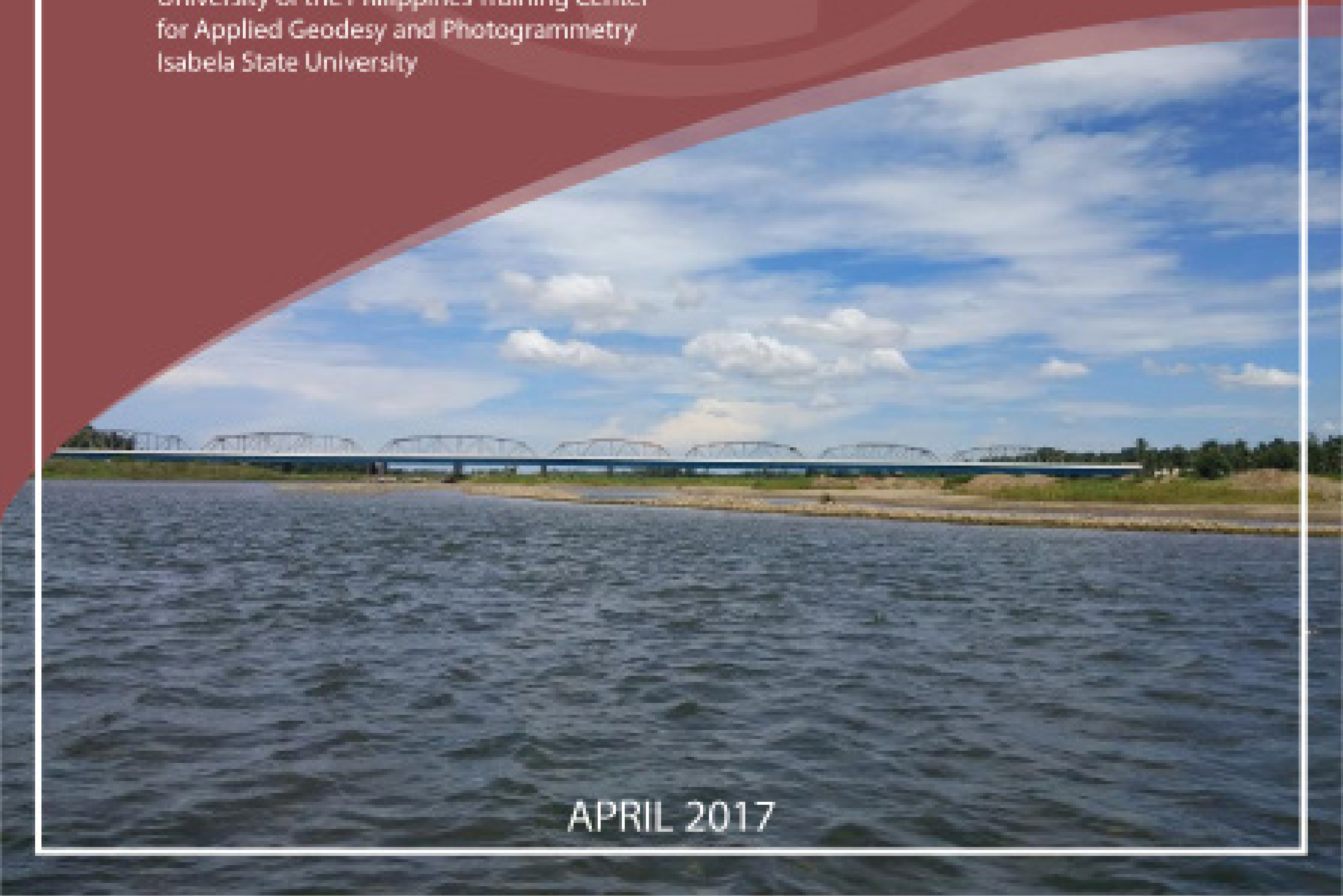
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Pamplona River

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



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

Enrico C. Paringit, Dr. Eng. and Dr. Januel Floresca

1.1 Background of the Phil-LiDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods described 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). ISU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 8 river basins in the Northeastern Luzon Region. The university is located in the Municipality of Echague in the province of Isabela.

1.2 Overview of the Pamplona River Basin

The Pamplona River is a stream that flows from its headwaters in the municipalities of Luna, Calanasan, Kabugao and Pudtol in the Province of Apayao and through the municipalities of Sanchez Mira, Pamplona and Claveria in the Province of Cagayan. It then meets the Babuyan Channel in Brgy. Nagtupacan, coastal barangay of Pamplona, Cagayan. Pamplona River, is part of the ten (10) river systems in Cagayan Region. According to the 2010 national census of NSO, a total of 29,524 people are residing within the immediate vicinity of the river which is distributed among twenty-four (24) barangays in the Municipalities of Flora, Luna, Pudtol, and Santa Marcela in Apayao; and Municipalities of Abulug in Cagayan.

The Pamplona River Basin (Figure 1) covers an area of 649.8813 kilometers and encompasses the municipality of Calanasan, Kabugao, Luna, and Pudtol in Apayao and Claveria, Pamplona, and Sanchez-Mira in Cagayan. The DENR River Basin Control Office identified the basin to have a drainage area of 706 km2 and an estimated 1,495 million cubic meter (MCM) annual run-off (RBCO, 2015). It consists of 73 sub basins, 36 reaches and 36 junctions. The basins were identified base on soil and land cover characteristics of the area.

Seasons in the province are not very pronounced. Relatively dry season occurs during the months of March to June and rainy season from July to October, although it is relatively cold during the months of November to February. Cagayan has three types of climate. Type I climate prevails in Santa Praxedes and in western Claveria, which have two pronounced seasons: wet, May to October and dry, the rest of the year. Type III climate is experienced in the eastern part of the Sierra Madre mountains and in the Babuyan group of islands, where rainfall is evenly distributed throughout the year mainly because of the northeast tradewinds. This further enhances the economic potential of the level land along the pacific coast of the province.

The rest of the province, which consists of the valley floor, has Type II climate, and that means no pronounced season; relatively wet from May to October. Maximum rain periods are not very pronounced and dry seasons last from one to three months.

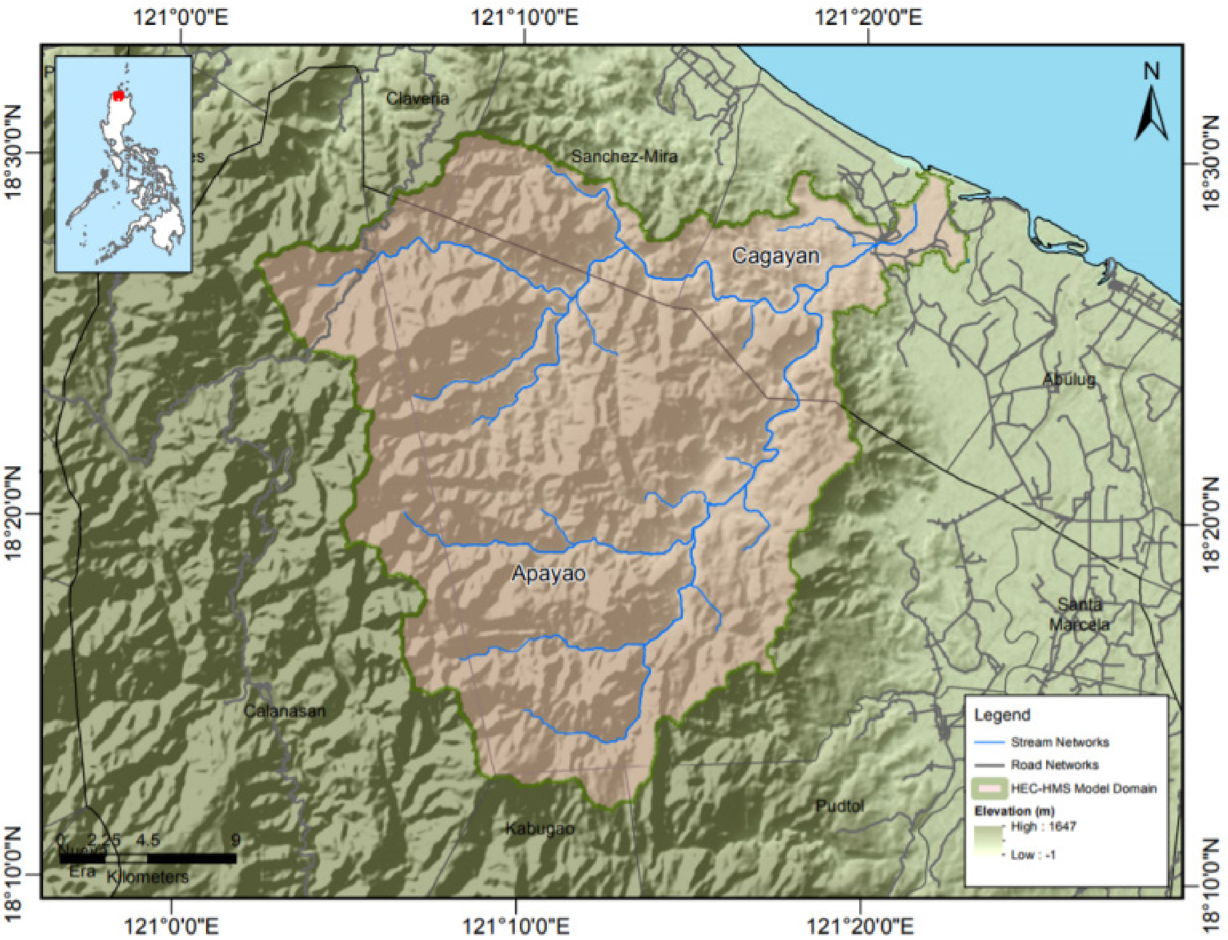

Figure 1. Map of the Pamplona River Basin (in brown)

Pamplona is composed of major and minor water bodies that serve as surface drainage for the municipality. Some of these intermittent or permanent rivers and streams are Pamplona River and its two tributaries, the Ziunan River and Zimigui River and other significant waterways and bodies of water.

The municipality of Pamplona is a fourth class municipality in the province of Cagayan, Philippines. According to the 2015 census, a total of 23, 236 people are currently residing along the river, distributed among eighteen (18) barangays, namely: Abbangkeruan, Allasitan, Bagu, Balingit, Bidduang, Cabaggan, Capalalian, Casitan, Centro, Curva, Gattu, Masi (formerly Zimigui-Ziuanan), Nagattatan, Nagtupacan, San Juan, Santa Cruz (Pimpila), Tabba, Tupanna.

Cited from a study about Socio-Economic condition in the Province of Cagayan, nipa-gathering is one of the main sources of income in the majority of Barangay surveyed including Pamplona, Cagayan. NIPA stands along the Pamplona River have given a community in Pamplona town in Cagayan province a source of clean fuel. Producing as much as 26,000 liters of alcohol in a hectare a year, nipa is four times more productive than sugarcane, which is also a source of alcohol. A hectare of sugarcane generates 6,700 liters of alcohol. With a capacity to produce 850 liters of bioethanol each day, the Pamplona distillery is expected to lead the way as the first local trading center of ethanol supply in the country.

In addition with, according to the PRCA Survey, the current mangrove area of Pamplona covers an approximate aggregate area of 702 hectares composed mostly of inland nipa swamps. The nipa swamps are located in barangay Tupanna, Tabba, Cabaggan, and Nagtupakan and draws inward in strip form up to barangay San Juan following river tributaries. There is also a 10 meter long strip of nipa clamps along Bangan River in barangay Allasitan and Bidduang. The species of mangroves that were observed to be growing dominantly and in good condition by the survey team are bungalon puti, tui, bagu, malabagu, talisai, bitaog, buta-buta, tabigi. There is also a mixture of vines, runo, grasses coconuts and bamboo observed on the area. Being used as raw materials, the nipa swamps are noted to be well-managed and protected by private individuals.

Agriculture is another primary source of livelihood of the populace. Most of them have their own land to till and only a few are non-agricultural workers. The municipality's principal products are rice and corn. (http://www.dilgcar.com/index.php/2015-07-10-07-15-03/municipality-of-luna, 2016) The most recent flood event in the area was on October 17, 2015 brought by Typhoon Lando. Residents near river basins were advised by the LGU to evacuate the area (http://www.abc.net.au/news/2015-10-18/typhoon-koppu-makes-landfall-in-the-philippines/6863662, 2015).

Fishing is considered to be the second major livelihood of the municipality. There are also fish culture activities like fish cages, fish pens, and fishponds in the area. Most of the fish cages are situated in Abbangkeraun and Tabba. Meanwhile, the fish pens are operated in Tupanna and Tabba, and commercial fishponds located in Tupanna and Casitan. There are also fishponds and other fish culturing activities in other barangays which are only considered as "backyard/experimental" fishponds since it is used mainly for family consumption. Municipal Agriculture Office (MAO) adduced samples of fish found in Pamplona River Basin, namely: Bluetail Mullet (Purung), Shrimp (Hipon), Crabs (Talangka), Eel (Igat), Dukyang, Malaga.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PAMPLONA FLOODPLAIN

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

2.1 Flight Plans

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

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK2A	1000	30	50	200	30	130	5
BLK2B	1000	30	50	200	30	130	5
BLK2D	1000	30	50	200	30	130	5
BLK2E	1000	30	50	200	30	130	5
BLK2F	1000	30	50	200	30	130	5
BLK2G	1000	30	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

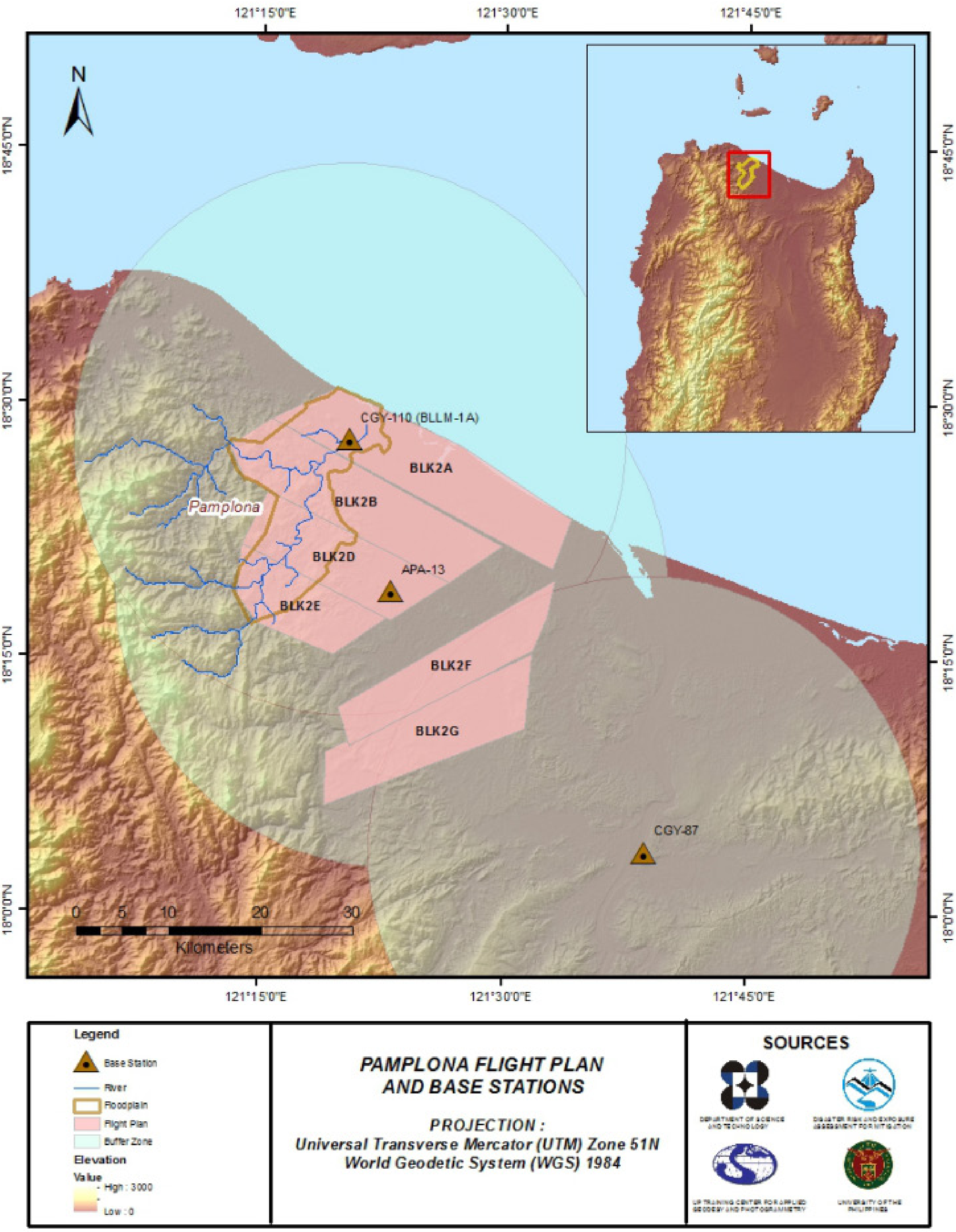

Figure 2. Flight Plan and base stations used for the Pamplona Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA horizontal reference points, APA-13, CGY-110, and CGY-87 which are of second (2nd) order accuracy. The certifications for the NAMRIA reference points are found in Annex A-2. These were used as base stations during flight operations for the entire duration of the survey (November 12-15, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Pamplona floodplain are shown in Figure 1.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 4 show the details about the following NAMRIA control stations, while Table 5 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization. The list of team members are found in Annex 4.

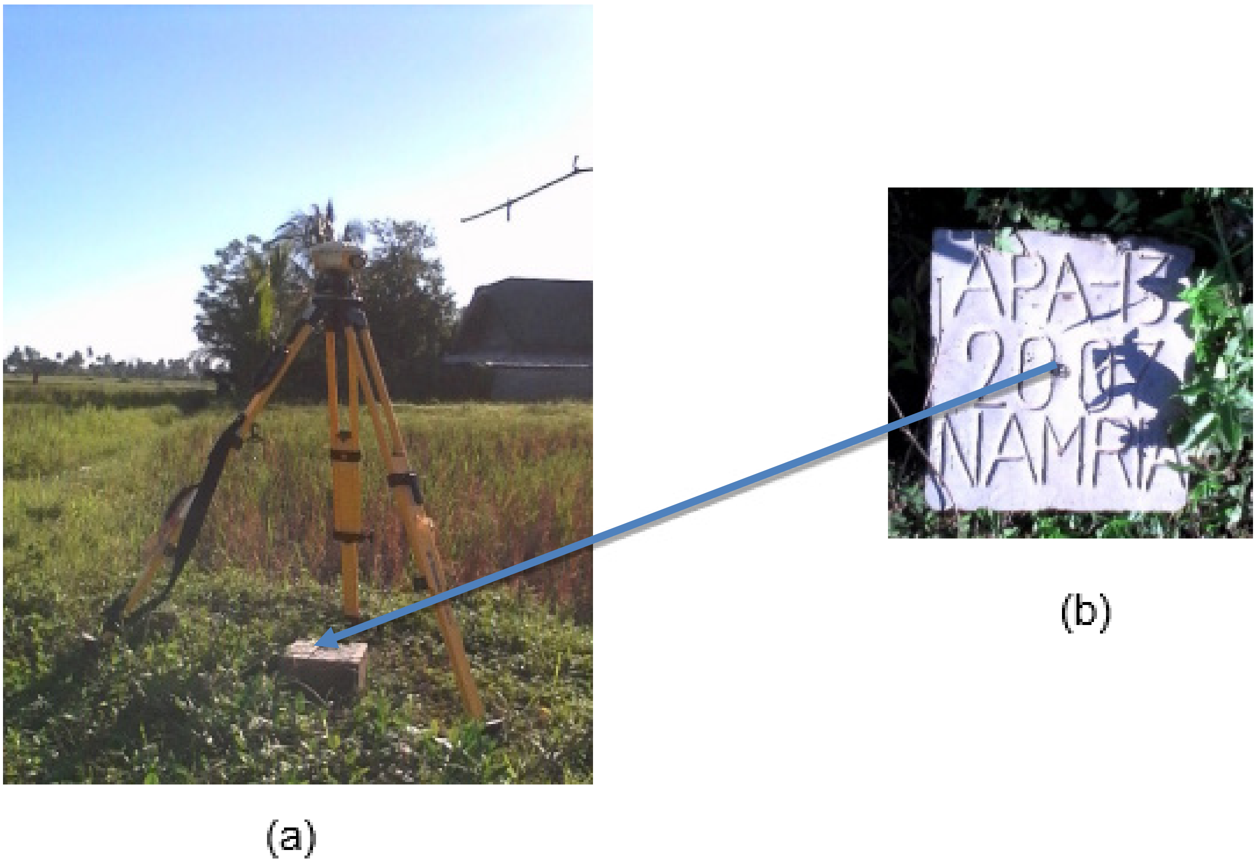

Figure 3. GPS set-up over APA-13 located at the edge of the PCCP, 70m NE of a waiting shed near the barangay hall in Tumog, Municipaity of Luna.

Table 2. Details of the recovered NAMRIA horizontal reference 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 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18°19’2.39264” North 121°22’58.62210” East 17.98200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	540482.023 meters 2025924.156 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18°18’56.17679” North 121°23’3.20117” East 51.00500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	329102.89 meters 2025930.60 meters

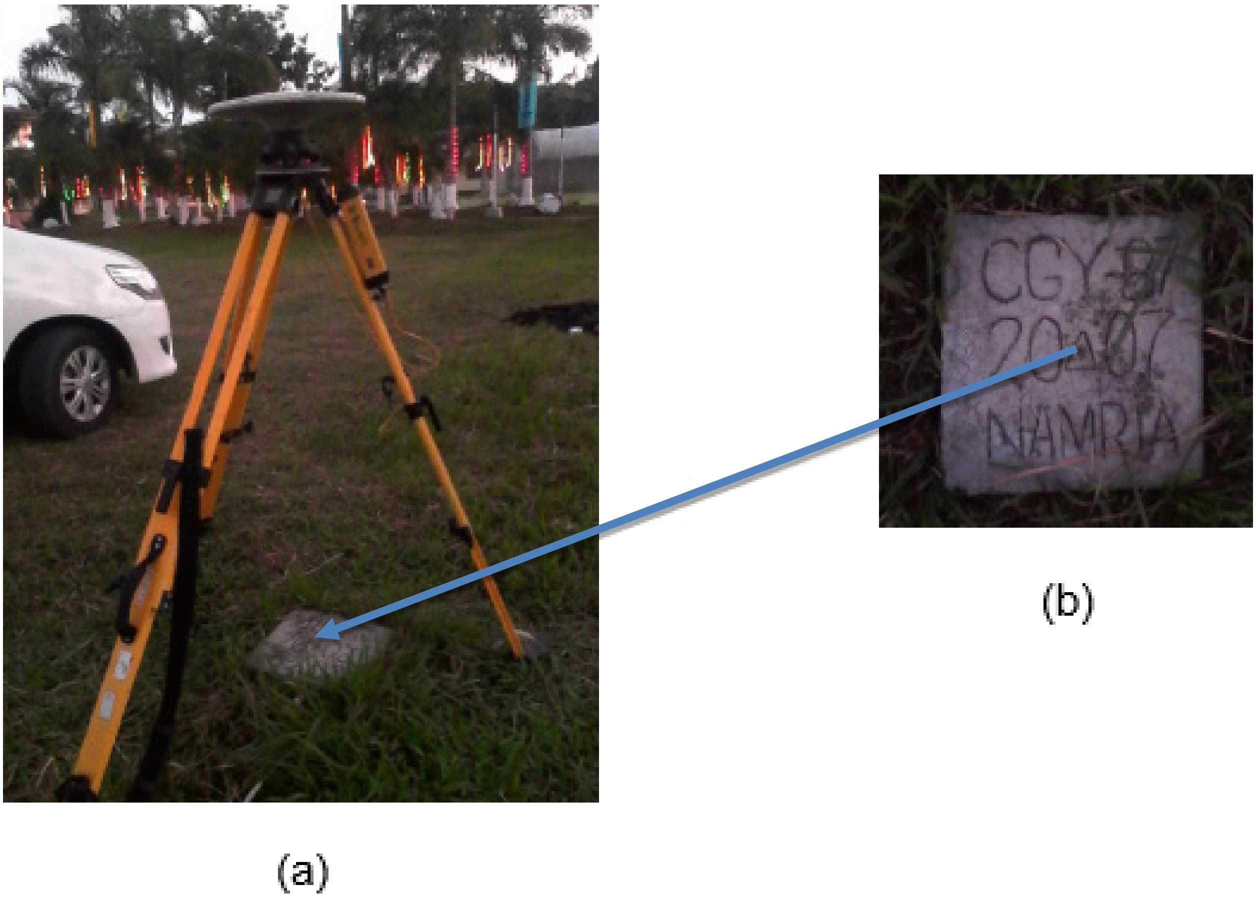

Figure 4. GPS set-up over CGY-87 located on a solar dryer at Brgy. Cabayabasan, fronting the barangay hall, in municipality of Lal-lo.

Table 3. Details of the recovered NAMRIA horizontal reference 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 Longitude Ellipsoidal Height	18° 3’ 46.30032”North 121° 38’ 38.76326”East 37.21200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	568188.029 meters 1997837.978 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 3’ 40.15861” North 121° 38’ 43.36193” East 71.69600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	356498.94meters 1997546.44meters

Figure 5. GPS set-up over CGY-110 located inside the compound of Pamplona Central School, Municipality of Pamplona.

Table 4. Details of the recovered NAMRIA horizontal reference point CGY-110 used as base station for the LiDAR acquisition.

Station Name	CGY-110	
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° 27' 58.94151"North 121° 20' 19.10441"East 16.83900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	535767.119 meters 2042410.05 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 27' 52.69074" North 121° 20' 23.67135" East 49.26200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	324569.86 meters 2042467.48 meters

Table 5. Ground control points that were used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 12, 2015	2842P	1BLK2B316A	CGY-110, APA-13
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	2850P	1BLK2DE318A	CGY-87, APA-13, CGY-110
November 14, 2015	2852P	1BLK2AS318B	CGY-87, APA-13, CGY-110
November 12, 2015	2842P	1BLK2DSG319A	CGY-87, APA-13, CGY-110

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR data acquisition in Pamplona floodplain, for a total of 20 hours and 42 minutes (20+42) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 6 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for the LiDAR data acquisition of the Pamplona Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	Flying Hours	
						Hr	Min
12-Nov-15	2842P	196.66	143.33	52.36	90.97	2	59
13-Nov-15	2846P	320.66	301.79	71.38	230.41	4	23
13-Nov-15	2848P	209.39	63.49	17.31	46.18	2	29
14-Nov-15	2850P	224	195.2	66.87	128.33	3	35
14-Nov-15	2852P	209.39	74.03	16.48	57.55	3	23
15-Nov-15	2854P	281.73	201.45	29.42	172.03	3	53
TOTAL		**906.39**	**867.43**	**216.18**	**651.25**	**20**	**42**

Table 7. Actual parameters used during the LiDAR data acquisition of the Pamplona Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2842P	850	30	50	200	30	130	5
2846P	1100	30	50	200	30	130	5
2848P	900	30	50	200	30	130	5
2850P	1100	30	50	200	30	130	5
2852P	900	30	50	200	30	130	5
2854P	1100/900	30	50	200	30	130	5

2.4 Survey Coverage

Pamplona floodplain is located in the provinces of Cagayan and Apayao with majority of the floodplain situated within the municipalities of Pamplona and Sanchez Mira. Municipalities of Abulug and Pamplonaa in Cagayan Province are mostly covered by the survey. The list of municipalities surveyed, with at least one (1) square kilometer coverage, is shown in Table 8. The actual coverage of the LiDAR acquisition for Pamplona floodplain is presented in Figure 6.

Table 8. List of municipalities and cities surveyed of the Pamplona Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Cagayan	Abulug	123.19	119.81	97.25
	Pamplona	206.54	184.85	89.46
	Ballesteros	117.92	80.42	68.20
	Allacapan	252.24	54.90	21.76
	Sanchez Mira	205.31	15.79	7.69
	Aparri	254.03	16.15	6.36
Apayao	Luna	603.01	39.24	39.24
	Santa Marcela	47.22	18.51	39.18
	Flora	321.67	106.35	33.06
	Pudtol	283.66	24.84	8.75
Total		**2,414.79**	**660.86**	**27%**

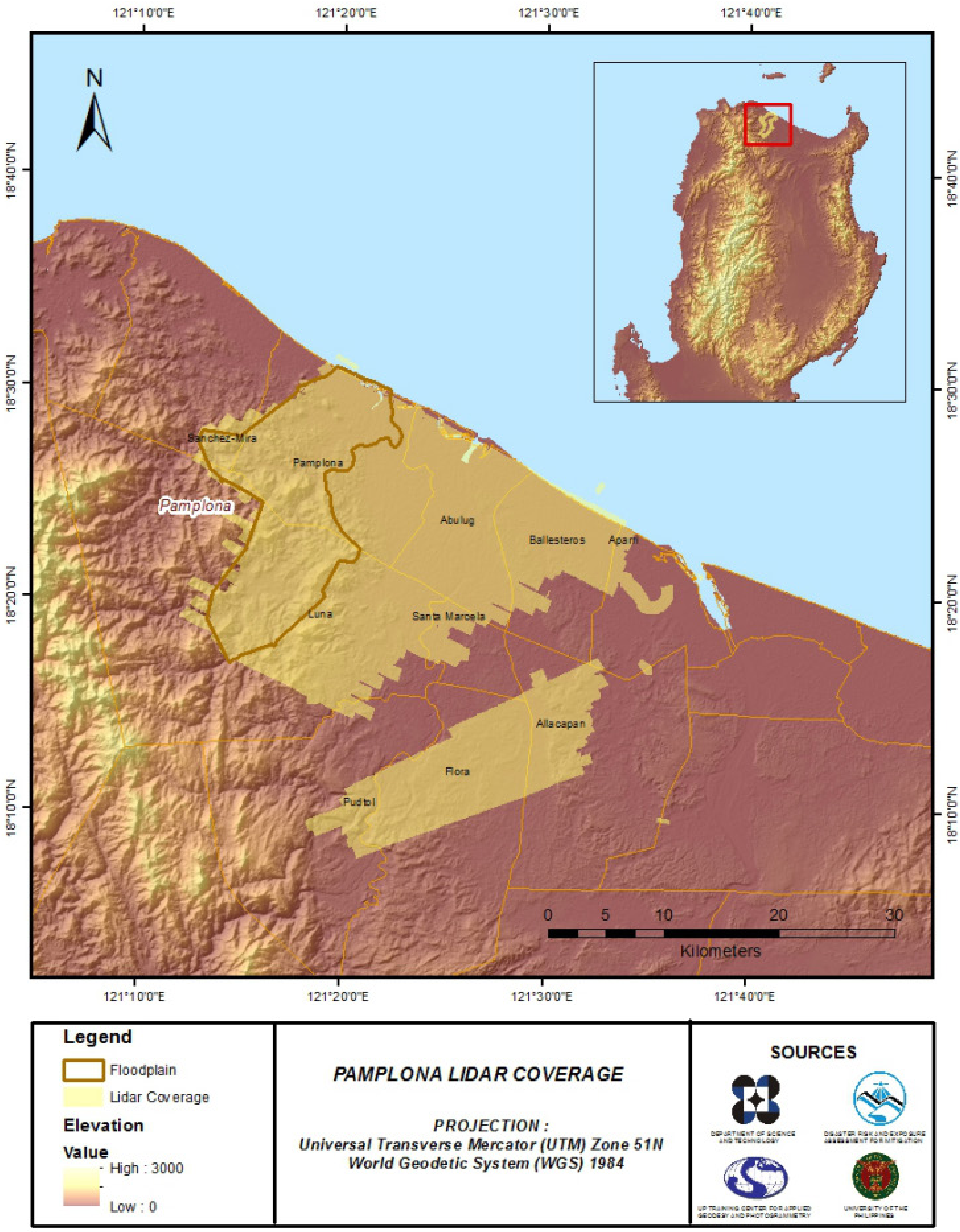

Figure 6. Actual LiDAR survey coverage of the Pamplona Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE PAMPLONA FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 7.

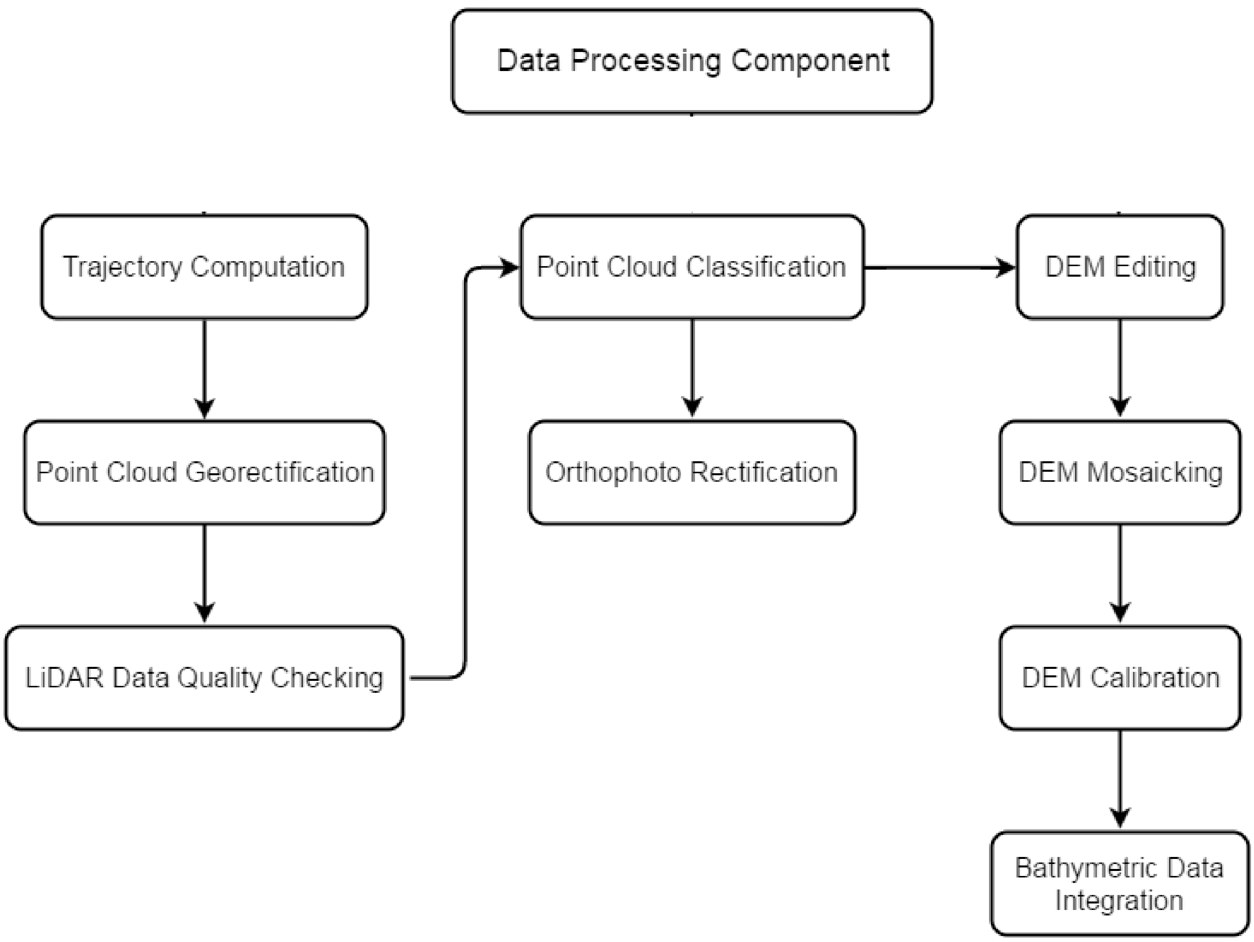

Figure 7. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pamplona floodplain can be found in Annex 5. Missions flown for all the surveys conducted on November 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Cagayan.

The Data Acquisition Component (DAC) transferred a total of 112.63 Gigabytes of Range data, 1.26 Gigabytes of POS data, 126.30 Megabytes of GPS base station data, and 179.47 Gigabytes of raw image data to the data server on November 12, 2015 for the first survey and November 15, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pamplona was fully transferred on November 24, 2015, as indicated on the Data Transfer Sheets for Pamplona floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2842P, one of the Pamplona flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on November 12, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

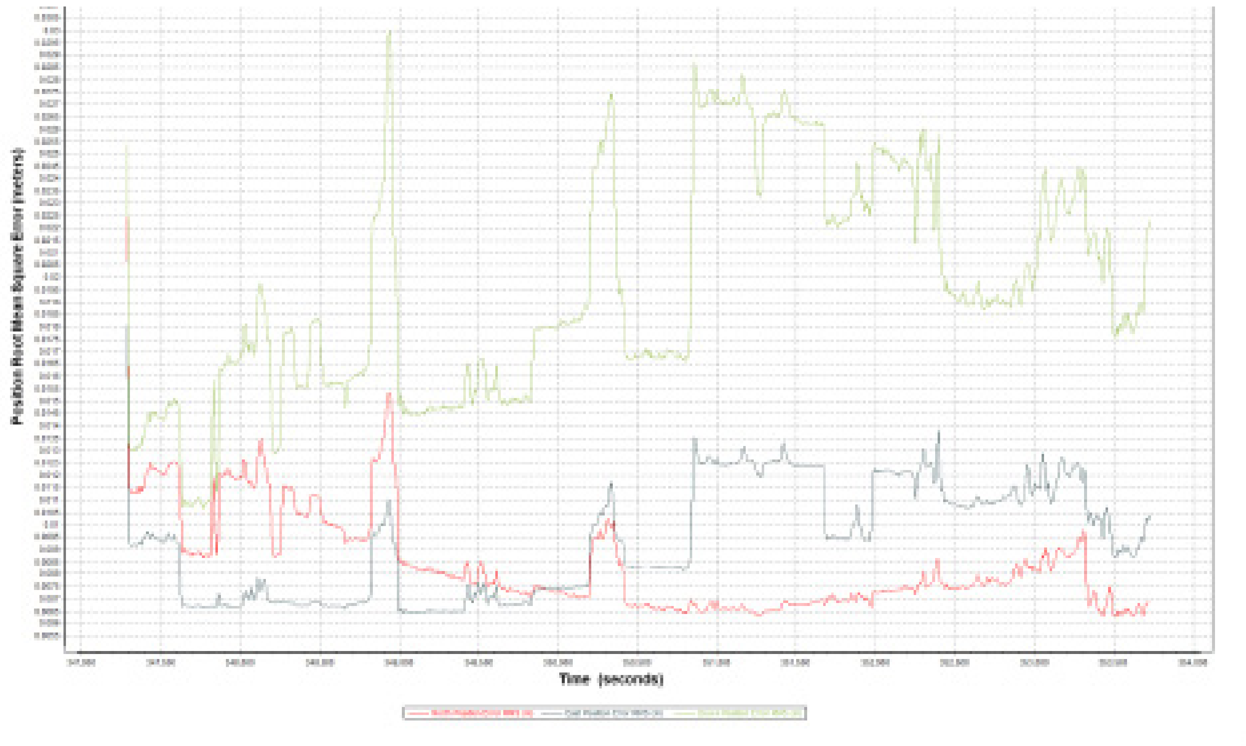

Figure 8. Smoothed Performance Metrics of Pamplona Flight 2842P.

The time of flight was from 347000 seconds to 354000 seconds, which corresponds to morning of November 12, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure B-2 shows that the North position RMSE peaks at 1.55 centimeters, the East position RMSE peaks at 1.40 centimeters, and the Down position RMSE peaks at 3.00 centimeters, which are within the prescribed accuracies described in the methodology.

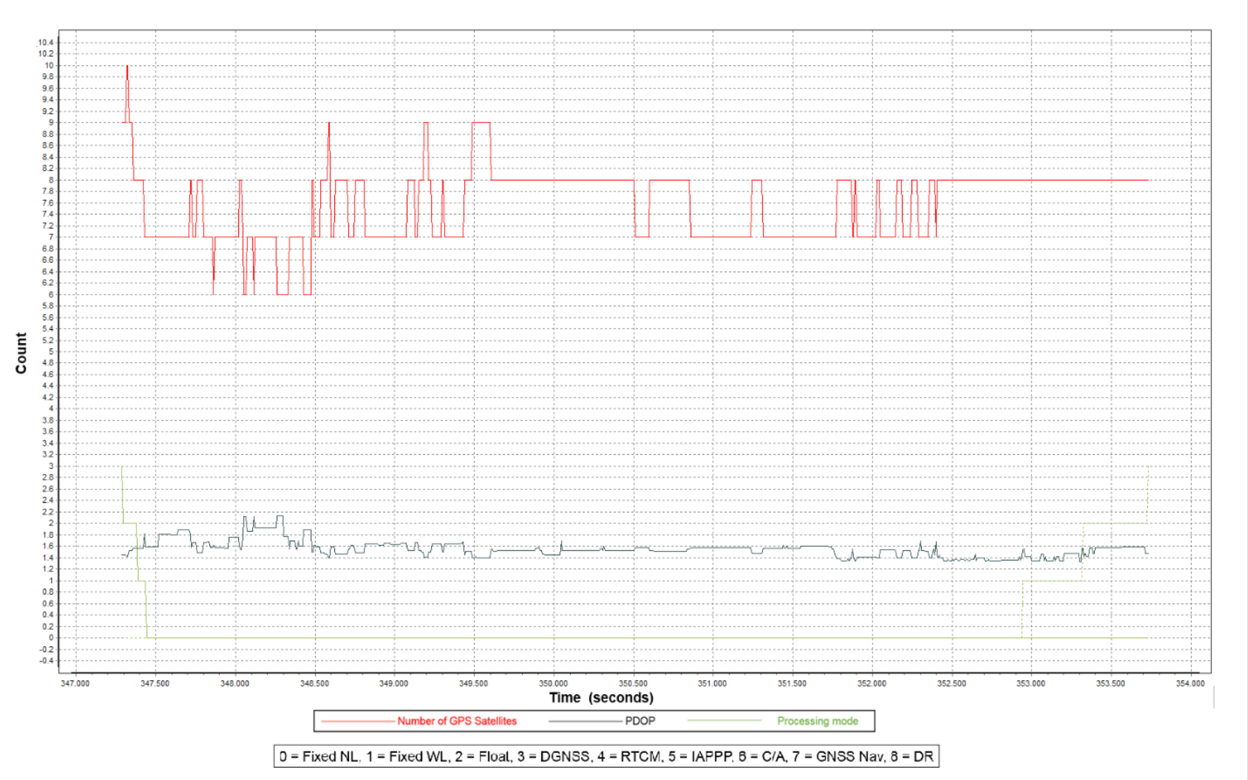

Figure 9. Solution Status Parameters of Pamplona Flight 2842P.

The Solution Status parameters of flight 2842P, one of the Pamplona flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure B-3. The graphs indicate that the number of satellites during the acquisition did not go below 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 or 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Pamplona flights is shown in Figure 10.

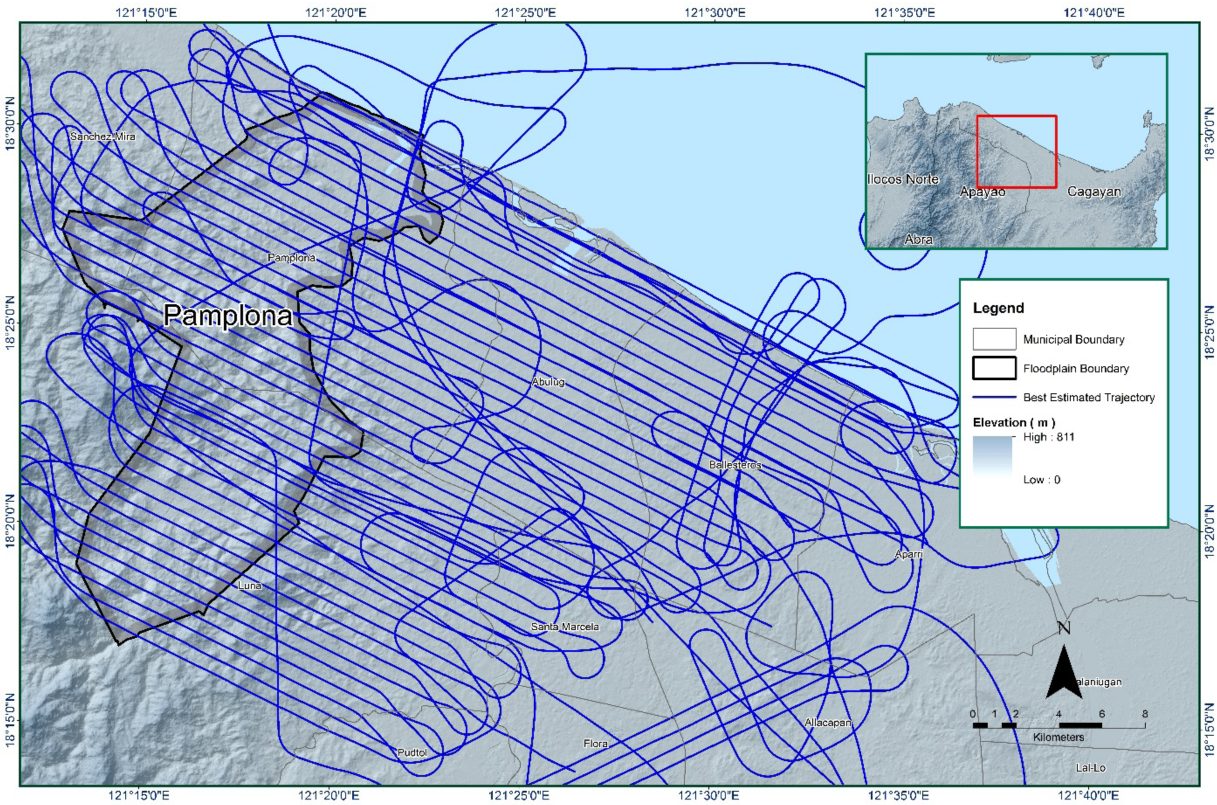

Figure 10. Best Estimated Trajectory of the LiDAR missions conducted over the Pamplona Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 32 flight lines, with each flight line containing one channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Pamplona floodplain are given in Table 9.

Table 9. Self-calibration Results values for Pamplona flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000693
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000879
GPS Position Z-correction stdev	<0.01meters	0.0024

The optimum accuracy is obtained for all Pamplona 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 boundary of the processed LiDAR data on top of a SAR Elevation Data over Pamplona Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

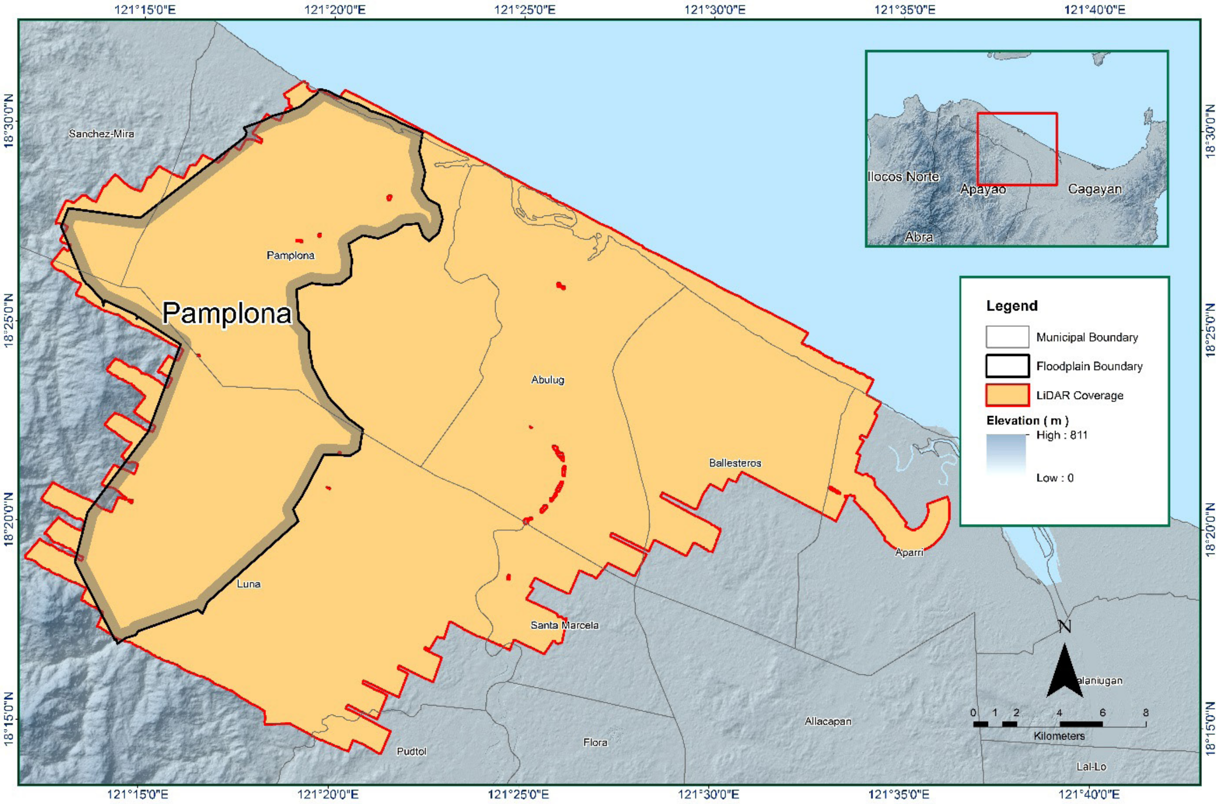

Figure 11. Boundary of the processed LiDAR data over Pamplona Floodplain

The total area covered by the Silaga missions is 1070.01 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into eight (8) blocks as shown in Table 16.

Table 10. List of LiDAR blocks for Pamplona Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cagayan_reflights_Tugegarao_Blk2A	2848P	131.64
	2852P	
Cagayan_reflights_Tugegarao_ Blk2A_supplement	2846P	199.64
Cagayan_reflights_Tugegarao_Blk2B	2842P	130.71
Cagayan_reflights_Tugegarao_ Blk2B_supplement	2846P	19.29
Cagayan_reflights_Tugegarao_ Blk2D	2854P	72.26
Cagayan_reflights_Tuguegarao_Blk2D_supplement_Blk2E	2850P	193.17
Cagayan_reflights_Tugegarao_Blk2A_additional	2848P	54.49
Cagayan_reflights_Blk1D	23696P	29.08
TOTAL		830.28 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Pegasus system employs two channels, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

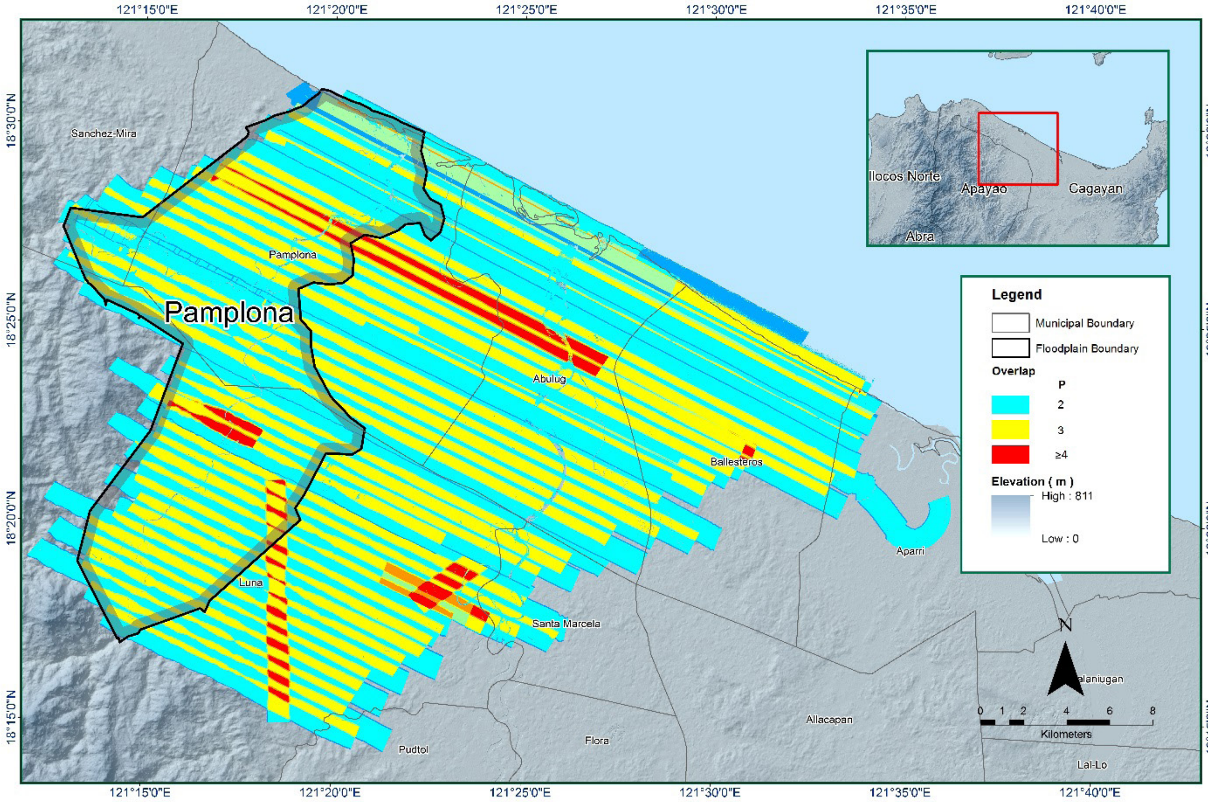

Figure 12. Image of data overlap for Pamplona Floodplain.

The overlap statistics per block for the Pamplona floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 38.74% and 51.57% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Pamplona floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.13 points per square meter.

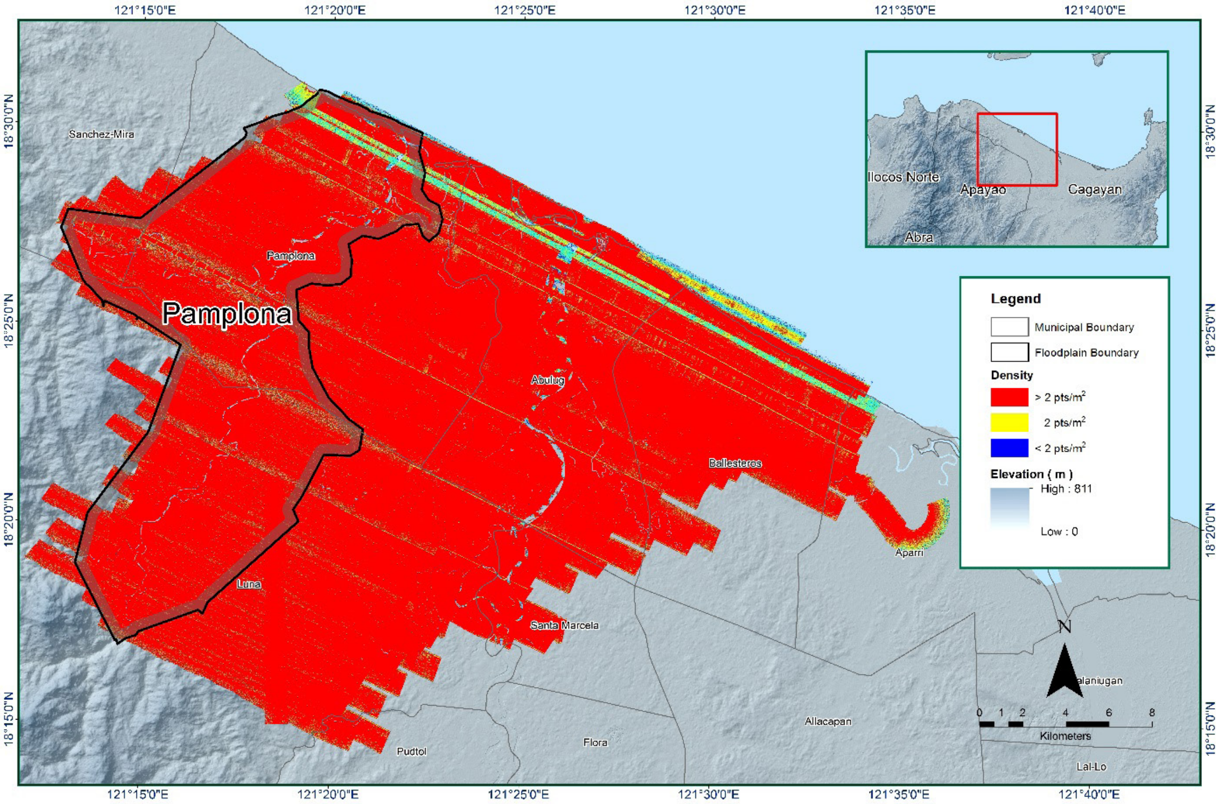

Figure 13. Pulse density map of merged LiDAR data for Pamplona Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

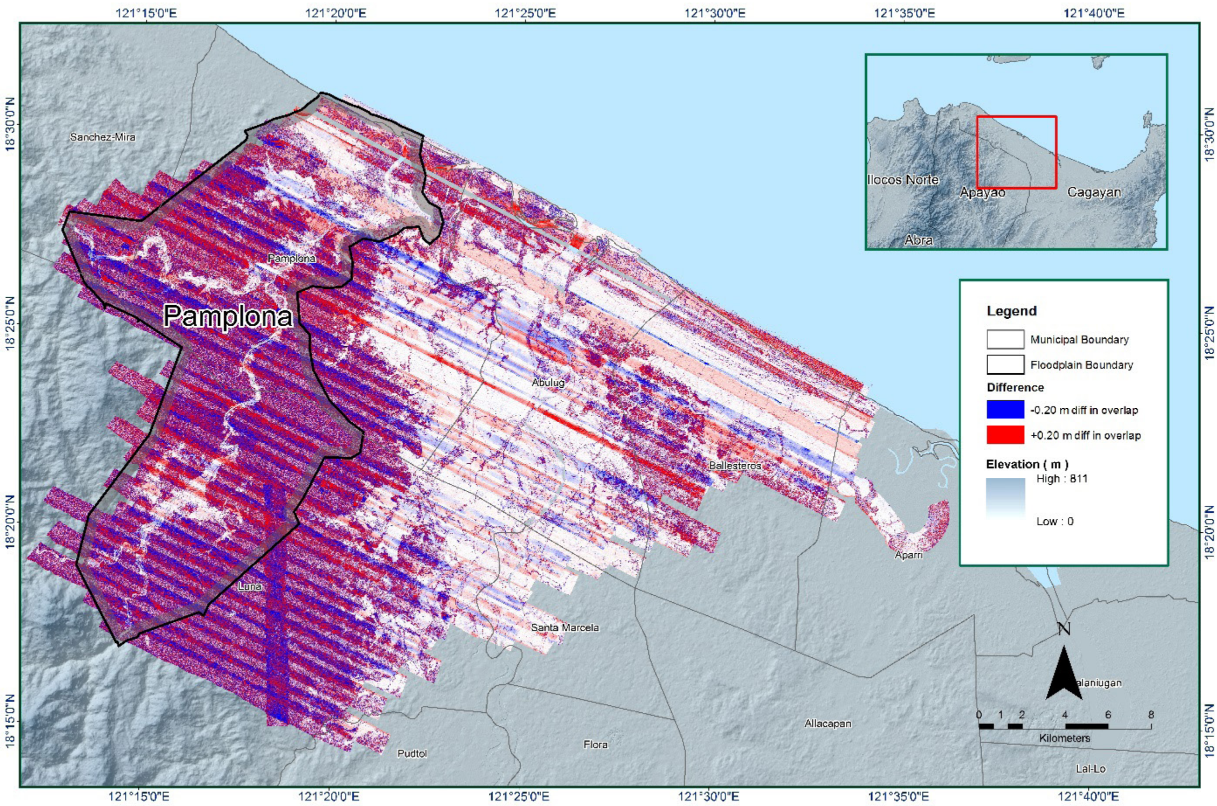

Figure 14. Elevation Difference Map between flight lines for Pamplona Floodplain Survey.

A screen capture of the processed LAS data from Pamplona flight 2842P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

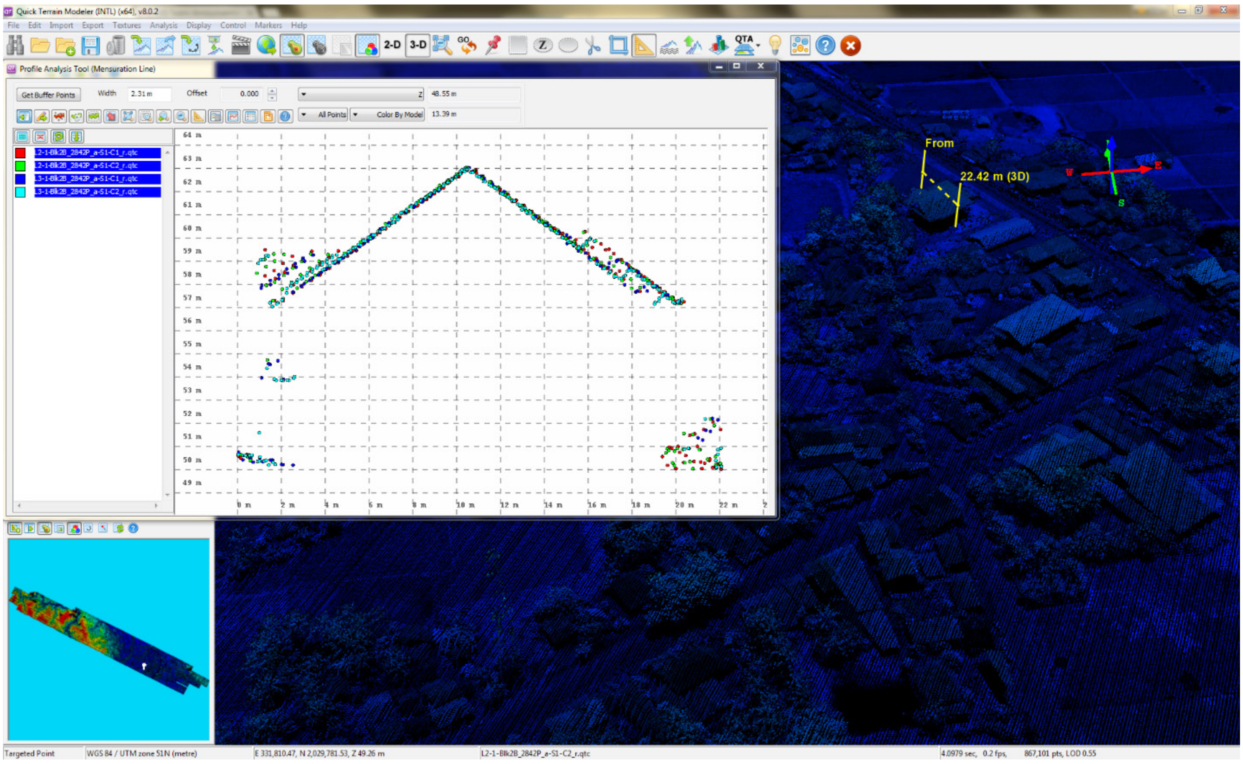

Figure 15. Quality checking for a Pamplona flight 2842P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Pamplona classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	730,120,761
Low Vegetation	476,358,859
Medium Vegetation	658,168,041
High Vegetation	2,900,490,221
Building	33,869,042

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pamplona floodplain is shown in Figure 16. A total of 1,059 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 629.94 meters and 28.54 meters respectively.

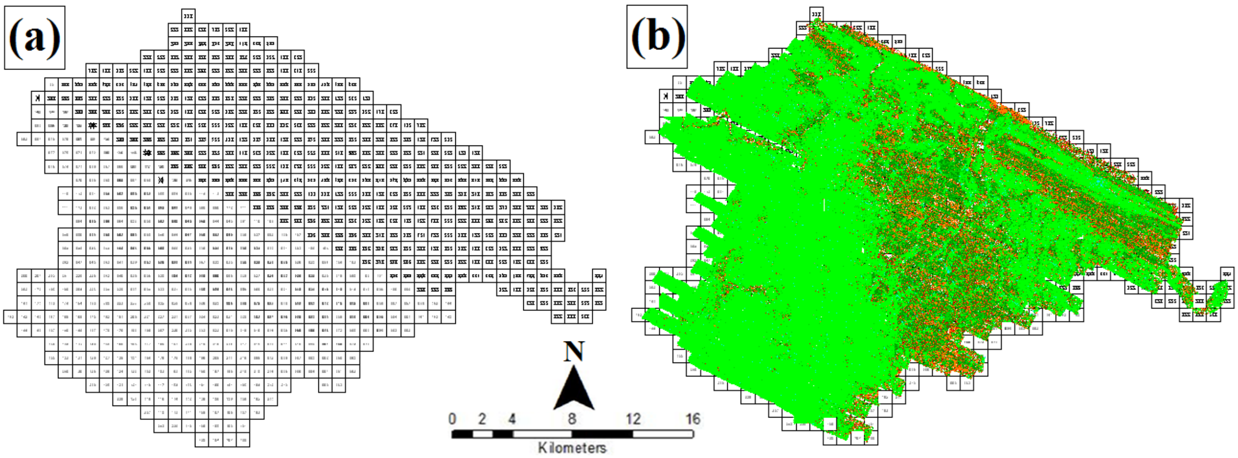

Figure 16. Tiles for Pamplona Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

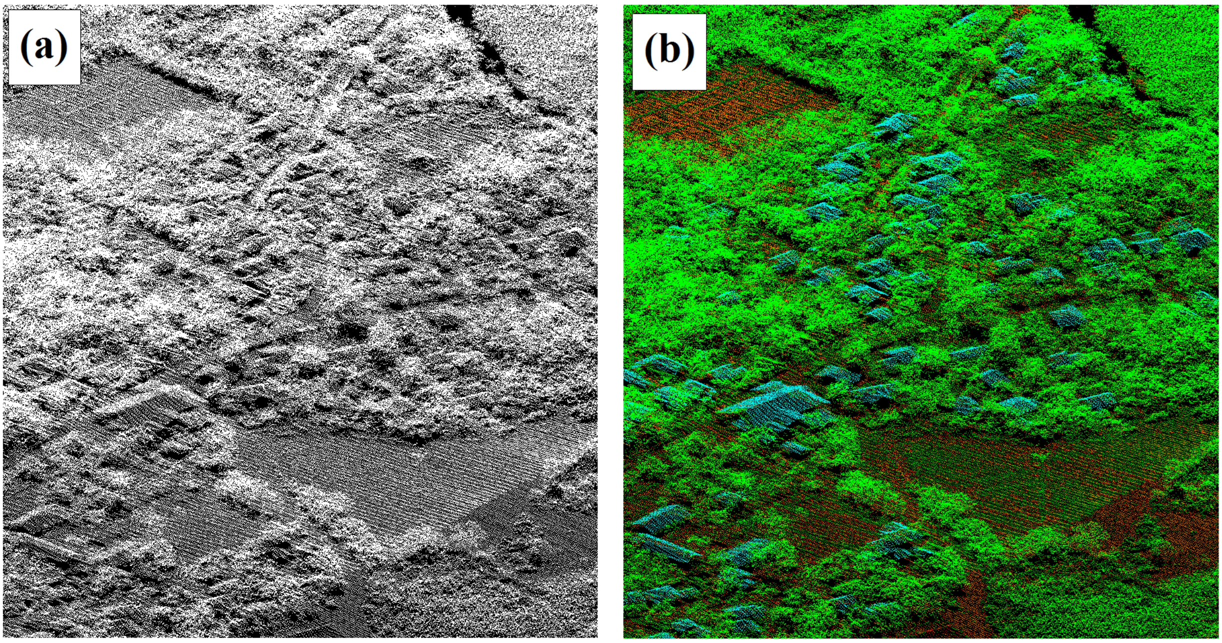

Figure 17. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 18. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

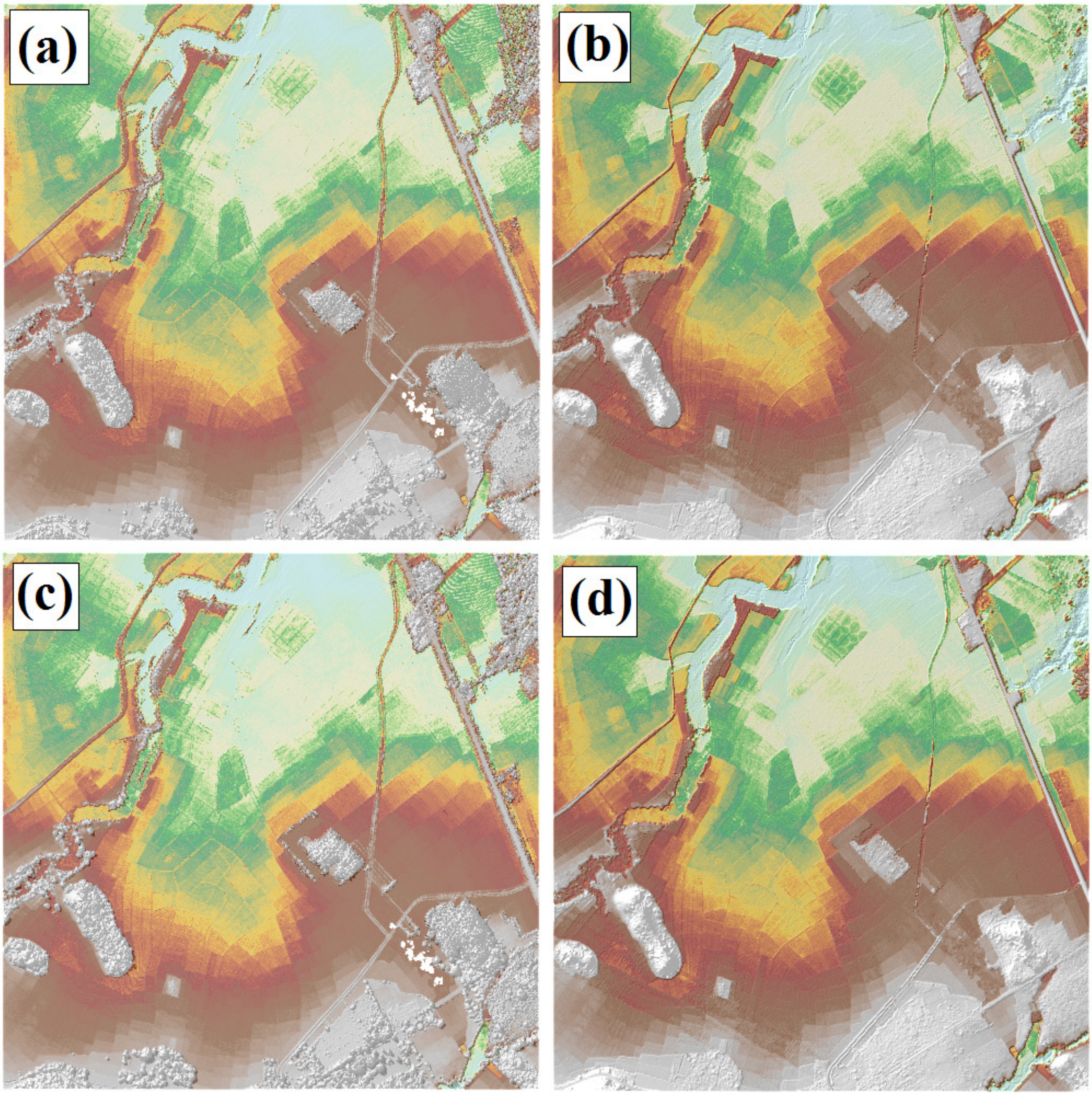

Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pamplona Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,114 1km by 1km tiles area covered by Pamplona floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Pamplona floodplain has a total of 692.81 sq.km orthophotogaph coverage comprised of 1,635 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

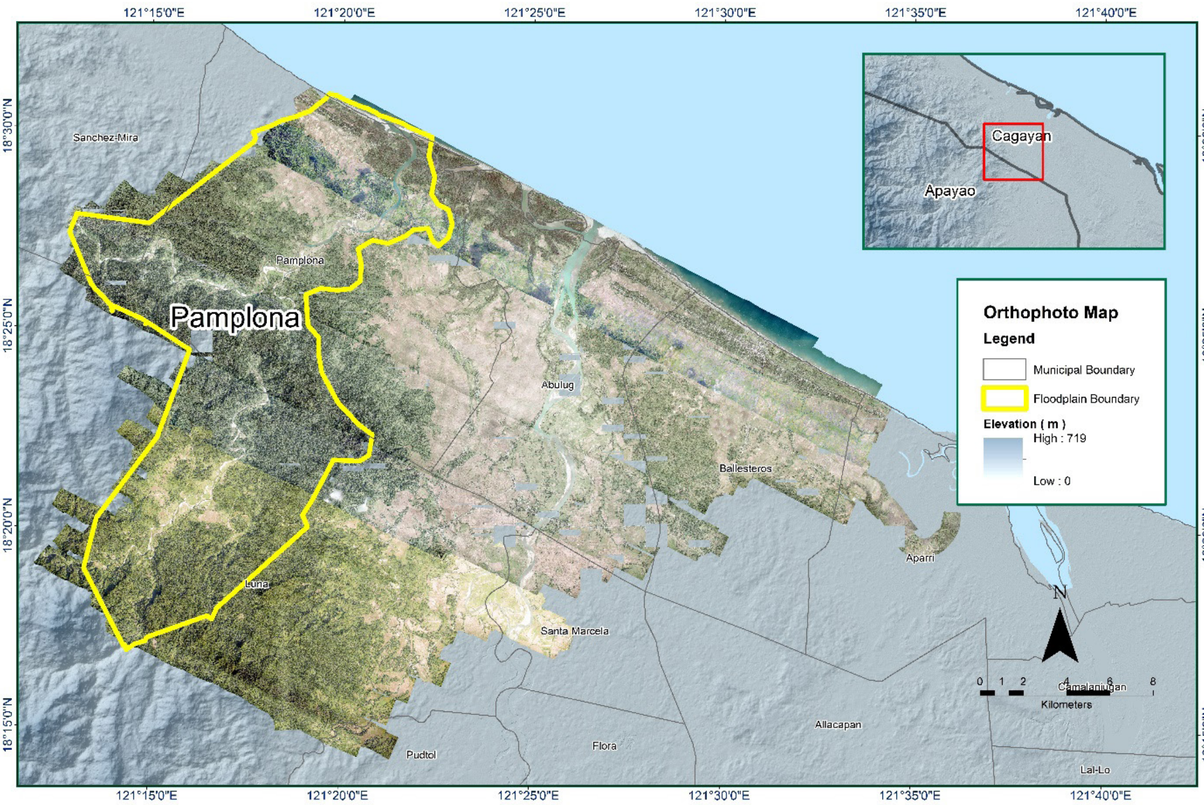

Figure 19. Pamplona Floodplain with available orthophotographs.

Figure 20. Sample orthophotograph tiles for Pamplona Floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Pamplona flood plain. These blocks are composed of Cagayan reflights and Cagayan reflights Tuguegarao blocks with a total area of 830.28 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Cagayan_reflights_Tugegarao_Blk2A	131.64
Cagayan_reflights_Tugegarao_ Blk2A_supplement	199.64
Cagayan_reflights_Tugegarao_Blk2B	130.71
Cagayan_reflights_Tugegarao_ Blk2B_supplement	19.29
Cagayan_reflights_Tugegarao_ Blk2D	72.26
Cagayan_reflights_Tuguegarao_Blk2D_ supplement_Blk2E	193.17
Cagayan_reflights_Tugegarao_Blk2A_additional	54.49
Cagayan_reflights_Blk1D	29.08
TOTAL	830.28 sq.km

Portions of DTM before and after manual editing are shown in Figure 21. A road (Figure 21a) has been misclassified and removed during classification process and has to be interpolated to complete the surface (Figure 21b) to allow the correct flow of water. Disconnected rivers (Figure 21c) are also edited (Figure 21d) in order to hydrologically correct the river. Another example is an interpolated river bank (Figure 21e) it has to be retrieved using object retrieval to achieve the actual surface (Figure 21f). A pit (Figure 21g) was removed through interpolation (Figure 21h).

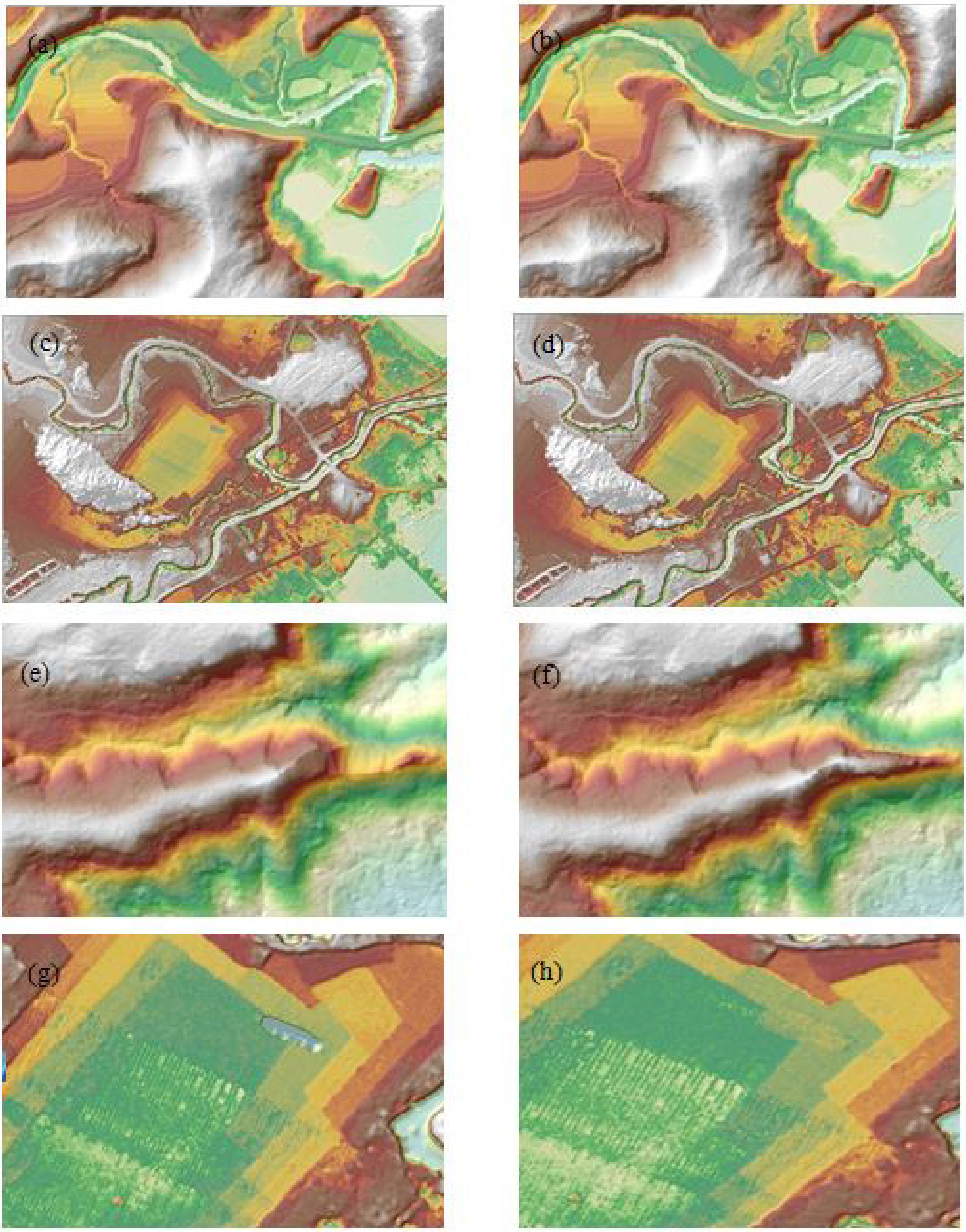

Figure 21. Portions in the DTM of Pamplona floodplain – a road before (a) and after (b) manual editing; disconnected rivers before (c) and after (d) manual editing; interpolated bank before (e) and after (f) object retrieval; and a pit before (g) and after (h) manual editing.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Cagayan DEM overlapping with the blocks to be mosaicked. Table 13 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Pamplona floodplain is shown in Figure 22. It can be seen that the entire Pamplona floodplain is 98.50% covered by LiDAR data.

Table 13. Shift values of each LiDAR block of Pamplona Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Cagayan_reflights_Tugegarao_Blk2A	6.14	4.76	-4.86
Cagayan_reflights_Tugegarao_ Blk2A_supplement	2.38	-1.27	-3.87
Cagayan_reflights_Tugegarao_Blk2B	2.54	-1.30	-5.14
Cagayan_reflights_Tugegarao_ Blk2B_supplement	2.54	-0.63	-3.84
Cagayan_reflights_Tugegarao_ Blk2D	0.63	0.00	-4.43
Cagayan_reflights_Tuguegarao_Blk2D_ supplement_Blk2E	0.45	-0.09	-1.65
Cagayan_reflights_Tugegarao_Blk2A_additional	0.00	0.00	0.00
Cagayan_reflights_Blk1D	0.00	0.00	0.00

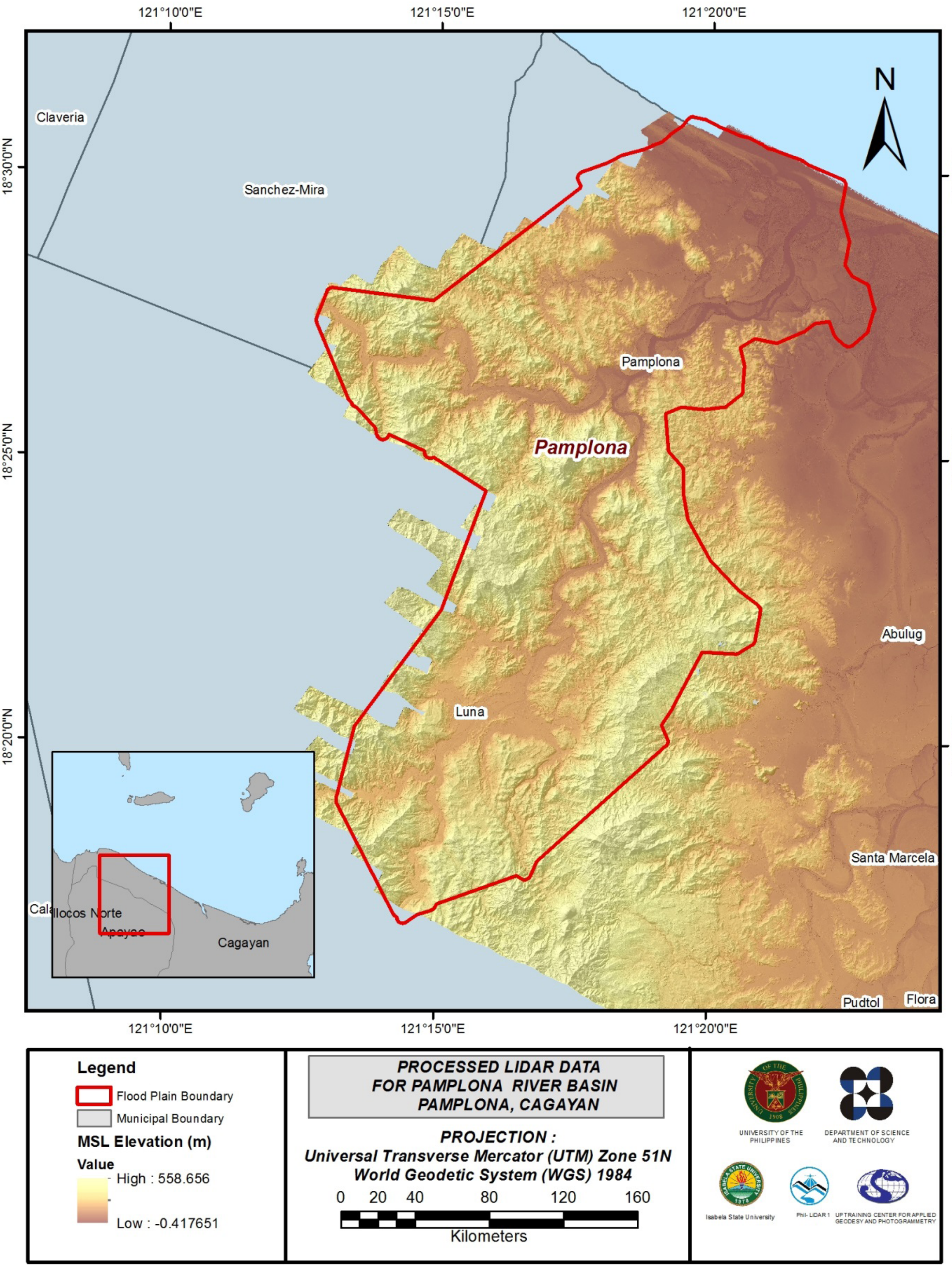

Figure 22 . Map of Processed LiDAR Data for Pamplona Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Pamplona to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 8,393 survey points were gathered for calibration and validation of Pamplona LiDAR data. However, the point dataset was not used for the calibration of the LiDAR data for Pamplona because during the mosaicking process, each LiDAR block was referred to the calibrated Cagayan DEM. Therefore, the mosaicked DEM of Pamplona can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Cagayan LiDAR DTM and ground survey elevation values is shown in Figure B-18. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration 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, to Cagayan mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between Cagayan LiDAR data and calibration data. These values were also applicable to the Pamplona DEM.

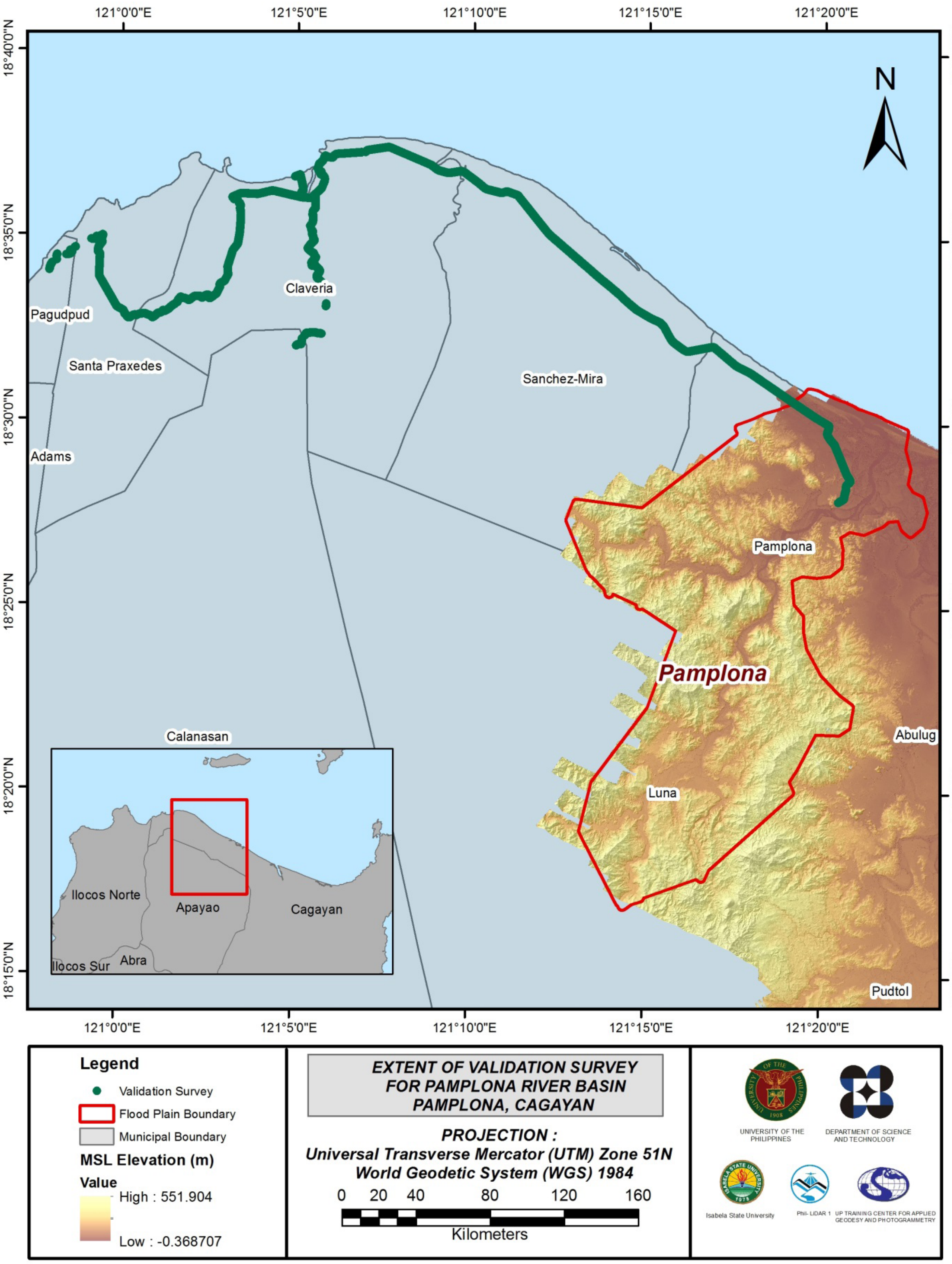

Figure 23. Map of Pamplona Floodplain with validation survey points in green.

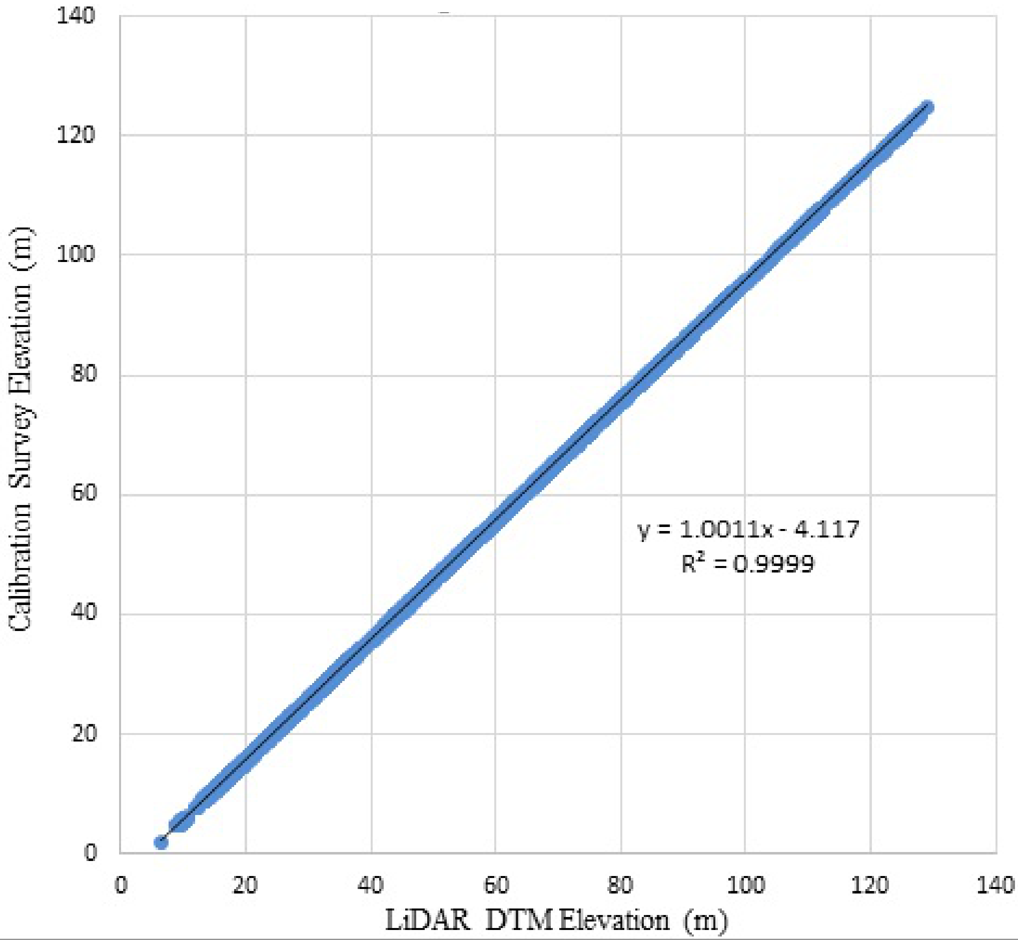

Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 14. 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 total survey points, resulting to 927 points, were used for the validation of calibrated Pamplona DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 1.00 meter with a standard deviation of 0.16 meters, as shown in Table 15.

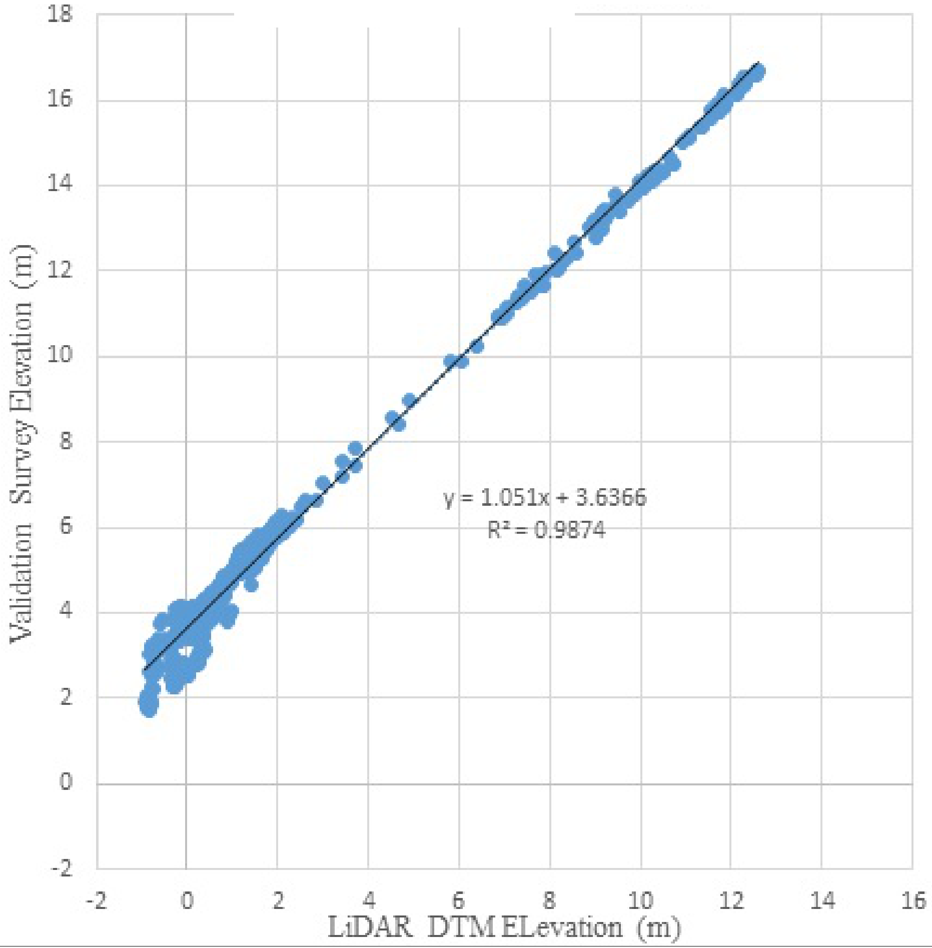

Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	1.00
Standard Deviation	0.16
Average	-0.99
Minimum	-1.42
Maximum	-0.57

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data was available for Pamplona with 11,803 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.40 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Pamplona integrated with the processed LiDAR DEM is shown in Figure 26.

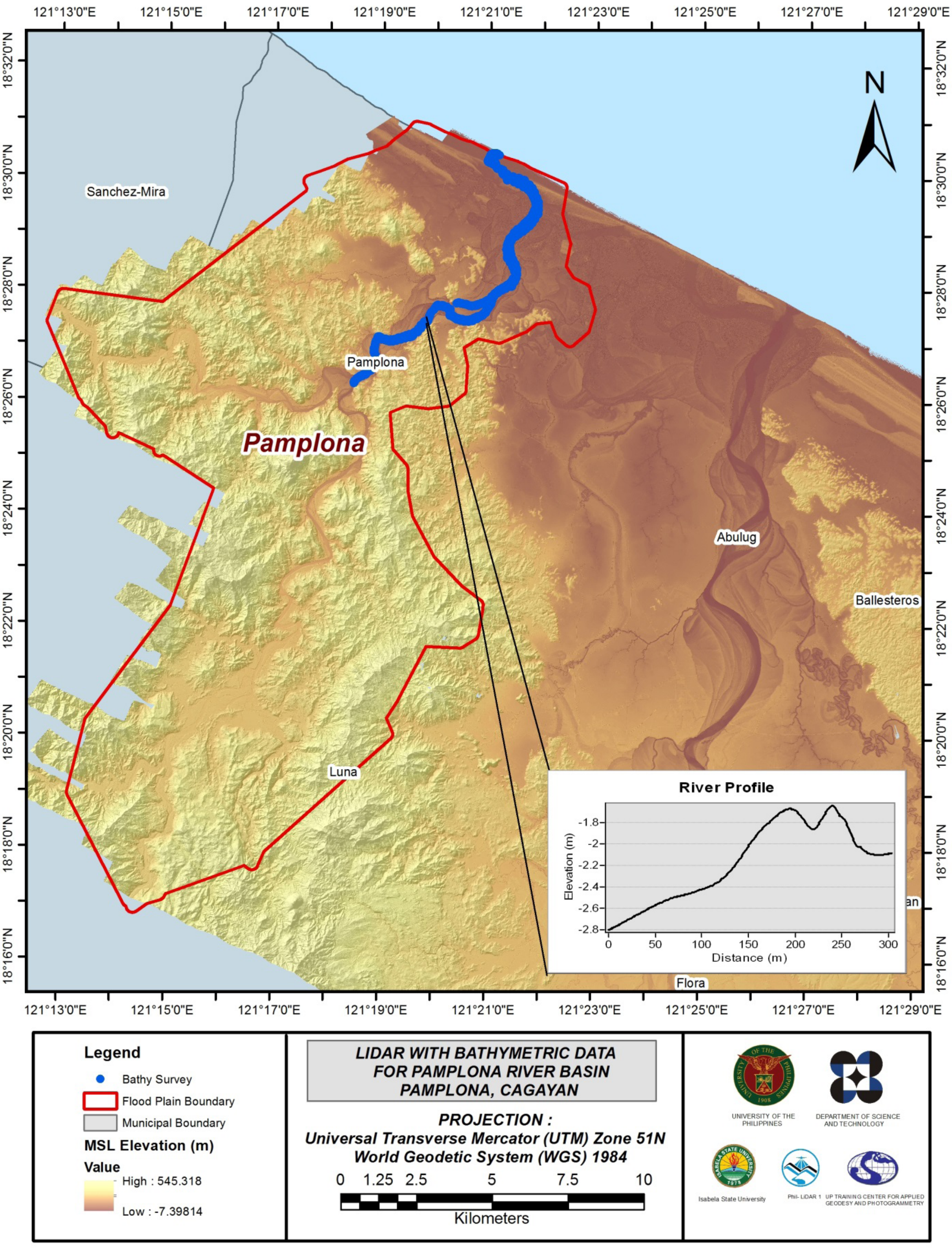

Figure 26. Map of Pamplona Floodplain with bathymetric survey points shown in blue.

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

3.12.1 Quality Checking of Digitized Features' Boundary

Pamplona floodplain, including its 200 m buffer, has a total area of 237.25 sq km. For this area, a total of 8.0 sq km, corresponding to a total of 706 building features, are considered for QC. Figure 27 shows the QC blocks for Pamplona floodplain.

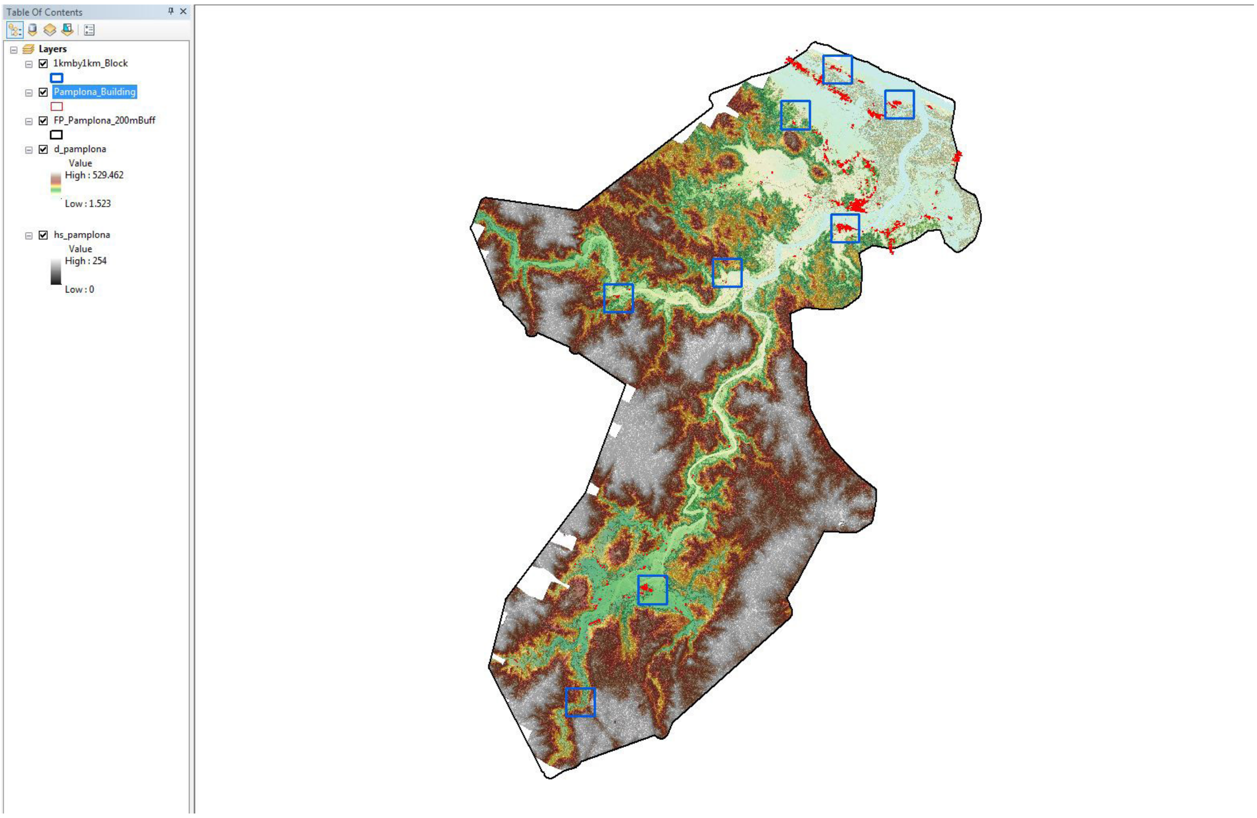

Figure27. Blocks (in blue) of Silaga building features that were subjected to QC

Quality checking of Pamplona building features resulted in the ratings shown in Table 16.

Table 16. Quality Checking Ratings for Pamplona Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Pamplona	97.61	98.44	90.37	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,036 building features in Pamplona floodplain. Of these building features, none was filtered out after height extraction, resulting to 4,036 buildings with height attributes. The lowest building height is at 3.68 m, while the highest building is at 9.39 m.

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 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 17 summarizes the number of building features per type. On the other hand, Table 18 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 17. Building Features Extracted for Pamplona Floodplain.

Facility Type	No. of Features
Residential	3,919
School	70
Market	2
Agricultural/Agro-Industrial Facilities	2
Medical Institutions	3
Barangay Hall	9
Military Institution	0
Sports Center/Gymnasium/Covered Court	6
Telecommunication Facilities	4
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	14
Bank	0
Factory	0
Gas Station	2
Fire Station	0
Other Government Offices	3
Other Commercial Establishments	2
Total	**4,036**

Table 18. Total Length of Extracted Roads for Pamplona Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Pamplona	38.56	3.07	11.4	11.39	4.85	69.32

Table 19. Number of Extracted Water Bodies for Pamplona Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Pamplona	32	2	0	0	20	2

A total of 11 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 28 shows the Digital Surface Model (DSM) of Pamplona floodplain overlaid with its ground features.

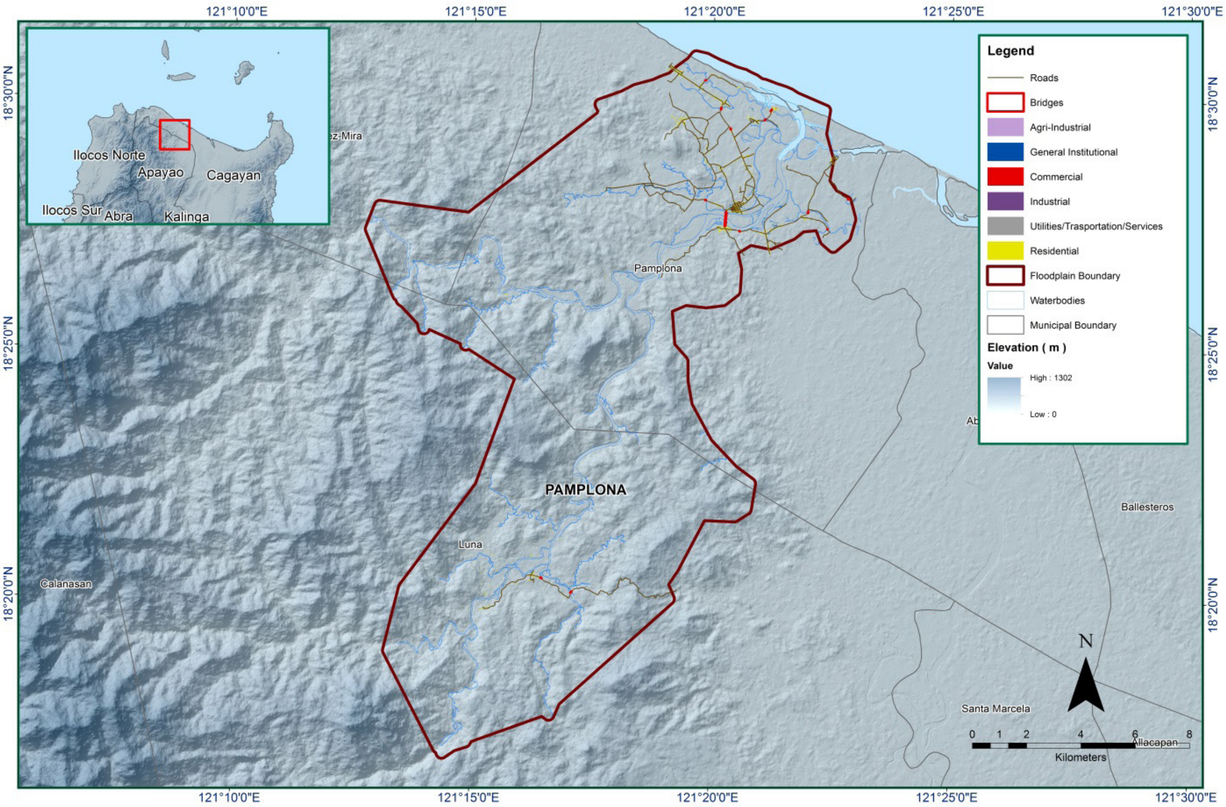

Figure 28. Extracted features for Pamplona Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE PAMPLONA 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 first and second river survey in the Silaga River were conducted on September 10 to 24, 2014 (Samar Phase 1) and on December 4 to 18, 2014 (Samar Phase 2) respectively. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (ii) the cross-section survey, bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Silaga Bridge (for Samar Phase 1) and (iv) the bathymetric survey of the Silaga River (for Samar Phase 2) from Brgy. Tulay down to Brgy. La Paz, where the mouth of the river is located; which reached an estimated length of 16.34 kms. using the PPK GNSS Survey Technique. Figure 33 illustrates the extent of the Silaga River Bathymetric Survey.

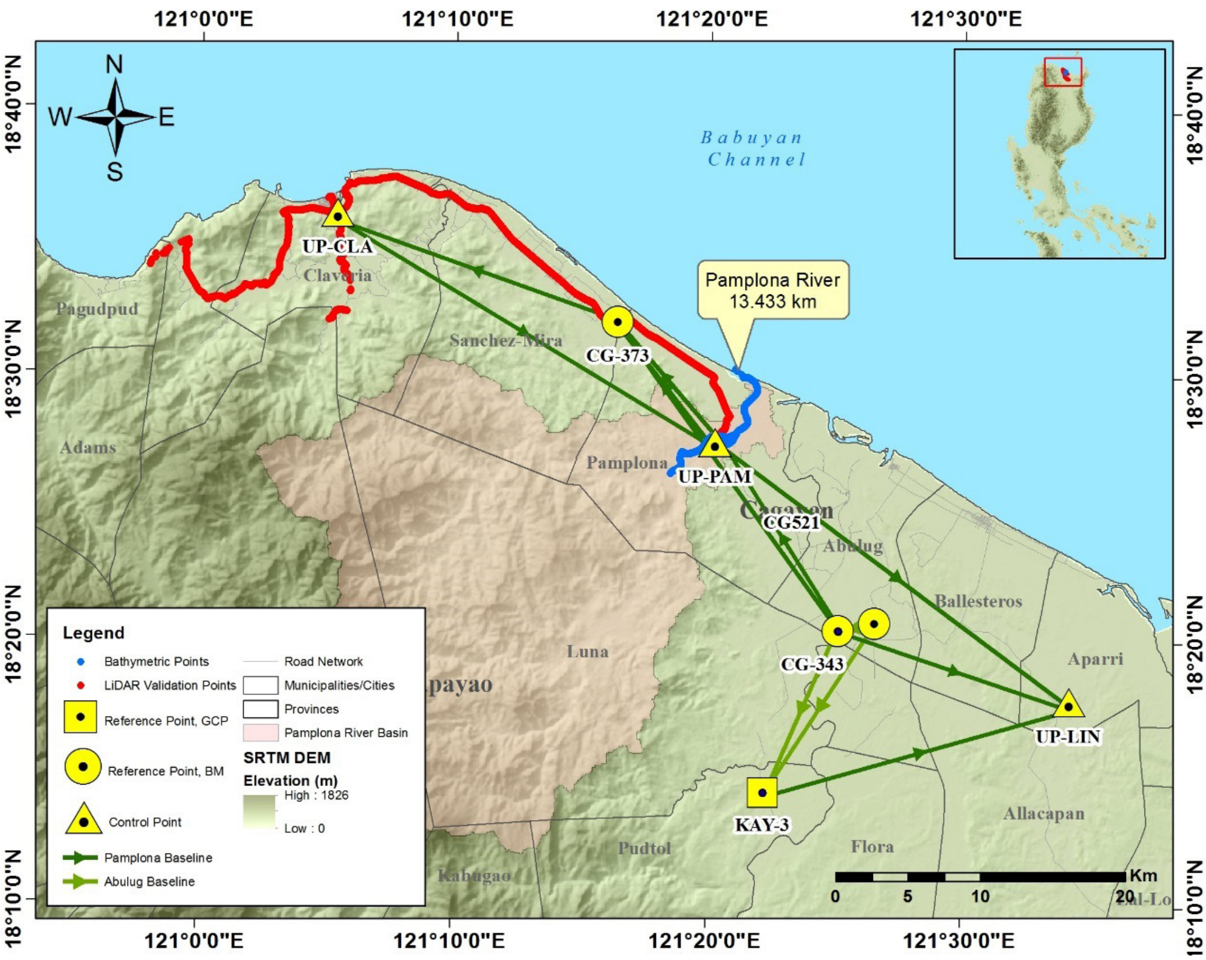


Figure 29. Extent of the bathymetric survey (in blue line) in Pamplona River and the LiDAR data validation survey (in red).

4.2 Control Survey

A GNSS network from Abulug River Survey was established on September 18, 2015 occupying the control points KAY-3, a second-order GCP, in Brgy. Imelda, Municipality of Pudtol; and CG-343, a first-order BM, in Brgy. Libertad, Muncipality of Abulug; both in Cagayan Province.

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

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

The summary of reference and control points and its location is summarized in Table 20 while the GNSS network established is illustrated in Figure 30.

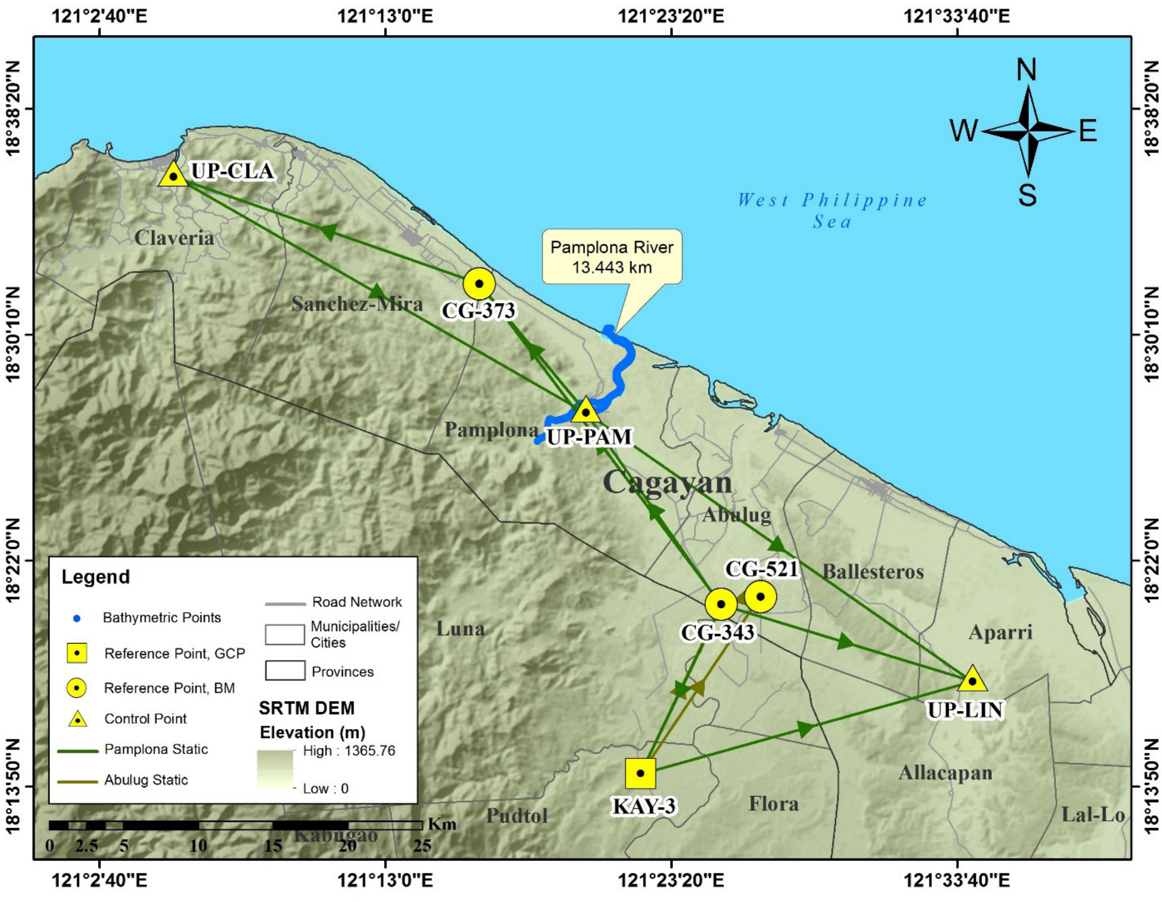


Figure 30. The GNSS Network established in the Panplona River Survey.

Table 20. List of Reference and Control Points occupied for Pamplona River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	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	1990
CG-343	1st order, BM	18°20'24.45282"N	121°25'08.22638"E	51.980	13.119	2007
CG-521	Used as Marker	18°20'41.57071"N	121°26'33.65512"E	47.372	8.593	2008
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	1990
CG-343	1st order, BM	18°20'24.45282"N	121°25'08.22638"E	51.980	13.119	2007
CG-373	1st order, BM	18°32'00.00627"N	121°16'23.37638"E	40.044	3.422	2007
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 Pamplona River are shown in Figure 31 to Figure 36.

Figure 31. GNSS base set up, Trimble® SPS 985, at KAY-3, situated on top of a flood gate near Pudtol Municipal Building in Brgy. Imelda, Municipality of Pudtol, Cagayan

Figure 32. GNSS receiver setup, Trimble® SPS 882, at CG-343, located at the approach of Likban Bridge in Brgy. Libertad, Municipality of Abulug, Cagayan

Figure 33. GNSS receiver setup, Trimble® SPS 882, at CG-373, located at the approach of Bangan Bridge in Brgy. Bangan, Municipality of Sanchez Mira, Cagayan

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

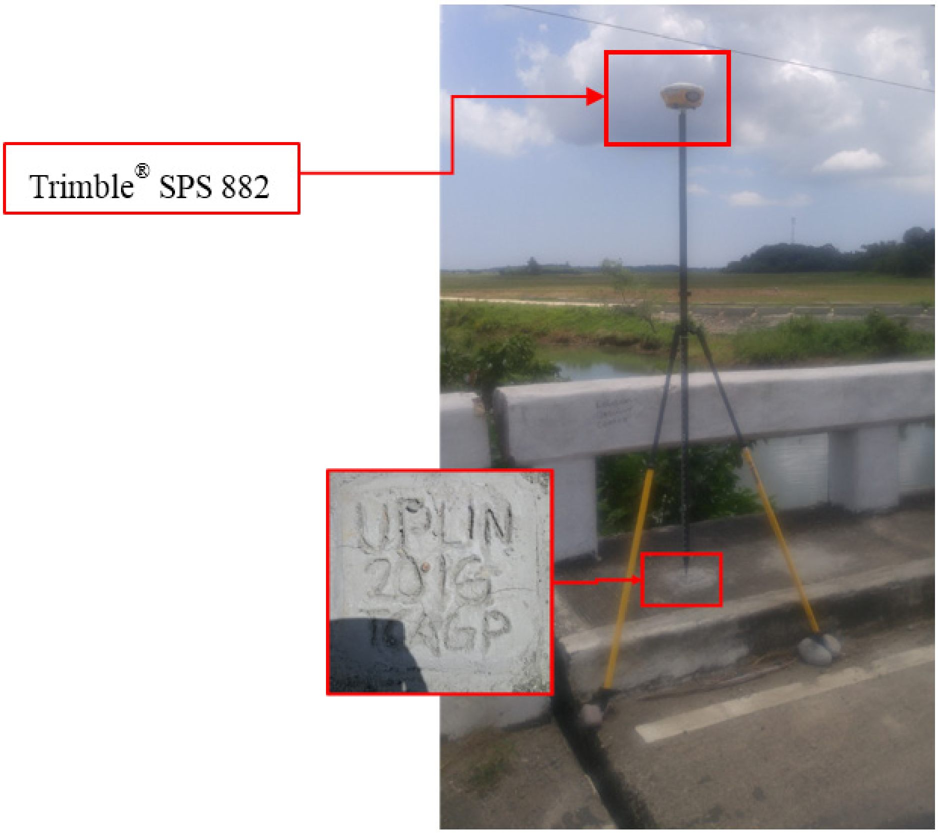


Figure 35. GNSS receiver setup, Trimble® SPS 882, at UP-LIN, located at the approach of Linao Bridge in Brgy. Bangag-Zingag, Municipality of Aparri, Cagayan

Figure 36. GNSS receiver setup, Trimble® SPS 985, at UP-PAM, located at the approach of New Pamplona Bridge in Brgy. 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 case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Pamplona River Basin is summarized in Table 21 generated by TBC software.

Table 21. Baseline Processing Summary Report for Pamplona River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CG-343 --- UP-LIN	06-16-16	Fixed	0.003	0.011	106°47'38"	16724.001	-8.874
UP-PAM --- CG-343	06-16-16	Fixed	0.004	0.015	326°39'56"	15653.196	-3.143
CG-343 --- KAY-3	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	06-16-16	Fixed	0.003	0.013	126°01'00"	30439.181	-5.723
UP-LIN --- KAY-3	06-16-16	Fixed	0.003	0.012	73°02'19"	22107.068	-16.071
CG-343 --- CG-373	06-16-16	Fixed	0.003	0.012	324°15'43"	26354.260	-10.043

As shown Table 21 a total of nine (9) baselines were processed with reference points KAY-3 and CG-343 held fixed for coordinate and elevation values, including CG-373 also fixed for elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

<20cm and

where:

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

for each control point. See the Network Adjustment Report shown in Table 22 to Table 25 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 as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. Constraints applied to the adjustment of the control points.

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 indicated in Table 23. The fixed control points KAY-3 and CG-343 have no values for grid errors while all three points including CG-373 have no values for elevation errors.

Table 23. Adjusted grid coordinates for the control points used in the Pamplona River Floodplain survey.

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 computation for the accuracy are as follows:

a. KAY-3
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. CG-343
horizontal accuracy = Fixed
vertical accuracy = Fixed

c. CG-373
horizontal accuracy = $\sqrt{((1.5)^2 + (1.4)^2}$
= $\sqrt{(2.25 + 1.96)}$
= $2.05 < 20$ cm
vertical accuracy = Fixed

d. 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

e. 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

f. 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 result of the two occupied control points are within the required precision.

Table 24. Adjusted geodetic coordinates for control points used in the Pamplona River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	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 25. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

Table 25. The reference and control points utilized in the Pamplona River Static Survey, with their 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 Water Level Marking

Cross-section and as-built survey were conducted on June 19 and 20, 2016 at the downstream side of New Pamplona Bridge in Brgy. Masi, Municipality of Pamplona, Cagayan as shown in Figure 37. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique and a Total Station through Open Traverse Method was utilized for this survey.

Figure 37. New Pamplona Bridge facing downstream

The cross-sectional line of New Pamplona Bridge is about 606 m with seven hundred seventy five (775) cross-sectional points using the control point UP-PAM as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 38 to Figure 40, respectively.

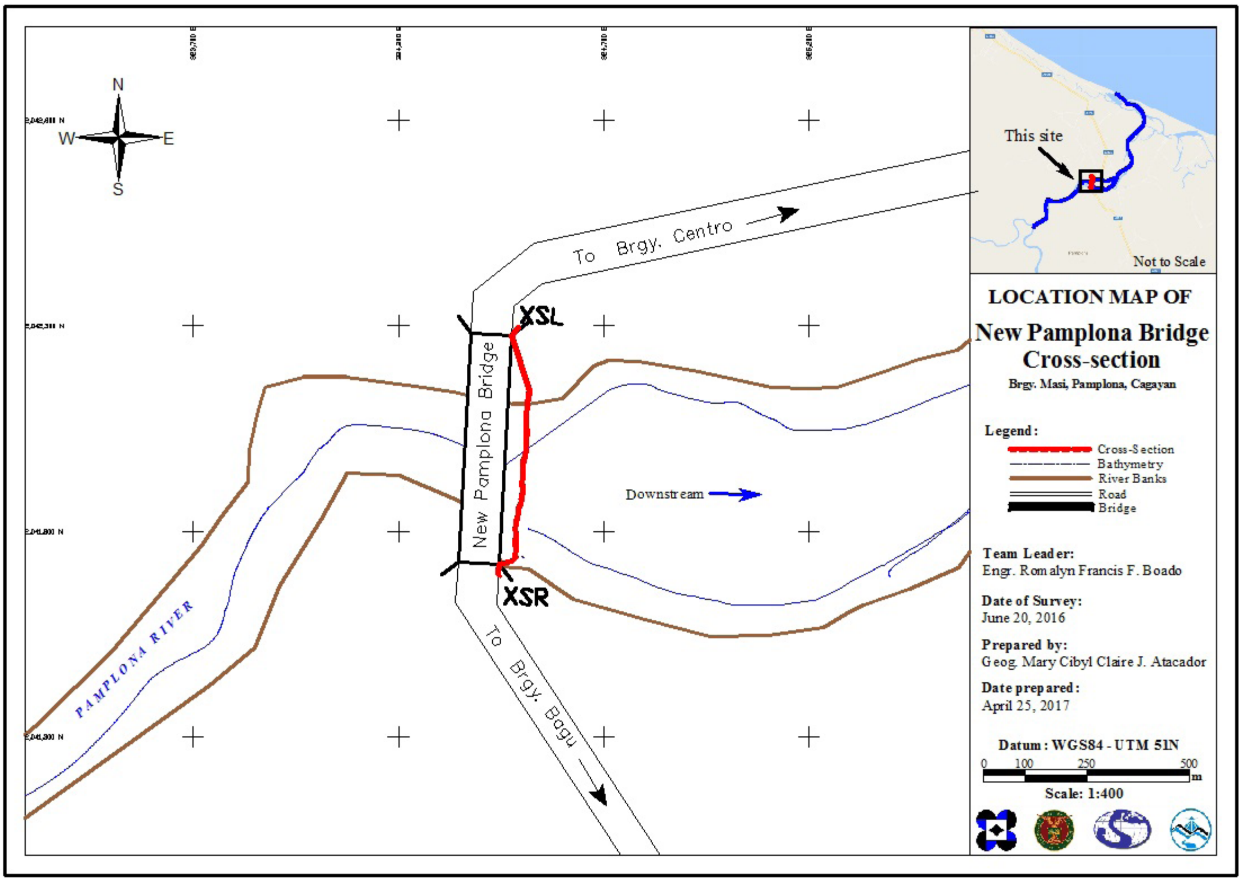


Figure 38. New Pamplona bridge cross-section location map

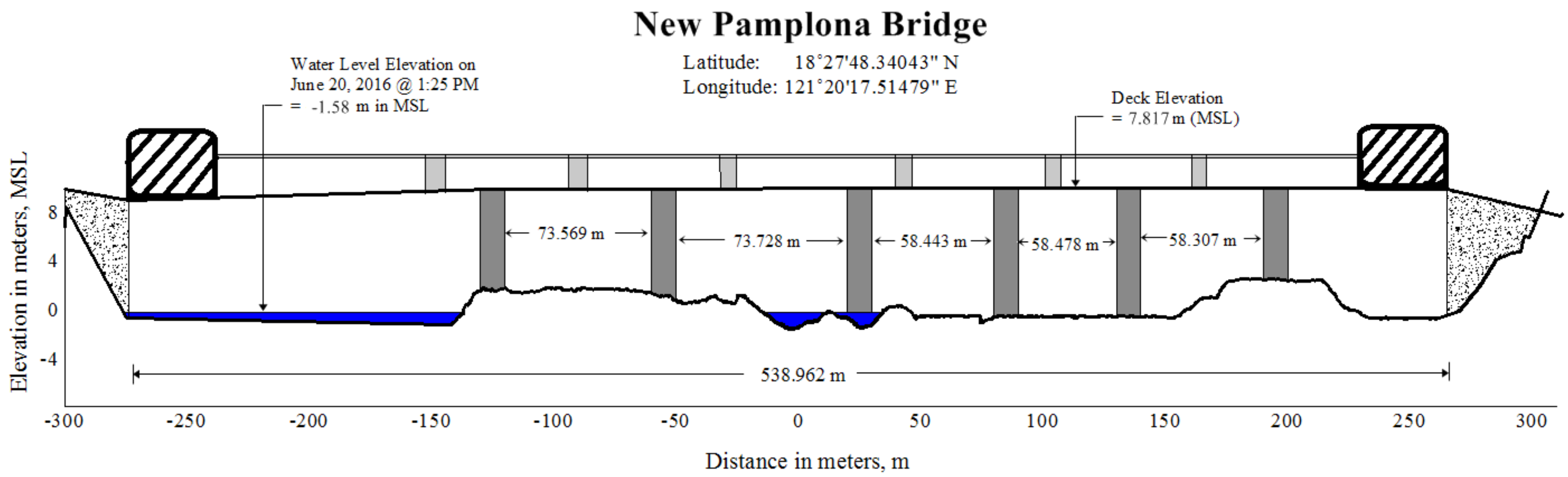


Figure 39. New Pamplona Bridge cross-section diagram

Bridge Data Form

Bridge Name: Pamplona Bridge **Date:** July 19 and 20, 2016

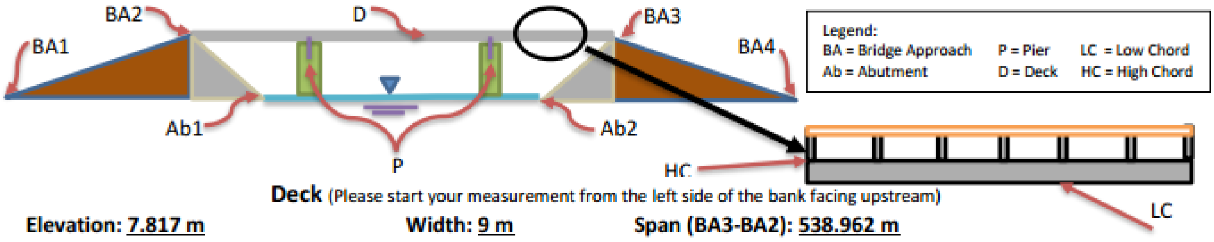
River Name: Pamplona River **Time:** 1:35 PM

Location (Brgy, City,Region): Brgy. Masi, Municipality of Pamplona, Cagayan

Survey Team: Romalyn Boado, Lorenz Taguse, Michael Labrador

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

Latitude: 18˚27'48.34043" N **Longitude:** 121˚20'17.51479" E



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

Elevation: 7.817 m **Width:** 9 m **Span (BA3-BA2):** 538.962 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	8.736 m	BA3	565.049 m	8.664 m
BA2	26.087 m	7.817 m	BA4	611.901 m	6.540 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: 6 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	174.802 m	8.710 m	NA
Pier 2	248.370 m	8.680 m	NA
Pier 3	322.099 m	8.789 m	NA
Pier 4	380.542 m	8.773 m	NA
Pier 5	439.020 m	8.795 m	NA
Pier 6	497.327 m	8.780 m	NA

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

Figure 40. Bridge as-built form of New Pamplona Bridge

Water surface elevation of Pamplona River was determined a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on June 20, 2016 at 1:25 PM with a value of -1.58 m below MSL as shown in Figure 38. This was translated into marking on the bridge's deck using the same technique as shown in Figure 41. The marking will serve as reference for flow data gathering and depth gauge deployment of Isabela State University for Pamplona River

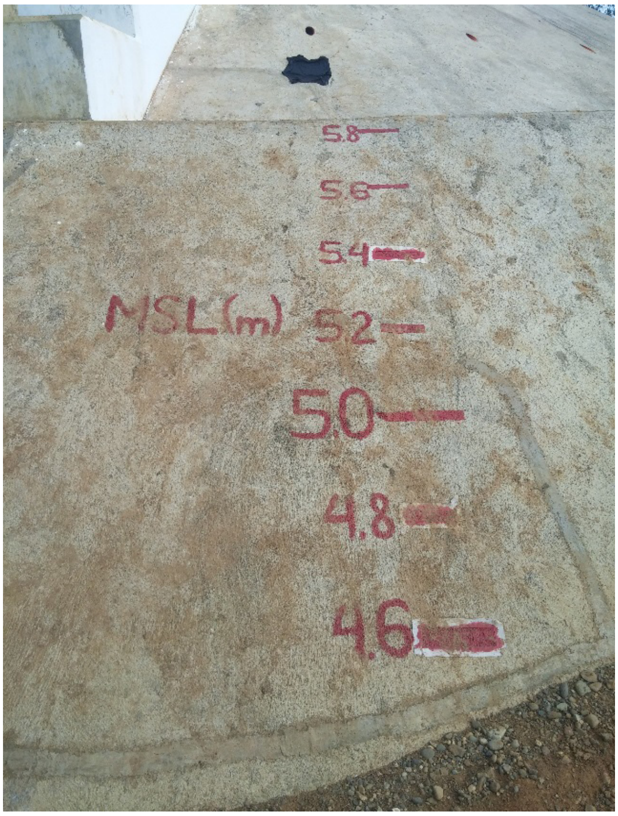


Figure 41. Water-level markings on New Pamplona Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on June 17 and 18, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 1.97 m and 1.939 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-CLA occupied as the GNSS base stations in the conduct of the survey.

Figure 42. Validation points acquisition survey set up along Pamplona River Basin

The survey started from the Cabicungan Bridge in Brgy. Dibalio, in the Municipality of Claveria; going east covering Municipality of Sanchez-Mira and ending in Brgy. Centro, Pamplona; going south covering ten barangays in Claveria, and ended in Brgy. Santa Filomena, Municipality of Calanasan; and finally going west covering fourteen (14) barangays which ended in Brgy. Pasaleng, Municipality of Pagudpud. The survey gathered a total of 10,490 points with approximate length of 69 km using UP-CLA as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 43.

Figure 43. Validation point acquisition survey of Pamplona River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on June 20, 21 and 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 44. The survey started from in Brgy. Masi, Municipality of Pamplona, with coordinates 18°26'18.59735"N, 121°18'29.20376"E, and ended at the mouth of the river in Brgy. Nagtupacan, also in Pamplona with coordinates 18°30'23.39828"N, 121°21'10.40927"E. The control point UP-PAM was used as the GNSS base station all throughout the entire survey.

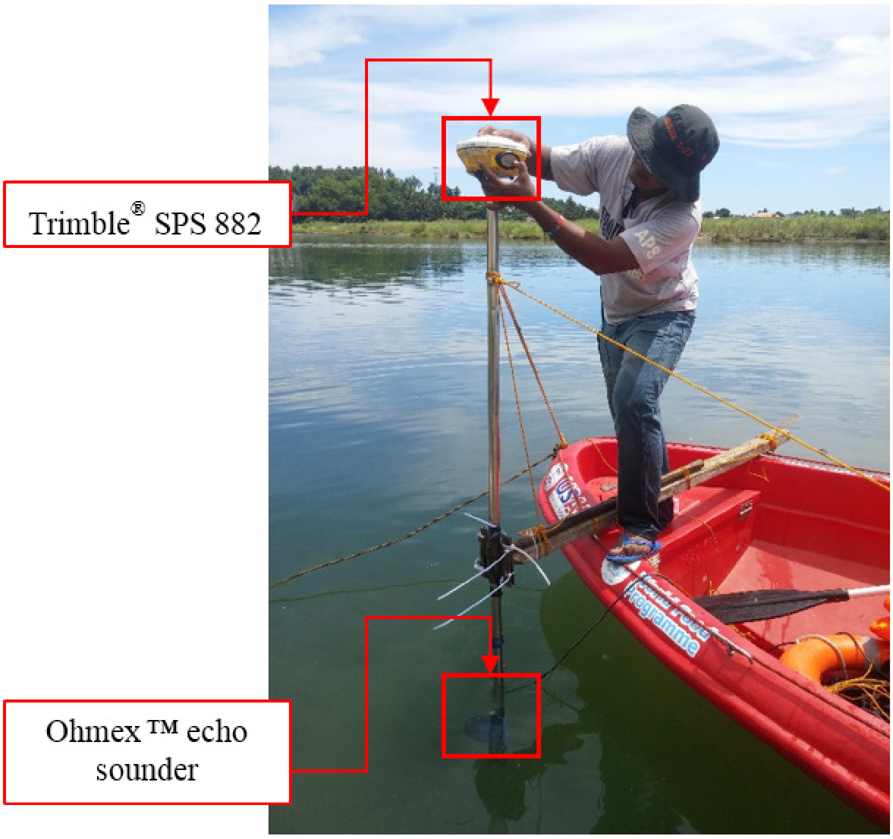


Figure 44. Bathymetric survey using Ohmex™ single beam echo sounder in Pamplona River

The bathymetric survey for Pamplona River gathered a total of 13,521 points covering 13,433 km of the river traversing seven (7) barangays in Municipality of Pamplona illustrated in Figure 45. A CAD drawing was also produced to illustrate the riverbed profile of Cabicungan River. As shown in Figure 46, the highest and lowest elevation has a 10-m difference. The highest elevation observed was -0.198 m above MSL located in Brgy. Masi, while the lowest was -10.516 m below MSL also located in Brgy. Masi, Pamplona.

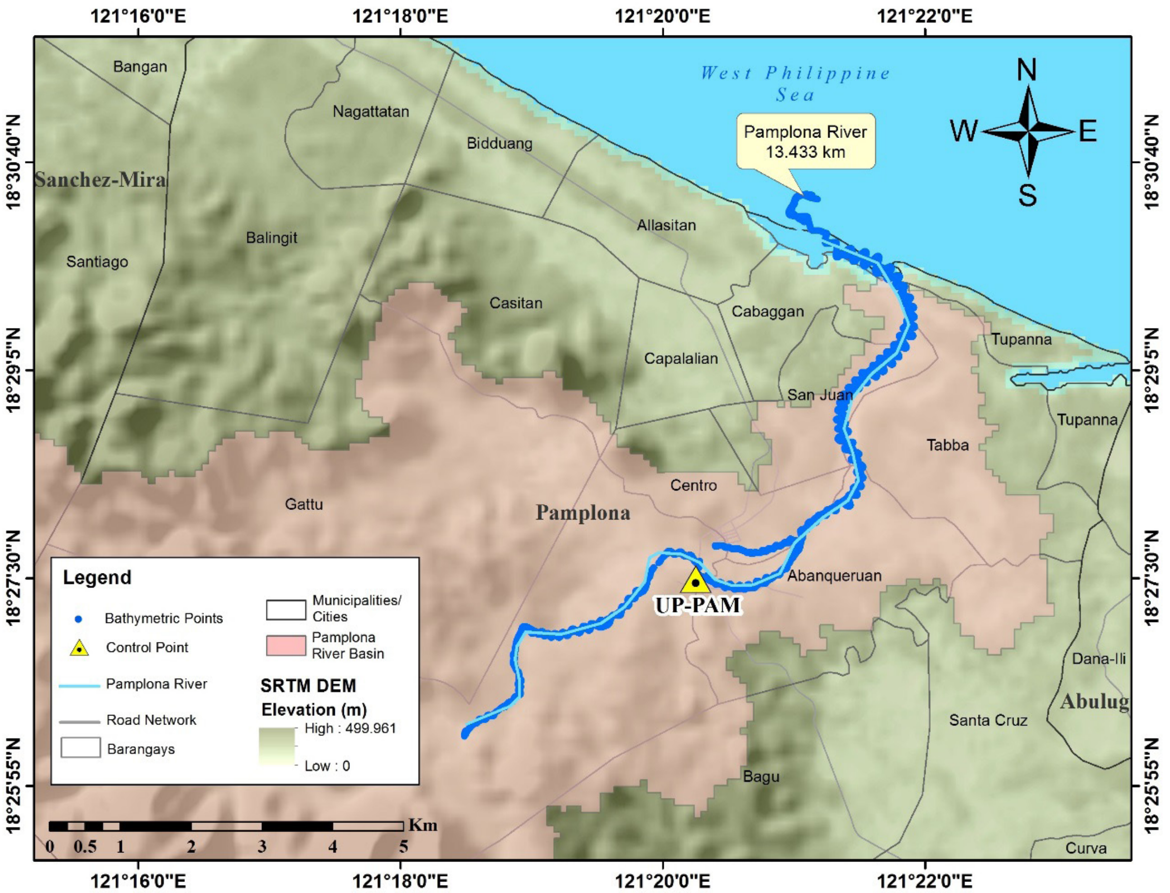


Figure 45. Extent of the Pamplona River Bathymetry Survey

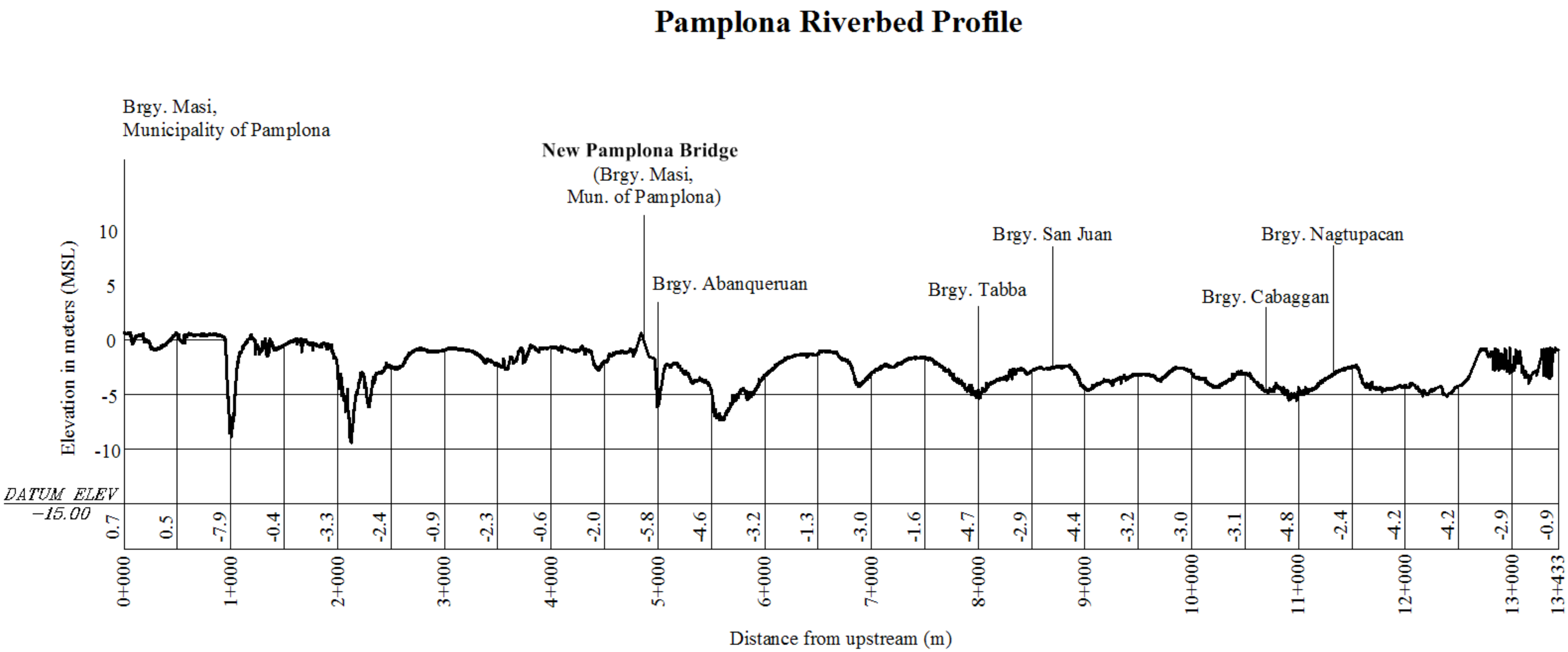


Figure 46. The Pamplona riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Alfredo Mahar Francisco A. Lagmay, Enrico C. Paringit, Dr. Eng., Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil R. 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

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

5.1.2 Precipitation

Cagayan, including the Pamplona River basin, was under Signal No. 2 during the landfall of Tropical Storm Carina last 31 July 2016. The hydrologic data collection covered the period 18:00 on 30 July 2016 until 21:00 on 2 August 2016. Hydrologic data include the river velocity, water depth and rain collected from data logging sensors (mechanical velocity meter, depth gauge and rain gauges) in specific time period. Precipitation data was taken from three automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This was the Pamplona ARG. The location of the rain gauges is seen in Figure 1. Rainfall data were downloaded from the web portal of Philippine E-Science Grid-ASTI (http://repo.pscigrid.gov.ph).

Total rain from Pamplona rain gauge is 67.2 mm. It peaked to 7.2 mm. on 31 July 2016 6:00 A.M. The lag time between the peak rainfall and discharge is thirteen hours and forty minutes. The ARG for Pamplona River Basin is shown in Figure 47.

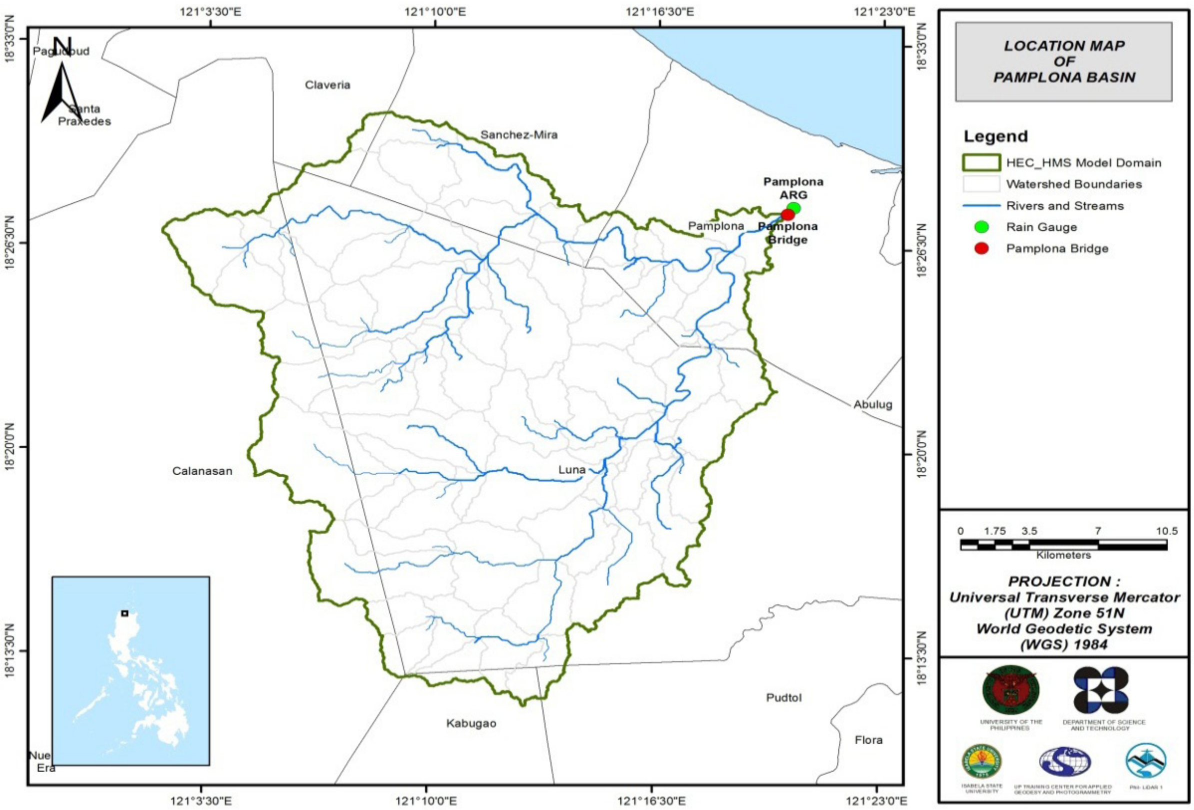


Figure 47. Location map of the Pamplona HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

Tropical Storm Carina that occurred on 30July – 2August 2016 contributed to a 1.35 meter water level rise with peak discharge of 602.6 m3/s recorded at 8:40 PM on 31 July 2016 with accumulated rainfall 67.2mm as shown in Figure 49. These hydrologic data is the actual event of Pamplona River and inputted to hydrologic modeling. Hydrologic measurements were taken from Pamplona Bridge, Masi, Pamplona, Cagayan.

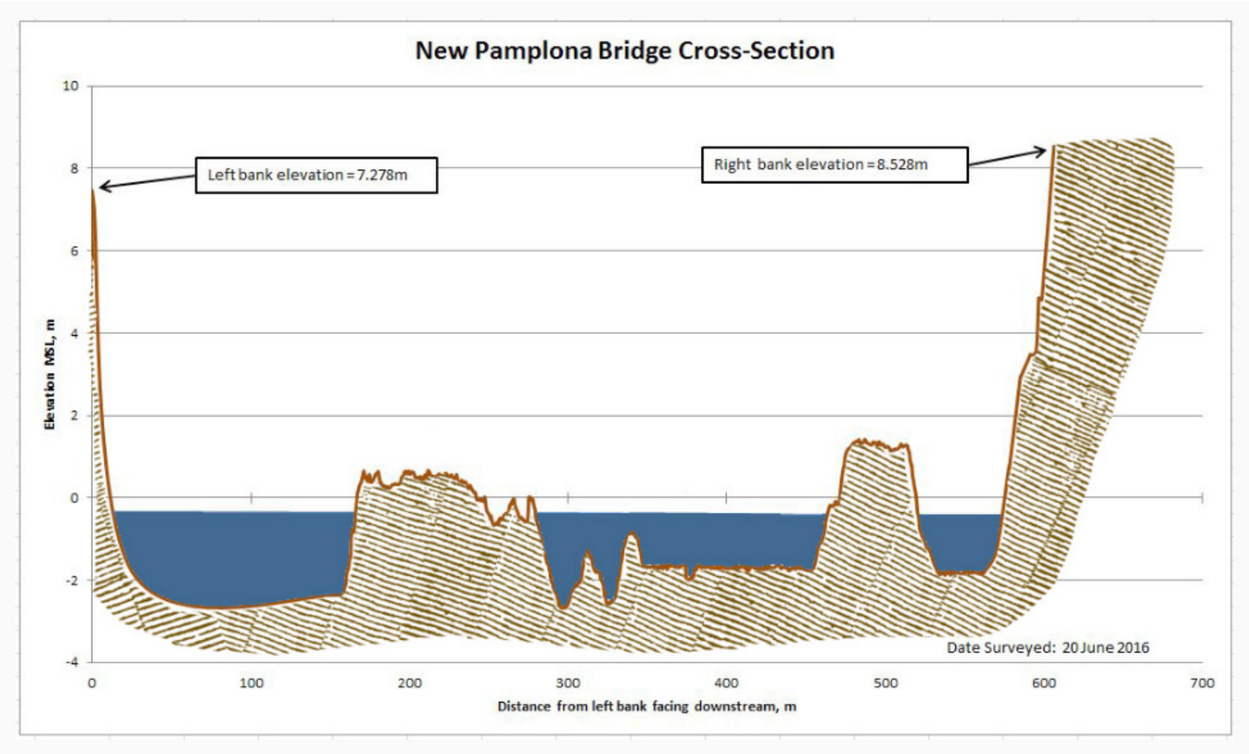


Figure 48. Cross-section plot of Pamplona Bridge

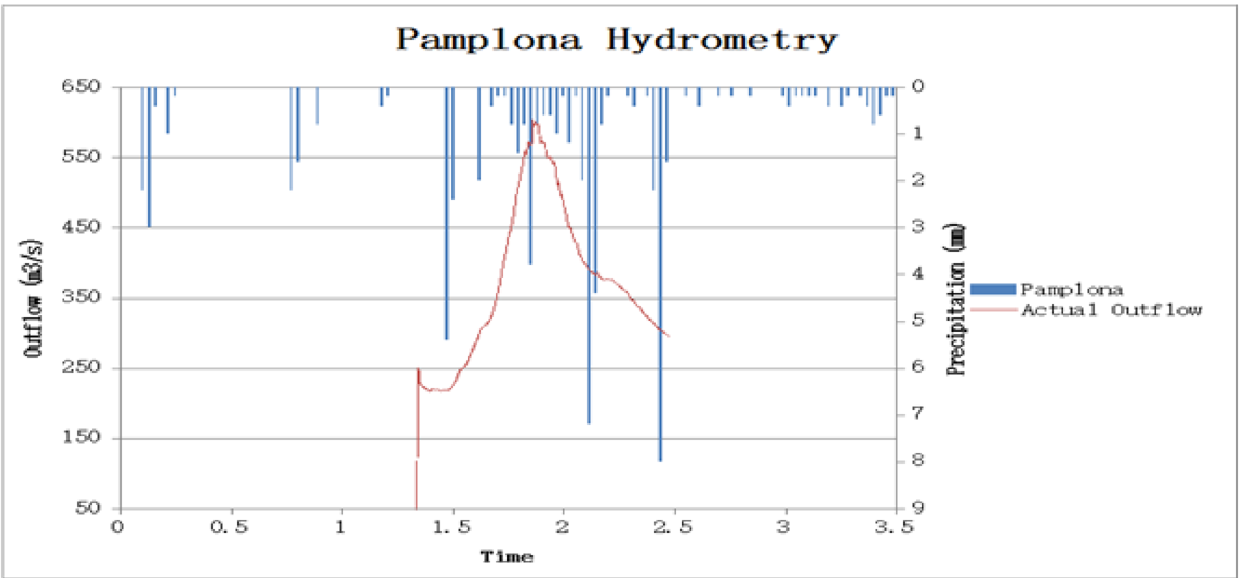


Figure 49. Rainfall and outflow data used for modeling

A rating curve was generated for the observed flow and water level. It shows the relationship of the two hydrologic data. 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.

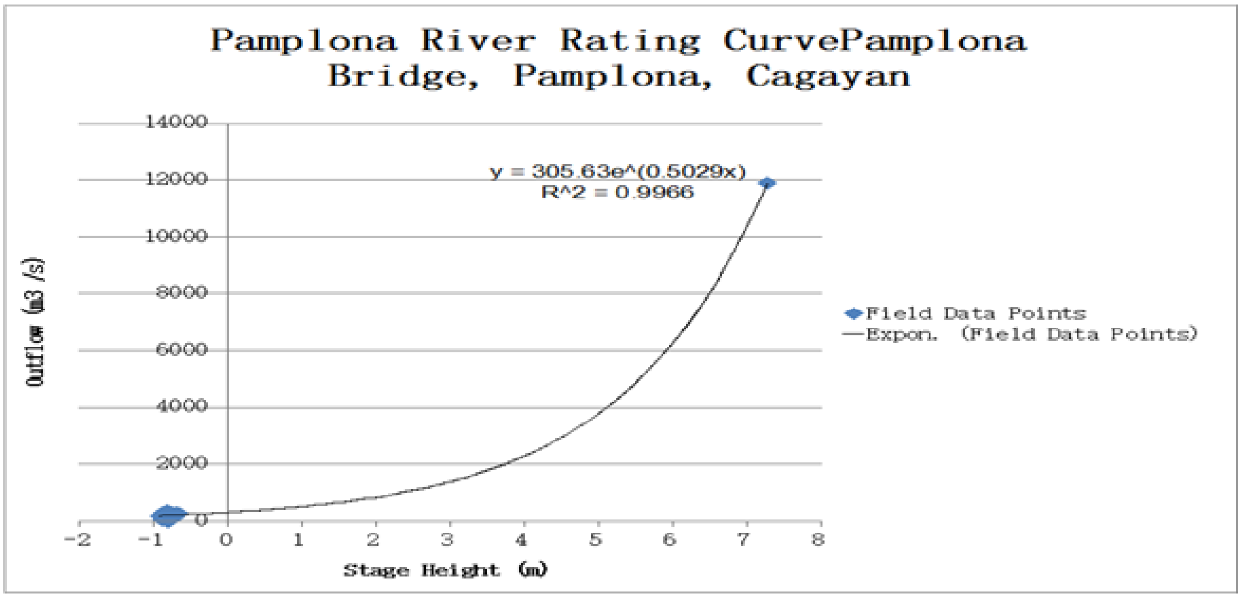


Figure 50. Rainfall and outflow data of Pamplona River Basin, which was used for modeling.

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Aparri Rain Gauge (Table 26). The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time (Figure 52). This station is chosen based on its proximity to the Linao watershed. The extreme values for this watershed were computed based on a 47-year record.

Table 26. RIDF values for 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

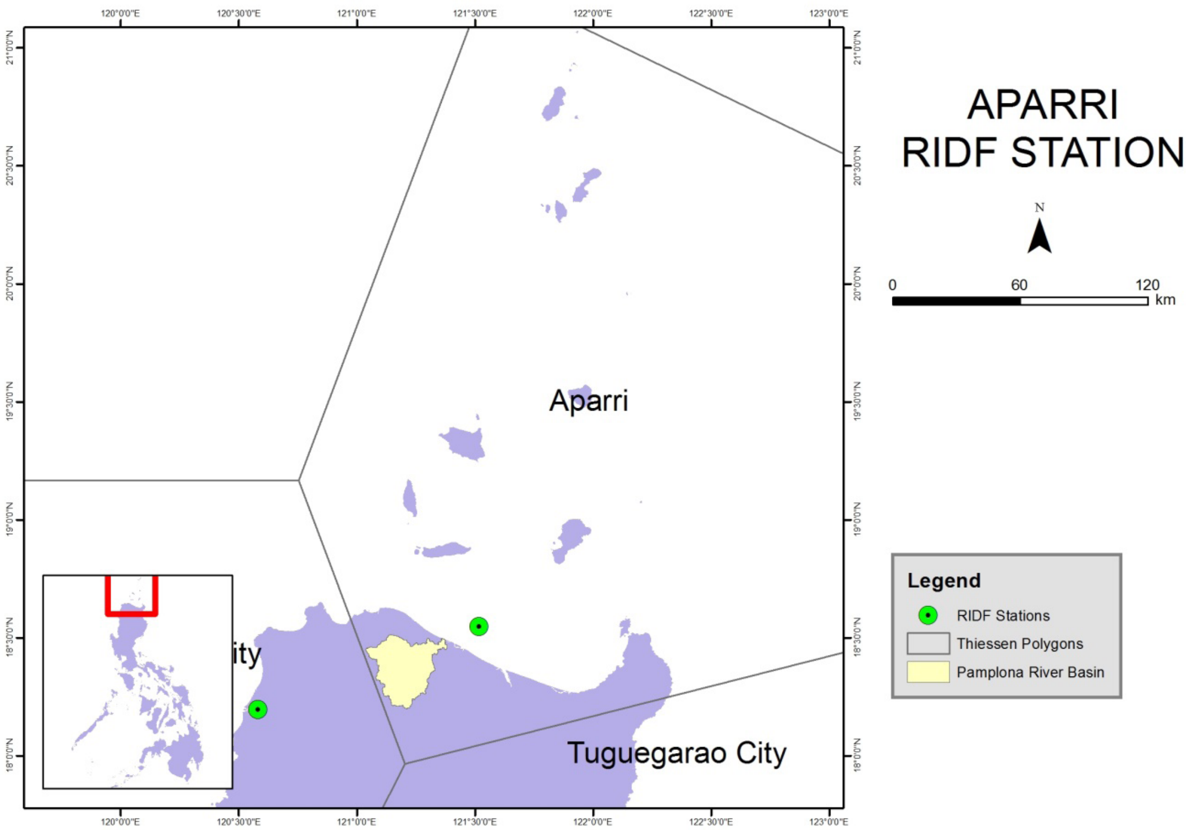


Figure 51. Location of Aparri RIDF Station relative to Pamplona River Basin

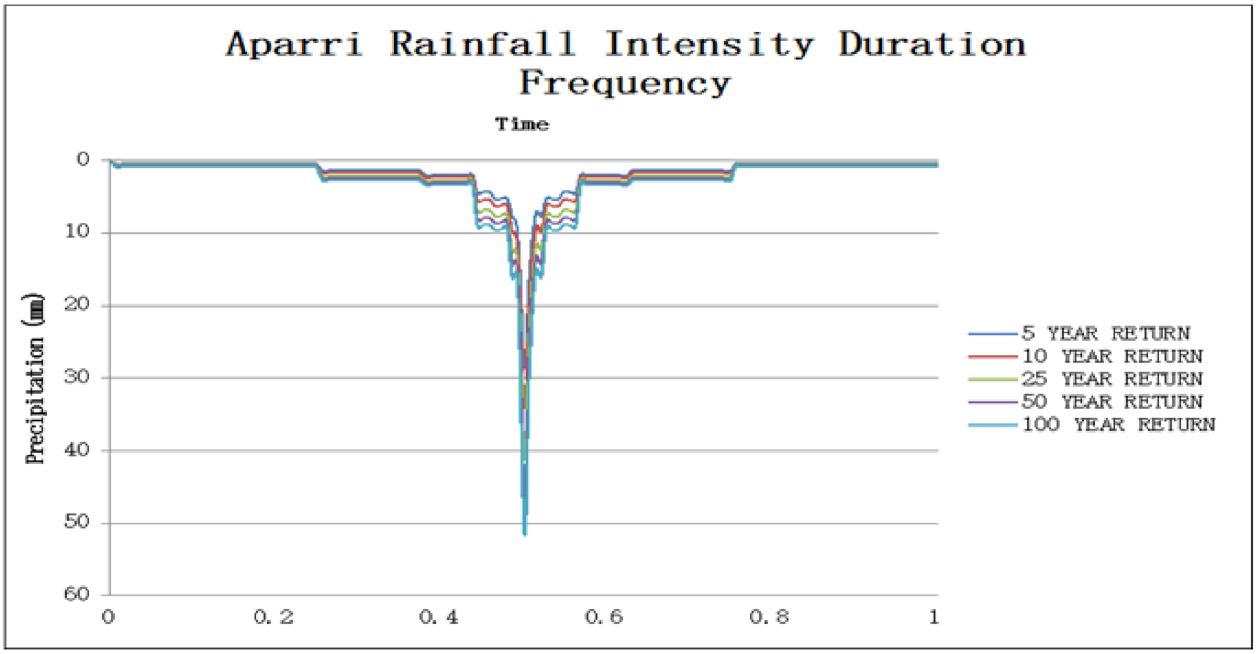


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

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

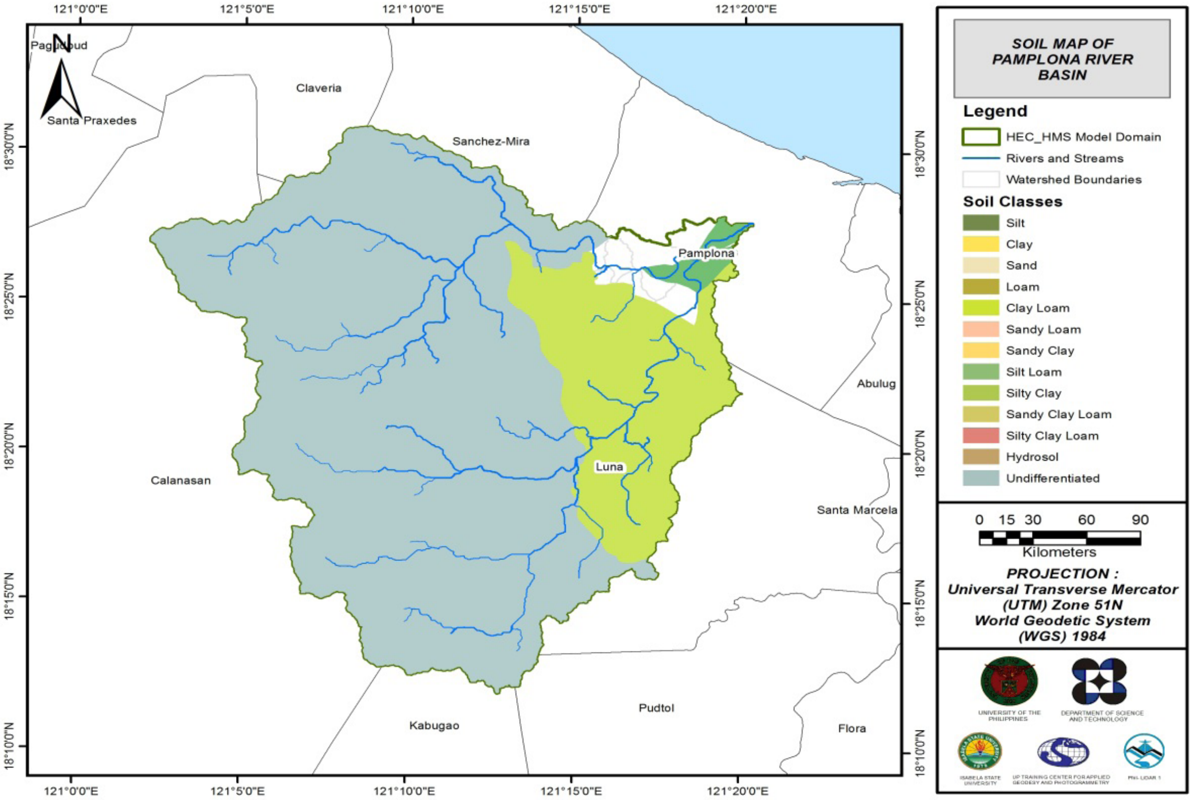


Figure 53. Soil Map of Pamplona River Basin

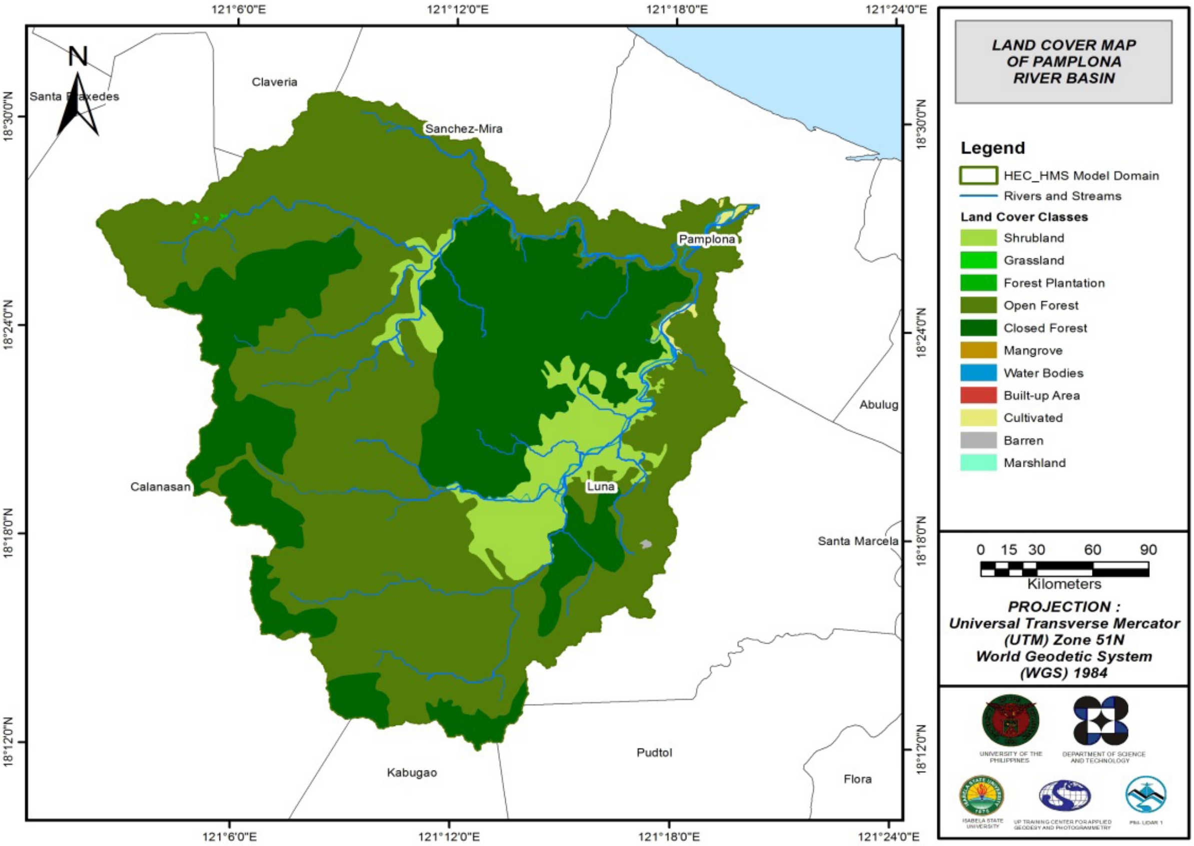


Figure 54. Land Cover Map of Pamplona River Basin

For Pamplona, thirteen soil classes were identified. These aresilt, 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 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.

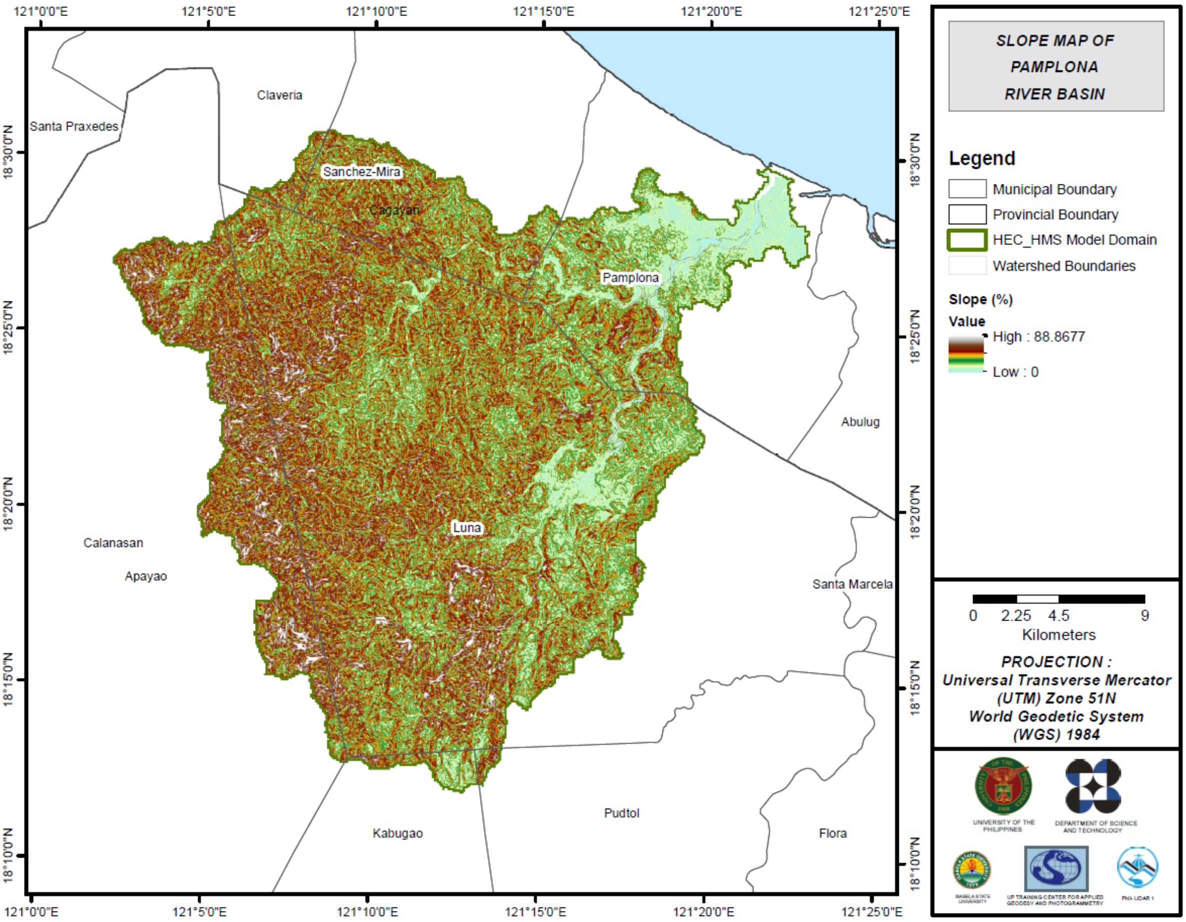


Figure 55. Slope Map of Pamplona River Basin

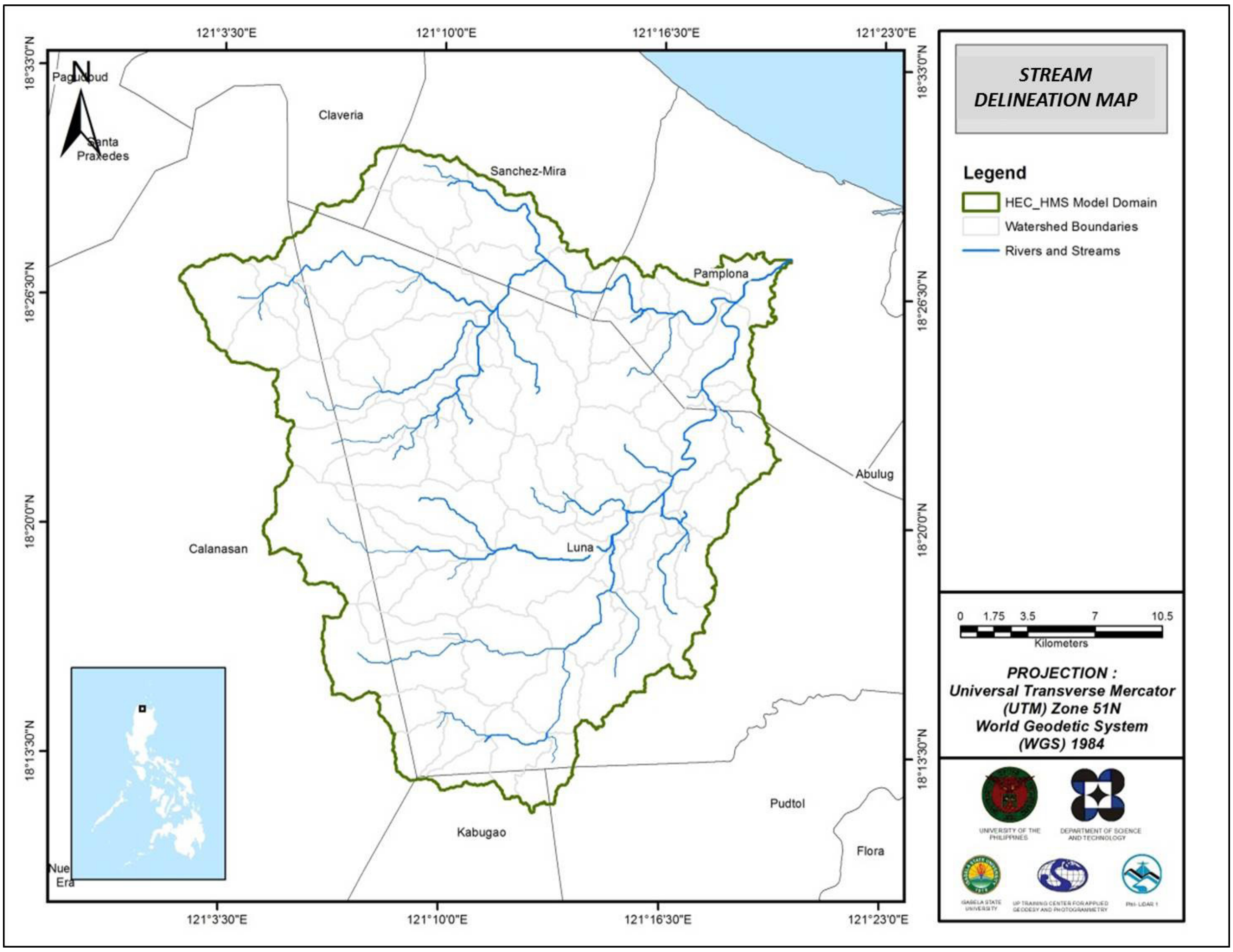


Figure 56. Stream Delineation Map of Pamplona River Basin

A drainage system includes the basin boundary, subbasin and the stream networks of the basin. Using ArcMap 10.2 with HEC-GeoHMS version 10.2 extension, the Pamplona River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the Linao river basin. The river centerline was digitized starting from upstream towards downstream in Google Earth (2014). 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 of 47 sub basins, 23 reaches, and 23 junctions. The main outlet is Outlet 1. This basin model is illustrated in Figure 57. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 9-11 February 2017 (Monsoon Rain) was taken from DOST rain gauges and Portable Rain Gauge. Finally, it was calibrated using data from the Pamplona depth gauge sensor.

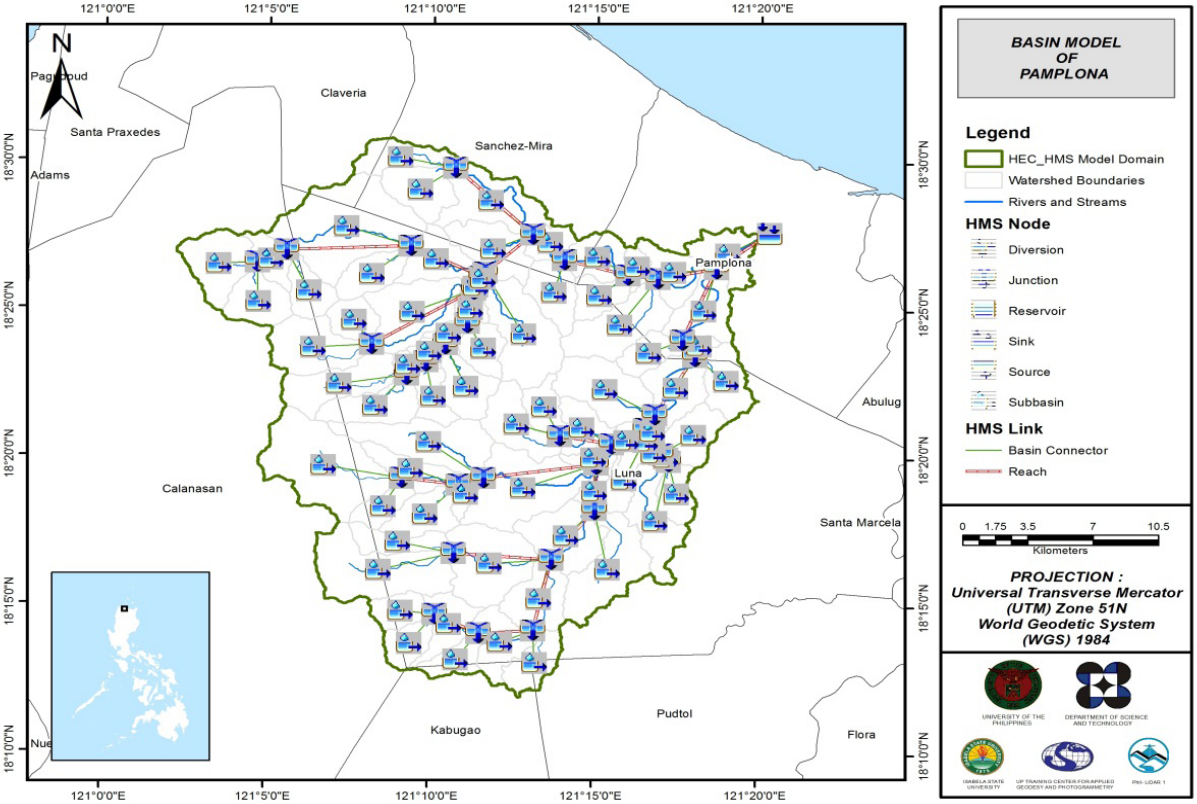


Figure 57. Pamplona River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS. This is illustrated in Figure 58.

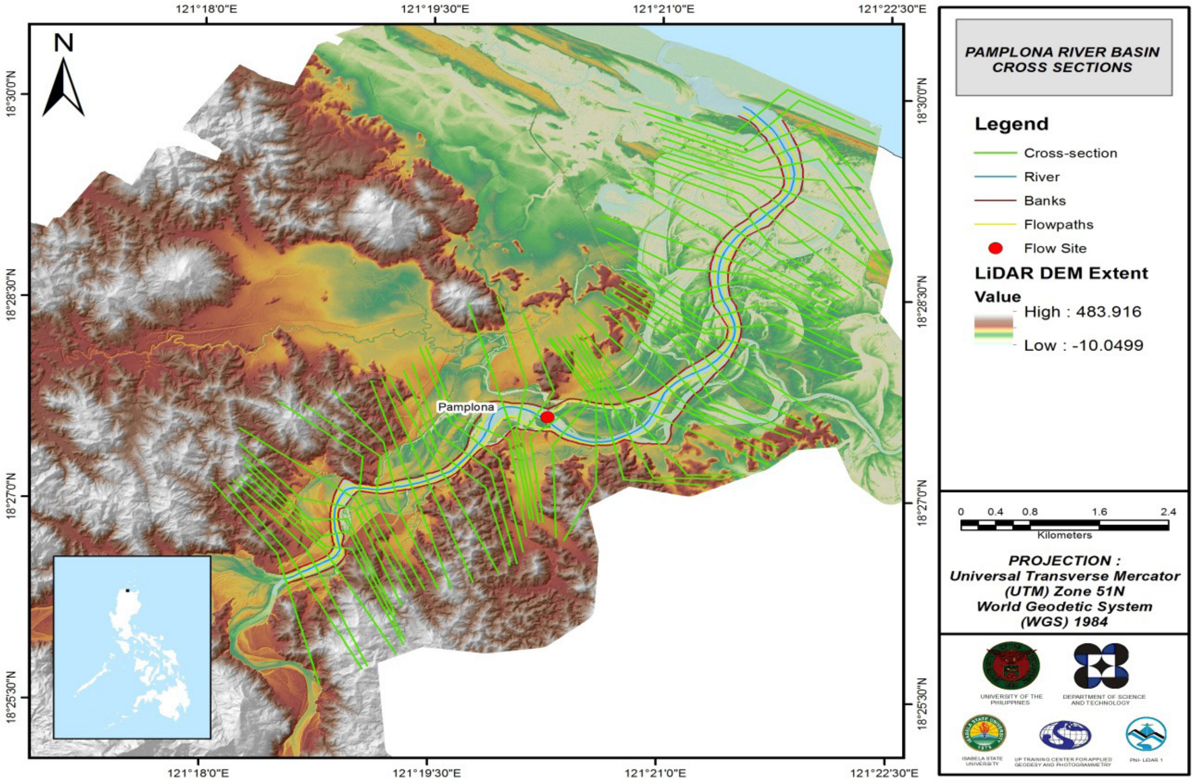


Figure 58. Linao River Cross-section generated using HEC GeoRAS tool.

5.5 Flo 2D Model

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

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

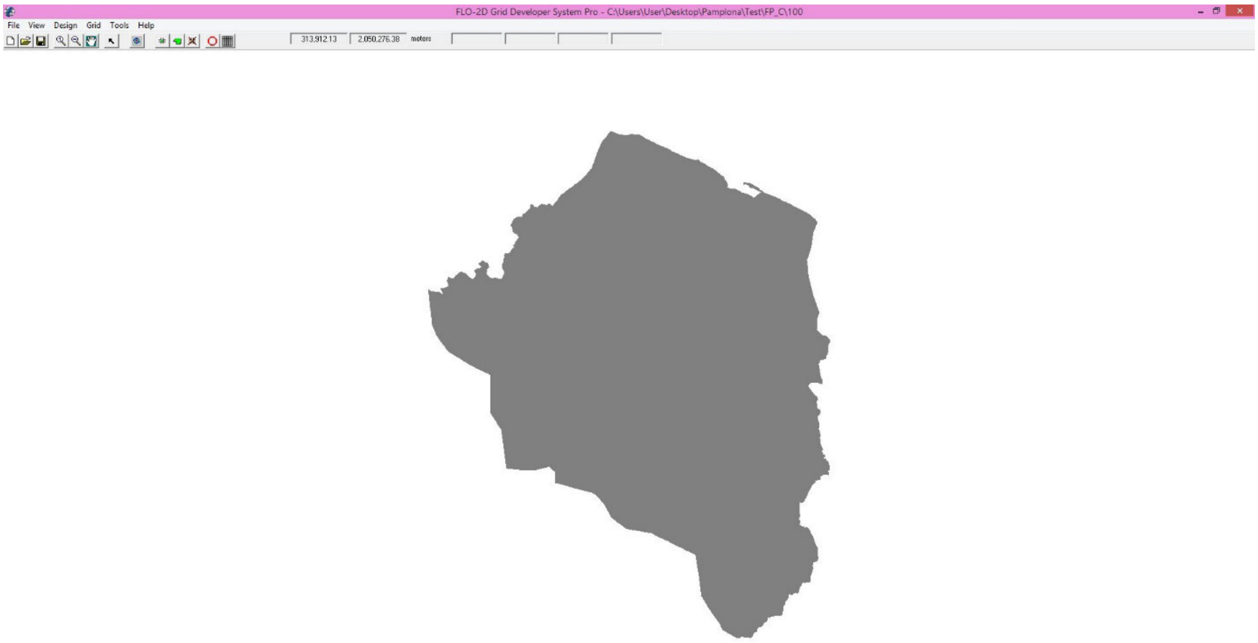


Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro as shown in Figure 59. This particular model had a computer run time of 39.55225 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 39 385 900.00 m2.

There is a total of 18 419 757.72 m3 of water entering the model. Of this amount, 10 725 727.85 m3 is due to rainfall while 7 694 029.87 m3 is inflow from other areas outside the model. 3 960 626.75 m3 of this water is lost to infiltration and interception, while 12 447 417.07 m3 is stored by the flood plain. The rest, amounting up to 2 011 714.06 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Pamplona HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 12 shows the comparison between the two discharge data.

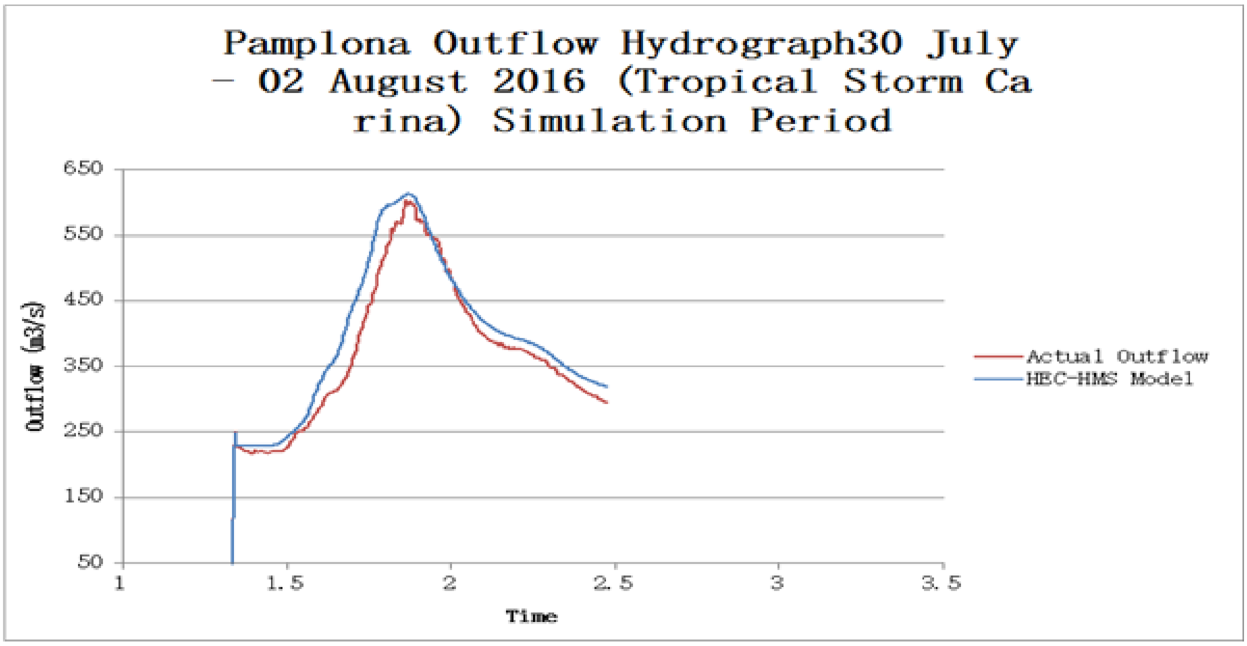


Figure 60. Outflow hydrograph of Pamplona produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 27 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of calibrated values for the Pamplona River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2 – 7.15
			Curve Number	77 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.31768 – 4.5
			Storage Coefficient (hr)	0.51468 - 7
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.37
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.023

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 2mm to 7.15mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 77 to 99 for curve number exceeds the advisable range of values for Philippine watersheds (70mm – 80mm) depending on the soil and land cover of the area. For Pamplona, the basin mostly consists of shrubland, open forest, and closed forest and the soil consists mostly of clay loam and undifferentiated soil.

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 0.32 hours to 7 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.37 indicates a steeper receding limb of the outflow hydrograph.
Manning's roughness coefficient of 0.023 is lies between the roughness coefficient for built up area (0.015) and grassland (0.03). (Brunner 2010)

Table 28. Summary of the Efficiency Test of the Pamplona HMS Model

Accuracy measure	Value
RMSE	32.5
r2	0.9651
NSE	0.90
PBIAS	-7.13
RSR	0.32

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 32.5 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9651.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.90.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -7.13.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.32.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Pamplona River outflow using the Aparri Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

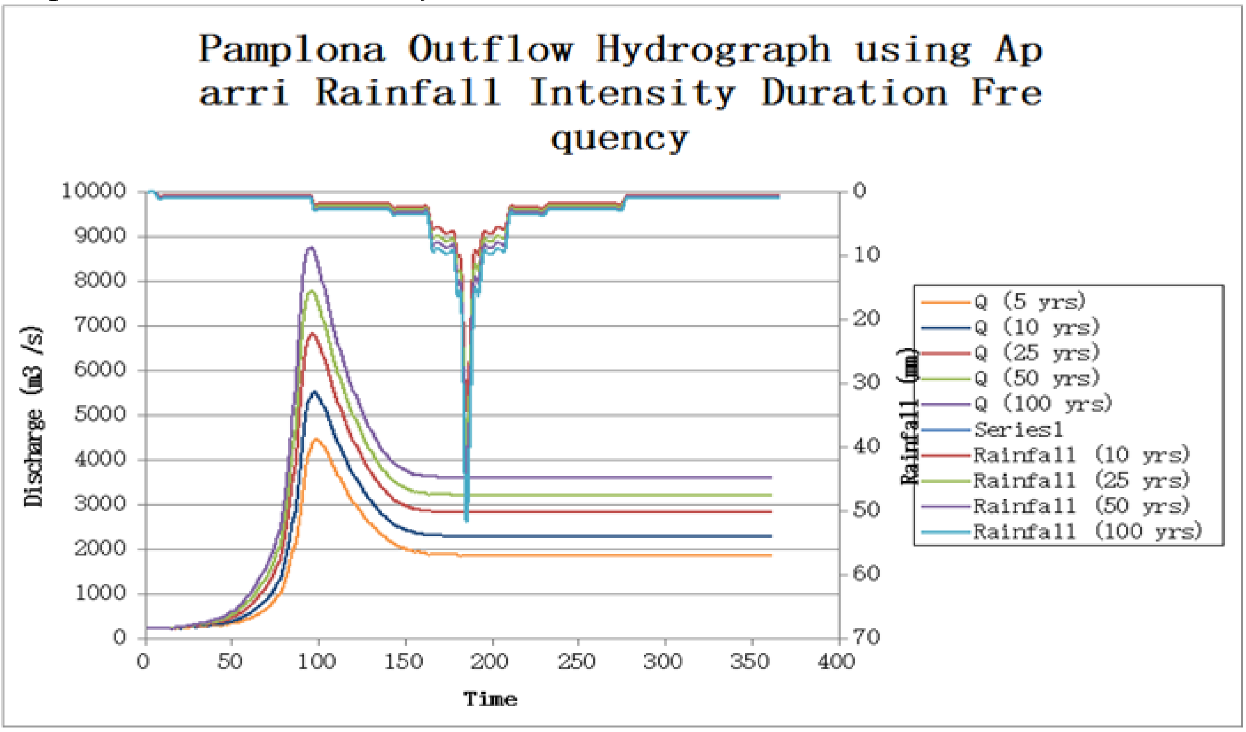


Figure 61. The Outflow hydrograph at the Pamplona Station generated using Aparri RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Pamplona discharge using the Aparri Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 29.

Table 29. Peak values of the Pamplona HEC-HMS Model outflow using the Aparri RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	252.5	28.5	4466.2	4 hours, 10 minutes
10-Year	308.5	34.1	5509.3	4 hours
25-Year	379.3	41.1	6825.0	3 hours, 50 minutes
50-Year	431.9	46.3	7790.0	3 hours, 50 minutes
100-Year	484	51.4	8756.6	3 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Pamplona River using the calibrated HMS base flow is shown in Figure 62.

Figure 62. Sample output map of Pamplona RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 63 to Figure 68 shows the 5-, 25-, and 100-year rain return scenarios of the Pamplona floodplain. The floodplain, with an area of 254.91 sq. km., covers four municipalites namely Pamplona, Sanchez-Mira, Calanasan, and Luna. Table 30 shows the percentage of area affected by flooding per municipality.

Table 30. Municipalities affected in Pamplona Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Pamplona	213.08	149.28	70.06%
Sanchez-Mira	138.32	9.27	6.70%
Calanasan	1363.72	7.07	0.52%
Luna	320.66	89.26	27.84%

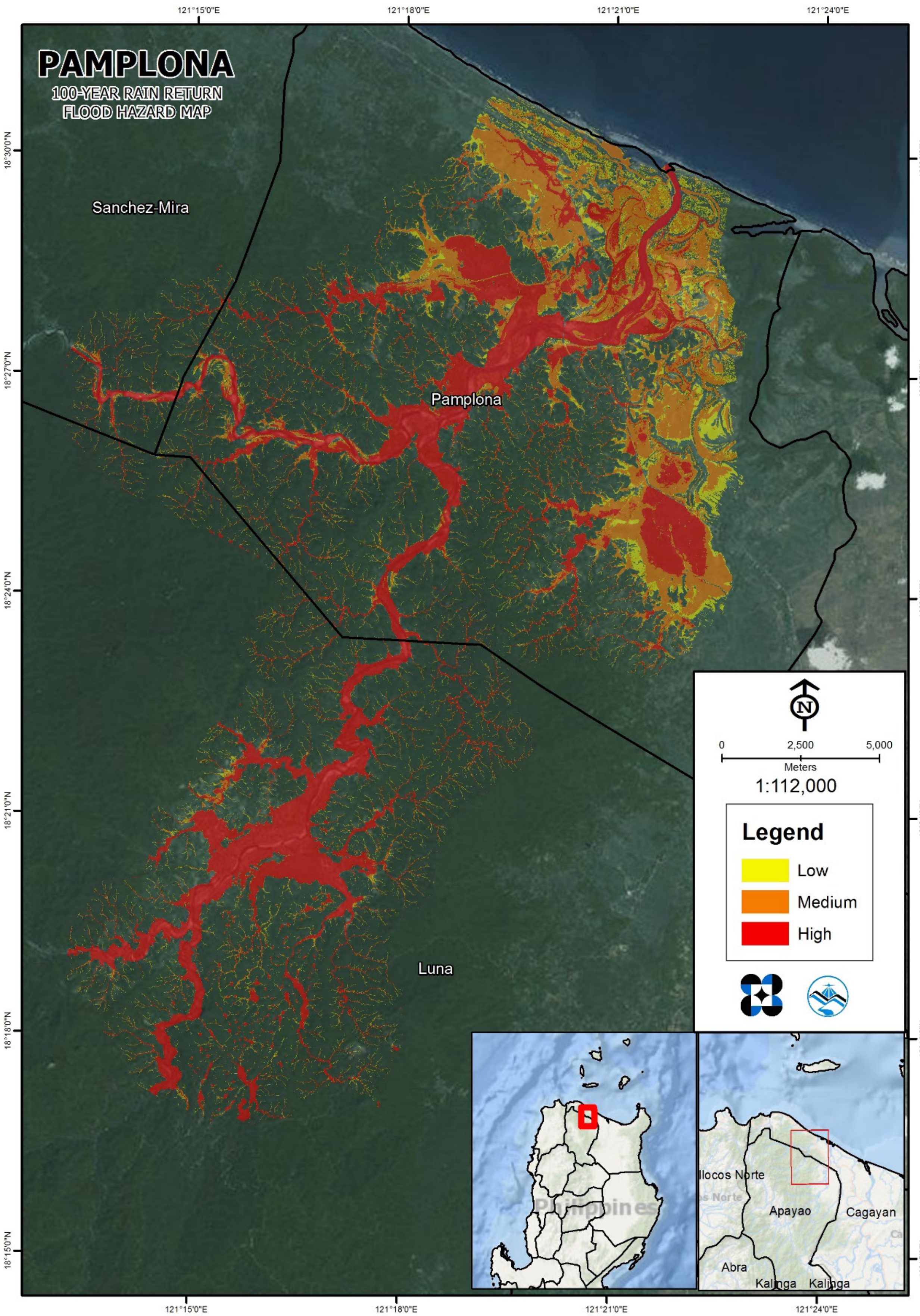


Figure 63. A 100-year flood hazard map for Pamplona Floodplain

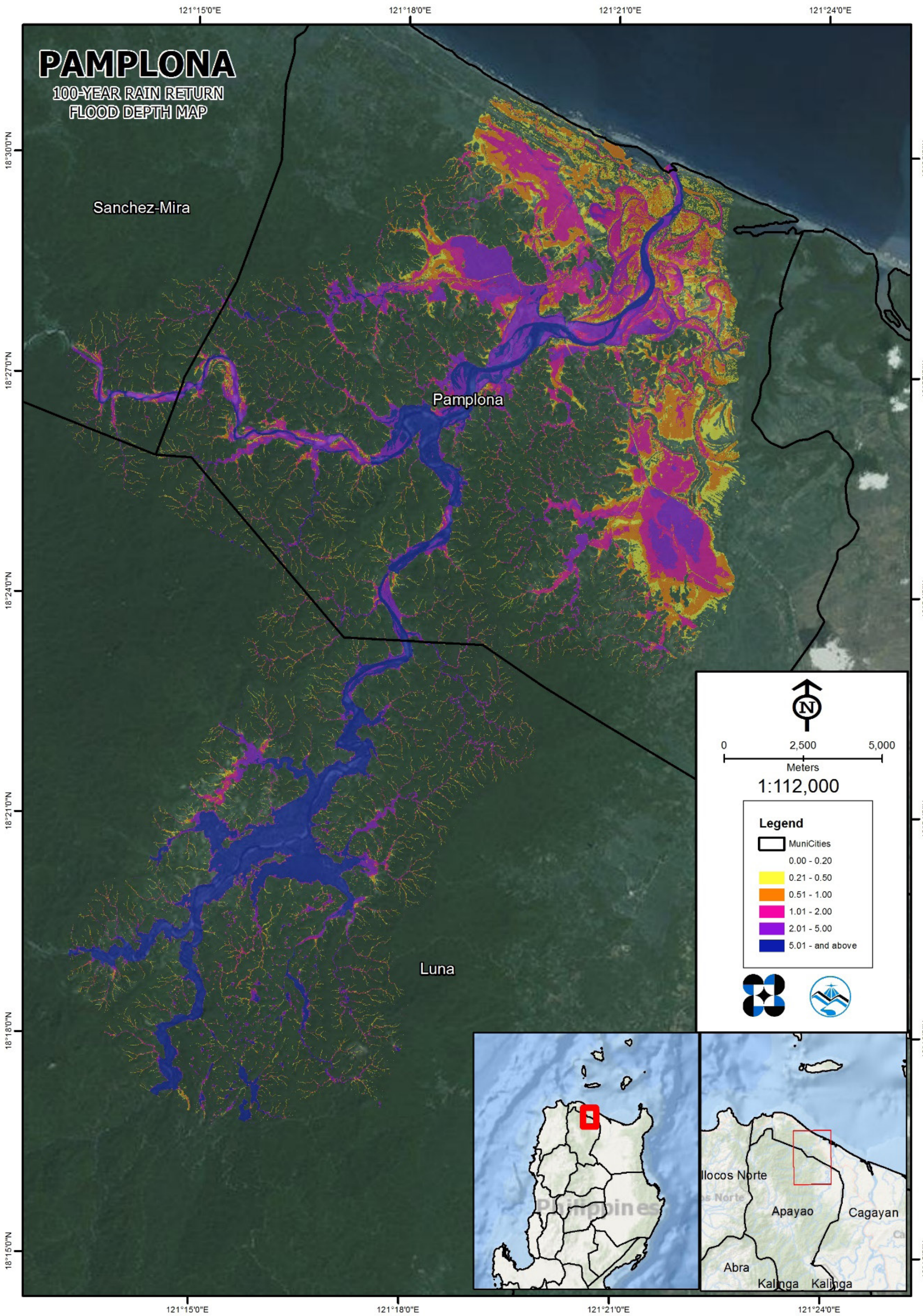


Figure 64. A 100-year Flow Depth Map for Pamplona Floodplain

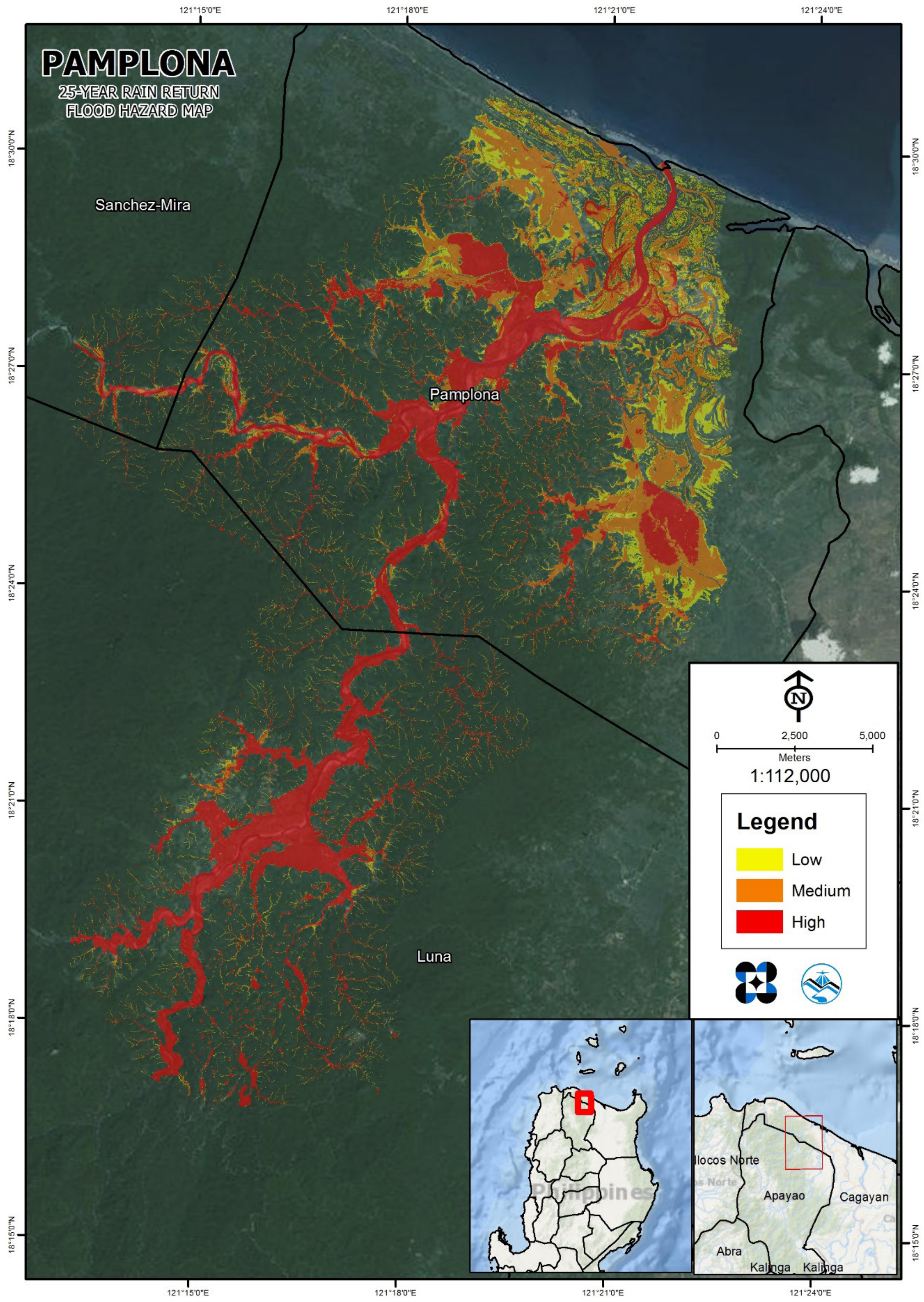


Figure 65. A 25-year Flood Hazard Map for Pamplona Floodplain

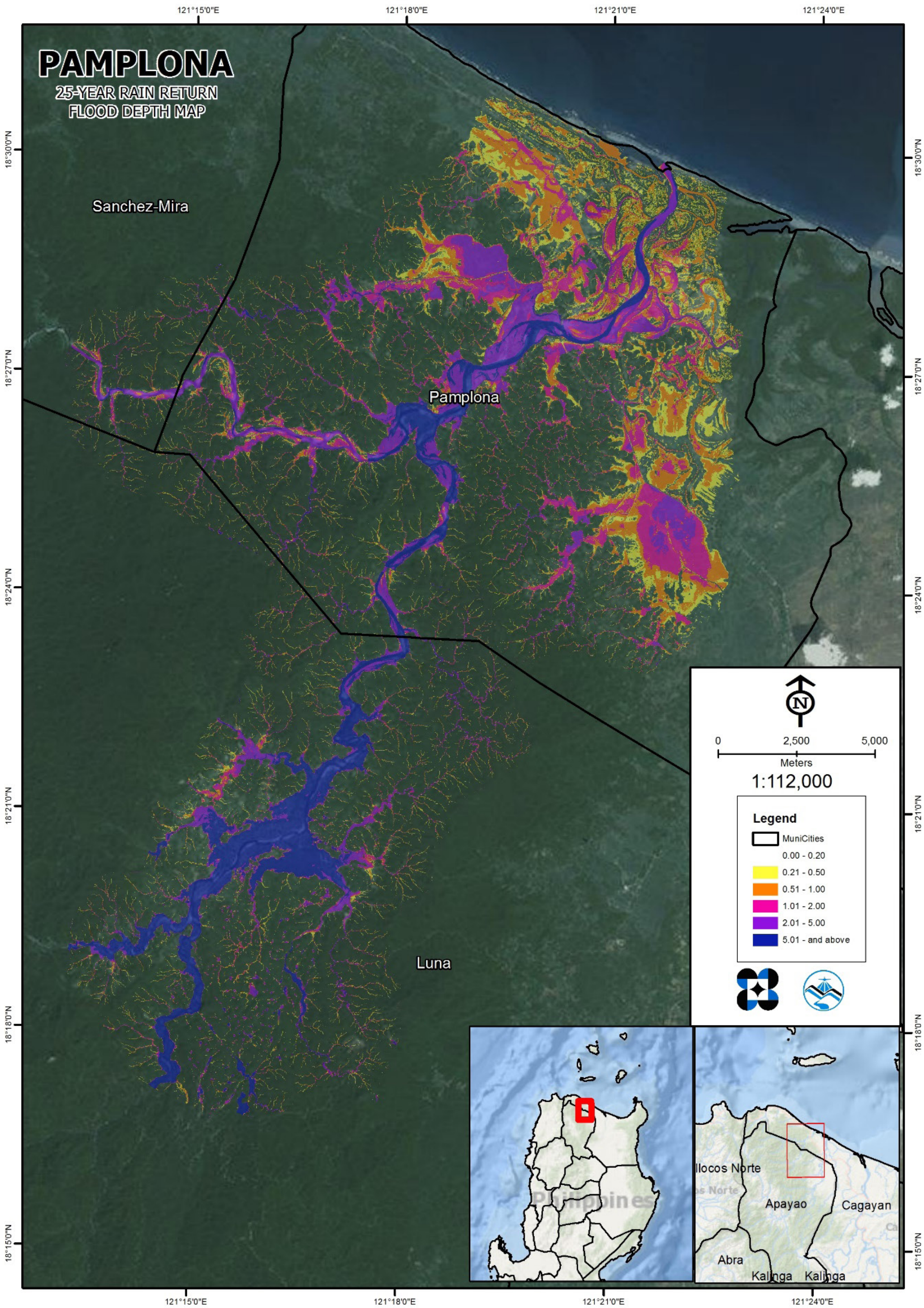


Figure 66. A 25-year Flow Depth Map for Pamplona Floodplain

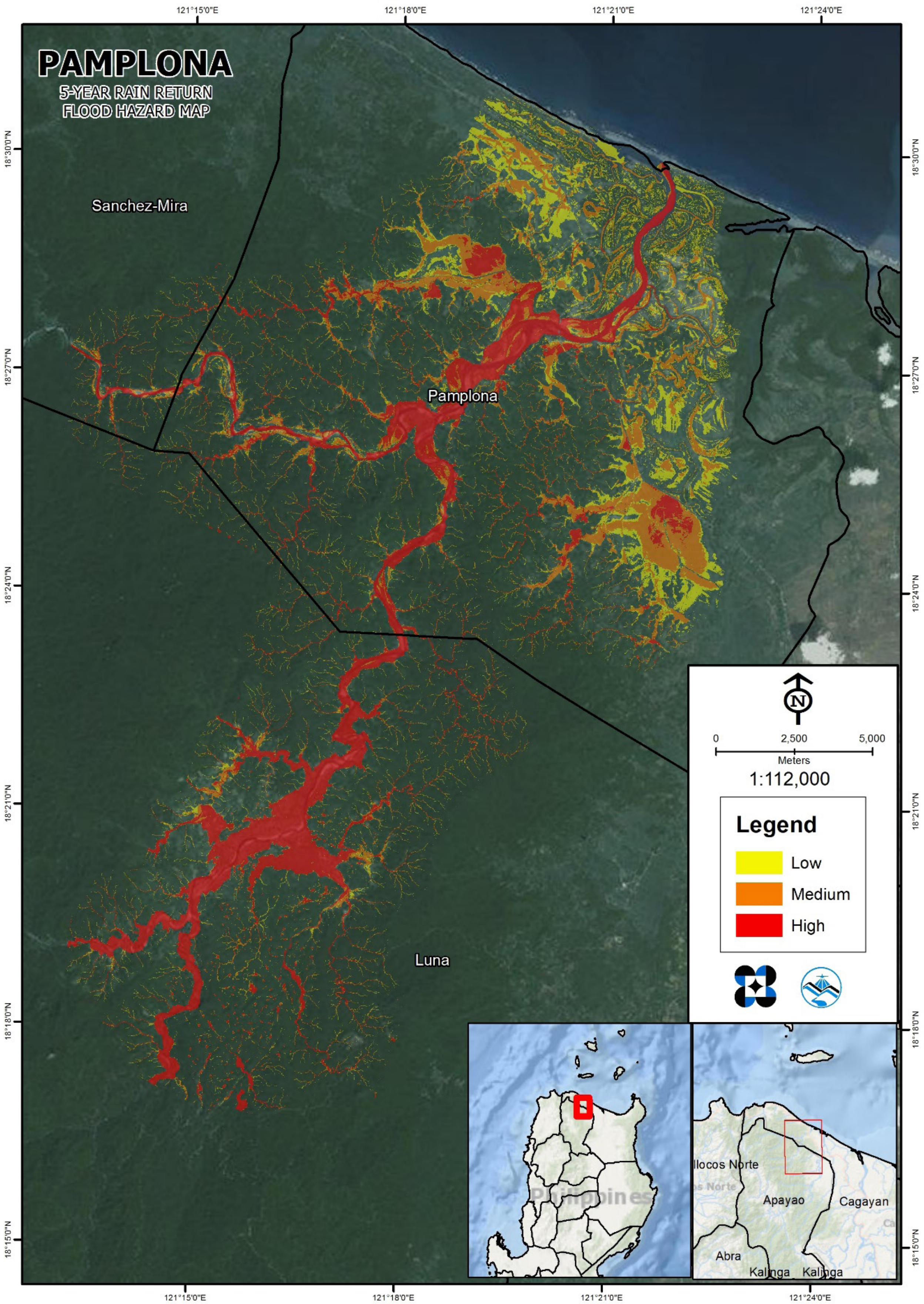


Figure 67. A 5-year Flood Hazard Map for Pamplona Floodplain

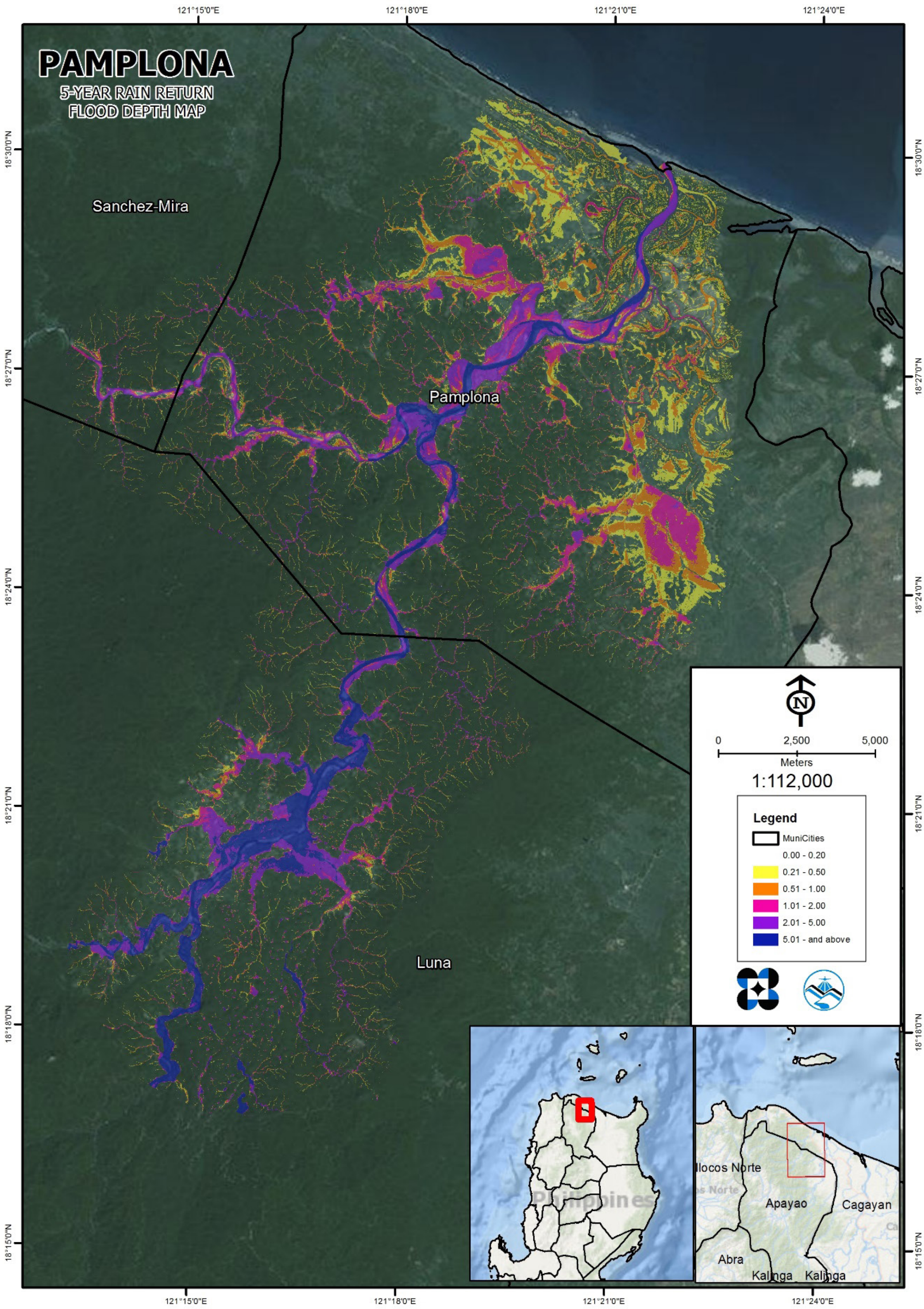


Figure 68. A 5-year Flow depth map for Pamplona Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Pamplona river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 27 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 13.06% of the municipality of Luna with an area of 603.007571 sq. km. will experience flood levels of less than 0.20 meters. 0.37% of the area will experience flood levels of 0.21 to 0.50 meters while 0.27%, 0.34%, 0.78%, and 1.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 31. Affected areas in Luna, Apayao during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km.)							
	Cagan-dungan	Calabigan	Lappa	Luyon	Marag	Shalom	Turod	Zumigui
0.03-0.20	9.42	14.2	7.99	10.86	12.44	2.19	18.58	3.08
0.21-0.50	0.39	0.35	0.3	0.27	0.33	0.06	0.44	0.094
0.51-1.00	0.34	0.19	0.27	0.19	0.23	0.035	0.31	0.069
1.01-2.00	0.52	0.19	0.42	0.22	0.24	0.03	0.32	0.12
2.01-5.00	1.05	0.39	1.32	0.38	0.96	0.069	0.4	0.13
> 5.00	1.19	0.26	1.52	0.44	2.57	0.1	0.33	0.082

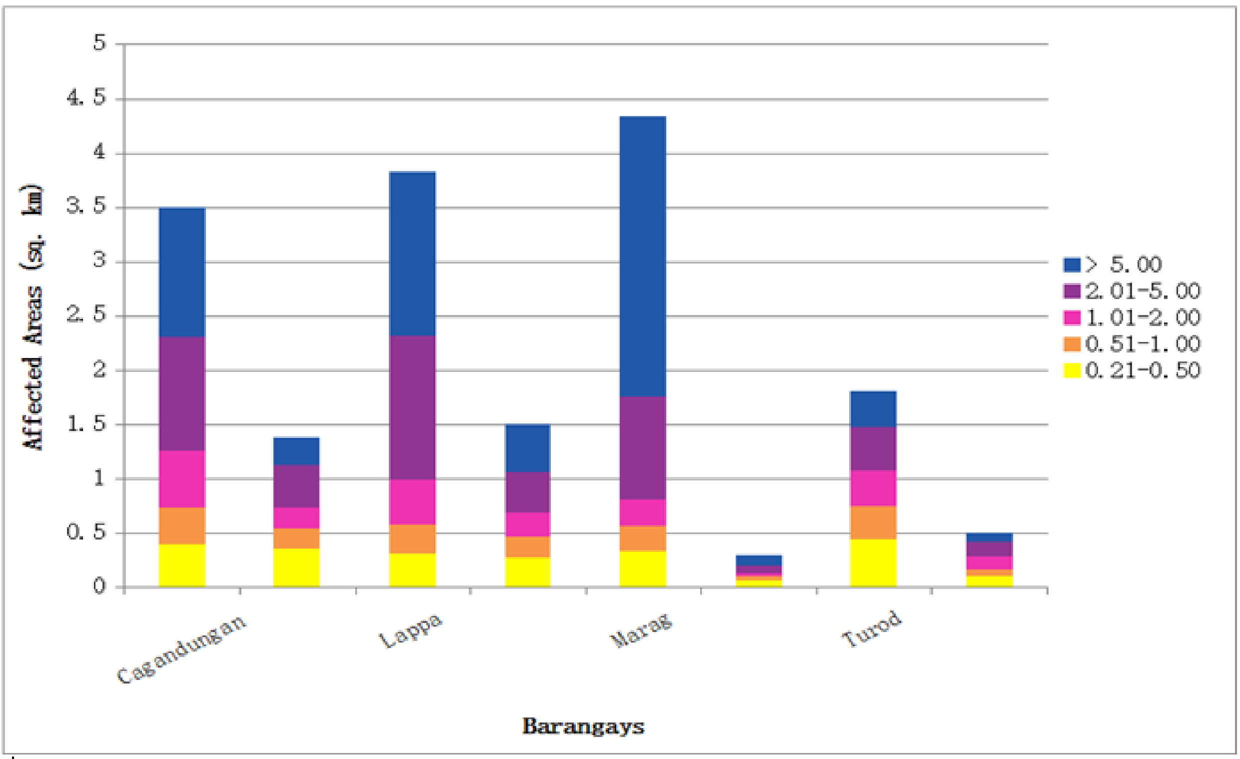


Figure 69. Affected Areas in Luna, Apayao during 5-Year Rainfall Return Period

For the 5-year return period, 51.75% of the municipality of Pamplona with an area of 206.545139 sq. km. will experience flood levels of less than 0.20 meters. 6.68% of the area will experience flood levels of 0.21 to 0.50 meters while 4.83%, 4.03%, 3.05%, and 1.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 32. Affected Areas in Pamplona, Cagayan during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pamplona (in sq. km.)								
	Abanqueruan	Allasitan	Bagu	Balingit	Bidduang	Cabaggan	Capalalian	Casitan	Centro
0.03-0.20	4.33	2.28	23.59	0.027	0.26	1.97	1.38	4.75	2.25
0.21-0.50	0.66	0.97	1.95	0.0004	0.11	0.53	0.79	0.78	0.48
0.51-1.00	0.56	0.52	1.46	0.00075	0.0076	0.21	0.28	0.47	0.27
1.01-2.00	0.5	0.1	1.11	0.00076	0.0004	0.11	0.064	0.17	0.16
2.01-5.00	0.33	0.0003	0.91	0.0004	0	0.047	0	0.024	0.15
> 5.00	0.29	0	0.46	0	0	0.0041	0	0	0.082

Table 33. Affected Areas in Pamplona, Cagayan during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pamplona (in sq. km.)							
	Curva	Gattu	Masi	Nagtupacan	San Juan	Santa Cruz	Tabba	Tupanna
0.03-0.20	2.33	14.94	30.17	0.13	2.09	12.63	3.34	0.41
0.21-0.50	0.71	1.1	1.38	0.13	0.55	2.58	1.02	0.062
0.51-1.00	0.55	1.32	1.34	0.0072	0.31	2.21	0.45	0.013
1.01-2.00	0.15	1.58	2.18	0	0.14	2	0.049	0.0017
2.01-5.00	0.02	0.86	3.51	0	0.27	0.13	0.046	0.011
> 5.00	0.0009	0.046	1.58	0	0.066	0.0009	0.044	0

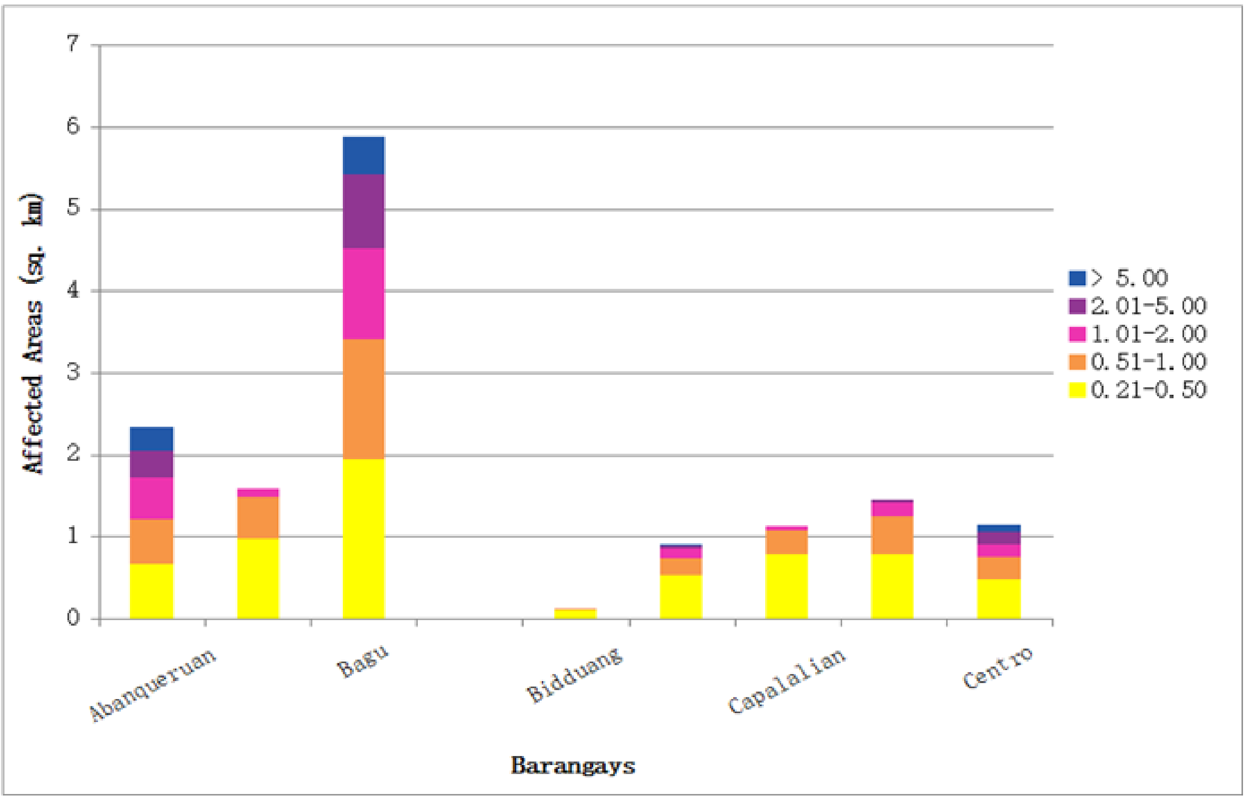


Figure 70. Affected Areas in Pamplona, Cagayan during 5-Year Rainfall Return Period

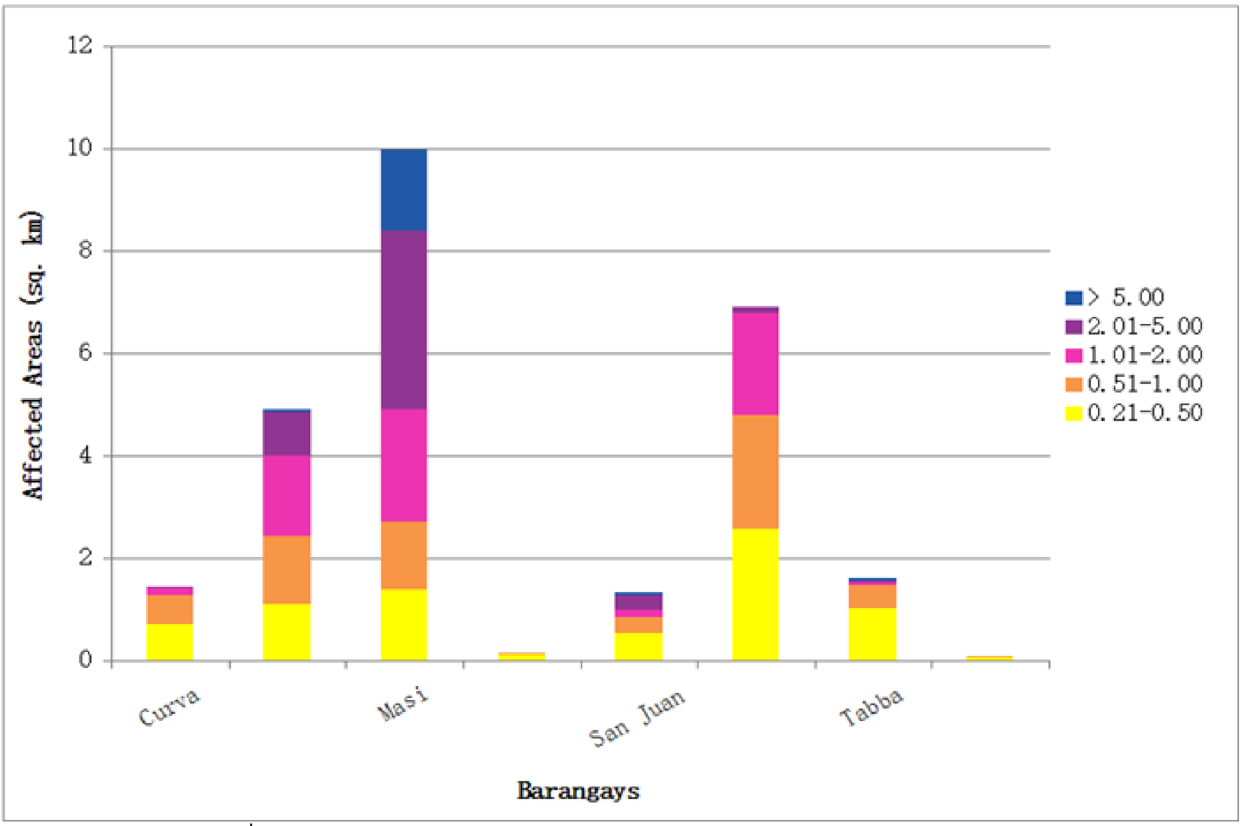


Figure 71. Affected Areas in Pamplona, Cagayan during 5-Year Rainfall Return Period

For the 5-year return period, 4.74% of the municipality of Sanchez-Mira with an area of 205.308857 sq. km. will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.14%, and 0.16% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected areas in Sanchez-Mira, Cagayan during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sanchez-Mira (in sq. km.)	
	Kittag	Santiago
0.03-0.20	1.07	8.67
0.21-0.50	0.034	0.27
0.51-1.00	0.019	0.22
1.01-2.00	0.044	0.24
2.01-5.00	0.011	0.32
> 5.00	0.0008	0.0033

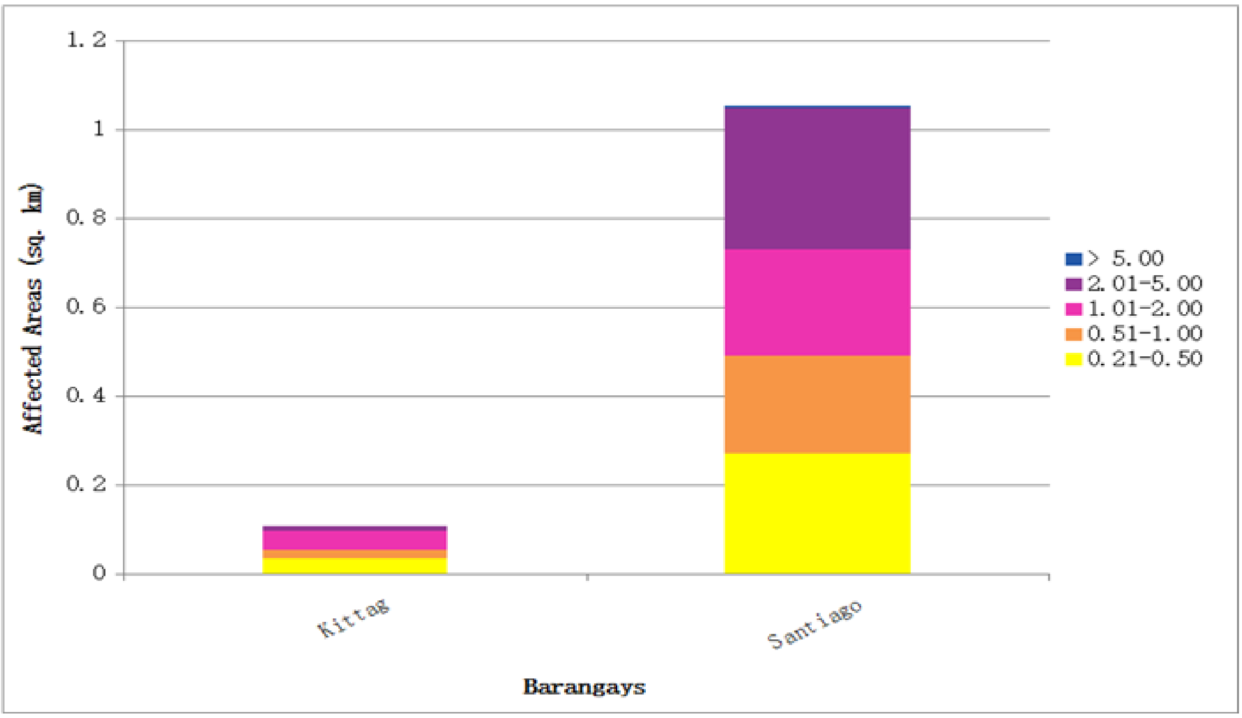


Figure 72. Affected Areas in Sanchez-Mira, Cagayan during 5-Year Rainfall Return Period

For the 25-year return period, 12.73% of the municipality of Luna with an area of 603.007571 sq. km. will experience flood levels of less than 0.20 meters. 0.40% of the area will experience flood levels of 0.21 to 0.50 meters while 0.27%, 0.30%, 0.58%, and 1.62% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Luna, Apayao during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km.)							
	Cagan-dungan	Calabigan	Lappa	Luyon	Marag	Shalom	Turod	Zumigui
0.03-0.20	9.11	14.02	7.57	10.7	12.09	2.12	18.16	3.01
0.21-0.50	0.38	0.39	0.29	0.29	0.35	0.067	0.52	0.11
0.51-1.00	0.29	0.22	0.21	0.21	0.23	0.044	0.35	0.071
1.01-2.00	0.38	0.17	0.3	0.21	0.24	0.032	0.36	0.089
2.01-5.00	0.84	0.36	0.76	0.35	0.47	0.064	0.5	0.16
> 5.00	1.91	0.41	2.68	0.6	3.39	0.17	0.48	0.13

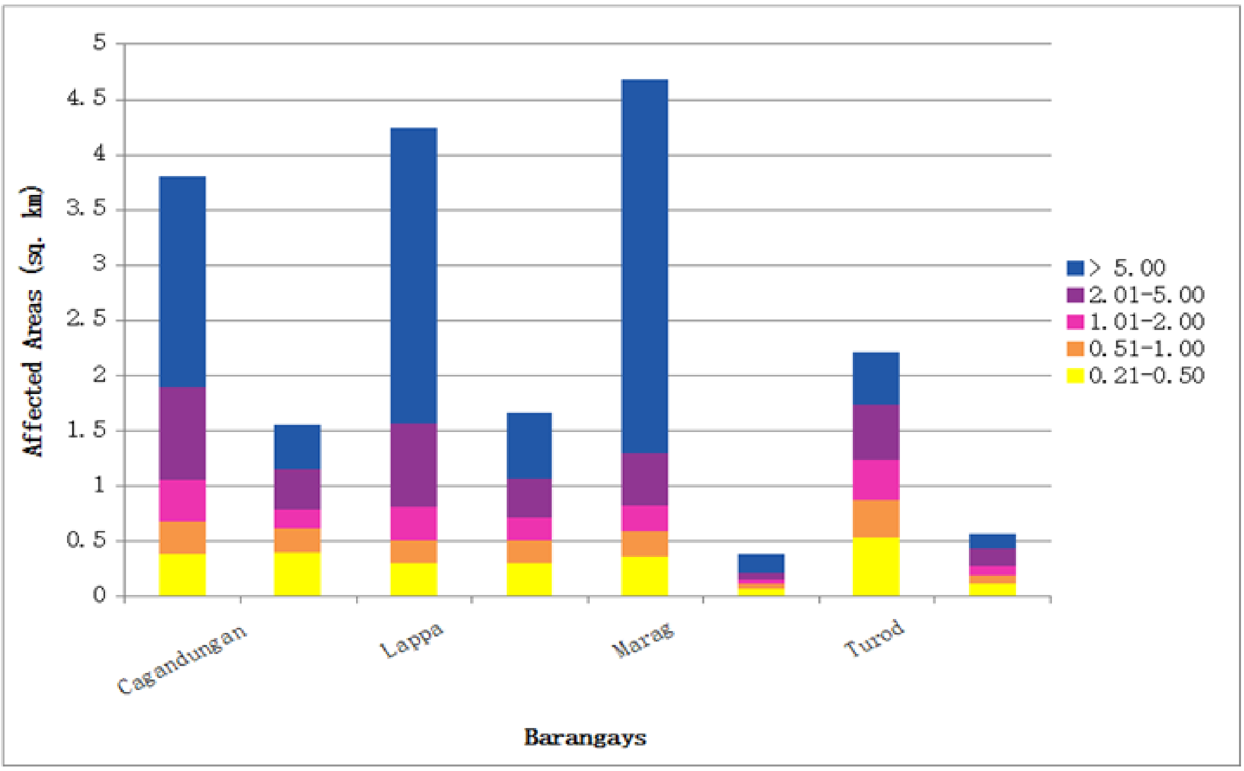


Figure 73. Affected Areas in Luna, Apayao during 25-Year Rainfall Return Period

For the 25-year return period, 46.25% of the municipality of Pamplona with an area of 206.545139 sq. km. will experience flood levels of less than 0.20 meters. 5.96% of the area will experience flood levels of 0.21 to 0.50 meters while 6.74%, 5.64%, 4.99%, and 2.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Pamplona, Cagayan during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pamplona (in sq. km.)								
	Abanqueruan	Allasitan	Bagu	Balingit	Bidduang	Cabaggan	Capalalian	Casitan	Centro
0.03-0.20	3.31	1.86	22.24	0.027	0.23	1.55	0.72	4.38	1.29
0.21-0.50	0.52	0.8	1.72	0.00034	0.073	0.63	0.44	0.72	0.35
0.51-1.00	0.65	0.93	2.07	0.0011	0.079	0.43	0.97	0.77	0.65
1.01-2.00	0.97	0.28	1.65	0.00076	0.0019	0.15	0.37	0.21	0.71
2.01-5.00	0.91	0.0023	1.11	0.0005	0	0.11	0.0084	0.098	0.3
> 5.00	0.3	0	0.71	0	0	0.0081	0	0	0.091

Table 32. Affected Areas in Pamplona, Cagayan during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pamplona (in sq. km.)							
	Curva	Gattu	Masi	Nagtupacan	San Juan	Santa Cruz	Tabba	Tupanna
0.03-0.20	1.83	14.18	28.83	0.11	1.18	11.06	2.36	0.38
0.21-0.50	0.6	0.89	1.33	0.021	0.57	2.45	1.13	0.076
0.51-1.00	0.75	1.15	1.31	0.13	0.55	2.46	1	0.024
1.01-2.00	0.54	1.63	1.74	0	0.57	2.49	0.33	0.00093
2.01-5.00	0.037	1.84	4.31	0	0.43	1.09	0.042	0.012
> 5.00	0.0021	0.16	2.64	0	0.13	0.0022	0.085	0

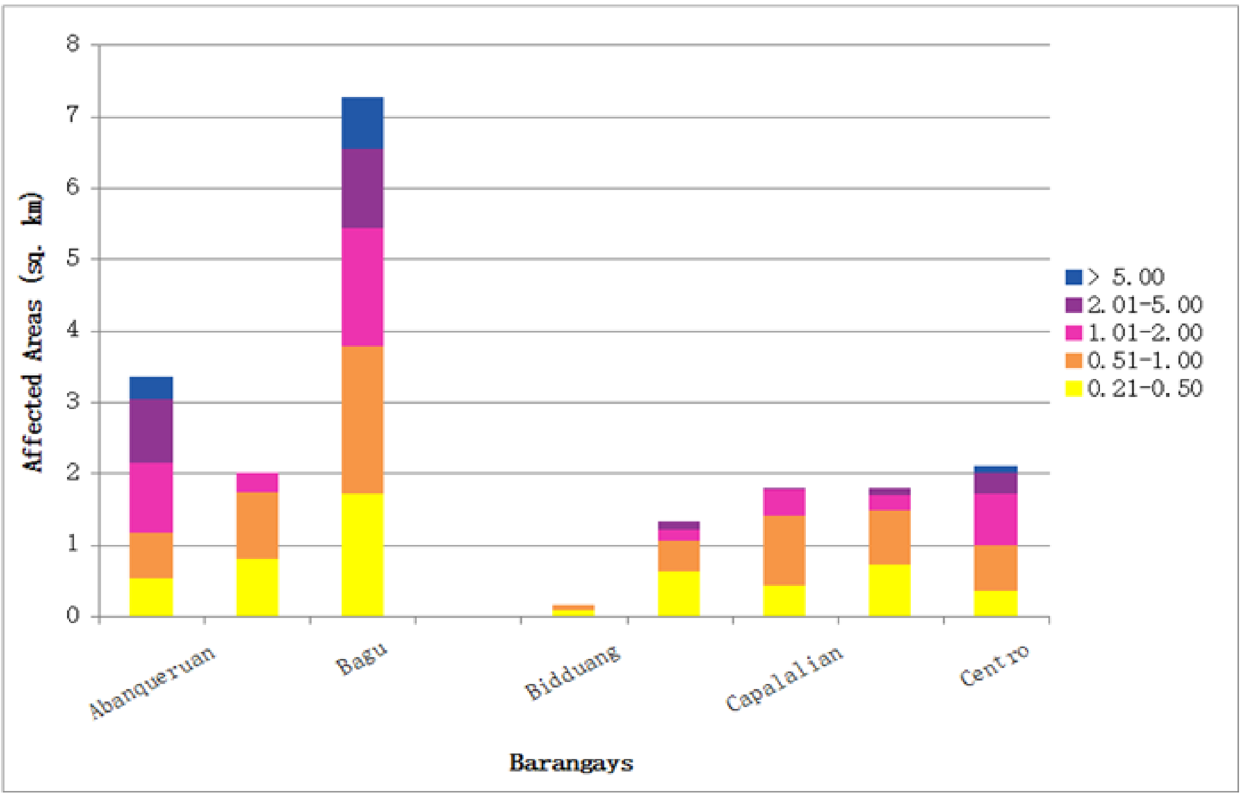


Figure 74. Affected Areas Pamplona, Cagayan during 25-Year Rainfall Return Period

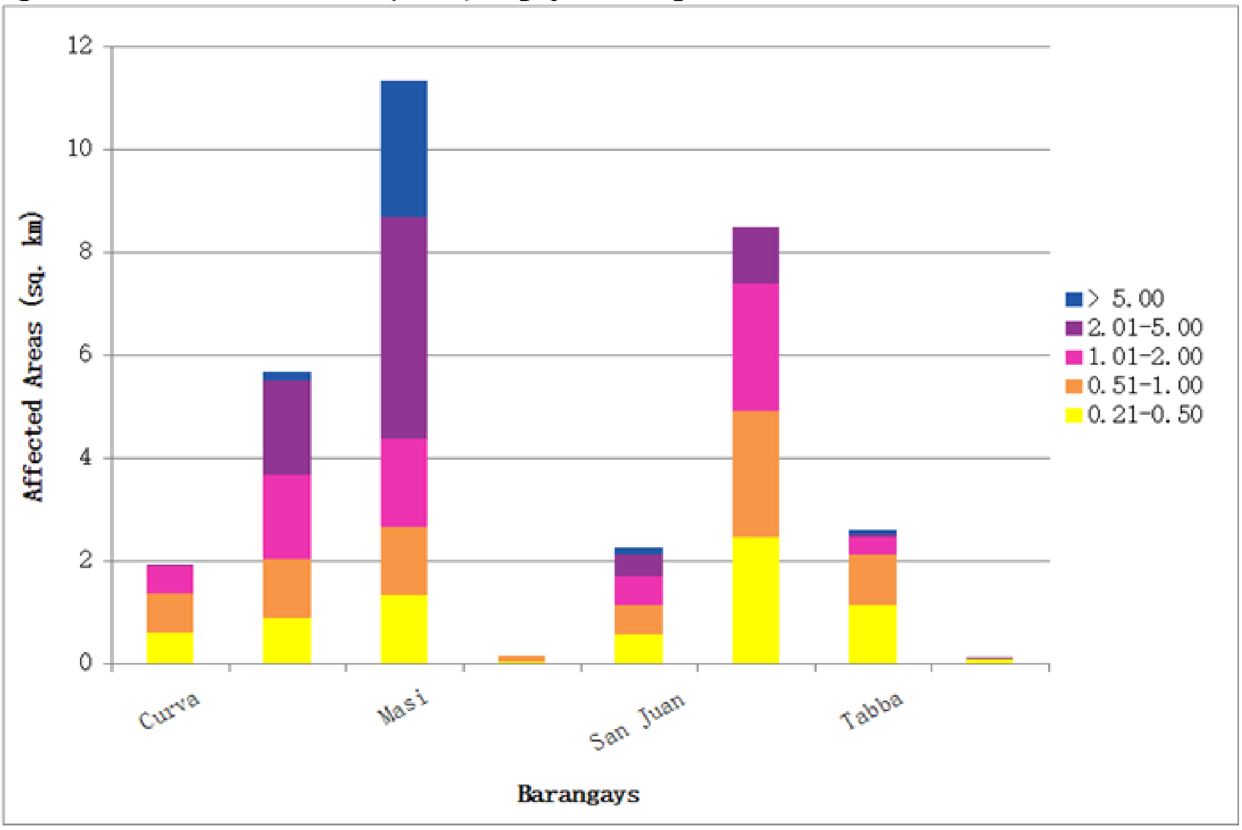


Figure 75. Affected Areas Pamplona, Cagayan during 25-Year Rainfall Return Period

For the 25-year return period, 4.65% of the municipality of Sanchez-Mira with an area of 205.308857 sq. km. will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.13%, 0.24%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Sanchez-Mira, Cagayan during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sanchez-Mira (in sq. km)	
	Kittag	Santiago
0.03-0.20	1.05	8.5
0.21-0.50	0.04	0.27
0.51-1.00	0.022	0.23
1.01-2.00	0.023	0.24
2.01-5.00	0.044	0.45
> 5.00	0.0009	0.031

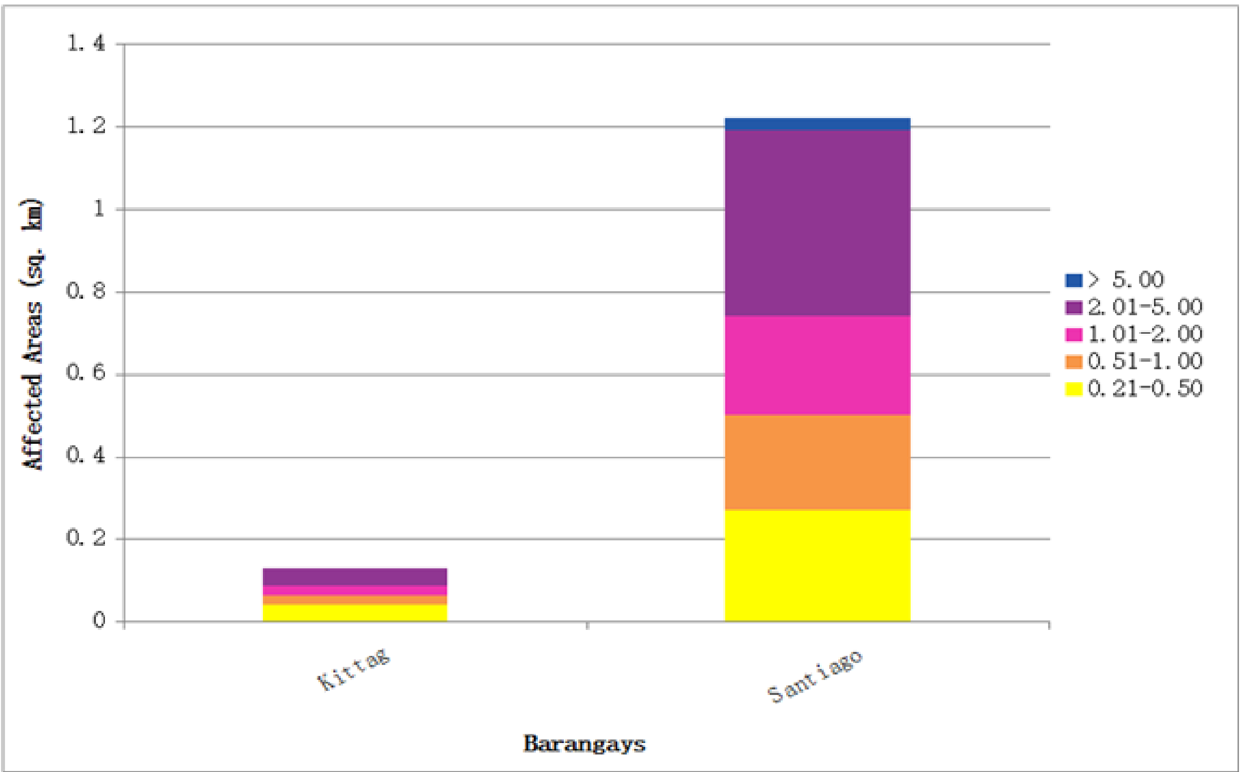


Figure 76. Affected Areas Sanchez-Mira, Cagayan during 25-Year Rainfall Return Period

For the 100-year return period, 12.51% of the municipality of Luna with an area of 603.007571 sq. km. will experience flood levels of less than 0.20 meters. 0.42% of the area will experience flood levels of 0.21 to 0.50 meters while 0.27%, 0.29%, 0.53%, and 1.87% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Luna, Apayao during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Luna (in sq. km.)							
	Cagan-dungan	Calabigan	Lappa	Luyon	Marag	Shalom	Turod	Zumigui
0.03-0.20	8.9	13.9	7.29	10.58	11.82	2.07	17.89	2.98
0.21-0.50	0.39	0.43	0.29	0.31	0.38	0.071	0.56	0.11
0.51-1.00	0.28	0.24	0.2	0.21	0.24	0.047	0.37	0.07
1.01-2.00	0.38	0.18	0.25	0.22	0.24	0.035	0.38	0.077
2.01-5.00	0.68	0.32	0.62	0.35	0.42	0.066	0.55	0.18
> 5.00	2.27	0.51	3.16	0.68	3.67	0.2	0.62	0.15

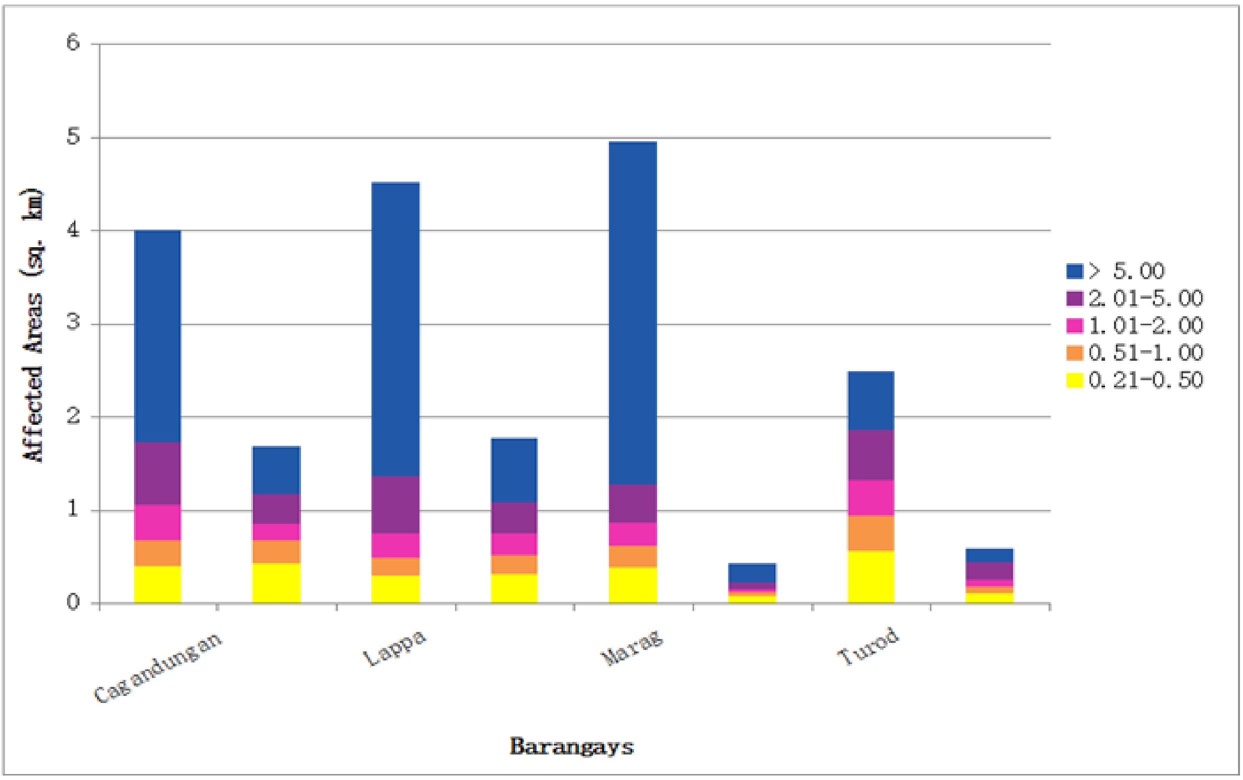


Figure 77. Affected Areas Luna, Apayao during 100-Year Rainfall Return Period

For the 100-year return period, 43.49% of the municipality of Pamplona with an area of 206.545139 sq. km. will experience flood levels of less than 0.20 meters. 4.99% of the area will experience flood levels of 0.21 to 0.50 meters while 6.88%, 7.78%, 5.80%, and 2.68% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Pamplona, Cagayan during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pamplona (in sq. km.)								
	Abanqueruan	Allasitan	Bagu	Balingit	Bidduang	Cabaggan	Capalalian	Casitan	Centro
0.03-0.20	3.15	1.6	21.59	0.027	0.19	1	0.47	4.22	1.09
0.21-0.50	0.49	0.66	1.41	0.00034	0.066	0.64	0.25	0.39	0.23
0.51-1.00	0.64	0.83	2.1	0.00095	0.11	0.63	0.58	0.82	0.49
1.01-2.00	1.05	0.75	2.26	0.0005	0.019	0.4	1.17	0.63	1.06
2.01-5.00	1.02	0.036	1.27	0.00086	0	0.19	0.041	0.13	0.43
> 5.00	0.31	0	0.87	0	0	0.013	0	0	0.1

Table 41. Affected Areas in Pamplona, Cagayan during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pamplona (in sq. km.)							
	Curva	Gattu	Masi	Nagtupacan	San Juan	Santa Cruz	Tabba	Tupanna
0.03-0.20	1.67	13.9	28.13	0.1	0.71	10.17	1.43	0.37
0.21-0.50	0.46	0.75	1.25	0.026	0.34	2.28	0.97	0.086
0.51-1.00	0.82	1.01	1.25	0.14	0.79	2.62	1.35	0.024
1.01-2.00	0.74	1.57	1.82	0.0023	0.87	2.73	1	0.006
2.01-5.00	0.052	2.37	4.06	0	0.49	1.76	0.11	0.013
> 5.00	0.0021	0.25	3.66	0	0.24	0.006	0.089	0.00016

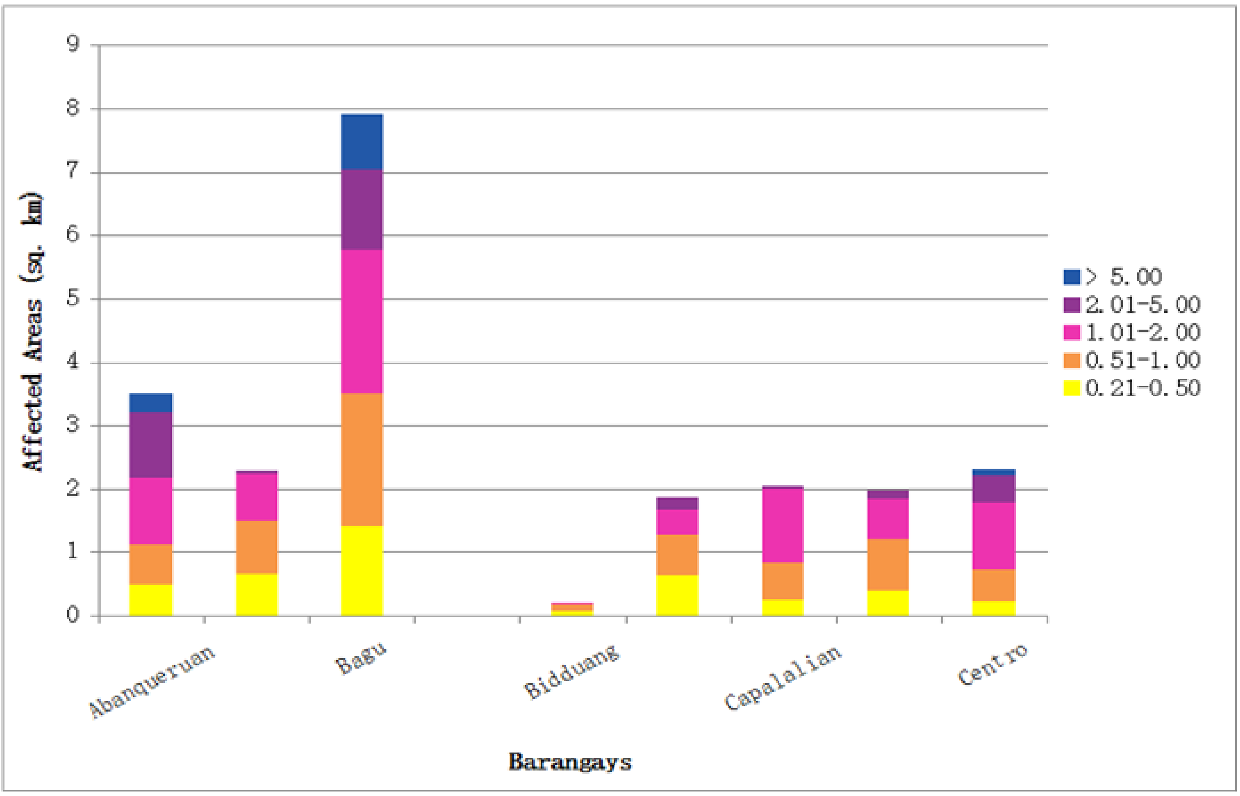


Figure 78. Affected Areas Pamplona, Cagayan during 100-Year Rainfall Return Period

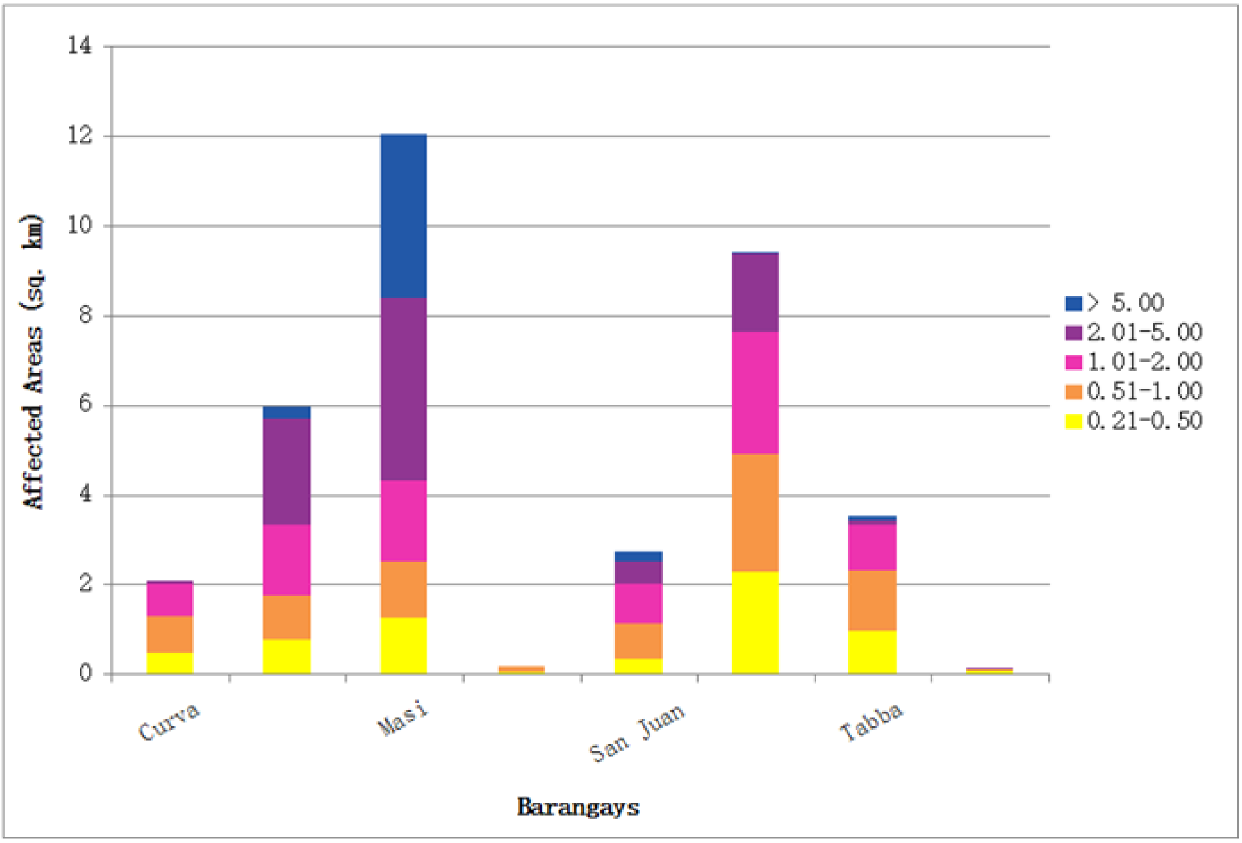


Figure 79. Affected Areas Pamplona, Cagayan during 100-Year Rainfall Return Period

For the 100-year return period, 4.60% of the municipality of Sanchez-Mira with an area of 205.308857 sq. km. will experience flood levels of less than 0.20 meters. 0.16% of the area will experience flood levels of 0.21 to 0.50 meters while 0.11%, 0.14%, 0.25%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Sanchez-Mira, Cagayan during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sanchez-Mira (in sq. km)	
	Kittag	Santiago
0.03-0.20	1.04	8.4
0.21-0.50	0.044	0.28
0.51-1.00	0.025	0.21
1.01-2.00	0.025	0.26
2.01-5.00	0.049	0.46
> 5.00	0.0011	0.11

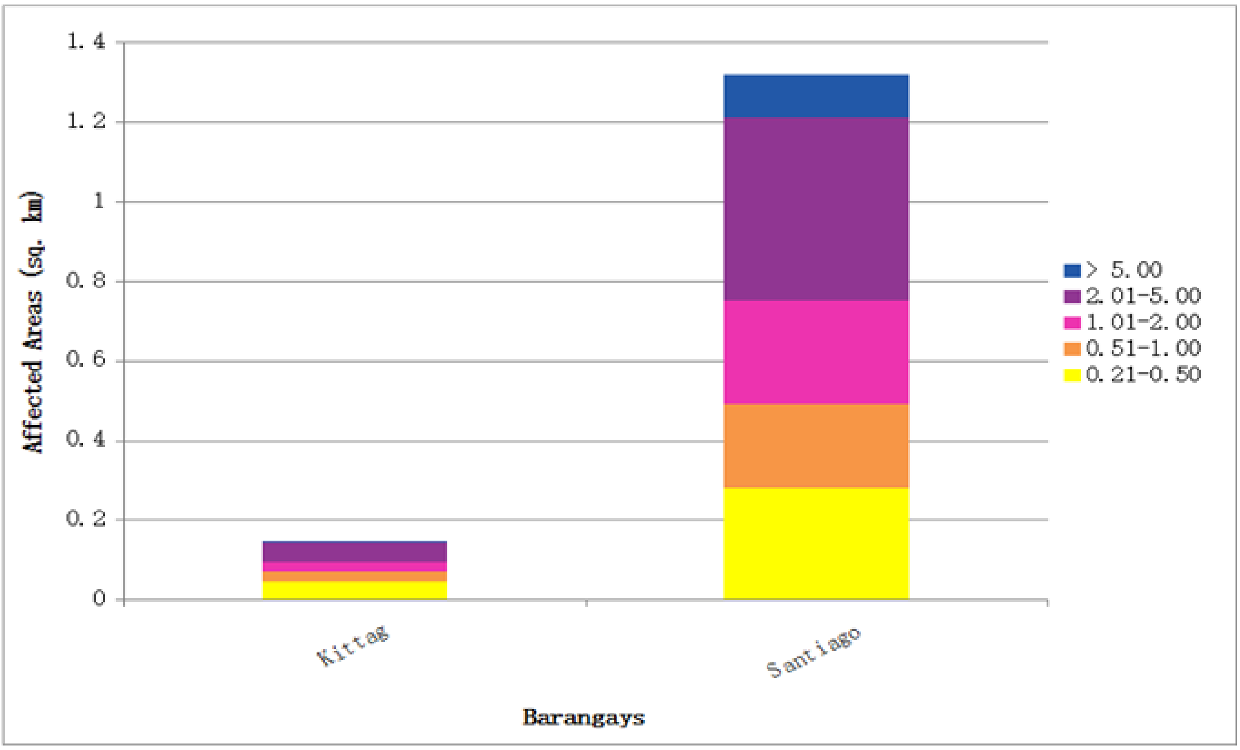


Figure 80. Affected Areas Sanchez-Mira, Cagayan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Luna in Apayao, Turod is projected to have the highest percentage of area that will experience flood levels at 3.38%. Meanwhile, Marag posted the second highest percentage of area that may be affected by flood depths at 2.78%.

Among the barangays in the municipality of Pamplona in Cagayan, Masi is projected to have the highest percentage of area that will experience flood levels at 6.66%. Meanwhile, Bagu posted the second highest percentage of area that may be affected by flood depths at 4.89%.

Among the barangays in the municipality of Sanchez-Mira in Cagayan, Santiago is projected to have the highest percentage of area that will experience flood levels at 1.61%. Meanwhile, Kittag posted the second highest percentage of area that may be affected by flood depths at 0.20%.

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

Table 43. 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	16.37	14.81	12.84
Medium	18.47	24.05	26.95
High	25.19	34.57	40.75
TOTAL	**60.03**	**73.43**	**80.54**

Of the 11 identified educational institutions in the Pamplona floodplain, only one school was assessed to be relatively prone to flooding as it is exposed to Medium level flooding in the 5-year rain return period, and High level flooding for the other two rainfall scenarios. Another institution was found to be also relatively susceptible to flooding, experiencing Low level flooding in the 5-year return period, and Medium level flooding in the 25- and 100-year rainfall scenarios. The educational institutions exposed to flooding are shown in Annex 12.

Only one medical institution was identified in the Pamplona floodplain. BEMNOC in Brgy. Masi was found to be relatively prone to flooding, having Low level flooding in all three rainfall scenarios. The medical institutions exposed to flooding are found in Annex 13.

5.11 Flood Validation

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

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

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 197 points randomly selected all over Pamplona floodplain. It has an RMSE value of 0.73.

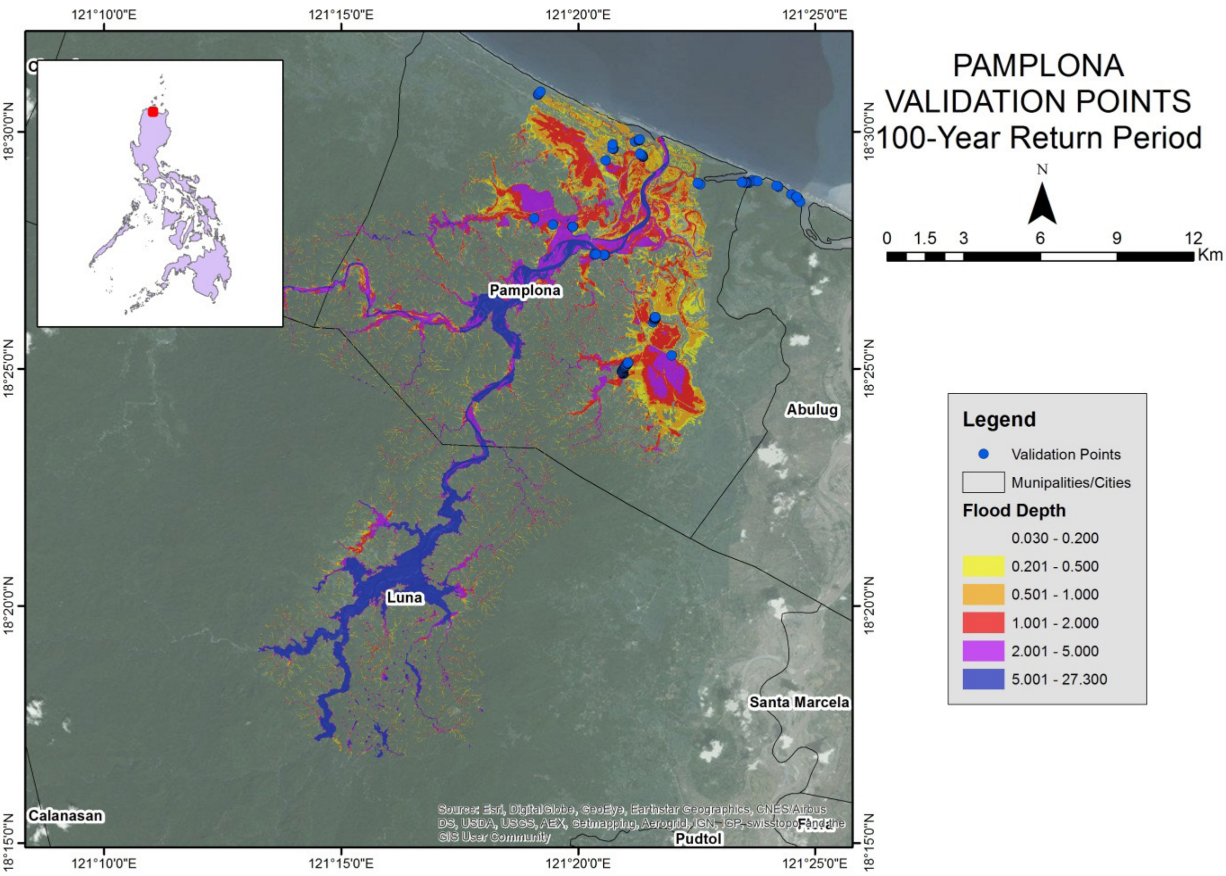


Figure 81. Pamplona Flood Validation Points

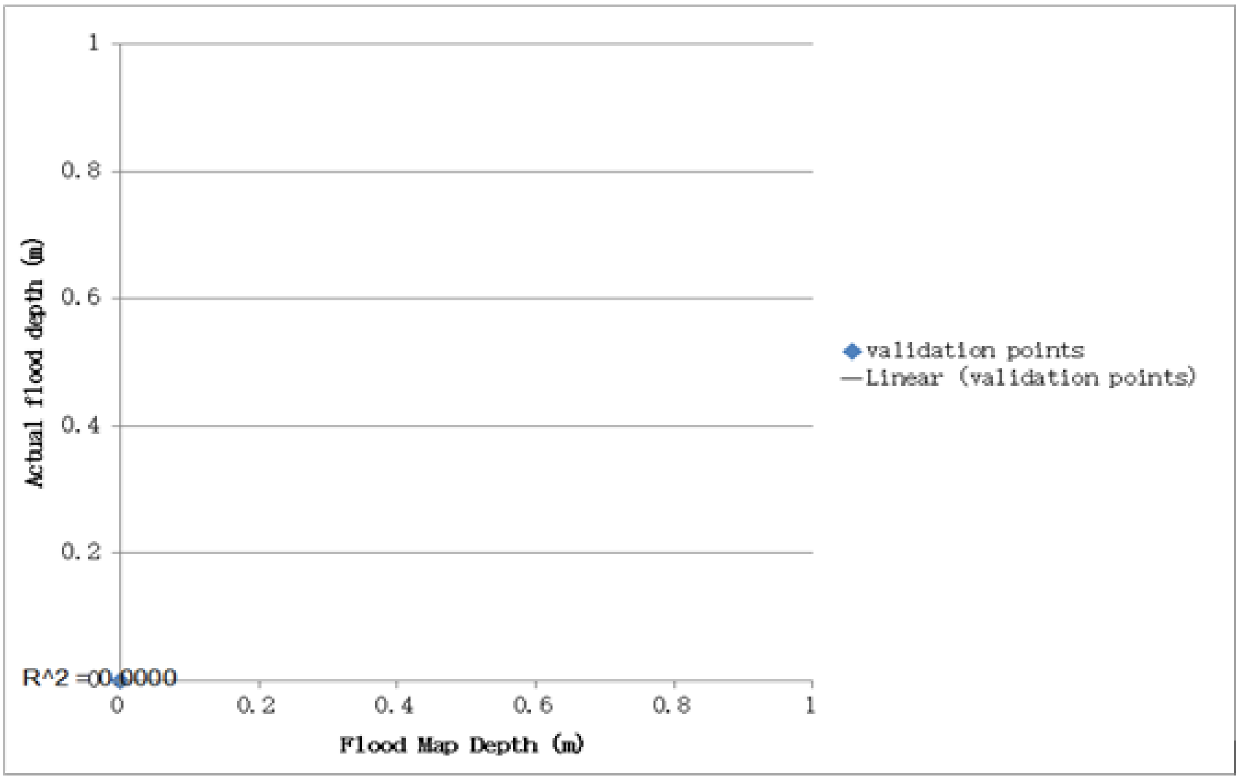


Figure 82. Flood map depth vs. actual flood depth

Table 44. Actual flood vs simulated flood depth at different levels in the Pamplona River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	64	13	6	3	1	0	87
0.21-0.50	23	5	6	3	0	0	37
0.51-1.00	24	11	5	1	1	0	42
1.01-2.00	14	4	11	1	0	0	30
2.01-5.00	1	0	0	0	0	0	1
> 5.00	0	0	0	0	0	0	0
Total	126	33	28	8	2	0	197

The overall accuracy generated by the flood model is estimated at 38.07%, with 75 points correctly matching the actual flood depths. In addition, there were 65 points estimated one level above and below the correct flood depths while there were 38 points and 19 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 34 points were overestimated while a total of 88 points were underestimated in the modelled flood depths of Pamplona. Table 45 depicts the summary of the Accuracy Assessment in the Pamplona River Basin Survey.

Table 45. The summary of the Accuracy Assessment in the Pamplona River Basin Survey

	No. of Points	%
Correct	75	38.07
Overestimated	34	17.26
Underestimated	88	44.67
Total	197	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor

Table A-1.1. Parameters and Specification of Pegasus Sensor

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

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

9 9 1 2 1 8 2 0 1 3 1 3 3 6 4 7

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

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

Figure A-2.1. APA-13

2. 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**	
Island: **LUZON**	Order: **2nd**	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

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

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

NAMRIA OFFICES:
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

Figure A-2.2. CGY-87

3. CGY-110

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

November 11, 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-110 (BLLM-1A)**
Order: **2nd**

Island: **LUZON**	Barangay: **CENTRO**	
Municipality: **PAMPLONA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **18° 27' 58.94151"**	Longitude: **121° 20' 19.10441"**	Ellipsoidal Hgt: **16.83900 m.**
	WGS84 Coordinates	
Latitude: **18° 27' 52.69074"**	Longitude: **121° 20' 23.67135"**	Ellipsoidal Hgt: **49.26200 m.**
	PTM / PRS92 Coordinates	
Northing: **2042410.05 m.**	Easting: **535767.119 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **2,042,467.48**	Easting: **324,569.86**	Zone: **51**

Location Description

CGY-110 (BLLM 1A)
From Magapit Bridge, travel along the nat'l. highway to Ilocos until reaching Pamplona Central School, which is across Pamplona Mun. Hall. Station is located inside the school compound, behind the first school bldg. to the left of the entrance gate. Mark is the head of a steel bolt centered and flushed on a 35 cm. x 35 cm. concrete monument, with inscriptions "BLLM No. 1A".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088606 I**
T.N.: **2015-3727**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. CGY-110

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

The Pamplona river basin has no baseline processing reports.

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	**Designation**	**Name**	**Agency/ Affiliation**
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, DR.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
	Research Associate (RA)	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	ENGR. FRANK NICOLAS ILEJAY	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. DIOSCORRO SOBERANO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JERICO JECIEL	AAC

Annex 5. Data Transfer Sheet for Pamplona Floodplain

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	174	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	1CAGS1CG315B	pegasus	80.3	140	2.52	99.8	6.07	120/13	[illegible]	NA	12.6	1KB	1KB	98	NA	Z:\DAC\RAW DATA
12-Nov-15	2842P	1BLK2BS316A	pegasus	1.43	889	6.34	115	24.1	1/2	14.3	NA	10.4	1KB	1KB	1	NA	Z:\DAC\RAW DATA
12-Nov-15	2844P	[illegible]	pegasus	NA	1.54	12.6	[illegible]	90.8	[illegible]	[illegible]	NA	24.9	1KB	NA	77/162/185	NA	Z:\DAC\RAW DATA
13-Nov-15	2848P	[illegible]	pegasus	122	121	[illegible]	[illegible]	7.57	64	5.33	NA	24.5	1KB	1KB	162/185	NA	Z:\DAC\RAW DATA
14-Nov-15	2850P	1BLK2DE318A	pegasus	1.57	1.35	11.8	230	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	162	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 AcBongat 11/24/2015

Figure A-5.1. Transfer Sheet for Pamplona Floodplain

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 2842P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: 1BLK2B316A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122	Flight Log No.: 2842
7 Pilot: C Alfonso	8 Co-Pilot: J Jerez	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: 0759 H	14 Engine Off: 1058 H	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

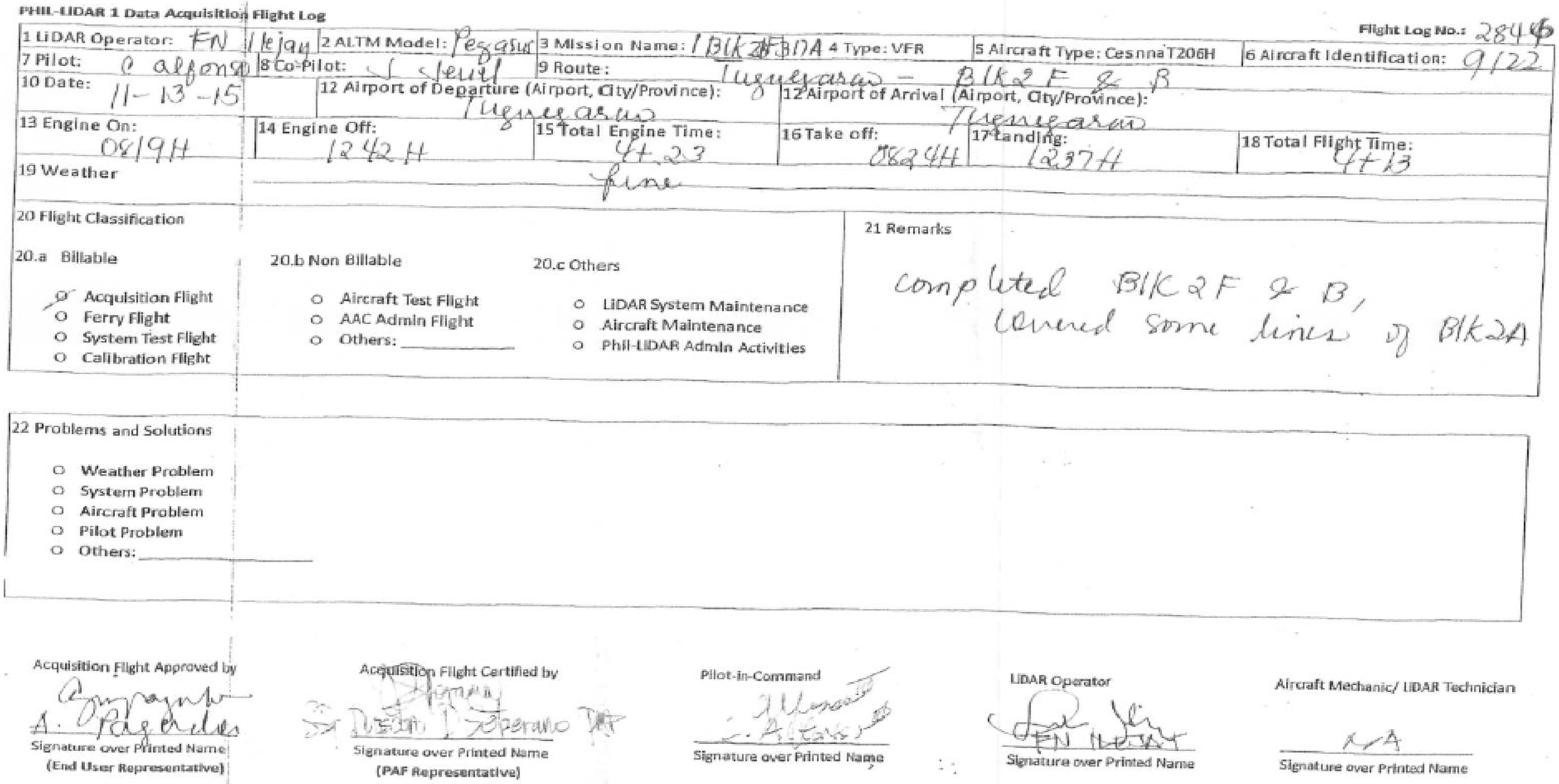
22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: __________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
A. OPAGA...			G. SINADJAN	NA
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-6.1. Flight Log for Mission 2842P

2. Flight Log for 2846P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2846

1 LiDAR Operator: FN Ilejay	2 ALTM Model: Pegasus	3 Mission Name: 1BLK2FB2A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C alfonso	8 Co-Pilot: J Jerul	9 Route: Tuguegarao – BLK2F & B			
10 Date: 11-13-15	12 Airport of Departure (Airport, City/Province): Tuguegarao		12 Airport of Arrival (Airport, City/Province): Tuguegarao		
13 Engine On: 0819H	14 Engine Off: 1242H	15 Total Engine Time: 4+23	16 Take off: 0824H	17 Landing: 1237H	18 Total Flight Time: 4+13
19 Weather: fine					

20 Flight Classification

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

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

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

21 Remarks

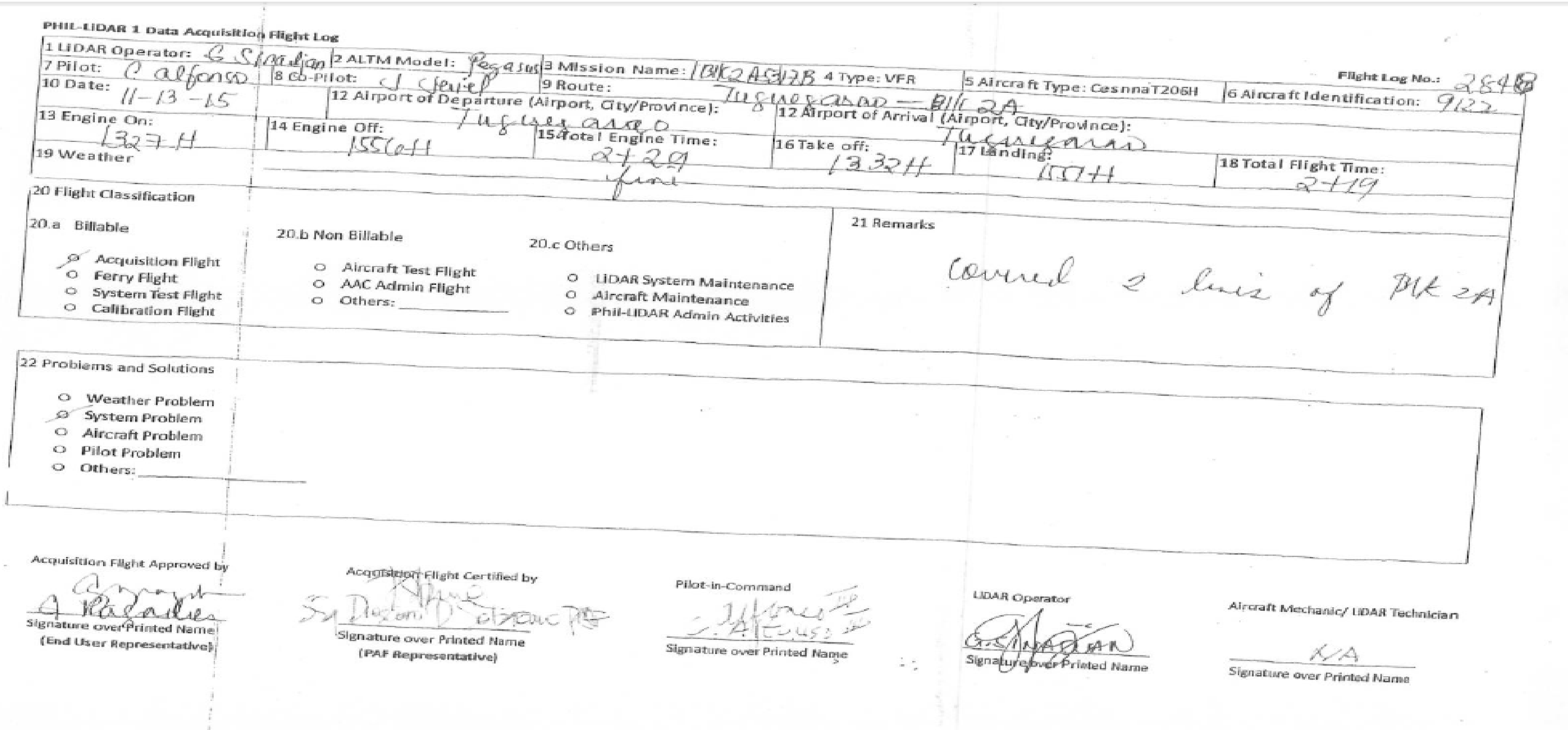
completed BlK2F & B, covered some lines of BlK2A

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
A. Pagaduan	[signature]	C. Alfonso	FN Ilejay	N/A
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-6.2. Flight Log for Mission 2846P

3. Flight Log for 2848P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: G Sinadjan	2 ALTM Model: Pegasus	3 Mission Name: BlK2AS312B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	Flight Log No.: 2848P
7 Pilot: C alfonso	8 Co-Pilot: J Jeriel	9 Route: Tuguegarao — BlK 2A			6 Aircraft Identification: 9122
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
- ø Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

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

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

21 Remarks

Covered 2 lines of BlK 2A

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

Acquisition Flight Approved by: A Palad... — 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: G. SINADJAN — Signature over Printed Name

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

Figure A-6.3. Flight Log for Mission 2848P

4. Flight Log for 2850P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2850P

1 LiDAR Operator: G. Sinadjan
2 ALTM Model: Pegasus
3 Mission Name: 1BLK2D318A
4 Type: VFR
5 Aircraft Type: Cesnna T206H
6 Aircraft Identification: 9122

7 Pilot: C. Alfonso
8 Co-Pilot: J. Jeruta
9 Route: Tuguegarao – BLK 2D

10 Date: 11-14-15
12 Airport of Departure (Airport, City/Province): Tuguegarao
12 Airport of Arrival (Airport, City/Province): Tuguegarao

13 Engine On: 0815H
14 Engine Off: 1150H
15 Total Engine Time: 3+35
16 Take off: 0820H
17 Landing: 1145H
18 Total Flight Time: 3+25

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

Completed BLK2E & covered some lines of BLK2A

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

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

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

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

LiDAR Operator: G. Sinadjan — Signature over Printed Name

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

Figure A-6.4. Flight Log for Mission 2850P

5. Flight Log for 2852P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2852P

1 LiDAR Operator: FN Ilejay	2 ALTM Model: Pegasus	3 Mission Name: 1BLK2AS323B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C Alfonso	8 Co-Pilot: J Jeriel	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	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2852P

6. Flight Log for 2854P Mission

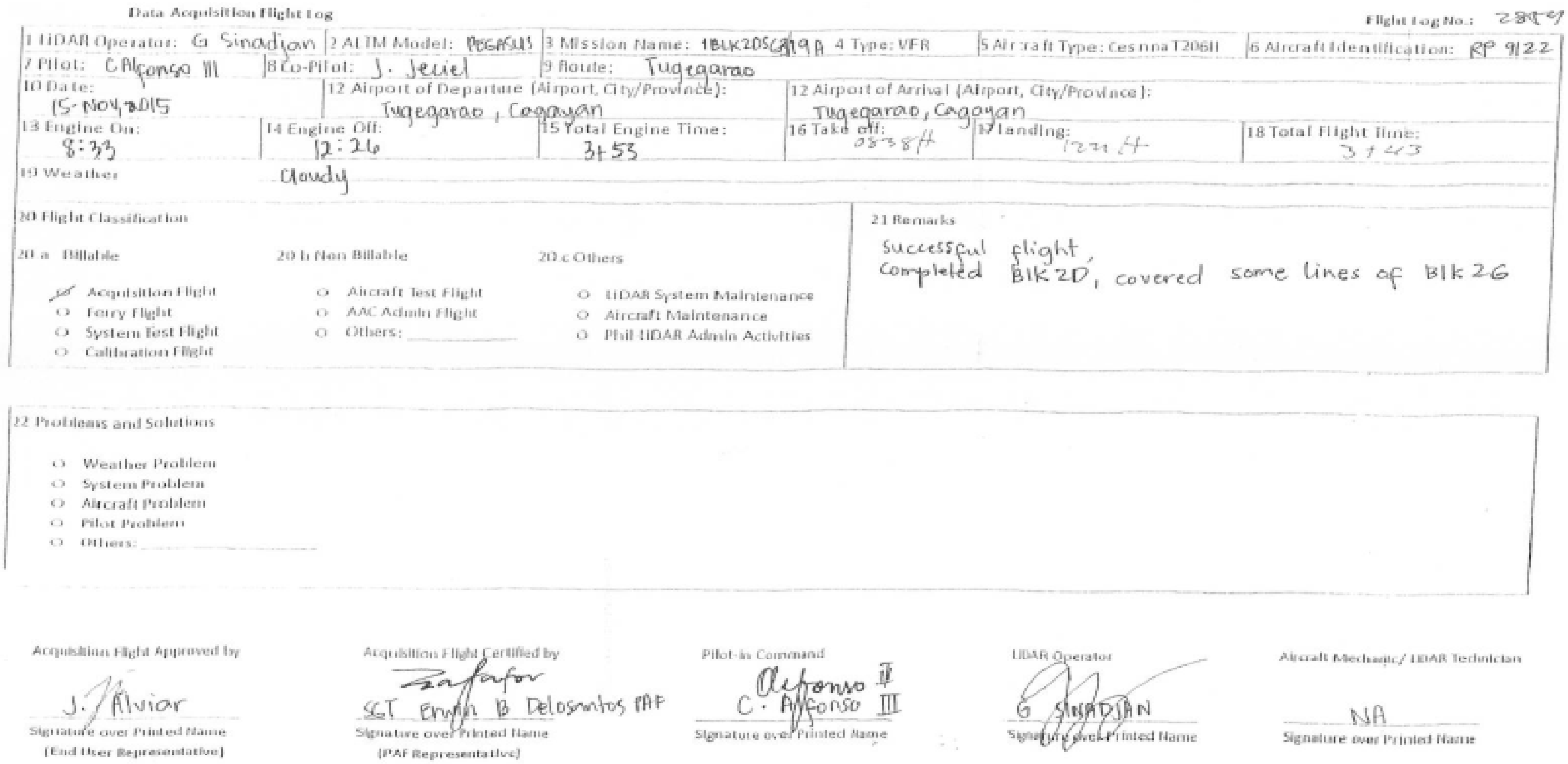


Figure A-6.6. Flight Log for Mission 2854P

Annex 7. Flight Status Reports

Cagayan-Apayao Mission
November 3-17, 2015

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
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
2850P	BLK2D, BLK2E	1BLK2DE318A	G SINADJAN	November 14, 2015	SURVEYED 15 LINES FOR BLK2D AND BLK2E
2852P	BLK3AS, BLK2CS	1BLK2AS318B	FN ILEJAY	November 14, 2015	SURVEYED 4 LINES FOR BLK2A, AND VOIDS OVER BLK2C
2854P	BLK2DS, BLK2G	1BLK2DSG319A	G SINADJAN	November 15, 2015	SURVEYED 18 LINES FOR BLK2D AND BLK2G

SWATH PER FLIGHT MISSION

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

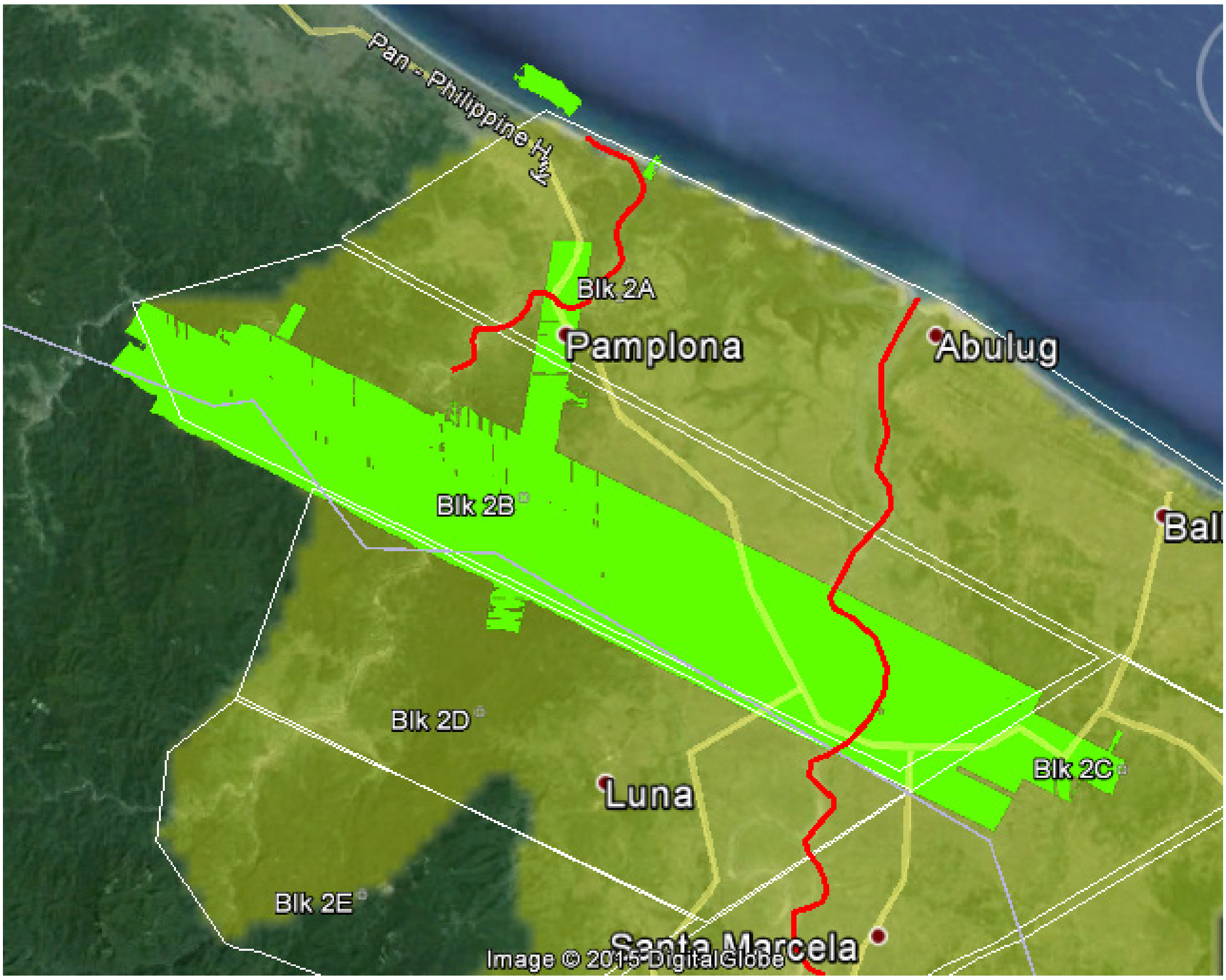


Figure A-7.1. Swath for Flight No. 2846

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

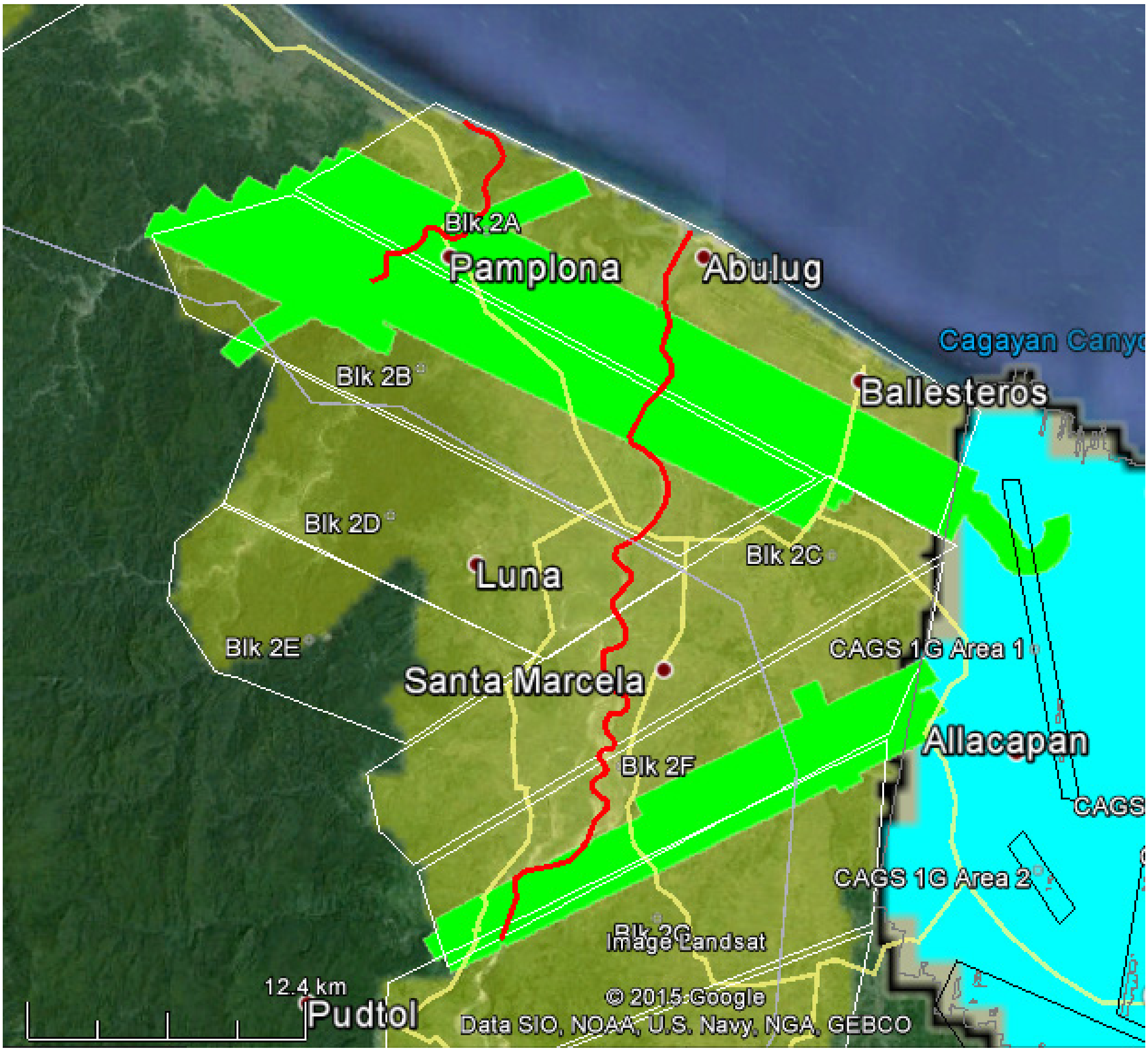


Figure A-7.2. Swath for Flight No. 2848

FLIGHT NO.:	2850	
AREA:	BLK2D, BLK2E	
MISSION NAME:	1BLK2DE318A	
ALT: 1100m	SCAN FREQ: 30	SCAN ANGLE: 25
SURVEYED AREA:	192.36 km2	

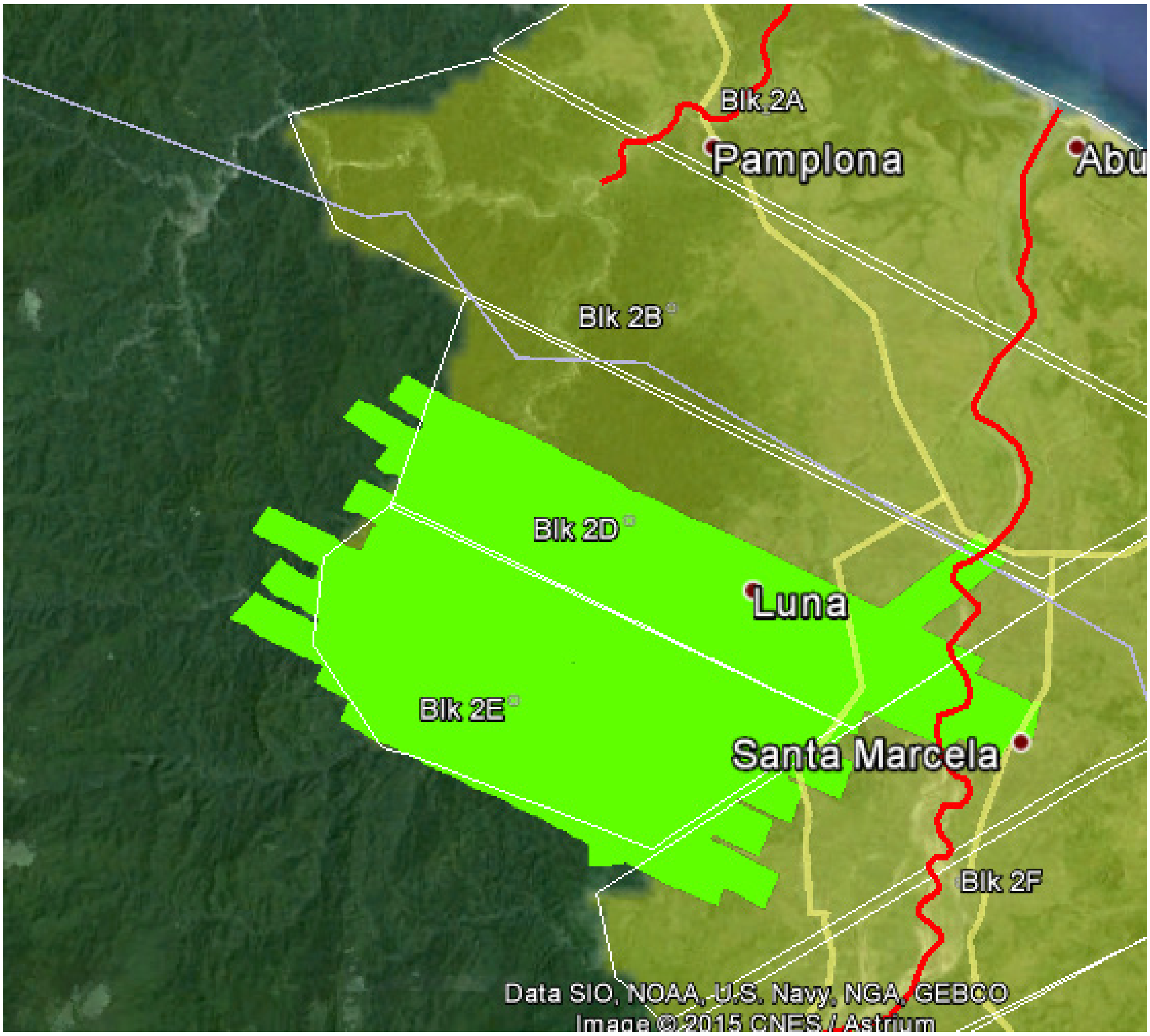


Figure A-7.3. Swath for Flight No. 2850

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

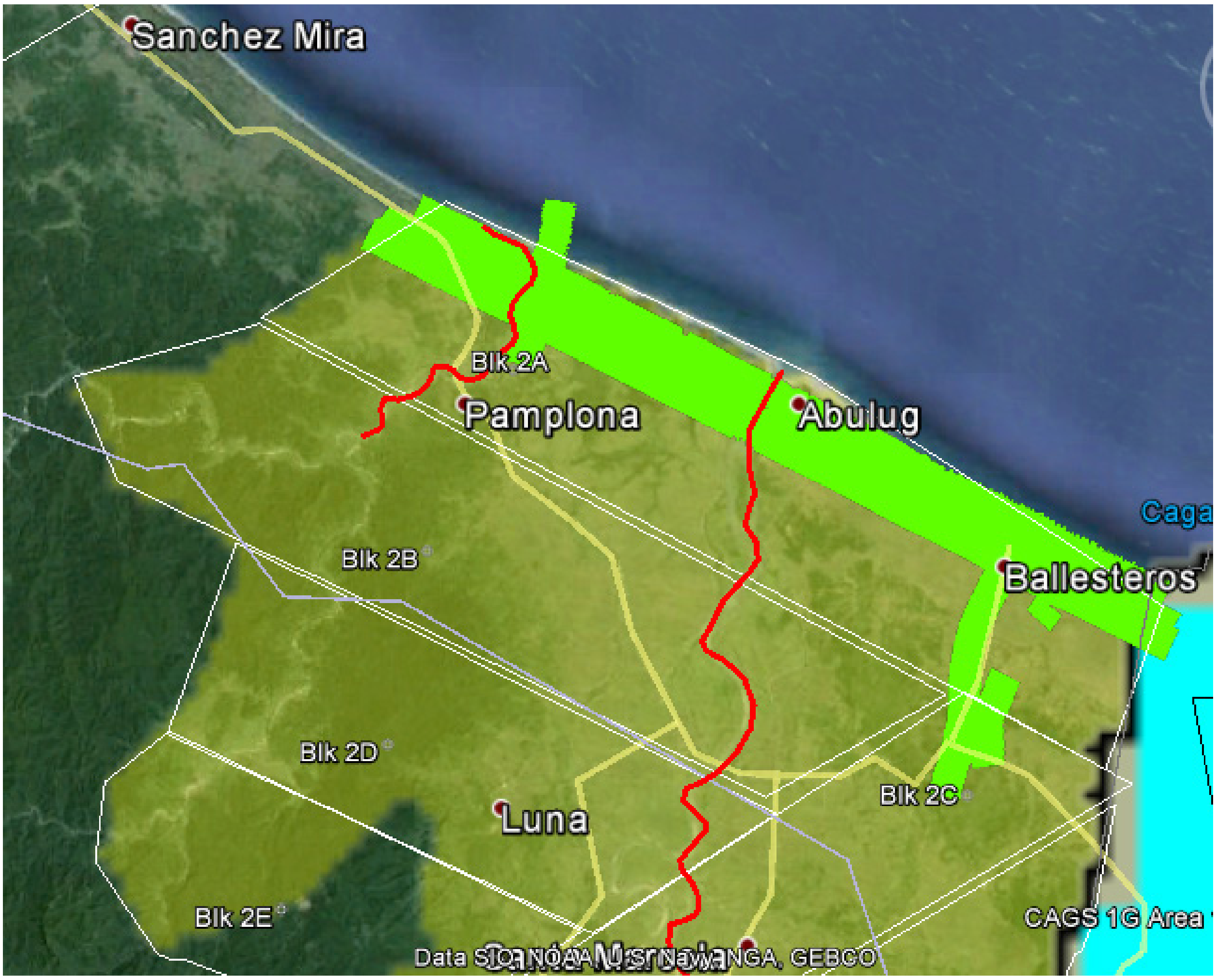


Figure A-7.4. Swath for Flight No. 2852

FLIGHT NO.:	2854	
AREA:	BLK2A, BLK2CS	
MISSION NAME:	1BLK2AS318B	
ALT: 1100m, then 900 m	SCAN FREQ: 30	SCAN ANGLE: 25
SURVEYED AREA:	291.09 km2	

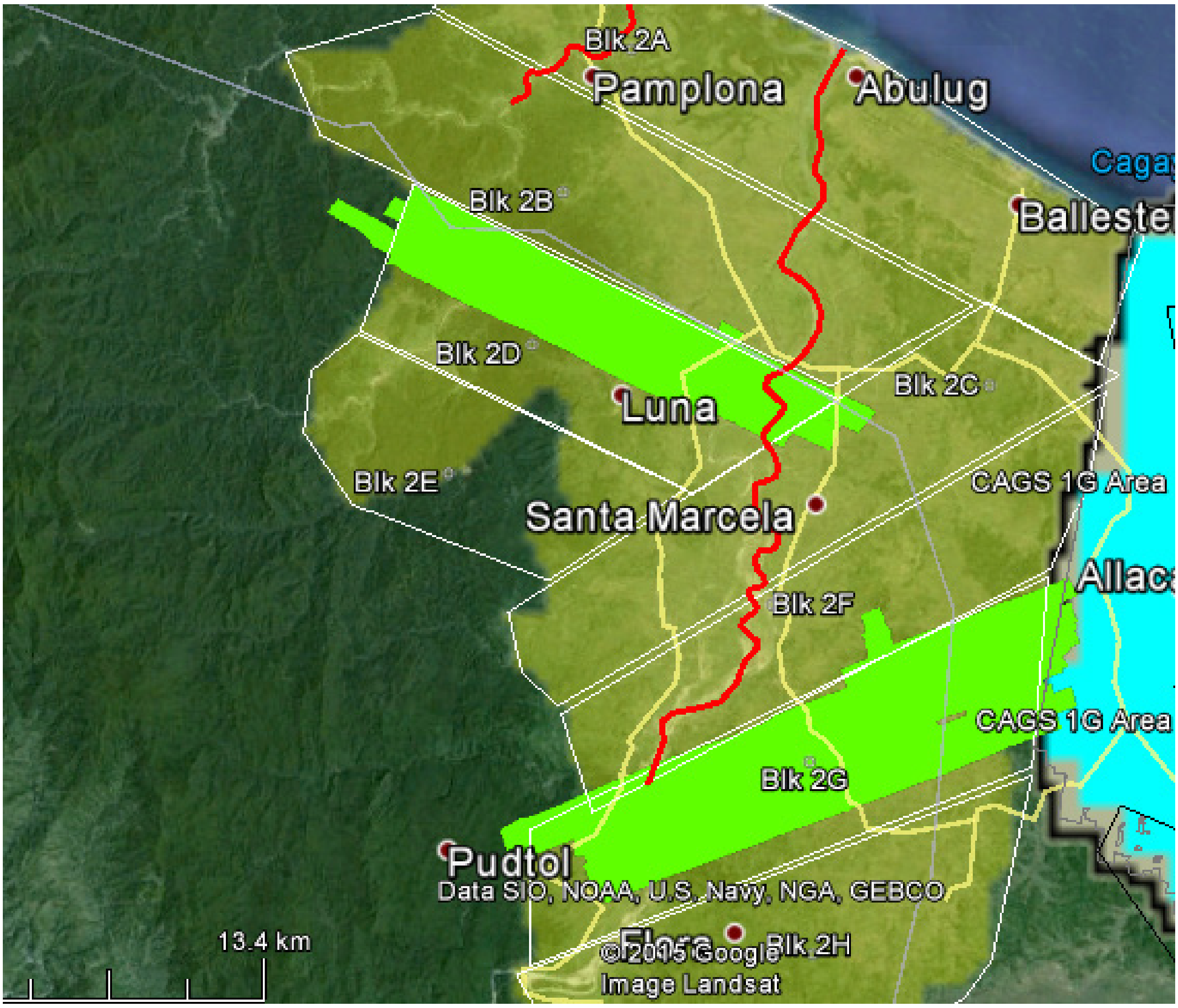


Figure A-7.5. Swath for Flight No. 2854

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk2D_supplement

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk2D_supplement
Inclusive Flights	2850P
Range data size	23.3GB
POS	230MB
Image	35.2MB
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)	1.17
RMSE for East Position (<4.0 cm)	1.62
RMSE for Down Position (<8.0 cm)	3.60
Boresight correction stdev (<0.001deg)	0.000255
IMU attitude correction stdev (<0.001deg)	0.001669
GPS position stdev (<0.01m)	0.0147
Minimum % overlap (>25)	51.38
Ave point cloud density per sq.m. (>2.0)	4.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	629.94 m
Minimum Height	33.11 m
Classification (# of points)	
Ground	114,681,685
Low vegetation	86,249,217
Medium vegetation	179,801,226
High vegetation	1,312,535,704
Building	12,298,531
Orthophoto	Yes
Processed by	Engr. Jennifer B. Saguran, Engr. Chelou Prado, Marie Denise Bueno

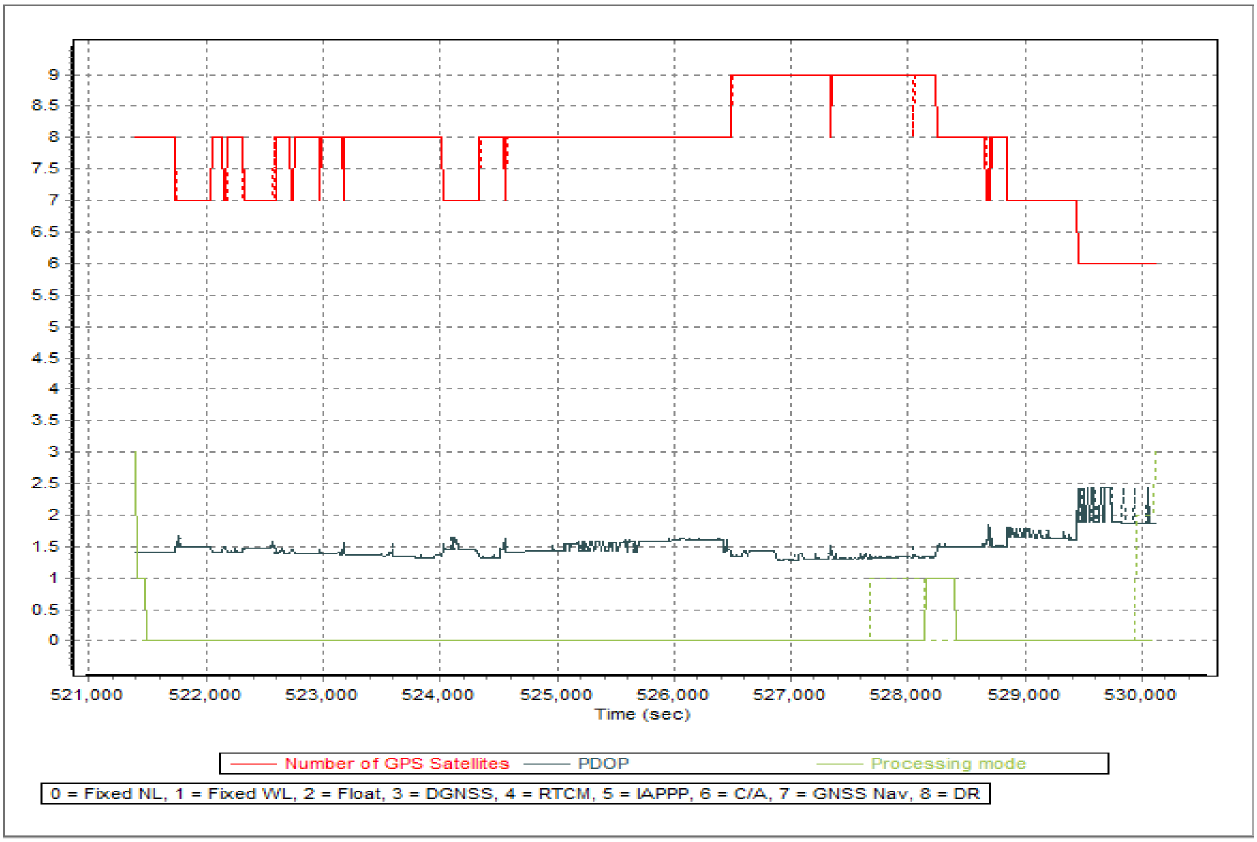


Figure A-8.1. Solution Status

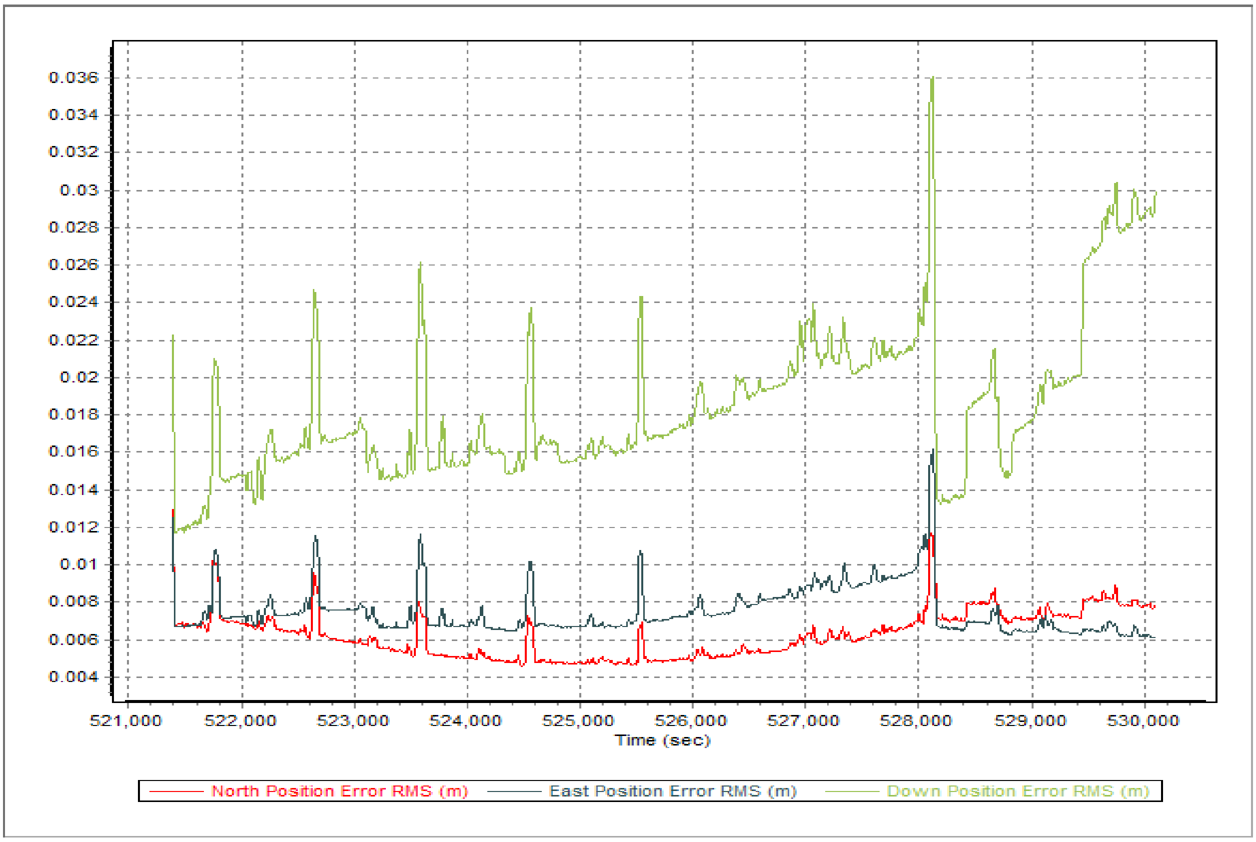


Figure A-8.2. Smoothed Performance Metrics Parameters

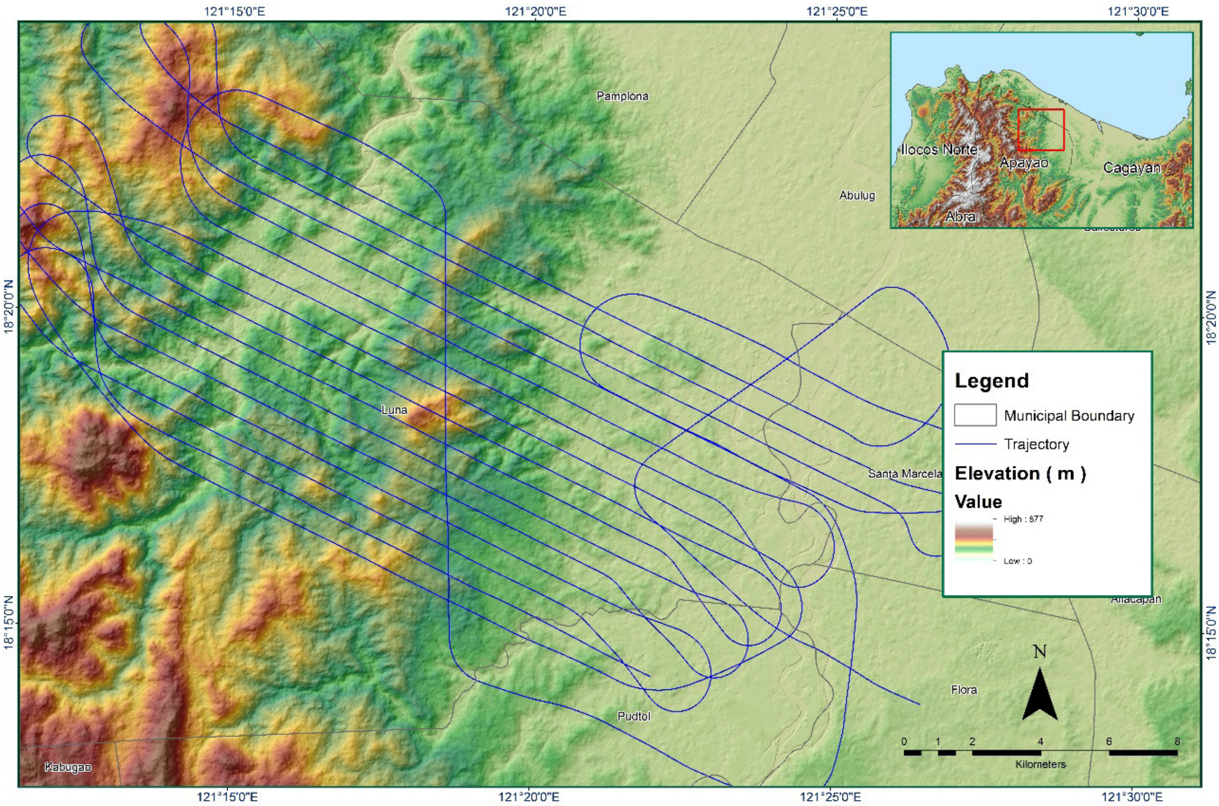


Figure A-8.3. Best Estimated Trajectory

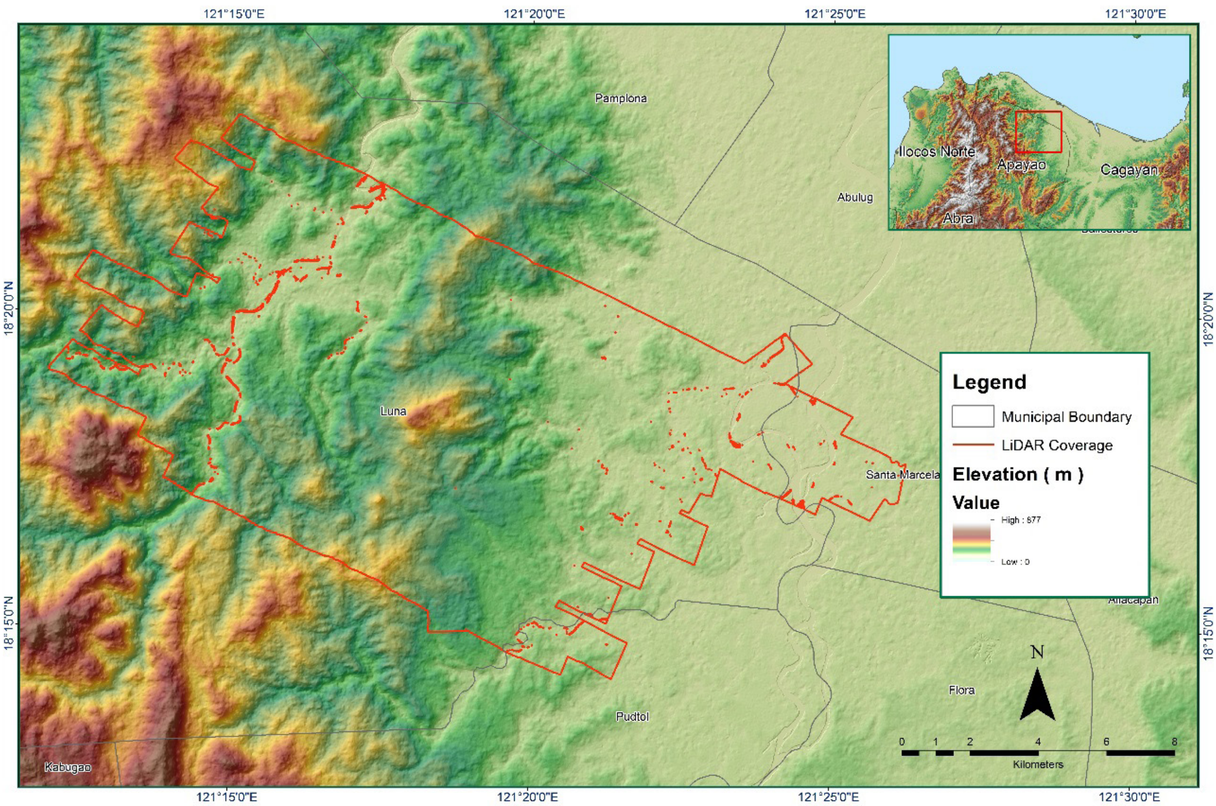


Figure A-8.4. Coverage of LiDAR data

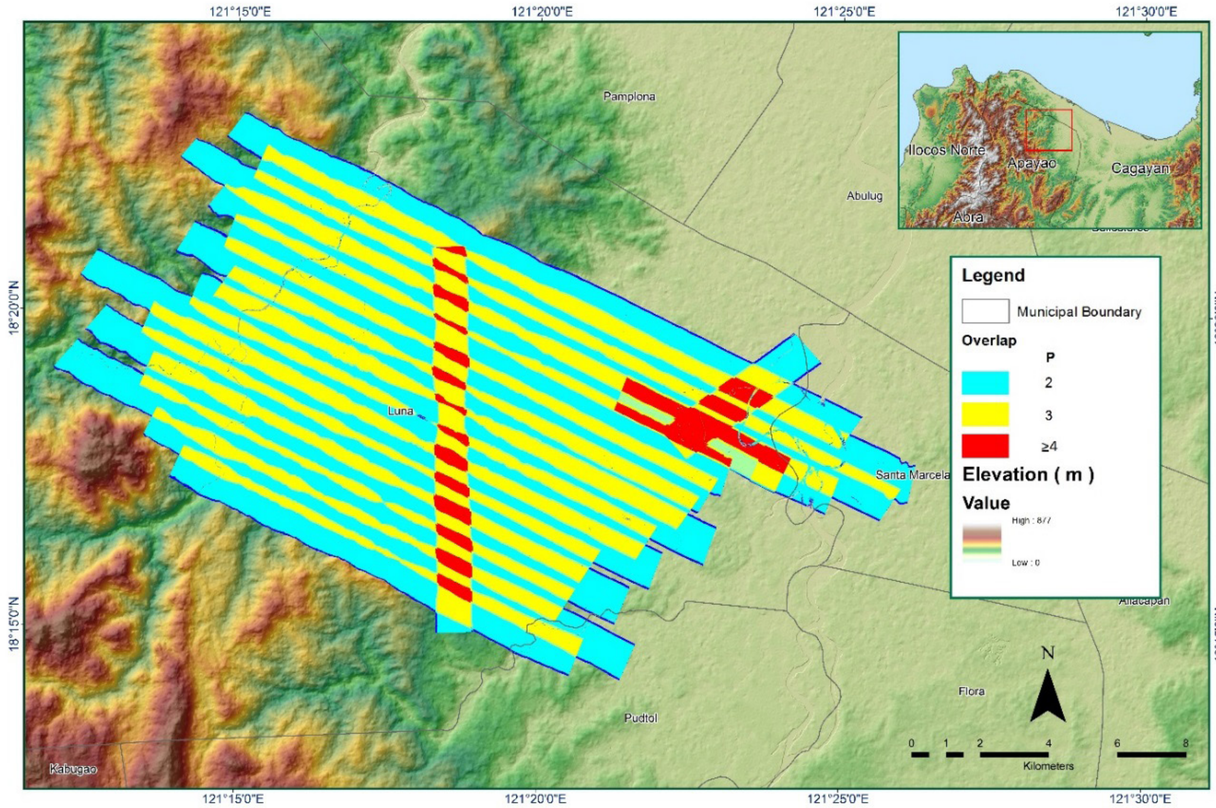


Figure A-8.5. Image of Data Overlap

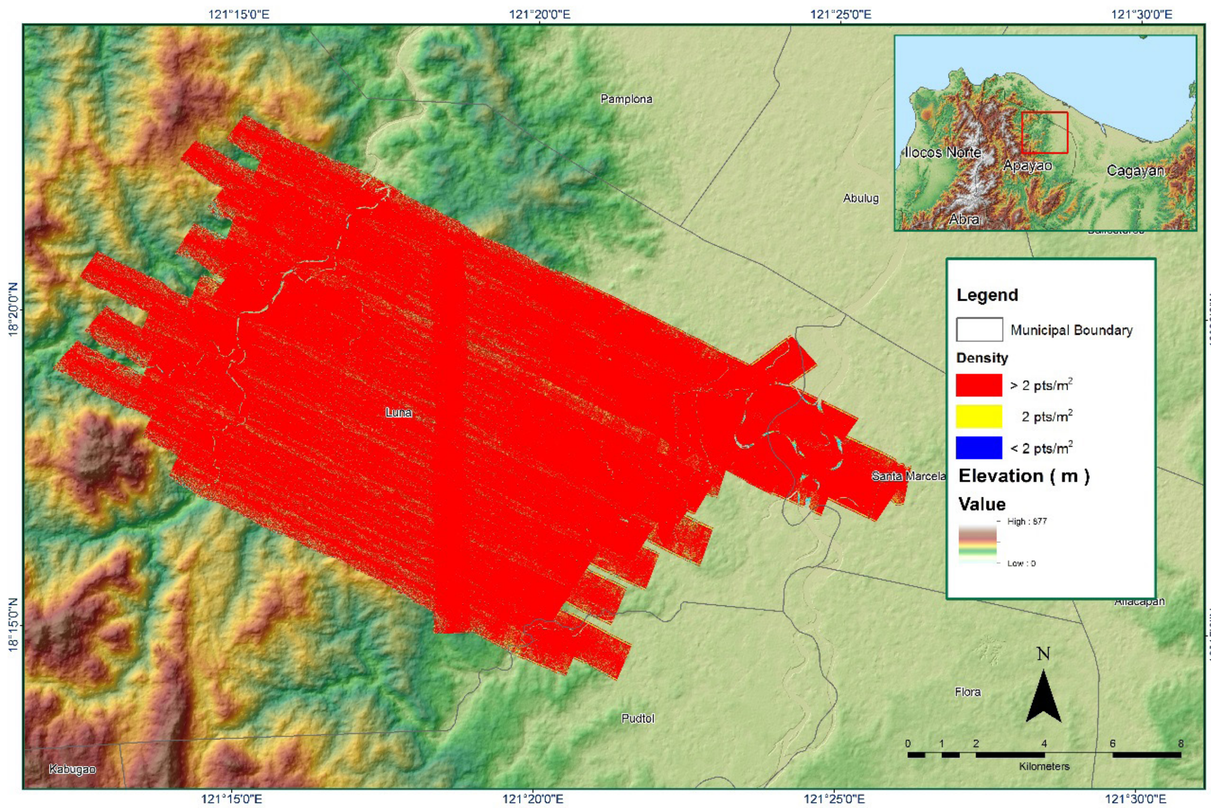


Figure A-8.6. Density map of merged LiDAR data

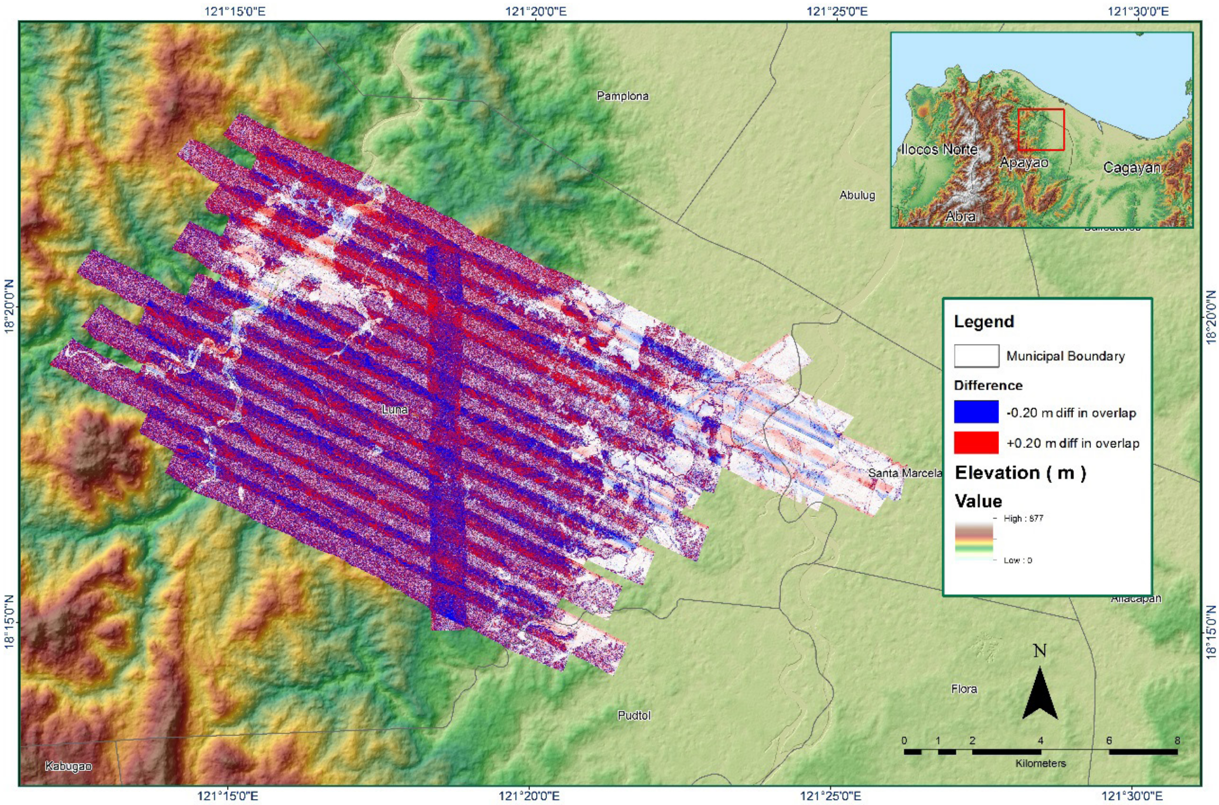


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission 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. Jovelle Canlas, Maria Tamsyn Malabanan

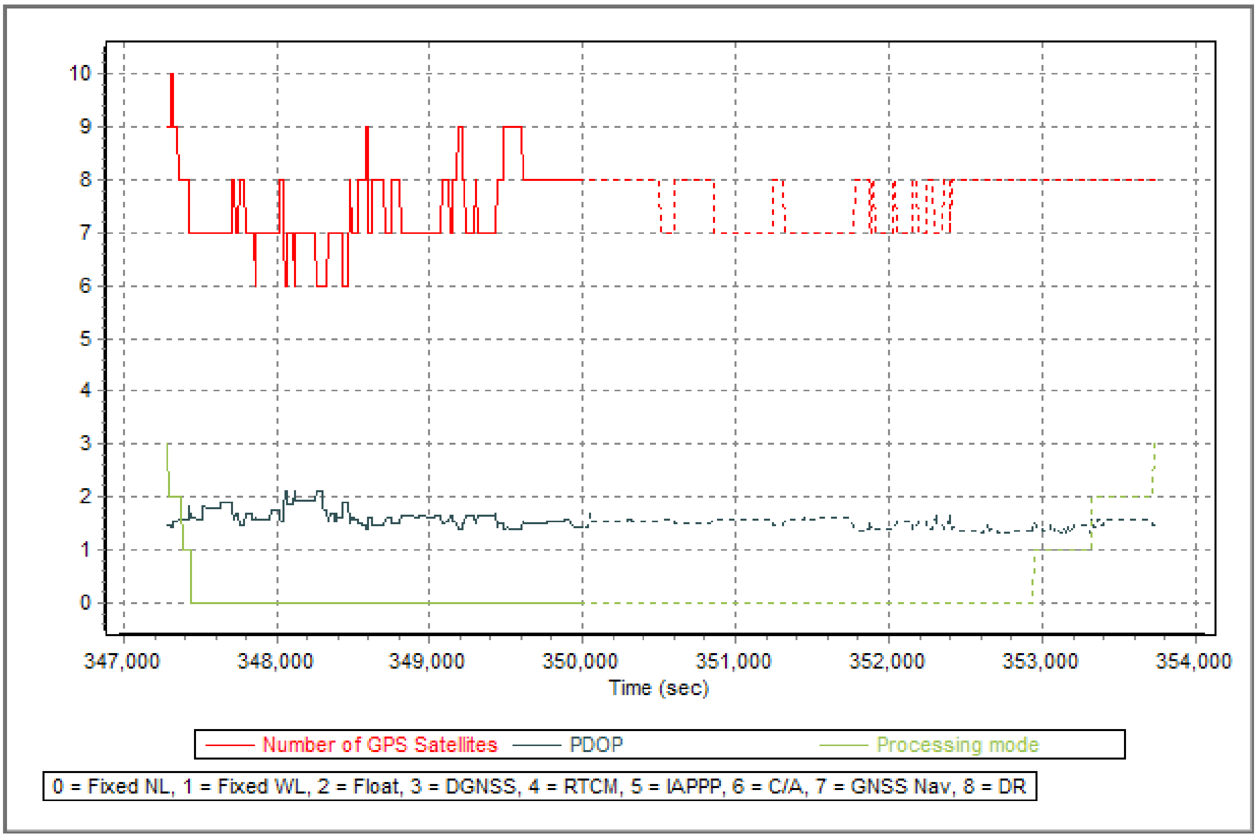


Figure A-8.8. Solution Status Parameters

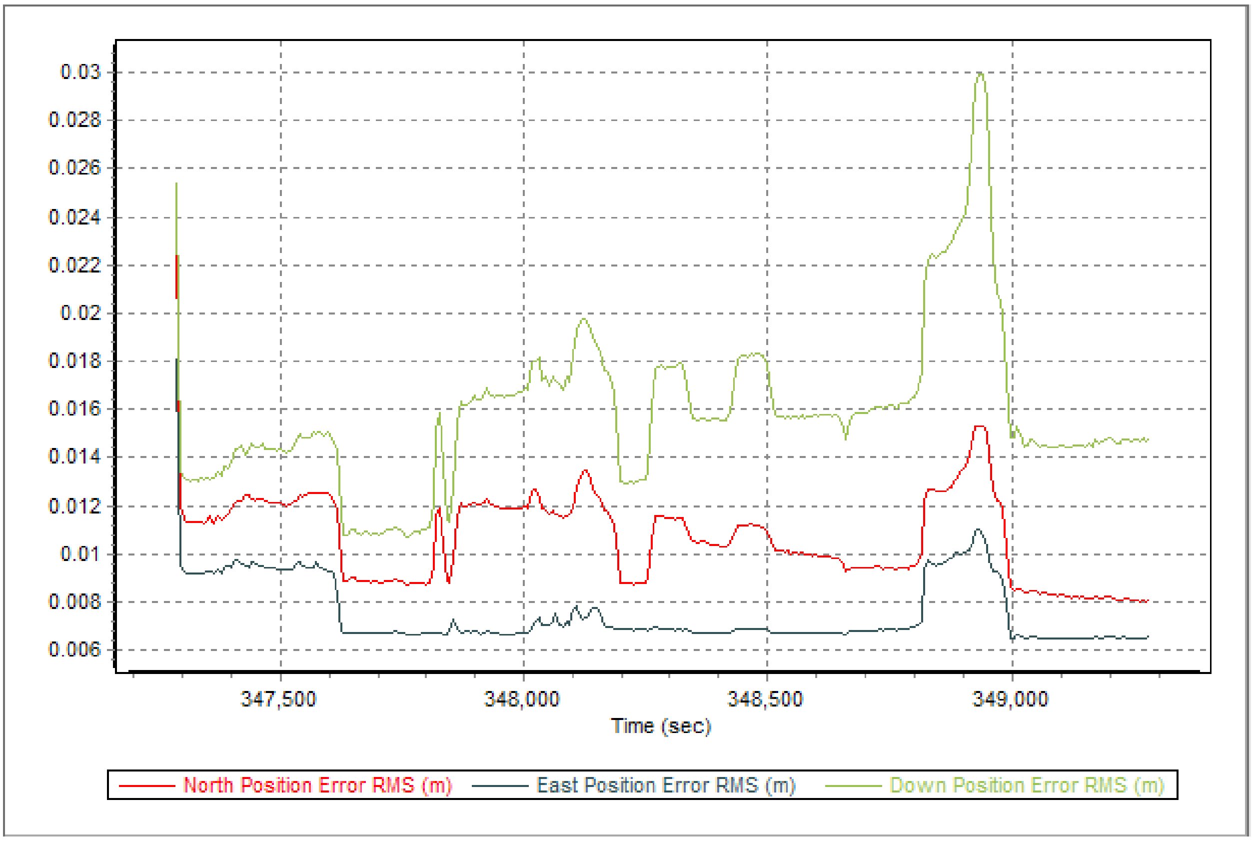


Figure A-8.9. Smoothed Performance Metrics Parameters

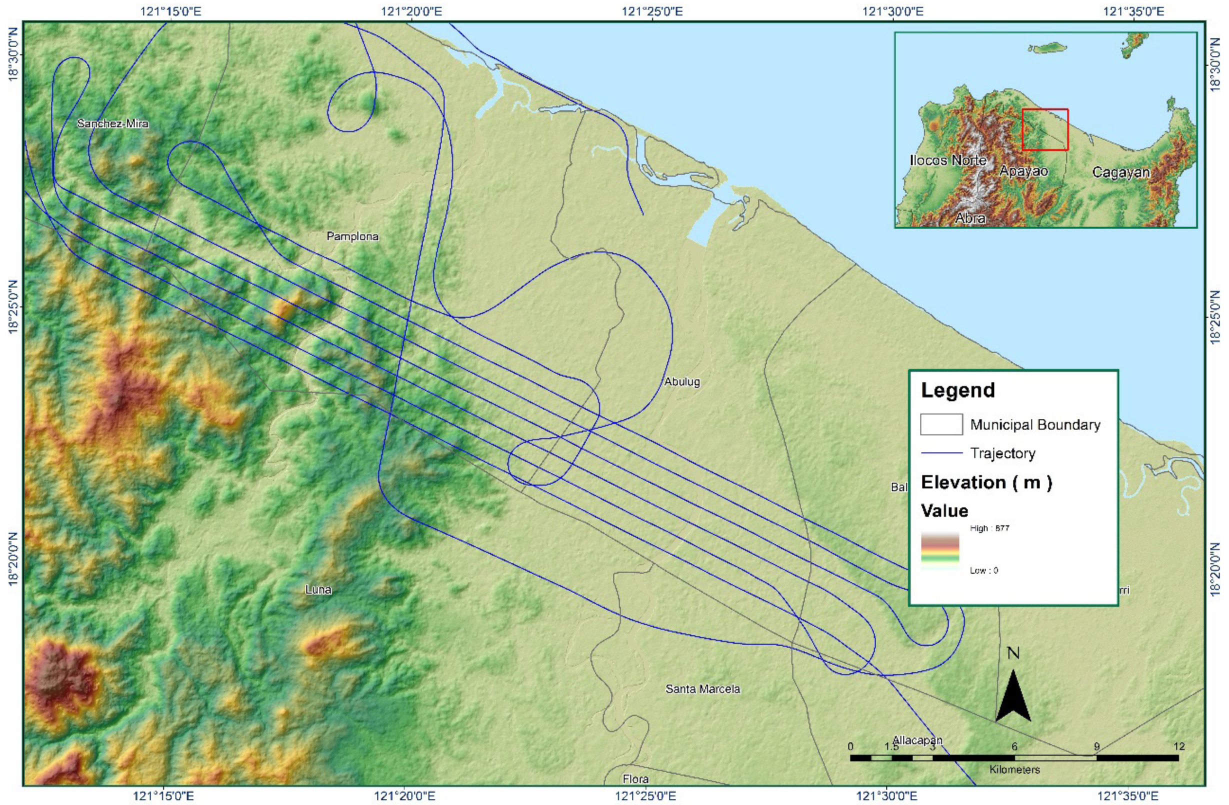


Figure A-8.10. Best Estimated Trajectory

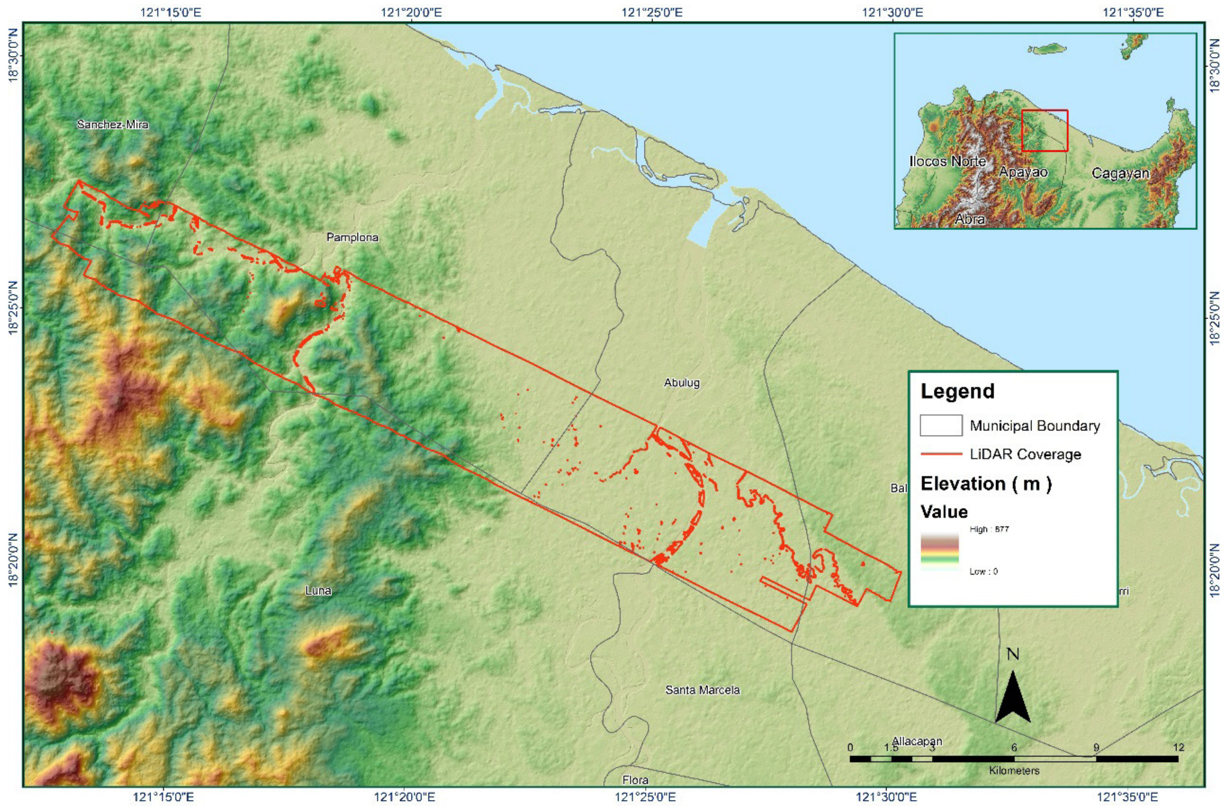


Figure A-8.11. Coverage of LiDAR data

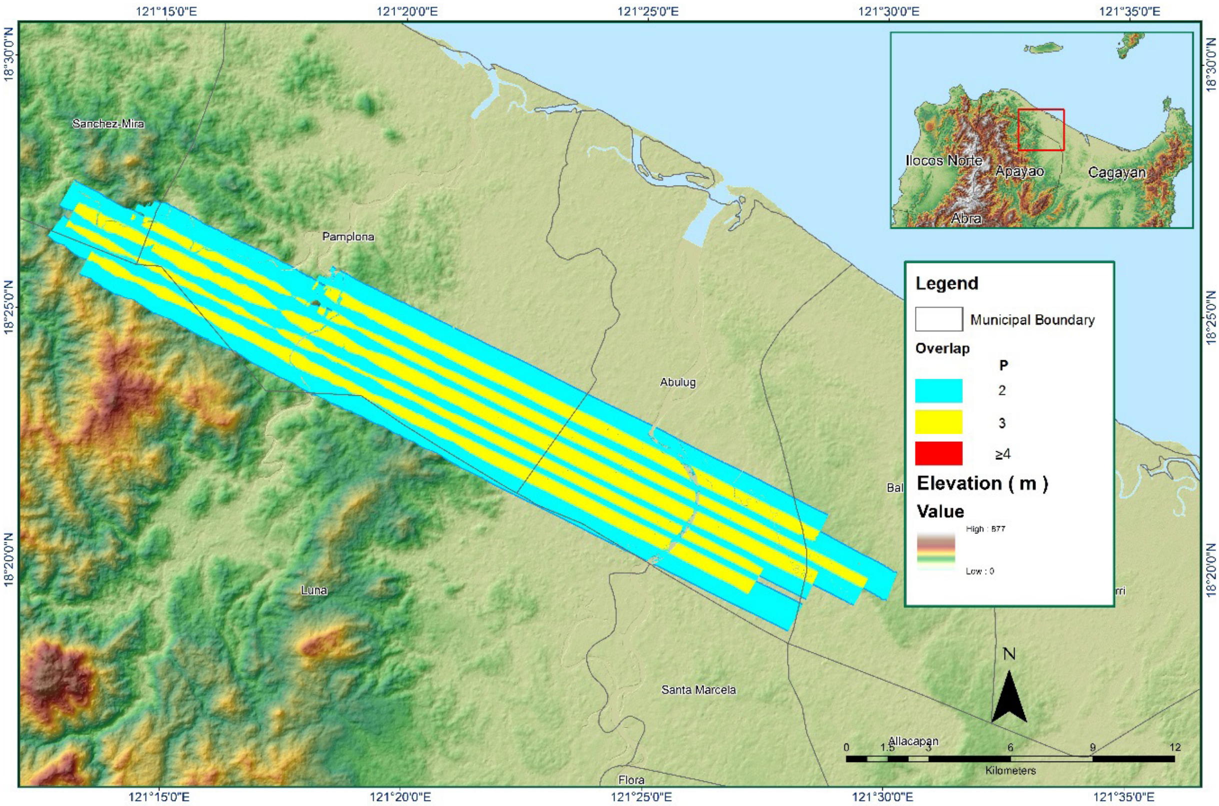


Figure A-8.12. Image of Data Overlap

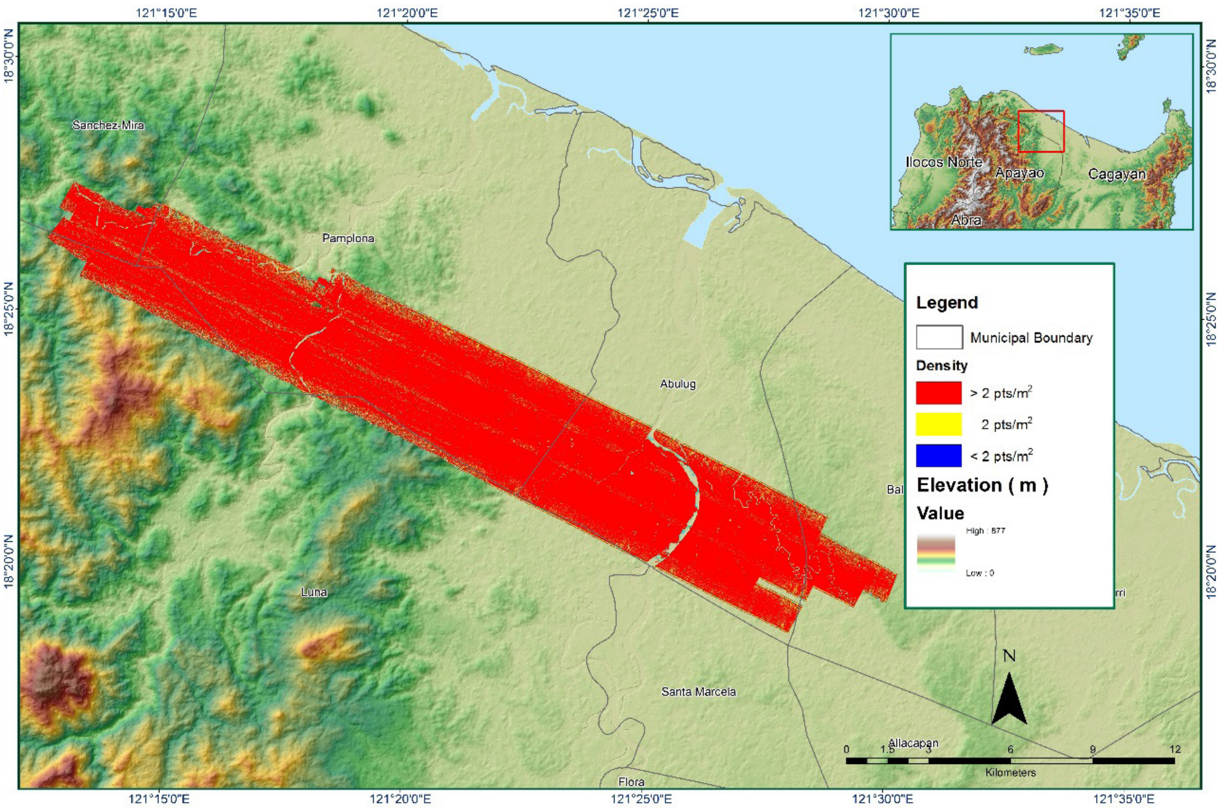


Figure A-8.13. Density map of merged LiDAR data

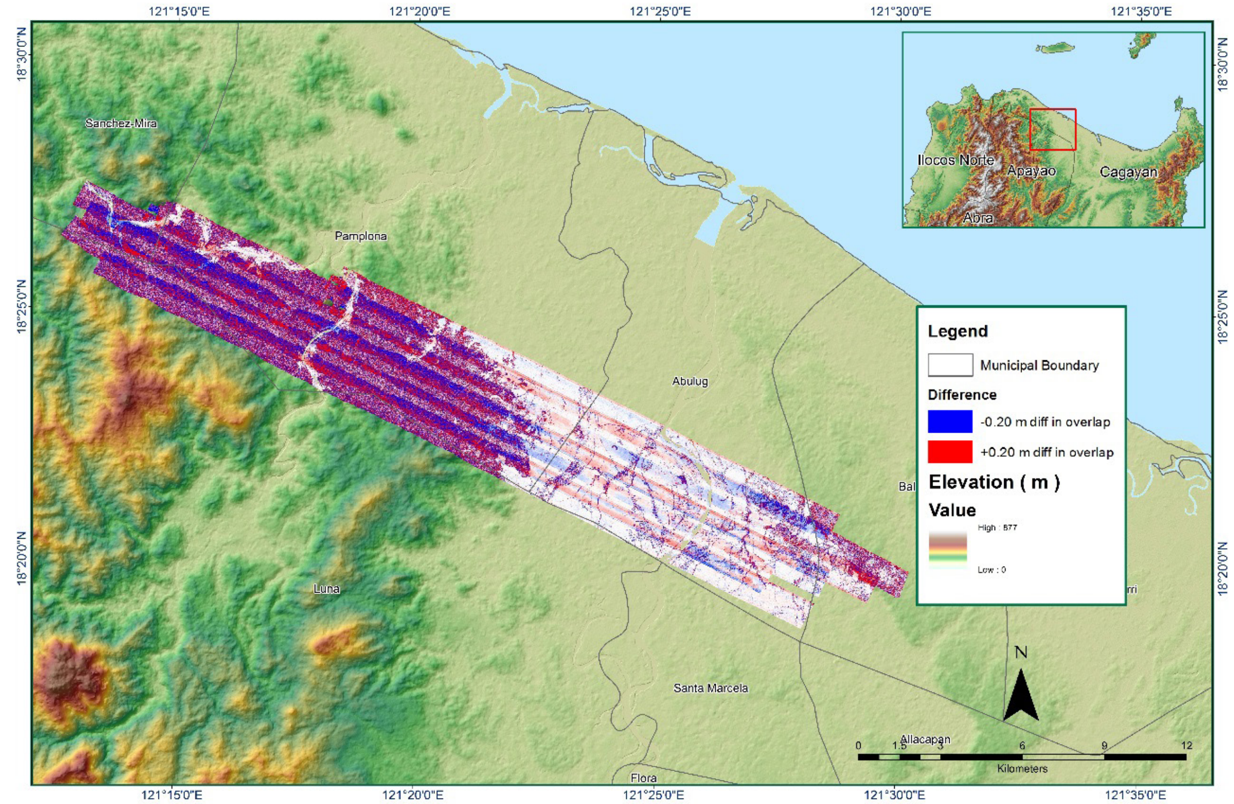


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk2E

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk2E
Inclusive Flights	2850P
Range data size	23.3GB
POS	230MB
Image	35.2MB
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)	1.17
RMSE for East Position (<4.0 cm)	1.62
RMSE for Down Position (<8.0 cm)	3.60
Boresight correction stdev (<0.001deg)	0.000255
IMU attitude correction stdev (<0.001deg)	0.001669
GPS position stdev (<0.01m)	0.0147
Minimum % overlap (>25)	51.38
Ave point cloud density per sq.m. (>2.0)	4.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	243
Maximum Height	629.94 m
Minimum Height	33.11 m
Classification (# of points)	
Ground	114,681,685
Low vegetation	86,249,217
Medium vegetation	179,801,226
High vegetation	1,312,535,704
Building	12,298,531
Orthophoto	Yes
Processed by	Engr. Jennifer B. Saguran, Engr. Chelou Prado, Marie Denise Bueno

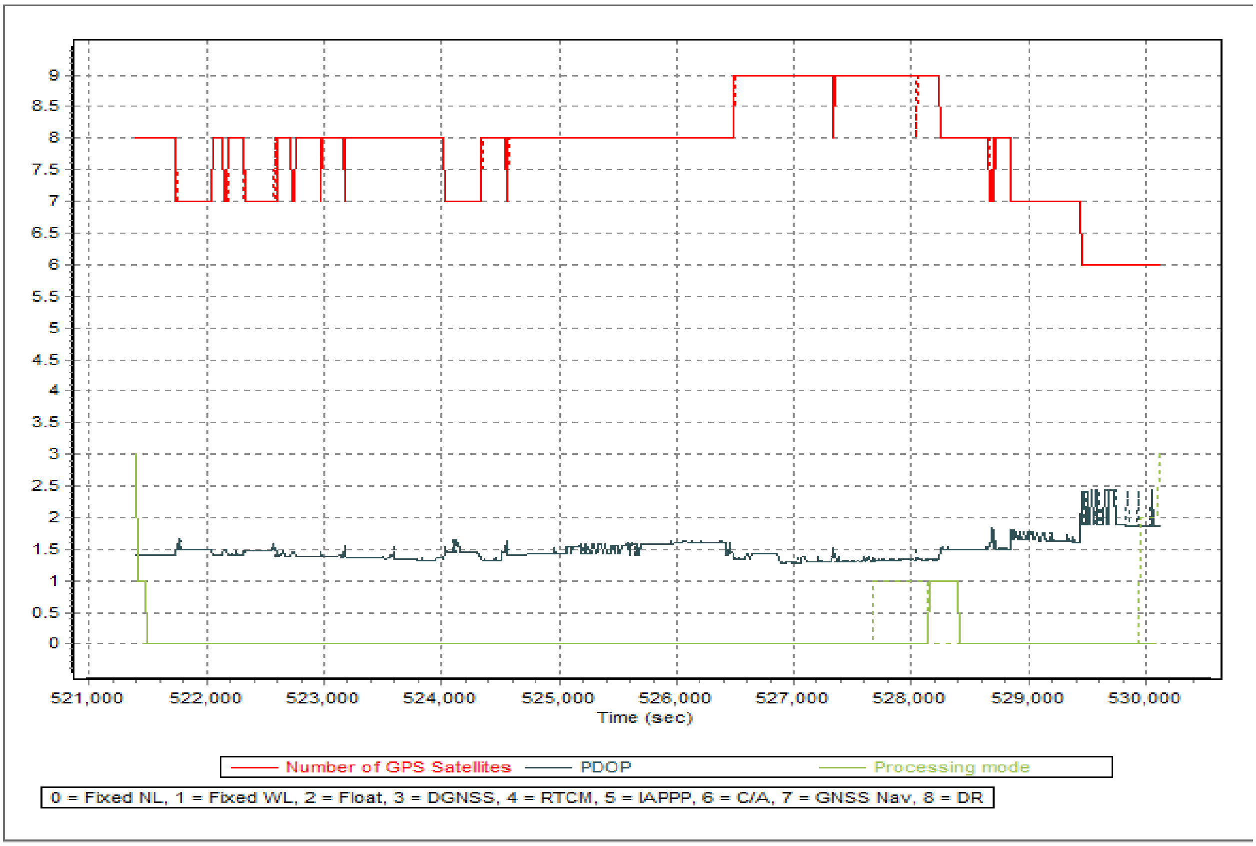


Figure A-8.15. Solution Status

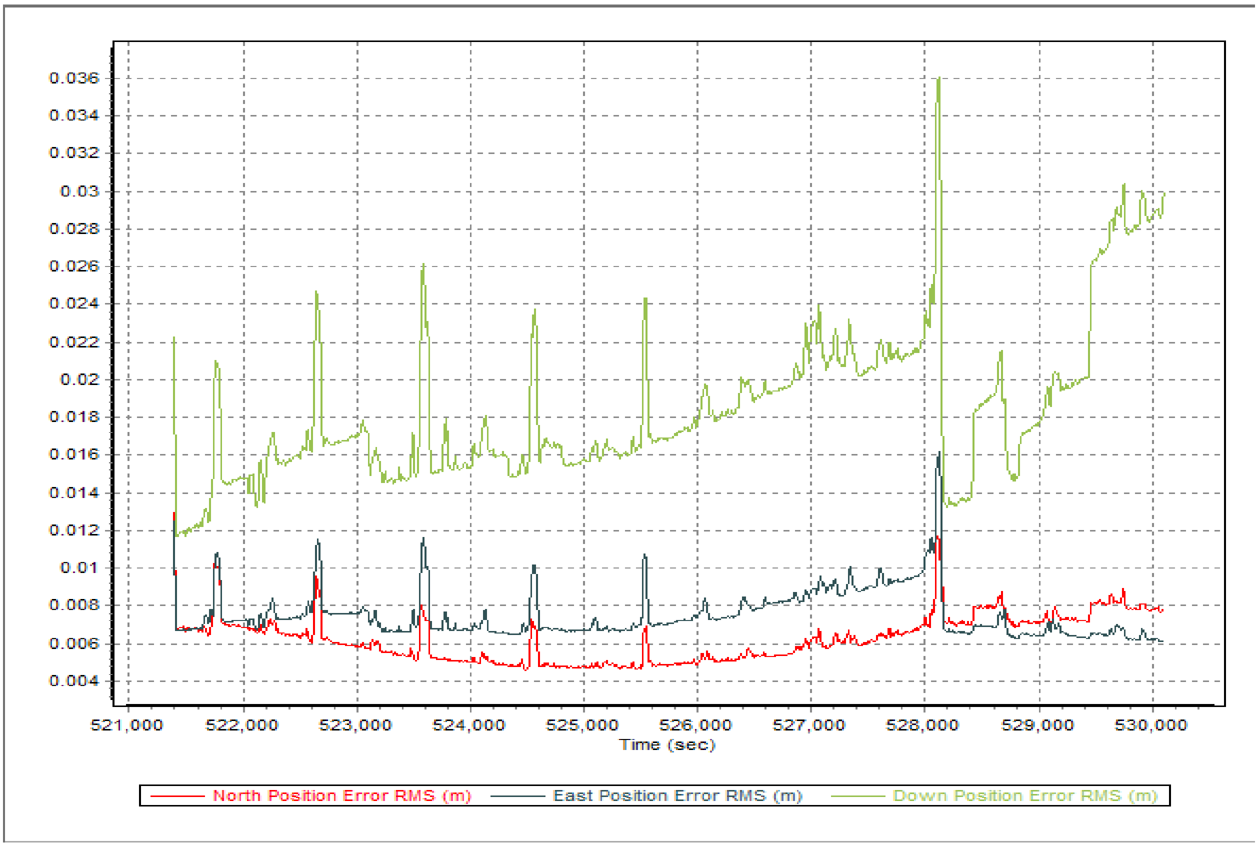


Figure A-8.16. Smoothed Performance Metric Parameters

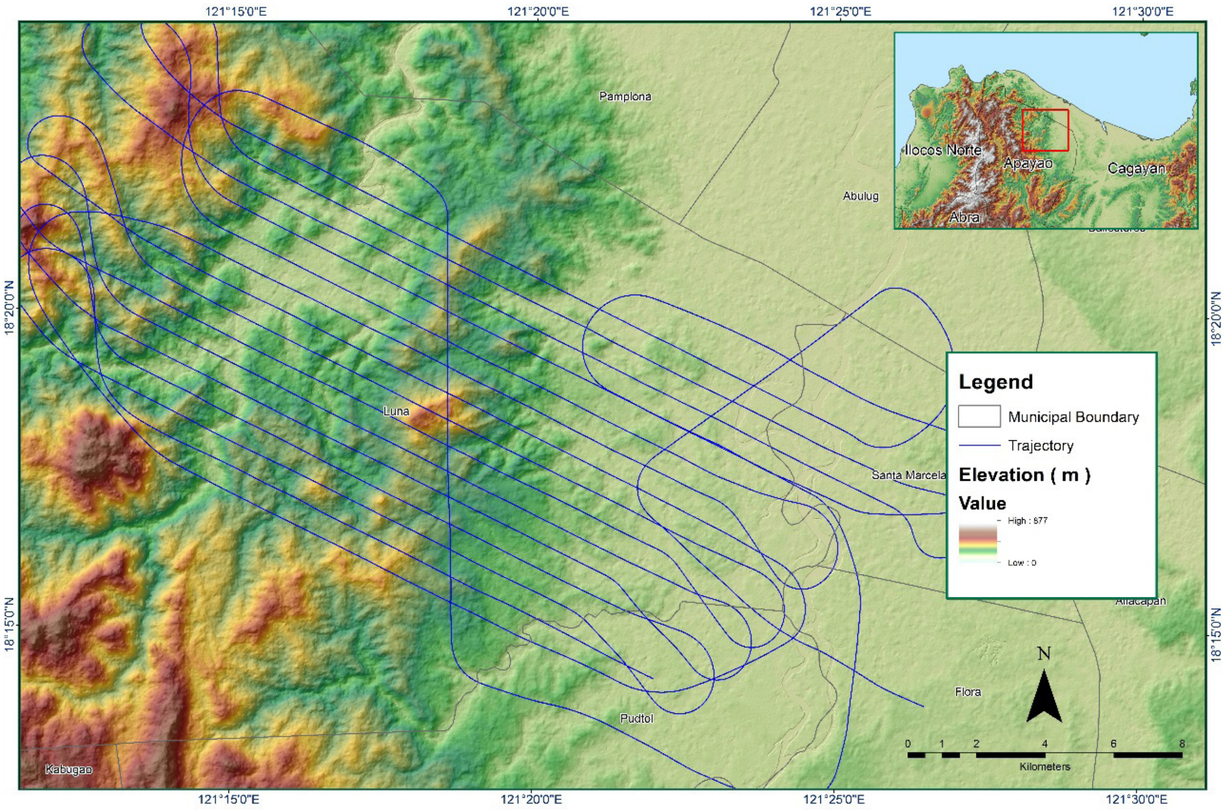


Figure A-8.17. Best Estimated Trajectory

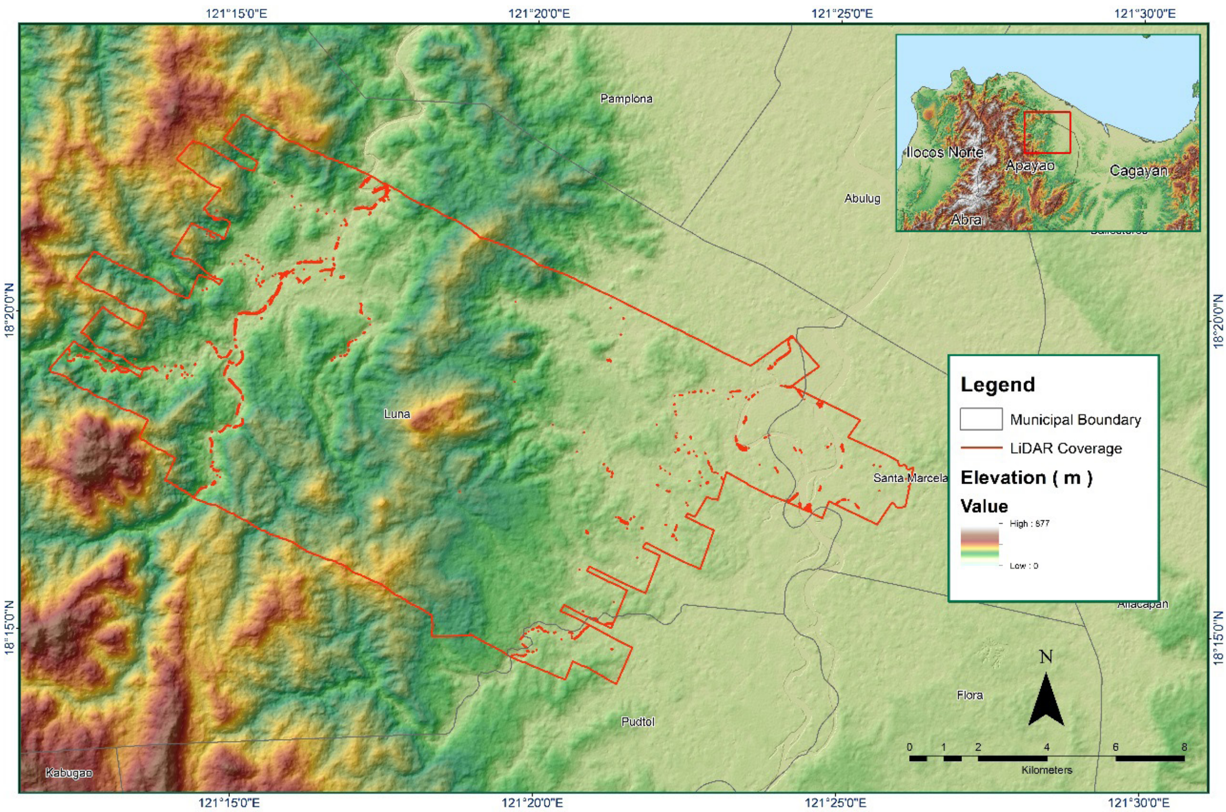


Figure A-8.18. Coverage of LiDAR data

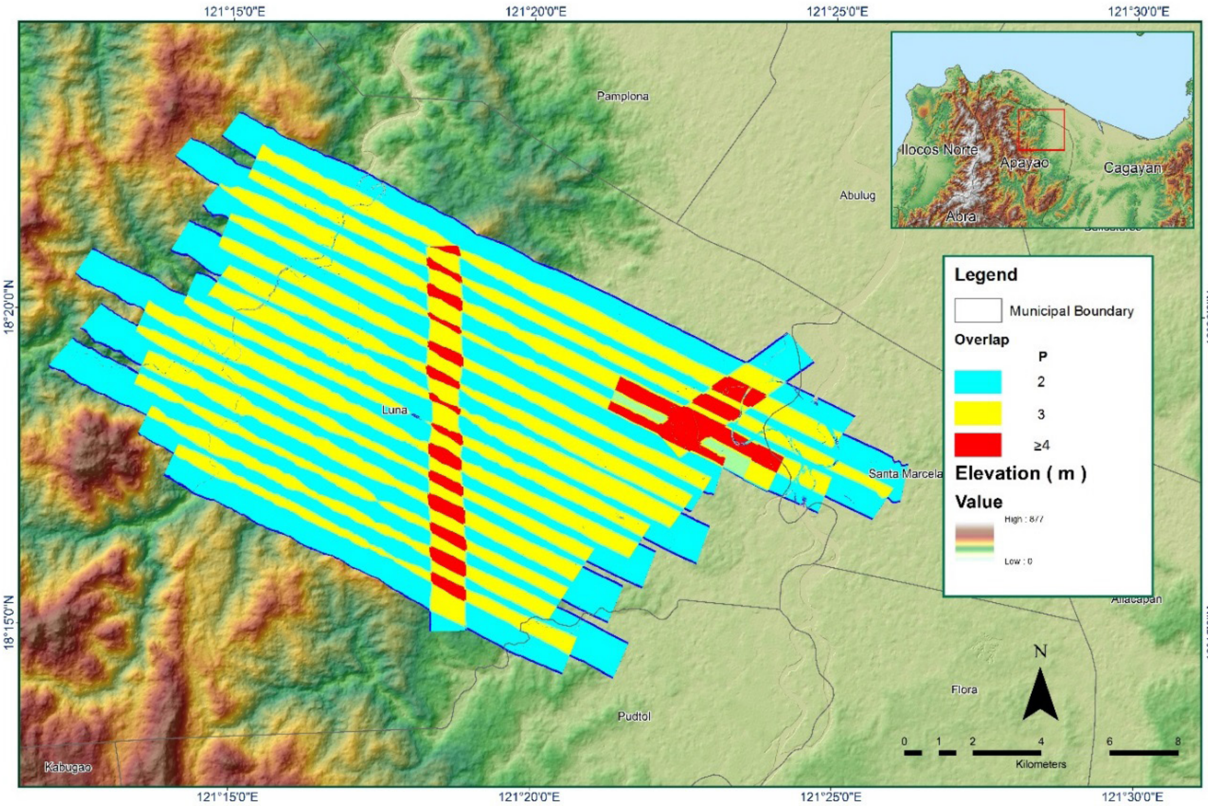


Figure A-8.19. Image of Data Overlap

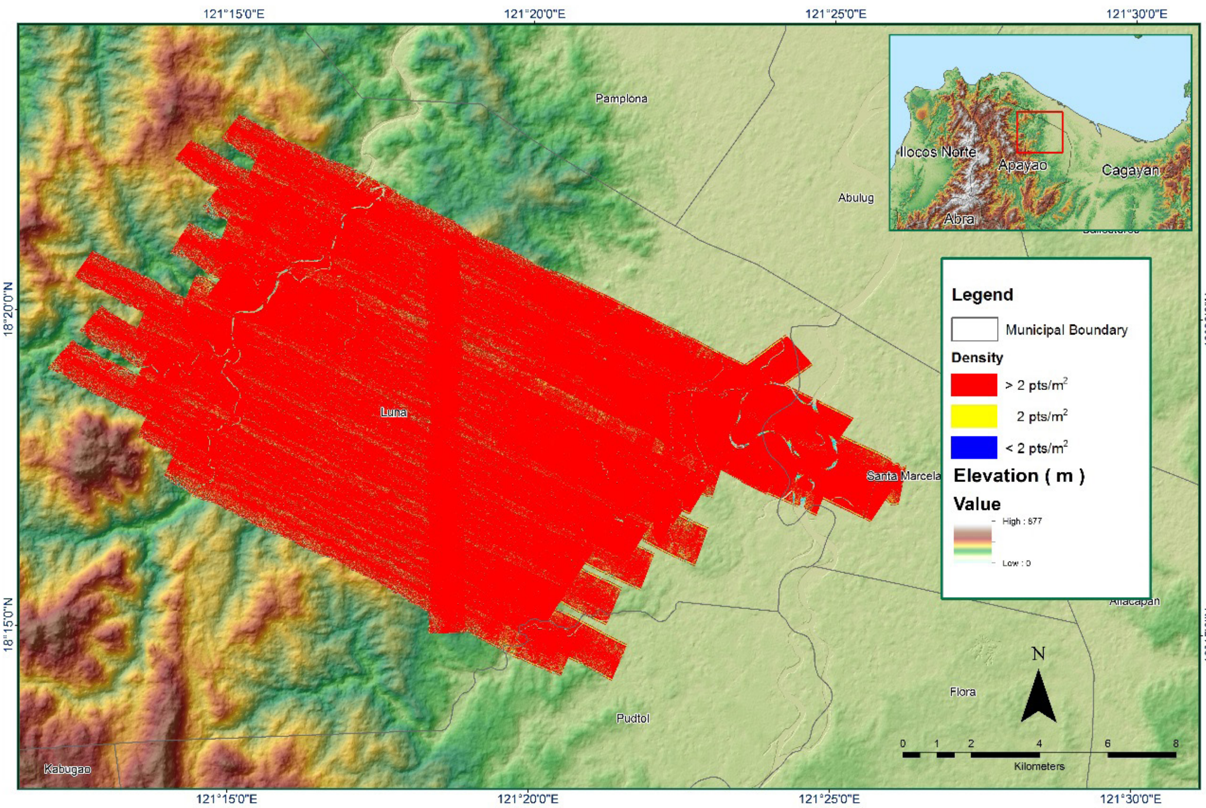


Figure A-8.20. Density map of merged LiDAR data

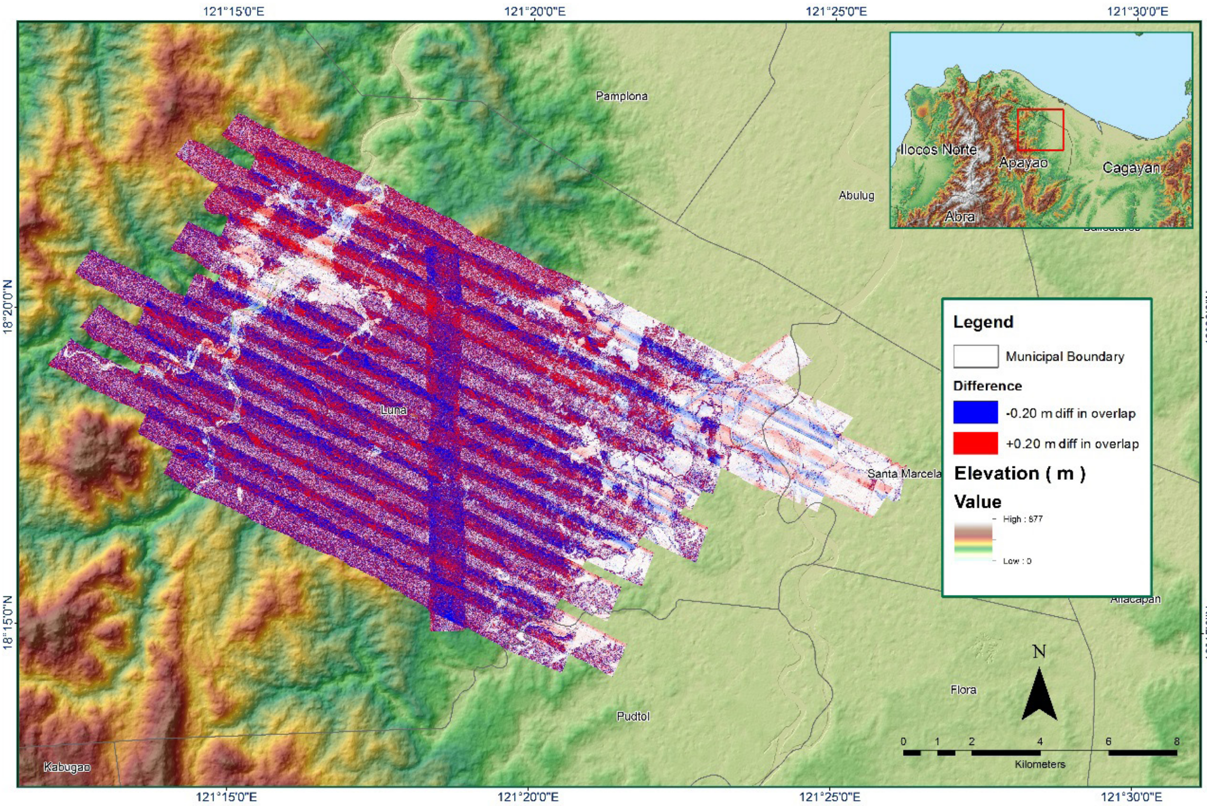


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk2D

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk2D
Inclusive Flights	2854P
Range data size	26.1GB
POS	247MB
Image	40.5MB
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)	1.01
RMSE for East Position (<4.0 cm)	1.33
RMSE for Down Position (<8.0 cm)	2.99
Boresight correction stdev (<0.001deg)	0.000449
IMU attitude correction stdev (<0.001deg)	0.000777
GPS position stdev (<0.01m)	0.0096
Minimum % overlap (>25)	46.71
Ave point cloud density per sq.m. (>2.0)	4.135
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	113
Maximum Height	579.99 m
Minimum Height	42.78 m
Classification (# of points)	
Ground	54,696,025
Low vegetation	48,721,614
Medium vegetation	57,326,160
High vegetation	399,639,419
Building	5,543,063
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Mark Joshua Salvacion, Kathryn Claudine Zarate

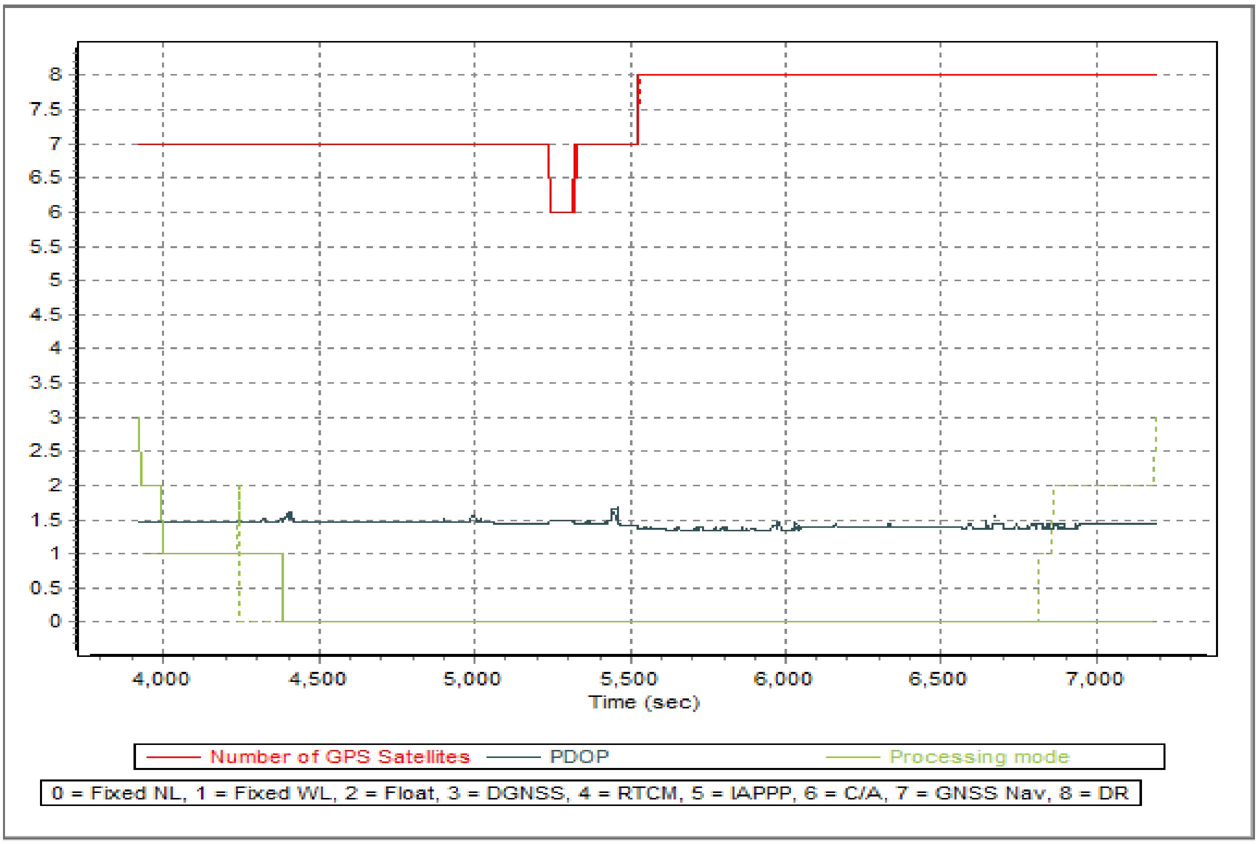


Figure A-8.22. Solution Status

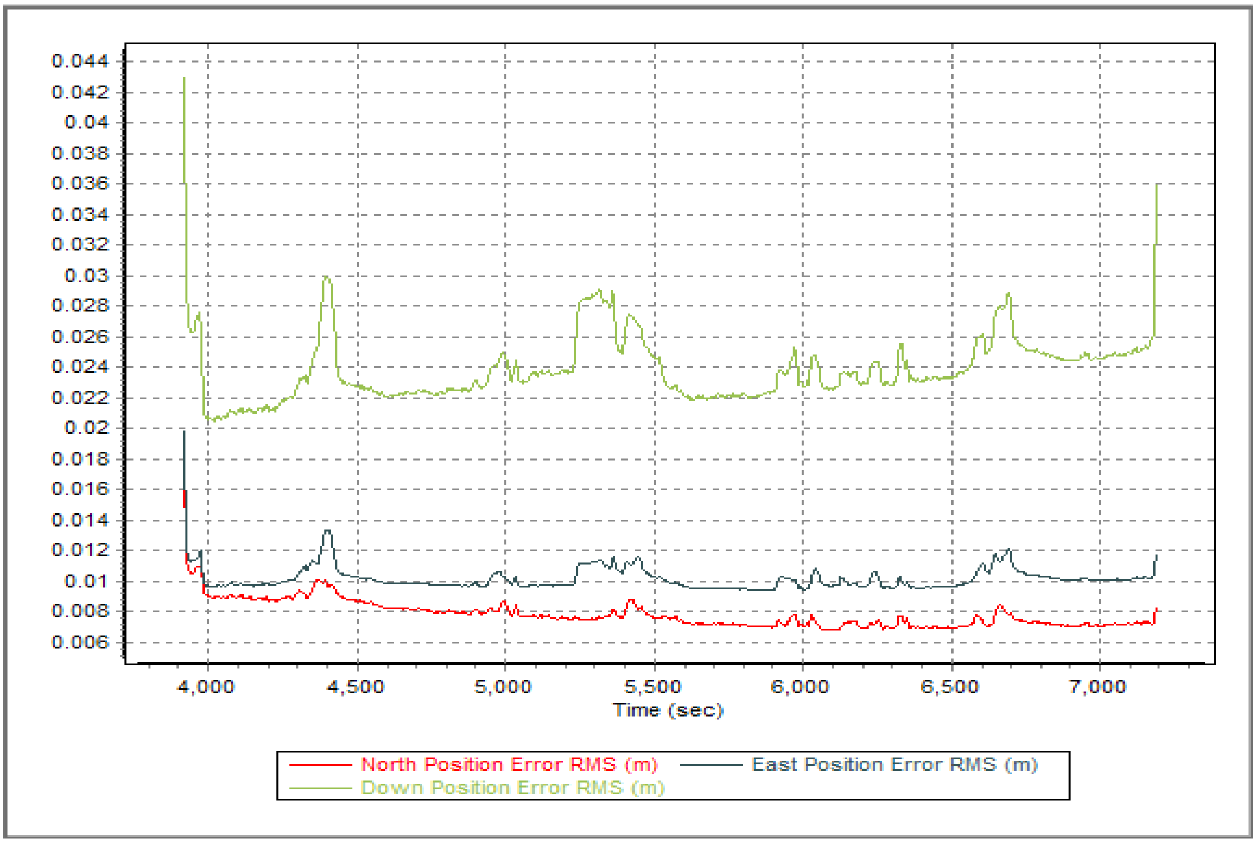


Figure A-8.23. Smoothed Performance Metric Parameters

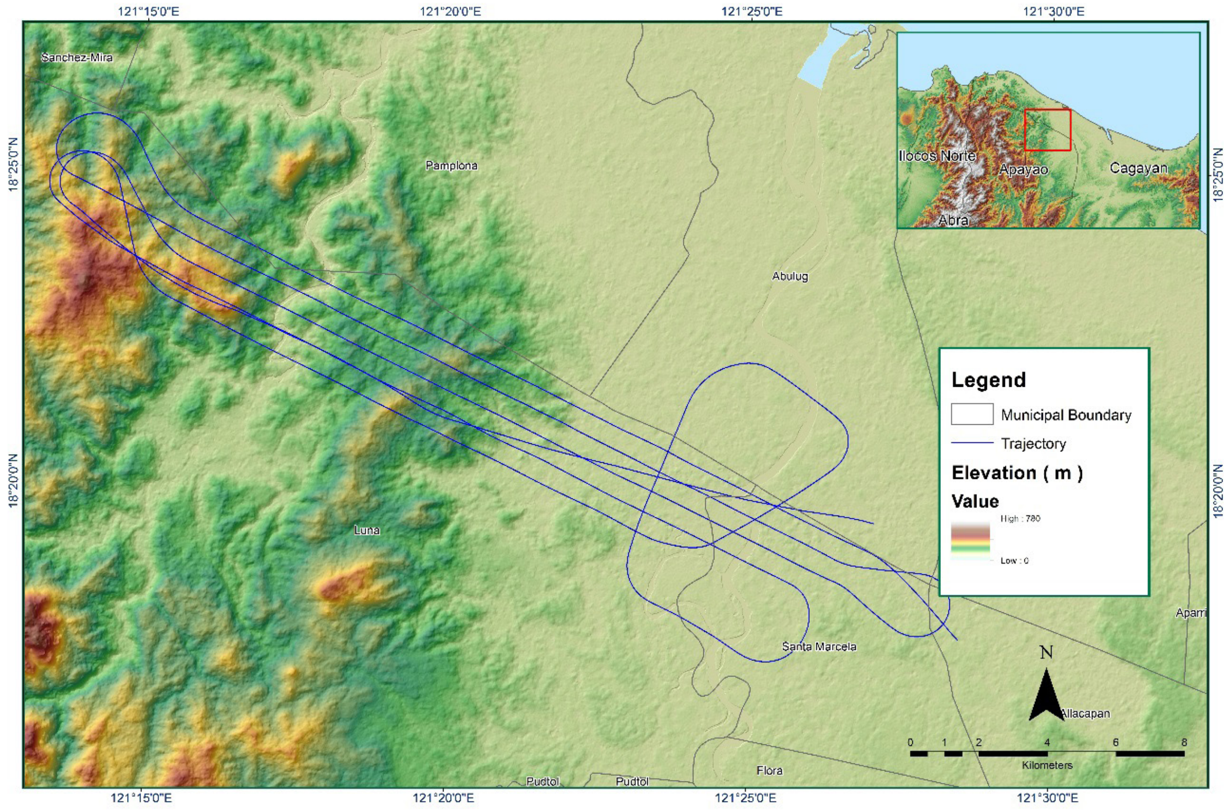


Figure A-8.24. Best Estimated Trajectory

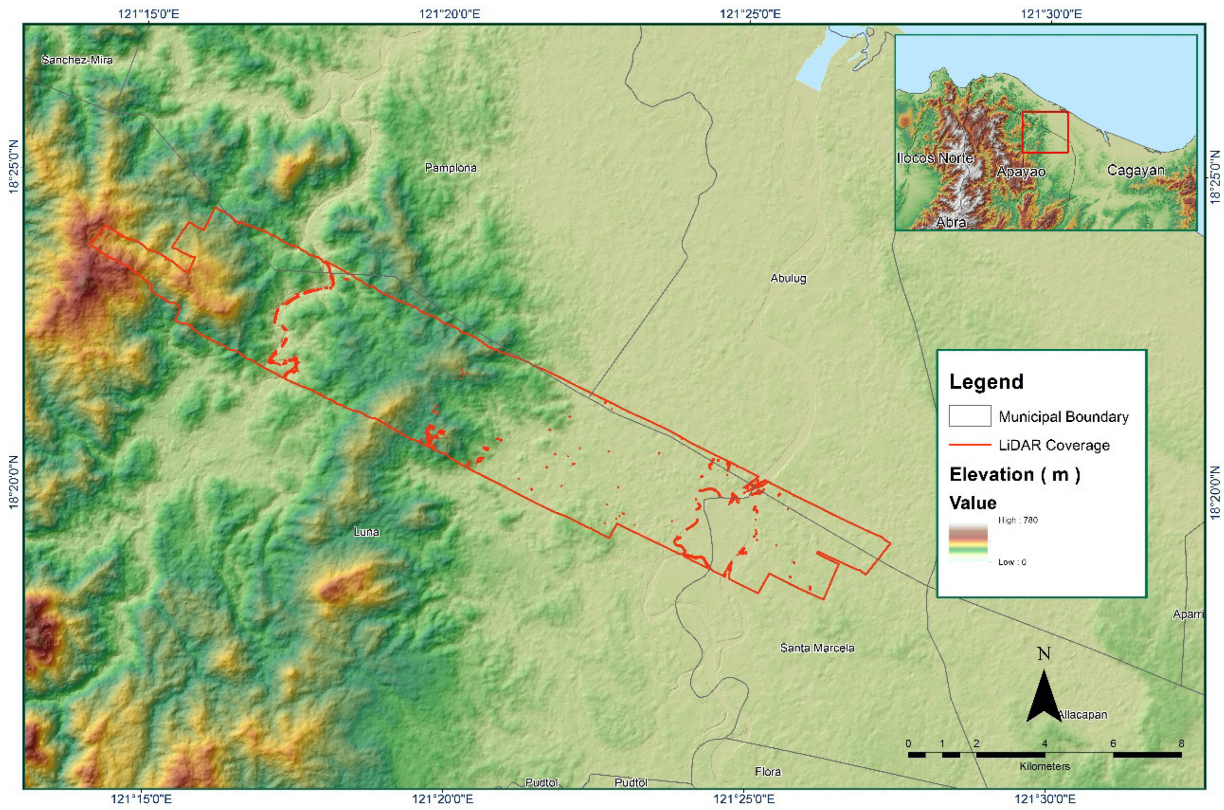


Figure A-8.25. Coverage of LiDAR data

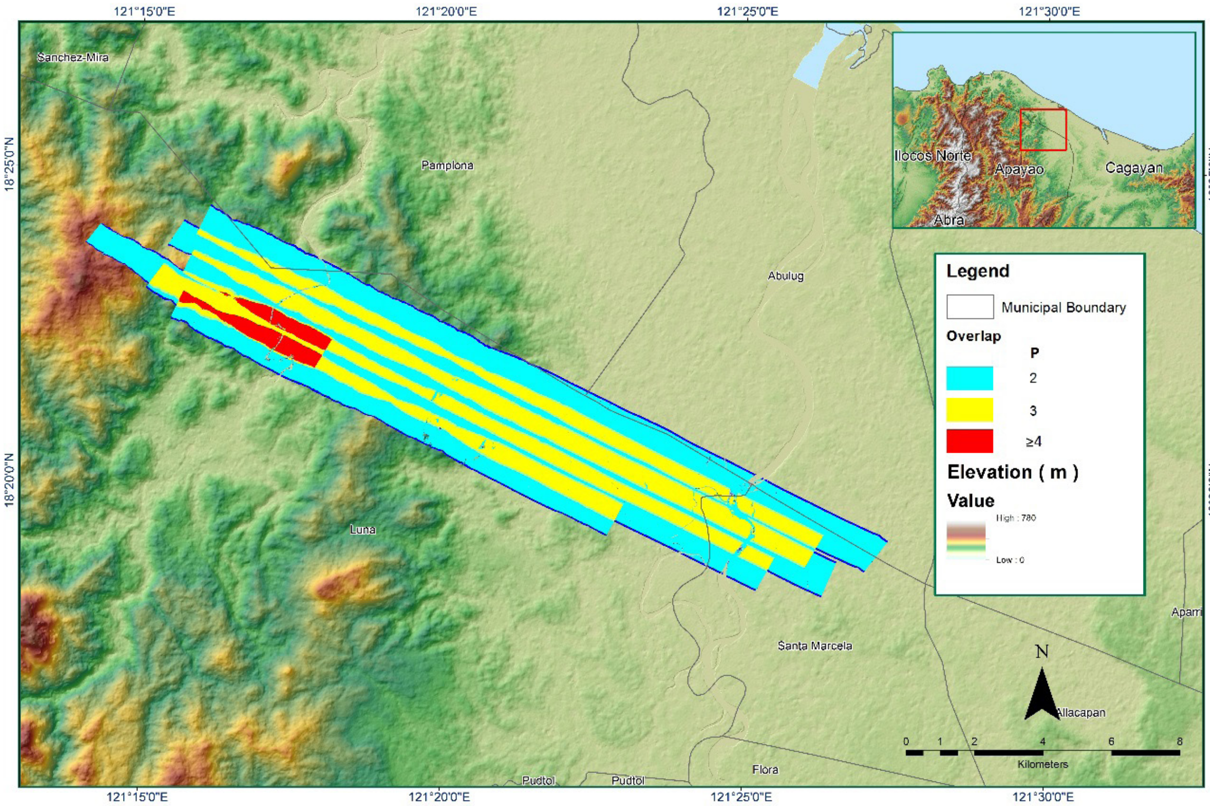


Figure A-8.26. Image of Data Overlap

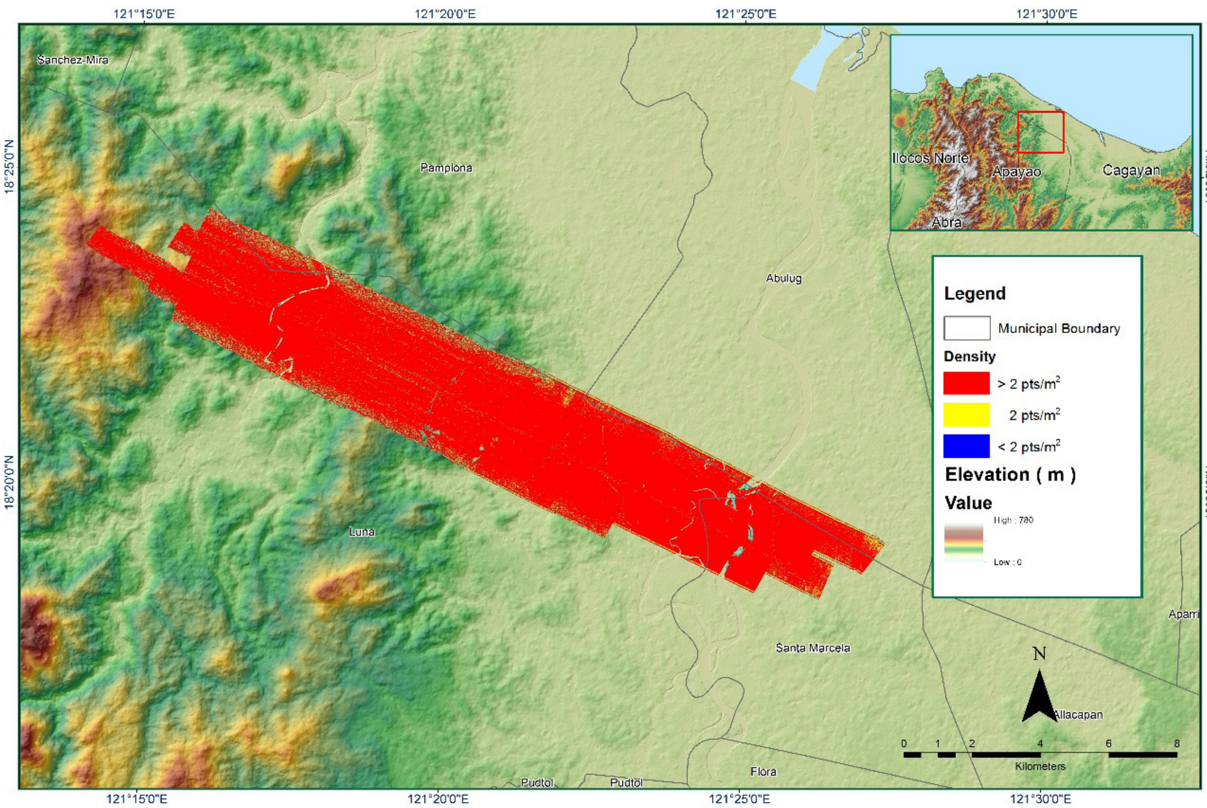


Figure A-8.27. Density map of merged LiDAR data

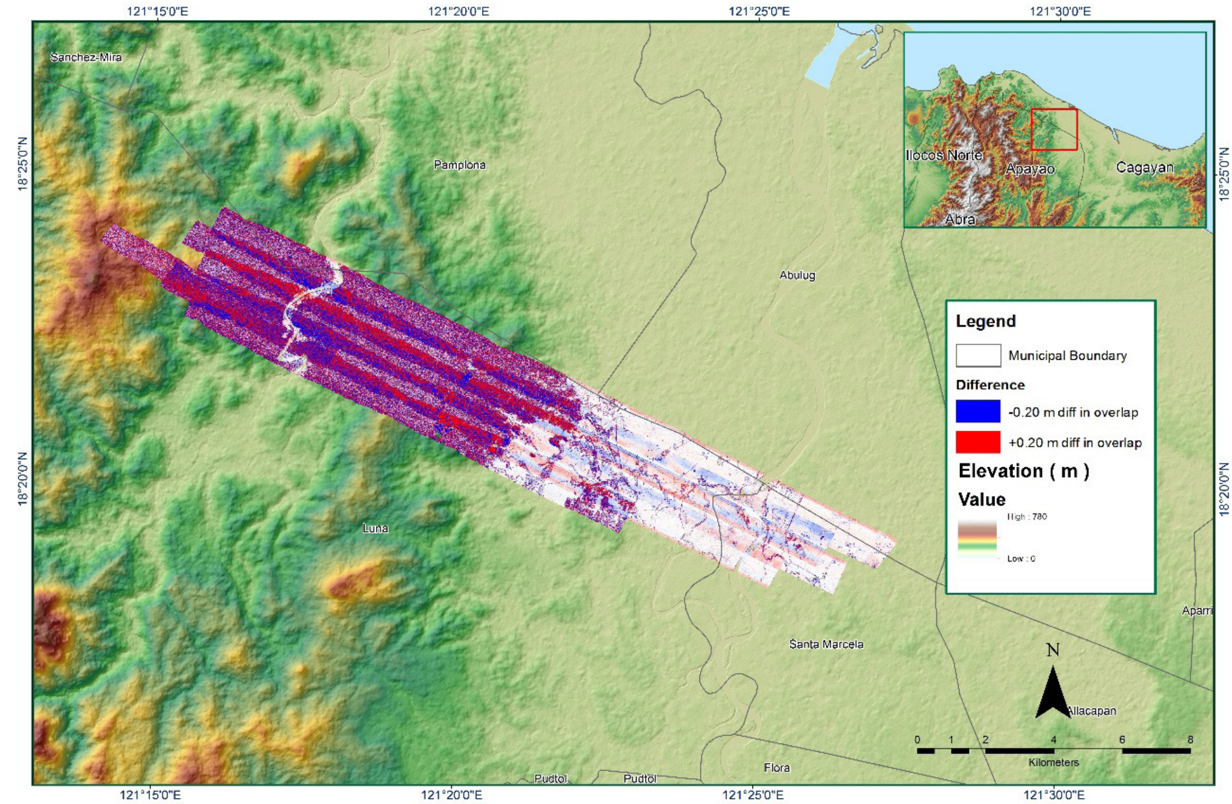


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk2B_supplement

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk2B_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)	0.002483
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	51.57
Ave point cloud density per sq.m. (>2.0)	3.165
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	40
Maximum Height	462.55 m
Minimum Height	43.63 m
Classification (# of points)	
Ground	11,786,737
Low vegetation	4,071,315
Medium vegetation	17,005,239
High vegetation	12,0302657
Building	1,496,293
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Edgardo Gubatanga Jr., Engr. Krisha Marie Bautista

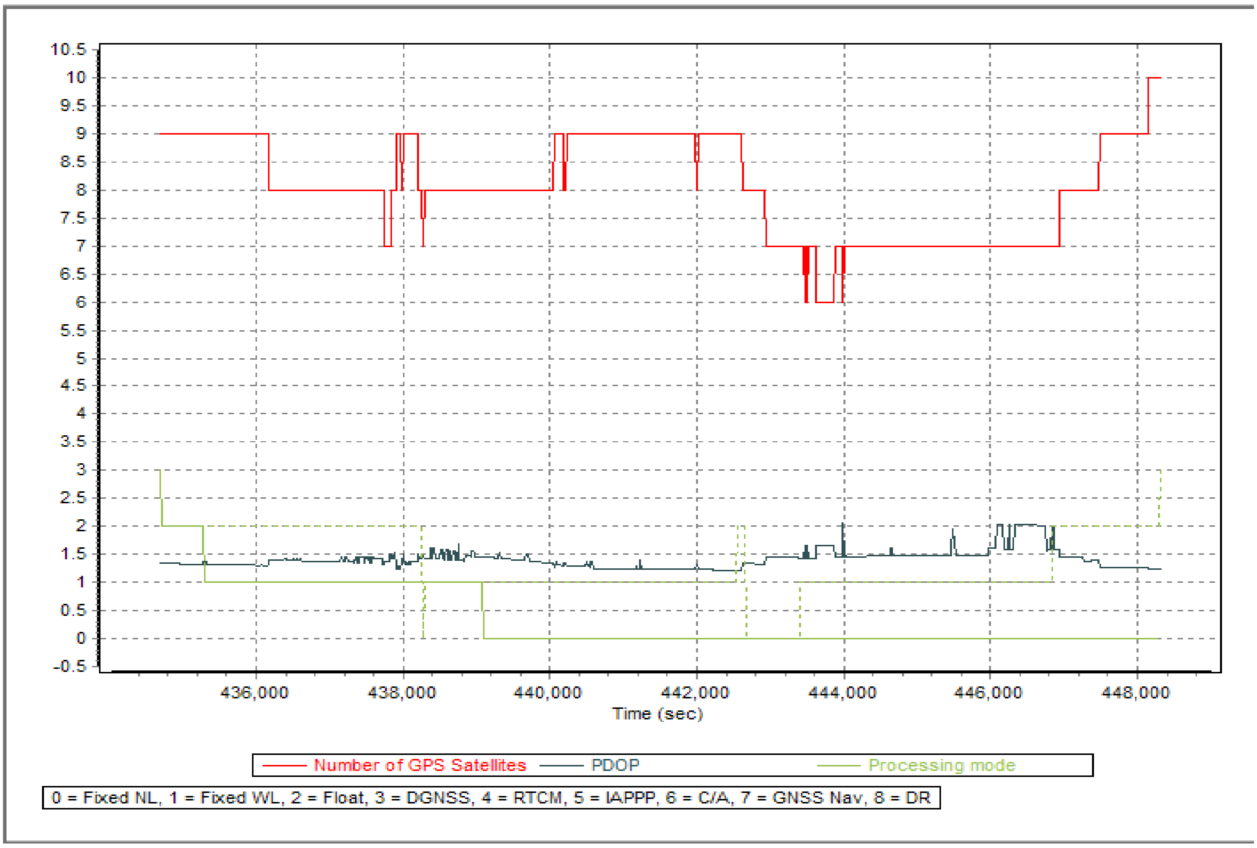


Figure A-8.29. Solution Status

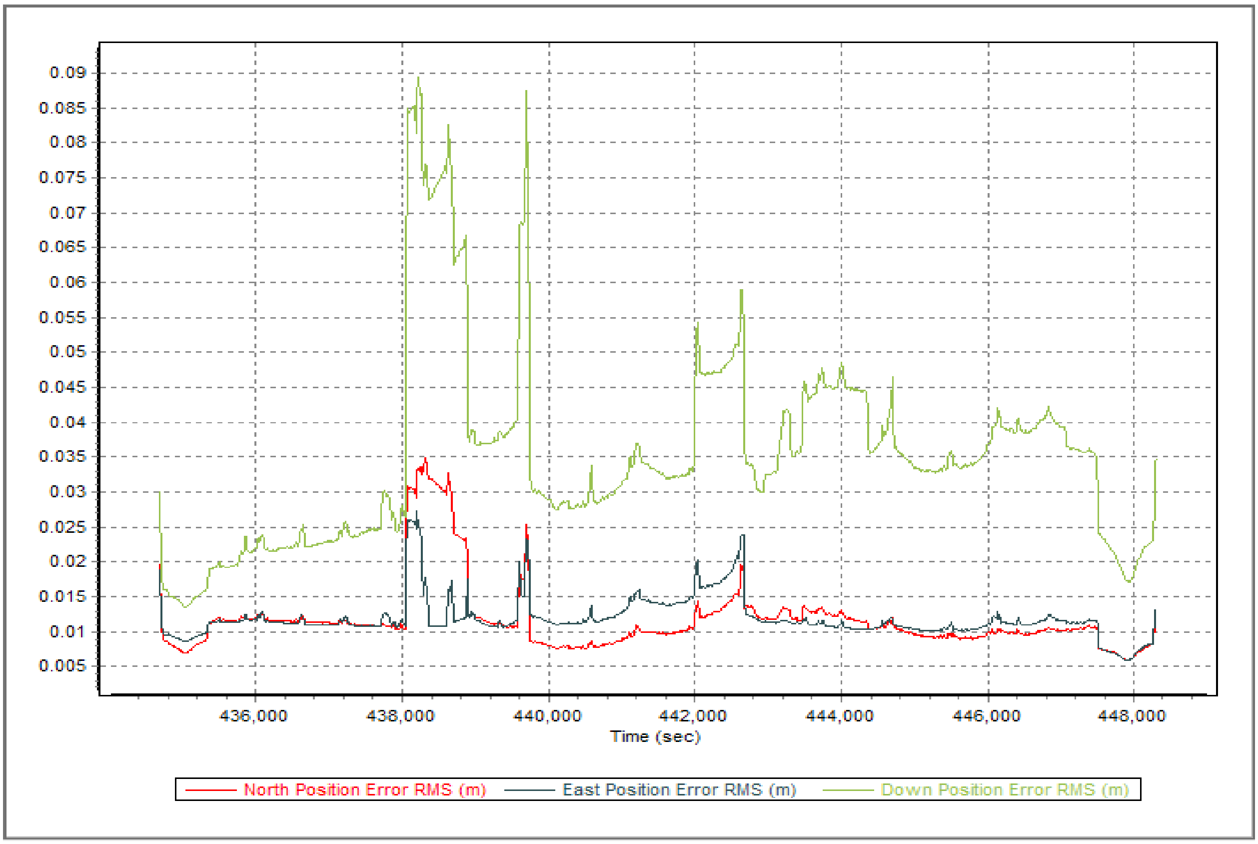


Figure A-8.30. Smoothed Performance Metric Parameters

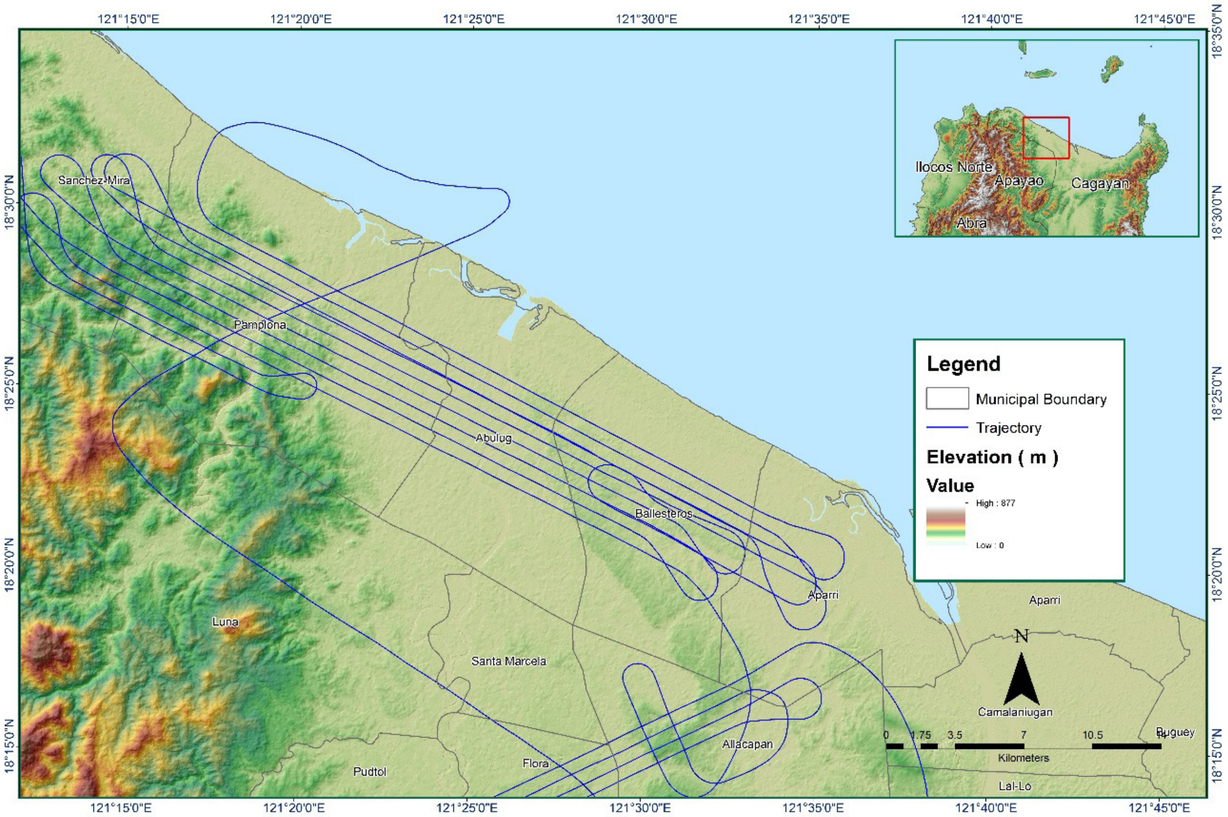


Figure A-8.31. Best Estimated Trajectory

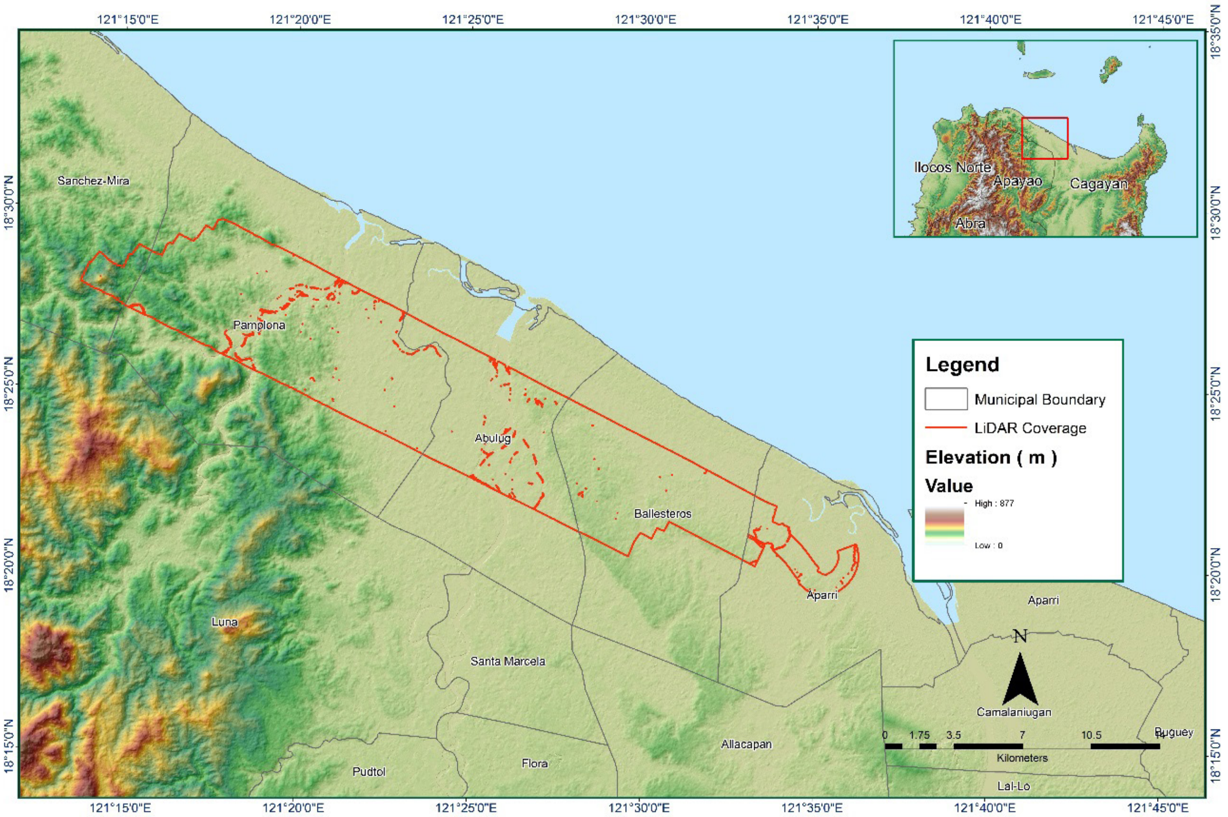


Figure A-8.32. Coverage of LiDAR data

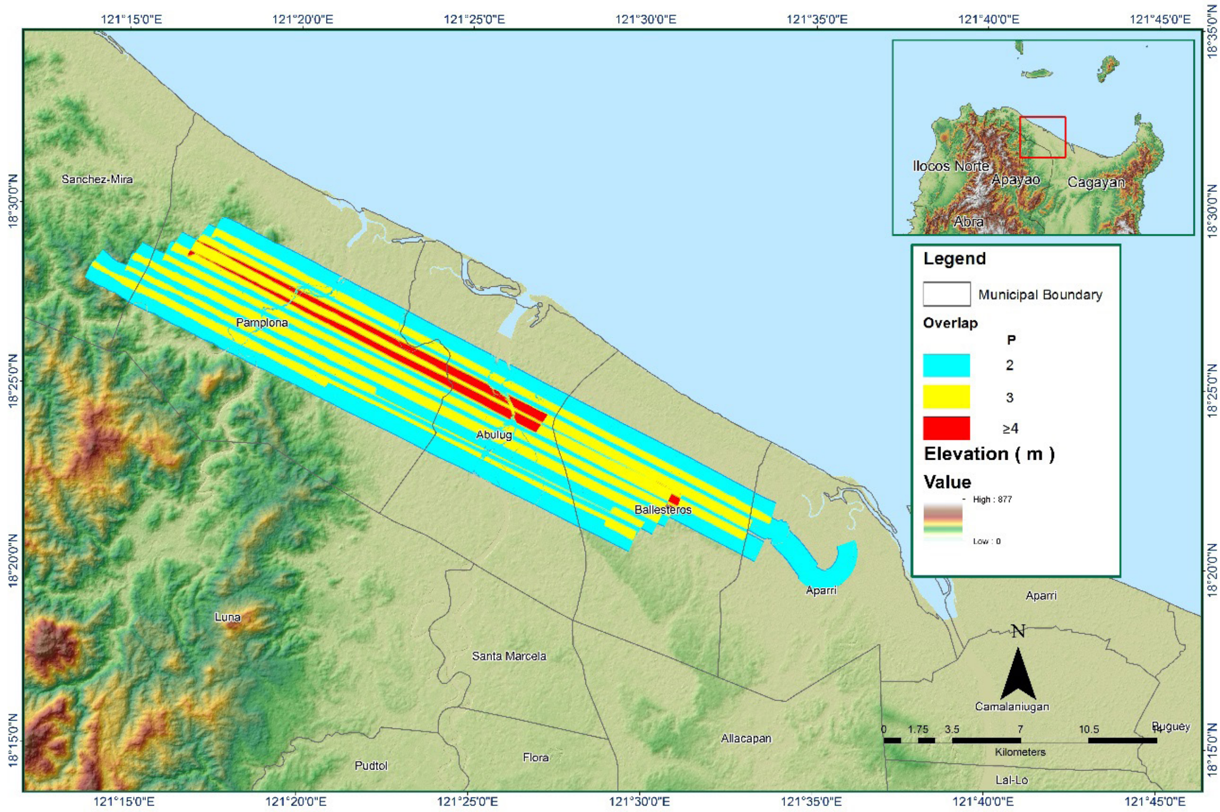


Figure A-8.33. Image of Data Overlap

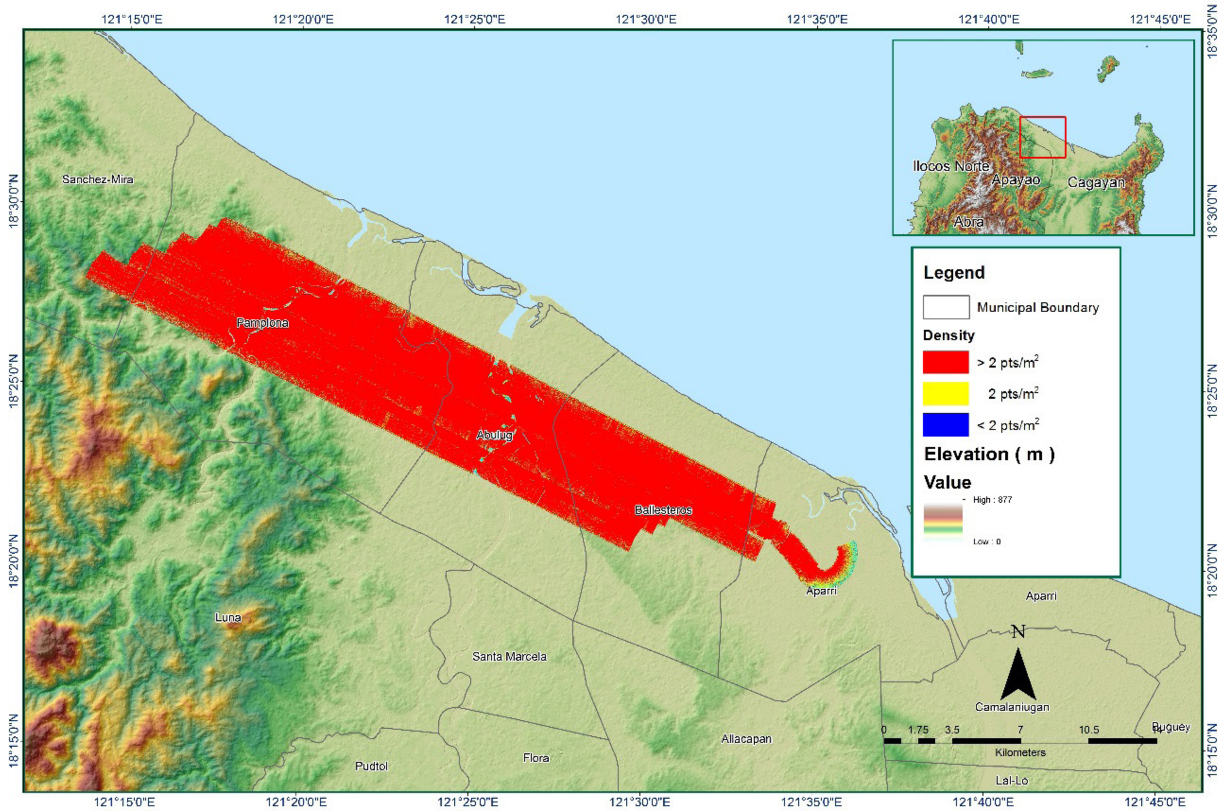


Figure A-8.34. Density map of merged LiDAR data

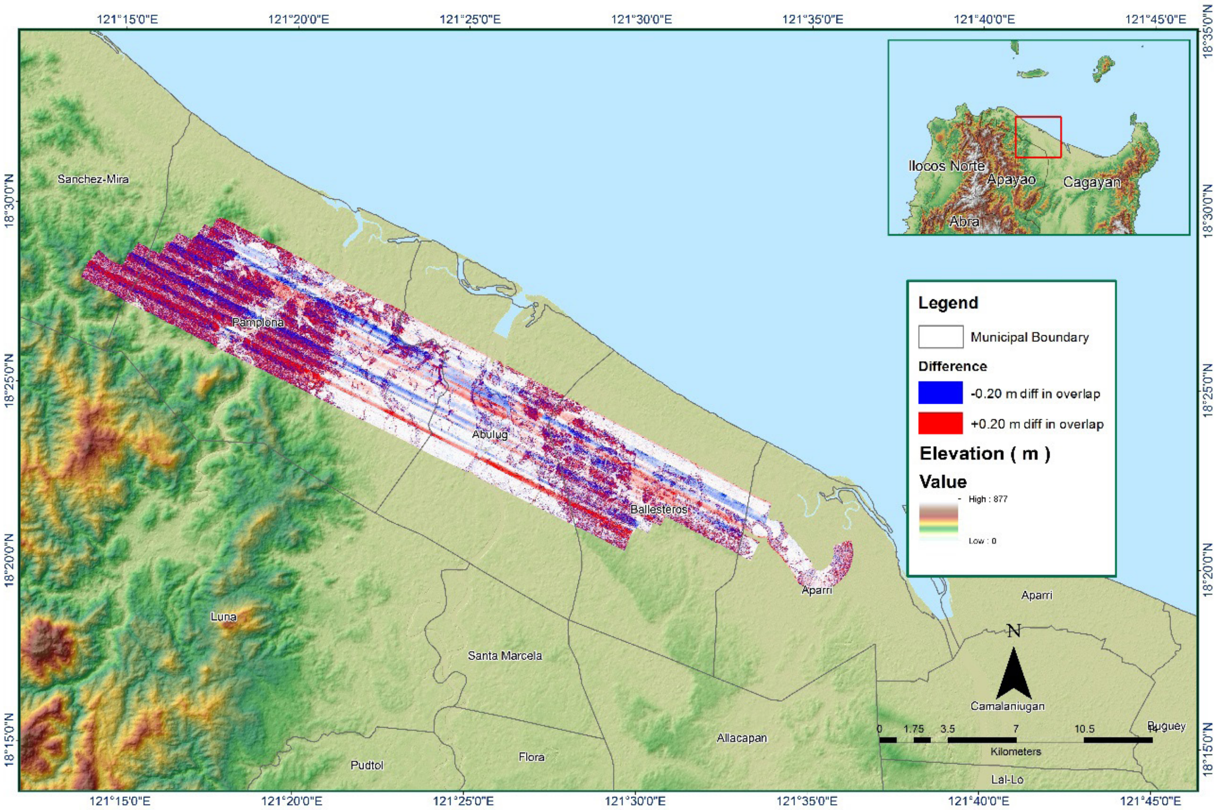


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission 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)	0.002483
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	51.57
Ave point cloud density per sq.m. (>2.0)	3.165
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

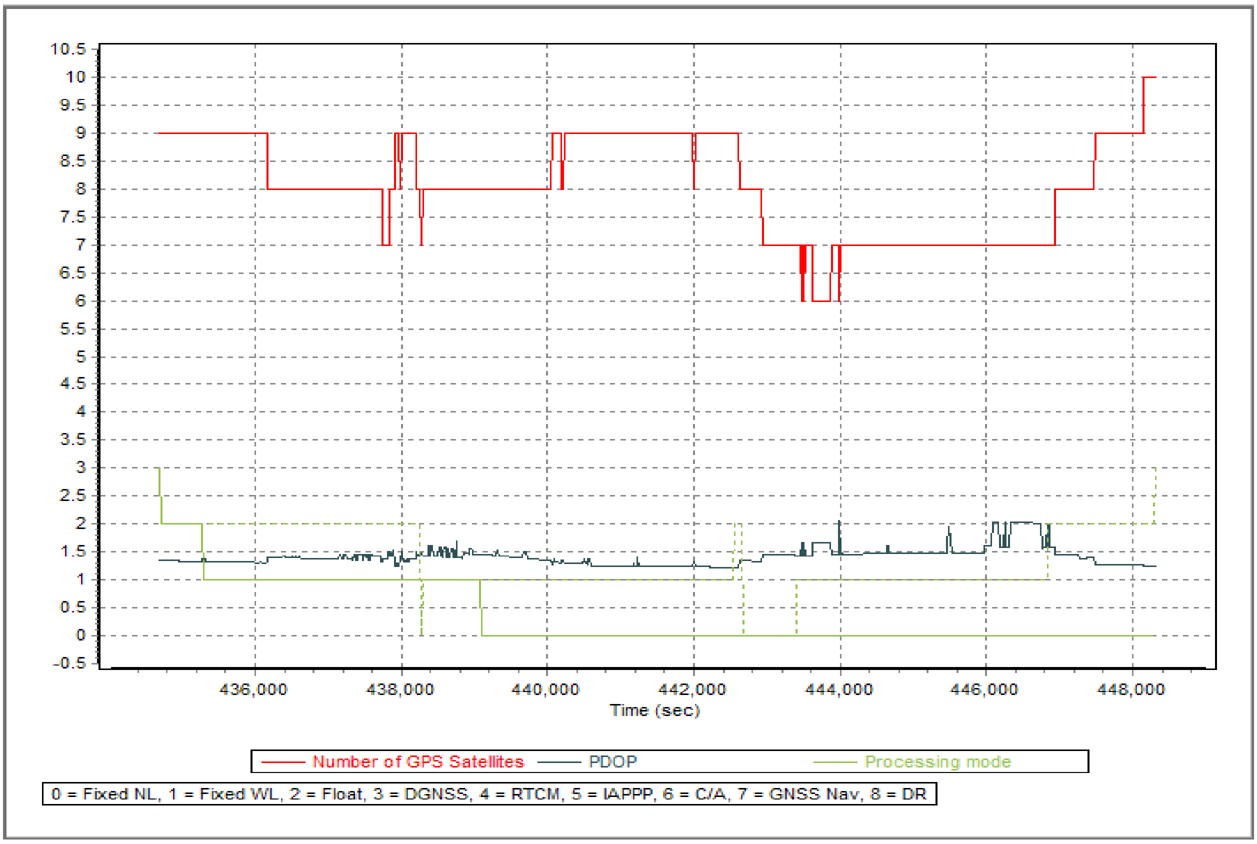


Figure A-8.36. Solution Status

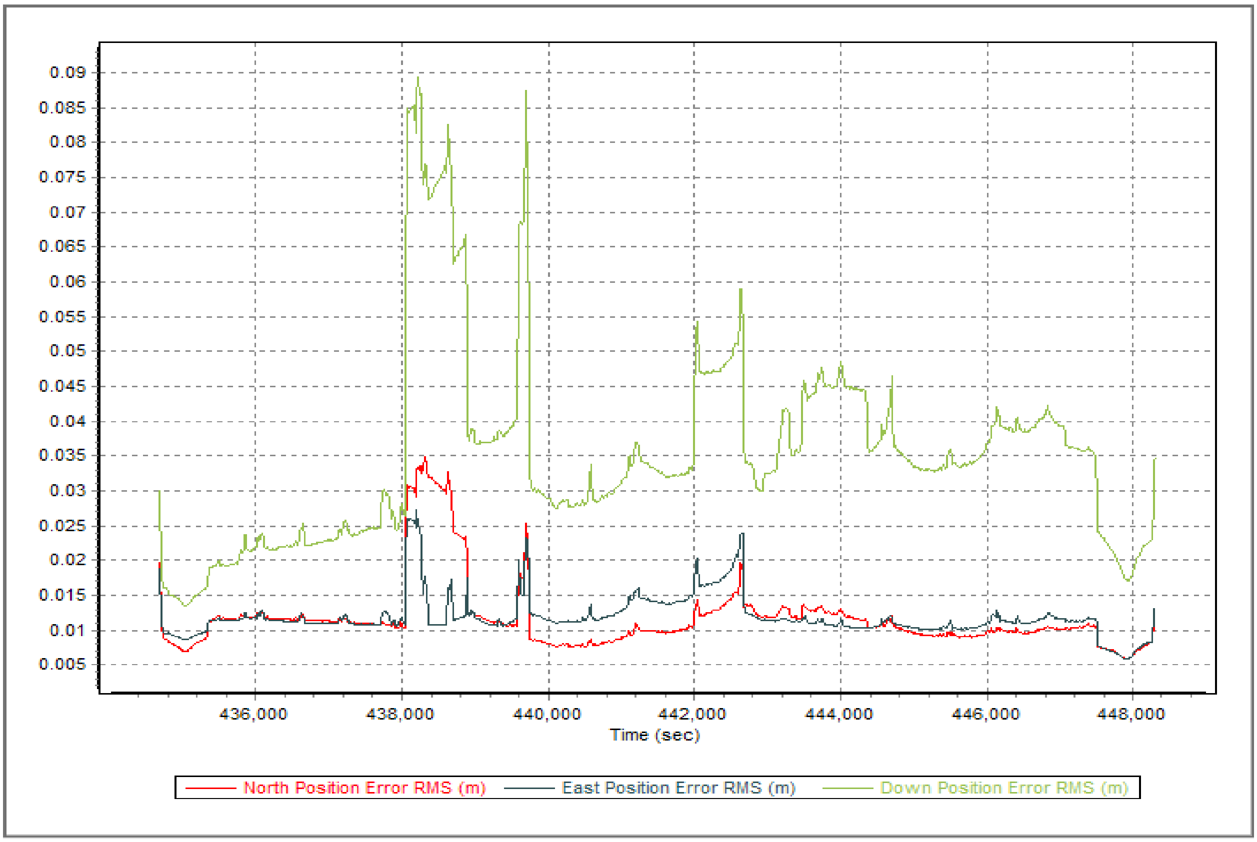


Figure A-8.37. Smoothed Performance Metric Parameters

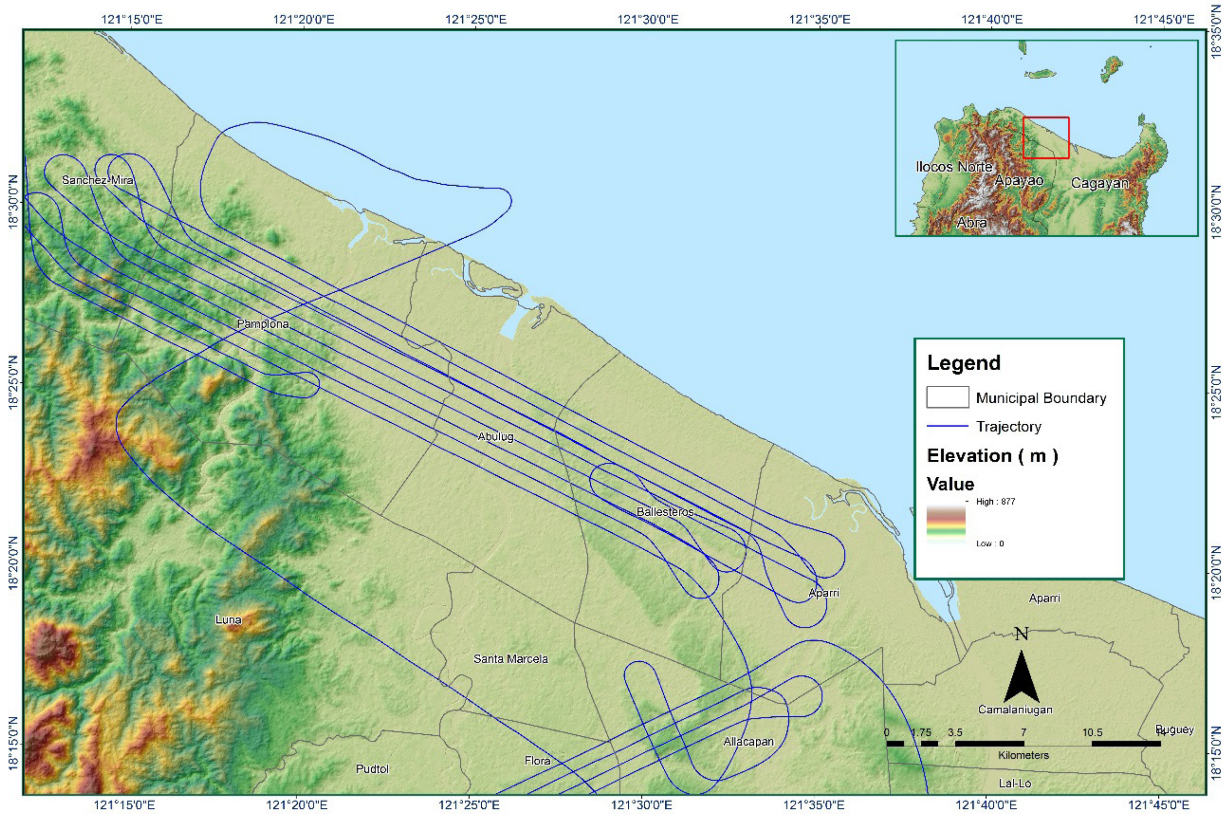


Figure A-8.38. Best Estimated Trajectory

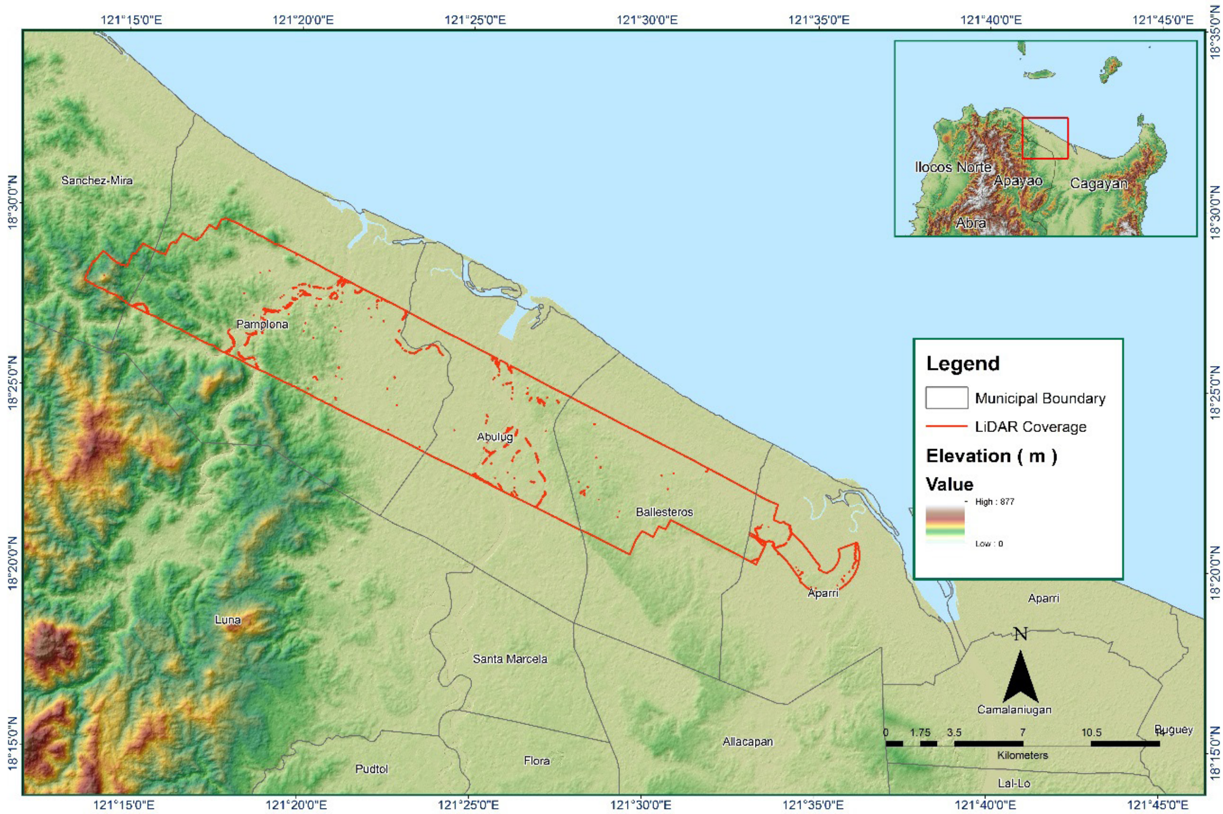


Figure A-8.39. Coverage of LiDAR data

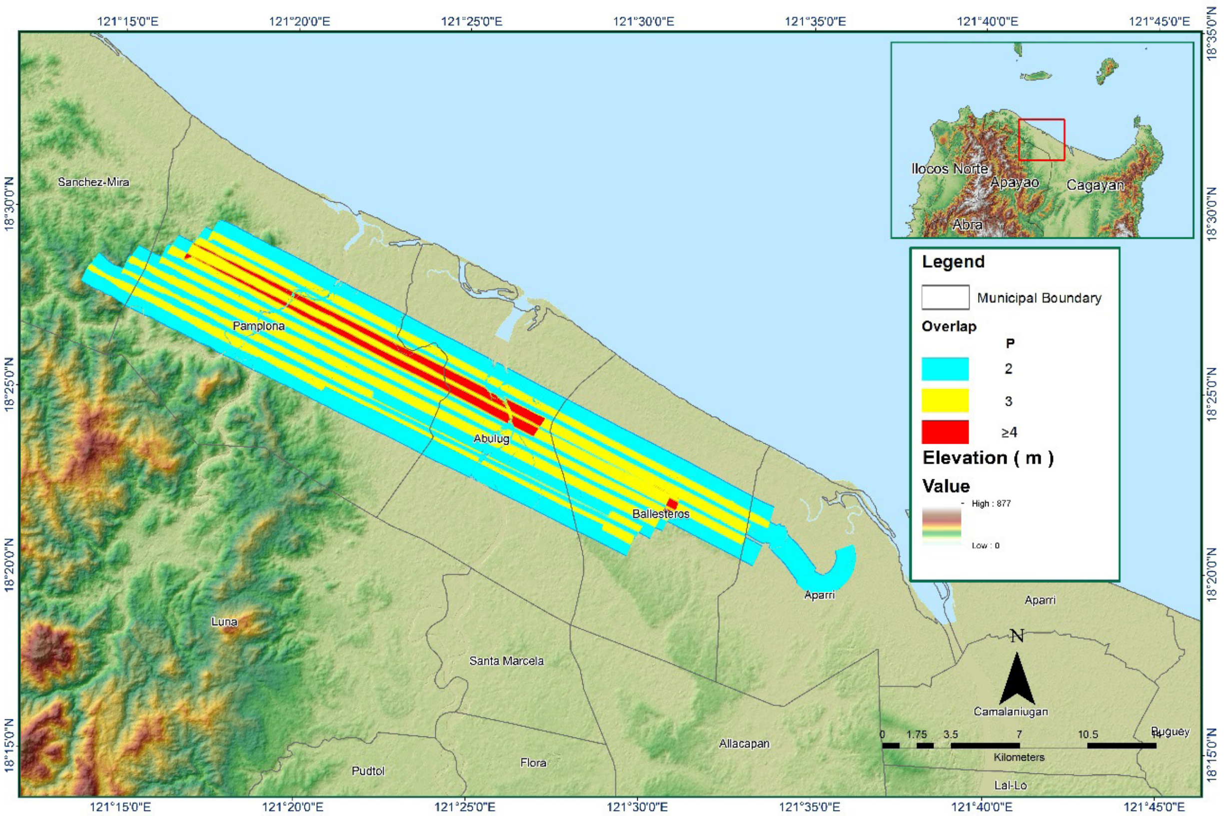


Figure A-8.40. Image of Data Overlap

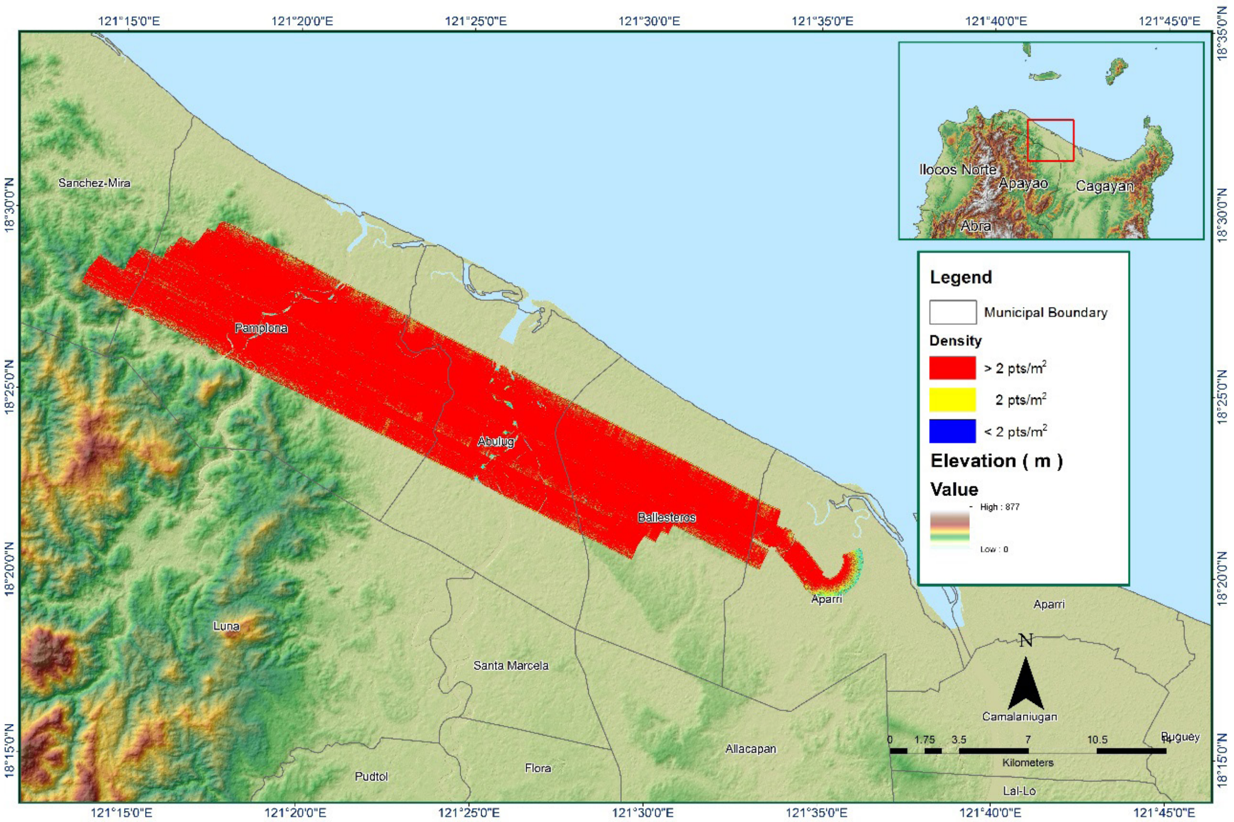


Figure A-8.41. Density map of merged LiDAR data

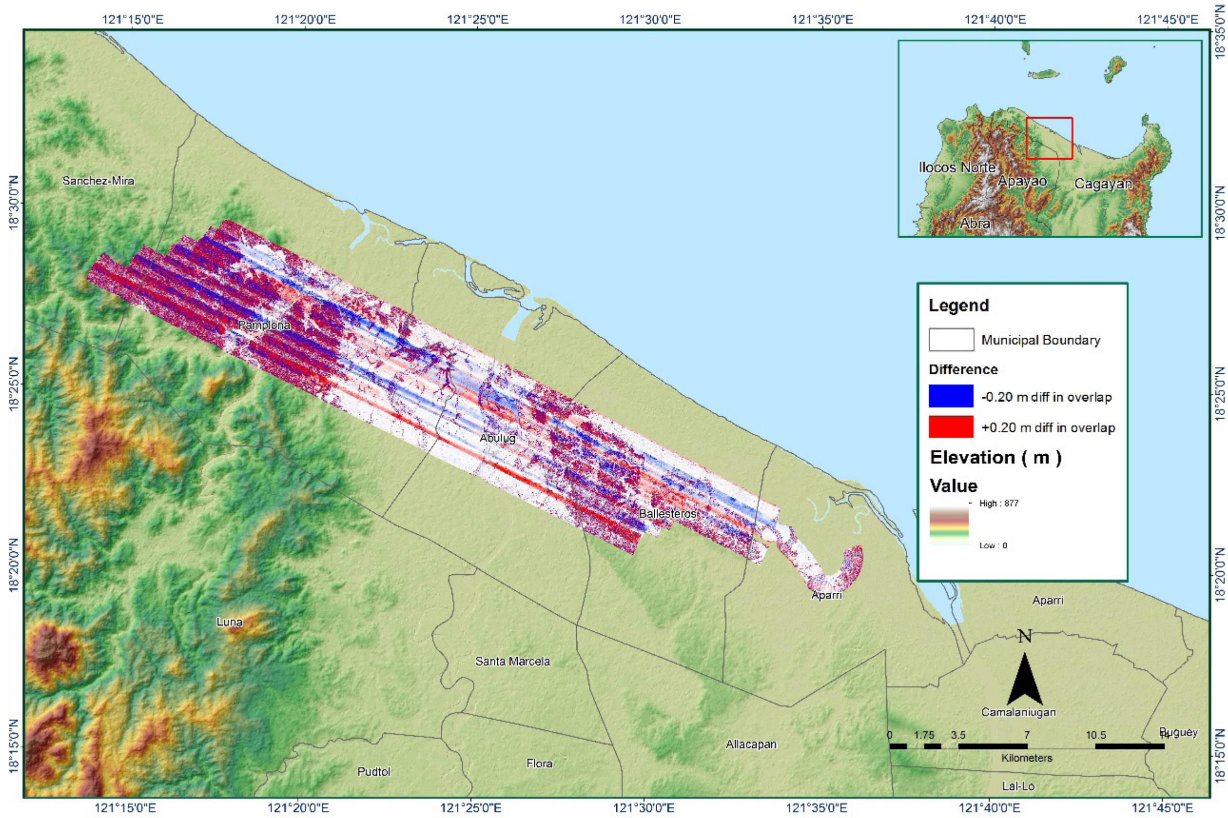


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission 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	266.52 m
Minimum Height	40.70 m
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. Mark Joshua Salvacion, Engr. Krisha Marie Bautista, Engr. Wilbert Ian San Juan

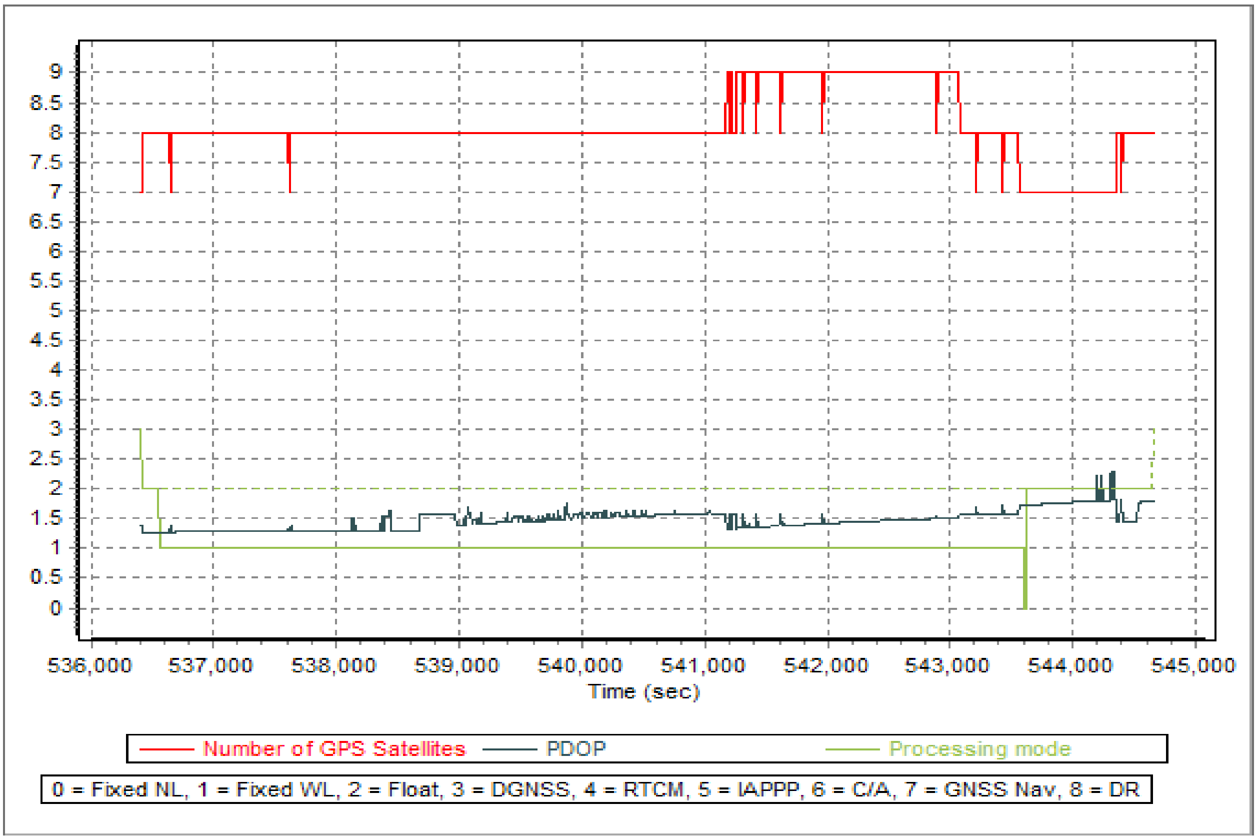


Figure A-8.43. Solution Status

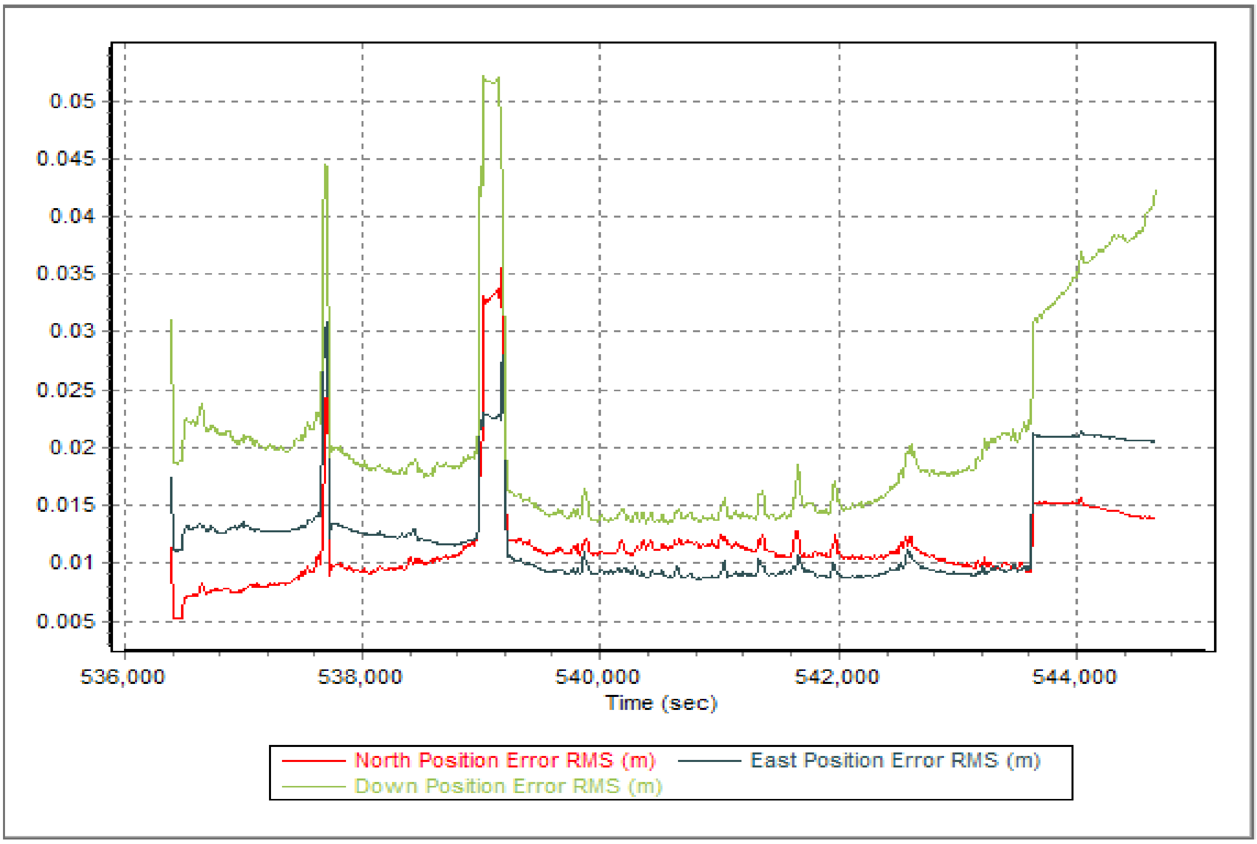


Figure A-8.44. Smoothed Performance Metric Parameters

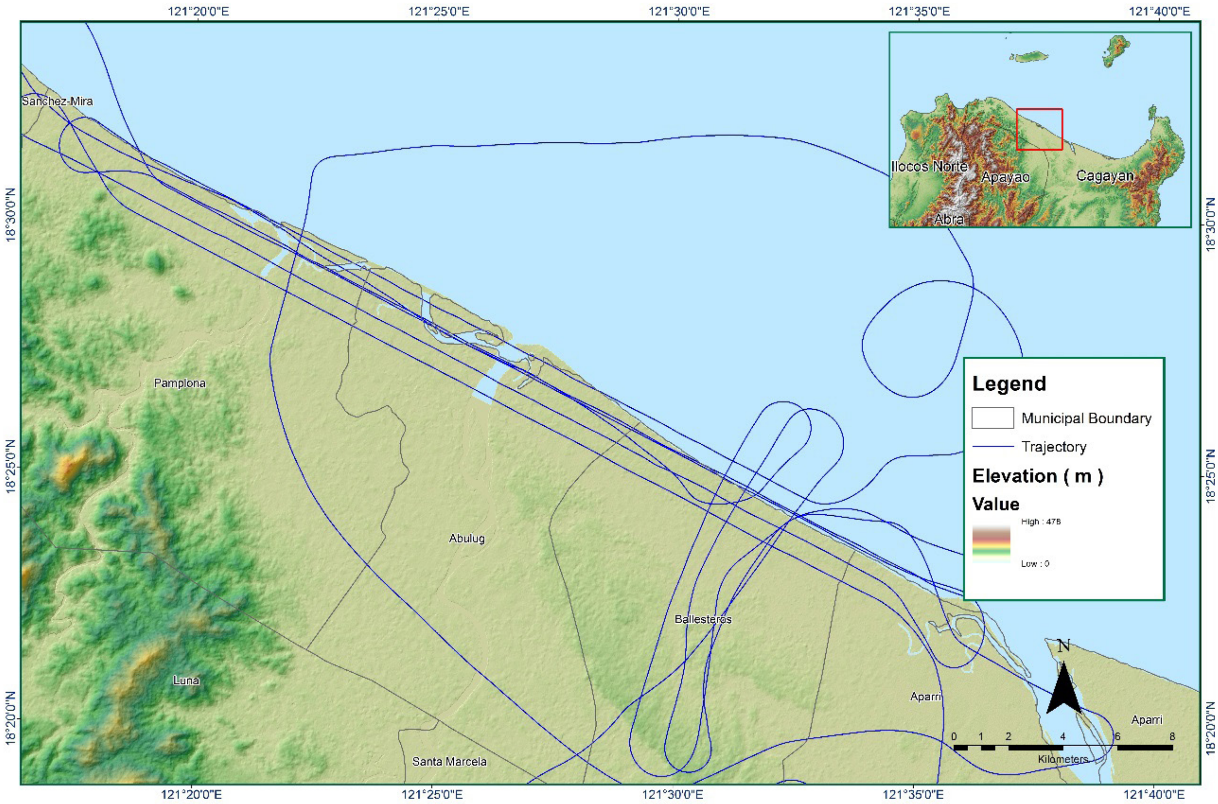


Figure A-8.45. Best Estimated Trajectory

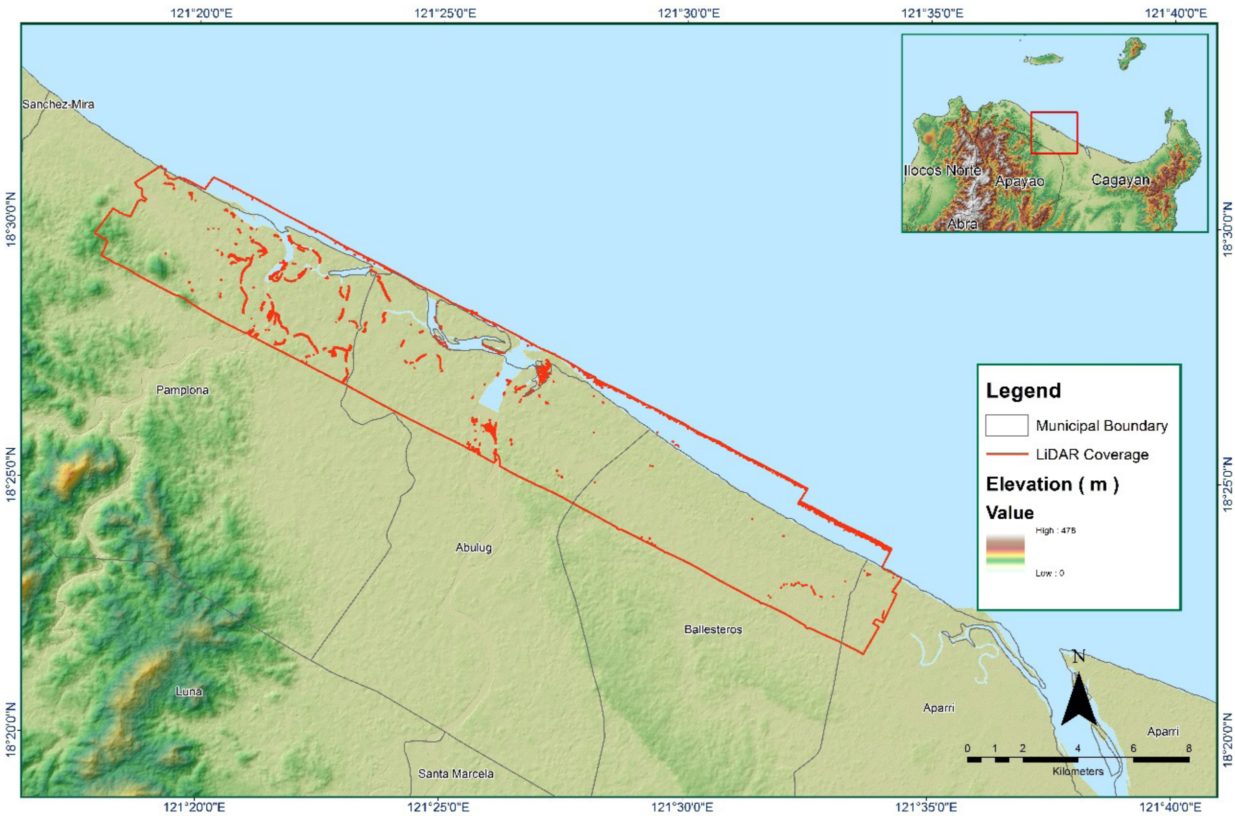


Figure A-8.46. Coverage of LiDAR data

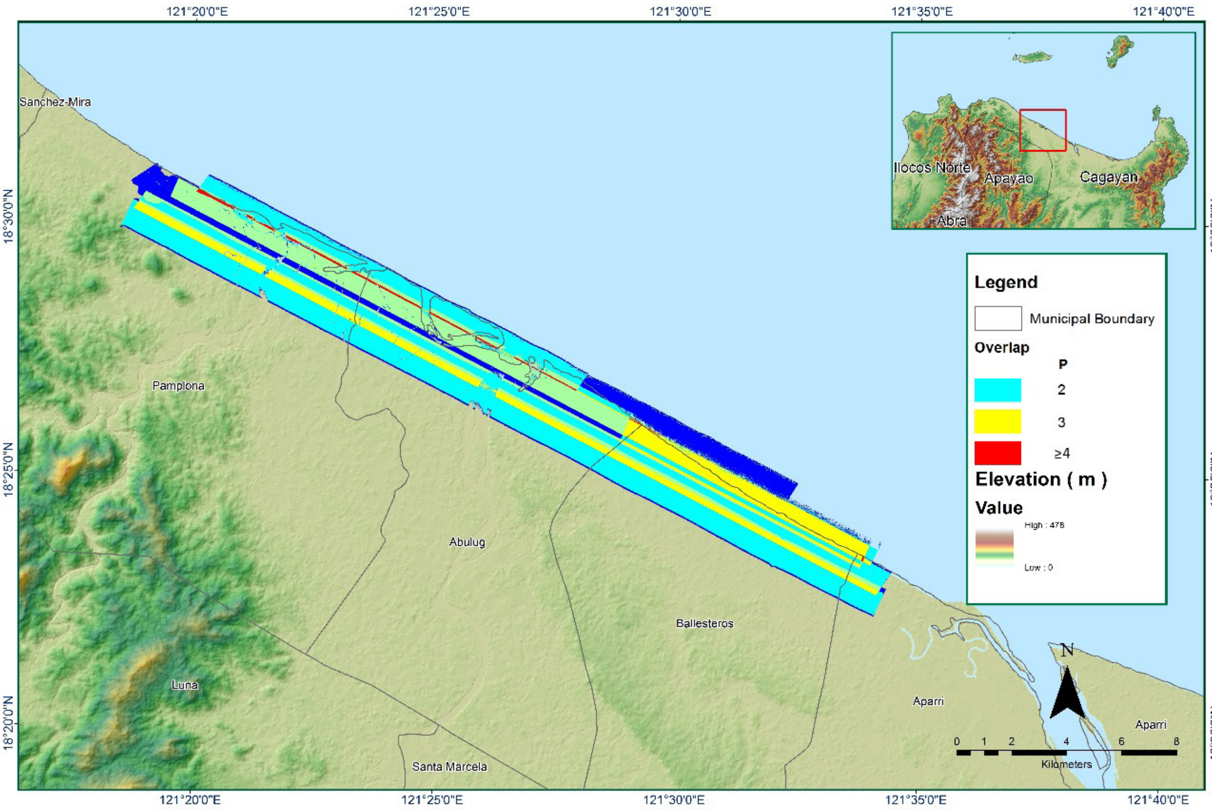


Figure A-8.47. Image of Data Overlap

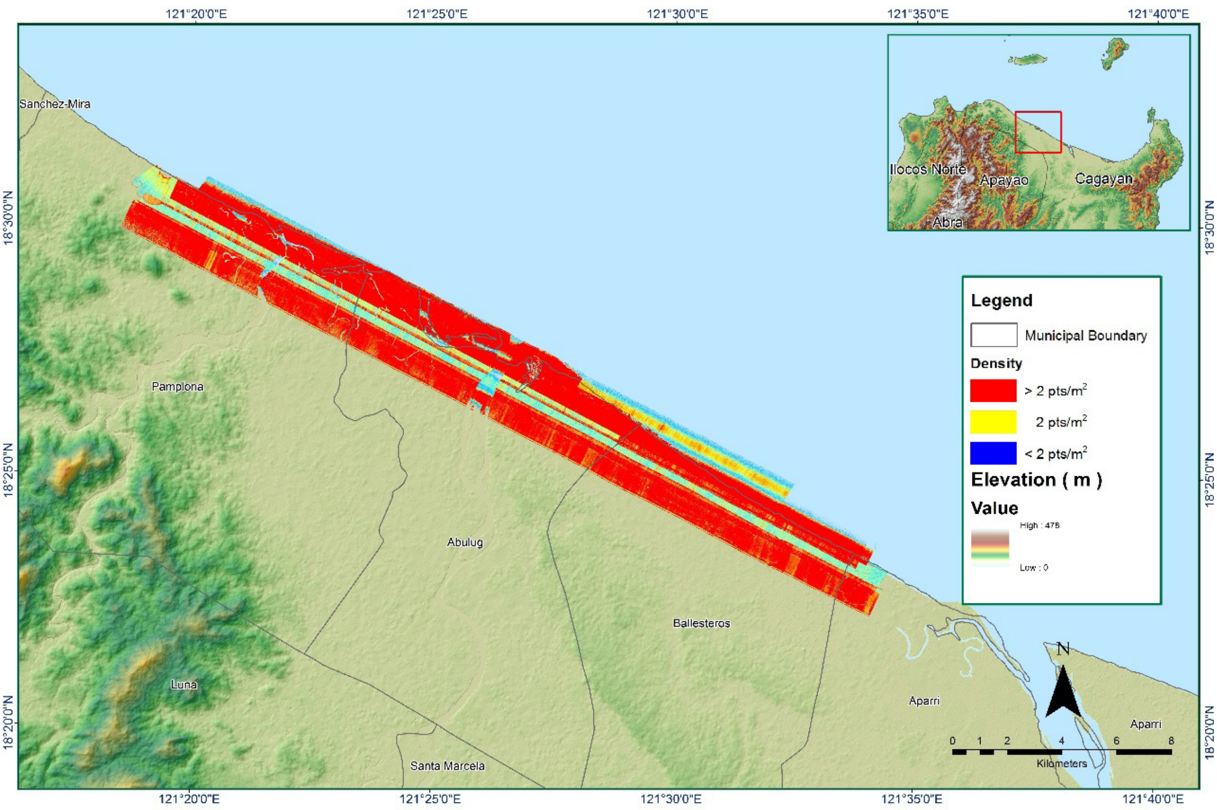


Figure A-8.48. Density map of merged LiDAR data

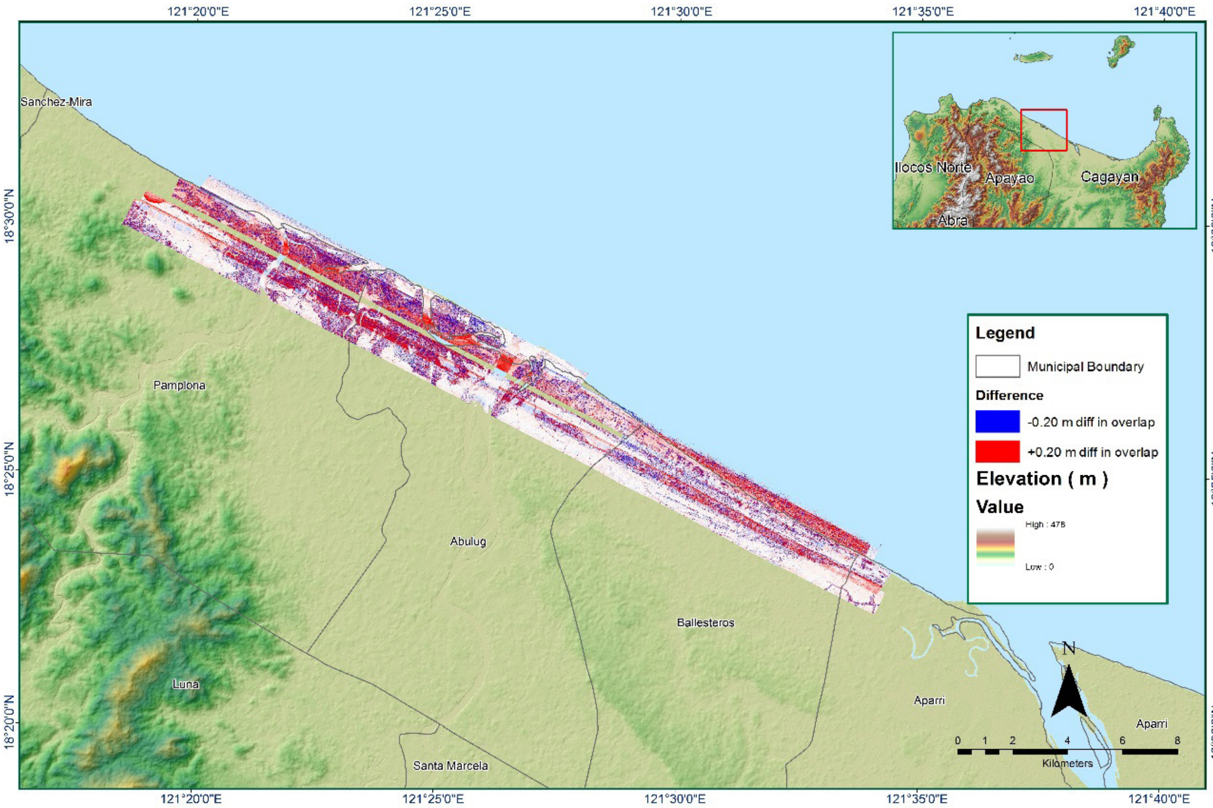


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission 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

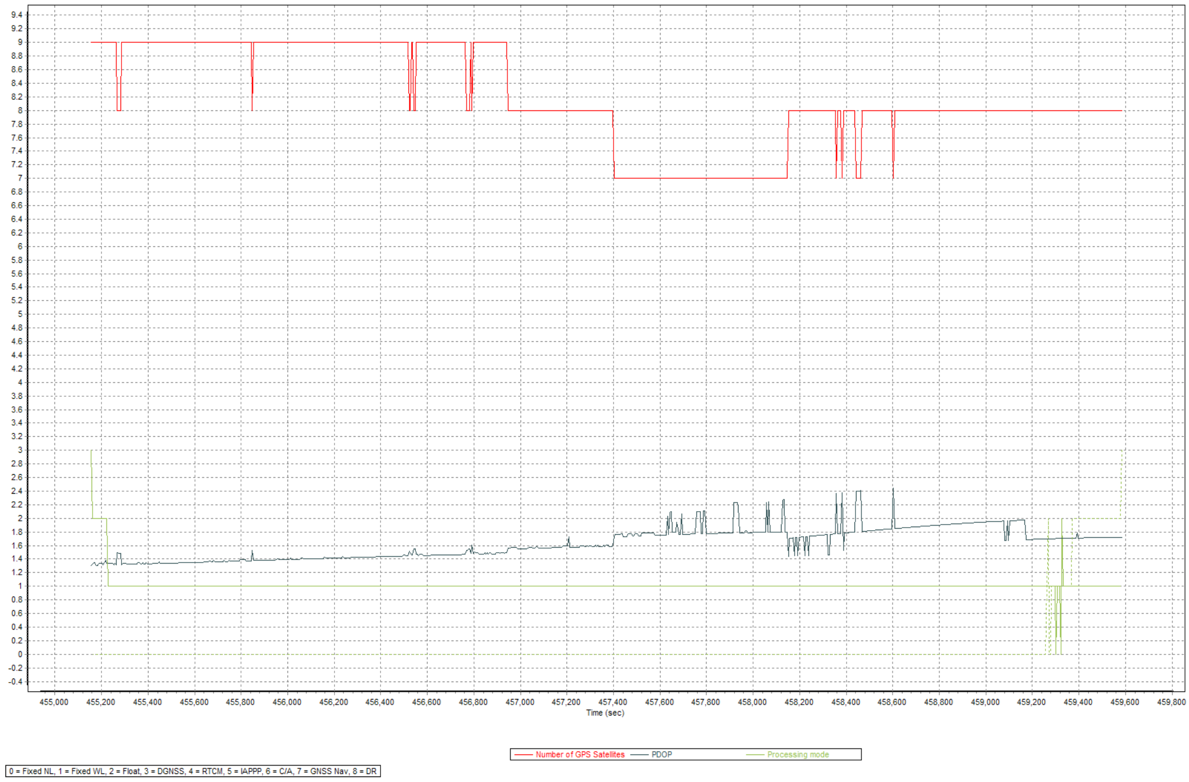


Figure A-8.50. Solution Status

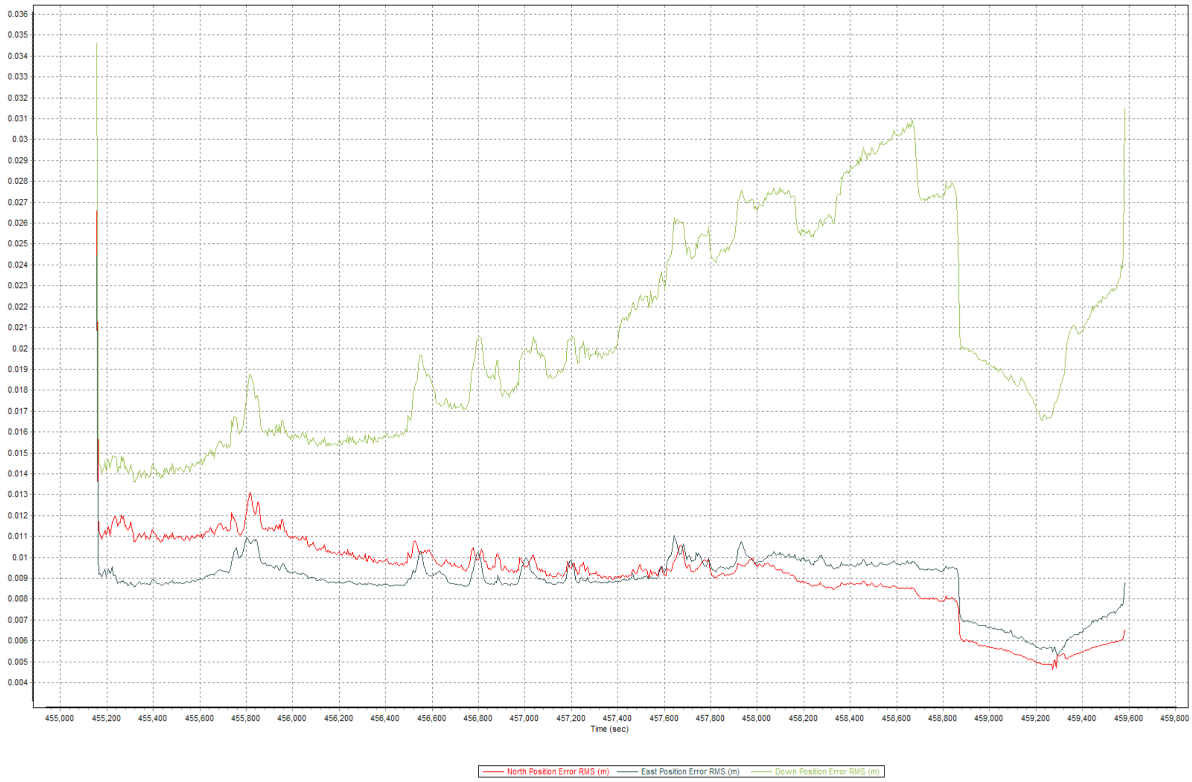


Figure A-8.51. Smoothed Performance Metric Parameters

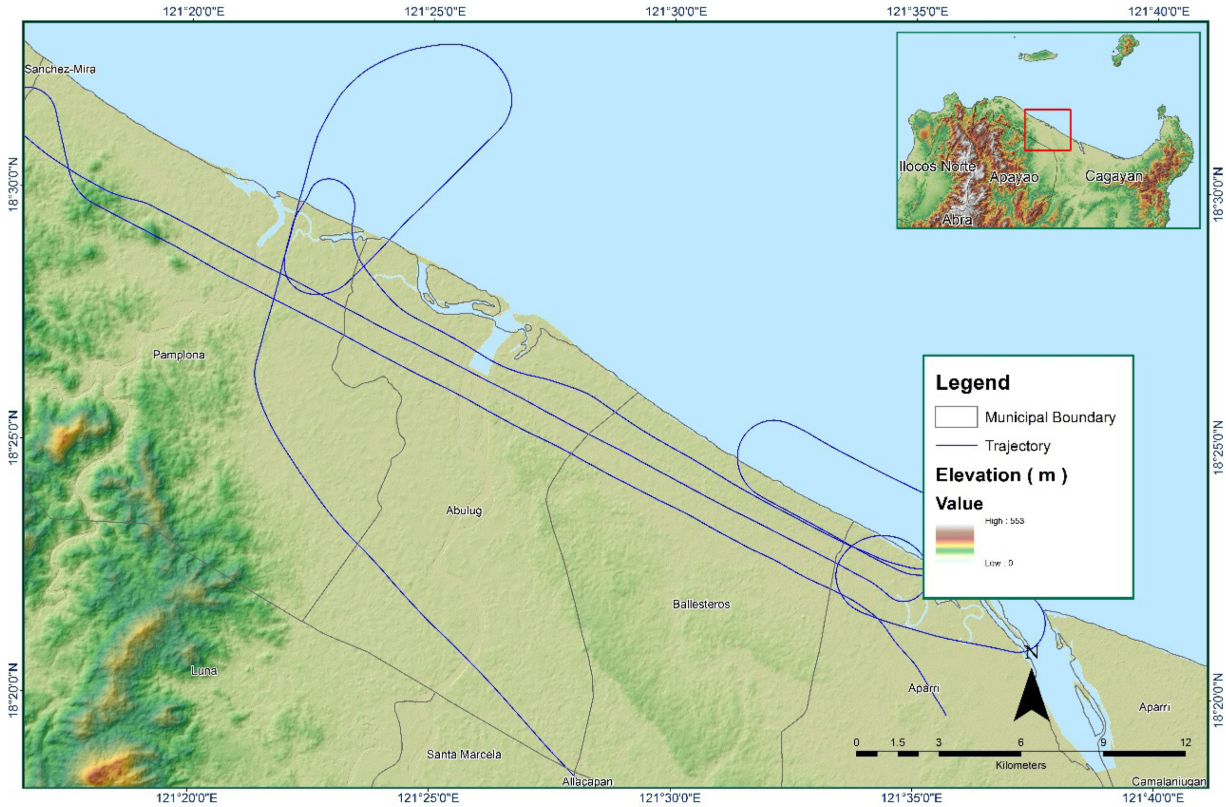


Figure A-8.52. Best Estimated Trajectory

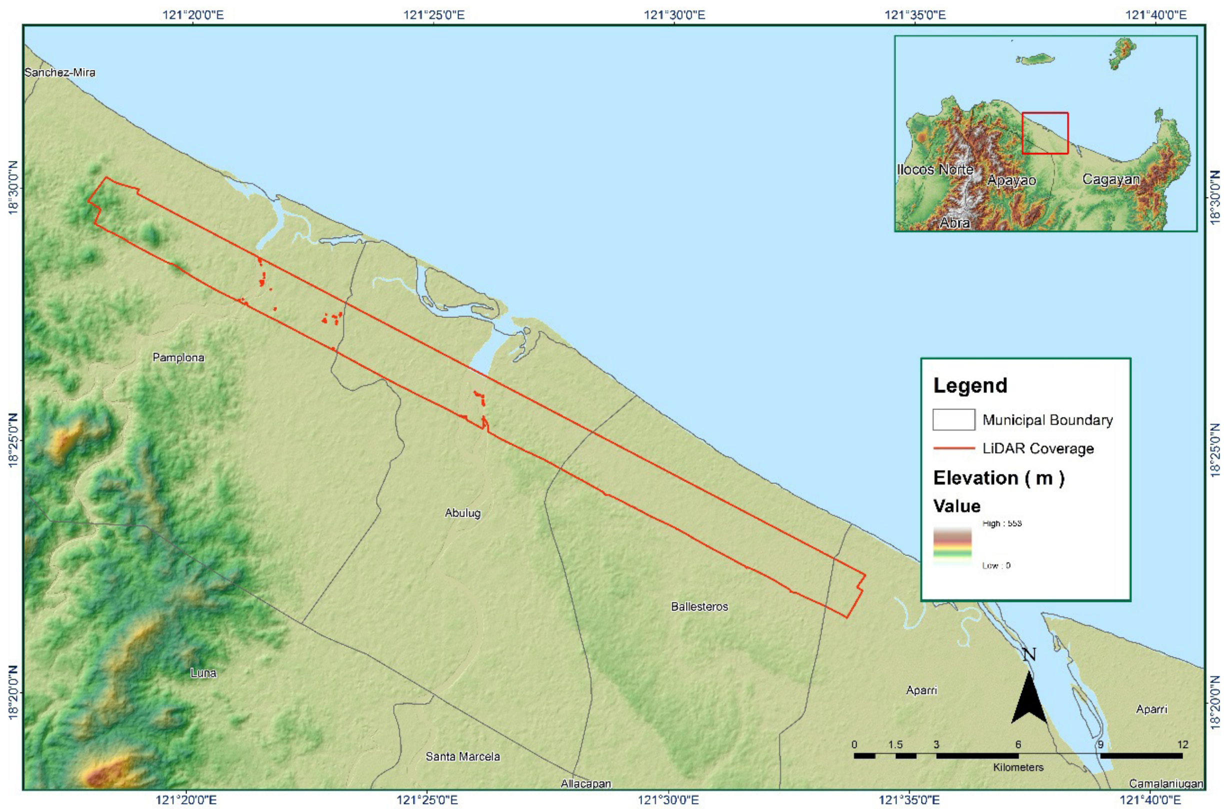


Figure A-8.53. Coverage of LiDAR data

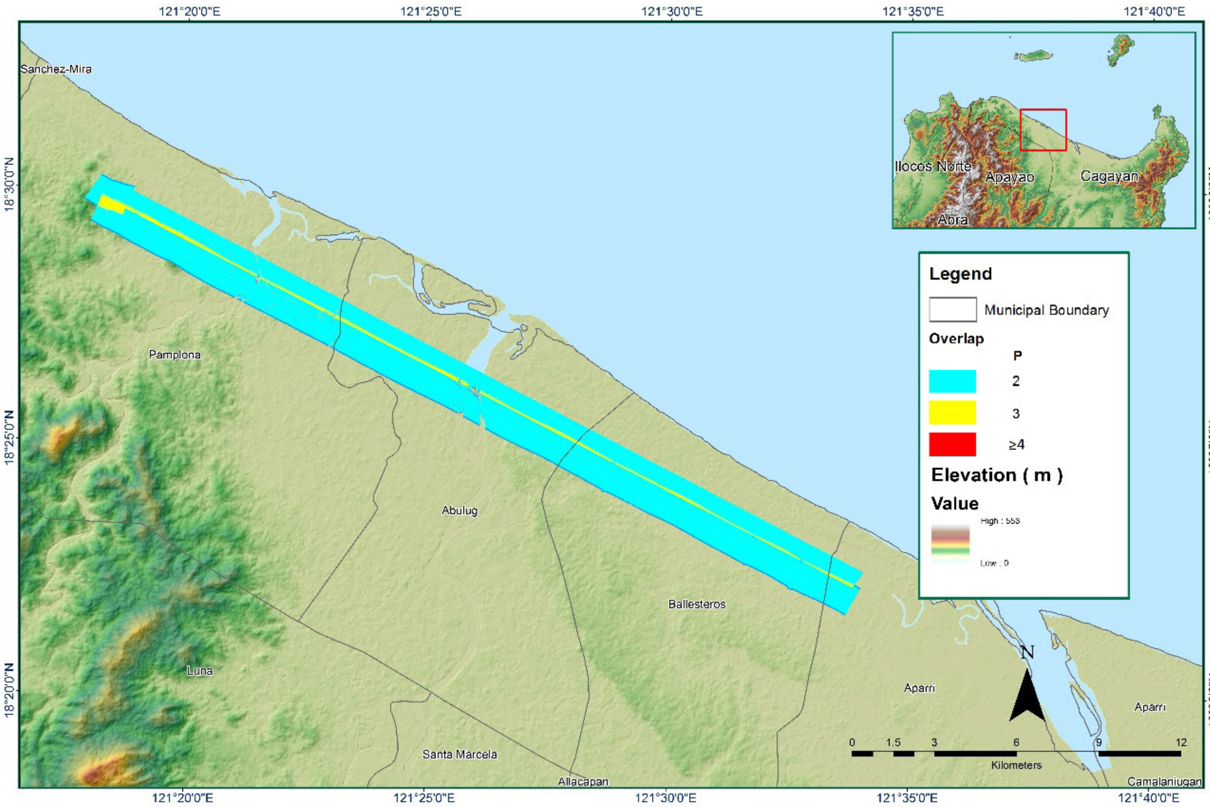


Figure A-8.54. Image of Data Overlap

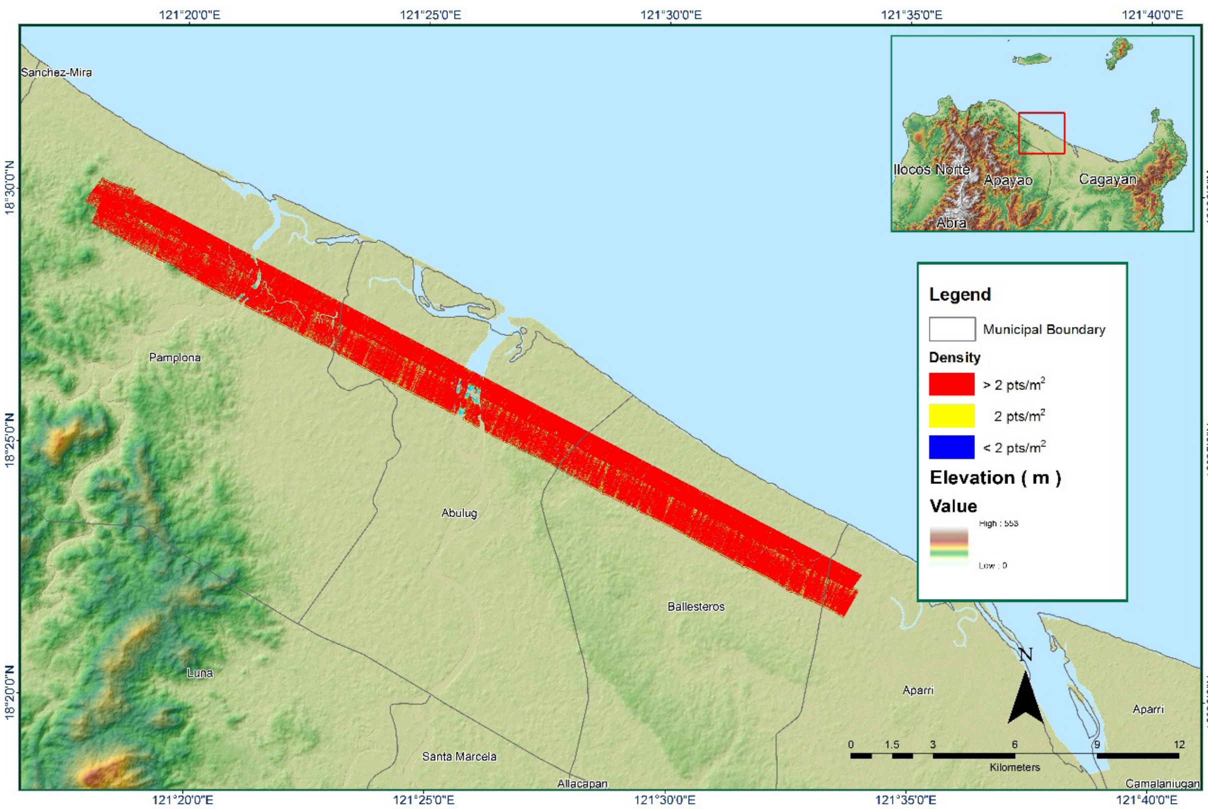


Figure A-8.55. Density map of merged LiDAR data

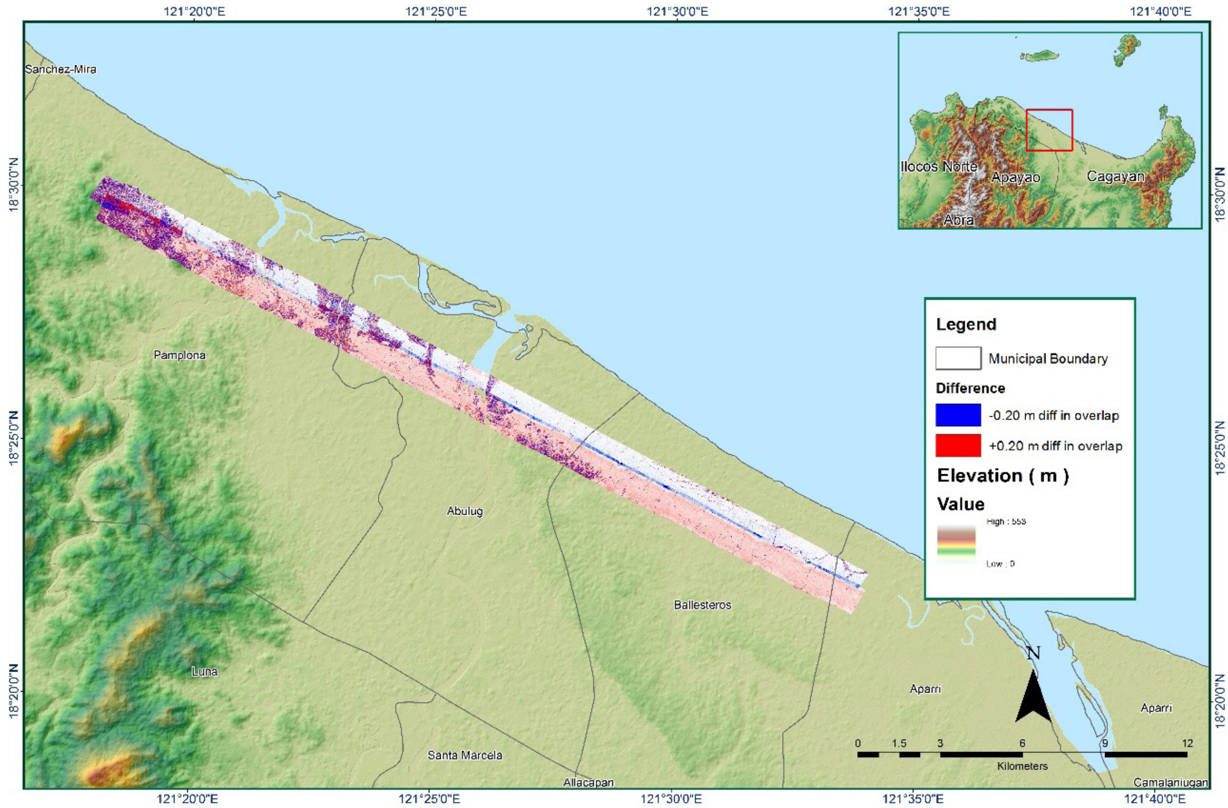


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission 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	

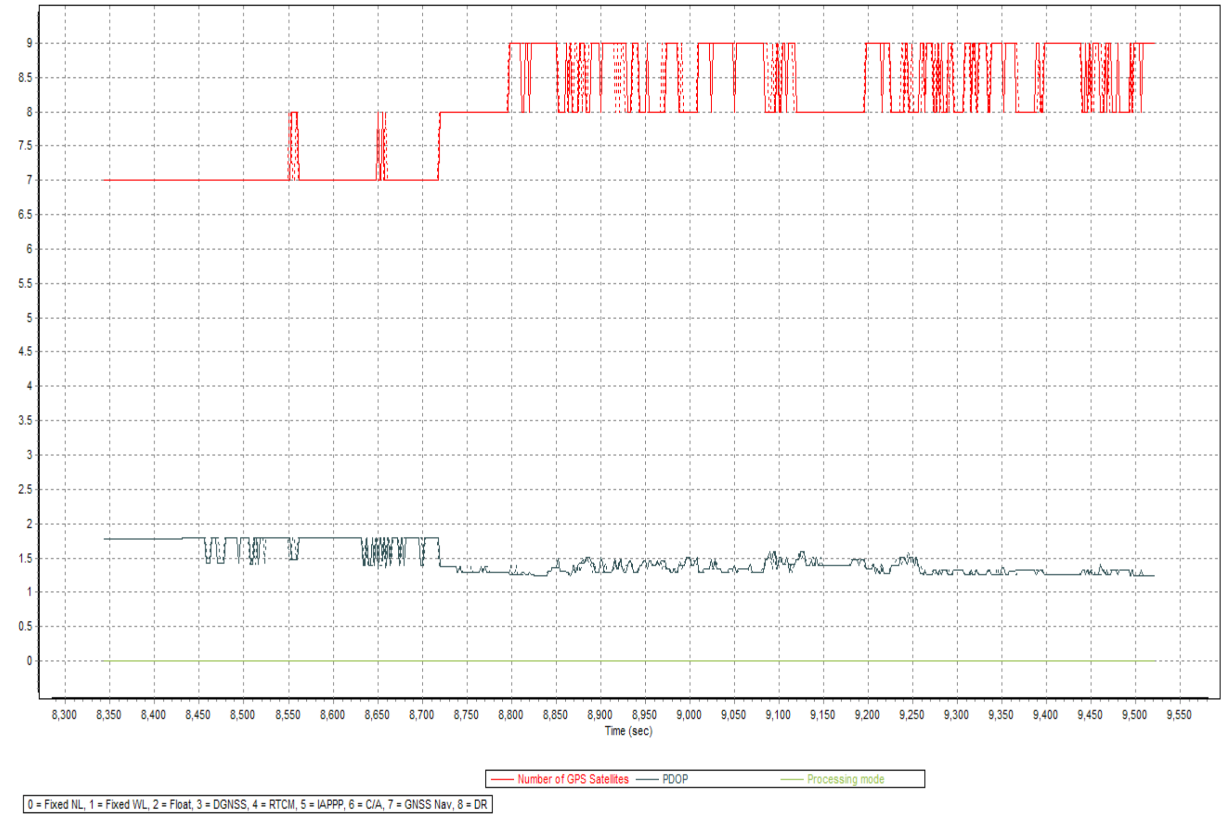


Figure A-8.57. Solution Status

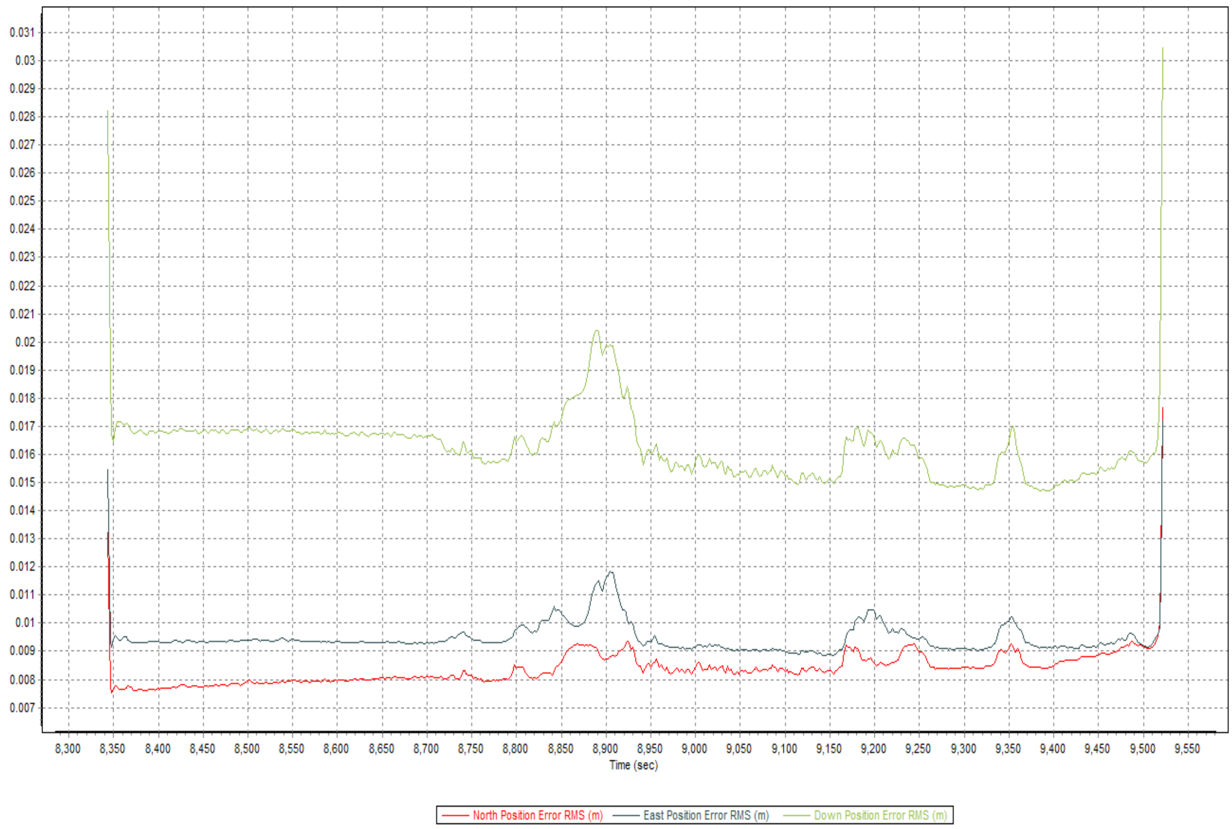


Figure A-8.58. Smoothed Performance Metric Parameters

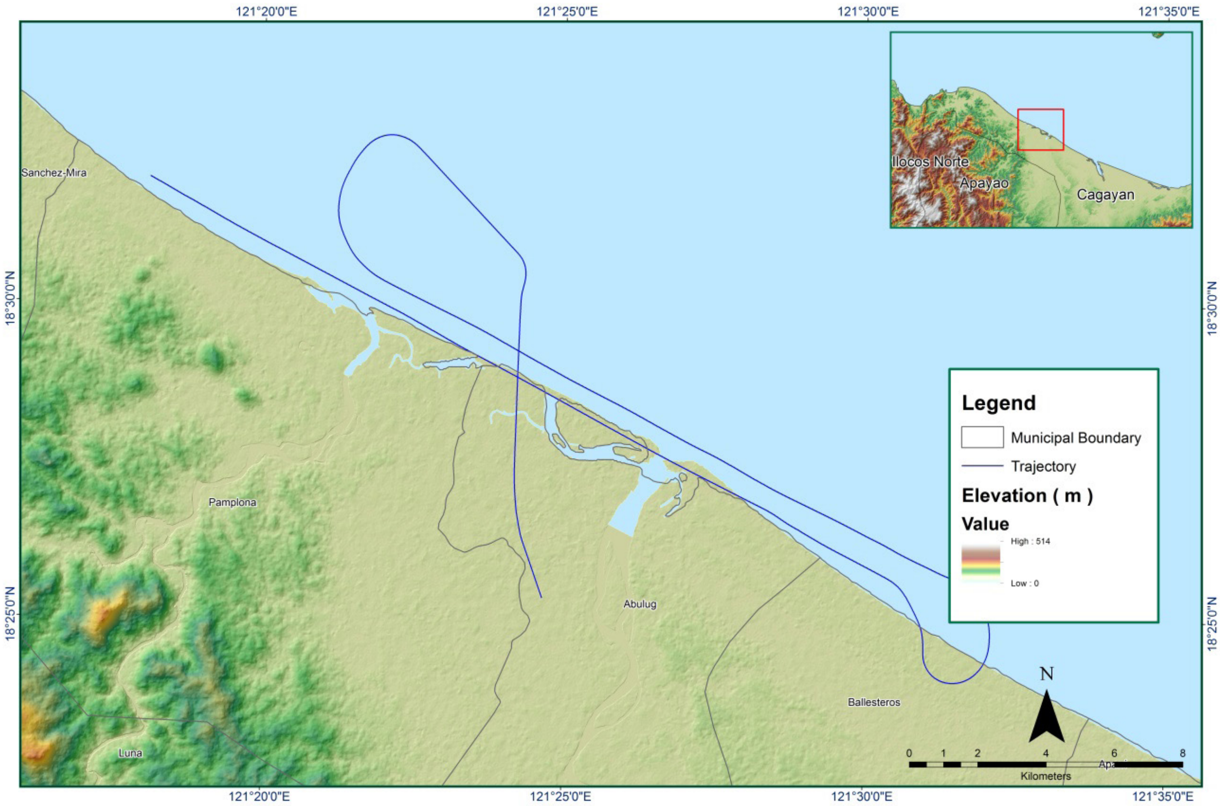


Figure A-8.59. Best Estimated Trajectory

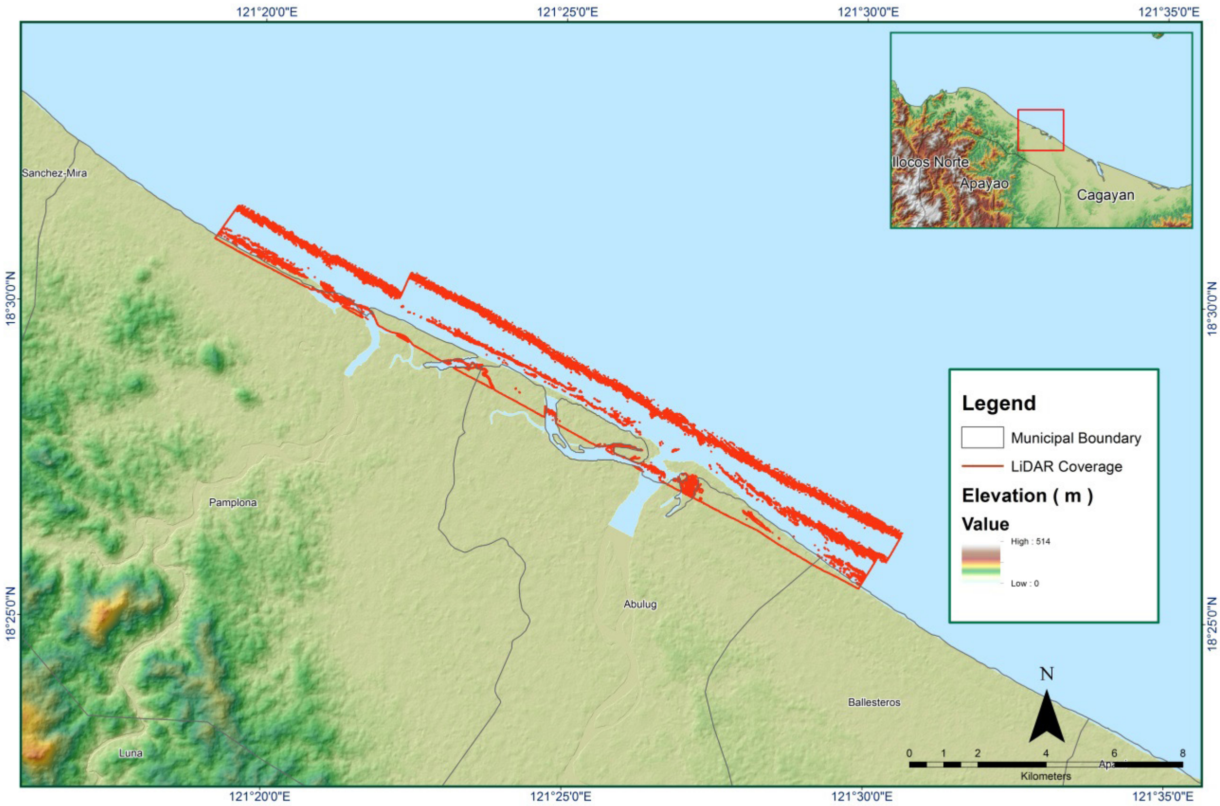


Figure A-8.60. Coverage of LiDAR data

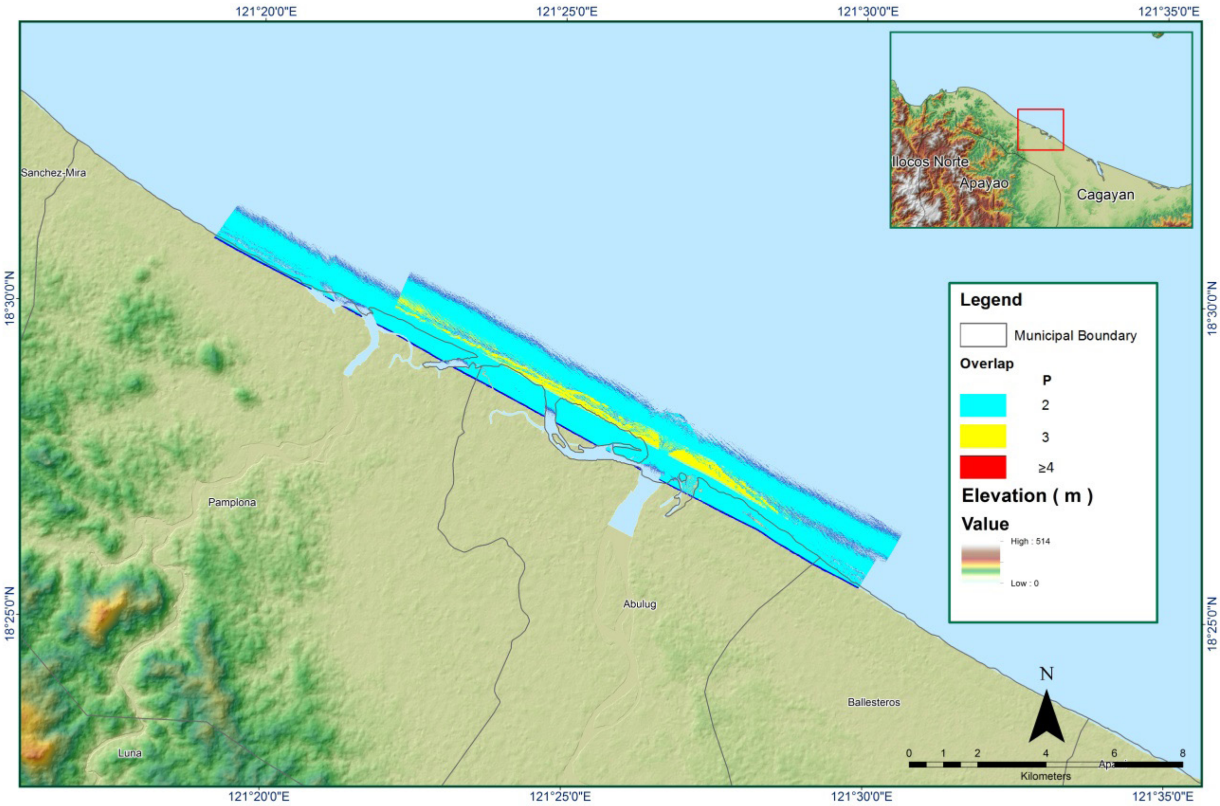


Figure A-8.61. Image of Data Overlap

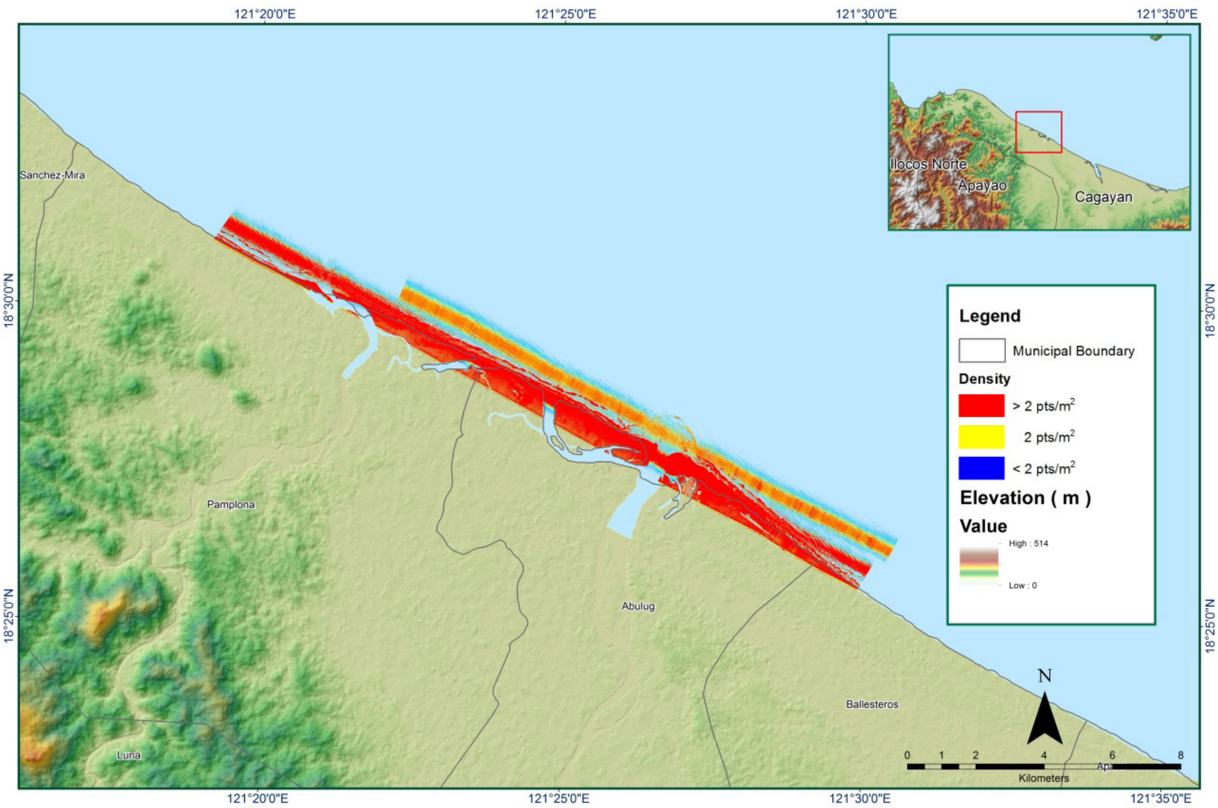


Figure A-8.62. Density map of merged LiDAR data

Figure A-8.63. Elevation difference between flight lines

Annex 9. Pamplona Model Basin Parameters

Table A-9.1. Pamplona Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1000	6.0759	83.456	0	1.7719	2.8917	Discharge	0.76568	1	Ratio to Peak	0.37
W1010	6.0062	83.883	0	1.0331	1.6859	Discharge	2.1017	1	Ratio to Peak	0.37
W1020	2.2902	99	0	1.0121	1.6517	Discharge	2.0771	1	Ratio to Peak	0.37
W1030	1.854	99	0	0.60658	0.98994	Discharge	0.65872	1	Ratio to Peak	0.37
W1040	5.8338	84.957	0	2.1845	3.5651	Discharge	4.9972	1	Ratio to Peak	0.37
W1050	5.4726	87.301	0	1.245	2.0318	Discharge	0.89367	1	Ratio to Peak	0.37
W1060	5.3649	88.025	0	2.088	3.4075	Discharge	3.1781	1	Ratio to Peak	0.37
W1070	2.0037	99	0	1.5621	2.5493	Discharge	3.2947	1	Ratio to Peak	0.37
W1080	2.2244	99	0	3.0181	4.9256	Discharge	3.8456	1	Ratio to Peak	0.37
W1090	5.08	90	0	1.1335	1.8499	Discharge	0.72199	1	Ratio to Peak	0.37
W1100	5.08	90	0	1.915	3.1252	Discharge	1.9383	1	Ratio to Peak	0.37
W1110	5.3085228	88.409	0	2.0351	3.3213	Discharge	3.6657	1	Ratio to Peak	0.37
W1120	5.3494	88.13	0	2.2604	3.689	Discharge	4.6312	1	Ratio to Peak	0.37
W1130	2.9839	99	0	1.7588	2.8704	Discharge	5.4503	1	Ratio to Peak	0.37
W1140	2.3612	99	0	1.0764	1.7568	Discharge	0.53516	1	Ratio to Peak	0.37
W1150	6.2345	82.5	0	2.0837	3.4006	Discharge	1.9914	1	Ratio to Peak	0.37
W1160	2.5859	99	0	1.4225	2.3215	Discharge	1.0941	1	Ratio to Peak	0.37
W1170	2.3931	99	0	0.83067	1.3557	Discharge	0.0169622	1	Ratio to Peak	0.37
W1180	5.3164	88.355	0	3.094	5.0495	Discharge	6.4857	1	Ratio to Peak	0.37
W1190	5.2588	88.7504	0	1.7824	2.909	Discharge	2.6572	1	Ratio to Peak	0.37
W1200	6.2236	82.565	0	2.9471	4.8097	Discharge	3.7718	1	Ratio to Peak	0.37
W1210	2.2892	99	0	1.6491	2.6913	Discharge	1.9003	1	Ratio to Peak	0.37
W1220	5.5861	86.551	0	1.7245	2.8144	Discharge	1.1013	1	Ratio to Peak	0.37

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
W1230	2.099	99	0	1.3194	2.1533	Discharge	3.0489	1	Ratio to Peak	0.37
W1240	2.8046	99	0	0.98306	1.6043599	Discharge	0.33655	1	Ratio to Peak	0.37
W1250	2.5832	99	0	0.31768	0.51846	Discharge	0.10490	1	Ratio to Peak	0.37
W1260	2.334	99	0	2.4083	3.9304	Discharge	4.2998	1	Ratio to Peak	0.37
W1270	2.0581	99	0	1.133	1.8491	Discharge	2.2240	1	Ratio to Peak	0.37
W1280	4.3502	95.487	0	1.4416	2.3527	Discharge	1.0012	1	Ratio to Peak	0.37
W1290	6.2127	82.63	0	4.3205	7.051	Discharge	7.9144	1	Ratio to Peak	0.37
W1300	5.08	90	0	2.0607	3.363	Discharge	2.4146	1	Ratio to Peak	0.37
W1310	5.8731	84.71	0	2.7522	4.4915	Discharge	10.141	1	Ratio to Peak	0.37
W1320	5.2783	88.617	0	1.1989	1.9565	Discharge	1.7744	1	Ratio to Peak	0.37
W1330	5.08	90	0	1.2059	1.968	Discharge	0.98441	1	Ratio to Peak	0.37
W1340	5.08	90	0	1.7002	2.7747	Discharge	3.2232	1	Ratio to Peak	0.37
W1350	7.0503	77.91277	0	2.5105634	4.0972	Discharge	5.0267	1	Ratio to Peak	0.37
W1360	4.2445	96.338	0	3.0876	5.0389	Discharge	6.0708	1	Ratio to Peak	0.37
W1370	5.1442	89.54755	0	1.9721	3.2185	Discharge	2.2994	1	Ratio to Peak	0.37
W1380	5.4659	87.346	0	3.0247	4.9363	Discharge	8.0541	1	Ratio to Peak	0.37
W1390	5.08	90	0	2.3012	3.7556	Discharge	3.9751	1	Ratio to Peak	0.37
W1400	5.0856	89.96	0	2.4609	4.0162	Discharge	6.5703	1	Ratio to Peak	0.37
W1410	5.1926	89.209	0	1.2885	2.1029	Discharge	2.0427	1	Ratio to Peak	0.37
W1420	5.2059	89.117	0	1.5114	2.4667	Discharge	2.7833	1	Ratio to Peak	0.37
W1430	5.7414	85.545	0	1.4747	2.4066904	Discharge	2.0933	1	Ratio to Peak	0.37
W1440	5.2571	88.762	0	2.0563	3.3559	Discharge	3.3455	1	Ratio to Peak	0.37
W1450	5.374	87.964	0	1.4381	2.347	Discharge	1.8953	1	Ratio to Peak	0.37
W1460	5.4921	87.171	0	2.3187	3.7842	Discharge	2.6556	1	Ratio to Peak	0.37
W740	5.08	90	0	2.2236	3.629	Discharge	2.7841	1	Ratio to Peak	0.37

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
W750	5.08	90	0	1.6562	2.7029	Discharge	3.5456	1	Ratio to Peak	0.37
W760	5.08	90	0	3.3236	5.4242	Discharge	5.6247	1	Ratio to Peak	0.37
W770	5.096	89.887	0	3.0167	4.9233	Discharge	11.506	1	Ratio to Peak	0.37
W780	4.0598	97.861	0	3.1667	5.1681	Discharge	3.1573	1	Ratio to Peak	0.37
W790	5.3867	87.878	0	2.4791	4.0458	Discharge	4.3129	1	Ratio to Peak	0.37
W800	4.7531	92.378	0	1.4317	2.3365	Discharge	1.7035	1	Ratio to Peak	0.37
W810	5.7826	85.282	0	1.9232	3.1386	Discharge	2.7494	1	Ratio to Peak	0.37
W820	4.4163	94.963	0	2.2751	3.713	Discharge	2.8100	1	Ratio to Peak	0.37
W830	5.7359	85.58	0	1.5741	2.5689	Discharge	2.4451	1	Ratio to Peak	0.37
W840	5.0929	89.909	0	1.0116	1.6509	Discharge	1.8419	1	Ratio to Peak	0.37
W850	2.6665	99	0	1.2096	1.9741	Discharge	3.1657	1	Ratio to Peak	0.37
W860	5.4261	87.612	0	1.5378	2.5097	Discharge	3.2267	1	Ratio to Peak	0.37
W870	5.1018	89.846	0	1.385	2.2603	Discharge	4.4146	1	Ratio to Peak	0.37
W880	5.342	88.181	0	1.9732	3.2203	Discharge	3.3279	1	Ratio to Peak	0.37
W890	5.0321	90.341	0	3.0421	4.9647	Discharge	2.9450	1	Ratio to Peak	0.37
W900	3.3858	99	0	2.5389	4.1435	Discharge	3.9694	1	Ratio to Peak	0.37
W910	7.1513	77.38	0	0.734	1.1979	Discharge	0.0658971	1	Ratio to Peak	0.37
W920	5.8861	84.628	0	3.6864	6.0163	Discharge	6.6460	1	Ratio to Peak	0.37
W930	4.9719	90.773	0	1.792	2.9245	Discharge	1.0115	1	Ratio to Peak	0.37
W940	2.5534	99	0	1.0899	1.7787	Discharge	2.2117	1	Ratio to Peak	0.37
W950	7.1079	77.608	0	0.9632	1.5719	Discharge	0.41437	1	Ratio to Peak	0.37
W960	2.5021	99	0	2.015	3.2884	Discharge	5.4445	1	Ratio to Peak	0.37
W970	5.4007	87.784	0	2.526	4.1224	Discharge	5.8491	1	Ratio to Peak	0.37
W980	6.4625	81.165	0	1.692	2.7614	Discharge	1.1059	1	Ratio to Peak	0.37
W990	6.6175	80.281	0	1.7513	2.8581	Discharge	2.2838	1	Ratio to Peak	0.37

Annex 10. Pamplona Model Reach Parameters

Table A-10.1. Pamplona Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	4048.6	0.00379	0.023	Trapezoid	560.427	0.3276
R120	Automatic Fixed Interval	4990.3	0.00979	0.023	Trapezoid	560.427	0.3276
R130	Automatic Fixed Interval	308.7	0.001	0.023	Trapezoid	560.427	0.3276
R140	Automatic Fixed Interval	5736.9	0.00351	0.023	Trapezoid	560.427	0.3276
R150	Automatic Fixed Interval	1783.6	0.00385	0.023	Trapezoid	560.427	0.3276
R190	Automatic Fixed Interval	4881.4	0.00154	0.023	Trapezoid	560.427	0.3276
R200	Automatic Fixed Interval	999.83	0.00153	0.023	Trapezoid	560.427	0.3276
R210	Automatic Fixed Interval	2336.8	0.00808	0.023	Trapezoid	560.427	0.3276
R240	Automatic Fixed Interval	6513.8	0.001	0.023	Trapezoid	560.427	0.3276
R260	Automatic Fixed Interval	2446.1	0.001	0.023	Trapezoid	560.427	0.3276
R280	Automatic Fixed Interval	8346.4	0.02434	0.023	Trapezoid	560.427	0.3276
R30	Automatic Fixed Interval	7849.2	0.01014	0.023	Trapezoid	560.427	0.3276
R300	Automatic Fixed Interval	1311.7	0.001	0.023	Trapezoid	560.427	0.3276
R320	Automatic Fixed Interval	1757.9	0.00743	0.023	Trapezoid	560.427	0.3276
R350	Automatic Fixed Interval	1538.5	0.0136	0.023	Trapezoid	560.427	0.3276
R390	Automatic Fixed Interval	6566.5	0.00201	0.023	Trapezoid	560.427	0.3276
R40	Automatic Fixed Interval	8963.2	0.01688	0.023	Trapezoid	560.427	0.3276
R410	Automatic Fixed Interval	1073	0.001	0.023	Trapezoid	560.427	0.3276
R430	Automatic Fixed Interval	783.14	0.00197	0.023	Trapezoid	560.427	0.3276
R450	Automatic Fixed Interval	2369.8	0.00461	0.023	Trapezoid	560.427	0.3276
R460	Automatic Fixed Interval	4176.6	0.02017	0.023	Trapezoid	560.427	0.3276
R480	Automatic Fixed Interval	1566.4	0.00532	0.023	Trapezoid	560.427	0.3276

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R50	Automatic Fixed Interval	2632.2	0.00318	0.023	Trapezoid	560.427	0.3276
R500	Automatic Fixed Interval	667.4	0.01838	0.023	Trapezoid	560.427	0.3276
R510	Automatic Fixed Interval	1810.7	0.001	0.023	Trapezoid	560.427	0.3276
R560	Automatic Fixed Interval	3486.9	0.01518	0.023	Trapezoid	560.427	0.3276
R570	Automatic Fixed Interval	1549.1	0.00802	0.023	Trapezoid	560.427	0.3276
R580	Automatic Fixed Interval	7814	0.00952	0.023	Trapezoid	560.427	0.3276
R600	Automatic Fixed Interval	3172.4	0.00815	0.023	Trapezoid	560.427	0.3276
R630	Automatic Fixed Interval	4783.2	0.01257	0.023	Trapezoid	560.427	0.3276
R640	Automatic Fixed Interval	6154.8	0.03044	0.023	Trapezoid	560.427	0.3276
R690	Automatic Fixed Interval	5299.7	0.03453	0.023	Trapezoid	560.427	0.3276
R70	Automatic Fixed Interval	2069.4	0.02252	0.023	Trapezoid	560.427	0.3276
R700	Automatic Fixed Interval	3145.5	0.03675	0.023	Trapezoid	560.427	0.3276
R720	Automatic Fixed Interval	3659.4	0.02558	0.023	Trapezoid	560.427	0.3276
R90	Automatic Fixed Interval	4080.5	0.001	0.023	Trapezoid	560.427	0.3276

Annex 11. Pamplona Field Validation Points

Table A-11.1. Pamplona Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	18.48209	121.39314	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
2	18.48209	121.39314	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
3	18.48208	121.39317	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
4	18.48208	121.39317	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
5	18.48204	121.39326	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
6	18.48218	121.39342	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
7	18.48219	121.39343	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
8	18.48237	121.39357	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
9	18.48299	121.39452	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
10	18.48278	121.39583	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
11	18.48268	121.39642	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
12	18.47799	121.40831	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
13	18.47799	121.40831	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
14	18.47795	121.40830	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
15	18.47795	121.40828	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
16	18.47796	121.40827	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
17	18.47795	121.40830	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
18	18.47800	121.40834	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
19	18.47803	121.40836	0.000	1.2	1.20	TS Vinta/ Oct 31, 2013	100-yr
20	18.47697	121.41000	0.000	0.5	0.50	TS Vinta/ Oct 31, 2013	100-yr
21	18.47696	121.41000	0.000	0.5	0.50	TS Vinta/ Oct 31, 2013	100-yr
22	18.47653	121.41055	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
23	18.47650	121.41054	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
24	18.47646	121.41052	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
25	18.47647	121.41050	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
26	18.47656	121.41057	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
27	18.47630	121.41073	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
28	18.47558	121.41113	0.000	0.8	0.80	TS Queenie	100-yr
29	18.47558	121.41113	0.000	0.8	0.80	TS Queenie	100-yr
30	18.47558	121.41113	0.000	0.8	0.80	TS Queenie	100-yr
31	18.47542	121.41128	0.000	0.8	0.80	TS Queenie	100-yr
32	18.47540	121.41132	0.000	0.8	0.80	TS Queenie	100-yr
33	18.47709	121.41020	0.000	0.2	0.20	TS Lawin/ Oct 20, 2016	100-yr
34	18.48066	121.40367	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
35	18.48073	121.40350	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
36	18.48098	121.40301	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
37	18.48232	121.39351	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
38	18.48207	121.39286	0.000	0.5	0.50	TS Lawin/ Oct 20, 2016	100-yr
39	18.48208	121.39255	0.000	0.8	0.80	TS Lawin/ Oct 20, 2016	100-yr
40	18.48212	121.39242	0.000	0.8	0.80	TS Lawin/ Oct 20, 2016	100-yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	18.48218	121.39221	0.000	0.8	0.80	TS Lawin/ Oct 20, 2016	100-yr
42	18.48220	121.39182	0.000	0.8	0.80	TS Lawin/ Oct 20, 2016	100-yr
43	18.48228	121.39097	0.000	0.8	0.80	TS Lawin/ Oct 20, 2016	100-yr
44	18.48228	121.39097	0.000	0.8	0.80	TS Lawin/ Oct 20, 2016	100-yr
45	18.48228	121.39096	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
46	18.48230	121.39096	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
47	18.48167	121.37590	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
48	18.48168	121.37589	0.000	0.8	0.80	TS Vinta/ Oct 31, 2013	100-yr
49	18.48165	121.37593	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
50	18.48164	121.37595	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
51	18.48160	121.37599	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
52	18.48162	121.37597	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
53	18.48161	121.37599	0.000	1	1.00	TS Vinta/ Oct 31, 2013	100-yr
54	18.48154	121.37611	0.000	0.9	0.90	Amihan/TS Lawin/ Oct 20, 2016	100-yr
55	18.48158	121.37613	0.000	0.9	0.90	Amihan/TS Lawin/ Oct 20, 2016	100-yr
56	18.48159	121.37617	0.000	0.9	0.90	Amihan/TS Lawin/ Oct 20, 2016	100-yr
57	18.48157	121.37616	0.000	0.9	0.90	Amihan/TS Lawin/ Oct 20, 2016	100-yr
58	18.48153	121.37617	0.000	0.9	0.90	Amihan/TS Lawin/ Oct 20, 2016	100-yr
59	18.48206	121.37532	0.100	0.5	0.40	TS Ondoy/ Sept 2009	100-yr
60	18.45665	121.34269	1.540	0.3	-1.24	Amihan/TS Lawin/ Oct 20, 2016	100-yr
61	18.45665	121.34269	0.580	0.3	-0.28	Amihan/TS Lawin/ Oct 20, 2016	100-yr
62	18.45663	121.34268	0.450	0.3	-0.15	Amihan/TS Lawin/ Oct 20, 2016	100-yr
63	18.45669	121.34253	1.440	0.3	-1.14	Amihan/TS Lawin/ Oct 20, 2016	100-yr
64	18.45686	121.33904	1.590	1.5	-0.09	TS Vinta/ Oct 31, 2013	100-yr
65	18.45691	121.33903	1.180	1.5	0.32	TS Vinta/ Oct 31, 2013	100-yr
66	18.45695	121.33905	1.180	1.5	0.32	TS Vinta/ Oct 31, 2013	100-yr
67	18.45689	121.33902	1.180	1.5	0.32	TS Vinta/ Oct 31, 2013	100-yr
68	18.45689	121.33904	1.180	1.5	0.32	TS Vinta/ Oct 31, 2013	100-yr
69	18.45689	121.33901	1.590	1.3	-0.29	TS Ondoy/ Sept 2009	100-yr
70	18.45696	121.33957	1.040	1.3	0.26	TS Ondoy/ Sept 2009	100-yr
71	18.45699	121.33961	1.070	1.3	0.23	TS Ondoy/ Sept 2009	100-yr
72	18.45699	121.33968	1.080	0.2	-0.88	TS Lawin/ Oct 20, 2016	100-yr
73	18.45698	121.33968	0.980	0.2	-0.78	TS Lawin/ Oct 20, 2016	100-yr
74	18.41485	121.34913	1.020	0.75	-0.27	Amihan/ Dec 2016	100-yr
75	18.41483	121.34914	1.020	0.75	-0.27	Amihan/ Dec 2016	100-yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
76	18.41486	121.34924	0.490	0.75	0.26	TS Vinta/ Oct 31, 2013	100-yr
77	18.41511	121.34918	0.540	0.75	0.21	TS Vinta/ Oct 31, 2013	100-yr
78	18.41519	121.34916	0.700	0.75	0.05	TS Vinta/ Oct 31, 2013	100-yr
79	18.41532	121.34912	0.570	0.75	0.18	TS Vinta/ Oct 31, 2013	100-yr
80	18.41542	121.34909	0.520	0.75	0.23	TS Vinta/ Oct 31, 2013	100-yr
81	18.41562	121.34899	0.450	0.8	0.35	TS Lawin/ Oct 20, 2016	100-yr
82	18.41562	121.34893	0.880	1.2	0.32	TS Lawin/ Oct 20, 2016	100-yr
83	18.41561	121.34890	0.880	1.2	0.32	TS Lawin/ Oct 20, 2016	100-yr
84	18.41564	121.34871	0.620	1.2	0.58	TS Lawin/ Oct 20, 2016	100-yr
85	18.41584	121.34882	0.780	1.2	0.42	TS Yolanda/ Nov 2013	100-yr
86	18.41587	121.34889	0.920	1.2	0.28	TS Yolanda/ Nov 2013	100-yr
87	18.41587	121.34888	0.920	1.2	0.28	TS Yolanda/ Nov 2013	100-yr
88	18.41581	121.34897	0.380	0.6	0.22	Amihan/ Dec 2016	100-yr
89	18.41598	121.34902	0.450	0.6	0.15	Amihan/ Dec 2016	100-yr
90	18.41619	121.34905	0.500	0.6	0.10	Amihan/ Dec 2016	100-yr
91	18.41643	121.34911	0.710	0.6	-0.11	Amihan/ Dec 2016	100-yr
92	18.41657	121.34919	0.580	0.6	0.02	Amihan/ Dec 2016	100-yr
93	18.41674	121.34929	0.640	0.6	-0.04	Amihan/ Dec 2016	100-yr
94	18.41690	121.34938	0.910	0.8	-0.11	Amihan/ Dec 2016	100-yr
95	18.41710	121.34958	0.630	0.8	0.17	Amihan/ Dec 2016	100-yr
96	18.41723	121.34968	0.920	0.48	-0.44	Amihan/ Dec 2016	100-yr
97	18.41732	121.34973	0.930	0.35	-0.58	Amihan/ Dec 2016	100-yr
98	18.41757	121.34994	0.870	0.35	-0.52	Amihan/ Dec 2016	100-yr
99	18.41758	121.34994	0.870	0.35	-0.52	Amihan/ Dec 2016	100-yr
100	18.41757	121.34997	0.870	0.35	-0.52	Amihan/ Dec 2016	100-yr
101	18.41778	121.34999	1.190	0.7	-0.49	Amihan/ Dec 2016	100-yr
102	18.41781	121.34994	0.860	0.4	-0.46	Amihan/ Dec 2016	100-yr
103	18.41795	121.35023	0.480	0.4	-0.08	Amihan/ Dec 2016	100-yr
104	18.41796	121.35022	0.530	0.78	0.25	Amihan/ Dec 2016	100-yr
105	18.41798	121.35021	0.530	0.78	0.25	Amihan/ Dec 2016	100-yr
106	18.41796	121.35031	0.350	0.48	0.13	Amihan/ Dec 2016	100-yr
107	18.41802	121.35035	0.220	0.48	0.26	Amihan/ Dec 2016	100-yr
108	18.41836	121.35062	1.240	0.48	-0.76	Amihan/ Dec 2016	100-yr
109	18.41850	121.35065	1.920	0.48	-1.44	Amihan/ Dec 2016	100-yr
110	18.41855	121.35063	1.920	0.4	-1.52	Amihan/ Dec 2016	100-yr
111	18.41880	121.35094	1.770	0.4	-1.37	Amihan/ Dec 2016	100-yr
112	18.41881	121.35095	1.770	1	-0.77	TS Lawin/ Oct 20, 2016	100-yr
113	18.43486	121.36044	0.260	1	0.74	Amihan/ Dec 2016	100-yr
114	18.43476	121.36041	0.540	1	0.46	Amihan/ Dec 2016	100-yr
115	18.43476	121.36036	0.540	1	0.46	Amihan/ Dec 2016	100-yr
116	18.43473	121.36039	0.530	1	0.47	Amihan/ Dec 2016	100-yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
117	18.43463	121.36036	0.420	1	0.58	Amihan/ Dec 2016	100-yr
118	18.43440	121.36030	0.240	1	0.76	Amihan/ Dec 2016	100-yr
119	18.43431	121.36039	0.030	1	0.97	Amihan/ Dec 2016	100-yr
120	18.43430	121.36041	0.030	0.4	0.37	TS Ondoy/ Sept 2009	100-yr
121	18.43430	121.36040	0.150	0.3	0.15	TS Karen/ Oct 17, 2016	100-yr
122	18.43436	121.36038	0.030	0.5	0.47	TS Lawin/ Oct 20, 2016	100-yr
123	18.43459	121.36024	0.210	0.8	0.59	TS Pepang/ Oct 1987	100-yr
124	18.43457	121.36028	0.250	0.8	0.55	TS Pepang/ Oct 1987	100-yr
125	18.43424	121.36021	0.390	0.8	0.41	TS Pepang/ Oct 1987	100-yr
126	18.43390	121.36013	0.700	0.8	0.10	TS Pepang/ Oct 1987	100-yr
127	18.43389	121.36006	0.700	0.8	0.10	TS Pepang/ Oct 1987	100-yr
128	18.43304	121.35964	0.600	0.8	0.20	TS Pepang/ Oct 1987	100-yr
129	18.42136	121.36616	2.440	0	-2.44	TS Pepang/ Oct 1987	100-yr
130	18.49229	121.35501	0.440	1.22	0.78	TS Pepang/ Oct 1987	100-yr
131	18.49193	121.35542	0.280	1.22	0.94	TS Pepang/ Oct 1987	100-yr
132	18.49175	121.35563	0.060	1.22	1.16	TS Pepang/ Oct 1987	100-yr
133	18.49156	121.35597	0.370	2.3	1.93	TS Igme/ Aug 18, 2012	100-yr
134	18.49153	121.35594	0.130	2	1.87	TS Pepang/ Oct 1987	100-yr
135	18.49150	121.35595	0.130	2	1.87	TS Vinta/ Oct 31, 2013	100-yr
136	18.49150	121.35595	0.130	2	1.87	TS Vinta/ Oct 31, 2013	100-yr
137	18.49149	121.35594	0.130	2	1.87	TS Vinta/ Oct 31, 2013	100-yr
138	18.49144	121.35599	0.410	2	1.59	TS Vinta/ Oct 31, 2013	100-yr
139	18.49131	121.35609	0.320	2	1.68	TS Vinta/ Oct 31, 2013	100-yr
140	18.49118	121.35619	0.310	2	1.69	TS Vinta/ Oct 31, 2013	100-yr
141	18.49660	121.35333	1.010	2	0.99	TS Vinta/ Oct 31, 2013	100-yr
142	18.49690	121.35469	0.170	1	0.83	TS Vinta/ Oct 31, 2013	100-yr
143	18.49690	121.35469	0.170	1	0.83	TS Vinta/ Oct 31, 2013	100-yr
144	18.49690	121.35471	0.320	1	0.68	TS Vinta/ Oct 31, 2013	100-yr
145	18.49689	121.35471	0.320	0.48	0.16	TS Vinta/ Oct 31, 2013	100-yr
146	18.49710	121.35484	0.120	0.48	0.36	TS Lawin/ Oct 20, 2016	100-yr
147	18.49723	121.35484	0.040	0.48	0.44	TS Lawin/ Oct 20, 2016	100-yr
148	18.49726	121.35488	0.040	2	1.96	TS Pepang/ Oct 1987	100-yr
149	18.49726	121.35493	0.110	2	1.89	TS Pepang/ Oct 1987	100-yr
150	18.49729	121.35490	0.110	2	1.89	TS Pepang/ Oct 1987	100-yr
151	18.49714	121.35483	0.120	0.48	0.36	TS Lawin/ Oct 20, 2016	100-yr
152	18.49702	121.35478	0.250	2	1.75	TS Pepang/ Oct 1987	100-yr
153	18.49656	121.35335	0.910	2	1.09	TS Pepang/ Oct 1987	100-yr
154	18.49551	121.34543	0.120	0.48	0.36	TS Lawin/ Oct 20, 2016	100-yr
155	18.49552	121.34542	0.030	0.48	0.45	TS Lawin/ Oct 20, 2016	100-yr
156	18.49395	121.34579	0.070	0.48	0.41	TS Lawin/ Oct 20, 2016	100-yr
157	18.49410	121.34548	0.050	1	0.95		100-yr

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
158	18.49412	121.34543	0.060	1	0.94		100-yr
159	18.49415	121.34538	0.060	1	0.94		100-yr
160	18.49409	121.34547	0.050	1	0.95		100-yr
161	18.49392	121.34578	0.070	0.48	0.41	TS Lawin/ Oct 20, 2016	100-yr
162	18.49391	121.34581	0.070	0.48	0.41	TS Lawin/ Oct 20, 2016	100-yr
163	18.48991	121.34303	0.180	0.4	0.22	TS Lawin/ Oct 20, 2016	100-yr
164	18.48991	121.34301	0.180	0.4	0.22	TS Lawin/ Oct 20, 2016	100-yr
165	18.46658	121.33138	2.940	1	-1.94	TS Lawin/ Oct 20, 2016	100-yr
166	18.46660	121.33143	0.780	1	0.22	TS Lawin/ Oct 20, 2016	100-yr
167	18.46739	121.32444	1.660	0.4	-1.26	TS Lawin/ Oct 20, 2016	100-yr
168	18.46960	121.31788	1.730	0.4	-1.33	TS Lawin/ Oct 20, 2016	100-yr

Annex 12. Educational Institutions affected by flooding in Pamplona Floodplain

Table A-12.1. Educational Institutions in Pamplona, Cagayan affected by flooding in Pamplona Floodplain

Cagayan				
Pamplona				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ABBANGKERUAN ELEM SCHOOL	Abanqueruan			
MASI PRIMARY SCHOOL	Abanqueruan	Medium	High	High
PAMPLONA NATIONAL SCHOOL OF FISHERY	Abanqueruan	Low	Low	Low
ALLASITAN ELEM SCHOOL	Allasitan			
CABAGGAN ELEM SCHOOL	Cabaggan			
CAPALALIAN ELEM SCHOOL	Capalalian	Low	Medium	Medium
PAMPLONA CENTRAL SCHOOL	Centro			
PAMPLONA INSTITUTE	Centro	Low	Low	Medium
PAMPLONA CENTRAL SCHOOL	Masi			
SAN JUAN ELEM SCHOOL	San Juan			
TABBA ELEM SCHOOL	Tabba			

Annex 13. Health Institutions affected by flooding in Pamplona Floodplain

Table A-13.1. Health Institutions in Pamplona, Cagayan affected by flooding in Pamplona Floodplain

Cagayan				
Pamplona				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BEMNOC	Masi	Low	Low	Low