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

LiDAR Surveys and Flood Mapping of Putiao River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
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LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva C. Plopenio, and Engr. Ferdinand E. Bien

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 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 Ateneo de Naga University (ADNU). VSU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 24 river basins in the Bicol Region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Putiao River Basin

Putiao is a combination of two (2) basins, which are called Putiao I and Putiao II. Putiao I is located west of Putiao II. The Putiao I River is about 62 km long, while the Putiao II River is about 48 km long. The general or combined Putiao River Basin covers the municipality of Pilar in Sorsogon and some portions of Daraga and Legazpi City in the province of Albay. The DENR River Basin Control Office identified the basin to have a drainage area of 188 km2, with an estimated annual run-off of 254 million cubic meter (MCM) (RBCO, 2015).

Putiao I and II are both bounded by the Sorsogon Bay to the Southeast, by Mt. Pulog to the Northeast, Albay Gulf to the north, and rolling hills to the west where the Ogod and Donsol river basins are. The main rivers empty out into one major stream to the northern part of the Ticao Pass. Mt. Pulog has an elevation of 1,020 mASL. A lakelet is located near the summit, which is called Lake Pulog. This mountain is typically visited for a day hike or side trip by mountaineers climbing Mt. Mayon or Mt. Bulusan.

The Putiao I River Basin is covered by three (3) municipalities namely, Pilar, Castilla and Daraga; and one (1) component city, which is Legazpi City. The Putiao II River Basin is covered by just Pilar and Castilla, and the same component city. Two (2) of the identified municipalities are first class: Pilar, with a population of 74,564 according to the 2015 census; and Daraga, with a population of 126,595 as per the 2015 census. Castilla is a third class municipality, with a population of 52,903, based on the 2010 census. Legazpi City is a component city with a population of 196,639, according to the 2015 census.

The population within the immediate vicinity of the river is 16,711, which is distributed among (thirteen) 13 barangays in the municipality of Pilar (NSO census, 2015).

The climate in the areas covered by the river basins is categorized into two (2) types. In the east, the climate is Type II, which has no distinct dry season and has very wet months from November until April. In the west, the climate is Type IV, characterized by a more or less even distribution of rainfall throughout the year. The landcover is mostly brushland and grassland with areas for cultivation of cacao, coconut, abaca, pili, and rice.

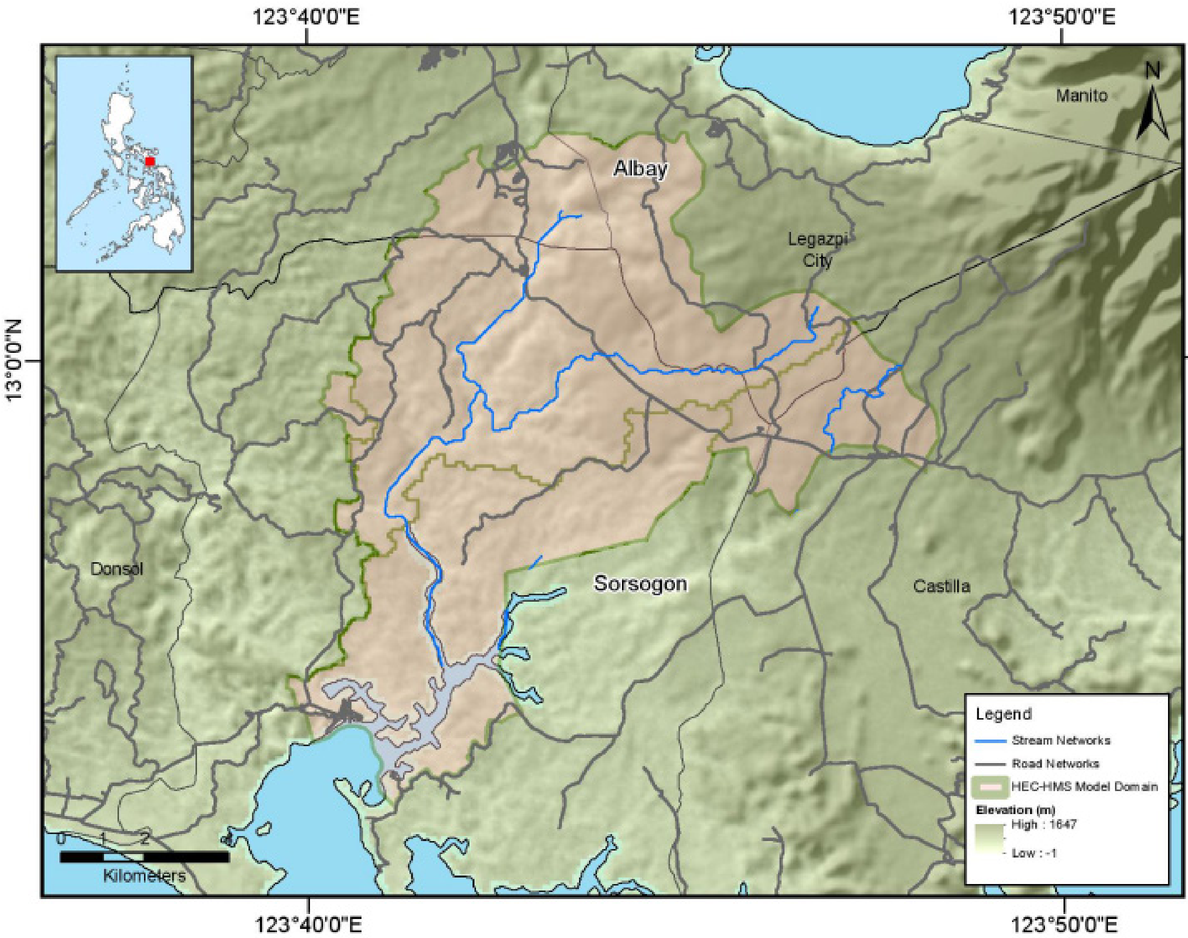

Figure 1. Map of the Putiao I River Basin (in brown)

As the major supplier of copra to the coconut oil milling industry in Bicol, the municipality's economic growth relies mainly on agriculture, with coconut as a major product. Among the coastal residents of Pilar, fishing is the main source of income (http://pilar-sorsogon.weebly.com/about-pilar.html, 2017).

According to the Regional Bureau of Mines and Geosciences, Pilar is one of the fifty-five (55) towns in the Bicol region vulnerable to flooding and landslides (http://newsinfo.inquirer.net/430099/half-of-bicol-prone-to-flood-and-landslides, 2017).

During the torrential rains in February 2008, Sorsogon placed eleven (11) of its towns under a state of calamity. According to the Sorsogon PDCC action officer Atty. Manuel Fortes, a total of PHP 6.9 M worth of damages was brought about by flooding and landslides in Pilar alone. According to the Mines and Geosciences Bureau, majority of the 18 to 50 percent slopes prone to severe erosions in the province of Solomon are found in the municipalities of Pilar, Donsol, and Sorsogon.

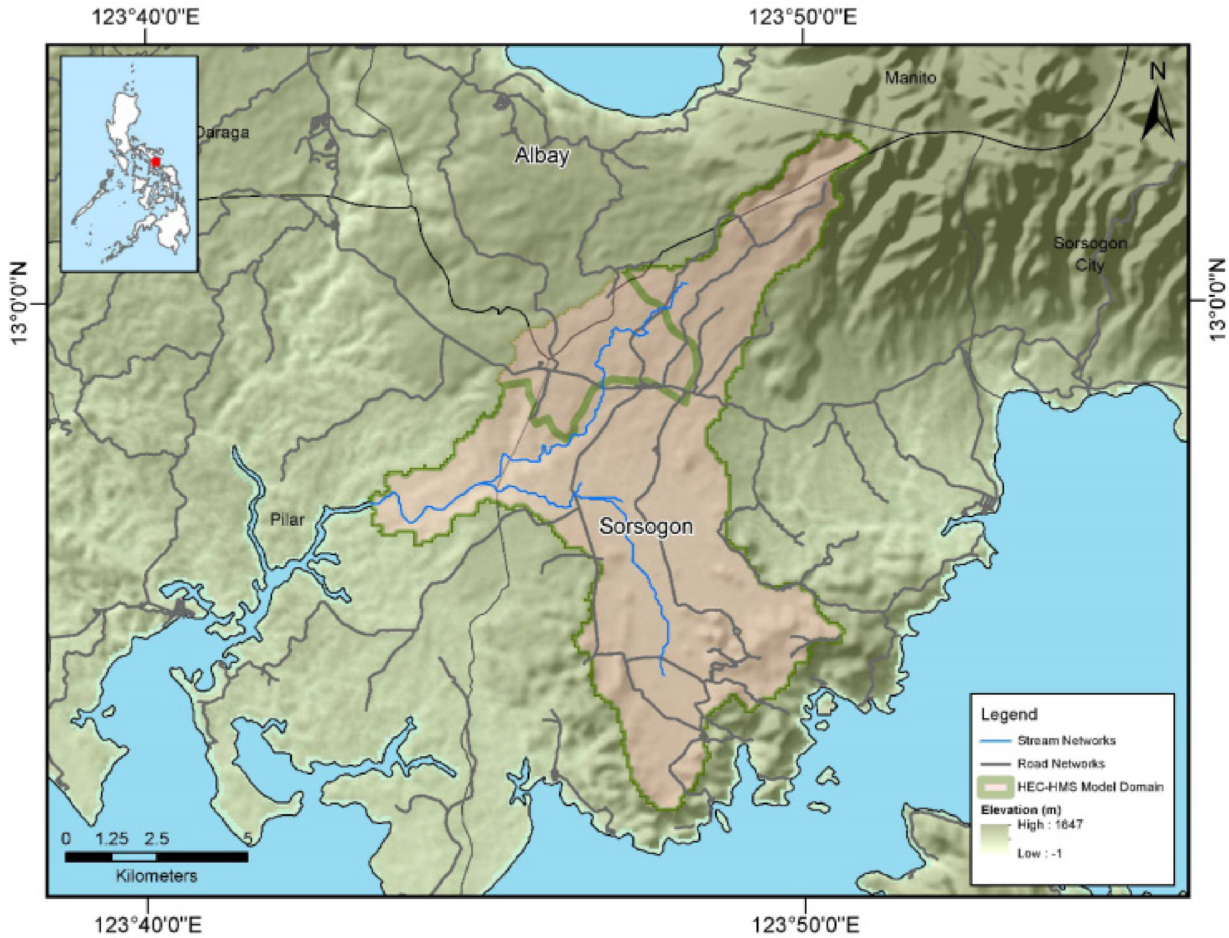

Figure 2. Map of the Putiao II River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PUTIAO FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Putiao Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Putiao floodplain in Albay and Sorsogon. These missions were planned for 10 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time using the Gemini LiDAR system (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system is found in Table 1. Figure 3 illustrates the flight plan for the Putiao floodplain.

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK19A	1000	30	50	125	50	130	5
BLK19E	1000	30	50	125	50	130	5
BLK19G	1000	30	50	125	50	130	5
BLK19I	1000	30	50	125	50	130	5
BLK19K	1000	30	50	125	50	130	5
	900	30	40	125	50	130	5
BLK19L	1000	30	50	125	50	130	5
	900	30	40	125	50	130	5
BLK19O	1000	30	50	125	50	130	5

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

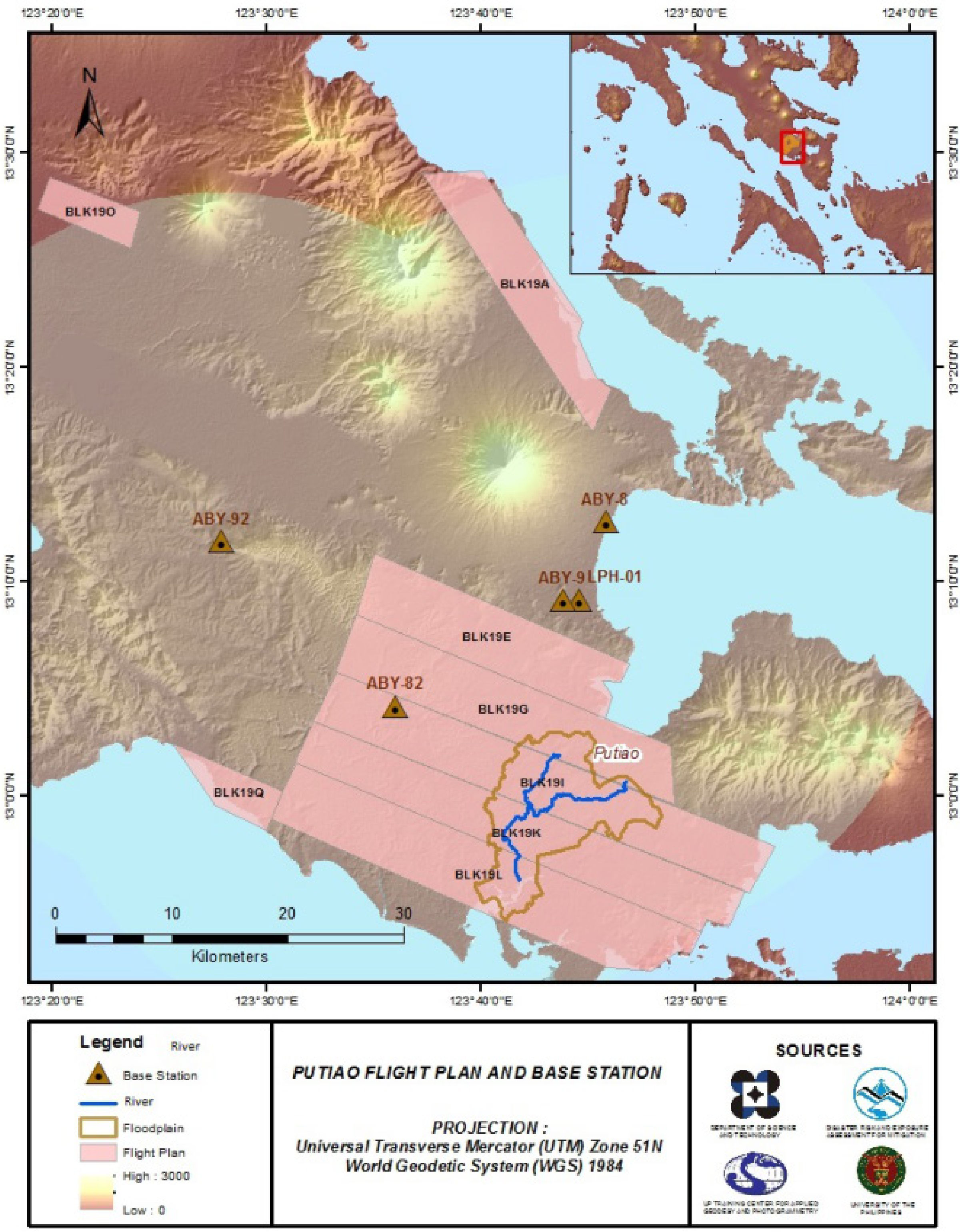
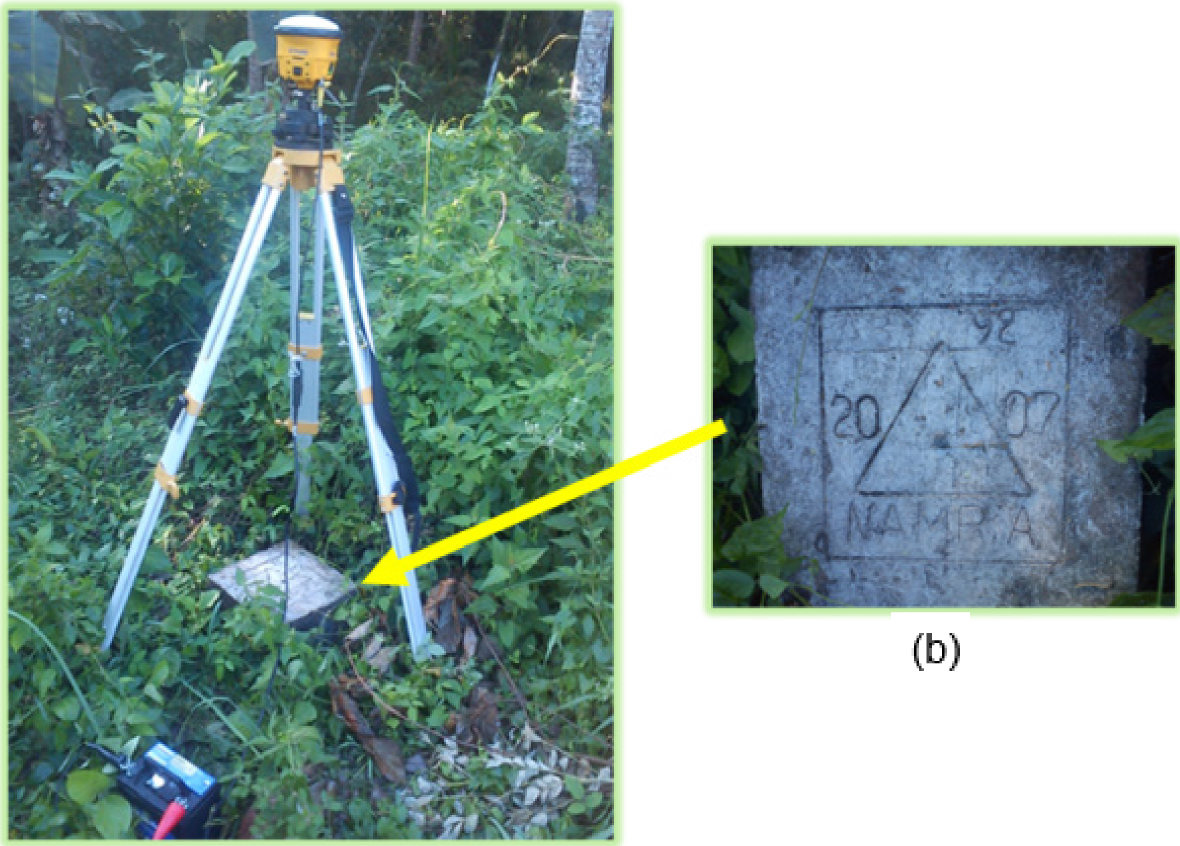


Figure 3. Flight Plan and base stations used for the Putiao Floodplain survey.

2.2 Ground Base Stations

The field team for this undertaking was able to recover four (4) NAMRIA horizontal ground control points of second (2nd) order accuracy, ABY-92, ABY-8 and ABY-82; and one (1) of third (3rd) order accuracy, ABY-9. The team established one (1) ground control point, LPH-1. The certifications for these base stations are found in Annex 2, while the baseline processing reports for the established ground control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey held on March 26 – April 30, 2014; and February 24 – March 20, 2016. The base stations were observed using dual frequency GPS receivers: TRIMBLE SPS SPS 985 and SPS 852. The flight plans and locations of base stations used during the aerial LiDAR acquisition in the Putiao floodplain are shown in Figure 3. The composition of the project team is shown in Annex 4.

Figure 4 to Figure 8 depict the recovered NAMRIA reference points within the area. Table 2 to Table 6 enumerate the details about the following NAMRIA control stations and established points, while Table 7 shows the list of all ground control points occupied during the acquisition, with the corresponding dates of survey.



(b)

(a)

Figure 4. GPS set-up over ABY-92 beside the baseline of the basketball court at about 19 meters from the barangay hall (a) and NAMRIA reference point ABY-92 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ABY-92 used as base station for the LiDAR acquisition.

Station Name	**ABY-92**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 11’ 56.27238” North 123° 27’ 47.60156” East 127.30900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	550193.31 meters 1459094.57 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 11’ 51.38974” North 123° 27’ 52.59990” East 180.74900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	550193.31 meters 1459094.57 meters

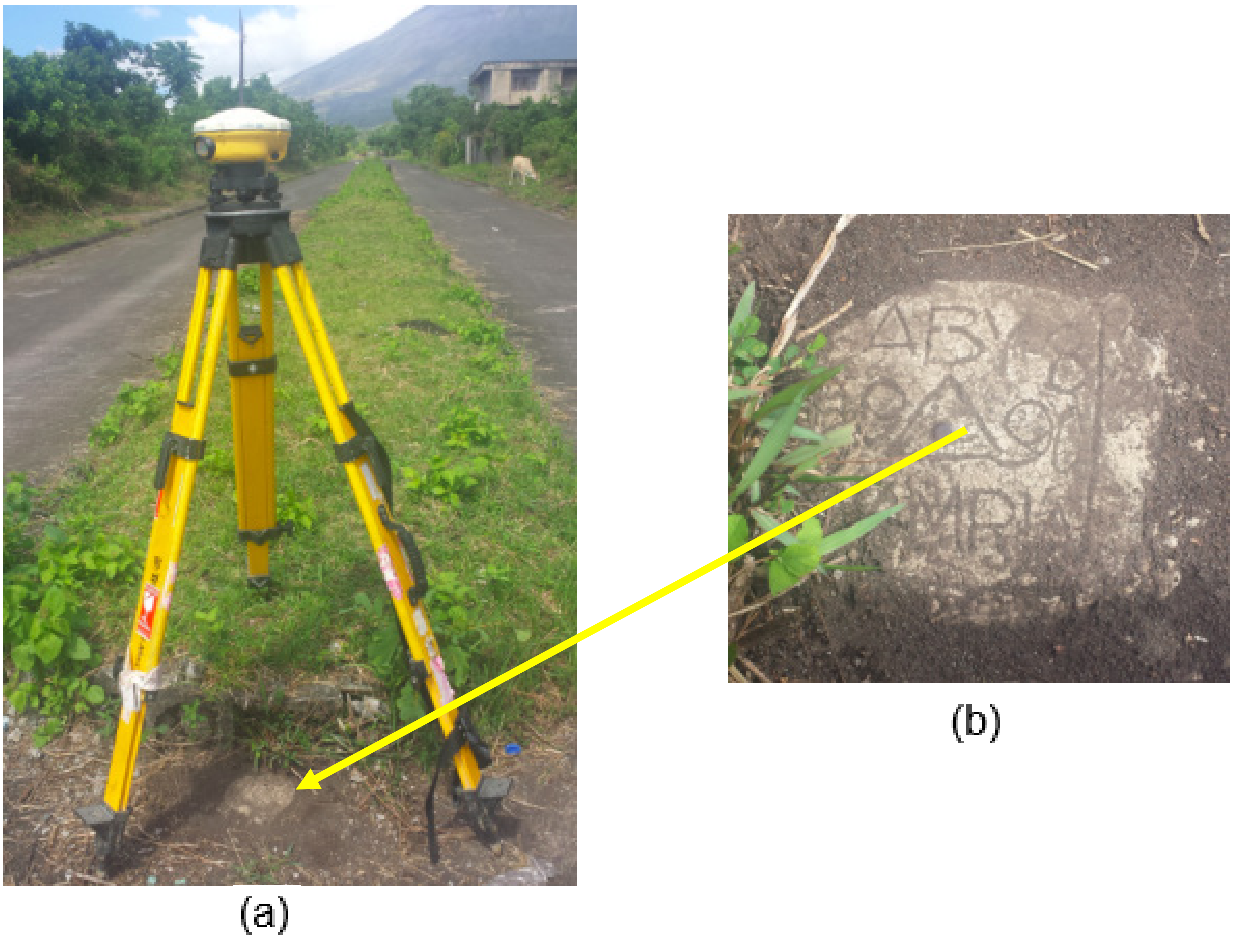
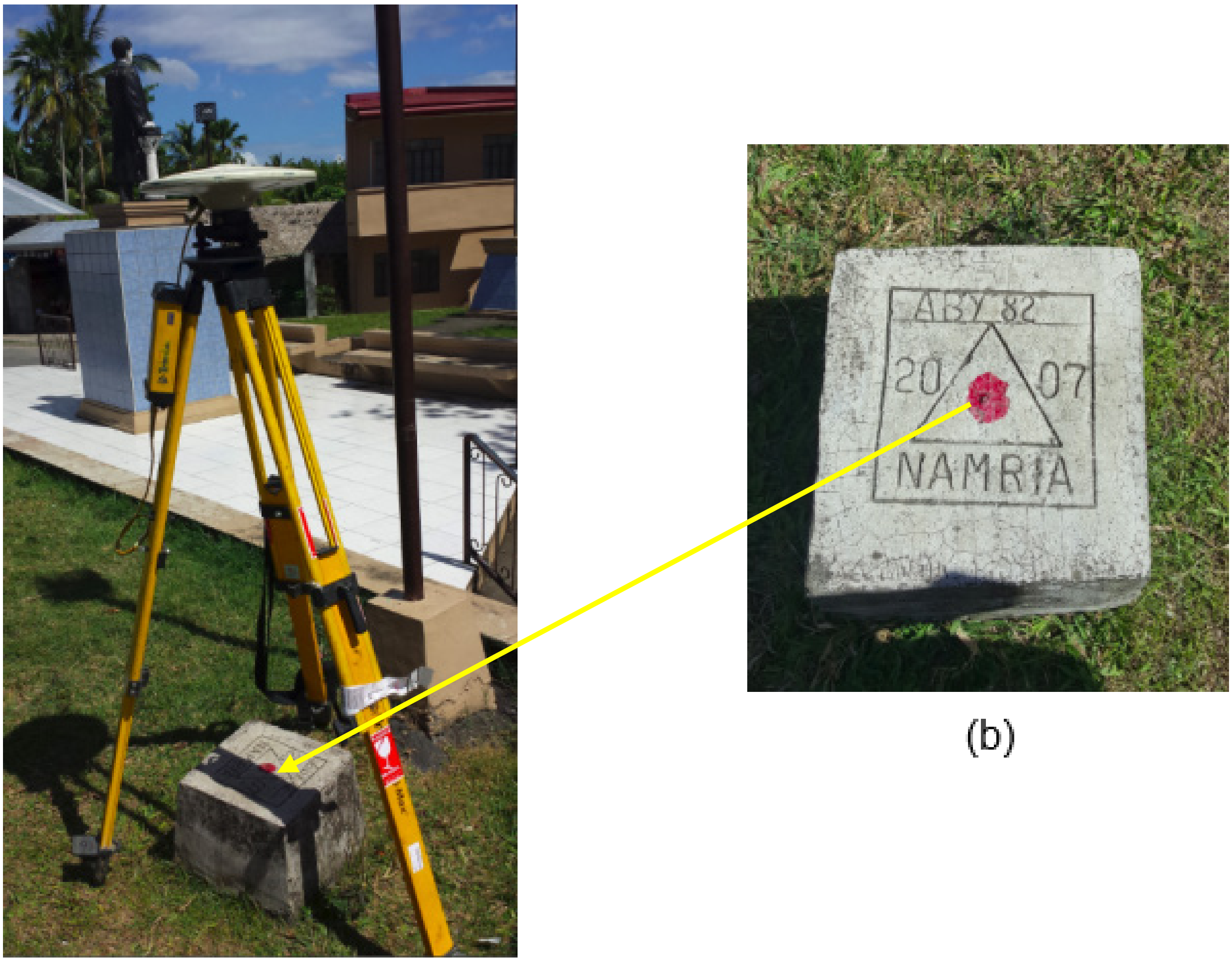


Figure 5. GPS set-up over ABY-8 at the center of the island of Mayon Riviera Subdivision. Highest prominent mark is the electric timber post 9.50 meters SE of the station (a) and NAMRIA reference point ABY-8 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point ABY-08 used as base station for the LiDAR acquisition.

Station Name	ABY-8	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 12’ 51.92876” North 123° 45’ 45.95336” East 6.33900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	582646.93 meters 1460883.61 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 12’ 47.06720” North 123° 45’ 50.94829” East 60.47000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	582646.93 meters 1460883.61 meters



(a)

(b)

Figure 6. GPS set-up over ABY-82 at the from the right corner (about 12 m) of the Rizal monument in front of Jovellar Catholic Church and 12 meters from the road centerline (a) and NAMRIA reference point ABY-82 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ABY-82 used as base station for the LiDAR acquisition.

Station Name	ABY-82	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 4' 16.27314" North 123° 35' 53.17428" East 39.77600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	564865.27 meters 1445500.97 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 4' 11.43271" North 123° 35' 58.18268" East 93.89000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	564, 842.57 meters 1,444,995.02 meters

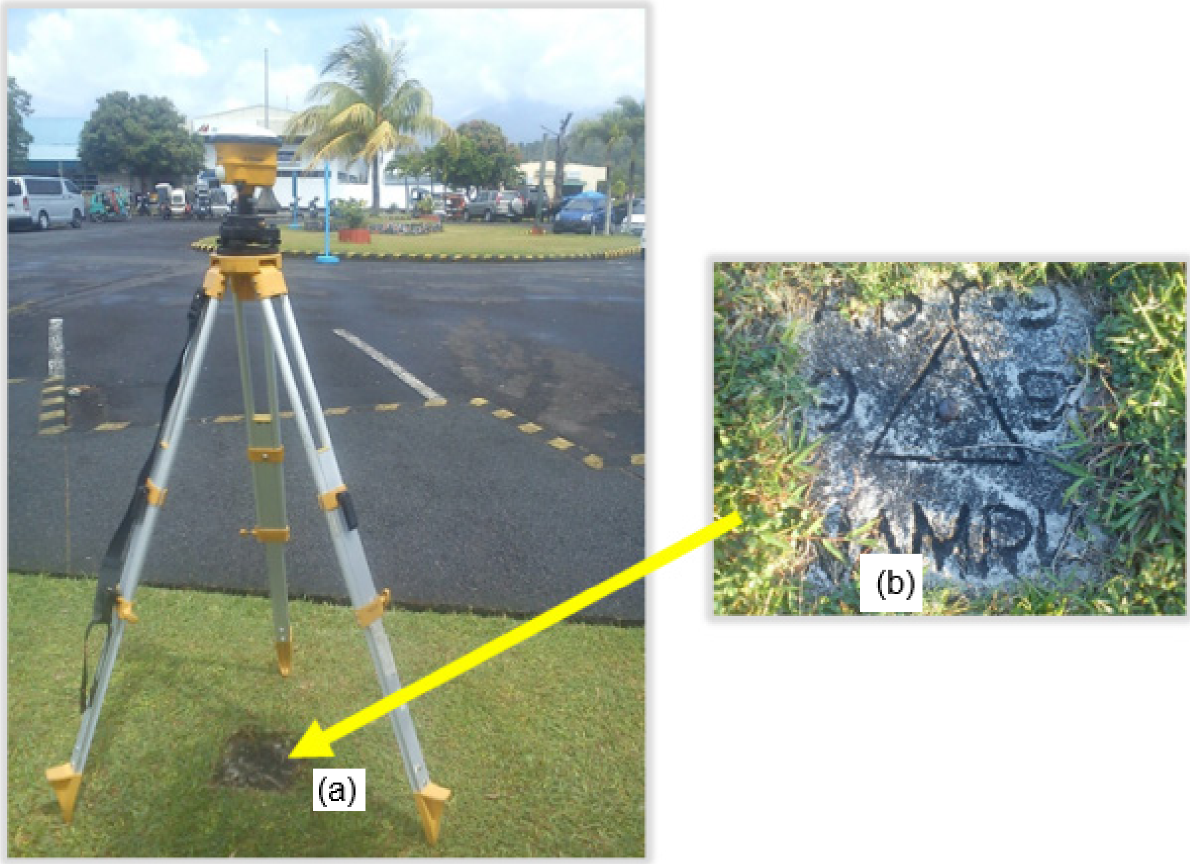


Figure 7. GPS set-up over ABY-9 inside Legaspi Airport Compound 52.0 meters SE of Legaspi Airport Flagpole, 35 meters NE of Legaspi Airport Welcome Post 3.30 meters NW of Lamp (a) and NAMRIA reference point ABY-9 (b) as recovered by the field team

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

Station Name	ABY-9	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 9’ 11.38733” North 123° 43’ 45.95874” East 14.54010 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	579082.538 meters 1454607.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 9’ 6.53800” North 123° 43’ 50.95900” East 68.754 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	579054.86 meters 1454097.98 meters

(a)

Figure 8. GPS set-up over LPH-01 the rooftop a building at La Piazza Hotel and Convention Center located at Tahao Road, Legazpi, Albay (a) as established by the field team.

Table 6. Details of the recovered NAMRIA vertical control point SM-271, which was used as a base station for the LiDAR acquisition with established coordinates.

Station Name	LPH-01	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 09' 08.50554" North 123° 44' 32.88949" East 65.236 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 09' 08.50554" North 123° 44' 32.88949" East 65.236 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	580467.016 meters 1454103.670 meters

Table 7. Ground Control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 29, 2014	7156GC	2BLK19E088A	ABY-9, LPH-01
March 30, 2014	7158GC	2BLK19ES089A & 2BLK19G089A	ABY-9, LPH-01
March 31, 2014	7160GC	2BLK19I90A	ABY-9, LPH-01
March 31, 2014	7161GC	2BLK19IS090B	ABY-9, LPH-01
April 3, 2014	7167GC	2BLK19K093A & 2BLK19IS093A	ABY-9, LPH-01
April 4, 2014	7168GC	2BLK19L094A	ABY-9, LPH-01
April 26, 2014	7213GC	2BLK19OS116B & VOIDS	ABY-8, ABY-9, ABY-92
April 28, 2014	7216GC	2BLK19AS118A & VOIDS	ABY-8, ABY-9
February 25, 2016	3813G	2BLK19IS056B	ABY-82
February 26, 2016	3815G	2BLK19KLS057A	ABY-82

2.3 Flight Missions

A total of ten flight (10) missions were conducted to complete the LiDAR data acquisition in the Putiao floodplain, for a total of thirty-two hours and twenty-one minutes (32+21) of flying time for RP-C9322 and RP-C9022 (See Annex 6 for the flight logs of the flight missions). All missions were acquired using the Gemini LiDAR system. Table 8 shows the total area of actual coverage per mission and the corresponding flying hours for each mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for the LiDAR data acquisition of the Putiao 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
March 29, 2014	7156GC	106.73	40.41	-	40.41	2	11
March 30, 2014	7158GC	241.81	282.19	17.19	265.00	4	29
March 31, 2014	7160GC	171.14	19.42	7.63	11.79	1	35
March 31, 2014	7161GC	171.14	138.71	41.78	96.93	2	29
April 3, 2014	7167GC	179.98	247.35	44.18	203.17	3	53
April 4, 2014	7168GC	171.15	229.12	17.53	211.59	3	29
April 26, 2014	7213GC	24.27	94.15	9.07	85.08	2	35
April 28, 2014	7216GC	122.54	135.24	5.21	130.03	3	11
February 25, 2014	3813G	107.10	121.93	82.43	39.50	4	17
February 26, 2014	3815G	100.75	118.22	27.95	90.27	3	35
TOTAL		**1396.61**	**1426.74**	**252.96**	**1173.78**	**32**	**21**

Table 9. Actual parameters used during the LiDAR data acquisition of the Putiao Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7156GC	1100	35	40	100	50	130	5
7158GC	1100	35	40	100	50	130	5
7160GC	1000	45	40	100	50	130	5
7161GC	1000	45	40	100	50	130	5
7167GC	1000	40	40	100	50	130	5
7168GC	1100	40	40	100	50	130	5
7213GC	1100	30	40	100	50	130	5
7216GC	1300	50	34, 40	100	50	130	5
3813G	650	40	50	125	40	130	5
3815G	900	40	50	125	40	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Putiao floodplain. The Putiao floodplain is located in the provinces of Albay and Sorsogon, with majority of the floodplain situated within Albay. The municipalities of Jovellar in Albay; and Pilar, Castilla, and Donsol in Sorsogon, were mostly covered by the survey (See Annex 7 for the flight status reports). The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for the Putiao floodplain is presented in Figure 9.

Table 10. List of municipalities and cities surveyed during Putiao floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Albay	Jovellar	82.35	77.32	94%
	Camalig	136.54	94.69	69%
	Daraga	135.66	90.17	66%
	Legazpi City	153.18	88.89	58%
	Guinobatan	174.07	43.35	25%
	Malilipot	45.42	7.37	16%
	Malinao	106.78	15.33	14%
	Tiwi	124.4	16.40	13%
	Pio Duran	133.24	15.36	12%
	Tabaco City	112.24	8.59	8%
	Bacacay	115.2	5.27	5%
	Oas	239.58	10.93	5%
	Santo Domingo	60.83	2.00	3%
	Ligao City	258.51	7.28	3%
Camarines Sur	Baao	106.5	19.75	19%
	Nabua	96.61	2.78	3%
	Iriga City	130.05	2.78	2%
Sorsogon	Pilar	196.62	175.43	89%
	Donsol	153	128.47	84%
	Castilla	197.27	157.63	80%
TOTAL		**2758.05**	**969.79**	**35.16%**

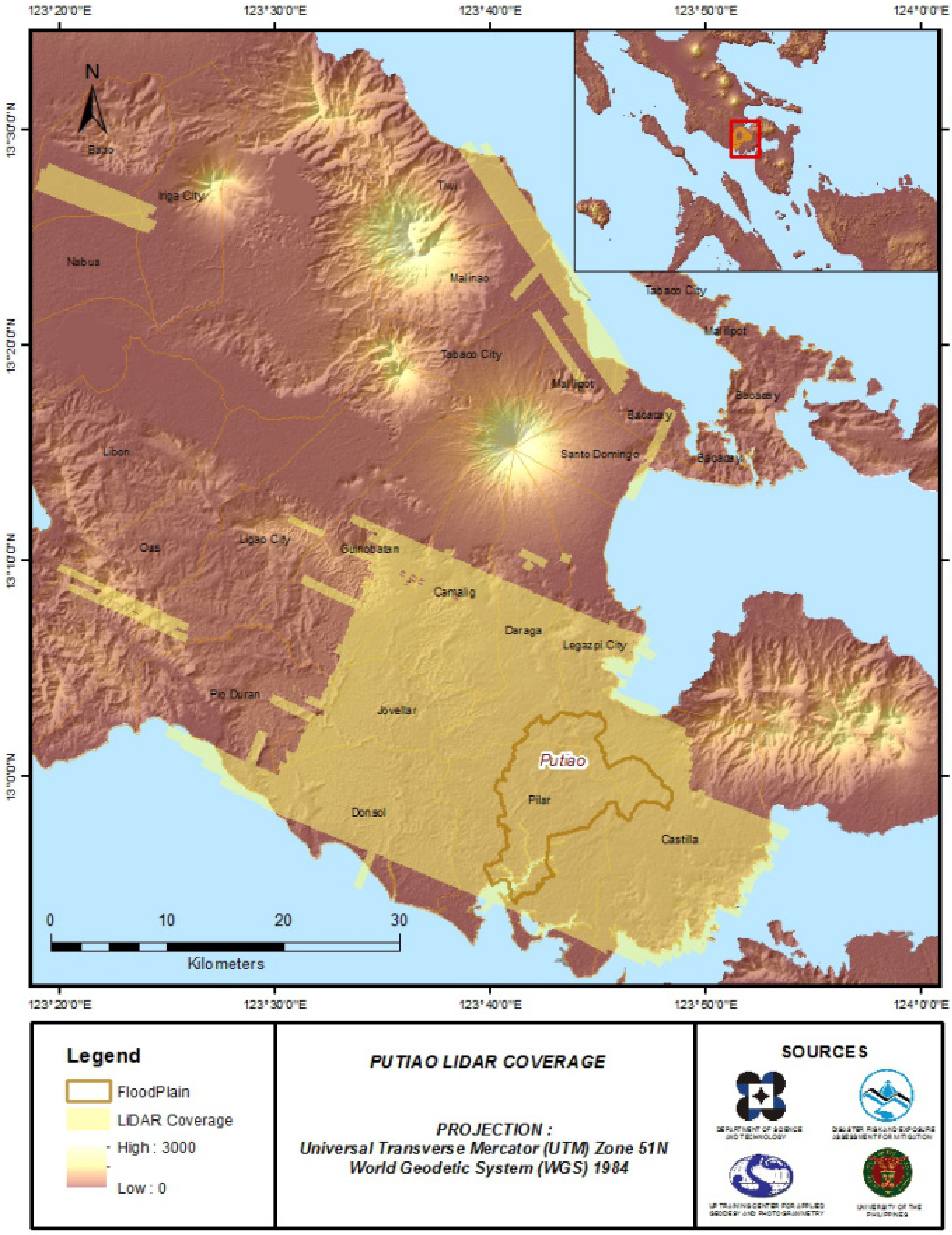


Figure 9. Actual LiDAR survey coverage of the Putiao Floodplain.

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

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

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

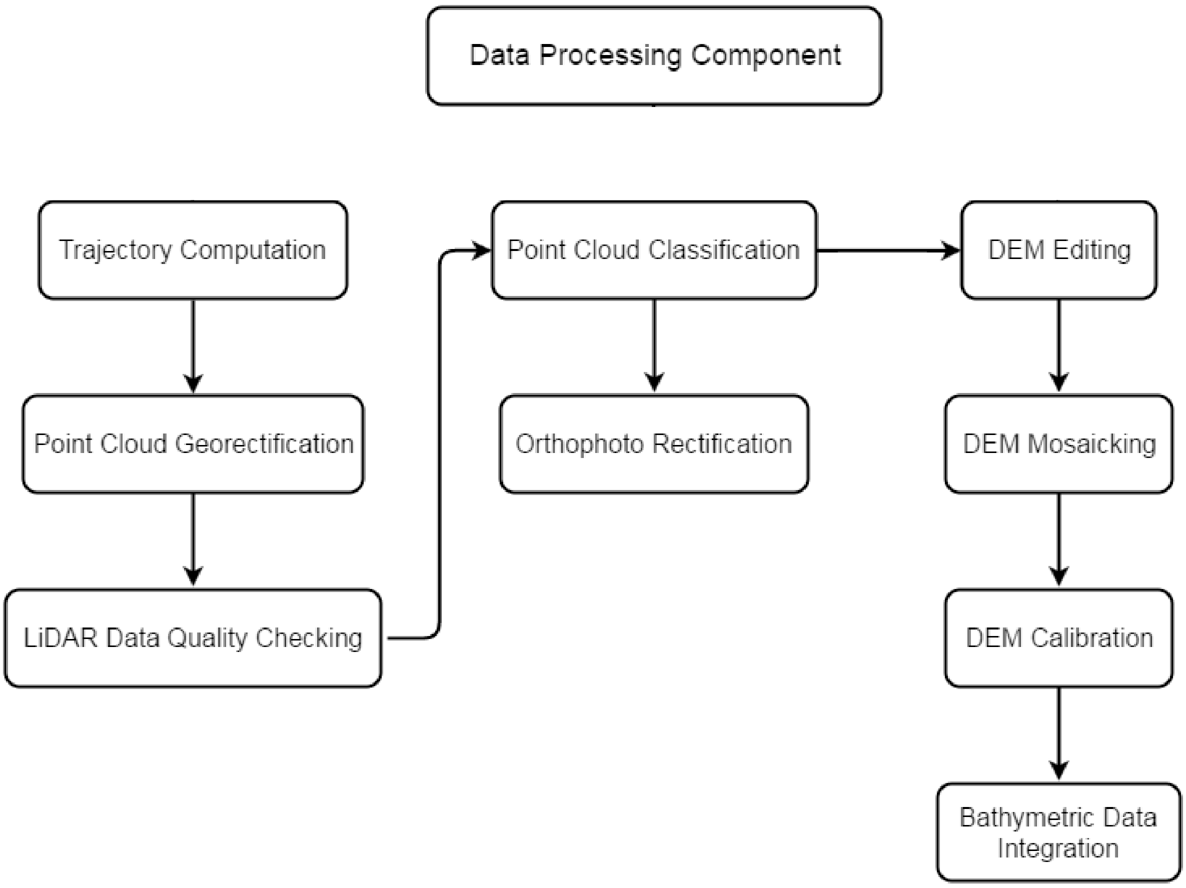


Figure 10. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Putiao floodplain can be found in Annex 5: Data Transfer Sheets. Missions flown during the first survey conducted in March 2014 and the second survey in April 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Pilar, Sorsogon. The DAC transferred a total of 120.51 Gigabytes of Range data, 1.31 Gigabytes of POS data, 56.60 Megabytes of GPS base station data, and 273.20 Gigabytes of raw image data to the data server on April 29, 2014 for the first survey, and on May 5, 2014 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Putiao was fully transferred on May 5, 2014, as indicated on the Data Transfer Sheets for the Putiao floodplain.

3.3 Trajectory Computation

he Smoothed Performance Metric parameters of the computed trajectory for flight 7161G, one of the Putiao flights, which are the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on March 31, 2014 00:00AM on that week. The y-axis is the RMSE value for that particular position.

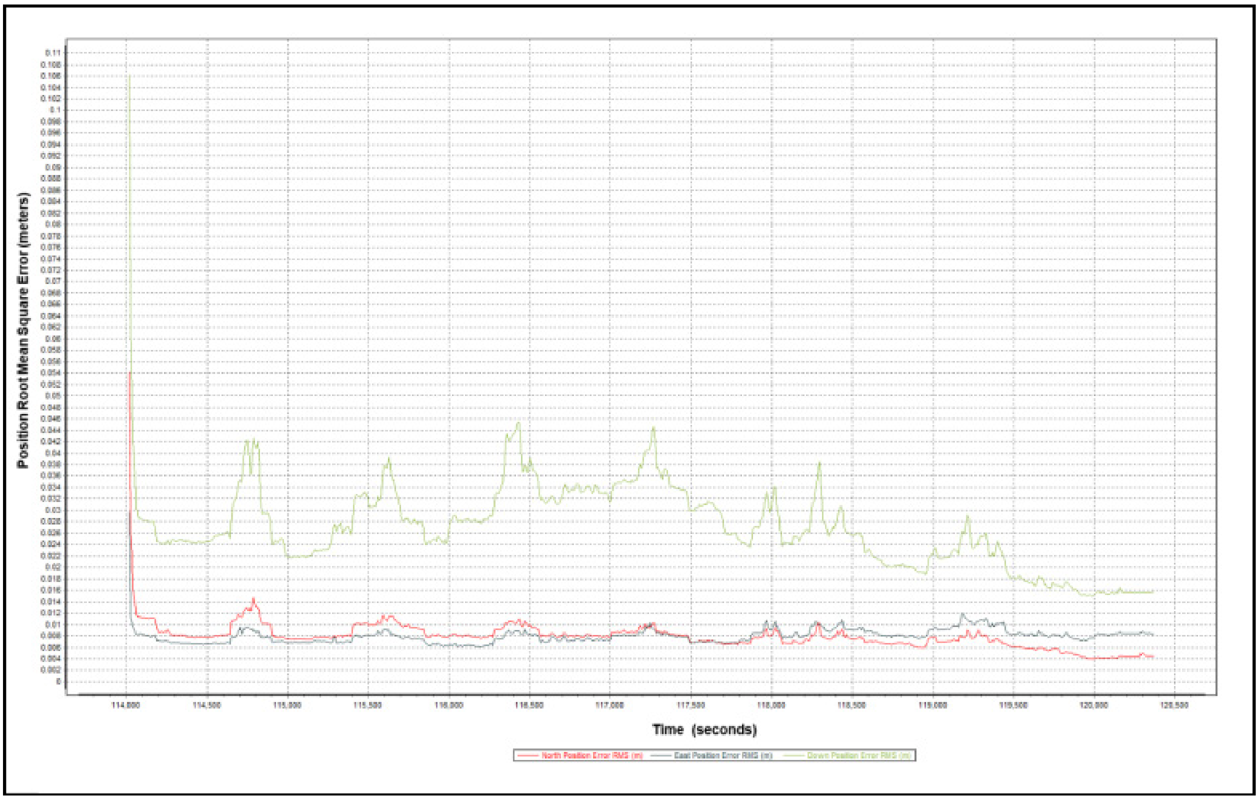


Figure 11. Smoothed Performance Metric Parameters of a Putiao Flight 7161G.

The time of flight was from 114000 seconds to 120500 seconds, which corresponds to the afternoon of May 31, 2014. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 1.50 centimeters, the East position RMSE peaks at 1. 20 centimeters, and the Down position RMSE peaks at 4.60 centimeters, which are within the prescribed accuracies described in the methodology.

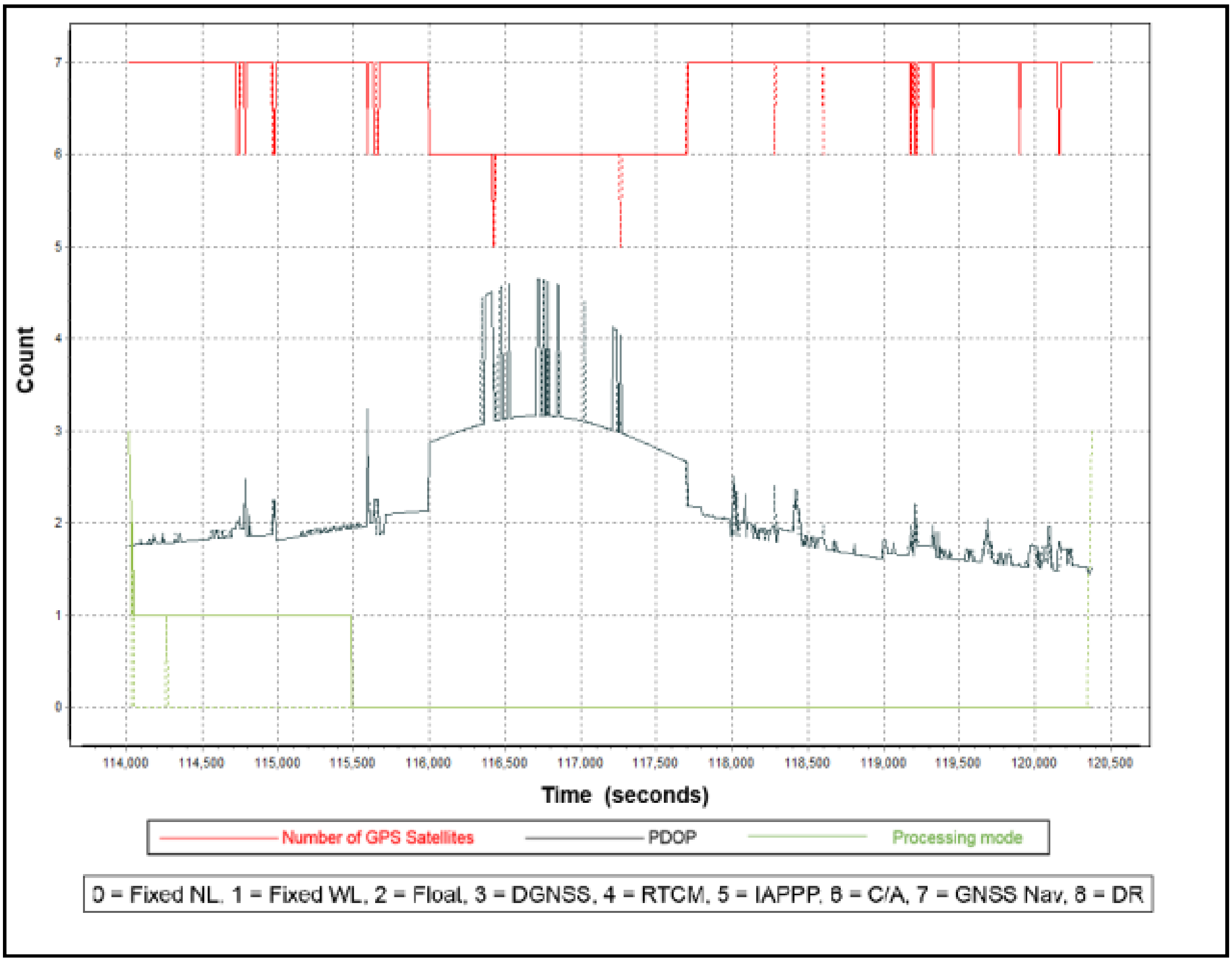


Figure 12. Solution Status Parameters of Putiao Flight 7161G

The Solution Status parameters of flight 7161G, one of the Putiao flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. Majority of the time, the number of satellites tracked was between six (6) and eight (8). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode stayed at the value of zero (0) for majority of the survey, with some peaks up to one (1), attributed to the turns performed by the aircraft. The value of zero (0) corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Putiao flights is shown in Figure 13.

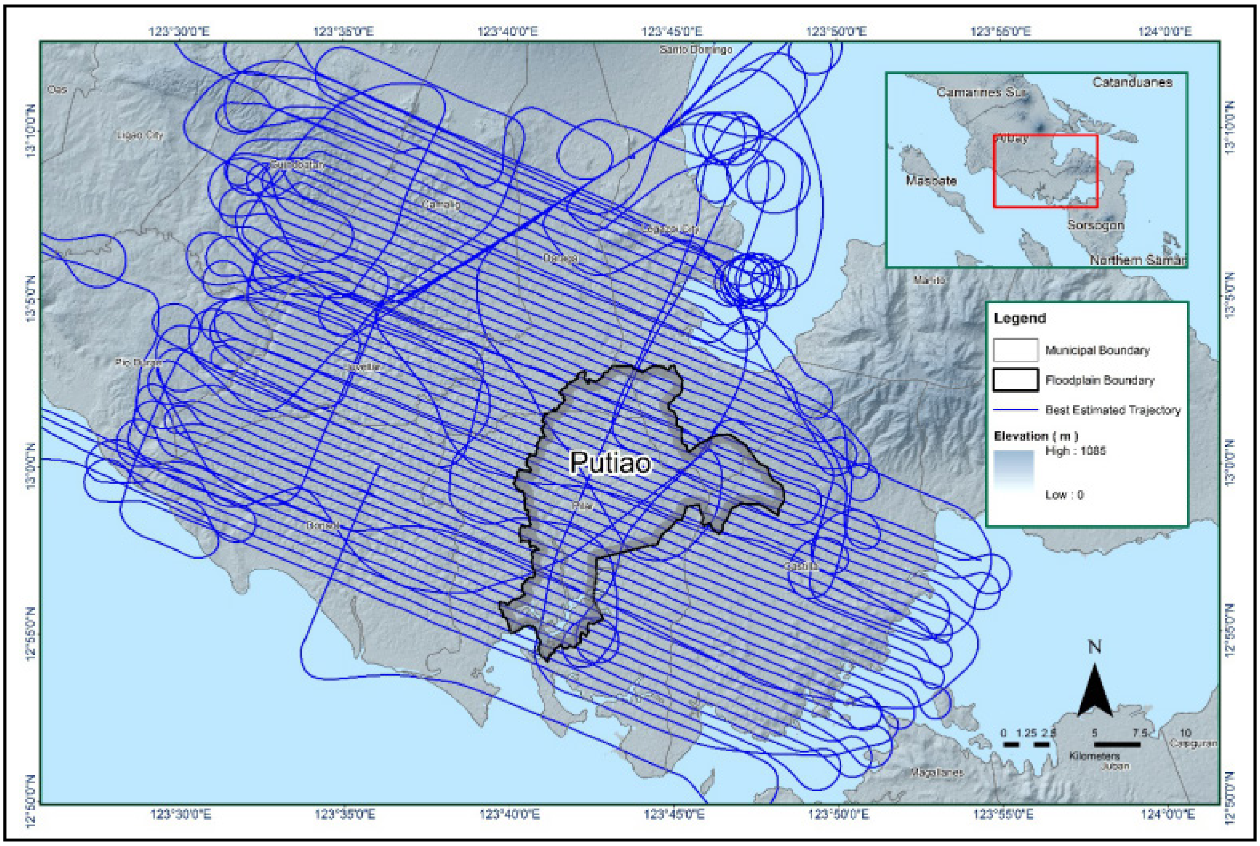


Figure 13. Best estimated trajectory conducted over the Putiao Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains sixty-nine (69) flight lines, with each flight line containing one channel, since the Gemini contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Putiao floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Putiao flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000214
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000503
GPS Position Z-correction stdev)	<0.01meters	0.0076

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Putiao floodplain is illustrated in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

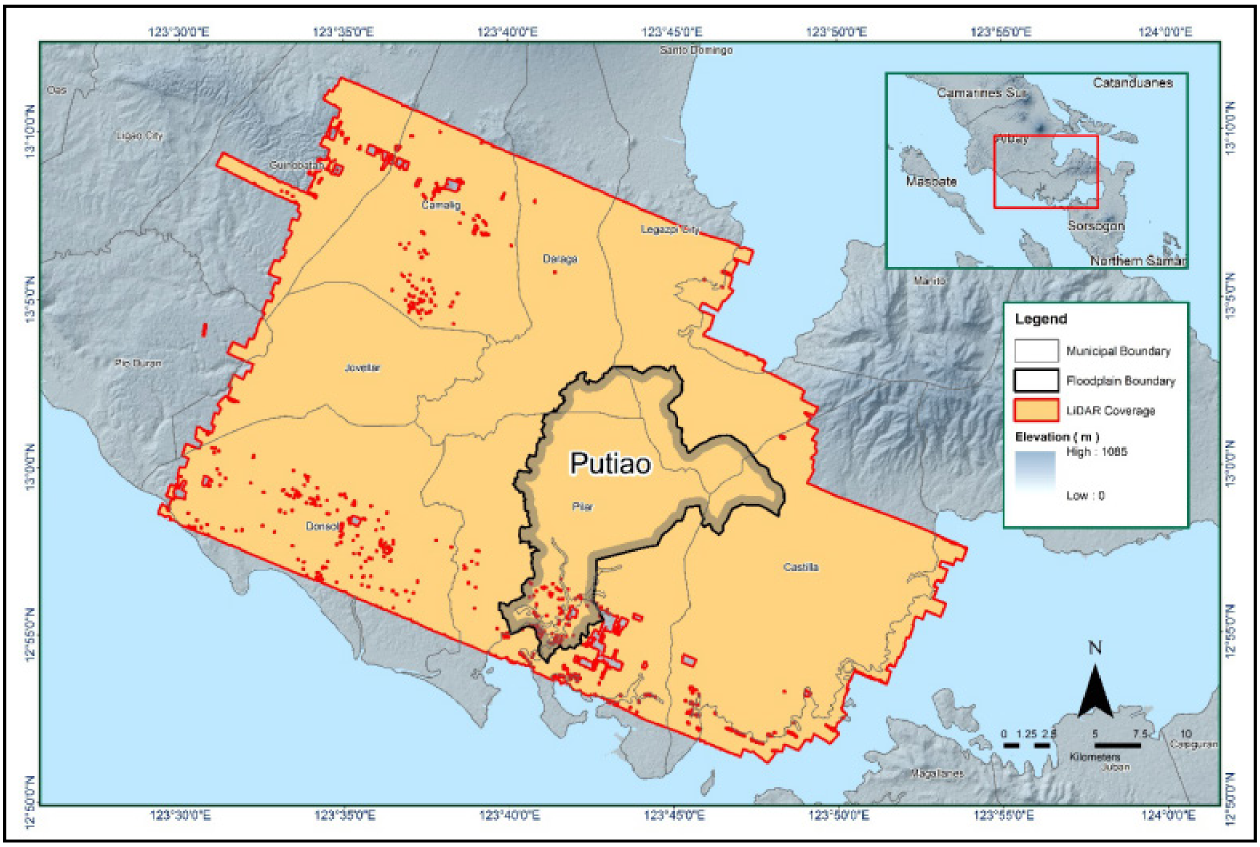


Figure 14. Boundaries of the processed LiDAR data over the Putiao Floodplain

The total area covered by the Putiao missions is 1362.15 sq.km, comprised of eleven (11) flight acquisitions grouped and merged into eight (8) blocks, as shown in Table 12.

Table 12. List of LiDAR blocks for Putiao Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Albay_Sorsogon_Blk19I	7160GC	407.11
	7161GC	
Albay_Sorsogon_Blk19EG	7156GC	301.83
	7158GC	
	7216GC	
Albay_Sorsogon_Blk19L_ additional	7213GC	1.20
Albay_Sorsogon_Blk19L	7168GC	192.24
Albay_Sorsogon_Blk19K	7167GC	238.90
Albay_Sorsogon_reflights_Blk19I	3813G	74.94
Albay_Sorsogon_reflights_ Blk19I_additional	3813G	75.08
Albay_Sorsogon_reflights_Blk19L	3815G	70.85
TOTAL		**1362.15 sq.km**

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

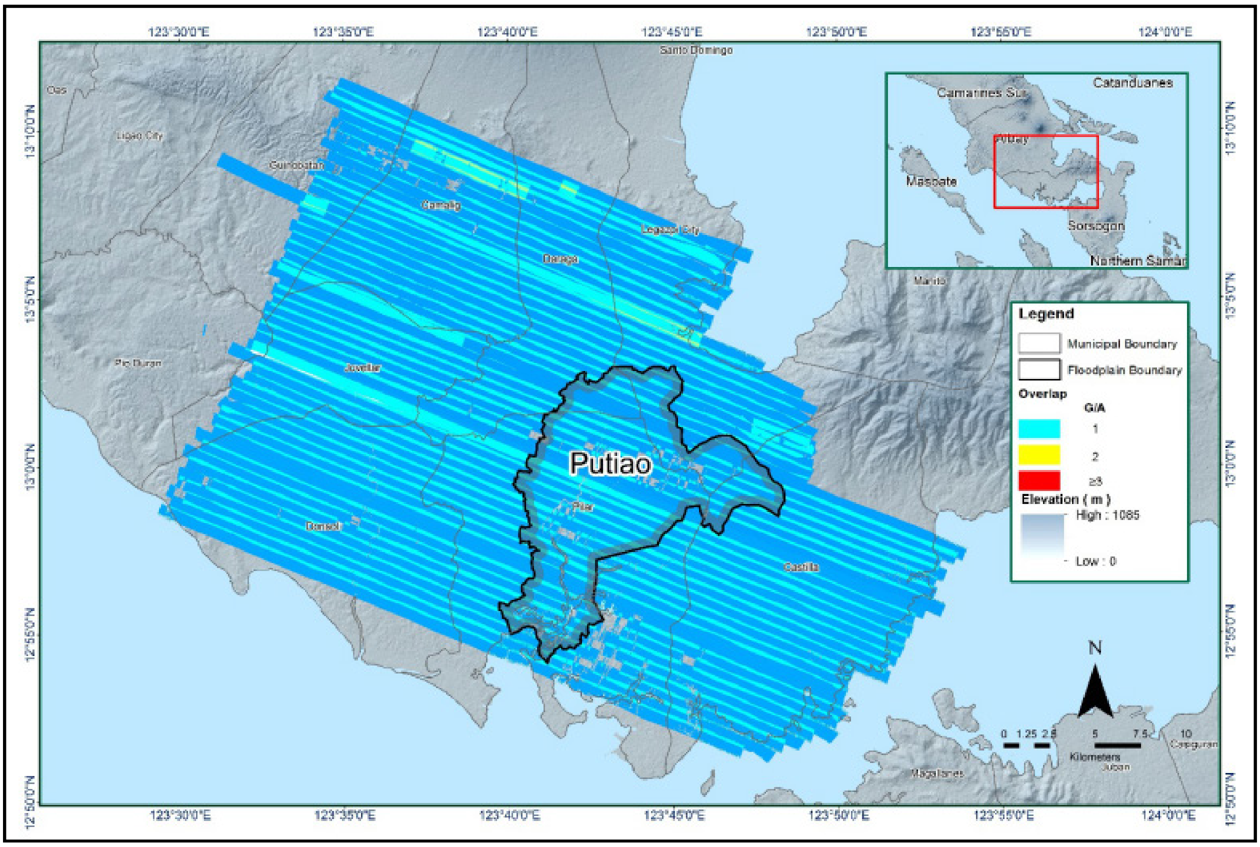


Figure 15. Image of data overlap for Putiao Floodplain.

The overlap statistics per block for the Putiao 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 21.81% and 30.62%, respectively.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for the Putiao floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.864 points per square meter.

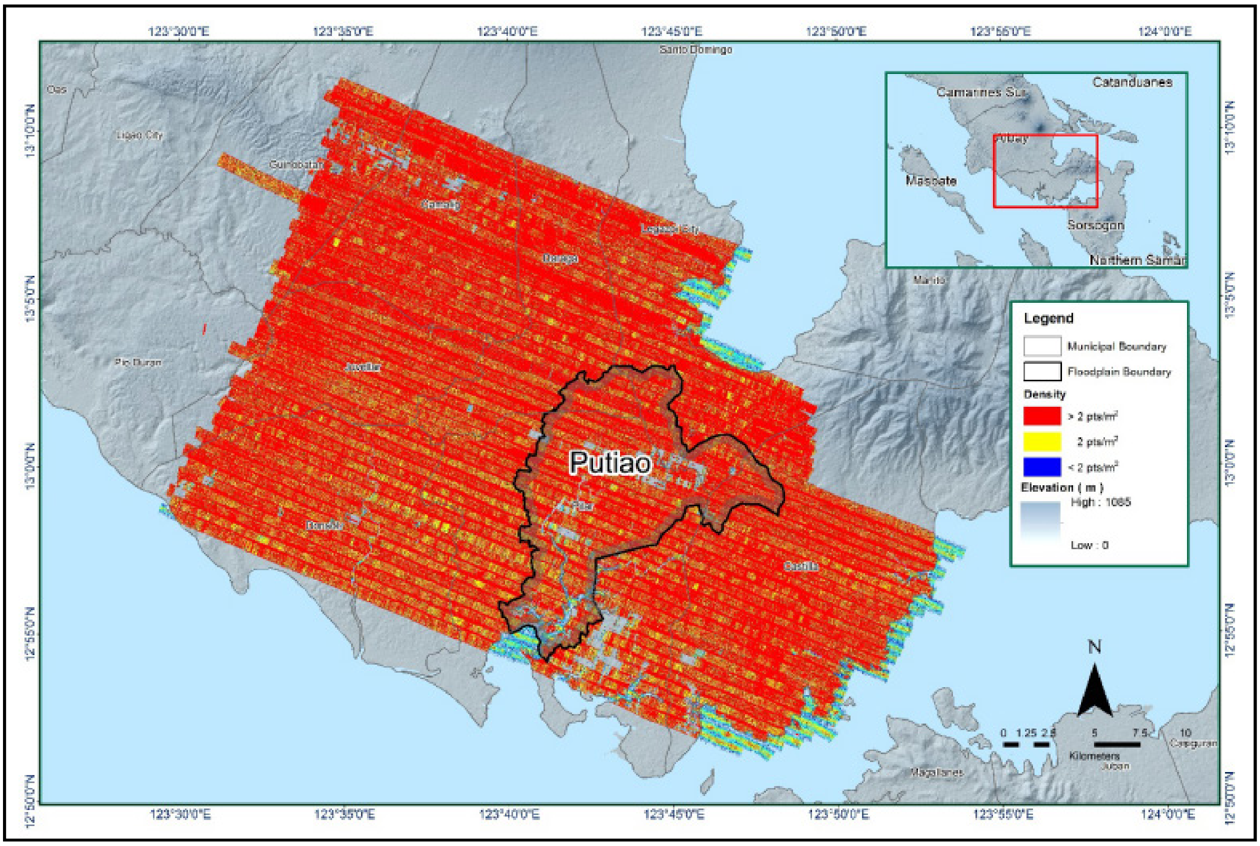


Figure 16. Pulse density map of merged LiDAR data for Putiao floodplain

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

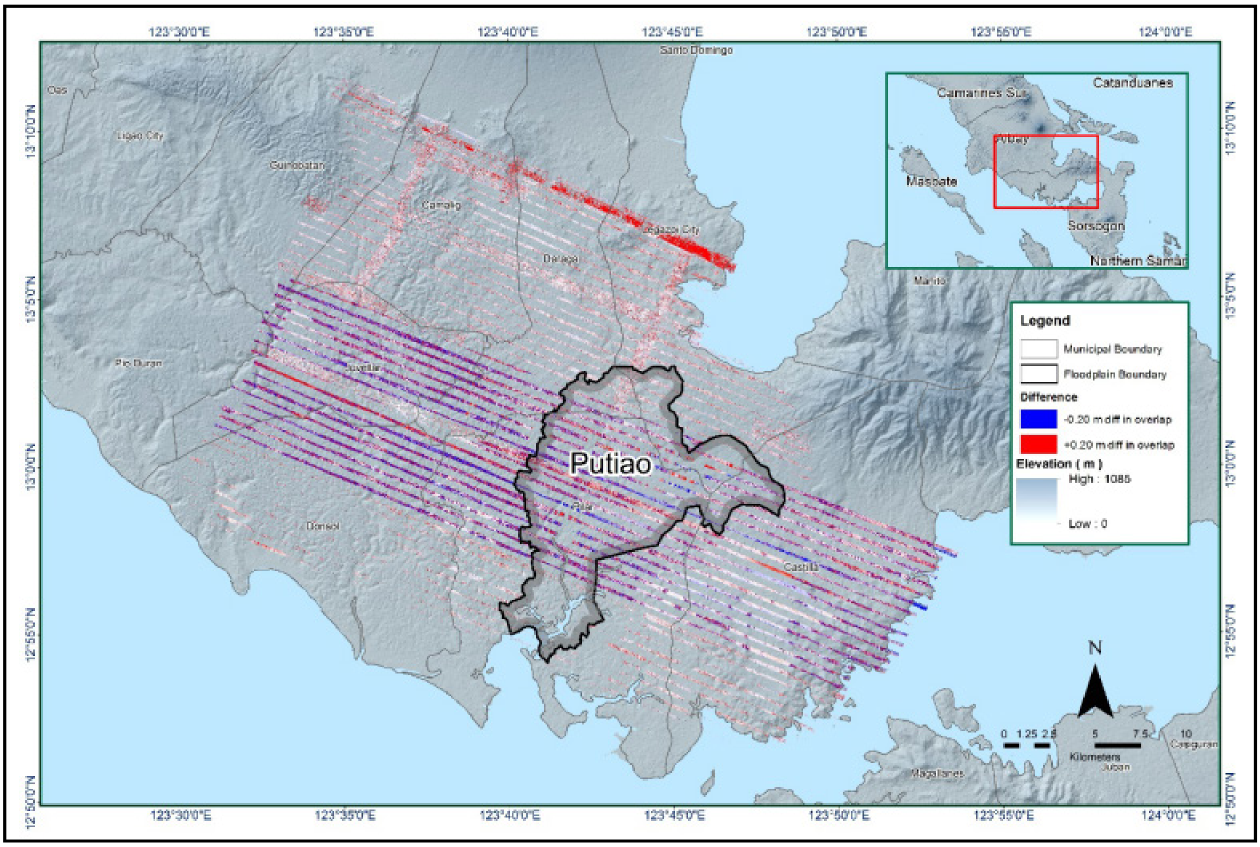


Figure 17. Elevation difference map between flight lines for Putiao Floodplain survey.

A screen capture of the processed LAS data from a Putiao flight 7161G loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there 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 became satisfactory. No reprocessing was done for this LiDAR dataset.

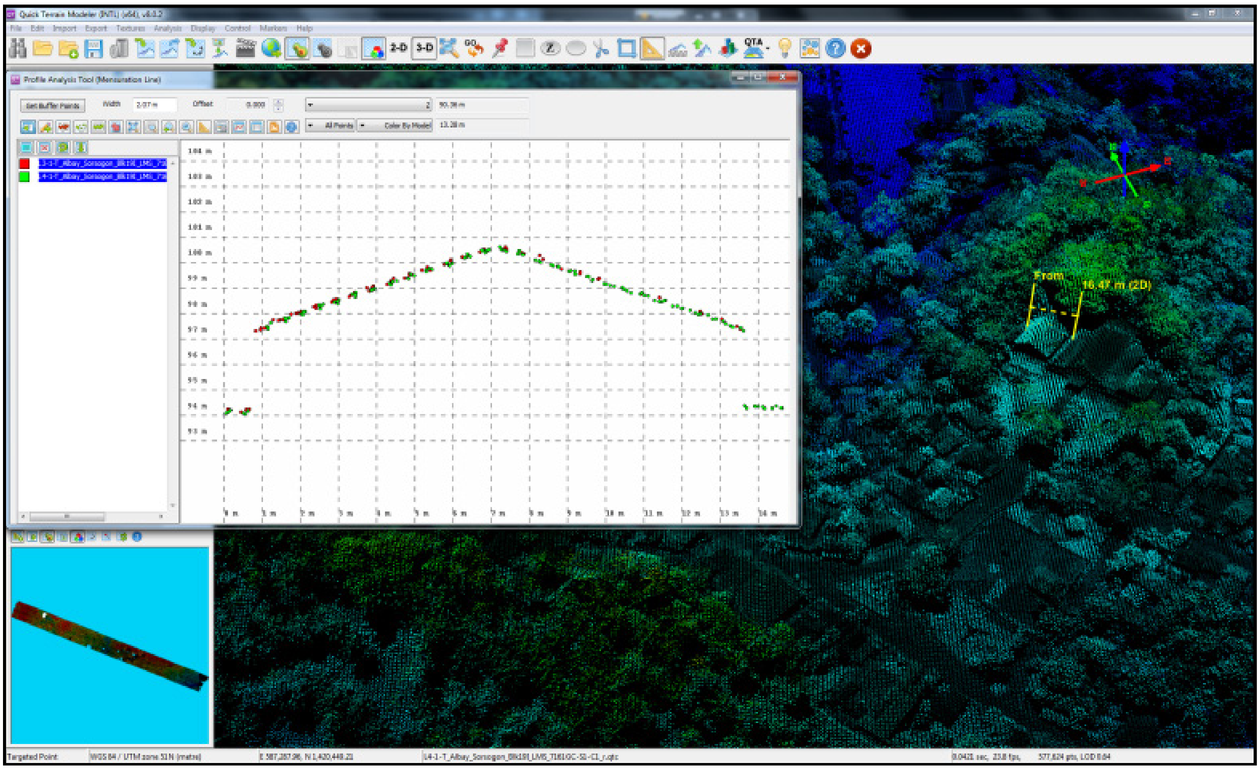


Figure 18. Quality checking for a Putiao flight 7161G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Putiao classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	460,608,494
Low Vegetation	418,520,693
Medium Vegetation	582,820,630
High Vegetation	1,471,973,075
Building	22,191,351

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in the Putiao floodplain is shown in Figure 19. A total of 1,433 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 314.54 meters and 52.76 meters, respectively.

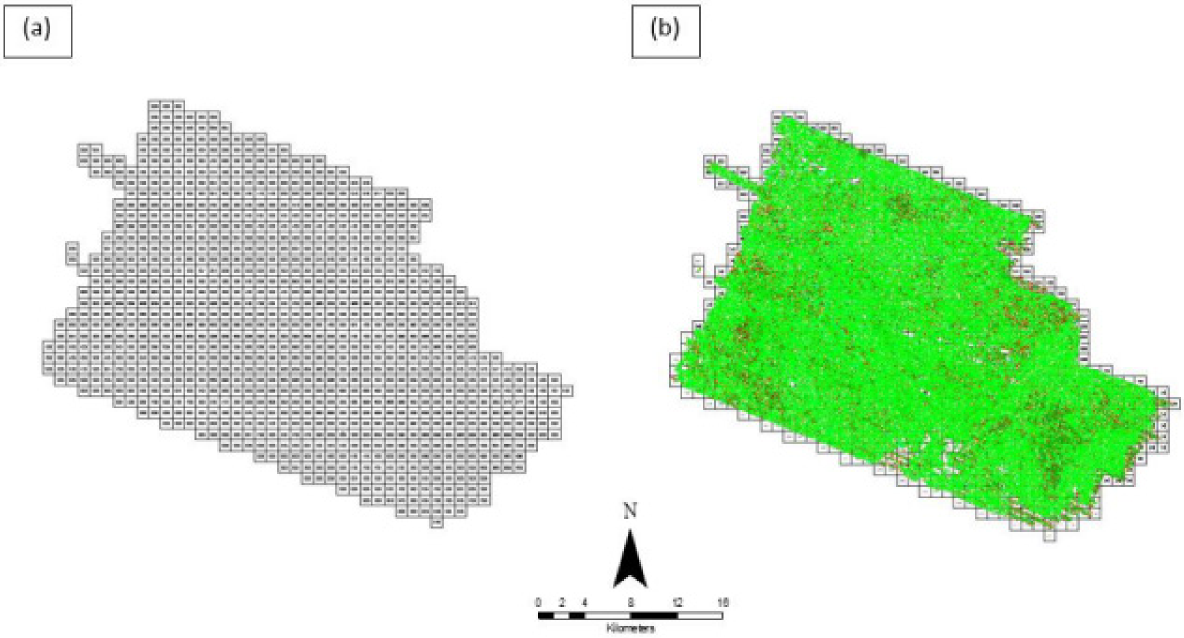


Figure 19. Tiles for Putiao floodplain (a) and classification results (b) in TerraScan.

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

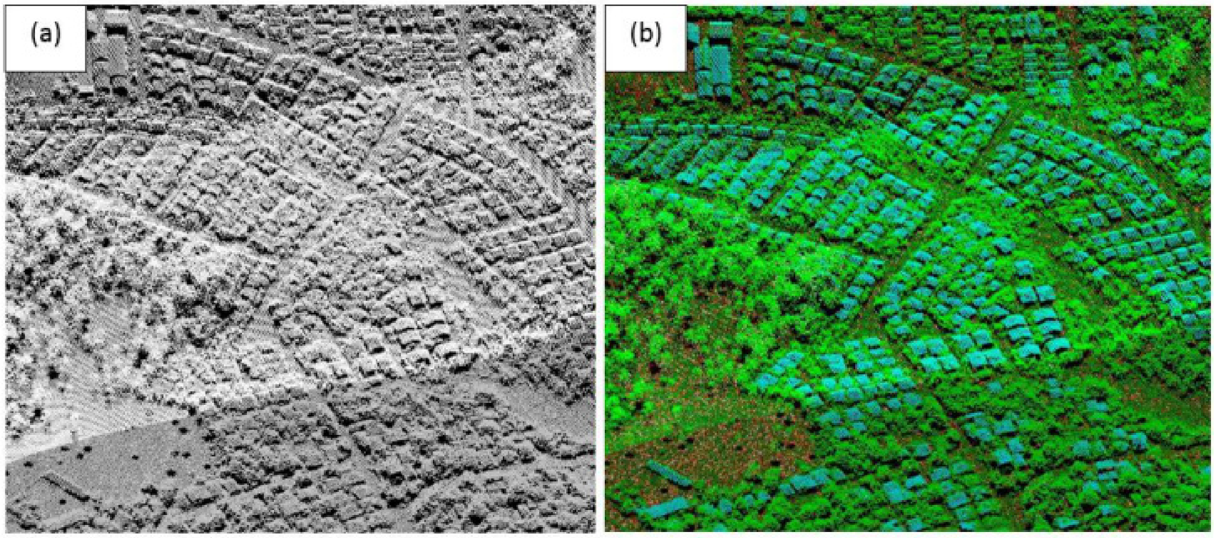


Figure 20. Point cloud before (a) and after (b) classification.

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

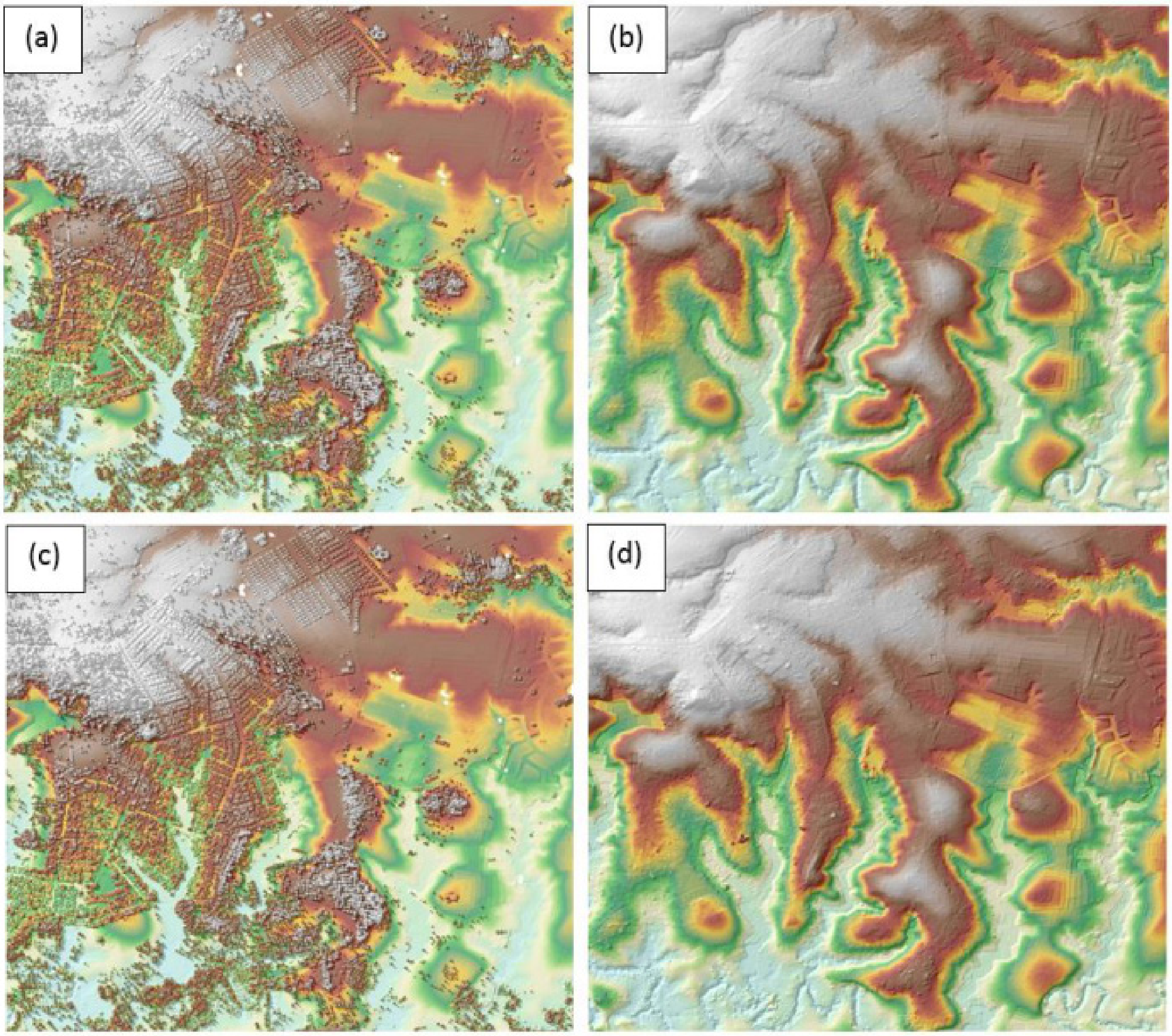


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Putiao floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orhophotographs for the Putiao floodplain

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for the Putiao floodplain. These blocks are composed of Albay_Sorsogon and Albay_Sorsogon_reflights blocks, with a total area of 1,362.15 square kilometers. Table 14 lists the name and corresponding area of each block, in square kilometers.

Table 14. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Albay_Sorsogon_Blk19I	407.11
Albay_Sorsogon_Blk19EG	301.83
Albay_Sorsogon_Blk19L_additional	1.20
Albay_Sorsogon_Blk19L	192.24
Albay_Sorsogon_Blk19K	238.90
Albay_Sorsogon_reflights_Blk19I	74.94
Albay_Sorsogon_reflights_Blk19I_additional	75.08
Albay_Sorsogon_reflights_Blk19L	70.85
TOTAL	**1362.15 sq.km**

Portions of DTM before and after manual editing are shown in Figure 22. The mountain ridge and road (Figure 22a) were considered to be an impedance to the flow of water along the river and had to be removed (Figure 22b) in order to hydrologically correct the river. The paddy field (Figure 22c) was misclassified and removed during classification process, and was retrieved to complete the surface (Figure 22d) to allow the correct flow of water.

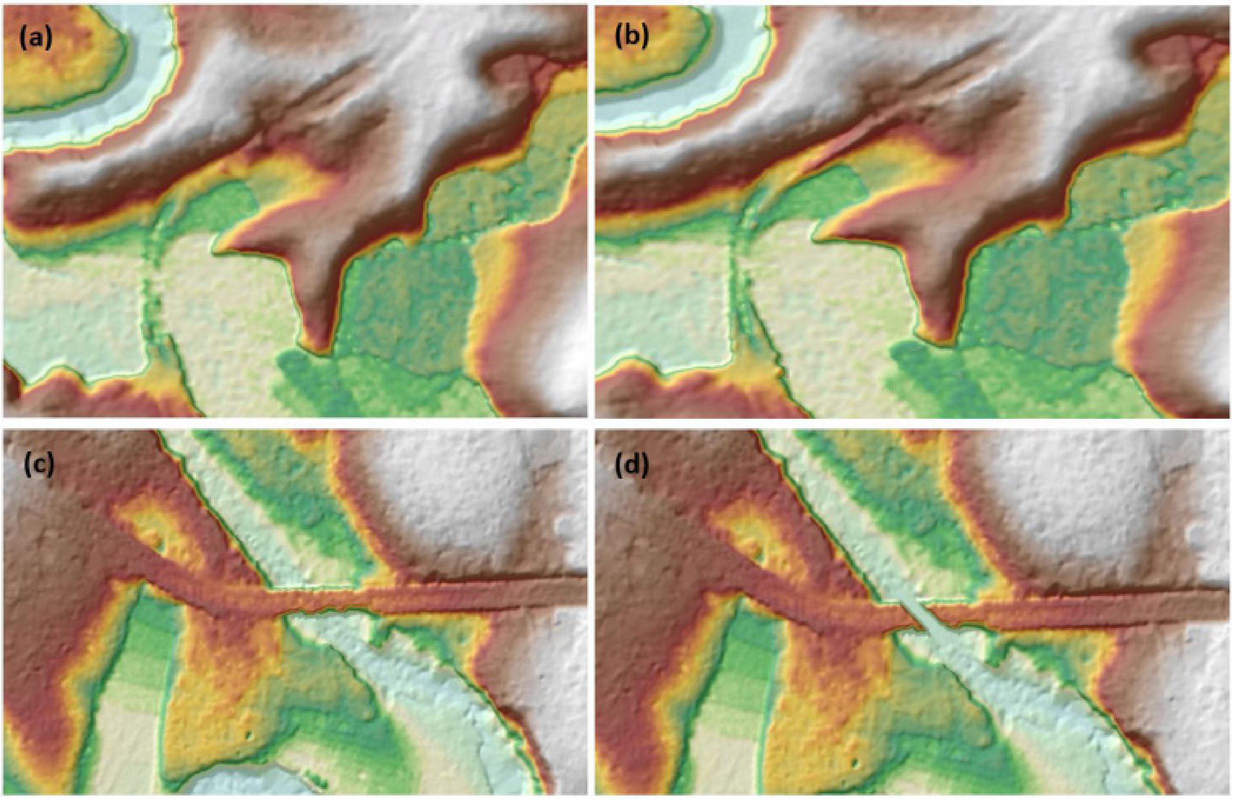


Figure 22. Portions in the DTM of Putiao floodplain – a mountain ridge before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking, because the identified reference for shifting was an existing calibrated Albay Sorsogon DEM overlapping with the blocks to be mosaicked. Table 15 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for the Putiao floodplain is shown in Figure 23. It can be seen that the entire Putiao floodplain is 99.60% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Putiao Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Albay_Sorsogon_Blk19L	0	2	-2.16
Albay_Sorsogon_Blk19L_additional	0	2	-2.17
Albay_Sorsogon_Blk19K	-1	1	-1.12
Albay_Sorsogon_Blk19I	0.26	1	-1.36
Albay_Sorsogon_Blk19EG	1	1.25	-1.34
Albay_Sorsogon_reflights_Blk19I	1	1	-1.67
Albay_Sorsogon_reflights_Blk19I_additional	1	2	-1.72
Albay_Sorsogon_reflights_Blk19L	0	0	-2.18

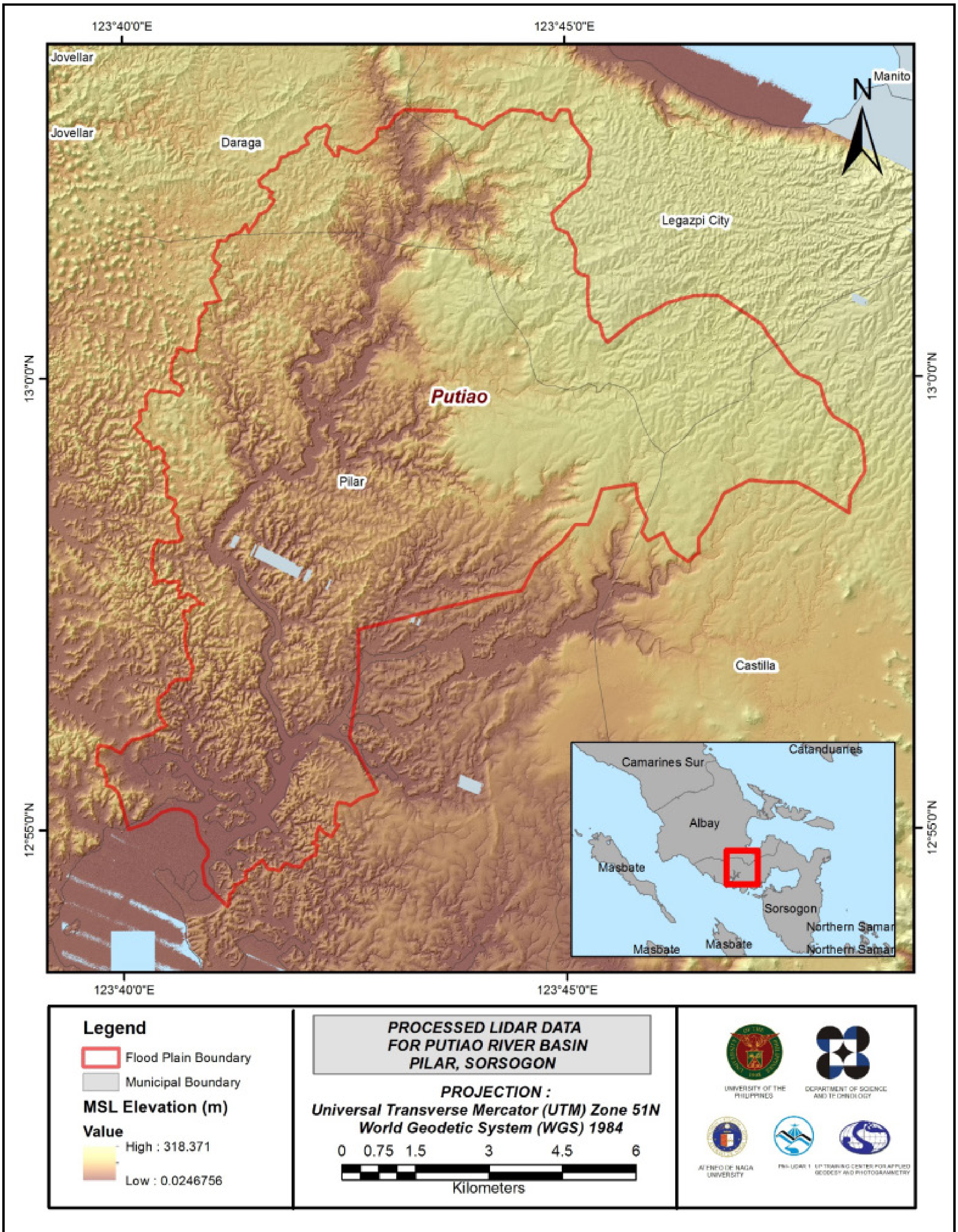


Figure 23. Map of Processed LiDAR Data for Putiao Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Putiao to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 11,856 survey points from the Bicol floodplain were used for calibration Putiao LiDAR data. Random selection of 80% of the survey points, resulting to 10,864 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.41 meters with a standard deviation of 0.17 meters. Calibration of Putiao LiDAR data was done by adding the height difference value, 0.41 meters, to Putiao mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

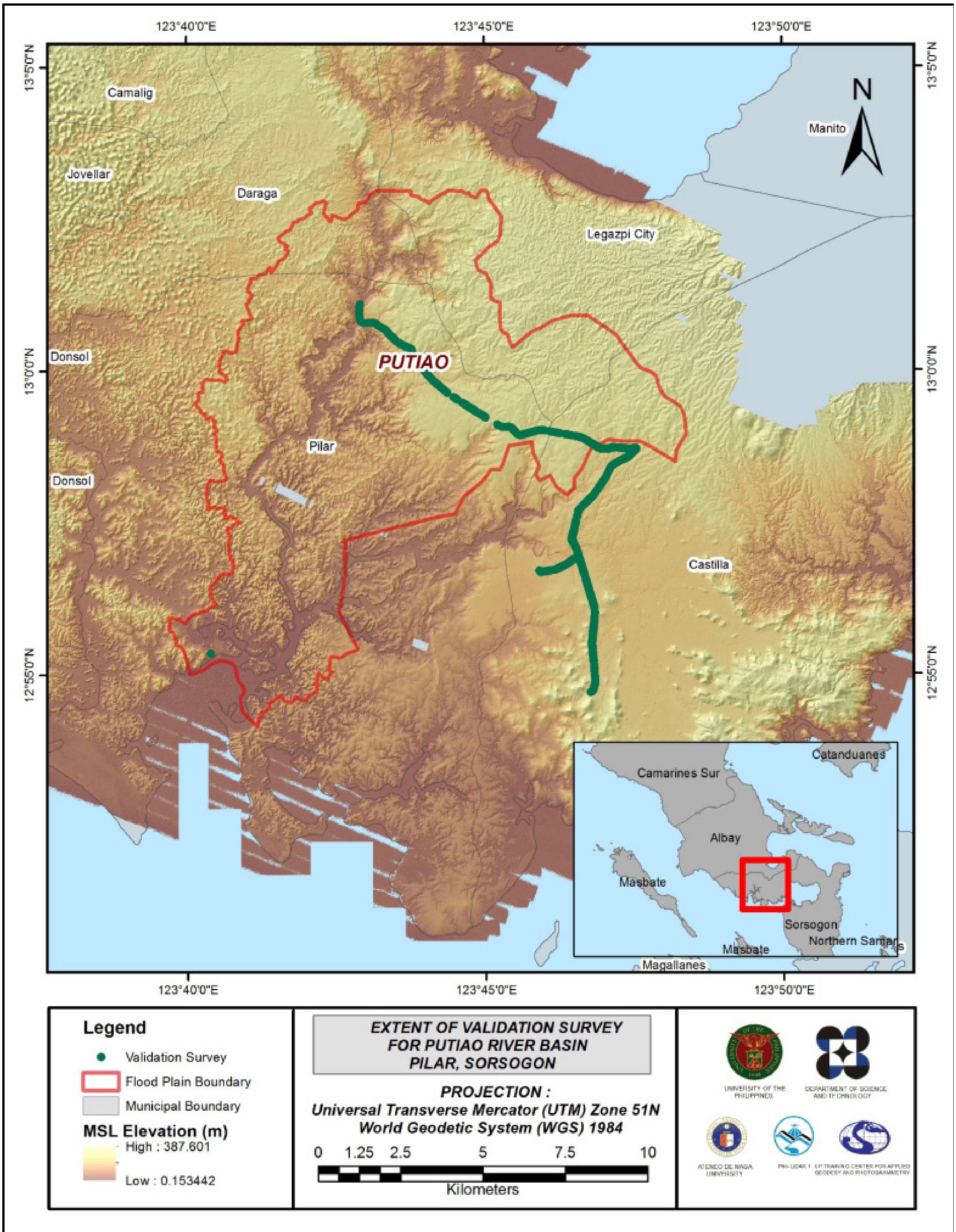


Figure 24. Map of the Putiao Floodplain with validation survey points in green.

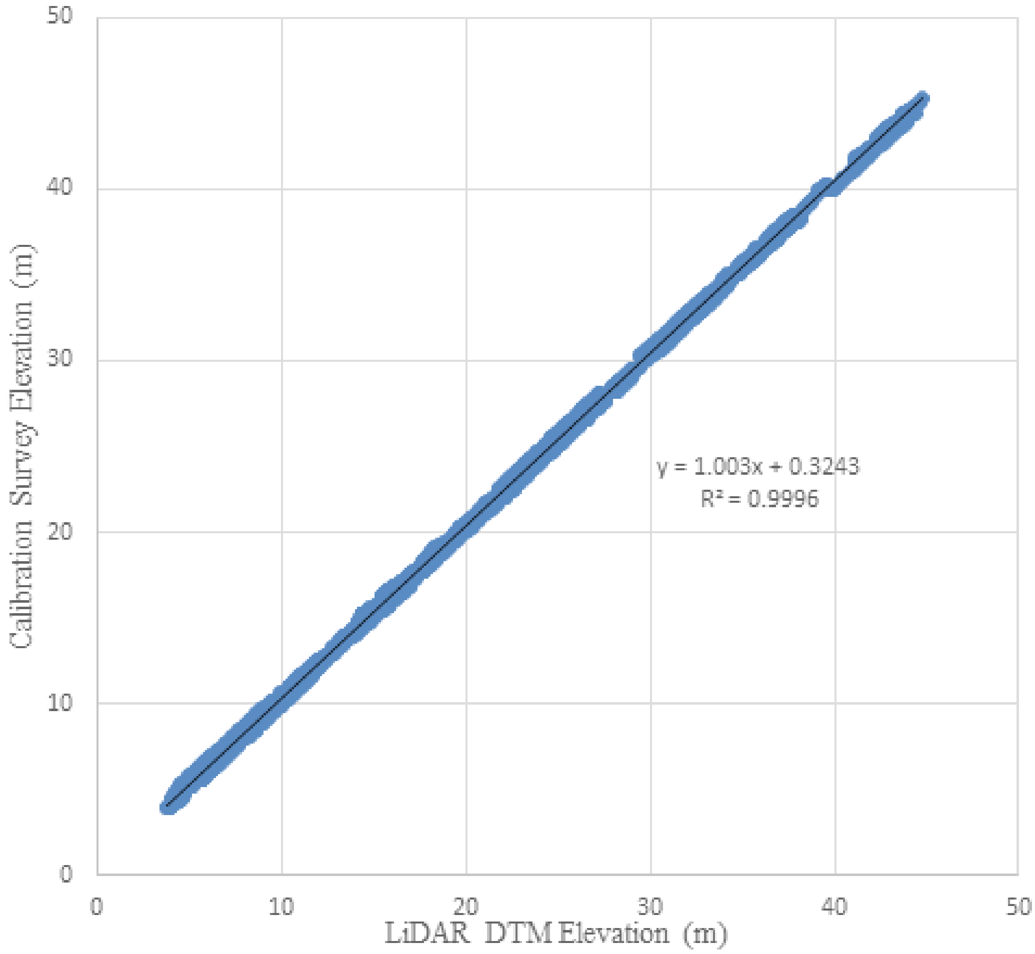


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	1.85
Standard Deviation	0.14
Average	-1.85
Minimum	-2.13
Maximum	-1.56

A total of 2,858 points were collected by the DVBC for the Putiao river basin. Random selection of points inside the floodplain boundary, resulting to 1,114 points, were used for the validation of calibrated Putiao DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.15 meters, with a standard deviation of 0.14 meters, as shown in Table 17.

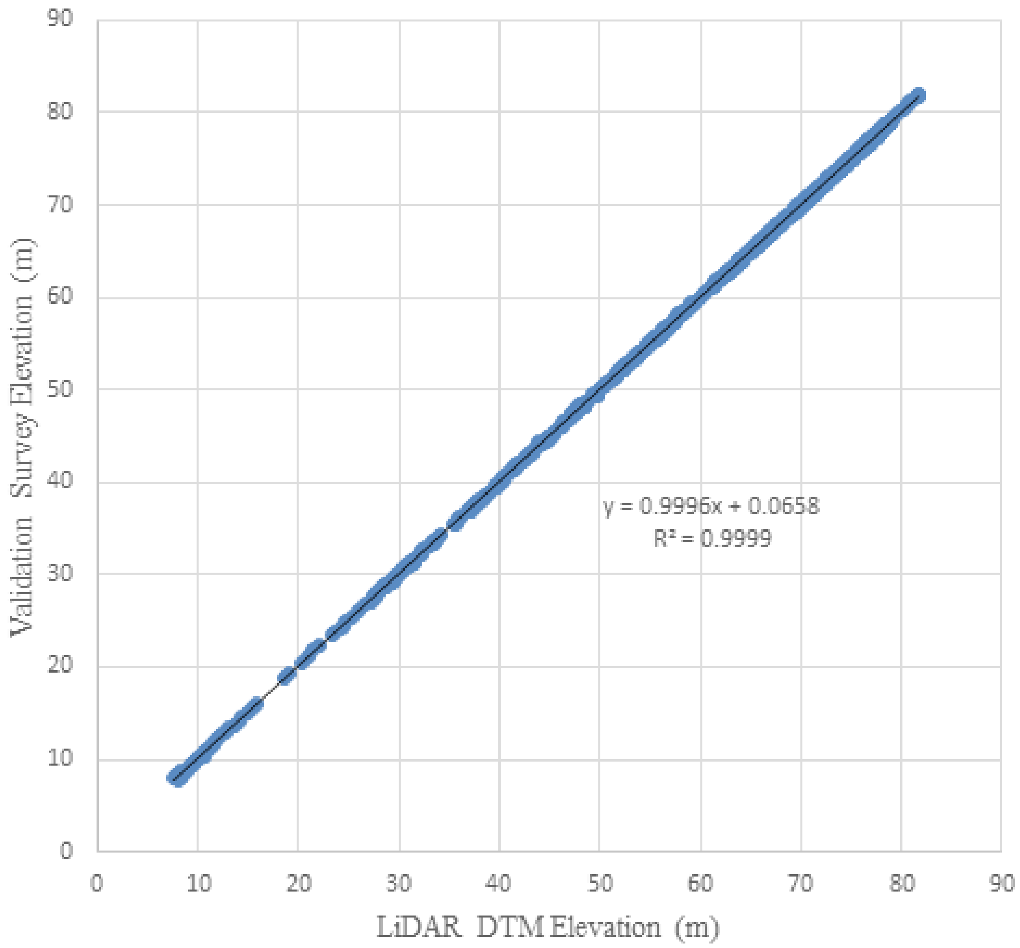


Figure 26. Correlation plot between validation survey points and LiDAR data

Table 17. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.15
Standard Deviation	0.14
Average	0.04
Minimum	-0.26
Maximum	0.35

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for the Putiao River Basin, with 8,386 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 0.022 meters. The extent of the bathymetric survey done by the DVBC in Putiao, integrated with the processed LiDAR DEM, is shown in Figure 27.

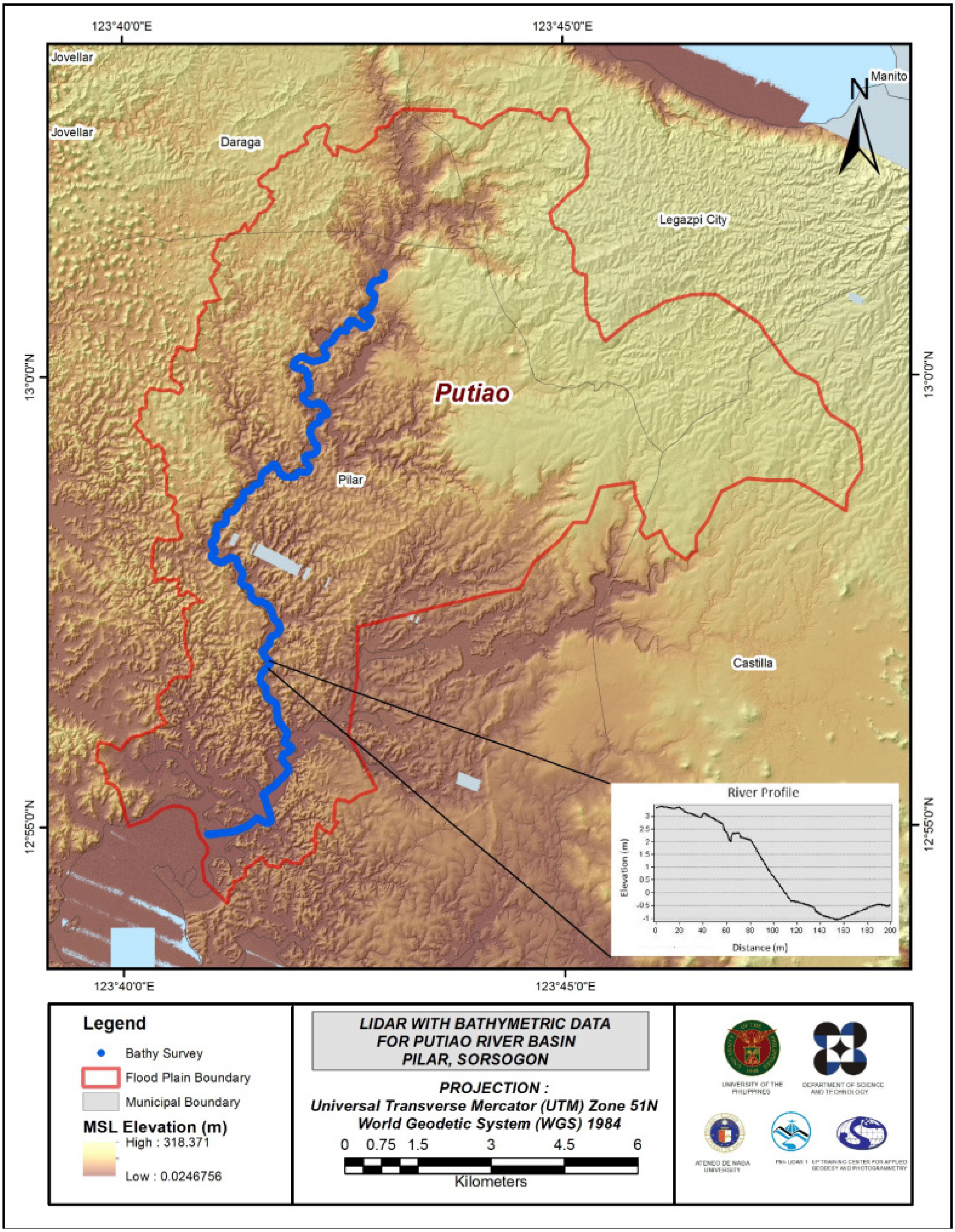


Figure 27. Map of Putiao Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area, with a 200-m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks are comprised 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

The Putiao floodplain, including its 200m buffer, has a total area of 129.40 sq. km. For this area, a total of 5.0 sq. km, corresponding to a total of 940 building features, were considered for QC. Figure 28 presents the QC blocks for the Putiao floodplain.

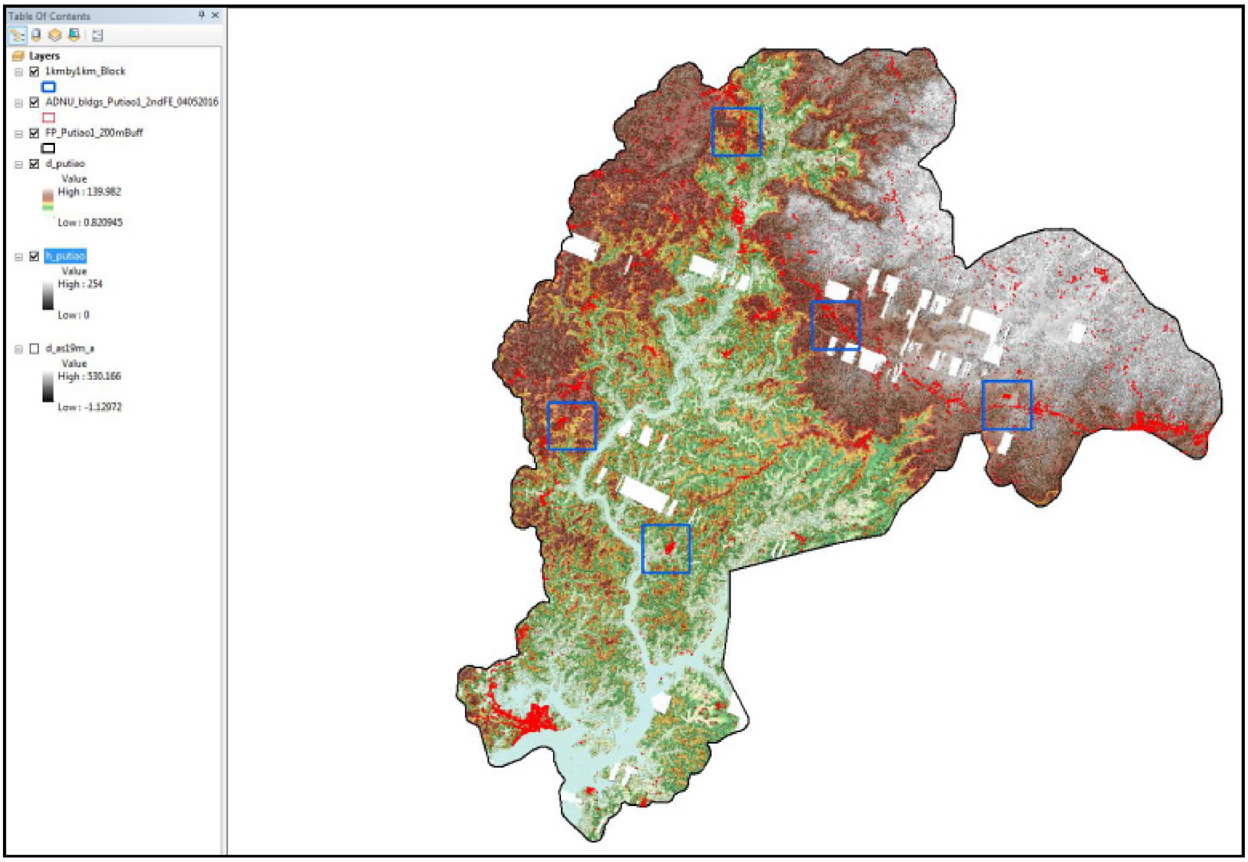


Figure 28. Blocks (in blue) of Putiao building features that were subjected to QC

Quality checking of Putiao building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Putiao Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Putiao	99.67	97.45	95.74	PASSED

3.12.2 Height Extraction

Height extraction was done for 11,840 building features in the Putiao floodplain. Of these building features, 241 were filtered out after height extraction, resulting in 11,599 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 16.75 m.

3.12.3 Feature Attribution

Feature Attribution was done for 11,599 building features in the Putiao Floodplain with the use of participatory mapping and innovations. For the participatory mapping approach, feature extracted maps in the area were created and spatial knowledge was presented to the community, with the premise that the local community representatives are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an Android application called reGIS. The Resource Extraction for Geographic Information System (reGIS) application was developed to supplement and increase the field gathering procedures conducted by the ADNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering, and enables feature attribution to further improve and accelerate the geotagging process. The application lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. These are all done through a few swipes with the help of the device's pre-defined list of exposure features. The application effectively allowed for the collection of unified and standardized sets of data.

Table 19 summarizes the number of building features per type. Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building Features Extracted for Putiao Floodplain

Facility Type	No. of Features
Residential	5,486
School	83
Market	1
Agricultural/Agro-Industrial Facilities	16
Medical Institutions	2
Barangay Hall	9
Military Institution	14
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	4
Power Plant/Substation	3
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	18
Bank	0
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	21
Other Commercial Establishments	21
Total	5,690

Table 20. Total Length of Extracted Roads for Putiao Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Putiao	67.6434	6.74901	0	39.4544	0.00	113.84

Table 21. Number of Extracted Water Bodies for Putiao Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Putiao	2	59	0	0	0	61

A total of six (6) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 29 shows the Digital Surface Model (DSM) of the Putiao floodplain overlaid with its ground features.

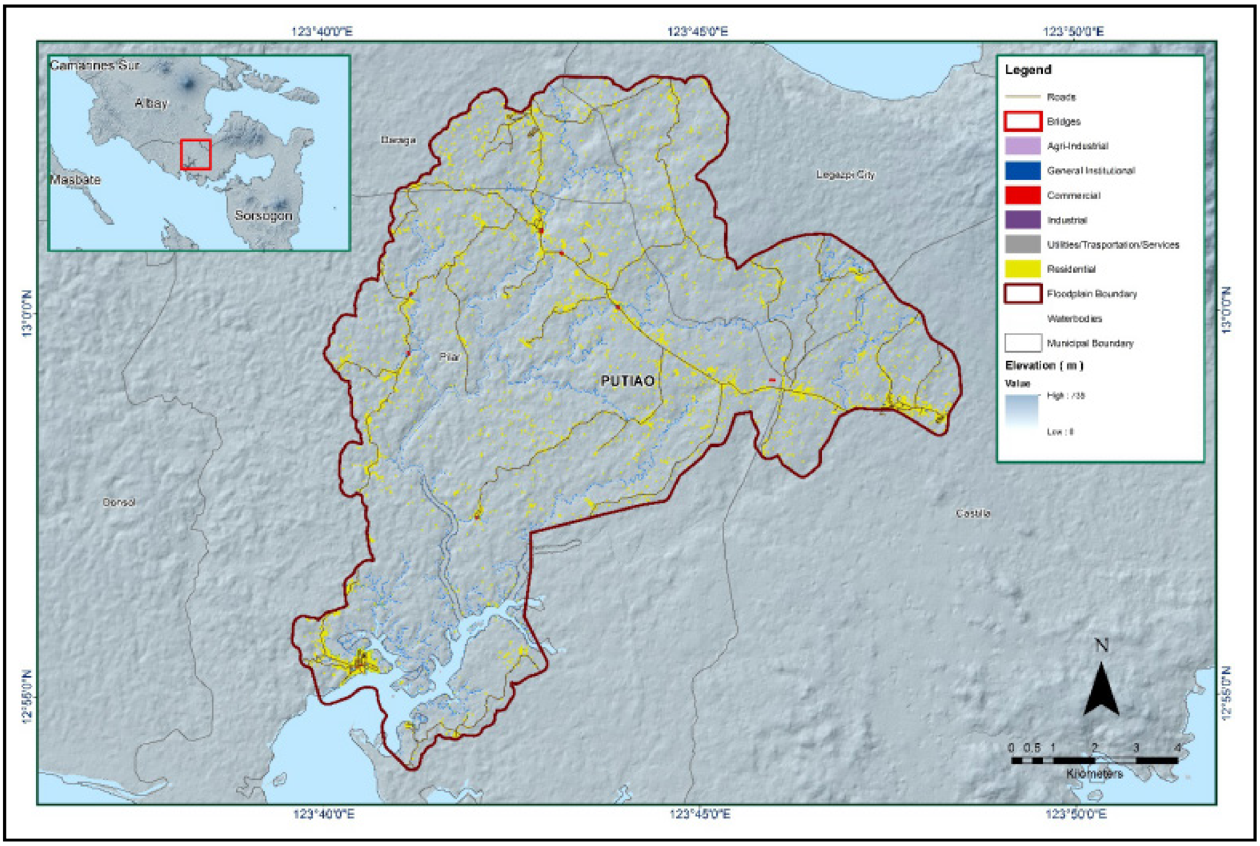


Figure 29. Extracted features for Putiao Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie Caballero, Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field surveys in the Putiao River in Sorsogon on August 11 to 20, 2015, with the following scope of work: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built survey at the Putiao Bridge in Barangay Putiao, Municipality of Pilar; (iv.) validation points acquisition of about 20 km covering the Putiao River Basin area; and (v.) bathymetric survey from the river's upstream in Barangay Putiao, down to its mouth located in Barangay Pineda in the municipality of Pilar, with an estimated length of seventeen (17) km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 30).

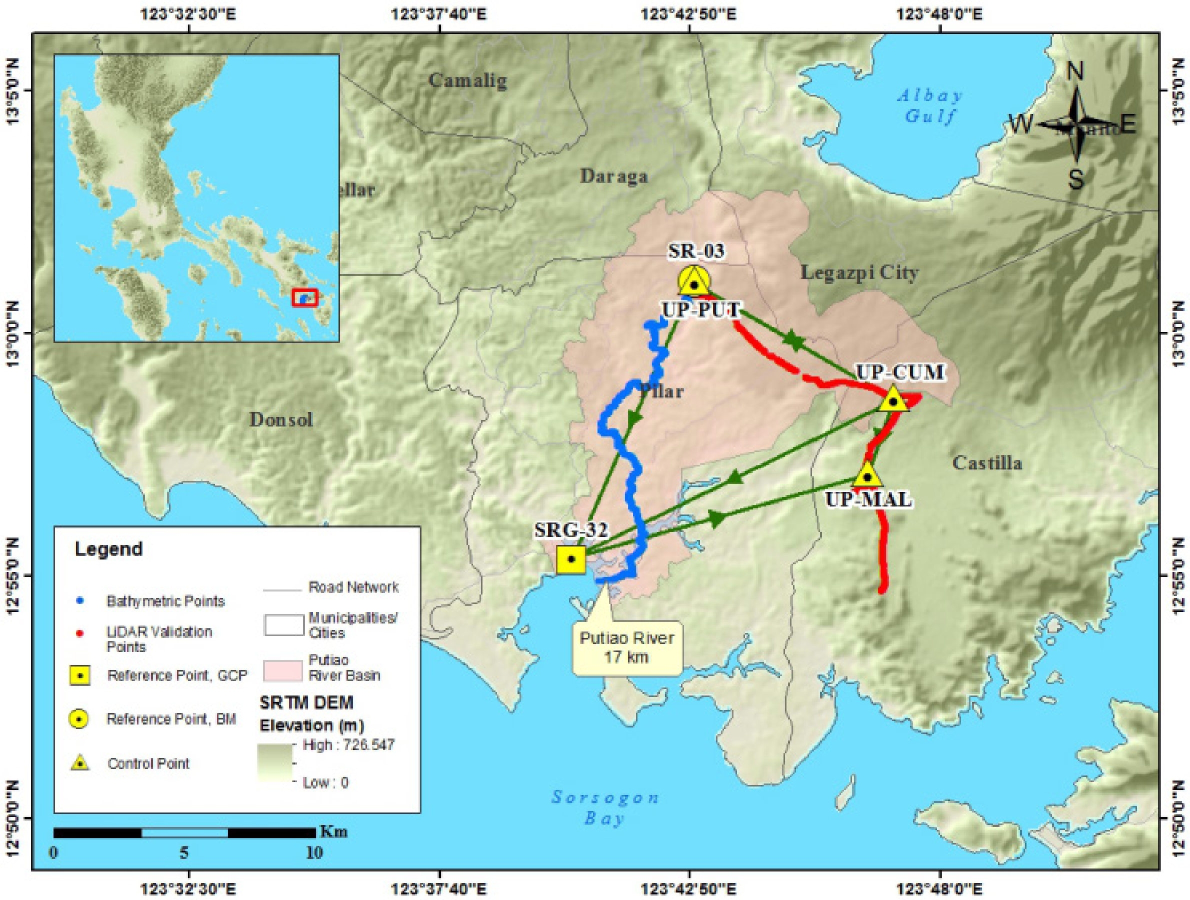


Figure 30. Extent of the bathymetric survey (in blue line) in Putiao River Survey and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Putiao River Basin is composed of three (3) loops established on August 15 and 19, 2015 occupying the following reference points: SRG-32, a second-order GCP inside the Pilar 1 Central Elementary School in Pilar; SR-03, a first-order BM located in the approach of Putiao Bridge in Pilar, Sorsogon.

Three (3) control points were established along the approach of bridges, namely; UP-CUM, in the Cumadcad Bridge in Barangay Cumadcad, Municipality of Castilla, Sorsogon; UP-MAL, in the Malbug Bridge in Barangay Malbug, Castilla; and UP-PUT in the Putiao Bridge, Pilar, Sorsogon.

The summary of references and control points and their locations is presented in Table 22, while the GNSS network established is illustrated in Figure 31.

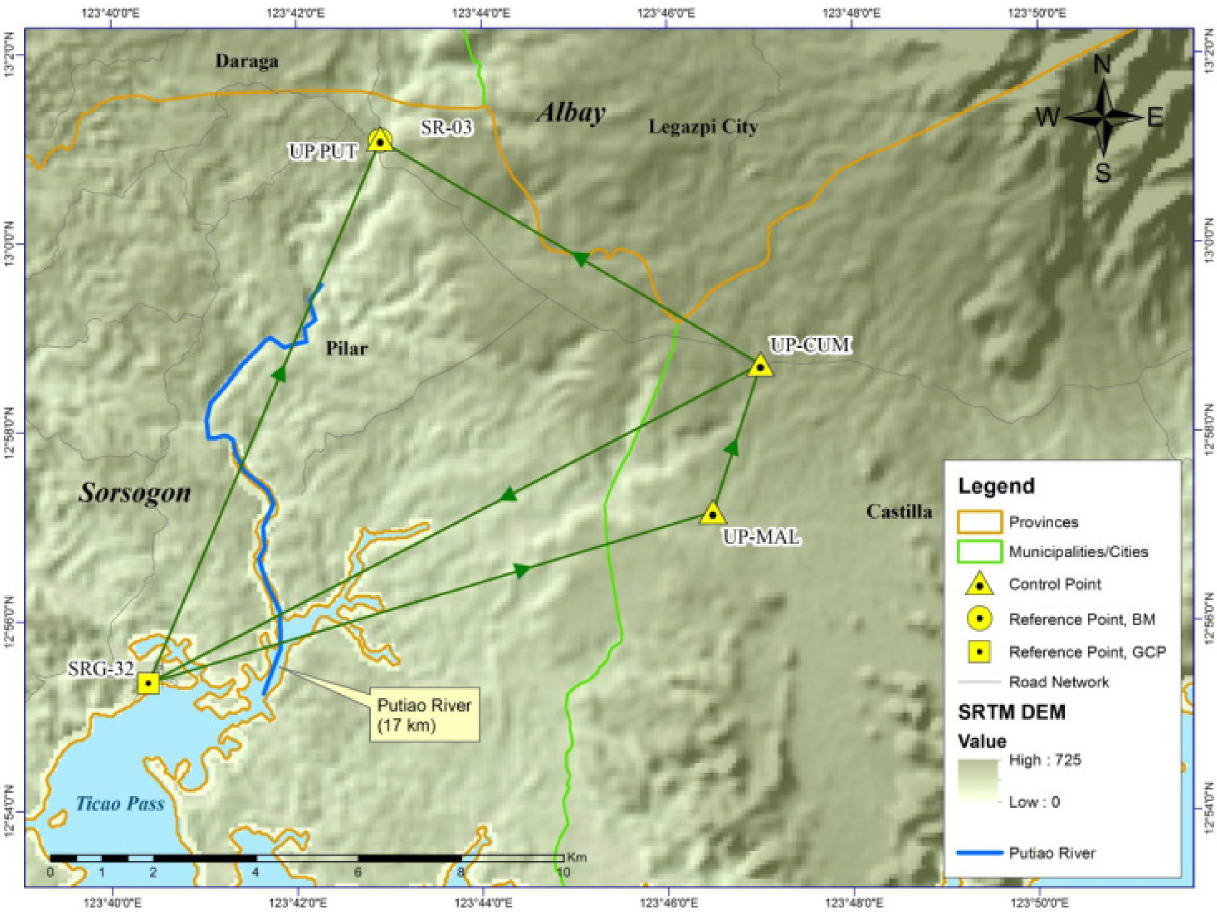


Figure 31. GNSS Network established for Putiao River Basin survey

Table 22. List of references and control points during the Putiao River Basin Survey
(Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
SME-18	2nd Order GCP	11°21'43.08127"	125°36'37.41862"	78.217	17.66	Sep 12, 2014
SE-85	1st Order BM	11°24'45.65441"	125°32'20.98934"	67.52	6.31	Sep 12, 2014
SME-12	Used as Marker	11°07'19.15395"	125°21'29.28283"	67.212	2.721	Sep 13, 2014
SMR-3322	Used as Marker	11°17'40.55190"	125°07'10.82309"	70.666	6.636	Sep 17, 016
SE-49	Used as Marker	11°12'34.48802"	125°31'52.42238"	66.981	3.779	Sep 13, 2014
SM-33S	Used as Marker	11°07'33.79721"	125°12'32.14831"	68.705	3.951	Sep 17, 2014
UP-CNG	UP Established	11°35'44.92939"	125°26'23.62776"	67.094	6.035	Sep 12, 2014
UP-SLG	UP Established	11°27'57.66166"	125°01'08.84182"	73.078	9.958	Sep 19, 2014

The GNSS set up on the recovered reference point, SR-03 and SRG-32 are shown in Figure 32 and Figure 33; while the established control points, UP-CUM, UP-MAL, and UP-PUT are shown in Figure 34, Figure 35 and Figure 36, respectively.

Figure 32. Trimble® SPS852 Base set-up at SR-03 on Putiao Bridge in Lunoy, Pilar

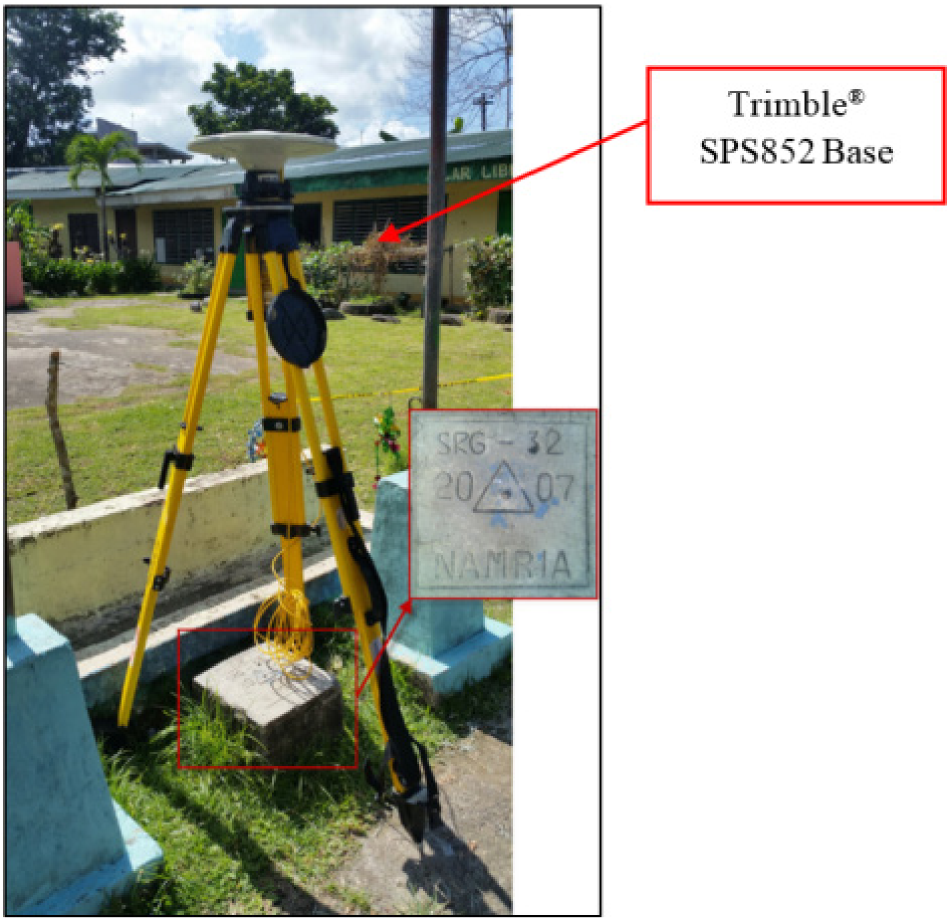


Figure 33. Trimble® SPS852 base set-up at SRG-32 in Pilar 1 Central Elementary School, Dao, Pilar

Figure 34. Trimble® SPS882 base set-up at UP-CUM on Cumadcad Bridge, Cumadcad, Castilla

Figure 35. Trimble® SPS882 base set-up at UP-MAL on Malbug Bridge, Malbug, Castilla

Figure 36. Trimble® SPS882 base set-up at UP-PUT on Putiao Bridge, Lunoy, Pilar

4.3 Baseline Processing

GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. The baseline processing results of control points used in the Putiao River Basin survey is summarized in Table 23, generated by TBC software.

Table 23. Baseline Processing Report for Putiao River Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-CUM --- SR-03	08-15-2015	Fixed	0.003	0.014	300°35'21"	8608.953	-52.322
UP-CUM --- SRG-32	08-15-2015	Fixed	0.003	0.014	242°38'49"	13465.19	-57.908
UP-CUM --- SRG-32	08-19-2015	Fixed	0.005	0.019	242°38'50"	13465.22	-57.988
UP-CUM --- UP-MAL	08-19-2015	Fixed	0.005	0.022	198°08'14"	3029.509	-20.863
SR-03 --- UP-PUT	08-15-2015	Fixed	0.001	0.002	357°15'35"	31.53	-0.233
SR-03 --- SRG-32	08-15-2015	Fixed	0.003	0.016	203°16'25"	11505.19	-5.588
SRG-32 --- UP-MAL	08-19-2015	Fixed	0.006	0.023	73°15'44"	11502.54	37.145
UP-PUT --- SRG-32	08-15-2015	Fixed	0.004	0.022	203°12'17"	11533.53	-5.409

As shown in Table 23, a total of nine (9) baselines were processed, and all of these satisfied the required accuracy set by the project.

4.4 Network Adjustment

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

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

where:

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

The five (5) control points, SRG-32, SR-03, UP-CAM, UP-MAL, and UP-PUT were occupied and observed simultaneously to form a GNSS loop. Coordinates of SRG-32, and elevation values of SR-03 were held fixed during the processing of the control points, as presented in Table 24. Through this reference point, the coordinates and elevation of the unknown control points were computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SR-03	Grid				Fixed
SRG-32	Global	Fixed	Fixed		
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation and computed standard errors of the control points in the network, is indicated in Table 25. The fixed control point, SRG-32, has no values for standard errors.

Table 25. Adjusted grid coordinates for the control points used in the Putiao River Floodplain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SRG-32	573030.718	?	1428665.097	?	6.501	0.043	LL
SR-03	577545.544	0.007	1439243.303	0.006	12.153	?	e
UP-CUM	584967.535	0.007	1434886.580	0.006	64.403	0.040	
UP-MAL	584033.603	0.013	1432005.612	0.011	43.538	0.075	
UP-PUT	577543.948	0.007	1439274.782	0.006	11.921	0.008	

The network is fixed at the reference points. The adjusted grid coordinates of the network are listed in Table 25. Using the aforementioned equation for horizontal, and for the vertical, following is the computation for accuracy, which satisfied the required precision:

a. **SRG-32**

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	4.3 cm < 10 cm

b. **SR-03**

Horizontal Accuracy	=	√ ((0.7) ² + (0.6) ²
	=	√(0.49 + 0.36)
	=	0.92 cm < 20 cm
Vertical Accuracy	=	Fixed

c. **UP-CUM**

Horizontal Accuracy	=	√ ((0.7) ² + (0.6) ²
	=	√(0.49 + 0.36)
	=	0.92 cm < 20 cm
Vertical Accuracy	=	4 cm < 10 cm

d. **UP-MAL**

Horizontal Accuracy	=	√ ((1.3) ² + (1.1) ²
	=	√(1.69 + 1.21)
	=	1.70 cm < 20 cm
Vertical Accuracy	=	7.5 cm < 10 cm

e. **UP-PUT**

Horizontal Accuracy	=	√ ((0.7) ² + (0.6) ²
	=	√(0.49 + 0.36)
	=	0.92 cm < 20 cm
Vertical Accuracy	=	0.8 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the three (3) occupied control points are within the required accuracy of the project.

Table 26. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
SR-03	N13°01'05.06083"	E123°42'54.45694"	65.698	?	e
SRG-32	N12°55'21.12456"	E123°40'23.64926"	60.094	0.043	LL
UP-CUM	N12°58'42.53457"	E123°47'00.40139"	118.011	0.040	
UP-MAL	N12°57'08.84941"	E123°46'29.11247"	97.190	0.075	
UP-PUT	N13°01'06.08567"	E123°42'54.40690"	65.465	0.008	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 26. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

Table 27. References and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
SRG-32	2nd order, GCP	12°55'21.12456"	123°40'23.64926"	60.094	1428665.097	573030.718	6.501
SR-03	1st order, BM	13°01'05.06083"	123°42'54.45694"	65.698	1439243.303	577545.544	12.153
UP-CUM	UP Established	12°58'42.53457"	123°47'00.40139"	118.011	1434886.580	584967.535	64.403
UP-MAL	UP Established	12°57'08.84941"	123°46'29.11247"	97.190	1432005.612	584033.603	43.538
UP-PUT	UP Established	13°01'06.08567"	123°42'54.40690"	65.465	1439274.782	577543.948	11.921

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

Cross Section and bridge as-built survey were done on August 18, 2015 in the downstream side of the Putiao Bridge in Barangay Putiao, Pilar, Sorsogon, using Trimble® SPS 882 GNSS in PPK survey technique, as shown in Figure 37. A total of twenty (20) points with an approximate length of 72 meters were gathered and surveyed for the Putiao Bridge cross section using the control point UP-PUT as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 38, Figure 39, and Figure 40, respectively.

Figure 37. Cross-section of Putiao Bridge using Trimble® SPS 882 GNSS in PPK survey technique

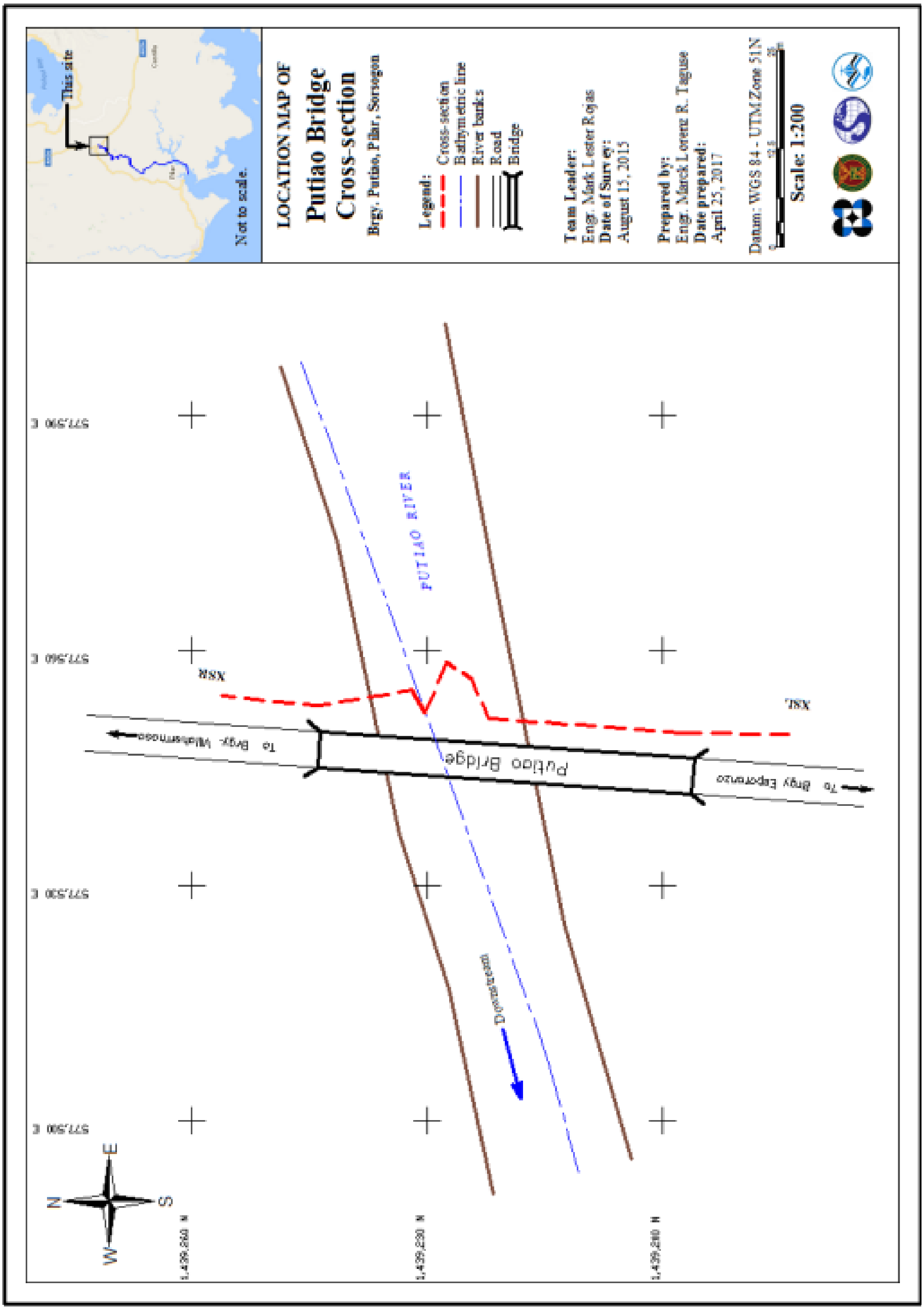


Figure 38. Location map of Putiao Bridge cross-section survey

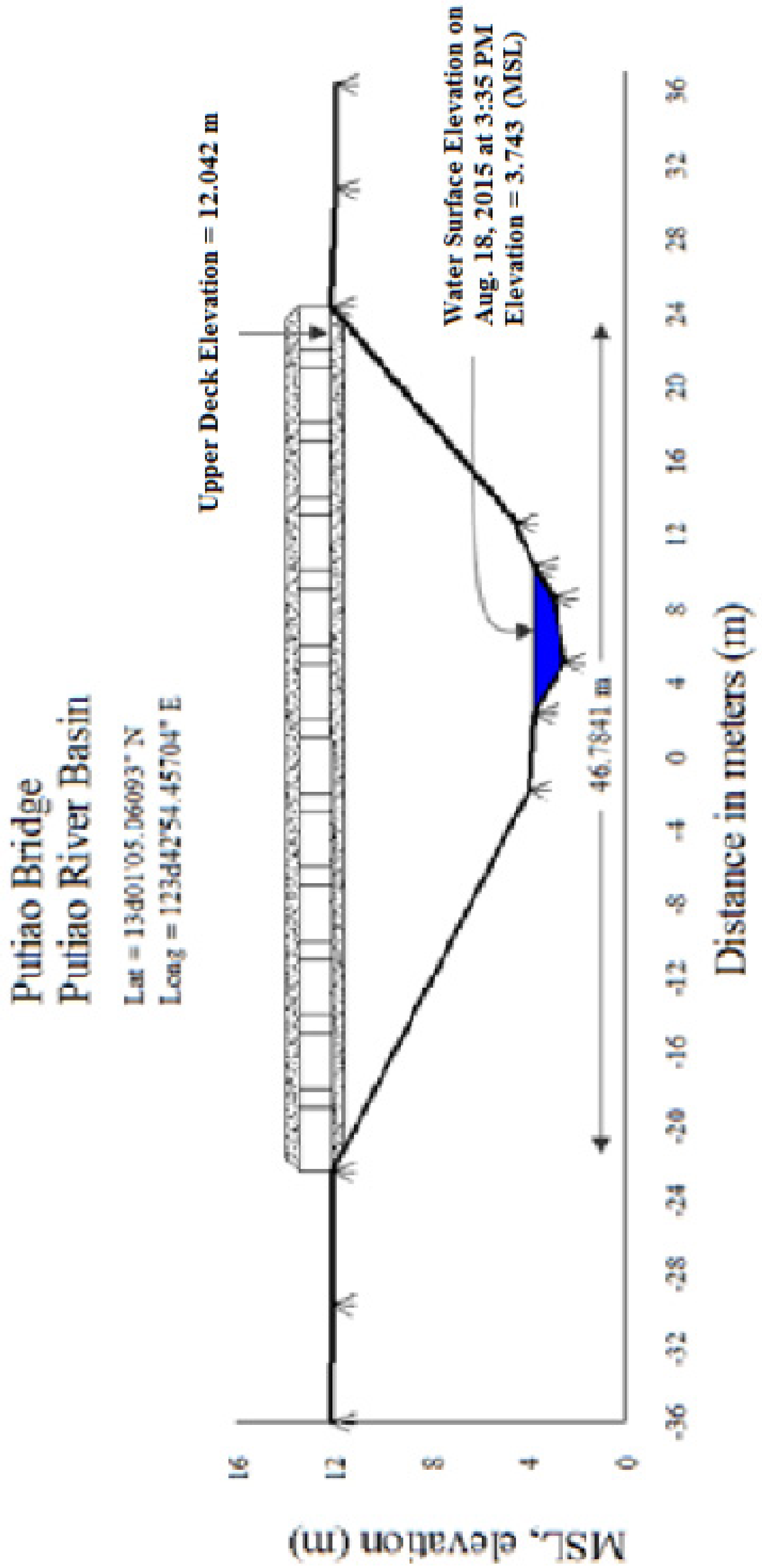


Figure 39. Cross-section diagram at Putiao Bridge in Pilar, Sorsogon

Bridge Data Form

Bridge Name: PUTIAO BRIDGE - **Date:** August 15, 2015

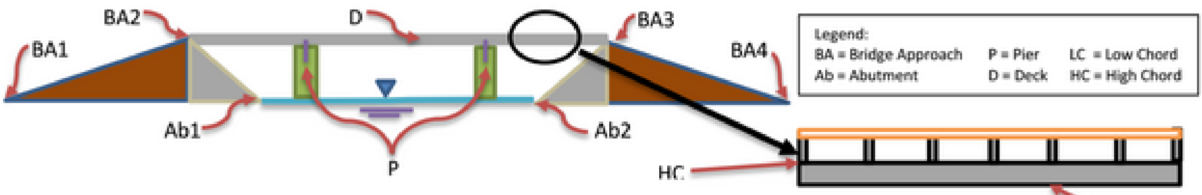
River Name: PUTIAO RIVER **Time:** 3:15 PM

Location (Brgy, City, Region): Brgy. Putiao, Municipality of Pilar, Sorsogon

Survey Team: TEAM MARK

Flow condition: low normal high **Weather Condition:** fair rainy

Latitude: 13d01'05.06093"N **Longitude:** 123d42'54.45704"E



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

Elevation 12.0326 m **Width:** 7.30 **Span (BA3-BA2):** 46.784 m

	Station	High Chord Elevation	Low Chord Elevation
1	6.341	12.0326	11.0326
2	13.555	12.0446	11.0446
3	48.370	12.0326	11.0326
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	12.0532	BA3	60.339	12.0852
BA2	13.555	12.0442	BA4	72.384	11.8892

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

	Station (Distance from BA1)	Elevation
Ab1	NA	NA
Ab2	48.135	4.3692

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

Shape: ________ **Number of Piers:** ________ **Height of column footing:** ________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 40. The Putiao Bridge as-built survey data.

Water surface elevation of the Putiao River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on August 15, 2015 at 3:35 PM, with a with a value of 3.743 m in MSL, as shown in Figure 40. This was translated into marking on the Putiao Bridge's abutment using the same technique, as shown in Figure 41. This served as the reference for flow data gathering and depth gauge deployment of the partner HEI responsible for the Putiao River, Ateneo de Naga University.

Figure 41. (a) Getting the MSL elevations of the existing markings on the dike (b) The existing markings with their corresponding MSL elevations

4.6 Validation Points Acquisition Survey

Validation points acquisition was conducted on August 18, 2015, using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on top 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 height was 2.535 m, 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, using SRG-32 as the GNSS base station.

Figure 42. Trimble® SPS 882 set up for the acquisition of LiDAR validation points

The map on Figure 43 shows that the validation line covered the municipalities of Pilar and Castilla in the province of Sorsogon. The survey gathered a total of 2,858 ground validation points, covering an approximate length of twenty (20) km.

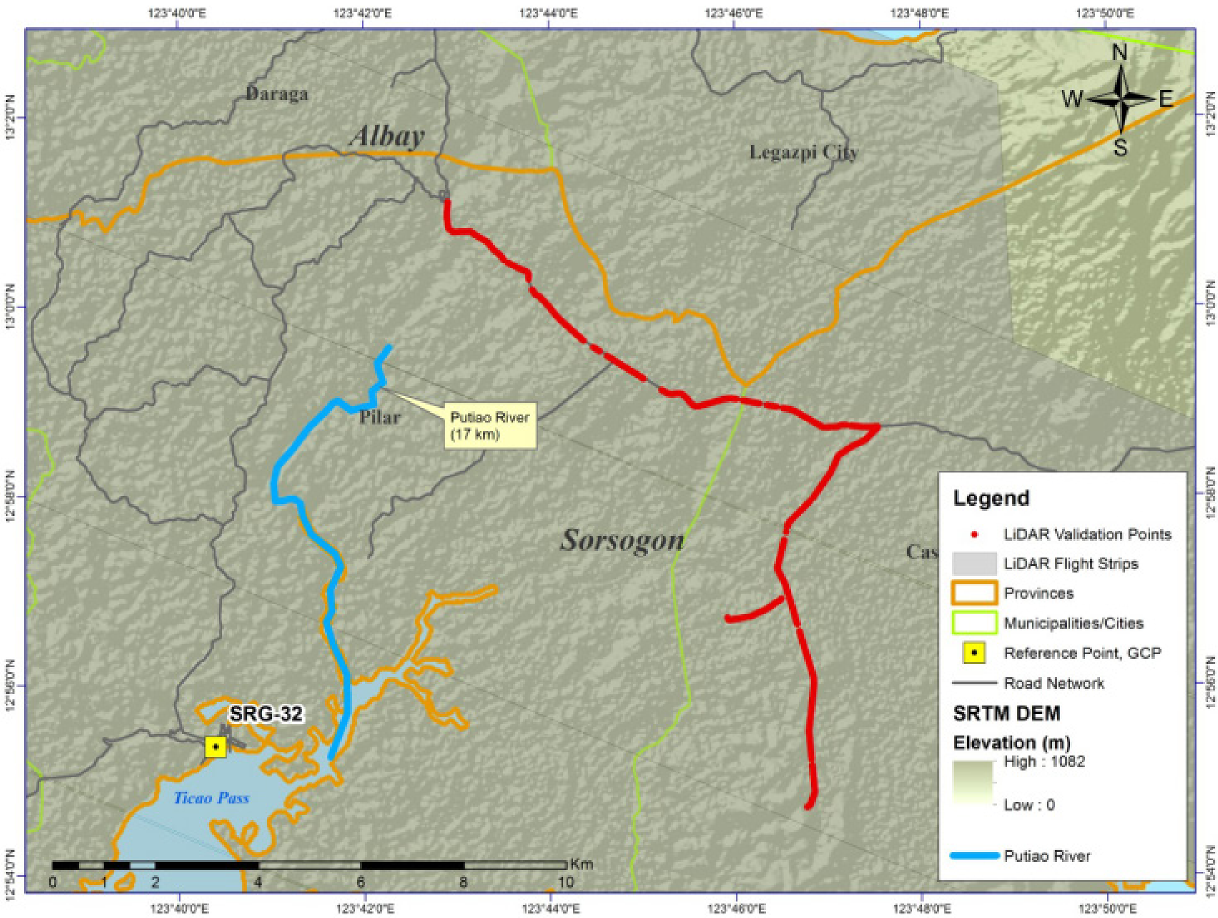


Figure 43. Extent of the LiDAR ground validation survey along Putiao River Basin

4.7 River Bathymetric Survey

A manual bathymetric survey was conducted on August 13, 2015 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode, as illustrated Figure 44. The survey started from the upstream in Barangay Putiao, Pilar, with coordinates 13°01'09.35507"N, 123°42'57.42260"E and ended down to the mouth of the river, with coordinates 12°54'55.17458", 123°40'57.03946" in Barangay Dao, Pilar, Sorsogon, as shown in Figure 45. The control point SRG-32 was used as GNSS base station all throughout the survey.

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

The bathymetric survey for the Putiao River gathered a total of 8,465 points, covering an estimated length of 17.5 kilometers traversing Barangay Putiao, Pilar down to the mouth of the river in Barangay Dao, Pilar, Sorsogon. To further illustrate this, a CAD drawing was also produced to depict the Putiao riverbed profile. The profile shows that the change of elevation is around twelve (12) meters, from the Kilicao Bridge in Barangay Binitayan two (2) kilometers down to Barangay Bogtong, as illustrated in Figure 46.

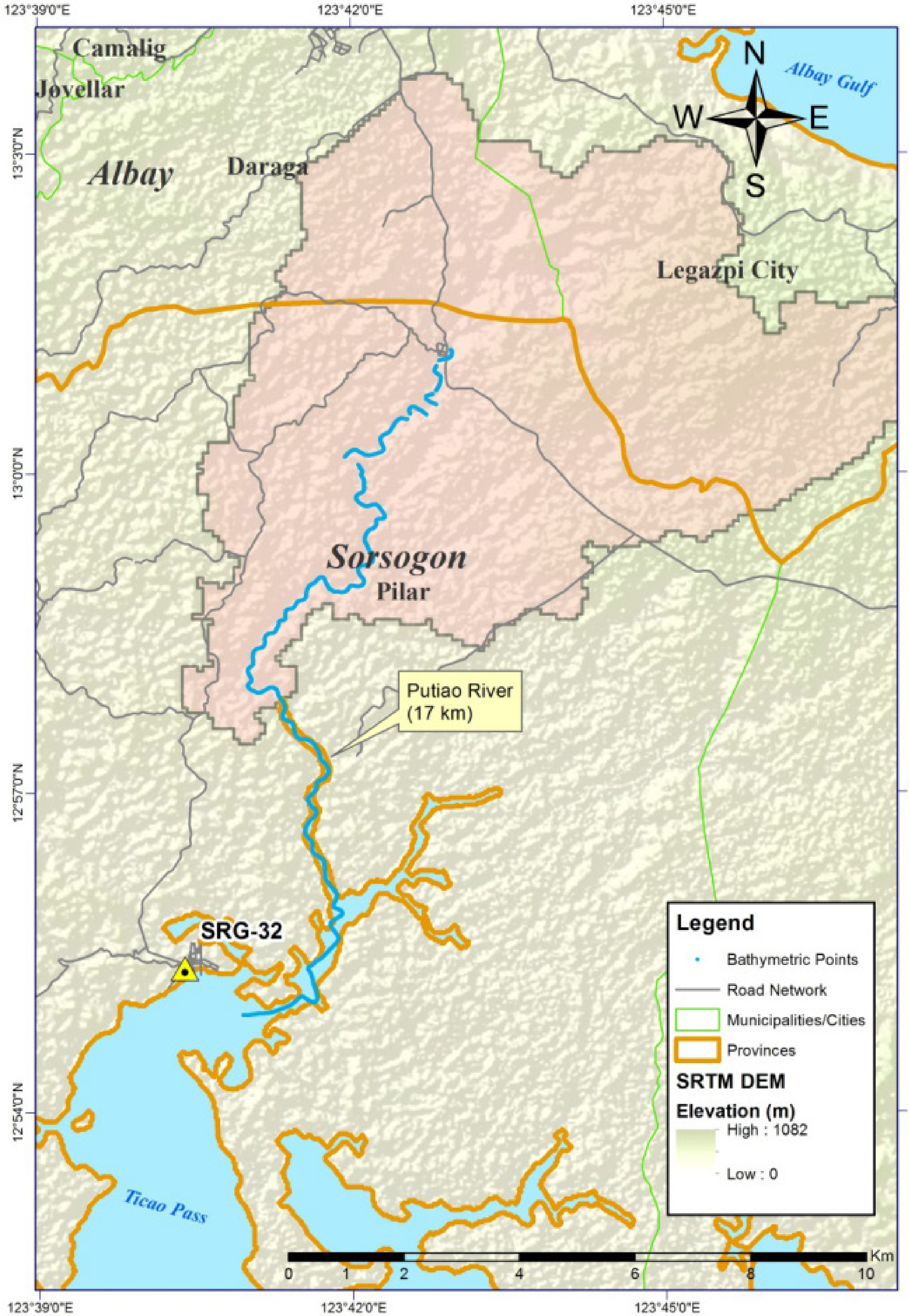


Figure 45. Extent of the bathymetric survey of Putiao River

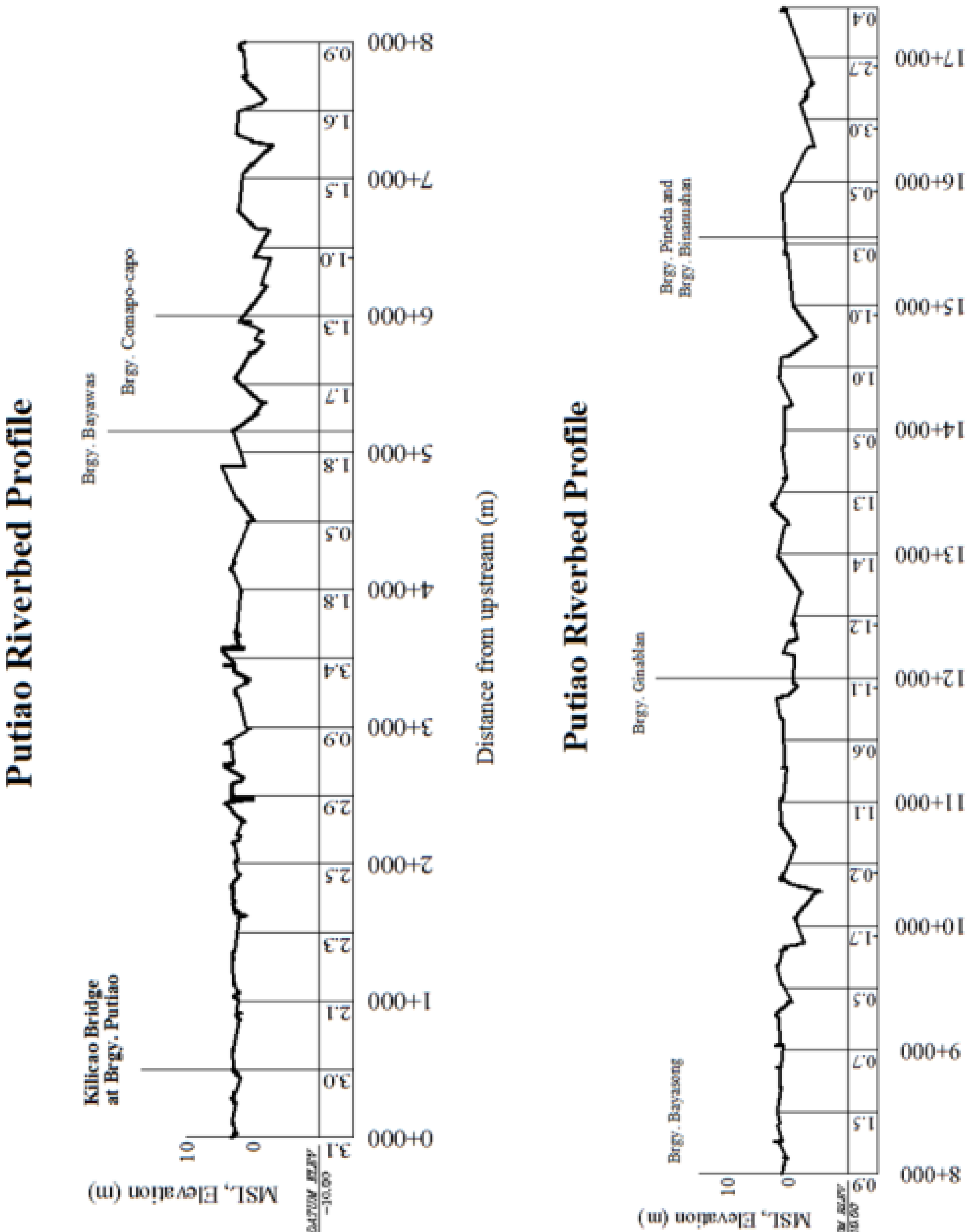


Figure 46. Riverbed Profile of Putiao River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Putiao 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 Putiao River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from Hobo RG SN:10683400, an automatic rain gauge (ARG) deployed by ADNU – Flood Modeling Component (FMC) beside the Bridge Railing at Pilar, Sorsogon. The rain gauge was installed at the local government unit (LGU) of Donsol (Figure 47). The precipitation data collection started on December 14, 2015 at 2:10 PM until December 15, 2015 at 2:30 PM, with a 10-minute recording interval.

The total precipitation for this event in the deployed ARG is 87.6 mm. It had a peak rainfall of 12 mm on December 14, 2015 at 7:50 PM. The lag time between the peak rainfall and discharge was three (3) hours.

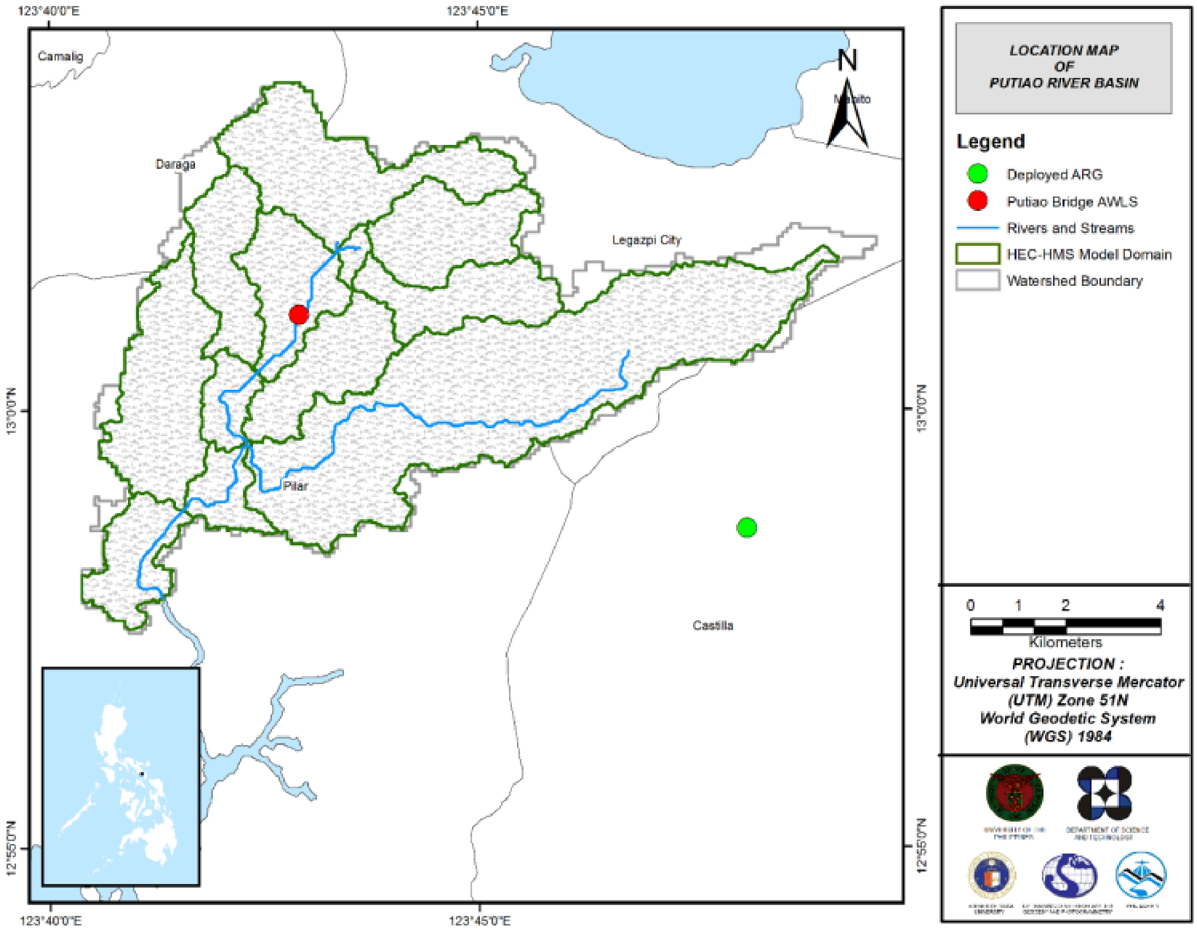


Figure 47. Location map of Putiao HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed in Putiao Bridge, Pilar, Sorsogon (13°1'5.7"N, 123°42'54.3"E) to establish the relationship between the observed water levels from the installed depth gauge at the Putiao Bridge and the outflow of the watershed at this location.

For the Putiao Bridge, the rating curve is expressed as Q=1.2719e0.5639h, as shown in Figure 49.

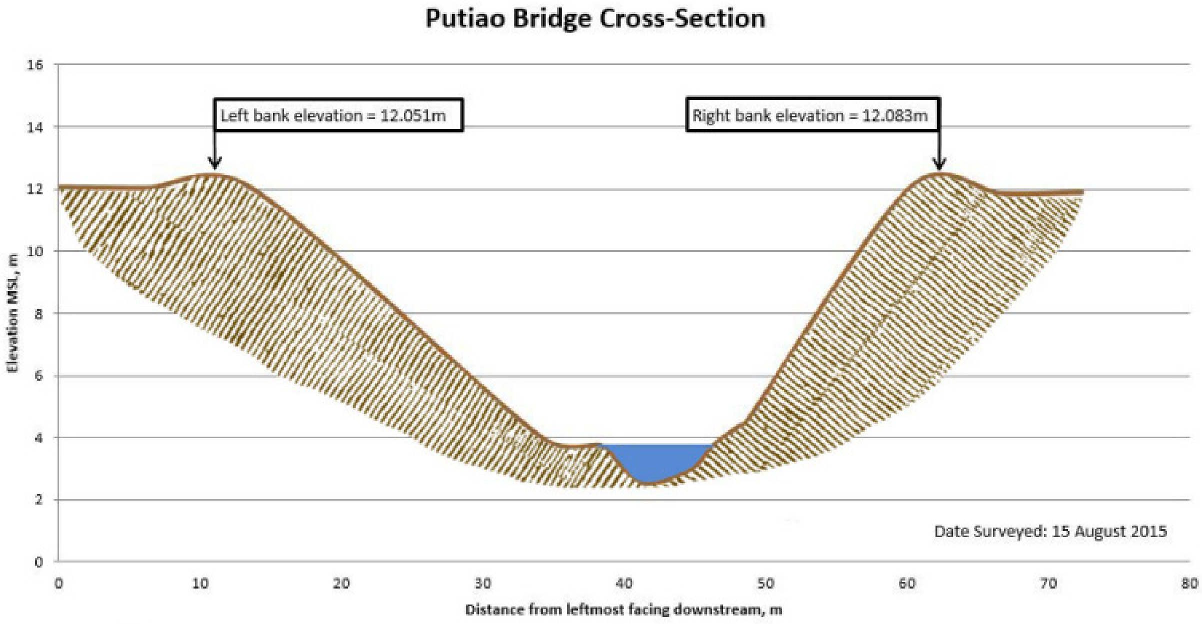


Figure 48. Cross-Section Plot of Putiao Bridge

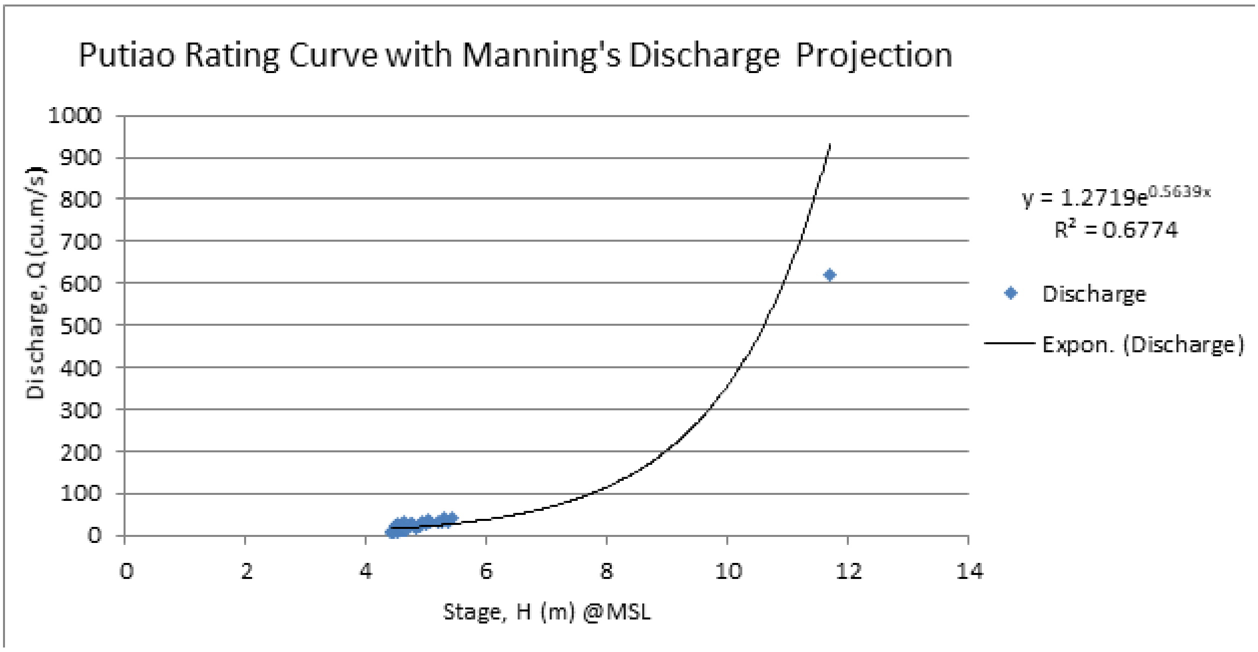


Figure 49. The rating curve of Putiao Bridge in Pilar, Sorsogon

This rating curve equation was used to compute the river outflow at the Putiao Bridge for the calibration of the HEC-HMS model, as shown in Figure 50. The total rainfall for this event is 87.6mm, and the peak discharge is 120.037m3/s at 10:50 PM of December 14, 2015.

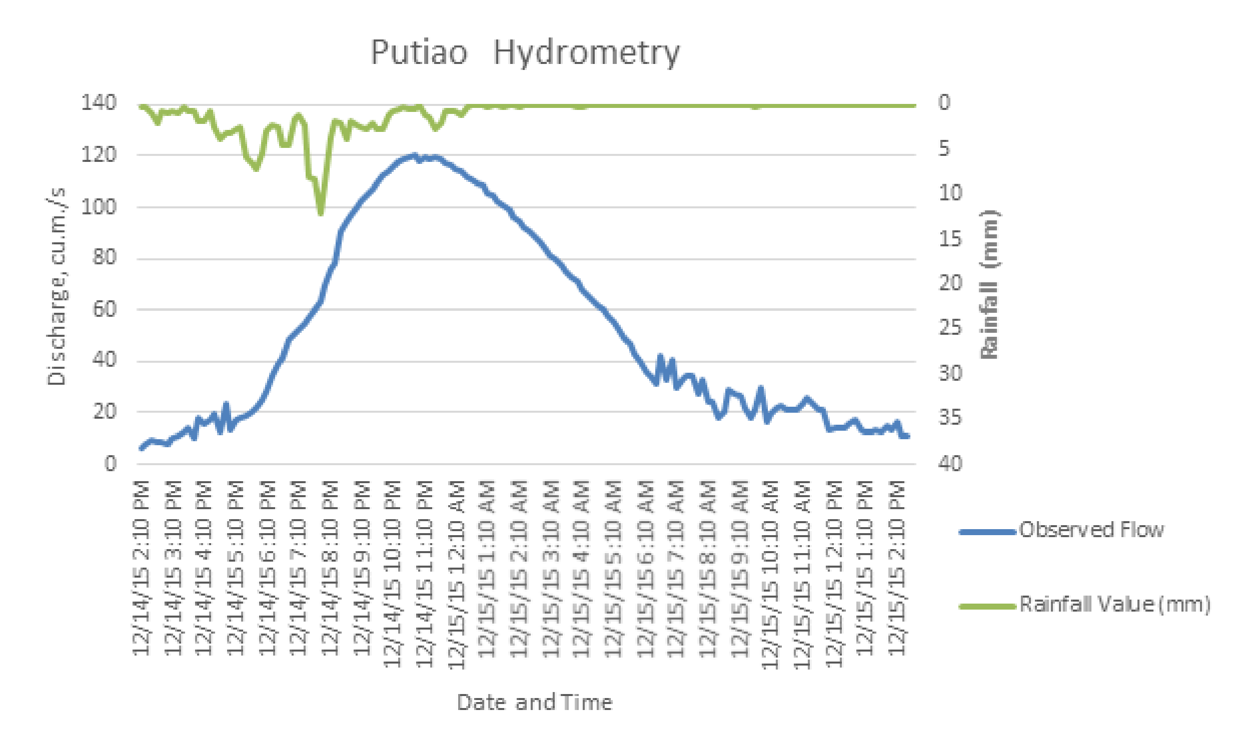


Figure 50. Rainfall and outflow data of the Putiao River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed the Rainfall Intensity Duration Frequency (RIDF) values for the Legazpi Rain Gauge (Table 28). This station selected based on its proximity to the Putiao watershed (Figure 51). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values such that a certain peak value will be attained at a certain time. The extreme values for this watershed were computed based on a 26-year record.

Table 28. RIDF values for Putiao 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	21	31.9	39.6	53.4	74.5	89.3	119.2	145.5	176.4
5	29.1	43.8	54.5	76.7	113.4	138.5	189.8	228.7	260.5
10	34.5	51.6	64.3	92.2	139.1	171.1	236.6	283.8	316.1
15	37.5	56	69.8	100.9	153.6	189.4	263	314.8	347.5
20	39.6	59.1	73.7	107	163.7	202.3	281.5	336.6	369.5
25	41.3	61.5	76.7	111.7	171.6	212.2	295.7	353.4	386.4
50	46.3	68.9	85.9	126.2	195.7	242.7	339.6	405	438.6
100	51.3	76.2	95.1	140.5	219.6	273.1	383.1	456.2	490.3

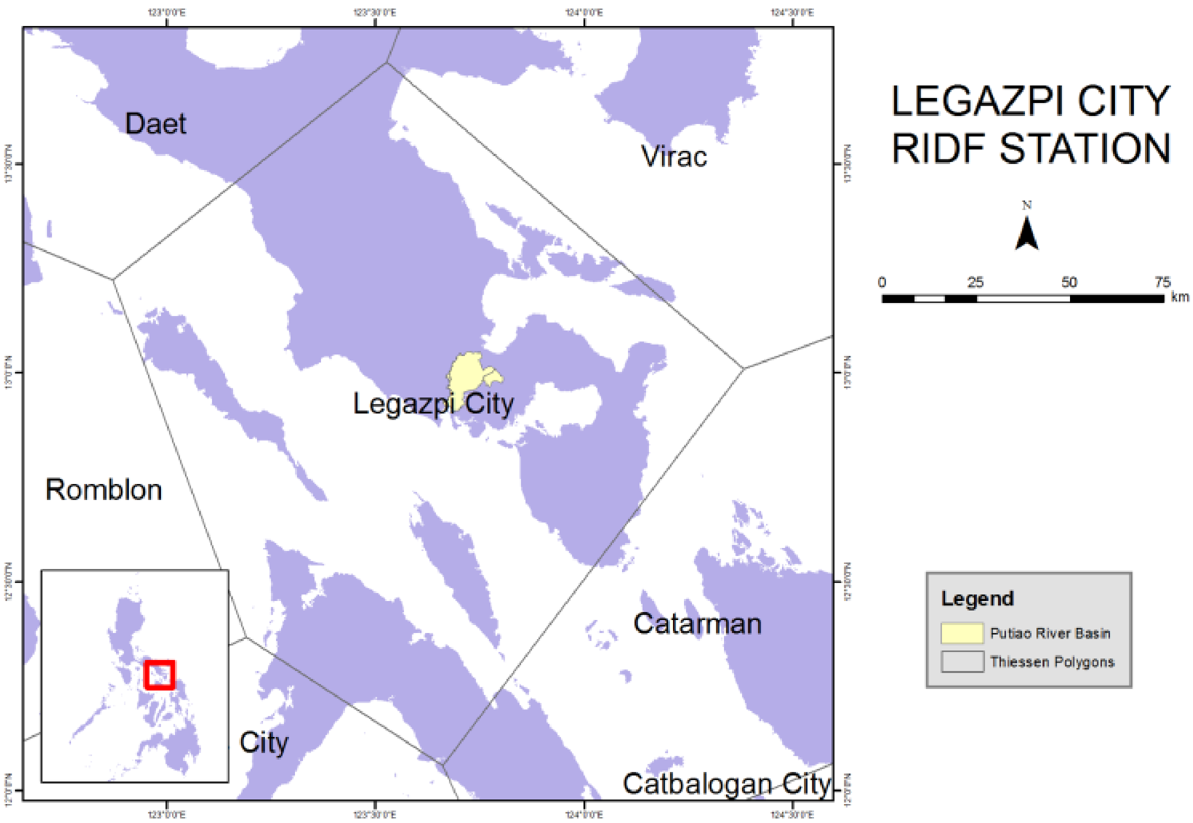


Figure 51. The location of the Legazpi City RIDF station relative to the Putiao River Basin

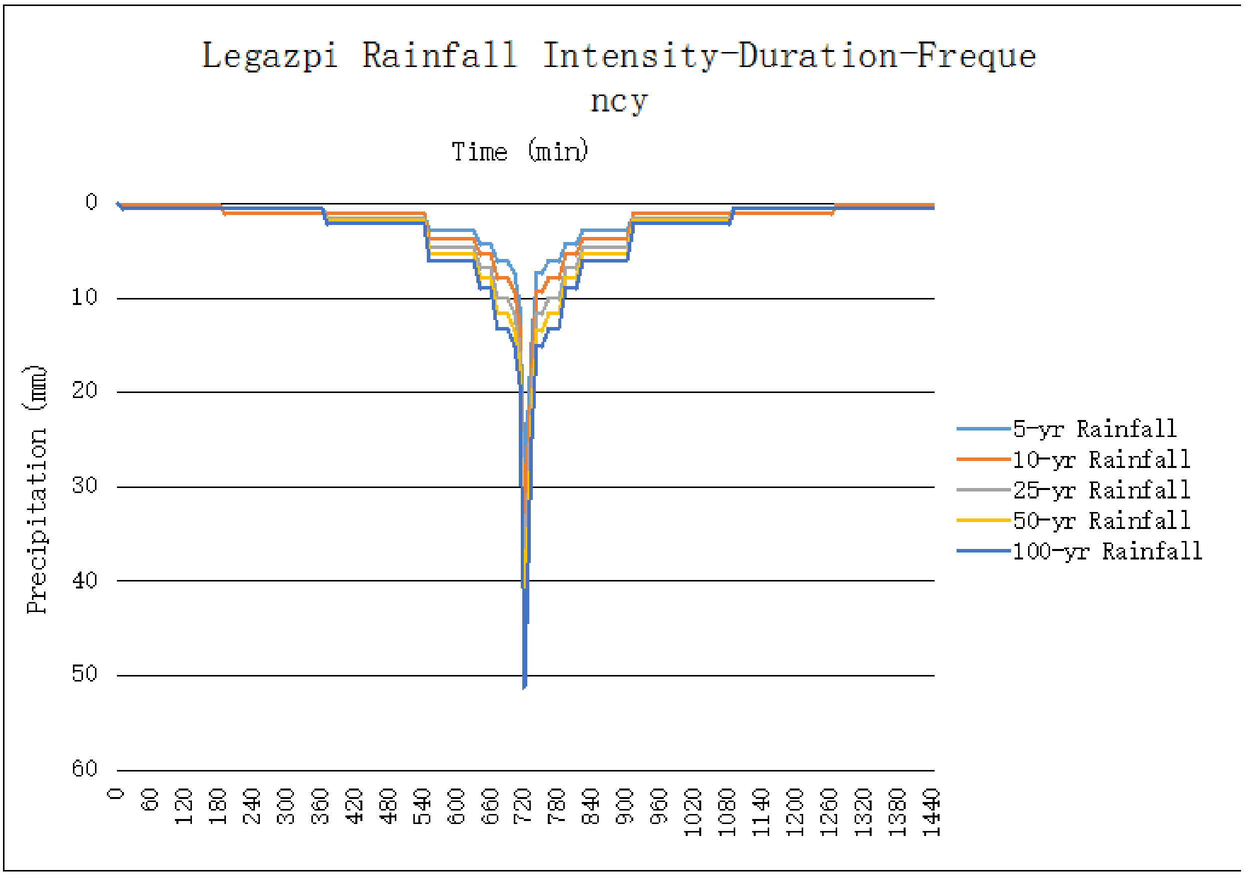


Figure 52. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover of the Putiao River Basin are shown in Figures 53 and 54, respectively.

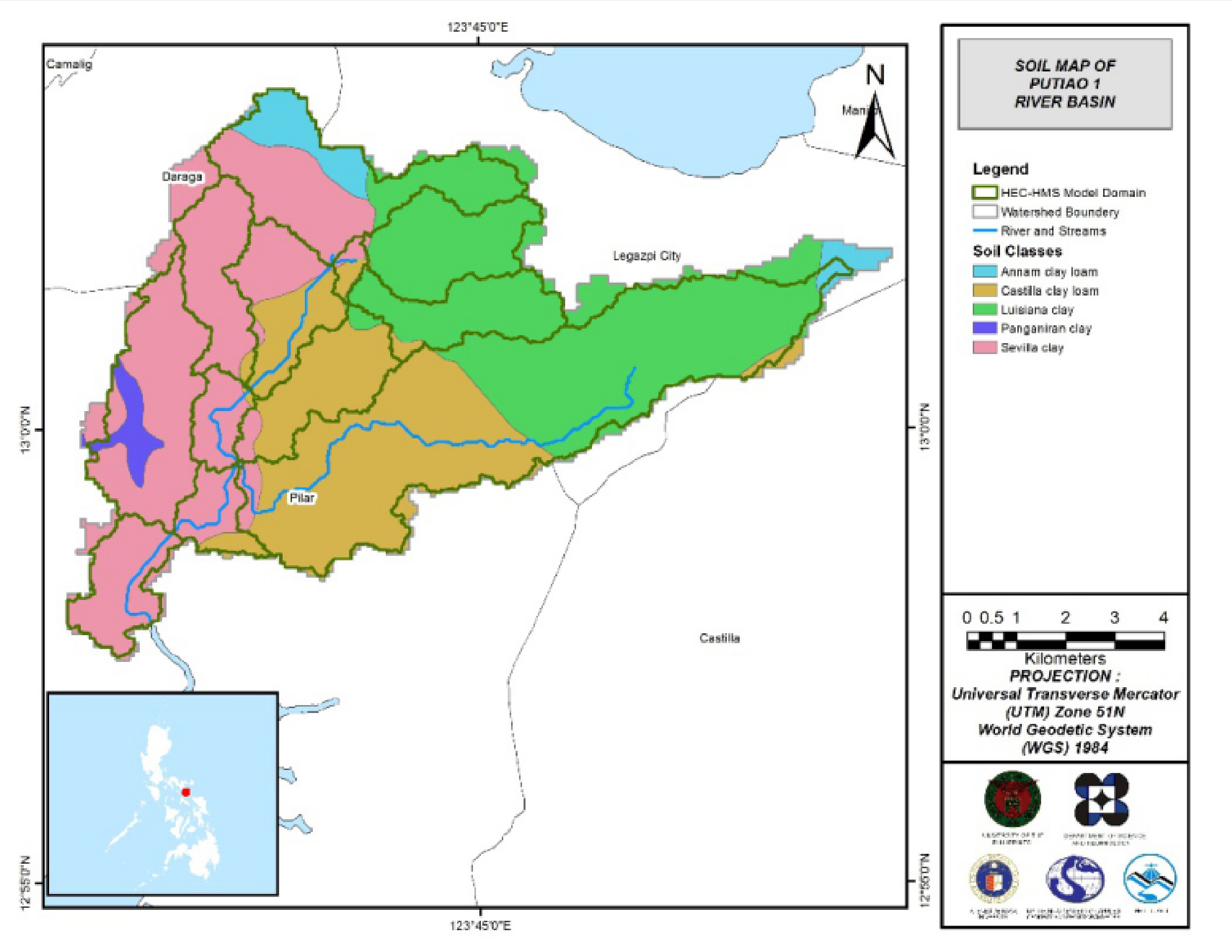


Figure 53. Soil map of Putiao River Bain (Source: DA)

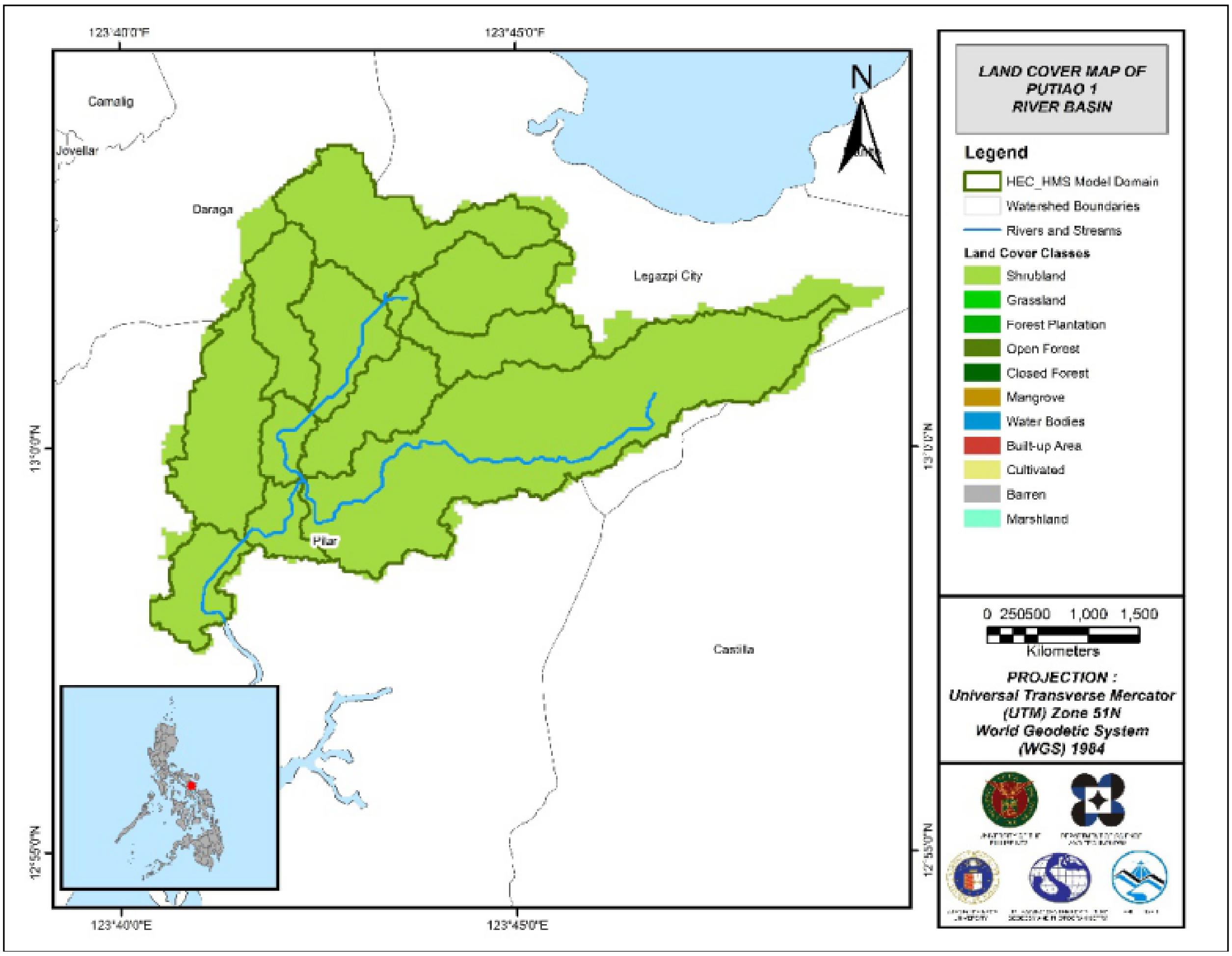


Figure 54. Land cover map of Putiao River Basin (Source: NAMRIA)

For Putiao, five (5) soil classes were identified. These are Annam clay loam, Castilla clay loam, Luisiana clay, Panganiran clay, and Sevilla clay. Moreover, one dominant land cover class was identified, which is shrubland.

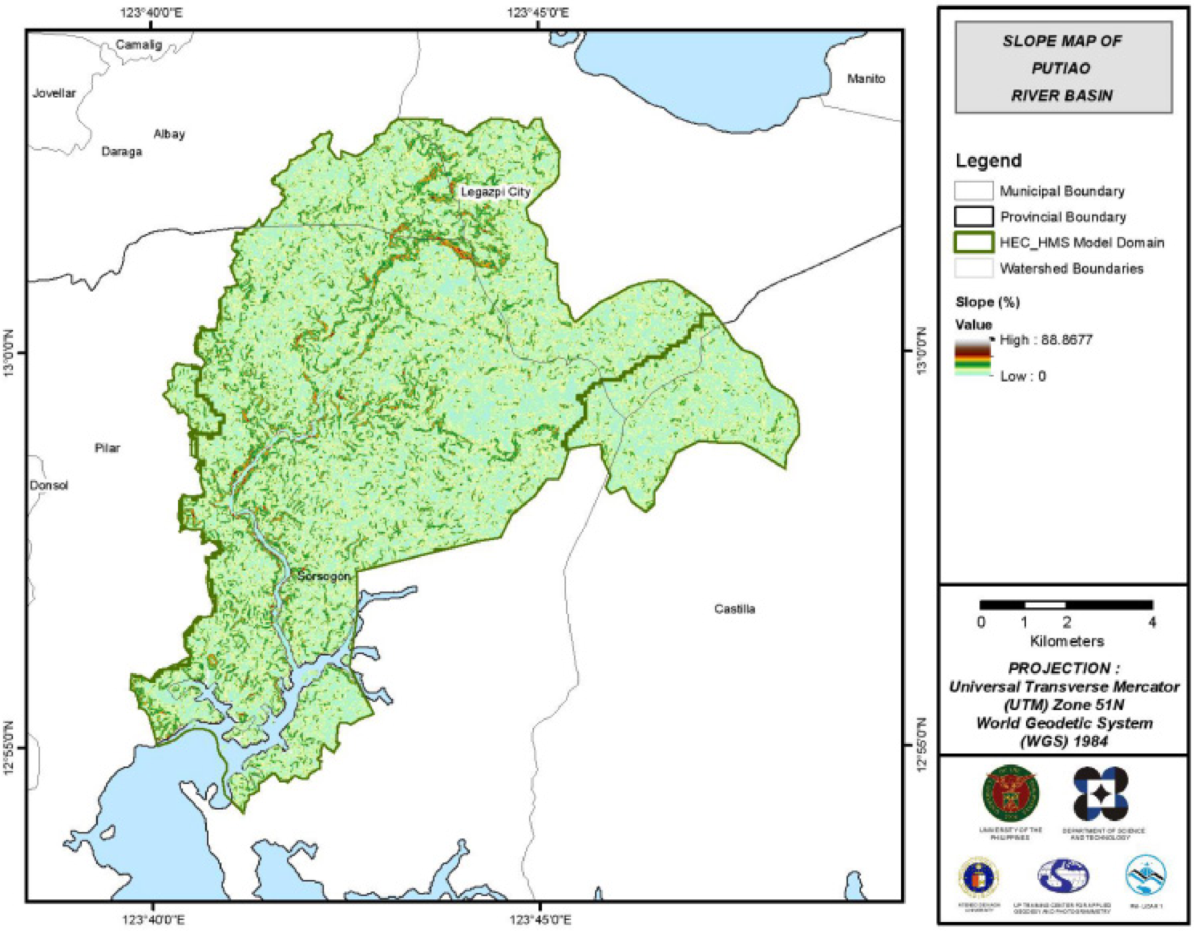


Figure 55. Slope map of Putiao River Basin

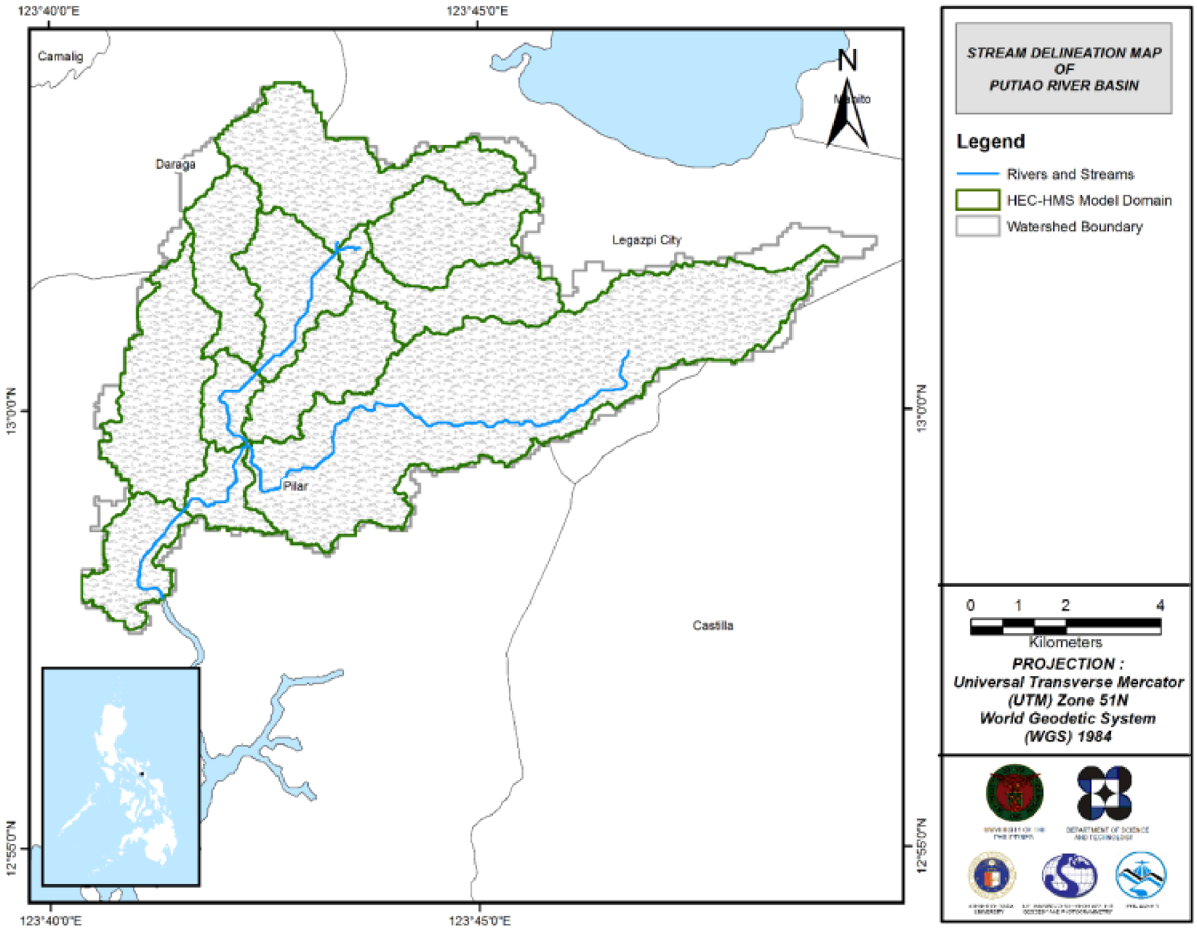


Figure 56. Stream delineation map of Putiao River Basin

Using the SAR-based DEM, the Putiao basin was delineated and further divided into sub basins. The Putiao River basin model consists of thirteen (13) sub basins, six (6) reaches, and six (6) junctions, as shown in Figure 57. The main outlet is the Putiao Bridge. See Annex 10 for the Model Reach Parameters.

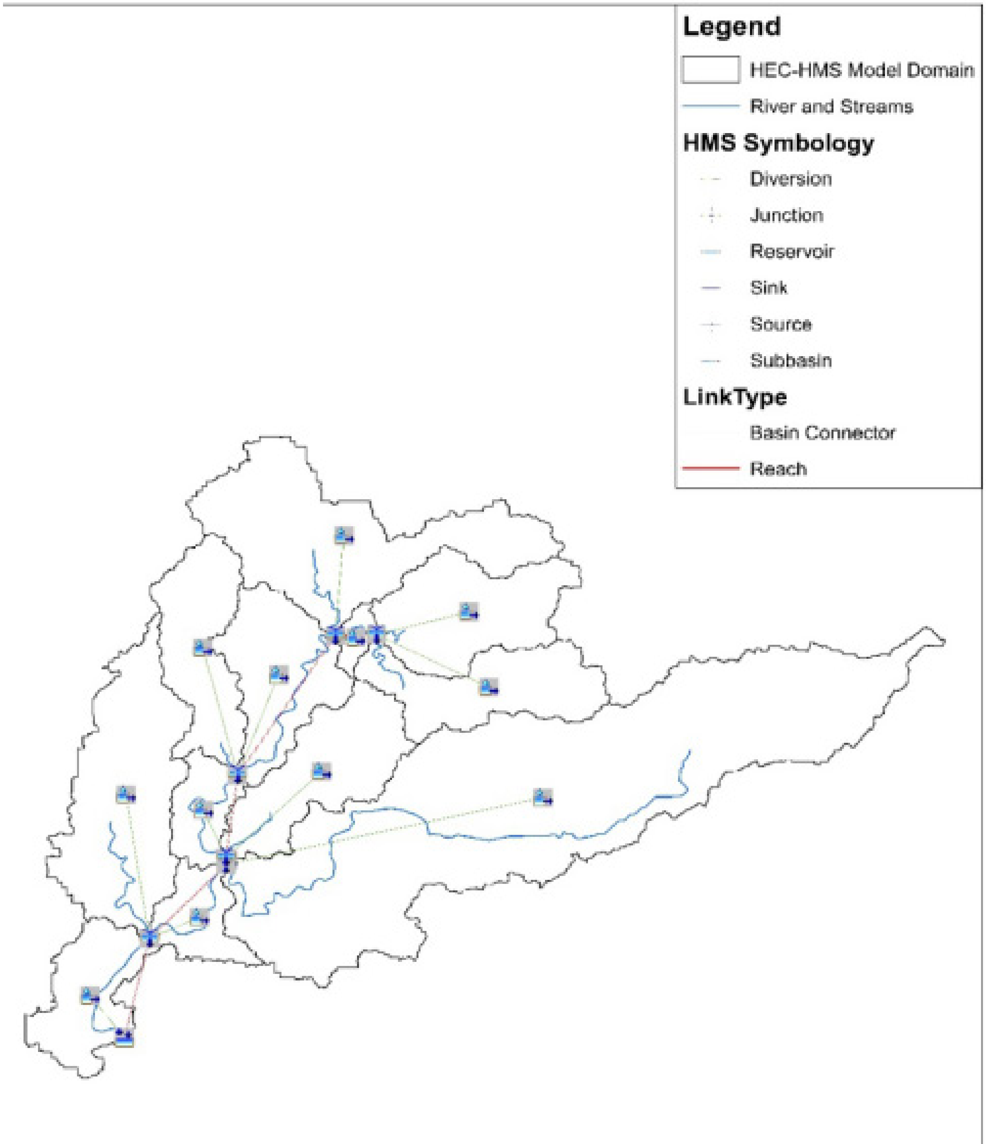


Figure 57. The Putiao river basin model generated using HEC-HMS

5.4 Cross-section Data

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

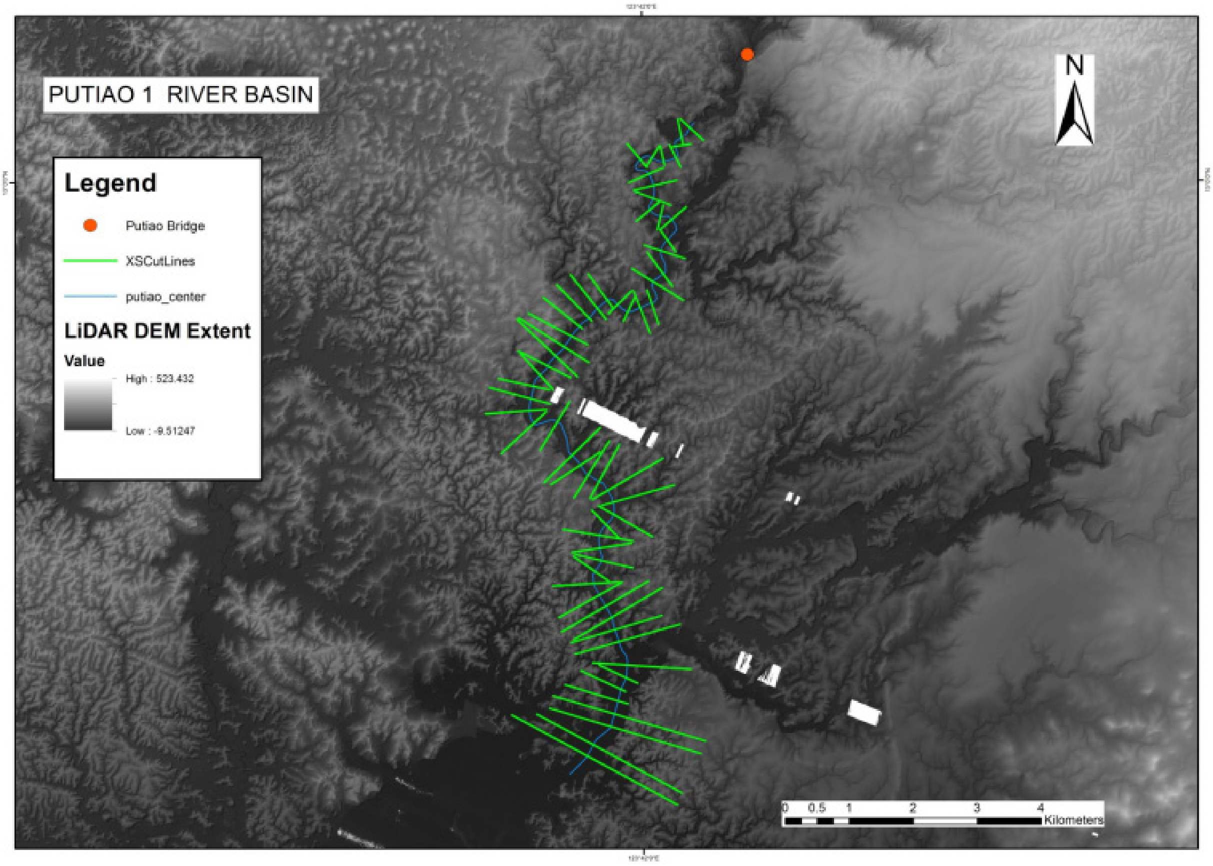


Figure 58. River cross-section of Putiao River generated through ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area (Figure 65). 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.

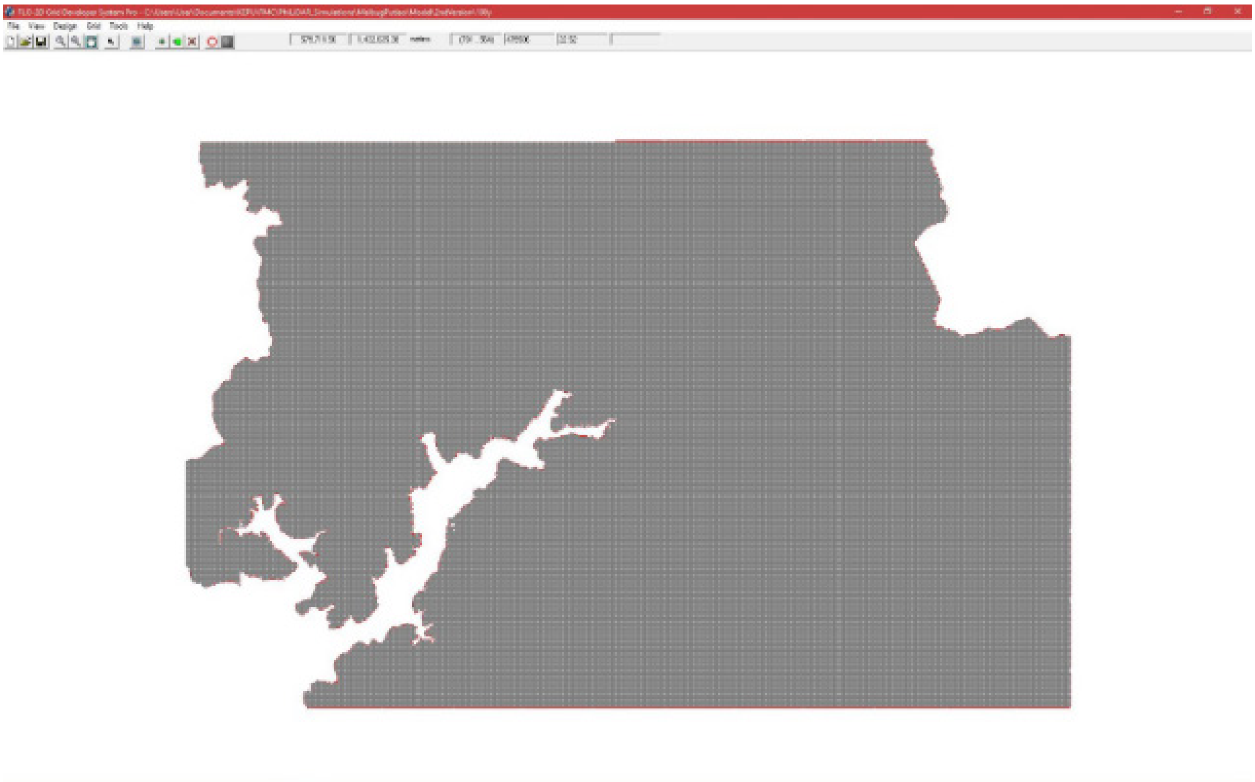


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 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 generated hazard maps for Silaga are in Figures 69, 71, and 73.

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. The generated flood depth maps for Silaga are in Figures 70, 72, and 74.

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 Putiao river basin HEC-HMS model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data. See Annex 9 for the Putiao Model Basin Parameters.

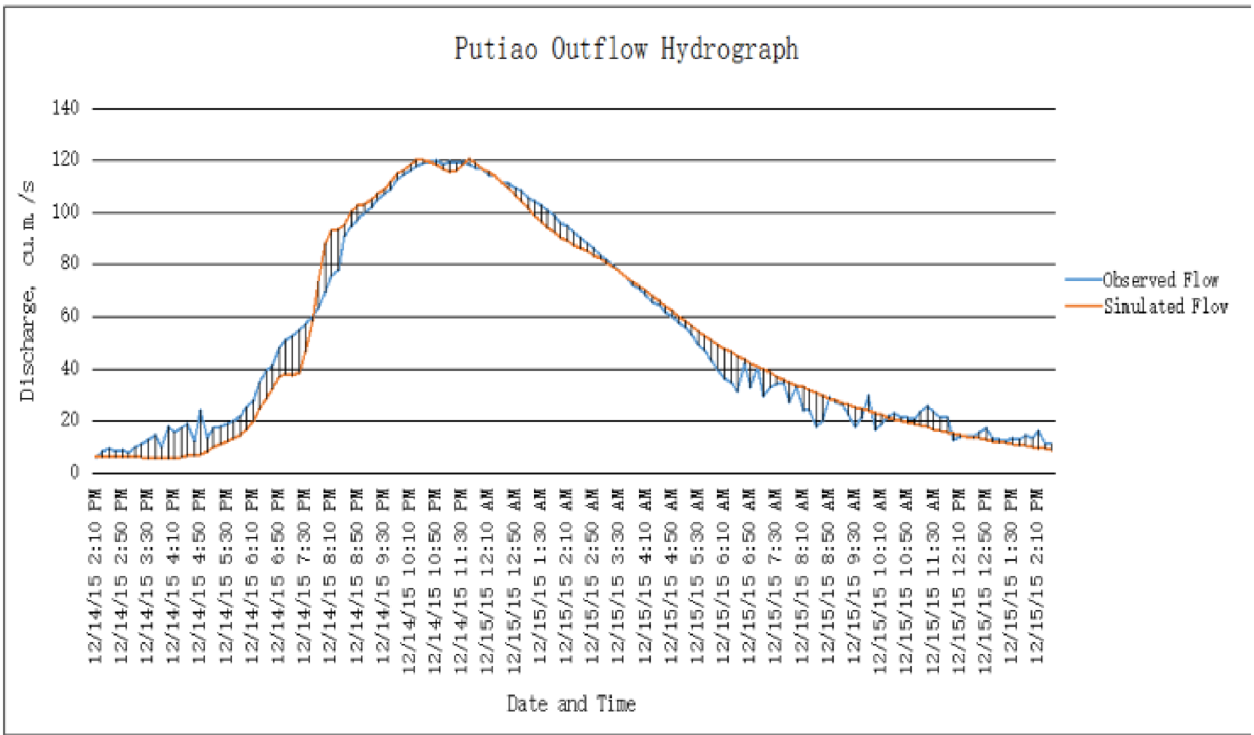


Figure 60. Outflow Hydrograph produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for Putiao

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.6-54
			Curve Number	35-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-2
			Storage Coefficient (hr)	0.1-4
	Baseflow	Recession	Recession Constant	0.00001-0.03
			Ratio to Peak	0.01-1
Reach	Routing	Muskingum-Cunge	Slope	0.0005-0.002
			Manning's Coefficient	0.005-0.1

Initial abstraction is defined as the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.6mm to 54mm means that there is minimal to average amount of infiltration, or rainfall interception, by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 99 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area. For Putiao, the basin mostly consists of grassland and the soil consists of Ubay clay, Himayangan sandy clay loam, and hydrosol.

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 0.02 hours to 4 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

The recession constant is the rate at which baseflow recedes between storm events, and ratio to peak is the ratio of the baseflow discharge to the peak discharge. For Putiao, it will take at least 14 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.1 corresponds to the common roughness in the Putiao watershed, which is determined to be shrubland with medium to dense brush (Brunner, 2010).

Table 30. Summary of the Efficiency Test of Putiao HMS Model

Accuracy measure	Value
RMSE	6.44
r2	0.97
NSE	0.97
PBIAS	1.62
RSR	0.17

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 6.44 (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 at 0.97.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model, where the optimal value is 1. The model attained an efficiency coefficient of 0.97.

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 1.62.

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 values are quantified. The model has an RSR value of 0.17.

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 Putiao outflow using the synthetic storm events, applying the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in five (5) different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods from 256.3m3/s in a 5-year return period, to 747.3m3/s in a 100-year return period.

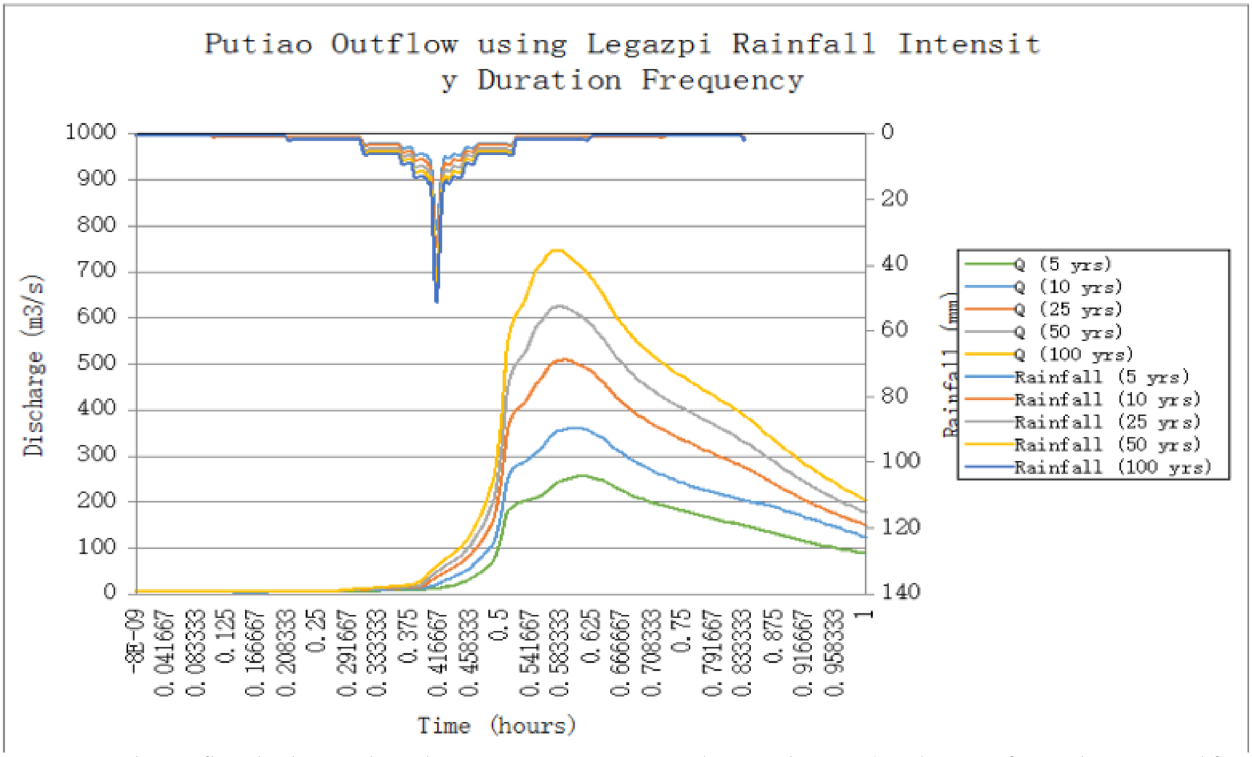


Figure 61. The outflow hydrograph at the Putiao Basin, generated using the simulated events for 24-hour period for Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Putiao discharge using the Legazpi RIDF in five (5) different return periods is shown in Table 31.

Table 31. Peak values of the Putiao HEC-HMS Model outflow using the Legazpi RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	260.5	29.1	256.3	4 hours, 50 minutes
10-Year	316.1	34.5	361.1	4 hours, 40 minutes
25-Year	386.4	41.3	508.6	4 hours, 40 minutes
50-Year	438.4	46.3	625.3	4 hours, 50 minutes
100-Year	490.3	51.3	747.3	4 hours, 50 minutes

5.7.2. Discharge data using Dr. Horritts's recommended hydrologic method

The river discharges for the three rivers entering the floodplain are shown in Figures 62 to 64, and the peak values are summarized in Tables 32 to 35.

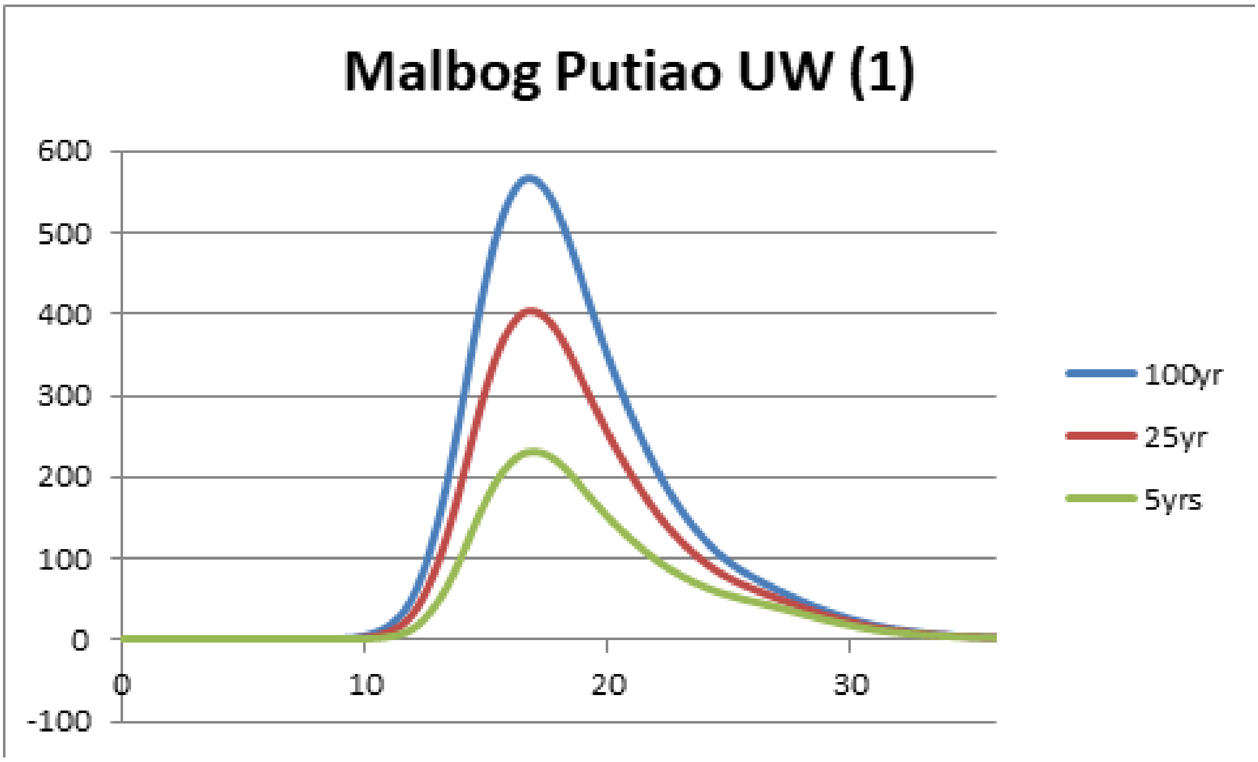


Figure 62. Putiao river (1) generated discharge using 5-, 25-, and 100-year Legazpi City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

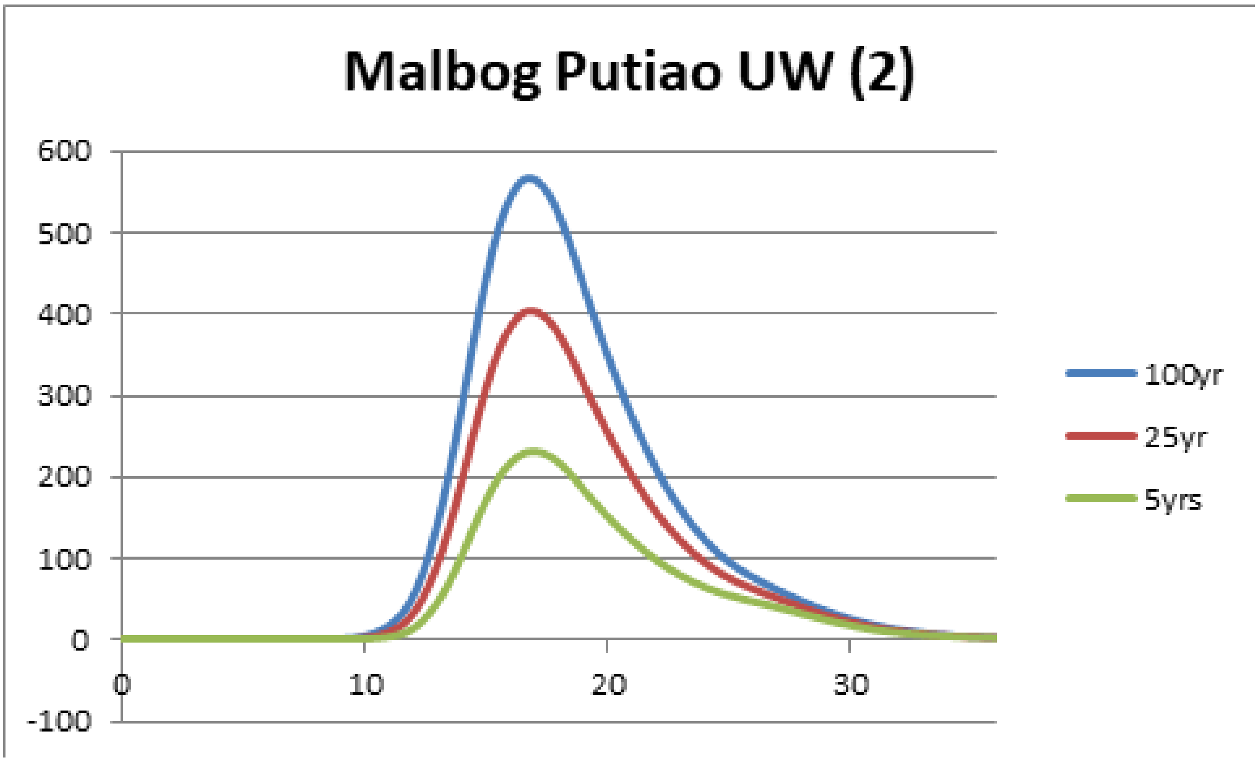


Figure 63. Putiao river (2) generated discharge using 5-, 25-, and 100-year Legazpi City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

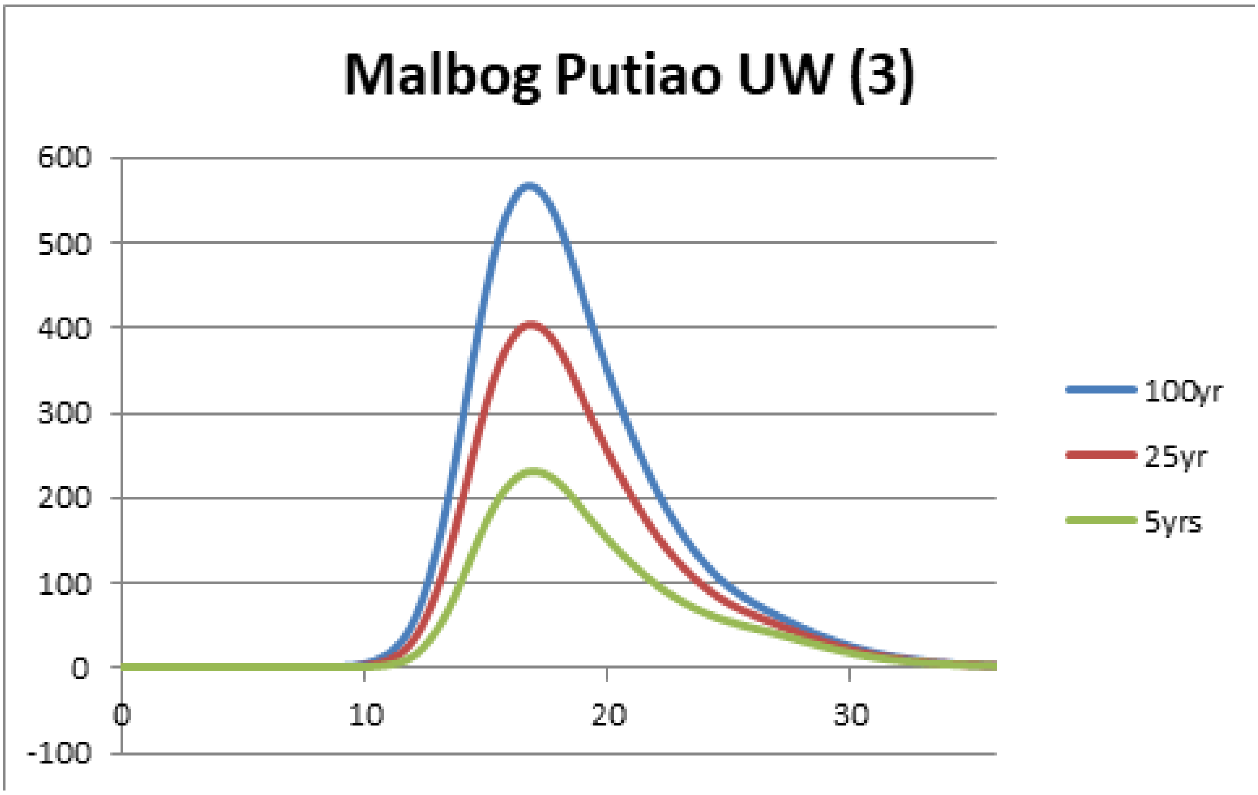


Figure 64. Putiao river (3) generated discharge using 5-, 25-, and 100-year Legazpi City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 32. Summary of Putiao river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	374.3	18 hours, 30 minutes
25-Year	257.1	18 hours, 40 minutes
5-Year	130.9	18 hours, 50 minutes

Table 33. Summary of Putiao river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	82.4	12 hours, 50 minutes
25-Year	58.3	12 hours, 50 minutes
5-Year	32.4	13 hours

Table 34. Summary of Putiao river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	566.5	16 hours, 50 minutes
25-Year	404.5	16 hours, 50 minutes
5-Year	230.8	17 hours

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 35.

Table 35. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Putiao (1)	115.192	599.476	587.995	Fail	Fail
Putiao (2)	28.512	419.997	88.392	Fail	Fail
Putiao (3)	203.104	112.239	579.920	Fail	Fail

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

5.8 River Analysis (RAS) Model Simulation

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

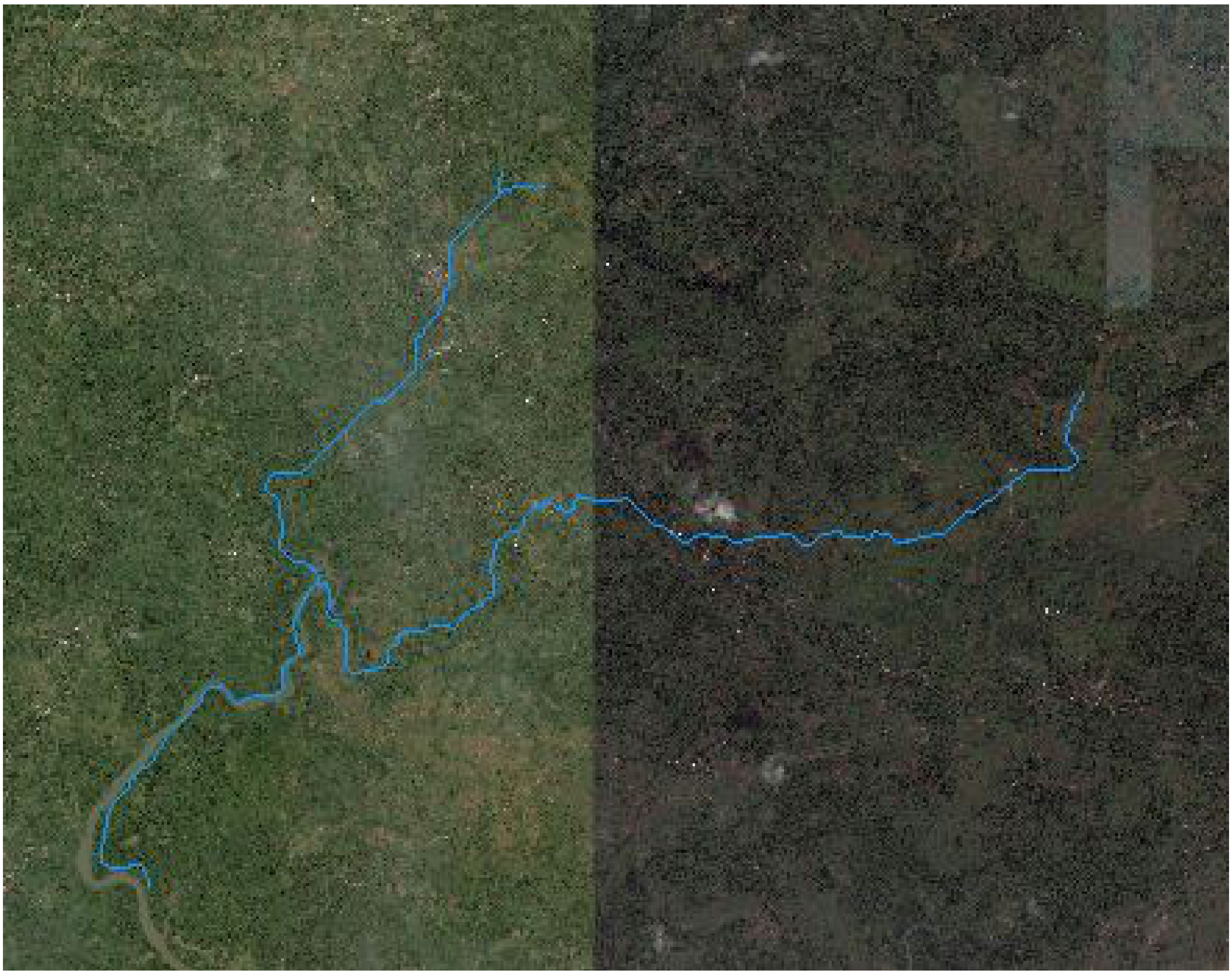


Figure 65. The sample output map of the Putiao RAS model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 66 to 71 show the 5-, 25-, and 100-year rain return scenarios of the Putiao flood plain. The flood plain, with an area of 176.47km2, covers two (2) municipalities, namely Castilla and Pilar. Table 36 shows the percentage of areas affected by flooding per municipality.

Table 36. Municipalities affected in Putiao Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Castilla	197.27	49.36	25.1
Pilar	196.62	4.78	2.42

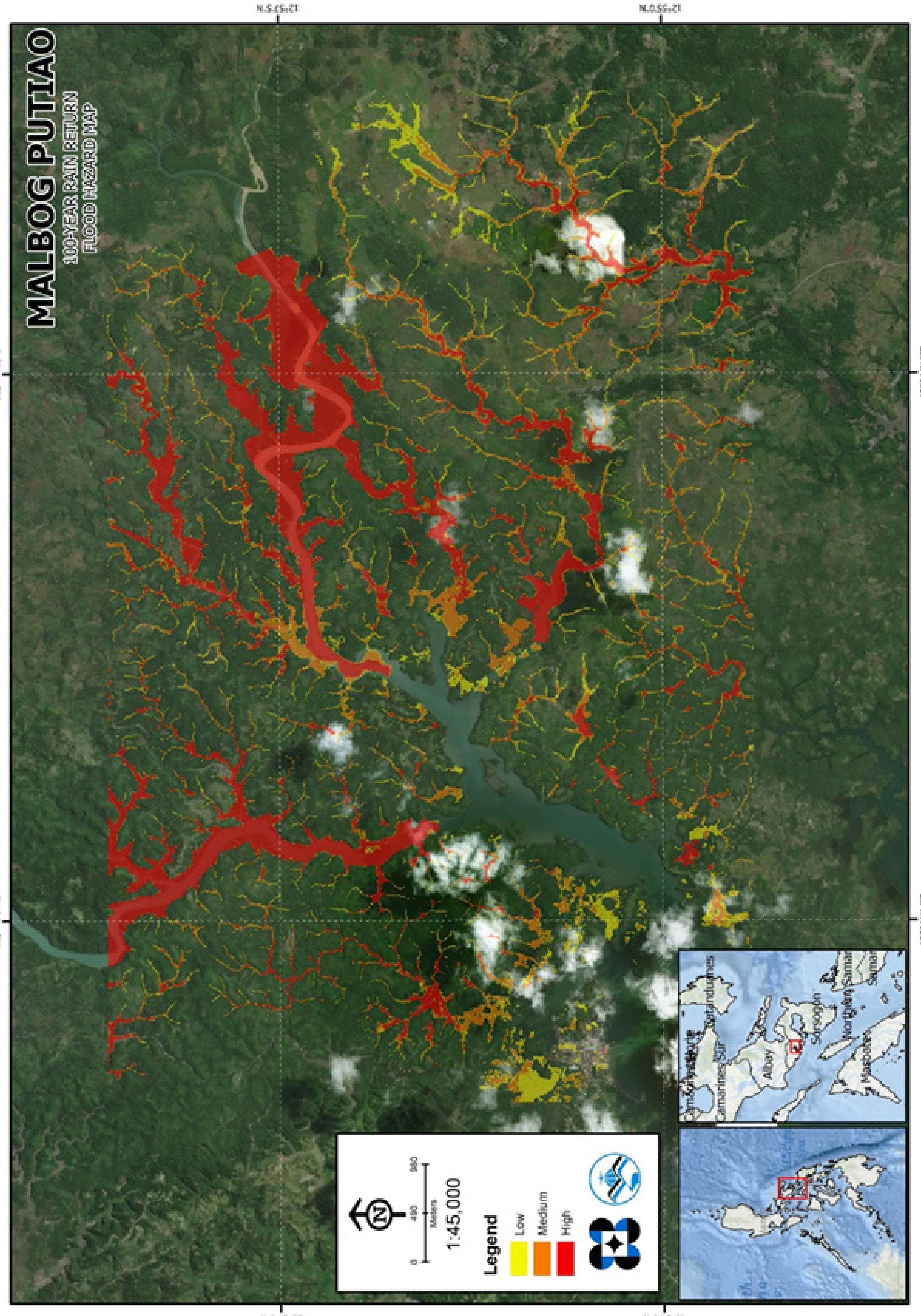


Figure 66. A 100-year flood hazard map for the Putiao Floodplain

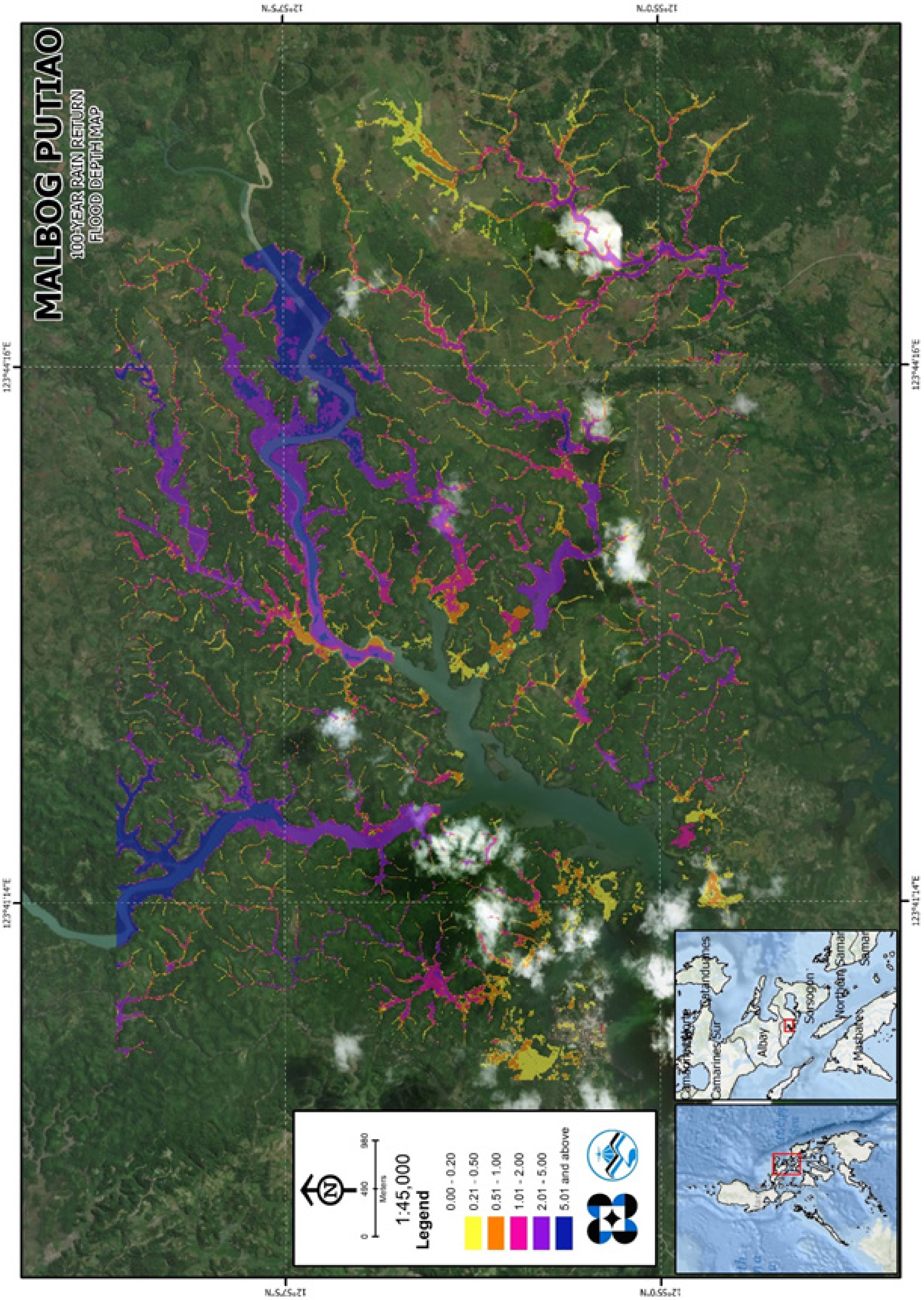


Figure 67. A 100-year Flow Depth Map for the Putiao Floodplain

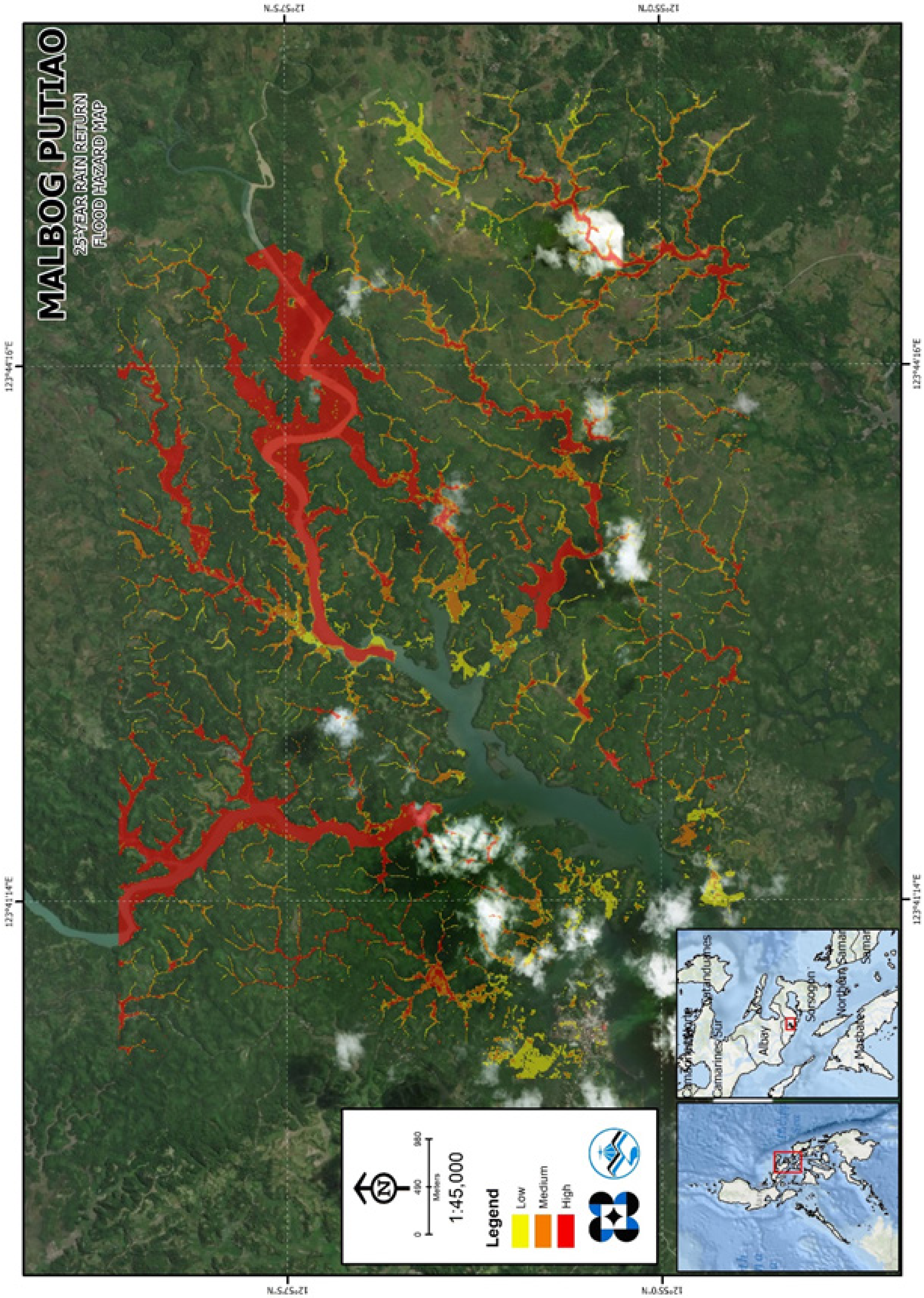


Figure 68. A 25-year Flood Hazard Map for Putiao Floodplain

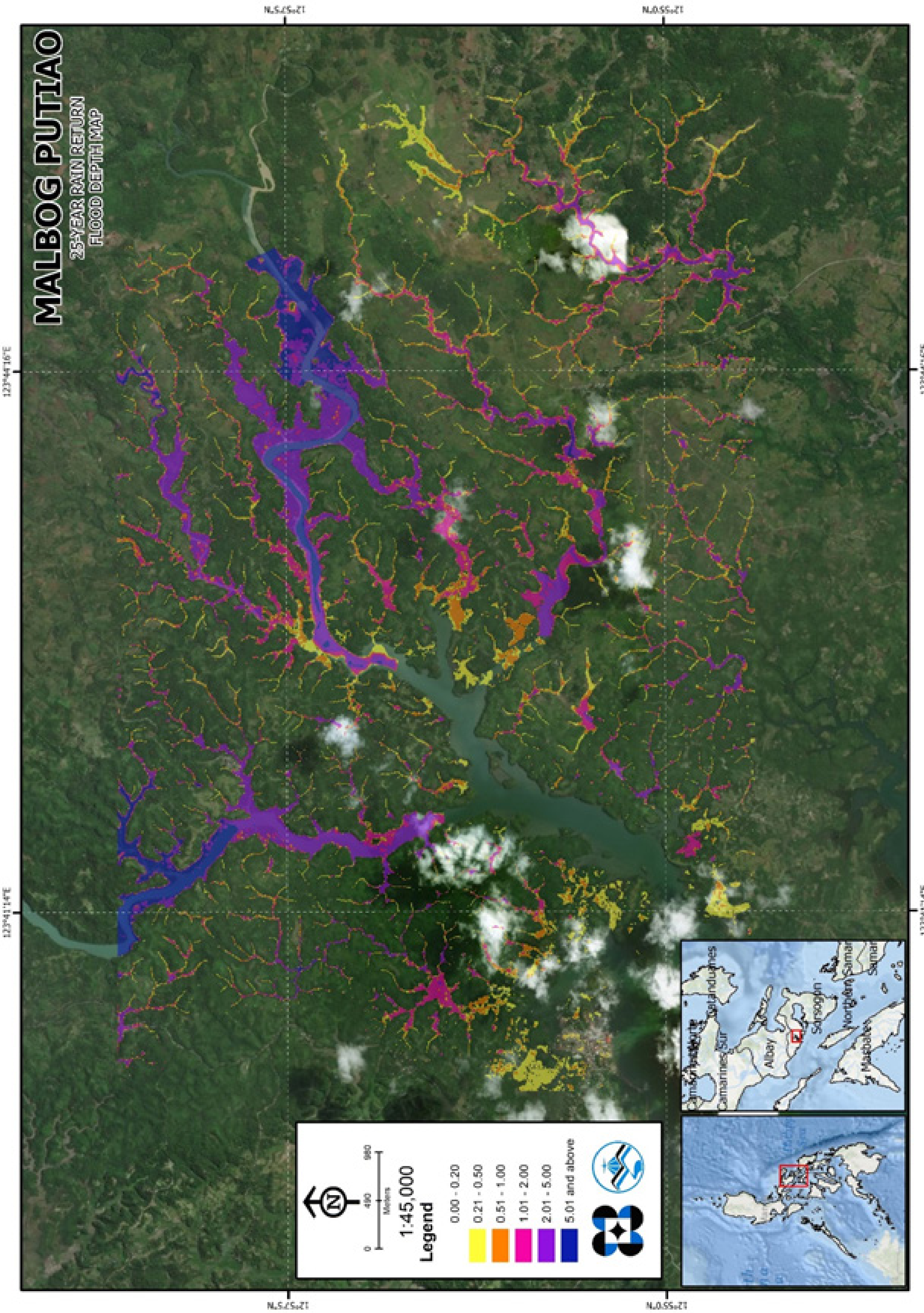


Figure 69. A 25-year Flow Depth Map for Putiao Floodplain

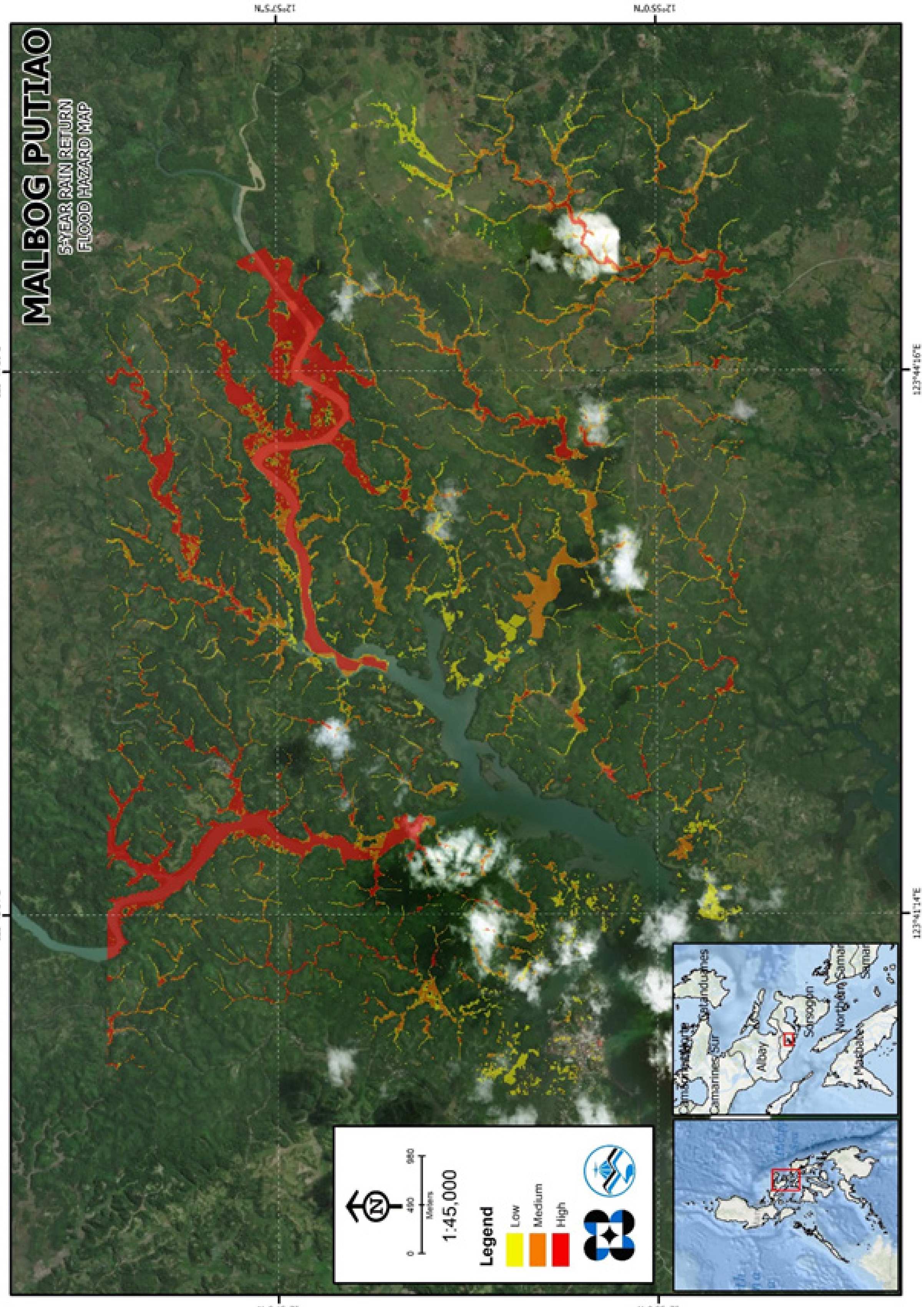


Figure 70. A 5-year Flood Hazard Map for Putiao Floodplain

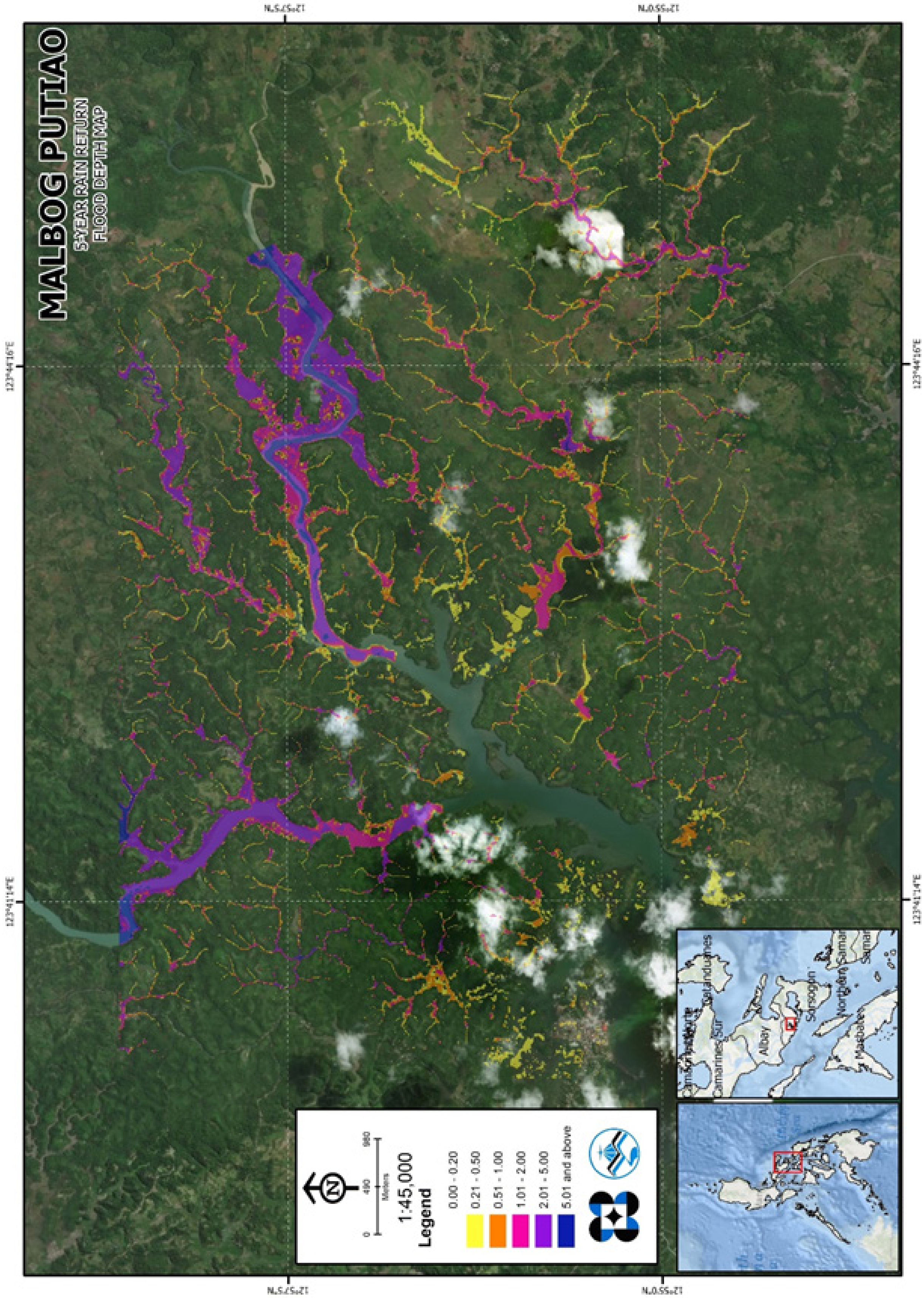


Figure 71. A 5-year Flow depth map for Putiao Floodplain.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Putiao River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of twenty (20) barangays are expected to experience flooding when subjected to the three (3) rainfall return period scenarios.

For the 5-year rainfall return period, 2.24% of the municipality of Castilla, with an area of 197.27 sq. km., will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.05%, 0.02%, and 0.002% 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. Table 37 depicts the areas affected in Castilla, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Castilla, Sorsogon during a 5-year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Castilla (in sq. km.)	
	Caburacan	Loreto
0.03-0.20	2.98	1.44
0.21-0.50	0.13	0.097
0.51-1.00	0.075	0.015
1.01-2.00	0.037	0.0014
2.01-5.00	0.0037	0
> 5.00	0	0

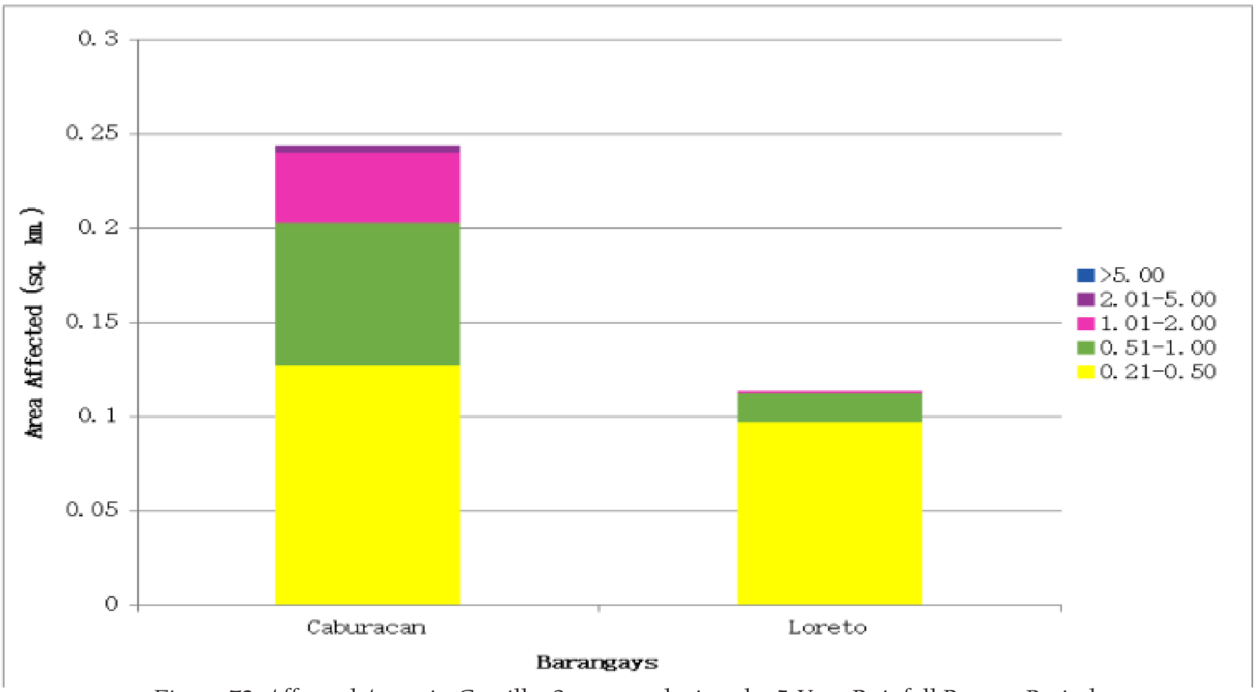


Figure 72. Affected Areas in Castilla, Sorsogon during the 5-Year Rainfall Return Period

For the municipality of Pilar, with an area of 196.62 sq. km., 11.43% will experience flood levels of less than 0.20 meters. 0.82% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.74%, 0.76%, 0.58%, and 12.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Pilar, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Pilar, Sorsogon during a 5-year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)								
	Abas	Banuyo	Bayasaong	Binanuahan	Calongay	Calpi	Dao	Ginablan	Inang
0.03-0.20	1.00032	0.63	2.43	1.38	1.89	5.59	0.0105	8.80	0.036
0.21-0.50	0.025	0.046	0.053	0.097	0.10	0.34	0	0.34	0.00048
0.51-1.00	0.026	0.0071	0.0509	0.045	0.089	0.29	0.000029	0.36	0.00030
1.01-2.00	0.039	0	0.072	0.013	0.039	0.26	0	0.54	0.00042
2.01-5.00	0.03	0	0.23	0.0004	0.0084	0.11	0	0.64	0
> 5.00	0.0025	0	0.081	0	0	0.0043	0	0.16	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)								
	Mabanate	Malbog	Marifosque	Palanas	Pangpang	Pineda	Sacnangan	San Jose	San Rafael
0.03-0.20	1.62	3.28	0.055	4.402	1.97	6.77	2.36	0.28	0.2009
0.21-0.50	0.034	0.12	0.018	0.16	0.065	0.25	0.066	0.0065	0.0074
0.51-1.00	0.026	0.083	0.000522	0.15	0.070	0.202	0.067	0.0060	0.001007
1.01-2.00	0.047	0.073	0	0.15	0.086	0.14	0.087	0.0067	0.0004
2.01-5.00	0.039	0.13	0	0.045	0.048	0.039	0.22	0.0026	0
> 5.00	0	0.00021	0	0.001	0.0003	0.0009	0.11	0	0

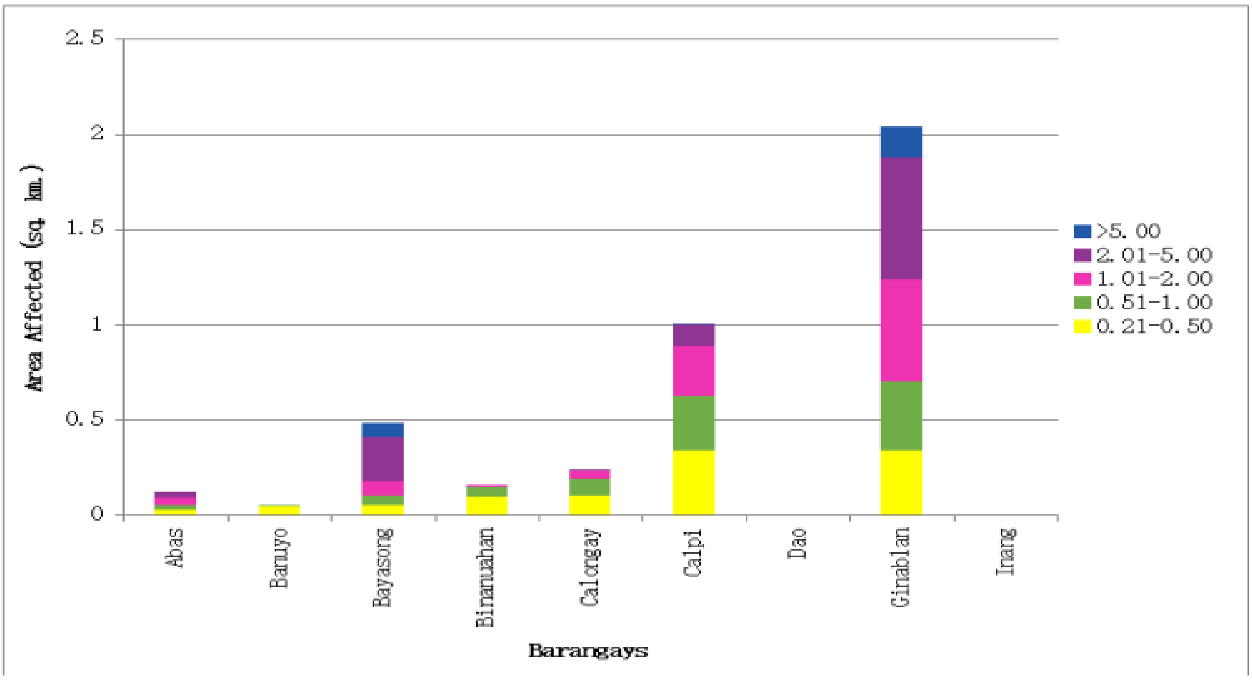


Figure 73. Affected Areas in Pilar, Sorsogon during the 5-Year Rainfall Return Period

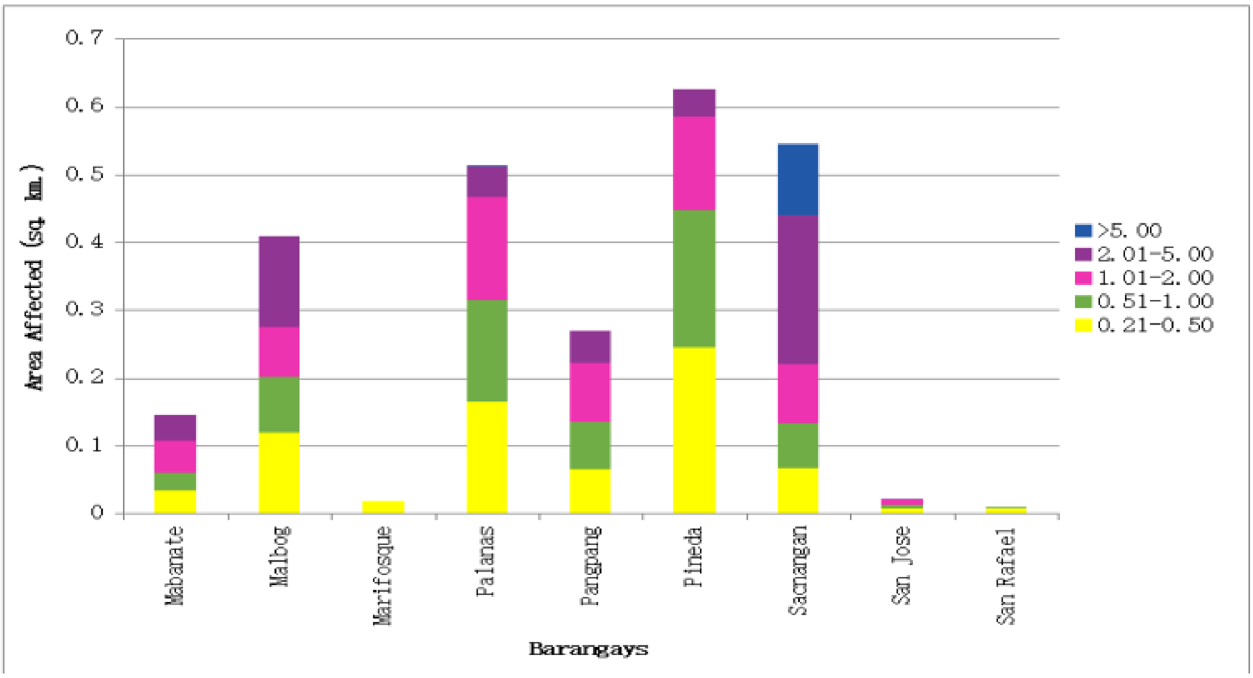


Figure 74. Affected Areas in Pilar, Sorsogon during the 5-Year Rainfall Return Period

For the 25-year rainfall return period, 2.19% of the municipality of Castilla, with an area of 197.27 sq. km., will experience flood levels of less than 0.20 meters. 0.14% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.06%, 0.03%, and 0.007% 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. Table 39 depicts the areas affected in Castilla, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Castilla, Sorsogon during a 25-year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Castilla (in sq. km.)	
	Caburacan	Loreto
0.03-0.20	2.93	1.39
0.21-0.50	0.13	0.14
0.51-1.00	0.095	0.025
1.01-2.00	0.051	0.0034
2.01-5.00	0.013	0
> 5.00	0	0

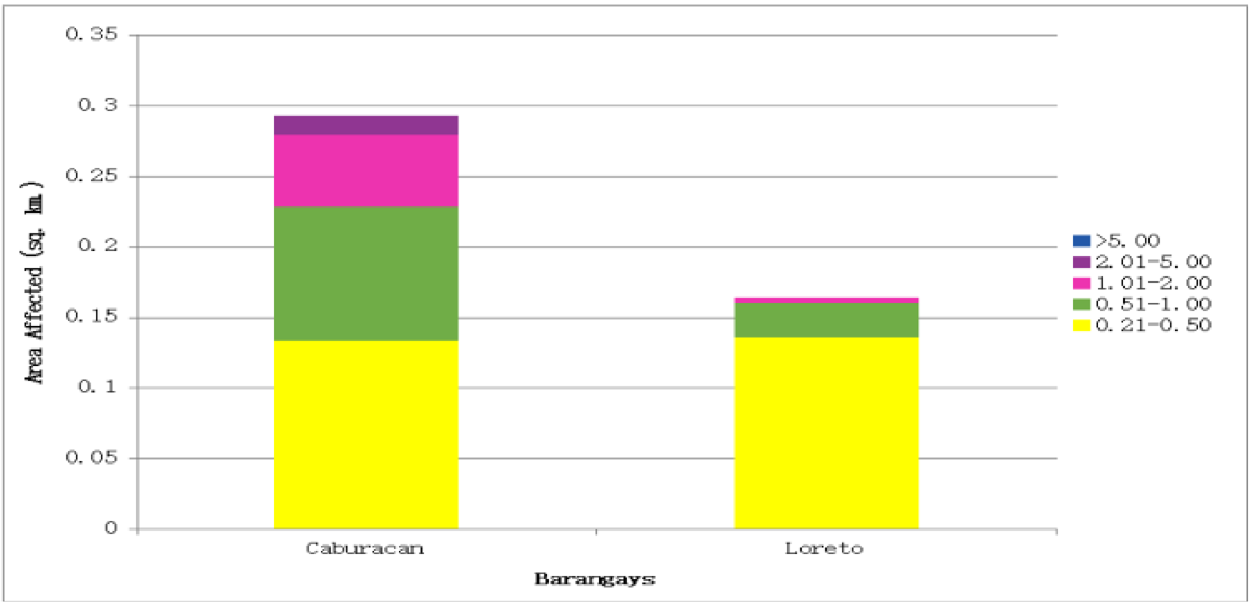


Figure 75. Affected Areas in Castilla, Sorsogon during the 25-Year Rainfall Return Period

For the municipality of Pilar, with an area of 196.62 sq. km., 11% will experience flood levels of less than 0.20 meters. 0.77% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.8%, 0.89%, 0.97%, and 12.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 40 depicts the areas affected in Pilar, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Pilar, Sorsogon during a 25-year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)								
	Abas	Banuyo	Bayasaong	Binanuahan	Calongay	Calpi	Dao	Ginablan	Inang
0.03-0.20	0.97	0.6	2.34	1.32	1.81	5.28	0.0105	8.48	0.035
0.21-0.50	0.024	0.065	0.061	0.12	0.090	0.24	0.000028	0.301	0.00073
0.51-1.00	0.024	0.014	0.051	0.070	0.086	0.30	0.000029	0.31	0.00040001
1.01-2.00	0.034	0.00017	0.059	0.024	0.13	0.43	0	0.45	0.00022
2.01-5.00	0.065	0	0.13	0.0012	0.020	0.33	0	1.0063	0.0003
> 5.00	0.0038	0	0.27	0	0	0.012	0	0.29	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)								
	Mabanate	Malbog	Marifosque	Palanas	Pangpang	Pineda	Sacnangan	San Jose	San Rafael
0.03-0.20	1.59	3.19	0.050	4.29	1.92	6.63	2.27	0.28	0.20
0.21-0.50	0.037	0.14	0.018	0.18	0.069	0.26	0.069	0.0067	0.0101
0.51-1.00	0.028	0.090	0.0048	0.15	0.069	0.19	0.067	0.0064	0.00107
1.01-2.00	0.043	0.088	0	0.18	0.099	0.21	0.077	0.0087	0.0008
2.01-5.00	0.065	0.097	0	0.106	0.084	0.11	0.16	0.0033	0
> 5.00	0	0.085	0	0.0038	0.0007	0.0012	0.26	0	0

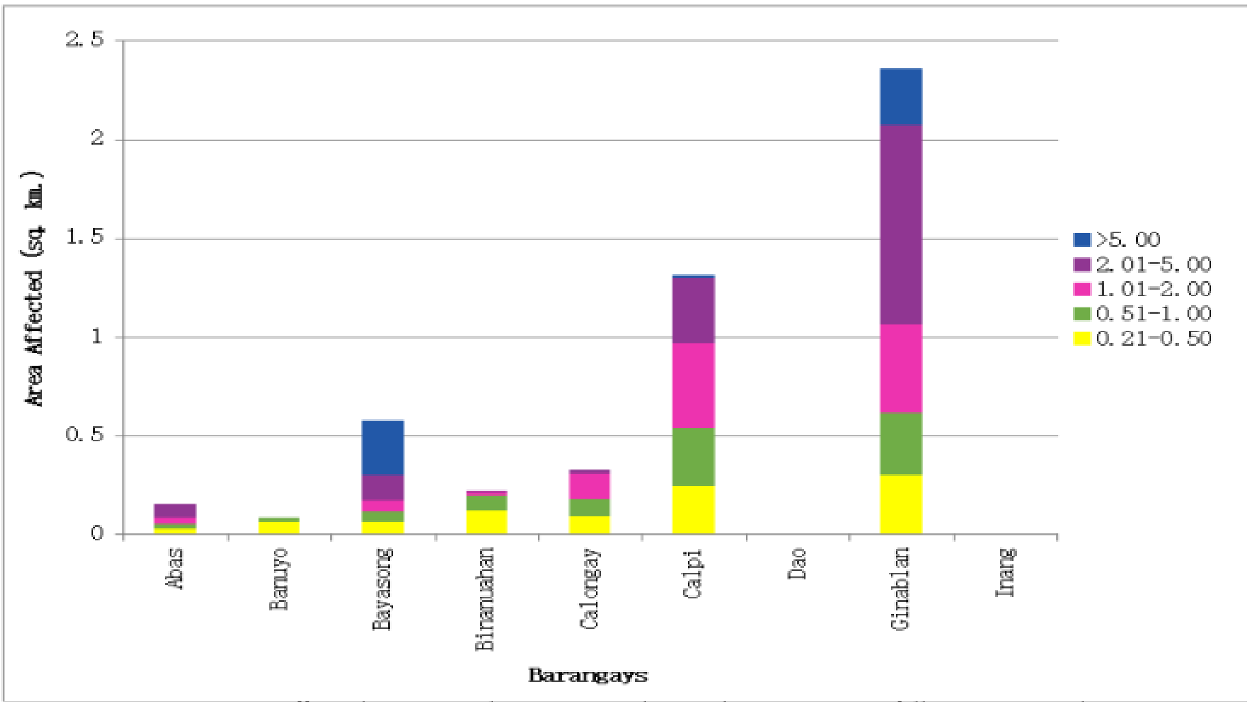


Figure 76. Affected Areas in Pilar, Sorsogon during the 25-Year Rainfall Return Period

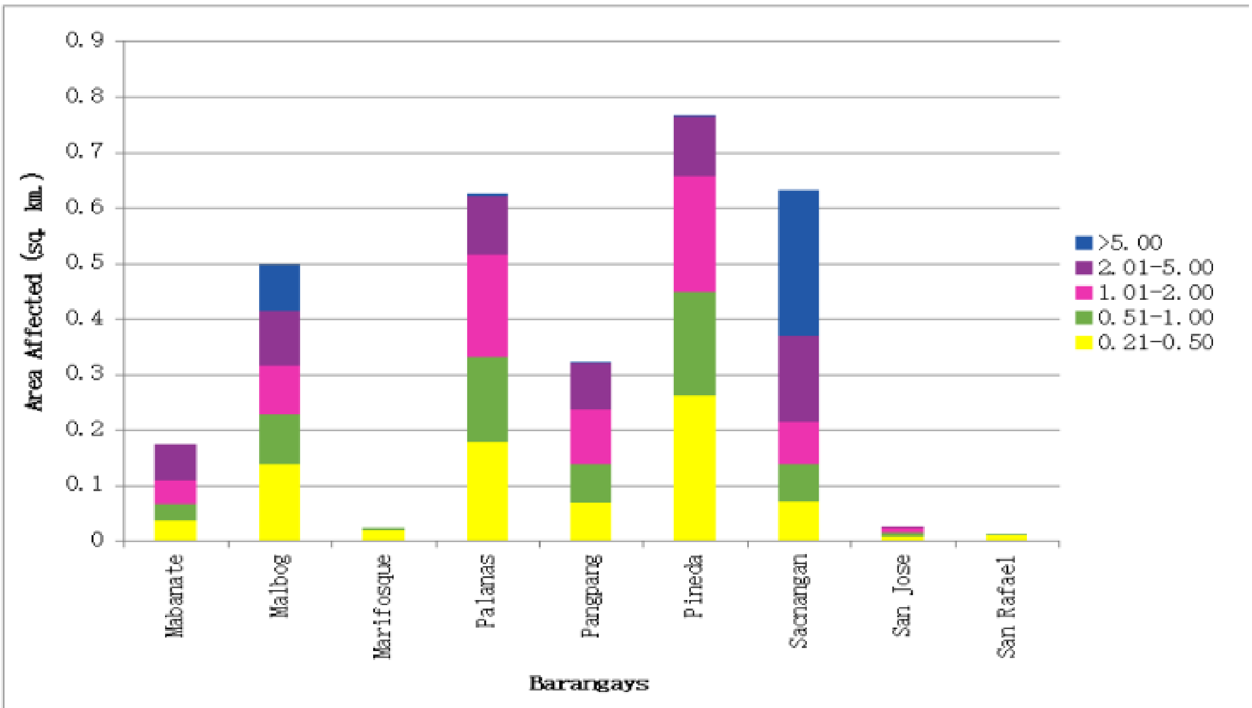


Figure 77. Affected Areas in Pilar, Sorsogon during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 2.15% of the municipality of Castilla, with an area of 197.27 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 0.08%, 0.04%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Table 41 depicts the areas affected in Castilla, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Castilla, Sorsogon during a 100-year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Castilla (in sq. km.)	
	Caburacan	Loreto
0.03-0.20	2.89	1.35
0.21-0.50	0.14	0.16
0.51-1.00	0.11	0.0404
1.01-2.00	0.064	0.0070
2.01-5.00	0.022	0
> 5.00	0	0

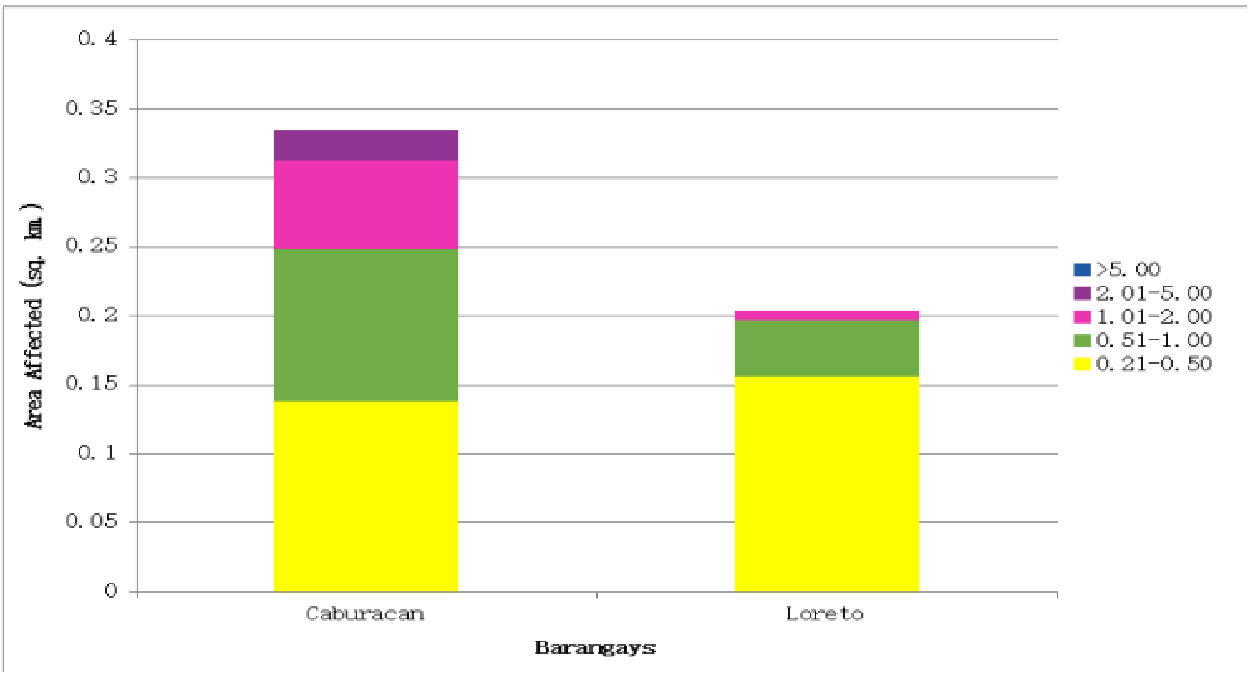


Figure 78. Affected Areas in Castilla, Sorsogon during the 100-Year Rainfall Return Period

For the municipality of Pilar, with an area of 196.62 sq. km., 10.77% will experience flood levels of less than 0.20 meters. 0.78% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.82%, 0.94%, 1.12%, and 12.45% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 42 depicts the areas affected in Pilar, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in Pilar, Sorsogon during a 100-year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)								
	Abas	Banuyo	Bayasaong	Binanuahan	Calongay	Calpi	Dao	Ginablan	Inang
0.03-0.20	0.96	0.58	2.27	1.29	1.76	5.14	0.0105	8.28	0.035
0.21-0.50	0.024	0.079	0.062	0.12	0.080	0.22	0.000028	0.28	0.00073
0.51-1.00	0.021	0.020	0.051	0.088	0.10	0.26	0.000029	0.31	0.00050
1.01-2.00	0.029	0.00047	0.066	0.034	0.15	0.39	0	0.44	0.00032
2.01-5.00	0.079	0	0.11	0.0016	0.042	0.51	0	0.98	0.0003
> 5.00	0.0102	0	0.36	0	0.0001	0.067	0	0.54	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)								
	Mabanate	Malbog	Marifosque	Palanas	Pangpang	Pineda	Sacnangan	San Jose	San Rafael
0.03-0.20	1.57	3.11	0.048	4.21	1.88	6.53	2.203	0.28	0.20
0.21-0.50	0.038	0.15	0.012	0.19	0.070	0.28	0.071	0.0077	0.0105
0.51-1.00	0.033	0.107	0.013	0.16	0.073	0.20	0.065	0.0063	0.0023
1.01-2.00	0.044	0.103	0	0.19	0.102	0.22	0.081	0.0086	0.0008
2.01-5.00	0.075	0.068	0	0.16	0.11	0.16	0.16	0.0051	0
> 5.00	0.0019	0.15	0	0.0048	0.0011	0.0014	0.32	0.0001	0

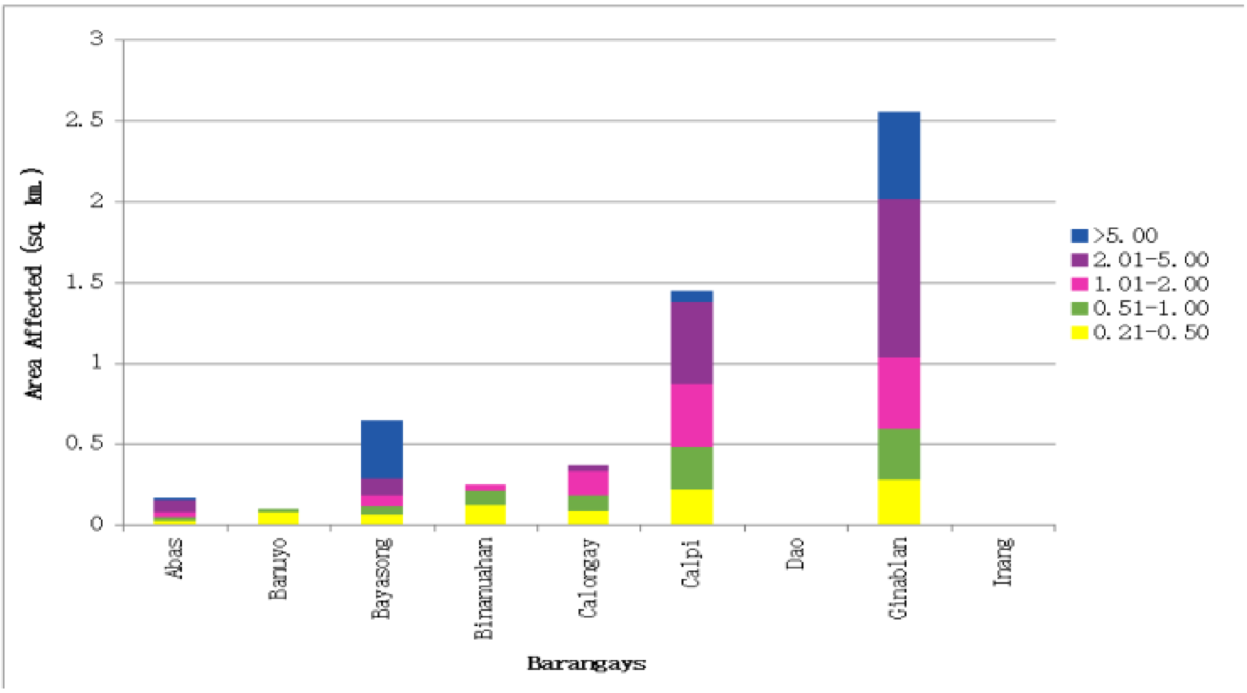


Figure 79. Affected Areas in Pilar, Sorsogon during the 100-Year Rainfall Return Period

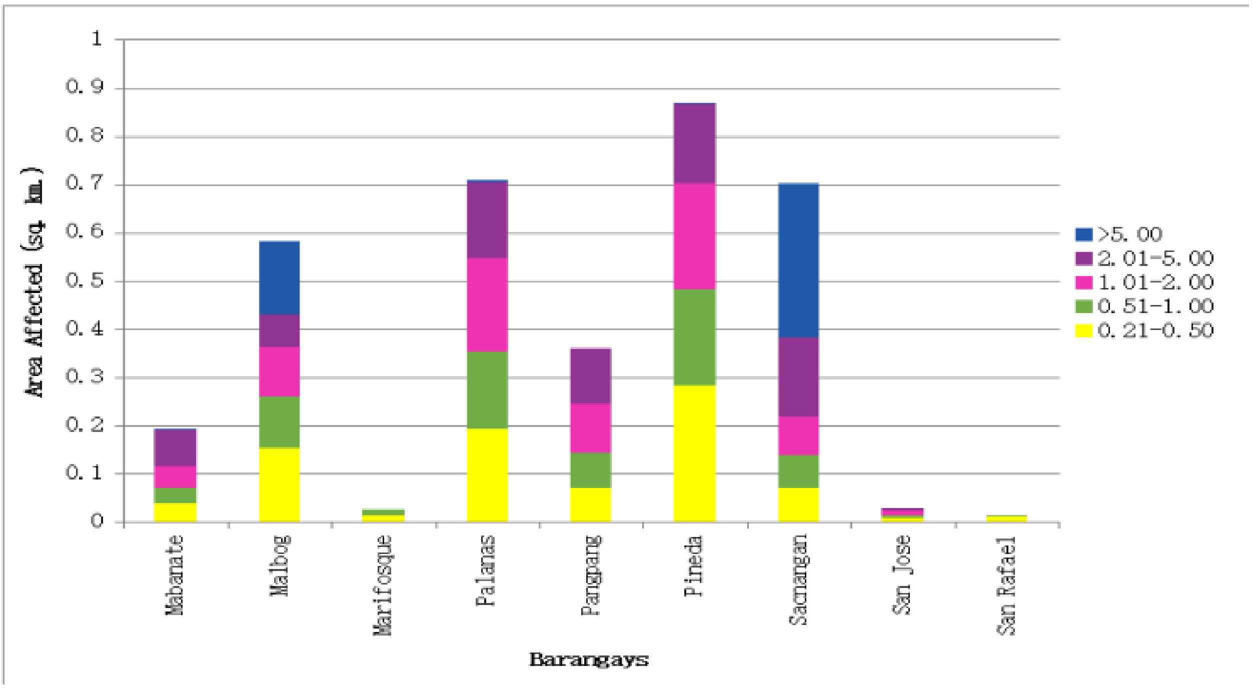


Figure 80. Affected Areas in Pilar, Sorsogon during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Castilla, Caburacan is projected to have the highest percentage of area that will experience flood levels at 1.63%. Meanwhile, Loreto posted the second highest percentage of area that may be affected by flood depths, at 0.79%.

Among the barangays in the municipality of Pilar, Ginablan is projected to have the highest percentage of area that will experience flood levels at 5.49%. Meanwhile, Calpi posted the second highest percentage of area that may be affected by flood depths, at 3.34%.

The generated flood hazard maps for the Putiao floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Annex 12 and Annex 13 present the educational and health institutions exposed to flooding, respectively.

Using the flood depth units of PAGASA for the hazard maps – “Low”, “Medium”, and “High” – the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-year, 25-year, 100-year).

Table 43. Area covered by each warning level with respect to rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	9.77	9.96	10.06
Medium	10.81	12.96	14.31
High	4.91	8.55	11.14
TOTAL	**25.49**	**31.47**	**35.51**

None of the twelve (12) identified educational institutions in the Putiao floodplain was assessed to be exposed to any flood level (Low, Medium, or High) in all of the flood hazard scenarios (5-, 25-, and 100-year).

The lone identified medical institution in the Putiao floodplain was also assessed to be unexposed to any flood level (Low, Medium, or High) in all of the flood hazard scenarios (5-, 25-, and 100-year).

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data, to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood maps. The points in the flood map versus the corresponding validation depths are illustrated in Figure 79.

The flood validation consists of 121 points randomly selected all over the Putiao floodplain. It has an RMSE value of 1.659691901. The validation points are found in Annex 11.

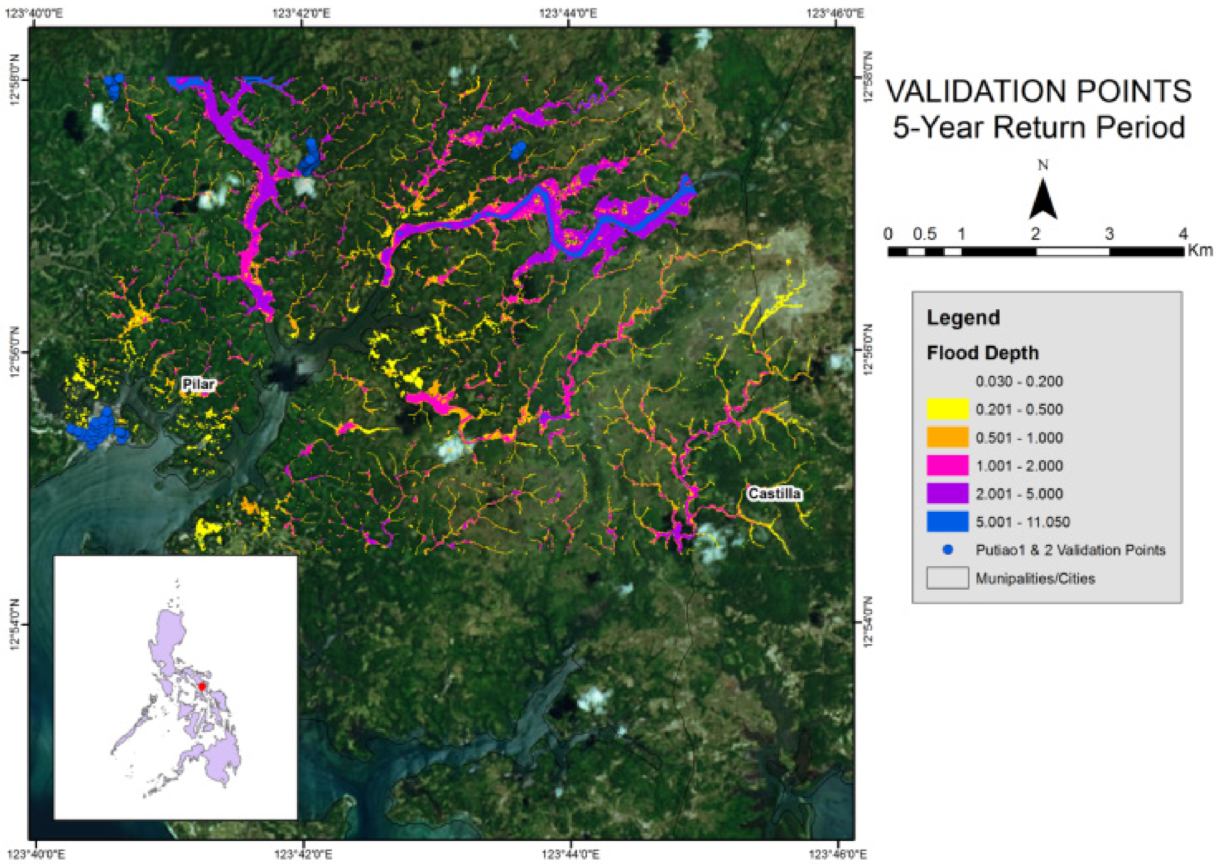


Figure 81. The validation points for the 5-Year flood depth map of the Putiao Floodplain

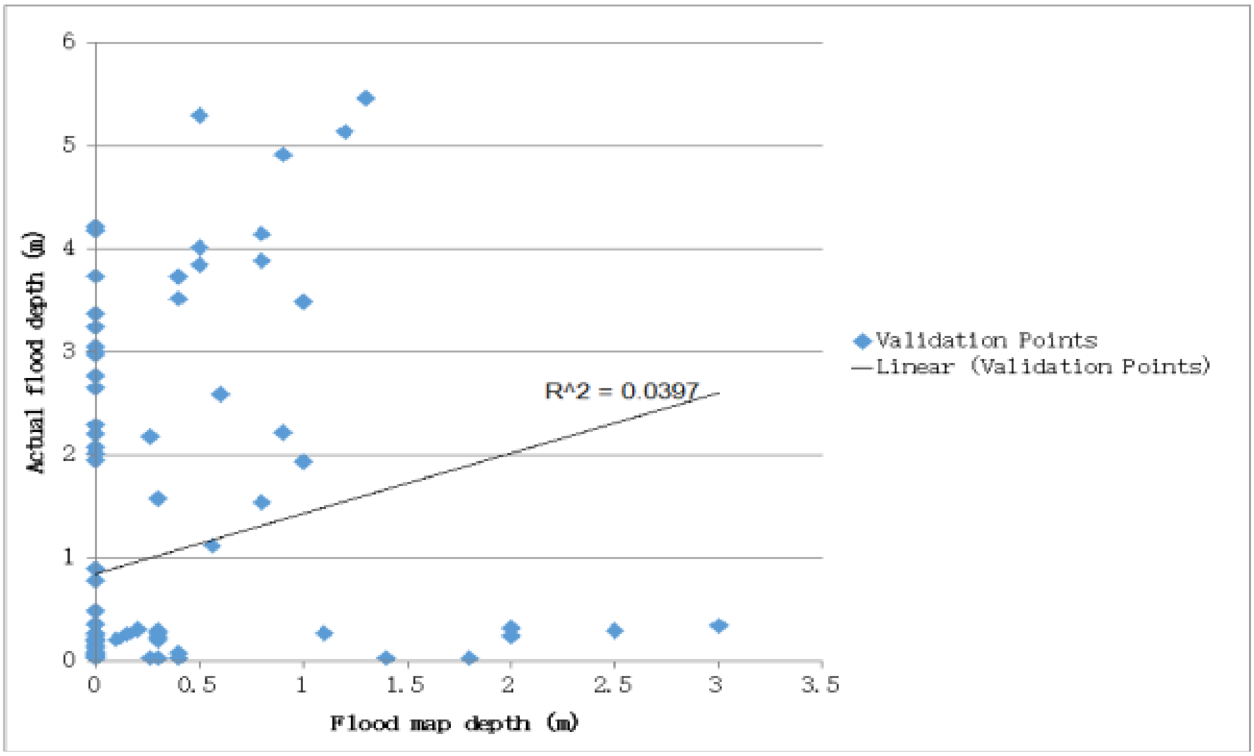


Figure 82 . Flood map depth vs actual flood depth

Table 44. Actual flood vs. simulated flood depth at different levels in Putiao 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	68	10	2	1	19	0	100
0.21-0.50	7	3	0	1	5	1	17
0.51-1.00	0	7	0	4	6	0	10
1.01-2.00	2	5	3	0	0	2	7
2.01-5.00	0	2	1	0	0	0	2
> 5.00	0	0	0	0	0	0	0
Total	77	18	2	6	30	3	136

The overall accuracy generated by the flood model is estimated at 52.21%, with seventy-one (71) points correctly matching the actual flood depths. In addition, there were twenty-one (21) points estimated one (1) level above and below the correct flood depths; fourteen (14) points estimated two (2) levels above and below; and thirty (30) points estimated three (3) or more levels above and below the correct flood depths. A total of fifty-one (51) points were overestimated, while a total of fourteen (14) points were underestimated in the modeled flood depths of Putiao. Table 41 depicts the summary of the accuracy assessment in the Putiao River Basin survey.

Table 45. The Summary of Accuracy Assessment in the Putiao River Basin Survey

	No. of Points	%
Correct	71	52.21
Overestimated	51	37.50
Underestimated	14	10.29
Total	136	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. Technical Specifications of the Gemini LIDAR Sensor used in the Putiao Floodplain Survey

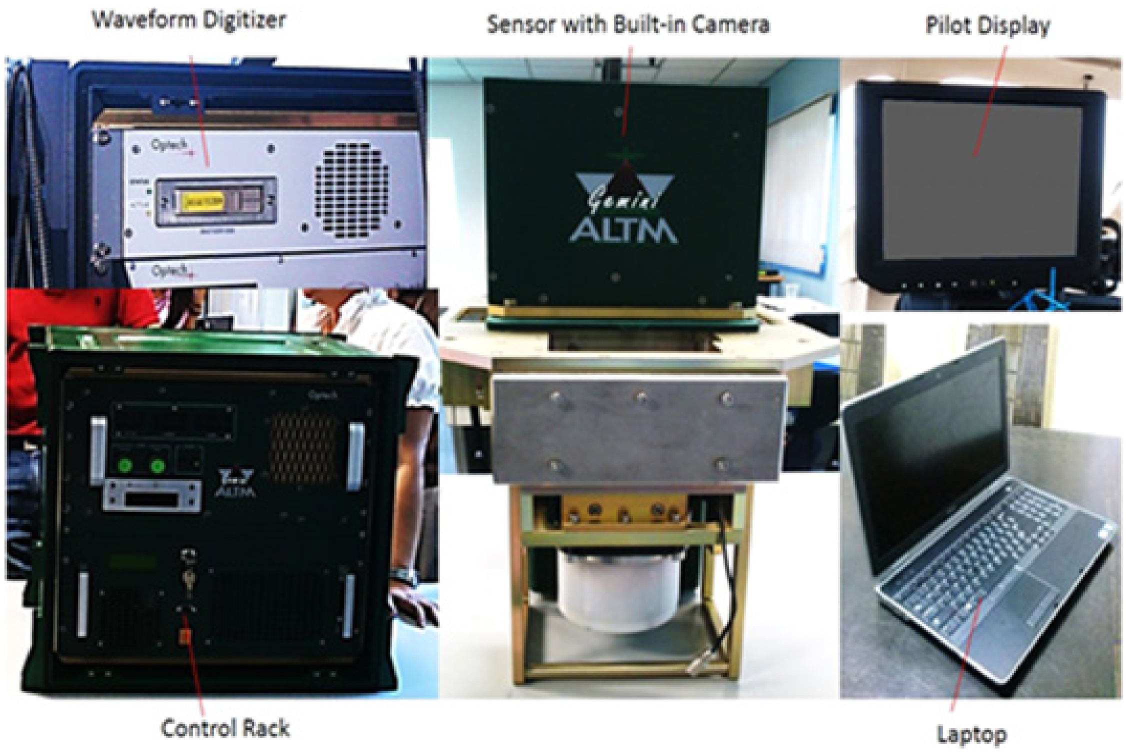


Figure A-1.1 Gemini Sensor

Table A-1.1 Parameters and Specifications of the Gemini Sensor

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

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

1. ABY-92

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ALBAY**
Station Name: **ABY-92**
Order: **2nd**

Island: **LUZON** Municipality: **CITY OF LIGAO**		Barangay: **ALLANG**
	PRS92 Coordinates	
Latitude: **13° 11' 56.27238"**	Longitude: **123° 27' 47.60156"**	Ellipsoidal Hgt: **127.30900 m.**
	WGS84 Coordinates	
Latitude: **13° 11' 51.38974"**	Longitude: **123° 27' 52.59990"**	Ellipsoidal Hgt: **180.74900 m.**
	PTM Coordinates	
Northing: **1459605.458 m.**	Easting: **550210.89 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,459,094.57**	Easting: **550,193.31**	Zone: **51**

Location Description

ABY-92
From Ligao City Hall, travel towards Brgy. Allang for about 13 km. Upon reaching Allang Brgy. Hall, walk for about 20 m. to reach the station. Station is located beside the baseline of the basketball court, about 19 m. from the said brgy. hall. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "ABY-92 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-833**

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

9 9 0 4 1 0 2 0 1 4 1 4 0 4 1 0

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 ABY-92

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

1. LPH - 01

LPH-01 - ABY-09 (9:36:54 AM-12:39:19 PM) (S1)

Baseline observation:	LPH-01 --- ABY-09 (B1)
Processed:	4/14/2014 8:54:10 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.003 m
RMS:	0.001 m
Maximum PDOP:	2.071
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	3/29/2014 9:37:04 AM (Local: UTC+8hr)
Processing stop time:	3/29/2014 12:39:19 PM (Local: UTC+8hr)
Processing duration:	03:02:15
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	ABY-09				
Grid		Local		Global	
Easting	579204.817 m	Latitude	N13°09'06.53800"	Latitude	N13°09'06.53800"
Northing	1454039.532 m	Longitude	E123°43'50.95900"	Longitude	E123°43'50.95900"
Elevation	15.448 m	Height	68.754 m	Height	68.754 m

To:	LPH-01				
Grid		Local		Global	
Easting	580467.016 m	Latitude	N13°09'08.50554"	Latitude	N13°09'08.50554"
Northing	1454103.670 m	Longitude	E123°44'32.88949"	Longitude	E123°44'32.88949"
Elevation	11.957 m	Height	65.236 m	Height	65.236 m

Vector					
ΔEasting	1262.199 m	NS Fwd Azimuth	87°15'26"	ΔX	-1040.600 m
ΔNorthing	64.138 m	Ellipsoid Dist.	1264.234 m	ΔY	-715.619 m
ΔElevation	-3.491 m	ΔHeight	-3.518 m	ΔZ	58.079 m

Standard Errors

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

2

Figure A-3.1 Baseline Processing Report - A

Annex 4. The LIDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, DR.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. LOUIE P. BALICANTA	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
		CHRISTOPHER JOAQUIN	UP-TCAGP
	Research Associates (RA)	LARAH KRISELLE PARAGAS	UP-TCAGP
		MA. VERLINA E. TONGA	
		MILLIE SHANE REYES	
		IRO NIEL ROXAS	
		KRISTINE ANDAYA	
		JERIEL PAUL ALAMBAN	
Ground Survey, Data Download and Transfer	Research Associates (RA)	KENNETH QUISADO	UP-TCAGP
		JASMIN DOMINGO	
		LANCE KERWIN CINCO	
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJIE CARBOLLEDO	PAF
	Pilots	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR ALFONSO III	AAC
		CAPT. RAUL CZ SAMAR II	AAC

Annex 5. Data Transfer Sheet for Putiao Floodplain

DATA TRANSFER SHEET
4/21/2014(ALBAY-SORSOGON)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS (KB)	POS (MB)	RAW IMAGES/ CASI (GB)	MISSION LOG FILE (KB)	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath in KB)							BASE STATIONS (MB)	Base Info (.txt)		Actual (KB)	KML	
Mar 29, 2014	7156GC	2BLK19E088A	GEMINI	NA	60	107	96.4	12.2	25/46KB	4.55	NA	7.33	1KB	1KB	41	7	Z:\Airborne_Raw\7156GC
Mar 30, 2014	7158GC	2BLK19ES089A & 2BLK19G089A	GEMINI	NA	400	666	266	20.2	49.7	30.1	NA	10.1	1KB	1KB	275	11	Z:\Airborne_Raw\7158GC
Mar 31, 2014	7160GC	2BLK19I90A	GEMINI	NA	9.18	58.5	71.4	NA	NA	2.89	NA	7.45	1KB	NA	3	NA	Z:\Airborne_Raw\7160GC
Mar 31, 2014	7161GC	2BLK19IS090B	GEMINI	NA	187	312	136	51.2	71.63/28.7	14.2	NA	4.18	1KB	1KB	129	7	Z:\Airborne_Raw\7161GC
Apr 2, 2014	7165G 7164GC	2BLK19CS092A	GEMINI	NA	149	260	120	40.1	70.4	11.3	NA	5.89	1KB	1KB	102	7	Z:\Airborne_Raw\7164GC
Apr 3, 2014	7167 7166GC	2BLK19K093A & 2BLK10IS093A	GEMINI	NA	677	550	222	93.5	106	25.5	NA	7.6	1KB	1KB	233	13	Z:\Airborne_Raw\7166GC
Apr 4, 2014	7168GC	2BLK19L094A	GEMINI	NA	90.5	485	193	54.6	142	22.4	NA	10.9	1KB	1KB	204	NA	Z:\Airborne_Raw\7168GC
Apr 4, 2014	7169GC	2BLK19B094B	GEMINI	NA	59.2	398	172	73.4	104	17.9	NA	11.1	1KB	1KB	137	10	Z:\Airborne_Raw\7169GC
Apr 5, 2014	7171GC	2BLK19M095A	GEMINI	NA	62.1	340	166	30.3	88.5	14.5	NA	11.6	1KB	1KB	257	NA	Z:\Airborne_Raw\7171GC
Apr 6, 2014	7172GC	2BLK19CS & 2BLKD096A	GEMINI	NA	560	674	263	NA	NA	30.9	NA	12.2	1KB	1KB	384	13	Z:\Airborne_Raw\7172GC

Received from

Name CHRIS V DADULAN

Position RA

Signature

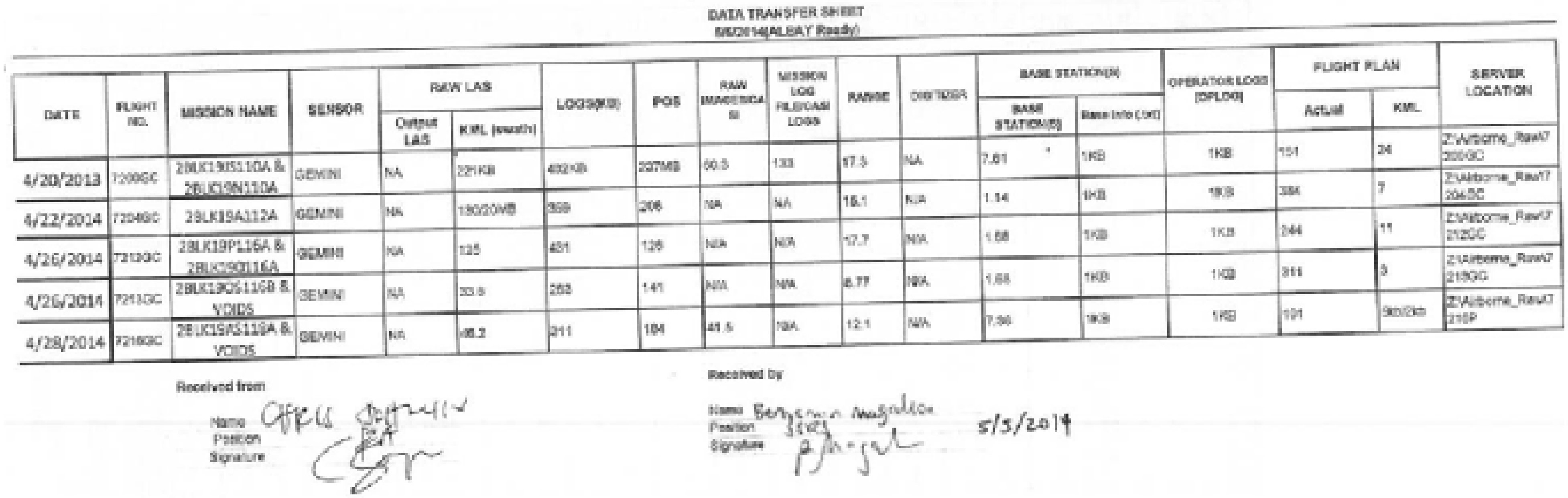
Received by

Name JENNIFER B. SAGUKAN

Position RA

Signature /04/21/2014

Figure A-5.1 Data Transfer Sheet for Putiao Floodplain - A



DATA TRANSFER SHEET
5/5/2014(ALBAY Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/20/2013	7200GC	2BLK19XS110A & 2BLK19N110A	GEMINI	NA	221KB	492KB	237MB	60.3	133	17.5	NA	7.61	1KB	1KB	151	24	Z:\Airborne_Raw\7200GC
4/22/2014	7204GC	2BLK19A112A	GEMINI	NA	180/20MB	359	206	NA	NA	16.1	N/A	1.14	1KB	1KB	384	7	Z:\Airborne_Raw\7204GC
4/26/2014	7212GC	2BLK19P116A & 2BLK19O116A	GEMINI	NA	125	451	126	N/A	N/A	17.7	N/A	1.68	1KB	1KB	244	11	Z:\Airborne_Raw\7212GC
4/26/2014	7213GC	2BLK19OS116B & VOIDS	GEMINI	NA	33.9	283	141	N/A	N/A	6.77	N/A	1.68	1KB	1KB	311	3	Z:\Airborne_Raw\7213GC
4/28/2014	7218GC	2BLK19AS119A & VOIDS	GEMINI	NA	68.2	211	184	41.5	NA	12.1	N/A	7.36	1KB	1KB	191	9kb/2kb	Z:\Airborne_Raw\7218P

Received from
Name
Position
Signature

Received by
Name Benjamin Magallon
Position
Signature
5/5/2014

Figure A-5.2 Data Transfer Sheet for Putiao Floodplain - B

DATA TRANSFER SHEET
ALBAY/SORSOGON 3/2/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
15-Feb-16	3813G	2BLK19BS 56B	GEMINI	NA	666	1.12	202	66.8	538	26.8	NA	5.61	1KB	2KB	34/33/40/36/ 12/11/12/12	NA	Z:\DAC\RAW DATA
26-Feb-16	3815G	2BLK19KS LS57A	GEMINI	NA	537	11.3	209	51.6	323	22.1	NA	7.02	1KB	1KB	12/9/9/9	NA	Z:\DAC\RAW DATA

Received from

Name M. Punto
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 5/4/2016

Figure A-5.3 Data Transfer Sheet for Putiao Floodplain - C

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 7156GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7156

1 LIDAR Operator: MVE Tongga	2 ALTM Model: GEMTCAS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R SAMAR II	8 Co-Pilot: CS ALFONSO III	9 Route:			
10 Date: 3-29-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 10+45	14 Engine Off: 12+56	15 Total Engine Time: 2+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Surveyed 3 lines (with CAS1)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Matira	B. Caballero	R. SAMAR II	MVE Tongga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for Mission 7156GC

2. Flight Log for 7158GC Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 7158

1 LiDAR Operator: MVETONGA	2 ALTM Model: Gemini & CAS1	3 Mission Name: 2BLK19ES089A & 2BLK19G089A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: R. SAMAR	8 Co-Pilot: CC ALFONSO	9 Route: RPLP - RPLP			
10 Date: 3-30-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 8+59	14 Engine Off: 13+28	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
AUBREY MATIRA	[illegible]	R. CAMAR [illegible]	MVE TONGA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for Mission 7158GC

3. Flight Log for 7160GC Mission

DREAM Data Acquisition Flight Log Gemini

Flight Log No.: 7160

1 LiDAR Operator: MVE Tonga	2 ALTM Model: CASI	3 Mission Name: 2BLK19TC090A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. SAMAR	8 Co-Pilot: CS ALFONSO	9 Route: RPLP - RPLP			
10 Date: 3-31-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 7+57	14 Engine Off: 9+32	15 Total Engine Time: 1+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Surveyed 1 line (without CASI)					

21 Problems and Solutions:

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

Figure A-6.3 Flight Log for Mission 7160GC

4. Flight Log for 7161GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7161

1 LiDAR Operator: MVE Tongga	2 ALTM Model: GemCASI	3 Mission Name: 2BLK19I50908	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C Alfonso IV	9 Route:			
10 Date: 3-31-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 15+8	14 Engine Off: 17+37	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				
20 Remarks: Successful flight; Surveyed 6 lines (with CASI)					

21 Problems and Solutions:

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

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

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

Lidar Operator
MVE Tongga
Signature over Printed Name

Figure A-6.4 Flight Log for Mission 7161GC

5. Flight Log for 7167GC Mission

DREAM Data Acquisition Flight Log 2BLK19K093A **Flight Log No.:** 7/

1 LiDAR Operator: MVE Tongga	2 ALTM Model: Gemini CAS/	3 Mission Name: 2BLK19K15 093A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: CS Alfonso III	9 Route:			
10 Date: 4-3-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 13+31	14 Engine Off: 17+24	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. MATIRA		R. SAMAR II	MVE Tongga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for Mission 7167GC

6. Flight Log for 7168GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7168

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini/CAS	3 Mission Name: 2BLK19L094A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route:			
10 Date: 4-4-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 7+58	14 Engine Off: 11+27	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission completed

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Matira	B. Castillo	R. Samar II	L. Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6 Flight Log for Mission 7168GC

7. Flight Log for 7213GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7213

1 LIDAR Operator: L Paragas	2 ALTM Model: CASI	3 Mission Name: 2BLK05I16B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9302
7 Pilot: R. SAMAR	8 Co-Pilot: C7 ALFONSO	9 Route: RPLP - RPLP			
10 Date: 4-26-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 1458H	14 Engine Off: 1733H	15 Total Engine Time: 2+35	16 Take off: 1501H	17 Landing: 1729H	18 Total Flight Time: 2+28
19 Weather: Cloudy					

20 Remarks:

Mission Completed without CASI (BLK 19 0)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Matin	A. Sarballedo	R. SAMAR	L Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7 Flight Log for Mission 7213GC

8. Flight Log for 7216GC Mission

DREAM Data Acquisition Flight Log Gemini

Flight Log No.: 7216

1 LiDAR Operator: MV Tonga	2 ALTM Model: CASI	3 Mission Name: 2BLK19A S118A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: OS Alfonso	9 Route: RPLP - RPLP			
10 Date: 4-28-14	12 Airport of Departure (Airport, City/Province): RPLP		12 Airport of Arrival (Airport, City/Province): RPLP		
13 Engine On: 0633H	14 Engine Off: 0944H	15 Total Engine Time: 3+11	16 Take off: 0638H	17 Landing: 0949 H	18 Total Flight Time: 3+03
19 Weather					
20 Remarks: Mission completed including voids (with CASI) BLK19A					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
A. Matira	B. Cartalledo	R. Samar	MVE Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.8 Flight Log for Mission 7216GC

9. Flight Log for 3813G Mission

DREAM | Data Acquisition Flight Log Flight Log No.: 3813

1 LIDAR Operator: MSREYES	2 ALTM Model: GEMINI	3 Mission Name: 2BLK19IS 056B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: J Mooney	8 Co-Pilot: D Cabudol	9 Route:			
10 Date: Feb 25 2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 1000	14 Engine Off: 1417	15 Total Engine Time: 4+17	16 Take off: 1005	17 Landing: 1412	18 Total Flight Time: 4+07
19 Weather	Cloudy with precipitation				

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
- ○ DREAM Admin Activities

21 Remarks

Surveyed blk 19IS & BLK 19KS

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
CHRIS [illegible]	[illegible] CABALLERO	[illegible]	MS REYES	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-6.9 Flight Log for Mission 3813GC

10. Flight Log for 3815G Mission

DREAM | Data Acquisition Flight Log — Flight Log No.: 3815

1 LiDAR Operator: J ALAMBAN	2 ALTM Model: Gemini	3 Mission Name: 2BLK19KS L557A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: J Mooney	8 Co-Pilot: D Cabudol	9 Route:			
10 Date: Feb 26, 2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 0903	14 Engine Off: 1238	15 Total Engine Time: 3+35	16 Take off: 0908	17 Landing: 1233	18 Total Flight Time: 3+25
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
- ○ DREAM Admin Activities

21 Remarks

Surveyed Blk 19K and 19L

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
CHRIS J. DAGOHOY IN	ENGR. CARBOLLEDO	J. Mooney	JF ALAMBAN	JJM
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-6.10 Flight Log for Mission 3815GC

Annex 7. Flight Status Reports

Albay and Sorsogon
March 26 - April 30, 2014 and February 24 - March 20, 2016

Table A-7.1 Flight Status Reports

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7156GC	BLK19E	2BLK19E088A	MVE TONGA	3/29/2014	Surveyed 3 lines (with CASI)
7158GC	BLK19EG	2BLK19ES089A & 2BLK19G089A	MVE TONGA	3/29/2014	Surveyed 3 lines (with CASI)
7160GC	BLK19I	2BLK19I90A	MVE TONGA	3/31/2014	Mission completed (with CASI)
7161GC	BLK19I	2BLK19IS090B	MVE TONGA	3/31/2014	Surveyed 6 lines (with CASI)
7167GC	BLK19KI	2BLK19K093A & 2BLK10IS093A	MVE TONGA	4/3/2014	Surveyed BLK19IS and half of BLK19KS
7168GC	BLK19L	2BLK19L094A	L. PARAGAS	4/04/2014	Mission completed (with CASI)
7213GC	BLK19O	2BLK19OS116B & VOIDS	L. PARAGAS	4/26/2014	Completed the rest of BLK19O and rest of void data (NO CASI)
7216GC	BLK19A	2BLK19AS118A & VOIDS	MVE TONGA	4/28/2014	Surveyed the rest of BLKA and the rest of void data (without CASI)
3813G	BLK19IS & BLK19KS	2BLK19IS056B	M. REYES	2/25/2016	Surveyed BLK19IS and half of BLK19KS
3815G	BLK19KL	2BLK19KLS057A	J. ALAMBAN	2/26/16	Surveyed rest of BLK19KS and BLK19LS

LAS/ SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	7156 GC
Area:	BLK19E
Mission Name:	2BLK19EO88A
Parameters:	Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 35 %

LAS/ SWATH

Figure A-7.1 Swath for Flight No. 7156GC

Flight No. :	7158 GC
Area:	BLK19E AND BLK19G
Mission name:	2BLK19ES089A & 2BLK19G089A
Parameters:	Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 35 %

LAS/ SWATH

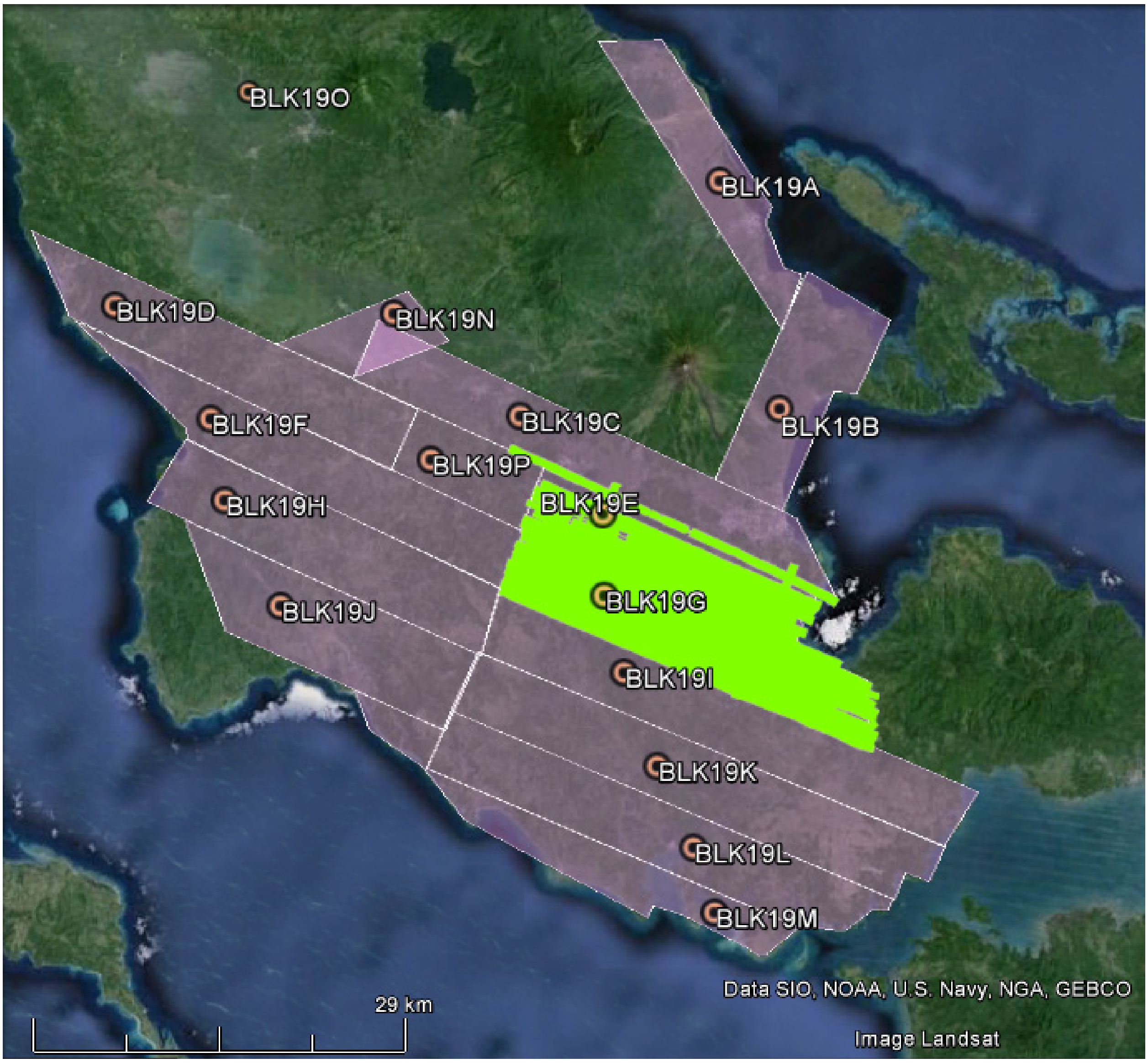


Figure A-7.2 Swath for Flight No. 7158GC

Flight No. :	7160 GC
Area:	BLK19I
Mission name:	2BLK19IS090A
Parameters:	Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 45 %

LAS/ SWATH

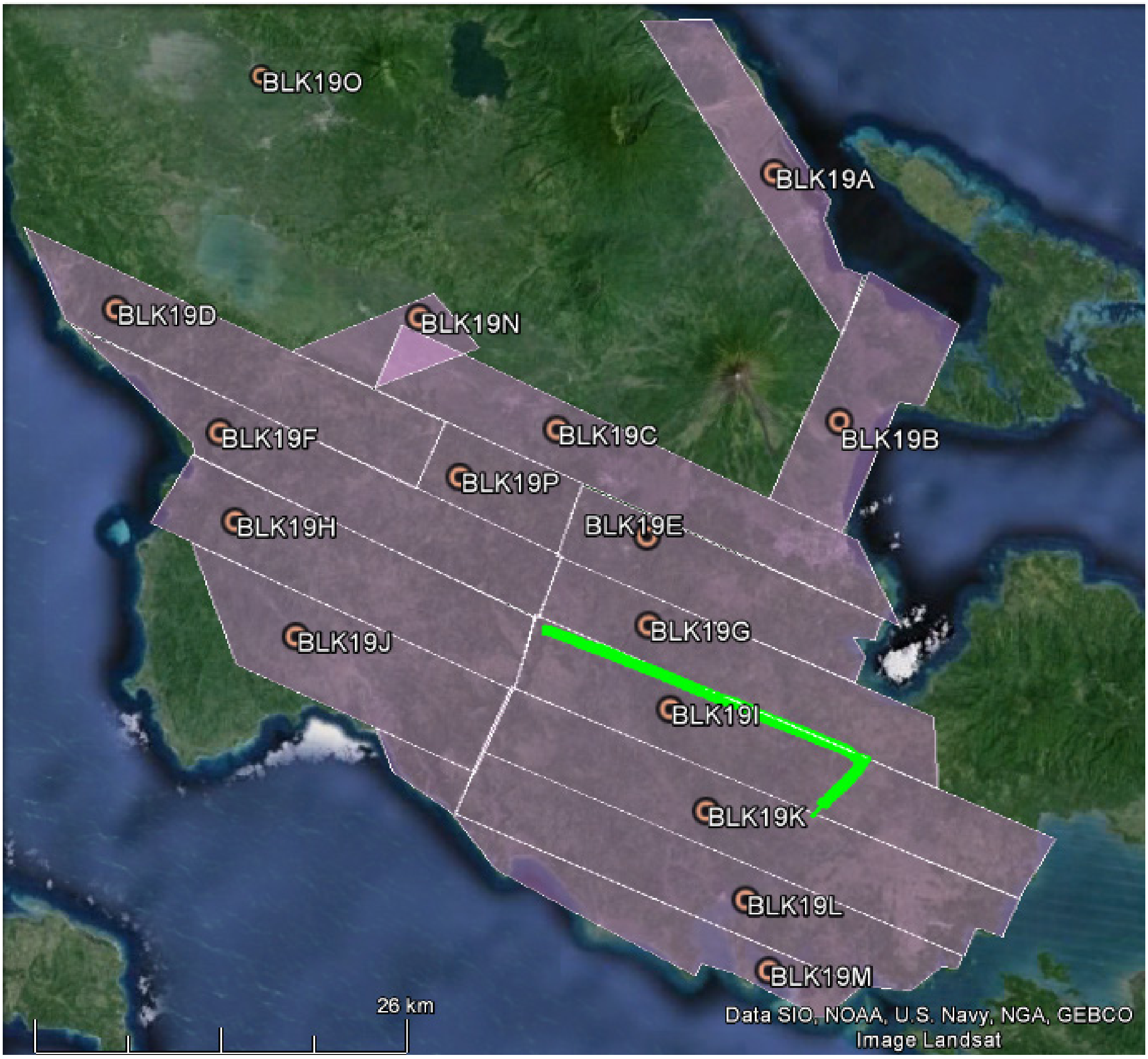


Figure A-7.3 Swath for Flight No. 7160GC

Flight No. :	7161 GC
Area:	BLK19I
Mission name:	2BLK19IS090B
Parameters:	Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 45 %

LAS/ SWATH

Figure A-7.4 Swath for Flight No. 7161GC

Flight No. :	7167 GC
Area:	BLK19K AND BLK19I
Mission name:	2BLK19K093A & 2BLK19IS093B
Parameters:	Altitude: 1000; Scan Frequency: 50; FOV: 40; Overlap: 40 %

LAS/ SWATH

Figure A-7.5 Swath for Flight No. 7167GC

Flight No. :	7168 GC
Area:	BLK19L
Mission name:	BLK19L
Parameters:	Altitude: 1100; Scan Frequency: 50; FOV: 40; Overlap: 40 %

LAS/ SWATH

Figure A-7.6 Swath for Flight No. 7168GC

Flight No. : 7213 GC
Area: BLK190
Mission name: 2BLK19OS116B & VOIDS
Parameters: Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30 %

LAS/ SWATH

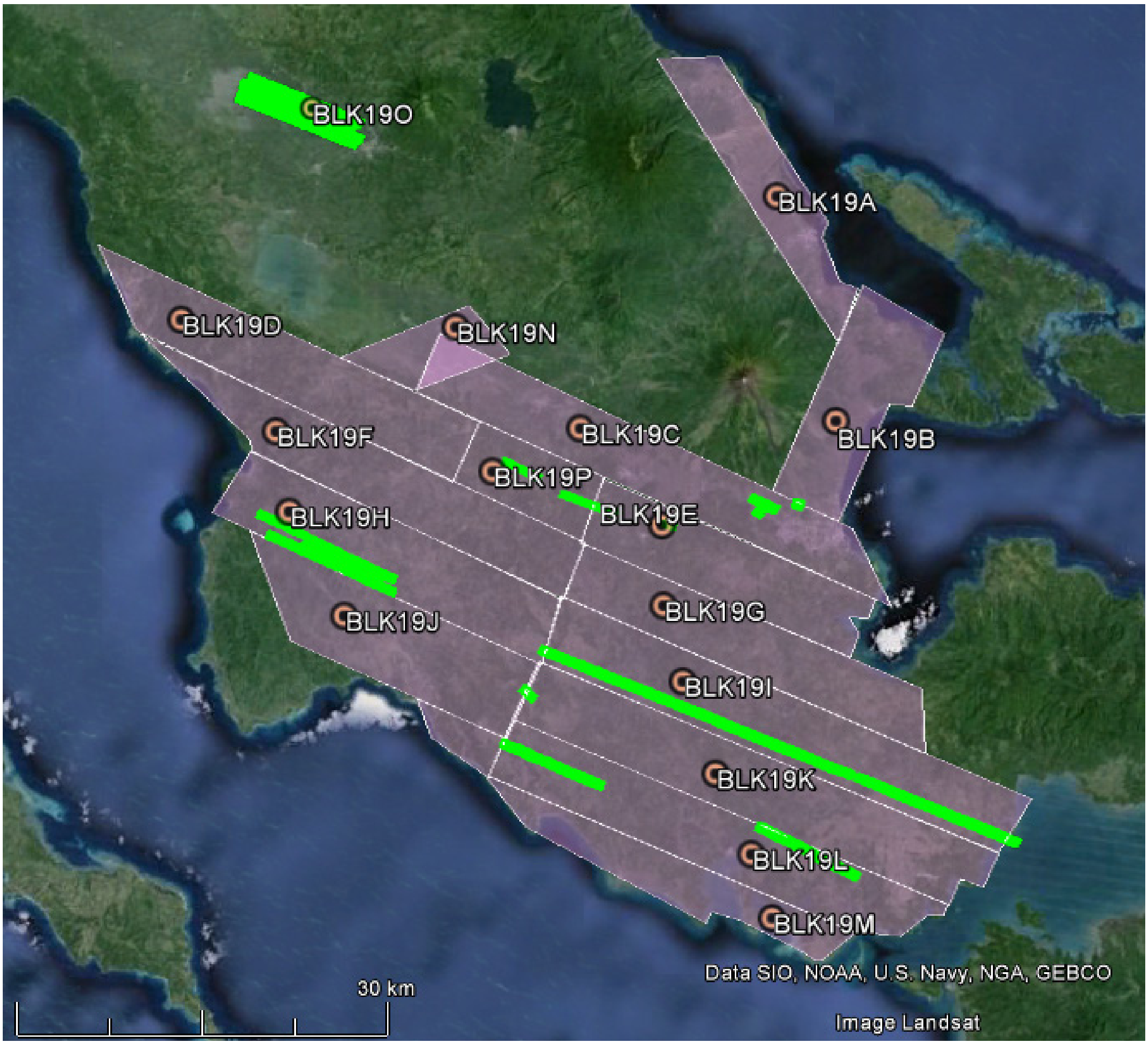


Figure A-7.7 Swath for Flight No. 7213GC

Flight No. :	7216 GC
Area:	BLK19A
Mission name:	2BLK19AS118A & VOIDS
Parameters:	Altitude: 1300; Scan Frequency: 50; Scan Angle: 17; Overlap: 50 %

LAS/ SWATH

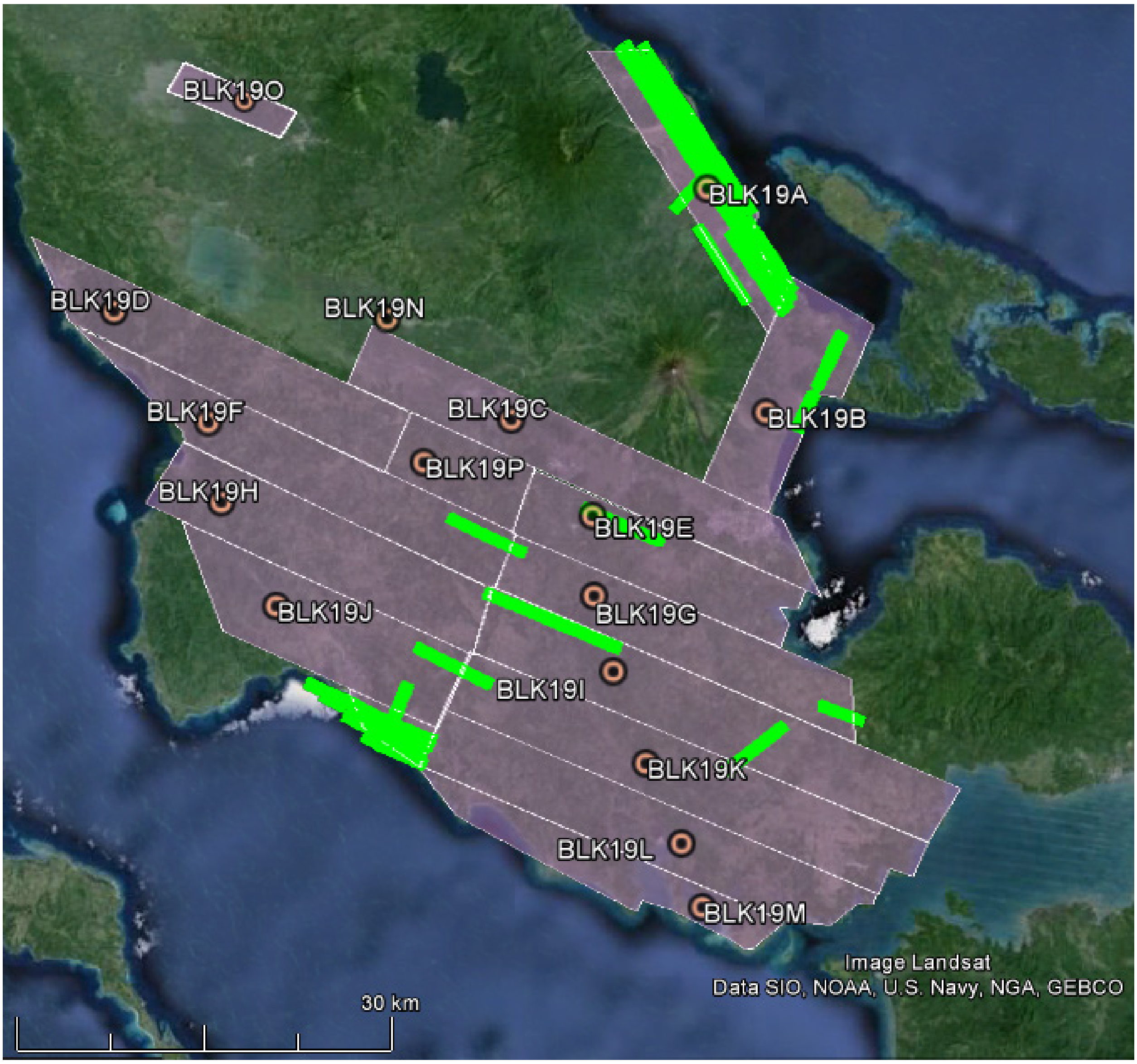


Figure A-7.8 Swath for Flight No. 7216GC

Flight No. : 3813G
Area: BLK19IS, BLK19KS
Mission Name: 2BLK19IS056B
Parameters: Altitude: 650; Scan Frequency: 40; FOV: 50; Overlap: 40 %

LAS/ SWATH

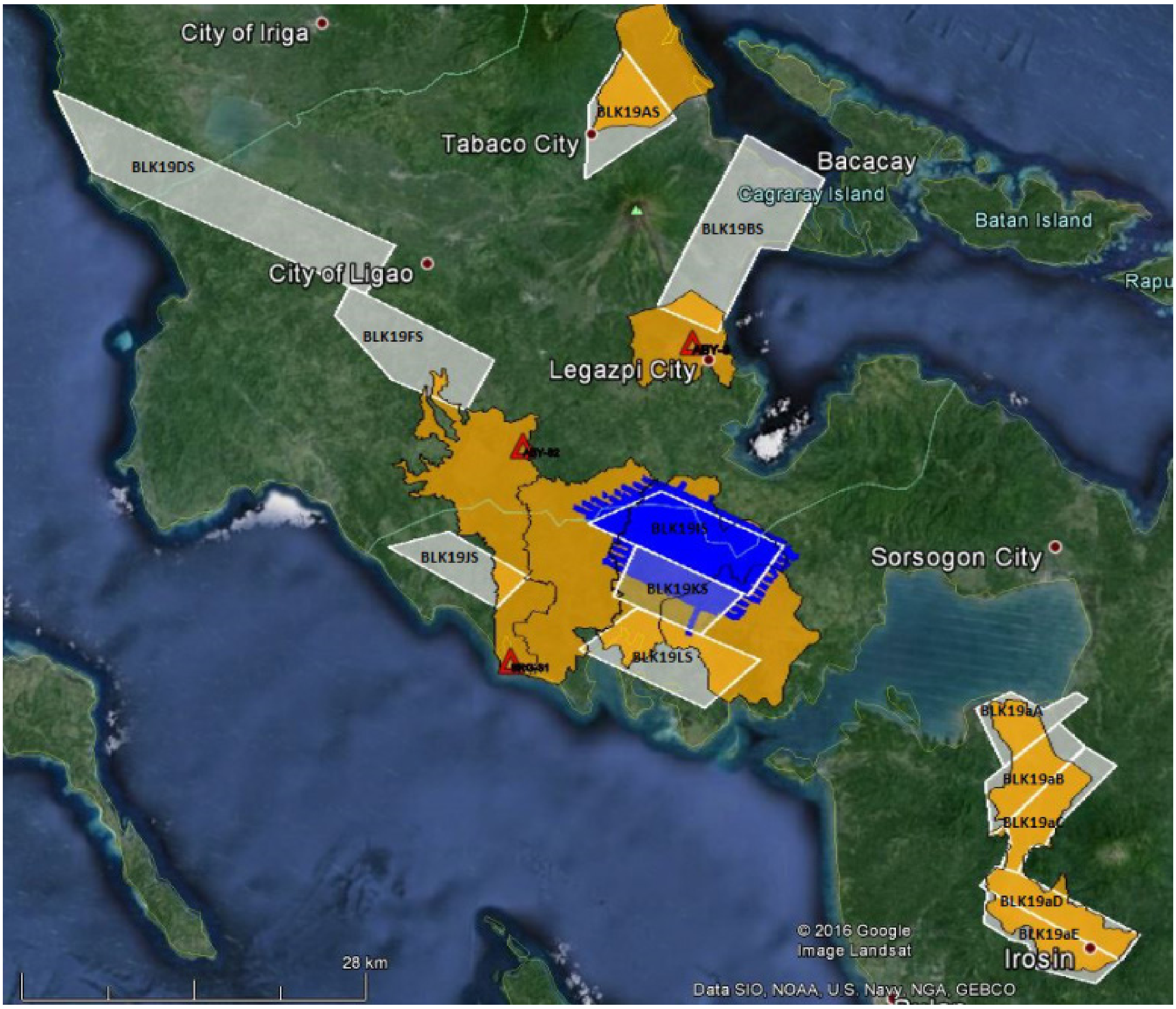


Figure A-7.9 Swath for Flight No. 3813GC

Flight No. : 3815G
Area: BLK19KS, BLK19LS
Mission Name: 2BLK19KLS057A
Parameters: Altitude: 900; Scan Frequency: 40; FOV: 50; Overlap: 40 %

LAS/ SWATH

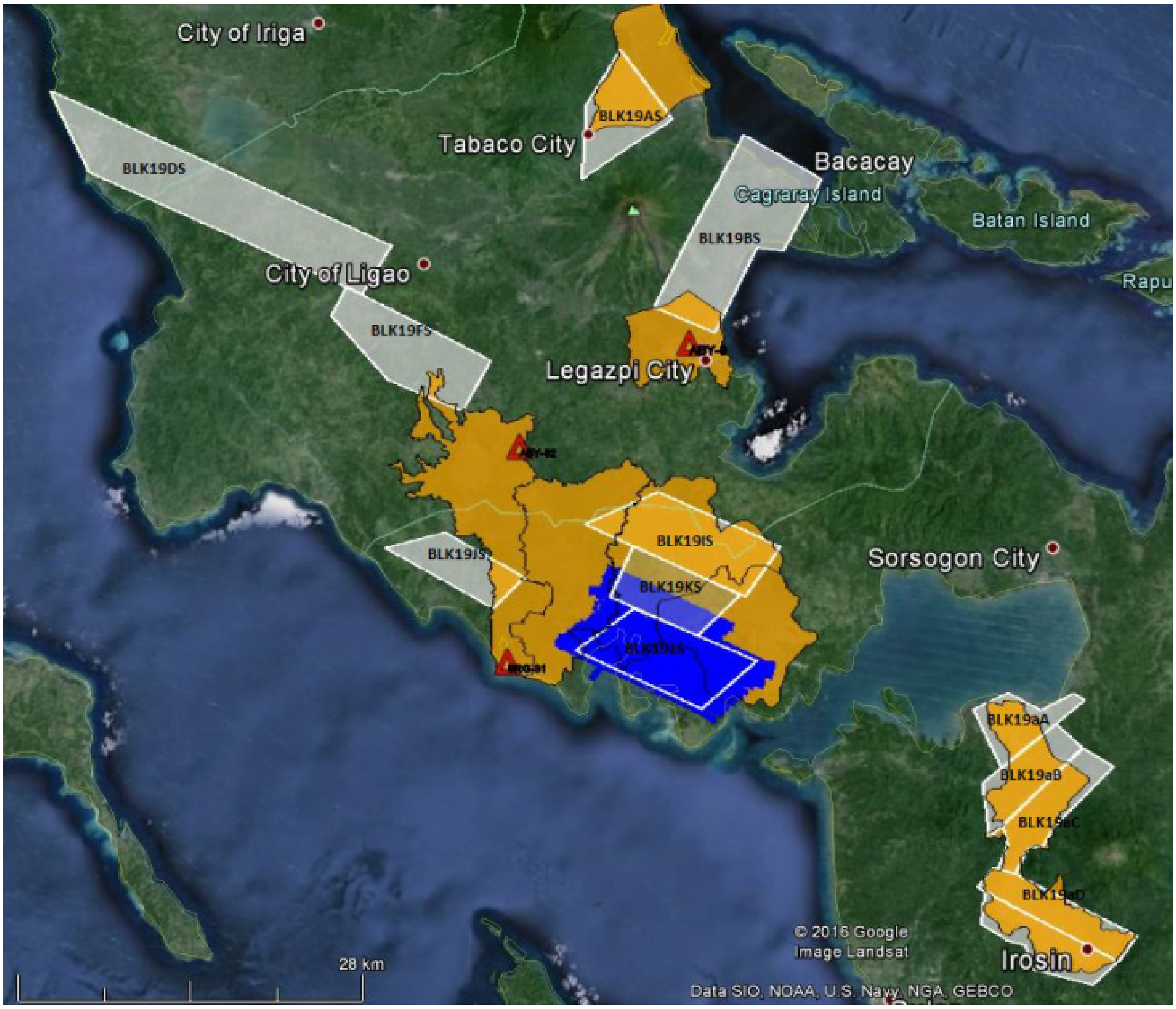


Figure A-7.10 Swath for Flight No. 3815GC

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk 19I

Flight Area	Albay/Sorsogon
Mission Name	Blk 19I
Inclusive Flights	7160GC, 7161GC, 7167GC, 7213GC
Range data size	51.36 GB
POS	570.4 MB
Image	---
Base data size	20.91 MB
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.13
RMSE for Down Position (<8.0 cm)	7.4
Boresight correction stdev (<0.001deg)	0.000140
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	27.42 %
Ave point cloud density per sq.m. (>2.0)	3.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	479
Maximum Height	314.54
Minimum Height	53.68
Classification (# of points)	
Ground	161,483,905
Low vegetation	147,862,292
Medium vegetation	219,358,011
High vegetation	579,999,947
Building	6,587,455
Orthophoto	No
Processed By	Engr. Benjamin Jonah Magallon, Victoria Rejuso, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda, Engr. Elainne Lopez

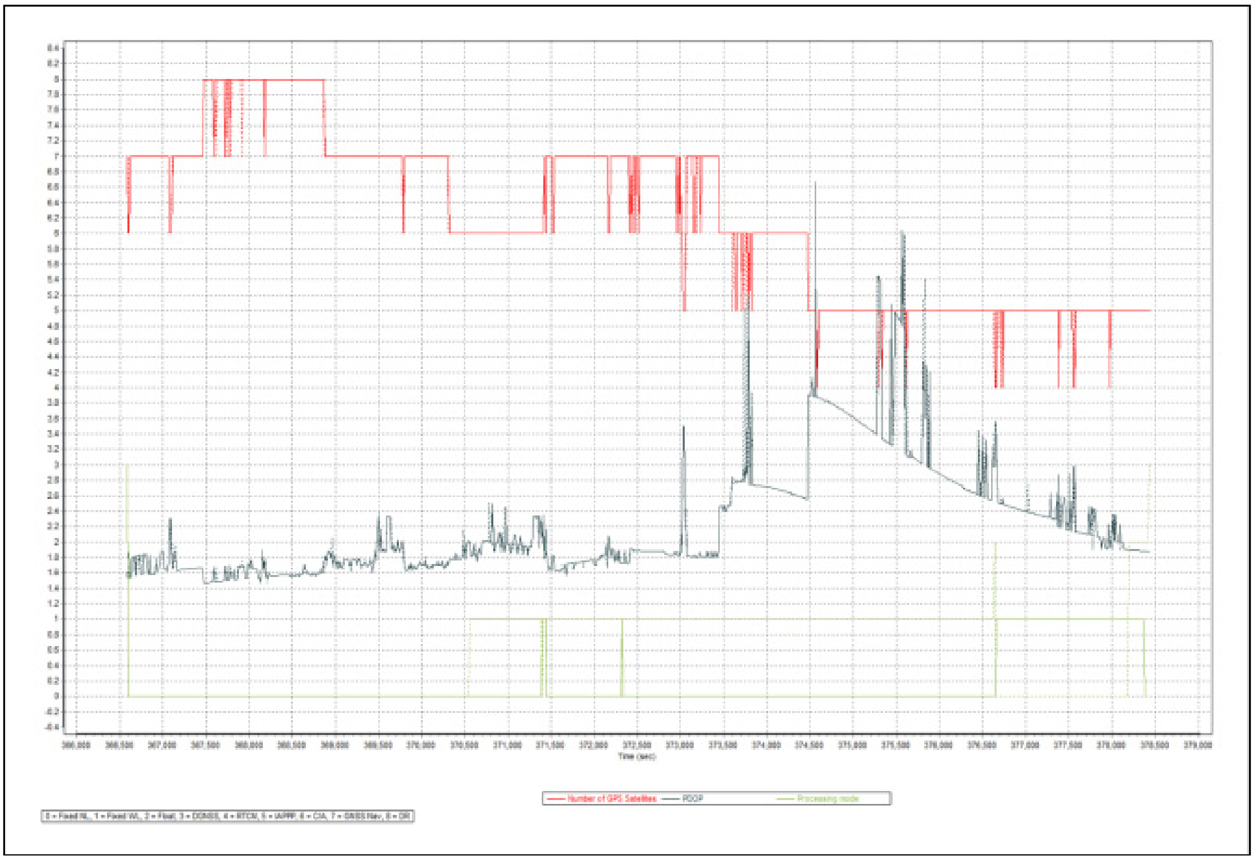


Figure A-8.1 Solution Status

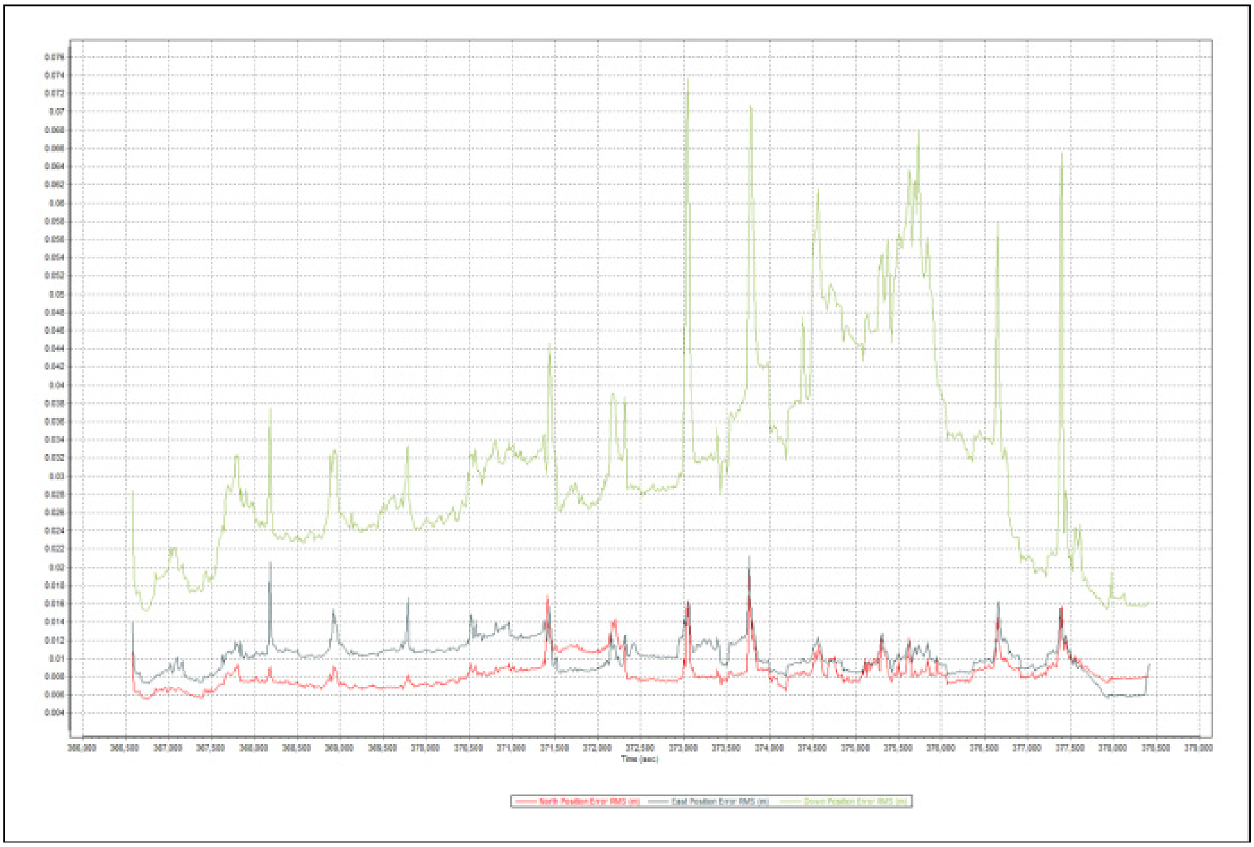


Figure A-8.2 Smoothed Performance Metrics Parameters

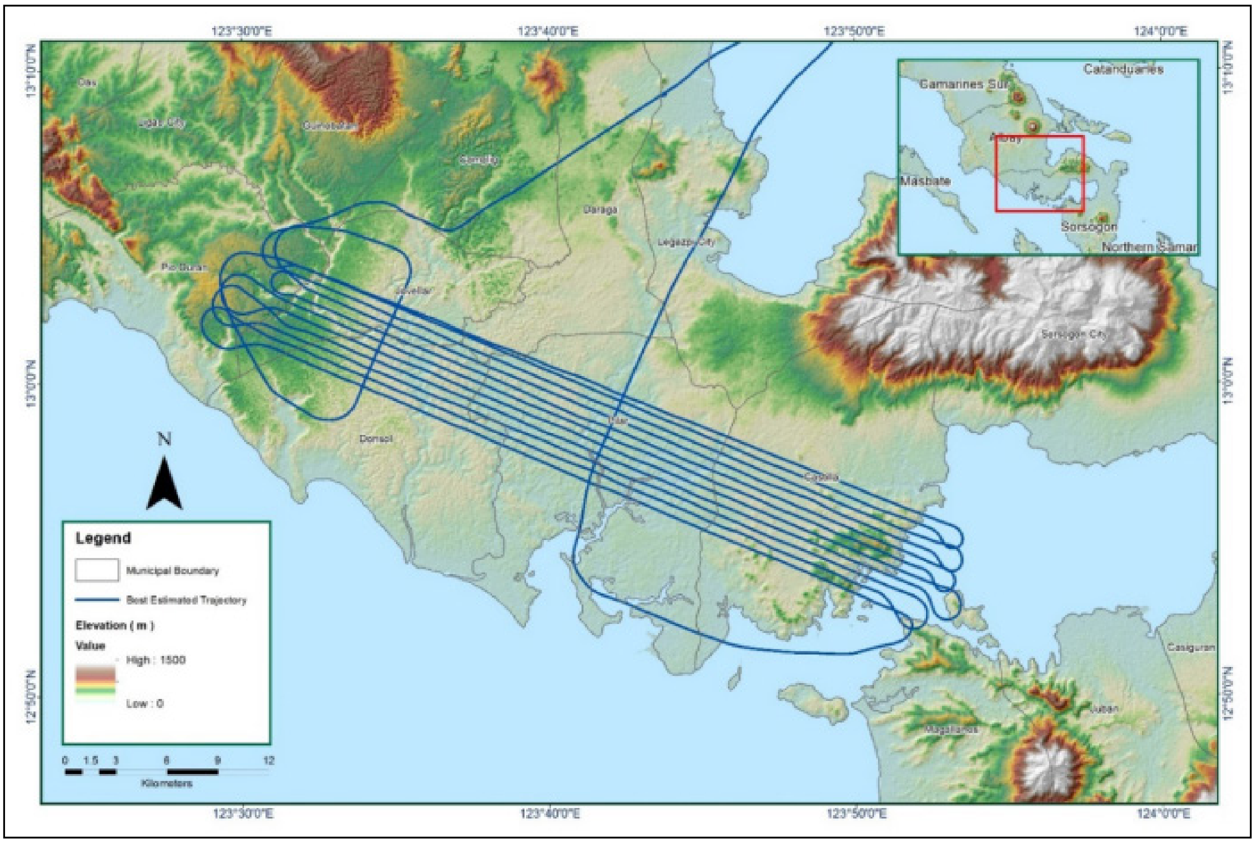


Figure A-8.3 Best Estimated Trajectory

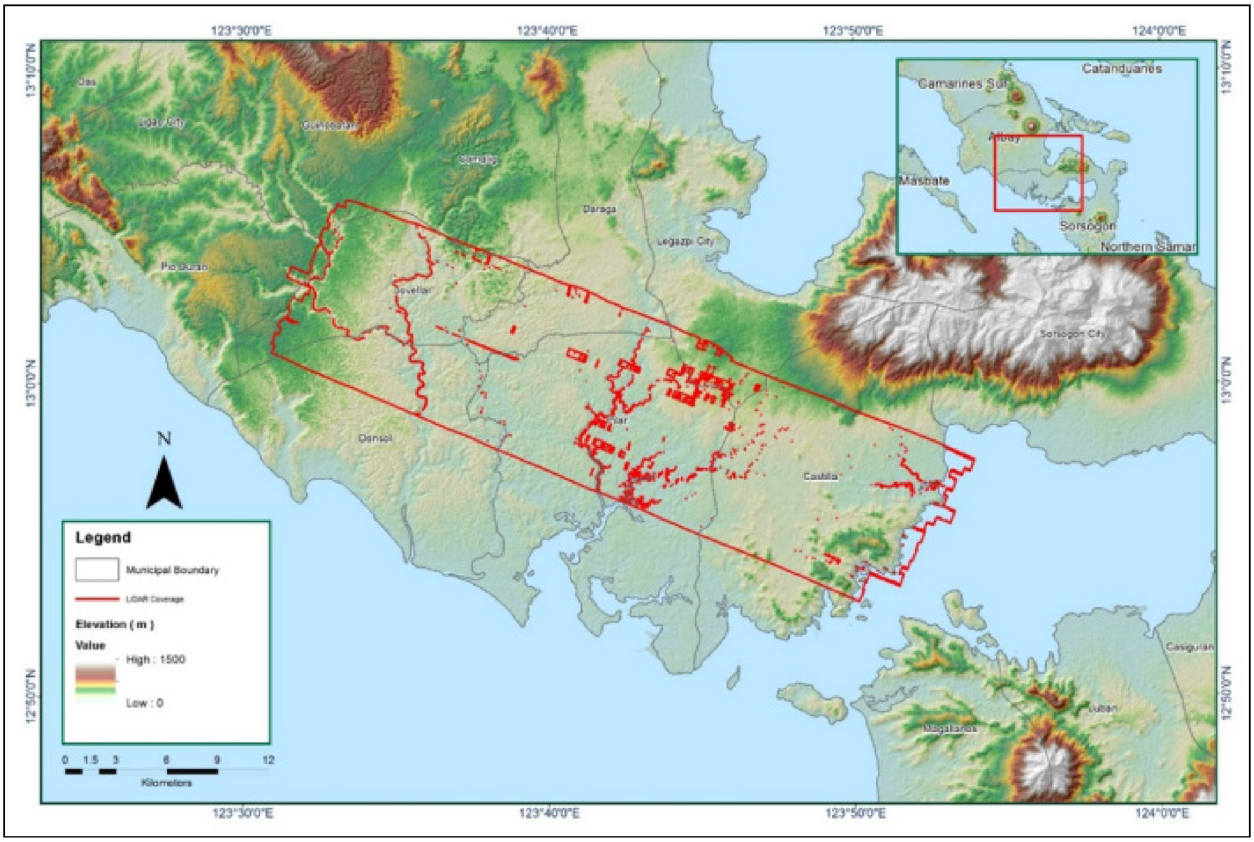


Figure A-8.4 Coverage of LiDAR data

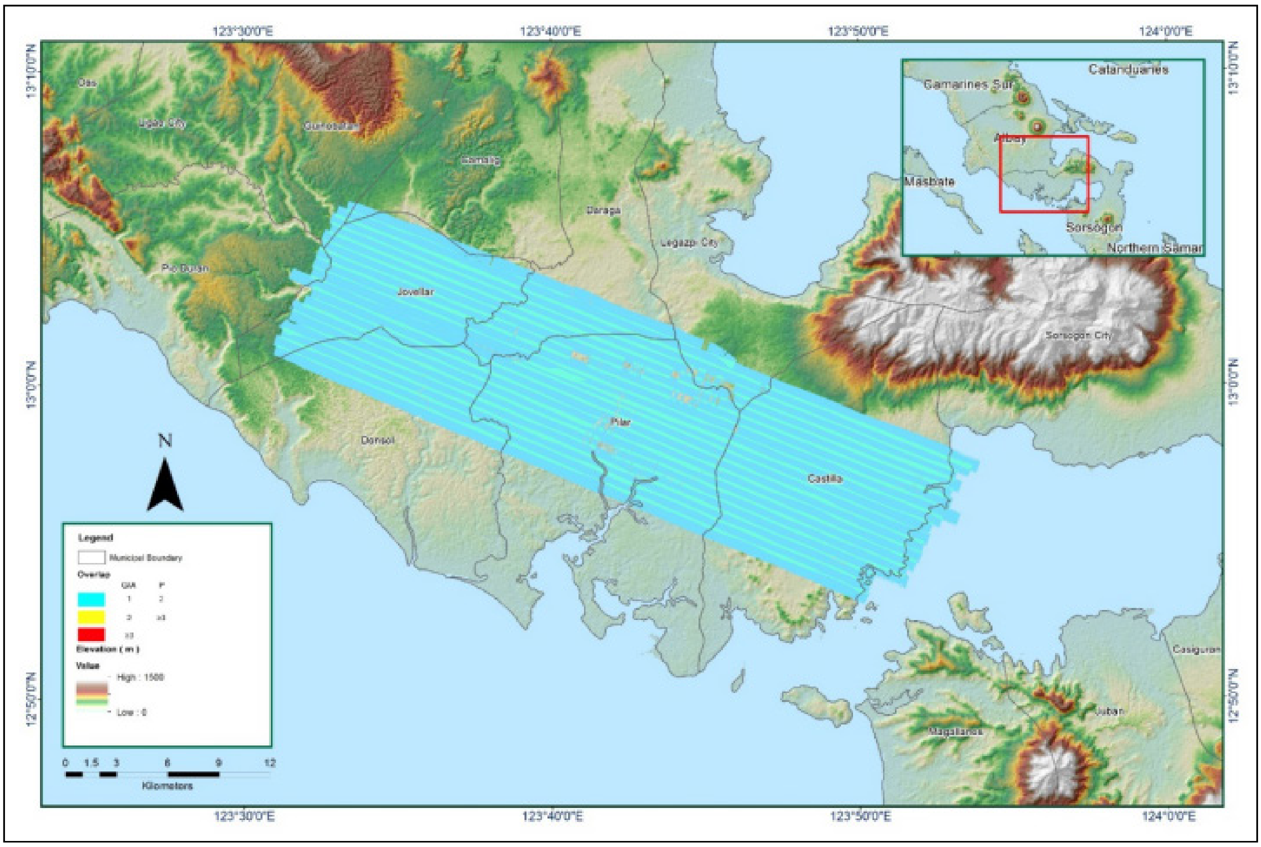


Figure A-8.5 Image of Data Overlap

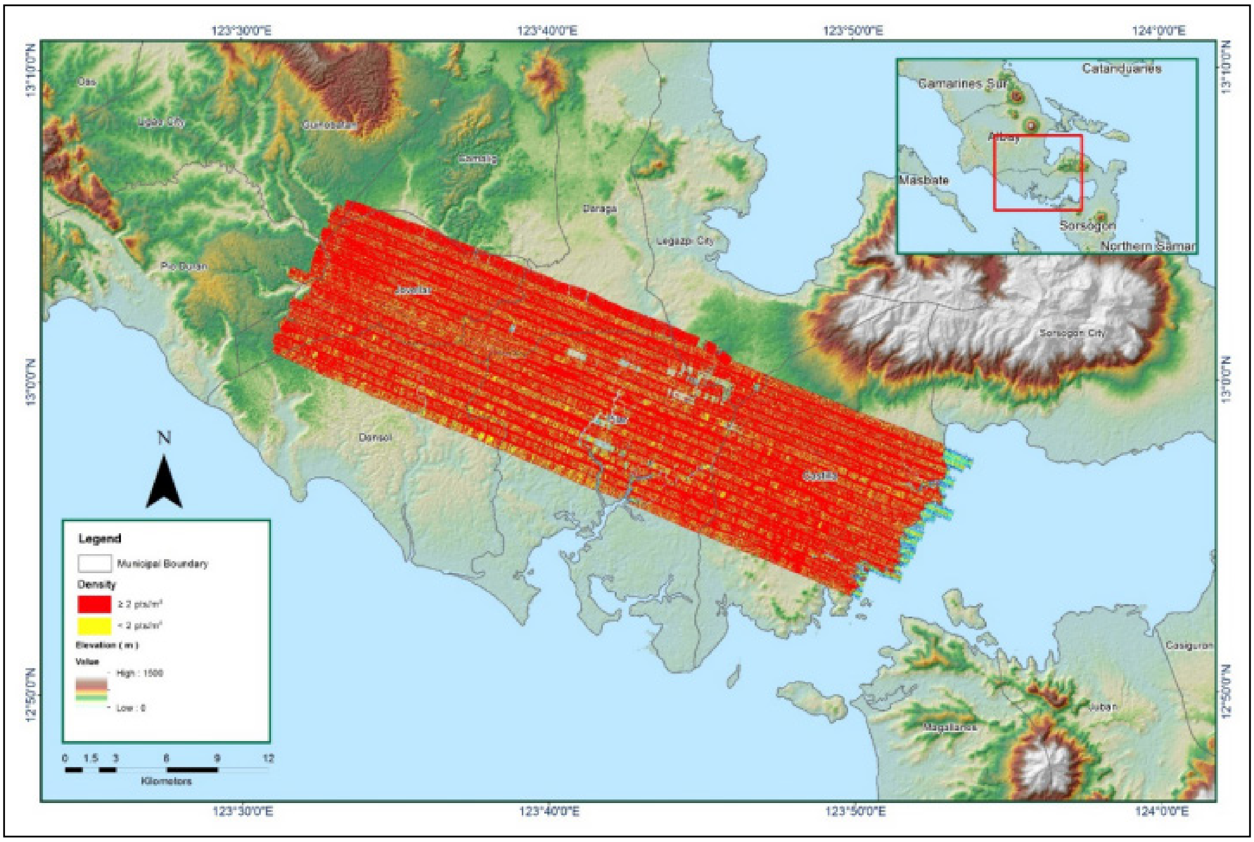


Figure A-8.6 Density map of merged LiDAR data

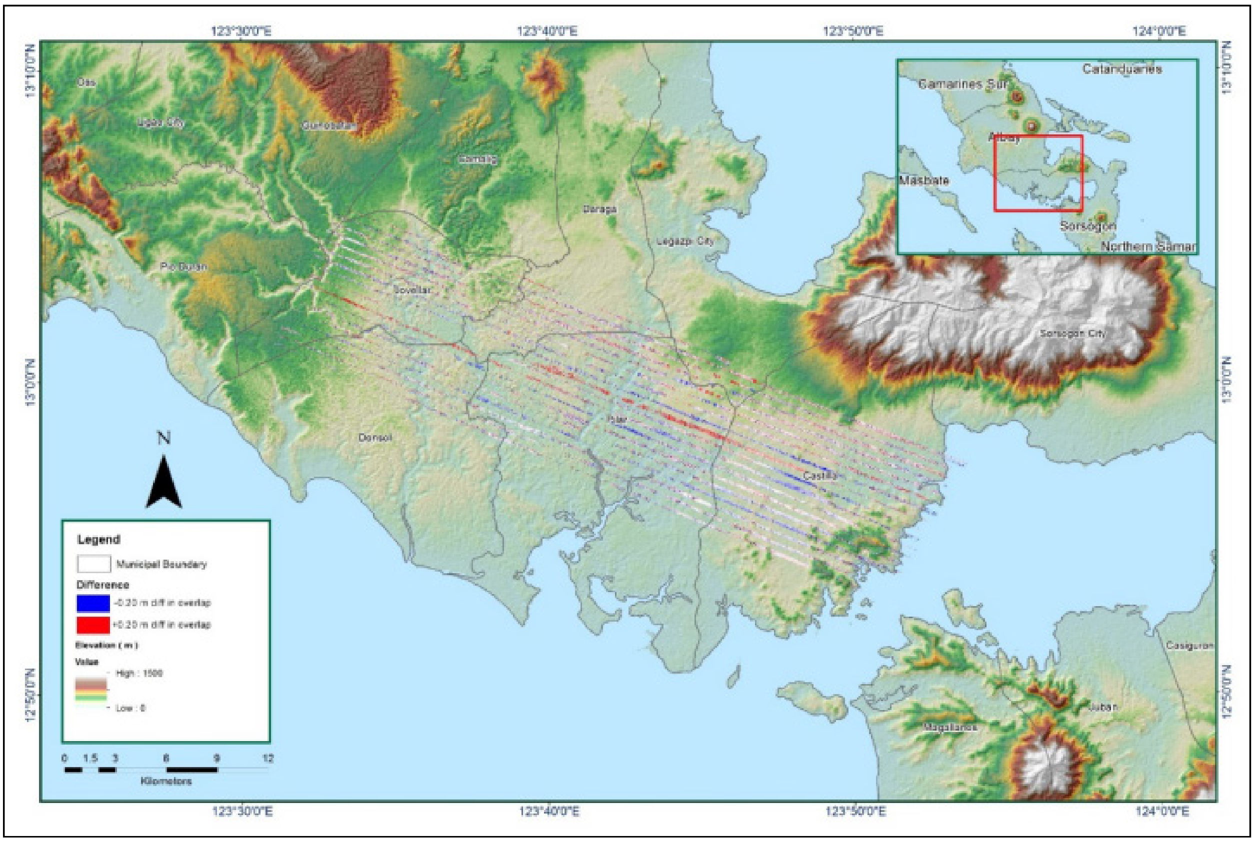


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk 19EG

Flight Area	ALBAY/SORSOGON
Mission Name	Blk 19EG
Inclusive Flights	7156GC, 7158GC, 7216GC
Range data size	46.75 GB
POS	547.4 MB
Image	---
Base data size	24.79 MB
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	7.0
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	10.2
Boresight correction stdev (<0.001deg)	0.000224
IMU attitude correction stdev (<0.001deg)	0.001635
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	30.62 %
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	373
Maximum Height	447.71
Minimum Height	53.24
Classification (# of points)	
Ground	145,515,827
Low vegetation	130,178,426
Medium vegetation	147,064,919
High vegetation	462,980,087
Building	7,156,764
Orthophoto	No
Processed By	Engr. Angelo Carlo Bongat, Engr. Irish Cortez, Aljon Rie Araneta, Engr. Gladys Mae Apat

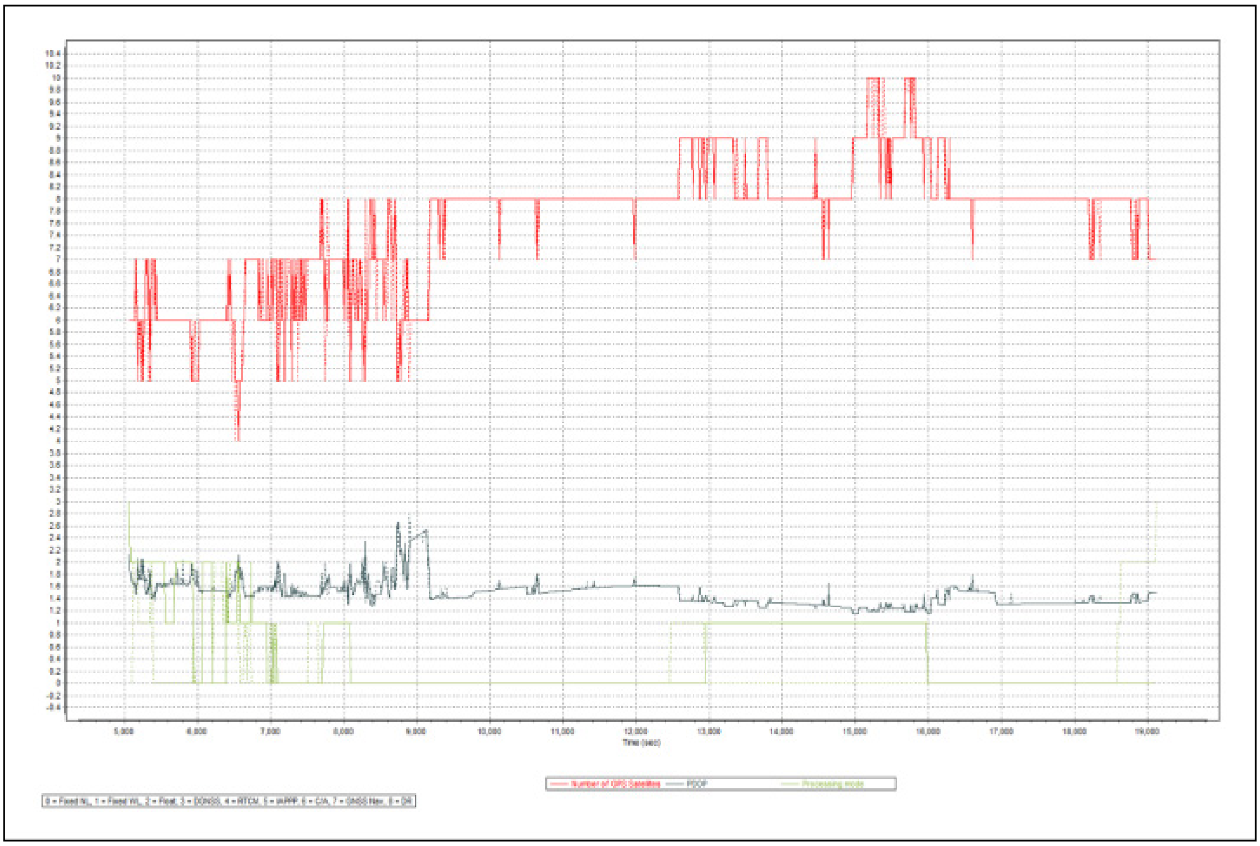


Figure A-8.8 Solution Status Parameters

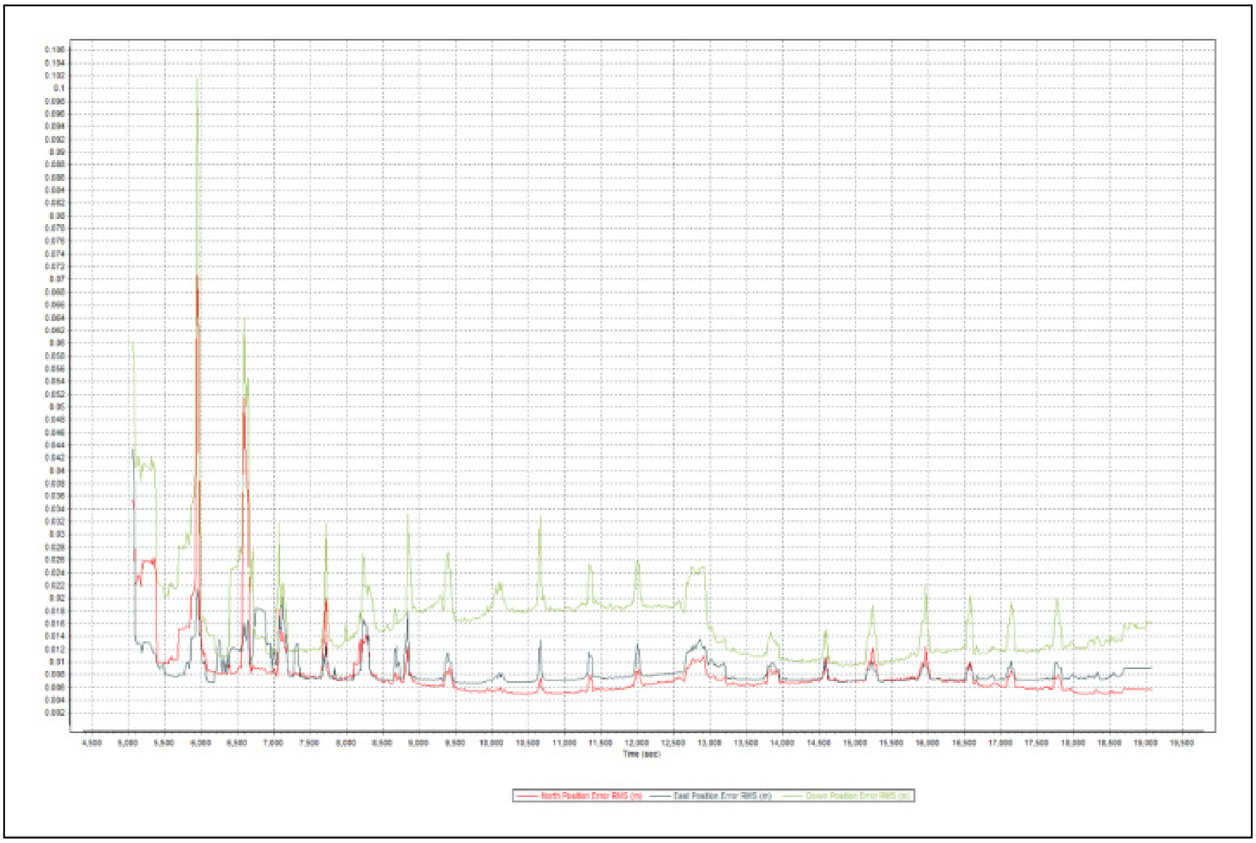


Figure A-8.9 Smoothed Performance Metrics Parameters

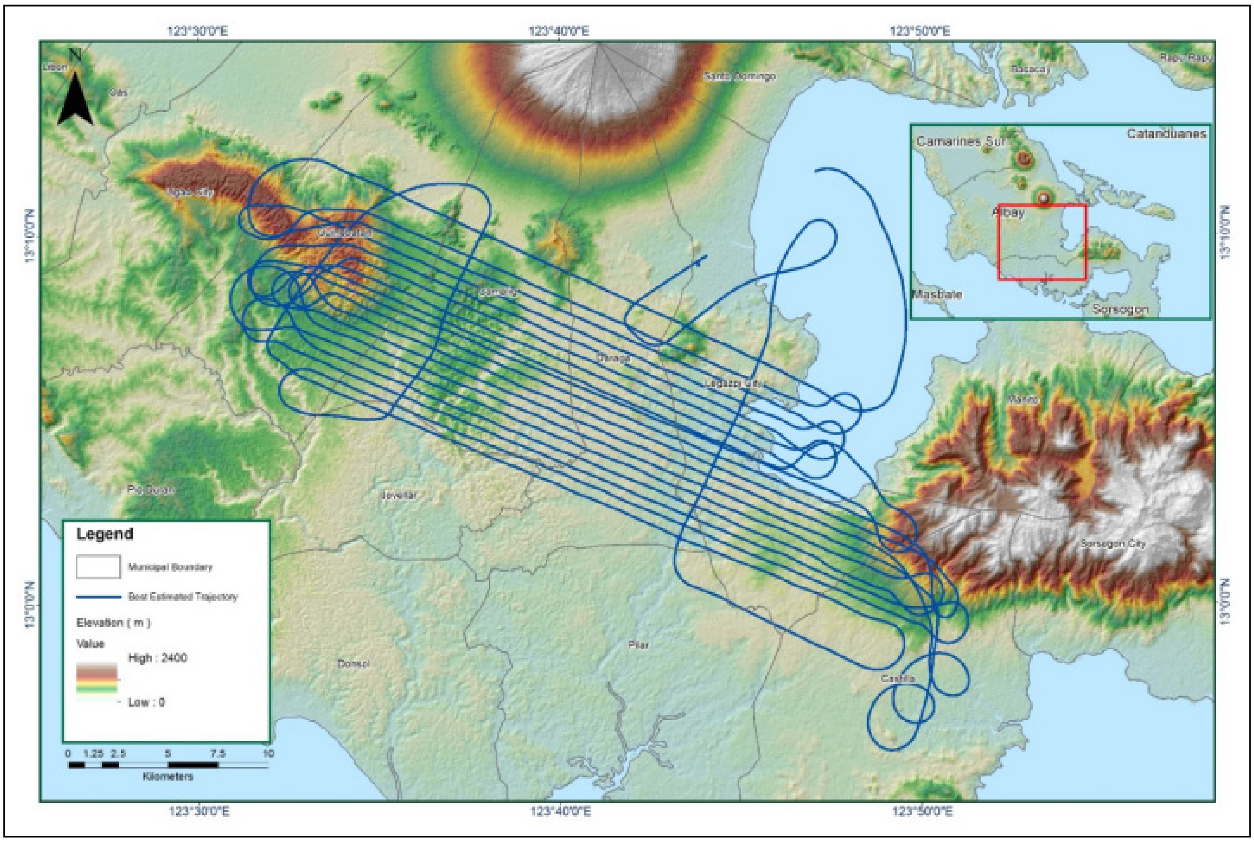


Figure A-8.10 Best Estimated Trajectory

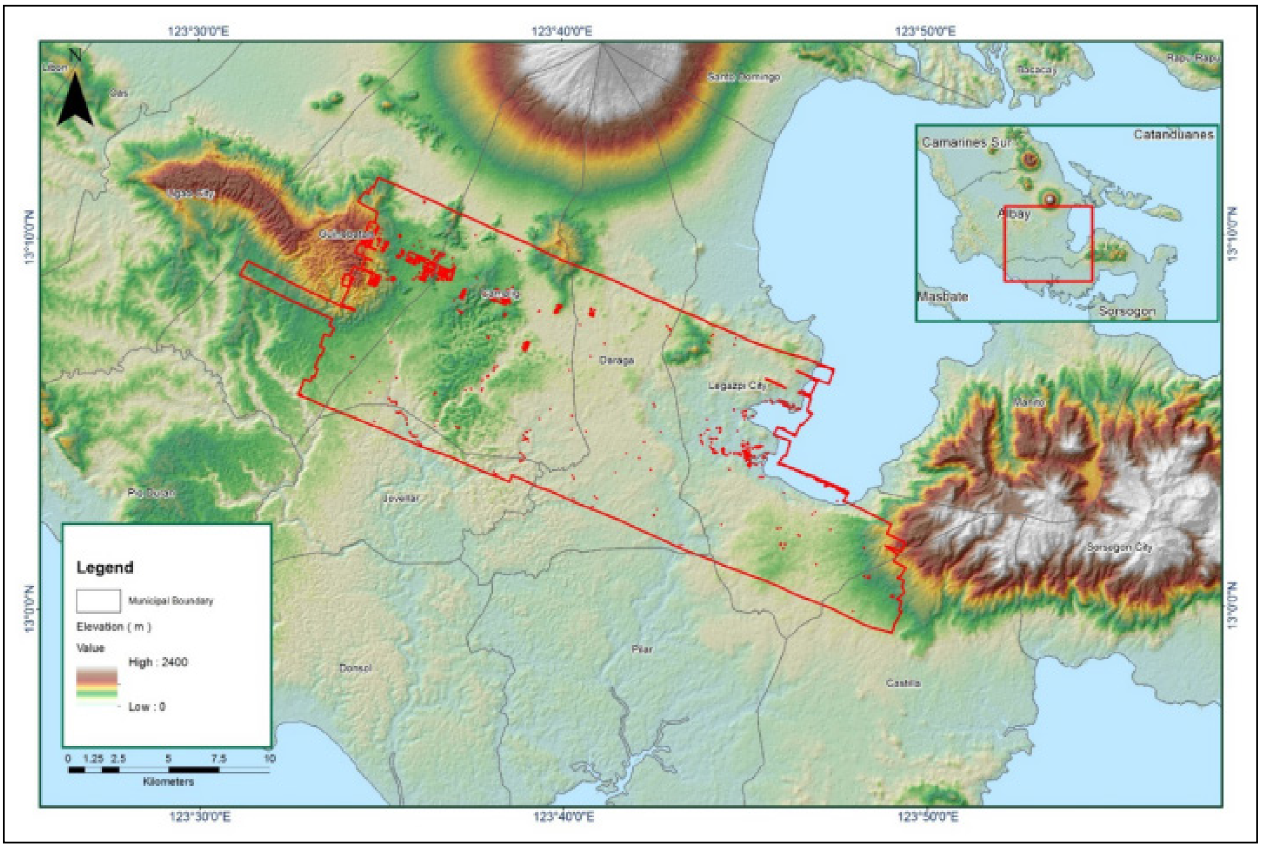


Figure A-8.11 Coverage of LiDAR data

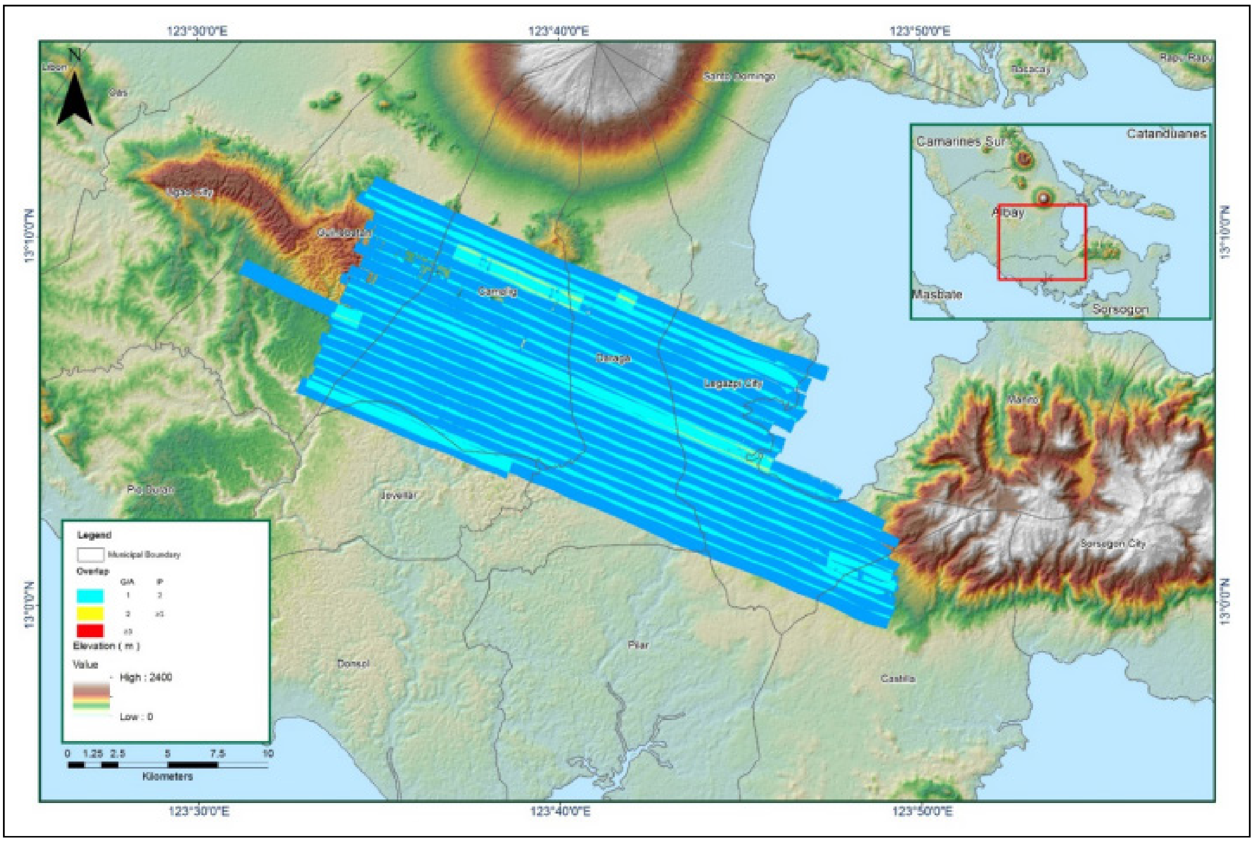


Figure A-8.12 Image of Data Overlap

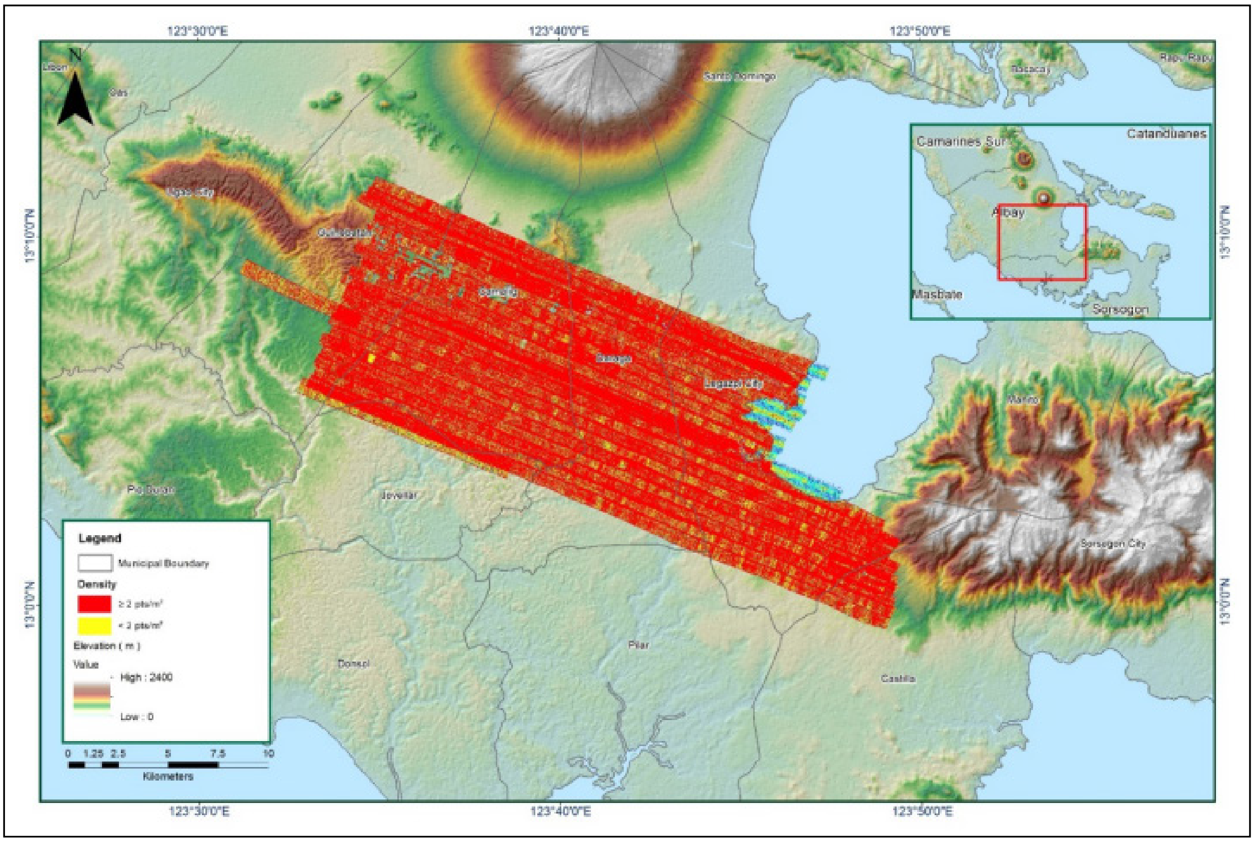


Figure A-8.13 Density map of merged LiDAR data

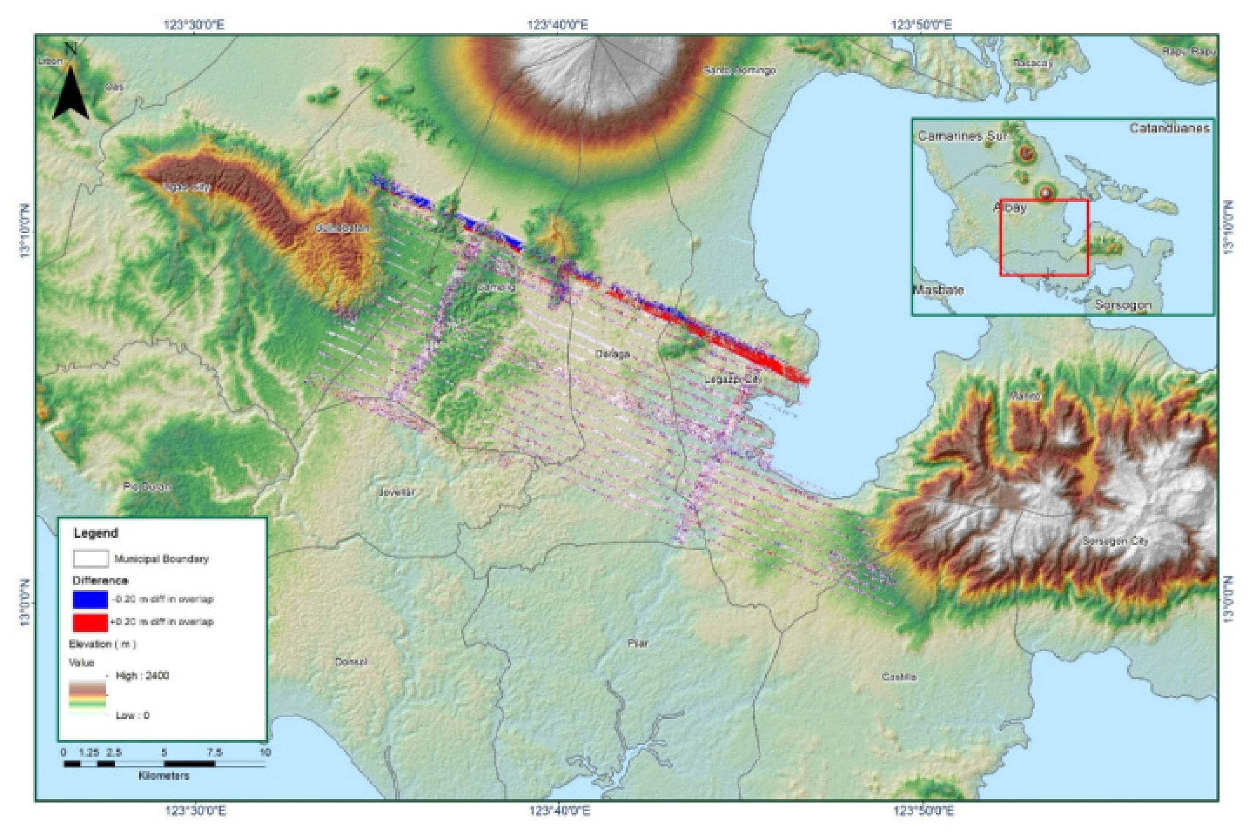


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk 19L_additional

Flight Area	ALBAY/SORSOGON
Mission Name	Blk 19L_additional
Inclusive Flights	7213G
Range data size	8.77 GB
POS	141 MB
Image	N/A
Base data size	1.68 MB
Transfer date	May 5, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	7.75
RMSE for East Position (<4.0 cm)	10.55
RMSE for Down Position (<8.0 cm)	17.44
Boresight correction stdev (<0.001deg)	0.000200
IMU attitude correction stdev (<0.001deg)	0.003237
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	2.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	9
Maximum Height	172.19 m
Minimum Height	53.72 m
Classification (# of points)	
Ground	350,380
Low vegetation	101,547
Medium vegetation	344,518
High vegetation	1,729,486
Building	1,216
Orthophoto	No
Processed By	Engr. Irish Cortez, Engr. Benjamin Jonah Magallon, Engr. Harmond Santos, Engr. Melissa Fernandez

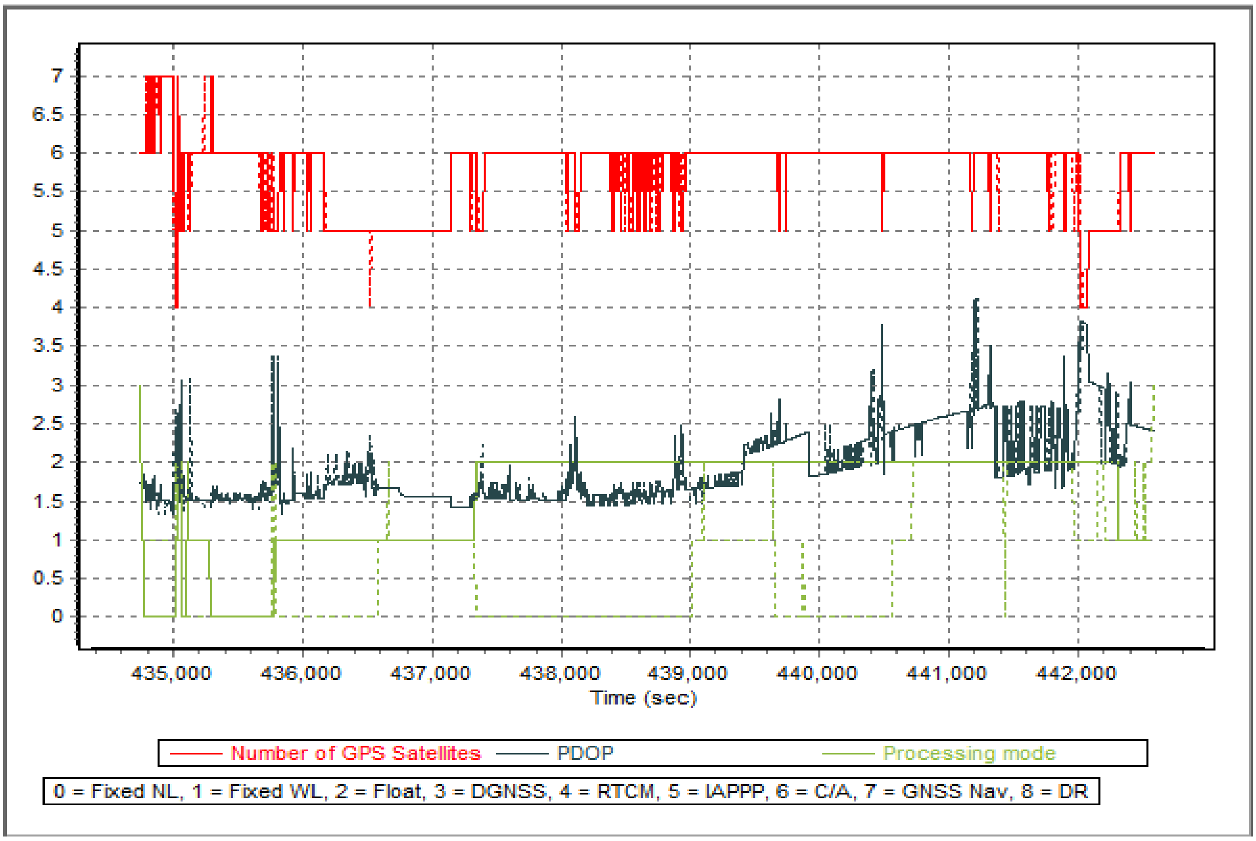


Figure A-8.15 Solution Status

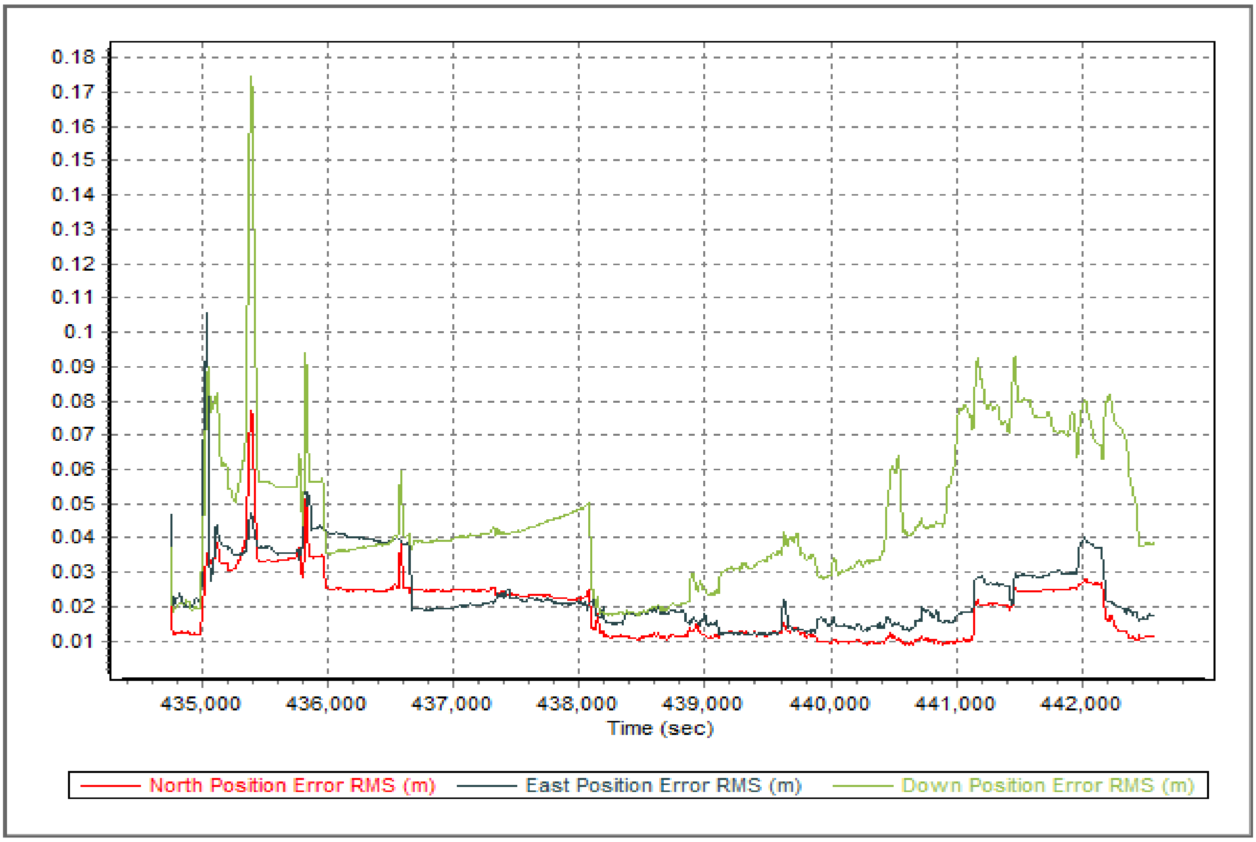


Figure A-8.16 Smoothed Performance Metric Parameters

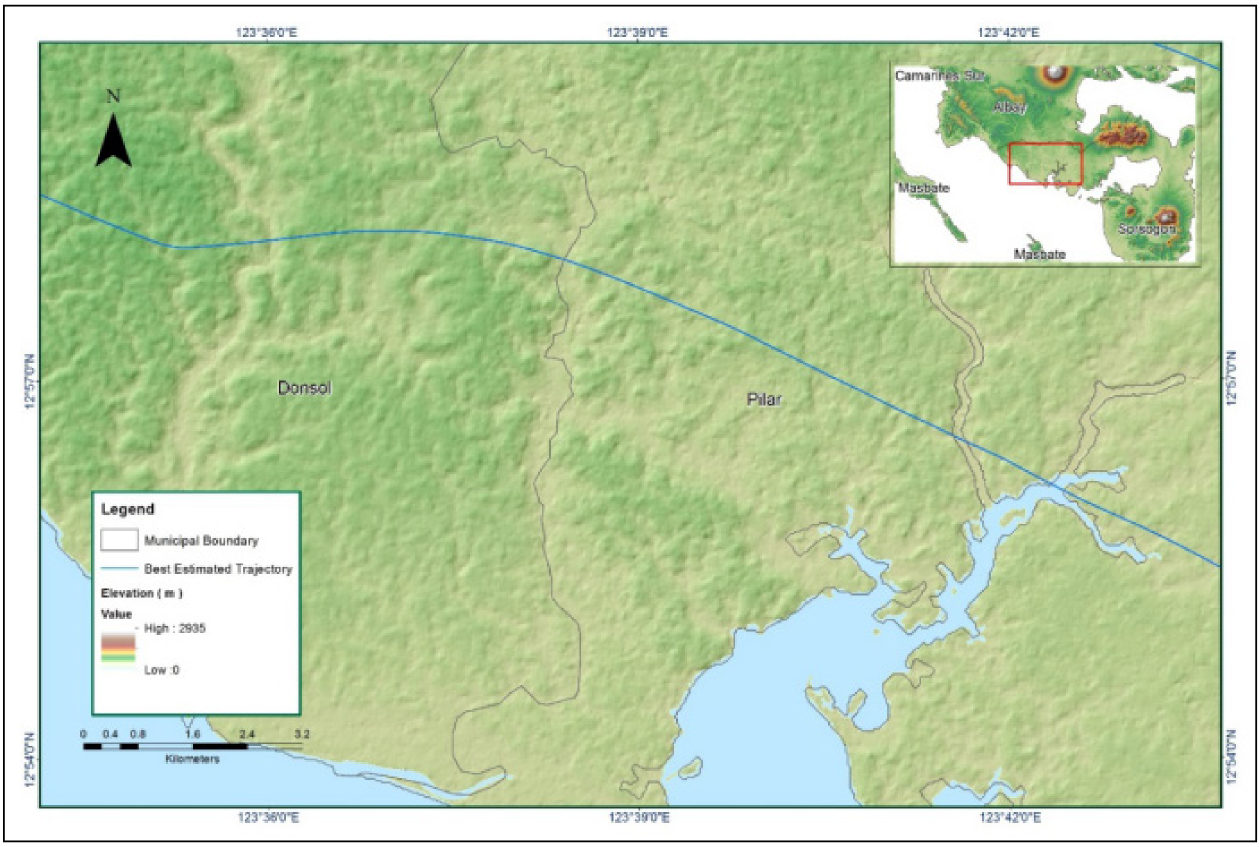


Figure A-8.17 Best Estimated Trajectory

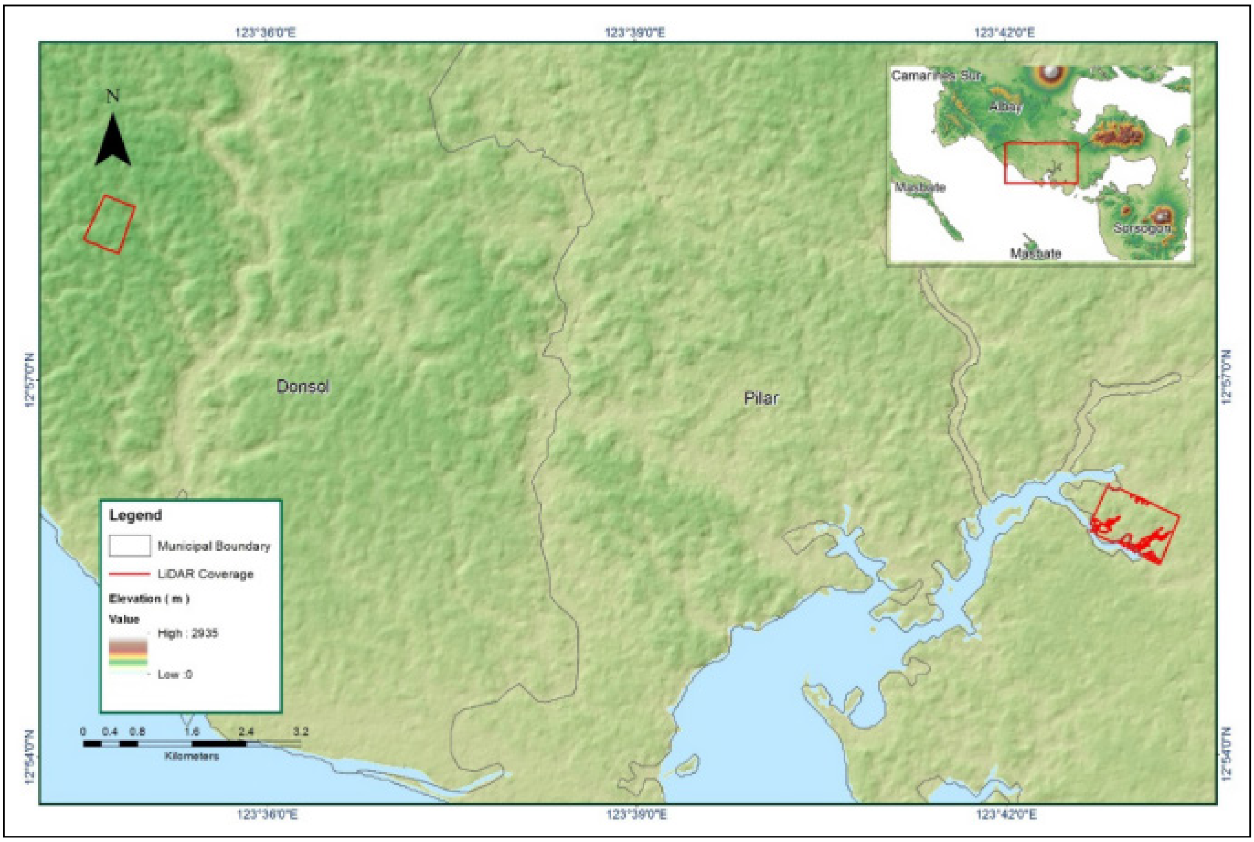


Figure A-8.18 Coverage of LiDAR data

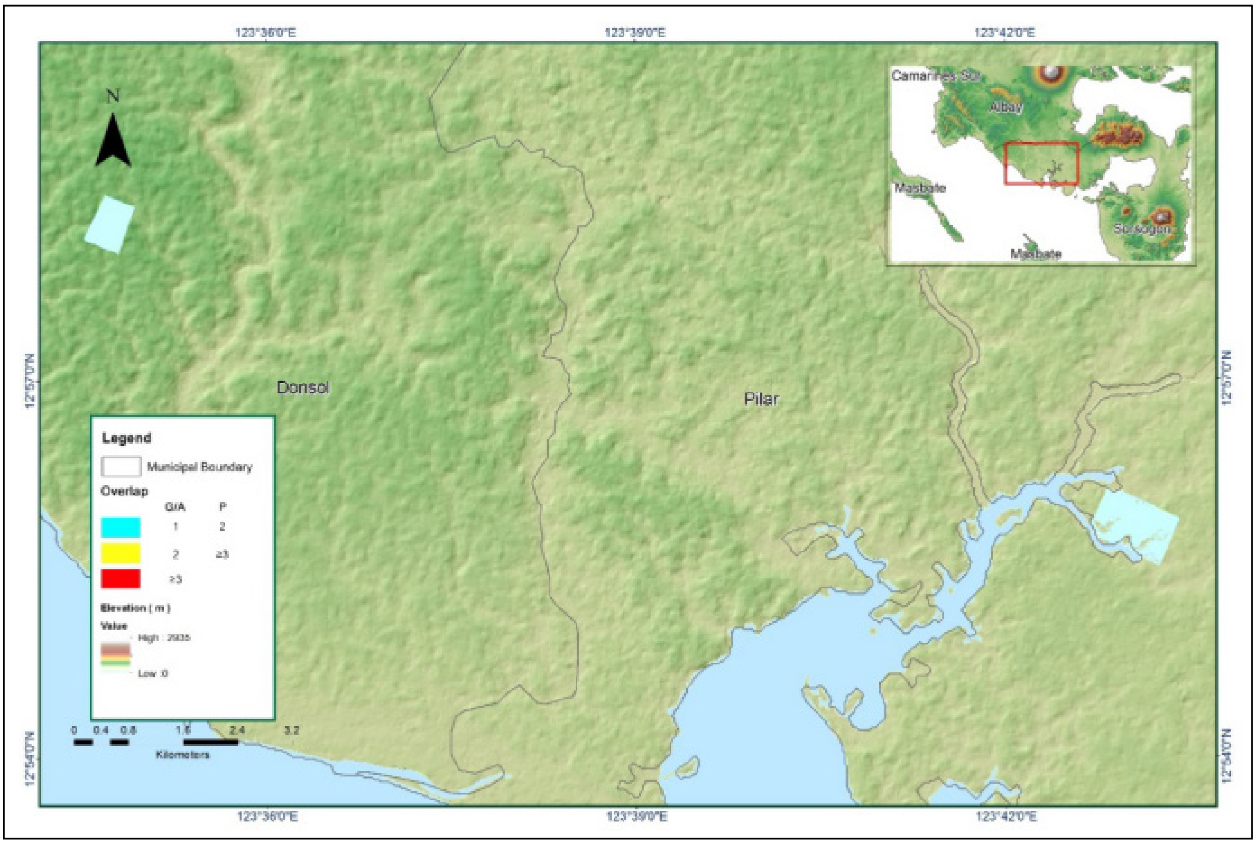


Figure A-8.19 Image of Data Overlap

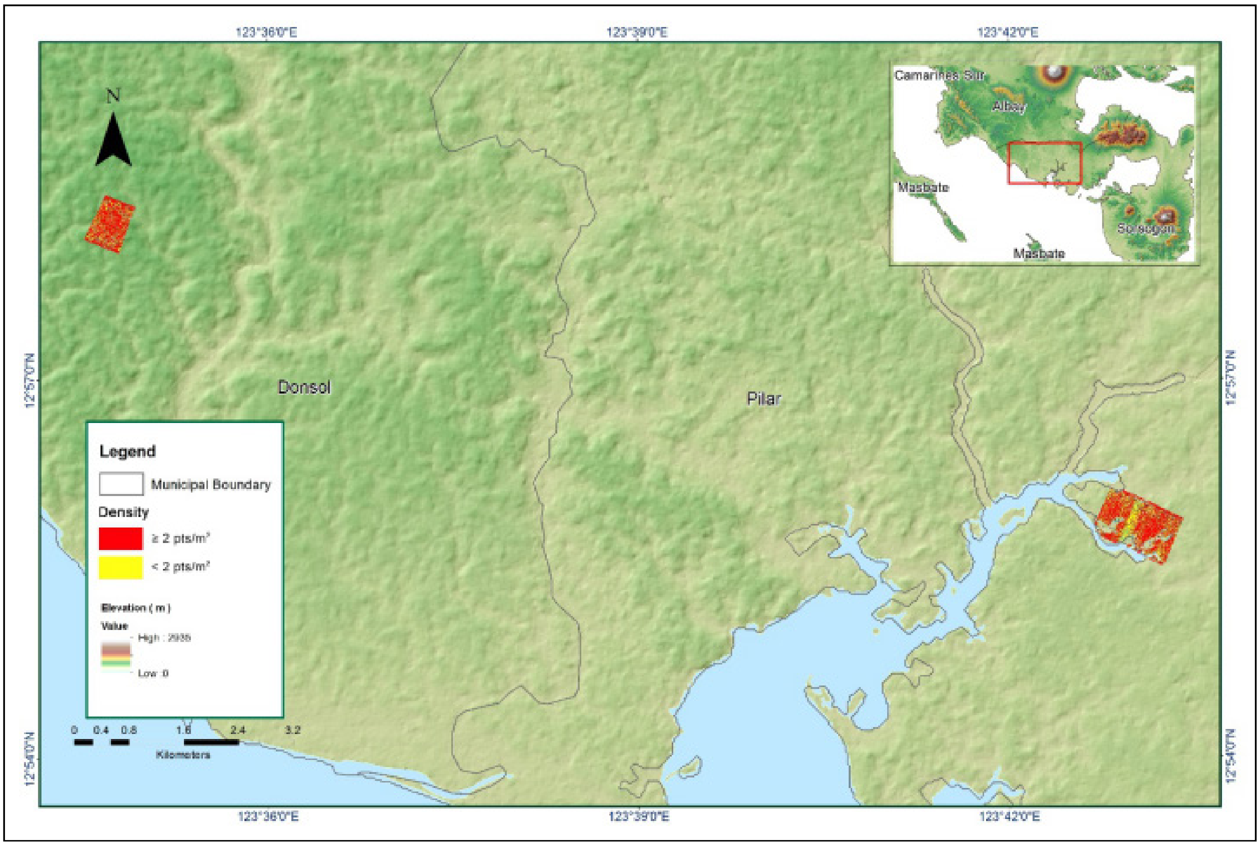


Figure A-8.20 Density map of merged LiDAR data

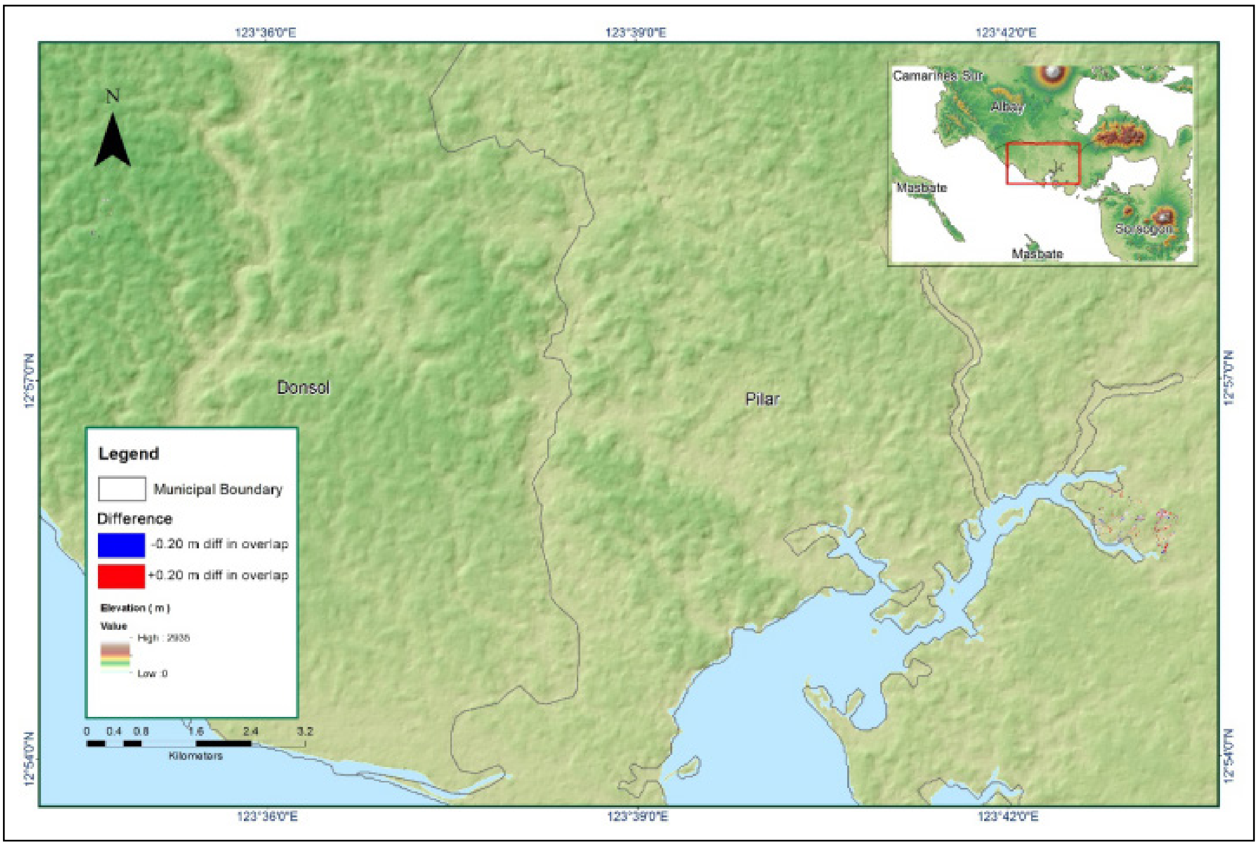


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk 19L

Flight Area	ALBAY/SORSOGON
Mission Name	Blk 19L
Inclusive Flights	7168GC
Range data size	22.4 GB
POS	193 MB
Image	---
Base data size	10.9 MB
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	7.7
RMSE for East Position (<4.0 cm)	10.6
RMSE for Down Position (<8.0 cm)	17.5
Boresight correction stdev (<0.001deg)	0.000200
IMU attitude correction stdev (<0.001deg)	0.001959
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	21.81 %
Ave point cloud density per sq.m. (>2.0)	2.70
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	265
Maximum Height	238.97
Minimum Height	52.76
Classification (# of points)	
Ground	58020284
Low vegetation	46865776
Medium vegetation	84917293
High vegetation	266182218
Building	2788874
Orthophoto	No
Processed By	Engr. Irish Cortez, Engr. Benjamin Jonah Magallon, Engr. Antonio Chua, Jr., Engr. Ma. Ailyn Olanda

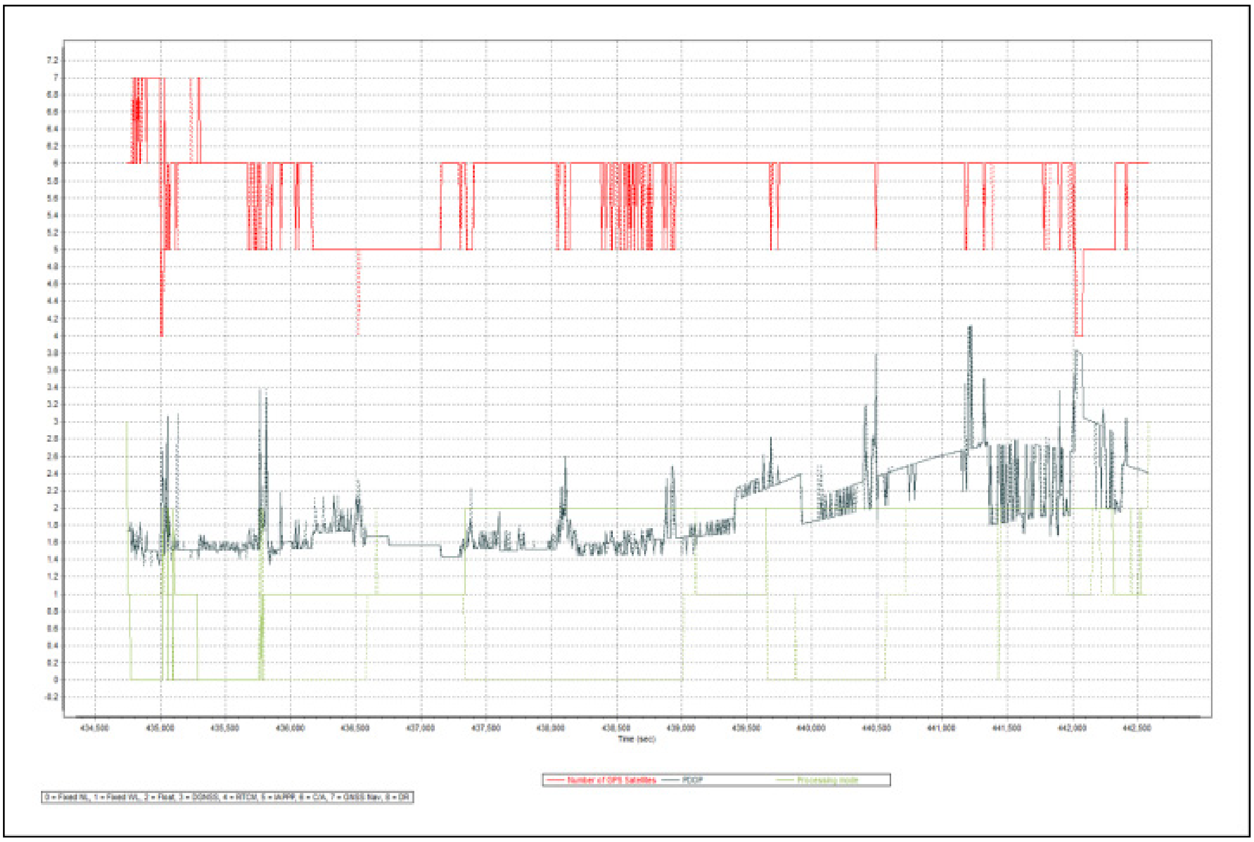


Figure A-8.22 Solution Status

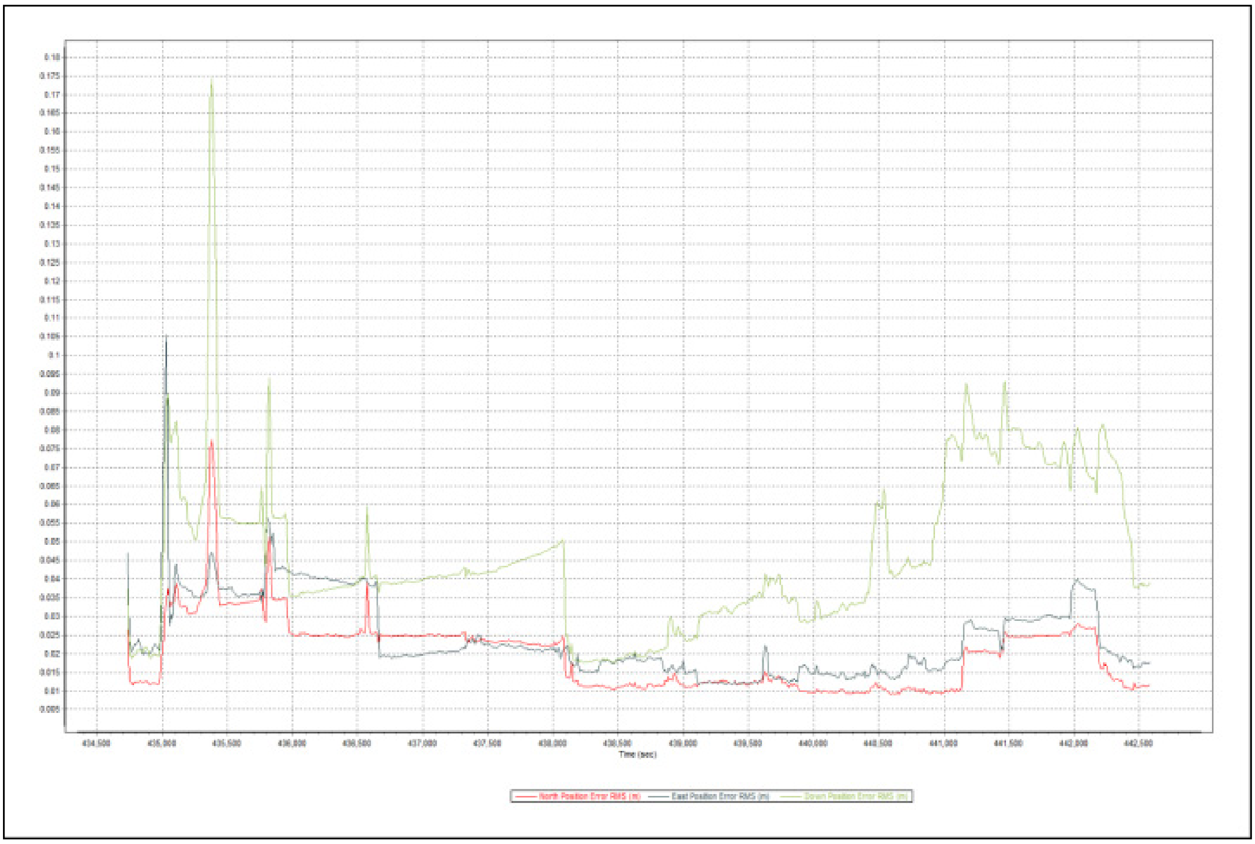


Figure A-8.23 Smoothed Performance Metric Parameters

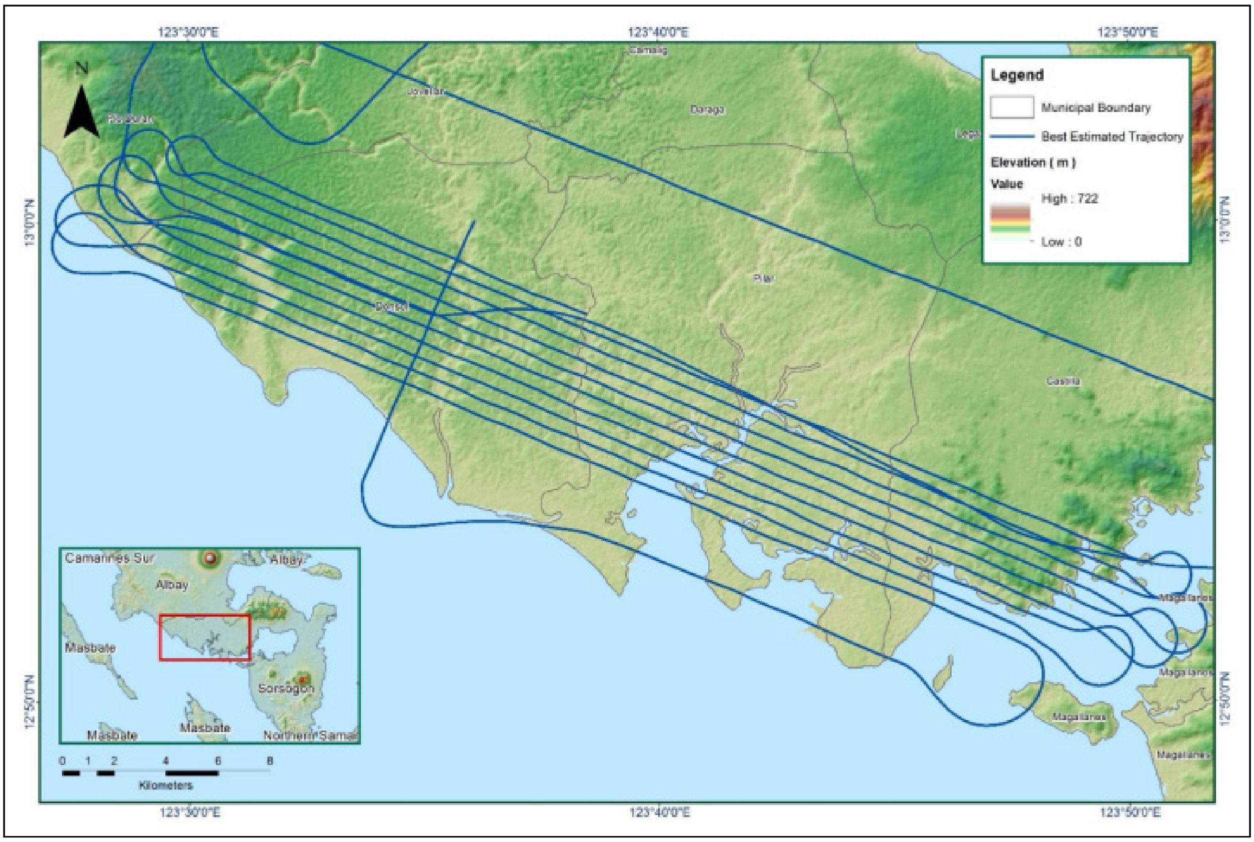


Figure A-8.24 Best Estimated Trajectory

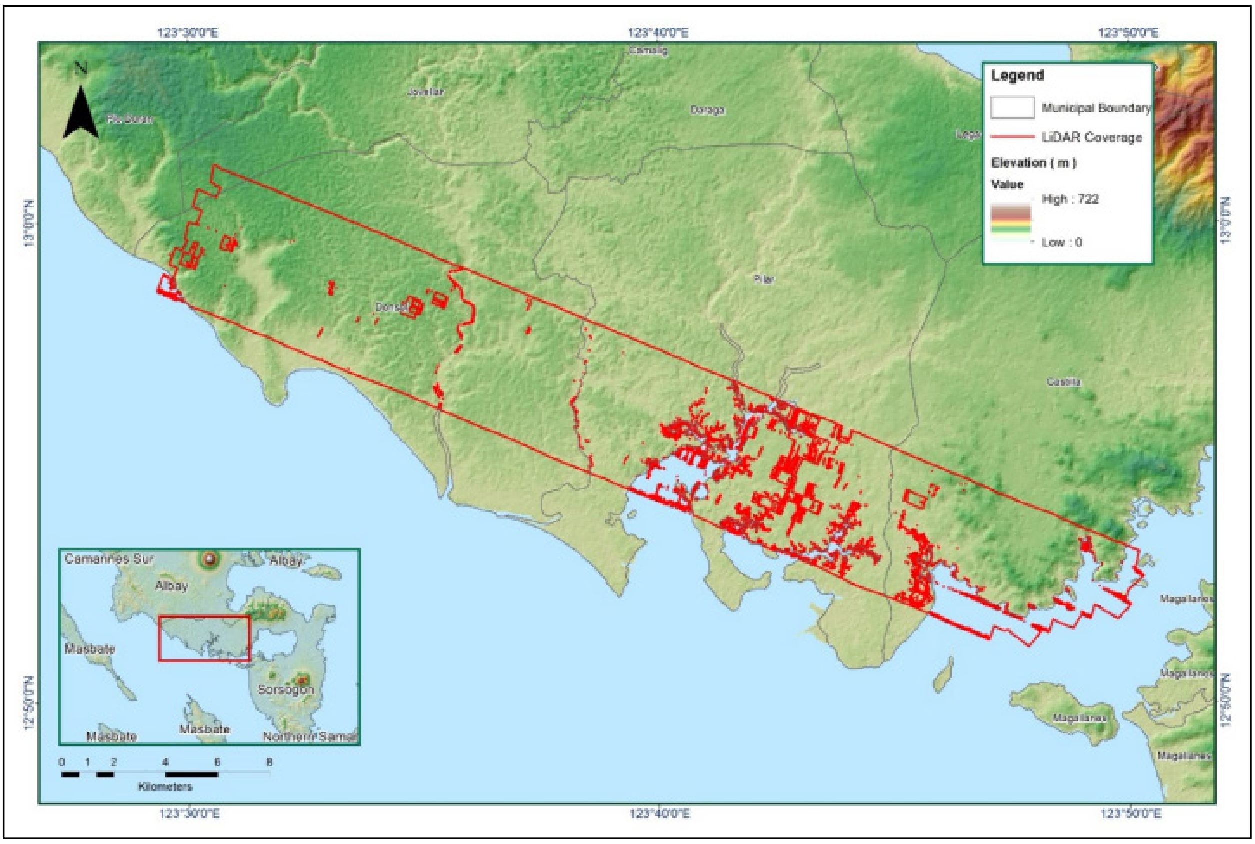


Figure A-8.25 Coverage of LiDAR data

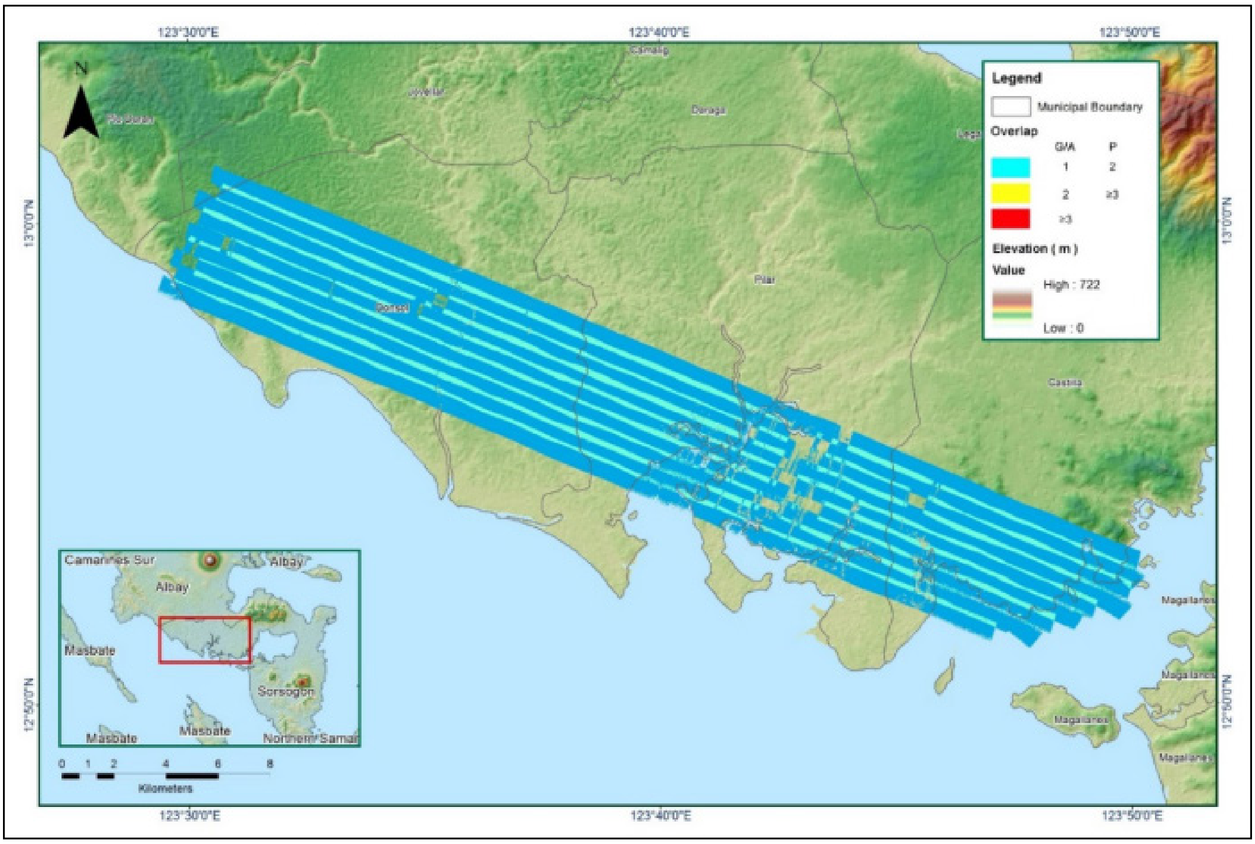


Figure A-8.26 Image of Data Overlap

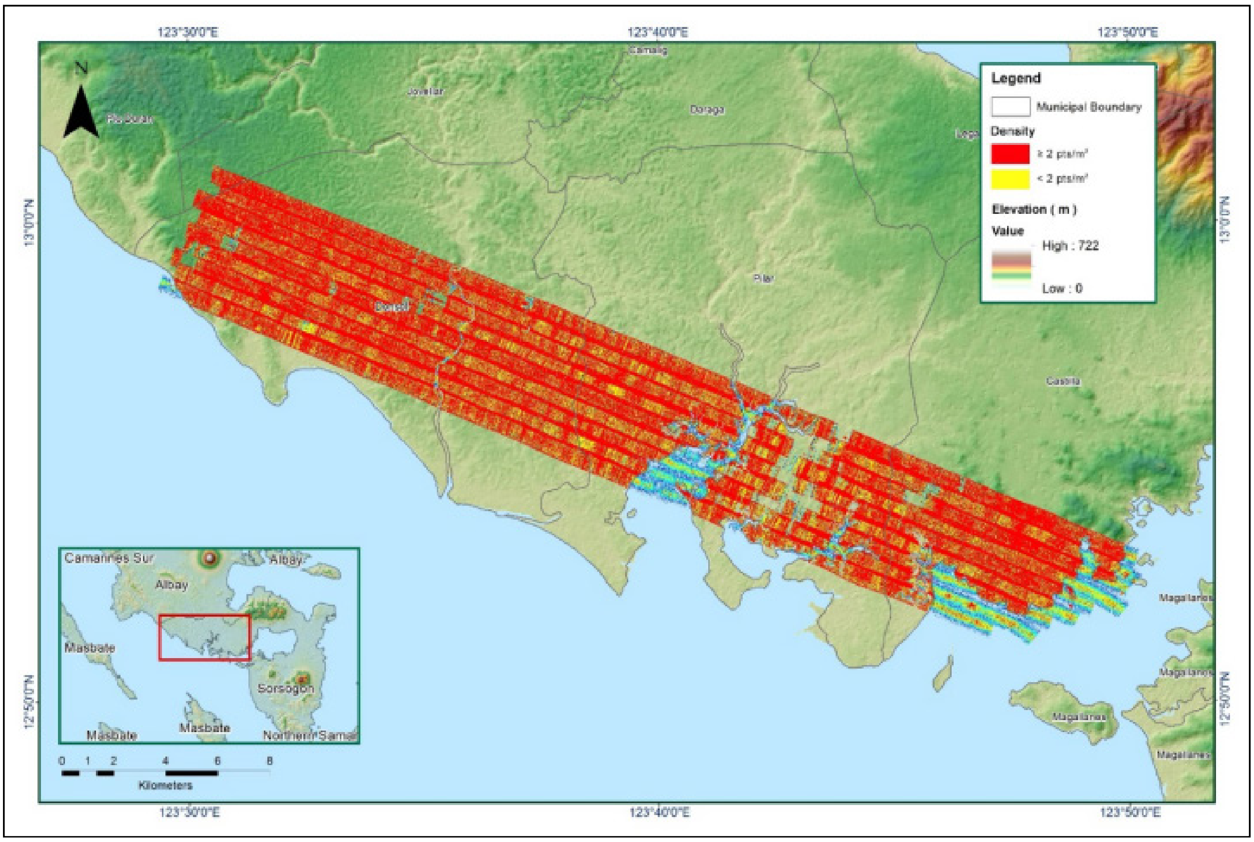


Figure A-8.27 Density map of merged LiDAR data

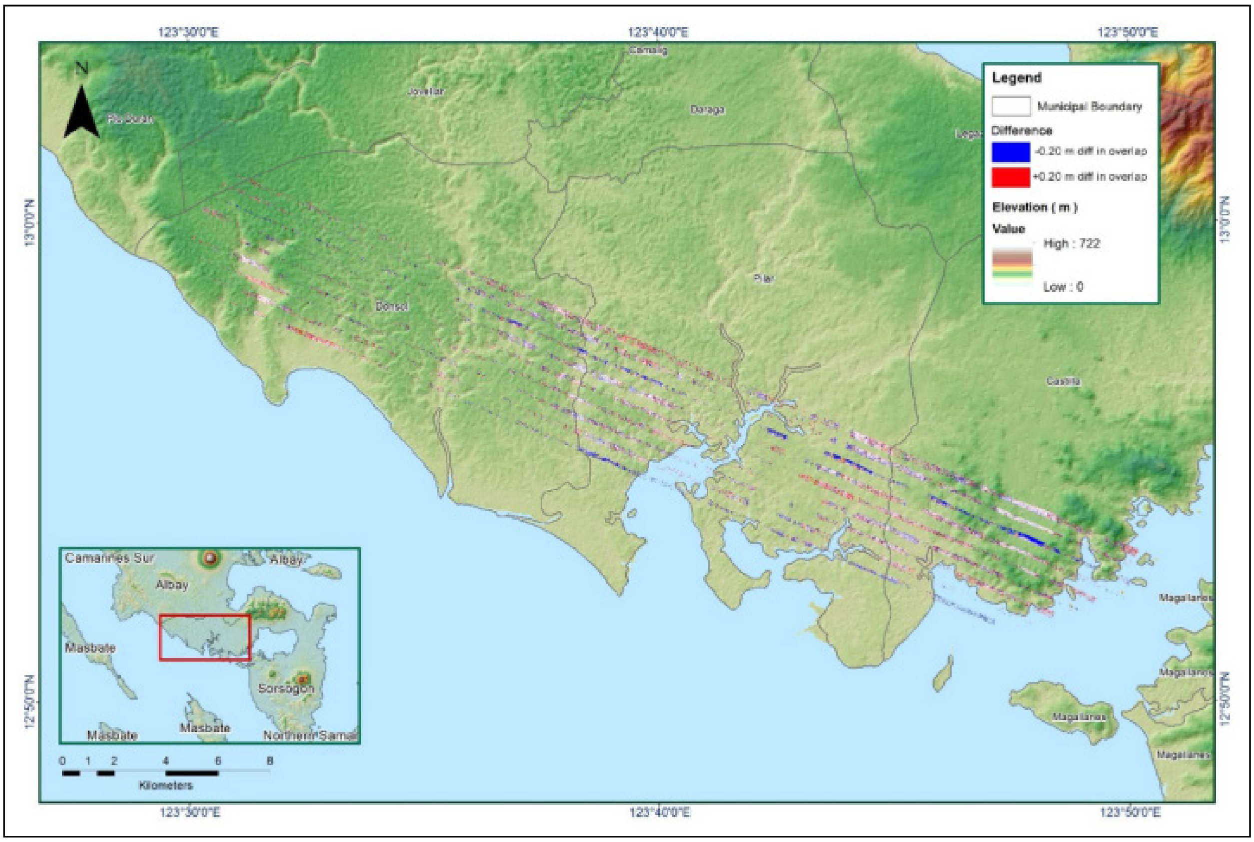


Figure A-8.28 Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk 19K

Flight Area	ALBAY/SORSOGON
Mission Name	Blk 19K
Inclusive Flights	7167GC
Range data size	25.5 GB
POS	222 MB
Image	---
Base data size	7.6 MB
Transfer date	April 29, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.95
RMSE for East Position (<4.0 cm)	2.13
RMSE for Down Position (<8.0 cm)	7.4
Boresight correction stdev (<0.001deg)	0.000214
IMU attitude correction stdev (<0.001deg)	0.000503
GPS position stdev (<0.01m)	0.0076
Minimum % overlap (>25)	30.10 %
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	308
Maximum Height	314.54
Minimum Height	54.37
Classification (# of points)	
Ground	95392016
Low vegetation	93507131
Medium vegetation	131188293
High vegetation	342412034
Building	3934510
Orthophoto	No
Processed By	Victoria Rejuso, Engr. Mark Joshua Salvacion, Engr. Jeffrey Delica

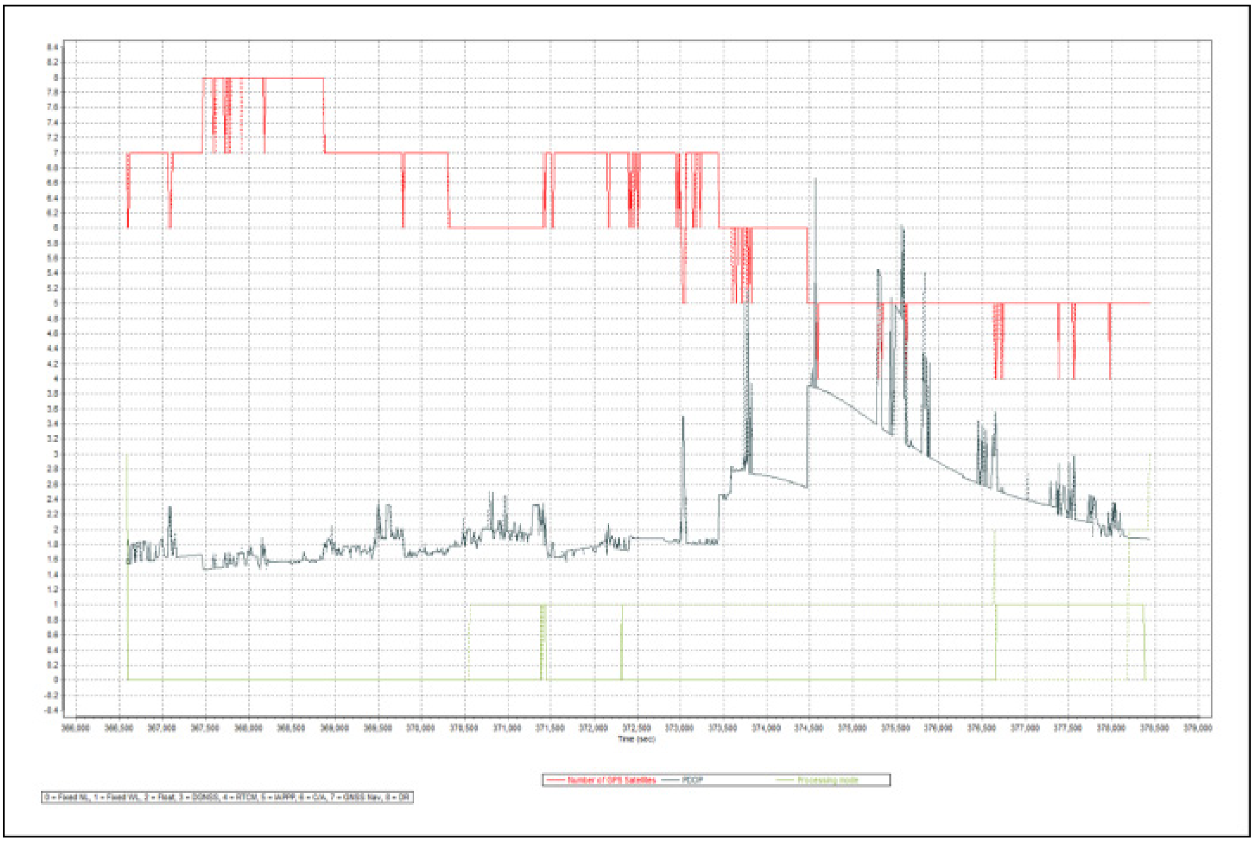


Figure A-8.29 Solution Status

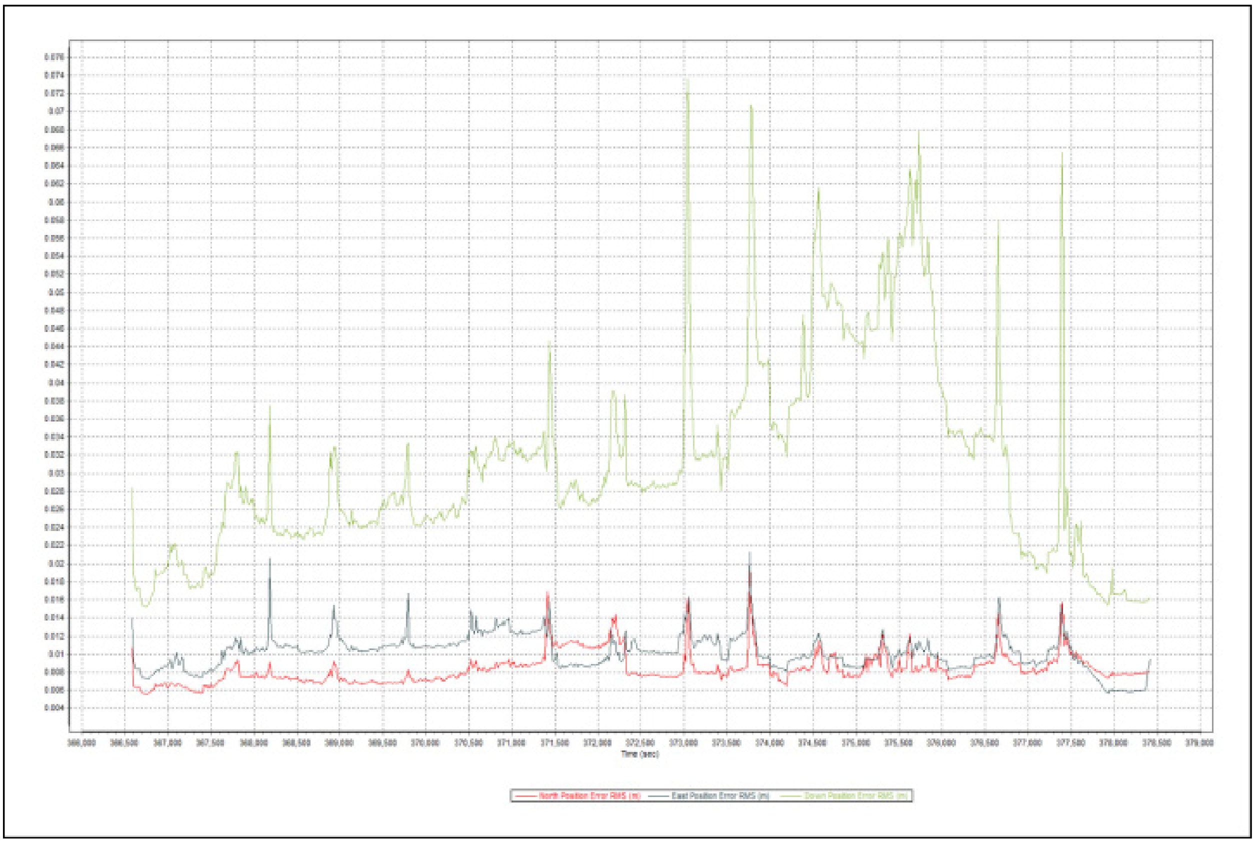


Figure A-8.30 Smoothed Performance Metric Parameters

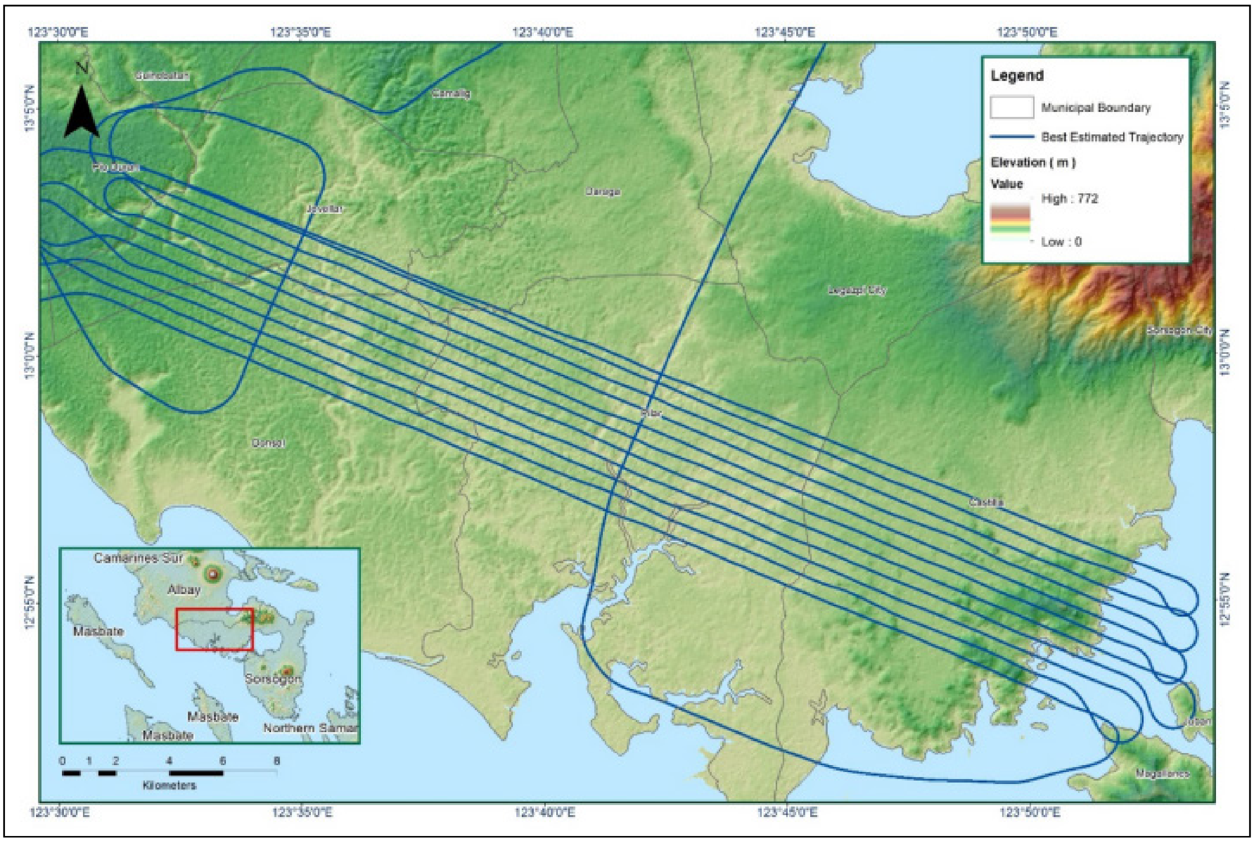


Figure A-8.31 Best Estimated Trajectory

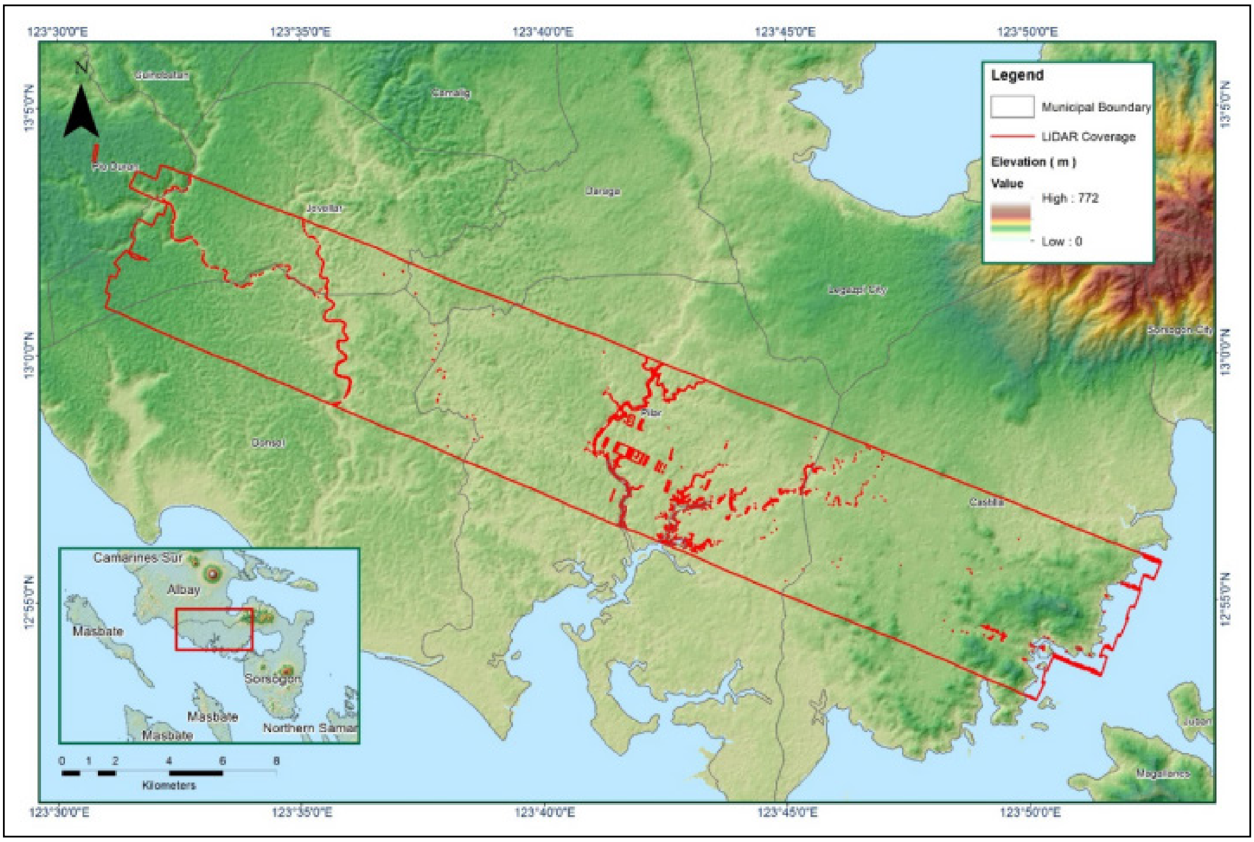


Figure A-8.32 Coverage of LiDAR data

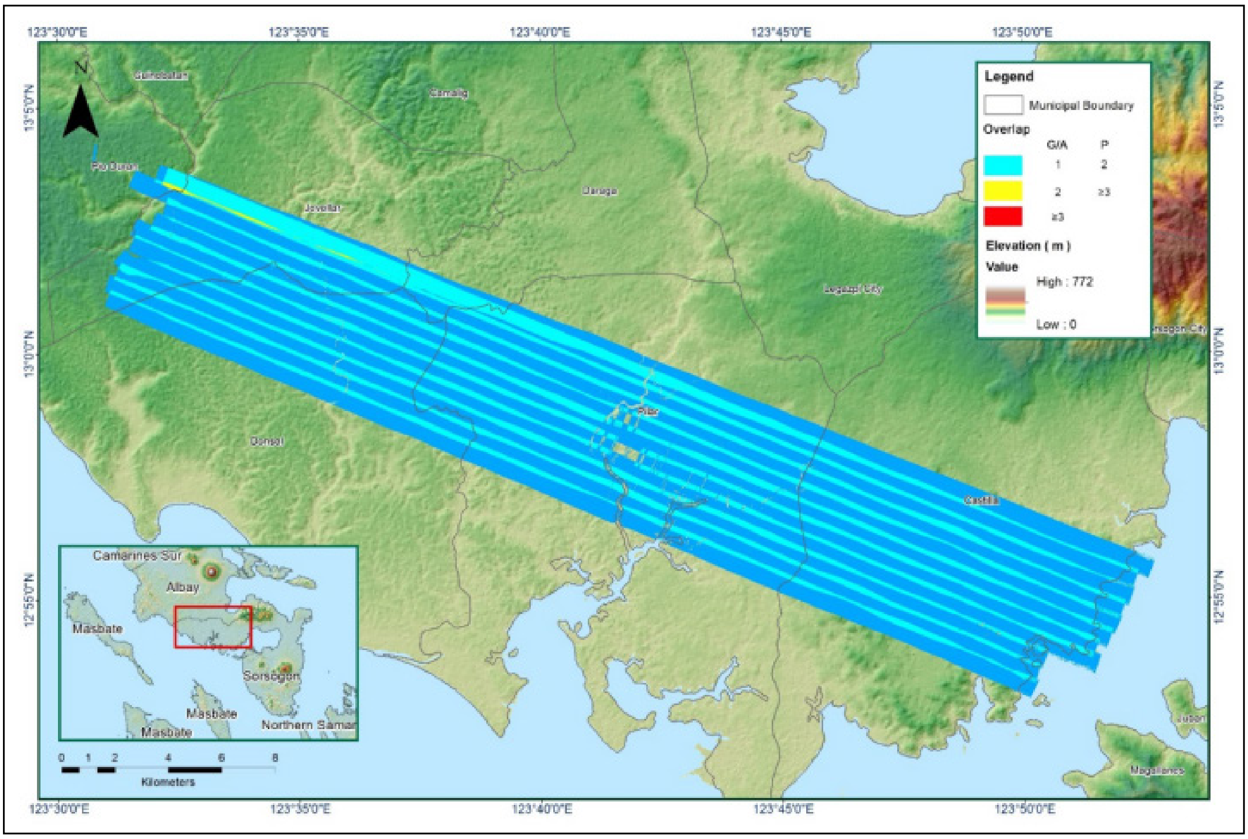


Figure A-8.33 Image of Data Overlap

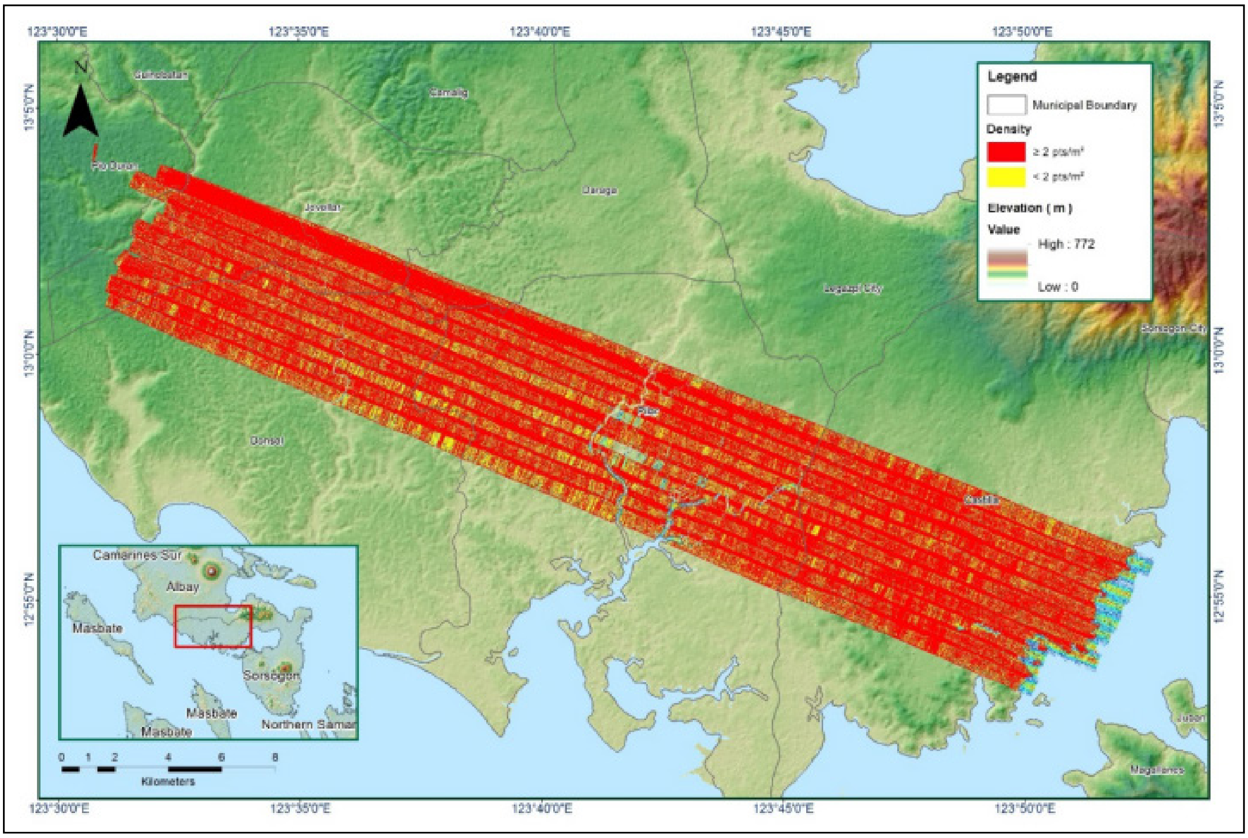


Figure A-8.34 Density map of merged LiDAR data

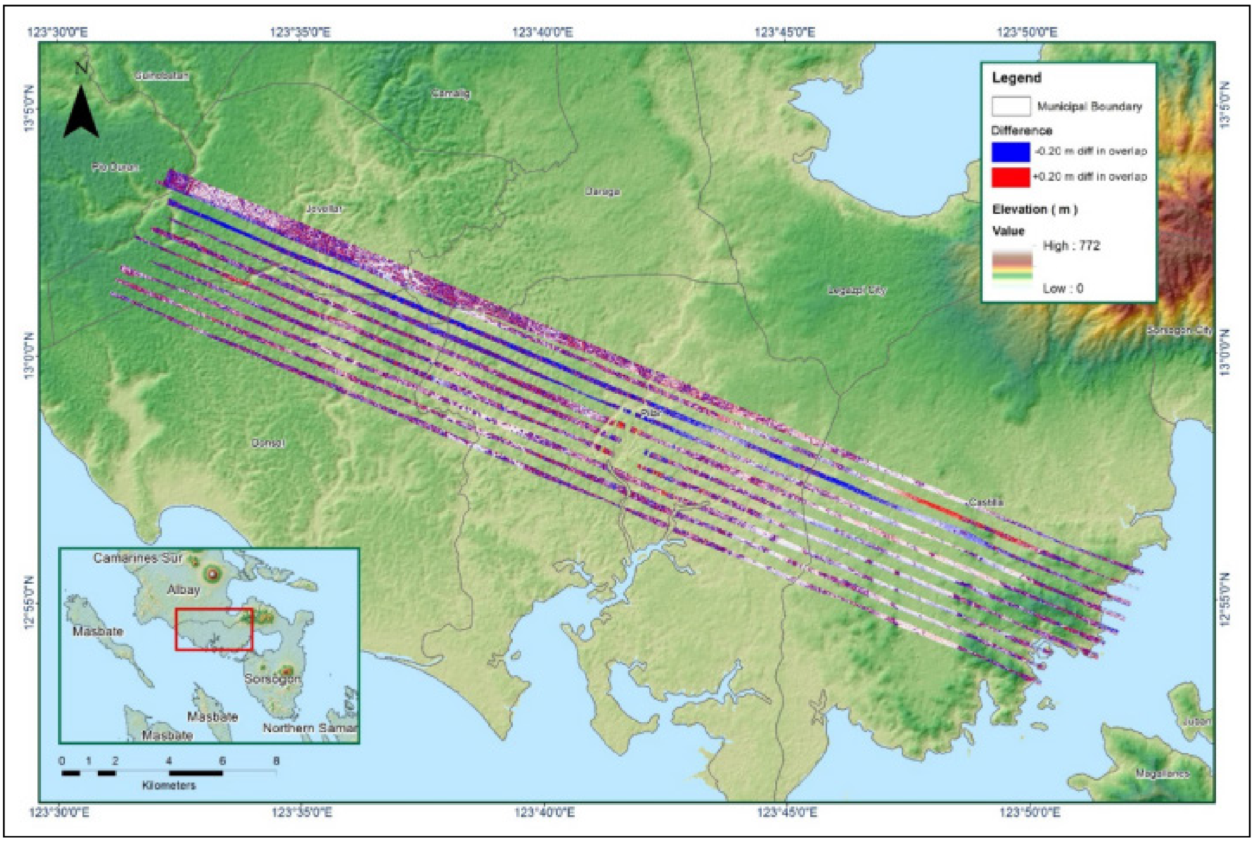


Figure A-8.35 Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk 19L

Flight Area	Albay-Sorsogon_reflights
Mission Name	Blk 19L
Inclusive Flights	3815G
Range data size	22.1 GB
POS data size	209 MB
Base data size	7.02 MB
Image	51.6 MB
Transfer date	March 4, 2016
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)	1.402
RMSE for East Position (<4.0 cm)	1.710
RMSE for Down Position (<8.0 cm)	3.345
Boresight correction stdev (<0.001deg)	0.000626
IMU attitude correction stdev (<0.001deg)	0.004092
GPS position stdev (<0.01m)	0.0161
Minimum % overlap (>25)	34.93 %
Ave point cloud density per sq.m. (>2.0)	6.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	200.52 m
Minimum Height	53.21 m
Classification (# of points)	
Ground	33,363,169
Low vegetation	35,353,120
Medium vegetation	199,279,746
High vegetation	167,904,428
Building	1,115,853
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Ryan Nicholai Dizon

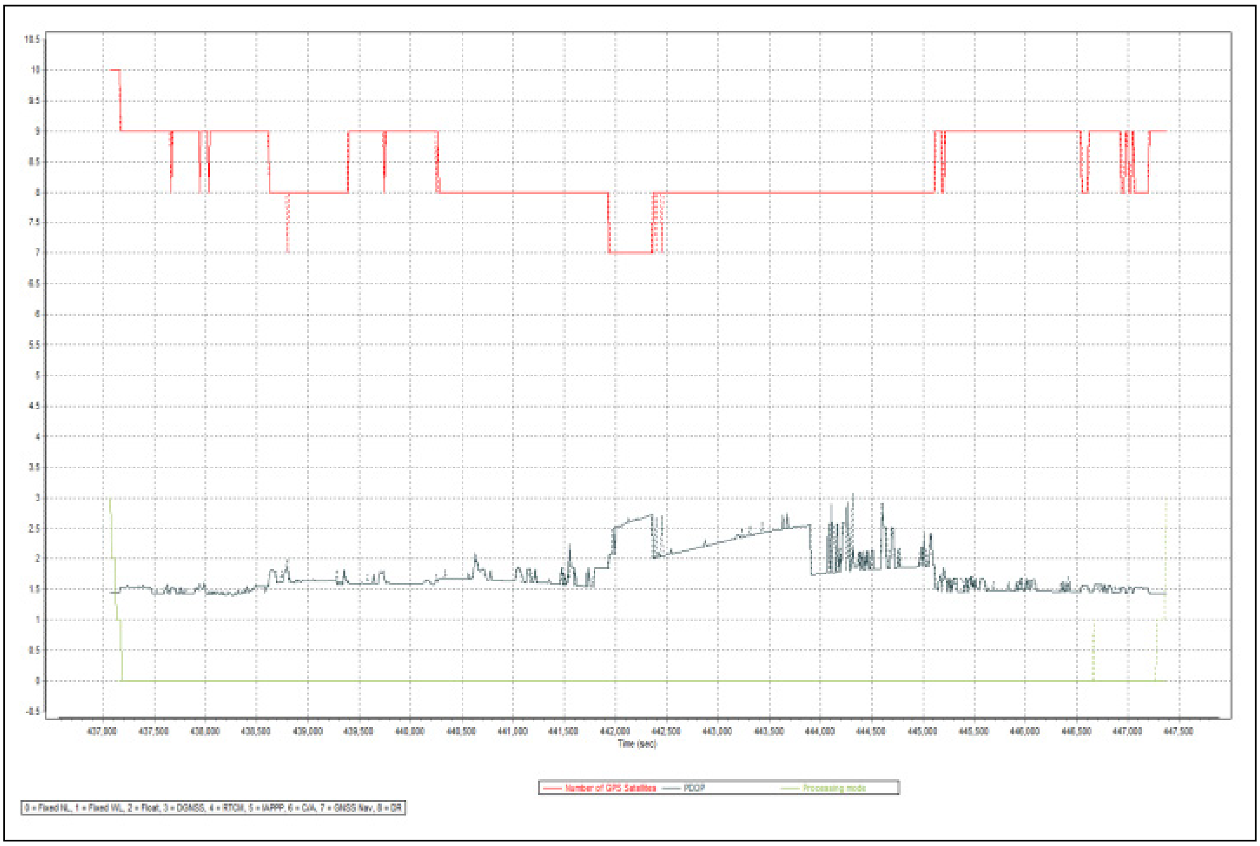


Figure A-8.36 Solution Status

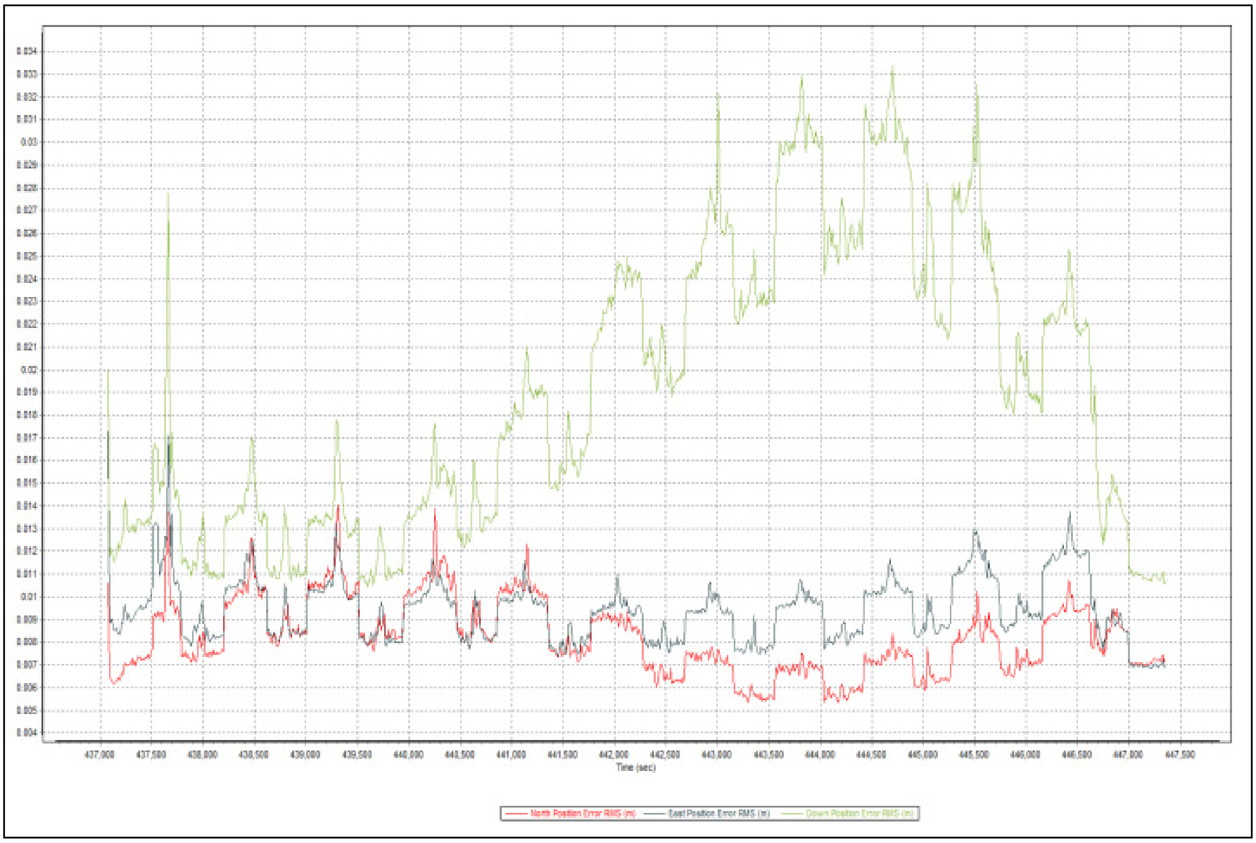


Figure A-8.37 Smoothed Performance Metric Parameters

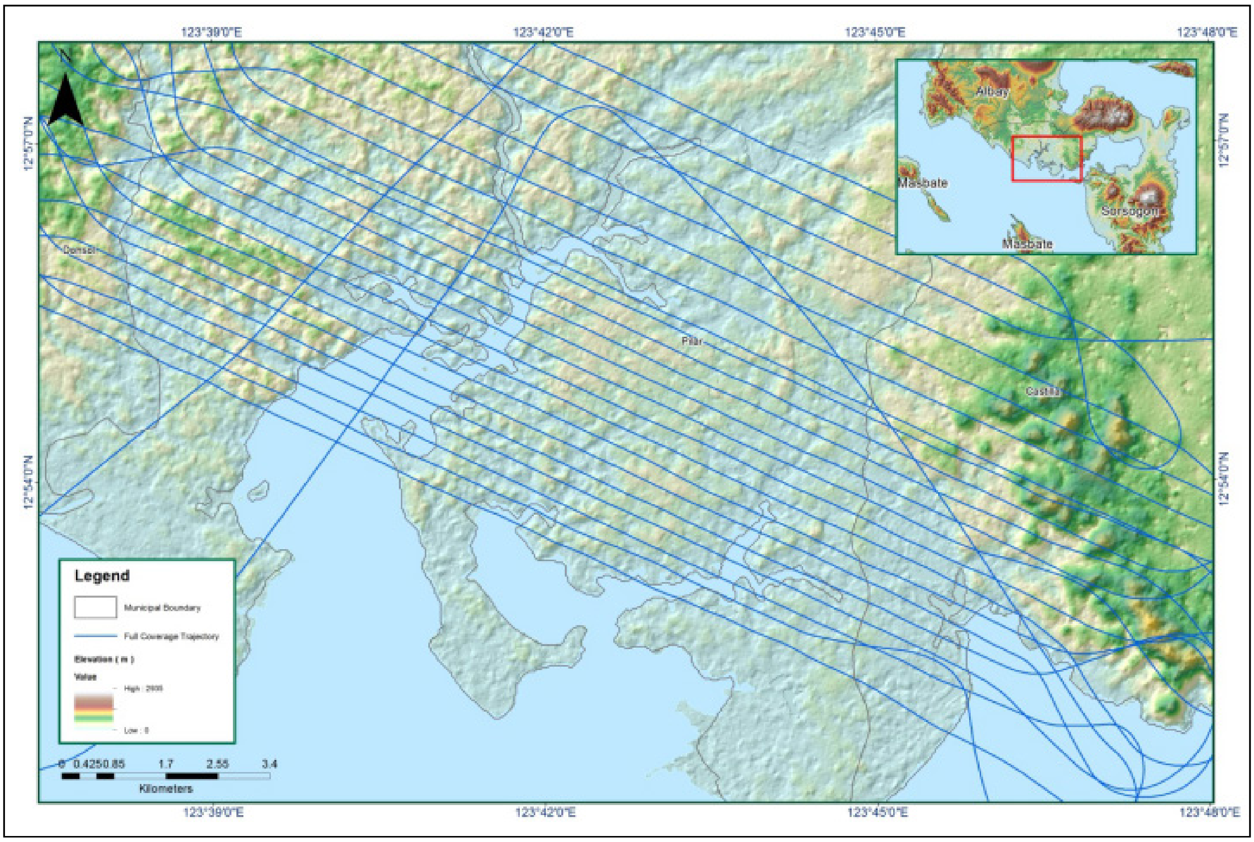


Figure A-8.38 Best Estimated Trajectory

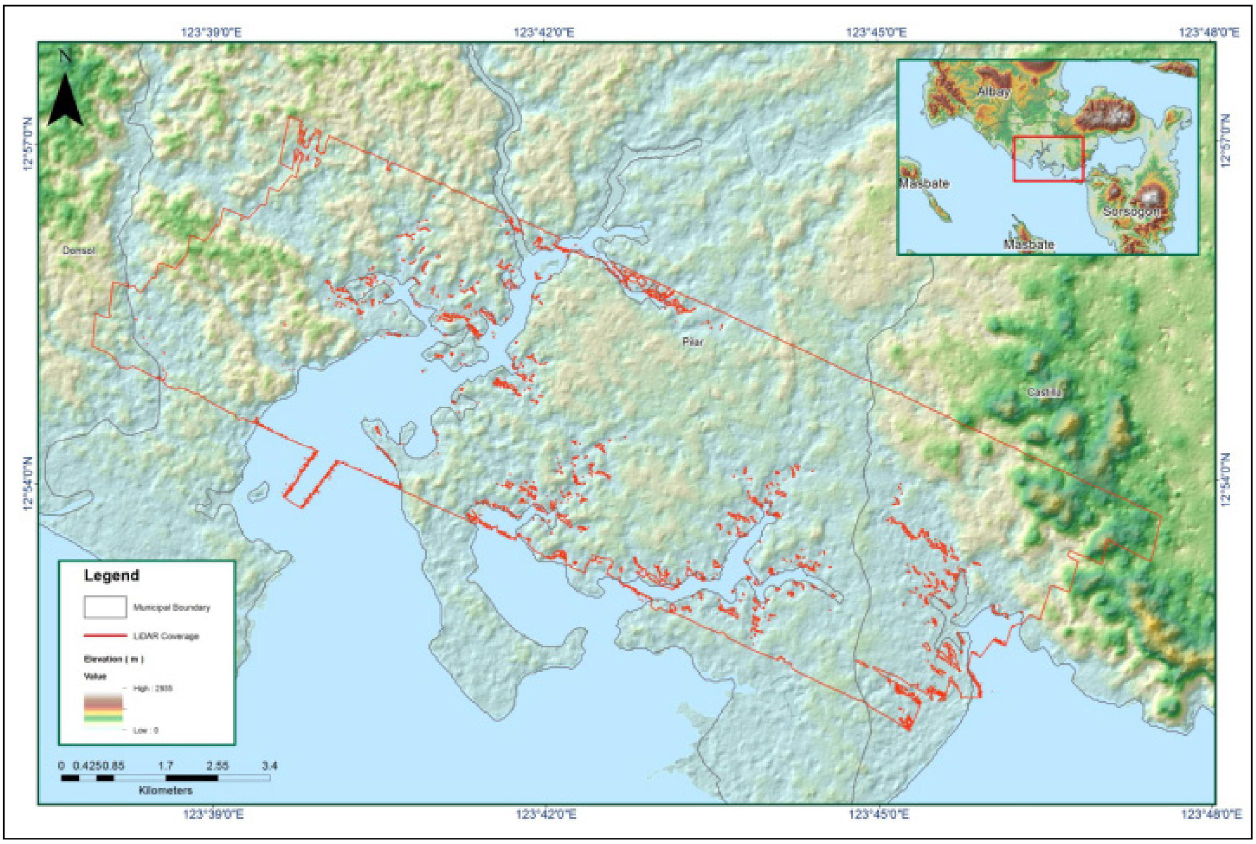


Figure A-8.39 Coverage of LiDAR data

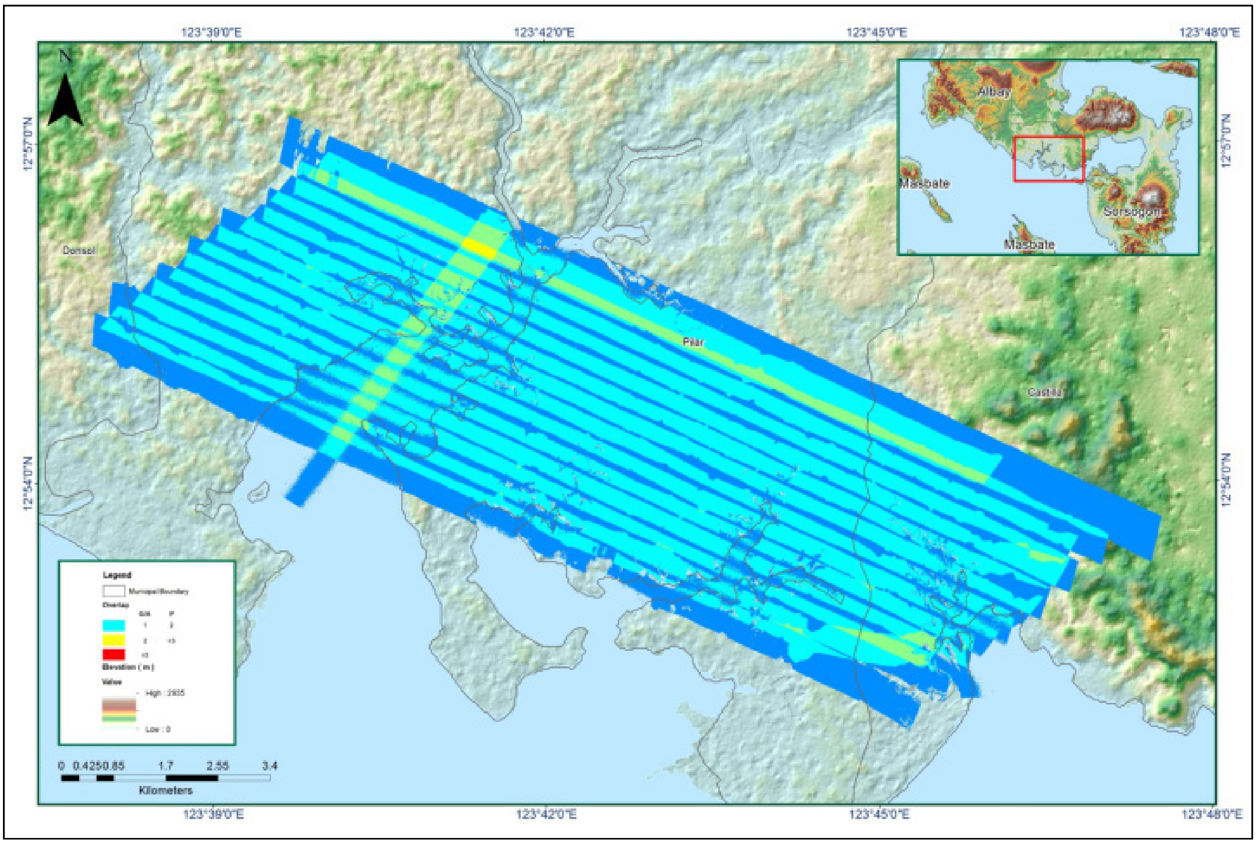


Figure A-8.40 Image of Data Overlap

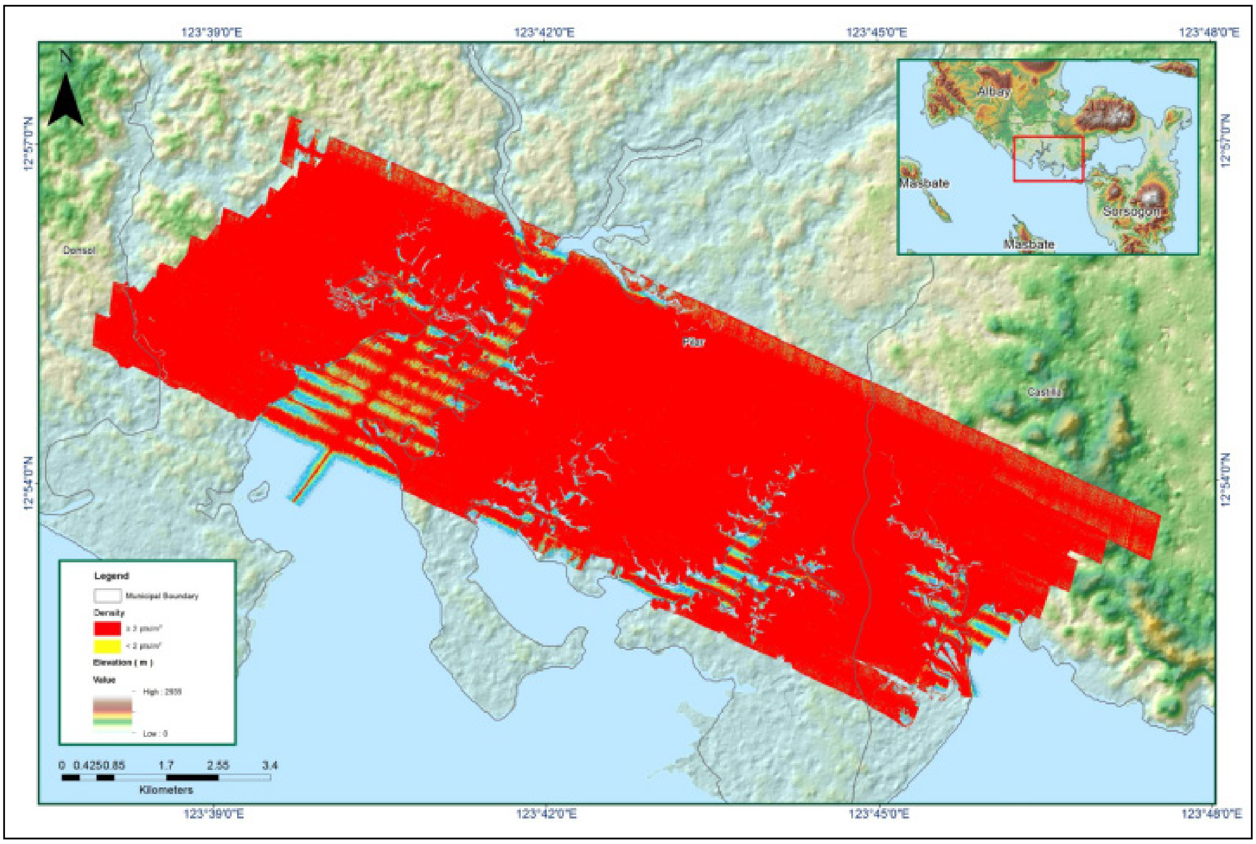


Figure A-8.41 Density map of merged LiDAR data

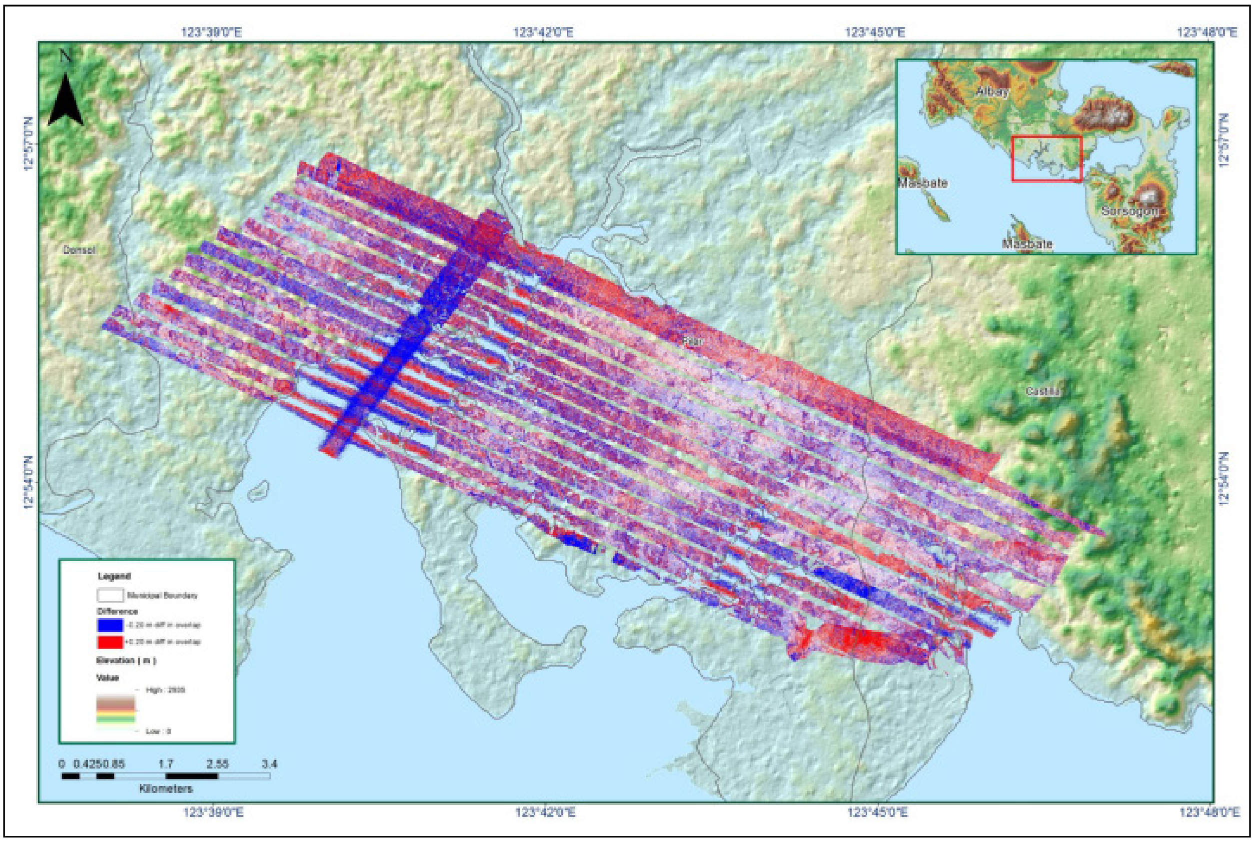


Figure A-8.42 Elevation difference between flight lines

Table A-8.7 Mission Summary Report for Mission Blk 19I

Flight Area	Albay-Sorsogon_reflights
Mission Name	Blk 19I
Inclusive Flights	3813G
Range data size	26.8 GB
POS data size	202 MB
Base data size	5.61 MB
Image	66.8 MB
Transfer date	March 4, 2016
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)	1.001
RMSE for East Position (<4.0 cm)	1.070
RMSE for Down Position (<8.0 cm)	2.090
Boresight correction stdev (<0.001deg)	0.002121
IMU attitude correction stdev (<0.001deg)	0.005422
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	28.49 %
Ave point cloud density per sq.m. (>2.0)	6.18
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	154
Maximum Height	222.00 m
Minimum Height	53.88 m
Classification (# of points)	
Ground	37,487,618
Low vegetation	42,720,599
Medium vegetation	181,607,838
High vegetation	162,838,123
Building	825,908
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan

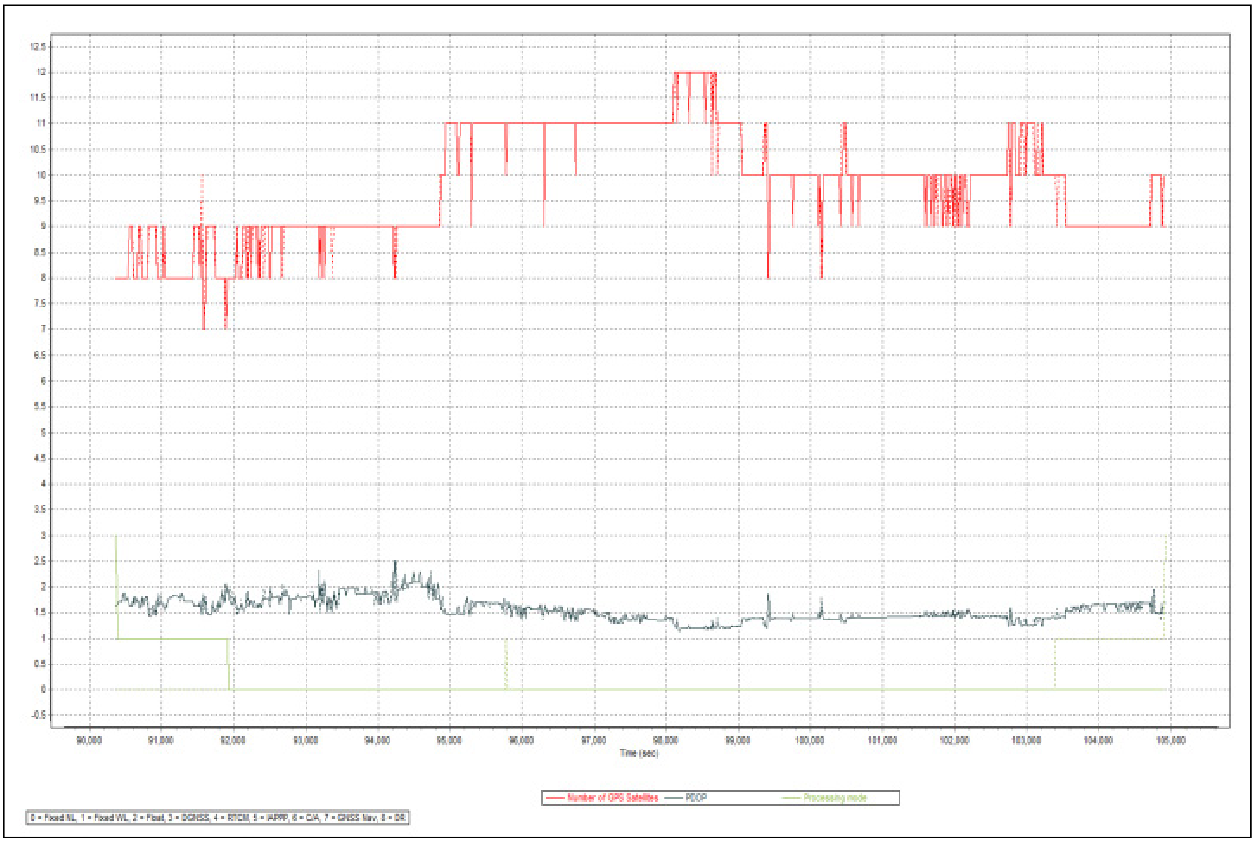


Figure A-8.43 Solution Status

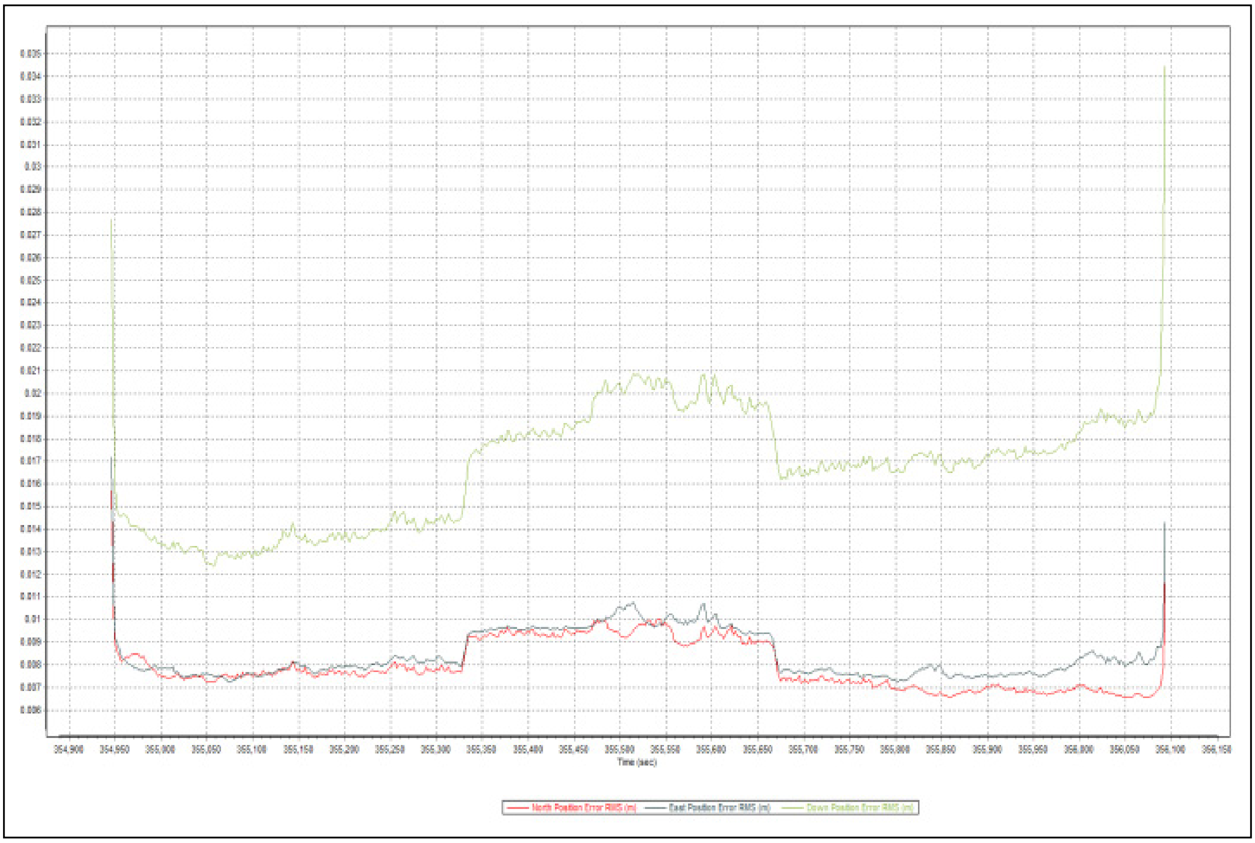


Figure A-8.44 Smoothed Performance Metric Parameters

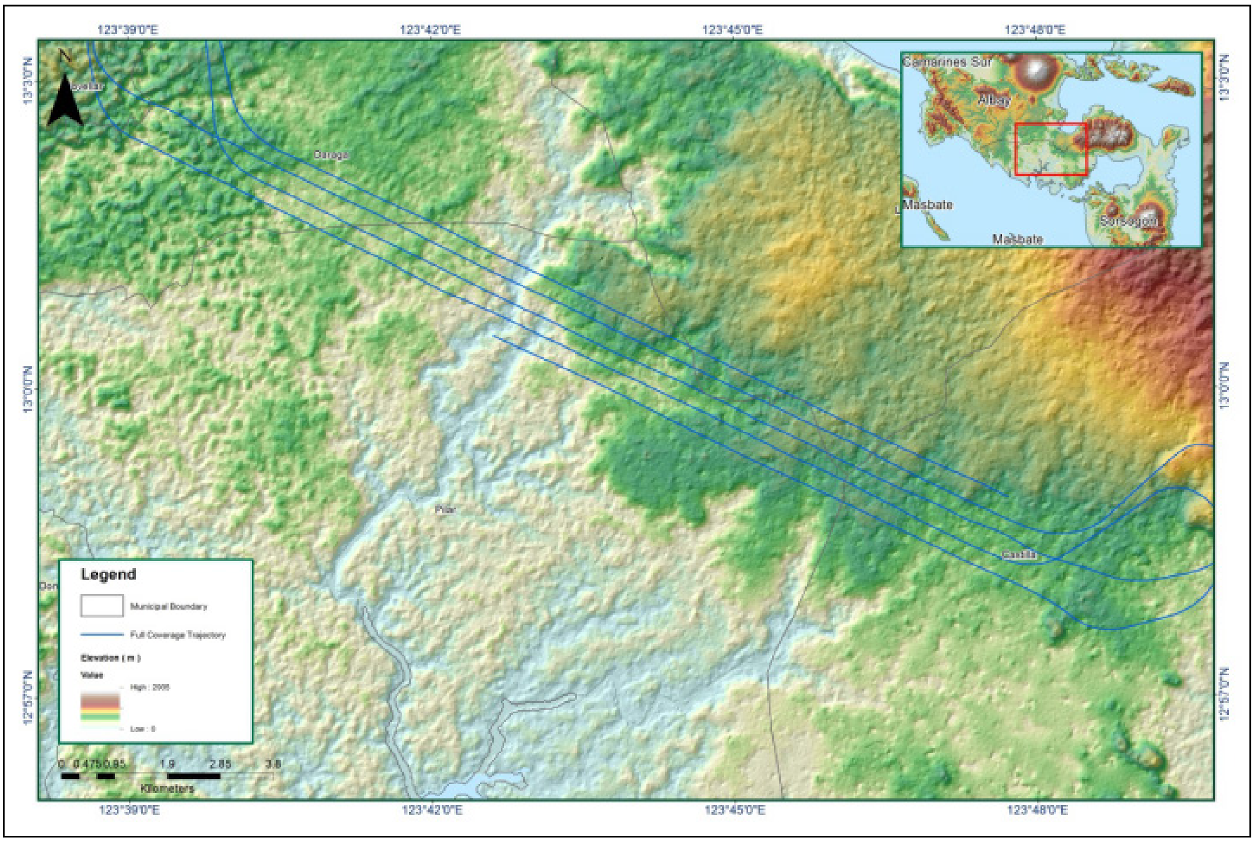


Figure A-8.45 Best Estimated Trajectory

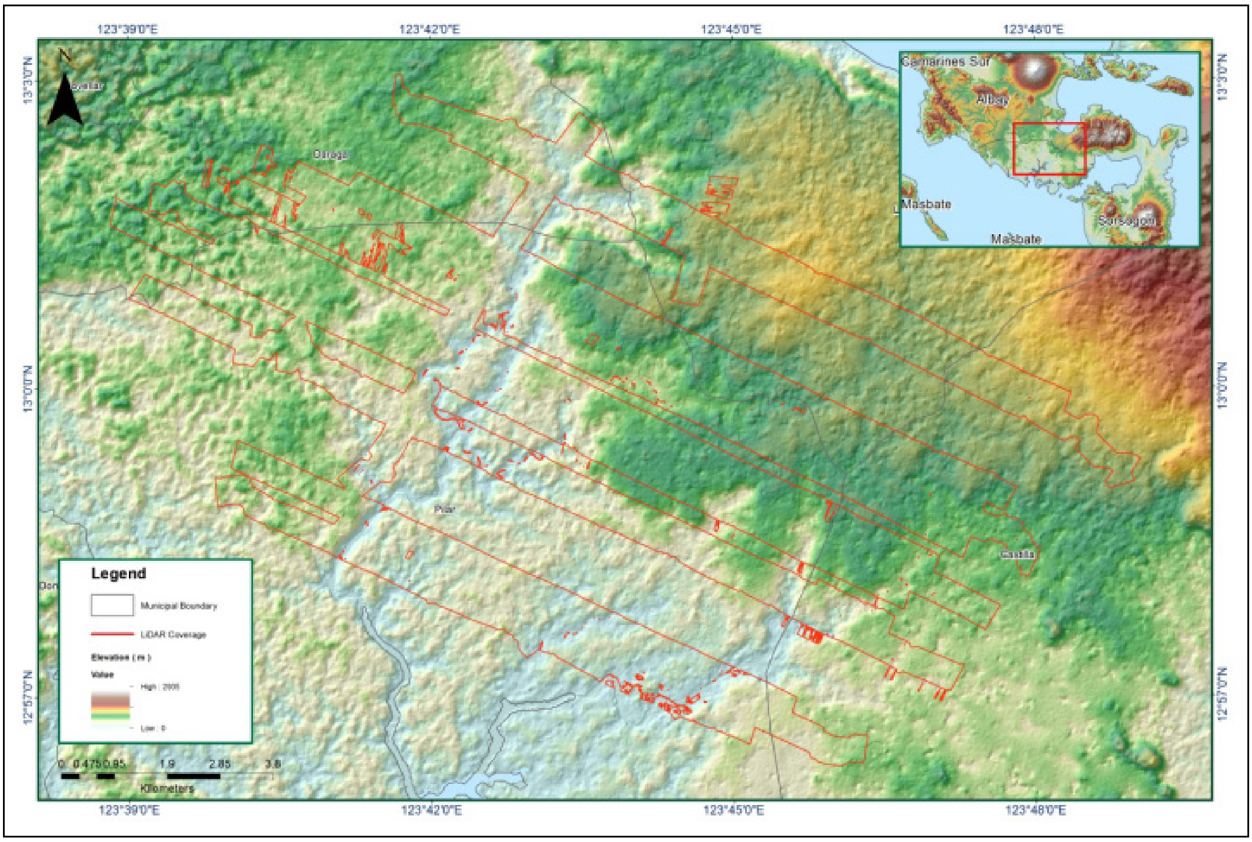


Figure A-8.46 Coverage of LiDAR data

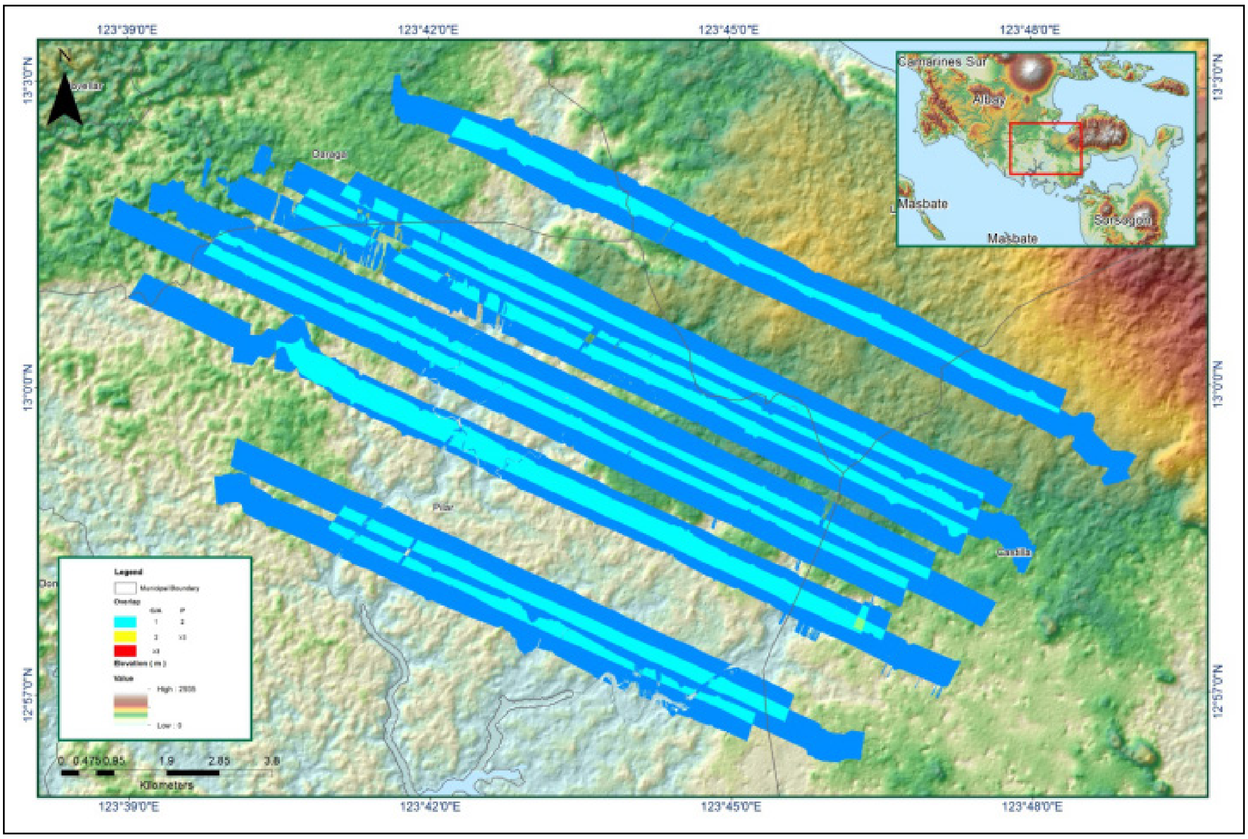


Figure A-8.47 Image of Data Overlap

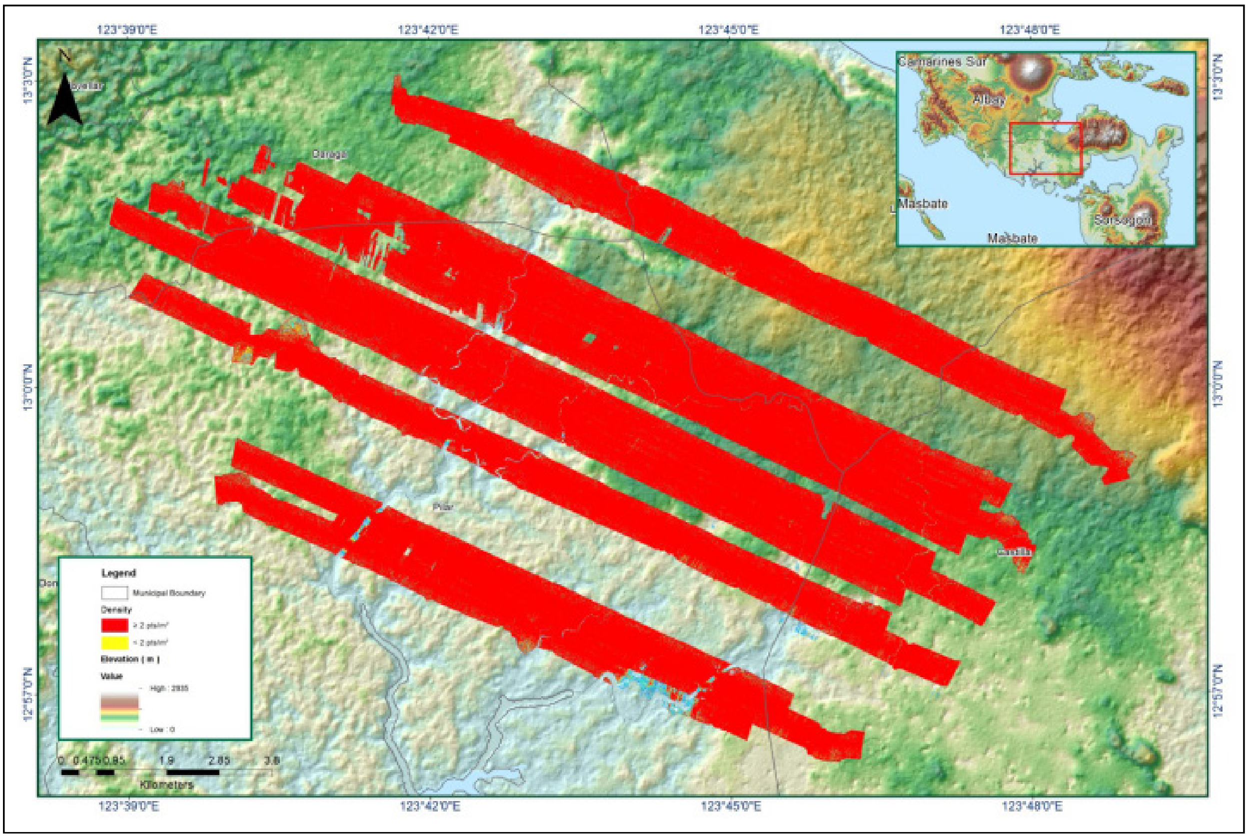


Figure A-8.48 Density map of merged LiDAR data

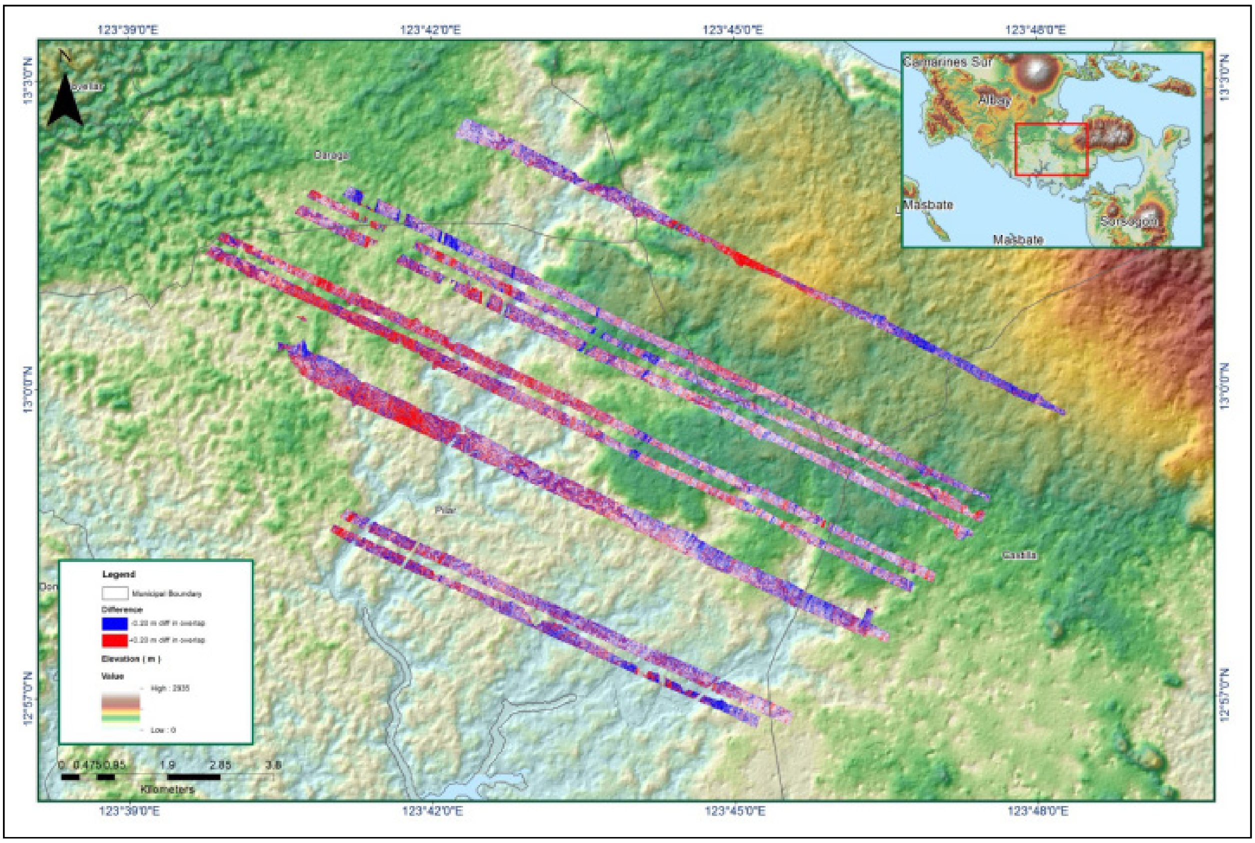


Figure A-8.49 Elevation difference between flight lines

Table A-8.8 Mission Summary Report for Mission Blk 19I_additional

Flight Area	Albay-Sorsogon_reflights
Mission Name	Blk 19I_additional
Inclusive Flights	3813G
Range data size	26.8 GB
POS data size	202 MB
Base data size	5.61 MB
Image	66.8 MB
Transfer date	March 4, 2016
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)	1.275
RMSE for East Position (<4.0 cm)	1.524
RMSE for Down Position (<8.0 cm)	3.333
Boresight correction stdev (<0.001deg)	0.000343
IMU attitude correction stdev (<0.001deg)	0.001725
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	26.86 %
Ave point cloud density per sq.m. (>2.0)	6.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	134
Maximum Height	198.30 m
Minimum Height	53.71 m
Classification (# of points)	
Ground	35,301,737
Low vegetation	47,816,552
Medium vegetation	180,246,768
High vegetation	152,332,905
Building	761,702
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Jovelle Canlas, Engr. Elainne Lopez

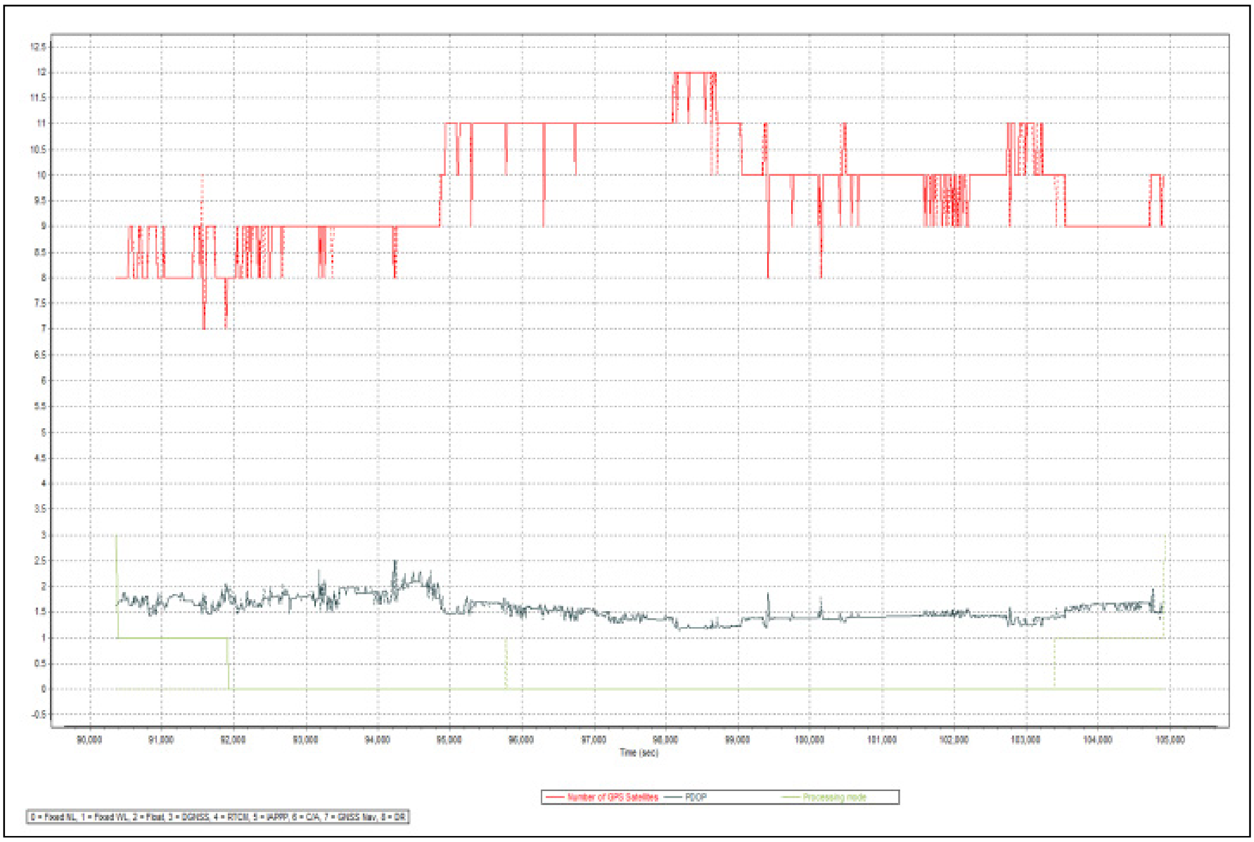


Figure A-8.50 Solution Status

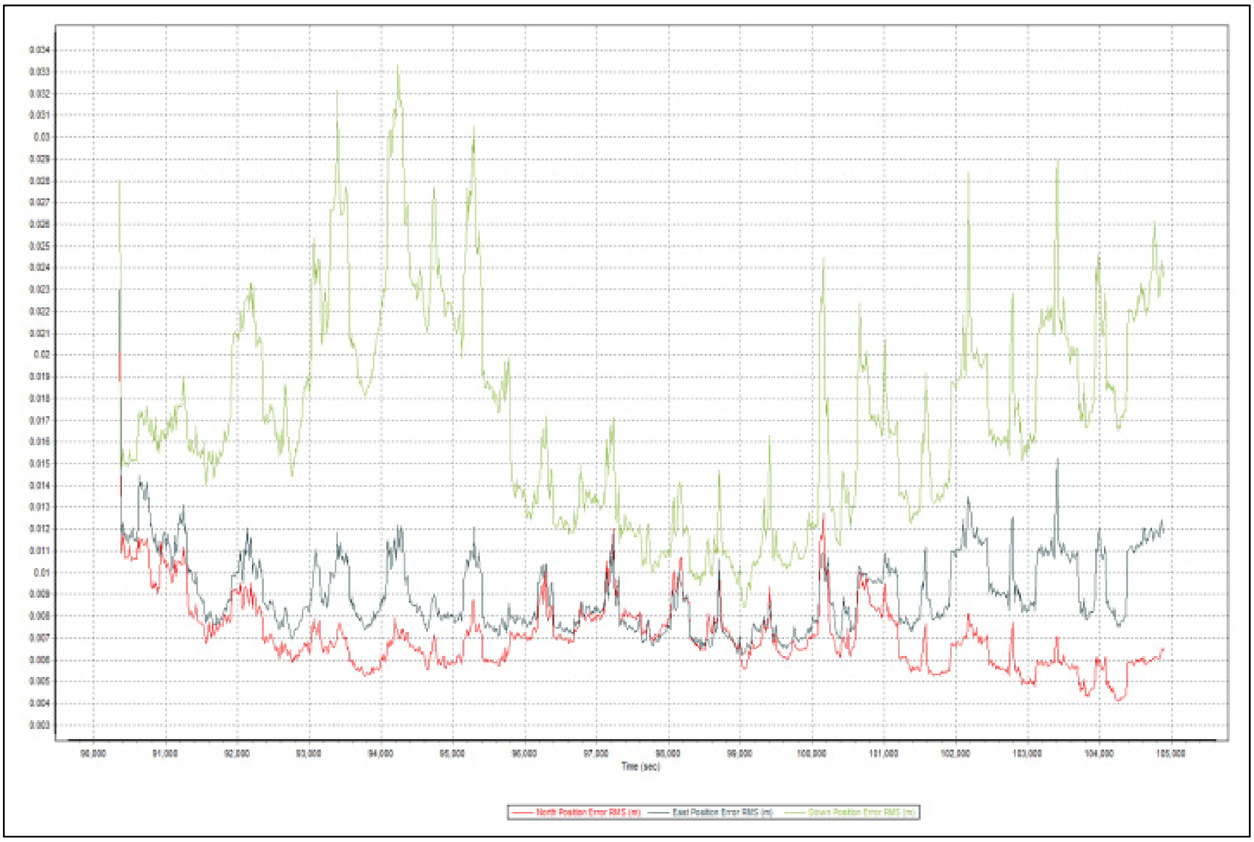


Figure A-8.51 Smoothed Performance Metric Parameters

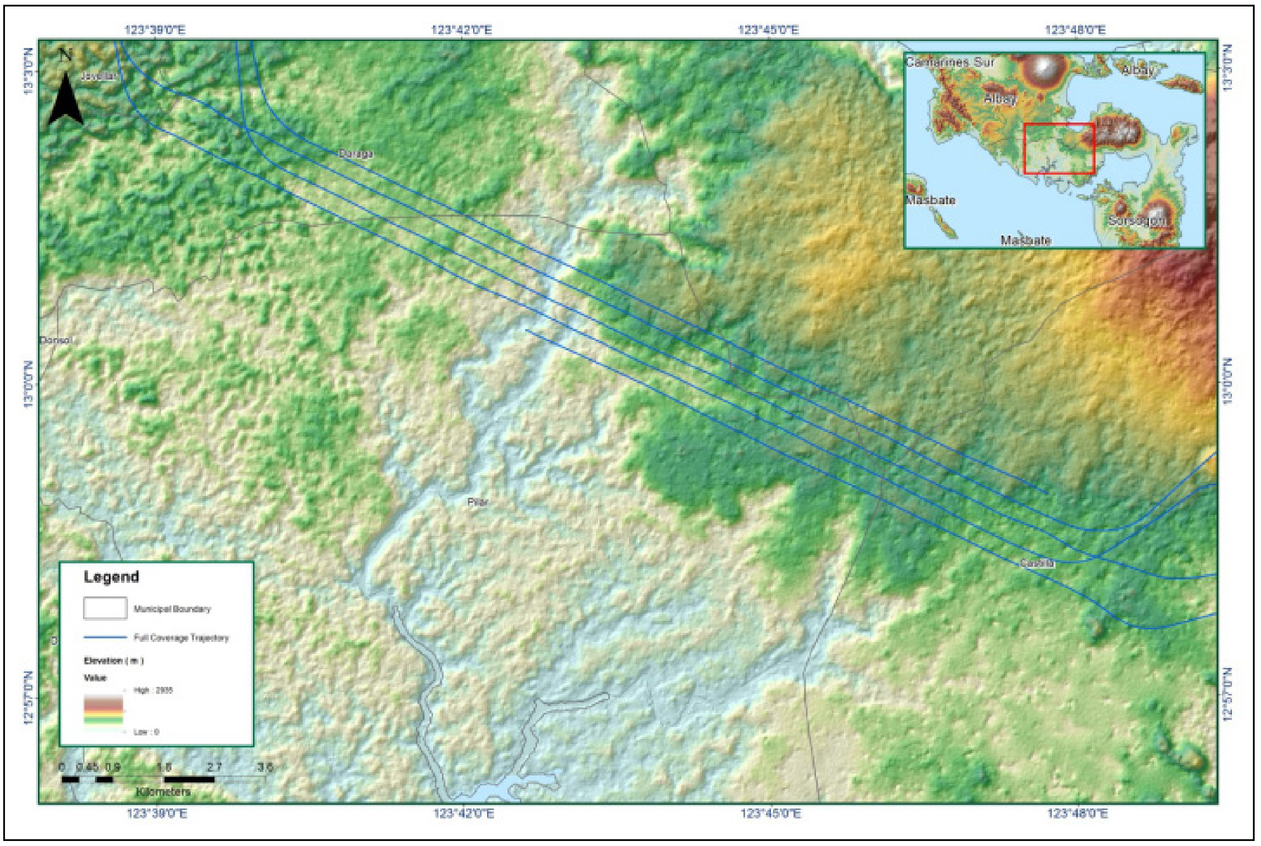


Figure A-8.52 Best Estimated Trajectory

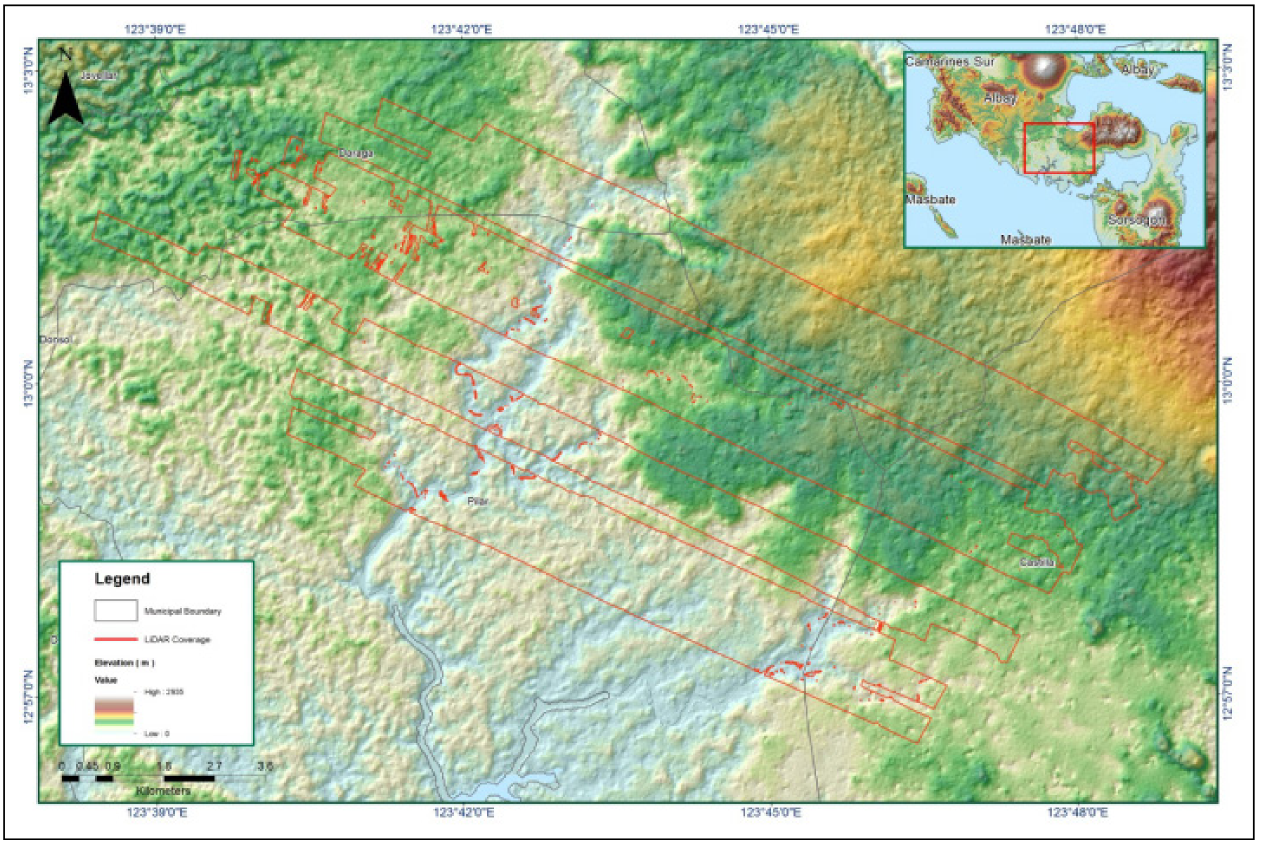


Figure A-8.53 Coverage of LiDAR data

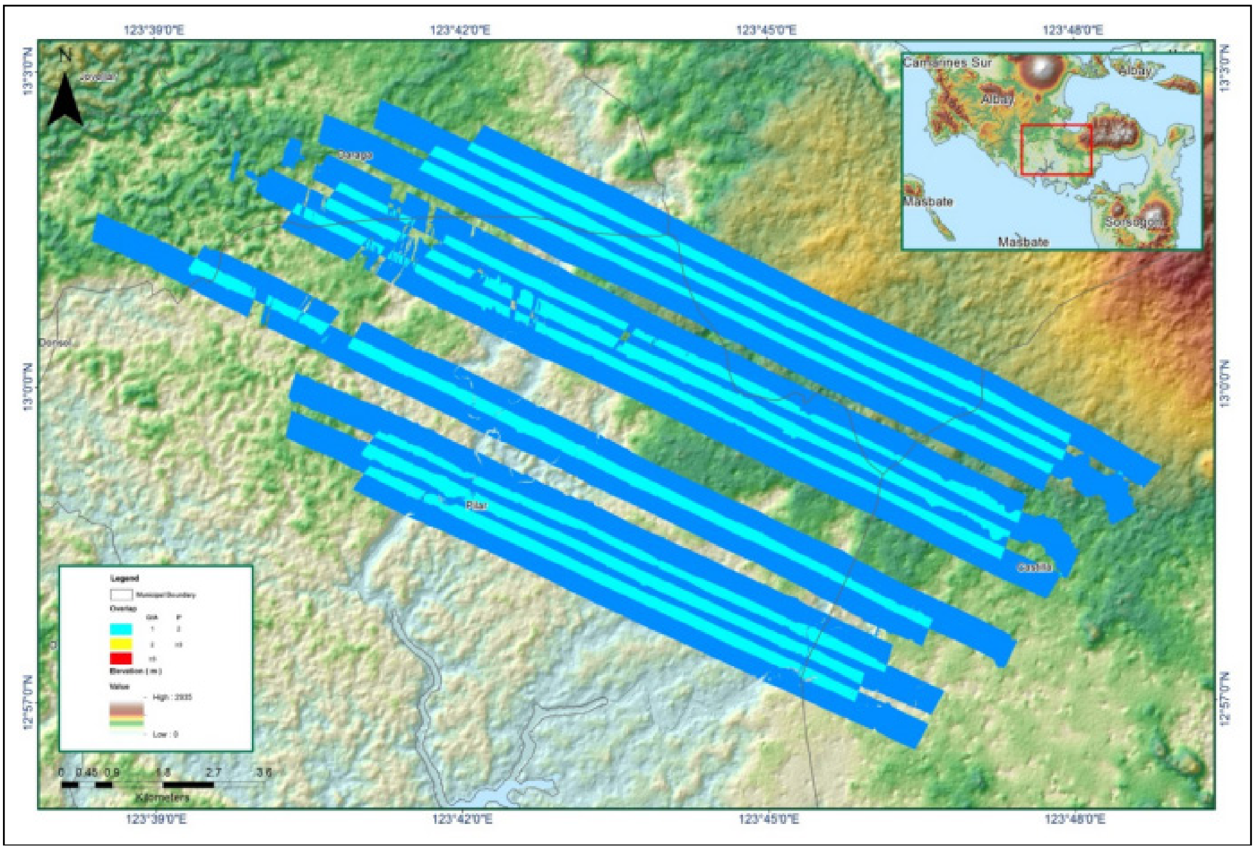


Figure A-8.54 Image of Data Overlap

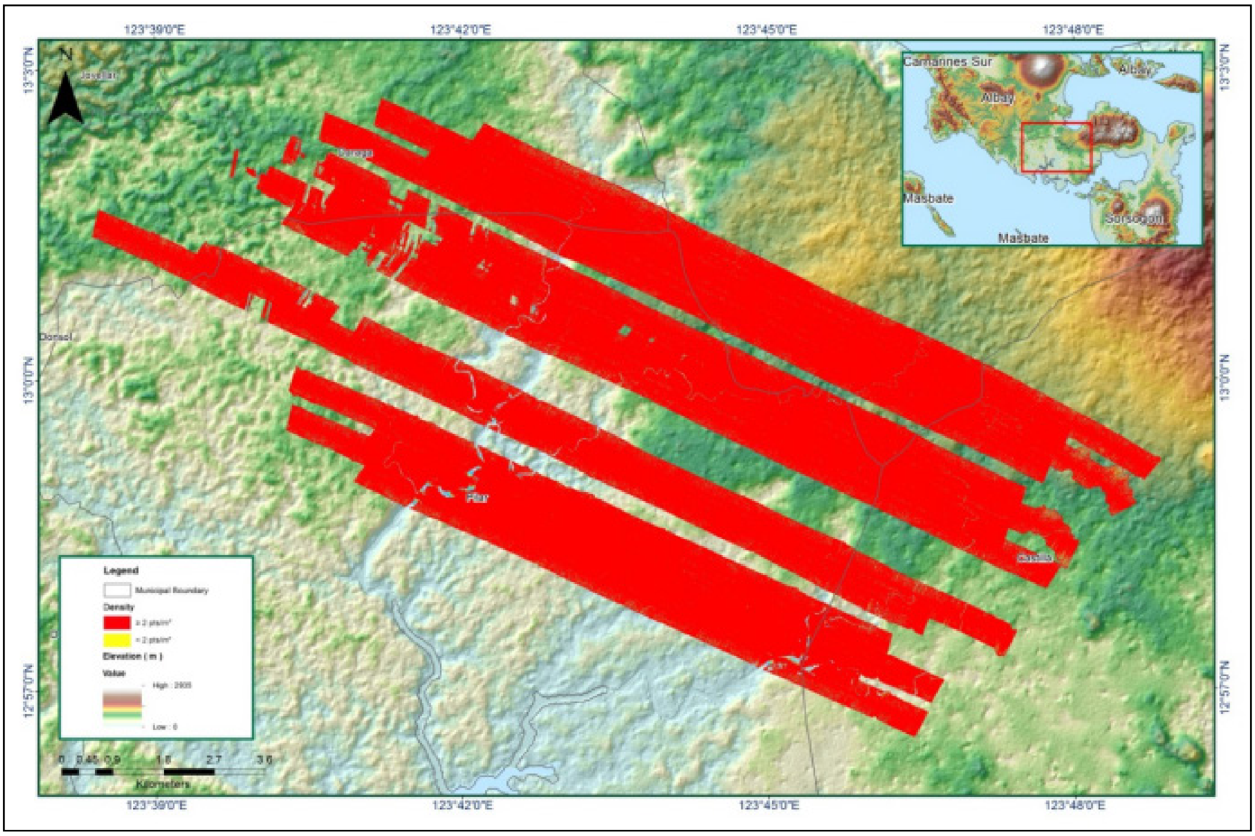


Figure A-8.55 Density map of merged LiDAR data

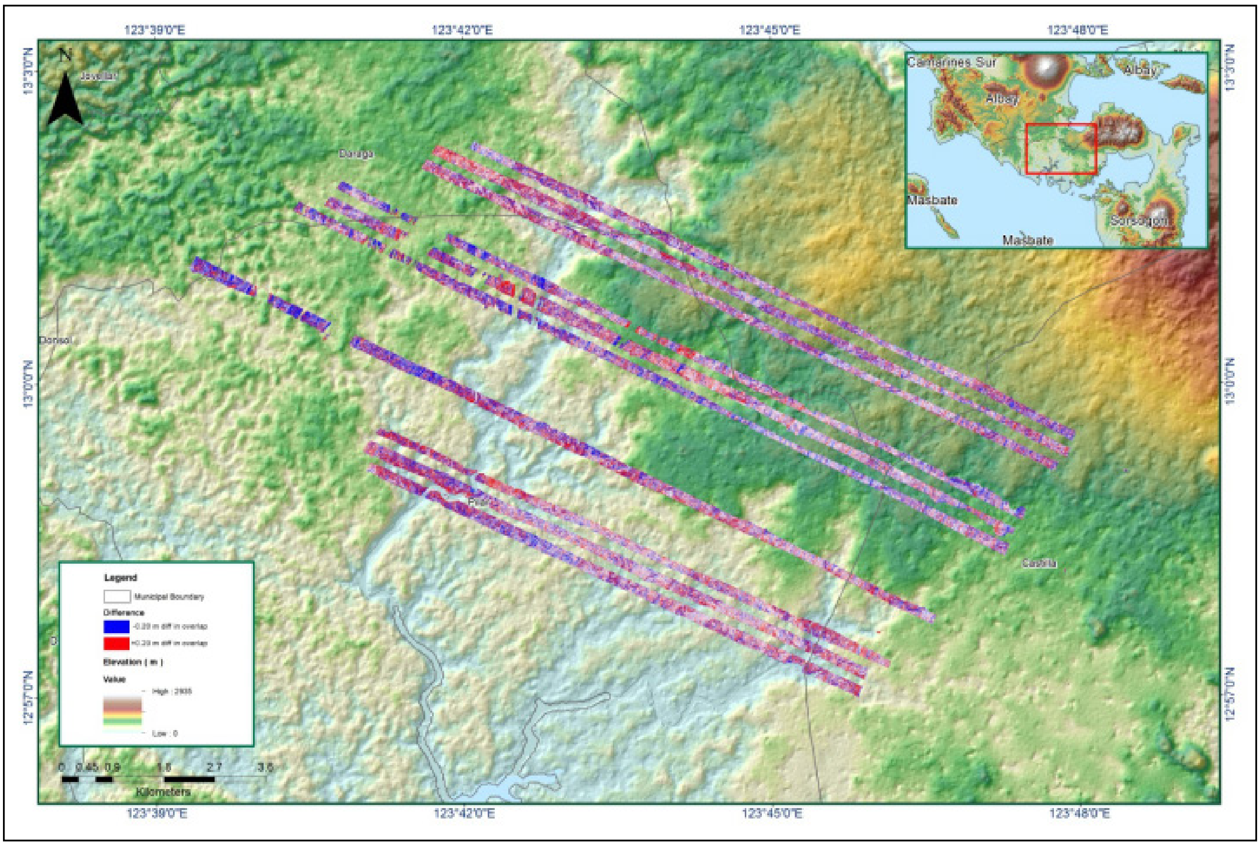


Figure A-8.56 Elevation difference between flight lines

Annex 9. Putiao Model Basin Parameters

Table A-9.1 Putiao 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
W140	4.550	39.809	0	1.688	0.38269	Discharge	0.7437	0.00050	Ratio to Peak	0.01463
W150	9.403	99.000	0	0.120	0.11261	Discharge	0.0448	0.01265	Ratio to Peak	0.26754
W160	0.639	35.218	0	0.133	3.72320	Discharge	0.4193	0.02506	Ratio to Peak	0.97663
W170	2.758	40.746	0	0.017	0.53899	Discharge	0.3684	0.00004	Ratio to Peak	0.00993
W180	13.308	77.027	0	0.166	3.15010	Discharge	0.3824	0.00015	Ratio to Peak	0.05904
W190	4.228	37.399	0	1.251	0.25910	Discharge	0.3544	0.01269	Ratio to Peak	0.24955
W200	19.915	37.163	0	7.905	3.91500	Discharge	2.2917	0.00001	Ratio to Peak	0.08329
W210	38.022	54.591	0	0.123	0.26879	Discharge	0.1475	0.01240	Ratio to Peak	0.96839
W220	3.453	43.217	0	0.166	0.14081	Discharge	0.3961	0.01259	Ratio to Peak	0.14656
W230	165.660	56.139	0	0.202	1.87100	Discharge	0.6535	0.01250	Ratio to Peak	0.52316
W240	5.364	99.000	0	0.148	0.10732	Discharge	0.0014	0.00850	Ratio to Peak	1.00000
W250	5.382	99.000	0	0.166	0.48130	Discharge	0.1631	0.00850	Ratio to Peak	0.66321
W260	54.373	84.767	0	0.178	0.20870	Discharge	0.2828	0.00561	Ratio to Peak	0.30970

Annex 10. Putiao Model Reach Parameters

Table A-10.1 Putiao Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	1196.4	0.00222	0.02206	Trapezoid	46.781	1
R70	Automatic Fixed Interval	4353.2	0.00167	0.10433	Trapezoid	46.781	1
R90	Automatic Fixed Interval	2863.9	0.00109	0.00482	Trapezoid	46.781	1
R110	Automatic Fixed Interval	160.7	0.00050	0.12664	Trapezoid	46.781	1
R130	Automatic Fixed Interval	2708.4	0.00050	0.01322	Trapezoid	46.781	1
R140	Automatic Fixed Interval	2713.8	0.00050	0.01691	Trapezoid	46.781	1

Annex 11. Putiao Field Validation Points

Table A-11.1 Putiao Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Depth	Accuracy (m)
	Lat	Long		
1	12.92389	123.675952	0	2.7
2	12.9235	123.677383	1.1	2
3	12.92348	123.67739	0	1.4
4	12.92349	123.677402	0.3	2.3
5	12.9234	123.677478	0.3	1
6	12.92269	123.677477	0	1.4
7	12.92328	123.67782	0	1
8	12.92359	123.677152	0.3	2.4
9	12.92483	123.675937	0.4	3
10	12.92497	123.675493	0.2	2.3
11	12.92582	123.675437	0	1.3
12	12.92609	123.675623	0	0.9
13	12.92604	123.675637	2	2.2
14	12.9256	123.675623	2	0.8
15	12.92538	123.675818	0	2.4
16	12.96647	123.676588	0	1.1
17	12.96627	123.676522	0	1.3
18	12.96585	123.67661	0	0.9
19	12.96552	123.676485	0	1.7
20	12.96586	123.676273	0	2.2
21	12.96604	123.676332	0	3
22	12.96605	123.676405	0	1
23	12.96599	123.676607	0	1.9
24	12.96617	123.676268	0	2.3
25	12.96638	123.676268	0	1.9
26	12.96639	123.676262	0	1.8
27	12.96639	123.676442	0	1.8
28	12.96597	123.676283	0	1.9
29	12.96637	123.67658	0	1.6
30	12.95637	123.701308	0	1.7
31	12.95631	123.701208	0	2.1
32	12.95624	123.701108	0	1.8
33	12.95609	123.701005	0	1.5
34	12.95609	123.700993	0	1.8
35	12.95584	123.700863	0	0.9
36	12.95564	123.70074	0	2
37	12.95563	123.700742	0	2
38	12.95565	123.700723	0	0.9
39	12.95573	123.700595	0	1.3

Point Number	Validation Coordinates (in WGS84)		Depth	Accuracy (m)
	Lat	Long		
41	12.95589	123.700932	0	0.9
42	12.95599	123.70107	0	1.3
43	12.95617	123.701303	0	2.2
44	12.95637	123.701632	0	2
45	12.92272	123.67461	1.8	1.3
46	12.92263	123.673692	0	1.3
47	12.92251	123.673612	0	0.9
48	12.92208	123.673582	0.15	1.2
49	12.92186	123.673748	0	1.4
50	12.92304	123.67344	0	1
51	12.92301	123.673032	0	1
52	12.92297	123.67272	0	1
53	12.92313	123.672297	0	1
54	12.92353	123.672477	0	1.2
55	12.92351	123.672277	0	1.2
56	12.92371	123.67181	0	0.9
57	12.92396	123.671145	0	1.2
58	12.96569	123.676677	0.26	0.8
59	12.96548	123.676602	0.9	1
60	12.96522	123.676703	0.6	1
61	12.96497	123.676728	0.26	1
62	12.96492	123.676558	0.3	0.9
63	12.96517	123.676418	0	1.1
64	12.9652	123.676393	0	1
65	12.96464	123.676665	0.3	1.3
66	12.96477	123.676655	0.3	1
67	12.95669	123.701538	0	1.2
68	12.95681	123.701553	0	0.8
69	12.95699	123.701595	0	0.9
70	12.95711	123.701562	0	0.8
71	12.95716	123.701608	0	0.8
72	12.95741	123.701602	0	1.1
73	12.95755	123.701578	0	0.8
74	12.95788	123.701462	0	0.8
75	12.95813	123.7014	0	0.8
76	12.95828	123.701358	0	0.8
77	12.95846	123.70132	0	0.9
78	12.9587	123.701247	0	0.8
79	12.95891	123.701177	0	0.8
80	12.95677	123.701335	0	1.1
81	12.95654	123.701472	0	0.8

Point Number	Validation Coordinates (in WGS84)		Depth	Accuracy (m)
	Lat	Long		
82	12.95652	123.70169	0	1.1
83	12.95784	123.727068	0	1.6
84	12.92356	123.674355	0	3
85	12.92401	123.674446	0	4
86	12.92434	123.674262	0.3	6
87	12.92433	123.674258	2.5	3
88	12.92446	123.674431	3	3
89	12.92472	123.674203	0	3
90	12.9237	123.675104	0	8
91	12.92417	123.675063	0.1	5
92	12.92463	123.675003	0	4
93	12.92497	123.675177	0	3
94	12.92336	123.67523	0	4
95	12.92338	123.674834	0	3
96	12.92314	123.67408	0	4
97	12.92357	123.673961	0	4
98	12.92432	123.673932	0	3
99	12.9235	123.673644	0	4
100	12.92364	123.67202	0	3
101	12.96643	123.676202	0.56	3
102	12.96651	123.676026	1	3
103	12.9666	123.67593	1	3
104	12.96648	123.676104	1	3
105	12.96658	123.676747	0.4	3
106	12.96658	123.676819	0.4	3
107	12.9667	123.676979	0.5	3
108	12.96687	123.677322	0.8	3
109	12.96681	123.677145	0.8	3
110	12.96682	123.677231	0.8	3
111	12.95682	123.701162	0	3
112	12.95683	123.70108	0	3
113	12.95682	123.700972	0	3
114	12.95673	123.700867	0	3
115	12.95665	123.700788	0	3
116	12.95654	123.700703	0	3
117	12.95643	123.700536	0	3
118	12.95637	123.70049	0	3
119	12.95626	123.700372	0	3
120	12.9563	123.700359	0	3
121	12.95615	123.700274	0	3
122	12.95611	123.700208	0.9	4

Point Number	Validation Coordinates (in WGS84)		Depth	Accuracy (m)
	Lat	Long		
123	12.95609	123.700213	0.5	4
124	12.95594	123.700258	0	4
125	12.95598	123.700103	0.5	6
126	12.95589	123.70025	0	3
127	12.9558	123.700407	0	4
128	12.95533	123.700562	1.4	3
129	12.95532	123.700525	0.4	4
130	12.95533	123.700569	0.4	4
131	12.95548	123.70048	1.2	9
132	12.95552	123.700618	1.3	5
133	12.95802	123.726818	0	4
134	12.95747	123.726742	0	3
135	12.95728	123.726561	0	4
136	12.95841	123.727405	0	3

Annex 12. Educational Institutions Affected by flooding in Putiao Floodplain

Table A-12.1 Educational Institutions in Castilla, Sorsogon Affected by Flooding in Putiao Floodplain

Sorsogon				
Castilla				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Cabucaran Day Care Center	Caburacan			
Cabucaran Elementary School	Caburacan			

Table A-12.2 Educational Institutions in Pilar, Sorsogon Affected by Flooding in Putiao Floodplain

Pilar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Calpi Day Care Center	Calpi			
Calpi Day Care Center 1	Calpi			
Calpi Elementary School 2	Calpi			
Palanas Elementary School	Palanas			
Under construction Palanas Elementary School	Palanas			
Palanas Day Care Center	Palanas			
Palanas Elementary School	Palanas			
Palanas High School (existing building 8)	Palanas			
Under construction Palanas High School	Palanas			
Pineda Elementary School	Pineda			

Annex 13. Health Institutions affected by flooding in Putiao Floodplain

Table A-13.1 Health Institutions in Pilar, Sorsogon Affected by Flooding in Putiao Floodplain

Masbate				
Pilar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Calpi Health Center	Calpi			