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

LiDAR Surveys and Flood Mapping of Linao River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Isabela State University (ISU)

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
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
ISU	Isabela State University
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSO	National Statistics Office
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
RBCO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LINAO RIVER

Enrico C. Paringit, Dr. Eng. and Januel P. Floresca, Ph.D.

1.1 Background of the Phil-LiDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through the Department of Science and Technology (DOST). The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Isabela State University (ISU). ISUis 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 ten (10) river basins in the Cagayan Valley Region.. The university is located in the Municipality of Echague in the province of Isabela.

1.2 Overview of the LinaoRiver Basin

The Linao River Basin is located in the central upper portion of the Cagayan Valley Region, andcovers the municipalities of Abulug, Aparri, and Ballesteros. The Department of Environment and Natural Resources (DENR) River Basin Control Office (RBCO) identified the basin to have a drainage area of 234 km2, and an estimated 496 million cubic meter (MCM) annual run-off (RBCO, 2015). It is a tributary of the Cagayan River.The river basin'smain stem, the Linao River, is part of the ten (10) river systems in Region II, or the Cagayan Valley Region.

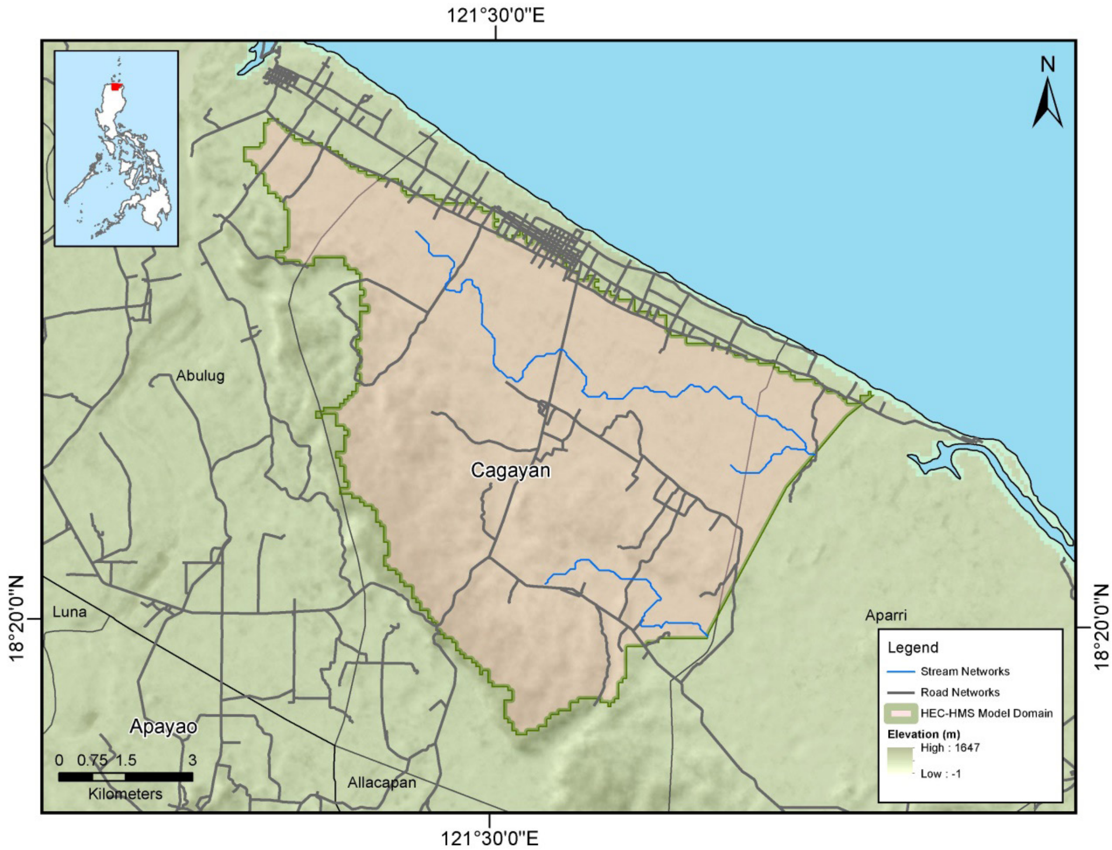

Figure 1. Location map of the Linao River Basin (in brown)

The region is also home to the Linao Swamp,an extensive wetland characterized by nipa (Nypa fruticans) swamps, mangroves, small lakes and tidal marshes. Various rivers and creeks cross the sparsely populated swamp. Irrigated rice fields are located at the eastern border. Domestic water buffaloes frequent the swamp. Large flocks of ducks, herons, and wadershave been observed in Linao, but most other birds have not been identified. Agricultural encroachment and the creation of fishponds threaten this undiscovered wetland. There iscurrently no available information on hunting levels in the area. Further surveys are needed to assess the status and significance of this site.

According to the 2010 national census conducted by the National Statistics Office (NSO), the population of residents within the immediate vicinity of the Linao River is 4,862 persons, which is distributed among the Barangaysof Bisagu, Bulala Norte, Linao, and Zinarag in the Municipality of Aparri. The main sources of livelihood of these communities are farming, fishing, and woodcraft furniture production(Lancion and de Guzman, 1995).

Aparri is a first-class municipality in the province of Cagayan. Itsits at the mouth of the Cagayan River, the longest river in the Philippines, located about 55 miles north of Tuguegarao, the provincial capital. Based on the 2015 NSO census, the Municipality of Aparrihas a total population of 65,649 persons. It is politically subdivided into forty-two (42) barangays: Backiling, Bangag, Binalan, Bisagu, Bukig, Bulala Norte, Bulala Sur, Caagaman, Centro 1 (Pob.), Centro 2 (Pob.), Centro 3 (Pob.), Centro 4 (Pob.), Centro 5 (Pob.), Centro 6 (Pob.), Centro 7 (Pob.), Centro 8 (Pob.), Centro 9 (Pob.), Centro 10 (Pob.), Centro 11 (Pob.), Centro 12 (Pob.), Centro 13 (Pob.), Centro 14 (Pob.), Centro 15 (Pob.), Dodan, Fuga Island, Gaddang, Linao, Mabanguc, Macanaya (Pescaria), Maura, Minanga, Navagan, Paddaya, Paruddun Norte, Paruddun Sur, Plaza, Punta, San Antonio, Sanja, Tallungan, Toran, and Zinarag. Four (4) of these barangays are within the immediate vicinity of the Linao River,

Aparri has an approximate annual income of PHP90 million. The valley is one of the largest tobacco-producing sections in the Philippines, and the municipalityitself runsa considerable coastwise trade. In most barangays of Aparri, nipa-gathering is another source of income. The municipality functions as the center of fishery, business, and trade inthe northern coastal area of Luzon. Upgrading of social services and industrial development is also prioritized by Aparri.

Ballesteros, on the other hand, is a fifth-class municipalityinthe CagayanProvince. It has a population of

34,299 persons (NSO, 2015), and is generally occupied by Ilocano people. It is politically subdivided into nineteen (19) barangays: Ammubuan, Baran, Cabaritan East, Cabaritan West, Cabayu, Cabuluan East, Cabuluan West, Centro East (Poblacion), Centro West (Poblacion), Fugu, Mabuttal East, Mabuttal West, Nararagan, Palloc, Payagan East, Payagan West, San Juan, Santa Cruz, and Zitanga. Ballesteros is famous for the production of patupat and royal bibingka.

The prevailing climate type in theCagayan Valley Region is Type III, in consonance with Corona's Classification of Climate. This particular climate type is characterized by unpronounced seasons. The dry season is very short, lasting only from one (1) to three (3) months;which is either from December to February, or from March to May. It is wet for the rest of the year.

The most recent flooding event in the regionoccurredin June 2012,which was caused by Typhoon Butchoy and enhanced by the southwest monsoon.The municipalities of Aparri and Ballesteros were among the areas devastated by Typhoon Ineng on August 21, 2015, as well as Typhoon Lawin on October 19, 2016.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LINAO FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Linao Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the Linao floodplain in the Cagayan province. These missions were planned for fourteen (14) lines that ran for at most four and a half (4.5) hours including take-off, landing and turning time. The Pegasus and Gemini LiDAR systems were used for the survey (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR systems used are found in Tables 1 and 2.Figure 2 illustratesthe flight plans for the Linao floodplain.

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

Block Name	Flying Height(m AGL)	Overlap (%)	Field of View(θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency(Hz)	Average Speed(kts)	Average Turn Time (Minutes)
BLK2A	1000	30	50	200	30	130	5
BLK2B	1000	30	50	200	30	130	5
BLK2C	1000	30	50	200	30	130	5
BLK2F	1000	30	50	200	30	130	5

Table 2. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height(m AGL)	Overlap (%)	Field of View(θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency(Hz)	Average Speed(kts)	Average Turn Time (Minutes)
CAG 11D	1000	30	50	200	30	130	5

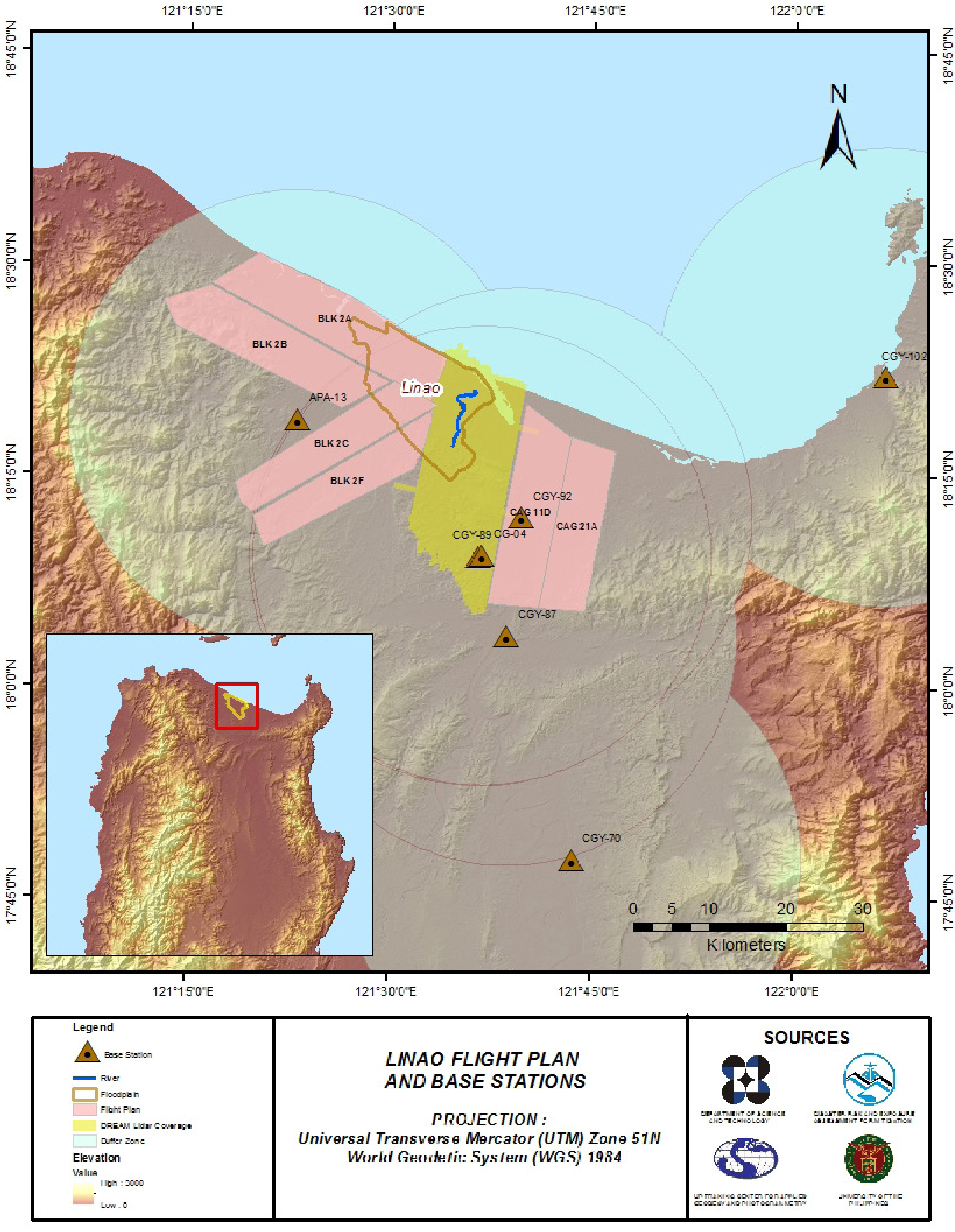

Figure 2. Flight plans and base stations used to cover the Linao floodplain survey

2.2 Ground Base Stations

The fieldteam for this undertaking was able to recover seven (7) NAMRIA horizontal reference points: APA-13, CGY-70, CGY-87, CGY-89, CGY-91, CGY-92, and CGY-102, which are of second (2nd) order accuracy. The team also recovered NAMRIA benchmark CG-04, which was also processed as a ground control point. The certifications for the NAMRIA reference points are found in Annex 2. The baseline processing report for CG-04 is in Annex 3. These were used as base stations during the flight operations for the entire duration of the survey, held on November 11-30, 2015 and May 5, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. The flight plans and locations of base stations used during the aerial LiDAR acquisition in the Linao floodplain are shown in Figure 2.The composition of the project team is presented in Annex 4.

Figure 3 to Figure 8 depict the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 8 providethe details ofthe following NAMRIA control stations. Table 9 lists all ground control points occupied during the acquisition,alongwith the corresponding dates of utilization.

(a)

(b)

Figure 3. GPS set-up over APA-13 located at the edge of the PCCP, 70 meters northeast of a waiting shed near the barangay hall in Tumog, Municipality of Luna.

Table 3. Details of the recovered NAMRIA horizontal control point APA-13, used as base station for the LiDAR acquisition.

Station Name	APA-13	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	18°19’2.39264” North
	Longitude	121°22’58.62210” East
	Ellipsoidal Height	17.98200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	540482.023 meters
	Northing	2025924.156 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	18°18’56.17679” North
	Longitude	121°23’3.20117” East
	Ellipsoidal Height	51.00500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	329102.89 meters
	Northing	2025930.60 meters

(a)

(b)

Figure 4. GPS set-up over CGY-70 located at the corner of the basketball court inside Estefania Elementary School campus (a) and NAMRIA reference point CGY-70 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point CGY-70, used as base station for the LiDAR acquisition.

Station Name	CGY-70	
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' 54.79038" North 121° 43' 31.26837" East 26.85900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	576904.118 meters 1968617.425 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17° 47' 48.71170" North 121° 43' 35.88859" East 62.40000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	364899.00 meters 1968239.03 meters

(a)

(b)

Figure 5. GPS set-up over CGY-87 located on a solar dryer at Barangay Cabayabasan, fronting the barangay hall, in the municipality of Lal-lo.

Table 5. Details of the recovered NAMRIA horizontal control point CGY-87, used as base station for the LiDAR acquisition.

Station Name	CGY-87	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	18° 3’ 46.30032”North
	Longitude	121° 38’ 38.76326”East
	Ellipsoidal Height	37.21200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	568188.029 meters
	Northing	1997837.978 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	18° 3’ 40.15861” North
	Longitude	121° 38’ 43.36193” East
	Ellipsoidal Height	71.69600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	356498.94meters
	Northing	1997546.44meters

(a)

(b)

Figure 6. GPS set-up over CGY-89 located on the left side of the access to Logac National High School in Barangay Logac, Municipality of Lal-lo (a) and NAMRIA horizontal reference point CGY-89 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point CGY-89, used as base station for the LiDAR acquisition.

Station Name	CGY-89	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	18° 9' 24.10576"North
	Longitude	121° 36' 27.80546" East15.88200 meters
	Ellipsoidal Height	
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	564302.582 meters
	Northing	2008210.132 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	18° 9' 17.94119" North
	Longitude	121° 36' 32.39657" East
	Ellipsoidal Height	49.97100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	352726.82 meters
	Northing	2007958.66 meters

(a)

(b)

Figure 7. GPS set-up over CGY-102 located about two (2) meters from the S corner of the triangular island intersection of the national highway and the road to Port Irene (a) and NAMRIA reference point CGY-102 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point CGY-102, used as base station for the LiDAR acquisition.

Station Name	CGY-102	
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	18° 22’ 15.98573” North 122° 6’ 41.74346” East 22.60800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	617476.569 meters 2032192.366 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 22’ 9.81367” North 122° 6’ 46.31361” East 57.19500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	406145.45 meters 2031351.34 meters

(a) (b)

Figure 8. GPS set-up over CG-04 located on a bridge near Logac National High School, Municipality of Lal-lo (a) and NAMRIA reference point CG-04 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA vertical reference point CG-04, with processed coordinates, used as base station for the LiDAR acquisition.

Station Name	CG-04	
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	18° 09' 06.42823" North 121° 36' 59.69517" East 20.039 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 09' 00.26539" North 121° 37' 04.28663" East 54.165 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	353659.894 meters 2007408.207 meters

Table 9. Ground control used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 11, 2015	2838P	1BLK2CF315A	CGY-110, APA-13
November 12, 2015	2842P	1BLK2B316A	CGY-87, APA-13, CGY-110
November 13, 2015	2846P	1BLK2FSBSA317A	CGY-87, APA-13, CGY-110
November 13, 2015	2848P	1BLK2AS317B	CGY-87, APA-13, CGY-110
November 14, 2015	2852P	1BLK2AS318B	CGY-87, APA-13, CGY-110
November 30, 2015	2914P	1BLK3A334A	CGY-70, CGY-92, CGY-102
May 5, 2016	3999G	2CAG2P126B	CGY—89, CG-04

2.3 Flight Missions

Three (3) flight missions conducted under the DREAM Program covered 82.54 square kilometers within the Linao floodplain. These missions are listed in Table 10. Seven (7) flight missions were conducted to complete the LiDAR data acquisition in the Linao floodplain, for a total of 22 hours and 15 minutes (22+15) of flying time for RP-C9122 and RP-C9022. All missions were acquired using the Pegasus and Gemini LiDAR systems. Annex 6 presents the flight logs for the survey. Table 11indicatesthe total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions under the DREAM Program which covered parts of the Linao floodplain.

Flight Number	Mission Name	Area Surveyed within the Flood-plain (km^2)
748G	2CAG11CS319B	7.74
750G	2CAG11B320A	60.20
752G	2CAG11BS320A	80.85

Table 11. Flight missions for LiDAR data acquisition in the Linao 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)	Number of Images	Flying Hours	
							Hr	Min
November 11, 2015	2838P	259.64	260.54	53.1	207.44		4	5
November 12, 2015	2842P	175.55	143.33	3.66	139.67	351	2	59
November 13, 2015	2846P	376.32	301.79	56.55	245.24	742	4	23
November 13, 2015	2848P	200.77	63.49	27.94	35.55	128	2	29
November 14, 2015	2852P	200.77	74.03	23.69	50.34	287	3	23
November 30, 2015	2914P	133.32	190.79	0	190.79	-	2	29
May 5, 2016	3999G	151.92	107.84	0	107.84	-	2	27
TOTAL		1124.04	1277	190.92	1086.08	1508	22	15

Table 12. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2838P	1100	30	50	200	30	130	5
2842P	850	30	50	200	30	130	5
2846P	1100	30	50	200	30	130	5
2848P	900	30	50	200	30	130	5
2852P	900	30	50	200	30	130	5
2914P	1100	25	50	200	30	130	5
3999G	1000	30	50	125	20	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Linao floodplain (See Annex 7 for the flight status reports). The Linao floodplain is located in the provinces of Cagayan and Apayao, with majority of the floodplain situated within the Municipalities of Ballesteros and Aparri in Cagayan. Both of these municipalities, as well as the Municipality of Santa Marcela in Apayao, are mostly covered by the survey. The list of municipalities surveyed, with at least one (1) square kilometer coverage, is givenin Table 13. The actual coverage of the LiDAR acquisition for the Linao floodplain is presented in Figure 9.

Table 13. List of municipalities and cities surveyed during the Linao floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed (%)
Cagayan	Ballesteros	117.92	117.51	99.65
	Abulug	123.19	119.81	97.25
	Pamplona	206.54	183.72	88.95
	Allacapan	252.24	165.63	65.66
	Camalaniugan	80.92	51.37	63.49
	Aparri	254.03	120.63	47.49
	Lal-lo	760.44	211.95	27.87
	Buguey	98.04	12.51	12.76
	Sanchez Mira	205.31	15.79	7.69
	Enrile	161.25	6.89	4.27
	Solana	238.48	7.78	3.26
	Tuguegarao City	129.61	1.70	1.31
	Amulung	231.16	2.33	1.01
Apayao	Santa Marcela	47.22	40.84	86.48
	Pudtol	283.66	67.19	23.69
	Flora	321.67	59.62	18.54
	Luna	603.01	42.71	7.08
Total		**4,114.69**	**1,227.98**	**29.84%**

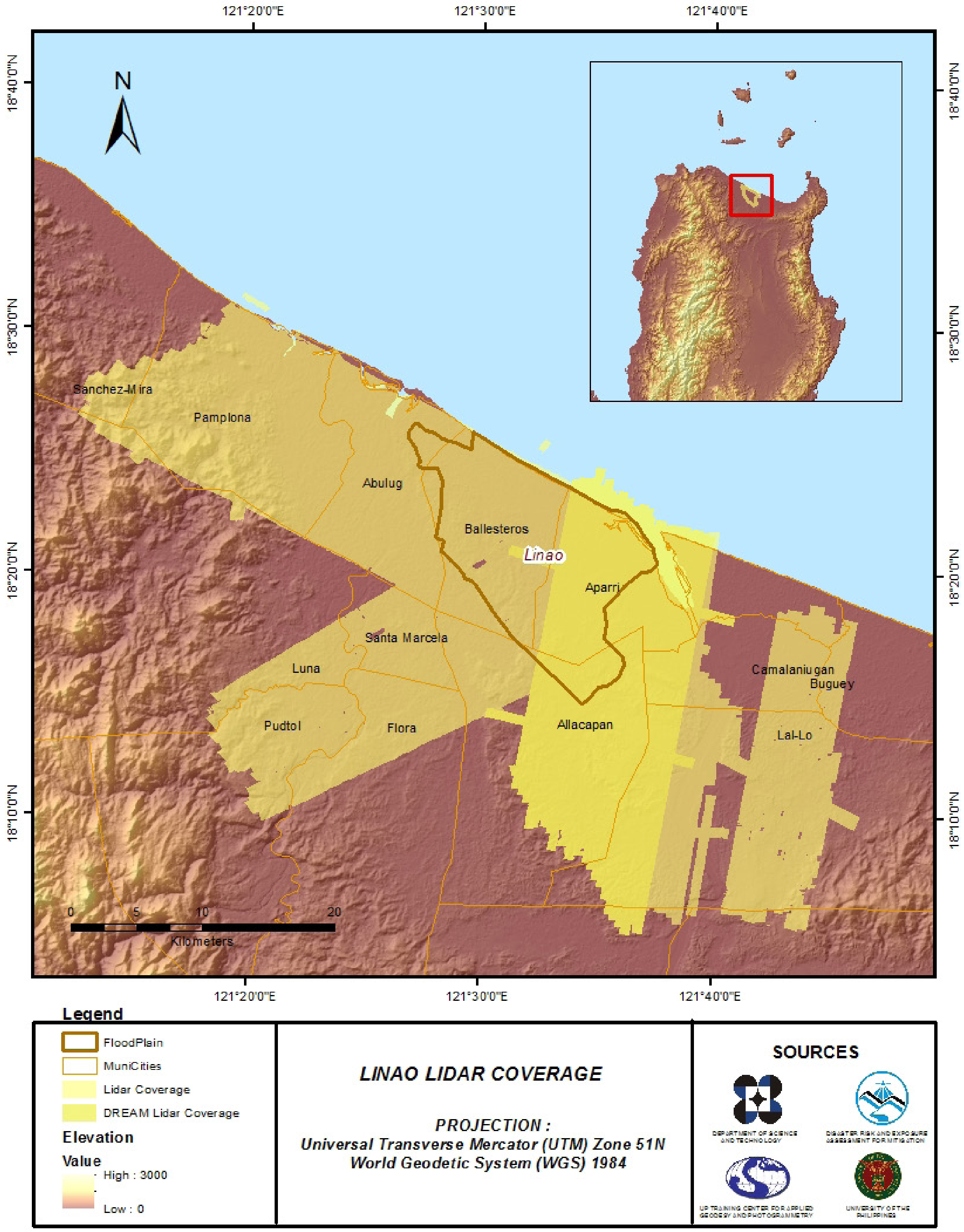

Figure 9. Actual LiDAR survey coverage of the Linao floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LINAO 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 DACwere checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was executedin order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

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 (DVBC). 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 diagram shown in Figure 10.

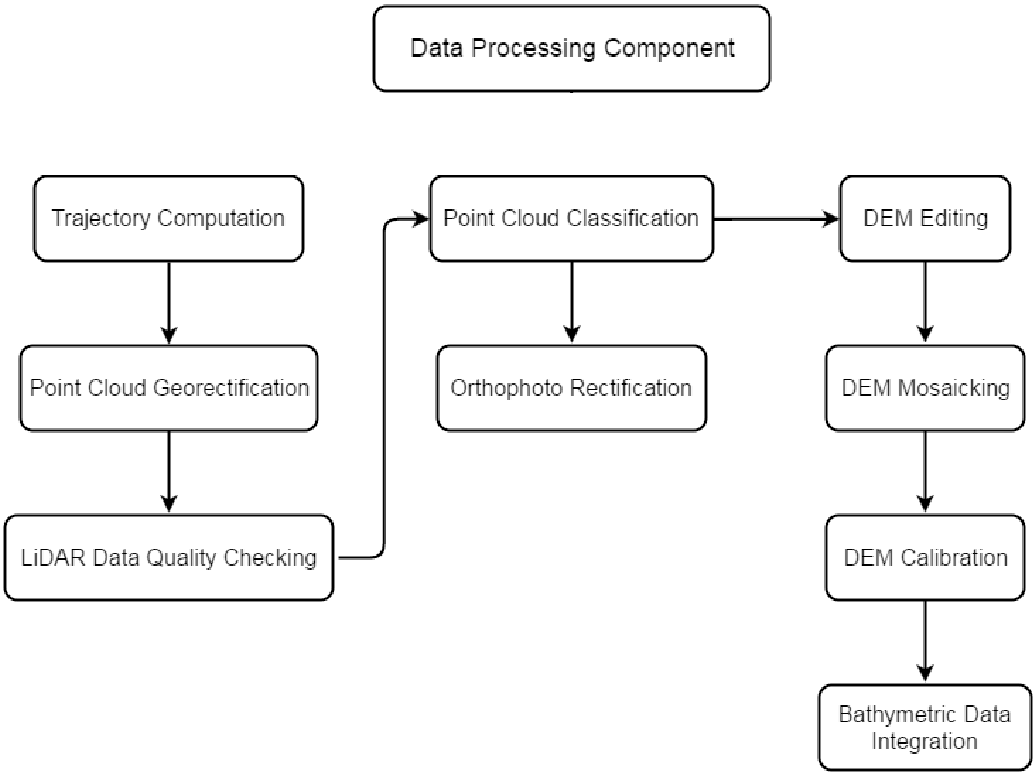

Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for the Linao floodplain can be found in Annex 5. Missions flown during the surveys conducted in November 2013 and May 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system; while missions acquired during the survey in November 2015 were flown using the Pegasus system over Ballesteros, Cagayan. The DACtransferred a total of 146.18 Gigabytes of Range data, 1.69 Gigabytes of POS data, 276.41 Megabytes of GPS base station data, and 220.47 Gigabytes of raw image data to the data server on December 5, 2013 for the first survey;on December 7, 2015 for the second survey; and on June 21, 2016 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Linao was fully transferred on December 8, 2015, as indicated on the Data Transfer Sheets for the Linao floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2914P, one of the Linao flights, which arethe North, East, and Down position RMSE values, are illustratedin 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 fell on November 30, 2015at 00:00hrs. on that week. The y-axis is the RMSE value for that particular position.

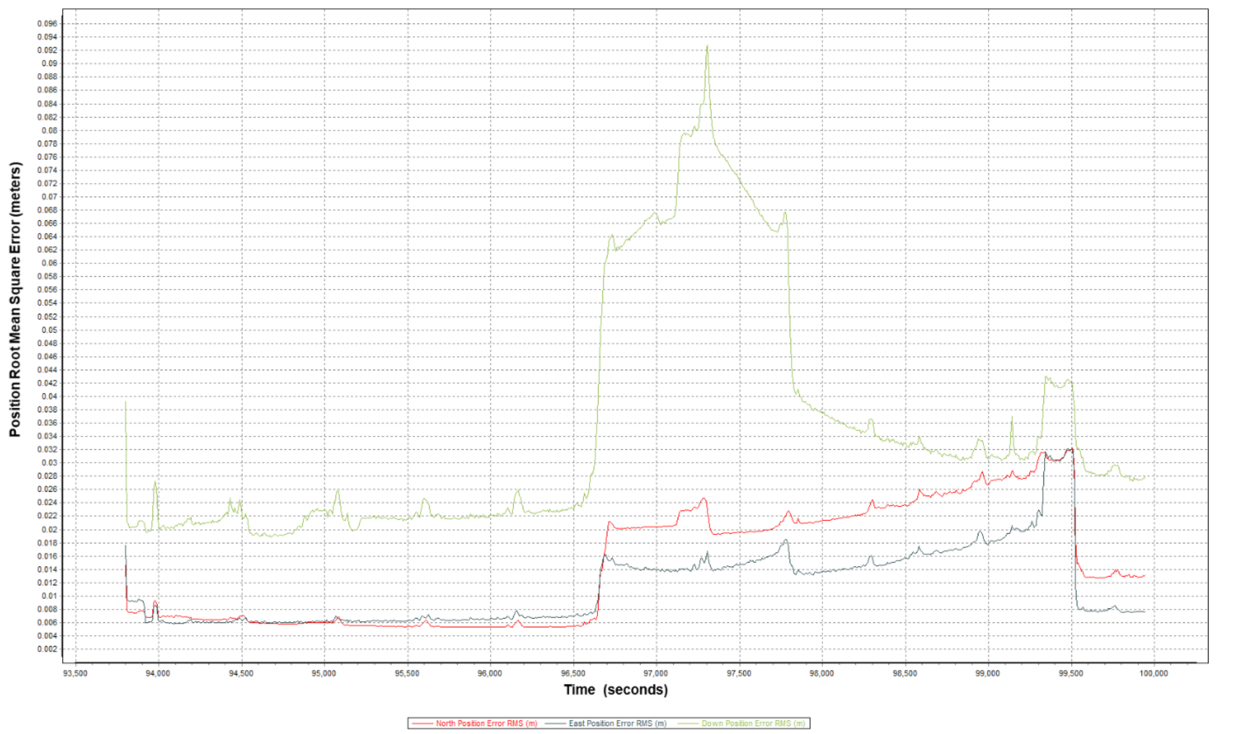

Figure 11. Smoothed Performance Metric Parameters of Linao Flight 2914P.

The time of flight was from 93500 seconds to 100000 seconds, which corresponds to the morning of November 30, 2015. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute 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 corresponds 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 peaked at 2.47 centimeters, the East position RMSE peaked at 1. 85 centimeters, and the Down position RMSE peaked at 9.28 centimeters, which are all within the prescribed accuracies described in the methodology.

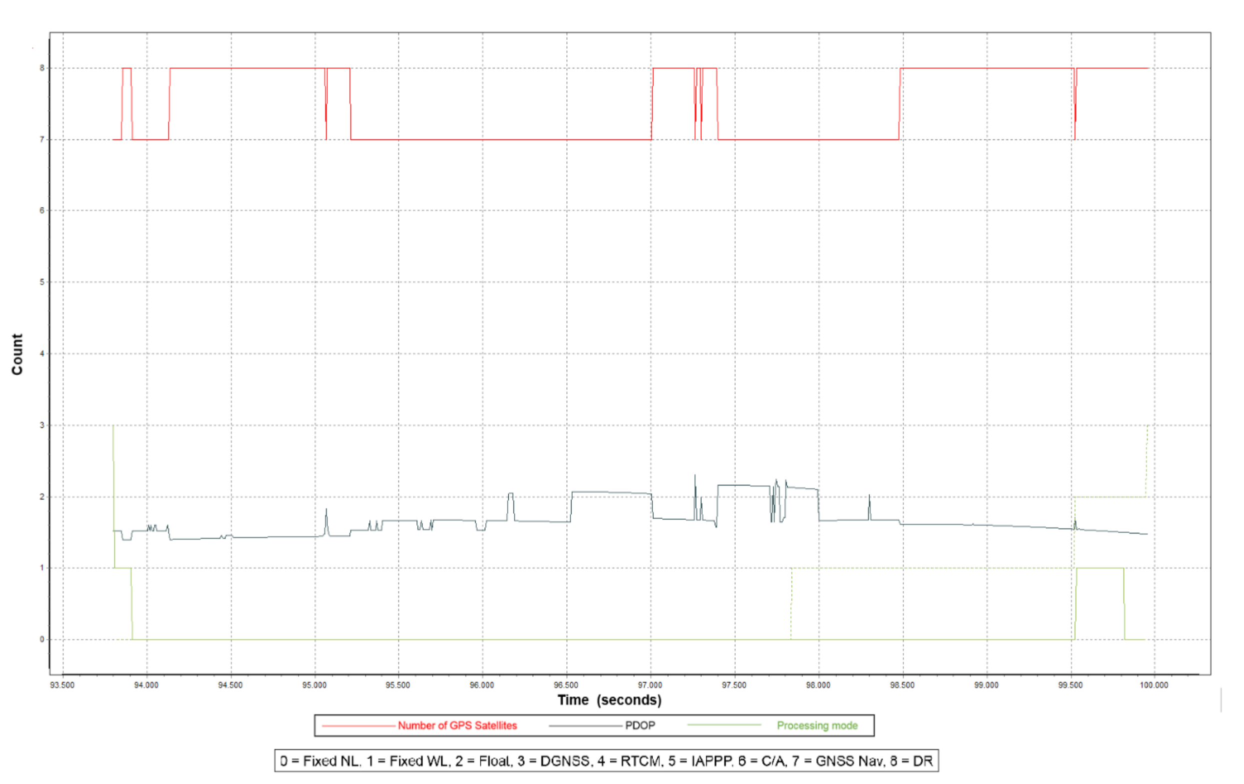

Figure 12. Solution Status Parameters of Linao Flight 2914P.

The Solution Status parameters of flight 2914P, one of the Linao flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to seven (7). Majority of the time, the number of satellites tracked was between seven (7) and eight(8). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remainedat the value of zero (0) for majority of the survey. The value of zero (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 withthe accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Linao flights is exhibited in Figure 13.

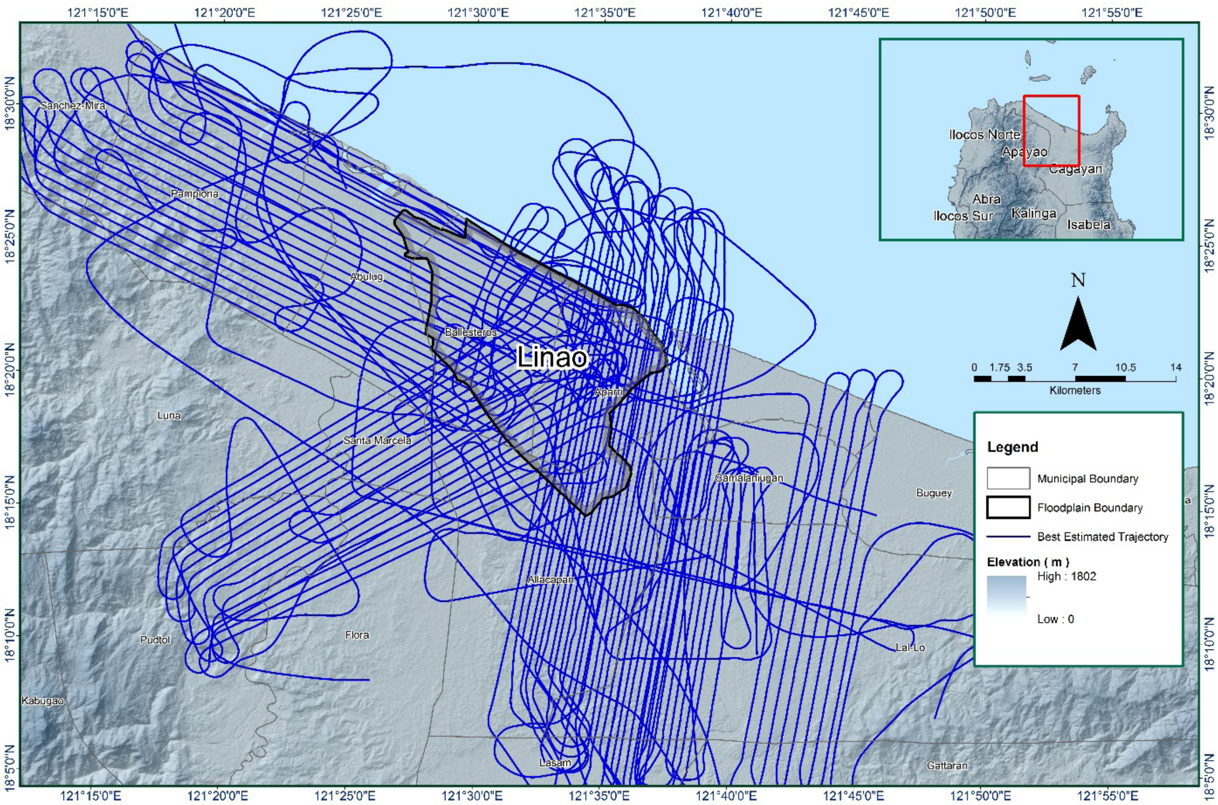

Figure 13. The best estimated trajectory conducted over the Linao floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains seventy-two (72) flight lines. Thirty-seven (37) flight lines contain one (1) channel since the Gemini system contains only one (1) channel, while thirty-five (35) flight lines contain two (2) channels using the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over theLinao floodplain are given in Table 14.

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

Parameter	Absolute Value	Computed Value
Boresight Correction stdev)	(<0.001degrees	0.000165
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000360
GPS Position Z-correction stdev	(<0.01meters)	0.0011

Optimum accuracy wasobtained for all Linao flights, based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Linao Floodplain are presented in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

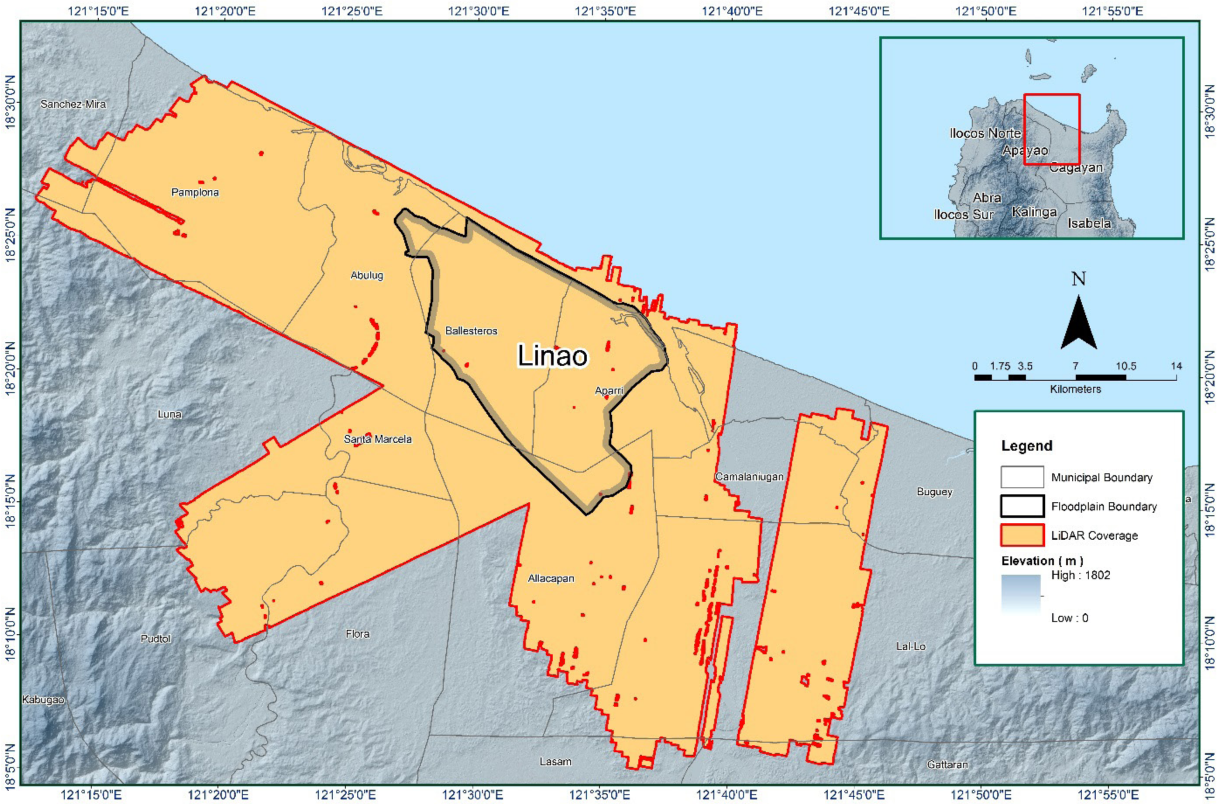

Figure 14. Boundaries of the processed LiDAR data over the Linao Floodplain

The total area covered by the Linao missions is 1215.08 sq.km, comprised of nine (9) flight acquisitions grouped and merged into eleven (11) blocks, as indicatedin Table 15.

Table 15. List of LiDAR blocks for the Linao floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cagayan_reflights_Tuguegarao_Blk2C_additional	2852P	14.08
Cagayan_reflights_Tuguegarao_Cag11D	2914P	164.63
Cagayan_reflights_Tuguegarao_Blk2F_supplement	2846P	71.96
Cagayan_reflights_Tuguegarao_Blk2A_supplement	2846P	199.64
Cagayan_reflights_Tuguegarao_Blk2A	2848P 2852P	131.64
Cagayan_reflights_Tuguegarao_Blk2A_additional	2848P	54.49
Cagayan_reflights_Tuguegarao_Blk2B	2842P	130.57
Cagayan_reflights_Blk11C	3999G	100.26
Cagayan_Blk11C	748G	174.26
Cagayan_Blk11Bs	752G	44.31
Cagayan_Blk11B	750G	129.24
	TOTAL	1,215.08 **sq.km**

The overlap data for the merged LiDAR blocks, reflecting the number of channels that pass through a particular location, is shown in Figure 15.Since the Gemini system employs only one (1) channel, it is expected to have an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

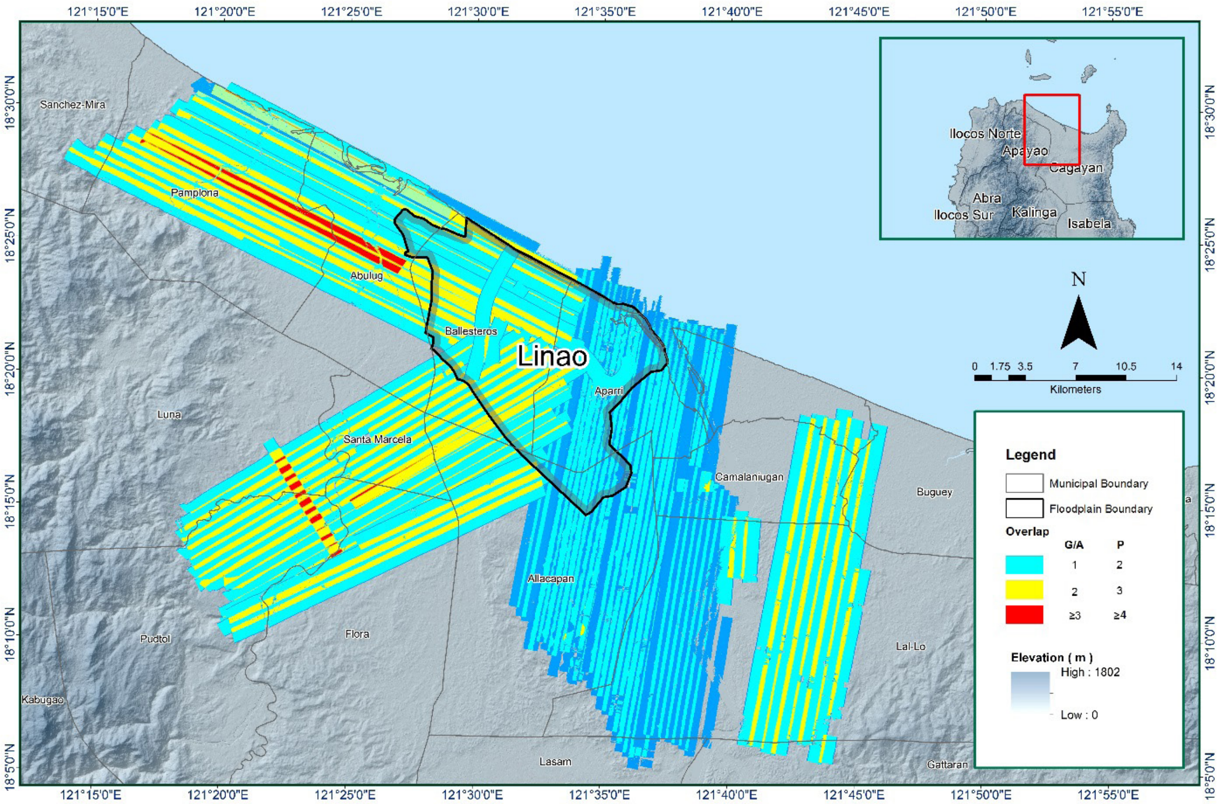

Figure 15. Image of data overlap for Linao floodplain.

The overlap statistics per block for the Linao floodplain can also be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.37% and 57.08%, respectively, which satisfiedthe 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is presentedin Figure 16. It was determined that all LiDAR data for the Linao floodplain satisfy the point density requirement, and that the average density for the entire survey area is 2.80 points per square meter.

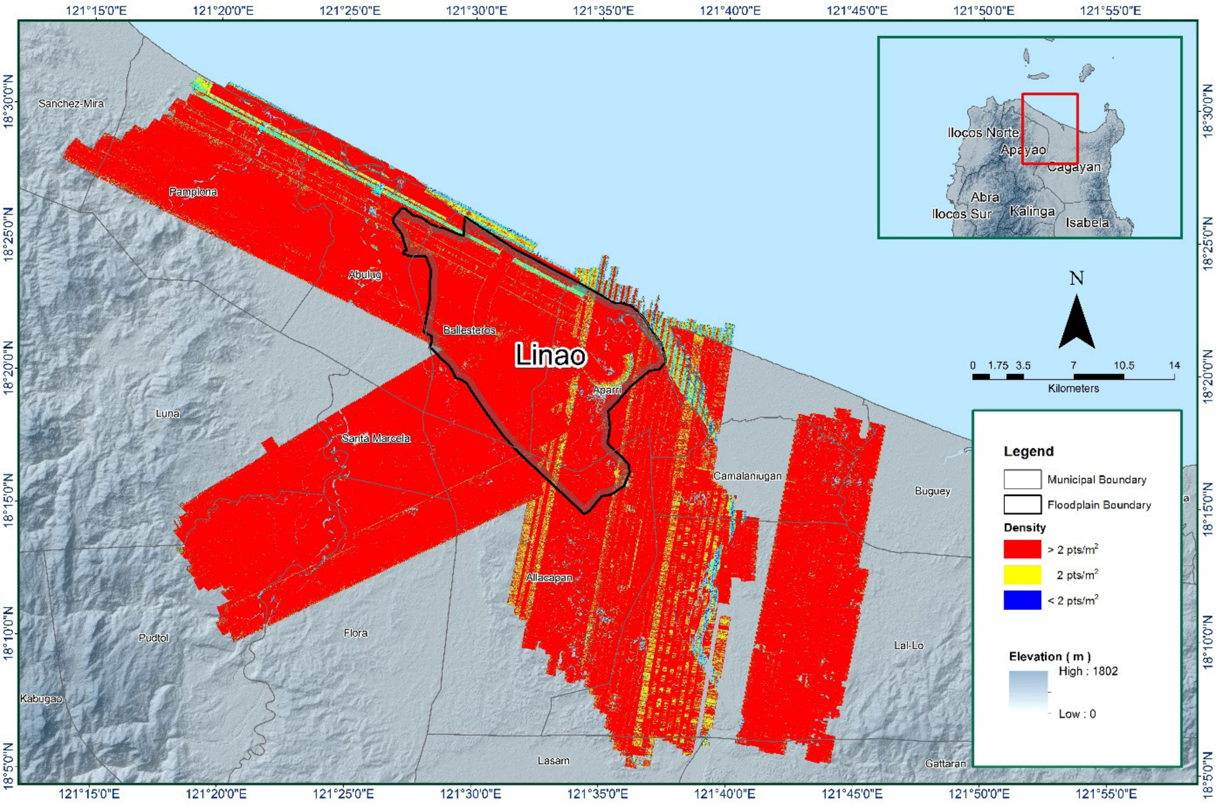

Figure 16. Pulse density map of merged LiDAR data for the Linao floodplain.

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 were investigated further using the Quick Terrain (QT) Modeler software.

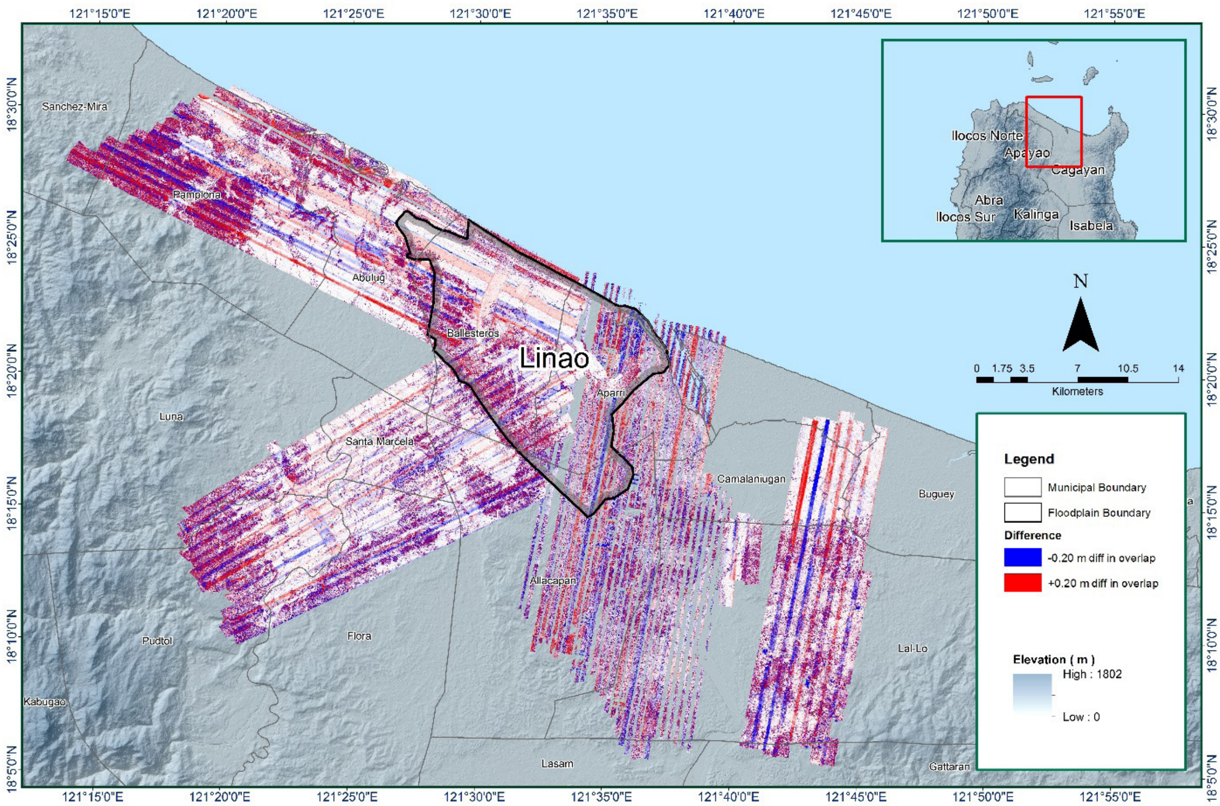

Figure 17. Elevation difference map between flight lines for Linao floodplain.

A screen capture of the processed LAS data from Linao flight 2914P loaded in QT Modeler is provided in Figure 18. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there weredifferences in elevation, but the differences didnot exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becamesatisfactory. No reprocessing was done for this LiDAR dataset.

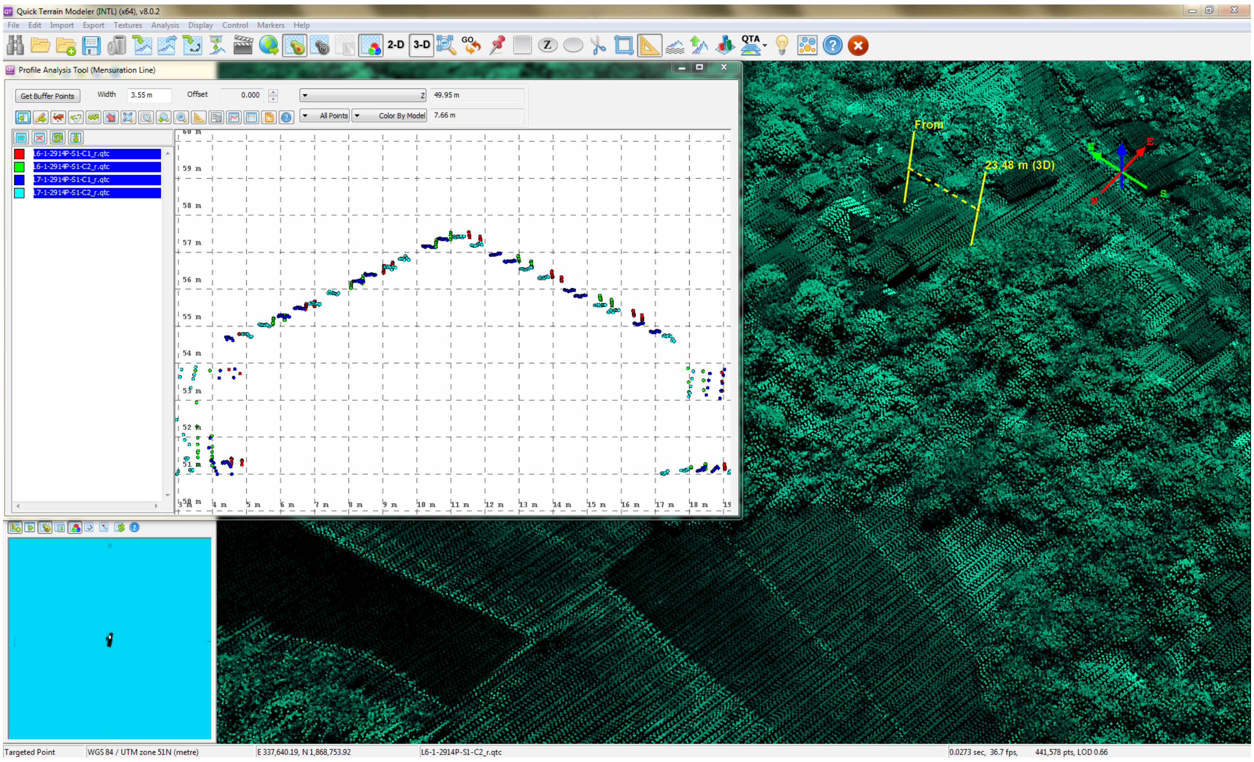

Figure 18. Quality checking for a Linao flight 2914P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Linao classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,441,007,935
Low Vegetation	1,015,863,925
Medium Vegetation	1,623,438,372
High Vegetation	2,103,119,127
Building	37,994,973

The tile system that the TerraScan employed for the LiDAR data and the final classification image for a block in the Linao floodplain is presented in Figure 19. A total of 2,035 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud had a maximum and minimum height of 487.63 meters and 27.00 meters, respectively.

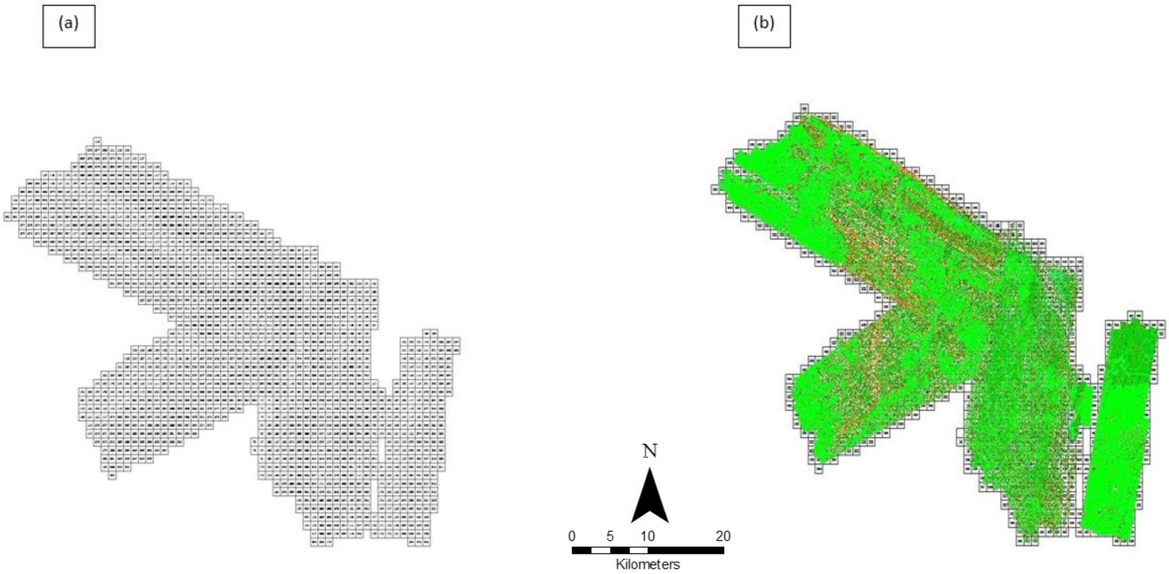

Figure 19. Tiles for Linao floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is exhibited 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 were classified correctly, due to the density of the LiDAR data.

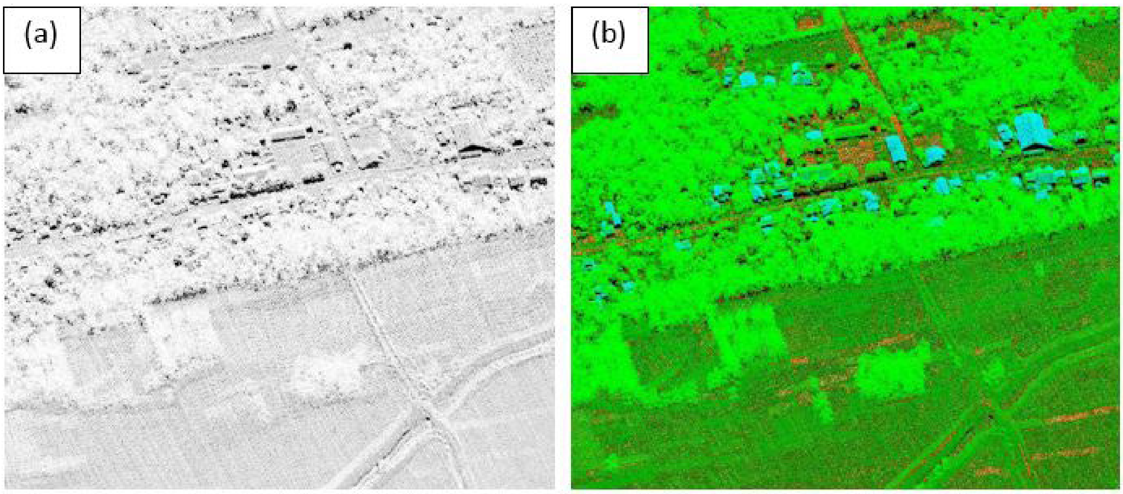

Figure 20. Point cloud before (a) and after (b) classification.

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

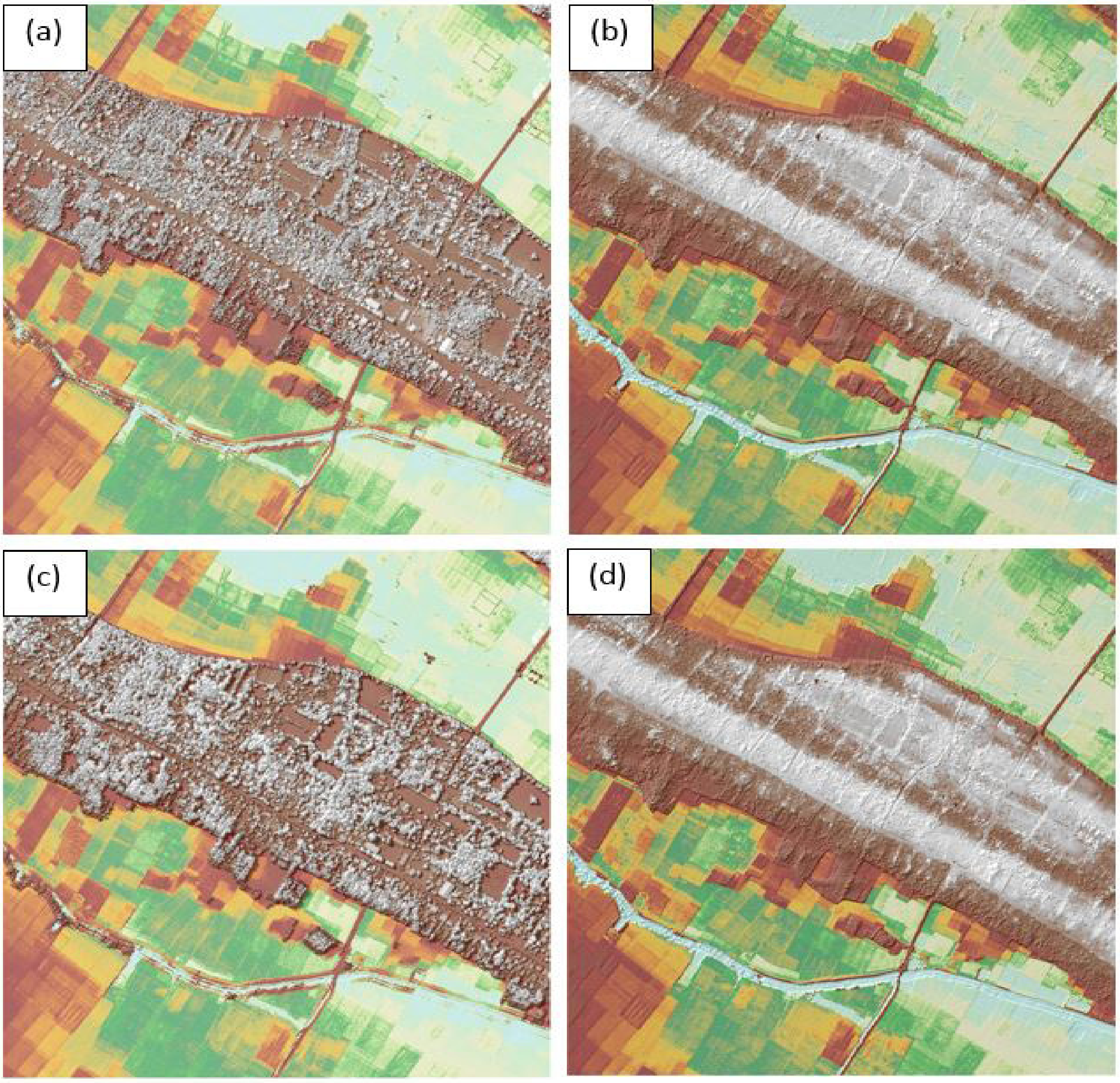

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of the Linao floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,683 1km by 1km tiles area covered by the Linao floodplain is illustratedin Figure 22. After employingtie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Linao floodplain survey attaineda total of 1,052.01 sq.km in orthophotographic coverage, comprised of 3,903 images. Zoomed in versions of sample orthophotographs named in reference to their tile numbers are shown in Figure 23.

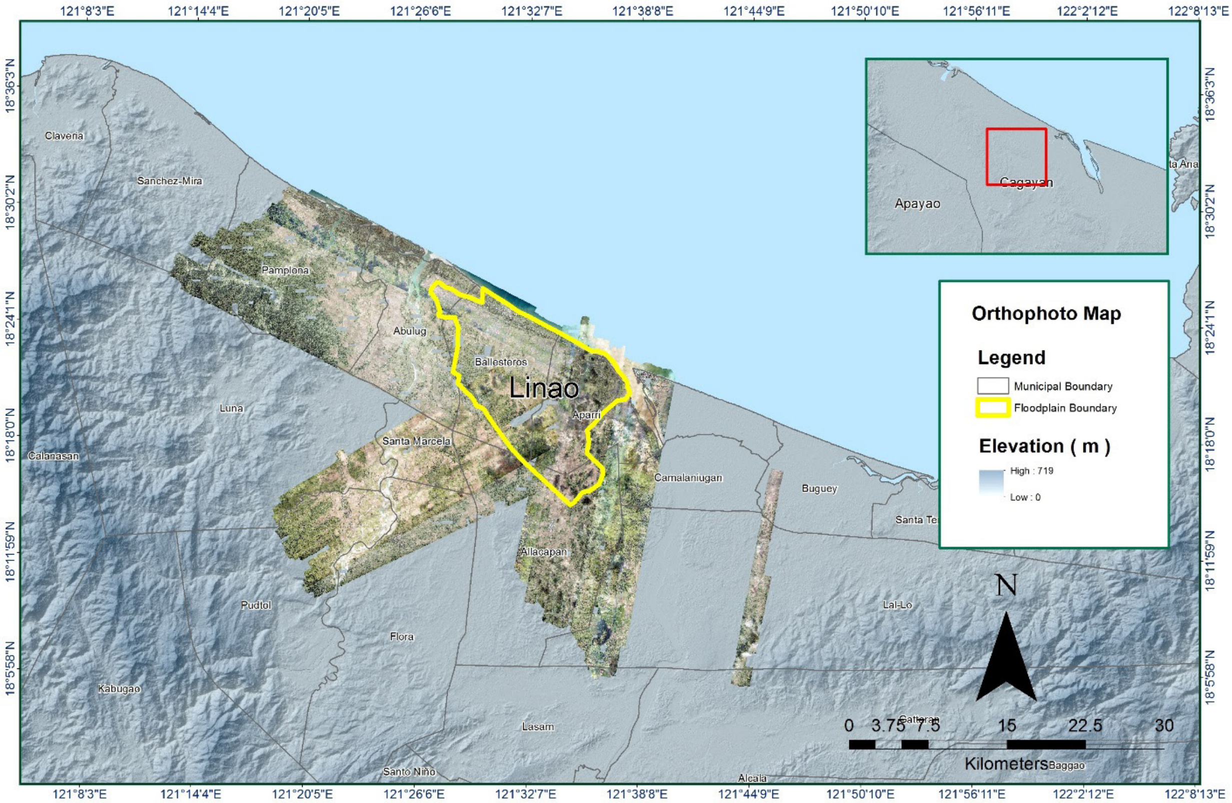

Figure 22. Linao floodplain with available orthophotographs.

Figure 23. Sample orthophotograph tiles for the Linao floodplain.

3.8 DEM Editing and Hydro-Correction

Eleven (11) mission blocks were processed for the Linao floodplain. These blocks are composed of Cagayan, Cagayan_reflights and Cagayan_reflights_Tuguegarao blocks, with a total area of 1,215.08 square kilometers. Table 17 providesthe name and corresponding area of each block, in square kilometers.

Blocks marked with an asterisk (*)in Table 17 were not edited by the ISU Phil – LiDAR 1 Team for this survey. These were already covered by other blocks previously edited by the ISU Phil – LiDAR 1 Team. Their area values written in Table 17 are based on the area coverage of their corresponding LiDAR point cloud data.

Table 17. LiDAR blocks with their corresponding areas.

LiDAR Blocks	Area (sq.km.)
Cagayan_reflights_Tuguegarao_Blk2C_additional	14.08
Cagayan_reflights_Tuguegarao_Cag11D	164.63
Cagayan_reflights_Tuguegarao_Blk2F_supplement	71.96
Cagayan_reflights_Tuguegarao_Blk2A_supplement	199.64
Cagayan_reflights_Tuguegarao_Blk2A	131.64
Cagayan_reflights_Tuguegarao_Blk2A_additional	54.49
Cagayan_reflights_Tuguegarao_Blk2B	130.57
Cagayan_reflights_Blk11C	100.26
Cagayan_Blk11C	174.26
Cagayan_Blk11Bs	44.31
Cagayan_Blk11B	129.24
TOTAL	**1,215.08 sq.km**

Portions of DTM before and after manual editing are shown in Figure 24. A road (Figure 24a) was misclassified and removed during the classification process and had to be interpolated to complete the surface (Figure 24b) to allow for the correct flow of water. An interpolated irrigation (Figure 24c) was retrieved (Figure 24d) in order to hydrologically correct the irrigation system. Another example is an interpolated ridge (Figure 24e) that hadto be recapturedusing object retrieval to achieve the actual surface (Figure 24f). Another caseis a building that wasstill present in the DTM after classification (Figure 24g) and had to be removed through manual editing (Figure 24h).

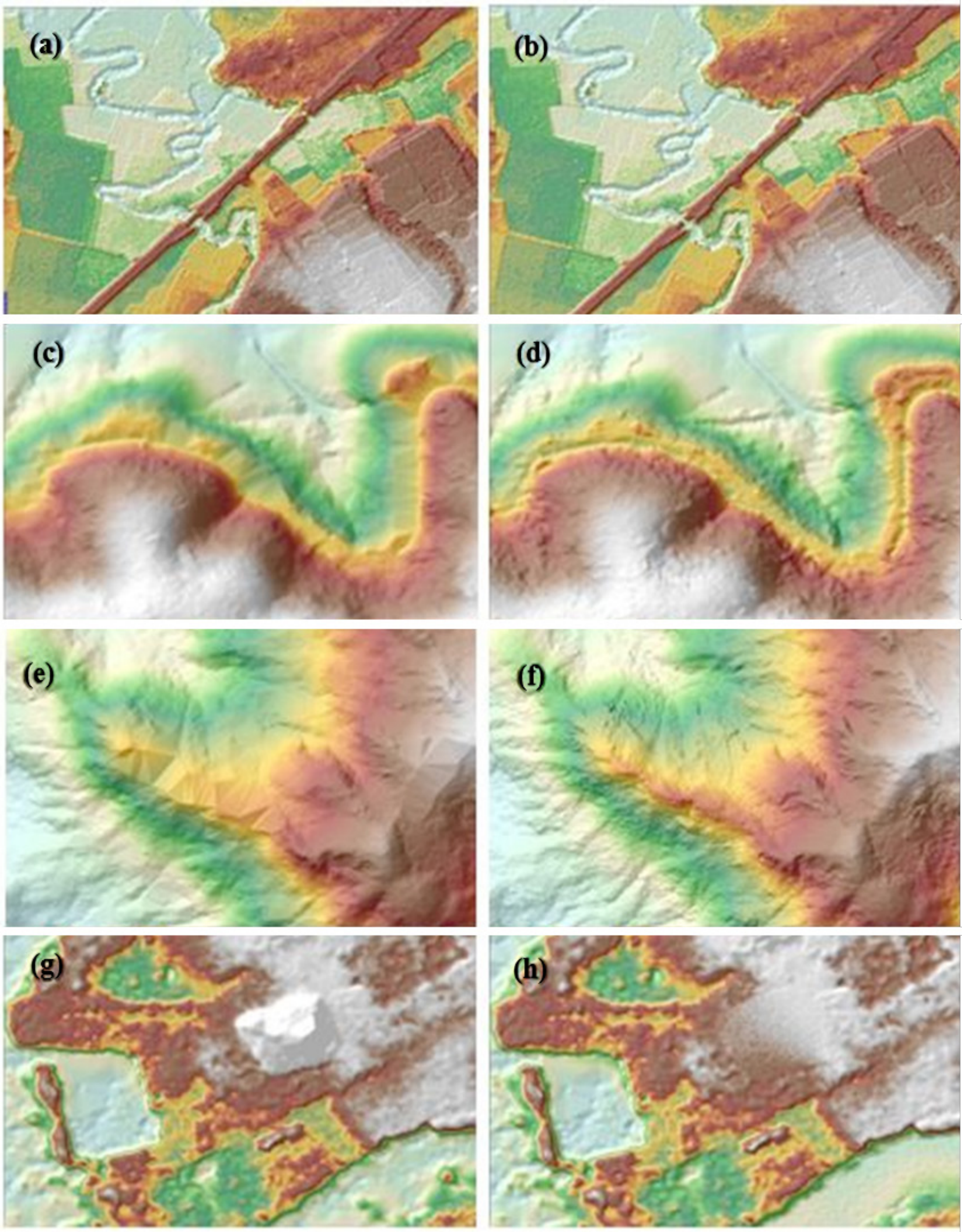

Figure 24. Portions in the DTM of the Linao floodplain – a road before (a) and after (b) manual editing; an irrigation before (c) and after (d) retrieval; interpolated ridge before (e) and after (f) object retrieval; and a building before (g) and after (h) manual editing.

3.9 Mosaicking of Blocks

Cagayan_reflights_Tuguegarao_Blk2G, which was shifted to an existing calibrated Cagayan DEM, was used as the reference block in mosaicking. Table 18 indicatesthe shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for the Linao floodplain is shown in Figure 25. It can be seen that the entire Linao floodplain is 100% covered by LiDAR data.

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

Mission Blocks	Shift Values (meters)		
	x	y	z
Cagayan_reflights_Tuguegarao_Blk2C_additional	-1.62	1.36	-3.95
Cagayan_reflights_Tuguegarao_Cag11D	0.00	0.00	0.00
Cagayan_reflights_Tuguegarao_Blk2F_supplement	-0.72	1.78	-3.77
Cagayan_reflights_Tuguegarao_Blk2A_supplement	-1.72	0.77	-3.92
Cagayan_reflights_Tuguegarao_Blk2A	-5.72	-5.22	-4.97
Cagayan_reflights_Tuguegarao_Blk2A_additional	0.00	0.00	0.00
Cagayan_reflights_Tuguegarao_Blk2B	0.00	0.00	0.00
Cagayan_reflights_Blk11C	0.00	0.00	0.00
Cagayan_Blk11C	0.00	0.00	0.00
Cagayan_Blk11Bs	0.00	0.00	0.00
Cagayan_Blk11B	0.00	0.00	0.00

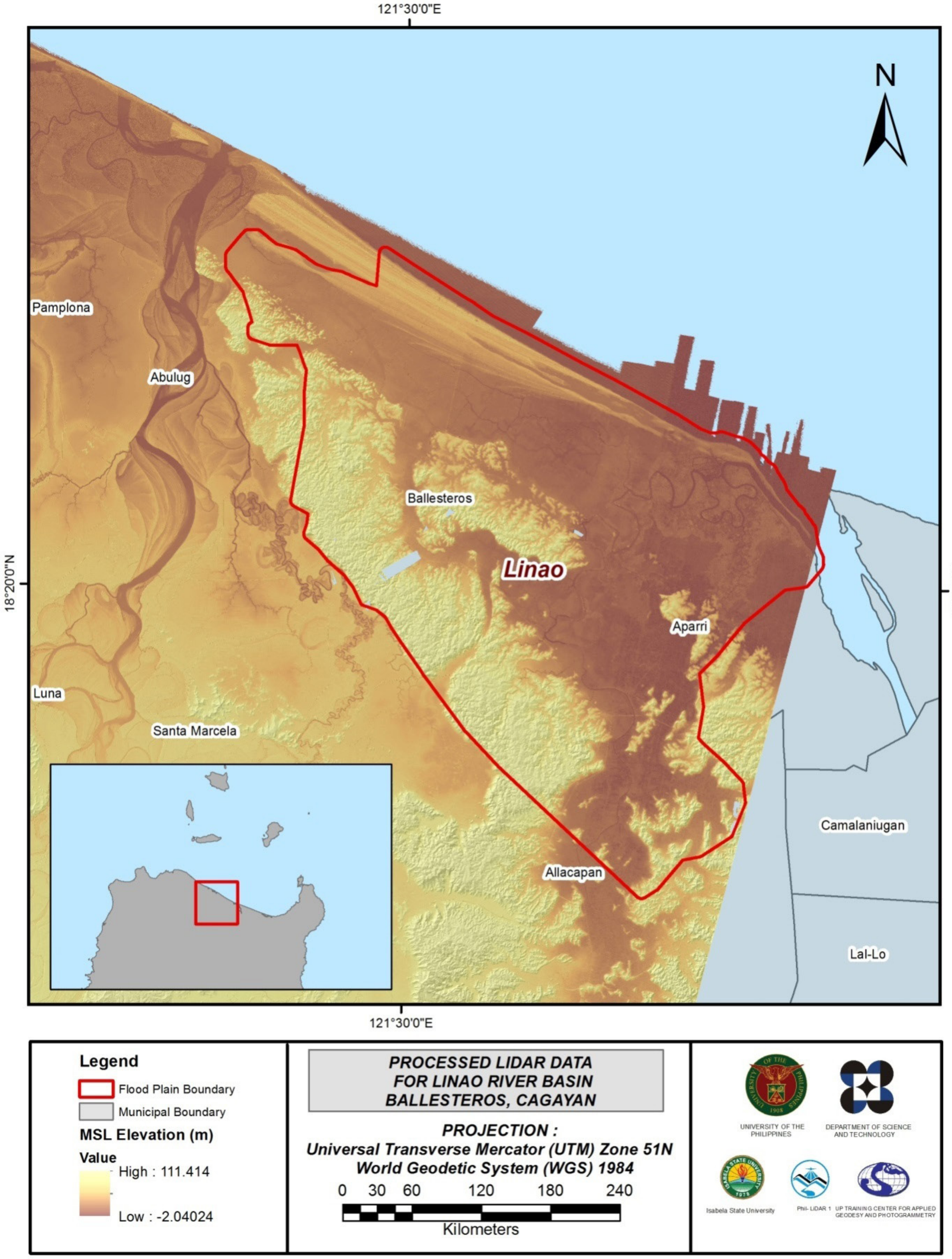

Figure 25. Map of processed LiDAR data for the Linao floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Linao floodplain. The extent of the validation survey in the Cagayan province to collect points with which the LiDAR dataset was validated is illustrated in Figure 26, with the validation survey points highlighted in green. A total of 4,577 survey points were gathered for all the floodplains within Northern Cagayan, where the Linao floodplain is located. However, the point dataset was not used for the calibration of the LiDAR data for Linao because during the mosaicking process, each LiDAR block was referred to the calibrated Cagayan DEM. Therefore, the mosaicked DEM of Linao can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Cagayan LiDAR DTM and ground survey elevation values is reflected in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data, and to obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 4.07 meters, with a standard deviation of 0.14 meters. Calibration of Cagayan LiDAR data was done by subtracting the height difference value, 4.07 meters, from the Cagayan mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between the Cagayan LiDAR data and the calibration data. These values arealso applicable to the Linao DEM.

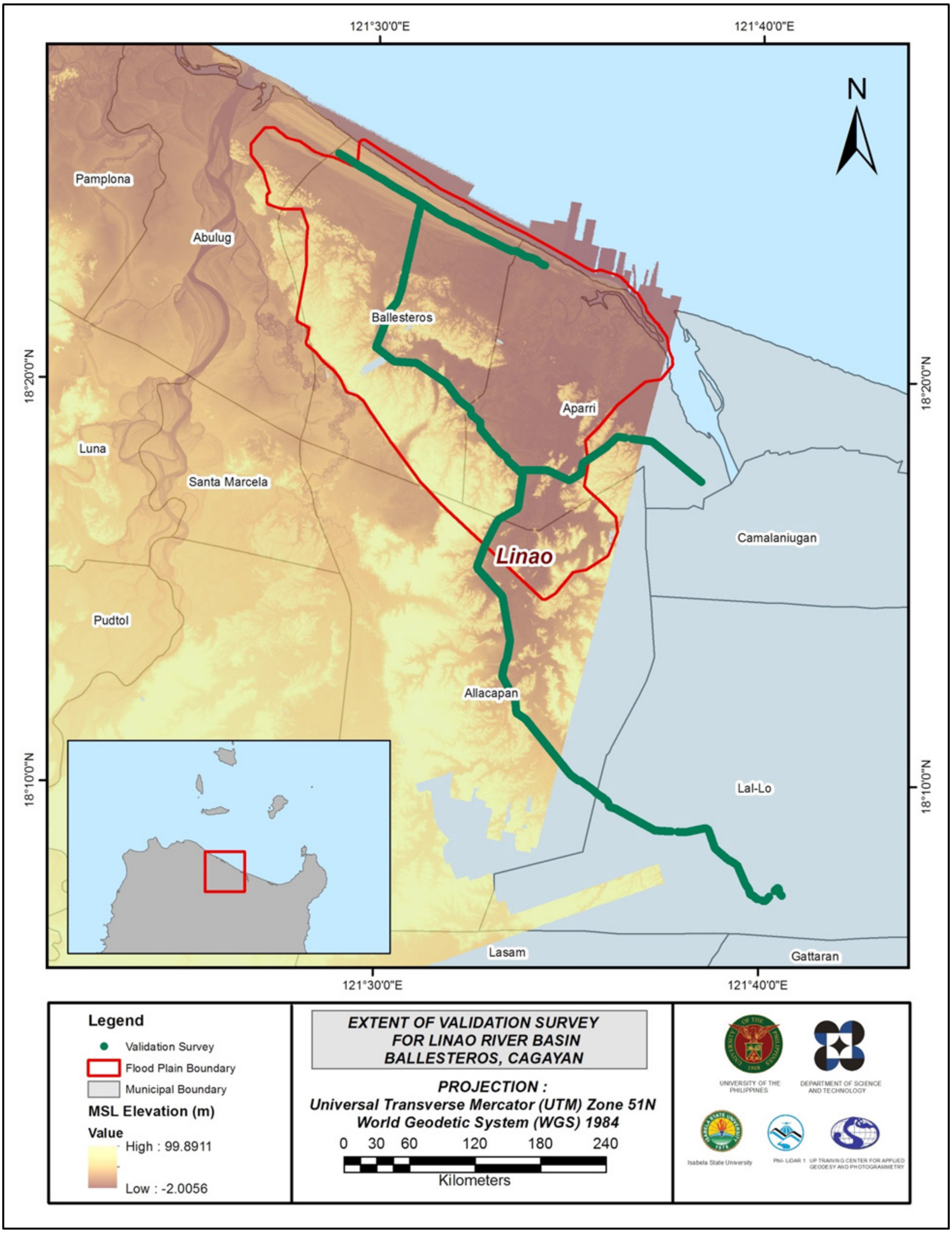

Figure 26. Map of the Linao floodplain with validation survey points in green.

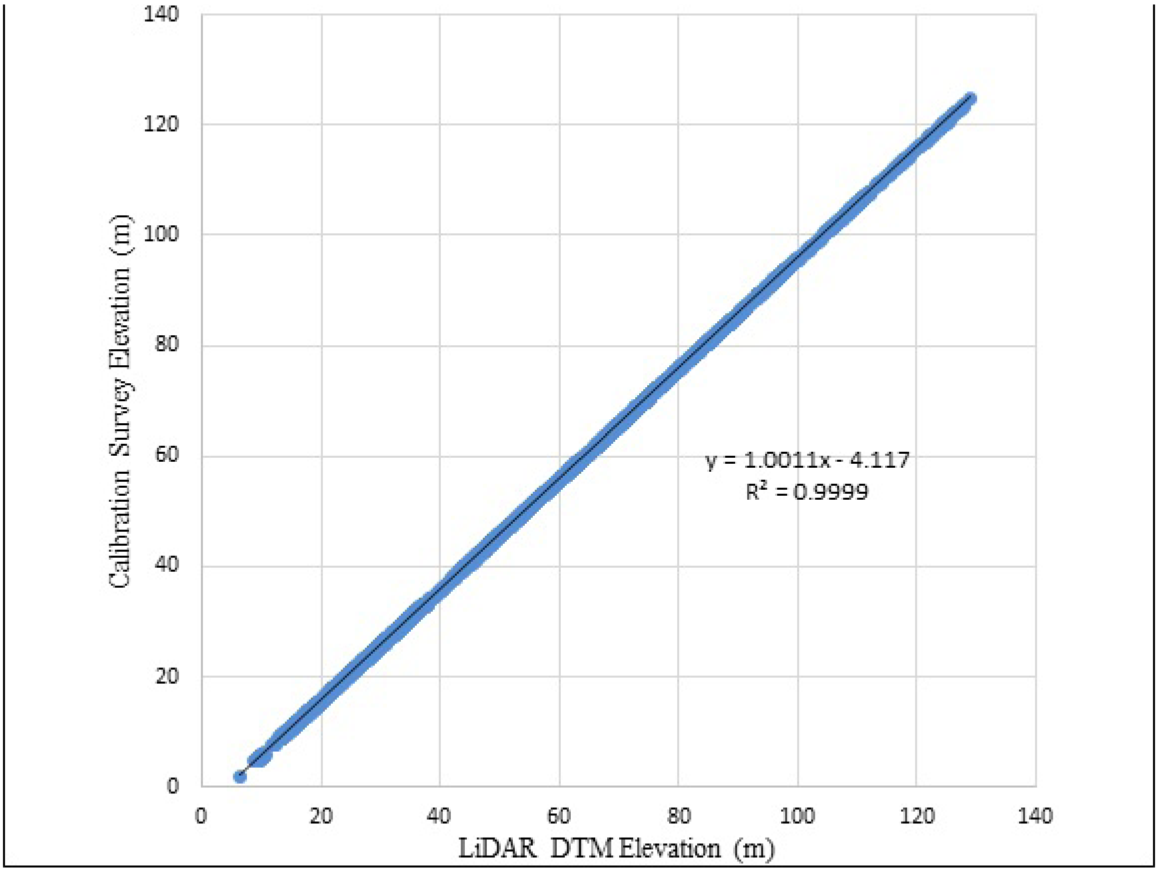

Figure 27. Correlation plot between the calibration survey points and the LiDAR data.

Table 19. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.07
Standard Deviation	0.14
Average	-4.07
Minimum	-4.50
Maximum	-3.77

The remaining twenty percent(20%) of the total survey points, resulting in764 points, were used for the validation of calibrated Linao 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 presentedin Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 1.29 meters, with a standard deviation of 0.21 meters, as indicatedin Table 20.

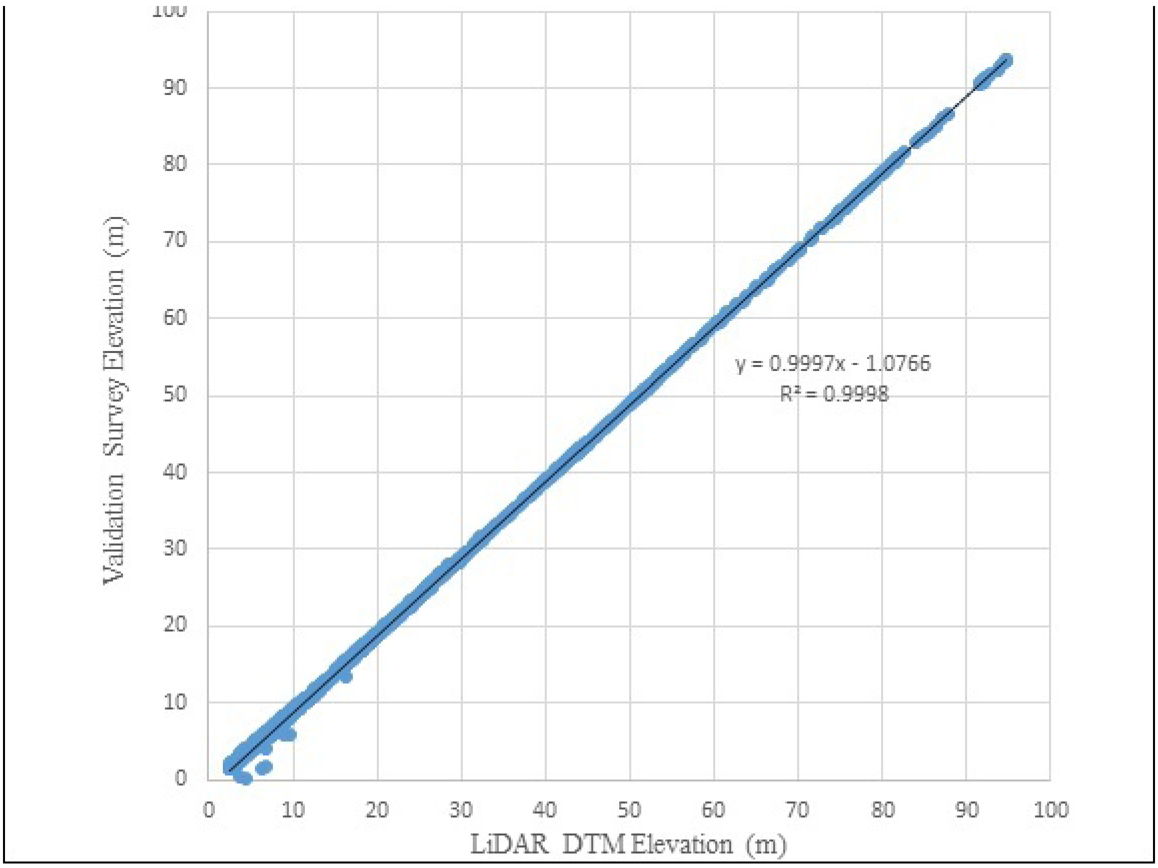

Figure 28. Correlation plot between the validation survey points and the LiDAR data.

Table 20. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	1.29
Standard Deviation	0.21
Average	1.27
Minimum	0.61
Maximum	1.57

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, zigzag and centerline data were available for Linao, with 5,514 bathymetric survey points. The resulting raster surface produced was achieved through the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.5 meters. The extent of the bathymetric survey done by the DVBC in Linao, integrated with the processed LiDAR DEM, is shown in Figure 29.

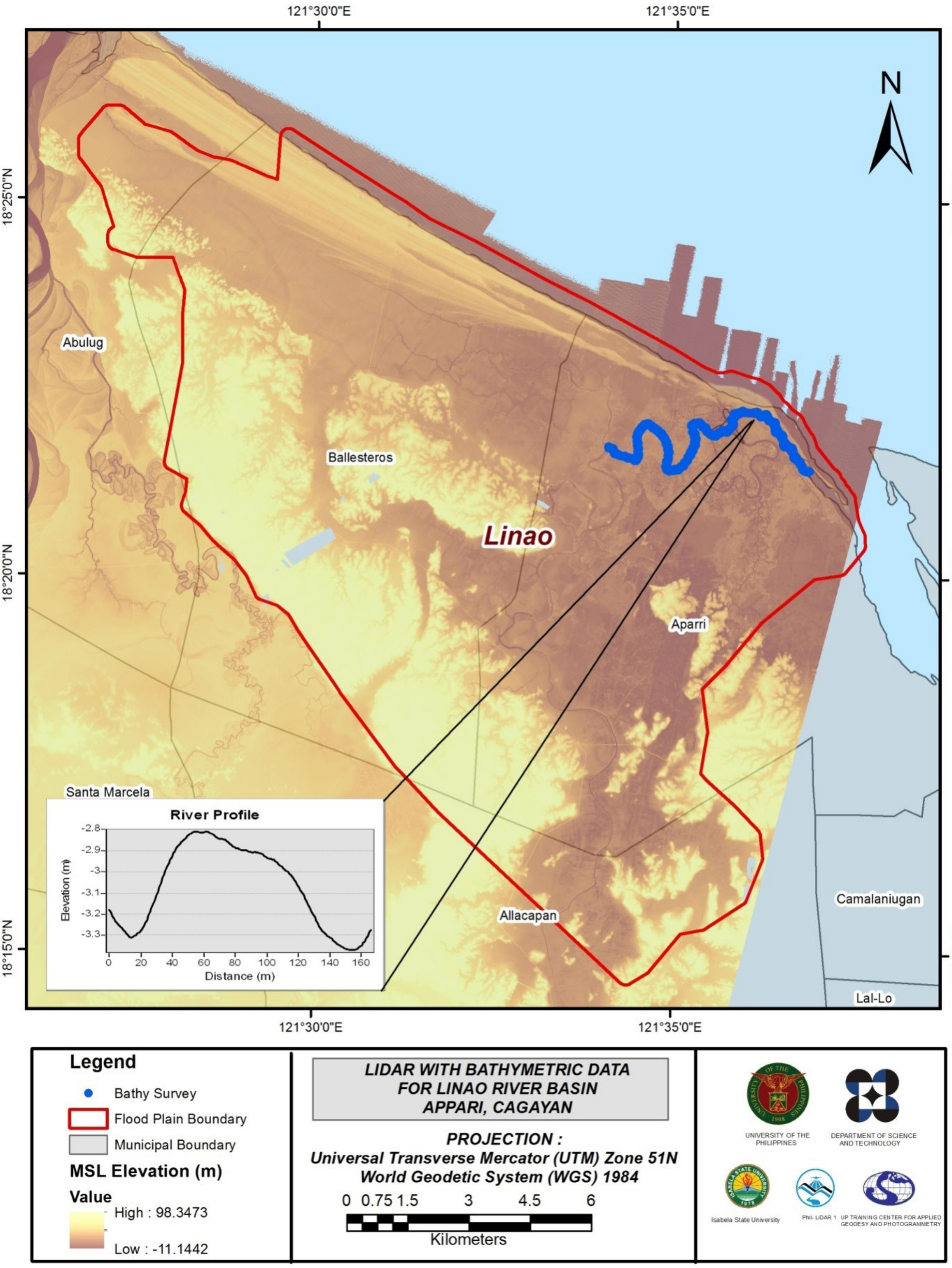

Figure 29. Map of the Linao floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Linao floodplain, including its 200-m buffer, has a total area of 204.77 sq. km. Of this area, 7.0 sq. km, corresponding to 2,108 building features, wereconsidered for quality checking(QC). Figure 30 illustratesthe QC blocks for the Linao floodplain.

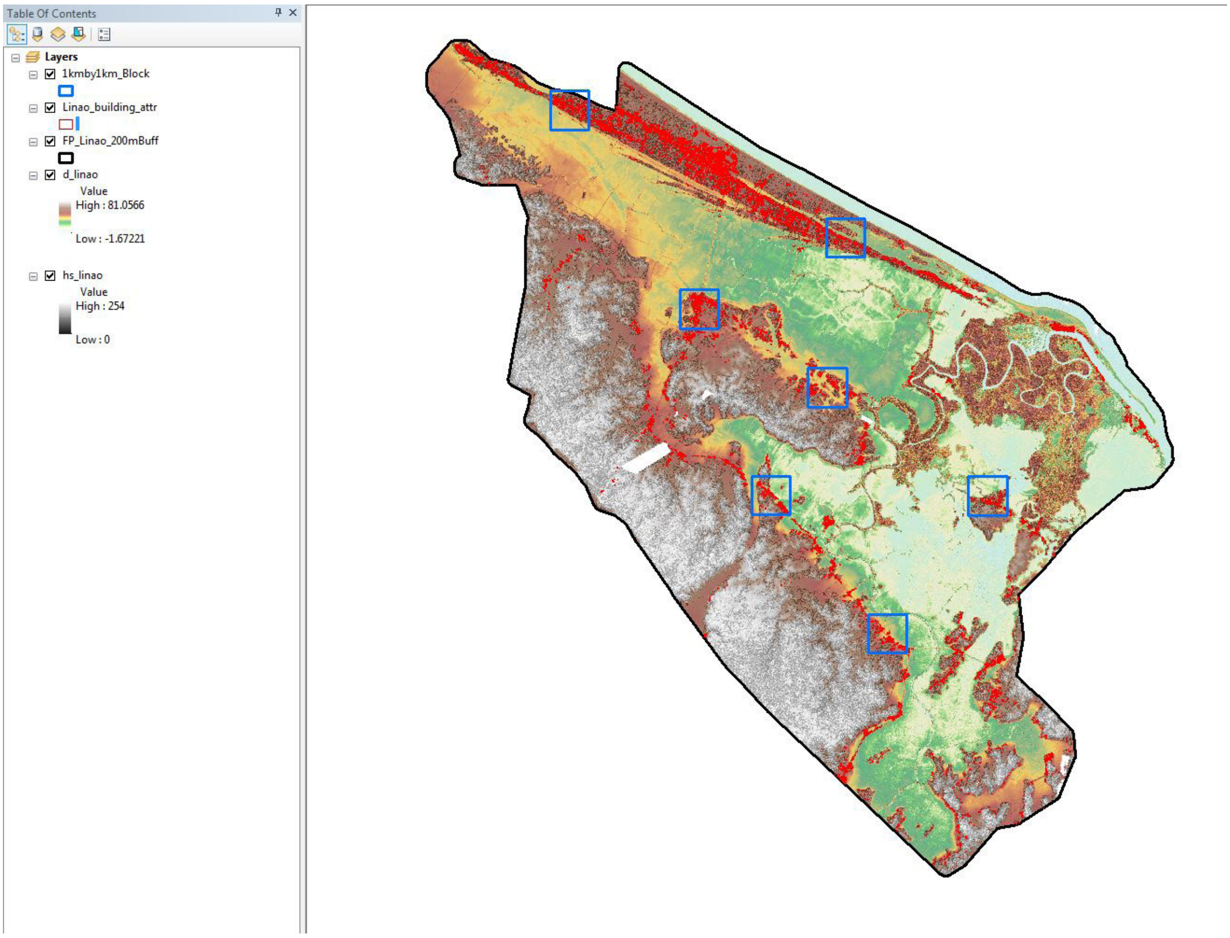

Figure 30. Blocks (in blue) of the Linao building features that were subjected to QC.

Quality checking of the Linao building features resulted in the ratings presentedin Table 21.

Table 21. Quality Checking Ratings for Linao Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Linao	98.15	99.94	93.89	PASSED

3.12.2 Height Extraction

Height extraction was performedfor 14,826 building features in the Linao floodplain. Of these building features, 1,499 were filtered out after height extraction, resulting in 13,327 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 4.1 m.

3.12.3 Feature Attribution

The digitized features were identified using participatory mapping. Stakeholders, preferably barangay officials, were invited to a forum and were given maps of their respective barangays. They first attributed non-residential buildings,such as barangay hall, schools, churches, commercial buildings, and the like. The remaining buildingswere then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of two (2) meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 22 summarizes the number of building features per type.Table 23 shows the total length of each road type, andTable 24 provides the number of water features extracted per type.

Table 22. Building Features Extracted for the Linao Floodplain.

Facility Type	No. of Features
Residential	12,606
School	250
Market	28
Agricultural/Agro-Industrial Facilities	94
Medical Institutions	14
Barangay Hall	20
Military Institution	0
Sports Center/Gymnasium/Covered Court	15
Telecommunication Facilities	0
Transport Terminal	5
Warehouse	42
Power Plant/Substation	0
NGO/CSO Offices	6
Police Station	2
Water Supply/Sewerage	1
Religious Institutions	35
Bank	0
Factory	0
Gas Station	8
Fire Station	0
Other Government Offices	53
Other Commercial Establishments	145
Total	**13,327**

Table 23. Total Length of Extracted Roads for the Linao Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Linao	169.88	11.15	12.64	19.55	0.00	**214.59**

Table 24. Number of Extracted Water Bodies for the Linao Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Linao	20	35	0	0	0	**55**

A total of twelve (12) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 31 shows the Digital Surface Model (DSM) of the Linao floodplain, overlaid with its ground features.

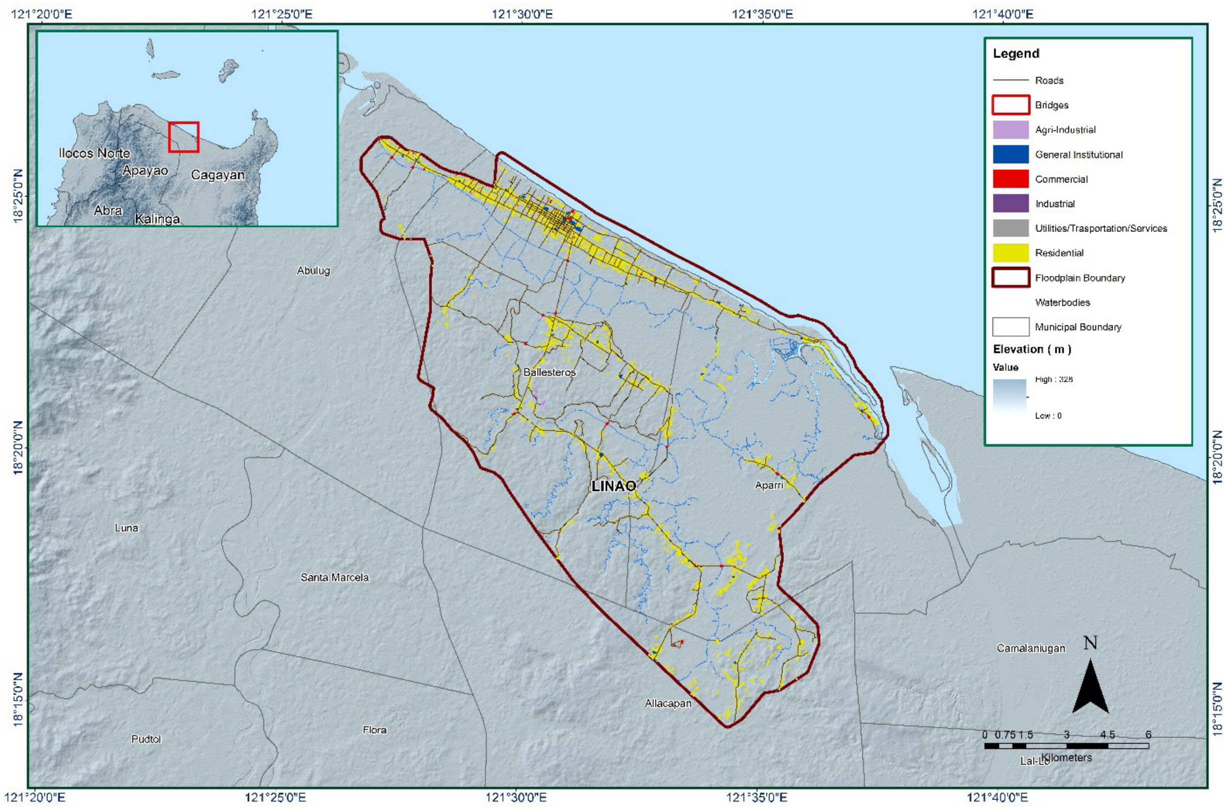

Figure 31. Extracted features for the Linao floodplain.

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

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Linao River on June 13 – 27, 2016, with the following scope of work: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built survey at the Linao Bridge in Barangay Bangag-Zinarag in the Municipality of Aparri; (iv.) validation points acquisition of about 66 km covering the Linao River Basin area; and (v.) bathymetric survey from the river'supstream side in Barangay Navagan untilthe mouth of the river located in Barangay Bisagu, both in the Municipality of Aparri, with an approximate length of 8.742 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 32).

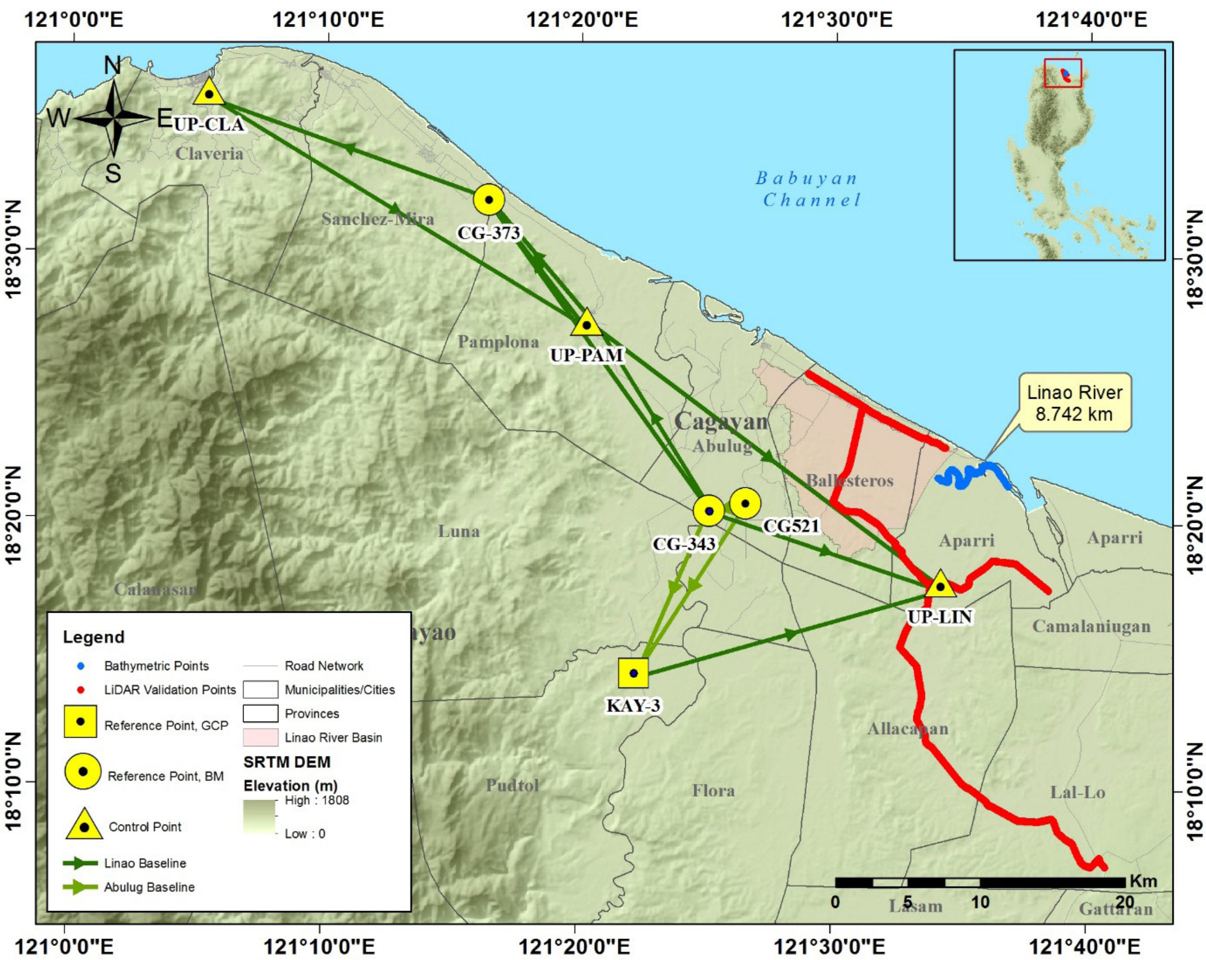


Figure 32. Extent of the bathymetric survey (in blue line) in the Linao River and the LiDAR data validation survey (in red).

4.2 Control Survey

A GNSS network was established for a previous fieldwork in the Abulug River on September 18, 2015, occupying the following control points in the Cagayan Province: (i.) KAY-3, a second-order GCP, in Barangay Imelda in the Municipality of Pudtol; and (ii.) CG-343, a first-order BM, in Barangay Libertad in theMunicipality of Abulug.

The GNSS network used for the Linao River Basin is composed of four (4) loops established on June 15-16, 2016, occupying the following reference points: (i.) KAY-3, a second-order GCPfrom the Abulug survey; (ii.) CG-343, a first-order BM, also from the Abulug survey; and (iii.) CG-373, a GCP with 95% class accuracy, in Barangay Bangan in the Municipality of Sanchez Mira.

Three (3) control points were established along the approach of bridges, which are: (i.) UP-CLA, located at the Cabicungan Bridge in Barangay Dibalio, Municipality of Claveria; (ii.) UP-LIN, at the Linao Bridge in, Barangay Bangag-Zingag, Municipality of Aparri; and (iii.) UP-PAM, at the New Pamplona Bridge in Barangay Masi, Municipality of Pamplona.

The summary of reference and control points and their correspondinglocations is givenin Table 25, while the GNSS network established is illustrated in Figure 33.

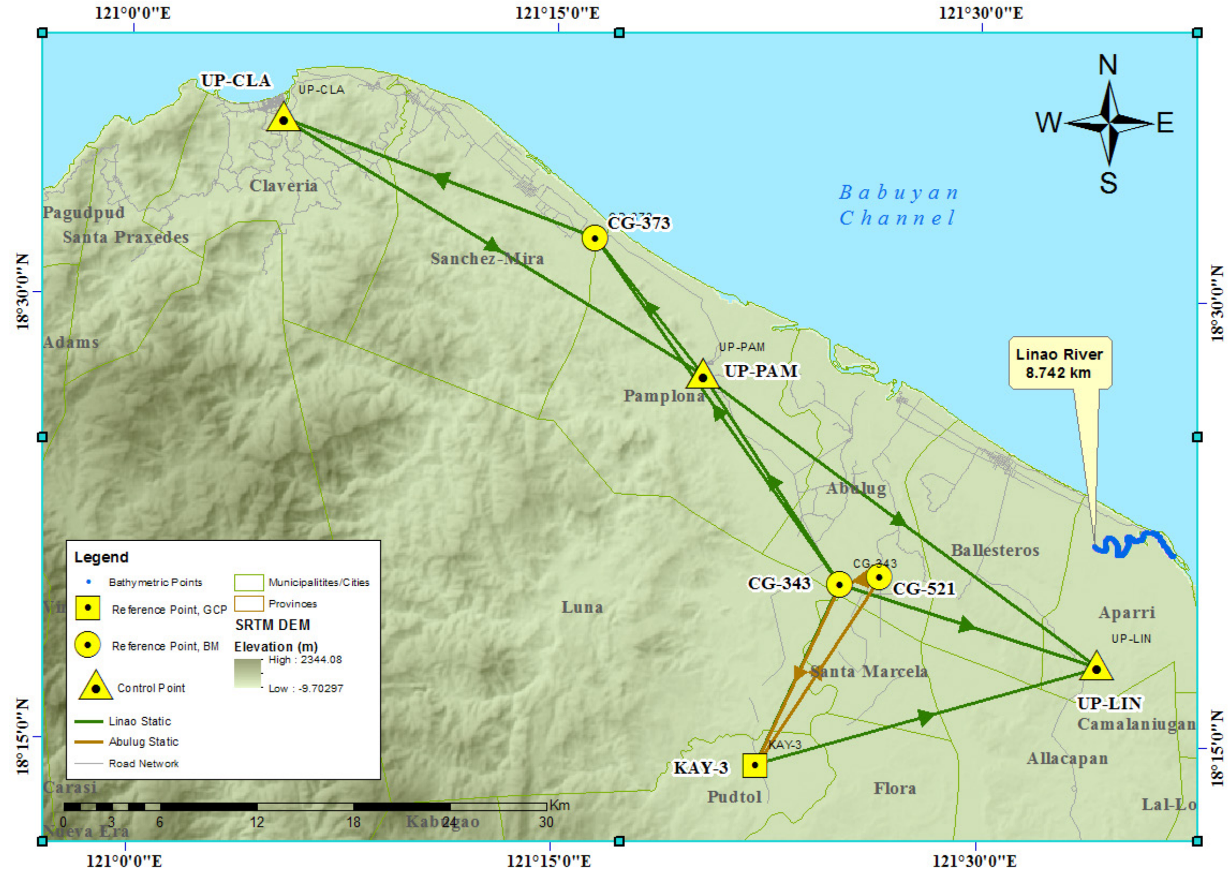


Figure 33. GNSS Network covering the Linao River

Table 25. List of Reference and Control Points Occupied for the Linao River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey on September 18, 2015						
KAY-3	2nd order, GCP	18°14’17.68665”N	121°22’13.38974”E	59.230	19.562	09-18-15
CG-343	1st order, BM	18°20’24.45282”N	121°25’08.22638”E	51.980	13.119	09-18-15
CG-521	Used as Marker	18°20’41.57071”N	121°26’33.65512”E	47.372	8.593	09-18-15
Control Survey on June 15 and 16, 2016						
KAY-3	2nd order, GCP	18°14’17.68665”N	121°22’13.38974”E	59.230	19.562	06-16-16
CG-343	1st order, BM	18°20’24.45282”N	121°25’08.22638”E	51.980	13.119	06-15-16
-CG-373	1st order, BM	18°32’00.00627”N	121°16’23.37638”E	40.044	3.422	06-15-16
UP-CLA	UP Established	-	-	-	-	06-15-16
UP-LIN	UP Established	-	-	-	-	06-16-16
UP-PAM	UP Established	-	-	-	-	06-15-16

The GNSS set-ups on recovered reference points and established control points in the Linao River are depictedin Figure 34 to Figure 39.

Figure 34. GNSS base set-up, Trimble® SPS 985, at KAY-3, situated on top of the flood gate near Pudtol Municipal Building in Barangay Imelda, Municipality of Pudtol, Cagayan

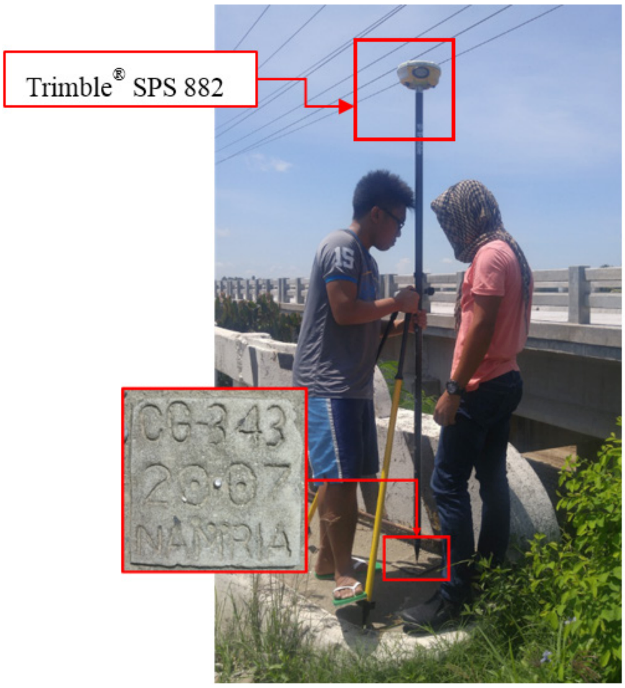


Figure 35. GNSS receiver set-up, Trimble® SPS 882, at CG-343, located at the approach of the Lukban Bridge in Barangay Libertad, Municipality of Abulug, Cagayan

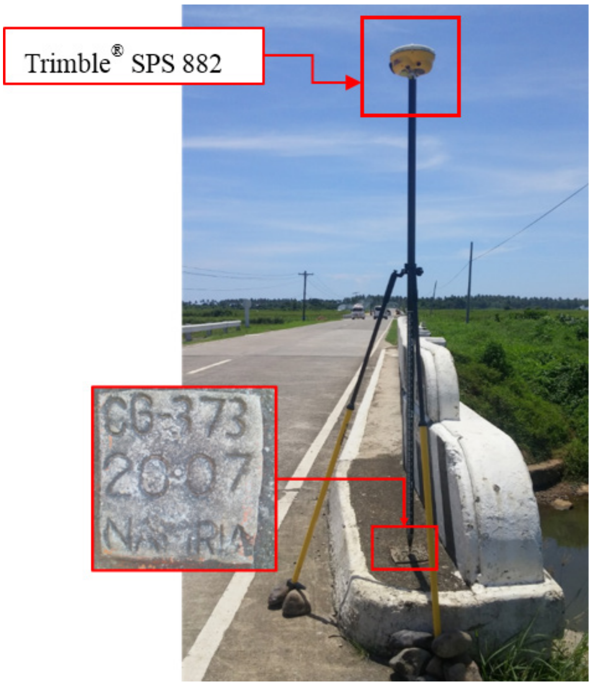


Figure 36. GNSS receiver set-up, Trimble® SPS 882, at CG-373, located at the approach of the Bangan Bridge in Barangay Bangan, Municipality of Sanchez Mira, Cagayan

Figure 37. GNSS receiver set-up, Trimble® SPS 852, at UP-CLA, located at the approach of Cabicungan Bridge in Barangay Dibalio, Municipality of Claveria, Cagayan

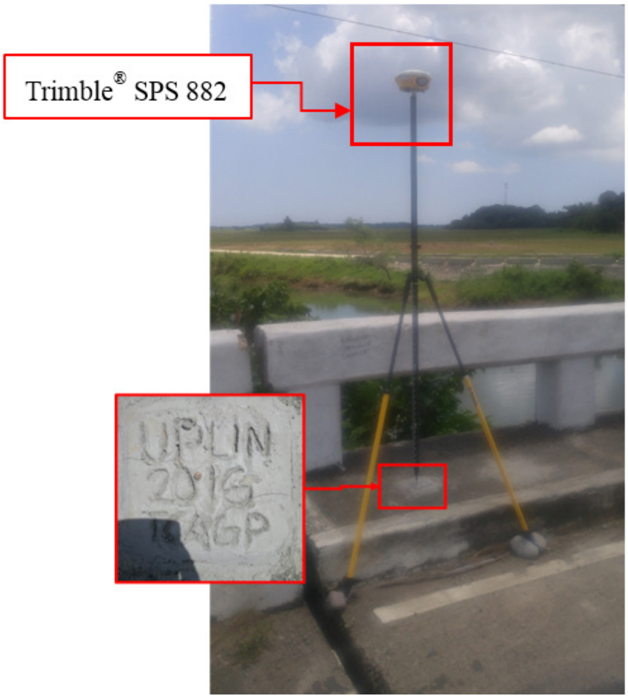


Figure 38. GNSS receiver set-up, Trimble® SPS 882, at UP-LIN, located at the approach of the Linao Bridge in Barangay Bangag-Zingag, Municipality of Aparri, Cagayan

Figure 39. GNSS receiver set-up, Trimble® SPS 985, at UP-PAM, located at the approach of the New Pamplona Bridge in Barangay Masi, Municipality of Pamplona, Cagayan

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of 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, a re-survey is initiated. The baseline processing results of control points in the Linao River Basin generated by the TBC software is summarized in Table 26.

Table 26. Baseline Processing Summary Report for the Linao River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
CG-343 --- UP-LIN	06-15-16 06-16-16	Fixed	0.003	0.011	106°47’38”	16724.001	-8.874
UP-PAM --- CG-343	06-15-16	Fixed	0.004	0.015	326°39’56”	15653.196	-3.143
CG-343 --- KAY-3	06-15-16 06-16-16	Fixed	0.004	0.015	204°29’26”	12390.499	7.221
UP-CLA --- UP-PAM	06-15-16	Fixed	0.003	0.011	120°54’39”	30613.328	6.126
CG-373 --- UP-PAM	06-15-16	Fixed	0.004	0.013	320°43’48”	10734.896	-6.898
UP-CLA --- CG-373	06-15-16	Fixed	0.003	0.012	290°56’38”	20827.307	0.766
UP-PAM --- UP-LIN	06-15-16 06-16-16	Fixed	0.003	0.013	126°01’00”	30439.181	-5.723
UP-LIN --- KAY-3	06-15-16 06-16-16	Fixed	0.003	0.012	73°02’19”	22107.068	-16.071
CG-343 --- CG-373	06-15-16	Fixed	0.003	0.012	324°15’43”	26354.260	-10.043

As shown Table 26 a total of nine (9) baselines were processed, with reference points KAY-3 and CG-343 held fixed for coordinate and elevation values.CG-373 was also held fixed for elevation values. All of the baselines satisfiedthe required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment wasperformed using TBC. Looking at the adjusted grid coordinates inTable 28of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm, or in equation form:

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

Where:

xe is the Easting Error,

yeis the Northing Error, and

zeis the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 27 to Table 30 for complete details.

The six (6) control points, KAY-3, CG-343, CG-373, UP-CLA, UP-LIN and UP-PAM, were occupied and observed simultaneously to form a GNSS loop. Coordinates of KAY-3 and CG-343; and elevation values of both controls including CG-373, were held fixed during the processing of the control points (Table 27). Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 27. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
KAY-3	Local	Fixed	Fixed	Fixed	
CG-343	Local	Fixed	Fixed	Fixed	
CG-373	Grid				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 providedin Table 28. The fixed control points KAY-3 and CG-343 have no values for grid errors,andall three (3) points including CG-373 have no values for elevation errors.

Table 28. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
KAY-3	327699.141	?	2017311.527	?	20.600	?	LLh
CG-343	332932.785	?	2028541.838	?	14.156	?	LLh
CG-373	317727.465	0.015	2050066.562	0.014	3.422	?	e
UP-CLA	298347.481	0.022	2057698.195	0.025	2.999	0.082	
UP-LIN	348899.614	0.009	2023571.535	0.011	6.573	0.079	
UP-PAM	324445.546	0.011	2041693.715	0.009	10.618	0.032	

With the mentioned equation, for horizontal and for the vertical, the computations for accuracy are as follows:

KAY-3

Horizontal Accuracy = Fixed

Vertical Accuracy = Fixed

CG-343

Horizontal Accuracy = Fixed

Vertical Accuracy = Fixed

CG-373

Horizontal Accuracy = $\sqrt{((1.5)^2 + (1.4)^2}$

= $\sqrt{(2.25 + 1.96)}$

= 2.05 < 20 cm

Vertical Accuracy = Fixed

UP-CLA

Horizontal Accuracy = $\sqrt{((2.2)^2 + (2.5)^2}$

= $\sqrt{(4.84 + 6.25)}$

= 3.33 < 20 cm

Vertical Accuracy = 8.2 cm < 10 cm

UP-LIN

Horizontal Accuracy	=	$\sqrt{((0.9)^2 + (1.1)^2}$
	=	$\sqrt{(0.81 + 1.21)}$
	=	1.42 < 20 cm
Vertical Accuracy	=	4.1 cm < 10 cm

UP-PAM

Horizontal Accuracy	=	$\sqrt{((1.1)^2 + (0.9)^2}$
	=	$\sqrt{(1.21 + 0.81)}$
	=	1.42 cm < 20 cm
Vertical Accuracy	=	3.2 cm < 10 cm

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

Table 29. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
KAY-3	N18°14’17.68665”	E121°22’13.38974”	59.230	?	LLh
CG-343	N18°20’24.45282”	E121°25’08.22638”	51.980	?	LLh
CG-373	N18°32’00.00627”	E121°16’23.37638”	40.044	?	e
UP-CLA	N18°36’01.81879”	E121°05’19.89261”	39.154	0.082	
UP-LIN	N18°17’47.07469”	E121°34’13.39315”	44.429	0.079	
UP-PAM	N18°27’29.74599”	E121°20’15.06060”	47.728	0.032	

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

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

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

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on September 18, 2015							
KAY-3	2nd order, GCP	18°14’17.68665”	121°22’13.38974”	59.230	2017311.527	327699.141	19.562
CG-343	1st order, BM	18°20’24.45282”	121°25’08.22638”	51.980	2028541.838	332932.785	13.119
CG-521	Used as Marker	18°20’41.57071”	121°26’33.65512”	47.372	2029046.466	335445.328	8.593
Control Survey on June 15 and 16, 2016							
KAY-3	2nd order, GCP	18°14’17.68665”	121°22’13.38974”	59.230	2017311.527	327699.141	19.562
CG-343	1st order, BM	18°20’24.45282”	121°25’08.22638”	51.980	2028541.838	332932.785	13.119
CG-373	1st order, BM	18°32’00.00627”	121°16’23.37638”	40.044	2050066.562	317727.465	3.422
UP-CLA	UP Established	18°36’01.81879”	121°05’19.89261”	39.154	2057698.195	298347.481	1.961
UP-LIN	UP Established	18°17’47.07469”	121°34’13.39315”	44.429	2023571.535	348899.614	5.535
UP-PAM	UP Established	18°27’29.74599”	121°20’15.06060”	47.728	2041693.715	324445.546	9.580

4.5 Cross-section and Bridge As-Built Survey and WaterLevel Marking

Cross-section and bridge as-built surveys were conducted on June 21, 2016 at the downstream side of the Linao Bridge in Barangay Bangag-Zinarag boundary, Municipality of Aparri, Cagayan,as exhibited in Figure 40. A survey-grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey.

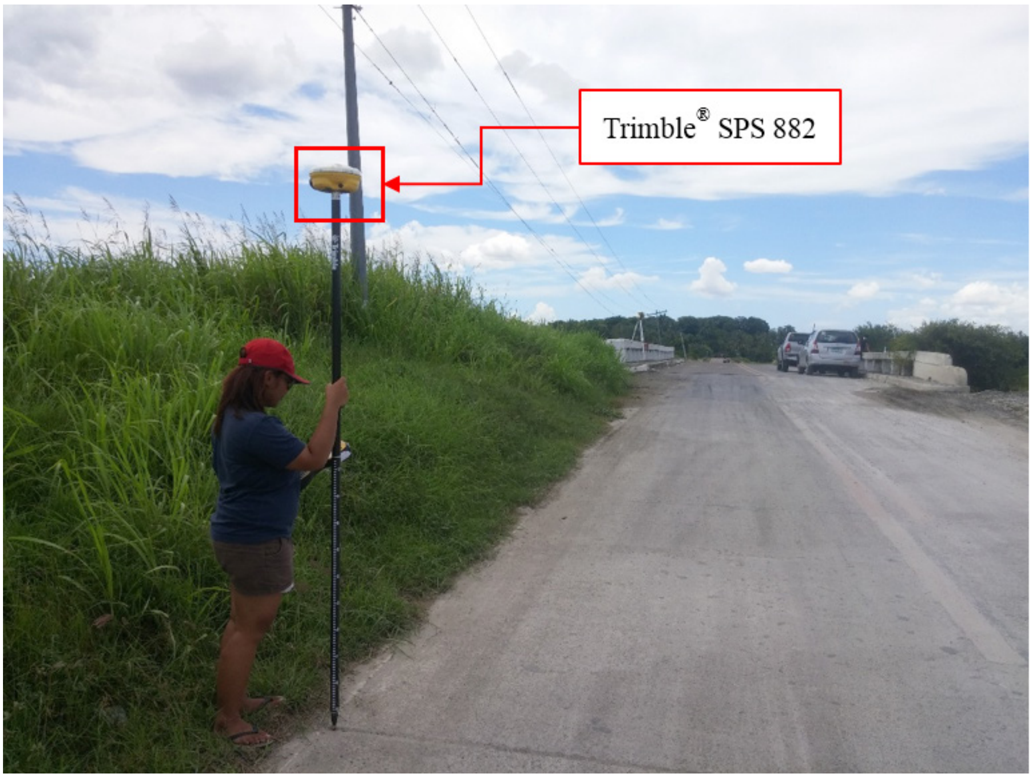


Figure 40. Cross-section conducted for the Linao River

The length of the cross-sectional line surveyed in the Linao Bridge is about 90 m, with seventy-two (72) cross-sectional points, using the control point UP-LIN as the GNSS base station. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 41 to Figure 43.

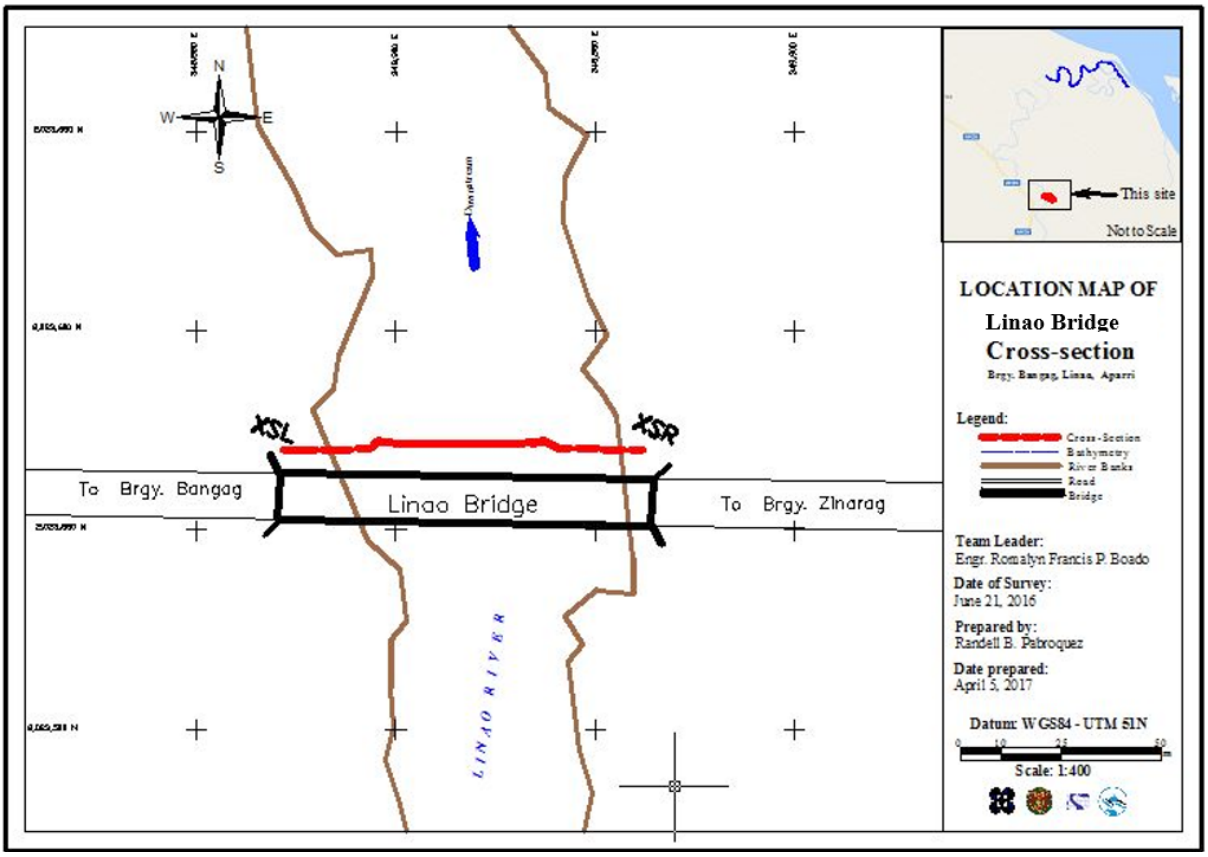


Figure 41. Linao bridge cross-section location map

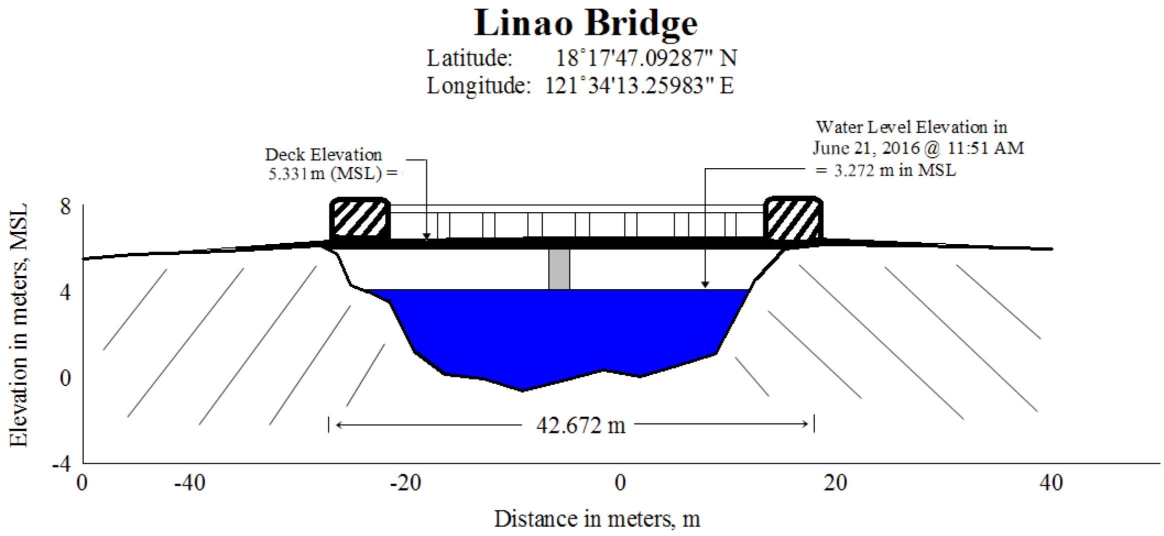


Figure 42. Linao Bridge cross-section diagram

Bridge Data Form

Bridge Name: Linao Bridge **Date: June 21, 2016**

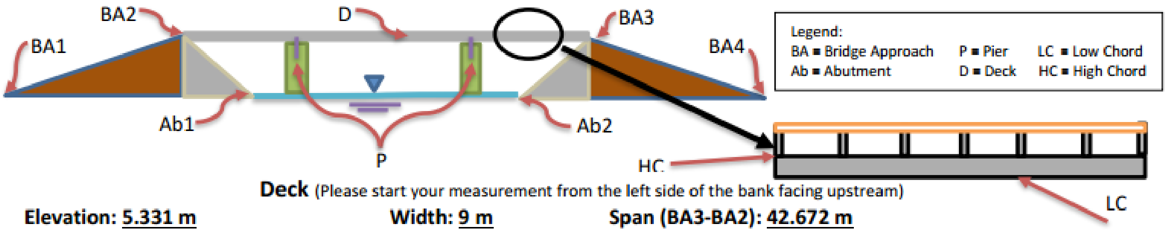
River Name: Linao River **Time: 11:51 AM**

Location (Brgy, City,Region): Brgy. Bangag-Zinarag, Municipality of Aparri, Cagayan

Survey Team: Romalyn Boado, Lorenz Taguse, Michael Labrador

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

Latitude: 18˚17'47.09287" N **Longitude: 121˚34'13.25983" E**



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

Elevation: 5.331 m **Width: 9 m** **Span (BA3-BA2): 42.672 m**

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0 m	4.447 m	BA3	65.770 m	5.479 m
BA2	23.072 m	5.331 m	BA4	90.02 m	4.935 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: Cylindrical Number of Piers: 1 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	44.411 m	5.492	NA

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

Figure 43. Bridge as-built form of the Linao Bridge

The water surface elevation of the Linao River was determined through a survey-grade GNSS receiver Trimble® SPS 882 in PPK survey technique on June 21, 2016 at 11:51 hrs. This resulted in the value of 3.272 m in MSL, as shown in Figure 42. This was translated into markings on the bridge's deck using the same technique, as shown in Figure 44. The markings served as reference for flow data gathering and depth gauge deployment by the ISU.

Figure 44. Water-level markings on the Linao Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on June 21-22, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle, as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 1.945 m and 1.950 m,measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with UP-LIN occupied as the GNSS base stationduringthe conduct of the survey.

Figure 45. Validation points acquisition survey set-up along the Linao River Basin

The survey started at theLinao Bridge in the Barangay Bangag Zinarag boundary in the Municipality of Aparri, andheadedeast,traversing seven (7) barangays until Barangay Mabanguc in the Municipality of Aparri.The survey then traveled south, covering eight (8) barangays inAllacapan and five (5) barangays in the Municipality of Lalo,ending in Barangay Bangag in Lalo. Afterwards, the survey headed northwest, encompassing twelve (12) barangays in the Municipality of Ballesteros, finally ending in Barangay Cabaritan. The survey gathered a total of 10,107 points with an approximate length of 66 km, using UP-LIN as the GNSS base station for the entire extent of the validation points acquisition survey. The extent of the survey is illustrated in the map in Figure 46.

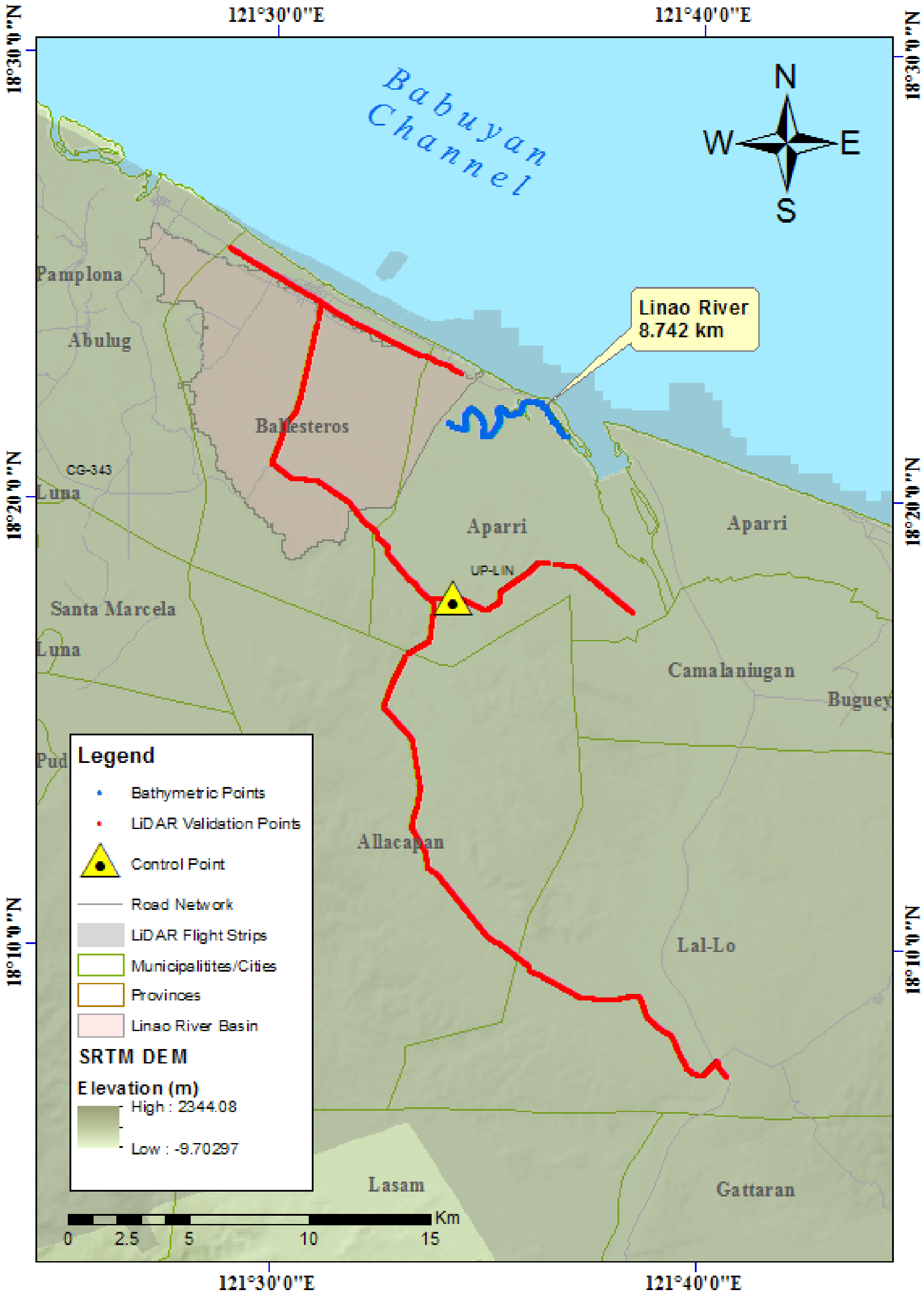


Figure 46. Extent of the LiDAR ground validation survey of the Linao River Basin

4.7 Bathymetric Survey

A manual bathymetric survey was executed on June 22, 2016 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode, as illustrated in Figure 47. The survey commenced in Barangay Navagan in the Municipality of Aparri, with coordinates 18°21’43.34860”N, 121°34’5.25947”E, and ended at the mouth of the river in Barangays Bisagu and Linao in Aparri, with coordinates 18°21’25.77697”N, 121°36’52.64947”E. The control point UP-LIN was used as the GNSS base station all throughout the survey.

Figure 47. Bathymetric survey using Ohmex™ single beam echo sounder in Linao River

The bathymetric survey for theLinao River gathered a total of 5,834 points, covering 8.742 km of the river. The surveytraversed the following barangaysin the Municipality of Aparri: Navagan, Zinarag, Bisagu, and Linao (Figure 48). A CAD drawing was also produced to illustrate the riverbed profile of the Linao River. As shown in Figure 49 the highest and lowest elevation had an 11-m difference. The highest elevation observed was 0.522 m above MSL, located in Barangay Navagan, while the lowest was -11.379 m below MSL, located in Barangay Zinarag. Both are in the Municipality of Aparri.

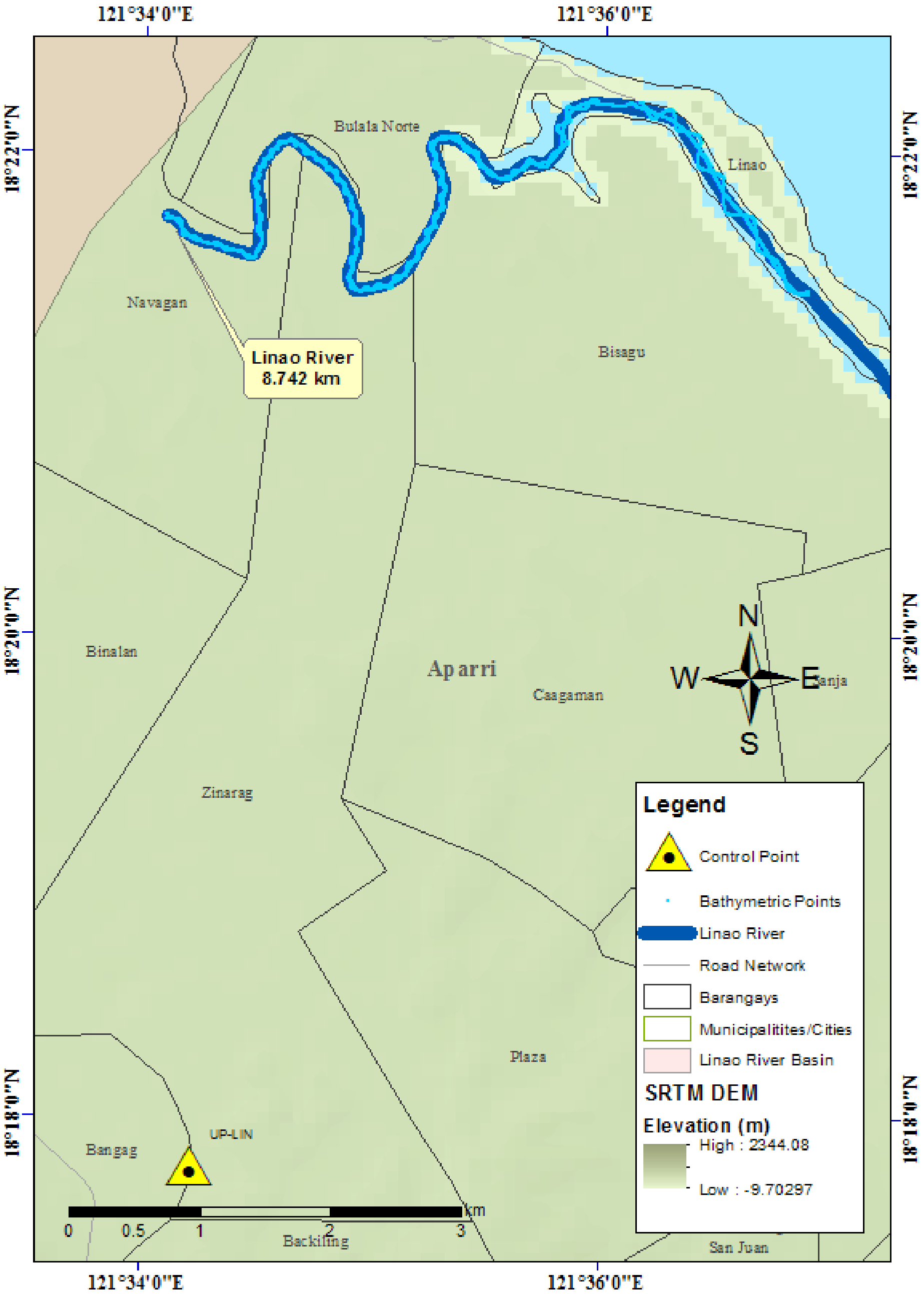


Figure 48. Extent of the bathymetric survey of the Linao River

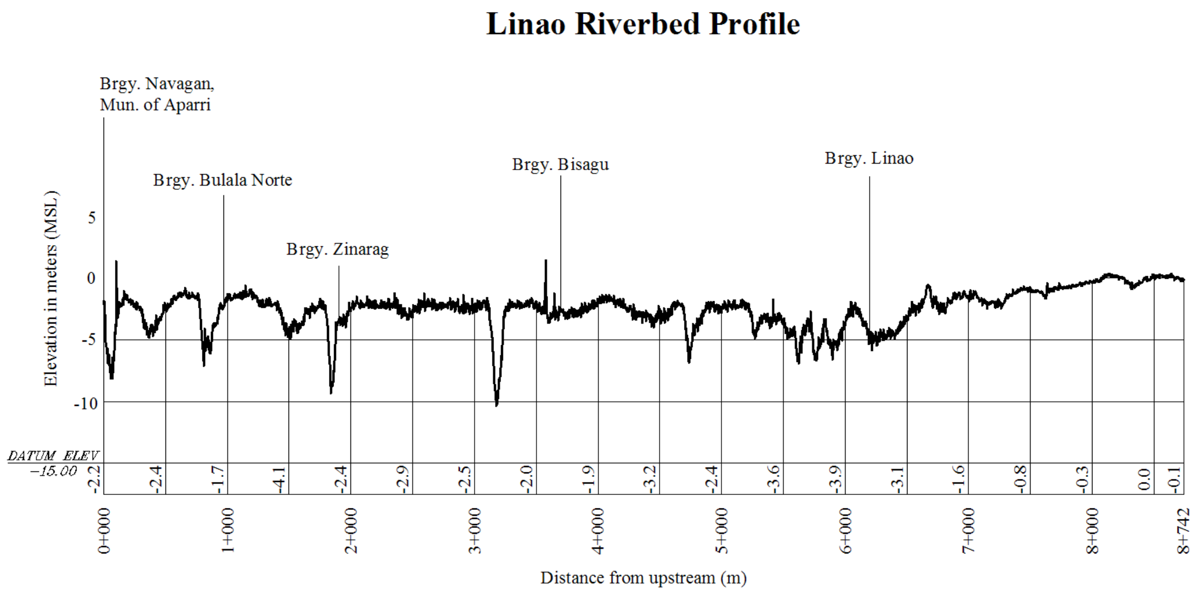


Figure 49. Linao Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

The Cagayan province, including the Linao River basin, experienced heavy and long-term rain caused by the monsoononFebruary 9-11, 2017. The hydrologic data collection covered the period February 9, 2017at 22:00 hrs. until February 11, 2017 at 11:00 hrs. Hydrologic data include the river velocity, water depth, and rain collected from data logging sensors (i.e., mechanical velocity meters, depth gauges and rain gauges) in a specific time period. Precipitation data was taken from the automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This was the Allacapan Municipal Hall ARG. Data was also acquired from the Portable Rain Gauge installed by ISU Phil – LiDAR1 Program. The location map of the rain gauges is presentedin Figure 50. Rainfall data were downloaded from the web portal of the Philippine E-Science Grid-ASTI (http://fmon.asti.dost.gov.ph).

Total rain from the Allacapan Municipal Hall ARG is 21.8 mm. It peaked at 2.4 mm on February 10, 2017at 00:30 hrs.Total rain from Portable Rain Gaugeis 45.6 mm. It peaked at 4.8 mm on February 10, 2017at 1:30 hrs. The lag time between the peak rainfall and discharge is 18 hours and 10 minutes. The ARG for the Linao River Basin is shown in Figure 50.

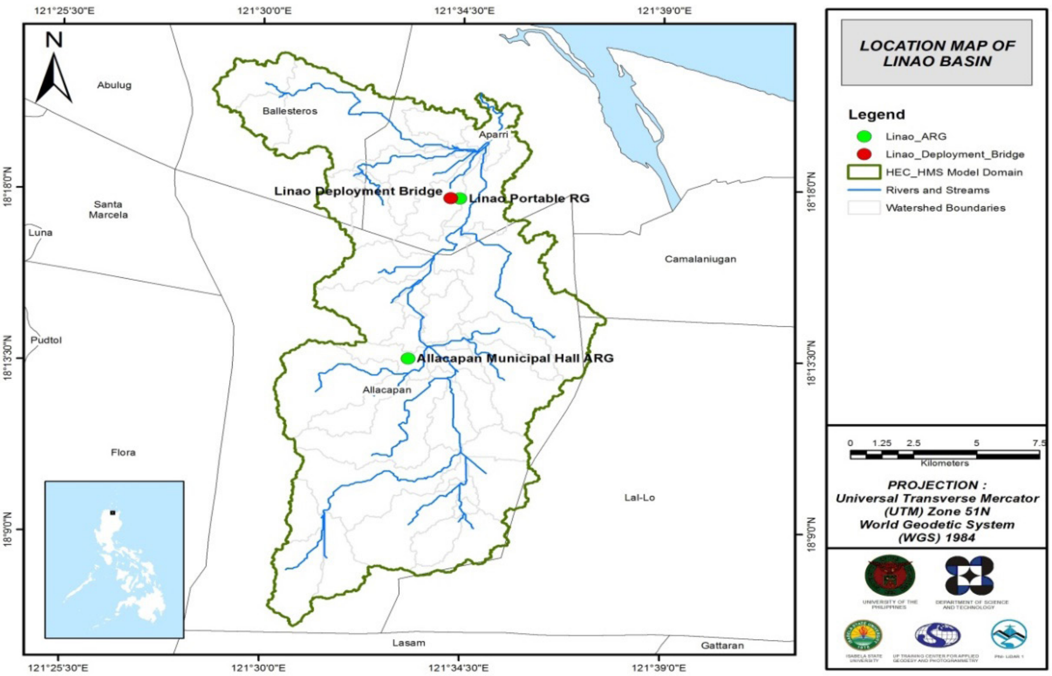


Figure 50. The location map of the Linao HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

The monsoon rains that occurred on February 9-11, 2017 contributed a 3.644-meter water level rise, with a peak discharge of 100.87m3/s recorded at 19:40 hrs. on February 10, 2017. The accumulated rainfall was 45.6 mm. These hydrologic data came from actual eventsin theLinao River, and were inputted into the hydrologic modeling. Hydrologic measurements were taken from the flow site at Barangay Zinarag in Aparri, Cagayan.

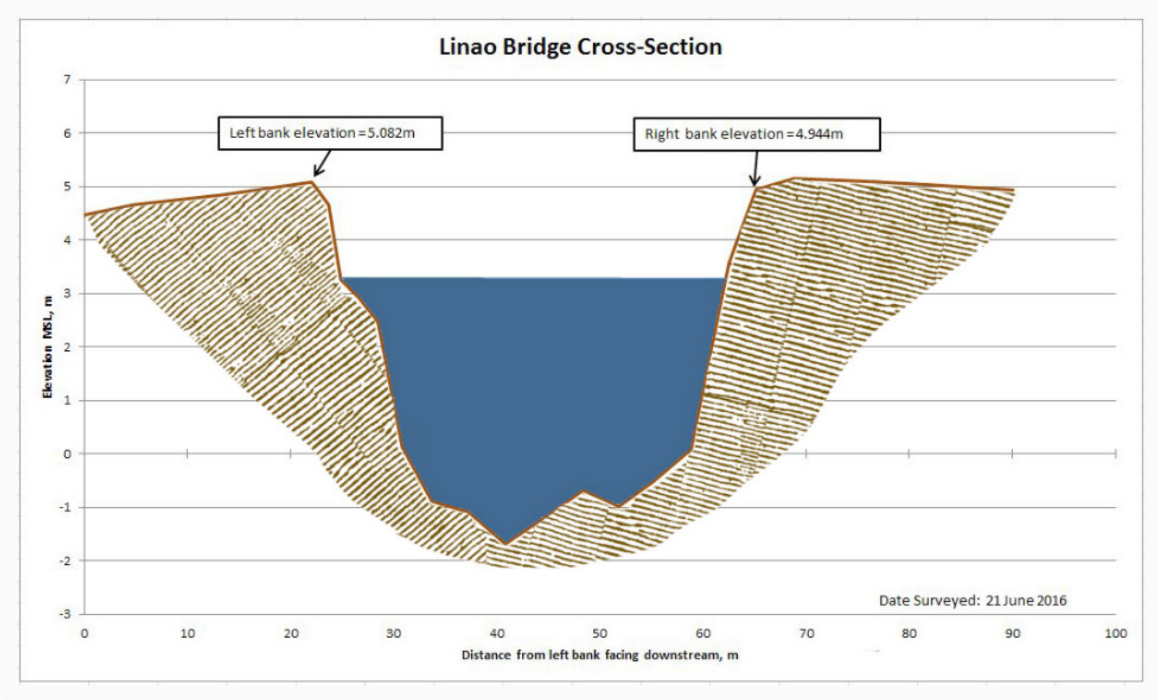


Figure 51. Cross-Section Plot of the Linao Bridge

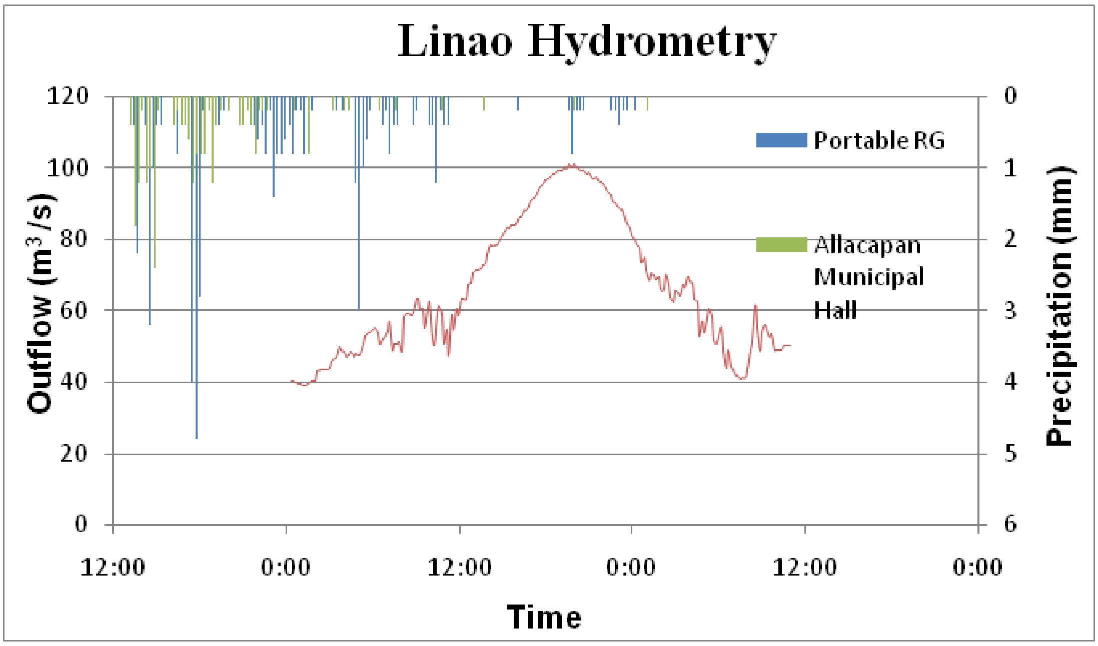


Figure 52. Rainfall and outflow data used for modeling

A rating curve was computedto establish the relationship between the observed water levels at the bridge and the outflow of the watershed at this location. It is expressed in the form of the following equation:

Q=anh

where,

Q	:	Discharge (m3/s),
h	:	Gauge height (reading from Linao Bridge depth gauge sensor), and
a and n	:	Constants.

The Linao River Rating Curve measured at the flow site is expressed as Q = 7.2113e0.724x (Figure 53).

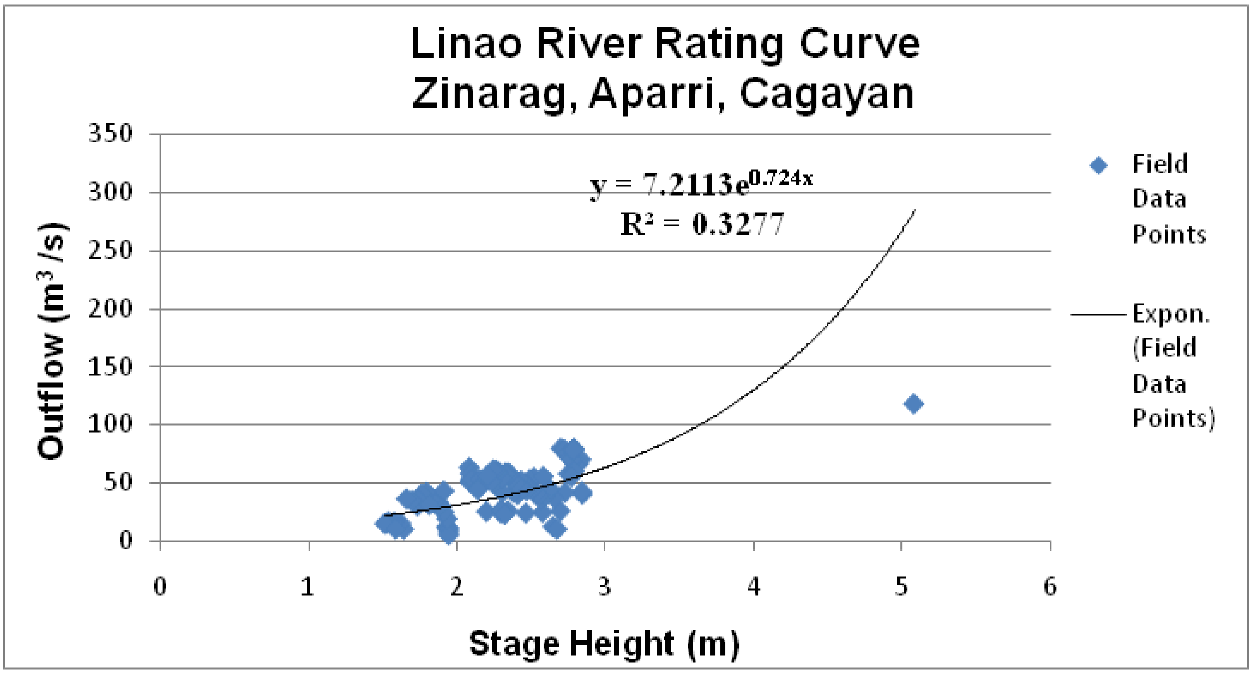


Figure 53. HQ Curve of the HEC-HMS model

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Aparri Rain Gauge(Table 31). This station was chosen based on its proximity to the Linao watershed (Figure 54).The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values such that a certain peak value will be attained at a certain time (Figure 55). The extreme values for this watershed were computed based on a 47-year record.

Table 31. RIDF values for the Aparri 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	20.1	31.4	39.4	53.3	75.6	92.2	119.4	147.7	167.9
5	28.5	44.9	55.8	78.7	110.4	137	173.6	221.2	252.5
10	34.1	53.8	66.6	95.6	133.4	166.6	209.5	269.9	308.5
15	37.2	58.8	72.7	105.1	146.5	183.4	229.7	297.4	340.2
20	39.4	62.3	77	111.8	155.6	195.1	243.9	316.6	362.3
25	41.1	65	80.3	116.9	162.6	204.1	254.8	331.4	379.3
50	46.3	73.4	90.5	132.7	184.2	231.9	288.4	377.1	431.9
100	51.4	81.7	100.6	148.4	205.6	259.5	321.7	422.4	484

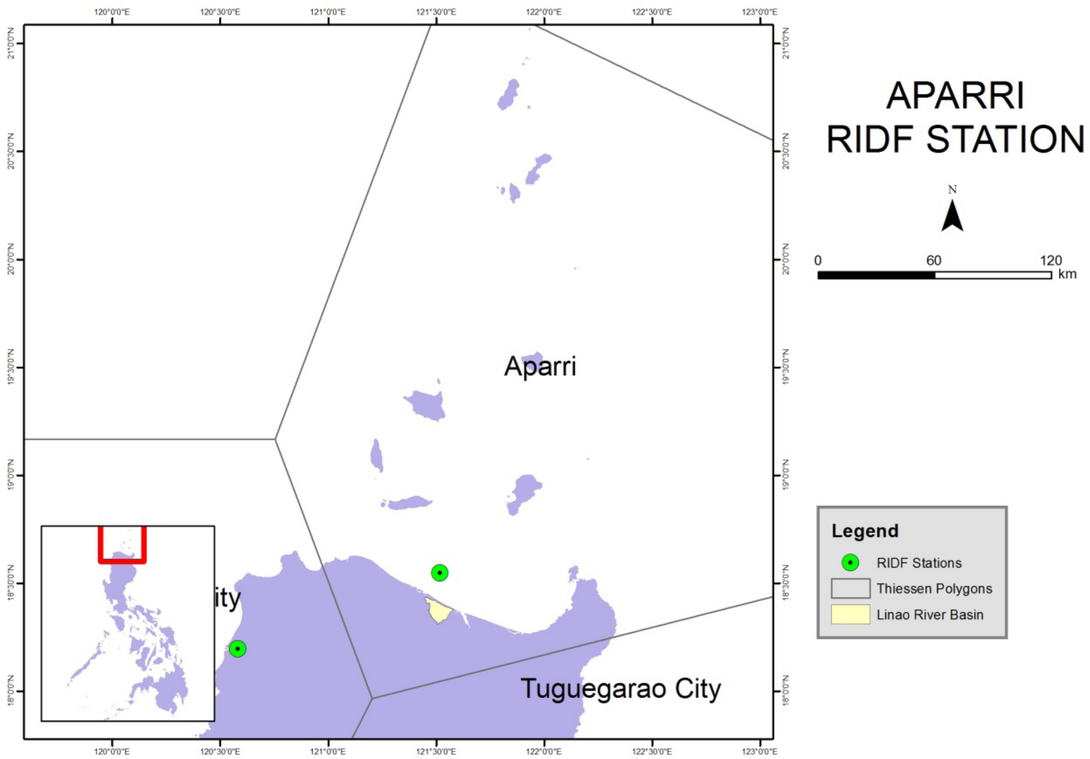


Figure 54. Location of the Aparri RIDF Station relative to the Linao River Basin

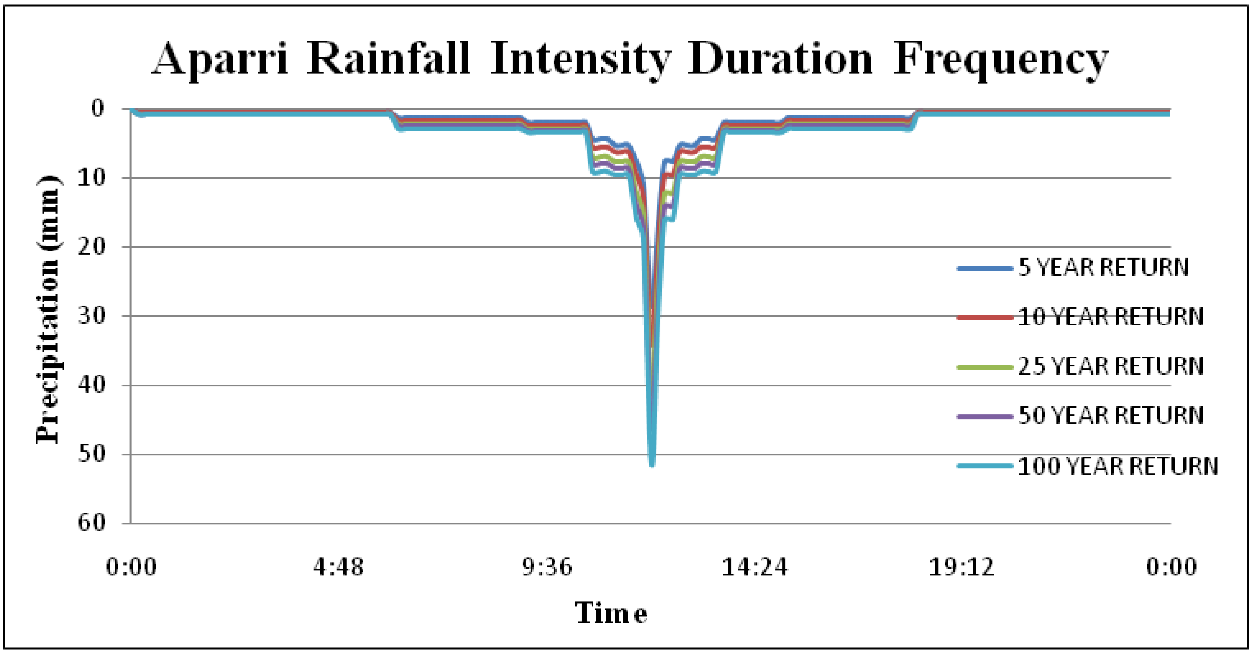


Figure 55. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Linao River Basin are providedin Figures 56 and 57, respectively.

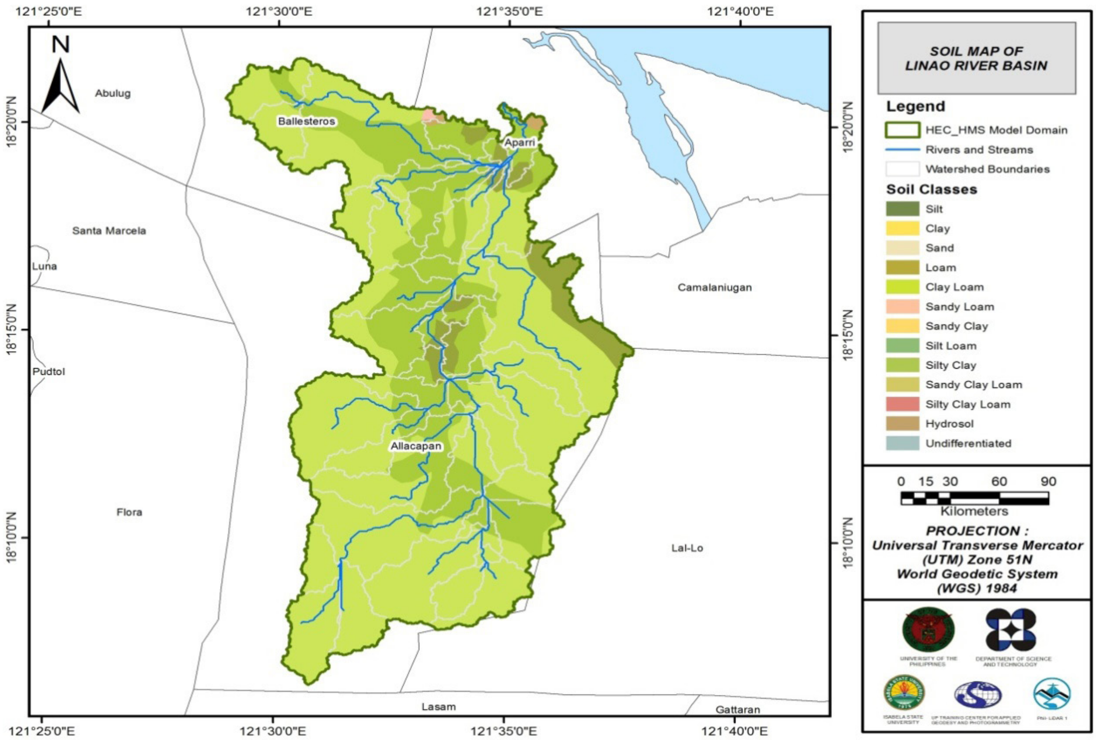


Figure 56. The soil map of the Linao River Basin (Source: DA)

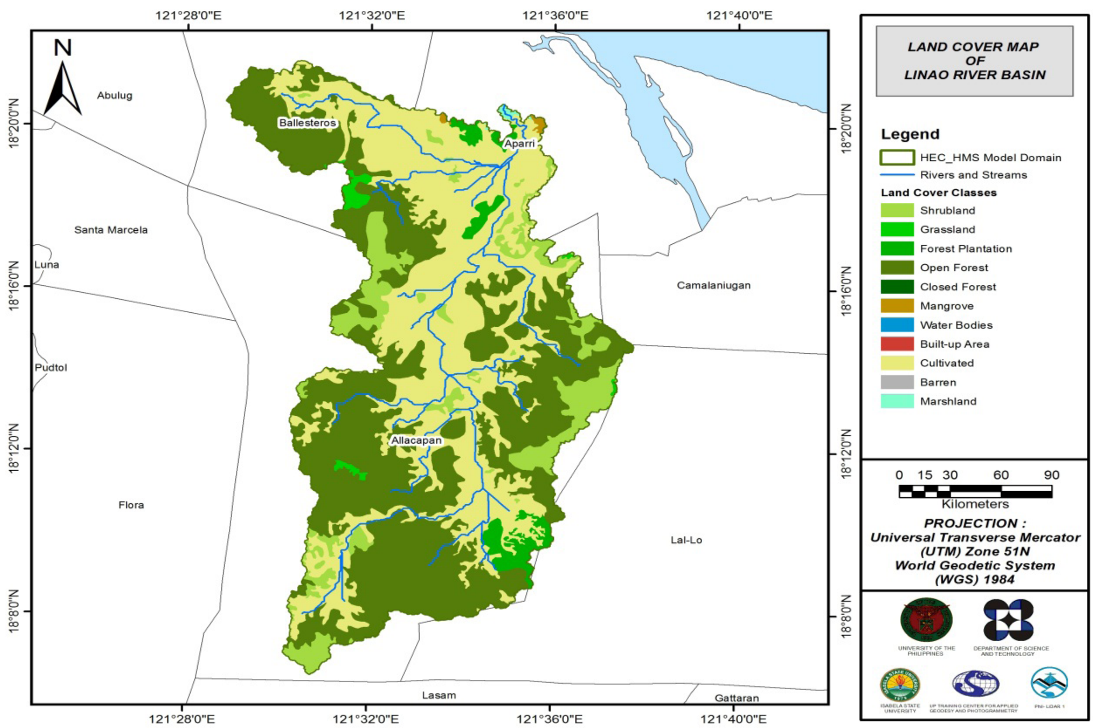


Figure 57. The land cover map of the Linao River Basin (Source: NAMRIA)

For Linao, thirteen (13) soil classes were identified. These are silt, clay, sand, loam, clay loam, sandy loam, sandy clay, silt loam, silty clay, sandy clay loam, silty clay loam, hydrosol, and undifferentiated soil. Moreover, eleven (11) land cover classes were identified. These are shrubland, grassland, forest plantation, open forest, closed forest, mangrove, water bodies, built-up area, cultivated, barren, and marshland.

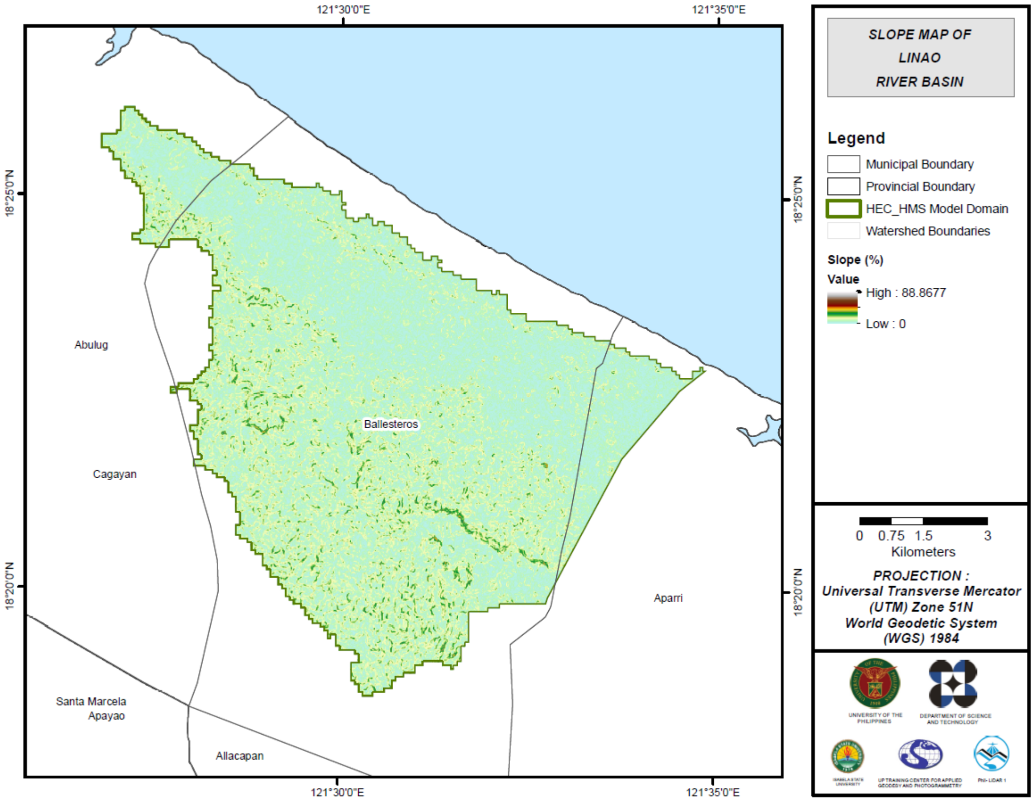


Figure 58. Slope map of the Linao River Basin

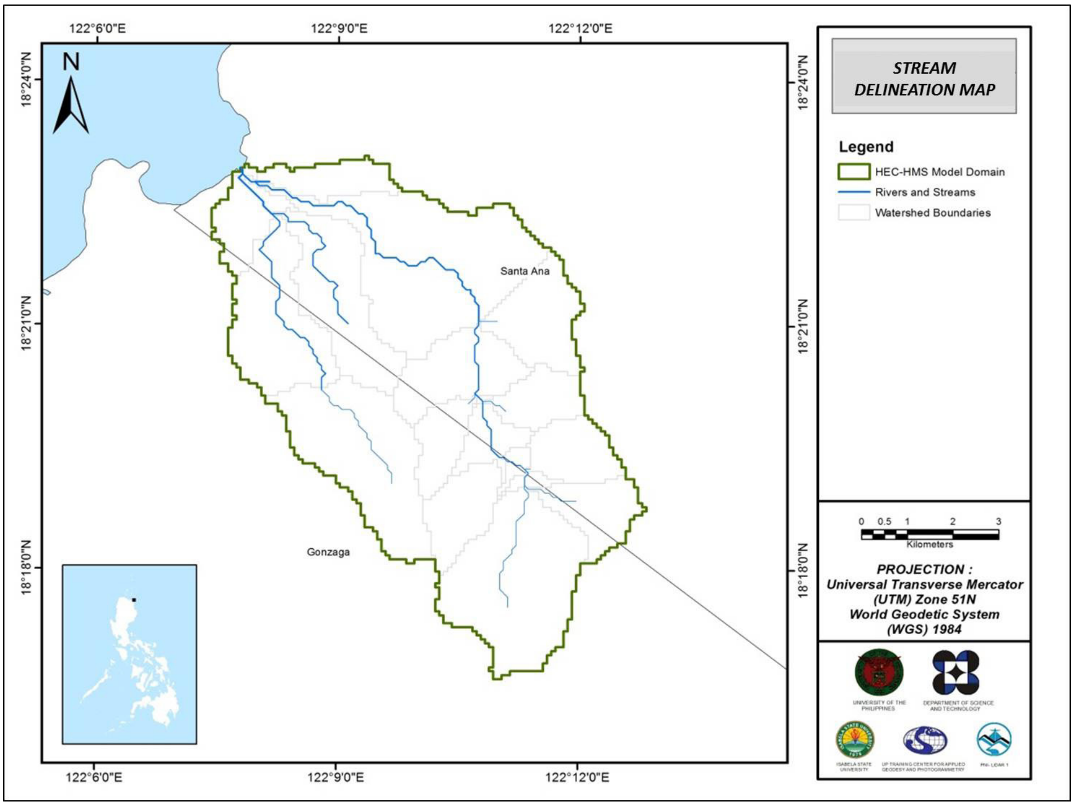


Figure 59. Stream delineation map of the Linao River Basin

A drainage system includes the basin boundaries, subbasins, and the stream networks of the basin. Using ArcMap 10.2 with HEC-GeoHMS version 10.2 extension, the Linao River centerline and SAR-DEM 10m resolution served as primary data for delineating the drainage system of the LinaoRiver Basin. The river centerline was digitized starting from the upstream towards the downstream on Google Earth (2014). The default threshold area used is 140 hectares.

Using the SAR-based DEM, the Linao basin was delineated and further subdivided into subbasins. The Linao basin model consists offorty-seven (47) sub basins, twenty-three (23) reaches, and twenty-three (23) junctions.The main outlet is Outlet 1. This basin model is illustrated in Figure 60.The model reach parameters can be found in Annex 10.The basins were identified based on the soil and land cover characteristics of the area. Precipitation from the monsoon rains on February 9-11, 2017 was taken from the DOST rain gauges and the Portable Rain Gauge. Finally, the modelwas calibrated using data from the Linao depth gauge sensor.

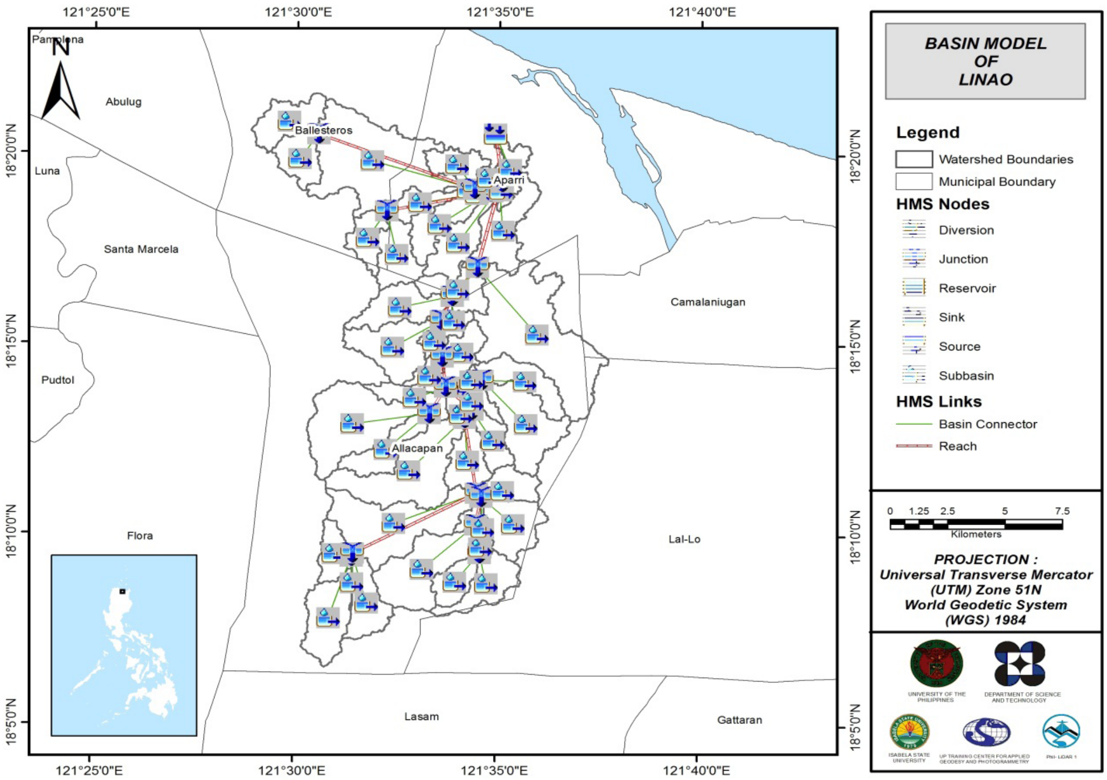


Figure 60. Linao River Basin Model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived fromthe LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 61).

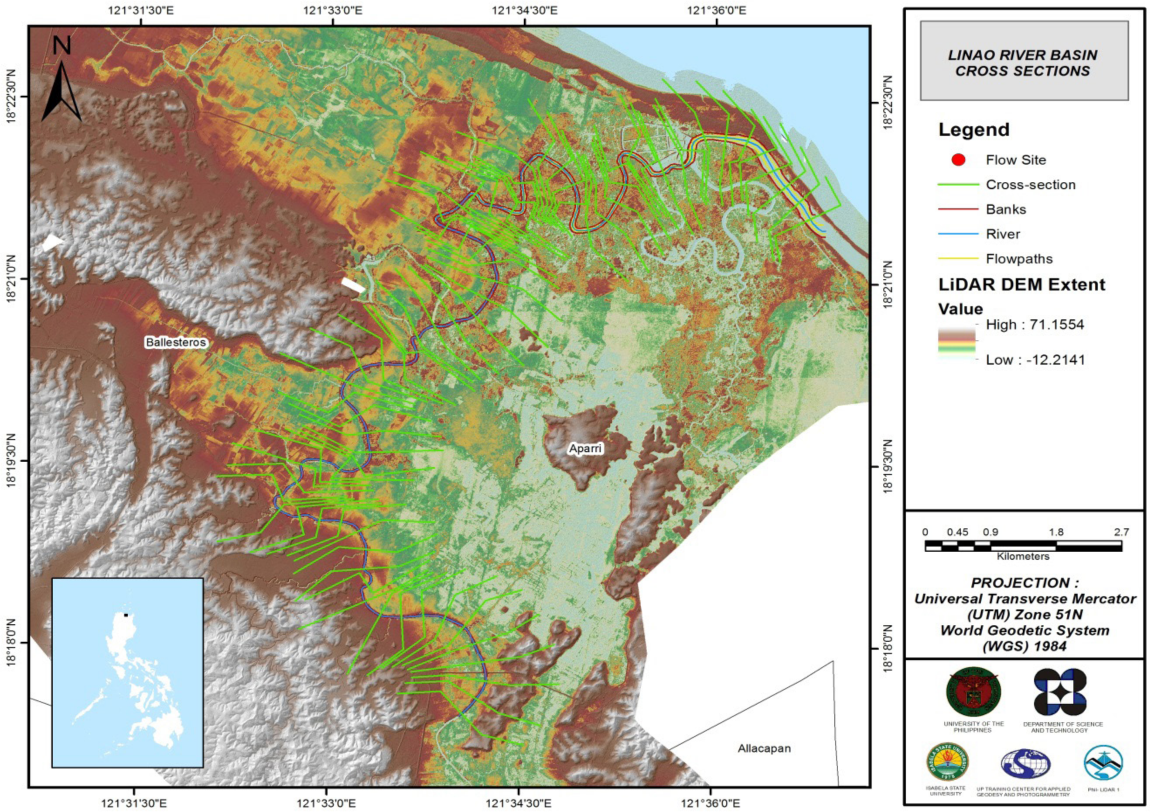


Figure 61. Linao River cross-section generated using HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowedfor 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 wasdivided into square grid elements, 10 meters by 10 meters in size. Each element wasassigned a unique grid element number, which servedas its identifier. Each element was then attributed with the parameters required for modeling, such as x-and y-coordinates of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements werearranged 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, and southwest).

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

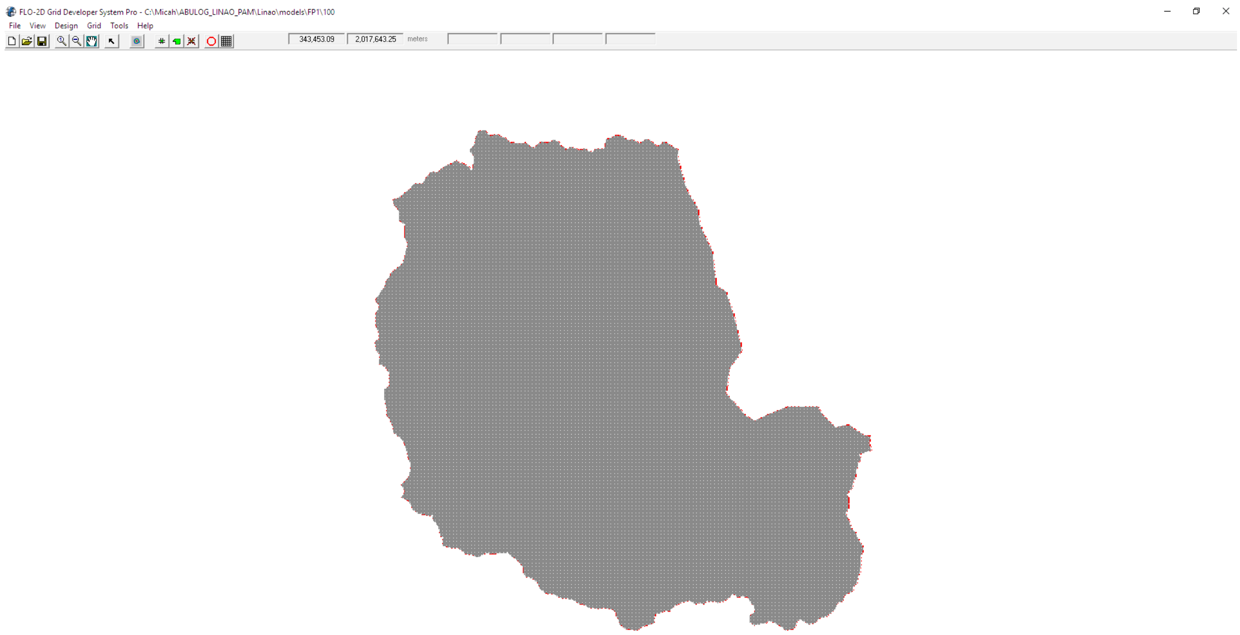


Figure 62. Screenshot of the sub catchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 86.35083 hours. After the simulation, the FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following flood hazard map. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 m, while the minimum vh (Product of maximum velocity (v) and maximum depth (h)) was set at0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map, depicting the maximum amount of inundation for every grid element.The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend wasused for the layout. In this particular model, the inundated parts covered a maximum land area of 50288000.00 m2.

There is a total of 64662554.29 m3 of water entering the model. Of this amount, 35816370.86 m3 is due to rainfall, while28846183.43 m3 is inflow from other areas outside the model.15170238.00 m3 of this water is lost to infiltration and interception, while 44662468.06 m3 is stored by the flood plain. The rest, amounting to up to 4829741.15 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Linao HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 illustrates the comparison between the two discharge data. See Annex 9 for the Linao model basin parameters.

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

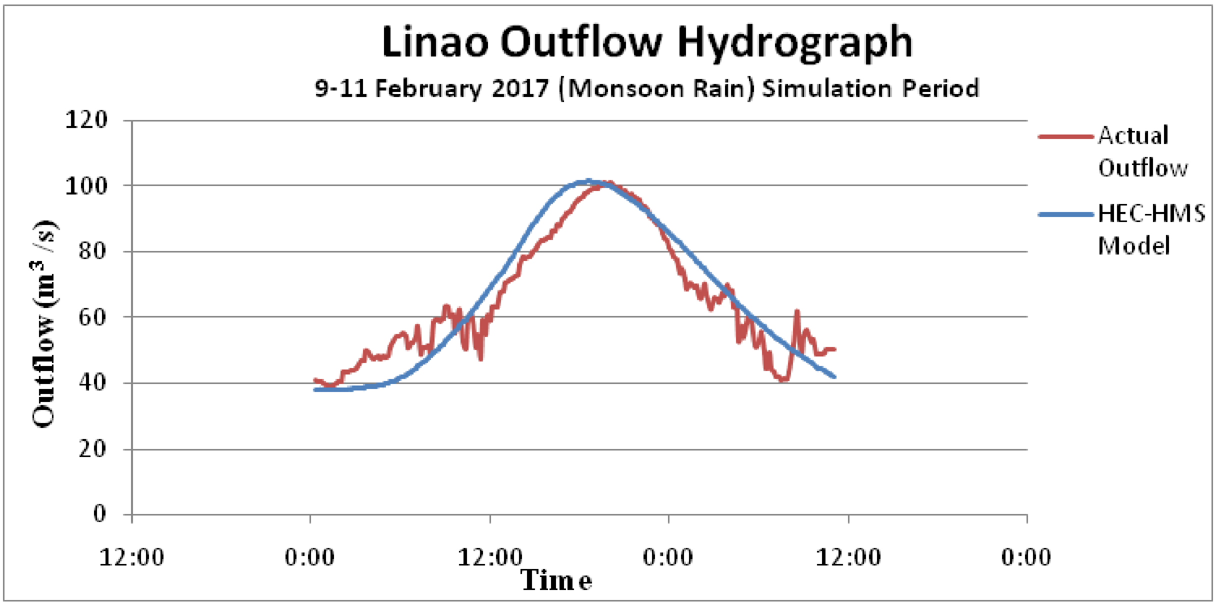


Figure 63. Outflow Hydrograph of Linao produced by the HEC-HMS model compared with observed outflow.

Table 32. Range of calibrated values for the Linao River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.8 - 5
			Curve Number	90-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1 - 22
			Storage Coefficient (hr)	0.9 - 17
	Baseflow	Recession	Recession Constant	0.3
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.001 - 0.03

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 0.8mm to 5mm signifies that there is minimal amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 90 to 99 for the curve number is greater than the advisable range for Philippine watersheds (70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Linao, the basin mostly consists of open forests and cultivated land, and the soil consists of clay loam and sandy clay loam.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.9 hours to 22 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.

The recession constant is the rate at which the baseflow recedes between storm events, while the ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.3 indicates that the basin is unlikely to quickly return to its original discharge, andwill be higherinstead. A ratio to peak of 0.2 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.001 – 0.003 is less than the roughness coefficient for cultivated land with mature field crops, which is 0.04 (Brunner, 2010).

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

Accuracy measure	Value
RMSE	7.1
r2	0.91
NSE	0.86
PBIAS	-1.41
RSR	0.38

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 7.1 (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 was measured at 0.9052.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. The optimal value is 1. The model attained an efficiency coefficient of 0.86.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. The optimal value is 0. In the model, the PBIAS was computed as-1.41.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error units of the valuesare quantified. The model has an RSR value of 0.38.

5.7 Calculated outflow hydrographys and Discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 64) shows the Linao River outflow using the Aparri Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

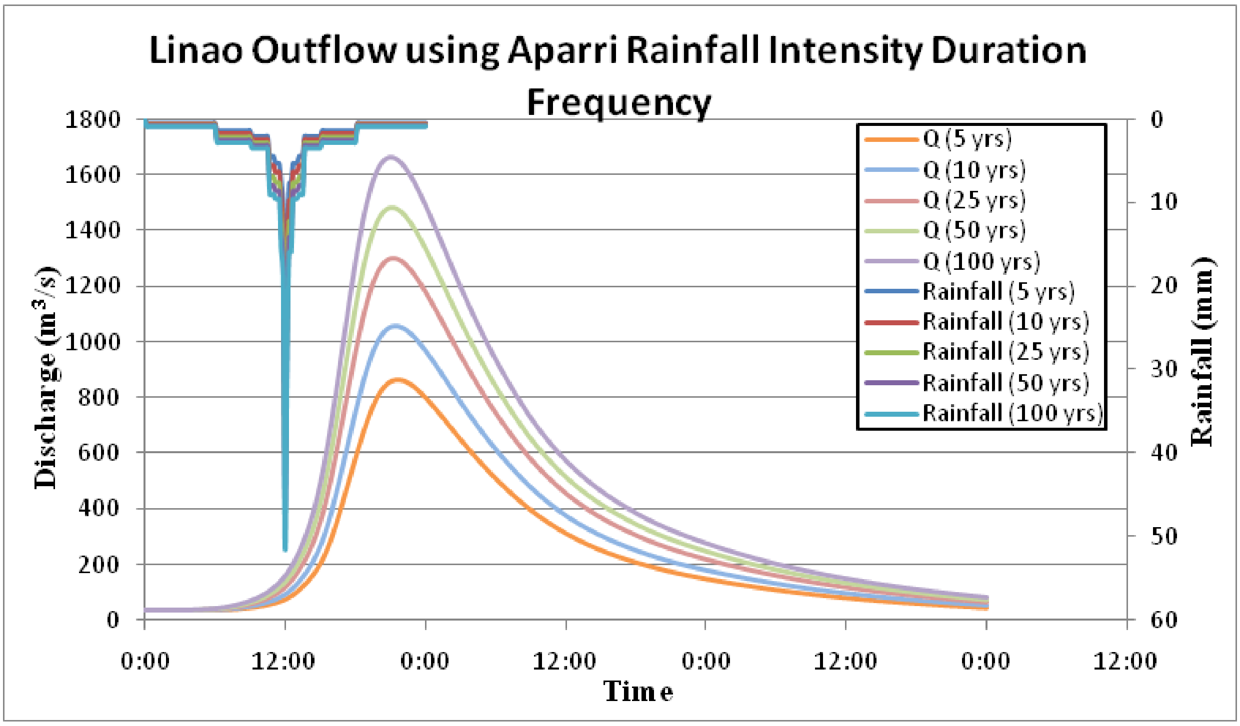


Figure 64. Outflow hydrograph at the Linao Station, generated using the Aparri RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Linao discharge using the Aparri RIDF in five (5) different return periods is indicatedin Table 34.

Table 34. Peak values of the Linao HECHMS Model outflow using the Aparri RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3s)	Time to Peak
5-Year	252.5	28.5	864.7	9 hour, 40 minutes
10-Year	308.5	34.1	1059.2	9 hour, 30 minutes
25-Year	379.3	41.1	1304.1	9 hour, 10 minutes
50-Year	431.9	46.3	1484.5	9 hour, 10 minutes
100-Year	484	51.4	1665.5	9 hour

5.8 River Analysis (RAS) Model Simulation

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

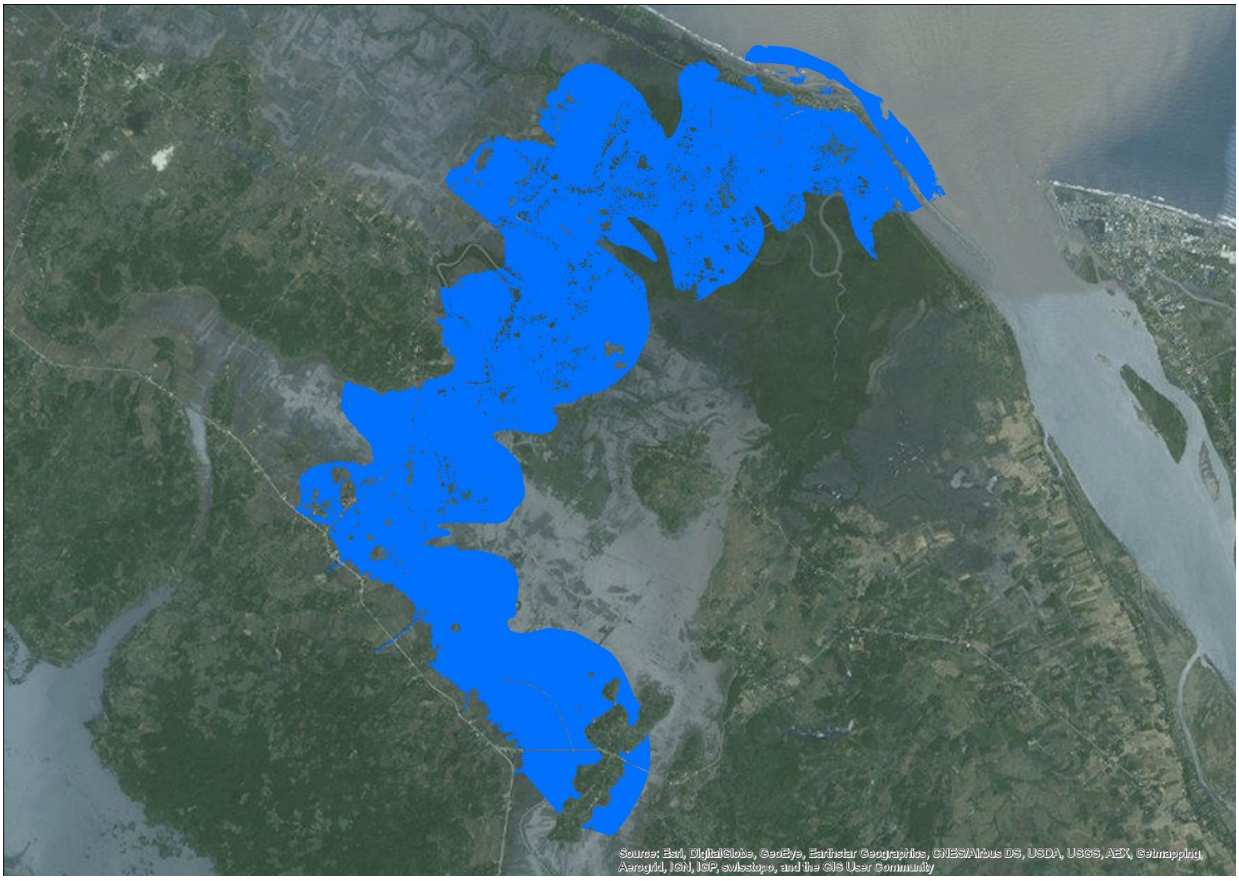


Figure 65. Sample output of the Linao RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 show the 5-, 25-, and 100-year rain return scenarios of the Linao floodplain. The floodplain, with an area of 248.84 sq. km., covers four (4) municipalities, namely Abulug, Allacapan, Aparri, and Ballesteros. Table 35summarizesthe percentage of area affected by flooding per municipality.

Table 35. Municipalities affected in the Linao floodplain

Municipality	Total Area	Area Flooded	% Flooded
Abulug	132.65	4.54	3.42%
Allacapan	230.60	81.67	35.42%
Aparri	261.22	67.53	25.85%
Ballesteros	129.41	94.98	73.39%

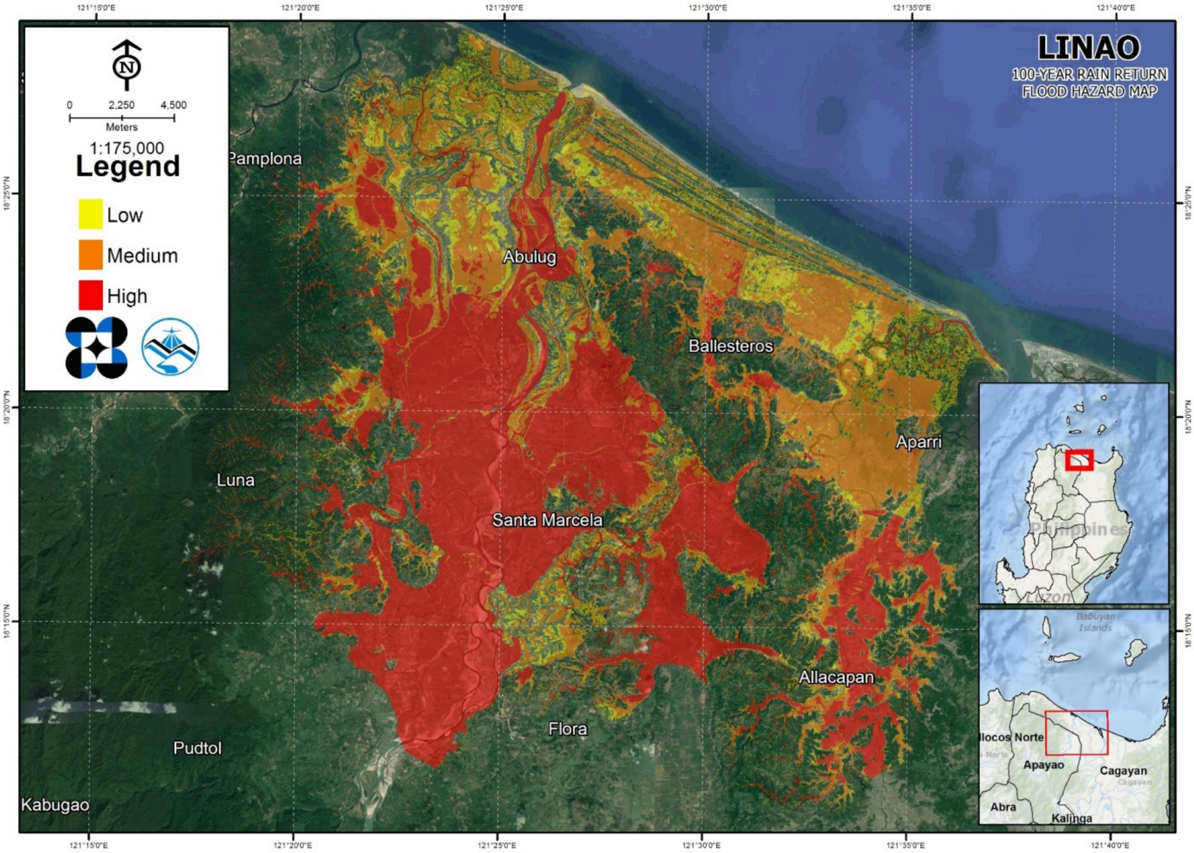


Figure 66. 100-year Flood Hazard Map for the Linao Floodplain

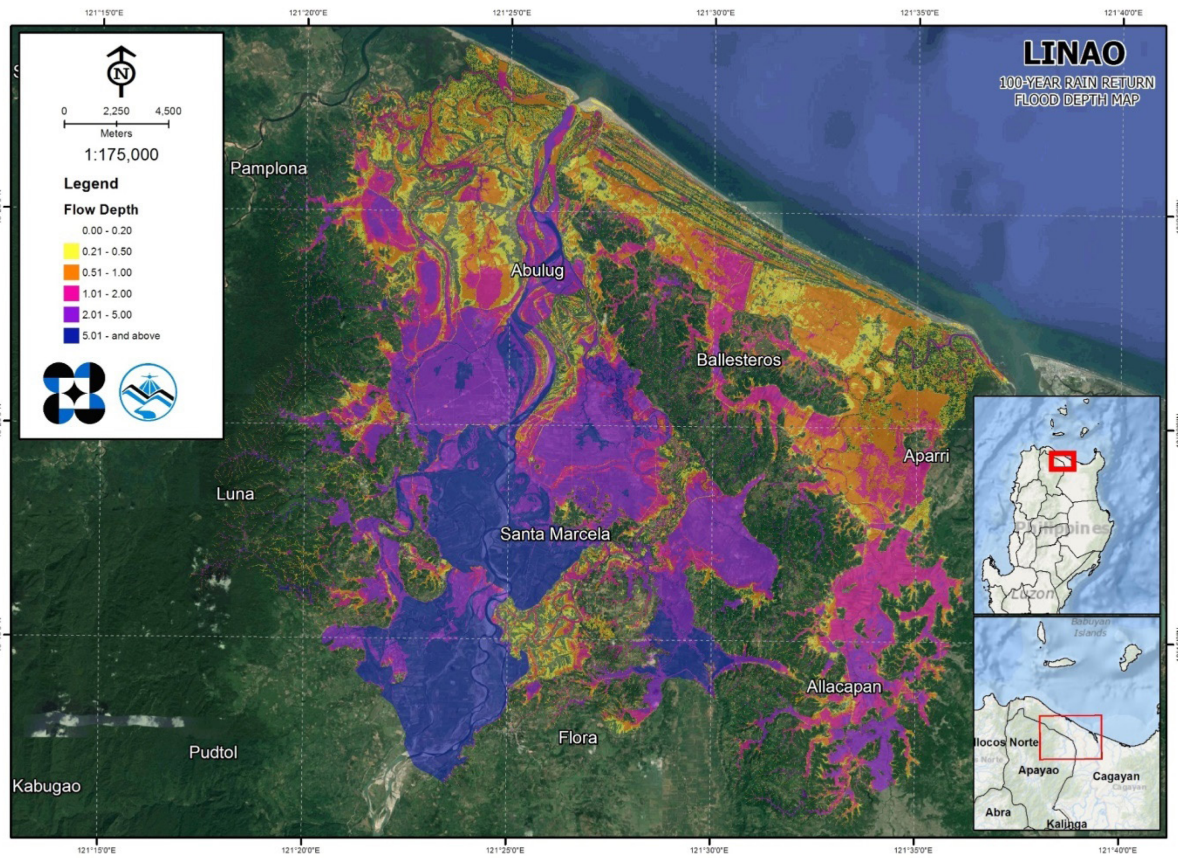


Figure 67. 100-year Flow Depth Map for the Linao Floodplain

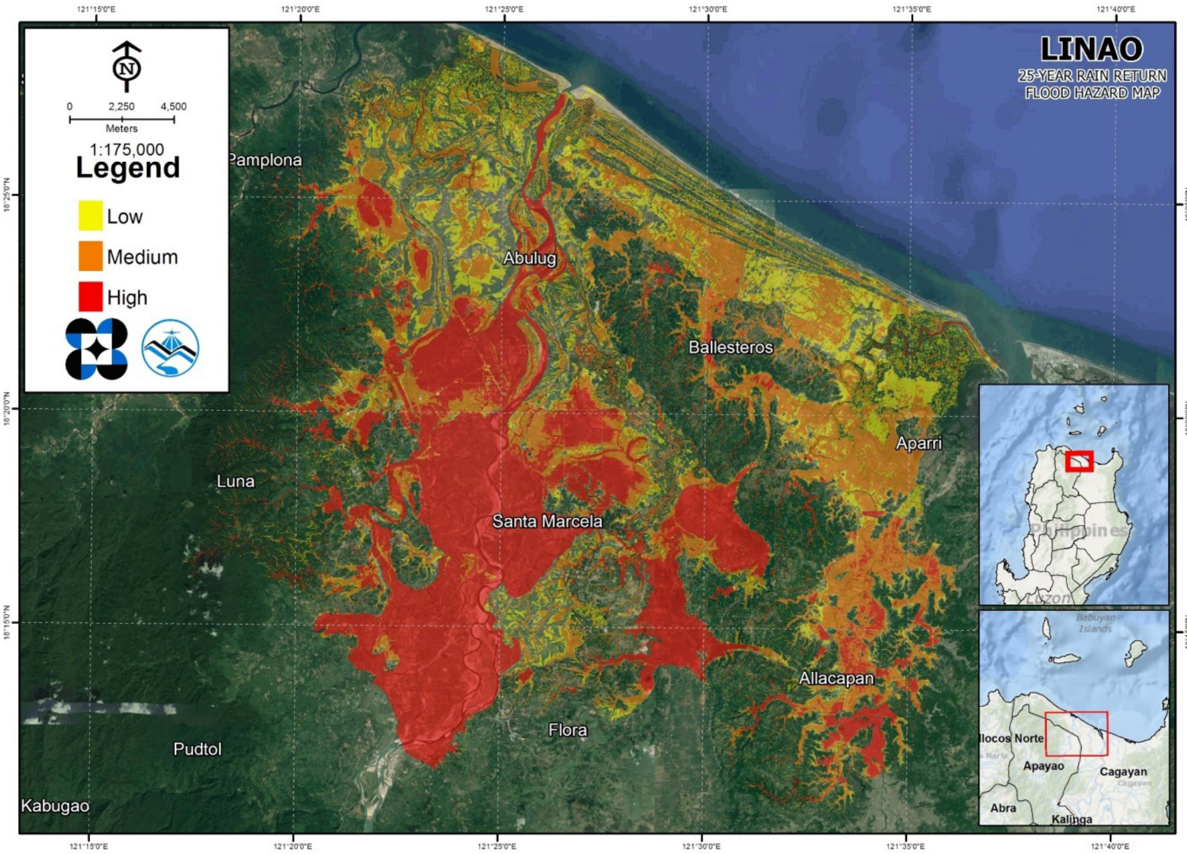


Figure 68. 25-year Flood Hazard Map for the Linao Floodplain

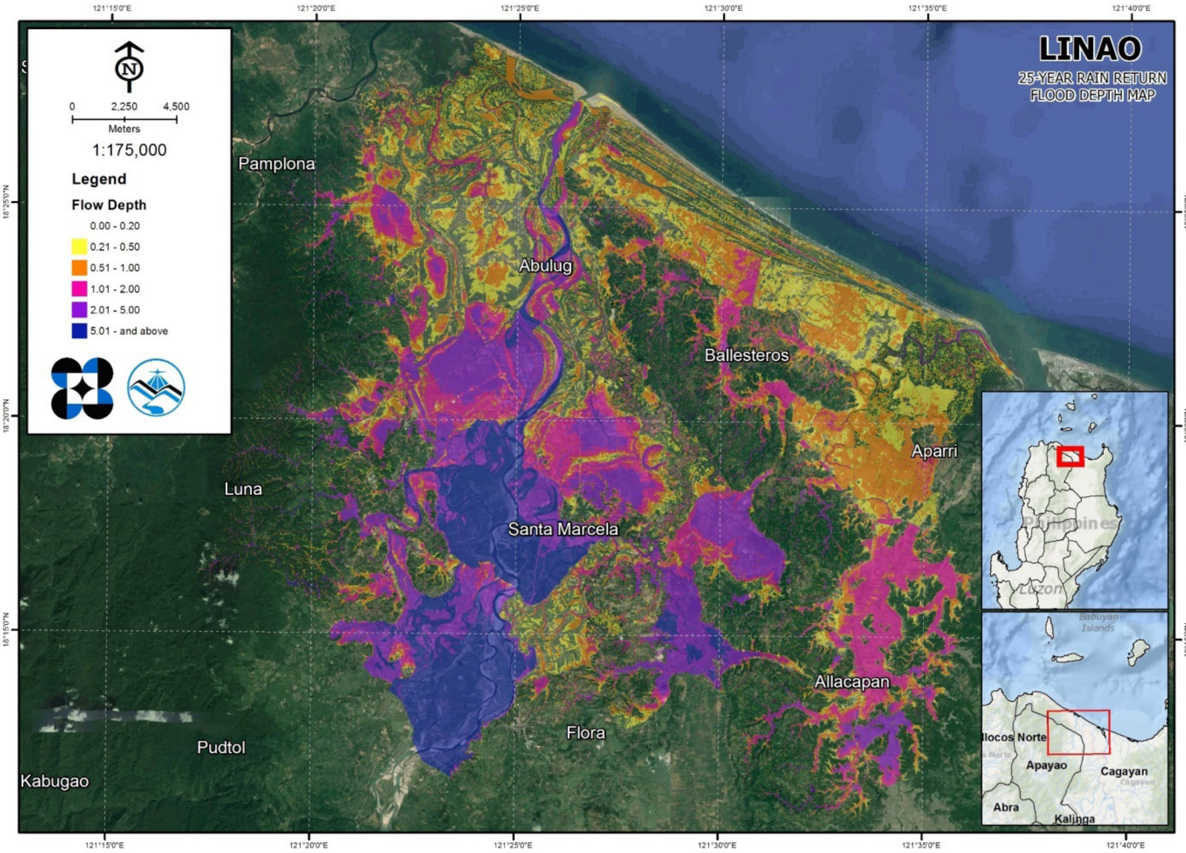


Figure 69. 25-year Flow Depth Map for the Linao Floodplain

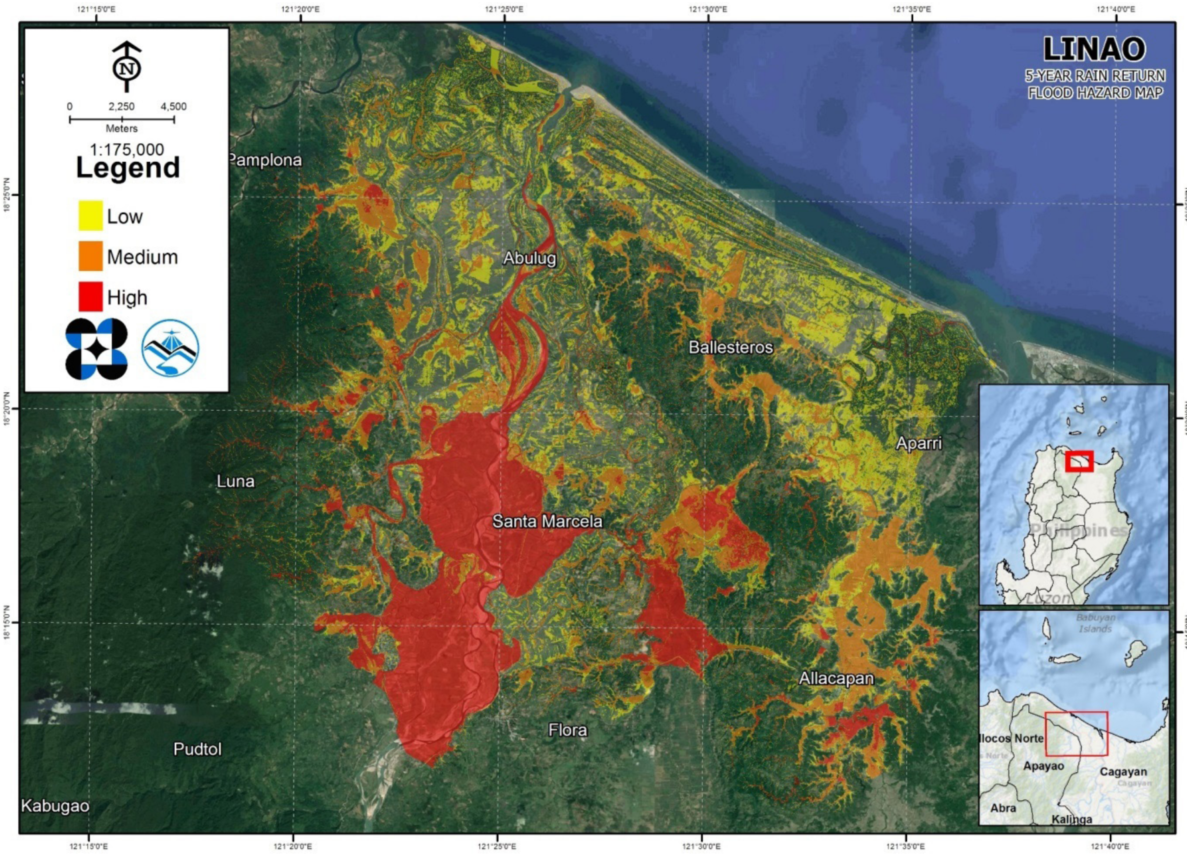


Figure 70. 5-year Flood Hazard Map for the Linao Floodplain

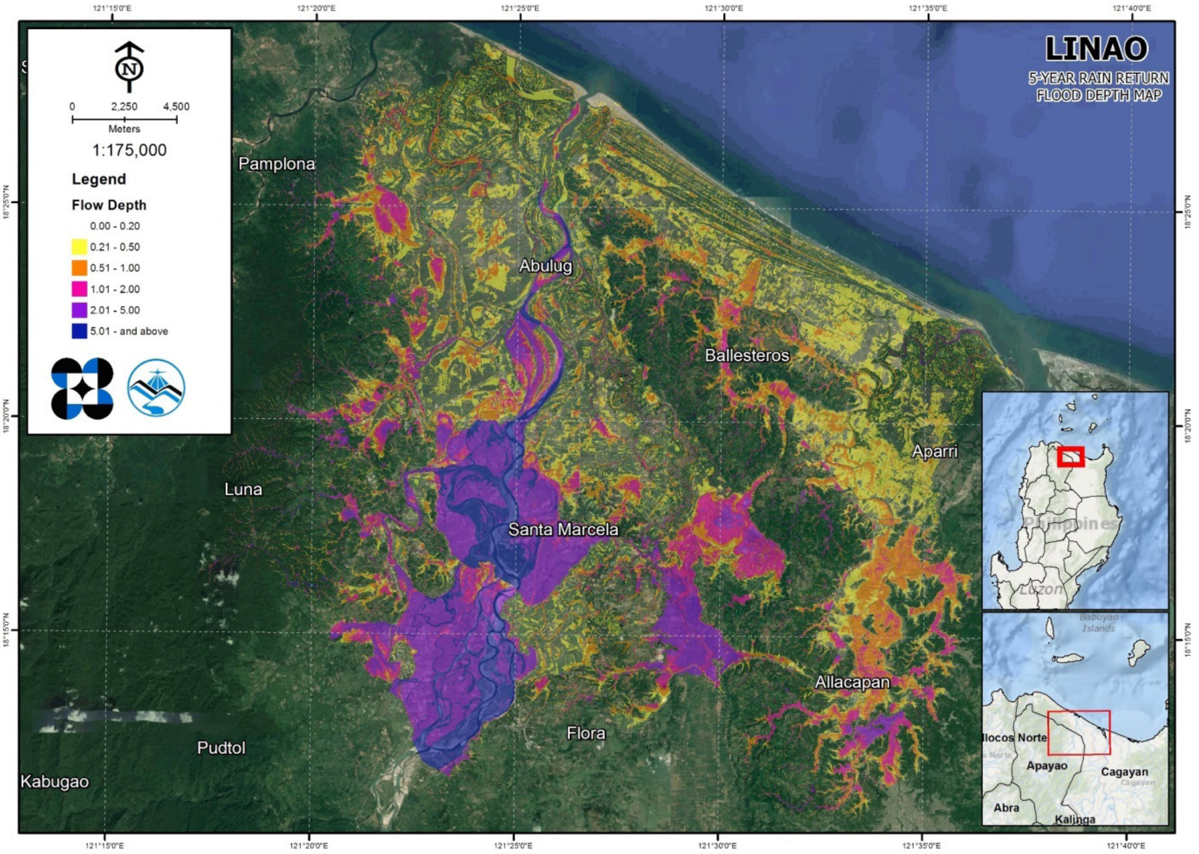


Figure 71. 5-year Flood Depth Map for the Linao Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in theLinao river basin, grouped by municipality, are listed below. For the said basin, four (4) municipalities consisting of fifty (50) barangays are expected to experience flooding when subjected to 5-, 25-, and 100-year rainfall return periods.

For the 5-year return period, 2.32% of the municipality of Abulug, with an area of 123.188782 sq. km., will experience flood levels of less than 0.20 meters. 0.51% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 0.33% and 0.03% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected Areas in Abulug, Cagayan during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Abulug (in sq. km)		
	Banguian	San Agustin	Santa Filomena
0.03-0.20	1.37	1.41	0.081
0.21-0.50	0.42	0.21	0.0014
0.51-1.00	0.24	0.17	0.0012
1.01-2.00	0.0085	0.025	0.0011
2.01-5.00	0.00048	0.0022	0
> 5.00	0	0	0

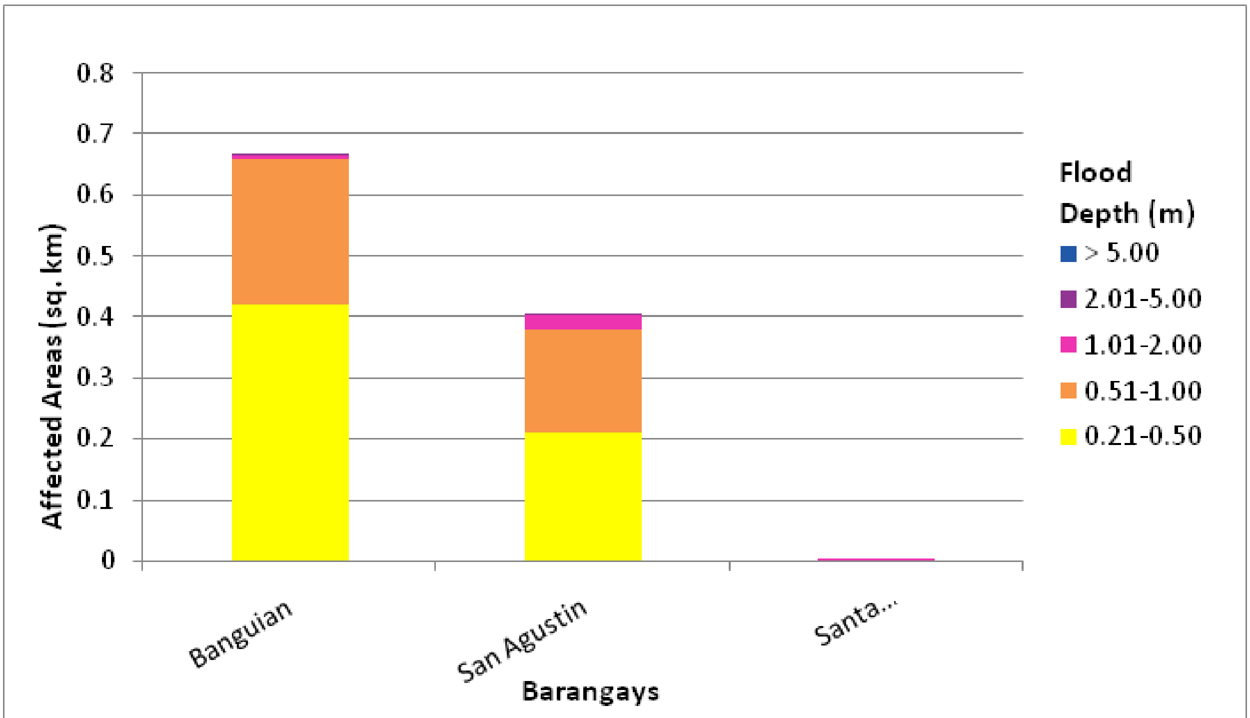


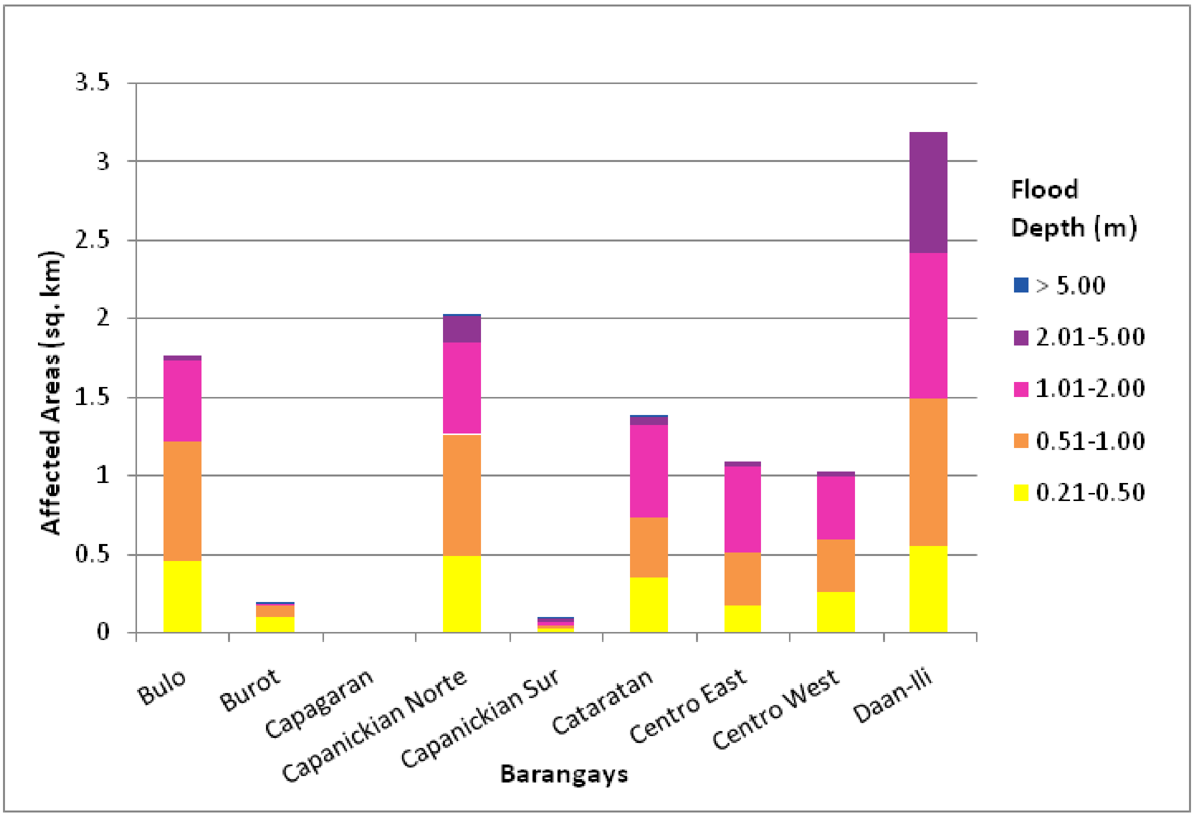
Figure 72. Affected Areas in Abulug, Cagayan during a 5-Year Rainfall Return Period

For the 5-year return period, 20.29% of the municipality of Allacapan, with an area of 252.240469 sq. km., will experience flood levels of less than 0.20 meters. 3.04% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 5.38%, 3.19%, and 0.66% 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 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected Areas in Allacapan, Cagayan during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Allacapan (in sq. km)								
	Bulo	Burot	Capagaran	Capanickian Norte	Capanickian Sur	Cataratan	Centro East	Centro West	Daan-Ili
0.03-0.20	2.33	0.92	0.013	11.32	0.77	6.5	0.93	1.2	1.93
0.21-0.50	0.45	0.1	0.0003	0.49	0.024	0.35	0.17	0.25	0.55
0.51-1.00	0.76	0.068	0.00022	0.77	0.02	0.38	0.34	0.34	0.94
1.01-2.00	0.52	0.015	0	0.59	0.024	0.59	0.54	0.4	0.92
2.01-5.00	0.032	0.0015	0	0.17	0.023	0.06	0.032	0.034	0.77
> 5.00	0	0.0001	0	0.0017	0.0006	0.0001	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Allacapan (in sq. km)							
	Dagupan	Gagaddangan	Labben	Pacac	San Juan	Silangan	Tamboli	Tubel
0.03-0.20	2.19	5.17	0.6	6.98	1.47	3.96	4.56	0.34
0.21-0.50	0.29	2.38	0.072	1.21	0.19	0.19	0.86	0.083
0.51-1.00	0.57	3.92	0.052	2.92	0.37	0.2	1.82	0.093
1.01-2.00	0.44	0.82	0.0032	1.8	0.16	0.12	1.07	0.035
2.01-5.00	0.034	0.047	0.0005	0.41	0.0076	0.029	0.0046	0.00057
> 5.00	0	0	0	0.0002	0.0003	0	0	0.0001



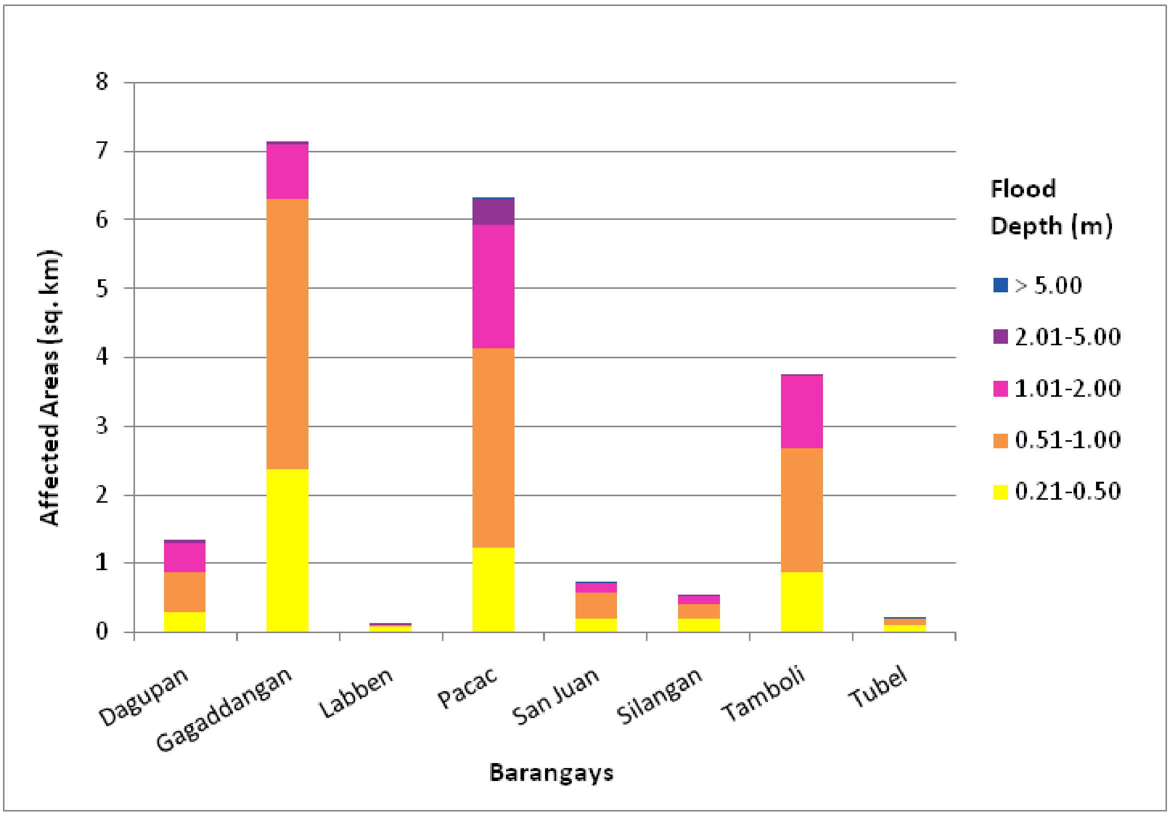


Figure 73. Affected Areas in Allacapan, Cagayan during a 5-Year Rainfall Return Period

For the 5-year return period, 13.59% of the municipality of Aparri, with an area of 254.033602 sq. km., will experience flood levels of less than 0.20 meters. 8.10% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.09%, 0.54%, and 0.06% 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 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected Areas in Aparri, Cagayan during a 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Aparri (in sq. km)										
	Backiling	Bangag	Binalan	Bisagu	Bulala Norte	Bulala Sur	Caagaman	Linao	Navagan	Plaza	Zinarag
0.03-0.20	1.68	7.46	2.66	4.38	2.23	1.58	2.39	0.66	4.77	0.84	5.88
0.21-0.50	0.41	2.36	3.36	1.34	1.28	1.23	1.36	0.071	2.83	0.89	5.45
0.51-1.00	2.06	2.42	0.94	0.27	0.14	0.032	0.29	0.029	0.46	0.18	1.03
1.01-2.00	0.29	0.77	0.029	0.11	0.039	0.002	0.016	0.0048	0.046	0.0014	0.064
2.01-5.00	0.0001	0.12	0	0.0035	0.011	0	0	0	0.017	0.0004	0.0084
> 5.00	0	0	0	0	0.0009	0	0	0	0.0013	0	0.0036

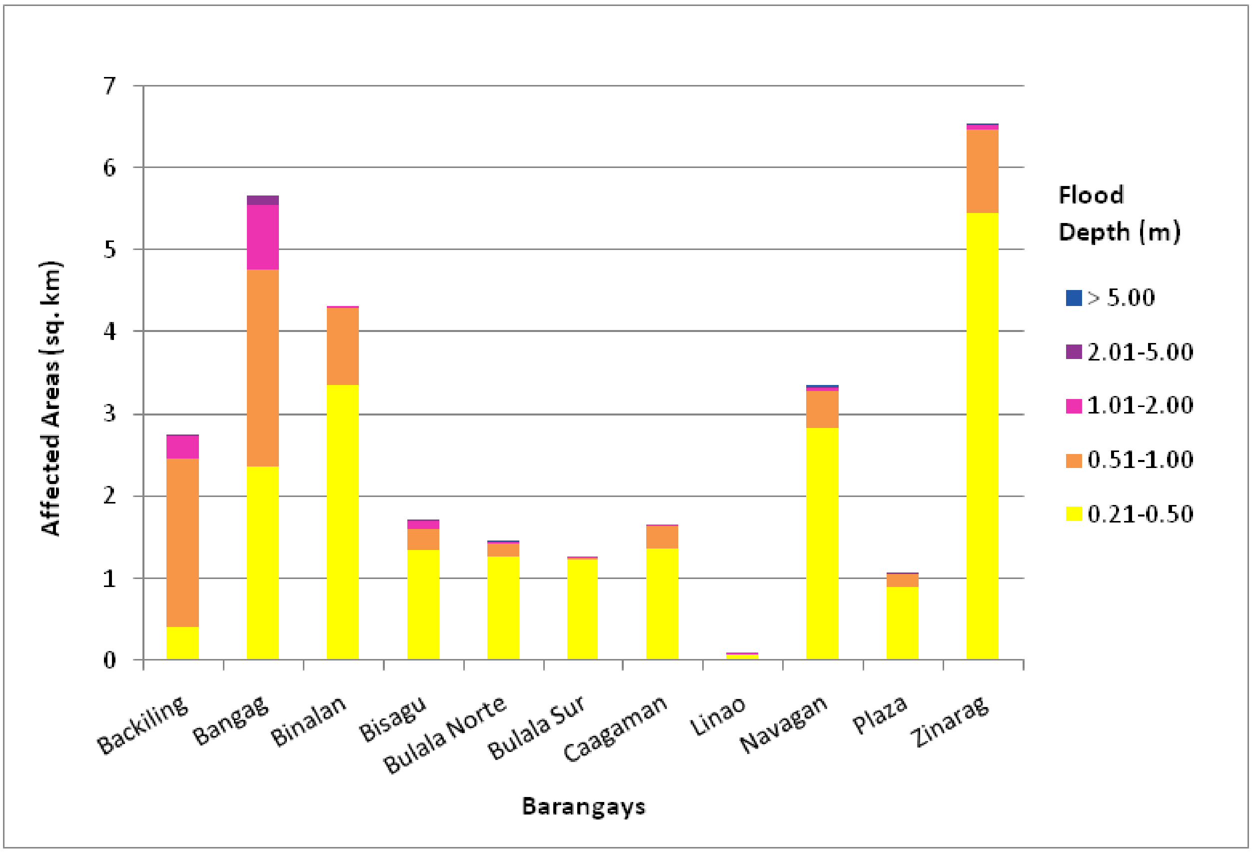


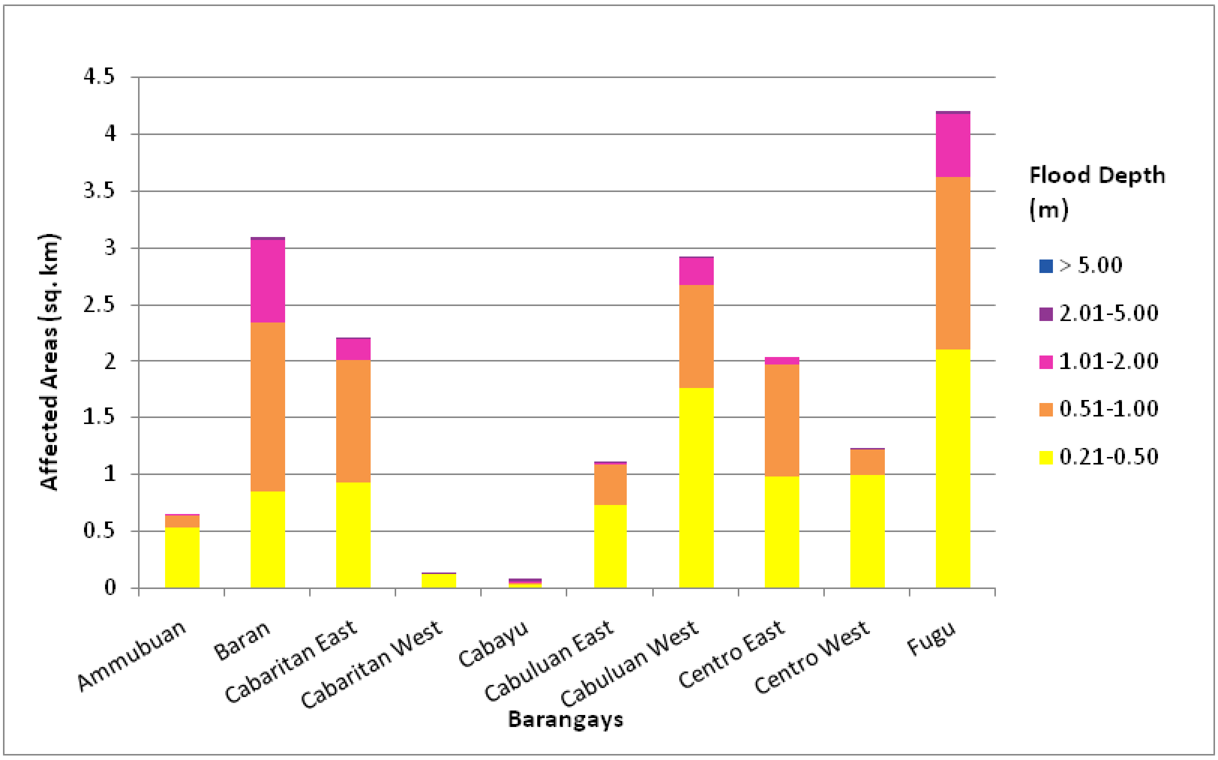
Figure 74. Affected Areas in Aparri, Cagayan during a 5-Year Rainfall Return Period

For the 5-year return period, 54.03% of the municipality of Ballesteros, with an area of 117.917491 sq. km., will experience flood levels of less than 0.20 meters. 15.11% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 9.63%, 3.24%, 0.34%, 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 39 are the affected areas, in square kilometers, by flood depth per barangay.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ballesteros (in sq. km)									
	Ammubuan	Baran	Cabaritan East	Cabaritan West	Cabayu	Cabuluan East	Cabuluan West	Centro East	Centro West	Fugu
0.03-0.20	1.37	6.78	4.51	0.4	0.68	1.49	3.6	1.35	1.6	8.09
0.21-0.50	0.53	0.85	0.93	0.12	0.022	0.73	1.76	0.97	0.99	2.1
0.51-1.00	0.12	1.49	1.07	0.013	0.017	0.35	0.9	0.99	0.23	1.52
1.01-2.00	0.0012	0.72	0.2	0.0014	0.02	0.023	0.24	0.071	0.004	0.55
2.01-5.00	0	0.024	0.0019	0.0002	0.014	0.0001	0.013	0	0.0008	0.033
> 5.00	0	0	0	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ballesteros (in sq. km)								
	Mabuttal East	Mabuttal West	Nararagan	Palloc	Payagan East	Payagan West	San Juan	Santa Cruz	Zitanga
0.03-0.20	2.56	1.4	4.54	2.39	2.52	3.58	4.5	2.81	9.54
0.21-0.50	0.47	0.26	0.14	1.75	2.41	1.41	0.15	1.26	0.96
0.51-1.00	0.39	0.42	0.13	0.17	0.53	0.86	0.16	0.33	1.67
1.01-2.00	0.11	0.35	0.15	0.0017	0.069	0.11	0.16	0.034	1.01
2.01-5.00	0.0002	0.021	0.062	0	0.0006	0	0.15	0.0006	0.08
> 5.00	0	0	0.0042	0	0	0	0.0028	0	0

Table 39. Affected Areas in Ballesteros, Cagayan during a 5-Year Rainfall Return Period



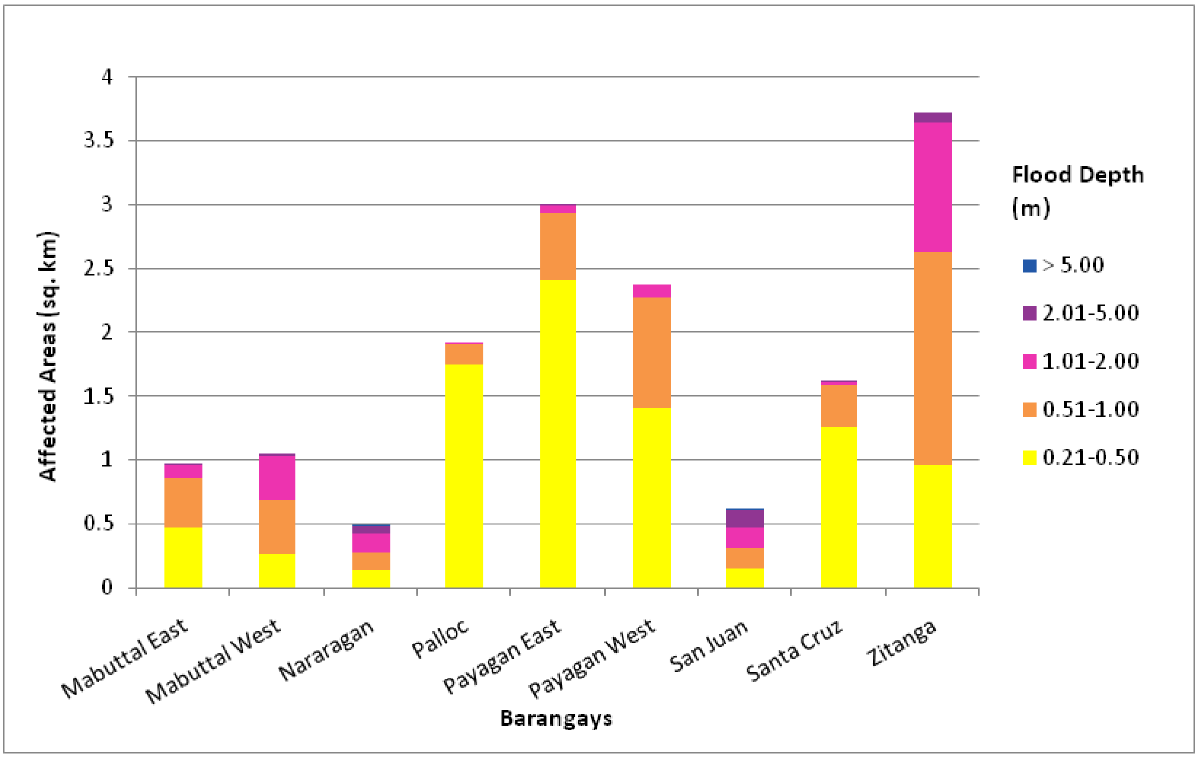


Figure 75. Affected Areas in Ballesteros, Cagayan during a 5-Year Rainfall Return Period

For the 25-year return period, 2.12% of the municipality of Abulug, with an area of 123.188782 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. Meanwhile, 0.58% and 0.13% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected Areas in Abulug, Cagayan during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Abulug (in sq. km)		
	Banguian	San Agustin	Santa Filomena
0.03-0.20	1.2	1.33	0.08
0.21-0.50	0.29	0.17	0.0017
0.51-1.00	0.48	0.23	0.0006
1.01-2.00	0.066	0.088	0.0019
2.01-5.00	0.0017	0.0037	0.0002
> 5.00	0	0	0

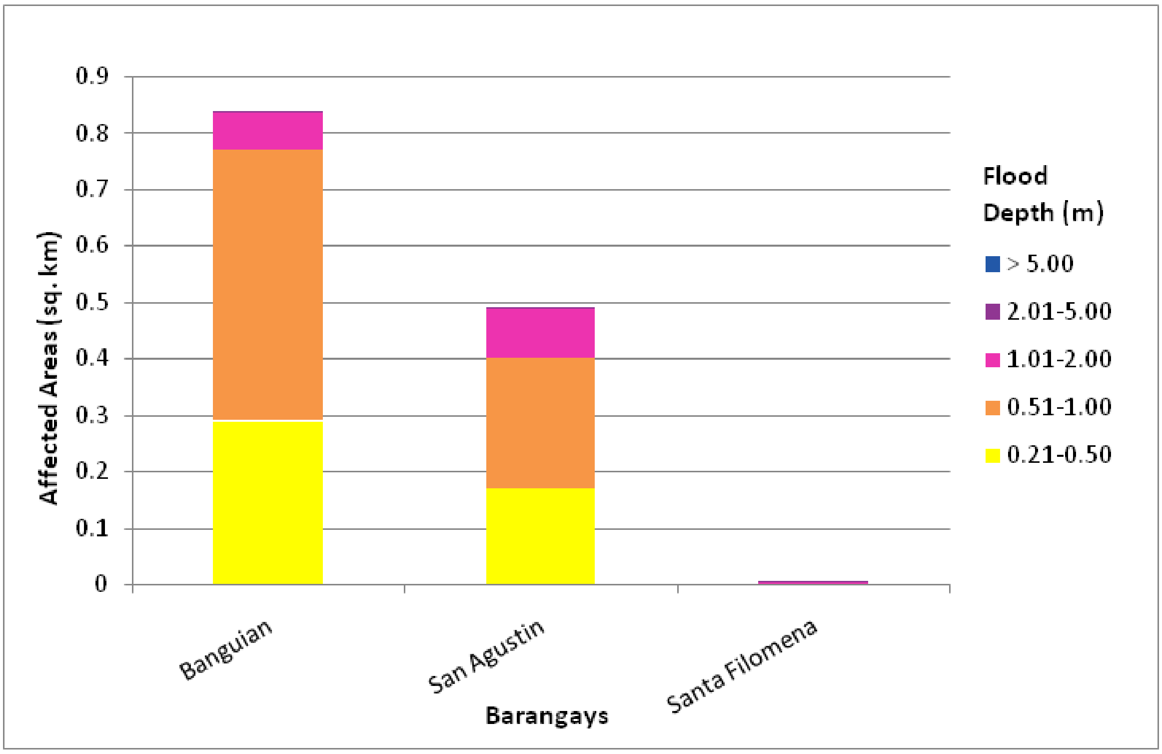


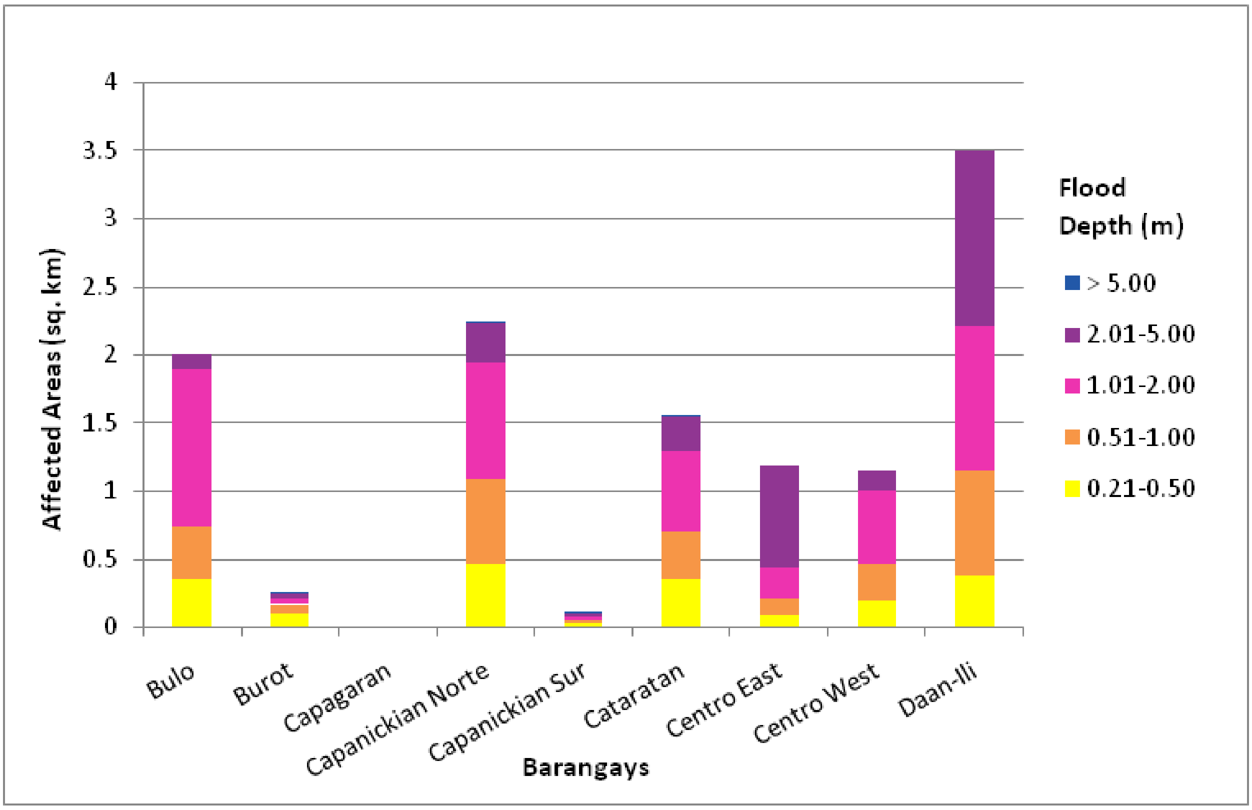
Figure 76. Affected Areas in Abulug, Cagayan during a 25-Year Rainfall Return Period

For the 25-year return period, 19.03% of the municipality of Allacapan, with an area of 252.240469 sq. km., will experience flood levels of less than 0.20 meters. 1.86% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 2.99%, 6.95%, and 1.72% 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 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected Areas in Allacapan, Cagayan during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Allacapan (in sq. km)								
	Bulo	Burot	Capagaran	Capanickian Norte	Capanickian Sur	Cataratan	Centro East	Centro West	Daan-Ili
0.03-0.20	2.11	0.86	0.013	11.1	0.76	6.33	0.83	1.08	1.62
0.21-0.50	0.35	0.096	0.0003	0.46	0.026	0.35	0.085	0.19	0.38
0.51-1.00	0.38	0.067	0.00023	0.62	0.02	0.35	0.12	0.27	0.77
1.01-2.00	1.16	0.042	0	0.86	0.024	0.59	0.23	0.54	1.06
2.01-5.00	0.11	0.042	0	0.29	0.032	0.26	0.74	0.14	1.28
> 5.00	0	0.0001	0	0.0056	0.0038	0.00011	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Allacapan (in sq. km)							
	Dagupan	Gagaddangan	Labben	Pacac	San Juan	Silangan	Tamboli	Tubel
0.03-0.20	2.05	4.43	0.59	6.4	1.4	3.87	4.25	0.32
0.21-0.50	0.17	0.84	0.058	0.68	0.14	0.2	0.61	0.058
0.51-1.00	0.36	1.59	0.074	1.44	0.28	0.18	0.89	0.12
1.01-2.00	0.72	5.34	0.009	3.84	0.37	0.2	2.5	0.04
2.01-5.00	0.22	0.14	0.0008	0.96	0.012	0.054	0.051	0.013
> 5.00	0	0	0	0.0005	0.0004	0	0	0.0001



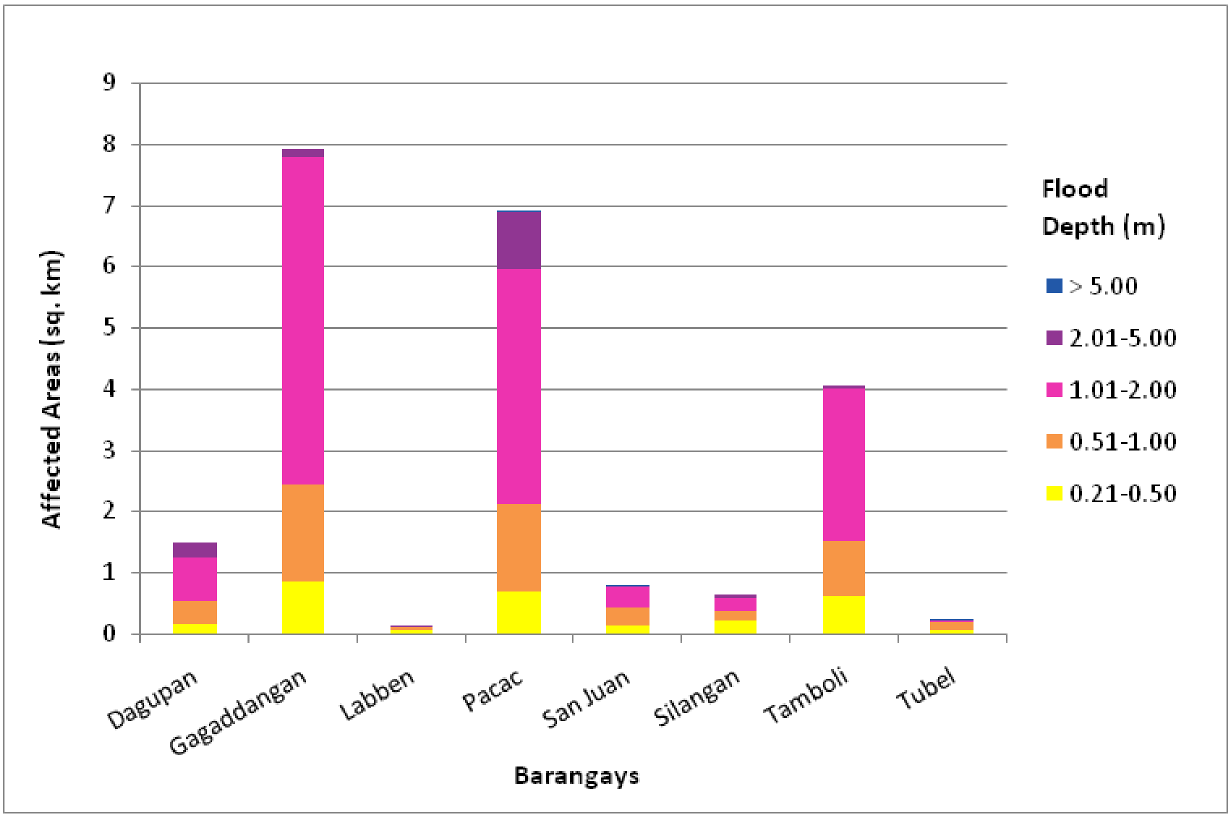


Figure 77. Affected Areas in Allacapan, Cagayan during a 25-Year Rainfall Return Period

For the 25-year return period, 9.36% of the municipality of Aparri, with an area of 254.033602 sq. km., will experience flood levels of less than 0.20 meters. 6.33% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 7.28%, 2.25%, and 0.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected Areas in Aparri, Cagayan during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Aparri (in sq. km)										
	Backiling	Bangag	Binalan	Bisagu	Bulala Norte	Bulala Sur	Caagaman	Linao	Navagan	Plaza	Zinarag
0.03-0.20	1.53	6.61	1.09	3.4	1.72	0.96	1.76	0.63	2.91	0.54	2.62
0.21-0.50	0.16	1.44	1.87	2	1.29	1.15	0.99	0.081	3.5	0.25	3.36
0.51-1.00	0.44	2.6	3.91	0.48	0.63	0.73	1.19	0.049	1.62	0.86	5.98
1.01-2.00	2.31	2.2	0.12	0.2	0.023	0.0029	0.13	0.01	0.055	0.26	0.41
2.01-5.00	0.007	0.29	0	0.022	0.048	0	0	0	0.039	0.0008	0.057
> 5.00	0	0	0	1.5E-06	0.0017	0	0	0	0.0057	0	0.0051

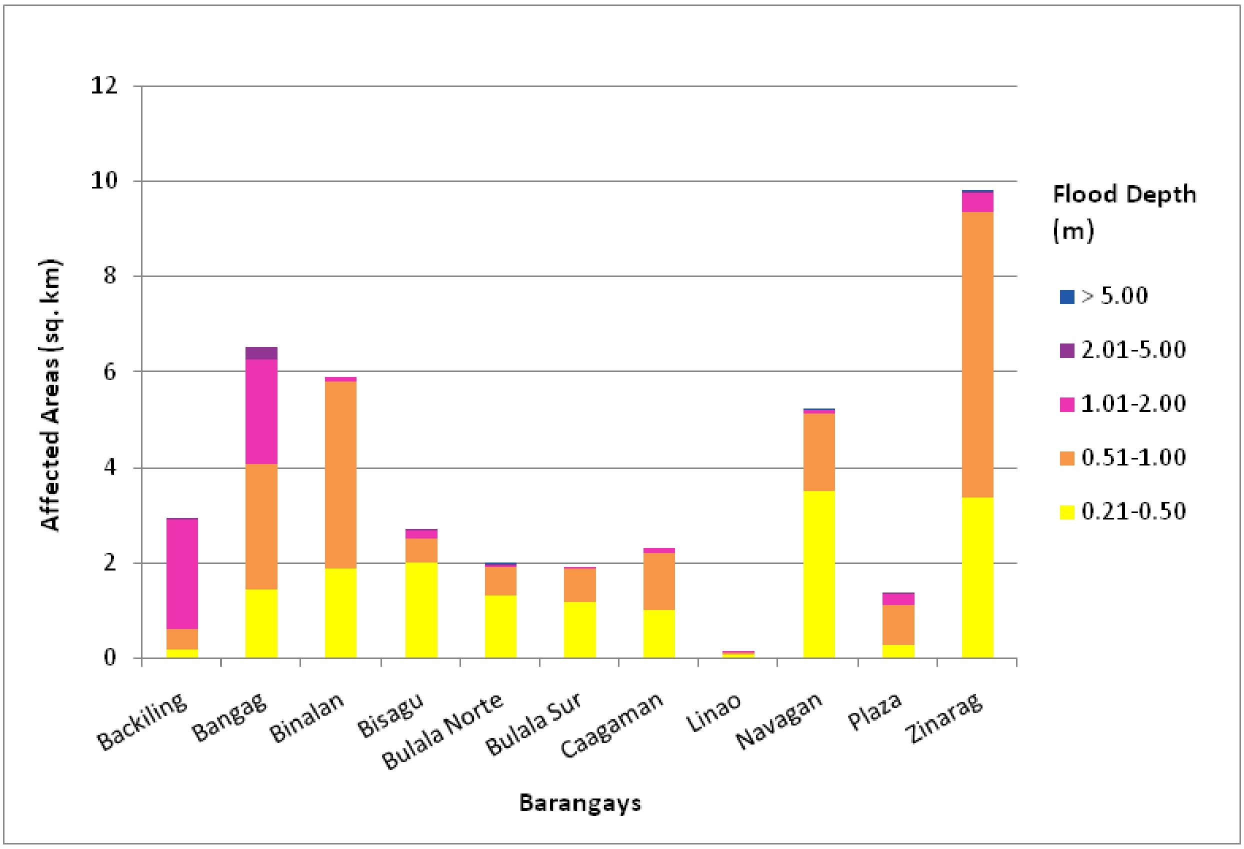


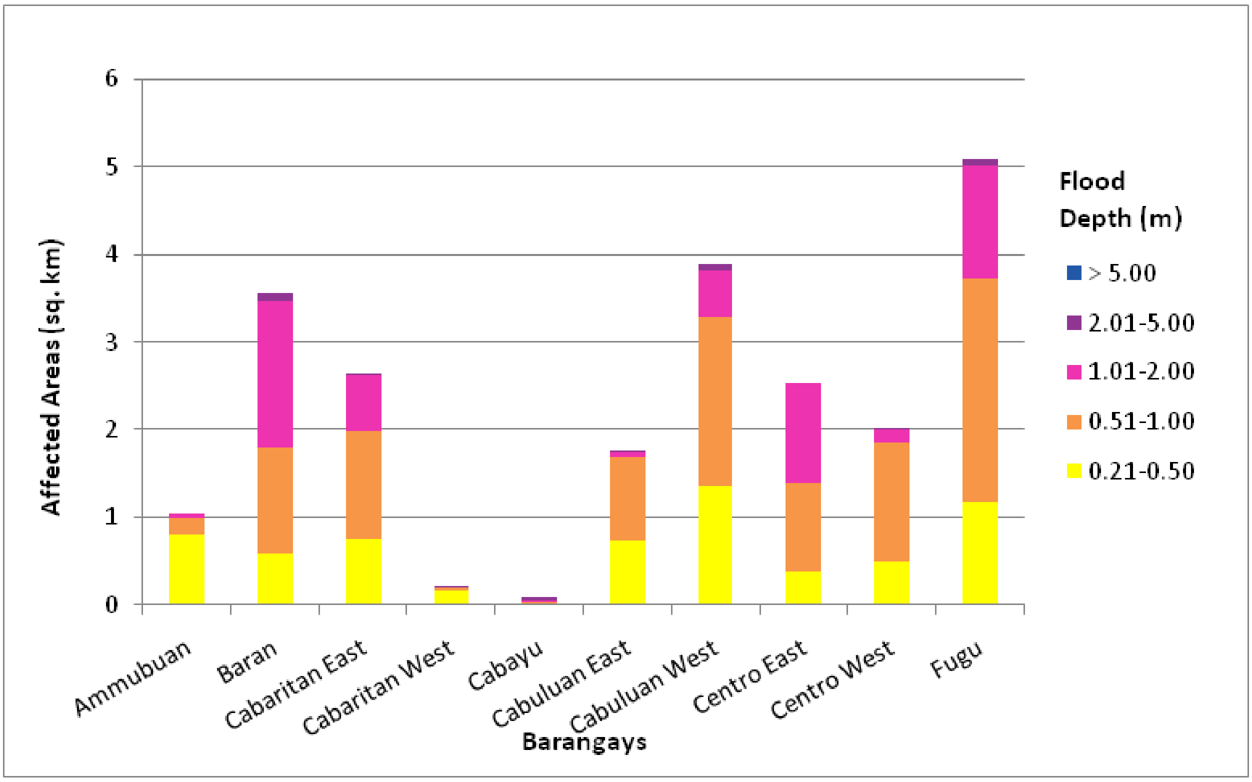
Figure 78. Affected Areas in Aparri, Cagayan during a 25-Year Rainfall Return Period

For the 25-year return period, 45.88% of the municipality of Ballesteros, with an area of 117.917491 sq. km., will experience flood levels of less than 0.20 meters. 11.70% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 15.97%, 7.94%, 0.89%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected Areas in Ballesteros, Cagayan during a 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ballesteros (in sq. km)									
	Ammubuan	Baran	Cabaritan East	Cabaritan West	Cabayu	Cabuluan East	Cabuluan West	Centro East	Centro West	Fugu
0.03-0.20	0.98	6.32	4.09	0.31	0.67	0.84	2.61	0.85	0.81	7.21
0.21-0.50	0.8	0.59	0.76	0.17	0.022	0.74	1.35	0.39	0.49	1.18
0.51-1.00	0.2	1.2	1.22	0.047	0.018	0.95	1.94	1.01	1.37	2.55
1.01-2.00	0.038	1.67	0.65	0.0018	0.021	0.074	0.52	1.13	0.15	1.27
2.01-5.00	0	0.1	0.0039	0.0002	0.022	0.0001	0.089	0	0.0009	0.087
> 5.00	0	0	0	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ballesteros (in sq. km)								
	Mabuttal East	Mabuttal West	Nararagan	Palloc	Payagan East	Payagan West	San Juan	Santa Cruz	Zitanga
0.03-0.20	2.26	1.29	4.46	1.7	1.63	2.61	4.39	1.99	9.08
0.21-0.50	0.54	0.2	0.15	1.09	1.35	1.47	0.16	1.66	0.69
0.51-1.00	0.44	0.35	0.14	1.51	2.34	1.41	0.15	0.63	1.36
1.01-2.00	0.29	0.49	0.17	0.005	0.2	0.48	0.21	0.16	1.83
2.01-5.00	0.0002	0.13	0.1	0	0.0022	0	0.2	0.0018	0.31
> 5.00	0	0	0.0091	0	0	0	0.02	0	0.0014



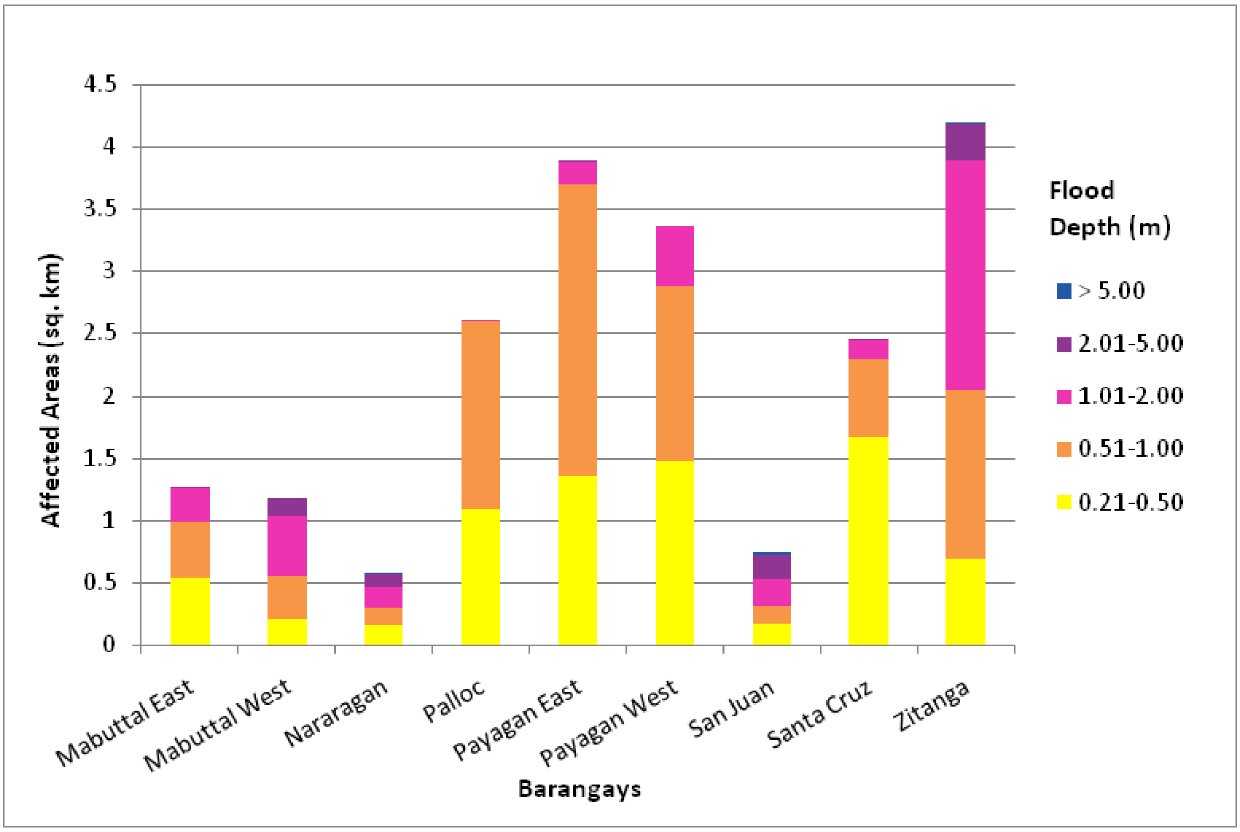


Figure 79. Affected Areas in Ballesteros, Cagayan during a 25-Year Rainfall Return Period

For the 100-year return period, 2.00% of the municipality of Abulug, with an area of 123.188782 sq. km., will experience flood levels of less than 0.20 meters. 0.31% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 0.62%, 0.27%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected Areas in Abulug, Cagayan during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Abulug (in sq. km)		
	Banguian	San Agustin	Santa Filomena
0.03-0.20	1.11	1.28	0.079
0.21-0.50	0.23	0.15	0.003
0.51-1.00	0.51	0.25	0.0007
1.01-2.00	0.19	0.14	0.0019
2.01-5.00	0.0028	0.0055	0.0004
> 5.00	0	0	0

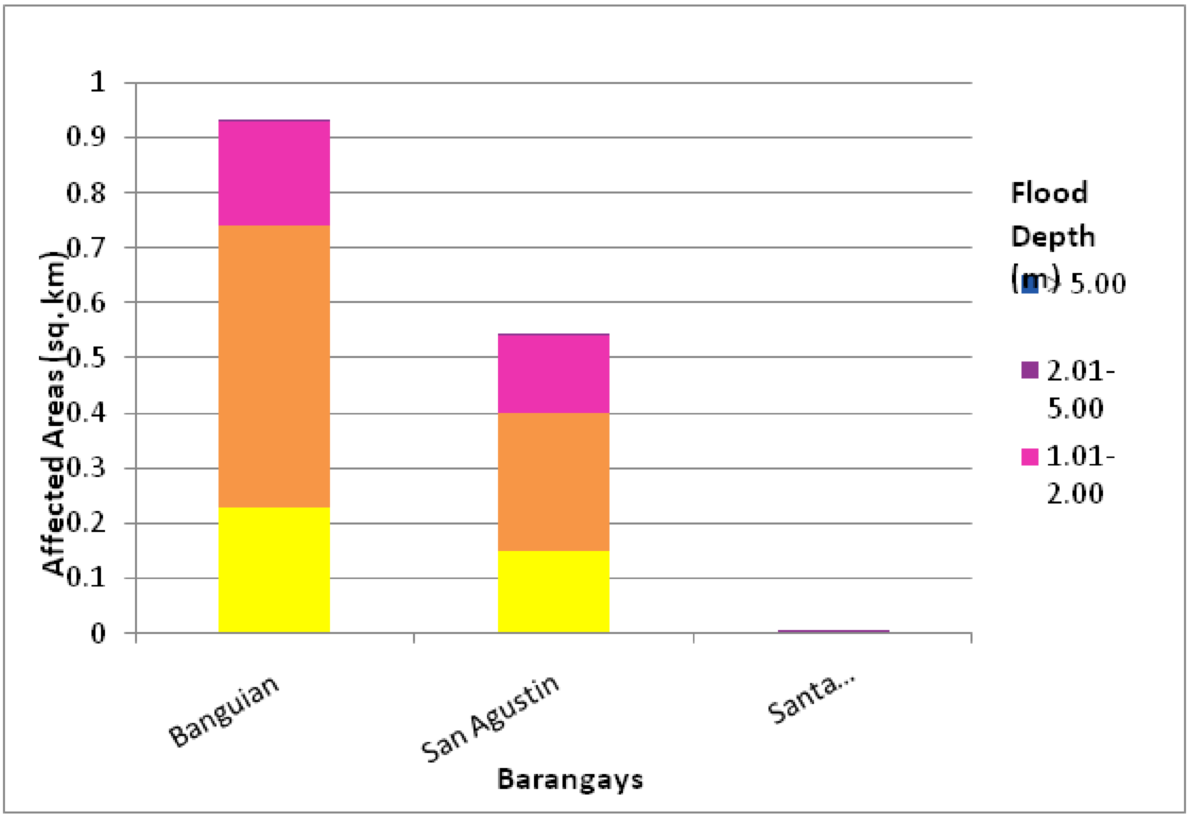


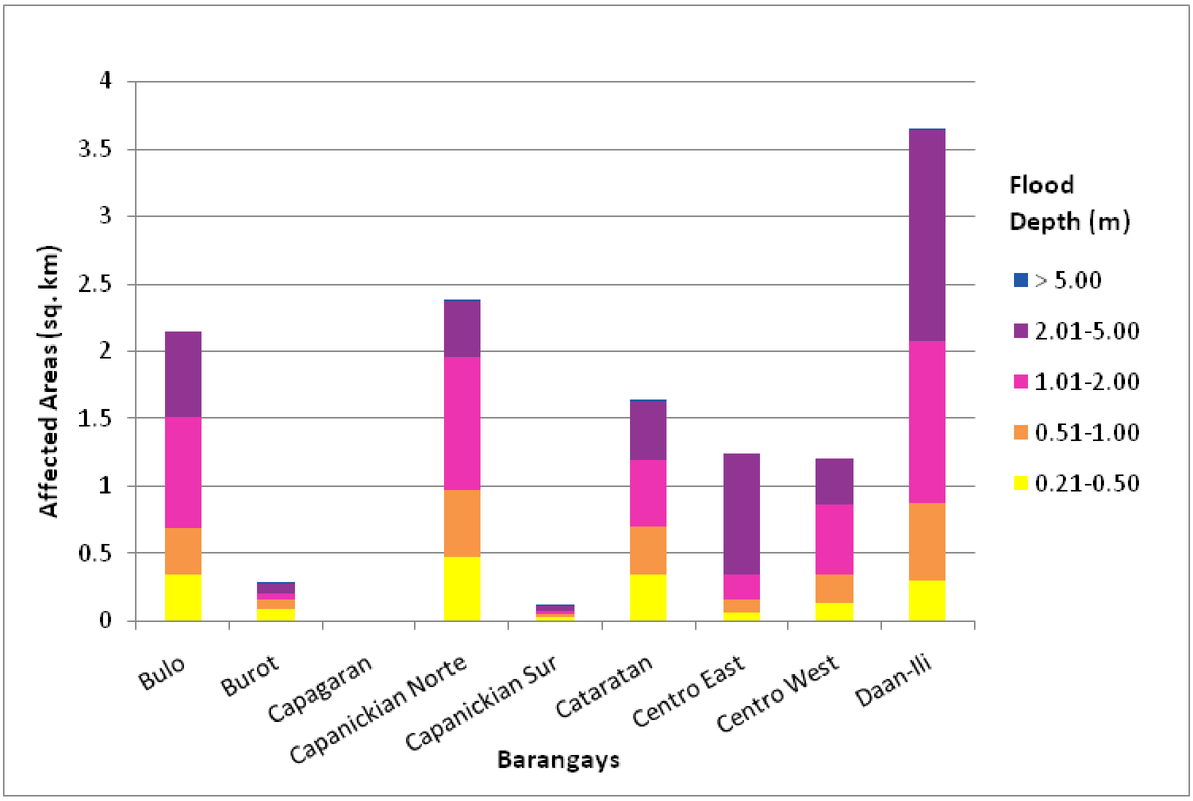
Figure 80. Affected Areas in Abulug, Cagayan during a 100-Year Rainfall Return Period

For the 100-year return period, 18.42% of the municipality of Allacapan, with an area of 252.240469 sq. km., will experience flood levels of less than 0.20 meters. 1.59% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 2.22%, 6.38%, 3.92%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected Areas in Allacapan, Cagayan during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Allacapan (in sq. km)								
	Bulo	Burot	Capagaran	Capanickian Norte	Capanickian Sur	Cataratan	Centro East	Centro West	Daan-Ili
0.03-0.20	1.96	0.83	0.013	10.96	0.75	6.24	0.77	1.02	1.47
0.21-0.50	0.34	0.086	0.0003	0.47	0.027	0.34	0.058	0.13	0.29
0.51-1.00	0.34	0.072	0.00023	0.5	0.021	0.35	0.098	0.21	0.58
1.01-2.00	0.83	0.043	0	0.98	0.022	0.5	0.18	0.52	1.2
2.01-5.00	0.63	0.079	0	0.42	0.038	0.45	0.9	0.34	1.57
> 5.00	0	0.0001	0	0.011	0.0068	0.00091	0	0	0.0054

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Allacapan (in sq. km)							
	Dagupan	Gagaddangan	Labben	Pacac	San Juan	Silangan	Tamboli	Tubel
0.03-0.20	1.98	4.17	0.58	6.14	1.36	3.81	4.1	0.31
0.21-0.50	0.14	0.66	0.048	0.54	0.12	0.2	0.51	0.042
0.51-1.00	0.27	0.91	0.082	1.01	0.23	0.17	0.63	0.13
1.01-2.00	0.49	5.19	0.017	2.65	0.46	0.24	2.72	0.054
2.01-5.00	0.64	1.4	0.0014	2.97	0.022	0.081	0.34	0.018
> 5.00	0	0	0	0.0007	0.0009	0	0	0.0003



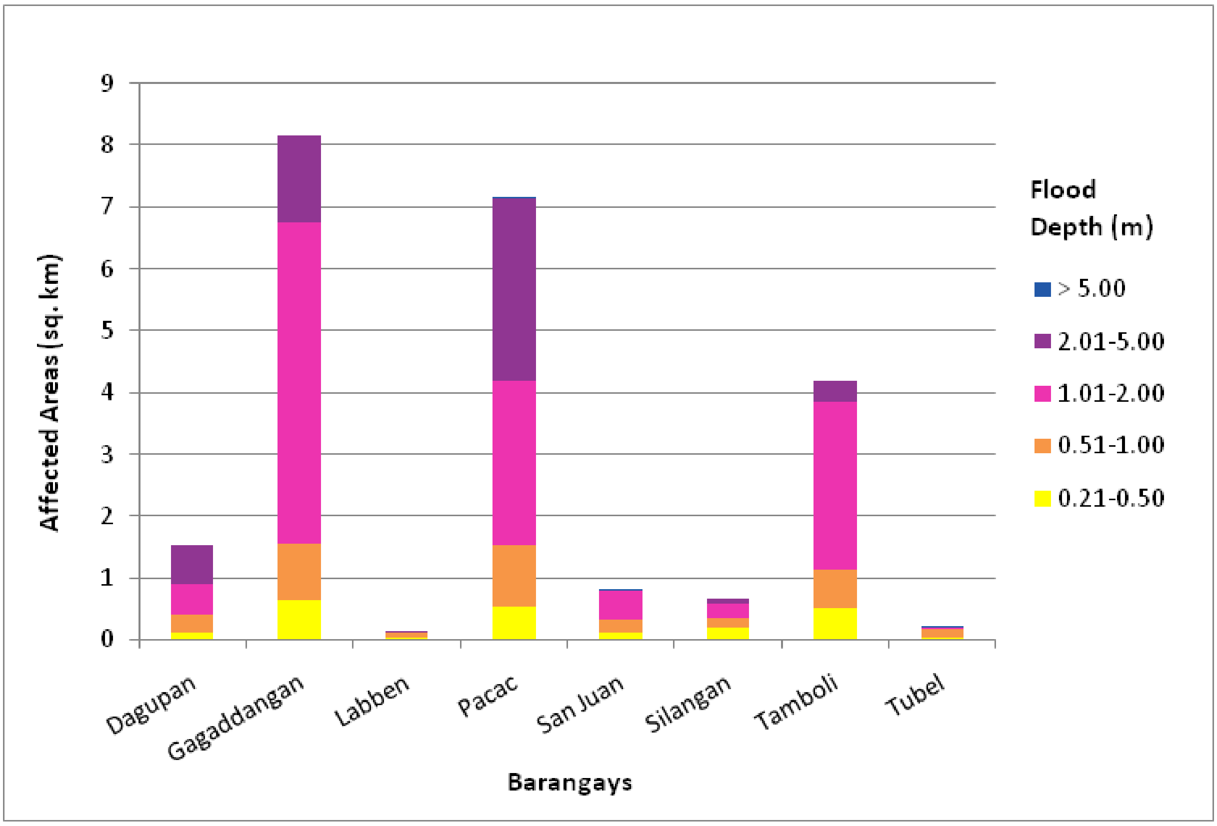


Figure 81. Affected Areas in Allacapan, Cagayan during a 100-Year Rainfall Return Period

For the 100-year return period, 7.77% of the municipality of Aparri, with an area of 254.033602 sq. km., will experience flood levels of less than 0.20 meters. 4.06% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 8.50%, 4.74%, 0.33%, 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 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected Areas in Aparri, Cagayan during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Aparri (in sq. km)										
	Backiling	Bangag	Binalan	Bisagu	Bulala Norte	Bulala Sur	Caagaman	Linao	Navagan	Plaza	Zinarag
0.03-0.20	1.49	6.3	0.74	2.81	1.34	0.77	1.49	0.61	1.59	0.49	2.12
0.21-0.50	0.13	1.03	0.74	1.93	1.01	0.44	0.57	0.082	2.95	0.24	1.18
0.51-1.00	0.26	2.67	4.5	1.07	1.26	1.63	1.18	0.061	3.39	0.21	5.35
1.01-2.00	2.47	2.6	1	0.26	0.037	0.0036	0.83	0.017	0.15	0.97	3.71
2.01-5.00	0.1	0.53	0.0002	0.026	0.053	0	0	4.8E-06	0.041	0.00097	0.077
> 5.00	0	0	0	1.5E-06	0.002	0	0	0	0.0082	0	0.0055

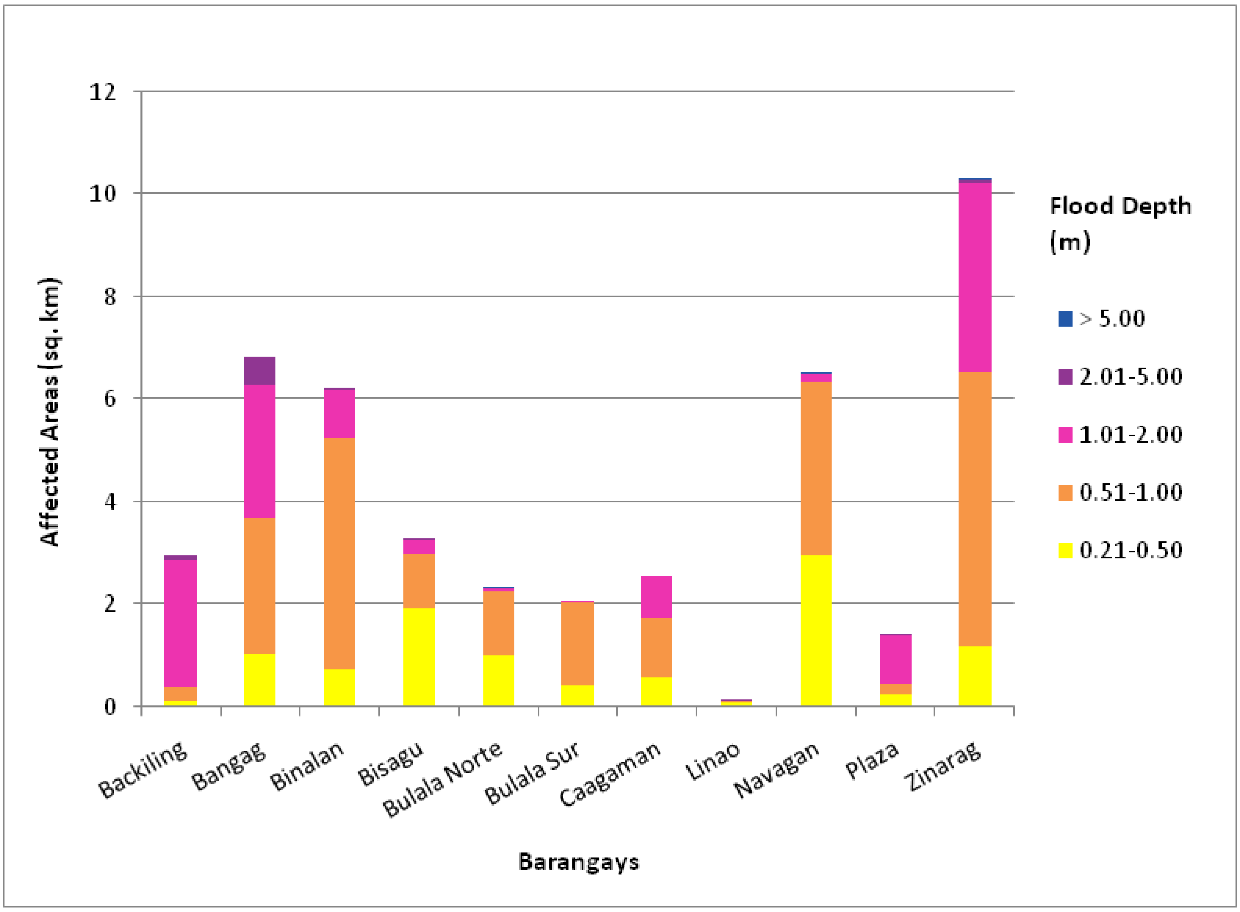


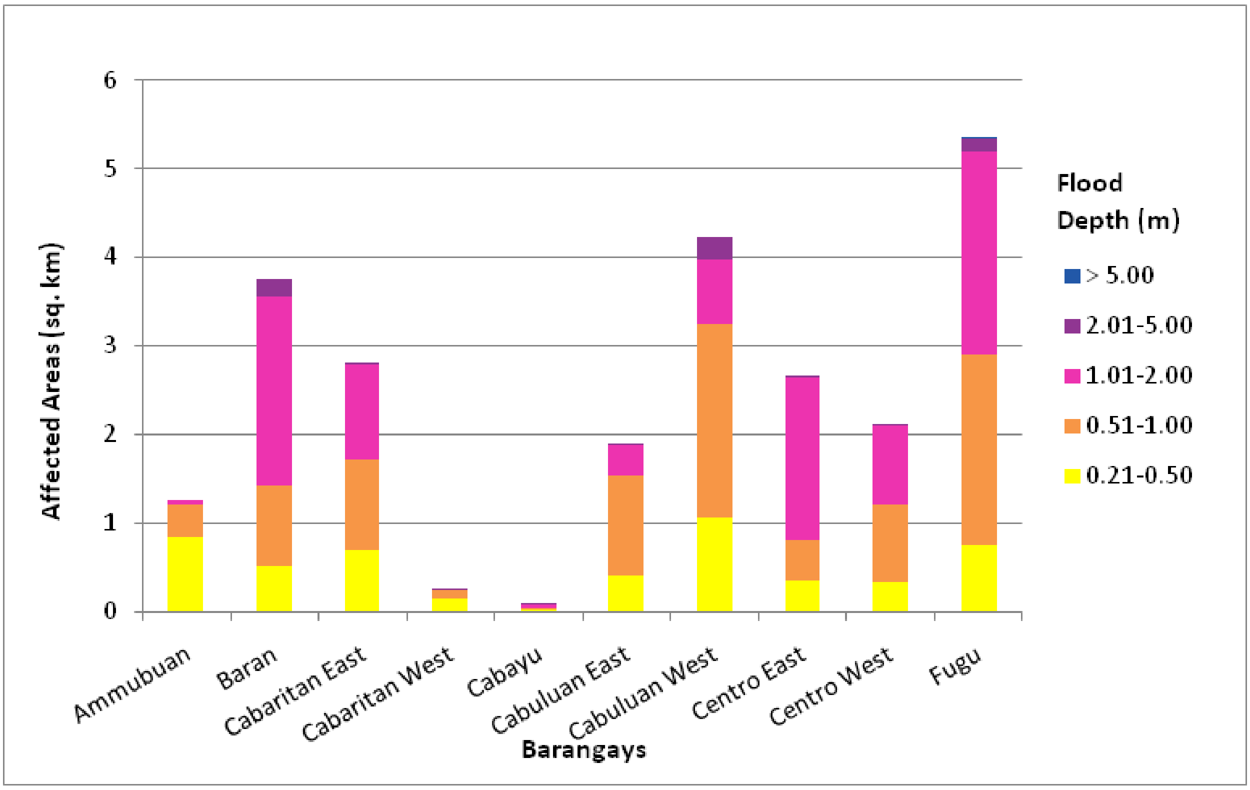
Figure 82. Affected Areas in Aparri, Cagayan during a 100-Year Rainfall Return Period

For the 100-year return period, 43.03% of the municipality of Ballesteros, with an area of 117.917491 sq. km., will experience flood levels of less than 0.20 meters. 8.95% of the area will experience flood levels of 0.21 to 0.50 meters.Meanwhile, 16.61%, 12.17%, 1.55%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected Areas in Ballesteros, Cagayan during a 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ballesteros (in sq. km)									
	Ammubuan	Baran	Cabaritan East	Cabaritan West	Cabayu	Cabuluan East	Cabuluan West	Centro East	Centro West	Fugu
0.03-0.20	0.75	6.12	3.89	0.27	0.66	0.7	2.28	0.72	0.7	6.93
0.21-0.50	0.84	0.51	0.69	0.15	0.024	0.4	1.06	0.35	0.33	0.74
0.51-1.00	0.36	0.92	1.03	0.1	0.019	1.14	2.18	0.45	0.87	2.16
1.01-2.00	0.063	2.12	1.09	0.0026	0.021	0.36	0.73	1.86	0.92	2.29
2.01-5.00	0	0.2	0.0054	0.0002	0.028	0.0002	0.26	0.0052	0.001	0.17
> 5.00	0	0	0	0	0	0	0	0	0	0.0002

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ballesteros (in sq. km)								
	Mabuttal East	Mabuttal West	Nararagan	Palloc	Payagan East	Payagan West	San Juan	Santa Cruz	Zitanga
0.03-0.20	2.06	1.23	4.41	1.48	1.47	2.27	4.32	1.65	8.83
0.21-0.50	0.56	0.16	0.16	0.63	0.6	0.95	0.17	1.63	0.6
0.51-1.00	0.5	0.29	0.14	2.18	3.09	1.99	0.15	0.93	1.09
1.01-2.00	0.39	0.56	0.18	0.027	0.36	0.74	0.21	0.23	2.2
2.01-5.00	0.014	0.21	0.13	0	0.011	0	0.24	0.0026	0.55
> 5.00	0	0	0.01	0	0	0	0.035	0	0.0026



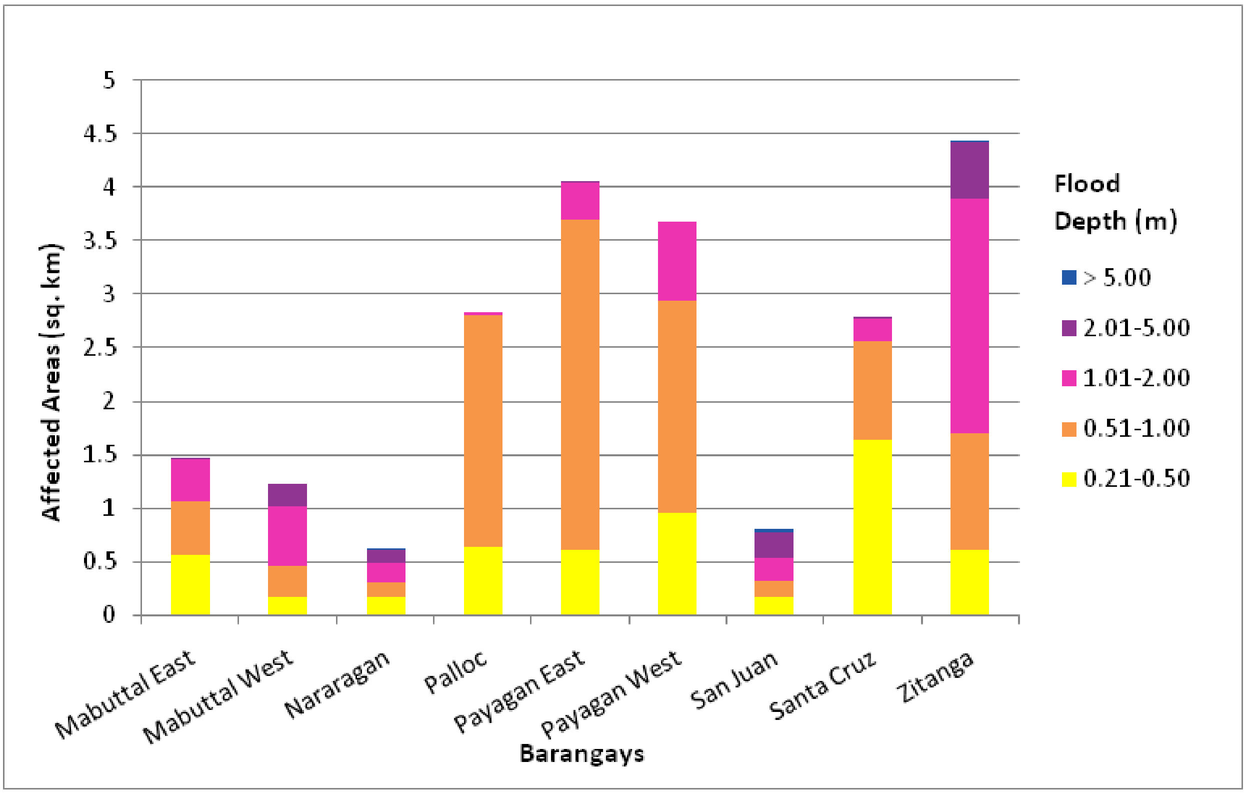


Figure 83. Affected Areas in Ballesteros, Cagayan during a 100-Year Rainfall Return Period

Among the barangays in the municipality of Abulug in the Cagayan province, Banguian is projected to have the highest percentage of area that will experience flood levels, at 1.66%. Meanwhile, Barangay San Agustin posted the second highest percentage of area that may be affected by flood depths, at 1.48%.

Among the barangays in the municipality of Allacapan the in Cagayan province, Capanickian Norte is projected to have the highest percentage of area that will experience flood levels, at 10.83%. Meanwhile, Barangay Pacac posted the second highest percentage of area that may be affected by flood depths, at 10.81%.

Among the barangays in the municipality of Aparri in the Cagayan province, Bangag is projected to have the highest percentage of area that will experience flood levels, at 10.66%. Meanwhile, Barangay Zinarag posted the second highest percentage of area that may be affected by flood depths, at 10.10%.

Among the barangays in the municipality of Ballesteros in the Cagayan province, Zitanga is projected to have the highest percentage of area that will experience flood levels, at 10.77%. Meanwhile, Barangay Fugu posted the second highest percentage of area that may be affected by flood depths, at 9.98%.

The generated flood hazard maps for the Linao Floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for hazard maps (i.e., “Low”, “Medium”, and “High”), the affected institutions were given anindividual assessment for each flood hazard scenario (5-year, 25-year, and 10-year).

Table 48. Areas 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	46.9934	35.2264	25.4063
Medium	43.4172	69.2971	74.1052
High	5.6044	15.5455	29.6756
TOTAL	**96.015**	**120.069**	**129.187**

Of the thirty-nine (39) identified educationalinstitutions in the Linao floodplain, six (6) schools were assessed to beexposed to Low-level flooding during a 5-year scenario.Meanwhile, two (2) schools were found to be exposed to Medium-level flooding in the same scenario.

In the 25-year scenario, nine (9) schools were found to be exposed to Low-level flooding, while three (3) schools were assessed to beexposed to Medium-level flooding.

For the 100-year scenario, nine (9) schoolswere assessed to be exposed to Low-level flooding, while five (5) schools were exposed to Medium-level flooding. See Annex 12 for a more detailed enumeration of the schools exposed to flooding in the Linao river basin.

Additionally, ten (10) medical institutions were identified in the Linao floodplain, and four (4) of these were assessed to be exposed to Low-level flooding in all the rain scenarios. See Annex 13 for the list of medical institutions exposed to flooding in the Linao 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 occurrences in the area within the major river system in the Philippines.

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

The validation personnel then went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared withthe simulated data to assess the accuracy of theflood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 85.

The flood validation consists of 232 points randomly selected all over the Linao floodplain. It has an RMSE value of 0.46.Table 49shows a contingency matrix of the comparison. The Linao validation points are found in Annex 11.

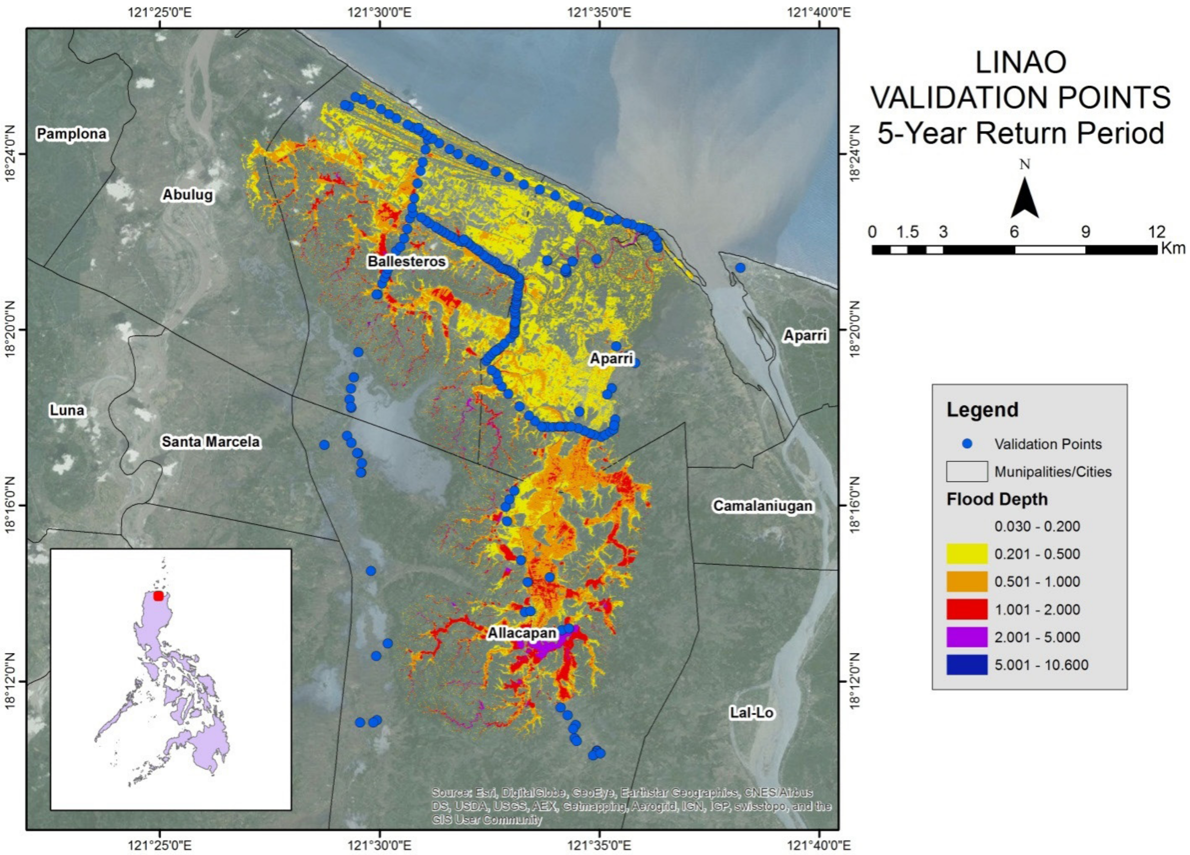


Figure 84. Validation points for a 5-year flood depth map of the Linao floodplain

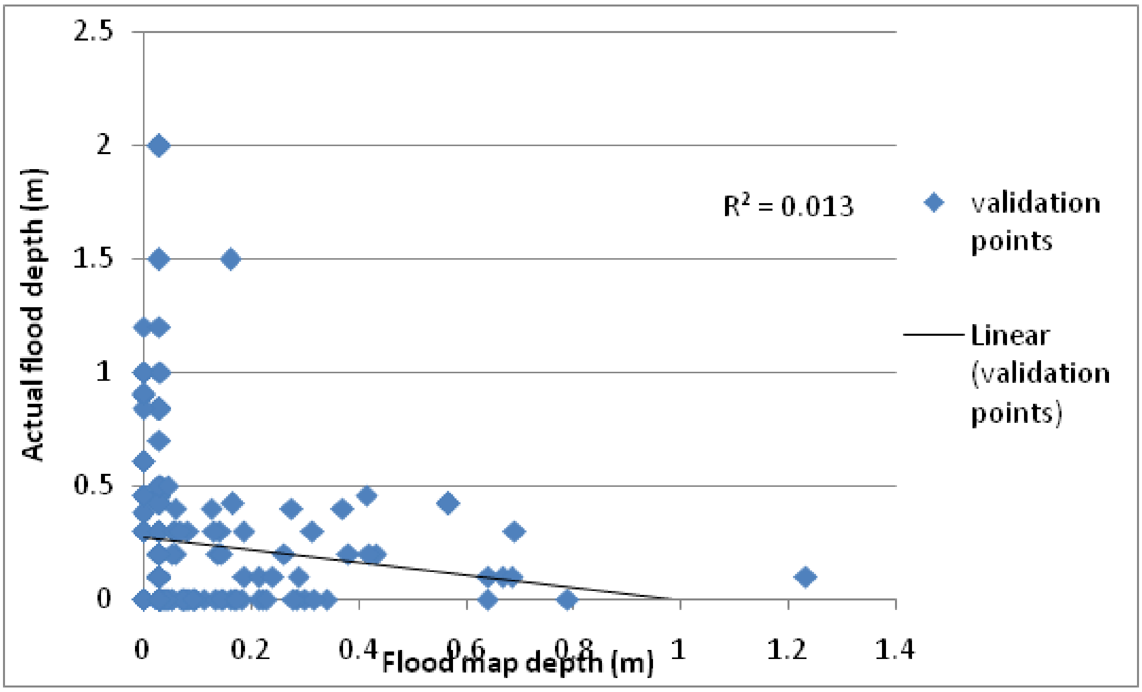


Figure 85. Flood map depth vs actual flood depth

Table 49. Actual flood vs simulated flood depth at different levels in the Linao River Basin

	LINAOBASIN	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total	
Actual Flood Depth (m)	0-0.20	130	15	5	1	0	0	151
	0.21-0.50	41	4	3	0	0	0	48
	0.51-1.00	26	0	0	0	0	0	26
	1.01-2.00	7	0	0	0	0	0	7
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	204	19	8	1	0	0	232

The overall accuracy generated by the flood model is estimated at 57.58%, with 133 points correctly matching the actual flood depths. In addition, there were fifty-nine (59) points estimated one (1) level above and below the correct flood depths. On the other hand,there were thirty-one (31) points and eight (8) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depth, respectively. A total of twenty-four (24) points were overestimated,anda total of seventy-four (74) points were underestimated in the modeled flood depths of the Linao floodplain.Table 50presentsthe summary of the Accuracy Assessment in the LinaoRiver Basin Survey.

Table 50. The summary of the Accuracy Assessment in the Linao River Basin Survey

	No. of Points	%
Correct	134	**57.76**
Overestimated	24	**10.34**
Underestimated	74	**31.90**
Total	232	**100.00**

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https://en.wikipedia.org/wiki/Tuguegarao

https://www.zamboanga.com/z/index.php?title=Linao,_Aparri,_Cagayan,_Philippines

Surveys of wetlands and waterbirds in Cagayan valley, Luzon, Philippines

(MERLIJN VAN WEERD and JAN VAN DER PLOE)

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Linao Floodplain Survey

Table A-1.1. Technical Specifications of the LiDAR Senros used in the Linao Floodplain Survey

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

1 Target reflectivity ≥20%

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

3 Angle of incidence ≤20˚

4 Target size ≥ laser footprint5 Dependent on system configuration

Table A-1.2. Specifications of the Gemini Sensor

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

Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. APA-13

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

December 18, 2013

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: **APAYAO**
Station Name: **APA-13**
Order: **2nd**

Island: **LUZON**
Municipality: **LUNA**
Barangay: **TUMOG**

	PRS92 Coordinates	
Latitude: **18° 19' 2.39264"**	Longitude: **121° 22' 58.62210"**	Ellipsoidal Hgt: **17.98200 m.**
	WGS84 Coordinates	
Latitude: **18° 18' 56.17679"**	Longitude: **121° 23' 3.20117"**	Ellipsoidal Hgt: **51.00500 m.**
	PTM Coordinates	
Northing: **2025924.156 m.**	Easting: **540482.023 m.**	Zone: **3**
	UTM Coordinates	
Northing: **2,025,930.60**	Easting: **329,102.89**	Zone: **51**

Location Description

APA-13

From the Mun. Hall of Luna, travel towards the direction going to Pudtol. In approx. 15 mins., you will reach the brgy. hall of Tumog in Luna. 30 m fromt he said brgy. hall, an access road is located. This access road will lead you to the brgy. property lot where the station was established. Station is located 8 m from the N edge of the PCCP, and 70 m NE of a waiting shed. Mark is the head of a brass rod with cross cut on top set flushed at the center of a 30 cm x 30 cm x 120 cm concrete monument with inscriptions, "APA-13, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8794962 A**
T.N.: **2013-1593**

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

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

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

Figure A-2.1. APA-13

2. CGY-70

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

November 05, 2013

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: **CAGAYAN**
Station Name: **CGY-70**
Order: **2nd**

Island: **LUZON**
Municipality: **AMULUNG**
Barangay: **ESTEFANIA**

PRS92 Coordinates

Latitude: **17° 47' 54.79038"**	Longitude: **121° 43' 31.26837"**	Ellipsoidal Hgt: **26.85900 m.**

WGS84 Coordinates

Latitude: **17° 47' 48.71170"**	Longitude: **121° 43' 35.88859"**	Ellipsoidal Hgt: **62.40000 m.**

PTM Coordinates

Northing: **1968617.425 m.**	Easting: **576904.118 m.**	Zone: **3**

UTM Coordinates

Northing: **1,968,239.03**	Easting: **364,899.00**	Zone: **51**

Location Description

CGY-70
Is located inside Estefania Elem. School campus. It is situated 1 m. E of the NE corner of the basketball court. Mark is the head of a 3 in. copper nail set flushed on top of a standard concrete monument, with inscriptions "CGY-70 2007 NAMRIA".

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**3947129 B**
T.N.:	**2013-1200**

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

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Figure A-2.2. CGY-70

3. CGY-87

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

November 05, 2013

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: **CAGAYAN**	
	Station Name: **CGY-87**	
	Order: **2nd**	
Island: **LUZON**		Barangay: **CABAYABASAN**
Municipality: **LAL-LO**		
	PRS92 Coordinates	
Latitude: **18° 3' 46.30032"**	Longitude: **121° 38' 38.76326"**	Ellipsoidal Hgt: **37.21200 m.**
	WGS84 Coordinates	
Latitude: **18° 3' 40.15861"**	Longitude: **121° 38' 43.36193"**	Ellipsoidal Hgt: **71.69600 m.**
	PTM Coordinates	
Northing: **1997837.978 m.**	Easting: **568188.029 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,997,546.44**	Easting: **356,498.94**	Zone: **51**

Location Description

CGY-87
Is located on a solar dryer at Brgy. Cabayabasan, fronting the brgy. hall. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-87 2007 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3947129 B**
T.N.: **2013-1201**

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

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CIP/4701/12/09/814

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Figure A-2.3. CGY-87

4. CGY-89

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

May 17, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**		
	Station Name: **CGY-89**		
	Order: **2nd**		
Island: **LUZON**	Barangay: **LOGAC**		
Municipality: **LAL-LO**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **18° 9' 24.10576"**	Longitude: **121° 36' 27.80546"**	Ellipsoidal Hgt:	**15.88200 m.**
	WGS84 Coordinates		
Latitude: **18° 9' 17.94119"**	Longitude: **121° 36' 32.39657"**	Ellipsoidal Hgt:	**49.97100 m.**
	PTM / PRS92 Coordinates		
Northing: **2008210.132 m.**	Easting: **564302.582 m.**	Zone:	**3**
	UTM / PRS92 Coordinates		
Northing: **2,007,958.66**	Easting: **352,726.82**	Zone:	**51**

Location Description

CGY-89
From Magapit Bridge, travel along the nat'l. highway to Ilocos. Logac Nat'l. High School is across Km. Post 705. Station is located on the left side of the access road to the entrance of the said school, about 8 m. S of the gate entrance. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-89 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8090370 I**
T.N.: **2016-1117**

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

Figure A-2.4. CGY-89

5. CGY-92

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

October 29, 2013

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: **CAGAYAN**
Station Name: **CGY-92**
Order: **2nd**

Island: **LUZON**
Municipality: **LAL-LO**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **18° 12' 11.42361"**	Longitude: **121° 39' 42.14392"**	Ellipsoidal Hgt: **14.47400 m.**

WGS84 Coordinates

Latitude: **18° 12' 5.25321"**	Longitude: **121° 39' 46.73084"**	Ellipsoidal Hgt: **48.54000 m.**

PTM Coordinates

Northing: **2013373.807 m.**	Easting: **569996.115 m.**	Zone: **3**

UTM Coordinates

Northing: **2,013,059.26**	Easting: **358,475.41**	Zone: **51**

Location Description

CGY-92
Is located inside the Lal-lo Nat'l. High School, about 5 m. W of the flagpole. Said school is 95 m. E of the Tuguegarao-Aparri nat'l. road, between Km Posts 562 and 563 and about 40 m. N of Lal-lo Mun. Hall. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. cement putty, with inscriptions "CGY-92 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **3947103 B**
T.N.: **2013-1171**

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

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Figure A-2.5. CGY-92

6. CGY-102

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

December 02, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-102**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **CASAMBALANGAN**	
Municipality: **SANTA ANA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **18° 22' 15.98573"**	Longitude: **122° 6' 41.74346"**	Ellipsoidal Hgt: **22.60800 m.**
	WGS84 Coordinates	
Latitude: **18° 22' 9.81367"**	Longitude: **122° 6' 46.31361"**	Ellipsoidal Hgt: **57.19500 m.**
	PTM / PRS92 Coordinates	
Northing: **2032192.366 m.**	Easting: **617476.569 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **2,031,351.34**	Easting: **406,145.45**	Zone: **51**

Location Description

CGY-102
From Gonzaga, travel along the nat'l. highway to Santa Ana. Station is located about 2 m. from the S corner of the triangular isalnd at the intersection of the nat'l. highway and the road to Port Irene. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-102 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088735 I**
T.N.: **2015-3961**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. CGY-102

Annex 3. Baseline Processing Reports of Control Points used in the LiDAR Survey

Table A-3.1. Baseline Processing Reports of Control Points used in the LiDAR Survey

Table A-3.1. CG-04

Vector Components (Mark to Mark)

From:	CGY-89				
Grid		Local		Global	
Easting	352726.821 m	Latitude	N18°09'24.10576"	Latitude	N18°09'17.94119"
Northing	2007958.660 m	Longitude	E121°36'27.80546"	Longitude	E121°36'32.39657"
Elevation	11.664 m	Height	15.882 m	Height	49.971 m

To:	CG-04				
Grid		Local		Global	
Easting	353659.894 m	Latitude	N18°09'06.42823"	Latitude	N18°09'00.26539"
Northing	2007408.207 m	Longitude	E121°36'59.69517"	Longitude	E121°37'04.28663"
Elevation	15.870 m	Height	20.039 m	Height	54.165 m

Vector					
ΔEasting	933.074 m	NS Fwd Azimuth	120°06'14"	ΔX	-889.082 m
ΔNorthing	-550.454 m	Ellipsoid Dist.	1083.485 m	ΔY	-343.762 m
ΔElevation	4.206 m	ΔHeight	4.157 m	ΔZ	-515.094 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.002 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.003 m
σ ΔElevation	0.003 m	σ ΔHeight	0.003 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000022515		
Y	-0.0000029405	0.0000082839	
Z	-0.0000008730	0.0000020152	0.0000020719

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
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	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA PAGADOR	UP-TCAGP
		JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	ENGR. FRANK NICOLAS ILEJAY	UP-TCAGP
	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	MA. REMEDIOS VILLANUEVA	UP-TCAGP
	RA	ENGR. GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. DIOSCORRO SOBERANO	PHILIPPINE AIR FORCE (PAF)
		SSG. ERWIN DELOS SANTOS	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JERICO JECIEL	AAC

Annex 5. Data Transfer Sheets for the Linao Floodplain Flights

Table A-5.1. Data Transfer Sheets for the Linao Floodplain Flights

DATA TRANSFER SHEET
cagayan 11/23/15

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
9-Nov	2830P	1CAGS1BD313A	pegasus	2.21	1.33	10.1	1M	23.3	1/1/165	20.6	NA	8.44	1KB	1KB	51	NA	Z:\DAC\RAW DATA
11-Nov-15	2838P	1BLK2CF315A	pegasus	3.11	1.83	11.7	254	46.7	41/298	20.9	NA	13.6	1KB	1KB	77	NA	Z:\DAC\RAW DATA
11-Nov-15	2840P	1CAGS1G315B	pegasus	99.3	140	2.52	99.8	8.07	126/13	3.35	NA	12.6	1KB	1KB	98	NA	Z:\DAC\RAW DATA
12-Nov-15	2842P	1BLK2BS316A	pegasus	1.45	889	6.34	185	24.1	172	14.3	NA	10.4	1KB	1KB	1	NA	Z:\DAC\RAW DATA
12-Nov-15	2846P	[illegible]	pegasus	NA	1.54	12.6	259	90.8	259	[illegible]	NA	24.8	1KB	NA	77/162/185	NA	Z:\DAC\RAW DATA
13-Nov-15	2848P	[illegible]	pegasus	122	101	3.8	169	7.57	64	5.53	NA	24.5	1KB	1KB	162/185	NA	Z:\DAC\RAW DATA
13-Nov-15	2850P	1BLK2DE318A	pegasus	1.57	1.35	11.8	250	35.2	200/54	23.3	NA	26	1KB	1KB	179	NA	Z:\DAC\RAW DATA
14-Nov-15	2852P	1BLK2AS318B	pegasus	619	533	6.82	192	20.9	152/3	12.3	NA	26	1KB	1KB	77	NA	Z:\DAC\RAW DATA
15-Nov	2854P	1BLK2DSG319A	pegasus	2.68	1.6	10.3	247	40.5	290	26.1	NA	14.1	1KB	1KB	47	NA	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position
Signature

Received by

Name AC Bongat
Position SSRS
Signature 11/24/2015

Figure A-5.1. Transfer Sheet for Linao Floodplain – A

DATA TRANSFER SHEET
21/06/2016 TUGUEGARAO

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/27/2016	3965G	2CAG2DGH118A	GEMINI	NA	367	585	251	NA	NA	28.2	NA	9.67	1KB	1KB	252	NA	Z:\DAC\RAWDATA
4/28/2016	3971G	2BLK3CAG2MQR119A	GEMINI	NA	193	559	252	NA	NA	21	NA	9.78	1KB	1KB	65.1	NA	Z:\DAC\RAWDATA
4/29/2016	3973G	2CAG2GSHS120A	GEMINI	NA	740	662	274	NA	NA	28.6	NA	9.24	1KB	1KB	506	NA	Z:\DAC\RAWDATA
4/30/2016	3977G	2CAG2FG121A	GEMINI	NA	392/99.5/404/107	767	255	NA	NA	29.4	NA	12.1	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
4/30/2016	3979G	2CAG2E121B	GEMINI	NA	99.5	193	71.1	NA	NA	7.57	NA	12.1	1KB	1KB	67.2	NA	Z:\DAC\RAWDATA
5/1/2016	3981G	2CAG2I122A	GEMINI	NA	404	730	263	NA	NA	30.2	NA	8.23	1KB	1KB	23.2/20.6/276/129	NA	Z:\DAC\RAWDATA
5/1/2016	3983G	2CAG2CJ122B	GEMINI	NA	107	220	103	NA	NA	8.25	NA	8.23	1KB	1KB	72.4	NA	Z:\DAC\RAWDATA
5/3/2016	3989G	2BLK3CAG2QSR124A	GEMINI	NA	136/319	514	245	NA	NA	17.1	NA	14.6	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
5/3/2016	3991G	2BLK3CAG2MNSQS124B	GEMINI	NA	204	228	143	NA	NA	8.65	NA	14.6	1KB	1KB	137	NA	Z:\DAC\RAWDATA
5/4/2016	3993G	2BLK3CAG2LMNQR125A	GEMINI	NA	435	161	244	NA	NA	21.2	NA	8.65	1KB	1KB	294	NA	Z:\DAC\RAWDATA
5/5/2016	3997G	2BLK3CAG2NO126A	GEMINI	NA	353	691	272	NA	NA	26.4	NA	13.9	1KB	1KB	239	NA	Z:\DAC\RAWDATA
5/5/2016	3999G	2CAG2P126B	GEMINI	NA	151	290	137	NA	NA	11.6	NA	13.9	1KB	1KB	102	151	Z:\DAC\RAWDATA
5/6/2016	4001G	2BLK3CAG2MRS127A	GEMINI	NA	208	459	245	NA	NA	16.1	NA	9.35	1KB	1KB	138	NA	Z:\DAC\RAWDATA
5/7/2016	4005G	2CAG2ABC128A	GEMINI	NA	316	NA	257	NA	NA	24	NA	8.88	1KB	1KB	215	NA	Z:\DAC\RAWDATA
5/8/2016	4009G	2CAG2K129A	GEMINI	NA	132	286	118	NA	NA	10	NA	5.85	1KB	1KB	114	NA	Z:\DAC\RAWDATA

Name DARRYL AUSTRIA
Position R.A.
Signature

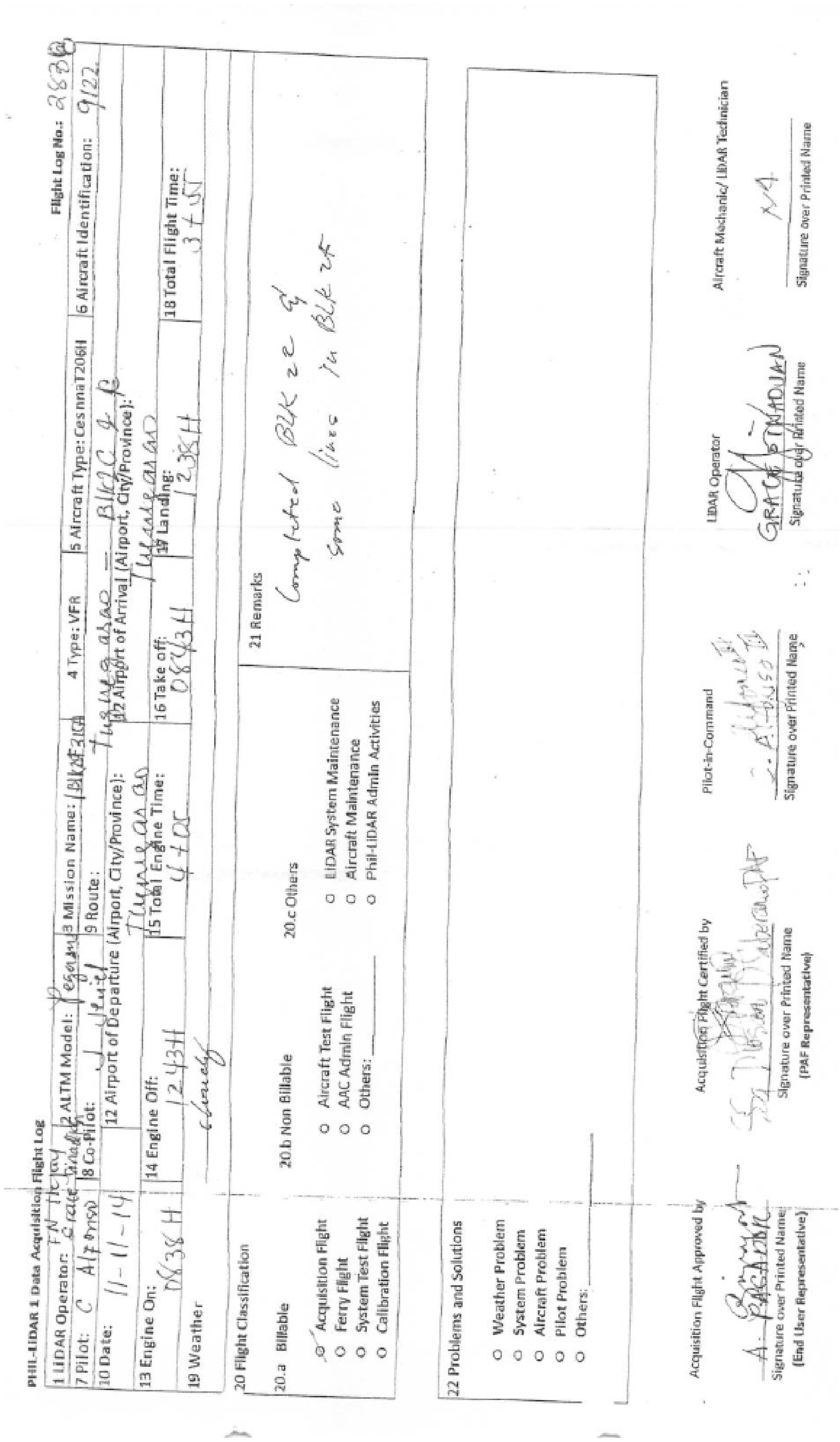
Name AC Bongat
Position SS RS
Signature 6/21/16

Figure A-5.2. Transfer Sheet for Linao Floodplain – B

Annex 6. Flight Logs for the Flight Missions

Table A-6.1. Flight Logs for the Flight Missions

1. Flight Log for 2838P Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2838P

1 LIDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: 1BLK23CDF	4 Type: VFR	5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9122				
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jerusalem	9 Route: Tuguegarao — BLK23C & B		
10 Date: 11-11-14	12 Airport of Departure (Airport, City/Province): Tuguegarao	12 Airport of Arrival (Airport, City/Province): Tuguegarao		
13 Engine On: 0838H	14 Engine Off: 1243H	15 Total Engine Time: 4+05	16 Take off: 0843H	17 Landing: 1238H
18 Total Flight Time: 3+55				
19 Weather: cloudy				

20 Flight Classification

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

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

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

21 Remarks

Completed BLK 23C & B. Some lines in BLK 23F

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

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

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

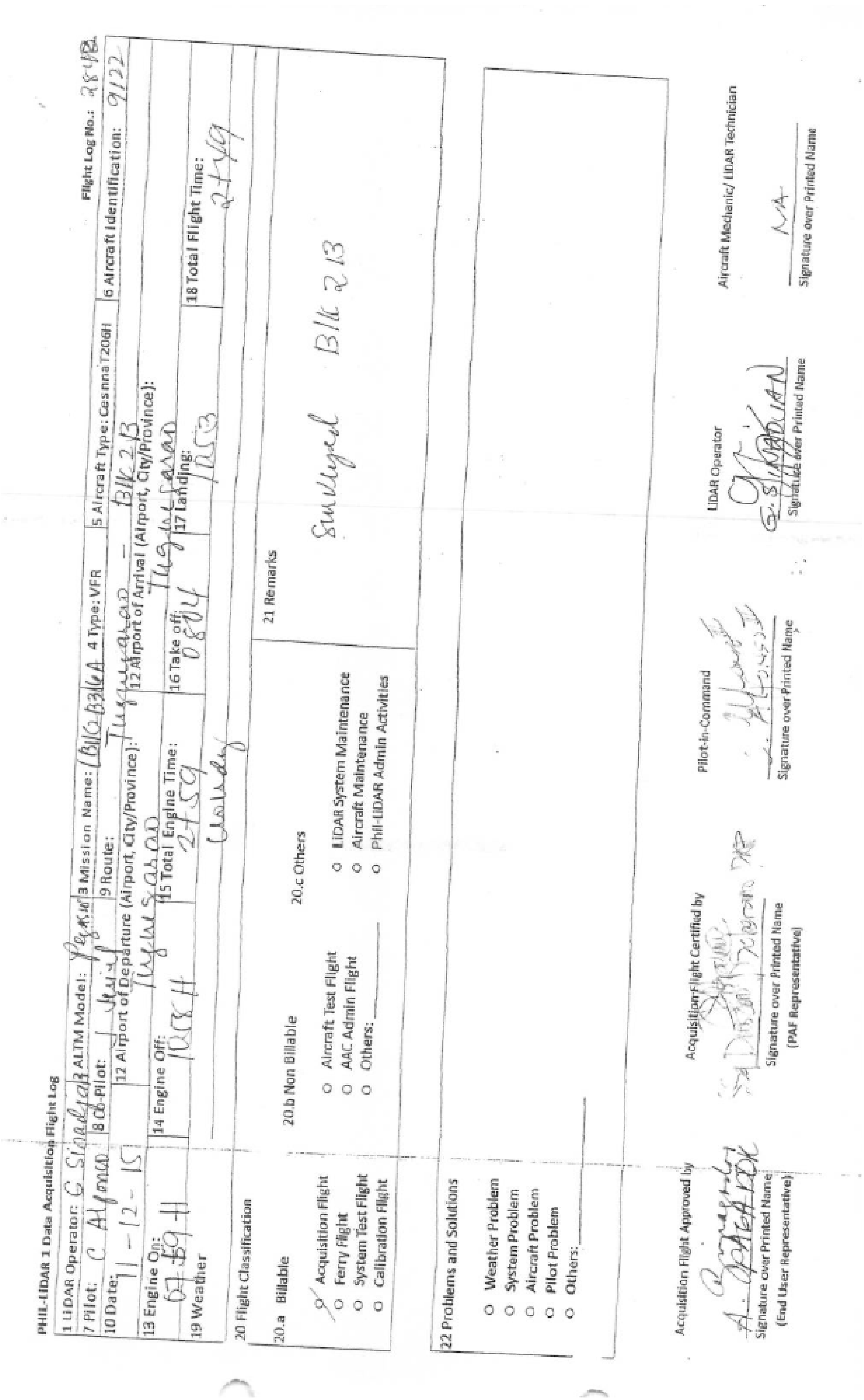
Pilot-in-Command: Signature over Printed Name

LIDAR Operator: GRACE SINADJAN, Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2838P

2. Flight Log for 2842P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2842P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: BlkB3BlkA	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeruel	9 Route: Tuguegarao – Blk 2B			
10 Date: 11-12-15	12 Airport of Departure (Airport, City/Province): Tuguegarao		12 Airport of Arrival (Airport, City/Province): Tuguegarao		
13 Engine On: 0759H	14 Engine Off: 1058H	15 Total Engine Time: 2+59	16 Take off: 0804	17 Landing: 1053	18 Total Flight Time: 2+49
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed Blk 2B

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

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

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

Pilot-in-Command: C. Alfonso — Signature over Printed Name

LiDAR Operator: G. Sinadjan — Signature over Printed Name

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

Figure A-6.2. Flight Log for Mission 2842P

3. Flight Log for 2846P Mission

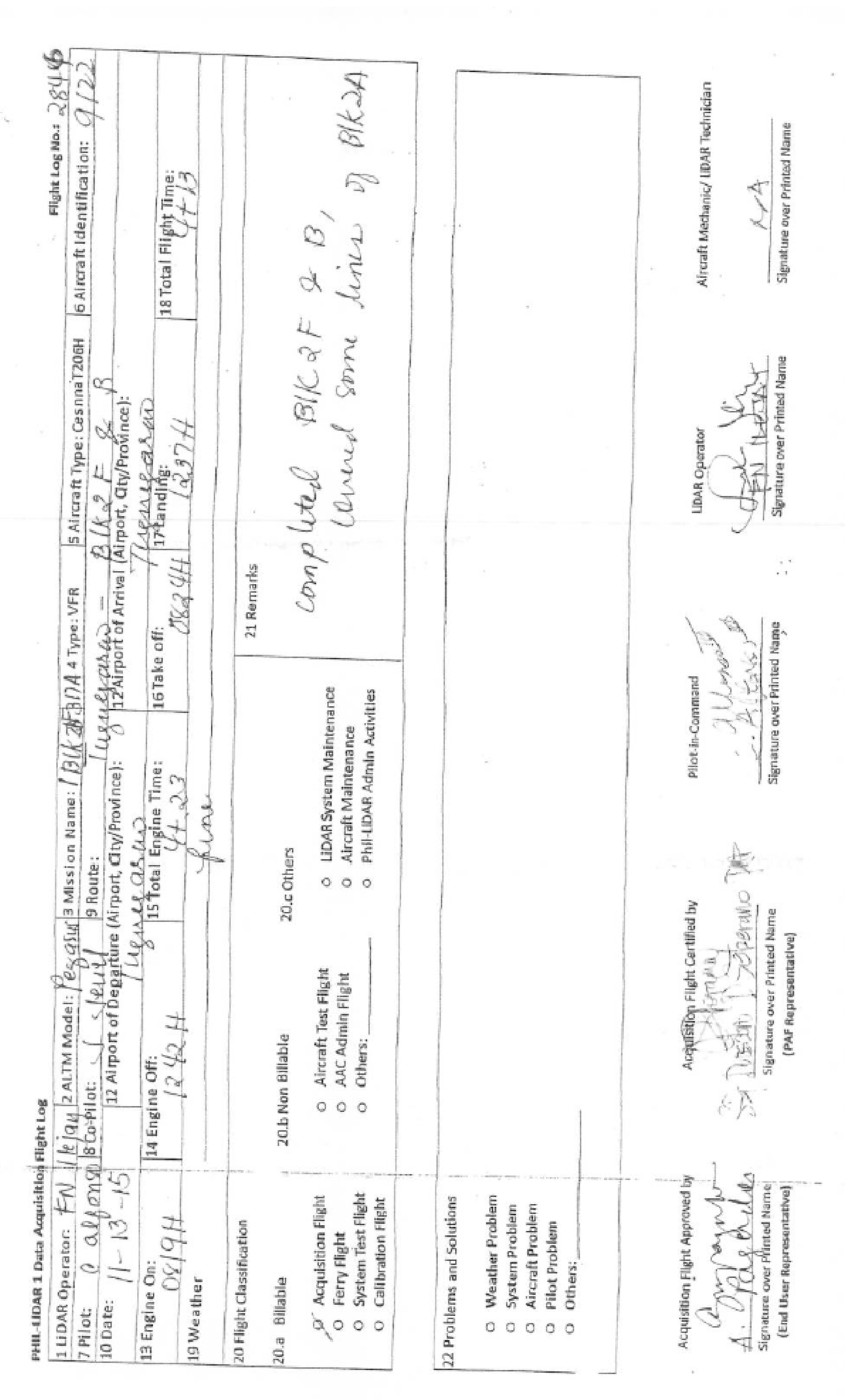
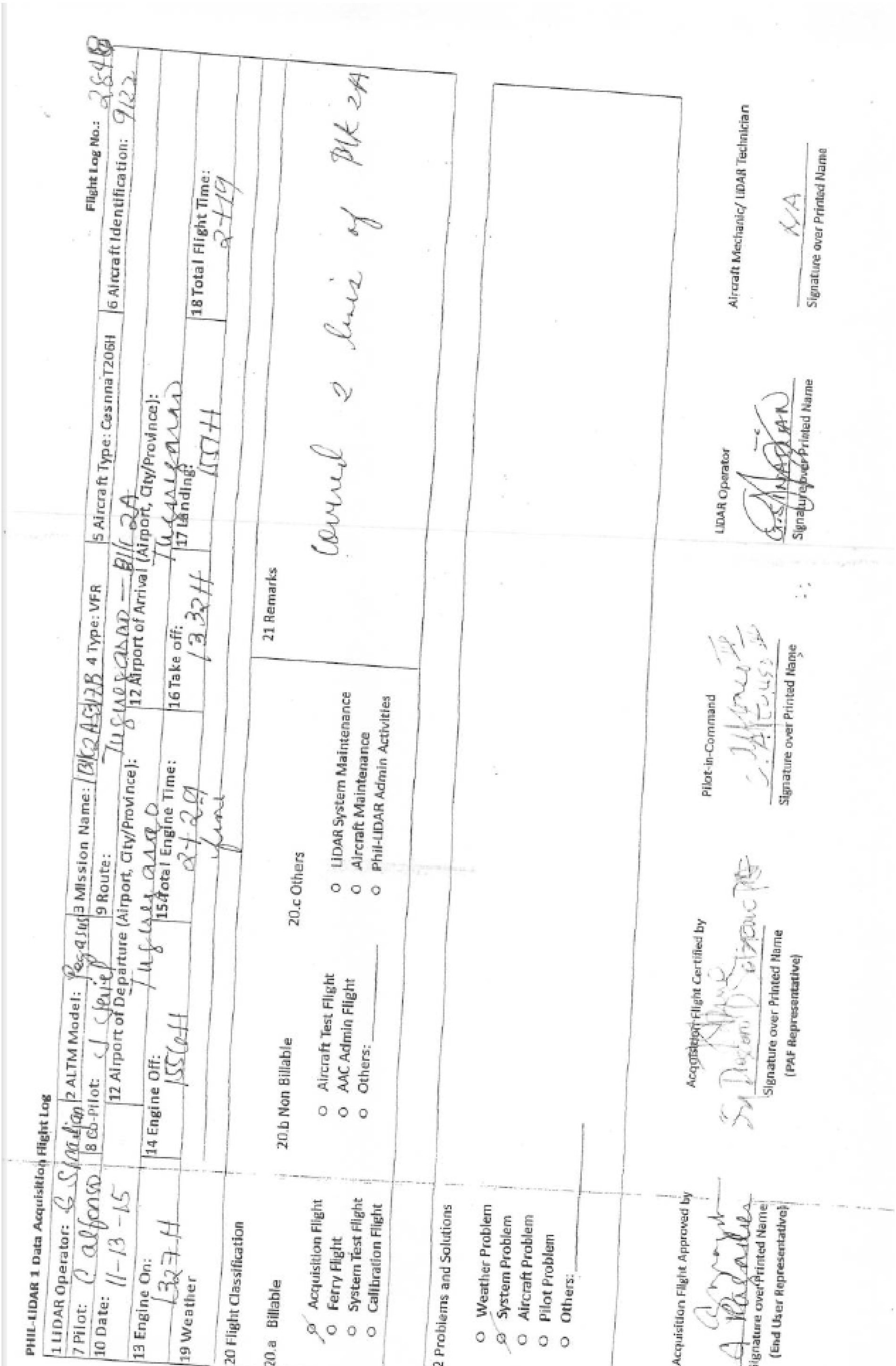


Figure A-6.3. Flight Log for Mission 2846P

4. Flight Log for 2848P Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2848P

1 LiDAR Operator: C. Alfonso | 2 ALTM Model: Pegasus | 3 Mission Name: 1BLK2AG328B | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9122

7 Pilot: J. Sinadjan | 8 Co-Pilot: J. Steviel | 9 Route: Tuguegarao – Blk 2A

10 Date: 11-13-15 | 12 Airport of Departure (Airport, City/Province): Tuguegarao | 12 Airport of Arrival (Airport, City/Province): Tuguegarao

13 Engine On: 1327H | 14 Engine Off: 1556H | 15 Total Engine Time: 2+29 | 16 Take off: 1332H | 17 Landing: 1551H | 18 Total Flight Time: 2+19

19 Weather: fine

20 Flight Classification

20.a Billable: Acquisition Flight; Ferry Flight; System Test Flight; Calibration Flight

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

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

21 Remarks: Covered 2 lines of Blk 2A

22 Problems and Solutions: Weather Problem; System Problem; Aircraft Problem; Pilot Problem; Others:

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

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

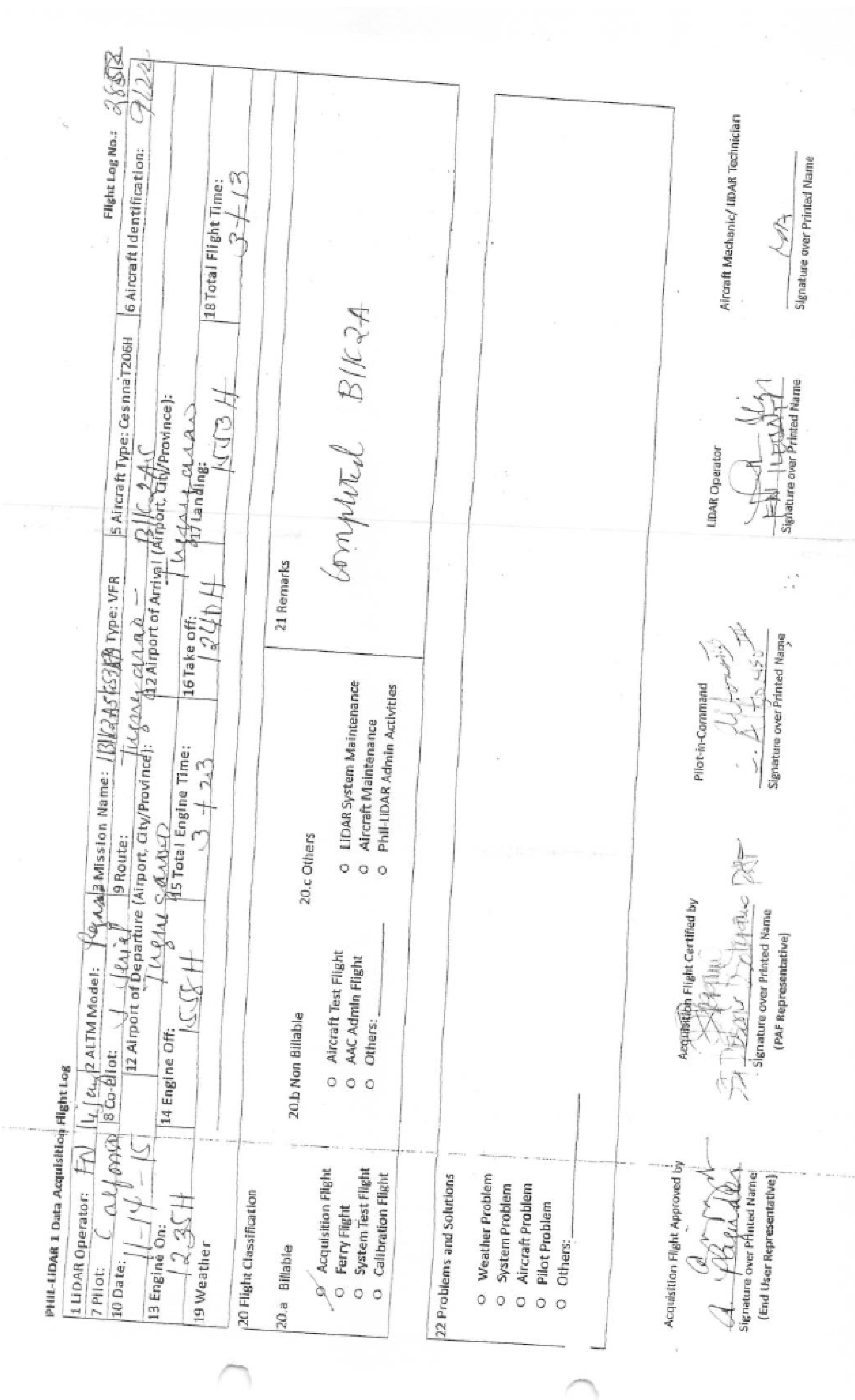
Pilot-in-Command: J. Sinadjan — Signature over Printed Name

LiDAR Operator: C. Alfonso — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2848P

5. Flight Log for 2852P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2852P

1 LIDAR Operator: FN Lilles	2 ALTM Model: Pegasus	3 Mission Name: 1BLK2AS	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jeciel	9 Route: Tuguegarao - BLK2AS			
10 Date: 11-14-15	12 Airport of Departure (Airport, City/Province): Tuguegarao		12 Airport of Arrival (Airport, City/Province): Tuguegarao		
13 Engine On: 1235H	14 Engine Off: 1558H	15 Total Engine Time: 3+23	16 Take off: 1240H	17 Landing: 1553H	18 Total Flight Time: 3+13
19 Weather					

20 Flight Classification

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

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

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

21 Remarks

Completed BLK2A

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

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

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

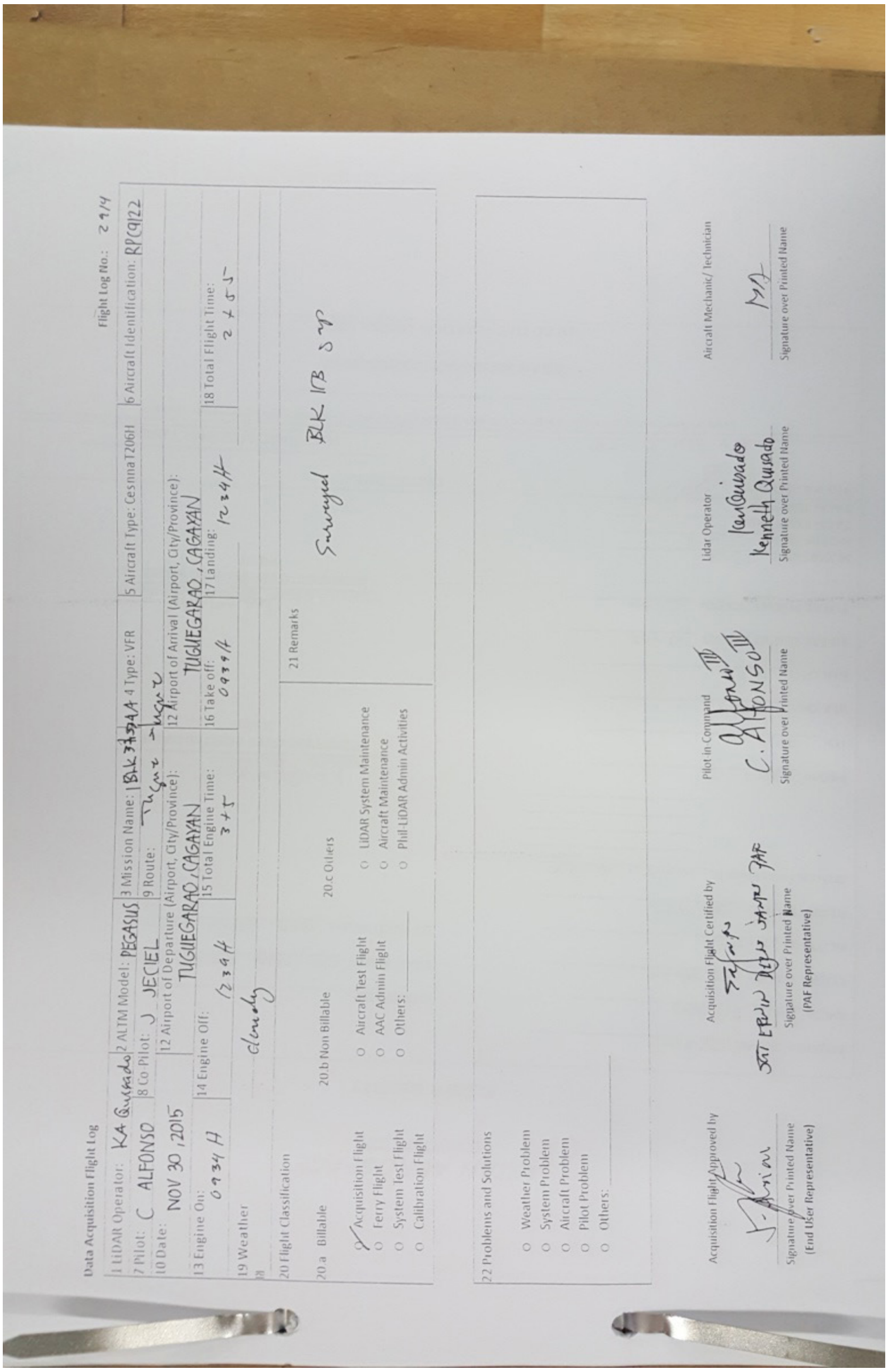
Pilot-in-Command — Signature over Printed Name

LIDAR Operator — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2852P

6. Flight Log for 2914P Mission


Data Acquisition Flight Log

Flight Log No.: 2914

1 LiDAR Operator: KA Quisado	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK37S334A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: C. ALFONSO	8 Co-Pilot: J. JECIEL	9 Route: Tugue - Tugue		
10 Date: NOV 30, 2015	12 Airport of Departure (Airport, City/Province): TUGUEGARAO, CAGAYAN		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO, CAGAYAN	
13 Engine On: 0934H	14 Engine Off: 1234H	15 Total Engine Time: 3+5	16 Take off: 0939H	17 Landing: 1234H	18 Total Flight Time: 2+55
19 Weather: cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 17B & 7P

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

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

Acquisition Flight Certified by: SSGT ERWIN DELOS SANTOS PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: C. ALFONSO III — Signature over Printed Name

Lidar Operator: Kenneth Quisado — Signature over Printed Name

Aircraft Mechanic/ Technician: — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 2914P

7. Flight Log for 3999G Mission

UP DREAM **Data Acquisition Flight Log**

Flight Log No.: 3999

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2CAG2P126B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 5. 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1333 H	14 Engine Off: 1600 H	15 Total Engine Time: 2+27	16 Take off: 1338 H	17 Landing: 1555 H	18 Total Flight Time: 2+17
19 Weather: PARTLY CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Completed CAG2P

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
I. ROXAS	JBC CARANDBON	J. MOONEY	J. ALMALVEZ	-
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 3999G

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

CAGAYAN AND CAGAYAN REFLIGHTS

(NOVEMBER 3-30, 2015 AND MAY 5, 2016)

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2838P	BLK2C, BLK2F	1BLK2CF315A	G SINADJAN, FN ILEJAY	November 11, 2015	SURVEYED 13 LINES FOR BLK2C AND F
2842P	BLK2B	1BLK2B316A	G SINADJAN	November 12, 2015	SURVEYED 6 LINES FOR BLK2B
2846P	BLK2FS, BLK2BS, BLK2A	1BLK2FSBSA317A	FN ILEJAY	November 13, 2015	SURVEYED 16 LINES FOR BLK2F, BLK2B AND BLK2A
2848P	BLK2A	1BLK2AS317B	G SINADJAN	November 13, 2015	SURVEYED 2 LINES FOR BLK2A
2852P	BLK3AS, BLK2CS	1BLK2AS318B	FN ILEJAY	November 14, 2015	SURVEYED 4 LINES FOR BLK2A, AND VOIDS OVER BLK2C
2914P	BLK 11DS, CAG 101DS	1BLK3A334A	K QUISADO	NOV 30	SURVEYED CAG11D AND CAG 101DS (ONE STRIP) 214.57 SQ.KM
3999P	CAG2P	2CAG2P126B	J. ALMALVEZ	May 5, 2016	COMPLETED CAG2P

SWATH PER FLIGHT MISSION

FLIGHT NO.: 2838P
AREA: BLK2C&F
MISSION NAME: 1BLK2CF315A
ALT: 1100 SCAN FREQ: 30 SCAN ANGLE: 25
SURVEYED AREA: 260.55 km2

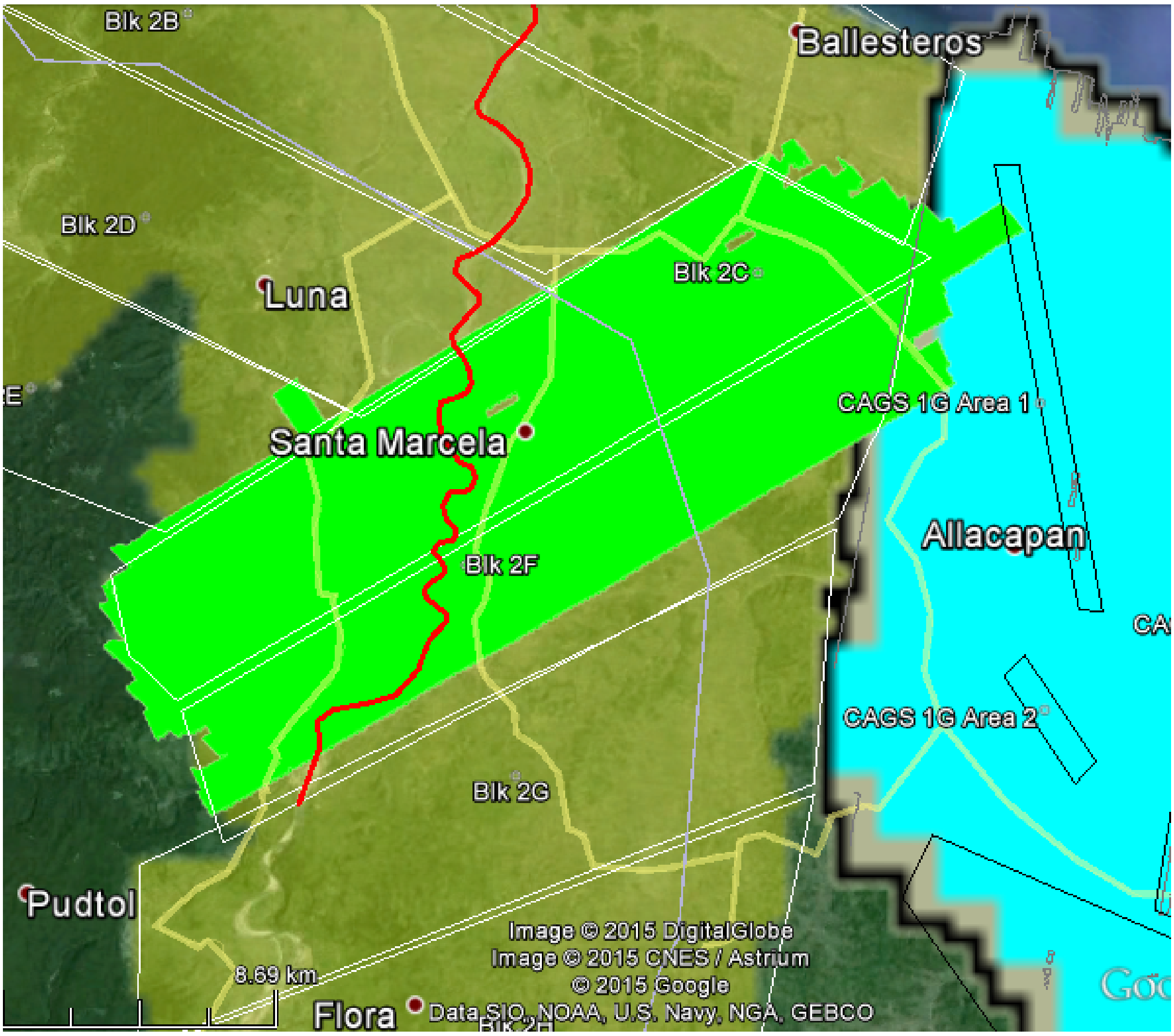


Figure A-7.1. Swath for Flight No. 2838P

FLIGHT NO.:	2842	
AREA:	BLK2B	
MISSION NAME:	1BLK2B316A	
ALT: 850 m	SCAN FREQ: 30	SCAN ANGLE: 25
SURVEYED AREA:	136.73 km2	

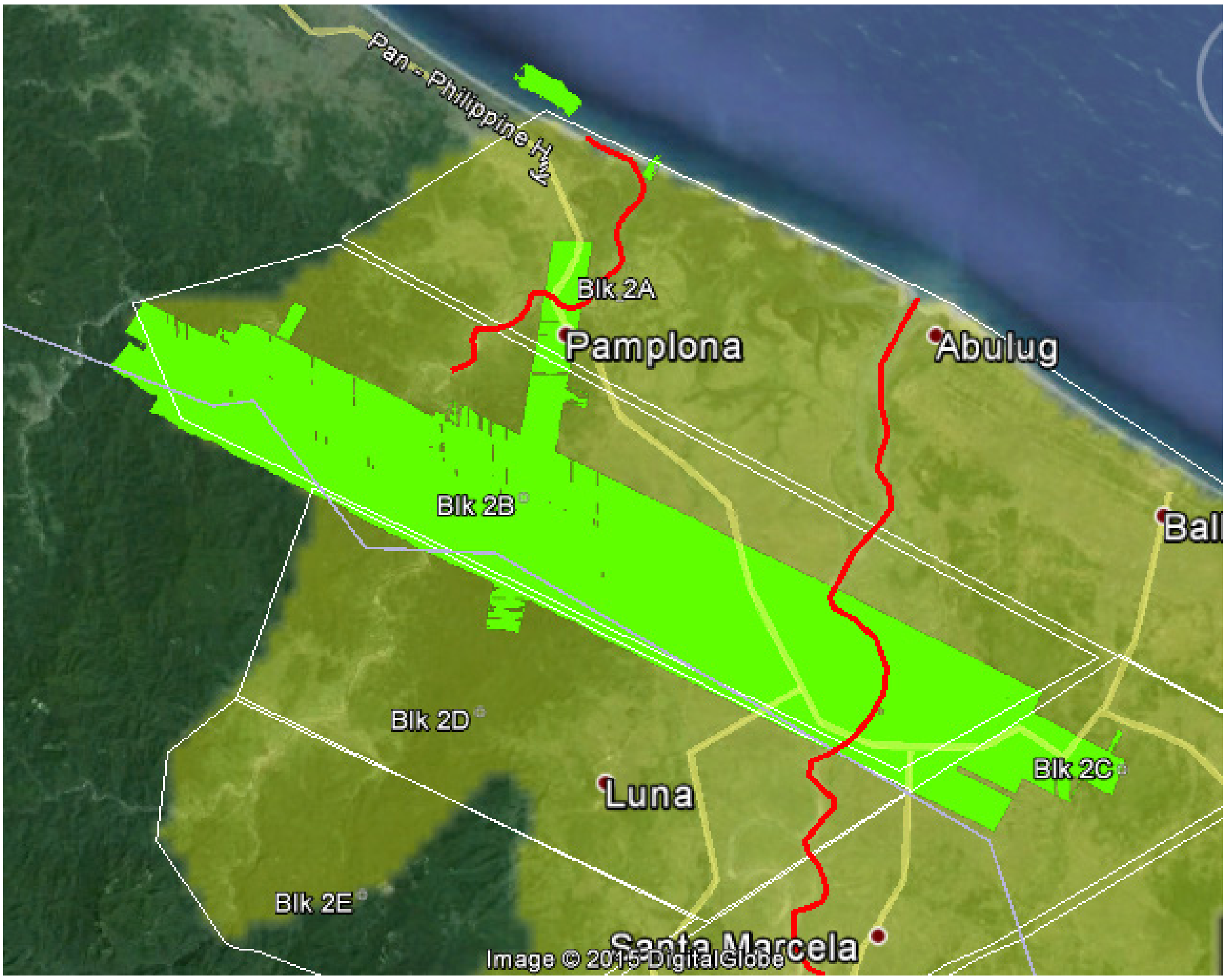


Figure A-7.2. Swath for Flight No. 2842

FLIGHT NO.:	2846	
AREA:	BLK2FS, BLK2BS, BLK2A	
MISSION NAME:	1BLK2FSBSA317A	
ALT: 1100 m	SCAN FREQ: 30	SCAN ANGLE: 25
SURVEYED AREA:	292.13 km2	

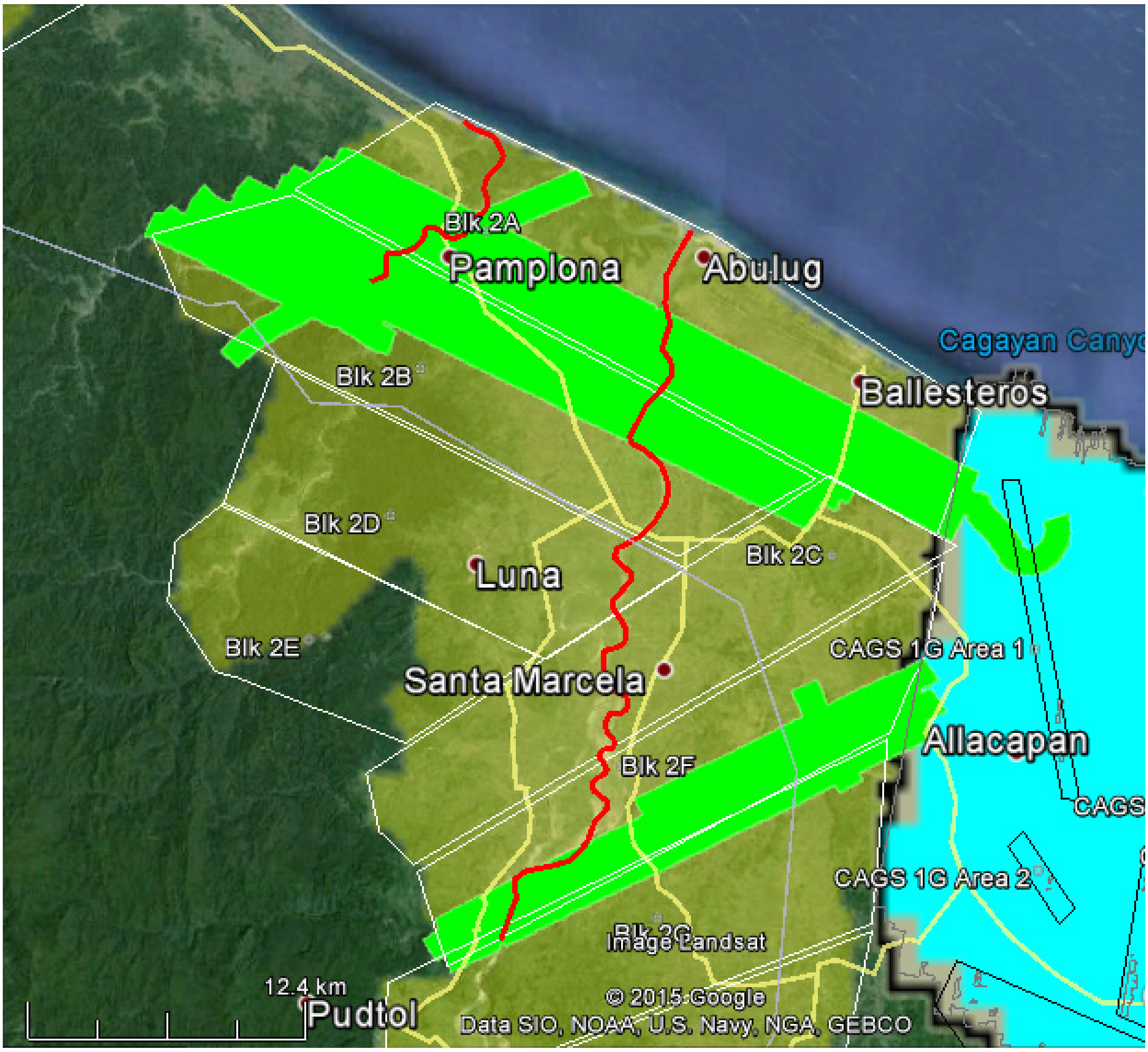


Figure A-7.3. Swath for Flight No. 2846

FLIGHT NO.:	2848	
AREA:	BLK2A	
MISSION NAME:	3BLK331P224A	
ALT: 900 m	SCAN FREQ: 30	SCAN ANGLE: 25
SURVEYED AREA:	73.514 km2	

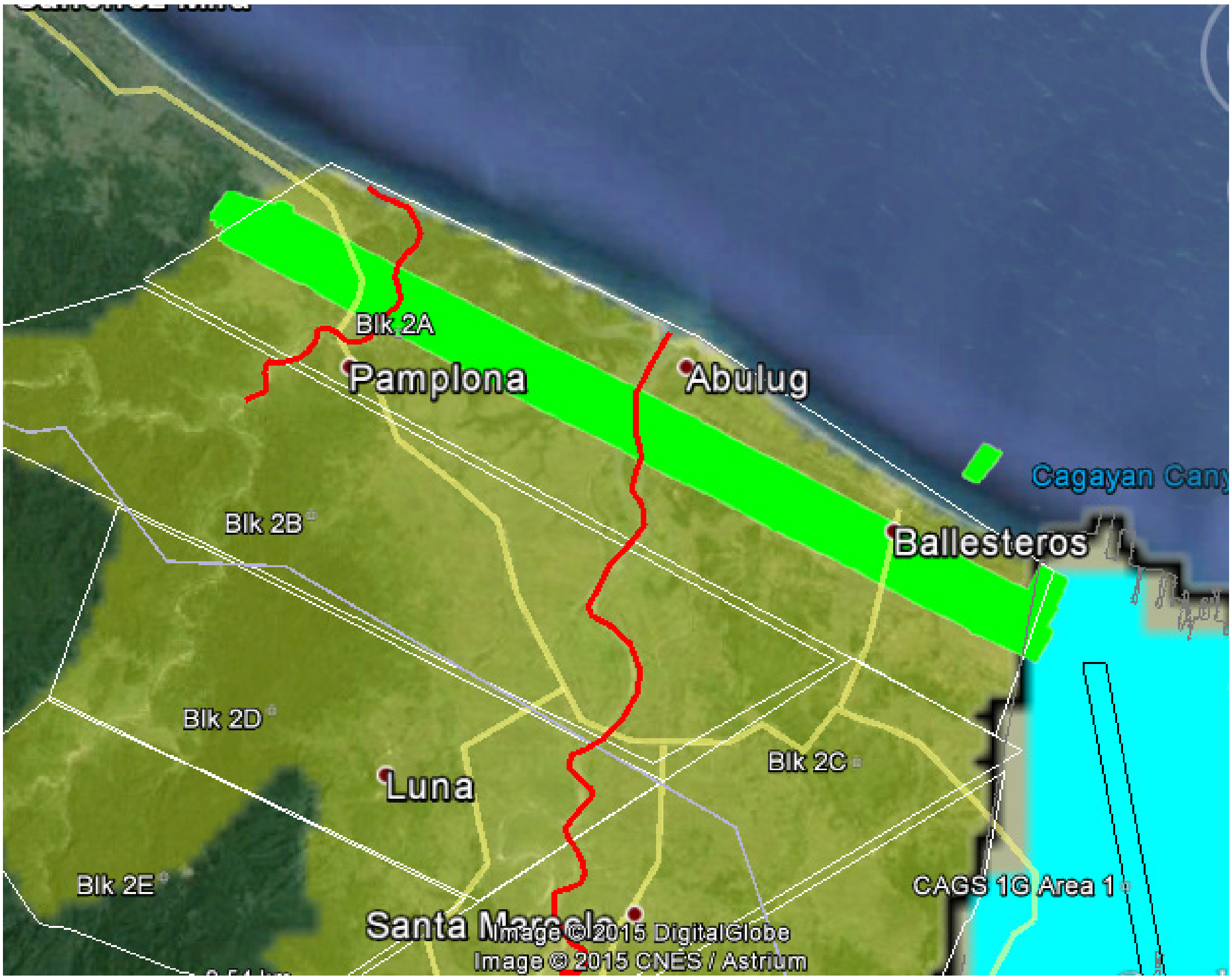


Figure A-7.4. Swath for Flight No. 2848

FLIGHT NO.:	2852	
AREA:	BLK2A, BLK2CS	
MISSION NAME:	1BLK2AS318B	
ALT: 900 m	SCAN FREQ: 30	SCAN ANGLE: 25
SURVEYED AREA:	89.01 km2	

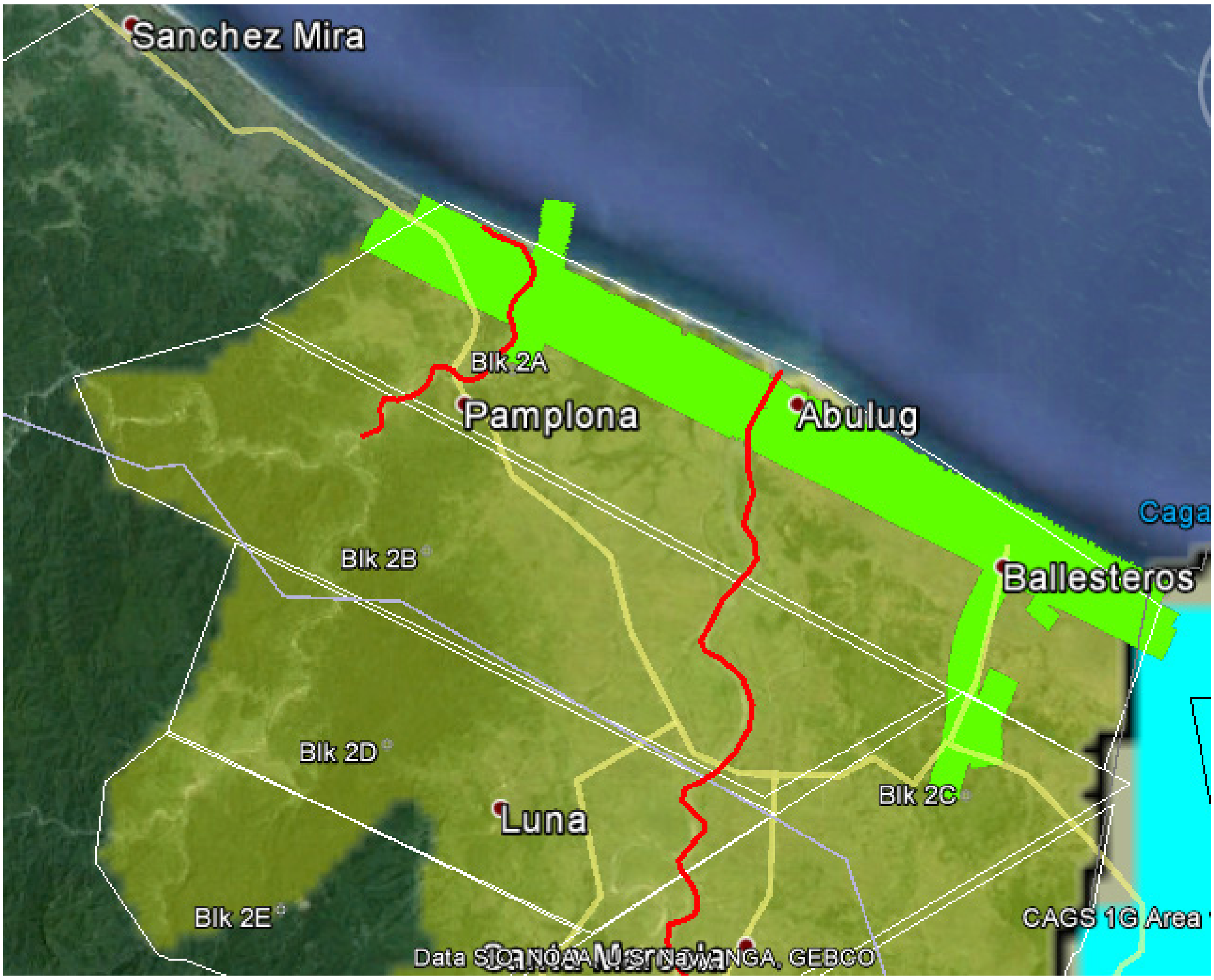


Figure A-7.5. Swath for Flight No. 2852

Flight No. :	2914P
Area:	BLK 11
Mission Name:	1BLK3A334A
Parameters:	PRF 200 SF 30 FOV 50

LAS/SWATH

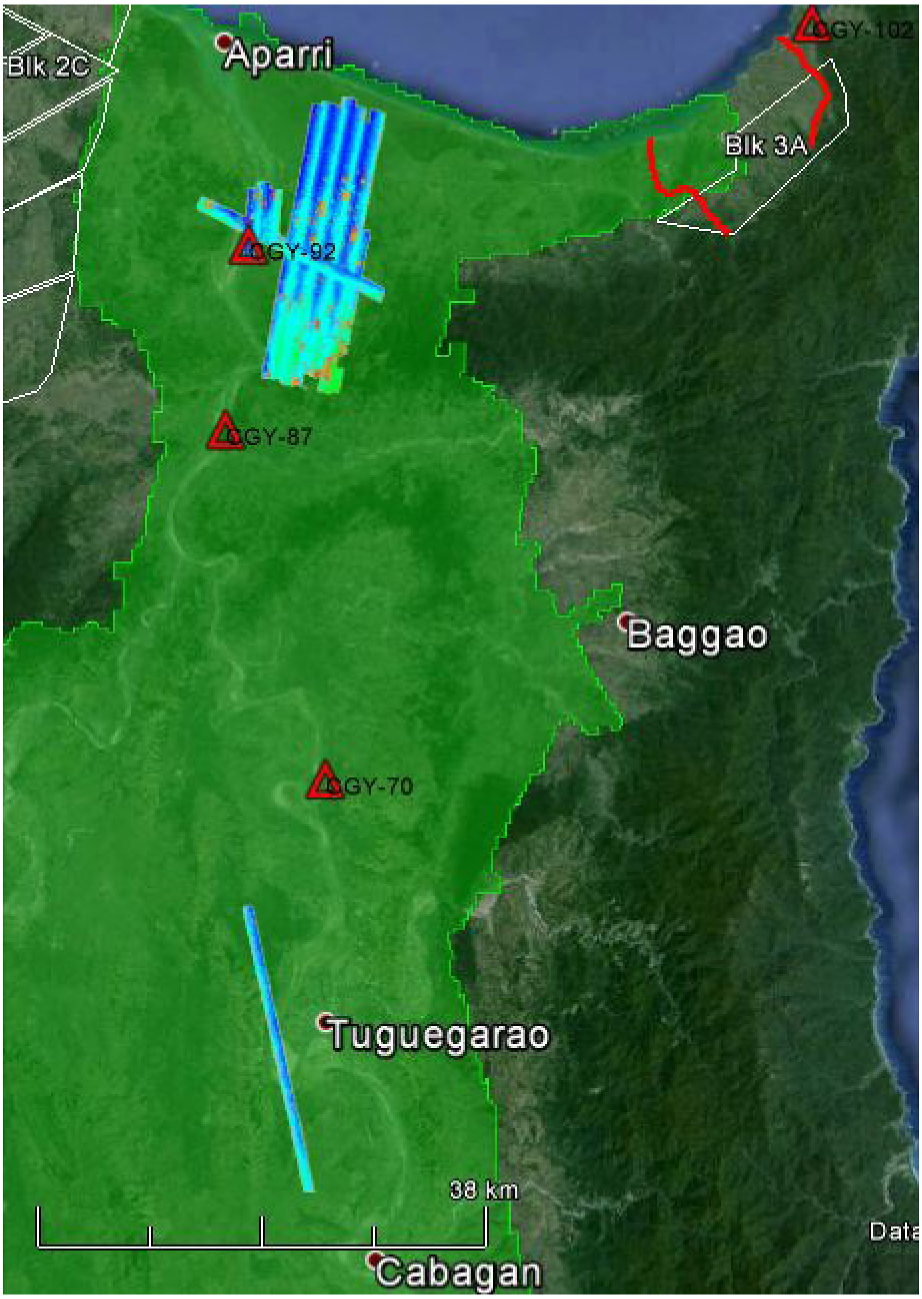


Figure A-7.6. Swath for Flight No. 2914P

FLIGHT NO.: 3999G
AREA: CAG2P
MISSION NAME: 2CAG2P126B

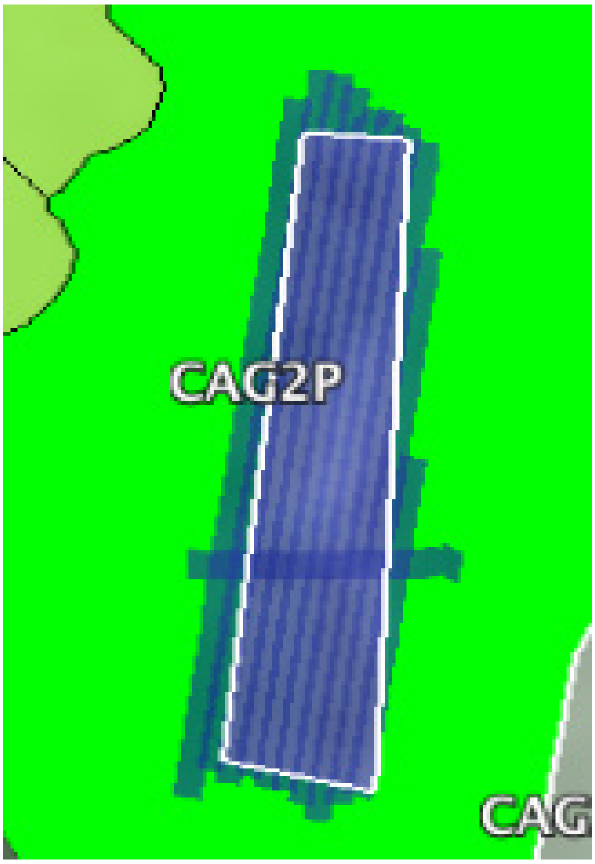


Figure A-7.7. Swath for Flight No. 3999G

Annex 8. Mission Summary Reports

Table A-8.1.Mission Summary Reoprts

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	**Blk2C_additional**
Inclusive Flights	2852P
Range data size	12.3GB
POS data size	
Base data size	192MB
Image	20.9MB
Transfer date	November 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
***Smoothed Performance Metrics* (in cm)**	
RMSE for North Position (<4.0 cm)	1.78
RMSE for East Position (<4.0 cm)	1.74
RMSE for Down Position (<8.0 cm)	2.62
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	31
Maximum Height	104.81 m
Minimum Height	39.96 m
Classification (# of points)	
Ground	12,895,871
Low vegetation	12,195,161
Medium vegetation	10,618,621
High vegetation	15,485,382
Building	559,173
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Chelou Prado, Kathryn Claudine Zarate

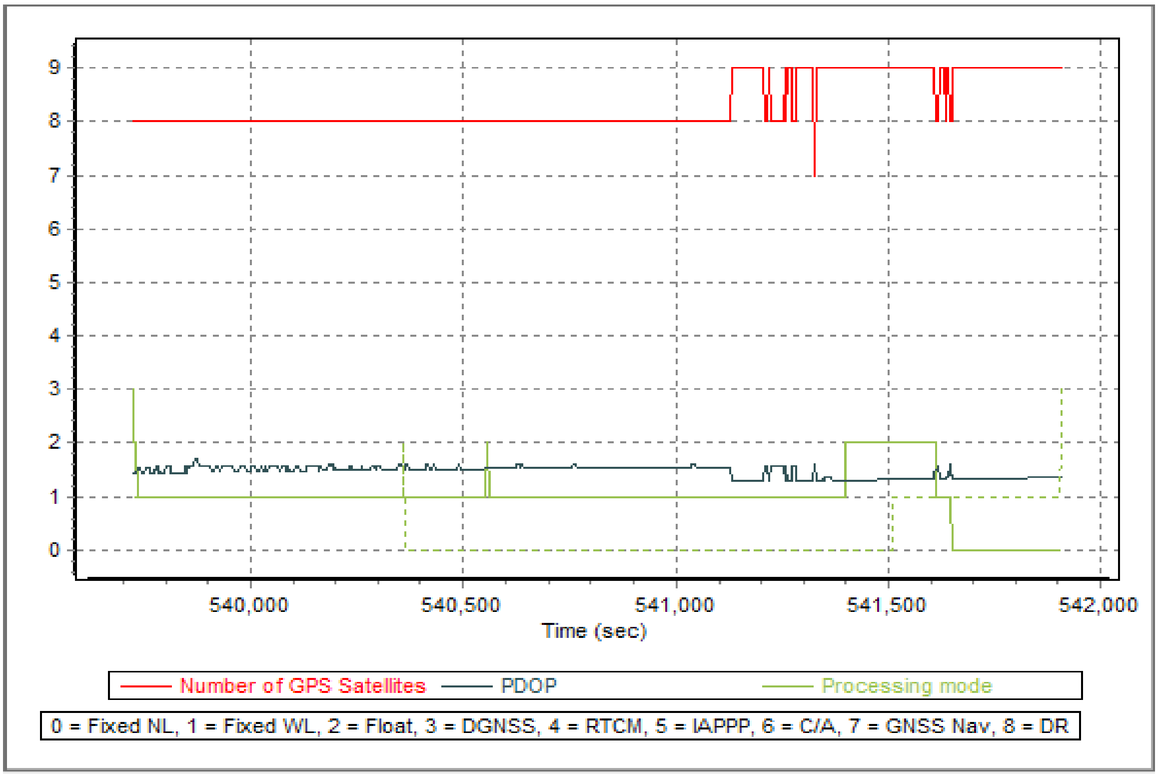


Figure A-8.1. Solution Status

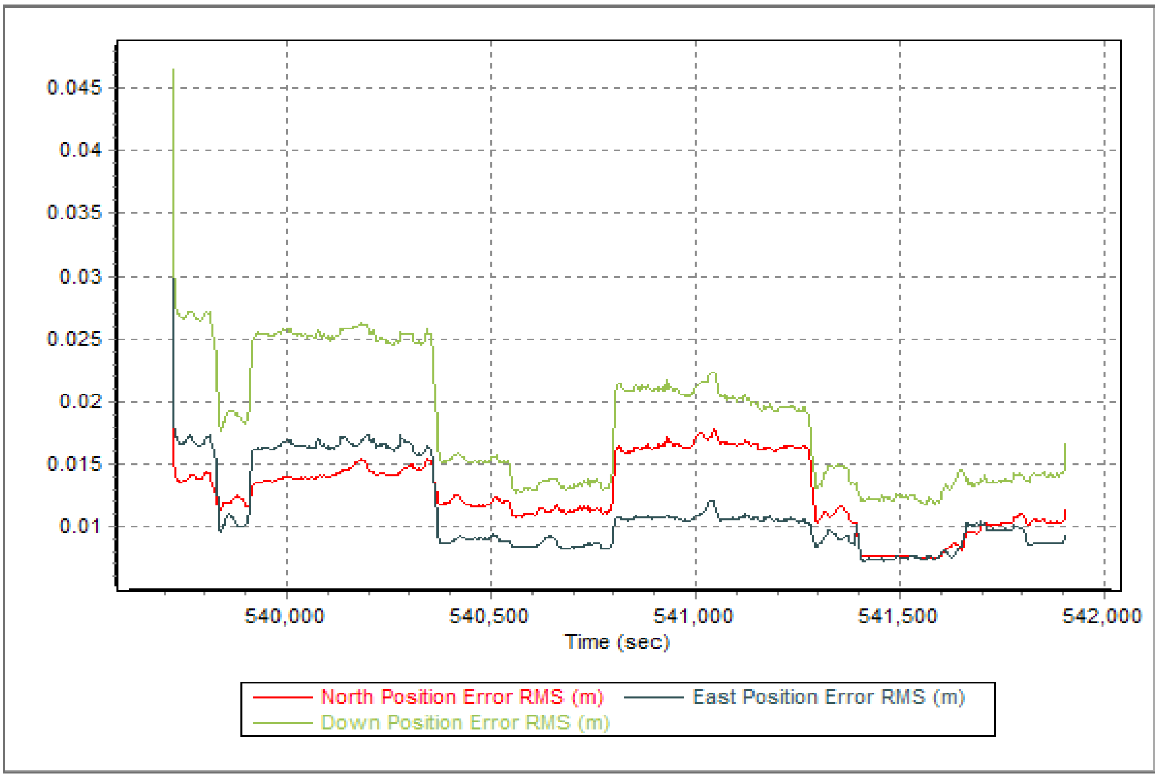


Figure A-8.2. Smoothed Performance Metric Parameters

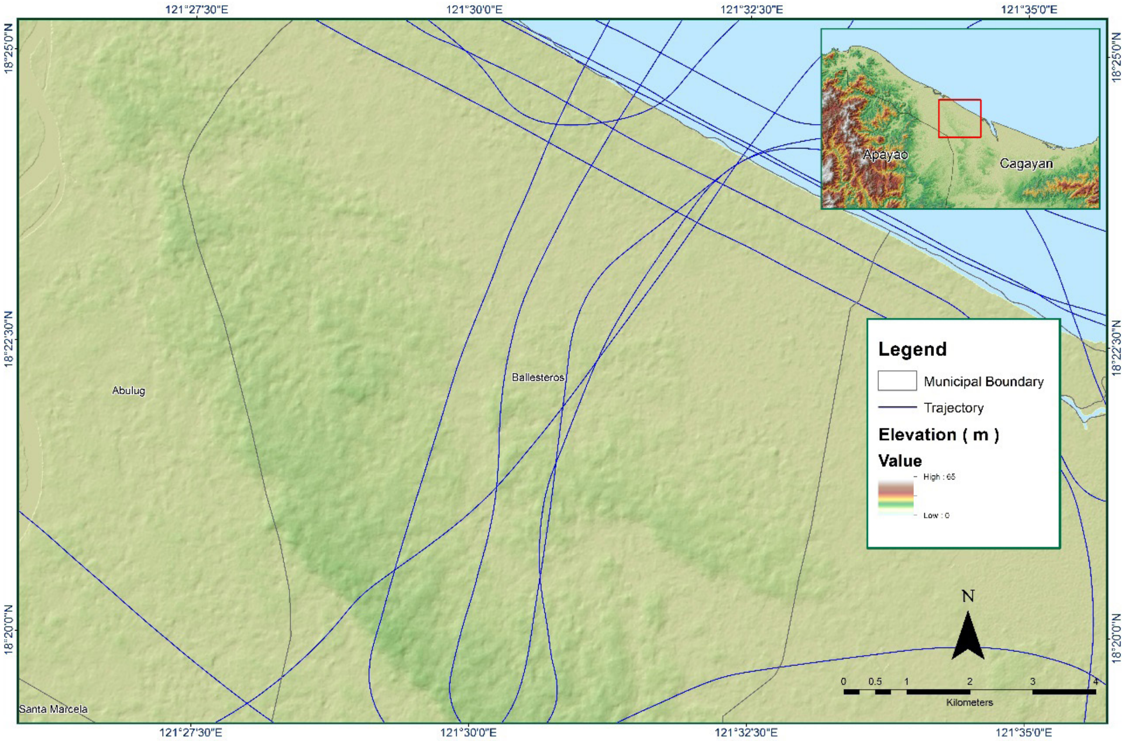


Figure A-8.3. Best Estimated Trajectory

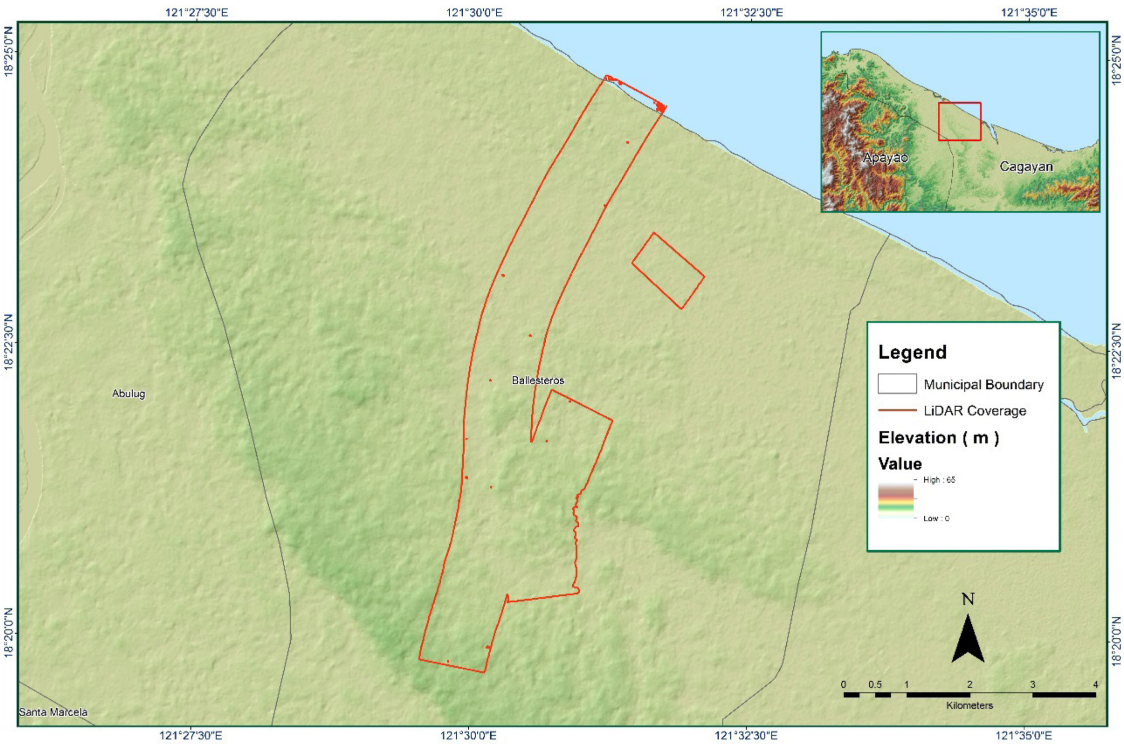


Figure A-8.4. Coverage of LiDAR data

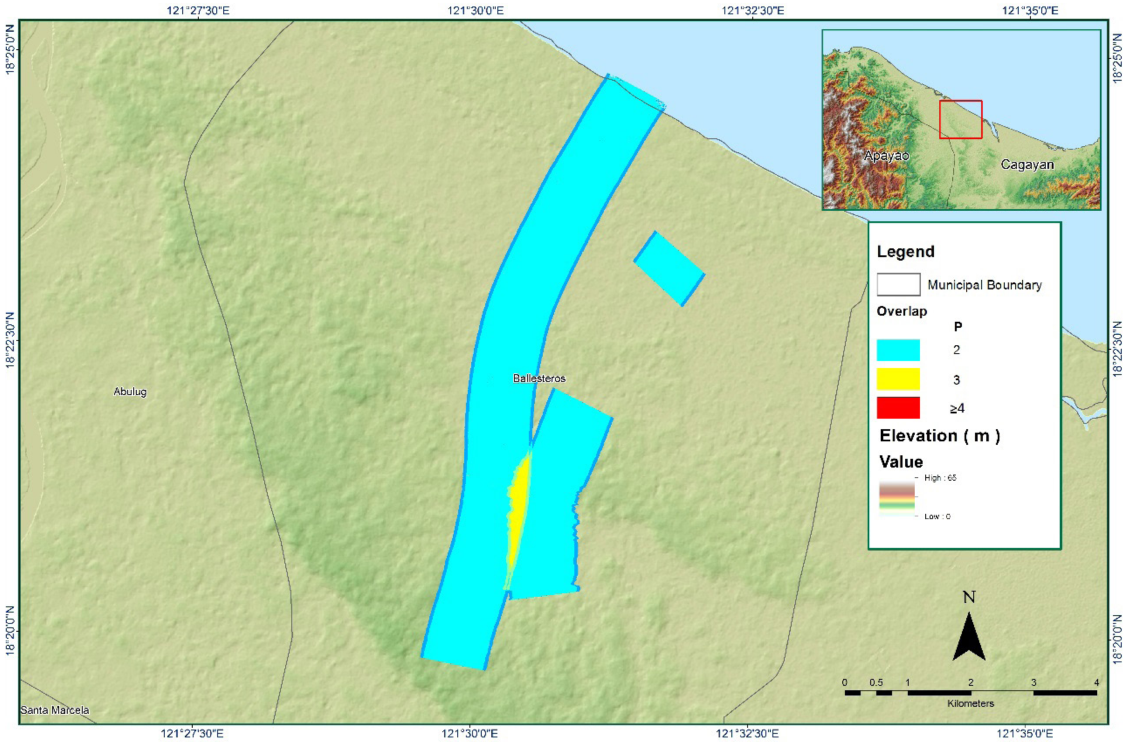


Figure A-8.5. Image of data overlap

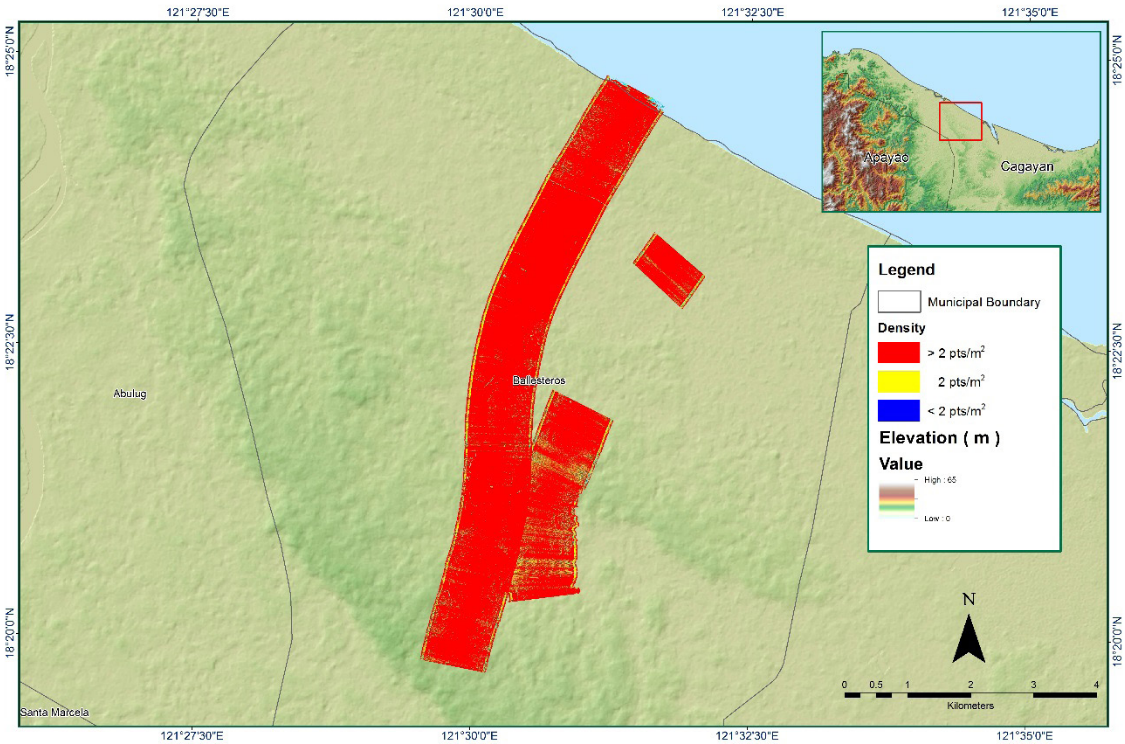


Figure A-8.6. Density map of merged LiDAR data

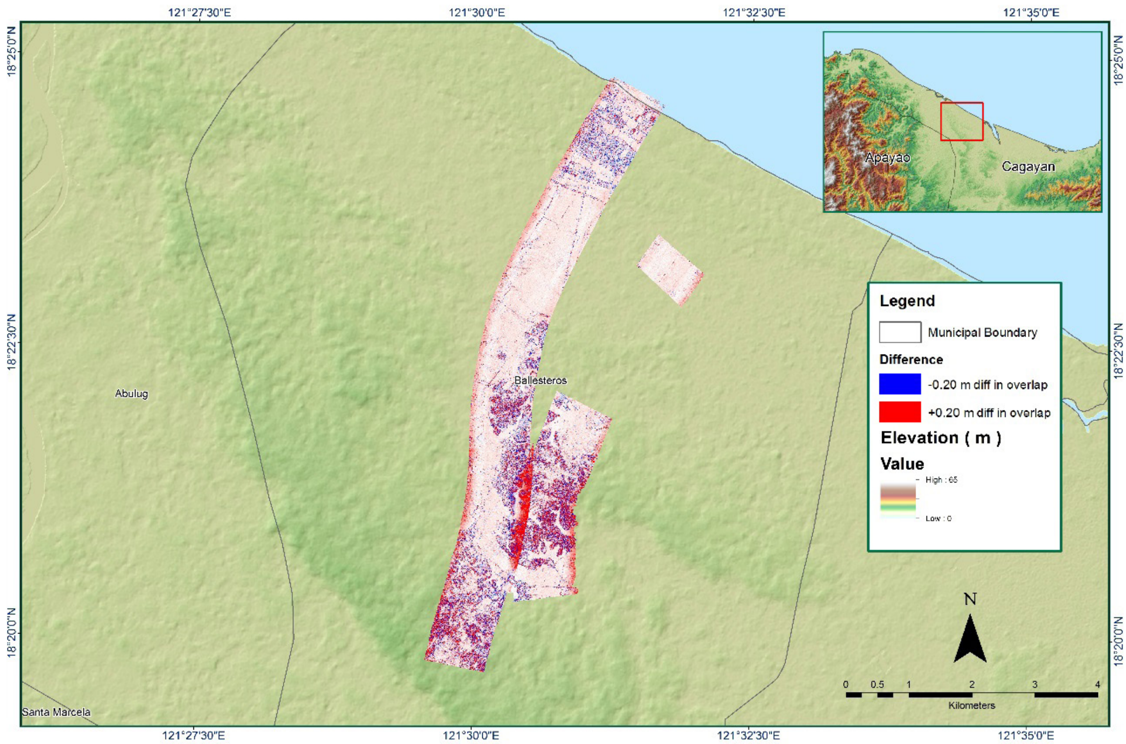


Figure A-8.7. Elevation difference between flight lines

Table A-8.2.Mission Summary Report for CAG11D

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	**CAG11D**
Inclusive Flights	2914P
Range data size	17.1GB
POS	190MB
Image	3.48MB
Transfer date	December 8, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.16
RMSE for East Position (<4.0 cm)	3.17
RMSE for Down Position (<8.0 cm)	9.29
Boresight correction stdev (<0.001deg)	0.000165
IMU attitude correction stdev (<0.001deg)	0.000360
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	216
Maximum Height	284.43 m
Minimum Height	34.67 m
Classification (# of points)	
Ground	173,366,780
Low vegetation	140,801,033
Medium vegetation	138,056,487
High vegetation	199,480,239
Building	7,100,166
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Christy Lubiano, Engr. Karl Adrian Vergara

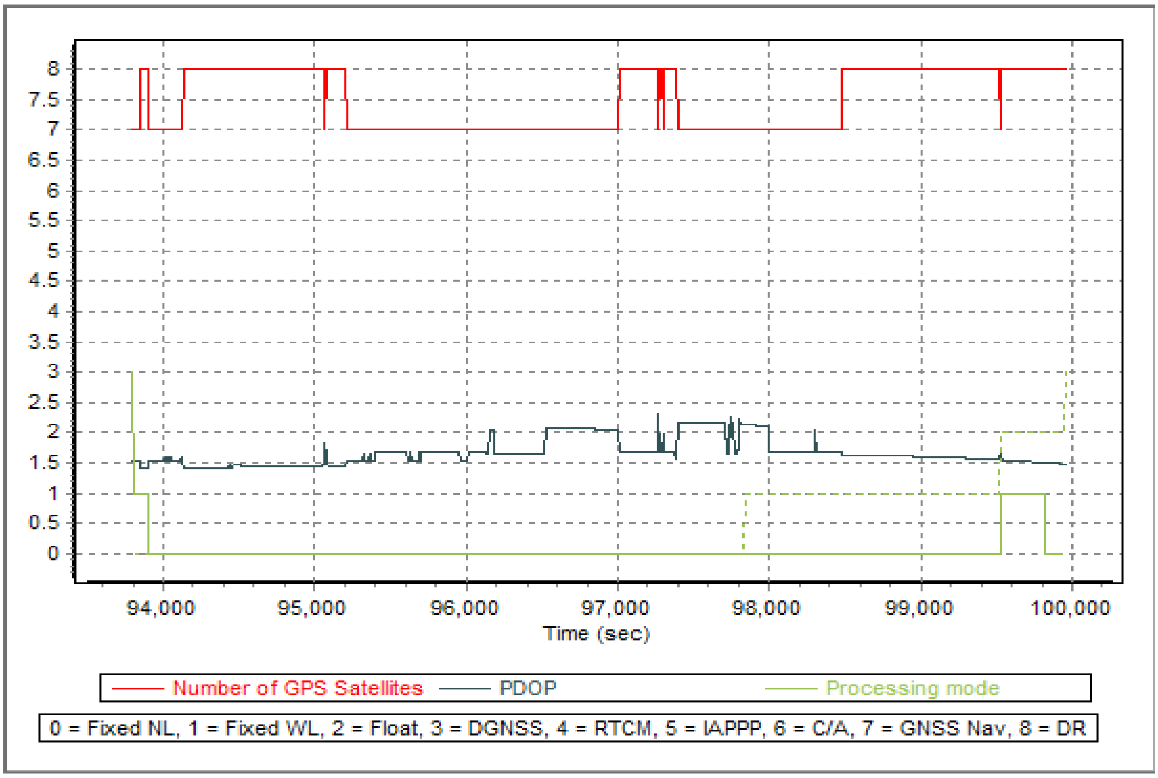


Figure A-8.8. Solution Status

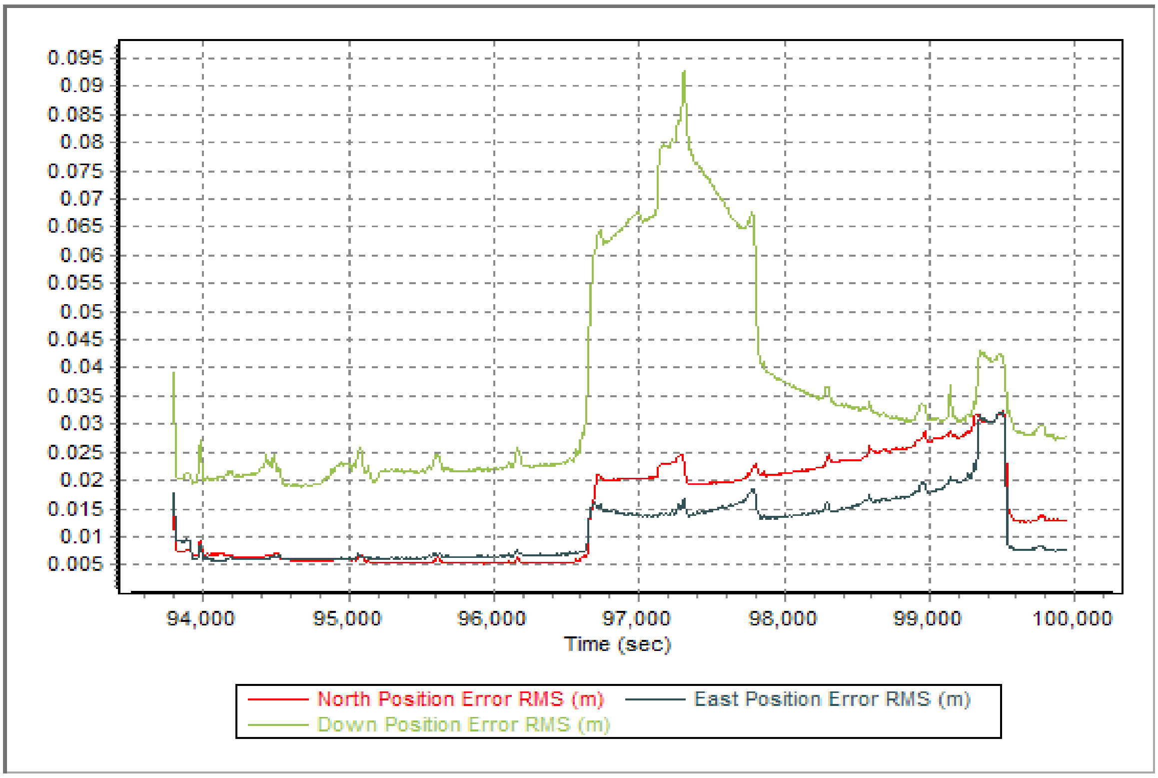


Figure A-8.9. Smoothed Performance Metric Parameters

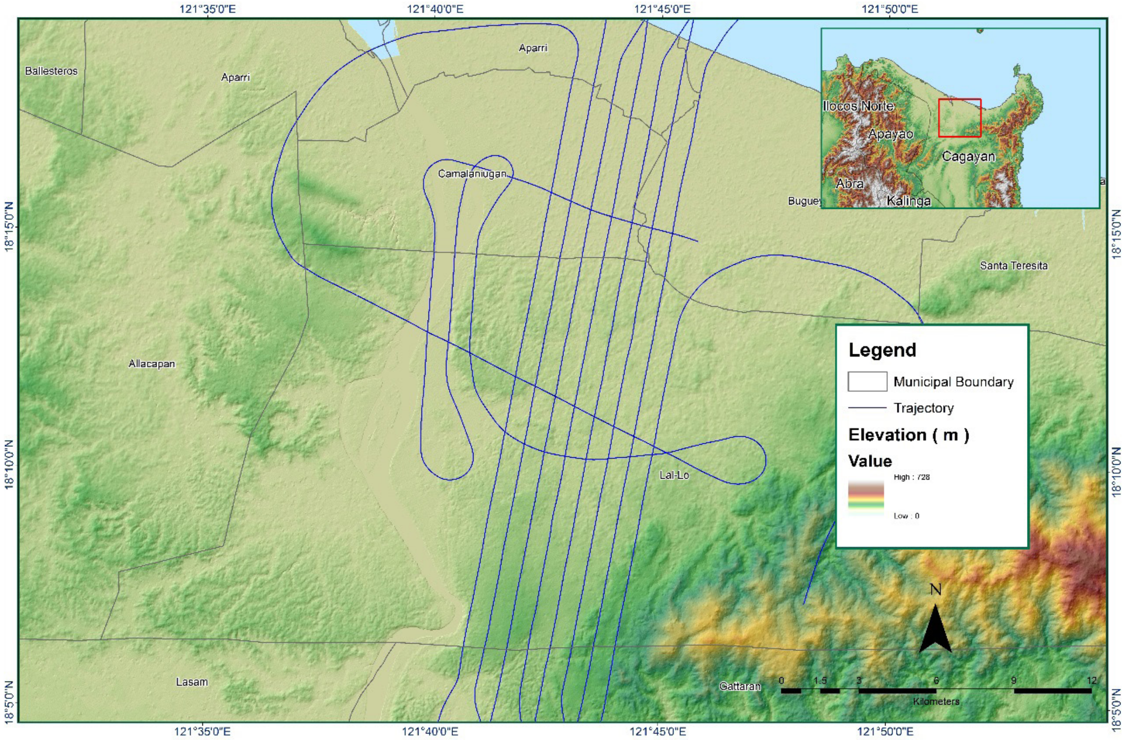


Figure A-8.10. Best Estimated Trajectory

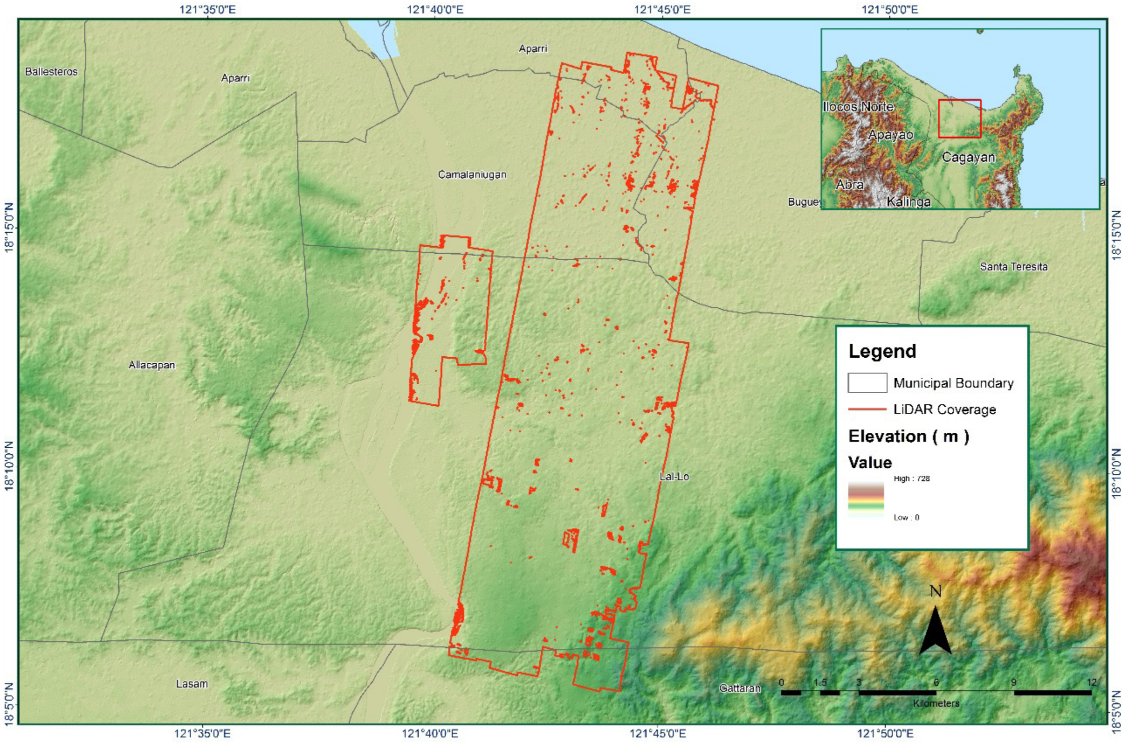


Figure A-8.11. Coverage of LiDAR data

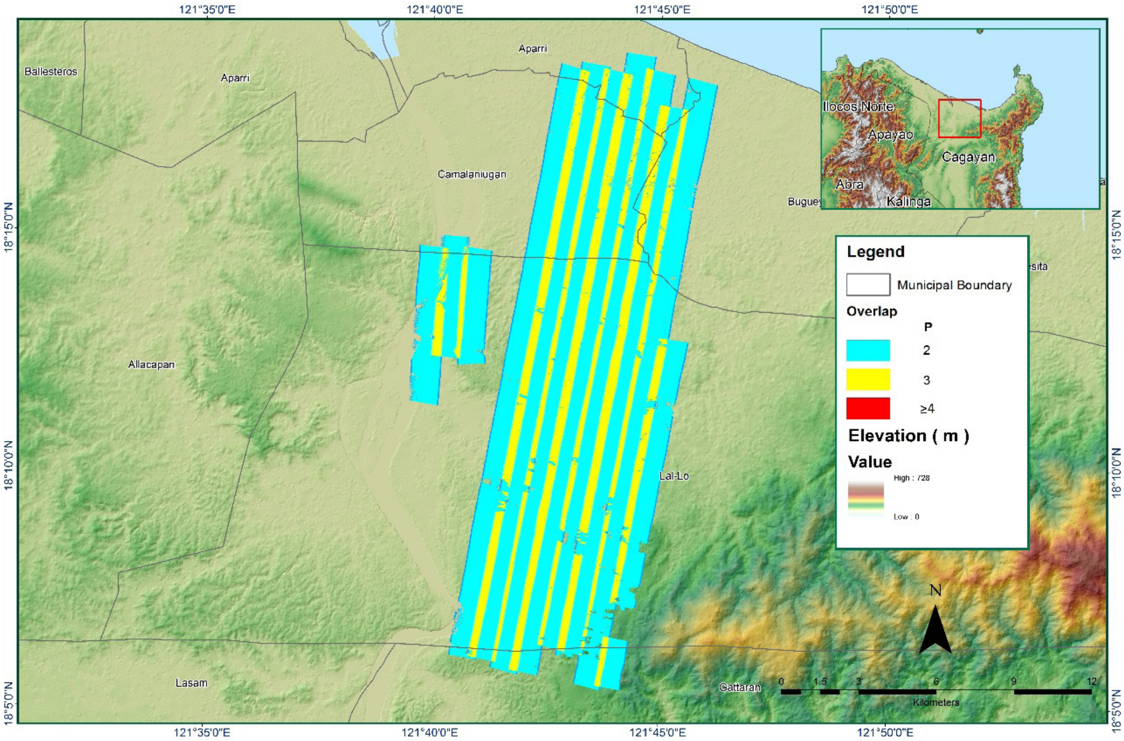


Figure A-8.12. Image of data overlap

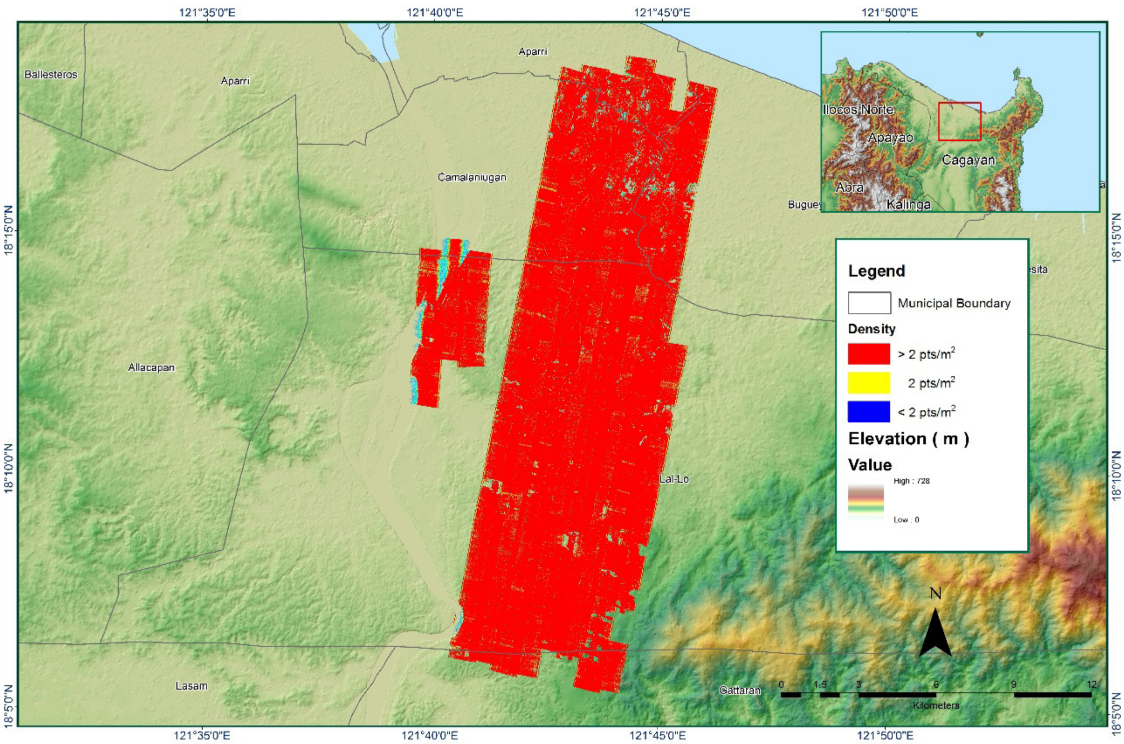


Figure A-8.13. Density map of merged LiDAR data

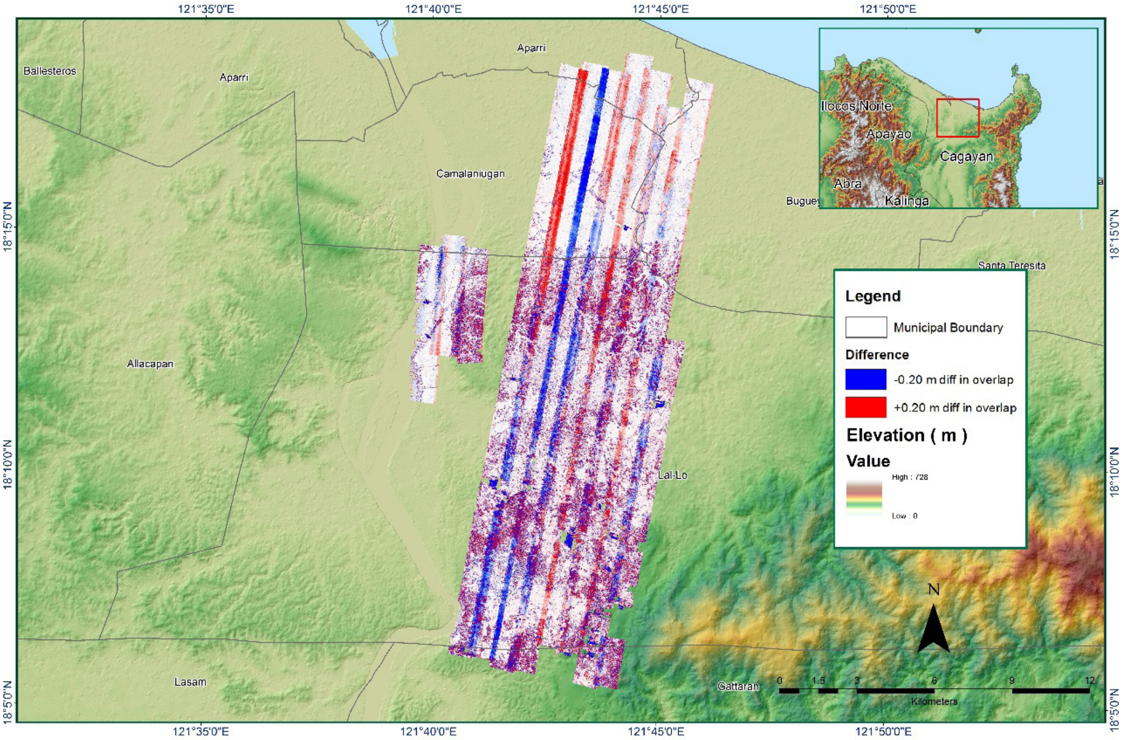


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Blk2F_supplement

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	**Blk2F_supplement**
Inclusive Flights	2846P
Range data size	31.3 GB
POS	299 MB
Image	50.8MB
Transfer date	November 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.48
RMSE for East Position (<4.0 cm)	2.73
RMSE for Down Position (<8.0 cm)	8.94
Boresight correction stdev (<0.001deg)	0.000335
IMU attitude correction stdev (<0.001deg)	0.002483
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	38.58
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	110
Maximum Height	269.14 m
Minimum Height	42.36 m
Classification (# of points)	
Ground	89,975,674
Low vegetation	45,492,631
Medium vegetation	76,938,547
High vegetation	162,740,157
Building	3,963,915
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Velina Angela Bemida, Tam

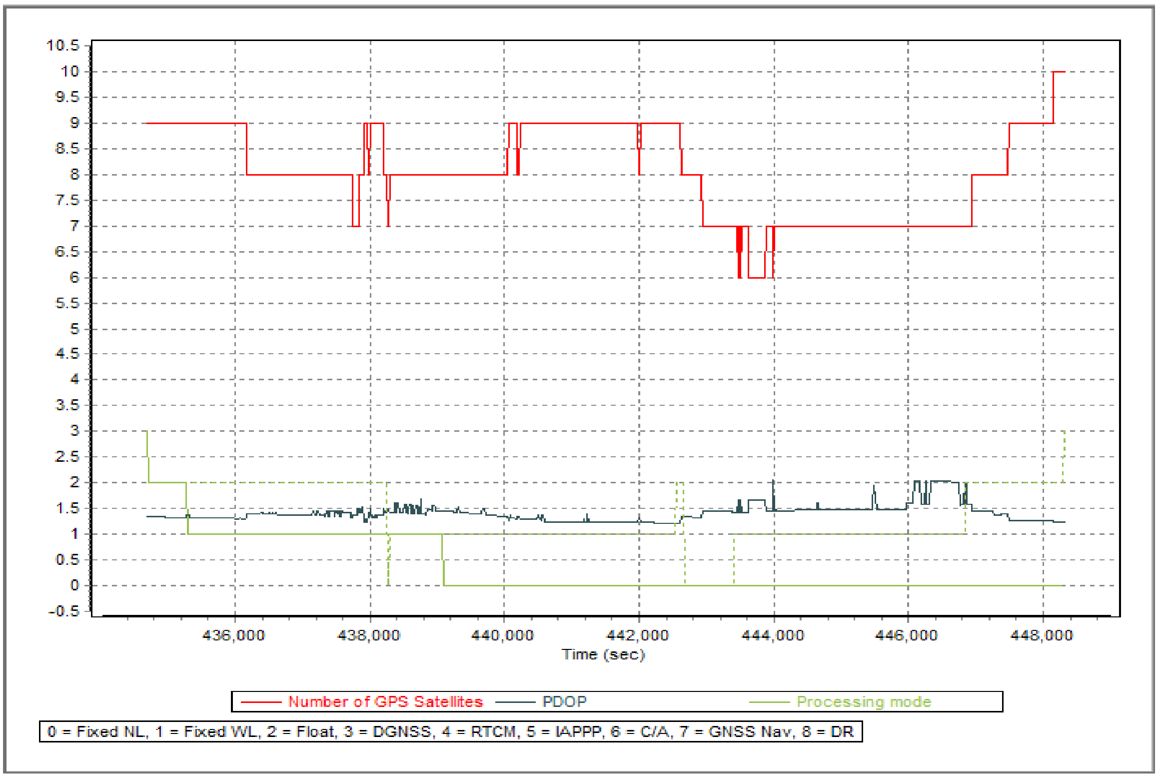


Figure A-8.15. Solution Status

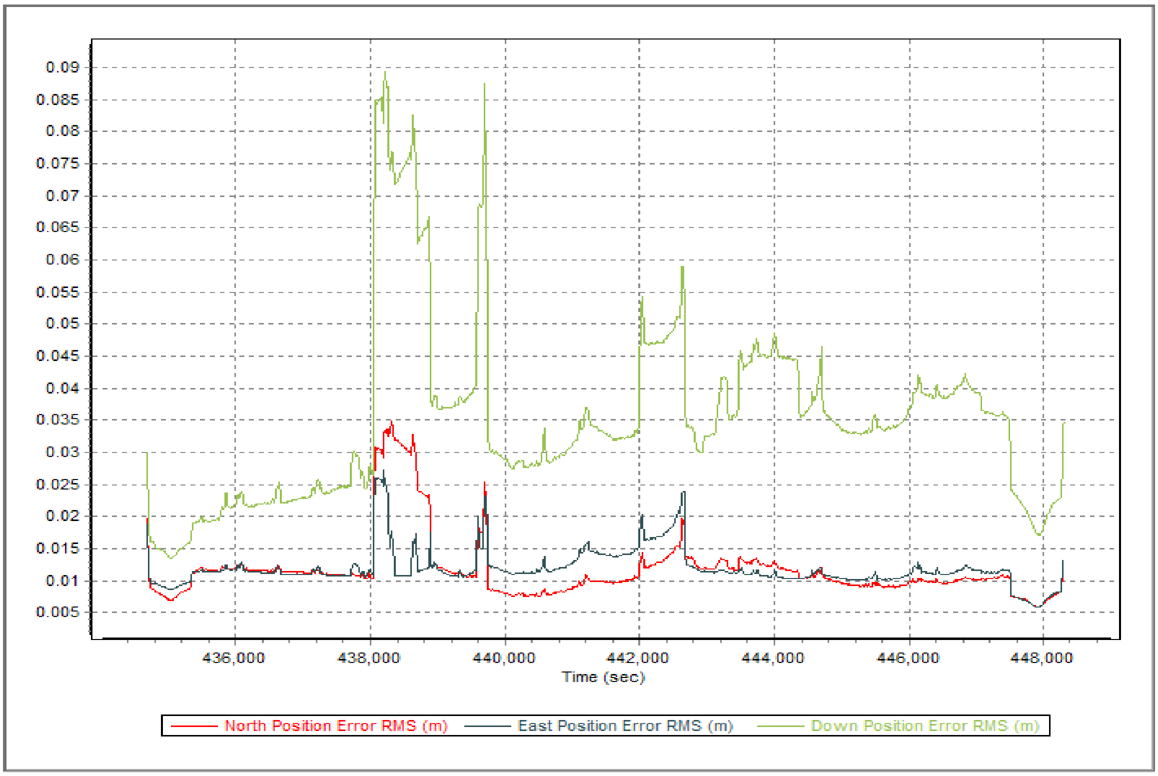


Figure A-8.16. Smoothed Performance Metric Parameters

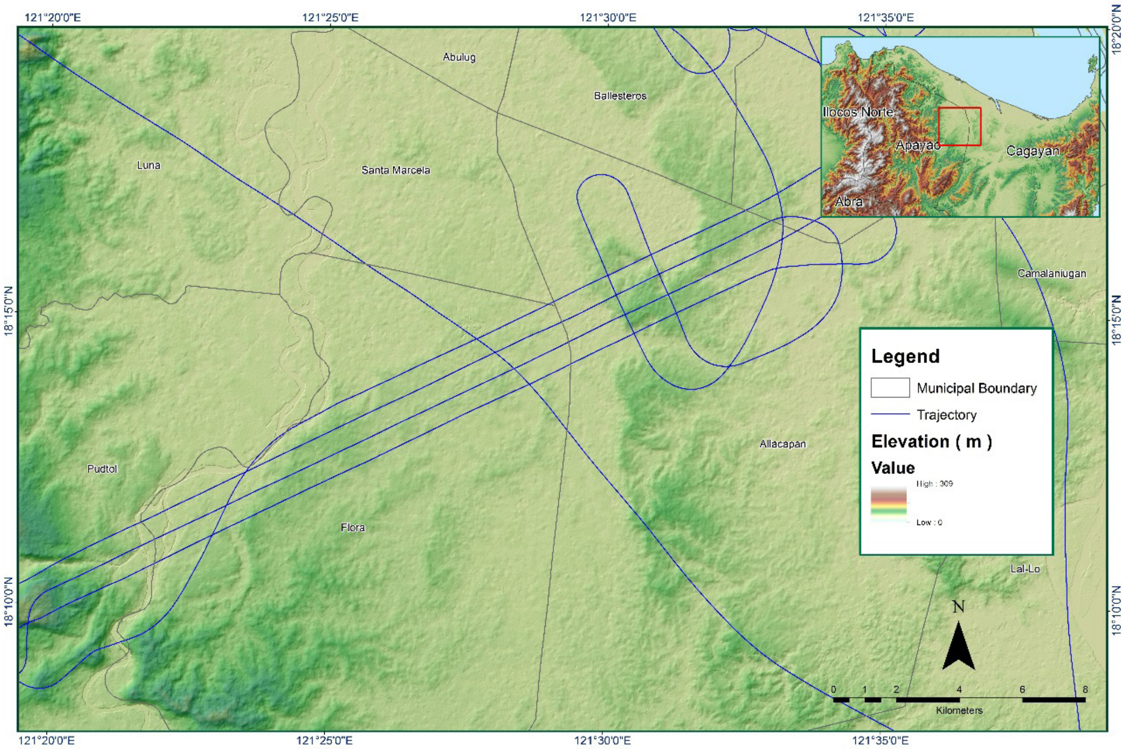


Figure A-8.17. Best Estimated Trajectory

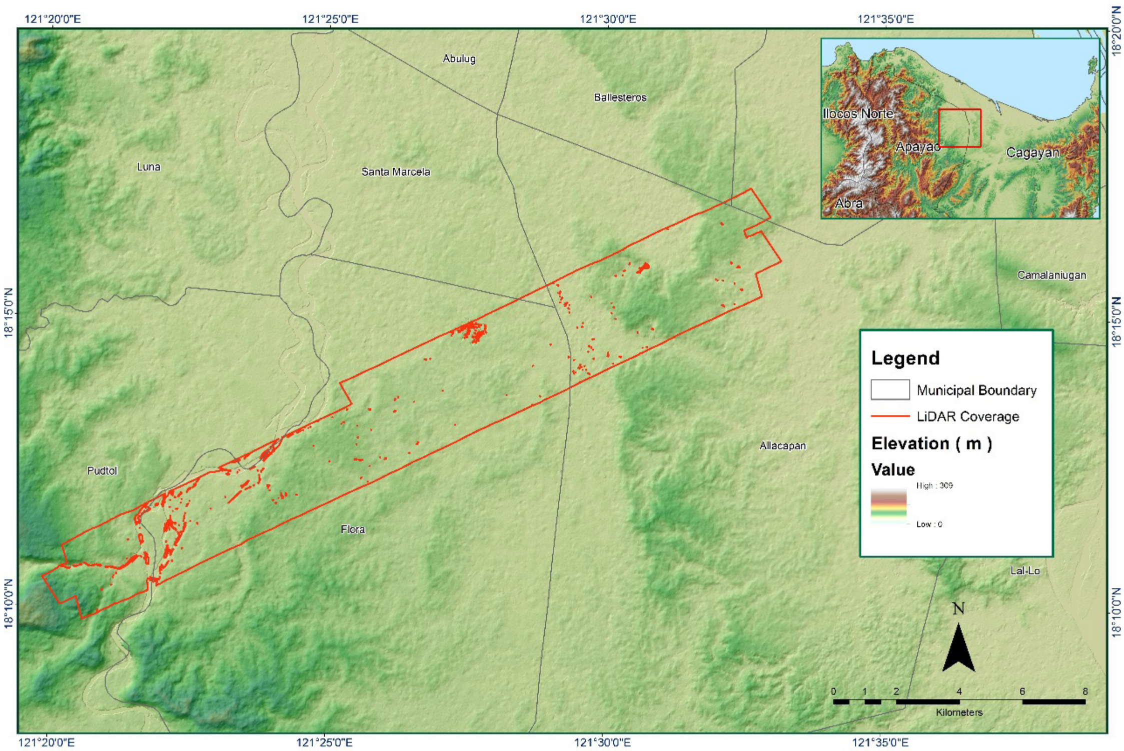


Figure A-8.18. Coverage of LiDAR data

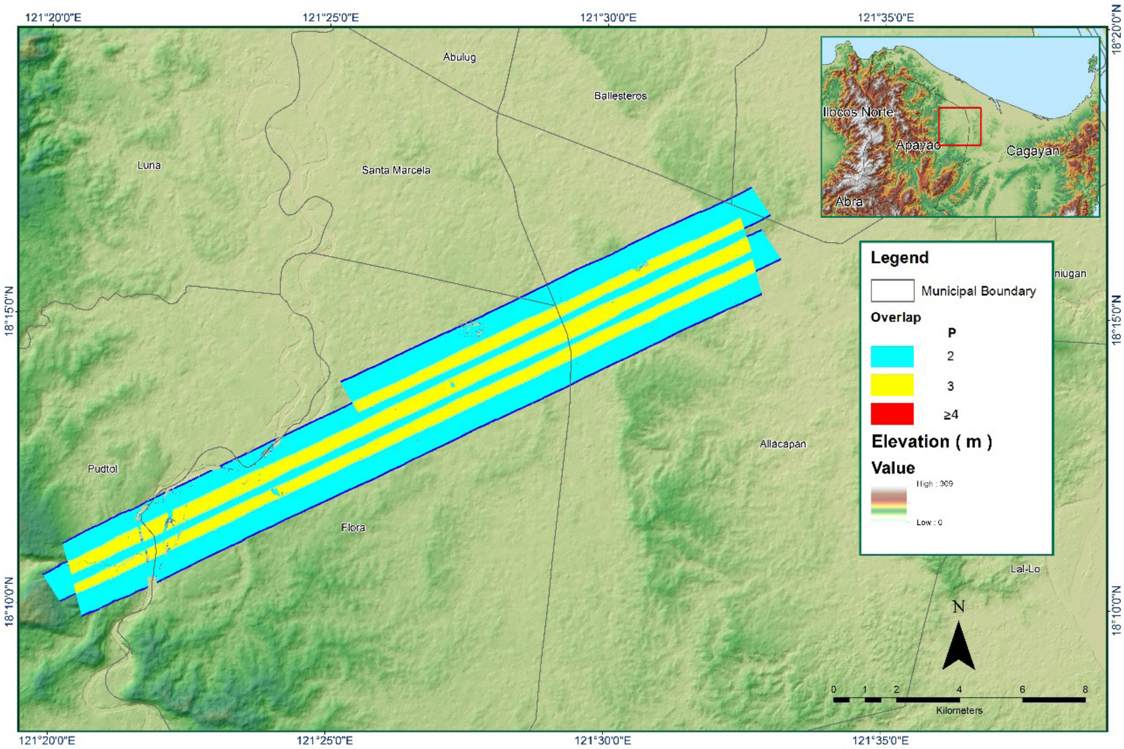


Figure A-8.19. Image of data overlap

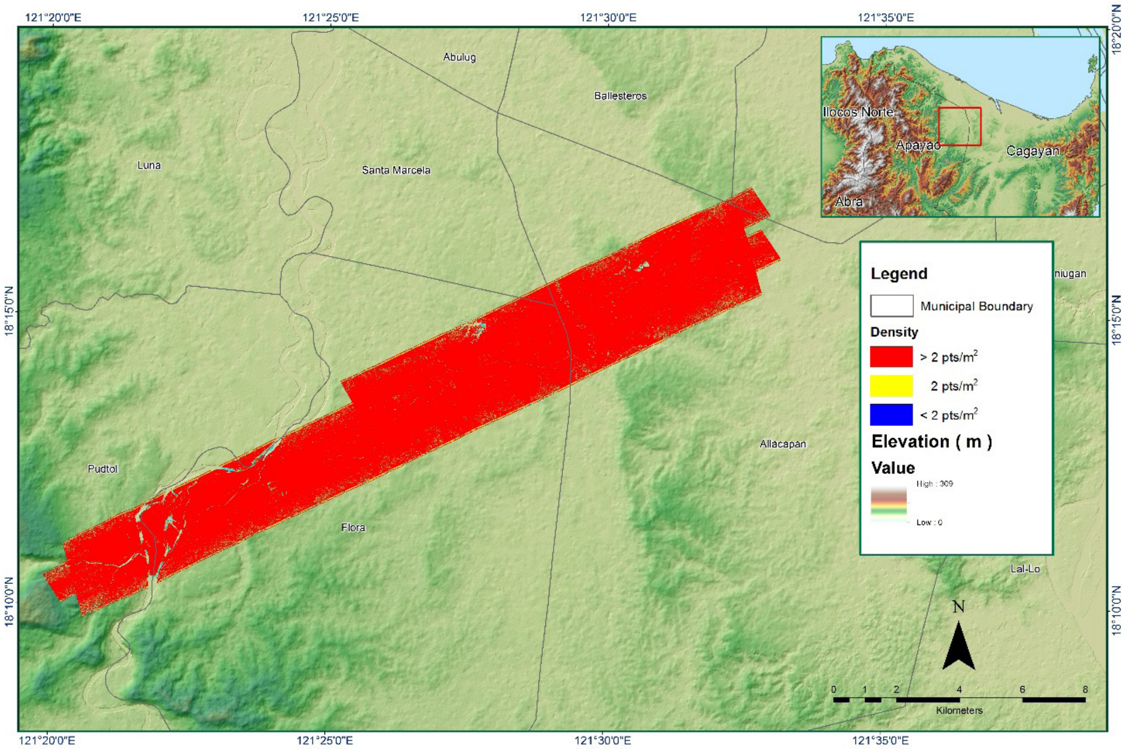


Figure A-8.20. Density map of merged LiDAR data

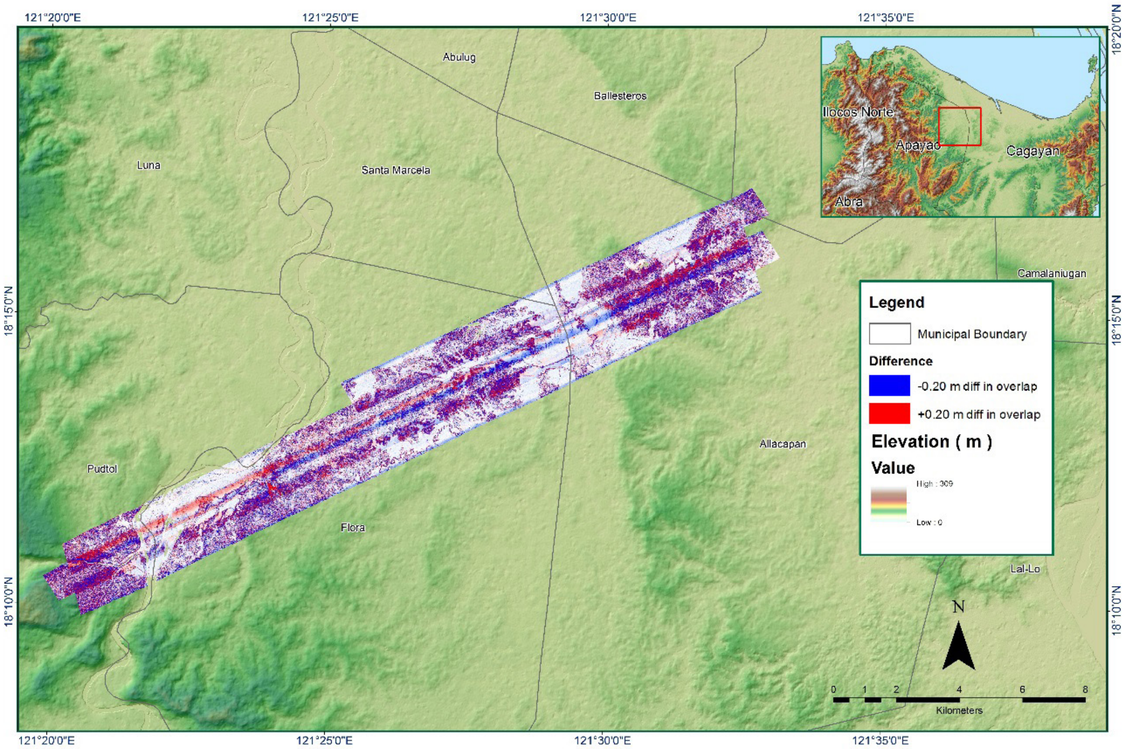


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Blk2F

Flight Area	**Cagayan Reflights(Tuguegarao)**
Mission Name	**Blk2F**
Inclusive Flights	2838P
Range data size	28.9 GB
POS	254 MB
Image	46.7 MB
Transfer date	November 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.16
RMSE for East Position (<4.0 cm)	1.33
RMSE for Down Position (<8.0 cm)	2.30
Boresight correction stdev (<0.001deg)	0.000324
IMU attitude correction stdev (<0.001deg)	0.001354
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	318
Maximum Height	927.58 m
Minimum Height	26.44 m
Classification (# of points)	
Ground	321,229,000
Low vegetation	311,186,721
Medium vegetation	332,571,906
High vegetation	529,282,178
Building	18,727,068
Orthophoto	Yes
Processed by	Raymund, Engr. Harmond Santos, Alex John Escobido

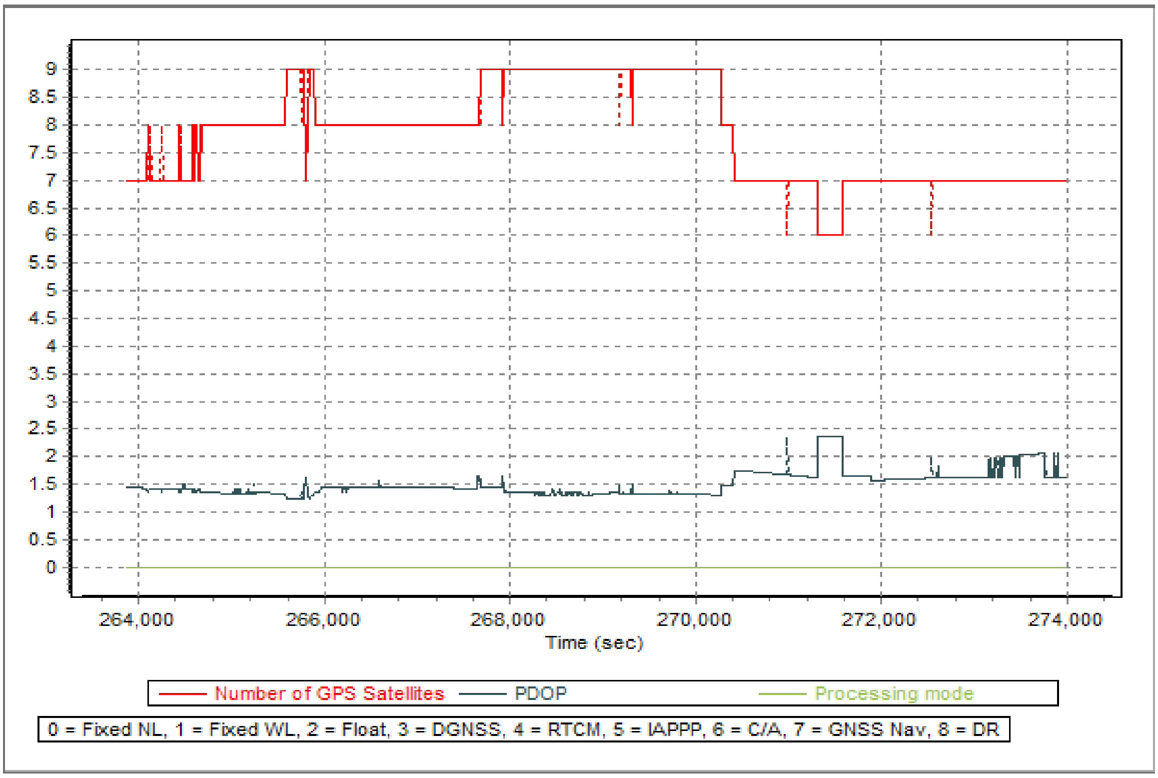


Figure A-8.22. Solution Status

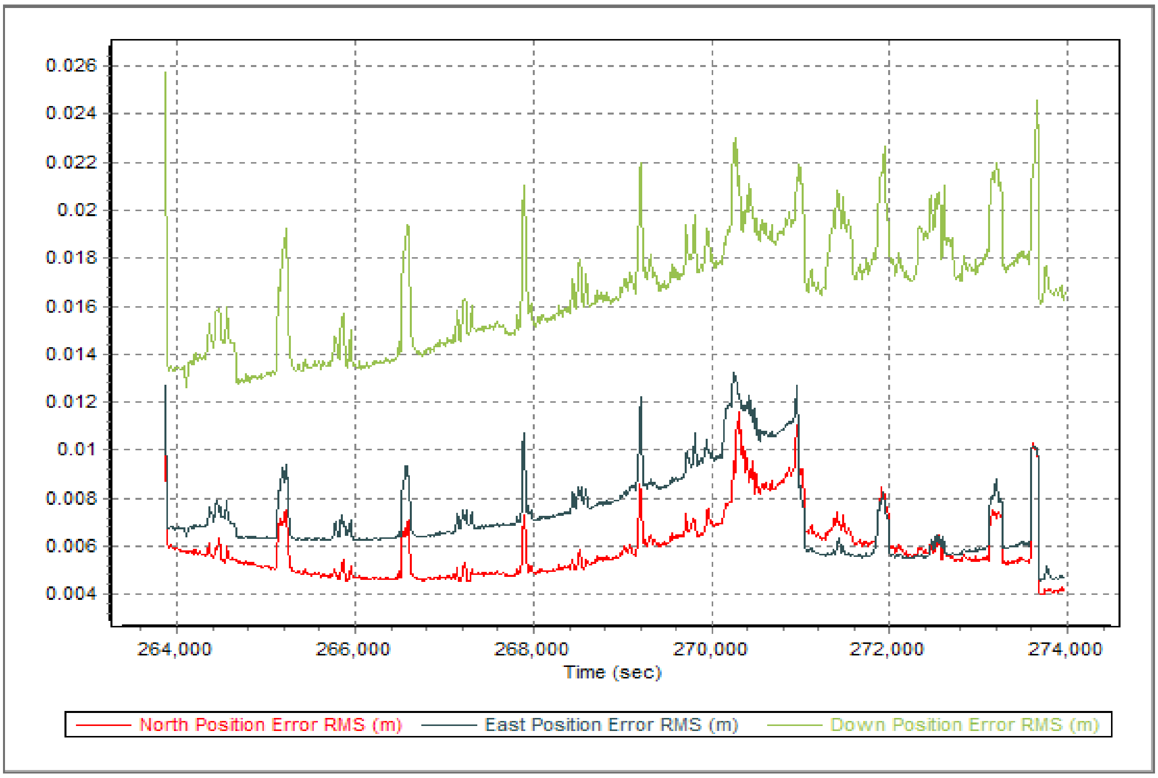


Figure A-8.23. Smoothed Performance Metric Parameters

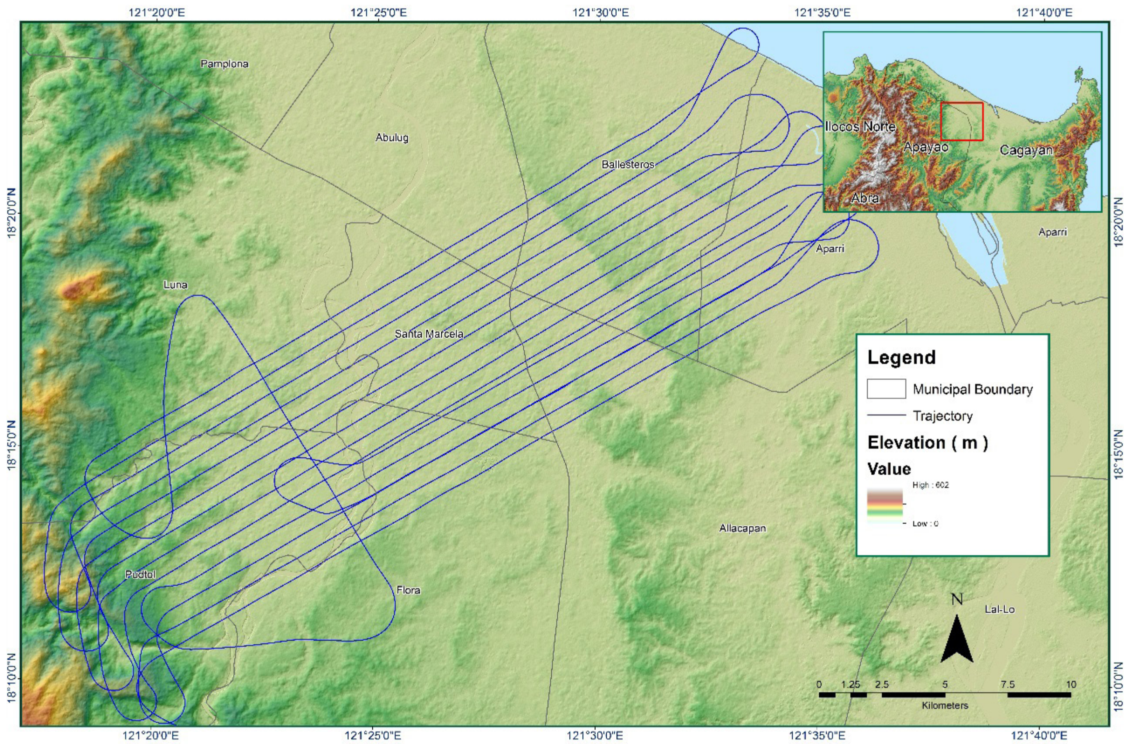


Figure A-8.24. Best Estimated Trajectory

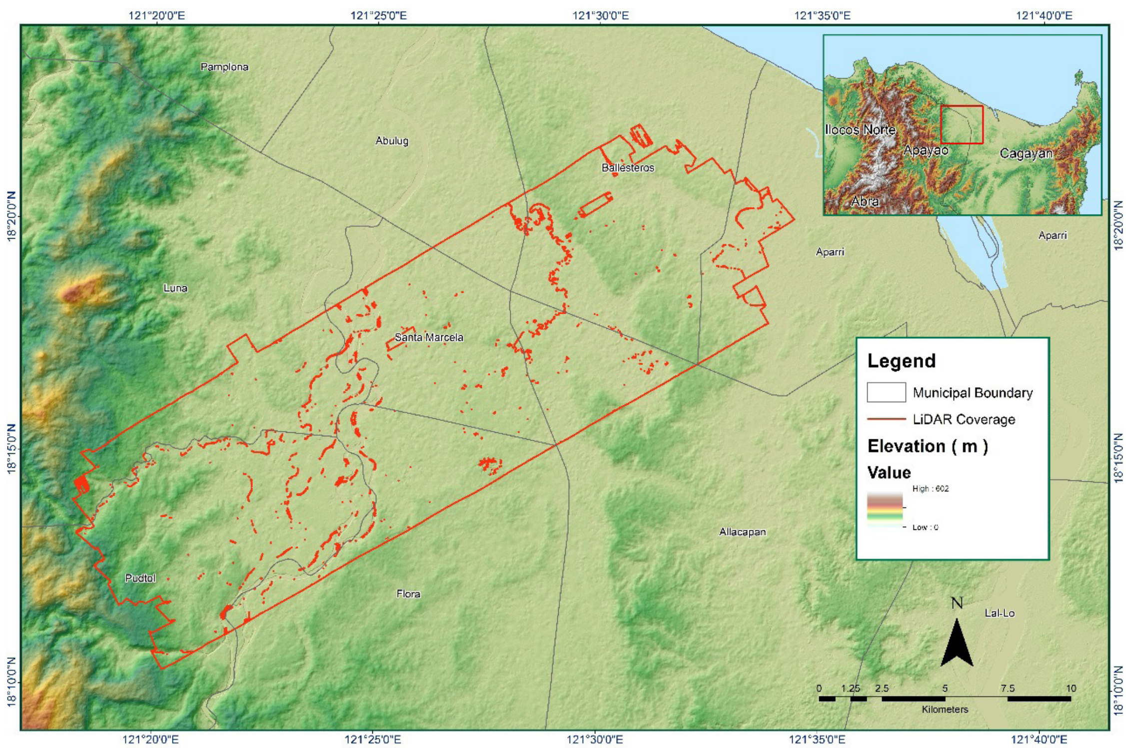


Figure A-8.25. Coverage of LiDAR data

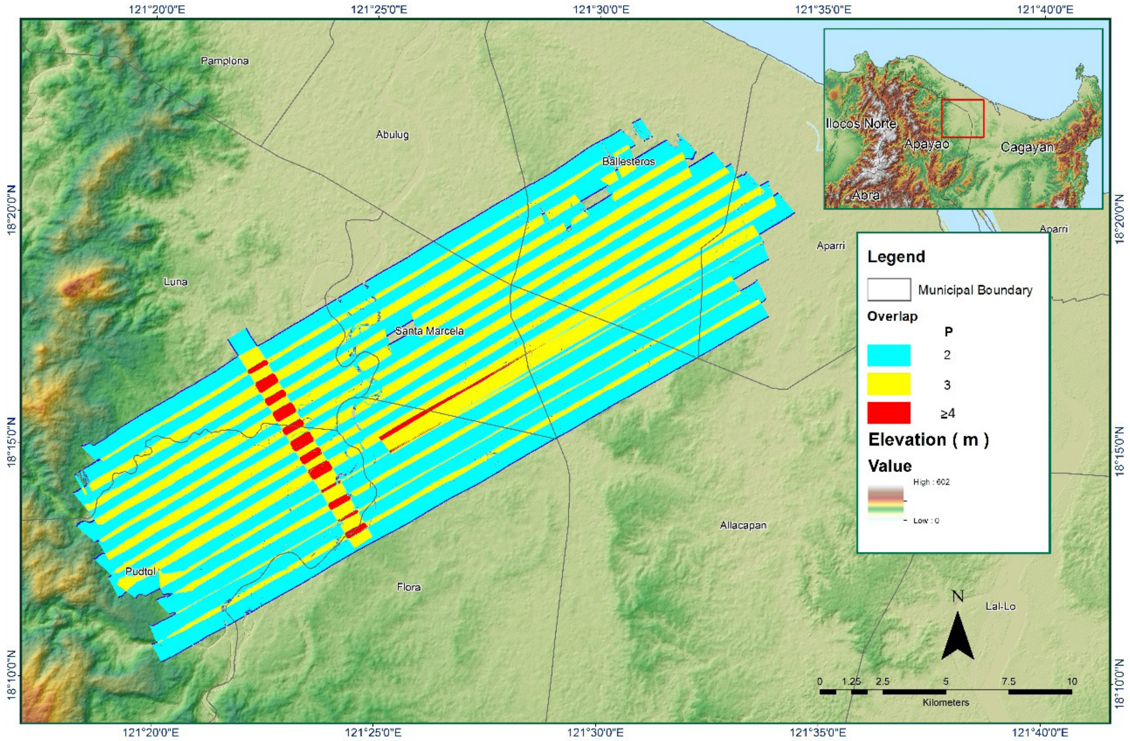


Figure A-8.26. Image of data overlap

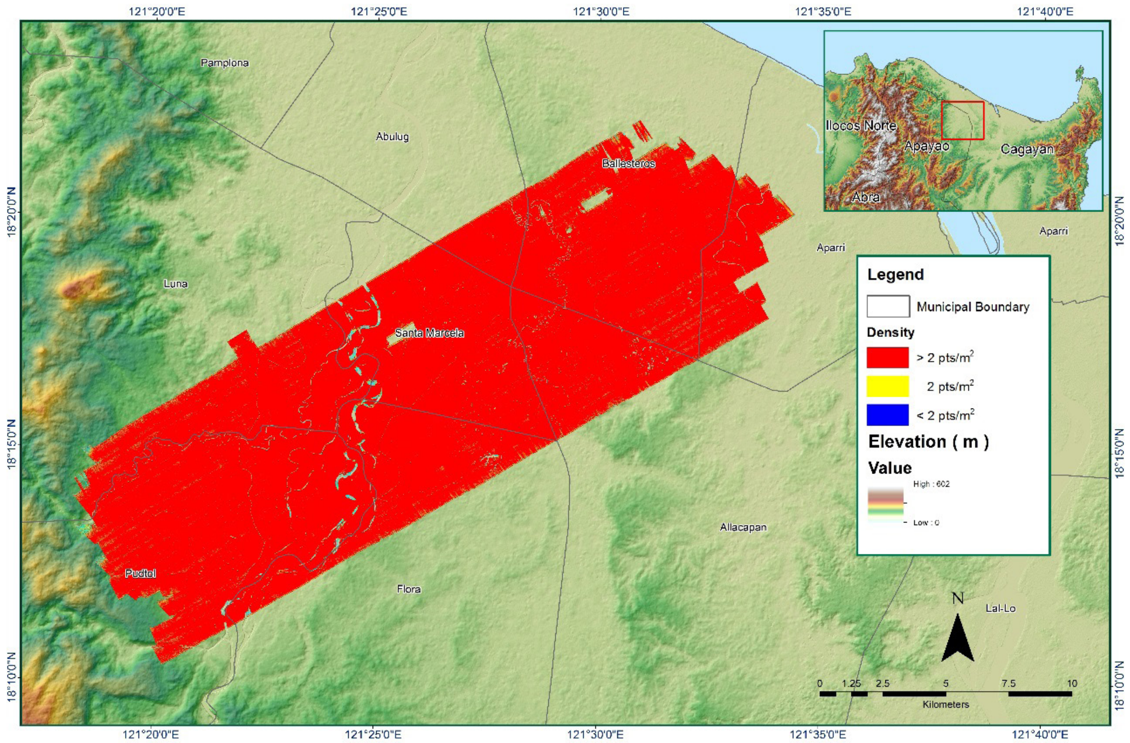


Figure A-8.27. Density map of merged LiDAR data

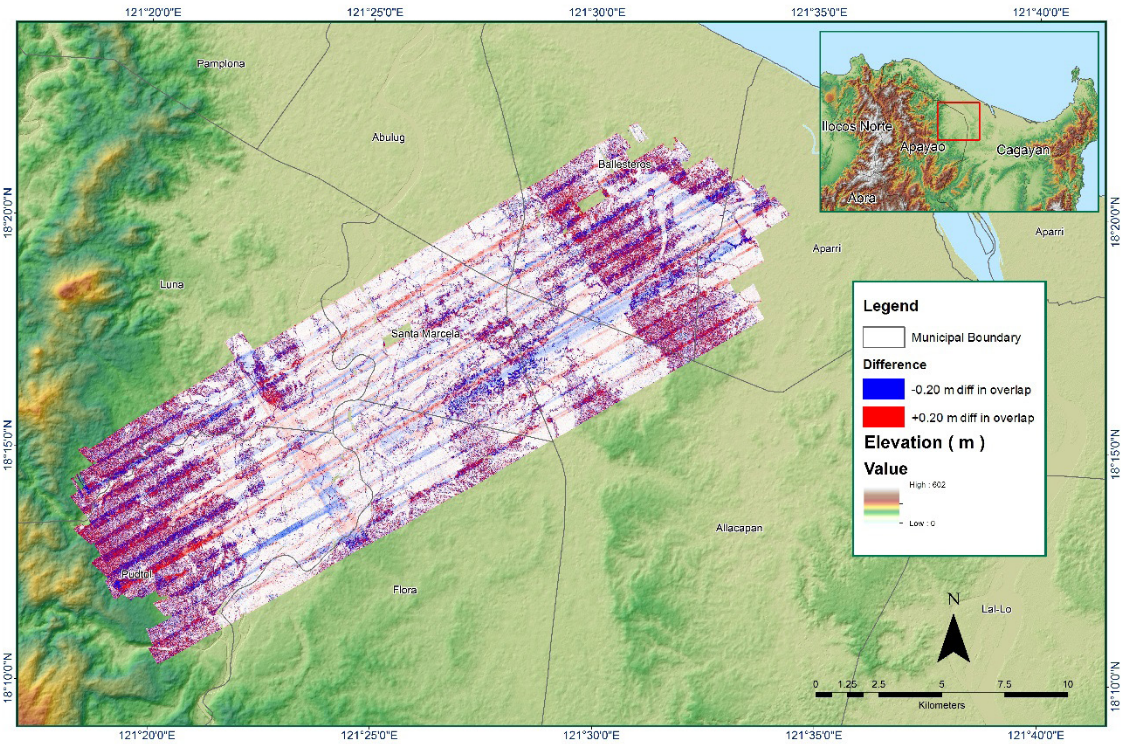


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Blk2A_supplement

Flight Area	**Cagayan Reflights(Tuguegarao)**
Mission Name	**Blk2A_supplement**
Inclusive Flights	2846P
Range data size	31.3GB
POS	299MB
Image	50.8MB
Transfer date	November 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.48
RMSE for East Position (<4.0 cm)	2.73
RMSE for Down Position (<8.0 cm)	8.94
Boresight correction stdev (<0.001deg)	0.000335
IMU attitude correction stdev (<0.001deg)	0.000776
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	51.57%
Ave point cloud density per sq.m. (>2.0)	3.17
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	267
Maximum Height	487.63 m
Minimum Height	38.22 m
Classification (# of points)	
Ground	199,764,057
Low vegetation	206,231,885
Medium vegetation	240,445,037
High vegetation	623,968,966
Building	16,265,221
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga Jr., Engr. Krisha Marie Bautista

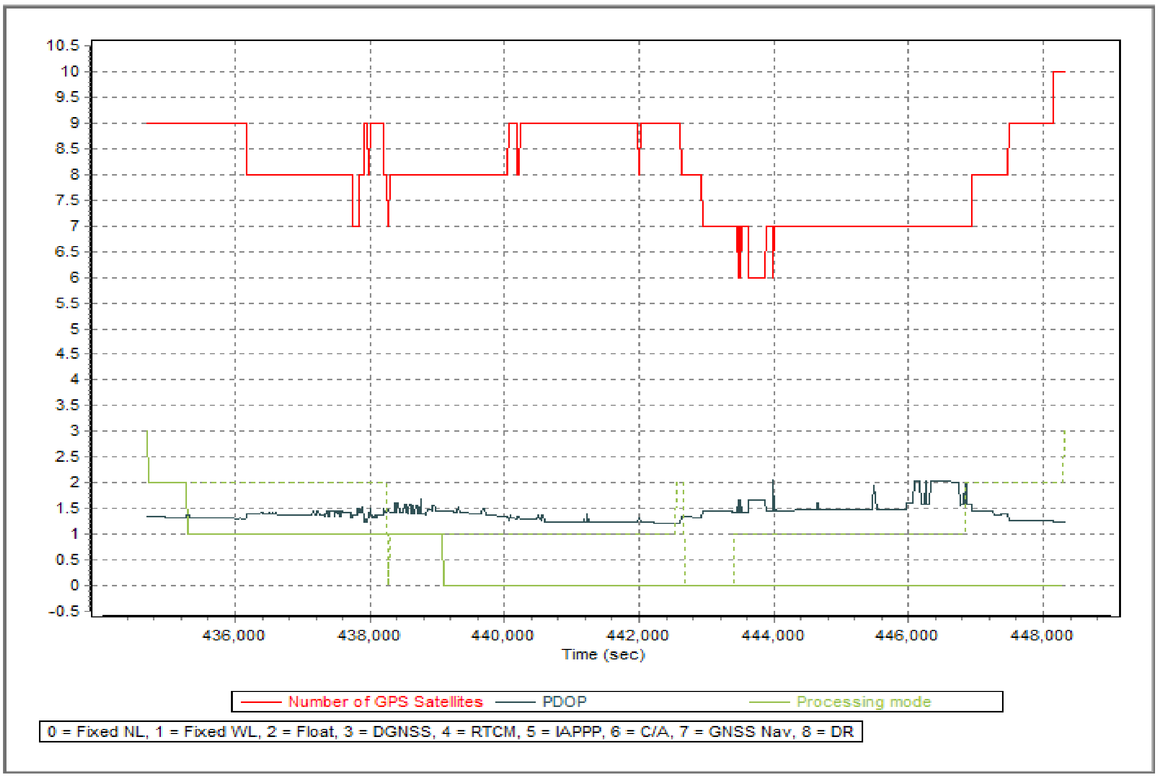


Figure A-8.29. Solution Status

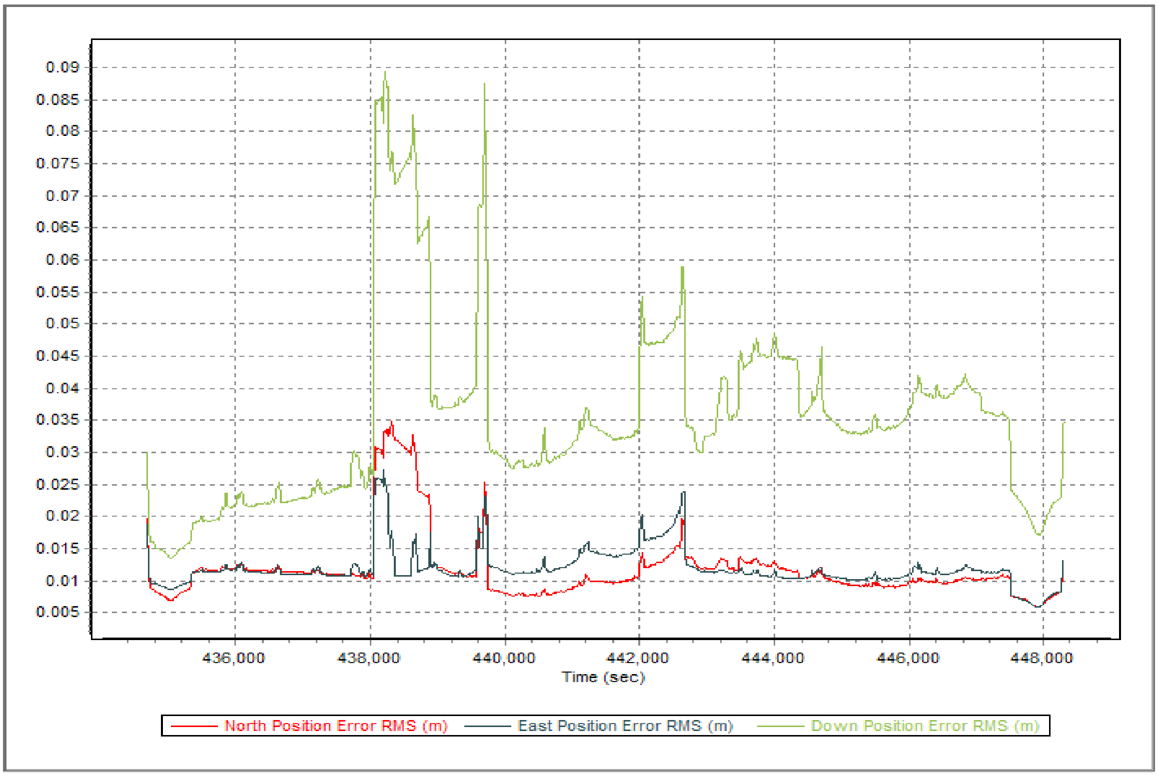


Figure A-8.30. Smoothed Performance Metric Parameters

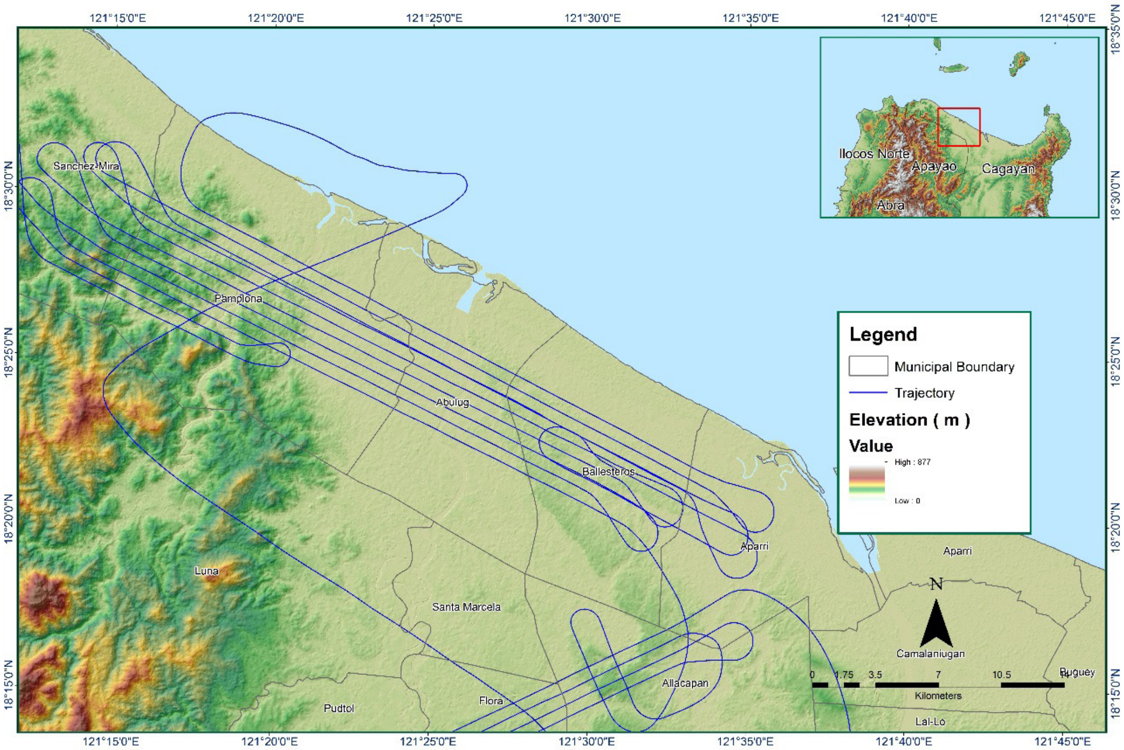


Figure A-8.31. Best Estimated Trajectory

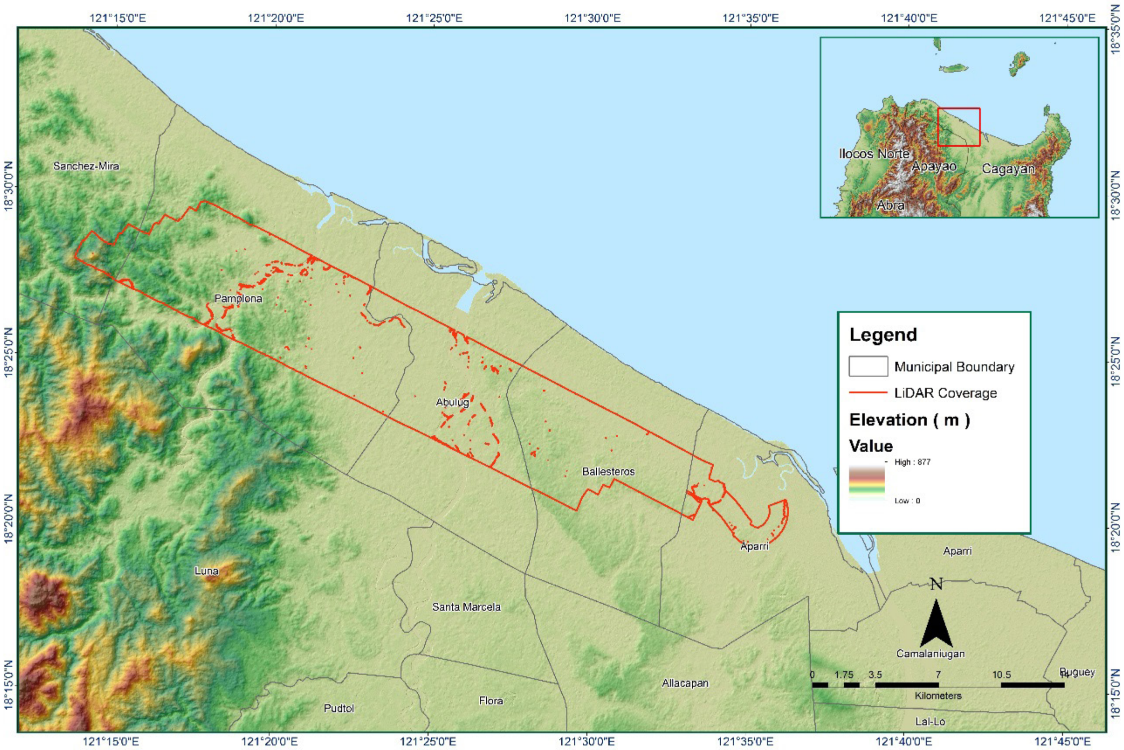


Figure A-8.32. Coverage of LiDAR data

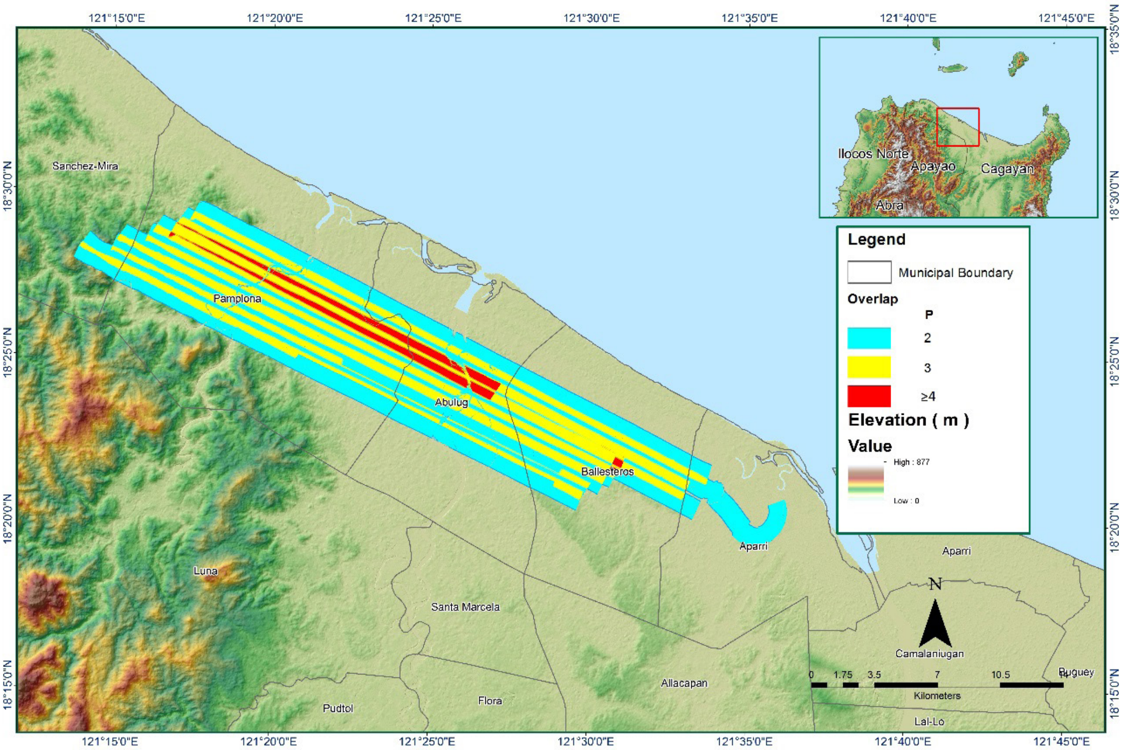


Figure A-8.33. Image of data overlap

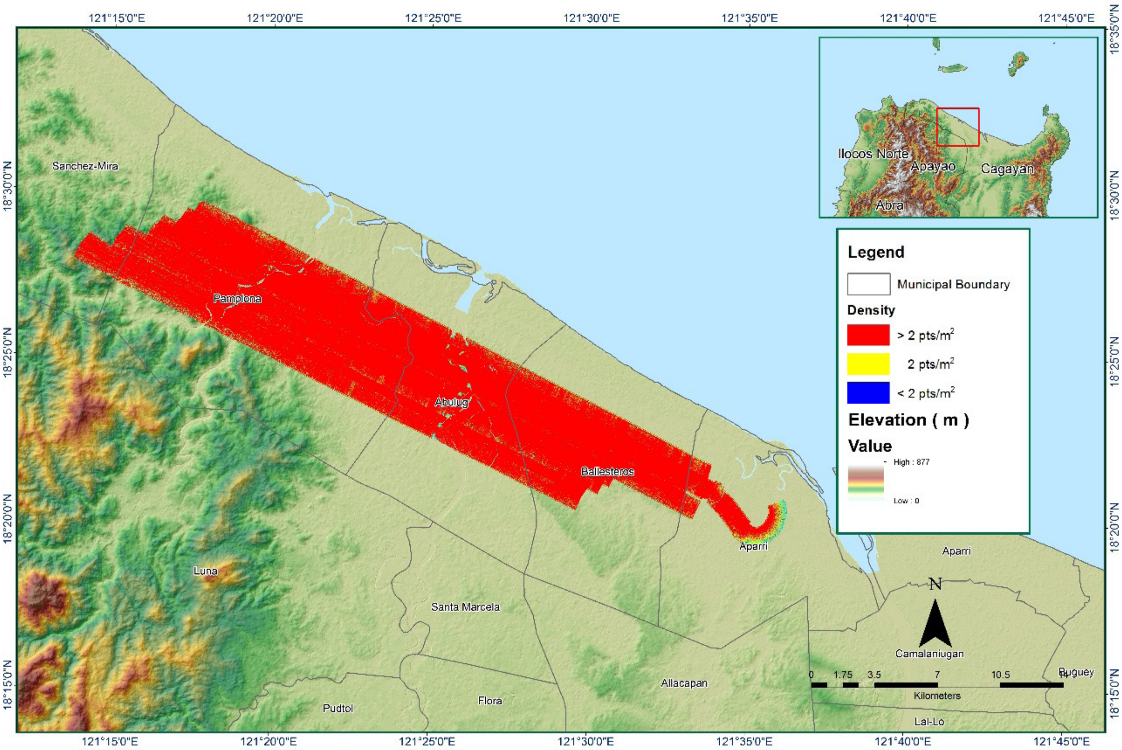


Figure A-8.34. Density map of merged LiDAR data

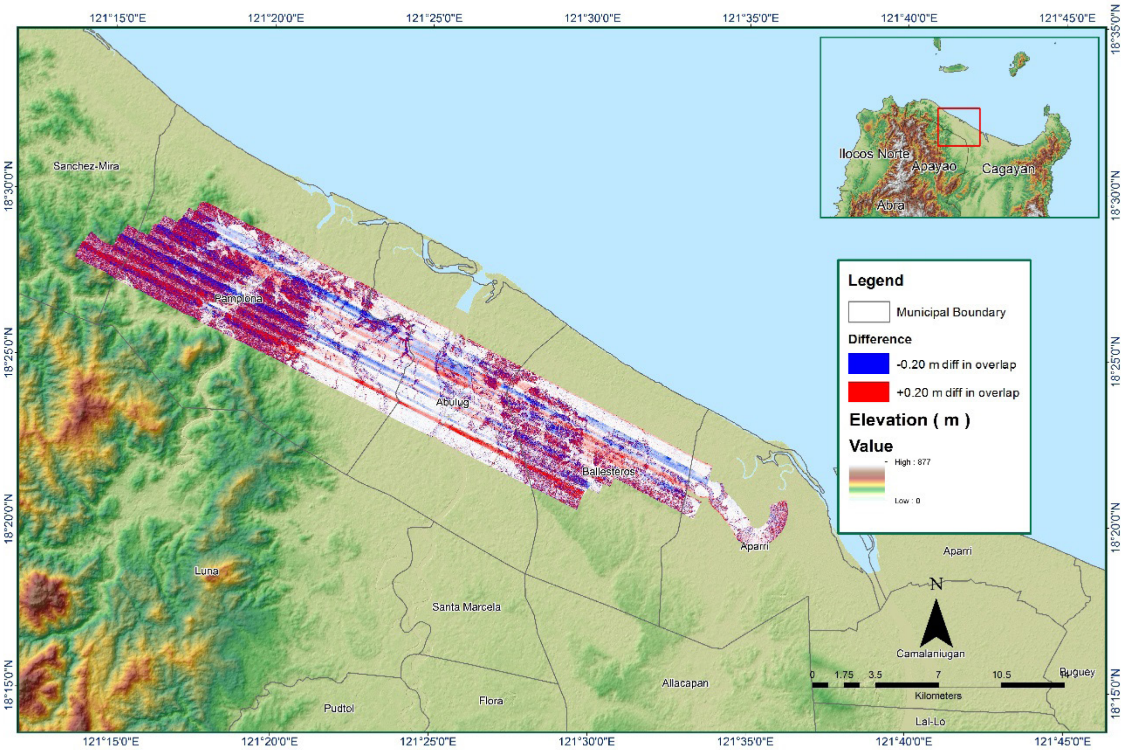


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Blk2A

Flight Area	**Cagayan Reflights(Tuguegarao)**
Mission Name	Blk2A
Inclusive Flights	2852P, 2848P
Range data size	17.63GB
POS	301MB
Image	28.87MB
Transfer date	November 24, 2015
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)	3.58
RMSE for East Position (<4.0 cm)	3.08
RMSE for Down Position (<8.0 cm)	5.22
Boresight correction stdev (<0.001deg)	0.000481
IMU attitude correction stdev (<0.001deg)	0.000374
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	38.74%
Ave point cloud density per sq.m. (>2.0)	1.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	183
Maximum Height	
Minimum Height	
Classification (# of points)	
Ground	193,048,741
Low vegetation	109,905,536
Medium vegetation	147,785,042
High vegetation	258,391,125
Building	5,416,447
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Krisha

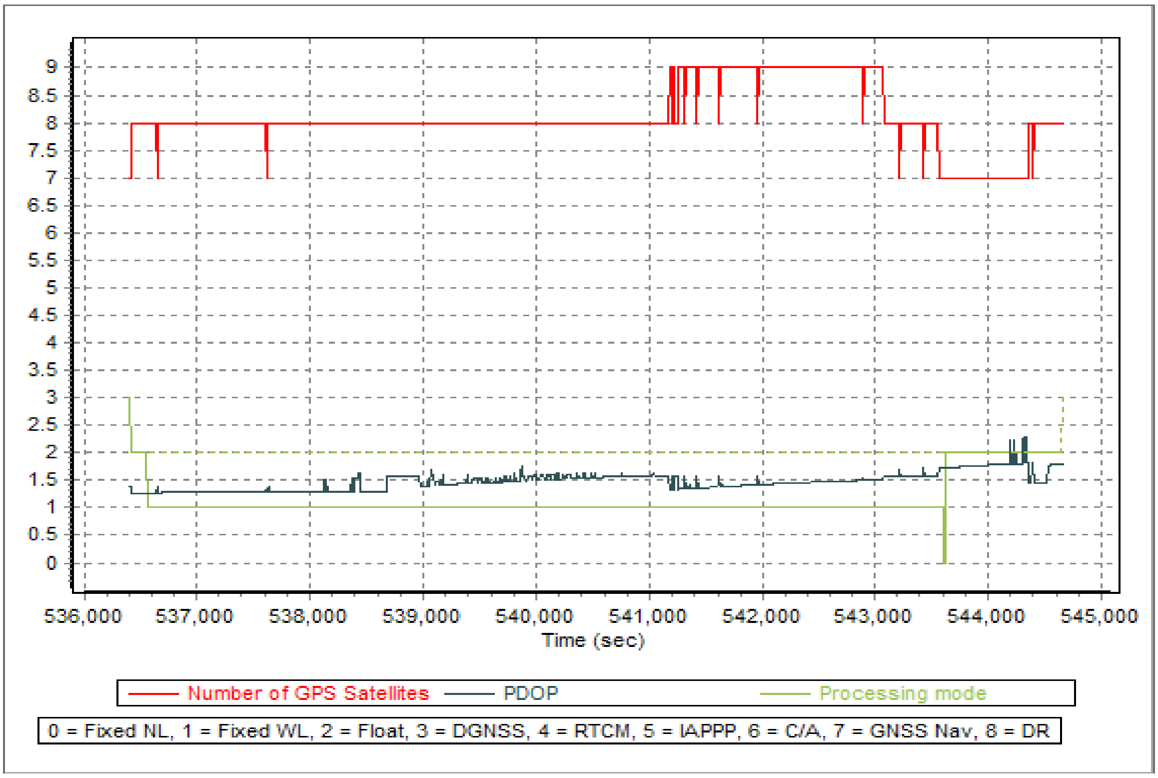


Figure A-8.36. Solution Status

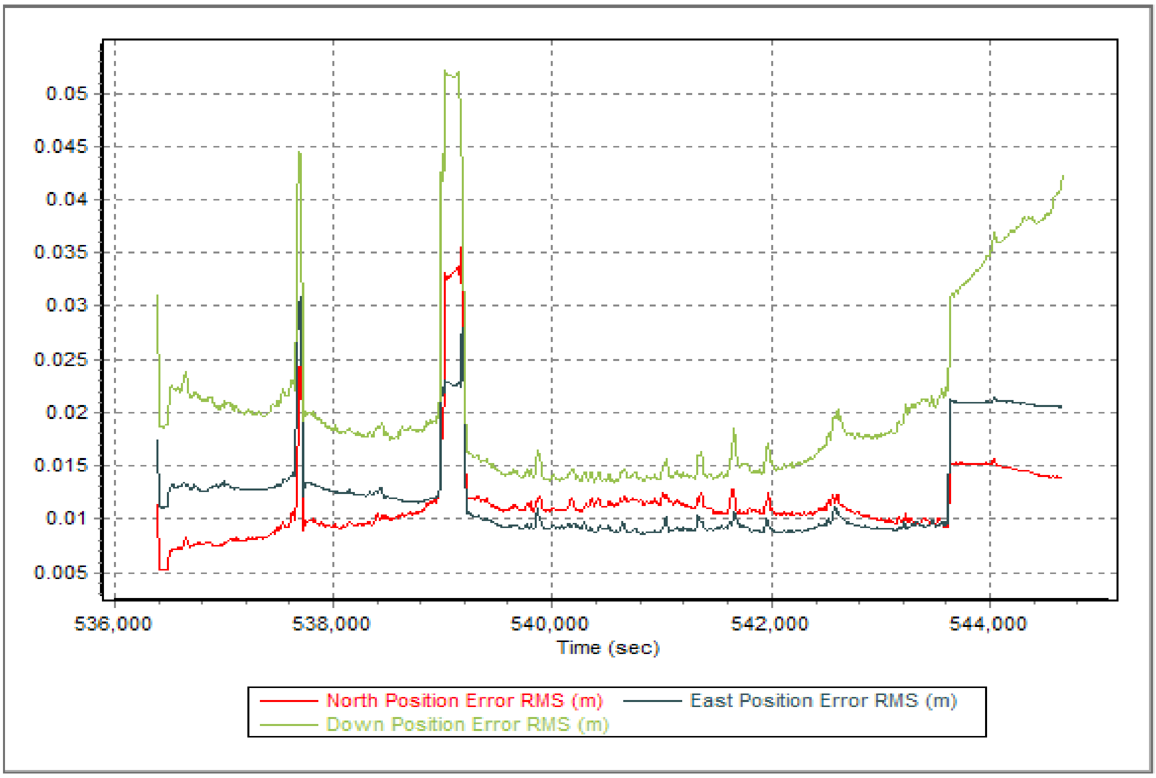


Figure A-8.37. Smoothed Performance Metric Parameters

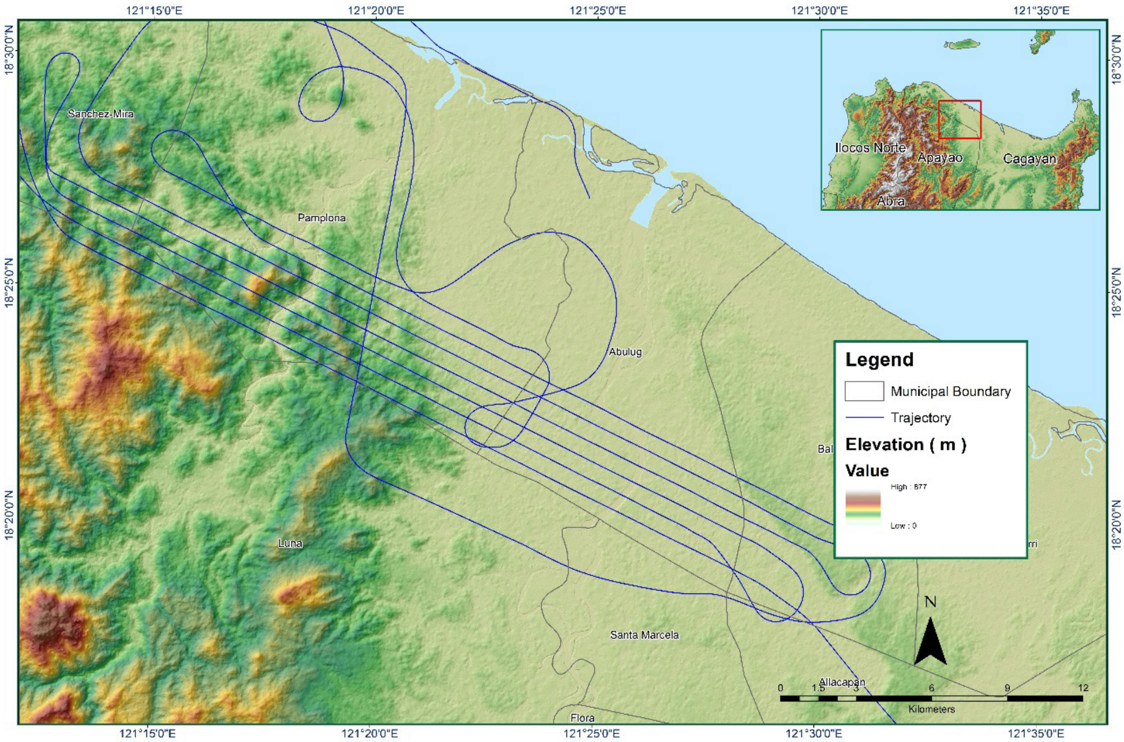


Figure A-8.38. Best Estimated Trajectory

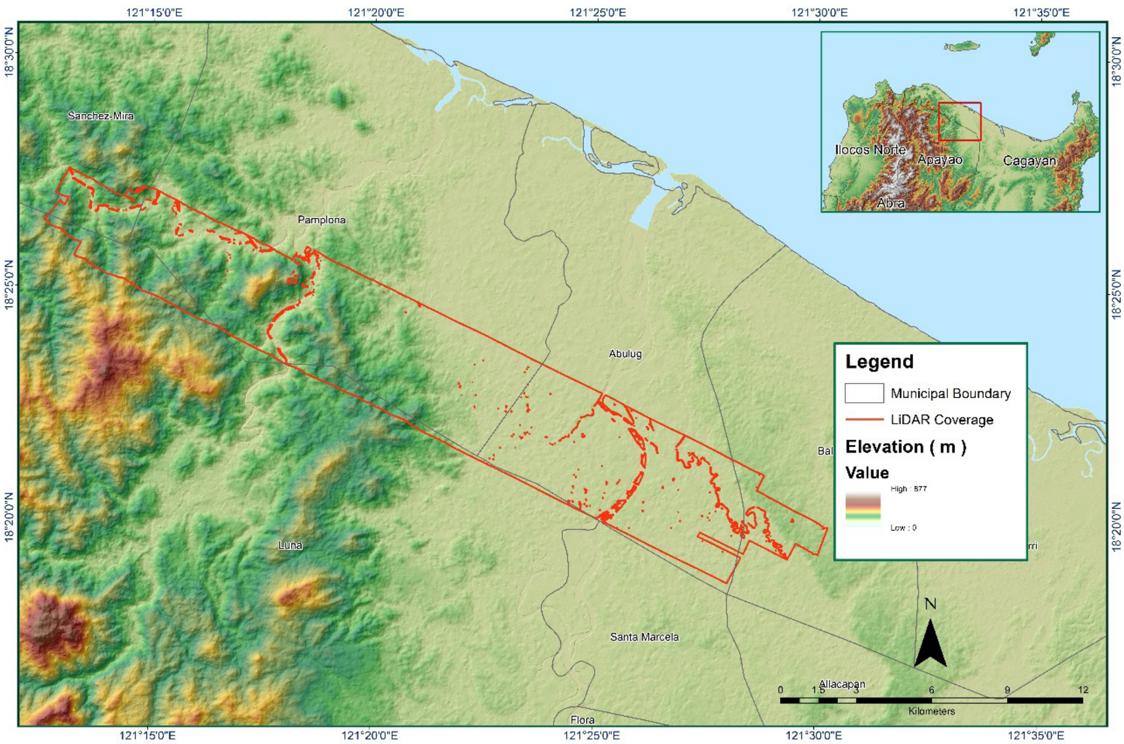


Figure A-8.39. Coverage of LiDAR data

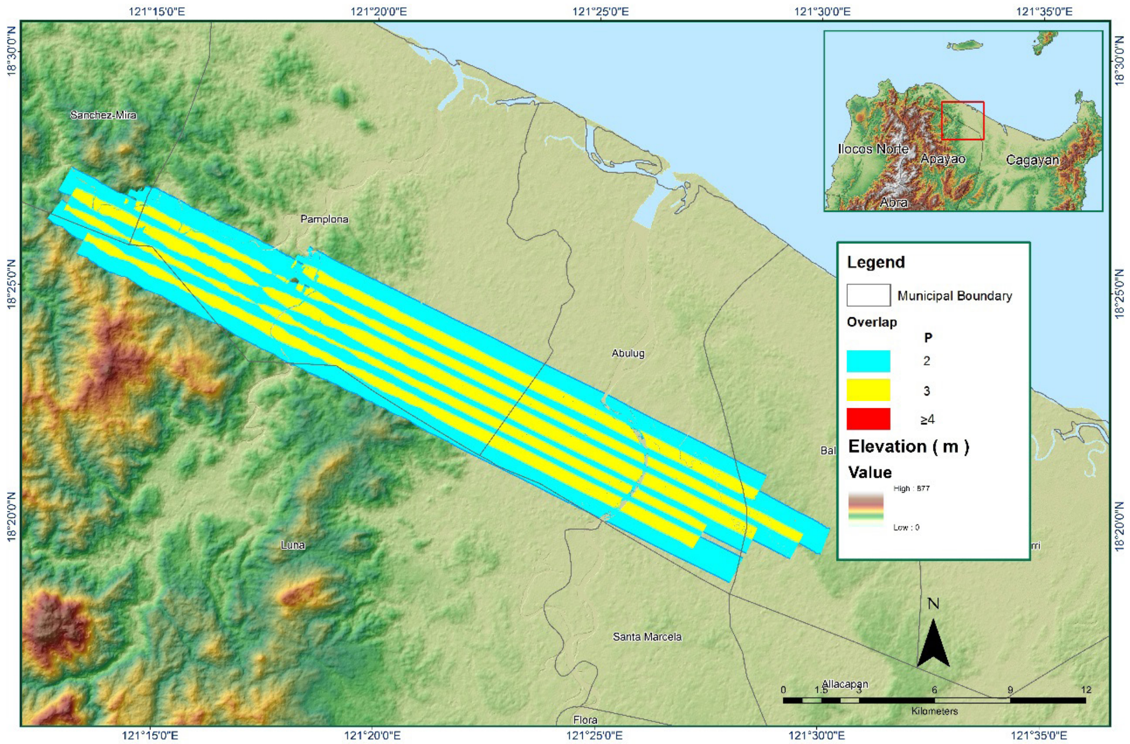


Figure A-8.40. Image of data overlap

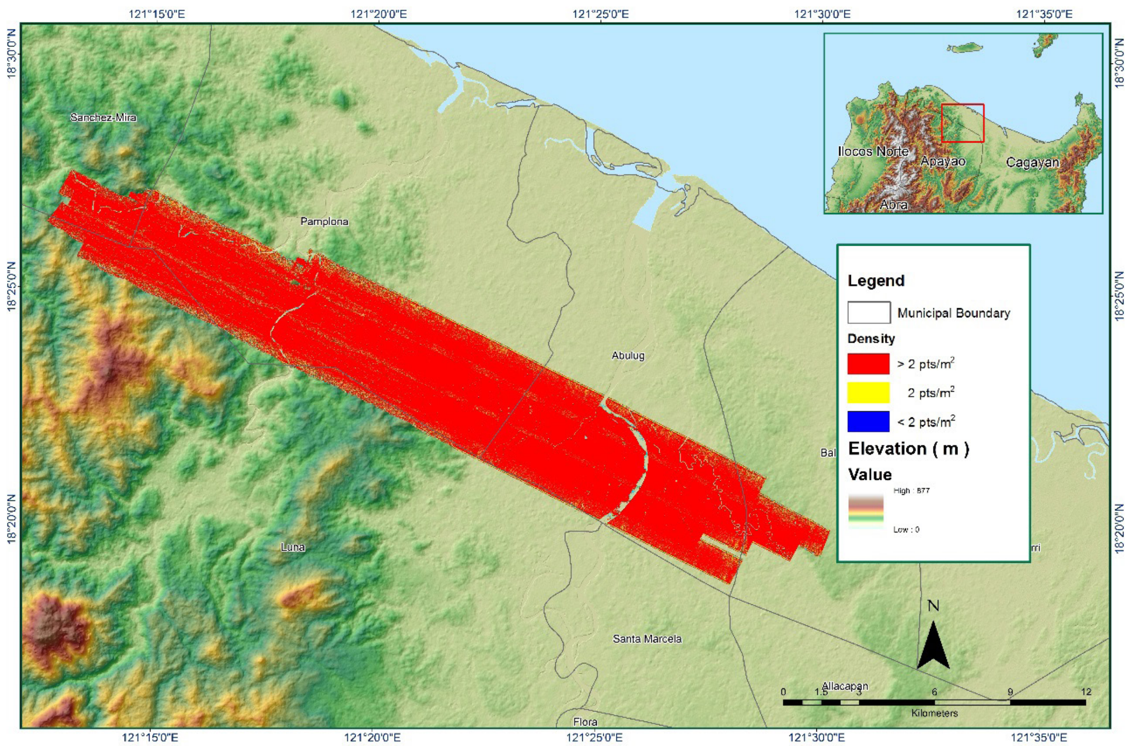


Figure A-8.41. Density map of merged LiDAR data

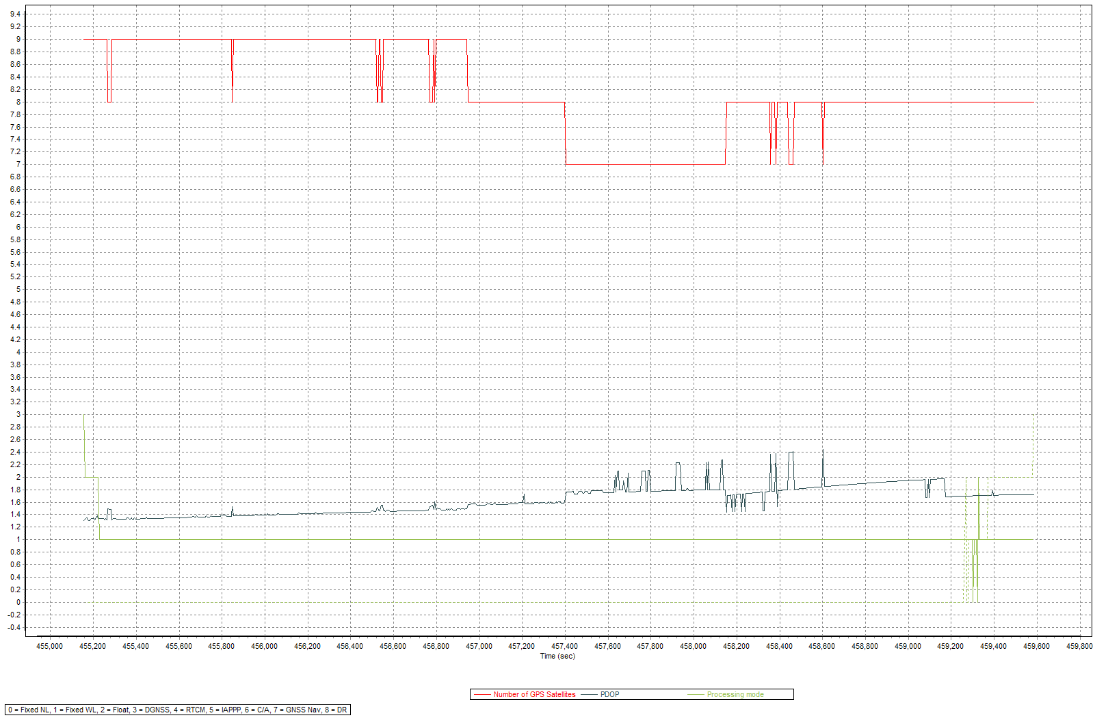


Figure A-8.42. Elevation difference between flight lines

Figure A-8.43. Solution Status

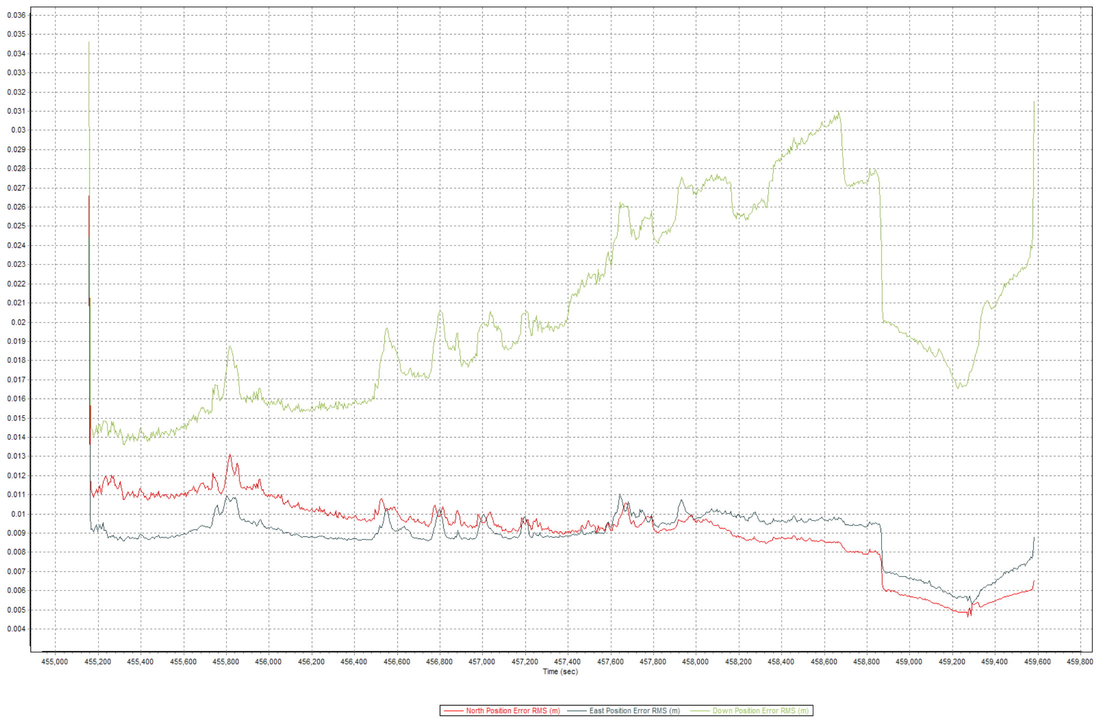


Figure A-8.44. Smoothed Performance Metric Parameters

Table A-8.7. Mission Summary Report for Blk2A_additional

Flight Area	Cagayan_reflights(Tuguegarao)
Mission Name	**Blk2A_additional**
Inclusive Flights	2848P
Range data size	5.83 GB
Base data size	24.9 MB
POS	169 MB
Image	7.97 MB
Transfer date	November 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000481
IMU attitude correction stdev (<0.001deg)	0.000374
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	6.85%
Ave point cloud density per sq.m. (>2.0)	1.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	101
Maximum Height	266.52 m.
Minimum Height	40.73 m.
Classification (# of points)	
Ground	53,937,277
Low vegetation	42,462,468
Medium vegetation	31,288,957
High vegetation	53,756,511
Building	485,048
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

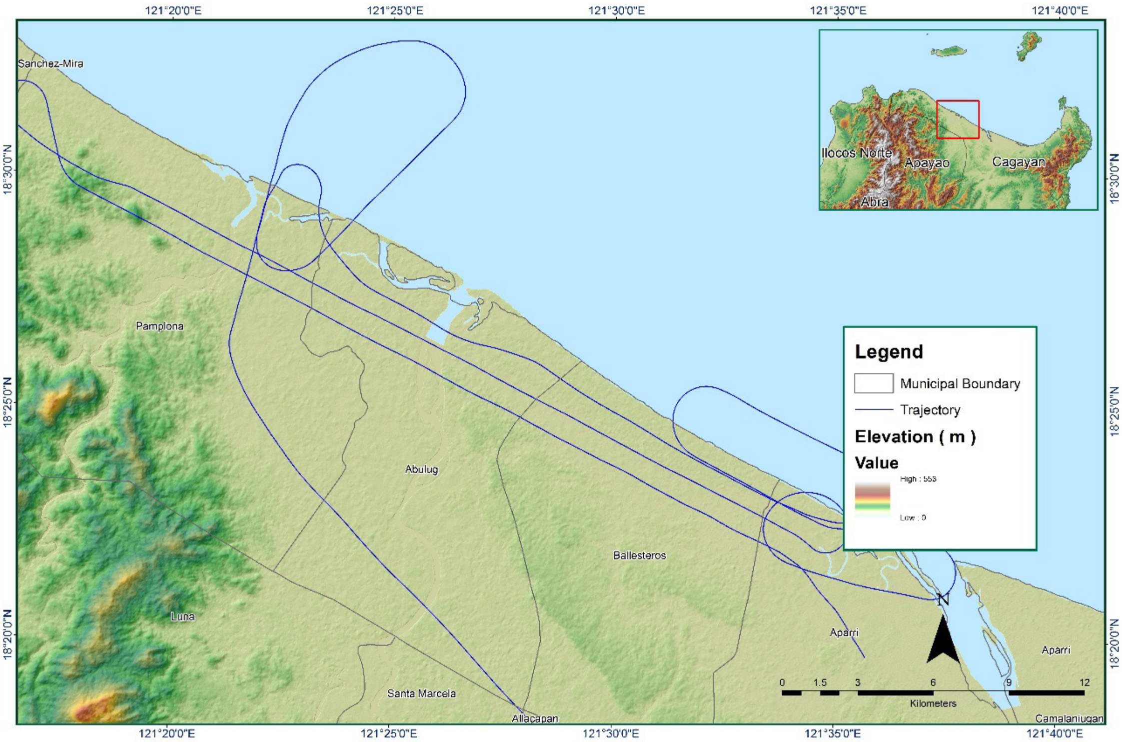


Figure A-8.45. Best Estimated Trajectory

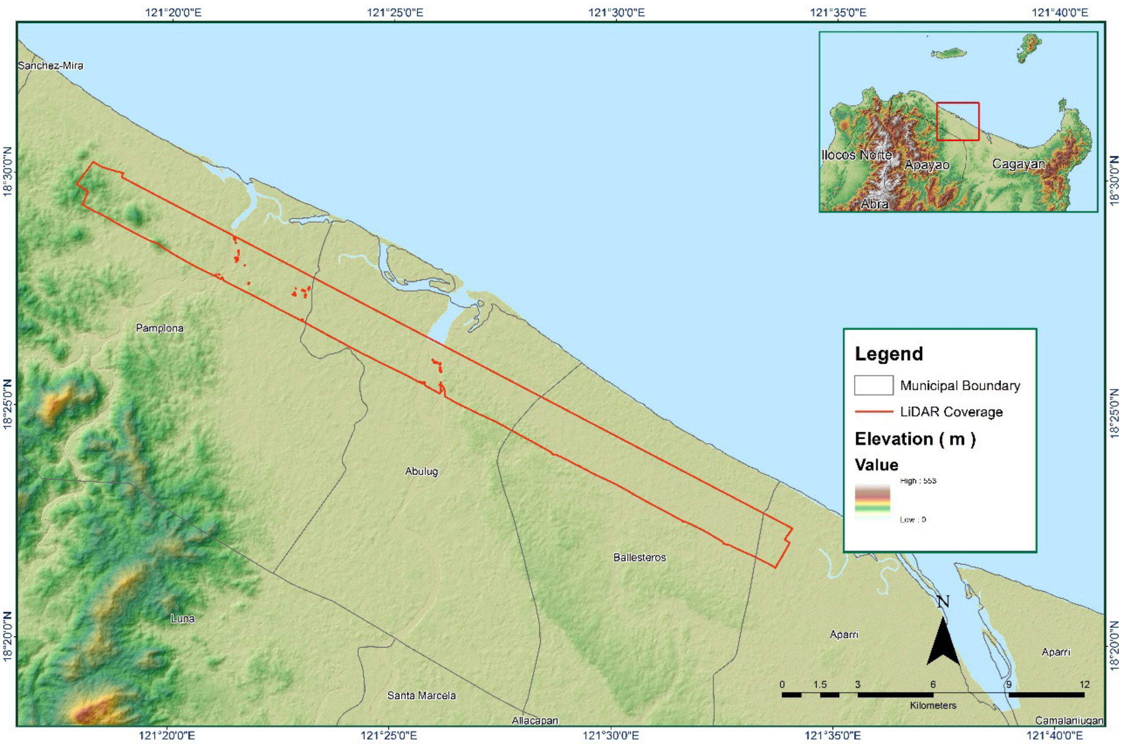


Figure A-8.46. Coverage of LiDAR data

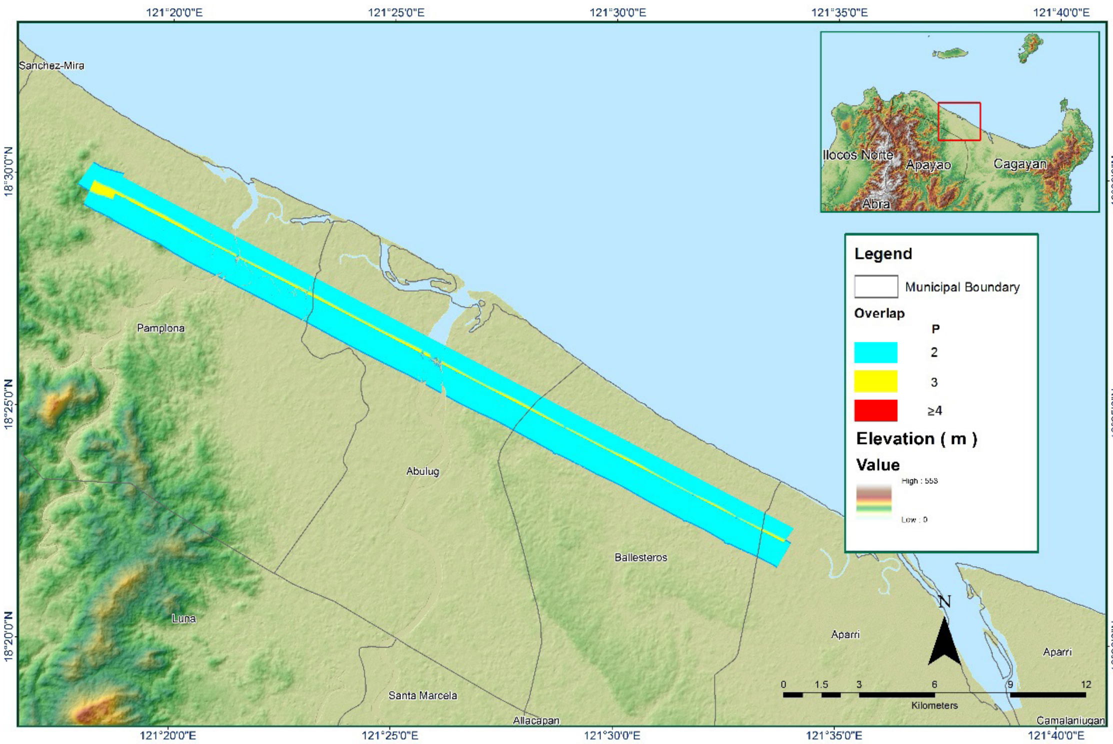


Figure A-8.47. Image of data overlap

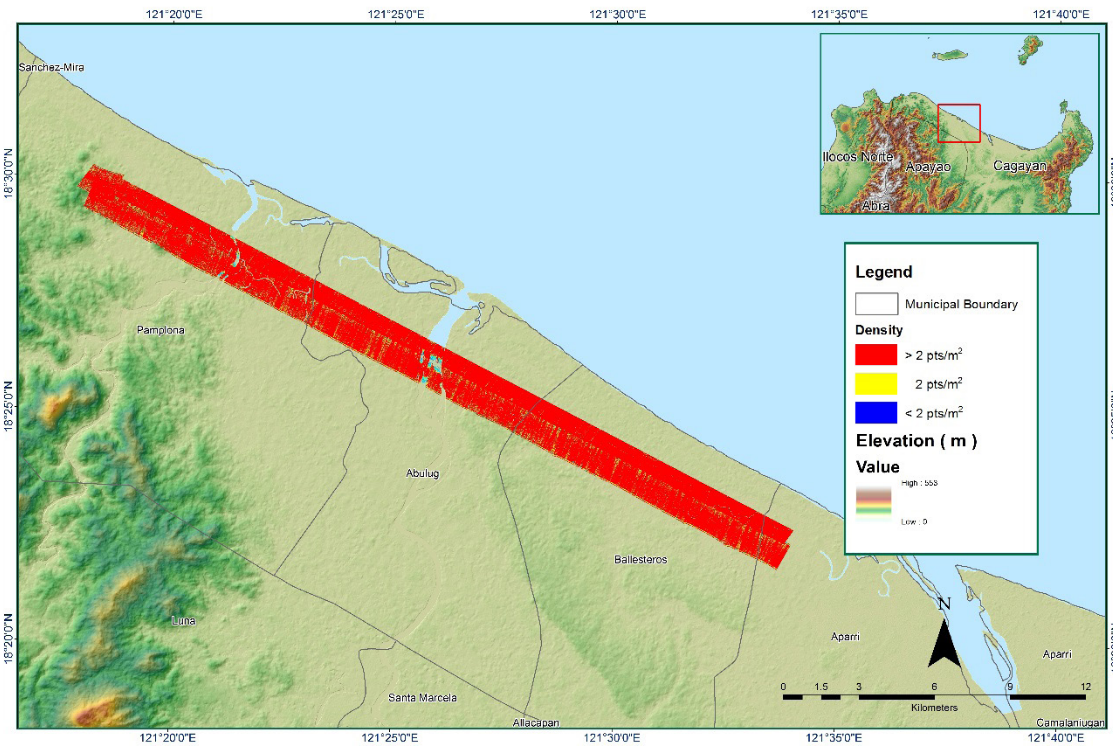


Figure A-8.48. Density map of merged LiDAR data

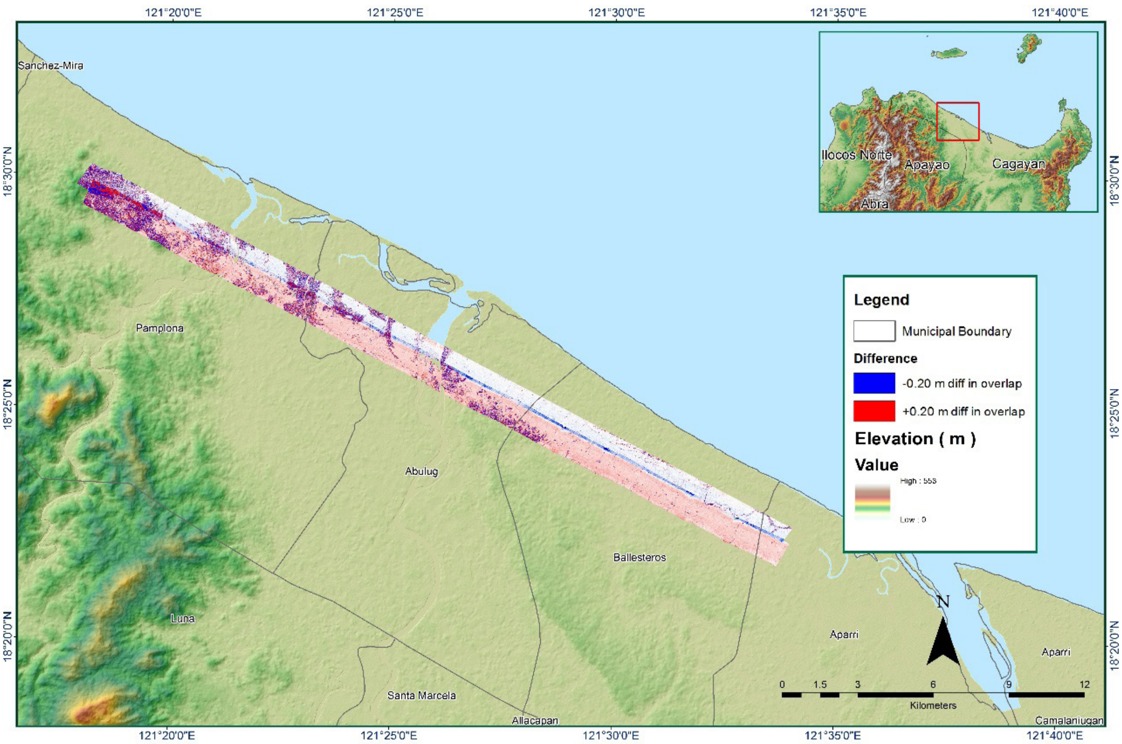


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Blk2B

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	**Blk2B**
Inclusive Flights	2842P
Range data size	14.3GB
POS	185MB
Image	24.1MB
Transfer date	November 24, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.53
RMSE for East Position (<4.0 cm)	1.39
RMSE for Down Position (<8.0 cm)	3.00
Boresight correction stdev (<0.001deg)	0.000693
IMU attitude correction stdev (<0.001deg)	0.001224
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	44.96
Ave point cloud density per sq.m. (>2.0)	3.25
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	182
Maximum Height	583.61 m
Minimum Height	35.45 m
Classification (# of points)	
Ground	141,569,019
Low vegetation	70,602,147
Medium vegetation	96,691,357
High vegetation	456,013,846
Building	4,544,117
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Harmond Santos, Engr. Gladys Mae Apat

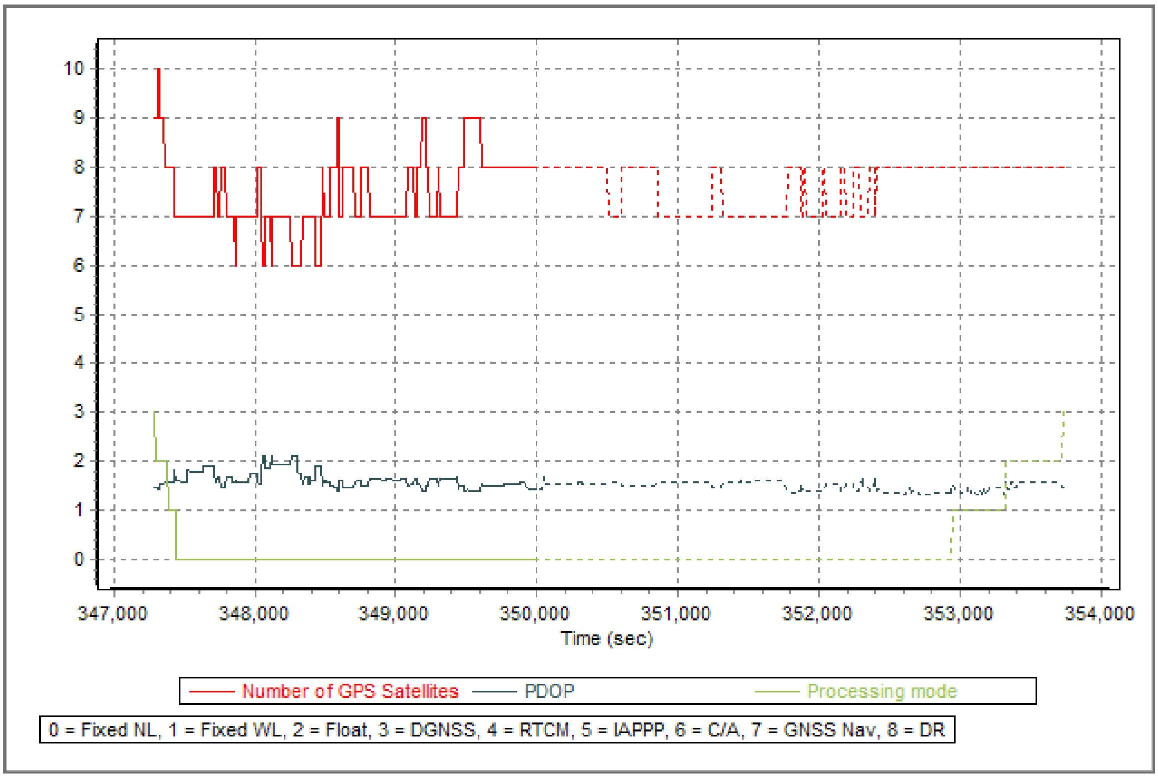


Figure A-8.50. Solution Status

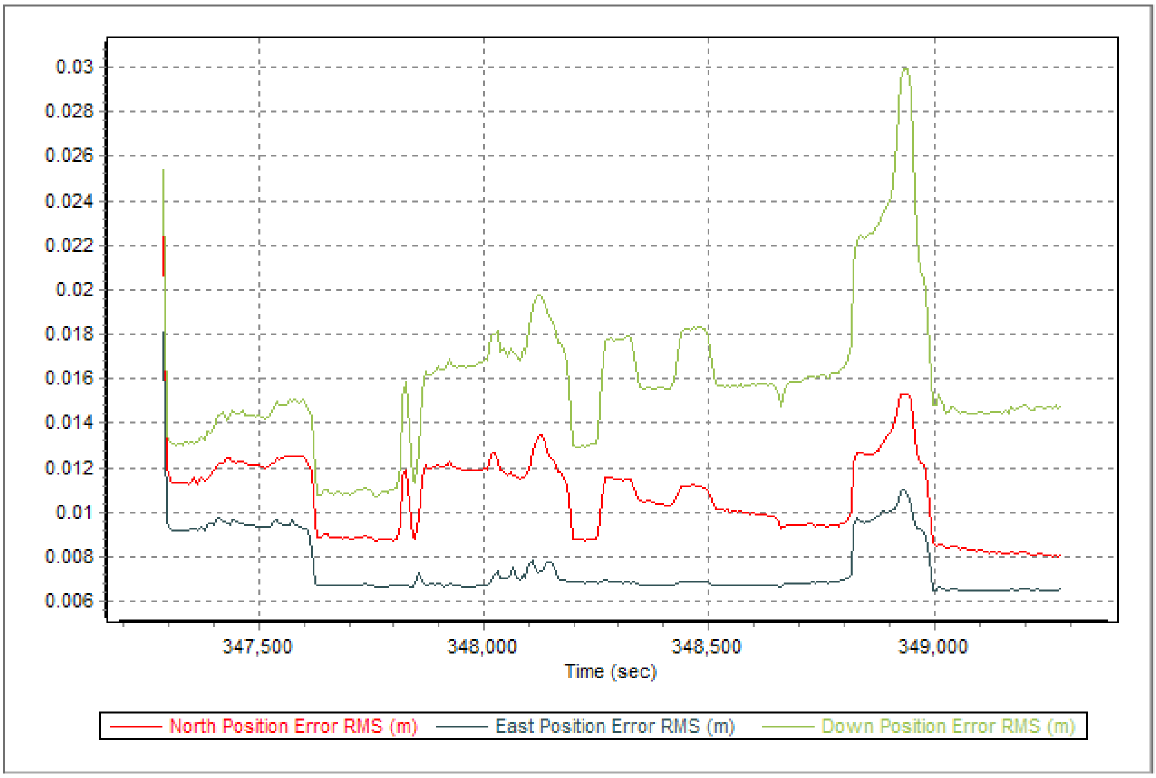


Figure A-8.51. Smoothed Performance Metric Parameters

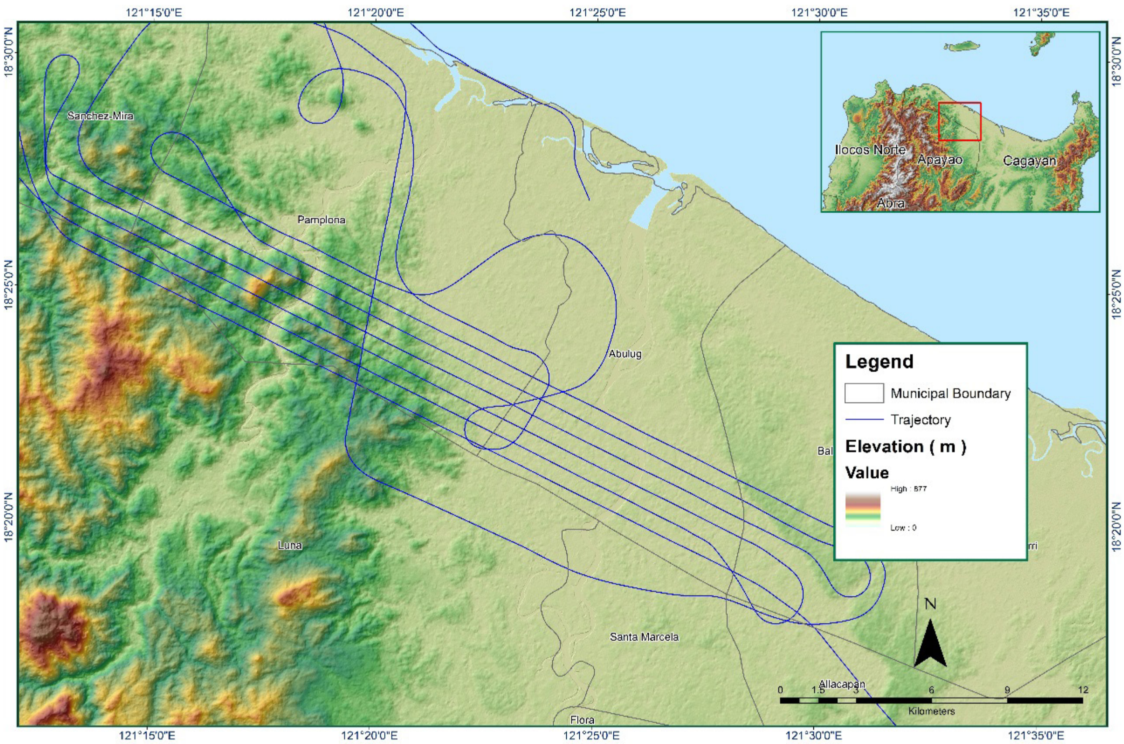


Figure A-8.52. Best Estimated Trajectory

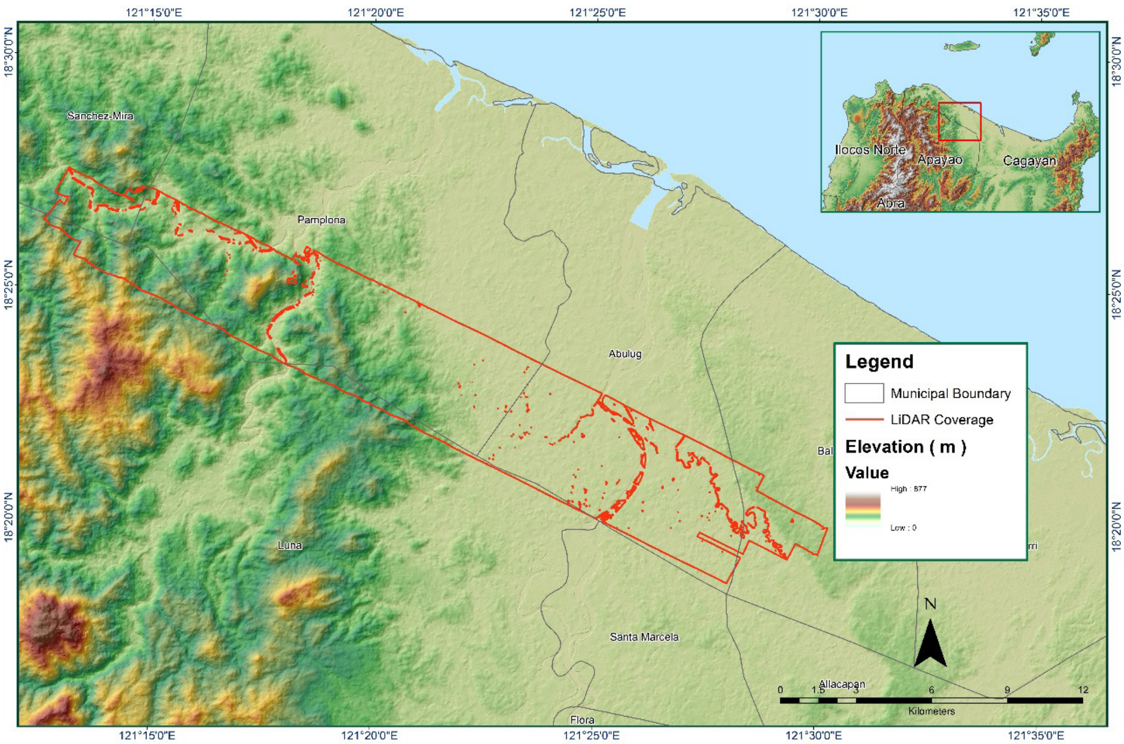


Figure A-8.53. Coverage of LiDAR data

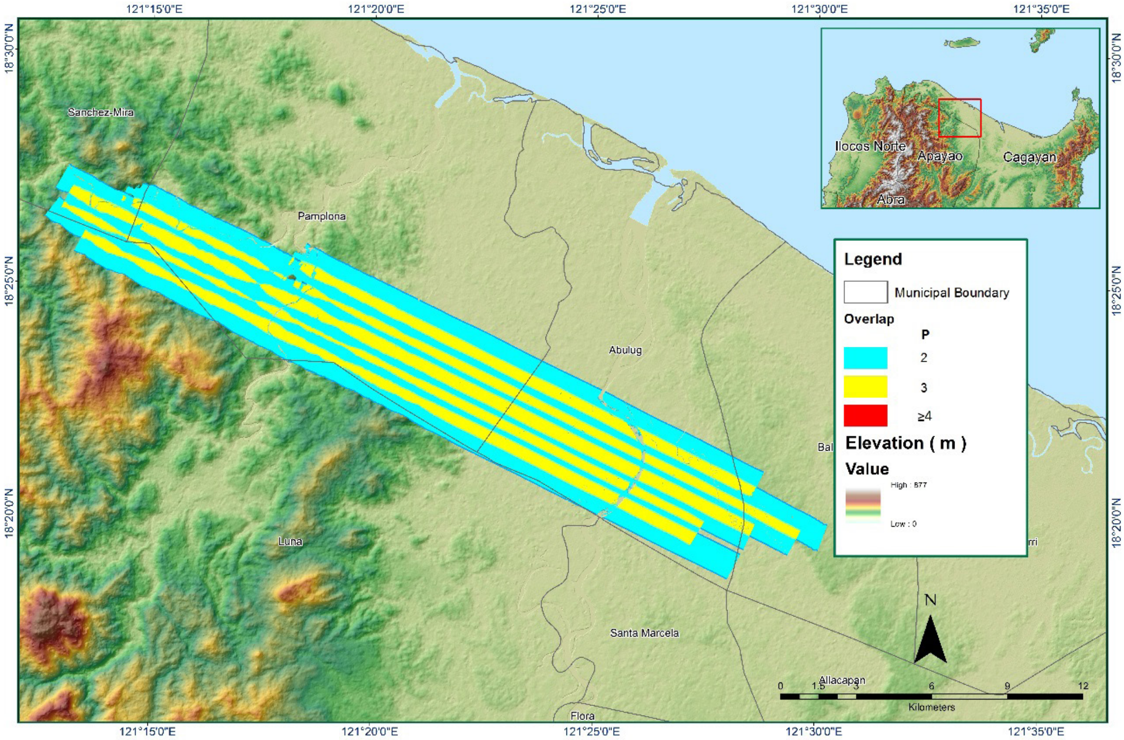


Figure A-8.54. Image of data overlap

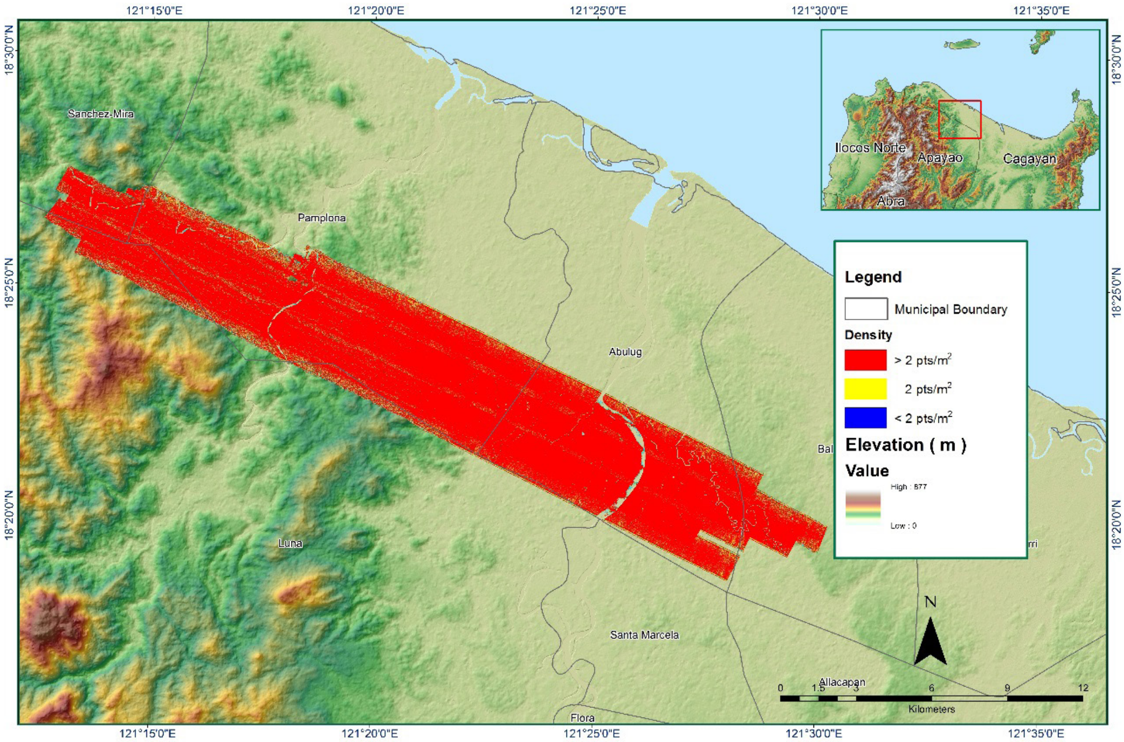


Figure A-8.55 Density map of merged LiDAR data

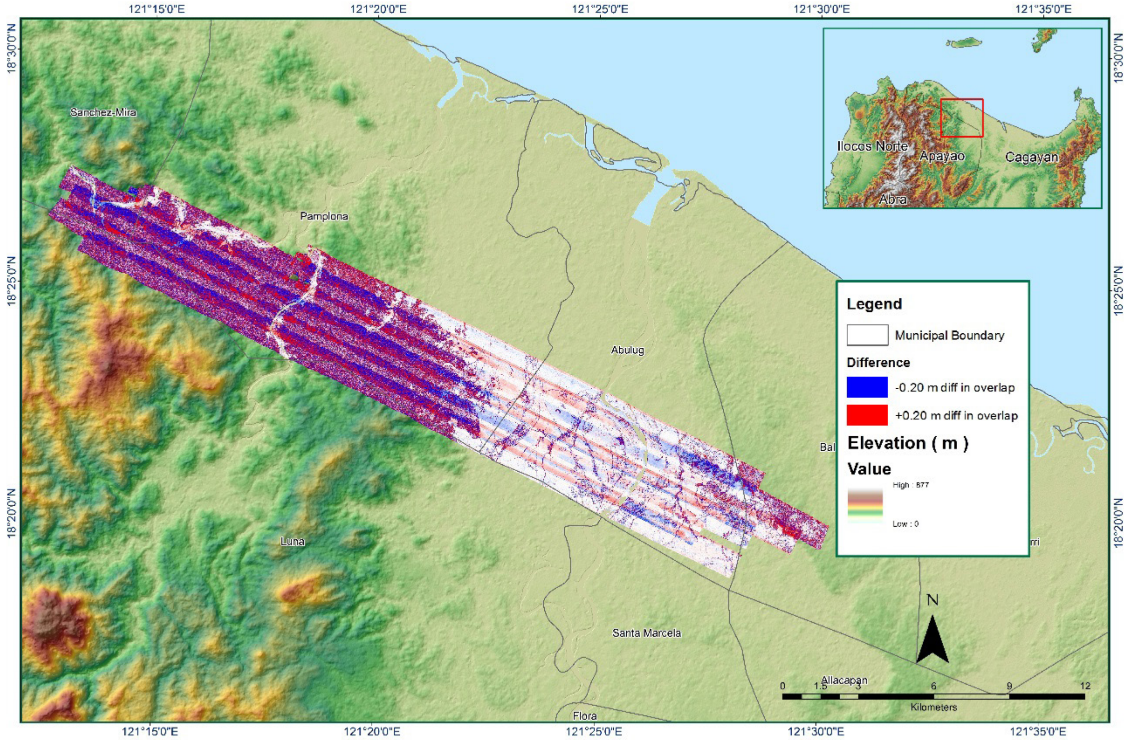


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Cagayan_reflights_Blk11C

Flight Area	Cagayan
Mission Name	**Cagayan_reflights_Blk11C**
Inclusive Flights	3999G
Range data size	11.6 GB
POS data size	137 MB
Base data size	13.9 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.6
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.5
Boresight correction stdev (<0.001deg)	0.000375
IMU attitude correction stdev (<0.001deg)	0.005289
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	26.89%
Ave point cloud density per sq.m. (>2.0)	3.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	160
Maximum Height	178.56 m
Minimum Height	40.49 m
Classification (# of points)	
Ground	71,780,275
Low vegetation	48,353,132
Medium vegetation	97,706,941
High vegetation	69,617,744
Building	387,214
Orthophoto	No
Processed by	Engr. Ben Joseph Harder, Engr. Edgardo Gubatanga Jr., Maria Tamsyn Malabanan

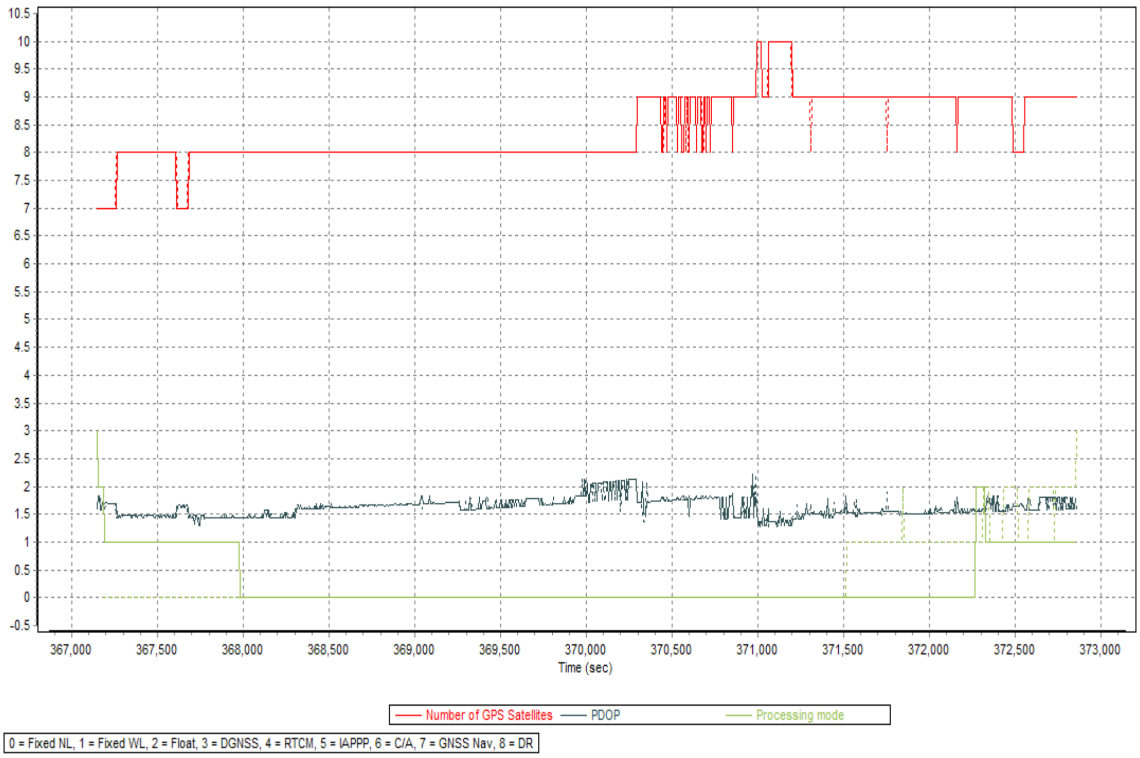


Figure A-8.57. Solution Status

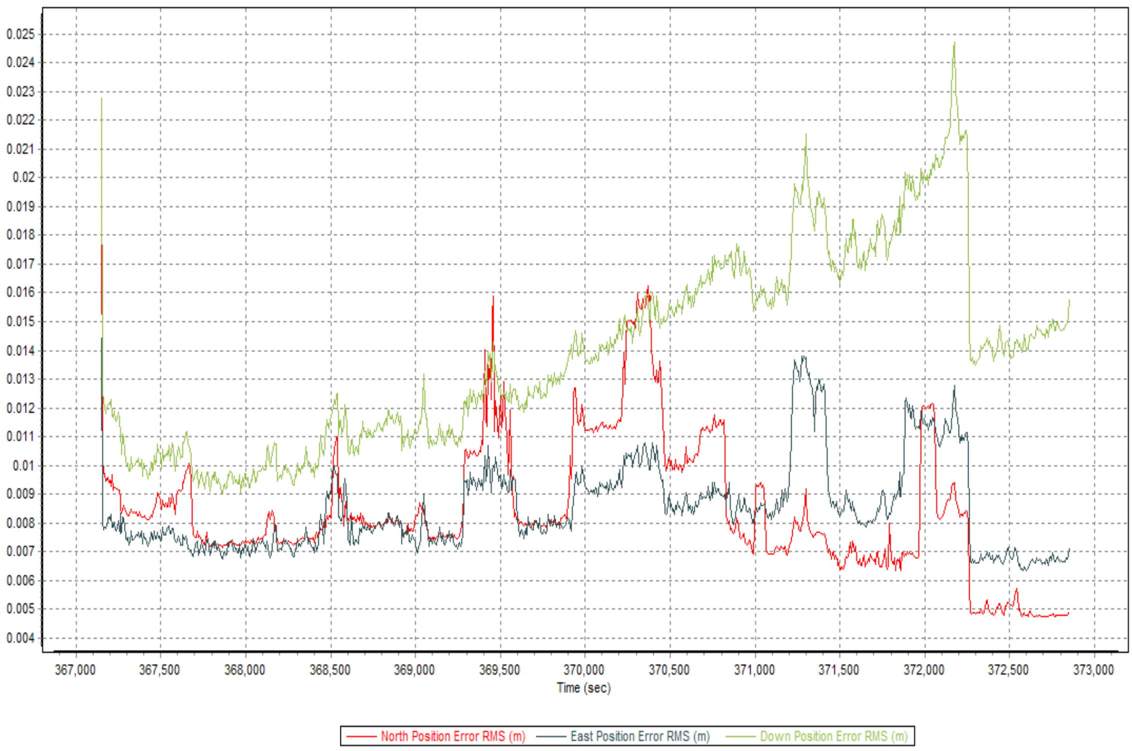


Figure A-8.58. Smoothed Performance Metric Parameters

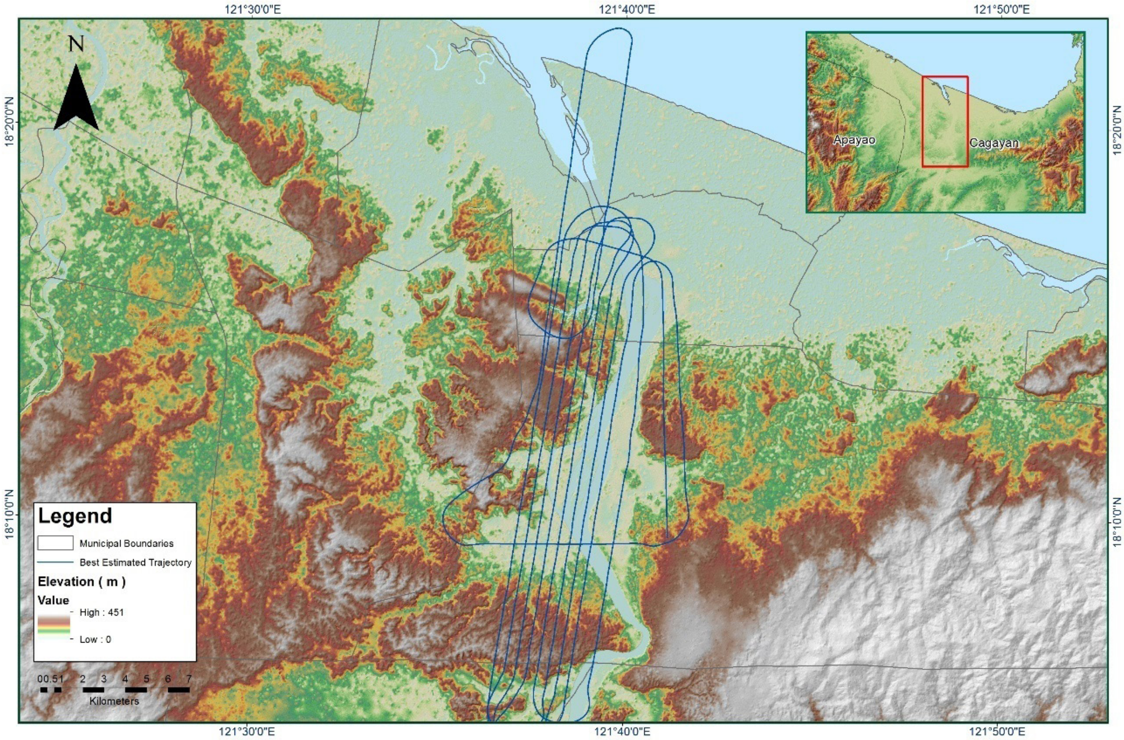


Figure A-8.59. Best Estimated Trajectory

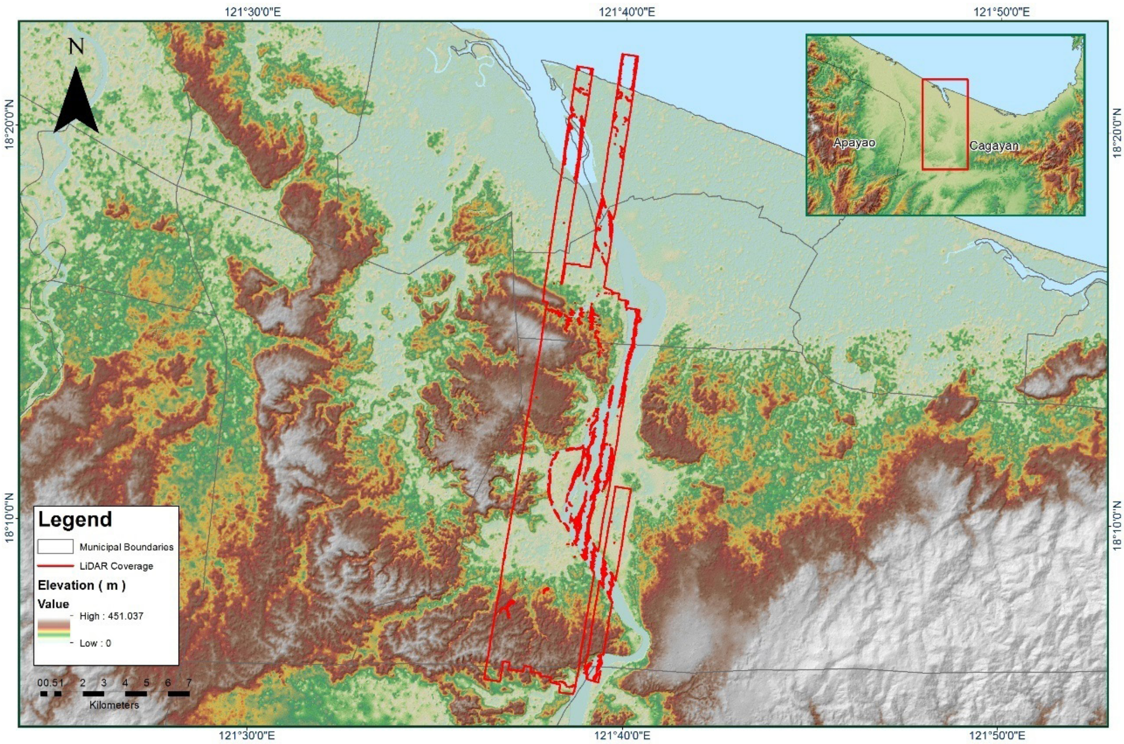


Figure A-8.60. Coverage of LiDAR Data

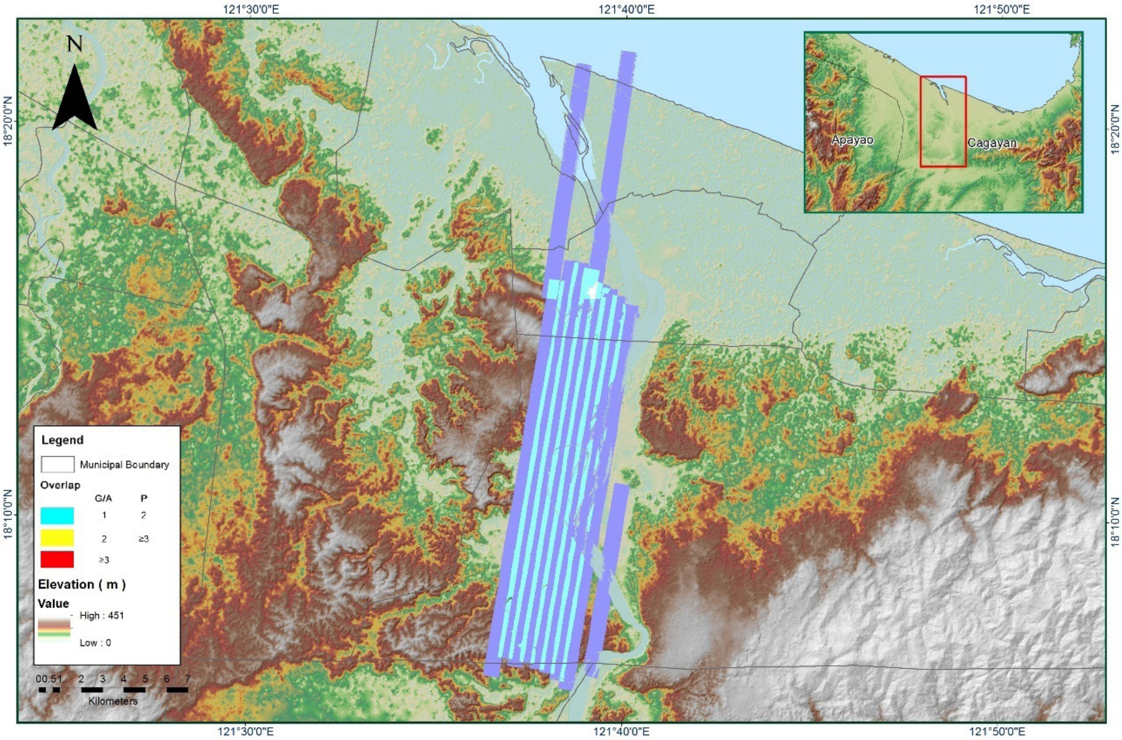


Figure A-8.61. Image of data overlap

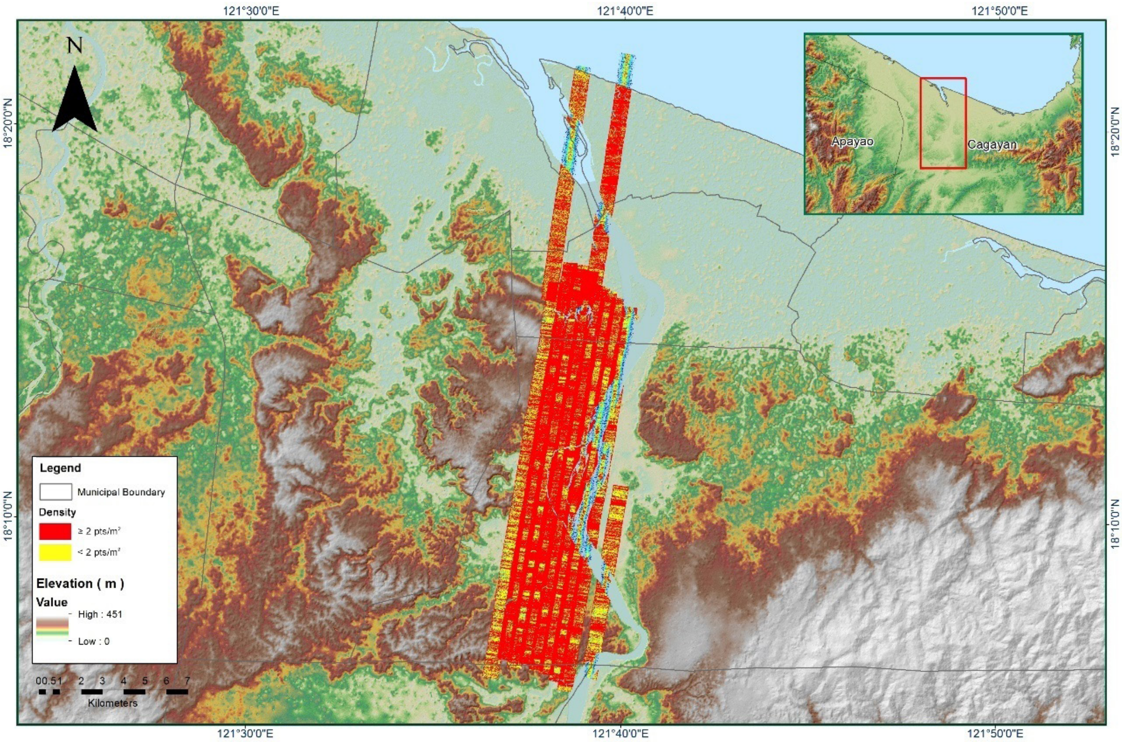


Figure A-8.62. Density map of merged LiDAR data

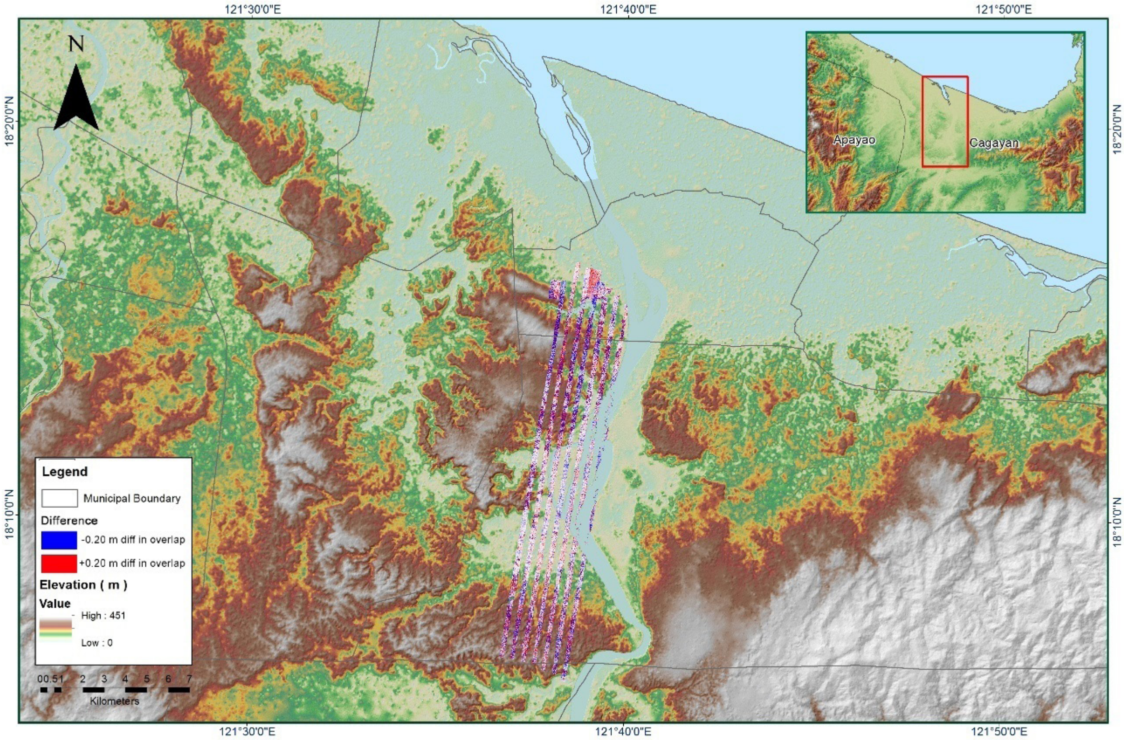


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Blk1D

Flight Area	Cagayan Reflights
Mission Name	**Blk1D**
Inclusive Flights	23696P
Range data size	8.9 GB
Base data size	5.71 MB
POS	192 MB
Image	NA
Transfer date	January 29, 2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.93
RMSE for East Position (<4.0 cm)	1.19
RMSE for Down Position (<8.0 cm)	2.05
Boresight correction stdev (<0.001deg)	0.001676
IMU attitude correction stdev (<0.001deg)	0.001341
GPS position stdev (<0.01m)	0.0188
Minimum % overlap (>25)	10.71
Ave point cloud density per sq.m. (>2.0)	1.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	71
Maximum Height	71.40 m
Minimum Height	39.07 m
Classification (# of points)	
Ground	35,403,186
Low vegetation	13,666,711
Medium vegetation	9,364,090
High vegetation	11,347,783
Building	156,416
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

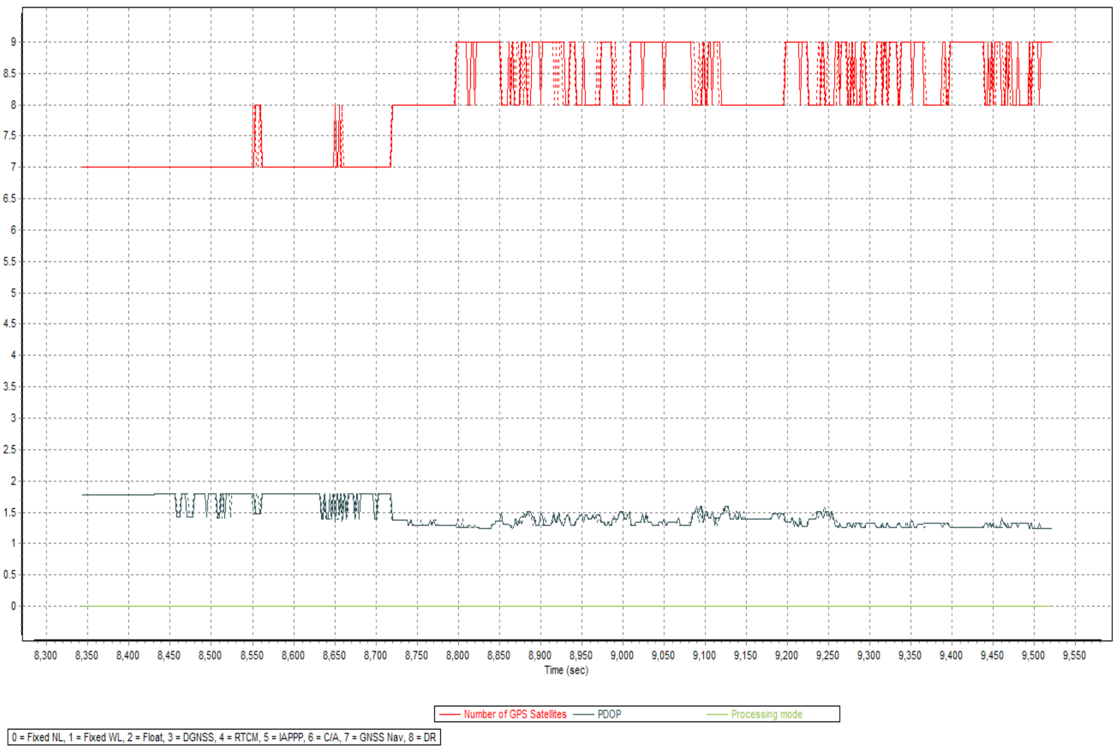


Figure A-8.64. Solution Status

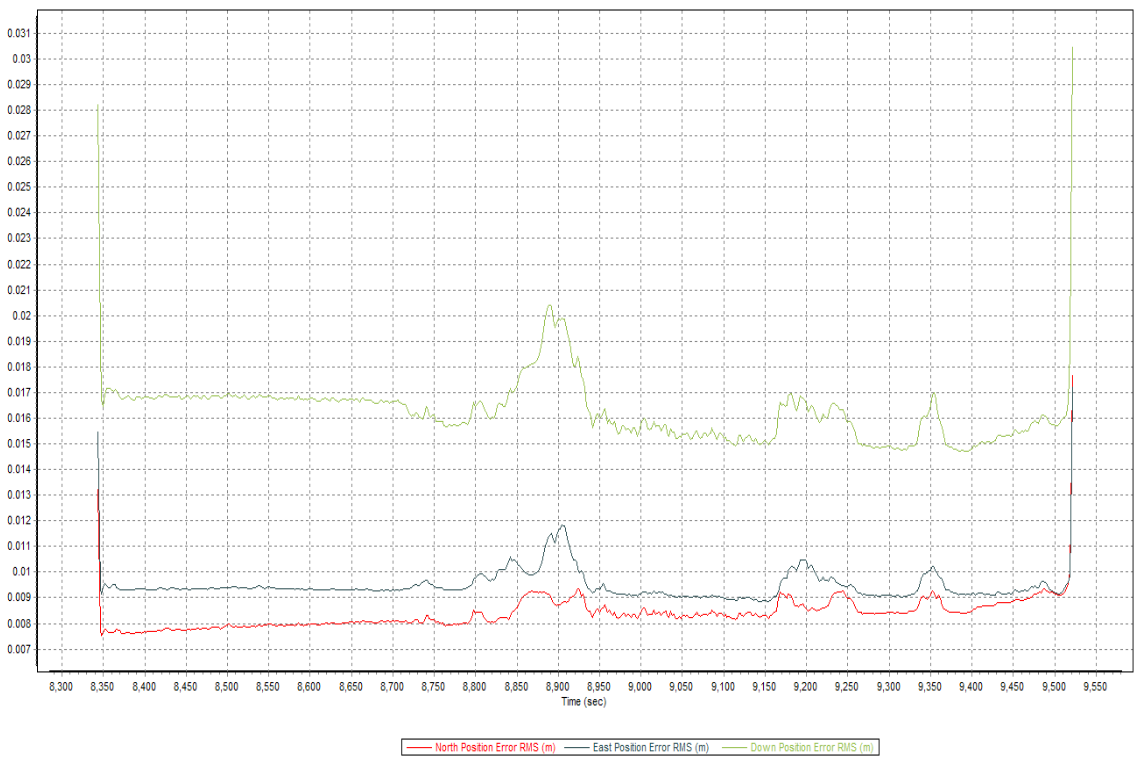


Figure A-8.65. Smoothed Performance Metric Parameters

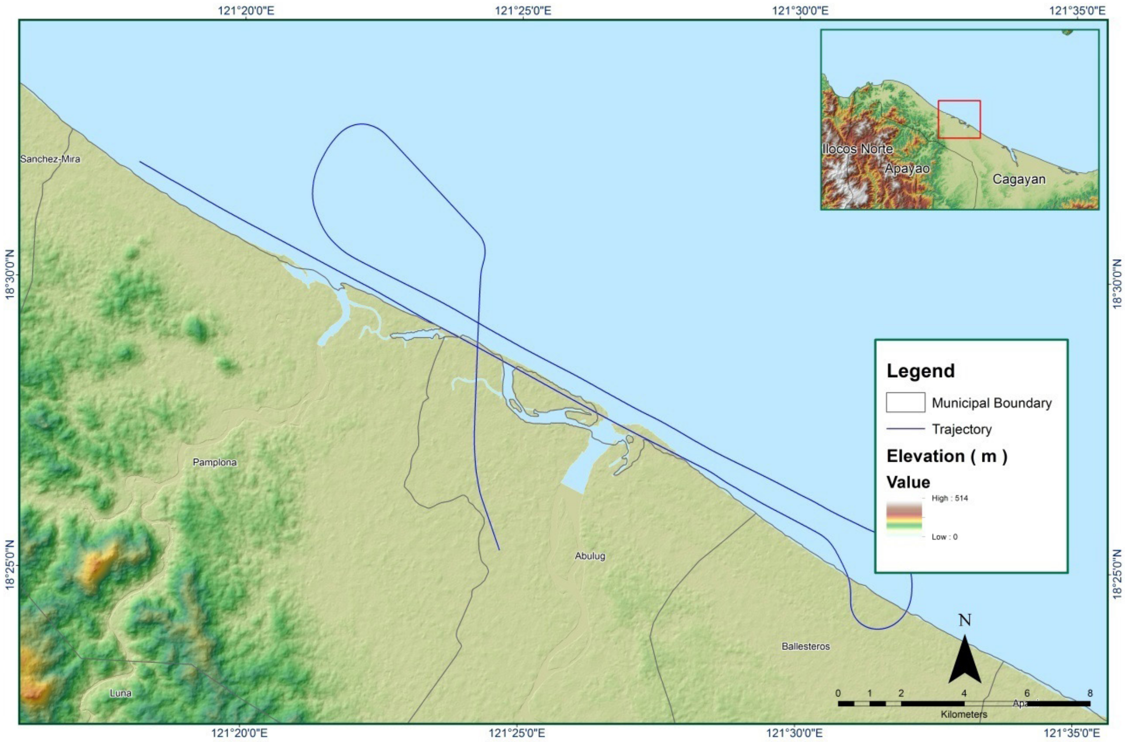


Figure A-8.66. Best Estimated Trajectory

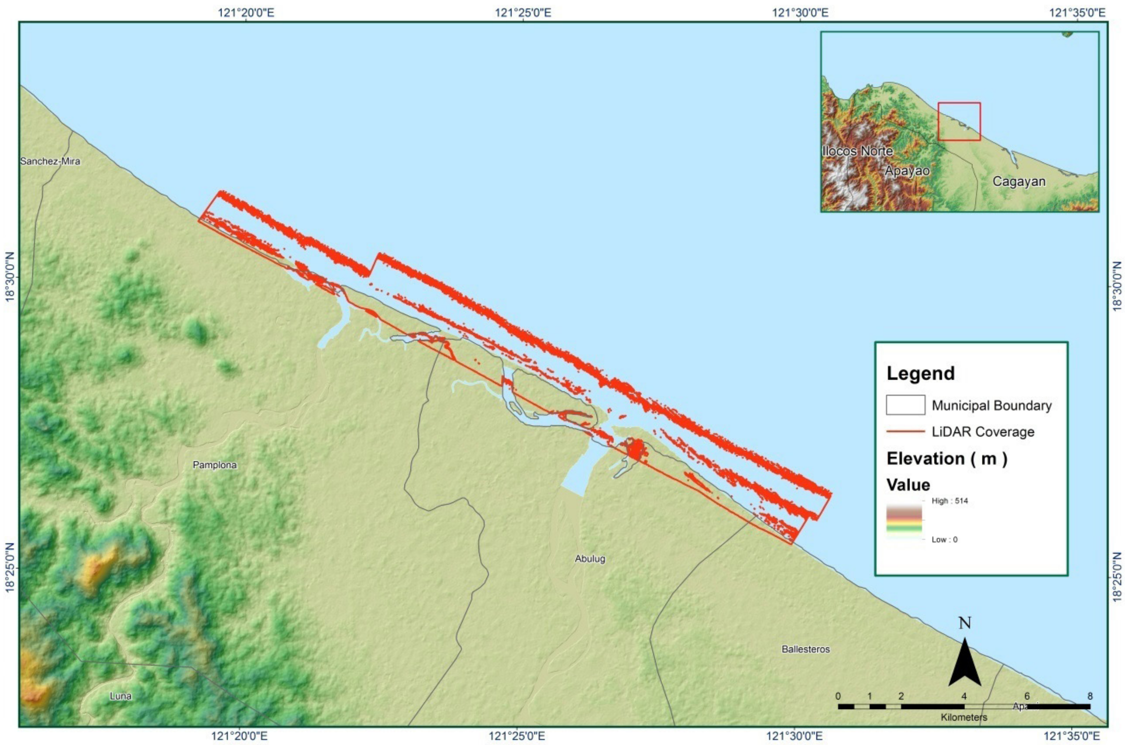


Figure A-8.67.Coverage of LiDAR data

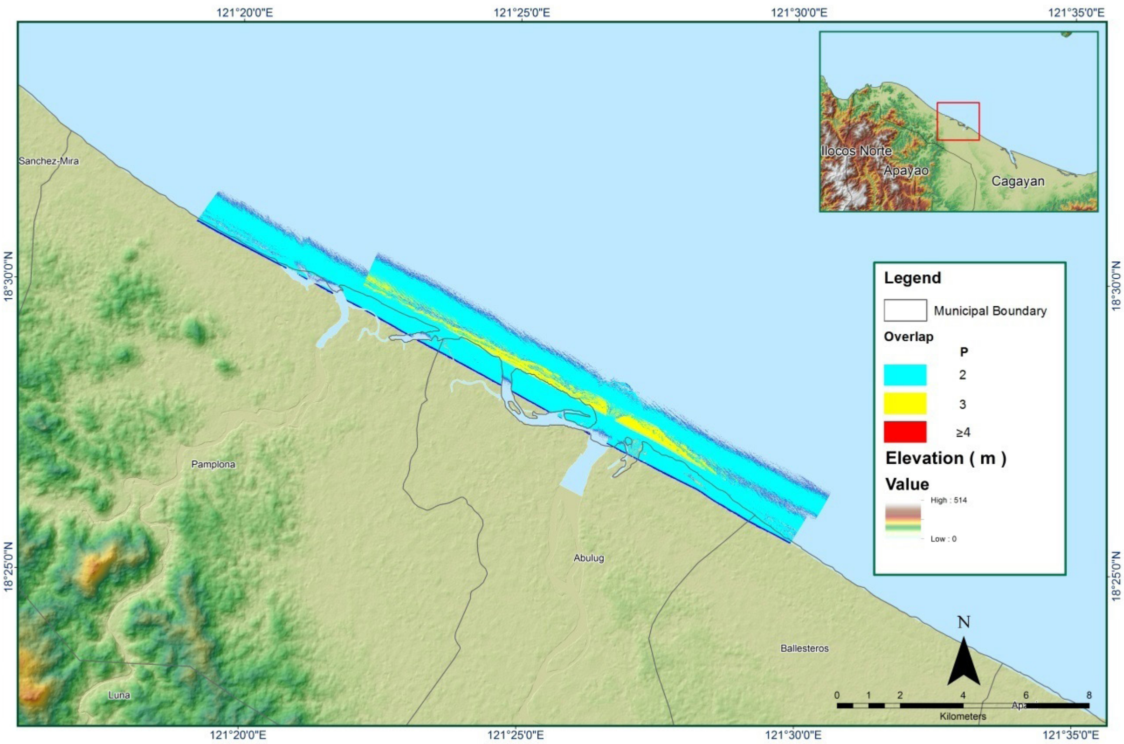


Figure A-8.68.Image of data overlap

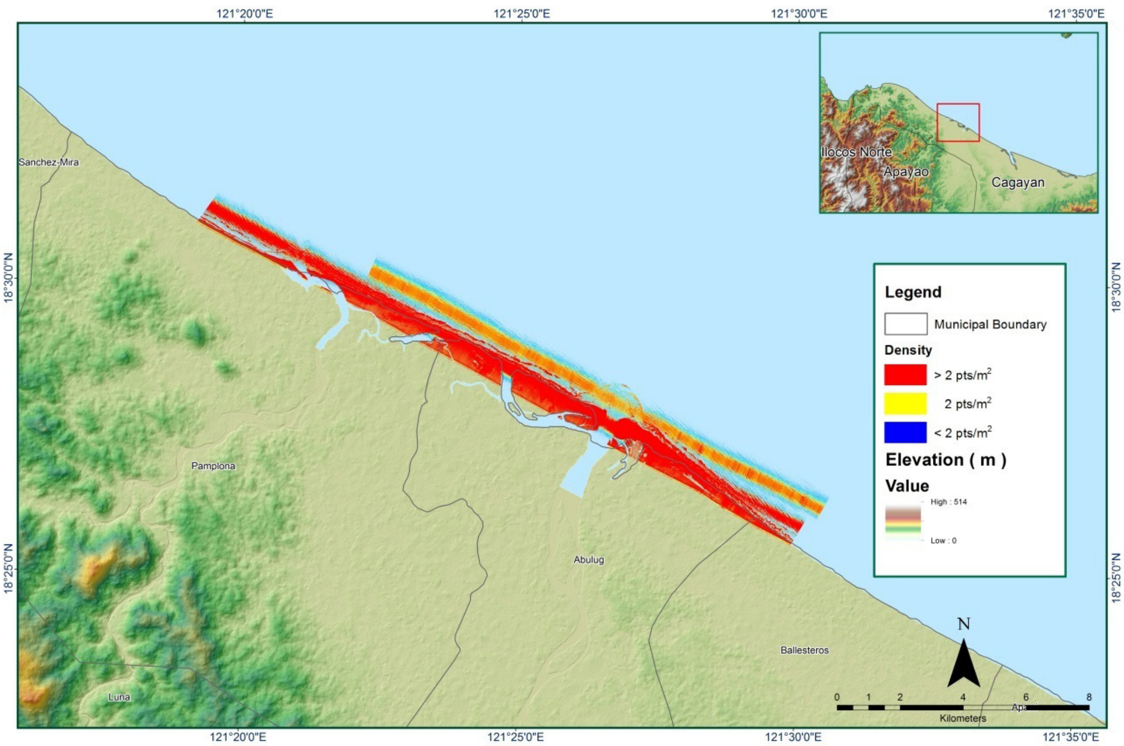


Figure A-8.69. Density map of merged LiDAR data

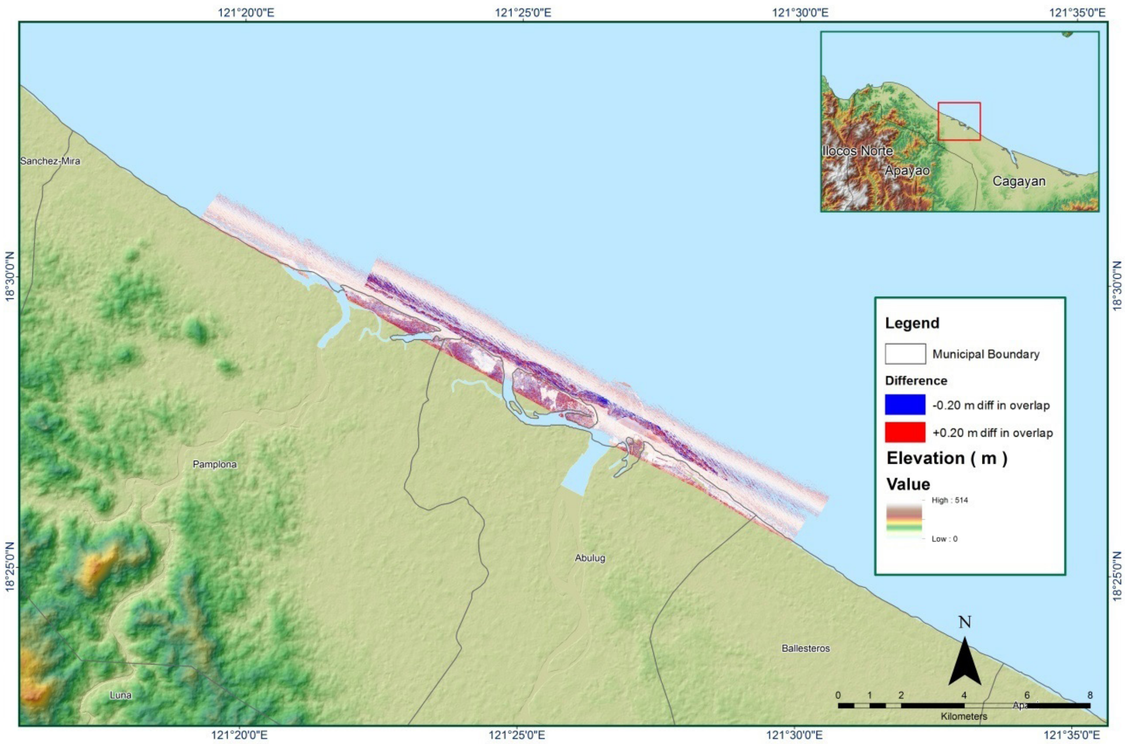


Figure A-8.70. Elevation difference between flight lines

Annex 9.Linao Model Basin Parameters

Table A-9.1. Linao 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
W480	1.9558	99	0	21.668	16.974	Discharge	3.2782	0.3	Ratio to Peak	0.2
W490	2.2687	98.245	0	6.1239	4.7972	Discharge	0.87362	0.3	Ratio to Peak	0.2
W500	2.64299	95.3920789	0	5.0786	3.9784	Discharge	0.66735	0.3	Ratio to Peak	0.2
W510	2.4208975	99	0	18.613	14.581	Discharge	0.53419	0.3	Ratio to Peak	0.2
W520	2.198805	98.797	0	2.8022	2.1952	Discharge	0.12677	0.3	Ratio to Peak	0.2
W530	1.56702	99	0	1.9320	1.5134	Discharge	0.0117927	0.3	Ratio to Peak	0.2
W540	1.395275	99	0	8.9637	7.0218	Discharge	0.56440	0.3	Ratio to Peak	0.2
W550	1.720985	99	0	9.2275	7.2284	Discharge	0.86915	0.3	Ratio to Peak	0.2
W560	1.851465	99	0	8.2012	6.4245	Discharge	1.2035	0.3	Ratio to Peak	0.2
W570	1.217755	99	0	5.5594	4.3550	Discharge	0.0672939	0.3	Ratio to Peak	0.2
W580	1.056265	99	0	12.817	10.041	Discharge	0.53129	0.3	Ratio to Peak	0.2
W590	1.479555	99	0	2.7334	2.1412	Discharge	0.0250938	0.3	Ratio to Peak	0.2
W600	1.76519	99	0	7.8832	6.1753	Discharge	0.79601	0.3	Ratio to Peak	0.2
W610	1.91436	94.5496475	0	5.8556	4.5870	Discharge	0.55433	0.3	Ratio to Peak	0.2
W620	4.7852	92.377	0	8.1842	6.4112	Discharge	0.85617	0.3	Ratio to Peak	0.2
W630	1.110725	99	0	6.1711	4.8342	Discharge	0.72032	0.3	Ratio to Peak	0.2
W640	3.42986	90.915	0	18.760	14.696	Discharge	3.6301	0.3	Ratio to Peak	0.2
W650	1.787205	95.901	0	7.0027	5.4856	Discharge	0.98500	0.3	Ratio to Peak	0.2
W660	1.57143	98.284	0	3.8682	3.0302	Discharge	0.27881	0.3	Ratio to Peak	0.2
W670	2.329005	98.138	0	6.7883	5.3177	Discharge	1.2372	0.3	Ratio to Peak	0.2
W680	1.40413	99	0	4.4729	3.5039	Discharge	0.23724	0.3	Ratio to Peak	0.2

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
W690	1.949605	94.182	0	4.1175	3.2255	Discharge	0.30450	0.3	Ratio to Peak	0.2
W700	1.945825	99	0	3.4627	2.7126	Discharge	0.62692	0.3	Ratio to Peak	0.2
W710	2.53477	97.053	0	8.9220	6.9891	Discharge	0.84054	0.3	Ratio to Peak	0.2
W720	1.10397	99	0	3.0842	2.4160	Discharge	0.15267	0.3	Ratio to Peak	0.2
W730	0.879025	99	0	1.2680818	0.99336	Discharge	0.0027254	0.3	Ratio to Peak	0.2
W740	1.87796	99	0	5.3090	4.1589	Discharge	0.56238	0.3	Ratio to Peak	0.2
W750	1.724205	99	0	4.8552	3.8034	Discharge	0.40063	0.3	Ratio to Peak	0.2
W760	2.69108	95.921	0	8.1449	6.3804	Discharge	1.4788	0.3	Ratio to Peak	0.2
W770	2.541385	97.002	0	8.8956	6.9685	Discharge	2.1757	0.3	Ratio to Peak	0.2
W780	1.746185	96.345	0	2.4134	1.8906	Discharge	0.0661969	0.3	Ratio to Peak	0.2
W790	2.13724	99	0	4.3116	3.3775	Discharge	0.52342	0.3	Ratio to Peak	0.2
W800	2.38945	98.114	0	6.5744	5.1501	Discharge	0.75261	0.3	Ratio to Peak	0.2
W810	2.338805	98.509	0	11.954	9.3639	Discharge	2.1455	0.3	Ratio to Peak	0.2
W820	1.827875	99	0	7.1804	5.6249	Discharge	0.75317	0.3	Ratio to Peak	0.2
W830	2.16608	99	0	3.6666	2.8722	Discharge	0.70928	0.3	Ratio to Peak	0.2
W840	1.45957	99	0	4.6313	3.6280	Discharge	0.15379	0.3	Ratio to Peak	0.2
W850	1.673595	99	0	6.1512	4.8186	Discharge	0.99174	0.3	Ratio to Peak	0.2
W860	2.54723	96.961	0	10.362	8.1175	Discharge	2.2793	0.3	Ratio to Peak	0.2
W870	2.724085	95.6862463	0	8.3677	6.5549	Discharge	1.6634	0.3	Ratio to Peak	0.2
W880	1.81566	99	0	3.9963	3.1305	Discharge	0.10925	0.3	Ratio to Peak	0.2
W890	1.220415	99	0	3.8352	3.0044	Discharge	0.0234654	0.3	Ratio to Peak	0.2
W900	2.060975	99	0	6.4766	5.0735	Discharge	0.83397	0.3	Ratio to Peak	0.2
W910	2.457945	97.604	0	6.0857	4.7673	Discharge	0.84342	0.3	Ratio to Peak	0.2
W920	2.642045	95.792	0	3.4616	2.7117	Discharge	0.51634	0.3	Ratio to Peak	0.2

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
W930	3.91265	96.424	0	9.4801	7.4263	Discharge	1.1545	0.3	Ratio to Peak	0.2
W940	2.627415	95.899	0	4.5732	3.5825	Discharge	0.52814	0.3	Ratio to Peak	0.2

Annex 10. Linao Model Reach Parameters

Table A-10.1. Linao Model Reach Parameters

Reach Number	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	5817.9	0.0019562	0.0549744	Trapezoid	49.583	44.411
R150	Automatic Fixed Interval	4453.3	0.001	0.046589	Trapezoid	49.583	44.411
R160	Automatic Fixed Interval	2693.6	0.001	0.0517656	Trapezoid	49.583	44.411
R180	Automatic Fixed Interval	1368.8	0.001	0.0228505	Trapezoid	49.583	44.411
R200	Automatic Fixed Interval	2283.2	0.001	0.054547	Trapezoid	49.583	44.411
R240	Automatic Fixed Interval	1624.0	0.001	0.0371753	Trapezoid	49.583	44.411
R250	Automatic Fixed Interval	1833.0	0.0039909	0.0829056	Trapezoid	49.583	44.411
R260	Automatic Fixed Interval	28.284	0.0127402	0.0828929	Trapezoid	49.583	44.411
R270	Automatic Fixed Interval	1760.4	0.0024172	0.0546235	Trapezoid	49.583	44.411
R290	Automatic Fixed Interval	1829.5	0.0014379	0.054697	Trapezoid	49.583	44.411
R30	Automatic Fixed Interval	3552.8	0.001	0.0550767	Trapezoid	49.583	44.411
R300	Automatic Fixed Interval	614.56	0.0026839	0.0554564	Trapezoid	49.583	44.411
R340	Automatic Fixed Interval	3909.9	0.0013811	0.0542708	Trapezoid	49.583	44.411
R360	Automatic Fixed Interval	282.84	0.001	0.0546727	Trapezoid	49.583	44.411
R380	Automatic Fixed Interval	1751.8	0.0045146	0.08085	Trapezoid	49.583	44.411
R390	Automatic Fixed Interval	8024.4	0.0023449	0.0345104	Trapezoid	49.583	44.411
R40	Automatic Fixed Interval	279.71	0.001	0.0507302	Trapezoid	49.583	44.411
R400	Automatic Fixed Interval	1552.5	0.001	0.0353859	Trapezoid	49.583	44.411
R410	Automatic Fixed Interval	176.57	0.001	0.0522938	Trapezoid	49.583	44.411
R50	Automatic Fixed Interval	10084	0.001	0.0544443	Trapezoid	49.583	44.411
R70	Automatic Fixed Interval	763.85	0.001	0.0234764	Trapezoid	49.583	44.411
R80	Automatic Fixed Interval	44.142	0.0296361	0.0108642	Trapezoid	49.583	44.411
R90	Automatic Fixed Interval	673.97	0.001	0.0345104	Trapezoid	49.583	44.411

Annex 11. Linao Field Validation Points

Table A-11.1. Linao Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	18.21941	121.5692	0.03	0	-0.03		5 Yr
2	18.22011	121.5718	0.03	0.84	0.81	TS Lawin/ Oct 20, 2016	5 Yr
3	18.22011	121.5718	0.03	0.84	0.81	TS Ondoy/Sept 2009	5 Yr
4	18.22631	121.5552	0.112	0	-0.112	TS Lawin/ Oct 20, 2016	5 Yr
5	18.22658	121.5573	0.569	0.42	-0.149	TS Lawin/ Oct 20, 2016	5 Yr
6	18.22658	121.5573	0.569	0.42	-0.149	TS Ondoy/Sept 2009	5 Yr
7	18.23759	121.5563	0.03	0.7	0.67	TS Lawin/ Oct 20, 2016	5 Yr
8	18.2394	121.5645	0.031	0.42	0.389	TS Lawin/ Oct 20, 2016	5 Yr
9	18.2459	121.5536	0.031	1	0.969	TS Ondoy/Sept 2009	5 Yr
10	18.26064	121.5483	0.03	0.46	0.43	TS Lawin/ Oct 20, 2016	5 Yr
11	18.26064	121.5483	0.03	0.46	0.43	TS Pepeng/October 2009	5 Yr
12	18.26611	121.5479	0.03	0	-0.03		5 Yr
13	18.26905	121.5493	0.03	0.84	0.81	TS Ondoy/Sept 2009	5 Yr
14	18.27214	121.5511	0.031	0.84	0.809	TS Ondoy/Sept 2009	5 Yr
15	18.29648	121.5685	0.415	0.46	0.045		5 Yr
16	18.29701	121.589	0.166	0.42	0.254		5 Yr
17	18.3022	121.5758	0.031	0.84	0.809	TS Ondoy/Sept 2009	5 Yr
18	18.3022	121.5758	0.031	0.84	0.809	TS Igme/ Aug 18, 2012	5 Yr
19	18.30864	121.5863	0.031	0.46	0.429		5 Yr
20	18.32328	121.5941	0.053		-0.053		5 Yr
21	18.32328	121.5941	0.053	0	-0.053		5 Yr
22	18.32524	121.5442	0.03	0.42	0.39	TS Ondoy/Sept 2009	5 Yr
23	18.32524	121.5442	0.03	0.42	0.39		5 Yr
24	18.32699	121.5897	0.03	0.46	0.43	TS Ondoy/Sept 2009	5 Yr
25	18.32699	121.5897	0.03	0.46	0.43	TS Igme/ Aug 18, 2012	5 Yr
26	18.33599	121.5515	0.03	0.42	0.39		5 Yr
27	18.35478	121.5709	0.076	0	-0.076		5 Yr
28	18.35537	121.5705	0.04	0	-0.04		5 Yr
29	18.35548	121.5704	0.072	0	-0.072		5 Yr
30	18.35628	121.5707	0.075	0	-0.075		5 Yr
31	18.35906	121.5732	0.148	0	-0.148		5 Yr
32	18.35937	121.5637	0.097	0	-0.097		5 Yr
33	18.35947	121.5636	0.164	0	-0.164		5 Yr
34	18.35996	121.5824	0.03	0	-0.03		5 Yr
35	18.36426	121.6056	0.031	0	-0.031		5 Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
36	18.36506	121.6056	0.301	0	-0.301		5 Yr
37	18.36717	121.6052	0.03	0	-0.03		5 Yr
38	18.3687	121.6042	0.03	0	-0.03		5 Yr
39	18.36885	121.6036	0.135	0	-0.135		5 Yr
40	18.40977	121.5149	0.03	0	-0.03		5 Yr
41	18.17374	121.5825	0	0	0		5 Yr
42	18.1735	121.5824	0	0	0		5 Yr
43	18.17267	121.5821	0	1	1	TS Lando/Oct 2015	5 Yr
44	18.17267	121.5821	0	1	1	TS Karen/Oct 2016	5 Yr
45	18.17267	121.5821	0	1	1	TS Mina/July 2011	5 Yr
46	18.17195	121.581	0	0.3	0.3	TS Lando/Oct 2015	5 Yr
47	18.17195	121.581	0	0.3	0.3	TS Ondoy/Sept 2009	5 Yr
48	18.17267	121.5839	0	0.3	0.3		5 Yr
49	18.17267	121.5839	0	0.3	0.3	TS Mina/July 2011	5 Yr
50	18.18338	121.5744	0	0.9	0.9	TS Lawin/ Oct 20, 2016	5 Yr
51	18.18198	121.5735	0	0.9	0.9	TS Lawin/ Oct 20, 2016	5 Yr
52	18.17838	121.574	0	0.9	0.9		5 Yr
53	18.17732	121.5747	0	0.9	0.9	TS Lawin/ Oct 20, 2016	5 Yr
54	18.19007	121.5687	0	0	0		5 Yr
55	18.1872	121.5713	0	0.46	0.46	TS Lawin/ Oct 20, 2016	5 Yr
56	18.18525	121.499	0	0.46	0.46	TS Lawin/ Oct 20, 2016	5 Yr
57	18.18431	121.4978	0	0.46	0.46	TS Lawin/ Oct 20, 2016	5 Yr
58	18.18442	121.4927	0	0.38	0.38		5 Yr
59	18.20959	121.4987	0	0.38	0.38		5 Yr
60	18.21433	121.5032	0	0	0		5 Yr
61	18.24188	121.4967	0	0.84	0.84		5 Yr
62	18.31107	121.588	0	0.46	0.46		5 Yr
63	18.32065	121.597	0	0.46	0.46		5 Yr
64	18.35676	121.6369	0	0	0		5 Yr
65	18.31088	121.4892	0	0.61	0.61	Habagat/ Dec 29, 2016	5 Yr
66	18.30676	121.4887	0	0.61	0.61	Habagat/ Dec 29, 2016	5 Yr
67	18.30676	121.4887	0	0.61	0.61	TS Vinta/Oct 2013	5 Yr
68	18.30361	121.4894	0	0	0		5 Yr
69	18.30397	121.4893	0	1	1	Habagat/ Dec 29, 2016	5 Yr
70	18.28954	121.4792	0	0	0		5 Yr
71	18.29296	121.4878	0	0.91	0.91	TS Lawin/ Oct 20, 2016	5 Yr
72	18.29043	121.4893	0	0.61	0.61		5 Yr
73	18.28641	121.4919	0	0.61	0.61	TS Lawin/ Oct 20, 2016	5 Yr
74	18.28651	121.4916	0	1.2	1.2		5 Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
75	18.28262	121.4933	0	0.3	0.3	Habagat/ Dec 29, 2016	5 Yr
76	18.2791	121.493	0	0	0		5 Yr
77	18.27915	121.493	0	0	0		5 Yr
78	18.31514	121.4903	0	0.91	0.91	Habagat/ Dec 29, 2016	5 Yr
79	18.32473	121.4919	0	0.91	0.91	Habagat/ Dec 29, 2016	5 Yr
80	18.29256	121.58409	0.031	0.1	0.069	TS Pepeng/Oct 2009	5 Yr
81	18.29336	121.58135	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
82	18.29347	121.58562	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
83	18.294	121.57979	0.031	0.1	0.069	TS Pepeng/Oct 2009	5 Yr
84	18.2946	121.58758	0.06	0.2	0.14	TS Pepeng/Oct 2009	5 Yr
85	18.2949	121.57774	0.031	0	-0.031		5 Yr
86	18.29547	121.58875	0.162	1.5	1.338	TS Pepeng/Oct 2009	5 Yr
87	18.29596	121.57533	0.032	0	-0.032		5 Yr
88	18.29633	121.56242	0.08	0	-0.08		5 Yr
89	18.29634	121.57047	1.233	0.1	-1.133	TS Pepeng/Oct 2009	5 Yr
90	18.29637	121.56374	0.03	0	-0.03		5 Yr
91	18.29638	121.56591	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
92	18.29641	121.56782	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
93	18.29642	121.56893	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
94	18.29643	121.57111	0.03	0	-0.03		5 Yr
95	18.29644	121.57272	0.03	0	-0.03		5 Yr
96	18.29648	121.56155	0.17	0	-0.17		5 Yr
97	18.29709	121.589	0.668	0.1	-0.568	TS Pepeng/Oct 2009	5 Yr
98	18.29864	121.55896	0.031	0	-0.031		5 Yr
99	18.29922	121.58931	0.031	0.1	0.069	TS Pepeng/Oct 2009	5 Yr
100	18.30067	121.55678	0.341	0	-0.341		5 Yr
101	18.30411	121.5532	0.03	0	-0.03		5 Yr
102	18.30889	121.54894	0.03	0	-0.03		5 Yr
103	18.31175	121.54643	0.286	0	-0.286		5 Yr
104	18.31408	121.54496	0.097	0	-0.097		5 Yr
105	18.3167	121.54424	0.183	0	-0.183		5 Yr
106	18.31801	121.54253	0.031	0	-0.031		5 Yr
107	18.32142	121.54051	0.094	0	-0.094		5 Yr
108	18.32241	121.54125	0.081	0	-0.081		5 Yr
109	18.3236	121.54224	0.031	0.1	0.069	TS Pepeng/Oct 2009	5 Yr
110	18.32465	121.54319	0.032	1	0.968	TS Pepeng/Oct 2009	5 Yr
111	18.32527	121.54434	0.03	0.3	0.27	TS Pepeng/Oct 2009	5 Yr
112	18.32566	121.54485	0.03	0	-0.03		5 Yr
113	18.32648	121.54575	0.318	0	-0.318		5 Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
114	18.32802	121.54739	0.03	0	-0.03		5 Yr
115	18.3301	121.54952	0.382	0.2	-0.182	TS Pepeng/Oct 2009	5 Yr
116	18.33156	121.55096	0.188	0.1	-0.088	TS Pepeng/Oct 2009	5 Yr
117	18.33221	121.5513	0.222	0	-0.222		5 Yr
118	18.33316	121.55127	0.14	0.2	0.06	TS Pepeng/Oct 2009	5 Yr
119	18.3341	121.55125	0.03	0.3	0.27	TS Pepeng/Oct 2009	5 Yr
120	18.33509	121.55126	0.03	0.3	0.27	TS Pepeng/Oct 2009	5 Yr
121	18.33561	121.55132	0.03	2	1.97	TS Pepeng/Oct 2009	5 Yr
122	18.33646	121.55167	0.03	0.5	0.47	TS Pepeng/Oct 2009	5 Yr
123	18.33778	121.55173	0.03	0.3	0.27	TS Pepeng/Oct 2009	5 Yr
124	18.33924	121.55151	0.059	0.3	0.241	TS Pepeng/Oct 2009	5 Yr
125	18.34006	121.55133	0.031	0.3	0.269	TS Pepeng/Oct 2009	5 Yr
126	18.34137	121.55148	0.37	0.4	0.03	TS Pepeng/Oct 2009	5 Yr
127	18.34258	121.55178	0.06	0.4	0.34	TS Pepeng/Oct 2009	5 Yr
128	18.34344	121.55193	0.033	0.5	0.467	TS Pepeng/Oct 2009	5 Yr
129	18.34428	121.55197	0.03	1.5	1.47	TS Pepeng/Oct 2009	5 Yr
130	18.34556	121.5521	0.032	0.5	0.468	TS Pepeng/Oct 2009	5 Yr
131	18.34613	121.55238	0.031	2	1.969	TS Pepeng/Oct 2009	5 Yr
132	18.34664	121.49938	0.096	0	-0.096		5 Yr
133	18.34664	121.49884	0.035	0	-0.035		5 Yr
134	18.34692	121.55244	0.276	0.4	0.124	TS Pepeng/Oct 2009	5 Yr
135	18.34827	121.55254	0.031	0.5	0.469	TS Pepeng/Oct 2009	5 Yr
136	18.34982	121.55288	0.03	0	-0.03		5 Yr
137	18.35052	121.55298	0.28	0	-0.28		5 Yr
138	18.35075	121.50108	0.03	0	-0.03		5 Yr
139	18.35169	121.55311	0.215	0.1	-0.115	TS Pepeng/Oct 2009	5 Yr
140	18.35264	121.55308	0.032	0	-0.032		5 Yr
141	18.35284	121.50191	0.03	0	-0.03		5 Yr
142	18.35305	121.55264	0.032	0	-0.032		5 Yr
143	18.35409	121.55109	0.031	0	-0.031		5 Yr
144	18.35455	121.5026	0.215	0	-0.215		5 Yr
145	18.35473	121.5506	0.144	0	-0.144		5 Yr
146	18.35531	121.54985	0.03	0	-0.03		5 Yr
147	18.35575	121.54898	0.031	0.2	0.169	TS Pepeng/Oct 2009	5 Yr
148	18.35606	121.548	0.031	0	-0.031		5 Yr
149	18.35627	121.50325	0.032	0	-0.032		5 Yr
150	18.35628	121.54713	0.692	0.3	-0.392	TS Pepeng/Oct 2009	5 Yr
151	18.35642	121.54666	0.142	0.3	0.158	TS Pepeng/Oct 2009	5 Yr
152	18.35677	121.54585	0.031	0	-0.031		5 Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
153	18.35747	121.54518	0.031	0	-0.031		5 Yr
154	18.3585	121.54427	0.031	0	-0.031		5 Yr
155	18.35903	121.54355	0.03	0	-0.03		5 Yr
156	18.35954	121.54242	0.433	0.2	-0.233	TS Pepeng/Oct 2009	5 Yr
157	18.36002	121.50444	0.791	0	-0.791		5 Yr
158	18.36018	121.54122	0.031	0	-0.031		5 Yr
159	18.36059	121.54061	0.054	0.2	0.146	TS Pepeng/Oct 2009	5 Yr
160	18.36149	121.5395	0.03	0	-0.03		5 Yr
161	18.36294	121.53777	0.24	0.1	-0.14	TS Pepeng/Oct 2009	5 Yr
162	18.36302	121.50636	0.03	0	-0.03		5 Yr
163	18.36329	121.53728	0.42	0.2	-0.22	TS Pepeng/Oct 2009	5 Yr
164	18.364	121.53624	0.289	0.1	-0.189	TS Pepeng/Oct 2009	5 Yr
165	18.36471	121.50791	0.047	0	-0.047		5 Yr
166	18.36508	121.53482	0.03	0	-0.03		5 Yr
167	18.36583	121.53396	0.031	0.1	0.069	TS Pepeng/Oct 2009	5 Yr
168	18.36626	121.53345	0.03	0	-0.03		5 Yr
169	18.36657	121.53149	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
170	18.36675	121.53028	0.686	0.1	-0.586	TS Pepeng/Oct 2009	5 Yr
171	18.36738	121.53212	0.031	0	-0.031		5 Yr
172	18.36784	121.50938	0.031	0	-0.031		5 Yr
173	18.36806	121.52803	0.03	0	-0.03		5 Yr
174	18.36884	121.52674	0.03	0	-0.03		5 Yr
175	18.36993	121.52491	0.031	0	-0.031		5 Yr
176	18.37066	121.60193	0.046	0.5	0.454	TS Pepeng/Oct 2009	5 Yr
177	18.37077	121.5235	0.642	0.1	-0.542	TS Pepeng/Oct 2009	5 Yr
178	18.37082	121.60126	0.082	0.3	0.218	TS Pepeng/Oct 2009	5 Yr
179	18.37104	121.60211	0.132	0.3	0.168	TS Pepeng/Oct 2009	5 Yr
180	18.37132	121.59985	0.145	0.2	0.055	TS Pepeng/Oct 2009	5 Yr
181	18.37143	121.51056	0.03	0	-0.03		5 Yr
182	18.37147	121.60092	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
183	18.37153	121.52225	0.03	0	-0.03		5 Yr
184	18.37181	121.59999	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
185	18.37191	121.59841	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
186	18.37221	121.52112	0.032	0	-0.032		5 Yr
187	18.37319	121.59579	0.059	0.3	0.241	TS Pepeng/Oct 2009	5 Yr
188	18.37352	121.51887	0.03	0	-0.03		5 Yr
189	18.37356	121.59369	0.068	0.3	0.232	TS Pepeng/Oct 2009	5 Yr
190	18.37457	121.51758	0.03	0	-0.03		5 Yr
191	18.37459	121.58694	0.127	0.4	0.273	TS Pepeng/Oct 2009	5 Yr

Point Num-ber	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
192	18.37496	121.59019	0.186	0.3	0.114	TS Pepeng/Oct 2009	5 Yr
193	18.37535	121.51145	0.03	0	-0.03		5 Yr
194	18.37585	121.51592	0.03	0	-0.03		5 Yr
195	18.37602	121.58308	0.315	0.3	-0.015	TS Pepeng/Oct 2009	5 Yr
196	18.37702	121.58108	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
197	18.37746	121.5127	0.03	0	-0.03		5 Yr
198	18.37782	121.57927	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
199	18.3795	121.51238	0.03	2	1.97	TS Pepeng/Oct 2009	5 Yr
200	18.37978	121.57545	0.262	0.2	-0.062	TS Pepeng/Oct 2009	5 Yr
201	18.3805	121.57365	0.032	0	-0.032		5 Yr
202	18.38307	121.5132	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
203	18.38409	121.56668	0.03	0	-0.03		5 Yr
204	18.38638	121.56088	0.031	0	-0.031		5 Yr
205	18.38826	121.55479	0.086	0	-0.086		5 Yr
206	18.38861	121.51445	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
207	18.391	121.549	0.055	0	-0.055		5 Yr
208	18.39317	121.54414	0.031	0	-0.031		5 Yr
209	18.39346	121.51558	0.03	0.2	0.17	TS Pepeng/Oct 2009	5 Yr
210	18.39558	121.53959	0.03	0	-0.03		5 Yr
211	18.3966	121.53711	0.229	0	-0.229		5 Yr
212	18.39682	121.51634	0.031	1.2	1.169	TS Pepeng/Oct 2009	5 Yr
213	18.39779	121.53467	0.075	0	-0.075		5 Yr
214	18.39984	121.52985	0.03	0	-0.03		5 Yr
215	18.40154	121.51743	0.03	0.1	0.07	TS Pepeng/Oct 2009	5 Yr
216	18.40171	121.52656	0.031	0	-0.031		5 Yr
217	18.40398	121.52266	0.03	0	-0.03		5 Yr
218	18.4053	121.51827	0.03	0	-0.03		5 Yr
219	18.40564	121.52008	0.03	0	-0.03		5 Yr
220	18.40697	121.518	0.031	0	-0.031		5 Yr
221	18.40791	121.51639	0.03	0	-0.03		5 Yr
222	18.40892	121.51466	0.091	0	-0.091		5 Yr
223	18.40991	121.51268	0.031	0	-0.031		5 Yr
224	18.4109	121.51069	0.03	0	-0.03		5 Yr
225	18.41328	121.5064	0.031	0	-0.031		5 Yr
226	18.41492	121.50373	0.03	0	-0.03		5 Yr
227	18.41674	121.50057	0.64	0	-0.64		5 Yr
228	18.4178	121.48849	0.03	0	-0.03		5 Yr

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
229	18.41844	121.48694	0.174	0	-0.174		5 Yr
230	18.41872	121.49692	0.045	0	-0.045		5 Yr
231	18.42052	121.49358	0.031	0	-0.031		5 Yr
232	18.42144	121.49092	0.03	0	-0.03		5 Yr

Annex 12. Educational Institutions Affected by Flooding in Linao Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in Linao Floodplain

Cagayan				
Allacapan				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Matucay Elementary School	Gagaddangan		Low	Low
Tubel Elementary School	San Juan			
San Juan Elementary School	Tamboli			
School	Tamboli			
Aparri				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Backling Elementary School	Backiling			
Zinarag Elementary School	Backiling			
Bangag Elementary School	Bangag			
Binalan Elementary School	Bangag			
Bulala Norte Elementary School	Bulala Sur			
Bulala Sur Elementary School	Bulala Sur			
School	Bulala Sur			
School	Bulala Sur			
School	Caagaman			
Linao Elementary School	Linao	Low	Low	Low
Navagan Elementary School	Navagan			Low
School	Navagan			Low
Zinarag Elementary School	Zinarag			
Ballesteros				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Seventh Day Adventist School	Ammubuan			
Cabaritan East Elementary School	Cabuluan West			
Cabuluan West Elementary School	Cabuluan West	Low	Medium	Medium
Ballesteros Central School	Centro East	Low	Low	Low
Ballesteros National High School	Centro East			
Day Care Center	Centro East	Low	Low	Low
Northern Cagayan Colleges Foundation Inc.	Centro East	Medium	Medium	Medium
Quezon Colleges of the North	Centro East		Low	Low
Ballesteros West Central School	Centro West	Low	Low	Medium

Northern Cagayan Colleges Foundation Inc.	Centro West	Medium	Medium	Medium
School	Centro West	Low	Low	Medium
Binalan Elementary School	Fugu		Low	Low
Fugu Elementary School	Fugu			
Mabuttal Elementary School	Mabuttal East			
Mabuttal Elementary School	Mabuttal West			
Palloc Elementary School	Palloc			
Seventh Day Adventist School	Palloc			
Day Care Center	Payagan West			
Payagan East Elementary School	Payagan West			
Payagan West Elementary school	Payagan West			
Ballesteros National High School	Santa Cruz		Low	Low
Zitanga Elementary School	Zitanga			

Annex 13. Medical Institutions Affected by Flooding in Linao Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in Linao Floodplain

Cagayan				
Aparri				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Aparri Medical Community Hospital	Bangag	Low	Low	Low
Aparri Medical Community Hospital	Bangag	Low	Low	Low
Ballesteros				
Ballesteros District Hospital	Cabuluan West			
Aquilizan Clinic	Centro East	Low	Low	Low
Ballesteros Lying-in Clinic	Centro East			
Dr. Estrella Fernandez Clinic	Centro East	Low	Low	Low
Ramos Clinic	Centro East			
Rural Health Unit	Centro East			
Ramos Clinic	Centro West			
Dental Clinic	Mabuttal West			