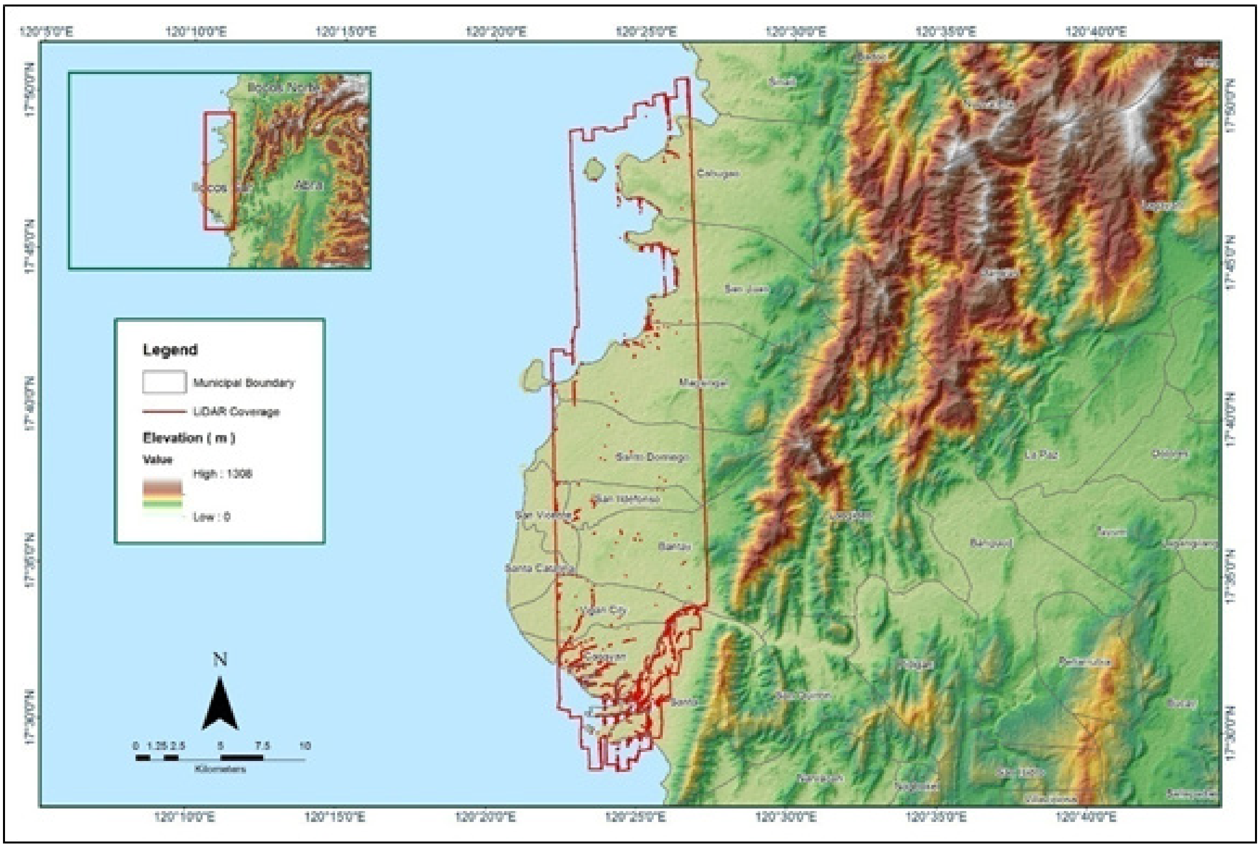


Figure A-8.11. Coverage of LiDAR data

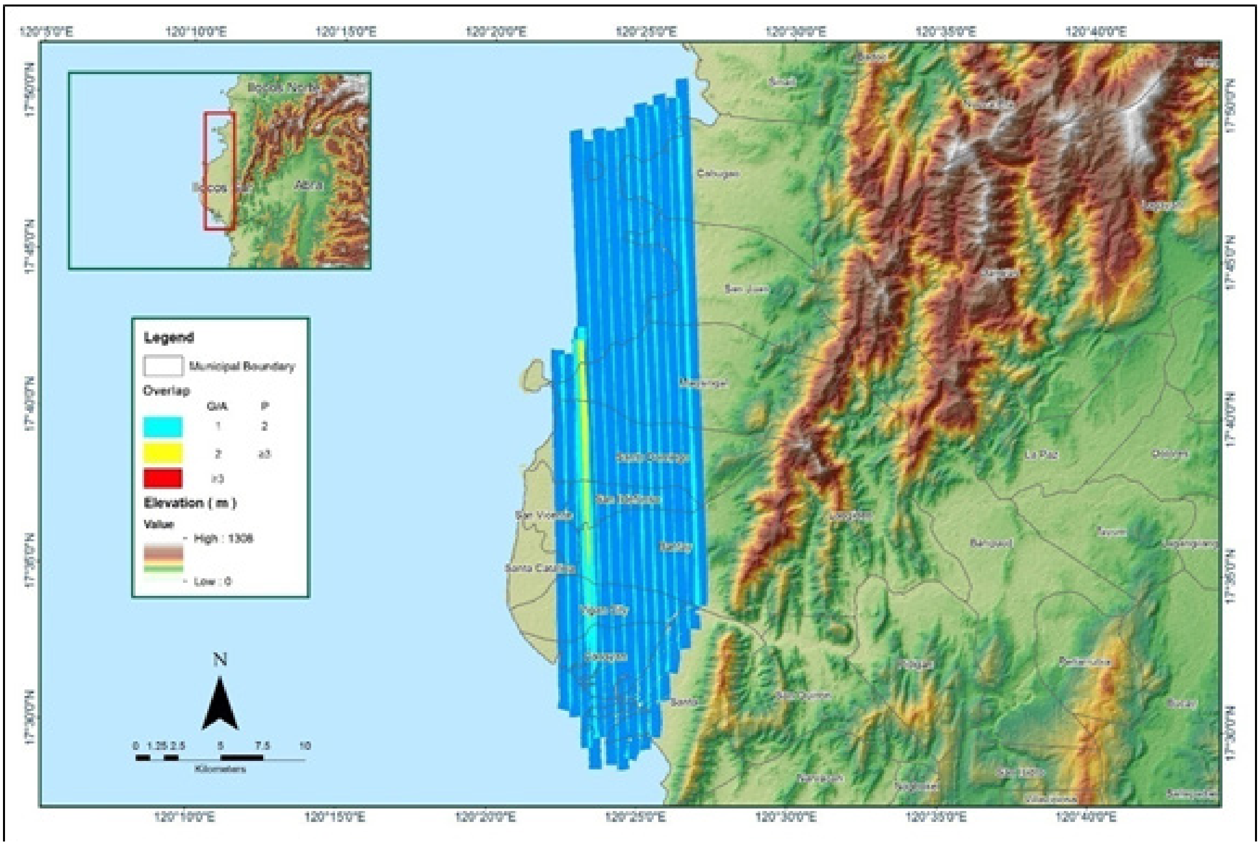


Figure A-8.12. Image of Data Overlap

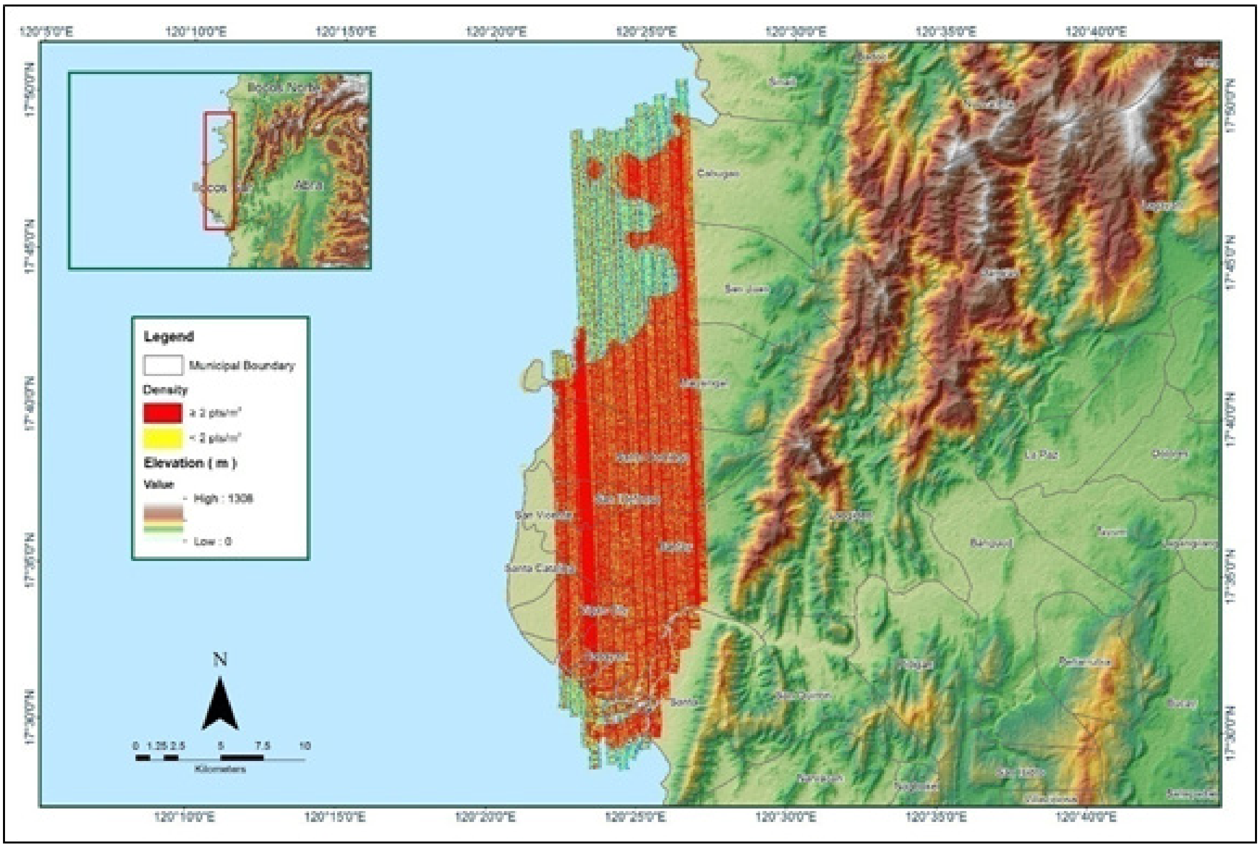


Figure A-8.13. Density map of merged LiDAR data

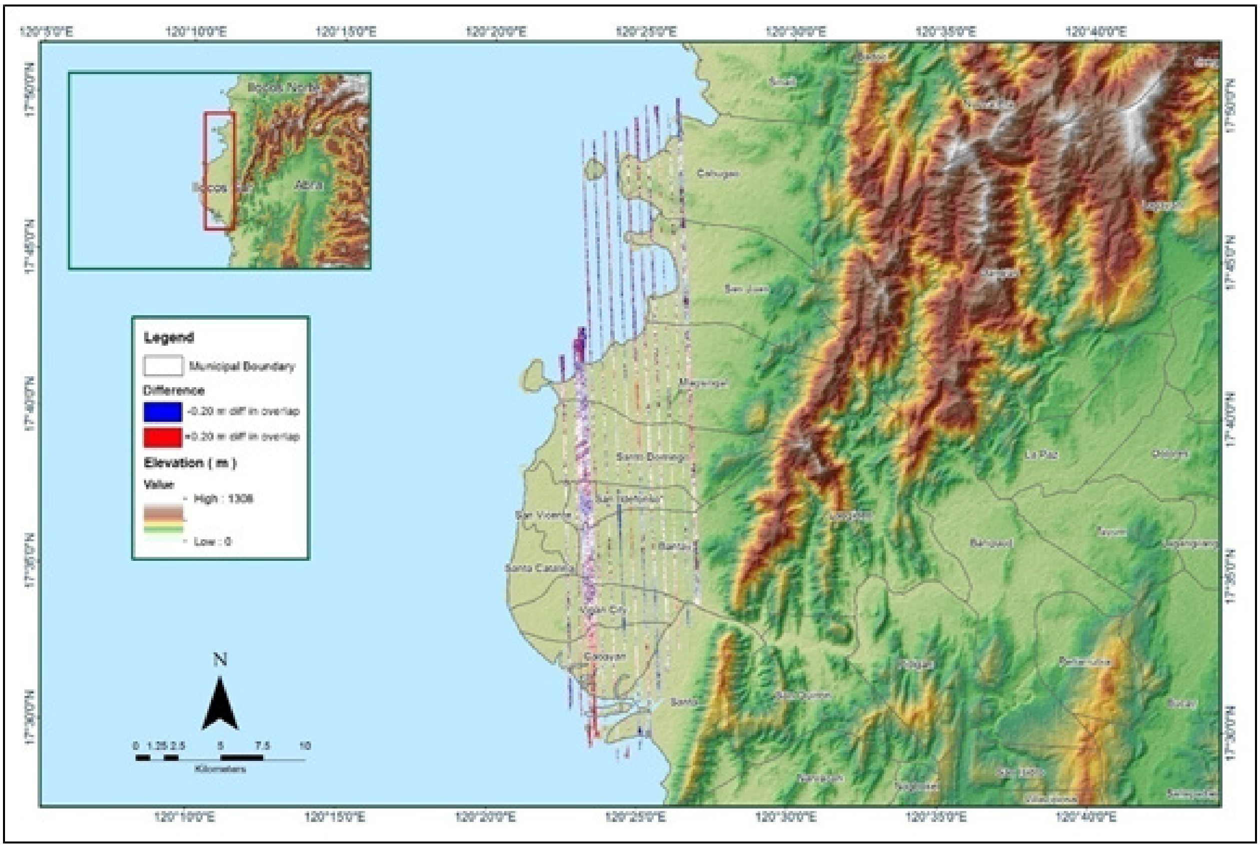


Figure A-8.14. Elevation difference between flight lines

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

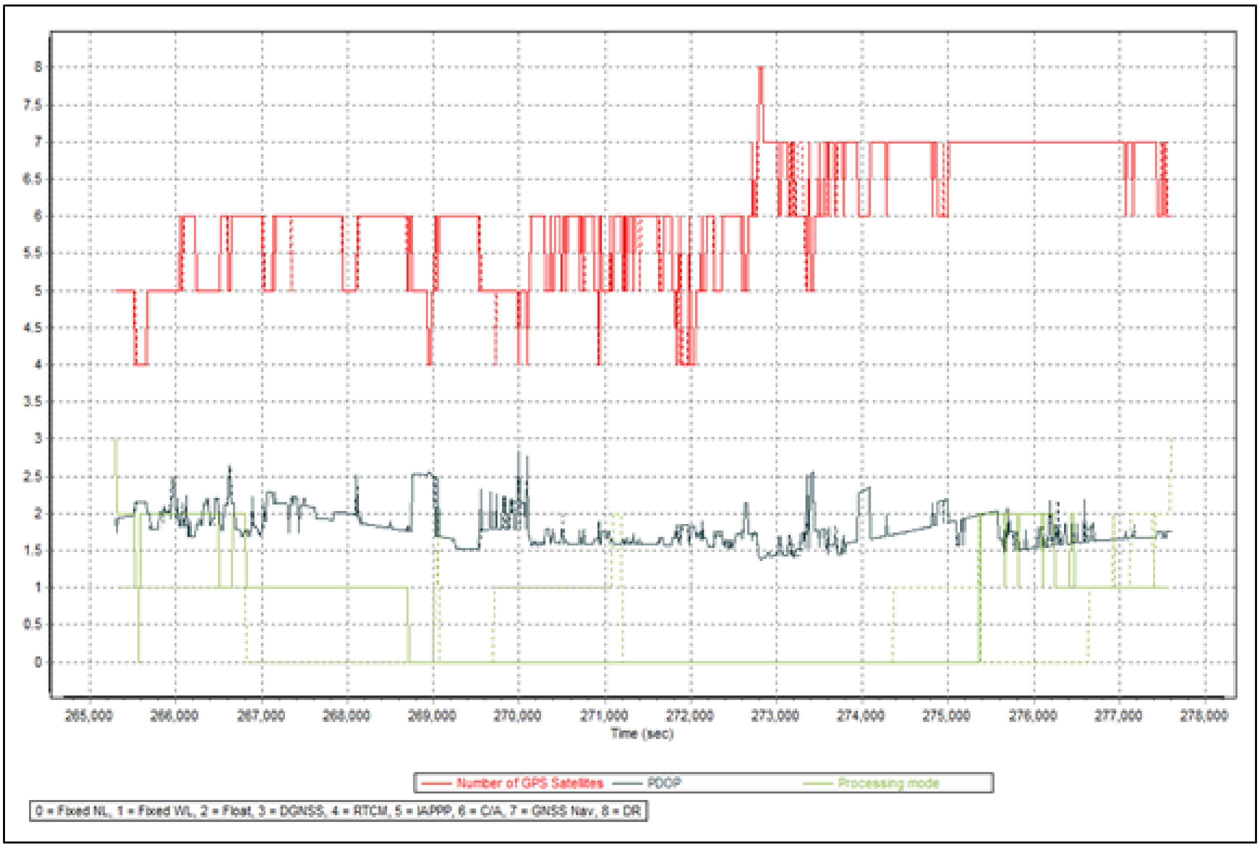


Figure A-8.15. Solution Status Parameters

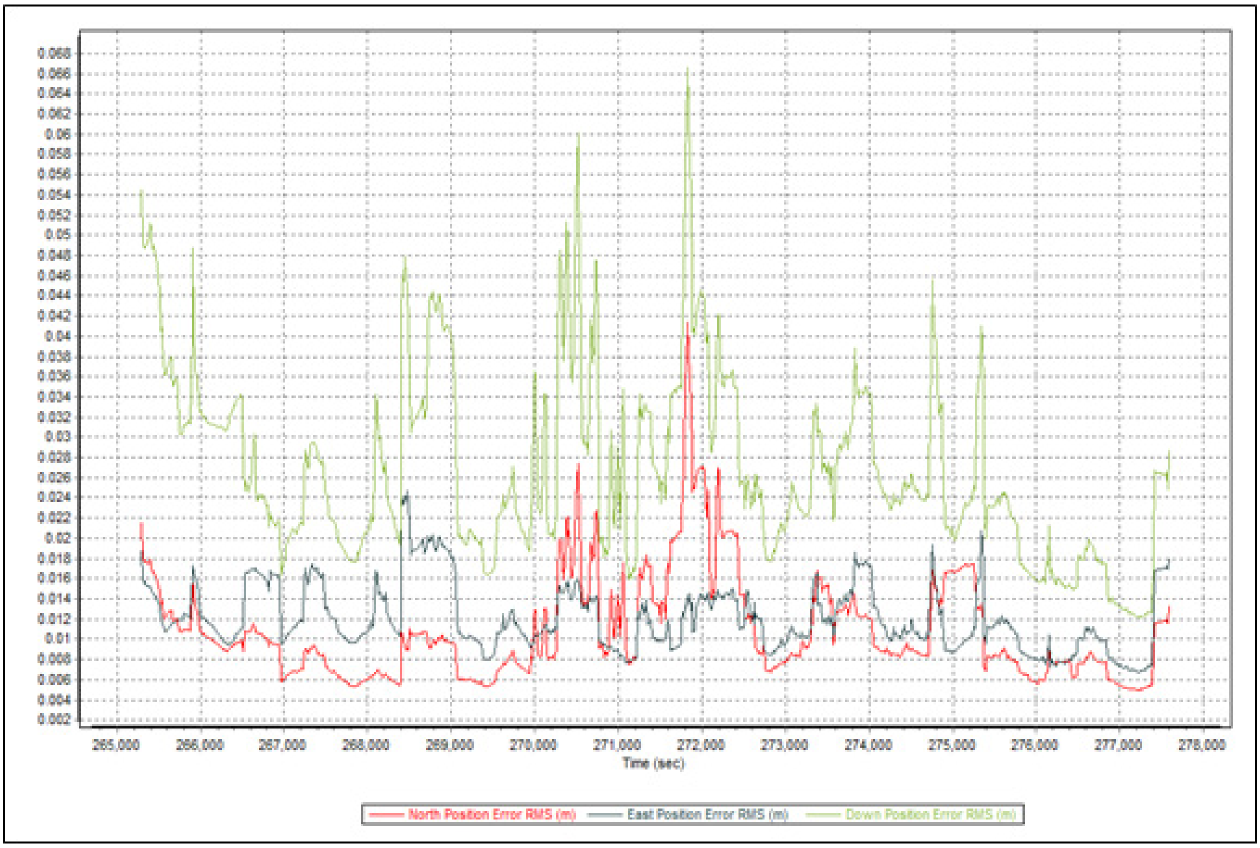


Figure A-8.16. Smoothed Performance Metrics Parameters

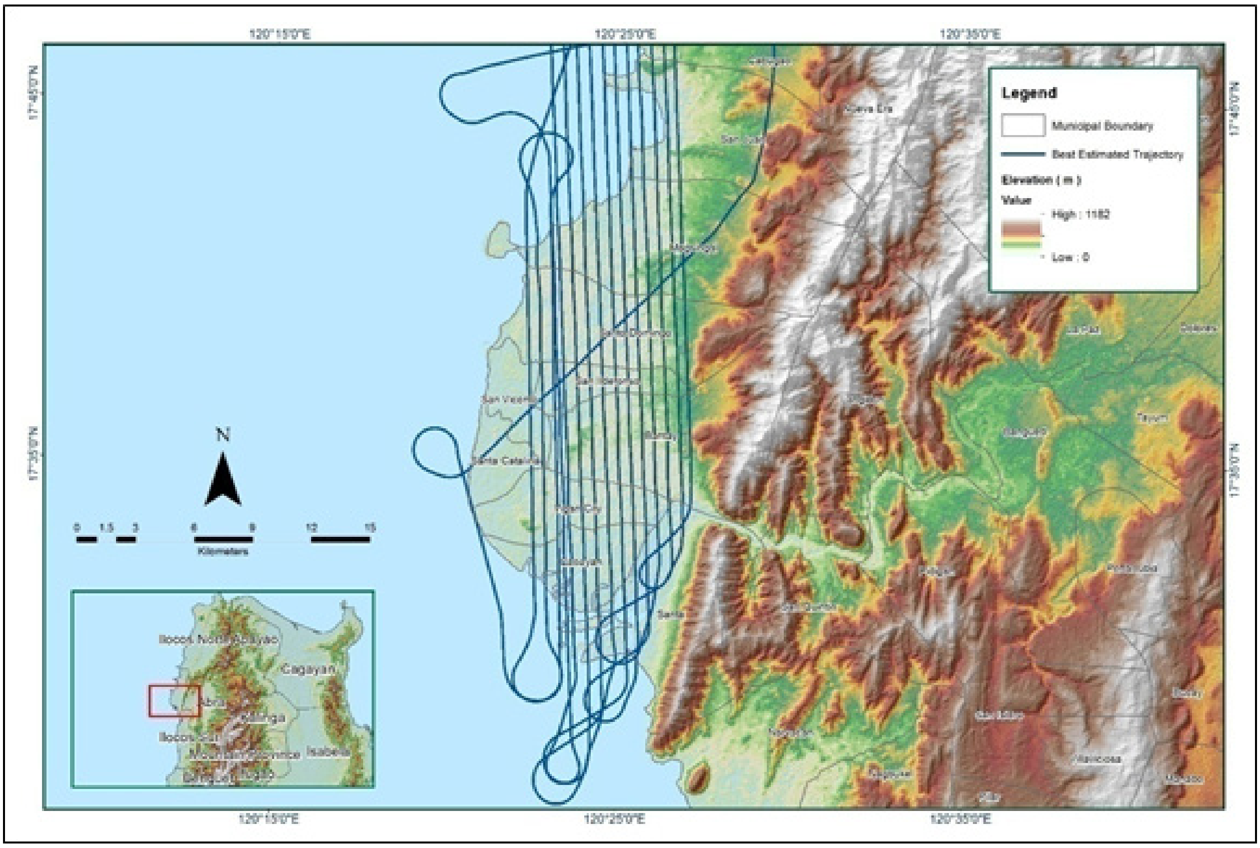


Figure A-8.17. Best Estimated Trajectory

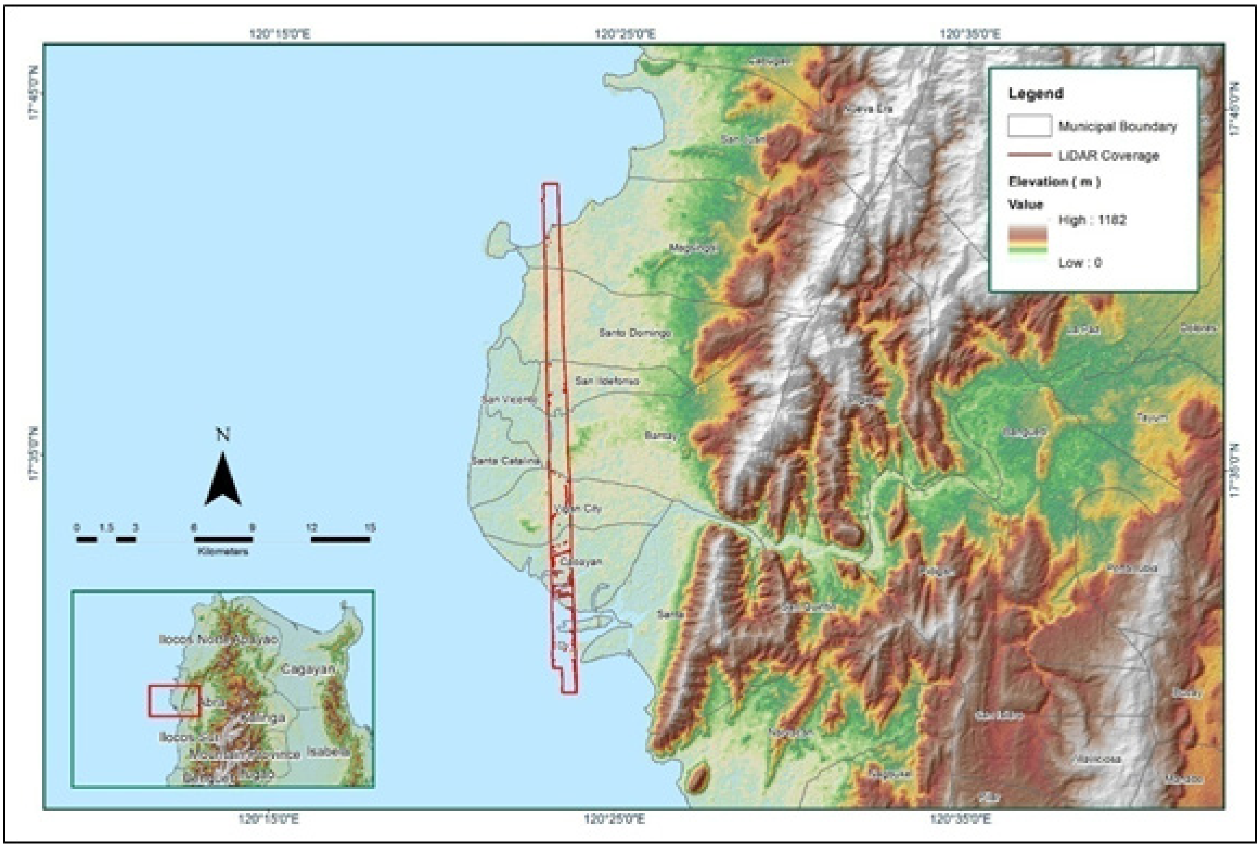


Figure A-8.18. Coverage of LiDAR data

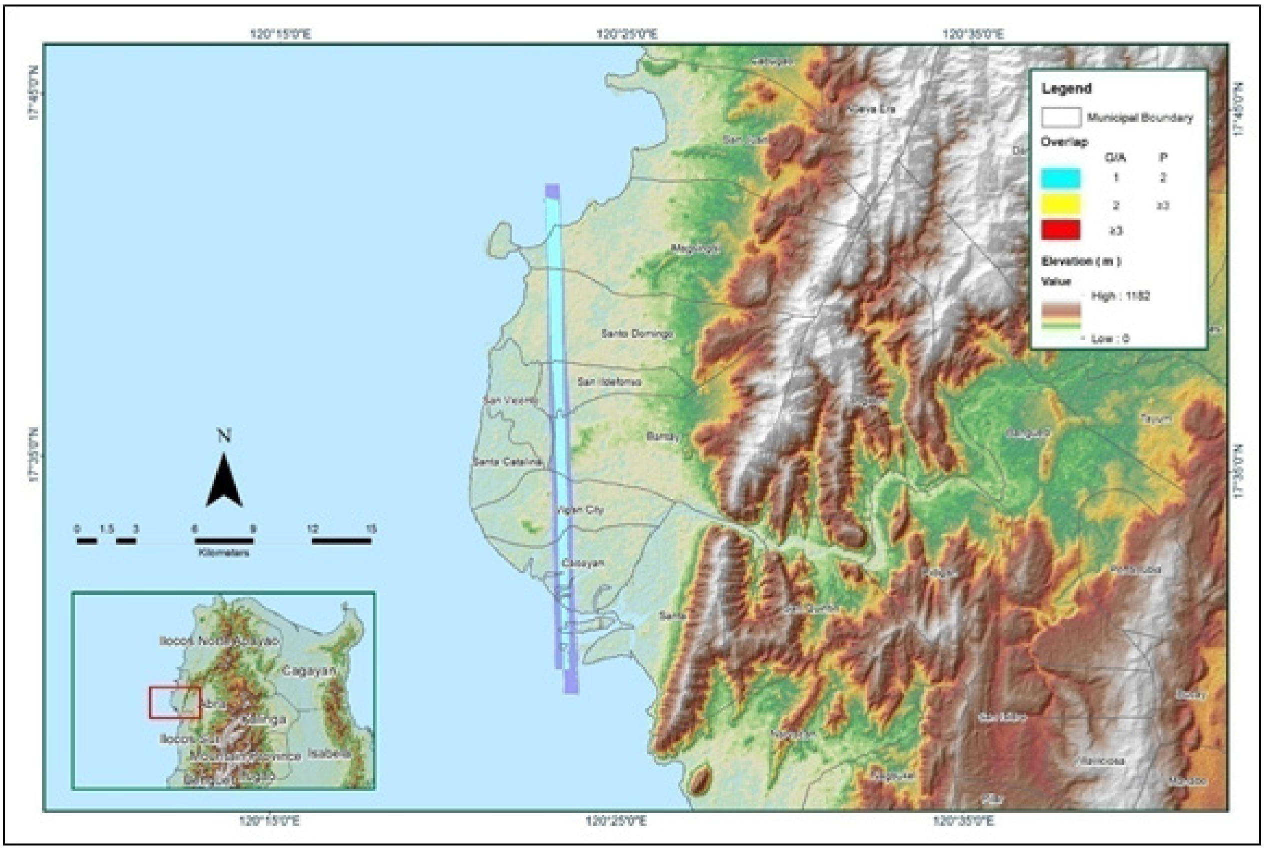


Figure A-8.19. Image of Data Overlap

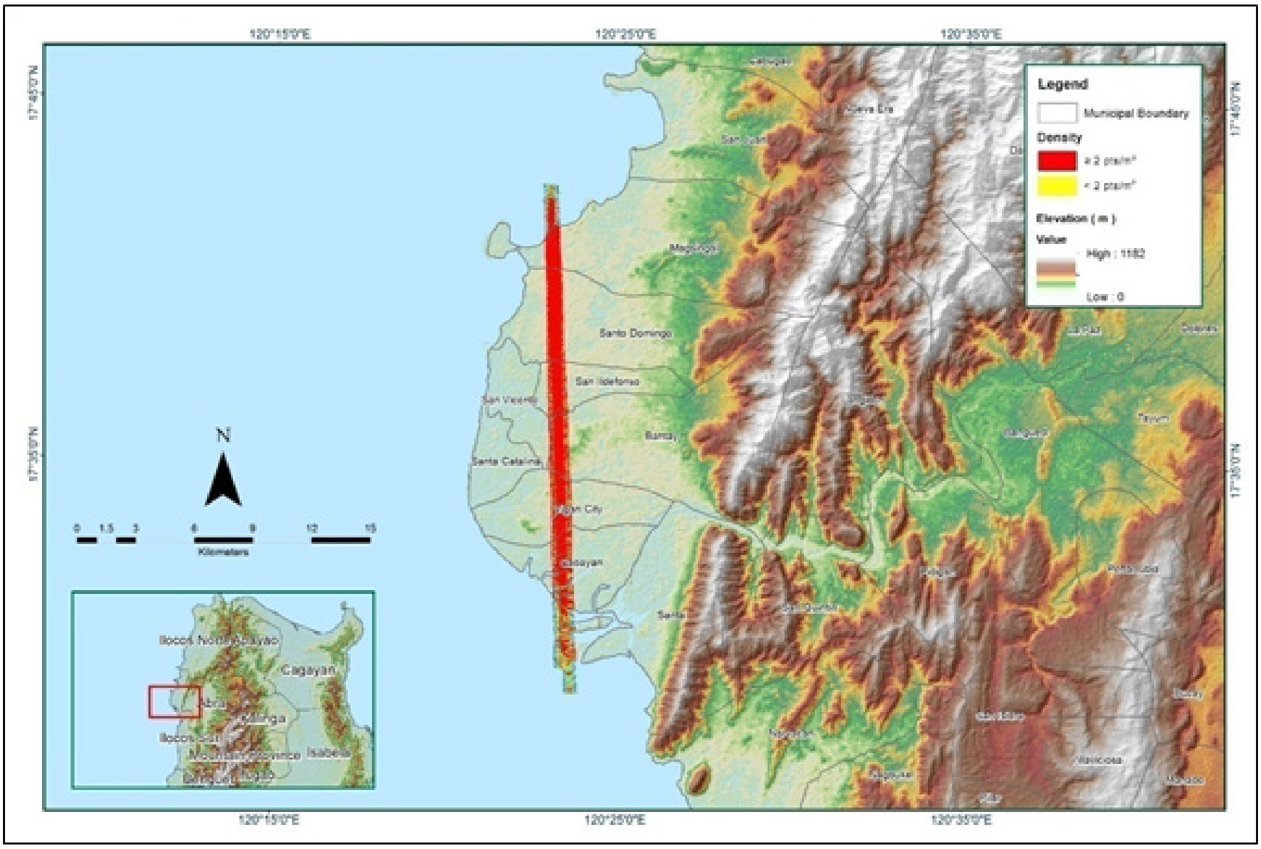


Figure A-8.20. Density map of merged LiDAR data

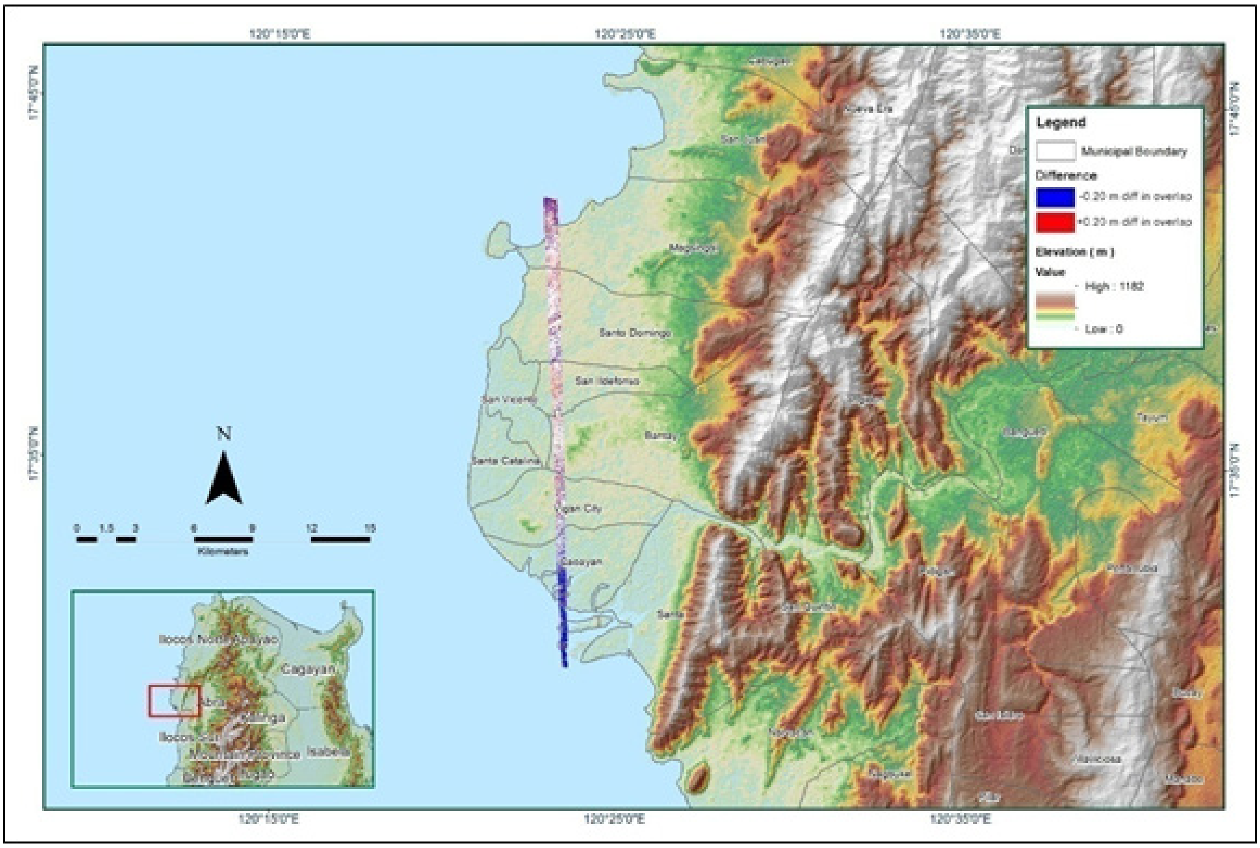


Figure A-8.21. Elevation difference between flight lines

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

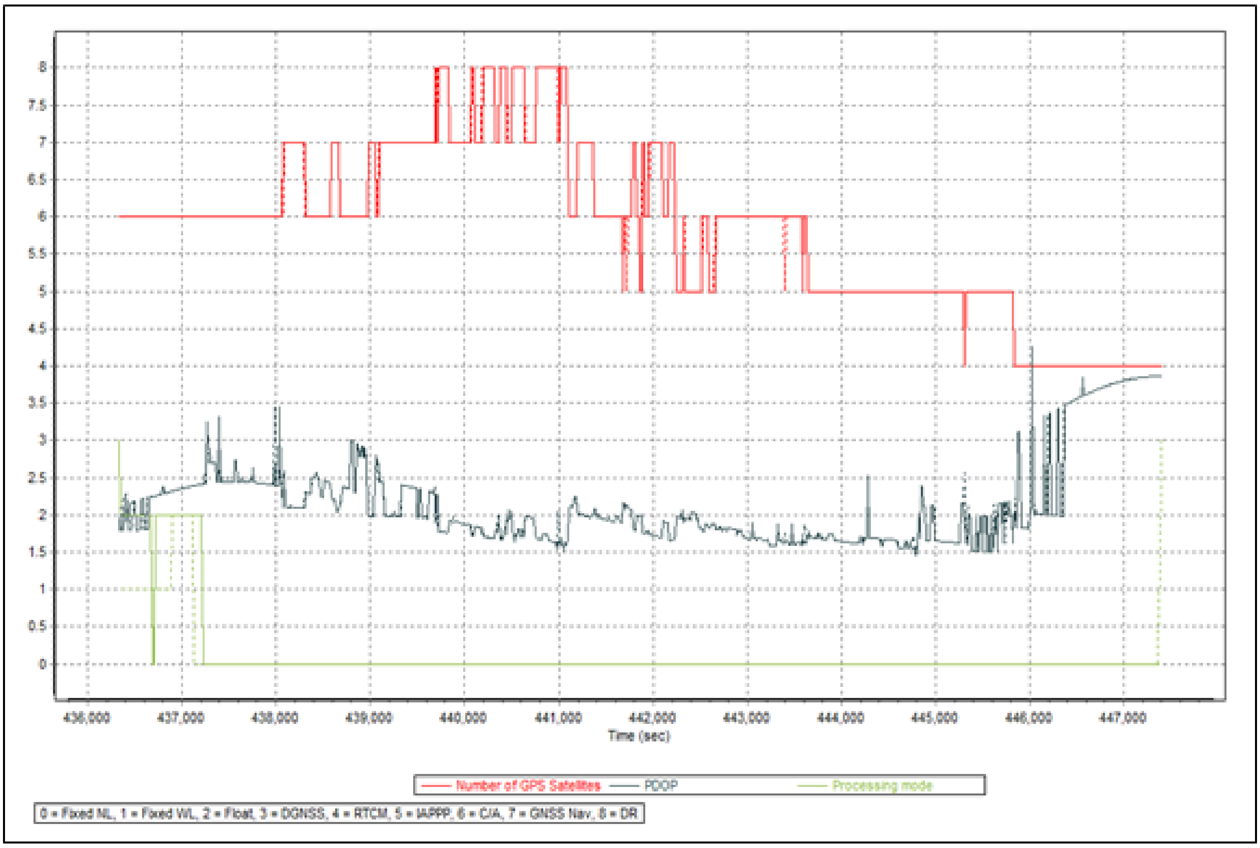


Figure A-8.22. Solution Status Parameters

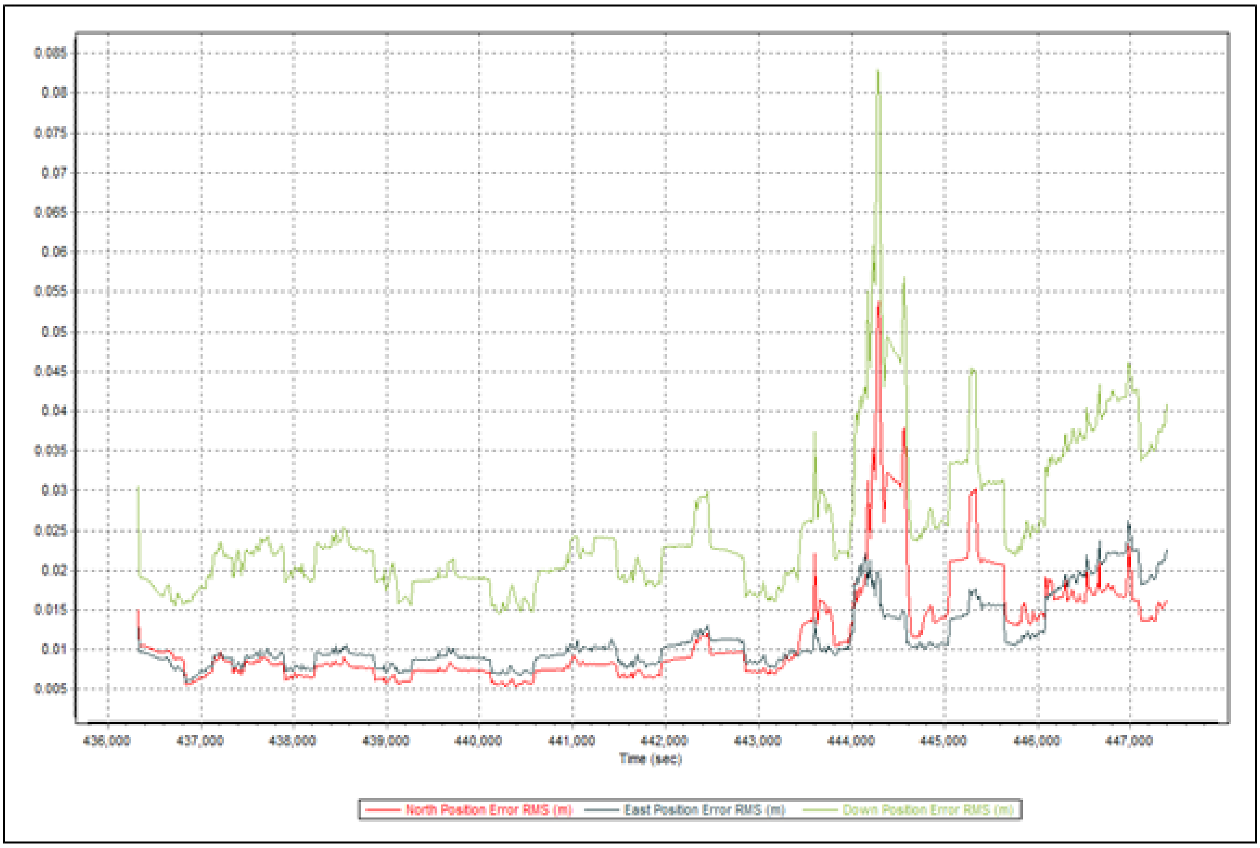


Figure A-8.23. Smoothed Performance Metrics Parameters

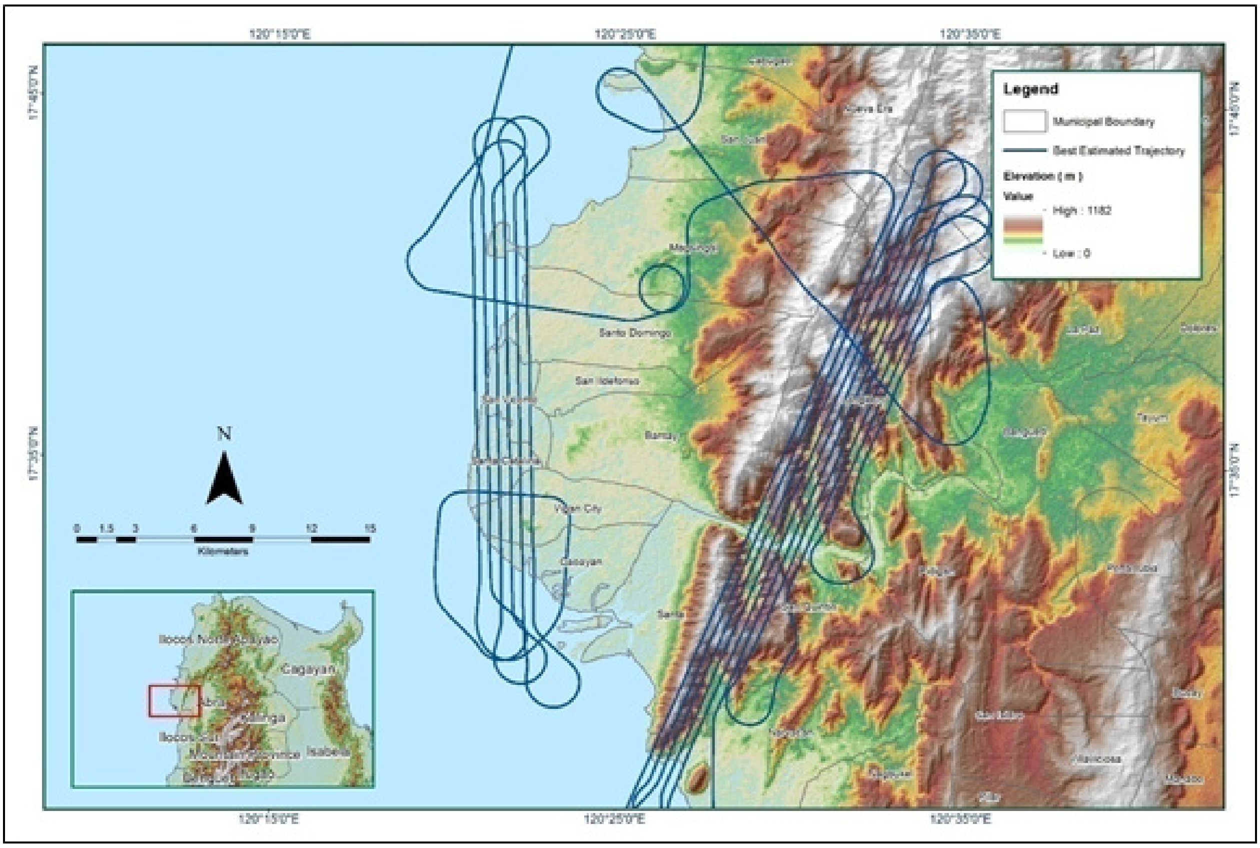


Figure A-8.24. Best Estimated Trajectory

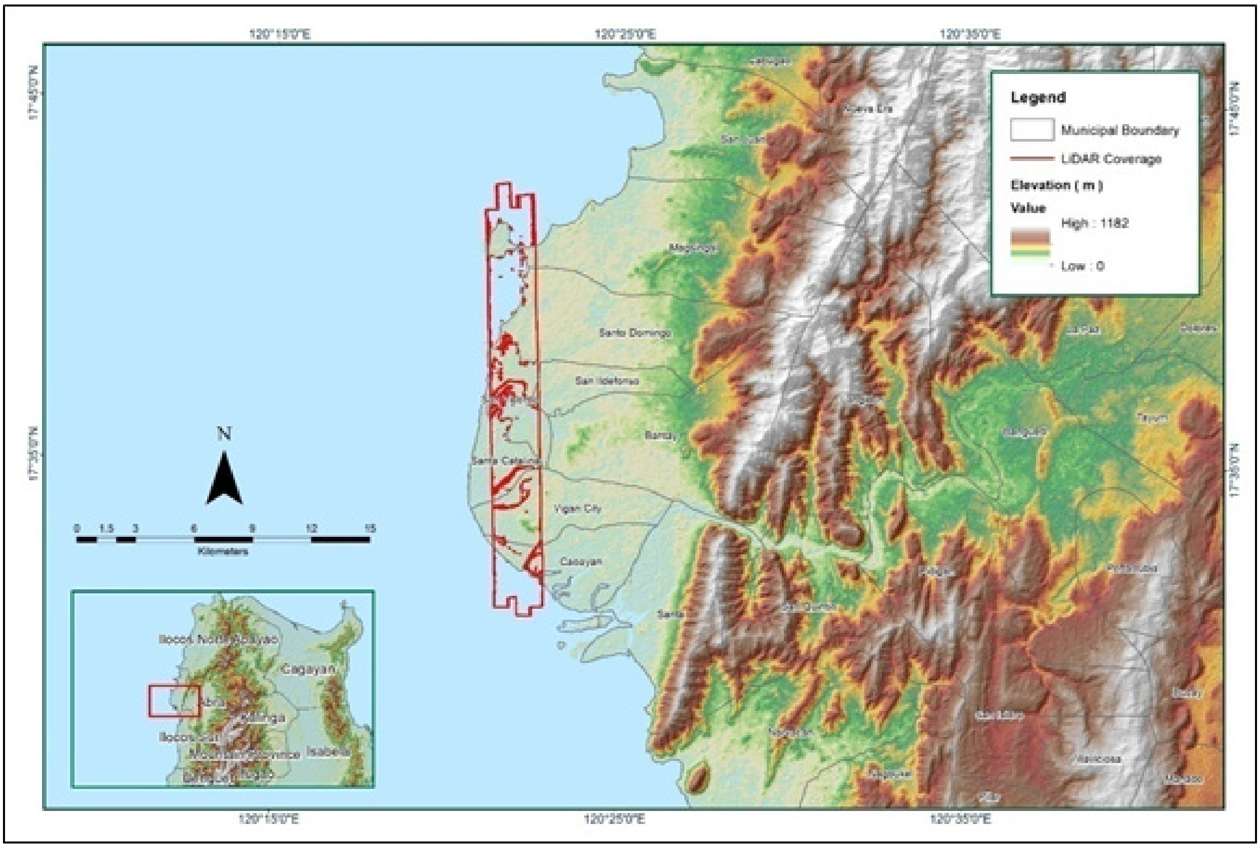


Figure A-8.25. Coverage of LiDAR data

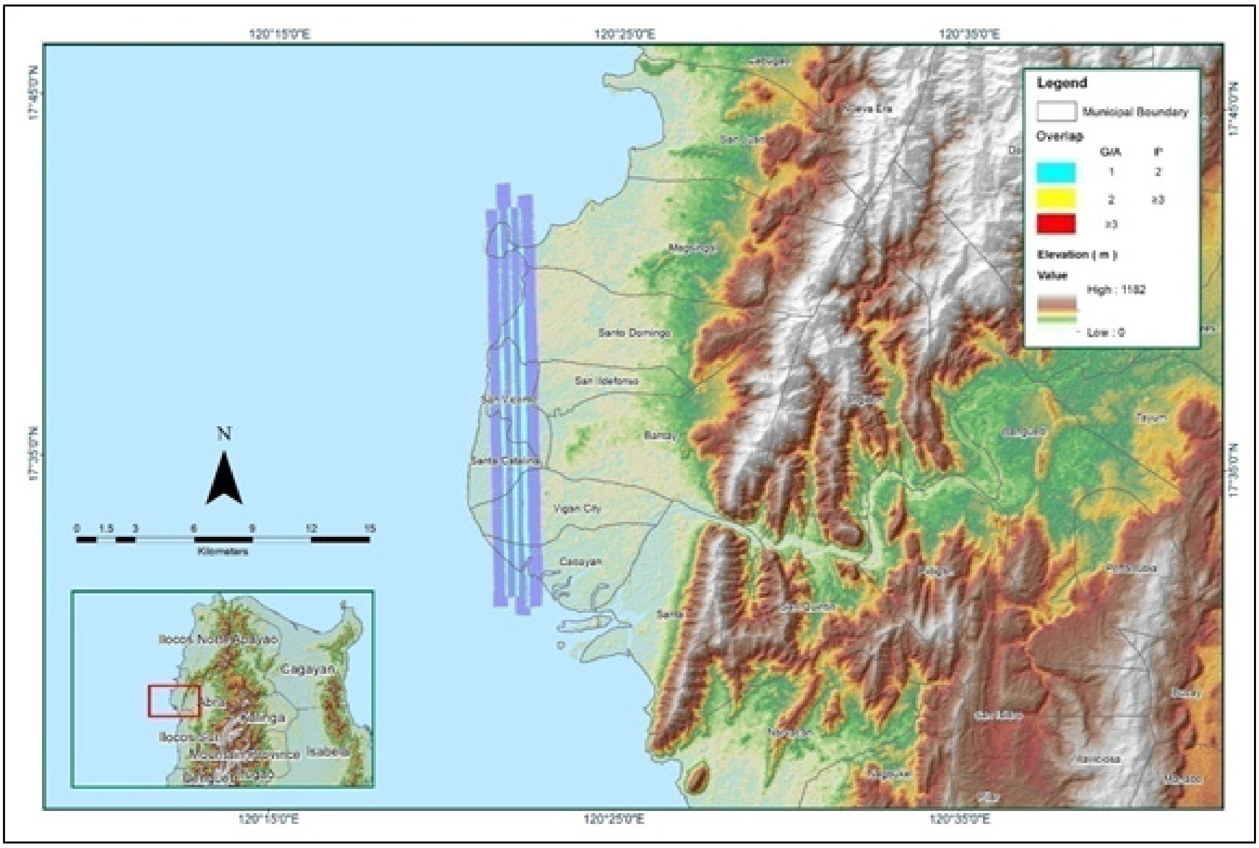


Figure A-8.26. Image of Data Overlap

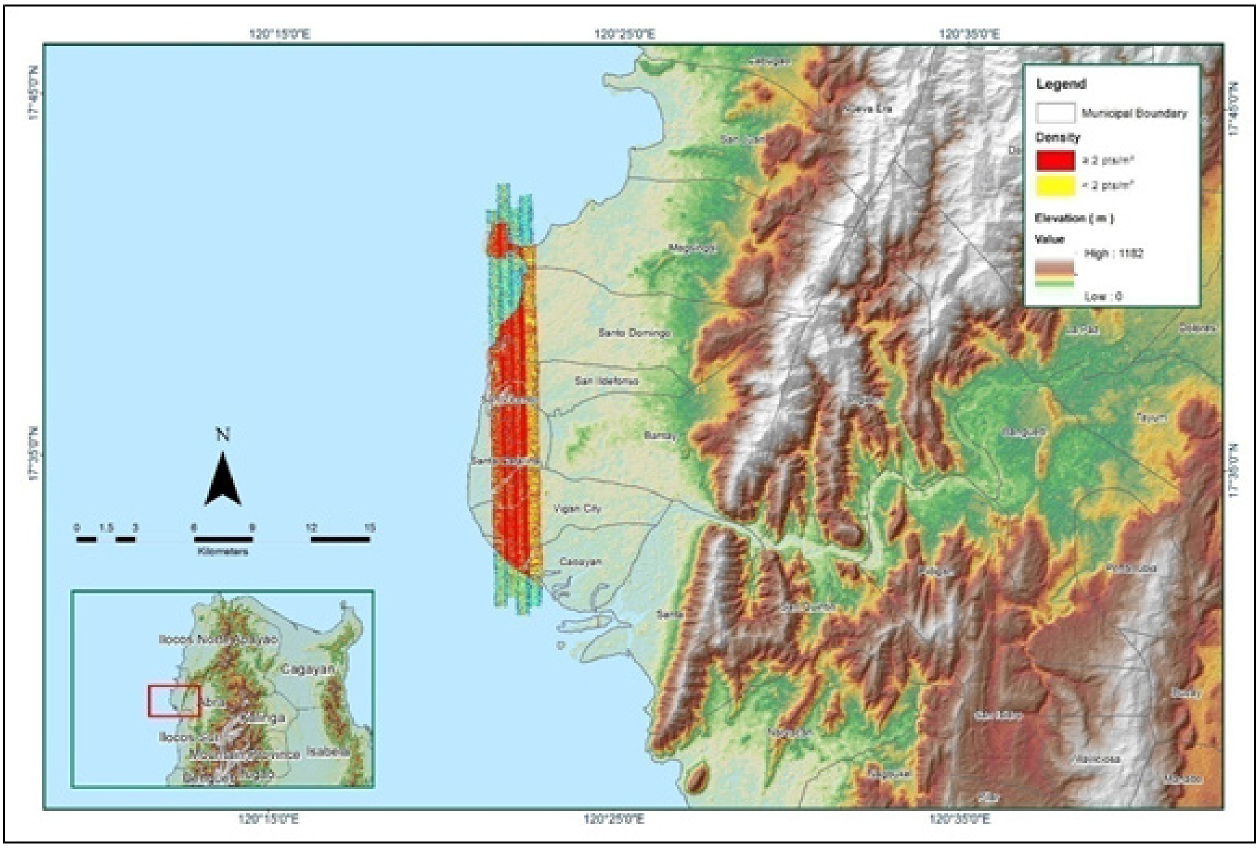


Figure A-8.27. Density map of merged LiDAR data

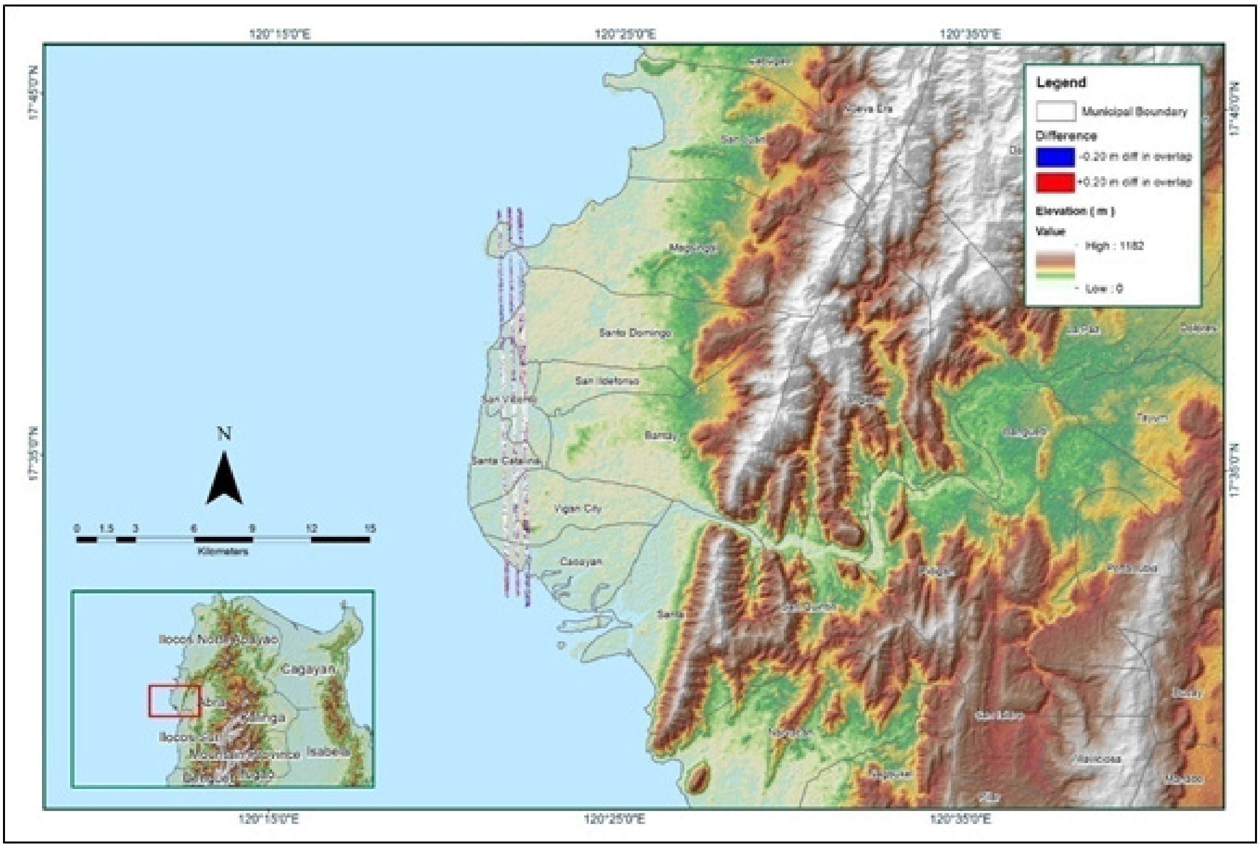


Figure A-8.28. Elevation difference between flight lines

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

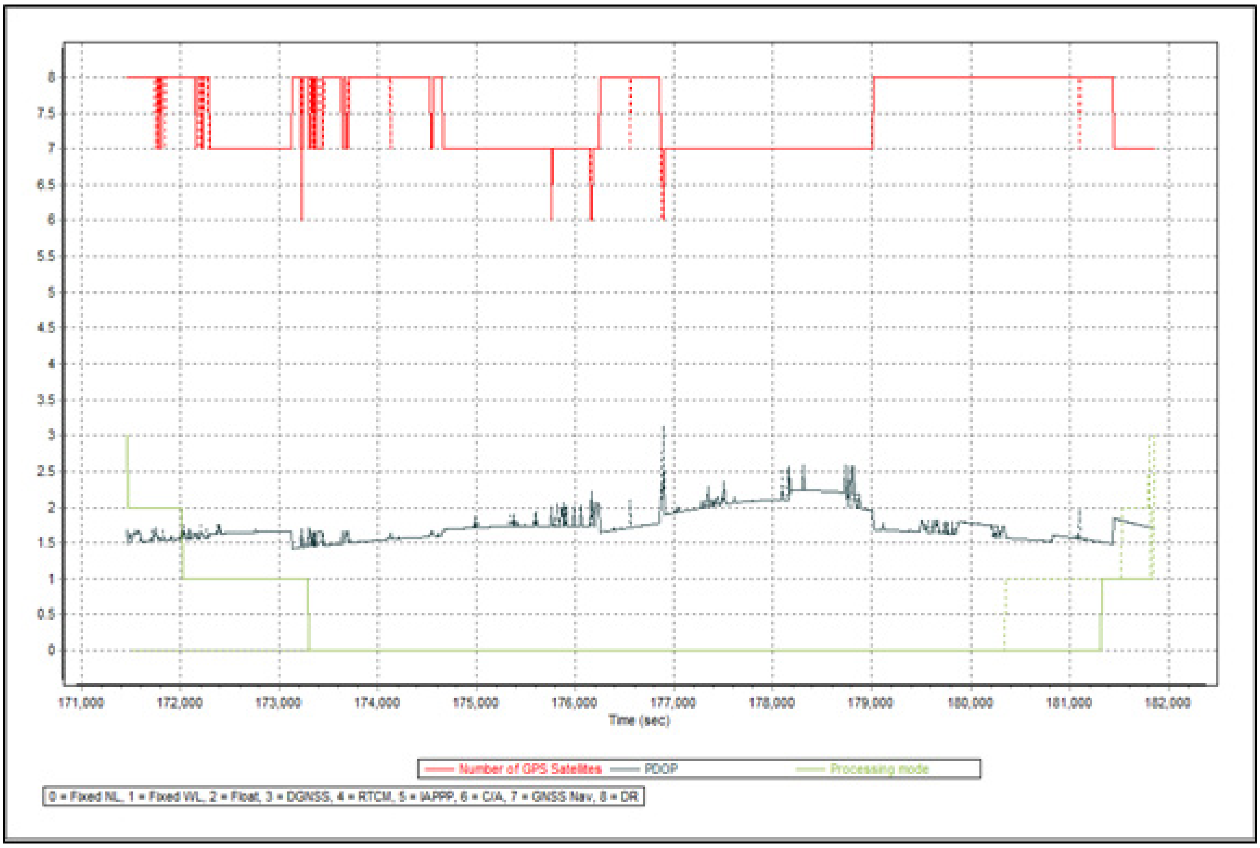


Figure A-8.29. Solution Status Parameters

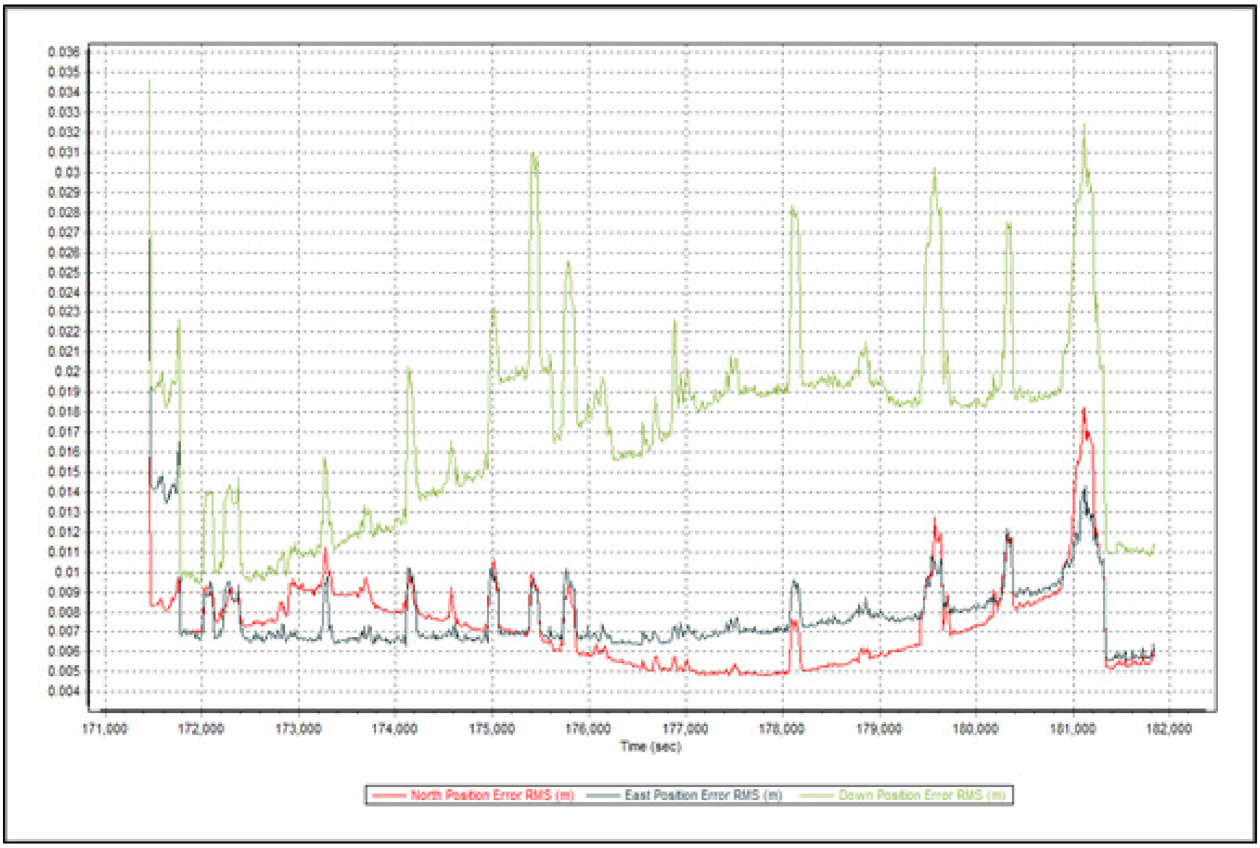


Figure A-8.30. Smoothed Performance Metrics Parameters

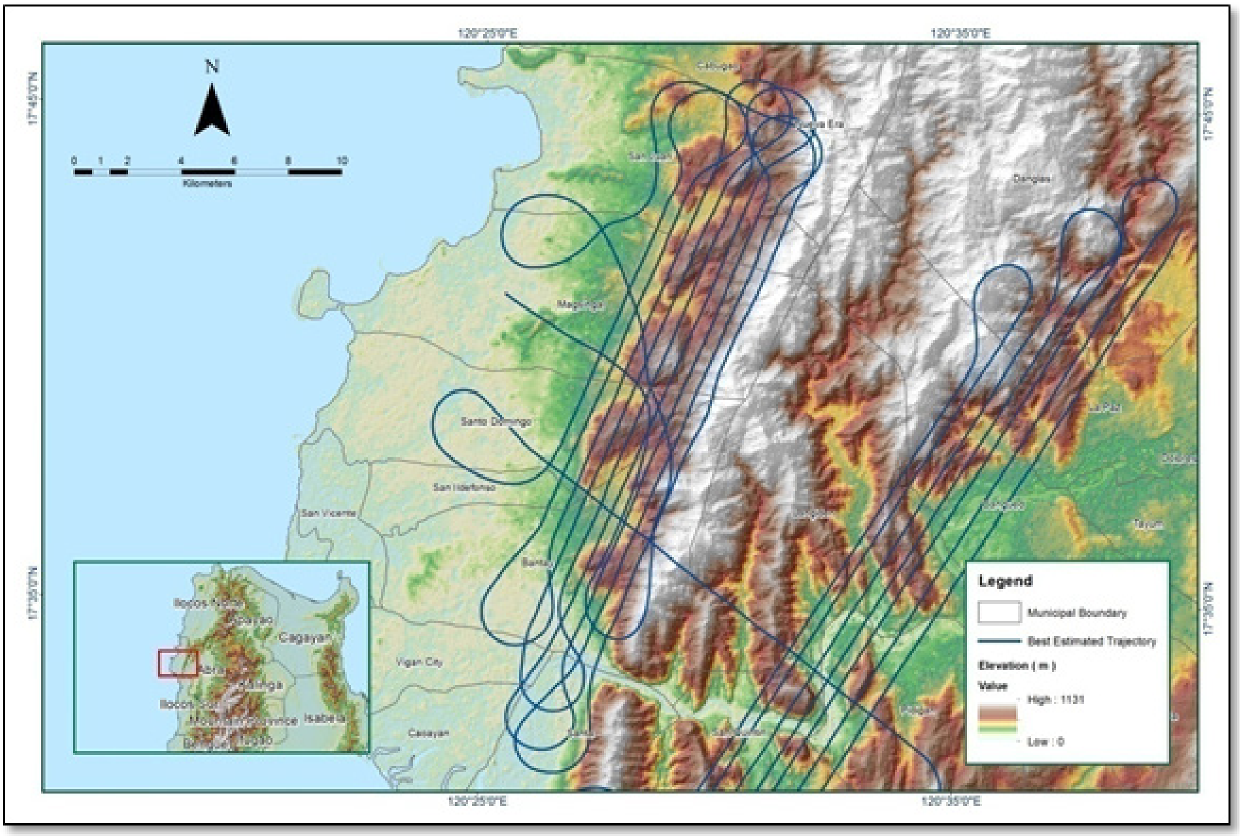


Figure A-8.31. Best Estimated Trajectory

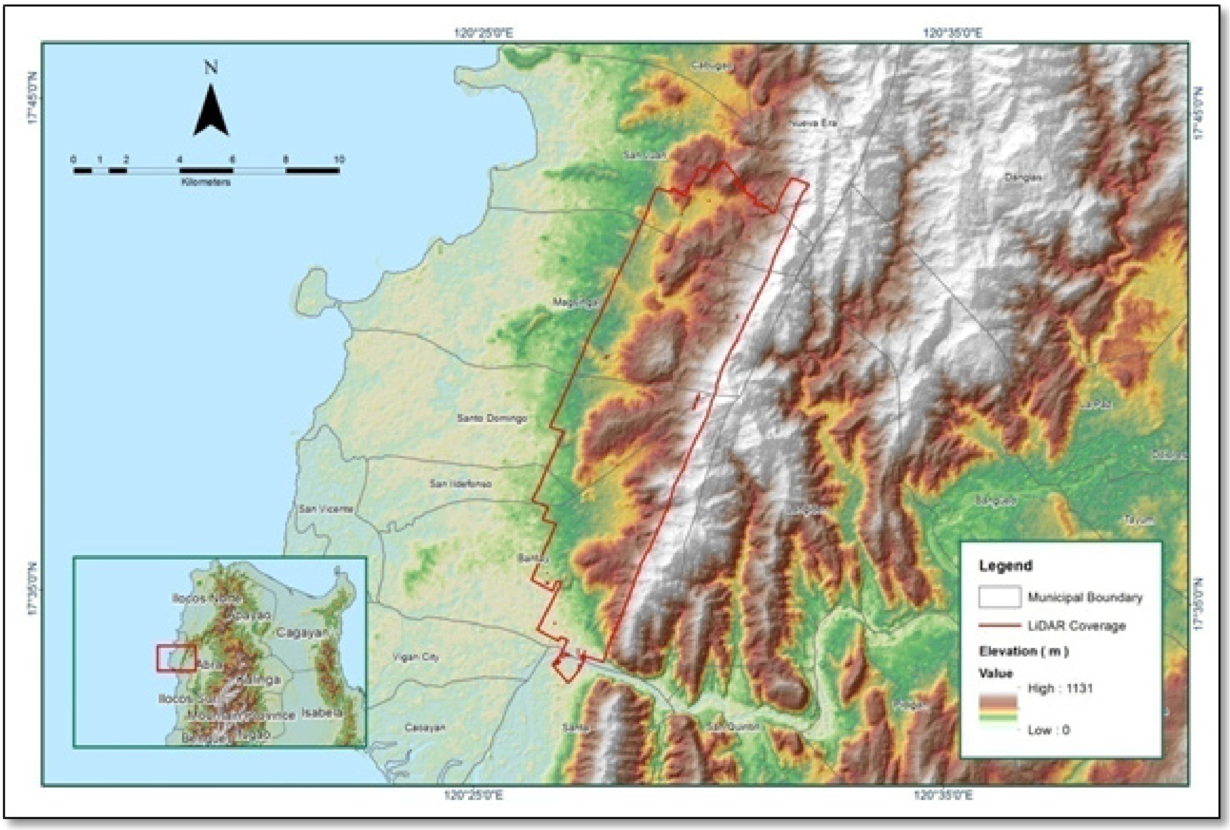


Figure A-8.32. Coverage of LiDAR data

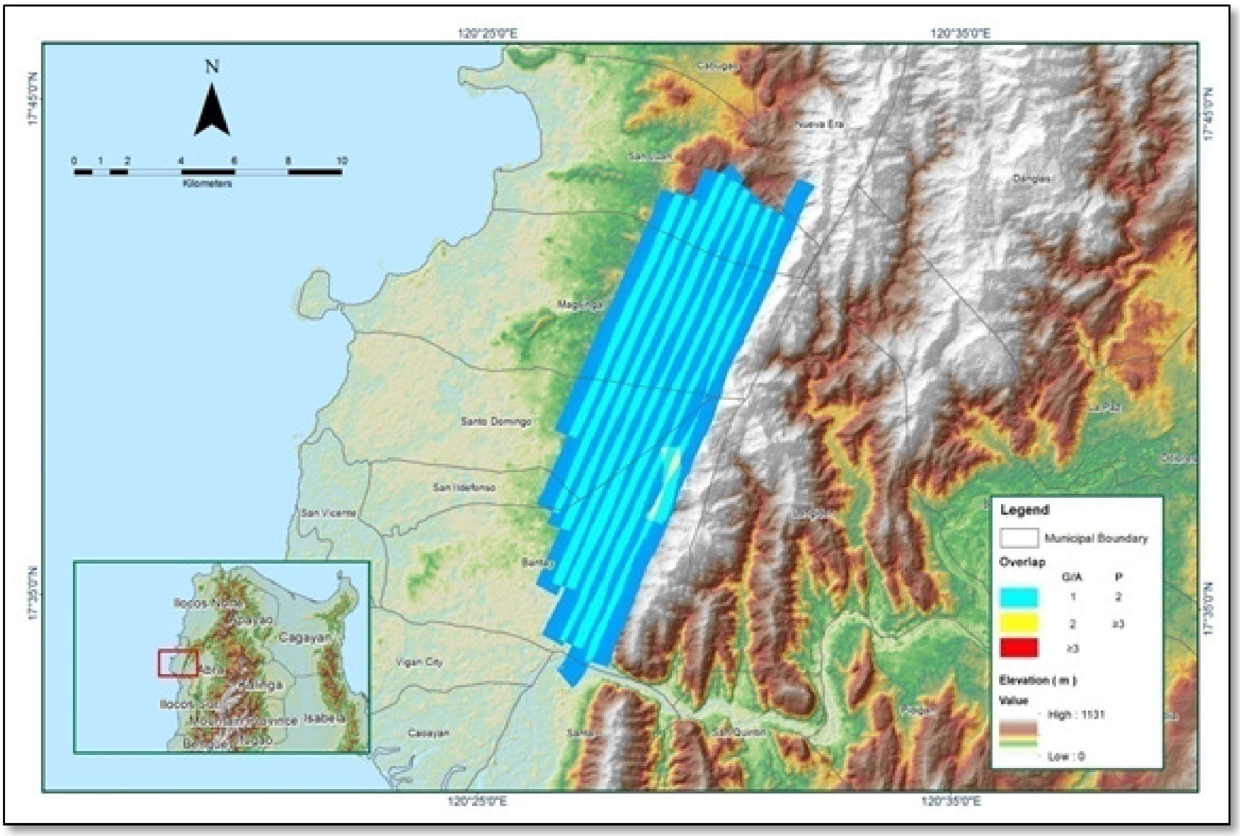


Figure A-8.33. Image of Data Overlap

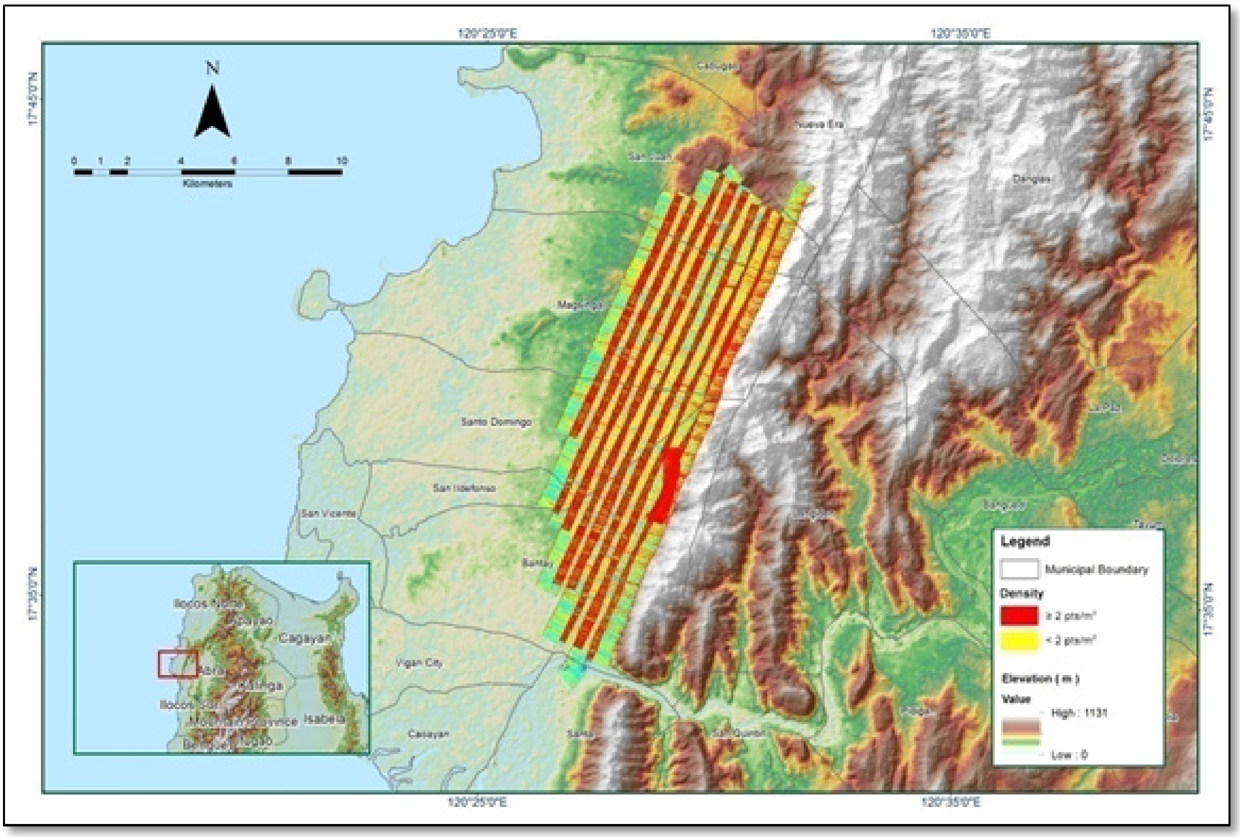


Figure A-8.34. Density map of merged LiDAR data

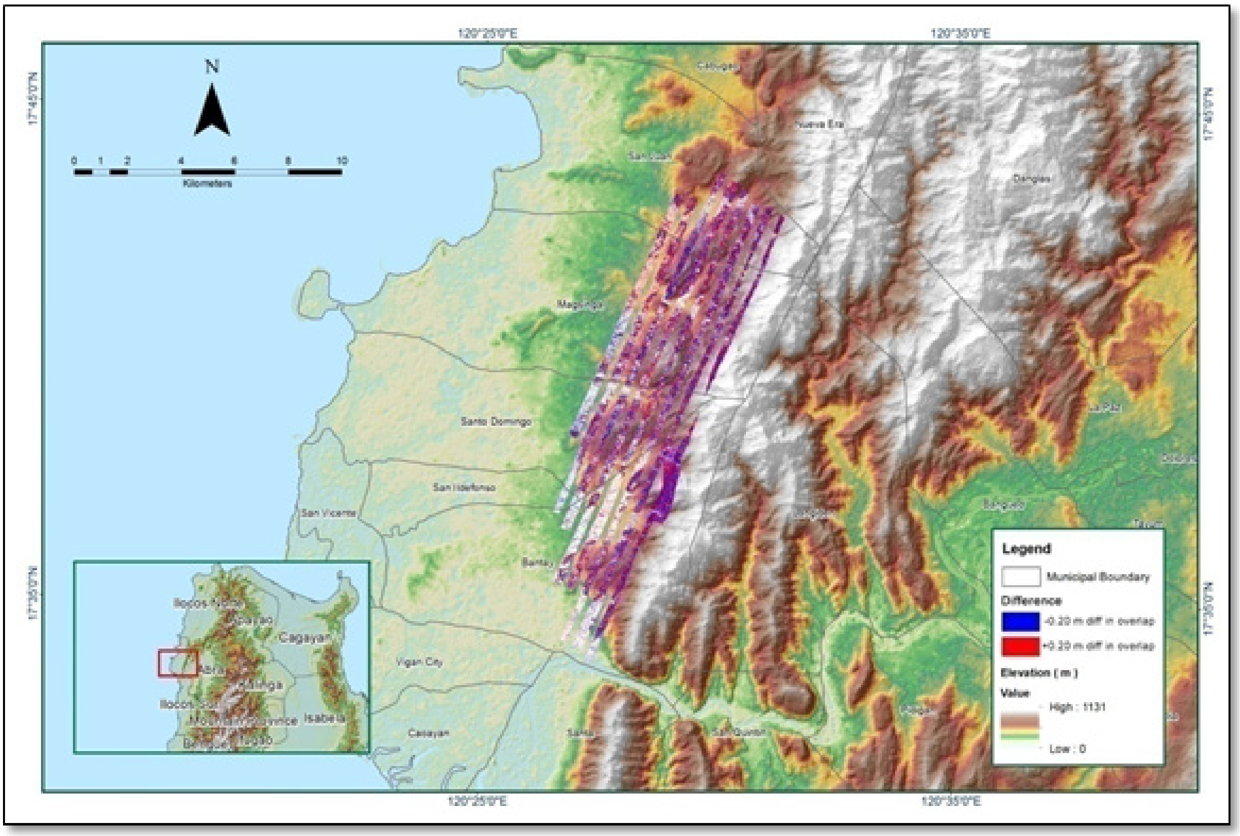


Figure A-8.35. Elevation difference between flight lines

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

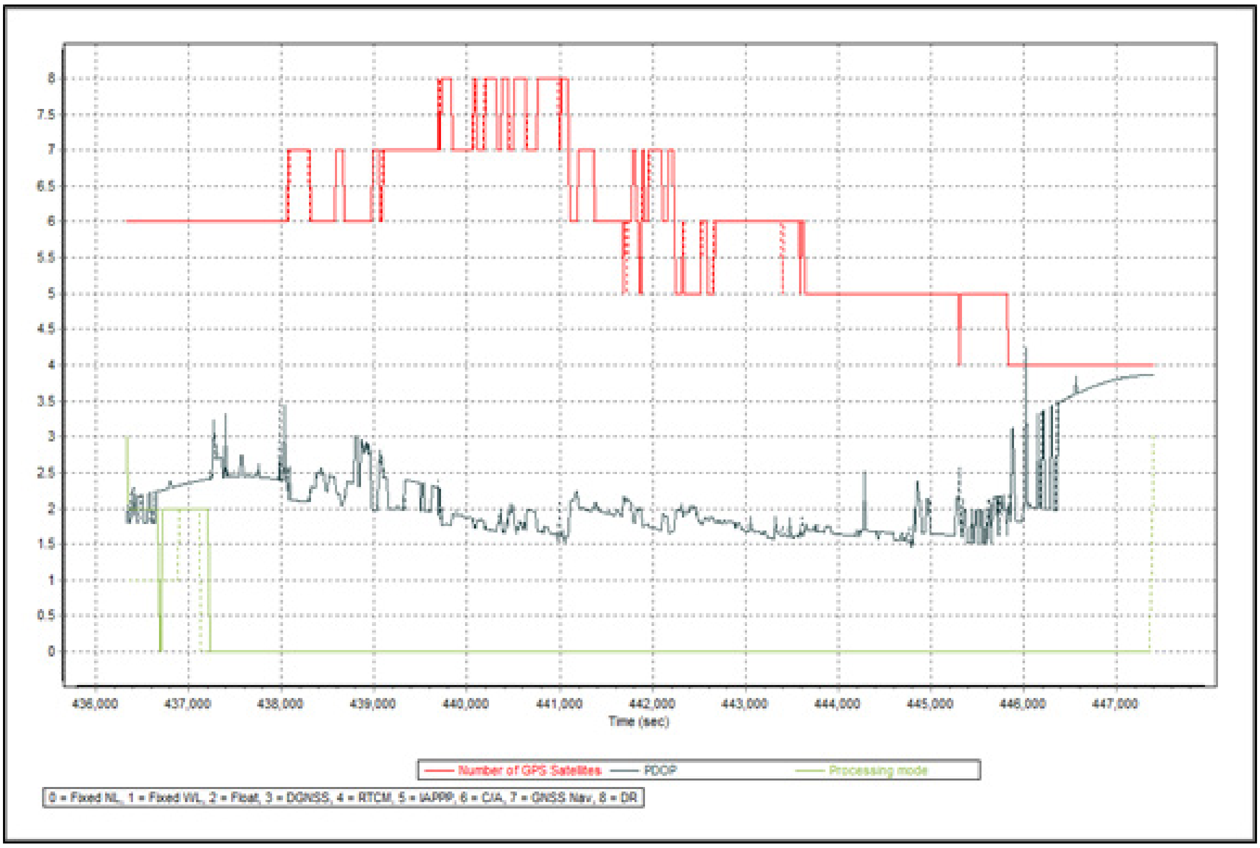


Figure A-8.36 Solution Status Parameters

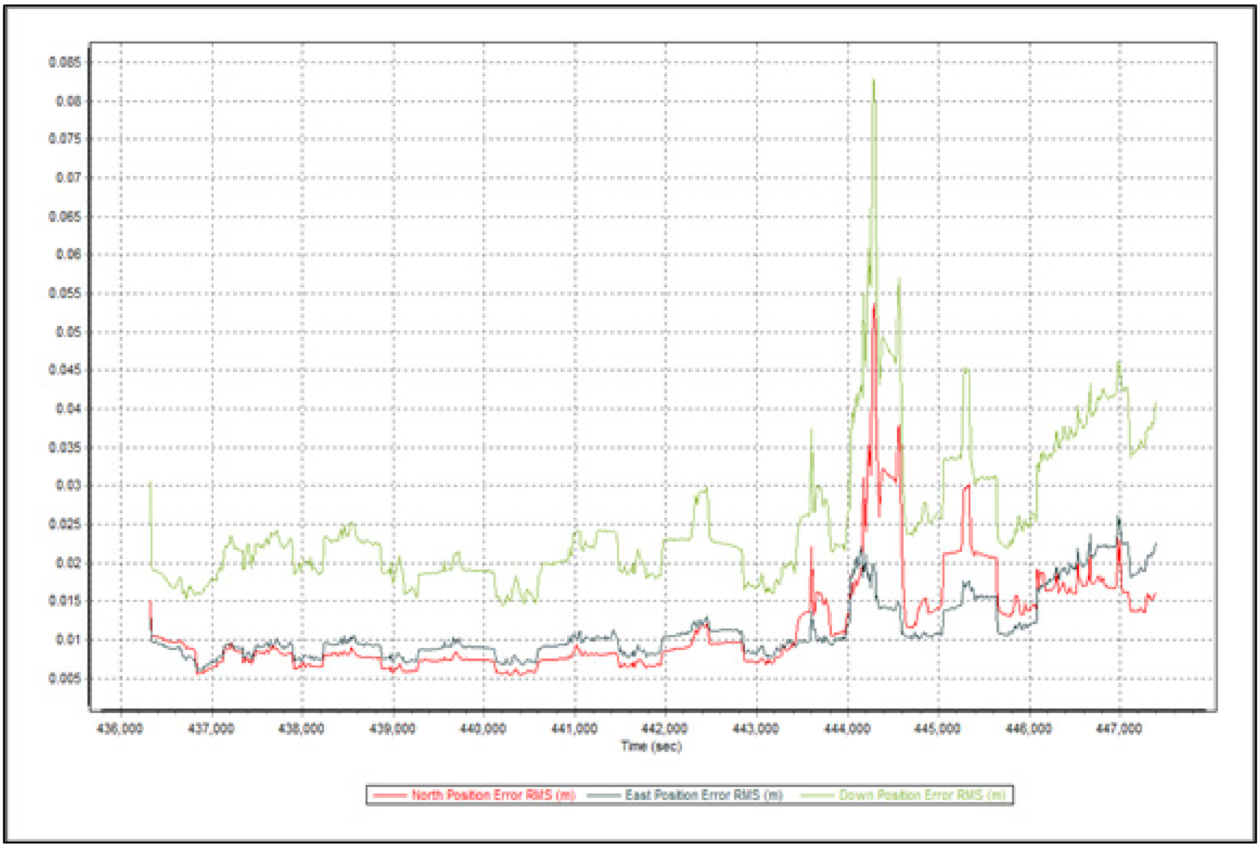


Figure A-8.37. Smoothed Performance Metrics Parameters

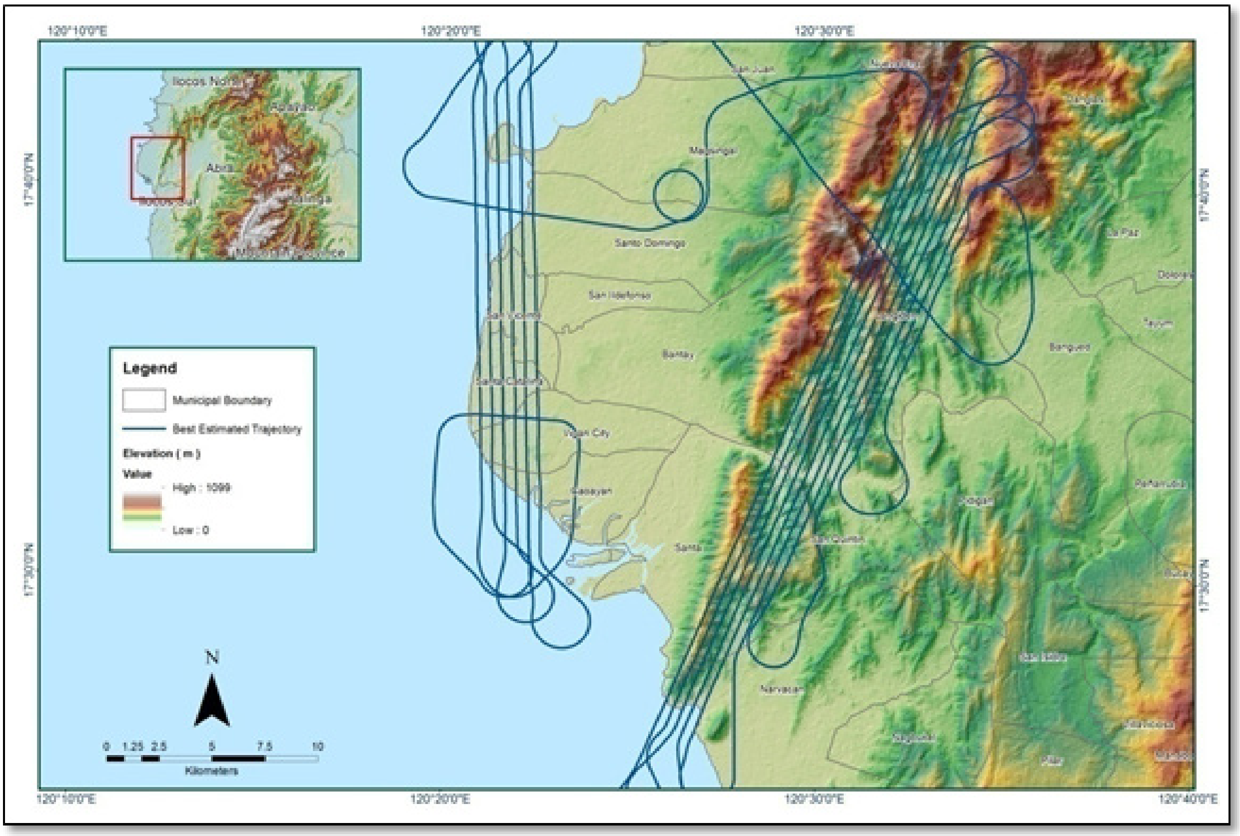


Figure A-8.38. Best Estimated Trajectory

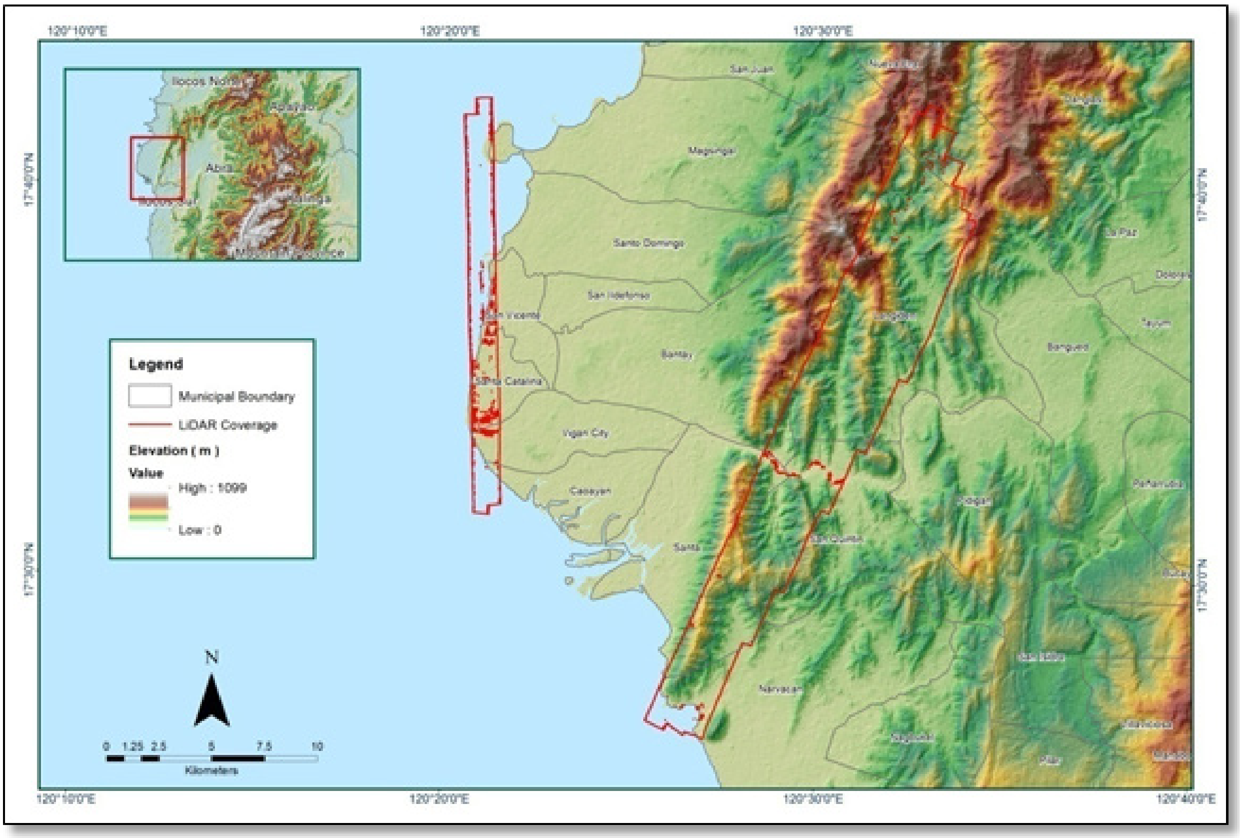


Figure A-8.39 Coverage of LiDAR data

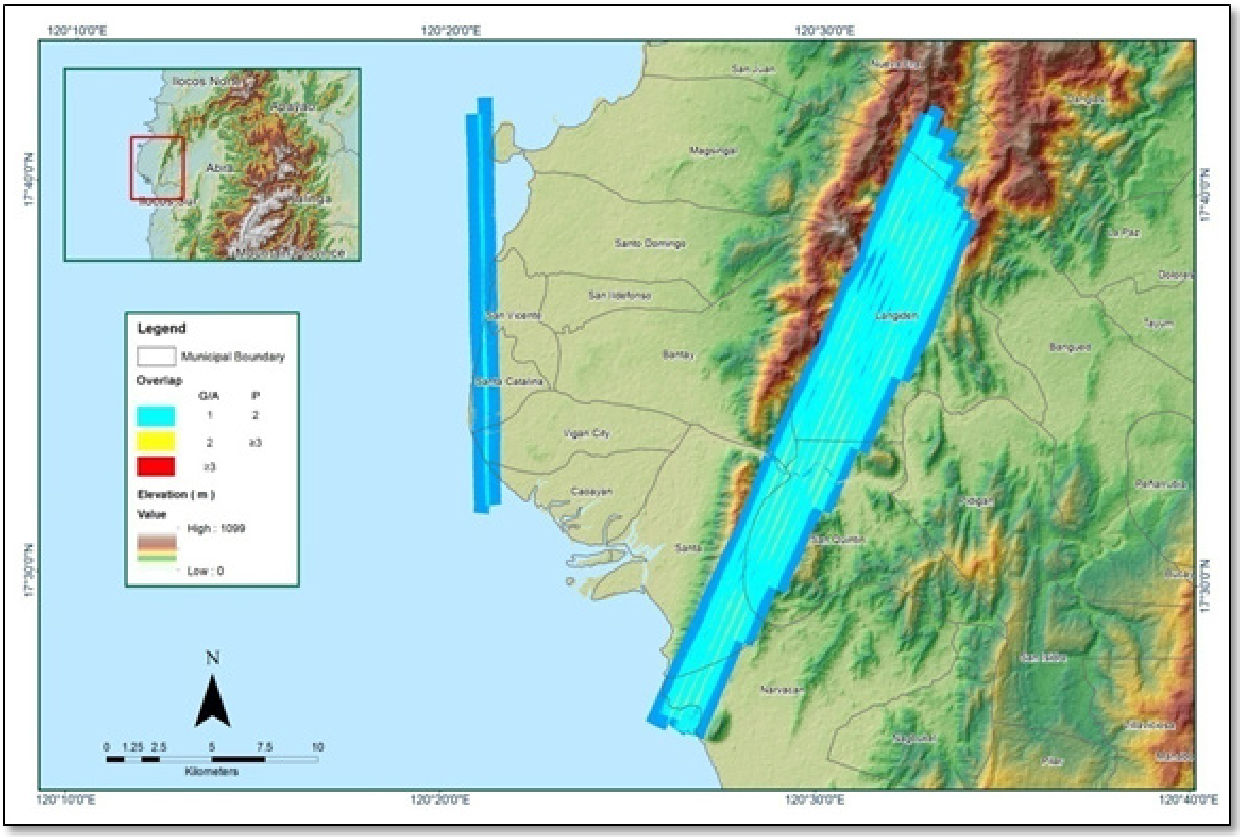


Figure A-8.40. Image of Data Overlap

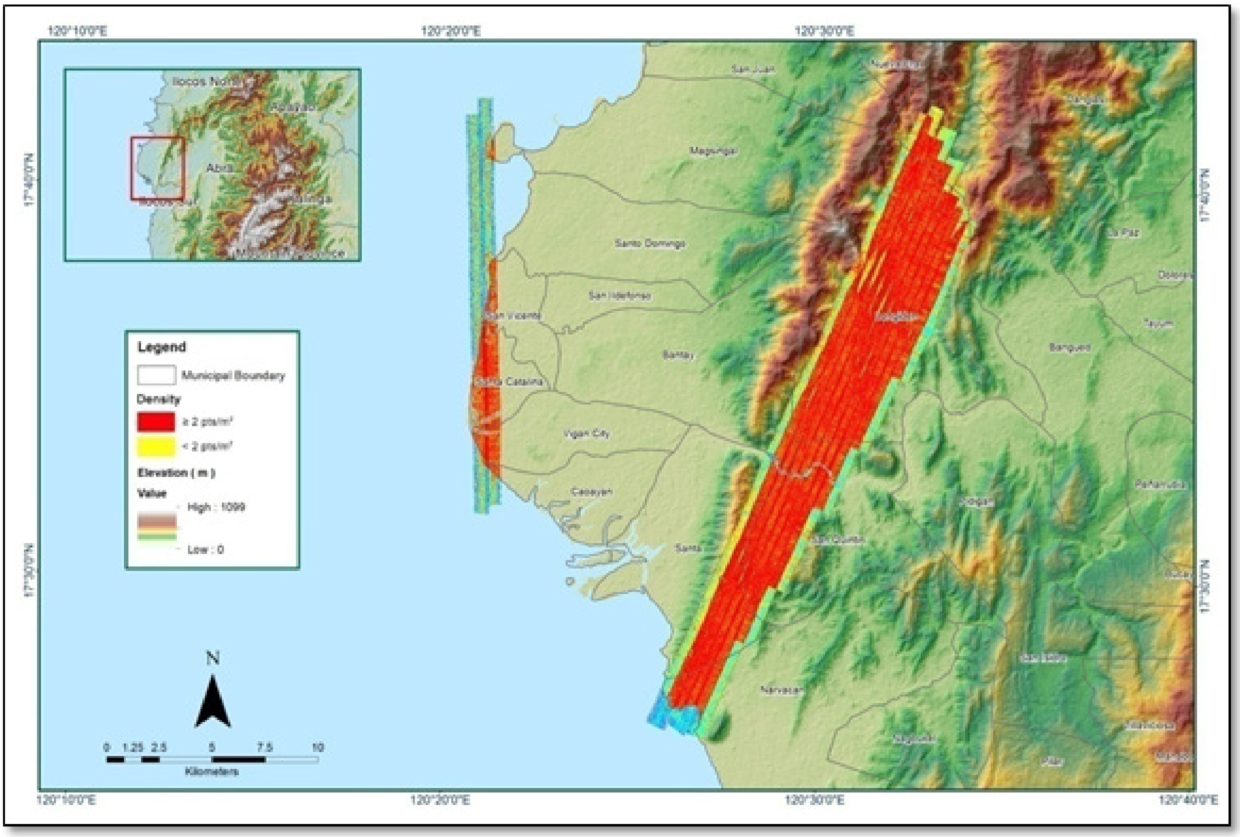


Figure A-8.41. Density map of merged LiDAR data

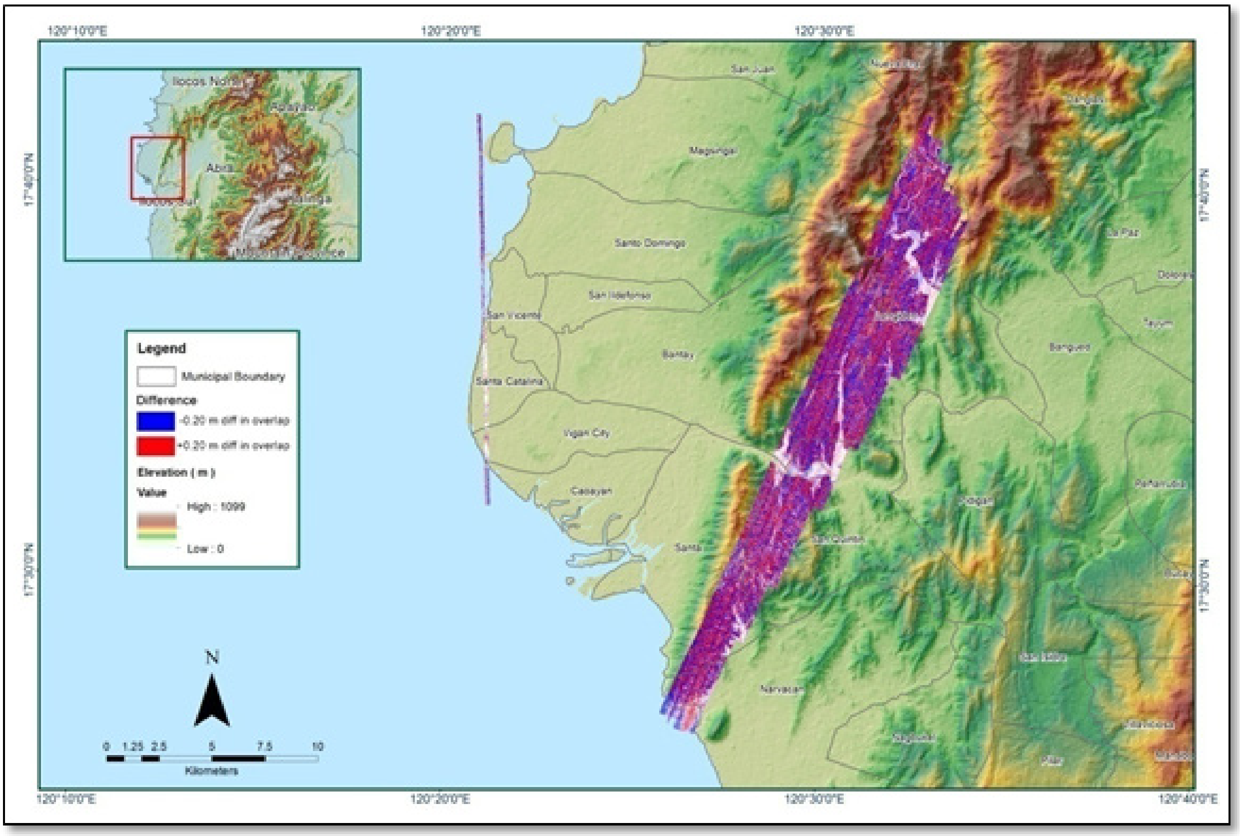


Figure A-8.42. Elevation difference between flight lines

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

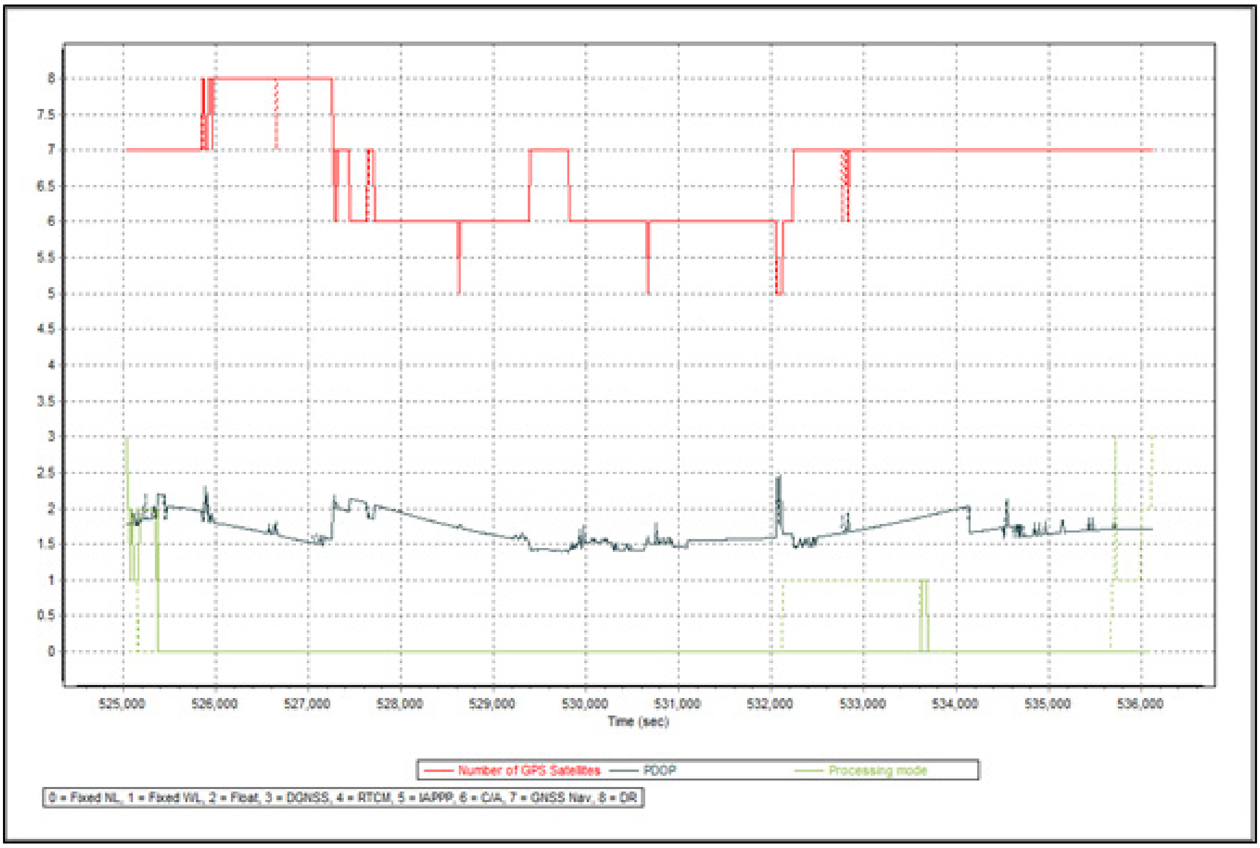


Figure A-8.43Solution Status Parameters

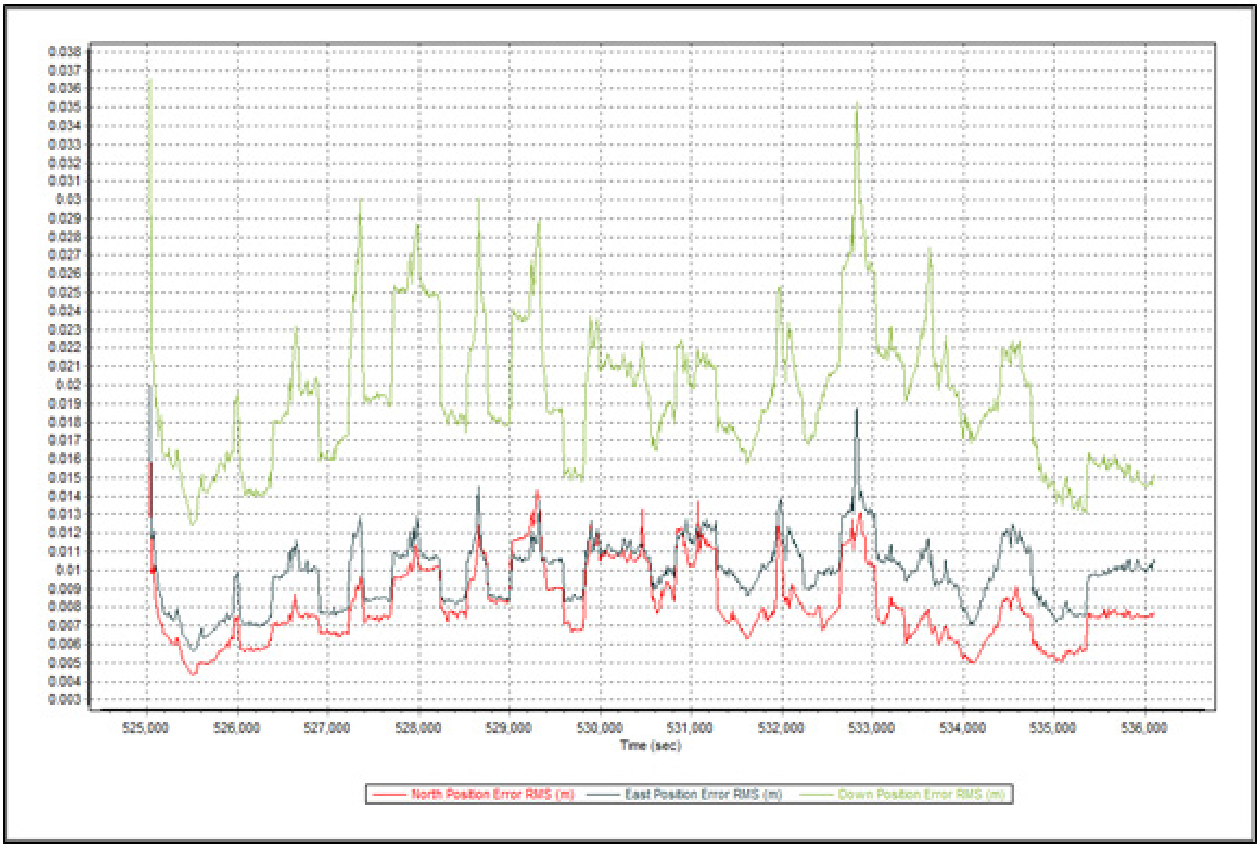


Figure A-8.44. Smoothed Performance Metrics Parameters

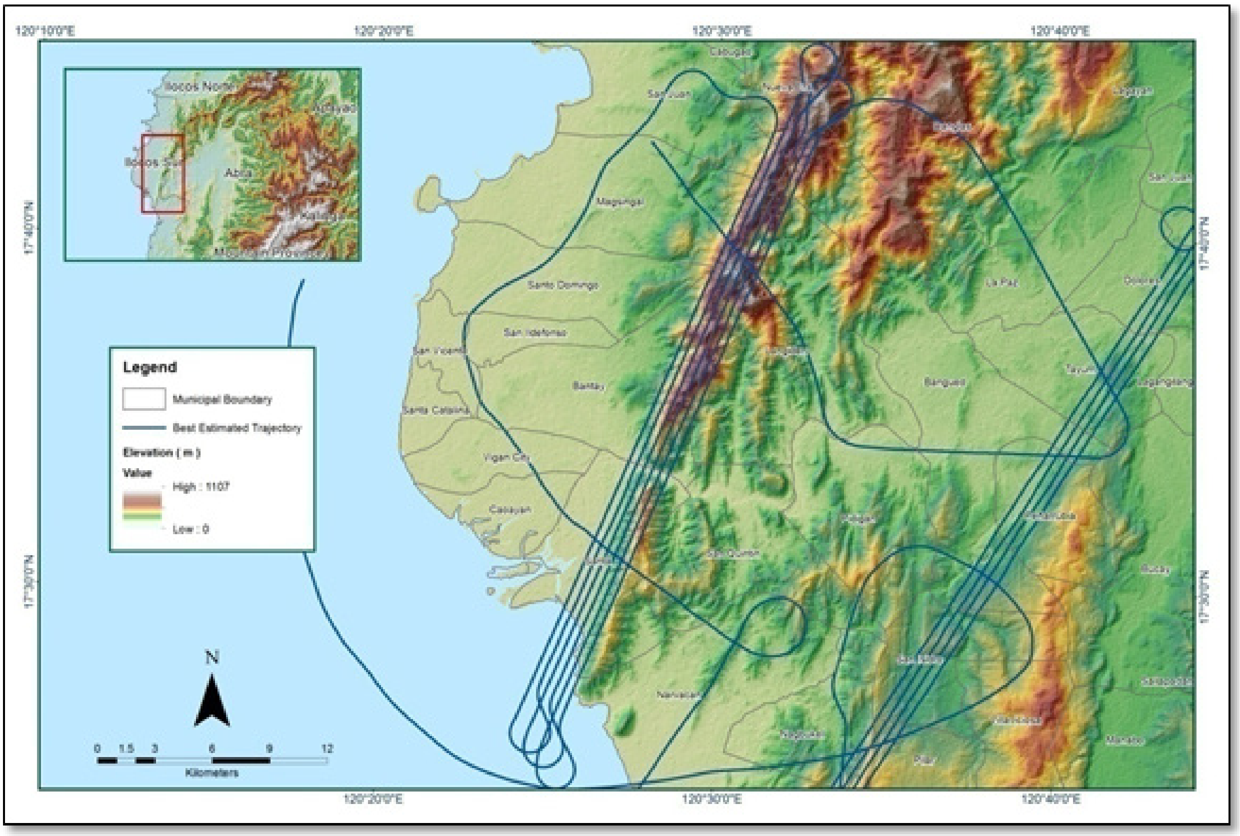


Figure A-8.45. Best Estimated Trajectory

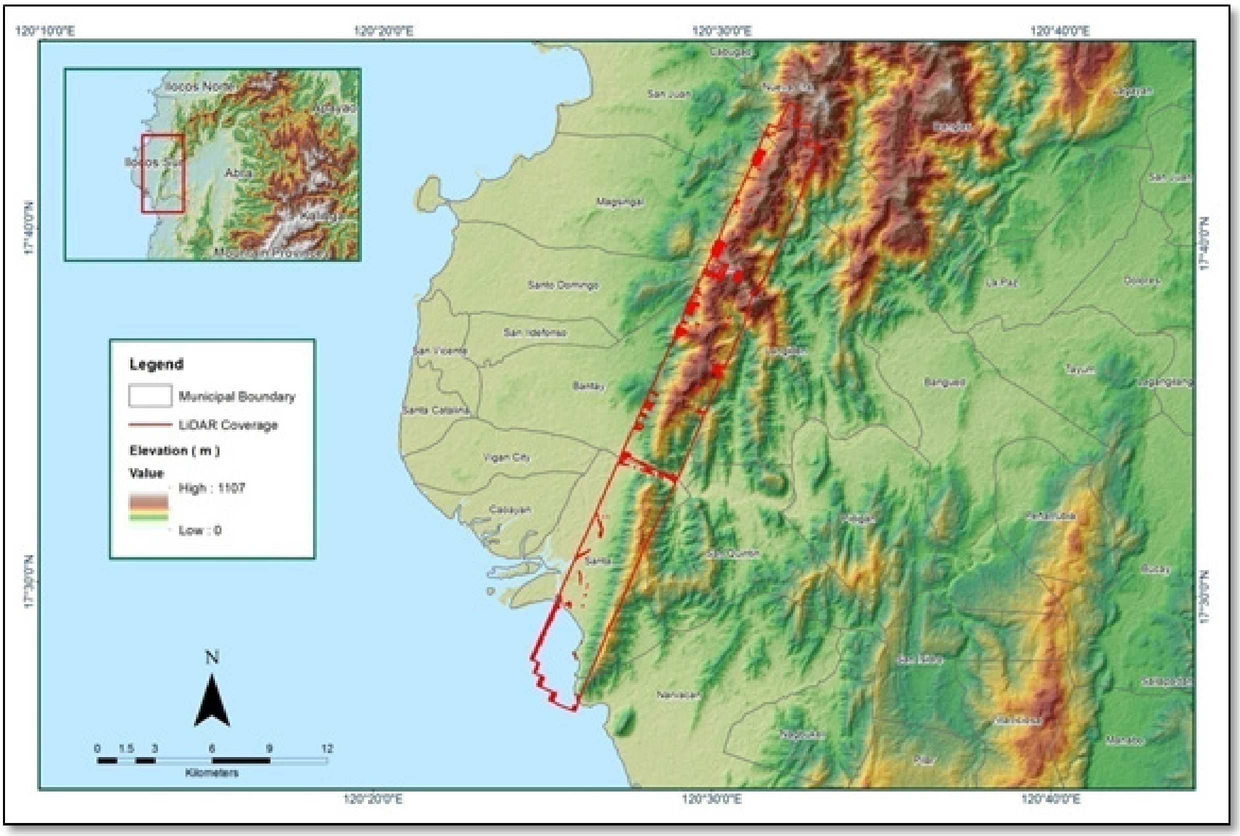


Figure A-8.46 Coverage of LiDAR data

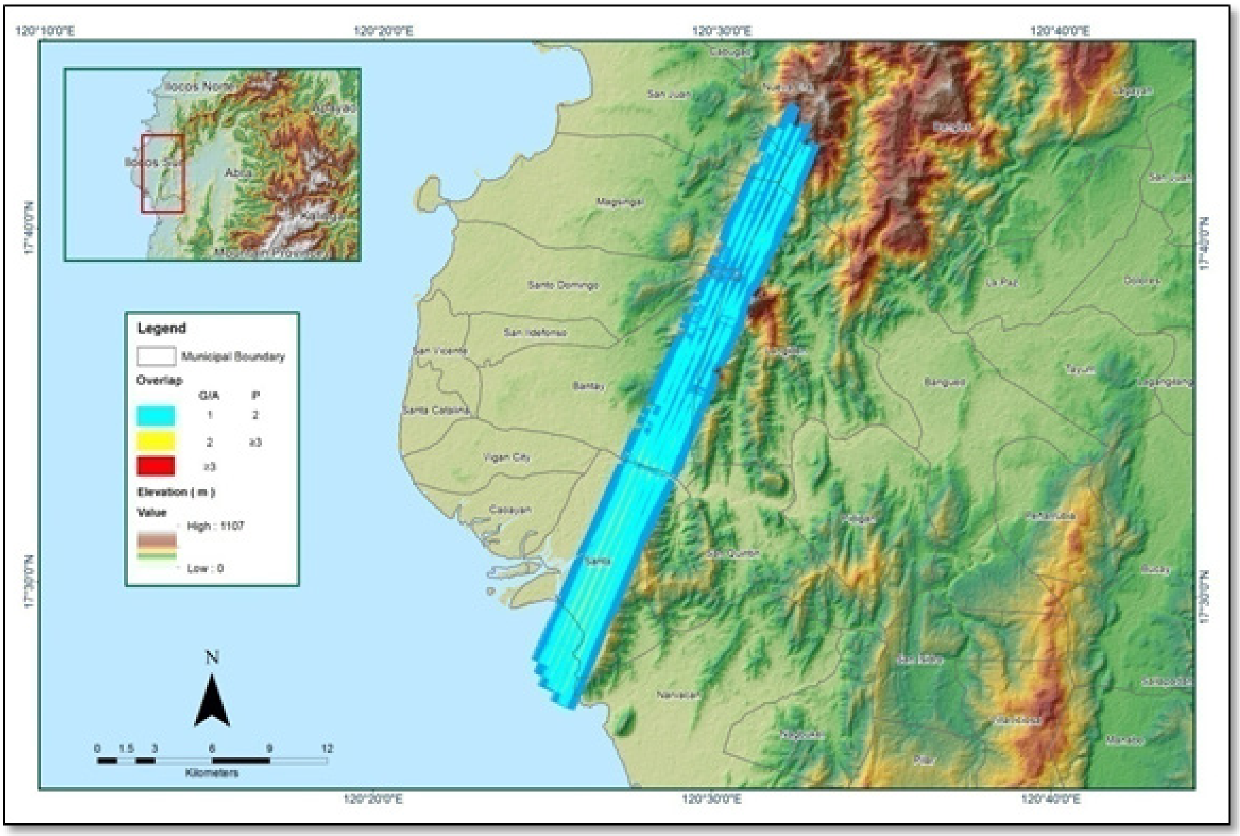


Figure A-8.47. Image of Data Overlap

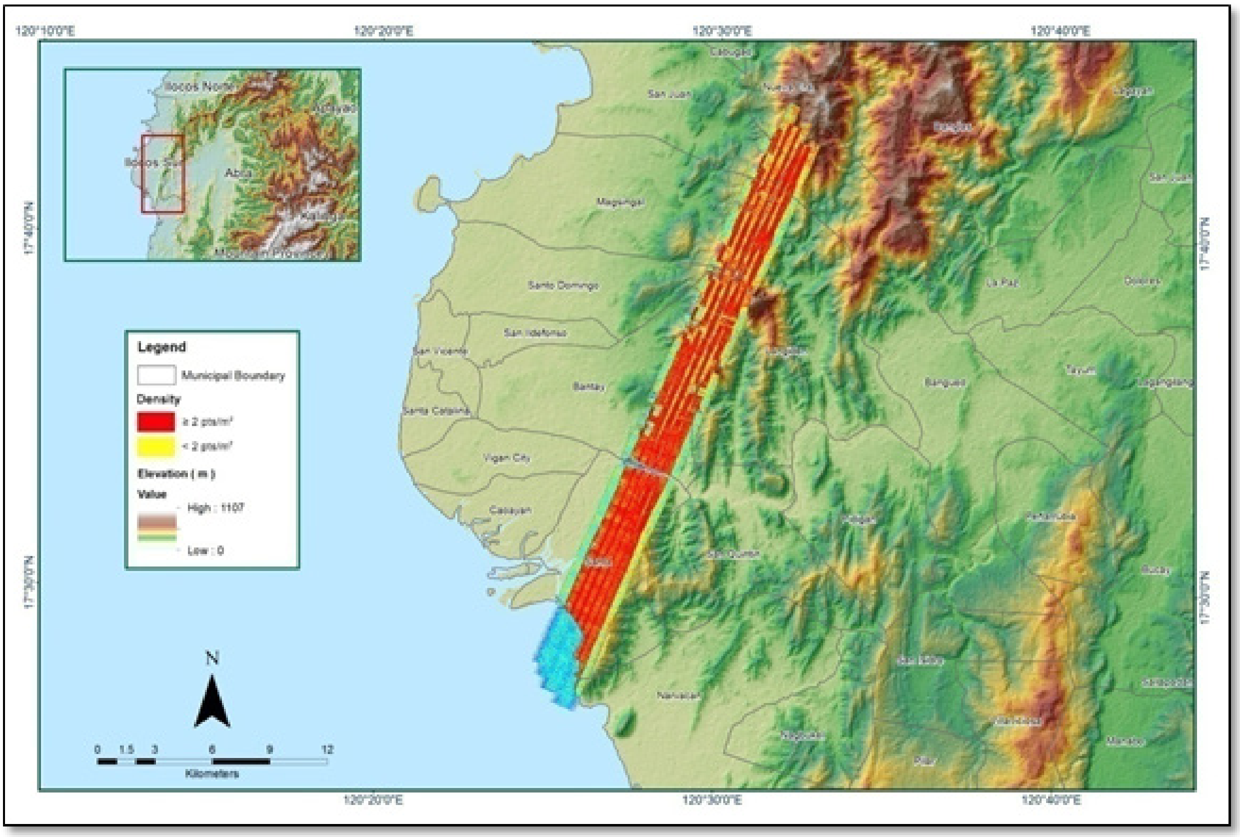


Figure A-8.48. Density map of merged LiDAR data

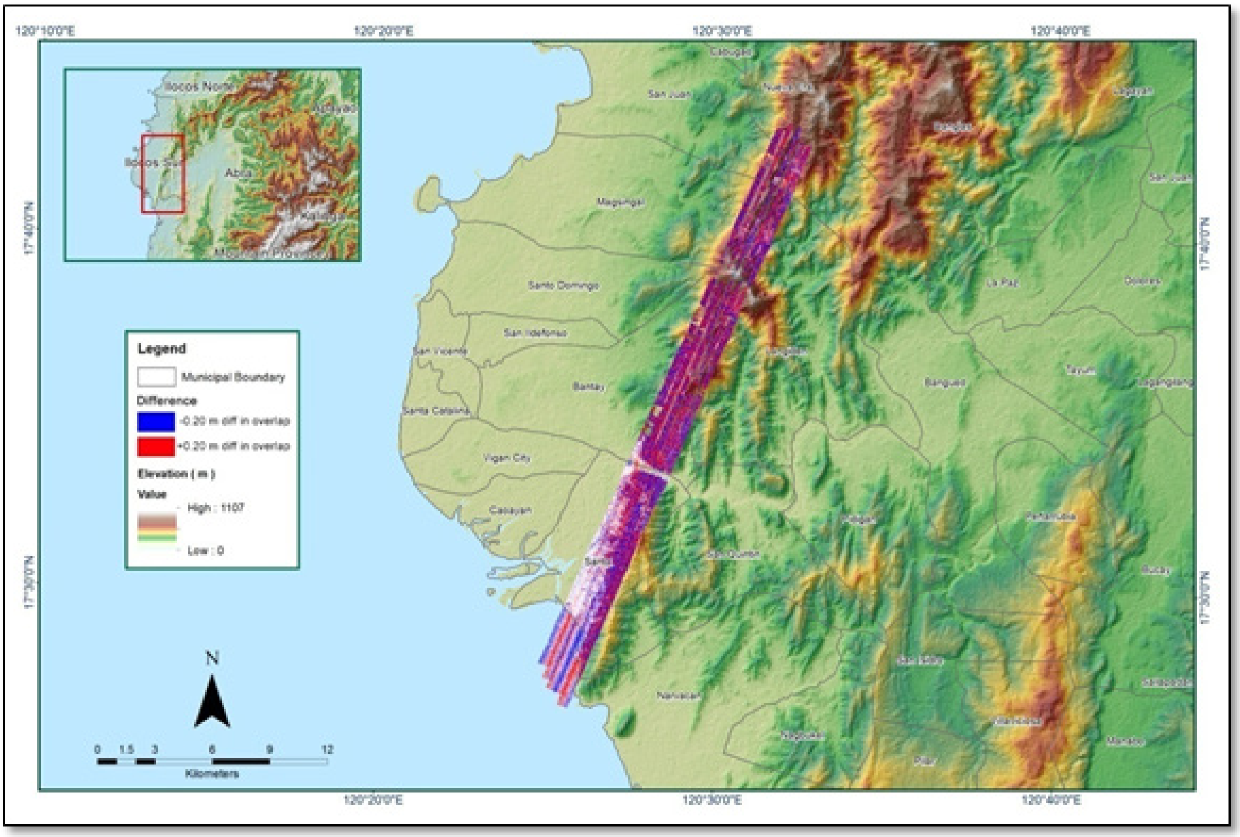


Figure A-8.49. Elevation difference between flight lines

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

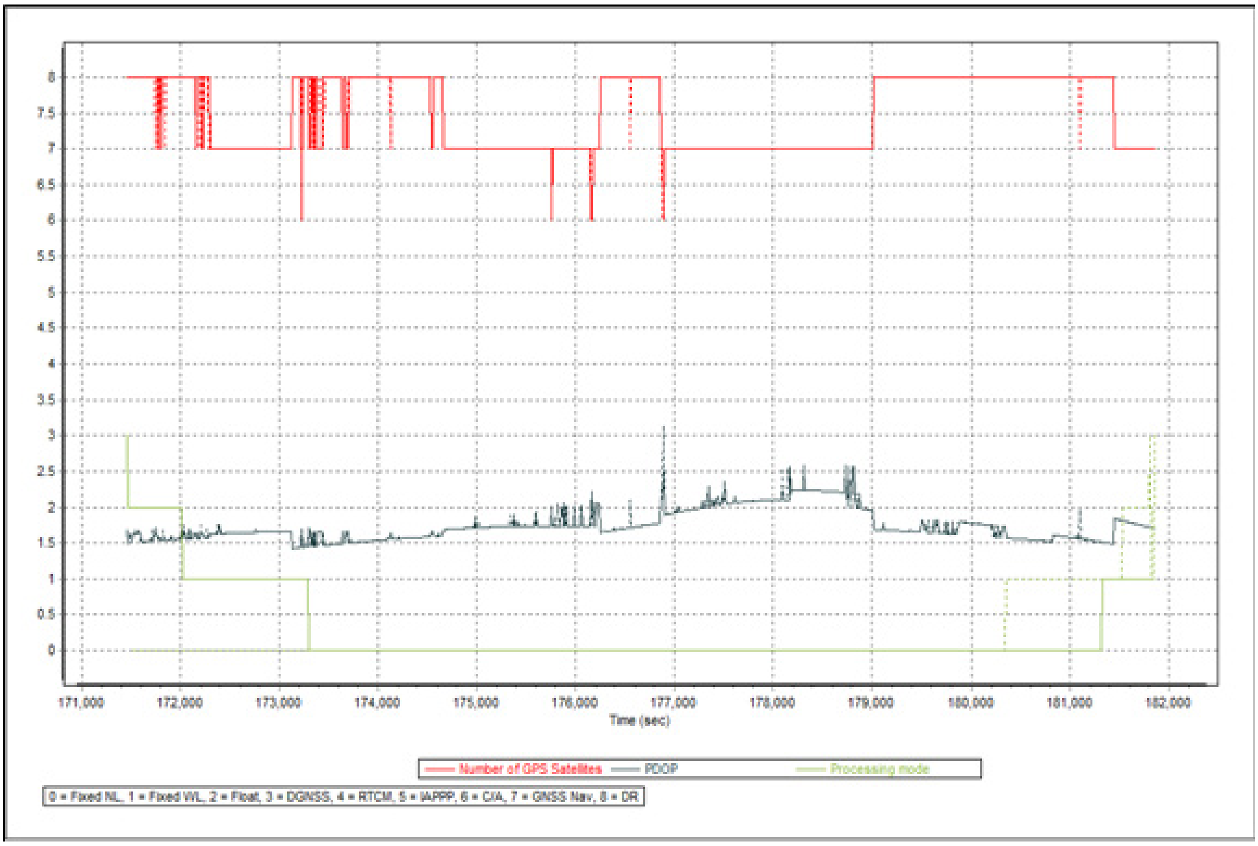


Figure A-8.50. Solution Status Parameters

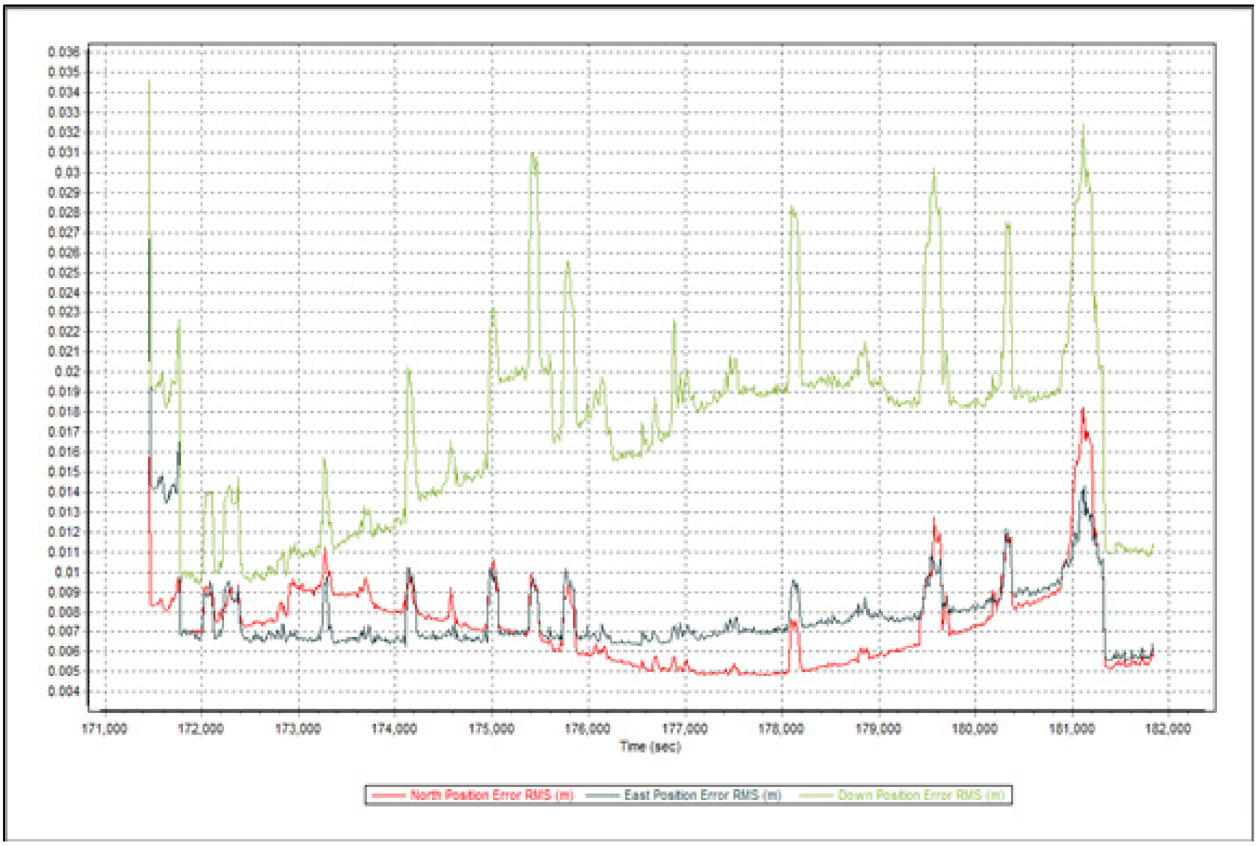


Figure A-8.51. Smoothed Performance Metrics Parameters

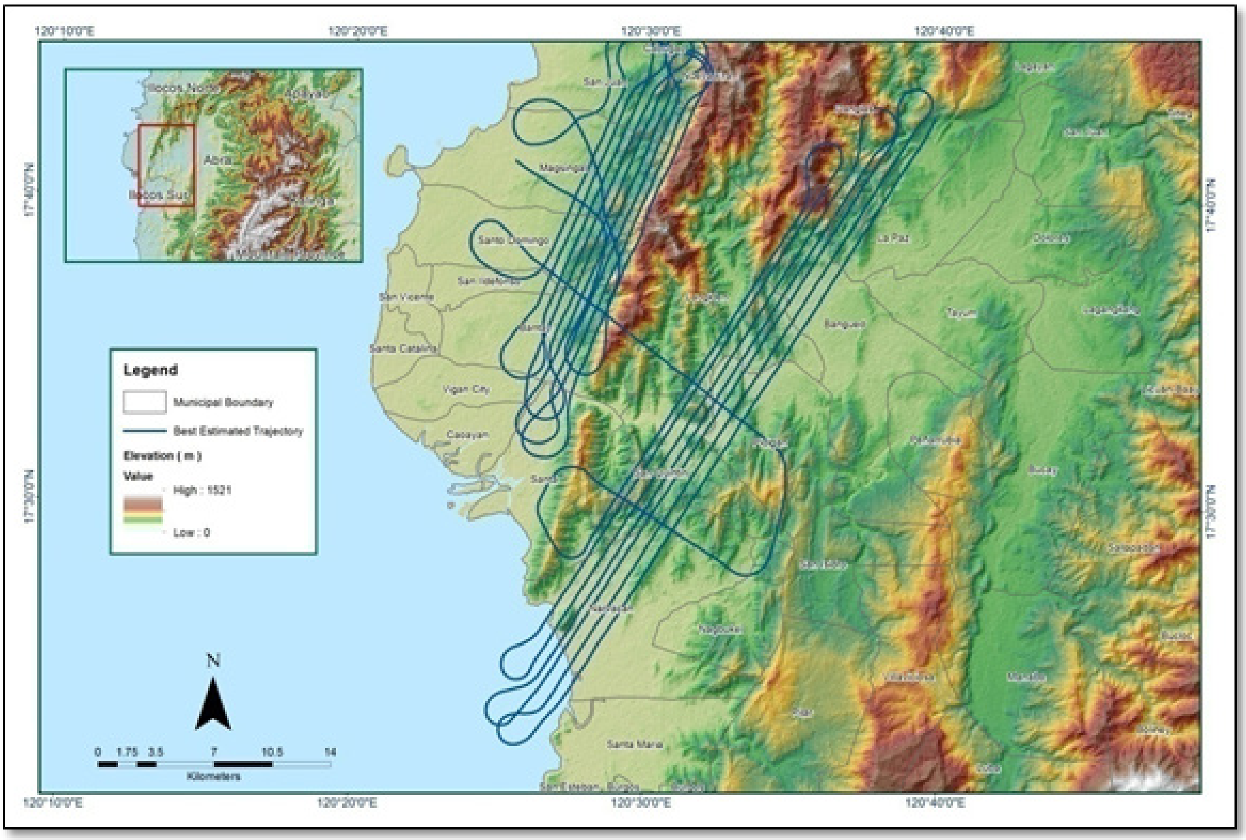


Figure A-8.52. Best Estimated Trajectory

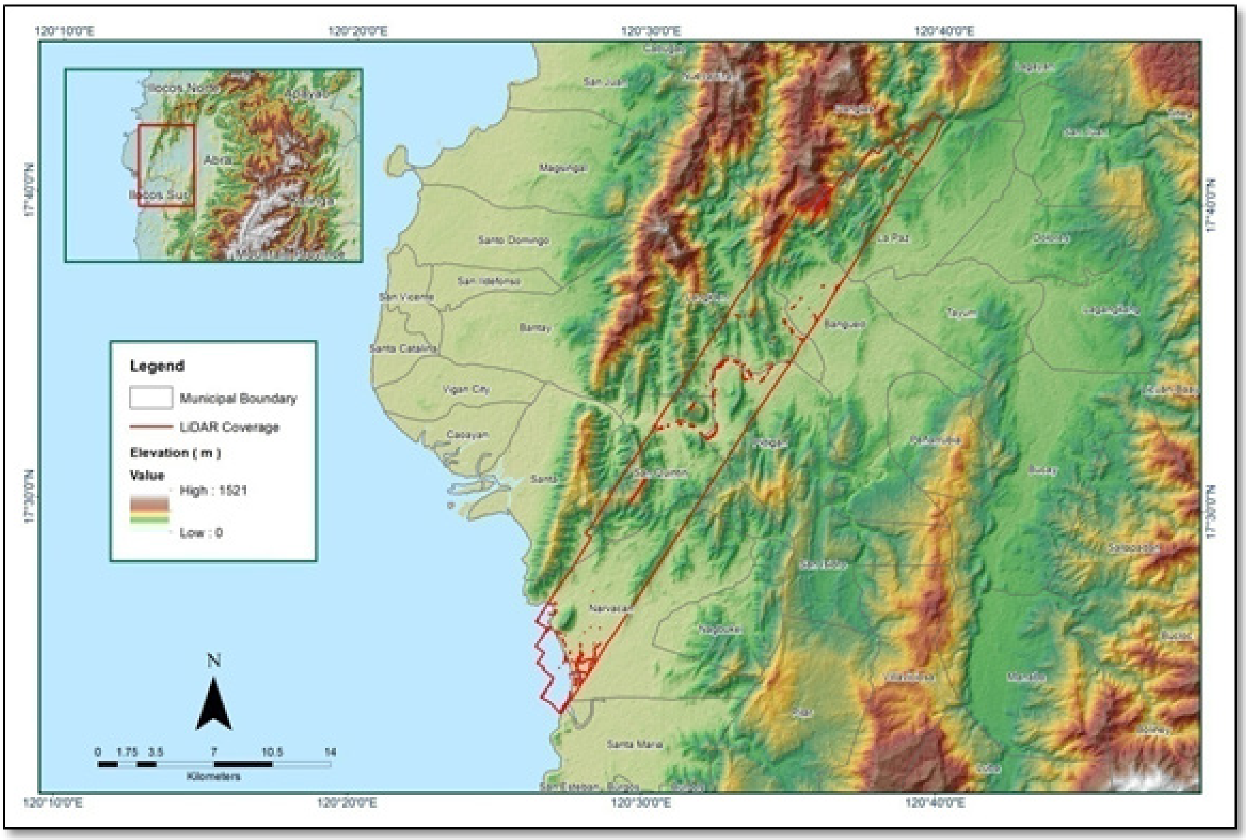


Figure A-8.53 Coverage of LiDAR data

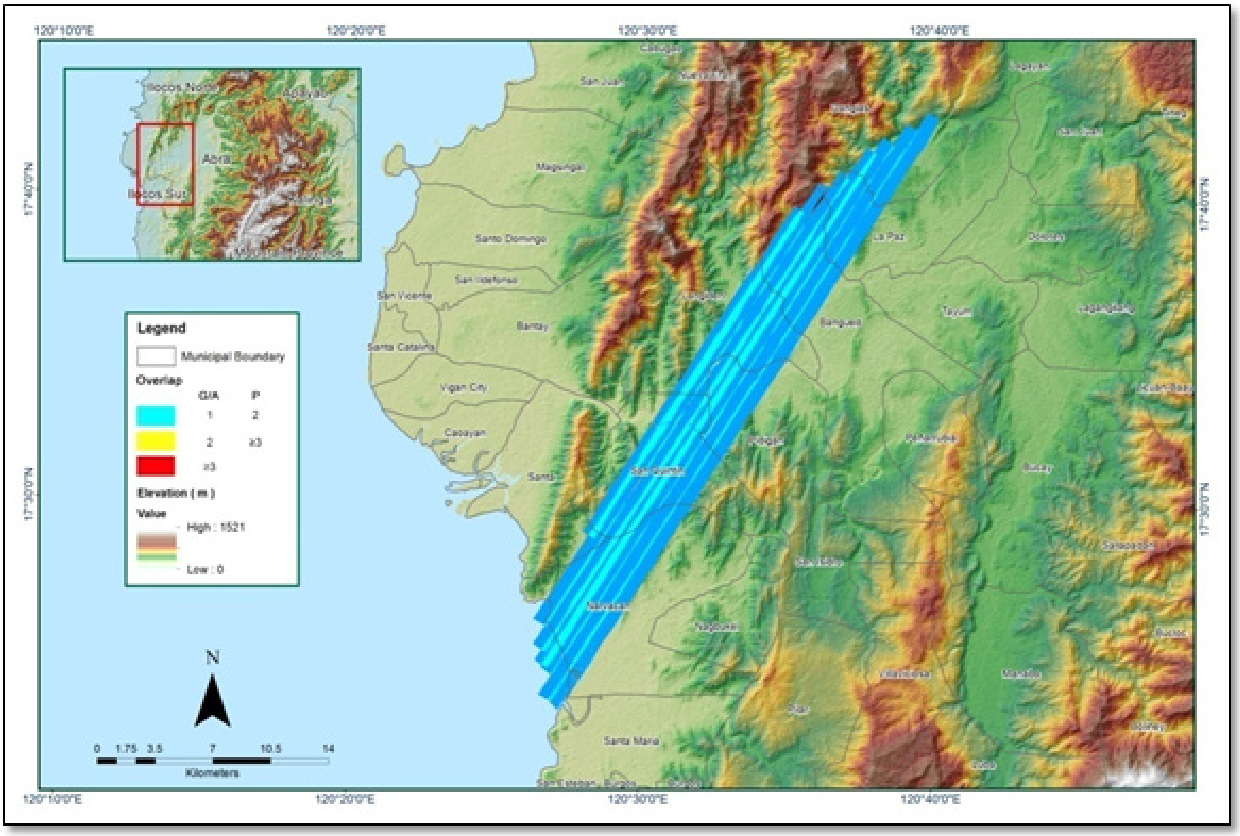


Figure A-8.54. Image of Data Overlap

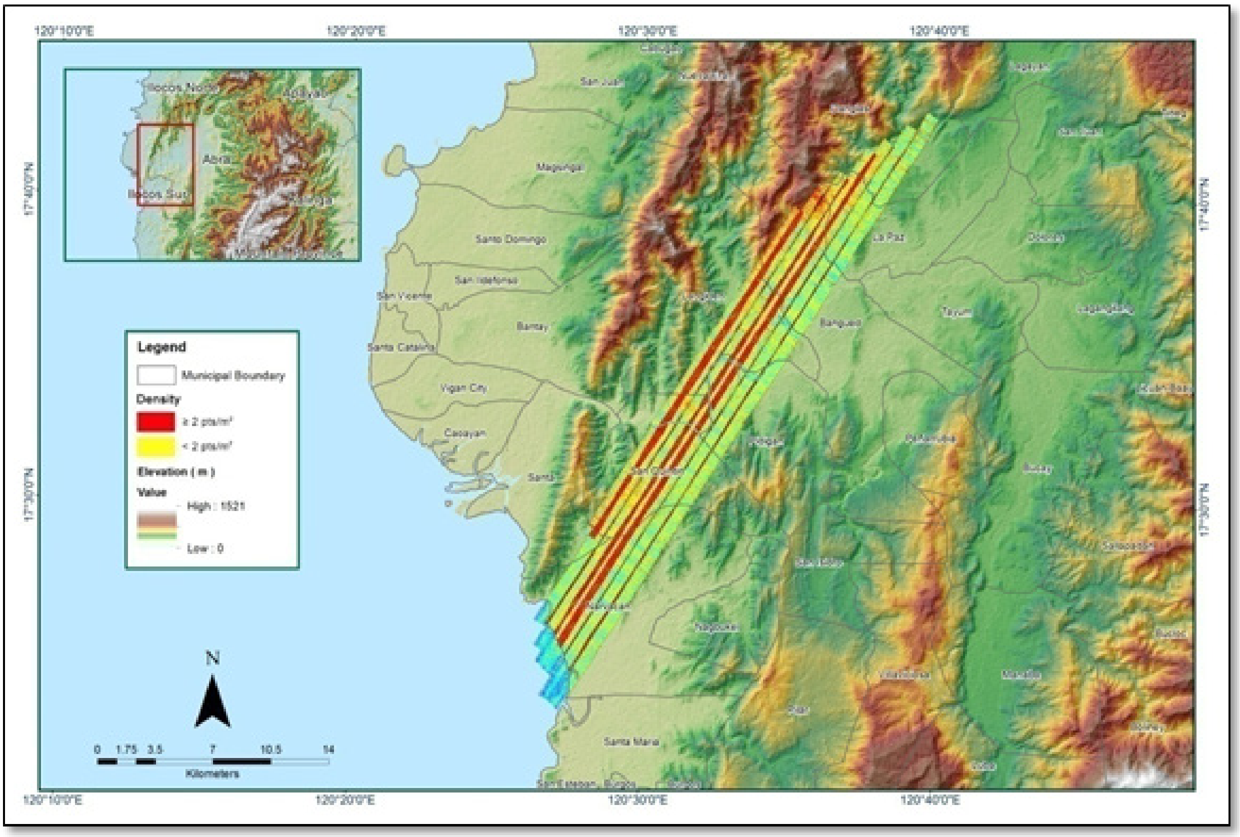


Figure A-8.55. Density map of merged LiDAR data

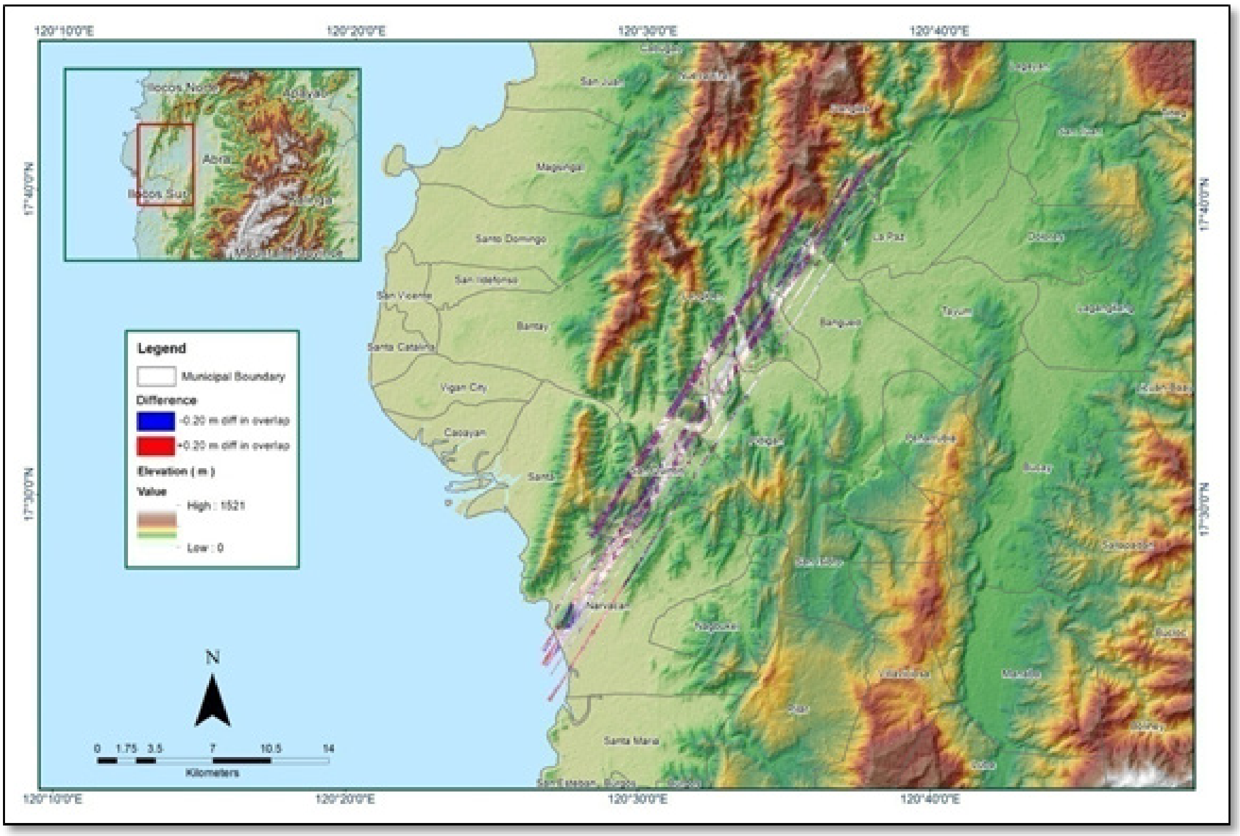


Figure A-8.56. Elevation difference between flight lines

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

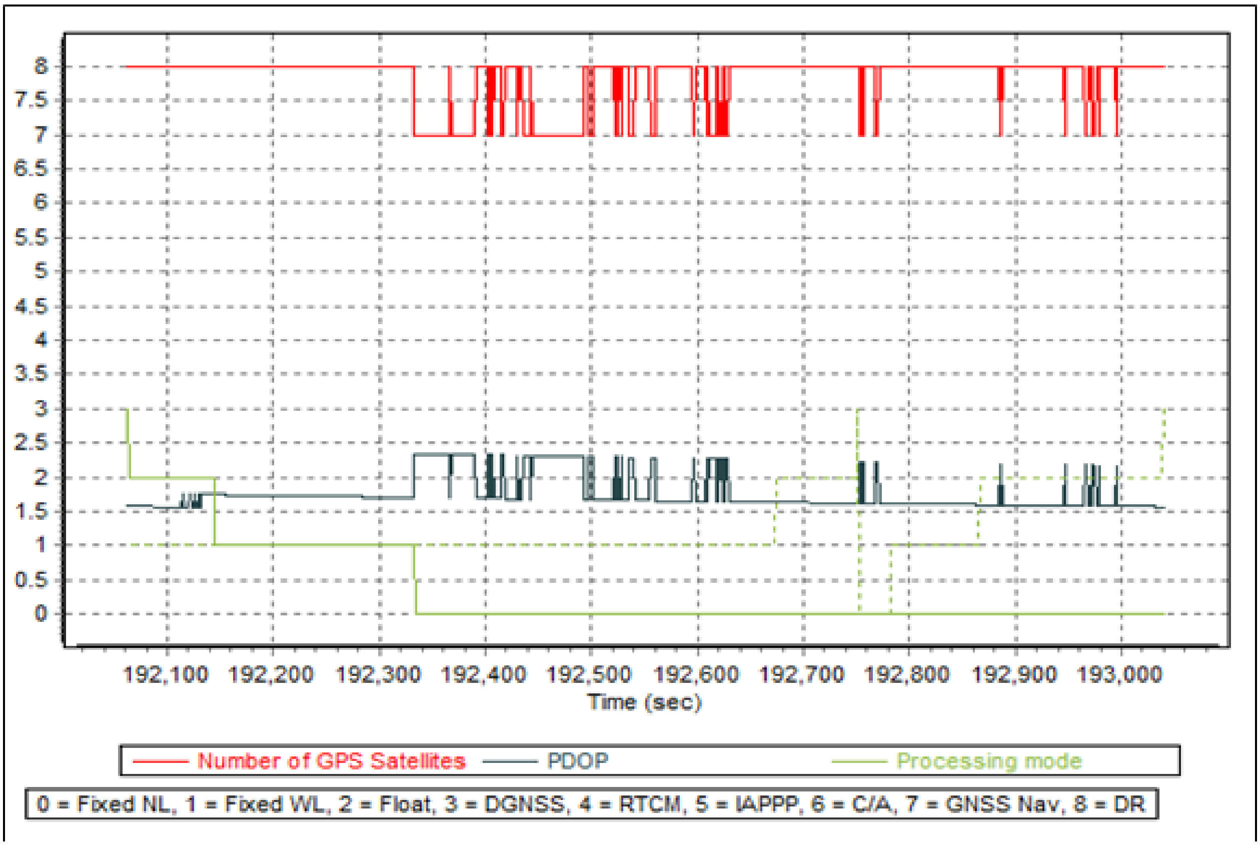


Figure A-8.57. Solution Status Parameters

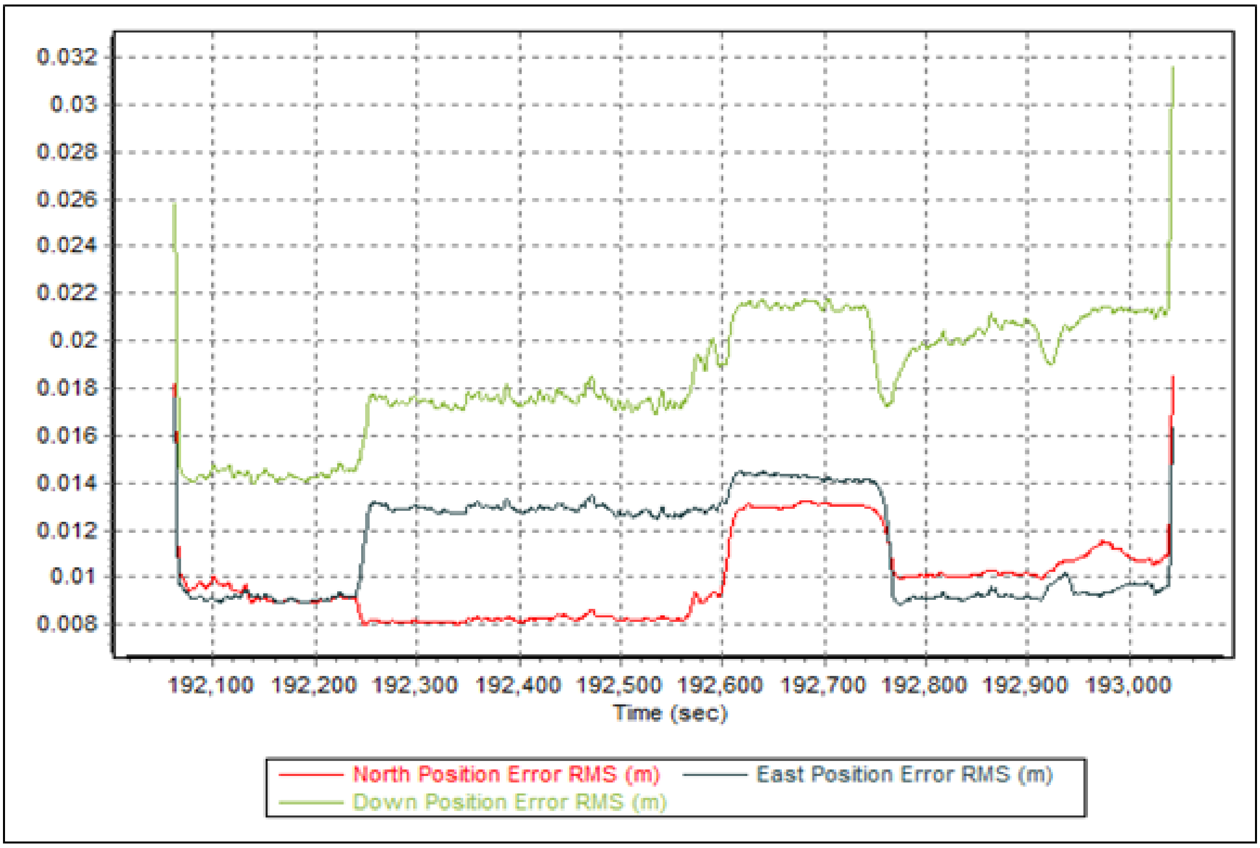


Figure A-8.58. Smoothed Performance Metrics Parameters

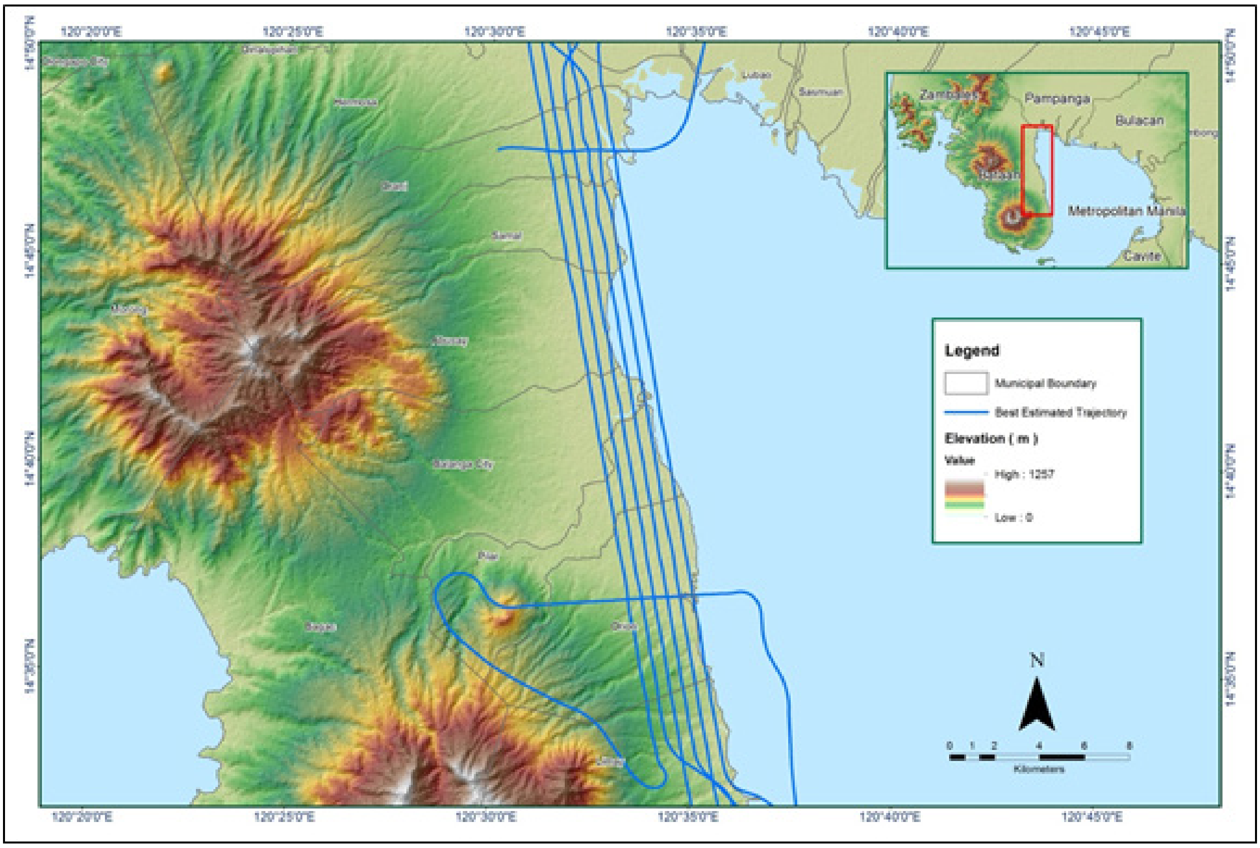


Figure A-8.59. Best Estimated Trajectory

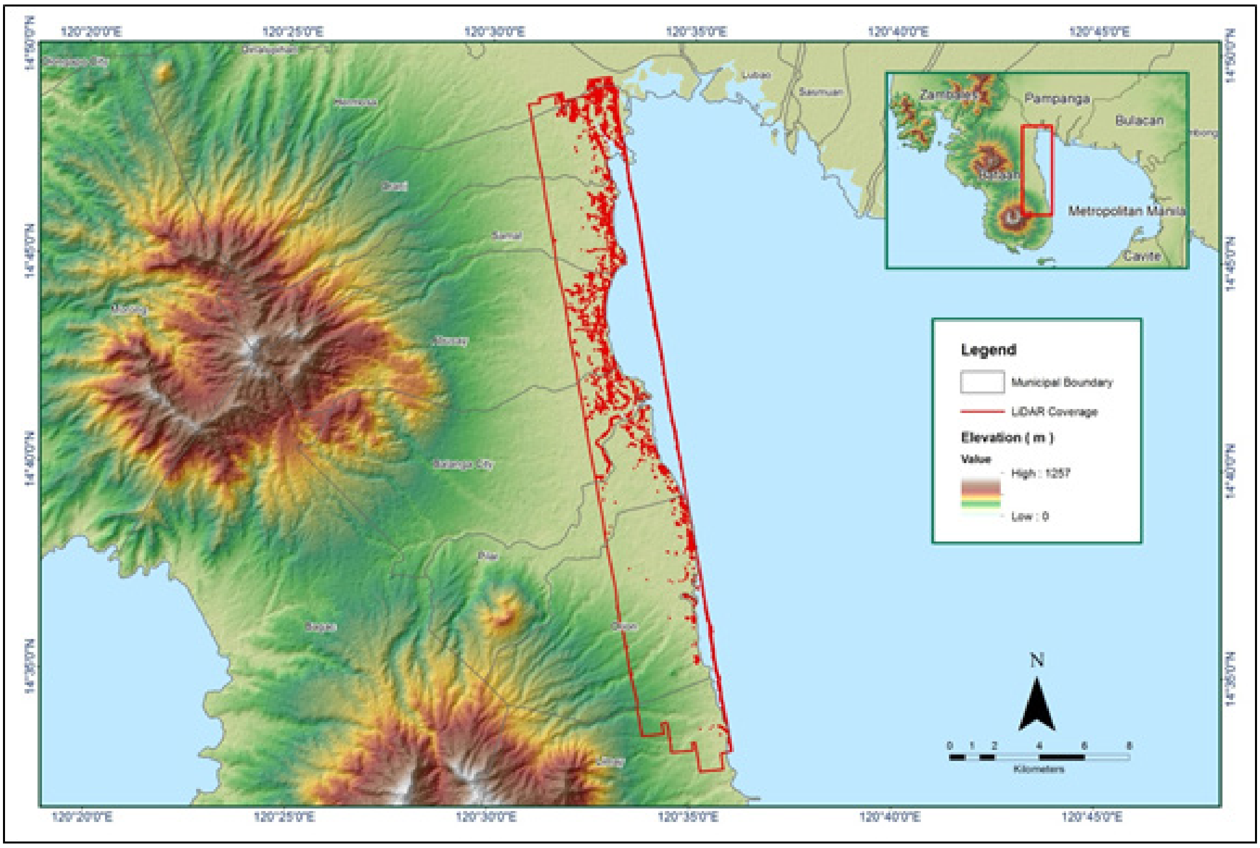


Figure A-8.60. Coverage of LiDAR data

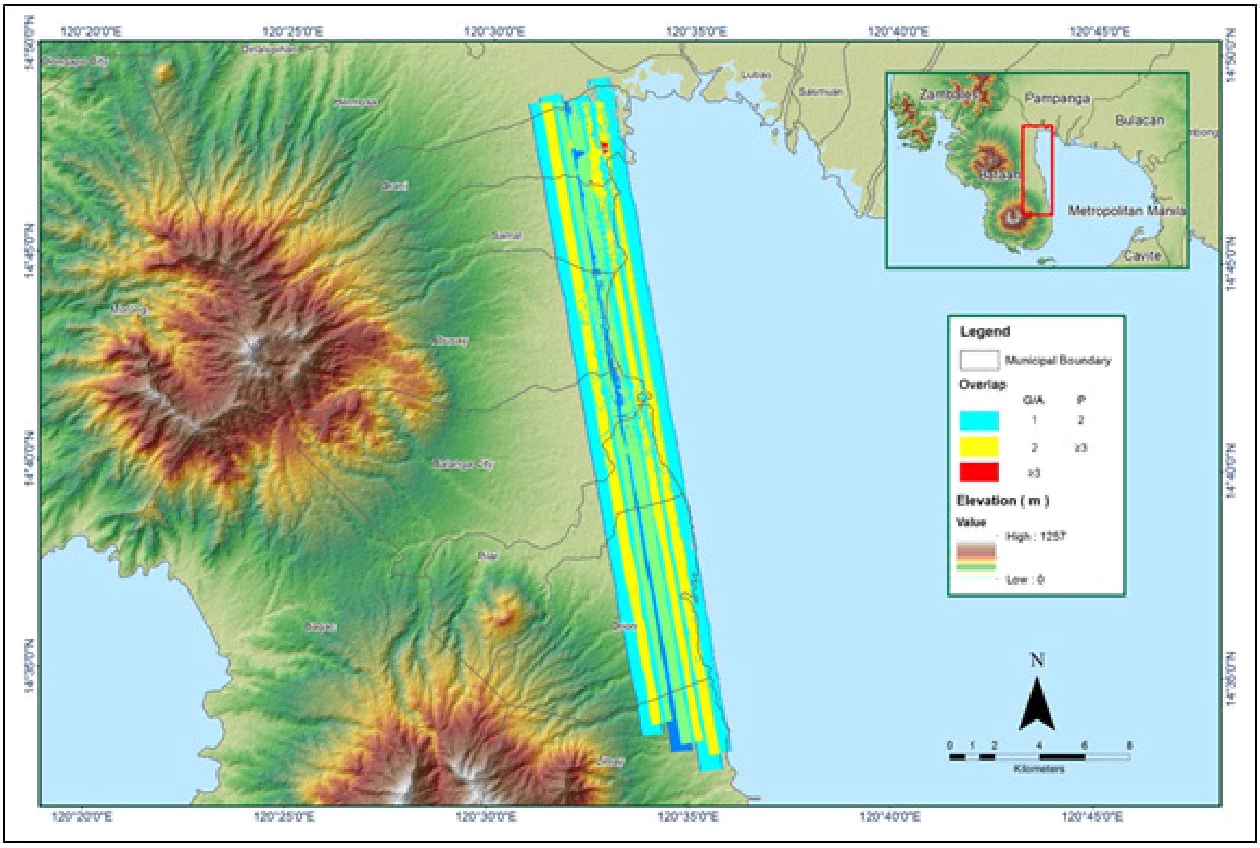


Figure A-8.61. Image of Data Overlap

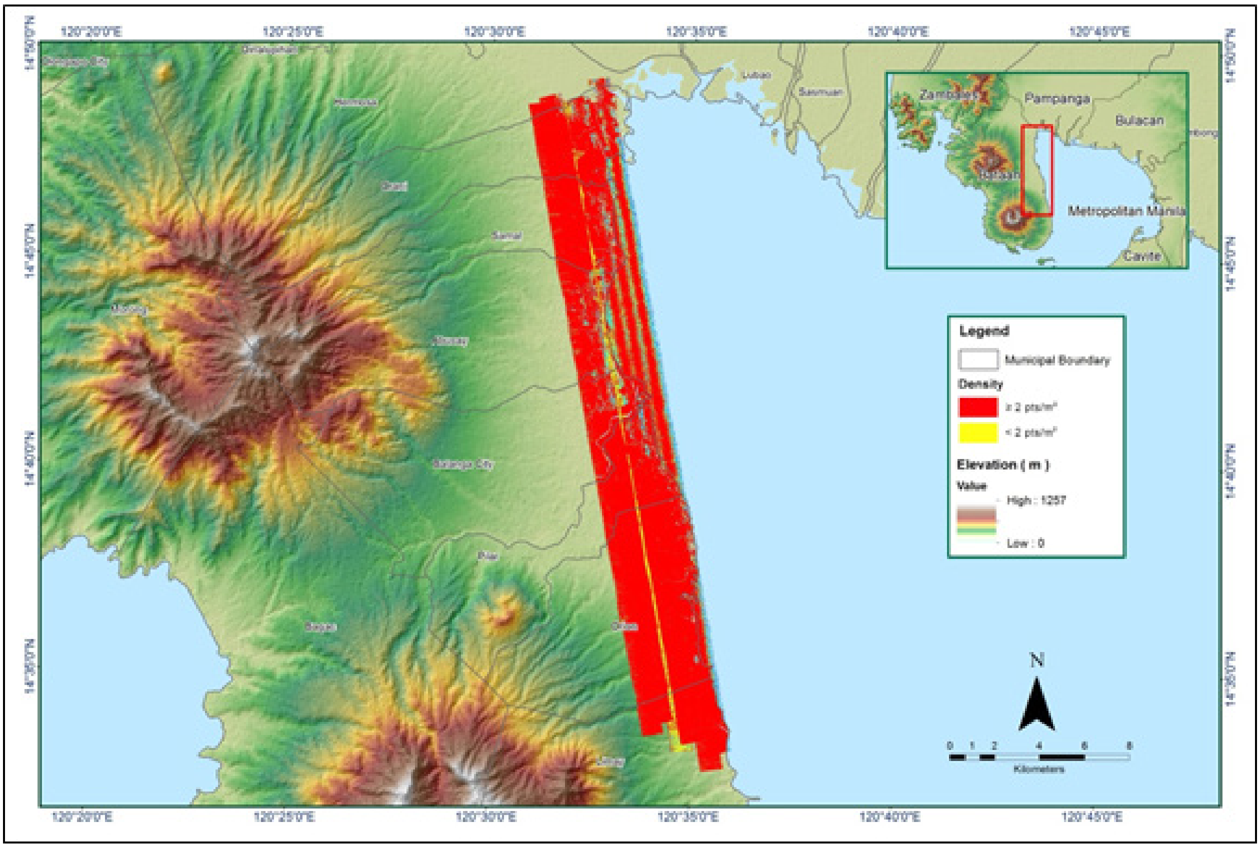


Figure A-8.62. Density map of merged LiDAR data

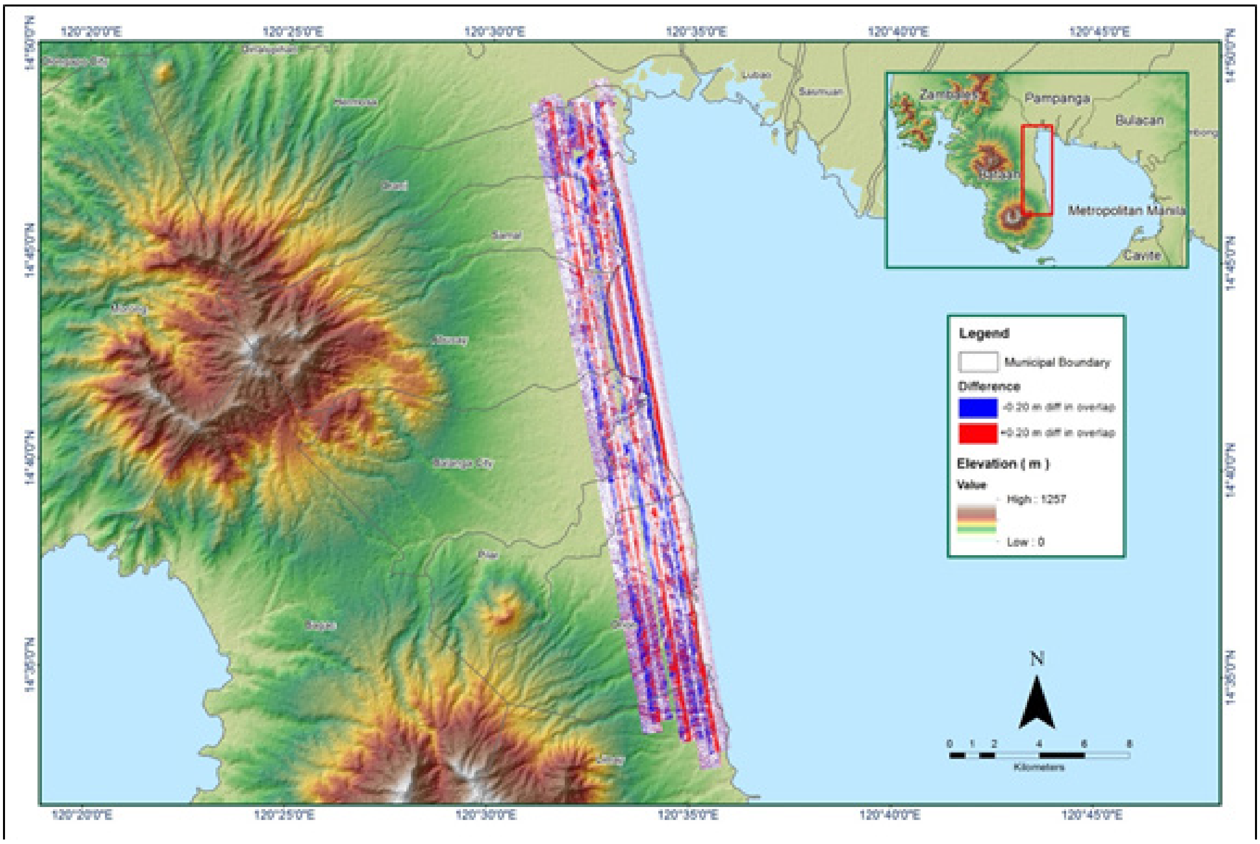


Figure A-8.63. Elevation difference between flight lines

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

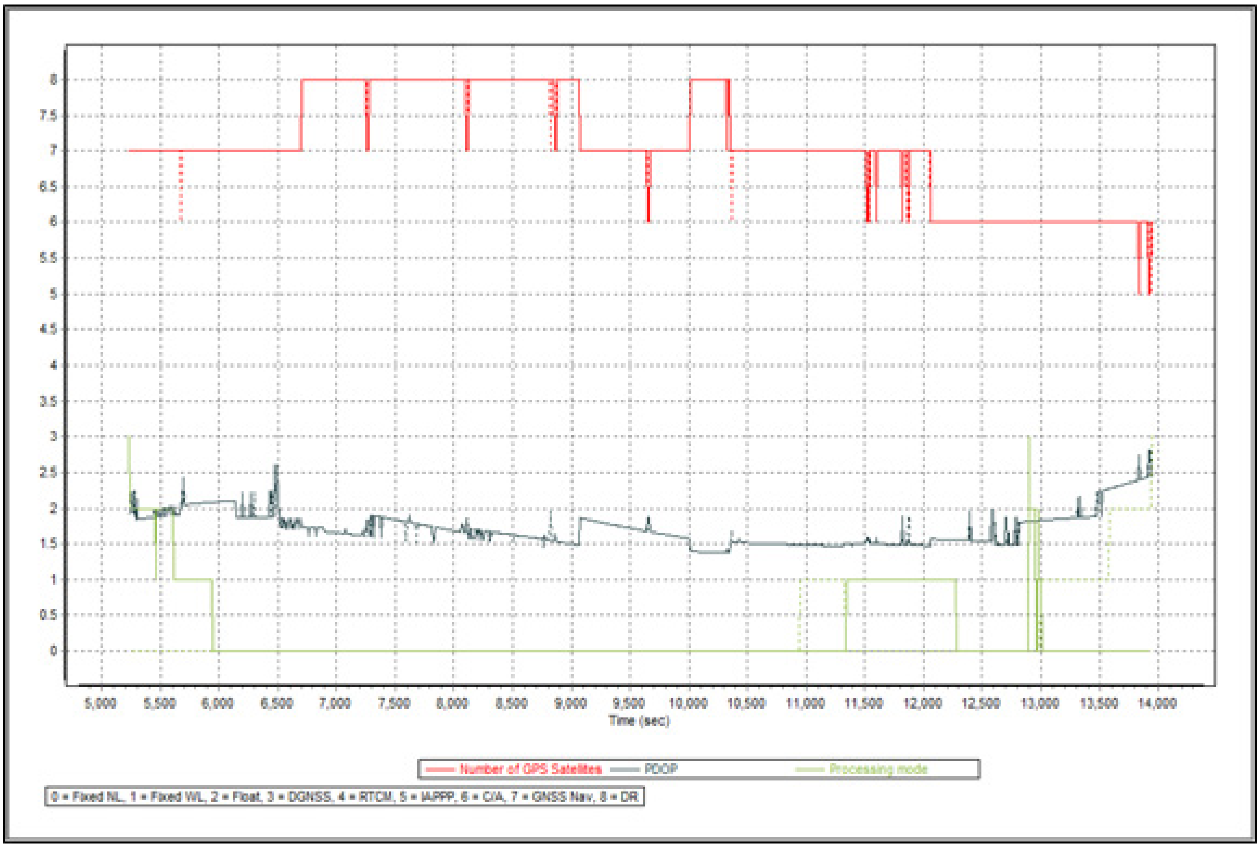


Figure A-8.64. Solution Status Parameters

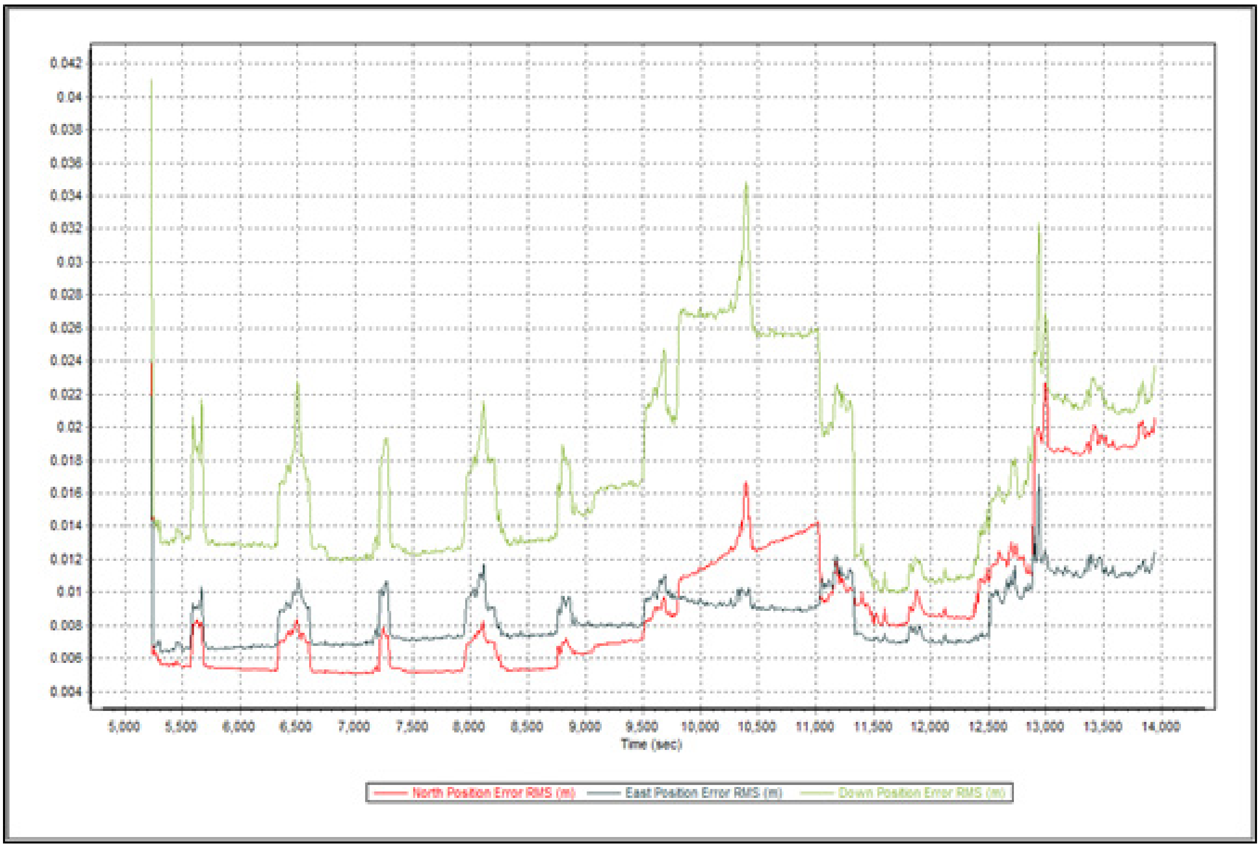


Figure A-8.65. Smoothed Performance Metrics Parameters

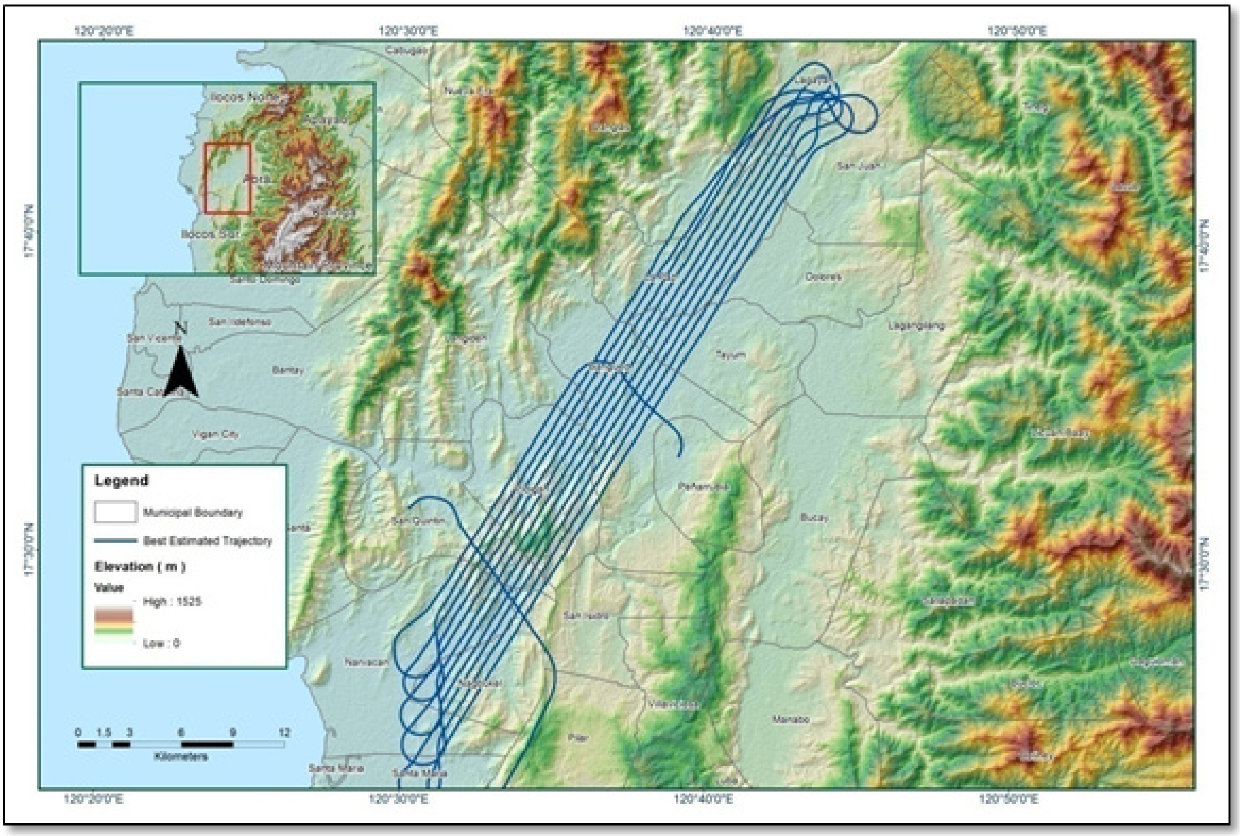


Figure A-8.66. Best Estimated Trajectory

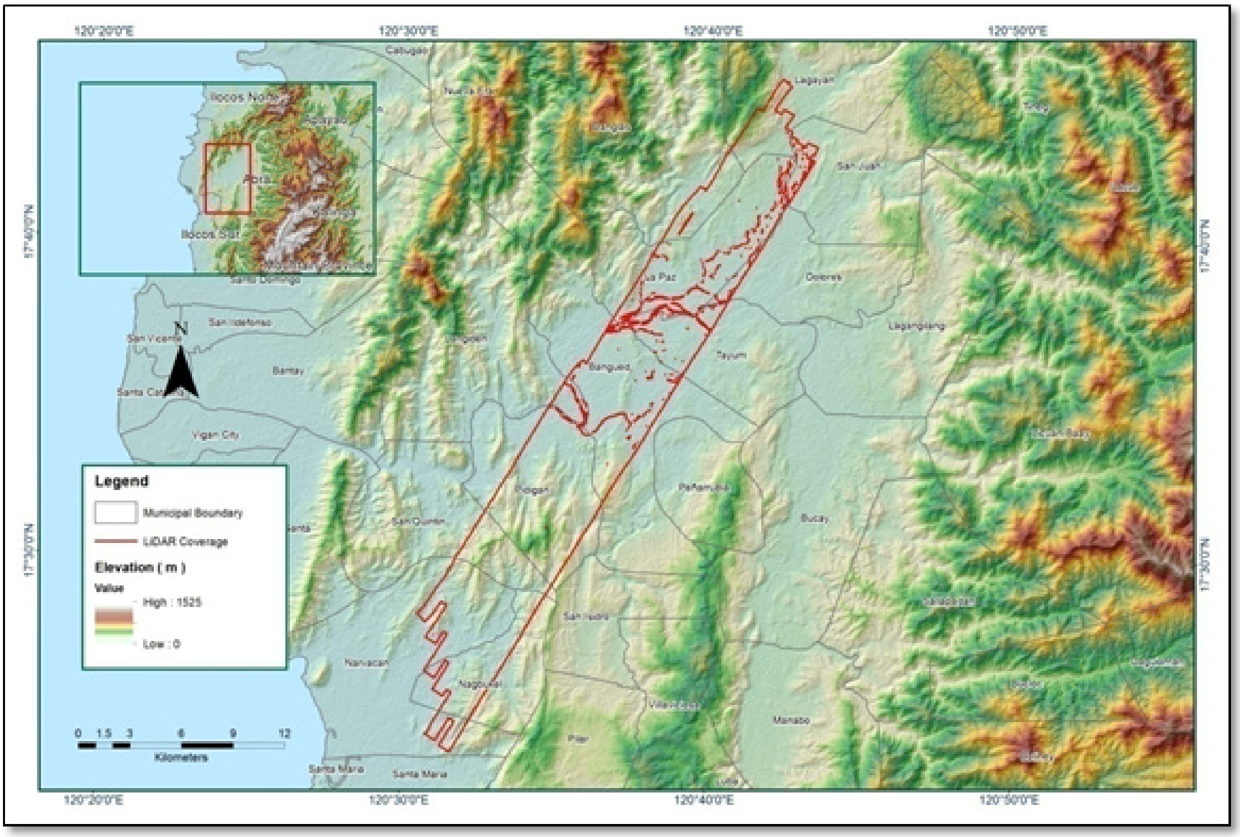


Figure A-8.67. Coverage of LiDAR data

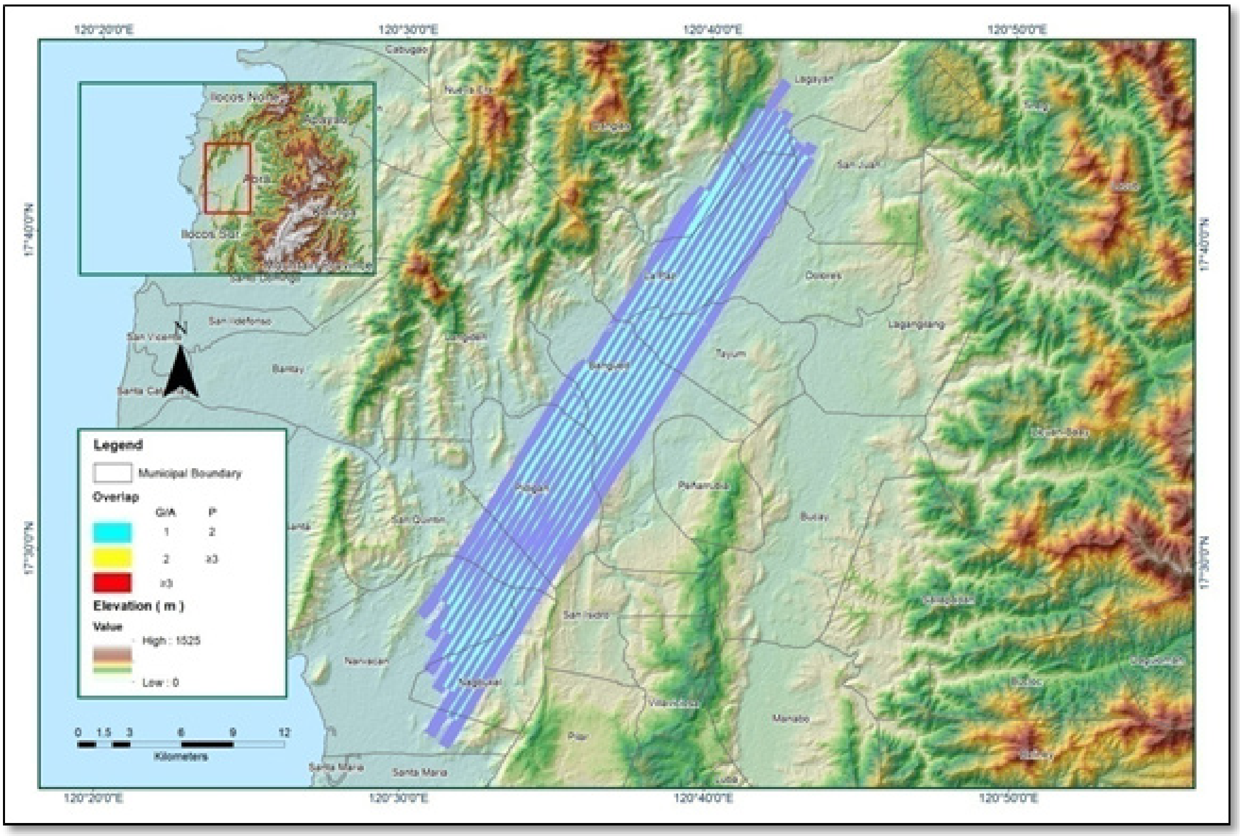


Figure A-8.68. Image of Data Overlap

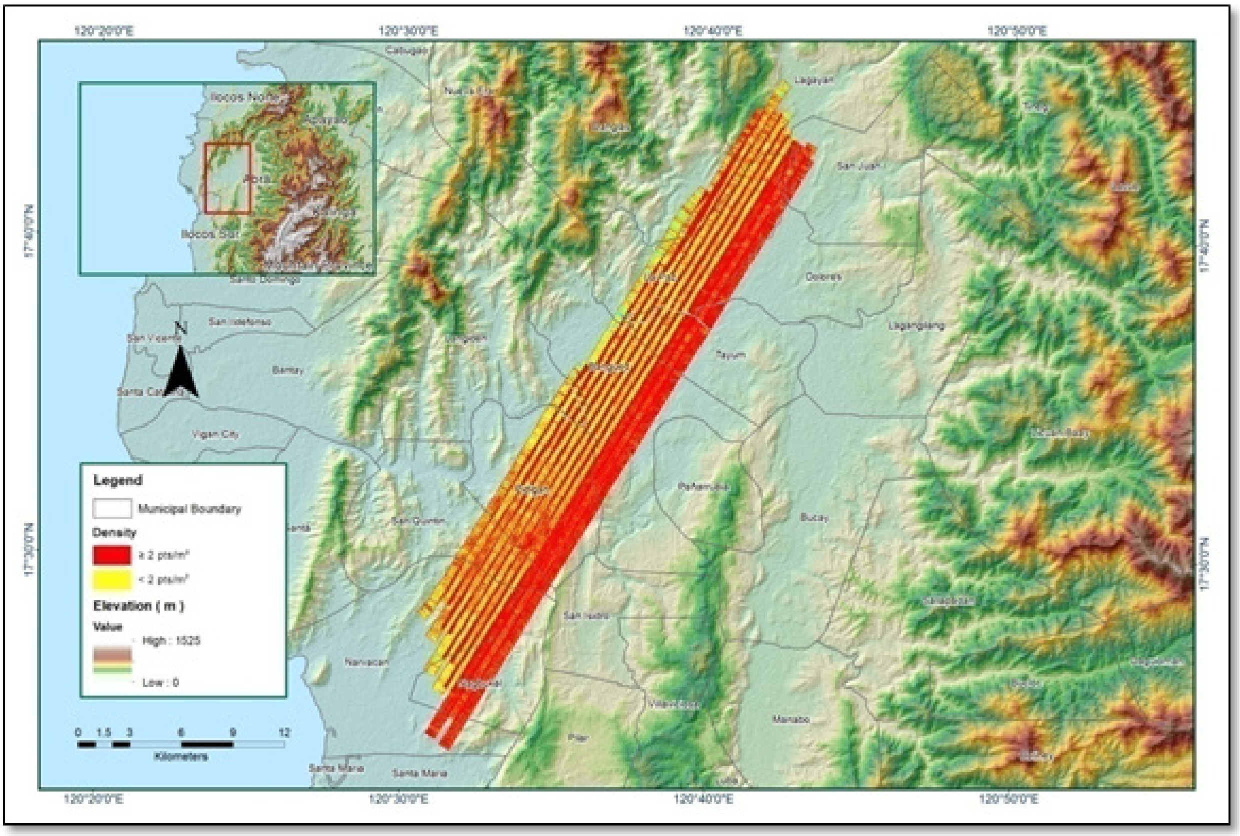


Figure A-8.69. Density map of merged LiDAR data

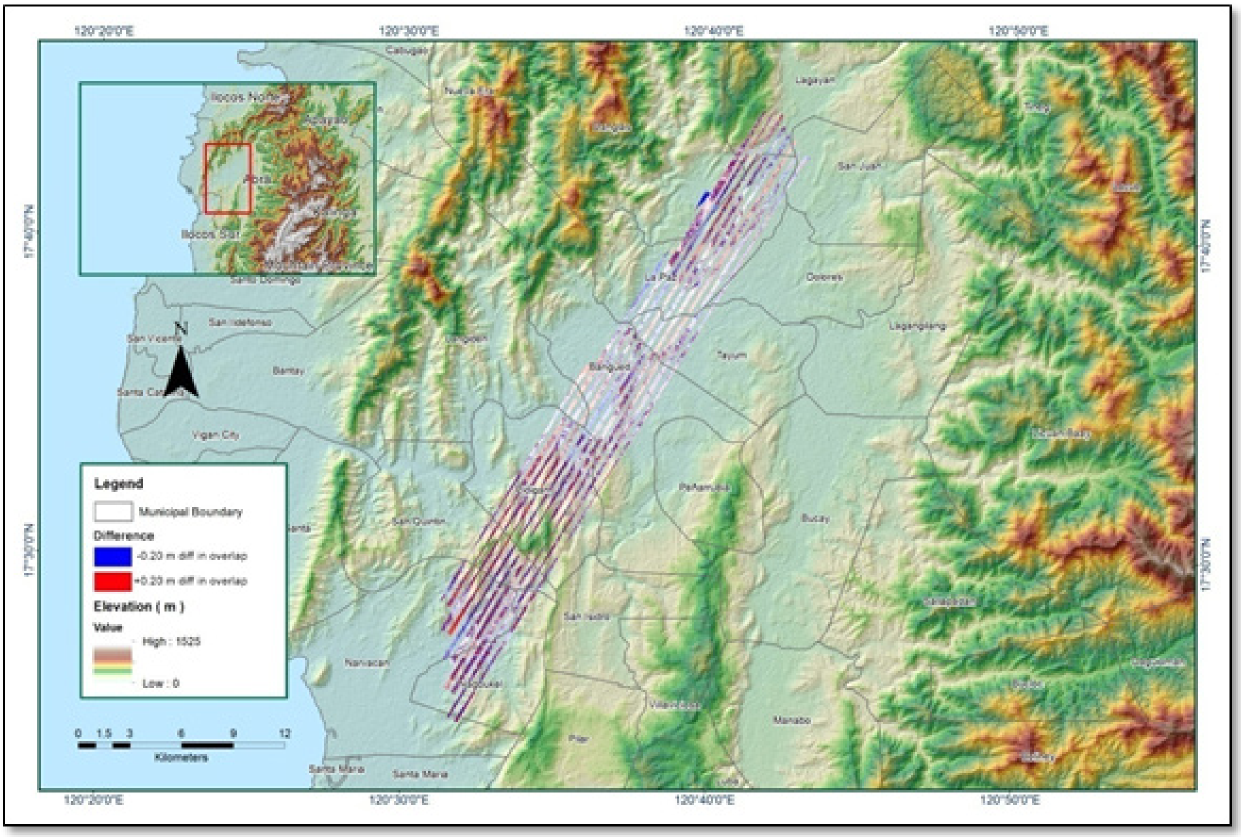


Figure A-8.70. Elevation difference between flight lines

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

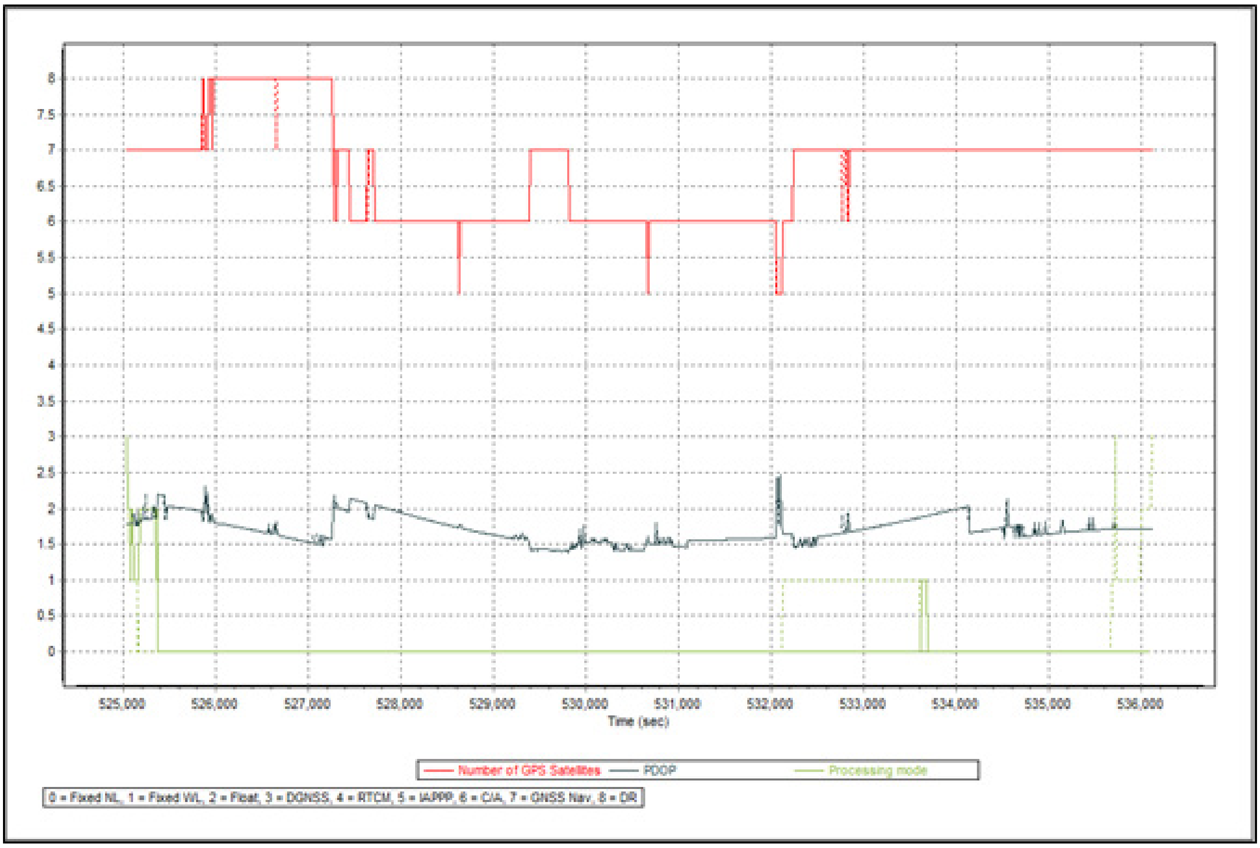


Figure A-8.71. Solution Status Parameters

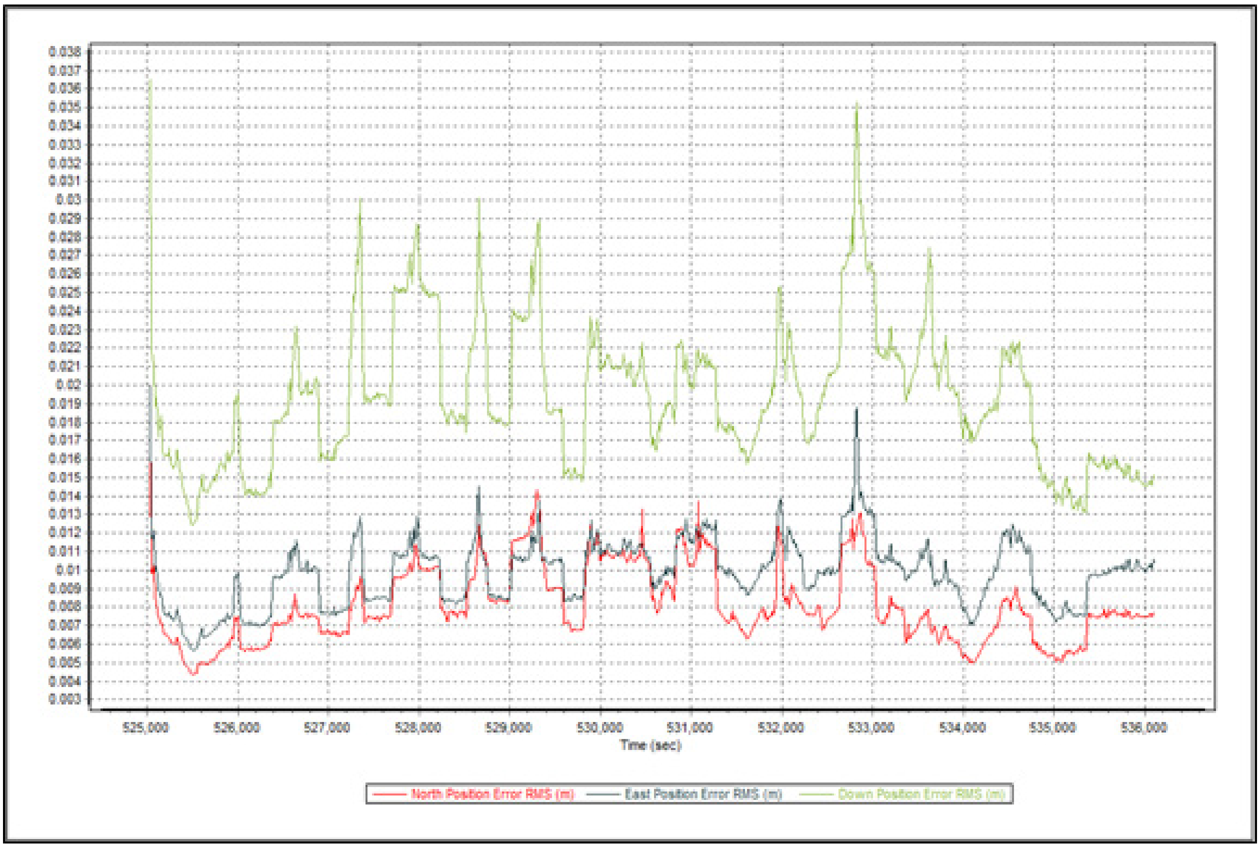


Figure A-8.72. Smoothed Performance Metrics Parameters

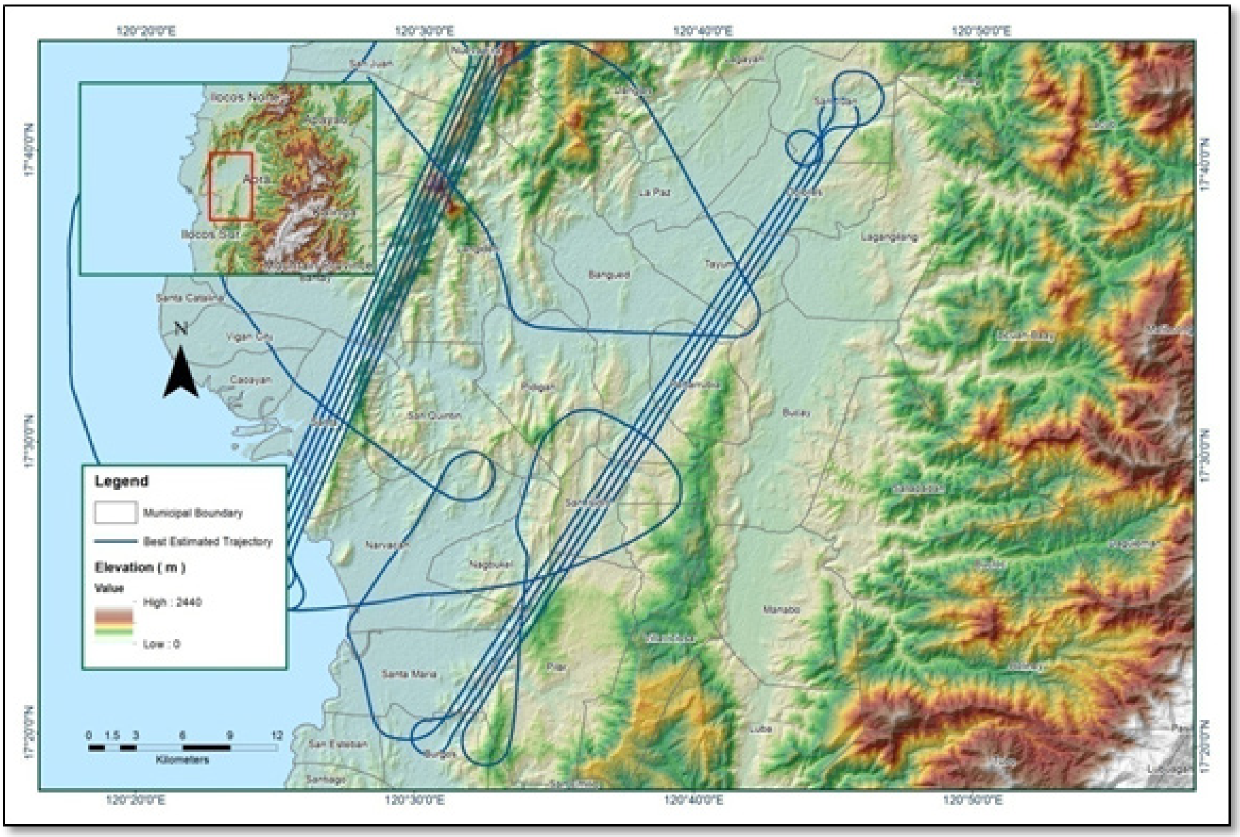


Figure A-8.73. Best Estimated Trajectory

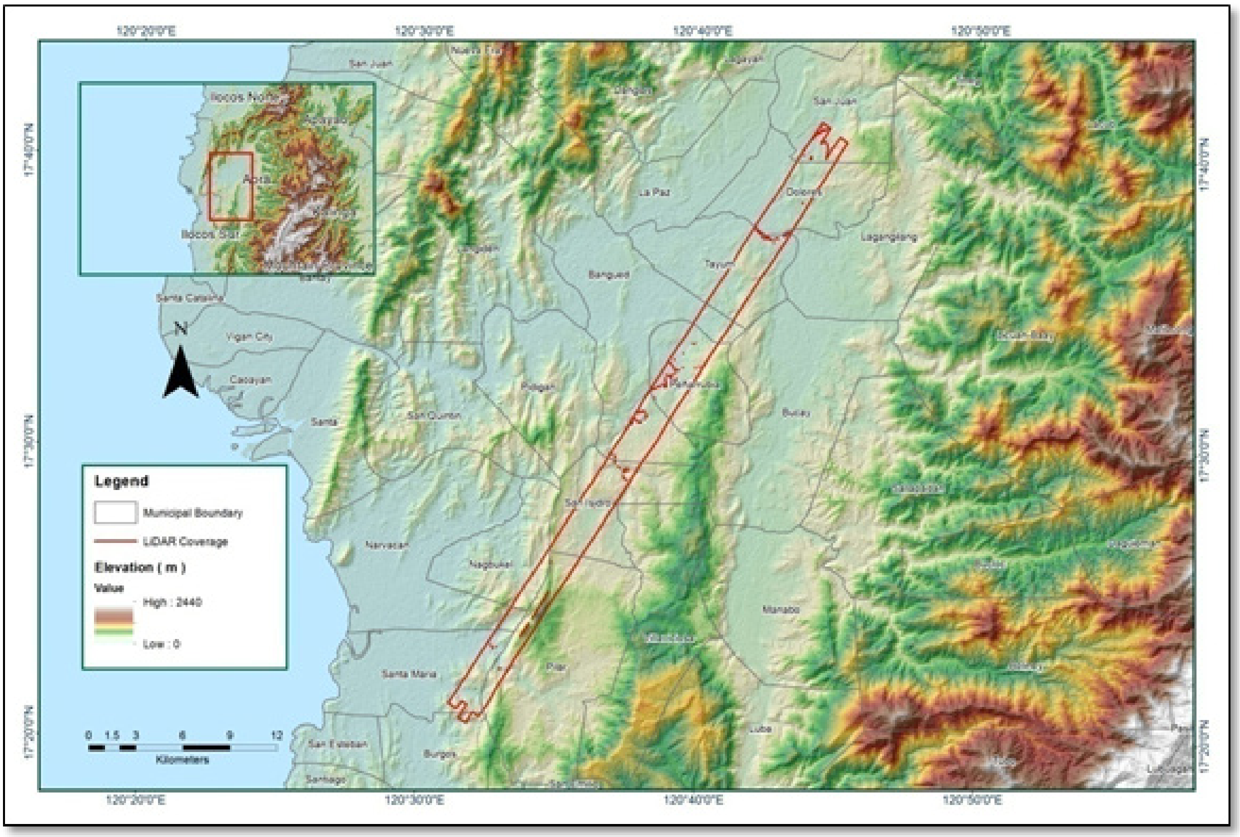


Figure A-8.74. Coverage of LiDAR data

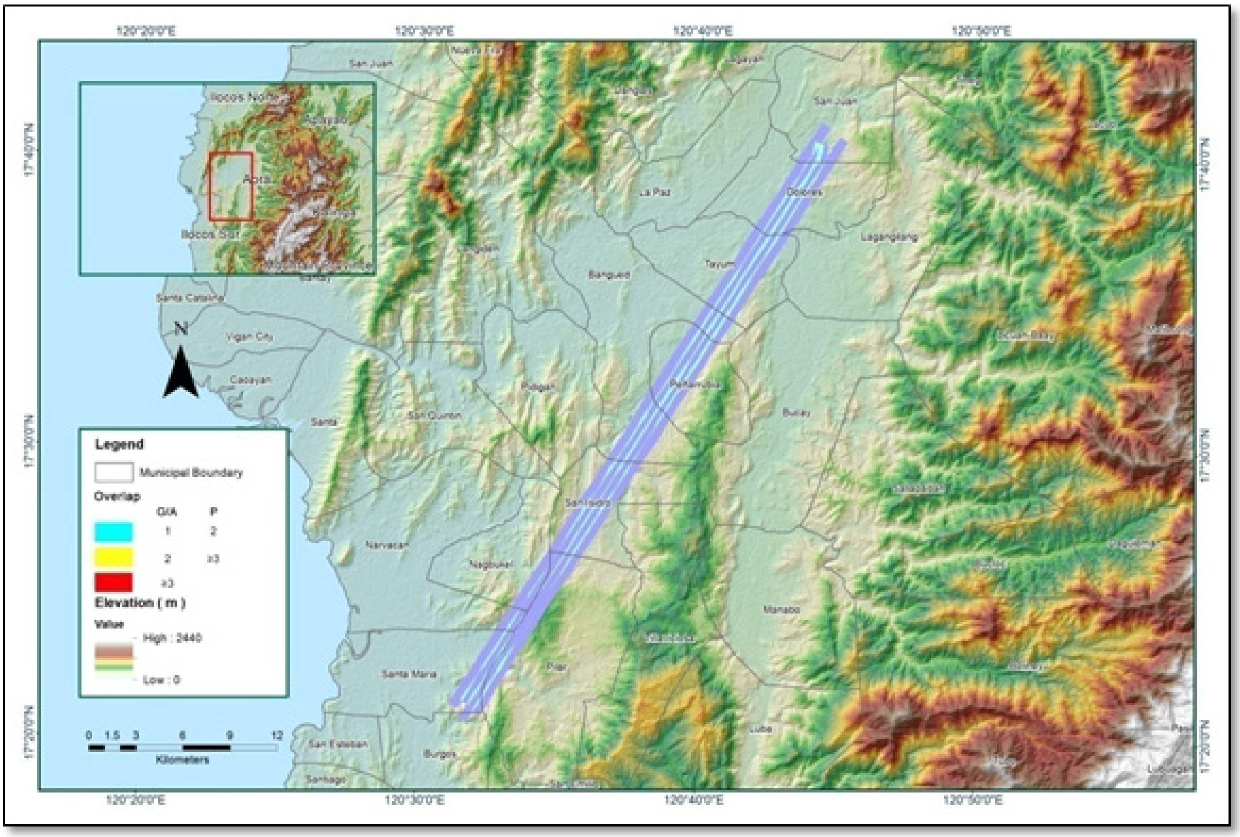


Figure A-8.75. Image of Data Overlap

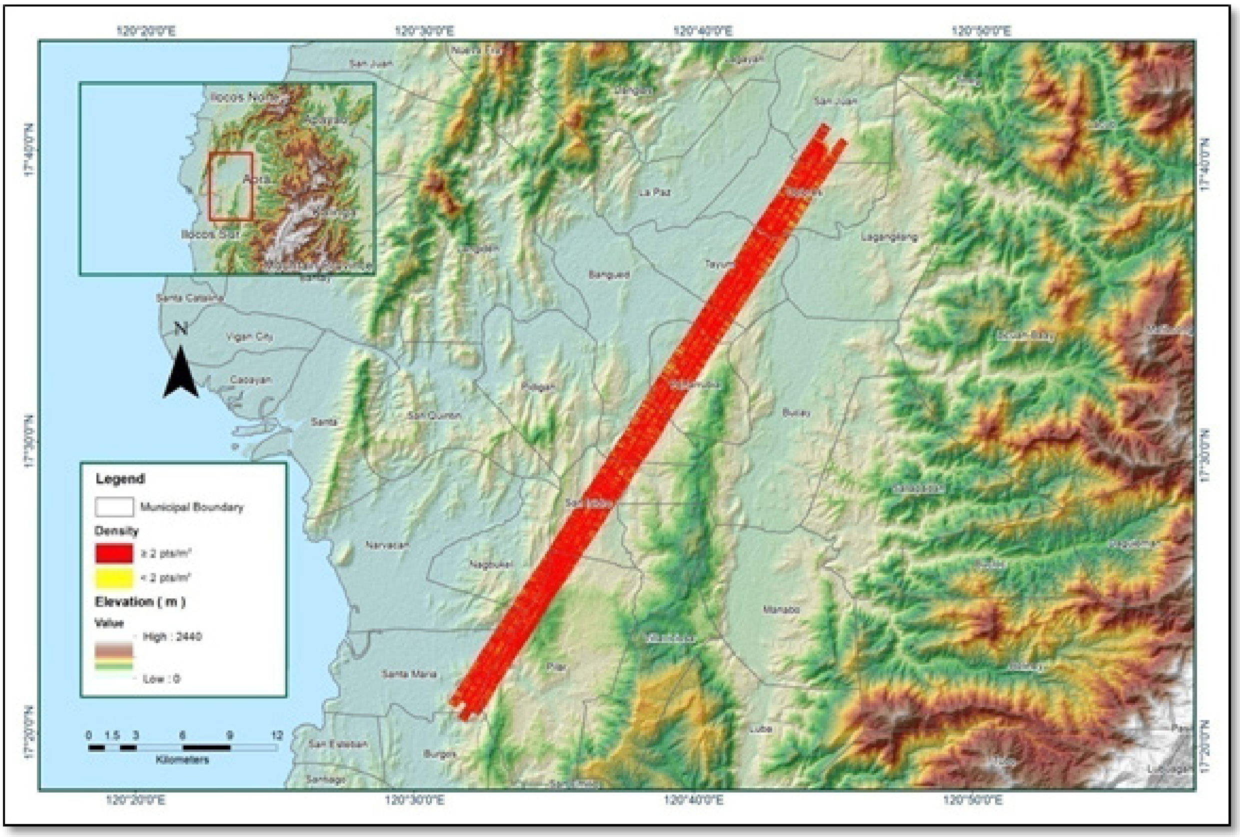


Figure A-8.76. Density map of merged LiDAR data

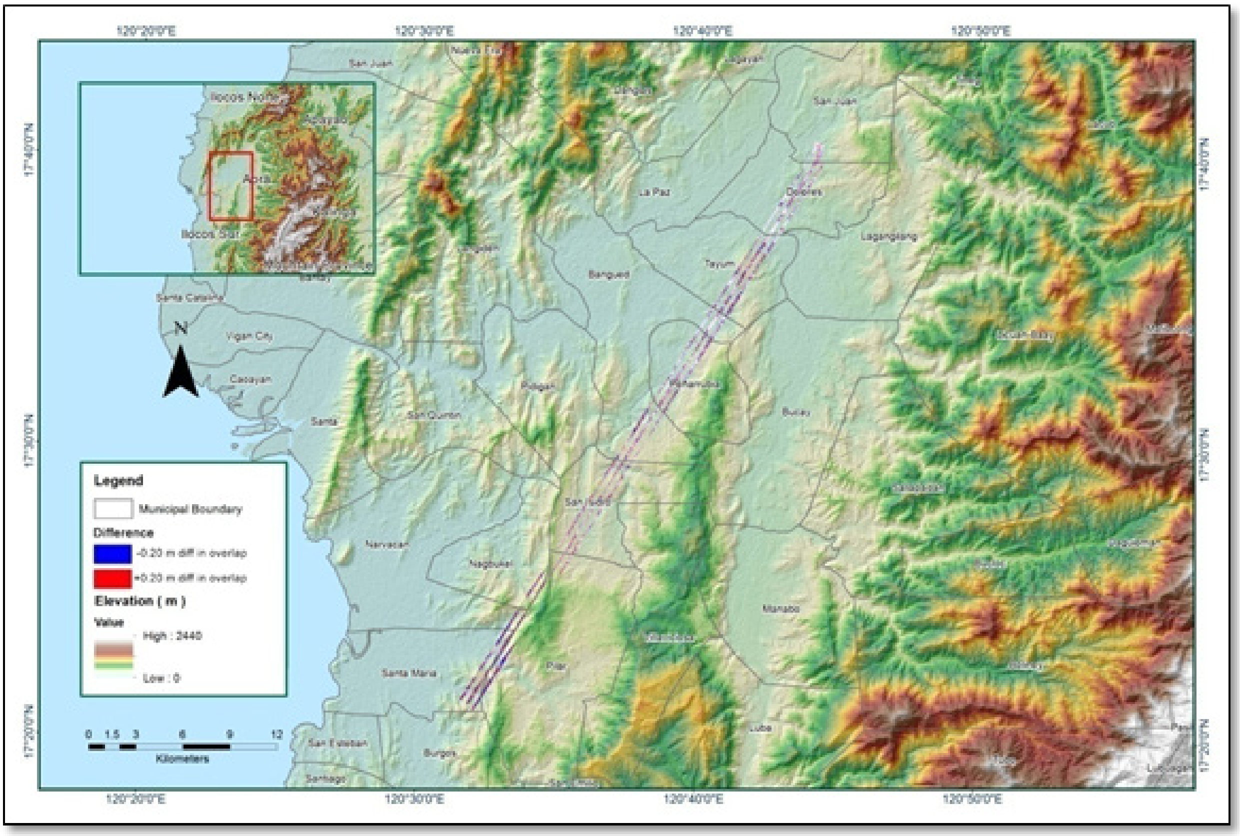


Figure A-8.77. Elevation difference between flight lines

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

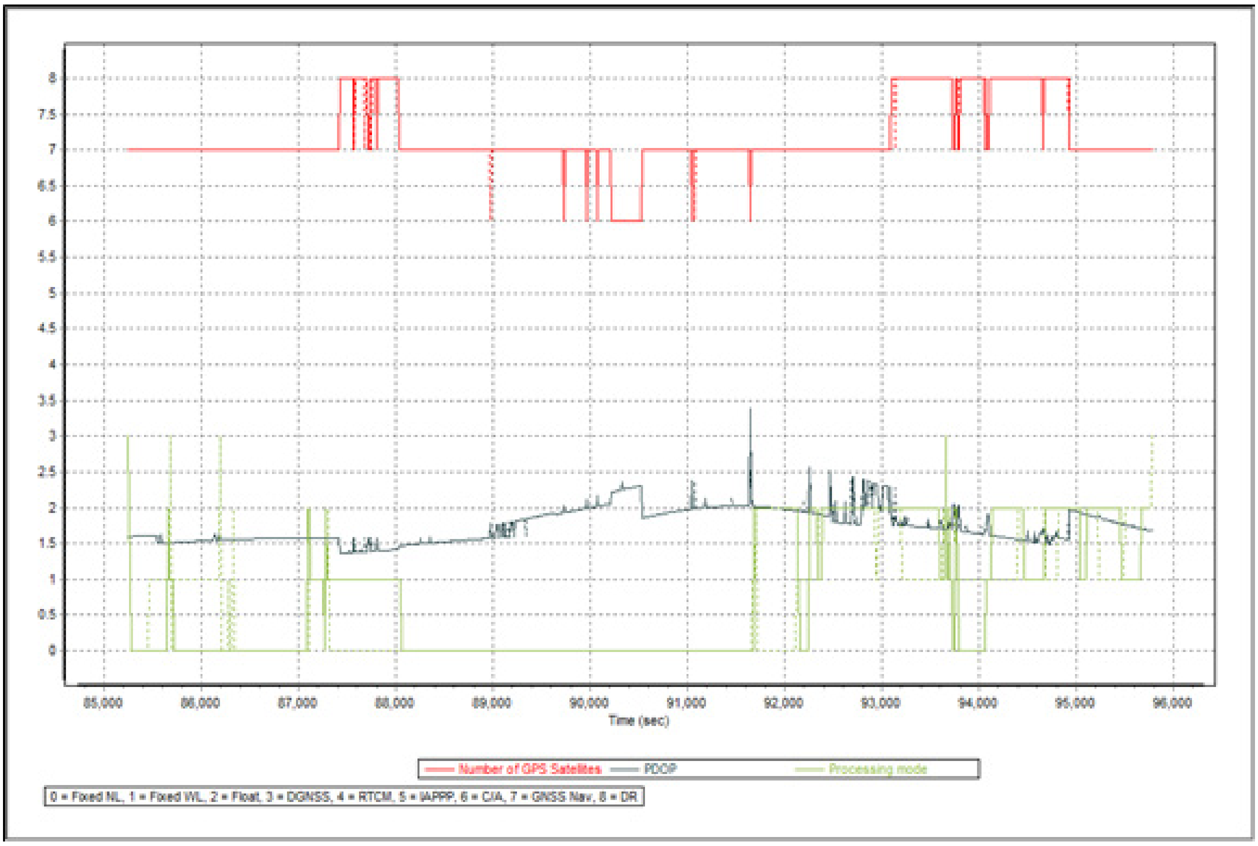


Figure A-8.78. Solution Status Parameters

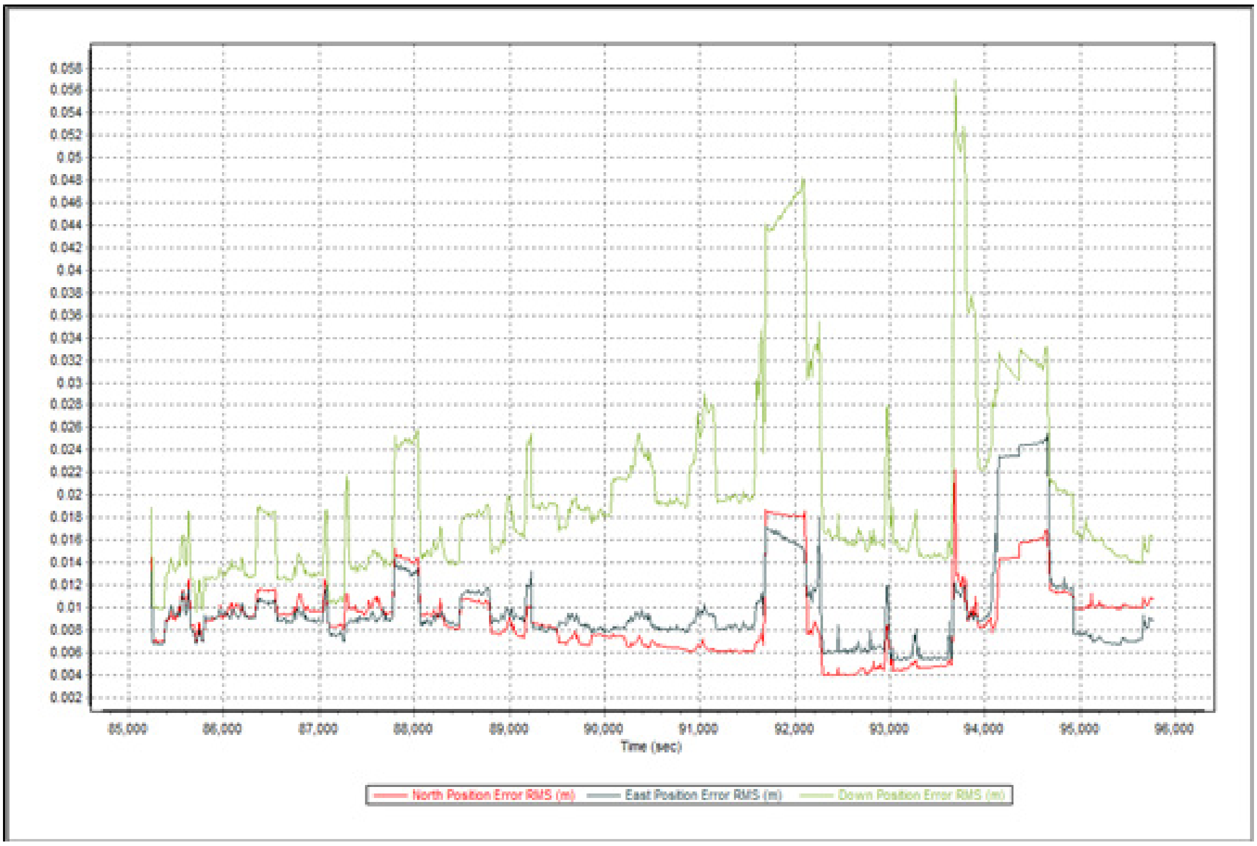


Figure A-8.79. Smoothed Performance Metrics Parameters

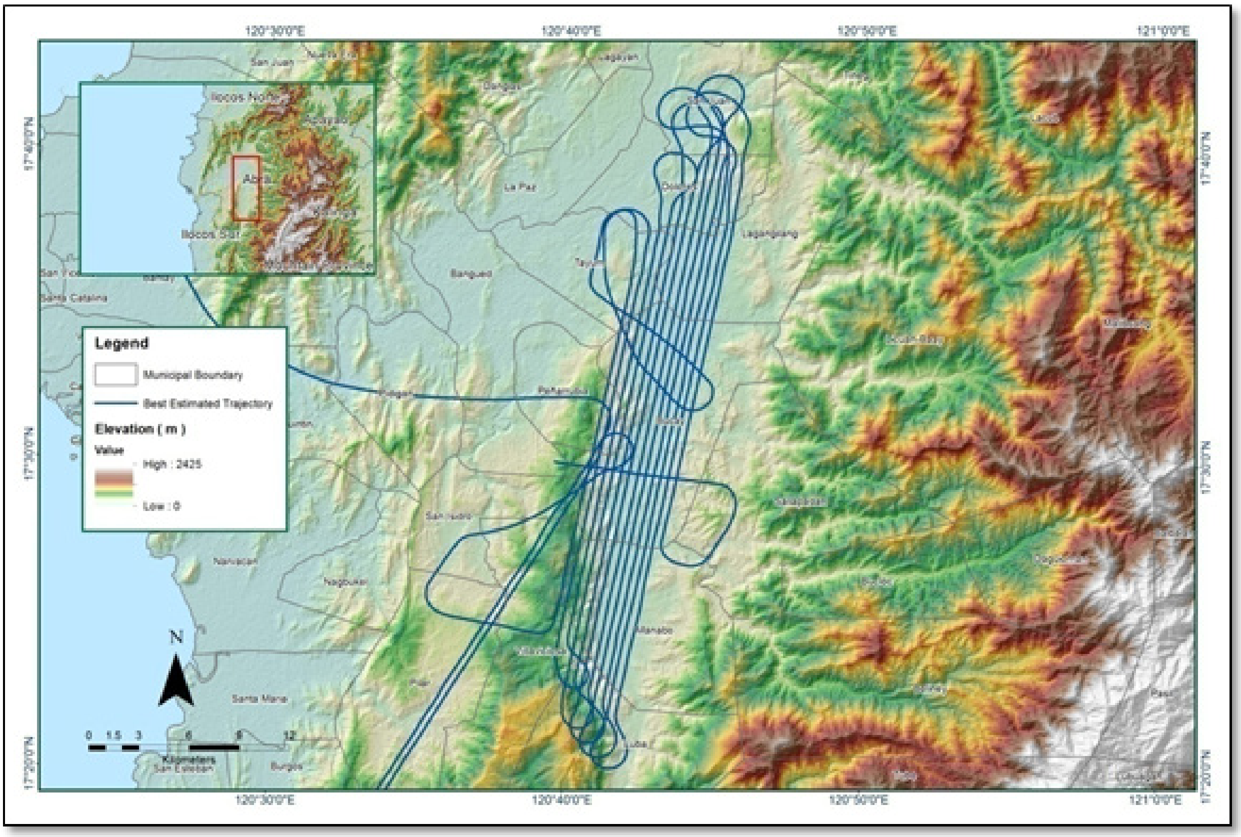


Figure A-8.80. Best Estimated Trajectory

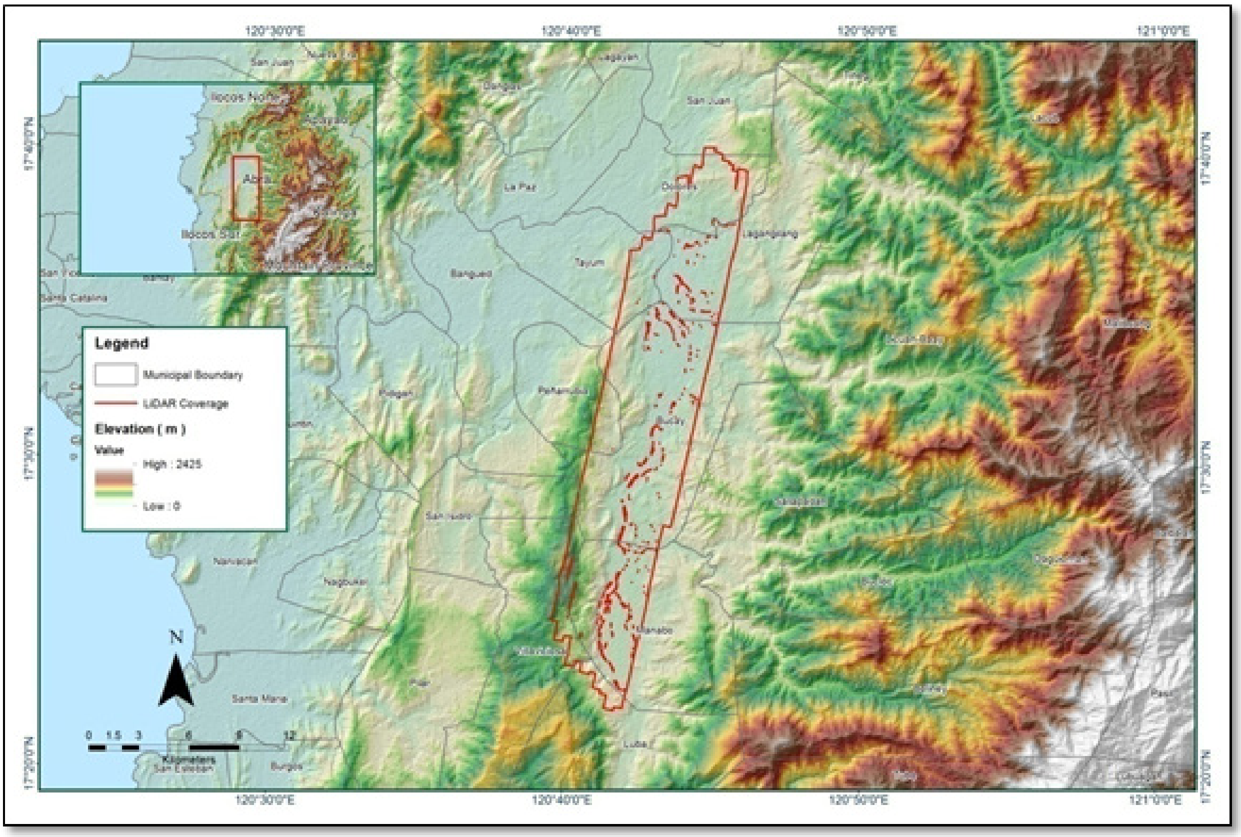


Figure A-8.81. Coverage of LiDAR data

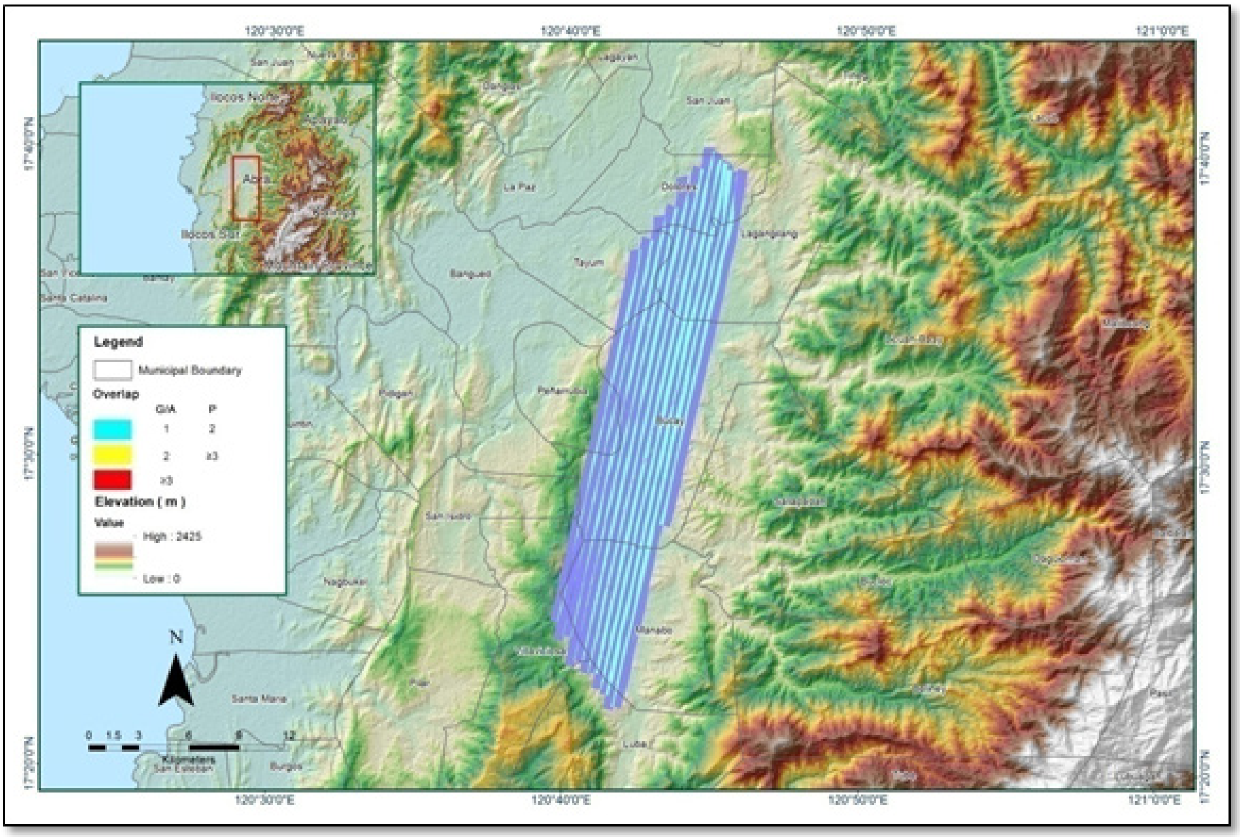


Figure A-8.82. Image of Data Overlap

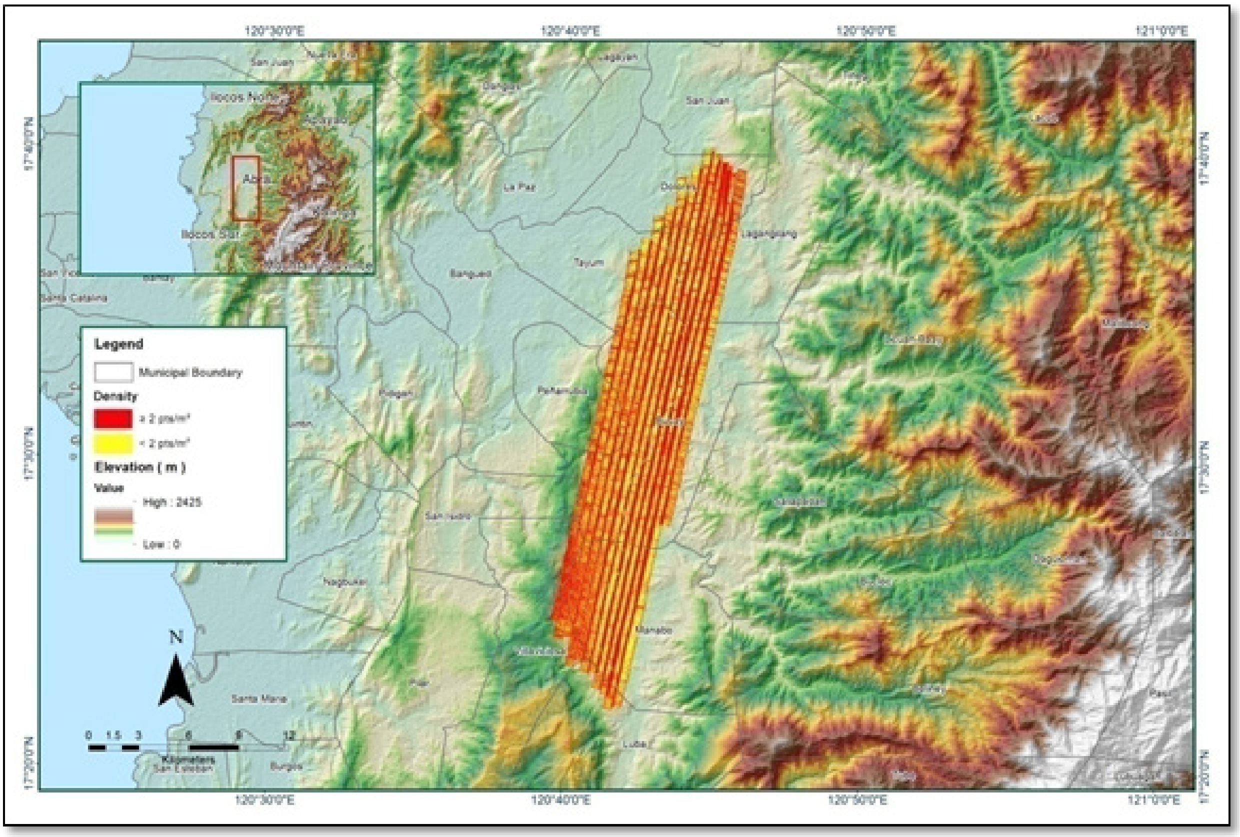


Figure A-8.83.. Density map of merged LiDAR data

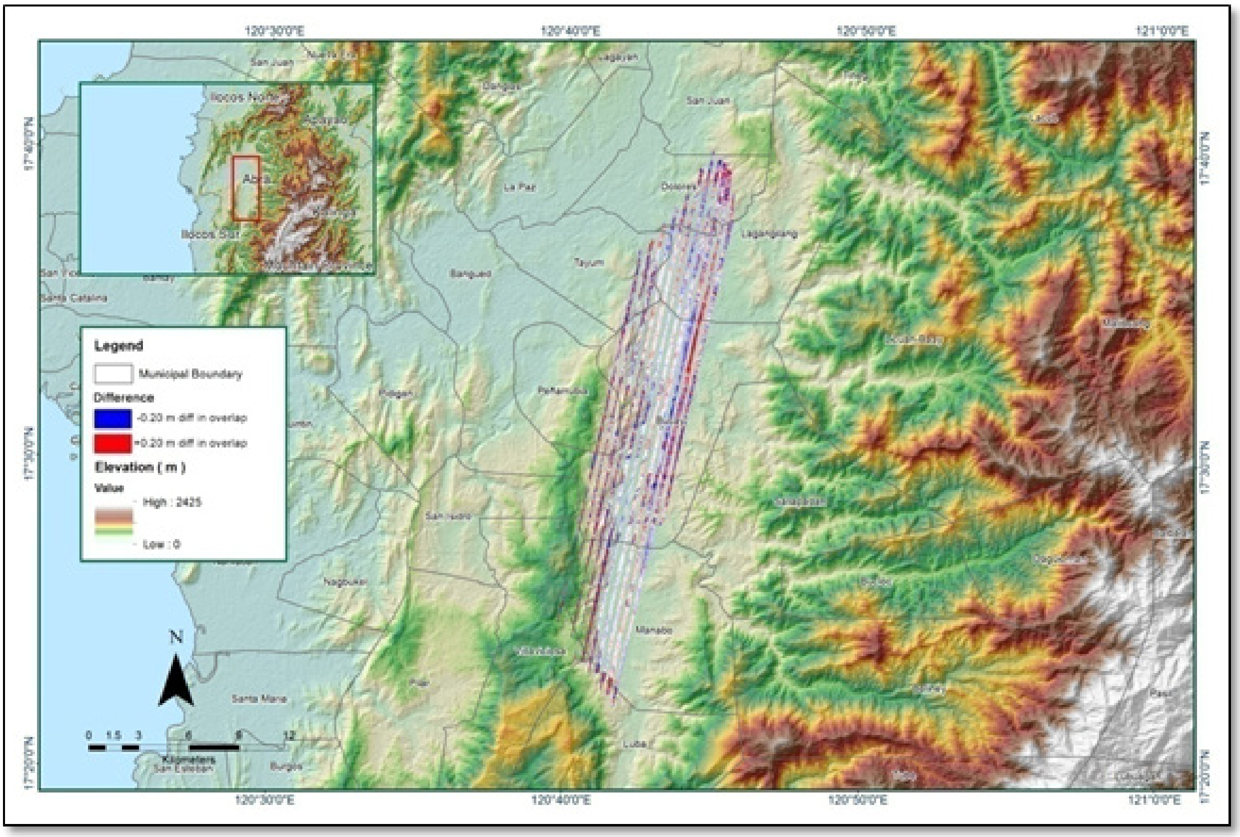


Figure A-8.84. Elevation difference between flight lines

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

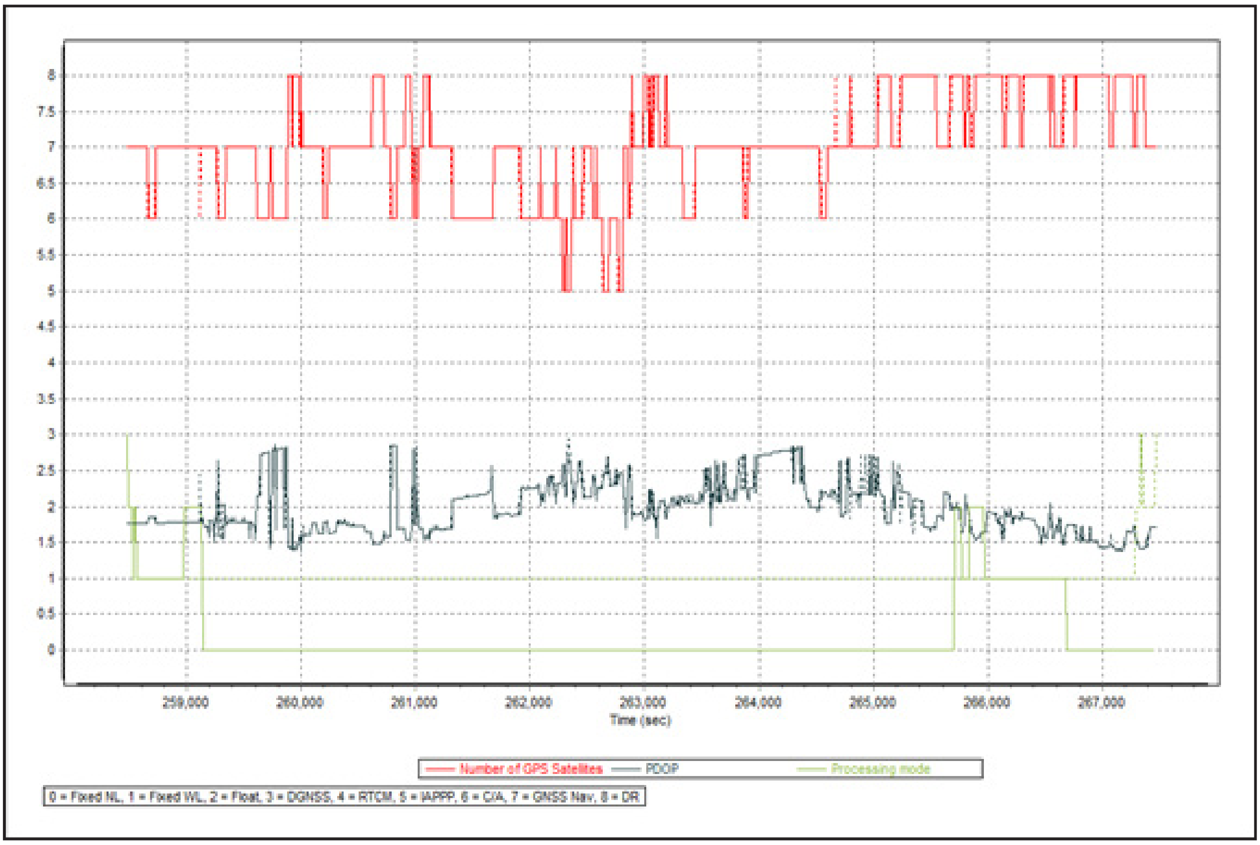


Figure A-8.85 Solution Status

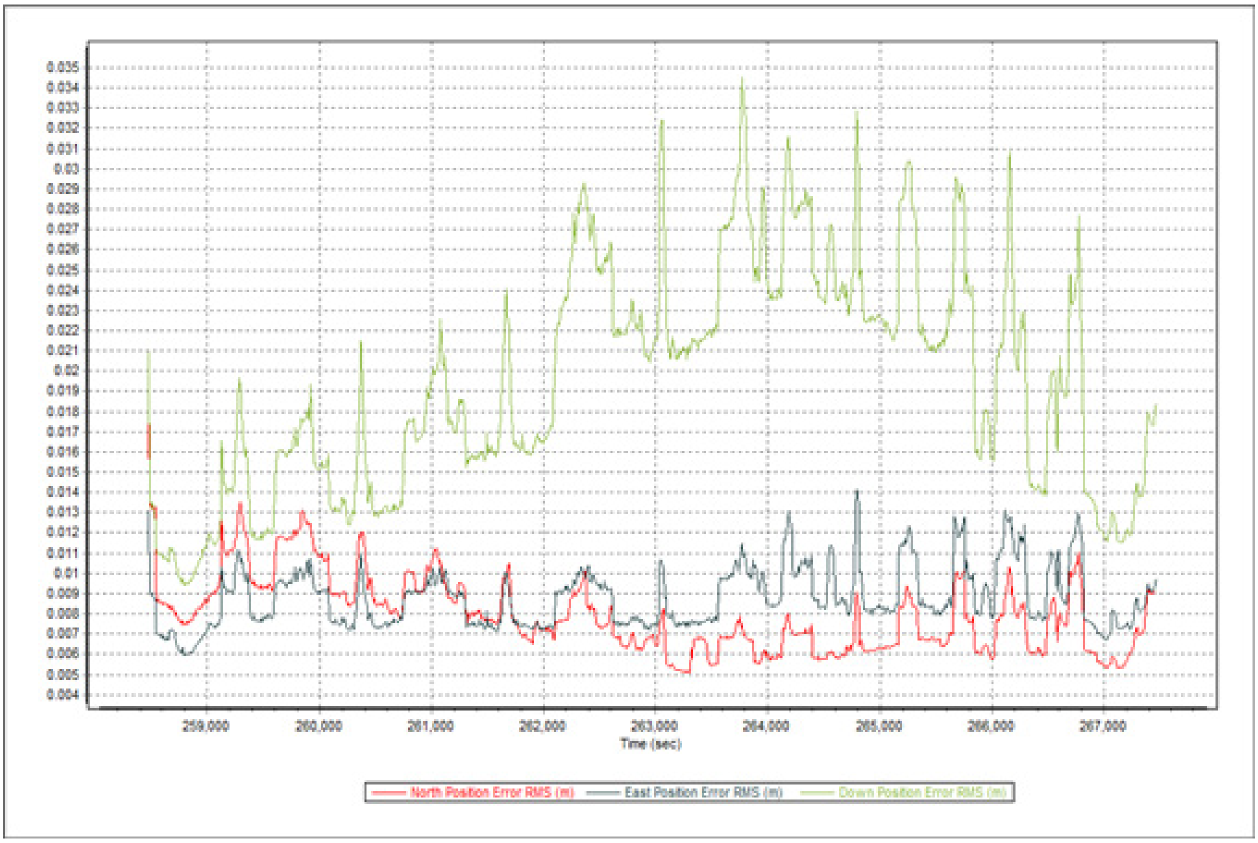


Figure A-8.86 Smoothed Performance Metrics Parameters

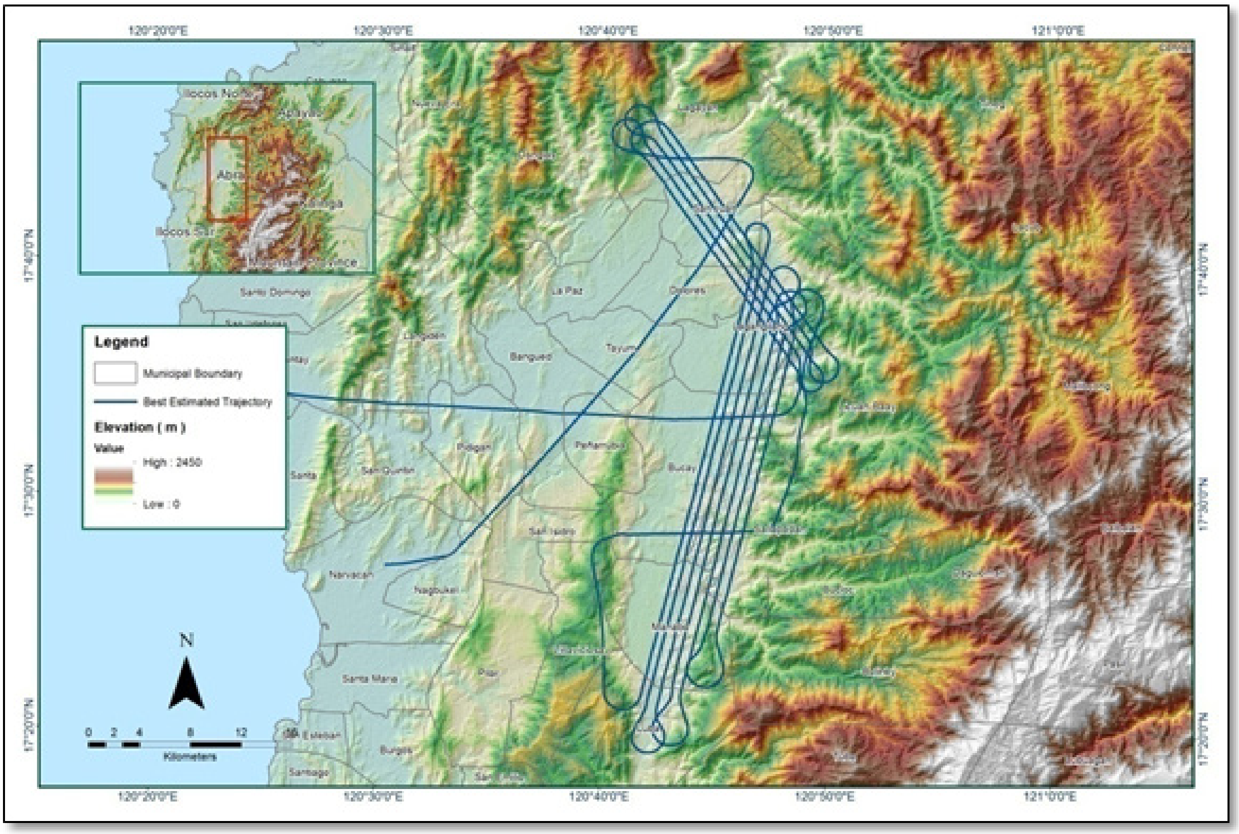


Figure A-8.87 Best Estimated Trajectory

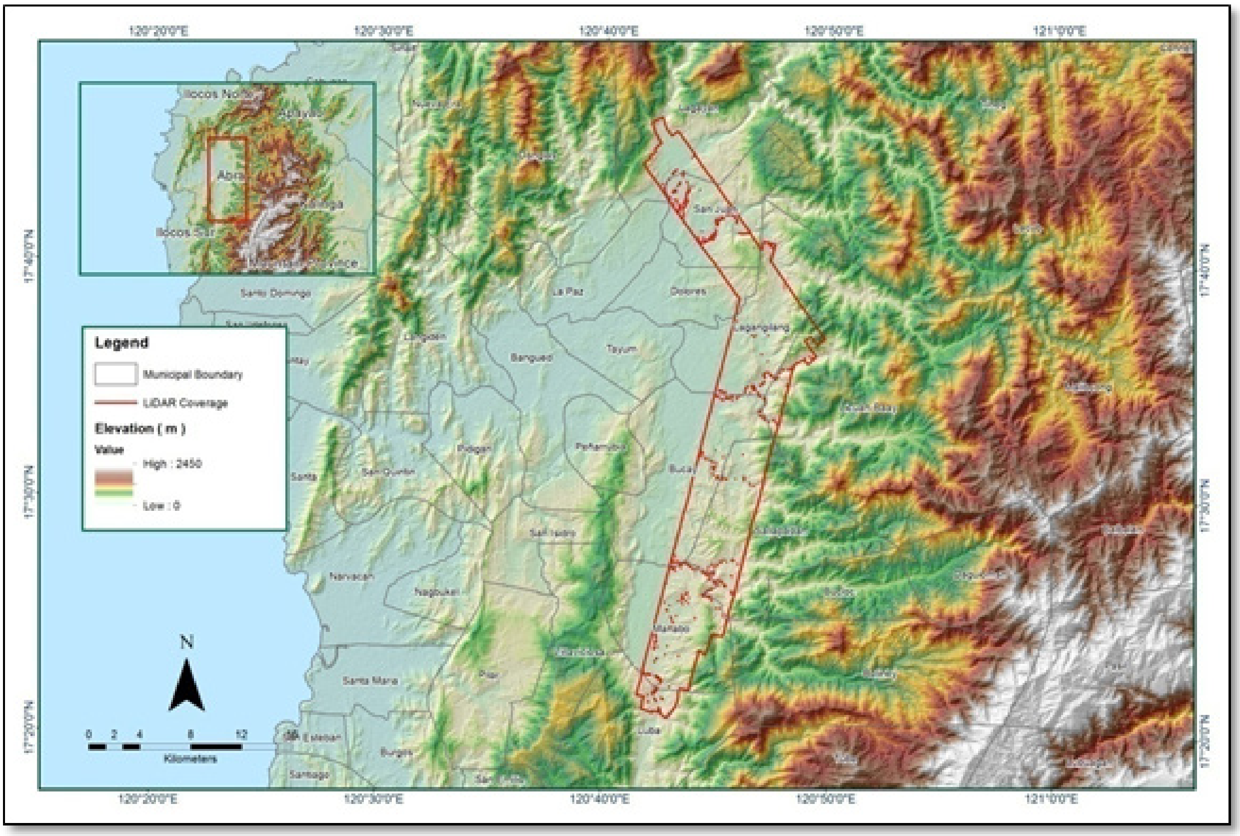


Figure A-8.88 Coverage of LiDAR data

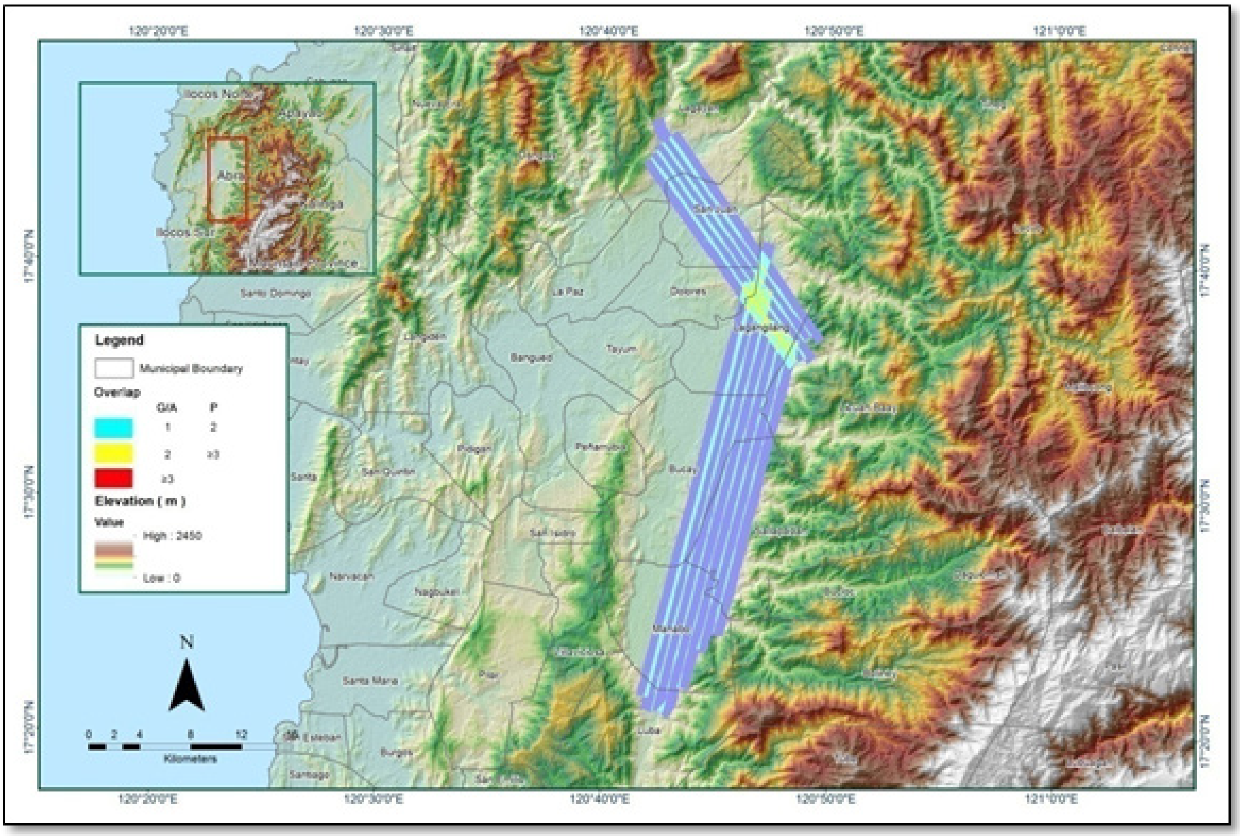


Figure A-8.89 Image of data overlap

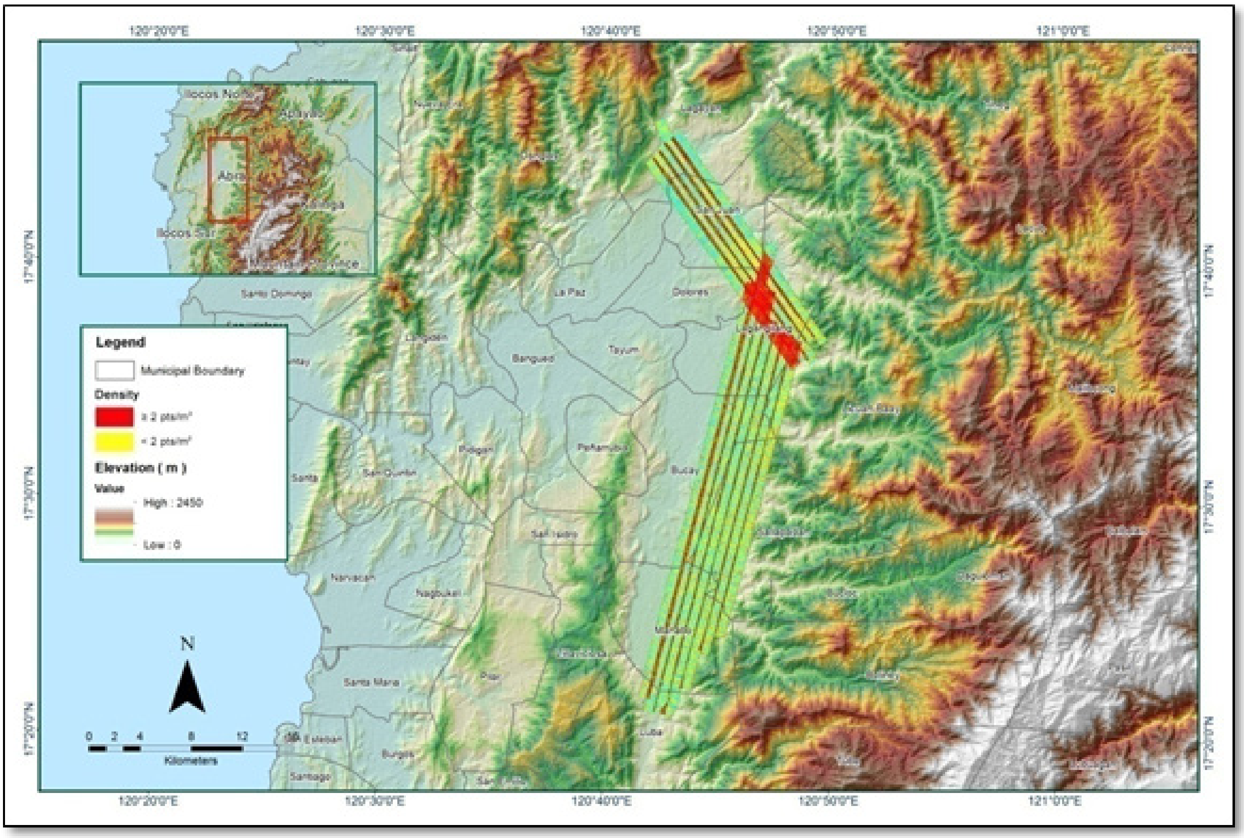


Figure A-8.90 Density map of merged LiDAR data

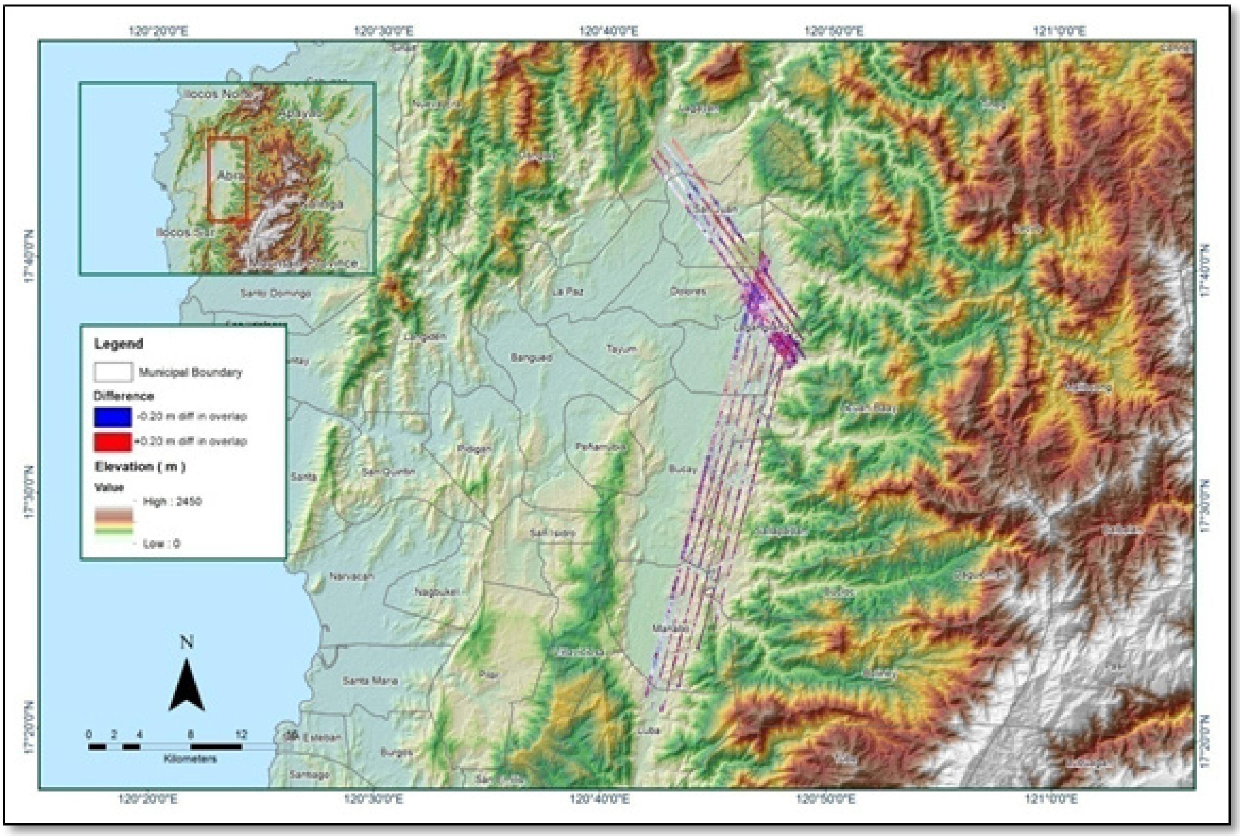


Figure A-8.91 Elevation difference between flight lines

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

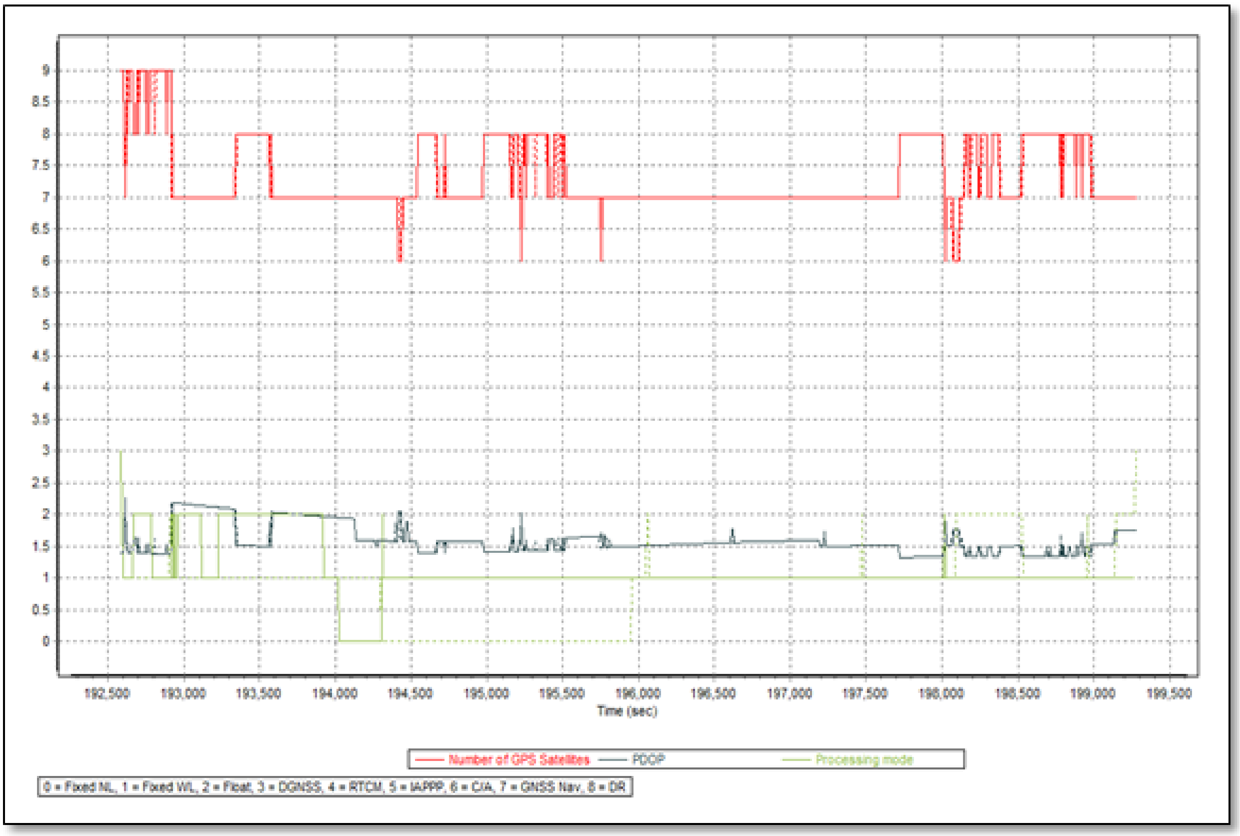


Figure A-8.92 Solution Status

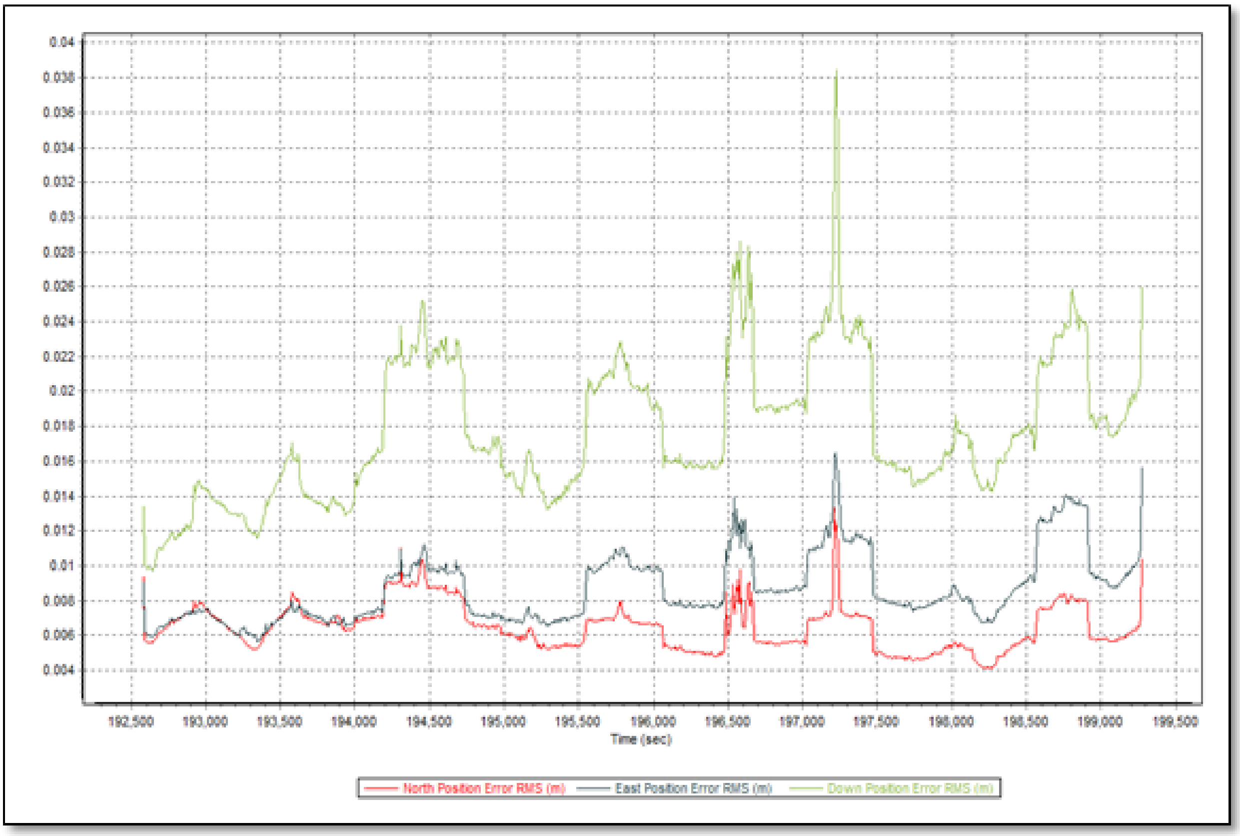


Figure A-8.93 Smoothed Performance Metrics Parameters

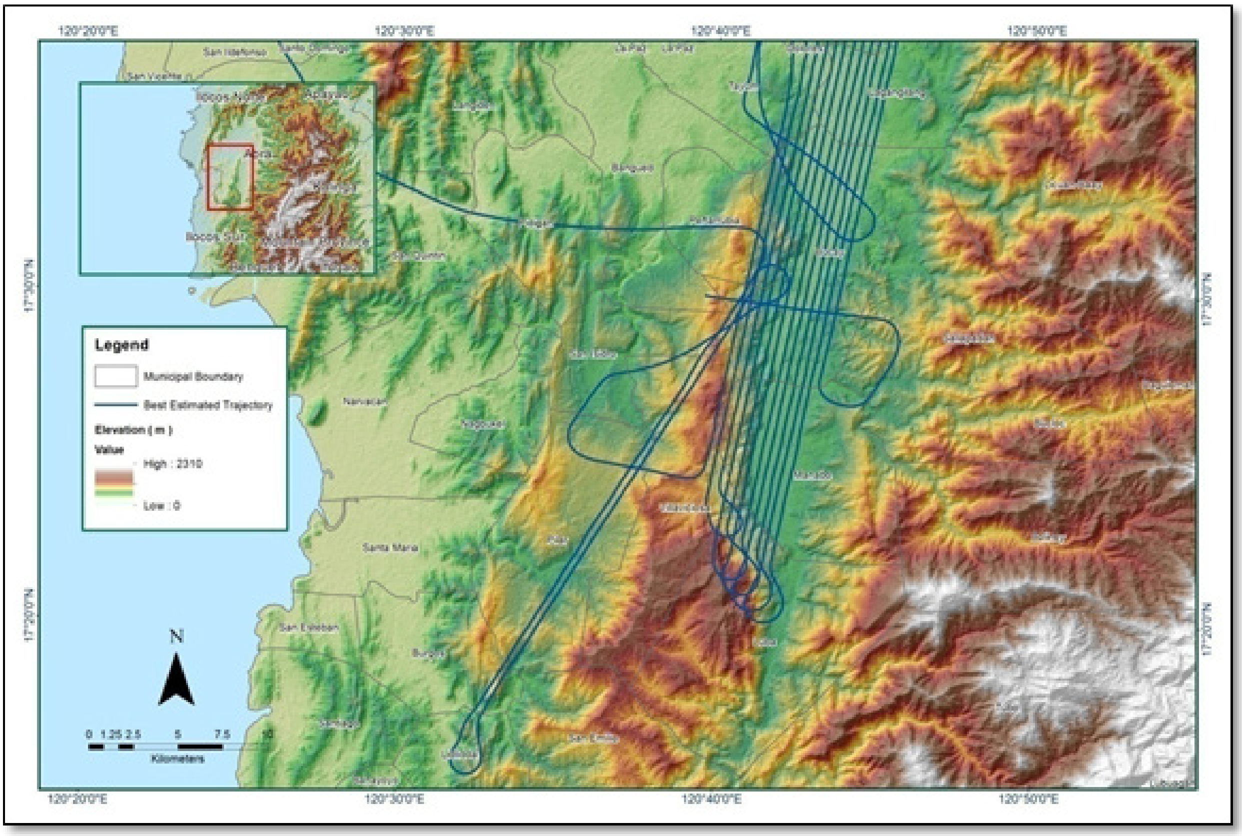


Figure A-8.94 Best Estimated Trajectory

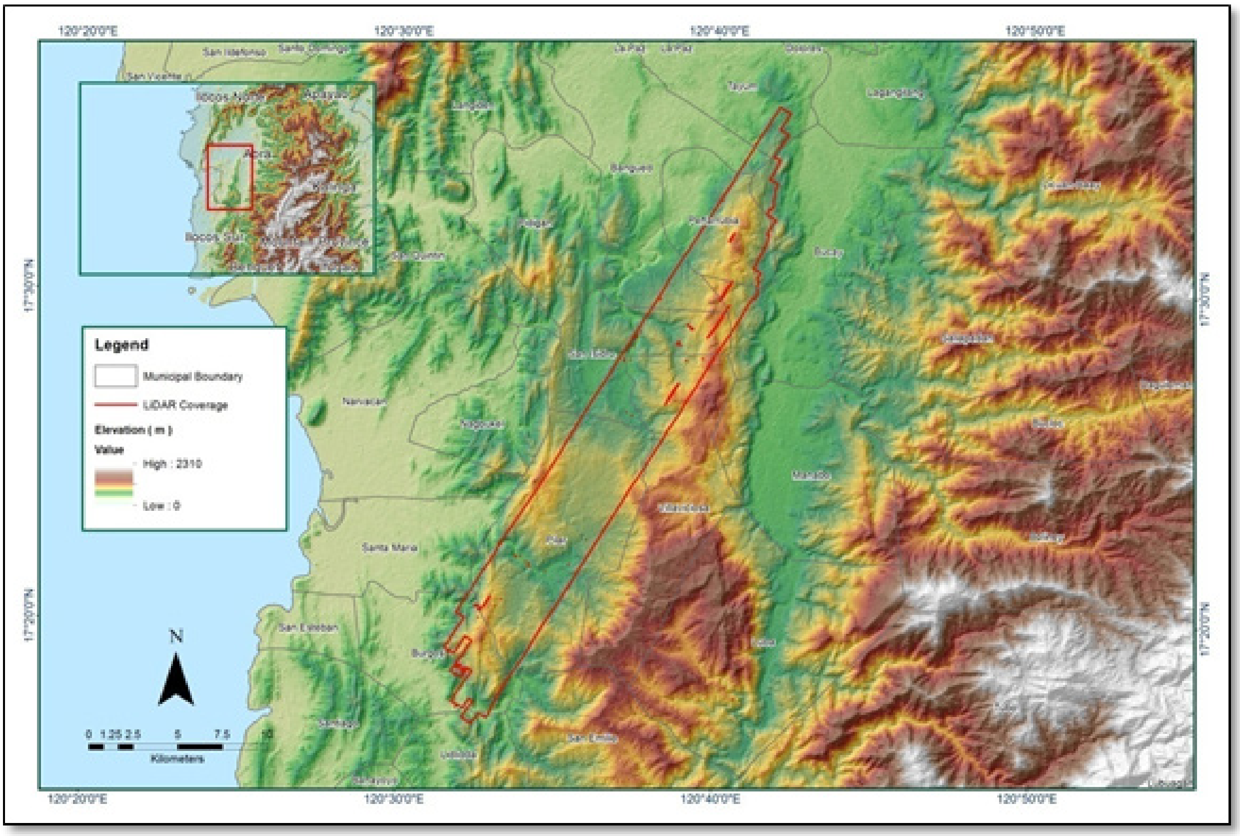


Figure A-8.95 Coverage of LiDAR data

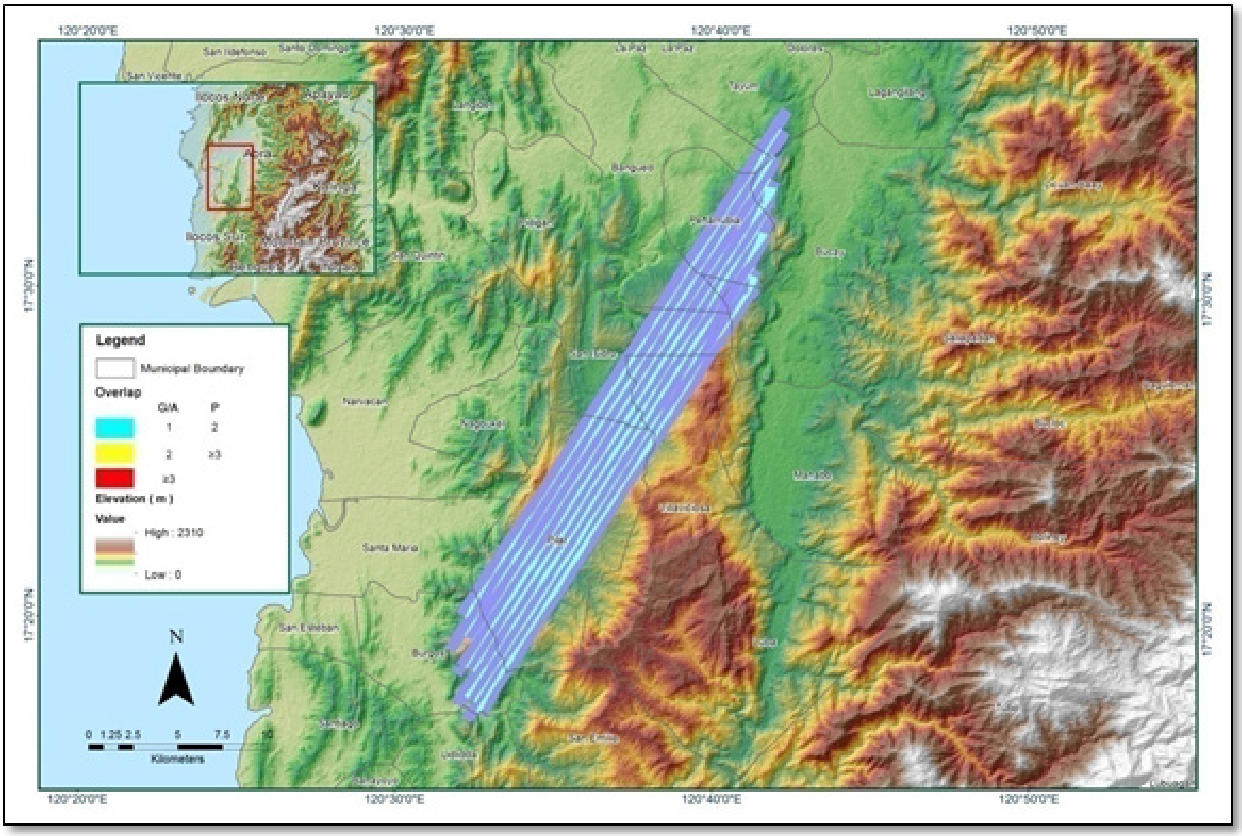


Figure A-8.96 Image of data overlap

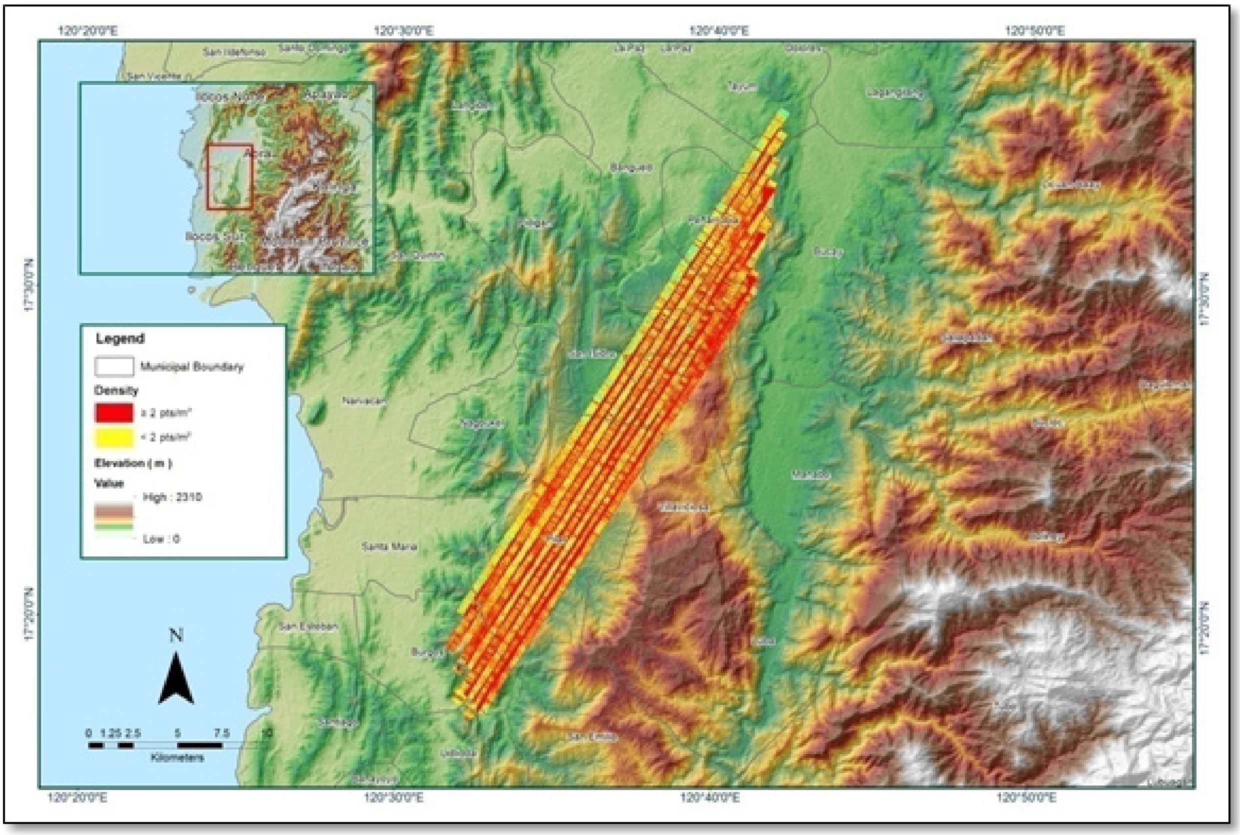


Figure A-8.97 Density map of merged LiDAR data

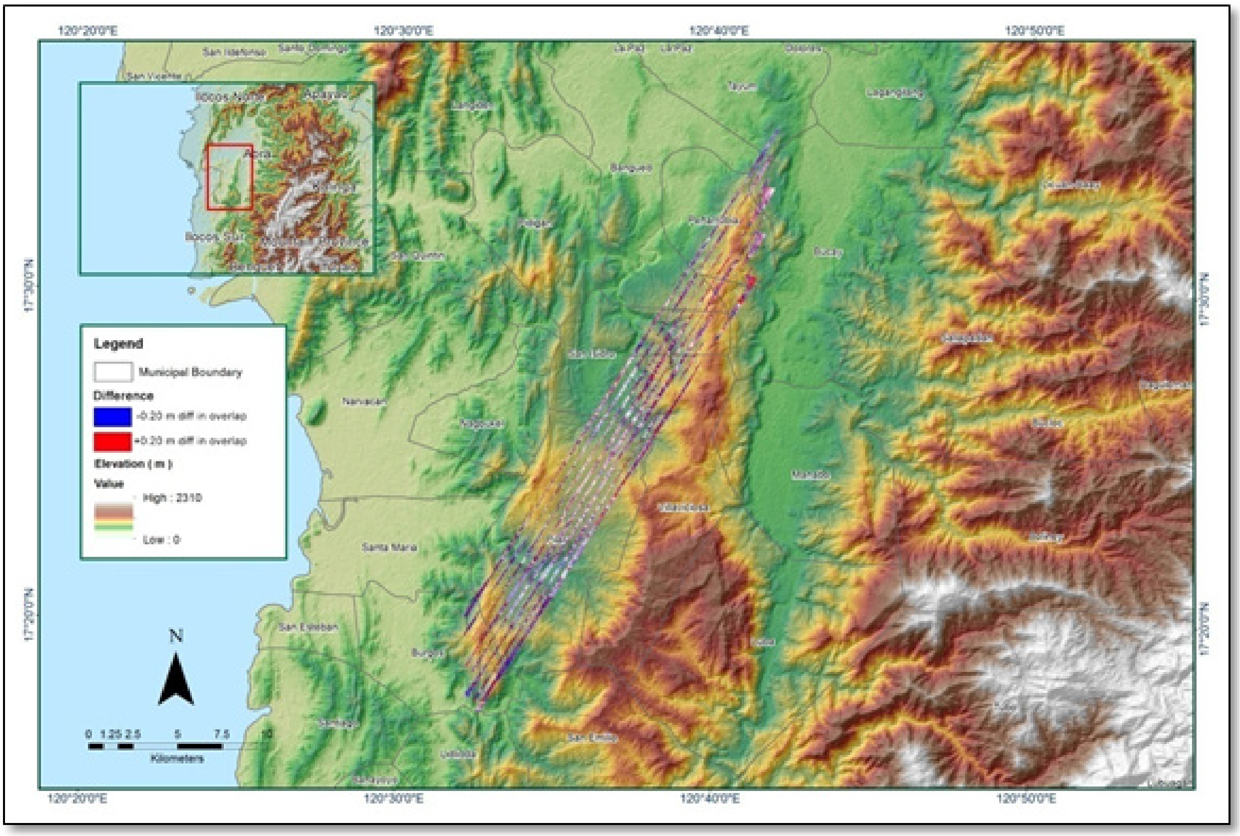


Figure A-8.98 Elevation difference between flight lines

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

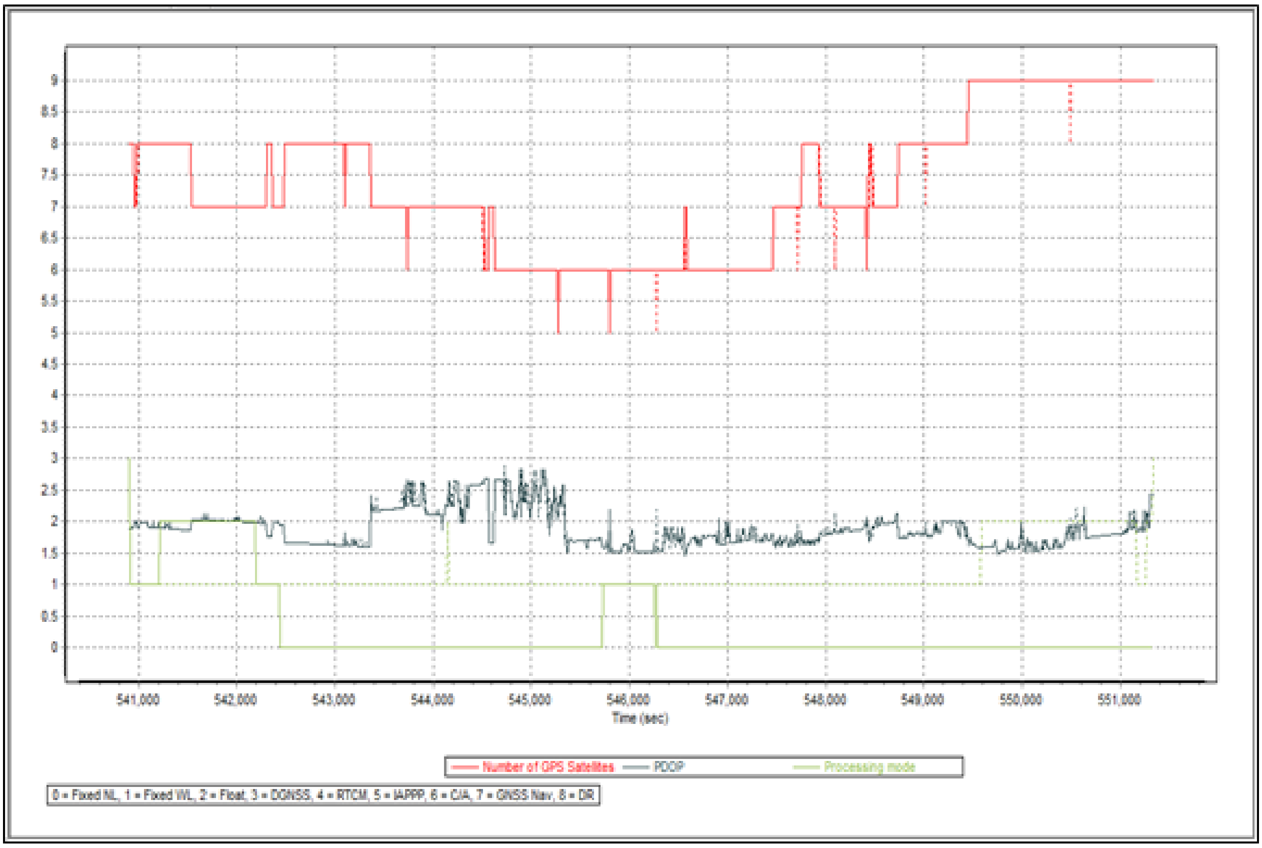


Figure A-8.99 Solution Status

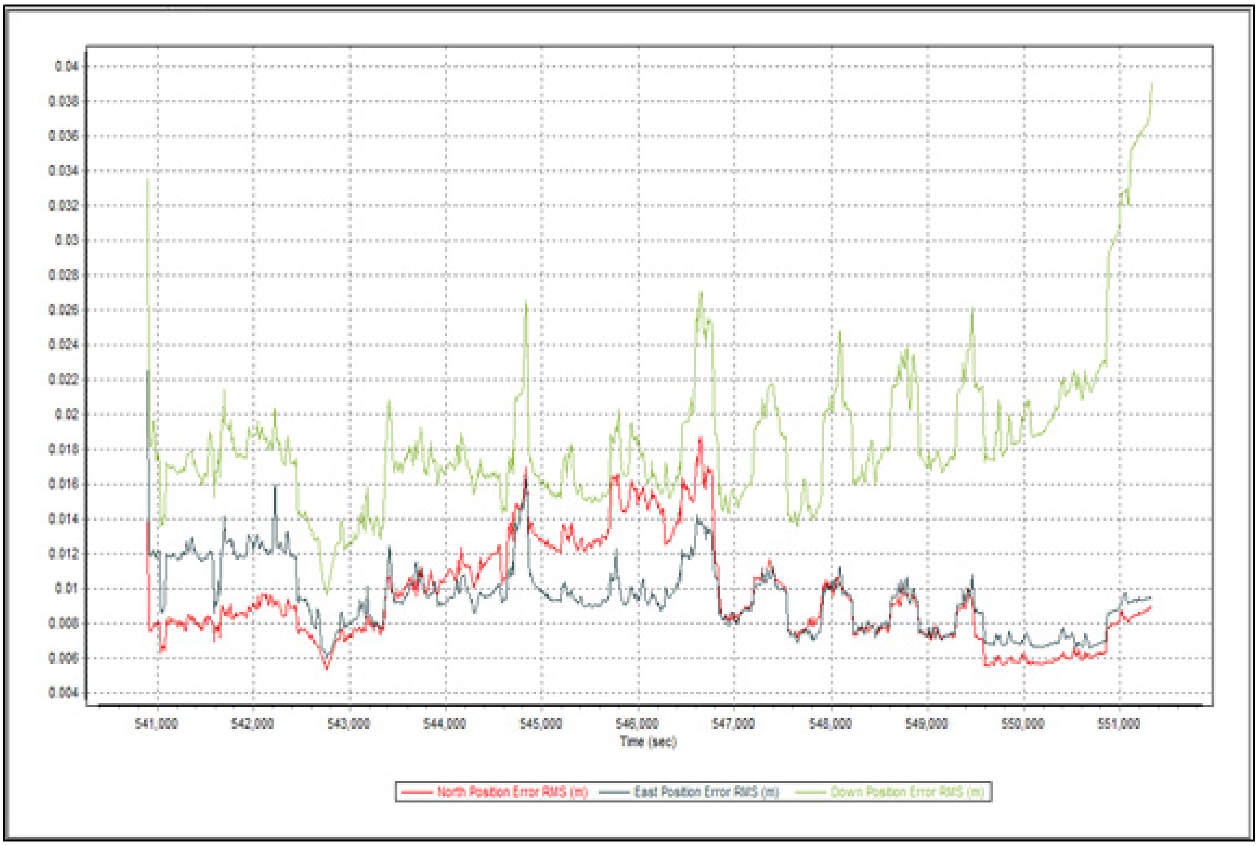


Figure A-8.100 Smoothed Performance Metric Parameters

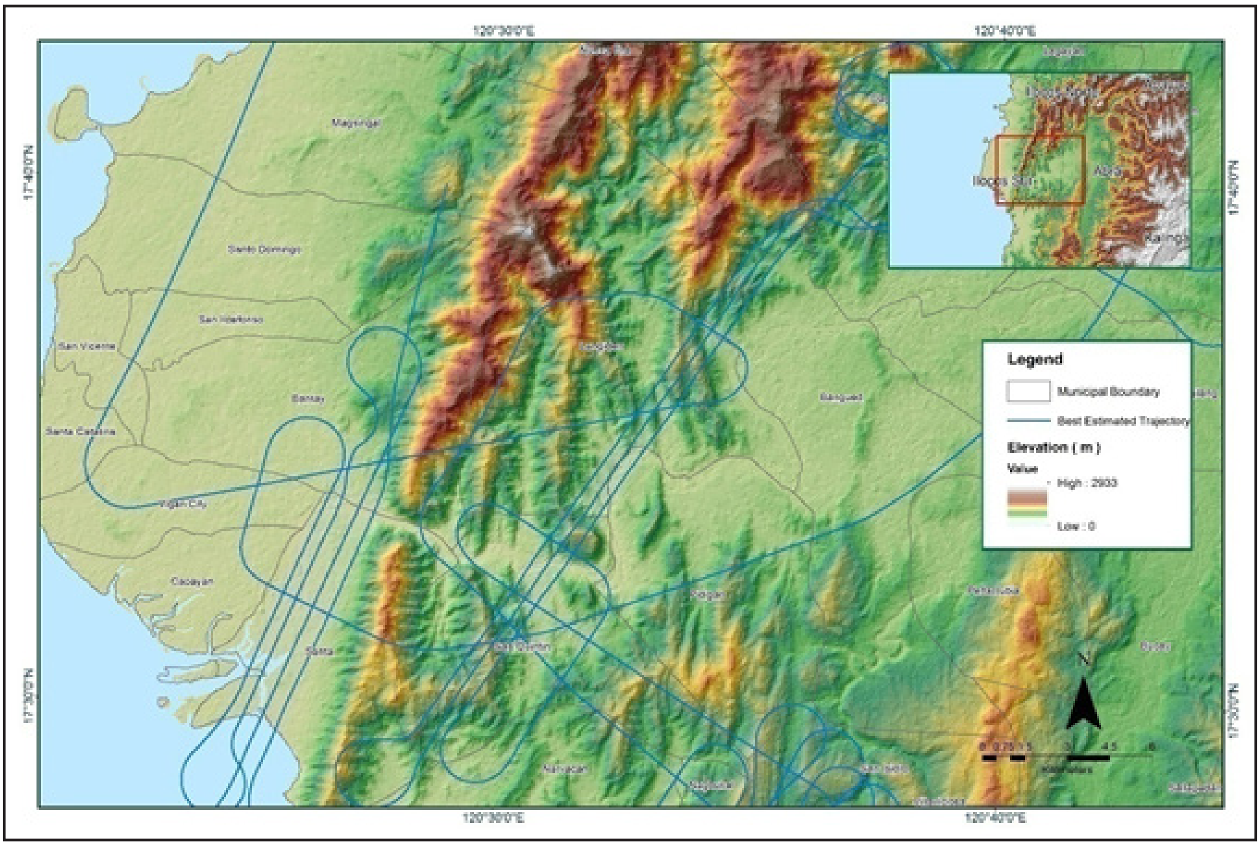


Figure A-8.101 Best Estimated Trajectory

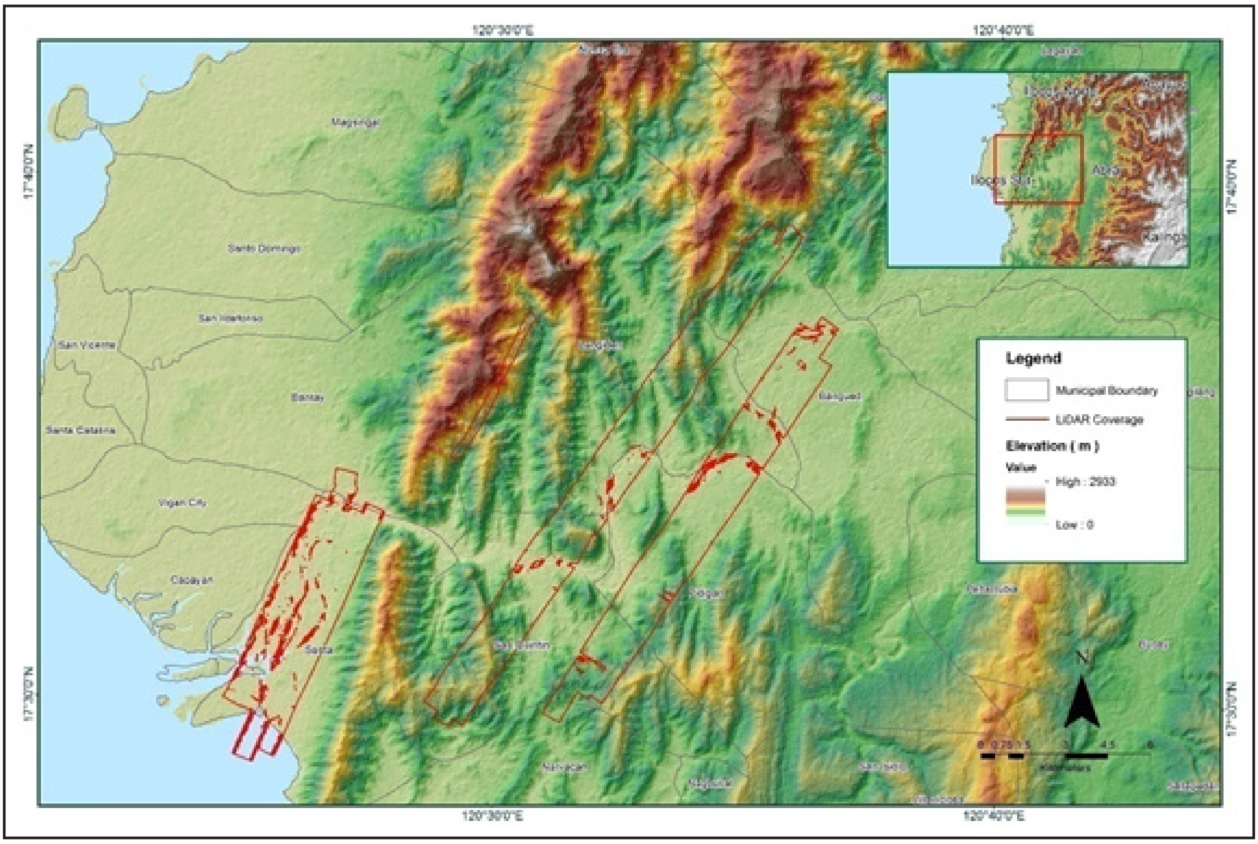


Figure A-8.102 Coverage of LiDAR Data

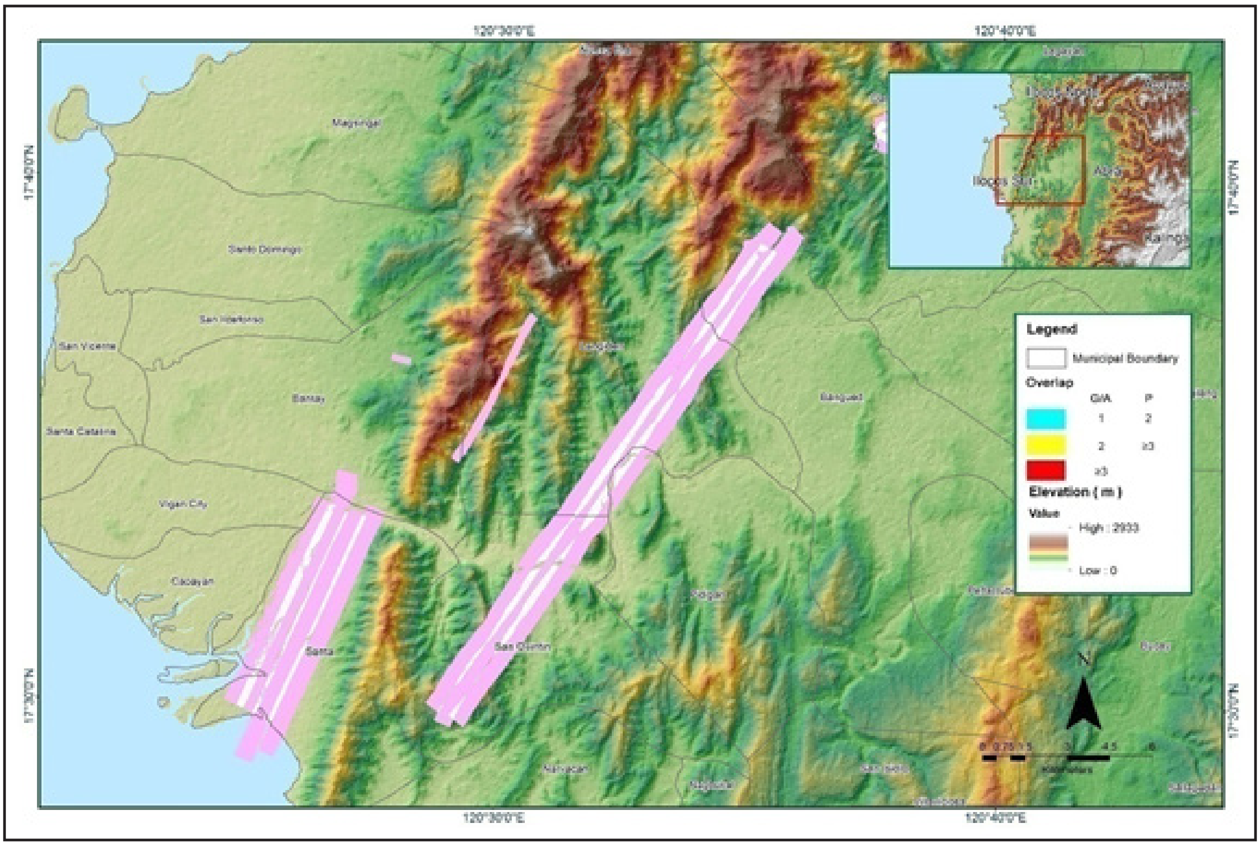


Figure A-8.103 Image of data overlap

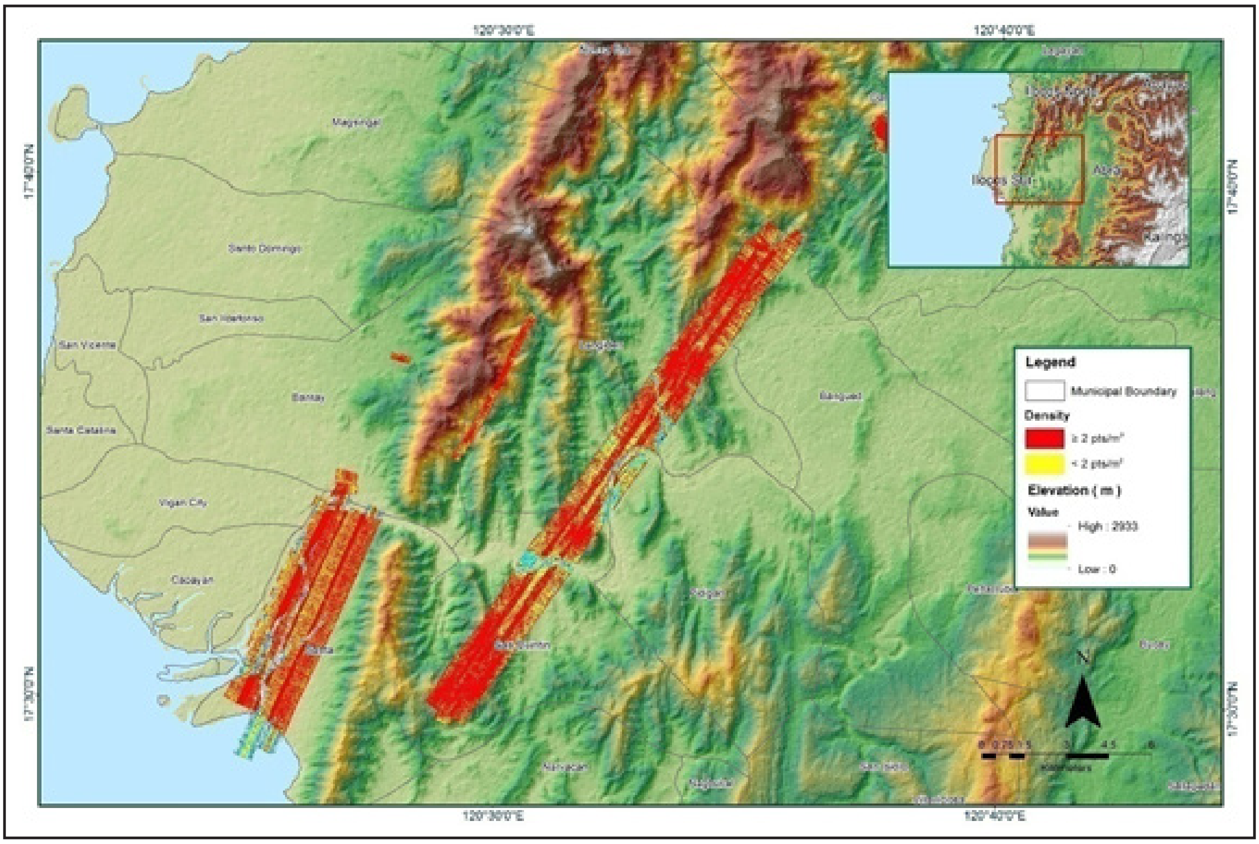


Figure A-8.104 Density map of merged LiDAR data

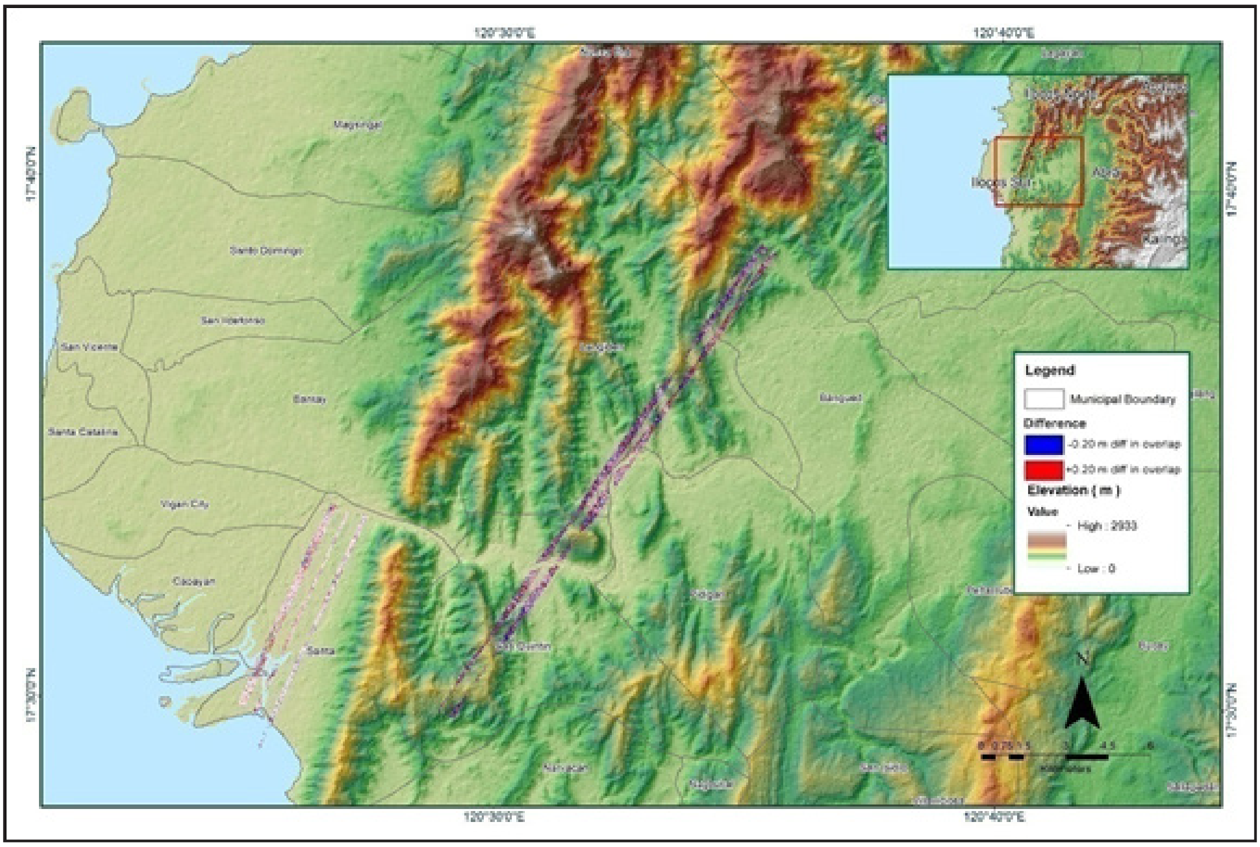


Figure A-8.105 Elevation difference between flight lines

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

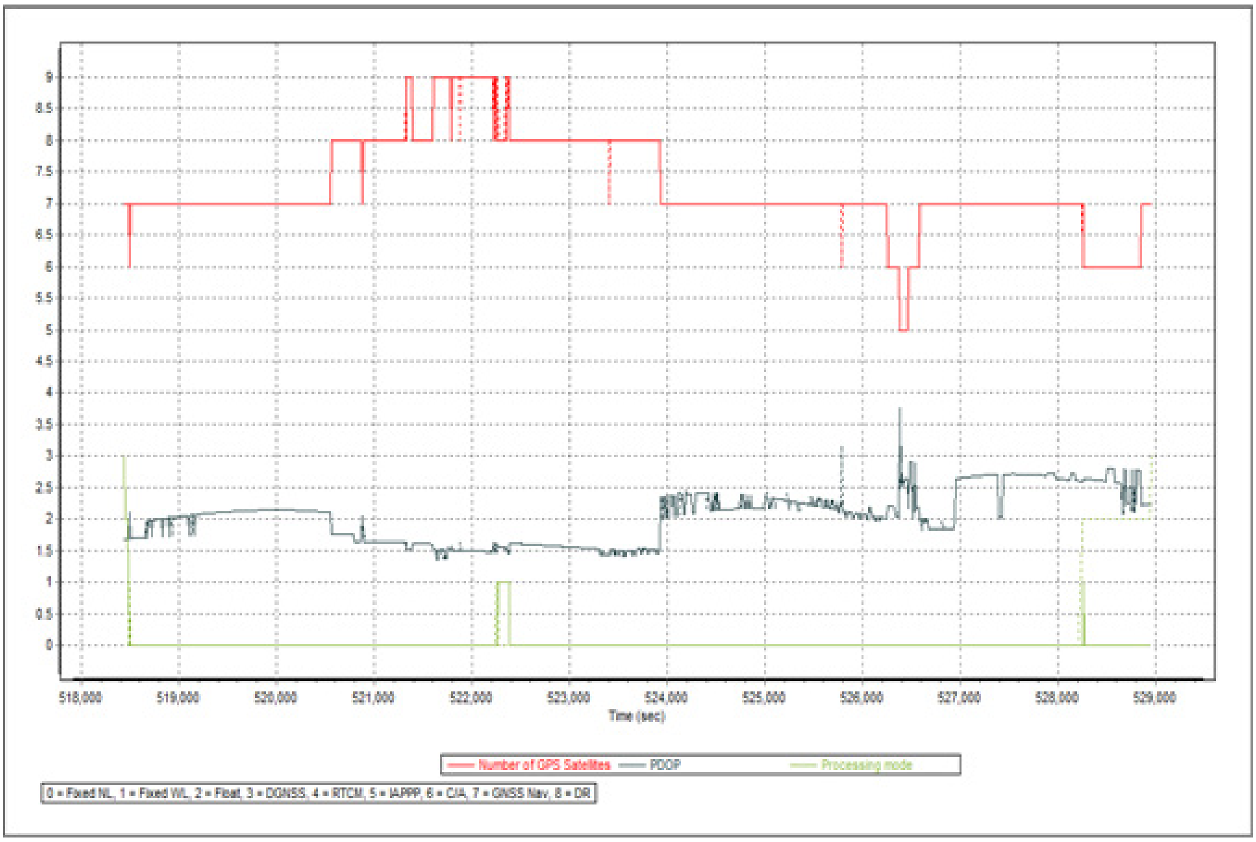


Figure A-8.106 Solution Status

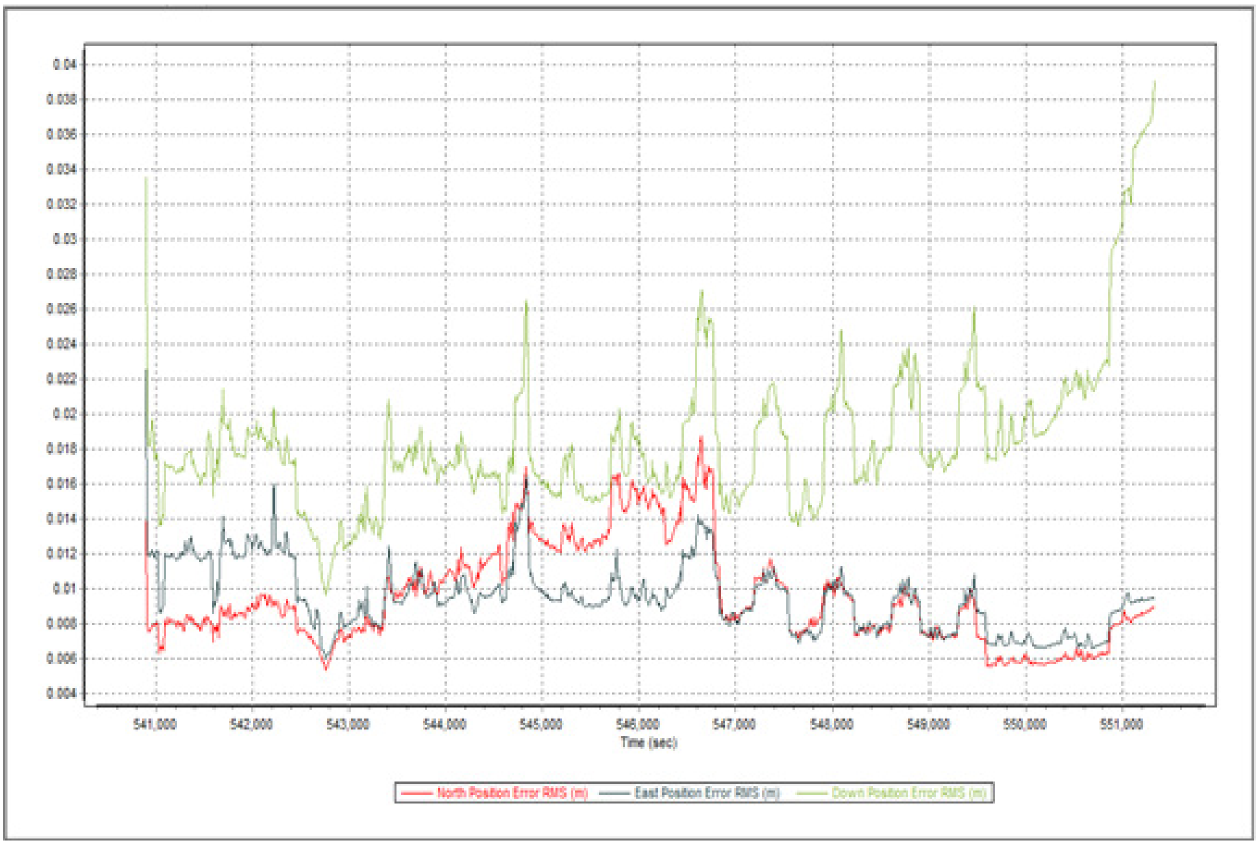


Figure A-8.107 Smoothed Performance Metric Parameters

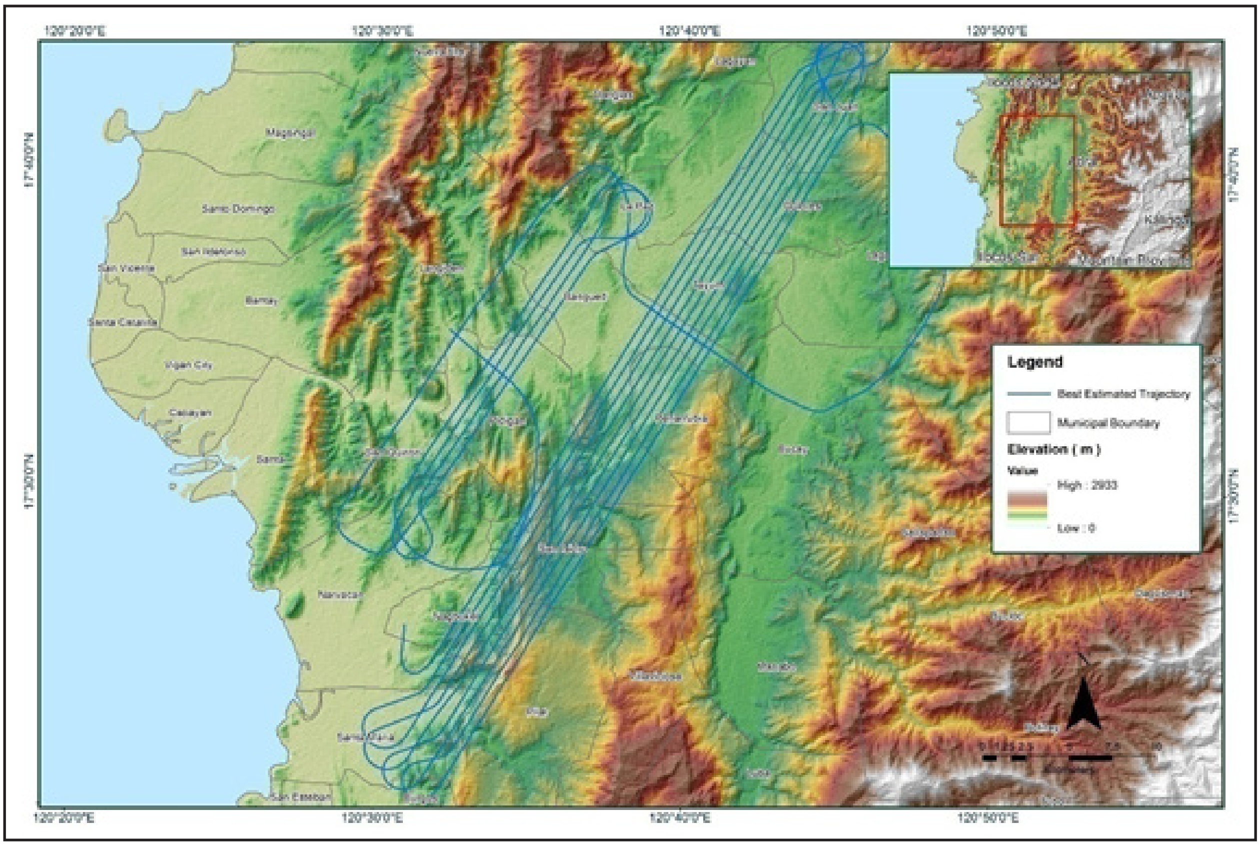


Figure A-8.108 Best Estimated Trajectory

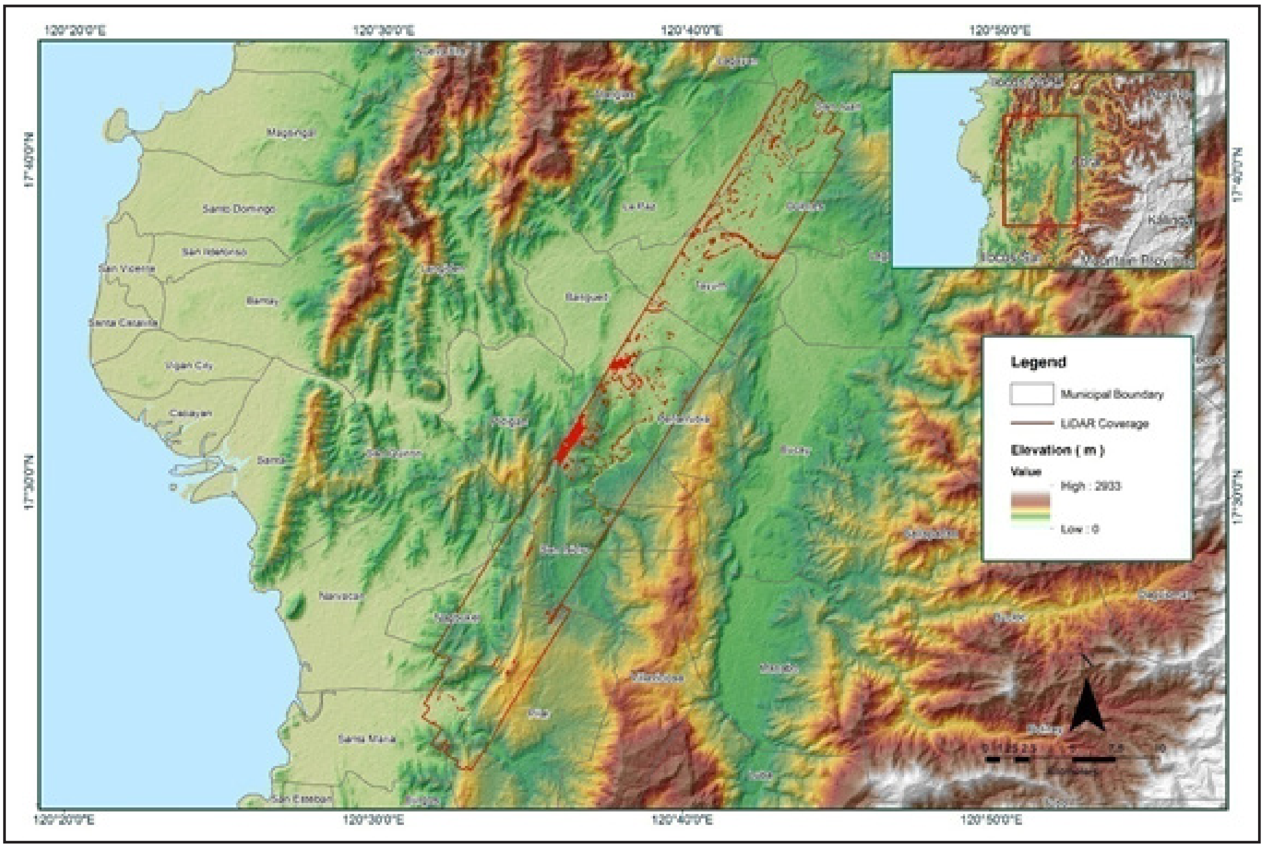


Figure A-8.109 Coverage of LiDAR Data

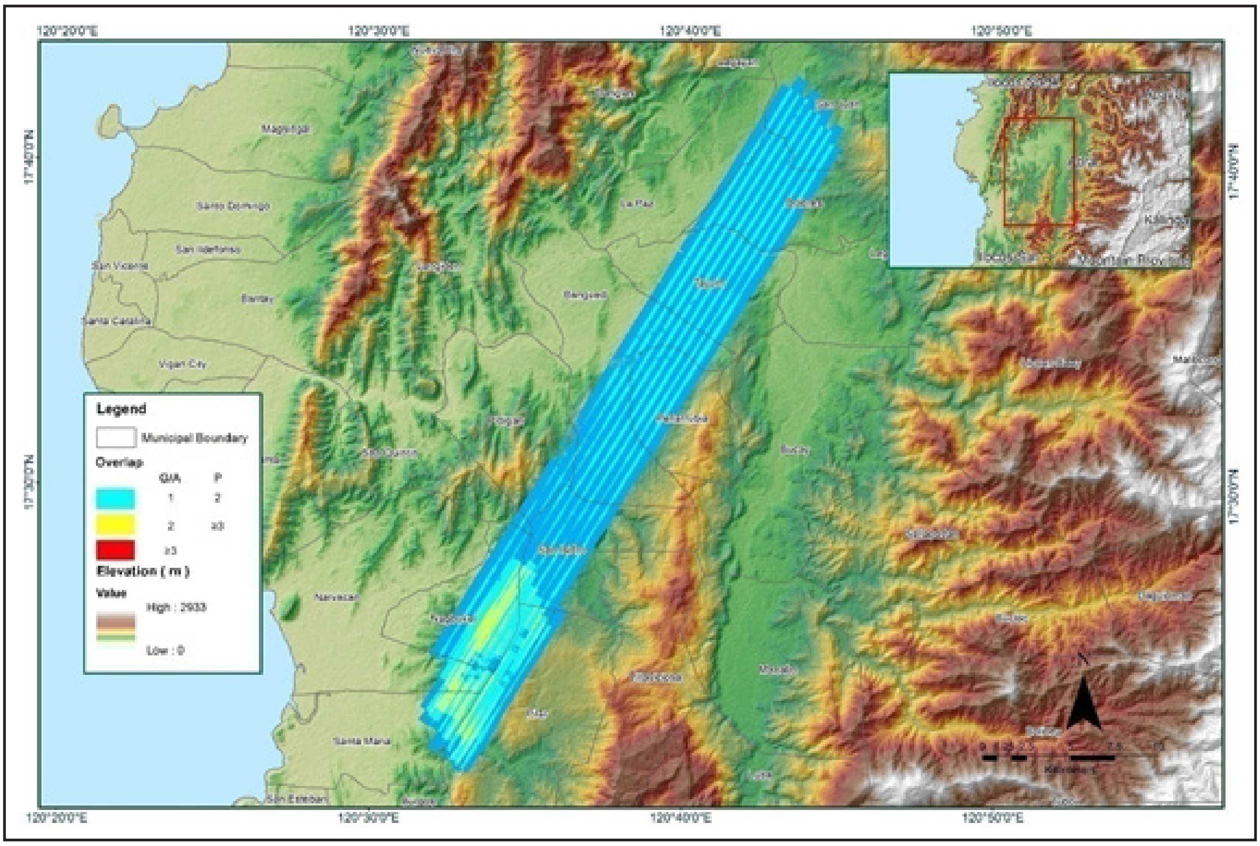


Figure A-8.110 Image of data overlap

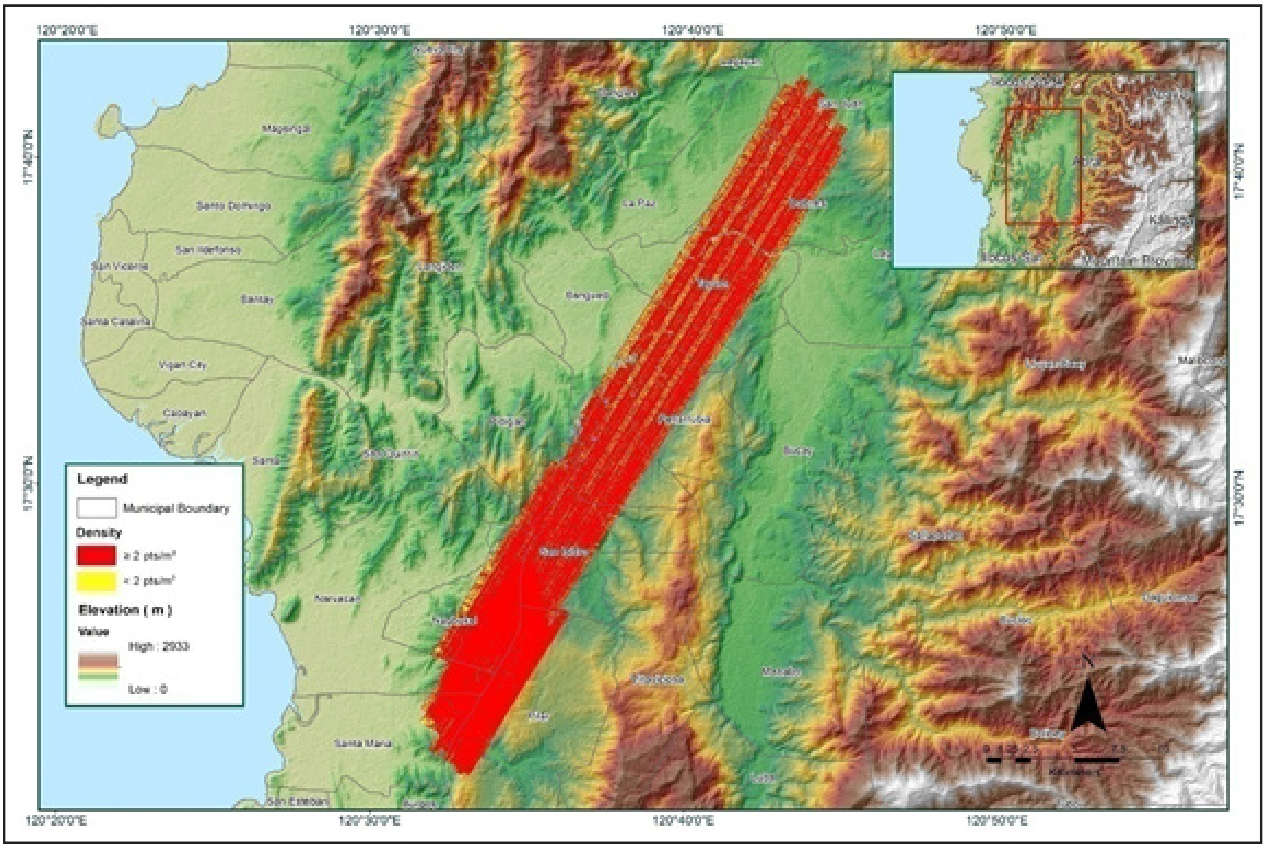


Figure A-8.111 Density map of merged LiDAR data

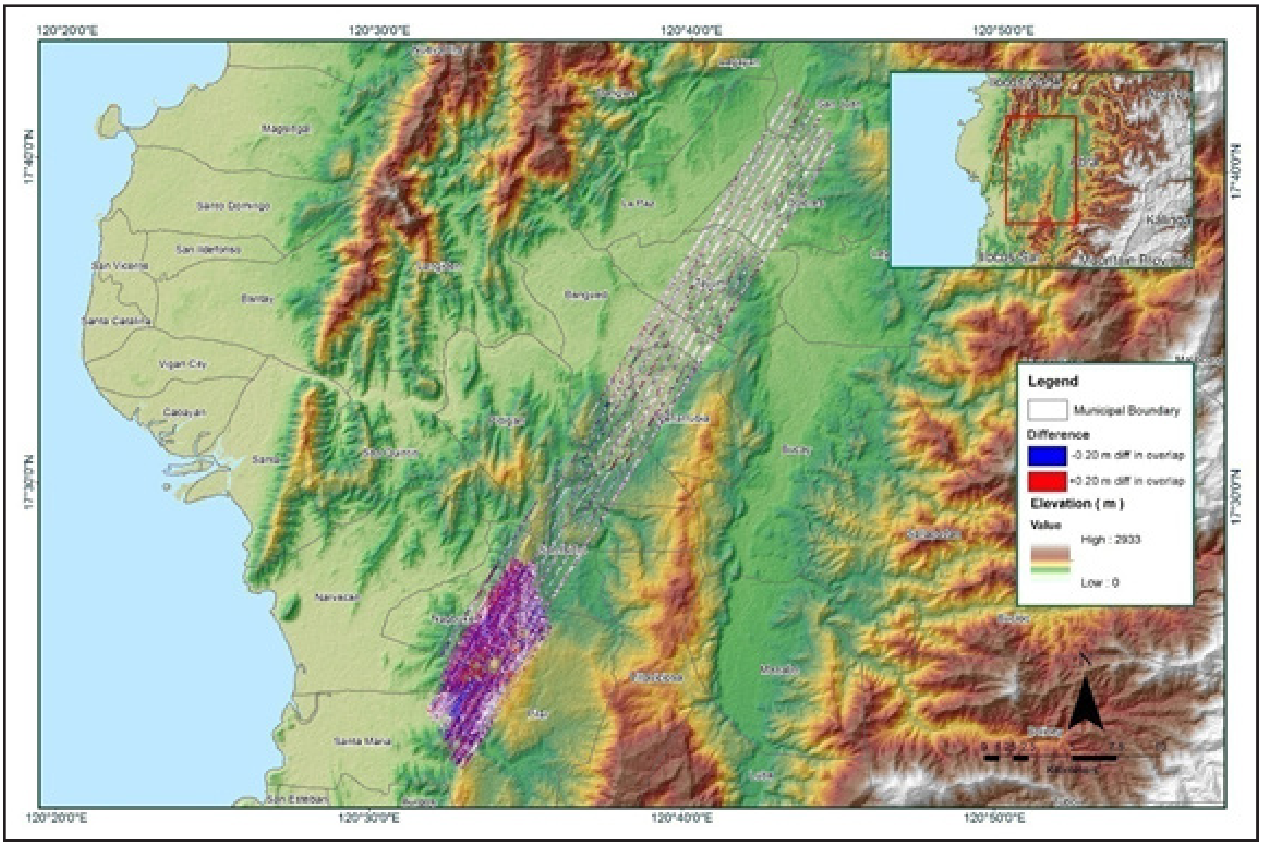


Figure A-8.112 Elevation difference between flight lines

ANNEX 9. Ikmin Model Basin Parameters

Table A-9.1. Ikmin 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
W1000	0.002038	99	0	4.6893	0.7507	Discharge	1.9287	1	Ratio to Peak	0.5
W1040	0.001823	99	0	3.2005	0.76781	Discharge	0.47348	1	Ratio to Peak	0.5
W1050	0.002019	99	0	3.1781	0.77665	Discharge	2.6584	1	Ratio to Peak	0.5
W470	0.001805	99	0	8.5465	2.0504	Discharge	8.6055	0.99081	Ratio to Peak	0.5
W480	0.002026	99	0	2.0761	0.33882	Discharge	1.2864	1	Ratio to Peak	0.5
W500	0.002142	99	0	2.0536	0.22799	Discharge	0.81693	1	Ratio to Peak	0.5
W510	0.001539	99	0	5.402	0.88161	Discharge	1.535	1	Ratio to Peak	0.5
W520	0.002263	99	0	1.589	0.17641	Discharge	1.1623	1	Ratio to Peak	0.5
W530	0.001816	90.20392	0	0.369486	0.40199	Discharge	0.85586	1	Ratio to Peak	0.5
W540	0.002038	99	0	1.3465	0.21974	Discharge	0.30123	1	Ratio to Peak	0.4802
W550	0.001121	98.6	0	0.016749	0.018222	Discharge	0.000434	1	Ratio to Peak	0.5
W560	0.001769	90.7294	0	0.53388	0.58086	Discharge	2.2794	1	Ratio to Peak	0.5
W570	0.00101	99	0	2.147	0.30317	Discharge	0.18013	1	Ratio to Peak	0.4904
W580	0.002038	99	0	4.301	0.31621	Discharge	0.84815	1	Ratio to Peak	0.5
W600	0.002147	99	0	2.1732	0.35466	Discharge	1.4992	1	Ratio to Peak	0.5
W610	0.00108	99	0	1.4071	0.22964	Discharge	1.5677	0.983	Ratio to Peak	0.5
W620	0.002334	99	0	2.3653	0.25733	Discharge	1.6573	1	Ratio to Peak	0.49
W630	0.001956	99	0	3.4117	0.81848	Discharge	0.85451	1	Ratio to Peak	0.5
W640	0.001898	99	0	6.4054	1.0427	Discharge	2.8199	1	Ratio to Peak	0.5
W650	0.001061	99	0	2.5749	0.27968	Discharge	0.88263	1	Ratio to Peak	0.5
W660	0.001776	99	0	4.8432	0.77554	Discharge	1.5737	1	Ratio to Peak	0.5
W670	0.001494	99	0	3.3522	0.8198	Discharge	1.5584	1	Ratio to Peak	0.5

W680	0.001878	99	0	5.6302	0.9184	Discharge	1.201	1	Ratio to Peak	0.5
W690	0.001136	99	0	5.7189	0.62533	Discharge	2.1501	1	Ratio to Peak	0.5
W700	0.001264	99	0	1.5866	0.25892	Discharge	0.96597	1	Ratio to Peak	0.5
W710	0.002213	99	0	2.0274	0.22014	Discharge	1.0905	1	Ratio to Peak	0.5
W720	0.002117	99	0	2.6778	0.22021	Discharge	2.4553	1	Ratio to Peak	0.5
W730	0.001061	99	0	2.2915	0.82095	Discharge	1.2493	1	Ratio to Peak	0.4802
W740	0.001998	99	0	5.1178	0.83479	Discharge	1.5477	1	Ratio to Peak	0.5
W750	0.001595	99	0	2.6299	0.2804	Discharge	0.94431	1	Ratio to Peak	0.4802
W760	0.001023	99	0	2.1615	0.23271	Discharge	0.15301	1	Ratio to Peak	0.5
W770	0.002038	99	0	2.6074	0.28277	Discharge	0.16035	1	Ratio to Peak	0.4802
W780	0.001144	99	0	2.7753	0.2562	Discharge	0.4271	1	Ratio to Peak	0.49
W790	0.001662	99	0	7.195	0.7988	Discharge	1.9474	1	Ratio to Peak	0.49
W800	0.001277	99	0	2.6201	0.18966	Discharge	0.86318	1	Ratio to Peak	0.5
W810	0.001094	99	0	2.8868	0.72111	Discharge	1.1094	1	Ratio to Peak	0.5
W820	0.001014	99	0	3.1025	0.26166	Discharge	0.99667	1	Ratio to Peak	0.5
W830	0.001193	99	0	2.6729	0.19305	Discharge	0.40332	1	Ratio to Peak	0.5
W850	0.002038	99	0	7.1595	0.54072	Discharge	0.54672	1	Ratio to Peak	0.5
W860	0.001231	99	0	2.6542	0.28192	Discharge	0.77512	1	Ratio to Peak	0.5
W870	0.001637	91.194	0	2.8228	0.26706	Discharge	1.9727	1	Ratio to Peak	0.5
W880	0.001906	99	0	6.3578	0.69519	Discharge	1.3441	1	Ratio to Peak	0.5
W890	0.002038	99	0	6.7916	1.0912	Discharge	1.1548	1	Ratio to Peak	0.5
W900	0.002038	81.85	0	2.9561	0.73841	Discharge	0.7751	1	Ratio to Peak	0.5
W910	0.001866	99	0	8.1069	0.62782	Discharge	1.9645	1	Ratio to Peak	0.4802
W920	0.00163	91.366	0	2.8439	0.26906	Discharge	1.3816	1	Ratio to Peak	0.5
W940	0.001106	99	0	2.8821	0.27268	Discharge	1.1353	1	Ratio to Peak	0.5
W950	0.001087	99	0	2.6048	0.63487	Discharge	1.3344	1	Ratio to Peak	0.49
W990	0.002038	81.85	0	2.1943	0.232	Discharge	0.080519	1	Ratio to Peak	0.5

ANNEX 10. Ikmin Model Reach Parameters

Table A-10.1. Ikmin Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1020	Automatic Fixed Interval	4603.6	0.011213	0.0001	Trapezoid	46.233	1
R1070	Automatic Fixed Interval	4615.8	0.047645	0.0001	Trapezoid	46.067	1
R120	Automatic Fixed Interval	2203.1	0.008464	0.0001	Trapezoid	139.6667	1
R140	Automatic Fixed Interval	1209.7	0.000758	0.0001	Trapezoid	73.433	1
R150	Automatic Fixed Interval	6429.6	0.014861	0.0001	Trapezoid	59.267	1
R160	Automatic Fixed Interval	6583.8	0.014581	0.0001	Trapezoid	71.633	1
R20	Automatic Fixed Interval	3374.9	0.084873	0.0001	Trapezoid	26.433	1
R220	Automatic Fixed Interval	5159.6	0.008332	0.0001	Trapezoid	90.633	1
R260	Automatic Fixed Interval	5557.4	0.017493	0.0001	Trapezoid	58.667	1
R280	Automatic Fixed Interval	7493	0.037829	0.0001	Trapezoid	30.533	1
R300	Automatic Fixed Interval	1569.4	0.022086	0.0001	Trapezoid	27.033	1
R310	Automatic Fixed Interval	1459.8	0.014807	0.0001	Trapezoid	44.167	1
R320	Automatic Fixed Interval	1313.3	0.004336	0.0001	Trapezoid	34.4	1
R350	Automatic Fixed Interval	1770	0.007515	0.0001	Trapezoid	37.2	1
R360	Automatic Fixed Interval	3106.9	0.039184	0.0001	Trapezoid	23.833	1
R380	Automatic Fixed Interval	3574	0.01741	0.0001	Trapezoid	45.167	1
R40	Automatic Fixed Interval	1123	0.010948	0.0001	Trapezoid	46.9	1
R400	Automatic Fixed Interval	2833.4	0.027713	0.0001	Trapezoid	38.733	1
R410	Automatic Fixed Interval	3357.4	0.009928	0.0001	Trapezoid	45.033	1
R420	Automatic Fixed Interval	3859.4	0.031729	0.0001	Trapezoid	25.733	1
R50	Automatic Fixed Interval	33.284	0.002257	0.0001	Trapezoid	0	1
R60	Automatic Fixed Interval	5425.7	0.007828	0.0001	Trapezoid	171.6667	1
R80	Automatic Fixed Interval	1236.8	0.022681	0.0001	Trapezoid	42.033	1

R90	Automatic Fixed Interval	1394.3	0.011878	0.0001	Trapezoid	62.867	1
R960	Automatic Fixed Interval	3297	0.01479	0.0001	Trapezoid	51.5	1

ANNEX 11. Ikmin Field Validation Points

Table A-11.1. Ikmin Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	17.53706	120.7769	0.03	0.6096	0.335936	Lawin/ 2016	5-Year
2	17.53706	120.7769	0.03	0.6096	0.335936	Feria/ 2005	5-Year
3	17.53706	120.7769	0.03	0.381	0.123201	Feria/ 2005	5-Year
4	17.53706	120.7769	0.03	0.3048	0.075515	Mina/ 2007	5-Year
5	17.53706	120.7769	0.03	0.3048	0.075515	Carina/ 2016	5-Year
6	17.53706	120.7769	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
7	17.53706	120.7769	0.03	0.6096	0.335936	Feria/ 2005	5-Year
8	17.53706	120.7769	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
9	17.53706	120.7769	0.03	0.6096	0.335936	Feria/ 2005	5-Year
10	17.53706	120.7769	0.03	0.3048	0.075515	Carina/ 2016	5-Year
11	17.4933	120.77	0.04	0.3048	0.070119	Feria/ 2005	5-Year
12	17.4933	120.77	0.04	0.3048	0.070119	Ondoy/ 2009	5-Year
13	17.4933	120.77	0.04	0.3048	0.070119	Mina/ 2007	5-Year
14	17.4933	120.77	0.04	0.3048	0.070119	Carina/ 2016	5-Year
15	17.4933	120.77	0.04	0.3048	0.070119	Feria/ 2005	5-Year
16	17.4933	120.77	0.04	0.6096	0.324444	Feria/ 2005	5-Year
17	17.4933	120.77	0.04	0.3048	0.070119	Carina/ 2016	5-Year
18	17.4933	120.77	0.04	0.3048	0.070119	Pepeng/ 2009	5-Year
19	17.4933	120.77	0.04	0.3048	0.070119	Ondoy/ 2009	5-Year
20	17.4933	120.77	0.04	0.3048	0.070119	Feria/ 2005	5-Year
21	17.51276	120.7927	0.03	0.6096	0.335936	Feria/ 2005	5-Year
22	17.51276	120.7927	0.03	0.3048	0.075515	Feria/ 2005	5-Year
23	17.51276	120.7927	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
24	17.51276	120.7927	0.03	0.3048	0.075515	Lando/ 2015	5-Year
25	17.51276	120.7927	0.03	0.3048	0.075515	Ondoy/ 2009	5-Year
26	17.51276	120.7927	0.03	0.3048	0.075515	Mina/ 2007	5-Year
27	17.51276	120.7927	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
28	17.51276	120.7927	0.03	0.3048	0.075515	Feria/ 2005	5-Year
29	17.51276	120.7927	0.03	0.3048	0.075515	Feria/ 2005	5-Year
30	17.51276	120.7927	0.03	0.3048	0.075515	Pepeng/ 2009	5-Year
31	17.51276	120.7927	0.03	0.3048	0.075515	Mina/ 2007	5-Year
32	17.51276	120.7927	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
33	17.51276	120.7927	0.03	0.3048	0.075515	Feria/ 2005	5-Year
34	17.51276	120.7927	0.03	0.3048	0.075515	Lawin/ 2016	5-Year
35	17.51276	120.7927	0.03	0.3048	0.075515	Feria/ 2005	5-Year

RMSE: 0.346129

ANNEX 12. Educational Institutions affected by flooding in Ikmin Floodplain

Table A-12.1. Educational Institutions affected by flooding in the Ikmin Floodplain

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 Ikmin 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. Health Institutions affected by flooding in Buaya Floodplain

Table A-13.1. Medical institutions affected by flooding in the Ikmin floodplain

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 affected by flooding in the Ikmin floodplain

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			