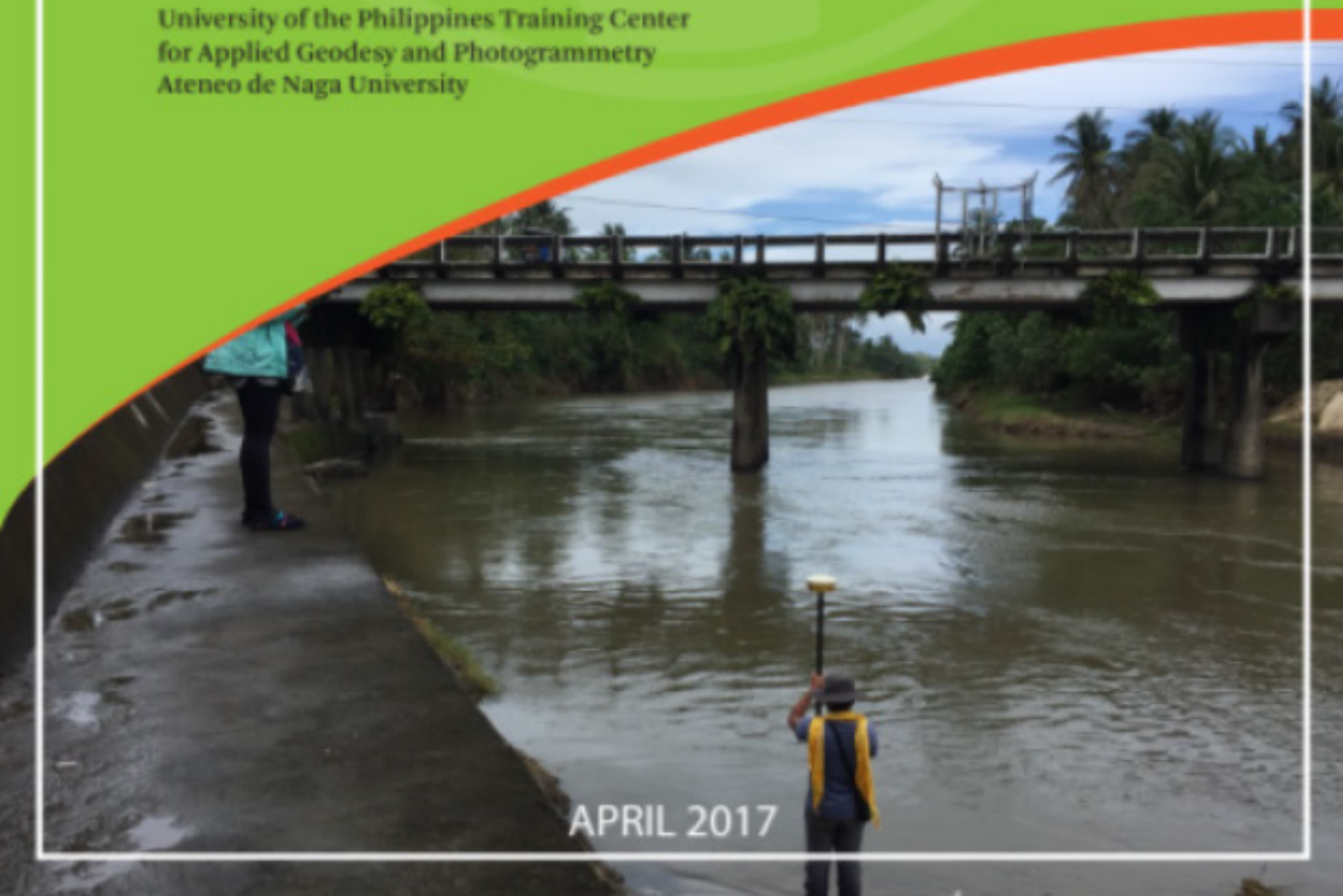
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Cadacan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Naga University



APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City 1101
PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grant-in-Aid Program and is to be cited as:

E.C. Paringit and J.C. Plopenio (eds.) (2017), LiDAR Surveys and Flood Mapping of Cadacan River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-241pp.

For questions/queries regarding this report, contact:

Ms. Joanaviva C. Plopenio
Project Leader, Phil-LiDAR 1 Program
Ateneo de Naga University
Naga City, Philippines 4400
E-mail: inecar@gbox.adnu.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-971-9695-62-2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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
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 CADACAN RIVER

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva C. Plopenio, and Engr. Ferdinand 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, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga University (ADNU). ADNU 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 Cadacan River Basin

The Cadacan River Basin covers five (5) municipalities of Sorsogon namely: Bulan, Bulusan, Casiguran, Irosin and Juban. Bulan is a first class municipality, Irosin is a second class municipality, and the other three (3) are fourth class: Juban, Casiguran and Bulusan. Bulan town has a population of 100,076 in its 63 barangays. The town of Irosin has a total of 56,662 population. Juban town has a population of 32,320. Casiguran and Bulusan 32,842 and 22,884 population respectively. The DENR River Basin Control Office identified the basin to have a drainage area of 197 km2 and an estimated annual runoff of 266 million cubic meter (MCM) (RBCO, 2015).

Type II climate is experienced in this river basin. Pronounced rain is experienced during November to April and the rest of the year is considered as wet, hence, there is no dry season in the area.

Its main stem, Cadacan River, is part of the part of the twenty four (24) river systems in the Bicol Region. The Cadacan River, the main river, is estimated to be 130 km long and empties out north in Sorsogon Bay. Its headwater comes from the slopes of Mt. Bulusan. Bulusan Volcano Natural Park is a protected area by virtue of initially Proclamation No. 811 signed in 1935 and classified as a natural park in November 2000 by Proclamation 421. Mt. Bulusan has an elevation of 1,565 mASL and erupted last December 2016.

According to the 2015 national census of NSO, a total of 11,580 persons are residing within the immediate vicinity of the river which is distributed among nine barangays in Municipality of Juban namely: Aroroy, Binanuahan, Catanagan, Cogon, Embarcadero, North Poblacion, Sipaya, South Poblacion, and Taboc.

Majority of the population around the river are engaged in fishing and farming as their primary source of livelihood. Main agricultural products in the area are pili, cacao, rice, coconut and abaca. For the coastal communities however, seaweed production is also being pushed by the provincial government. There are seaweed farmers in areas near the river (FAO-UN, 1996). In fact seaweeds is among the three (3) products identified as top commodities in the area together with coconut and pili. This is because all municipalities in the province of Sorsogon are coastal except for Irosin which is landlocked.

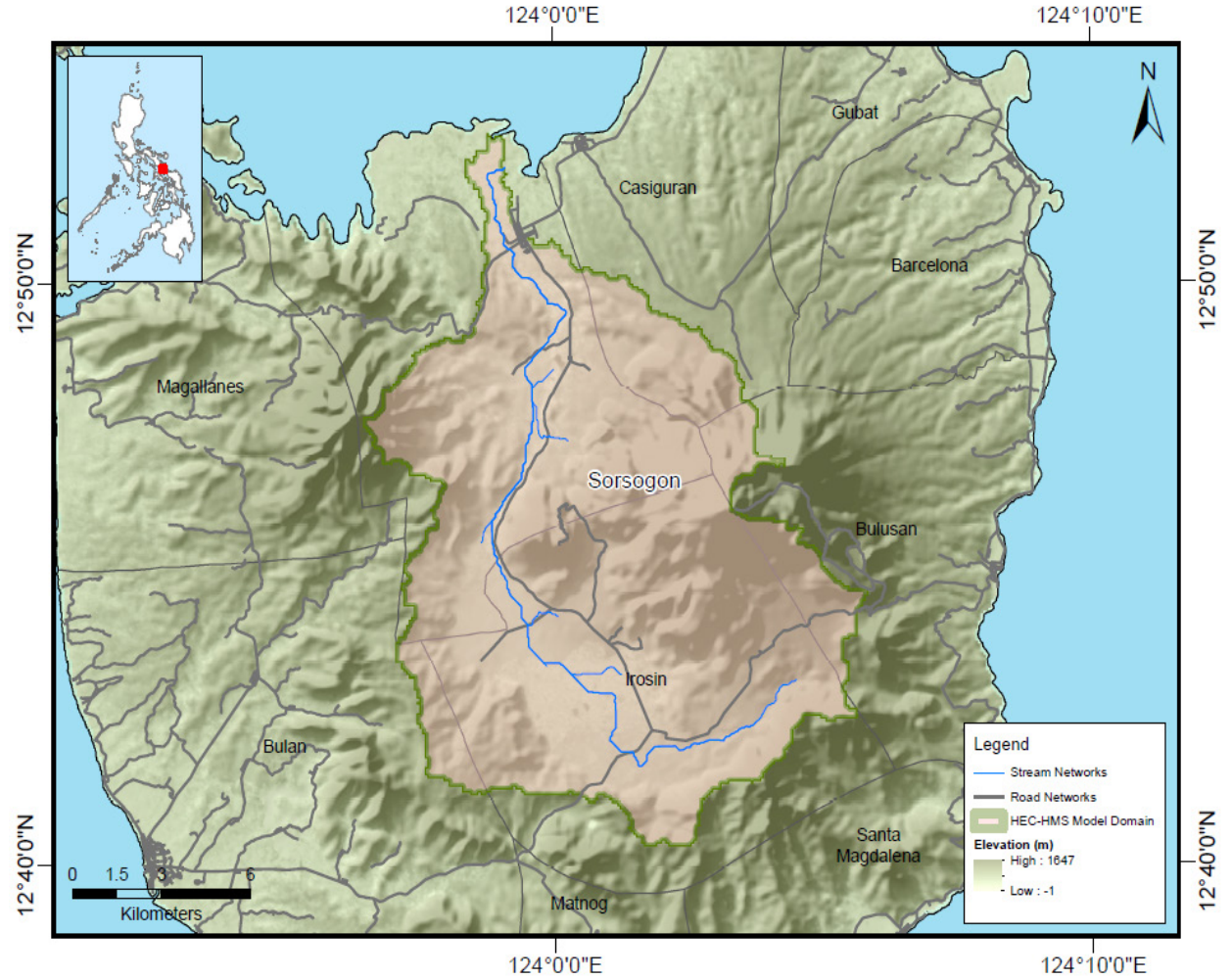


Figure 1. Map of the Cadacan River Basin

On Novermber 2016, there were flashfloods reported due to incessant rains brought by an Intertropical Convergence Zone (ITCZ) which caused Cadacan River to overflow (http://newsinfo.inquirer.net/839685/classes-suspended-as-flash-flood-hits-sorsogon, 2016).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CADACAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, For. Ma. Verlina Tonga, and Jasmine Alviar

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Cadacan floodplain in Albay and Sorsogon. These missions were planned for 10 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Cadacan floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK19aA	1000	30	50	125	50	130	5
BLK19AB	1000	30	50	125	50	130	5
BLK19aC	1000	30	50	125	50	130	5
BLK19cD	1000	30	50	125	50	130	5
BLK19aE	1000	30	50	125	50	130	5
BLK19aF	1000	30	50	125	50	130	5
BLK19aH	1000	30	50	125	50	130	5
BLK19aI	1000	30	50	125	50	130	5
BLK19aJ	1000	30	50	125	50	130	5
BLK19aK	1000	30	50	125	50	130	5
BLK19aL	1000	30	50	125	50	130	5
BLK19aM	1000	30	50	125	50	130	5
BLK19N	1000	30	50	125	50	130	5
BLK19O	1000	30	50	125	50	130	5
BLK19voids	1000	30	50	125	50	130	5
BLK19ASM	1000	30	50	125	50	130	5

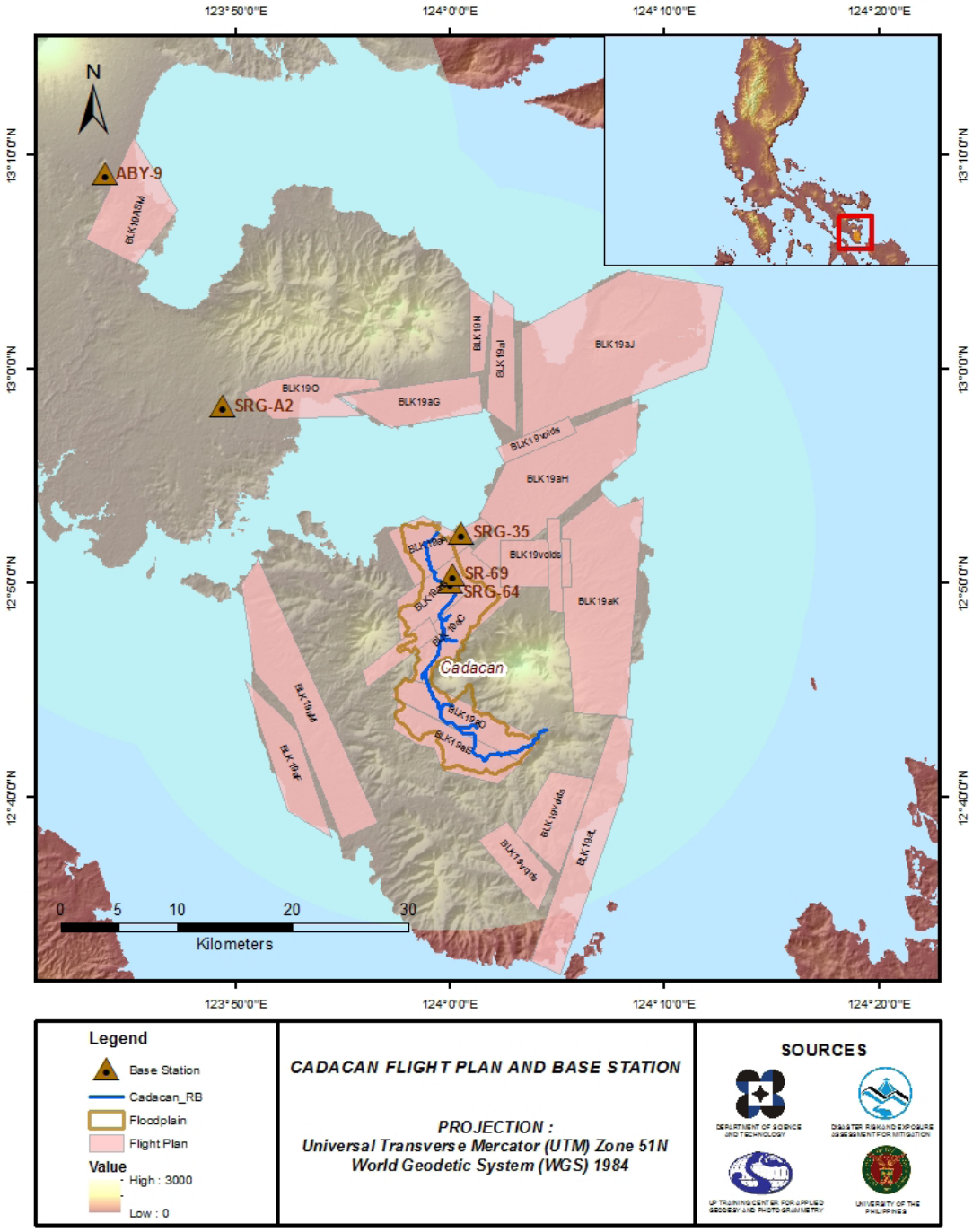


Figure 2. Flight plan and base stations used for Cadacan Floodplain.

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA horizontal ground control points of second (2nd) and third (3rd) order accuracy, SRG-35 and ABY-9, respectively. Two (2) NAMRIA benchmarks were recovered, SR-64 and SR-69, which are of second (2nd) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. Also, established one (1) ground control point, SRG-A2. The certification for the base station is found in Annex 2 while the baseline processing reports for established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 22 – March 20, 2016) especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 882, SPS 985, SPS 852 and SPS985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Cadacan floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 show 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 utilization.

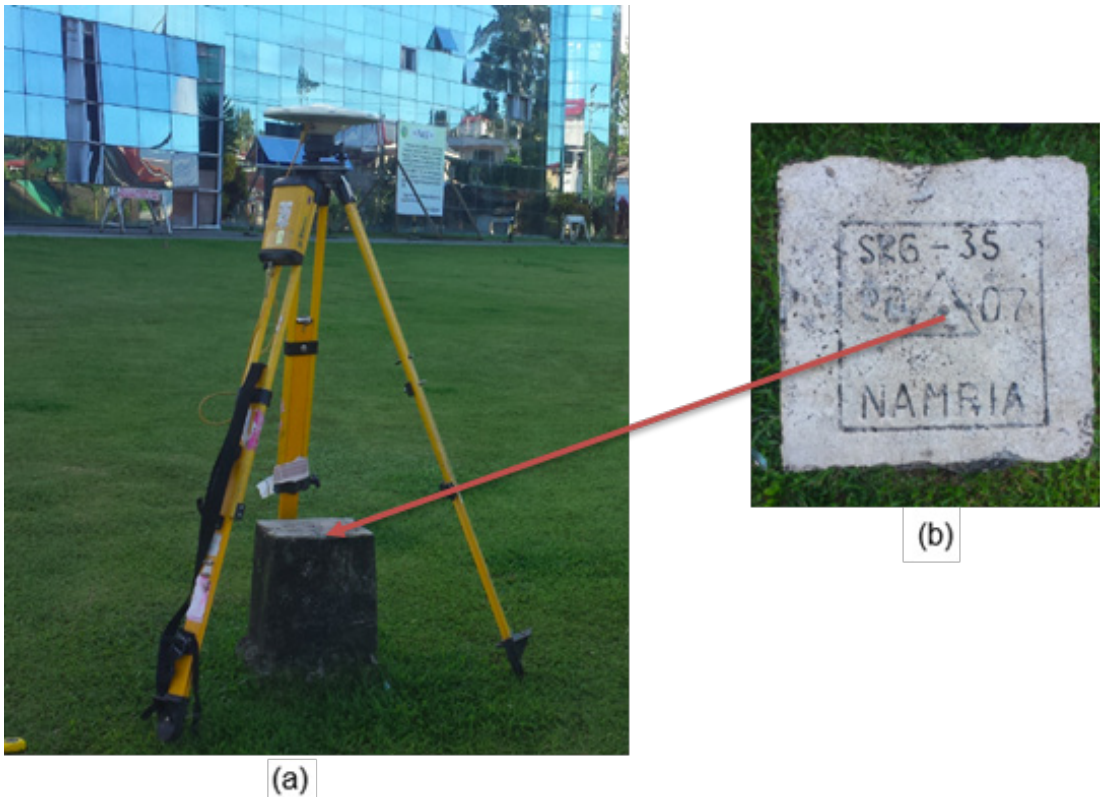


Figure 3. GPS set-up over SRG-35 as recovered in front of Casiguran Municipal Hall from the concrete fence and 13 meters from the flagpole (a) and NAMRIA reference point SRG-35 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal reference point SRG-35 used as base station for the LiDAR Acquisition.

Station Name	**SRG-35**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 52’ 25.33226” North
	Longitude	124° 0’ 23.80097” East
	Ellipsoidal Height	8.55500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	609257.97 meters
	Northing	1423792.96 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 52’ 20.57407” North
	Longitude	124° 0’ 28.82318” East
	Ellipsoidal Height	64.19400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	609219.73 meters
	Northing	1423294.61 meters

Figure 4. 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 3. Details of the recovered NAMRIA horizontal reference 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	13° 9' 11.38733" North
	Longitude	123° 43' 45.95874" East
	Ellipsoidal Height	14.54010 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	579082.538 meters
	Northing	1454607.115 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	13° 9' 6.53800" North
	Longitude	123° 43' 50.95900" East
	Ellipsoidal Height	68.754 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	579054.86 meters
	Northing	1454097.98 meters

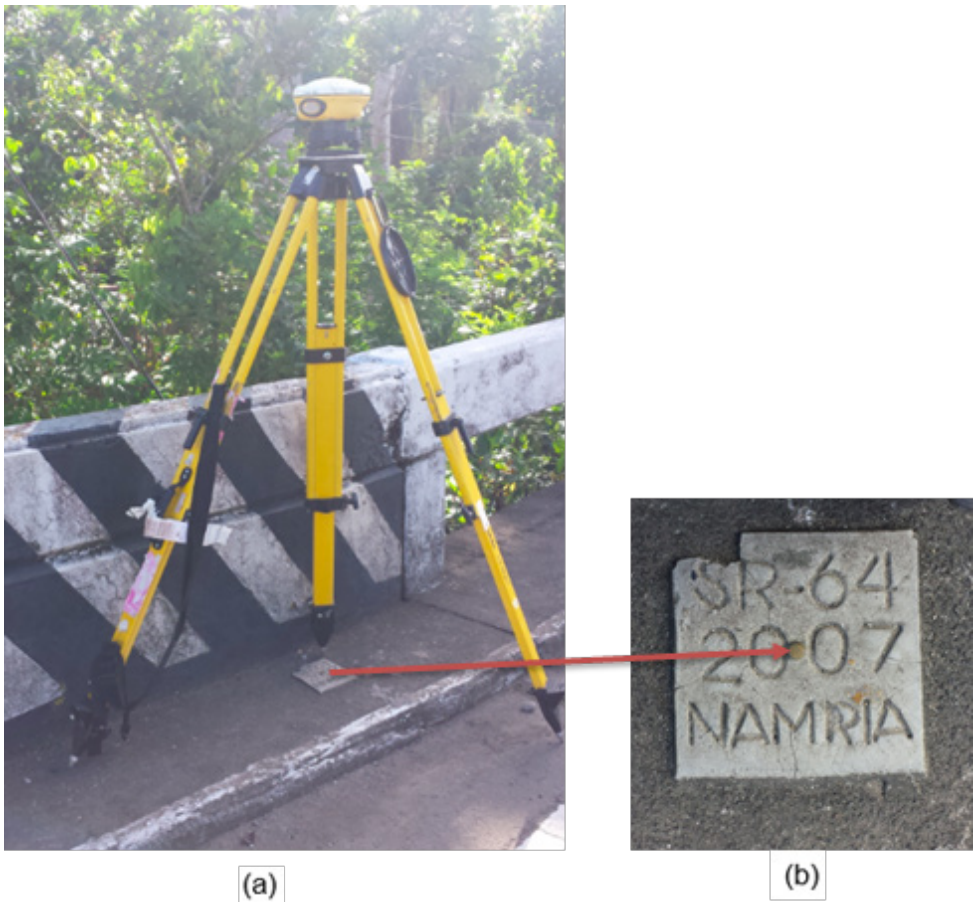


Figure 5. GPS set-up over SR-64 along National Highway No. 1 at km 645+80 in Barrio caluscus, Irosin, Sorsogon Province (a) and NAMRIA reference point SR-64 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA benchmark SR-64 used as base station for the LiDAR Acquisition.

Station Name	**SR-64**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 50’ 05.60456” North
	Longitude	123° 59’ 55.52119” East
	Ellipsoidal Height	12.638 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 50’ 00.85524” North
	Longitude	124° 00’ 00.54683” East
	Ellipsoidal Height	68.361 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	608383.958 meters
	Northing	1418998.779 meters

Figure 6. GPS set-up over SR-69 along Legazpi-Matnog National Road, at about 62 meters south east of KM Post 609 (a) and NAMRIA reference point SR-69 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA benchmark SR-69 used as base station for the LiDAR Acquisition.

Station Name	**SR-69**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 47’ 36.54292” North
	Longitude	123° 59’ 45.34233” East
	Ellipsoidal Height	21.144 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 47’ 31.80353” North
	Longitude	123° 59’ 50.37157” East
	Ellipsoidal Height	76.969 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	608094.752 meters
	Northing	1414418.362 meters

Figure 7. GPS set-up over SRG-A2 beside the flag pole of San Rafael Barangay Hall, Castilla, Sorsogon near kilometer post 556 (a) and NAMRIA reference point SRG-A2 (b) as established by the field team.

Table 6. Details of the established horizontal control point SRG-A2 used as base station for the LiDAR Acquisition.

Station Name	SRG-A2	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 58' 19.68256" North
	Longitude	123° 49' 14.551238" East
	Ellipsoidal Height	50.561 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 58' 14.88482" North
	Longitude	123° 49' 19.56657" East
	Ellipsoidal Height	105.483 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PS2)	Easting	589012.581 meters
	Northing	1434108.317 meters

Table 7. Ground Control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
06-Mar-16	3851G	2BLK19aAB066A	SRG 35; SR 64
09-Mar-16	3863G	2BLK19aCEFG069A	SRG 35; SR 64
11-Mar-16	3871G	2BLK19aADG071A (BLK19aBCDGI)	SRG 35; SR 64
11-Mar-16	3873G	2BLK19aH071B	SRG 35; SR 64
13-Mar-16	3879G	2BLK19aJ073A	SRG 35; SR 64
14-Mar-16	3883G	2BLK19aJSKM074A	SRG 35; SR 69
14-Mar-16	3885G	2BLK19aKSMS074B	SRG 35; SR 69
15-Mar-16	3887G	2BLK19aLAS075A	SRG 35; SR 69
15-Mar-16	3889G	2BLK19aLS075B	SRG 35; SR 69
18-Mar-16	3899G	2BLK19aS078A (Blk19aON)	SRG 35; SR 64
19-Mar-16	3903G	2BLK19S079A (BLK19ASM)	ABY-09 & SRG-A2

2,3 Flight Missions

Ten (10) missions were conducted to complete the LiDAR data acquisition in Cadacan floodplain, for a total of forty three hours and twenty minutes (43+20) of flying time for RP-C9022. All missions were acquired using the Gemini LiDAR system. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Cadacan floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within Floodplain (km2)	Area Surveyed Outside Floodplain (km2)	Flying Hours	
						Hr	Min
06-Mar-16	3851G	56.1	101.64	37.37	64.27	3	17
09-Mar-16	3863G	125.2	183.87	52.41	131.46	4	21
11-Mar-16	3871G	147.84	171.62	37.69	133.93	4	30
11-Mar-16	3873G	87.45	118.33	-	118.33	3	17
13-Mar-16	3879G	156.52	155.01	-	155.01	4	23
14-Mar-16	3883G	348.59	280.26	-	280.26	4	41
14-Mar-16	3885G	183.63	122.92	-	122.92	3	23
15-Mar-16	3887G	183.41	155.98	3.0	152.92	4	29
15-Mar-16	3889G	39.83	61.23	-	61.23	2	47
18-Mar-16	3899G	81.58	120.92	-	120.92	4	23
19-Mar-16	3903G	105.67	103.19	8.17	95.02	3	41
TOTAL		1744.59	1574.97	138.64	1436.27	43	20

Table 9. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3851G	750	40	50	125	40	130	5
3863G	900	40	50	125	40	130	5
3871G	1000	40	40	100	50	130	5
	850	40	50	125	40	130	5
3873G	1000	40	40	100	50	130	5
3879G	750	40	50	125	40	130	5
3883G	1000 and 800	40	40	100	50	130	5
3885G	750 and 900	40	50	125	40	130	5
3887G	600 and 900	40	50	125	40	130	5
3889G	550 and 900	40	50	125	40	130	5
3899G	650	40	50	125	40	130	5
	850	40	50	142	40	130	5
3903G	850	40	50	125	40	130	5

2.4 Survey Coverage

Cadacan Floodplain is located in the provinces of Albay, and Sorsogon with majority of the floodplain situated within the municipalities Gubat and Prieto Diaz in Sorsogon Province. The list of municipalities and cities surveyed is shown in Table 10. The actual coverage of the LiDAR acquisition for Cadacan floodplain is presented in Figure 8.

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

Province	Municipality/City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Albay	Legazpi City	153.18	53.10	35%
	Manito	95.35	3.88	4%
	Daraga	135.66	4.22	3%
Sorsogon	Gubat	95.05	95.05	100%
	Prieto Diaz	46.03	46.02	100%
	Barcelona	58.77	57.63	98%
	Santa Magdalena	54.52	50.43	92%
	Casiguran	87.30	78.56	90%
	Juban	127.78	98.86	77%
	Bulusan	93.11	60.79	65%
	Irosin	130.17	76.07	58%
	Bulan	187.31	109.11	58%
	Sorsogon City	299.79	164.34	55%
	Magallanes	117.60	49.52	42%
	Matnog	146.20	53.14	36%
	Castilla	197.27	17.38	9%
	Pilar	196.62	2.35	1%
	TOTAL	2221.71	1020.45	45.93%

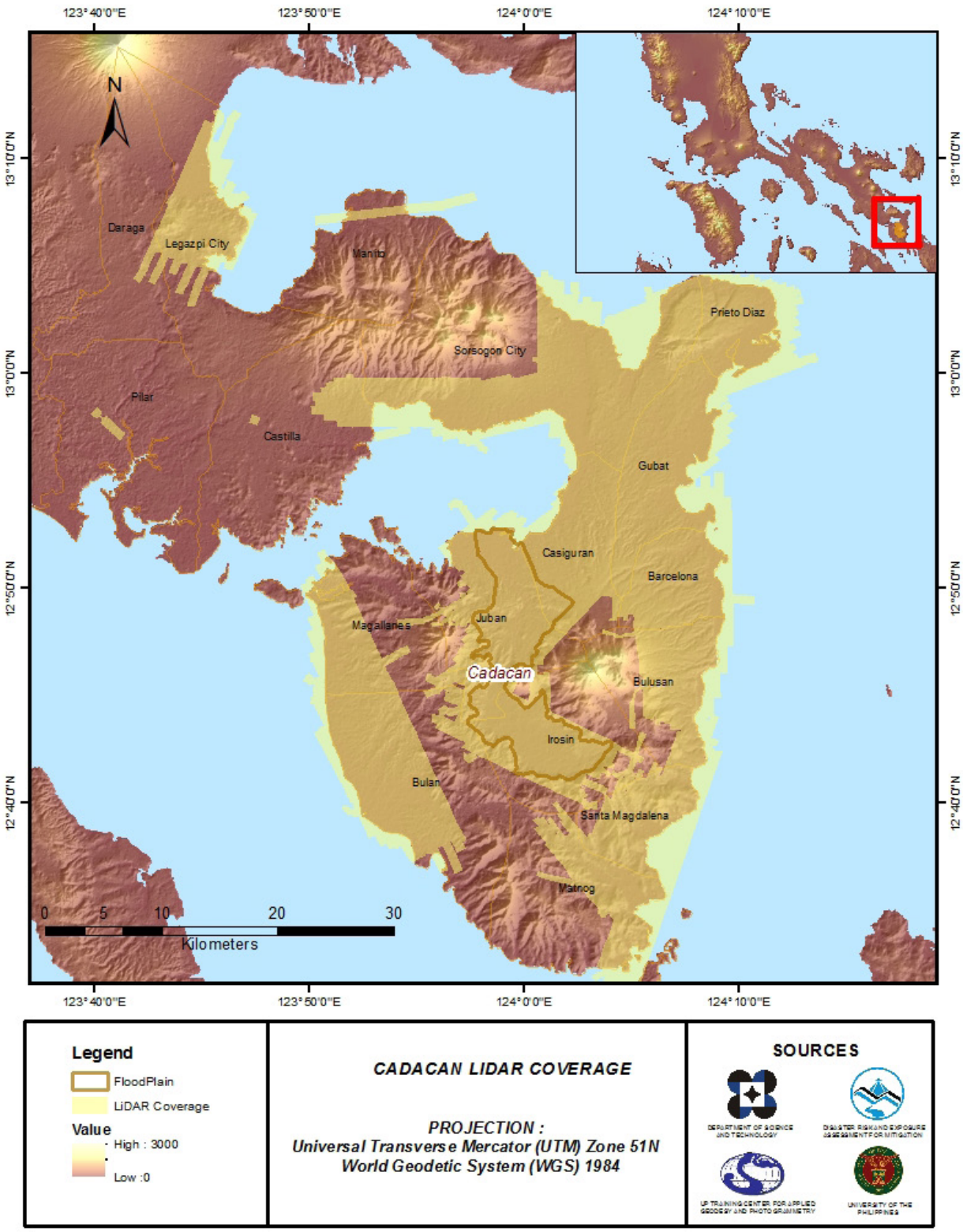


Figure 8. Actual LiDAR survey coverage for Cadacan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE CADACAN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo, Engr. Gladys Mae Apat, Engr. Harmond F. Santos, Engr. Ma. Ailyn L. Olanda, Engr. Velina Angela S. Bemida, Engr. Christy T. Lubiano, Jerry P. Ballori, Jaylyn L. Paterno, Engr. Ferdinand E. Bien, Engr. Francis Patray P. Bolaños, Carlota M. Davocol, Arnulfo G. Enciso, Jr., Engr. Jan Karl T. Ilarde, Engr. Kevin Kristian L. Peñaserada, Richmund P. Saldo, Engr. Jayrik T. San Buenaventura, and Engr. Jess Andre S. Soller

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

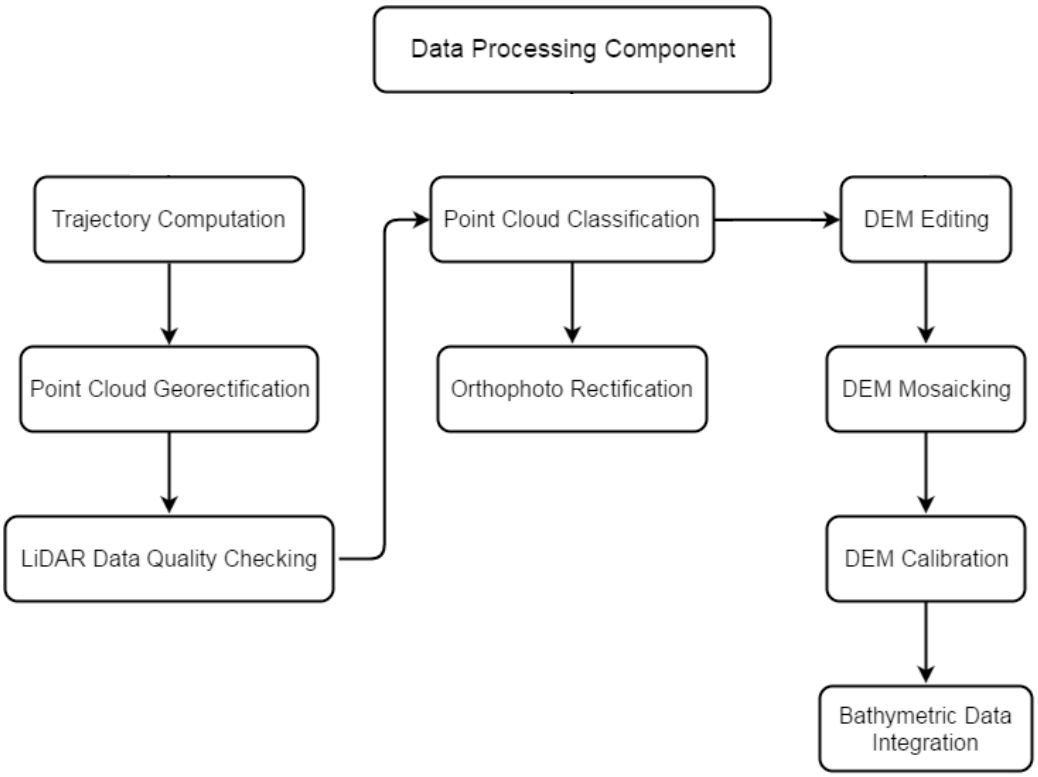


Figure 9. Schematic Diagram for Data Pre-Processing Component

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

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

These processes are summarized in the flowchart shown in Figure 9.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Cadacan floodplain can be found in Annex 5. Missions flown during the survey conducted on March 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system were flown over Juban, Irosin, Sorsogon. The Data Acquisition Component (DAC) transferred a total of 233.7 Gigabytes of Range data, 2.59 Gigabytes of POS data, 122.39 Megabytes of GPS base station data, and 389.1 Gigabytes of raw image data to the data server on February 6, 2016 for the first survey and March 31, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Cadacan was fully transferred on March 31, 2016, as indicated on the Data Transfer Sheets for Cadacan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3887G, one of the Cadacan flights, which is the North, East, and Down position RMSE values are shown in Figure B-2. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on March 15, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

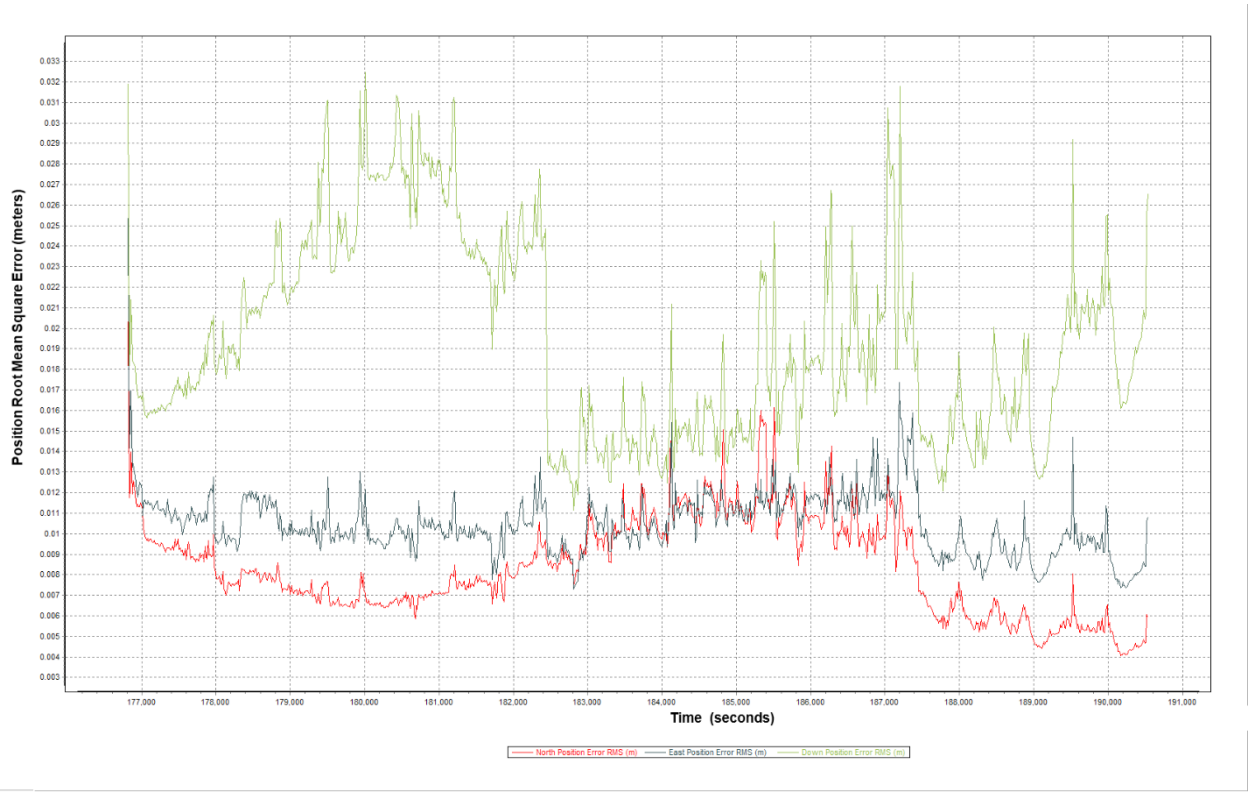


Figure 10. Smoothed Performance Metrics of a Cadacan Flight 3887G.

The time of flight was from 177000 seconds to 191000 seconds, which corresponds to afternoon of March 15, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.11 centimeters, the East position RMSE peaks at 1. 16 centimeters, and the Down position RMSE peaks at 5.95 centimeters, which are within the prescribed accuracies described in the methodology.

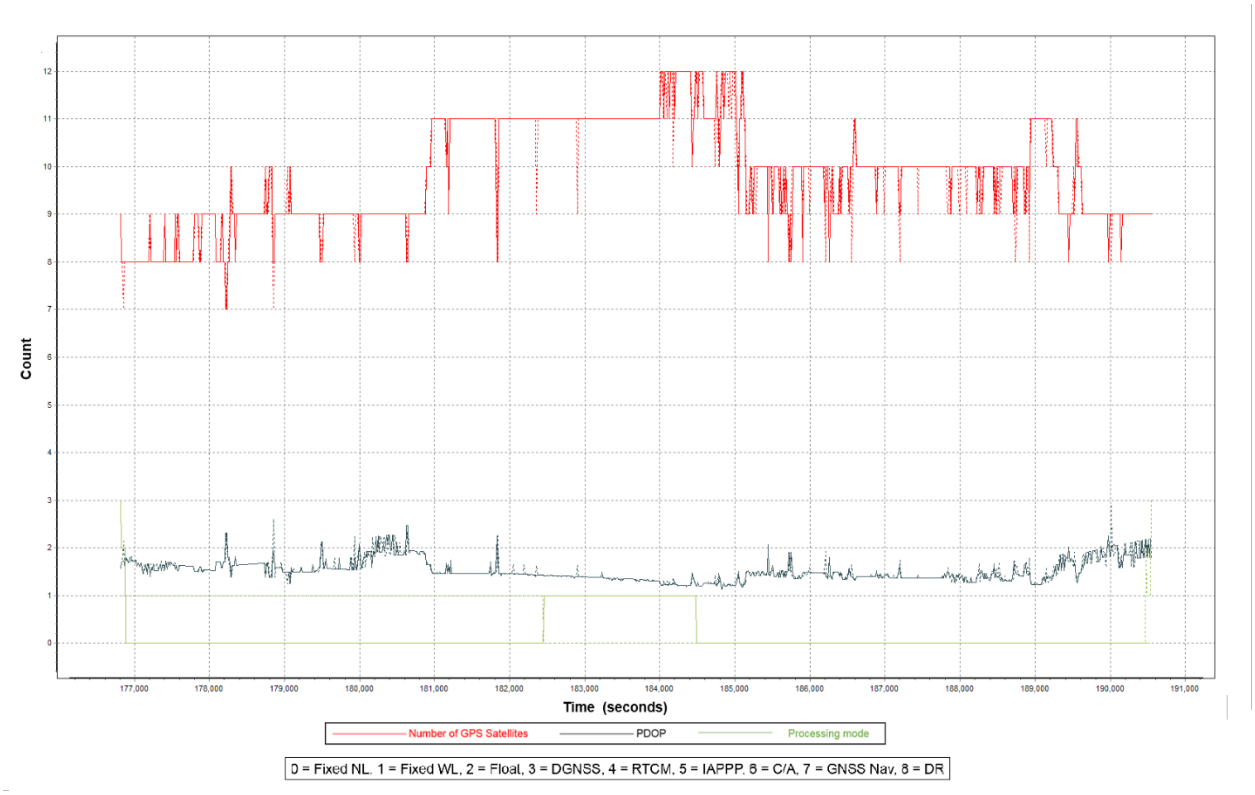


Figure 11. Solution Status Parameters of Cadacan Flight 3887G.

The Solution Status parameters of flight 3887G, one of the Cadacan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Cadacan flights is shown in Figure 12.

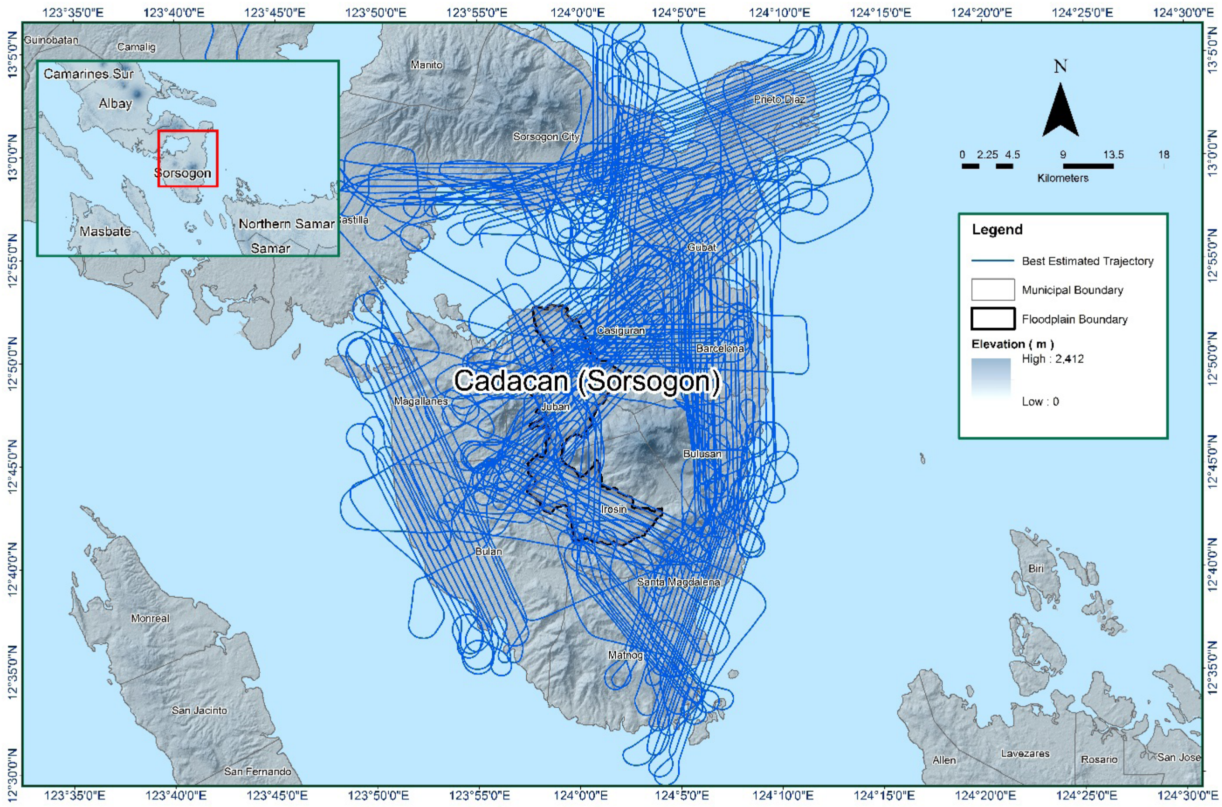


Figure 12. Best Estimated Trajectory for Cadacan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 217 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Cadacan floodplain are given in Table 11.

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

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000011
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000865
GPS Position Z-correction stdev (<0.01meters)	0.0022

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Cadacan Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

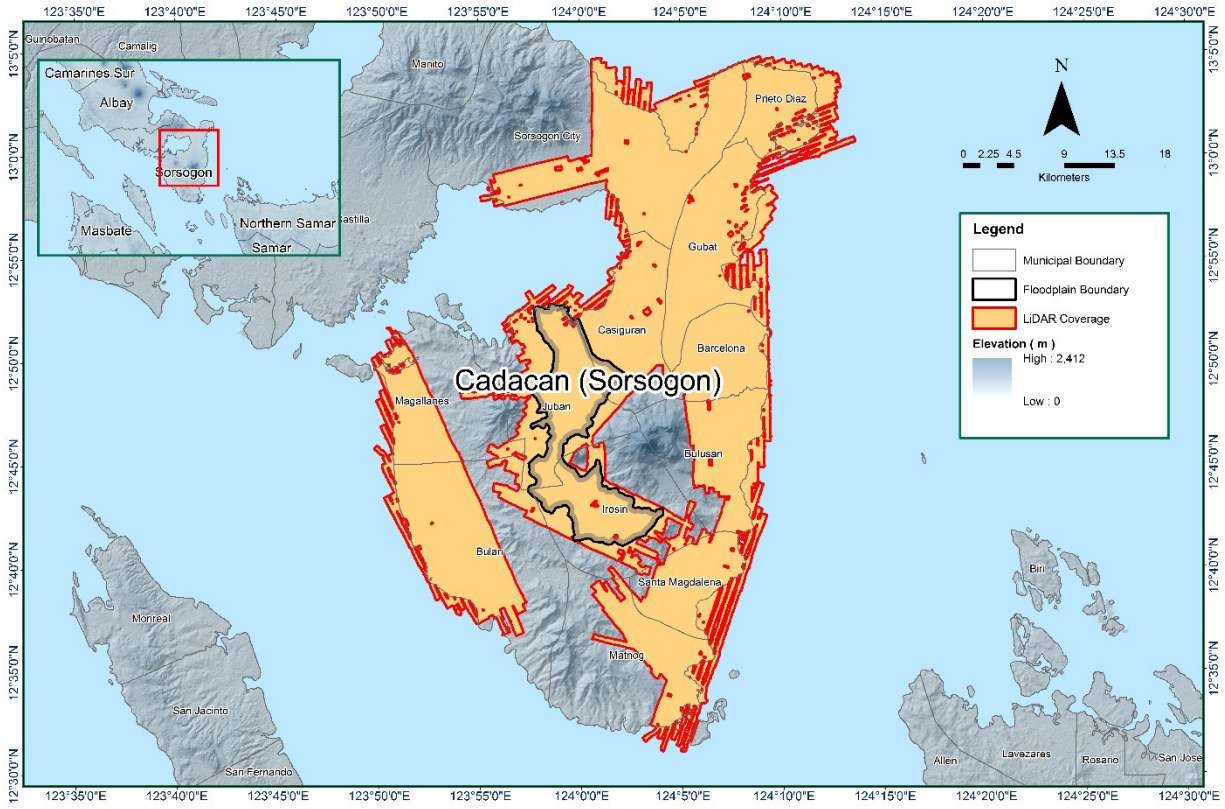


Figure 13. Boundary of the processed LiDAR data over Cadacan Floodplain

The total area covered by the Cadacan missions is 1,173.92 sq.km that is comprised of ten (10) flight acquisitions grouped and merged into seventeen (17) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Cadacan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Albay_Sorsogon_reflights_Blk19aG	3863G	30.91
	3871G	
Albay_Sorsogon_reflights_Blk19R_supplement	3871G	15.17
	3887G	
Albay_Sorsogon_reflights_Blk19R	3851G	89.02
Albay_Sorsogon_reflights_Blk19aN	3899G	23.28
Albay_Sorsogon_reflights_Blk19aM	3883G	117.94
	3885G	
Albay_Sorsogon_reflights_Blk19aL	3887G	121.37
	3889G	
Albay_Sorsogon_reflights_Blk19aL_supplement	3887G	38.90
	3889G	
Albay_Sorsogon_reflights_Blk19aK_supplement	3889G	26.22
Albay_Sorsogon_reflights_Blk19aK_additional	3903G	9.20
Albay_Sorsogon_reflights_Blk19aJ	3879G	177.15
	3883G	
Albay_Sorsogon_reflights_Blk19aK	3883G	158.20
	3885G	
	3887G	
	3889G	
Albay_Sorsogon_reflights_Blk19aI	3871G	40.95
Albay_Sorsogon_reflights_Blk19aH	3873G	112.87
	3899G	
Albay_Sorsogon_reflights_Blk19aF	3863G	45.91
Albay_Sorsogon_reflights_Blk19aE	3863G	43.33
Albay_Sorsogon_reflights_Blk19aD	3871G	51.43
Albay_Sorsogon_reflights_Blk19aC	3863G	72.07
	3871G	
	3903G	
TOTAL		1,173.92 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 B-6. 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.

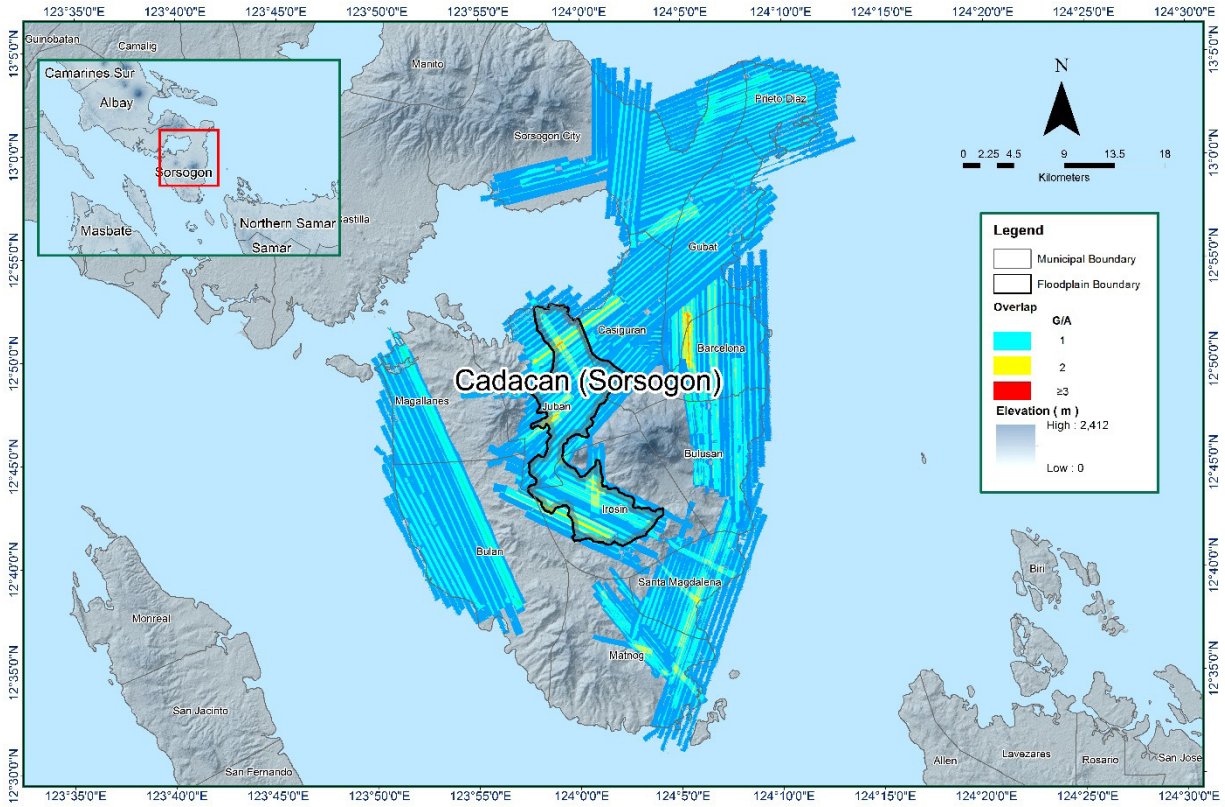


Figure 14. Image of data overlap for Cadacan floodplain.

The overlap statistics per block for the Cadacan 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 30.27% and 44.37% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Cadacan floodplain satisfy the point density requirement, and the average density for the entire survey area is 5.21 points per square meter.

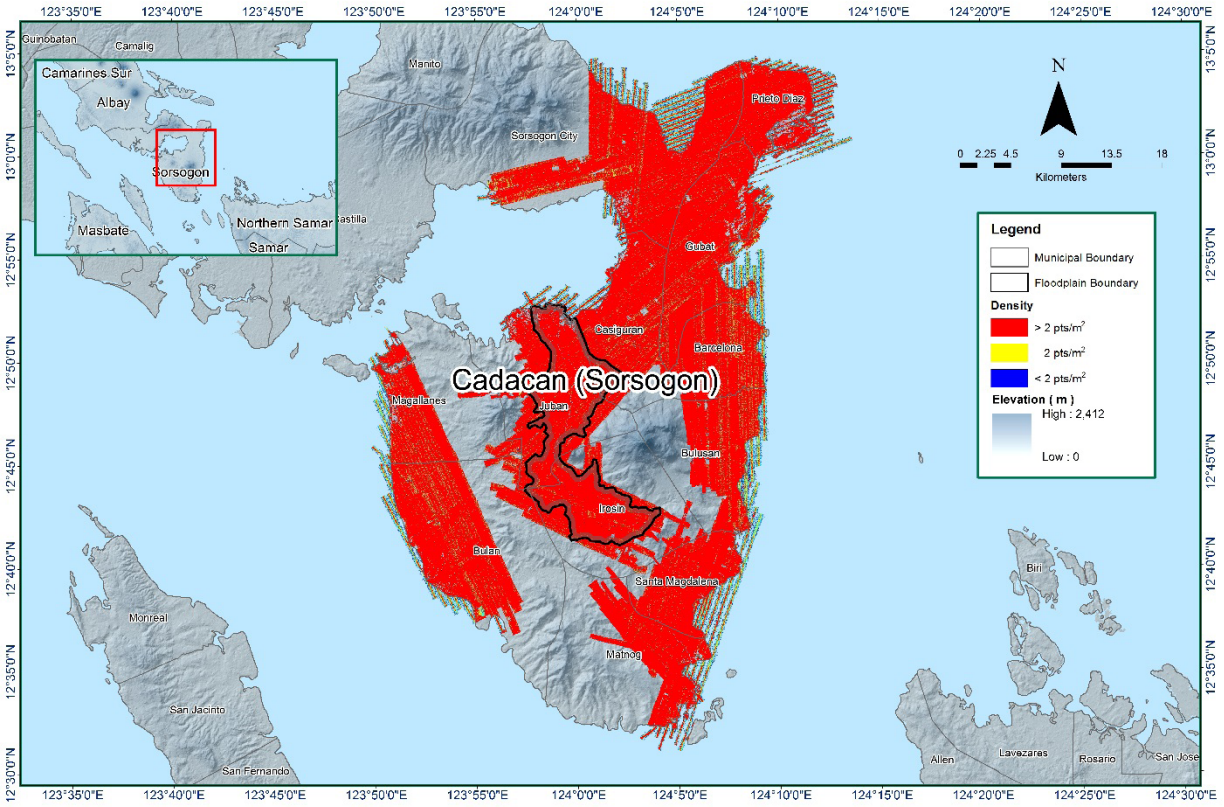


Figure 15. Pulse density map of merged LiDAR data for Cadacan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

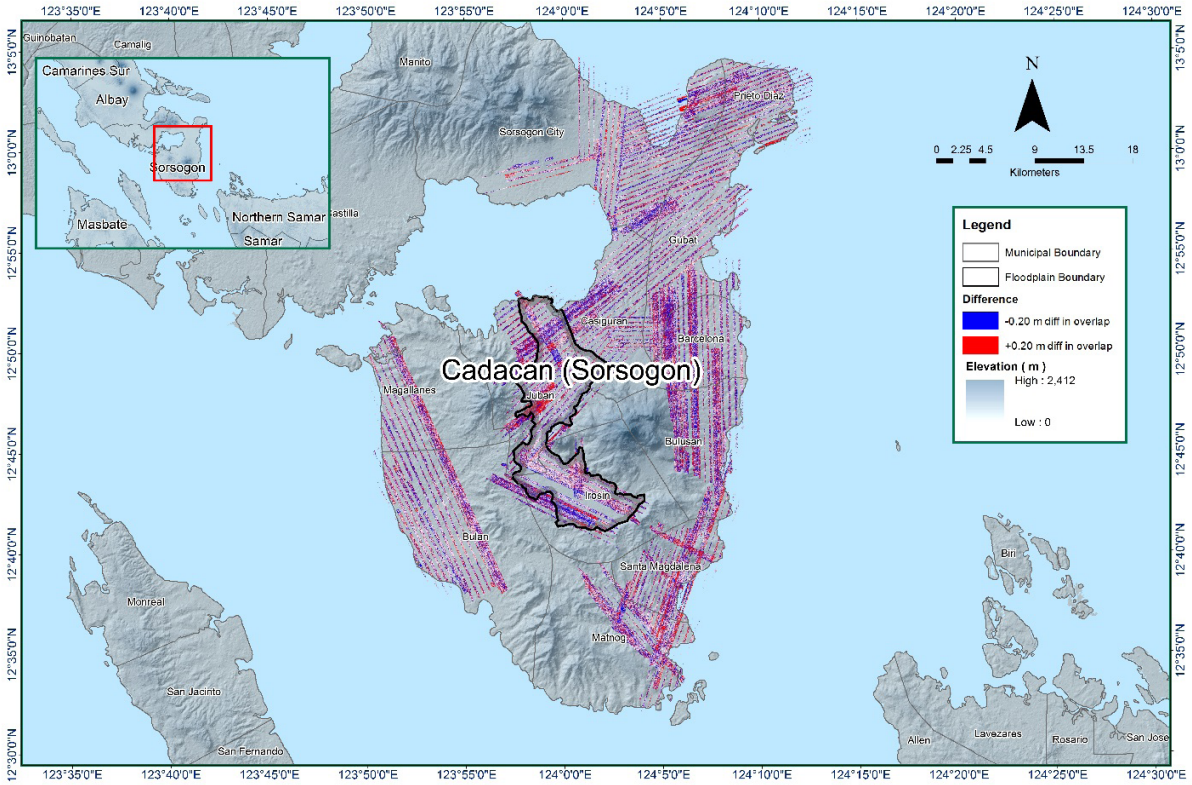


Figure 16. Elevation difference map between flight lines for Cadacan floodplain.

A screen capture of the processed LAS data from a Cadacan flight 3887G loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

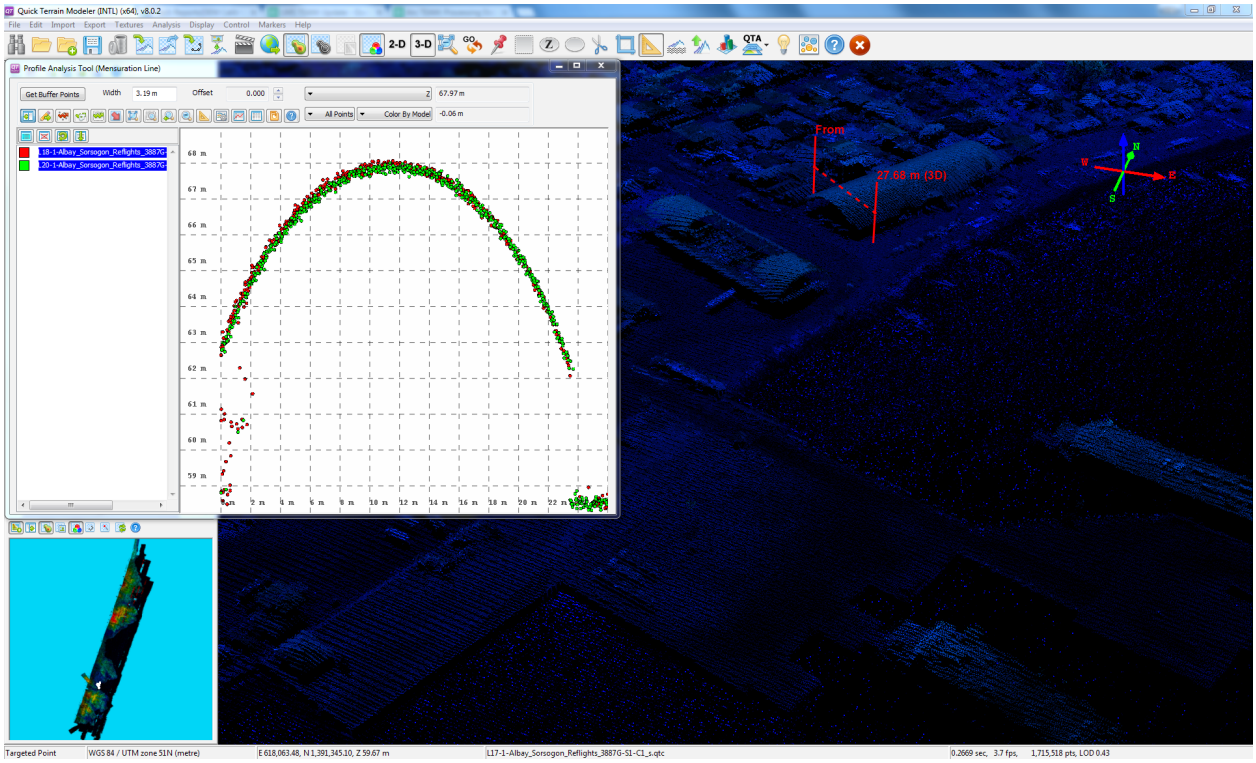


Figure 17. Quality checking for a Cadacan flight 3887G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Cadacan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	549,162,679
Low Vegetation	345,716,740
Medium Vegetation	2,353,136,949
High Vegetation	2,308,099,223
Building	6,459,951

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Cadacan floodplain is shown in Figure 18. A total of 1,800 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 868.27 meters and 51.97 meters respectively.

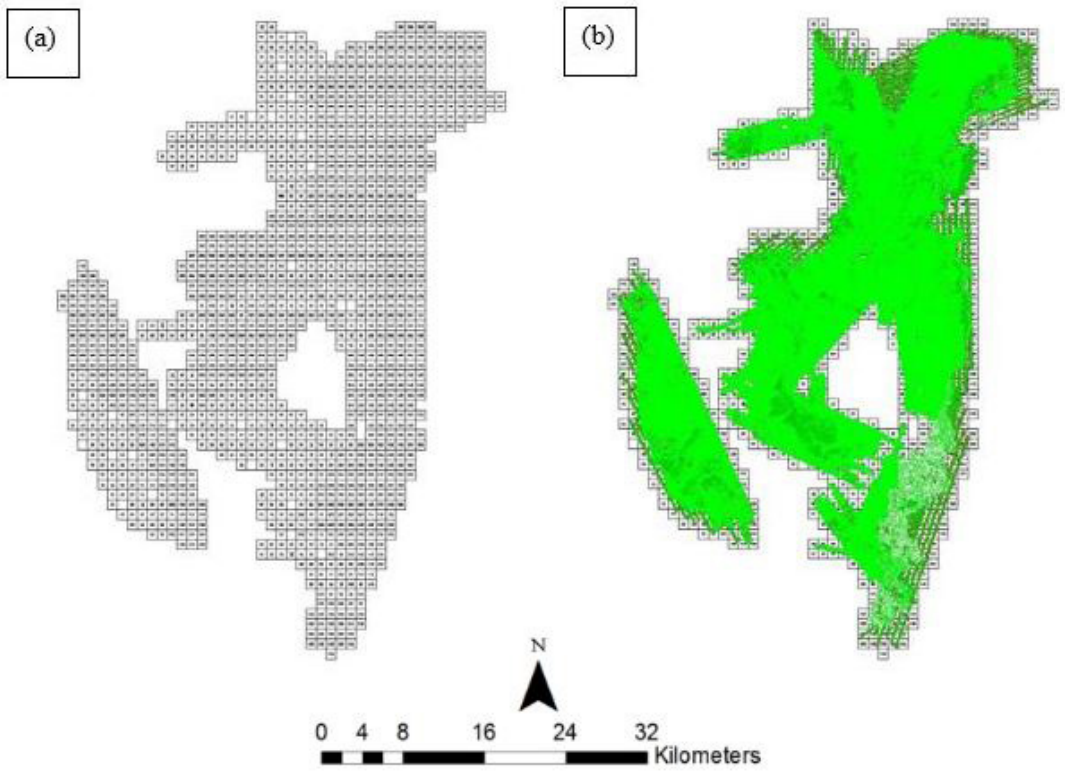


Figure 18. Tiles for Cadacan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

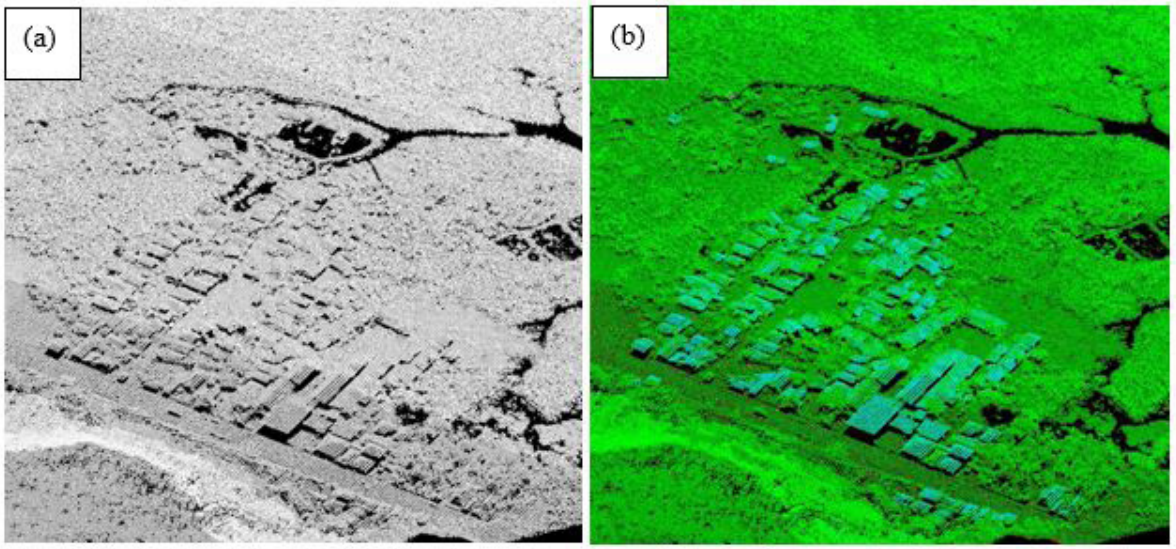


Figure 19. Point cloud before (a) and after (b) classification.

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 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

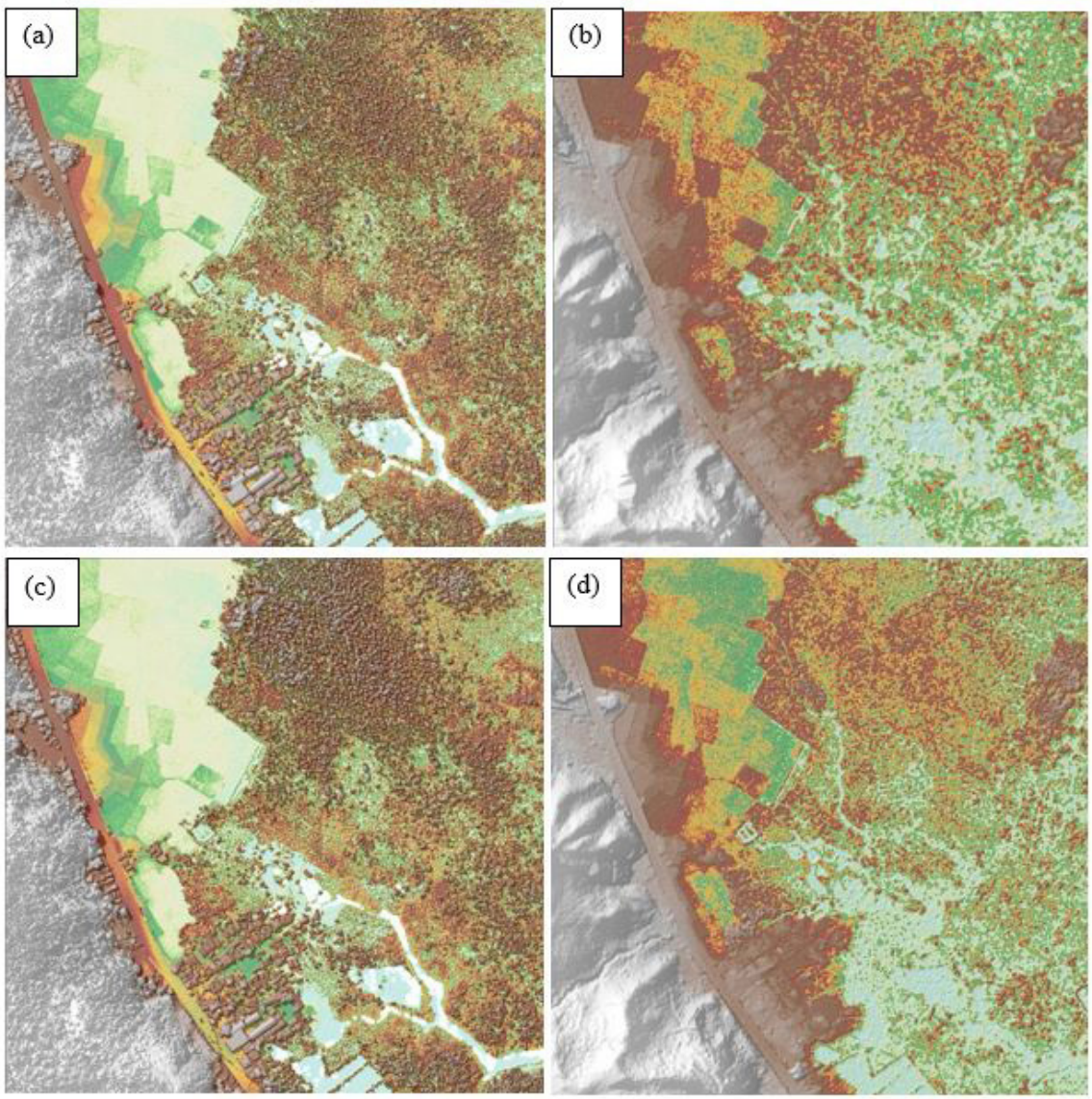


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Cadacan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,674 1km by 1km tiles area covered by Cadacan floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Cadacan floodplain has a total of 990.67 sq.km orthophotogaph coverage comprised of 6,586 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

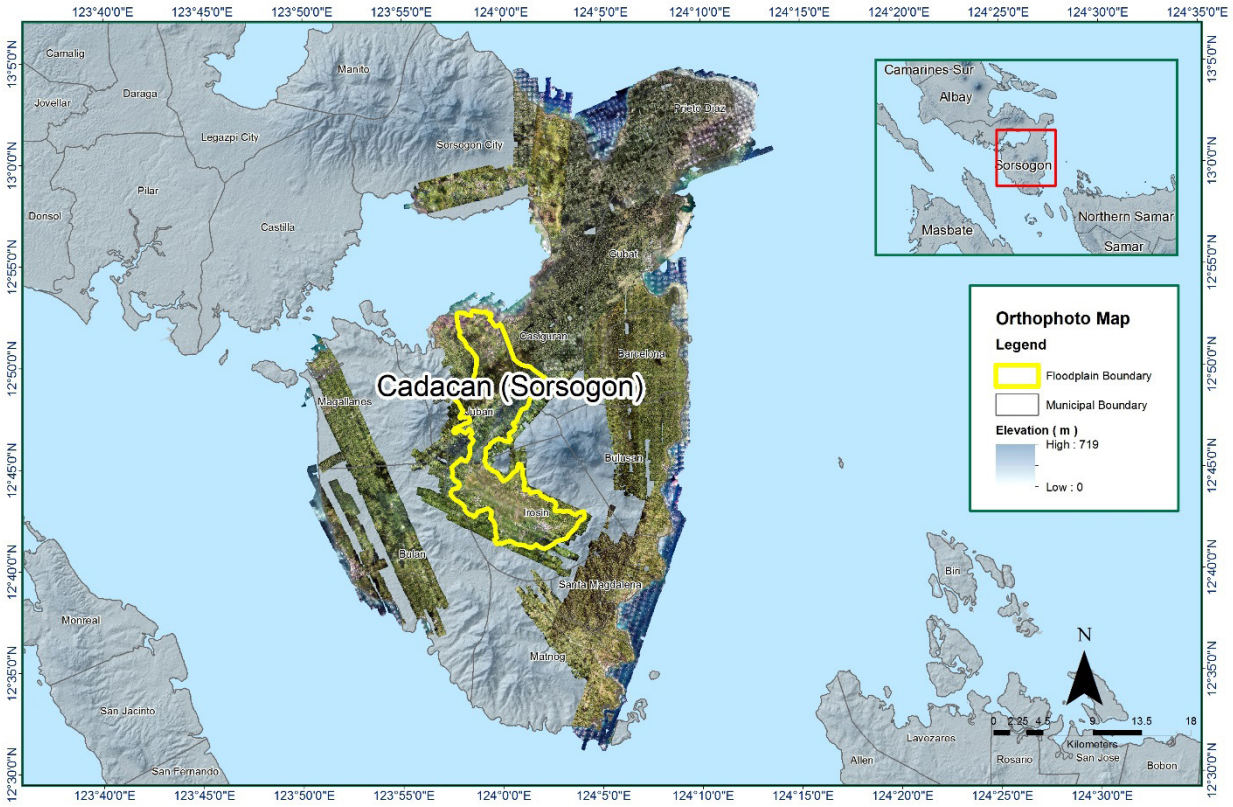


Figure 21. Cadacan floodplain with available orthophotographs.

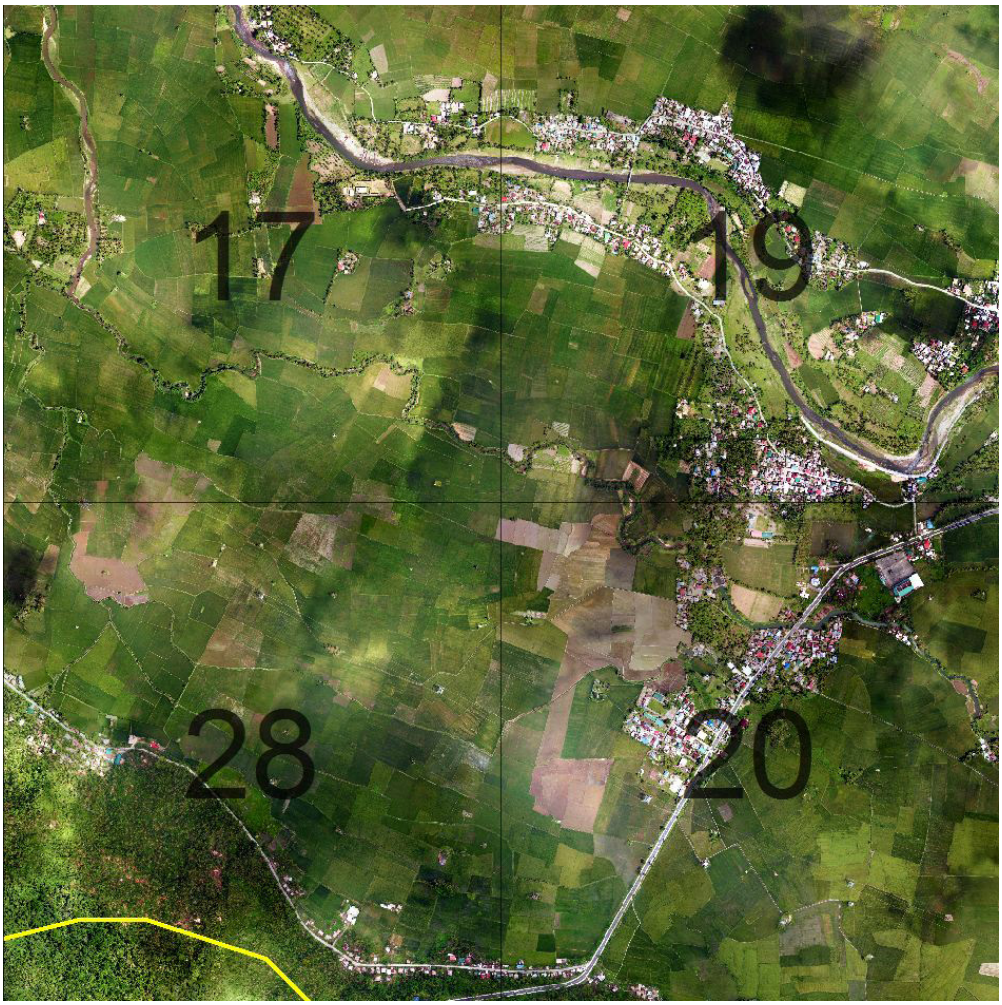


Figure 22. Sample orthophotograph tiles for Cadacan floodplain.

3.8 DEM Editing and Hydro-Correction

Seventeen (17) mission blocks were processed for Cadacan flood plain. These blocks are composed of Albay_Sorsogon_reflights blocks with a total area of 1,173.92 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Albay_Sorsogon_reflights_Blk19aG	30.91
Albay_Sorsogon_reflights_Blk19R_supplement	15.17
Albay_Sorsogon_reflights_Blk19R	89.02
Albay_Sorsogon_reflights_Blk19aN	23.28
Albay_Sorsogon_reflights_Blk19aM	117.94
Albay_Sorsogon_reflights_Blk19aL	121.37
Albay_Sorsogon_reflights_Blk19aL_supplement	38.90
Albay_Sorsogon_reflights_Blk19aK_supplement	26.22
Albay_Sorsogon_reflights_Blk19aK_additional	9.20
Albay_Sorsogon_reflights_Blk19aJ	177.15
Albay_Sorsogon_reflights_Blk19aK	158.20
Albay_Sorsogon_reflights_Blk19aI	40.95
Albay_Sorsogon_reflights_Blk19aH	112.87
Albay_Sorsogon_reflights_Blk19aF	45.91
Albay_Sorsogon_reflights_Blk19aE	43.33
Albay_Sorsogon_reflights_Blk19aD	51.43
Albay_Sorsogon_reflights_Blk19aC	72.07
TOTAL	1,173.92 sq. km

Portions of DTM before and after manual editing are shown in Figure 23. The hilltop (Figure 23a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23b) to allow the correct flow of water. The bridge (Figure 23c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23d) in order to hydrologically correct the river.

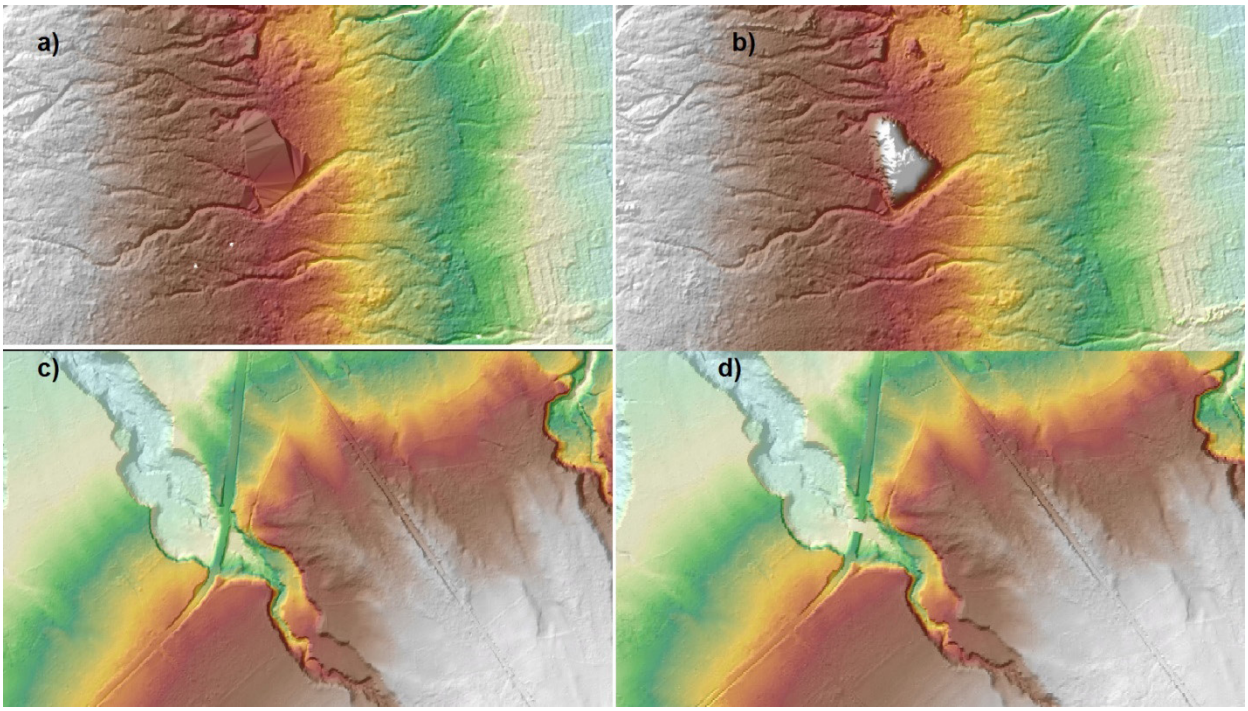


Figure 23. Portions in the DTM of Cadacan floodplain – a hilltop before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

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 Cadacan floodplain is shown in Figure 24. It can be seen that the entire Cadacan floodplain is 99.6% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Cadacan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Albay_Sorsogon_reflights_Blk19aG	-2	2	-2.14
Albay_Sorsogon_reflights_Blk19R_supplement	-2	2	-1.50
Albay_Sorsogon_reflights_Blk19R	-2	2	-1.11
Albay_Sorsogon_reflights_Blk19aN	-2	2	-1.26
Albay_Sorsogon_reflights_Blk19aM	-2	5	-2.21
Albay_Sorsogon_reflights_Blk19aL	-2	2	-1.49
Albay_Sorsogon_reflights_Blk19aL_supplement	-2	2	-1.52
Albay_Sorsogon_reflights_Blk19aK_supplement	-2	2	-1.23
Albay_Sorsogon_reflights_Blk19aK_additional	-2	2	-1.17
Albay_Sorsogon_reflights_Blk19aJ	-2	2	-1.18
Albay_Sorsogon_reflights_Blk19aK	-2	2	-1.15
Albay_Sorsogon_reflights_Blk19aI	-2	2	-1.10
Albay_Sorsogon_reflights_Blk19aH	-2	2	-1.05
Albay_Sorsogon_reflights_Blk19aF	-2	2	-2.22
Albay_Sorsogon_reflights_Blk19aE	-2	2	-1.29
Albay_Sorsogon_reflights_Blk19aD	-2	2	-1.35
Albay_Sorsogon_reflights_Blk19aC	-2	2	-1.40

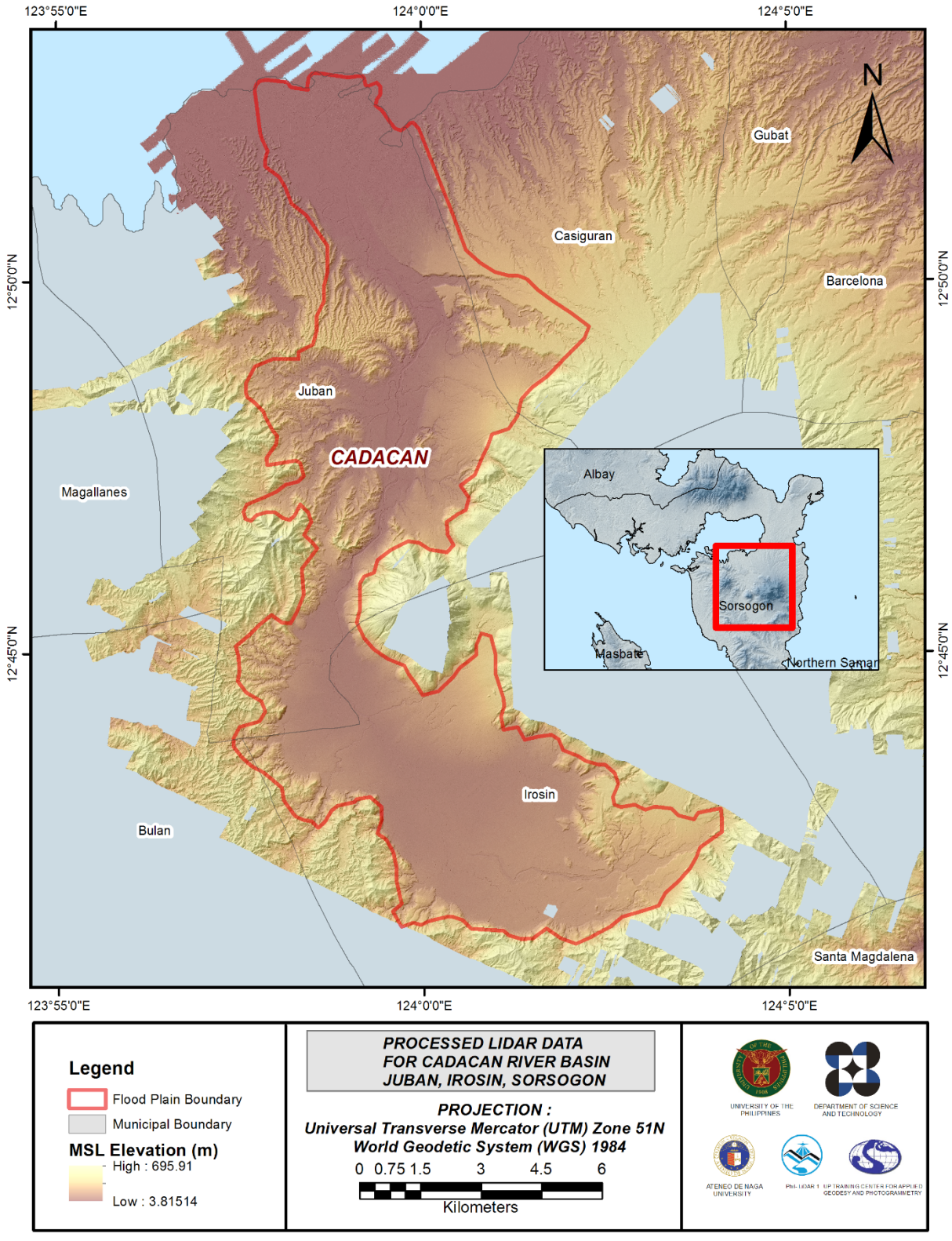


Figure 24. Map of Processed LiDAR Data for Cadacan Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Cadacan to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 11,856 survey points from the Bicol floodplain were used for calibration Cadacan 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 26. 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 Cadacan LiDAR data was done by adding the height difference value, 0.41 meters, to Cadacan mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

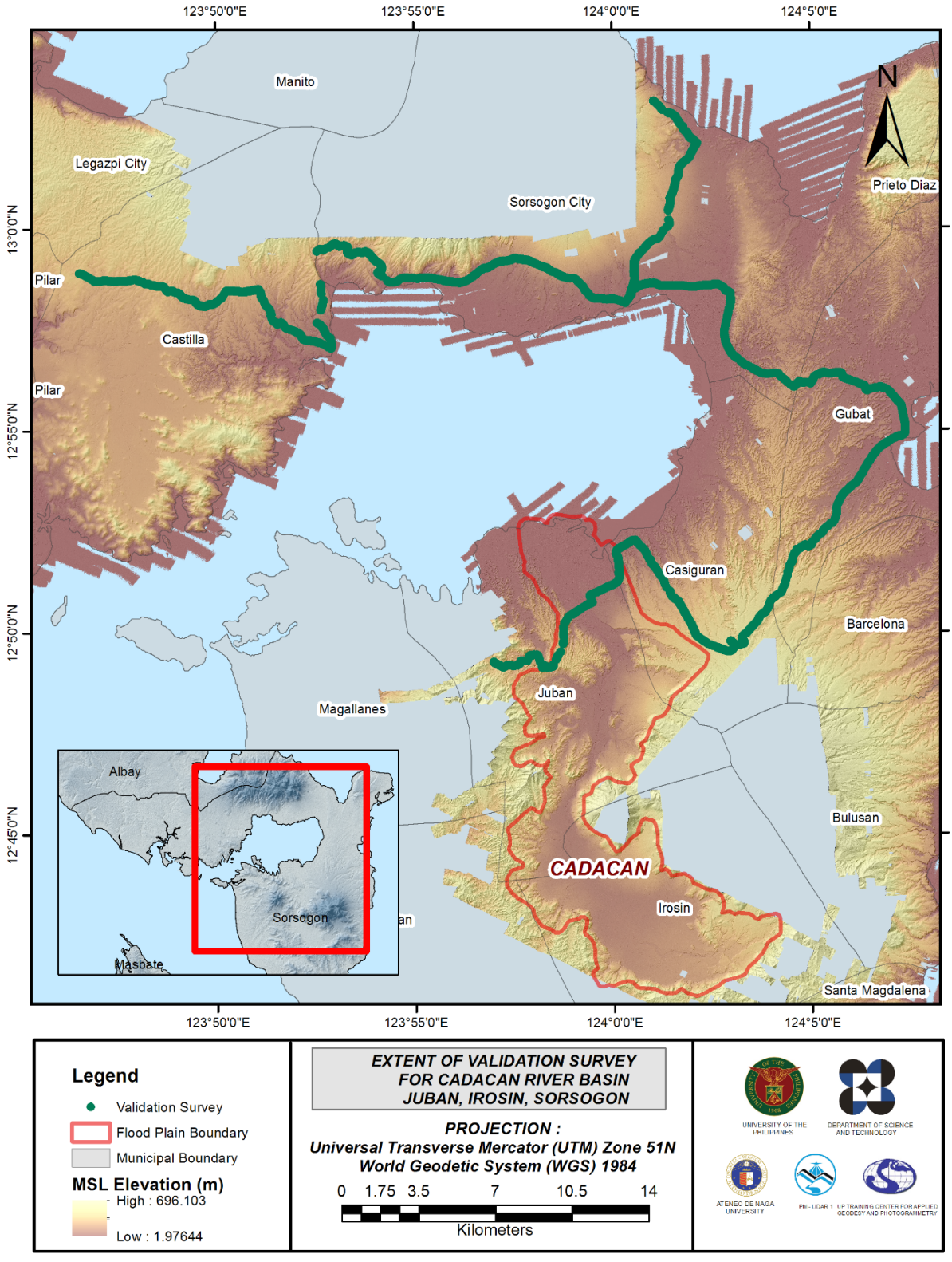


Figure 25. Map of Cadacan Flood Plain with validation survey points in green.

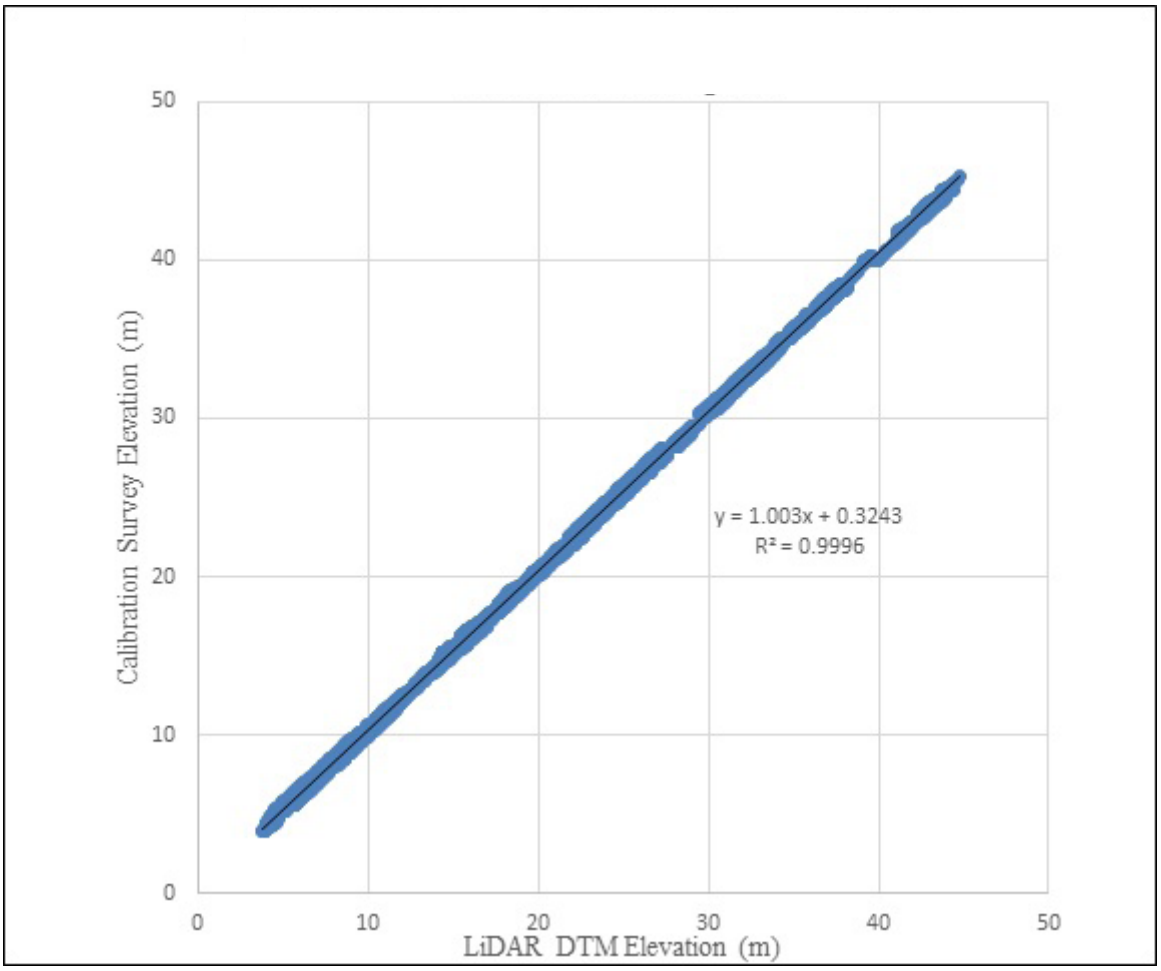


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.41
Standard Deviation	0.17
Average	0.38
Minimum	-0.08
Maximum	0.83

A total of 12,140 survey points were collected by DVBC for the Cadacan river basin. Random selection of points within the floodplain boundary, resulting to 645 points, were used for the validation of the calibrated Cadacan 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.21 meters with a standard deviation of 0.17 meters, as shown in Table 17.

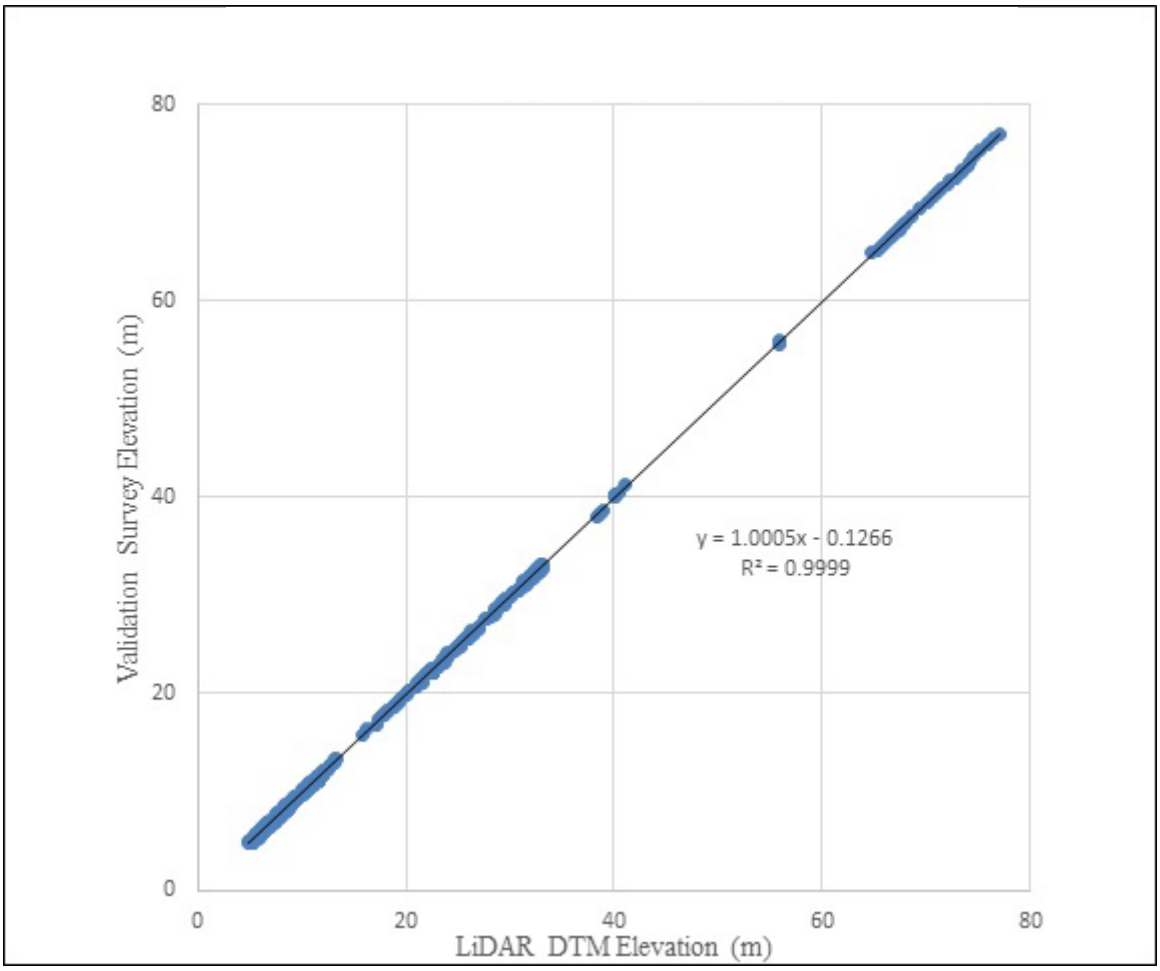


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.21
Standard Deviation	0.17
Average	-0.12
Minimum	-0.47
Maximum	0.25

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Cadacan with 19,235 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 0.34 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Cadacan integrated with the processed LiDAR DEM is shown in Figure 28.

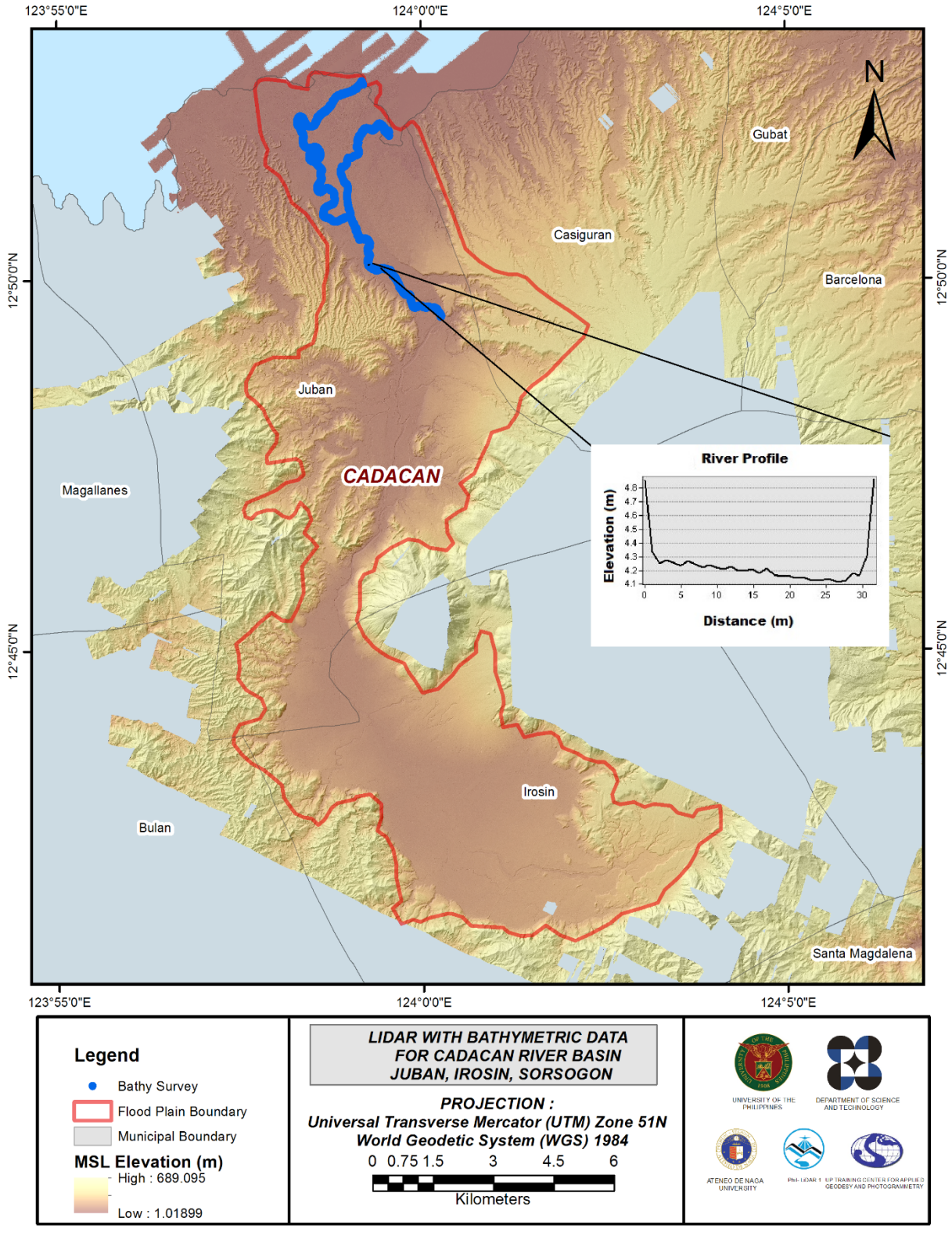


Figure 28. Map of Cadacan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Cadacan floodplain, including its 200 m buffer, has a total area of 125.50 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,775 building features, are considered for QC. Figure 29 shows the QC blocks for Cadacan floodplain.

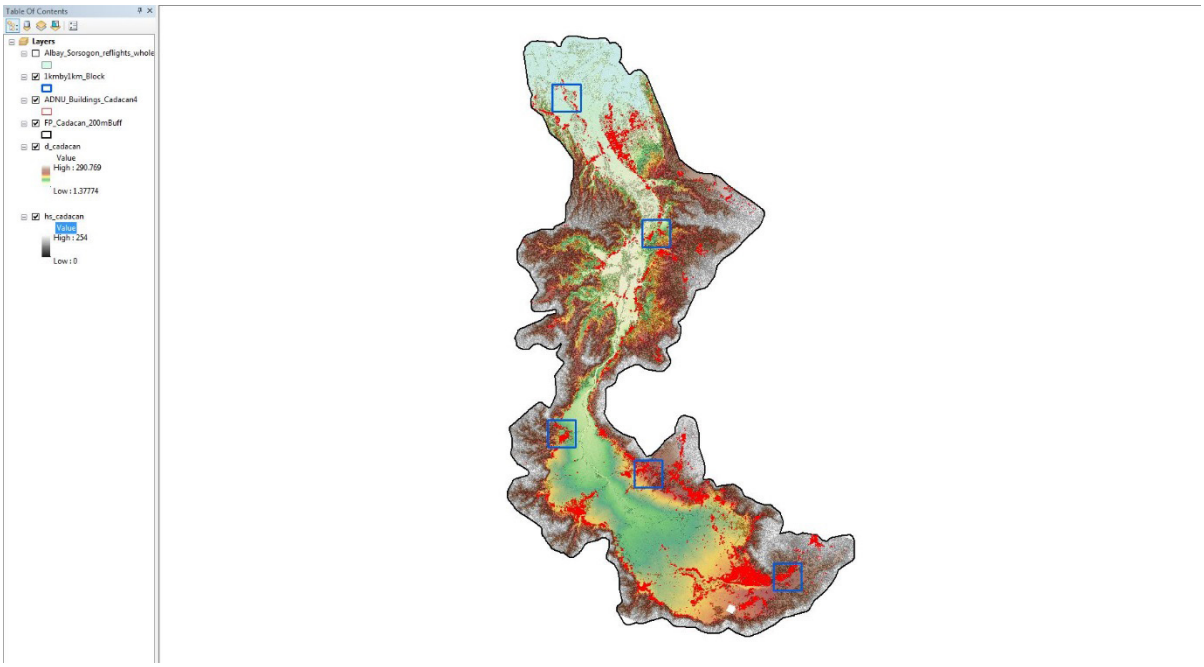


Figure 29. QC blocks for Cadacan building features.

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

Table 18. Quality Checking Ratings for Cadacan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Cadacan	98.28	99.61	96.73	PASSED

3.12.2 Height Extraction

Height extraction was done for 19,206 building features in Cadacan floodplain. Of these building features, 342 were filtered out after height extraction, resulting to 18,864 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.31 m.

3.12.2 Feature Attribution

Feature Attribution was done for 18,864 building features in Cadacan Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area 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)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

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

[1] Resource Extraction for Geographic Information System (reGIS), 17 March 2015

Table 19. Building Features Extracted for Cadacan Floodplain.

Facility Type	No. of Features
Residential	17,850
School	396
Market	23
Agricultural/Agro-Industrial Facilities	82
Medical Institutions	29
Barangay Hall	46
Military Institution	41
Sports Center/Gymnasium/Covered Court	7
Telecommunication Facilities	4
Transport Terminal	0
Warehouse	19
Power Plant/Substation	6
NGO/CSO Offices	4
Police Station	2
Water Supply/Sewerage	7
Religious Institutions	86
Bank	5
Factory	0
Gas Station	13
Fire Station	1
Other Government Offices	45
Other Commercial Establishments	198
Total	**18,864**

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Cadacan	86.02	39.11	0	2.51	0	127.63

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

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cadacan	8	133	0	0	0	**141**

A total of 29 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 30 shows the Digital Surface Model (DSM) of Cadacan floodplain overlaid with its ground features.

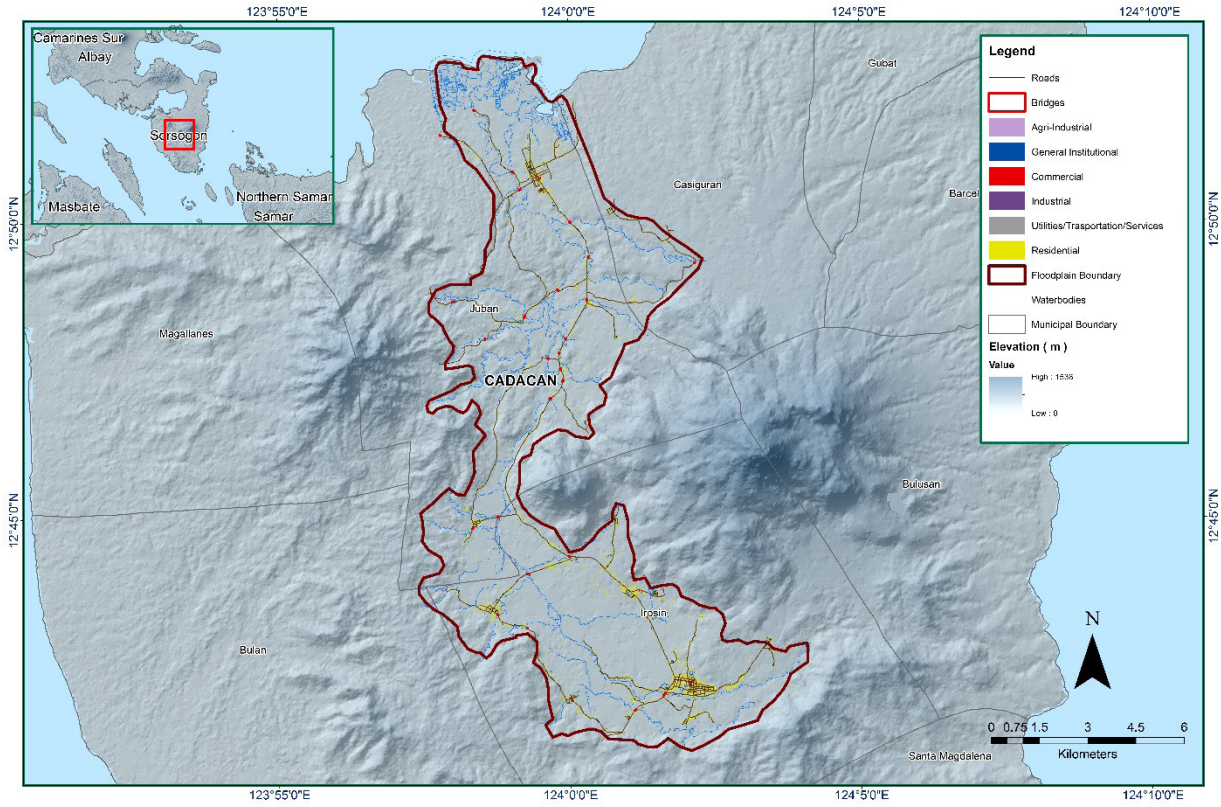


Figure 30. Extracted features for Cadacan floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto, Cybil Claire Atacador, and Engr. Lorenz R. Taguse

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Cadacan River on January 17-25, 2017 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey of Taboc Bridge in Brgy. Taboc, Municipality of Juban; validation points acquisition of about 95 km covering the Cadacan River Basin area; and bathymetric survey from its upstream in Brgy. Aroroy down to the two mouth of the river located in Brgy. Embarcadero and Brgy. Catanagan, both in Municipality of Juban, with an approximate length of 14.794 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 31).

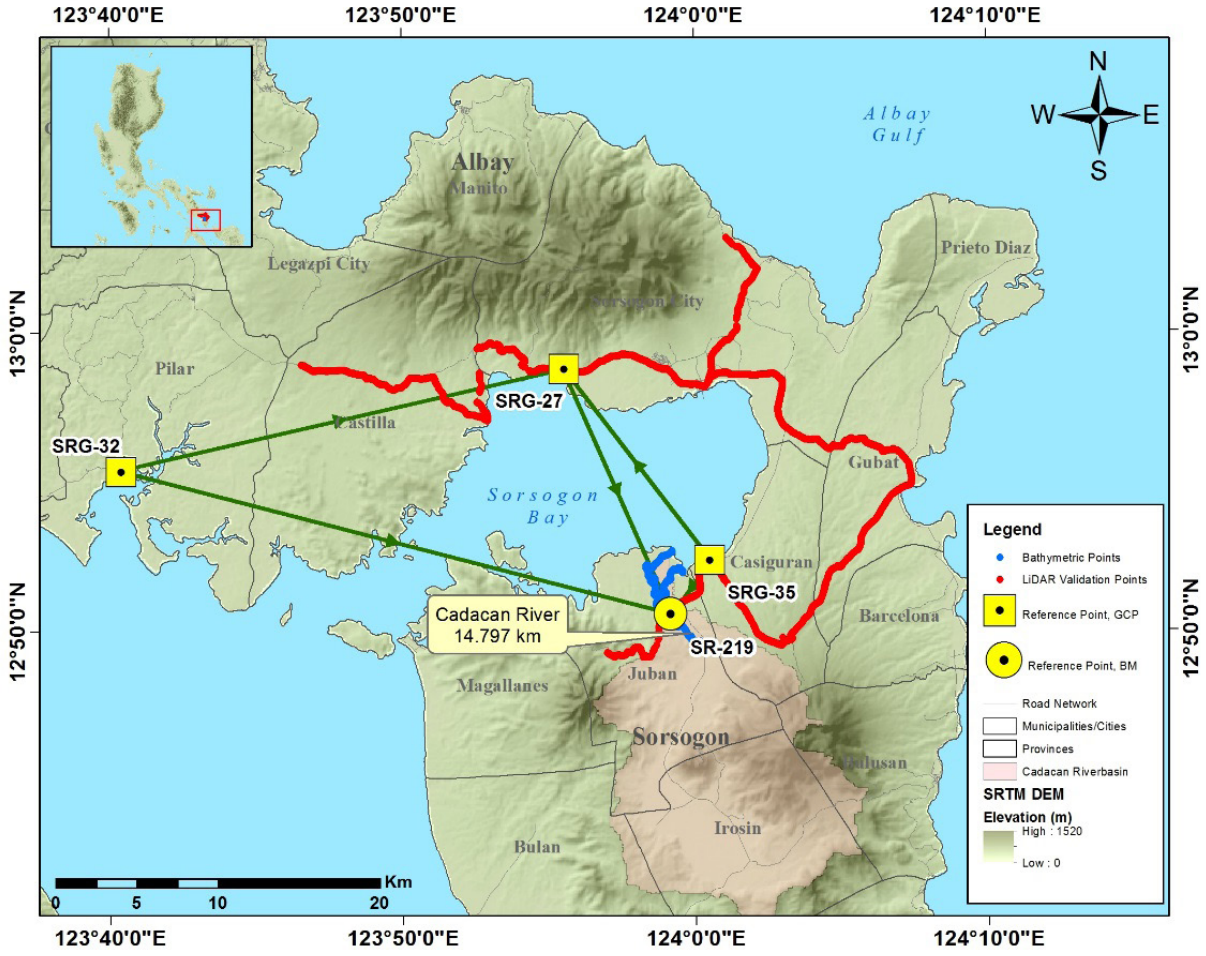


Figure 31. Cadacan River Survey Extent

4.2 Control Survey

The GNSS network used for Cadacan River Basin is composed of two (2) loops established on January 18, 2017 occupying the following reference points: SRG-27, a second order GCP in Brgy. Bulabog, Sorsogon City; SRG-35, a second order GCP in Brgy. Central, Municipality of Casiguran; and SR-219, a first order BM in Brgy. Taboc, Municipality of Juban; all in the province of Sorsogon.

A NAMRIA established control point namely SRG-32, located in Brgy. Banuyo, Municipality of Pilar, was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 22 while the GNSS network established is illustrated in Figure 32.

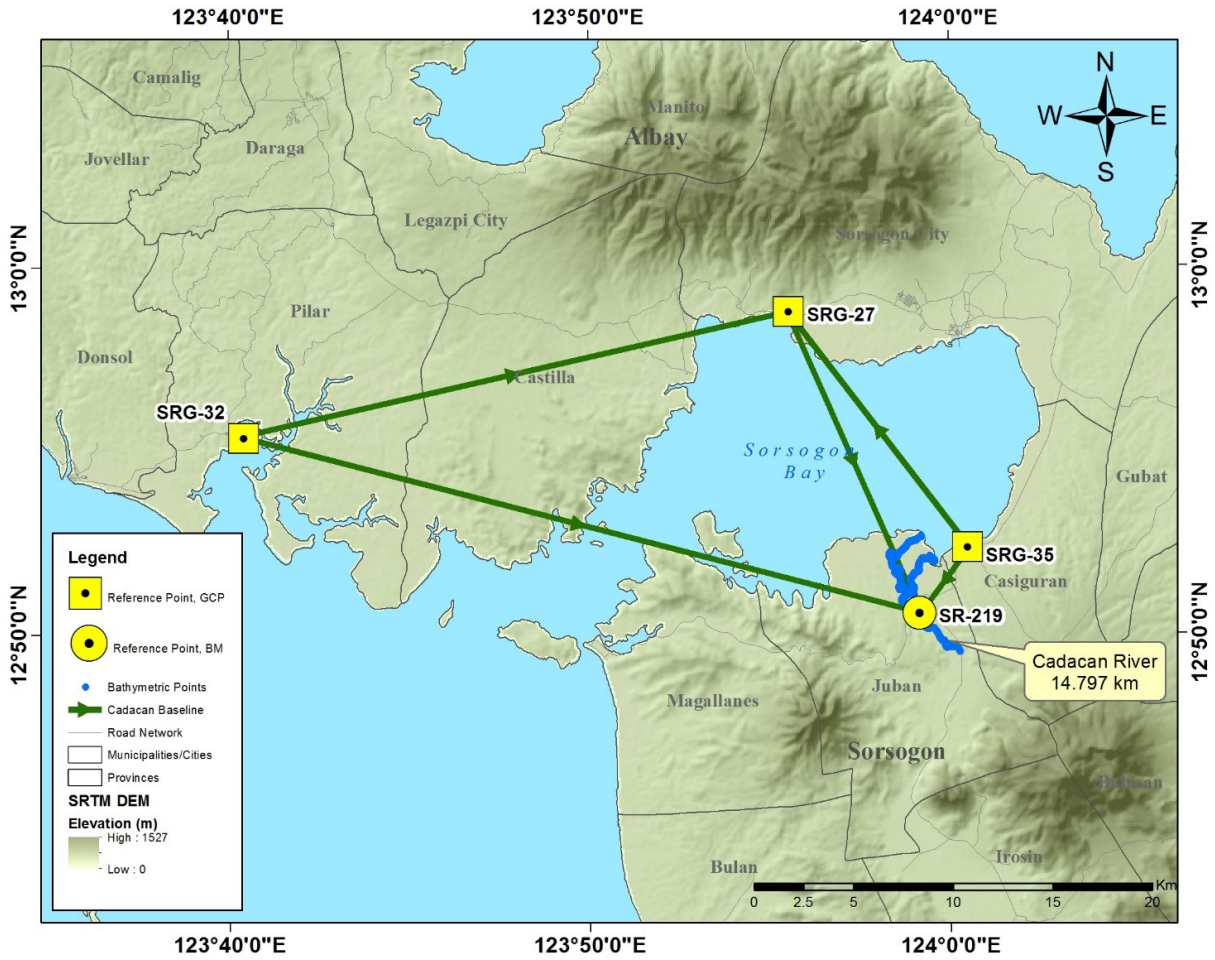


Figure 32. GNSS Network covering Cadacan River

Table 22. List of Reference and Control Points occupied for Cadacan River Survey
(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
SRG-27	2nd order, GCP	12°58'45.37172"	123°55'32.01031"	69.228	-	2007
SRG-35	2nd order, GCP	12°52'20.57407"	124°00'28.82318"	65.989	-	2007
SR-219	1st order, BM	-	-	65.866	11.451	2008
SRG-32	Used as Marker	-	-	58.699	-	2007

The GNSS set-ups on recovered reference points and established control points in Cadacan River are shown in Figure 33 to Figure 36.

Figure 33. GNSS base set up, Trimble® SPS 985, at SRG-27, located in front of the Barangay Hall in Brgy. Bulabog, Sorsogon City, Sorsogon.

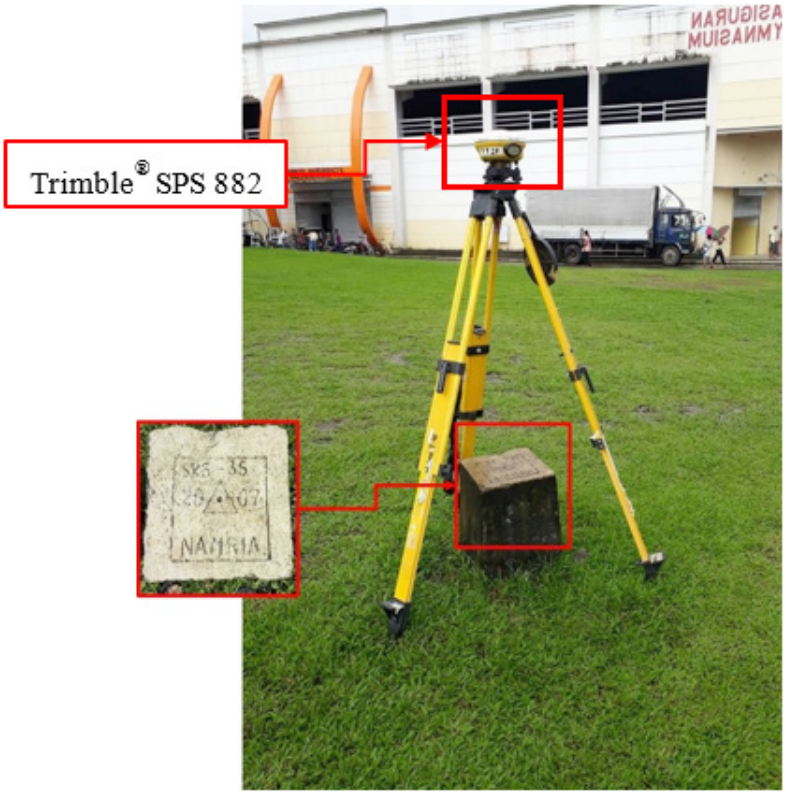


Figure 34. GNSS receiver setup, Trimble® SPS 882, at SRG-35, located in front of the Casiguran Municipall Hall in Brgy. Central, Municipality of Casiguran, Sorsogon.

Figure 35. GNSS receiver setup, Trimble® SPS 985, at SR-219, located along the approach of Taboc Bridge in Brgy. Taboc, Municipality of Juban, Sorsogon

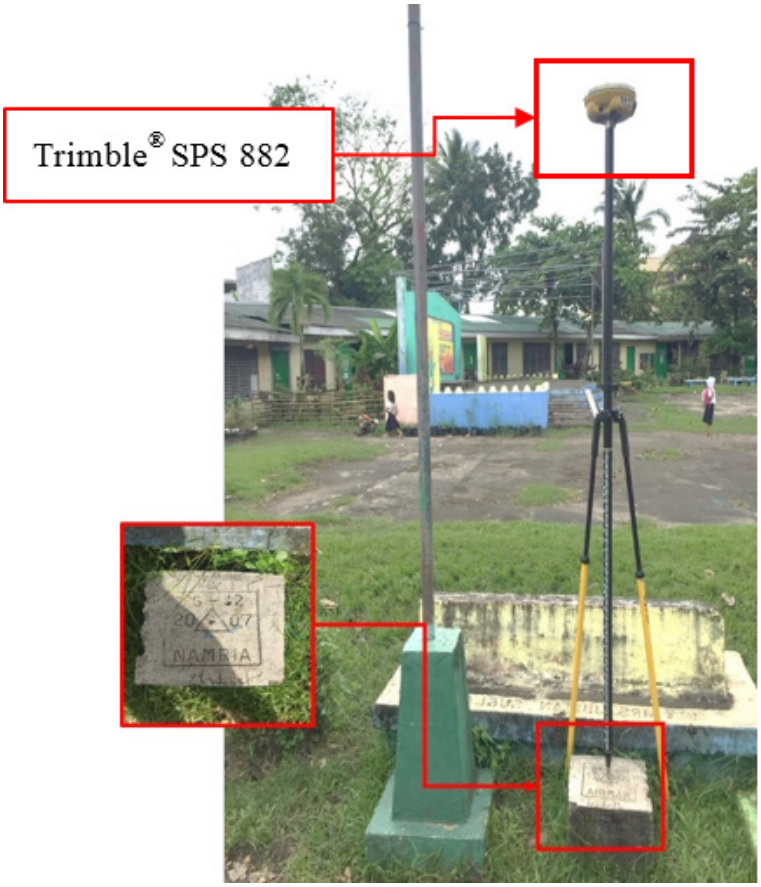


Figure 36. GNSS receiver setup, Trimble® SPS 882, at SRG-32, located inside Banuyo Elementary School in Brgy. Banuyo, Municipality of Pilar, Sorsogon.

4.3 Baseline Processing

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

Table 23. Baseline Processing Summary Report for Cadacan River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
SRG-27 --- SRG-32	07-24-16	Fixed	0.004	0.029	77°03'34"	28089.026	10.531
SRG-32 --- SR-219	07-24-16	Fixed	0.004	0.022	104°36'30"	35062.814	7.170
SRG-27 --- SR-219	07-24-16	Fixed	0.006	0.059	156°38'27"	16491.547	-3.397
SRG-35 --- SRG-27	07-24-16	Fixed	0.007	0.046	322°53'50"	14828.526	3.223
SRG-35 --- SR-219	07-24-16	Fixed	0.002	0.010	216°01'44"	4099.553	-0.122

As shown Table 23 a total of five (5) baselines were processed with reference points SRG-27 and SRG-35 held fixed for coordinate values; and SR-219 fixed for elevation values. All of them passed the required accuracy.

‘

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table 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:

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table C-3 to Table C-6 for complete details.

The four (4) control points, SRG-27, SRG-35, SR-219 and SRG-32 were occupied and observed simultaneously to form a GNSS loop. Coordinates of SRG-27 and SRG-35; and elevation value of SR-219 were held fixed during the processing of the control points as presented in Table 24. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
SRG-27	Local	Fixed	Fixed		
SRG-35	Local	Fixed	Fixed		
SR-219	Grid				Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. The fixed controls BTN-68 and BTN-71 have no values for grid errors while BA-68 has no value for elevation error.

Table 25. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SR-291	606972.592	0.002	1419913.396	0.002	11.451	?	e
SRG-27	600381.092	?	1435025.374	?	15.494	0.024	LL
SRG-32	573030.785	0.006	1428665.114	0.006	5.107	0.019	
SRG-35	609370.290		1423237.311		11.752	0.010	LL

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

SRG-27
horizontal accuracy = Fixed
vertical accuracy = 2.4 cm < 10 cm

SRG-35
horizontal accuracy = Fixed
vertical accuracy = 1.0 cm < 10 cm

SR-219
horizontal accuracy = $\sqrt{((0.2)^2 + (0.2)^2}$
= $\sqrt{(0.4 + 0.4)}$
= 0.89 < 20 cm
vertical accuracy = Fixed

SRG-32
horizontal accuracy = $\sqrt{((0.6)^2 + (0.6)^2}$
= $\sqrt{(0.36 + 0.36)}$
= 0.85 < 20 cm
vertical accuracy = 1.9 cm < 10 cm

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

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
SR-291	N12°50'32.68559"	E123°59'08.85550"	65.866	?	e
SRG-27	N12°58'45.37172"	E123°55'32.01031"	69.228	0.024	LL
SRG-32	N12°55'21.12512	E123°40'23.65149"	58.699	0.019	
SRG-35	N12°52'20.57407"	E124°00'28.82318"	65.989	0.010	LL

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

The summary of reference and control points used is indicated in Table 27.

Table 27. Reference 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	Easting	BM Ortho (m)
SRG-27	2nd order, GCP	12°58'45.37172"	123°55'32.01031"	69.228	1435025.374	600381.092	15.494
SRG-35	2nd order, GCP	12°52'20.57407"	124°00'28.82318"	65.989	1423237.311	609370.290	11.752
SR-219	1st order, BM	12°50'32.68559"	123°59'08.85550"	65.866	1419913.396	606972.592	11.451
SRG-32	UP Established	12°58'45.37172"	123°55'32.01031"	69.228	1428665.114	573030.785	15.494

4.5 Cross-section, Bridge As-Built Survey, and Water Level Marking

Cross-section and as-built survey were conducted on January 18,19,21,23, and 24, 2017 at the downstream side of Taboc Bridge in Brgy. Taboc, Municipality of Juban, Sorsogon as shown in Figure 37 using Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 38.

Figure 37. Taboc Bridge facing upstream

Figure 38. Bridge As-Built Survey using PPK Technique.

The cross-sectional line of Taboc Bridge is about 200 m with seventy-eight (78) cross-sectional points using the control point SR-219 as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 39 to Figure 41, respectively.

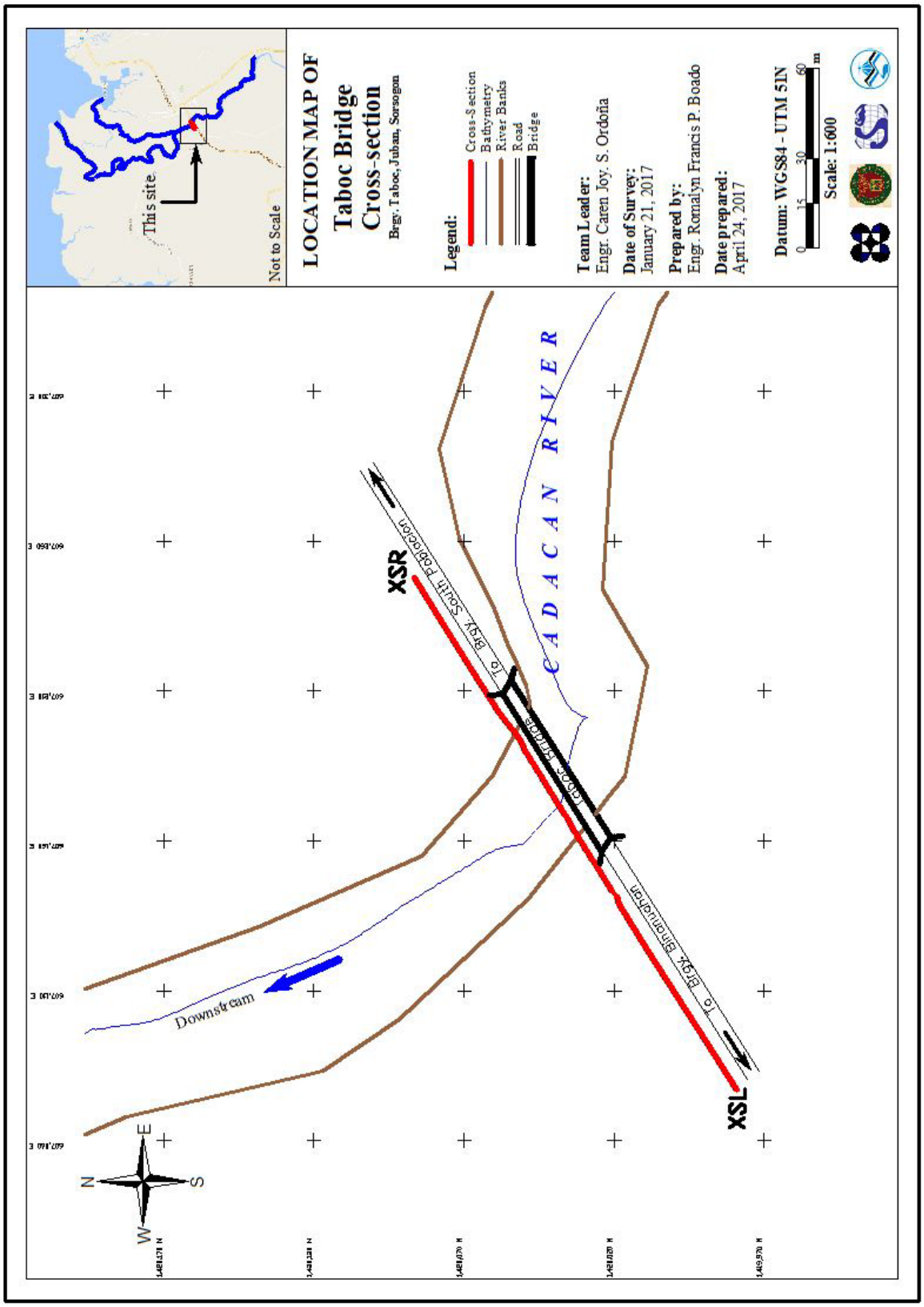


Figure 39. . Taboc Bridge cross-section diagram

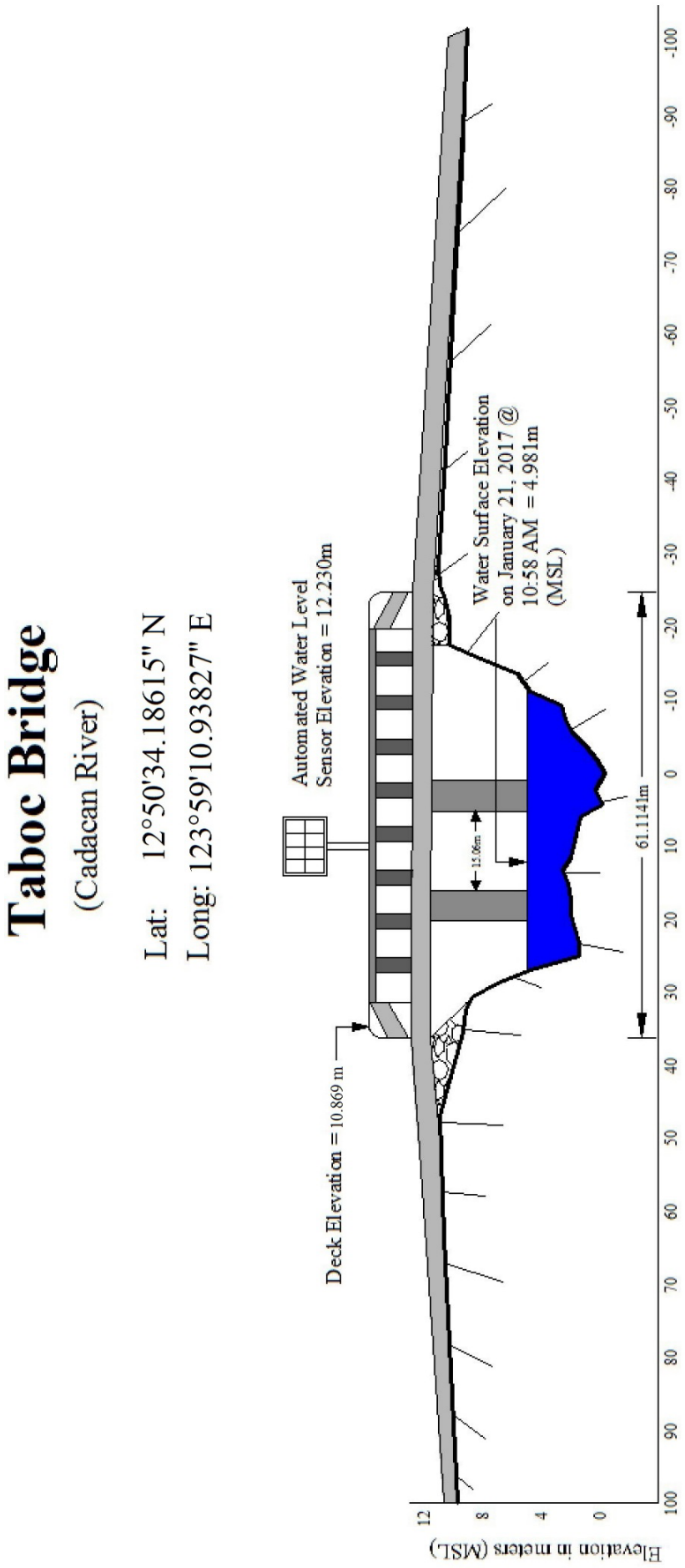


Figure 40. Taboc bridge cross-section planimetric map

Bridge Data Form

Bridge Name: Taboc Bridge **Date:** January 21, 2017

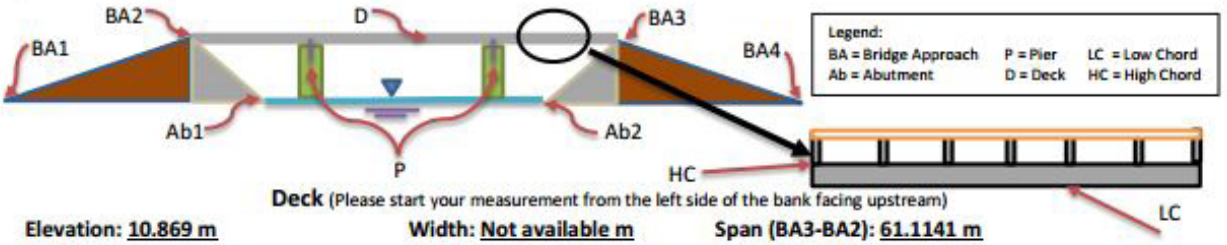
River Name: Cadacan River **Time:** 10:58 AM

Location (Brgy, City,Region): Brgy. Taboc, Municipality of Juban, Sorsogon

Survey Team: Caren Ordoña, Marion Dimain, John Christopher Santos

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

Latitude: 12°50'34.18615" N **Longitude:** 123°59'10.93827" E



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

Elevation: 10.869 m **Width:** Not available m **Span (BA3-BA2):** 61.1141 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	10.869 m	BA3	78.87629 m	11.417 m
BA2	17.762 m	11.566 m	BA4	154.89253 m	9.048 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available

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

Shape: cylindrical Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	35.89107 m	11.520 m	Not available
Pier 2	50.95443	11.482 m	Not available

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

Figure 41. Bridge as-built form of Taboc Bridge

Water surface elevation of Cadacan River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on January 21, 2017 at 10:58 AM with a value of 4.981 m in MSL as shown in Figure 39. This was translated into marking on the Taboc bridge's deck using the same technique as shown in Figure 42. This will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for Cadacan river, the Ateneo De Naga University.

Figure 42. Water-level markings on Taboc Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on January 19 and 20, 2017 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on top of a vehicle as shown in Figure 43. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.90 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with SR-219 occupied as the GNSS base station.

Figure 43. Validation points acquisition survey set up along Cadacan River Basin

The survey started from Brgy. Sogoy, Municipality of Castilla, going south traversing Sorsogon City, Municipality of Gubat, Municipality of Casiguran, and Municipality of Juban via national highway, and ended in Brgy. Lajong, Municipality of Juban, Sorsogon. A total of 13,464 points were gathered with approximate length of 95 km using SR-219 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 44.

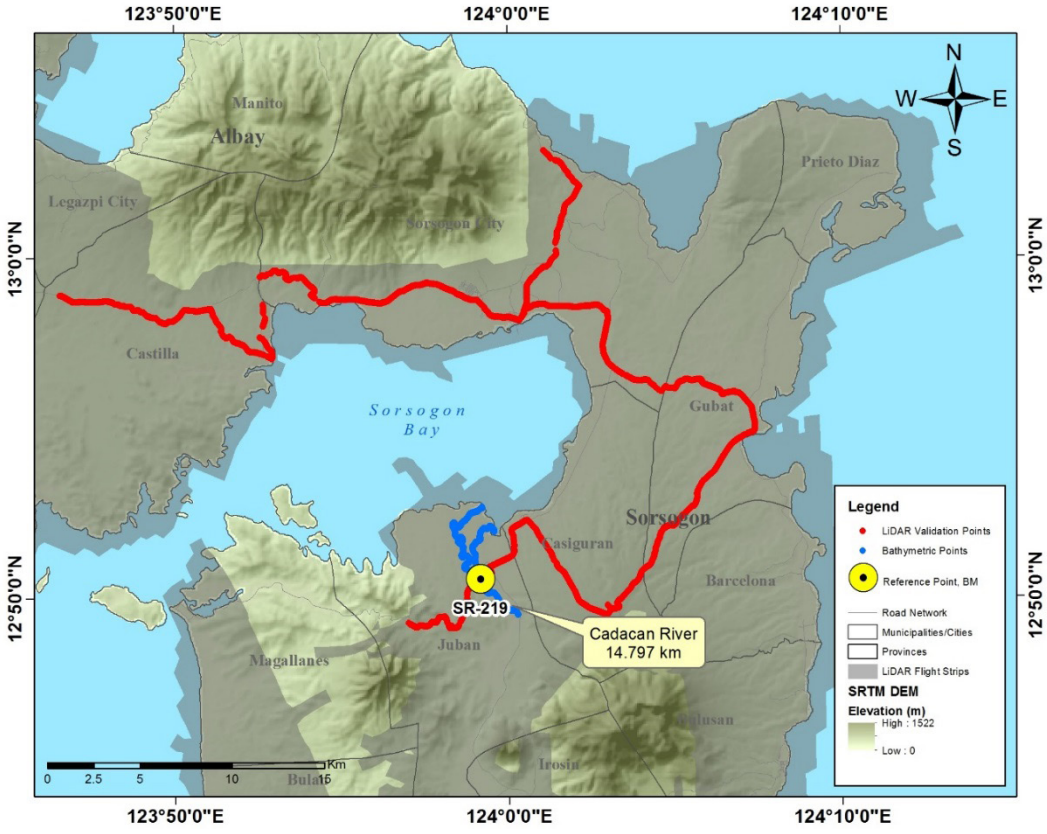


Figure 44. Validation point acquisition survey of Cadacan River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on January 19, 20 and 23, 2017 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 45. The survey started in the upstream part of the river in Brgy. Aroroy, Municipality of Juban with coordinates 12°49›31.23041»N, 124°00›15.61602»E, and ended at two different mouth of the river with coordinates 12°52›34.94940»N, 123°59›06.55820»E and 12°51›57.08012»N, 123°59›32.96368»E, both in Brgy. Embarcadero, Municipality of Juban, Sorsogon.

Figure 45. Bathymetric survey using Ohmex™ single beam echo sounder in Cadacan River

Manual bathymetric survey was executed on January 23, 2017 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode. The survey covered 200 meters from one of the mouth of the river with coordinates 12°52›39.29182»N, 123°59›11.00378»E up to where the bathymetric survey started, both in Brgy. Embarcadero, Municipality of Juban. The control point SR-219 was used as the GNSS base station throughout the entire survey.

Figure 46. Manual Bathymetric survey using in Cadacan River

The bathymetric survey for Cadacan River gathered a total of 20,611 points covering 14.797 km of the river traversing nine (9) barangays in Municipality of Juban namely: Aroroy, Binanuahan, Catanagan, Cogon, Embarcadero, North Poblacion, Sipaya, South Poblacion, and Taboc. A CAD drawing was also produced to illustrate the riverbed profile of Cadacan River. As shown n Figure 48 and Figure 49, the highest and lowest elevation has a 18-m difference. The highest elevation observed was 8.507 m in MSL located in Brgy. Aroroy, while the lowest elevation value gathered was -9.878 m below MSL located in Brgy. Catanagan, both in Municipality of Juban.

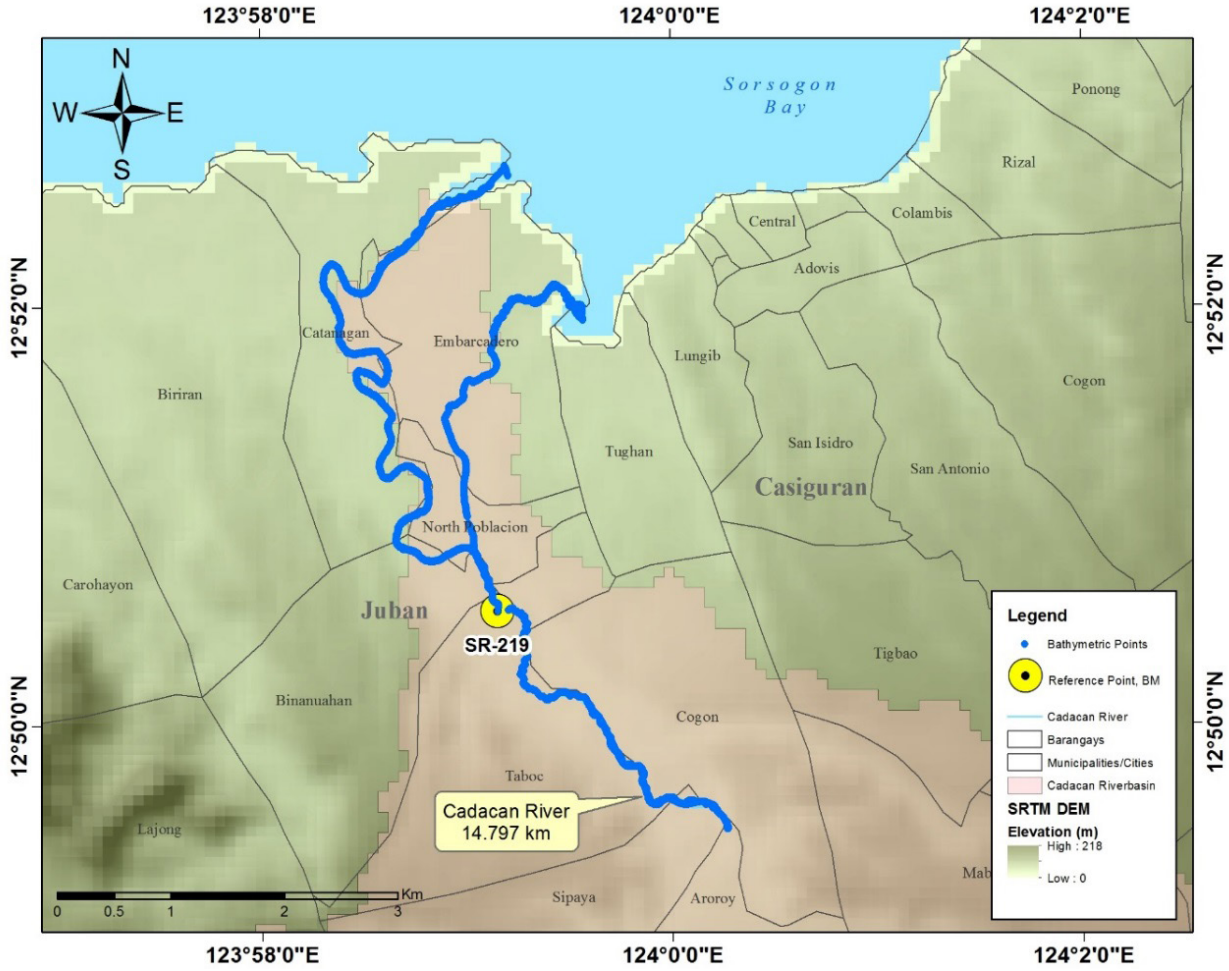


Figure 47. Bathymetric survey of Cadacan River

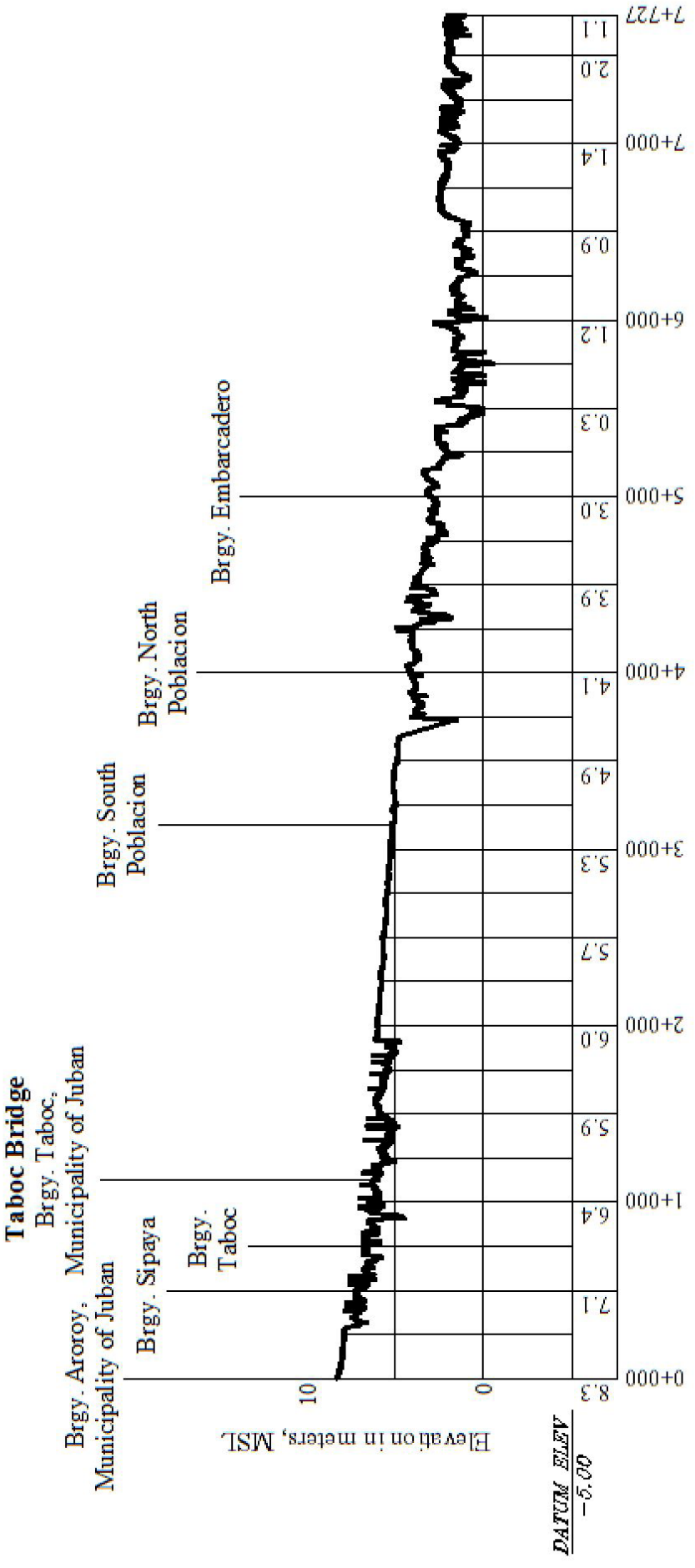


Figure 48. Cadacan Riverbed Profilel

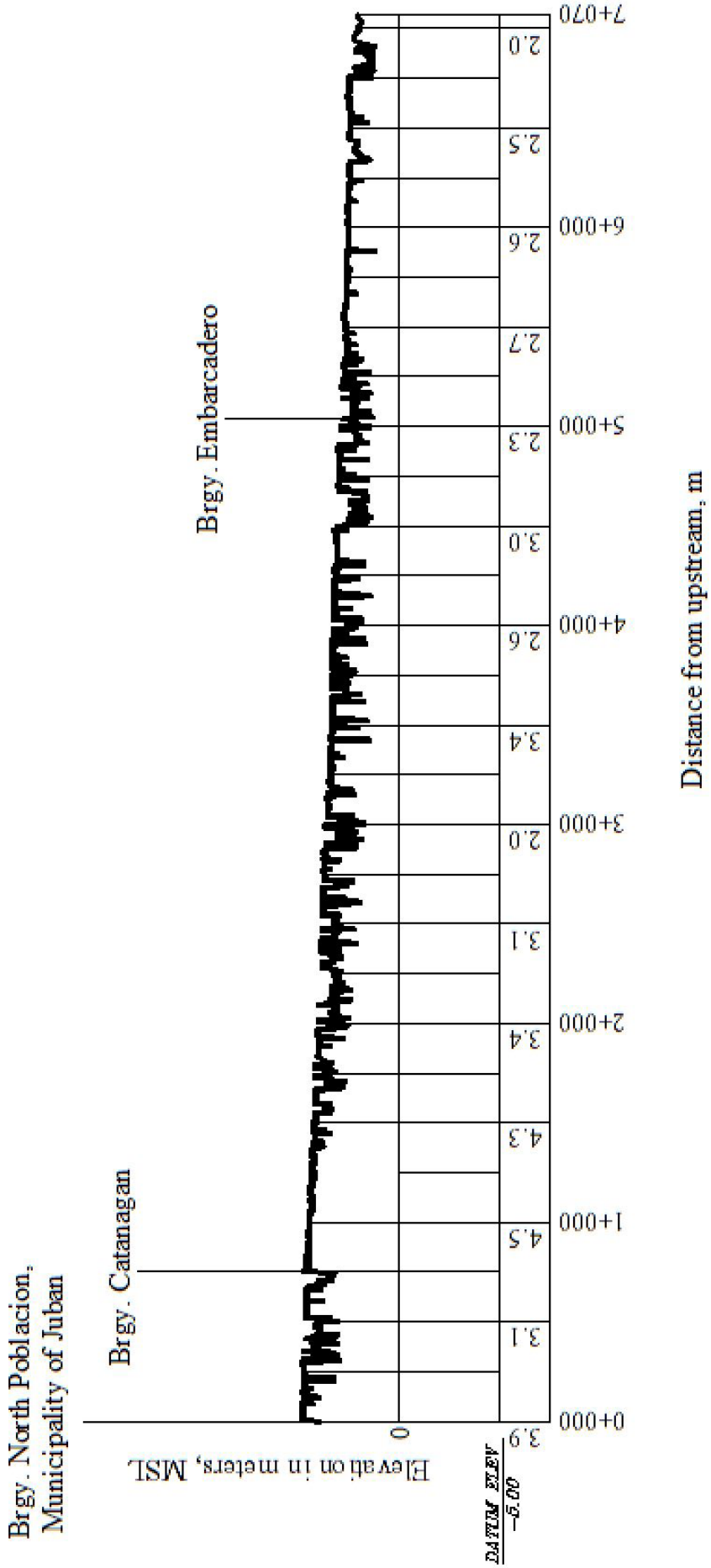


Figure 49. Cadacan Riverbed Profile2

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Gianni Sumajit, Christian Javier B. Arroyo, Engr. Mary Ruth A. Bongon, Sarah Mae F. Fulleros, Jan Carlo C. Plopenio, Aaron San Andres, Julius Hector S. Manchete, Engr. Herminio Magpantay, Mark D. Delloro, and Engr. Ferdinand E. Bien

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 Hyrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The rain gauge was installed at Brgy. Guruyan (Figure 50). The precipitation data collection started from October 14, 2016 at 2:00 PM to October 16, 2016 at 12:00 PM with a 10-minute recording interval.
The total precipitation for this event in Brgy. Guruyan ARG is 220mm. It has a peak rainfall of 11mm on October 14, 2016 at 11:20 PM. The lag time between the peak rainfall and discharge is 21 hours and 20 minutes.

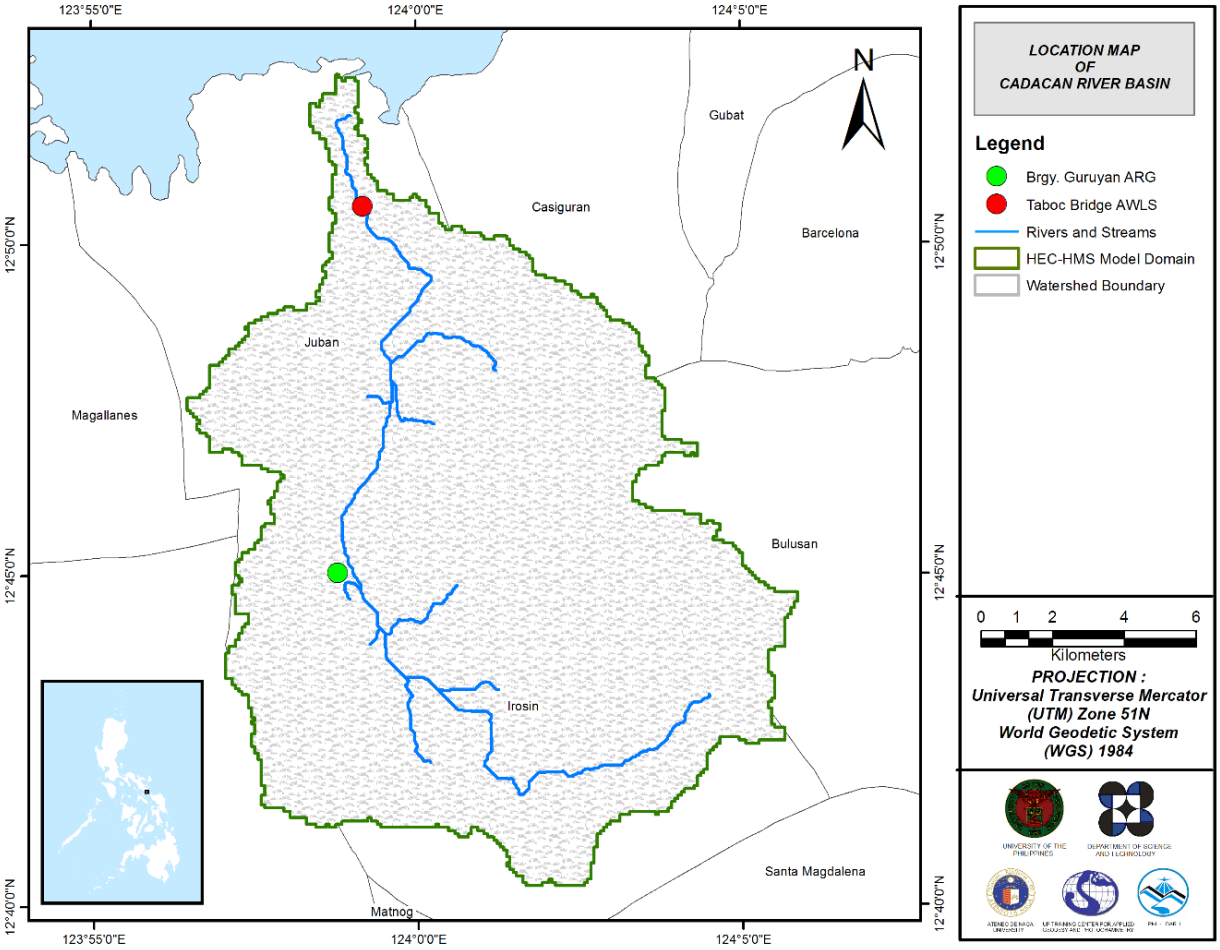


Figure 50. The location map of Cadacan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Taboc Bridge, Cadacan, Sorsogon (12°50'34.2"N, 123°59'10.2"E). It gives the relationship between the observed water levels at Taboc Bridge and outflow of the watershed at this location.

For Taboc Bridge, the rating curve is expressed as $Q = 0.6025e^{0.8988h}$ as shown in Figure 52.

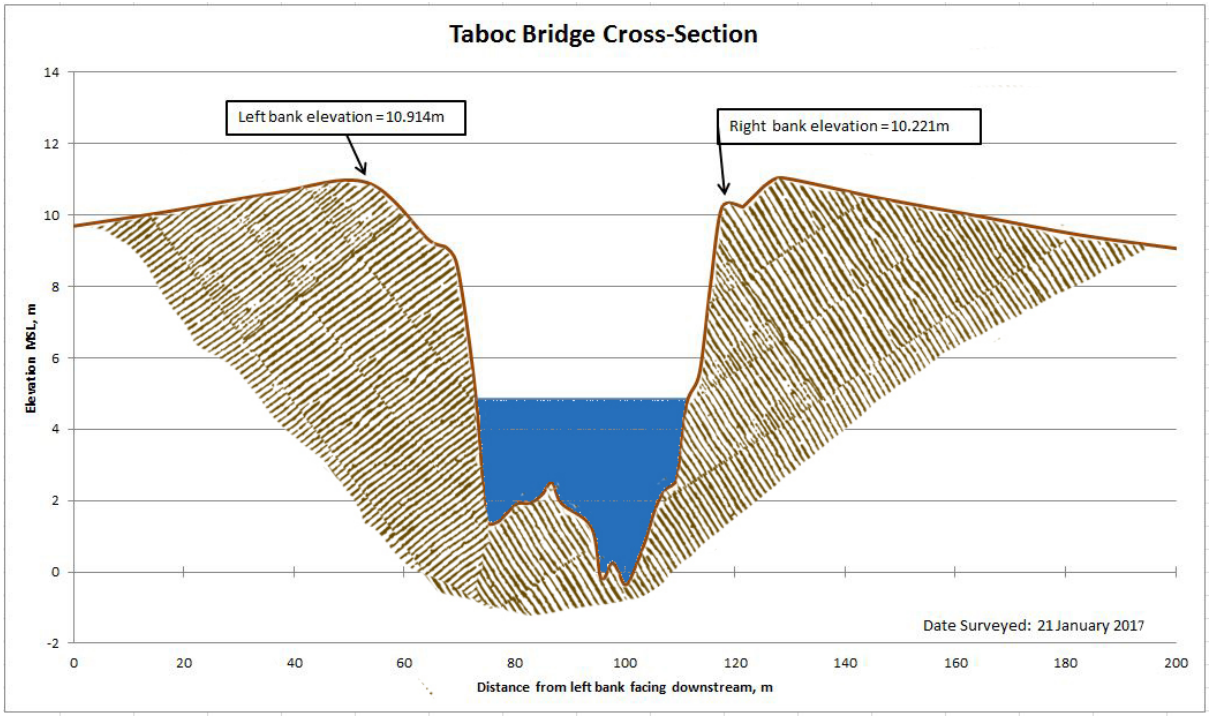


Figure 51. The cross-section plot of Taboc Bridge

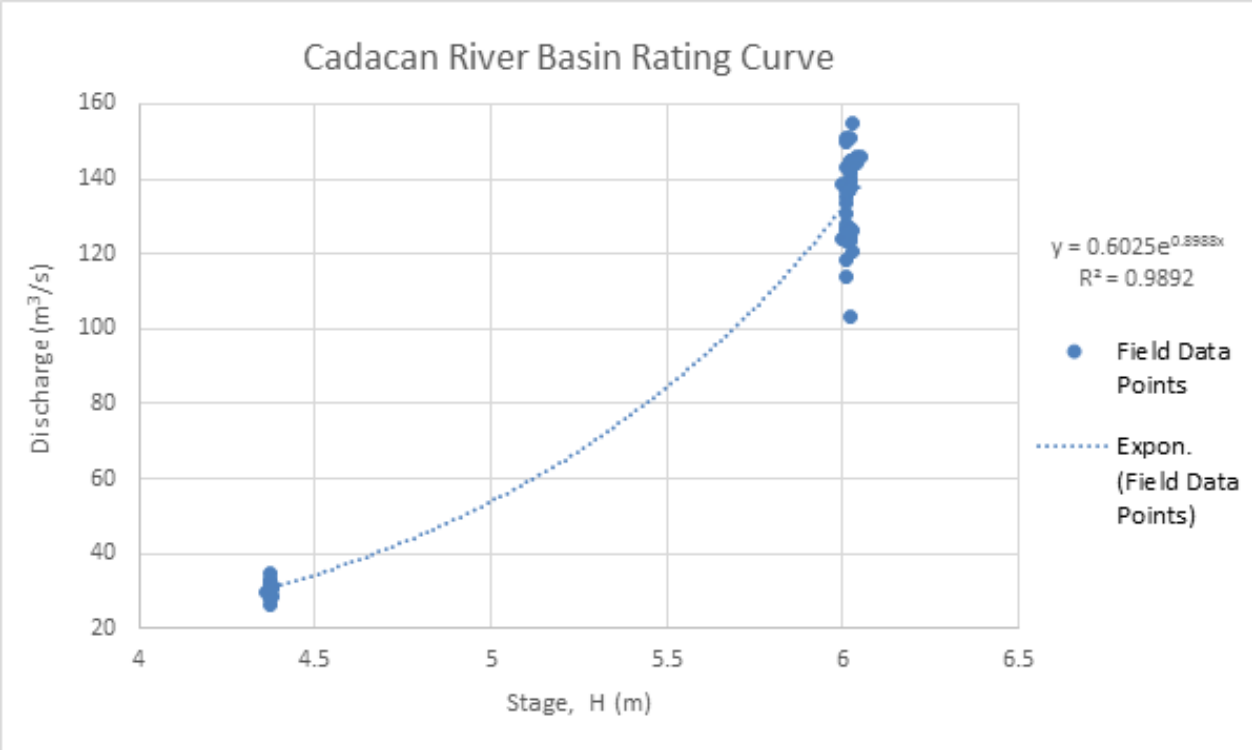


Figure 52. The rating curve of Taboc Bridge in Cadacan, Sorsogon

This rating curve equation was used to compute the river outflow at Taboc Bridge for the calibration of the HEC-HMS model shown in Figure 53. The total rainfall for this event is 220mm and the peak discharge is 157.1m^3/s at 11:00 PM, October 15, 2016.

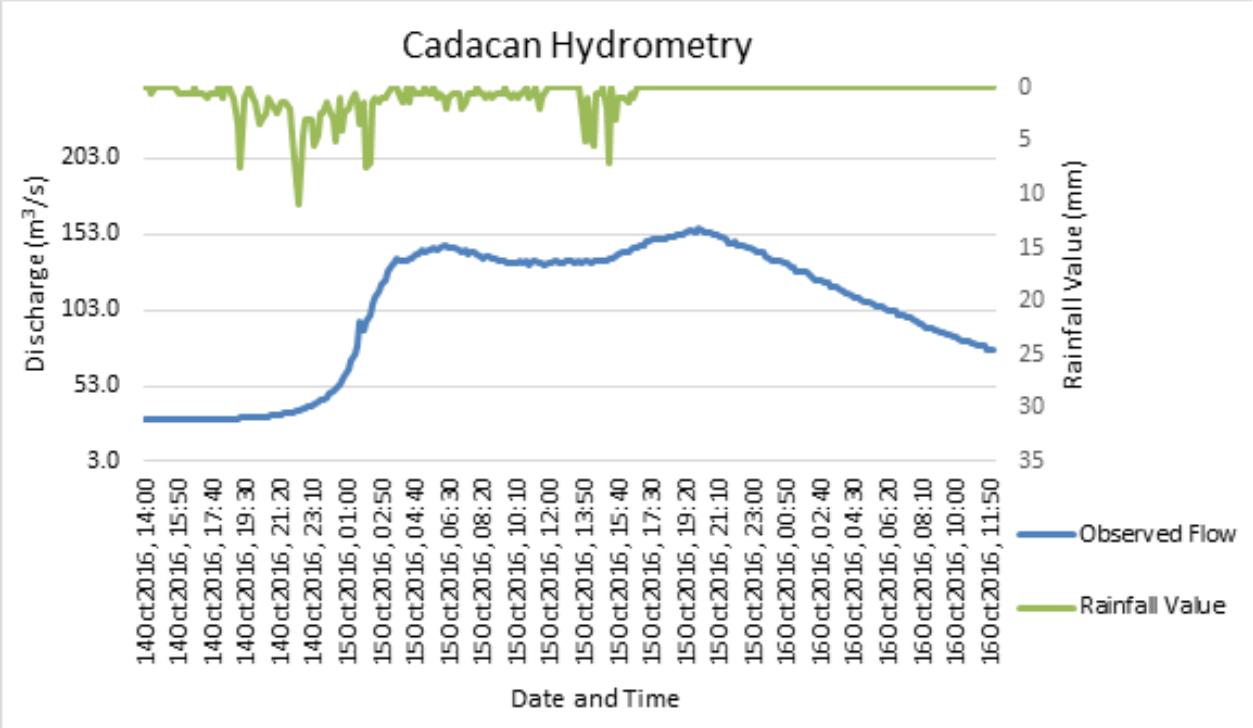


Figure 53. Rainfall and outflow data of the Cadacan River Basin, which was used for modeling

5.2 RIDF Station

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

Table 28. RIDF values for Cadacan Rain Gauge computed by PAG-ASA

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

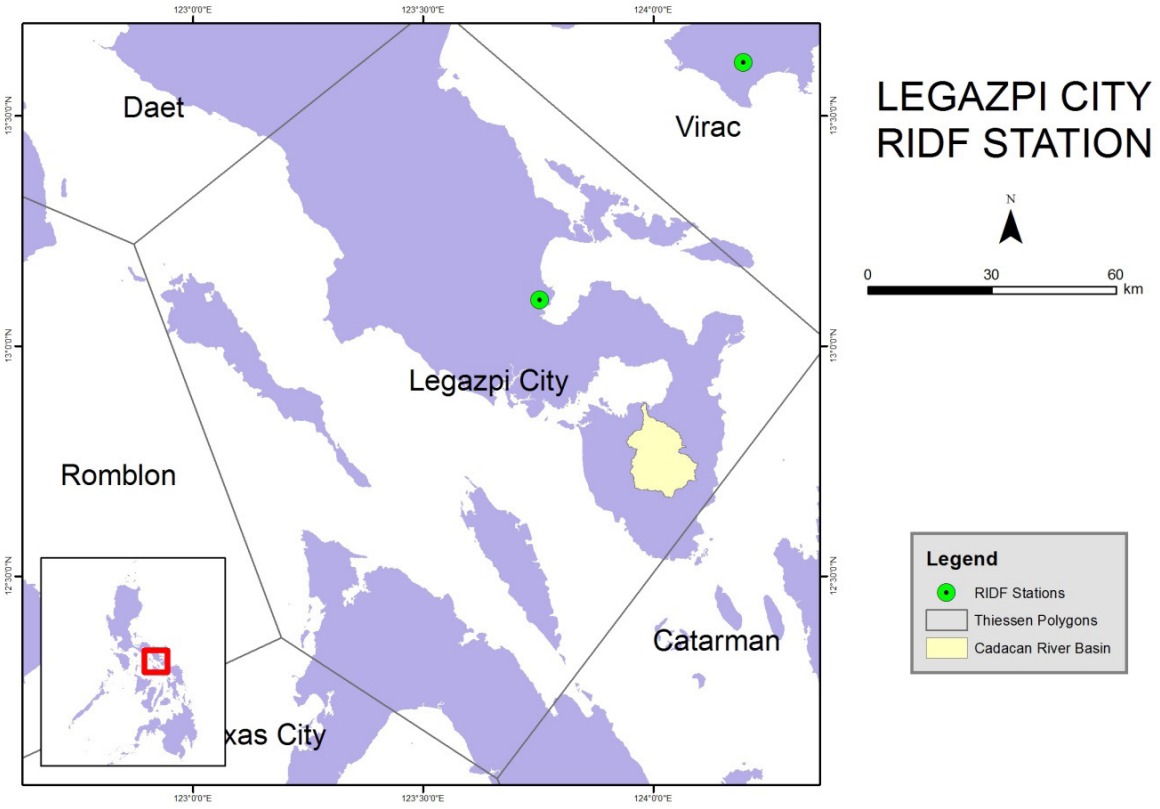


Figure 54. The location of the Legazpi City RIDF station relative to the Cadacan River Basin

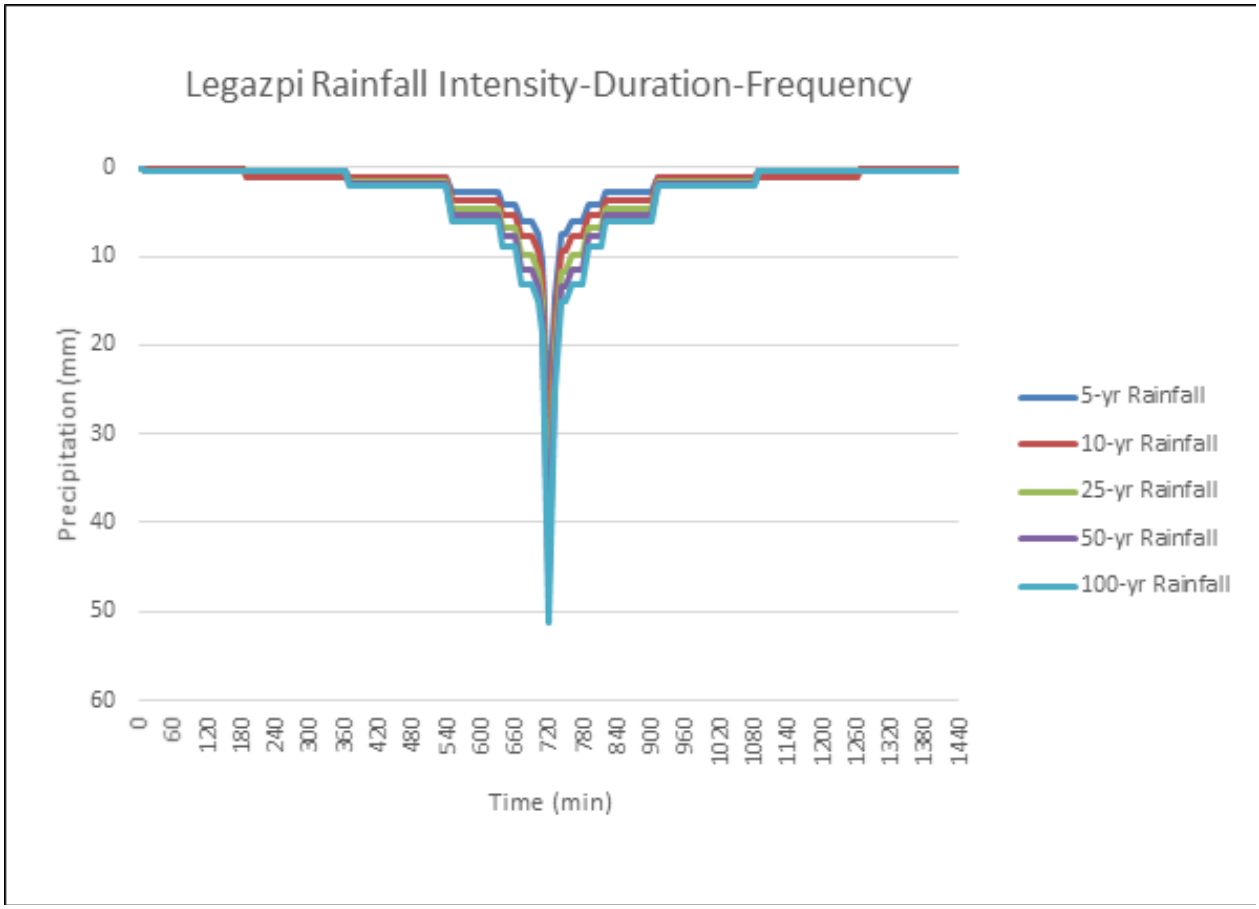


Figure 55. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management of the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Cadacan River Basin are shown in Figure 56 and Figure 57, respectively.

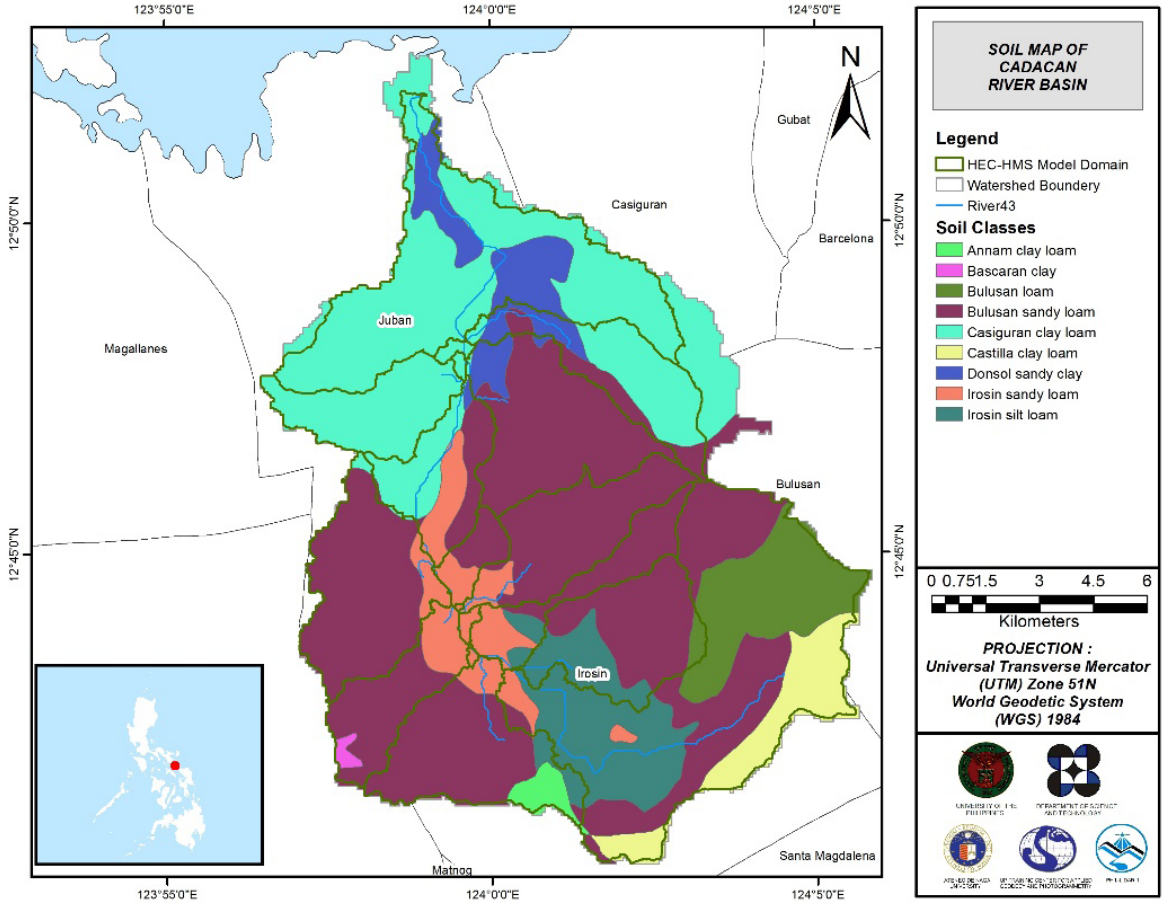


Figure 56. Soil map of Cadacan River Basin

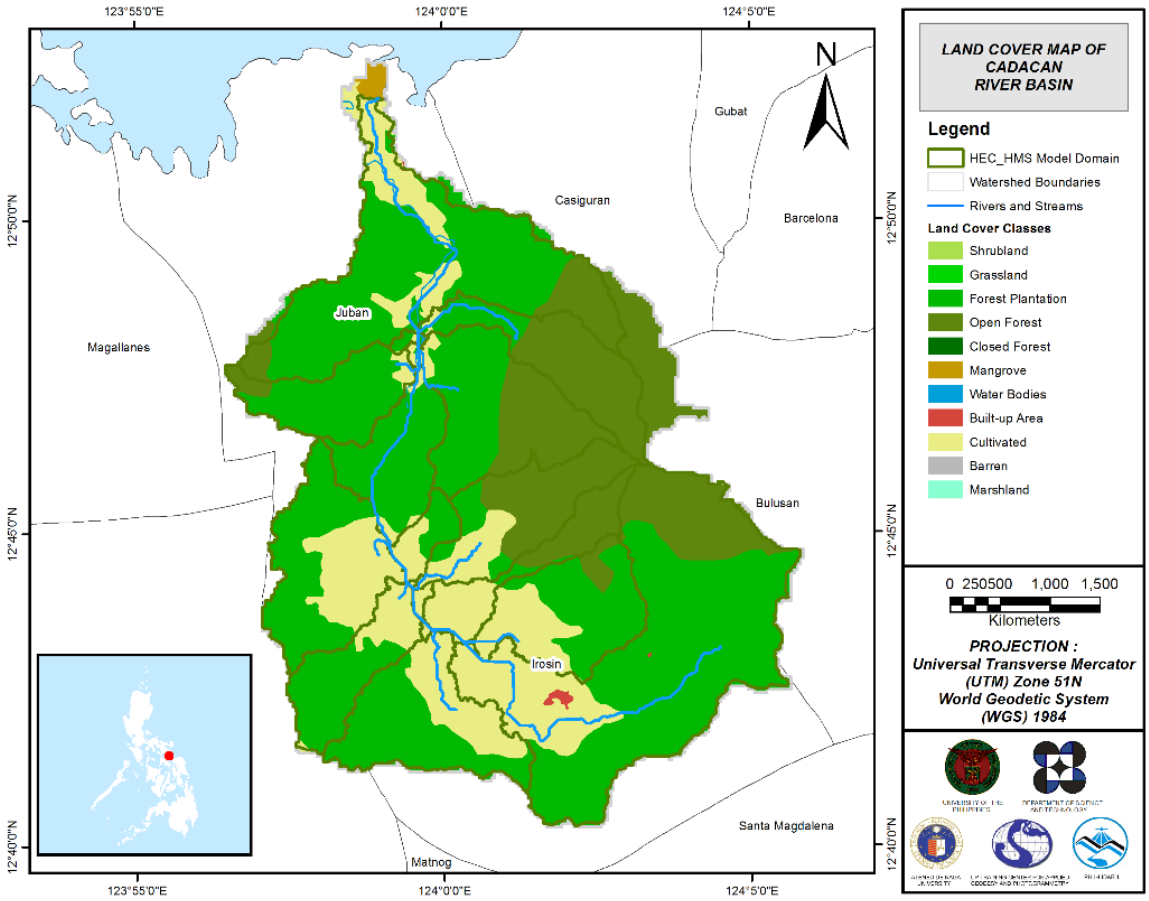


Figure 57. Land cover map of Cadacan River Basin

For Cadacan river basin, nine (9) soil classes were identified. These are Annam clay loam, Bascaran clay, Bulusan loam and sandy loam, Casiguran clay loam, Castilla clay loam, Donsol sandy clay, Irosin sandy loam, and Irosin silt loam. Moreover, four (4) land cover classes were identified. These are grassland, open forest, mangrove, cultivated, and built-up areas.

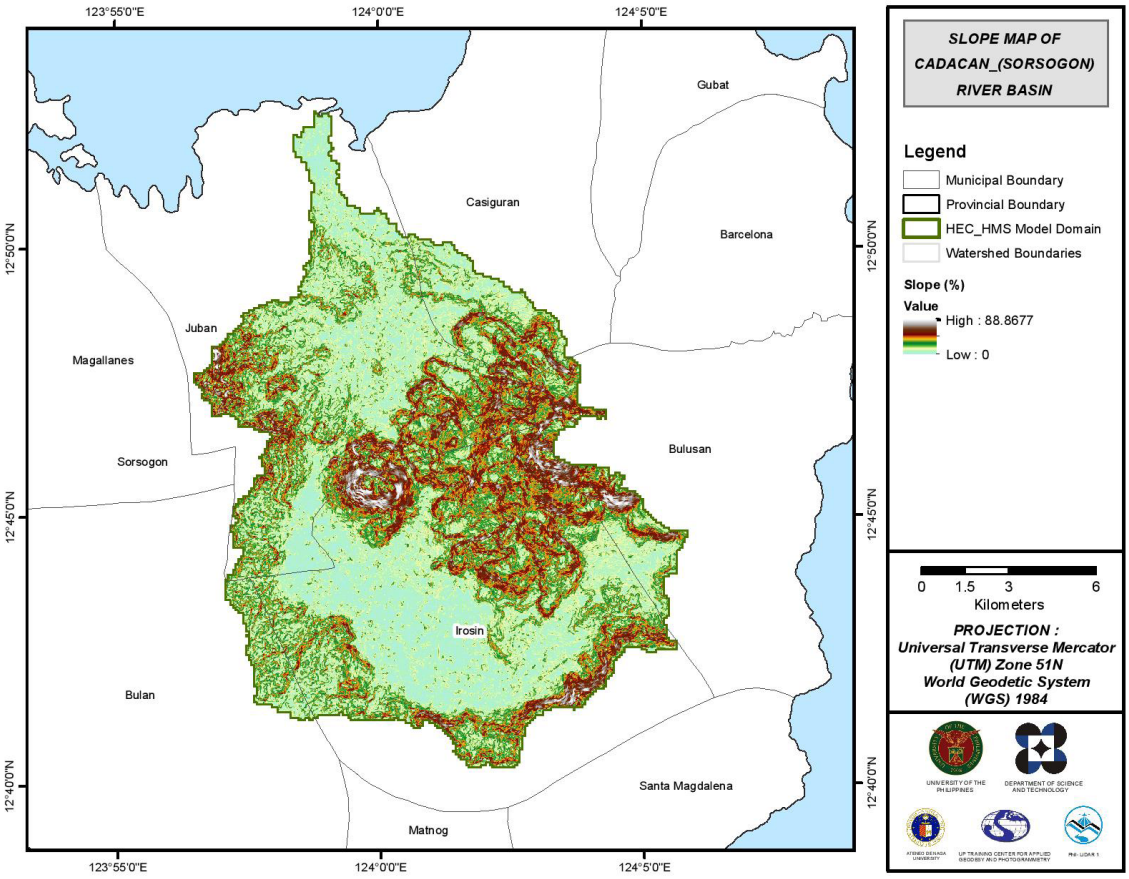


Figure 58. Slope map of Cadacan River Basin

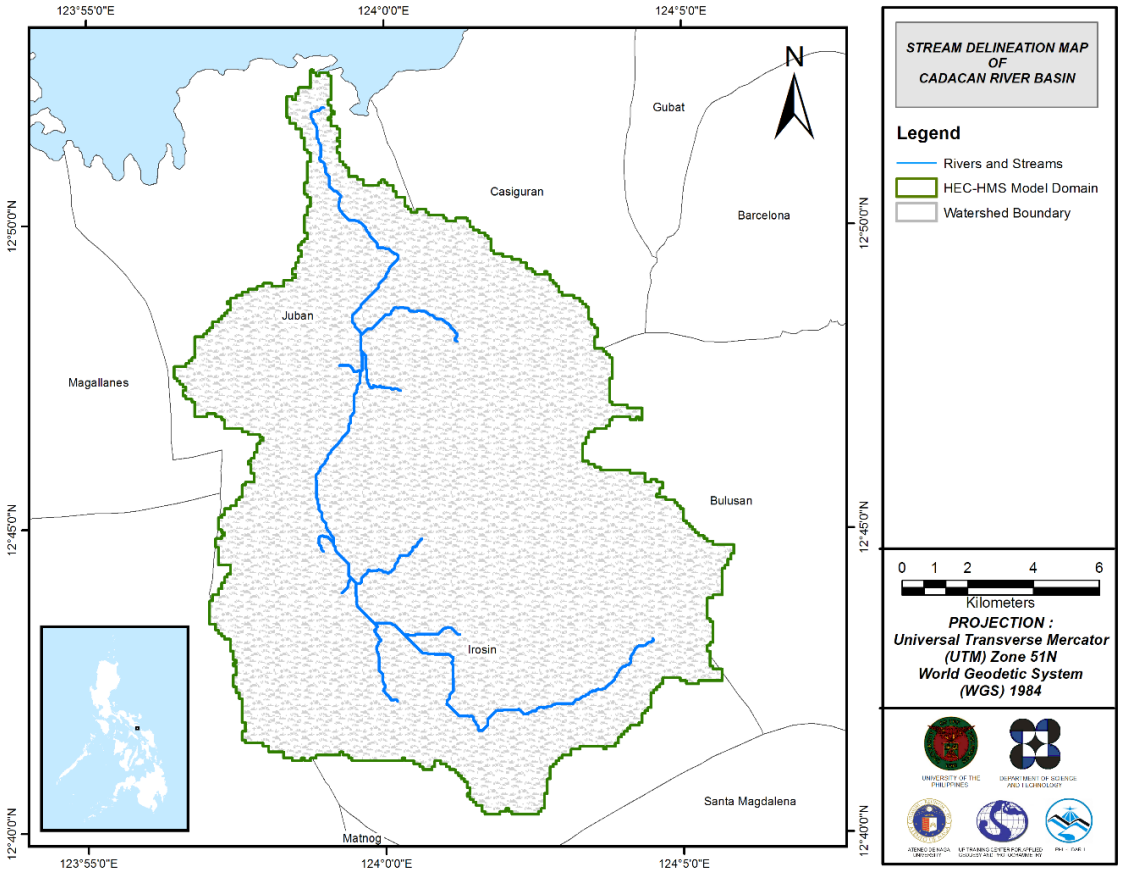


Figure 59. Stream delineation map of Cadacan River Basin

Using the SAR-based DEM, the Cadacan basin was delineated and further divided into subbasins. The model consists of 19 sub basins, 9 reaches, and 9 junctions, as shown in Figure 60. The main outlet is Taboc Bridge.

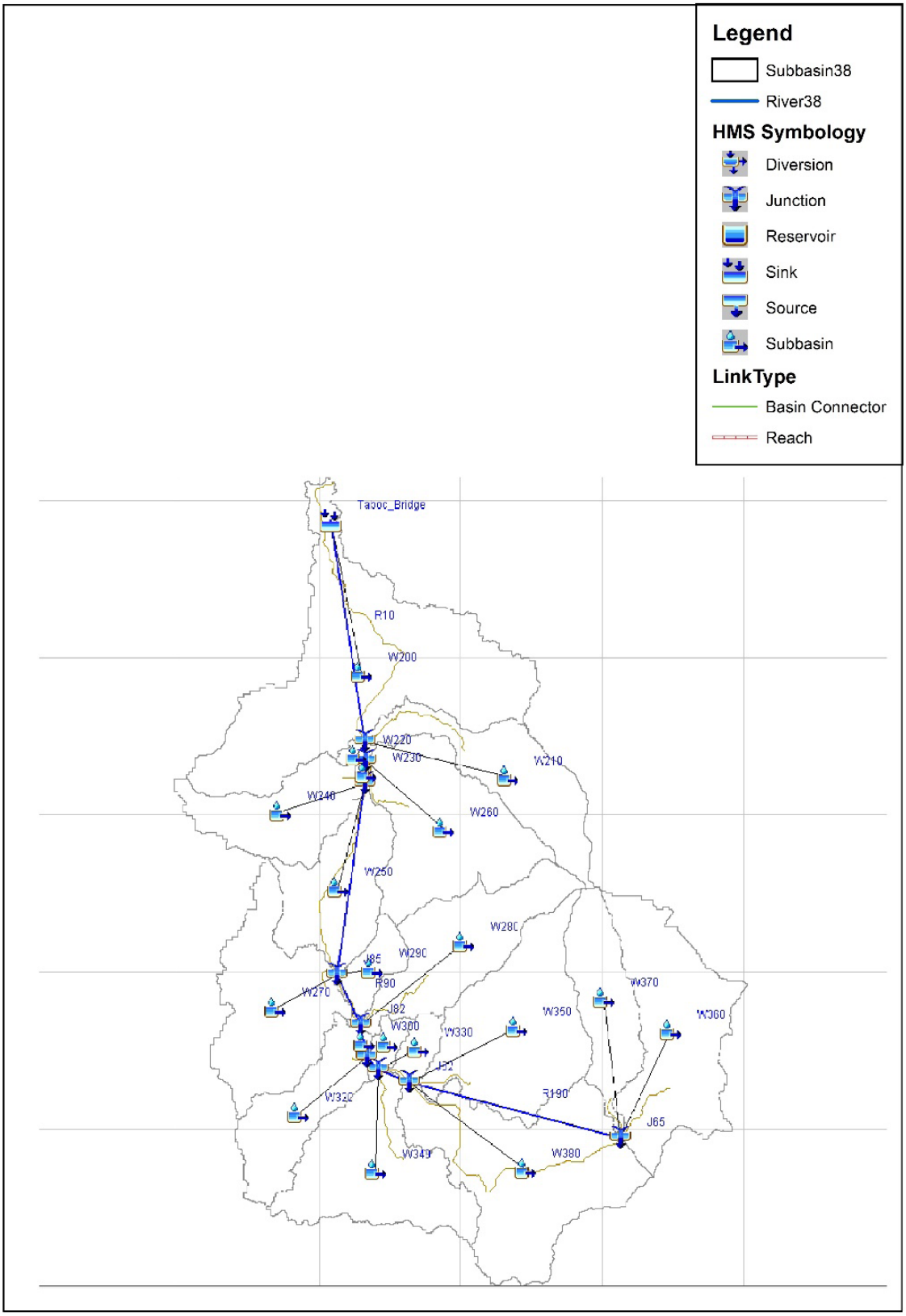


Figure 60. The Cadacan river basin model generated using HEC-HMS

5.4 Cross-Section Data

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

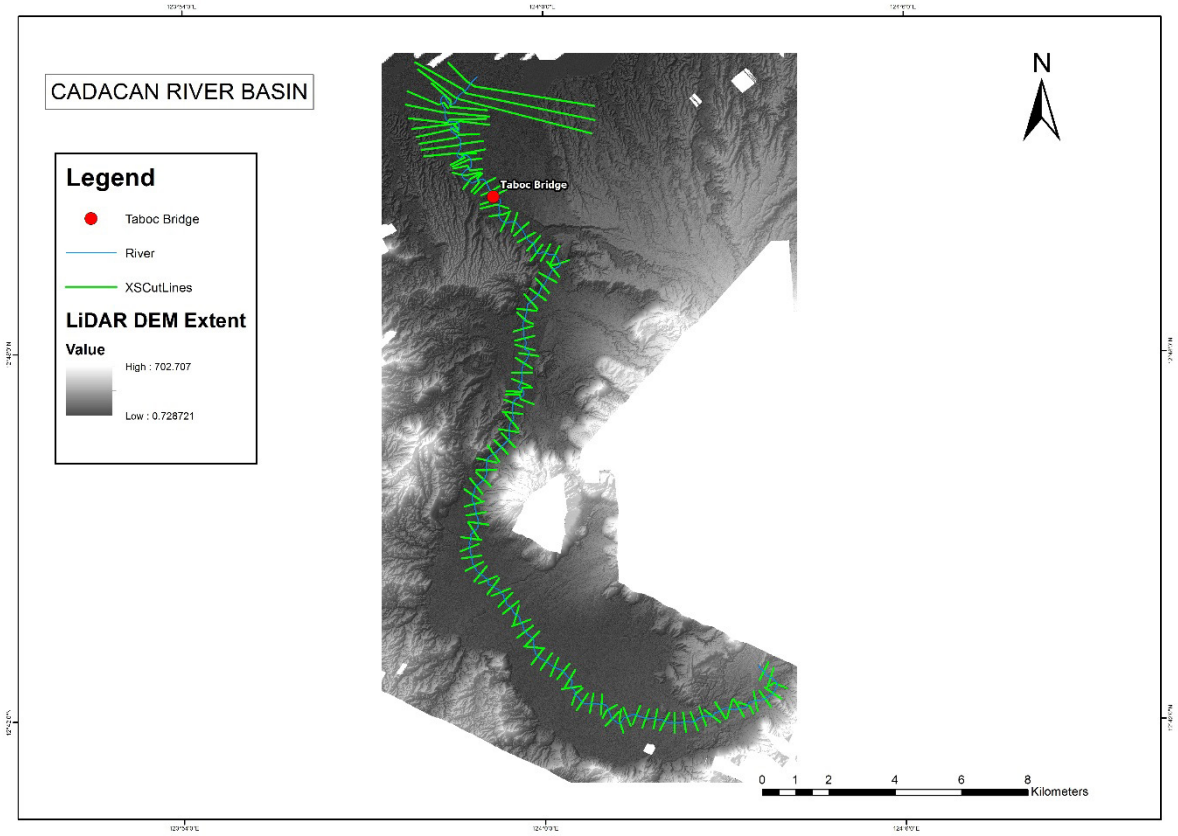


Figure 61. River cross-section of Cadacan River generated through Arcmap HEC GeoRAS tool

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

Figure 62. 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 28.47900 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 0m^2/s. The generated hazard maps for Cadacan are in Figures 17, 19, and 21.

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 42,322,900.00m^2. The generated flood depth maps for Cadacan are in Figures 18, 20, and 22.

There is a total of 33,727,138.84m^3 of water entering the model. Of this amount, 13,609,479.43m^3 is due to rainfall while 20,117,659.41m^3 is inflow from other areas outside the model. 4,726,368.00m^3 of this water is lost to infiltration and interception, while 8,709,829.02m^3 is stored by the flood plain. The rest, amounting up to 20,290,930.41m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Cadacan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

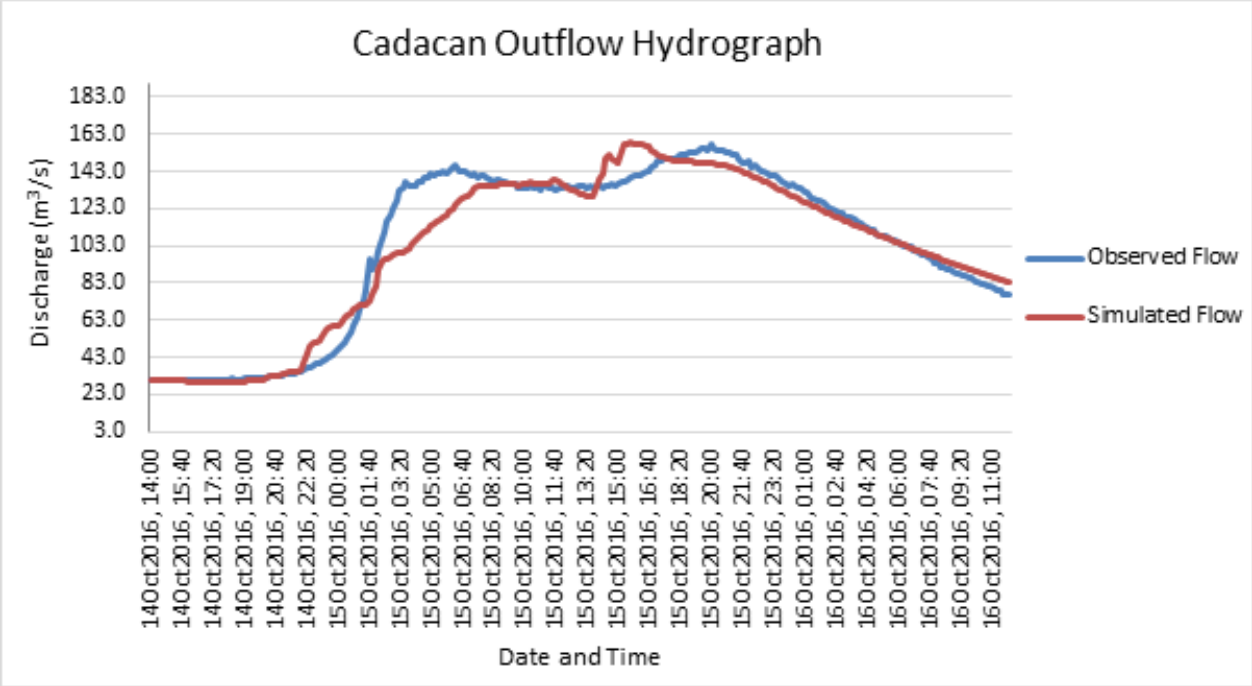


Figure 63. Outflow hydrograph of Cadacan River Basin produced by the HEC-HMS model compared with observed outflow

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 the Cadacan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.007 – 301
			Curve Number	35 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 36
			Storage Coefficient (hr)	0.07 – 22
	Baseflow	Recession	Recession Constant	0.00001 – 1
			Ratio to Peak	0.009 – 1
Reach	Routing	Muskingum-Cunge	Slope	0.0002 – 0.007
			Manning's n	0.0001 – 0.6

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.007mm to 301mm means that there is minimal to high 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 curve number is wider than the advisable for Philippine watersheds (70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Cadacan, the basin mostly consists of grassland and the soil consists of Bulusan sandy clay loam, Casiguran clay loam, and Irosin sandy loam.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 36 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. For Cadacan, it will take at least 20 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness in Cadacan watershed, which is determined to be built-up area that is concrete and float-finished (Brunner, 2010).

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

Accuracy Measure	Value
RMSE	10.35
r^2	0.95
NSE	0.94
PBIAS	1.82
RSR	0.24

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 10.35 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.95.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.94.

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 1.82.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.24.

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 64) shows the Cadacan outflow using the synthetic storm events using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods 235.1m^3/s in a 5-year return period to 605.2m^3/s in a 100-year return period.

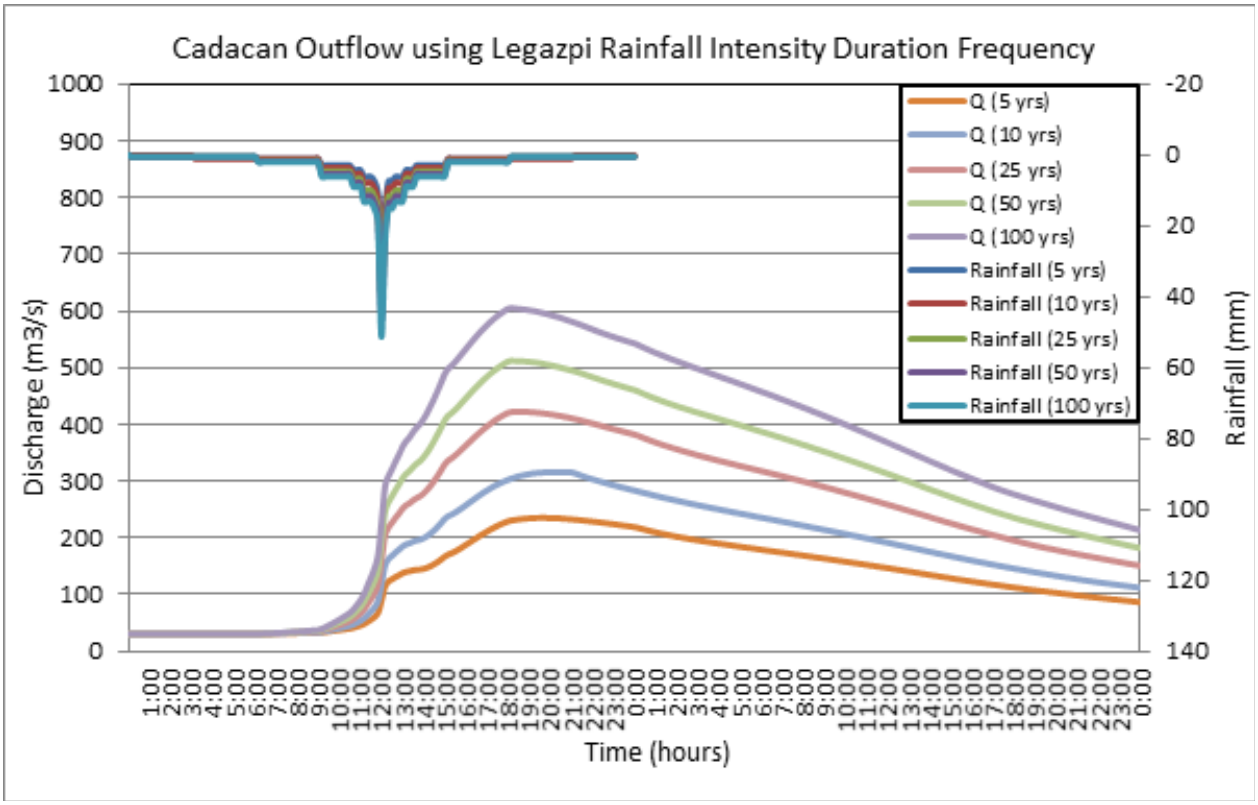


Figure 64. The outflow hydrograph at the Cadacan River Basin, generated using the simulated rain events for 24-hour period for Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Cadacan discharge using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. outlines the peak values of the Cadacan HEC-HMS Model outflow using the Legazpi RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m ^{3}/s)	Time to Peak
5-Year	260.50	29.1	235.1	7 hours, 30 minutes
10-Year	316.10	34.5	316	8 hours, 20 minutes
25-Year	386.40	41.3	422.1	6 hours, 40 minutes
50-Year	438.40	46.3	512.3	6 hours, 10 minutes
100-Year	490.30	51.3	605.2	hours, 10 minutes

5.8 River Analysis (RAS) Model Simulation

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

Figure 65. Sample output of Cadacan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 show the 5-, 25-, and 100-year rain return scenarios of the Cadacan flood plain. The flood plain, with an area of 238.82km^2, covers six (6) municipalities, namely Bulan, Bulusan, Casiguran, Irosin, Juban, and Magallanes. Table 5 shows the percentage of area affected by flooding per municipality.

Table 32. Municipalities affected in Cadacan floodplain

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Bulan	187.31	6.05	3.23
Bulusan	93.11	11.13	11.96
Casiguran	87.3	13.81	15.82
Irosin	130.17	99.55	76.47
Juban	127.78	107.99	84.51
Magallanes	117.6	0.002	0.001

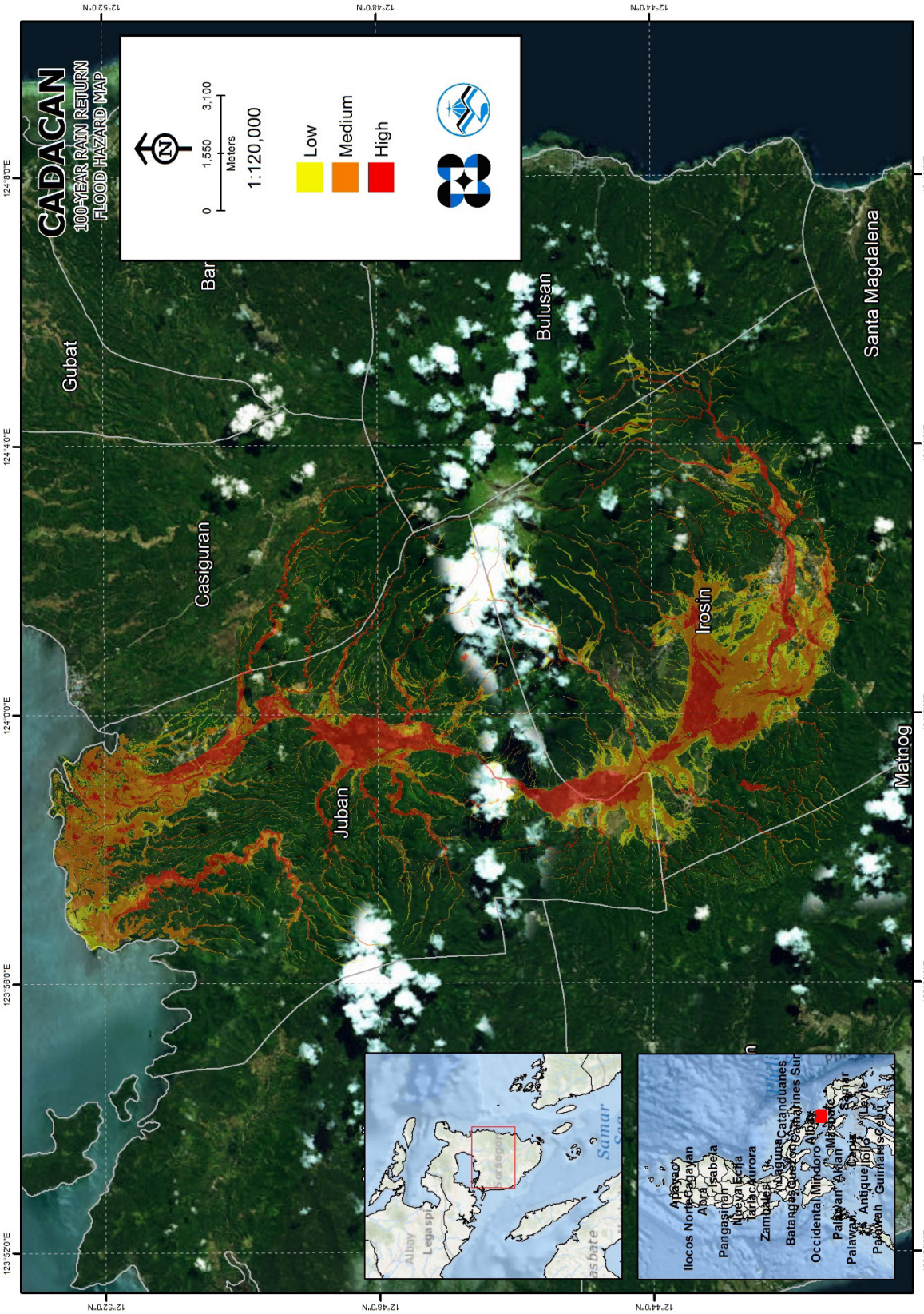


Figure 66. 100-year flood hazard map for the Cadacan flood plain overlaid on Google Earth imagery

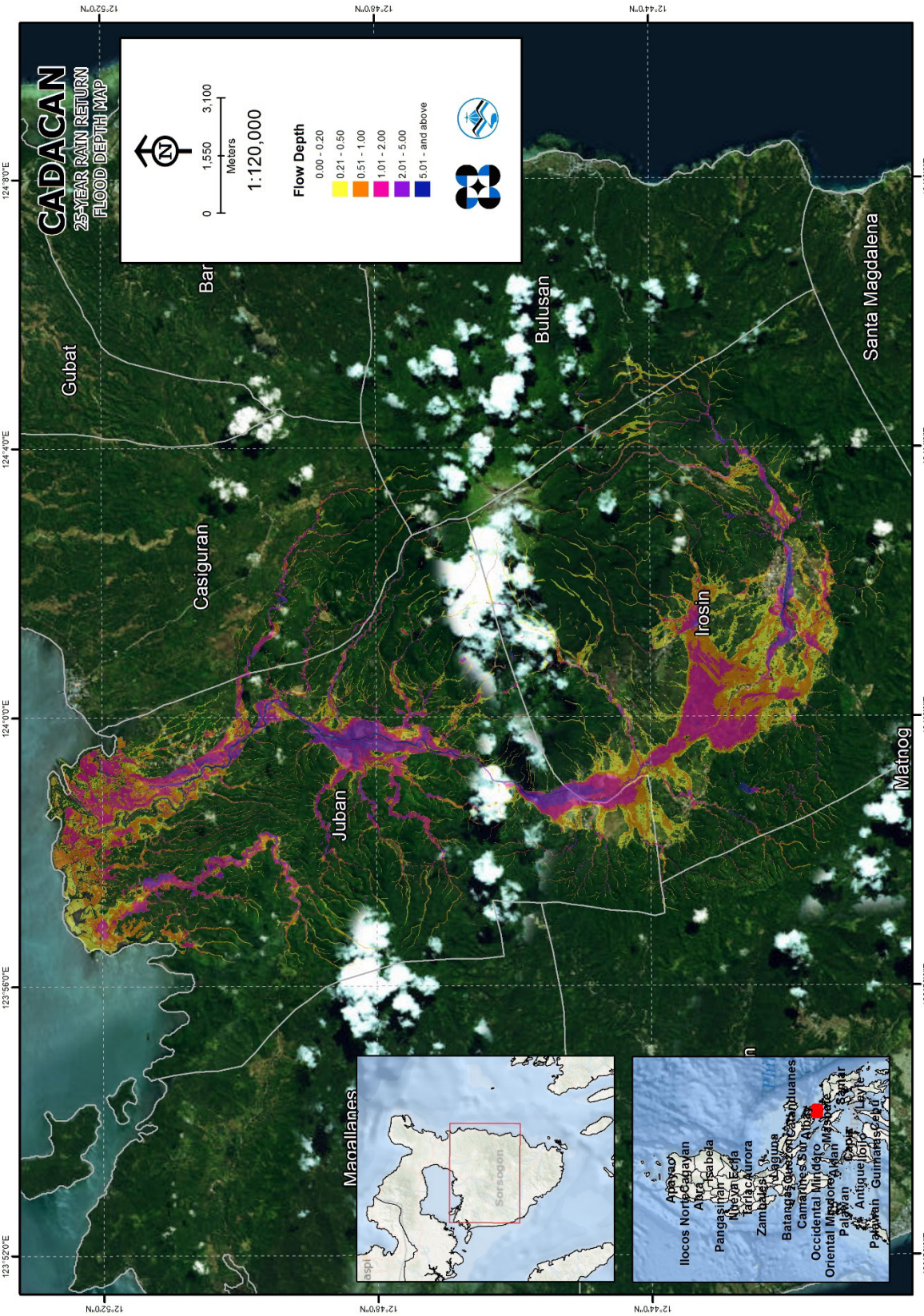


Figure 67. 100-year flow depth map for the Cadacan flood plain overlaid on Google Earth imagery

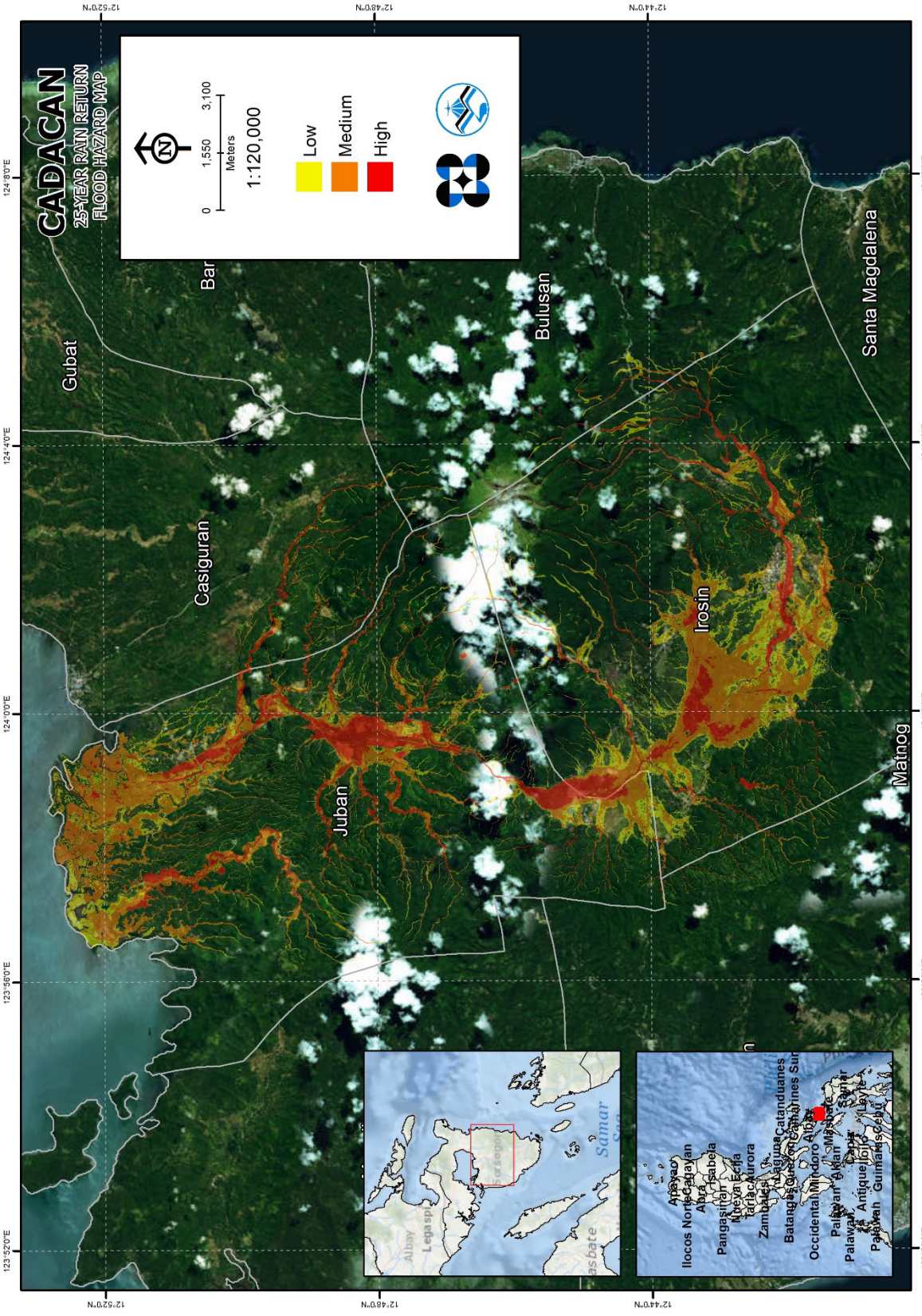


Figure 68. 25-year flood hazard map for the Cadacan flood plain overlaid on Google Earth imagery

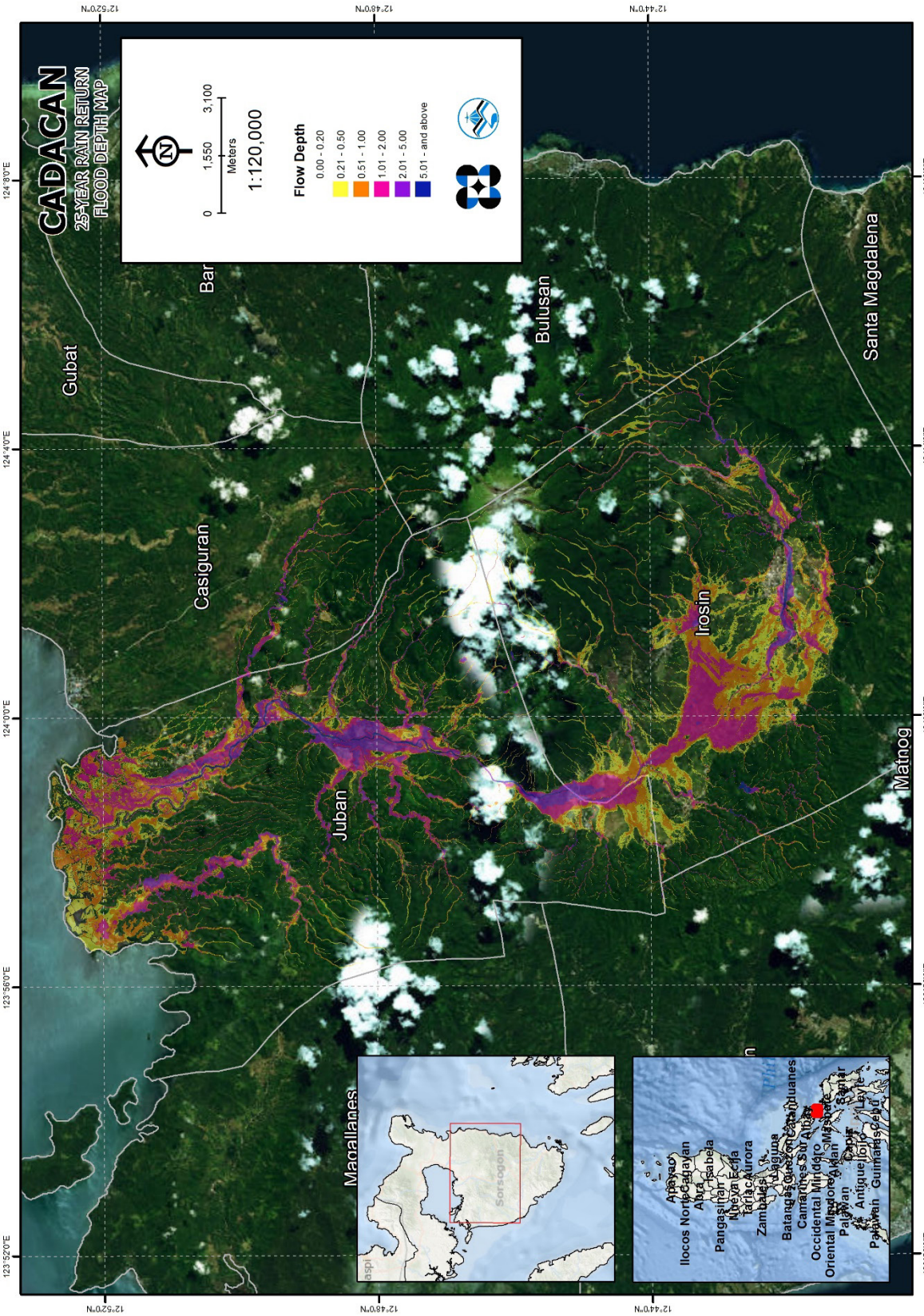


Figure 69. 25-year flow depth map for the Cadacan flood plain overlaid on Google Earth imagery

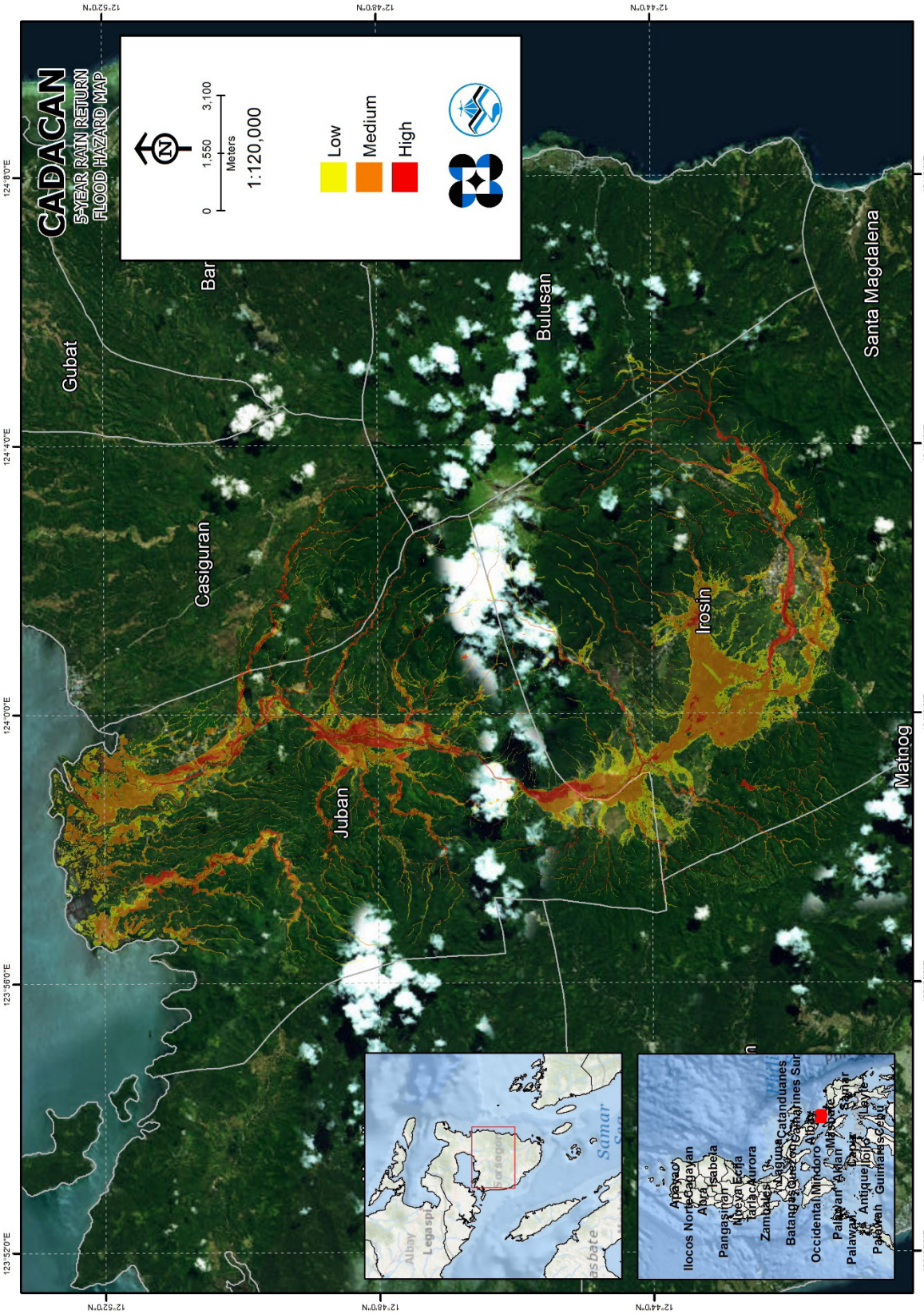


Figure 70. 5-year flood hazard map for the Cadacan flood plain overlaid on Google Earth imagery

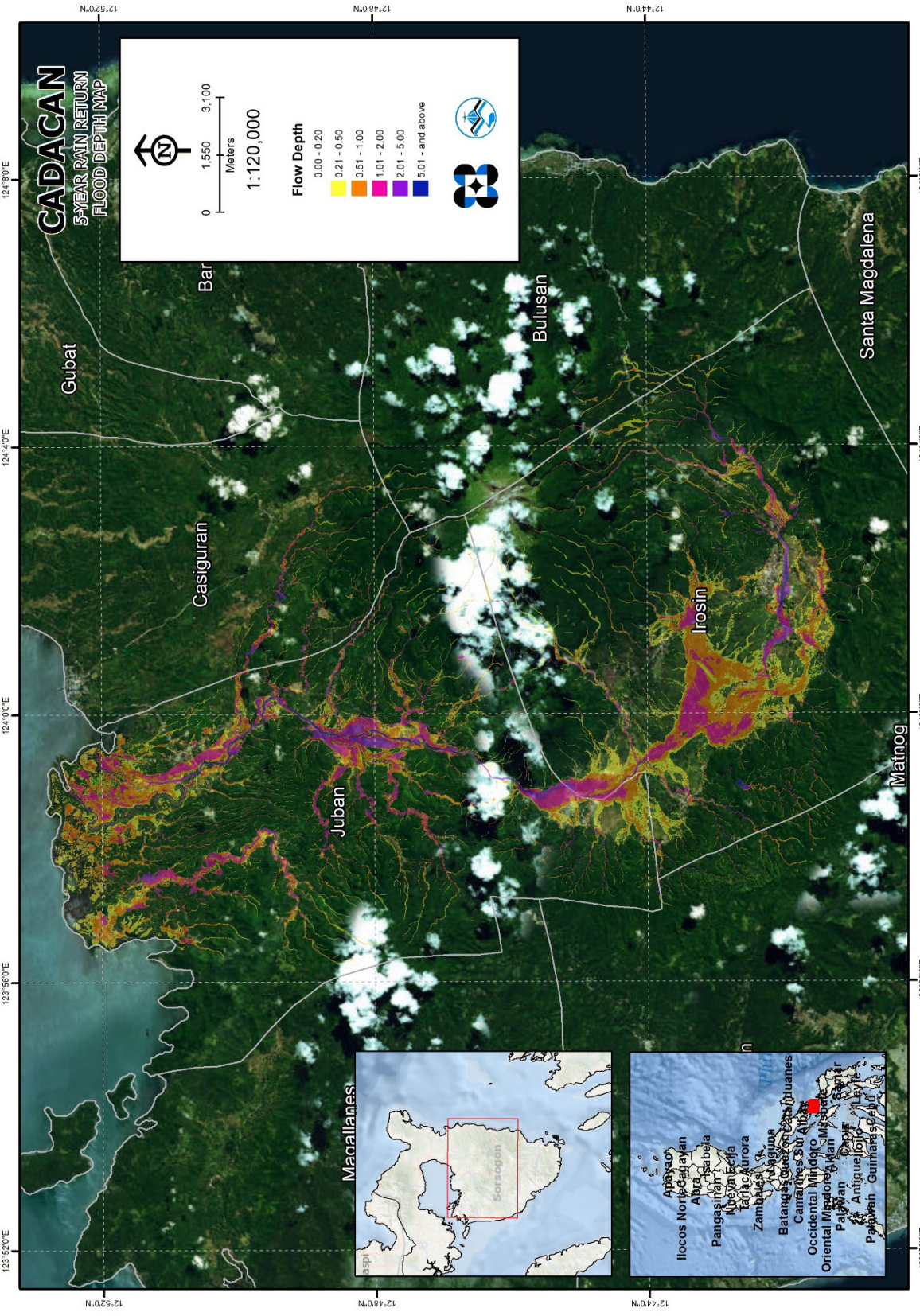


Figure 71. 5-year flow depth map for the Cadacan flood plain overlaid on Google Earth imagery

5.10 Inventory of Affected Areas

Listed below are the barangays affected by the Cadacan River Basin, grouped accordingly by municipality. For the said basin, six (6) municipalities consisting of 67 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 3.04% of the municipality of Bulan with an area of 187.31 sq. km. will experience flood levels of less than 0.20 meters. 0.1% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.06%, 0.02%, 0.008%, and 0.0002% 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 _ depicts the areas affected in Bulan in square kilometers by flood depth per barangay.

Table 33. Affected Areas in Bulan, Sorsogon during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bulan					
	Bical	Calpi	Daganas	Dolos	Montecalvario	Padre Diaz
0.03-0.20	2.18	0.00056	0.59	0.018	1.81	1.11
0.21-0.50	0.062	0	0.017	0	0.063	0.038
0.51-1.00	0.029	0	0.0088	0	0.05	0.018
1.01-2.00	0.018	0	0.00011	0	0.019	0.008
2.01-5.00	0.013	0	0	0	0.0027	0
>5.00	0.0003	0	0	0	0	0

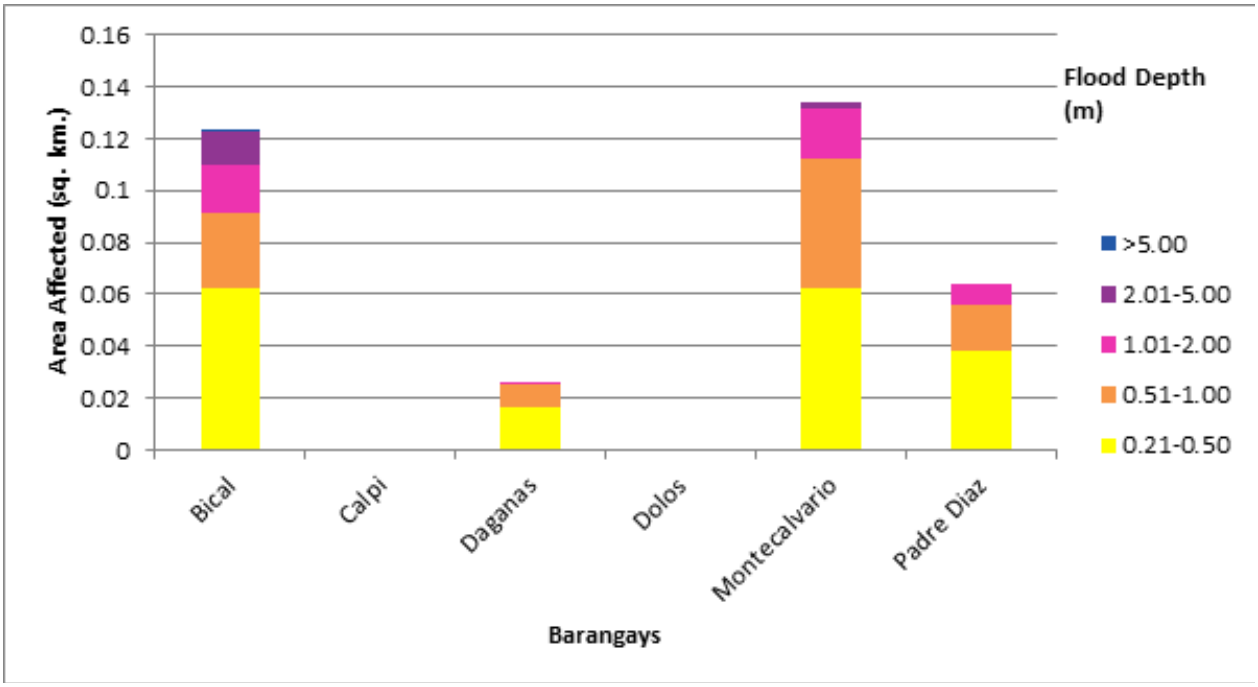


Figure 72. Affected Areas in Bulan, Sorsogon during the 5-Year Rainfall Return Period

For the municipality of Bulusan with an area of 93.11 sq. km., 11.4% will experience flood levels of less than 0.20 meters. 0.4% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.12%, 0.03%, 0.009%, and 0.005% 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 34 depicts the areas affected in Bulusan in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Bulusan, Sorsogon during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bulusan			
	Salvacion	San Isidro	San Roque	Santa Barbara
0.03-0.20	1.1	0.68	5.03	3.79
0.21-0.50	0.075	0.009	0.2	0.086
0.51-1.00	0.019	0.0011	0.064	0.029
1.01-2.00	0	0.0001	0.021	0.0084
2.01-5.00	0	0	0.0081	0.0006
>5.00	0	0	0.0042	0

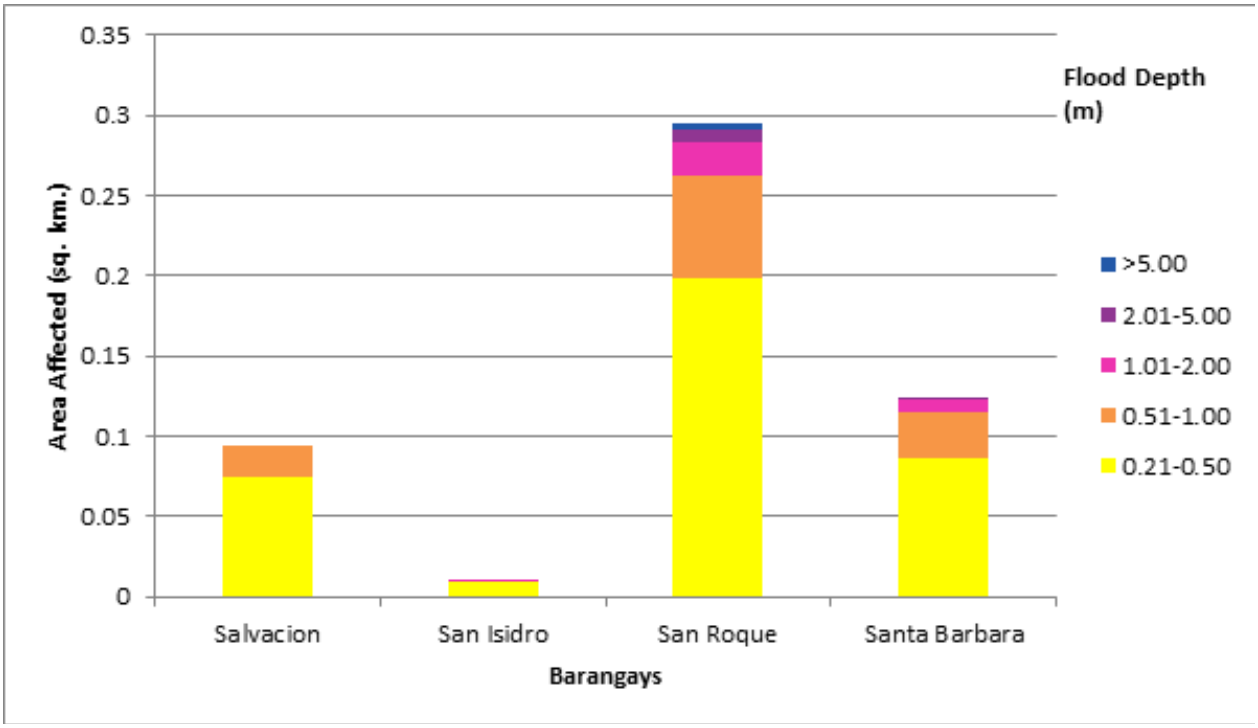


Figure 73. Affected Areas in Bulusan, Sorsogon during the 5-Year Rainfall Return Period

For the municipality of Casiguran with an area of 87.3 sq. km., 14.29% will experience flood levels of less than 0.20 meters. 0.52% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.43%, 0.37%, 0.2%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table _ depicts the areas affected in Casiguran in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Casiguran, Sorsogon during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Casiguran				
	Escuala	Inlagadian	Mabini	San Juan	Tigbao
0.03-0.20	0.3	5.98	5.27	0.21	0.72
0.21-0.50	0.015	0.18	0.22	0.0089	0.028
0.51-1.00	0.025	0.14	0.17	0.0081	0.024
1.01-2.00	0.03	0.094	0.19	0.0059	0.01
2.01-5.00	0.0089	0.028	0.13	0.0018	0.0012
>5.00	0	0.0011	0.0087	0	0

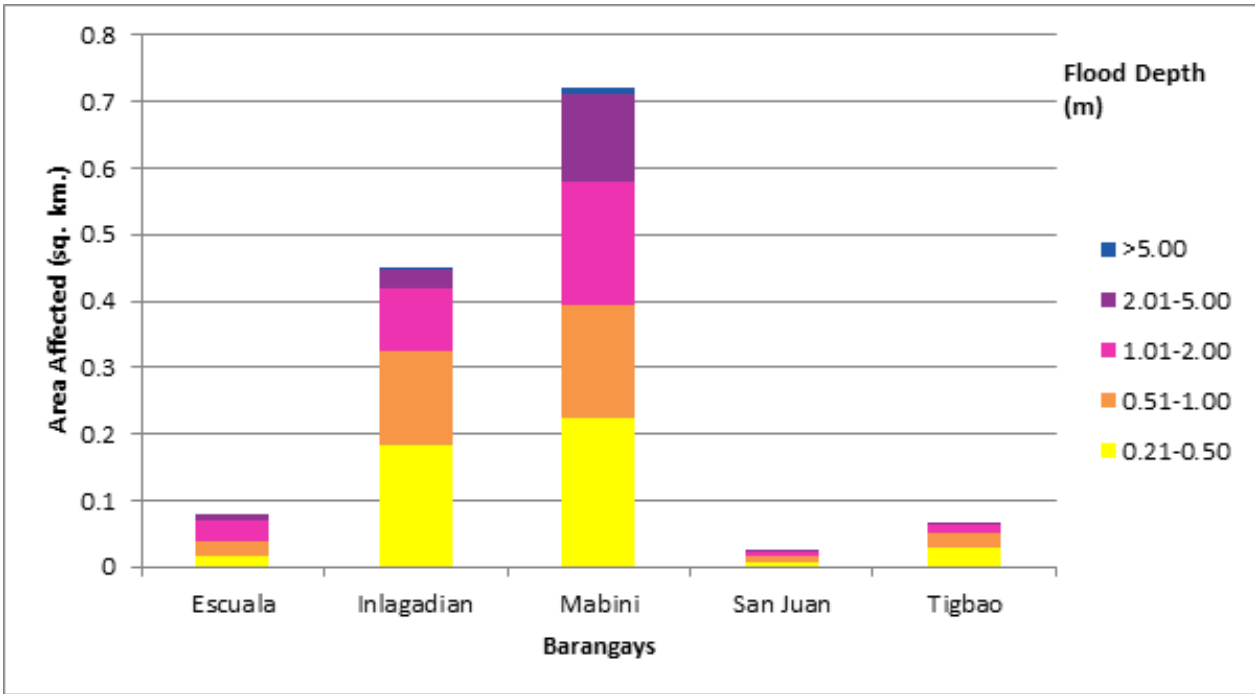


Figure 74. Affected Areas in Casiguran, Sorsogon during the 5-Year Rainfall Return Period

For the municipality of Irosin with an area of 130.17 sq. km., 61.35% will experience flood levels of less than 0.20 meters. 6.23% of the area will experience flood levels of 0.21 to 0.50 meters, while 5.09%, 2.99%, 0.68%, and 0.13% 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 _ depicts the areas affected in Irosin in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Irosin, Sorsogon during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Irosin								
	Bacolod	Bagsangan	Batang	Bolos	Buenavista	Bulawan	Carriedo	Cawayan	Cogon
0.03-0.20	0.16	6.1	2.82	1.6	0.76	1.63	3.74	5.26	17.84
0.21-0.50	0.021	0.48	0.58	0.32	0.27	0.31	0.29	0.21	0.76
0.51-1.00	0.0033	0.39	0.73	0.33	0.24	0.092	0.23	0.061	0.2
1.01-2.00	0.0044	0.16	0.19	0.42	0.17	0.022	0.11	0.028	0.086
2.01-5.00	0.027	0.0034	0.019	0.054	0.1	0.0073	0.054	0.016	0.037
>5.00	0.017	0	0.0012	0.00059	0.057	0.0002	0.013	0.0005	0.0045
Affected area (sq. km.) by flood depth (in m.)	**Gabao**	**Gulang-Gulang**	**Gumapia**	**Liang**	**Macawayan**	**Mapaso**	**Monbon**	**Patag**	**Salvacion**
0.03-0.20	1.61	3.57	2.8	0.068	1.36	7.19	3.57	4.28	2.34
0.21-0.50	0.28	0.63	0.26	0.0002	0.56	0.39	0.55	0.31	0.37
0.51-1.00	0.14	0.38	0.54	0.0001	0.67	0.21	0.9	0.2	0.18
1.01-2.00	0.083	0.24	0.38	0.0001	0.17	0.16	0.44	0.1	0.055
2.01-5.00	0.032	0.08	0.028	0	0.096	0.062	0.0037	0.039	0.00068
>5.00	0	0.0006	0.013	0	0.0053	0.013	0	0.0005	0
Affected area (sq. km.) by flood depth (in m.)	**San Agustin**	**San Isidro**	**San Juan**	**San Julian**	**San Pedro**	**Santo Domingo**	**Tabon-Tabon**	**Tinampo**	**Tongdol**
0.03-0.20	0.52	2.62	0.52	0.4	1.24	1.79	1.35	2	2.71
0.21-0.50	0.021	0.56	0.027	0.11	0.28	0.13	0.11	0.099	0.21
0.51-1.00	0.016	0.35	0.022	0.038	0.18	0.068	0.15	0.16	0.16
1.01-2.00	0.0084	0.066	0.0069	0.0071	0.088	0.066	0.14	0.59	0.12
2.01-5.00	0.012	0.038	0.0003	0	0.056	0.05	0.041	0.0031	0.026
>5.00	0.0022	0.0005	0	0	0.0081	0.0068	0.0033	0	0.017

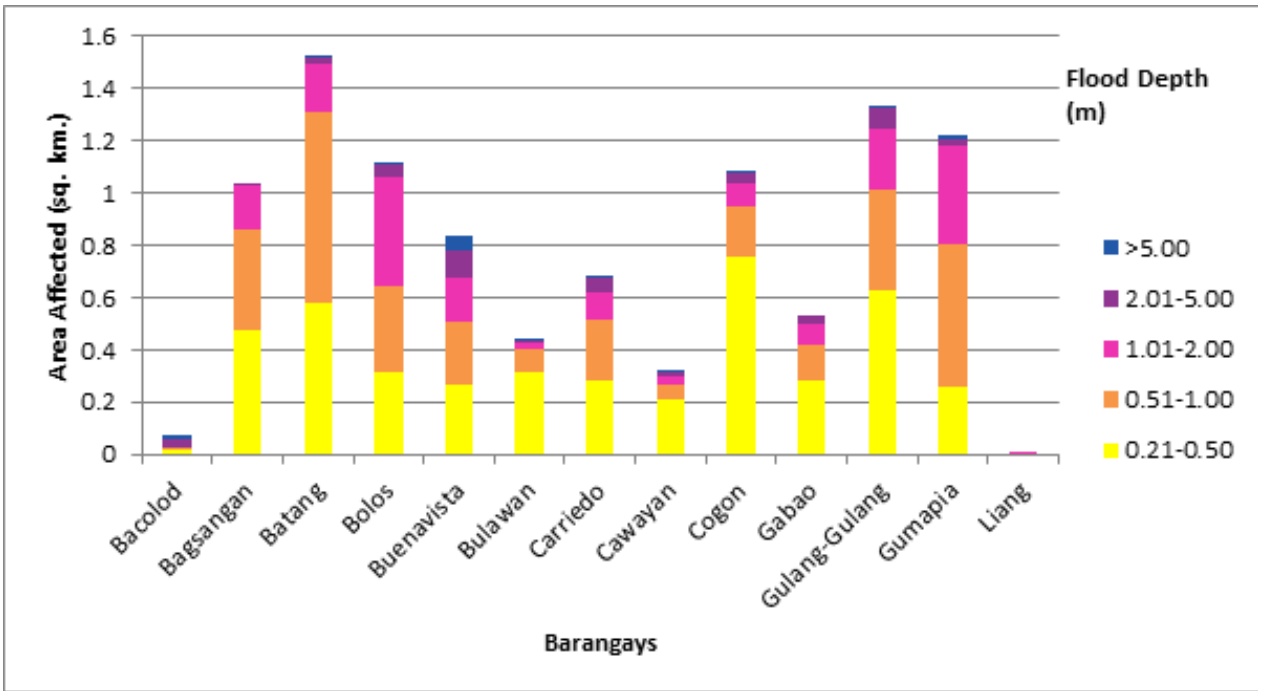


Figure 75. Affected Areas in Irosin, Sorsogon during the 5-Year Rainfall Return Period

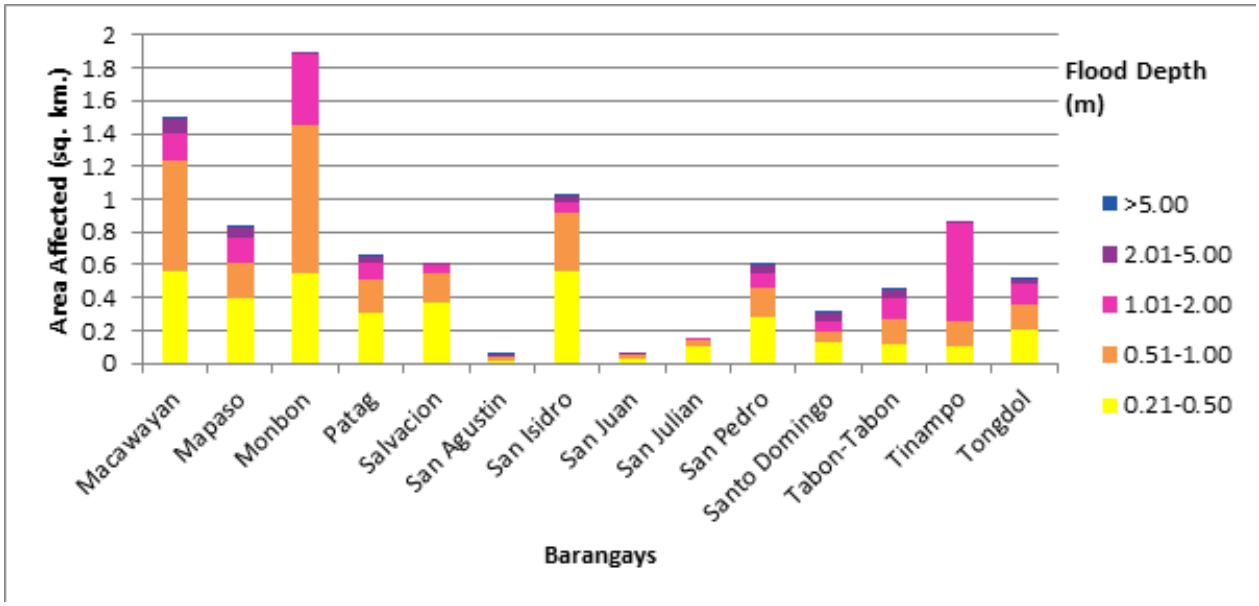


Figure 76. Affected Areas in Irosin, Sorsogon during the 5-Year Rainfall Return Period

For the municipality of Juban with an area of 127.78 sq. km., 65.75% will experience flood levels of less than 0.20 meters. 6.63% of the area will experience flood levels of 0.21 to 0.50 meters, while 6.19%, 4.26%, 1.48%, and 0.2% 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 37 depicts the areas affected in Juban in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Juban, Sorsogon during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Irosin											
	Anog	Aroroy	Bacolod	Binanuahan	Biriran	Buraburan	Calateo	Calmayon	Carohayon	Catanagan	Catanusan	Cogon
0.03-0.20	9.09	1.61	0.47	3.33	4.93	5.8	0.99	7.49	3.51	2.2	1.77	2.87
0.21-0.50	0.32	0.24	0.15	0.23	1.23	0.43	0.11	0.37	0.49	0.72	0.23	0.35
0.51-1.00	0.18	0.16	0.18	0.24	1.09	0.22	0.17	0.38	0.38	0.55	0.33	0.4
1.01-2.00	0.15	0.16	0.12	0.21	0.55	0.3	0.2	0.3	0.13	0.12	0.33	0.35
2.01-5.00	0.077	0.1	0.065	0.097	0.12	0.19	0.047	0.067	0.014	0.051	0.29	0.088
>5.00	0.0021	0.056	0.011	0.0016	0	0.035	0	0	0	0	0.0048	0.0099
Affected area (sq. km.) by flood depth (in m.)	**Embarcadero**	**Guruyan**	**Lajong**	**Maalo**	**North Poblacion**	**Puting Sapa**	**Rangas**	**Sipaya**	**South Poblacion**	**Taboc**	**Tinago**	**Tughan**
0.03-0.20	1.17	10.54	7.4	7.09	0.31	3.84	1.73	2.5	0.35	3.37	1	0.65
0.21-0.50	0.66	1.26	0.34	0.25	0.13	0.13	0.19	0.2	0.054	0.22	0.04	0.15
0.51-1.00	1.18	0.84	0.3	0.13	0.26	0.064	0.26	0.19	0.043	0.23	0.02	0.1
1.01-2.00	0.68	0.58	0.17	0.093	0.18	0.045	0.3	0.25	0.091	0.12	0.0046	0.005
2.01-5.00	0.044	0.11	0.05	0.028	0.038	0.027	0.18	0.13	0.0078	0.08	0	0
>5.00	0	0.0088	0.0004	0.0001	0.0008	0.0002	0.028	0.037	0.0075	0.052	0	0

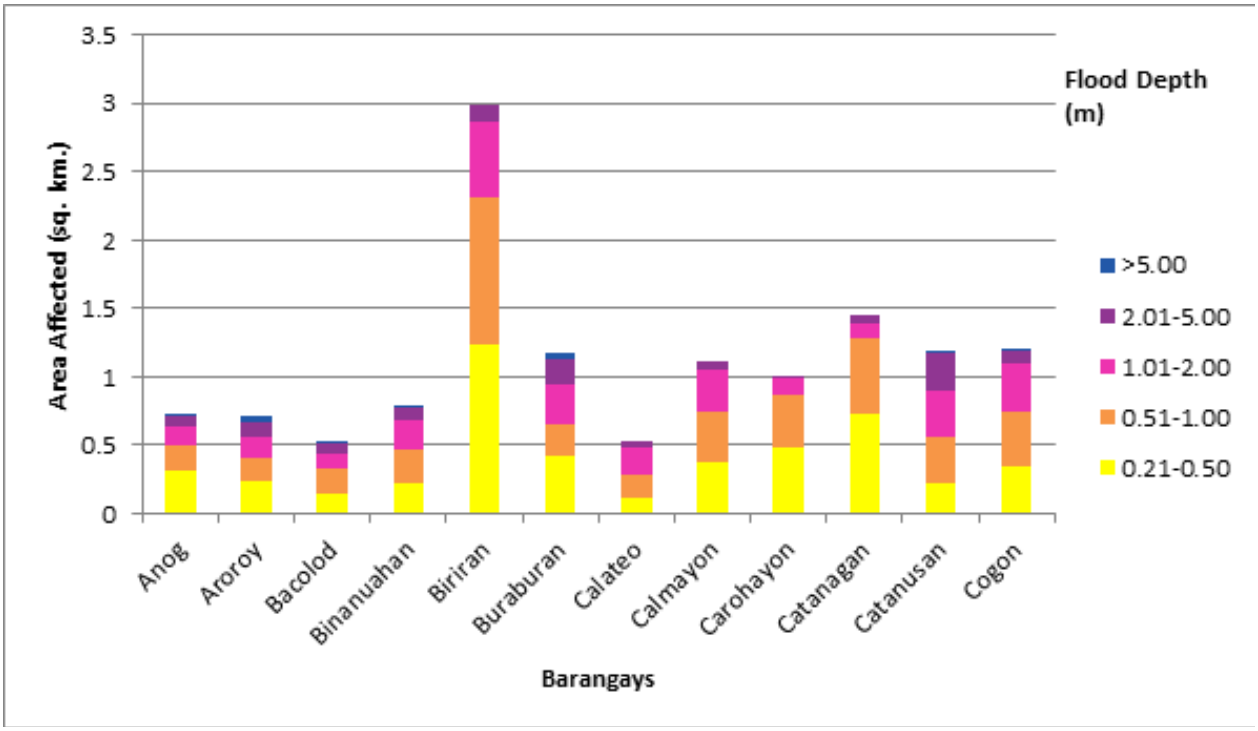


Figure 77. Affected Areas in Juban, Sorsogon during the 5-Year Rainfall Return Period

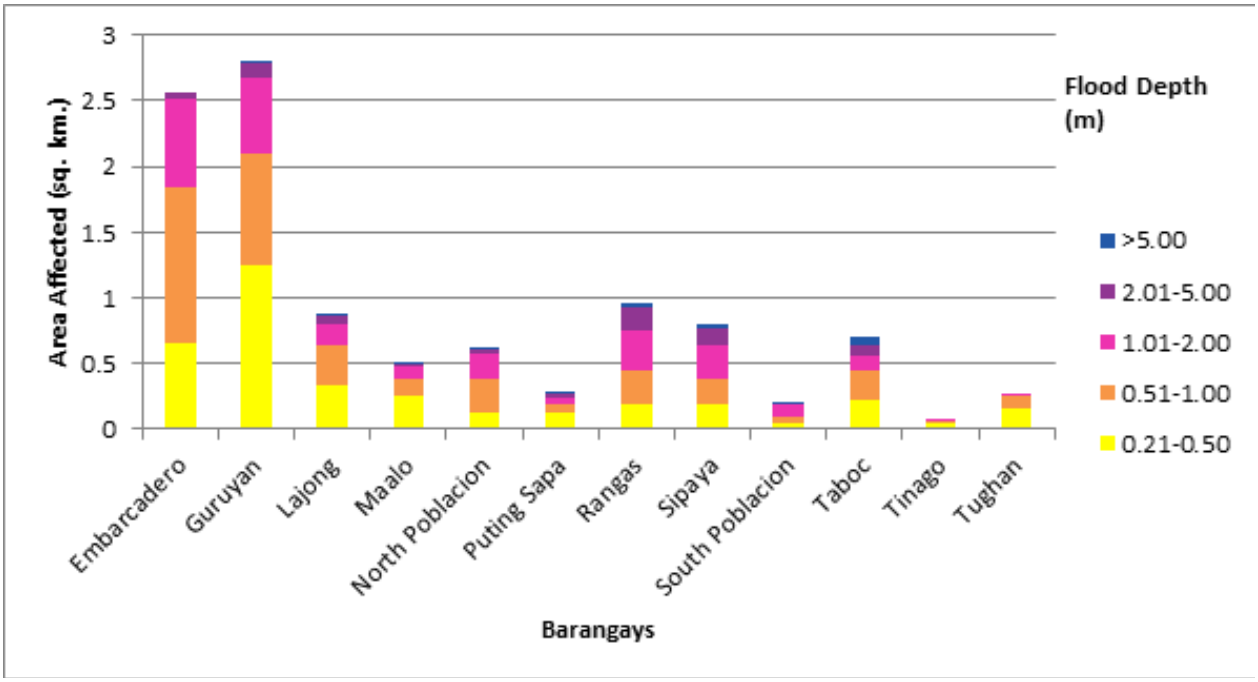


Figure 78. Affected Areas in Juban, Sorsogon during the 5-Year Rainfall Return Period

For the municipality of Magallanes with an area of 117.6 sq. km., 0.001% will experience flood levels of less than 0.20 meters. Table 38 depicts the areas affected in Magallanes in square kilometers by flood depth per barangay.

For the 25-year rainfall return period, 3.01% of the municipality of Bulan with an area of 187.31 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 0.07%, 0.03%, 0.01%, and 0.0003% 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 Bulan in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Bulan, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bulan					
	Bical	Calpi	Daganas	Dolos	Montecalvario	Padre Diaz
0.03-0.20	2.16	0.00056	0.59	0.018	1.79	1.09
0.21-0.50	0.067	0	0.019	0	0.065	0.047
0.51-1.00	0.036	0	0.012	0	0.055	0.021
1.01-2.00	0.023	0	0.00017	0	0.028	0.011
2.01-5.00	0.015	0	0	0	0.0035	0.0001
>5.00	0.0006	0	0	0	0	0

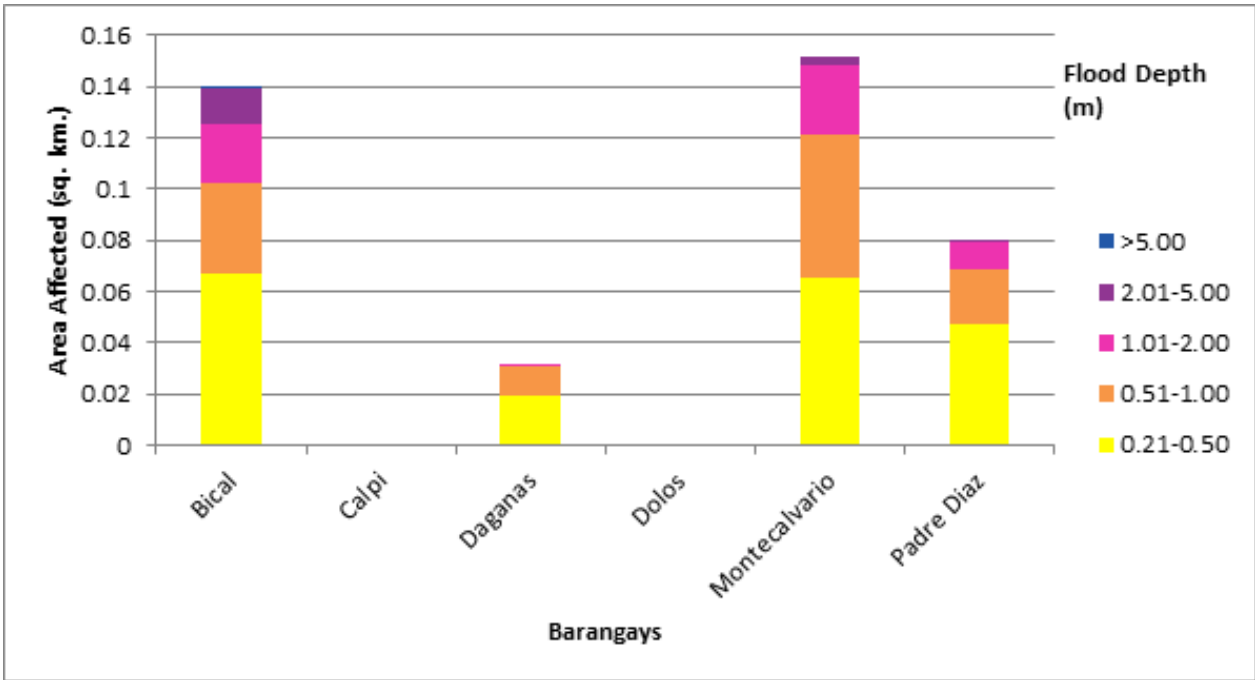


Figure 79. Affected Areas in Bulan, Sorsogon during the 25-Year Rainfall Return Period

For the municipality of Bulusan with an area of 93.11 sq. km., 11.21% will experience flood levels of less than 0.20 meters. 0.51% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.16%, 0.06%, 0.02%, and 0.007% 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 39 depicts the areas affected in Bulusan in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Bulusan, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bulusan			
	Salvacion	San Isidro	San Roque	Santa Barbara
0.03-0.20	1.07	0.68	4.94	3.75
0.21-0.50	0.091	0.013	0.26	0.11
0.51-1.00	0.032	0.0014	0.077	0.036
1.01-2.00	0.0016	0.0001	0.038	0.014
2.01-5.00	0	0	0.013	0.0015
>5.00	0	0	0.0066	0

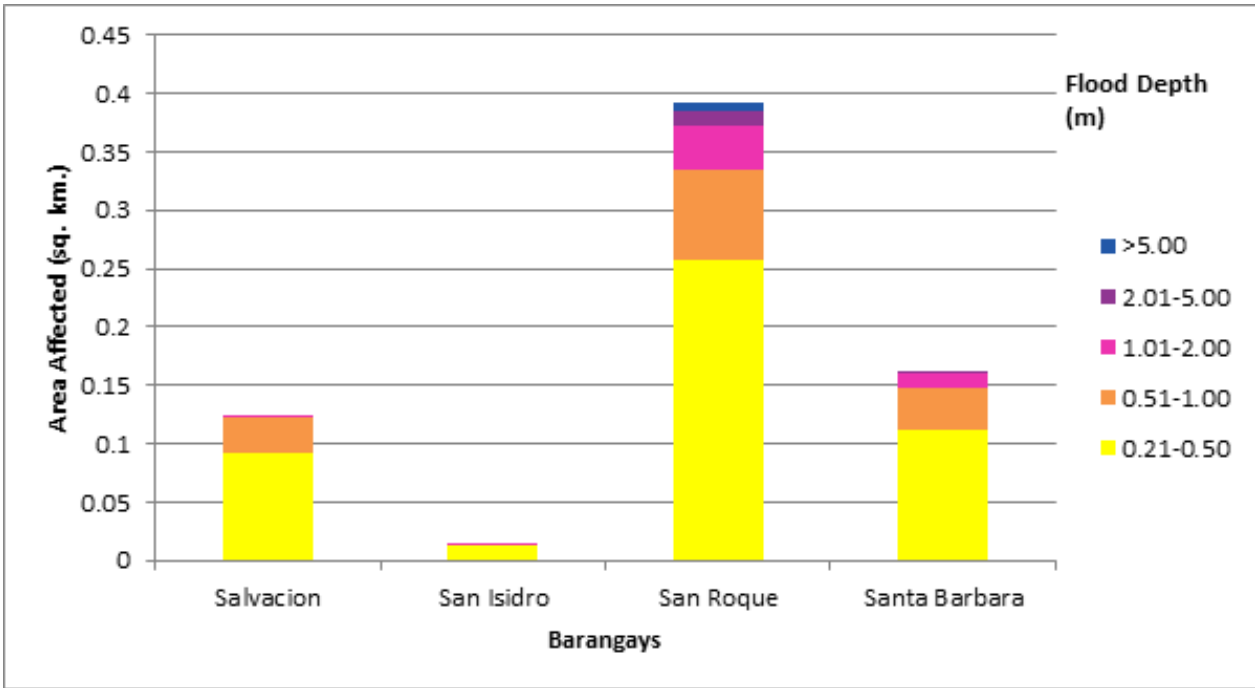


Figure 80. Affected Areas in Bulusan, Sorsogon during the 25-Year Rainfall Return Period

For the municipality of Casiguran with an area of 87.3 sq. km., 14.04% will experience flood levels of less than 0.20 meters. 0.56% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.41%, 0.48%, 0.3%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 40 depicts the areas affected in Casiguran in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Casiguran, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Casiguran				
	Escuala	Inlagadian	Mabini	San Juan	Tigbao
0.03-0.20	0.29	5.91	5.15	0.21	0.71
0.21-0.50	0.018	0.2	0.24	0.0095	0.027
0.51-1.00	0.016	0.14	0.17	0.0083	0.026
1.01-2.00	0.037	0.13	0.23	0.0075	0.017
2.01-5.00	0.018	0.049	0.19	0.0024	0.0022
>5.00	0	0.0016	0.014	0	0

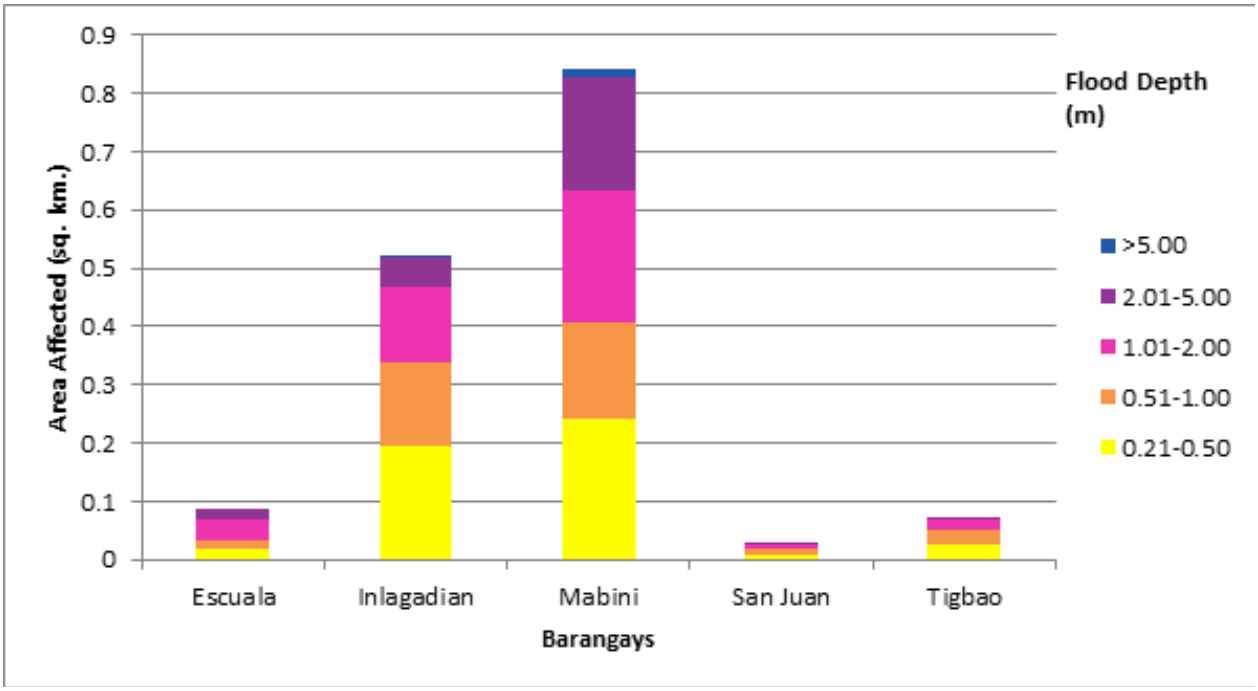


Figure 81. Affected Areas in Casiguran, Sorsogon during the 25-Year Rainfall Return Period

For the municipality of Irosin with an area of 130.17 sq. km., 58.03% will experience flood levels of less than 0.20 meters. 6.62% of the area will experience flood levels of 0.21 to 0.50 meters, while 5.63%, 4.84%, 1.16%, and 0.2% 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 41 depicts the areas affected in Irosin in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Irosin, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Irosin								
	Bacolod	Bagsangan	Batang	Bolos	Buenavista	Bulawan	Carriedo	Cawayan	Cogon
0.03-0.20	0.14	5.96	2.7	1.5	0.46	1.53	3.6	5.18	17.54
0.21-0.50	0.022	0.48	0.44	0.26	0.29	0.35	0.31	0.25	0.96
0.51-1.00	0.0065	0.43	0.77	0.15	0.41	0.14	0.26	0.078	0.25
1.01-2.00	0.017	0.26	0.4	0.55	0.22	0.029	0.16	0.035	0.12
2.01-5.00	0.02	0.0092	0.03	0.27	0.15	0.01	0.063	0.022	0.048
>5.00	0.031	0	0.0022	0.0023	0.067	0.0002	0.03	0.0007	0.0089
Affected area (sq. km.) by flood depth (in m.)	**Gabao**	**Gulang-Gulang**	**Gumapia**	**Liang**	**Macawayan**	**Mapaso**	**Monbon**	**Patag**	**Salvacion**
0.03-0.20	1.49	3.3	2.67	0.068	0.51	7	3.41	4.18	2.22
0.21-0.50	0.27	0.66	0.19	0.00025	0.78	0.47	0.39	0.31	0.37
0.51-1.00	0.21	0.5	0.32	0.0001	1.04	0.23	0.68	0.25	0.27
1.01-2.00	0.13	0.35	0.78	0.0001	0.38	0.18	0.97	0.12	0.079
2.01-5.00	0.041	0.1	0.039	0	0.14	0.13	0.0067	0.073	0.0027
>5.00	0	0.001	0.027	0	0.01	0.017	0	0.0014	0
Affected area (sq. km.) by flood depth (in m.)	**San Agustin**	**San Isidro**	**San Juan**	**San Julian**	**San Pedro**	**Santo Domingo**	**Tabon-Tabon**	**Tinampo**	**Tongdol**
0.03-0.20	0.5	2.25	0.51	0.35	0.95	1.7	1.28	1.93	2.59
0.21-0.50	0.021	0.62	0.03	0.13	0.43	0.16	0.1	0.12	0.21
0.51-1.00	0.021	0.52	0.025	0.054	0.24	0.081	0.13	0.079	0.19
1.01-2.00	0.014	0.2	0.0099	0.011	0.13	0.073	0.19	0.71	0.19
2.01-5.00	0.013	0.044	0.0006	0	0.08	0.08	0.088	0.025	0.03
>5.00	0.0041	0.0019	0	0	0.02	0.0094	0.0045	0	0.025

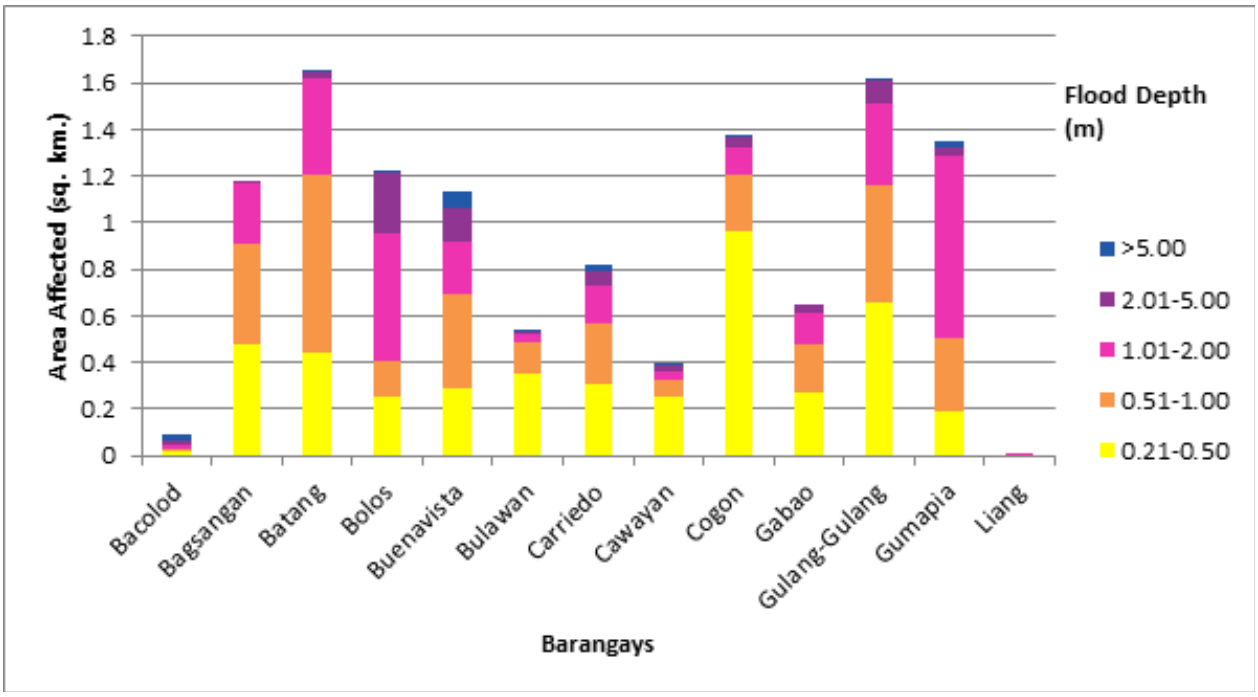


Figure 82. Affected Areas in Irosin, Sorsogon during the 25-Year Rainfall Return Period

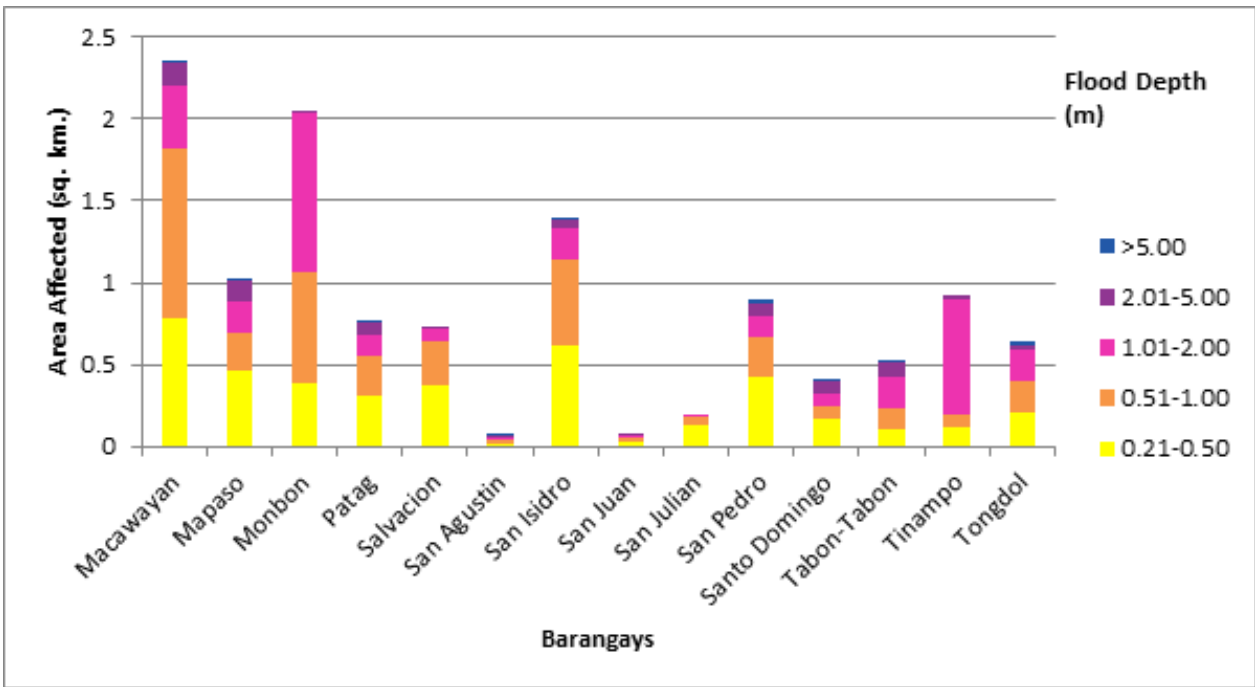


Figure 83. Affected Areas in Irosin, Sorsogon during the 25-Year Rainfall Return Period

For the municipality of Juban with an area of 127.78 sq. km., 61.8% will experience flood levels of less than 0.20 meters. 6.24% of the area will experience flood levels of 0.21 to 0.50 meters, while 6.83%, 6.42%, 2.92%, and 0.3% 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 Juban in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Juban, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Irosin											
	Anog	Aroroy	Bacolod	Binanuahan	Biriran	Buraburan	Calateo	Calmayon	Carohayon	Catanagan	Catanusan	Cogon
0.03-0.20	8.93	1.42	0.37	3.15	3.77	5.59	0.94	7.36	3.34	1.54	1.62	2.62
0.21-0.50	0.39	0.24	0.14	0.21	1.29	0.48	0.089	0.35	0.38	0.73	0.18	0.31
0.51-1.00	0.19	0.21	0.17	0.31	1.6	0.26	0.092	0.36	0.57	0.89	0.22	0.37
1.01-2.00	0.18	0.21	0.2	0.31	1	0.24	0.25	0.42	0.19	0.43	0.41	0.54
2.01-5.00	0.12	0.18	0.09	0.12	0.26	0.33	0.15	0.12	0.04	0.061	0.52	0.2
>5.00	0.0044	0.07	0.025	0.012	0	0.059	0	0	0	0	0.011	0.015
Affected area (sq. km.) by flood depth (in m.)	**Embarcadero**	**Guruyan**	**Lajong**	**Maalo**	**North Poblacion**	**Puting Sapa**	**Rangas**	**Sipaya**	**South Poblacion**	**Taboc**	**Tinago**	**Tughan**
0.03-0.20	0.83	10.08	7.3	7	0.21	3.79	1.63	2.34	0.32	3.24	0.99	0.59
0.21-0.50	0.47	1.12	0.32	0.27	0.079	0.14	0.16	0.14	0.062	0.21	0.041	0.18
0.51-1.00	1	0.97	0.31	0.16	0.21	0.079	0.14	0.17	0.043	0.24	0.029	0.12
1.01-2.00	1.36	0.81	0.25	0.1	0.31	0.055	0.3	0.3	0.083	0.21	0.0062	0.025
2.01-5.00	0.068	0.34	0.08	0.059	0.1	0.038	0.42	0.29	0.041	0.1	0	0
>5.00	0	0.016	0.0005	0.0003	0.0056	0.002	0.044	0.048	0.0078	0.065	0	0

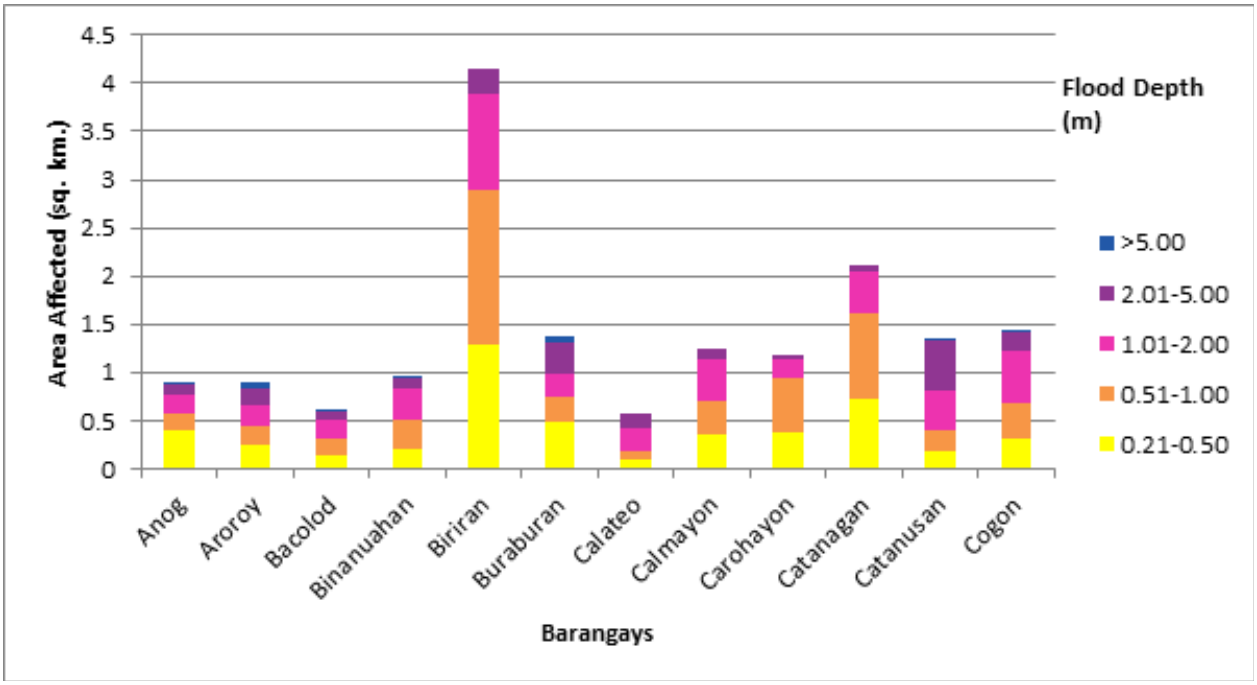


Figure 84. Affected Areas in Juban, Sorsogon during the 25-Year Rainfall Return Period

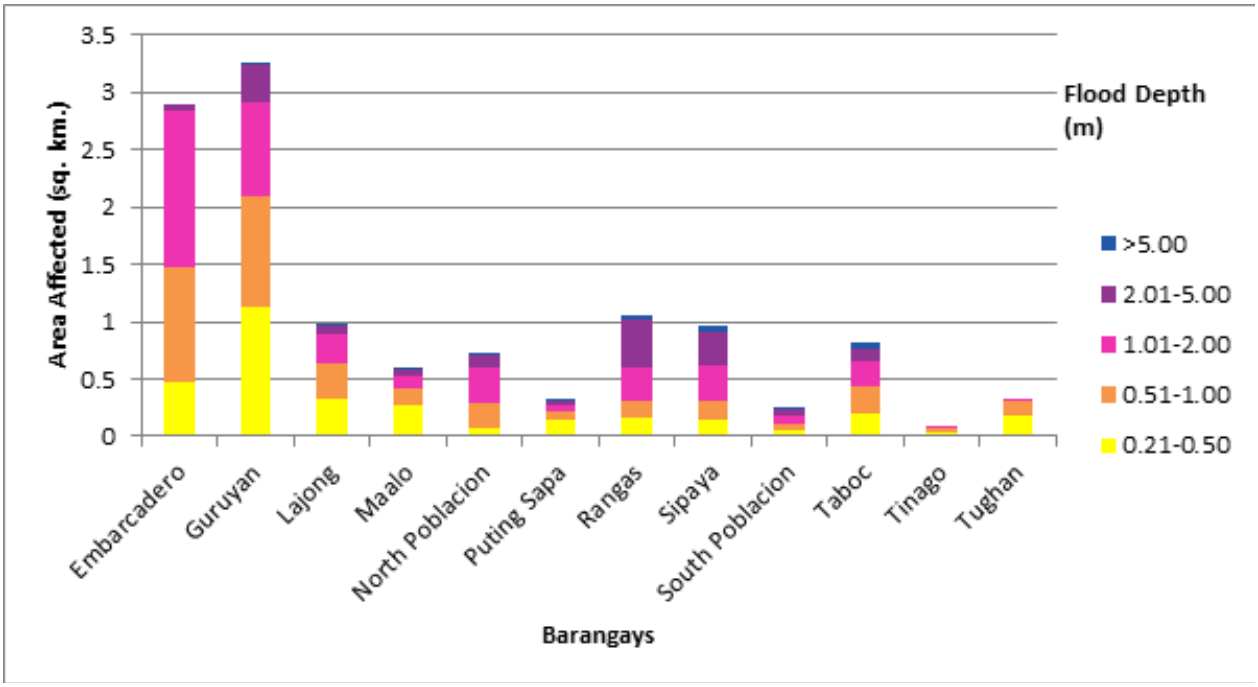


Figure 85. Affected Areas in Juban, Sorsogon during the 25-Year Rainfall Return Period

For the municipality of Magallanes with an area of 117.6 sq. km., 0.001% will experience flood levels of less than 0.20 meters. Table 43 depicts the areas affected in Magallanes in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Magallanes, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Magallanes**
	Tulatula Sur
0.03-0.20	0.0023
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
>5.00	0

(This bar graph is not available as the values in Table 43 are too low.)

Figure 86. Affected Areas in Magallanes, Sorsogon during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 2.99% of the municipality of Bulan with an area of 187.31 sq. km. will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.07%, 0.04%, 0.01%, and 0.0005% 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 44 depicts the areas affected in Bulan in square kilometers by flood depth per barangay.

Table 44. Affected Areas in Bulan, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bulan					
	Bical	Calpi	Daganas	Dolos	Montecalvario	Padre Diaz
0.03-0.20	2.14	0.00056	0.58	0.018	1.78	1.08
0.21-0.50	0.072	0	0.023	0	0.069	0.053
0.51-1.00	0.039	0	0.013	0	0.058	0.024
1.01-2.00	0.026	0	0.00077	0	0.036	0.013
2.01-5.00	0.017	0	0	0	0.0043	0.0005
>5.00	0.0009	0	0	0	0.0001	0

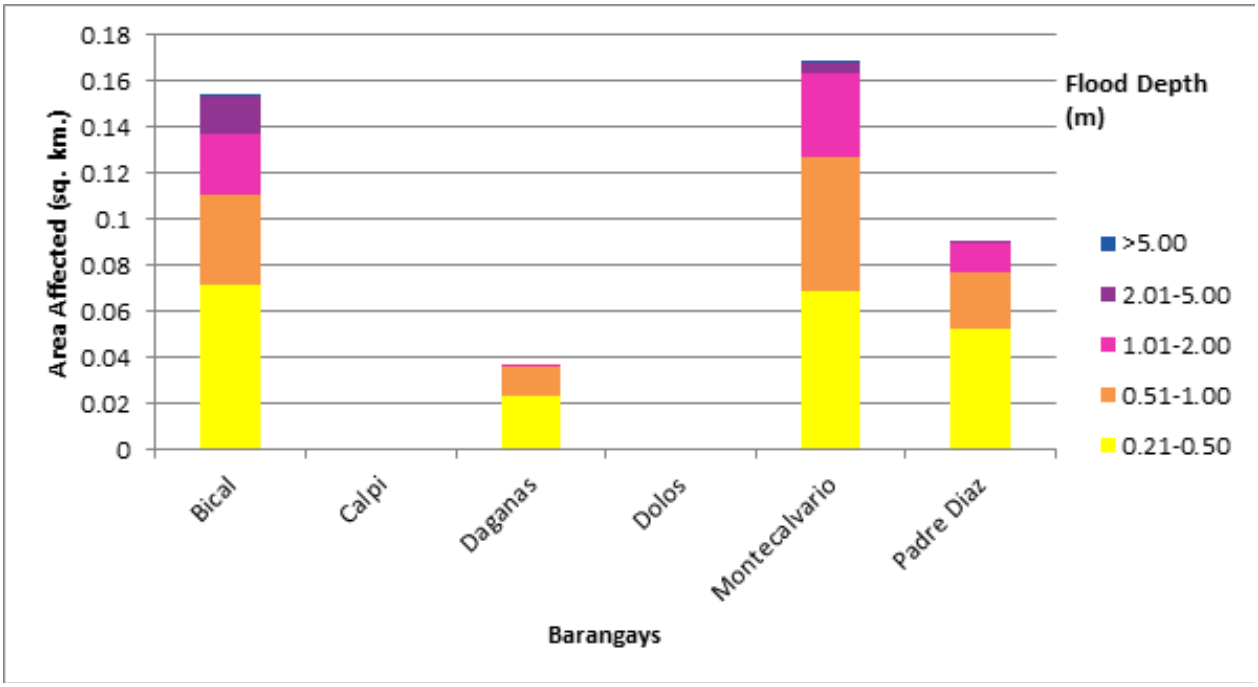


Figure 87. Affected Areas in Bulan, Sorsogon during the 100-Year Rainfall Return Period

For the municipality of Bulusan with an area of 93.11 sq. km., 11.05% will experience flood levels of less than 0.20 meters. 0.6% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.19%, 0.09%, 0.02%, and 0.008% 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 45 depicts the areas affected in Bulusan in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Bulusan, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bulusan			
	Salvacion	San Isidro	San Roque	Santa Barbara
0.03-0.20	1.05	0.68	4.85	3.72
0.21-0.50	0.095	0.015	0.31	0.13
0.51-1.00	0.046	0.0018	0.086	0.042
1.01-2.00	0.0073	0.0002	0.057	0.019
2.01-5.00	0	0	0.018	0.0026
>5.00	0	0	0.0078	0.0001

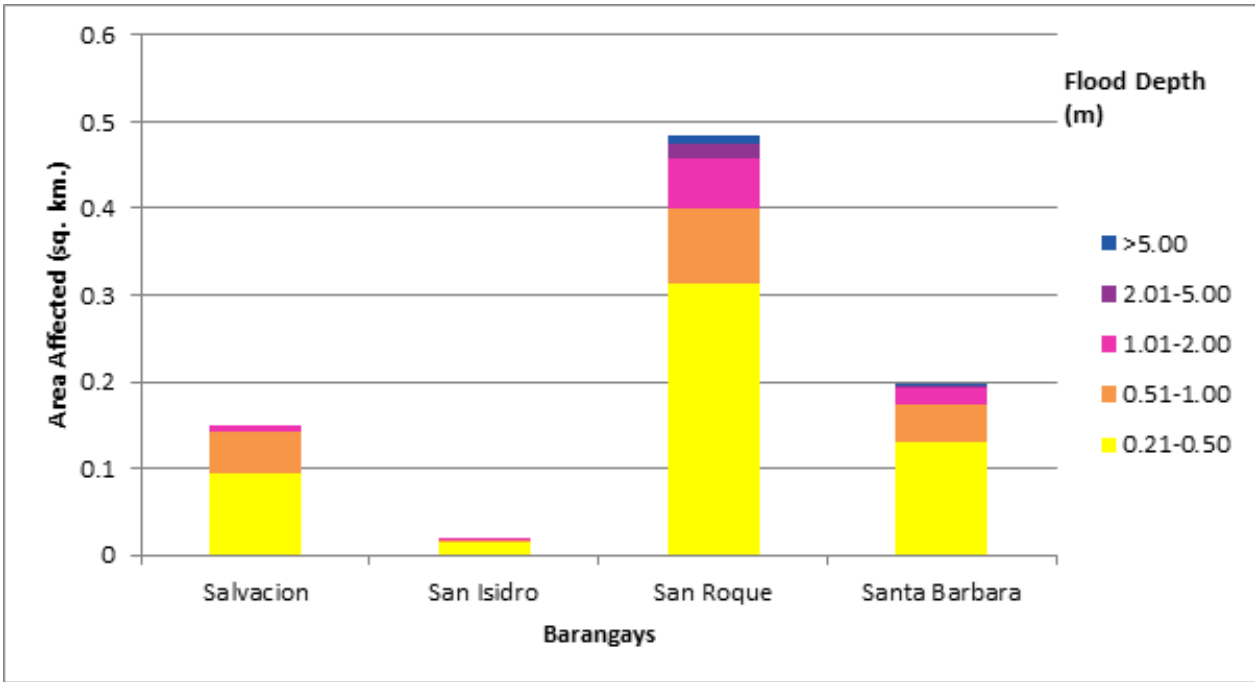


Figure 88. Affected Areas in Bulusan, Sorsogon during the 100-Year Rainfall Return Period

For the municipality of Casiguran with an area of 87.3 sq. km., 13.84% will experience flood levels of less than 0.20 meters. 0.62% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.4%, 0.53%, 0.4%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 46 depicts the areas affected in Casiguran in square kilometers by flood depth per barangay.

Table 46.Affected Areas in Casiguran, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Casiguran				
	Escuala	Inlagadian	Mabini	San Juan	Tigbao
0.03-0.20	0.28	5.85	5.06	0.2	0.7
0.21-0.50	0.02	0.22	0.27	0.011	0.029
0.51-1.00	0.014	0.14	0.16	0.0066	0.025
1.01-2.00	0.038	0.15	0.24	0.011	0.023
2.01-5.00	0.026	0.074	0.24	0.0026	0.0032
>5.00	0	0.003	0.025	0	0.0001

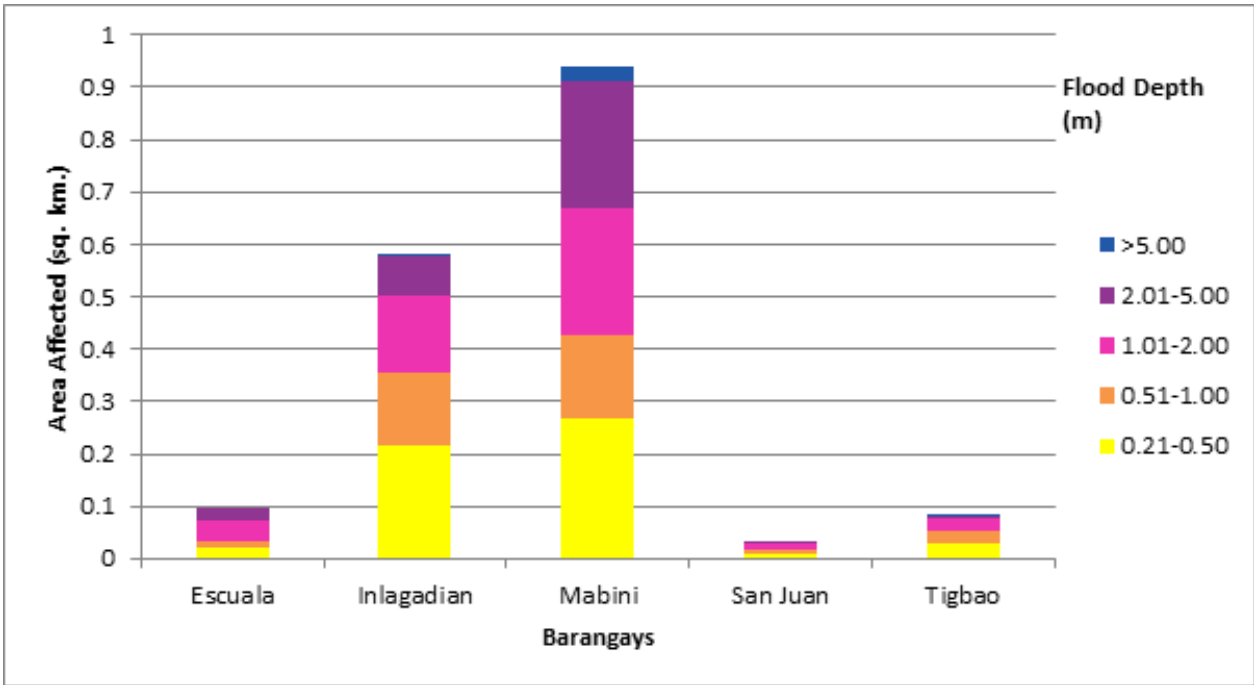


Figure 89. Affected Areas in Casiguran, Sorsogon during the 100-Year Rainfall Return Period

For the municipality of Irosin with an area of 130.17 sq. km., 55.79% will experience flood levels of less than 0.20 meters. 6.73% of the area will experience flood levels of 0.21 to 0.50 meters, while 5.74%, 5.82%, 2.13%, and 0.26% 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 47 depicts the areas affected in Irosin in square kilometers by flood depth per barangay.

Table 47. Affected Areas in Irosin, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Irosin								
	Bacolod	Bagsangan	Batang	Bolos	Buenavista	Bulawan	Carriedo	Cawayan	Cogon
0.03-0.20	0.096	5.85	2.62	1.43	0.36	1.45	3.46	5.13	17.3
0.21-0.50	0.021	0.49	0.37	0.25	0.23	0.39	0.35	0.28	1.1
0.51-1.00	0.045	0.43	0.6	0.1	0.46	0.18	0.3	0.094	0.3
1.01-2.00	0.021	0.33	0.71	0.33	0.31	0.034	0.2	0.042	0.14
2.01-5.00	0.013	0.033	0.047	0.6	0.18	0.012	0.083	0.027	0.057
>5.00	0.04	0	0.0024	0.0055	0.07	0.0005	0.036	0.0015	0.015
Affected area (sq. km.) by flood depth (in m.)	**Gabao**	**Gulang-Gulang**	**Gumapia**	**Liang**	**Macawayan**	**Mapaso**	**Monbon**	**Patag**	**Salvacion**
0.03-0.20	1.39	3.07	2.6	0.068	0.26	6.83	3.32	4.11	2.13
0.21-0.50	0.28	0.7	0.17	0.00045	0.58	0.53	0.37	0.3	0.37
0.51-1.00	0.26	0.53	0.17	0.0001	1.12	0.26	0.39	0.27	0.33
1.01-2.00	0.16	0.47	0.88	0.0001	0.73	0.2	1.22	0.14	0.11
2.01-5.00	0.05	0.14	0.16	0	0.16	0.18	0.17	0.11	0.0063
>5.00	0.000009	0.0013	0.041	0	0.012	0.032	0	0.0033	0
Affected area (sq. km.) by flood depth (in m.)	**San Agustin**	**San Isidro**	**San Juan**	**San Julian**	**San Pedro**	**Santo Domingo**	**Tabon-Tabon**	**Tinampo**	**Tongdol**
0.03-0.20	0.5	2.05	0.51	0.29	0.6	1.61	1.25	1.88	2.49
0.21-0.50	0.019	0.56	0.03	0.15	0.58	0.22	0.081	0.13	0.22
0.51-1.00	0.021	0.63	0.03	0.093	0.33	0.1	0.12	0.08	0.22
1.01-2.00	0.022	0.35	0.011	0.016	0.2	0.065	0.21	0.45	0.23
2.01-5.00	0.012	0.048	0.0009	0	0.11	0.1	0.13	0.32	0.039
>5.00	0.0066	0.0022	0	0	0.022	0.013	0.0053	0.0002	0.029

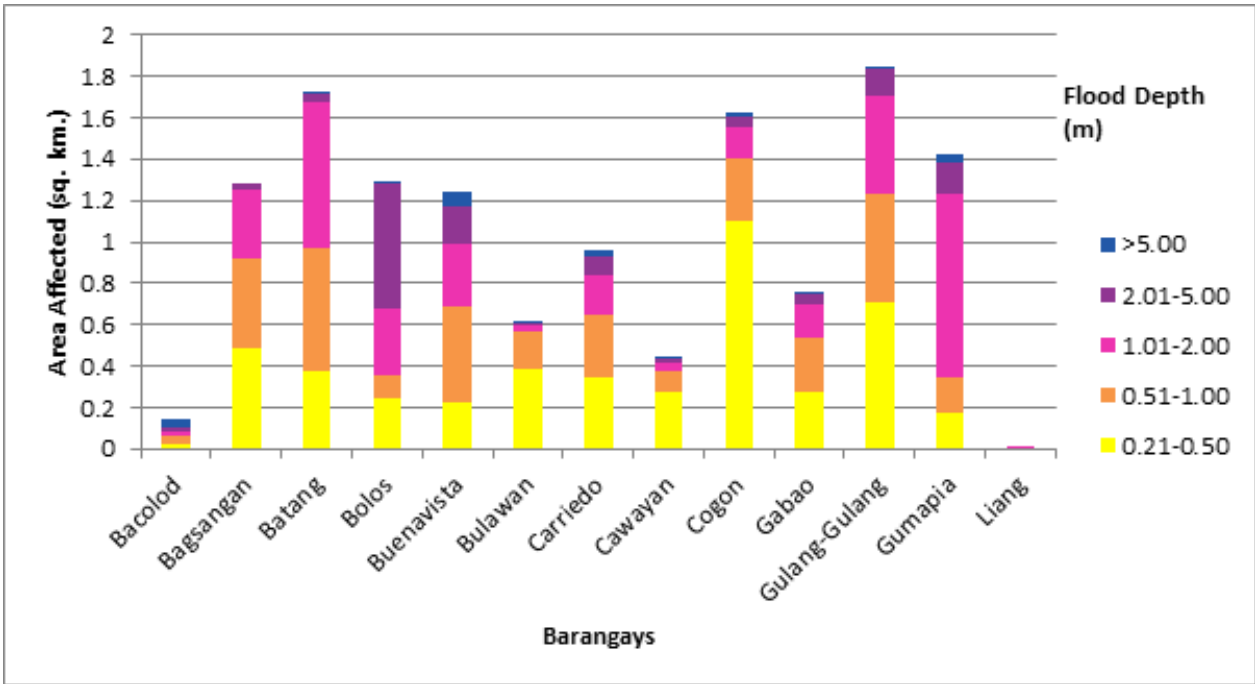


Figure 90. Affected Areas in Irosin, Sorsogon during the 100-Year Rainfall Return Period

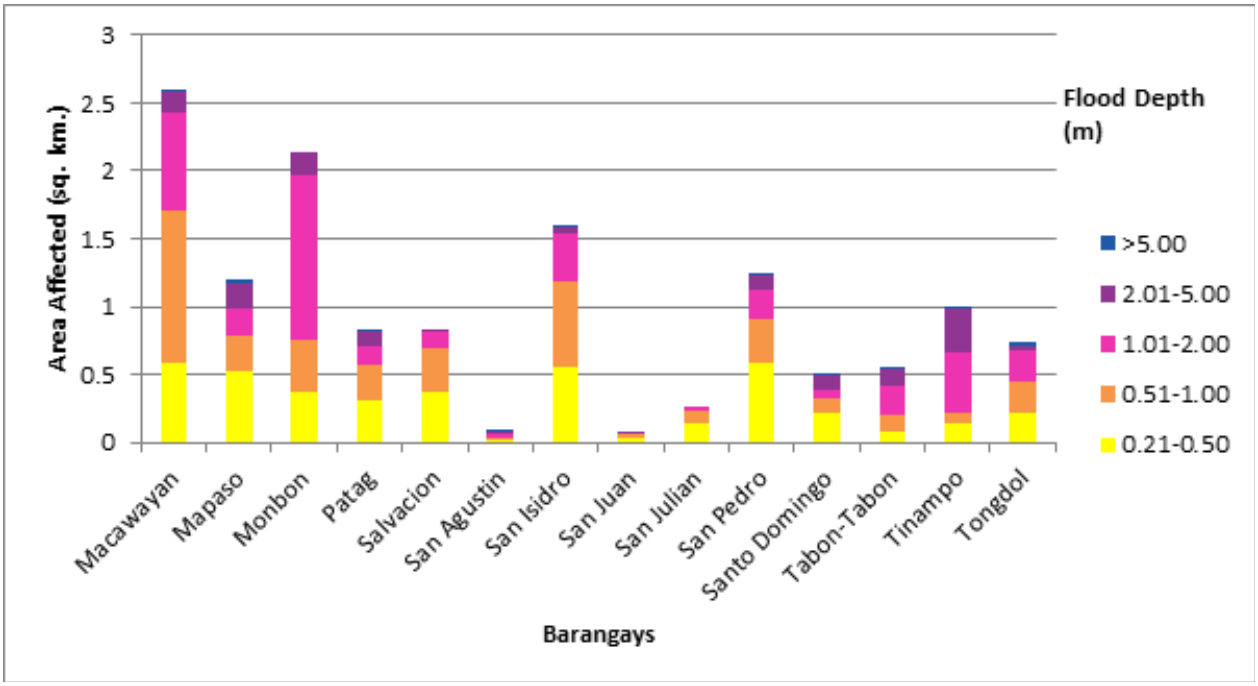


Figure 91. Affected Areas in Irosin, Sorsogon during the 100-Year Rainfall Return Period

For the municipality of Juban with an area of 127.78 sq. km., 59.6% will experience flood levels of less than 0.20 meters. 5.68% of the area will experience flood levels of 0.21 to 0.50 meters, while 6.66%, 7.8%, 4.37%, and 0.42% 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 48 depicts the areas affected in Juban in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Juban, Sorsogon during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Irosin											
	Anog	Aroroy	Bacolod	Binanuahan	Biriran	Buraburan	Calateo	Calmayon	Carohayon	Catanagan	Catanusan	Cogon
0.03-0.20	8.8	1.29	0.32	3.06	3.26	5.41	0.9	7.25	3.27	1.17	1.55	2.5
0.21-0.50	0.46	0.25	0.11	0.18	1.01	0.52	0.087	0.34	0.32	0.62	0.13	0.31
0.51-1.00	0.19	0.23	0.15	0.27	1.78	0.3	0.077	0.34	0.62	0.92	0.16	0.29
1.01-2.00	0.2	0.22	0.22	0.43	1.48	0.23	0.19	0.49	0.25	0.87	0.39	0.57
2.01-5.00	0.15	0.26	0.16	0.17	0.4	0.42	0.26	0.19	0.064	0.076	0.67	0.37
>5.00	0.0079	0.081	0.032	0.019	0	0.079	0.0001	0.0002	0	0	0.054	0.021
Affected area (sq. km.) by flood depth (in m.)	**Embarcadero**	**Guruyan**	**Lajong**	**Maalo**	**North Poblacion**	**Puting Sapa**	**Rangas**	**Sipaya**	**South Poblacion**	**Taboc**	**Tinago**	**Tughan**
0.03-0.20	0.68	9.79	7.22	6.94	0.18	3.75	1.56	2.29	0.3	3.17	0.98	0.53
0.21-0.50	0.4	0.98	0.32	0.28	0.037	0.15	0.15	0.11	0.06	0.18	0.038	0.19
0.51-1.00	0.8	0.97	0.3	0.18	0.13	0.091	0.12	0.13	0.047	0.21	0.038	0.15
1.01-2.00	1.75	0.9	0.31	0.11	0.41	0.067	0.2	0.27	0.066	0.3	0.0077	0.04
2.01-5.00	0.093	0.67	0.12	0.082	0.15	0.046	0.59	0.44	0.074	0.14	0	0
>5.00	0.00042	0.023	0.0007	0.001	0.017	0.0033	0.056	0.056	0.0083	0.073	0	0

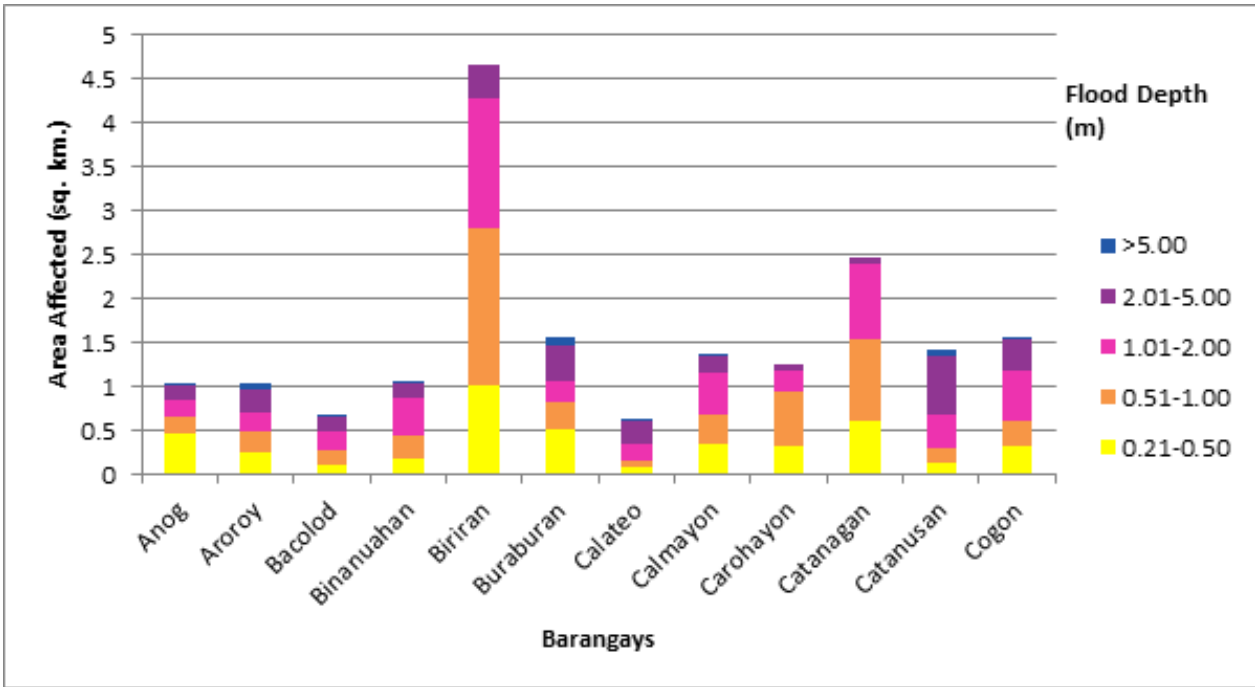


Figure 92. ffected Areas in Juban, Sorsogon during the 100-Year Rainfall Return Period

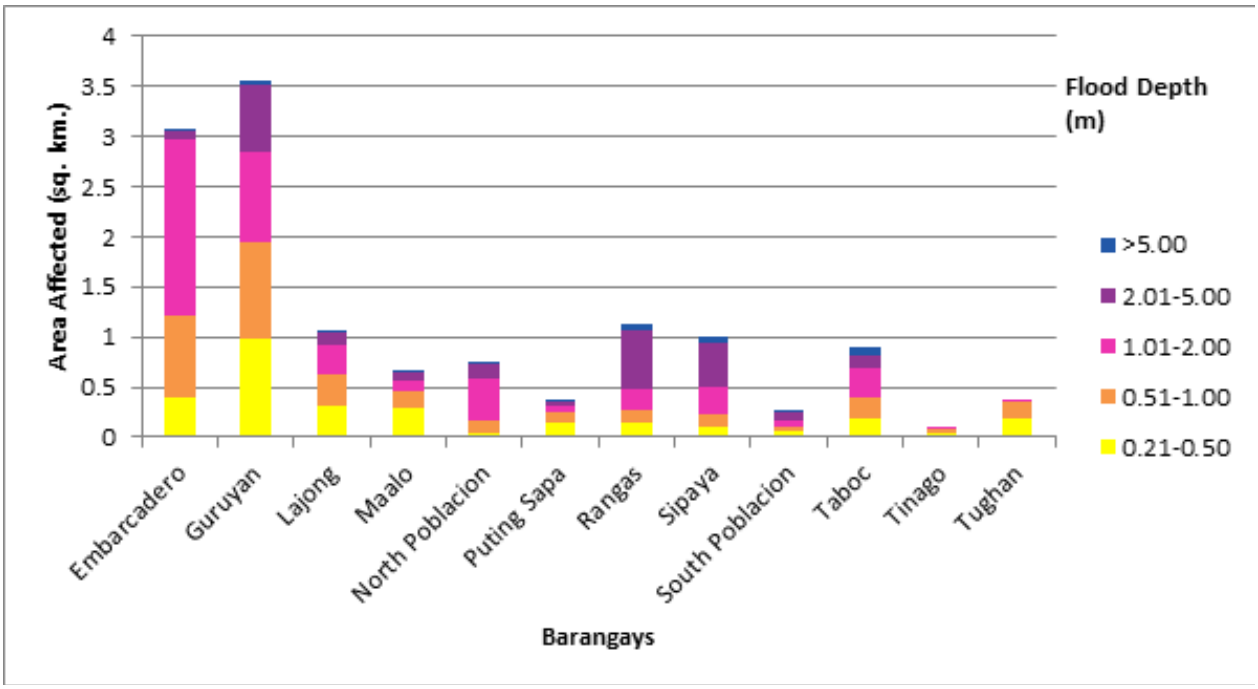


Figure 93. Affected Areas in Juban, Sorsogon during the 100-Year Rainfall Return Period

For the municipality of Magallanes with an area of 117.6 sq. km., 0.001% will experience flood levels of less than 0.20 meters. Table 49 depicts the areas affected in Magallanes in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Magallanes, Sorsogon during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Magallanes
	Tulatula Sur
0.03-0.20	0.0023
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
>5.00	0

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

Table 50. 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	17.14	17.37	16.95
Medium	21.8	25.77	27
High	7.76	13.38	18.7
Total	**46.7**	**56.52**	**62.65**

Of the 84 identified Educational Institutions in Cadacan flood plain, 11 were assessed to low, 12 to medium, and 3 to high level flooding during the 5-year scenario. In the 25-year scenario, 13 were assessed to be exposed to low, 12 to medium, and 7 to high level flooding. In the 100-year scenario, 15 were assessed to be exposed to low, 11 to medium, and 11 to high level flooding.

Of the 20 identified Medical Institutions in Cadacan flood plain, 2 were assessed to be exposed to low, while none was assessed to be exposed to both medium and high level flooding in the 5-year scenario. In the 25-year scenario, 2 were assessed to be exposed to both low and medium, while none was assessed to be exposed to high level flooding. In the 100-year scenario, 2 were assessed to be exposed to low, 3 to medium, and none to high level flooding.

5.11 Flood Validation

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

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

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

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

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. OPTECH Technical Specification of the 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 Certificates of Reference Points Used

SRG-35

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

March 08, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SORSOGON**
Station Name: **SRG-35**
Order: **2nd**

Island: **LUZON**
Municipality: **CASIGURAN**
Barangay:
MSL Elevation:

PRS92 Coordinates

Latitude:	**12° 52' 25.33226"**	Longitude:	**124° 0' 23.80097"**	Ellipsoidal Hgt:	**8.55500 m.**

WGS84 Coordinates

Latitude:	**12° 52' 20.57407"**	Longitude:	**124° 0' 28.82318"**	Ellipsoidal Hgt:	**64.19400 m.**

PTM / PRS92 Coordinates

Northing:	**1423792.96 m.**	Easting:	**609257.97 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,423,294.61**	Easting:	**609,219.73**	Zone:	**51**

Location Description

SRG-35
From Sorsogon City Proper, travel for about 22 km. to reach Pob. Casiguran. Station is located in front of Casiguran Mun. Hall, 1 m. from the concrete fence and 13 m. from the flagpole. 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, with inscriptions "SRG-35 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089979 I**
T.N.: **2016-0566**

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

9903082016120938

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 95
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

ABY-9

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-9**
Order: **3rd**

Island: **LUZON**
Municipality: **LEGASPI CITY**
Barangay:

PRS92 Coordinates

Latitude:	**13° 9' 11.38733"**	Longitude:	**123° 43' 45.95874"**	Ellipsoidal Hgt:	**14.54010 m.**

WGS84 Coordinates

Latitude:	**13° 9' 6.53800"**	Longitude:	**123° 43' 50.95900"**	Ellipsoidal Hgt:	**68.75400 m.**

PTM Coordinates

Northing:	**1454607.115 m.**	Easting:	**579082.538 m.**	Zone:	**4**

UTM Coordinates

Northing:	**1,454,097.98**	Easting:	**579,054.86**	Zone:	**51**

Location Description

ABY-9
From Albay Capitol Building, Legaspi City travel along Washington Drive about 2.0 km., turn left at road intersection and travel at about 1.0 km. to Legaspi Airport. Station is located at Legaspi Airport Compound, 52.0 m. SE of Legaspi Airport Flagpole, 35 m. NE of Legaspi Airport Welcome Post, 3.30 m. NW of Lamp. Station mark is 12.5 mm. dia. steel bar centered on a triangle on 0.30 m. x 0.30 m concrete block protruding 0.05 m. above the ground surface and mark with "NAMRIA ABY-9, 1990". Reference mark is Flagpole, Welcome Post, Lamp.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-832**

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

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

CERTIFICATION INTERNATIONAL ISO 9001:2008 CIP/4701/12/09/814
ACCREDITED QMS Certification Body Accreditation No: MSA-001

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

SR-64

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

March 08, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SORSOGON**
Station Name: **SR-64**

Island: **LUZON**	Municipality: **IROSIN**	Barangay: **CALUSCUS**
Elevation: **15.6375 +/- 0.0374 m.**	Accuracy Class at 95% C.L: **4 cm**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

BM SR 64
is in the province of Sorsogon, town of Irosin, barrio Caluscus, along National Highway No. 1 and at km. 645 + 80. Mark is set on top center of a PC&GS standard concrete monument, situated on a lot owned by Jesus Ubalde, about 11.60 m. SE of the centerline of the highway. Mark is the the top center of the brass rod, with an inscription around the mark thus: PC&GS SR 64 1954.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089979 I**
T.N.: **2016-0564**

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

9903082014120833

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) 241-3484 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

SR-69

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

March 16, 2016

CERTIFICATION

To whom it may concern:

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

Province: **SORSOGON**
Station Name: **SR-69**

Island: **Luzon**	Municipality: **JUBAN**	Barangay: **BACOLOD**
Elevation: **23.7717 +/- 0.0371 m.**	Accuracy Class at 95% C.L: **4 cm**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1988. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

SR-69
Along Legazpi-Matnog National Road. The station is located at the north west of Bacolod Bridge footwalk, and about 62 meters south east of KM Post 609 and about 4 meters south west of the centerline of the road. A brass rod is set on a drilled hole and cemented flushed on top of a 15cm x 15cm cement putty witg inscription SR-69 2007 NAMRIA".

Requesting Party: **UP-Lidar 1**
Purpose: **Reference**
OR Number: **8090044 I**
T.N.: **2016-0647**

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

9903162016114256

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

Annex 3. Baseline Processing Report

SR-64

SRG-35 - SR-64 (8:22:03 AM-1:14:28 PM) (S3)

Baseline observation:	SRG-35 --- SR-64 (B3)
Processed:	4/7/2016 6:32:41 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.013 m
RMS:	0.003 m
Maximum PDOP:	3.358
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/11/2016 8:22:21 AM (Local: UTC+8hr)
Processing stop time:	3/11/2016 1:14:28 PM (Local: UTC+8hr)
Processing duration:	04:52:07
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SRG-35				
Grid		**Local**		**Global**	
Easting	609219.728 m	**Latitude**	N12°52'25.33226"	**Latitude**	N12°52'20.57407"
Northing	1423294.607 m	**Longitude**	E124°00'23.80097"	**Longitude**	E124°00'28.82318"
Elevation	9.957 m	**Height**	8.555 m	**Height**	64.194 m

To:	SR-64				
Grid		**Local**		**Global**	
Easting	608383.958 m	**Latitude**	N12°50'05.60456"	**Latitude**	N12°50'00.85524"
Northing	1418998.779 m	**Longitude**	E123°59'55.52119"	**Longitude**	E124°00'00.54683"
Elevation	13.849 m	**Height**	12.638 m	**Height**	68.361 m

Vector					
ΔEasting	-835.770 m	**NS Fwd Azimuth**	191°14'01"	**ΔX**	170.382 m
ΔNorthing	-4295.828 m	**Ellipsoid Dist.**	4377.484 m	**ΔY**	1271.984 m
ΔElevation	3.892 m	**ΔHeight**	4.083 m	**ΔZ**	-4185.144 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.004 m
σ ΔNorthing	0.001 m	**σ Ellipsoid Dist.**	0.001 m	**σ ΔY**	0.005 m
σ ΔElevation	0.007 m	**σ ΔHeight**	0.007 m	**σ ΔZ**	0.002 m

SR-69

SRG-35 - SR-69 (8:42:13 AM-1:30:42 PM) (S5)

Baseline observation:	SRG-35 --- SR-69 (B5)
Processed:	4/7/2016 6:33:28 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.014 m
RMS:	0.010 m
Maximum PDOP:	4.885
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/14/2016 8:42:13 AM (Local: UTC+8hr)
Processing stop time:	3/14/2016 1:30:42 PM (Local: UTC+8hr)
Processing duration:	04:48:29
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	SRG-35				
Grid		**Local**		**Global**	
Easting	609219.728 m	**Latitude**	N12°52'25.33226"	**Latitude**	N12°52'20.57407"
Northing	1423294.607 m	**Longitude**	E124°00'23.80097"	**Longitude**	E124°00'28.82318"
Elevation	9.957 m	**Height**	8.555 m	**Height**	64.194 m

To:	SR-69				
Grid		**Local**		**Global**	
Easting	608094.752 m	**Latitude**	N12°47'36.54292"	**Latitude**	N12°47'31.80353"
Northing	1414418.362 m	**Longitude**	E123°59'45.34233"	**Longitude**	E123°59'50.37157"
Elevation	22.196 m	**Height**	21.144 m	**Height**	76.969 m

Vector					
ΔEasting	-1124.976 m	**NS Fwd Azimuth**	187°26'48"	**ΔX**	-147.917 m
ΔNorthing	-8876.245 m	**Ellipsoid Dist.**	8949.524 m	**ΔY**	2292.676 m
ΔElevation	12.239 m	**ΔHeight**	12.589 m	**ΔZ**	-8649.629 m

SRG-A2

ABY-09 - SRG-A2 (9:59:03 AM-3:00:17 PM) (S1)

Baseline observation:	ABY-09 --- SRG-A2 (B1)
Processed:	3/22/2016 2:43:19 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.014 m
RMS:	0.006 m
Maximum PDOP:	4.385
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/19/2016 9:59:03 AM (Local: UTC+8hr)
Processing stop time:	3/19/2016 3:00:17 PM (Local: UTC+8hr)
Processing duration:	05:01:14
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	ABY-09				
Grid		Local		Global	
Easting	579054.857 m	Latitude	N13°09'11.38752"	Latitude	N13°09'06.53800"
Northing	1454097.983 m	Longitude	E123°43'45.95871"	Longitude	E123°43'50.95900"
Elevation	15.448 m	Height	14.540 m	Height	68.754 m

To:	SRG-A2				
Grid		Local		Global	
Easting	589012.581 m	Latitude	N12°58'19.68256"	Latitude	N12°58'14.88482"
Northing	1434108.317 m	Longitude	E123°49'14.55138"	Longitude	E123°49'19.56657"
Elevation	51.835 m	Height	50.561 m	Height	105.483 m

Vector					
ΔEasting	9957.725 m	NS Fwd Azimuth	153°41'06"	ΔX	-10765.155 m
ΔNorthing	-19989.666 m	Ellipsoid Dist.	22339.537 m	ΔY	-1712.417 m
ΔElevation	36.387 m	ΔHeight	36.021 m	ΔZ	-19499.714 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Annex 4. The Survey Team

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	
		LOVELYN ASUNCION	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA-PAGADOR	UP-TCAGP
		ENGR. CHRISTOPHER JOAQUIN	
	Research Associate (RA)	JERIEL PAUL ALAMBAN	
		MILLIE SHANE REYES	
		KRISTINE ANDAYA	
		IRO NIEL ROXAS	
Ground Survey, Data Download and Transfer	RA	JASMIN DOMINGO	
LiDAR Operation	Airborne Security	TSG. BENJIE CARBOLLEDO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. GEROME MOONEY	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. DEXTER CABUDOL	

Annex 5. Data Transfer Sheets for Cadacan Floodplain Flights

DATA TRANSFER SHEET
ALBAY/SORSOGON 3/18/2016

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	
28-Feb-16	3825G	2BLK19JFS 059B	GEMINI	NA	233	13.3	176	4.37	37	19.1	NA	6.33	1KB	2KB	15/11	233	Z:\DAC\RAW DATA
29-Feb-16	3827G	2BLK19AB S060A	GEMINI	NA	NA	2.03	265	2.2	1	33.6	NA	11.7	1KB	3KB	36/29/30	376	Z:\DAC\RAW DATA
29-Feb-16	3829G	2BLK19FS 060B	GEMINI	NA	665	1.98	130	26.9	252	14	NA	11.7	1KB	1KB	36/32/29/30/30	NA	Z:\DAC\RAW DATA
4-Mar-16	3843G	2BLK19DS 064A	GEMINI	NA	942	5.18	274	88.1	735	39.2	NA	9.29	1KB	1KB	32/29	NA	Z:\DAC\RAW DATA
6-Mar-16	3851G	2BLK19aA B066A	GEMINI	NA	331	587	183	28.7	227	16	NA	4.19	1KB	1KB	30/28/27	331	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position PA
Signature

Received by

Name ACE BONOT
Position ASSTO
Signature 3/21/16

DATA TRANSFER SHEET

ALBAY/SORSOGON 3/28/2016

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	
7-Mar-16	3855G	2BLK19AS 067A	GEMINI	NA	NA	796	170	28.6	223	8.28	NA	11.5	1KB	1KB	36/30/28	NA	Z:\DAC\RA\ DATA
9-Mar-16	3863G	2BLK19aC EFG069A	GEMINI	NA	545	1.34	262	46.6	359	25.9	NA	10.1	1KB	1KB	33/211	NA	Z:\DAC\RA\ DATA
10-Mar-16	3869G	2BLK19AS BSI070A	GEMINI	NA	667	7.77	283	32.5	283	18.9	NA	10	1KB	1KB	28	NA	Z:\DAC\RA\ DATA
11-Mar-16	3871G	2BLK19aC DGI071A	GEMINI	NA	1035	1.99	279	45.5	344	23.9	NA	18.8	1KB	1KB	33	NA	Z:\DAC\RA\ DATA
11-Mar-16	3873G	2BLK19aH 071B	GEMINI	NA	352	749	189	35.4	250	17	NA	12.3	1KB	2KB	21/22	NA	Z:\DAC\RA\ DATA
13-Mar-16	3879G	2BLK19aJ 073A	GEMINI	NA	565	1.14	267	52.7	404	26.8	NA	11.1	1KB	NA	18	4	Z:\DAC\RA\ DATA
14-Mar-16	3883G	2BLK19JS KM074A	GEMINI	NA	1290	3.03	288	69.3	516	33.6	NA	15.5	1KB	1KB	17	1290	Z:\DAC\RA\ DATA
14-Mar-16	3885G	2BLK19aK SMS074B	GEMINI	NA	70	1.79	197	17.2	161	16.2	NA	9.34	1KB	1KB	18	2	Z:\DAC\RA\ DATA
15-Mar-16	3887G	2BLK19aK LS075A	GEMINI	NA	627	2.1	271	60.9	470	27.9	NA	17.8	1KB	1KB	15	4	Z:\DAC\RA\ DATA
15-Mar-16	3889G	2BLK19aK LS075B	GEMINI	NA	239	1.4	166	22.3	187	10.4	NA	17.8	1KB	1KB	17	NA	Z:\DAC\RA\ DATA

Received from

Name R. PUNTO

Position RA

Signature

Received by

Name ANALYN M. NALDO

Position RA

Signature 3/31/2016

DATA TRANSFER SHEET

[illegible] ALBAY SORSOGON

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	
3/16/2016	3892G	2BLK19AC5076A	GEMINI	NA	505	1.48	264	74.1	456	24.9	NA	15.4	1KB	1KB	23	NA	Z:\DAC\RAWDATA
[illegible]	[illegible]	[illegible]	[illegible]	NA	447	[illegible]	[illegible]	[illegible]	[illegible]	20.8	NA	[illegible]	1KB	1KB	21	NA	Z:\DAC\RAWDATA

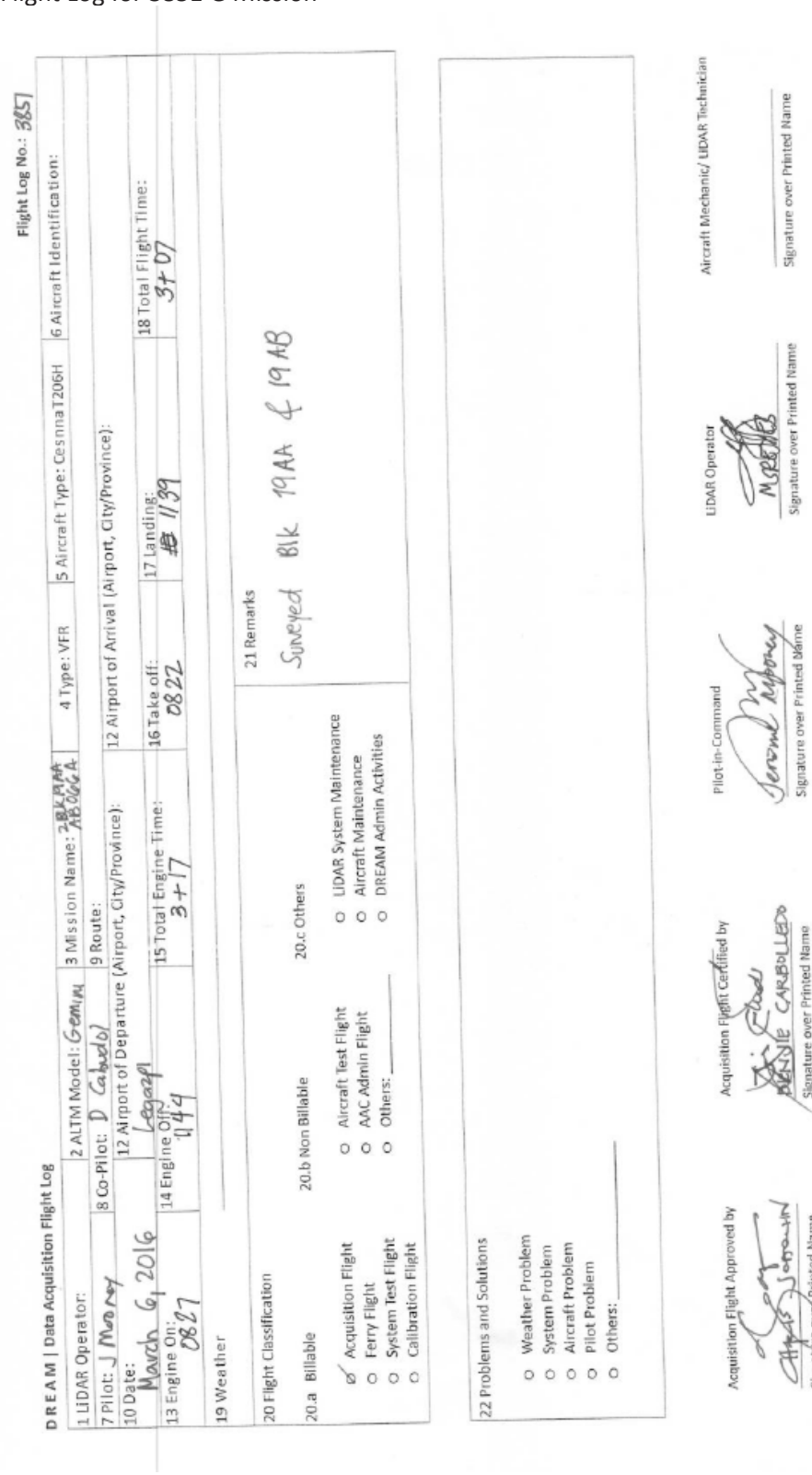
18 19 20 21 3899G 3903G

Name KJ ANDAYA
RA

Name Analyn M. Naldo
RA
3/21/2016

Annex 6. Flight Logs

Flight Log for 3851 G Mission



DREAM | Data Acquisition Flight Log

Flight Log No.: 3851

1 LiDAR Operator:
2 ALTM Model: Gemini
3 Mission Name: 2BLK19AA ABGGGA
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification:

7 Pilot: J Monroy
8 Co-Pilot: D Cabudol
9 Route:

10 Date: March 6, 2016
11 Airport of Departure (Airport, City/Province): Legaspi
12 Airport of Arrival (Airport, City/Province):

13 Engine On: 0827
14 Engine Off: 1144
15 Total Engine Time: 3+17
16 Take off: 0822
17 Landing: #8 1139
18 Total Flight Time: 3+07

19 Weather

20 Flight Classification

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

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

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

21 Remarks: Surveyed Blk 19AA & 19AB

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

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

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

Pilot-in-Command
Signature over Printed Name

LiDAR Operator
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name

Data Acquisition Flight Log — Flight Log No.: 3855 6

1 LiDAR Operator: Tin Andaya	2 ALTM Model: Gemini	3 Mission Name: 2BLK19AS063A	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: 03-07-2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 0800	14 Engine Off: 1111	15 Total Engine Time: 3 + 11	16 Take off: 0805	17 Landing: 1106	18 Total Flight Time: 3 + 01
19 Weather: cloudy					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
ø Acquisition Flight	o Aircraft Test Flight	o LiDAR System Maintenance
o Ferry Flight	o AAC Admin Flight	o Aircraft Maintenance
o System Test Flight	o Others: _____	o Phil-LiDAR Admin Activities
o Calibration Flight		

21 Remarks: covered BLK 19 AS

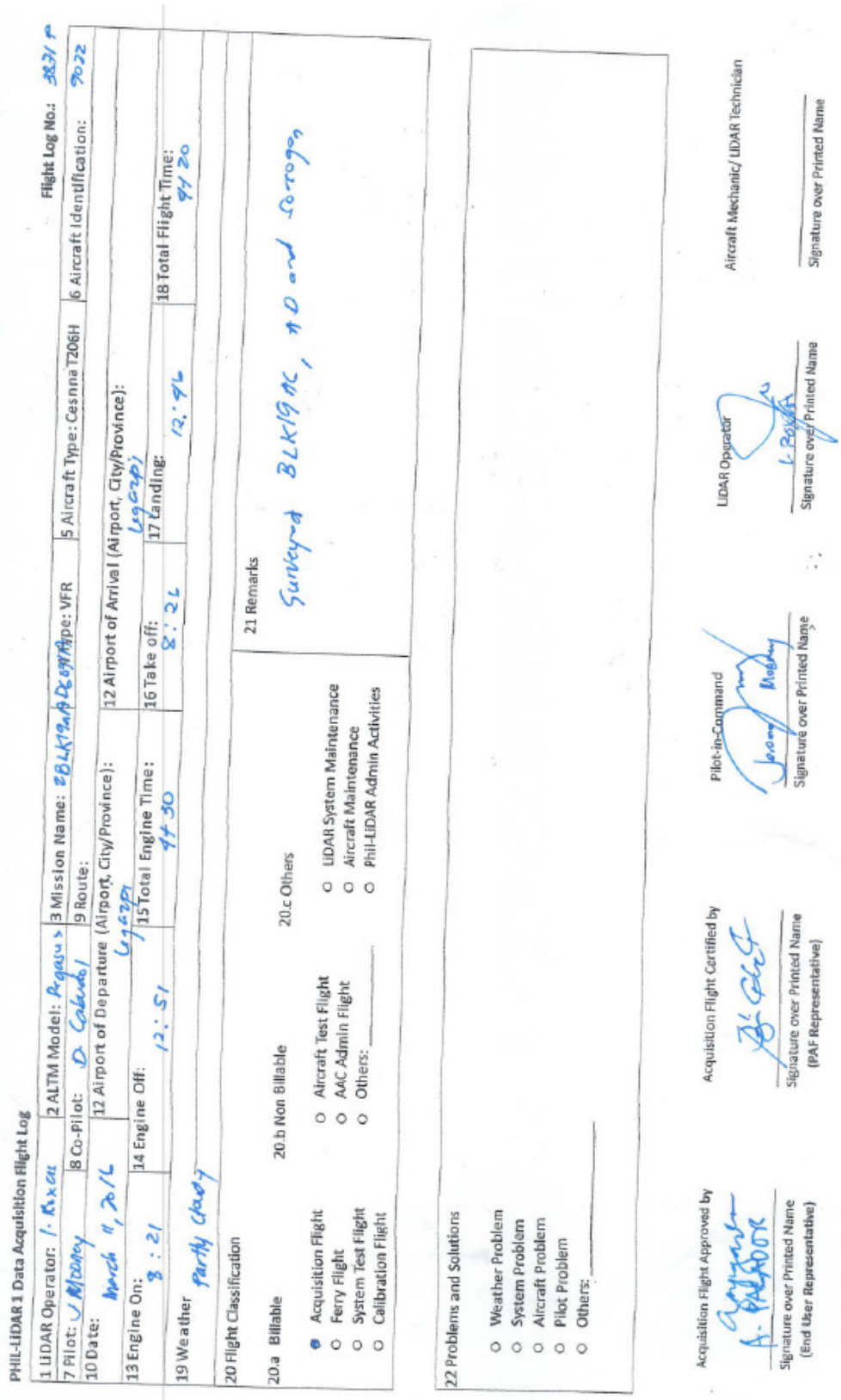
22 Problems and Solutions

- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- ø Others: _____

had to ferry back due to unavailability of radio frequency signal in the survey area.

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Techni
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

Flight Log for 3871 G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3871 G

1 LIDAR Operator: J. Rixan	2 ALTM Model: Pegasus	3 Mission Name: BLK13AB Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: J. Medoro	8 Co-Pilot: D. Cabuslay	9 Route:		
10 Date: March 11, 2016	12 Airport of Departure (Airport, City/Province): Legazpi	12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 8:21	14 Engine Off: 12:51	15 Total Engine Time: 4+30	16 Take off: 8:24	17 Landing: 12:46
19 Weather Partly Cloudy				18 Total Flight Time: 4+20

20 Flight Classification

20.a Billable

- ● Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks

Survey of BLK13AB, 10 and 50 meters

22 Problems and Solutions

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

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

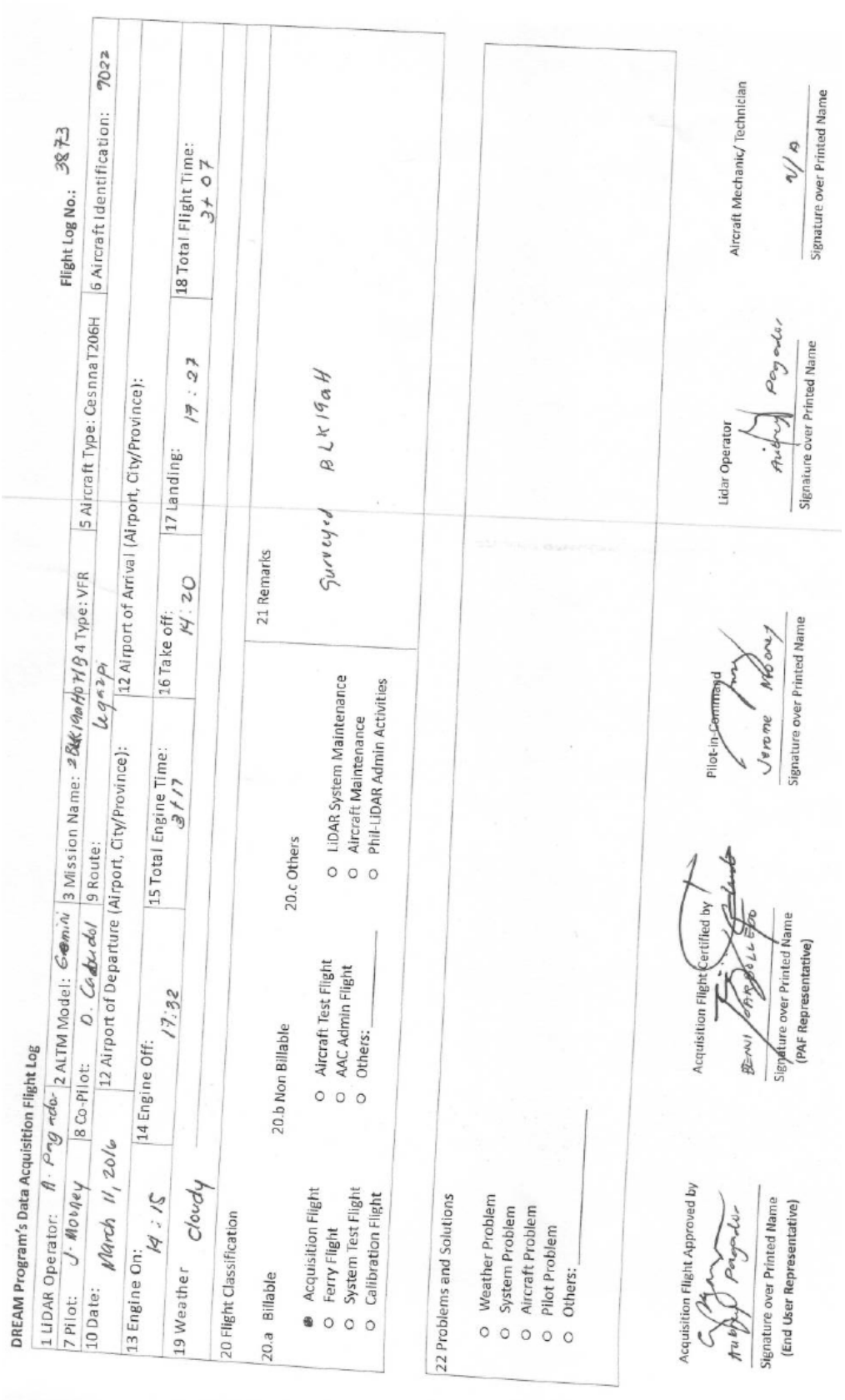
LiDAR Operator

Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician

Signature over Printed Name

Flight Log for 3873 G Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 3873

1 LiDAR Operator: A. Pogador | 2 ALTM Model: Gemini | 3 Mission Name: 2BLK19aH19 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: 7022

7 Pilot: J. Money | 8 Co-Pilot: O. Cadacdol | 9 Route: Lgazpi

10 Date: March 11, 2016 | 12 Airport of Departure (Airport, City/Province): Lgazpi | 12 Airport of Arrival (Airport, City/Province):

13 Engine On: 14:15 | 14 Engine Off: 17:32 | 15 Total Engine Time: 3:17 | 16 Take off: 14:20 | 17 Landing: 17:27 | 18 Total Flight Time: 3:07

19 Weather Cloudy

20 Flight Classification

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

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

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

21 Remarks: Surveyed BLK19aH

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

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

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

Pilot-in-Command
Jerome Money
Signature over Printed Name

Lidar Operator
Aircraft Mechanic/ Technician
Signature over Printed Name

Flight Log for 3879 G Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 3879

1 LiDAR Operator: K. Medoya	2 ALTM Model: Gemini	3 Mission Name: BLK9AUG28A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: J. Monroy	8 Co-Pilot:	9 Route: D. Cordova Lagaspi			
10 Date: March 13, 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:38	14 Engine Off: 13:1	15 Total Engine Time: 5+23	16 Take off: 8:48	17 Landing: 13:56	18 Total Flight Time: 5+33
19 Weather Cloudy					

20 Flight Classification

20.a Billable

- ● Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks

Covered Pinatubo Dio 2

22 Problems and Solutions

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

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

Aircraft Mechanic/ Technician

N/A

Signature over Printed Name

Flight Log for 3883 G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3883G

1 LIDAR Operator: J. Roxas	2 ALTM Model: GEMA	3 Mission Name: 2BLK [illegible] 4 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification: RP-C9012
7 Pilot: J. Monsay	8 Co-Pilot: D. Cebrale	9 Route:		
10 Date: 14 May 16	11 Airport of Departure (Airport, City/Province): Legazpi	12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 0839H	14 Engine Off: 1320H	15 Total Engine Time: 9141	16 Take off: 0849H	17 Landing: 1315H
19 Weather: Partly Cloudy				18 Total Flight Time: 4431

20 Flight Classification

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

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

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

21 Remarks: Surveyed BLK 9 ok, ok and ok.

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

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

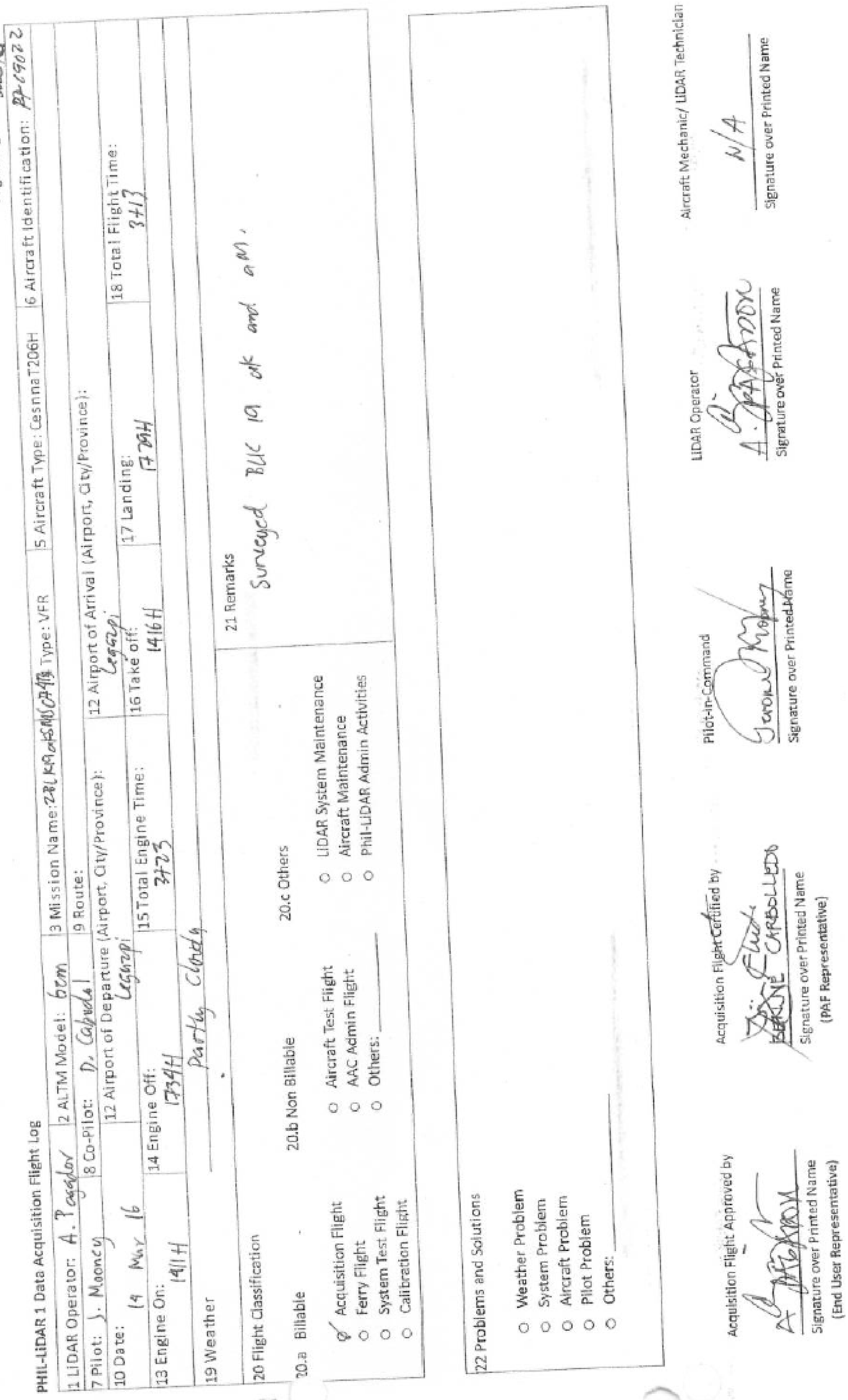
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

LiDAR Operator
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name

Flight Log for 3885 G Mission



Flight Log No.: 3885G

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: A. Pagador	2 ALTM Model: Gem	3 Mission Name: 2BLK19abcSMSC074B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Mooney	8 Co-Pilot: D. Cabudol	9 Route:			
10 Date: 14 May 16	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 1411H	14 Engine Off: 1734H	15 Total Engine Time: 3+23	16 Take off: 1416H	17 Landing: 1729H	18 Total Flight Time: 3+13
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 19 ok and am.

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

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

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

Pilot-in-Command: Jerome Mooney — Signature over Printed Name

LiDAR Operator: A. Bagadion — Signature over Printed Name

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

Flight Log for 3887 G Mission

Flight Log No.: 3887G

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: I. Rogers	2 ALTM Model: Gem	3 Mission Name: 3887G	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9027
7 Pilot: J. Mendoza	8 Co-Pilot: Tz. Casabal	9 Route:			
10 Date: 05-15-2016	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		18 Total Flight Time: 4+19
13 Engine On: 0830H	14 Engine Off: 1314H	15 Total Engine Time: 4+29	16 Take off: 0853H	17 Landing: 1314H	
19 Weather: Cloudy					

20 Flight Classification

20.a Billable

- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks: Surveyed Mantrog

22 Problems and Solutions

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

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

LiDAR Operator

I. Rogers

Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician

Signature over Printed Name

Flight Log for 3889 G Mission

Flight Log No.: 35866

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: RJ Aguilar	2 ALTM Model: Gem	3 Mission Name: ZBlock45CW84 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification: RP-C9026
7 Pilot: J. Meonada	8 Co-Pilot: D. Cabahug	9 Route:		
10 Date: 03-15-2016	12 Airport of Departure (Airport, City/Province): Cegazp	12 Airport of Arrival (Airport, City/Province): Cegazp		18 Total Flight Time: 2.37
13 Engine On: 1431H	14 Engine Off: 1718H	15 Total Engine Time: 2.47	16 Take off: 1436H	17 Landing: 1713H

19 Weather: Cloudy

20 Flight Classification

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

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

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

21 Remarks: Surveyed Blk 19a2

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

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

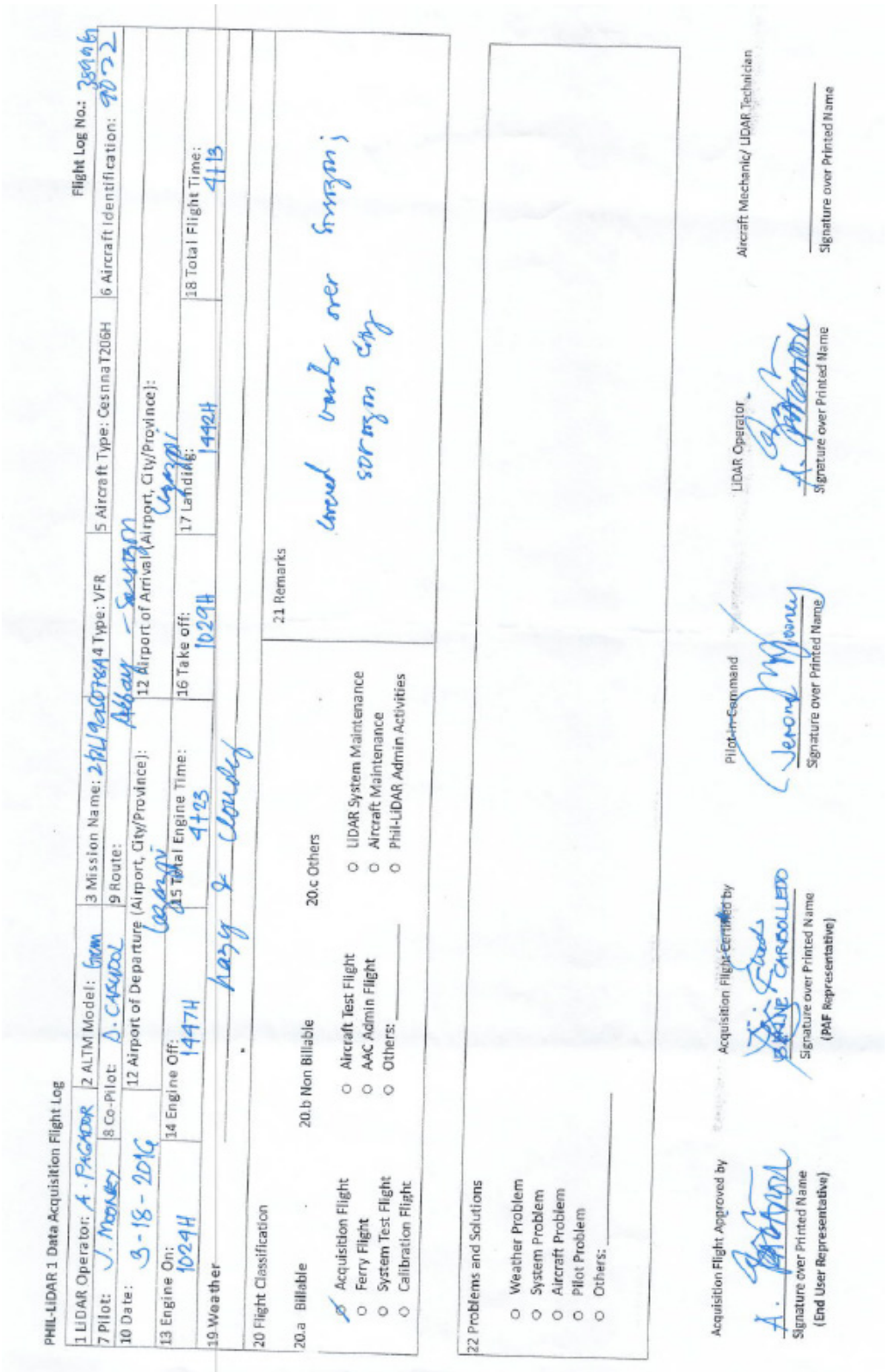
Acquisition Flight Certified by
ENGR. CARDO LLED
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

LIDAR Operator
Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician
Signature over Printed Name

Flight Log for 3899 G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3899G

1 LiDAR Operator: A. PAGADOR	2 ALTM Model: Gem	3 Mission Name: 2BLK74DTSA	4 Type: VFR
5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9032		
7 Pilot: J. Mooney	8 Co-Pilot: D. CASUDAL	9 Route: Abbay – Sorsogon – Cagayan	
10 Date: 3-18-2016	11 Airport of Departure (Airport, City/Province): Cagayan	12 Airport of Arrival (Airport, City/Province): Cagayan	
13 Engine On: 1024H	14 Engine Off: 1447H	15 Total Engine Time: 4+23	16 Take off: 1029H
17 Landing: 1442H	18 Total Flight Time: 4+13		
19 Weather: Hazy & Cloudy			

20 Flight Classification

20.a Billable

- ☑ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks: Acquisition over Sorsogon City

22 Problems and Solutions

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

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

LiDAR Operator

Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician

Signature over Printed Name

Flight Log for 3903 G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3903G

1 LiDAR Operator: I. Paras	2 ALTM Model: Gem	3 Mission Name: 2 BLK65C 079A	4 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Montes	8 Co-Pilot: D. Cabadas	9 Route:			
10 Date: 6 Mar 16	12 Airport of Departure (Airport, City/Province): Legazpi		12 Airport of Arrival (Airport, City/Province): Legazpi		
13 Engine On: 1004 H	14 Engine Off: 1245 H	15 Total Engine Time: 2+41	16 Take off: 1004H	17 Landing: 1345H	18 Total Flight Time: 2+31

19 Weather: Cloudy

20 Flight Classification

20.a Billable

- ☑ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable

- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: _____

20.c Others

- ○ LiDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LiDAR Admin Activities

21 Remarks: Surveyed roads over Sorsogon City and Legazpi City

22 Problems and Solutions

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

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

Signature over Printed Name

LiDAR Operator

I. Paras

Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician

Signature over Printed Name

Acquisition Flight Approved by

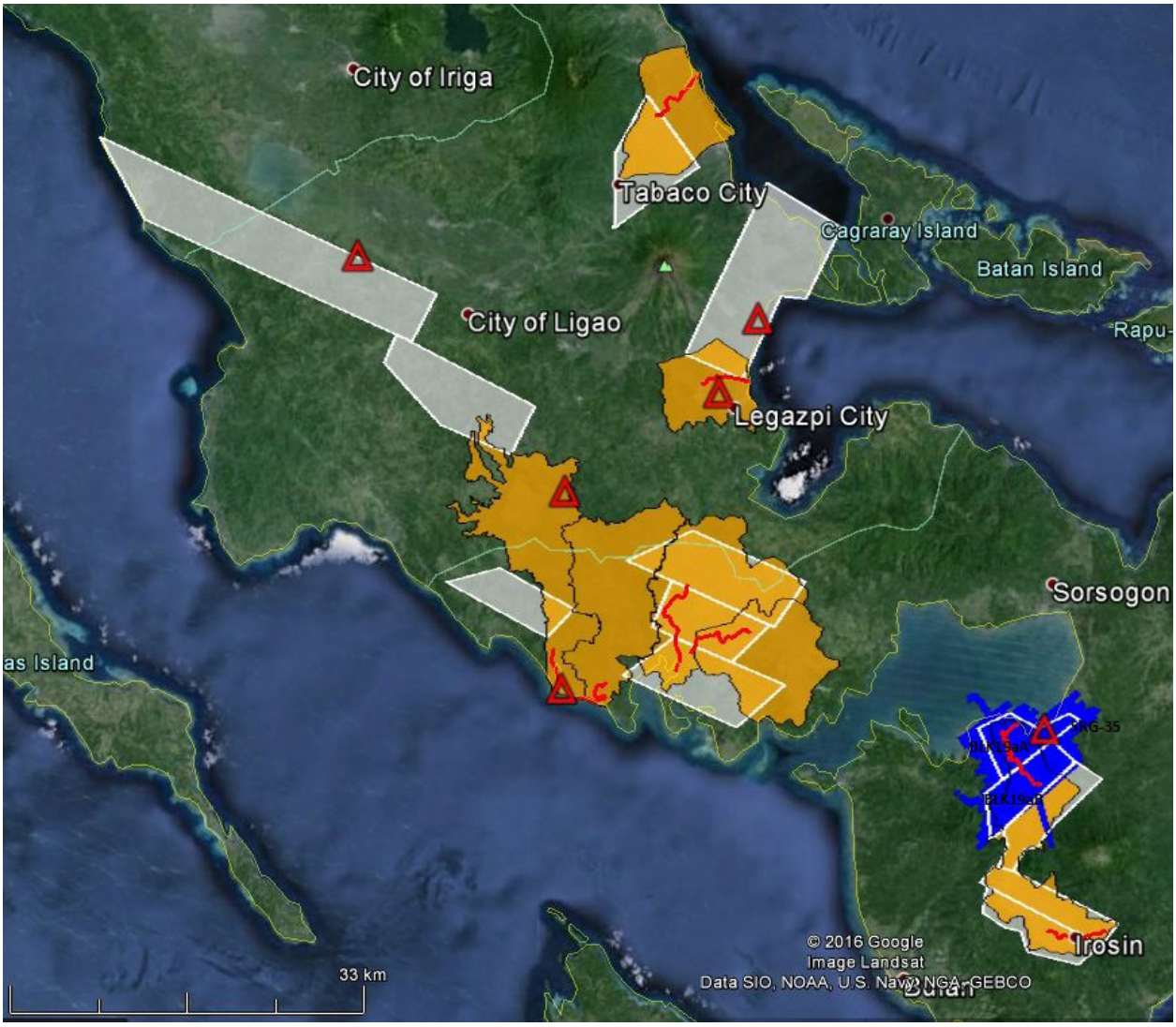
Signature over Printed Name
(End User Representative)

Annex 7. Flight Status Report

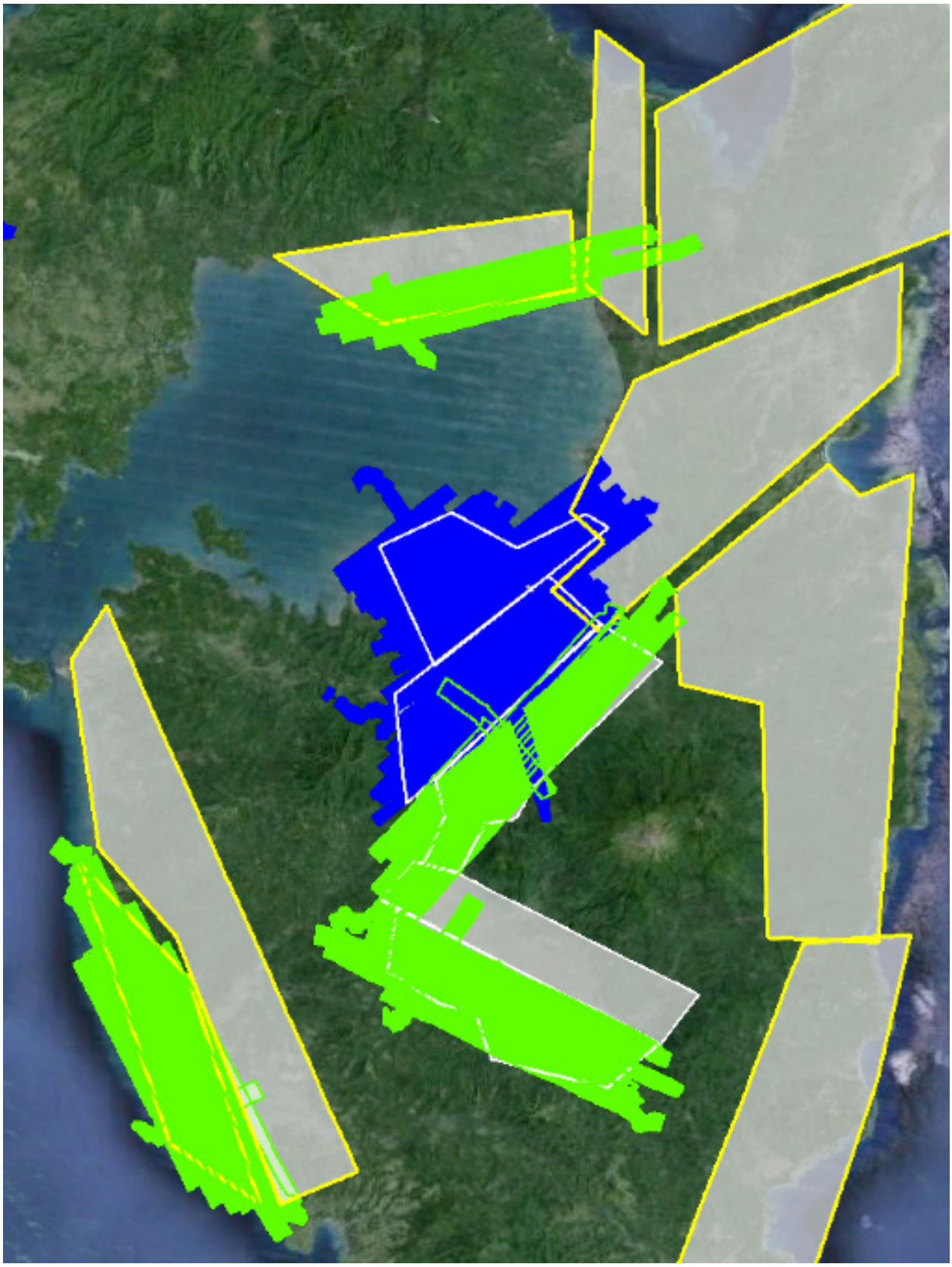
ALBAY AND SORSOGON (February 24 – March 20, 2016)					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
3851G	BLK19AA,BLK19AB, Cadacan	2BLK19aAB066A	M. Reyes	06-Mar-16	Surveyed BLK19AA, BLK19AB
3863G	BLK19aC, E, F, G	2BLK19aCEFG069A (BLK19aBCGI)	I Roxas	09-Mar-16	Covered BLK19aC and G, Completed BLK19aE and F
3871G	BLK19C, E, G, I	2BLK19aCDGI071A	I Roxas	11-Mar-16	Completed BLK19aC, D and I
3873G	BLK19aH	2BLK19aH071B	A Pagador	11-Mar-16	Completed BLK19aH
3879G	BLK19aJ	2BLK19aJ073A	KJ Andaya	13-Mar-16	Covered BLK19aJ
3883G	BLK19aJ, K, M	2BLK19JSKM074A	I Roxas	14-Mar-16	Completed BLK19aJ, covered BLK19aK and M
3885G	BLK19AK, M	2BLK19aKSMS074B	A Pagador	14-Mar-16	Completed BLK19aM, covered BLK19aK
3887G	BLK19aK, L	2BLK19aKLS075A	I Roxas	15-Mar-16	Covered BLK19aK and L
3889G	BLK19AK, L	2BLK19aKSLS075B	KJ Andaya	15-Mar-16	Completed BLK19aK and L
3899G	VOIDS (BLK19a)	2BLK19aS078A (BLK19aON)	A Pagador	18-Mar-16	Covered gap between BLK19aC and BLK19aK; surveyed Sorsogon City
3903G	VOIDS (BLK19A and BLK19a)	2BLK19S079A (BLK19ASM)	I Roxas	19-Mar-16	Covered gap over Cadacan river basin then voids in Daraga river basin

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

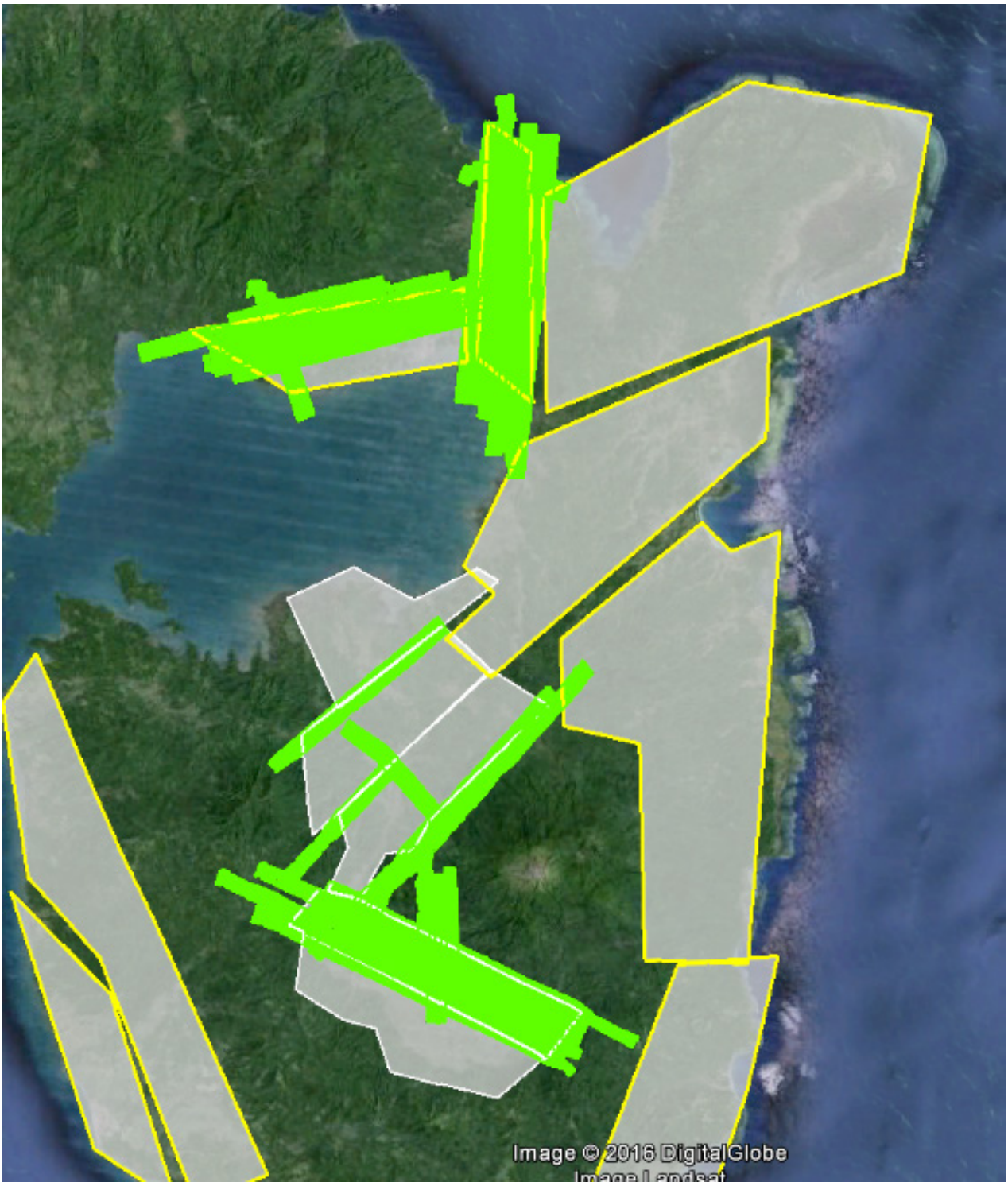
Flight No. : 3851G
Area: BLK19aA, BLK19AB
Mission Name: 2BLK19AAB066A
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 750 m



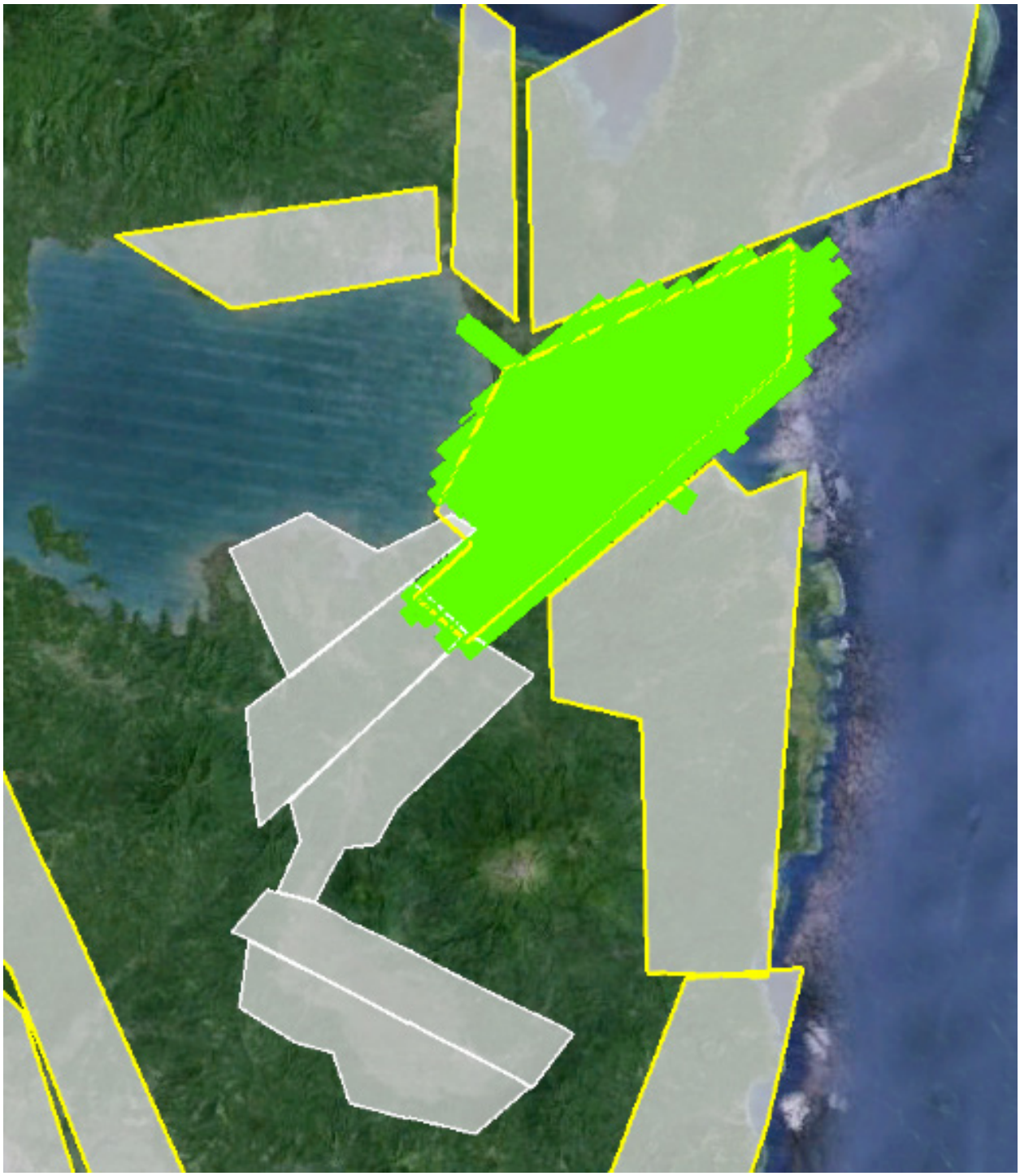
Flight No.: 3863P
Area: BLK19aCEFG
Mission Name: 2BLK19aCEFG069A
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 900 m



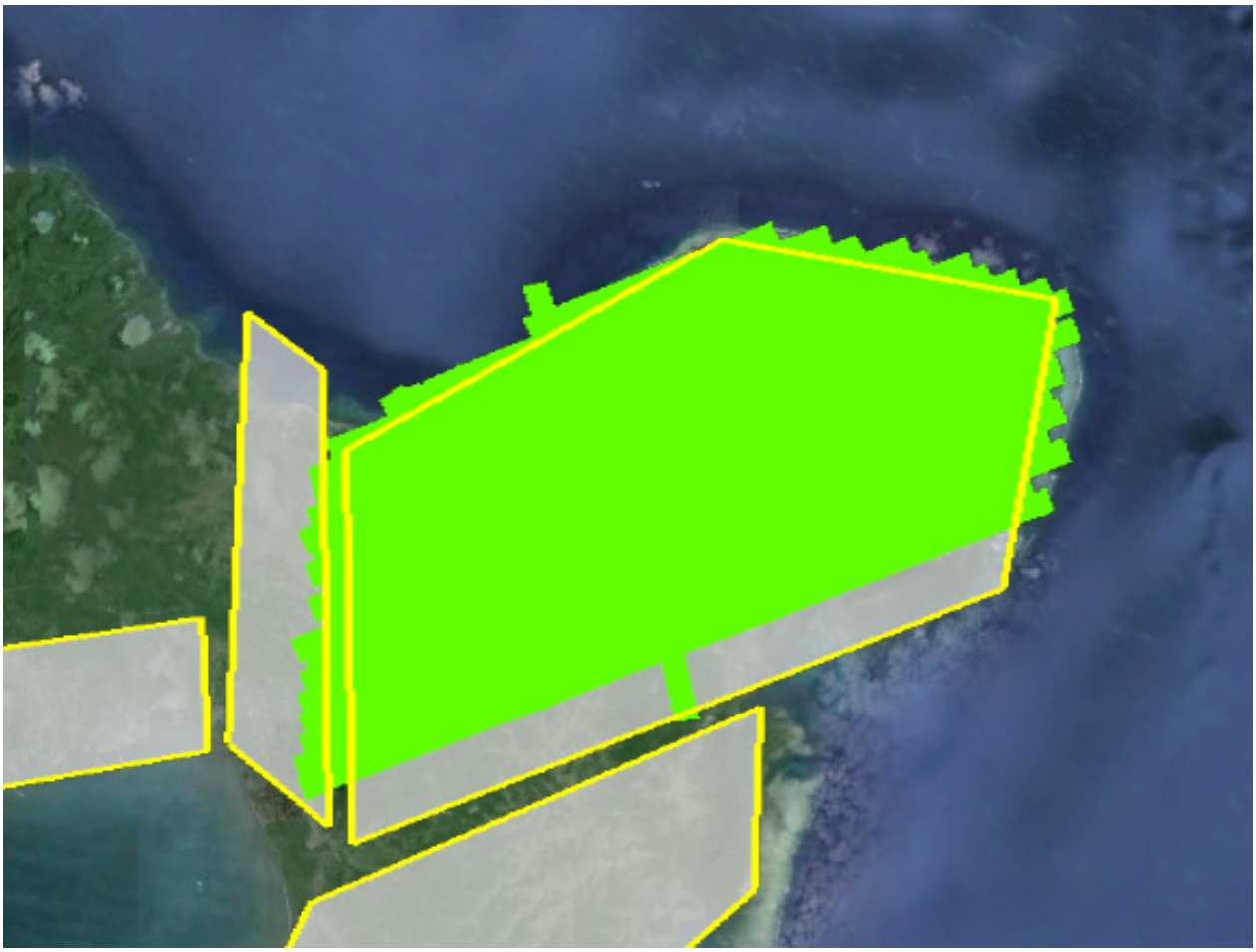
Flight No.: 3871P
Area: BLK19aCDI (BLK19aBCGI)
Mission Name: 2BLK19aCDGI071A
Parameters: PRF 100 SF 50 FOV 40
Flying Height: 1000 m
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 850 m



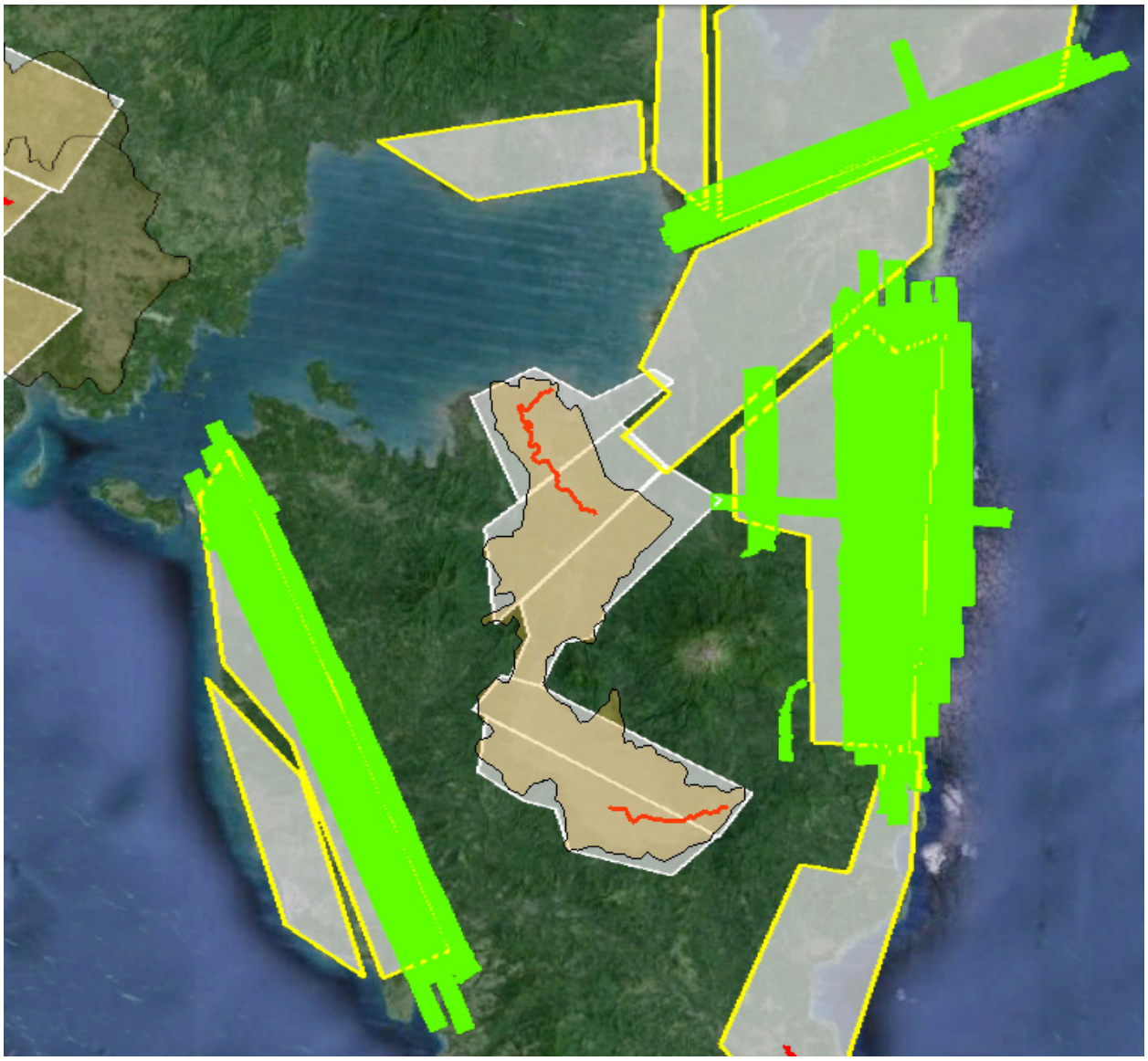
Flight No.: 3873P
Area: BLK19aH
Mission Name: 2BLK19aH071B
Parameters: PRF 100 SF 50 FOV 40
Flying Height: 1000 m



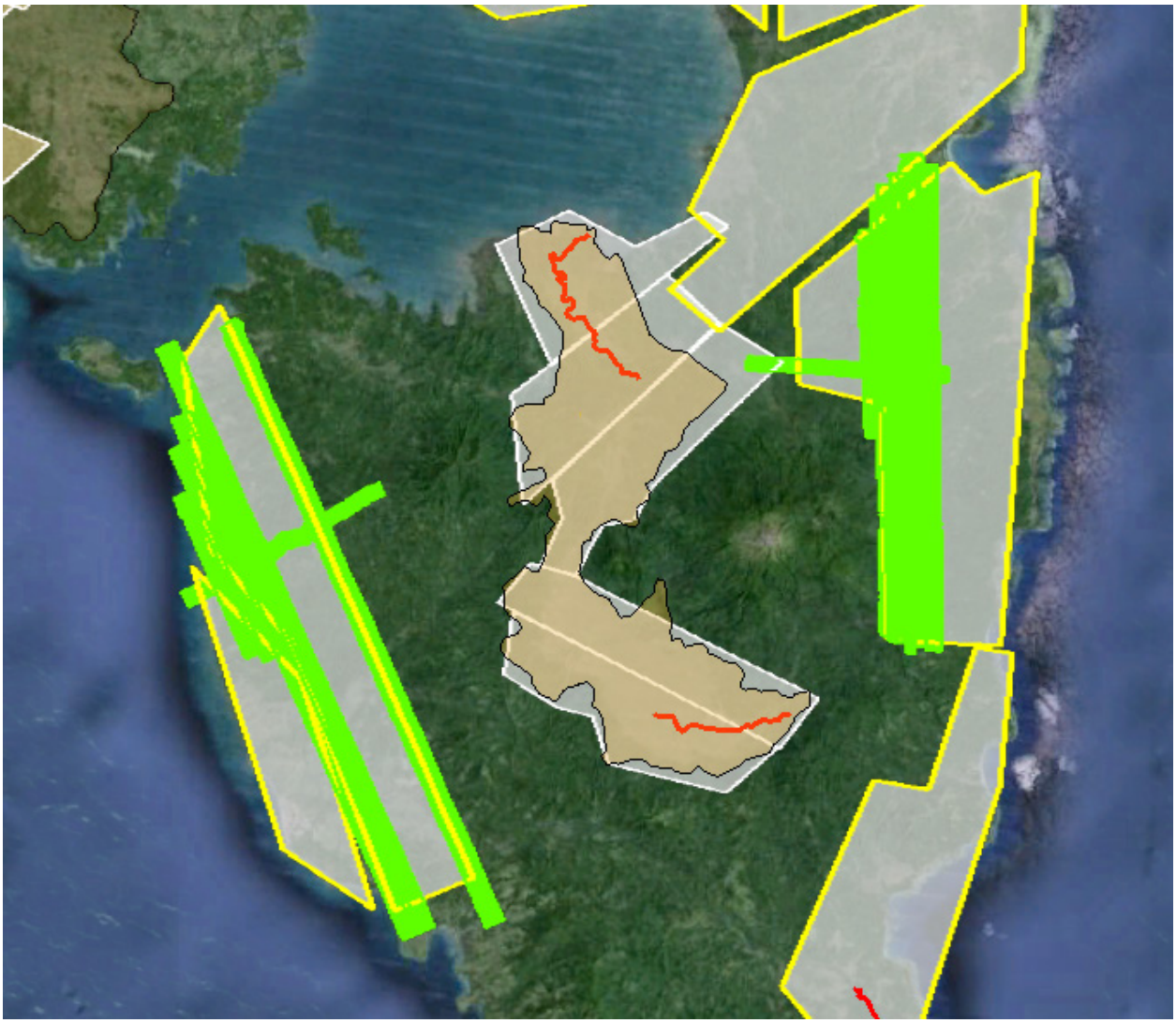
Flight No.: 3879G
Area: BLK19aJ
Mission Name: 2BLK19aJ073A
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 750 m



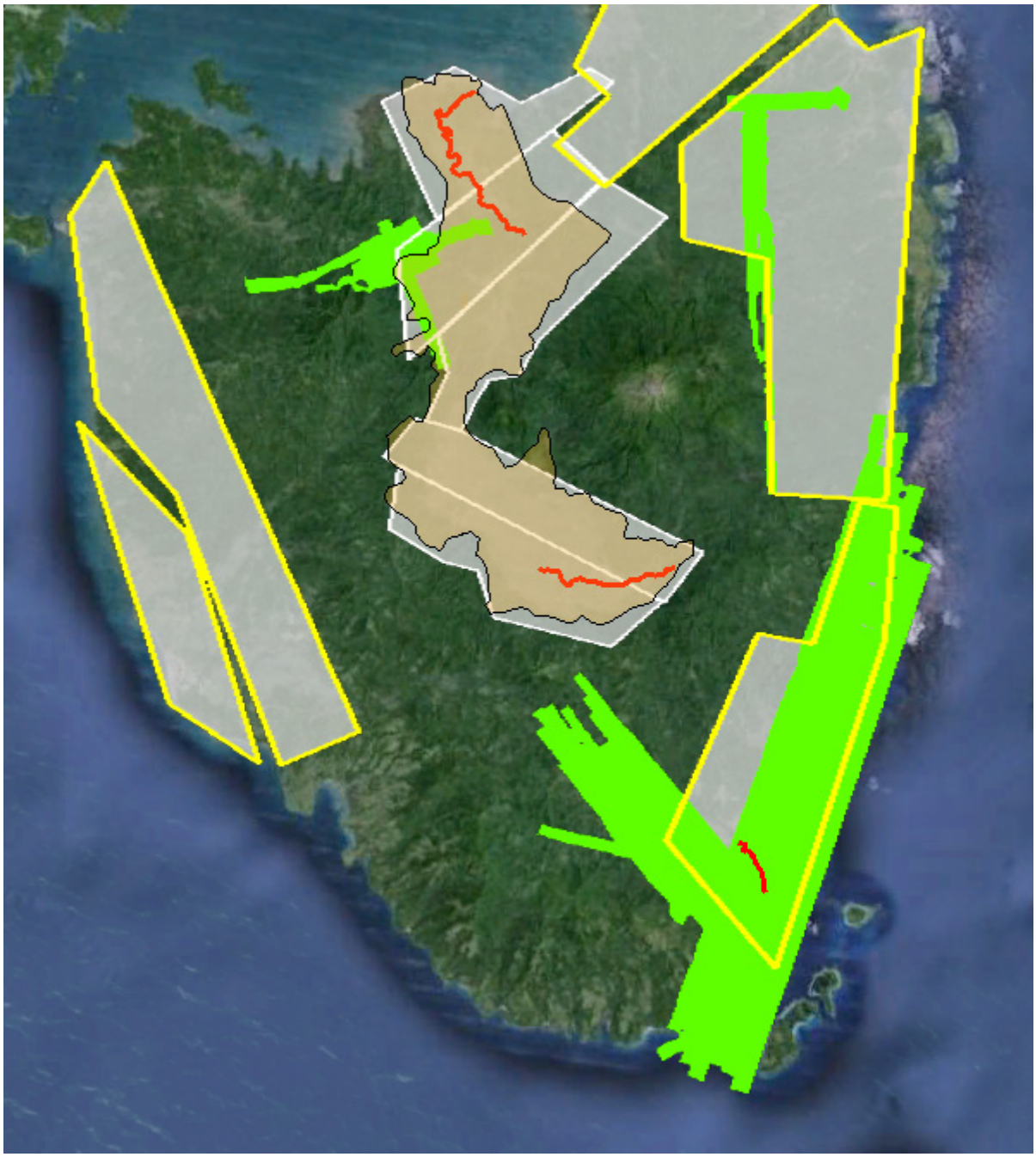
Flight No.: 3883G
Area: BLK19AJ, K and M
Mission Name: 2BLK19JSKM074A
Parameters: PRF 100 SF 50 FOV 40
Flying Height: 1000 and 800 m



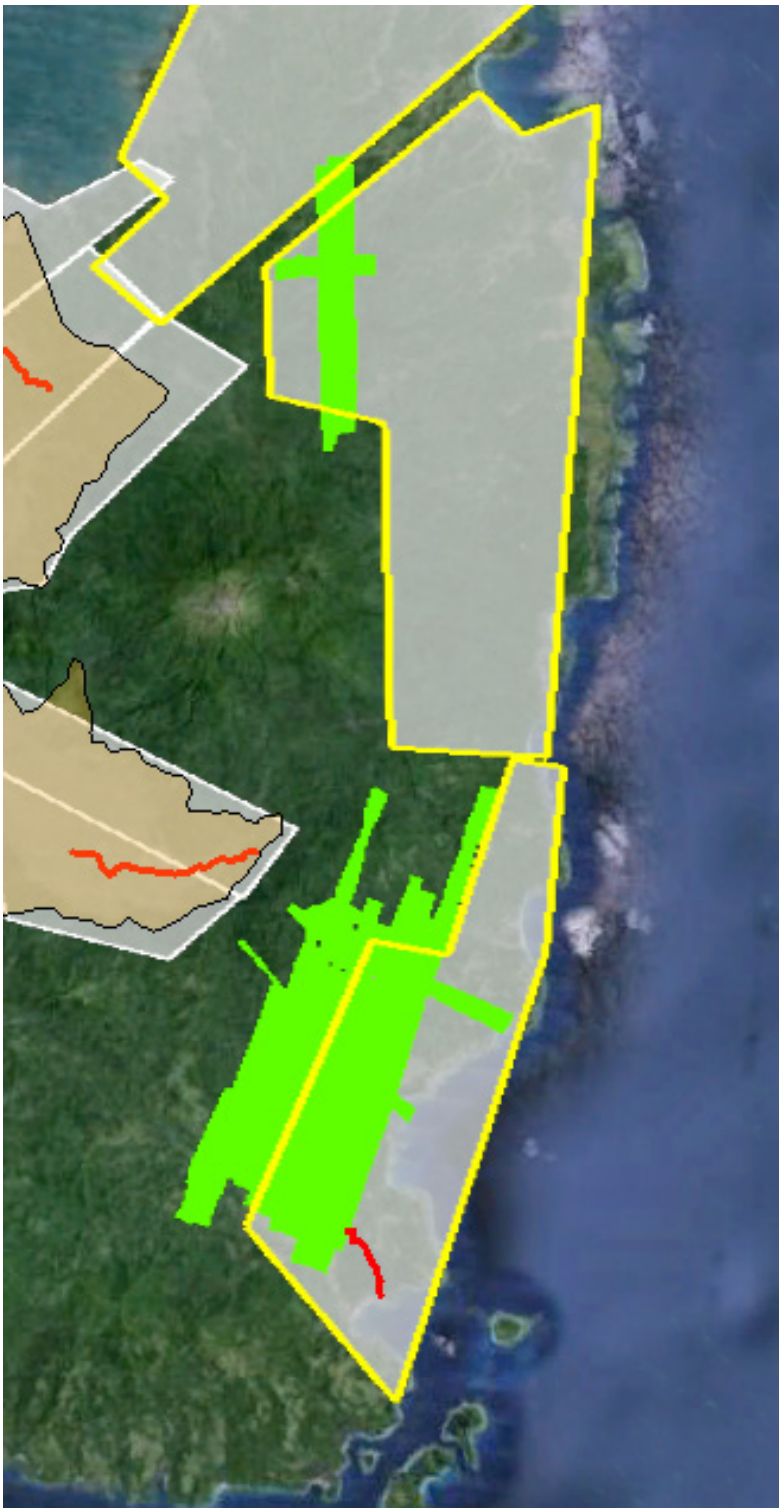
Flight No.: 3885G
Area: BLK19AK, M, S
Mission Name: 2BLK19aKSMS074B
Parameters: PRF 100 SF 50 FOV 40
Flying Height: 750 and 900 m



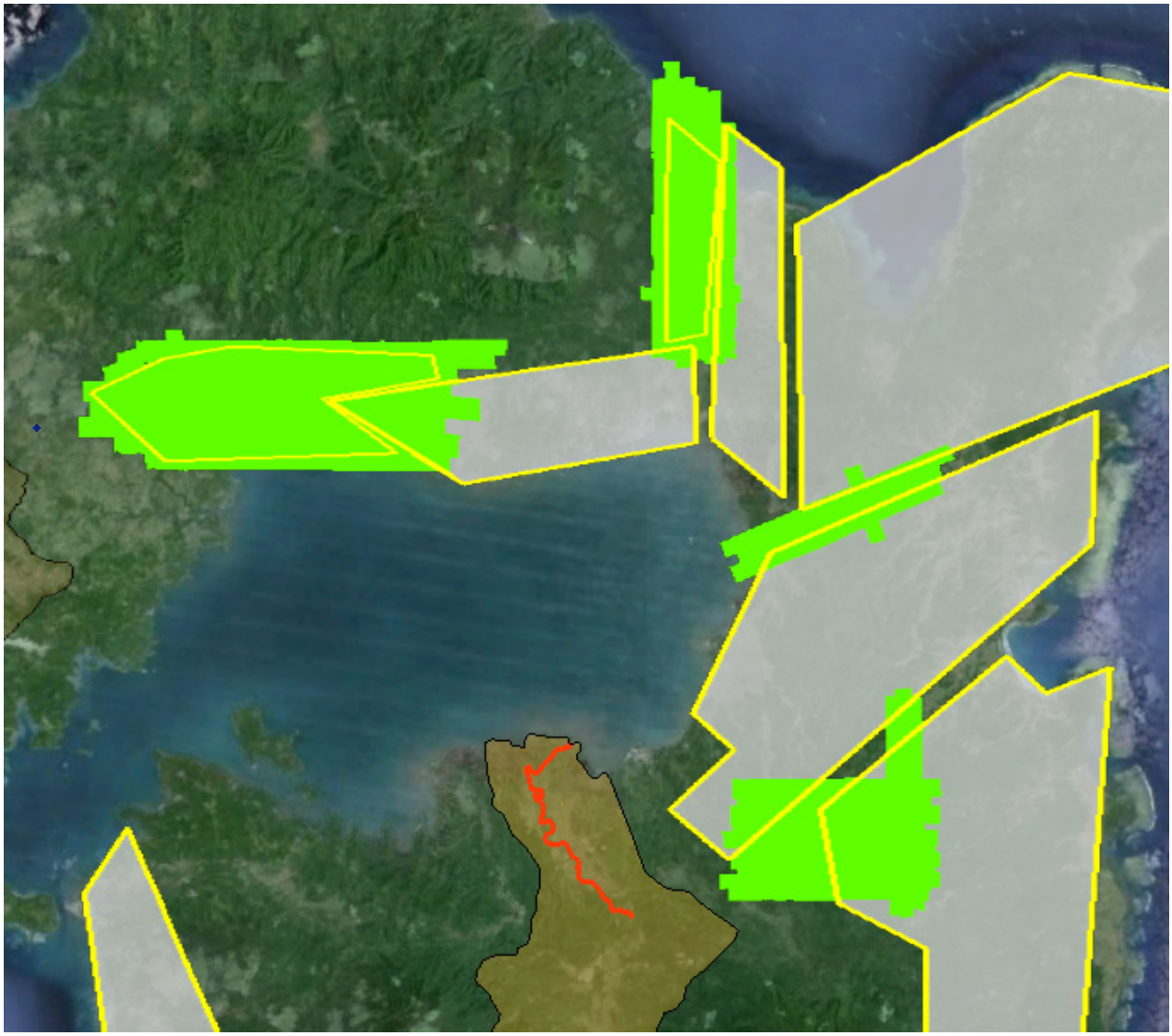
Flight No.: 3887G
Area: BLK19AK, L
Mission Name: 2BLK19aKLS075A
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 600 and 900 m



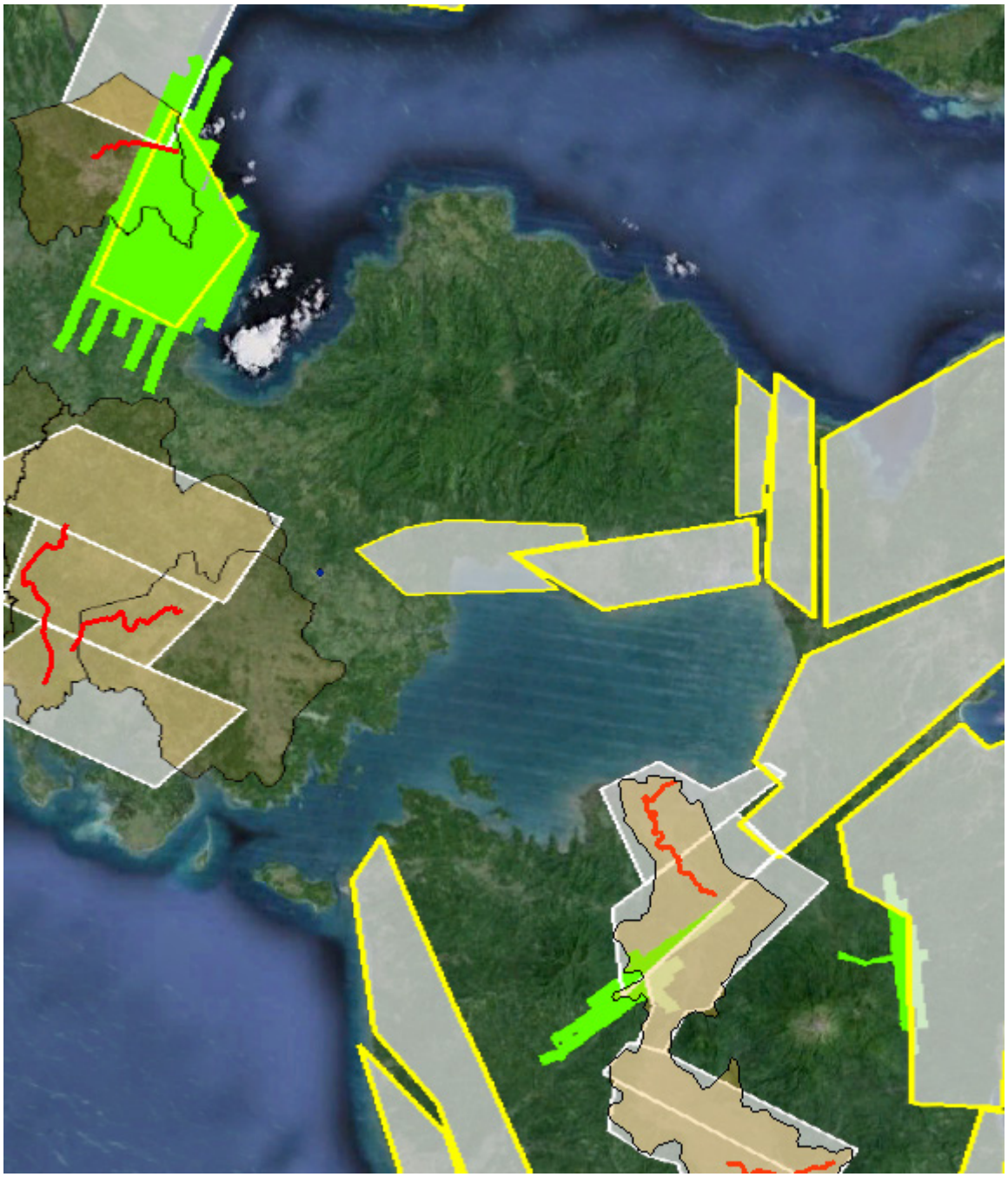
Flight No.: 3889G
Area: BLK19aK, L
Mission Name: 2BLK19aKSLS075B
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 900 and 550 m



FLIGHT NO.: 3899G
AREA: BLK19aS covered gap between BLK19aC and BLK19aK; surveyed Sorsogon City (BLK19aON)
MISSION NAME: 2BLK19aS078A
Parameters: PRF 125 SF 40 FOV 50
Flying Height: 650 m
Parameters: PRF 142 SF 40 FOV 50
Flying Height: 850 m



FLIGHT NO.: 3903G
AREA: BLK19ASM
MISSION NAME: 2BLK19S079A
Parameters: PRF 142 SF 40 FOV 50
Flying Height: 850 m



Annex 8. Mission Summary Report

Flight Area	**Albay_Sorsogon_reflights**
Mission Name	Blk 19aG
Inclusive Flights	3871G
Range data size	23.9 GB
POS data size	279 MB
Base data size	18.8 MB
Image	45.5 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.250
RMSE for East Position (<4.0 cm)	1.325
RMSE for Down Position (<8.0 cm)	6.90
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	16.81 %
Ave point cloud density per sq.m. (>2.0)	3.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	55
Maximum Height	222.62 m
Minimum Height	52.80 m
Classification (# of points)	
Ground	11,724,094
Low vegetation	10,646,962
Medium vegetation	49,065,531
High vegetation	30,017,927
Building	514,648
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Melanie Hingpit, Tam

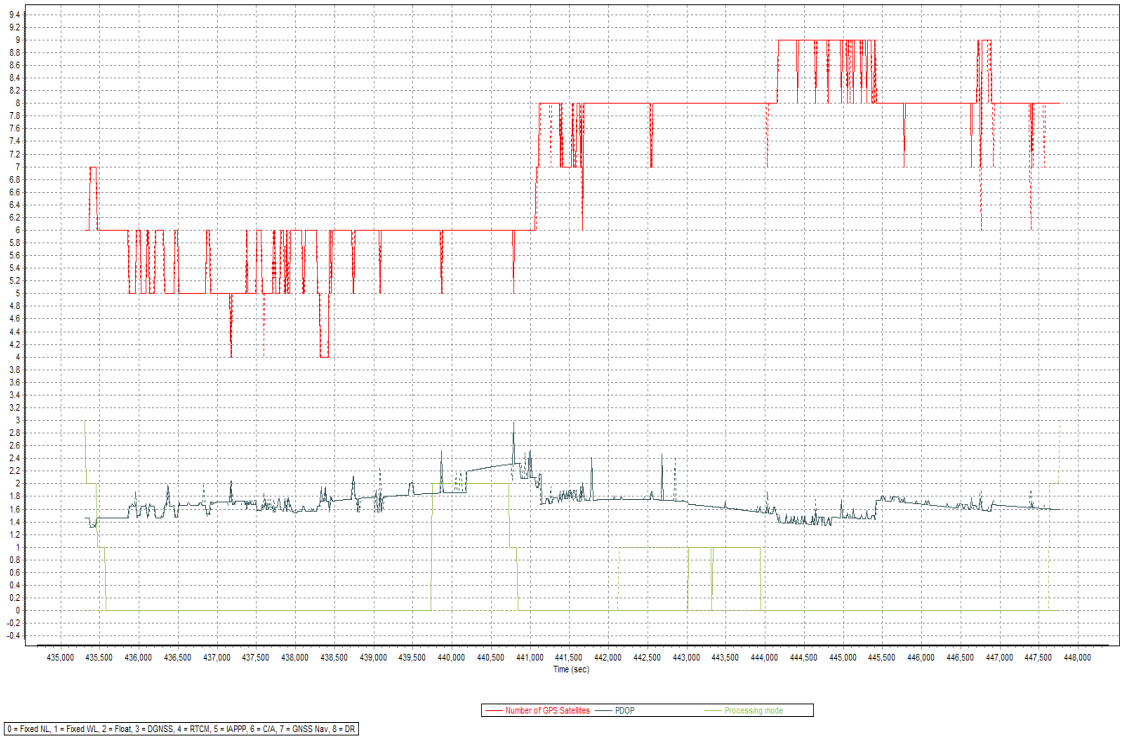


Figure 1.1.1. Solution Status

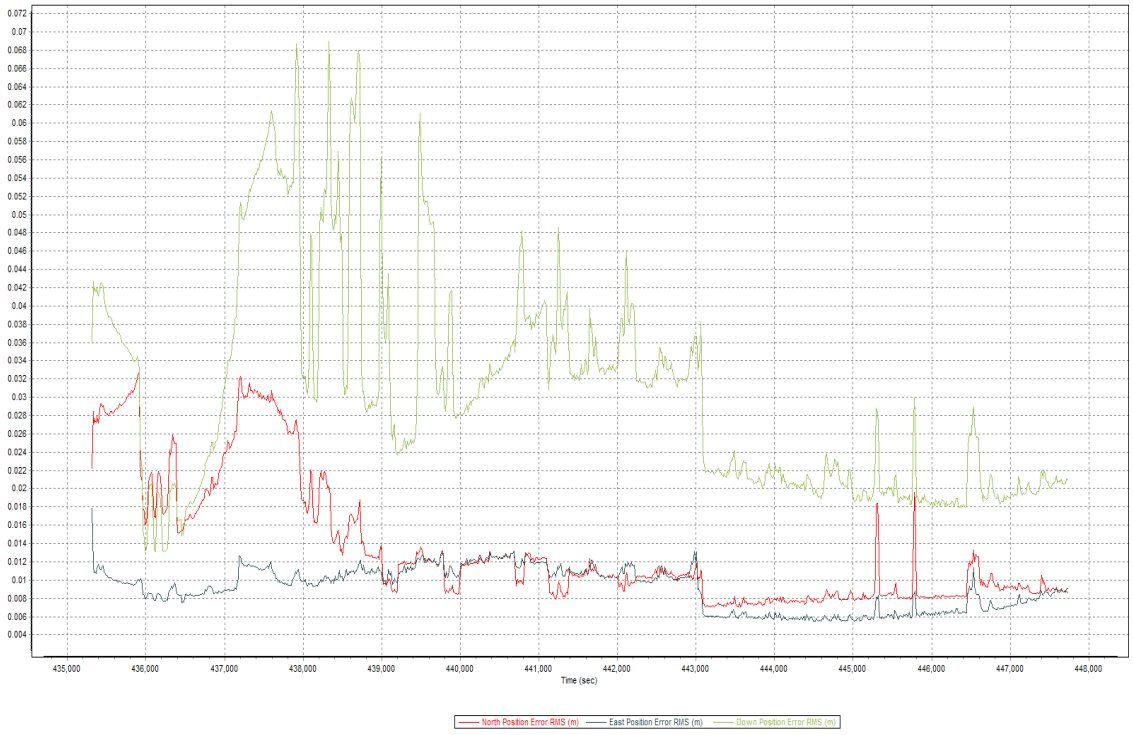


Figure 1.1.2. Smoothed Performance Metric Parameters

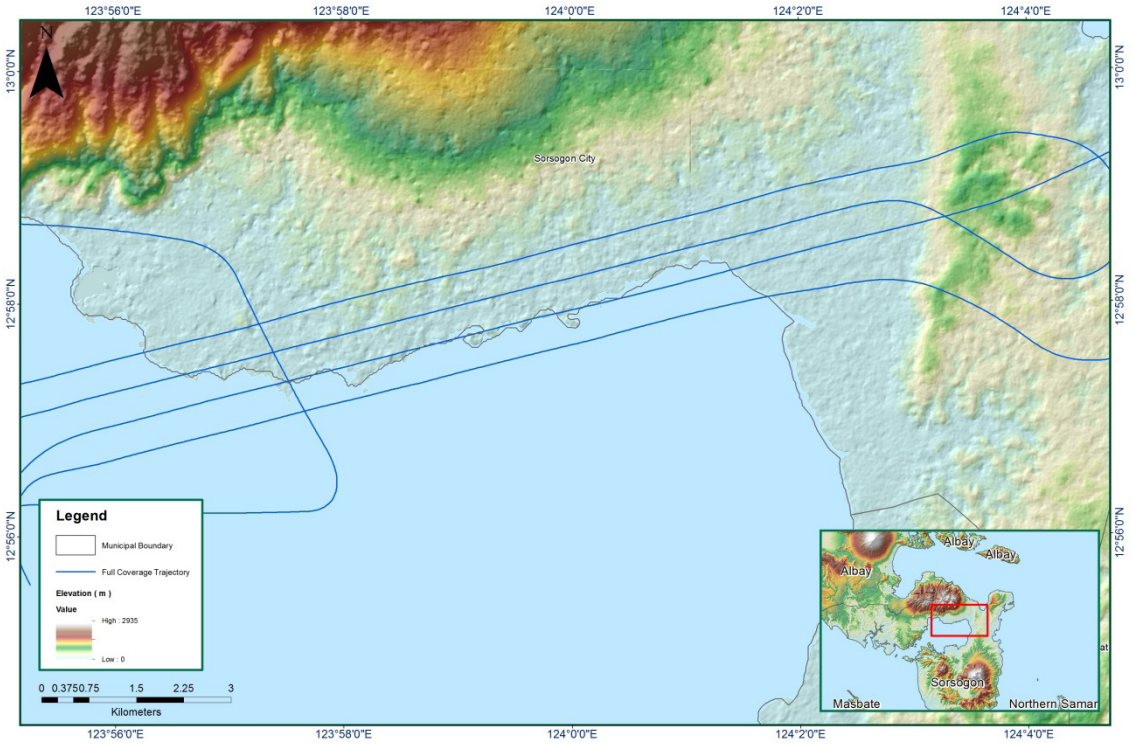


Figure 1.1.3. Best Estimated Trajectory

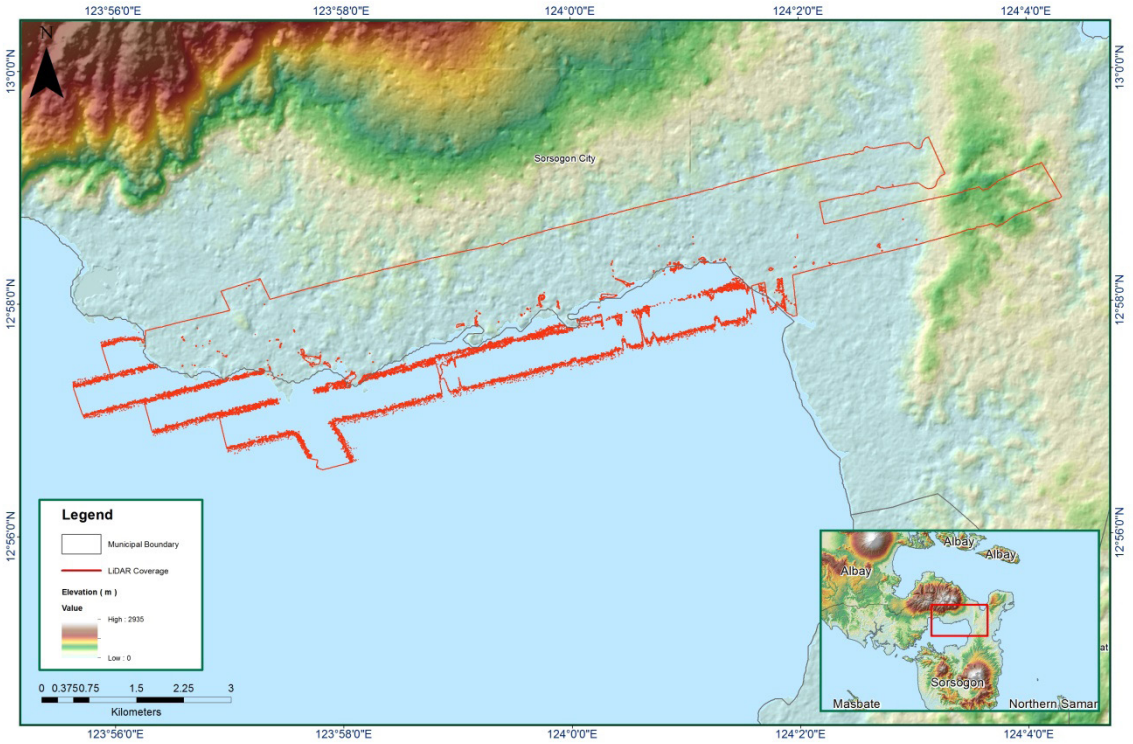


Figure 1.1.4. Coverage of LiDAR Data

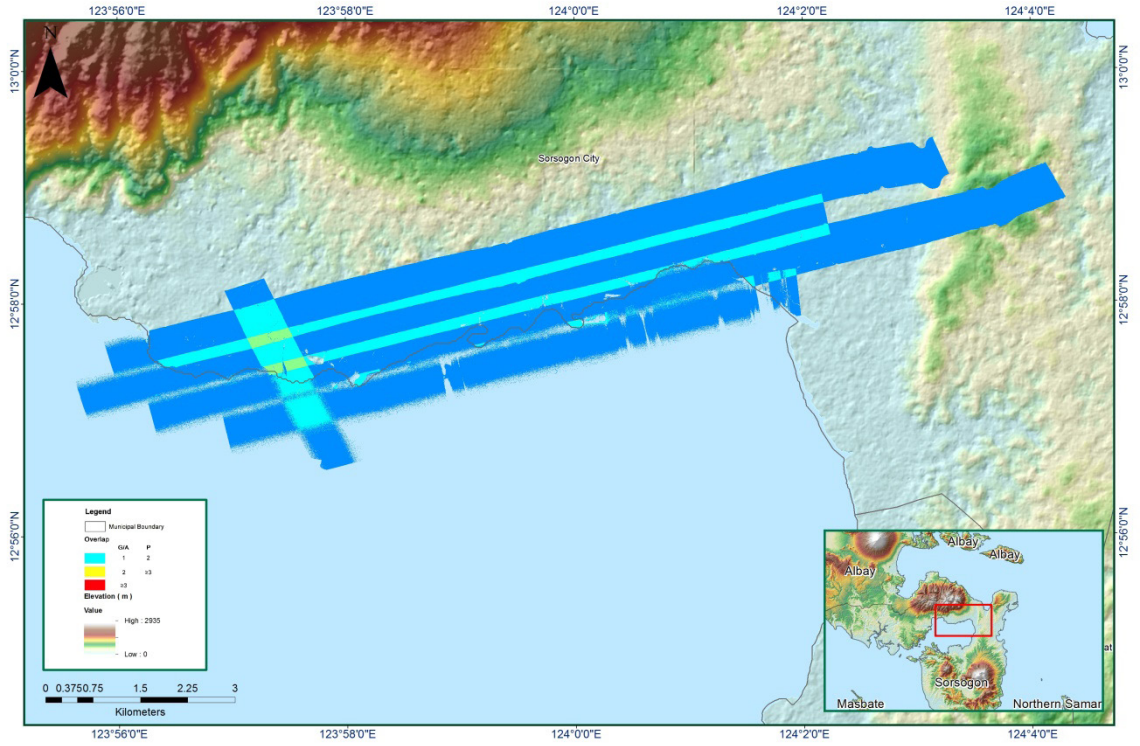


Figure 1.1.5. Image of data overlap

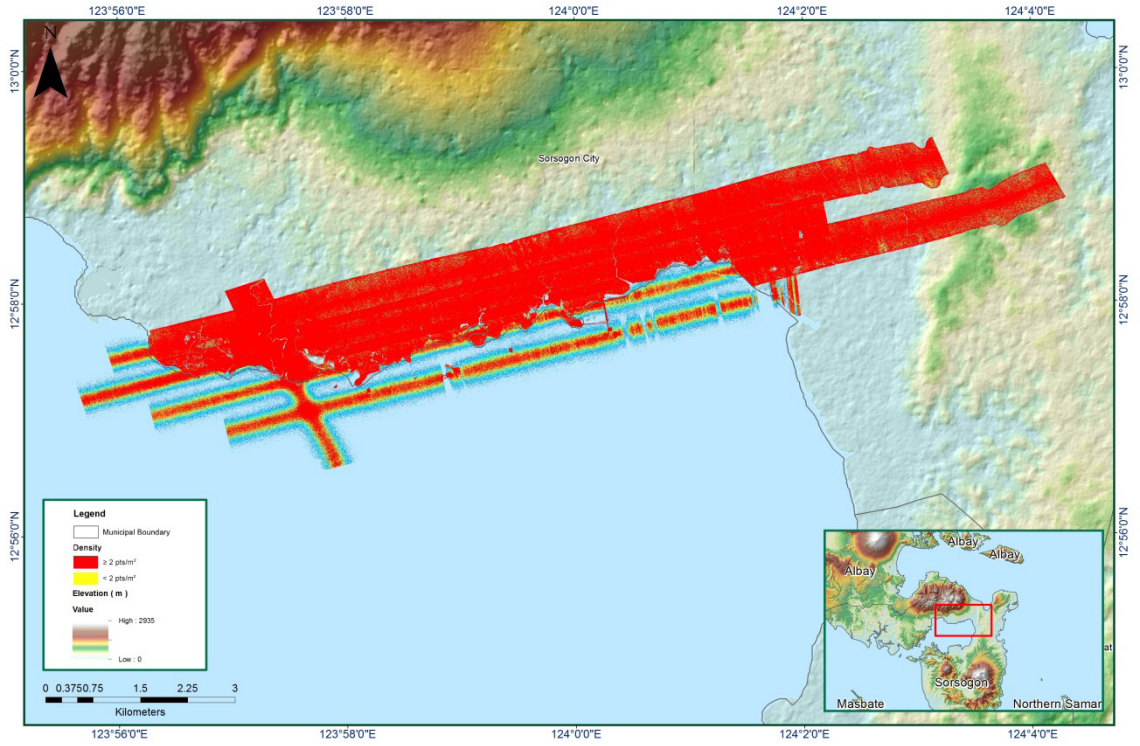


Figure 1.1.6. Density map of merged LiDAR data

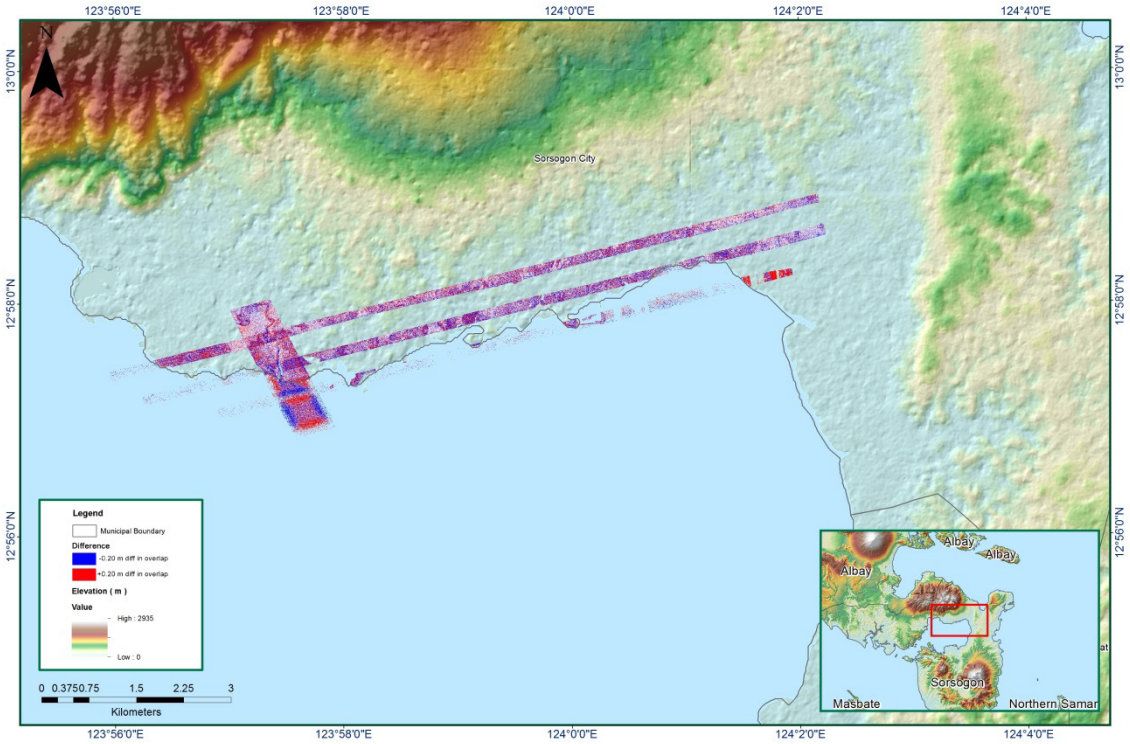


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19R_supplement
Inclusive Flights	3871G, 3887G
Range data size	51.8 GB
POS data size	550 MB
Base data size	36.6 MB
Image	106.4 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.30
RMSE for East Position (<4.0 cm)	5.30
RMSE for Down Position (<8.0 cm)	10.20
Boresight correction stdev (<0.001deg)	0.006487
IMU attitude correction stdev (<0.001deg)	0.980477
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	20.40 %
Ave point cloud density per sq.m. (>2.0)	5.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	41
Maximum Height	595.80 m
Minimum Height	55.98 m
Classification (# of points)	
Ground	9,300,247
Low vegetation	4,135,689
Medium vegetation	31,733,291
High vegetation	37,142,128
Building	63,832
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Edgardo Gubatanga, Engr. Czarina Jean Anoñuevo

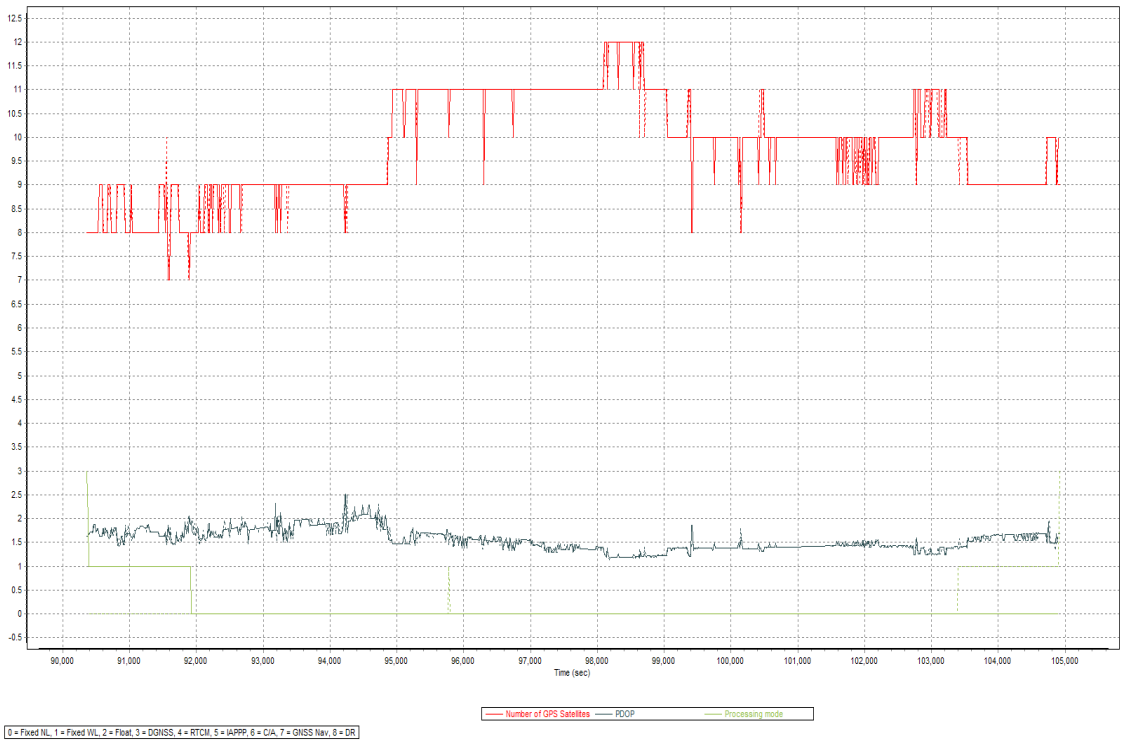


Figure 1.2.1. Solution Status

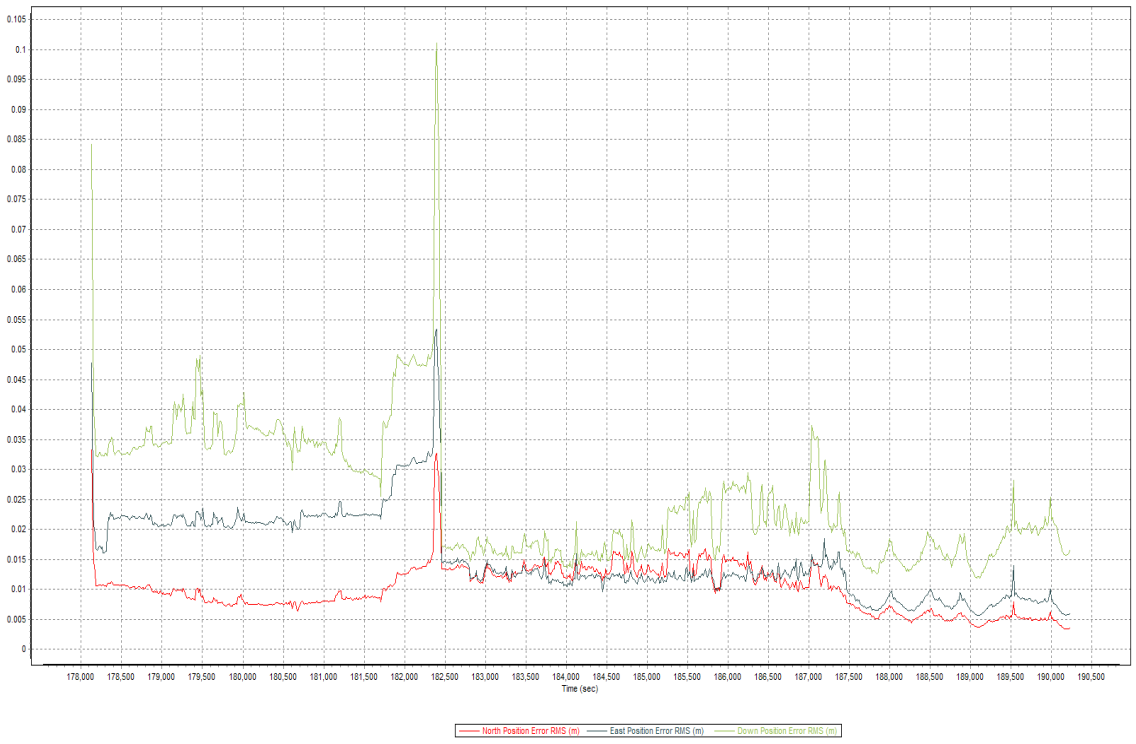


Figure 1.2.2. Smoothed Performance Metric Parameters

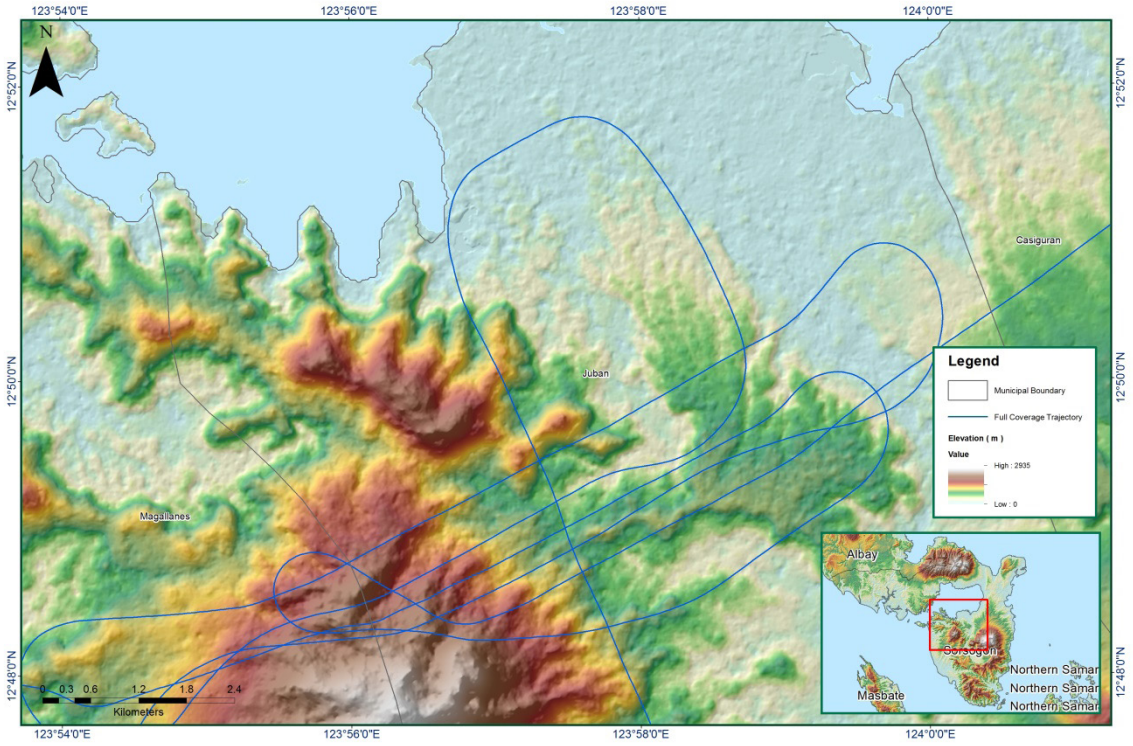


Figure 1.2.3. Best Estimated Trajectory

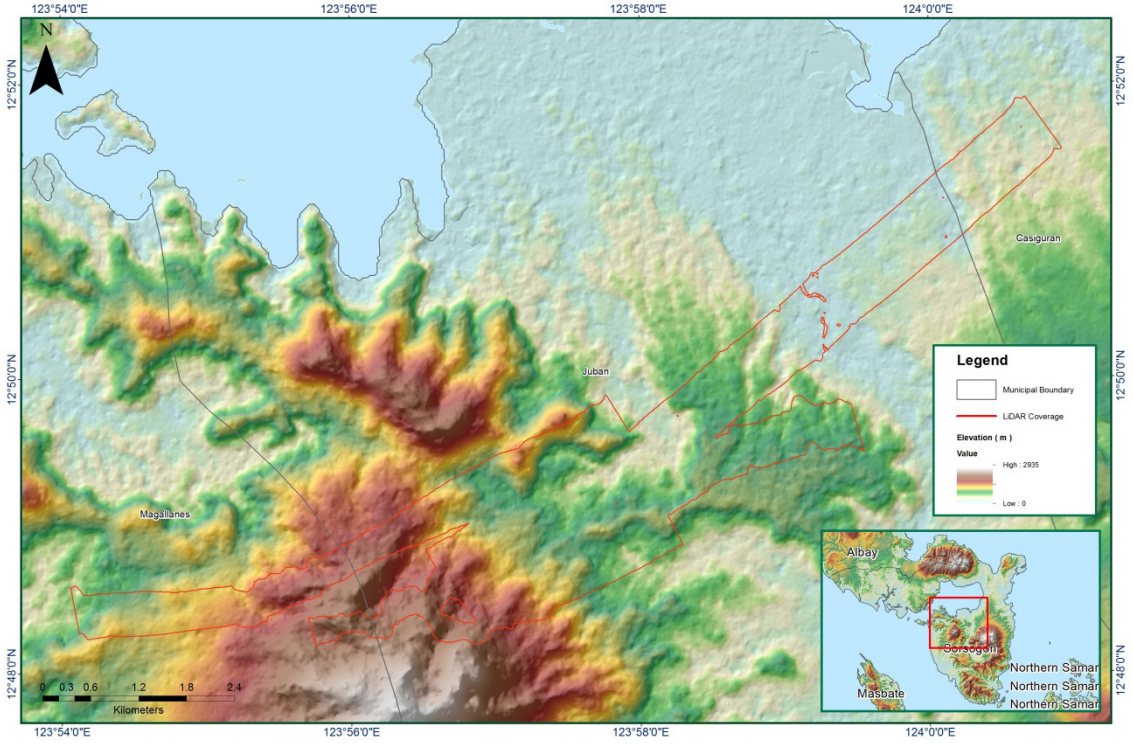


Figure 1.2.4. Coverage of LiDAR Data

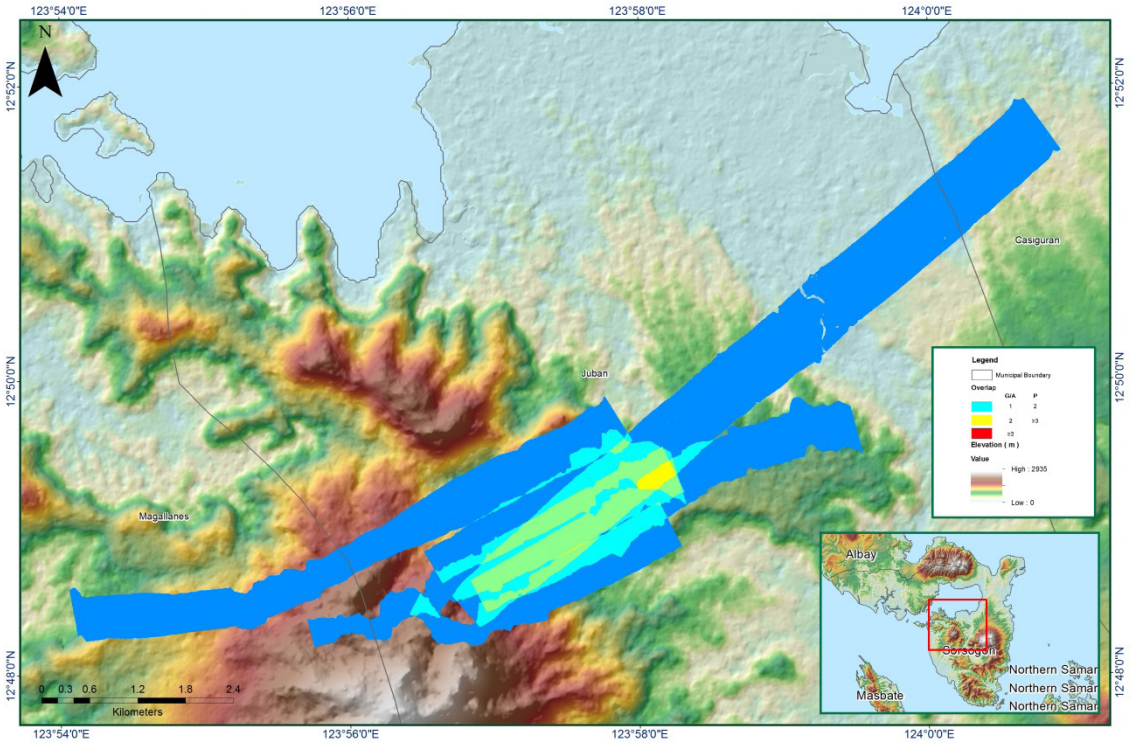


Figure 1.2.5. Image of data overlap

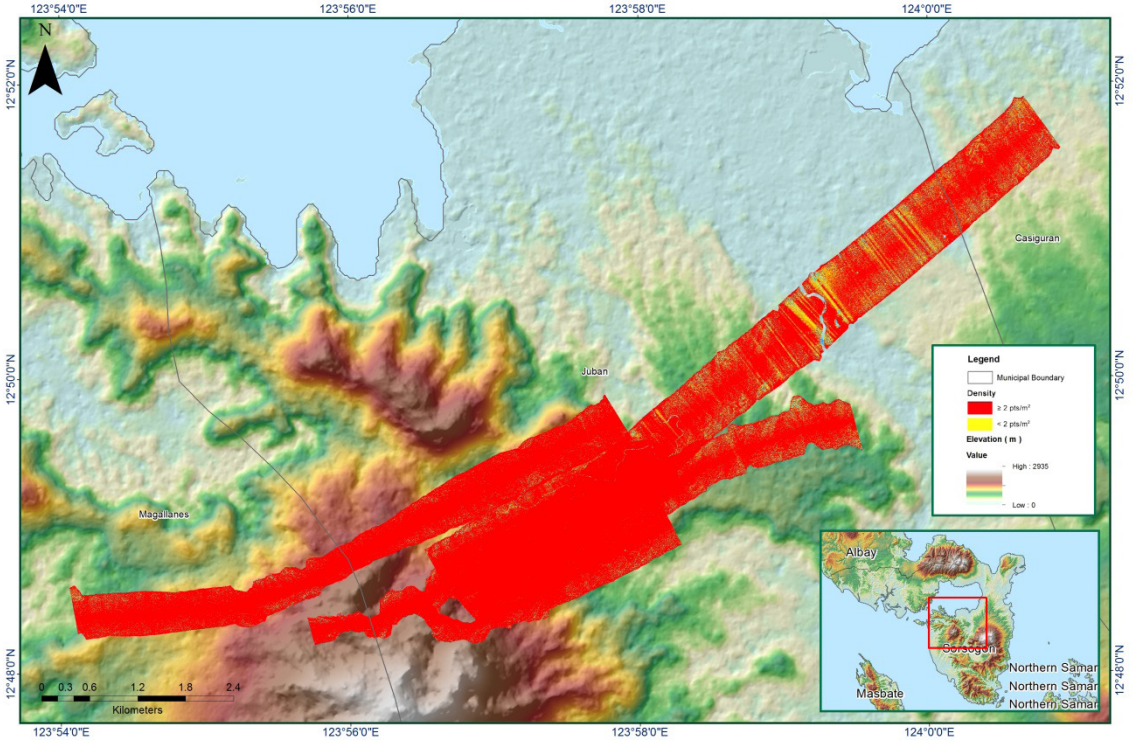


Figure 1.2.6. Density map of merged LiDAR data

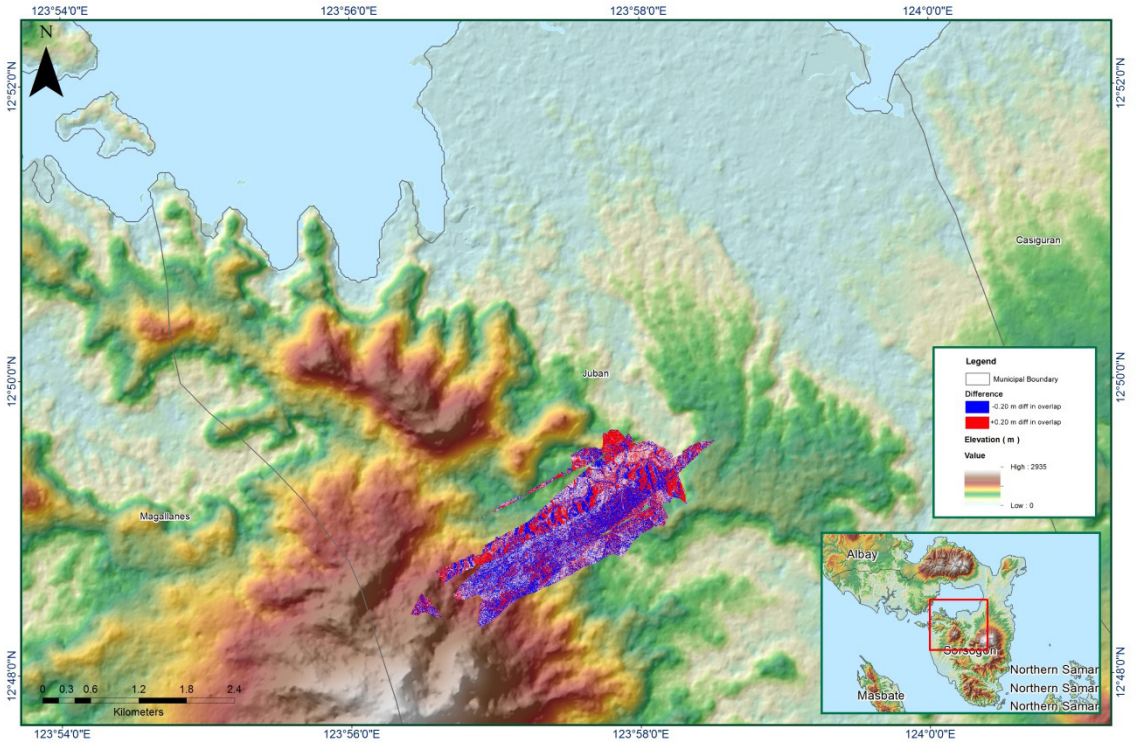


Figure 1.2.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19R
Inclusive Flights	3851G
Range data size	16 GB
POS data size	183 MB
Base data size	4.19 MB
Image	28.7 MB
Transfer date	March 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.954
RMSE for East Position (<4.0 cm)	1.210
RMSE for Down Position (<8.0 cm)	3.550
Boresight correction stdev (<0.001deg)	0.016345
IMU attitude correction stdev (<0.001deg)	0.242007
GPS position stdev (<0.01m)	0.0215
Minimum % overlap (>25)	41.52 %
Ave point cloud density per sq.m. (>2.0)	5.03
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	127
Maximum Height	486.27 m
Minimum Height	52.95 m
Classification (# of points)	
Ground	49,123,751
Low vegetation	28,413,489
Medium vegetation	189,177,450
High vegetation	149,332,191
Building	200,128
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga, Tam

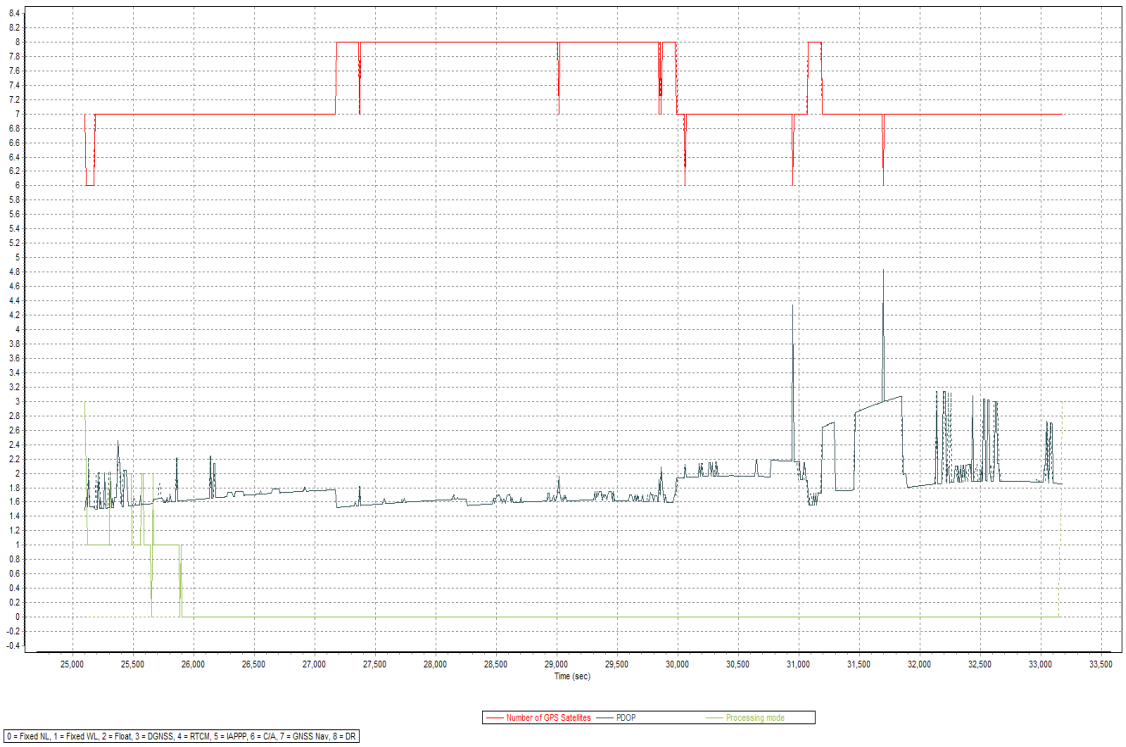


Figure 1.3.1. Solution Status

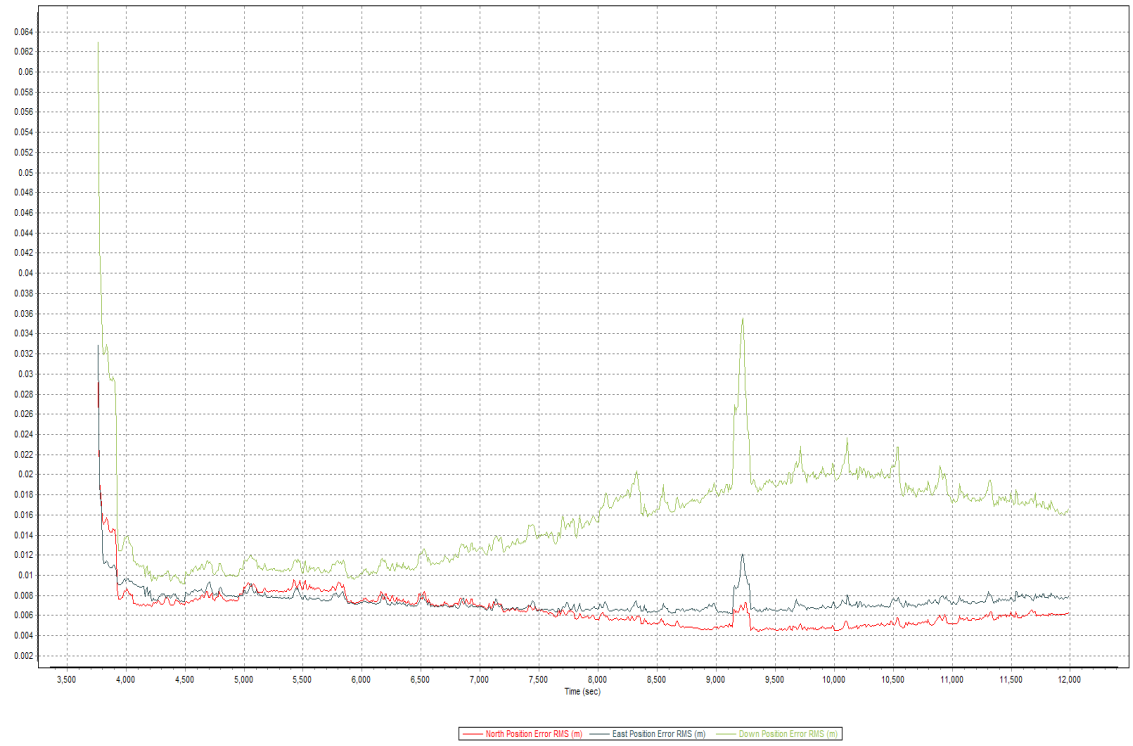


Figure 1.3.2. Smoothed Performance Metric Parameters

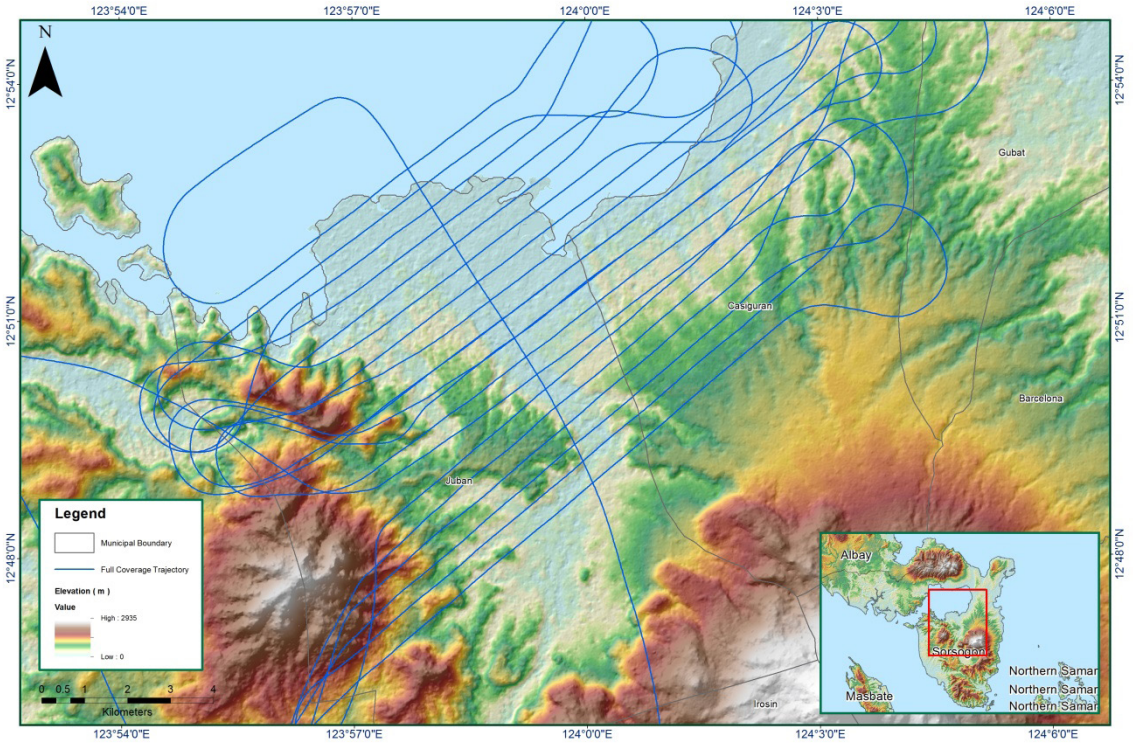


Figure 1.3.3. Best Estimated Trajectory

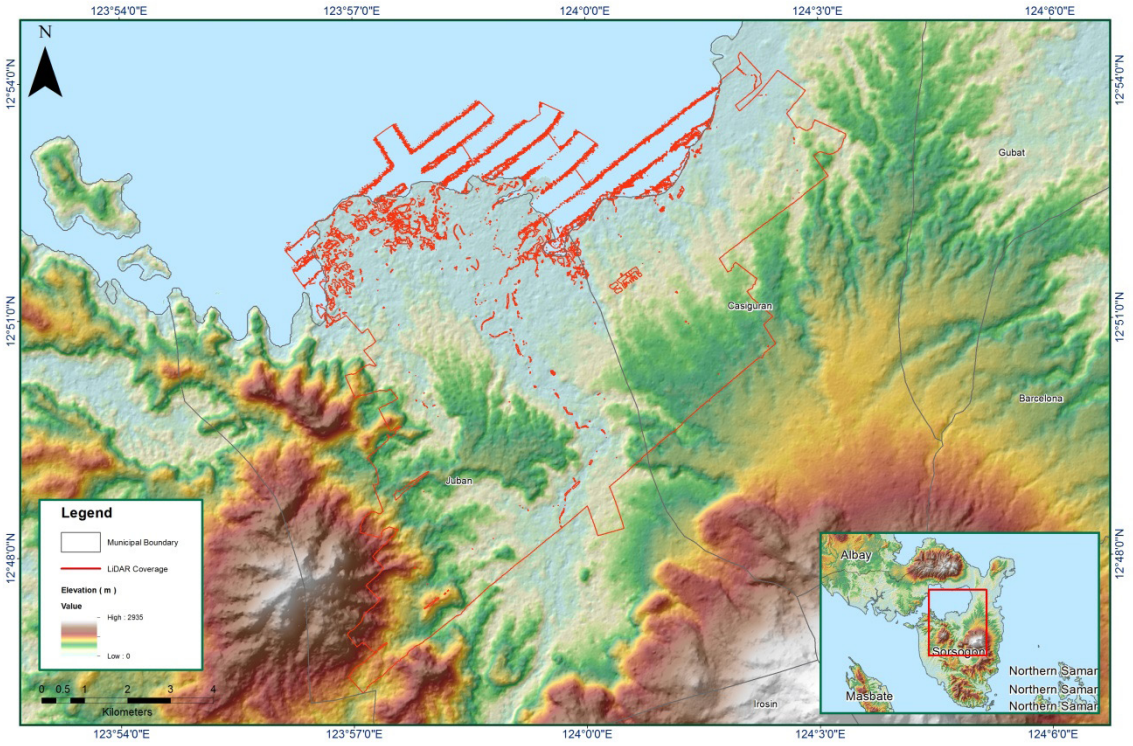


Figure 1.3.4. Coverage of LiDAR Data

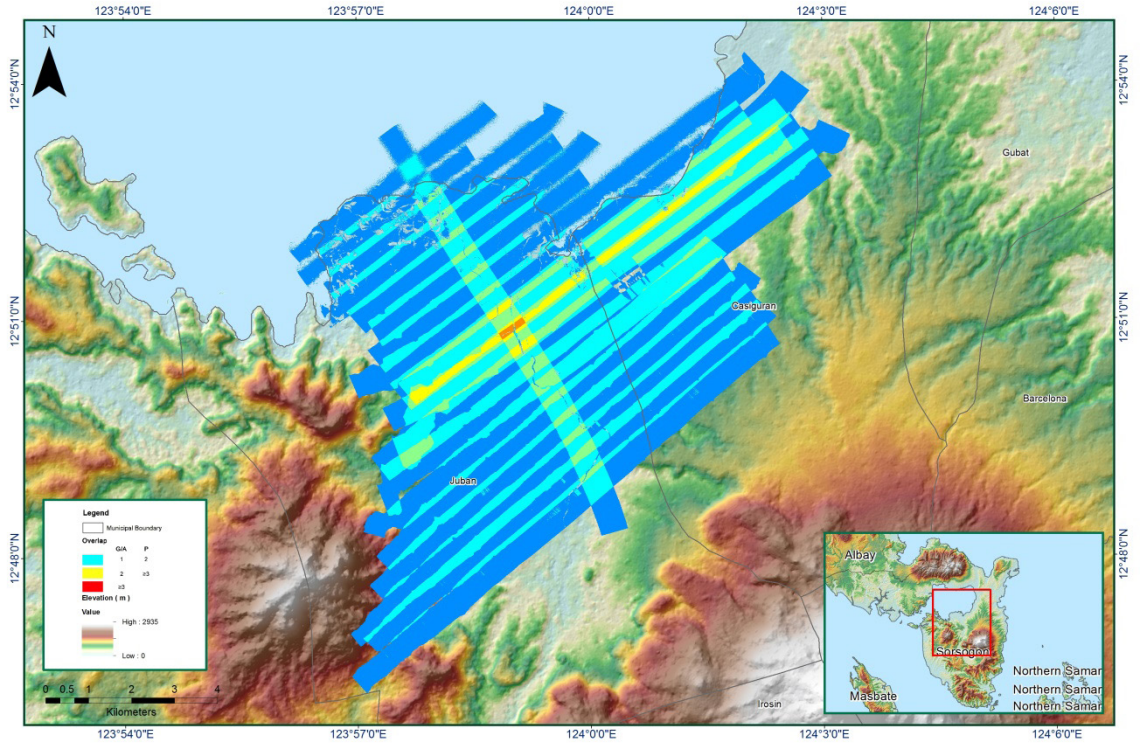


Figure 1.3.5. Image of data overlap

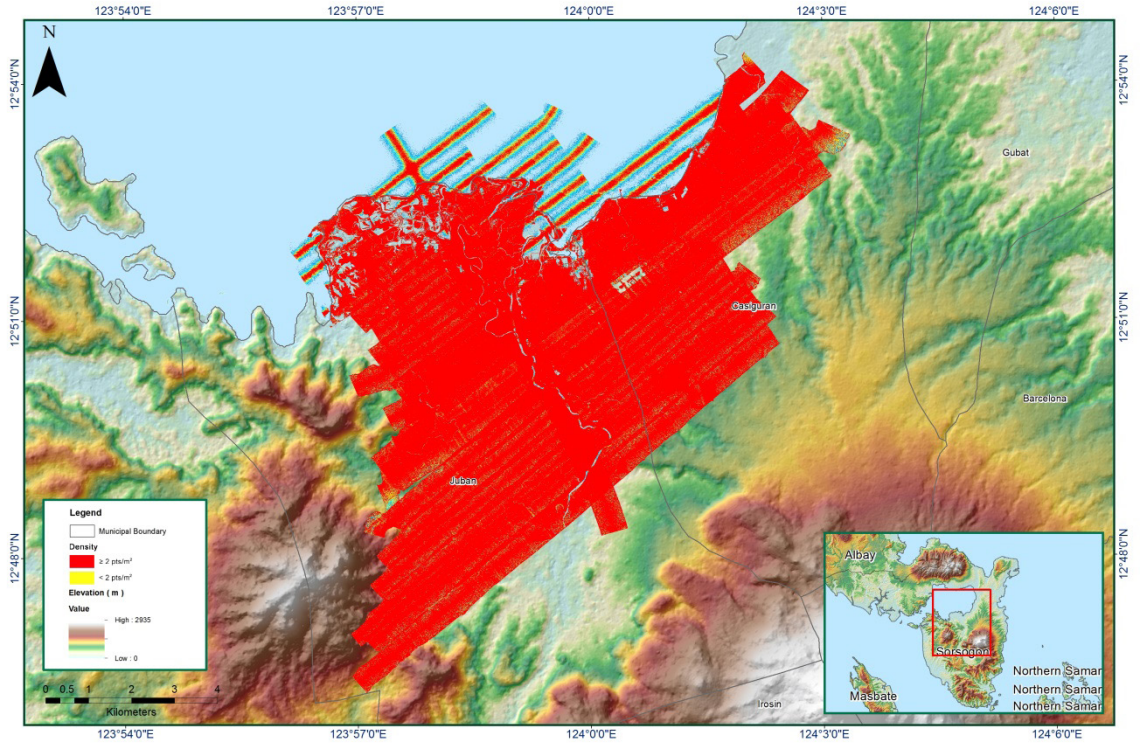


Figure 1.3.6. Density map of merged LiDAR data

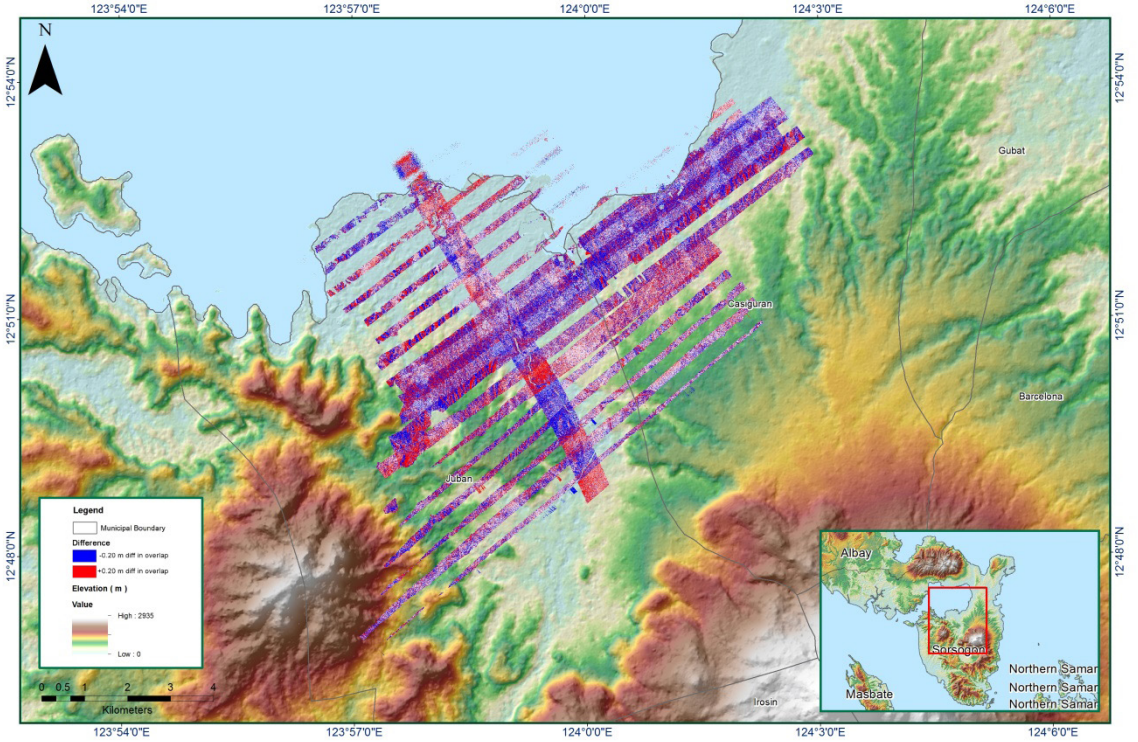


Figure 1.3.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aN
Inclusive Flights	3899G
Range data size	20.2 GB
POS data size	264 MB
Base data size	9.65 MB
Image	40.6 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.155
RMSE for East Position (<4.0 cm)	1.262
RMSE for Down Position (<8.0 cm)	2.677
Boresight correction stdev (<0.001deg)	0.003977
IMU attitude correction stdev (<0.001deg)	0.005946
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	15.95 %
Ave point cloud density per sq.m. (>2.0)	4.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	41
Maximum Height	224.26 m
Minimum Height	52.84 m
Classification (# of points)	
Ground	8,982,960
Low vegetation	10,806,207
Medium vegetation	44,253,853
High vegetation	47,488,992
Building	664,606
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Justine Francisco, Tam

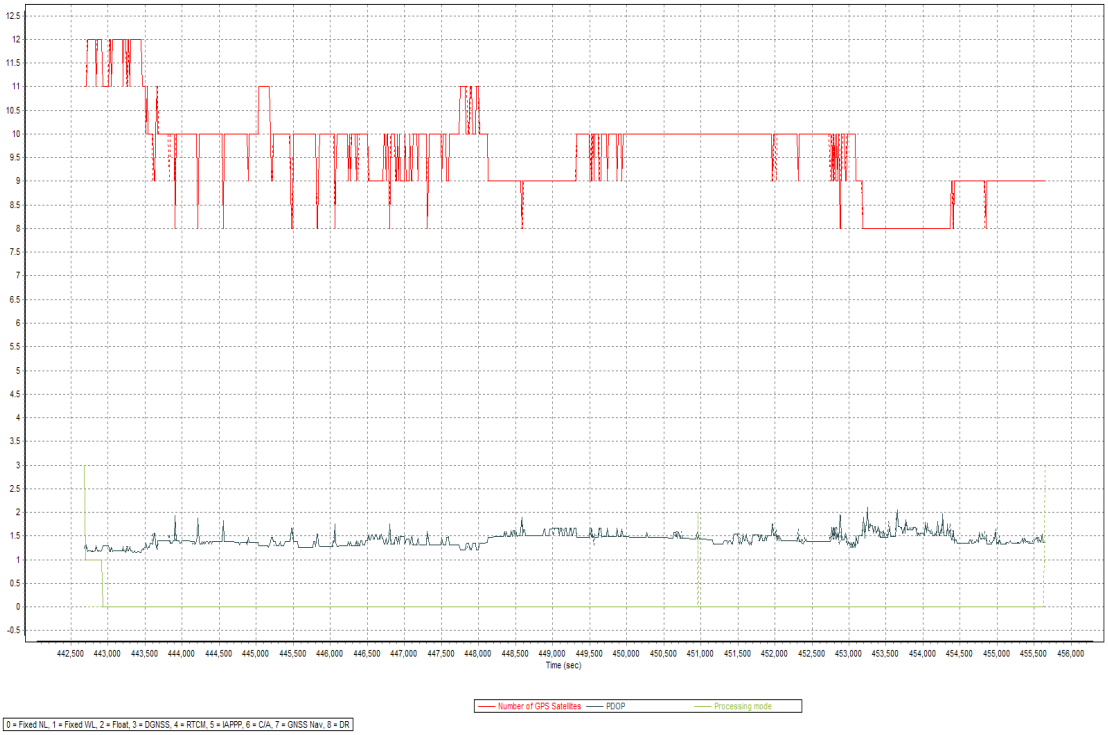


Figure 1.4.1. Solution Status

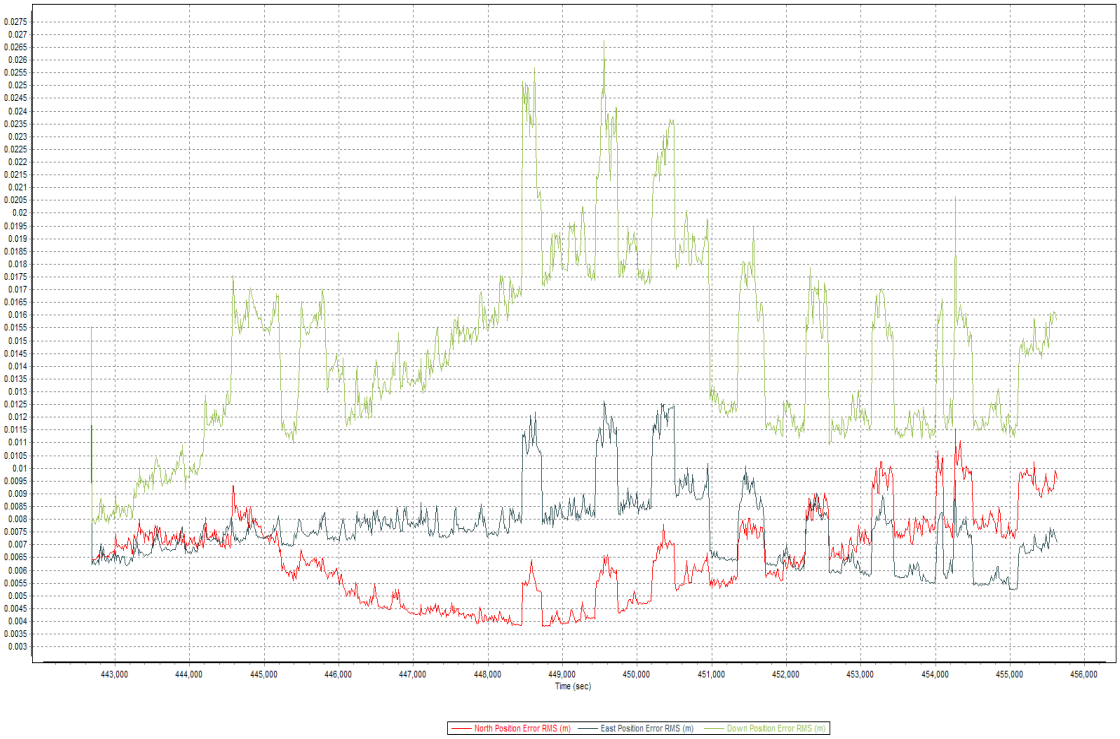


Figure 1.4.2. Smoothed Performance Metric Parameters

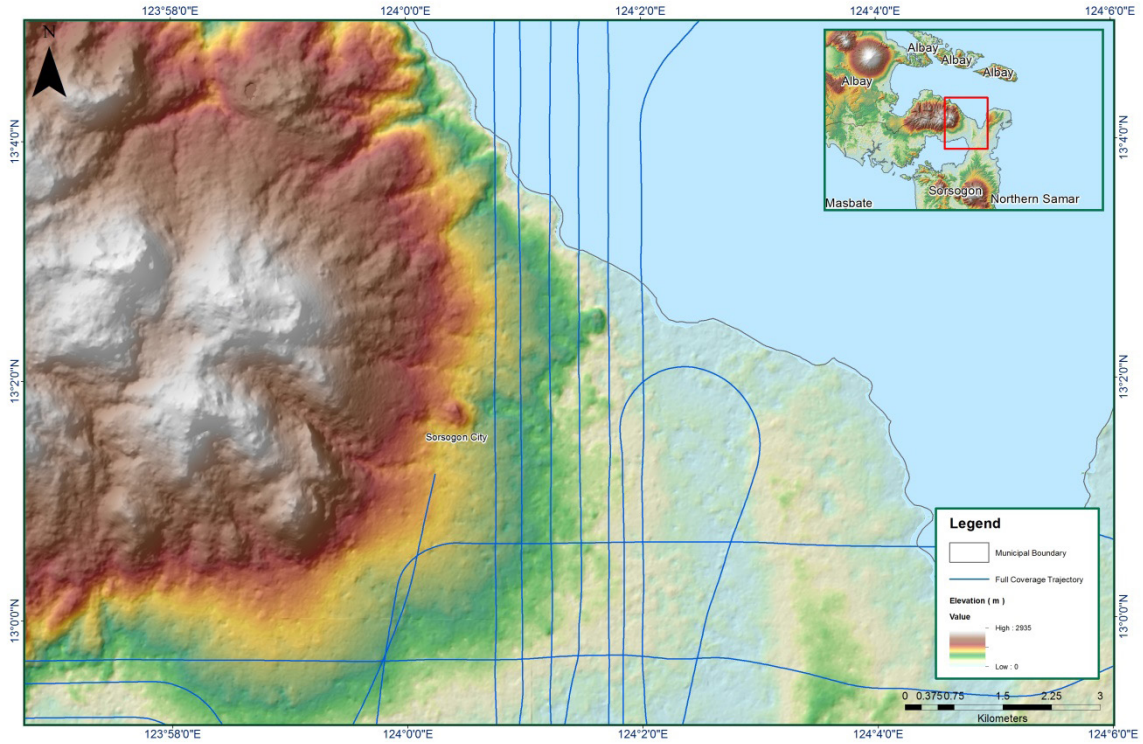


Figure 1.4.3. Best Estimated Trajectory

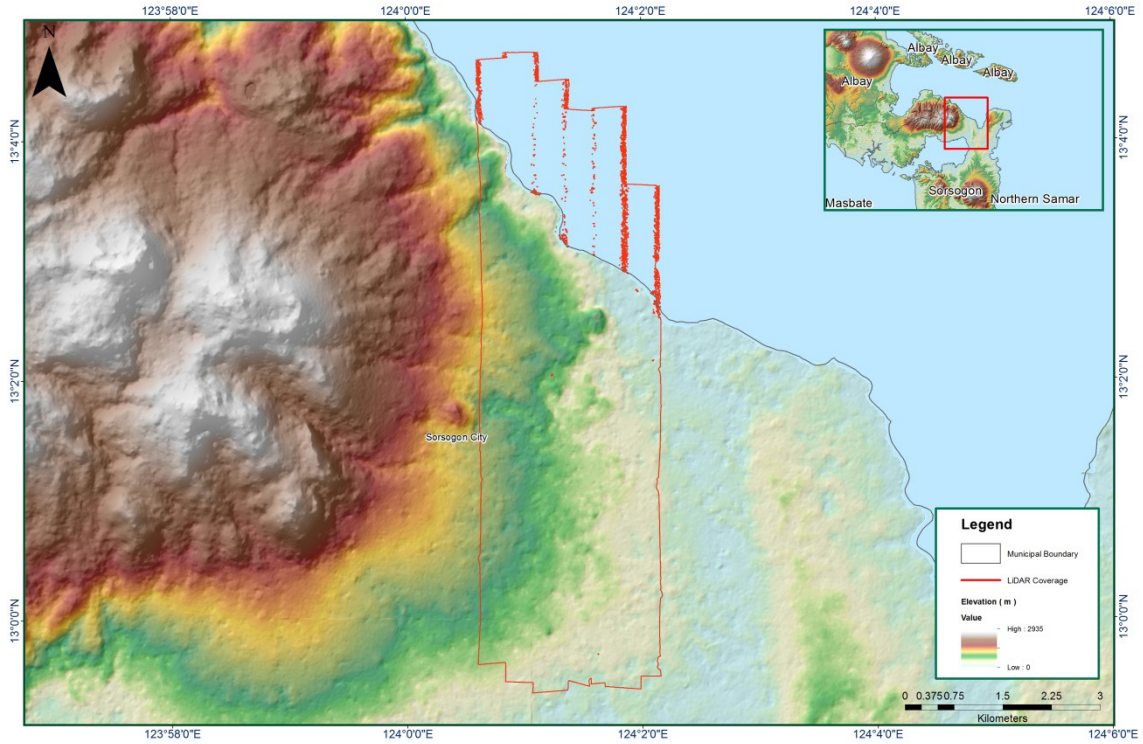


Figure 1.4.4. Coverage of LiDAR Data

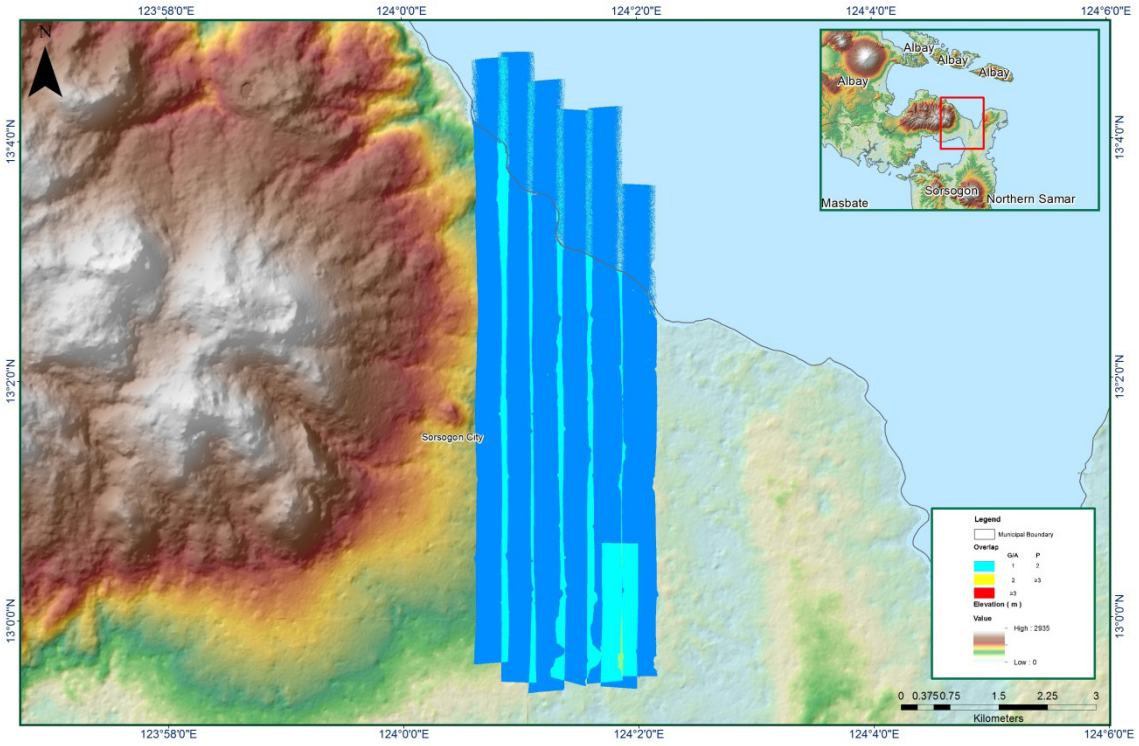


Figure 1.4.5. Image of data overlap

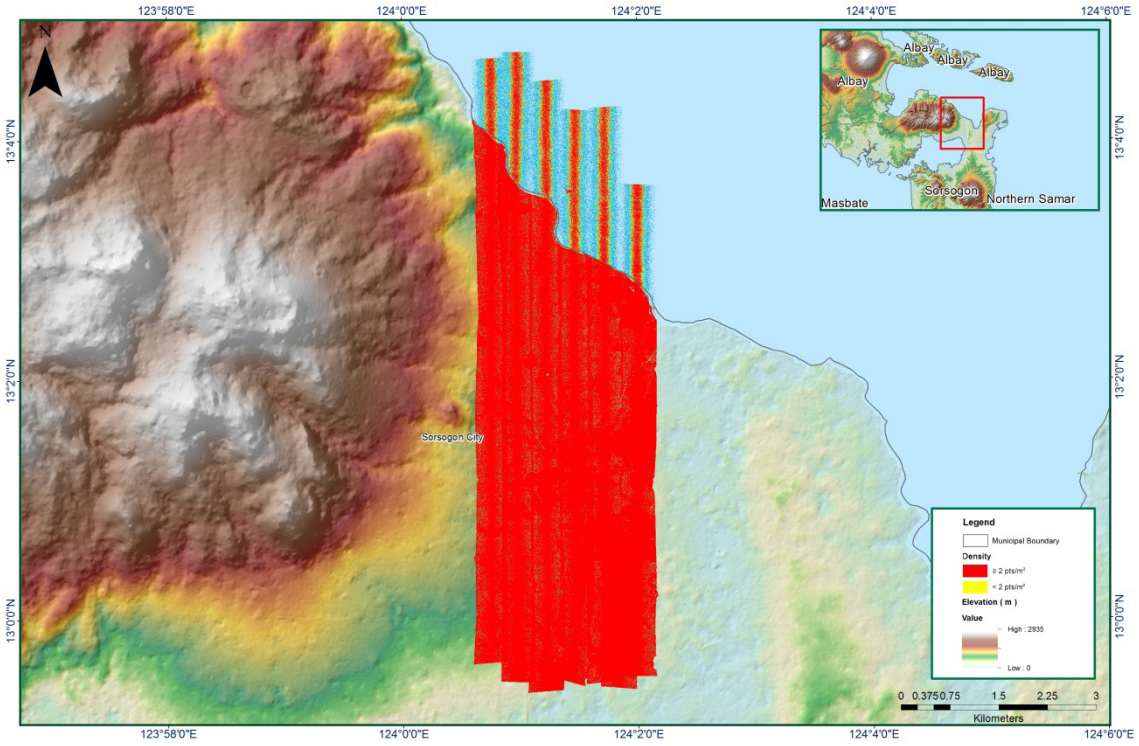


Figure 1.4.6. Density map of merged LiDAR data

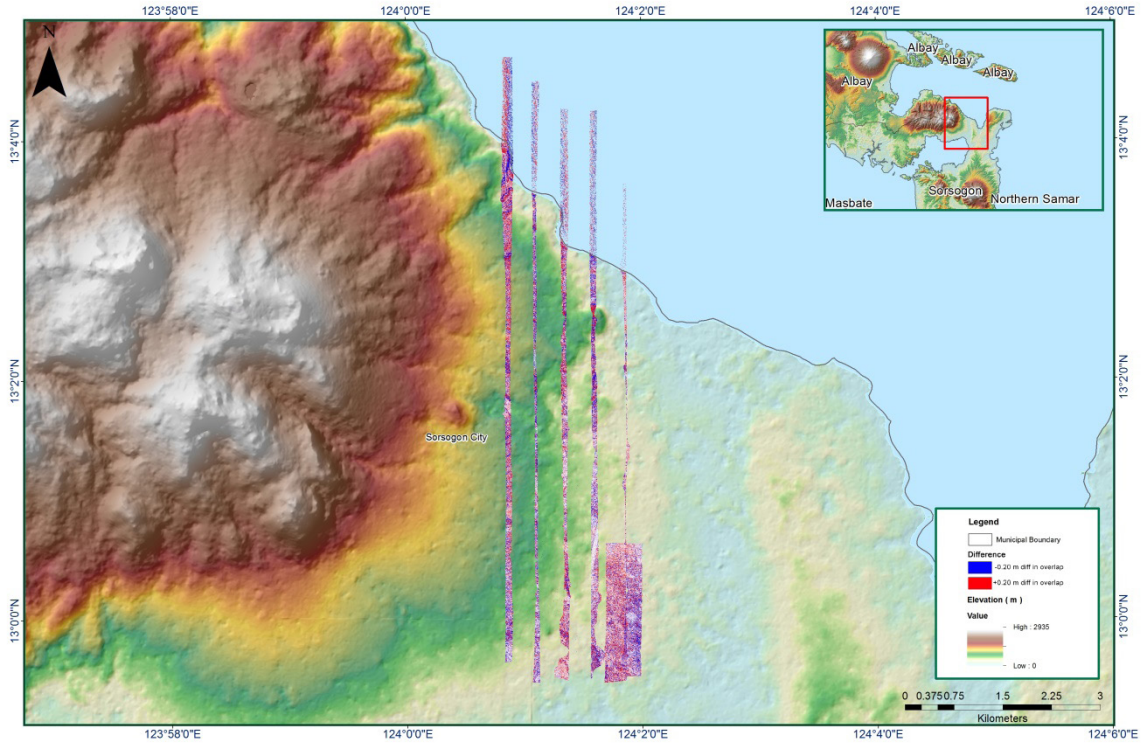


Figure 1.4.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aM
Inclusive Flights	3883G, 3885G
Range data size	49.8 MB
POS data size	485 MB
Base data size	24.84 MB
Image	86.5 MB
Transfer date	March 31, 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)	1.251
RMSE for East Position (<4.0 cm)	1.560
RMSE for Down Position (<8.0 cm)	3.331
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	34.70 %
Ave point cloud density per sq.m. (>2.0)	4.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	171
Maximum Height	276.86 m
Minimum Height	56.01 m
Classification (# of points)	
Ground	63,644,057
Low vegetation	29,004,970
Medium vegetation	181,586,126
High vegetation	207,499,247
Building	269,310
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Marie Denise Bueno

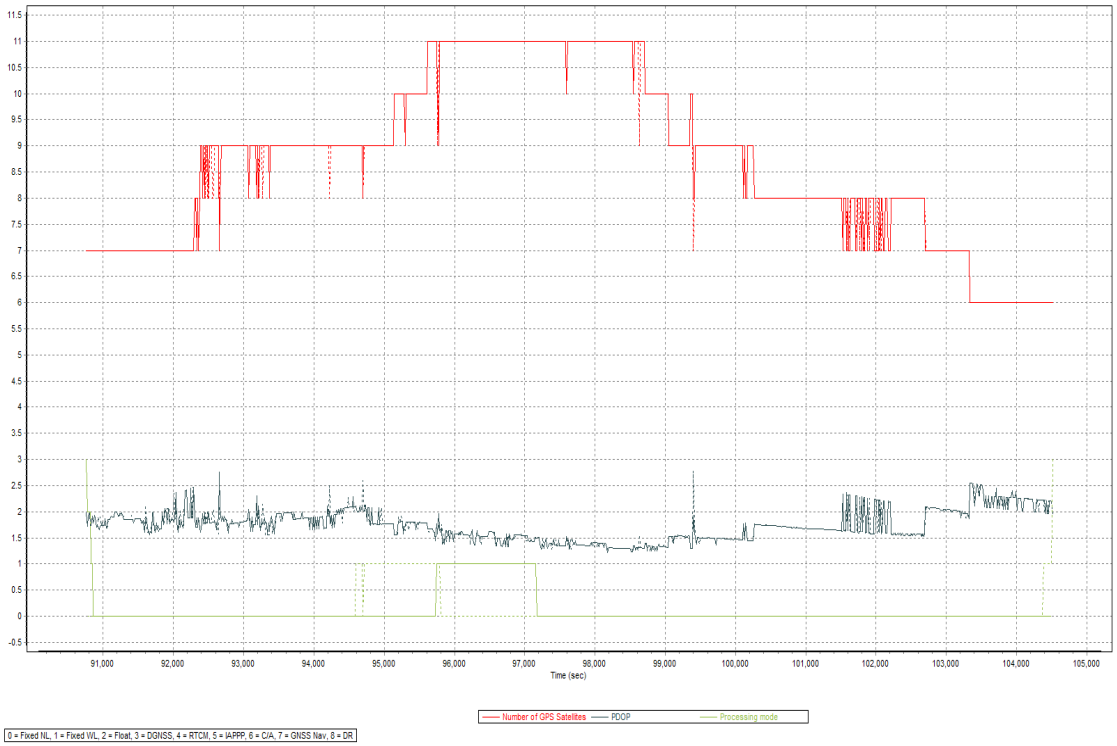


Figure 1.5.1. Solution Status

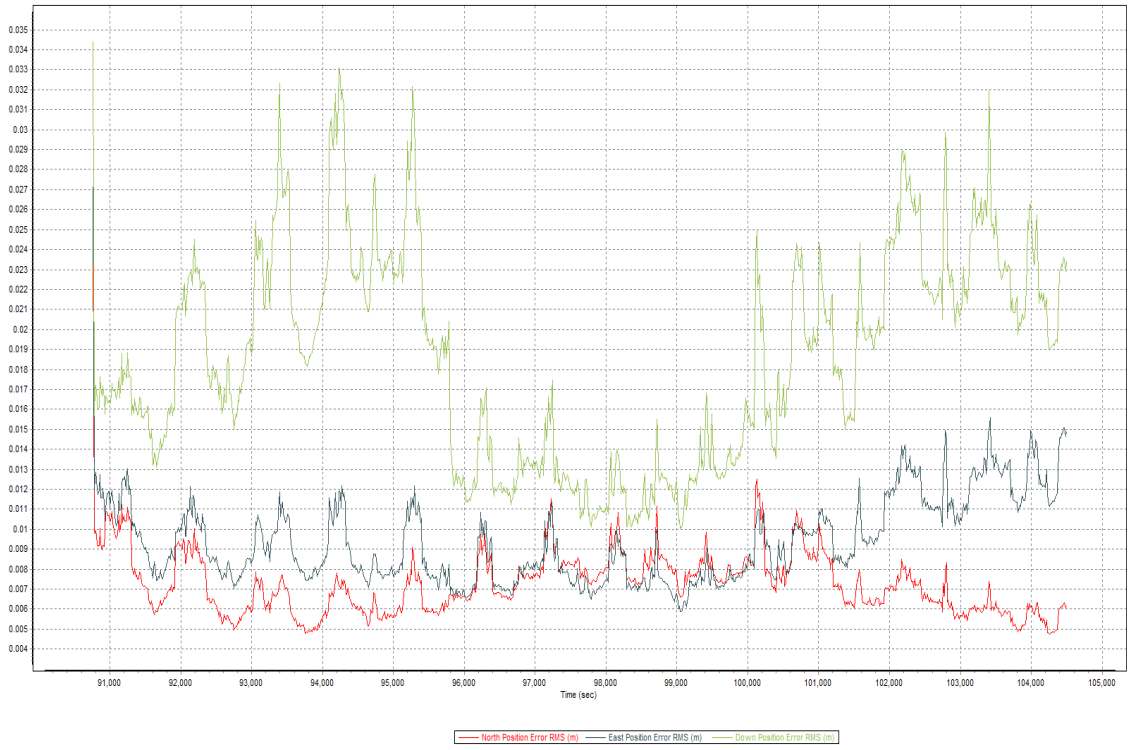


Figure 1.5.2. Smoothed Performance Metric Parameters

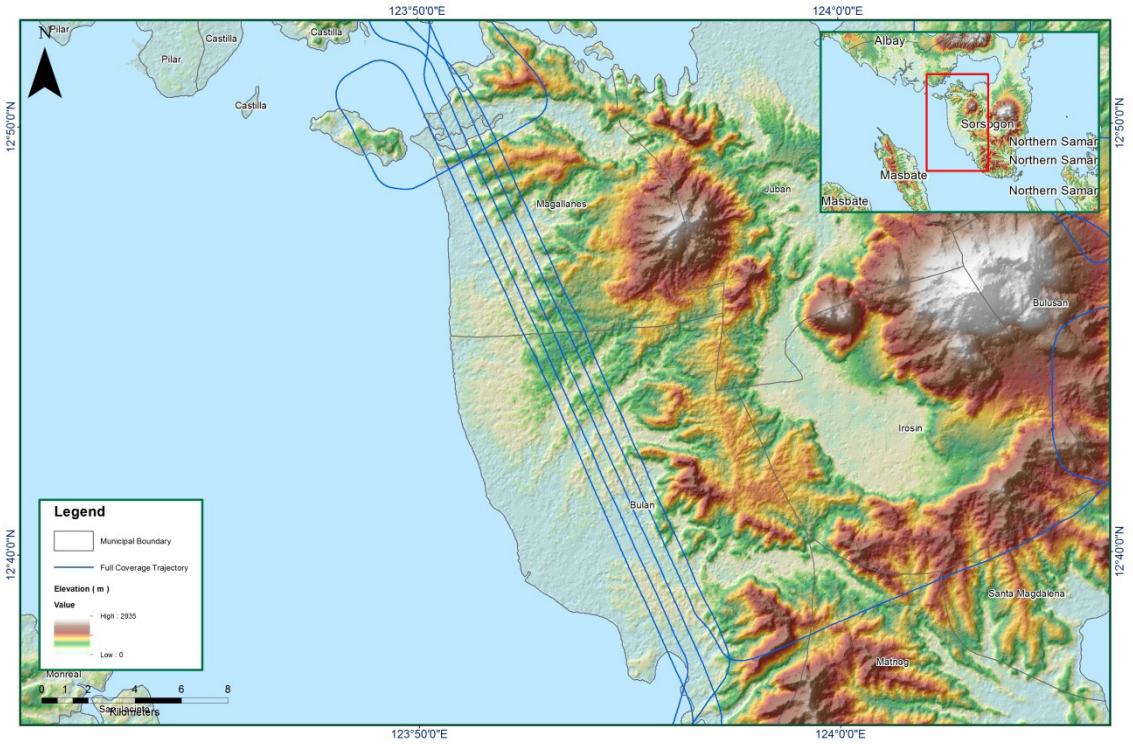


Figure 1.5.3. Best Estimated Trajectory

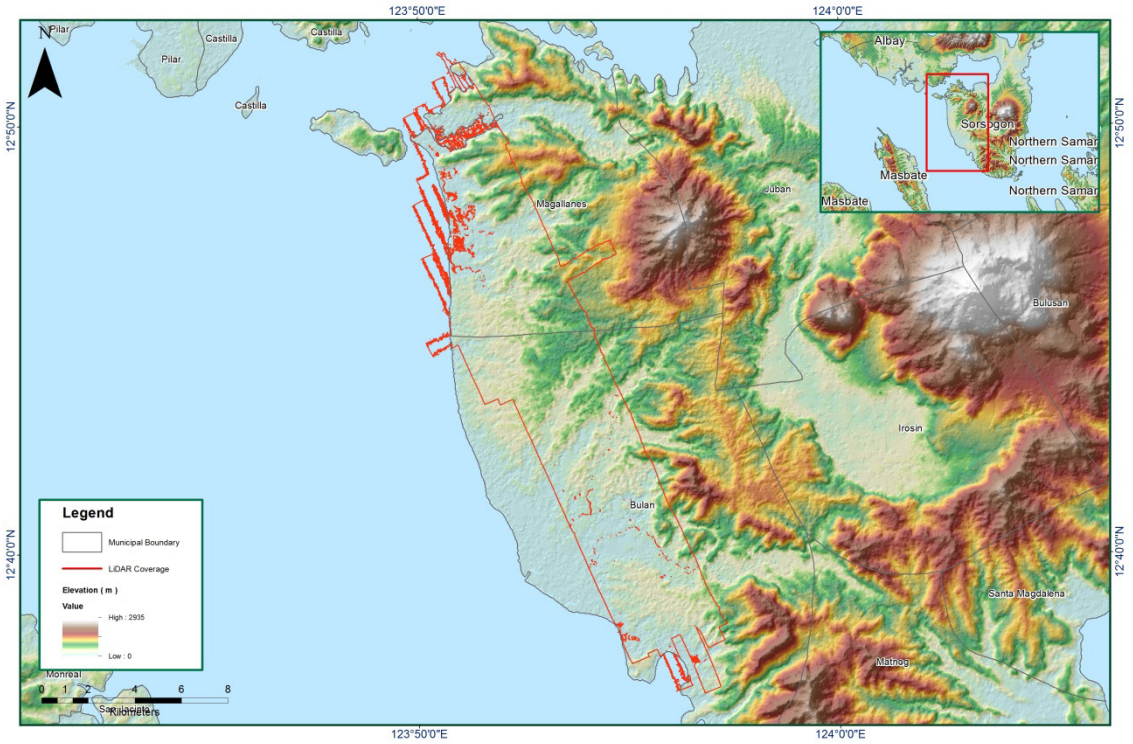


Figure 1.5.4. Coverage of LiDAR Data

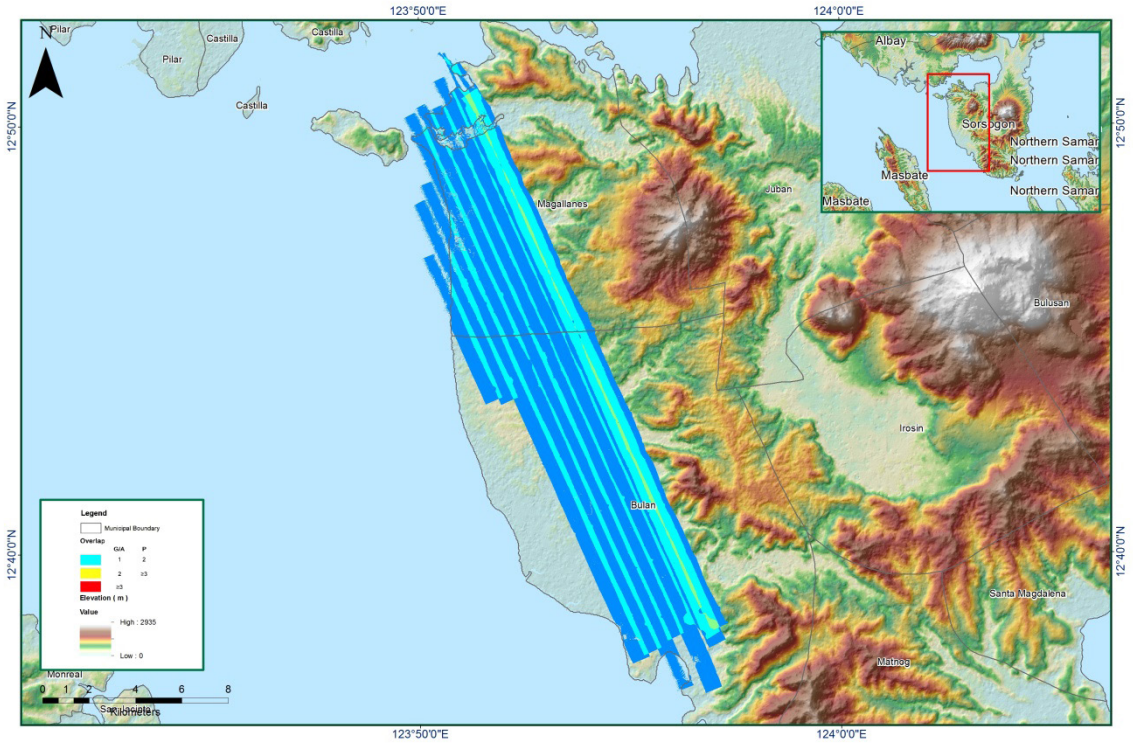


Figure 1.5.5. Image of data overlap

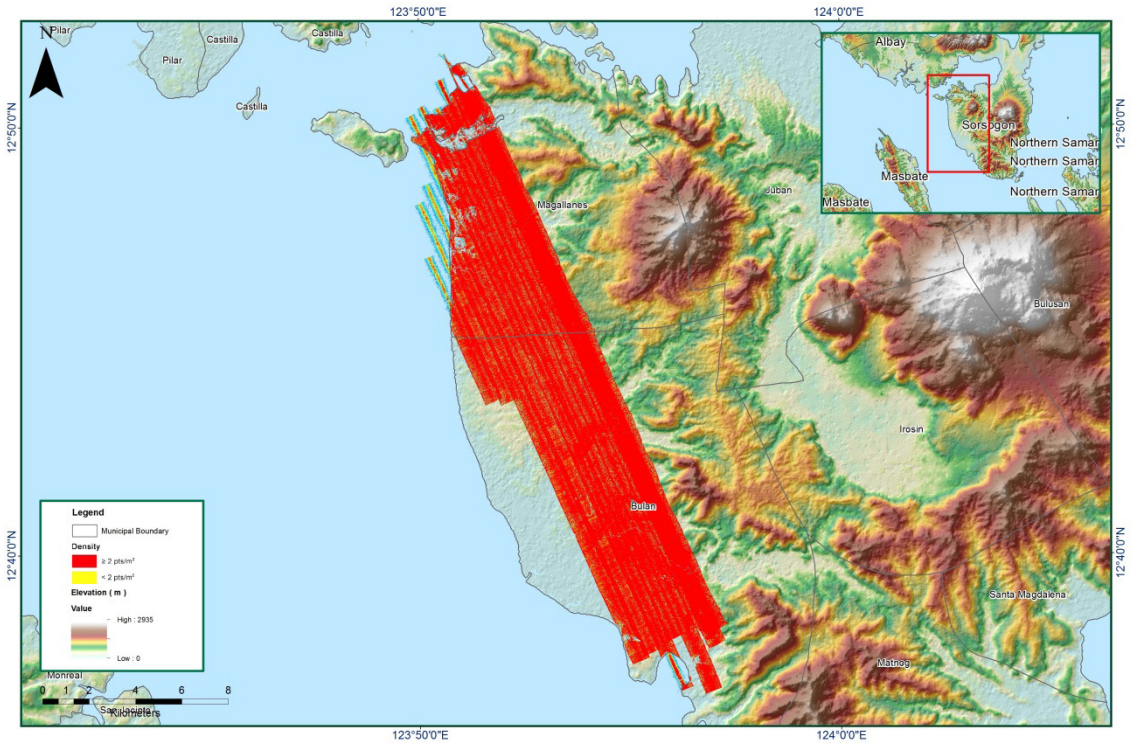


Figure 1.5.6. Density map of merged LiDAR data

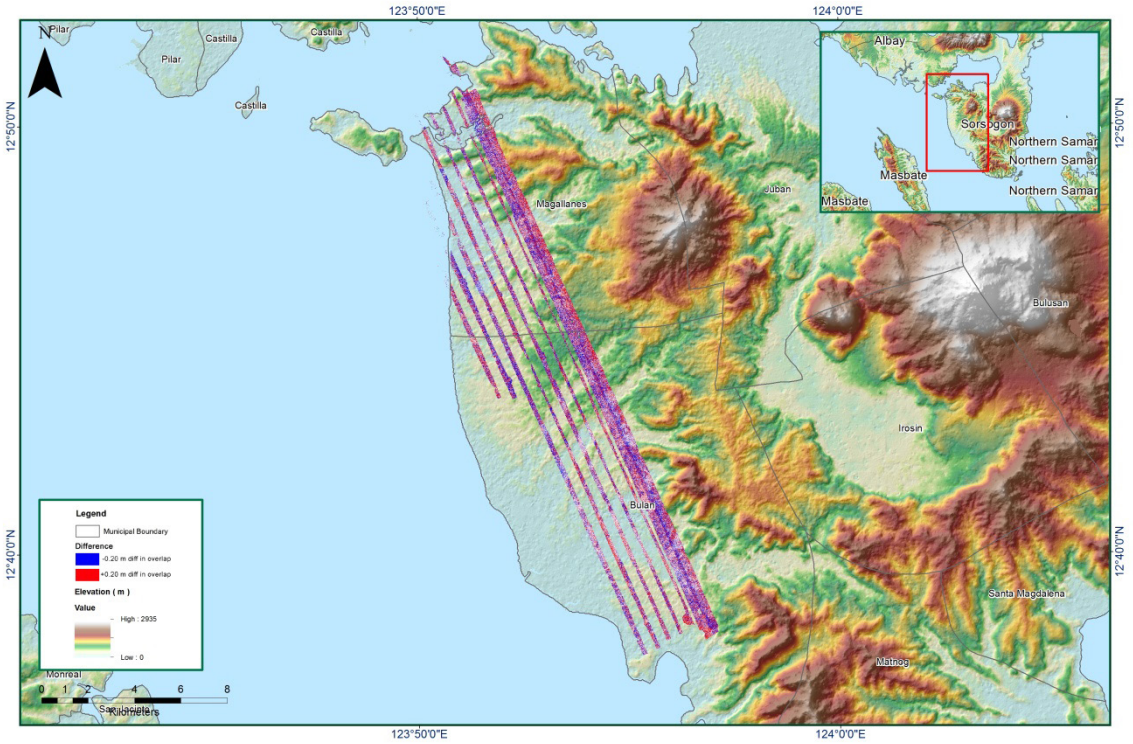


Figure 1.5.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aL
Inclusive Flights	3889G, 3887G
Range data size	38.3 GB
POS data size	437 MB
Base data size	35.6 MB
Image	83.2 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.111
RMSE for East Position (<4.0 cm)	1.162
RMSE for Down Position (<8.0 cm)	5.950
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	34.93 %
Ave point cloud density per sq.m. (>2.0)	5.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	195
Maximum Height	601.52 m
Minimum Height	54.79 m
Classification (# of points)	
Ground	72,494,585
Low vegetation	41,217,292
Medium vegetation	255,590,397
High vegetation	191,909,531
Building	1,154,822
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga, Marie Denise Bueno

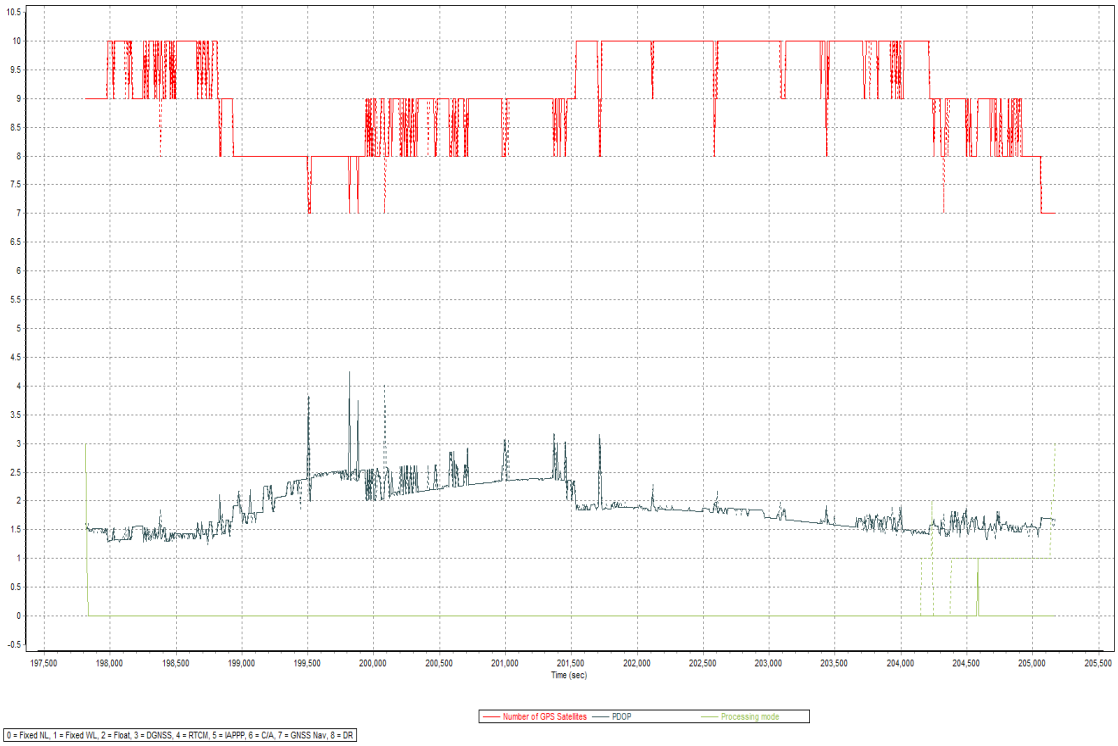


Figure 1.6.1. Solution Status

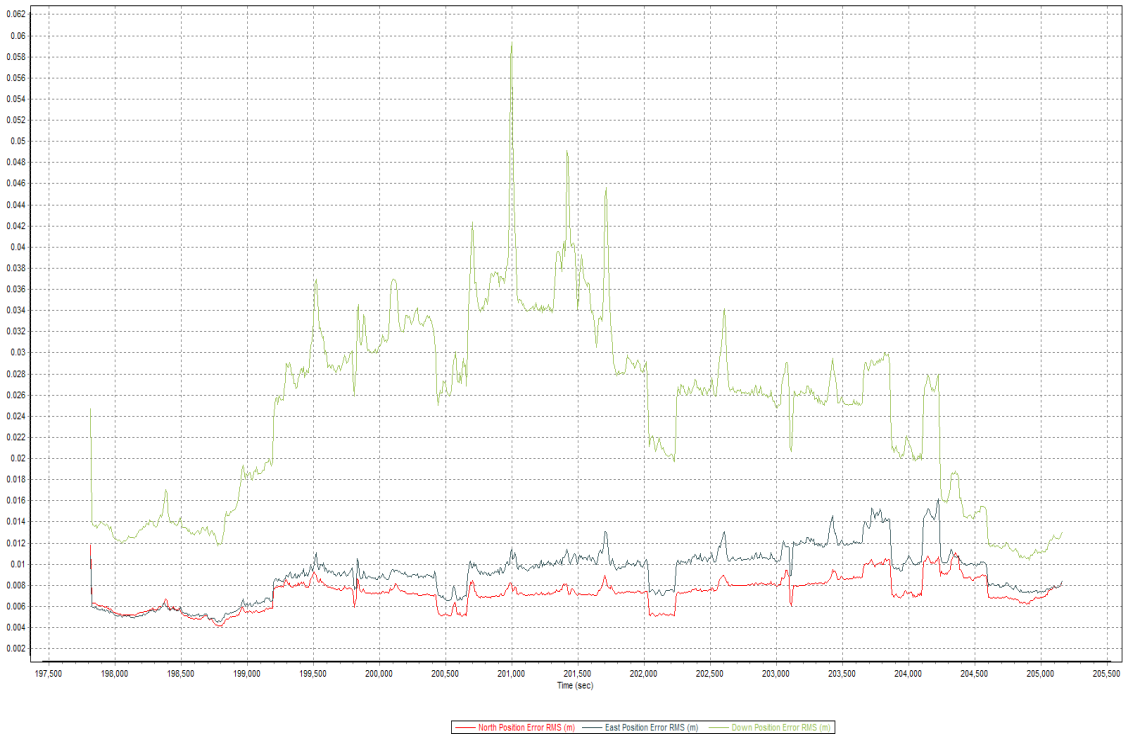


Figure 1.6.2. Smoothed Performance Metric Parameters

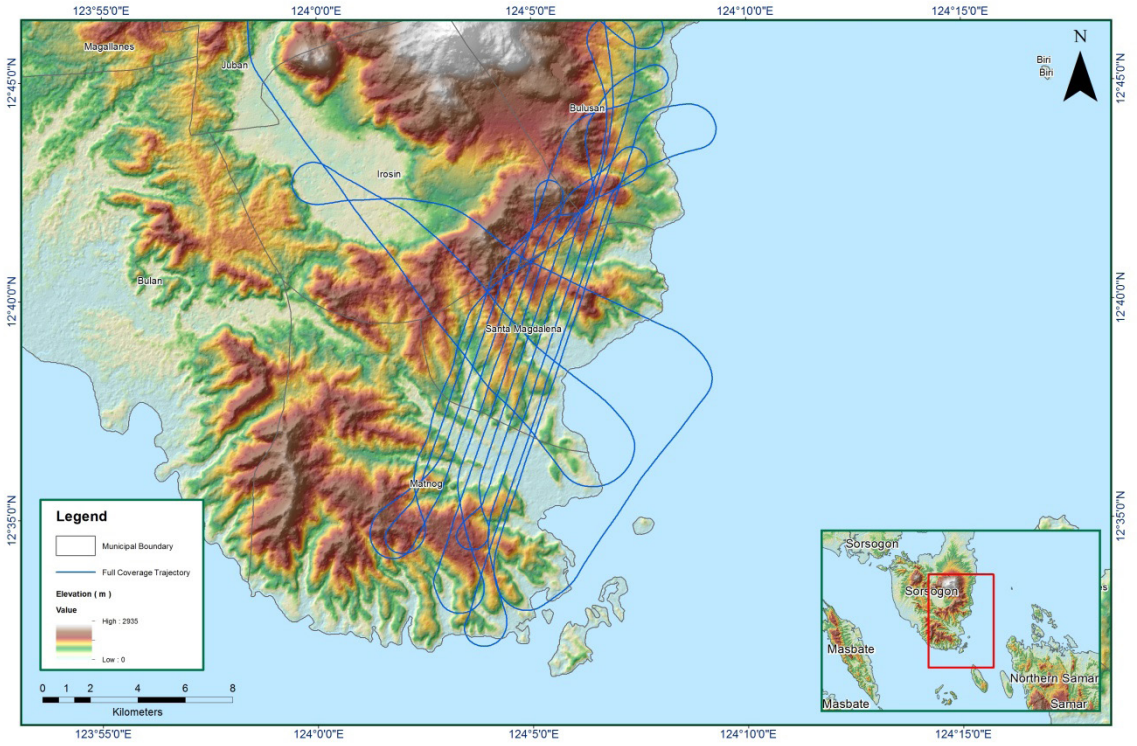


Figure 1.6.3. Best Estimated Trajectory

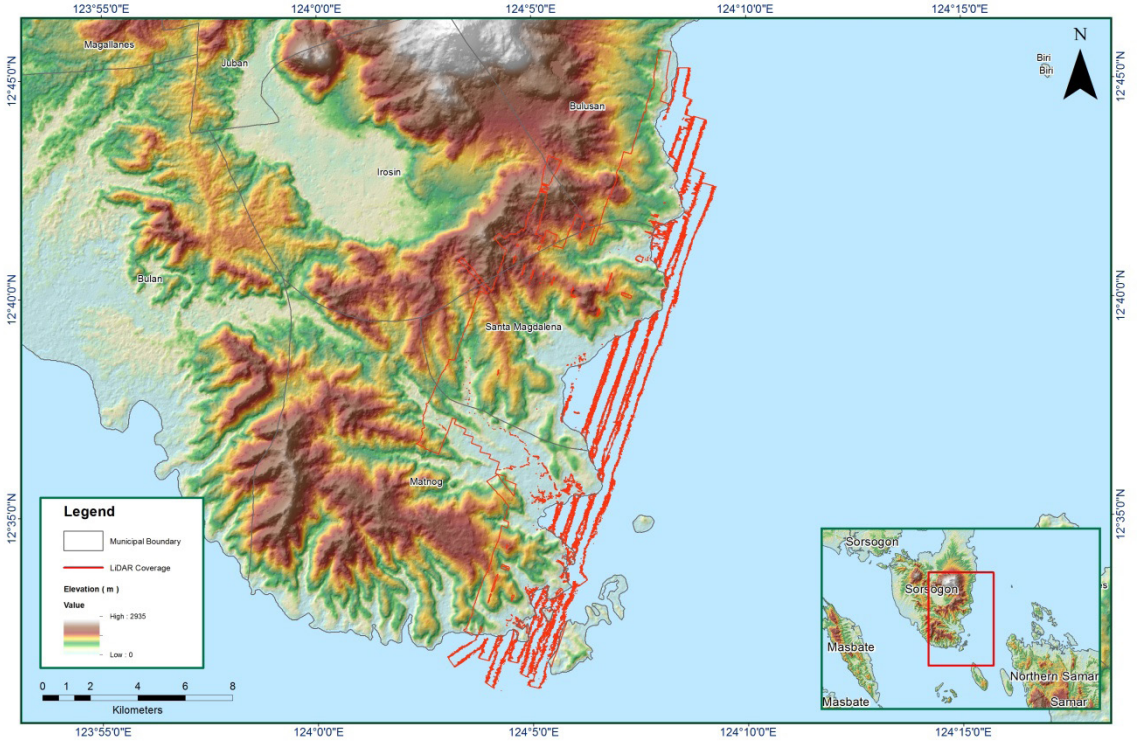


Figure 1.6.4. Coverage of LiDAR Data

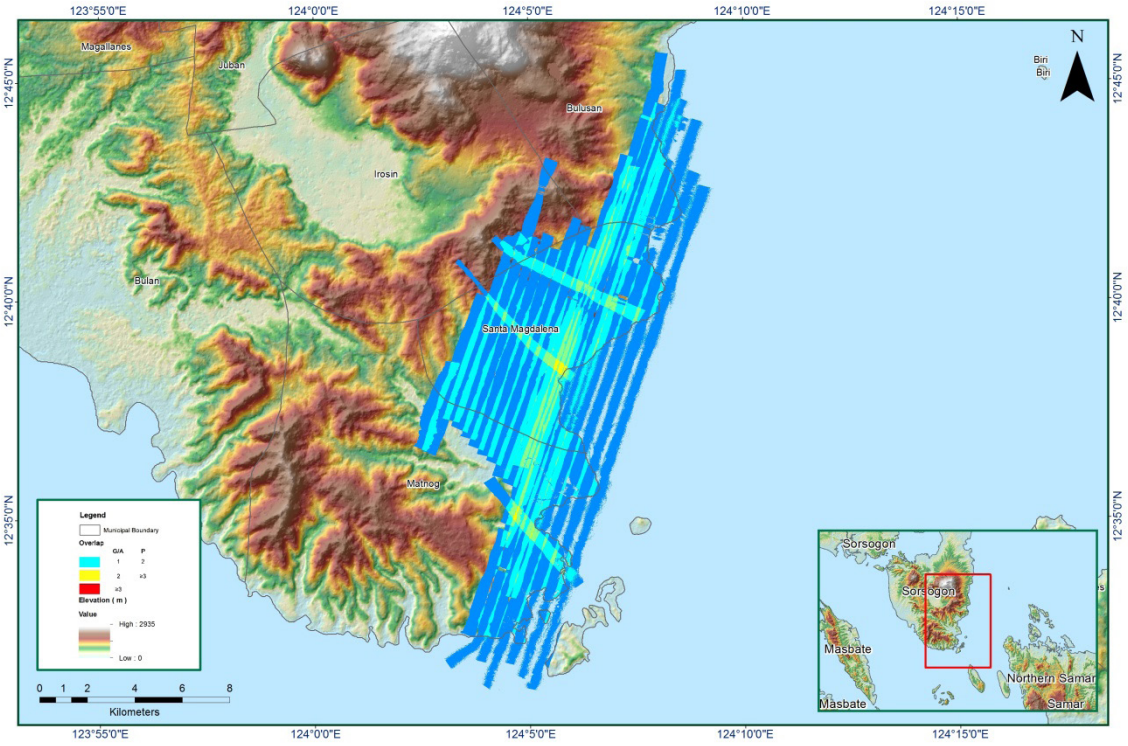


Figure 1.6.5. Image of data overlap

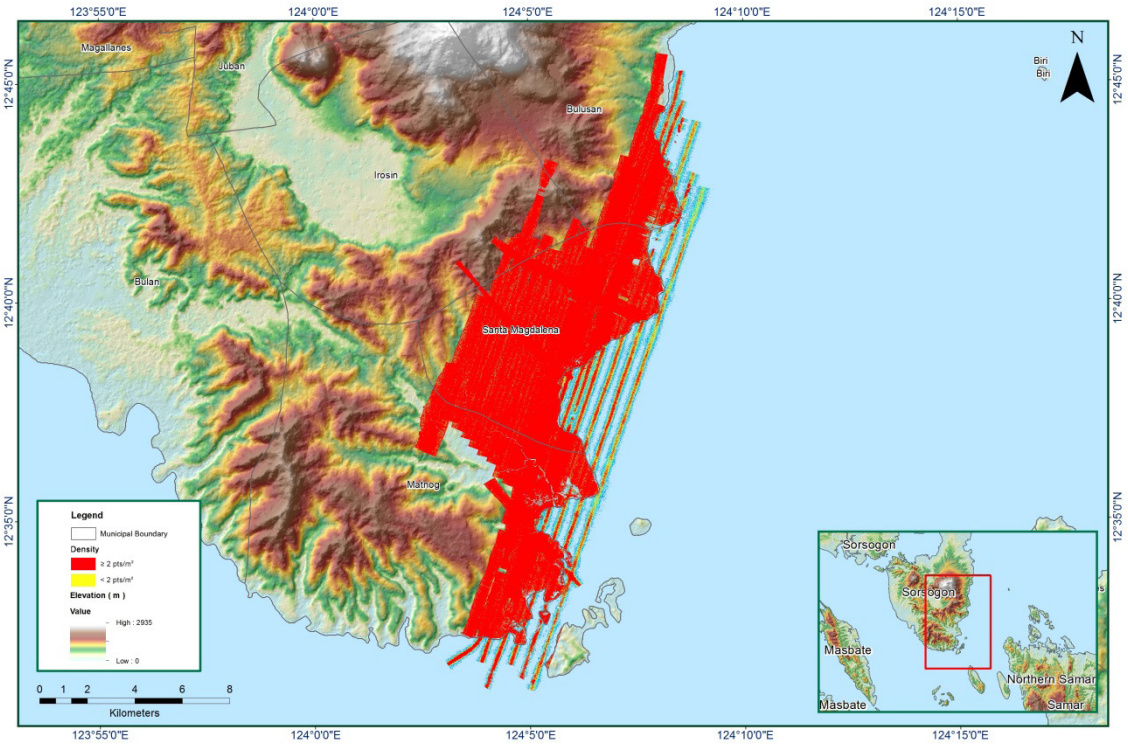


Figure 1.6.6. Density map of merged LiDAR data

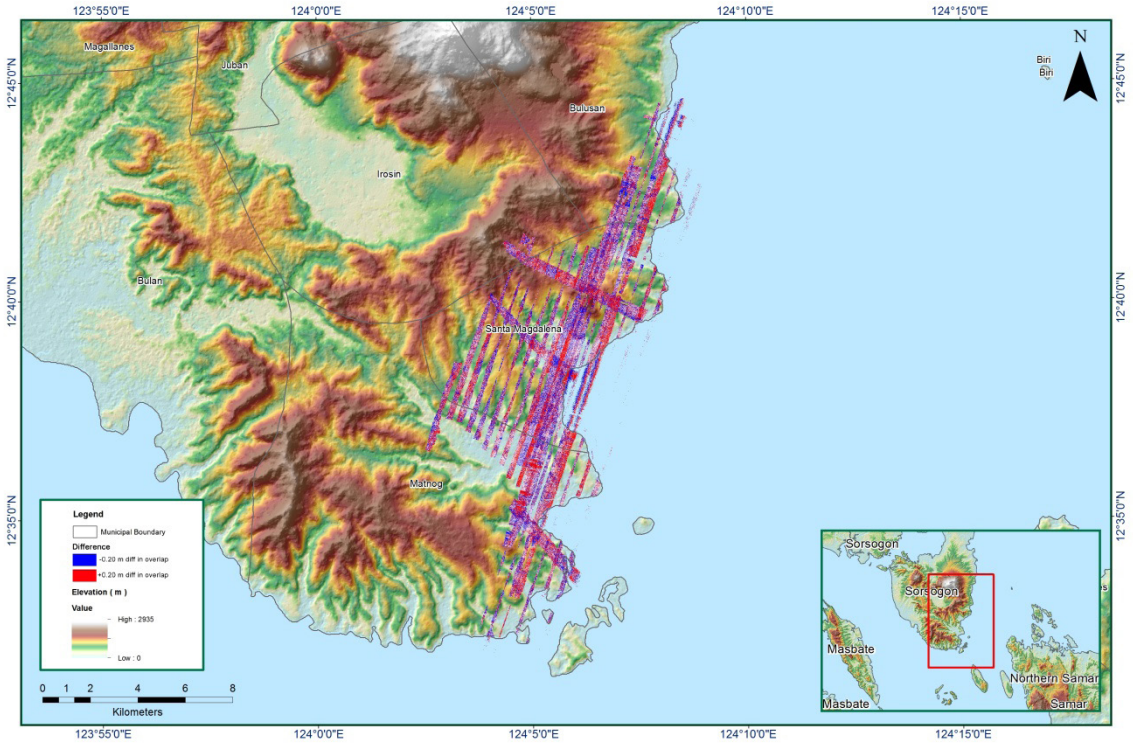


Figure 1.6.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aL_supplement
Inclusive Flights	3887G, 3889G
Range data size	38.3 GB
POS data size	437 MB
Base data size	35.6 MB
Image	83.2 MB
Transfer date	March 31, 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)	1.613
RMSE for East Position (<4.0 cm)	1.735
RMSE for Down Position (<8.0 cm)	3.248
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	44.37 %
Ave point cloud density per sq.m. (>2.0)	7.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	71
Maximum Height	345.05 m
Minimum Height	55.71 m
Classification (# of points)	
Ground	20,005,116
Low vegetation	21,700,954
Medium vegetation	132,284,511
High vegetation	104,287,467
Building	780,794
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Ma. Joanne Balaga, Marie Denise Bueno

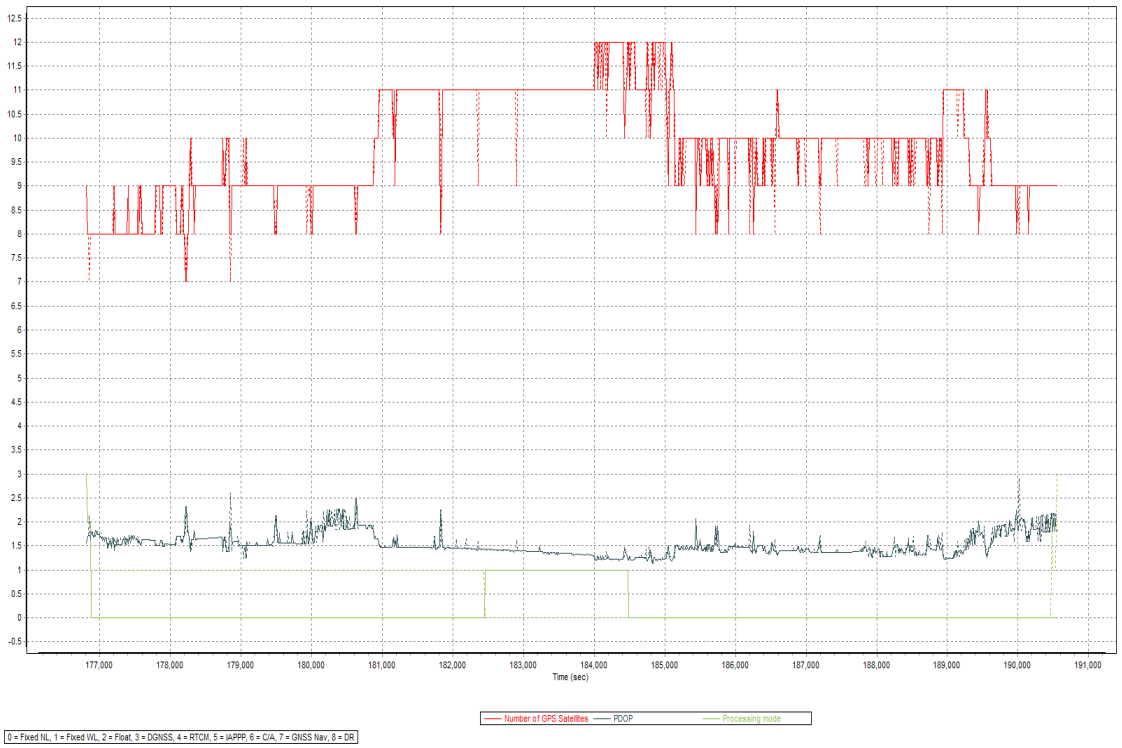


Figure 1.7.1. Solution Status

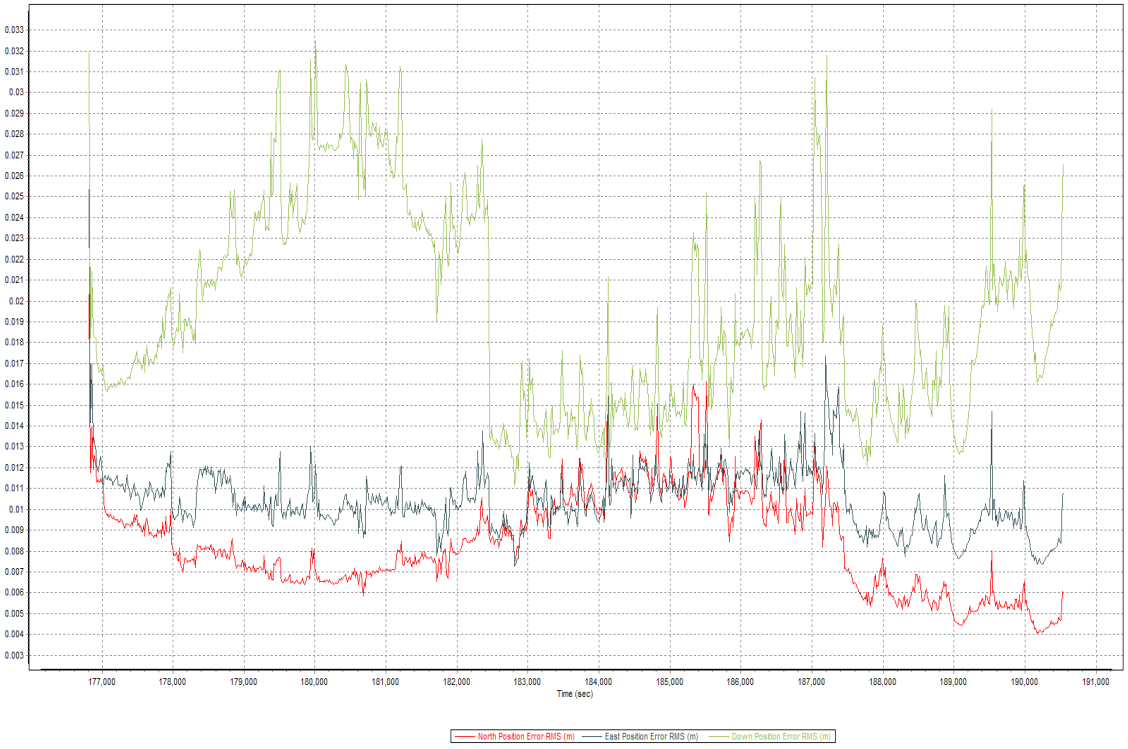


Figure 1.7.2. Smoothed Performance Metric Parameters

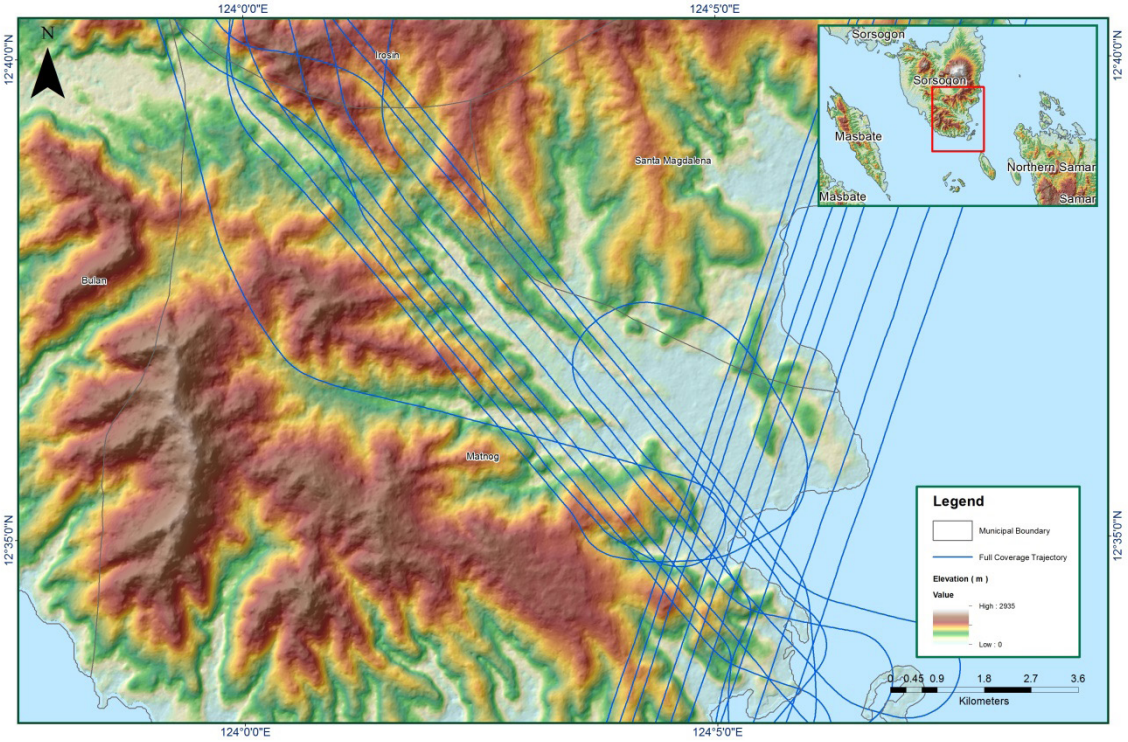


Figure 1.7.3. Best Estimated Trajectory

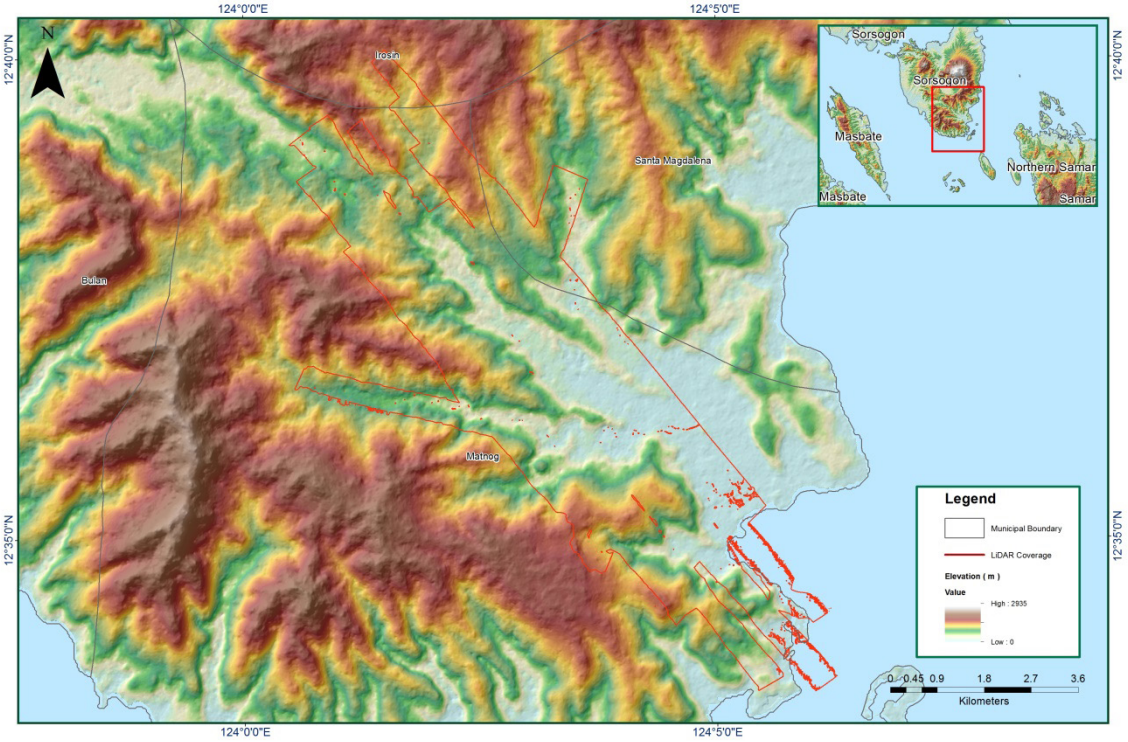


Figure 1.7.4. Coverage of LiDAR Data

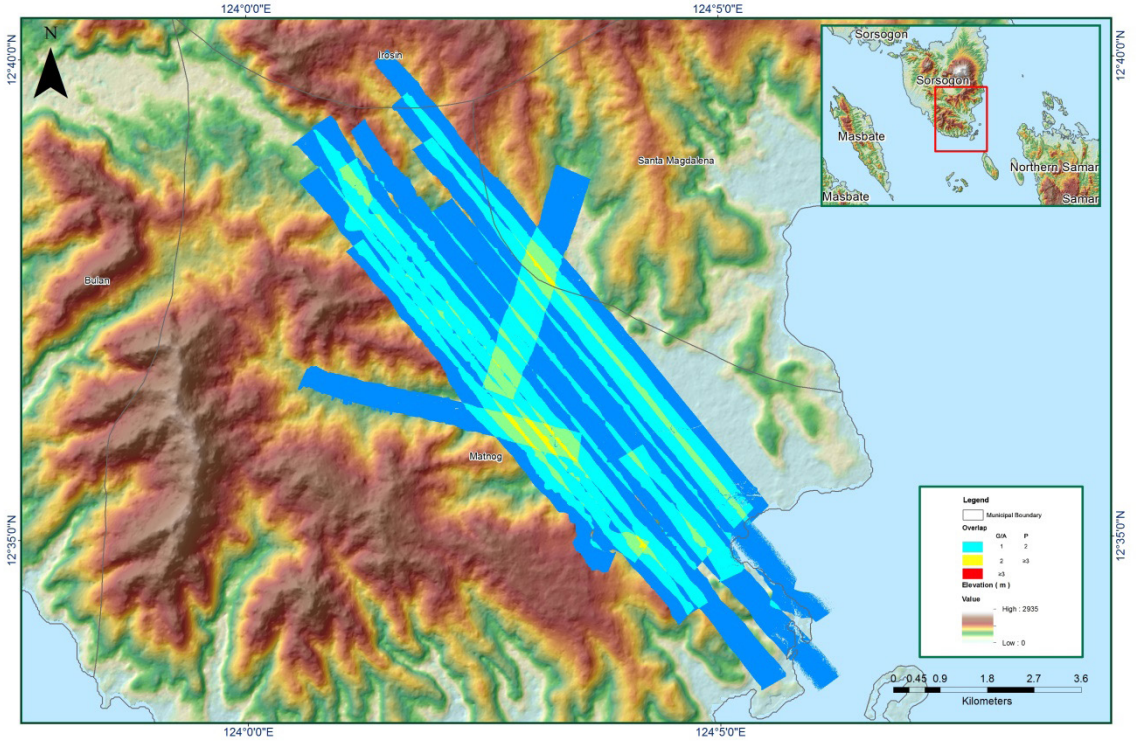


Figure 1.7.5. Image of data overlap

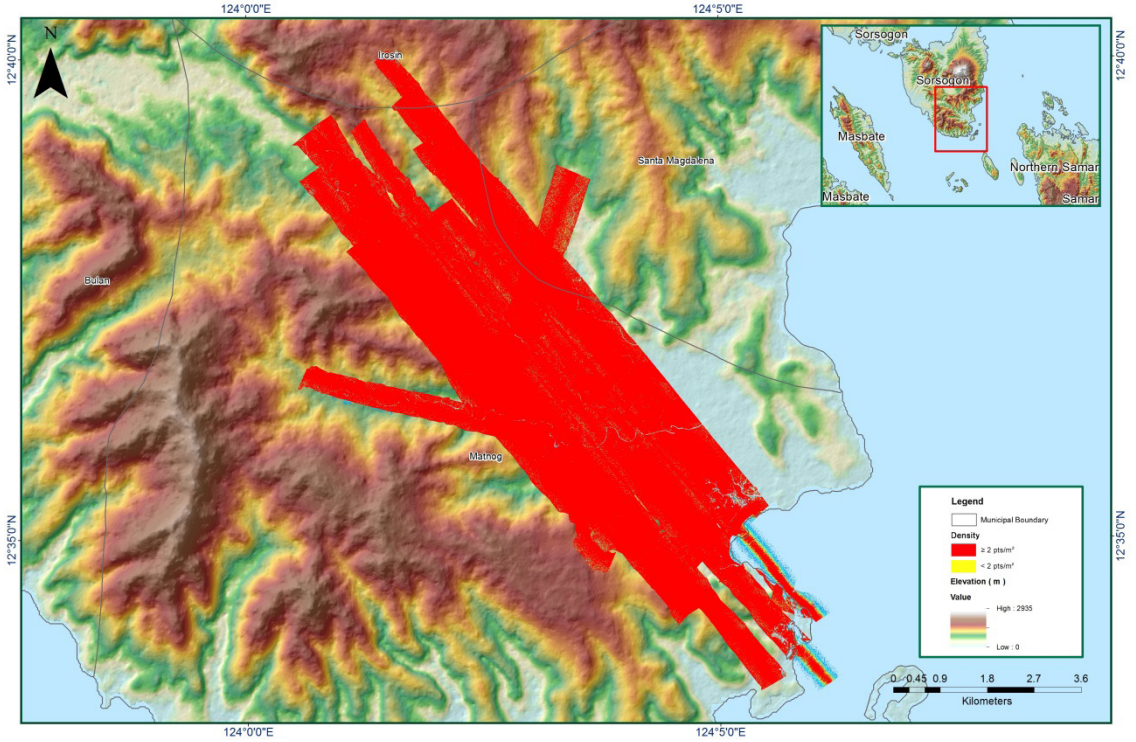


Figure 1.7.6. Density map of merged LiDAR data

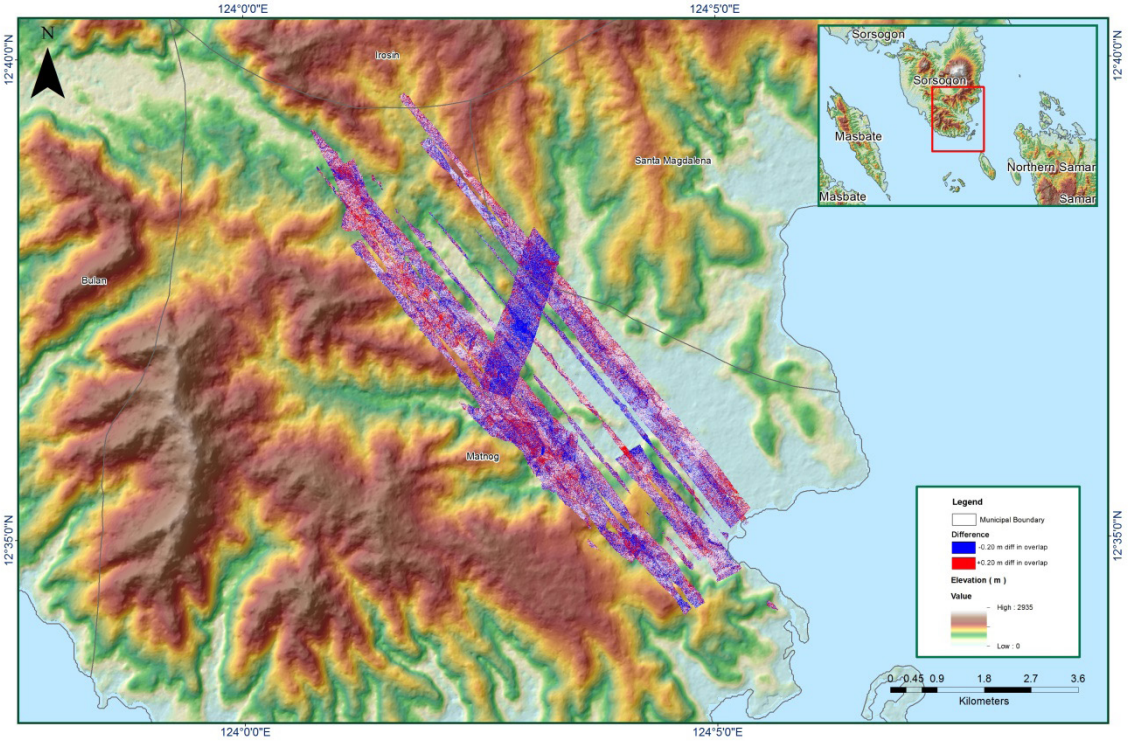


Figure 1.7.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aK_supplement
Inclusive Flights	3899G
Range data size	20.2 GB
POS data size	264 MB
Base data size	9.65 MB
Image	40.6 MB
Transfer date	March 31. 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.155
RMSE for East Position (<4.0 cm)	1.263
RMSE for Down Position (<8.0 cm)	2.677
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	28.22 %
Ave point cloud density per sq.m. (>2.0)	6.69
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	41
Maximum Height	231.78 m
Minimum Height	75.49 m
Classification (# of points)	
Ground	11,785,893
Low vegetation	11,495,992
Medium vegetation	68,385,128
High vegetation	80,417,625
Building	179,781
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Ma. Joanne Balaga, Alex John Escobido

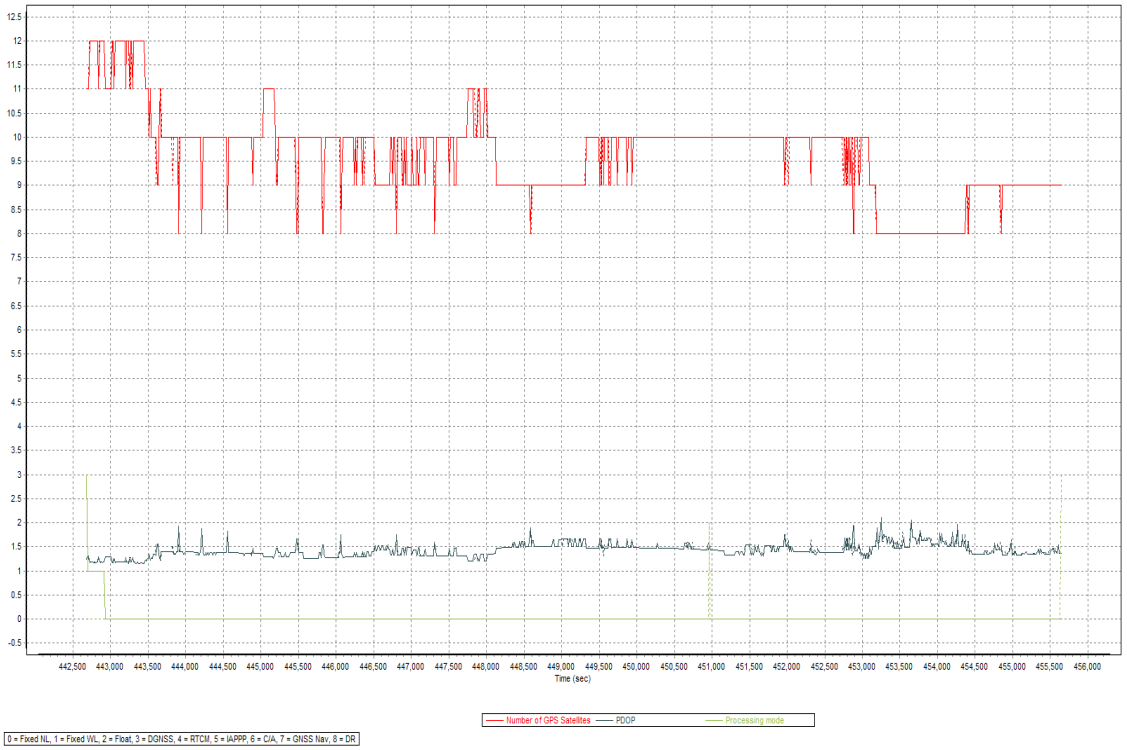


Figure 1.8.1. Solution Status

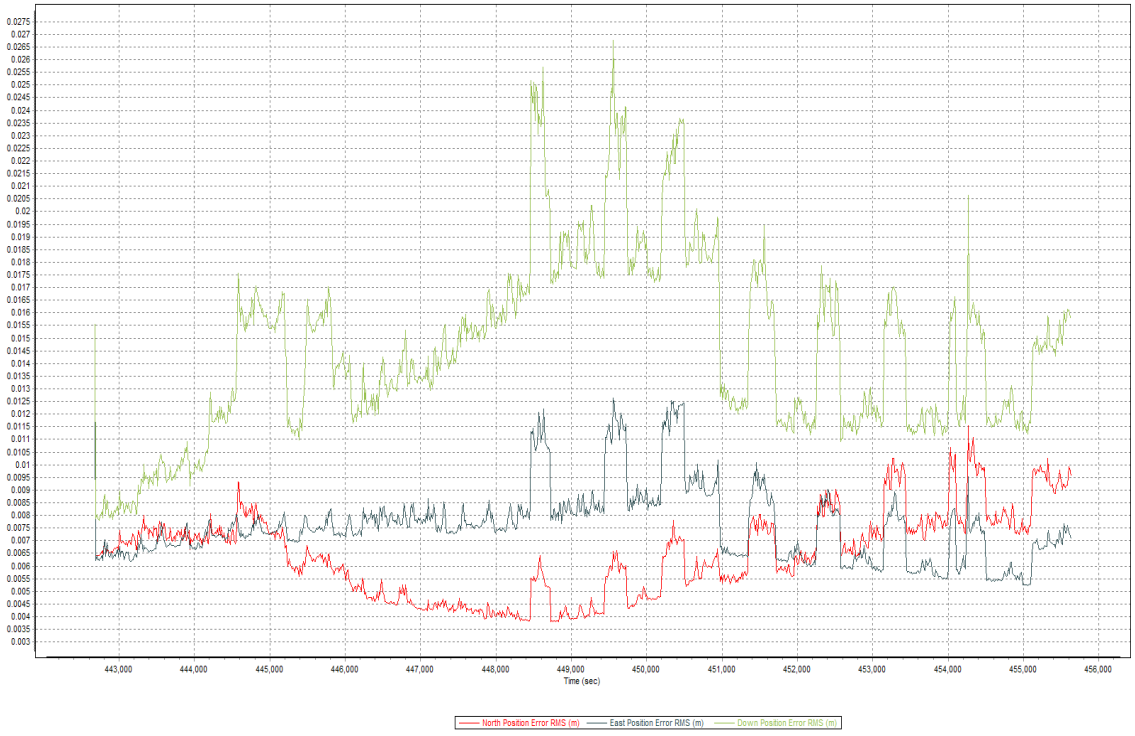


Figure 1.8.2. Smoothed Performance Metric Parameters

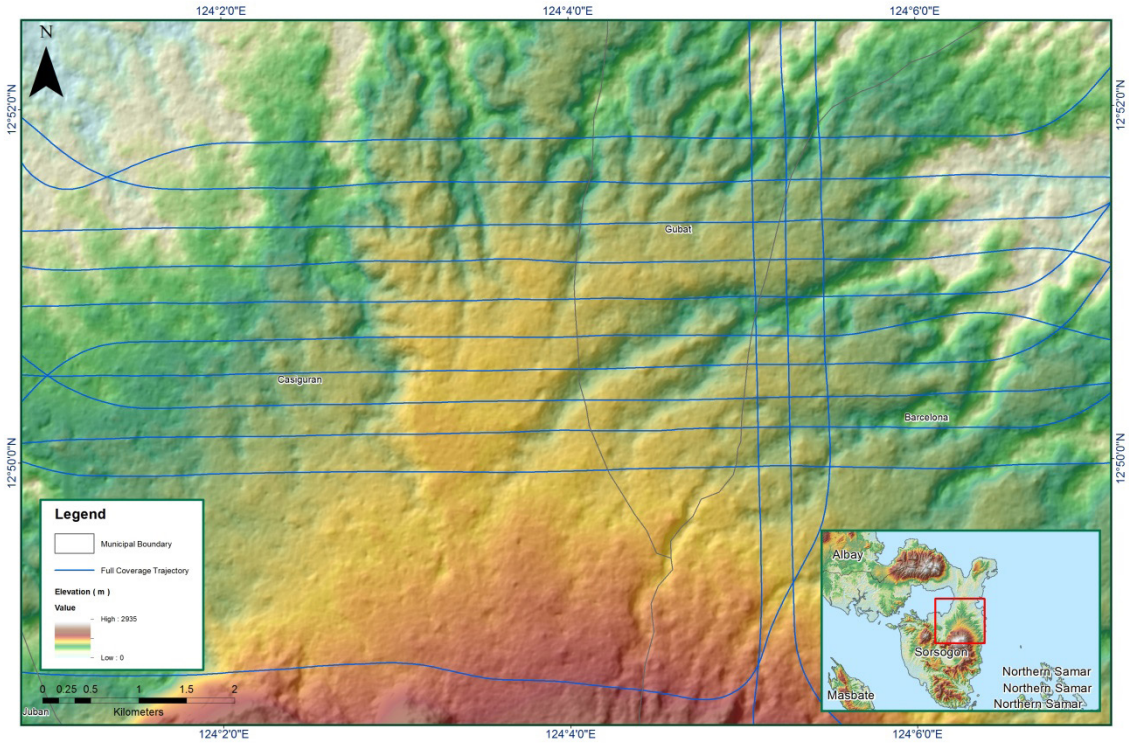


Figure 1.8.3. Best Estimated Trajectory

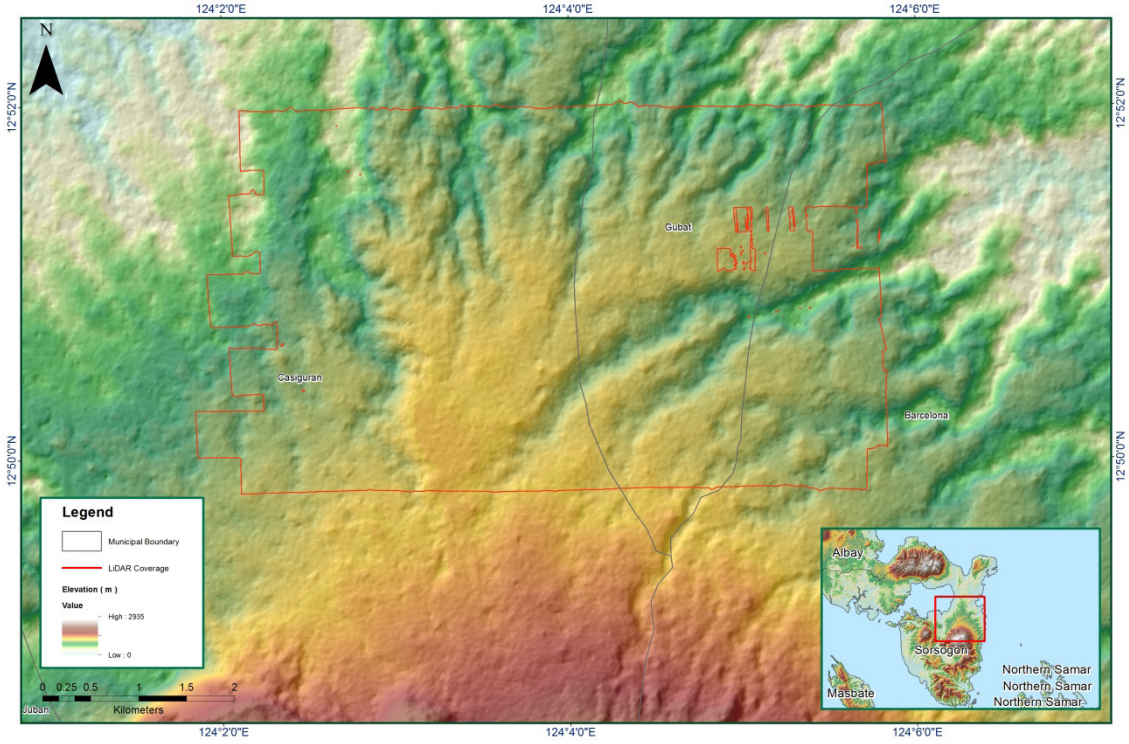


Figure 1.8.4. Coverage of LiDAR Data

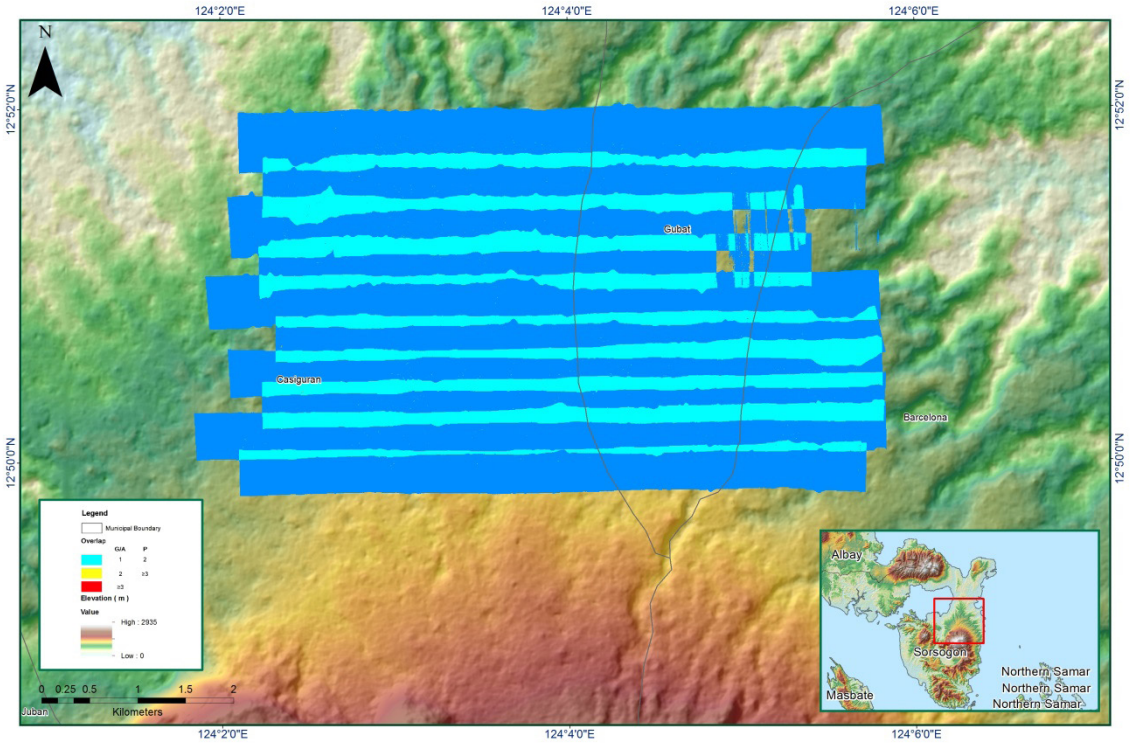


Figure 1.8.5. Image of data overlap

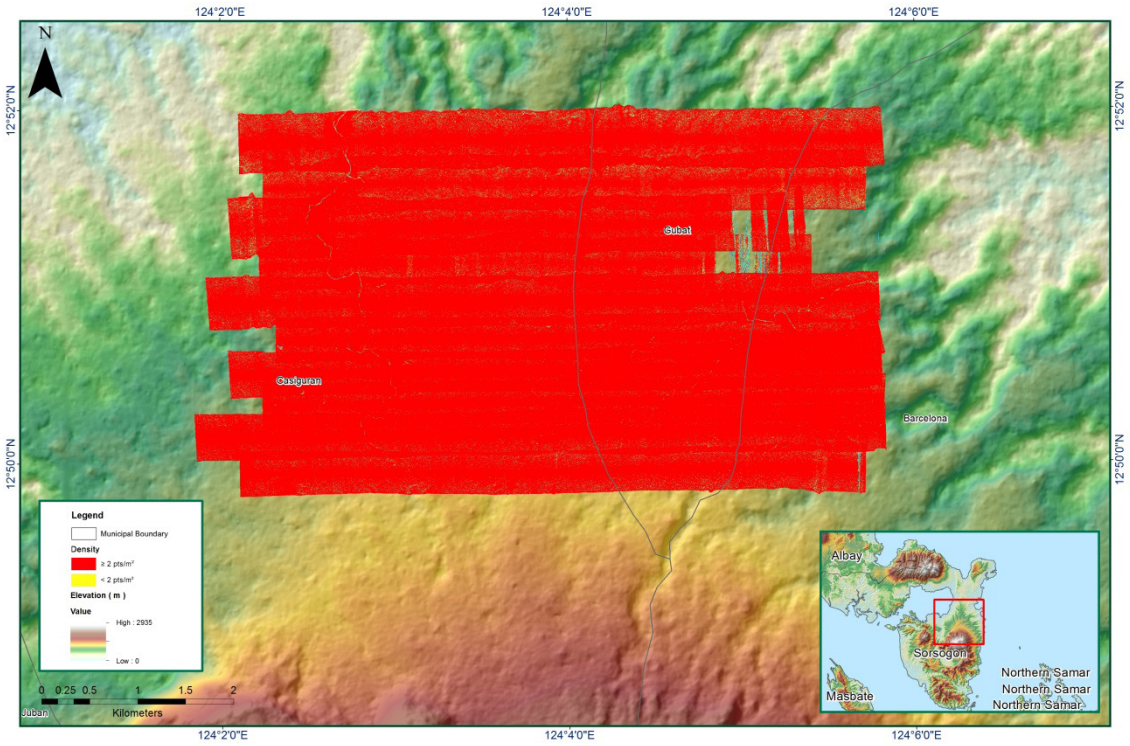


Figure 1.8.6. Density map of merged LiDAR data

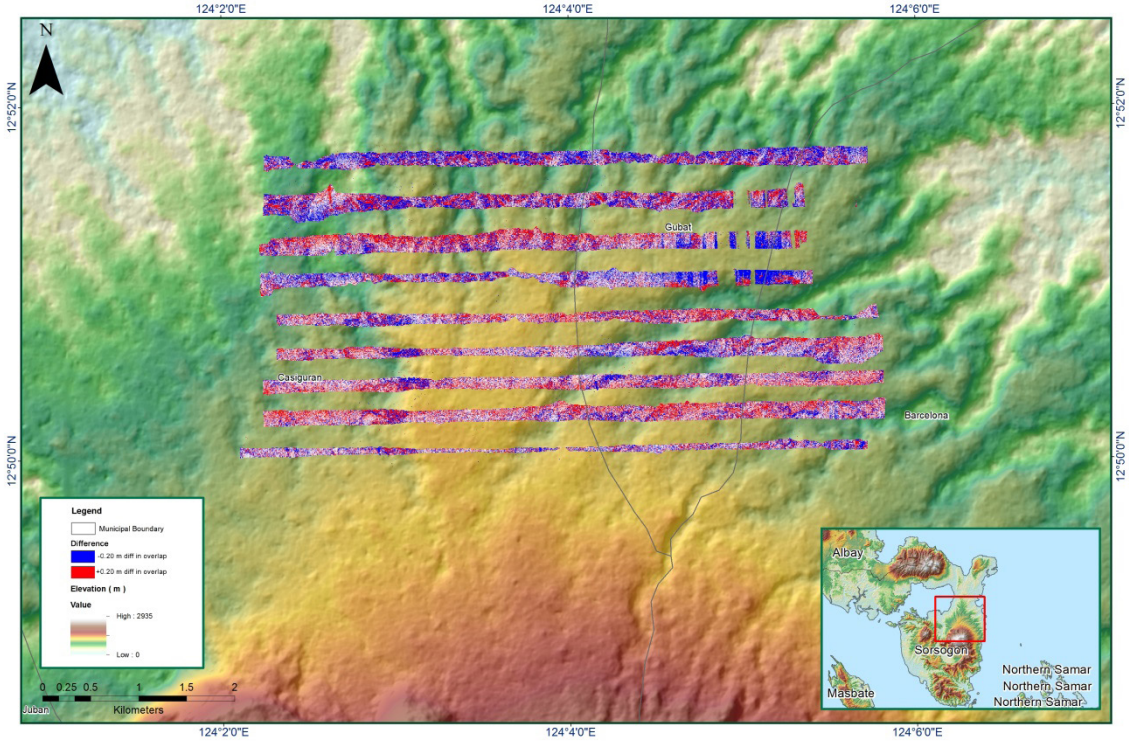


Figure 1.8.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aK_additional
Inclusive Flights	3903G
Range data size	15.8 GB
POS data size	219 MB
Base data size	12.9 MB
Image	30.9 MB
Transfer date	March 31, 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)	1.684
RMSE for East Position (<4.0 cm)	1.475
RMSE for Down Position (<8.0 cm)	2.774
Boresight correction stdev (<0.001deg)	0.006872
IMU attitude correction stdev (<0.001deg)	0.009347
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	37.63 %
Ave point cloud density per sq.m. (>2.0)	8.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	23
Maximum Height	596.74 m
Minimum Height	137.18 m
Classification (# of points)	
Ground	3,334,198
Low vegetation	2,843,319
Medium vegetation	22,726,599
High vegetation	48,313,267
Building	151,844
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Velina Angela Bemida, Jovy Narisma

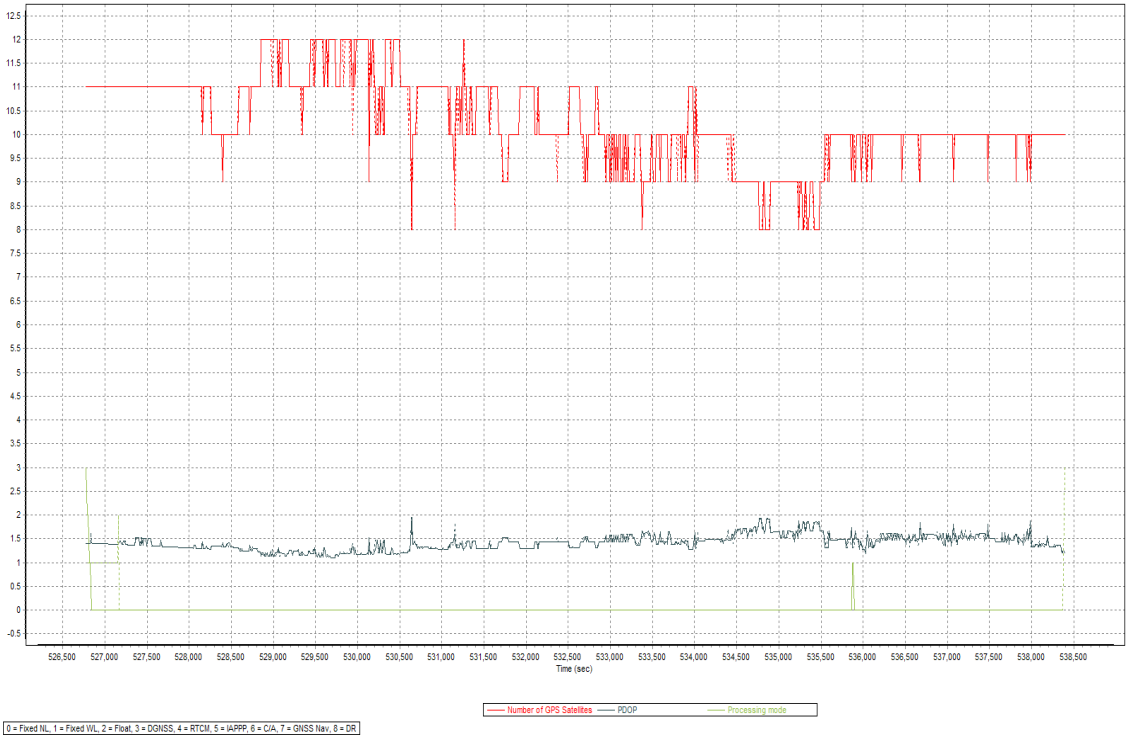


Figure 1.9.1. Solution Status

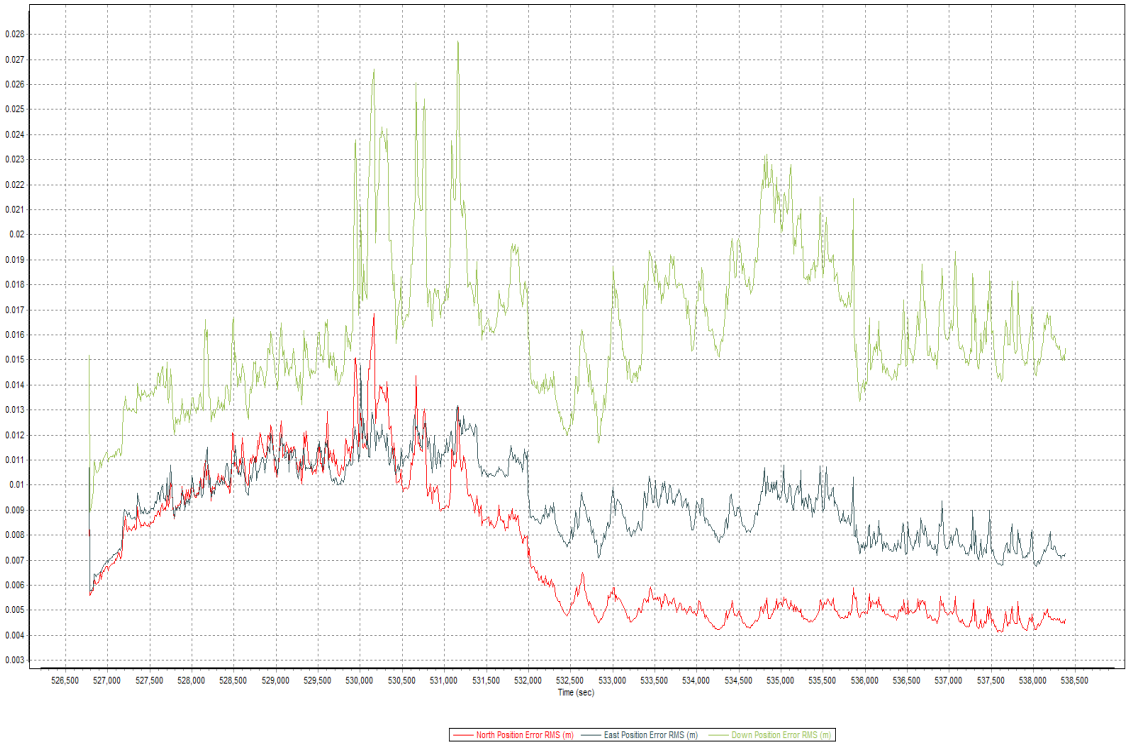


Figure 1.9.2. Smoothed Performance Metric Parameters

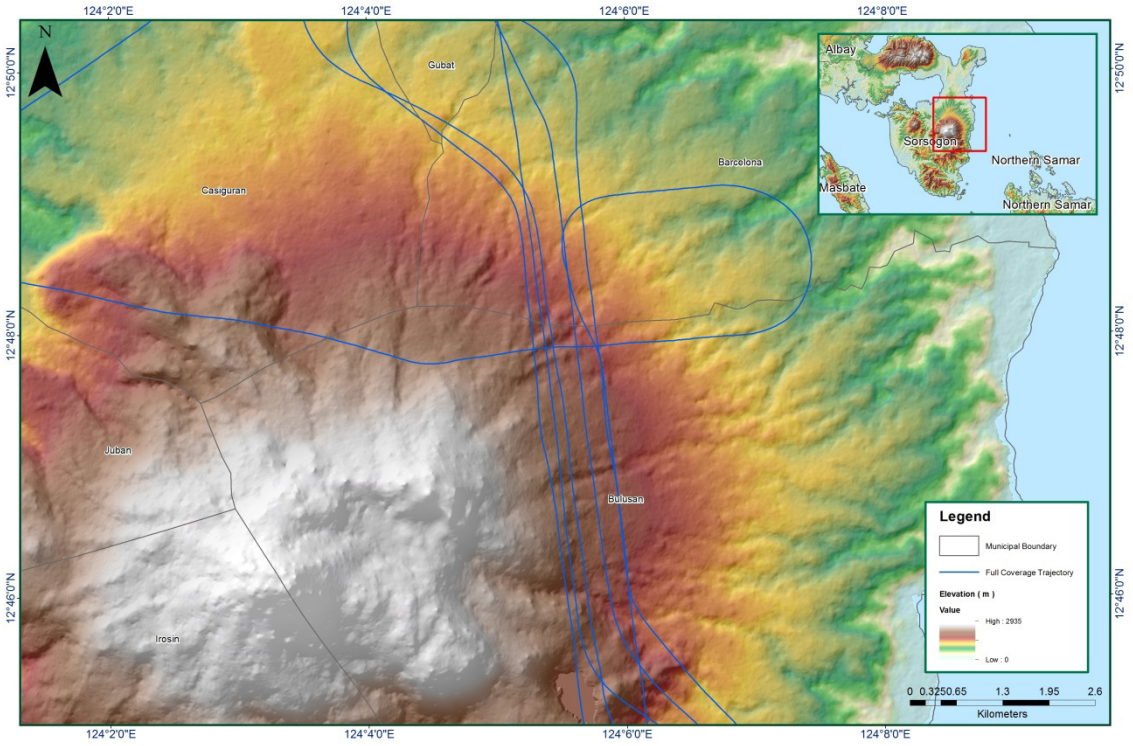


Figure 1.9.3. Best Estimated Trajectory

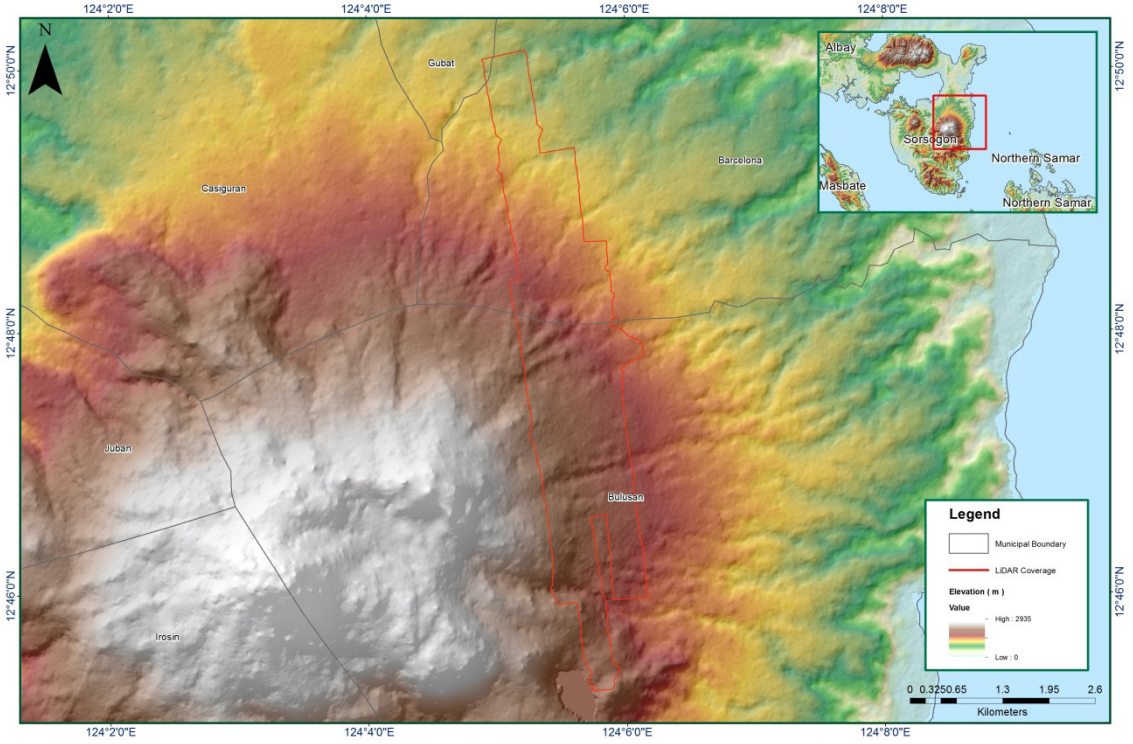


Figure 1.9.4. Coverage of LiDAR Data

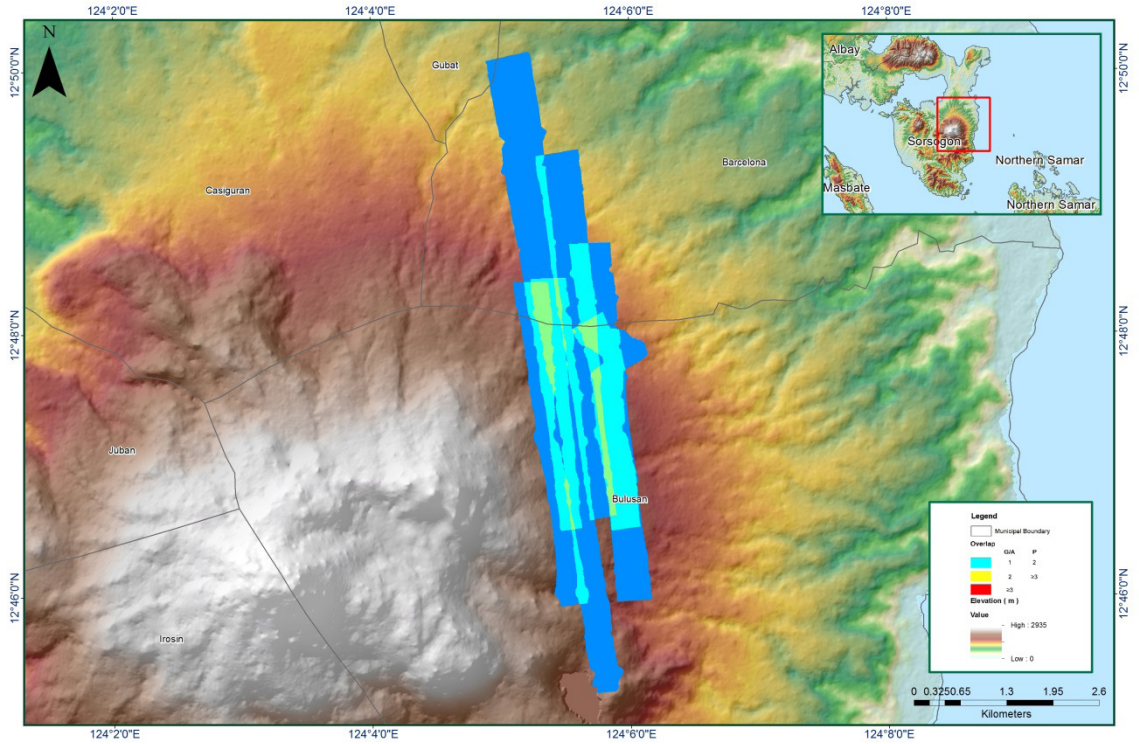


Figure 1.9.5. Image of data overlap

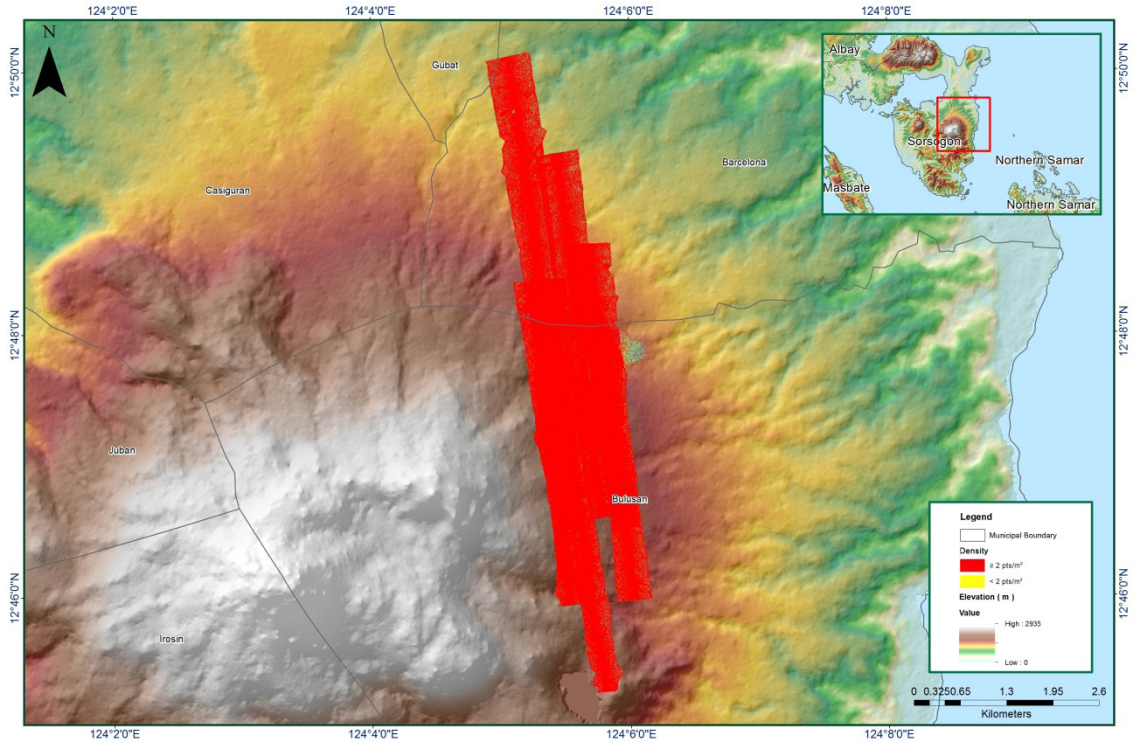


Figure 1.9.6. Density map of merged LiDAR data

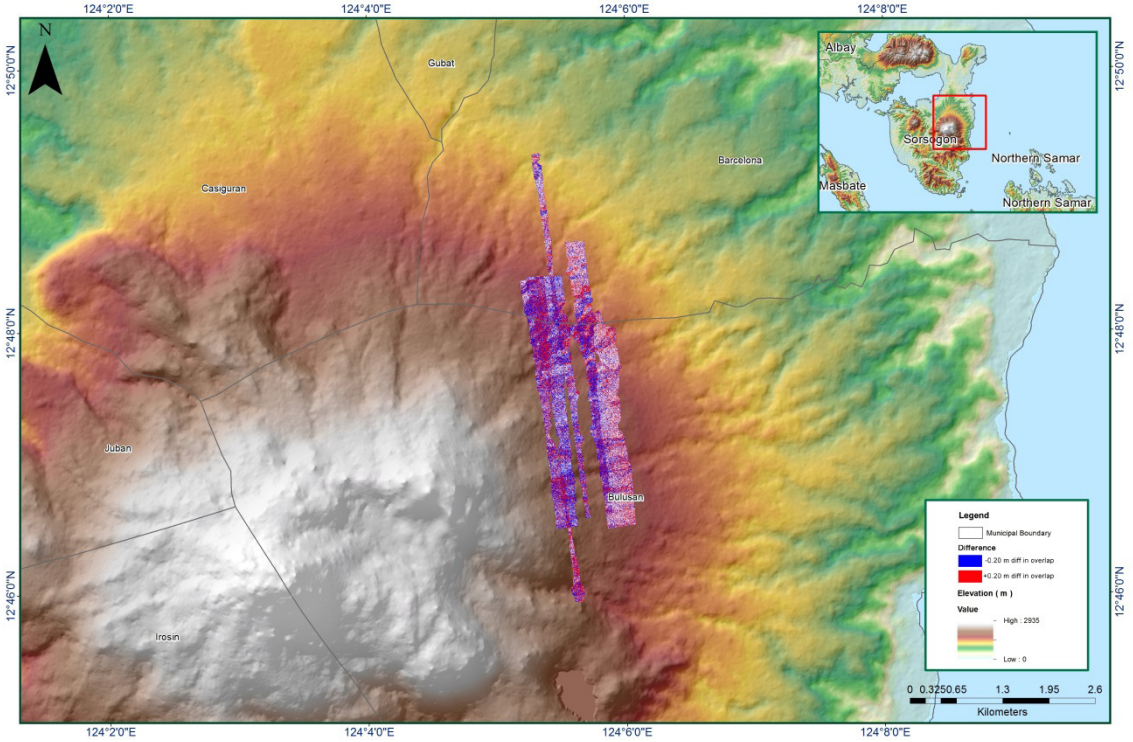


Figure 1.9.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aJ
Inclusive Flights	3879P, 3883G
Range data size	60.40 GB
POS data size	555 MB
Base data size	26.60 MB
Image	122 GB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.666
RMSE for East Position (<4.0 cm)	1.965
RMSE for Down Position (<8.0 cm)	4.805
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	34.20 %
Ave point cloud density per sq.m. (>2.0)	4.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	236
Maximum Height	306.01 m
Minimum Height	52.06 m
Classification (# of points)	
Ground	88,435,597
Low vegetation	44,728,352
Medium vegetation	289,863,219
High vegetation	386,642,086
Building	797,032
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Edgardo Gubatanga, Maria Tamsyn Malabanan

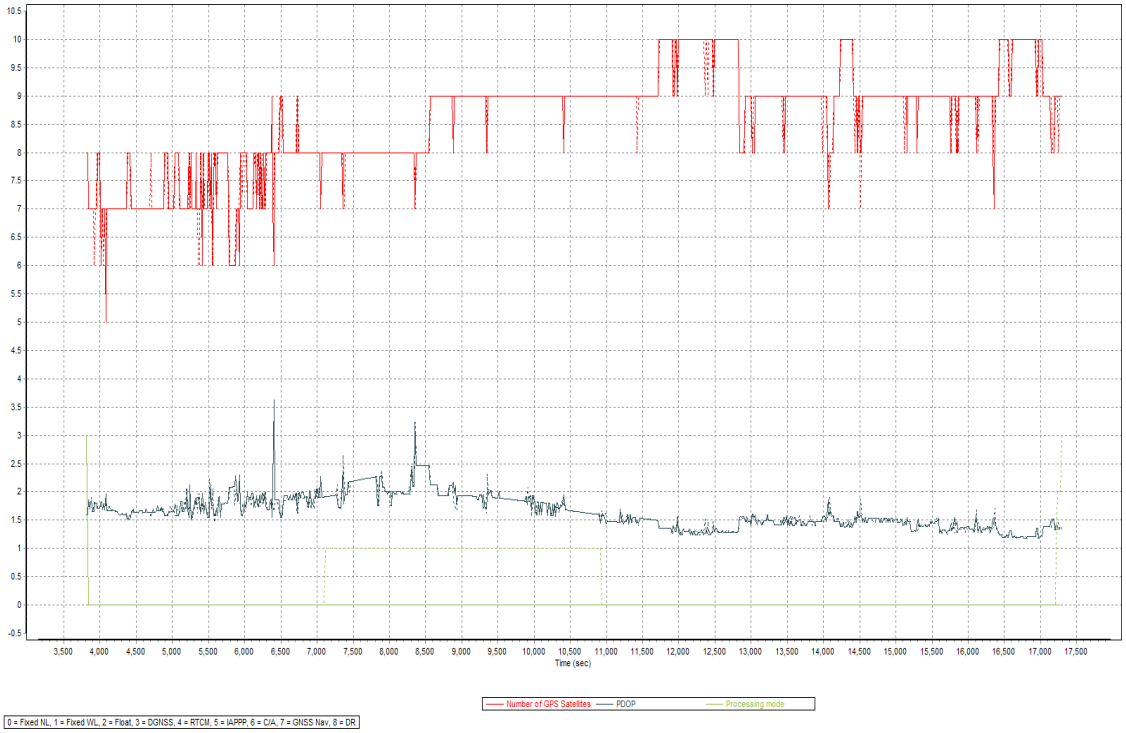


Figure 1.10.1. Solution Status

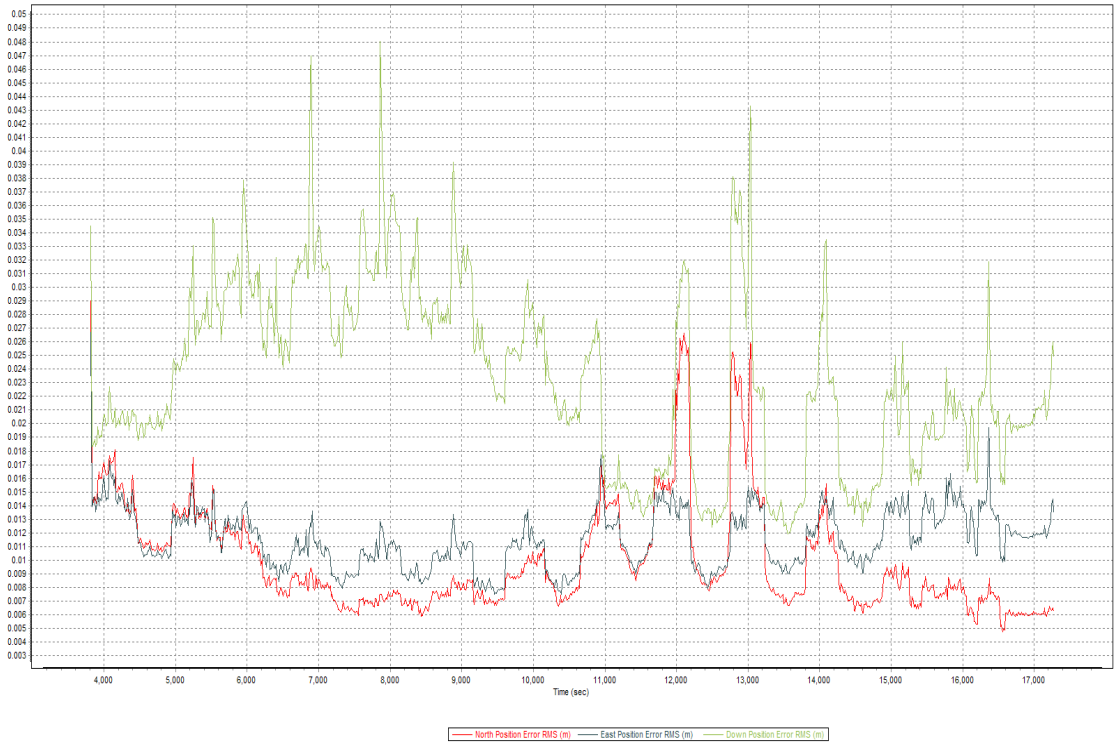


Figure 1.10.2. Smoothed Performance Metric Parameters

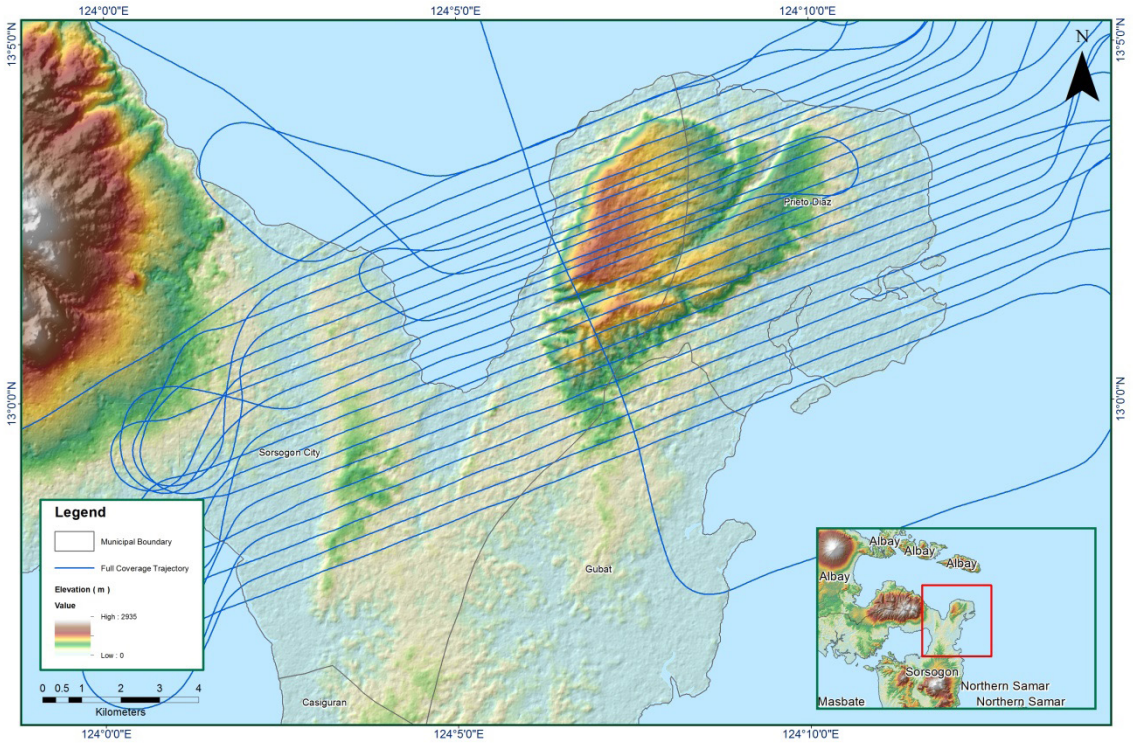


Figure 1.10.3. Best Estimated Trajectory

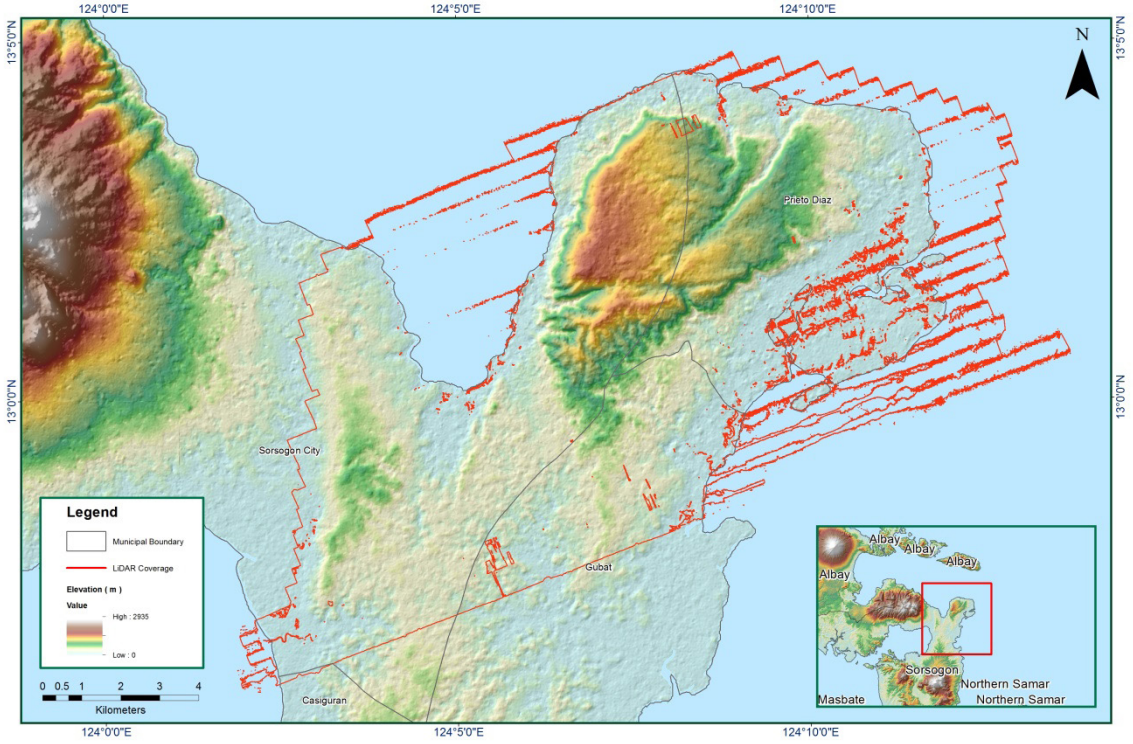


Figure 1.10.4. Coverage of LiDAR Data

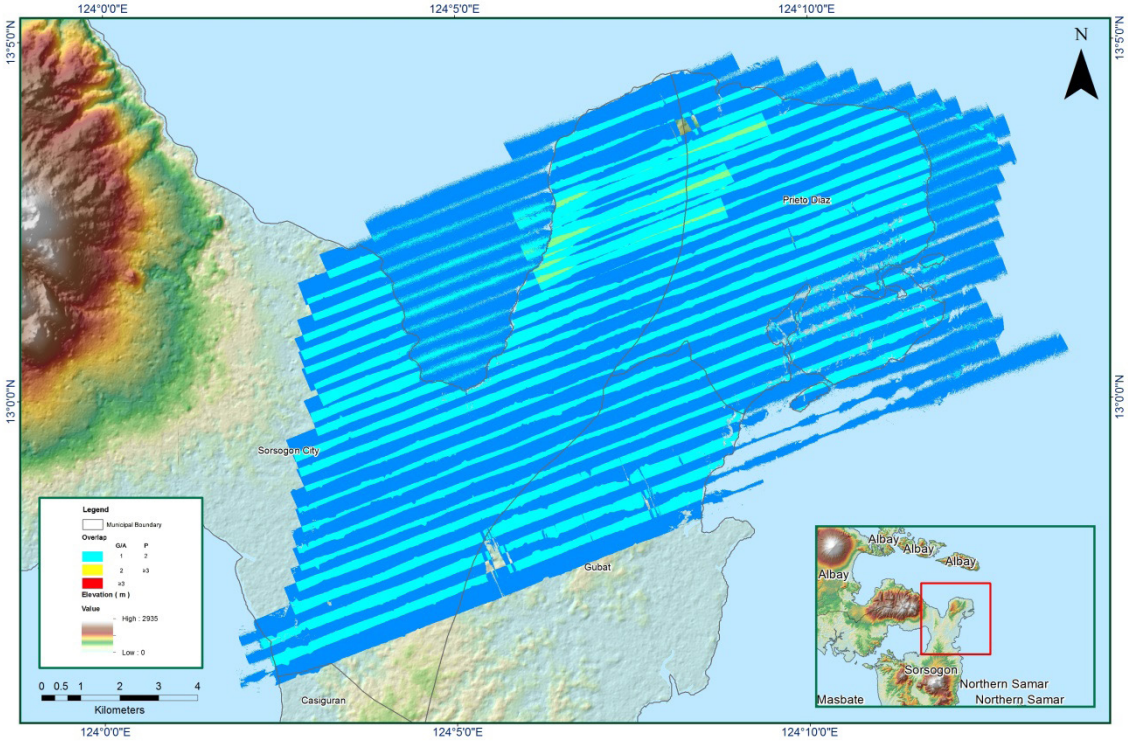


Figure 1.10.5. Image of data overlap

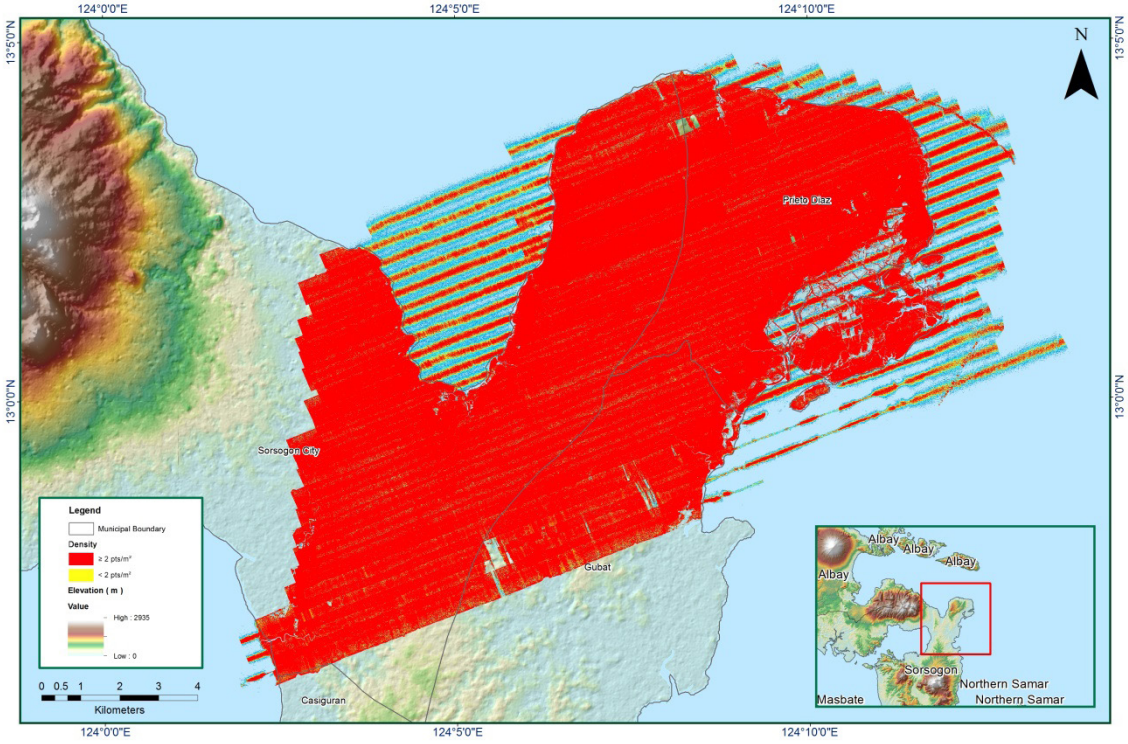


Figure 1.10.6. Density map of merged LiDAR data

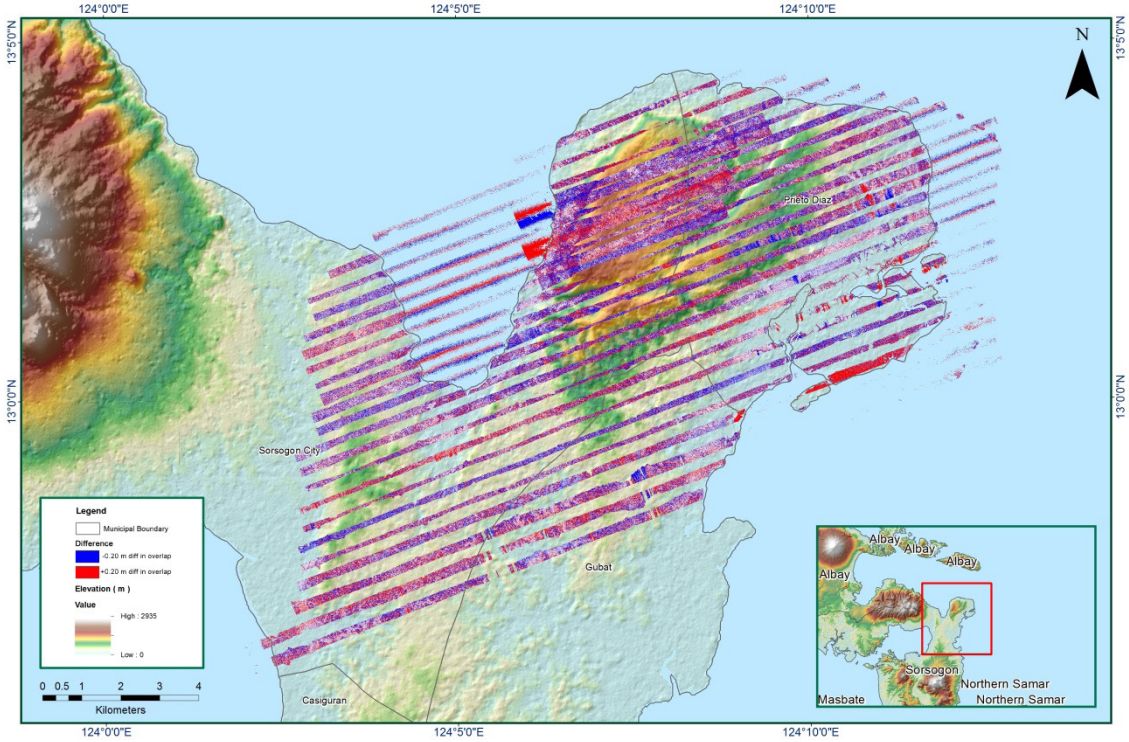


Figure 1.10.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aK
Inclusive Flights	3883G, 3885G, 3887G, 3889G, 3899G
Range data size	108.3 GB
POS data size	1186 MB
Base data size	70.12 MB
Image	210.3 MB
Transfer date	March 31, 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)	0.003611
IMU attitude correction stdev (<0.001deg)	0.010301
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	43.84 %
Ave point cloud density per sq.m. (>2.0)	5.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	216
Maximum Height	681.94 m
Minimum Height	53.41 m
Classification (# of points)	
Ground	68,076,528
Low vegetation	45,788,355
Medium vegetation	332,055,980
High vegetation	425,587,140
Building	915,777
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Justine Francisco, Maria Tamsyn Malabanan

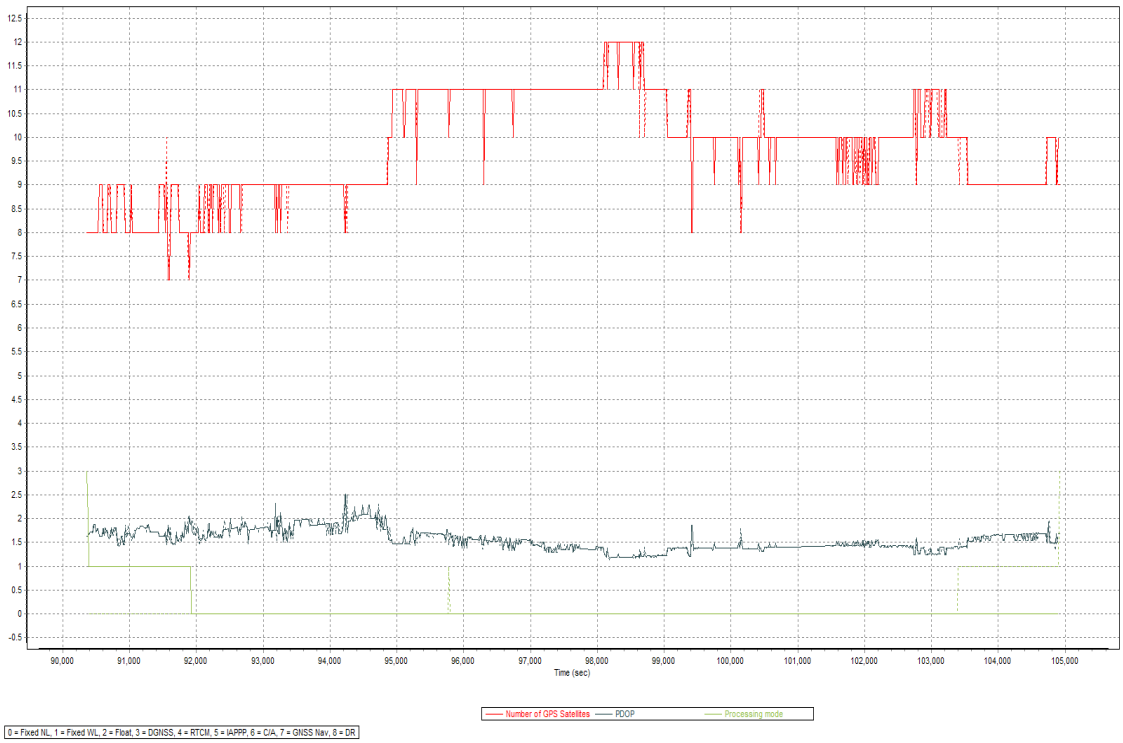


Figure 1.11.1. Solution Status

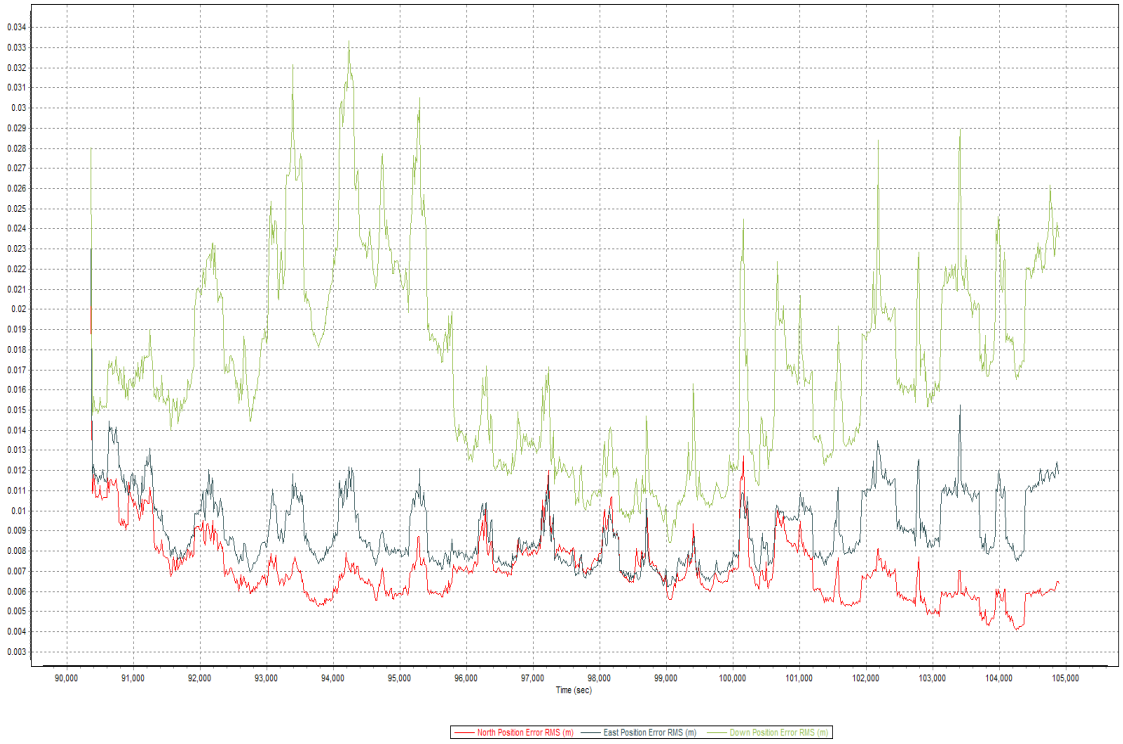


Figure 1.11.2. Smoothed Performance Metric Parameters

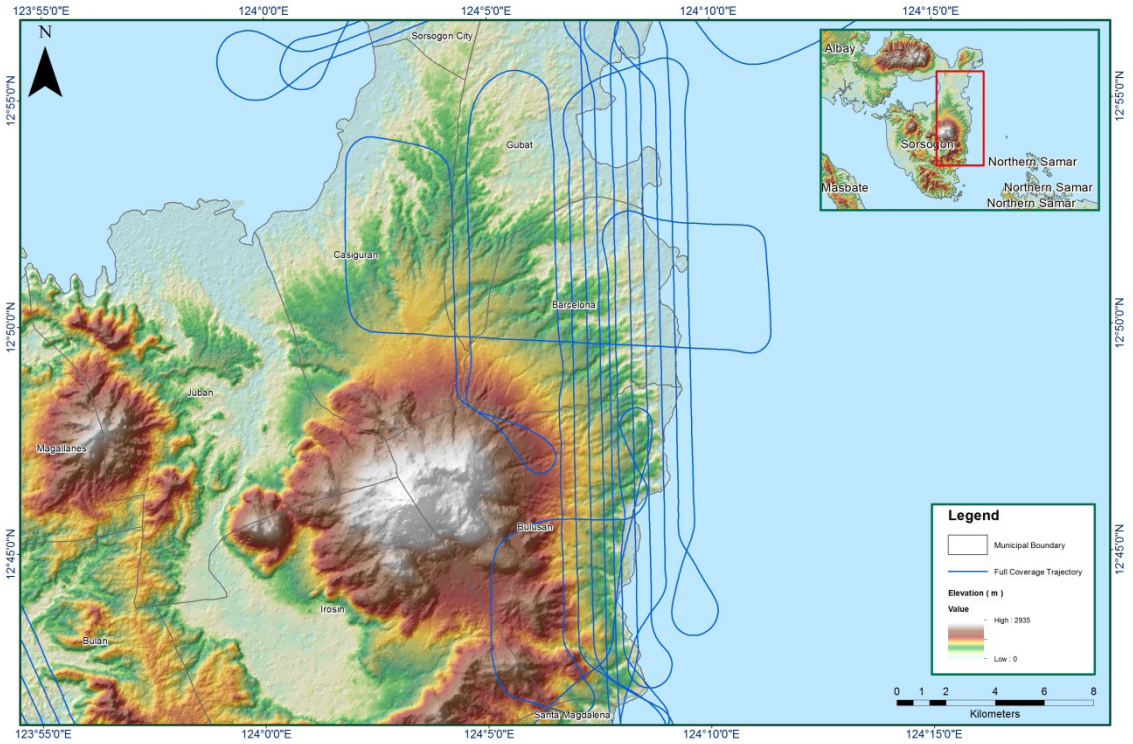


Figure 1.11.3. Best Estimated Trajectory

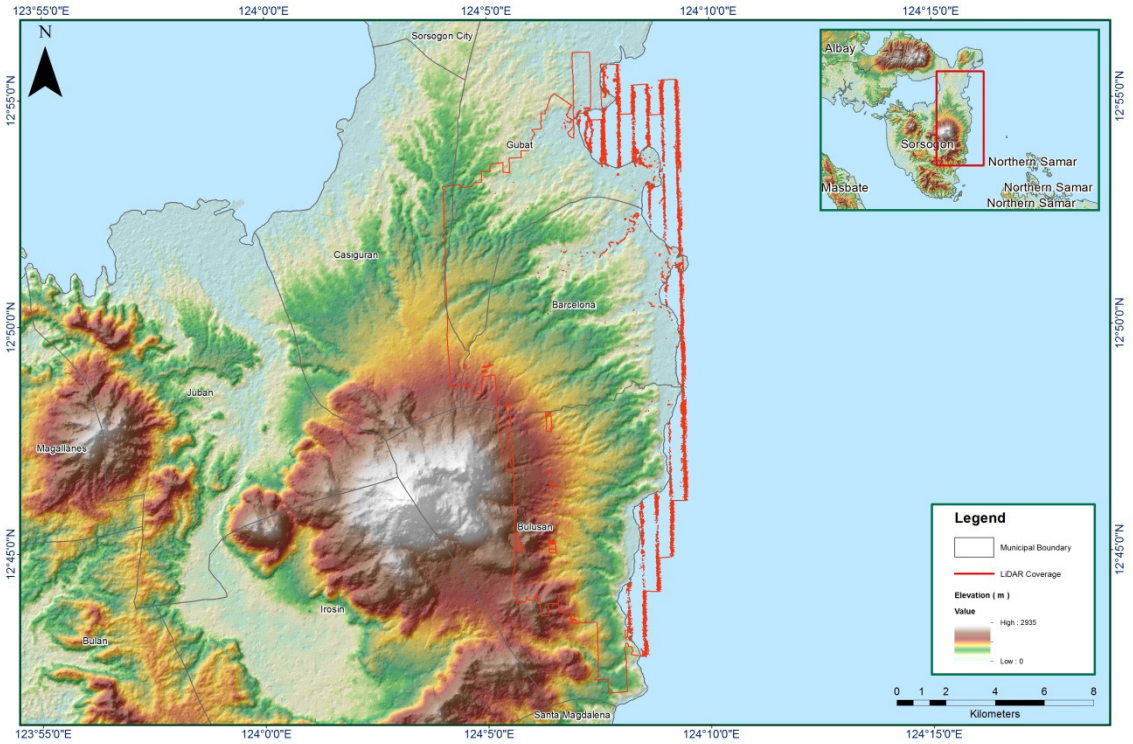


Figure 1.11.4. Coverage of LiDAR Data

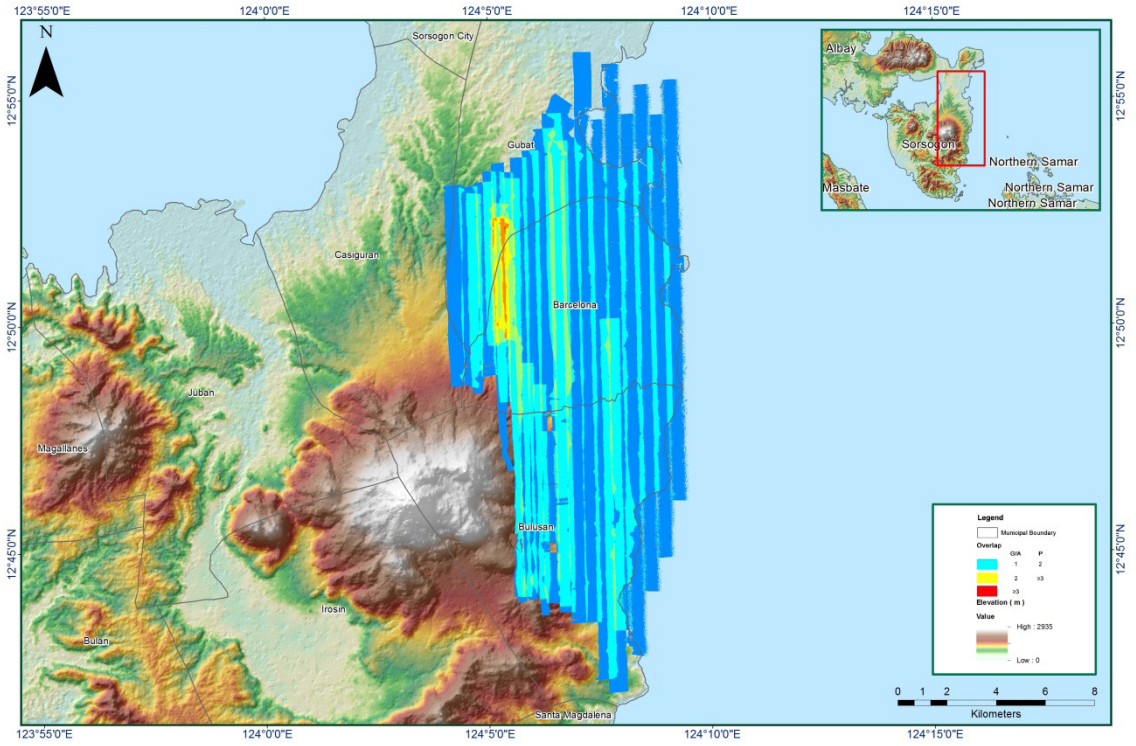


Figure 1.11.5. Image of data overlap

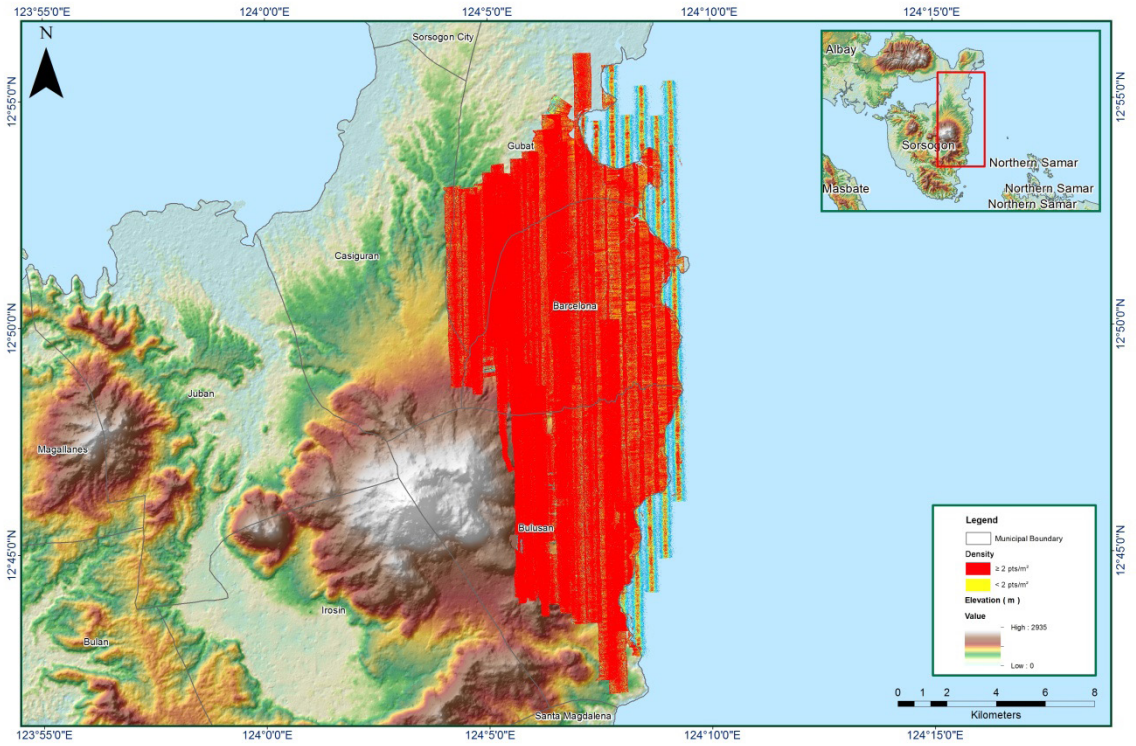


Figure 1.11.6. Density map of merged LiDAR data

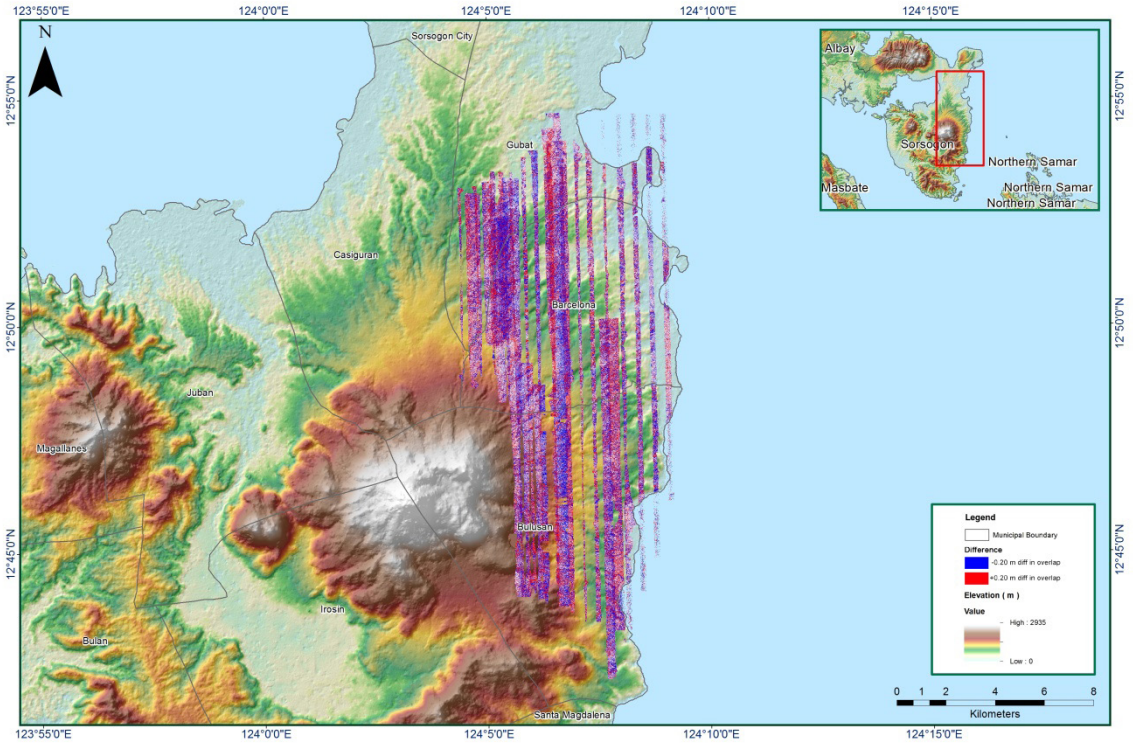


Figure 1.11.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aI
Inclusive Flights	3871G
Range data size	23.9 GB
POS data size	279 MB
Base data size	18.8 MB
Image	45.5 MB
Transfer date	March 31, 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)	1.485
RMSE for East Position (<4.0 cm)	1.628
RMSE for Down Position (<8.0 cm)	3.323
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	24.52 %
Ave point cloud density per sq.m. (>2.0)	3.55
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	72
Maximum Height	125.79 m
Minimum Height	51.97 m
Classification (# of points)	
Ground	13,423,462
Low vegetation	11,263,551
Medium vegetation	71,624,229
High vegetation	39,465,311
Building	168,261
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Ma. Joanne Balaga, Marie Denise Bueno

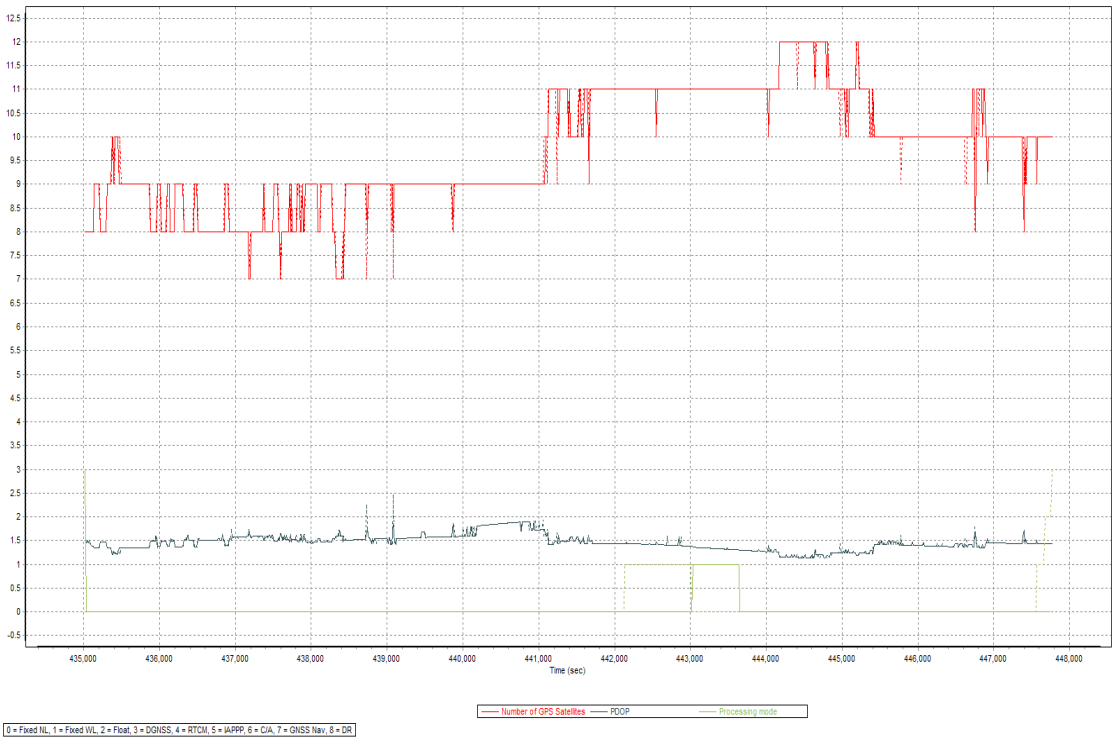


Figure 1.12.1. Solution Status

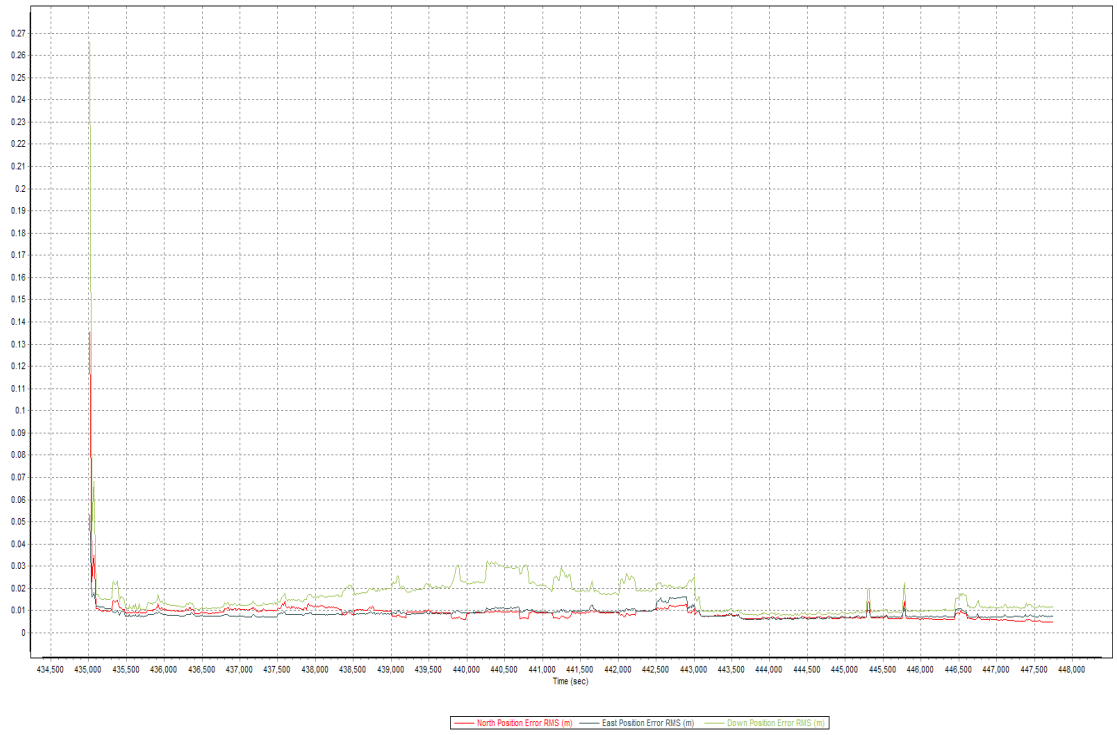


Figure 1.12.2. Smoothed Performance Metric Parameters

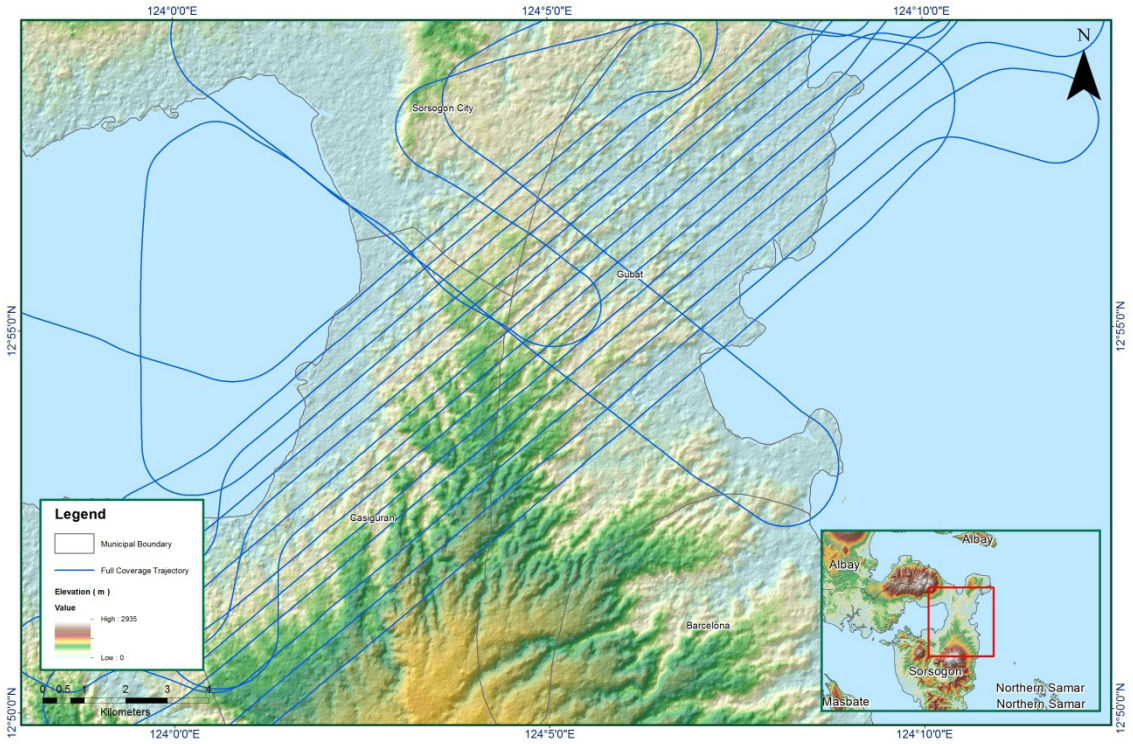


Figure 1.12.3. Best Estimated Trajectory

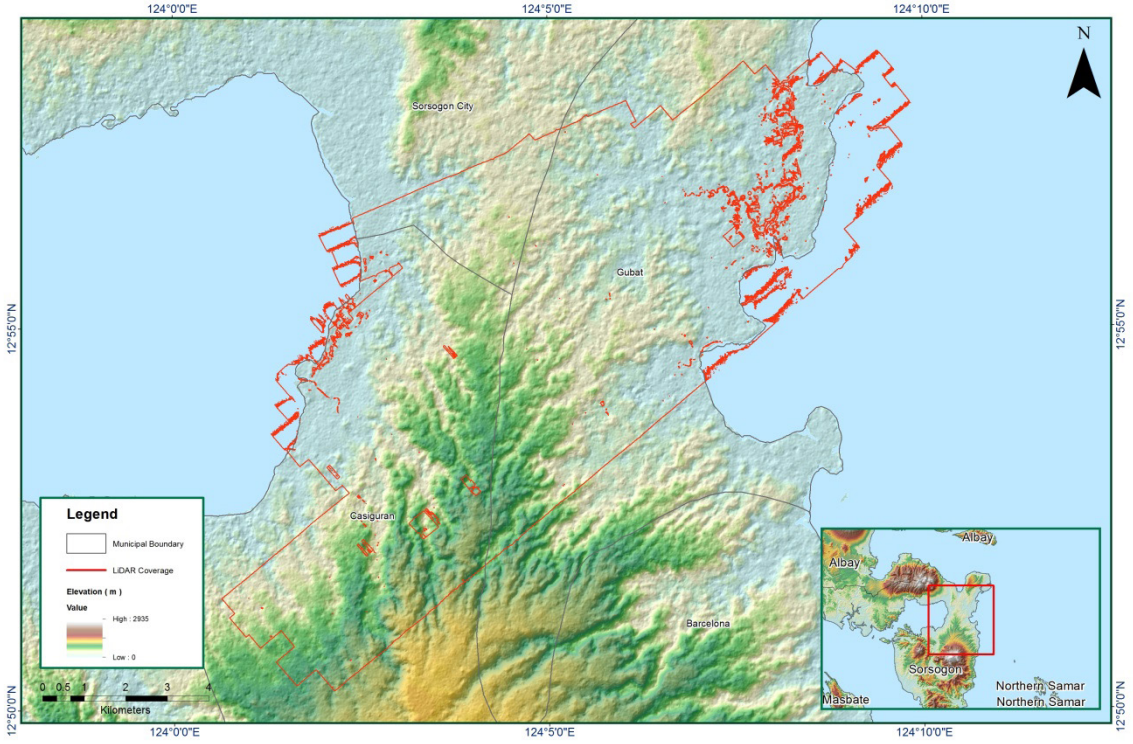


Figure 1.12.4. Coverage of LiDAR Data

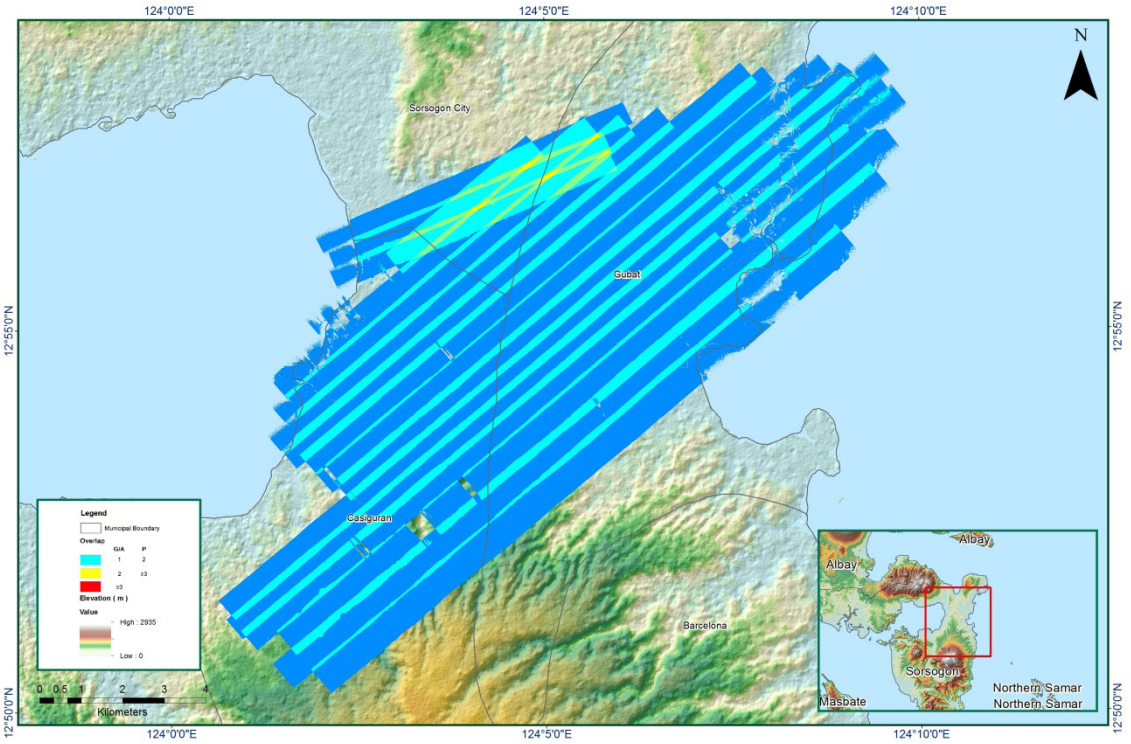


Figure 1.12.5. Image of data overlap

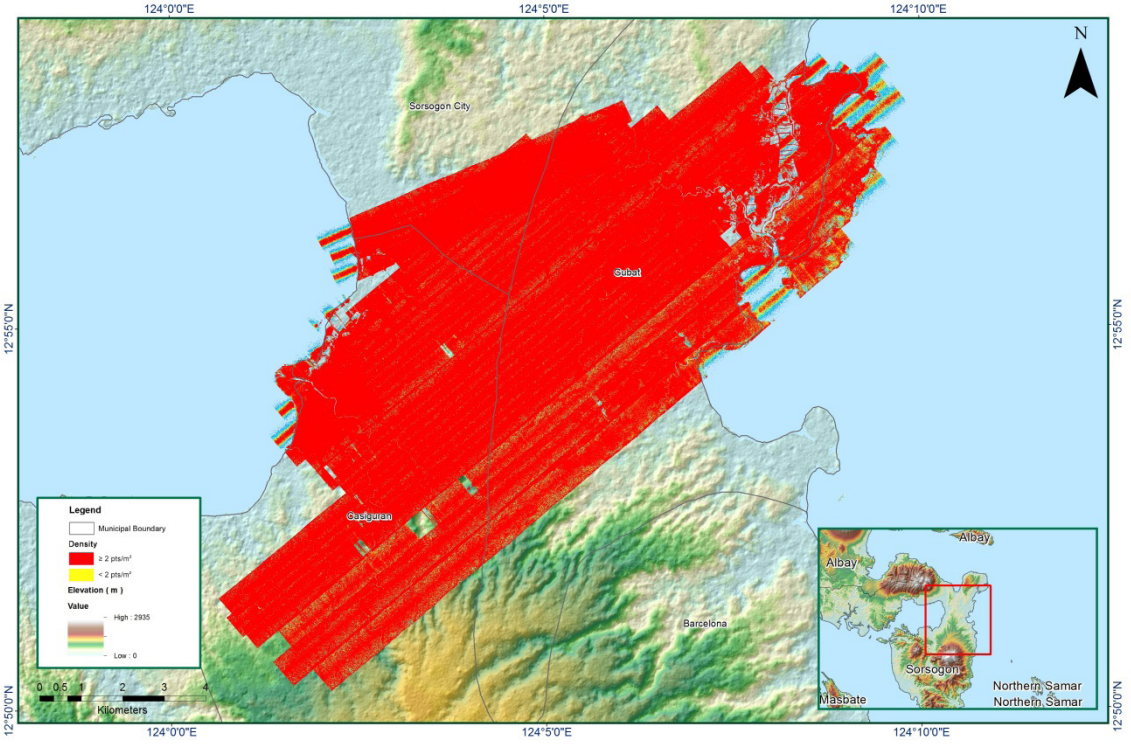


Figure 1.12.6. Density map of merged LiDAR data

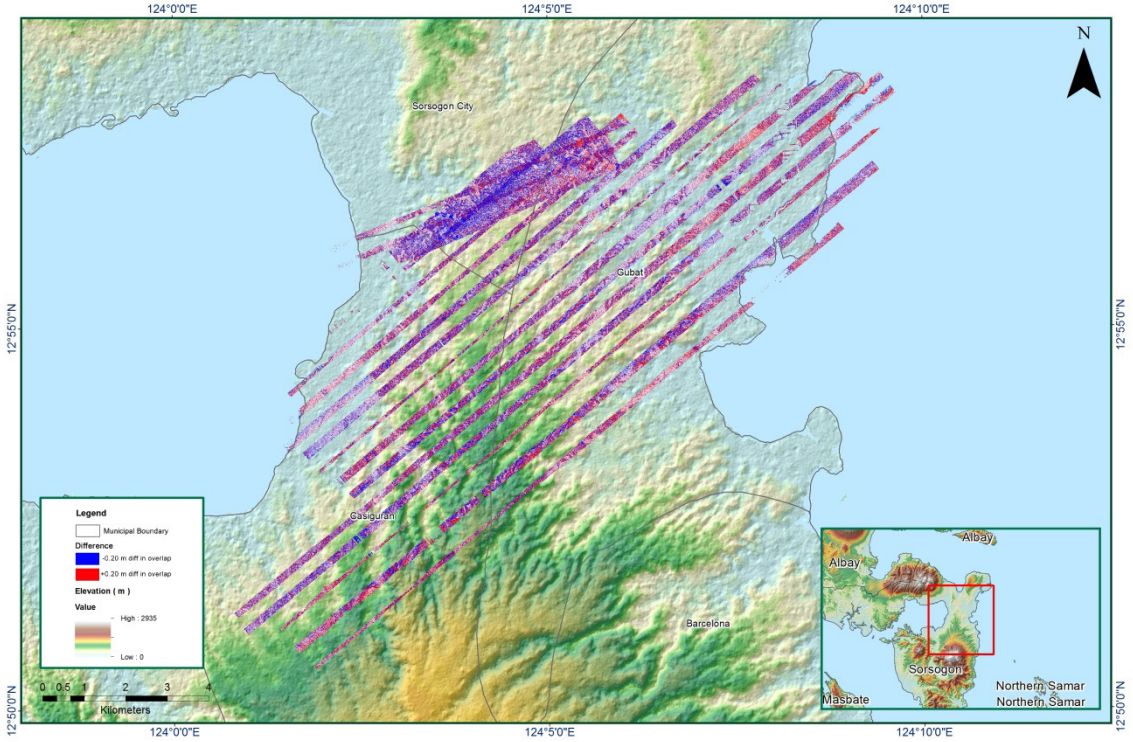


Figure 1.12.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aH
Inclusive Flights	3873G, 3899G
Range data size	37.2 GB
POS data size	453 MB
Base data size	21.93 MB
Image	76 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.982
RMSE for East Position (<4.0 cm)	1.240
RMSE for Down Position (<8.0 cm)	3.522
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	30.27 %
Ave point cloud density per sq.m. (>2.0)	4.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	295.02 m
Minimum Height	52.33 m
Classification (# of points)	
Ground	39,225,382
Low vegetation	28,862,088
Medium vegetation	231,981,613
High vegetation	201,168,019
Building	130,407
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Ma. Joanne Balaga, Engr. Melissa Fernandez

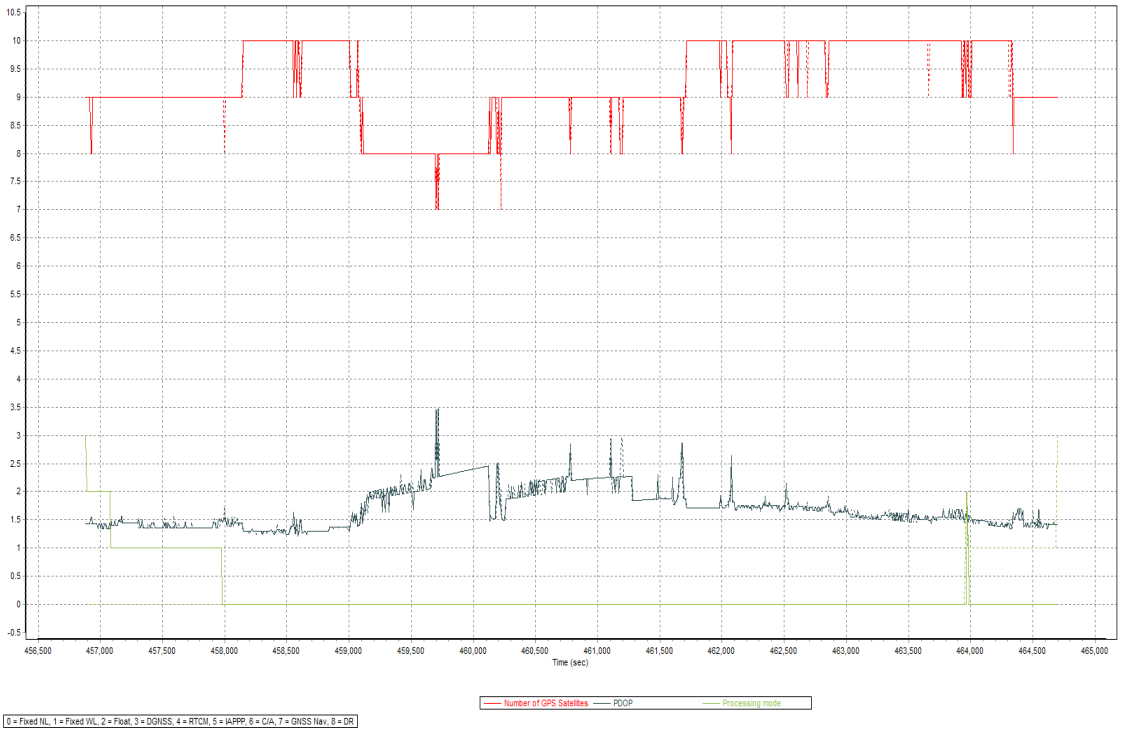


Figure 1.13.1. Solution Status

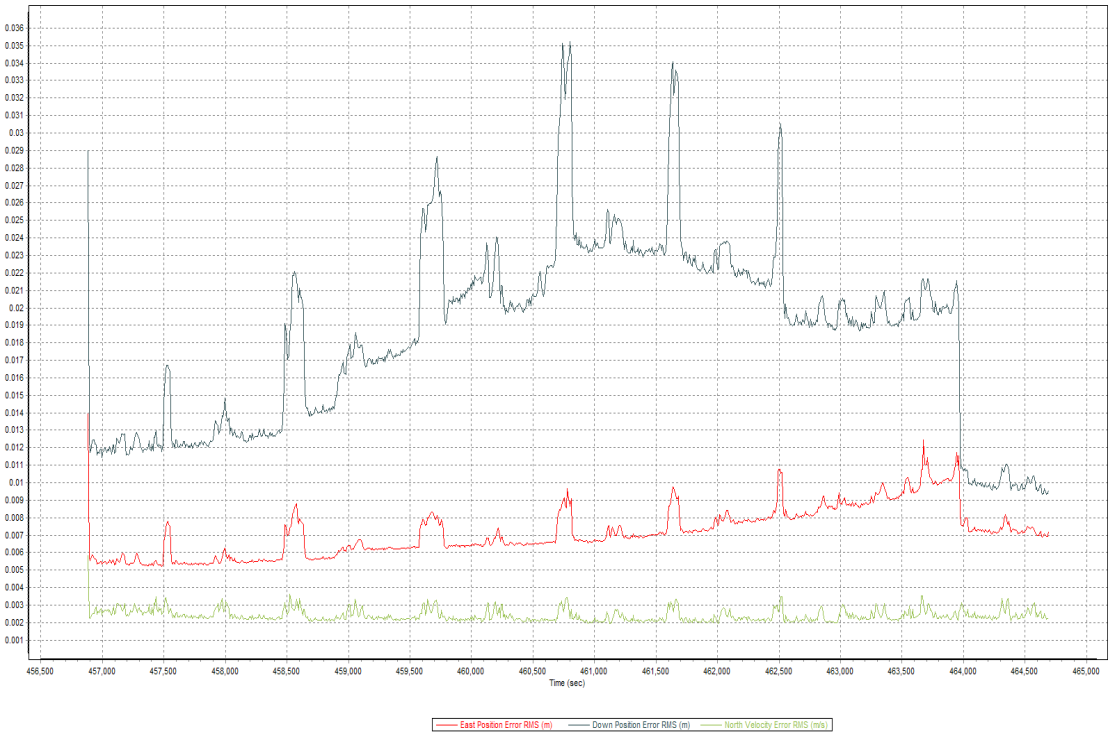


Figure 1.13.2. Smoothed Performance Metric Parameters

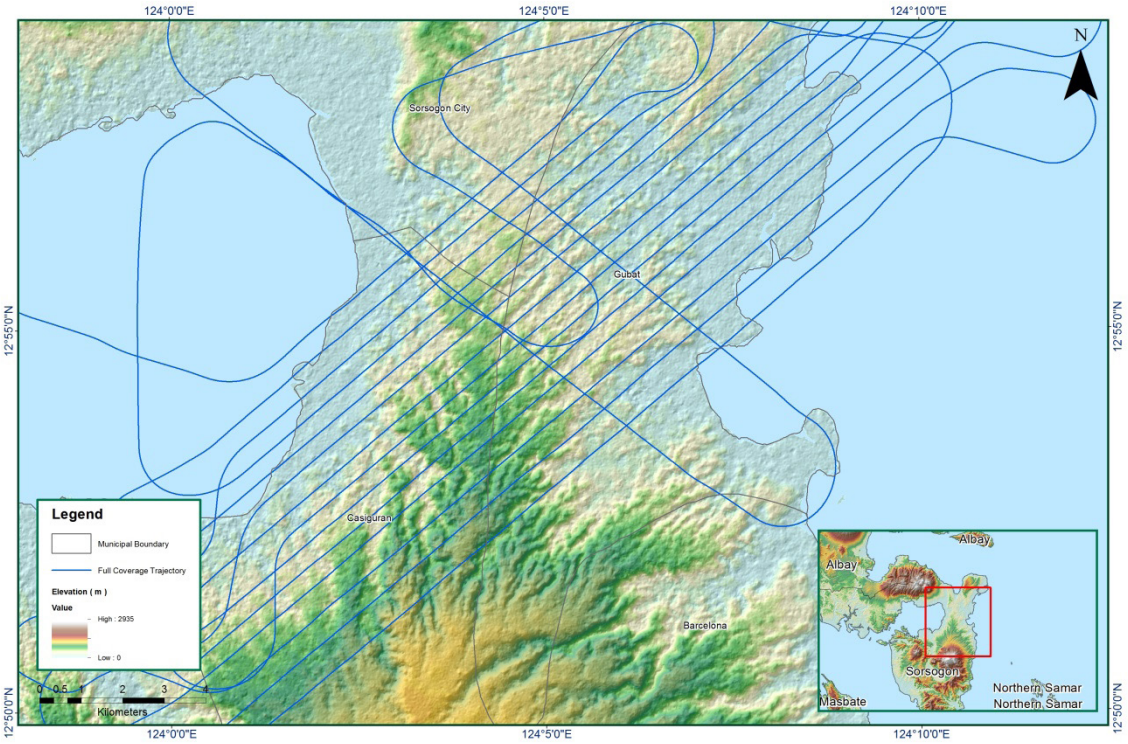


Figure 1.13.3. Best Estimated Trajectory

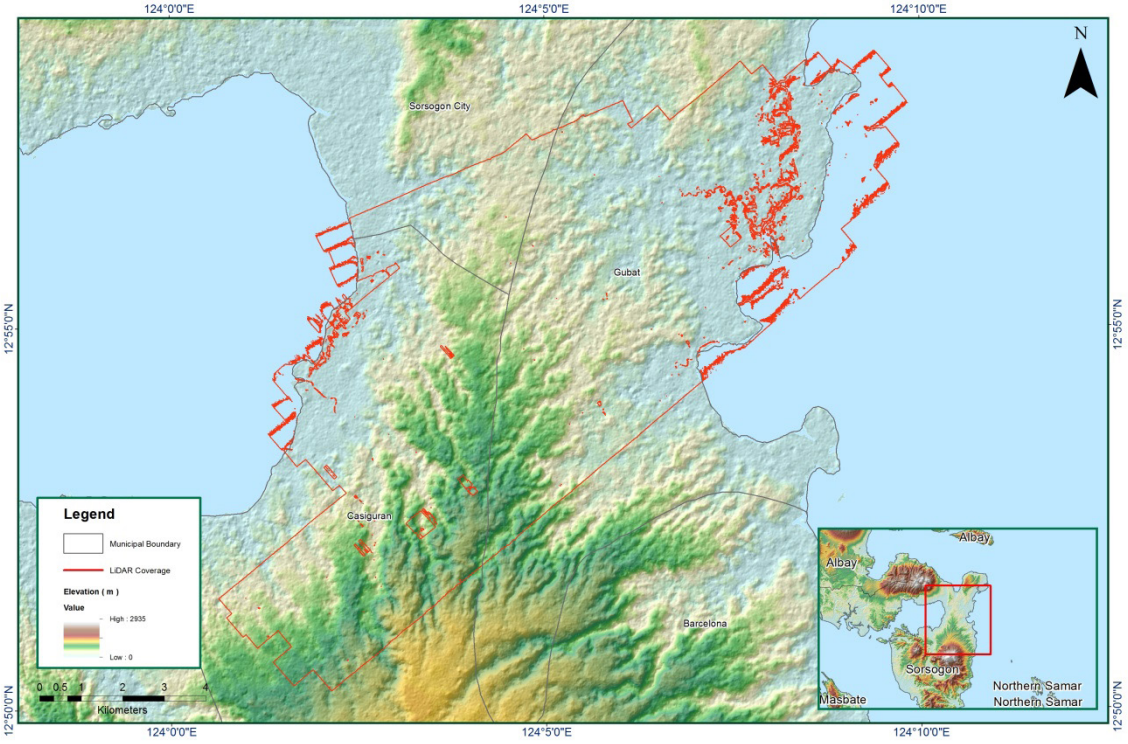


Figure 1.13.4. Coverage of LiDAR Data

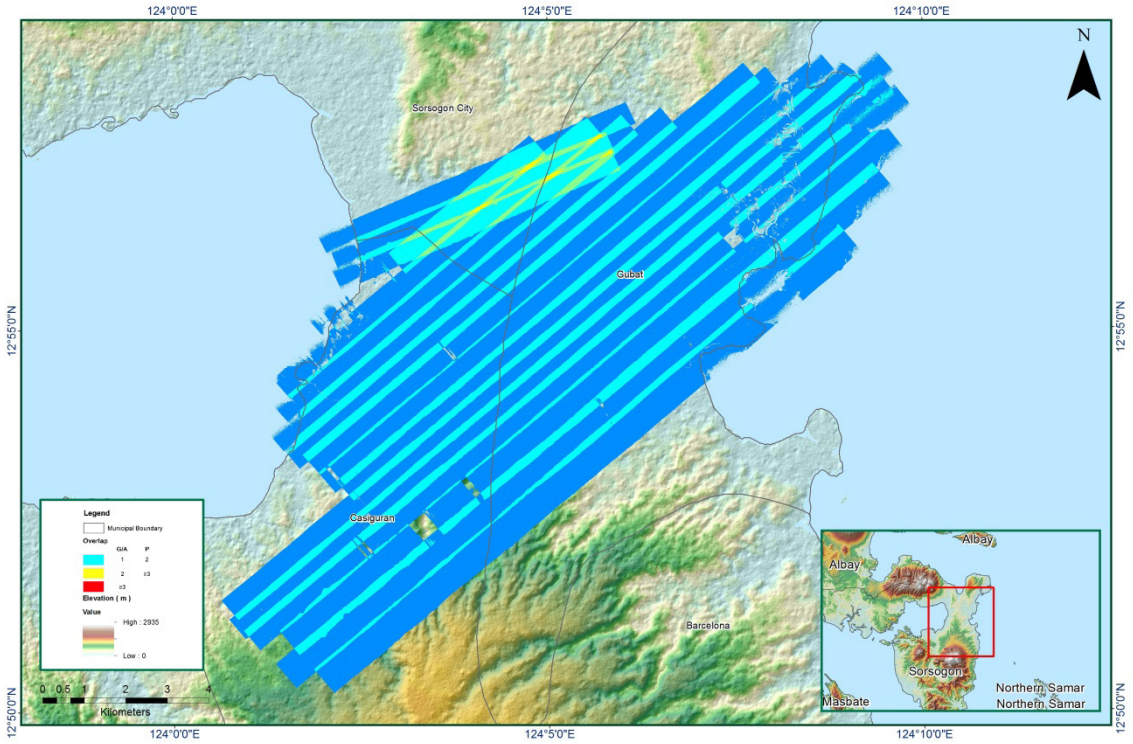


Figure 1.13.5. Image of data overlap

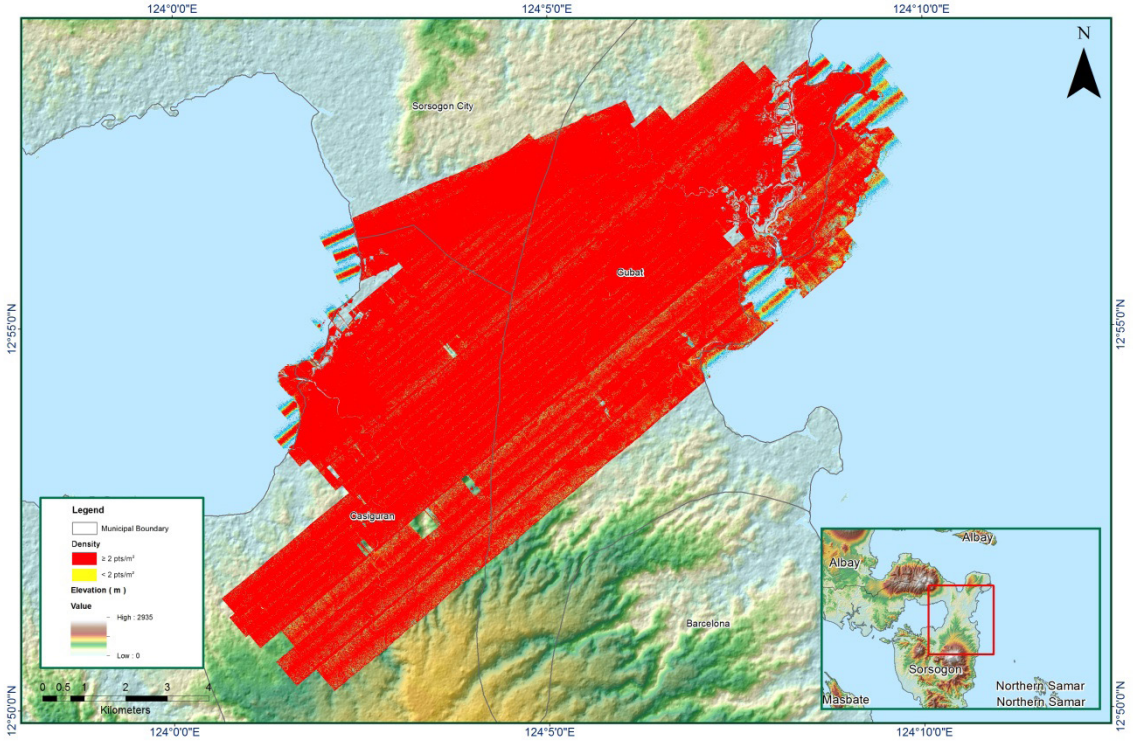


Figure 1.13.6. Density map of merged LiDAR data

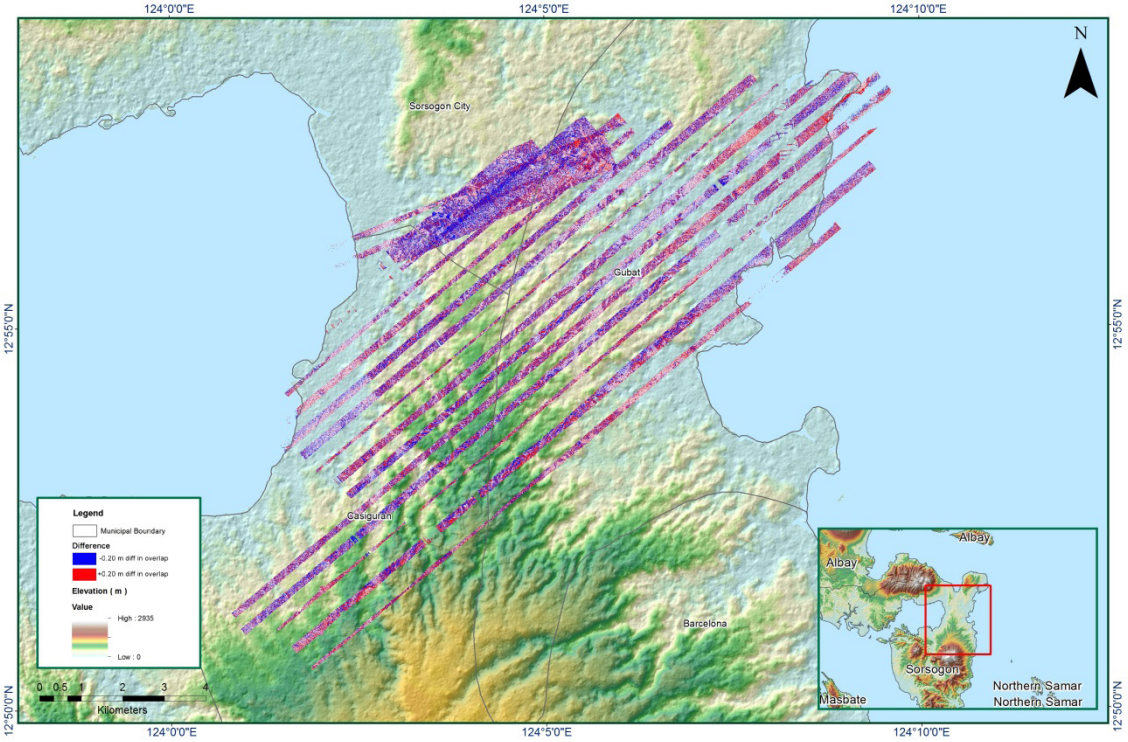


Figure 1.13.7. Elevation difference between flight lines

Flight Area	Albay-Sorsogon
Mission Name	Blk 19aF
Inclusive Flights	3863G
Range data size	25.9 GB
POS data size	262 MB
Base data size	10.1 MB
Image	46.6 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.016
RMSE for East Position (<4.0 cm)	0.980
RMSE for Down Position (<8.0 cm)	1.92
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	32.49 %
Ave point cloud density per sq.m. (>2.0)	3.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	84
Maximum Height	154.86 m
Minimum Height	54.63 m
Classification (# of points)	
Ground	17,706,791
Low vegetation	11,013,393
Medium vegetation	77,281,529
High vegetation	44,031,418
Building	75,386
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Ma. Joanne Balaga, Melissa, Maria Tamsyn Malabanan

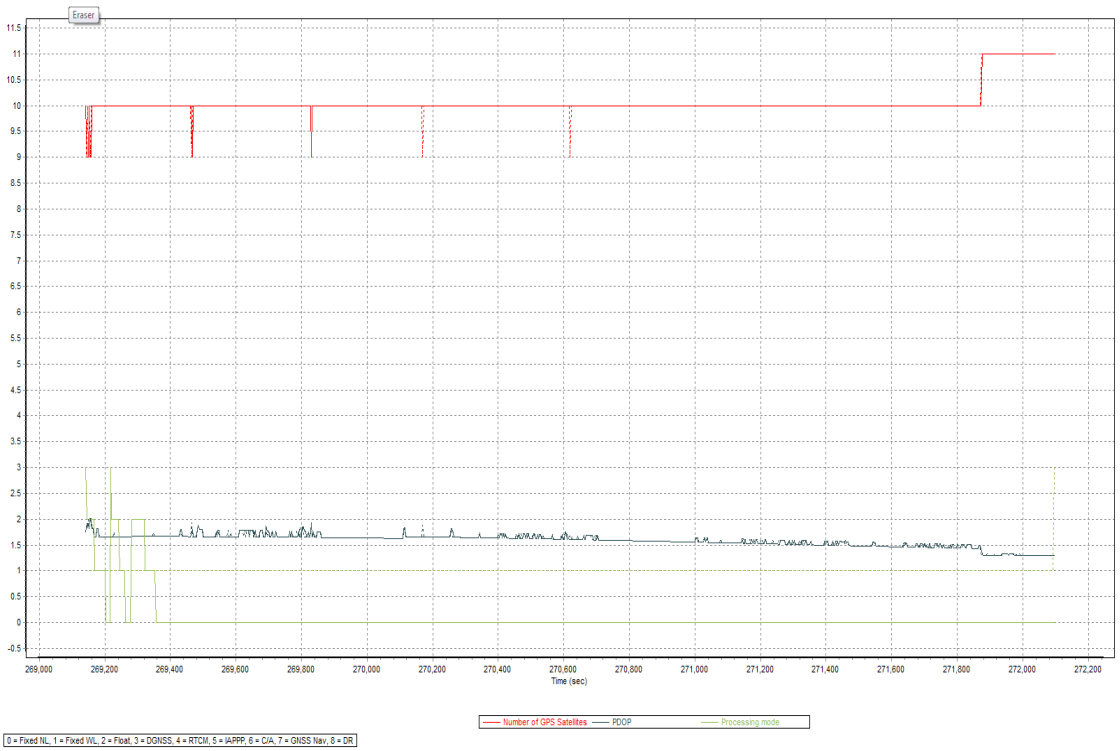


Figure 1.14.1. Solution Status

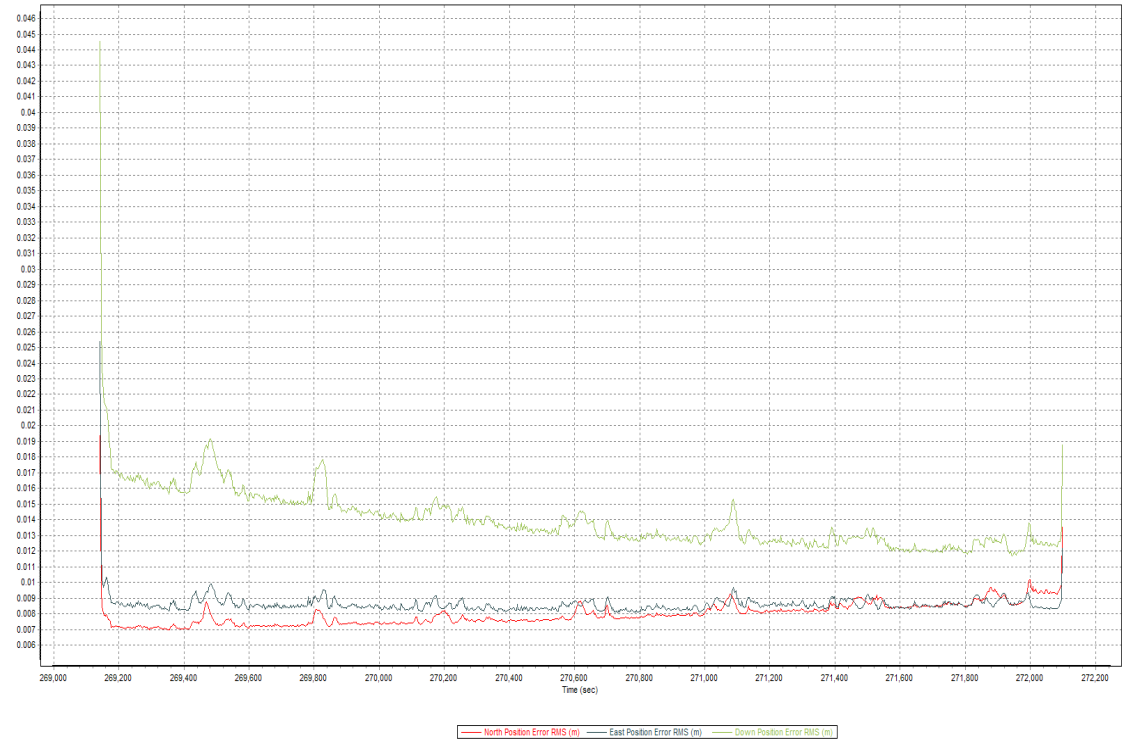


Figure 1.14.2. Smoothed Performance Metric Parameters

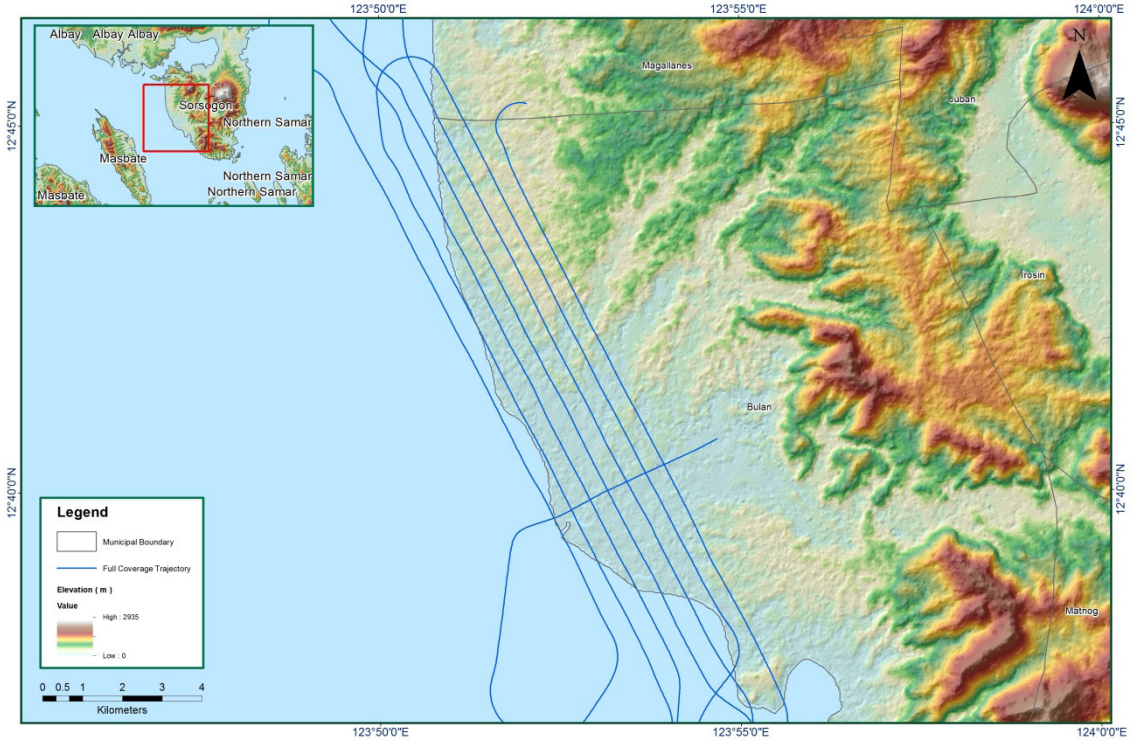


Figure 1.14.3. Best Estimated Trajectory

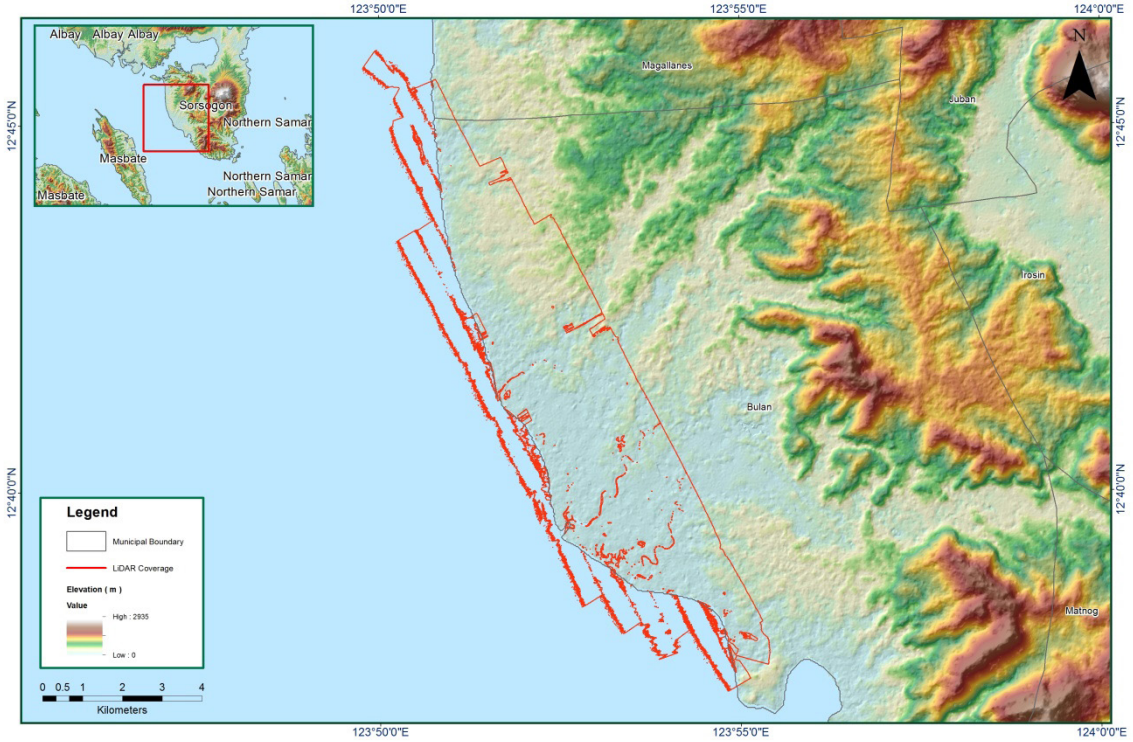


Figure 1.14.4. Coverage of LiDAR Data

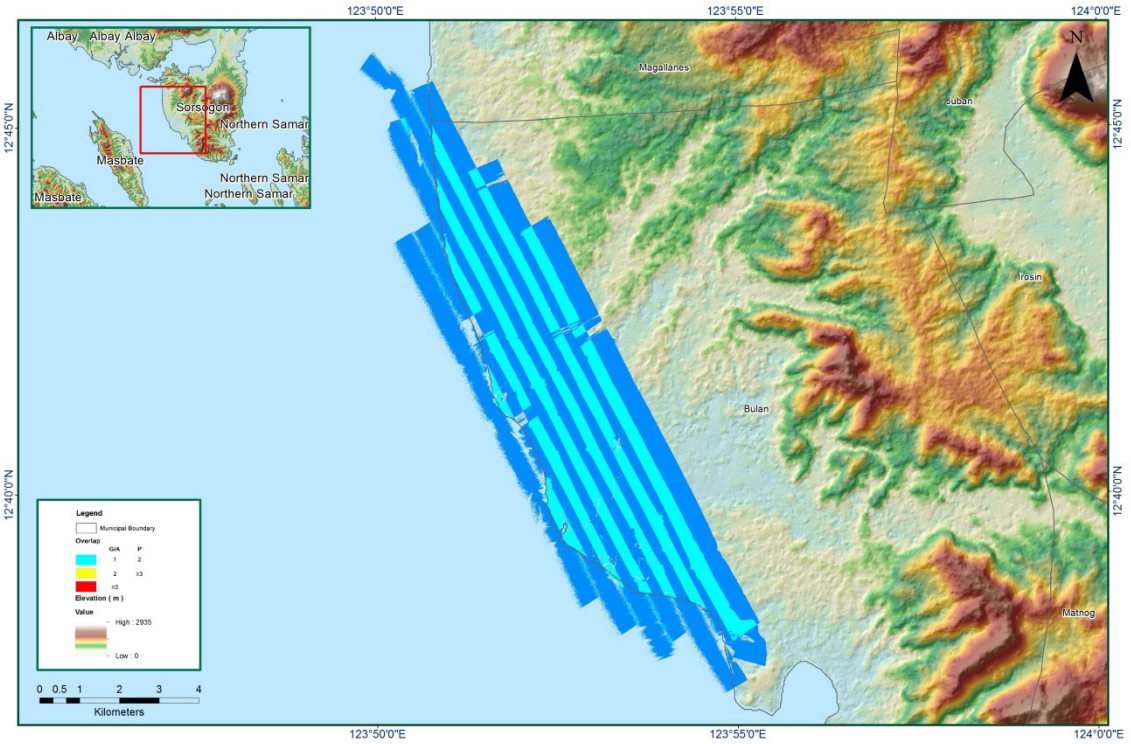


Figure 1.14.5. Image of data overlap

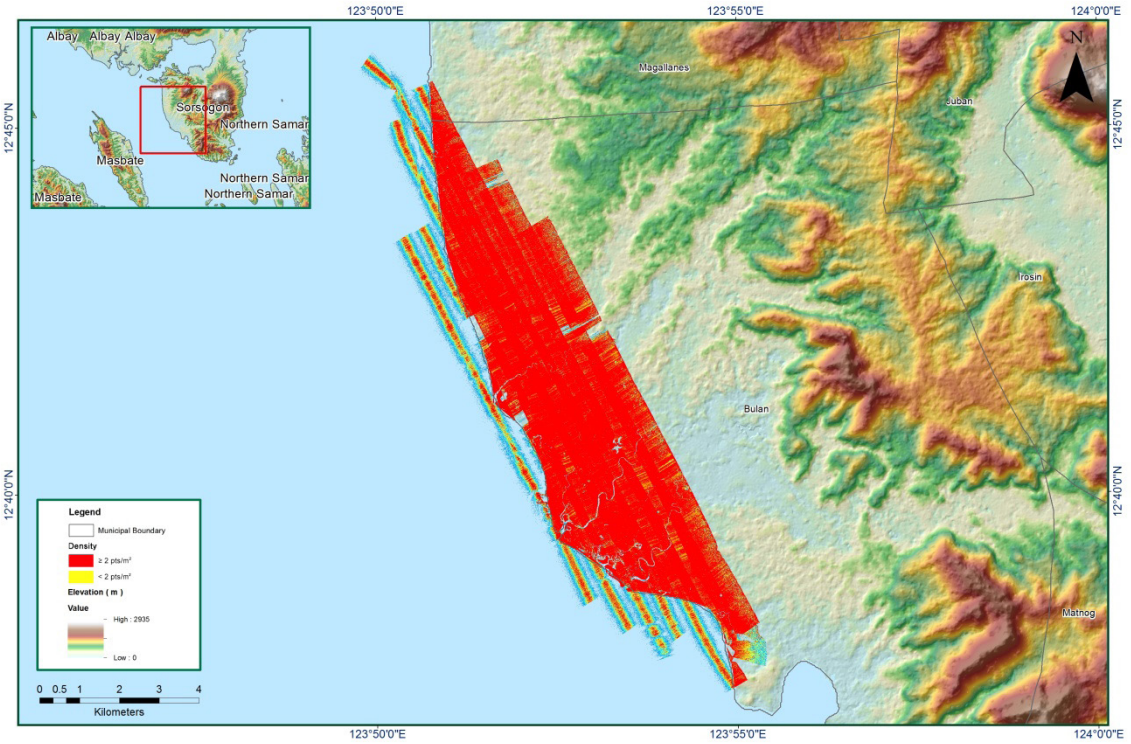


Figure 1.14.6. Density map of merged LiDAR data

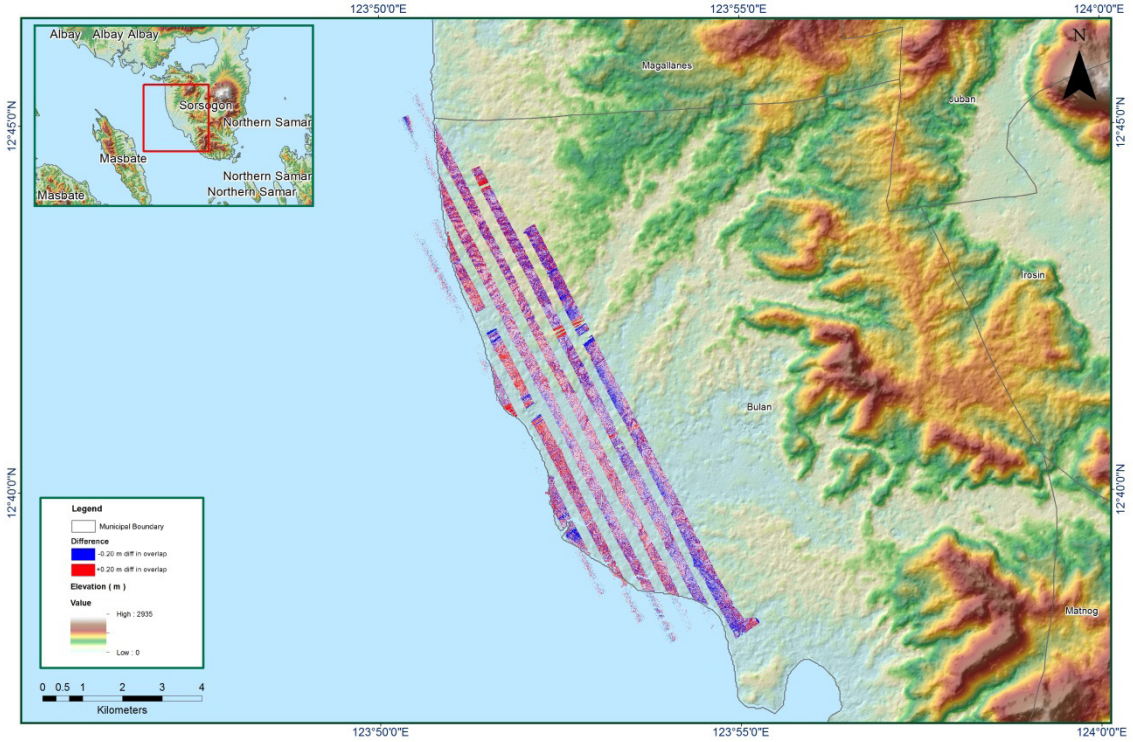


Figure 1.14.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk 19aE
Inclusive Flights	3863G
Range data size	25.9 GB
POS data size	262 MB
Base data size	10.1 MB
Image	46.6 GB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.111
RMSE for East Position (<4.0 cm)	1.095
RMSE for Down Position (<8.0 cm)	3.335
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	41.13 %
Ave point cloud density per sq.m. (>2.0)	5.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	75
Maximum Height	455.47 m
Minimum Height	76.60 m
Classification (# of points)	
Ground	21,234,739
Low vegetation	10,540,073
Medium vegetation	103,740,224
High vegetation	80,553,482
Building	53,708
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan

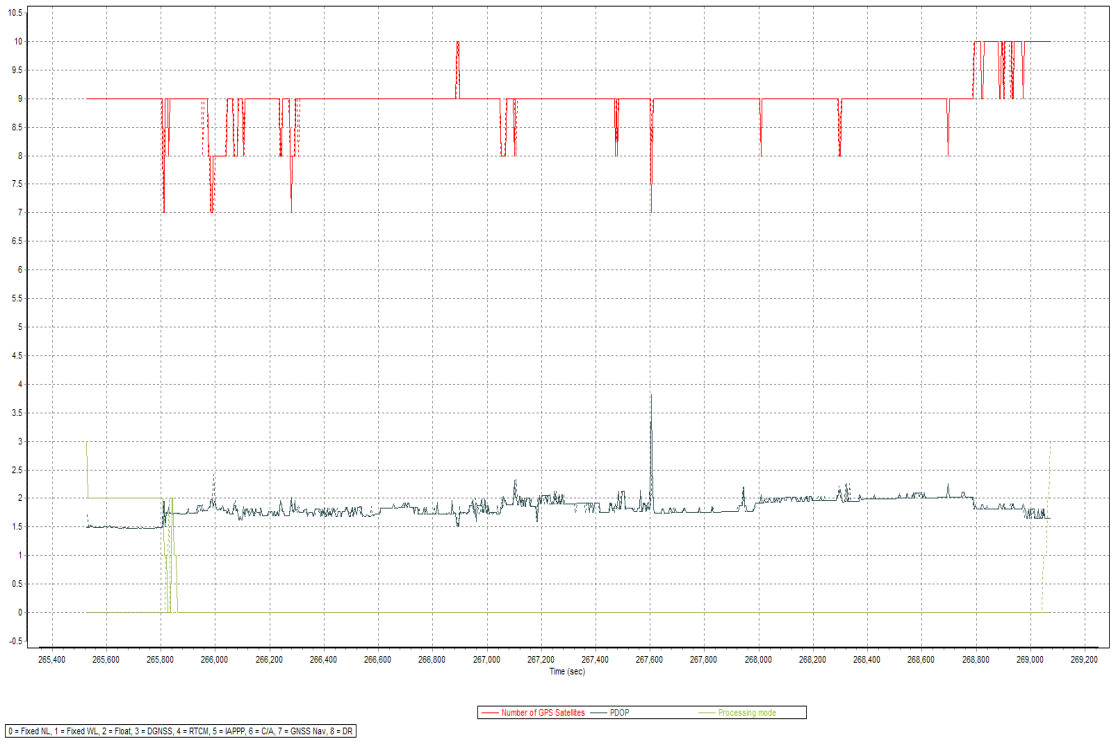


Figure 1.15.1. Solution Status

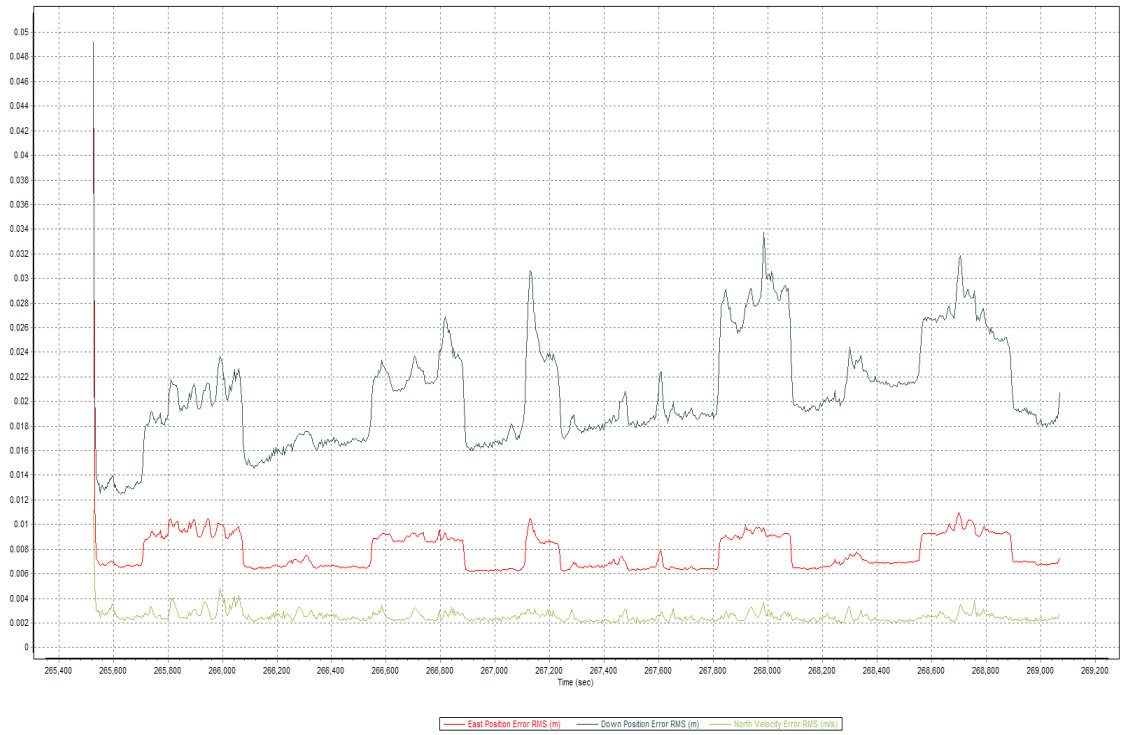


Figure 1.15.2. Smoothed Performance Metric Parameters

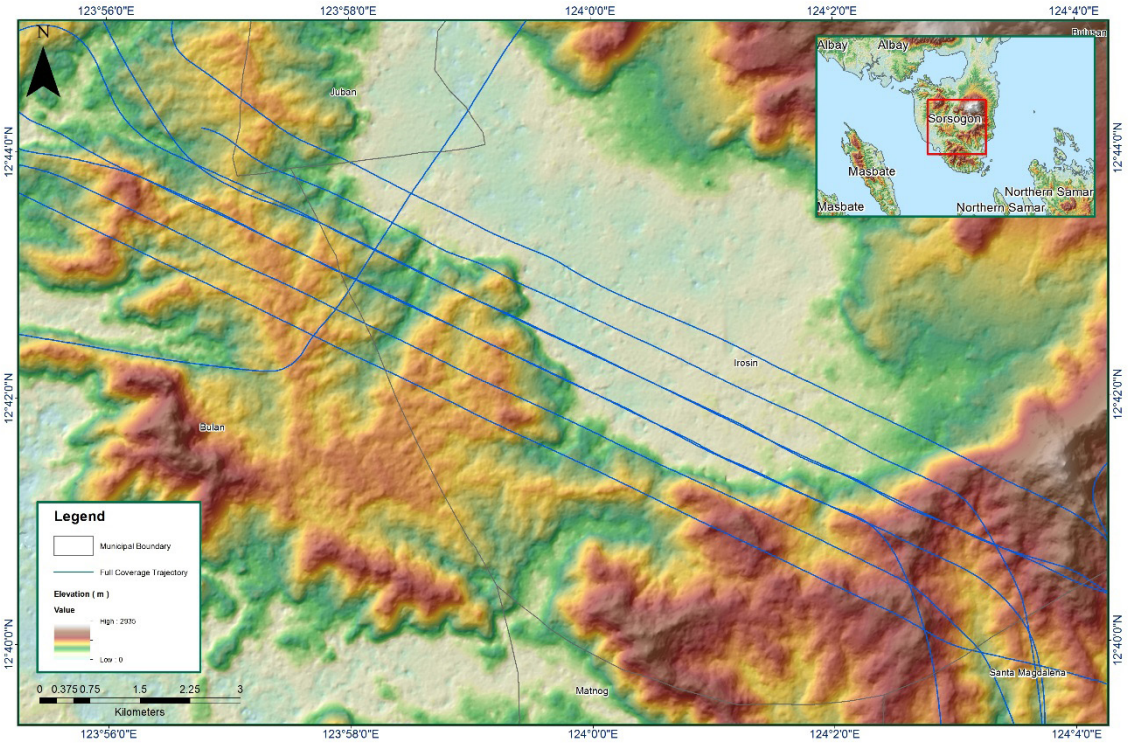


Figure 1.15.3. Best Estimated Trajectory

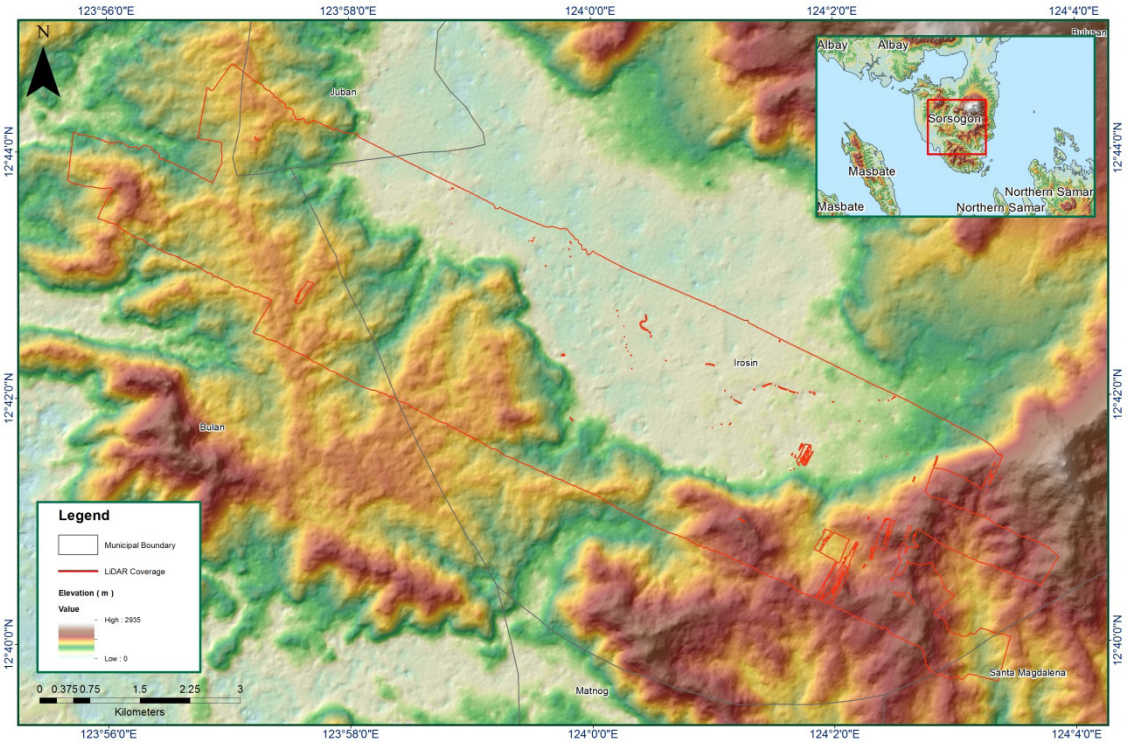


Figure 1.15.4. Coverage of LiDAR Data

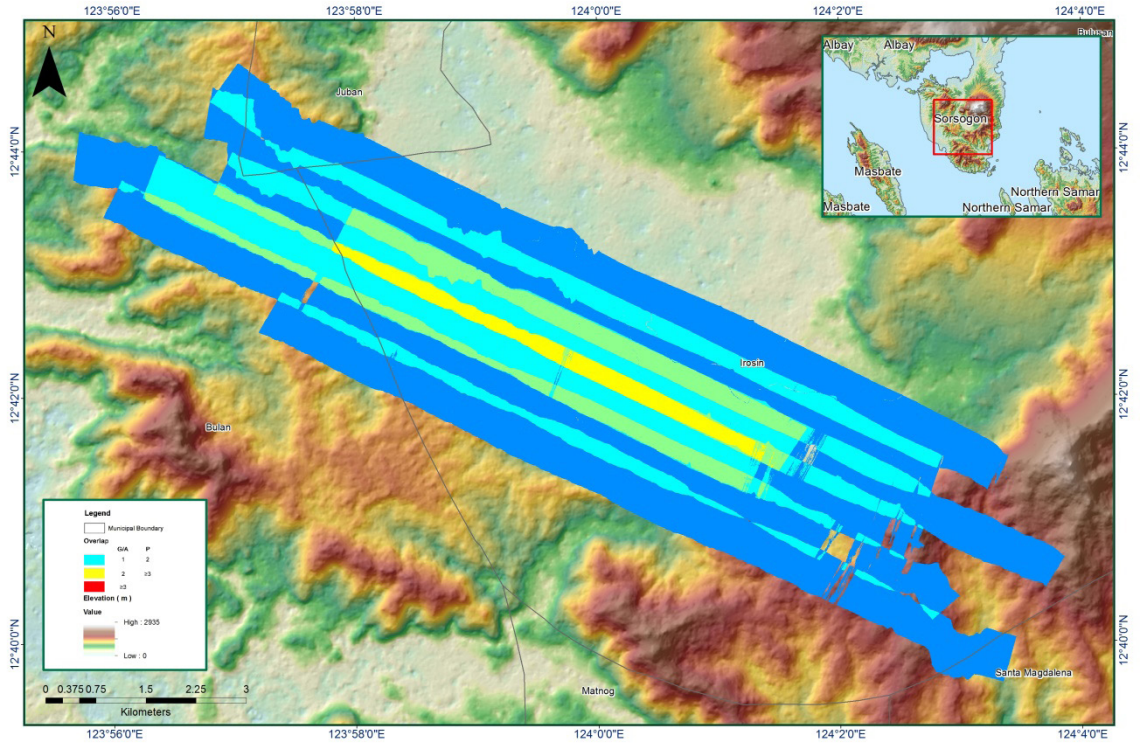


Figure 1.15.5. Image of data overlap

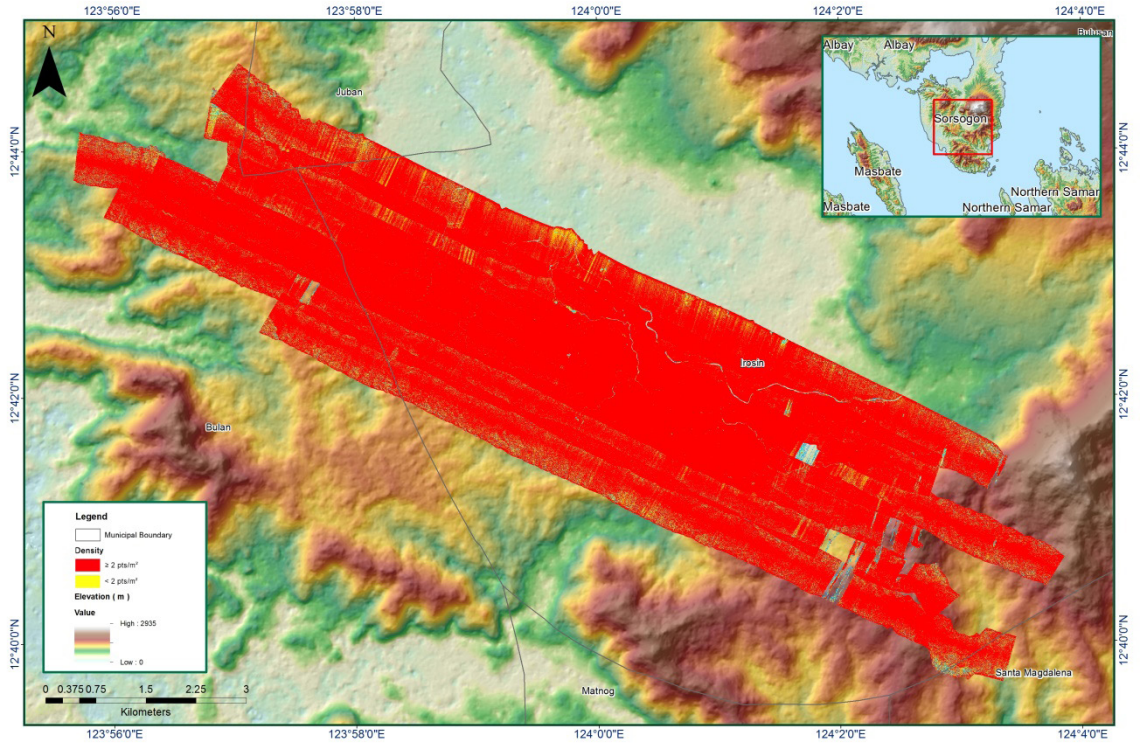


Figure 1.15.6. Density map of merged LiDAR data

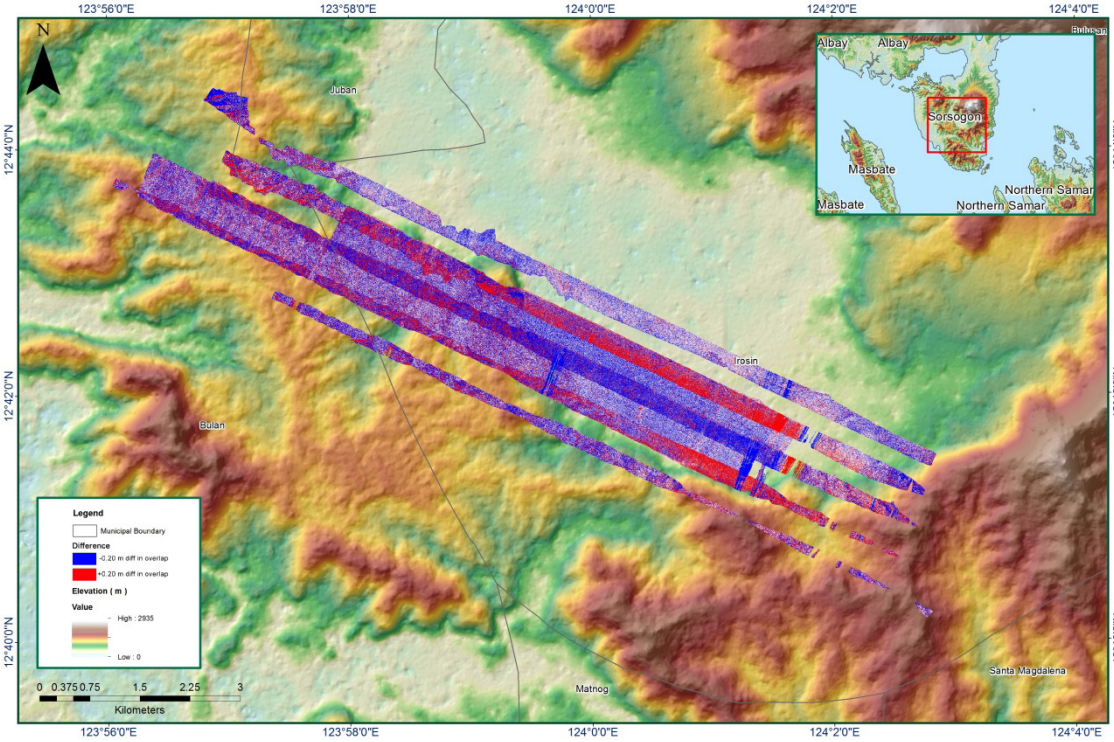


Figure 1.15.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk19aD
Inclusive Flights	3871G
Range data size	23.9 GB
POS data size	279 MB
Base data size	18.8 MB
Image	45.5 MB
Transfer date	March 31,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.412
RMSE for East Position (<4.0 cm)	1.105
RMSE for Down Position (<8.0 cm)	2.438
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	41.54 %
Ave point cloud density per sq.m. (>2.0)	4.69
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	86
Maximum Height	742.80 m
Minimum Height	70.70m
Classification (# of points)	
Ground	19,600,677
Low vegetation	15,332,308
Medium vegetation	124,381,573
High vegetation	76,246,512
Building	125,771
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Ma. Joanne Balaga, Jovy Narisma

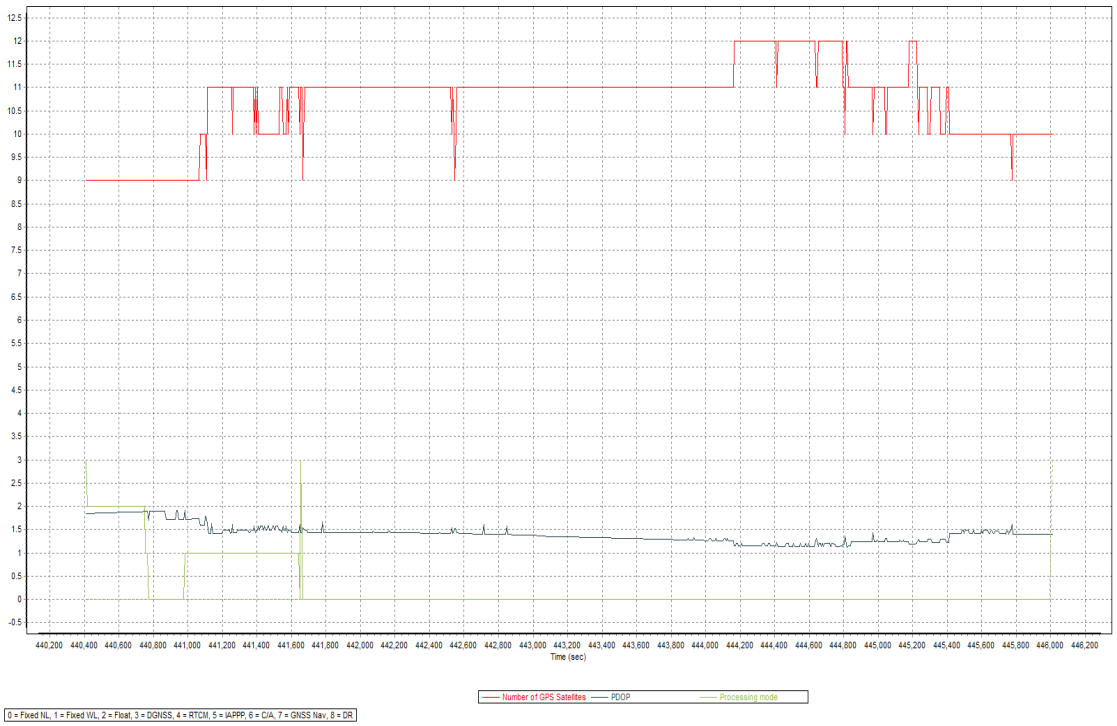


Figure 1.16.1. Solution Status

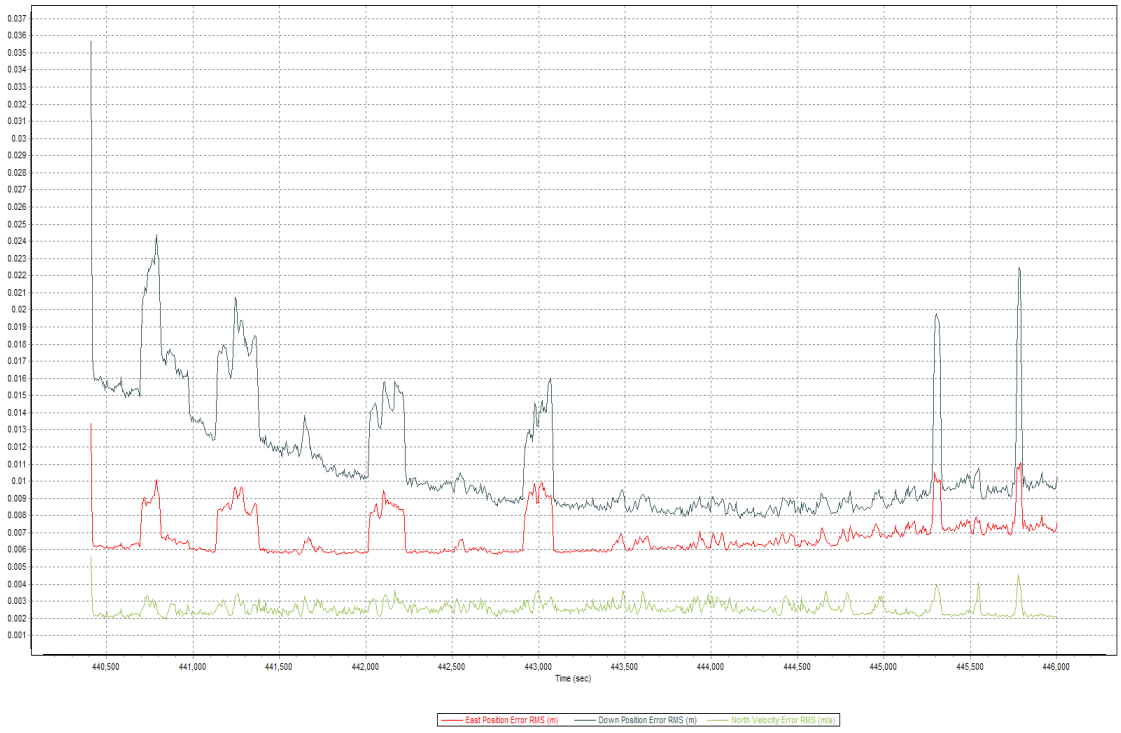


Figure 1.16.2. Smoothed Performance Metric Parameters

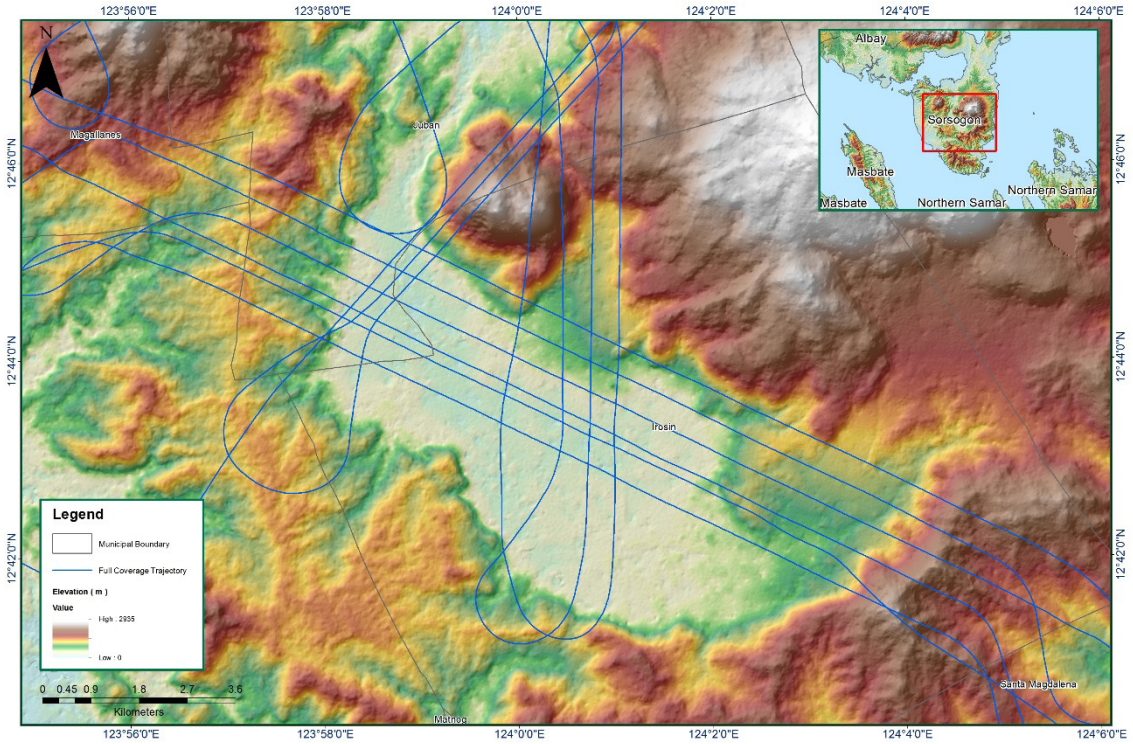


Figure 1.16.3. Best Estimated Trajectory

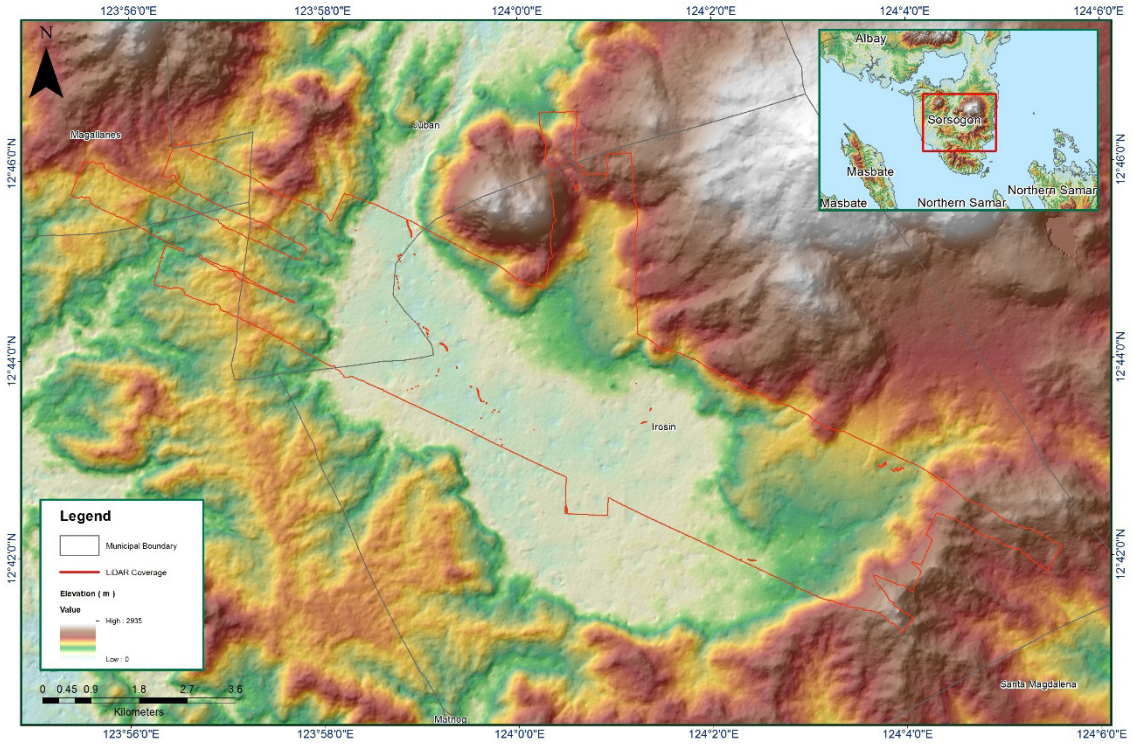


Figure 1.16.4. Coverage of LiDAR Data

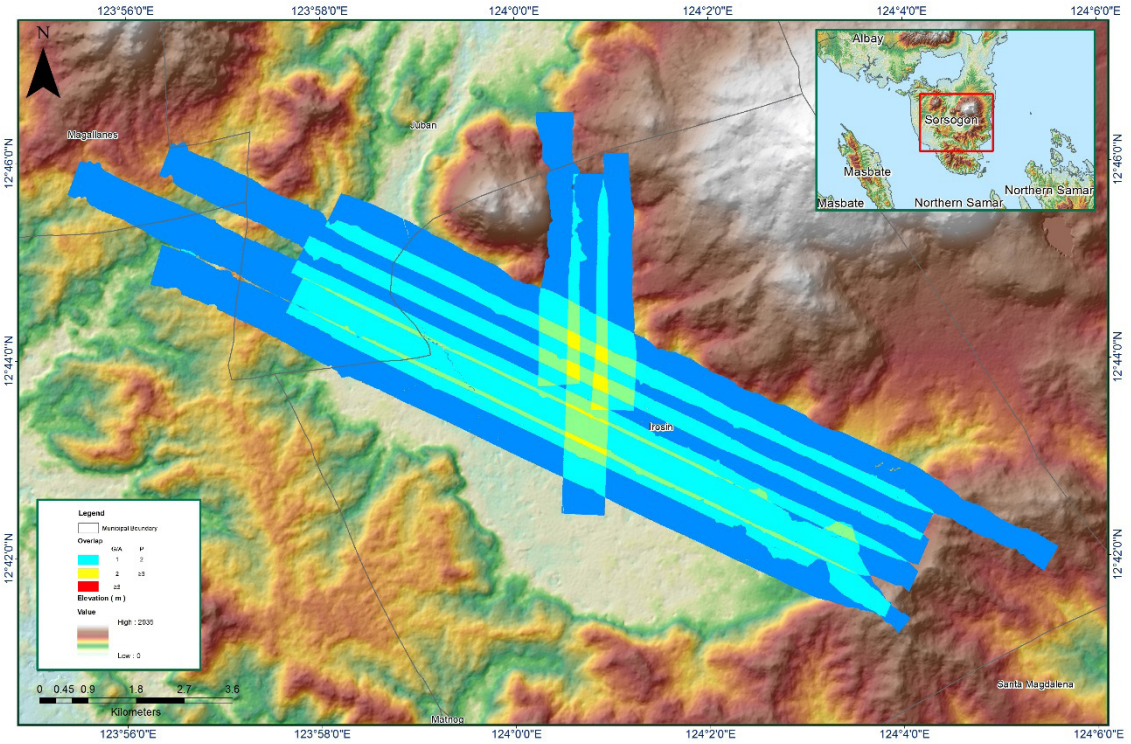


Figure 1.16.5. Image of data overlap

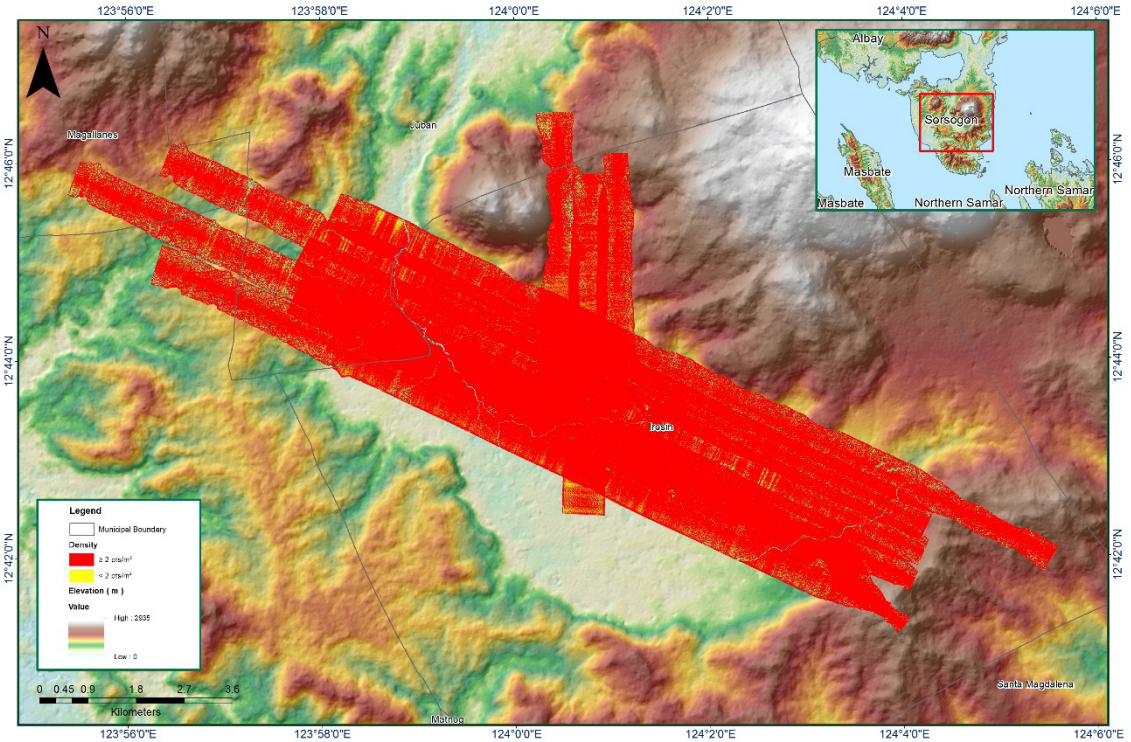


Figure 1.16.6. Density map of merged LiDAR data

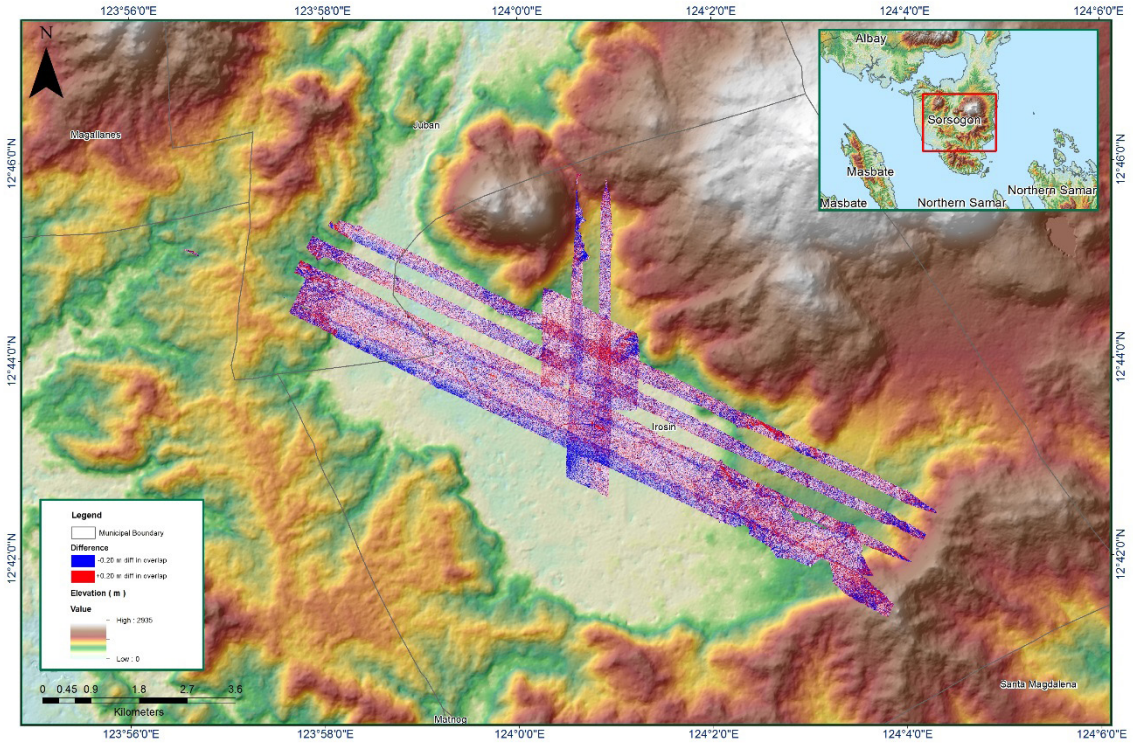


Figure 1.16.7. Elevation difference between flight lines

Flight Area	Albay_Sorsogon_reflights
Mission Name	Blk19aC
Inclusive Flights	3863G, 3871G, 3903G
Range data size	41.7 GB
POS data size	501 MB
Base data size	23 MB
Image	77.5 MB
Transfer date	March 31, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.826
RMSE for East Position (<4.0 cm)	5.158
RMSE for Down Position (<8.0 cm)	8.187
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	33.47 %
Ave point cloud density per sq.m. (>2.0)	5.05
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	110
Maximum Height	868.27 m
Minimum Height	62.01 m
Classification (# of points)	
Ground	31,064,602
Low vegetation	17,923,746
Medium vegetation	147,405,696
High vegetation	157,996,880
Building	213,844
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Ma. Joanne Balaga, Jovy Narisma

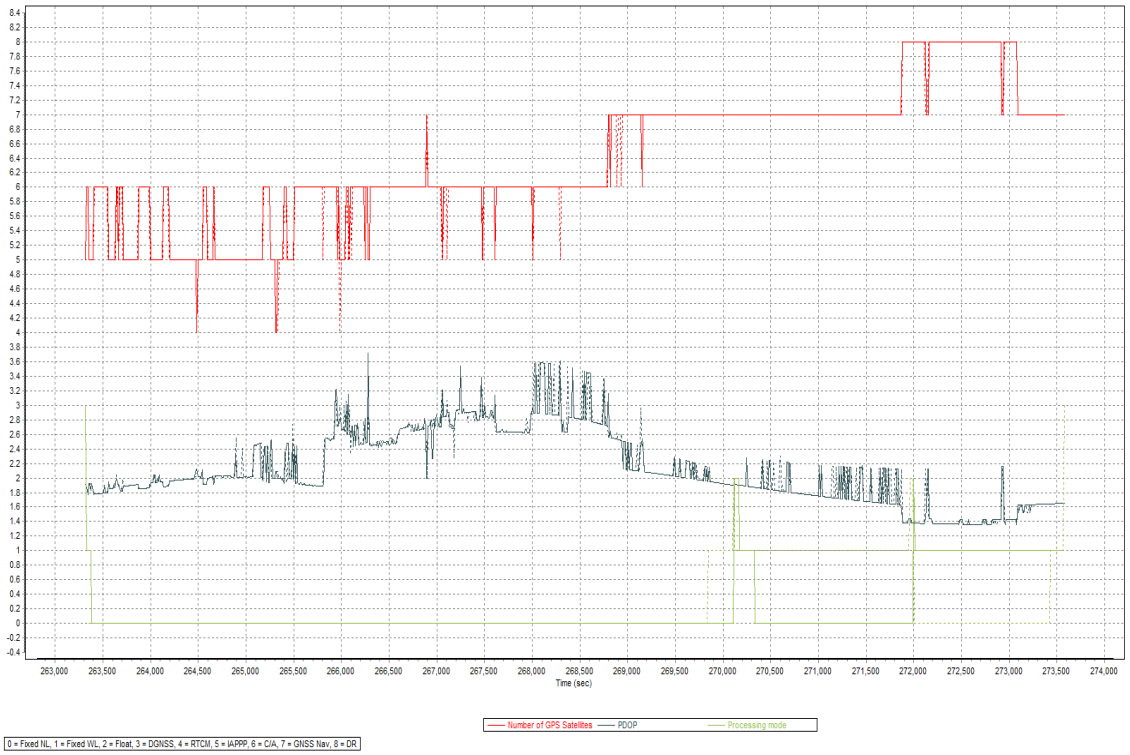


Figure 1.17.1. Solution Status

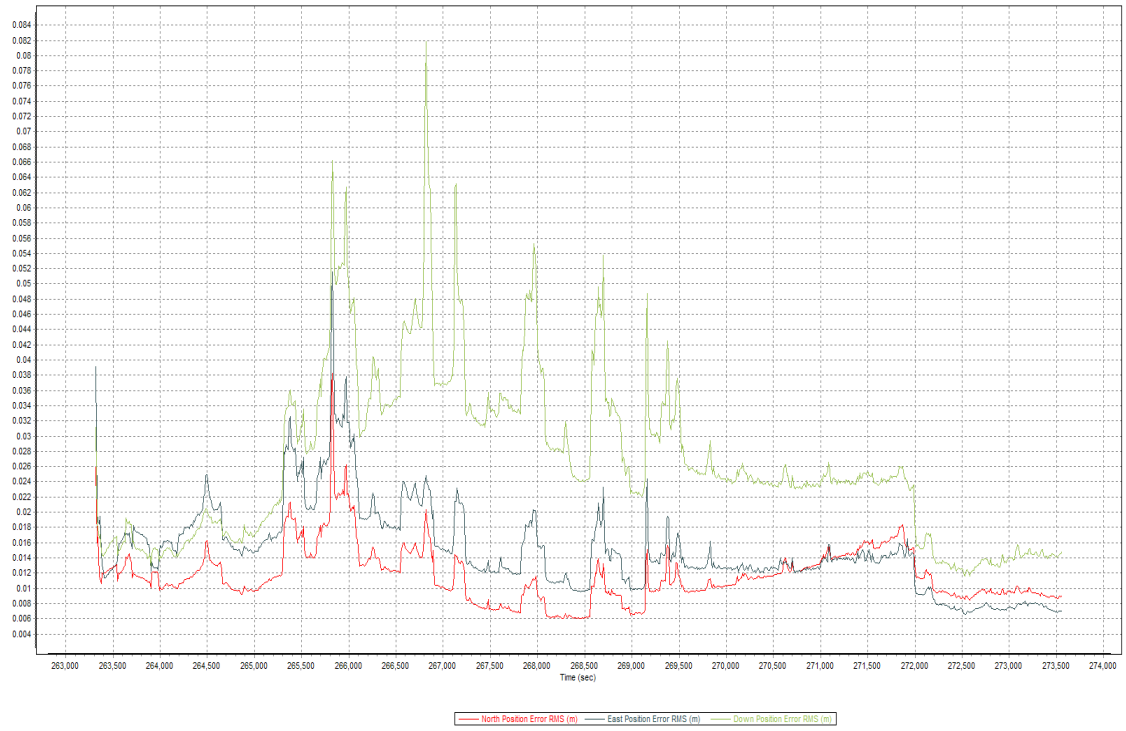


Figure 1.17.2. Smoothed Performance Metric Parameters

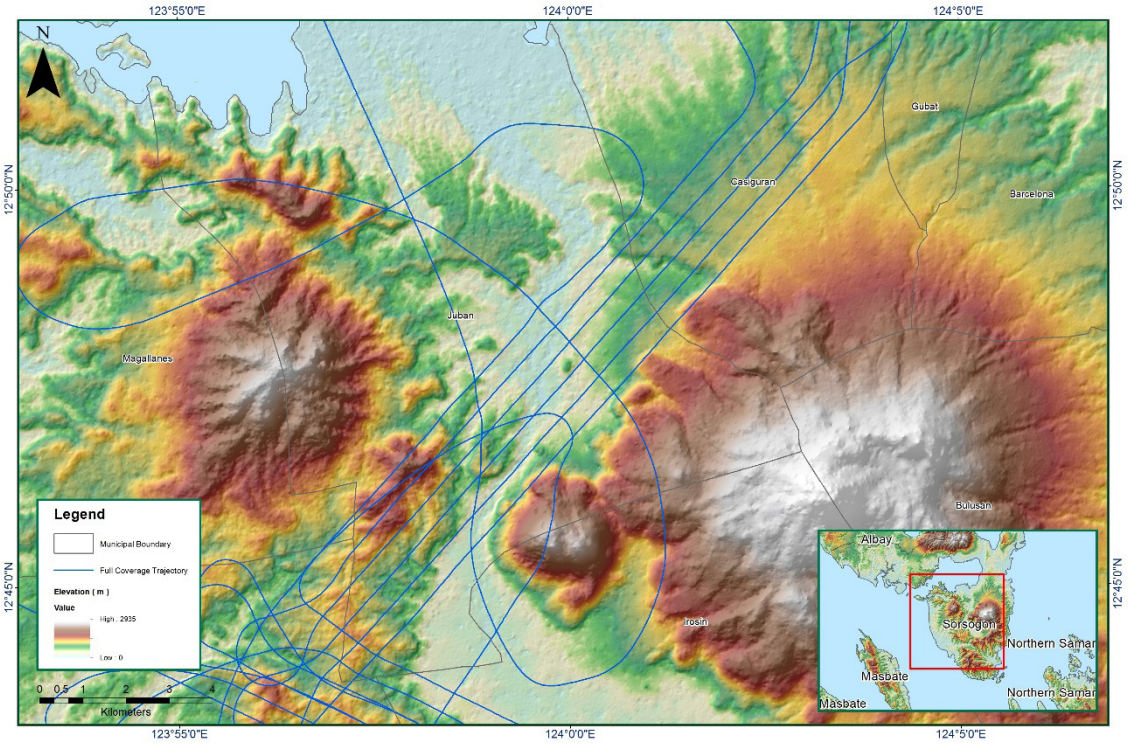


Figure 1.17.3. Best Estimated Trajectory

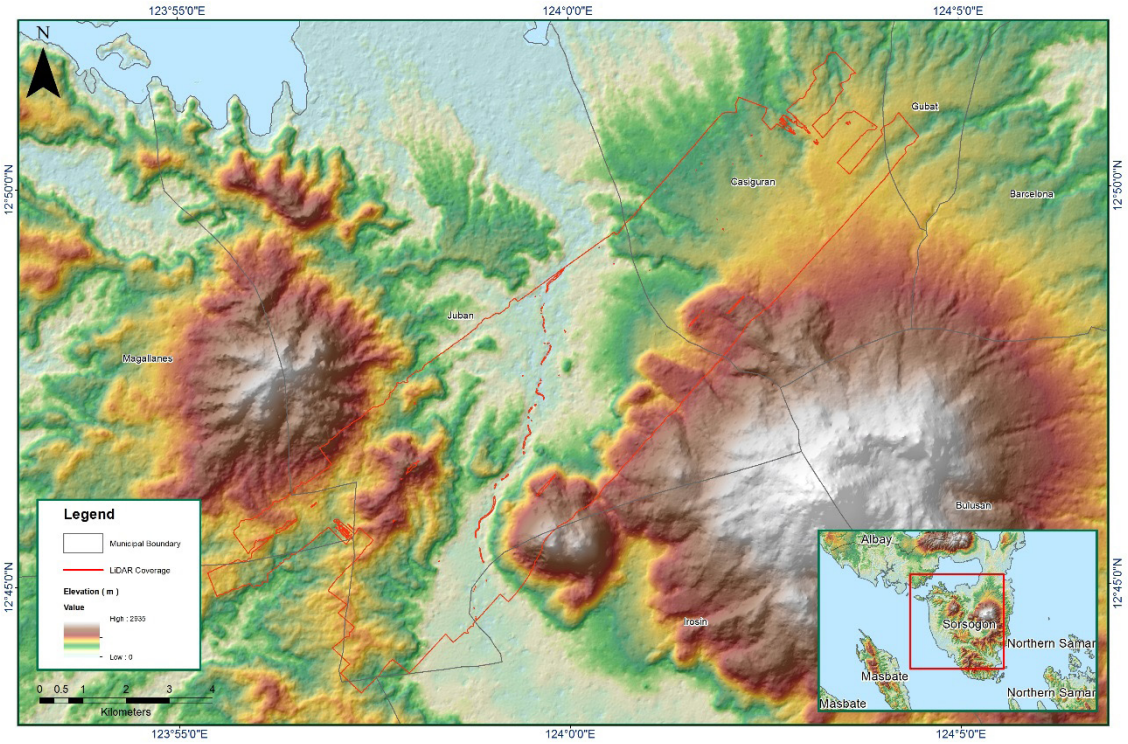


Figure 1.17.4. Coverage of LiDAR Data

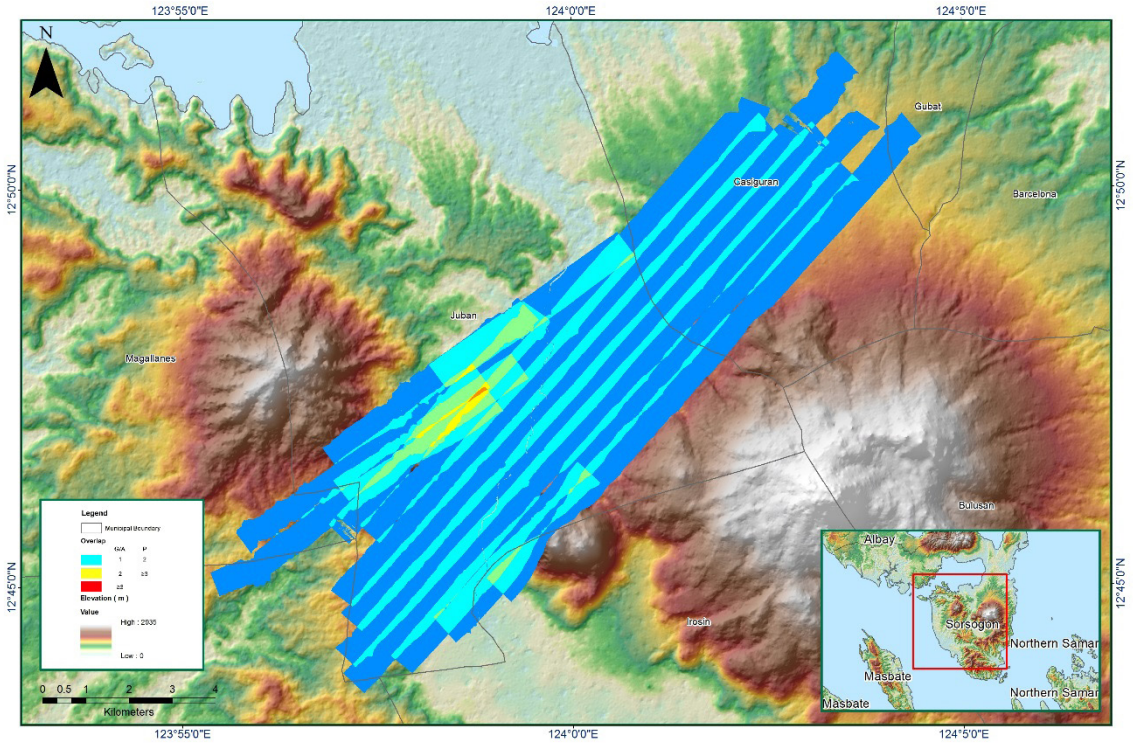


Figure 1.17.5. Image of data overlap

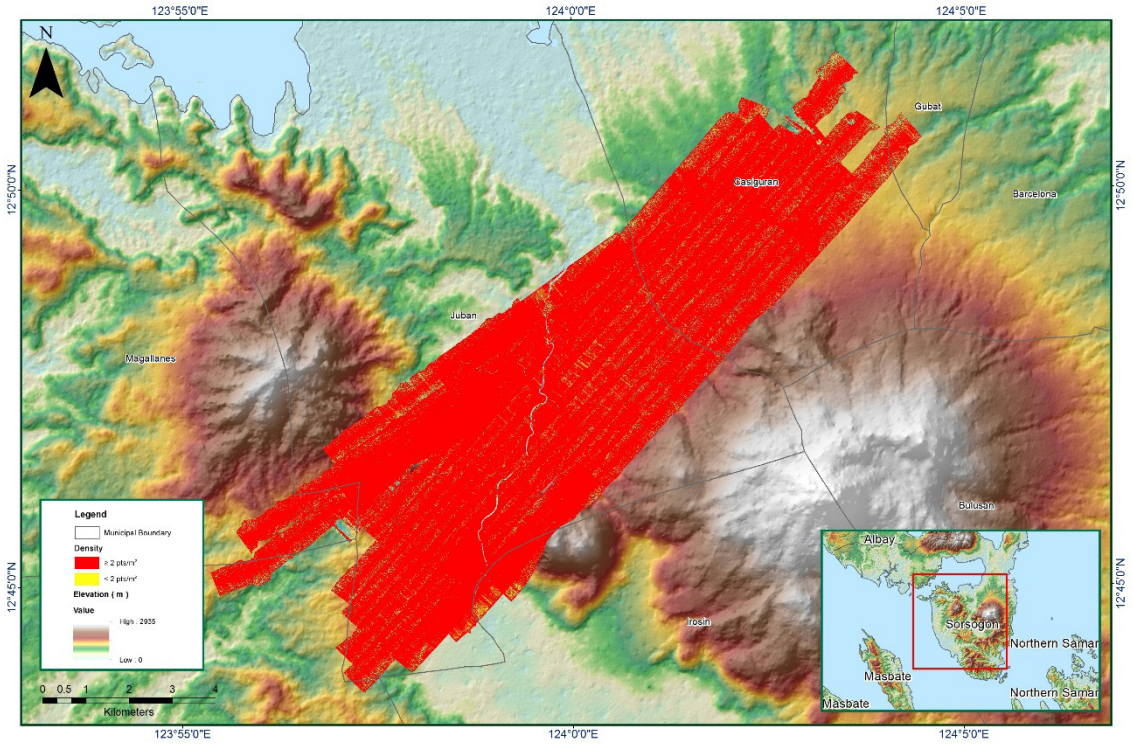


Figure 1.17.6. Density map of merged LiDAR data

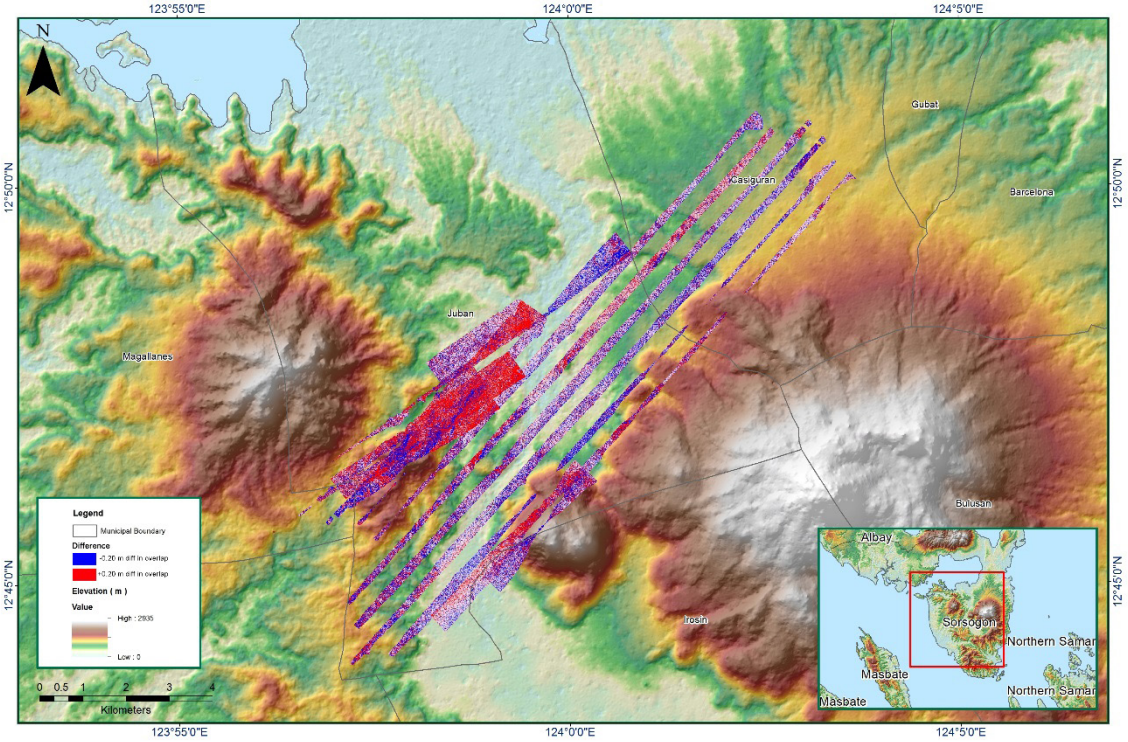


Figure 1.17.7. Elevation difference between flight lines

Annex 9. Cadacan Model Basin Parameters

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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
W200	57.84400	51.6370	0	0.01700	15.25900	Discharge	5.0000	1.00000	Ratio to Peak	0.26283
W210	4.93570	35.2820	0	0.16300	1.40570	Discharge	1.6299	1.00000	Ratio to Peak	0.00910
W220	16.92100	35.2330	0	0.12121	0.07496	Discharge	0.0942	0.00001	Ratio to Peak	0.02084
W230	0.00710	99.0000	0	35.54100	0.07487	Discharge	0.0118	0.01747	Ratio to Peak	0.17522
W240	0.03402	99.0000	0	25.31700	6.72790	Discharge	1.3822	1.00000	Ratio to Peak	0.00910
W250	0.62370	52.5330	0	0.01700	6.96700	Discharge	1.5674	0.06030	Ratio to Peak	0.01283
W260	56.54700	99.0000	0	12.52600	16.63600	Discharge	2.4732	1.00000	Ratio to Peak	0.19884
W270	21.41100	62.5880	0	4.12260	3.56780	Discharge	2.2355	0.29630	Ratio to Peak	0.36098
W280	271.27000	52.8980	0	17.79200	9.57820	Discharge	1.8517	1.00000	Ratio to Peak	0.03709
W290	254.34000	52.9100	0	5.16400	22.26300	Discharge	0.4487	0.29630	Ratio to Peak	0.70000
W300	83.01700	99.0000	0	0.14300	17.08800	Discharge	0.0367	0.29630	Ratio to Peak	0.31111
W310	58.78800	99.0000	0	2.39730	3.41730	Discharge	0.1907	0.19753	Ratio to Peak	0.61492
W320	0.16899	62.1190	0	0.14299	2.97120	Discharge	1.2901	0.60357	Ratio to Peak	0.86716
W330	0.03772	61.9520	0	2.10780	10.86400	Discharge	0.2877	0.00854	Ratio to Peak	0.10979
W340	242.64000	52.8420	0	5.69000	20.52200	Discharge	2.2326	1.00000	Ratio to Peak	1.00000
W350	9.85620	35.2970	0	35.25200	0.10448	Discharge	2.6277	1.00000	Ratio to Peak	0.16882
W360	301.25000	52.8120	0	0.15979	443.0000	Discharge	2.6090	0.00001	Ratio to Peak	0.07319
W370	289.43000	52.9110	0	8.02800	12.75700	Discharge	1.2989	0.00001	Ratio to Peak	1.00000
W380	242.57000	52.7680	0	0.32200	13.79800	Discharge	3.3483	1.00000	Ratio to Peak	0.16947

Annex 10. Cadacan Model Reach Parameters

Muskingum-Cunge Channel Routing							
Reach Number	**Time Step Method**	**Length (m)**	**Slope (m/m)**	**Manning's n**	**Shape**	**Width (m)**	**Side Slope**
R10	Automatic Fixed Interval	9685.3	0.00206	0.00010	Trapezoid	34.974	1
R30	Automatic Fixed Interval	528.28	0.00048	0.00010	Trapezoid	34.974	1
R40	Automatic Fixed Interval	634.85	0.00529	0.00010	Trapezoid	34.974	1
R70	Automatic Fixed Interval	5886.3	0.00147	0.27796	Trapezoid	34.974	1
R90	Automatic Fixed Interval	1615.8	0.00025	0.03031	Trapezoid	34.974	1
R110	Automatic Fixed Interval	952.84	0.00227	0.11577	Trapezoid	34.974	1
R130	Automatic Fixed Interval	480.83	0.00195	0.55103	Trapezoid	34.974	1
R140	Automatic Fixed Interval	1055	0.00018	0.00164	Trapezoid	34.974	1
R190	Automatic Fixed Interval	9694.5	0.00659	0.12307	Trapezoid	34.974	1

Annex 11. Educational Institutions Affected in Cadacan Floodplain

Sorsogon				
Casiguran				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Mabini Elementary School, Mabini Casiguran	Mabini			
Irosin				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
bacolod elem school	Bacolod	Low	Low	Medium
Bagsangan Elementary School	Bagsangan	Medium	Medium	High
batang daycare	Batang	Medium	Medium	Medium
batang daycare 2	Batang	Low	Low	Low
batang elem school	Batang	Low	Low	Low
gumapia elem school	Batang		Low	Low
Bolos Elementary School	Bolos			
macawayan severino fortes elem school	Buenavista	Low	Low	Low
Bulawan Elementary School	Bulawan			
Gabao National High School	Bulawan			
Carriedo day Care	Carriedo			
Carriedo Elementary School	Carriedo			
Cogon Elementary School	Cogon			
Gabao Elementary School	Gabao			
Gabao National High School	Gabao			Low
Gulang gulang Elementary School	Gulang-Gulang	Low	Medium	Medium
Irosin North High School	Gulang-Gulang			
Omagom Elementary School	Gulang-Gulang			
gumapia daycare	Gumapia			Low
Gallanosa National High School	Macawayan	Medium	Medium	High
macawayan benedicto gabito elem school	Macawayan	Medium	High	High
macawayan elem school	Macawayan		Low	Low
Bliss Primary School	Monbon			Low
Monbon Elementary School	Monbon			
patag daycare	Patag			
patag elem school	Patag			
buenavista elem school	Salvacion	Medium	Medium	Medium
tabon tabon elem school	San Agustin	High	High	High
batang daycare 2	San Isidro		Low	Low
san isidro daycare	San Isidro			
san isidro elem school	San Isidro	Medium	Medium	Medium
ICDC irosin child development. center	San Juan			
irosin central school	San Juan	Medium	Medium	Medium

San Agustin Day Care center	San Juan			
san agustin elem school	San Juan			
San Juan daycare	San Juan			
irosin central school	San Julian	Low	Low	Low
irosin institute of science and tech	San Julian			
Veritas College of Irosin	San Julian			
Gallanosa National High School	San Pedro		Medium	Medium
holy spirit academy of irosin	San Pedro	Medium	High	High
Tesda	San Pedro	Low	Low	Medium
Veritas College of Irosin	San Pedro			
sto domingo daycare	Tabon-Tabon			
sto domingo elem school	Tabon-Tabon			
tabon tabon elem school	Tabon-Tabon	Medium	Medium	High
Tinampo Elementary School	Tinampo			
Tongdol Elementary School (both road sides)	Tongdol	Low	Low	Low
Juban				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Anog Elementary School, Anog Juban Sorsogon	Anog			
Barangay Day Care Center, Anog Juban Sorsogon	Anog			
Tublijon Elementary School, Aroroy Juban	Aroroy			
Bacolod Elementary School, Bacolod Juban Sorsogon	Bacolod	High	High	High
catanagan day care center	Biriran			
Buraburan Day Care Center	Buraburan			
Day Care Center, Puting Sapa Juban Sorsogon	Buraburan			
Puting Sapa Elementary School, Juban Sorsogon	Buraburan			Low
Sangkayon Elementary School, Juban Sorsogon	Buraburan			
Calateo Elementary School, Calateo Juban Sorsogon	Calateo		Low	Medium
Day Care Center, Calateo Juban Sorsogon	Calateo			
catanagan elem. school	Catanagan	Low	Low	Low
Catanusan Day Care Center	Catanusan	High	High	High
Catanusan Elem. School, Catanusan, Juban	Catanusan	Medium	High	High
cogon day care center	Cogon			
cogon elem. school	Cogon			
juban national hi. school	Cogon			
embarcadero day care center	Embarcadero			
embarcadero elem. school	Embarcadero			
Guruyan National High school	Guruyan			
jga elem school	North Poblacion			
Jose alindogan elem school	North Poblacion			
Catanusan Elem. School, Catanusan, Juban	Rangas	Medium	High	High
Mario G. Guarina Elem. School, Rangas Juban	Rangas			
Olimpio A. Guarin Jr. National HS,Bacolod Juban	Rangas			
Sipaya Day Care Center, Sipaya Juban Sorsogon	Sipaya	Low	Medium	High

Sipaya Elementary School, Sipaya Juban Sorsogon	Sipaya		Medium	Medium
esmaje school	South Poblacion			
jga elem school	South Poblacion			Low
Jose alindogan elem school	South Poblacion			
juban institute bicol college(high school)	South Poblacion	Medium	Medium	Medium
s. POB day care	South Poblacion			
Taboc Day Care Center	Taboc			
taboc elem. school	Taboc			
juban institute bicol college(high school)	Tughan	Low	Low	Low

Annex 12. Medical Institutions Affected in Cadacan Floodplain

Sorsogon				
Irosin				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
gumapia health center	Batang	Low	Low	Low
buenavista health center	Buenavista			
irosin general hospital	Buenavista		Medium	Medium
Gabao Health Center	Bulawan			
Carriedo Health Center	Carriedo			
Gabao Health Center	Gabao			
macawayan health center	Macawayan		Low	Medium
patag health center	Patag			
san isidro health center	San Isidro			
San Juan health center	San Juan			
Daintys Dental Clinic	San Julian			
Irosin District Hospital	San Julian			
rhu municipal health ofc	San Julian			
San Pedro Irosin Nutrition Center	San Pedro			Low
Tinampo Health Center	Tinampo			
Juban				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Barangay Health Center, Calateo Juban Sorsogon	Calateo	Low	Medium	Medium
cogon health center	Cogon			
Barangay Health Center, Rangas Juban Sorsogon	Rangas			
department oh health	South Poblacion			
juban x-ray center	South Poblacion			